BNL-52660
FORMAL REPORT

Proceedings of RIKEN BNL Research Center Workshop Volume 37

RHIC Spin Collaboration Meeting VI (Part 2)

November 15, 2001

Organizers:

Les Bland & Naohito Saito

RIKEN BNL Research Center

Building 510A, Brookhaven National Laboratory, Upton, NY 11973-5000, USA

Available electronically at-

`http://www.doe.gov/bridge`

Available to U.S. Department of Energy and its contractors in paper from-

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
(423) 576-8401

Available to the public from-

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22131
(703) 487-4650

Printed on recycled paper

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.

During the first year, the Center had only a Theory Group. In the second year, an Experimental Group was also established at the Center. At present, there are seven Fellows and eight Research Associates in these two groups. During the third year, we started a new Tenure Track Strong Interaction Theory RHIC Physics Fellow Program, with six positions in the first academic year, 1999-2000. This program has increased to include ten theorists and one experimentalist in the current academic year, 2001-2002. Beginning this year there is a new RIKEN Spin Program at RBRC with four Researchers and three Research Associates.

In addition, the Center 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 thirty-six 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.

T. D. Lee
August 2, 2001

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

CONTENTS

Meeting Summary

L.C. Bland and Naohito Saito

March 26, 2002

The second part of the sixth RHIC Spin Collaboration (RSC) meeting was held on November 15, 2001 at Brookhaven National Laboratory. Previous meetings have elaborated on the new generation of proton spin-structure studies (*e.g.* gluon polarization and flavor separation of q and $\bar{q}$ polarizations via real $W^{\pm}$ production) enabled by studying polarized proton collisions at energies and momentum transfers where perturbative QCD models are expected to be applicable. The focus of this meeting was on many of the experimental issues that must be resolved to achieve these physics goals. This summary is written with the benefit of hindsight following the completion of the first-ever run of a polarized proton collider. This first run can be considered as a successfully completed milestone of the RHIC Spin Collaboration. Other milestones remain important.

Long term machine items were identified in Waldo Mackay's talk, the most important being the completion of the spin rotator magnets that will be installed in 2002 to allow the flexible orientation of the proton beam polarization at the PHENIX and STAR experiments. At the meeting Waldo discussed a stronger partial snake magnet for the AGS as a means of producing highly polarized proton beams to inject into RHIC. Developments subsequent to this meeting suggest that a superconducting helical dipole magnet may be feasible for the AGS, and is likely to be needed to achieve the 70% beam polarization in RHIC. Longer term items were also presented, including potential increases in luminosity by the addition of electron cooling to RHIC and the possibility of increasing the collision energy by $\sim$20% by replacement of the DX magnets. These items could be considered for a second generation of RHIC spin experiments.

The other topics covered at the meeting were related to polarimetry and to the absolute calibration of the proton beam polarization in RHIC. These topics were divided into short- and long-term solutions to polarimetry issues. George Igo led a discussion about the addition of a Coulomb-Nuclear Interference (CNI) polarimeter to the AGS prior to FY2003 RHIC operations. The experience from the first RHIC spin run reinforces the need for reducing the time needed to complete polarization measurements in the AGS, and illustrated the importance of polarization measurements at different energies in the RHIC injectors. Progress continues to be made on the completion of a CNI polarimeter for the AGS prior to the FY2003 run.

Doug Fields discussed the possibility of improving the calibration of the RHIC CNI polarimeter at the RHIC injection energy by studying the elastic scattering of polarized proton beams extracted from the AGS from an existing polarized proton target. The effective analyzing power of the RHIC CNI polarimeter at high energies can be determined by measuring the beam polarization at the RHIC injection energy before and after an acceleration/deceleration cycle. In the short term, once deceleration ramps are commissioned, and polarization loss through up- and down-ramps is minimized, knowledge of the absolute proton beam polarization at flat top in RHIC will be limited by the uncertainties in the analyzing power for $\vec{p}p$ elastic scattering. Until the completion of a polarized gas jet target to study $\vec{p}\vec{p}$ elastic scattering from beams accelerated and stored in RHIC, polarization measurements at RHIC injection energies before and after an acceleration/decelertion cycle remain the sole means of measuring the beam polarization magnitude. There is a window of opportunity to employ a polarized target made by the group at the University of Virginia for such measurements.

It is generally agreed that the long-term solution to an absolute measurement of the proton beam polarization after acceleration in RHIC requires the measurement of the analyzing power for $\vec{p}p$ elastic scattering from a polarized gas jet target. These measurements will calibrate the effective analyzing power of the CNI polarimeters. Tom Wise gave a detailed status report about adapting a polarized atomic beam source and Breit-Rabi polarimeter design, presently in use in the HERMES experiment at DESY, for use at RHIC. Substantial design work on the polarized target has been completed, but detailed engineering is still required. To enable the completion of this target for commissioning in the FY2004 run, it is critical that the design phase of the polarized gas jet gets completed soon, so that construction work can begin. The calibration measurement itself was described in talks by Ed Stephenson and Alessandro Bravar. The experience of the UA6 collaboration in cleanly detecting pp elastic scattering events at small $|t|$ by observing only the low-energy recoil proton suggests that recoil detectors alone, without forward proton tagging detectors, should be sufficient for the polarization calibration measurement. One significant complication is the effect of the target magnetic field on the low energy recoil protons. A moderate magnetic field is required to eliminate depolarization associated with the fields produced by the circulating beams. More complete simulations of the recoil proton detection, accounting for the target magnetic field and a realistic density profile of the gas jet are needed to assess whether the systematic errors can be controlled at the needed level.

These are exciting times for the RHIC spin collaboration. Substantial work remains to be done to obtain precise measurements of the proton beam polarization.

2

RHIC SPIN Collaboration Meeting VI-2

RBRC Workshop

November 15, 2001

Naohito Saito

RIKEN / RIKEN BNL Research Center

RIKEN

RHIC Spin Collaboration Meeting –VI-1

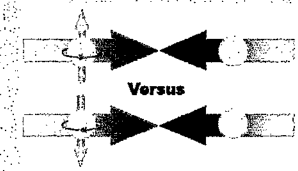
- Progress in Machine, Experiments, and Theory
- Machine
  - OPPIS 80% Polarization Achieved
  - 200 MeV Polarimeter
  - AGS 66% "Spin Transmittance" with Westinghouse; AtR 96% → Total "Spin Transmittance" from OPPIS to RHIC = 63.4%
  - Snakes, Spin Flipper
  - RHIC Polarimeter (currently 60 bunch mode assumed; 120 bunch "doable" but NOT trivial)
- Experiments
  - New Detectors for pp run
    - STAR : BB, FPD
    - PHENIX : NTC, (Local Polarimeter), Trigger Boards
    - Pp2pp : Inelastic Detectors, Roman Pots
- Theory
  - Better understanding of uncertainties in "year-1" signal - HADRONS

RIKEN

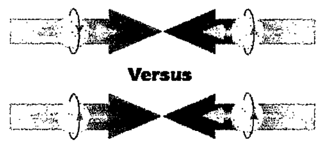
Goals of the 1st Spin Physics Run

RHIC

- Establish Stable Asymmetry Measurements
  - Beam Polarization > 50%
  - Luminosity ~5E30cm^{-2}s^{-1} → 1.7E30cm^{-2}s^{-1}
- 1 week of transverse polarization (~0.75 pb^{-1})
  - A_N ~ Higher Twist Effects



- 4 weeks of longitudinal polarization (~3 pb^{-1})
  - A_{LL} for pion ~ Δg Measurements
  - A_{LL} for J/ψ in muon Arm



- Change over from "T" to "L" subject to achievements

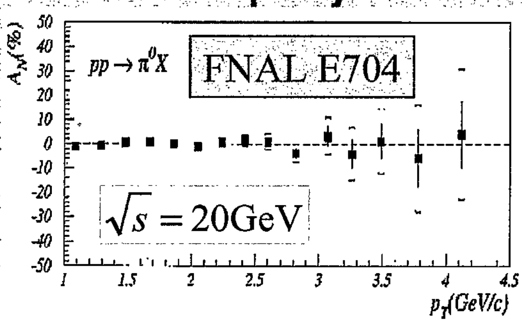
RIKEN

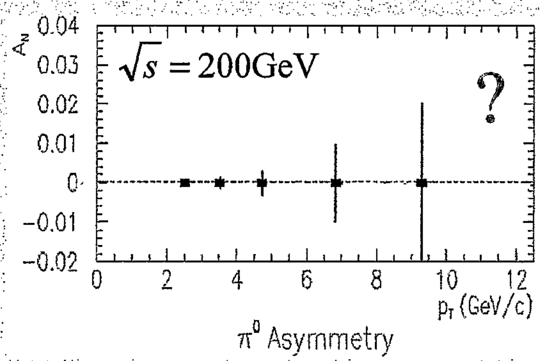
Naohito Saito (RIKEN/ RBRC)

Single Transverse Spin Asymmetry

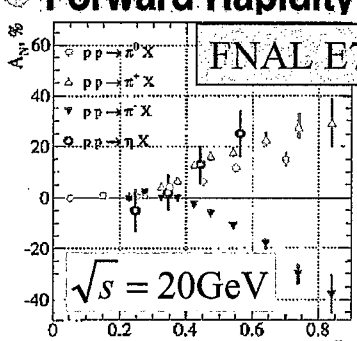
RHIC

- Central Rapidity





- Forward Rapidity



STAR Forward Pion Detector

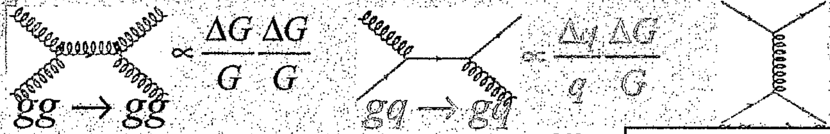
Local Polarimeter @ 12 o'clock

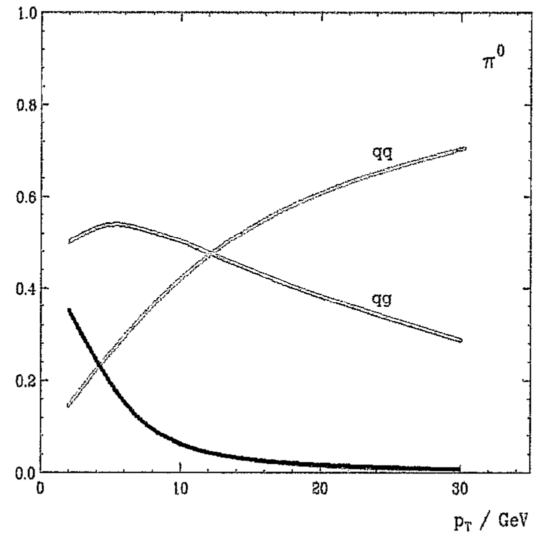
R

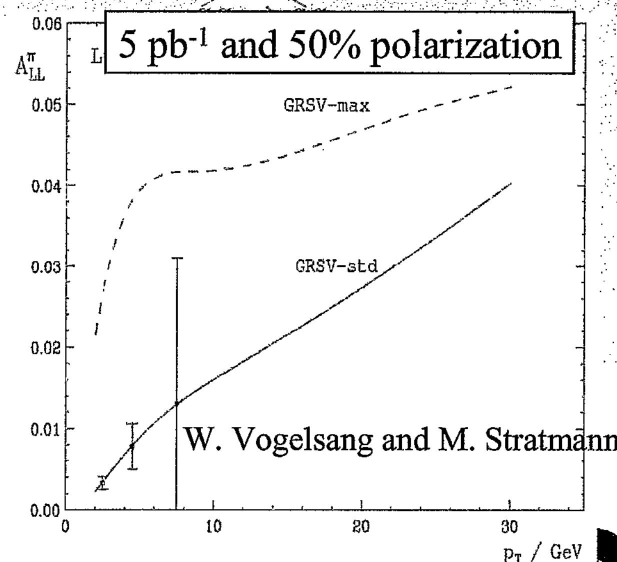
Naohito Saito (RIKEN/ RBRC)

Double Longitudinal Spin Asym

Hi Statistics Pion Data! Sensitive to $\Delta g(x)$!



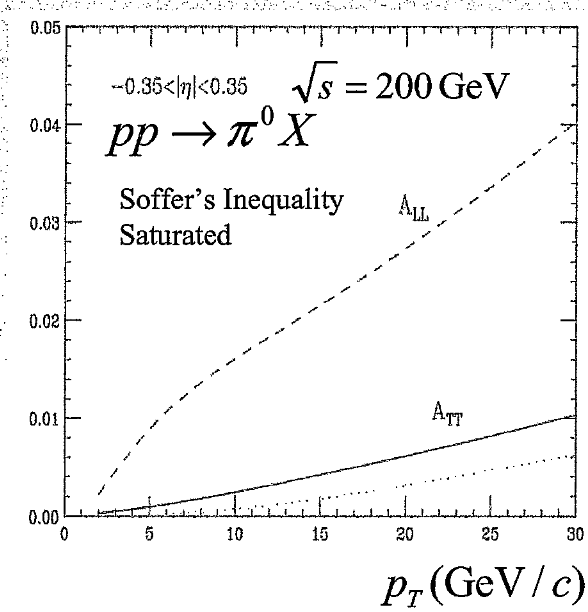


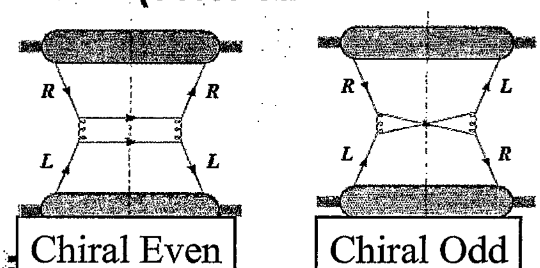


QCD Selection Rule

R.L. Jaffe and N. Saito PLB382(96)165; W.Vogelsang (01)

- $A_{TT} << A_{LL}$ due to
  - No gluon "transversity"
  - Even for qq; Chiral Odd Requires exchange process (color suppression)





RHIC Spin Plan (PHENIX and STAR)

Year	CM Energy	Weeks	Int. Lum.	Remarks
FY2001	200 GeV	5	7 pb^{-1}	Gluon pol. with pions
FY2002	200 GeV	8	160 pb^{-1}	Gluon pol. with direct γ, jets/ TT
	500 GeV	2	90 pb^{-1}	PV W production, u-quark pol.
FY2003	200 GeV	8	160 pb^{-1}	Gluon pol. with γ + jet/ TT
	500 GeV	2	120 pb^{-1}	First ubar,dbar pol. meas..
FY2004	500 GeV	8	480 pb^{-1}	Gluon pol. with γ+jet, γ,jet+jet, heavy flavor, ubar, dbar pol.
	200 GeV	2	48 pb^{-1}	Gluon pol. with γ, γ+jet, heavy flavor/TT
FY2005	500 GeV	5	300 pb^{-1}	More statistics
	200 GeV	5	120 pb^{-1}	
FY2006	200 GeV	10	210 pb^{-1}	

Still on track if we change FY → CY or JFY

RIKEN

Absolute Beam Polarization

- **Ultimate Calibration from Polarized Gas Jet Target →** Afternoon Session
  - **Plan / Budget / Man Power**
- **Intermediate Solution→** Morning Session
  - **Hal & Doug's Summary: ΔP_B=20-25% basing on**
    - E925 (9%(stat) + 12%(syst)) → 15%
    - E950 (10%(stat)+5%(syst)) → 11%
    - Acceleration + Deceleration (1.4%)
- **Discussion →** Late Afternoon

Beat Them!

RIKEN

Future of RHIC SPIN

- RHIC II
  - Upgrades in Detectors
  - L (x25) and E (x1.3) Upgrades
- EIC
- Polarized TEVATRON? LHC?

- Workshop in Spring/Summer to discuss physics cases

Naohito Saito (RIKEN/ RBRC)

RHIC Detector and CDF II

- RHIC Detectors barely covers hadron collider detector capabilities:
  - *e*-detection: EW, heavy flavor, beyond
  - γ-detection: QCD, EW, beyond
  - μ-detection: EW, heavy flavor,beyond
  - Jet detection: QCD, beyond
  - *b/c*-tagging: QCD, beyond, CKM
  - Missing E_T: EW, beyond
- Spin measurements often requires Particle Correlation
  - γ+jet , J/ψ+γ, W+γ, 2-pion or 3-pion
- Large Acceptance with Lepton-ID and Missing-ET Capabilities desirable

	PHENIX	PHENIX-u	STAR	STAR-u	CDFII
electron detection	yes	yes	yes	yes	yes
photon detection	yes	yes	yes	yes	yes
muon detection	yes	yes	no	no	yes
jet detection	no	yes?	yes	yes	yes
b-tagging	no	yes?	no	yes?	yes
c-tagging	no	yes?	no	yes?	?
missing ET detection	no	no	no	no	yes

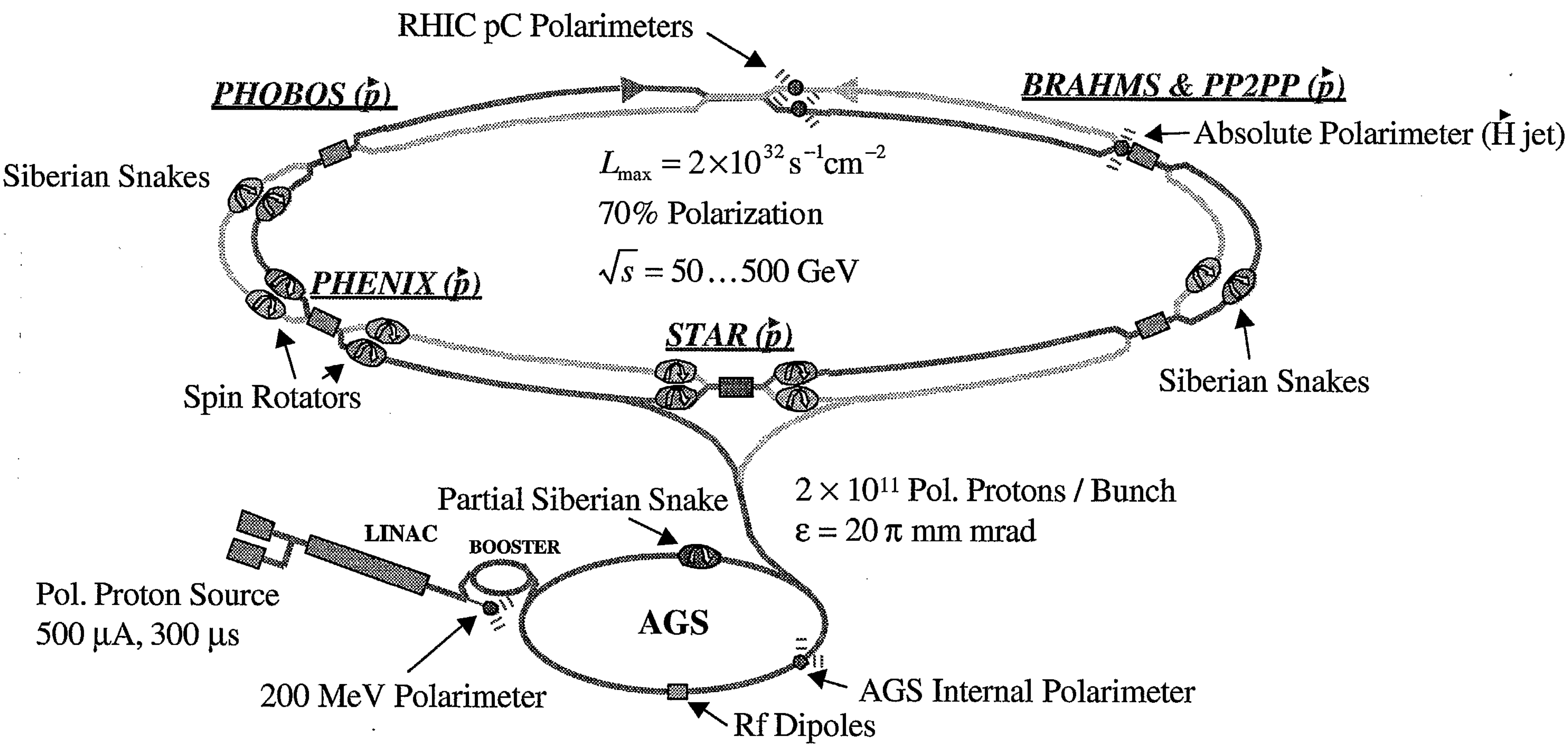
Naohito Saito (RIKEN/ RBRC)

MACHINE ISSUES FOR RHIC SPIN

Waldo MacKay
15 November, 2001

for
RHIC Spin Collaboration Meeting VI (Part 2)
RIKEN BNL Research Center

Machine Issues for RHIC Spin



Waldo MacKay
15 November, 2001

Goals

This run:

- Trans. pol. protons colliding at $\sim$100 GeV per beam ($P > 50\%$).
- Long. pol. protons colliding at $\sim$100 GeV per beam ($P > 50\%$).
- Commission acceleration of pol. protons to 250 GeV per beam.

Next Run:

- Long. Pol. at STAR and PHENIX with 250 GeV per beam.

Schedule of Current Run

- 8 Nov: 1 shift shutdown to install AGS polarimeter.
- 9 → 26 Nov: Au in RHIC; pol protons in AGS.
- 26 → 29 Nov: Shutdown to change RHIC to pol. protons.
  Run pol. protons in AGS.
- 30 Nov. → 21 Dec.: Commission pol. protons in RHIC.
- 22 Dec. → ∼25 Jan.: Physics with pol. protons.

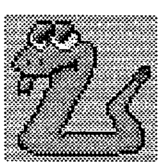
12

Waldo MacKay
15 November, 2001

Commissioning Progress

- Power supplies connected to all four snakes.
  - Not yet tested to full field.
  - Not yet tested with beam.
- Polarized beam in AGS ($G\gamma = 7.5$ as of yesterday).
- $\beta^* = 3$ m injection test scheduled for this afternoon.

  - Vertical flattening to surveyed positions yet to be done.
- Spin flipper installed.
  - System previously tested outside ring.
  - Requires ring access when we first power it.

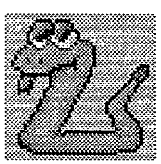


Status of Future Additions

- 4 rotators completed and awaiting installation in RHIC.
- 5th rotator cold mass being assembled.
- 6th rotator all four helices cold tested.
- 7th rotator: 4th helix being cold tested.
- 8th rotator:
  - 3 of 4 helices stacked and in various stages of wiring the ends
  - last helix remains to be stacked and wired.
- All helices to be finished by Dec., 2001.
- Last rotator to be finished by April., 2002.
- All 8 rotators to be installed in RHIC by Oct., 2002.

- New AGS Partial snake: Helical
  - requires more study: warm or supercond.
  - no definite plan yet.

- Polarized Jet Target: see following talks



Other links

- AGS commissioning plan:
  http://www.rhichome.bnl.gov/People/huang/pp02/FY02plan.htm
- Previous talks:
  http://www.rhichome.bnl.gov/RHIC/Spin/spinfigs/figslist.html
  http://www.rhichome.bnl.gov/RHIC/Spin/spinfigs/wwm-rsc1oct01.pdf
- Polarization angles at IR's and polarimeters for different energies:
  http://www.rhichome.bnl.gov/RHIC/Spin/spinfigs/100GeV-1snake.html
- Other ideas for upgrades:
  http://www.rhichome.bnl.gov/RHIC/luminosity/

Possible RHIC Upgrades

- Luminosity increase RHIC II: electron cooling
  - cool protons at injection (double luminosity over RDM+)
  - ◦ spin cooling with polarized electrons?
- eRHIC: polarized electrons and proton collisions
- Energy increase: (20–30%)

Waldo MacKay
15 November, 2001

Parameters for Proton Collisions

Scheme		RDM	RDM+	RHIC II
Emittance (95%), ϵ	$[\pi \mu\mathrm{m}]$	20	20	12*
IP beta function, β^*	[m]	2.0	1.0	1.0
Number of bunches, M		60	120	120
Bunch population, N	$[10^{11}]$	1.0	2.0	2.0
Beam-beam parameter per IR, ξ		.0037	.0073†	.012‡
Angular beam size, σ'^*	$[\mu\mathrm{rad}]$	79	112	86
RMS beam size, σ^*	$[\mu\mathrm{m}]$	158	112	86
Peak Luminosity, L_0	$[10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	1.5	24	40

* For RHIC II assumes electron cooling at injection to reduce emittance.

† For RDM+ assumes only collisions at 3 IR's.

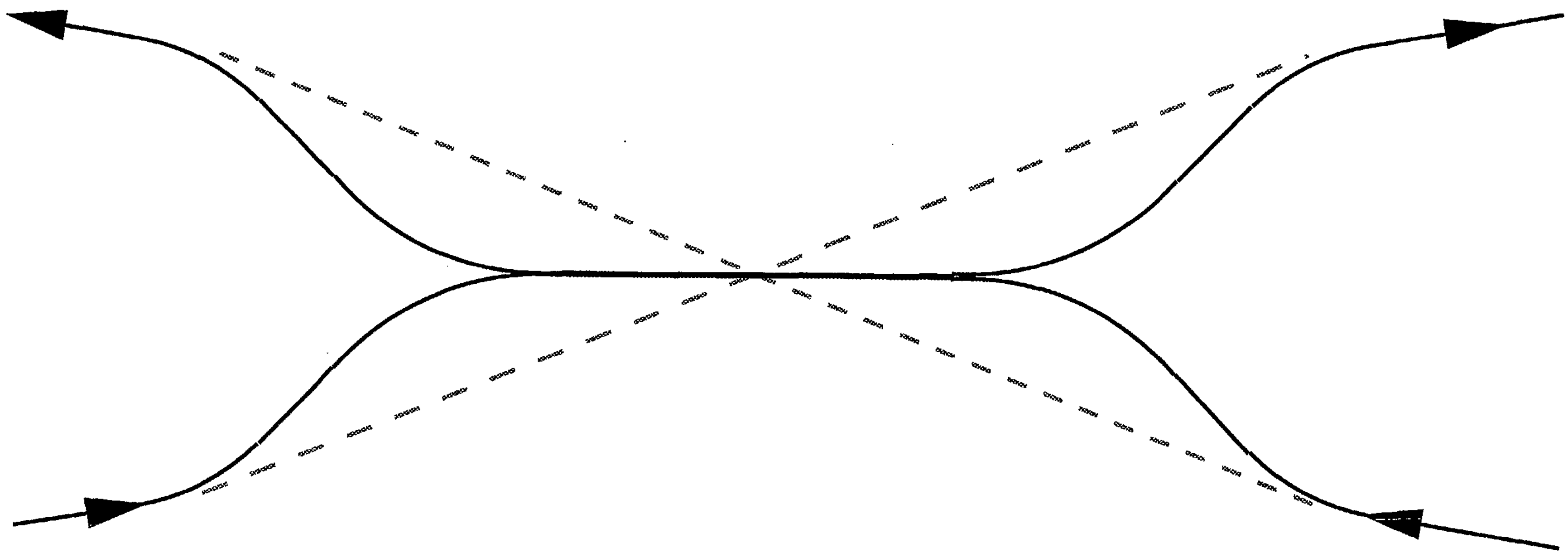
‡ For RHIC II assumes only collisions at 2 IR's.

Waldo MacKay
15 November, 2001

Increasing Energy

We have considered the possibility of increasing the energy of beams in RHIC by as much as 30% with a modest trade-off in luminosity. The arc dipoles and quadrupoles were designed with considerable margin. For higher energies (> 100 GeV/nucleon) the minimum β^* may be required to increase as the interaction region triplets saturate. The separator magnets (DX) have the least margin for increased field, so we consider three scenarios: allowing for a small crossing angle with the present DX magnets, upgrading the DX magnets to higher strength, and permitting a crossing angle of $\sim 1^\circ$ by removing the DX magnets altogether.

Trajectories of Both Beams Through IR



The dashed lines indicate trajectories without DX magnets.
The crossing angle without DX's is $\alpha = 0.18$ mrad.

Waldo MacKay
15 November, 2001

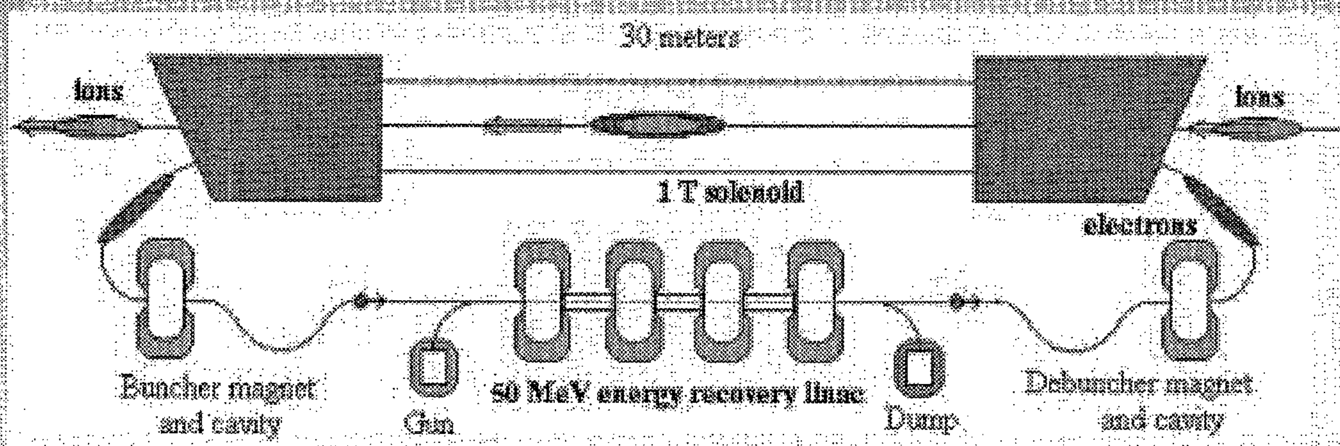
Conclusions for an energy upgrade

- 25 → 30% increase in energy looks possible.
- 0° crossing angle requires new D0 & DX magnets.
  - Higher energies require all new dipoles.
- 2.5 mrad crossing angle perhaps possible with existing magnets.
  - DX magnets may only make 10–15% more energy.
- 18 mrad crossing angle
  - DX magnet not needed.
  - D0 magnet runs at low field ($B \sim 1.6$ T).
- Snakes work in all scenarios.
- Spin rotators should work.
  - For 18 mrad crossing angle: reverse power supplies.

Waldo MacKay
15 November, 2001

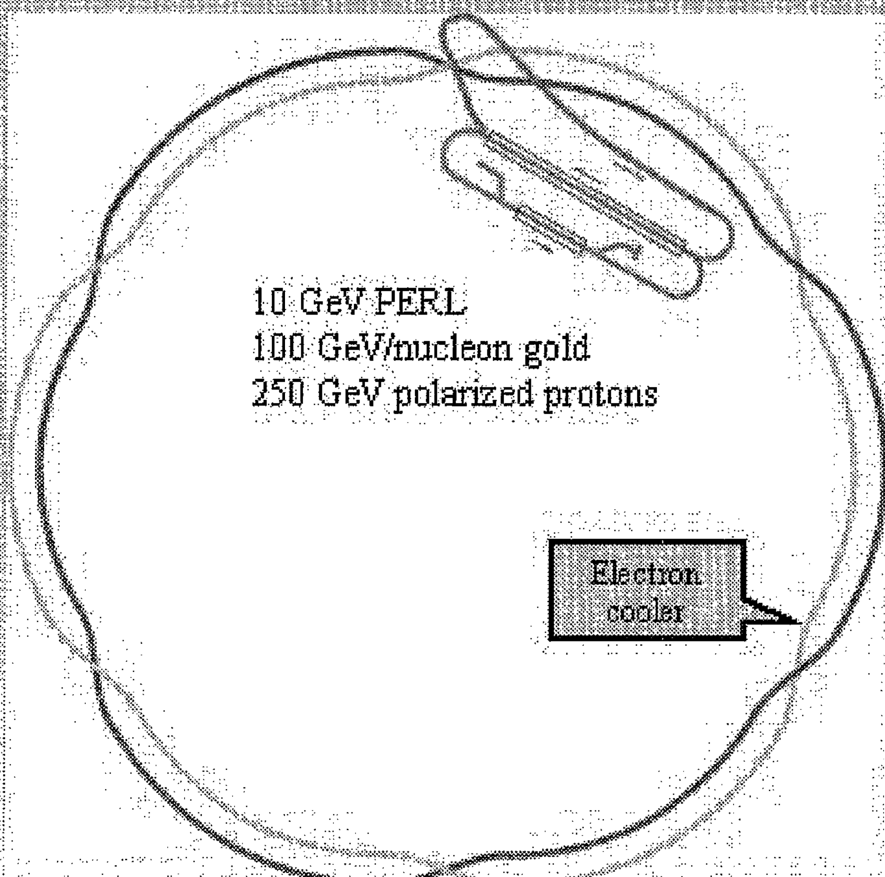
Schematic of the RHIC Cooler

- Energy Recovery Linac
- Buncher - debuncher



> x10 increase in the integrated luminosity of RHIC, as well as better accumulation of rare species.

eRHIC – a Polarized Electron on Ion or Polarized Proton in RHIC



The Electron-Ion Collider is proposed as an essential tool for research into the fundamental structure of matter:

- What is the *structure* of hadrons in terms of their quark and gluon constituents?
- How do quarks and gluons *evolve* into hadrons via the dynamics of confinement?
- How do the quarks and gluons *reveal* themselves in the structure of atomic nuclei?

A CNI Polarimeter for the AGS

G. Igo, UCLA

1) Need for fast, high statistics measurements of the AGS beam polarization

a) at RHIC injection energy

b) while ramping

2) Luminosity & Rate Estimate

3) Some Questions about the CNI Detector Characteristics

4) Objective: CNI polarimeter for the AGS for next year's run

Meeting: CNI Polarimetry for the AGS – 28 June 2001

Attendees: Les Bland, Gerry Bunce, George Igo, Kazu Kurita, Yousef Makdisi,
Tom Roser, Naohito Saito, Dave Underwood

Count rate estimate:

$I = 10^{11}(protons\, in\, bunch)\ x\ 1/2.6\mu s(AGS\ frequency)$

$= 4\ x\ 10^{16}\ p/s$

$T = (w\ x\ 2\sigma_x)/(\pi\sigma_x^{\ 2})\ x\ \rho l\ x\ N_A/12$

where w is the width of the carbon foil, σ_x is the half-width of the beam, ρl, the areal density of the carbon foil.

For a 0.02 micrometer thick target,

$T = (5x\,10^{-2} cm\ x\ 2x\ .08\ cm)/(\pi\ x\ (.08cm)^2)\ x\ \ 4x\,10^{-6} g/cm^2\ x\ \ (6x10^{23})/12$

$T = 8x\,10^{16} carbon\ atoms/cm^2$

L = I x T= 3.2 x 10^{33} cm^{-2} s^{-1}

Rate =

$L\int d\sigma/dt\,\Delta t\,\Delta\varphi/2\pi$

Where $d\sigma/dt = 0.7\, barns/GeV^2, t = 4.5x10^{-3} GeV^2$

$\Delta t = 3x\ 10^{-3}\ GeV^2, \Delta\varphi/2\pi = 10cm/2\pi x 10cm = 0.14$

Rate = 3.2 x10^{33} $cm^{-2} s^{-1}$ x 0.7 x10^{-24} cm^2/GeV^2 x 3 x10^{-3} GeV^2 x 0.14
= 0.9 x 10^6 events/s

On the basis of a 10^6 events/s count rate, Tom Roser thought it possible to use the CNI to accumulate polarization data during ramping dividing the count rate into order of tens of milliseconds bins.

Accumulating 10^6 events in 1 second would give Δ asym = 10^{-3}. The asymmetry is PA_N = 0.5 x 0.02 = 0.01, and $\Delta P/P = 10^{-1}$.

Because of the length of the AGS bunch, it may be necessary to move the detectors further away, possibly to 15 cm, thus reducing the rate or alternately to increase the sizes of the silicon arrays to keep the event rate high.

The magnitude of the proton-carbon elastic cross section at the t-value where the measurements are made needs to be researched.
Another meeting will be scheduled shortly.

3. CNI Detector Characteristics

TOF start from beam bunch arrival time.
Si recoil detectors only in left-right orientation for transverse polarization measurements. Do we want to measure radial polarization component?
0.5 mm wide, 500 μg carbon target- Bill Lozowski

4) Summary and Objective
Come to an agreement about CNI detector design features
Left-right detectors only?
TOF start?
0.5 mm wide C target
Objective: CNI detector for AGS for next year's run.

IMPROVING THE DETERMINATION OF RHIC BEAM POLARIZATION

Douglas E. Fields
UNM/RBRC
15 November, 2001

for
RHIC Spin Collaboration Meeting VI (Part 2)
RIKEN BNL Research Center

Improving the Determination of RHIC Beam Polarization

Summary: At the last RSC meeting, I concluded that the beam polarization uncertainty at full RHIC energy was about 20%, much of which came from the uncertainty in the analyzing power used to calibrate the beam polarization used in E950. This could be improved in a new experiment where a p+C CNI polarimeter was set up in conjunction with a polarized solid target in an AGS fixed target line. With the CNI polarimeter set up in a fixed target line, you could get approximately 1M events in 30 shifts. During the discussion it seemed perhaps a better idea to leave the CNI polarimeter in the AGS ring, with a foil or wide ribbon target, so that statistics would not be a problem, although one would have to rely on the spin tracking to make sure that the polarization in the AGS and the polarization at the solid target experiment were understood. There were questions about the ability of the solid target experiment to determine the beam polarization to better than 5%. Several issues were brought up including whether or not the spin direction could be flipped with the holding magnetic field unchanged. This can, in fact be done. Also, the field can be flipped to check systematic uncertainties. Also, I misspoke during the presentation referring to ^{3}He recirculation rather than ^{4}He. For the 5T field, cheaper ^{4}He is sufficiently cold to maintain the polarization, and depending upon the length of the run needed, could just be vented or captured.

Improving the Determination of RHIC Beam Polarization

- Get physics analyzing power from E950 asymmetry measurement, needs beam polarization from E925.
  - E925 determines beam polarization with total uncertainty ~15%.
  - The systematic uncertainty (12%) is dominated by the determination of the analyzing power calculated from other measurements.
- E950 has statistical uncertainties ~10% in low –t region.
  - The value of the asymmetry at low –t is very stable with even gross changes in the analyzing procedure, and therefore has systematic uncertainty ~5%.
- Needs extrapolation from E950 energy to RHIC injection energy.
- Statistical uncertainties expected to be ~1% during upcoming run.
  - Uncertainty in the theoretical energy dependence of asymmetry ~5% (from fits to E950 data using range of real part of μ_p extrapolated to injection energy).

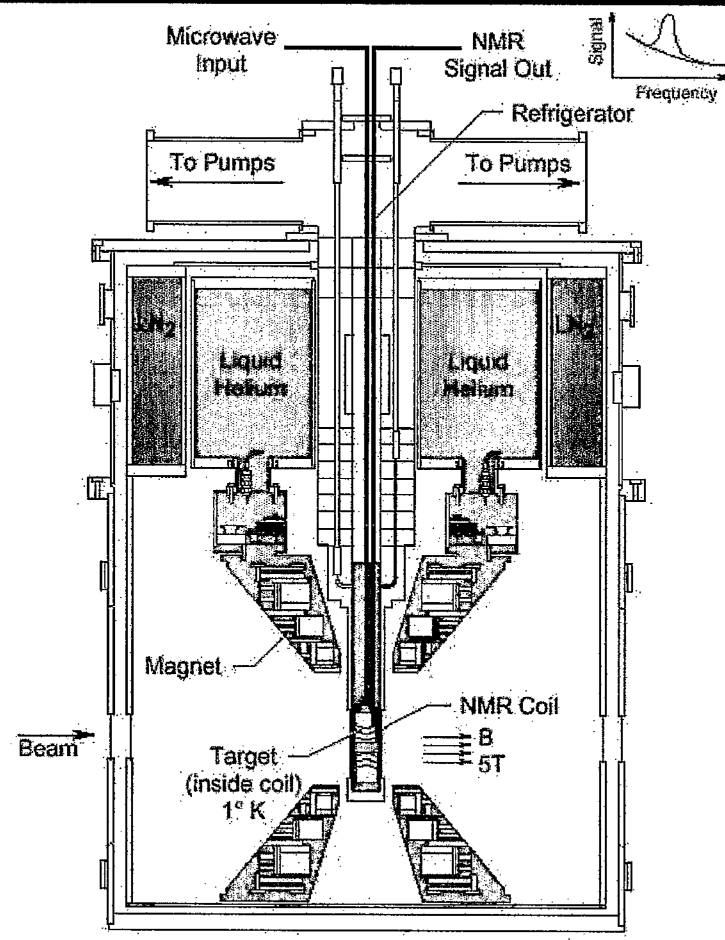
Calibrating the RHIC Polarimeter at Injection Energy

- New calibration experiment at injection energy.
  - "RHIC polarimeter" in an AGS fixed target line.
  - Followed by a solid polarized target experiment to determine the beam polarization to <5%.
- Proposed gains:
  - Measurement at injection energy – no extrapolation uncertainty.
  - Better statistics and systematics and lower threshold (not in the AGS ring, longer run)
  - Much improved beam polarization measurement using the polarized target.
  - Better determination of the hadronic spin-flip term helps to understand energy dependence of asymmetry.

Calibrating the RHIC Polarimeter at Injection Energy

31

- Polarized Target:
  - Solid target.
  - 5T field.
  - Longitudinal polarization can be modified to give sideways (and possibly transverse).
  - Can be ready by summer 2002 at BNL (given appropriate services).



Calibrating the RHIC Polarimeter at Injection Energy

- Previous experiment (Crabb et al., '76):
  - Measured pp elastic from $0.1 \le |t| \le 0.9$.
    - 0.8 – 2.5 degrees lab angle.
    - Recoil energy 55 – 480MeV.
  - Coincident detection of recoil and scattered protons.
  - Luminosity monitors.
  - Fairly simple TOF setup.
- Could re-use E925 detectors?
  - Forward counters
  - Recoil detectors

Calibrating the RHIC Polarimeter at Injection Energy

- Problems:
  - Sideways polarization (?).
  - Opening in coils for recoil proton detection.

    AND/OR
  - Small angle scattered proton detection.
  - ^{4}He recirculation.
  - Beam scanning of target or defocusing.
  - Need good CNI statistics – next slide.

Calibrating the RHIC Polarimeter at Injection Energy

- CNI statistics:
  - Could use carbon foil instead of ribbon (5μg/cm^2).
    - Cover entire beam spot.
    - Beam focused on target.
  - Assume beam of 1×10^{11}protons/bunch.
    - Gives Luminosity of 1×10^{28}cm^{-2}sec^{-1}.
    - 5×10^2 lower than E950.
  - Increased detector acceptance x3.
    - 14 events/sec (28 per bunch).
  - Increased running time x10 (30 shifts).
    - 1.3 million events (50% duty factor).
  - E950 had 20 million events.

Calibrating the RHIC Polarimeter at Injection Energy

- CNI systematics:
  - Bunched beam.
    - Gives much better TOF.
    - -t calculation improves.
  - External beam line.
    - Reduced noise.
    - Can go to much lower –t (higher asymmetry).
  - Improved energy calibration.
    - Have learned much since E950.
  - Beam polarization determined using same sample of beam.

Douglas E. Fields
UNM/RBRC

Estimate of Improved Beam Polarization Uncertainty

- Injection Energy:
  - From this proposal. (~5%)
- Full energy:
  - From Acceleration/Deceleration. (Statistics dominated, ~1.4%)
- From Theory:
- Overall double spin asymmetry scale uncertainty from beam polarization <15%

The Polarized Proton Jet for RHIC

Yousef I. Makdisi
RSC meeting II November 15, 2001

The view from the RSC

The view from BNL

The view from DOE

Where are we?

The MOU

The CDR

The Timetable

The view from the RSC

- The jet is an integral part of the polarized proton effort
- It is designed to provide the absolute beam polarization calibration to the desired 5% level.
- It is designed to make a measurement within a 1 store time interval
- It will be utilized to calibrate the fast p-Carbon CNI polarimeters at any energy.

The view from BNL

- The goal of a 5% measurement was set by T. Kirk
- The concept was introduced into the FWP to DOE in FY 2000
- A detailed entry with cost estimates was added to the FWP in FY 2001 and the projected FY 2002 with $750k in each
- We had an internal discussion with T. Kirk in June 2001 to discuss the minimal needs in FY 2002 which were set to $500k
- This assumed that the sextupoles will be ordered in FY 2001

The view from DOE

- DOE accepted that Wisconsin redirect its efforts in support of the Jet.
- DOE's B. Tippins supported the concept and a draft of the MOU was provided during a meeting in Germantown attended by G. Bunce, M. Mutragh, and T. Kirk.
- J. Simon-Gillo approved a request to redirect FY 2001 equipment funds from the BNL medium energy group to procure the sextupoles. This was intended to jump start the process.
- On the other hand, there were no funds earmarked for the Jet in the DOE supplemental allocation to BNL late summer.
- With the FY 2002 budget, it is not clear that we have funds earmarked either.

The MOU

- A draft was written and circulated to the principal institutions
- While the feedback was generally positive, we had two potential stumbling blocks:

  IUCF has significant expertise. Support for personnel is an issue that has yet to be resolved.

  There was no response from NIKHEF. Recently I re-connected with Jo van de Brand and sent him the MOU and request for equipment that were part of the discussion.

The CDR

- Work began on a draft of the CDR by G. Bunce
- E. Stephenson (IUCF) as promised carried out a detector simulation and forwarded the results to be included in the CDR.
- E. Stephenson provided his data and code to A. Bravar (BNL) who will be carrying this to completion. He will become the resident expert.
- We need to add a section on the ABS and Breit Rabbi polarimeter

Timetables

Complete the CDR by the end of this year

Develop a project cost estimate and resources

Subject the process to an internal design review

Start parallel efforts at the various institutions in particular at BNL

BNL:

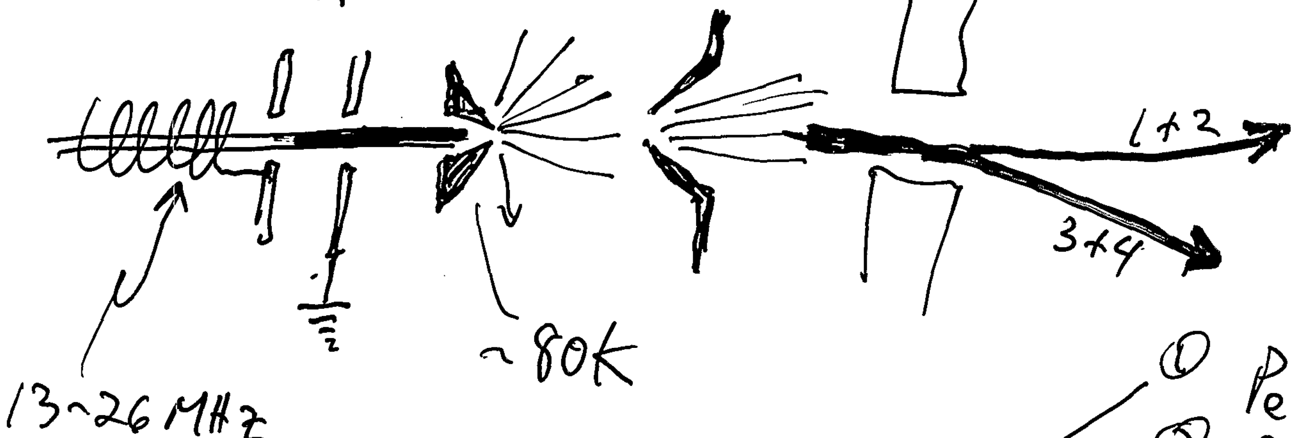
- Assign an overall project engineer (G. Mahler)
- Design the holding field magnet and its cancellation
- Engage the controls group
- Engage the vacuum group
- Engage the source group
- Start work on a staging area and design of the conventional construction and facilities support.

POLARIZED JET
DESIGN ISSUES AND OPTIMIZATION

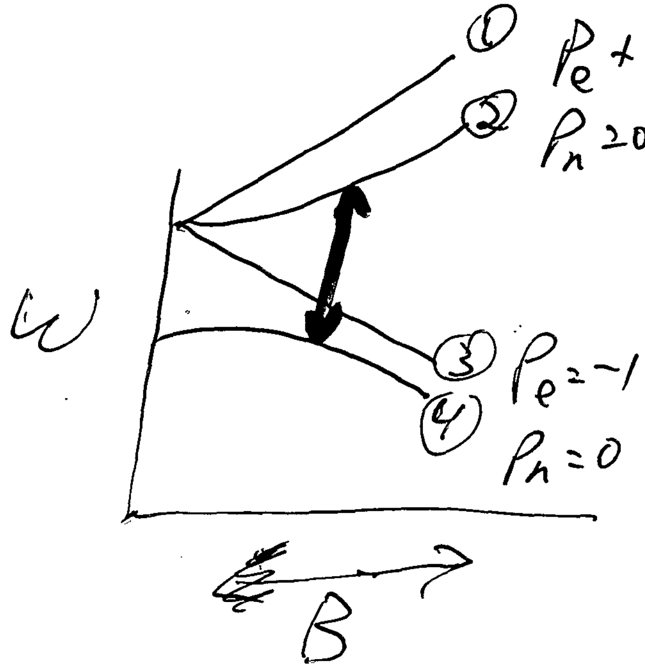
WISCONSIN: T. Wise, P. Quin, W. Haeberli

MIT: H. Kolster

Atomic Beam



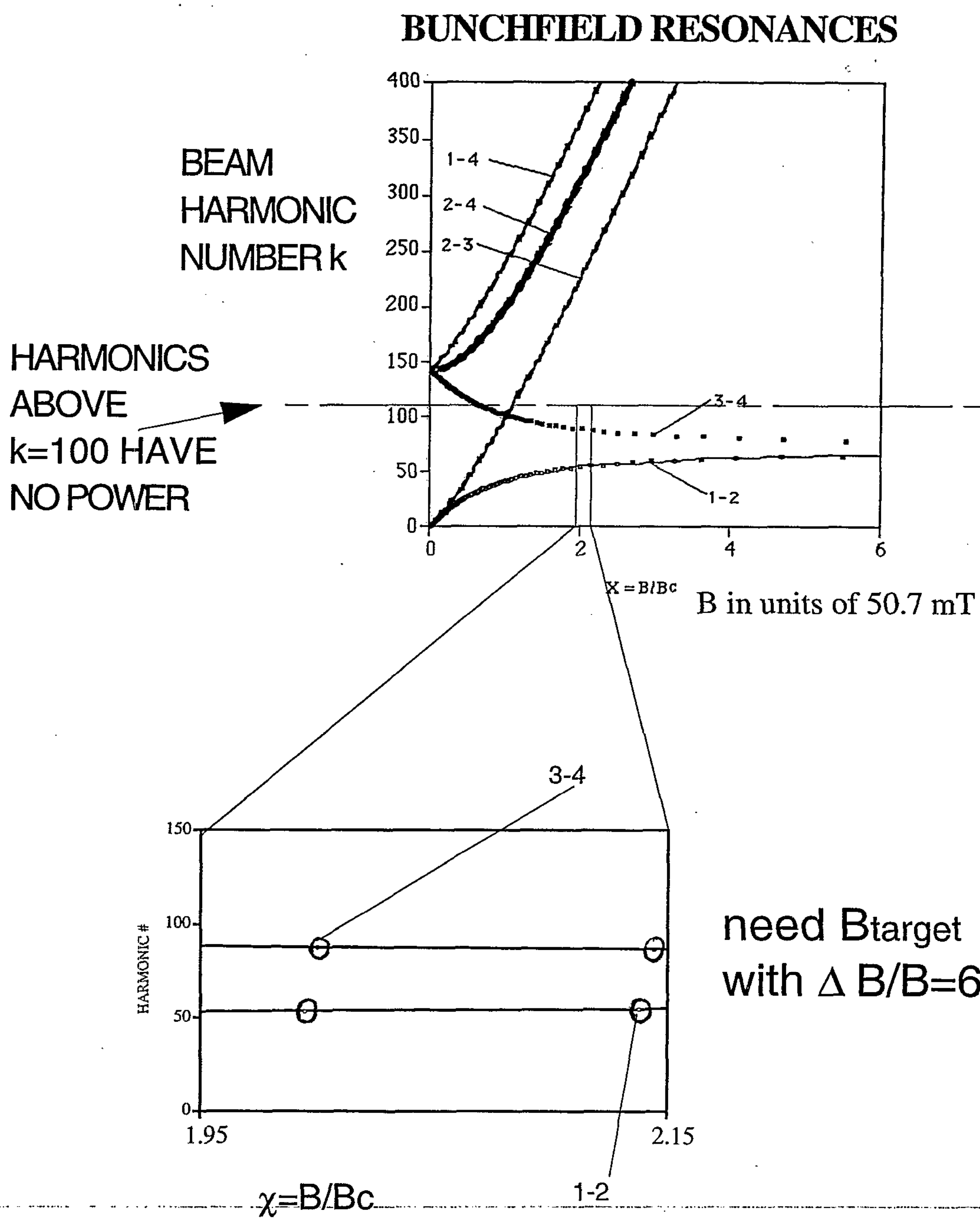
Rf transition required



for use as Calibration
Need more than High intensity

we Need to know occupation #'s
for the 4 Substates.

TARGET REGION CONSTRAINTS



need B_{target} > 1kG
with $\Delta B/B = 6.3 \times 10^{-3}$

- ~32mm POLETIP GAP FOR CIRCULATING BEAM
- MINIMIZE MAGNETIC FIELD FOR LOW ENERGY RECOIL PROTONS
- VERTICAL ABS MUST ACCOMODATE 69" (1765mm) TO FLOOR

6-pole

MAGNET DESIGN

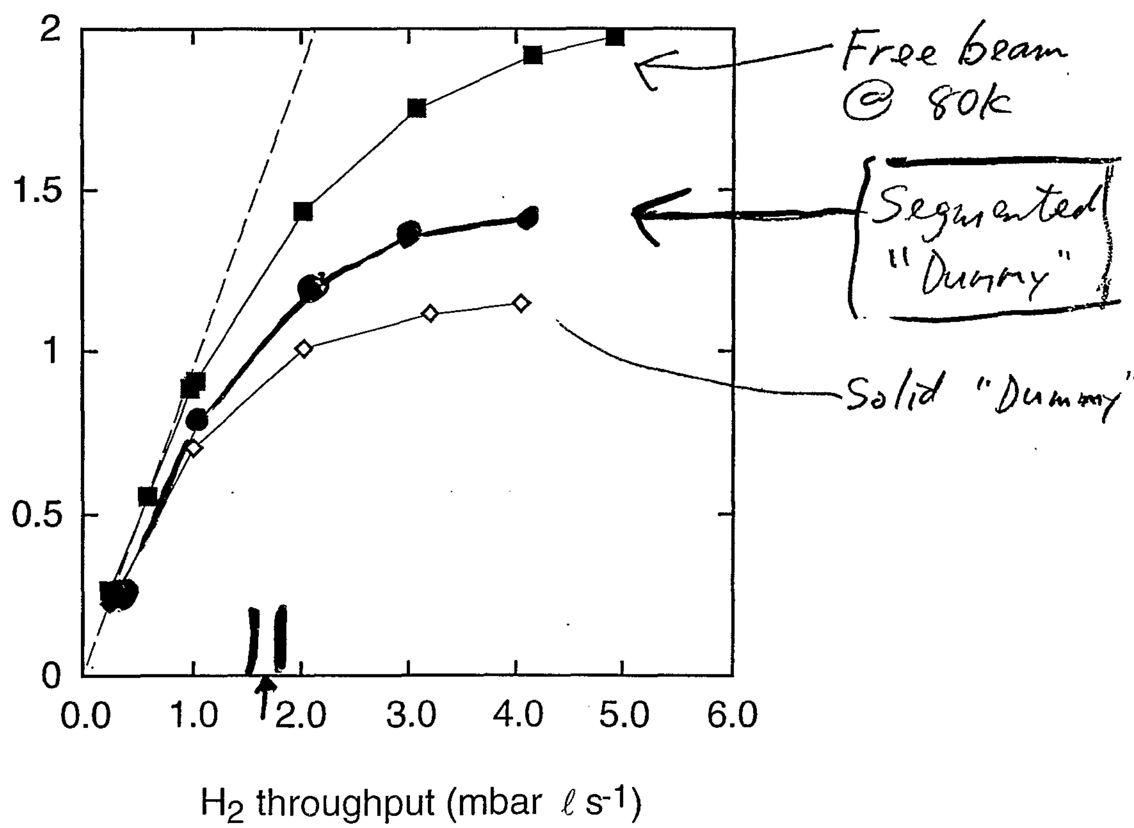
- Two codes used
- Both had errors
- Now they agree (two weeks ago)

One version picks random geometries and fills a 10 parameter space.

The other starts somewhere and performs a gradient search.

We added some factors to the output:

a) BEAM ATTENUATION -- gas scattering. (wisconsin 1992)

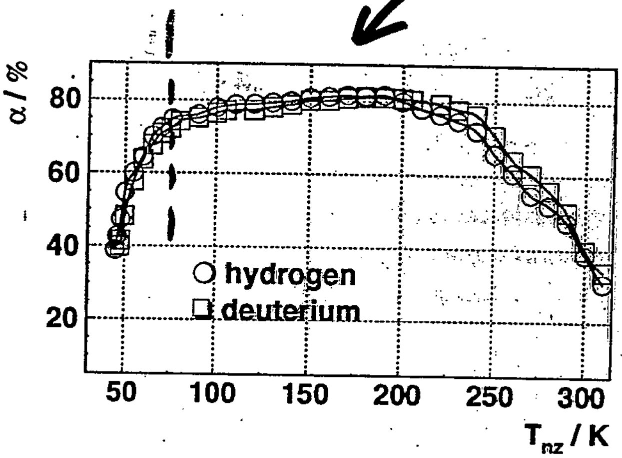


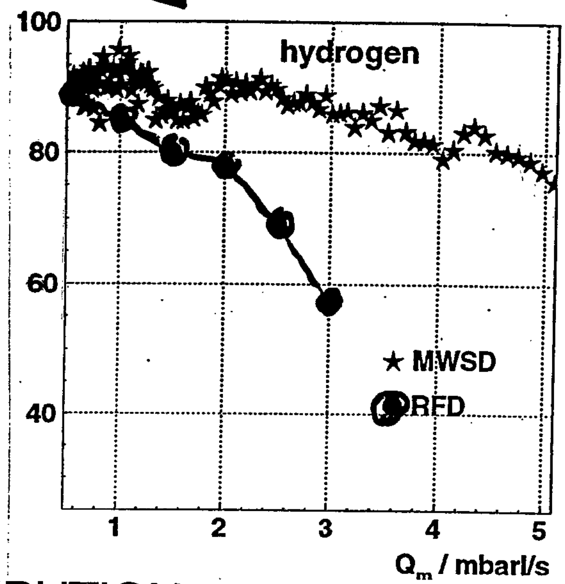
(b) DEGREE OF DISSOCIATION $\alpha = \#H/(\#H + 2 * \#H_2)$

Wisconsin 1992 and N. Koch thesis HERMES--1999

$\alpha(Q,T) = \alpha(Q) * \alpha(T)$

Assume Q, T dependence is separable





(c) START-VELOCITY DISTRIBUTION

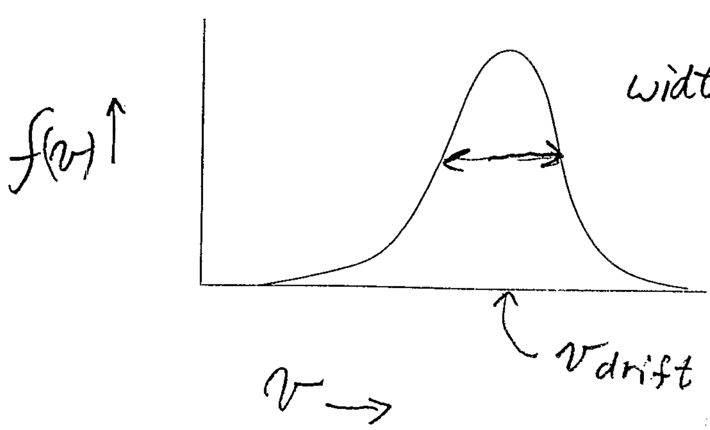
B. LORENTZ DIPLOMARBEIT, HEIDELBERG 1993

based on measurements with rf dissociated atomic beam

$$f(v) = 4\pi v^2 \left(\frac{m}{2\pi k T_{beam}} \right)^{\frac{3}{2}} \exp\left\{ -\left(\frac{m}{2 k T_{beam}} \right) (v - V_{drift})^2 \right\}$$

V_{drift} depends on Tnozzle and Q (mbar liter/s)

T_{beam} depends onTnozzle and Q (mbar liter/s)



width ∝ Tbeam

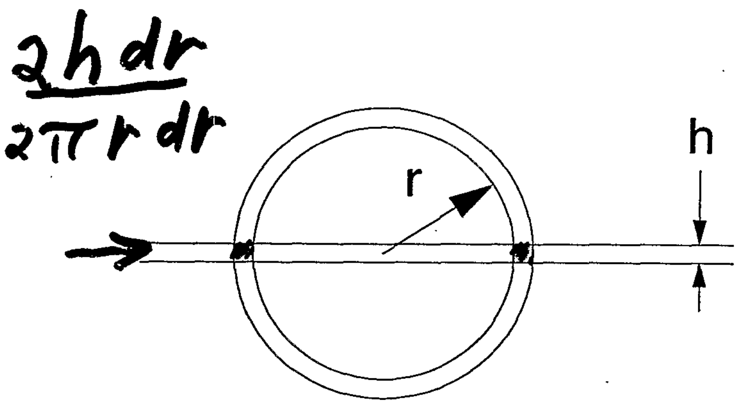
Vdrift ≈ 1900 Meter/s

Tbeam ≈ 20K

(d) WE HAVE JET, NOT STORAGE CELL:
We give increased weighting to lower velocity atoms to account for their longer time in beam path.

$$\sum 1/v$$

(e) RHIC BEAM IS LINE CHARGE: improve statistics of ray trace code by summing 1/r.



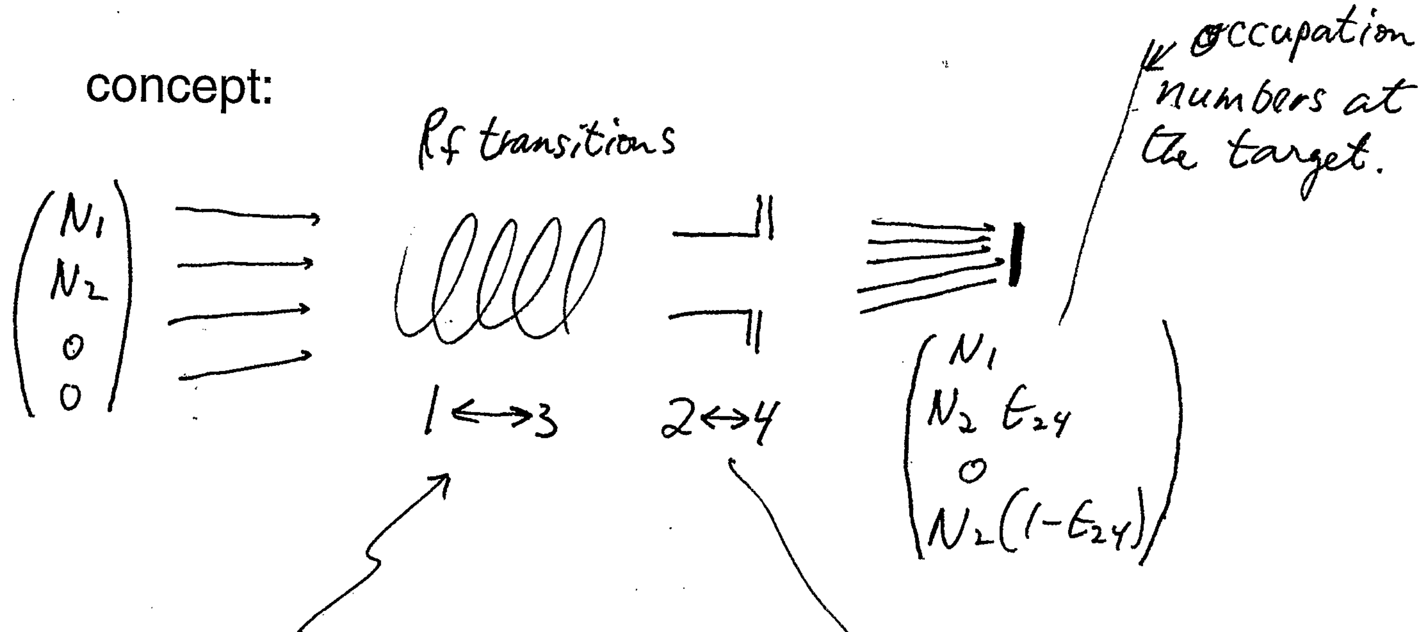
fraction of calculated trajectories at radius r that are seen by RHIC = h/r.
RHIC density prop. to 1/h.

COMBINING ALL OF ABOVE we optimize the function:

$$\tau(Q,T) = Q * \alpha(Q) * \alpha(T) * \{1 - A(Q,T)\} * \frac{\Omega}{N} * \sum_{N} \frac{1}{vr}$$

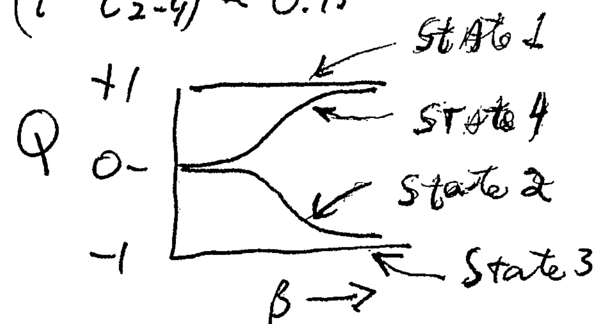
WHAT IS THE JET POLARIZATION?

concept:



efficiancy $= (1-\epsilon_{1-3}) \simeq 0.95$ $\qquad (1-\epsilon_{2-4}) \simeq 0.95$

EXAmple above 1–3 is <u>off</u>
2–4 is <u>on</u>.



State 1 polarization $\quad Q_1 = 1$

State 2 " $\quad -a \equiv Q_2 = \dfrac{-\chi}{\sqrt{1+\chi^2}} \simeq -0.9 \text{ @ } \chi \simeq 2$

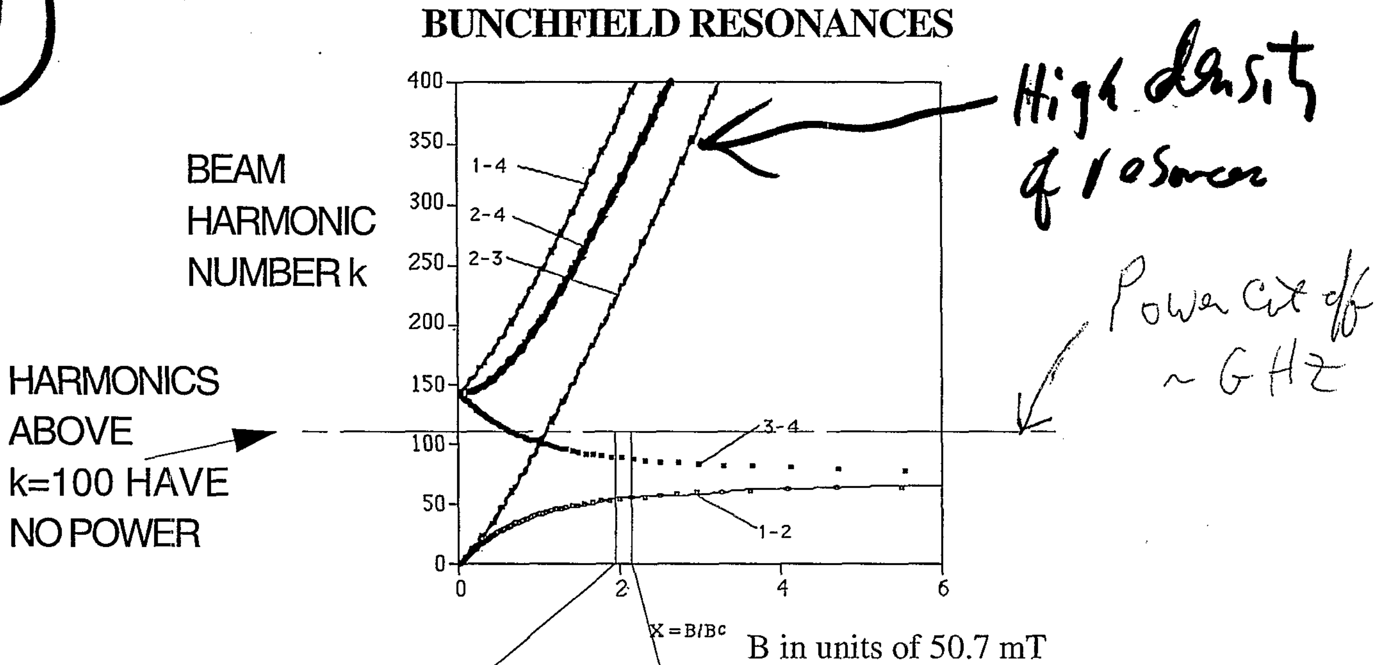
$$Q_3 = -1$$

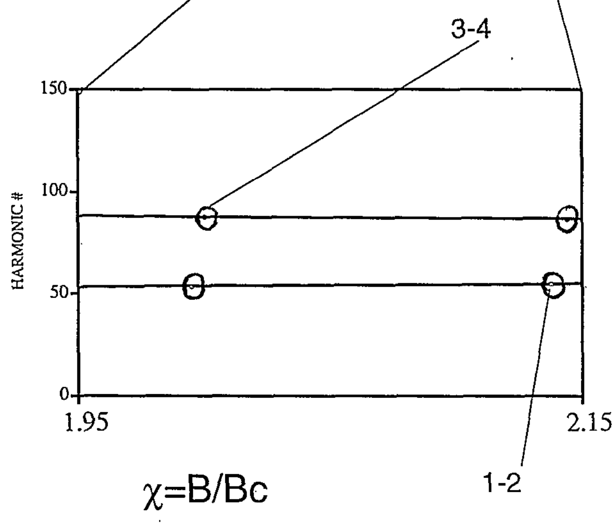
$$+a \equiv Q_4 = \frac{+\chi}{\sqrt{1+\chi^2}} \simeq 0.9 \text{ @ } \chi \simeq 2$$

$$Q_{24} = \frac{N_1 - a\,\epsilon_{2-4} N_2 - 0 + a(1-\epsilon_{24}) N_2}{N_1 + N_2}$$

$$Q_{13} = \frac{\epsilon_{13} N_1 - a N_2 - (1-\epsilon_{13}) N_1 + 0}{N_1 + N_2}$$

TARGET REGION CONSTRAINTS





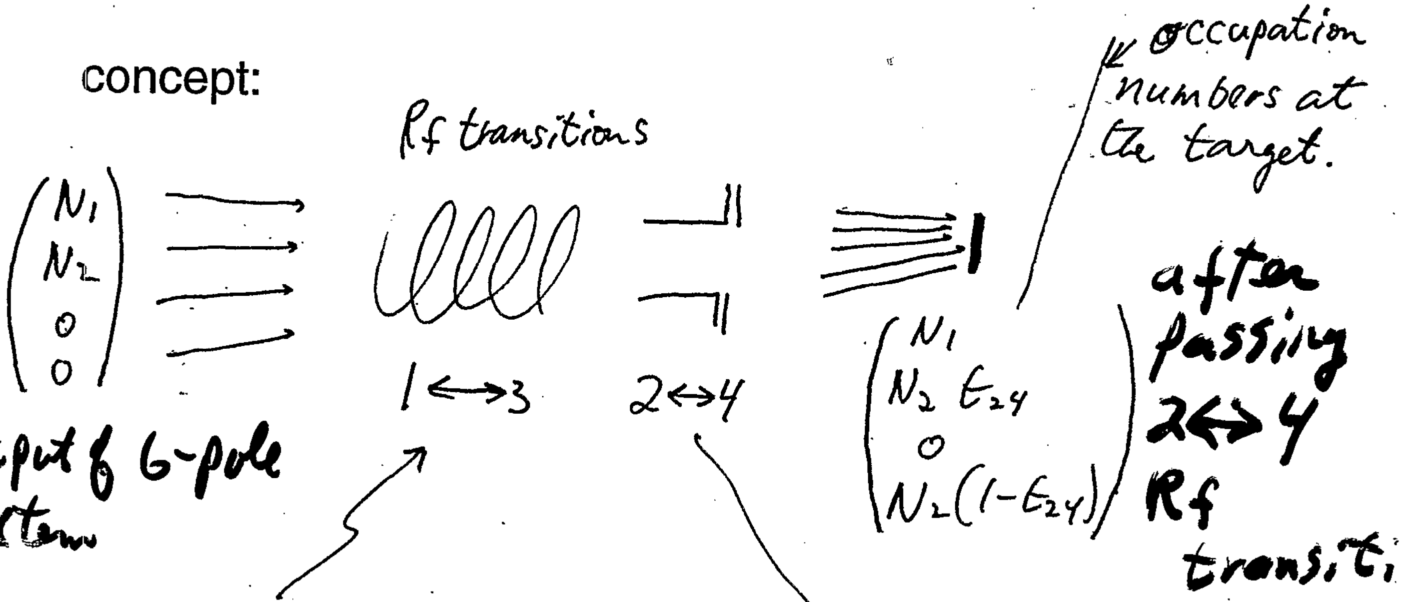
need Btarget > 1kG
with Δ B/B=6.3X10^-3

low field => tighter uniformity

- ~32mm POLETIP GAP FOR CIRCULATING BEAM
- MINIMIZE MAGNETIC FIELD FOR LOW ENERGY RECOIL PROTONS
- VERTICAL ABS MUST ACCOMODATE 69" (1765mm) TO FLOOR

WHAT IS THE JET POLARIZATION?

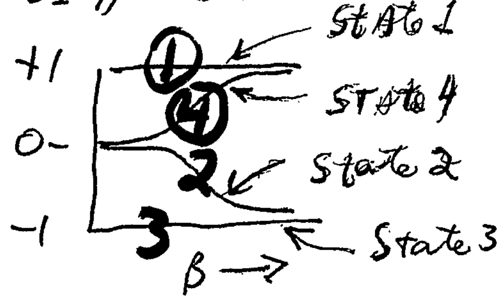
concept:



efficiancy $= (1-\epsilon_{1-3}) \simeq 0.95$ $\qquad (1-\epsilon_{2-4}) \approx 0.95$

EXAmple above 1-3 is off

2-4 is on.



State 1 polarization $\quad Q_1 = 1$

State 2 " $\quad \boxed{-a} \equiv Q_2 = \dfrac{-\chi}{\sqrt{1+\chi^2}} \approx -0.9 \;@\; \chi \simeq 2$

state 3 " $\quad Q_3 = -1$

State 4 " $\quad \boxed{+a} \equiv Q_4 = \dfrac{+\chi}{\sqrt{1+\chi^2}} \simeq +0.9 \;@\; \chi \approx 2$

$$Q_{24} = \frac{N_1 - a\,\epsilon_{2\text{-}4} N_2 - 0 + a(1-\epsilon_{24}) N_2}{N_1 + N_2} \simeq \underline{1}$$

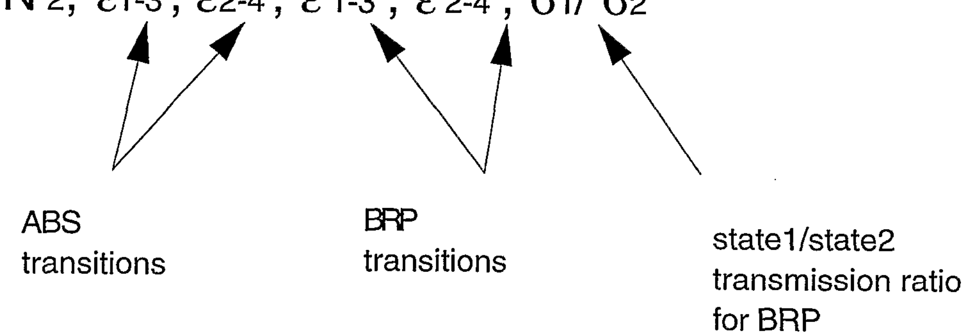
$$Q_{13} = \frac{\epsilon_{13} N_1 - a N_2 - (1-\epsilon_{13}) N_1 + 0}{N_1 + N_2} \approx -\underline{1}$$

NEED TO KNOW N_1/N_2, $\varepsilon_{1\text{-}3}$ AND $\varepsilon_{2\text{-}4}$.
(not easily done)

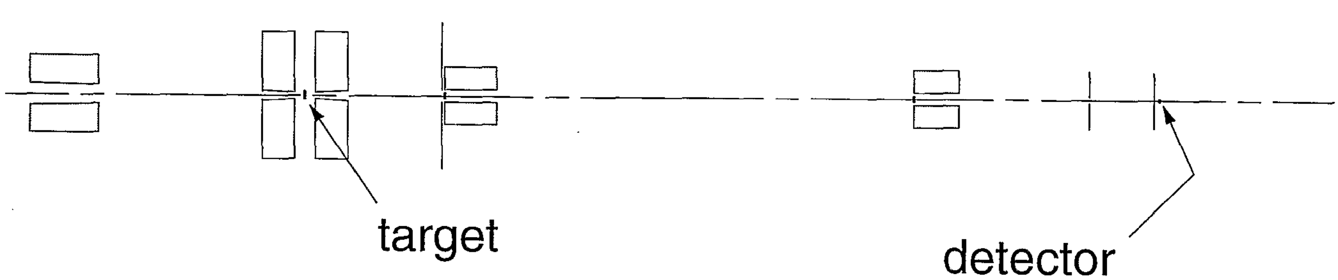
Our solution:

1) Add two additional rf transitions and separation magnets.
2) Completely remove rejected states (3,4) at each stage by use of on-axis beam blockers.
3) Run multiple combinations of Rf transitions to generate 10 intensity measurements and solve for five unknowns.

N_1/N_2, $\varepsilon_{1\text{-}3}$, $\varepsilon_{2\text{-}4}$, $\varepsilon'_{1\text{-}3}$, $\varepsilon'_{2\text{-}4}$, σ_1/σ_2



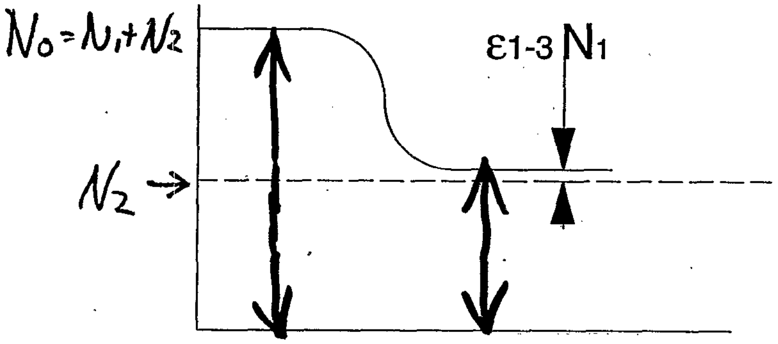
present BRP solution



Also Very Long.
Same scale as ABS Solution

USEFUL WAY TO LOOK AT THE PROBLEM (Abs Polarimeter)

BEAM INTENSITY AS RF1-3 IS TURNED ON. — as Seen by QMS.



$$R_{13} = \frac{\varepsilon_{13} N_1 + N_2}{N_0}$$

$$R_{24} = \frac{N_1 + \varepsilon_{24} N_2}{N_0}$$

AFTER SOME ALGEBRA WE FIND CHANGE IN POLARIZATION:

$\Delta Q = Q_{1-3} - |Q_{2-4}|$:

$$\Delta Q = 2(1 + a - R_{1-3} - aR_{2-4})$$

N_1/N_2 does not effect ΔQ

$\langle Q \rangle$ does depend on N_1/N_2

Helpful Notation

$$\frac{N_1}{N_0} = \frac{1}{2}(1 \pm X_{abs}) \qquad \frac{N_2}{N_0} = \frac{1}{2}(1 \mp X_{abs})$$

$$\frac{N_1}{N_2} = \frac{(1 + X_{abs})}{(1 - X_{abs})}$$

After Some Algebra:

$$\langle P \rangle = \frac{P_{13} + P_{24}}{2} = \frac{-a\epsilon_{24} + \epsilon_{13} - X(a\epsilon_{24} + \epsilon_{13})}{2}$$

Error by ignoring $X_{abs} \neq 0$ is $\frac{-X(a\epsilon_{24} + \epsilon_{13})}{2}$

for $X = .03$ $\left(\frac{N_1}{N_2} = 1.06\right)$

$\epsilon_{13} \simeq \epsilon_{24} = 0.05$ Error in $\langle P \rangle = 0.0015$

Not the entire story !!

BRP also has unequal state 1, state 2 transmission.

i.e. $\frac{\sigma_1}{\sigma_2} \neq 1$

Error from ignoring $\sigma_1/\sigma_2 \neq 1$:

BRP Detector sees $\dfrac{N_1\sigma_1}{N_2\sigma_2} = \dfrac{1+X}{1-X} \simeq$

$$\simeq \frac{1 + X_{abs} + X_{brp}}{1 - X_{abs} - X_{brp}}$$

After some algebra, **X_{abs} cancels**

$$\boxed{\text{Error } \Delta P} = X_{brp}(\epsilon_{13} - a\,\epsilon_{24} + a - 1)$$

($a - 1$ dominates.)

$$\boxed{\Delta P \simeq -0.1\, X_{brp}}$$

$$\boxed{\text{Error } \langle p \rangle} = -\frac{X_{brp}(a\,\epsilon_{24} + \epsilon_{13})}{2}$$

for $X_{brp} = 0.05$ $\left(\frac{\sigma_1}{\sigma_2} \simeq 1.1\right)$

$\epsilon_{13} \simeq \epsilon_{24} = 0.04$

$a = 0.9$

Error $\Delta P \simeq -.005$

Error $\langle p \rangle = -.002$

Design conclusions:

1) although not critical we aim for
$N_1/N_2 = 1$

2) BRP must transmit close to
$\sigma_1/\sigma_2 = 1$ to avoid errors in target polarization measurement.

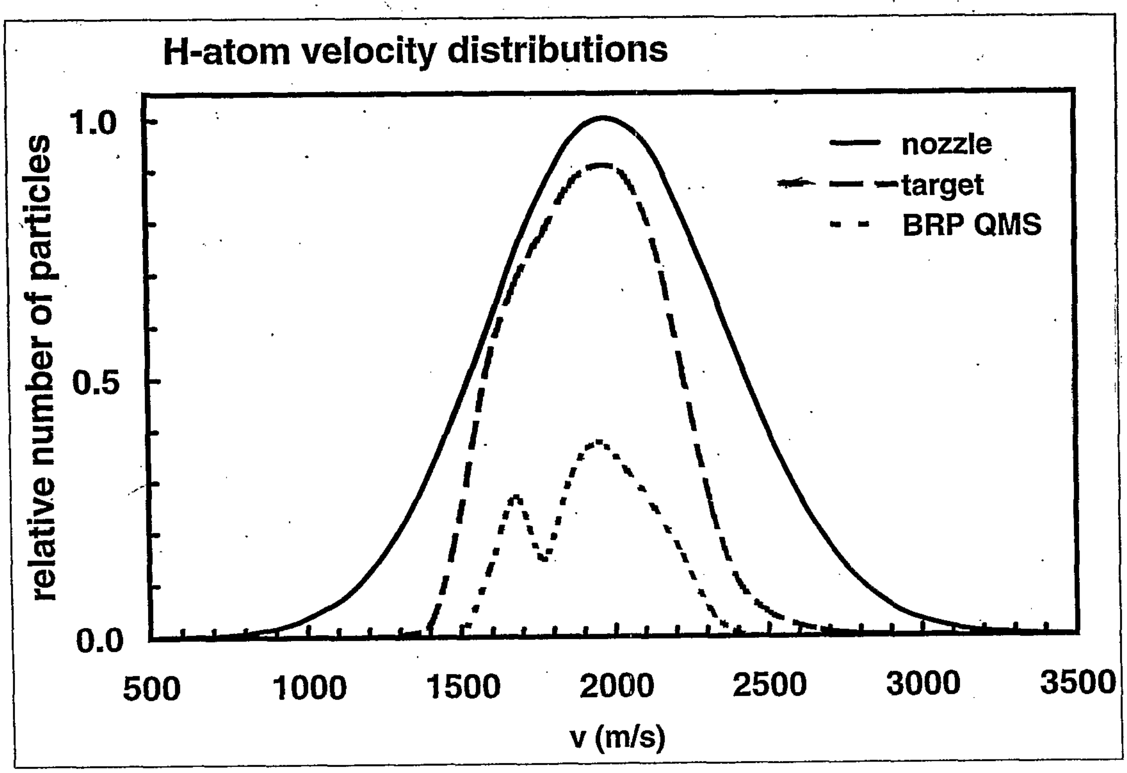
Ray tracing results

$$\frac{N_1}{N_2}\left(\Sigma \frac{1}{rv}\right) = 0.987 \Rightarrow X_{abs} = -0.007$$

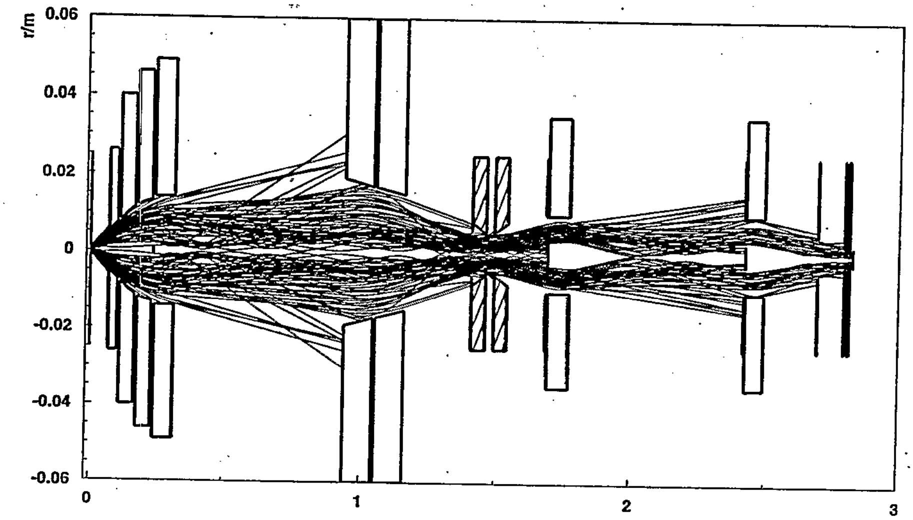
$$\frac{N_1\sigma_1}{N_2\sigma_2}\left(\Sigma \frac{1}{rv}\right) = .976 \Rightarrow X_{BRP} = -0.006$$

velocity dependent attenuation not accounted for yet.

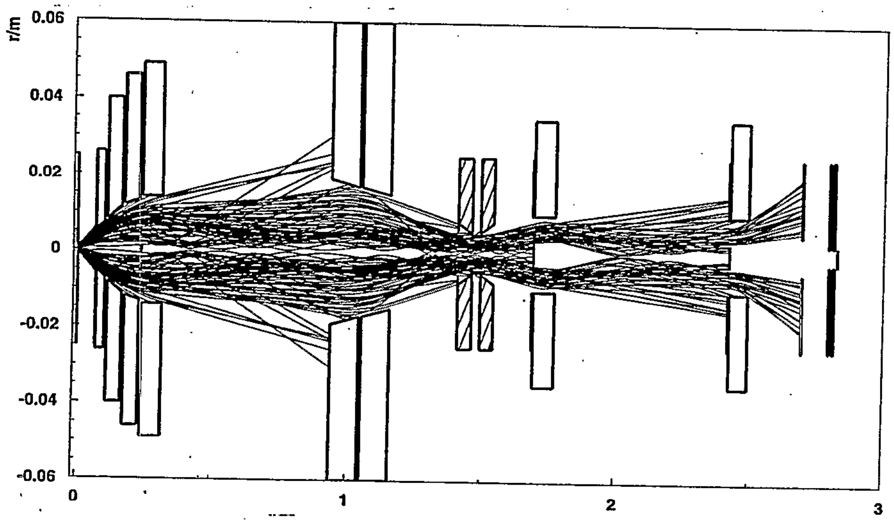
Rejection of states 3, 4 better than 10^{-3}


H-atom velocity distributions
relative number of particles
1.0
0.5
0.0
nozzle
target
BRP QMS
500
1000
1500
2000
2500
3000
3500
v (m/s)

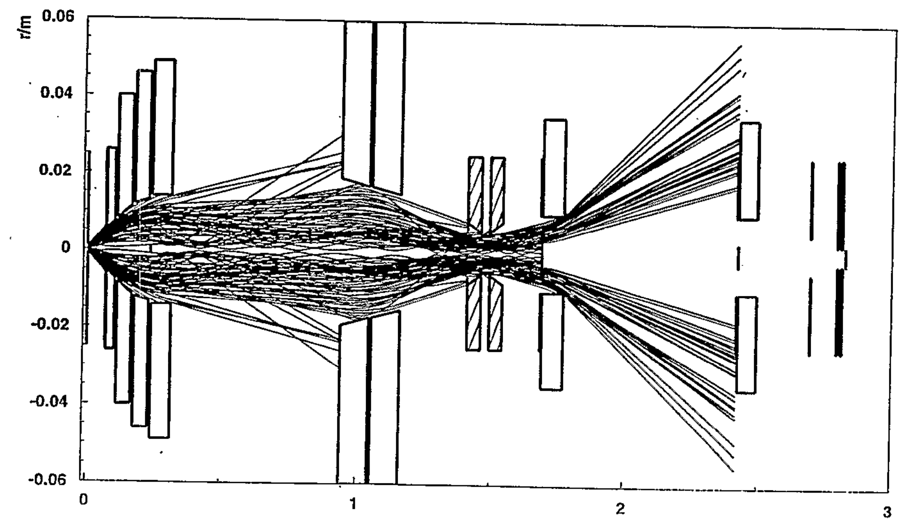
100 RAYS
each ray is
~1% effect.



1, 1, 1
No Rf on



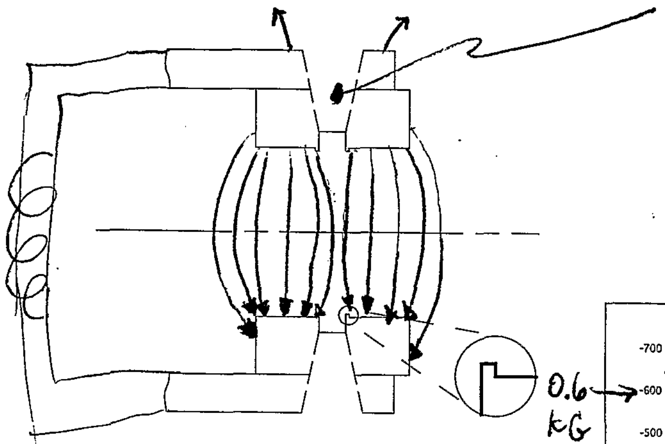
1, 1, 3 BRP
Rf 1⟷3
ON

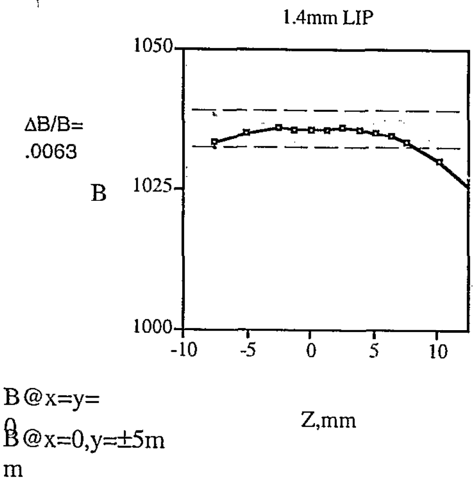


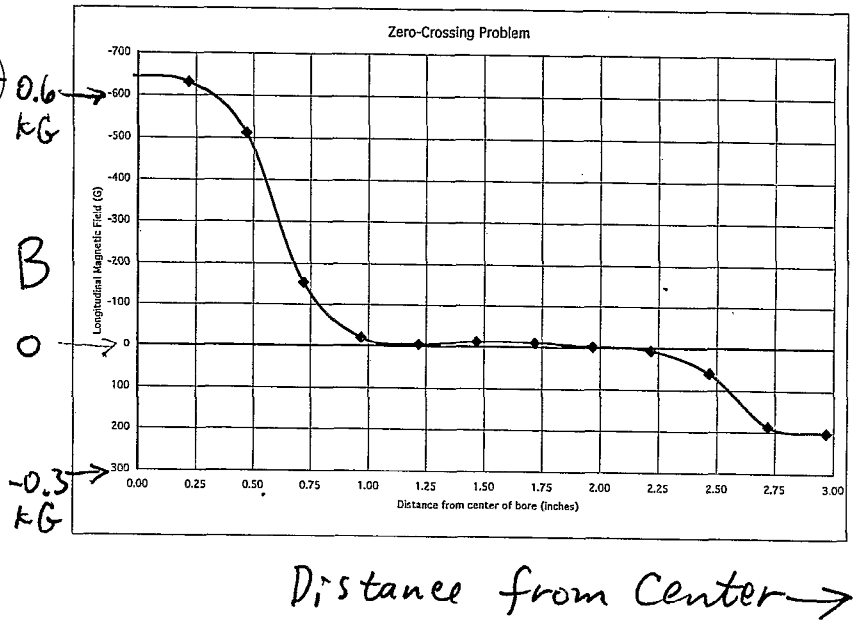
1, 3, 1
Both ABS+BRP
Rf 1⟷3 ON

TARGET REGION MAGNET.

uniformity issue already solved
We have new problem--<u>ZERO CROSSING</u>







we added ceramic magnet pellets to make transverse field.--only partially sucessful.

Computer modeling required.

Simulation Studies for Recoil Detectors

E.J. Stephenson
Indiana University Cyclotron Facility, Bloomington, IN 47408

The purpose of the calibration experiment is to transfer the known polarization of a jet target to the analyzing power of the CNI polarimeters by first obtaining the beam polarization from the observation of p+p elastic scattering from the RHIC beam passing through the polarized jet. Elastic scattering is a preferred process since it offers the same analyzing power for both beam and target. The p+p CNI region offers large cross sections and analyzing powers that are reliably on the scale of a at least a few percent over a range of energies.

If p+p recoils are observed on both sides of the beam and it is possible to flip the spins of either the target or the beam, then there are 8 available experimental quantities. If normalized to a luminosity monitor (an issue that must deal with spin correlations), certain combinations (see slide 2) of these 8 rates yield quantities proportional to just the beam or target polarization. The ratio of these two is the first step in the calibration. Other combinations yield information independently on "reversal failures" in which either the target or beam polarization does not complete reverse, or there are asymmetries between the left and right detector efficiencies.

The count rate estimates on slide 3 suggests that we can obtain the 1.3M events needed for a 5% calibration in roughly one day of continuous running.

The atomic beam target, which will be about 1.2 cm across, will sit in a holding field that must be at least 1 kG to avoid depolarizing resonances from RF in the beam.

The recoil detectors are likely to be silicon strip. From these we will get energy, position, and time. Detected energies, including consideration of the silicon detector dead layer, will range from 0.5 to 5.2 MeV for $0.0015 < -t < 0.010$ $(\mathrm{GeV/c})^2$. These will be closely related to $-t$. For detectors about 30 cm from the target (see slide 5), values of the time-of-flight values ranges between 8 and 29 ns. This is well away from the 55-ns time for the beam to go to the intersection region and return to a point 8.2 m away (the separation between pulses from the two beams passing through the jet target).

The holding field generates left/right asymmetries in the position of tracks on the face of the detectors, as shown in slide 6. For either polarity of the holding field, detectors 6.4 cm across will capture all the relevant protons for a measurement with the limits above on $-t$. The calibration requires clean identification of the elastic recoil protons. To be safe, other processes should be less than a percent of the signal; some UA6 data shown on slide 7 suggests that it may be as high as 2-3%. Additional detectors for the forward proton could help by providing an additional coincidence and coplanarity information. It is not known how close such "Roman Pot" detectors can be placed to the beam, but problems here might mean operating at larger values of $-t$ where both the cross sections and the analyzing powers are smaller.

RHIC Polarization Calibration Experiment

General Comments

Calibration reference standard:

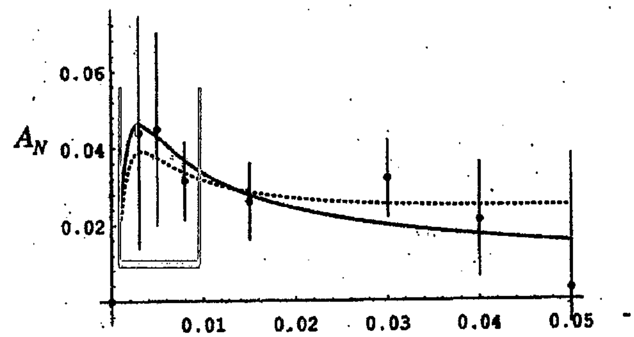
atomic beam polarized proton target

measure p with Breit-Rabi polarimeter (known to <3%)

Process: p+p elastic scattering in the CNI region

calculated A is above 0.033

for $0.0015 < -t < 0.01$ (GeV/c)^2



N.H. Buttimore *et al.*, PRD **59**, 114010

Features:

•same analyzing power A for beam or target in same geometry
(any reaction would have to match two acceptances)

•CNI has A that is present independent of energy

•CNI has large cross sections
rapid measurements
large signal/noise ratio (other processes)

•hopefully simple, inexpensive experimental setup

Issues:

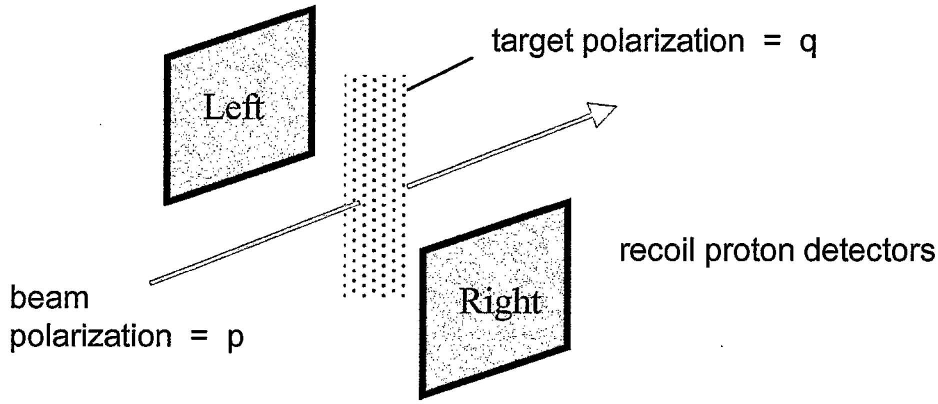
•low analyzing power makes systematic errors important

Goal:

calibration of blue/yellow ring p+C CNI polarimeters to <5%

reference standard for p+C CNI systematic studies

Simple geometry (for recoils)



Example: measure on both sides and flip either spin = 8 rates
Consider vertical spin only.

Calibration is a measure of this ratio

$$8\sigma \begin{bmatrix} 1 \\ pA \\ qA \\ pqA_{NN} \\ G \\ H \\ J \\ K \end{bmatrix} = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -1 & +1 & +1 & -1 & -1 & +1 \\ +1 & -1 & +1 & -1 & -1 & +1 & -1 & +1 \\ +1 & +1 & -1 & -1 & -1 & -1 & +1 & +1 \\ +1 & +1 & +1 & +1 & -1 & -1 & -1 & -1 \\ +1 & -1 & -1 & +1 & -1 & +1 & +1 & -1 \\ +1 & -1 & +1 & -1 & +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 & +1 & +1 & -1 & -1 \end{bmatrix} \begin{bmatrix} L_{++} \\ R_{++} \\ L_{-+} \\ R_{-+} \\ L_{+-} \\ R_{+-} \\ L_{--} \\ R_{--} \end{bmatrix}$$

G = H = J = K = 0 unless there is a "reversal failure." Such failures are absent in their leading order from the first 4 terms.

incomplete beam flip

$$p_+ = \delta + p$$
$$p_- = \delta - p$$

$$J = \delta A$$
$$G = \delta q\, A_{NN}$$

incomplete target flip

$$q_+ = \varepsilon + q$$
$$q_- = \varepsilon - q$$

$$J = \varepsilon A$$
$$K = \varepsilon p\, A_{NN}$$

left/right imbalance

$$L \leftarrow L(1+\phi)$$
$$R \leftarrow R(1-\phi)$$

$$J = \phi$$
$$K = \phi p\, A$$
$$G = \phi q\, A$$
$$H = \phi pq\, A_{NN}$$

Count Rate Estimates

Proton beam: 10^{11} /bunch, 55 bunches

Target: 3×10^{11} /cm^2

luminosity = 1.3×10^{29} /cm^2/s

Cross section: 29 μb into one detector
for $0.0015 < -t < 0.01$ (GeV/c)^2
[calculated using $\rho = -0.09$, b = 11 (GeV/c)$^{-2}$

Rate = 15 /s (for 4 detectors, all bunches)

What is needed?

Analyzing power: 0.035

Beam polarization (target will be larger): 0.5

Asymmetry: 0.018

A 5% error requires $\delta\varepsilon = 0.00088$

Statistical precision requires more than 1.3×10^6 events

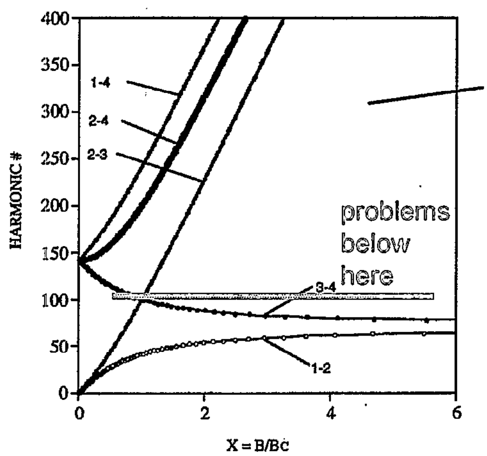
Run time = 24 hours (average over all bunches)

Effect on beam lifetime negligable from nuclear reactions.

Target Properties:

Atomic beam will be about 1.2 cm across. This spreads the origin point for events as seen by the recoil detectors.

It will be important to avoid resonant depolarization from RF in the beam. There is significant power at harmonics up through 100.



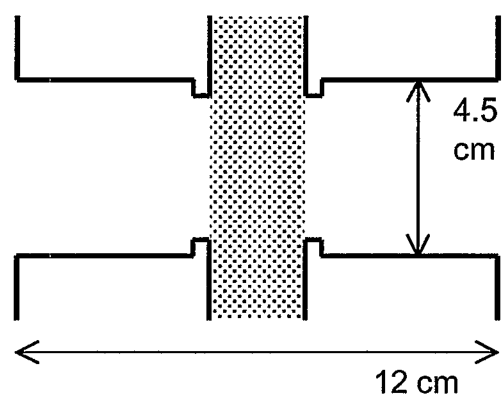
Use a holding field to retain polarization.

Plot shows resonances (dots) to be avoided as a function of harmonic number and holding field strength.

Magnetic field has to be high enough so that the space between resonances will allow for field non-uniformities.

B ~ 1.1 kG

There will be a holding field magnet something like: →



NOTE: There needs to be a way to test (RF cavity?) to know whether field is off resonance.

This create left/right differences in the recoil proton trajectories! So plan to reverse field to cancel systematic errors.

Detectors likely to be silicon strip (cooled).
Pitch along beam path can be 2-3 mm.

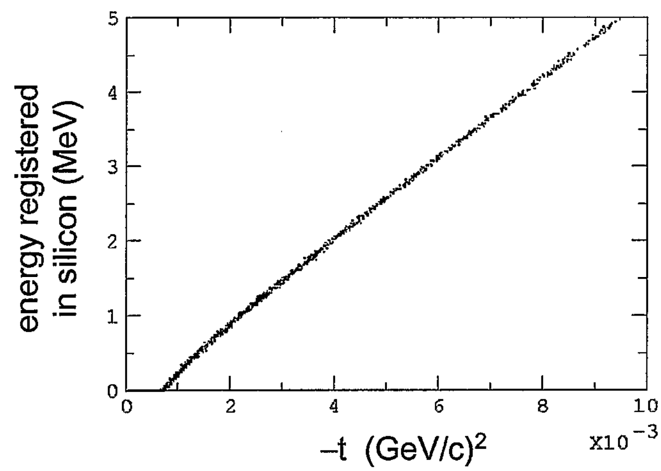
Grid will be needed between target and detector to shield and contain beam RF.

Detector/target chamber must be differentially pumped. Proton energies are too low for a separator foil.

What information is available from recoil measurement?

(1) energy

Within 0.0015 < –t < 0.01 $(GeV/c)^2$, energy seen in silicon detector ranges from 0.5 to 5.2 MeV.

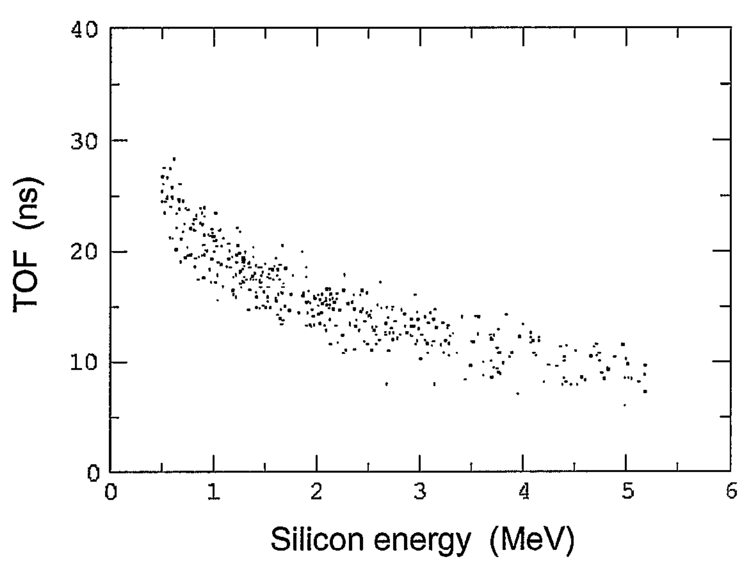


(2) position

2-3 mm resolution along beam direction is adequate.

(3) time of flight (relative to RF?)

Correlation of TOF with energy (0.5 – 5.2 MeV range):



Tracking proton trajectories to each detector:

Toy simulation

Use information on IUCF double-sided silicon strip detectors from thesis of Todd Peterson. Detectors are 6.4 ⨯ 6.4 cm^2.

Include silicon detector dead layer

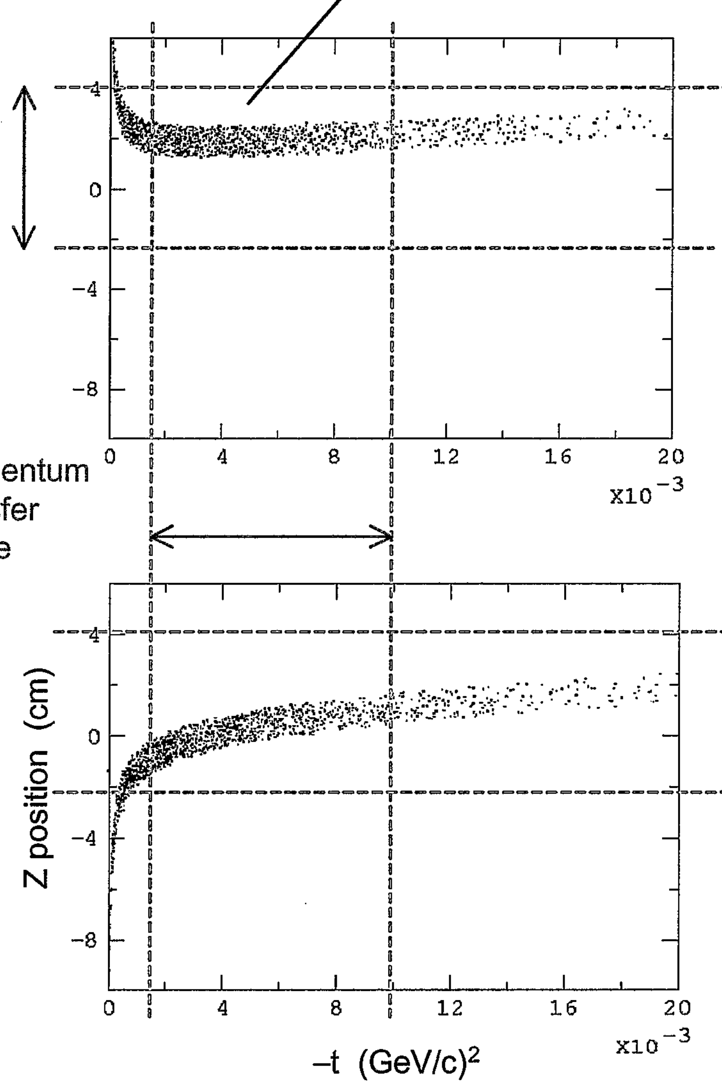
Include 55-keV noise, 1.6-ns time jitter

Sharp-edged B-field

Randomize source spot

Place detectors at 30-cm distance

That turning point comes near CNI region is coincidental.



With detectors 6.4 cm wide at 30 cm, CNI recoil protons hit for both field directions.

With target 8.2 m from BRAHMS I.P., blue and yellow beams are separated by 55 ns, almost exactly half of pulse separation period. For TOF to fall in the middle, detectors must be closer than 50 cm.

Background: at what level does it matter?

Assume background is a fraction δ of the signal.

Then we measure

$$A_{\mathrm{exp}} = A - \delta(A' - A)$$

p+p elastic analyzing power (A) — background analyzing power (A')

Assume $\langle A \rangle$ = 0.035 near CNI peak.
Systematic errors should be < 5%, or < 0.0018.

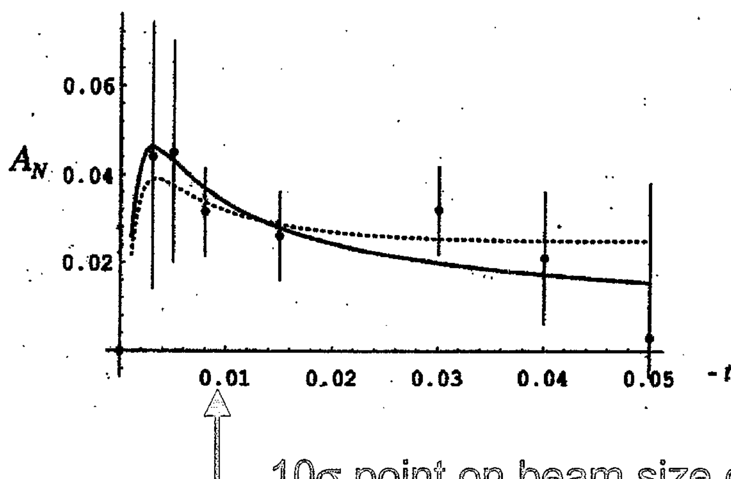
If A is:	then δ is:
1 (safe)	< 0.002
0.3	< 0.006

Can pp2pp Roman pots help?

require coincidence with forward proton

segmentation of Roman pot silicon and vertical direction on proton recoils makes possible a coplanarity cut

* minimum separation of forward detectors from beam may change CNI acceptance range



10σ point on beam size comes roughly here for 250 (GeV/c)²

Limits imposed by non-Gaussian halo not known, may be strong function of location, time into store, other targets...

Moving out in momentum transfer reduces δ.

Background simulations needed to determine whether coincidences and cuts can meet δ goal.

Almost No Simulations

Alessandro Bravar

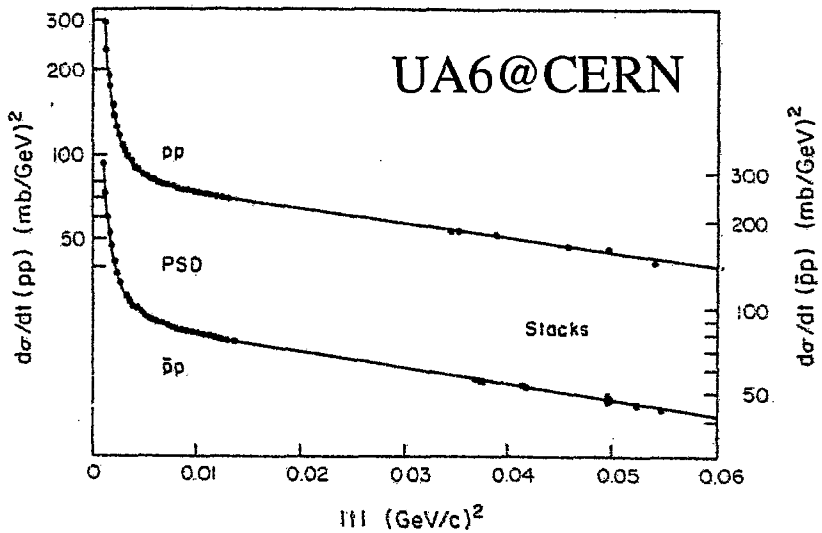
RHIC Spin Coll. Meeting VIb

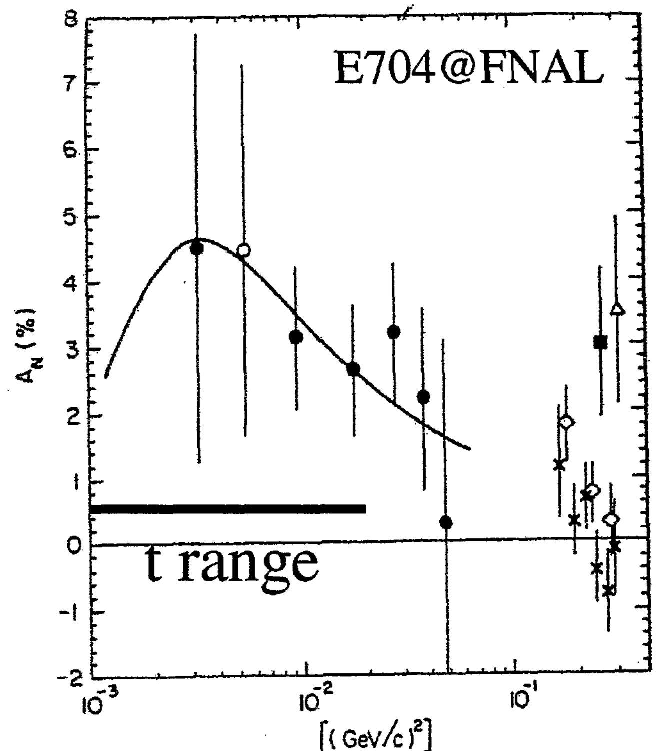
- ❖Introduction
- ❖Rates
- ❖Elastic pp kinematics
- ❖Backgrounds
- ❖Recoil detector
- ❖Conclusions

Nov. 15, 2001

BROOKHAVEN
NATIONAL LABORATORY

Elastic *pp* $d\sigma / dt$ & A_N



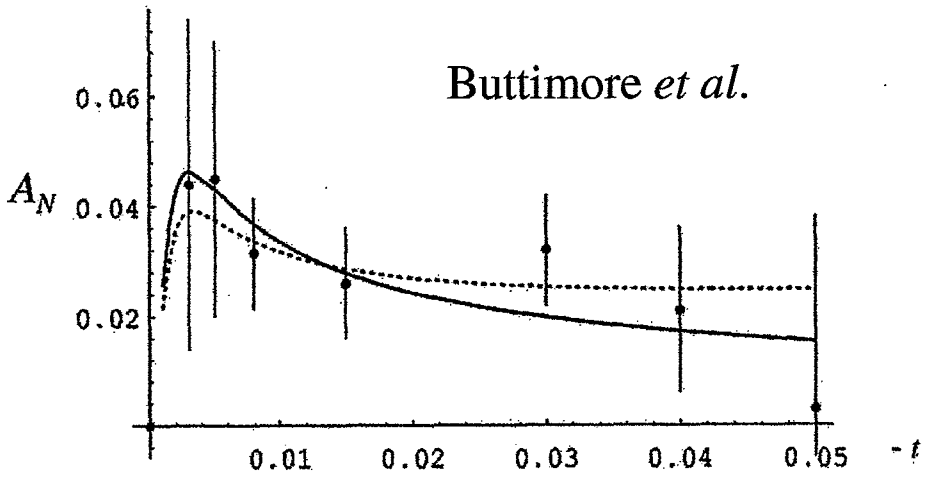


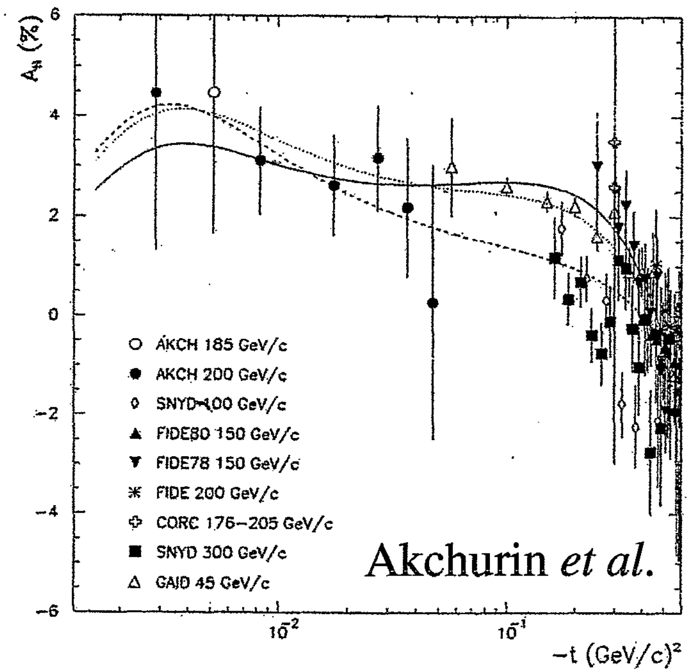
$0.001 < |t| < 0.02\ GeV^2$

$<\sigma> = 3$ mbarn

$<A_N> = 0.03$

CNI & hadronic spin-flip





- If no pronounced maximum in CNI *t* region, any *t* region as good as CNI region
- With recoil detector & roman pots can cover broad *t* range

Comparison of different t regions

Figure of Merit = $< A_N >^2 < \sigma >$

	CNI	Small |t|	Medium |t|	Large |t|	Elastic ep
|t| range (GeV^2)	$10^{-3} - 2\ 10^{-2}$	$2\ 10^{-2} - 0.1$	0.1 – 0.4	0.7 – 1.4	
$< \sigma >$ (cm^2)	$3\ 10^{-27}$	$3\ 10^{-27}$	$2\ 10^{-27}$	$3\ 10^{-30}$	
$< A_N >$	0.03	0.02 – 0.03	0.02 – 0.03	0.1	
f. o. m.	$2.7\ 10^{-30}$	$1.8\ 10^{-30}$	$0.8\ 10^{-30}$	$2\ 10^{-33}$	

Procedure

- Measure A_N with unpolarized beam and polarized target

$$\Delta P_{beam} / P_{beam} < 0.05 \quad \Rightarrow \begin{cases} \Delta A_N < 10^{-3} \\ \Delta P_{targ} / P_{targ} < 0.02 \\ \text{background} < 1\% \end{cases}$$

- Measure P_{beam} using A_N with polarized beam and unpolarized target

- Continous monitoring with polarized beam and polarized target

  $\rightarrow$ A_{NN} for free

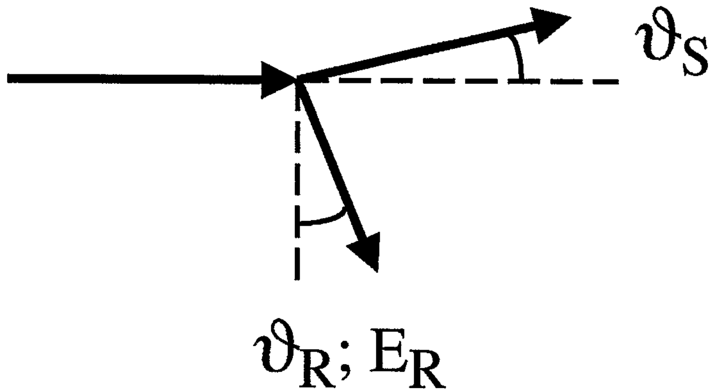
NB *Self-Calibration* works with elastic scattering only

RATES

BEAM	TARGET
$2\ 10^{11}$ p / bunch 120 bunches 78 kHz	$3\ 10^{11}$ atoms / cm^2

- $\mathcal{L} = 2\ 10^{11} \times 120 \times 78\ 10^{3} \times 3\ 10^{11} = 5.6\ 10^{29}\ \mathrm{cm^{-2}s^{-1}}$
  $= 4.7\ 10^{27}\ \mathrm{cm^{-2}s^{-1}}$ / bunch
- $N = \mathcal{L} <\sigma>$ *acc* $(\Delta\varphi = 30^\circ/2\pi) = 140$ evt s^{-1}
  $\sim$ 1 evt s^{-1} / bunch
- in 3 hours can collect 1.5×10^{6} events

Kinematics



t : 0.001 – 0.02 GeV^2
ϑ_R : 16. – 75. Mrad
T_{kin} : 0.5 – 10 MeV
p_R : 30. – 140 MeV

Essentially 1 free parameter: t (+ φ) ⇒

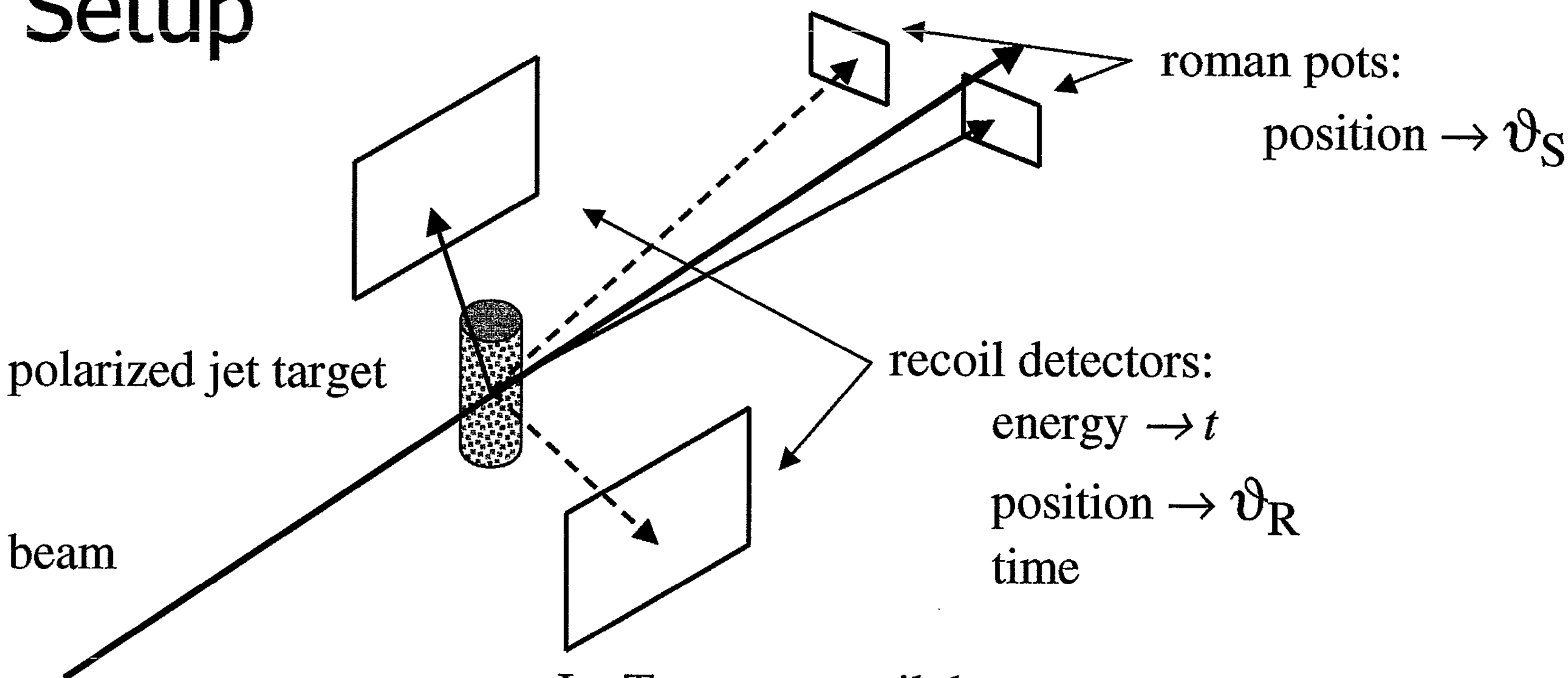
elastic *pp* kinematics fully constrained

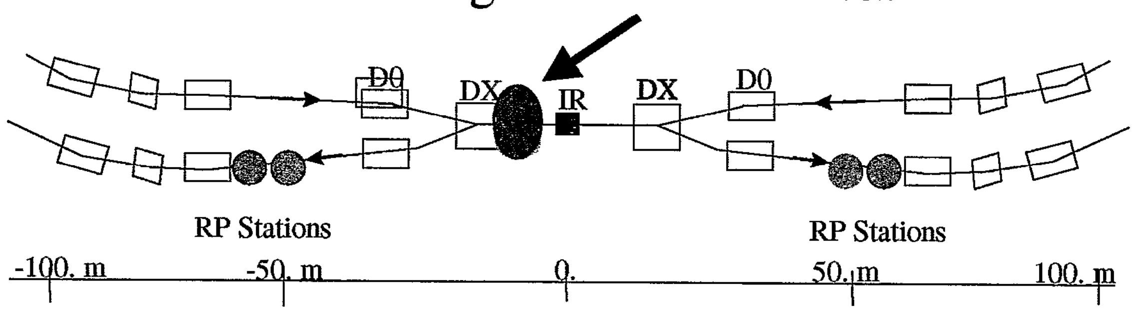
$$\sin\vartheta_R = \left(1 + \frac{m_p}{p_{beam}}\right)\frac{\sqrt{|t|}}{2m_p}$$

$$t = -2m_p T_{kin}$$

measure position and energy of recoil => ϑ_R and t

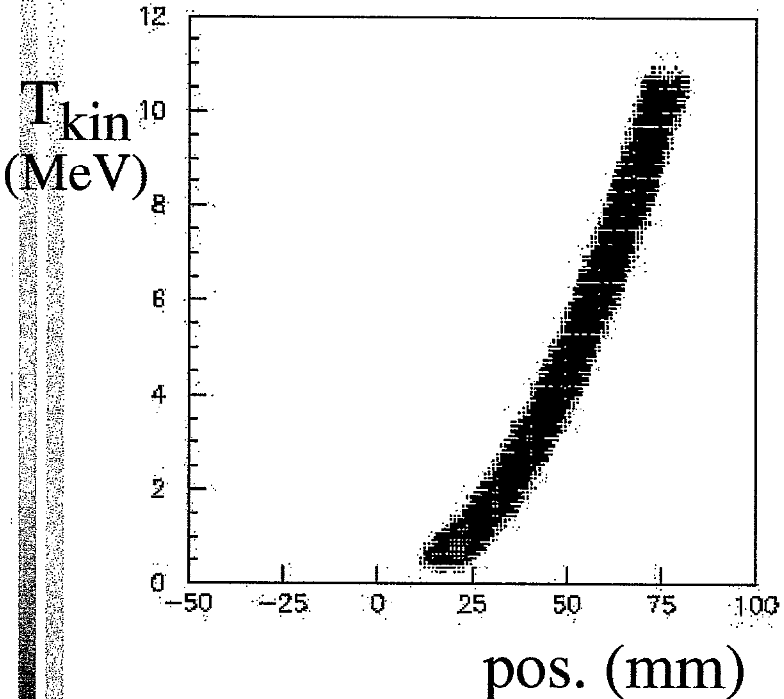
Setup



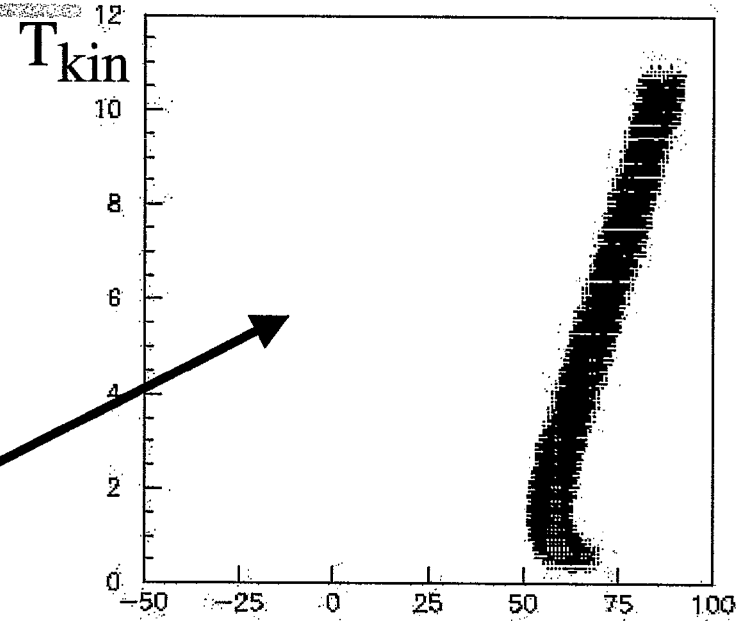


BROOKHAVEN NATIONAL LABORATORY

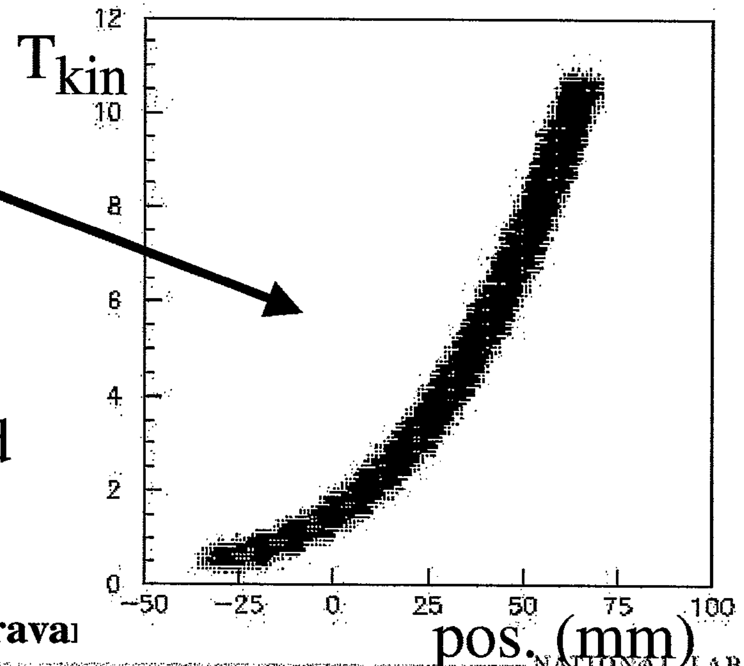
Recoil energy vs position



left



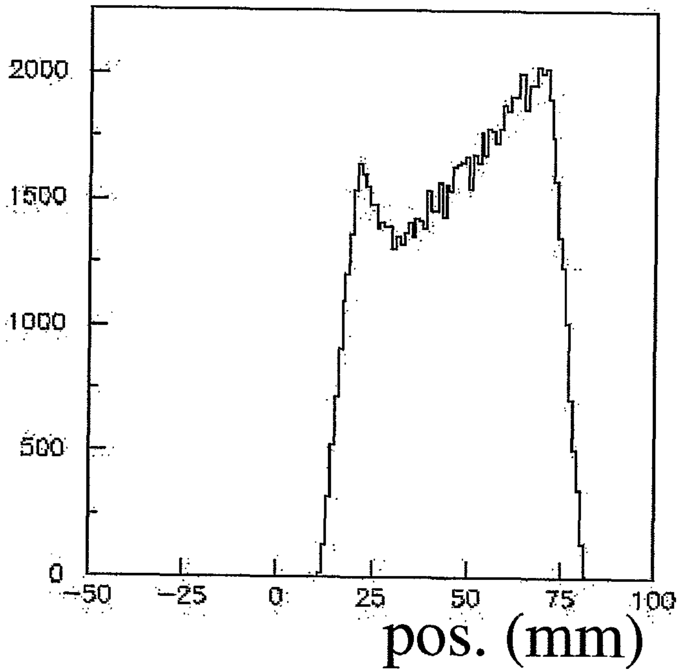
right



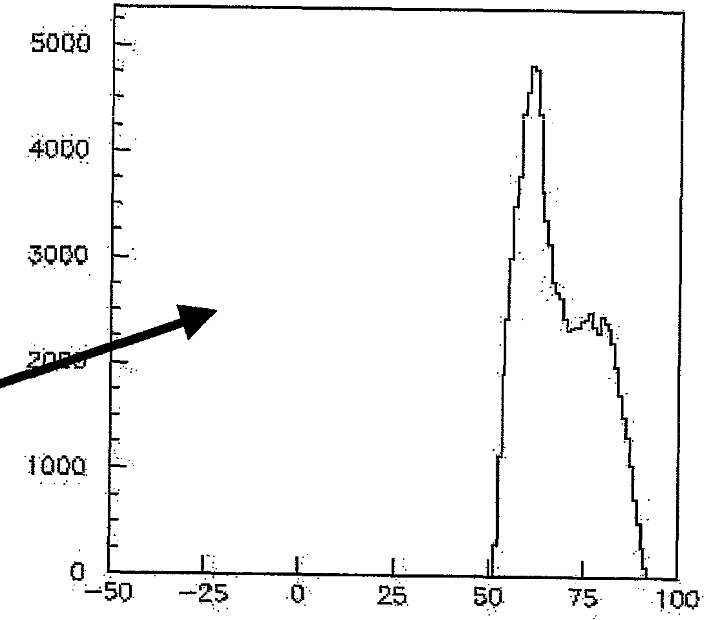
Effect of target holding field

Bdl ~ 0.005 – 0.01 Tm

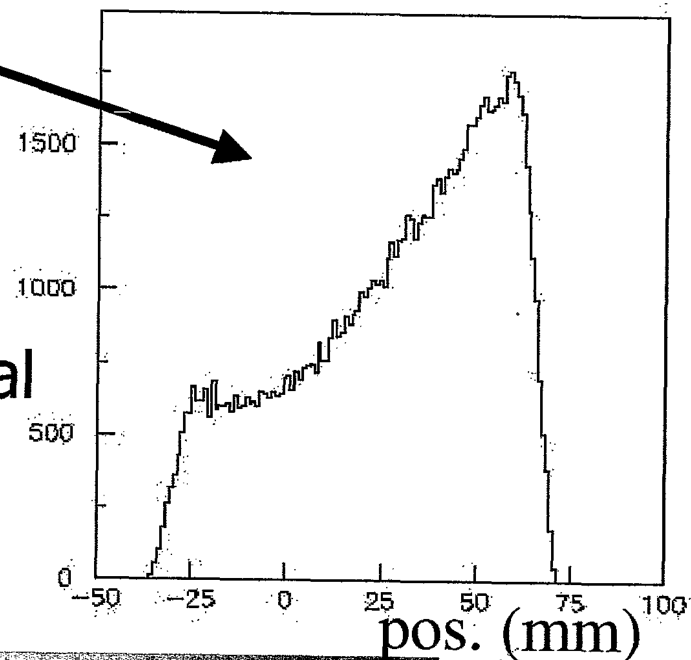
Recoil hit profiles @ 1 m



left



right



$acc^{\uparrow}_{left} \neq acc^{\downarrow}_{left}$

under P_{targ} reversal

$acc^{\uparrow}_{right} \neq acc^{\downarrow}_{right}$

Asymmetry Extraction

$$N_r^{\uparrow} = \sigma_0 \cdot L^{\uparrow} \cdot acc_r^{\uparrow}\left(1 + A_N P_{targ} \cos\varphi\right)$$

$$N_l^{\downarrow} = \ldots$$

$$\ldots$$

$$A_N = \frac{1}{\langle \cos\varphi \rangle} \cdot \frac{1}{\langle P_{targ} \rangle} \cdot \frac{\sqrt{N_l^{\uparrow} \cdot N_r^{\downarrow}} - \sqrt{N_r^{\uparrow} \cdot N_l^{\downarrow}}}{\sqrt{N_l^{\uparrow} \cdot N_r^{\downarrow}} + \sqrt{N_r^{\uparrow} \cdot N_l^{\downarrow}}}$$

81

Luminosities $L^{\uparrow\downarrow}$ and acceptances $acc_{l/r}$ cancels in the geometric mean provided that

$acc^{\uparrow}_{left} = acc^{\downarrow}_{left}$ and $acc^{\uparrow}_{right} = acc^{\downarrow}_{right}$

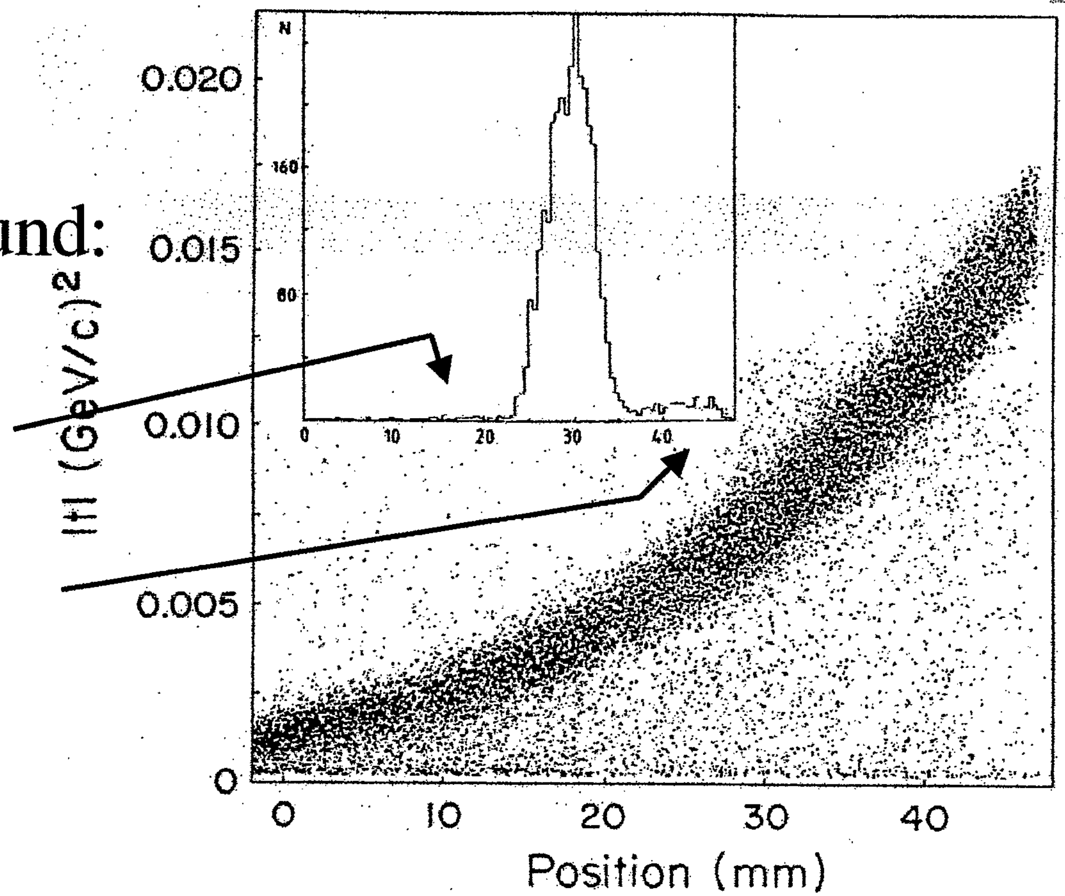
$\Rightarrow$ Introduce compensating field for target holding field ?

|t| vs pos. from UA6 → background

two sources of background:

a) beam gas interactions
< 1%

b) beam proton dissociation
< 1% below elastic peak



Background !? We have to live with it !

- Mainly two sources of background:
  - Beam gas interactions: at 10^{-9} torr, ~ 10^{7} atoms / cm^{3}
  - Proton dissociation $pp \to Xp$ dissociation

- Acceptable level of background:

$$A_N^{mes} = A_N - \left(A_N - A_N^{BG}\right) \cdot R \qquad R = \frac{N^{BG}}{N^S + N^{BG}}$$

$$\Delta A_N < 10^{-3} \quad \Rightarrow \quad \left|A_N - A_N^{BG}\right| \cdot R < 10^{-3}$$

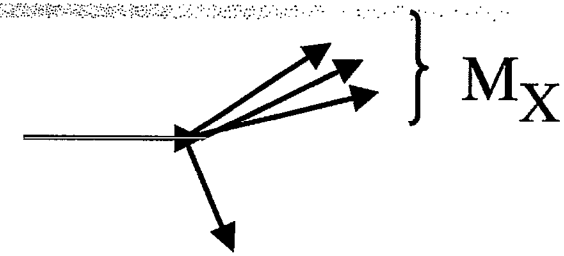
For $A_N^{BG} \sim 10\%$, $R \sim 1\%$ acceptable

- Otherwise Background Subtraction

For $R \sim 5\%$ (2%) $\to$ $\Delta R \sim 5\%$ (2%) OK for $A_N^{BG} \sim 30\%$

For $R \sim 2\%$ $\to$ $\Delta R \sim 10\%$ OK for $A_N^{BG} \sim 30\%$

$pp \to Xp$ Dissociation



Kinematically quite different from elastic process

$$\sin\vartheta_R^{Xp} = \frac{M_X^2 - m_p^2}{2p_b\sqrt{|t|}} + \sin\vartheta_R^{el} \quad > \quad \sin\vartheta_R^{el}$$

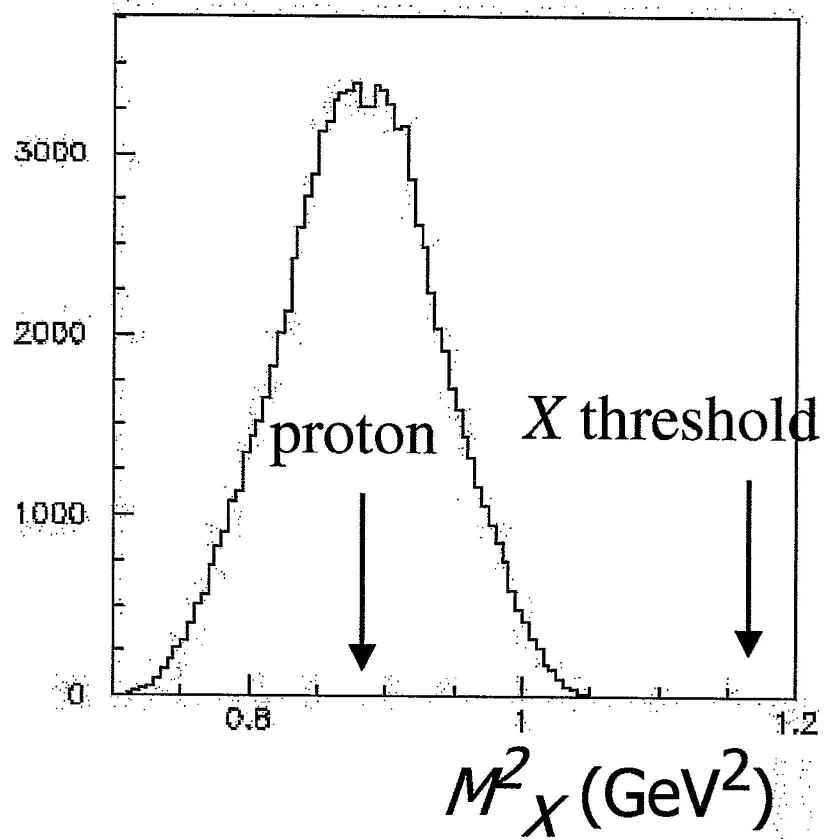
Suppresion of $pp \to Xp$ depends on how well one can reconstruct M_X

$$\Delta M_X^2 \approx 2p_b\sqrt{|t|}\,\Delta\vartheta_R$$

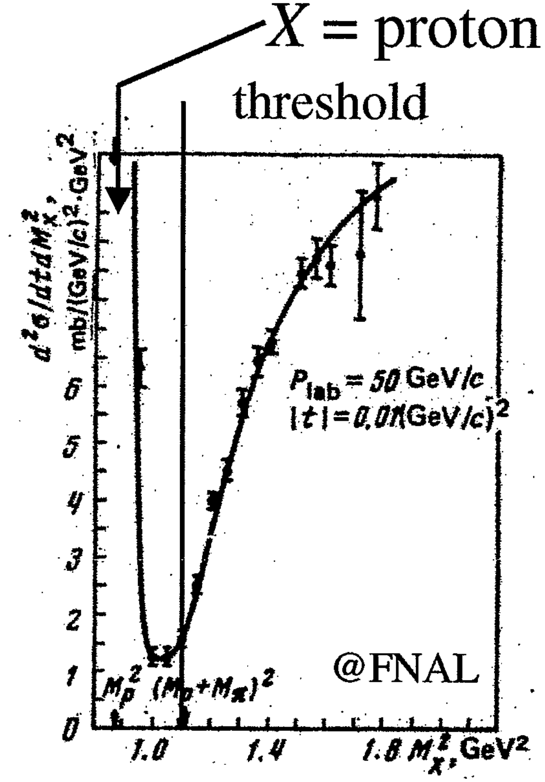
if $\Delta M_X^2 \ll (m_p + m_\pi)^2 - m_p^2$ OK

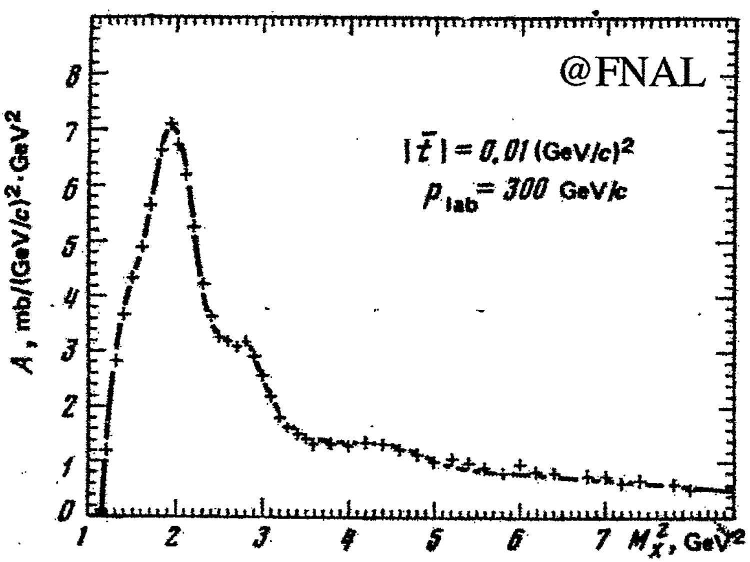
resolution on ϑ_R depends on distance from target and target long. ext.

NB at threshold coplanarity doesn't help !



$\Delta\sigma$ / dM^2_X



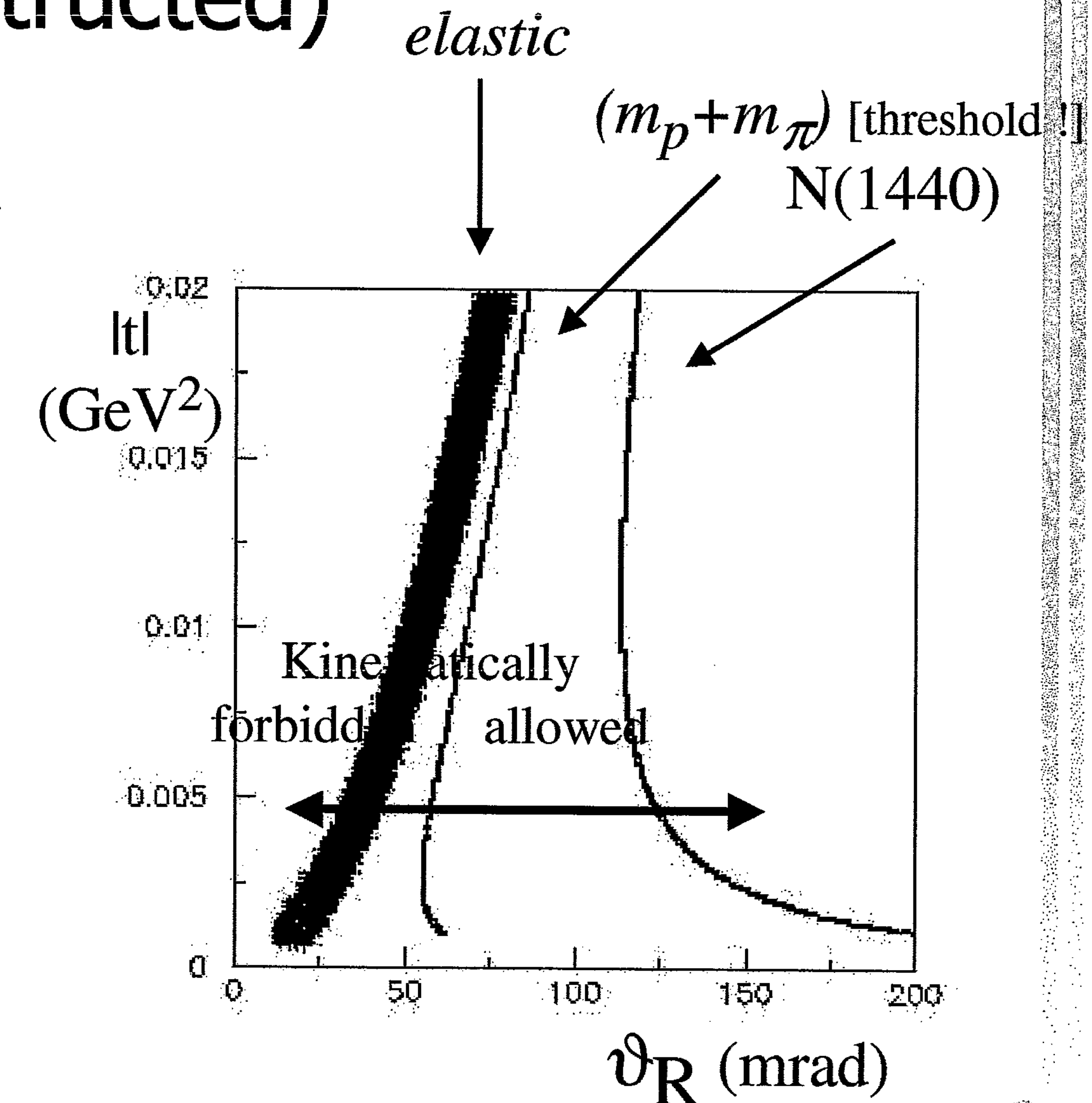


σ (*elastic*) ~ 100 x σ ($pp \rightarrow Xp$) at threshold !

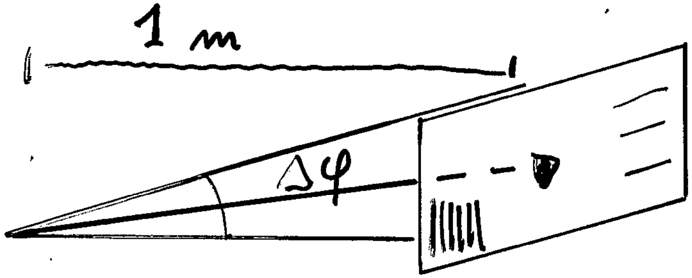
t vs ϑ_R (reconstructed)

$\Delta\vartheta_R$= targ. ext. / dist.
~ 5 mrad

$t = 2\, m_p\, T_{kin}$
$\Delta\, T_{kin} < 0.1$ MeV



Recoil Detector 2



requirements

- good energy resolution $\Delta E < 0.1$ MeV
- space resolution $\Delta x \sim$ mm
- time resolution $\Delta t \sim 1-2$ ns

$\Delta\varphi = 15^\circ \Rightarrow 80\,(h) \times 250\,(v)\ mm^2$

try 5 Si detectors of $80 \times 50\ mm^2$

$\Downarrow$

vertical segmentation ~ 3 mm

horizonthal segment: ~10 mm ⇒ $\delta\varphi = 10$ mrad

Thickness: 10 MeV p → ~1 mm (quite thick)

use instead stack of Si detectors

Conclusions

- Comfortable statistics (10^6 events in ~ 3 hours)
- $\Delta p_{beam} / p_{beam} < 5\%$
  $\Rightarrow \Delta A_N < 10^{-3}$ … feasible, but $\Delta p_{targ} / p_{targ} \sim 2\%$
- Background under control (not too bad !)
  - Roman pots not really necessary in CNI region
  - Roman pots essential for larger *t* (use *pp2pp*)
- Holding field $\Rightarrow acc^{\uparrow}_{left} \neq acc^{\downarrow}_{left}$ ($acc^{\uparrow}_{right} \neq acc^{\downarrow}_{right}$)
  - compensating field?
- Recoil detector based on existing technology
- Don't forget: also very interesting physics !!!

ep-POLARIMETER FOR RHIC REVISITED

F. Meissner, LBNL, November 2001

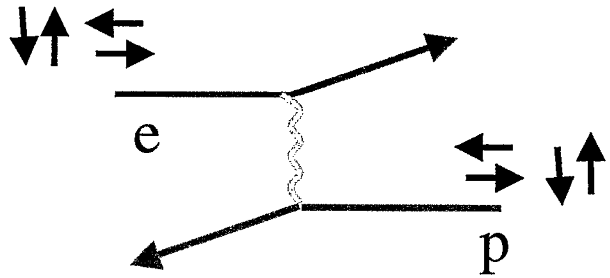
for
RHIC Spin Collaboration Meeting VI (Part 2)
RIKEN BNL Research Center

ep-Polarimeter for RHIC

Revisited

F. Meissner, LBNL, NOV 2001

Use spin asymmetry in elastic electron proton scattering for an absolute polarization measurement.



- Fixed target:
  p-beam on electron at rest
  gas jet target / free electron target
- (Anti)-Collider
  use electron cooler for polarimeter.

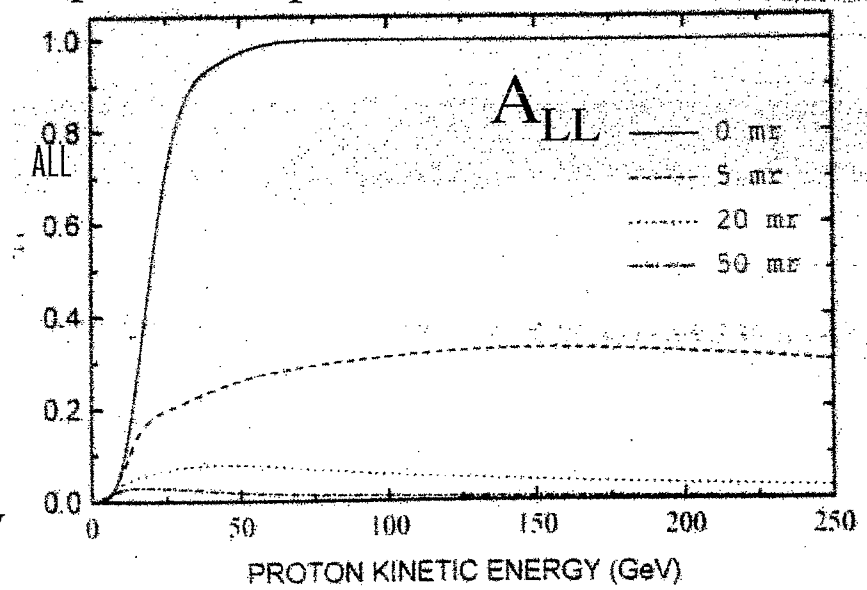
- Calculable
- Large cross sections and asymmetries
- Many data

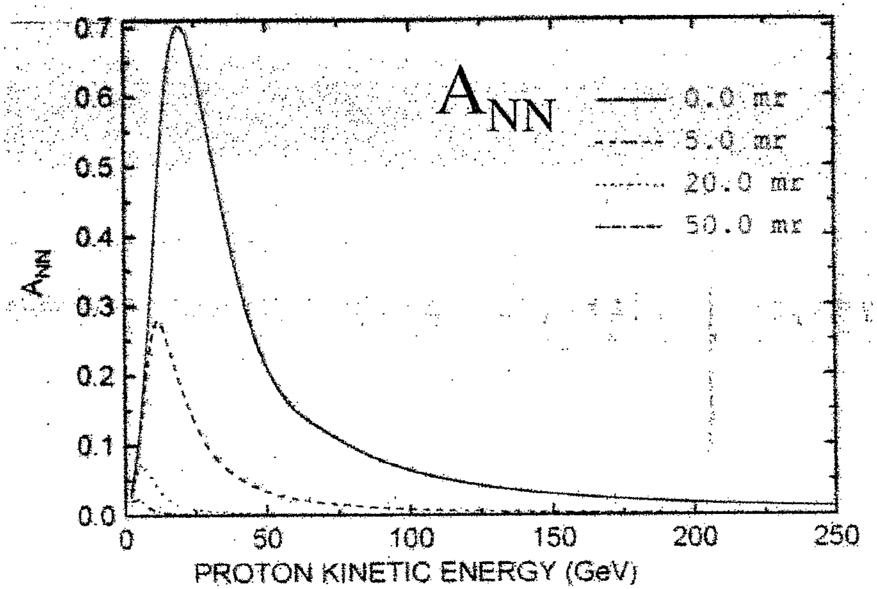
Glavanakov et.al NIM A318 (1996) 275 and Pis'ma Zh Eksp.Teor.Fiz. 65 No.2 (1997) 123; Nikolenko et.al (Spin96); Igo(Spin 96)

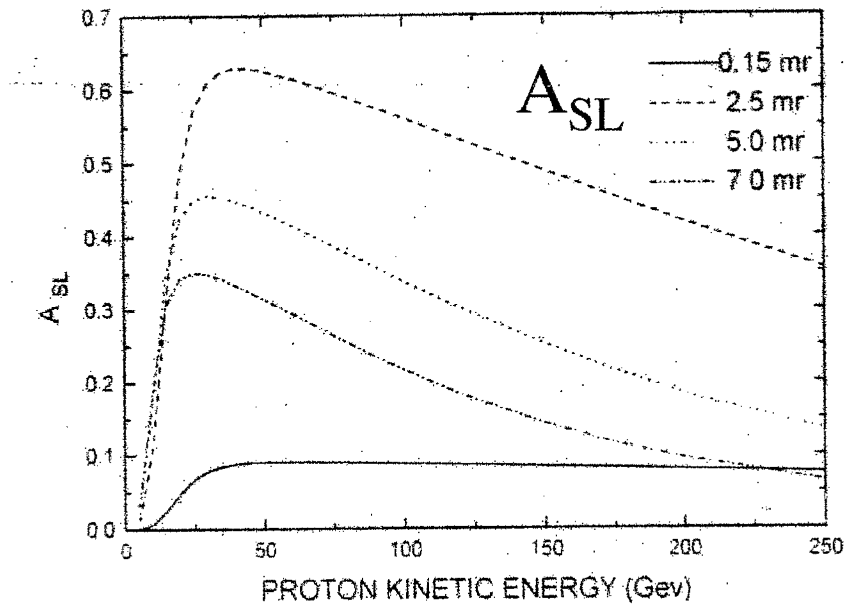
Asymmetries

(p on fixed proton, Glavanakov et.al)

- A_{LL}-expensive
- A_{NN}-small (<1%) in the interesting kinematics
- A_{SL}~0.1-0.4
- A_N single spin l-r asymmetry
  Transv. pol. proton on unpol. electron
  Mott-Schwinger, very low Q^2







Fixed Target

Electrons at rest from gas jet target

Particles bend out for detection

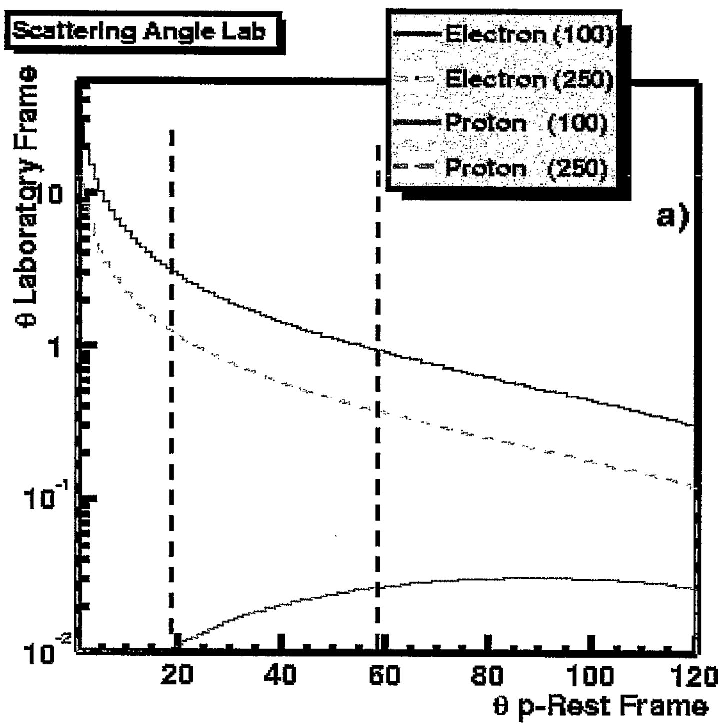
Background from pp ?!

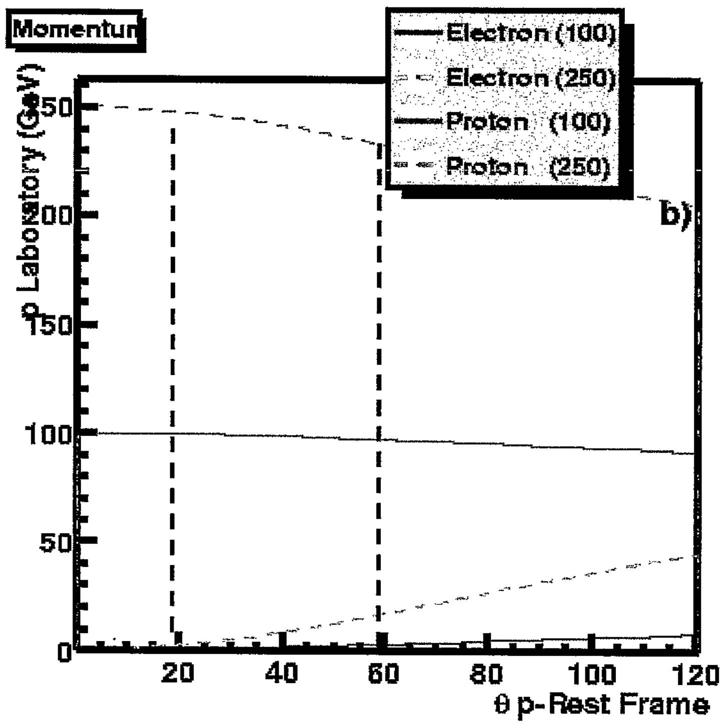
Assume: 10^11 atms/cm^2

Pe=1. Pb=0.5 ANN~0.01 ASL~0.1

Free electron target ? – No background !

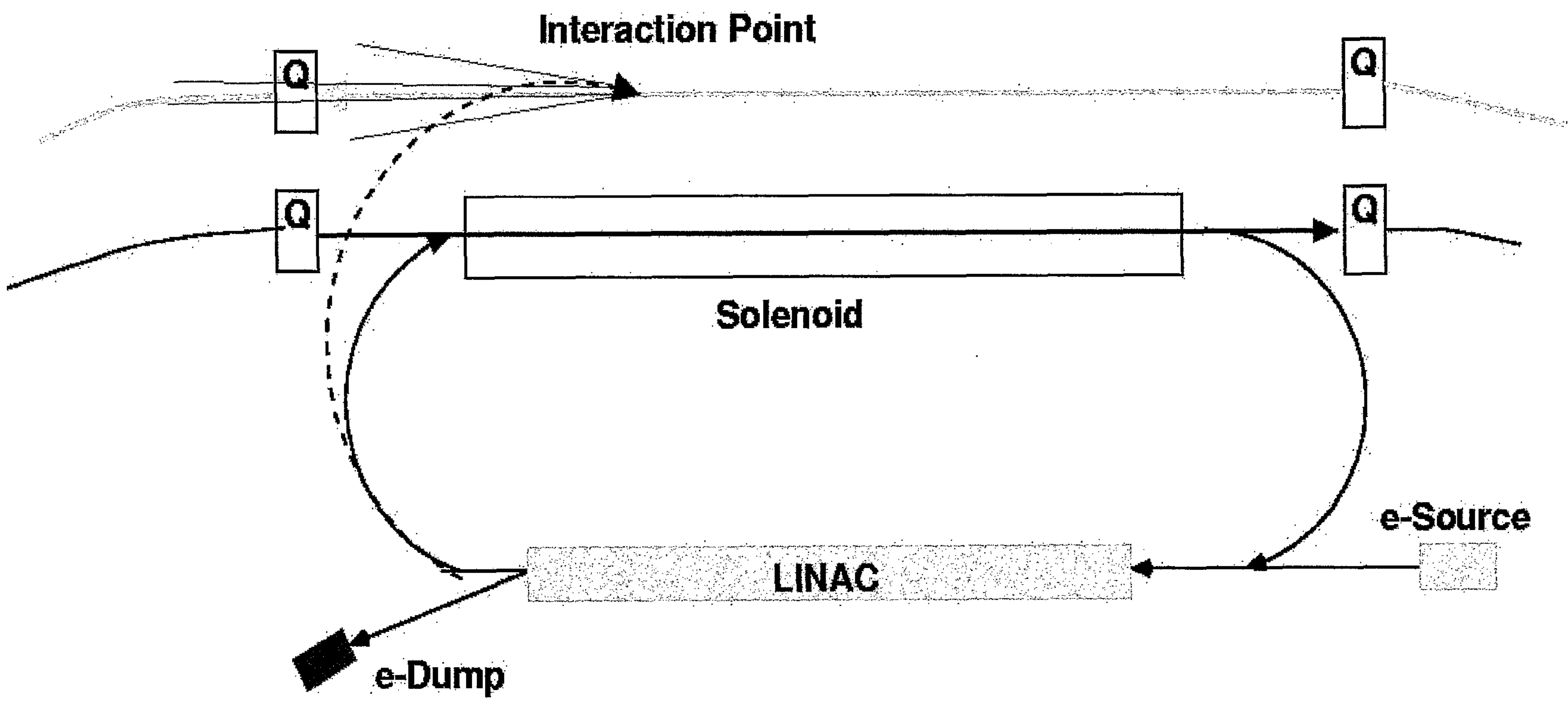
Pp (GeV)	100	250
X-section (mb) $20<\theta_{p\text{-rest}}<60$	1.3	0.2
Hz	30	12
dA_{NN}/A_{NN} (10hrs)	~0.2	~0.3
dA_{SL}/A_{SL} (10hrs)	~0.02	~0.03



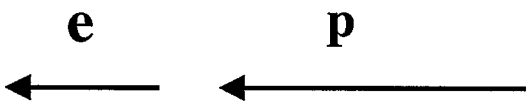


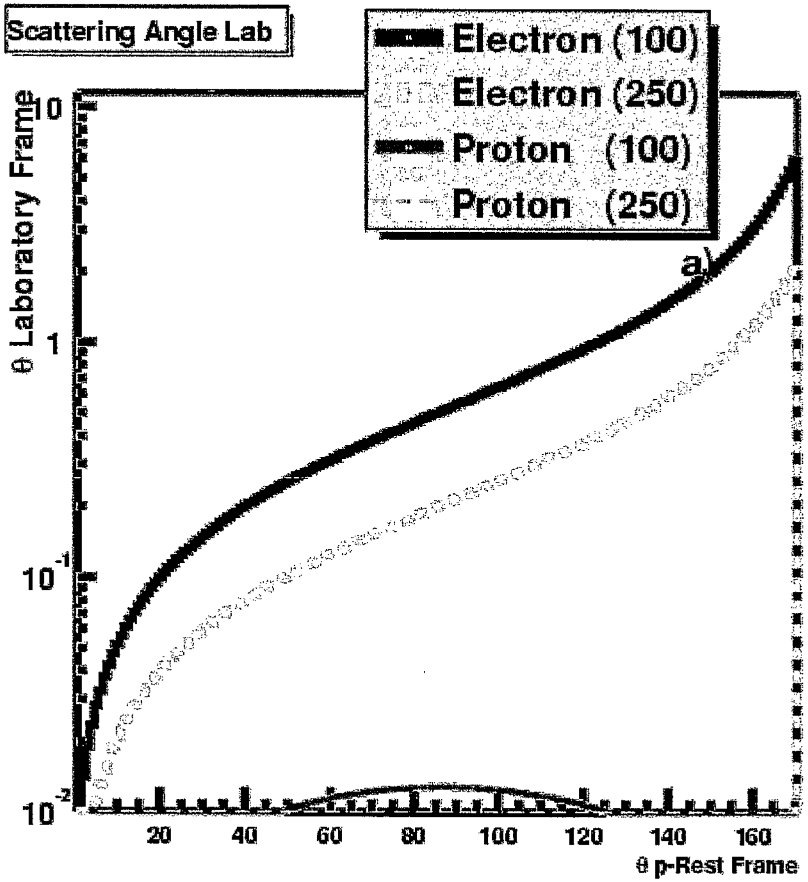
Electron Cooler

- Electron parallel to Au beam in solenoid
- Ee~50MeV; Ie ~100mA
- Not used as cooler for protons, tune kinematics with Ee
- Can put polarimeter option into design
- Measure A_N, A_{SL}



Anti-Collider





(Glavanakov et.al)

- Electrons parallel to p-beam
- Ee~2Mev
- Large x-section and asymmetries
- Low Q2

⇒Small scattering angles and momentum change w.r.t. incoming part.

⇒Difficult to detect

Collider

Assume:

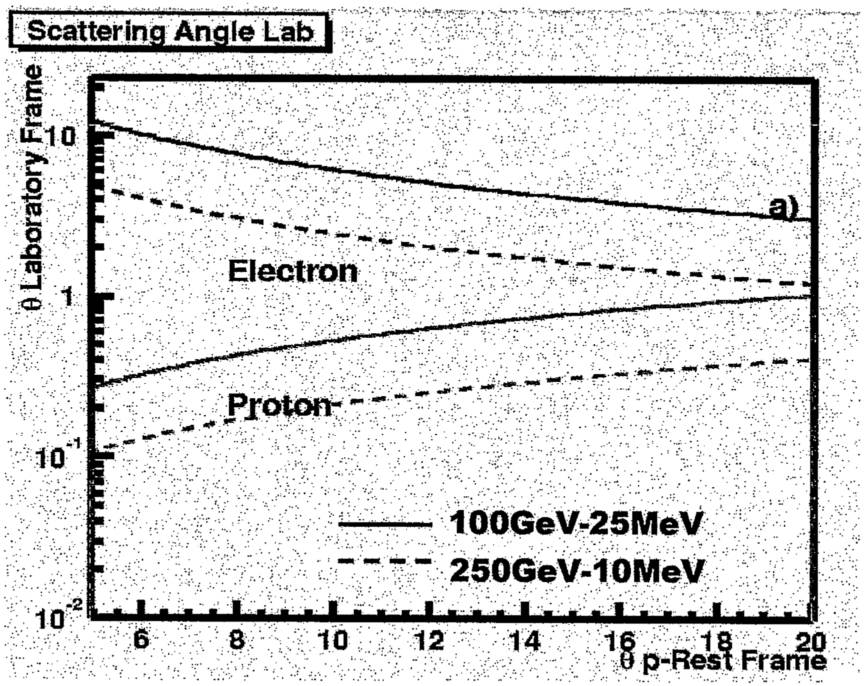
- Acceptance: 2π x 0.1-10 deg
- Luminosity: 2*10^31 $cm^{-2}s^{-1}$

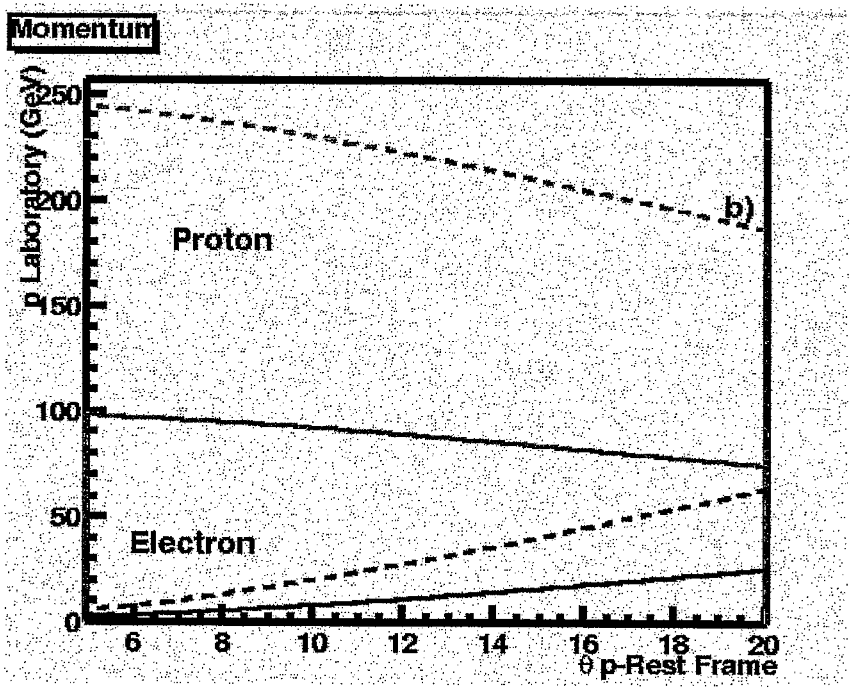
1% EIC, 10% pp Ie ~50mA (15mA)

- Polarizations: P_B=0.5, P_e=1

ASL measurable with 2% statistical uncertainty within a 10hr fill

Pp - Pe (GeV)	100-0.025 250-0.010
X-section (mb) $5<\theta_{p\text{-}rest}<20$	0.004
Hz	10
dA_{NN}/A_{NN} (10hrs)	~0.2
dA_{SL}/A_{SL} (10hrs)	~0.02





Summary

Ep from Gas Target:

-A_N, A_{NN} only

- pp-background, kinematics tricky

+comes with the target

Free electron target ? Measure A_N

Cooler

+if cooler is built see were we are in terms of pol. measurements

A_N, A_{SL} good options

anti-collider: large analyzing power but unfavorable kinematics

collider: favoured setup, needs ‘cross over’ e-beam

Polarimeter option could be included in the cooler design.

RHIC SPIN MEETING ~ DISCUSSION

G. Bunce, November 15, 2001

for
RHIC Spin Collaboration Meeting VI (Part 2)
RIKEN BNL Research Center

15 Nov. 01, G. Bunce

RHIC Spin Meeting---Discussion

We discussed each of the proposed polarimeters:

1. AGS proton-carbon CNI polarimeter. First concern---calibration over the AGS energy range. We can calibrate at AGS injection energy at COSY. We can use the present AGS polarimeter to do the calibration (with some difficulties, since the pp polarimeter uses low intensity and debunched beam). The issue is to get a calibration good to 10-15%. With that, the AGS CNI polarimeter would be a very attractive diagnostic tool to improve and check AGS polarization. It is particularly attractive to measure the polarization on the ramp, since we would not then need to sit on a flattop to make measurements, which can cause polarization loss from weak resonances. This is a very attractive polarimeter. A question came up on whether we would want to do a vertical scan for polarization (which would mean 45 degree detectors, rather than only left-right).

2. AGS experiment to improve knowledge of RHIC polarization. Measure the analyzing power of pC CNI by measurement of pp elastic scattering from a polarized target in an extracted AGS beamline. If the analyzing power can be measured to 5% it would represent an independent measurement, to be compared with results from the internal polarized jet target at RHIC. This was first suggested as a means of getting a better polarization normalization for RHIC, in advance of the installation of the jet target for 2004. If, however, this can provide a very good measurement, it may be useful even if done after the jet. There is a concern that the cost and effort would be a large diversion from the jet. We have decided to look into it further.

3. RHIC polarized jet. This is the gold standard for RHIC polarization. One issue which came up (from Anatoli Zelinski) was whether a holding field is necessary. This will be studied. Several of us met after the RHIC spin meeting to go over details for the jet. The goal is to have the jet in place for the 2004 RHIC spin running.

4. An ep polarimeter using A_{SL}, with L for electrons was discussed by Falk Meissner.

RHIC Spin Collaboration Meeting VI (Part 2)
November 15, 2001
RIKEN BNL Research Center

LIST OF REGISTERED PARTICIPANTS

NAME	AFFILIATION AND ADDRESS	E-MAIL ADDRESS
Christine Aidala	BNL Physics, Bldg. 510C Upton, N.Y. 11973-5000	caidala@bnl.gov
Peter D. Barnes	Los Alamos National Laboratory MS H846 P-25 Los Alamos, N.M. 87545	pdbarnes@lanl.gov
Les Bland	BNL Physics, Bldg. 510A Upton, N.Y. 11973-5000	bland@bnl.gov
Alessandro Bravar	BNL Physics, Bldg. 510A Upton, N.Y. 11973-5000	bravar@bnl.gov
David S. Brown	New Mexico State University P.O. Box 754 Upton, N.Y. 11973-5000	brownds@rcf2.rhic.bnl.gov
Stephen Bueltmann	BNL Physics, Bldg. 510A Upton, N.Y. 11973-5000	bueltmann@bnl.gov
Gerry Bunce	RBRC / BNL Physics, Bldg. 510A Upton, N.Y. 11973-5000	bunce@bnl.gov
Mike Butler	DOE Bldg. 464 Brookhaven National Laboratory Upton, N.Y. 11973-5000	butler1@bnl.gov
Abhay L. Deshpande	RBRC Physics, Bldg. 510A Upton, N.Y. 11973-5000	abhay@bnl.gov
Douglas E. Fields	RBRC / University of New Mexico Bldg. 510A / 800 Yale NE Upton, N.Y. / Albuquerque, NM 11973-5000 / 87131	fields@unm.edu
Ron Gill	BNL Physics, Bldg. 510 Upton, N.Y. 11973-5000	rongill@bnl.gov
Yuji Goto	RBRC Physics, Bldg. 510A Upton, N.Y. 11973-5000	goto@bnl.gov
Wlodek Guryn	BNL Physics, Bldg. 510C Upton, N.Y. 11973-5000	guryn@bnl.gov
Willy Haeberli	University of Wisconsin Physics Dept. 1525 Sterling Hall 475 N. Charter St. Madison, WI. 53706	willy@haeberli.wm
Haixin Huang	BNL Bldg. 911B Upton, N.Y. 11973-5000	huanghai@bnl.gov

RHIC Spin Collaboration Meeting VI (Part 2)
November 15, 2001
RIKEN BNL Research Center

LIST OF REGISTERED PARTICIPANTS

NAME	AFFILIATION AND ADDRESS	E-MAIL ADDRESS
Vernon Hughes	Yale University Physics Department P.O. Box 208121 New Haven, CT. 06520-8121	hughes@hepmail.yale.edu
George Igo	BNL / UCLA Bldg. 902B ~ STAR Upton, N.Y. 11973-5000	igo@physics.ucla.edu
Osamu Jinnouchi	RBRC / RIKEN Physics, Bldg. 510A Upton, N.Y. 11973-5000	josamu@bnl.gov
Joanna Kiryluk	UCLA Physics & Astronomy 405 Hilgard Ave. Los Angeles, CA 90095-1547	joanna@physics.ucla.edu
Ming X. Liu	Los Alamos National Lab / BNL Bldg. 902C M21 Upton, N.Y. 11973-5000	mliu@lanl.gov
Thomas Ludlam	BNL Bldg. 510 – Physics Dept. Upton, N.Y.. 11973-5000	ludlam@bnl.gov
Waldo Mackay	BNL - CAD Bldg. 1005S Upton, N.Y. 11973-5000	mackay@bnl.gov
Yousef Makdisi	BNL Bldg. 911B Upton, N.Y. 11973-5000	makdisi@bnl.gov
Falk Meissner	Lawrence Berkeley National Lab MS 70-319 1 Cyclotron Rd. Berkeley, CA 94720	FMeissner@lbl.gov
Akio Ogawa	BNL – STAR / Penn State Univ. Physics, Bldg. 510 Upton, N.Y. 11973-5000	akio@bnl.gov
Jeff Porter	BNL Bldg. 510A – Physics Upton, N.Y. 11973-5000	porter@bnl.gov
Greg Rakness	Indiana University Cyclotron Facility 2401 Milo B Sampson Ln. Bloomington, IN 47408	rakness@iucf.indiana.edu
Naohito Saito	RBRC / RIKEN Physics, Bldg. 510A Upton, N.Y. 11973-5000	saito@bnl.gov
Mark Sakitt	BNL Bldg. 197C Upton, N.Y. 11973-5000	sakitt@bnl.gov
Hiroki Sato	RBRC / Kyoto University Physics, Bldg. 510A Upton, N.Y. 11973-5000	satohiro@bnl.gov
Hal Spinka	Argonne National Laboratory Bldg. 362 – HEP Argonne, IL 60439	hms@hep.anl.gov

RHIC Spin Collaboration Meeting VI (Part 2)
November 15, 2001
RIKEN BNL Research Center

LIST OF REGISTERED PARTICIPANTS

NAME	AFFILIATION AND ADDRESS	E-MAIL ADDRESS
Edward J. Stephenson	Indiana University Cyclotron Facility 2401 Milo B. Sampson Lane Bloomington, IN 47408	stephens@iucf.indiana.edu
Bernd Surrow	BNL Bldg. 510, Physics Dept. Upton, N.Y. 11973-5000	surrow@bnl.gov
Atsushi Taketani	RBRC Physics, Bldg. 510A Upton, N.Y. 11973-5000	taketani@bnl.gov
Kiyoshi Tanida	RIKEN Hirosawa, Wako, Saitama 351-0198 Japan	tanida@rarfaxp.riken.go.jp
Michael J. Tannenbaum	BNL Physics, Bldg. 510C Upton, N.Y. 11973-5000	mjt@bnl.gov
Junji Tojo	RBRC / Kyoto University Physics, Bldg. 510A Upton, N.Y. 11973-5000	tojo@bnl.gov
Hisayuki Torii	RBRC / Kyoto University Physics, Bldg. 510A Upton, N.Y. 11973-5000	htorii@bnl.gov
Robert E. Tribble	Texas A&M University Cyclotron Institute College Station, TX 77843	tribble@comp.tamu.edu
David G. Underwood	Argonne National Laboratory Bldg. 362 – HEP Argonne, IL. 60439	dgu@hep.anl.gov
Steven E. Vigdor	Indiana University Dept. of Physics Swain Hall West Bloomington, IN 47405	vigdor@iucf.indiana.edu
Yiqun Wang	BNL / University of Texas at Austin Bldg. 902C room M6 Upton, N.Y. 11973-5000	yqwang@rcf.rhic.bnl.gov
Yasushi Watanabe	RIKEN Hirosawa, Wako, Saitama 351-0198 Japan	watanaby@riken.go.jp
John W. Watson	Kent State University Dept. of Physics Kent, OH 44242	jwatson@cnr5.physics.kent.edu
Charles A. Whitten Jr.	UCLA Department of Physics 405 Hilgard Avenue Los Angeles, CA 90095	whitten@physics.ucla.edu
Thomas S. Wise	University of Wisconsin Physics Dept. 1525 Sterling Hall 475 N. Charter St. Madison, WI. 53706	wise@uwnuc0.physics.wisc.edu
Scott W. Wissink	Indiana University Cyclotron Facility 2401 Milo B. Sampson Lane Bloomington, IN 47408	wissink@iucf.indiana.edu

RHIC Spin Collaboration Meeting VI (Part 2)
November 15, 2001
RIKEN BNL Research Center

LIST OF REGISTERED PARTICIPANTS

NAME	AFFILIATION AND ADDRESS	E-MAIL ADDRESS
Jeff Wood	UCLA PO Box 516 Upton, N.Y. 11973-5000	wood@physics.ucla.edu
Anatoli Zelenski	BNL – CAD Bldg. 930 Upton, N.Y. 11973-5000	zelenski@bnl.gov

RIKEN BNL Research Center

RHIC Spin Collaboration Meeting VI (Part 2)

November 15, 2001

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

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

Opening Session

09:00 - 09:15	Summary of RSC Meeting VI – Part I / Goals of Part II...	N. Saito
09:15 - 09:50	Machine Issues for RHIC Spin (Run 3 & Beyond)......... *(spin rotators/flipper; snake/rotator spares; AGS partial snake)*	W. MacKay
09:50 – 10:00	Discussion..	All
10:00 - 10:20	Run 3 Polarization Calibration................................	G. Igo
10:20 - 10:40	Run 3 Polarization Calibration................................	D. Fields
10:40 - 11:00	Discussion..	All

11:00 – 13:00 Lunch (Seminar Room unavailable ~ Particle Physics Seminar)

Afternoon Session

13:00 - 13:15	Introduction to Polarization Calibration......................	Y. Makdisi
13:15 - 14:00	Final Polarization Calibration: Pol'd Gas Jet...............	T. Wise
14:00 - 14:30	Simulation Studies for Recoil Detectors......................	E. Stephenson
14:30 - 15:00	Break	
15:00 - 15:30	Additional Simulation Studies..................................	S. Bravar
15:30 - 16:30	Discussion	G. Bunce
16:30 - 17:00	Summary .... *(includes summary of action items from present meeting; subsequent meeting plans; discussion at future meeting of future directions of RSC)*	L. Bland

---

Additional RIKEN BNL Research Center Proceedings:

Volume 37 – RHIC Spin Collaboration Meeting VI (Part 2) – BNL-
Volume 36 – RHIC Spin Collaboration Meeting VI – BNL-52642
Volume 35 – RIKEN Winter School – Quarks, Hadrons and Nuclei – QCD Hard Processes and the Nucleon Spin – BNL-52643
Volume 34 – High Energy QCD: Beyond the Pomeron – BNL-52641
Volume 33 – Spin Physics at RHIC in Year-1 and Beyond – BNL-52635
Volume 32 – RHIC Spin Physics V – BNL-52628
Volume 31 – RHIC Spin Physics III & IV Polarized Partons at High Q^2 Region – BNL-52617
Volume 30 – RBRC Scientific Review Committee Meeting – BNL-52603
Volume 29 – Future Transversity Measurements – BNL-52612
Volume 28 – Equilibrium & Non-Equilibrium Aspects of Hot, Dense QCD – BNL-52613
Volume 27 – Predictions and Uncertainties for RHIC Spin Physics & Event Generator for RHIC Spin Physics III – Towards Precision Spin Physics at RHIC – BNL-52596
Volume 26 – Circum-Pan-Pacific RIKEN Symposium on High Energy Spin Physics – BNL-52588
Volume 25 – RHIC Spin – BNL-52581
Volume 24 – Physics Society of Japan Biannual Meeting Symposium on QCD Physics at RIKEN BNL Research Center – BNL-52578
Volume 23 – Coulomb and Pion-Asymmetry Polarimetry and Hadronic Spin Dependence at RHIC Energies – BNL-52589
Volume 22 – OSCAR II: Predictions for RHIC – BNL-52591
Volume 21 – RBRC Scientific Review Committee Meeting – BNL-52568
Volume 20 – Gauge-Invariant Variables in Gauge Theories – BNL-52590
Volume 19 – Numerical Algorithms at Non-Zero Chemical Potential – BNL-52573
Volume 18 – Event Generator for RHIC Spin Physics – BNL-52571
Volume 17 – Hard Parton Physics in High-Energy Nuclear Collisions – BNL-52574
Volume 16 – RIKEN Winter School - Structure of Hadrons - Introduction to QCD Hard Processes – BNL-52569
Volume 15 – QCD Phase Transitions – BNL-52561
Volume 14 – Quantum Fields In and Out of Equilibrium – BNL-52560
Volume 13 – Physics of the 1 Teraflop RIKEN-BNL-Columbia QCD Project First Anniversary Celebration – BNL-66299
Volume 12 – Quarkonium Production in Relativistic Nuclear Collisions – BNL-52559
Volume 11 – Event Generator for RHIC Spin Physics – BNL-66116
Volume 10 – Physics of Polarimetry at RHIC – BNL-65926
Volume 9 – High Density Matter in AGS, SPS and RHIC Collisions – BNL-65762
Volume 8 – Fermion Frontiers in Vector Lattice Gauge Theories – BNL-65634

Additional RIKEN BNL Research Center Proceedings:

Volume 7 – RHIC Spin Physics – BNL-65615

Volume 6 – Quarks and Gluons in the Nucleon – BNL-65234

Volume 5 – Color Superconductivity, Instantons and Parity (Non?)-Conservation at High Baryon Density – BNL-65105

Volume 4 – Inauguration Ceremony, September 22 and Non -Equilibrium Many Body Dynamics – BNL-64912

Volume 3 – Hadron Spin-Flip at RHIC Energies – BNL-64724

Volume 2 – Perturbative QCD as a Probe of Hadron Structure – BNL-64723

Volume 1 – Open Standards for Cascade Models for RHIC – BNL-64722

For information please contact:

Ms. Pamela Esposito
RIKEN BNL Research Center
Building 510A
Brookhaven National Laboratory
Upton, NY 11973-5000 USA

Phone: (631) 344-3097
Fax: (631) 344-4067
E-Mail: pesposit@bnl.gov

Ms. Tammy Heinz
RIKEN BNL Research Center
Building 510A
Brookhaven National Laboratory
Upton, NY 11973-5000 USA

Phone: (631) 344-5864
Fax: (631) 344-2562
E-Mail: theinz@bnl.gov

Homepage: http://quark.phy.bnl.gov/www/riken.html
http://penguin.phy.bnl.gov/www/riken.html

RIKEN BNL RESEARCH CENTER

RHIC Spin Collaboration Meeting VI (Part 2)

November 15, 2001

Li Keran

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

Speakers:

L. Bland	S. Bravar	G. Bunce	D. Fields	G. Igo
W. Mackay	Y. Makdisi	N. Saito	E. Stephenson	T. Wise

Organizers: Les Bland & Naohito Saito