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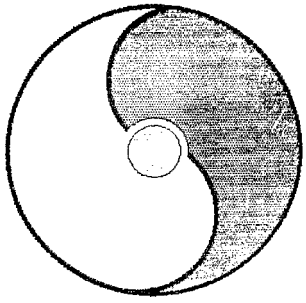
RHIC Spin Collaboration Meetings XXVII, XXVIII, XXX

(see RBRC Proceedings Volume 66 for Meeting XXIX, October 2004, Italy)

July 22, 2004
September 2, 2004
December 6, 2004



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Preface to the Series

The RIKEN BNL Research Center (RBRC) was established in April 1997 at Brookhaven National Laboratory. It is funded by the "Rikagaku Kenkyusho" (RIKEN, The Institute of Physical and Chemical Research) of Japan. The Center is dedicated to the study of strong interactions, including spin physics, lattice QCD, and RHIC physics through the nurturing of a new generation of young physicists.

The RBRC has both a theory and experimental component. At present the theoretical group has 4 Fellows and 3 Research Associates as well as 11 RHIC Physics/University Fellows (academic year 2003-2004). To date there are approximately 30 graduates from the program of which 13 have attained tenure positions at major institutions worldwide. The experimental group is smaller and has 2 Fellows and 3 RHIC Physics/University Fellows and 3 Research Associates, and historically 6 individuals have attained permanent positions.

Beginning in 2001 a new RIKEN Spin Program (RSP) category was implemented at RBRC. These appointments are joint positions of RBRC and RIKEN and include the following positions in theory and experiment: RSP Researchers, RSP Research Associates, and Young Researchers, who are mentored by senior RBRC Scientists. A number of RIKEN Jr. Research Associates and Visiting Scientists also contribute to the physics program at the Center.

RBRC has an active workshop program on strong interaction physics with each workshop focused on a specific physics problem. Each workshop speaker is encouraged to select a few of the most important transparencies from his or her presentation, accompanied by a page of explanation. This material is collected at the end of the workshop by the organizer to form proceedings, which can therefore be available within a short time. To date there are sixty-five proceeding volumes available.

The construction of a 0.6 teraflops parallel processor, dedicated to lattice QCD, begun at the Center on February 19, 1998, was completed on August 28, 1998 and is still operational. A 10 teraflops QCDOC computer in under construction and expected to be completed this year.

N. P. Samios, Director
November 2004

*Work performed under the auspices of U.S.D.O.E. Contract No. DE-AC02-98CH10886.

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Contact Information

RHIC Spin Collaboration Meeting XXVII

July 22, 2004

RHIC pp FY05 Run Preparation

Mei Bai
Collider-Accelerator Department
Brookhaven National Laboratory

Goals for Run 5

- Physics data taking
- Continuous machine development efforts to achieve maximum performance
  - Polarization
  - Luminosity
- Machine development for the future

Synder Room, CAD

RHIC Run5 projection

	bunch intensity [10^{11}]	# of bunch	# of collision points	$\mathcal{L}_{store\ average}$ [10^{30} $cm^{-2}s^{-1}$]	$\mathcal{L}_{per\ week}$ [pb-1]	polarization at store
Run5 min	0.7	56	4(3)	4.0	1.0	40%
Run5 goal	1.0	56	4(3)	8.0	2.0	45%
Run5 alternative	0.7	112	4(3)	8.2	2.0	50%

Job List – Shutdown period

- During the shut-down
  - improve the online model
    - tune control
    - chromaticity control
    - beta: re-fitting for the new working point
  - improve the off-line non-linear model
  - improve the orbit control
    - bpm upgrade
    - predict the beam position for the missing bpm based on the online model
  - Spin tracking studies with the current working point
    - orbit effect
    - snake resonances

Job List – Shutdown period

- During the shut-down
  - polarimeter upgrade T. D'Ottavio, Osamu, operation team
    - a more user-friendly application
      - helps to consolidate the useful information instead of fumbling through different pet pages which are only supposedly to be used for experts
      - a strip chart of polarization measurement is always good for operations
    - automated tracking of target with beam position
    - measure the beam polarization average over its distribution Johannes, Osamu, Haixin
    - separate the DAQ electronics among the three polarimeters: RHIC Blue and Yellow polarimeters as well as H Jets polarimeter Osamu ?

Igo, Dima, ...?

Synder Room, CAD

Machine developments for Run 5

- commission the polarimeter upgrades
  - target tracking
  - average polarization over the beam profile
  - turn by turn spin precession measurement
- the integrity of the snake configuration
- spin flipping
- ramp up to 200 – 217 GeV, depending on what type of light ions.
- injection & ramping with the rotators on

Synder Room, CAD

Summary

- Run 5 is expected to be a long run for Physics
- The Physics will start with the minimum performance we have achieved during Run4 and expect to achieve best performance based on the continuous tuning up efforts in RHIC and AGS, esp. the AGS progress on the cold snake
- Efforts will also be made for achieving the goals for the long run

Synder Room, CAD

Preliminary Run Plan

- During the 2-weeks of setup (42 shifts)
  - H Jets installation and common cavity short-out: 3 days: 9 shifts
    - AGS synchro setup
    - ps work if needed
    - others
  - establish injection:12 shifts
    - injection kicker timing, circulating, capturing: 1
    - set the rf frequency and adjust the dipole fields to center the beam:1
    - rf loop setup: 0.5
    - instrumentation setup: 8
      - polarimeter
      - Artus, transverse damper
      - Bpms
      - WCM, PLL, IPM, BLM, …
    - machine tuning: 1.5
      - orbit correction, decoupling, chromaticity correction

Synder Room, CAD

Preliminary Run Plan

- energy ramp development: 12 shifts
  - rf setup: brho loop
  - decoupling along the ramp
  - establish tunes/chromaticity/orbit at store
  - decoupling at store
  - cogging setup
- rotator ramp development: 2 shifts
  - tunes/chromaticities along the ramp
  - adjust the store rf frequency for different path length
- establish the collision: 1 shifts
    - IR steering
    - fine cogging setup
- 56x56 bunch development: 4 shifts + 2 shifts of overnight store
  - provide stores overnight for detector timing
  - collimator setup
  - vernier scan

Preliminary Run Plan

- During the 1-week of ramp-up
  - continue the machine tuning 8-12 hours during the daytime and provide production stores afterwards
  - fine tuning of the ramp to improve the beam&polarization transmission efficiency
    - orbit correction
    - IR non-linear correction
    - chromaticity along the ramp
  - snake current scan
  - polarization ramp measurements
- During the production period
  - deliver the production stores: operation crew
  - scheduled machine developments
    - directly related to the RHIC spin program
  - planned weekly beam-experiment
    - more wide range

AGS Cold Snake Status

W. MacKay, BNL

for
RHIC Spin Collaboration Meeting XXVII
July 22, 2004
RIKEN BNL Research Center

AGS Cold Snake Status

- Design operating current: 350 A (helix and solenoid); correctors 25 A
- Cold mass finished and in vertical cryostat.
- The magnet was cooled down last Thursday.
- Single short to ground in coil # 10 of inner cylinder.
- Set up of power supplies and quench heaters completed.
- Quench heaters pulsed to produce quenches at several currents. Time constant for pulses adjusted for optimum performance.
- Helix ramped up to 375 A, solenoid 350 A, correctors: 45 A
- Field measurements to start next.

Figures at http://www.rhichome.bnl.gov/RHIC/Spin/gallery/AGScoldsnake/

PHENIX Spin
Run-5 Beam Use Proposal

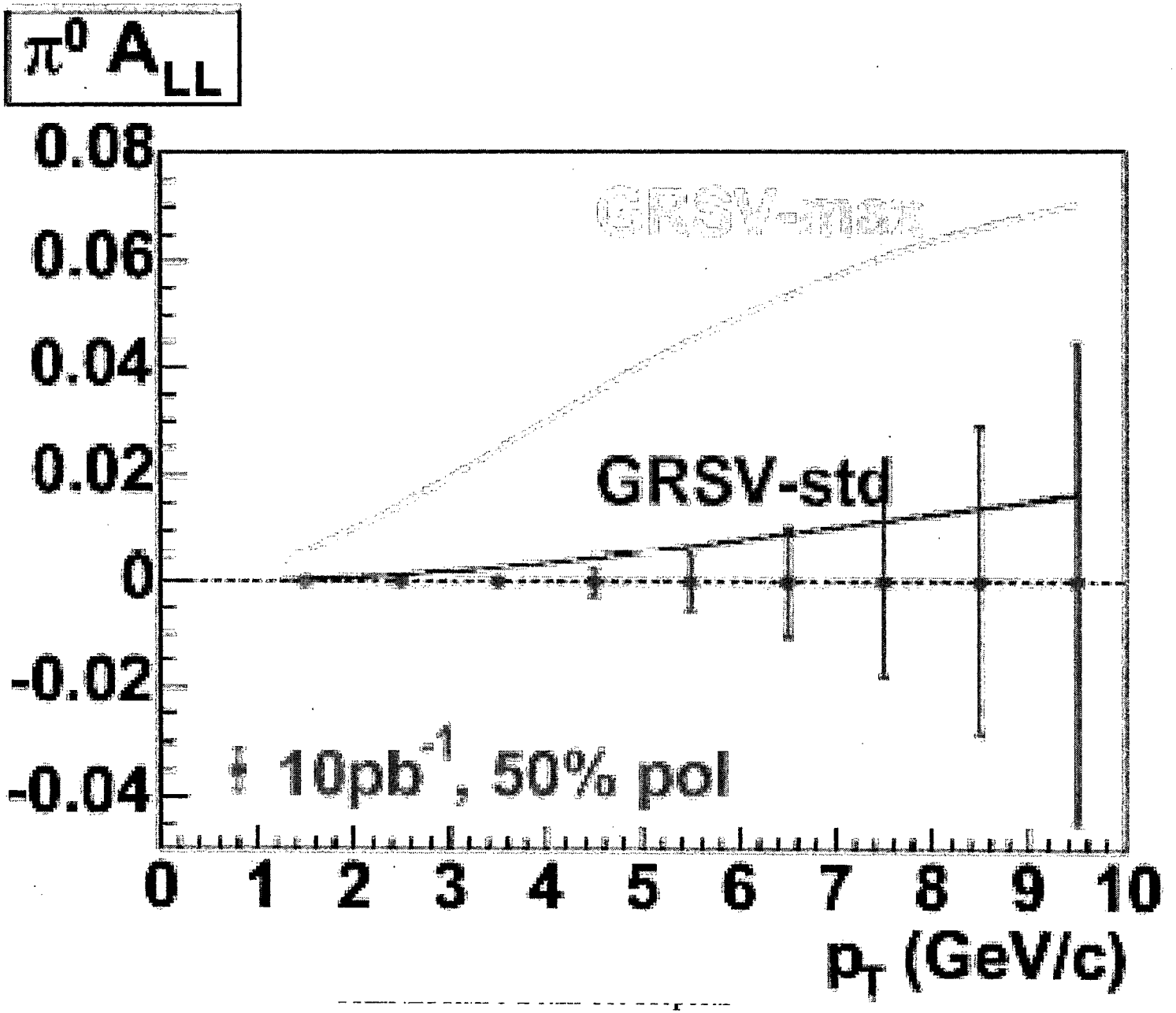
Abhay Deshpande
For
PHENIX Spin WG
July 22, 2004

Expectation from Spin Run-5

- We assume: 5 weeks (commissioning) + 10 weeks (physics) running
  - Toward the end of 5 weeks commissioning we expect
    - Fills for physics running (night shifts, detector tune-up)
    - Tests of polarized RHIC at 500 GeV (see discussed later)
  - During the 10 wk Physics running:
    - ~1 pb-1/wk --> 10 pb-1 (written) over all 10 wks
    - Average beam polarization ~50%
- Based on the success of Run-3 and Run-4 (machine) PHENIX plans to make the first high sensitive measurement of polarized gluon distribution using the π^0 production in polarized pp scattering
- Transverse physics data taking during the 5-wk machine commissioning period. PHENIX will NOT ask for transverse physics running during the 10 wk physics period.

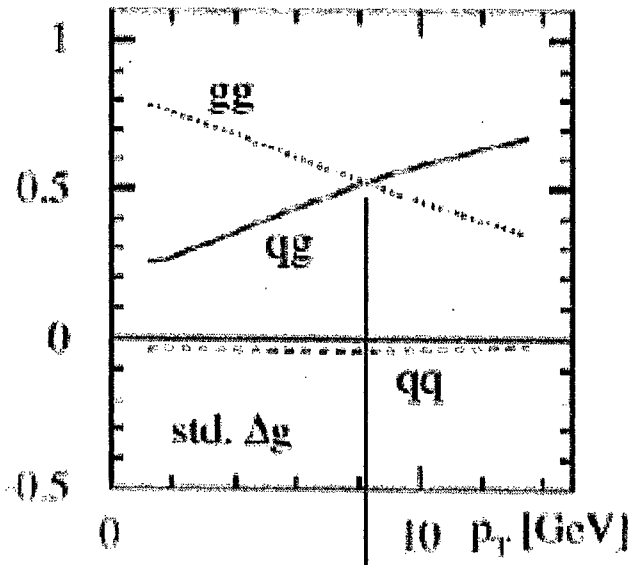
Physics & Learning during Run-5

- **Physics:**
  - Double spin asymmetry in π^0 production leading to ΔG (pT-range 1.5 GeV/c to 10 GeV/c)
    - Higher momentum region important for the g-q component of the polarized contribution, allows determination of the sign of ΔG
  - Double spin asymmetry in charged pion production
    - Relative sizes of double spin asymmetries for $\pi+$ and $\pi-$ indicators of the sign of ΔG
- **Learning:**
  - Unpolarized cross section for direct photon (asymmetry in Run-6)
  - Exploratory measurements of electron/muon final states leading towards charm physics in PHENIX in future

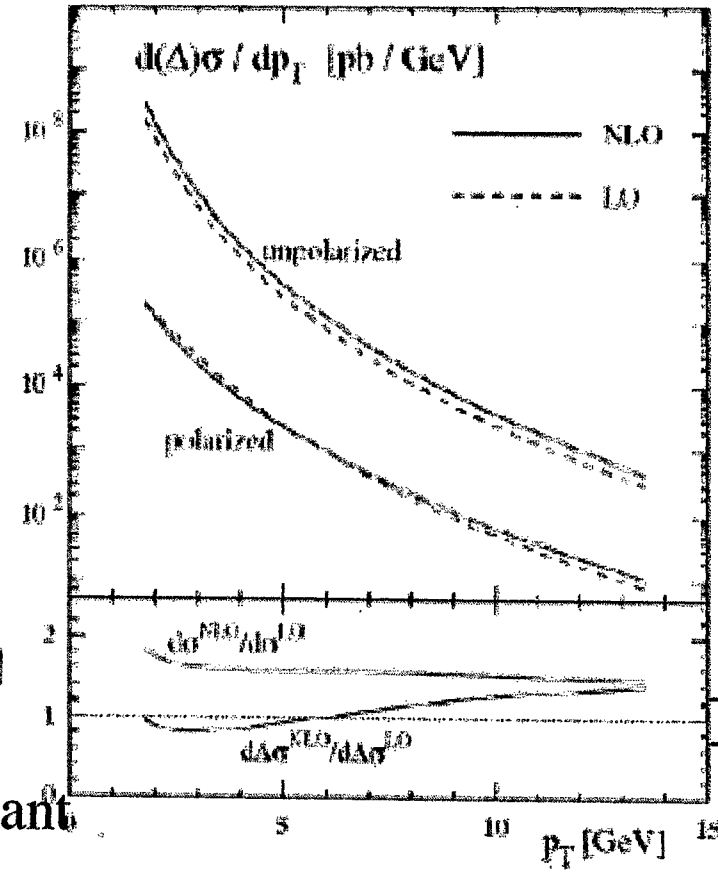

π^0 A_{LL}
0.08
0.06
0.04
0.02
0
-0.02
-0.04
GRSV-max
GRSV-std
10pb^{-1}, 50% pol
0 1 2 3 4 5 6 7 8 9 10
p_T (GeV/c)

Contributing processes & NLO corrections to polarized scattering

Polarized pp--> π^0 + X

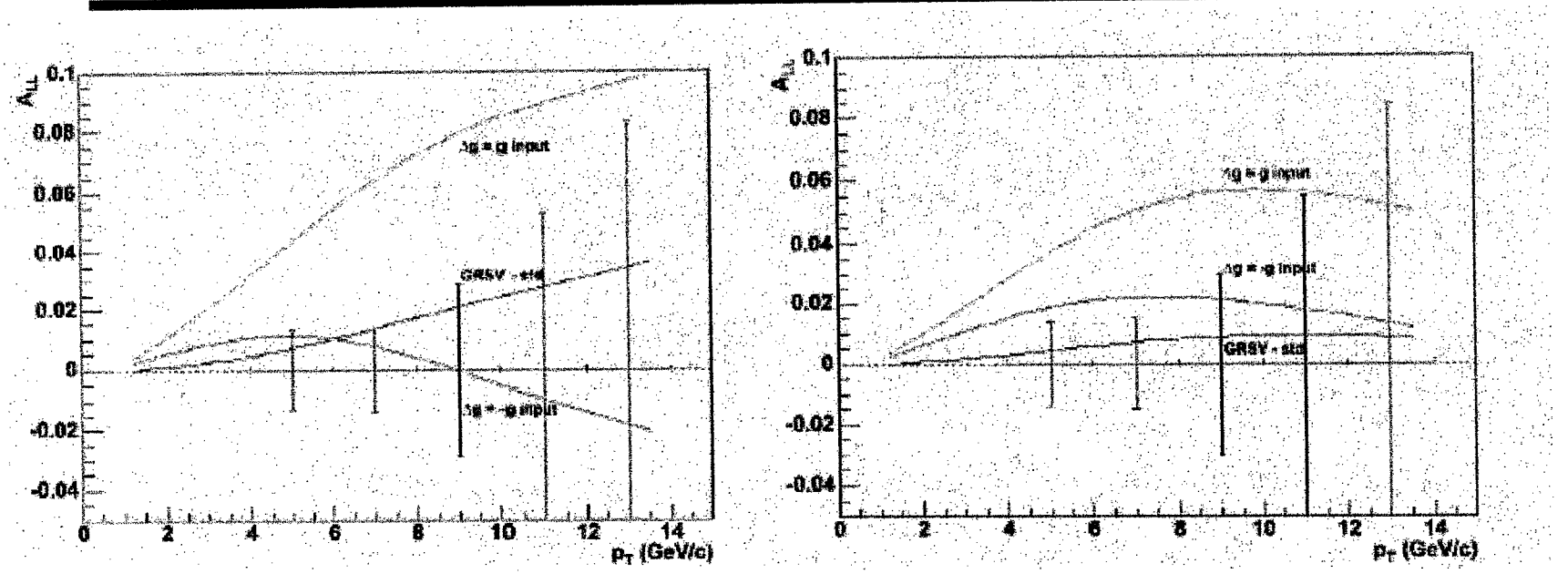


g-q dominant



Small Correct--ions

$\pi^{+/-}$ double spin asymmetries



- Left: pi+ , Right: pi- asymmetries. Statistical uncertainties for Run-5 shown.
- Difference in shapes of positive and negative DG scenario need to be measured. Probably possible only in Run-6

Physics in Run-6

- **Assumptions:**
  - 70% beam polarization
  - 5+10/11 weeks of pp running
  - ***At least*** a factor ~2 up luminosity compared to Run-5 => 20 pb^{-1}
- **Physics:**
  - Direct photon double spin asymmetry
  - Increased statistics for charged and neutral pion production
  - Based on exploratory Run-5 measurements of transversity, a certain fraction associated with this physics
  - Exploratory cross section measurements for electron and muon physics (charm physics)

Run-7 and beyond

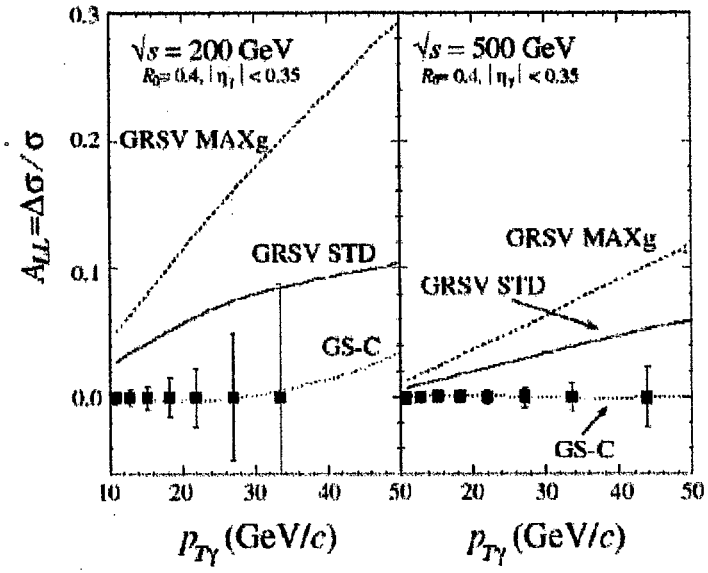
- Assumption of PHENIX decadal plan (not writing on stone!)
  - No spin pp in Run-7; only in Run-8,9
- Total luminosity written to tape 120 pb^{-1} and 70% beam polarization
- Physics:
  - Direct photon, photon+jet with Si VTX (run 8,9 ?)
  - Start of charm physics (?)
  - Muon trigger upgrade run-9 =>Exploratory W physics run-9 (?)
  - Charged and neutral pion production

- **When should we move to 500 GeV?**
  - Is W physics the only argument?
  - **Are there others?**

When should we move to 500 GeV?

- Since W physics at STAR & PHENIX need detector upgrades expected some time around 2009-10, people think of 500 GeV RHIC running ONLY after that, in the "RHIC-II" era
- For polarized gluon measurements, it is important to cover as wide an x- range as possible: the first moment is crucial, not just the value of $\Delta G/G$ at a fixed or narrow range of x.
- What do we do if in Run-5 we learnt that $A_{LL}(\pi^0)$ is zero or very small?
  - Do we try to make finer measurements at the same kinematics or should we go to lower-x?
    - Lower x => higher CM (500 GeV)
  - Assuming direct photon or photon+jet measurements would be the "in" thing at the time we see:

Direct photon A_{LL} 200 vs. 500 GeV



- 320 pb-1 and 800 pb-1 assumed for 200 and 500 GeV
- Polarization 70% at both CMs & no issues with the measurements
- Background levels low
- Relative luminosities issues under control

- Ratio of statistical uncertainty to the difference between different polarized gluon distribution scenarios favorable at 500 GeV at comparable pT of the direct photon.
- **200 GeV data only significant for Comparison with Heavy Ions?**

Summary

- Run 5 will make the first highly sensitive measurement of ΔG and will start exploratory measurements crucial for the rest of the Spin program
- Run 6 will focus mainly on direct photon physics and measure ΔG using this method along with significantly improved statistics in neutral and charged pions
- Runs 8,9 will consolidate the RHIC-I spin physics goals and embark up on the next phase: gamma-jet, charm and W physics
- If gluon distribution at intermediate to high x is low, it might be worth moving to 500 GeV RHIC running as early as Run 6

STAR
FY05 Beam Use Request
and
beyond

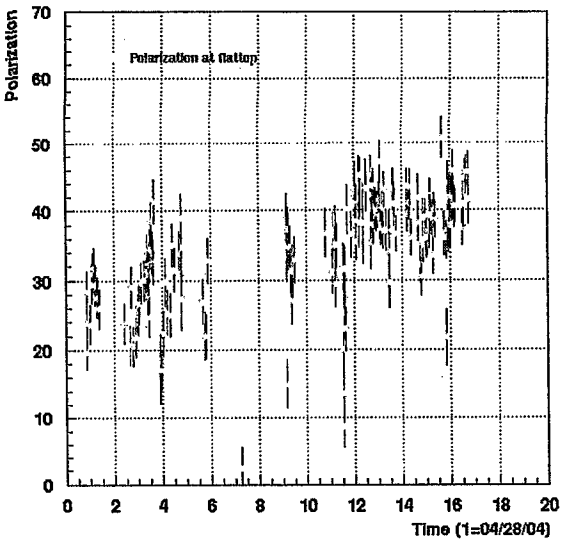
Bernd Surrow
MIT

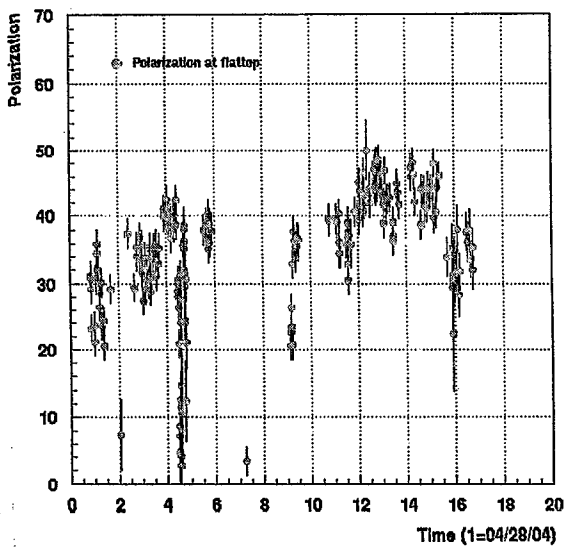
Guidelines on machine performance

- Machine performance overview (FY02-FY05)
  - Overview of performance parameter

	Bunch intensity [10^{11}]	# of bunches	Lpeak [10^{30}] cm^{-2} s^{-1}	Lavg [10^{33}] cm^{-2} s^{-1}	Lweek [pb^{-1}]	Polarization [%]
FY02	0.7	56	2	1.5	0.2	15
FY03	0.7	56	6	3	0.6	30
FY04	0.7	56	6	4	0.9	40
FY05	1.0	79	16	9	2.3	45

  - Status
    - ☑ Siberian snake and spin rotator magnets successfully commissioned
    - ☑ Fast polarimeters in AGS/RHIC demonstrated to work
    - ☑ Spin transfer AGS to RHIC demonstrated to work
    - ☑ Successful commissioning of polarized gas-jet target (Absolute beam polarization measurement!)
    - ☑ Successful installation and commissioning of warm AGS Siberian snake
    - ☐ Installation and commissioning of cold AGS Siberian snake magnet
    - ☐ Commissioning of 250GeV ramp





Beam polarization

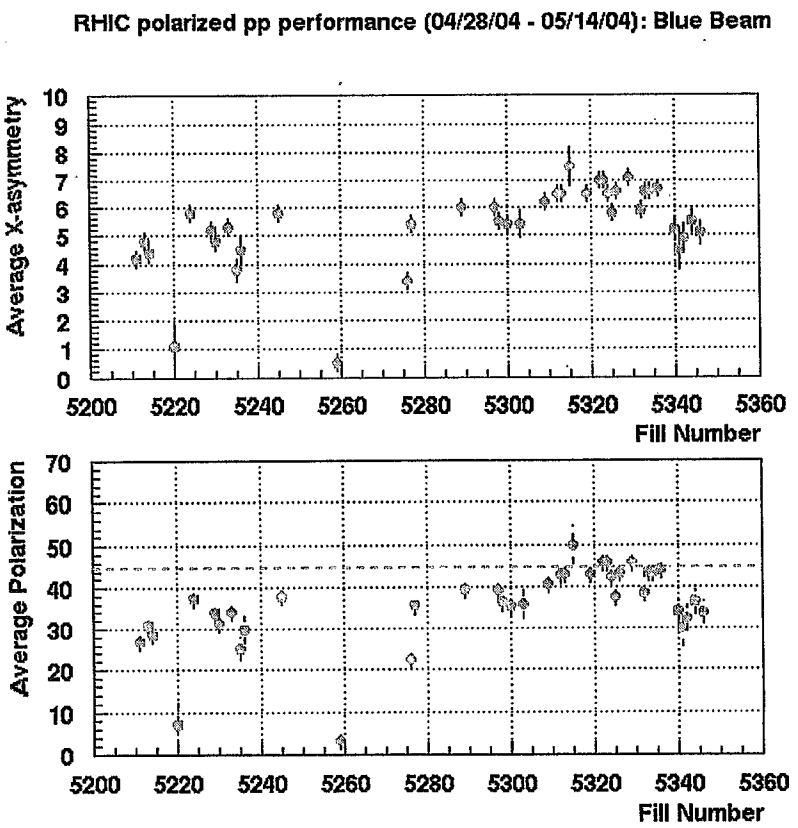
Blue and

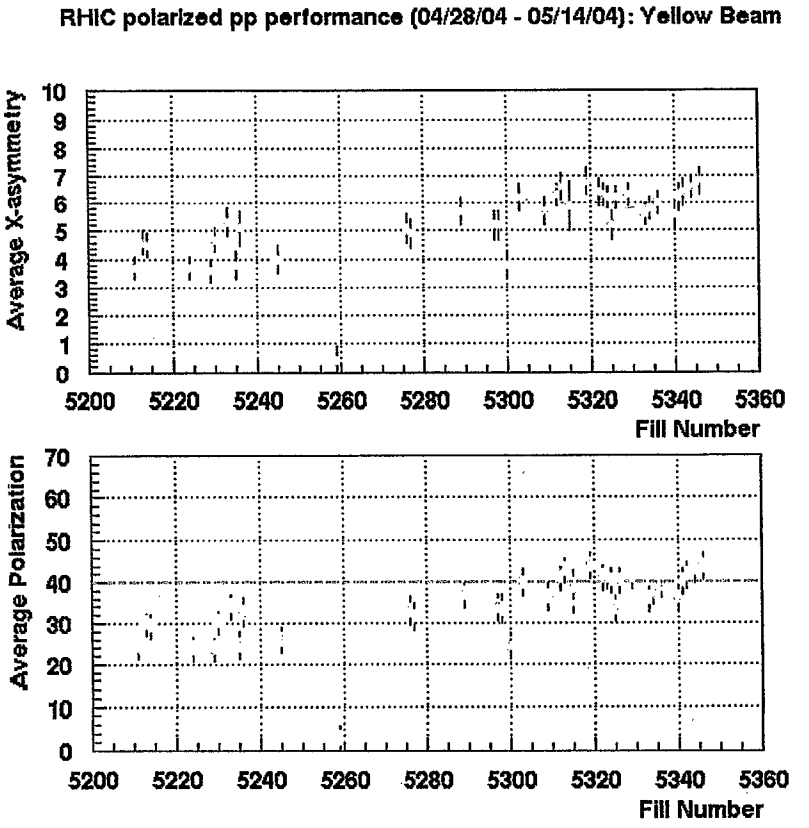
Adequate time for commissioning and luminosity development is absolutely essential!

Bernd Surrow

Guidelines on machine performance

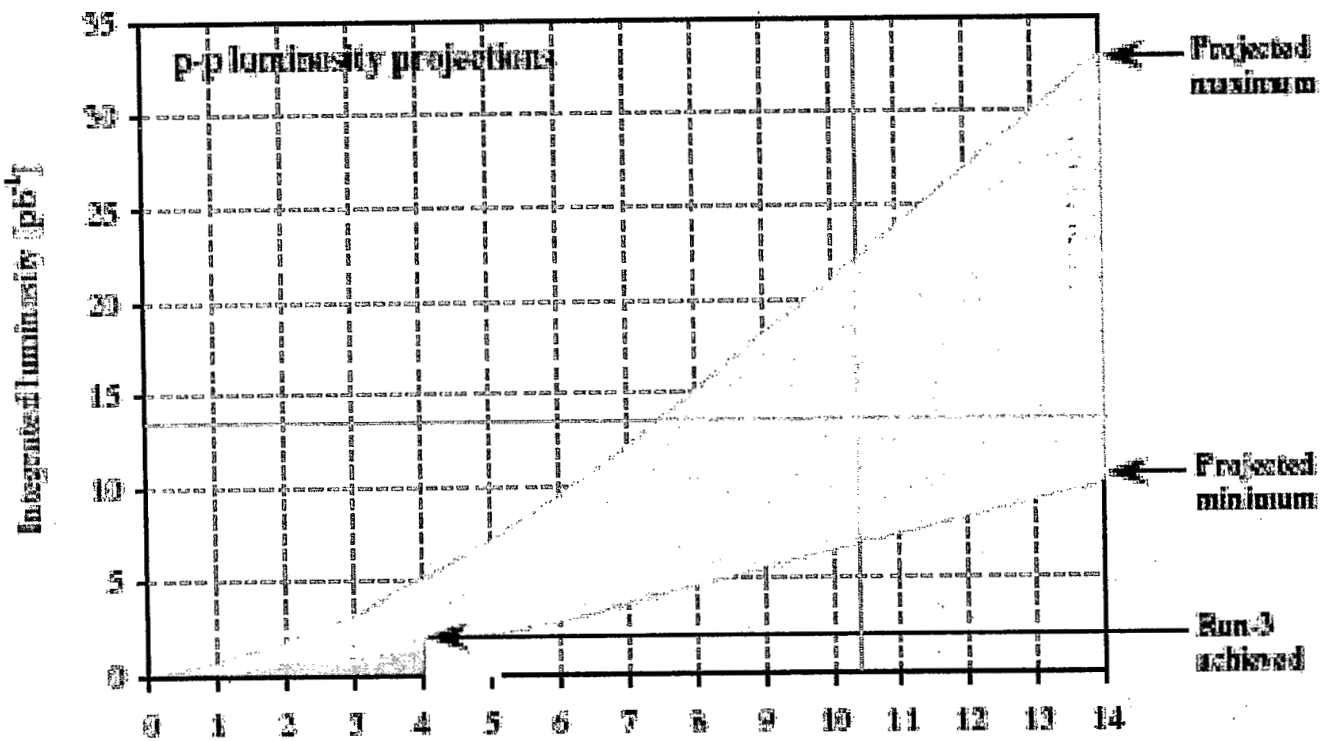
- Summary of achieved polarization performance in FY04





Expectations on RHIC performance

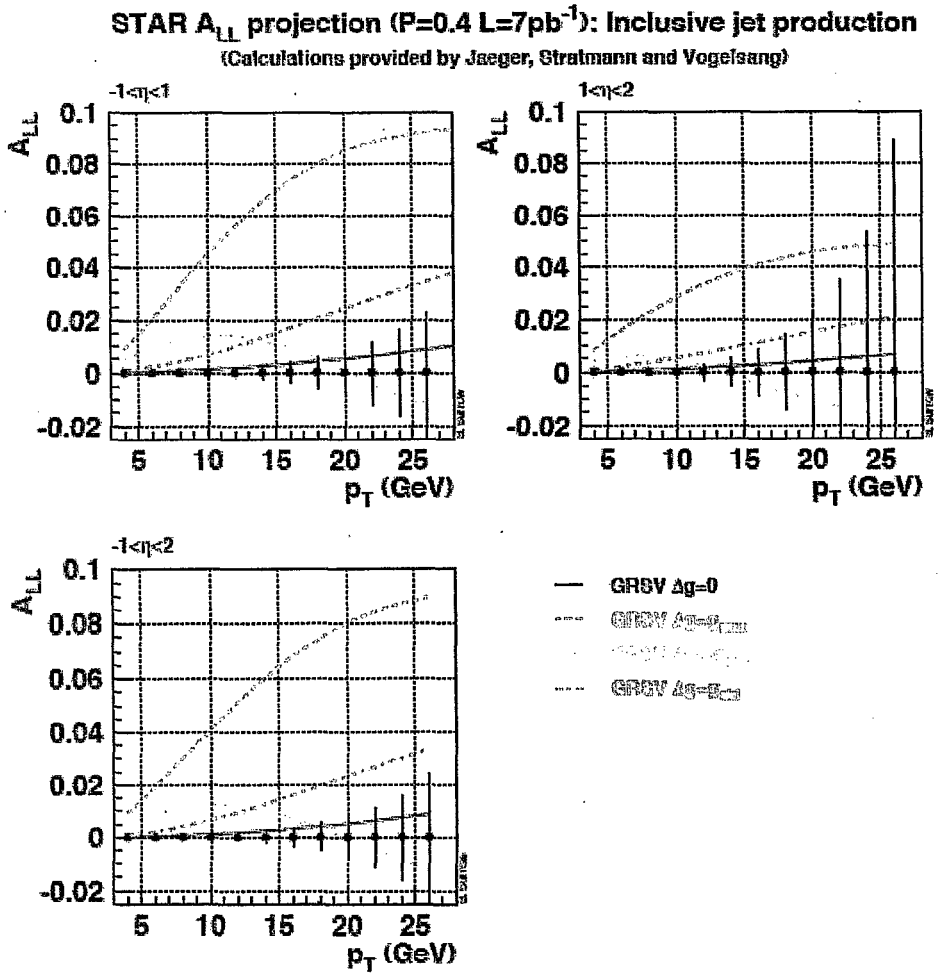
- Expectations for FY05

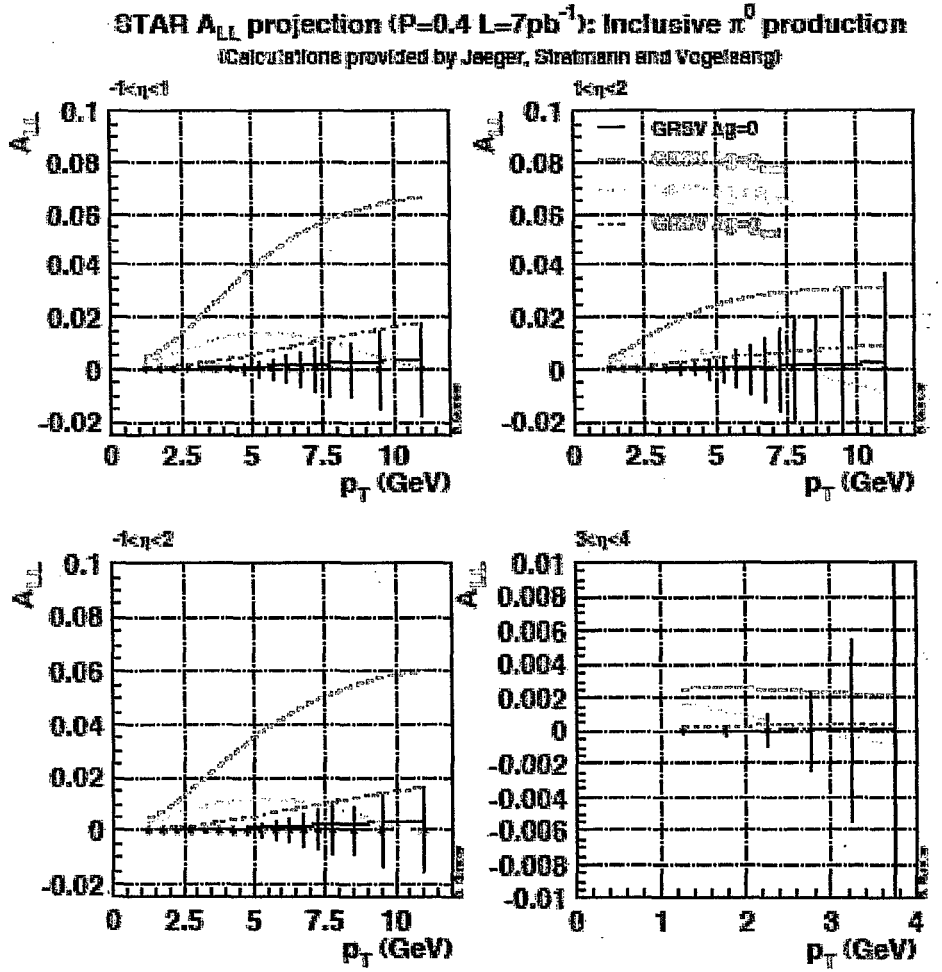


Overview of FY05 STAR SPIN BUR

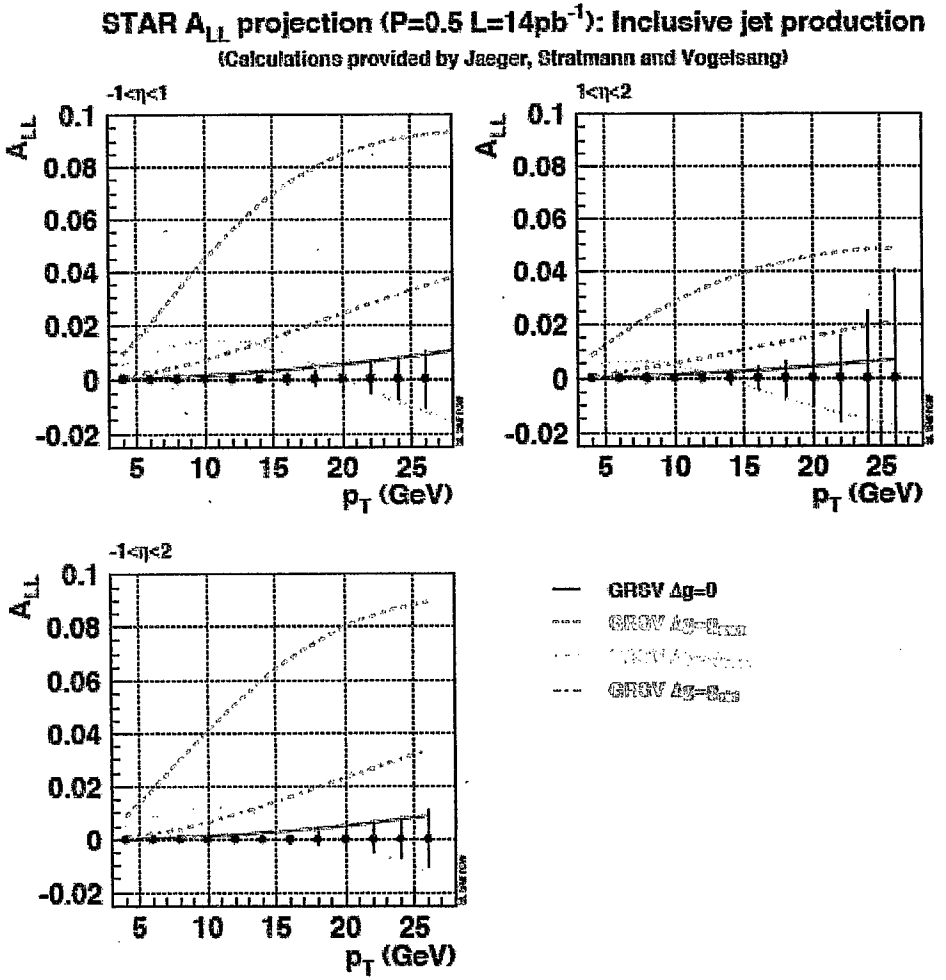
- Comments on FY05 polarized pp physics run request
  - 3+11 weeks (3 weeks setup and 11 weeks polarized pp collisions
  - Long polarized pp run is crucial to make significant progress on the RHIC performance
  - Physics goals:
    - Primary goal: Gluon contribution to proton spin (7 pb-1 at 40% beam polarization)
      - A_{LL} of π^0 production to p_T to ~8 GeV/c
      - A_{LL} of inclusive jet production to p_T to ~20 GeV/c
    - Secondary goals: Transverse spin phenomena, provided that 7pb^{-1} for the anticipated A_{LL} measurements can be achieved: Goal collect 4 pb-1 of transverse pp data
      - Measurements of transverse spin dependence of di-jet back-to-back correlations to the gluon Sivers functions
      - Analyzing power of forward π^0 production with the FPD besides BEMC/EEMC
  - Strongly endorse recommendation by C-AD
    - Polarized pp run should follow measurements with another species: Commissioning work of cold snake (Success of commissioning is not considered critical for the FY05 run)
    - Other critical tasks: Spin flipper commissioning and 250GeV ramp (Important for long-term spin program)

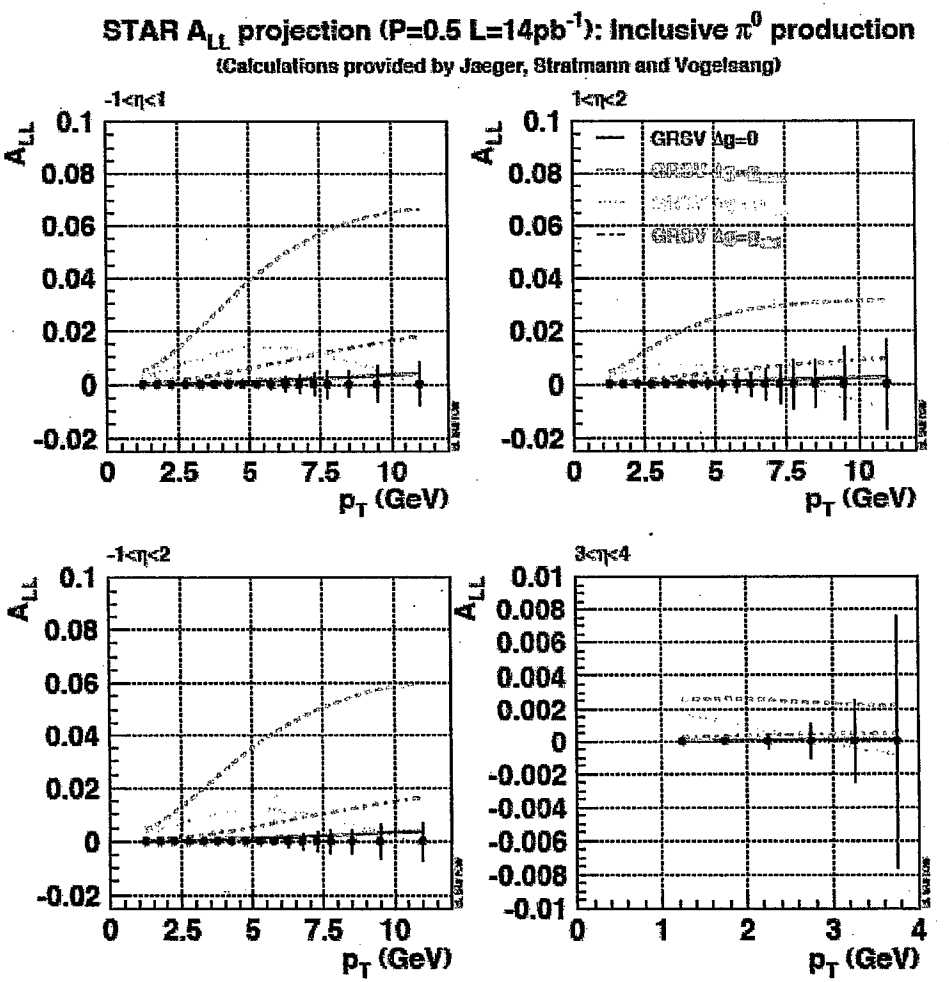
A_{LL} for inclusive jet and π^0 production



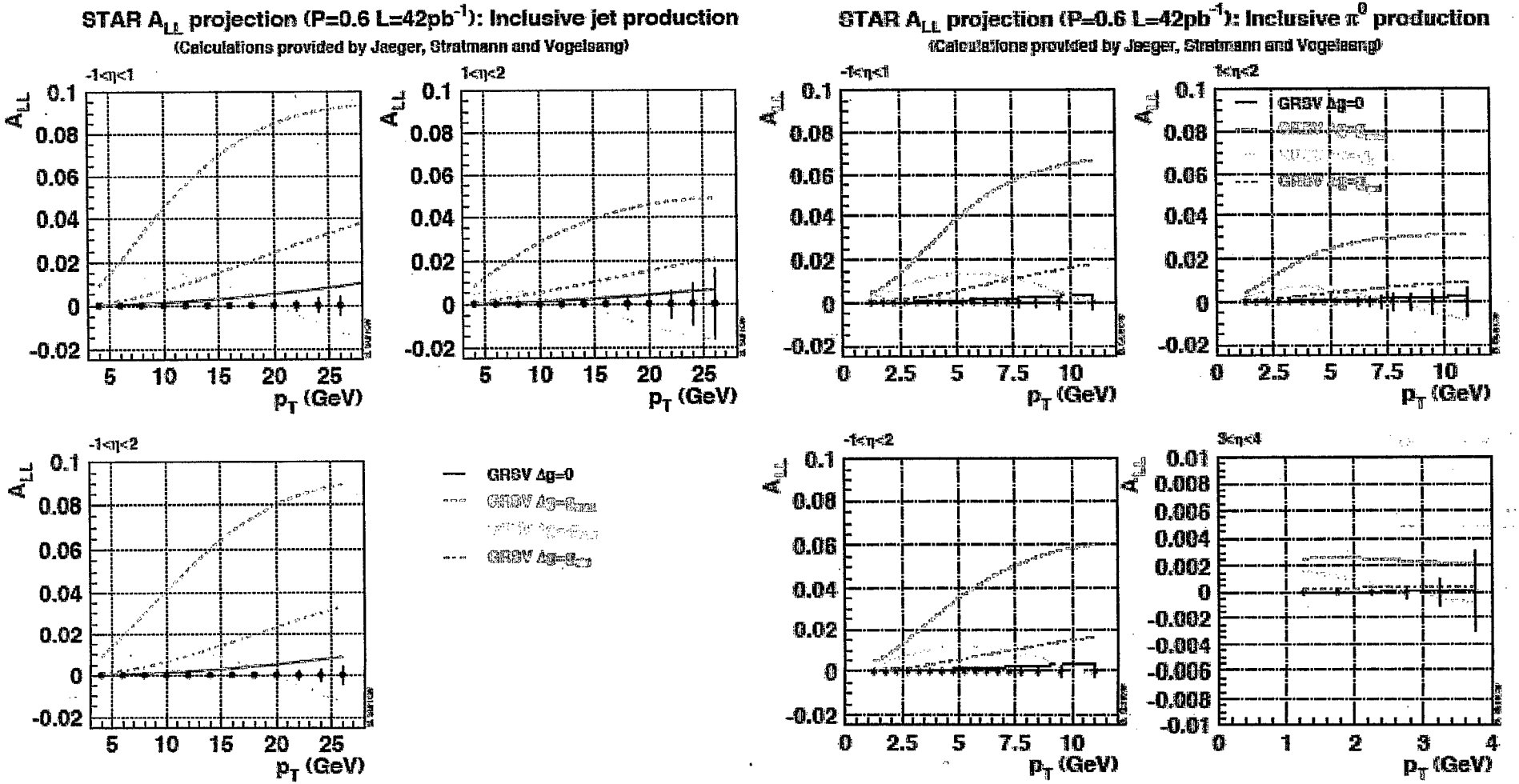


A_{LL} for inclusive jet and π^0 production





A_{LL} for inclusive jet and π^0 production



RHIC collider projections

- Expected RHIC pp performance FY05-FY08

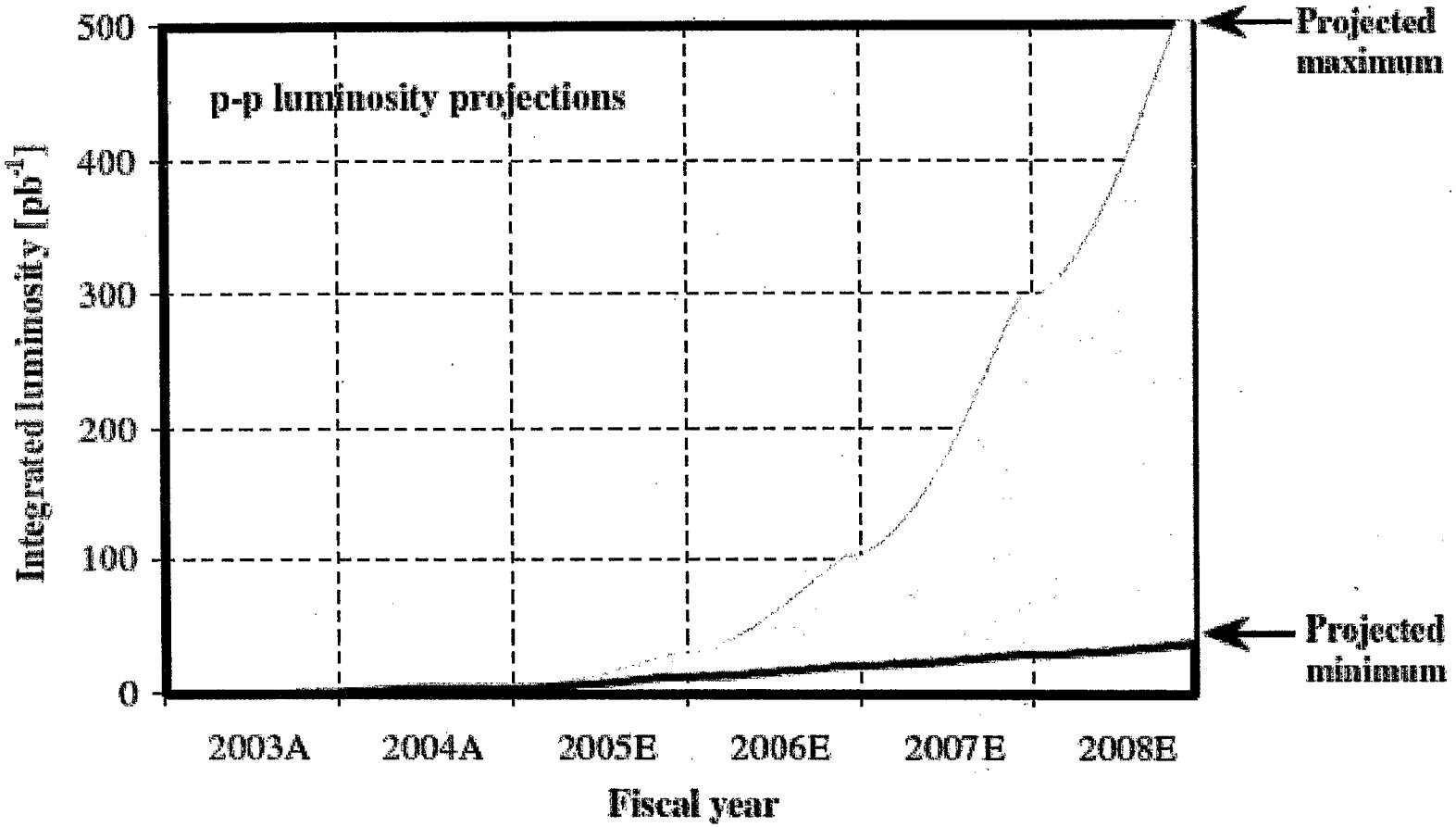
	Bunch intensity [10^{11}]	# of bunches	Lpeak [10^{30}] $cm^{-2}\ s^{-1}$	Lavg [10^{33}] $cm^{-2}\ s^{-1}$	Lweek [pb^{-1}]	Polarization [%]
FY05	1.0	79	16	9	2.8	45
FY06	1.4	79	31	22	7.1	65
FY07	2.0	112	80	64	21.6	70
FY08	2.0	112	89	72	26	70

- Essential upgrades and improvements of the RHIC polarized pp collider complex:
  - FY05
    - Survey and realignment
    - AGS cold snake commissioning
    - NEG coating 100m warm beam pipe sections
    - 250GeV ramp studies
  - FY06
    - AGS cold snake operational
    - More NEG coating
  - FY07
    - New solenoid for the polarized proton source OPPIS
  - FY08
    - First 250GeV polarized pp run (STAR 5-year BUR)
  - FY09
    - Potential first long 250GeV production run ? (Beyond STAR 5-year BUR)

Adequate time for commissioning and luminosity development is absolutely essential!

Expectations on RHIC performance

- Expectations for FY06 and beyond



STAR 5-year BUR

- STAR 5-year BUR (FY05-FY08): Twenty-Year Planning Study for RHIC at BNL

Fiscal Year	27 weeks/year BUP (submitted 8/03)		"Optimized Constant Effort" Scenario		32 weeks each year run scenario	
2004	5+14 Au+ Au 200	5+0 pp 200	5+14 Au+ Au 200	5+0 pp 200	5+14 Au+ Au 200	5+0 pp 200
2005	5+9 Au+ Au Escan	5+5 pp 200			6+8 Au+ Au Escan	5+10 pp 200
			6+11 Au+ Au Escan	5+12 pp 200		
2006	5+9 d+Au 200	5+5 pp 200			5+8 d+Au 200	5+11 pp 200
			5+9 d+Au 200	5+13 pp 200		
2007	5+5 Au+ Au 200	5+9 pp 200			5+10 Au+ Au 200	5+9 Cu+ Cu 200
			5+15 Au+ Au 200	5+8 Cu+ Cu 200		
2008	5+10 Au+ Au 200	5+5 pp 500			5+10 Au+ Au 200	5+9 pp 200
$\int L_{max}$ dt pp 200	76 pb^{-1}		88 pb^{-1}		156 pb^{-1}	
$\int L_{max}$ dt post-TOF Au+Au	1.4 nb^{-1}		1.6 nb^{-1}		2.1 nb^{-1}	
What's missing?	Any Cu+Cu 200; 2nd+3rd long pp		3rd long pp; 2 pp devel. chances		1 pp devel. chance	

BNL-71881-2003

Long-term physics goals such as: Prompt photon production and W production (500GeV running critical!)

Overview and timeline - STAR tracking upgrade

- Integrated Tracking upgrade
  - The study of heavy flavors and W production will require an upgrade of the STAR inner/forward tracking system
    - Integrated tracking design of a new inner and forward STAR tracking system is mandatory
    - Staging of tracking upgrade in accordance with readiness of detector technology and beam development
  - STAR tracking upgrade program actively pursued by several STAR institutions
  - STAR tracking upgrade working group
    - W physics case (Flavor structure of quark helicities)
    - Heavy flavor spin case under investigation (Strong dependence of partonic asymmetry on heavy quark mass- study of heavy flavor tagged jets): STAR Heavy flavor program driven by STAR's relativistic heavy-ion program
    - Simulation work and integrated design of detector layout based on pixel, silicon and triple-GEM technology (R&D work has been started) has been started
  - Possible scenario:
    - Stage 1: Installation of pixel detector together with a minimal new barrel tracking detector based on silicon technology ($-1 < \eta < 1$) (Heavy Flavor Physics)
      - Goal: Proposal by summer 2005
      - Installation of new inner tracking system in time for next long Au-Au run
    - Stage 2: Upgrade of the forward (inner silicon and outer GEM) tracking system ($1 < \eta < 2$) (W physics)
      - Goal: Proposal by summer 2006
      - Installation of forward system in time for 500GeV production run
  - Dedicated time for machine development with polarized protons to achieve high luminosity and high polarization is vital for the success of this novel program!

Documented in STAR decadal plan and AGS/RHIC PAC

Update on the H-Jet

(Discussion)

A. Nass, BNL

for

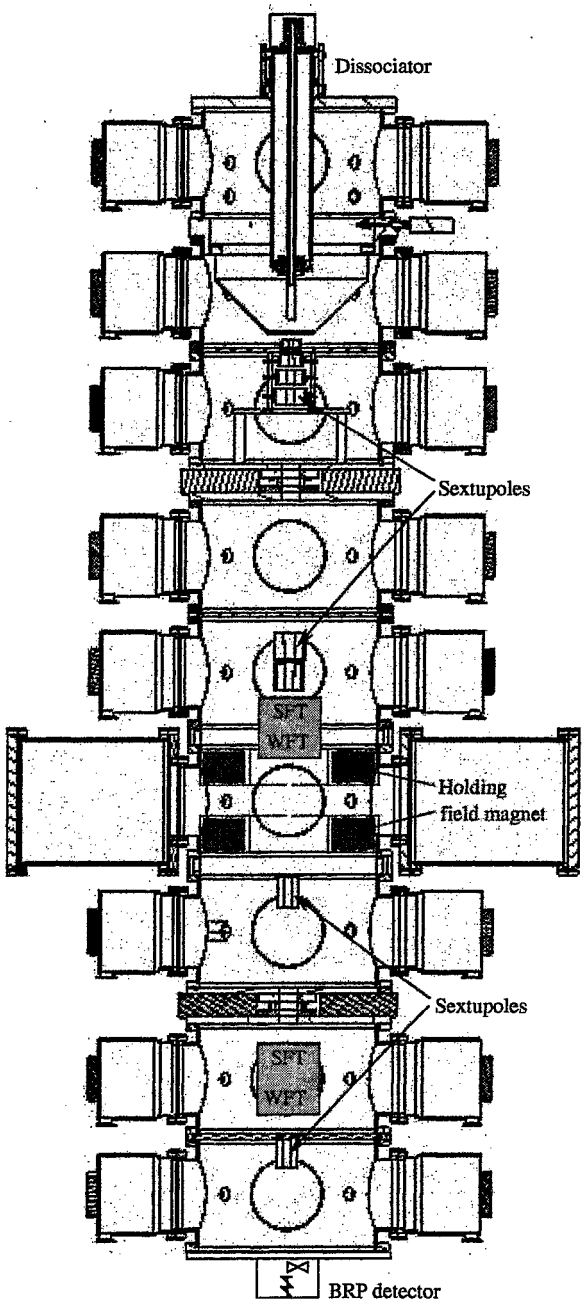
RHIC Spin Collaboration Meeting XXVII

July 22, 2004

RIKEN BNL Research Center

Update on the H-Jet

1. Polarization data for 2004 run
2. SFT slow turn on fixed
3. Plans for TOF measurement



Alexander Nass, Brookhaven National Laboratory July 22nd 2004

Atomic polarization data

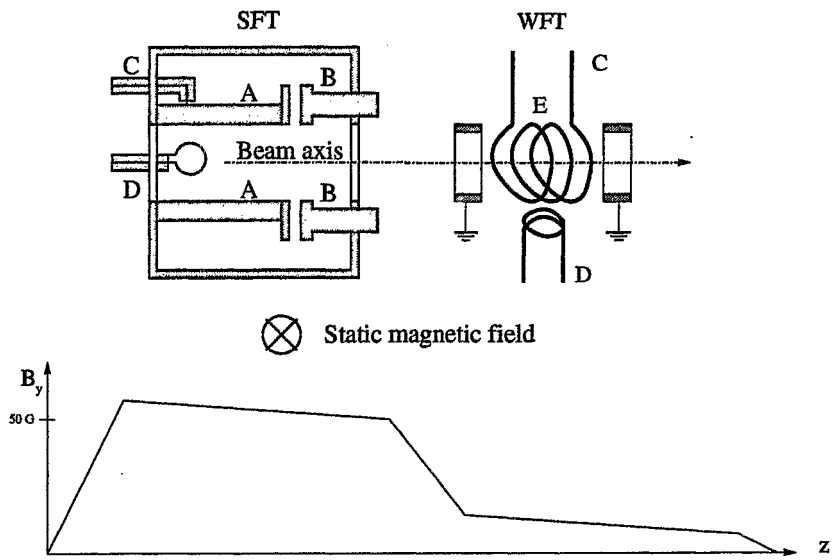
Day	B	avg.rates +	avg.rates -	avg.rates 0	Pol.+	Pol -
April 26	N	10490±1	10436±1	56.9±0.2	+95.70	-95.91
April 27	N	10526±0.4	10469±0.4	55.9±0.1	+95.69	-95.93
April 28	N	10180±1	10134±1	54.1±0.2	+95.73	-95.89
April 29	N	9716±1	9656±1	51.5±0.1	+95.66	-95.97
April 30	N	10056±0.8	9999.6±0.8	50.7±0.1	+95.70	-95.96
May 1	N	10169±0.3	10119±0.3	50.7±0.1	+95.73	-95.92
May 2	N	10345±0.5	10288±0.5	53.0±0.1	+95.70	-95.96
May 4	R	9251.5±0.5	9232.0±0.5	54.3±0.1	+95.82	-95.74
May 5	R	10602±0.7	10568±0.7	55.7±0.1	+95.80	-95.82
May 5	N	10791±0.6	10755±0.6	51.5±0.1	+95.81	-95.85
May 6	N	8388.8±0.5	8355.4±0.5	39.9±1	+95.78	-95.89
May 7	N	8971.3±0.6	8897.1±0.6	40.2±0.1	?	?
8am to 4pm, instable behaviour of SFT						
Corrected		8971.3±0.6	8897.1±0.6	74.2±0.1	+95.42	-95.93
May 7	N	9141.5±0.5	9110.3±0.5	47.6±0.1	+95.79	-95.84
after 4pm, stable behaviour SFT, everything OK						
May 8	N	9394.1±0.5	9350.9±0.5	47.2±1	+95.74	-95.91
May 9	N	9205.3±0.5	9171.4±0.5	47.1±0.1	+95.78	-95.86
May 10	N	9677.0±0.4	9635.5±0.4	47.6±0.1	+95.76	-95.90
May 11	N	10133±0.4	10084±0.4	46.4±0.1	+95.75	-95.94
don't use data between 12:00 and 16:30 (2 programs running)						
May 12	N	10435±0.4	10390±0.4	47.6±0.1	+95.78	-95.91
May 13	N	10838±0.4	10791±0.4	48.1±0.1	+95.78	-95.92
May 14	N	11196±0.6	11151±0.6	49.1±0.1	+95.80	-95.90

Mean values:

+95.73±0.05/-95.91±0.03 (April 26-May 14, normal field direction)
+95.81±0.01/-95.78±0.05 (May 4-May 5, reversed field direction)

Alexander Nass, Brookhaven National Laboratory July 22nd 2004

Slow turn on of SFT



- High frequency transitions used to exchange occupation numbers of the atomic hydrogen states.
  ⇒ Nuclear polarization
- Problem: Slow start up (up to 10s) of the strong field transition caused by creating short living plasma in cavity.
- Creation of the plasma depends on surrounding magnetic fields, gas density and RF-power.
- Rise time of RF-power shortend after using RF-switch, but problem still occured.
- Too many magnetic fields (static, gradient, main target field) to puls.

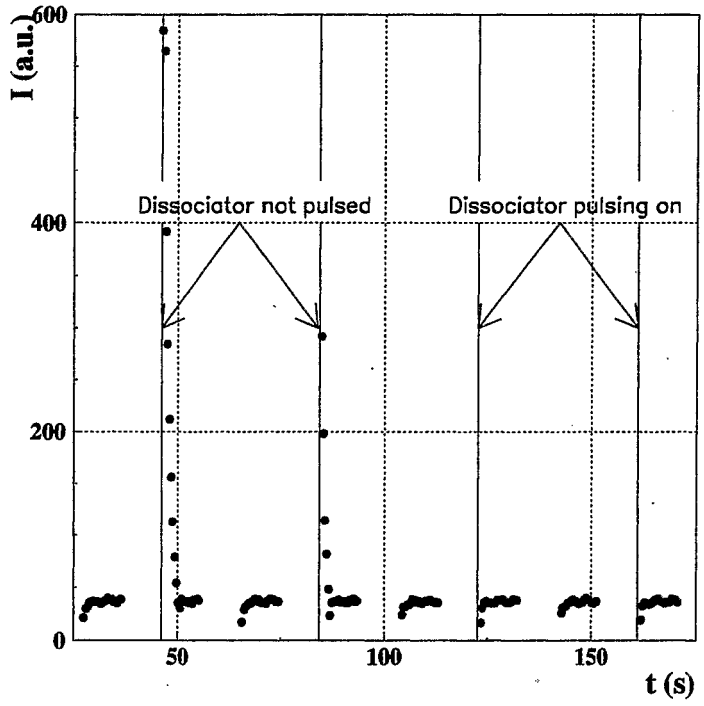
Solving the problem

Switching off the dissociator for 10 ms before turning on the SFT.

⇒ Gas density reduced in the cavity.

⇒ Plasma creation suppressed.

Deadtime should be as small as possible but longer than the drift time of the atoms from dissociator to cavity (2ms)



Lines denote when SFT is turned on.

Plan for TOF Measurement

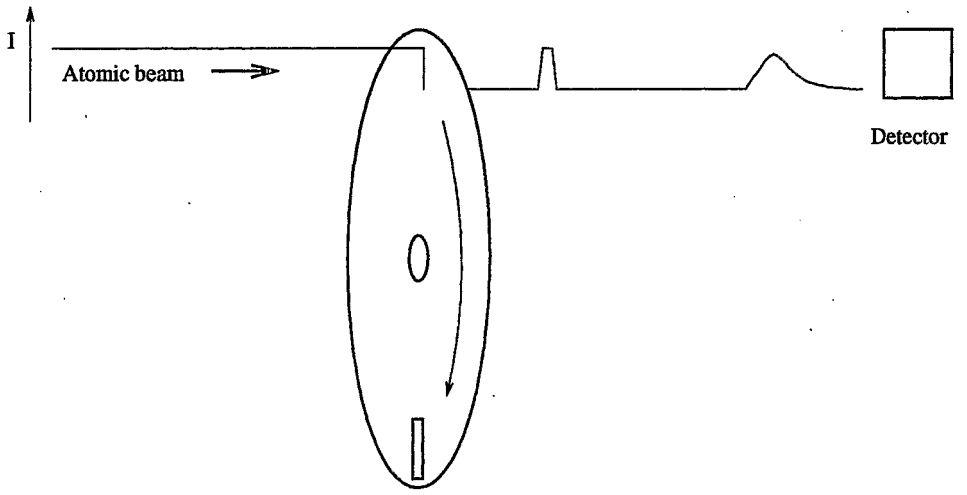
- Recent TOF measurements done using a high frequency transition and BRP.

  But: Velocity distribution was altered by the sextupole system of the BRP.
  ⇒ No clear information about velocity at IP.

- New plan includes insertion of a fast chopper (300 Hz) in chamber #4 and measurement of the TOF distribution at the IP.

  ⇒ Direct measurement of the velocity distribution at the IP.

  ⇒ Exact determination of the target density.



H-jet problems and plans

A. Zelenski

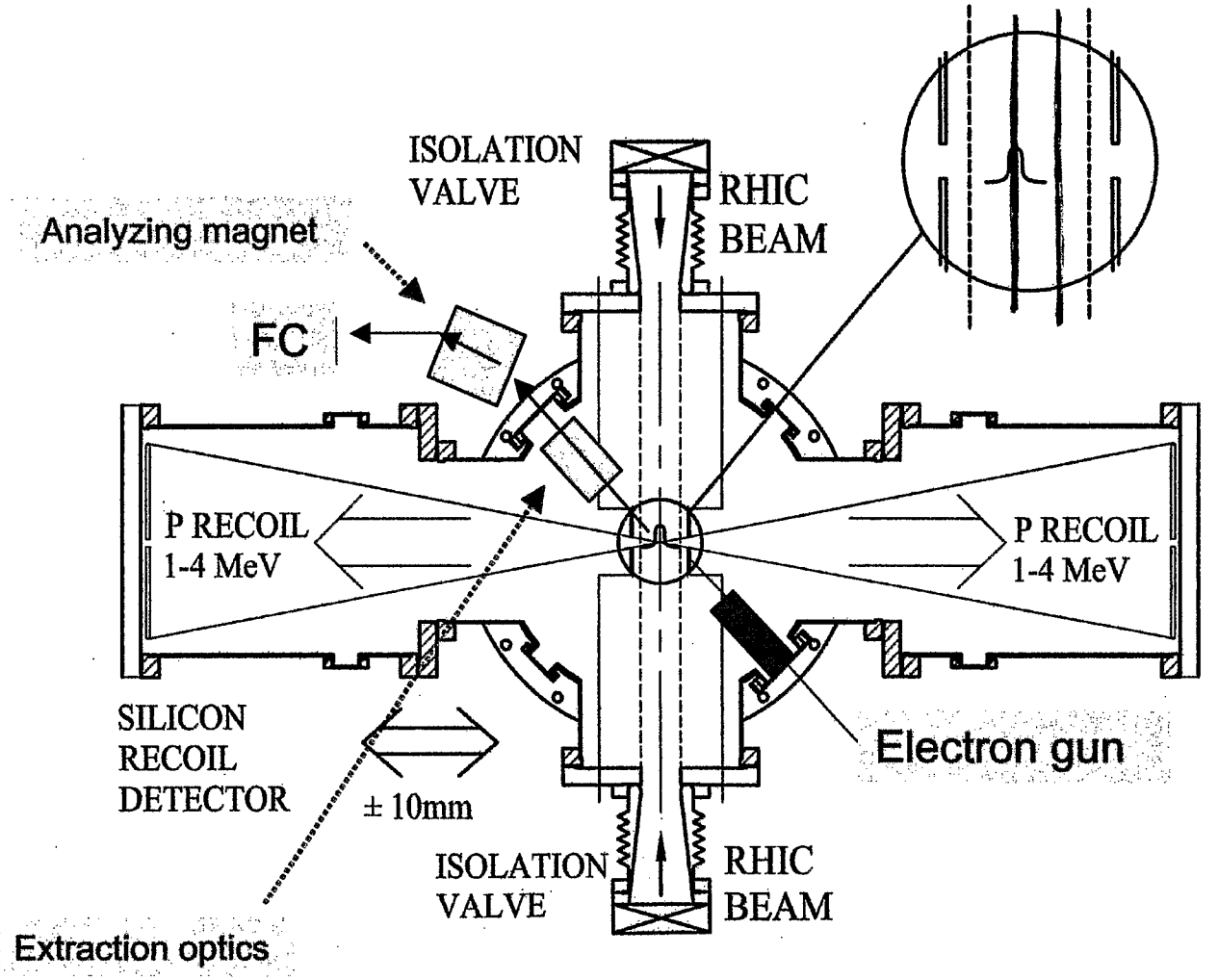
RSC meeting July 22, 2004

Problems.

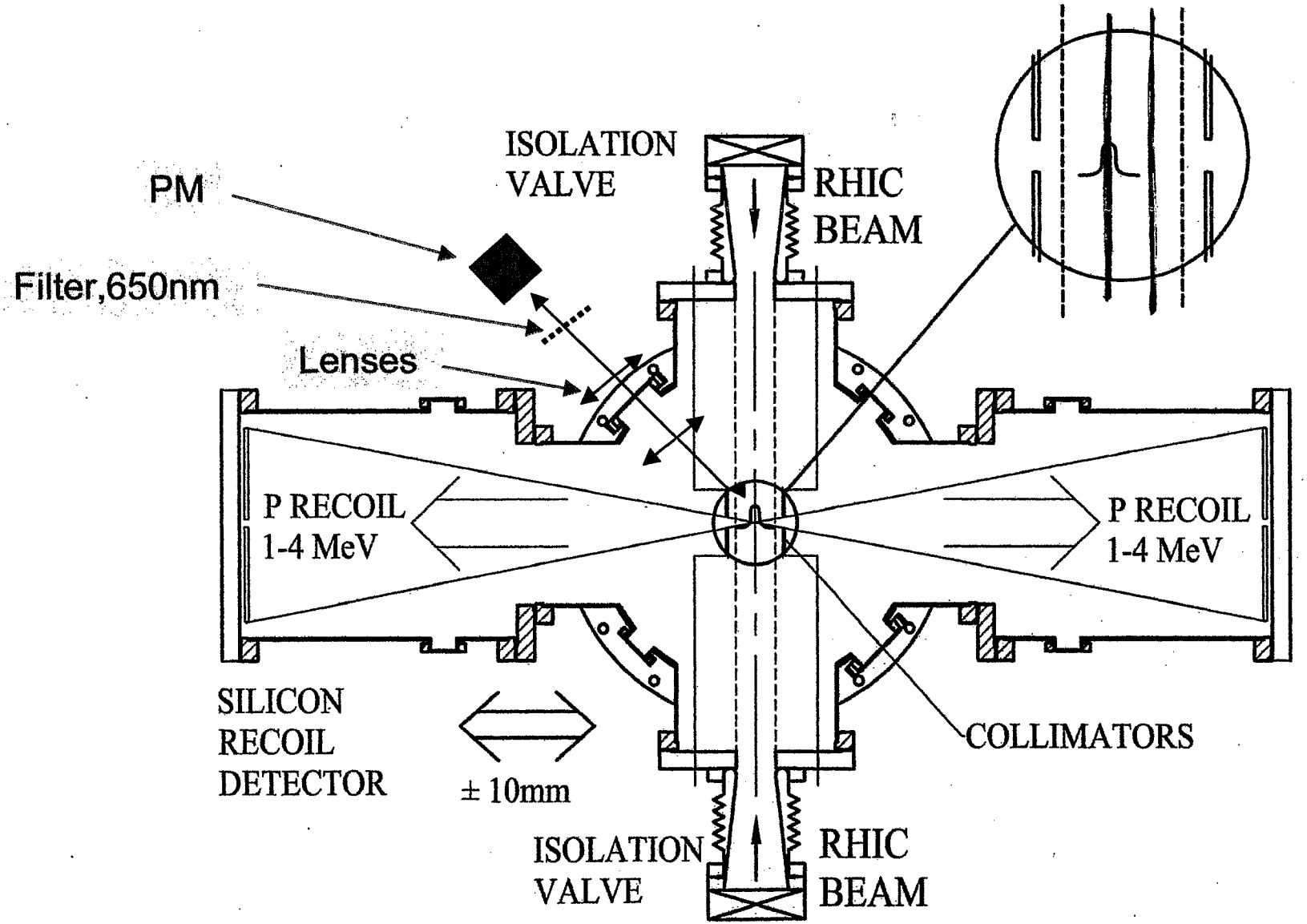
- Turbomolecular pump failures.
- Frequent dissociator maintenance.

- Plans.
- Improve dissociator operation stability and lifetime between services..
- Measure atomic beam velocity to get a better accuracy for the target thickness.
- Develop diagnostics devices for molecular hydrogen component measurements.

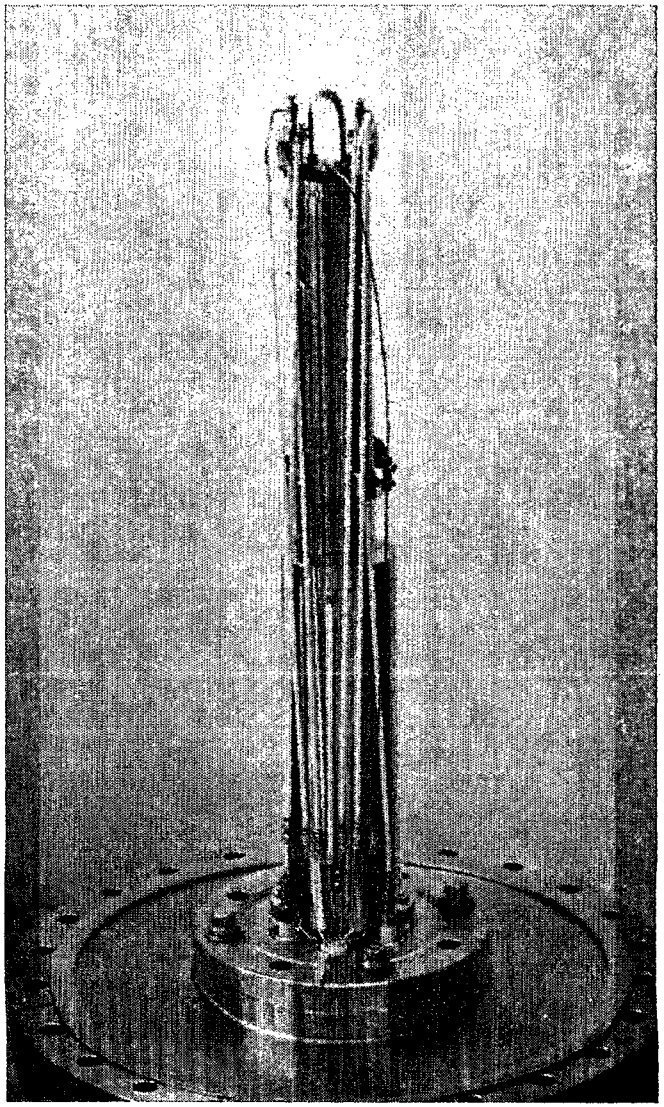
H-JET POLARIMETER SCATTERING CHAMBER

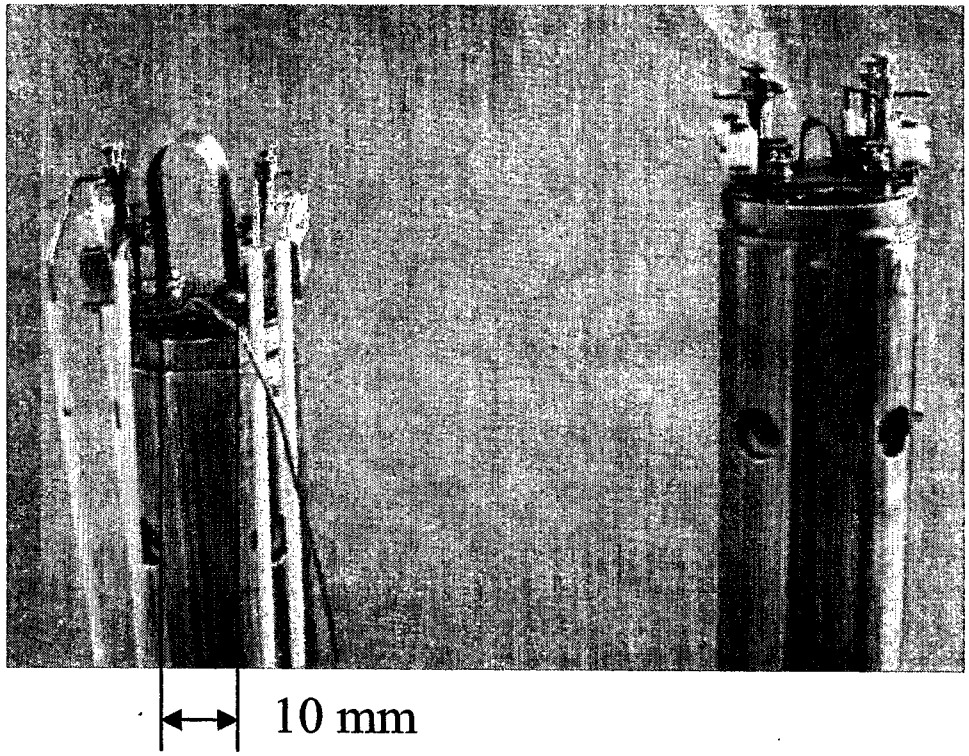


H-JET POLARIMETER SCATTERING CHAMBER



QMA upgrade for H-jet measurements.

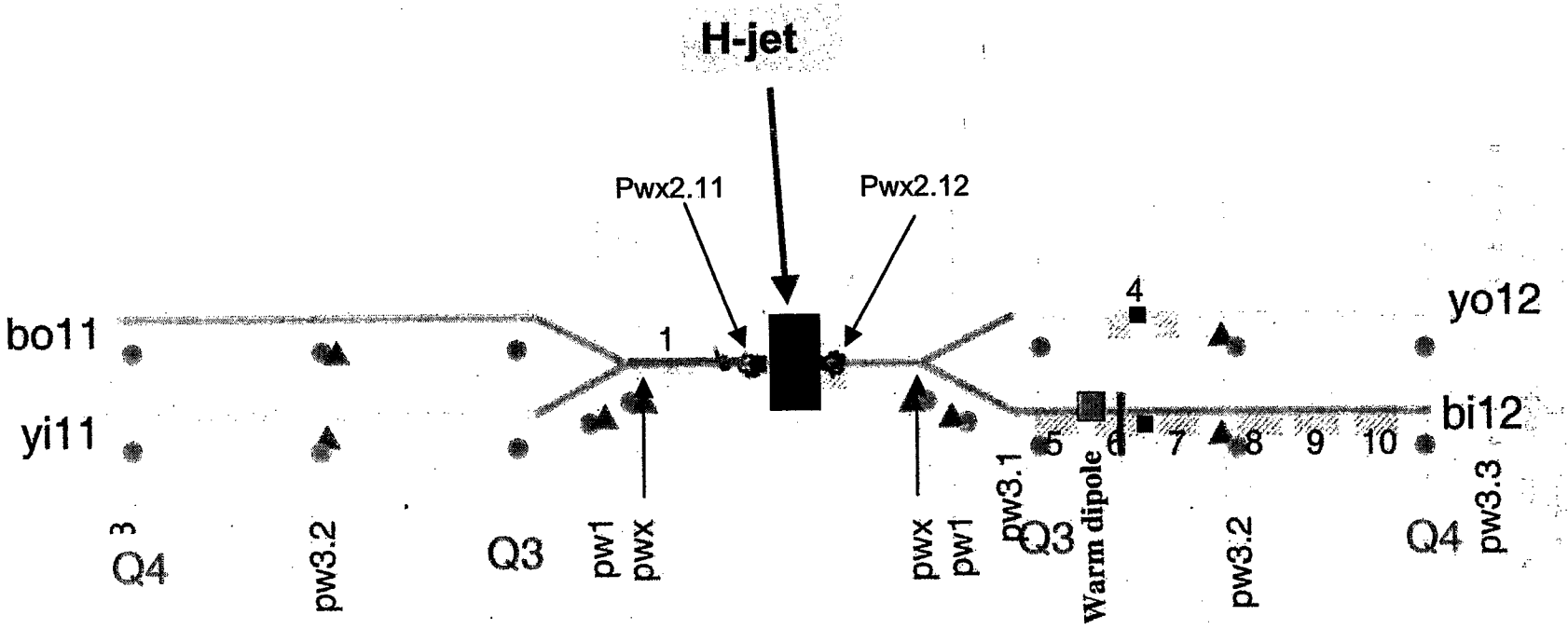




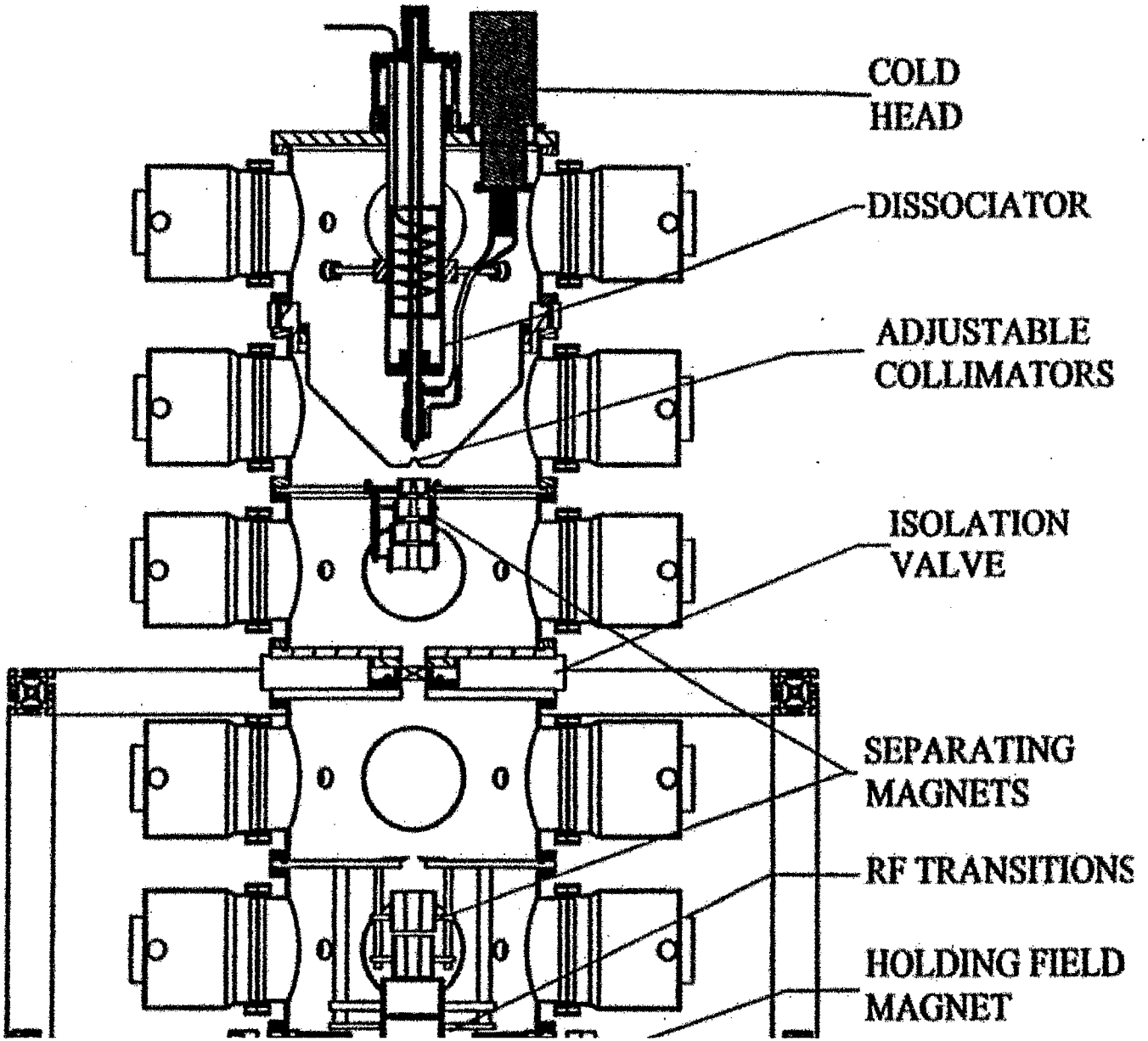
Original QMA geometry (right)

Expanded QMA sensitive volume (left)

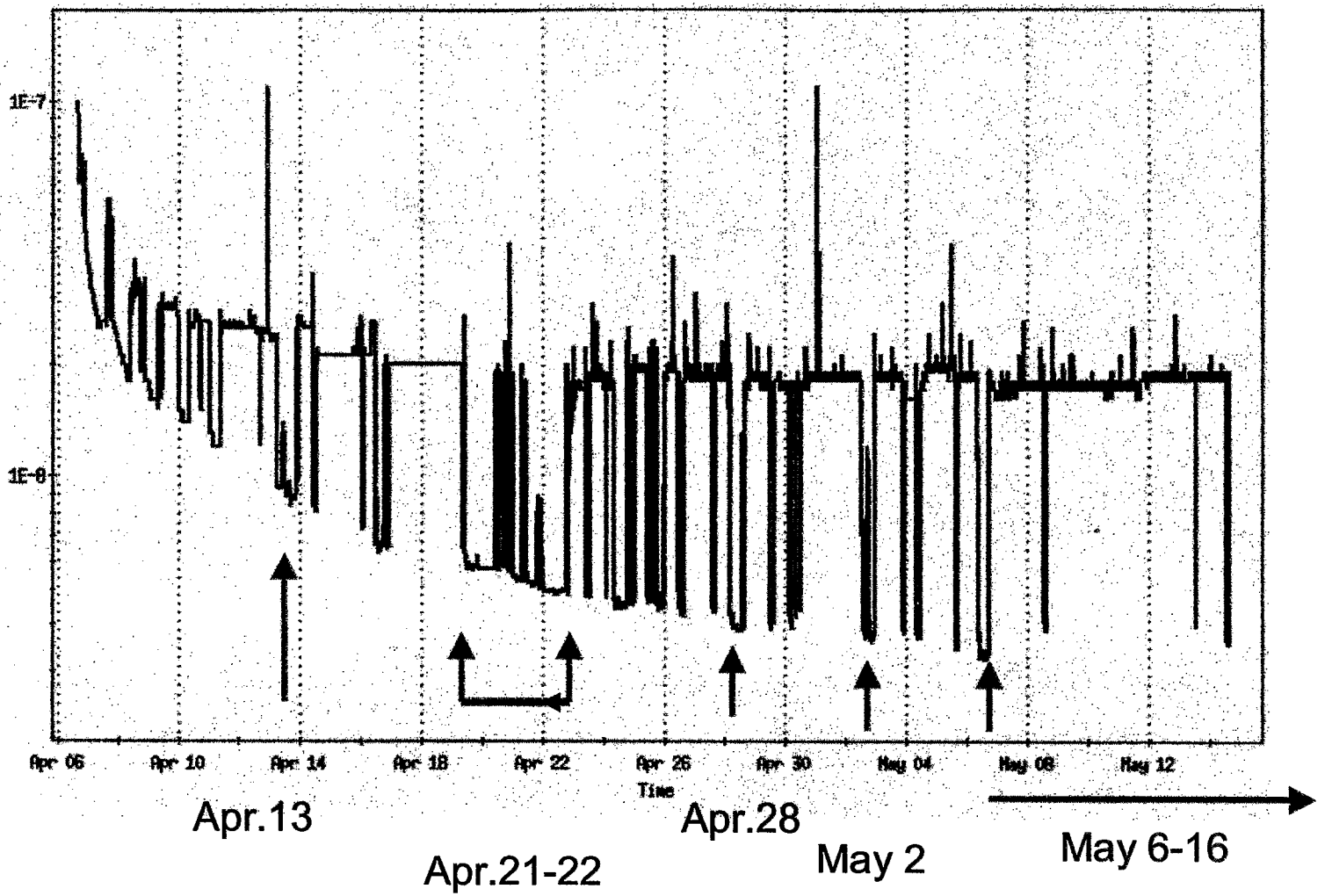
IR 12-vacuum schematic diagram



Dissociator maintanence



H-jet operation April 6 – May 14



RHIC Polarimetry

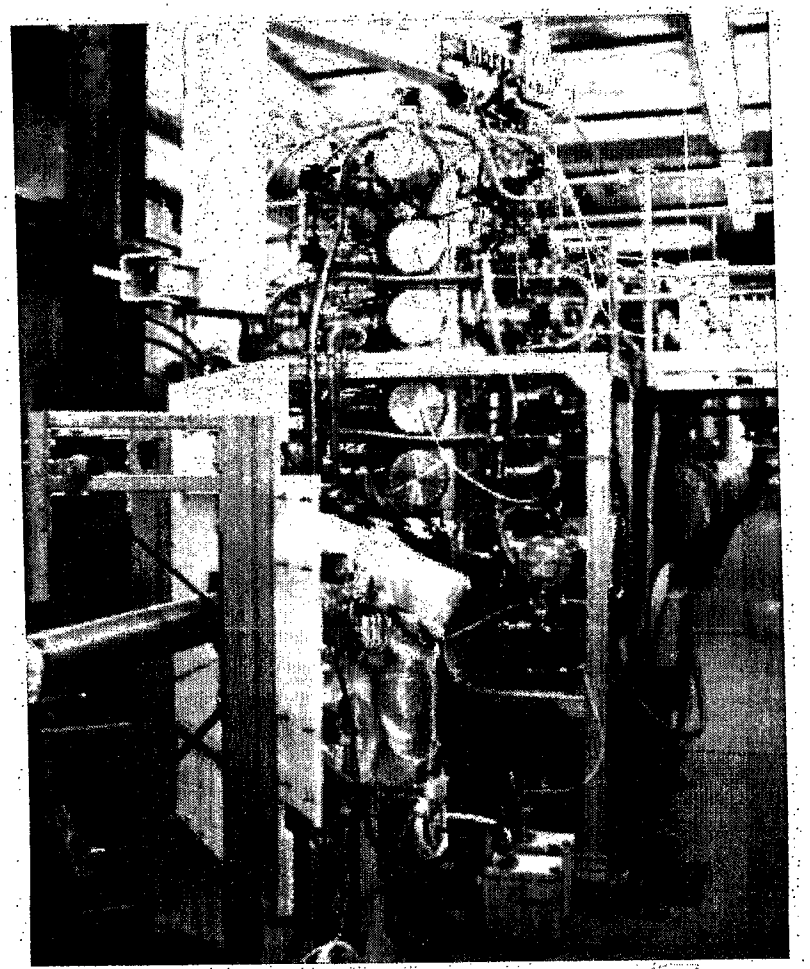
Status of Polarimeters

Progress during 2004

Plans for 2005

Analysis of JET and RHIC *pC*

Where do we stand and what next



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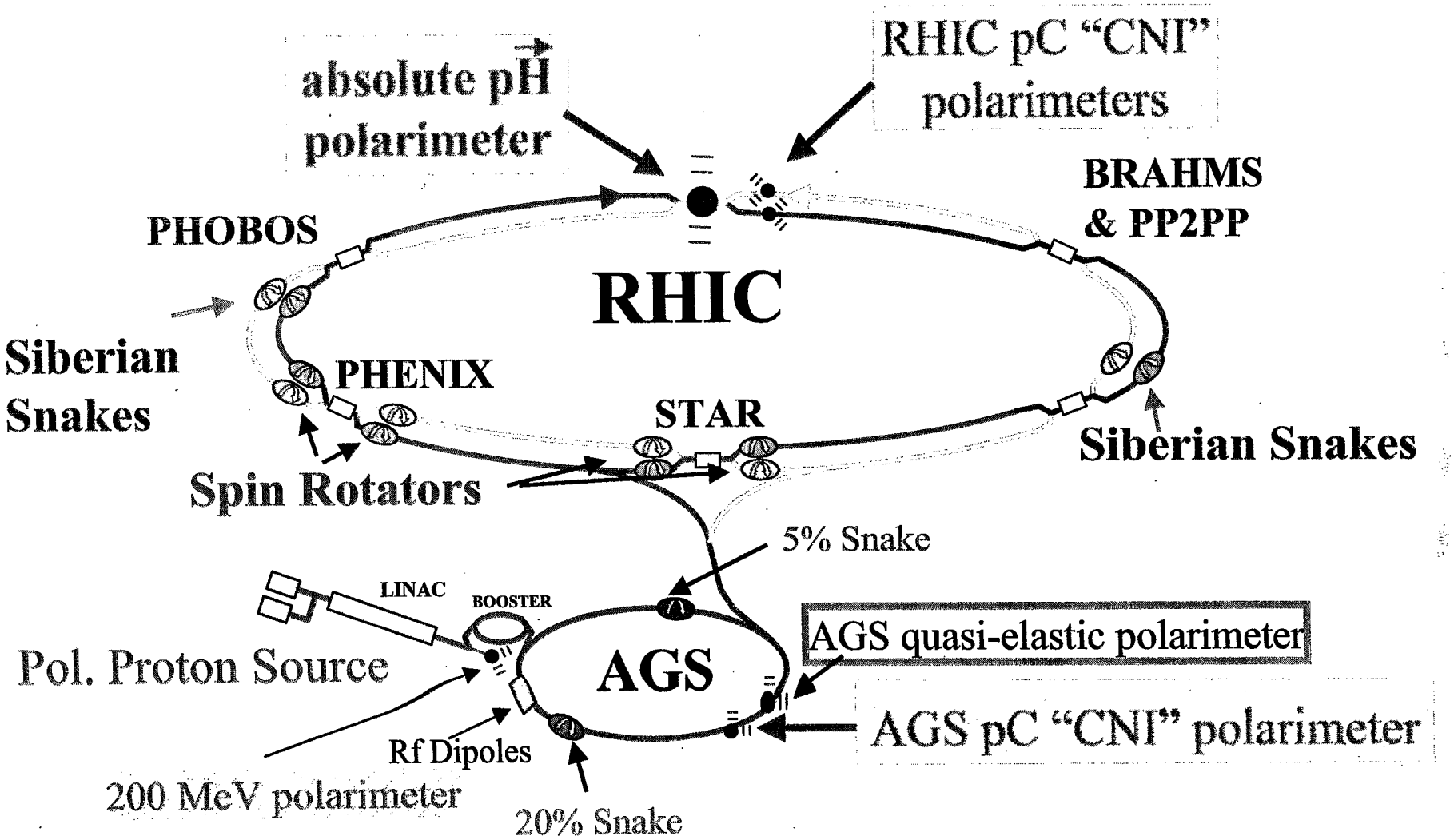
Alessandro Bravar et al.

RSC meeting, July 22 '04

RHIC *pp* accelerator complex & Polarimeters



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AGS *pC* polarimeter

- No more beam induced pickups !
  - solved all intensity related issues
  - works reliably up to and above 2×10^{11} p / bunch

- Further developments in parallel with RHIC *pC* upgrades
  - faster DAQ
  - automated calibrations
  - computer controlled Power Supplies
- 45^0 detectors ?
  - in principle ready, need more electronics
- Pending issues to be solved before next run: TARGET !
  - target position
  - polarimeter chamber alignment w.r.t. beam

- Otherwise, ready to restart operations anytime (few days to warm up)

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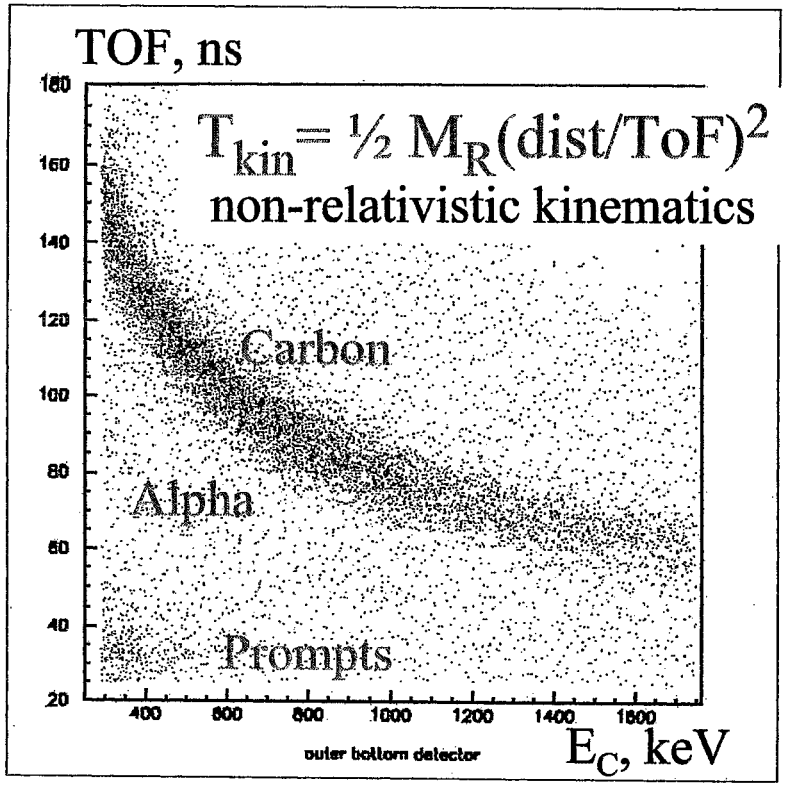
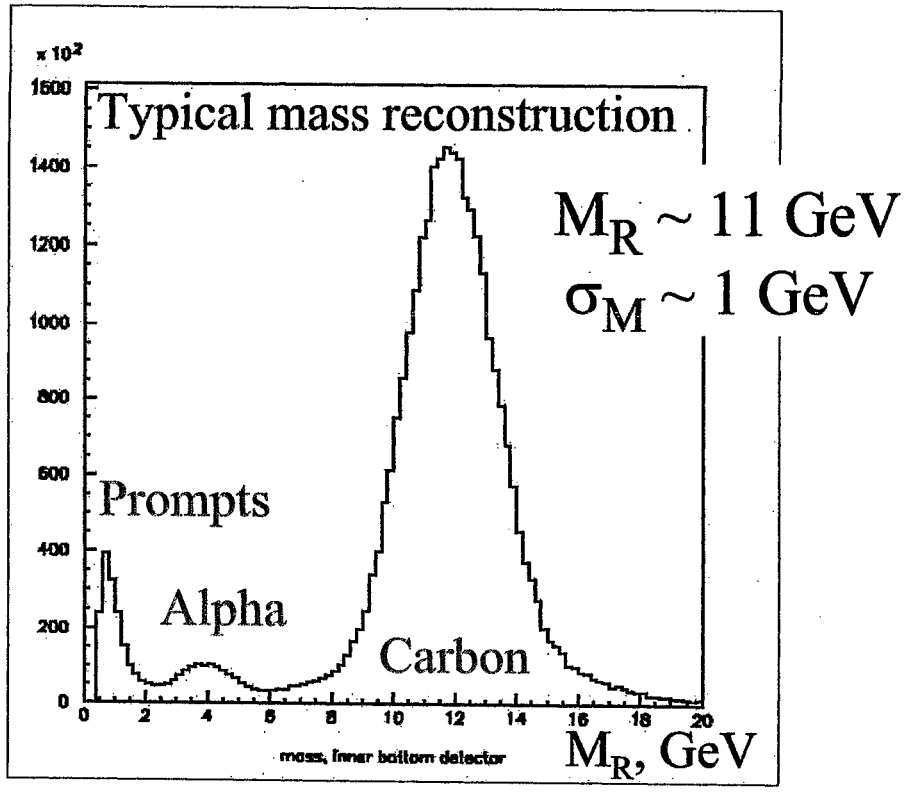
Performance





- Very clean data
- Good separation of recoil carbon from α ($C^* \rightarrow \alpha + X$) and prompts
  very low background, may allow going to very high $|t|$ values
- Low χ^2 of sequential measurements – stable operation

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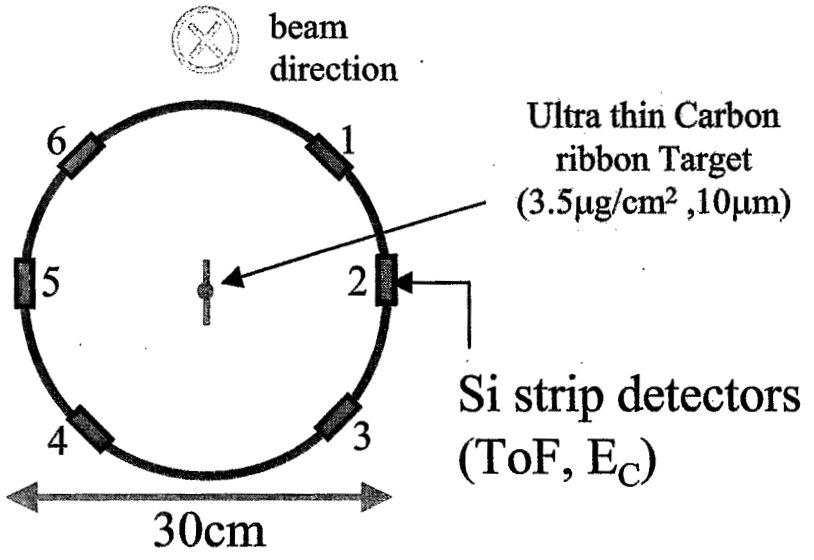
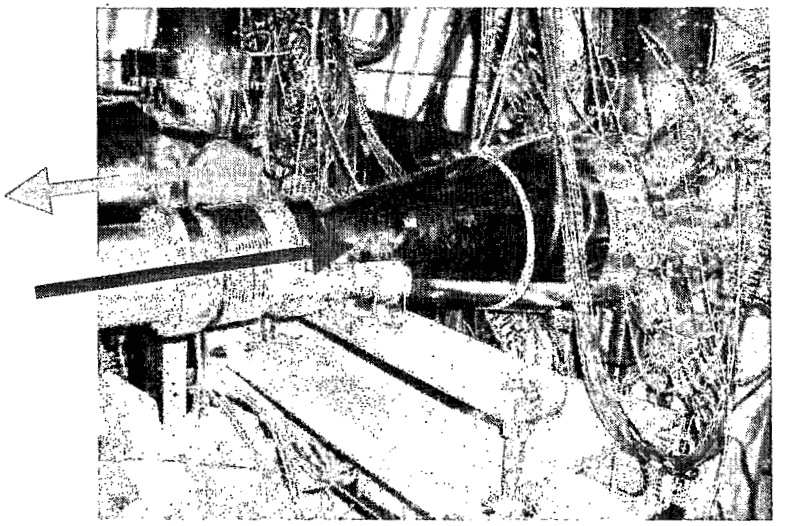
RHIC *pC* Polarimeters



RHIC × 2 rings

inside RHIC ring @IP12



- 2 × 72 channels read out with Wave Form Digitizers (2 × 48 in 2003)
- very large statistics per measurement (~ 20 × 10^6 events) → detailed analysis
  - bunch by bunch analysis
  - channel by channel (each channel is an "independent polarimeter")
  - 45° detectors: sensitive to vertical and radial components of $\vec{P}_{beam}$
    → unphysical asymmetries

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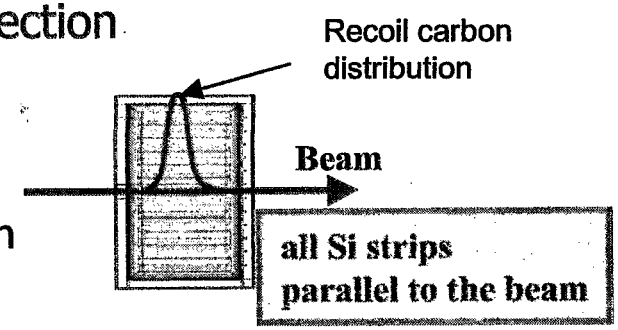
New ++ features from Run-04

- All Si detectors (strips) now parallel to the beam direction



- Readout all 72 strips (48 strips in Run-03)
  - approximately double the acceptance
  - no direct information about longitudinal target position
- Additional information : revolution numbers
  → event builder
  - complete time stamp for each event
  - although independent, all channels can be correlated
- Lowered the Carbon energy threshold to get better dP/P (400keV → 320keV)
  - A_N=0.016, Nev=20M → dP=1.4% (in Run-03: 2.0%)
  - however smaller signals !
    & more sensitive on dead layer correction !
- Several minor improvements on electronics
  → Very stable operation / performance during the whole run
- Several ramp measurements
- Spin tune measurements

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pC Polarimeter systematic issues

- calibration only at 22 GeV to ± 30%
  assume: A_N (E950) = A_N (24.3 GeV) = A_N (100 GeV)
  soon will have absolute calibration from JET target
- observed systematic error of relative measurements to $\Delta P = \pm 3\%$
- during '04 run very stable operation
  - effective A_N for each measurement very stable and around 1.5 %
  - very low backgrounds
- energy scale
  - dead layer energy correction
    small change → small change in |t| → significant change in $A_N(t)$
  - however radiation damage not an issue
- beam wake fields induced pickups
  - solved in AGS, will be implemented in RHIC for '05 run
- beam polarization profile
  - the *pC* CNI polarimeter sees only the beam center while the experiments & JET integrate over the whole profile

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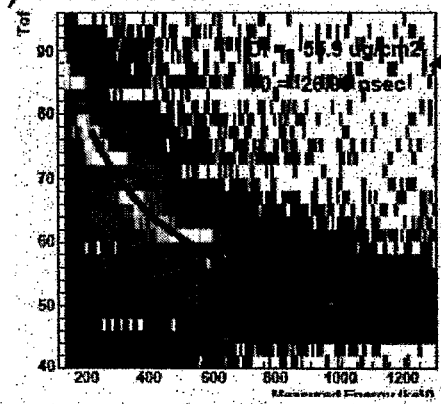
Update on Si dead layer

Osamu

Si dead layer is estimated by kinematic fit (2parameters) to carbon locus
Energy scale set by AM α source
A run with low bunch intensity (~0.1x10^{11}/bunch) was used

$$Tof(ns) = \sqrt{\frac{M_C}{2}\frac{Distance}{\sqrt{E_{elastic}}}} + t_0$$

$$E_{elastic} = f(E_{deposit}, D_{width})$$

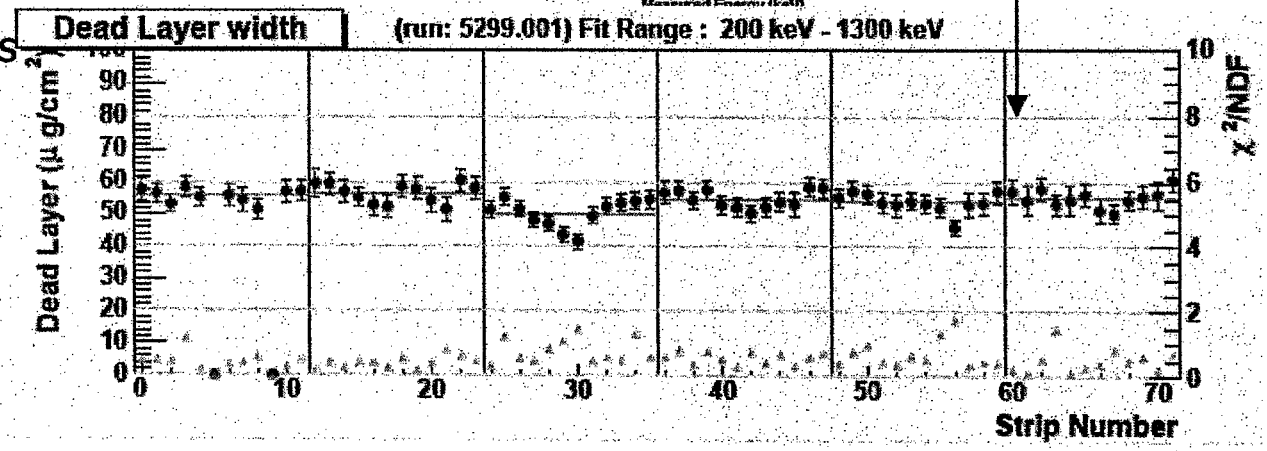


fit example for one strip

Fit result summary strip by strip distribution
blue – estimated values
pink – χ^2 of the fit

Carbon locus based on (Amplitude, TDC at max pulse height) is used for the fit

TDC bins at the periodical peaks (highest, and lowest of 6-point structure in WFD, expected to have wrong timings) removed from the fit



ISSUES

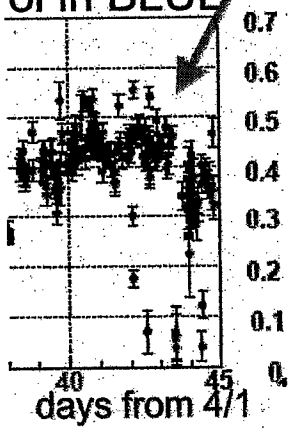
- Mean value (54μg/cm²) large compared to estimates from B implantation energy (40keV→ 33μg/cm²)
- baseline shifts / subtractions, beam pickups, energy calibration, additional SiO_2 layer are possible explanations
- Try other parameterizations for better fit results
- **Comparisons with Tandem tests and ^{241}Am source measurements are necessary, however,** ultimately the thickness of the entrance window must come from the actual data

Osamu

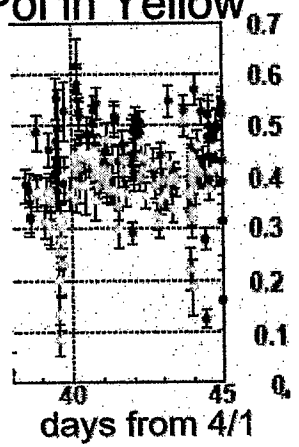
Low blue polarization during last 1.5 days

Polarization drop was observed, when the target was switched from vertical to horizontal (black:24GeV color:100GeV)

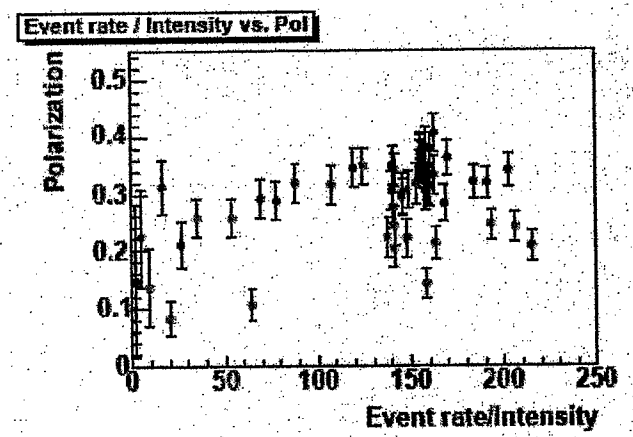
Pol in BLUE

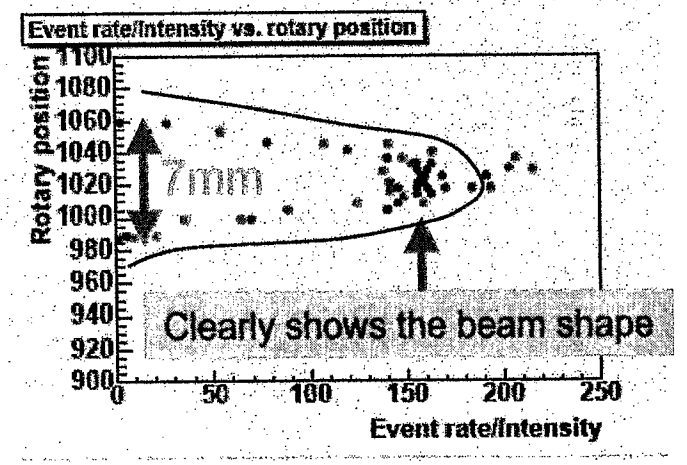


Pol in Yellow



Some correlations for this horizontal target





It is understood that the flattop (100GeV) runs in the last 1.5days (Black points) are mostly taken at the center of the beam

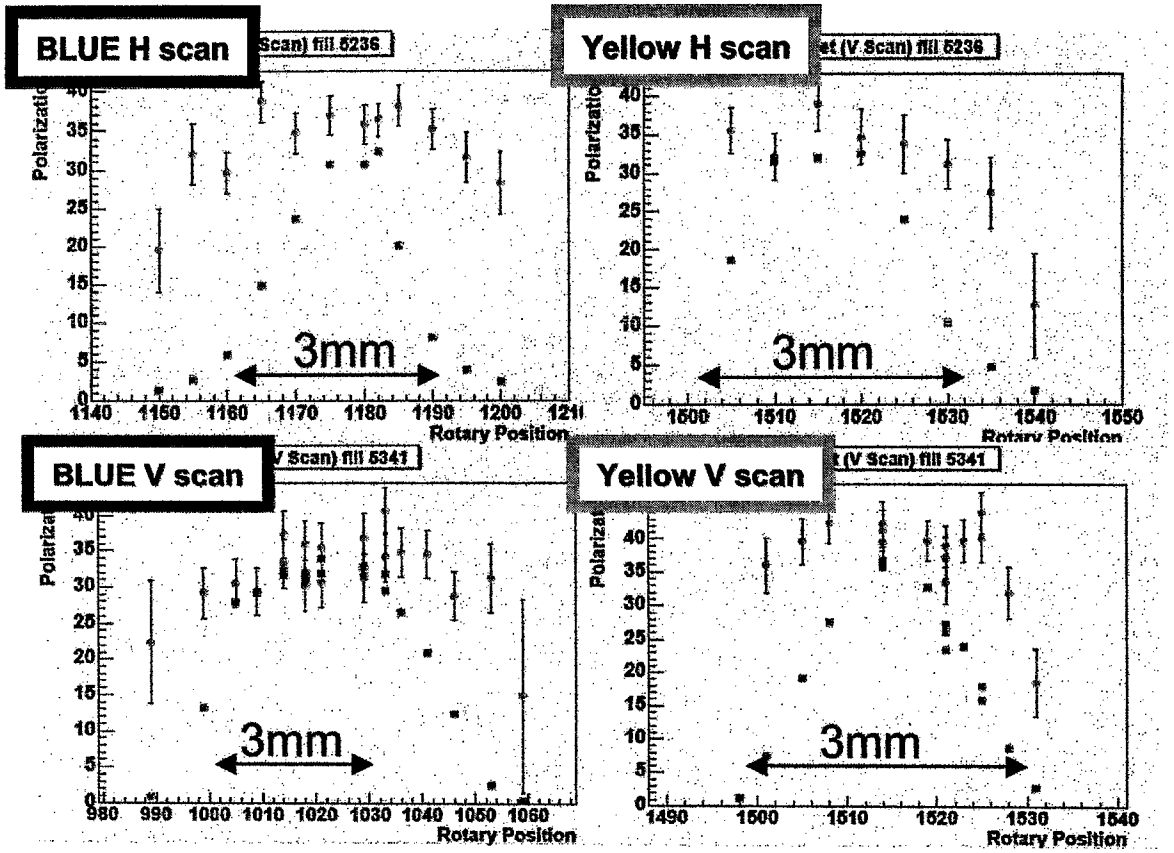
Red points are the data from other period of time when this target was used (in April)

Longitudinal target position was also confirmed to be correct with $-t$ slope

False asymmetries (cross/radial) were normal

During the run the X45 asymmetires always consistent with X90 ones

RHIC polarization profile



- ● Polarization
- ■ Beam Intensity

H Scan --horizontal scan with vertical target

V Scan – vertical scan with horizontal target

large polarization profile in vertical direction (small profile in horizontal)
observed position dependent fluctuation in polarization measurements

an issue for "calibration": the JET integrates over the full beam profile
the pC CNI polarimeter measures the beam center

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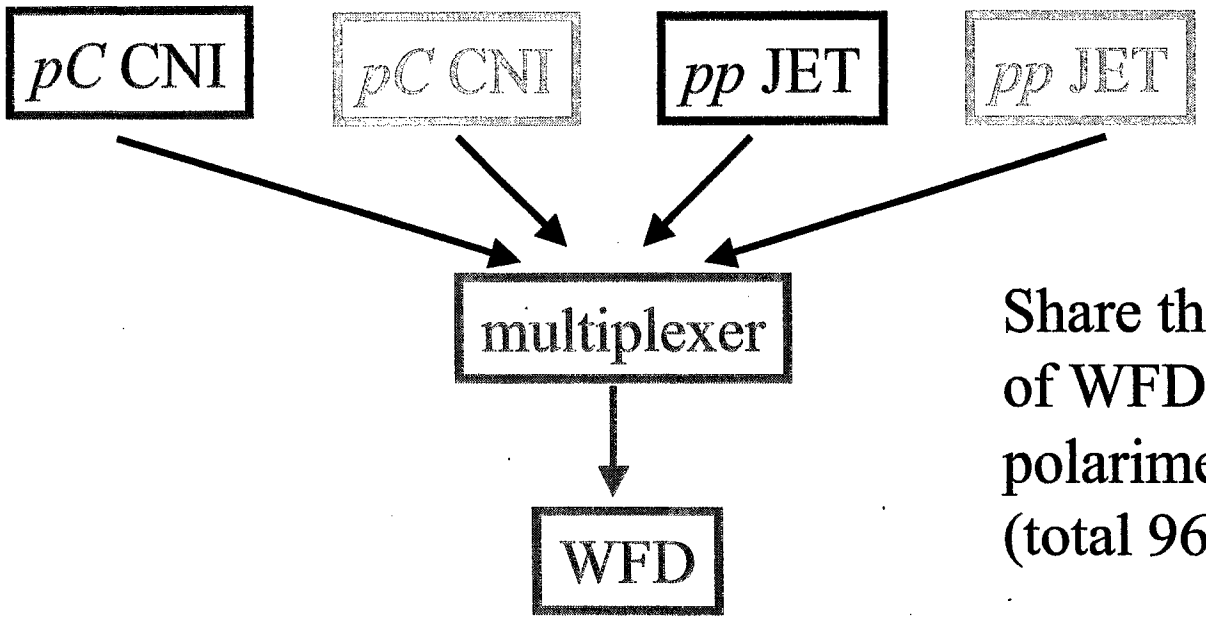
Running scheme in 2004

alternate measurements with *pp* CNI (JET) and *pC* CNI polarimeters about each hour

pp measurement: only fraction of whole statistics
pC measurement: $> 2 \times 10^7$ events (full measurement)



Share the same set of WFDs for all RHIC polarimeters (total 96 ch.)

same WFD code for *pC* CNI and JET polarimeters

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2005 *pC* upgrades

- Rebuild polarimeter as the AGS to remove beam pickups
  - for 2005 run will use UHV components everywhere
    however not all materials can be baked
- Definitively solve all target related issues
- All upgrade works / developments expected to be fully completed before the end of 2004 (vacuum, detectors, electronics, slow control, etc.)
  - however not in time for installation before the cool down
  - install during 3 day shut down for JET target installation
- New scheme for target controls and
  New scheme for polarization measurements
- Faster DAQ
- Upgraded FPGA algorithms
- 2nd generation Front End electronics
- Solve all Si entrance window (dead layer) related issues
- however not yet ready for 120 bunch mode operation

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Recoil Si spectrometer

$A_N^{beam}(t) = -A_N^{target}(t)$

for elastic scattering only!

$P_{beam} = -P_{target} \cdot \varepsilon_N^{beam} / \varepsilon_N^{target}$

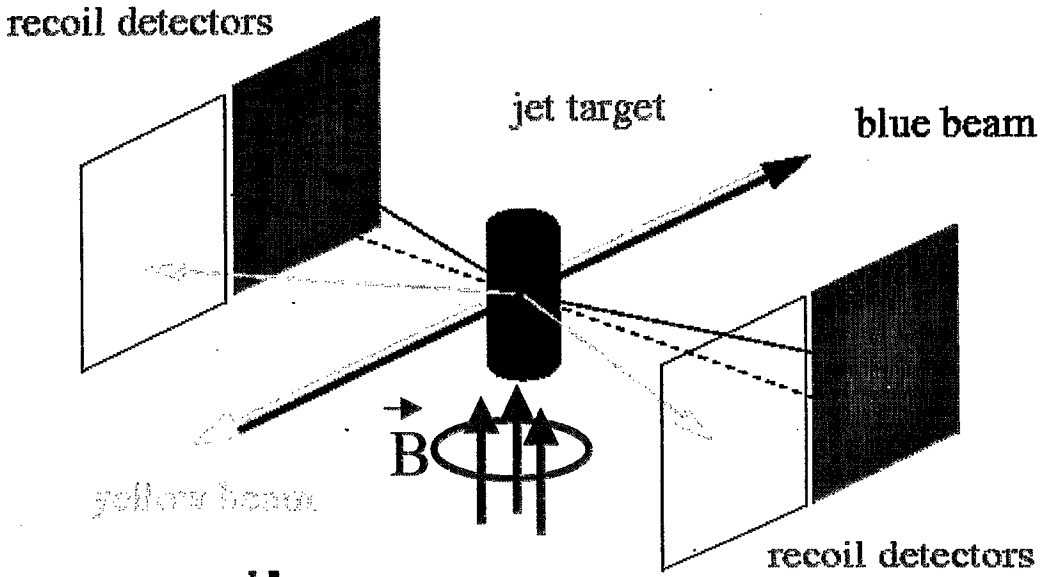
6 Si detectors covering blue beam

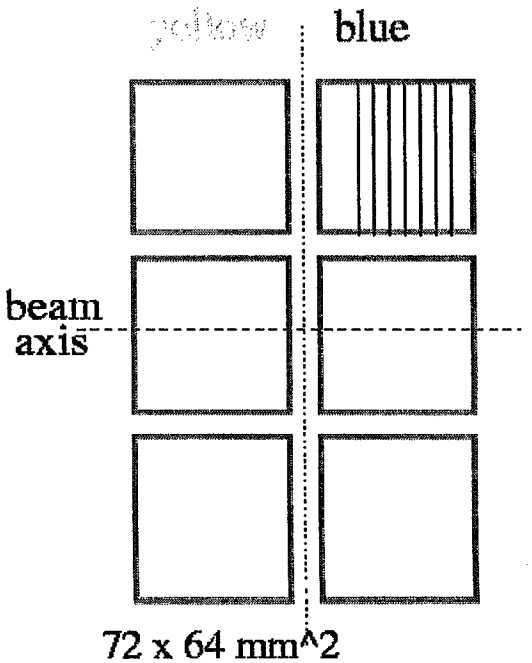
MEASURE

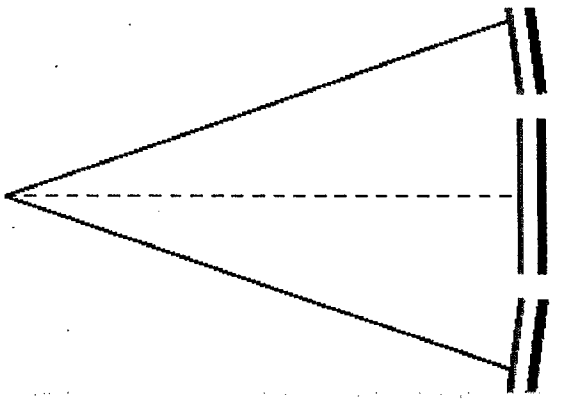
- energy (res. < 50 keV)
- time of flight (res. < 2 ns)
- scattering angle (res. ~ 5 mrad)

of recoil protons from

$pp \rightarrow pp$ elastic scattering







HAVE "design" azimuthal coverage

one Si layer only

⇒ smaller energy range

⇒ reduced bckgrnd rejection power

Si detectors from BNL Inst. and Hamamatsu

Electronics developed by BNL Inst. and Physics

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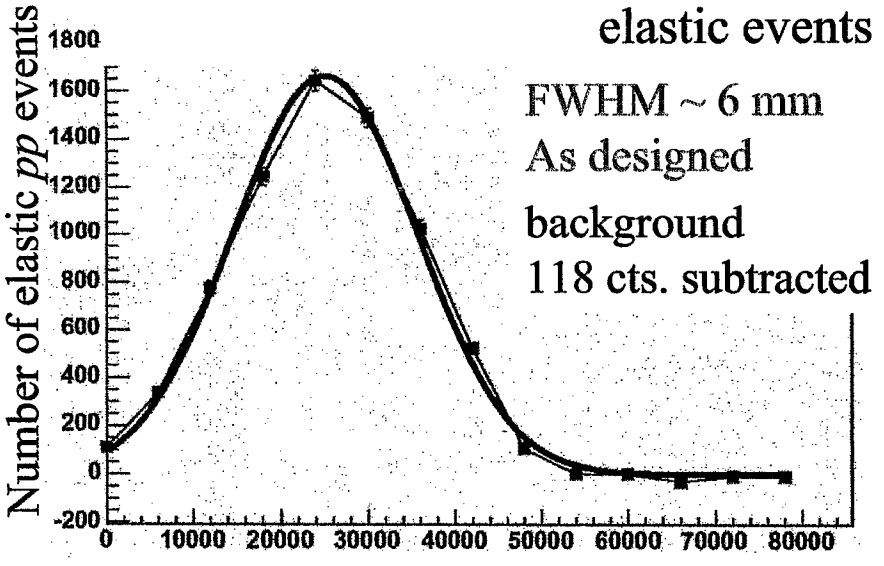
pp elastic data collected

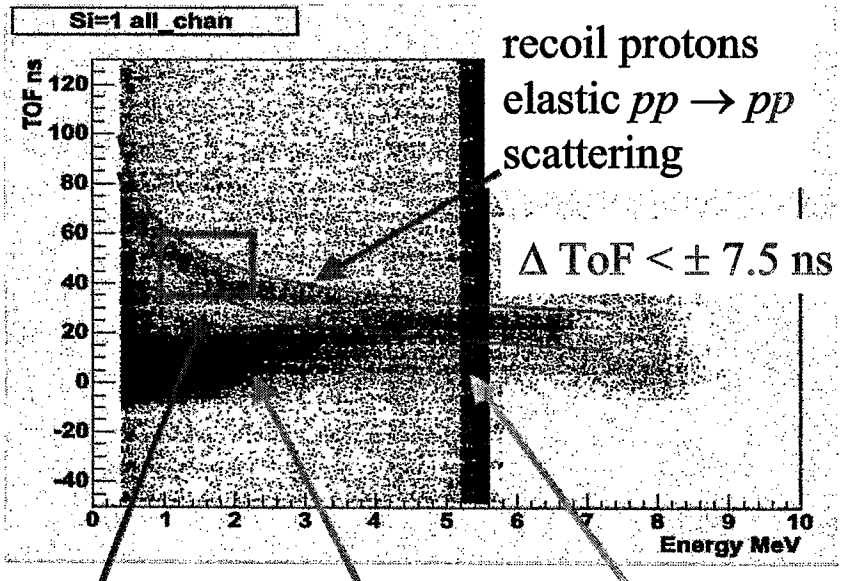
ToF vs E_{REC} correlation
$T_{kin} = \frac{1}{2} M_R (dist/ToF)^2$

JET Profile: measured selecting *pp* elastic events



FWHM ~ 6 mm
As designed
background
118 cts. subtracted

Hor. pos. of Jet 10000 cts. = 2.5 mm



recoil protons elastic $pp \rightarrow pp$ scattering

Δ ToF < ± 7.5 ns

CNI peak A_N
$1 < E_{REC} < 2$ MeV

prompt events and beam gas

α source calibration

- recoil protons unambiguously identified !
- 100 GeV ~ 700,000 events at the peak of A_N ~ 100 hours
  (~ 2 - 3 × 10^6 total useful *pp* elastic events)
- 24 GeV ~ 120,000 events at the peak of A_N ~ 17 hours
  (~ 4 × 10^5 total useful *pp* elastic events)

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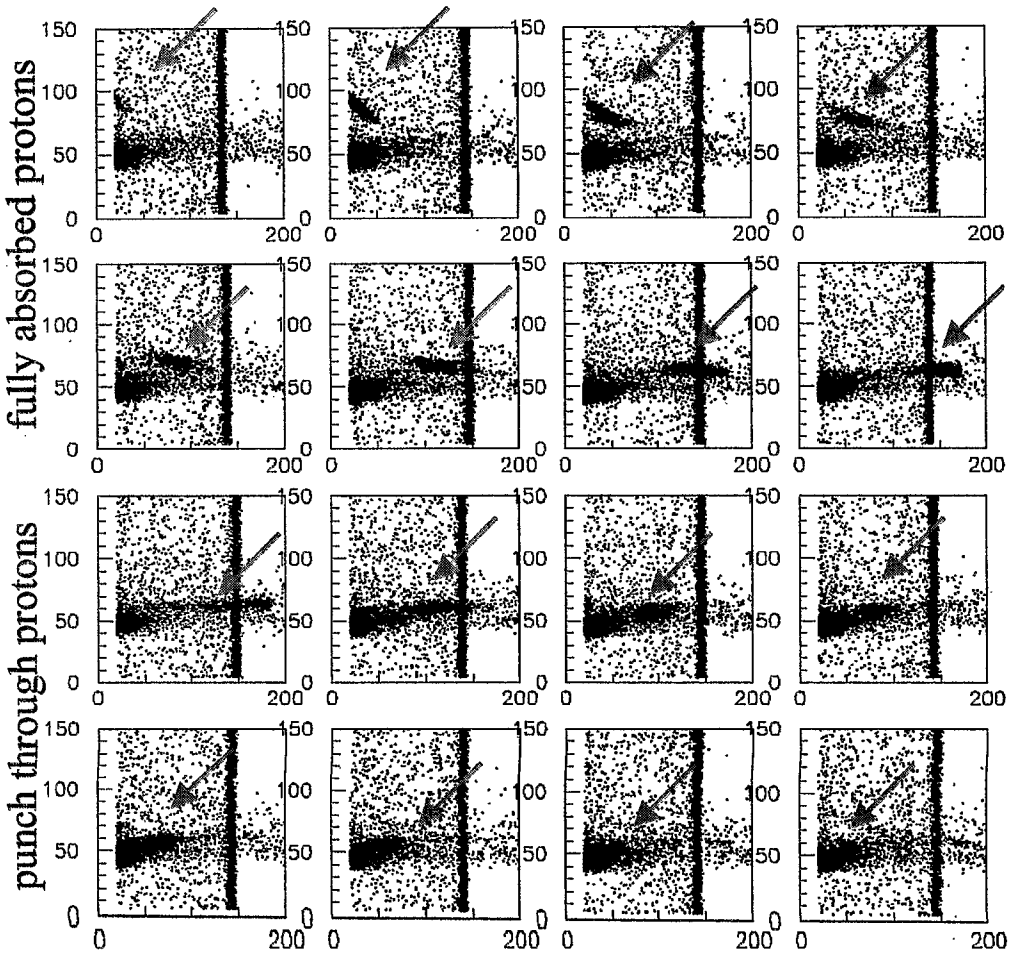
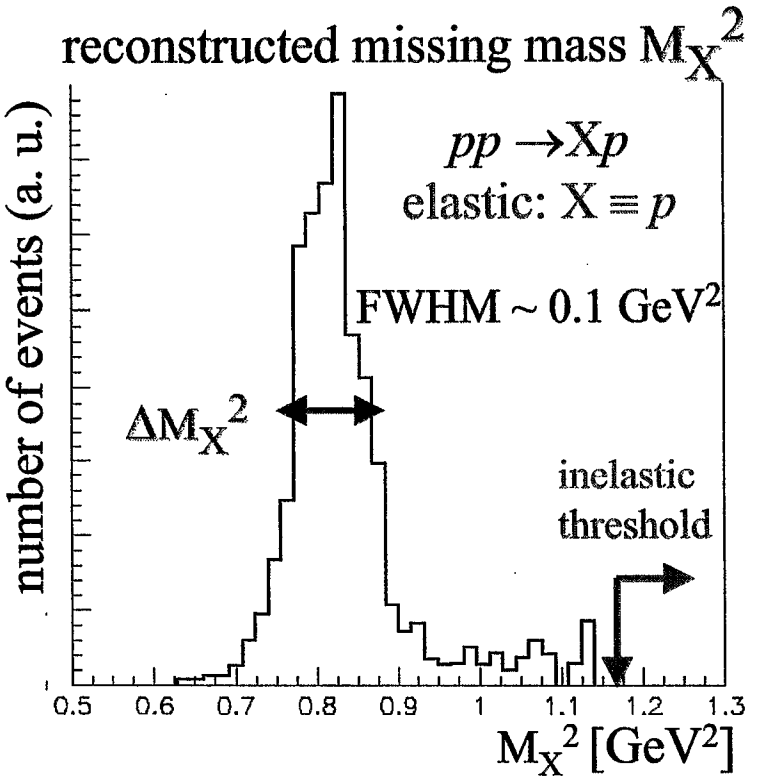
Energy - Position correlations

$T_{kin} \propto \theta^2$ (i.e. position^2)



TDC vs ADC individual channels



pp elastic events clearly identified !

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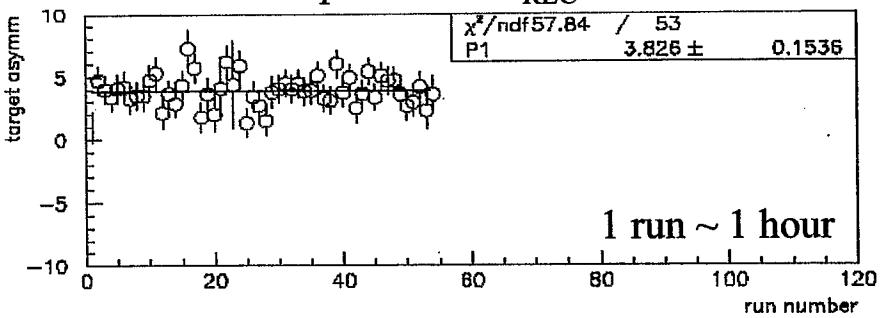
"ONLINE" measured asymmetries & Results

ONLINE ≡ statistical errors only
no background corrections
no systematic studies
no false asymmetries studies
approximate run selection

data divided into 3 p energy energy bins

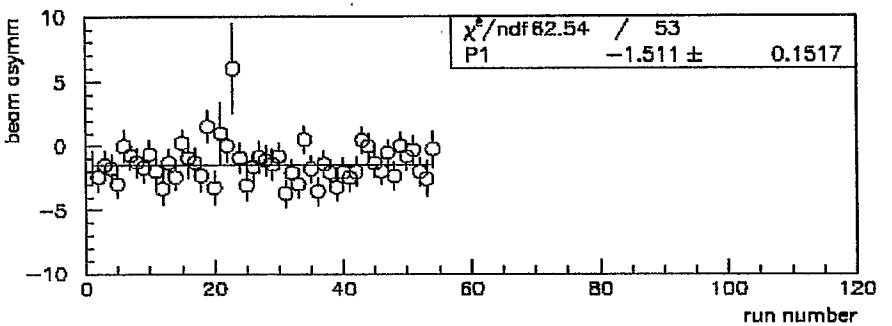
an example: $750 < E_{REC} < 1750$ keV

"Target": average over beam polarization



blue beam with alternating bunch polarizations: ↑↓ ↑↓ ↑↓ …

"Beam": average over target polarization



good uniformity from run to run (stable JET polarization)
JET polarization reversed each ~ 5 min.

$$P_{beam} = -P_{target} \cdot \frac{\varepsilon_{beam}}{\varepsilon_{target}}$$

$P_{beam} = 36.9\ \% \pm 1.9\ \%$

$\langle P_{beam}\ (pC\ \mathrm{CNI}) \rangle = 38.1\ \%$

No major surprises ?

(statistical errors only !)

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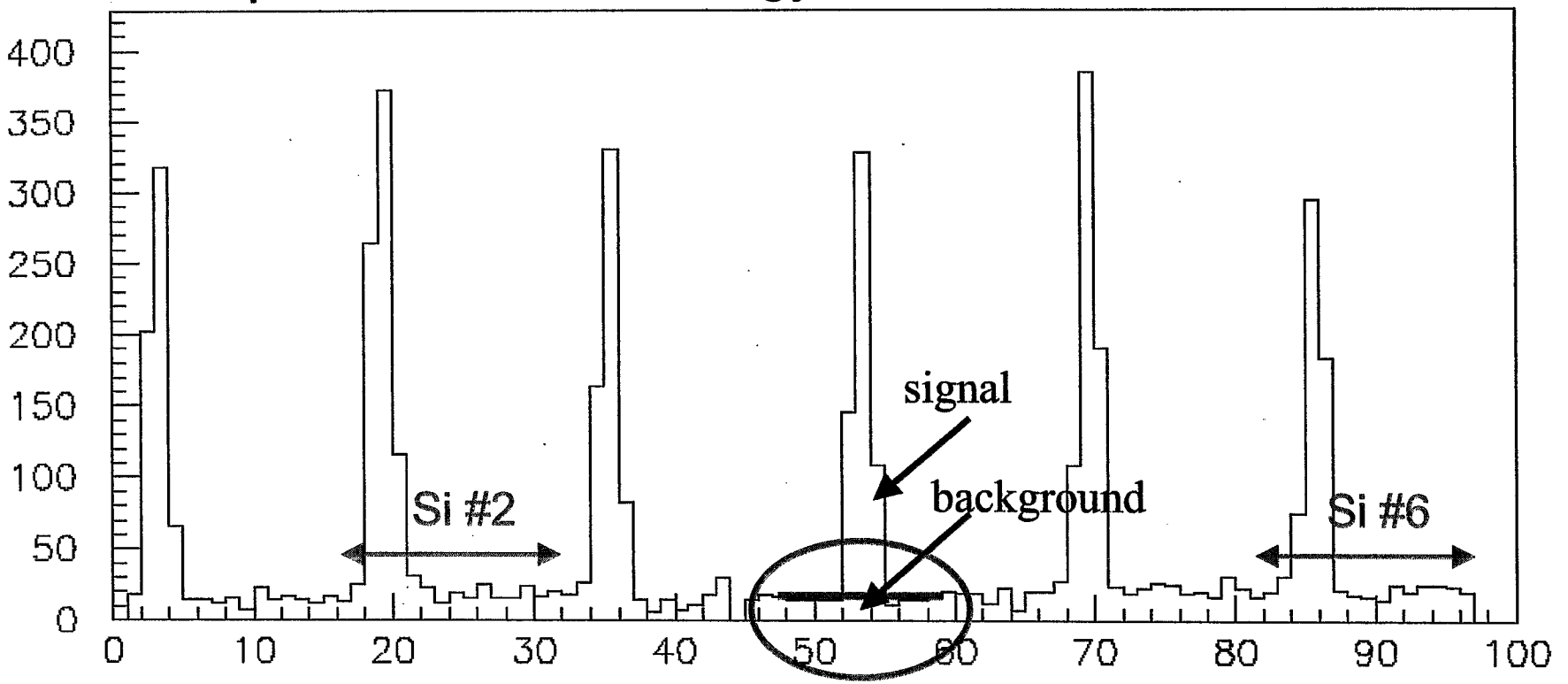
Event selections

Strip distribution for energy interval: 1250 – 1750 keV



visually implement the energy / angle correlation in selecting elastic *pp* events

typically, for each energy bin, select 3 to 4 strips per detector

future: replace this selection with a selection on M_X

Background only from selected channels not from whole detector (4 – 5 × smaller !)

Total Backgrounds < 8 %, α source ~ 4%, Physics Background ~ 4 %

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Backgrounds

- Divide sources of backgrounds in different categories
- α source: ~ 2 – 4 %
  unpolarized, uncorrelated → only dilution of measured asymmetries
  cancels in double ratio $\varepsilon_B / \varepsilon_T \rightarrow P_{beam}$
- beam gas interactions ~ 1 – 3 %
  (mostly from Blue beam)
- target interactions < 5%
  (estimated from the "data")

All backgrounds can be further reduced with tighter selections.

This level of backgrounds will not change our "ONLINE" conclusions, however need to take into account when finalizing the analysis

More dedicated studies being performed
in particular upper limit on "physics" background asymmetry

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The Road to P_{beam} with the JET target

Requires several independent measurements

0 JET target polarization P_{target} (Breit-Rabi polarimeter)

1 A_N for elastic *pp* in CNI region: $A_N = -1 / P_{target}\, \varepsilon_N'$

2 $P_{beam} = 1 / A_N\, \varepsilon_N''$

1 & 2 can be combined in a single measurement: $P_{beam} / P_{target} = -\varepsilon_N' / \varepsilon_N''$

"self calibration" works for elastic scattering only

3 CALIBRATION: A_N^{pC} for *pC* CNI polarimeter in covered kinematical range:

$A_N^{pC} = 1 / P_{beam}\, \varepsilon_N'''$

(1 +) 2 + 3 measured simultaneously with several insertions of carbon target

4 BEAM POLARIZATION: $P_{beam} = 1 / A_N^{pC}\, \varepsilon_N''''$ to experiments

at each step pick-up some measurement errors:

$$\frac{\Delta P_{beam}}{P_{beam}} = \left(\frac{\Delta P_{target}}{P_{target}}\right) \xrightarrow{\oplus} \left(\frac{\Delta \varepsilon}{\varepsilon}\right)_{pp} \xrightarrow{\oplus} \left(\frac{\Delta A_N}{A_N}\right)_{pC} \xrightarrow{\oplus} \left(\frac{\Delta \varepsilon}{\varepsilon}\right)_{pC} \leq 6\%$$

expected precision

transfer calibration measurement

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What next for JET in 2005

- Complete Setup - install Si detectors also for the Yellow beam
  - several discussions with instrumentation division
  - agreed to process 16 wafers ⇒ should yield 8 good detectors
  - expect delivery sometime in December '04
  - then we need about 10 weeks for installation / operation readiness

- Slower shaping amplifiers and new shaper boards
- New hybrid preamplifiers

- Extend $|t|$ range ⇒ increase F.o.M. of JET polarimeter

- Add shutters to turn off the α sources for data taking

Prepare for the next run

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RHIC Spin Collaboration Meeting
July 22, 2004
RIKEN BNL Research Center

LIST OF PARTICIPANTS

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RHIC Spin Collaboration Meeting
July 22, 2004
RIKEN BNL Research Center

LIST OF PARTICIPANTS

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RIKEN BNL Research Center

RHIC Spin Collaboration Meeting XXVII

July 22, 2004

BNL Physics Department, Small Seminar Room

Brookhaven National Laboratory

*******AGENDA*******

RHIC pp FY05 Run Preparation.....M. Bai

AGS Cold Snake Status.....W. MacKay

RUN5 BUR & Plans Beyond RUN5

PHENIX Plan.....A. Deshpande

STAR Plan.....B. Surrow

Discussions.....G. Bunce

.....A. Nass

.....A. Zelenski

Gas-Jet & CNI Polarimeter Updates.....A. Bravar et. al.

Next RSC Meeting ~ September 2, 2004 @ BNL

See webpage http://www.bnl.gov/riken/RSC-meetings.htm for tentative agenda

RHIC Spin Collaboration Meeting XXVIII

September 2, 2004

Magnetic Measurement Results in the AGS Cold Snake HSD601 (a.k.a. DSM101)

Animesh Jain

Superconducting Magnet Division, BNL

11 August, 2004

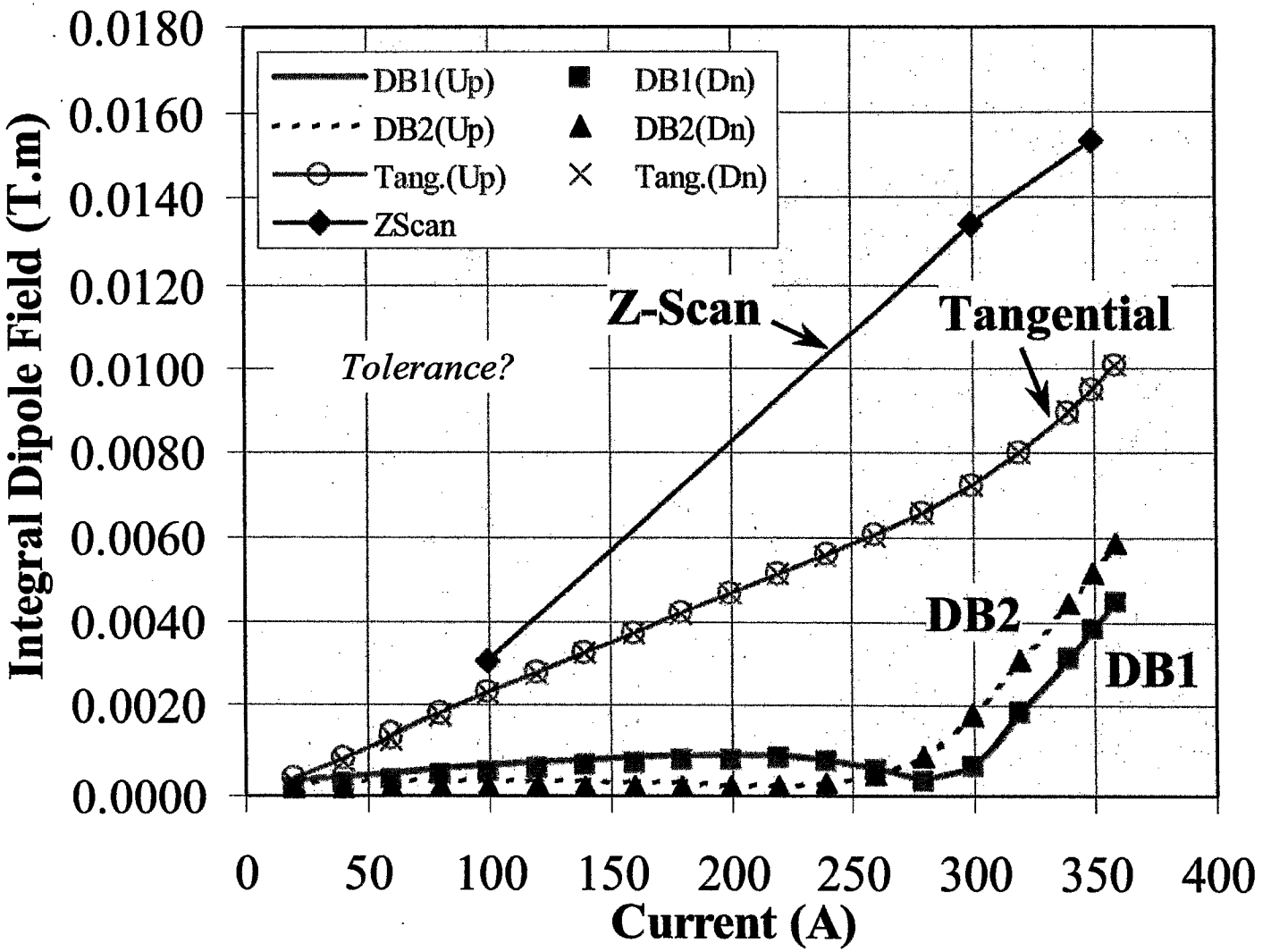
Measurements in the Cold Snake (HSD601)

- Integral dipole field in the main helical magnet:
  - Full excitation curve using a 3.58 m long rotating coil.
    - 3 separate windings (DB1, DB2 and Tangential).
  - Integral from axial scans at 100 A, 300 A and 350 A.
  - Solenoid corrector was off during the measurements.
  - Results are subject to large uncertainties due to impact of measuring coil construction errors in a helical field.
- Integral harmonics in the dipole correctors:
  - Main dipole powered at 350 A; solenoid off.
  - Harmonics measured at 24 mm radius, but scaled to 31 mm reference radius (for consistency).

Measurements in the Cold Snake (Contd.)

- Axial scans using 51 mm long coil:
  - 67 axial positions in 2 inch steps, covering ~3.4 m.
  - Measurements at 100 A, 300 A and 350 A.
  - Harmonics at 31 mm radius (only 30% of coil radius):
    - only a few low order harmonics are significant.
- Excitation curves in the straight section:
  - Using a 51 mm long, 34 mm radius rotating coil.
  - 3 axial positions; roughly at the centers of the three sections with a well defined pitch:
    - axial center and ±29.5 inch (~0.75 m) from center.
  - Solenoid corrector was off during the measurements.
  - Measurements at 20 A to 360 A; both Up & Dn ramps.

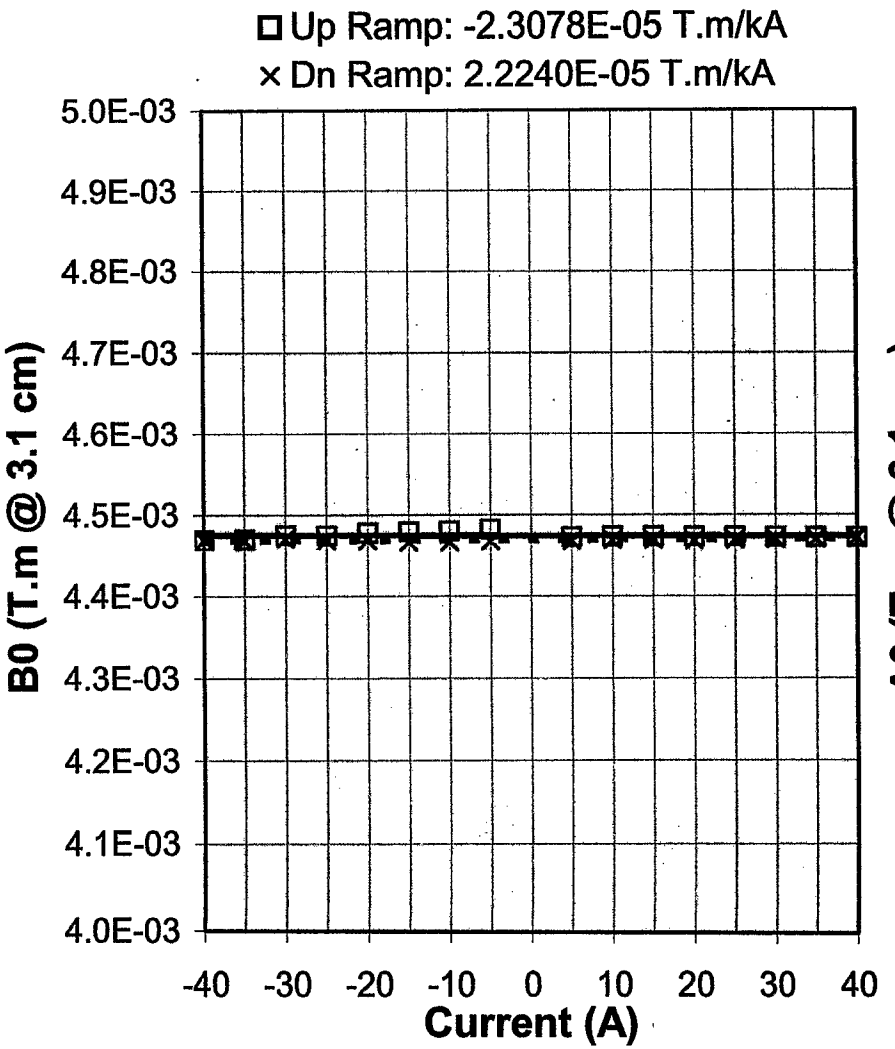
Integral Dipole Field in the AGS Cold Snake

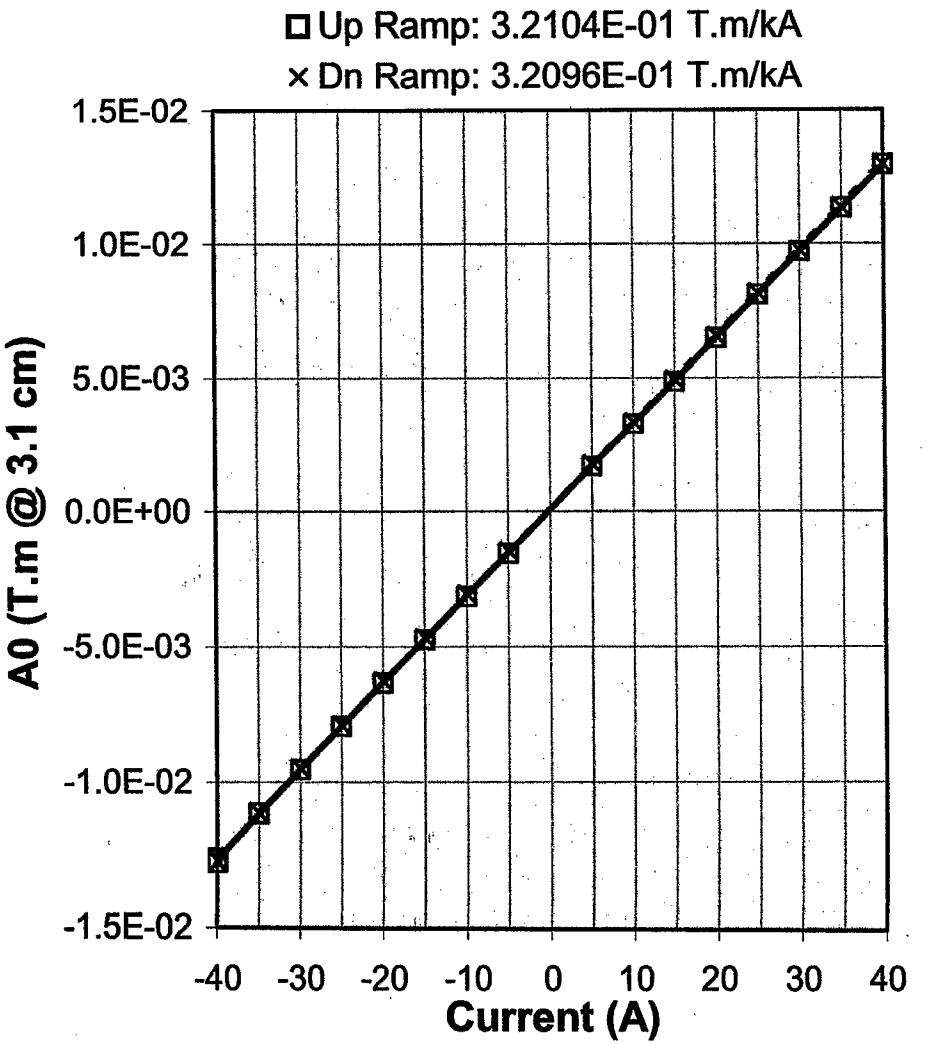


Integral Field: Dipole Correctors

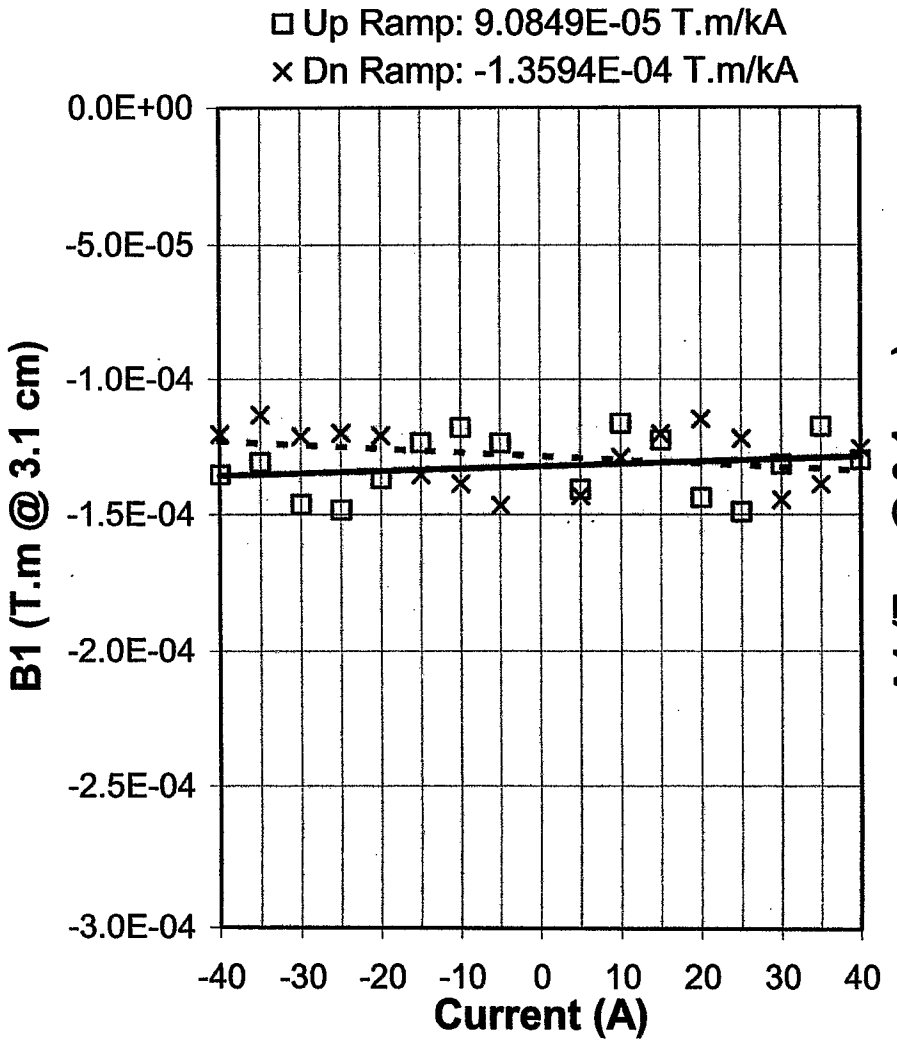
- Two dipole correctors – one on each end.
- Measured with the main dipole powered at 350 A.
- Solenoid is not powered during the measurements.
- Measurements from +5 A to +40 A, and –5 A to –40 A; both up and down ramps.
- Transfer function and harmonics are obtained from the **slope** of a straight line fitted to the normal and skew harmonics as a function of current.
- The **intercept** of the line gives background field from the main dipole.
- Measurements at 24 mm radius, scaled to 31 mm.

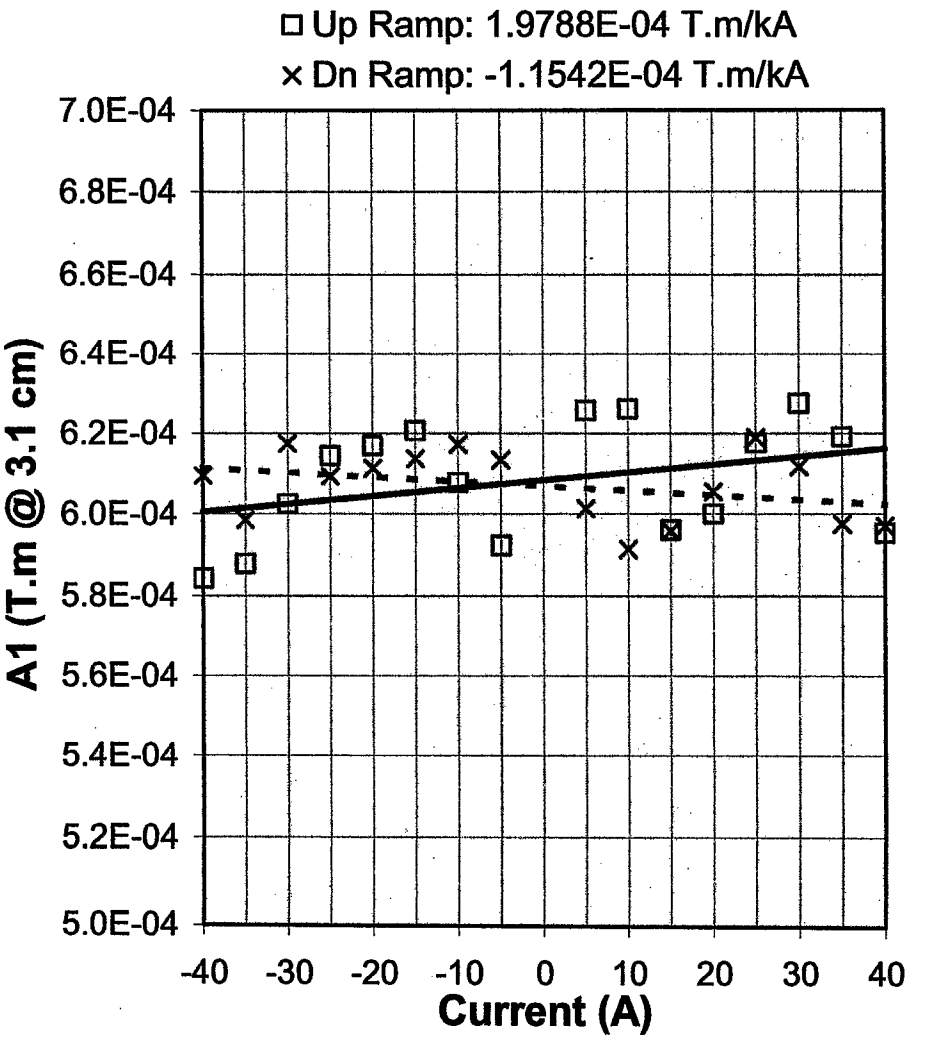
AGS Cold Snake HSD601 LE Corrector Dipole (Runs 110 through 113)





AGS Cold Snake HSD601 LE Corrector Dipole (Runs 110 through 113)





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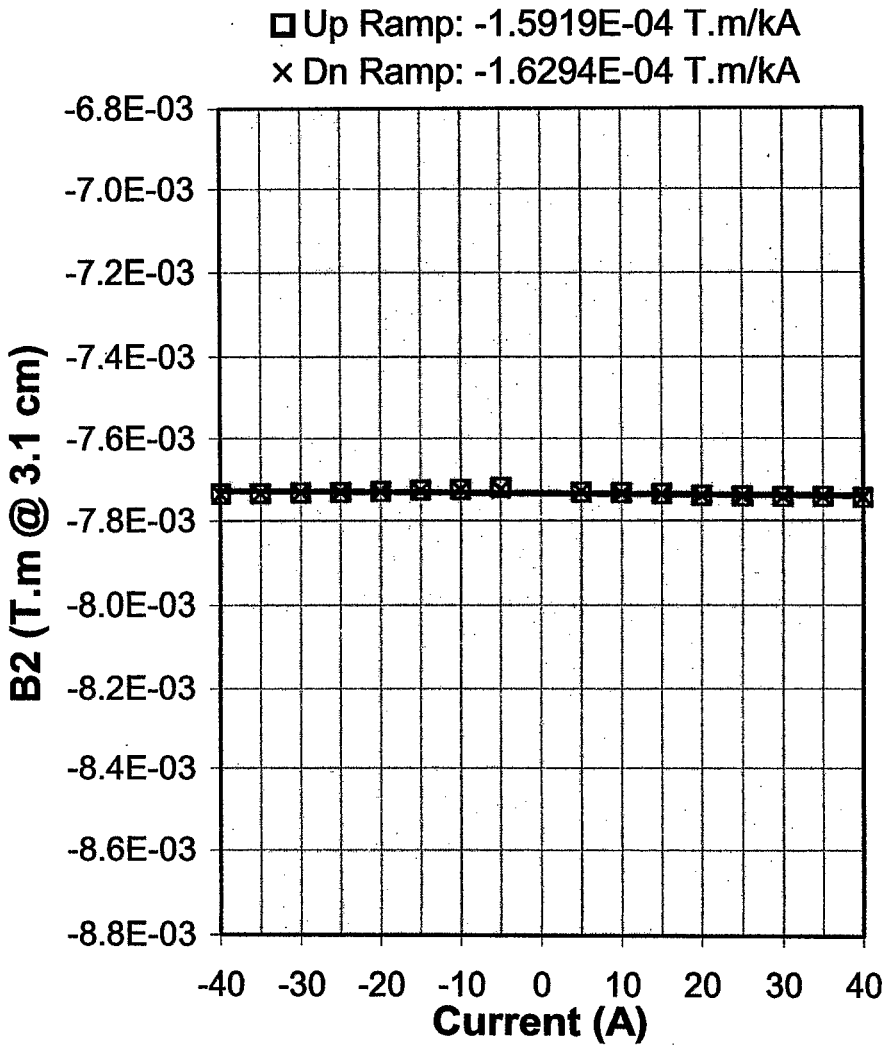

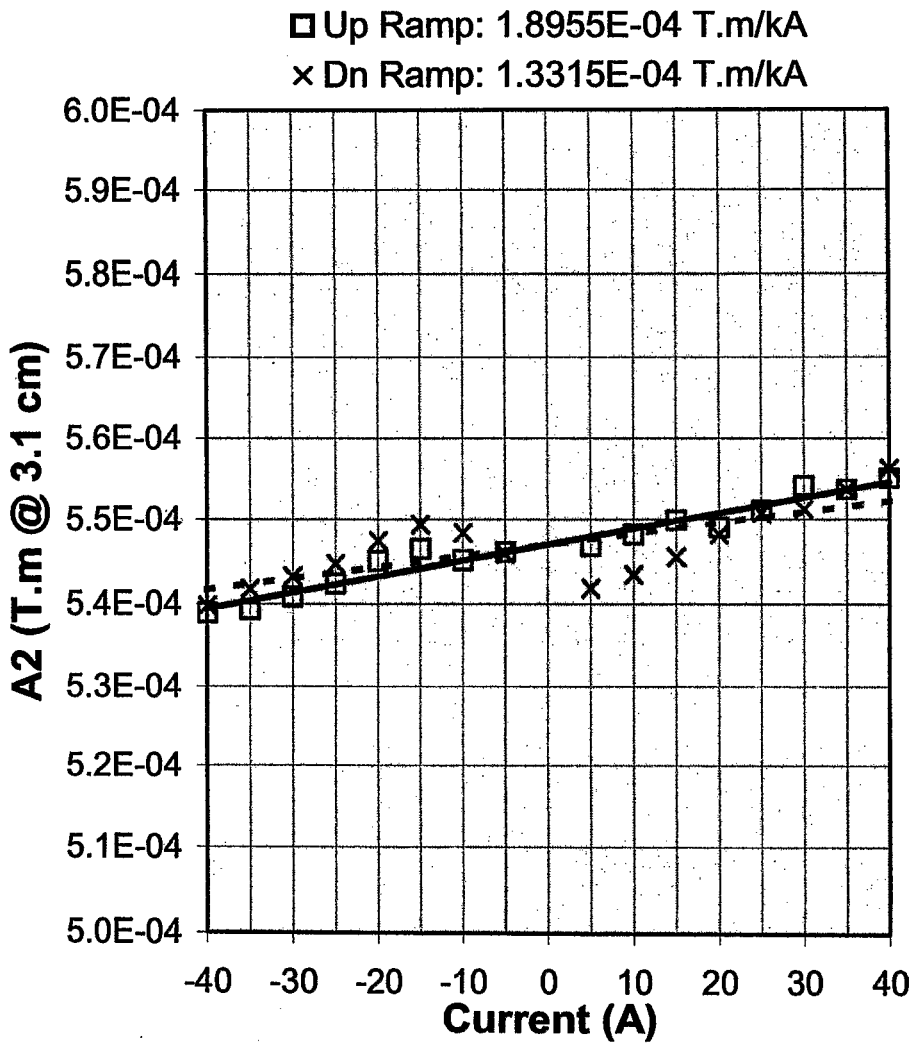

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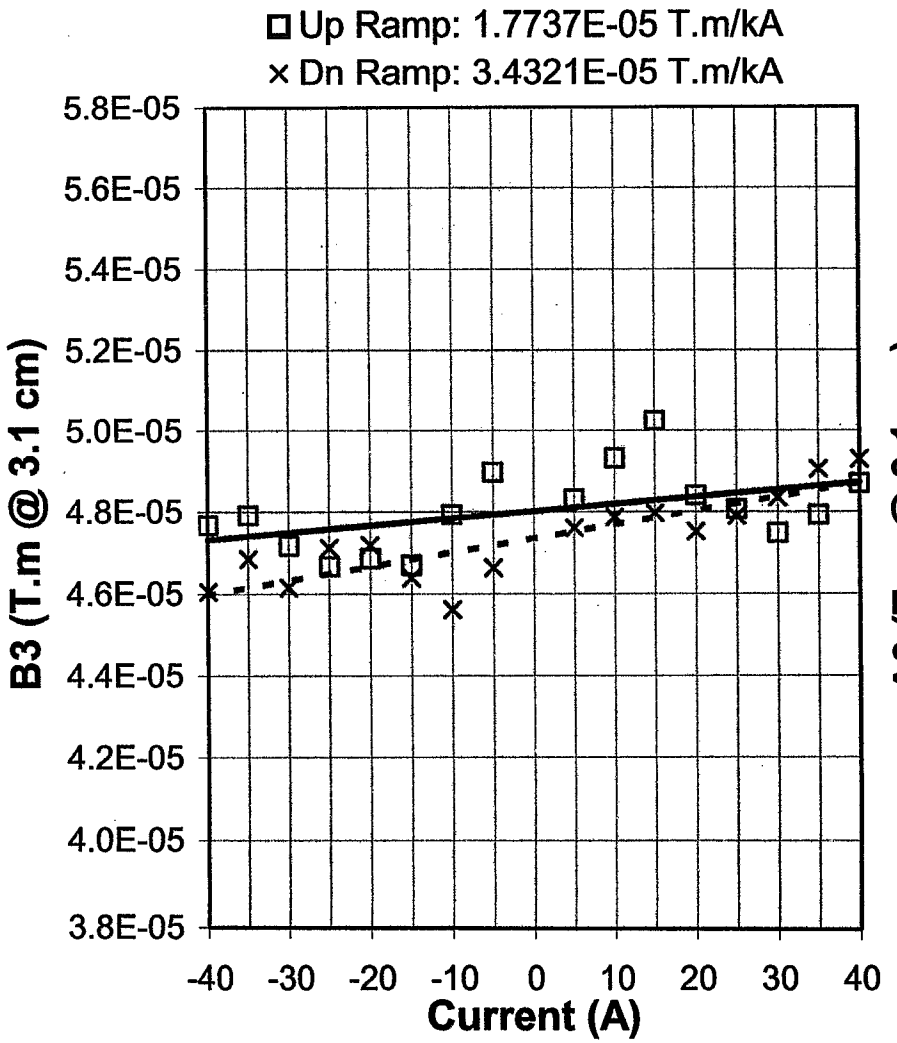
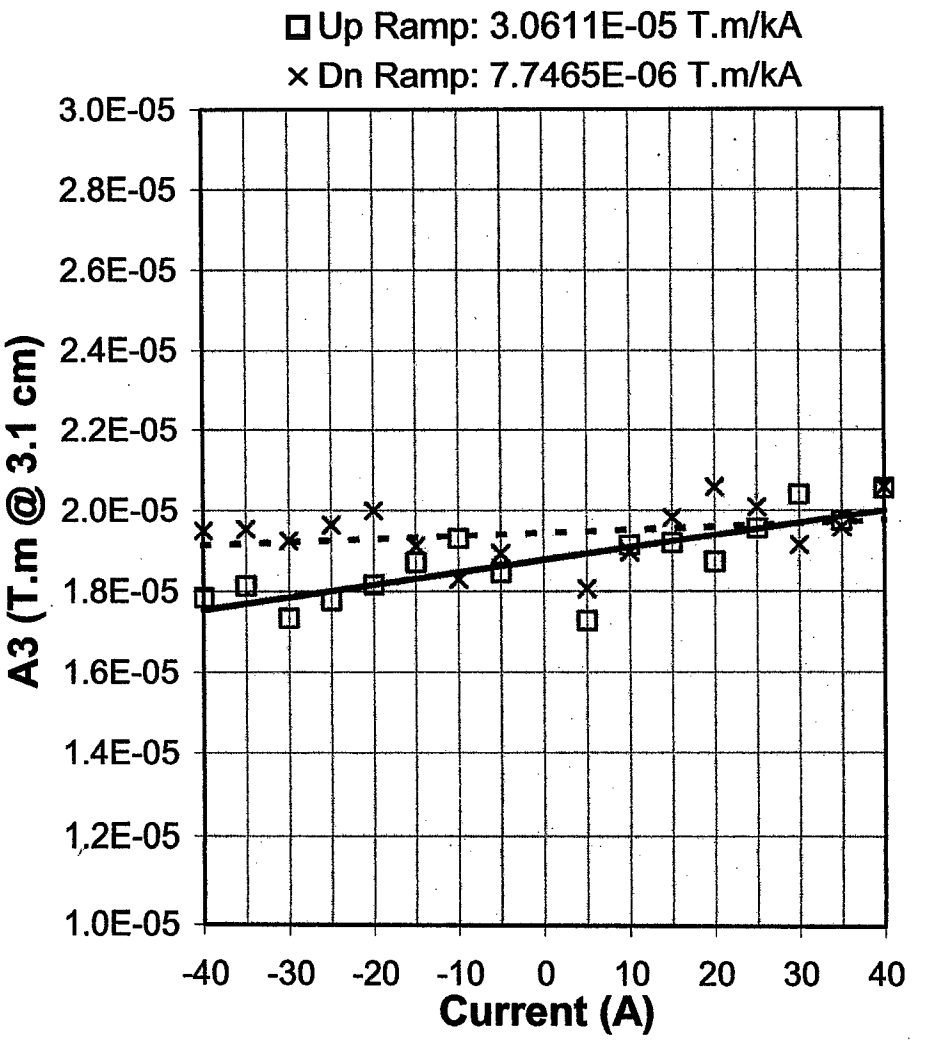
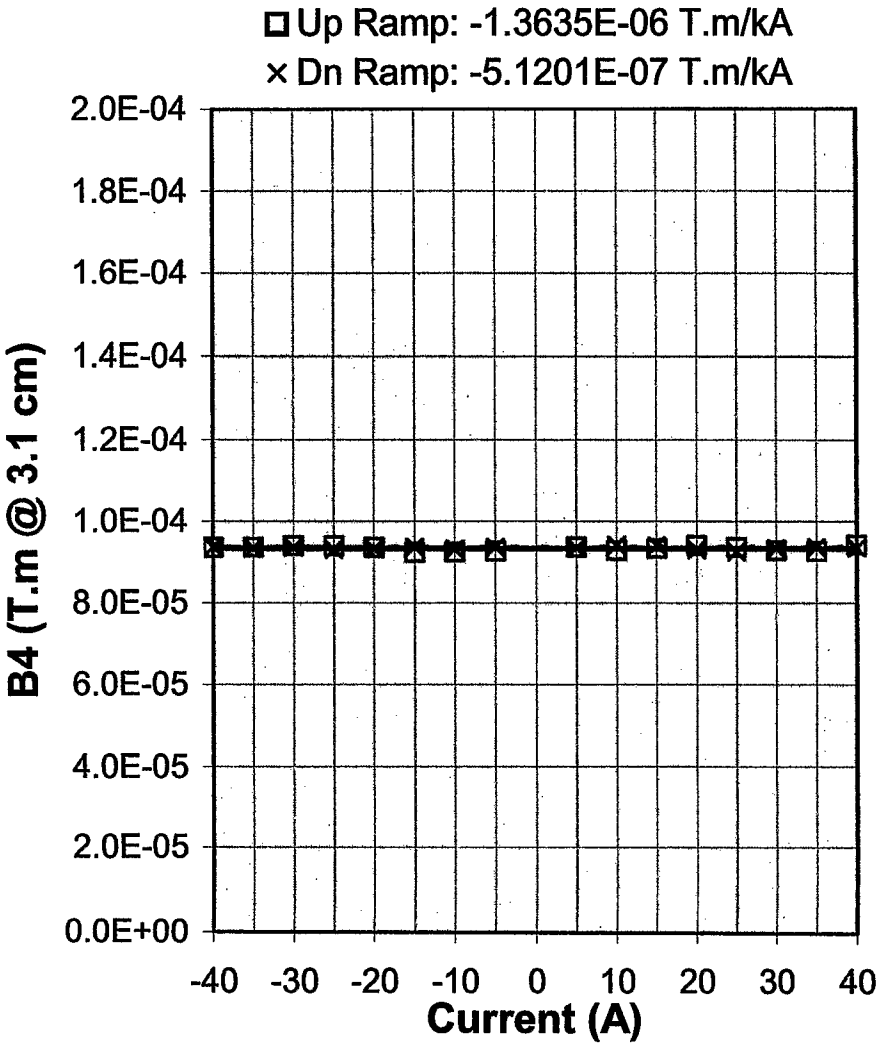
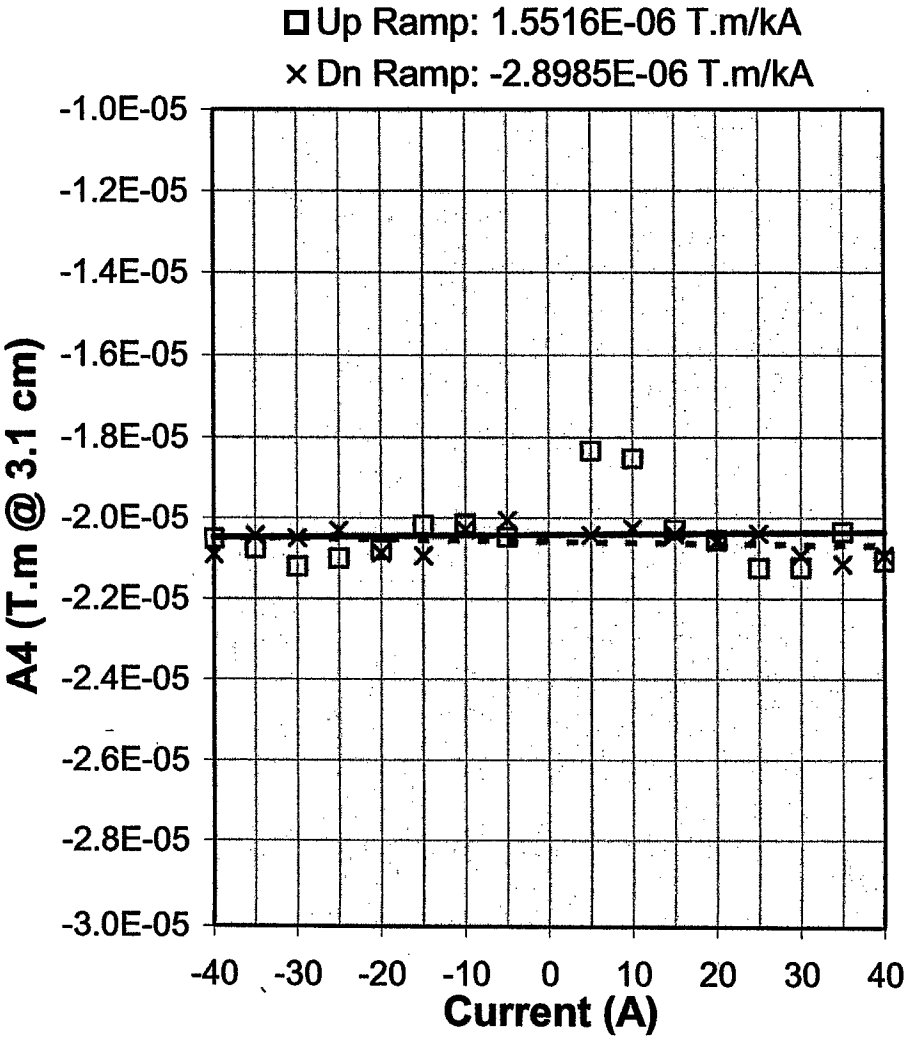




AGS Cold Snake HSD601 LE Corrector Dipole (Runs 110 through 113)



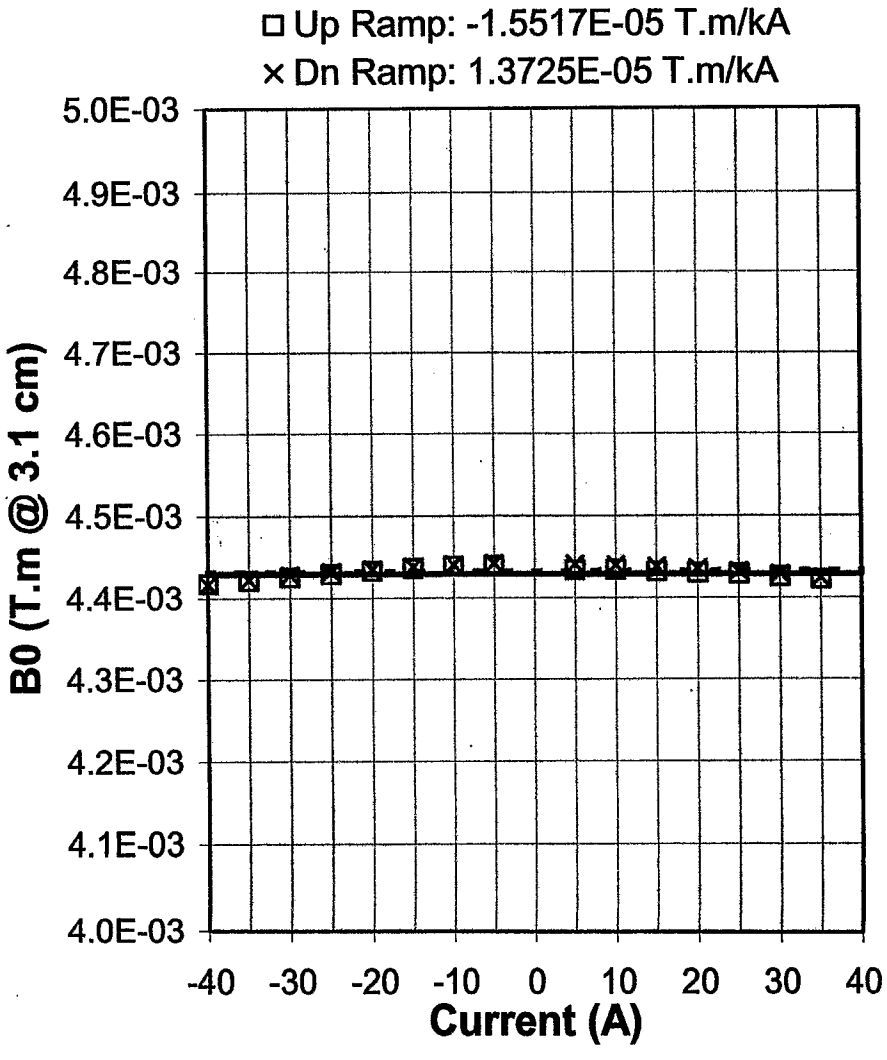


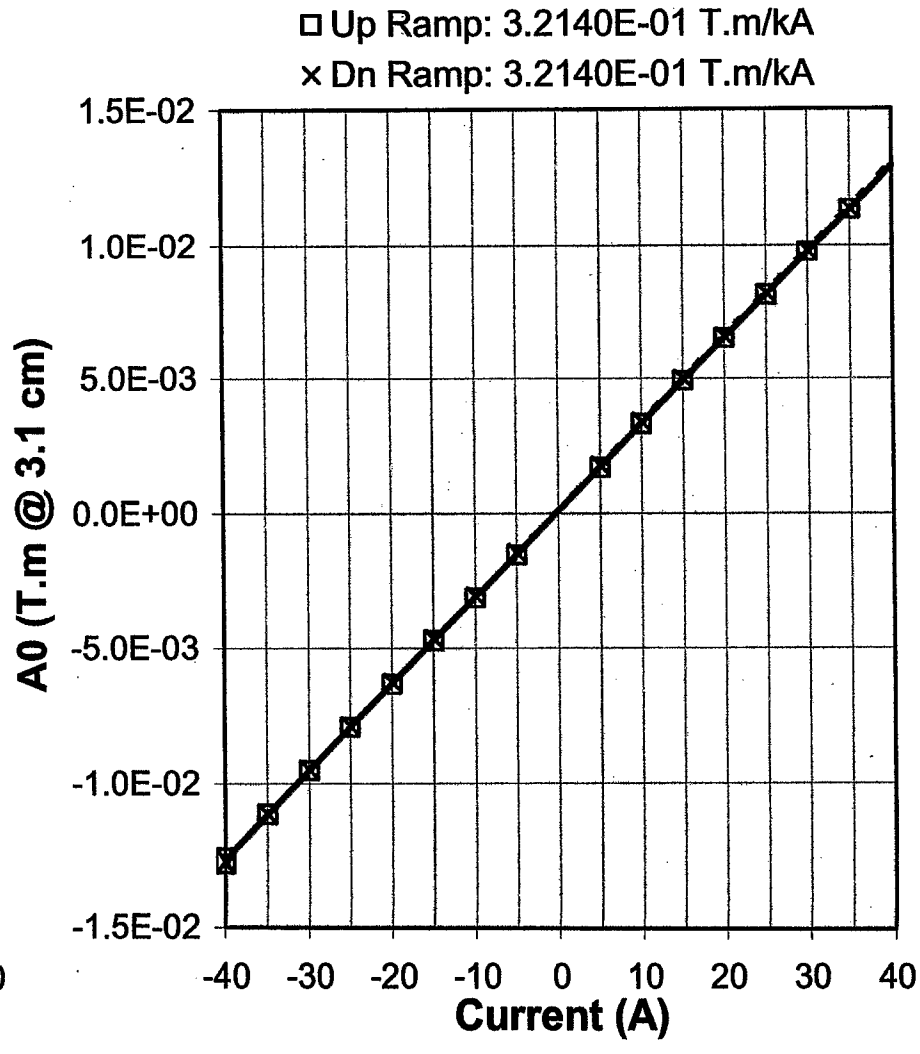
Lead End Corrector: Integral Harmonics

ITF(Up)	ITF(Dn)
0.3210	0.3210
T.m/kA	T.m/kA

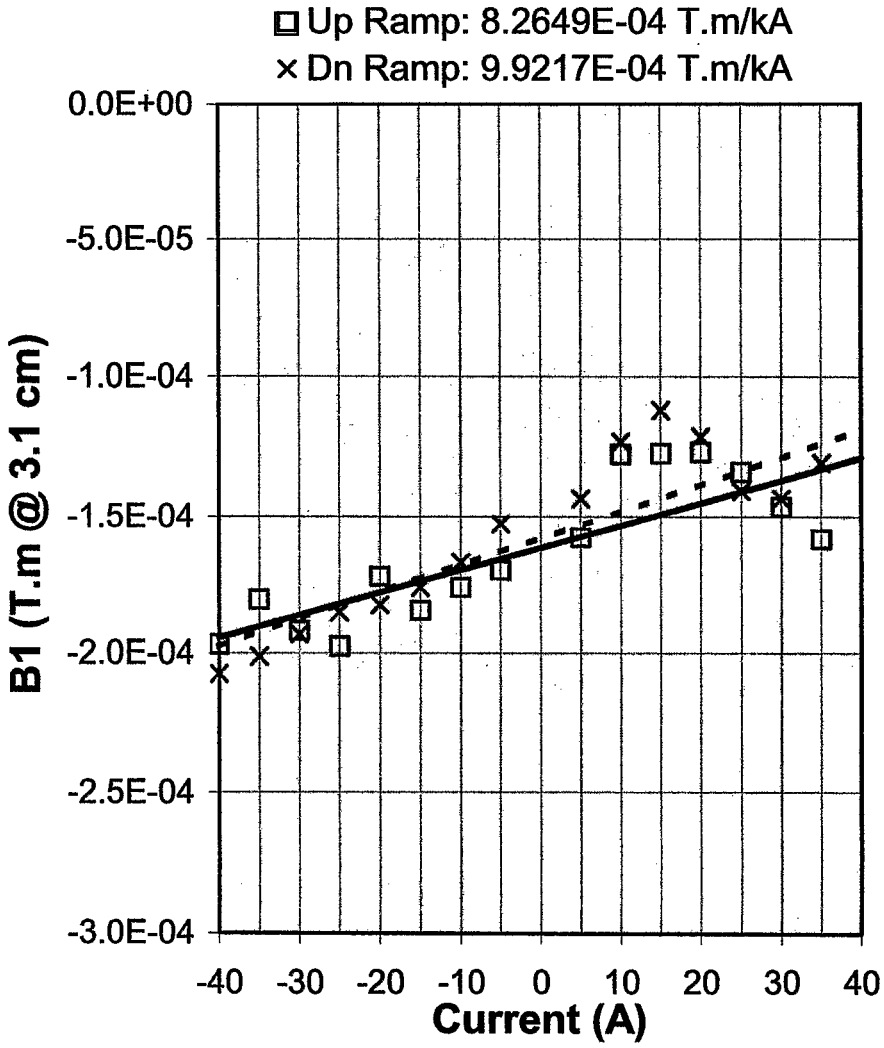
n	"True" Fields ("units" at 3.1cm radius)			
	Bn(Up)	An(Up)	Bn(Dn)	An(Dn)
0	-0.7	10000.0	0.7	10000.0
1	2.8	6.2	-4.2	-3.6
2	-5.0	5.9	-5.1	4.1
3	0.6	1.0	1.1	0.2
4	0.0	0.0	0.0	-0.1
5	-0.3	-0.5	0.4	-0.5
6	-0.1	0.4	0.1	0.3
7	0.2	0.1	-0.1	-0.4
8	0.1	-0.7	-0.2	0.4
9	-0.5	0.3	0.7	0.0
10	1.4	1.2	-0.8	-0.8

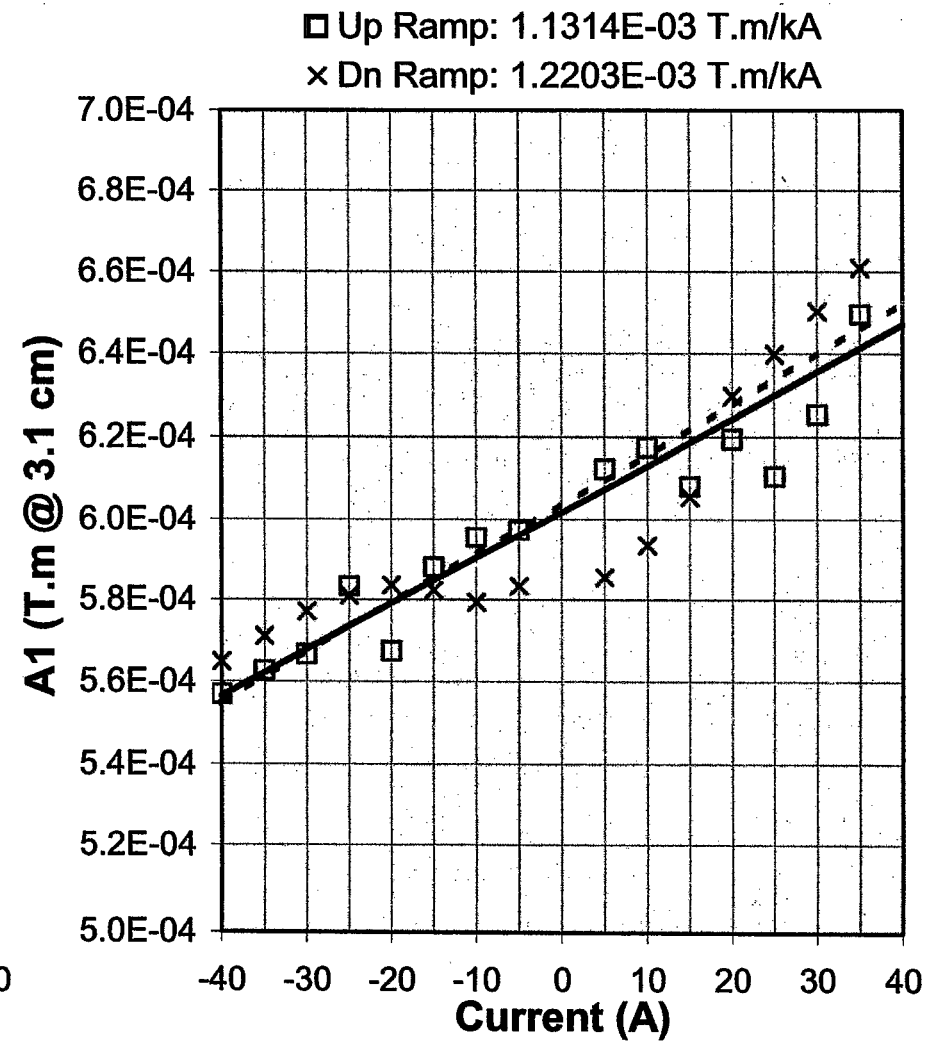
AGS Cold Snake HSD601 NLE Corrector Dipole (Runs 105 through 108)



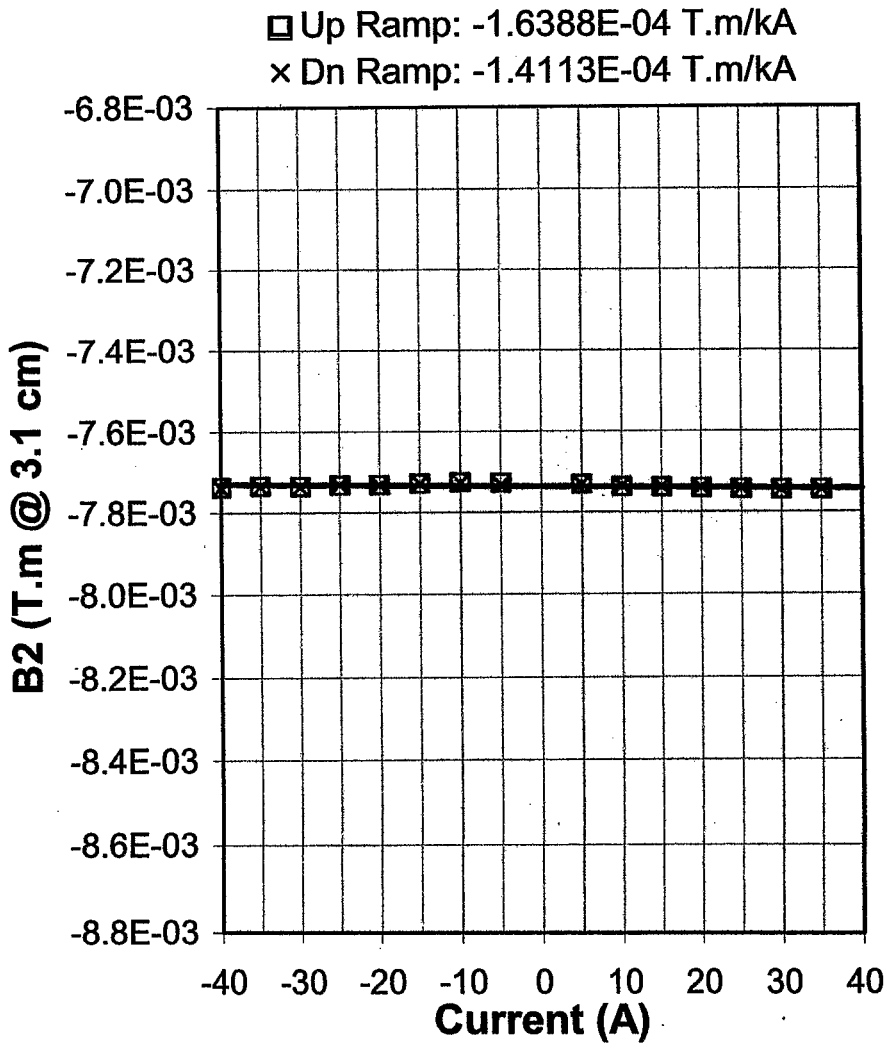


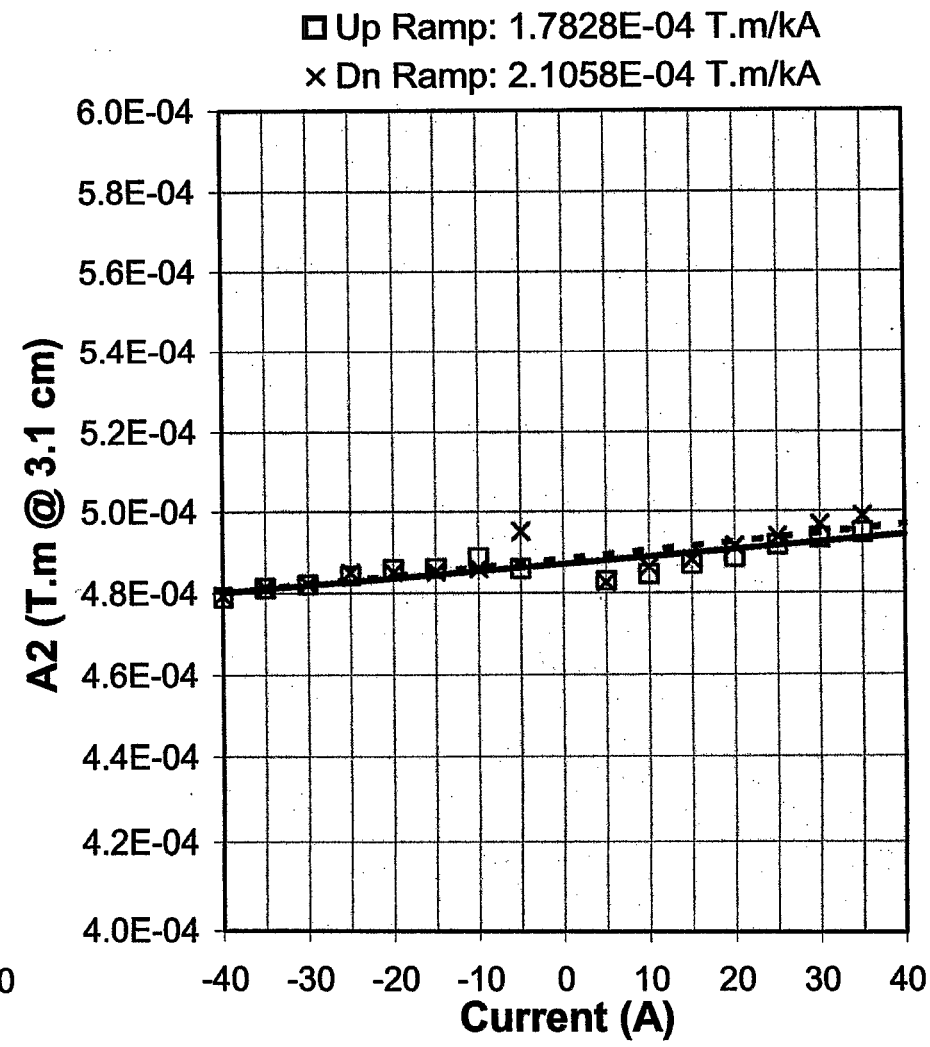
AGS Cold Snake HSD601 NLE Corrector Dipole (Runs 105 through 108)



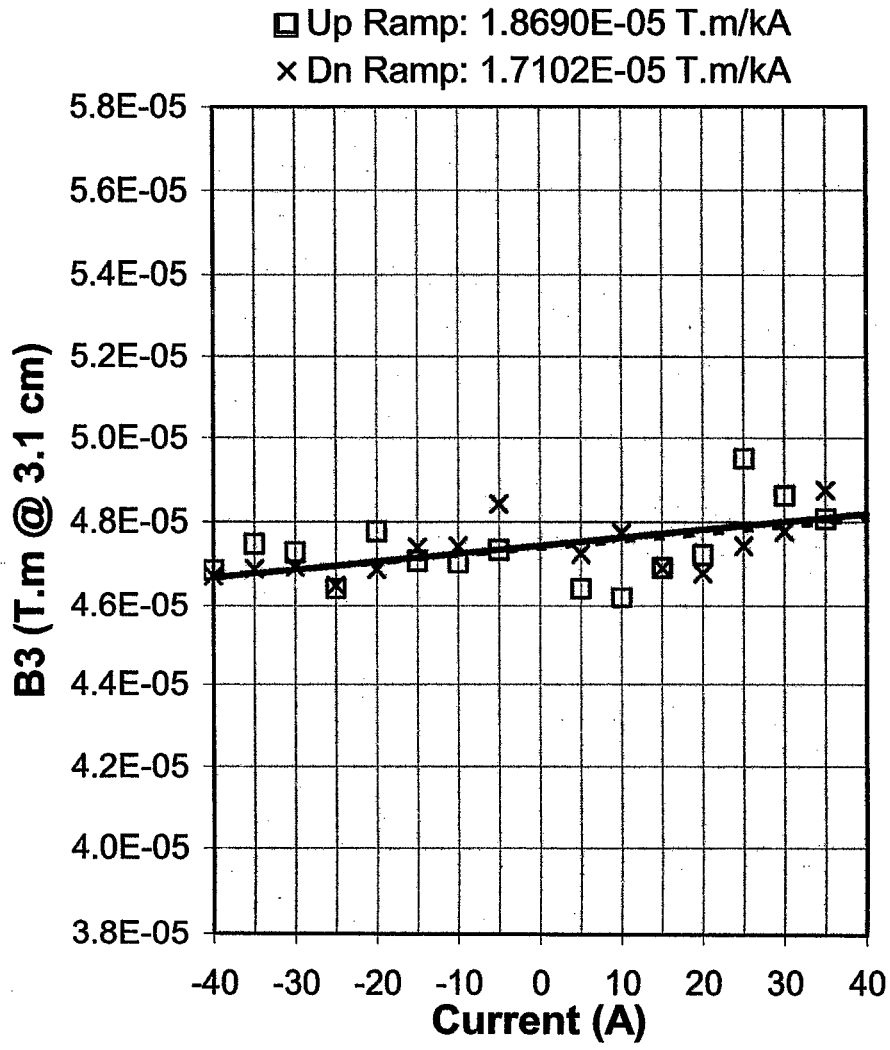


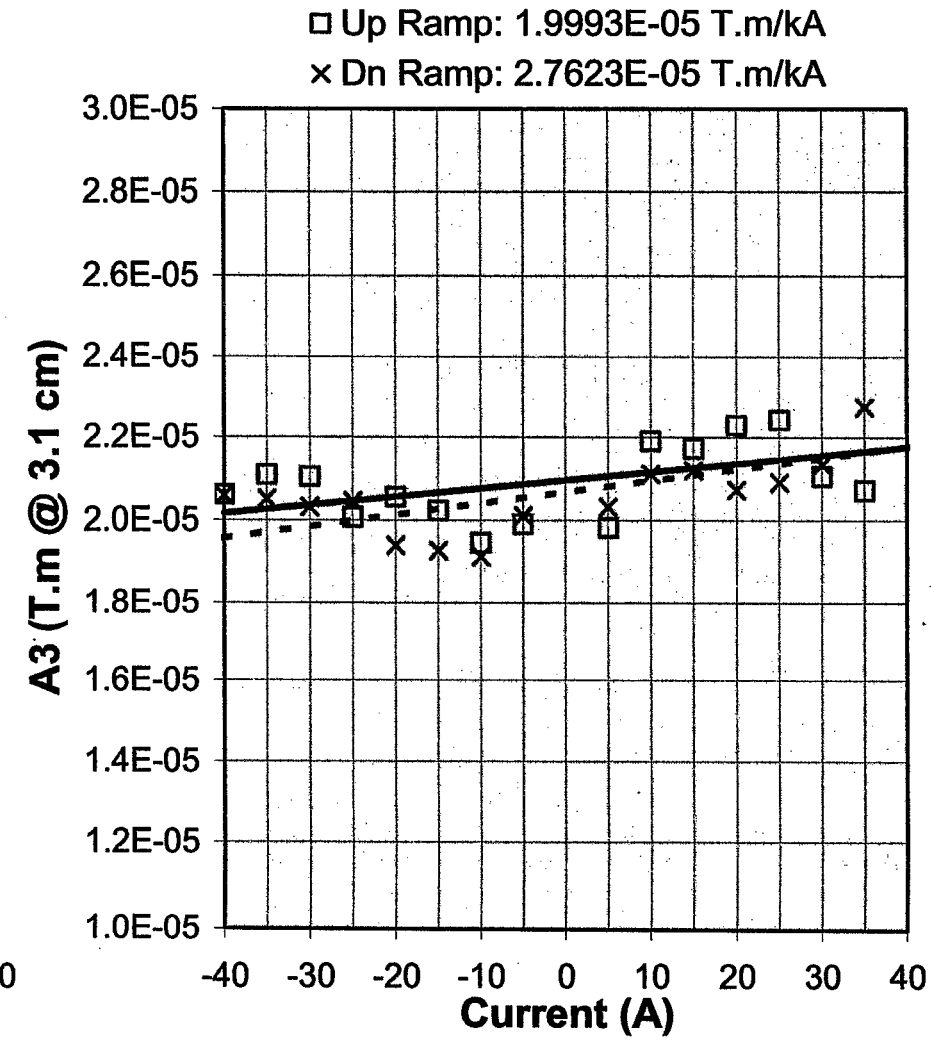
AGS Cold Snake HSD601 NLE Corrector Dipole (Runs 105 through 108)





AGS Cold Snake HSD601 NLE Corrector Dipole (Runs 105 through 108)





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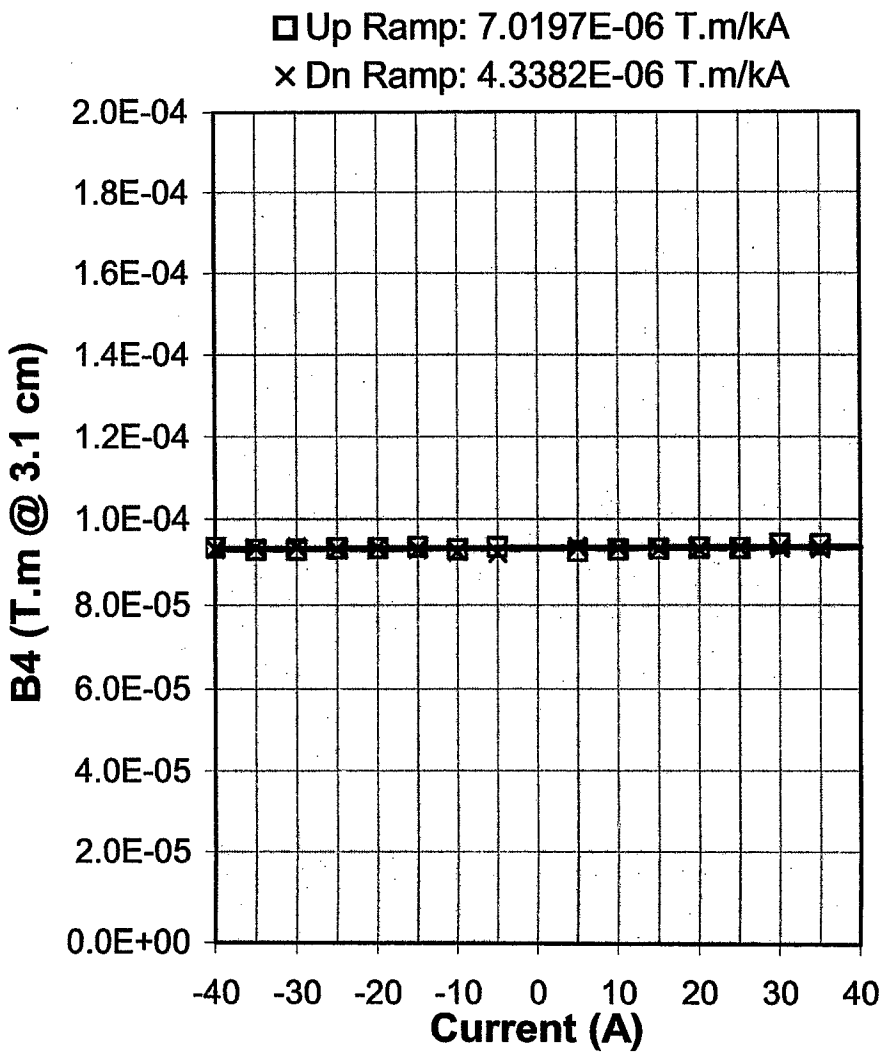
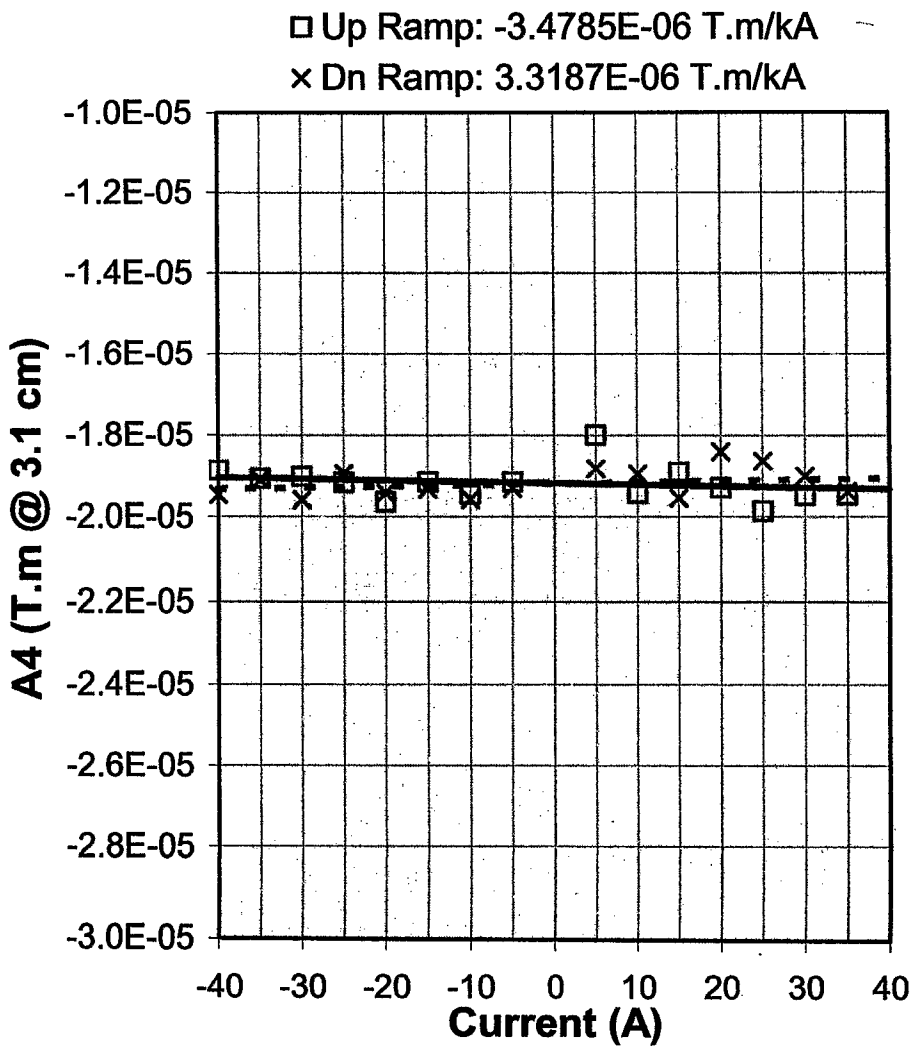




Non-Lead End Corrector: Integ. Harmonics

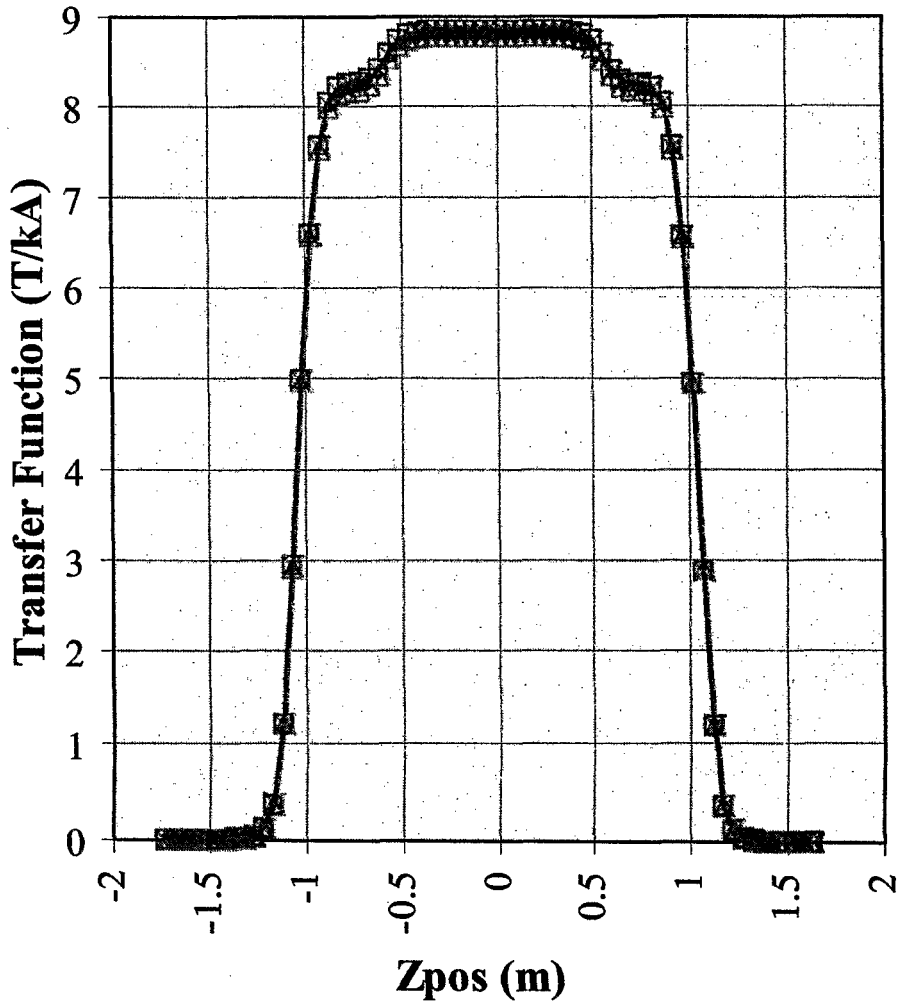
ITF(Up)	ITF(Dn)
0.3214 T.m/kA	0.3214 T.m/kA

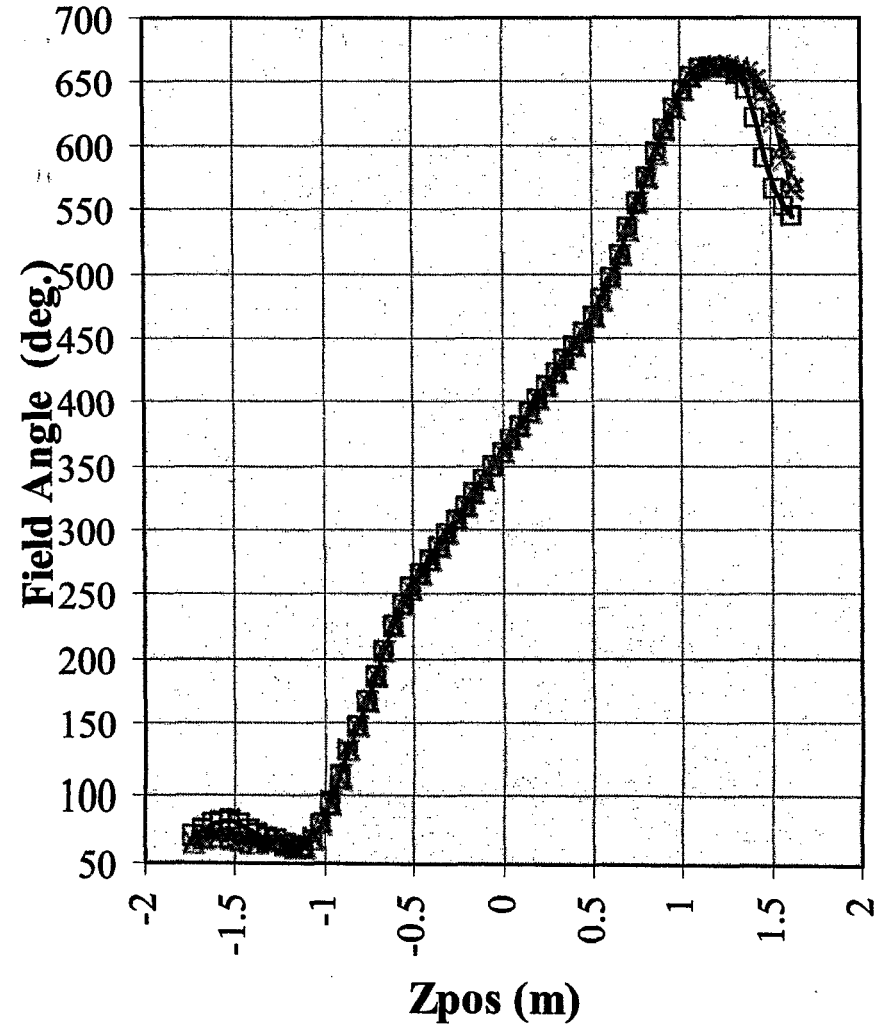
n	"True" Fields ("units" at 3.1cm radius)			
	Bn(Up)	An(Up)	Bn(Dn)	An(Dn)
0	-0.5	10000.0	0.4	10000.0
1	25.7	35.2	30.9	38.0
2	-5.1	5.5	-4.4	6.6
3	0.6	0.6	0.5	0.9
4	0.2	-0.1	0.1	0.1
5	0.0	0.0	0.1	-0.6
6	-0.1	0.1	0.1	0.5
7	0.3	0.2	0.5	0.1
8	0.0	0.4	-0.6	0.2
9	-0.1	0.7	0.3	0.3
10	0.4	-0.1	0.9	-2.5

Axial Scans in the Main Dipole: Harmonics in a Space-fixed Reference Frame

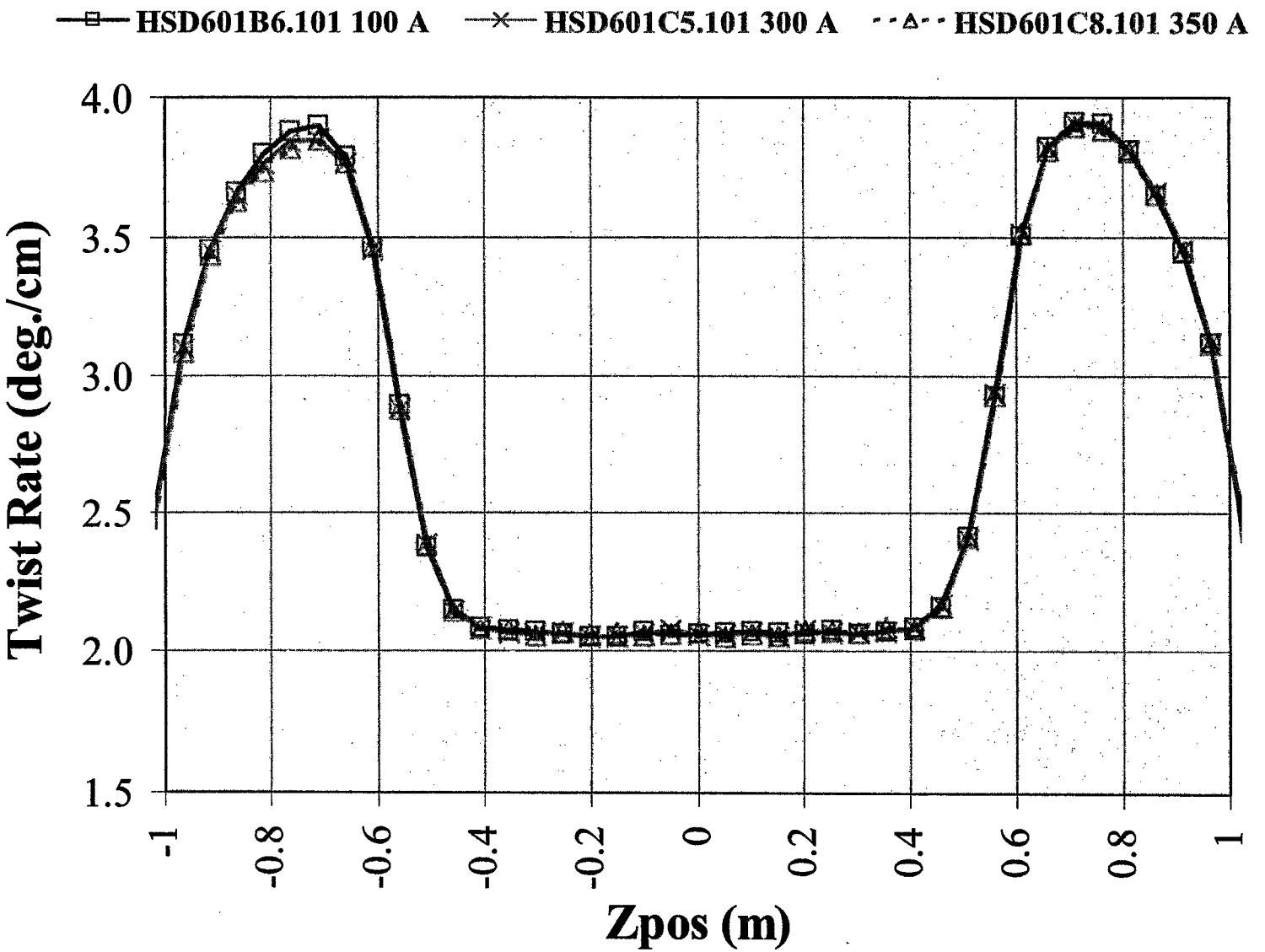
Axial Scans: Trans. Func. & Field Angle

HSD601B6.101 100 A HSD601C5.101 300 A HSD601C8.101 350 A



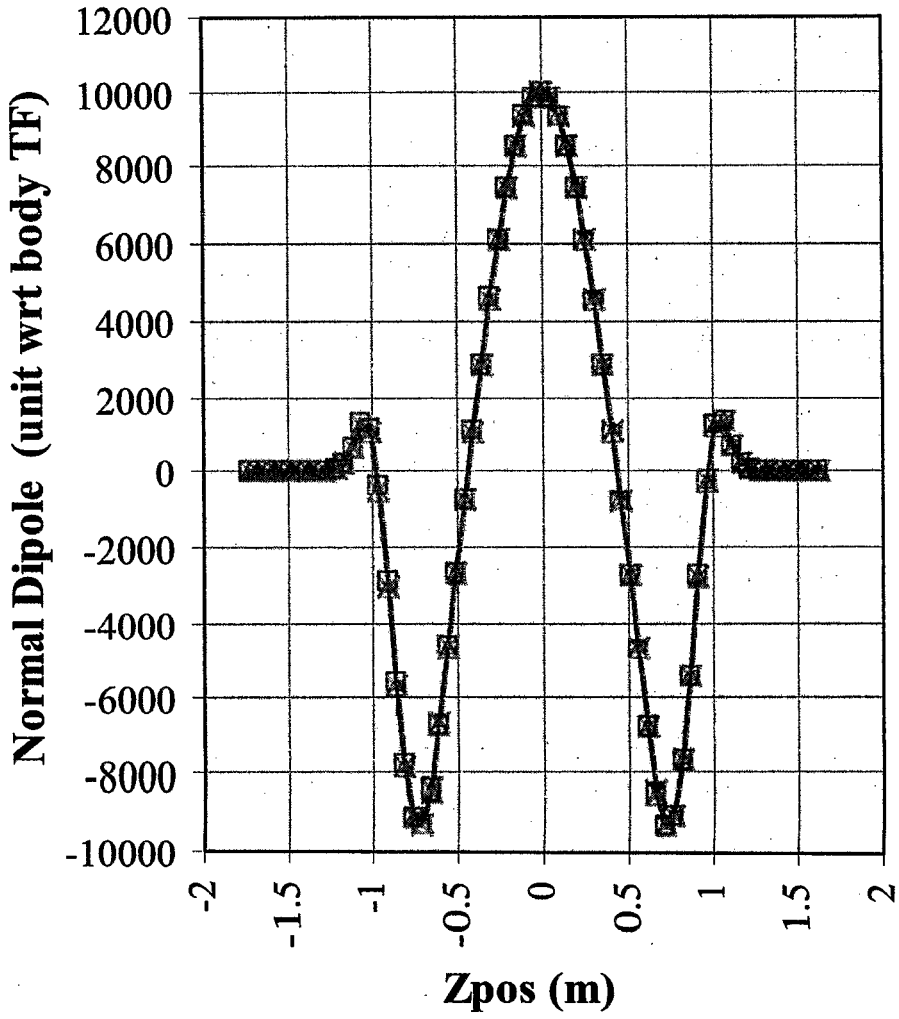


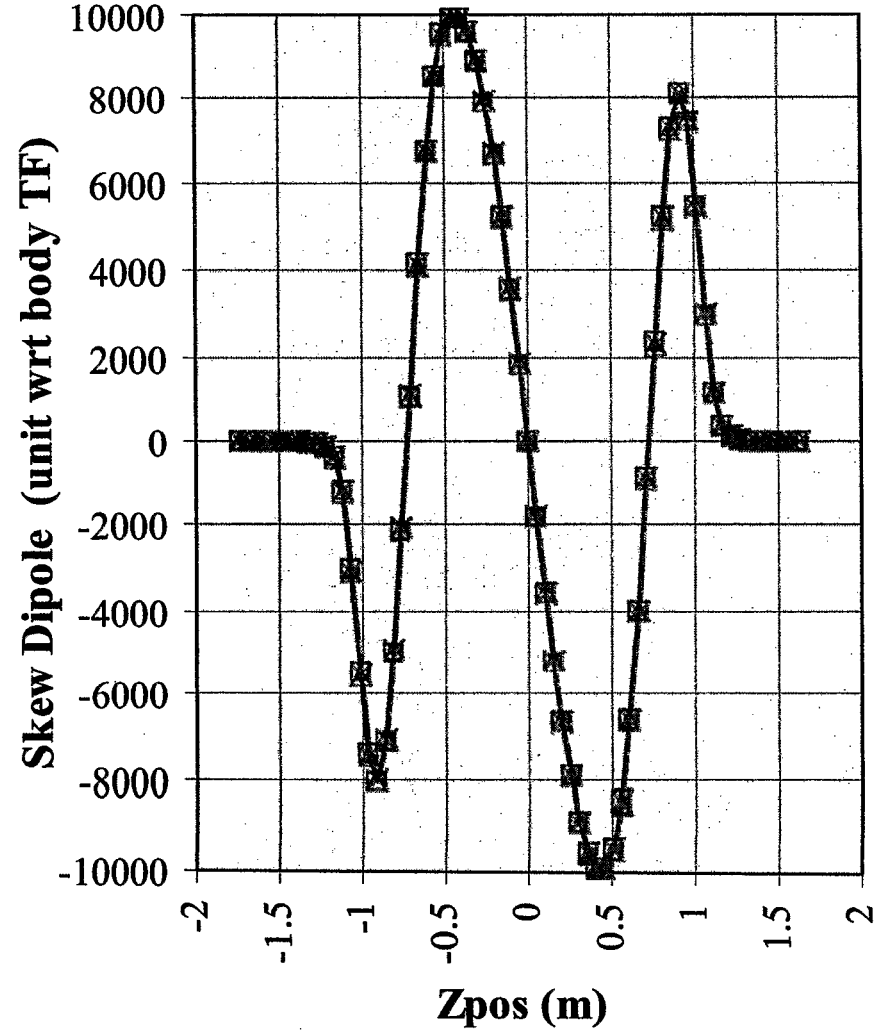
Axial Scans: Twist Rate



Axial Scans: Dipole Terms

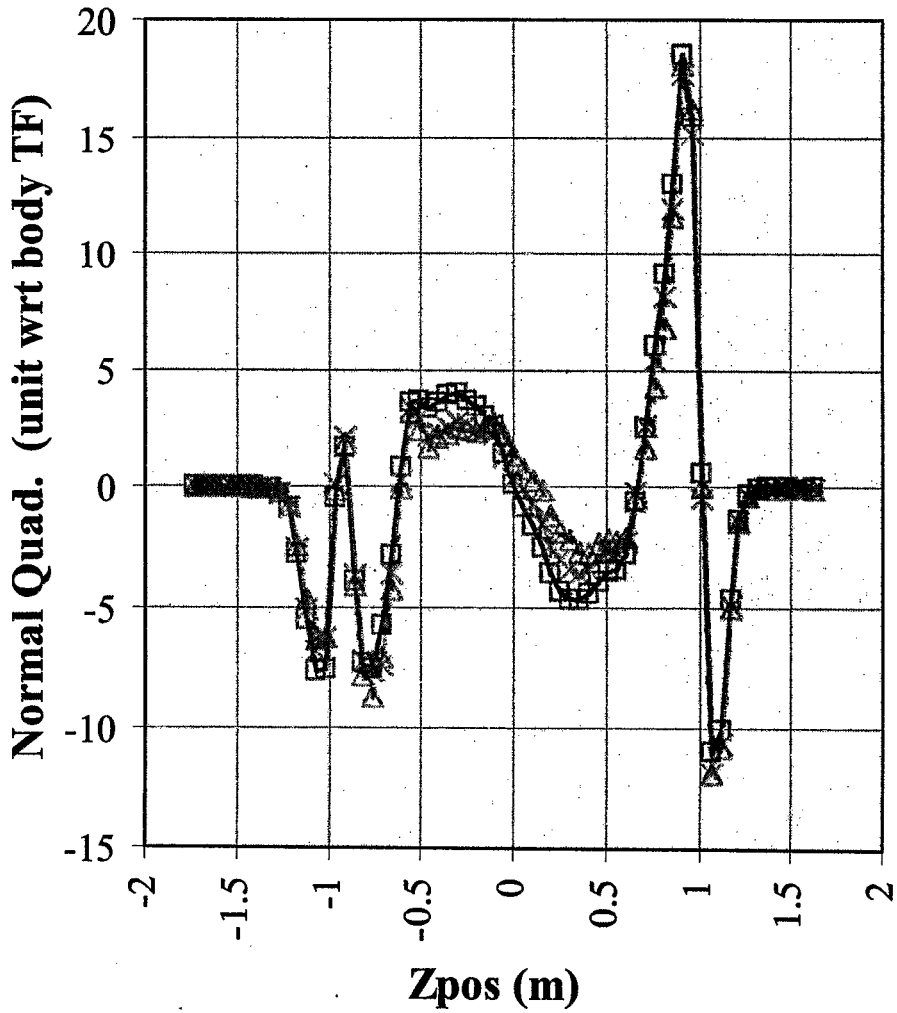
HSD601B6.101 100 A HSD601C5.101 300 A HSD601C8.101 350 A

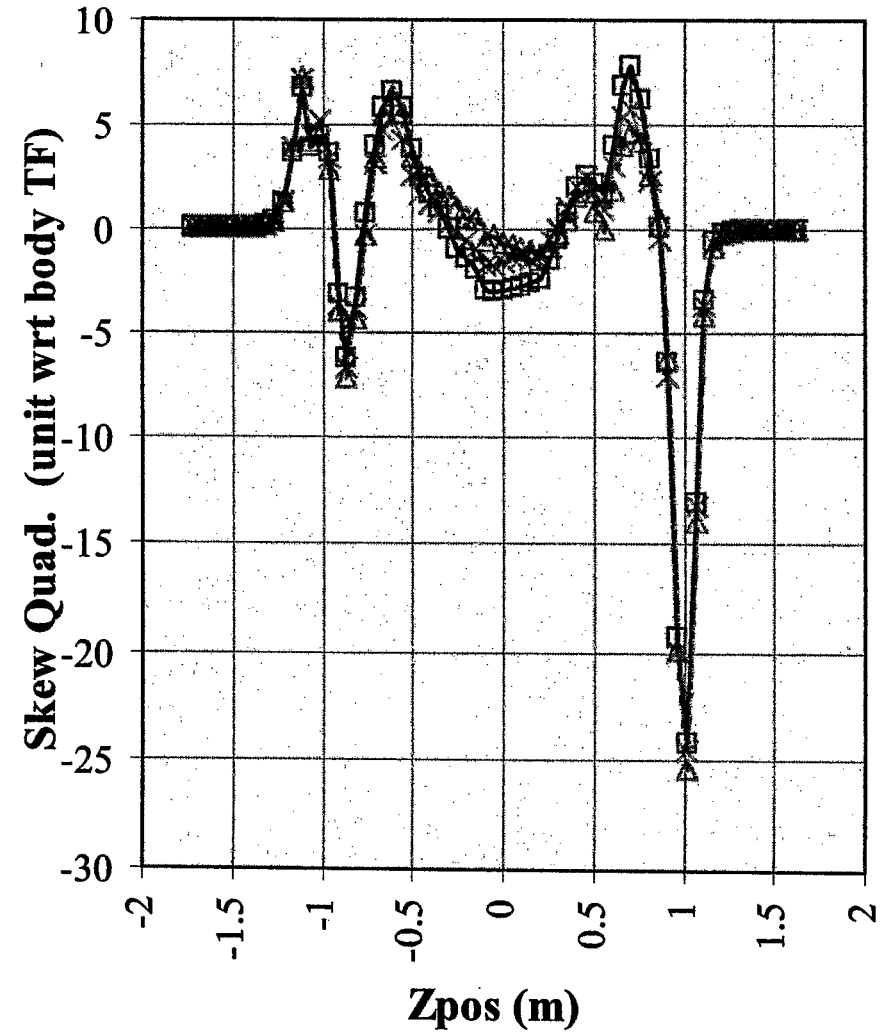




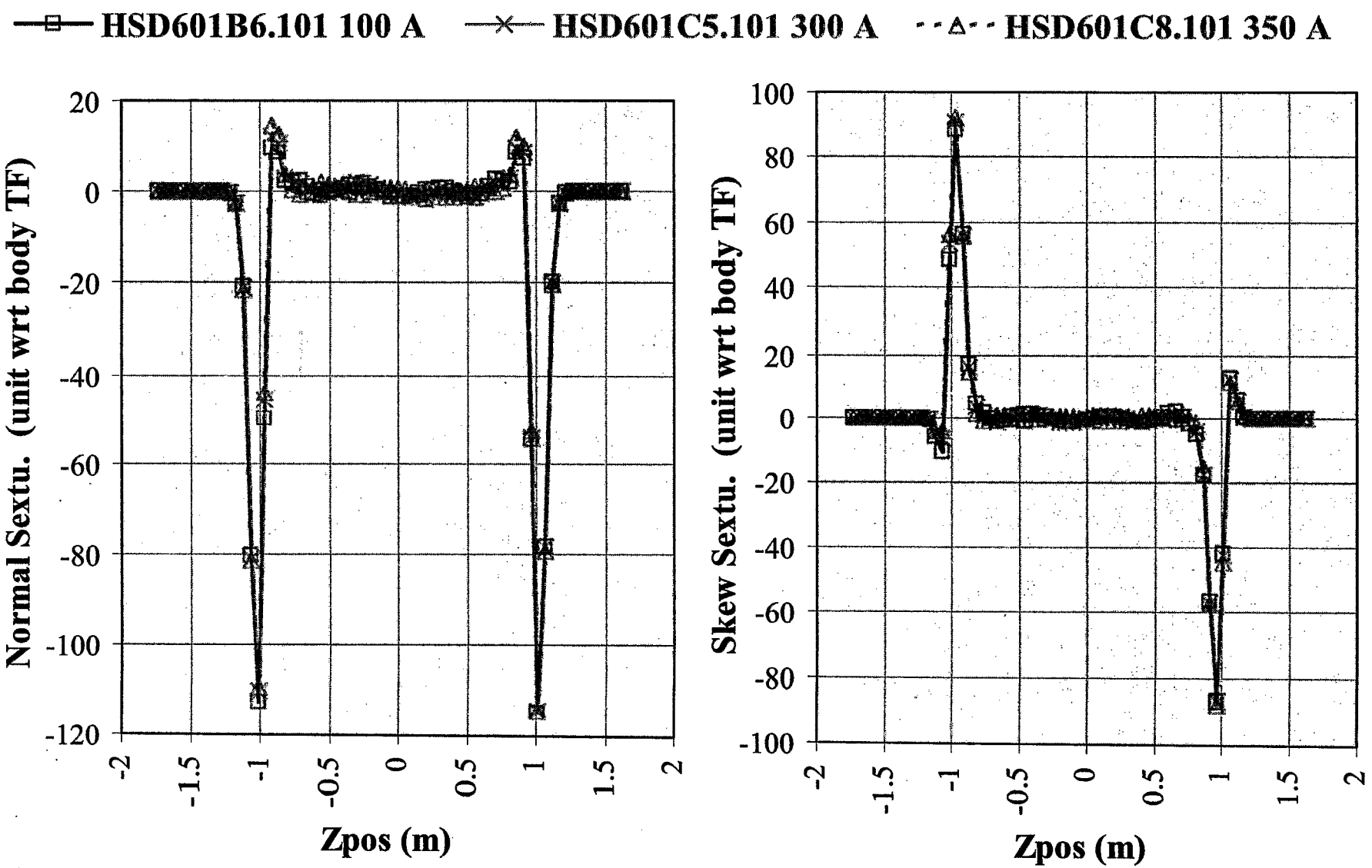
Axial Scans: Quadrupole Terms

HSD601B6.101 100 A HSD601C5.101 300 A HSD601C8.101 350 A



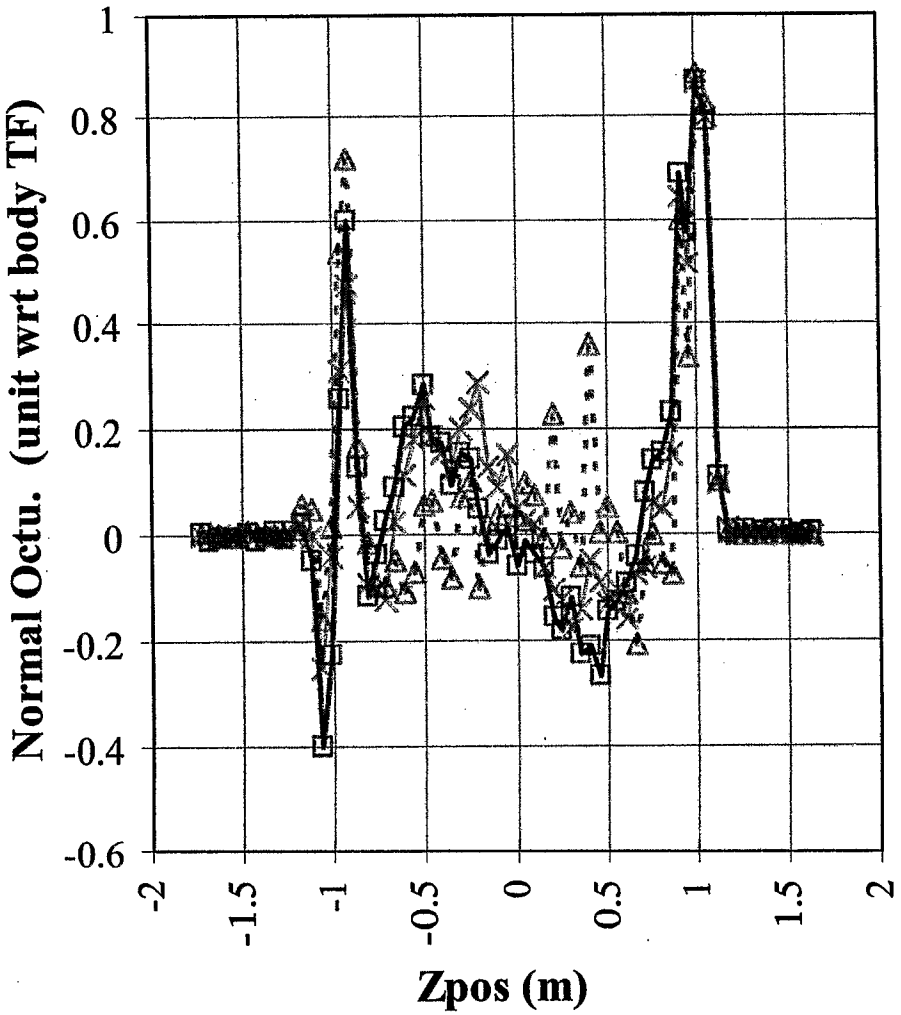


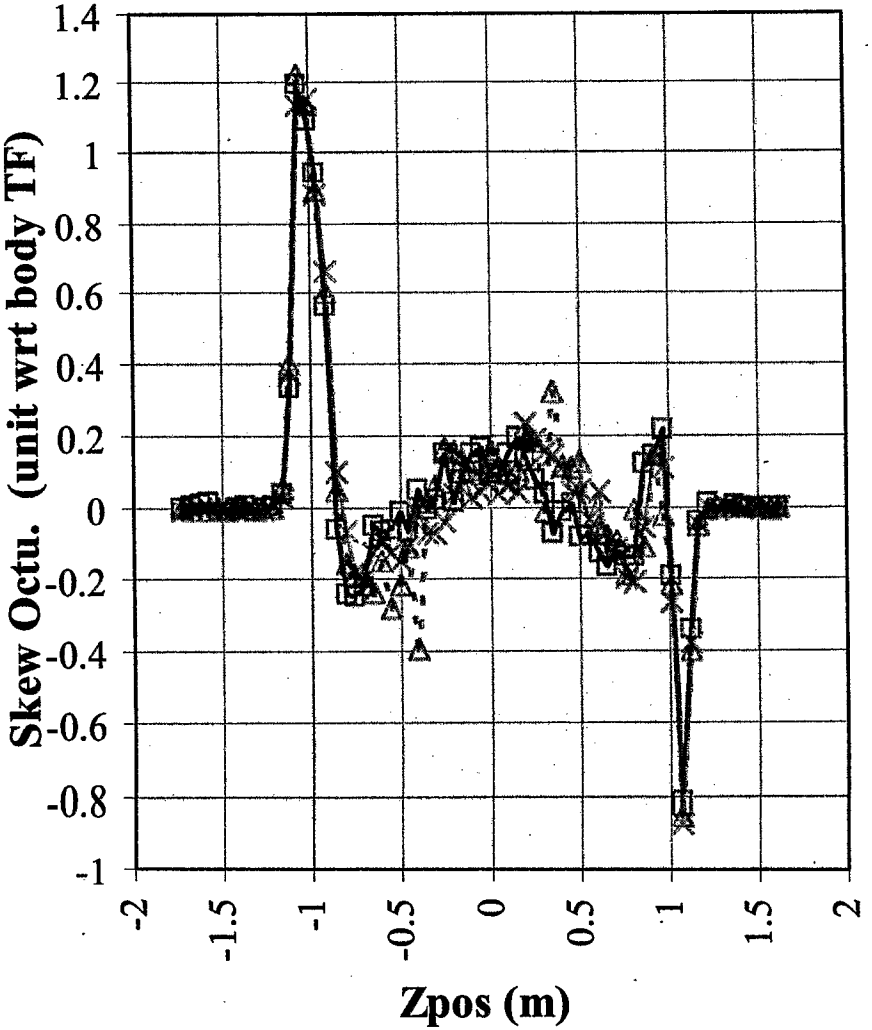
Axial Scans: Sextupole Terms



Axial Scans: Octupole Terms

HSD601B6.101 100 A HSD601C5.101 300 A HSD601C8.101 350 A





Axial Scans: Decapole Terms

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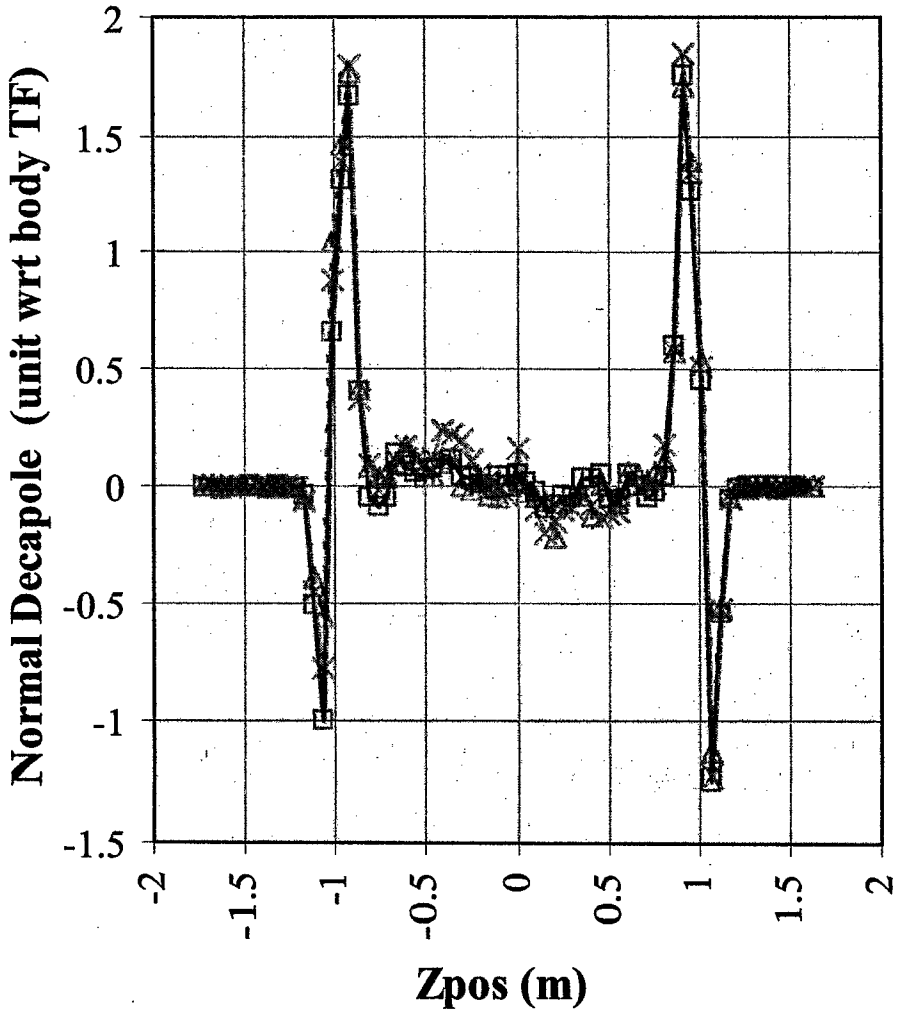
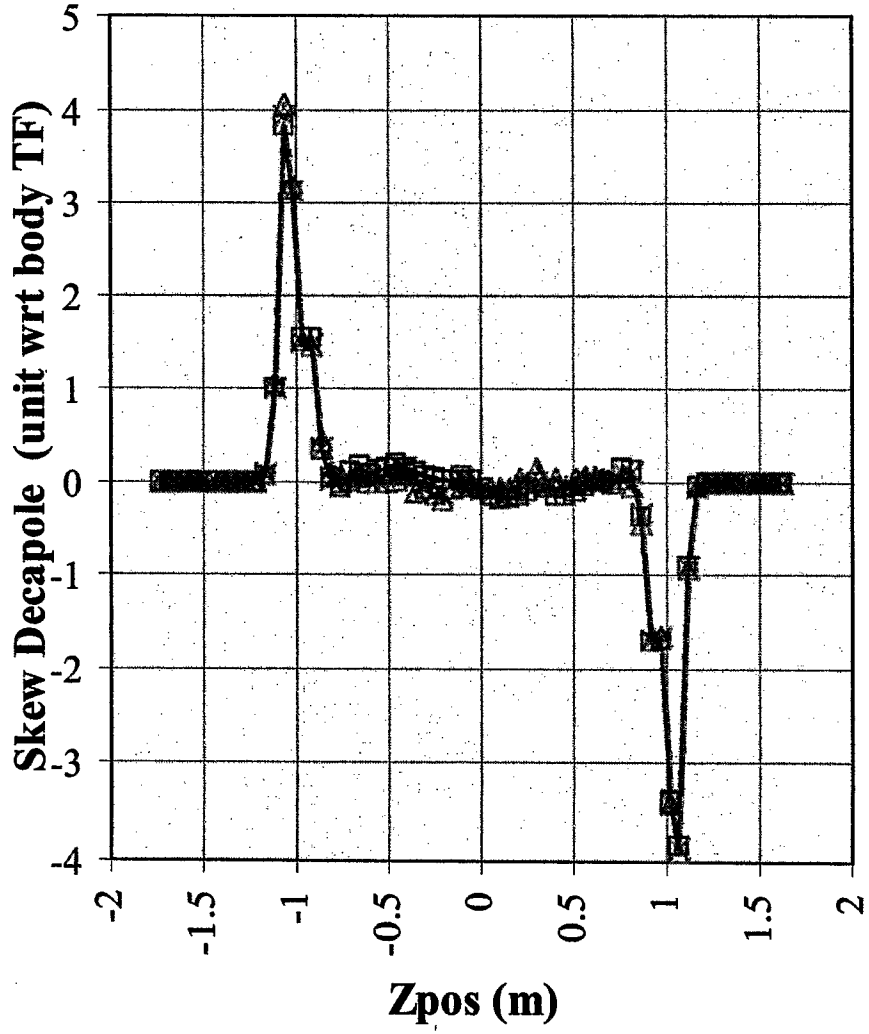
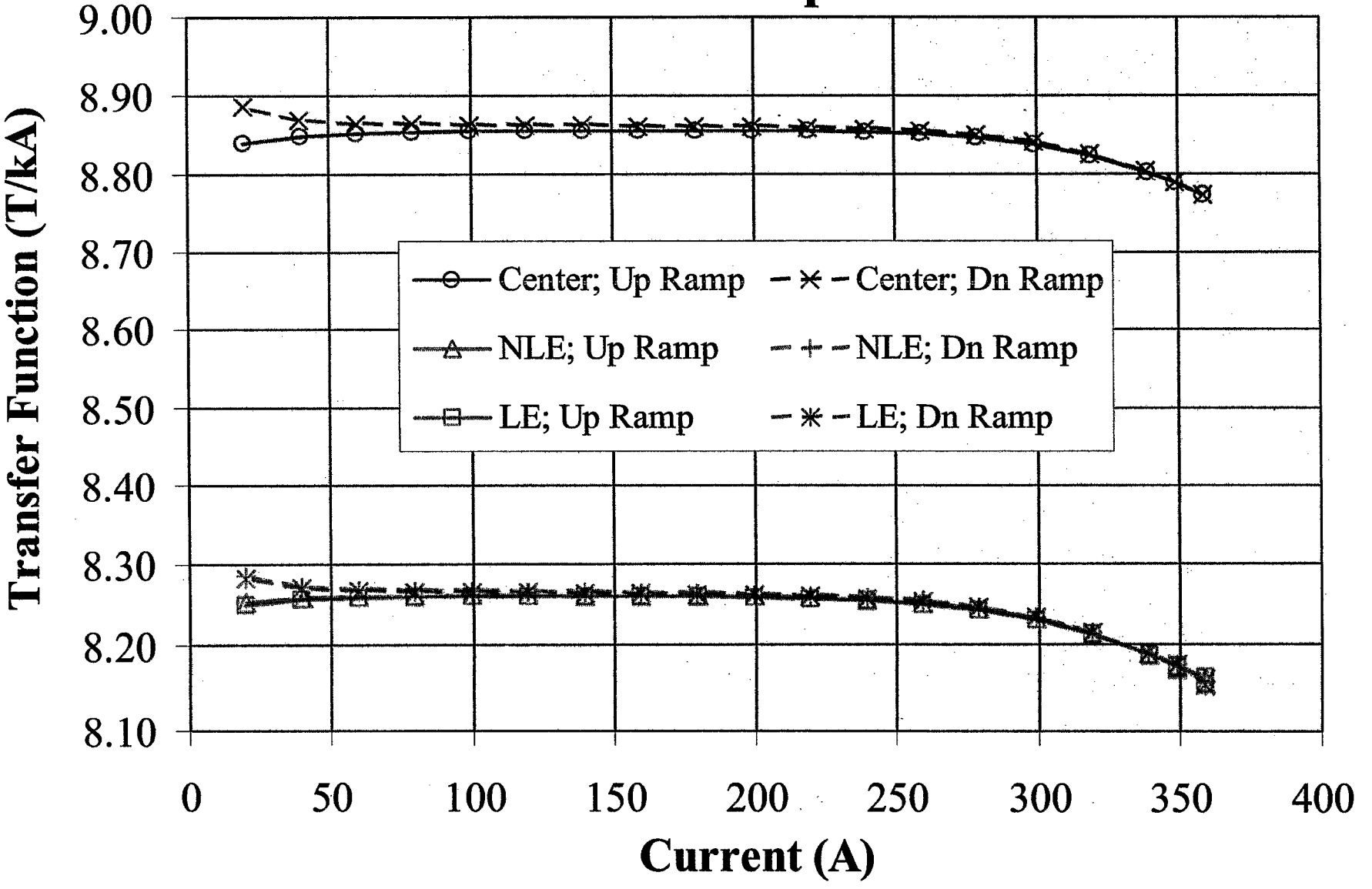


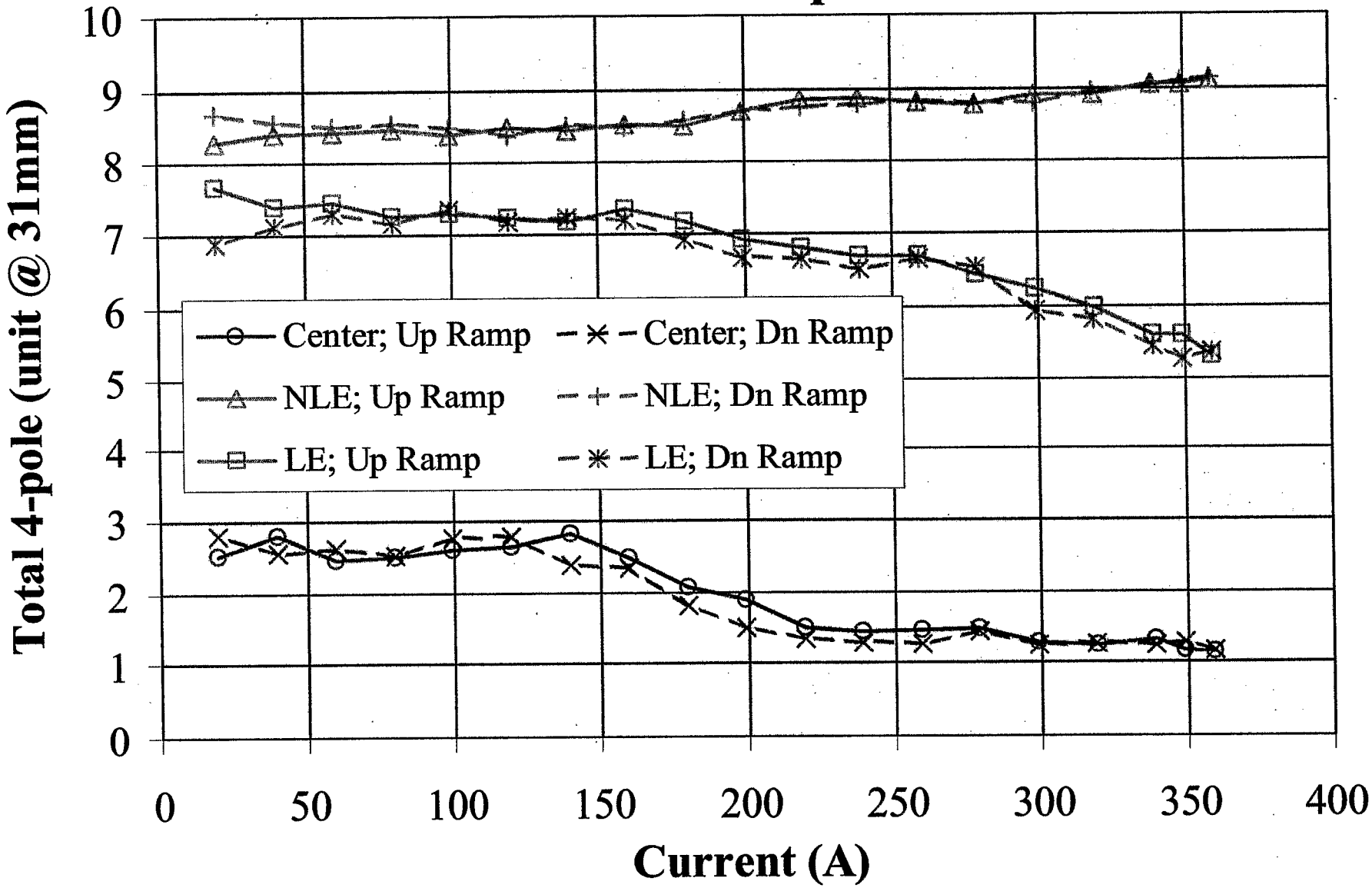


Excitation Curves in the Main Dipole: Axial Center and ±0.75 m

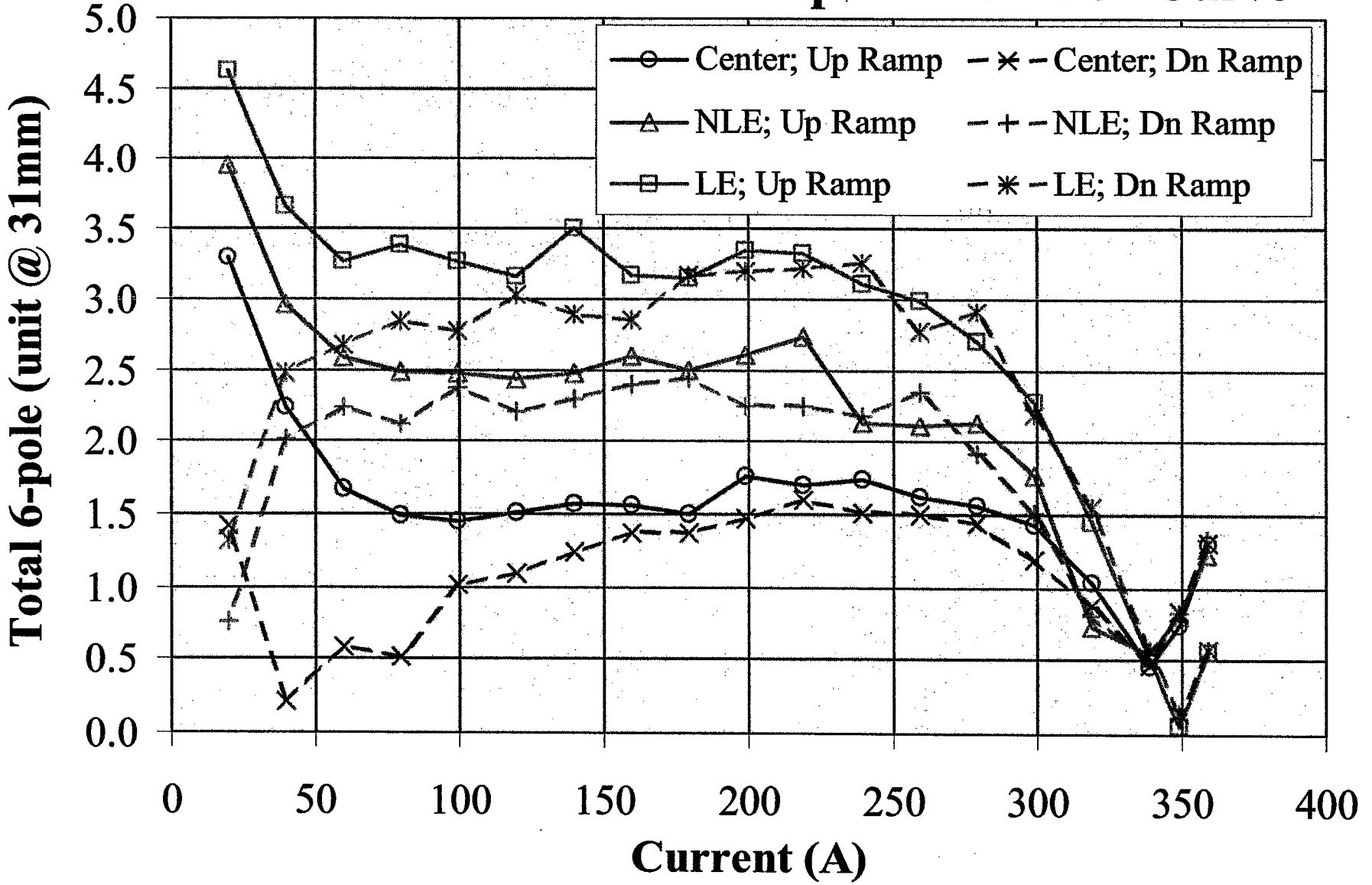
AGS Cold Snake: Main Dipole Excitation Curve



AGS Cold Snake: Main Dipole Excitation Curve



AGS Cold Snake: Main Dipole Excitation Curve



Summary of Field Quality in HSD101

- Cold measurements have been completed in the AGS cold snake (HSD101; a.k.a. DSM101).
- Integral dipole field is below 0.01 T.m at 350 A, with an uncertainty of about a factor of 2.
- Transfer functions of the main dipole and the skew dipole correctors are as expected.
- Only a few low order harmonics could be measured with the available probes.
- Field quality of the main dipole, as well as the two skew dipole correctors, appears satisfactory.

AGS Cold Snake Update

W. MacKay, BNL

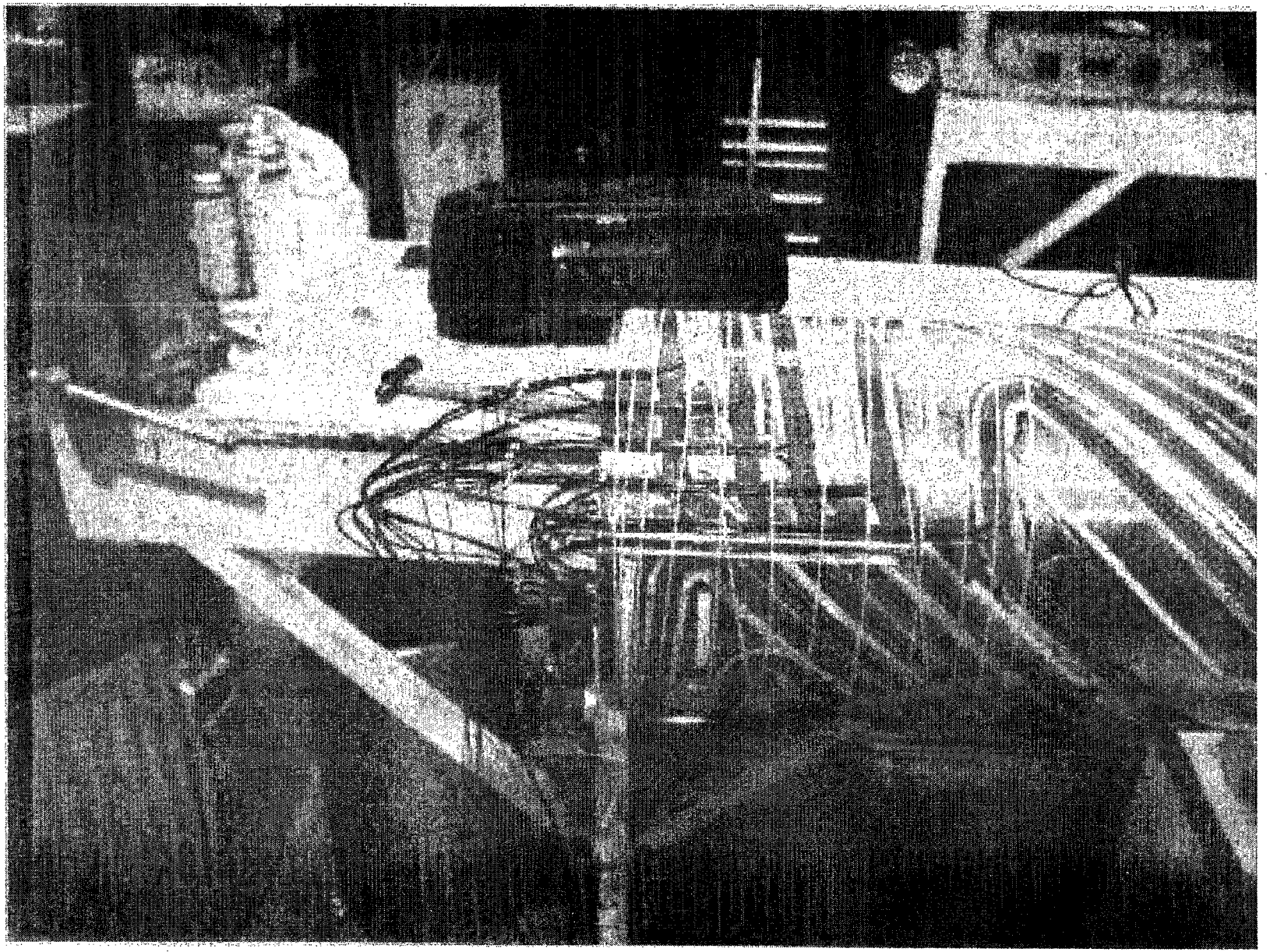
for
RHIC Spin Collaboration Meeting XXVIII
September 2, 2004
RIKEN BNL Research Center

AGS Cold Snake Status

- Cold mass completed and tested in vertical dewar.
  - On cooldown: short to ground developed on inner coil. Completed test with floating supplies.
- Short repaired and cold mass being prepared for another dunk into LHe
  - Magnet division on break next week.
- Schedule
  - Cryostat parts in shop being machined.
  - Cold mass into horizontal cryostat: ~10 Nov.
  - Cryostat to be completed: ~mid Dec.
  - Cooldown and test starts just before ~Xmas
  - Est. delivery to tunnel: 7 Feb., 2005

Slides of measurements from Animesh Jain:

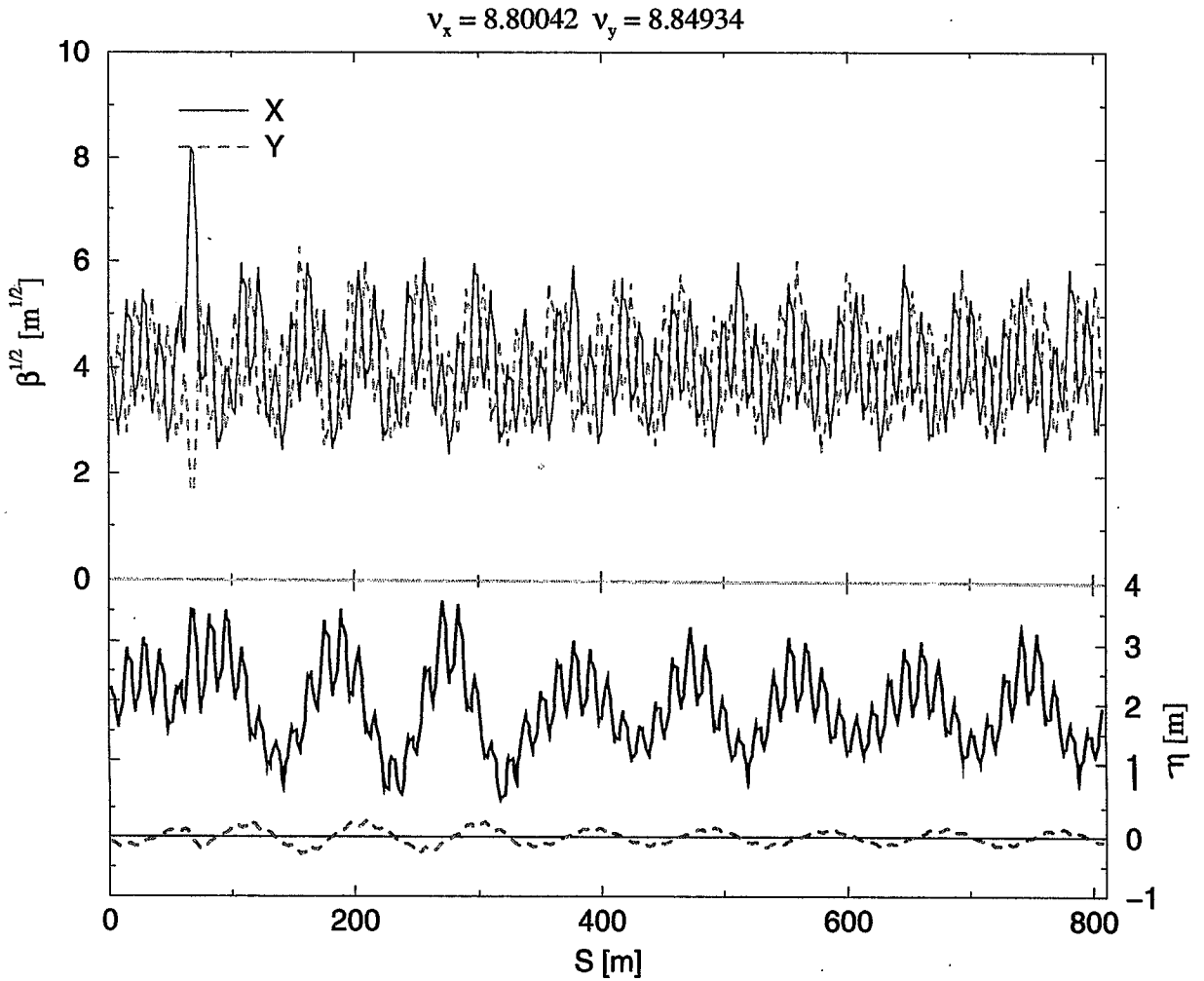
http::/www.agsrhichome.bnl.gov/RHIC/Spin/spinfigs/hsd601sum.pdf



Ramp and Quench, etc. Tests

- Used actual power supplies and quench protection circuits for use in AGS. (A lot of stuff has been debugged!)
- Magnet thermal cycled 4 times with no other problems than the one short to ground.
- Some training quenches plus quite a few quenches to check out protection scheme.
- All four coils achieved design current.
  - Helix and solenoid: 350 A, dipole correctors: 25 A
- In vertical dewar, it is possible to quench the solenoid without quenching the helix.

Two snakes 15% and 6.7% at injection



Cold snake:
A20

Warm snake:
E20

Extra Quads:
A17, A19,
B1, B3

Preliminary Result of A_N Measurement in $p^{\uparrow}p^{\uparrow}$ Elastic Scattering at RHIC, at $\sqrt{s} = 200$ GeV

Włodek Guryn
for pp2pp collaboration
Brookhaven National Laboratory, Upton, NY, USA

OUTLINE of the TALK

- Description of the experiment
- Description of analysis
- Results and interpretation
- Where do we go from here?

Spin Dependence in Elastic Scattering

Five helicity amplitudes describe proton-proton elastic scattering

$$\phi_1(s,t) \propto \langle ++ | M | ++ \rangle \Leftarrow non-flip$$
$$\phi_2(s,t) \propto \langle ++ | M | -- \rangle \Leftarrow double-flip$$
$$\phi_3(s,t) \propto \langle +- | M | +- \rangle \Leftarrow non-flip$$
$$\phi_4(s,t) \propto \langle +- | M | -+ \rangle \Leftarrow double-flip$$
$$\phi_5(s,t) \propto \langle +- | M | -+ \rangle \Leftarrow single-flip$$

$$\phi_i(s,t) = \phi_i^{em}(s,t) + \phi_i^{had}(s,t)$$
$$\phi_+ = \tfrac{1}{2}(\phi_1 + \phi_3)$$
$$\phi_- = \tfrac{1}{2}(\phi_1 - \phi_3)$$
$$\phi_i^{had} = \phi_i^{R} + \phi_i^{Asympt.}$$

Some of the measured quantities are

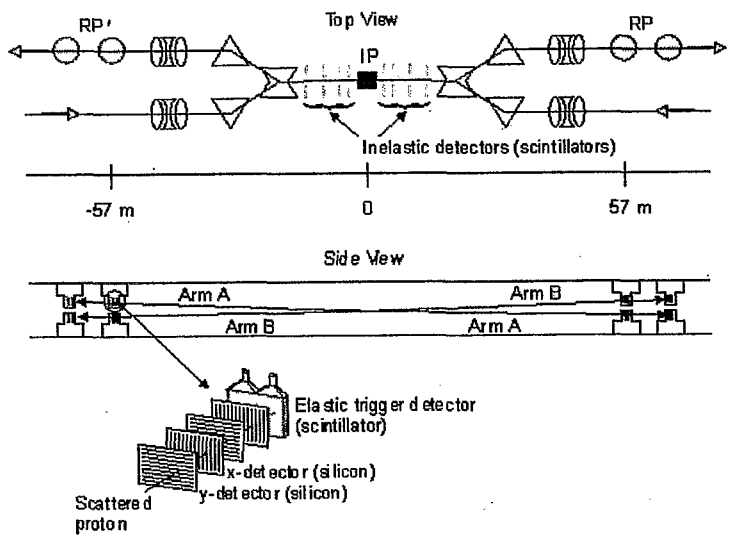
$$\sigma_{tot}(s) = \frac{4\pi}{s} \mathrm{Im}[\phi_+(s,t)]_{t=0}$$

Regge Model of σ_{tot} of gives s dependence of ϕ_+

$$\frac{d\sigma}{dt} = \frac{2\pi}{s^2}(|\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + |\phi_4|^2 + 4|\phi_5|^2)$$

Contributes to the shape of A_N

Principle of the Measurement



- Elastically scattered protons have very small scattering angle θ^*, hence beam transport magnets determine trajectory scattered protons
- The optimal position for the detectors is where scattered protons are well separated from beam protons
- Need Roman Pot to measure scattered protons close to the beam without breaking accelerator vacuum

Beam transport equations **relate measured position at the detector to scattering angle.**

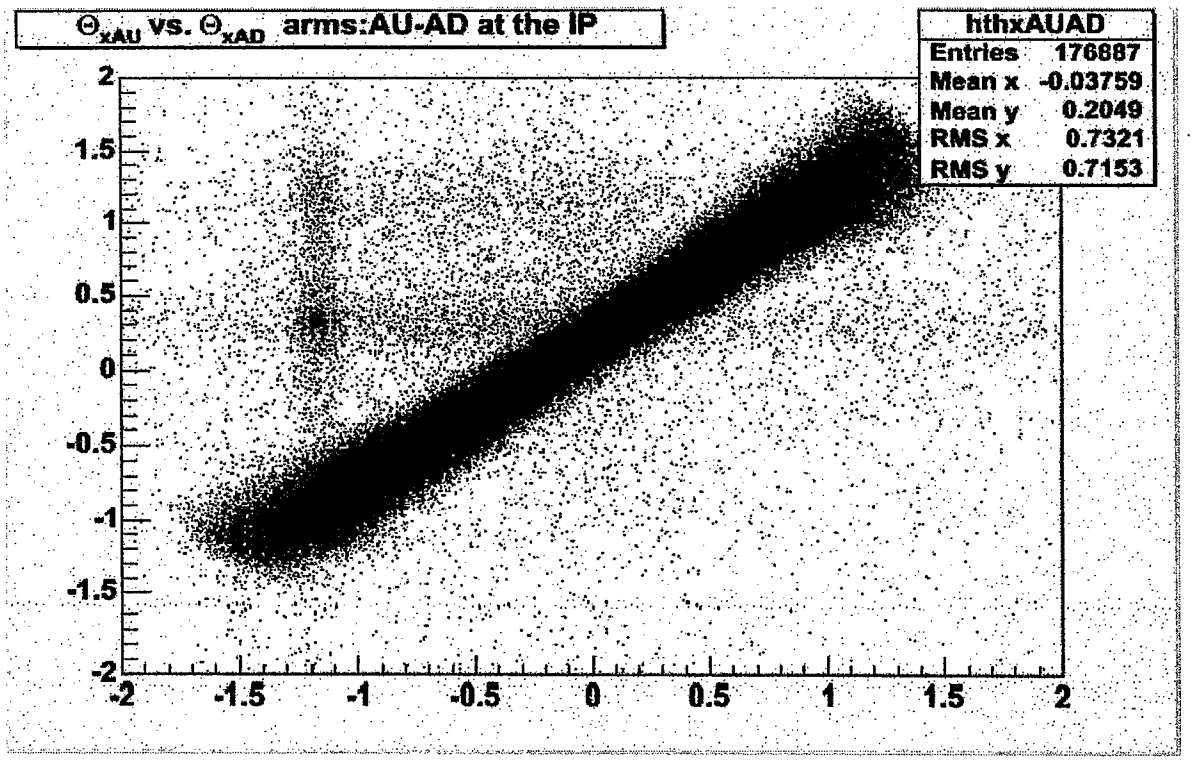
$$\begin{pmatrix} x_D \\ \Theta_D^x \\ y_D \\ \Theta_D^y \end{pmatrix} = \begin{pmatrix} a_{11} & L_{eff}^x & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & L_{eff}^y \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \begin{pmatrix} x_0 \\ \Theta_x^* \\ y_0 \\ \Theta_y^* \end{pmatrix}$$

x_0, y_0: Position at Interaction Point
Θ^*_x Θ^*_y : Scattering Angle at IP
x_D, y_D : Position at Detector
Θ^x_D, Θ^y_D : Angle at Detector

Angle (hit) Correlations Before the Cuts

Events with only eight hits

Note: the background appears enhanced because of the "saturation" of the main band



Hit selection

1. Pedestal value, pedestal width (σ) and dead channels (only six) were determined;
2. Valid hit, single strip, has dE/dx > 5σ above the pedestal;
3. Cluster size is ≤ 5 consecutive strips above pedestal cut;
4. Valid hit in the Si plane for event reconstruction:
   - is a cluster whose dE/dx > 20 ADC counts above pedestal and
   - is within fiducial area of the detector (slide);
   - has for a y-plane y > 0.2mm from the edge of the detector.
5. Coordinate for x and y formed from adjacent hits in Sin for each Roman Pot

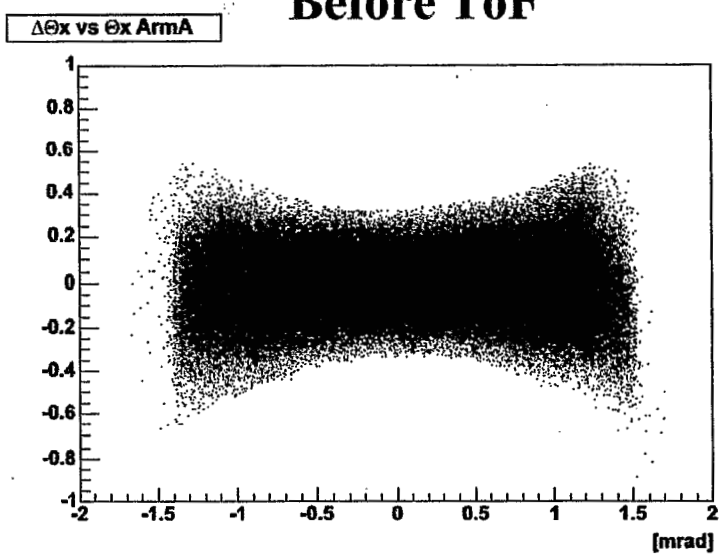
After finding matching hits in x and y:

- Choose events with one track in x and one track in y and $\geq$ 6hits.
- Veto on the Sc signal in the opposite arm, TDC cut.
- Choose collinear tracks within 3σ in angles.
- Plot dN/dt and calculate asymmetries.

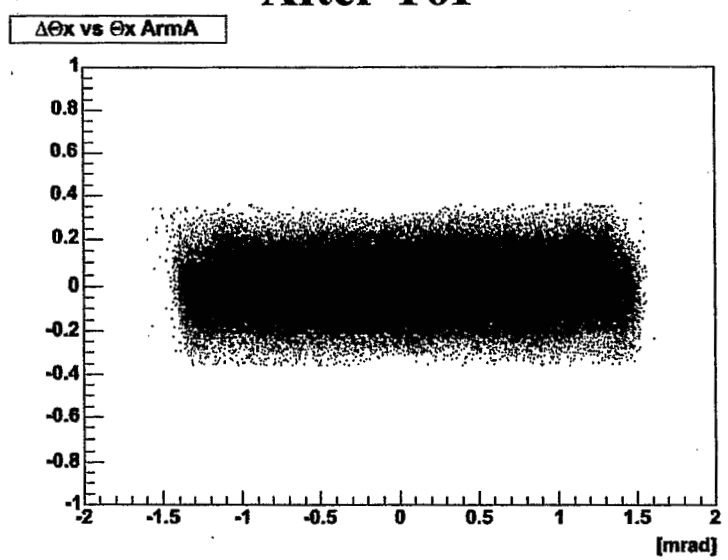
Calculation of Scattering Angle

1. Using matched hits scattering angels can be calculated.
2. Use transport and and average (x_0, y_0) and beam angles obtained from vectors reconstructed using all eight RPs.
3. Make z-vertex correction using ToF.

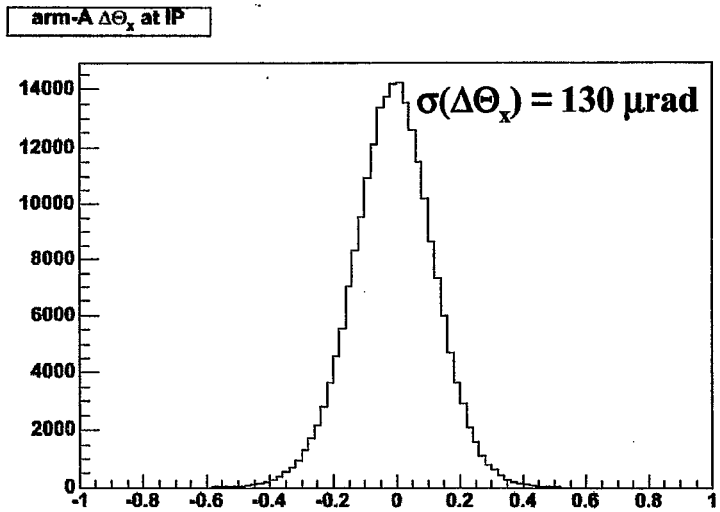
Before ToF

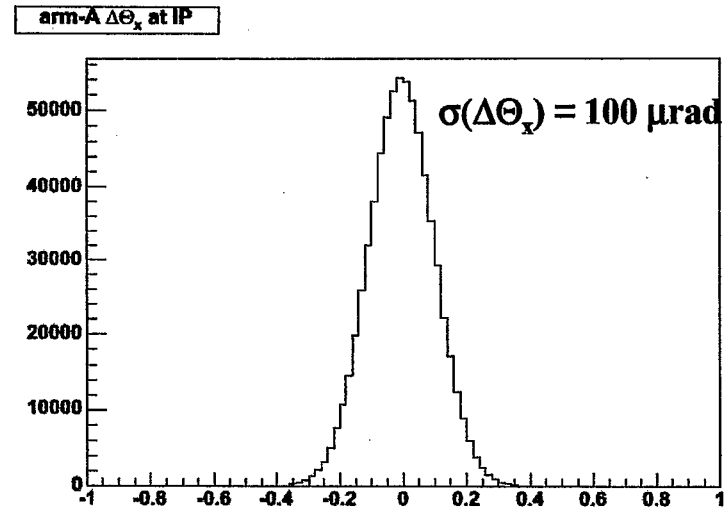


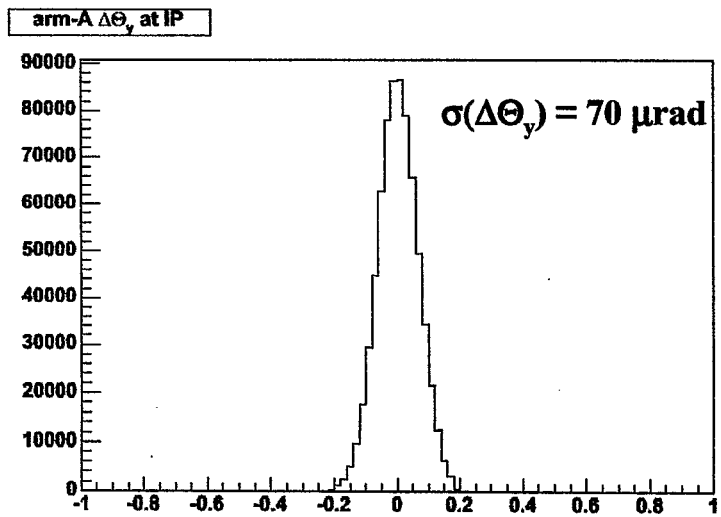
After ToF



Collinearity: $\Delta\Theta_x$ before and after z-correction, and $\Delta\Theta_y$







Determination of A_N

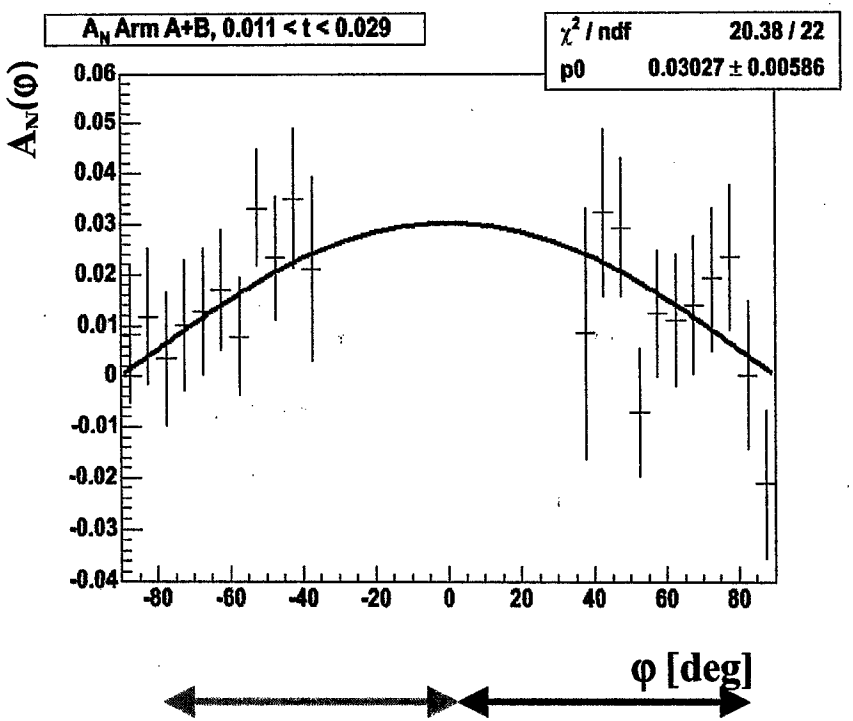
Use *Square-Root-Formula* to calculate raw and false asymmetries, since it cancel luminosity dependence. It uses ↑↑, ↓↓ and ↑↓, ↓↑ bunch combinations.

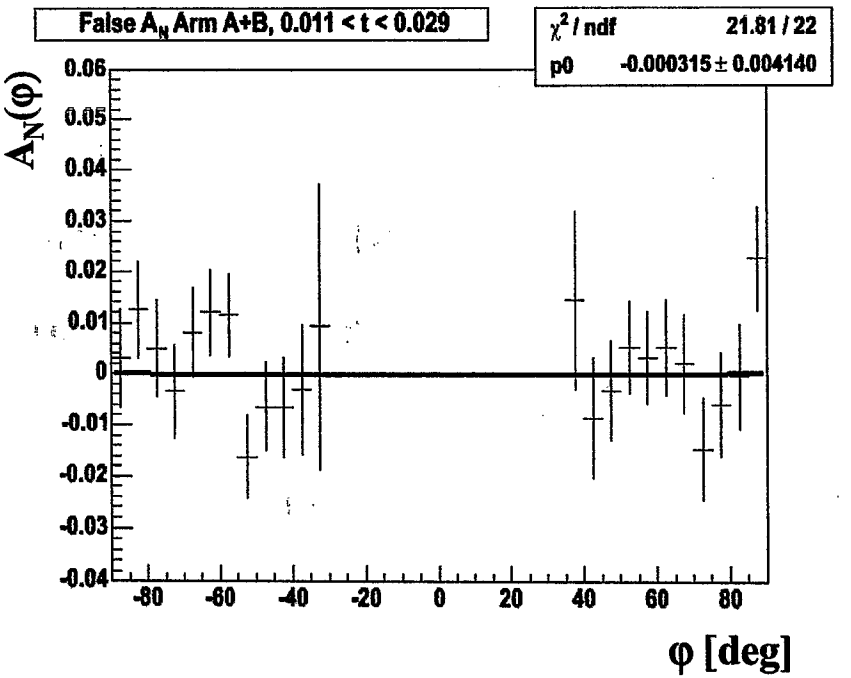
$$A_N(\varphi) = \frac{1}{(P_1 + P_2)\cos\varphi} \frac{\sqrt{N_L^{\uparrow\uparrow} N_R^{\downarrow\downarrow}} - \sqrt{N_R^{\uparrow\uparrow} N_L^{\downarrow\downarrow}}}{\sqrt{N_L^{\uparrow\uparrow} N_R^{\downarrow\downarrow}} + \sqrt{N_R^{\uparrow\uparrow} N_L^{\downarrow\downarrow}}}$$

$$A_N^{False}(\varphi) = \frac{1}{(P_1 + P_2)\cos\varphi} \frac{\sqrt{N_L^{\uparrow\downarrow} N_R^{\downarrow\uparrow}} - \sqrt{N_R^{\uparrow\downarrow} N_L^{\downarrow\uparrow}}}{\sqrt{N_L^{\uparrow\downarrow} N_R^{\downarrow\uparrow}} + \sqrt{N_R^{\uparrow\downarrow} N_L^{\downarrow\uparrow}}}$$

Preliminary Results: Full bin $0.011 < -t < 0.029$ $(GeV/c)^2$

Fit $A_N \cos(\varphi)$ dependence to obtain A_N



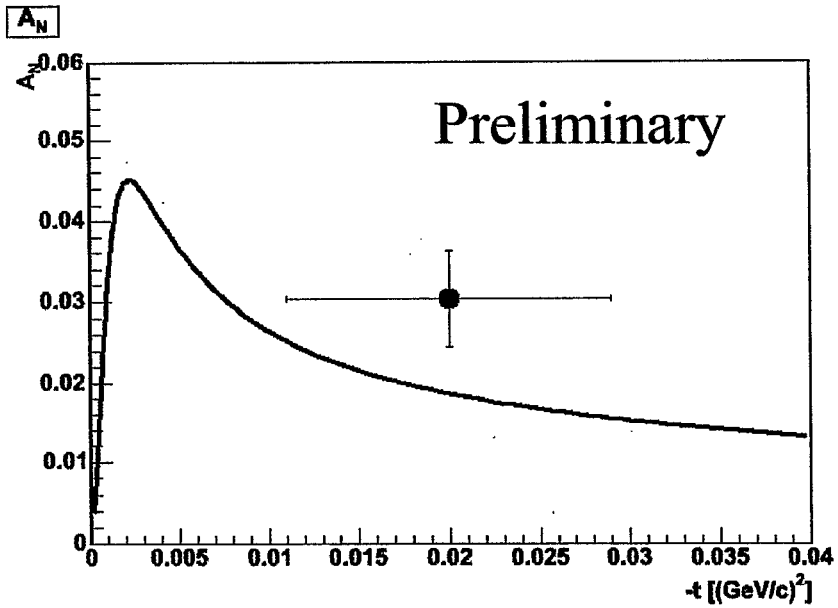


Arm A Arm B

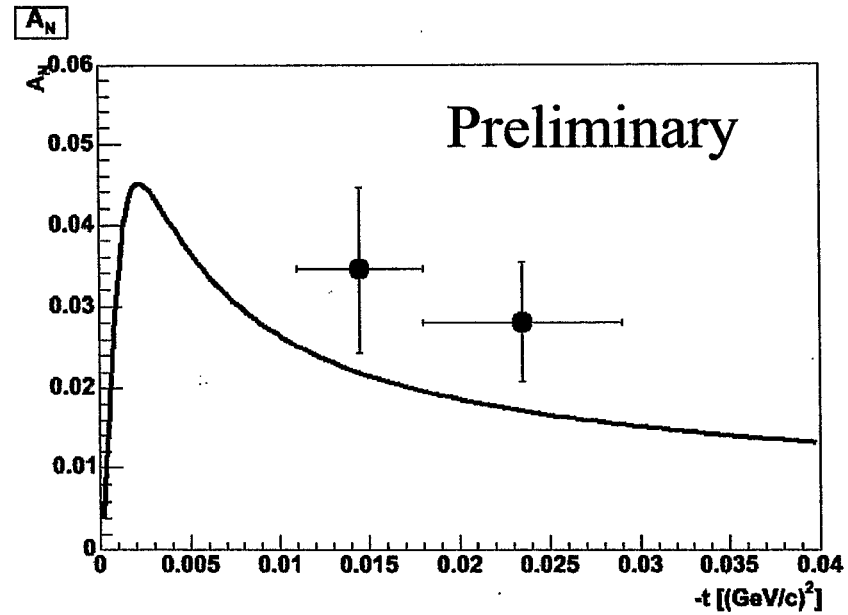
Results: $P_{Yellow} + P_{Blue} = 0.67$ (central value) and CNI curve

(σ_{tot}, ρ from world data, B from pp2pp result)

One point for the full t-interval [0.011,0.029]



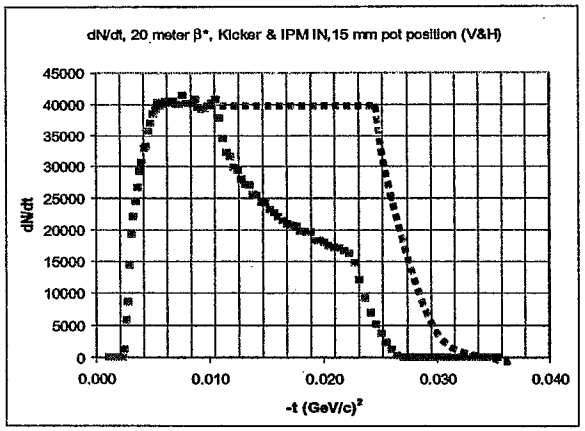
Two points for two half intervals



Note: $P_{Yellow} + P_{Blue} = 0.67$ can vary by ± 15% (a working number)

Future Possibility – Big Improvement

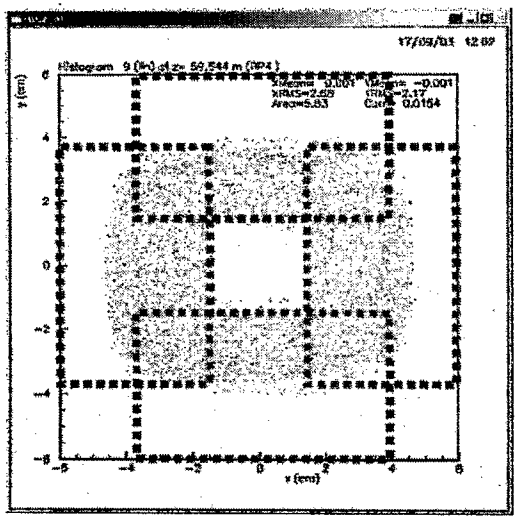
dN/dt



Full acceptance at √s 200 GeV
Without IPM and kicker

With IPM and kicker

x-y



√s (GeV)	β*	|t|-range (Gev/c)²	Typical errors
200	**20 m**	**0.003 < |t| < 0.02**	**$\Delta B = 0.3$, $\Delta\sigma_{tot} = 2 - 3$ mb** **$\Delta\rho = 0.007$ and $\Delta A_N = 0.002$**
Cost: $ 25k			

Summary

1. We have measured the single spin analyzing power A_N in polarized pp elastic scattering at $\sqrt{s} = 200$ GeV in t-range [0.011,0.29] $(GeV/c)^2$.
2. The A_N is $\approx$ 4-5σ from zero.
3. The A_N is $\approx$ 1-2σ away from a CNI curve, which does not have hadronic spin flip amplitude.
4. We discussed interpretation of the result by Larry Trueman and Boris Kopeliovich.

RHIC is a great and unique place to do this physics!

Update on the H-Jet

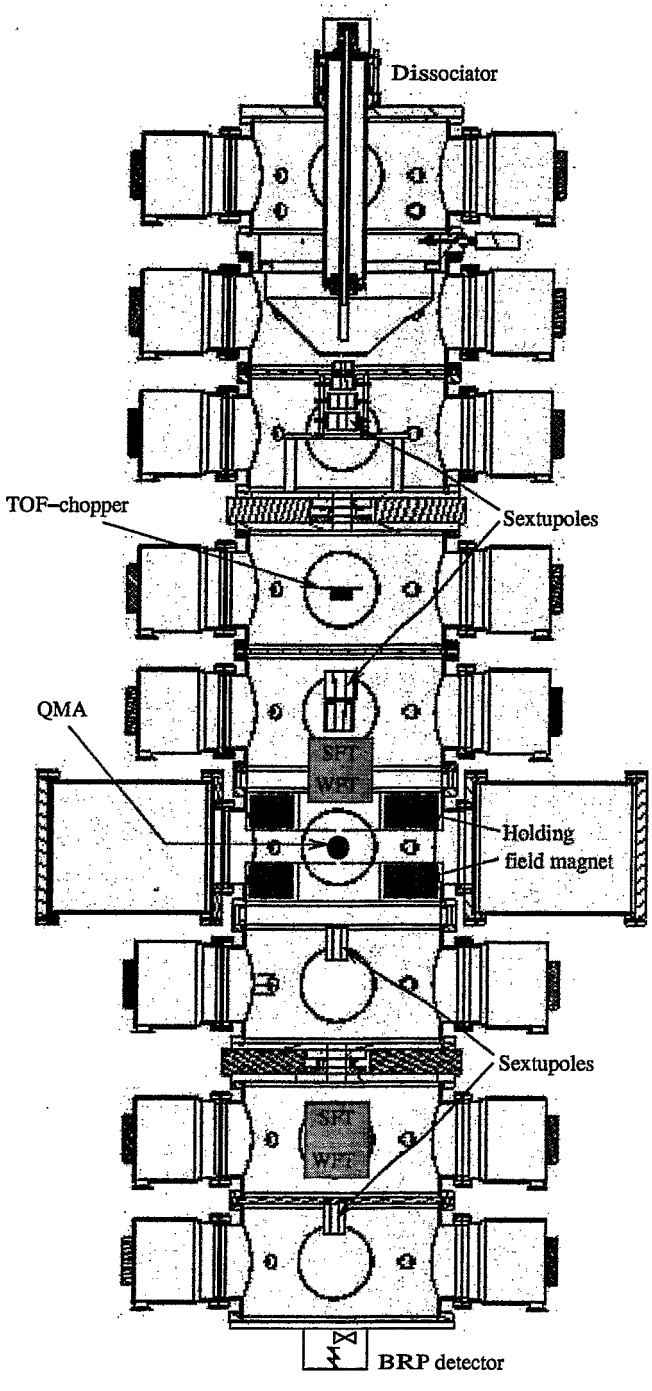
A. Nass, BNL

for
RHIC Spin Collaboration Meeting XXVIII
September 2, 2004
RIKEN BNL Research Center

Update on the H-Jet

1. TOF measurements

2. First setup to measure the degree of dissociation using an electron gun (JET beam analyzer)



Alexander Nass, Brookhaven National Laboratory

September 2nd 2004

TOF Measurement

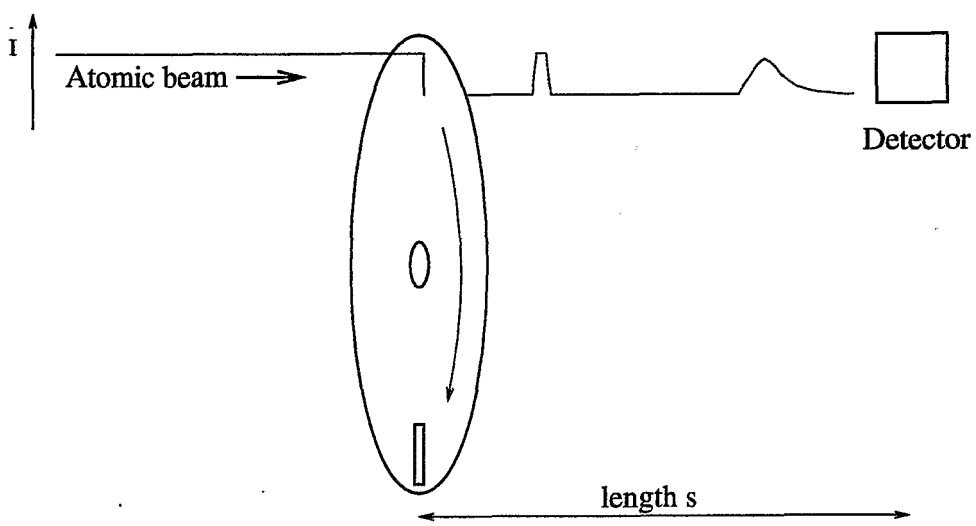
- TOF measurements done using a high frequency transition and BRP.

  But: Velocity distribution was altered by the sextupole system of the BRP.
  ⇒ No clear information about velocity at IP.

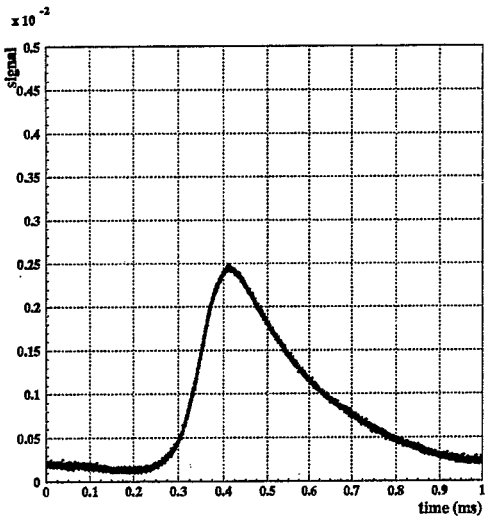
- New setup includes insertion of a fast chopper (up to 300 Hz) in chamber #4 and measurement of the TOF distribution at the IP.

  ⇒ Direct measurement of the velocity distribution at the IP.

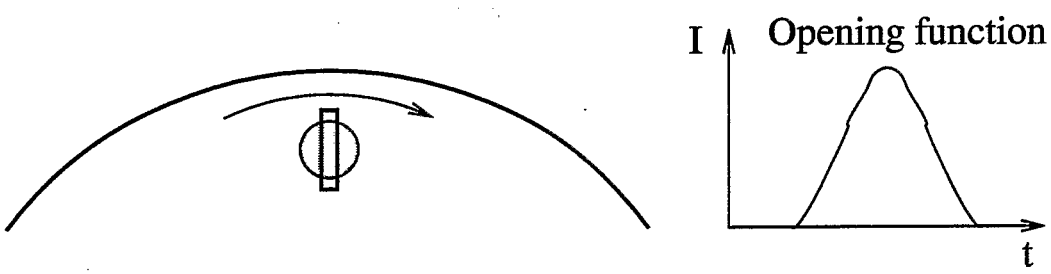
  ⇒ Exact determination of the target density.



TOF Measurement



- Light break on the chopper gives reference time
- Time measured until atoms arrive at the QMA
- Signal is a convolution of the velocity distribution of the atoms and the so-called opening function of the chopper window

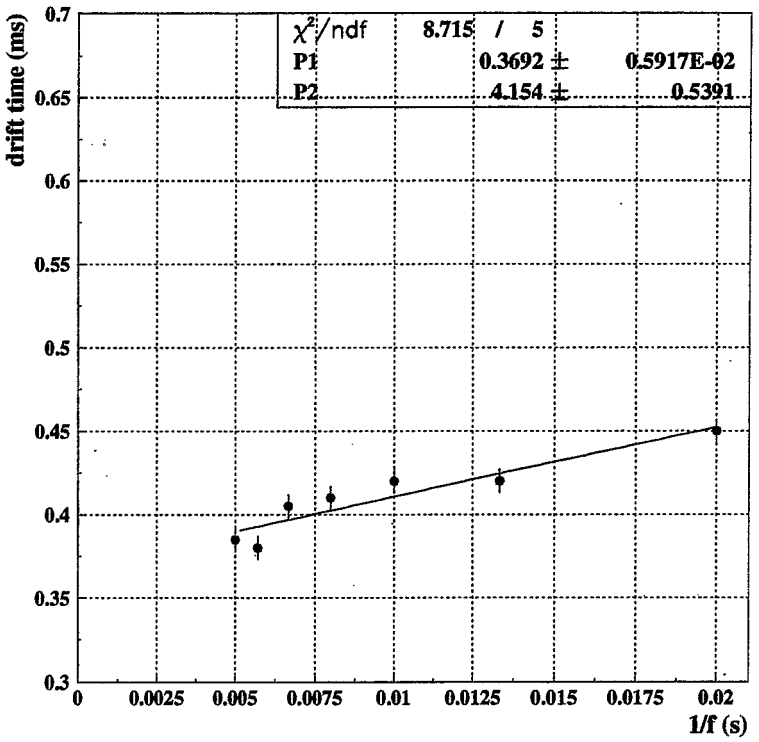


⇒ Deconvolution necessary

TOF Measurement

- Parametrization of the TOF signal necessary for deconvolution, but difficult due to non-Maxwellian distribution.
- Influence of the opening function is decreasing as the speed of the chopper increases.

  ⇒ Measurements at different speeds and extrapolation.



⇒ Result: v = 0.65m/0.369ms = 1760±20 m/s

Variations in dissociator parameters (H_2 flux, T_{nozzle}, P_{RF}) changed this value by 50 m/s maximum since the velocity is almost fixed by the transmission function of the sextupole magnets.

Areal density of the JET

- FWHM of the JET (measured): 5.5 mm
- Measured intensity of full beam: $12.5 \cdot 10^{16}$ atoms/s
- Using measured velocity: $\rho_z = 7.35 \cdot 10^{10}$ atoms/mm
- Assuming Gaussian distribution:

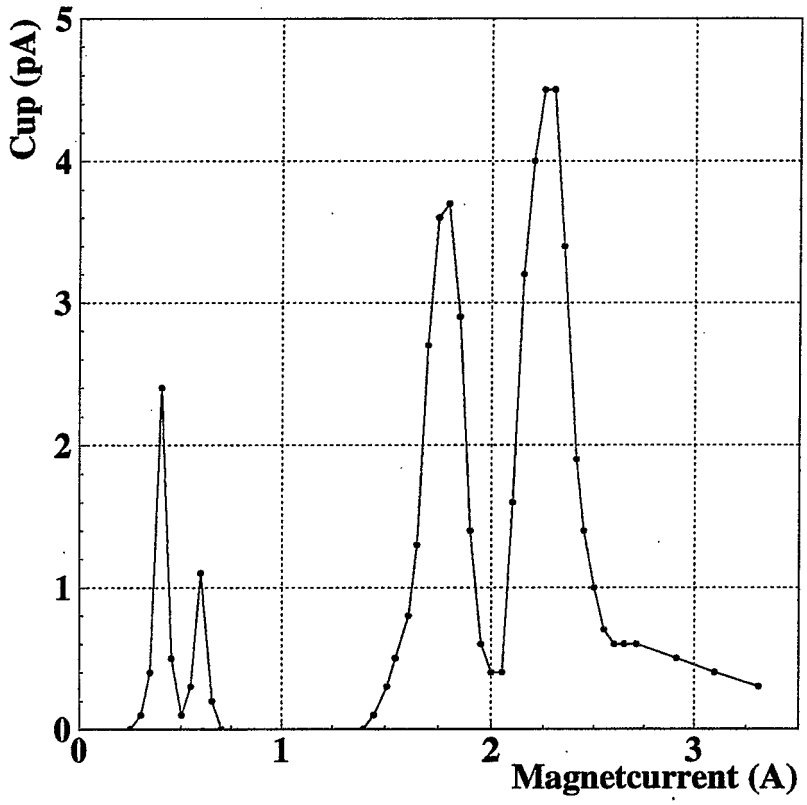
$$f(x,y) = \frac{\rho_z}{2\pi\sigma^2} \exp \frac{-(x^2+y^2)}{2\sigma^2} \qquad (1)$$

- Density for RHIC interaction (square of 1mm x 1mm):

$$\begin{aligned}
\rho_{\mathrm{RHIC}} &= \int_{-0.5}^{0.5}\int_{-0.5}^{0.5}\int_{-\infty}^{\infty} f(x,y)dxdydz \\
&= 1.19 \cdot 10^{12} atoms/cm^2 \quad \text{(centered beam)} \\
&= 1.09 \cdot 10^{12} atoms/cm^2 \quad \text{(1mm off center)} \\
&= 0.84 \cdot 10^{12} atoms/cm^2 \quad \text{(2mm off center)}
\end{aligned}$$

$\Rightarrow$ Centering very important

JET beam analyzer setup (Wisconsin)



- Resolution of mass 1, 2, (14+16+18), (28+32) achieved
- Next tasks:
  - Improve resolution (separate mass 14,16,18,28,32)
  - Verify that the peak heights and/or peak integrals reflect the gas composition. Will be done with water vapor whose cracking ratio at our e- energy of 600V is known to 2%.

Update on RHIC *pC* CNI analysis

Osamu Jinnouchi (RBRC)
for CNI Group

At RSC 9/2/2004

The goal of the current study

- Obtain the absolute A_N for *pC* elastic scattering
  - Calibration with Jet target data
  - Get the energy dependence (24,100GeV)
  - Quote reasonable systematic error of the measurement
  - Fit $-t$ dependent A_N with the function and get r_5 parameter

(updates of polarization values for each run will be done, when this study is converged (i.e. after the conferences…))

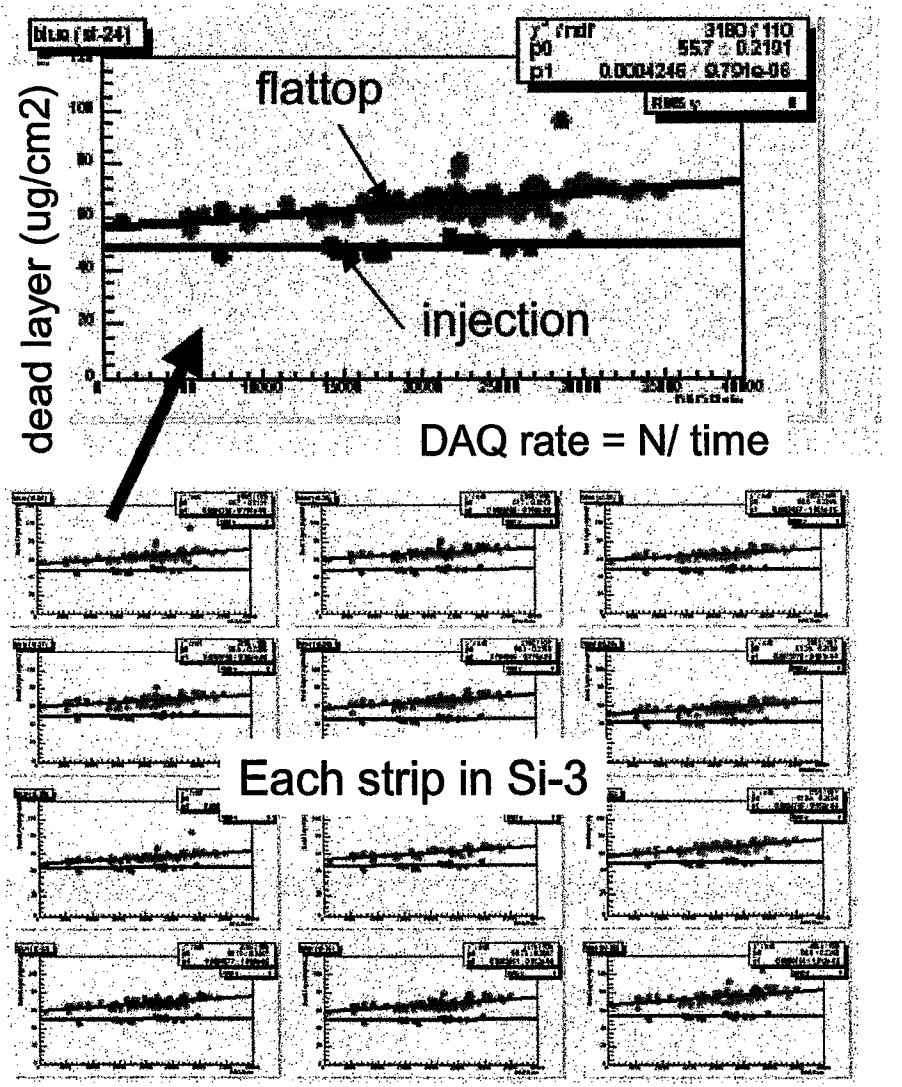
Sytematic error

- Main systematic error sources
  - **Si dead layer estimation (define –*t* range)**
  - Carbon cut condition dependence (bkg contamination, defined by invariant mass)
  - False asymmetries (device oriented)
    - X90/X45, Y-asym, Cross-asym
    - Si strip by strip differences
  - Calibration error from jet
  - Any other dependencies on A_N
  - Other errors are negligible….

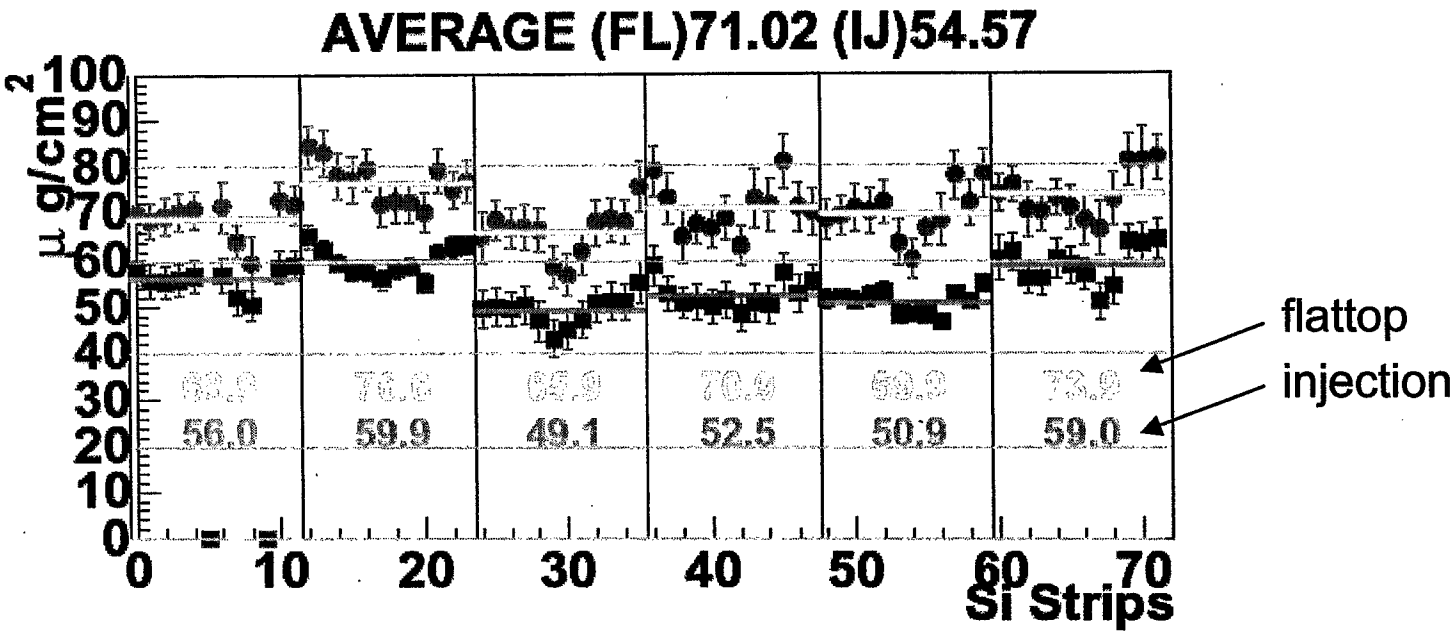
Si dead layer: effect on systematic error

- The thickness of dead layer is estimated from the fit of banana curve (Tof vs. Deposit Energy)
- The results have a strong correlation with the luminosity
- The kinematics is actually changing from Injection to Flattop

- Since we do not have the definite understanding of this mechanism, the size of systematic error is estimated from the size of distribution (in each energy)
- The mean values of the distributions are used as constant dead layer



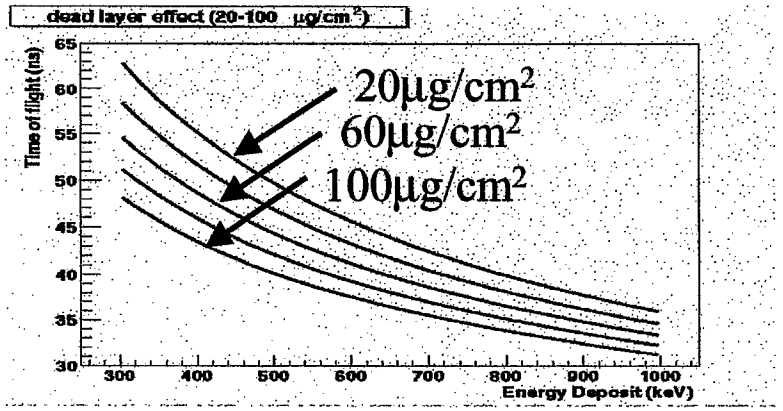
Si dead layer distribution



- The data points are the Mean of the each distribution (error bar represents RMS)
- The size of ambiguity in determination of the dead layer is +/- ~10ug/cm2 which corresponds to ~+/- 25keV shift in recoil Carbon energy → dA_N/A_N ~ 5%

Carbon PID

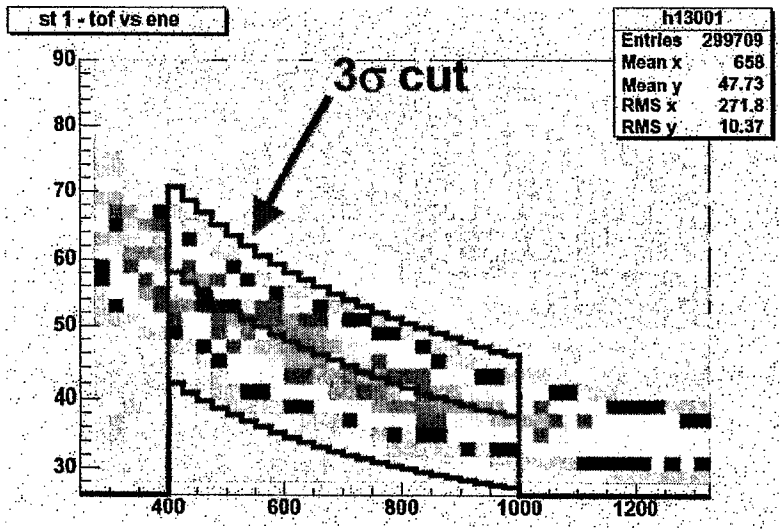
- Once the dead layers are fixed (determined), the timing (T0) is corrected for each strip/ each run to bring the mass to Carbon's



- Carbon cut is done with Invariant mass information (at online, timing cut +/-12nsec was used)
- Good quality carbon band is obtained in the range

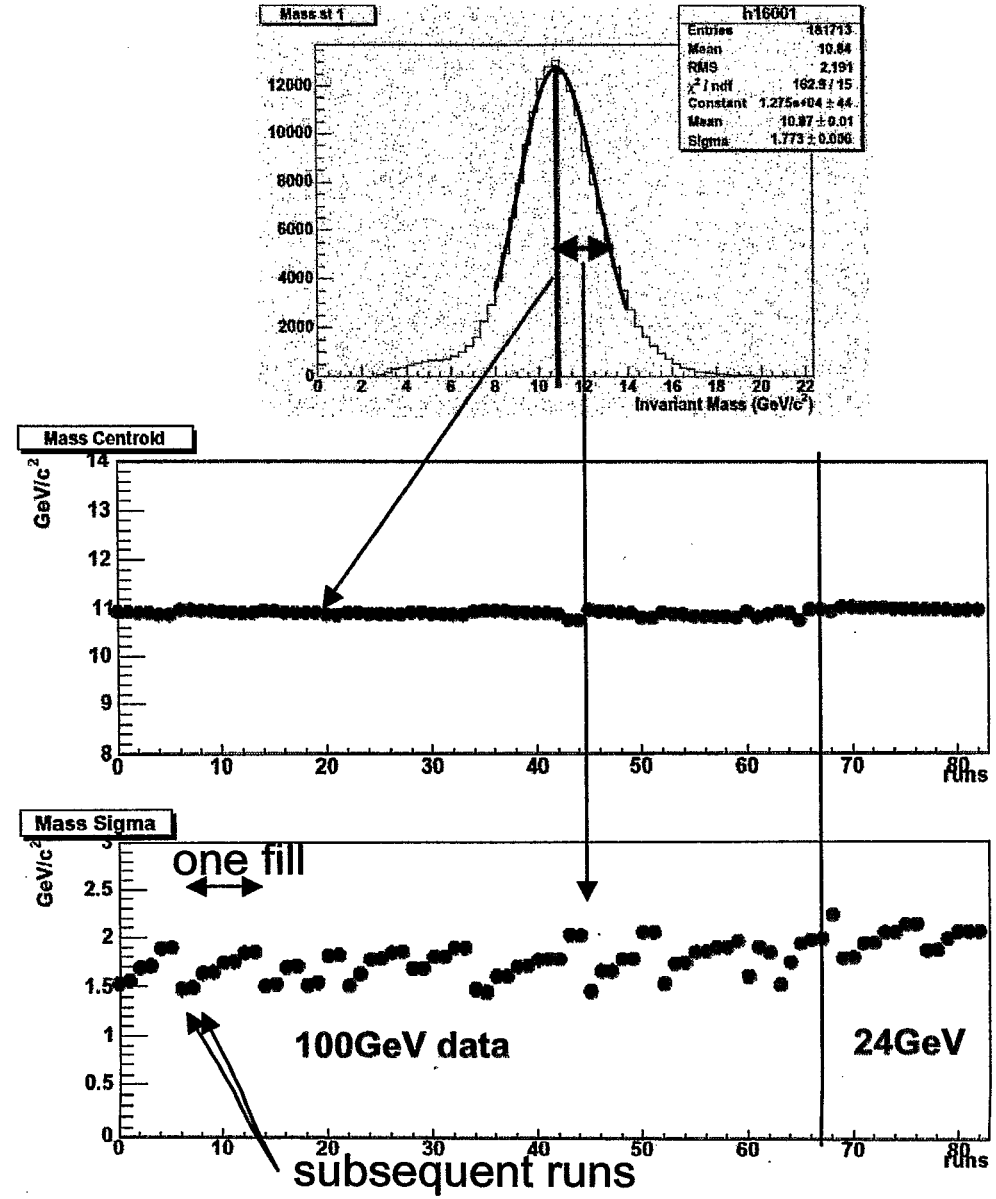
  300keV<Ekin<1300keV

  (0.007<|t|<0.029)
- The range 400-1000keV is used for calibration

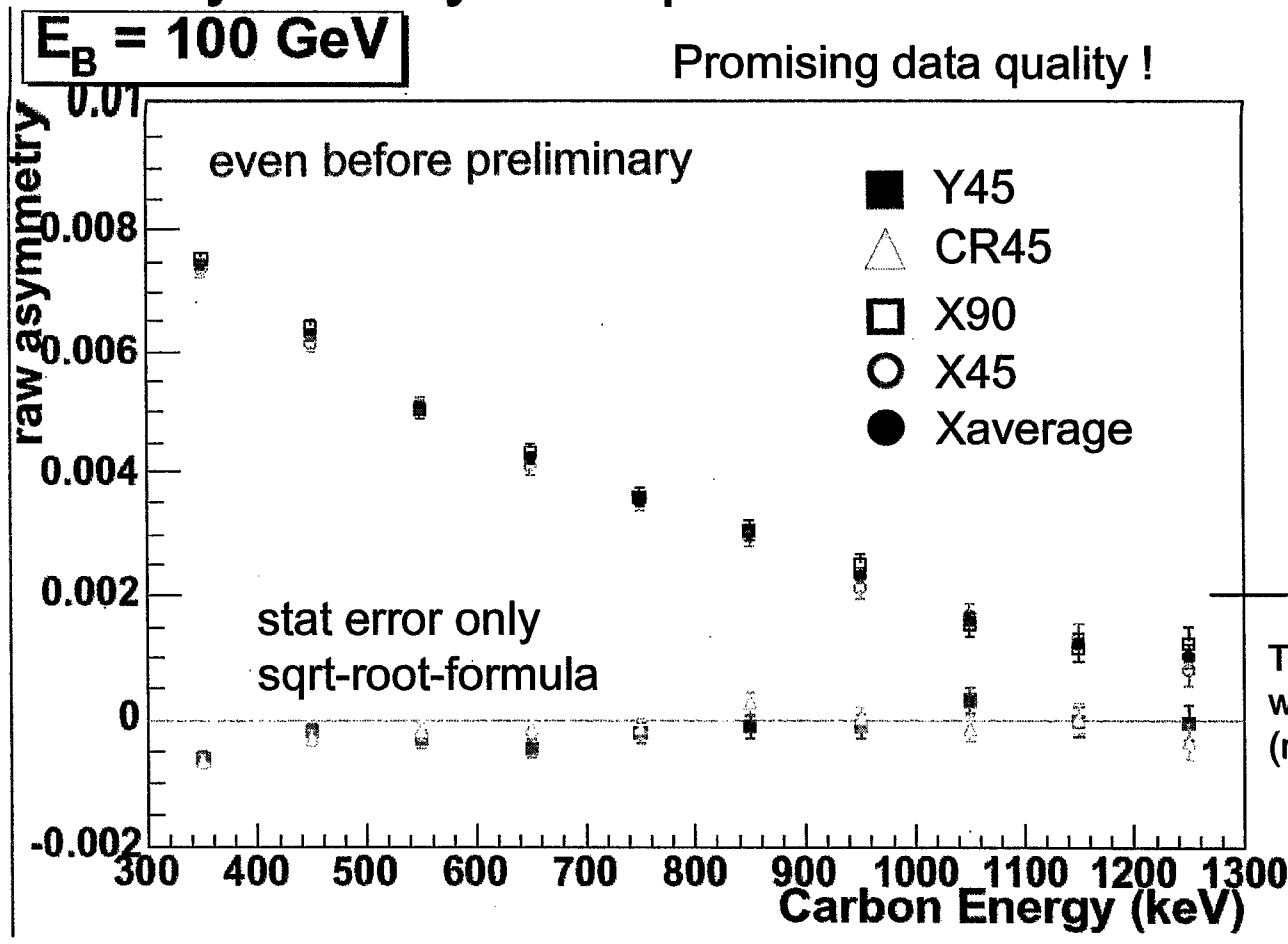


Carbon PID(2)

- About 85 CNI runs are selected as the calibration runs with Jet
- The centroids are stable/constant, the sigmas of the measurements are quite stable and reproducible
- 3σ (1σ,2σ as well) cut is used as Carbon identification



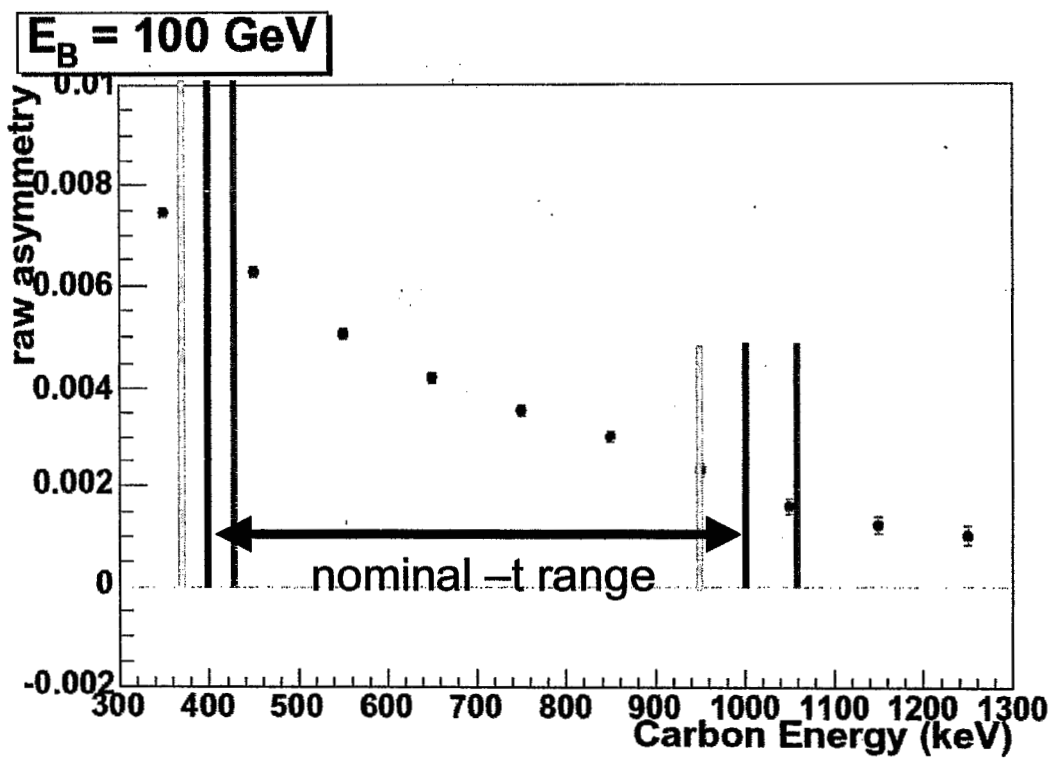
Raw asymmetry –t dependence



There is also a data set which has x2 –t range (not analyzed yet)

- x90, x45 agree well
- false asymmetries (Y45, cross) are very small
- not calibrated yet (but the shape will not be changed much)

The effect of the dead layer uncertainty



- If we consider the case 70+/-10ug/cm2, this uncertainty corresponds to

  +/-25keV around 400keV

  +/-50keV around 1000keV

which end up with 5% change in average A_N

- relative 5% is still OK for Run-04, but it will be major concern for the coming runs

Having a jet running every year / dead layer estimation

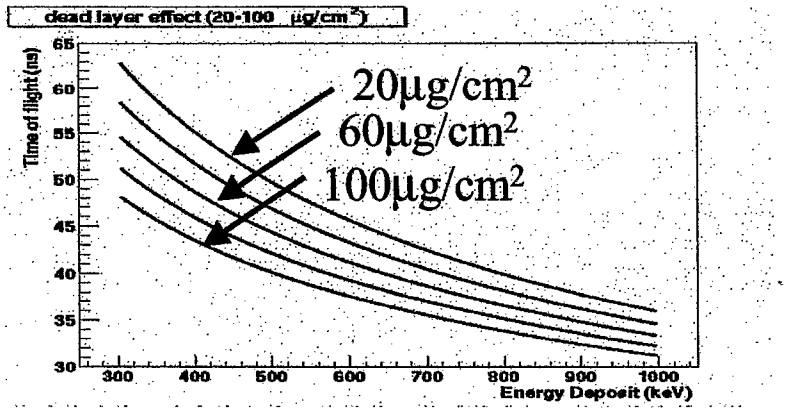
- Absolute Si dead layer info is needed for
  - A_N Physics
  - The data we took till last year (Run-03), and for the next run
    - The dead layer is different
  - The data for yellow
    - The jet data is only in Blue
- Relative values are still OK for
  - Polarization measurement for Run04 Blue

    (Once we define $-t$ range, no need to know the absolute value)
  - As long as we have Jets in both rings in every year

Summary

- The quality of the asymmetry $-t$ dependence is encouraging !
- Calibration by Jet (Absolute P_B) will be carried out very soon
- E_B dependence (24/100GeV), extracting hadronic spin-flip contribution (r_5) is the goal before the next RSC meeting in Trino

Fit to Carbon locus



- Fits with non-relative kinematics

$$t.o.f.(ns) = \frac{1181.6}{\sqrt{E_{kin}}} + t0$$

$$E_{kin} = f(E_{deposit}, D_{width})$$

- With the factor 1181.6, the fit is forced to the Carbon mass (11.17GeV/c^2, assuming the distance 15cm)
- Non-linear effect of dE/dx is expressed with approximation

A Few Polarimeter Studies

- Polarization profiles have been measured in RHIC this past year. Evidence is seen for lower polarization in the edges of the beam compared to the center for some profiles.

- Data from three scans taken during fill 5236 have been analyzed:
  - Individual bunch centroids and widths were calculated
  - Average asymmetries for narrower and wider bunches have been computed.

- Some tentative conclusions are drawn.

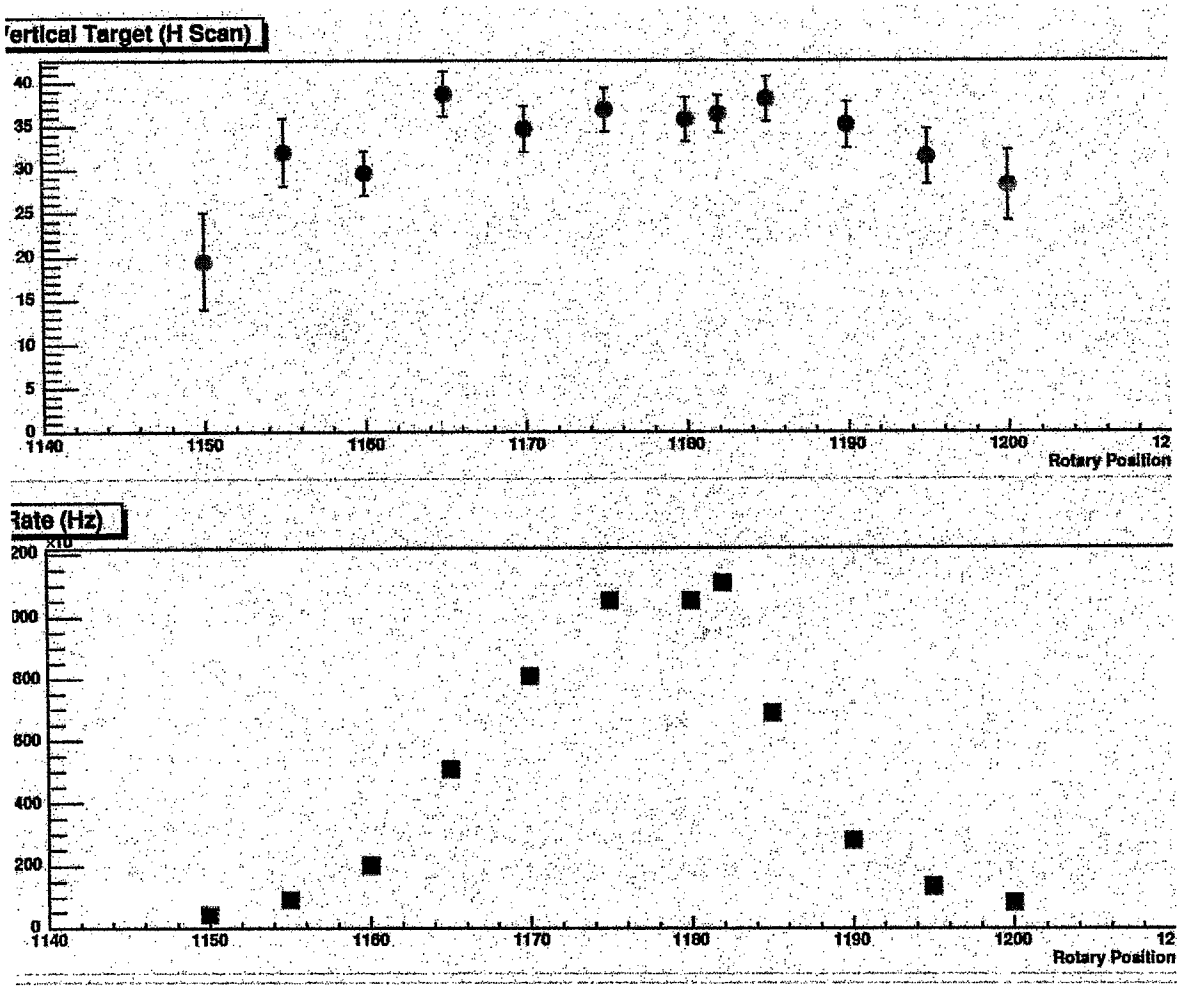
RSC meeting
2 September 2004
H. Spinka

2004 Scan Data from Osamu

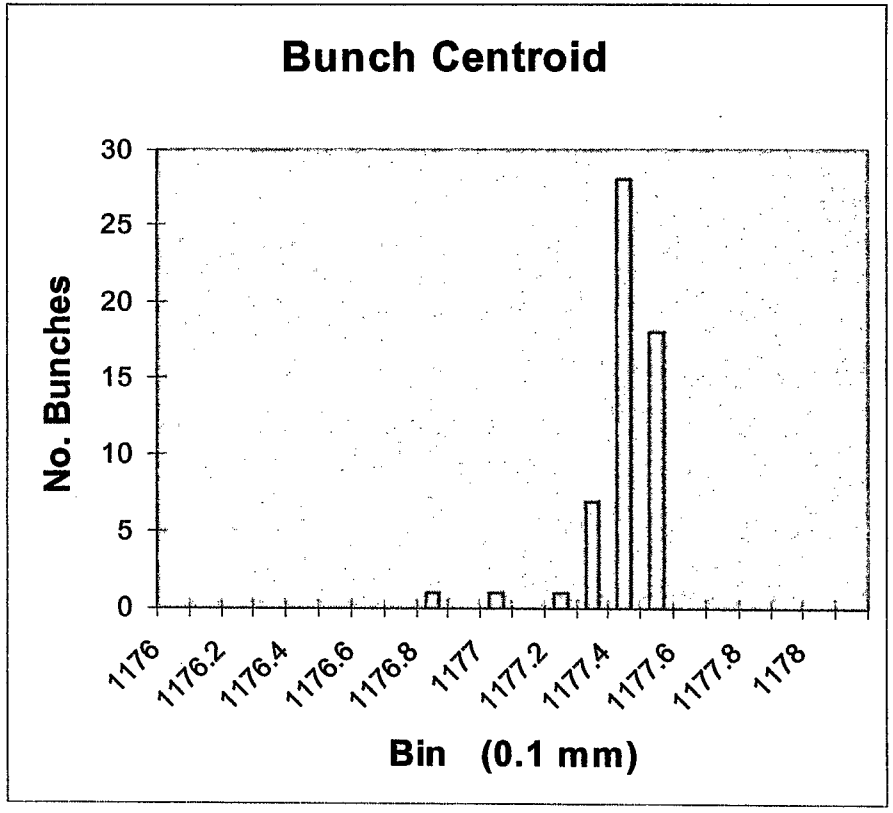
- Horizontal scan for fill 5236 in blue beam (vertical target).
- Vertical scan for fill 5236 in blue beam.
- Vertical scan for fill 5236 in yellow beam.
- Vertical scan for fill 5341 in blue beam.
- Vertical scan for fill 5341 in yellow beam.
- All scans are at flattop. All have roughly comparable dropoff in asymmetry far from the bunch center.
- All are from scaler mode data, and were at the beginning of the fill. However, there were beam losses <u>during</u> the scans due to scattering from the polarimeter target.
- (There are two scans at injection in fills 5208 and 5209 as well. These will be analyzed in the future.)

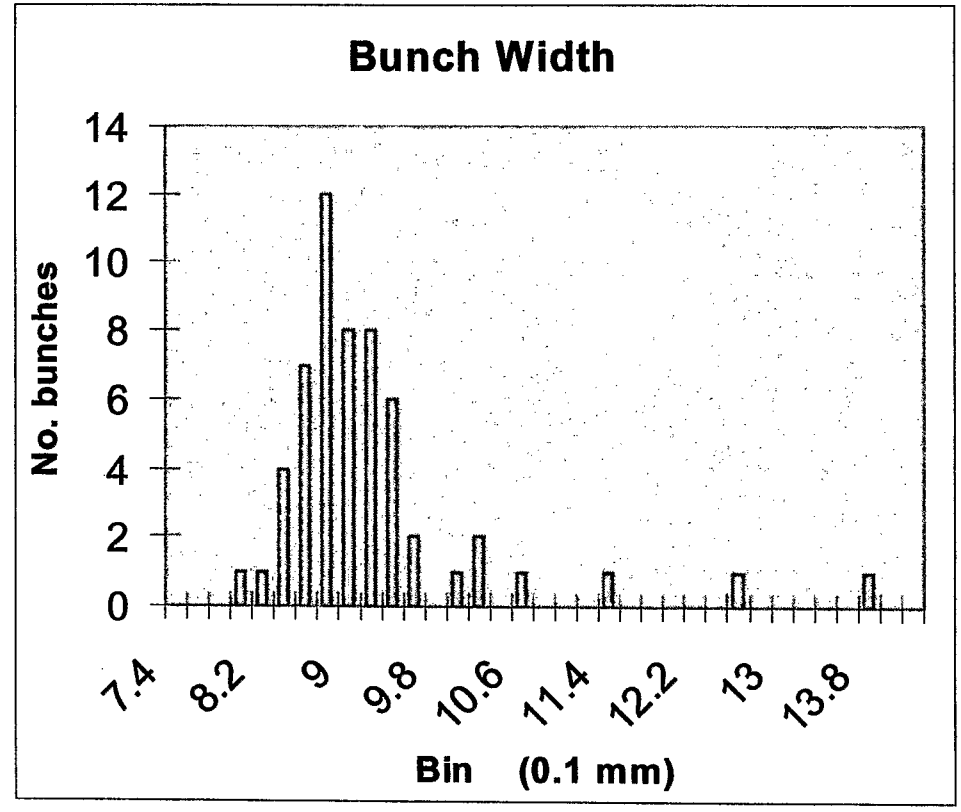
Horizontal Polarization and Intensity Profiles for Fill 5236

- These data are for the blue beam and with a vertical ribbon target (horizontal scan – scaler mode).
- These data were analyzed by Osamu Jinnouchi.
- Note that the rotary position range of 1150 – 1200 corresponds to about 5 mm



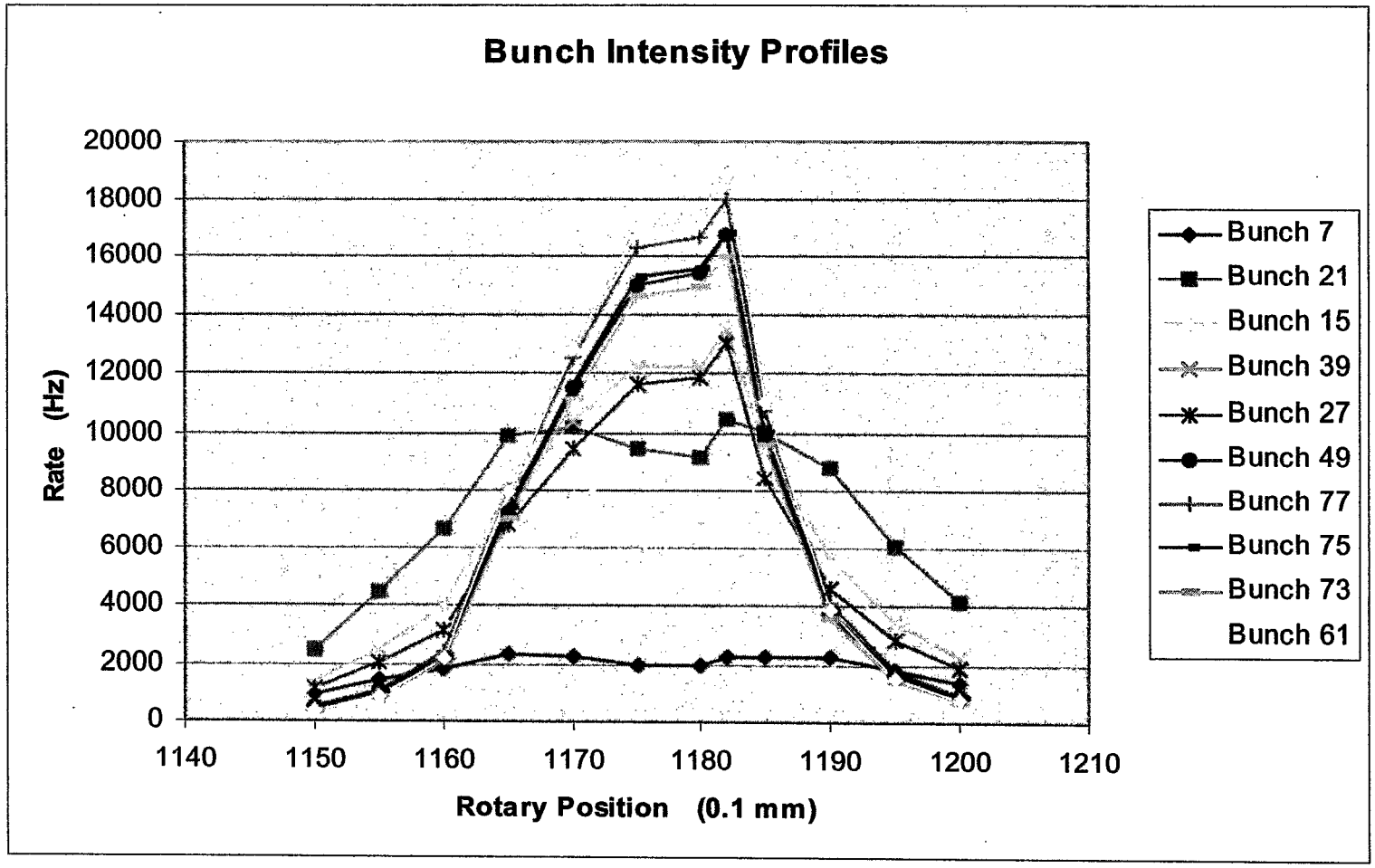
Bunch Centroids and Widths Computed from the Horizontal Scan in Fill 5236





- A correlation of bunch centroid with width is observed, but the effect is very small and it may be caused by asymmetric limits in the range of measurements. To a good approximation, the centers of all bunches are equal.
- Note the long tail on the bunch width distribution.

Bunch Profiles for the 5 Widest and 5 Narrowest Bunches



- Blue beam bunches shown are plotted from widest to narrowest (out of 120 bunches, with the numbering starting after the abort gap).
  (Bunch 21 is "kicked" during the ramp to measure the tune.)

Asymmetries vs. Position

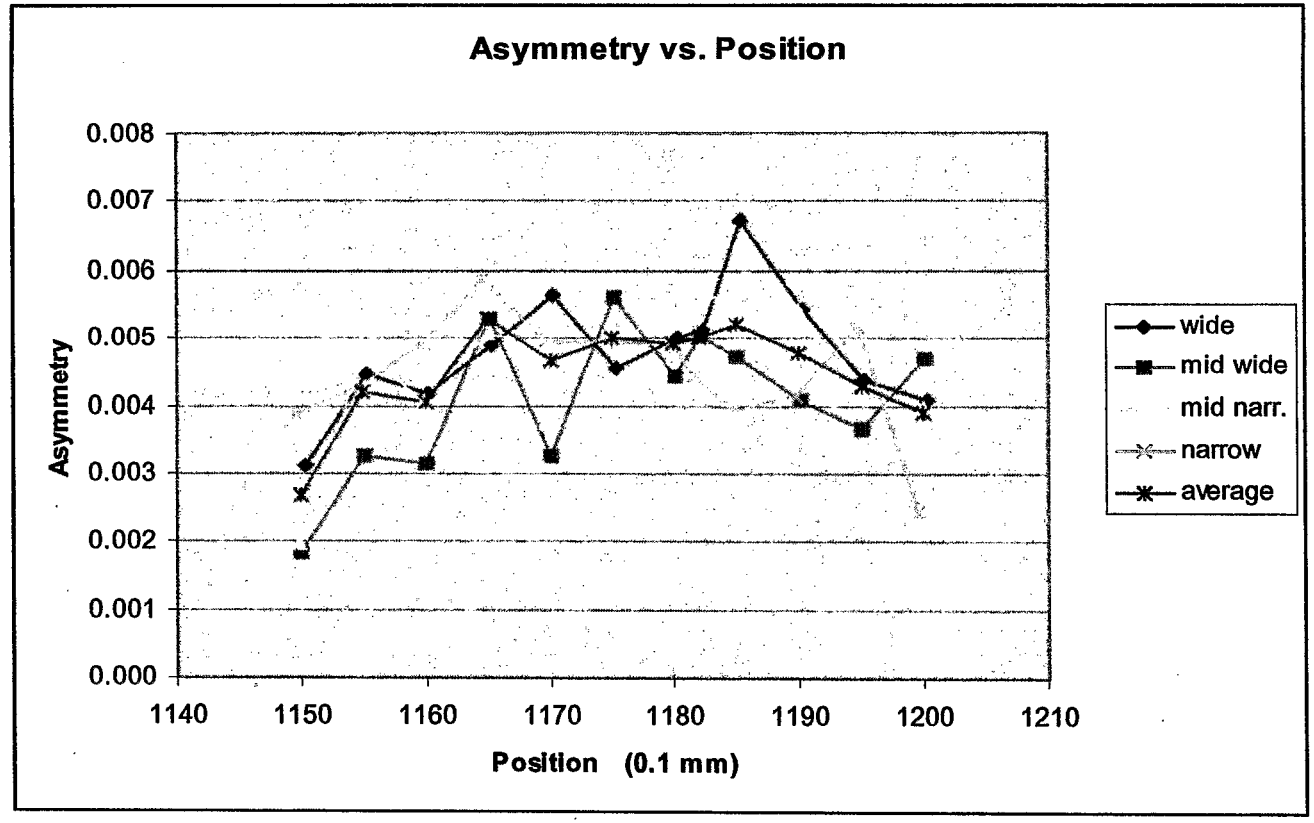
Statistical uncertainties on each point are about ± 0.0008 – 0.0016, and half that for the average. The uncertainties are largest at the edges of the bunches.

$$\langle \varepsilon_{narrow} \rangle = (4.66 \pm 0.24) \times 10^{-3}$$

$$\langle \varepsilon_{mid_narr} \rangle = (4.99 \pm 0.25) \times 10^{-3}$$

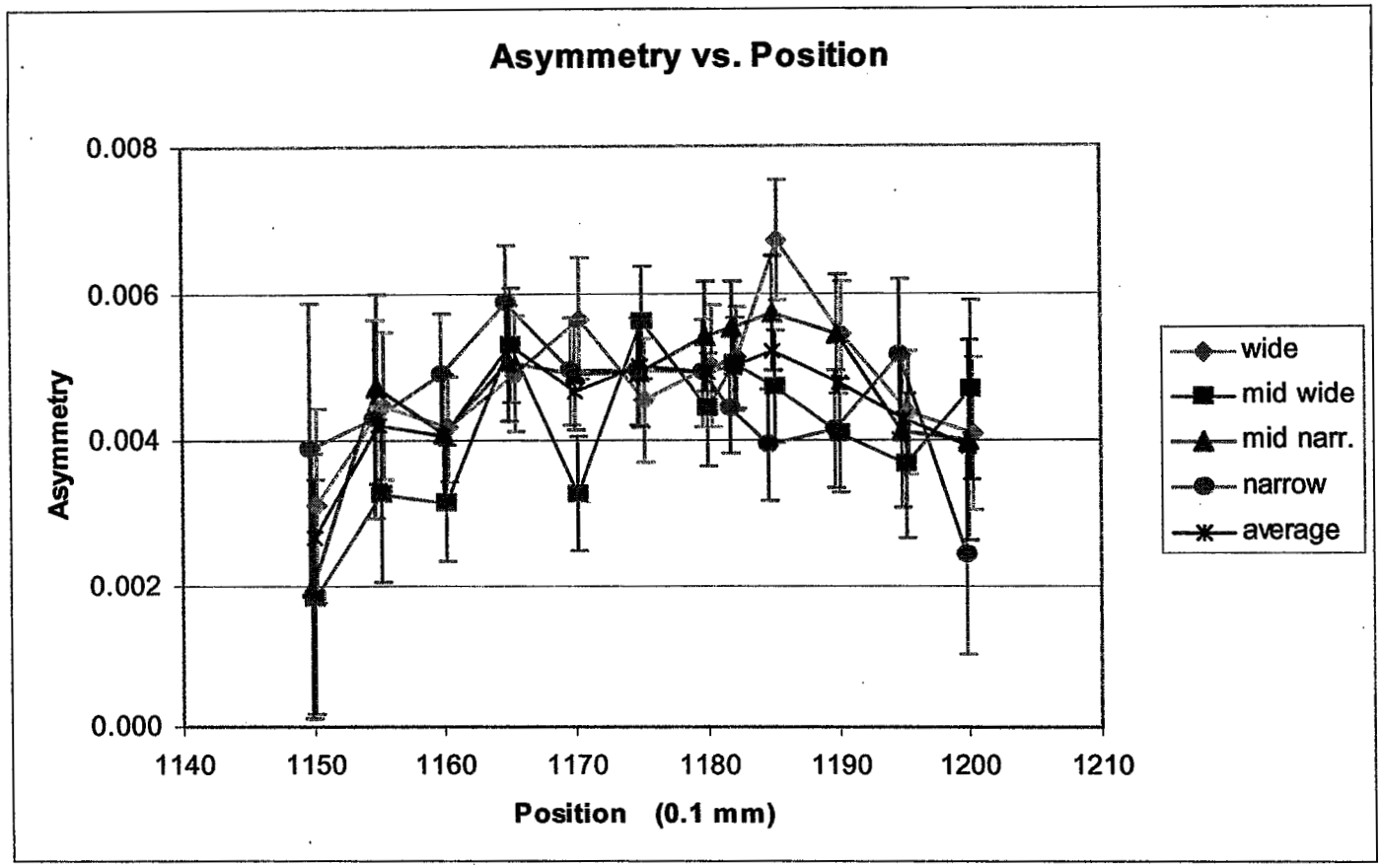
$$\langle \varepsilon_{mid_wide} \rangle = (4.32 \pm 0.24) \times 10^{-3}$$

$$\langle \varepsilon_{wide} \rangle = (4.92 \pm 0.24) \times 10^{-3}$$



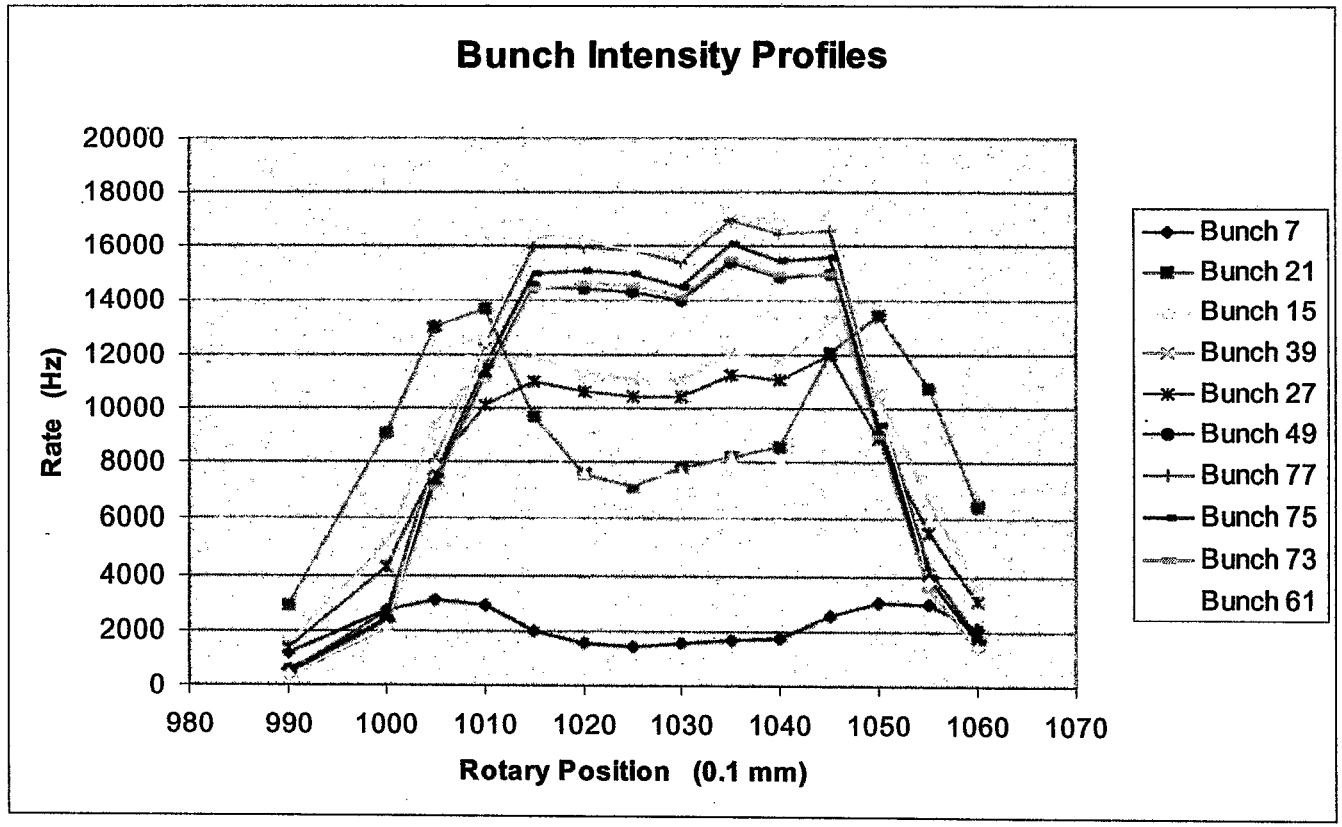
- The 56 bunches were separated into 4 sets of 14, each with 7 + and 7 – bunches, approximately according to width. The average asymmetries appear equal within statistical uncertainties. Each of the 4 sets are consistent with being constant as a function of position (χ^2 = 10.7, 13.7, 7.5, 7.3 for 11 d.f.).

Revised Plot of Asymmetry Profile



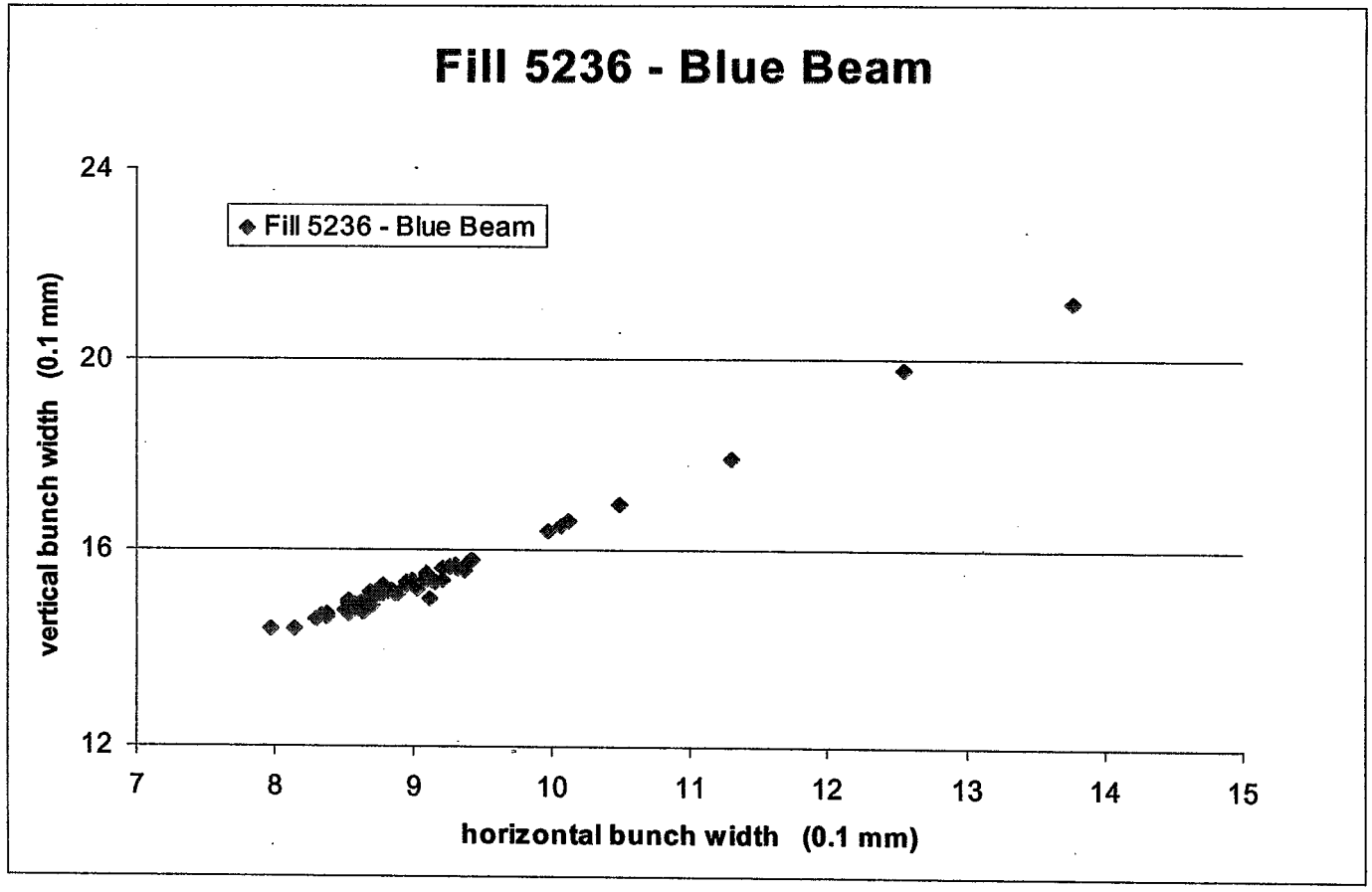
- This plot is identical to a previous one, and shows error bars. All asymmetries appear consistent with a constant value ~ 0.0048.
- The scan was taken near the beginning of fill 5236 in scaler mode, in two passes from small to large position values. (Blue beam, horizontal profile, vertical polarimeter target.)

Vertical Intensity Profiles for Fill 5236



- The vertical intensity profiles for the same fill and the blue beam as for the previous horizontal profile is shown above. The same bunches are also plotted.

Correlation of Bunch Widths for Fill 5236

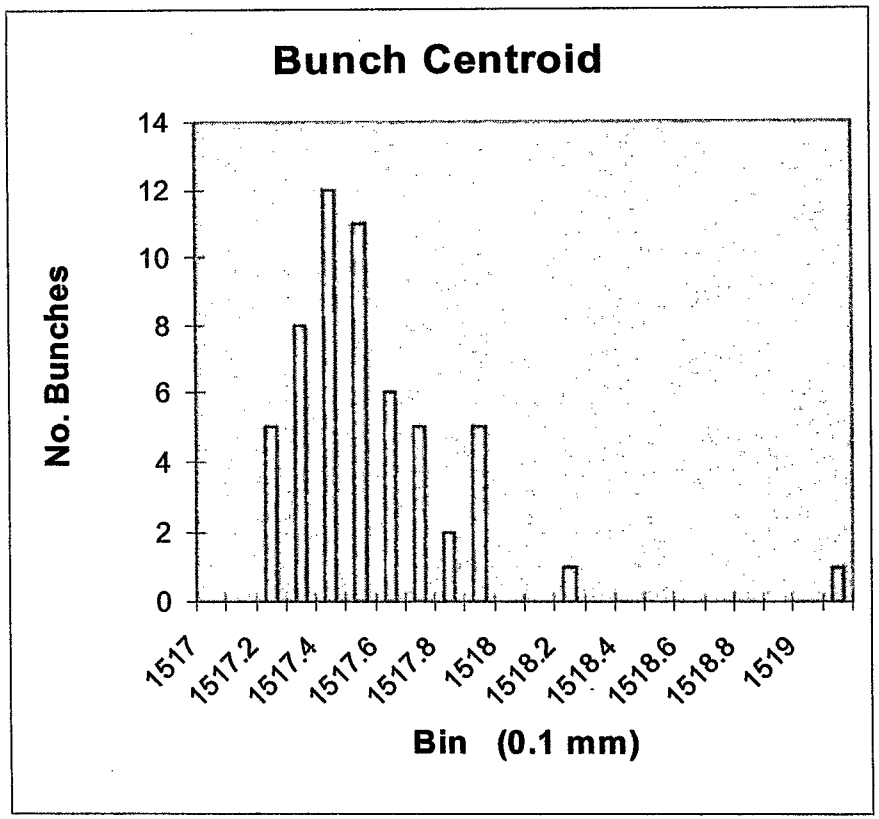


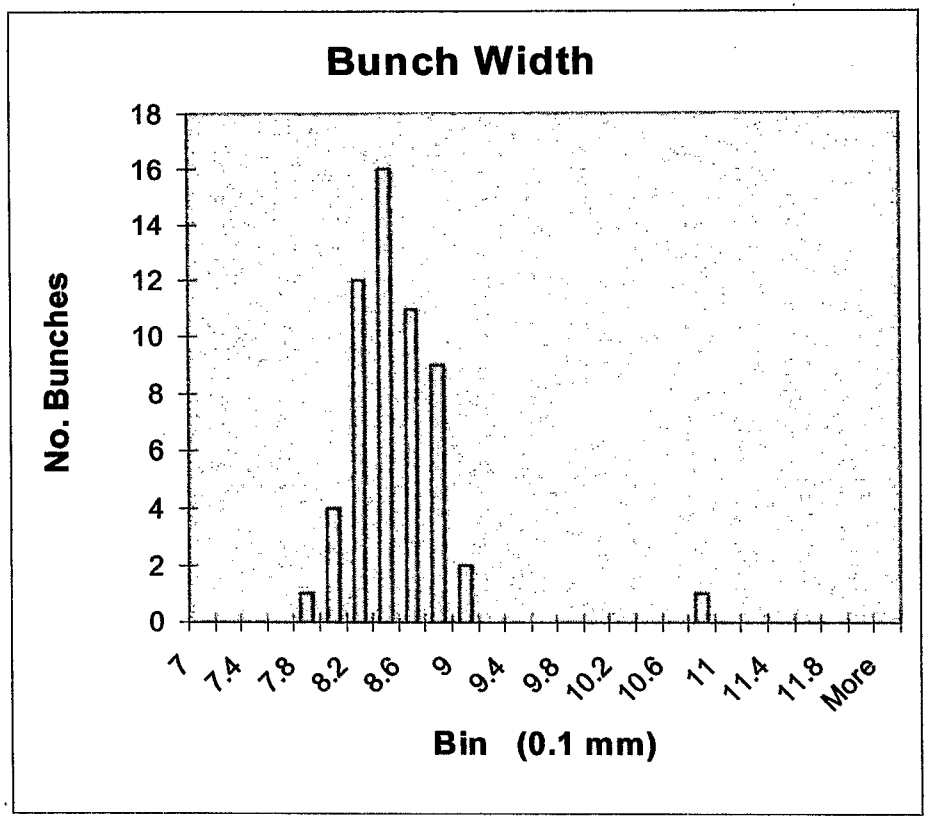
The vertical and horizontal widths of the bunches in the blue beam for fill 5236 are well correlated. (What about the longitudinal profile??)

- Inserted comment by du:

- Is correlation because rms depends on amplitude with the size at the base constant?

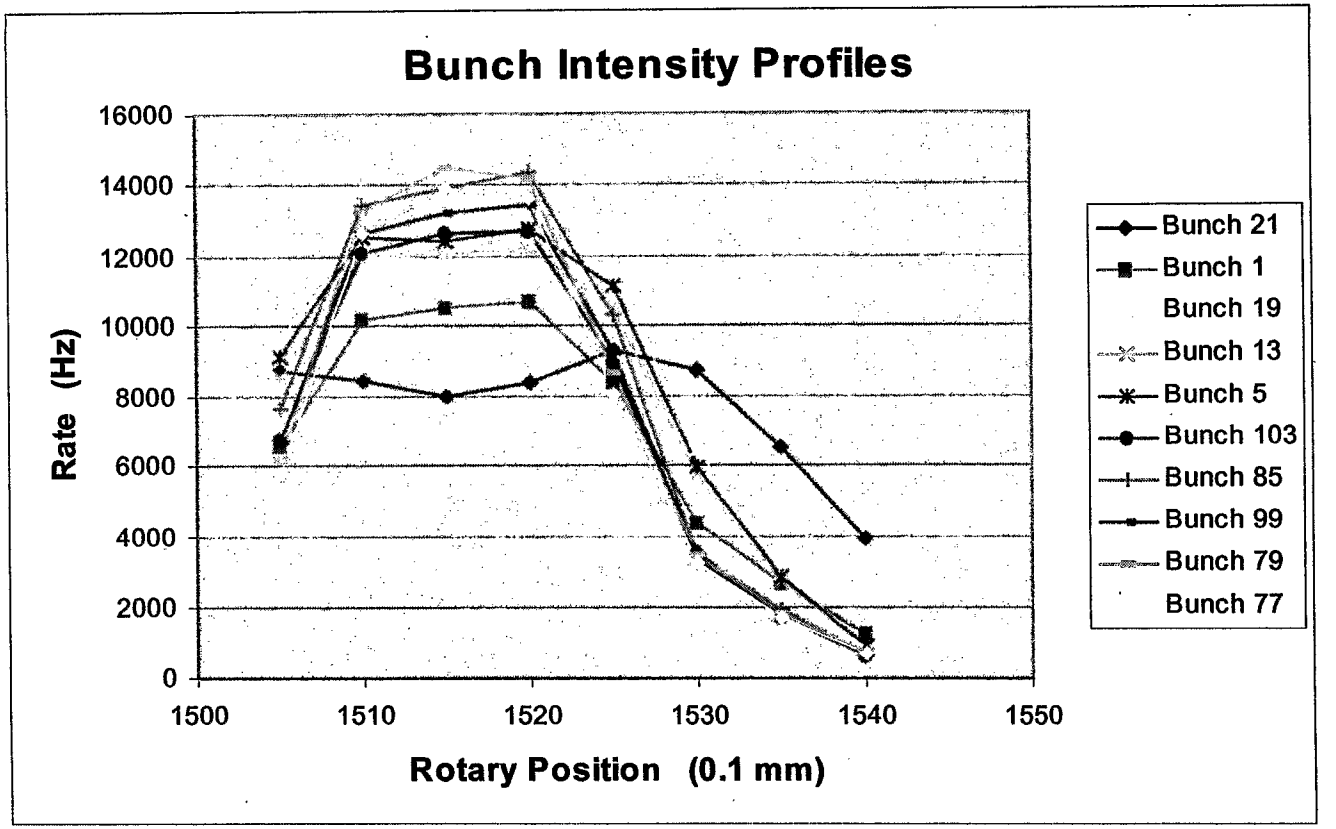
Bunch Centroids and Widths Computed from the Vertical Scan in Fill 5236





- The distributions of bunch centroids and widths for the <u>yellow</u> beam in fill 5236 are shown. The one outlier corresponds to the bunch "kicked" to measure the tune. However, the dropoff in asymmetry with position is similar to that seen in the blue beam for this fill.

Bunch Profiles for the 5 Widest and 5 Narrowest Bunches



- Yellow beam bunches shown are plotted from widest to narrowest (this is also fill 5236, vertical scan, horizontal polarimeter target).
  (Bunch 21 is "kicked" during the ramp to measure the tune.)

Conclusions

- The bunch centroids are all nearly identical in a given beam and fill.
- The bunch widths show considerable variation for at least one beam and fill, in both transverse directions. The widths are well correlated.
- Asymmetries for narrow bunches are consistent with those from wide bunches within statistics.
  - In particular, the polarization profile of the full beam is probably not the result of a combination of wide bunches with low, constant polarization plus narrow bunches with high, constant polarization.
- It is not clear that scanning the polarimeter target through the beam during polarization measurements will give a more accurate result than with a fixed target location, given the variation in bunch widths.
  - This idea was suggested at a recent RSC meeting.
  - Suppose at one detector, only narrow bunches collide with wide bunches. Then polarization sampling only over the narrow bunch width would be appropriate, and a scan across the full beam profile would give too small a polarization. Fill 5236 would satisfy this condition.

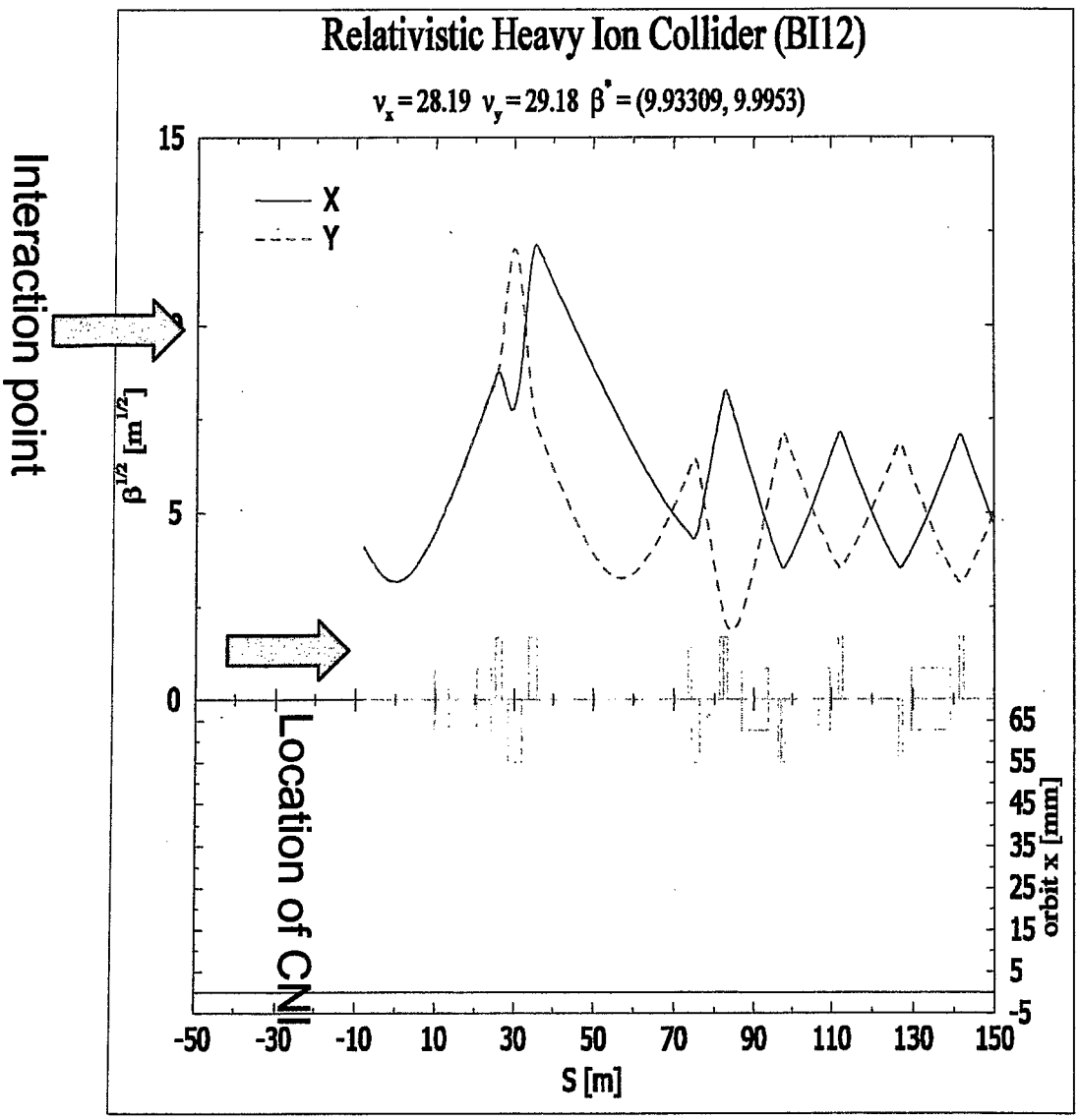
Tasks Remaining

- Check bunch intensity and polarization profiles for at least one more target scan that showed significant polarization variation. (Done)
- Check bunch intensity and polarization profiles for at least one target scan that showed NO significant polarization variation.
- For a beam and fill where both a vertical and horizontal target scan occurred, compare bunch intensity and polarization profiles in the two directions on a bunch-by-bunch basis. (Done)
- Estimate potential magnitude of error in derived polarization.
- Check scans at injection and flattop.
- Other??

Additional Slides by DU

- Bunches have similar widths, slopes, and lack of tails, even though they have different # protons
- Is this because they encounter effective aperture of RHIC when the beam is big at injection or because of scraping before polarization measurements?
- (Is bunch 21 kicked after both acceleration and scraping ?)

- Is lower polarization at the edges due to depolarization of larger part of phase space, or just a local rotation due to quadrupoles near interaction point?
- One can find examples of both effects in different accelerators
- A) Saclay polarization in the beam core
- B) rotation by low beta quads would be 90 deg at edge of beam for SSC interaction point.


Relativistic Heavy Ion Collider (BI12)
$\nu_x = 28.19$ $\nu_y = 29.18$ $\beta^* = (9.93309, 9.9953)$
X
Y
$\beta^{1/2}$ [$m^{1/2}$]
orbit x [mm]
S [m]
Interaction point
Location of CNI

RHIC Spin Collaboration Meeting XXVIII
September 2, 2004
RIKEN BNL Research Center

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September 2, 2004
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RIKEN BNL Research Center
RHIC Spin Collaboration Meeting XXVIII
September 2, 2004
BNL Physics Department, Small Seminar Room
Brookhaven National Laboratory

*******AGENDA*******

9:00 – 9:30	Cold Snake Update	A. Jain
	Cold Snake Update	W. MacKay
9:30 – 9:45	Run 6-9	ALL
9:45 – 10:15	Preliminary Results & Interpretation of A_N Measurement with pp2pp	W. Guryn
10:15 – 10:30	Coffee Break	
10:30 – 11:00	Gas-jet in Run5	A. Bravar
11:00 – 11:30	CNI 2004	O. Jinnouchi
11:30 – 12:00	Polarization Profile	D. Underwood

Next RSC Meeting ~ October 2004 ~ Torino, Italy
See webpage http://www.bnl.gov/riken/RSC-meetings.htm for tentative agenda

RHIC Spin Collaboration Meeting XXX

December 6, 2004

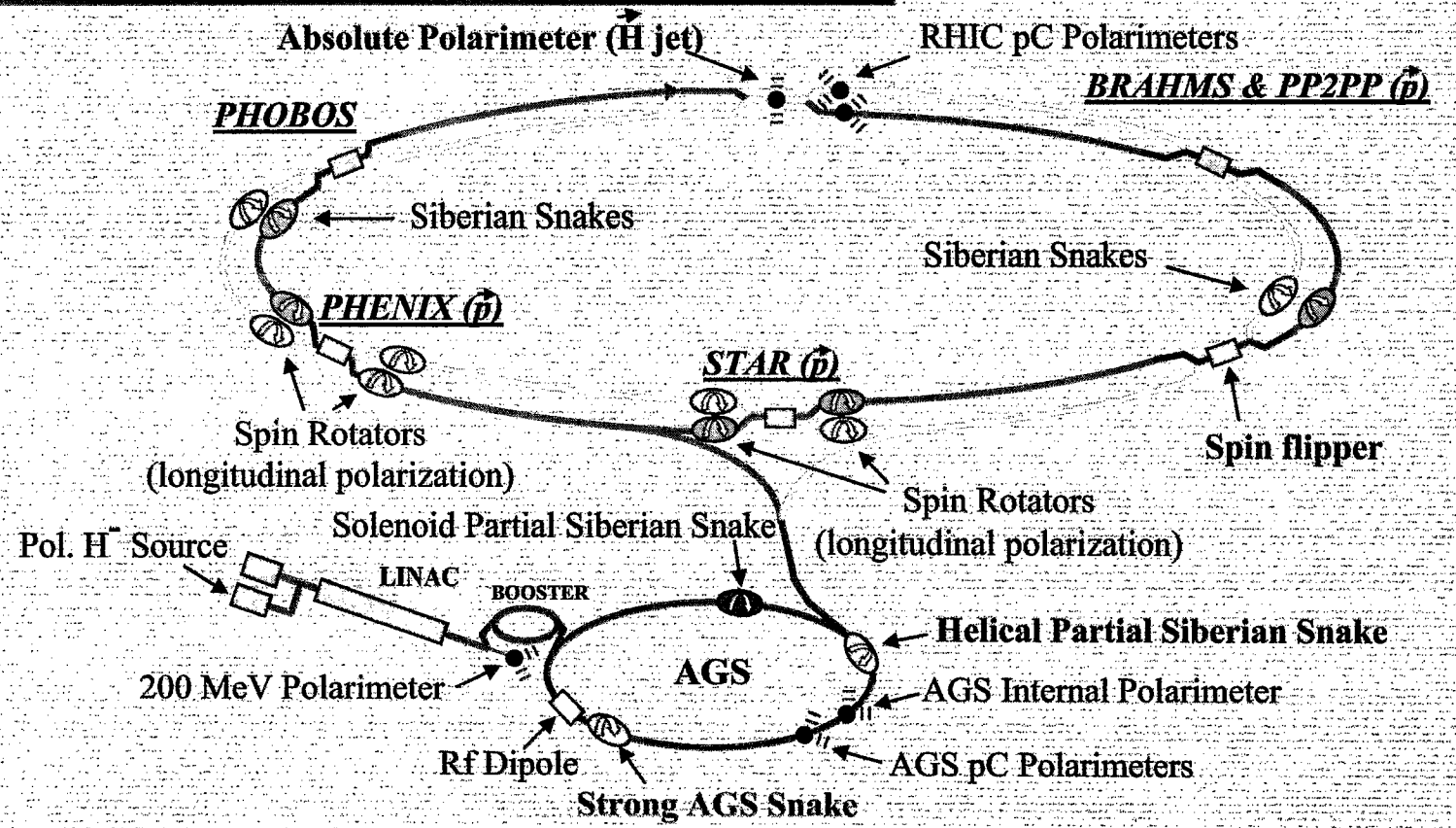
Polarized Proton Operations in AGS and RHIC

Mei Bai
Brookhaven National Laboratory

Outline

- Layout of polarized proton acceleration complex
  - Milestones of RHIC polarized proton program
- Spin Dynamics
  - Spin depolarization resonances
- Status
  - AGS capability
  - RHIC capability
- Challenges and Future Plans
  - Machine developments for the future

Polarized Proton Acceleration Complex Layout



- Installed and commissioned during FY04 run
- Plan to be commissioned during FY05 run
- Plan to be installed and commissioned during FY05 run

Milestones of RHIC Spin Program

	Milestone
FY00	New polarized proton source (OPPIS) commissioned One snake was installed in the sector 9 in Blue ring By slowly turning on this snake after the pp was injected, a radial polarization was measured and demonstrated that the snake was working as expected CNI polarimeter in Blue installed and commissioned
FY02	All snakes for both rings installed and commissioned CNI polarimeter in Yellow installed and commissioned
FY03	Spin rotators installed and commissioned provided longitudinal polarizations at STAR and PHENIX for physics data taking
FY04	RHIC new working point commissioned RHIC absolute polarimeter using Hydrogen Jet target installed and commissioned AGS 5% helical warm snake installed and commissioned

Goal for the Polarized Proton in RHIC

- Polarization
  - 70% beam polarization at RHIC store energy 250 GeV/c
- Luminosity
  - bunch intensity: $2x10^{11}$ protons per bunch
  - 112 bunch per ring
  - with a normalized beam emittance of 20π mm-mrad, a luminosity of
    - $60x10^{30}$ $cm^{-2}s^{-1}$ is expected at 100 GeV/c
    - $150x10^{30}$ $cm^{-2}s^{-1}$ is expected at 250 GeV/c

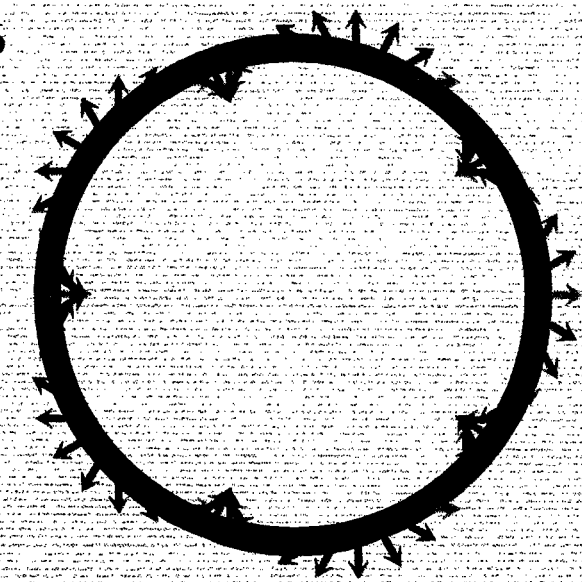
Spin Dynamics

- Spin precession in a planar circular accelerator

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S} = -\frac{e}{\gamma m}[(1+G\gamma)\vec{B}_{\perp} + (1+G)\vec{B}_{//}] \times \vec{S}$$

- Orbital motion

$$\frac{d\vec{P}}{dt} = \vec{\Omega}_{rev} \times \vec{P} = -\frac{e}{\gamma m}[\vec{B}_{\perp} \qquad] \times \vec{P}$$



- Spin tune

$$\nu_s = \frac{\Omega - \Omega_{rev}}{\Omega_{rev}} = G\gamma$$

In the frame which moves with the particle

Spin Depolarization resonances

- First order spin depolarization resonance
  - Imperfection resonance
    - Due to the additional kick on the spin vector by the dipole field from the correctors or magnet misalignments

$$\nu_s = n$$

  - Intrinsic resonance
    - Due to the additional kicks from the quadrupole fields particle experiences during the betatron oscillation

$$\nu_s = m \pm \nu_y$$

    - For a machine with P super-periodicity

$$\nu_s = Pn \pm \nu_y$$

Overcome Spin Depolarization resonances

- Siberian Snake:
  - Rotates spin vector by 180°

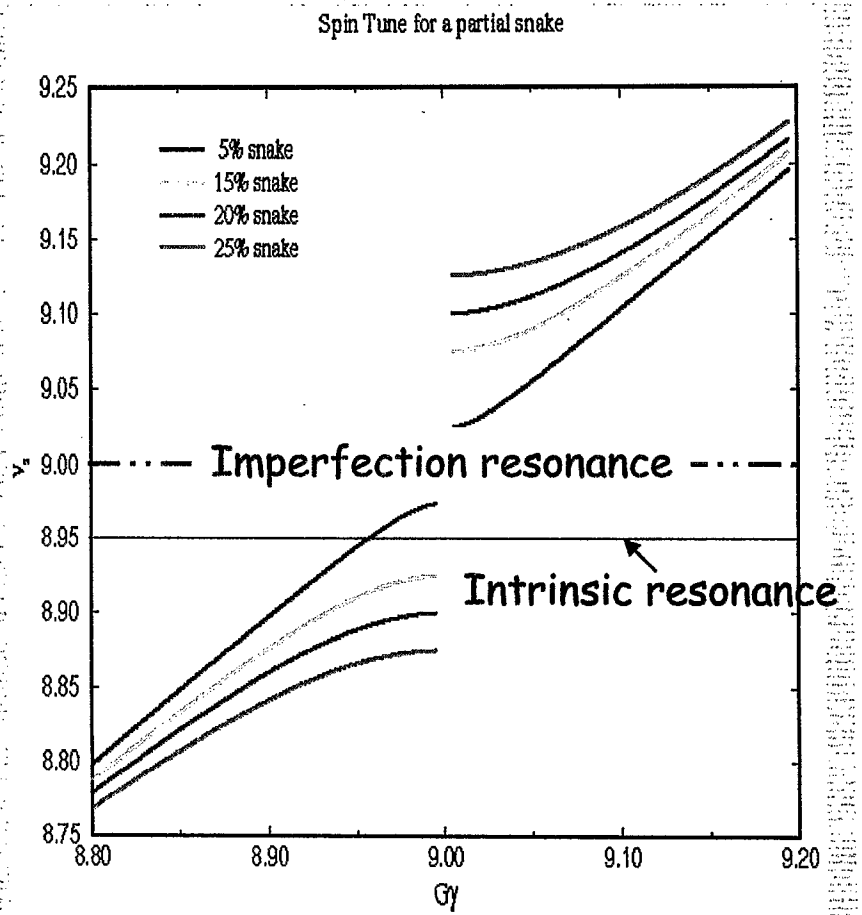
$$\nu_s = \frac{1}{2}$$

- Partial Snake

$$\nu_s = \frac{1}{\pi}\cos^{-1}\left(\cos(\delta/2)\cos(\pi G\gamma)\right)$$

Rotation angle of the spin vector from the partial snake

- AC dipole
  - Provide large coherent oscillation at a intrinsic spin resonance to achieve a full spin flip at normal acceleration speed.



Current AGS Setup

- Machine parameters
  - Lattice
    - 12 fold superperiodicity, 5 FODO cells per super-period
  - Energy:
    - Injection: 2.2 GeV
    - Extraction: 24.3 GeV
- Spin depolarization resonances
  - Imperfection spin resonance
    - A total of 42 resonances at $G\gamma$ = integer
    - Overcome by helical 5% partial snake
  - Intrinsic spin resonance
    - A total of 7 significant intrinsic resonances
    - 4 strong ones at $G\gamma = 0+Qy$, $12+Qy$ and $36\pm Qy$ are overcome by the AC dipole
    - 3 weak ones at $G\gamma = 24\pm Qy$ and $48-Qy$ are crossed without any corrections

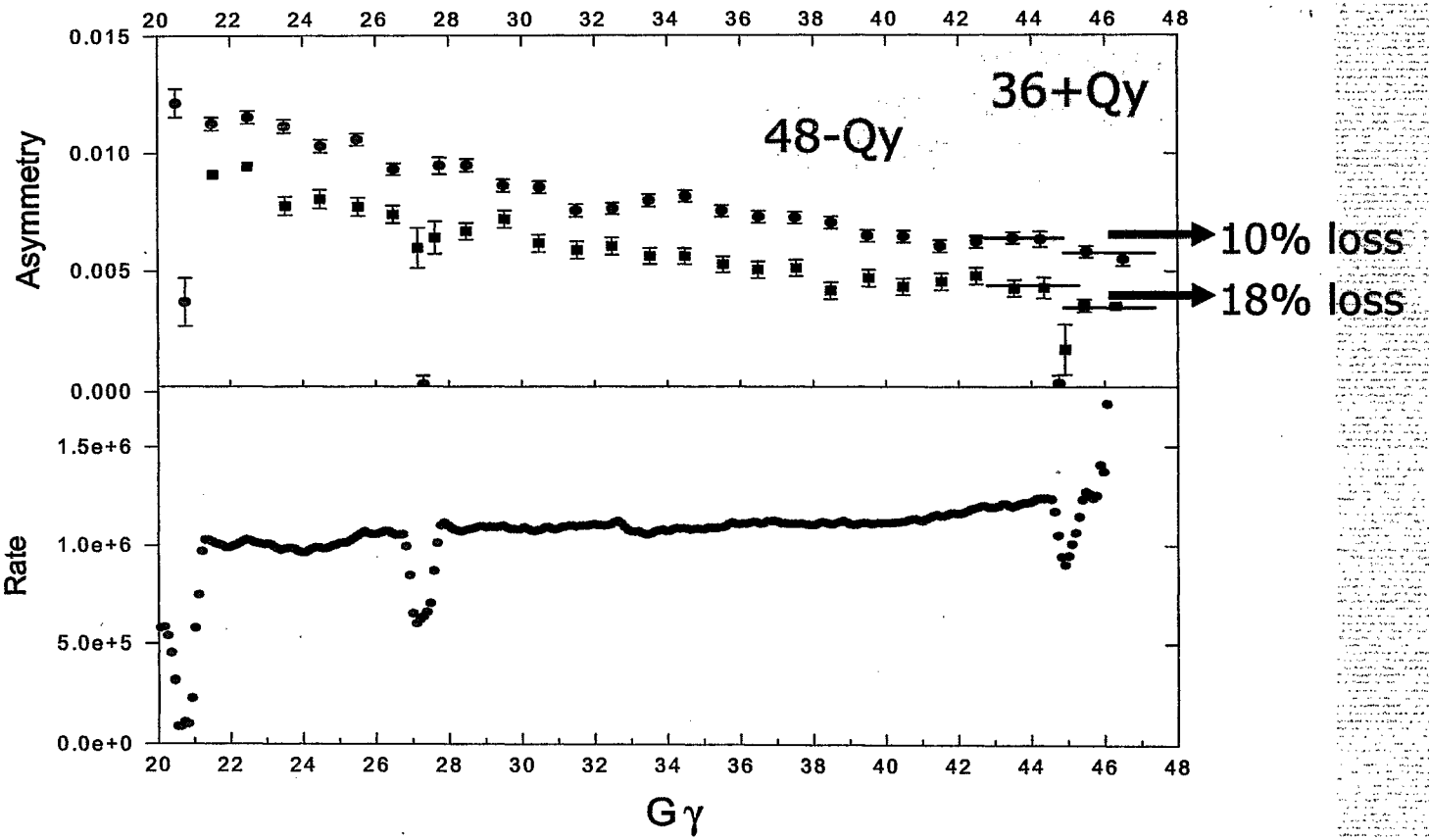
AGS Current Capability

- routinely provide a beam of 0.7×10^{11} bunch intensity with 50% polarization at RHIC injection energy

- Demonstrated the capability of providing 1.0×10^{11} bunch intensity with 50% polarization at RHIC injection energy

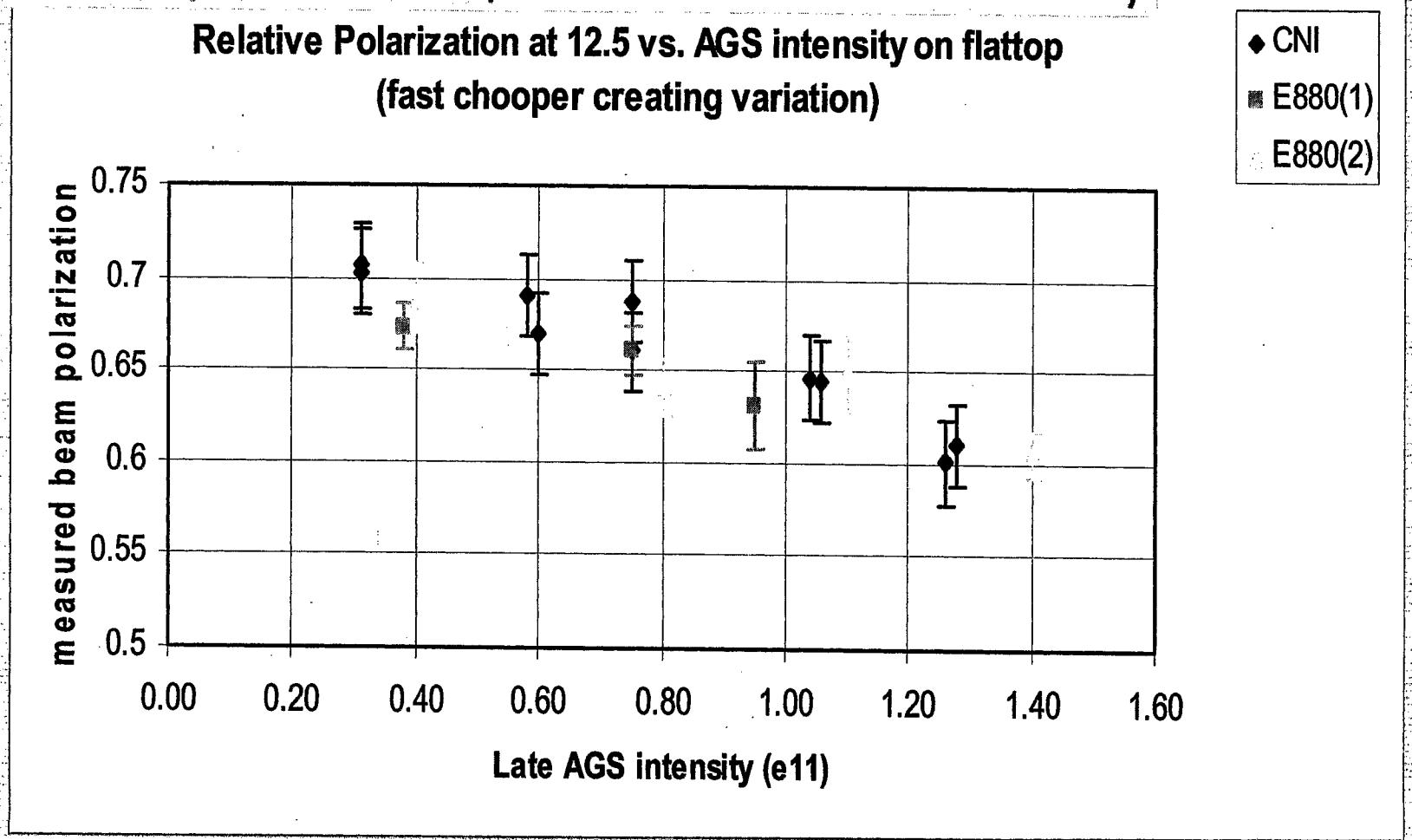
Challenges of reaching > 70% at the AGS extraction

- Polarization losses due to weak intrinsic resonance
- polarization losses due to coupling resonance



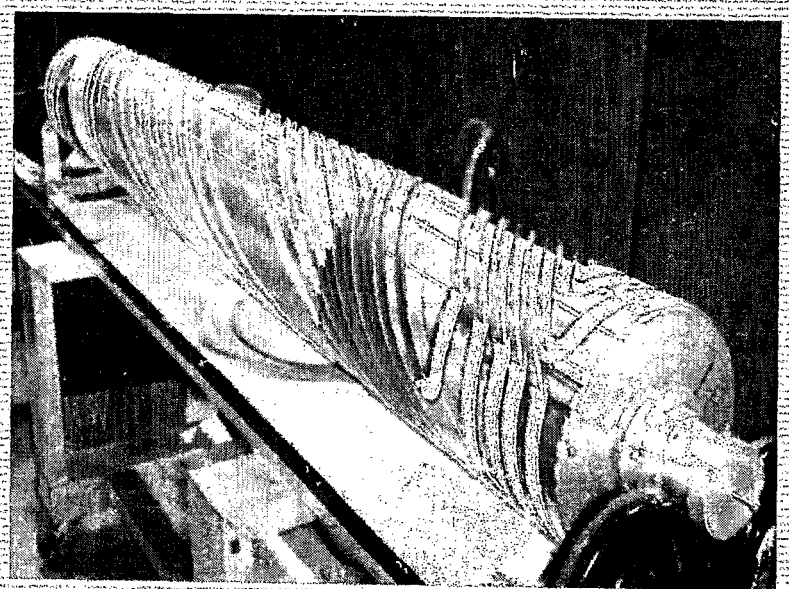
Other Challenges of Improving AGS Performance

- Beam polarization dependance on the bunch intensity

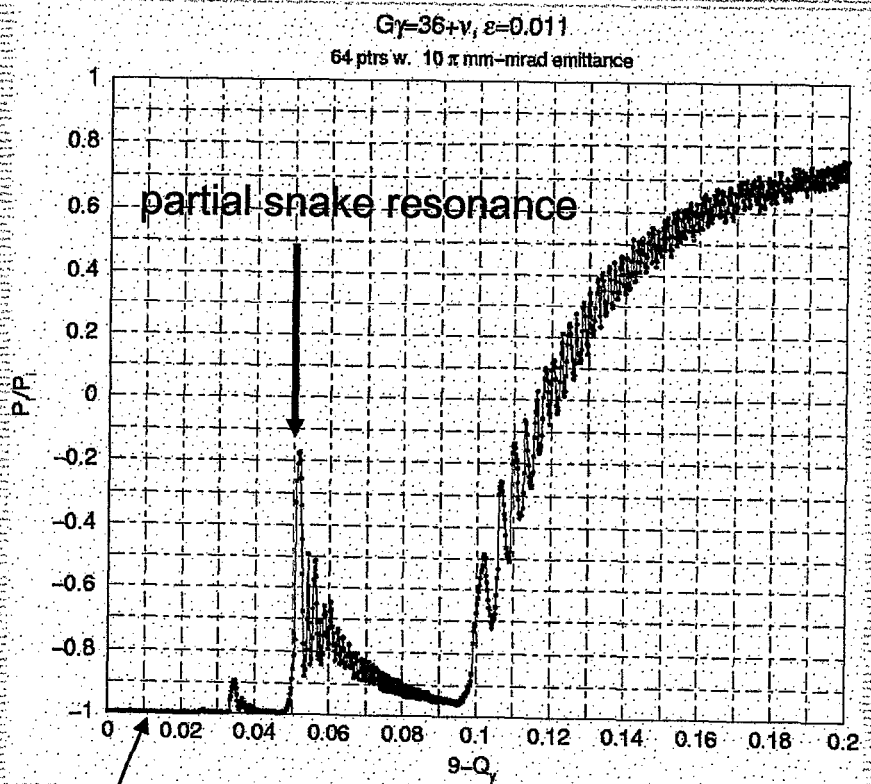


Solution I: a strong partial snake

- AGS strong cold snake, funded by DOE, is expected to yield 100% polarization transmission efficiency from AGS injection energy to extraction energy. The expected absolute polarization is 70%.

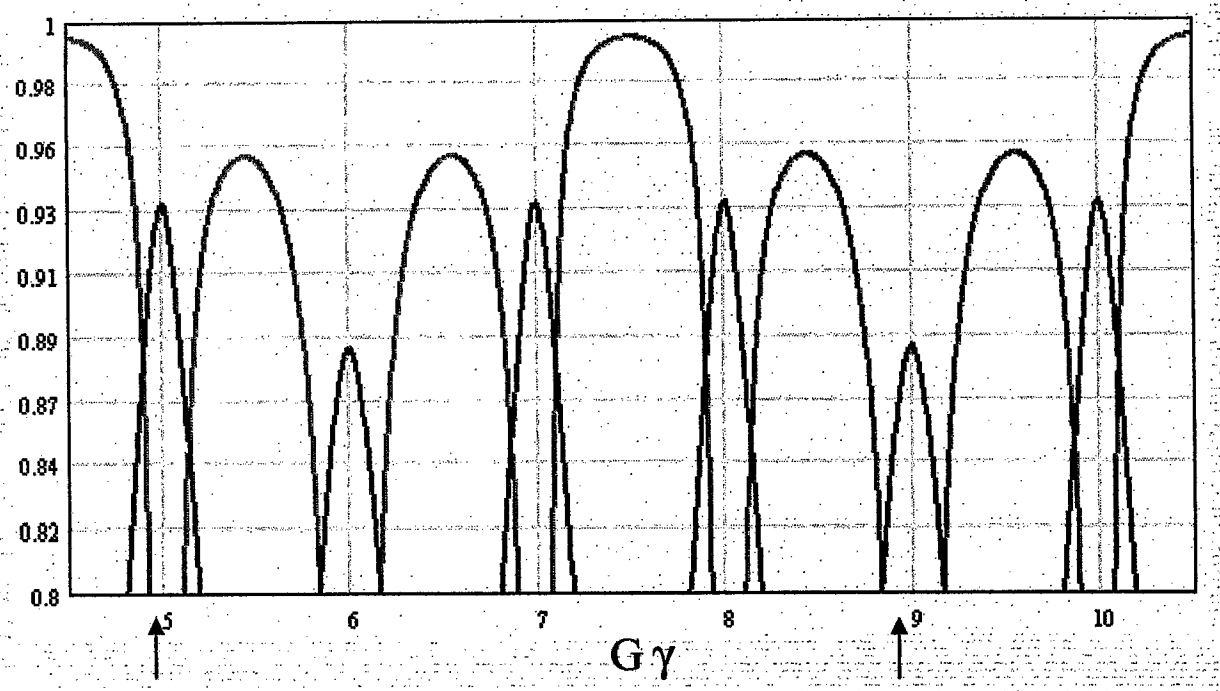


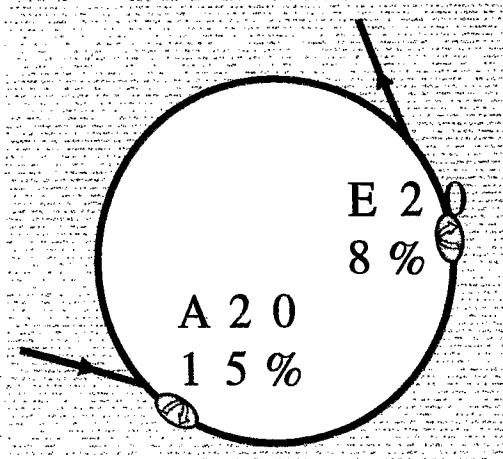
30% s.c. helical snake build at SMD (AIP)



desired vertical betatron tune to avoid depolarization

Solution II: two snakes





Injection

First intrinsic resonance (0+Qy)

Vertical component of stable spin direction

Spin tune

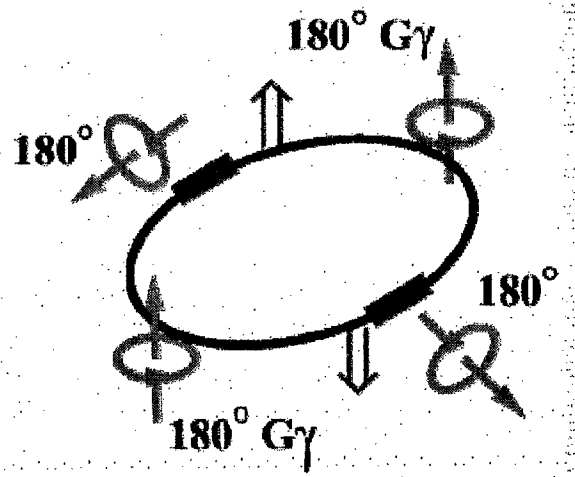
AGS Plan for Run 5

- operational: warm helical partial snake + AC dipole (the same setup as RHIC pp FY04 Run)
- commission the two snake solution (cold helical snake at 2.5Tesla field + warm helical snake at 1.5 Tesla field)

RHIC pp Setup

- Two full Siberian snakes per ring. The two snakes are located 180° apart with their precession axes perpendicular to each other

$$\nu_s = \frac{1}{\pi}\left|\phi_1 - \phi_2\right|$$

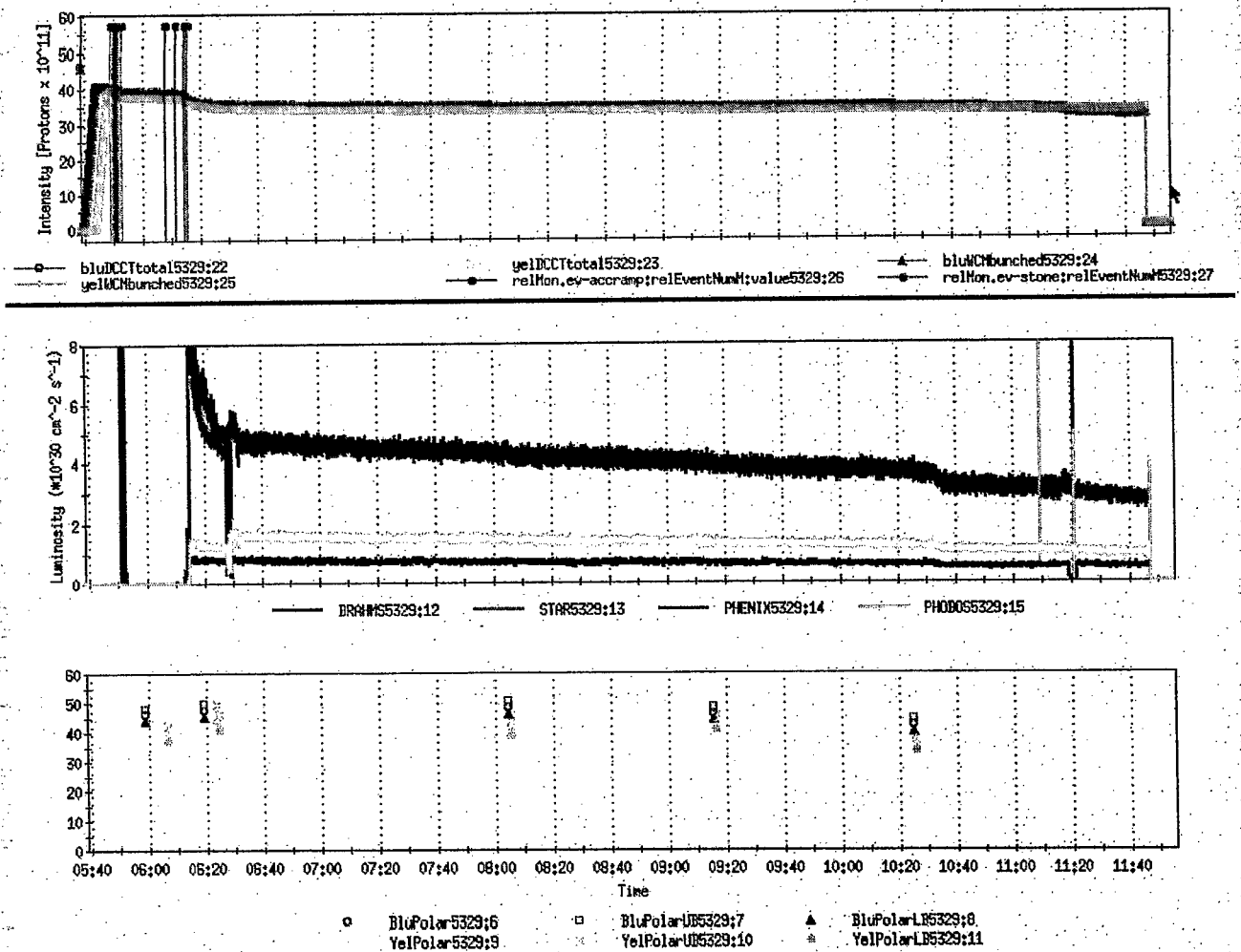


Energy at injection	24.3	GeV/u
Energy at Store	100.2	GeV/c
Interaction points	6 8 10 12 2 4	clock
β* at injection	10 10 10 10 10 10	m
β* at store	1 1 10 10 10 10	m
Working points	Inj & ramp: (28.73, 28.72) Store: (28.69, 29.68)	
Snakes current	DC	
Spin rotator current	Ramp up after store	
Experimental magnets	STAR, PHENIX: on DC from inj. to top	
RF accelerating cavities	At injection: 100 kV ramp: 300 kV At store: 300 kV	
RF storage cavities	No rebucketing	

RHIC Achieved Performance

	bunch intensity [10^{11}]	# of bunch	$\mathcal{L}_{peak}$ [10^{30}] $cm^{-2}s^{-1}$	$\mathcal{L}_{store\ average}$ [10^{30}] $cm^{-2}s^{-1}$	$\mathcal{L}_{per\ week}$ [pb^{-1}]	polarization at store
FY04	0.70	56	5.4	4.0	1.0	40-45%
FY04 Unpolarized proton	1.70	28	10.0	--	--	--

A typical store



Challenges in RHIC

- Improve the luminosity performance
  - Goal:
    - 60×10^{30} $cm^{-2}s^{-1}$ is expected at 100 GeV/c
    - 150×10^{30} $cm^{-2}s^{-1}$ is expected at 250 GeV/c
- Achieve > 70% beam polarization at 100 GeV/c as well as 250 GeV/c

Challenges in RHIC -- Luminosity

- Beam-beam effect on the luminosity lifetime
  - Beam emittance blowup
  - beam lifetime dominated by the beam-beam driven resonances

Treatment: proper working point

- Total beam intensity limit due to the dynamic pressure rise

Treatment: NEG coating the warm beam pipes

Polarization challenges in RHIC: snake resonances

- Snake resonance

$$\nu_s = m\nu_y + k \xrightarrow{\nu_s = \frac{1}{2}} \nu_y = \frac{2k+1}{2m}$$ K, m are integers

- even order resonance: m is even, driven by overlapping imperfection and intrinsic resonance. The stronger the two resonances, the stronger the snake resonance
- odd order resonance: m is odd, driven by intrinsic resonance

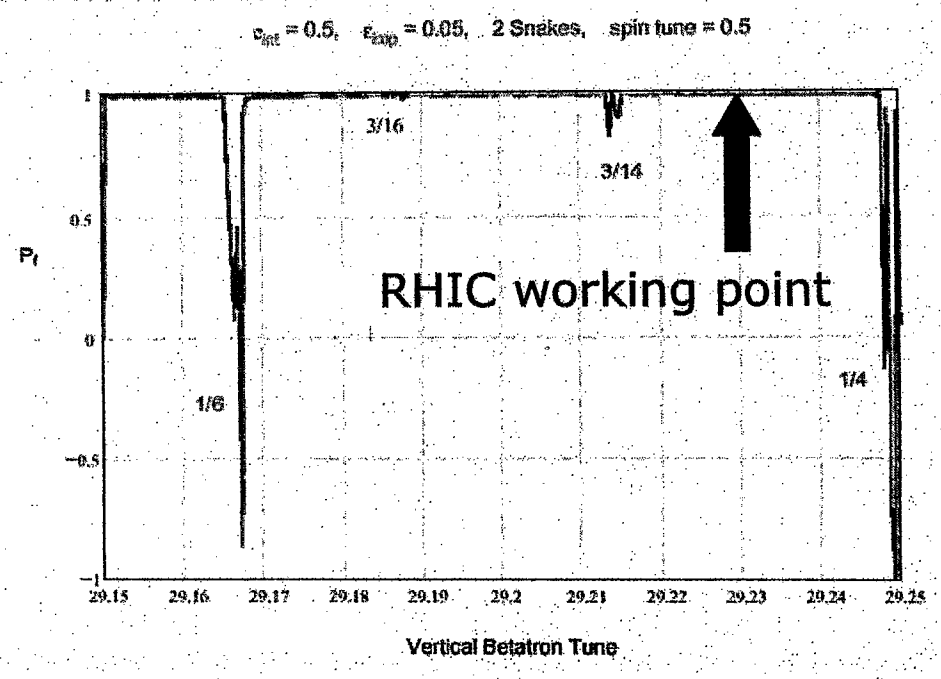
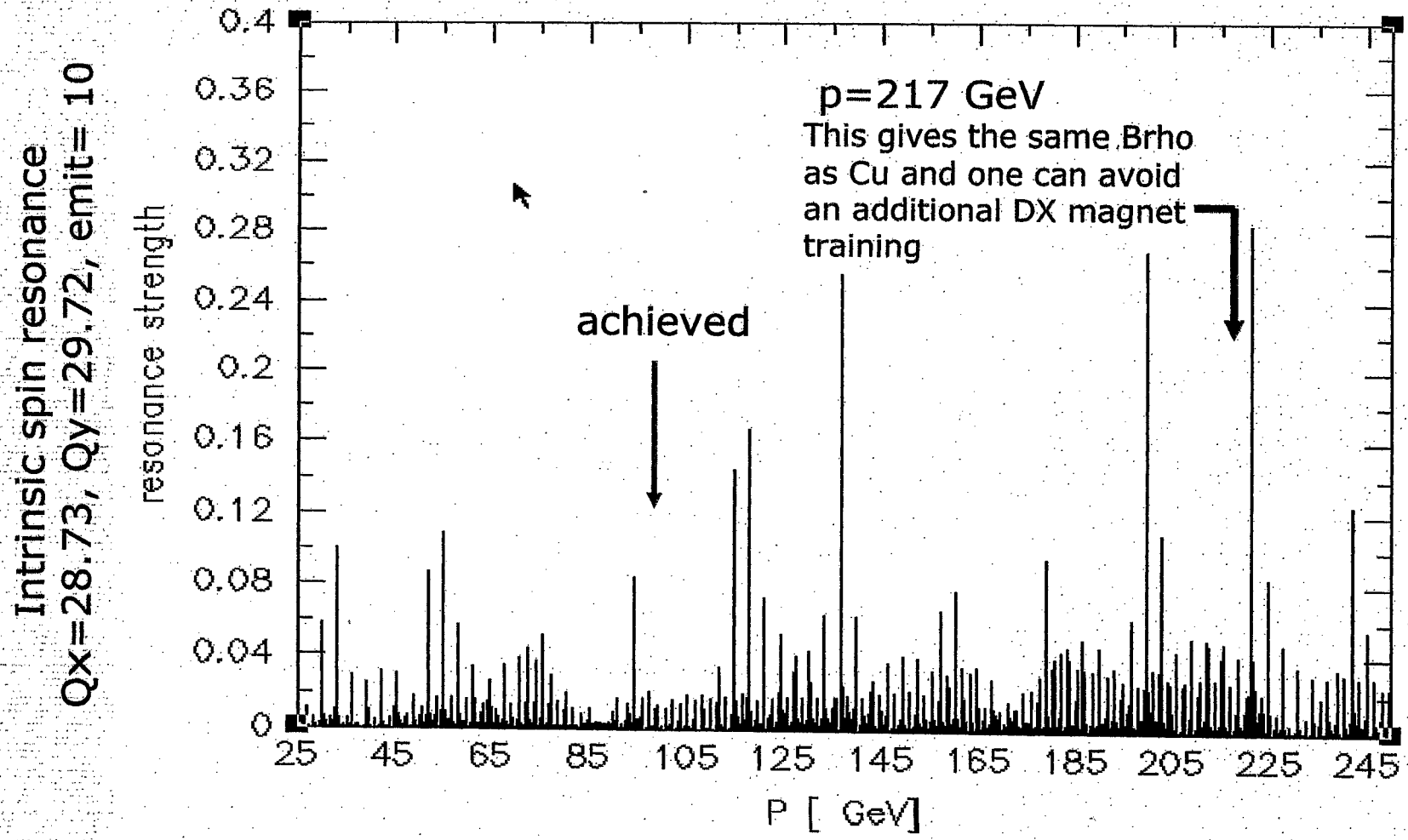


Figure 5.3: Vertical component of the polarization after acceleration through a strong intrinsic resonance and a moderate imperfection resonance shown as a function of the vertical betatron tune.

See V. Ptitsyn's talk

RHIC Intrinsic spin resonance spectrum

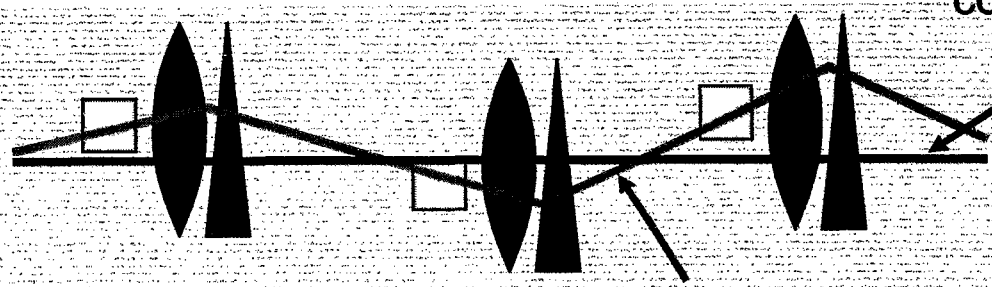


Solution I: precise orbit control

Details in V. Ptitsyn's talk

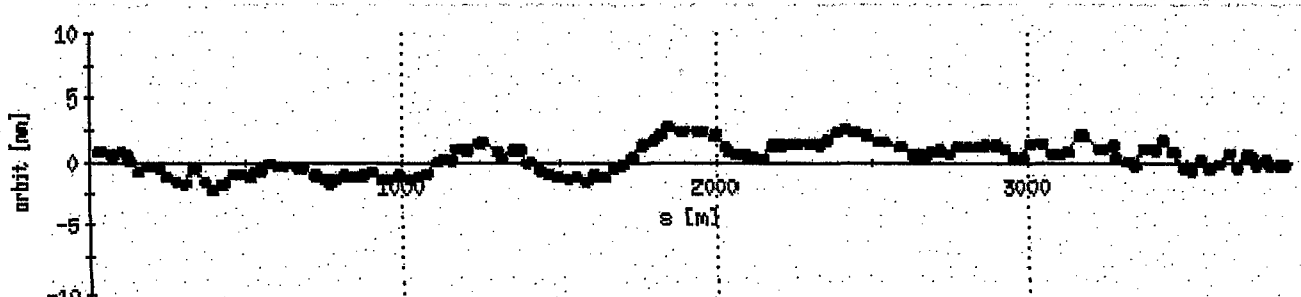
Goal: rms orbit distortion < 0.3mm

Flat orbit:
Sum of kicks on the spin vector from quads as well as the dipole correctors = 0

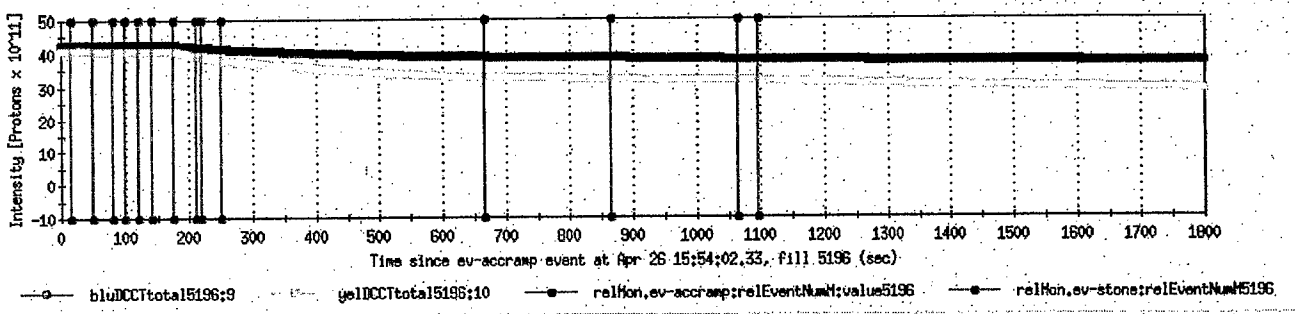


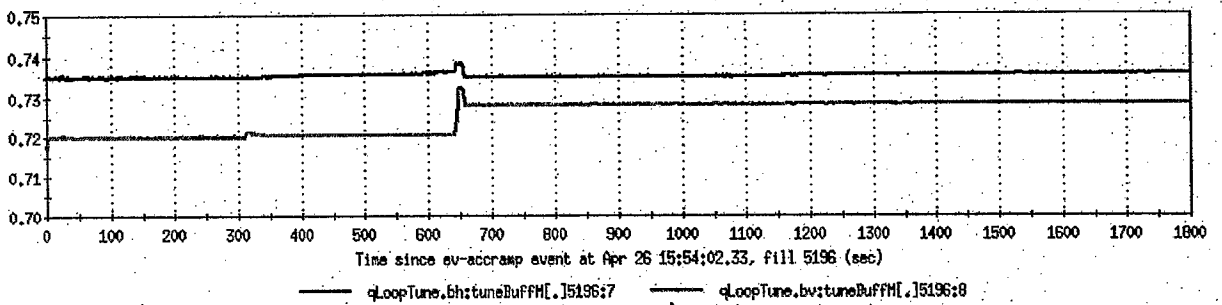
Orbit through the center of bpms

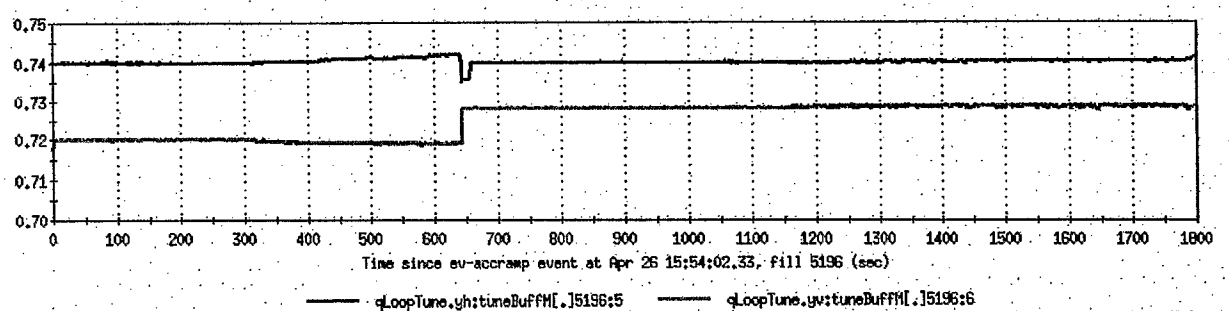
golden orbit using the latest survey



Solution 2: precise tune control







The tune feedback system has been demonstrated during the RHIC PP FY04 Run

RHIC Plan for Reaching the Machine Goal

- During the summer shut-down
  - Resurvey and re-alignment of IP12
  - BPM system upgrade
- Plan for Machine development
  - Polarimeter development: H. Huang's talks
  - Spin tune measurement: H. Huang's talks
    - This will allow us to check the snake current settings at top energy
  - **Explore pp acceleration beyond 100 GeV towards 250 GeV**

If time permits

  - Spin flipping commissioning
  - Establish injection with both snake and spin rotators on at full field
    - This will allow us to save ~7 minutes per store.

Summary

- Source performance: measured at the end of LINAC
  - Achieved: Average polarization 80% with 3~5x10^{11} protons per pulse
  - Expect: Average polarization 85% with >5x10^{11} protons per pulse
- AGS performance: 50% polarization with 0.7~1.0x10^{11} bunch intensity
- RHIC performance: 40~45% polarization with average 1 pb^{-1}/week luminosity

FY05	survey and realignment IP12 BPM(Beam Position Monitor) system uprade AGS cold snake commissioning NEG coating 250m warm beam pipes acceleration beyond 100 GeV better solenoid for the polarized proton source OPPIS
FY06	realignment more areas AGS cold snake operational more NEG coating more luminosity improvement

RHIC Status and Plan

Mei Bai
Brookhaven National Laboratory

Outline

- Goals of Run 05
- Status
  - Machine status
  - Timeline
- RUN Plan
- Machine developments for the future

RUN 5 Goal

- Physics data taking
- Explore the pp acceleration beyond 100 GeV
- RHIC Machine developments
  - Spin tune measurement
  - Spin flipping commissioning
  - Establish injection with both snake and spin rotators on at full field
- AGS cold snake commissioning

Machine Status

- Progress in RHIC Cu Run
  - Blue:
    - Beam was successfully accelerated to top energy with Cu8: beta squeeze to 1m during the ramp and then squeeze from 1m to 0.85 at flattop
    - instrumentation setup done
    - Skew quad modulation decoupling application is under commissioning
    - High intensity test:
      - 56 bunches with 1.5×10^{11} charges/per bunch were successfully injected. Pressure rise was also observed during the test

Machine Status

- Progress in RHIC Cu Run
  - Yellow
    - Had beam in for ~300 turns at injection
    - Two shorts were discovered
      - Short to ground at Yellow D6-8 in sector 10
      - Quadrupole buss to buss short in sector 12 probably near Yellow tripplet

AGS Cold Snake Status

- AGS cold snake is still expected to be available for installation at the end of January
- Details in Waldo's talk

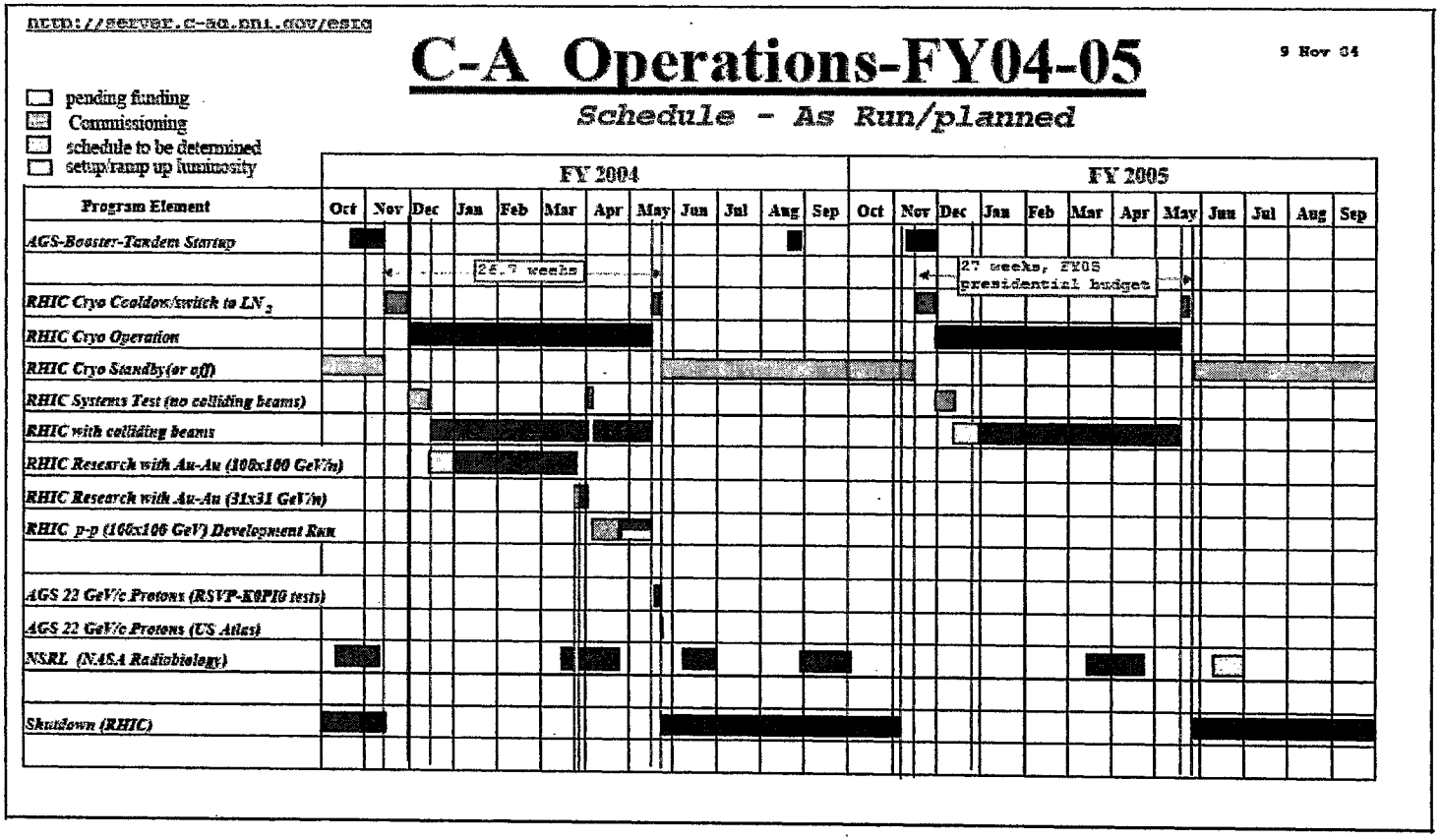
Plan for RHIC polarimeter

- New silicon detectors as well as targets are expected to be available before the pp run starts
- Replace the target & silicon detectors at the beginning of pp Run together with the H jet installation
- The new silicon detectors will be calibrated in 2~3 days, during this period the CNI polarimeters are not available
- The deterioration of the silicon detector will be monitored during the run. According to Sandro, the lifetime of the silicon detectors is about 8 weeks. So, it is expected to open the vacuum to replace the target and detectors in the early part of the physics run

Plan for RHIC polarimeter

- The impact of opening the CNI polarimeter on vacuum:
  - The replacement of the target and detectors takes about one shift(8hours) including to close and vacuum and get it back down to 10^{-7}
  - It takes about one week to get the vacuum down to10^{-8}
  - another week is needed to get the vacuum down to10^{-9}
- **The replacement of the detectors in the middle of the run certainly have an impact on the integrated luminosity. So, it is worth of looking for ways of making the detector more robust.**

Timeline


RLUD://server.c-ad.bnl.gov/esis
C-A Operations-FY04-05
9 Nov 04
Schedule - As Run/planned
pending funding
Commissioning
schedule to be determined
setup/ramp up luminosity
FY 2004
FY 2005
Program Element
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
AGS-Booster-Tandem Startup
24.7 weeks
27 weeks, FY05 presidential budget
RHIC Cryo Cooldow/switch to LN2
RHIC Cryo Operation
RHIC Cryo Standby(or off)
RHIC Systems Test (no colliding beams)
RHIC with colliding beams
RHIC Research with Au-Au (100x100 GeV/n)
RHIC Research with Au-Au (31x31 GeV/n)
RHIC p-p (100x100 GeV) Development Run
AGS 22 GeV/c Protons (RSVP-K0PI0 tests)
AGS 22 GeV/c Protons (US Atlas)
NSRL (NASA Radiobiology)
Shutdown (RHIC)

Timeline

1	15-Nov-2004	2 weeks cooldown,	Cooldown starts Nov 18
2	22-Nov-2004	80K->4K	First BLUE beam Nov 22
3	29-Nov-2004	2 weeks RHIC start-up	Beam in both rings ~Nov 29
4	06-Dec-2004		
5	13-Dec-2004	2 weeks RHIC ramp-up	Collisions overnight,
6	20-Dec-2004		starting ~Dec 13
7	27-Dec-2004	8 weeks Cu-Cu Physics,	Starts ~Dec 27
8	03-Jan-2005	200 GeV/n	
9	10-Jan-2005		
10	17-Jan-2005		
11	24-Jan-2005		
12	31-Jan-2005		
13	07-Feb-2005		
14	14-Feb-2005		
15	21-Feb-2005	3 weeks p-p set-up	
16	28-Feb-2005		
17	07-Mar-2005		
[illegible]	[illegible]	[illegible]	[illegible]
27	15-May-2005	1 week warm-up	

RHIC Cu Run

AGS pp setup

2-week setup
- RHIC Jet target installation
- AGS cold snake installation

1-week ramp up

9-week Physics Run + machine development

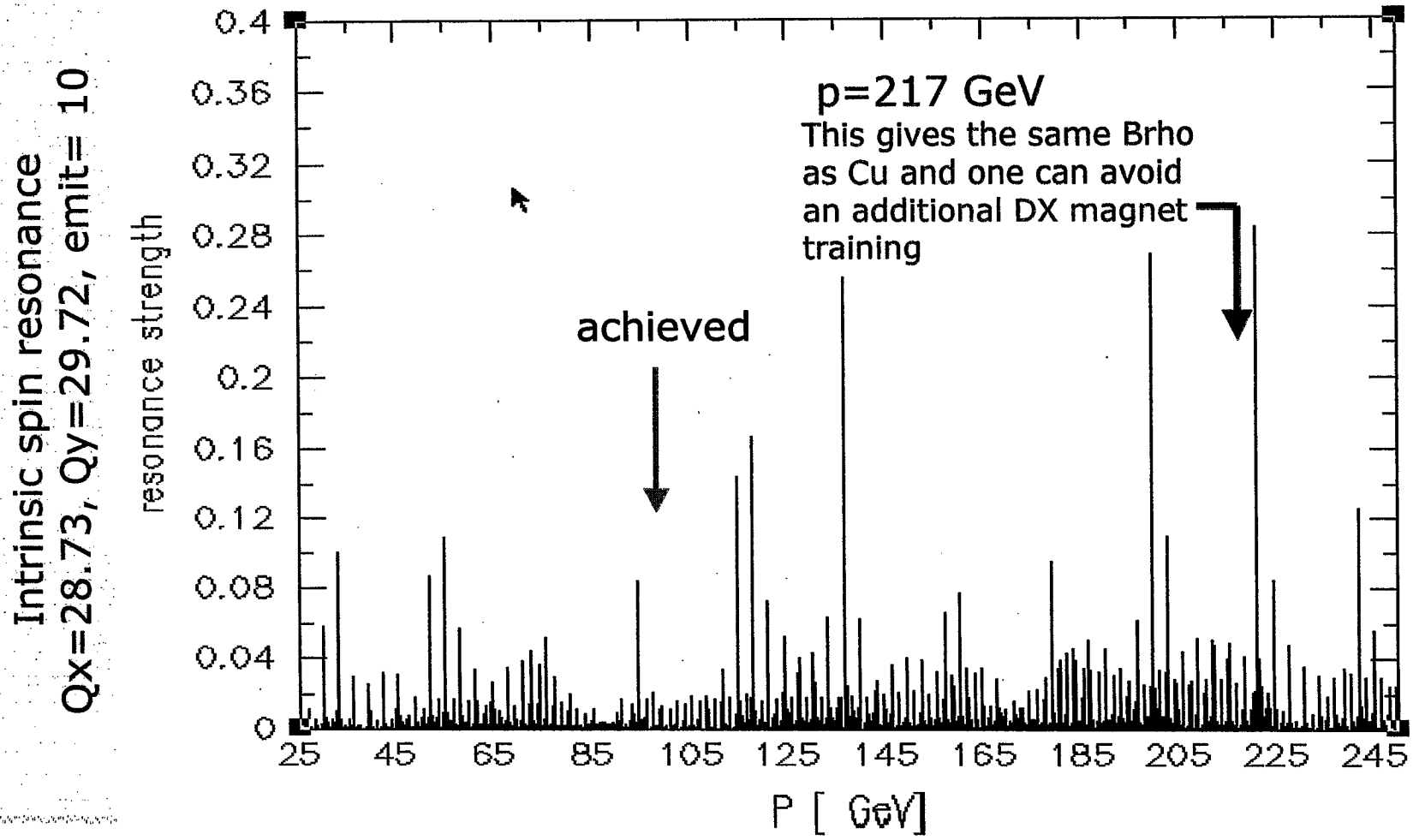
Acceleration beyond 100 GeV

- Goal
  - To evaluate the spin dynamics beyond 100 GeV
    - What's the impact of 1mm rms orbit distortion(achieved) on the polarization transmission efficiency?
    - How much can we correct the orbit with the existing RHIC orbit correction system at higher energy?
  - To provide a guidance/justification for the full ring re-alignment of RHIC during summer of 2005
- Expection
  - Little or no polarization is expected at energy of 217 GeV with 1mm orbit distortion
  - Polarization ramp measurement will be the key technique in exploring the depolarization mechanisms and locations.

Acceleration beyond 100 GeV

- Plan
  - Simulation
    - Spin tracking with ~1mm rms orbit distortion
    - Spin tracking with different orbit distortions to evaluate the tolerance of orbit distortions.
  - With beam
    - Develop the ramp to 170 GeV
      - Measure the polarization/orbit distortion along the ramp
      - Vary the orbit distortion around 135 GeV where the strong intrinsic resonance is located
    - Develop the ramp to 217 GeV
      - Measure the polarization/orbit distortion along the ramp

Challenge of going beyond 100 GeV

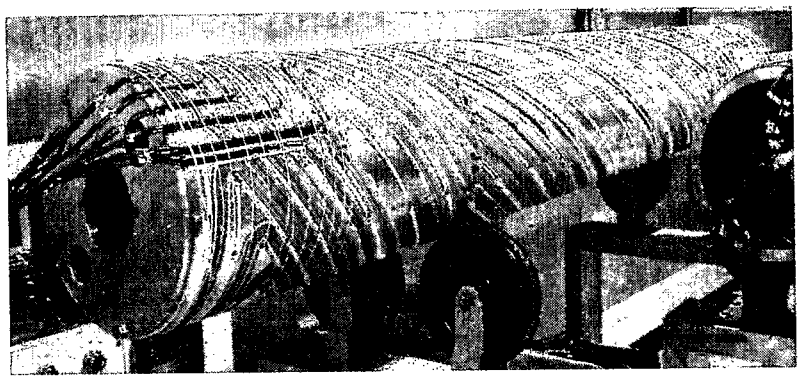


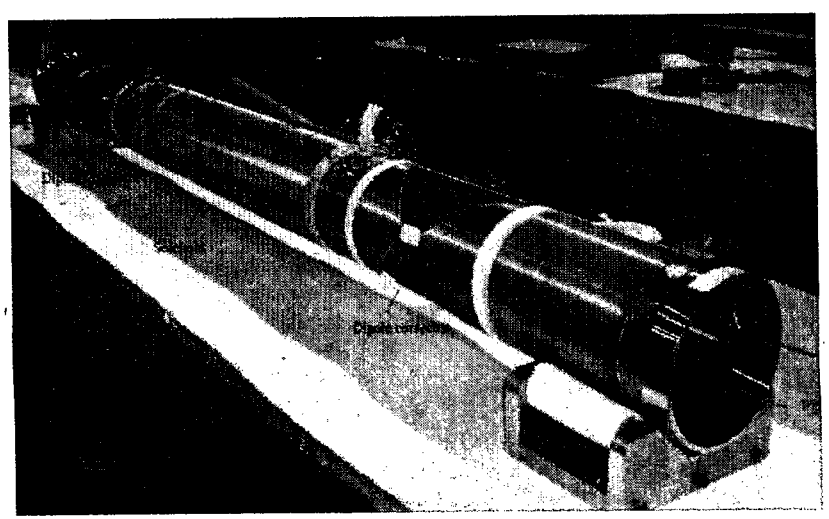
Status and Commissioning Plans of AGS Cold Snake

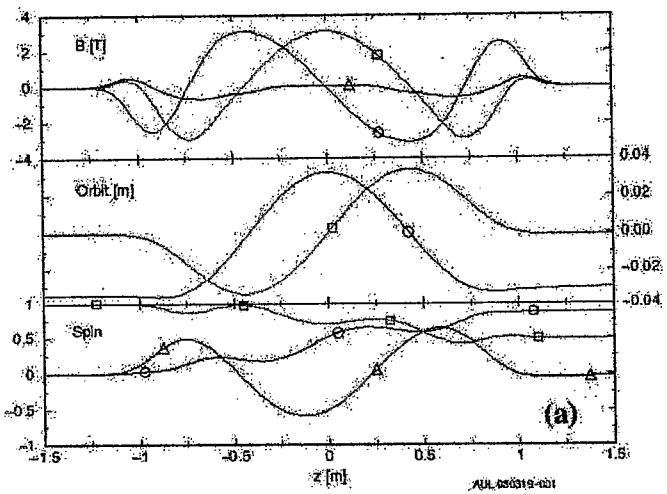
Waldo MacKay

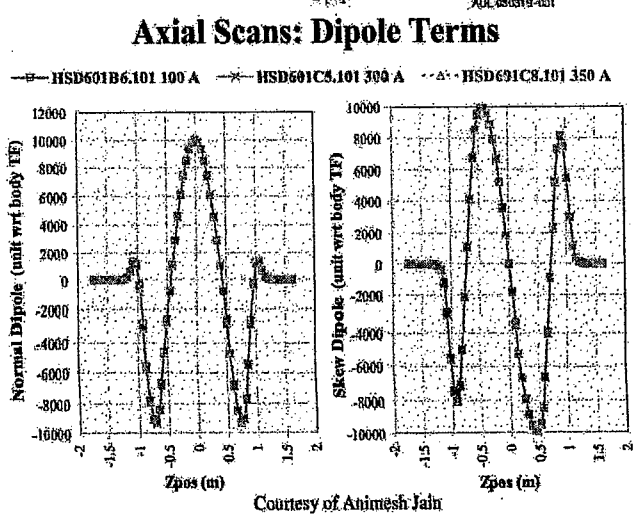
BROOKHAVEN
NATIONAL LABORATORY

New AGS cryogenic snake



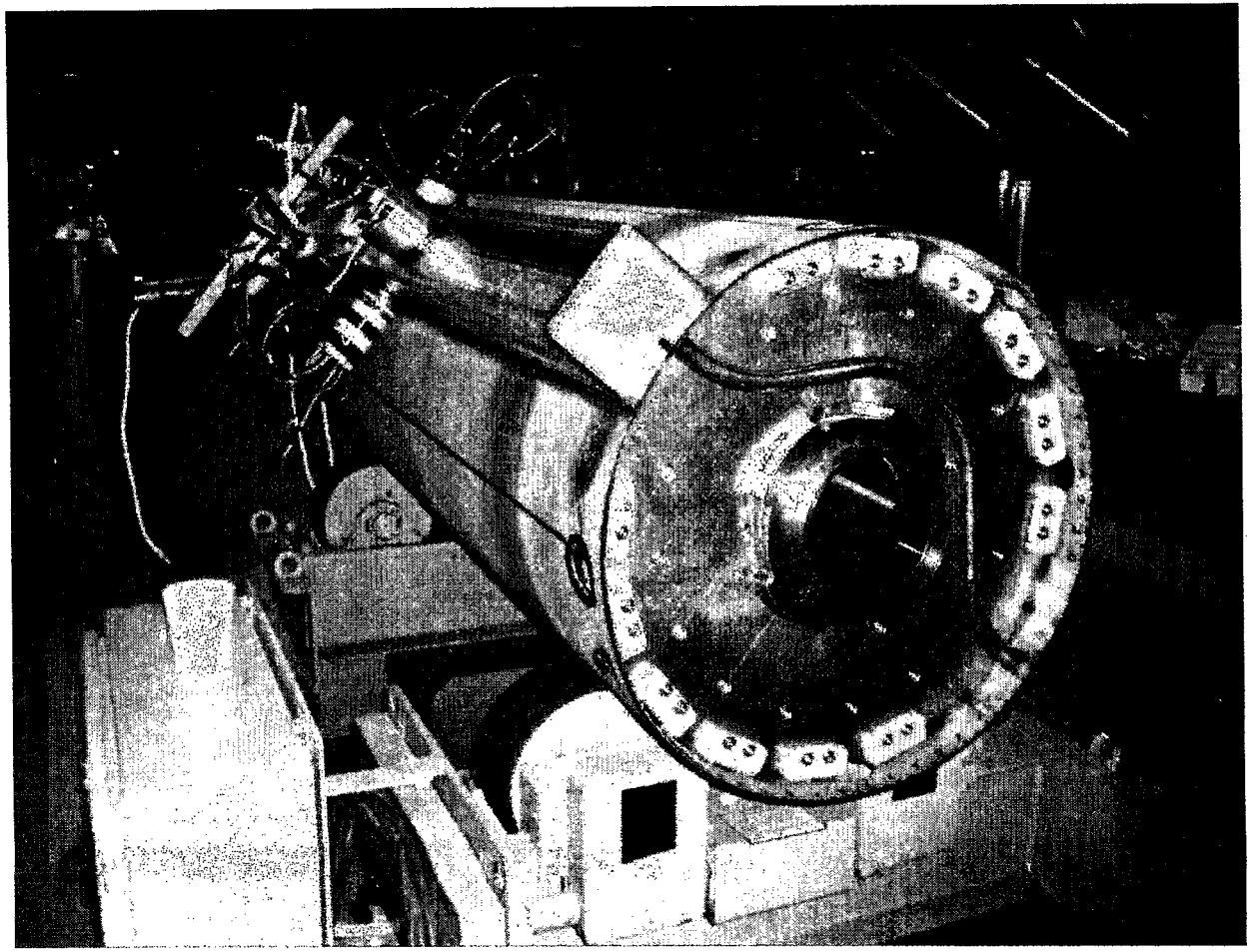




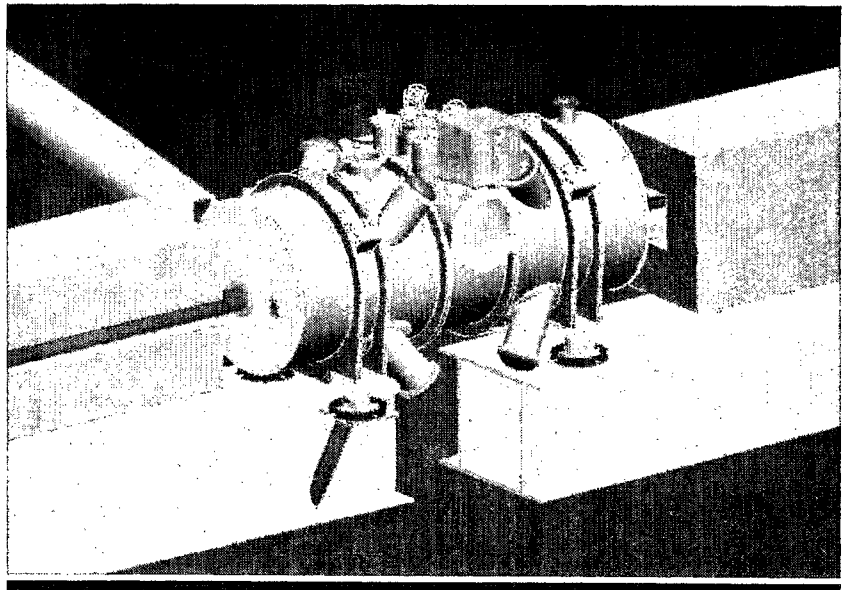


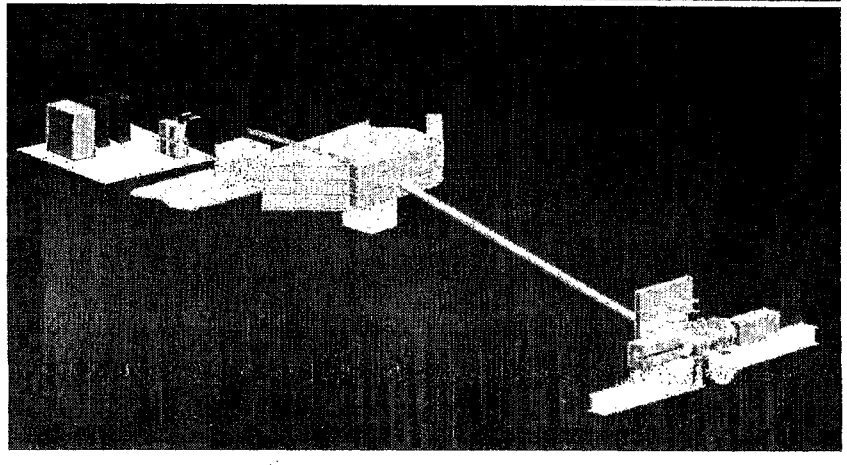
Courtesy of Animesh Jain

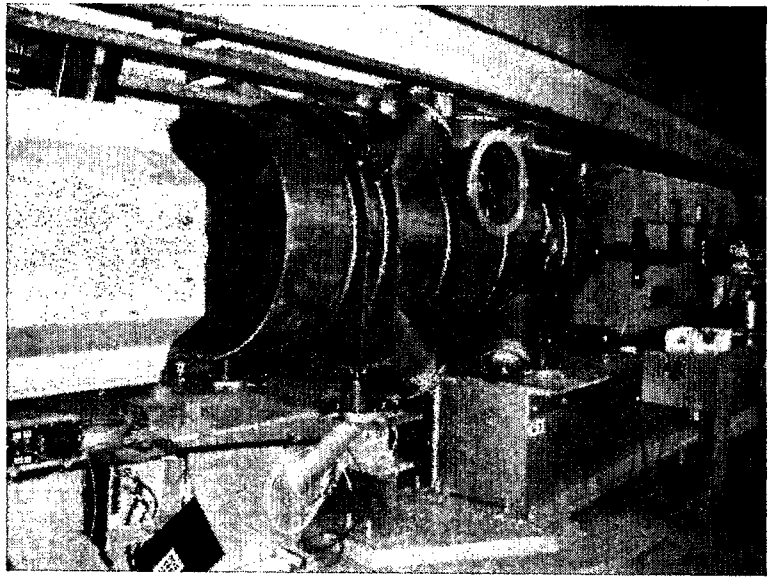
Cold mass with buffer volume

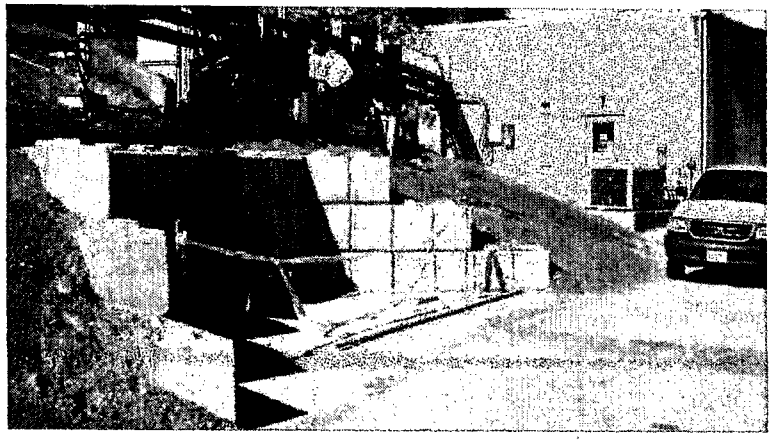


Cold Snake Cryostat

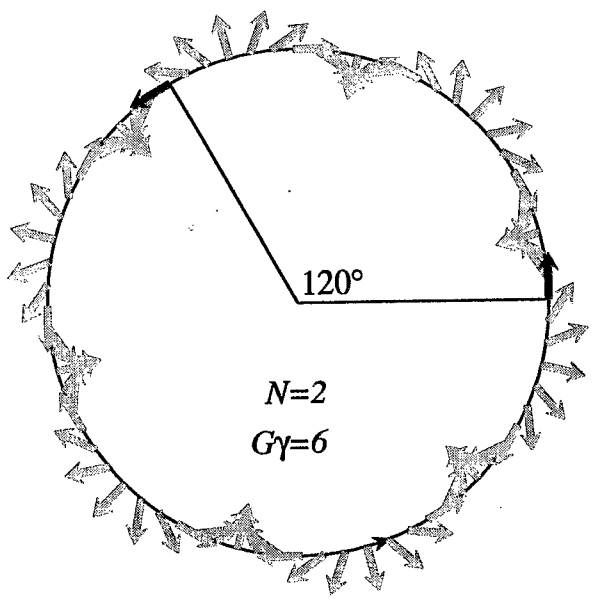


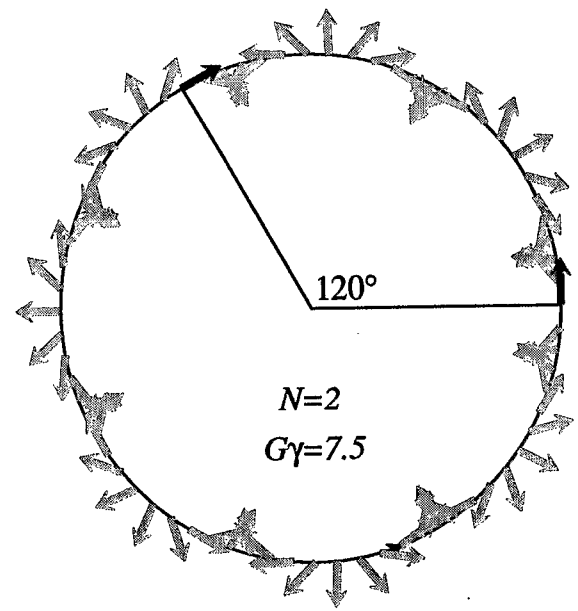






2 Partial Snakes spaced by 1/3 Ring



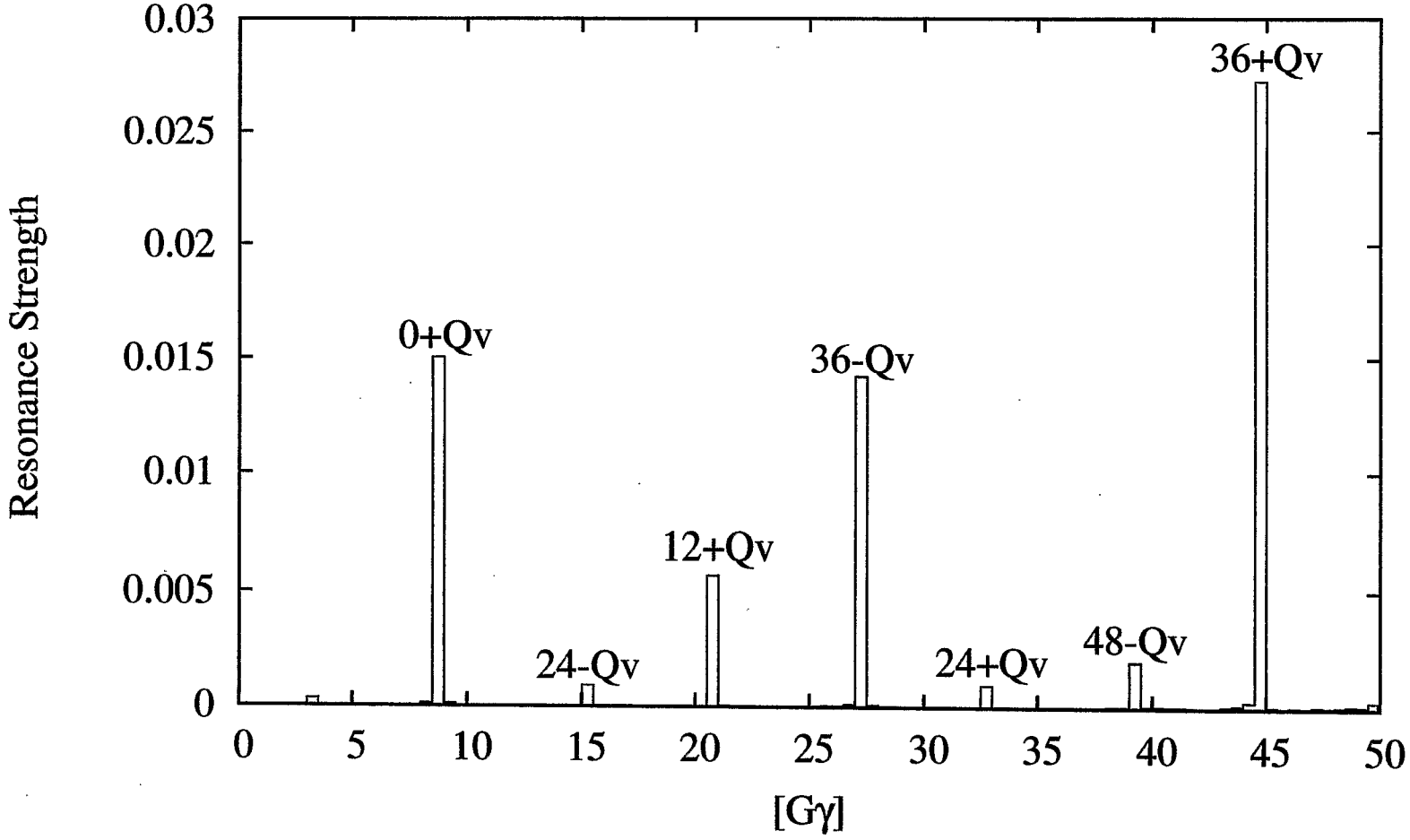


$G\gamma = 3 \times N$
Snakes strengths add.

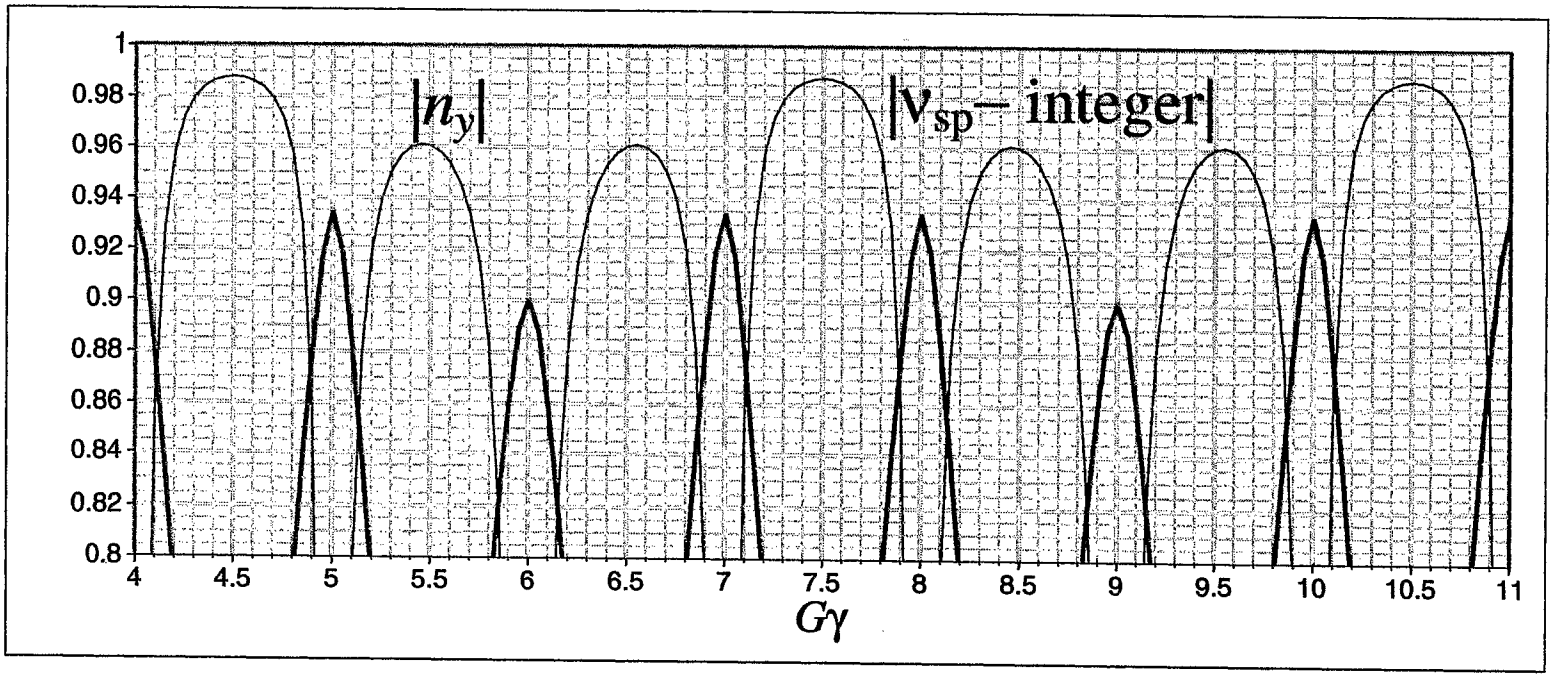
$G\gamma = 3 \times (N + 0.5)$
Snakes strengths subtract.

AGS has superperiodicity of 12.
Injection: $G\gamma = 4.5$ Extraction: $G\gamma = 46.5$

AGS Intrinsic Resonances



Two Helical Partial Snakes in AGS

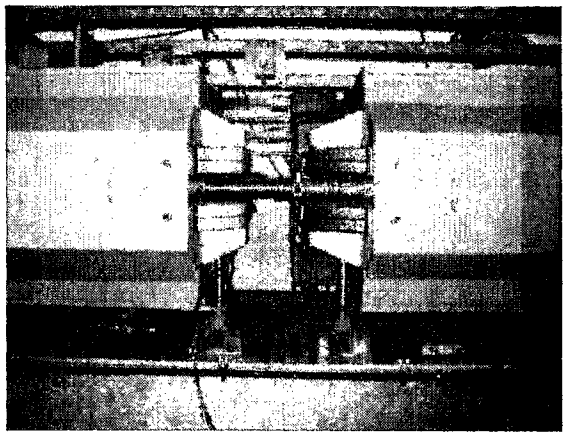


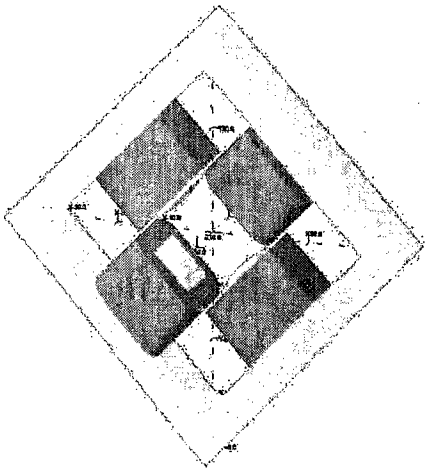
A20 Cold snake: 15%
E20 Warm snake: 5%
Superperiodicity: 12

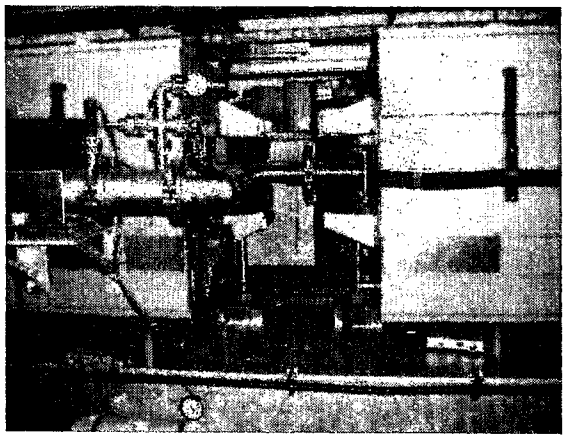
Spin tune stop bands: integer$\pm$0.065
Putting $Q_y = 8.96$ eliminates intrinsic resonances.
Pattern repeats every 3 integers

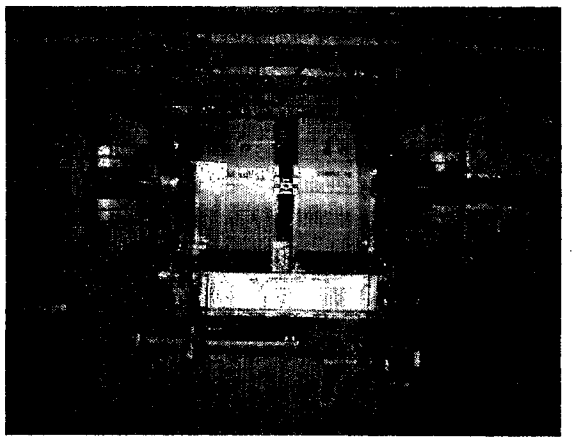
Spin almost vertical at injection ($G\gamma = 4.5$) and extraction (46.5)

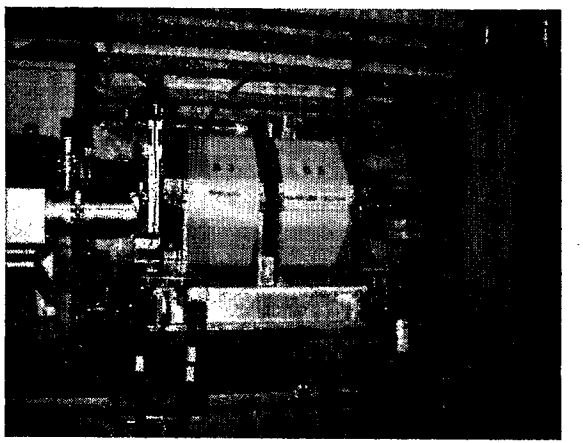
New Correction Quadrupoles



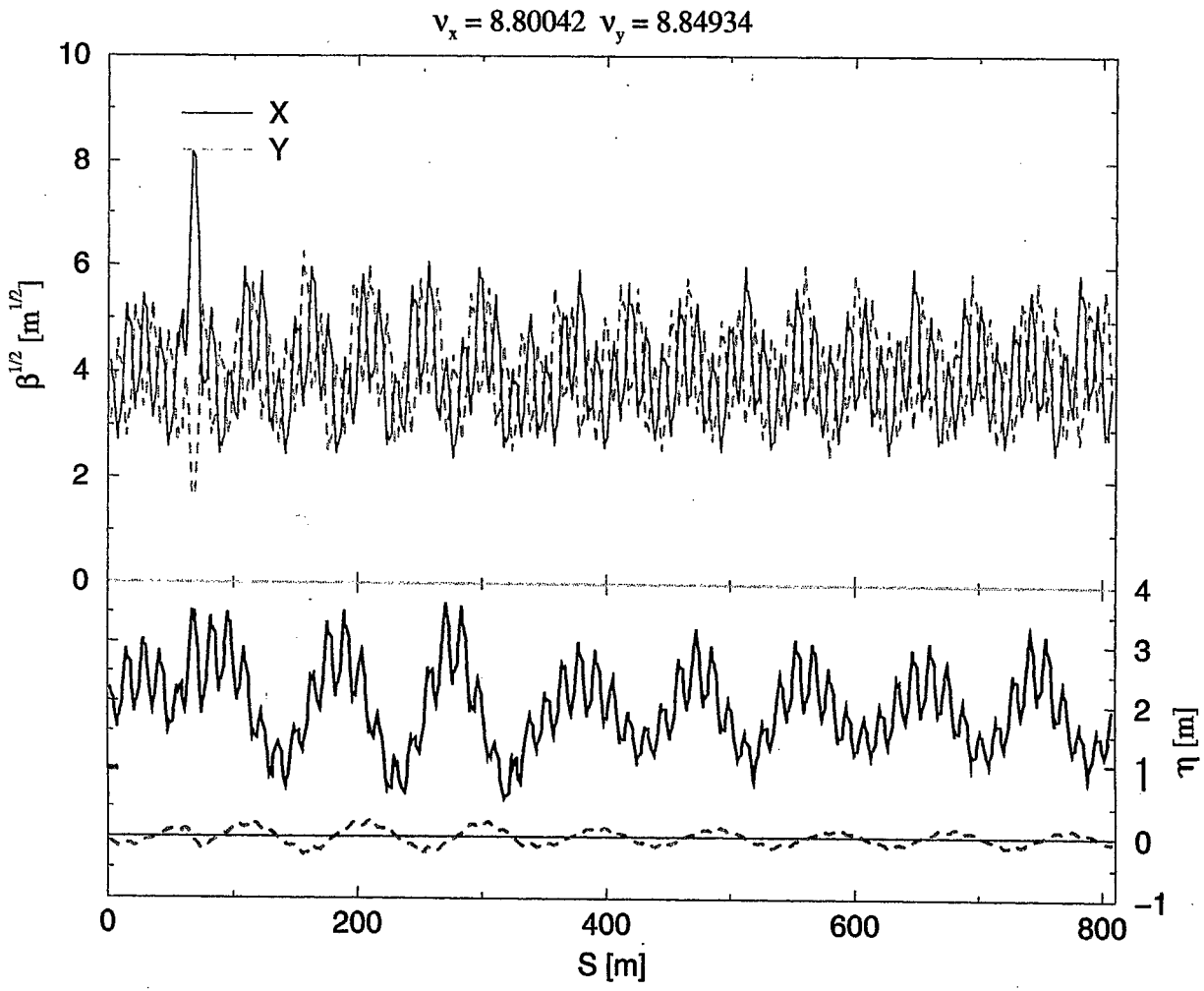








Two snakes 15% and 6.7% at injection



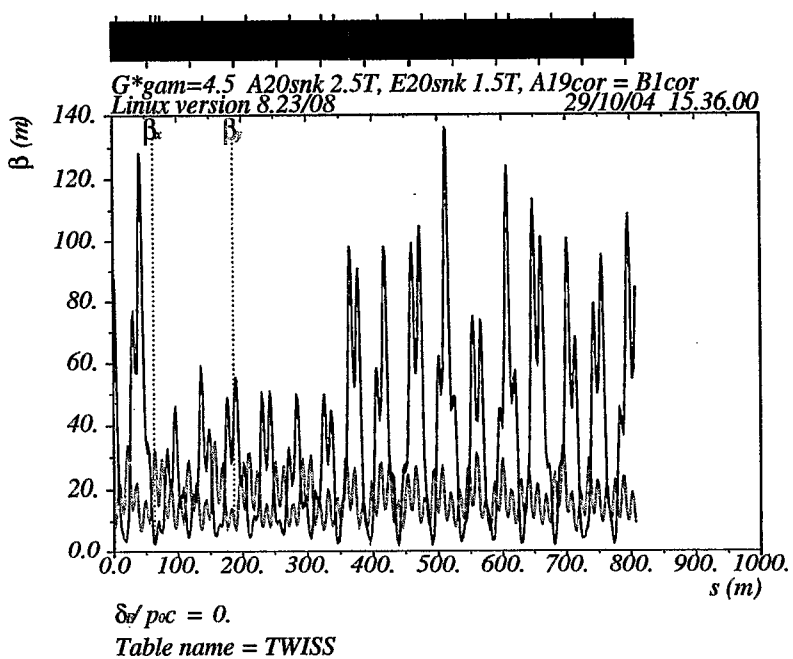
Cold snake:
A20

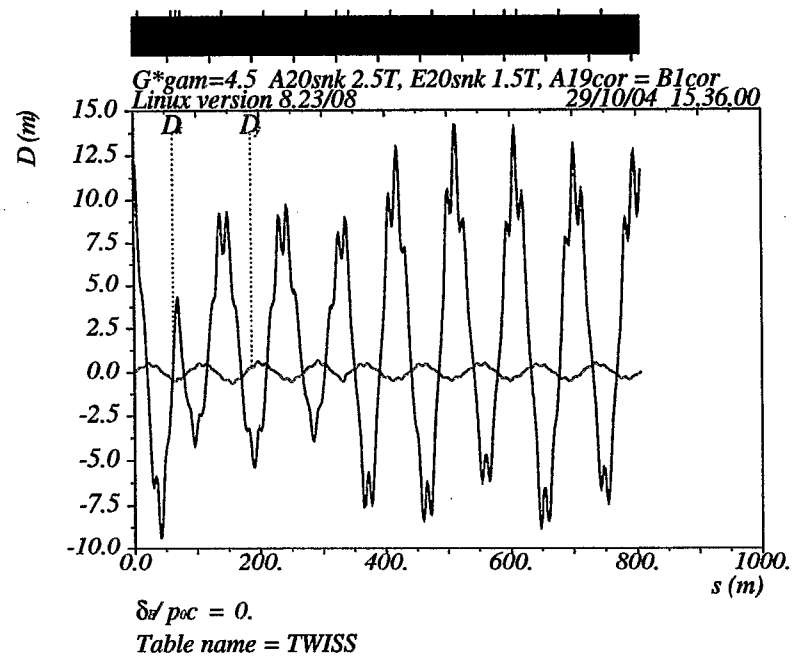
Warm snake:
E20

Extra Quads:
A17, A19,
B1, B3

Courtesy of
Mei Bai

Optics correction with 2 Quads

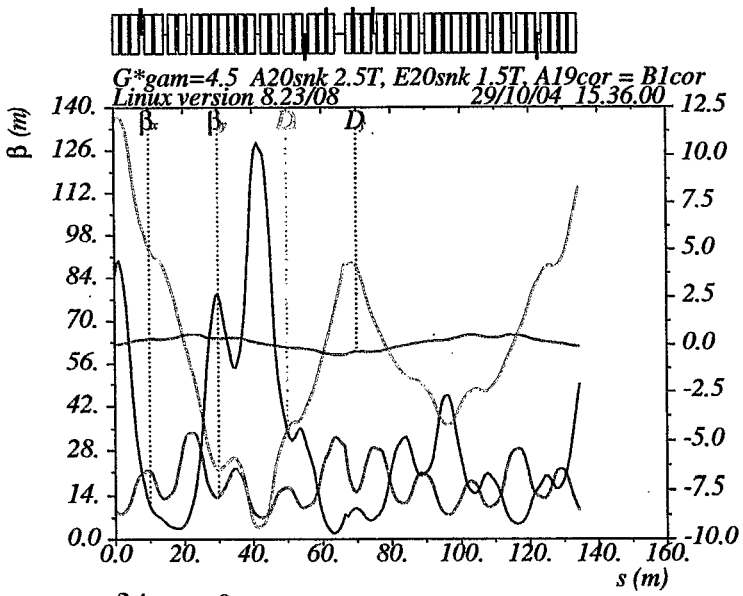




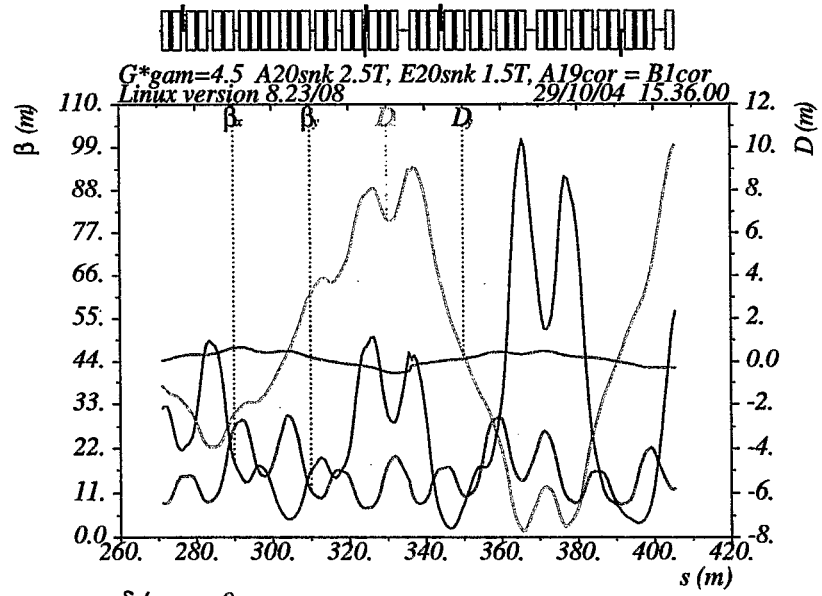
Injection tunes: $(G\gamma = 4.5)$

- $Q_x = 8.717$
- $Q_y = 8.743$

Optics correction with 2 Quads



$\delta_E/p_0c = 0.$
Table name = TWISS



$\delta_E/p_0c = 0.$
Table name = TWISS

Schedule

- Cryostat complete: End of Decemeber
- Testing in 902: 3–4 weeks
  - warm tests
  - quench tests
  - magnetic measurements
  - heat load and cryocooler performance
- Install in AGS: End of January
  - Put in ring
  - Finish connections during maintenance days (over next 2 or 3 weeks)
- Cool down
  - Check connections during maintenance
  - Turn on supplies (1st time) during maintenance

Commissioning Plan

Commissioning will occur during RHIC stores with polarized protons.

- Initial conditions:
  - Start with new copy of "AGS User" for single warm snake.
  - Turn off ac dipole pulses on this "User".
  - Use single small bunches ($\lesssim 10^9$ protons).
  - Inject individual bunches on demand only.
  - Turn on J10 extraction bumps on injection porch to prevent losses up ramp (rf loops might fail).
- Set up injection with two snakes.
  - Turn cold snake on in steps with bumps and quad corrections. Measure orbits and correct.

With injection working at desired snake strength:

- Increase bunch intensity to $\sim 7 \times 10^{10}$.
  - Measure injected polarization.
- Turn off J10 dump bumps and accelerate the beam.
  - Adjust tunes up ramp: $Q_y = 8.96$ at $G\gamma = 7.5$ and above.
- Ramp to $G\gamma = 12.5$ and measure polarization.
- Ramp to extraction energy $G\gamma = 46.5$.
  - Measure polarization at top energy.
- Tune up extraction.
- Increase intensity — goal: 2×10^{11} per bunch at extraction.

- Starting tracking studies with 2-quad lattice.

Radial polarization from RHIC CNI
(Precise measurement for small angle)

Osamu Jinnouchi (RBRC)
CNI group
RSC 2004.12.6

Strip by strip polarimeters

- By taking up-down asymmetry, each strip can be considered as individual polarimeter

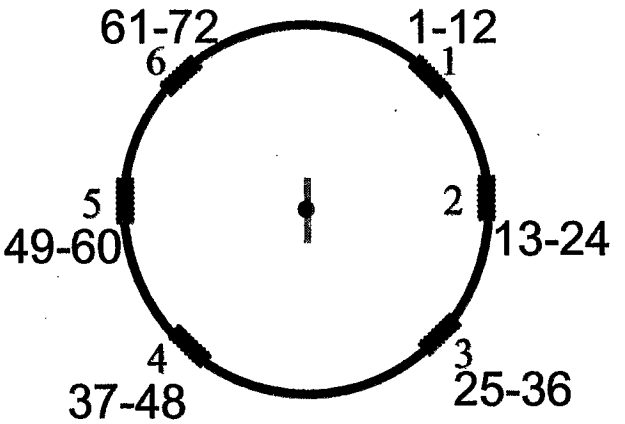
$$\varepsilon^{(i)} = \frac{(N_u^{(i)} - RN_d^{(i)})}{(N_u^{(i)} + RN_d^{(i)})} \quad R = \frac{\sum_i N_u^{(i)}}{\sum_i N_d^{(i)}}$$

$N_u^{(i)}, N_d^{(i)}$ Number of carbons in i-th strip for Up(Down) spin

$i = 1, 2, \cdots 72$

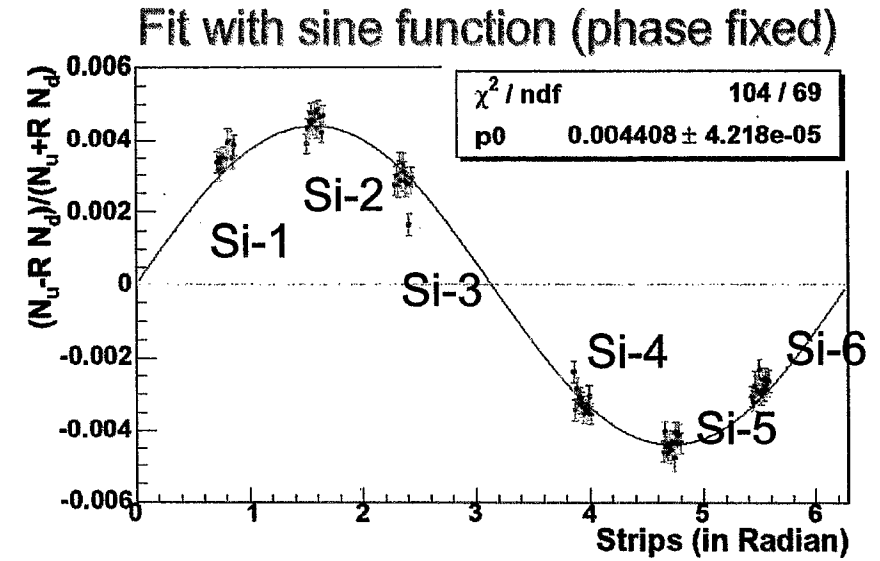
- ε should behave as phi asymmetry
- Variations more than statistical uncertainties are regarded as systematic of the measurement

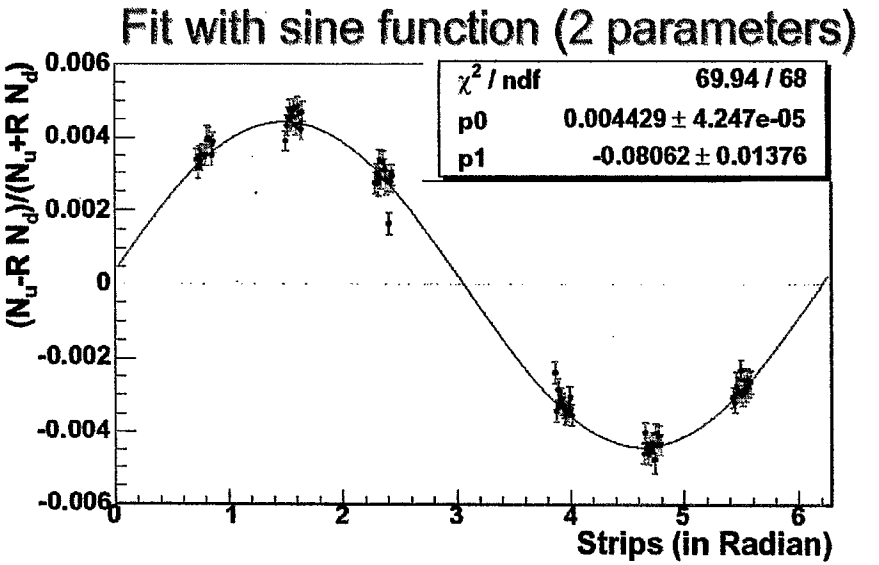
$$\sigma_{sys} = \sqrt{\sigma_{total}^2 - \sigma_{stat}^2}$$

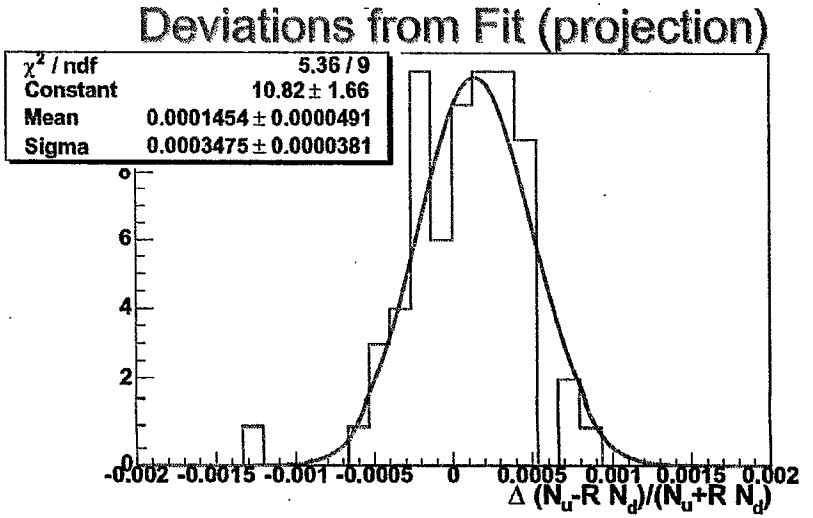


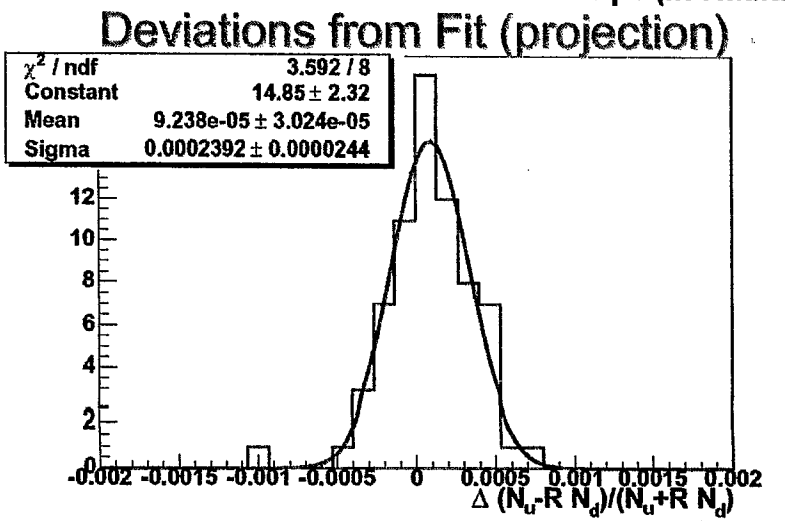
- the data used for this study from next page is,
  - 66 CNI runs in BLUE accumulated
  - event data taken with Jet

Strip by strip variations in asymmetry

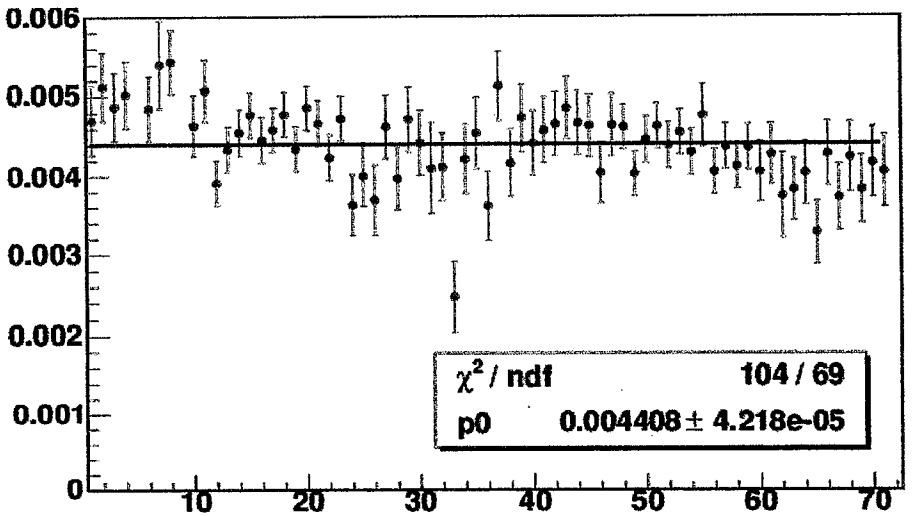


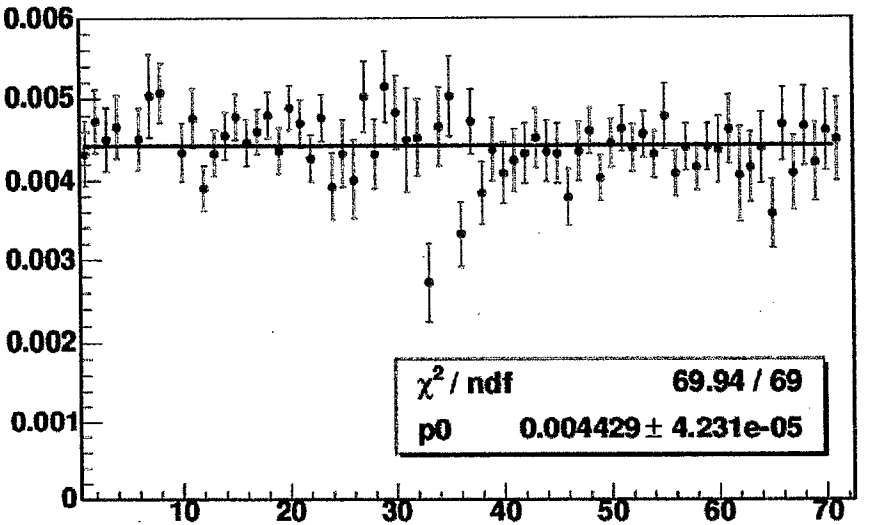






Asymmetry as a function of strip#





1-parameter
The phase shift not allowed
Structure 1-2-3 4-5-6 seen

2-parameters
Phase = 0.081 assumed
Uniform distribution

Numerical comparison

1 parameter fit	2 parameter fit
χ^2/ndf = 104/69	χ^2/ndf = 70/68
$\sigma_{sys} = \sqrt{\sigma_{total}^2 - \sigma_{stat}^2}$	$\sigma_{sys} = \sqrt{\sigma_{total}^2 - \sigma_{stat}^2}$
$\sigma_{total} = 3.5 \times 10^{-4}$	$\sigma_{total} = 2.4 \times 10^{-4}$
$\sigma_{stat} = 2.8 \times 10^{-4}$	$\sigma_{stat} = 2.8 \times 10^{-4}$
$\downarrow$	$\downarrow$
$\sigma_{sys} = 2.1 \times 10^{-4}$	$\sigma_{sys} = \text{negligible}$

The angle -0.081 +/- 0.014 corresponds to
-4.6 +/- 0.8 degree

This could be
- real polarization angle
- geometrical dislocation of detectors (5 degree is Δ=1.2cm at Si)
- some other reason …

Dead layer dependence, cut dependence

- Si dead layer correction change the A_N for each strip
  - the plots so far assumed 59μg/cm^2 for all strips
  - use individual values for each strip

    → χ^2/ndf = 67/68 $\Delta\phi$ = -0.068 +/- 0.014

  - use ±10μg/cm^2 cases 49 μg/cm^2 → χ^2/ndf = 68/68 $\Delta\phi$ = -0.066 +/- 0.015

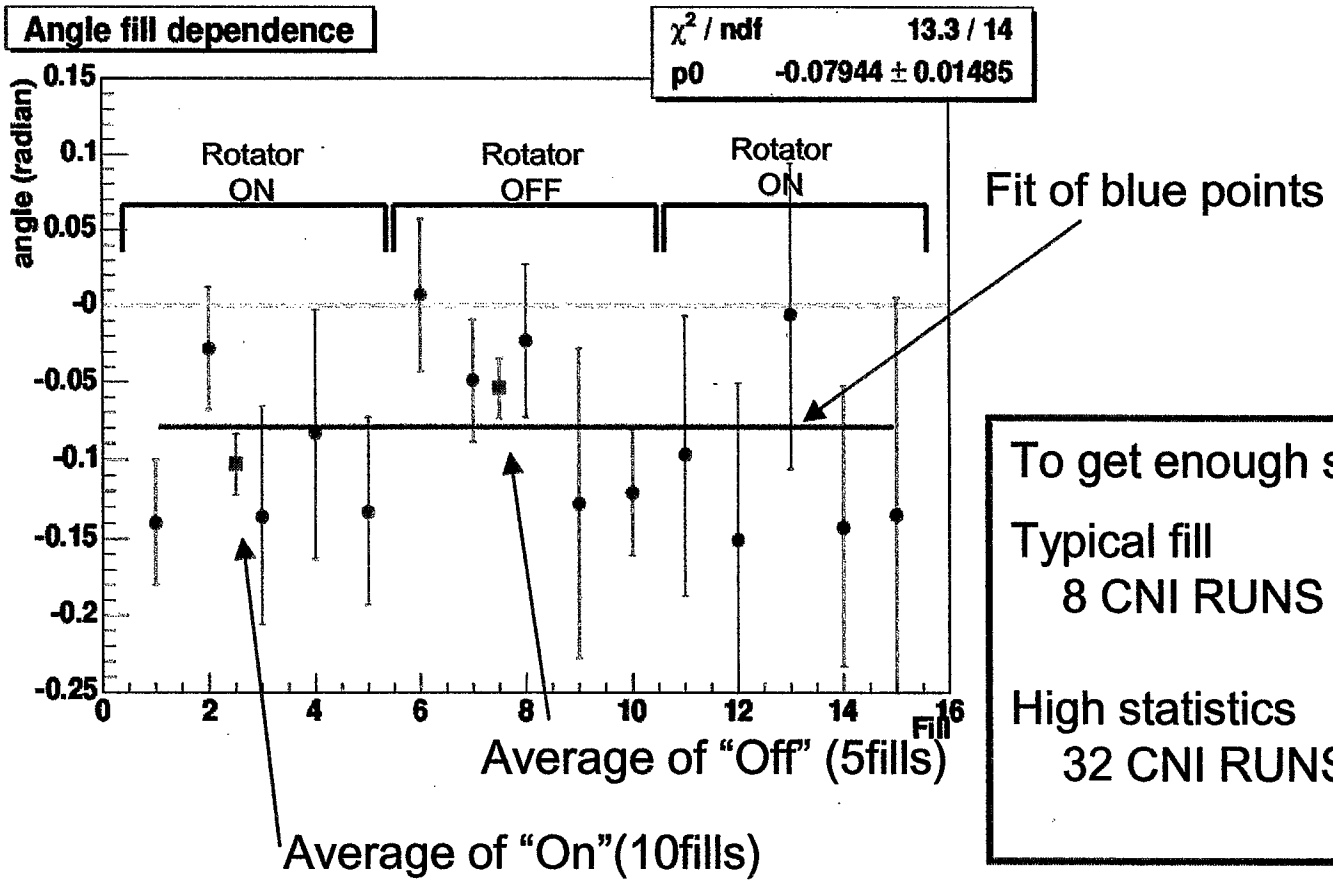
    69 μg/cm^2 → χ^2/ndf = 67/68 $\Delta\phi$ = -0.081 +/- 0.013

- Different event cut condition
  - use 2-sigma (instead of standard 3-sigma) carbon invariant mass cut

    → χ^2/ndf = 71/68 $\Delta\phi$ = -0.078 +/- 0.014

- The measured angle value is quite stable against various changes

Fill dependence



To get enough statistics,

Typical fill
8 CNI RUNS → 40mrad
→ **The 1st blue point**

High statistics
32 CNI RUNS → 20mrad
→ **red point**

- Fill by fill fluctuations look to be just statistical
- Spin rotator dependence is not so obvious

Summary and outlook

- RHIC pC CNI measurement
  - negligible systematic error on strip by strip fluctuation
  - good sensitivity for radial component
  - - 4.6 ± 0.8 degree tilting of polarization vector

- Outlook for calibration by Jet data
  - will obtain final consensus/agreement on P_{beam} among Jet collaboration fairly soon
  - systematic error check with Yellow ring data
  - Update of Run-04, Run-03 with Jet-data take place in January (?)

Relative Luminosity Measurement at PHENIX

D. Kawall, BNL

for
RHIC Spin Collaboration Meeting XXX
December 6, 2004
RIKEN BNL Research Center

Relative Luminosity Measurement at PHENIX

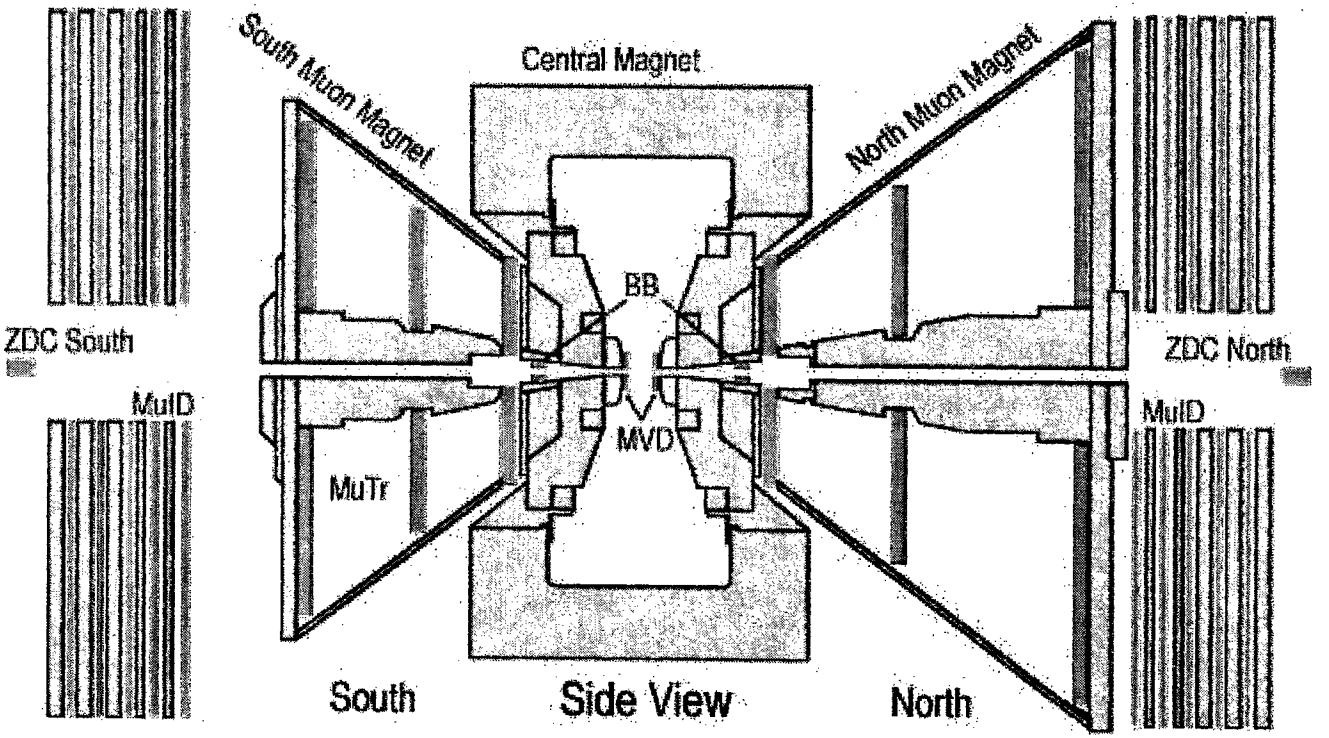
$$
\begin{aligned}
A_{LL} &= \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} \\
&= \frac{1}{|\langle P_b P_y \rangle|} \cdot \frac{N_{++} - R \cdot N_{+-}}{N_{++} + R \cdot N_{+-}}; \quad R = \frac{L_{++}}{L_{+-}} \\
\frac{\partial A_{LL}}{\partial R} \delta R &\approx \frac{1}{2|\langle P_b P_y \rangle|} \delta R
\end{aligned}
$$

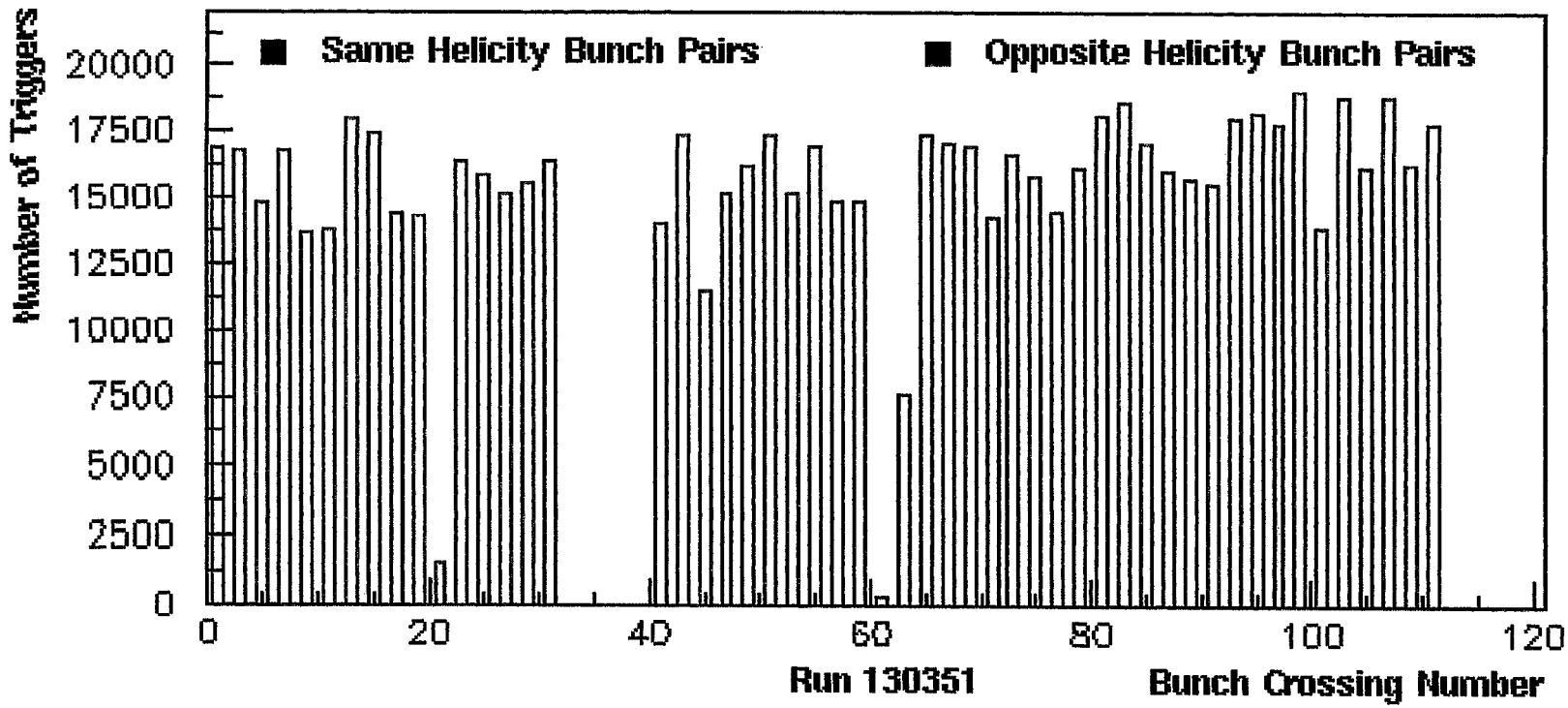
- To measure 1% asymmetry with $P_{beam} \approx 40\%$, need $\delta R < 10^{-3}$
- Higher polarization reduces sensitivity to uncertainty in R
- Order of magnitude requirement : $\delta R \leq \text{few} \times 10^{-4}$

- How do measure relative luminosity?
- What are some of the difficulties we expect as $\mathcal{L}$ increases?
- What should we do? (Work in progress)

Relative Luminosity Measurement at PHENIX

- Located at ± 1.44 m from interaction point, cover $\Delta\phi = 2\pi,\ 3.0 \leq |\eta| \leq 3.9$
- Collisions defined by coincidence of signals in Beam-Beam Counters (BBCs)
- Average hit time is formed from PMTs in north and south BBC arms separately
- From difference of north and south BBC hit times can reconstruct z of vertex, require $|z| < 30$ cm
- Have separate scalers for each bunch pair to measure collison rate for different helicity combinations
- Measure R with scalers attached to this minimum-bias trigger, $R = \frac{BBC_{++} + BBC_{--}}{BBC_{+-} + BBC_{-+}}$





- Ideally $R = 1$, blue and red bars identical in height
- Typical value of $|R - 1| \approx$ few percent in any run, 0.5% overall in Run 3
- Variation in bunch intensity develops at extraction and injection - can be improved by CAD
- In Run 3, $\delta R \approx 2.5 \times 10^{-4}$ (stat)
- Rate variation is one problem another is due to different vertex distributions

Complications in Extracting R as Luminosity Increases

- In Run 4, probability of minimum-bias trigger/crossing ≈ 0.02
- Roughly 1 percent of all triggers contained a second pp collision
- In Run 5, ≈ 4 percent of all triggers may contain a second pp collision
- At design luminosity, we expect ≈ 1 pp collision/crossing $\Rightarrow$ 70 percent of all triggers may contain 2 or more pp collisions !

At least two complications will result :

(1) Scaler counting minimum-bias triggers only counts 0 or 1 pp interaction/crossing

$\Rightarrow$ we need to correct for possibility of multiple pp interactions/crossing

(2) With multiple pp interactions we are likely to :

(a) lose some events which should pass the vertex cut

(b) count some events which shouldn't pass the vertex cut

$\Rightarrow$ PHENIX will acquire a sensitivity to bunch longitudinal profiles

Complications in Extracting R as Luminosity Increases

Extracting R from a single-arm detector is relatively easy :

- Let μ=average number of pp interactions/crossing passing vertex cut
- Let ϵ=probability that we can detect a pp collision
- Let $\delta = 1 - \epsilon$=probability we miss a pp collision

Then the fraction of crossings with 0 triggers is :

$$\begin{aligned} P(0) &= \sum_{n=0}^{\infty} \frac{e^{-\mu}\mu^n}{n!}\delta^n \\ &= e^{-\mu}e^{\mu\delta}\sum_{n=0}^{\infty}\frac{e^{-\mu\delta}\,(\mu\delta)^n}{n!} \\ &= e^{-\mu\epsilon} \end{aligned}$$

$$\text{Then} \quad \mu = -\log P(0)/\epsilon \qquad \Rightarrow \quad R = \frac{\mu_{++}}{\mu_{+-}} = \frac{-\log P_{++}(0)/\epsilon}{-\log P_{+-}(0)/\epsilon}$$

$$R = \frac{\log P_{++}(0)}{\log P_{+-}(0)}$$

$\Rightarrow$ dependence on ϵ has dropped out

Complications in Extracting R as Luminosity Increases

How can we account for multiple pp interactions/crossing using the BBC trigger rate?

- Let μ=average number of pp interactions/crossing passing vertex cut
- Let ϵ=probability that one arm of BBC detects the collision
- Let $\delta = 1 - \epsilon$=probability one arm misses the collision

Now extract the fraction of beam crossings yielding a minimum-bias trigger :

$$\begin{aligned} P(1+) &= \sum_{n=1}^{\infty} \frac{e^{-\mu}\mu^n}{n!} (1-\delta^n)(1-\delta^n) \\ &= 1 - e^{-\mu(1-\delta)} \left(2 - e^{-\mu\delta(1-\delta)}\right) \\ &= 1 - e^{-\mu\epsilon} \left(2 - e^{-\mu\epsilon(1-\epsilon)}\right) \end{aligned}$$

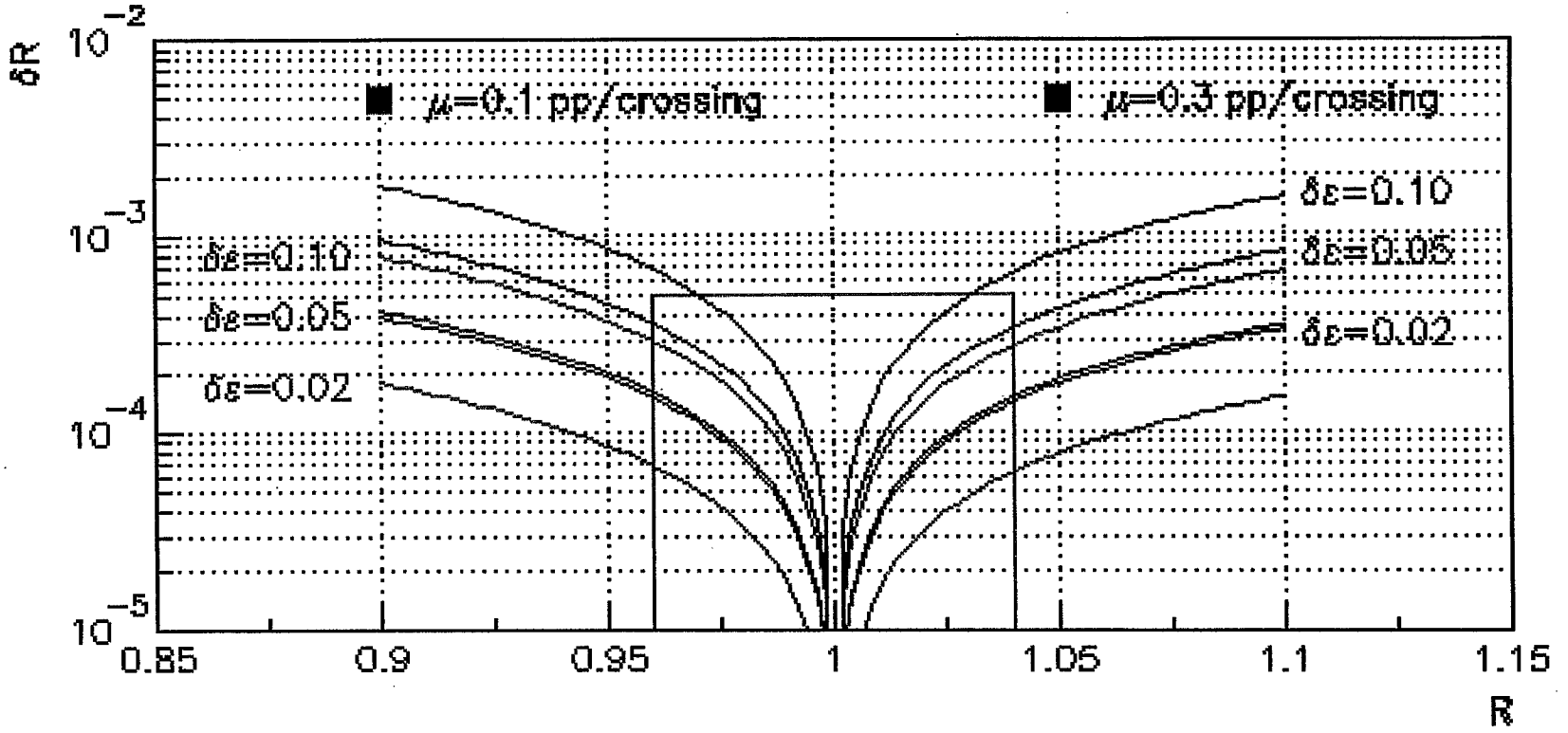
- We measure $P_{++}(1+)$ and $P_{+-}(1+)$, want to extract μ_{++} and μ_{+-}

$\Rightarrow$ Accuracy in extracting $R = \mu_{++}/\mu_{+-}$ depends on knowledge of ϵ (not true for single arm)

$\Rightarrow$ Minimum-bias trigger rate not simple function of luminosity

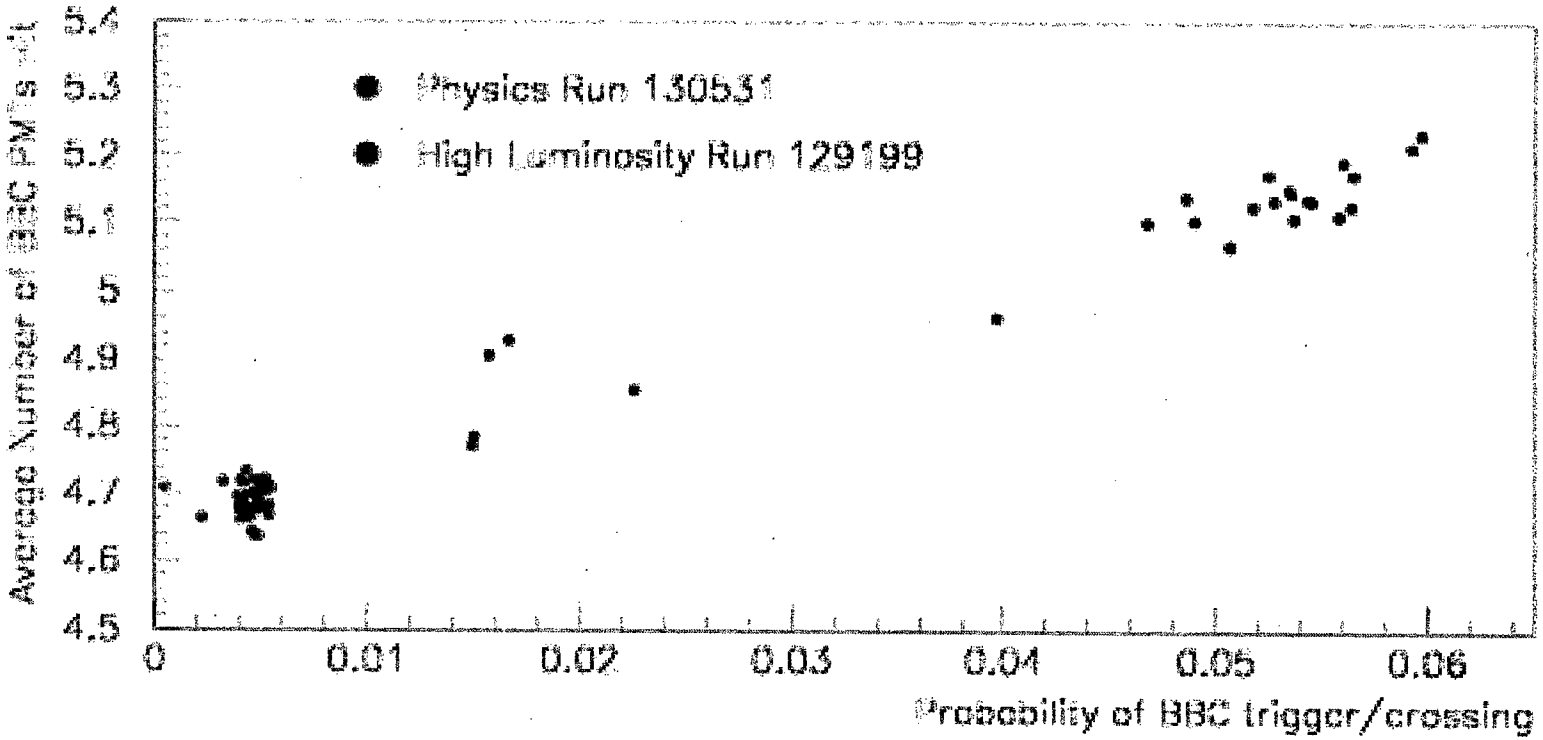
- Limits $\epsilon \rightarrow 0$ or $\epsilon \rightarrow 1$ reduce uncertainty on R due to uncertainty on ϵ

Complications in Extracting R as Luminosity Increases



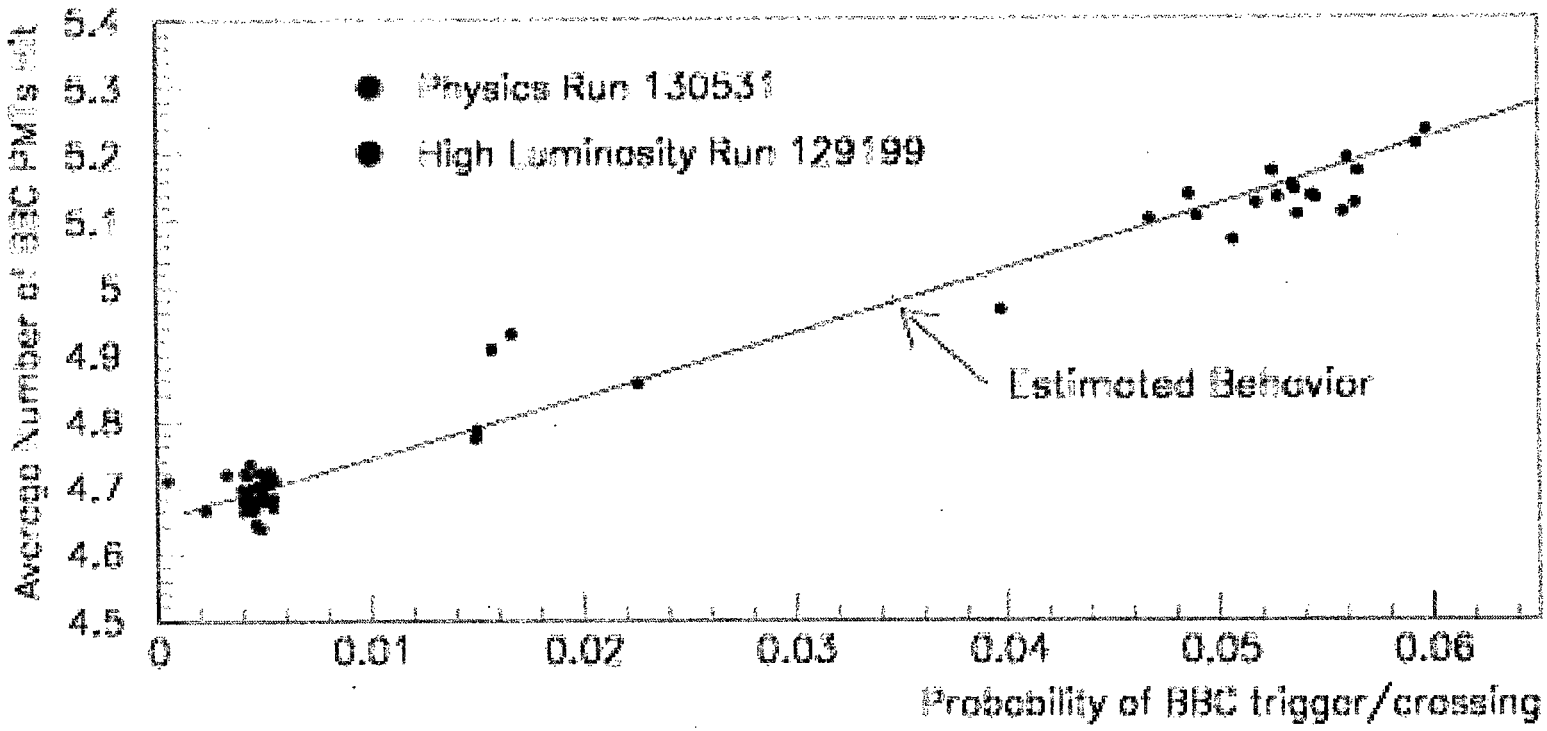
- What is our uncertainty δR on R given an uncertainty $\delta\epsilon$ on ϵ?
- δR increases as rate μ increases
- δR increases as uncertainty $\delta\epsilon$ on probability ϵ BBC detects a pp collision increases
- Perhaps recording BBC charge or tube multiplicity will decrease the uncertainty δR

Complications in Extracting R as Luminosity Increases



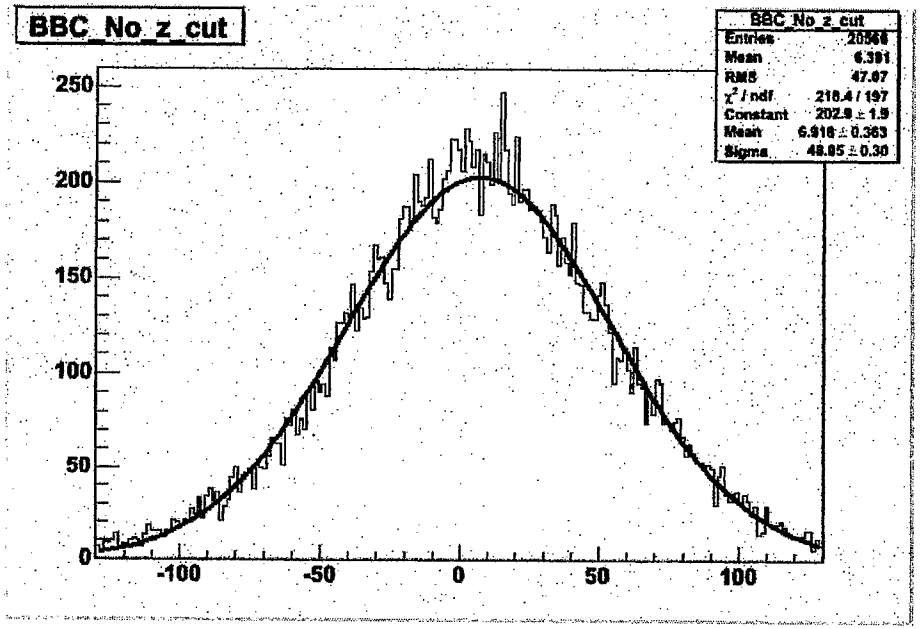
- As rate increases we will sometimes detect 2 pp interactions/crossing
- Average number of BBC PMTs hit in those cases will be double normal number
- Number of PMTs hit is sensitive to rate and probability ϵ BBC arm detects a collision
- $\epsilon \approx \sqrt{\sigma_{BBC}/\sigma_{PP}} \approx 0.73$

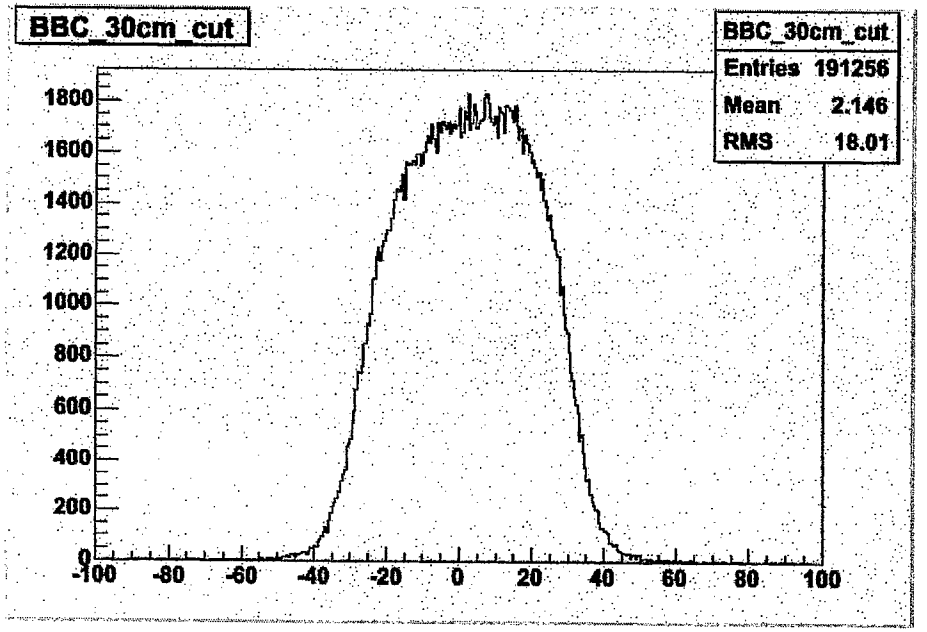
Complications in Extracting R as Luminosity Increases

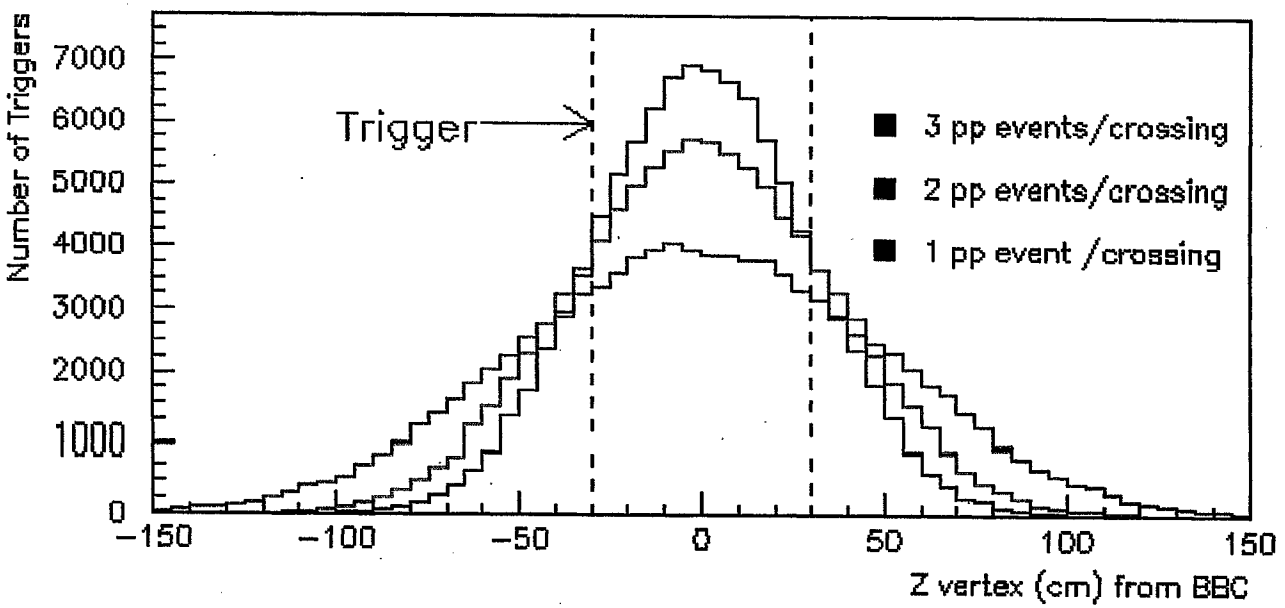


- As rate increases we will sometimes detect 2 pp interactions/crossing
- Average number of BBC PMTs hit in those cases will be double normal number
- Number of PMTs hit is sensitive to rate and probability ϵ BBC arm detects a collision
- $\epsilon \approx \sqrt{\sigma_{BBC}/\sigma_{PP}} \approx 0.73$
- Could be luck, or possible handle on ϵ, correction for multiple pp interactions/crossing

Complications in Determining the Z Vertex with the BBC

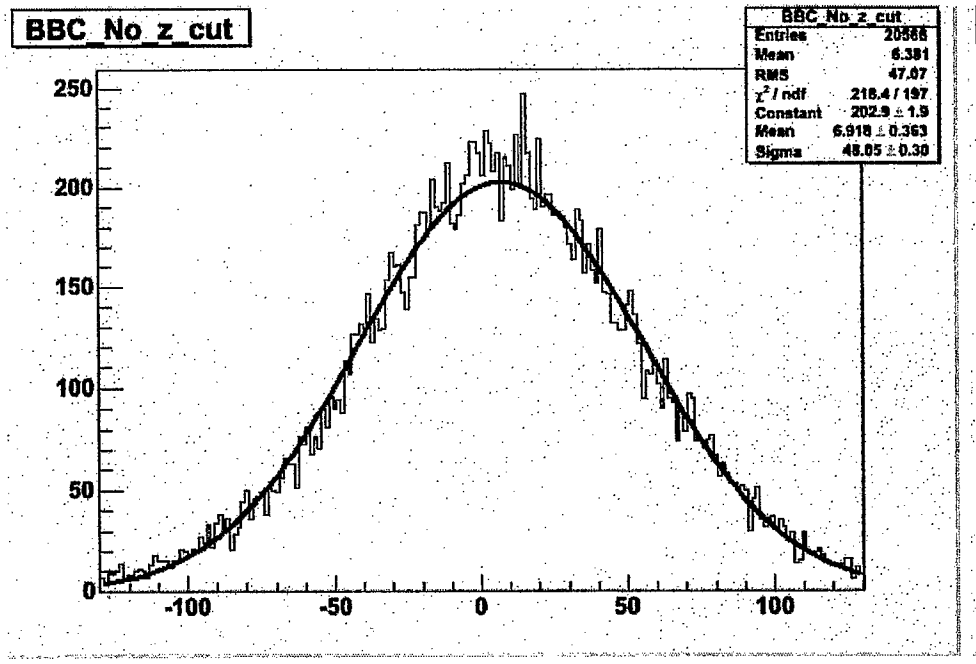


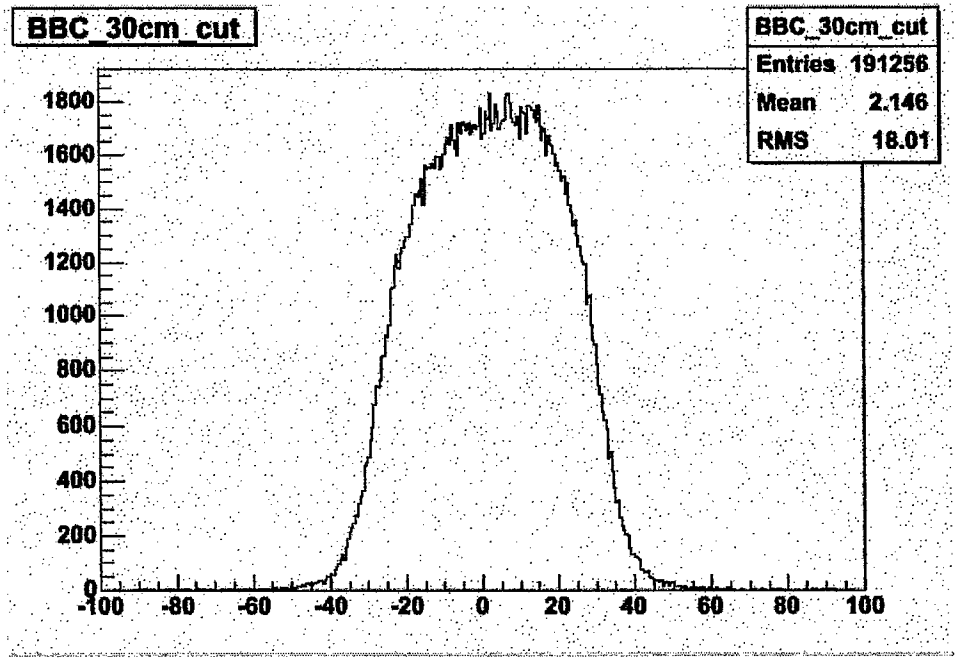


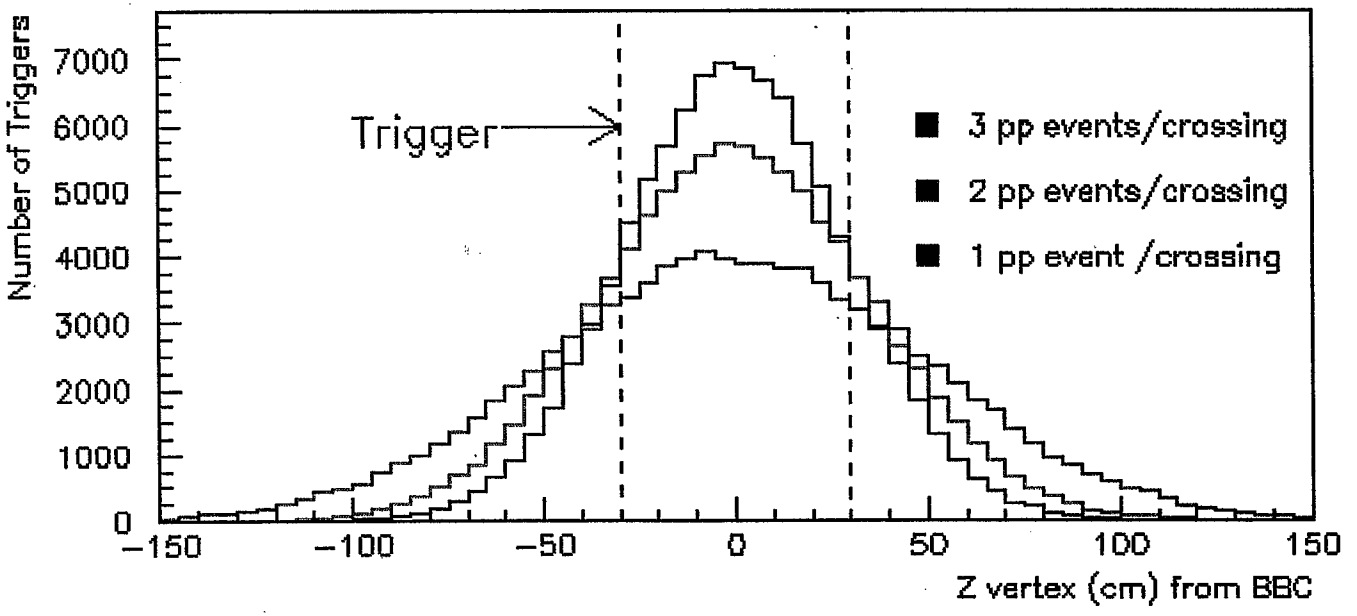


- We will need bunch longitudinal profiles
- Perhaps use Wall Current Monitor ?

Complications in Determining the Z Vertex with the BBC







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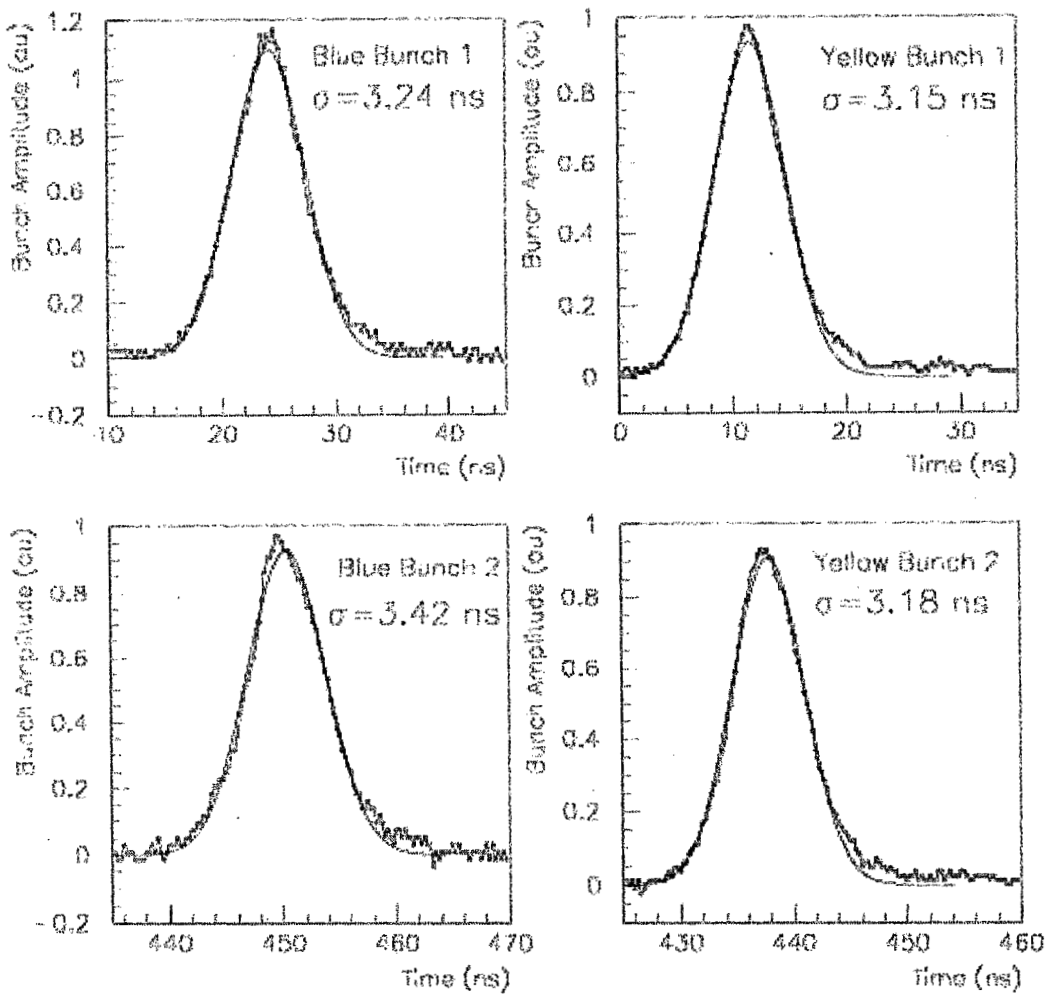
Complications in Determining the Z Vertex with the BBC



- Wall current monitor samples profile in 0.25 nsec bins
- Wide bunches seem to correspond to wide vertex
- 1st pair : 47 cm; 2nd pair : 51 cm
- Still to do : predict vertex dist. from WCM
- Alternating between bunches $\rightarrow$ 0.125 nsec bins $\rightarrow$ improved vertex reconstruction
- To do : see if WCM data describes BBC,ZDC trigger rates and vertex distributions well enough for R

Possible Approaches to Determining Relative Luminosity

- From independent measurements of $\sigma_{pp}^{\mathrm{inel+DD}}$ and vernier scan - can extract ϵ to $5-10\%$
  - With ϵ, can use BBC scaler data to extract R
  - Could output total charge in BBC PMTs or multiplicity to scalers
  - Can compare results to triggers formed from ZDC or ZDCN||S && opposite BBC arm
  - Need to correct scaler data for vertex shape as $\mathcal{L}$ increases !

    $\Rightarrow$ use wall current monitor to get bunch profiles and charge?
- Construct new small acceptance detector with vertexing ability, insensitivity to A_{LL} - Relative Luminosity Telescope (Wei Xie)
- Get spin flipper commissioned
- Try to reconstruct $\mathcal{L}$ from wall current monitor measurements of charge and bunch profiles
- Lots of ideas to try

RHIC Spin Collaboration Meeting XXX
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RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting XXX - Monday, December 6, 2004 ~ 9am-4pm

Location: BNL Bldg. 1005, Third Floor Large Conference Room

Bridge Line: 631-344-6363 from off-site, x-6363 from on-site

VRVS: Weather/Sunny

Preliminary Agenda:

Morning Session (9-12):
CAD Update - Mei
Source upgrade with superconducting solenoid - Anatoli
Cold snake update -Waldo
Radial pol from RHIC CNI - Osamu
Relative luminosity at high L from PHENIX - Dave

Afternoon Session (1:30-4):
Discussions on the report to DOE - All

Additional RIKEN BNL Research Center Proceedings:

Volume 65 – RHIC Spin Collaboration Meetings XXVII (July 22, 2004), XXVIII (September 2, 2004), XXX (December 6, 2004) - BNL-

Volume 64 – Theory Summer Program on RHIC Physics – BNL-73263-2004

Volume 63 – RHIC Spin Collaboration Meetings XXIV (May 21, 2004), XXV (May 27, 2004), XXVI (June 1, 2004) – BNL-72397-2004

Volume 62 – New Discoveries at RHIC, May 14-15, 2004 – BNL- 72391-2004

Volume 61 – RIKEN-TODAI Mini Workshop on "Topics in Hadron Physics at RHIC", March 23-24, 2004 – BNL-72336-2004

Volume 60 – Lattice QCD at Finite Temperature and Density – BNL–72083-2004

Volume 59 – RHIC Spin Collaboration Meeting XXI (January 22, 2004), XXII (February 27, 2004), XXIII (March 19, 2004)– BNL-72382-2004

Volume 58 – RHIC Spin Collaboration Meeting XX – BNL-71900-2004

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RIKEN BNL RESEARCH CENTER

RHIC Spin Collaboration Meetings XXVII, XXVIII, XXX

July 22, 2004 * September 2, 2004 * December 6, 2004

Li Keran

Nuclei as heavy as bulls
Through collision
Generate new states of matter.
T.D. Lee

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Speakers:

M. Bai	A.Bravar	A. Deshpande	W. Guryn
A. Jain	O. Jinnouchi	D. Kawall	W. MacKay
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Organizer: A. Ogawa