STAR Physics Program

STAR Five-year Beam Use Request for FY09-13

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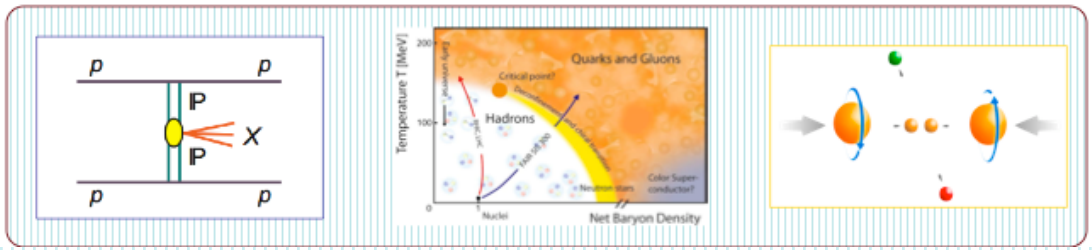


Outline

1) Introduction

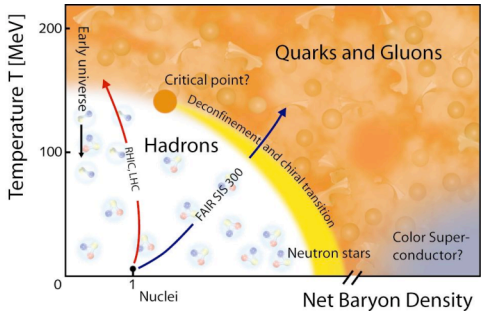
2) STAR Physics Results
- **Spin:**
- Heavy Ion:
- Run 8 performance:

3) STAR Hardware Upgrades
- DAQ1000:
- MRPC TOF:

4) BUR for Runs 09 - 13
- **Runs 9 -10:**
- Runs 11 - 13:

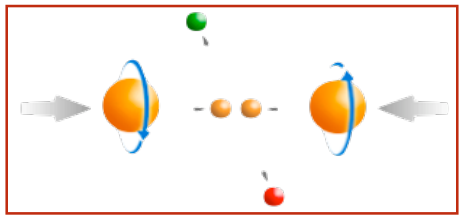
5) Summary

STAR Physics Focus at the QCD Lab



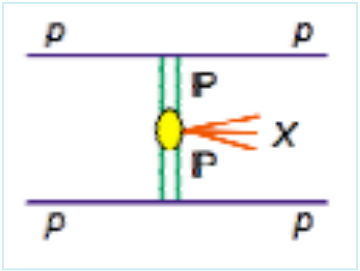
1) Heavy-ion program
   - Study ***medium properties, EoS***
   - pQCD in hot and dense medium

2) RHIC beam energy scan
   - Search for ***critical point***
   - Chiral symmetry restoration



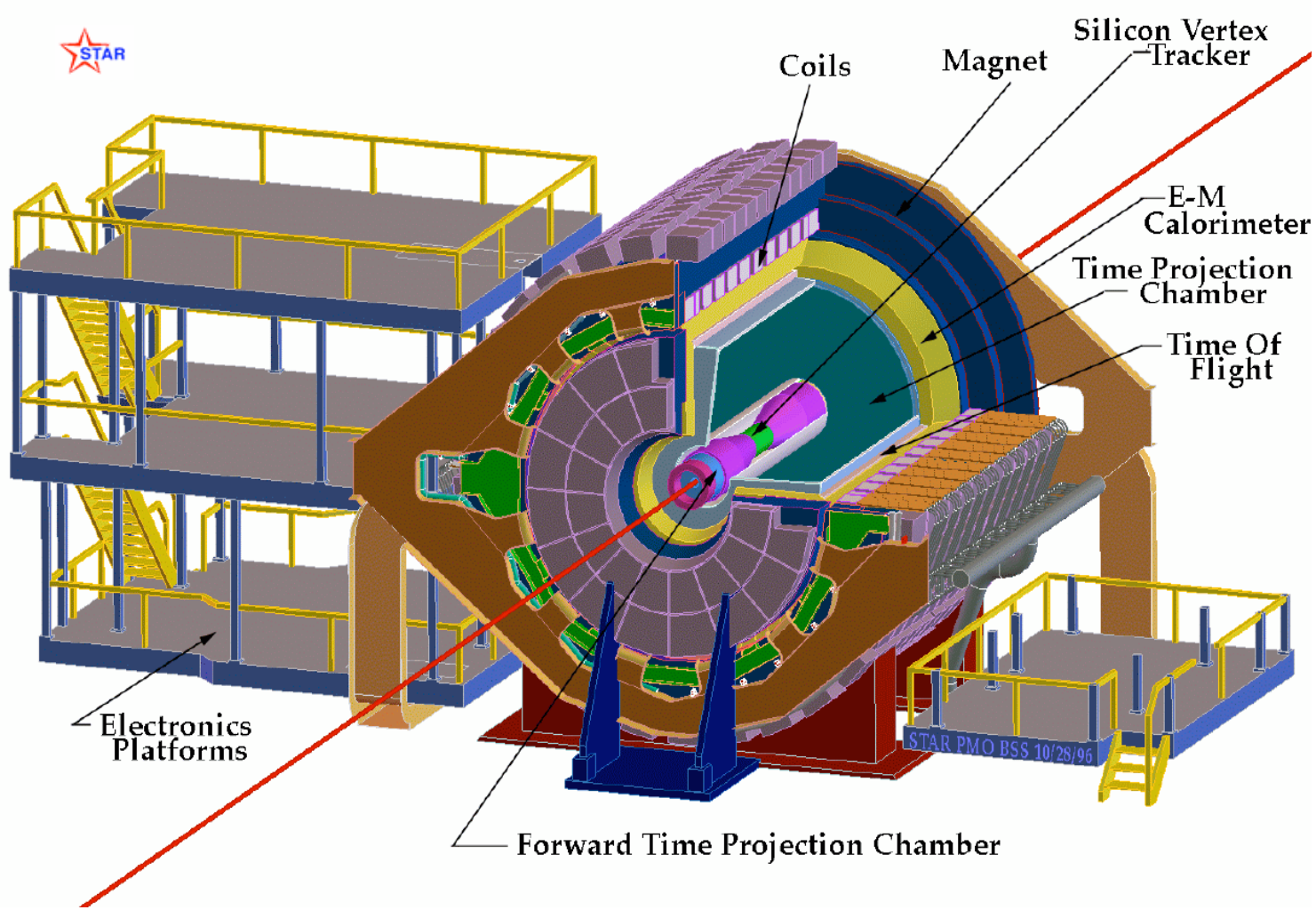
1) Longitudinal and transverse spin programs
   - Study ***proton intrinsic properties***

2) Forward programs
   - Study low-x properties and search for ***CGC***

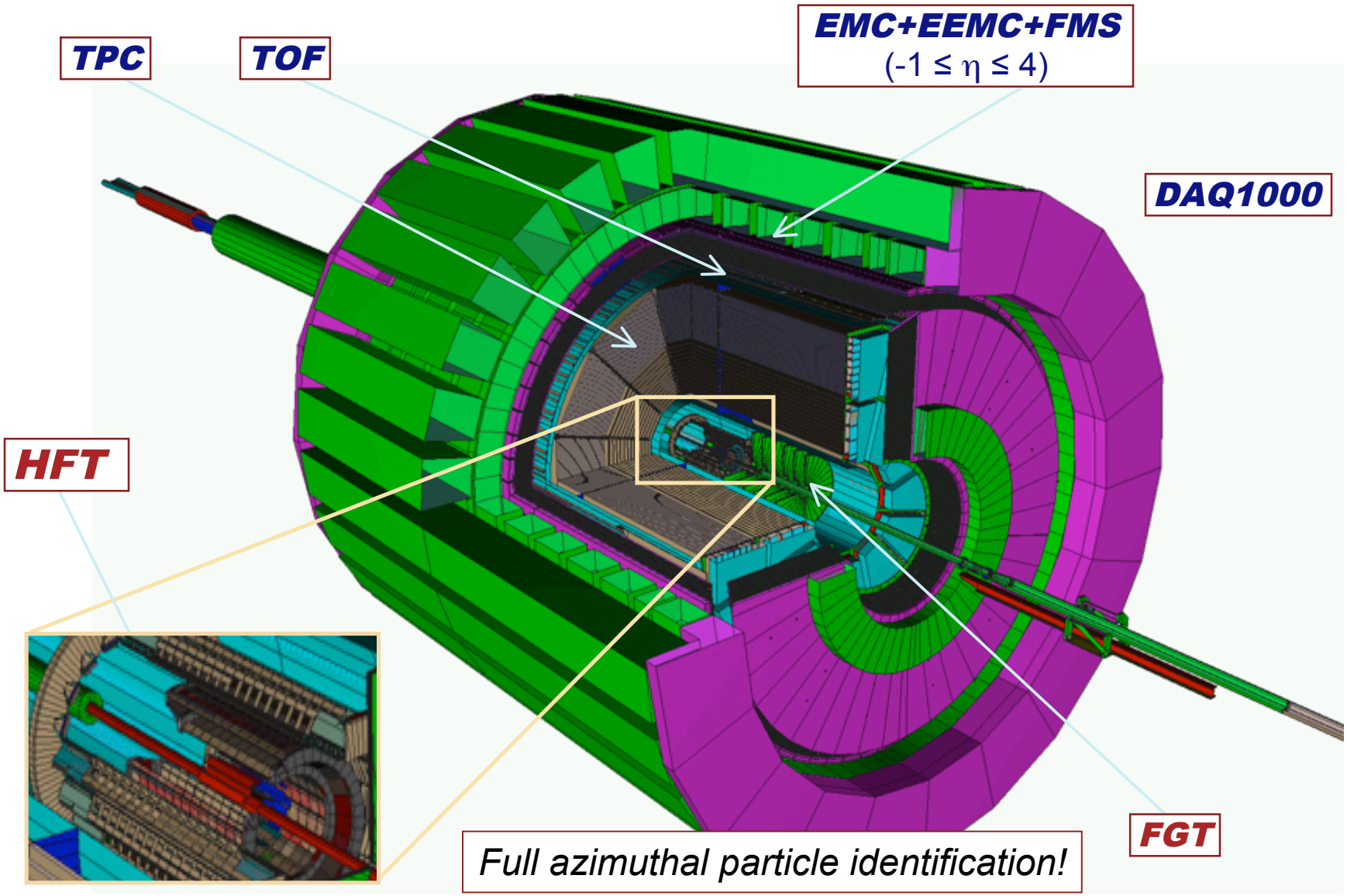


Tagged forward protons
- Study elastic and inelastic processes
- Investigate ***gluonic exchanges*** and search for ***gluonic matter***

STAR Detector



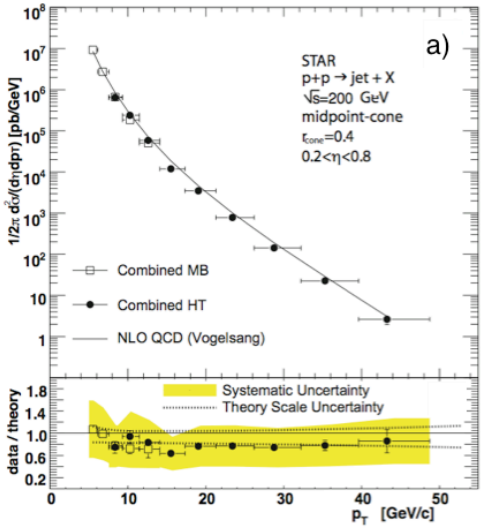
STAR Detectors



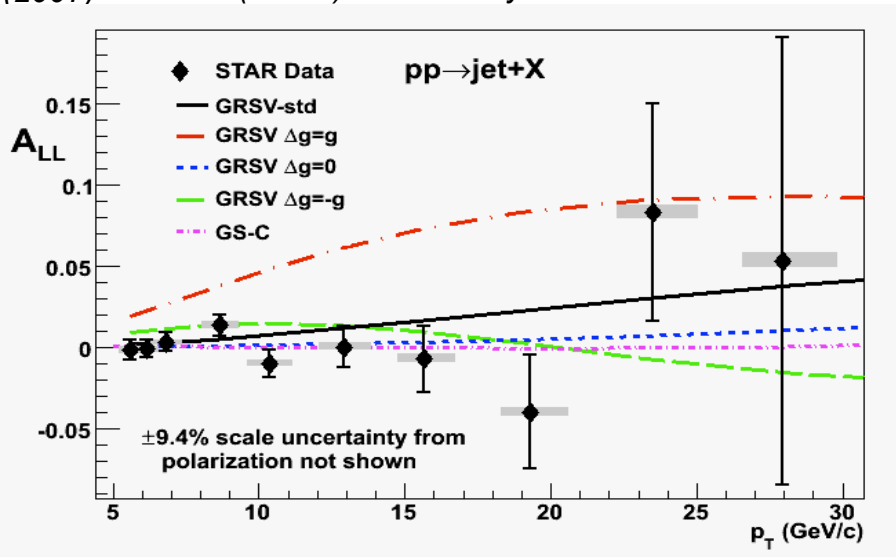
Selected STAR Spin Results

STAR Spin Results

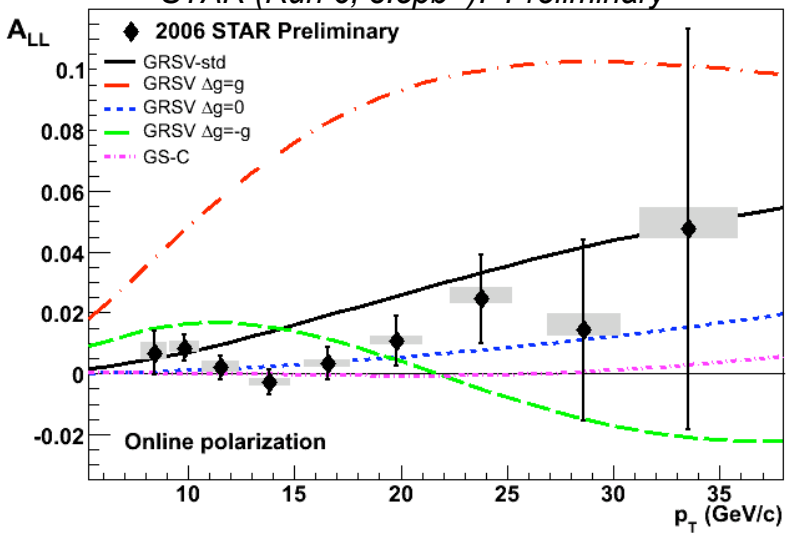
STAR (Runs 3 & 4): Phys. Rev. Lett. ***97****, 252001(2007)*



STAR (Run 5): sub. to Phys. Rev. Lett. arXiv: 0710.2048



STAR (Run 6, 8.5pb^{-1}): Preliminary

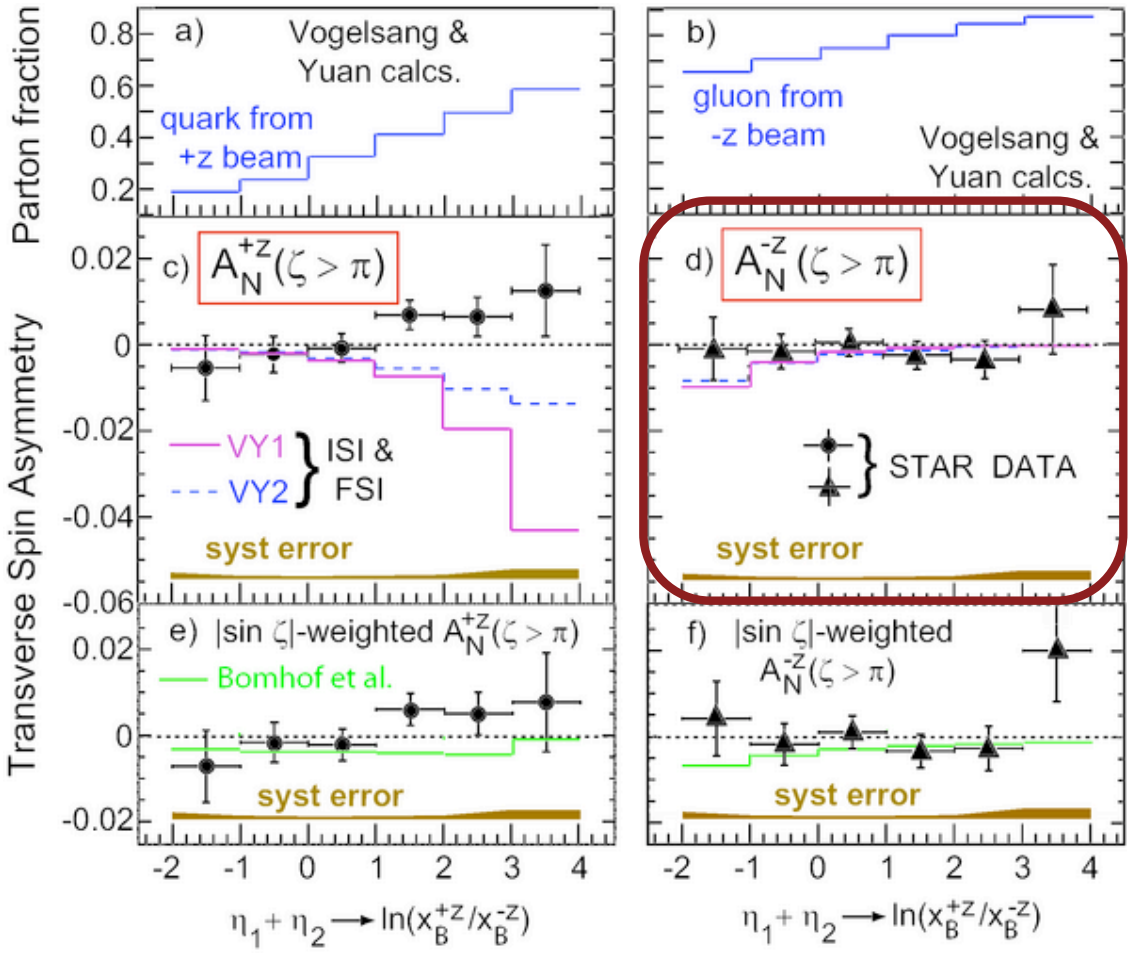


- Our A_{LL} measurement for inclusive jets has gained significant precision and kinematic reach from Runs 3 & 4 (published) to Run 5 (sub.) and, once more, to Run 6.

- Have placed significant new constraints on the magnitude of ΔG for $0.02 < x < 0.3$. Our most precise data to date (Run 6) remain statistics limited.

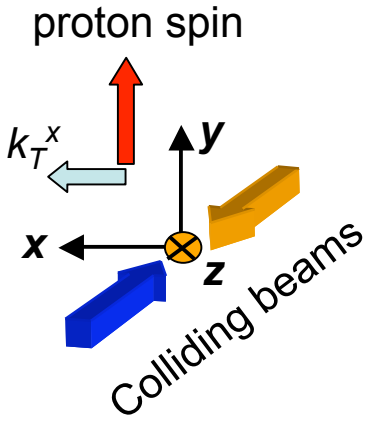
STAR Transverse Spin Results

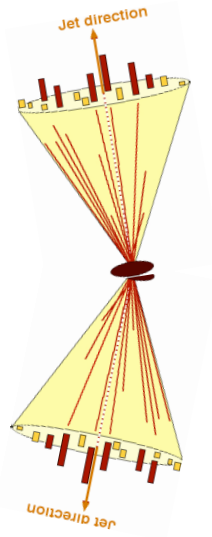
STAR, Phys. Rev. Lett. ***99****, 142003(2007)*
arXiv: 0801.2990



STAR data from Run 6 and compared with theoretical calculations

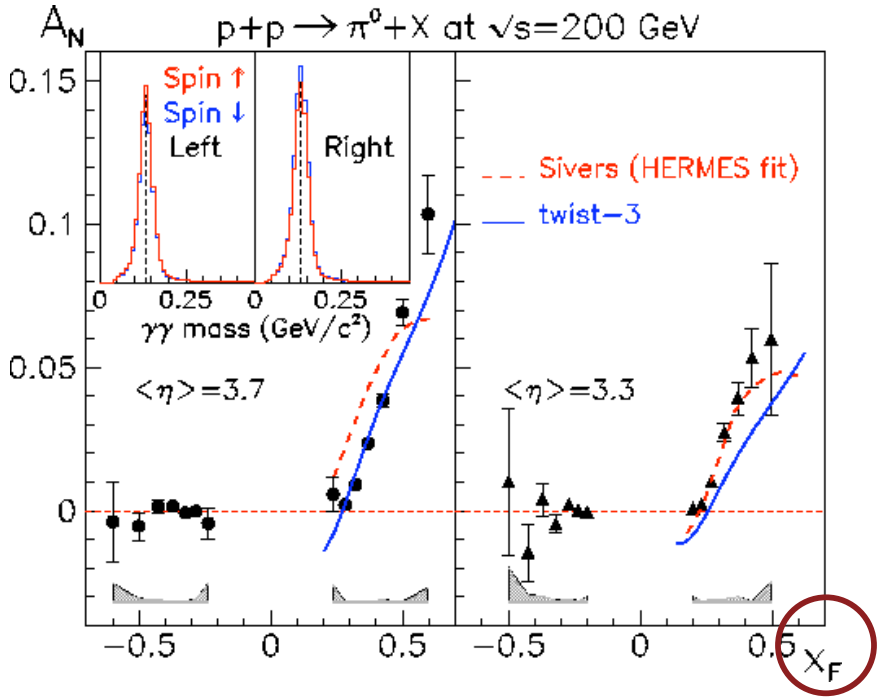
⇒ First STAR ***di-jet analysis*** using jets from calorimeters, has been published ***unexpected smallness*** observed for the Sivers transverse spin phenomena for $-1 < \eta < 2$

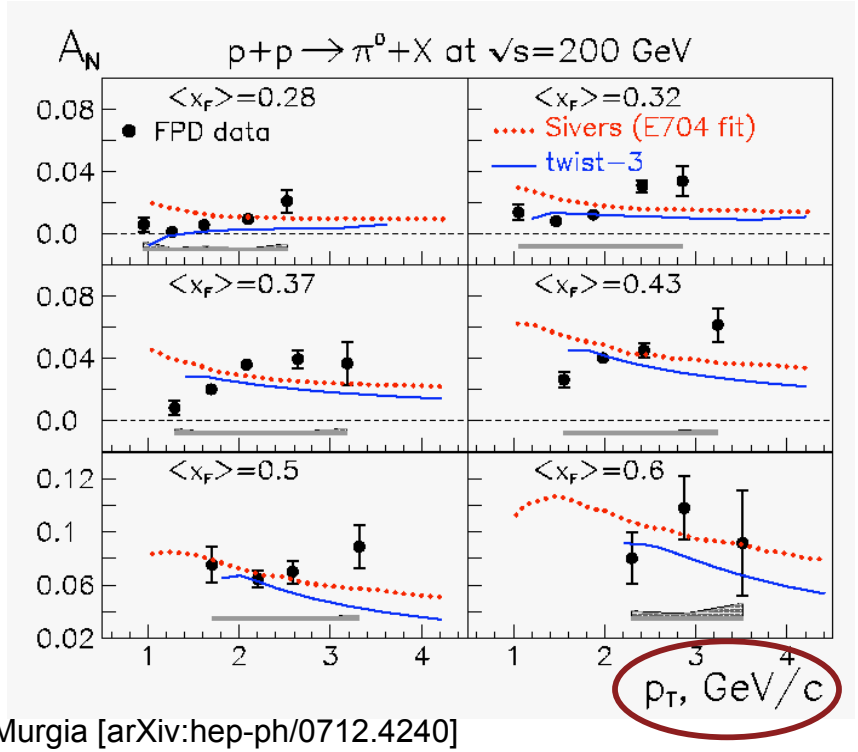




$A_N(x_F)$ for Forward π^0 Production

STAR: Sub. to PRL, hep-ex/0801.2990





Theory (**Red**): M. Boglione, U. D'Alesio, F. Murgia [arXiv:hep-ph/0712.4240]

Theory (**Blue**): C. Kouvaris, J. Qiu, W. Vogelsang, F. Yuan, PRD **74** (2006) 114013

Left: Calculations based on phenomenological fits to SIDIS data account for x_F dependence

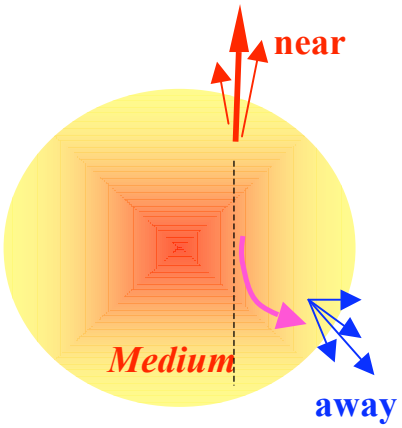
Right: Sivers mechanism based calculations require A_N to decrease with p_T. This trend is not what is observed.

Selected STAR Heavy Ion Results

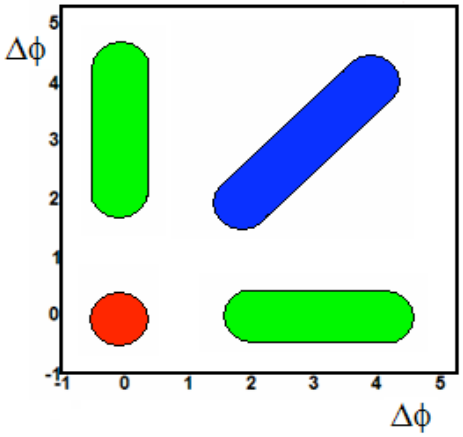
Search for Mach Cone

with Three Particle Correlations

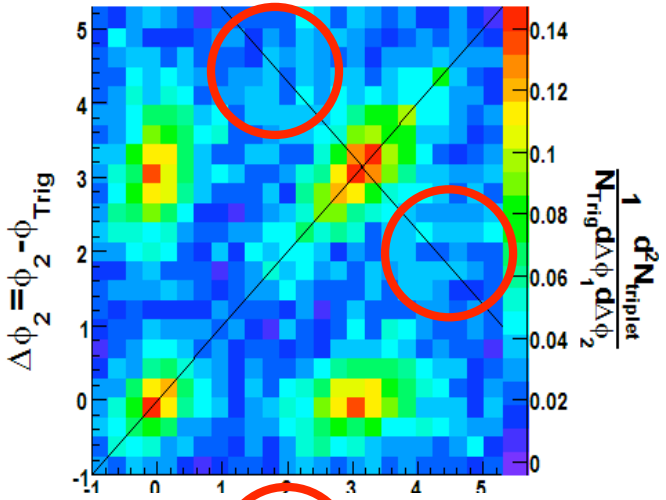
STAR: sub. to PRL, arXiv: 0805.0622

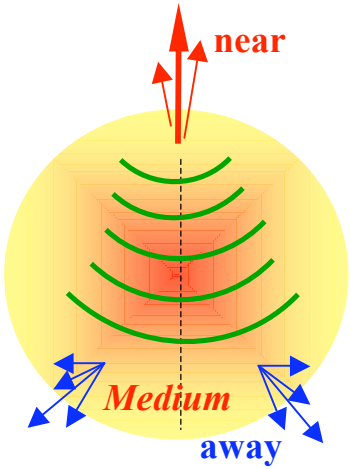


deflected jets

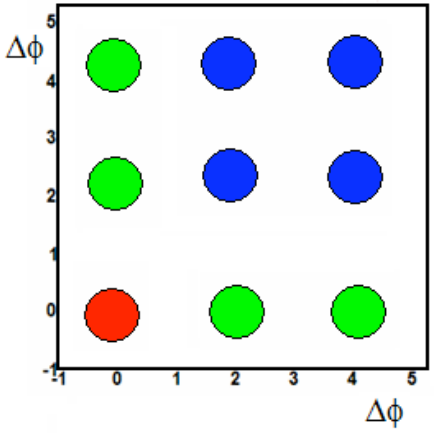


d+Au



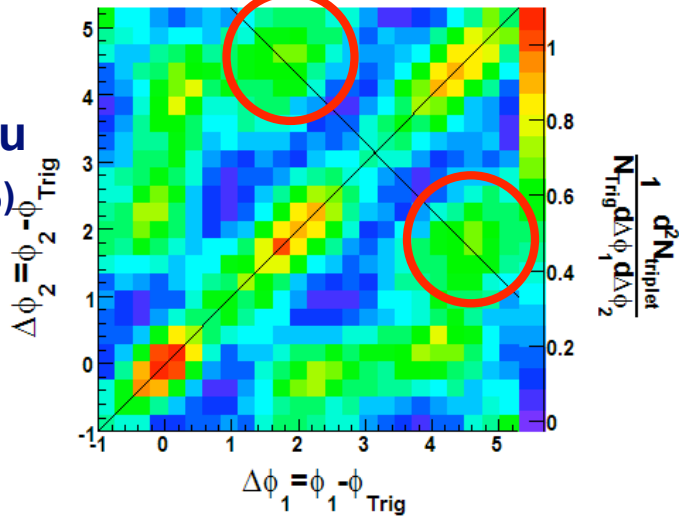


Conical Emission



Au+Au

(0-12%)



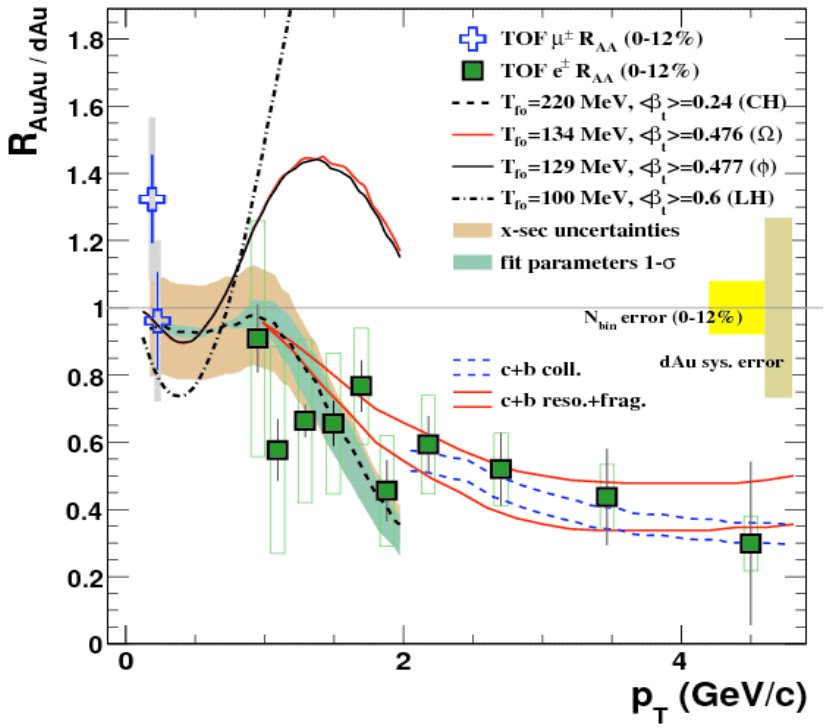
$$\cos\vartheta^{Mach} = \sqrt{p/\varepsilon}$$

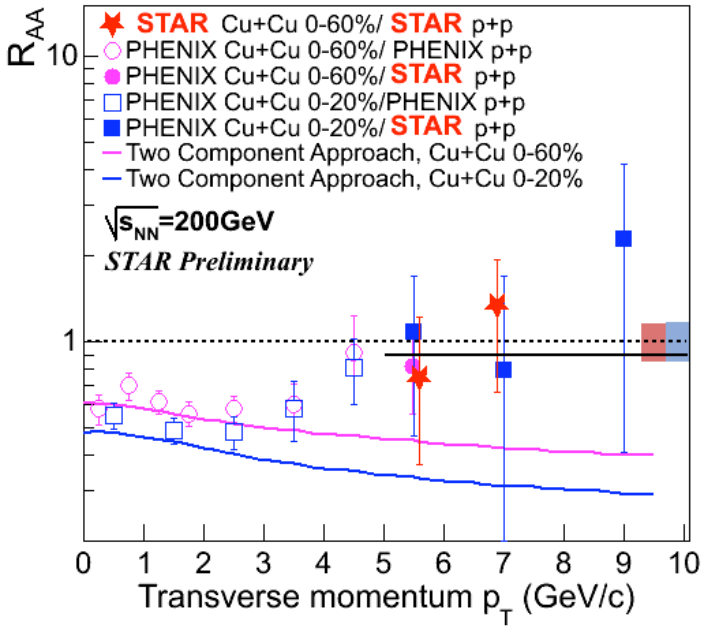
"Evidence of conical emission …"

Open Charm and J/ψ $R_{AA}(p_T)$

STAR: sub. to PRL, arXiv: 0805.0364

Heavy flavor hadrons freeze-out earlier than light flavor (*u,d,s*) hadrons



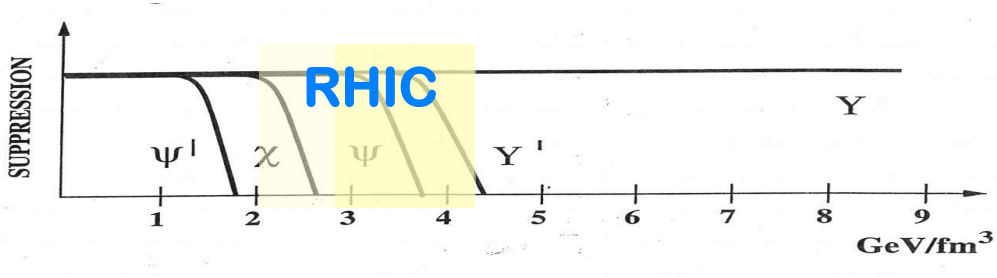


STAR Preliminary:

The Cu+Cu data consistent with no suppression at high p_T:
$R_{AA}(p_T > 5$ GeV/c) = 0.9 ± 0.2

- Low-p_T R_{AA} ~ 0.5-0.6 (PHENIX)
- Most models expect R_{AA} to decrease at high p_T.

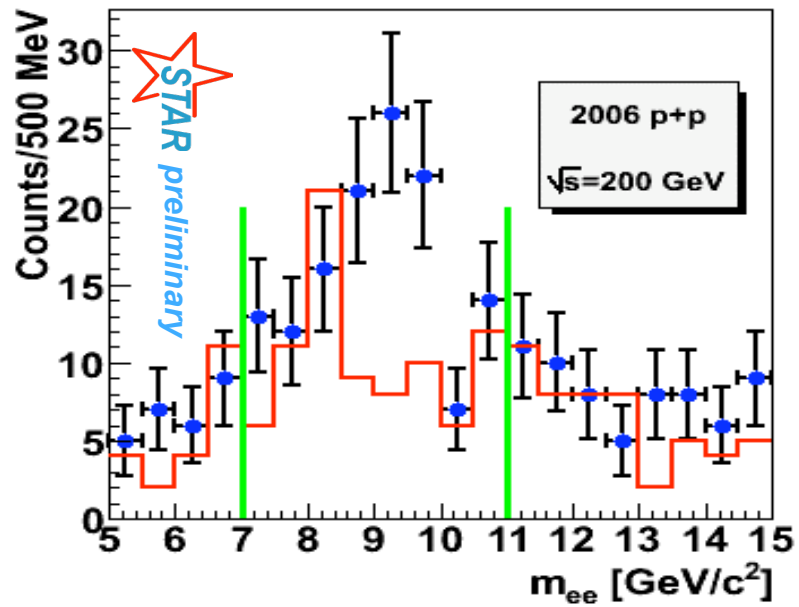
Extending to Higher Mass: ϒ



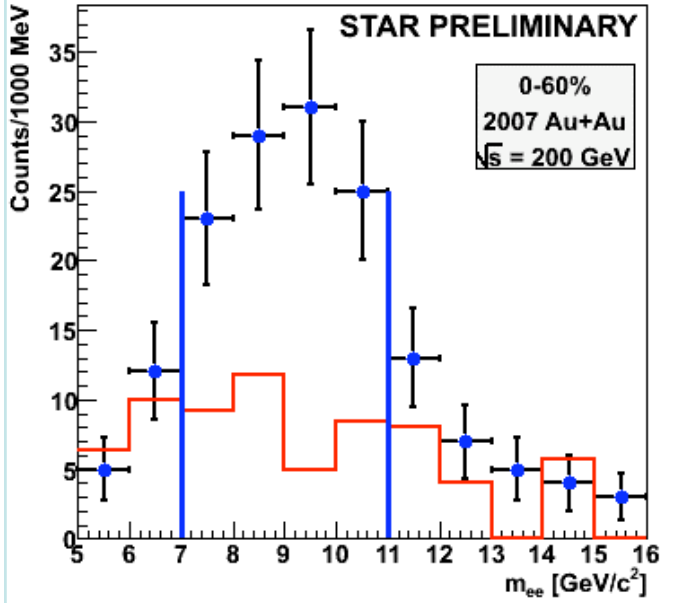
Sequential dissociation of quarkonia is sensitive to energy density of plasma

ϒ (1S+2S+3S) → e^+e^-

Run 6: 200 GeV p+p

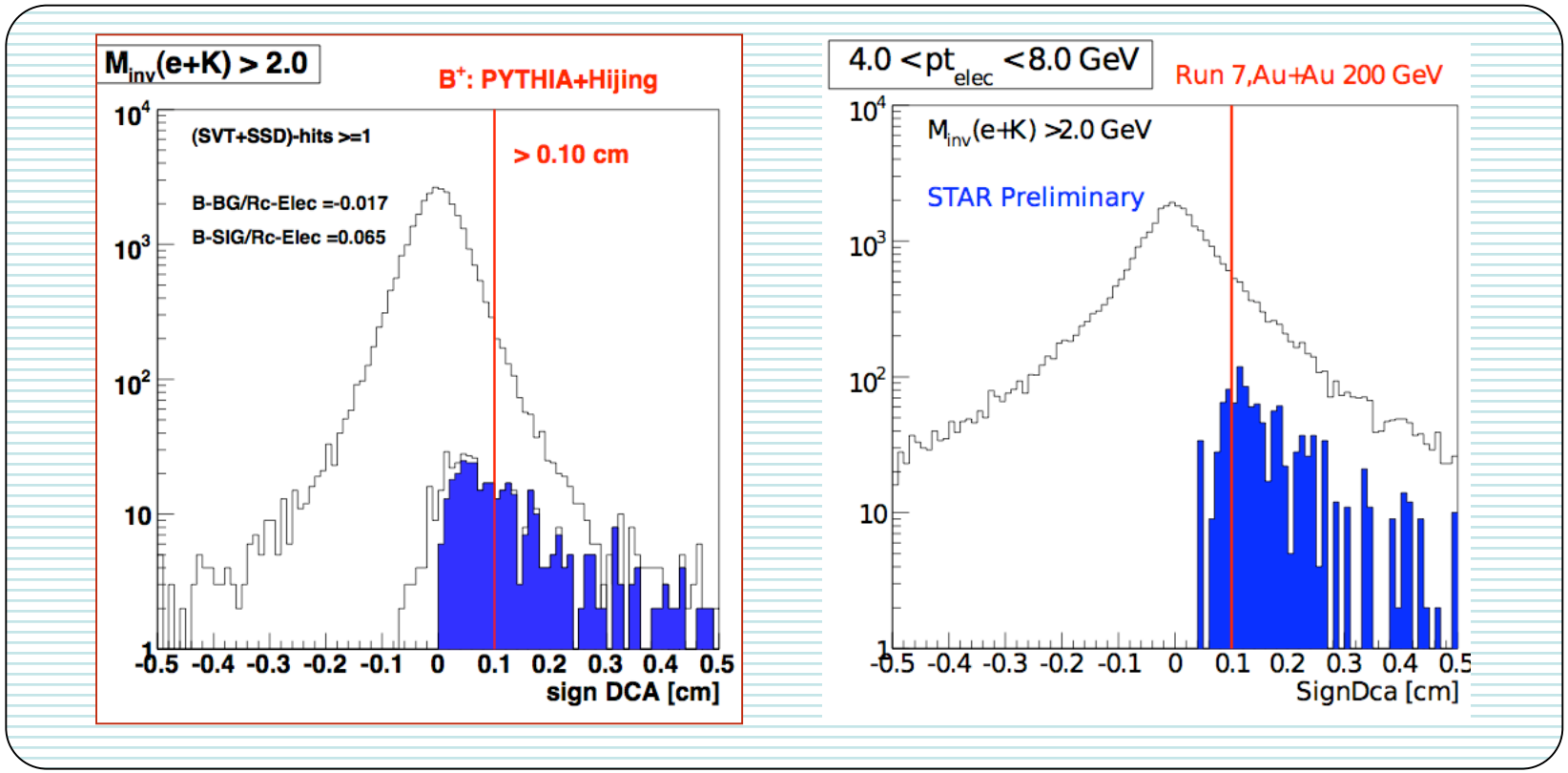


Run 7: 200 GeV Au+Au



STAR high p_T topological electron trigger works!

Bottom Decay Electron Study

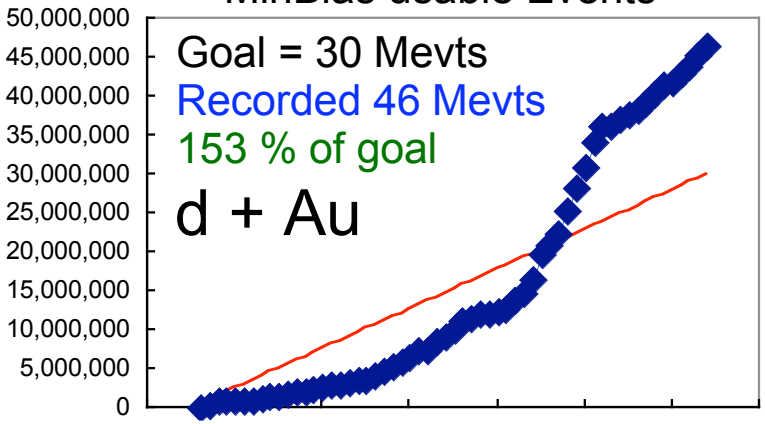


- EMC trigger + SSD+SVT vertex cuts: high energy electrons from Bottom
- In the future: HFT will provide a much more powerful tool for studying heavy flavor hadrons

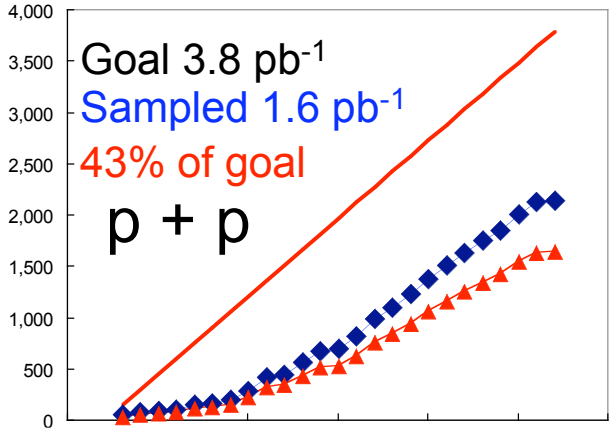
Results from Run 8

Run 8: d-Au and Polarized p+p

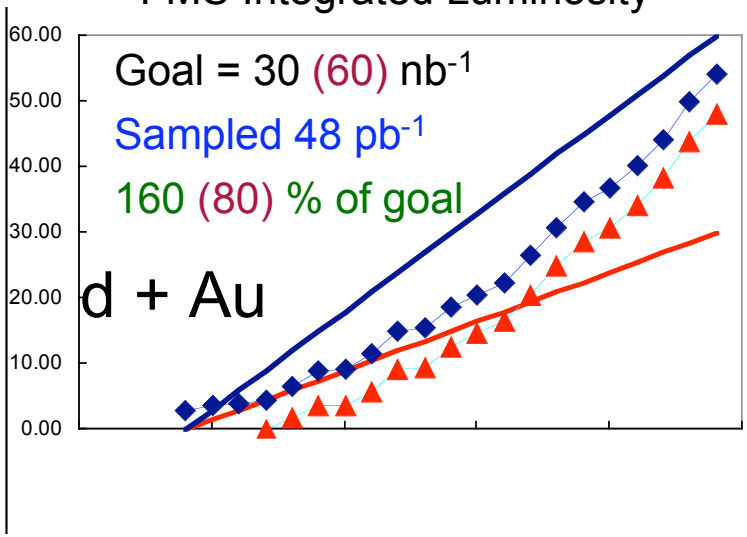
MinBias usable Events



Integrated FMS FOM (nb^{-1})



FMS Integrated Luminosity



I. d+Au run: **Success!**

II. Polarized p+p run:

(1) FMS CGC reference data: **Good**

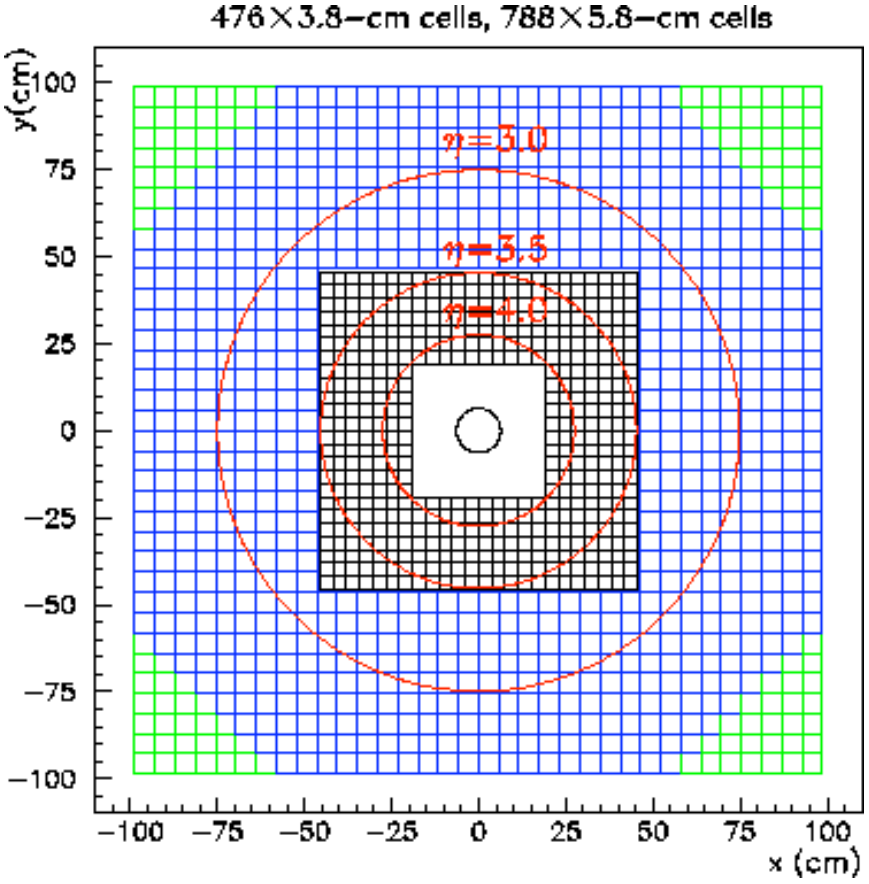
(2) Forward A_N (x_F, p_T): **Short of what we had intended to achieve**

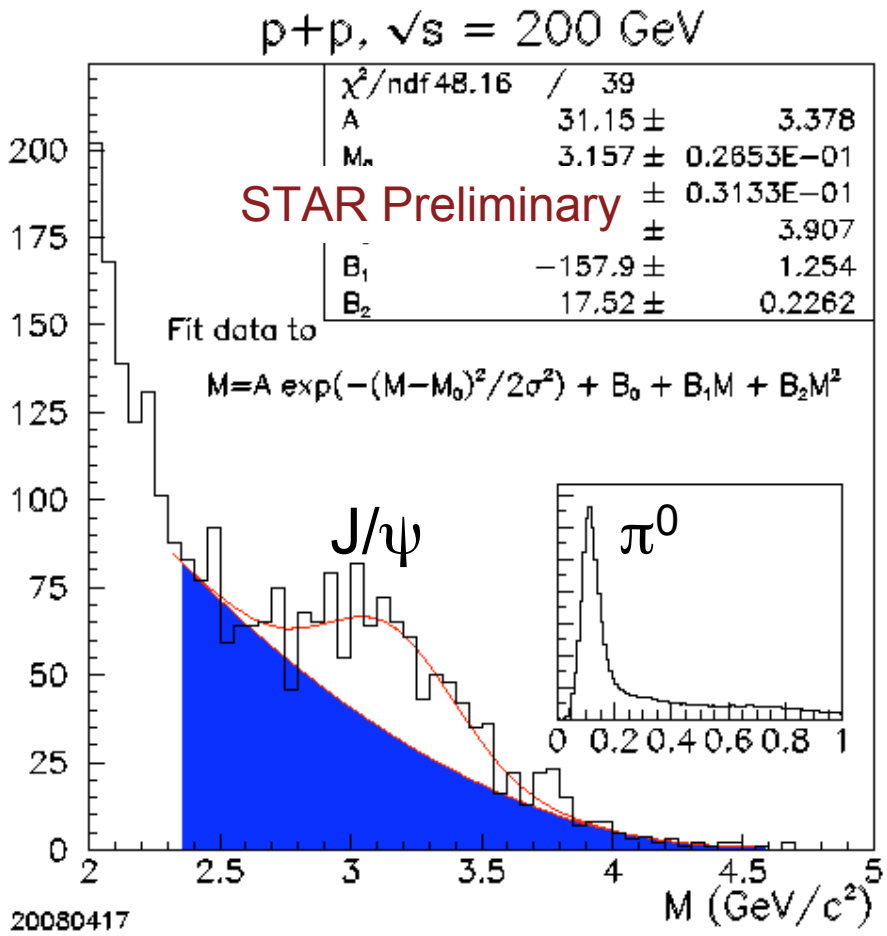
(3) Forward direct photon asymmetries: **Not enough**

(4) Electrons from Charm and Bottom, with low material, to resolve STAR/PHENIX discrepancy: **Good**

Forward Meson Spectrometer (FMS)

$2.5 \le \eta \le 4$, $\mathbf{0.2 \le x_F \le 0.25}$

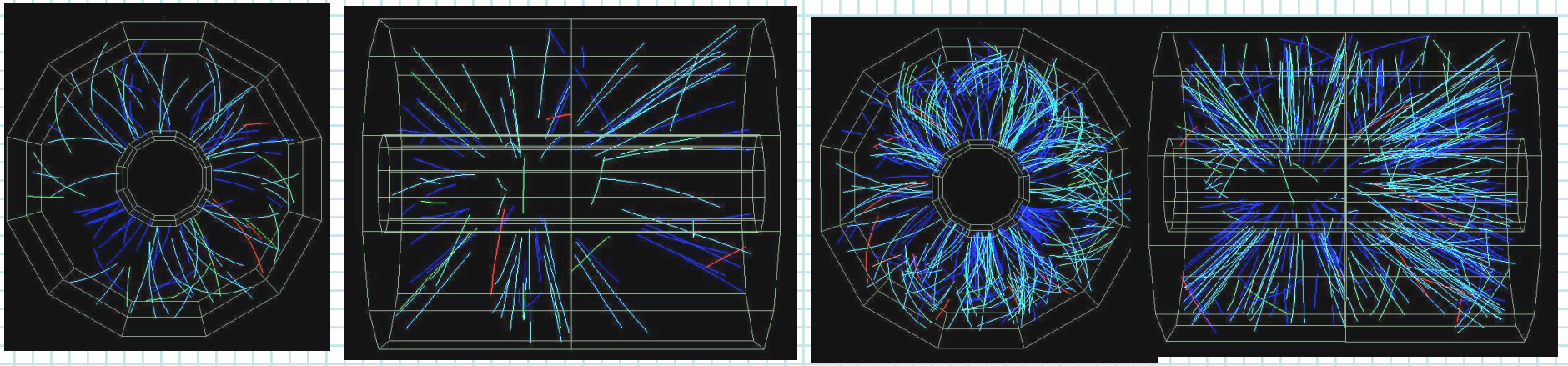




FMS: calibration in progress

Low Energy Test Run (9 GeV)

Au + Au Collisions!

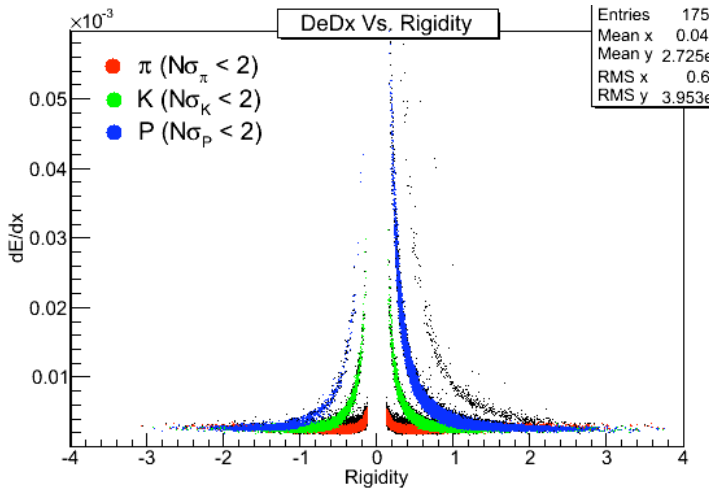


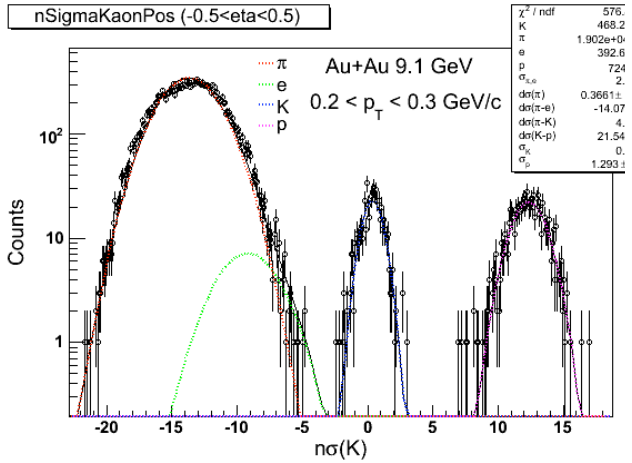
1) **~ 3500 collisions collected**
2) **Gain understanding of triggering issues**
3) **Determine Luminosity: rate ~ 0.6 Hz at 9 GeV**
4) **STAR studying the following:**

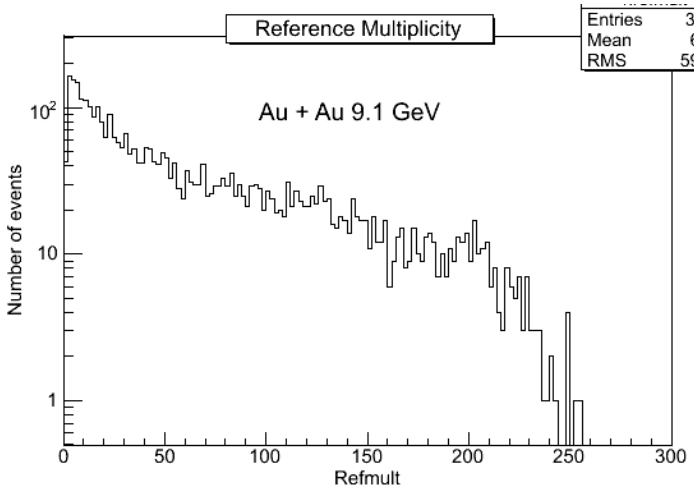
   Particle identification in TPC; total charged multiplicity

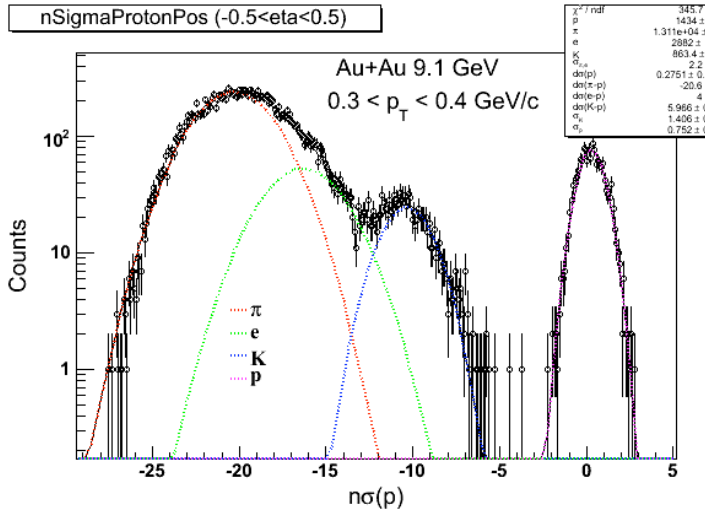
   π-π interferometry, particle ratios; v_1 and v_2
5) **Physics ready with 2 - 4 Hz collisions**

Ready for Physics at Energy Scan





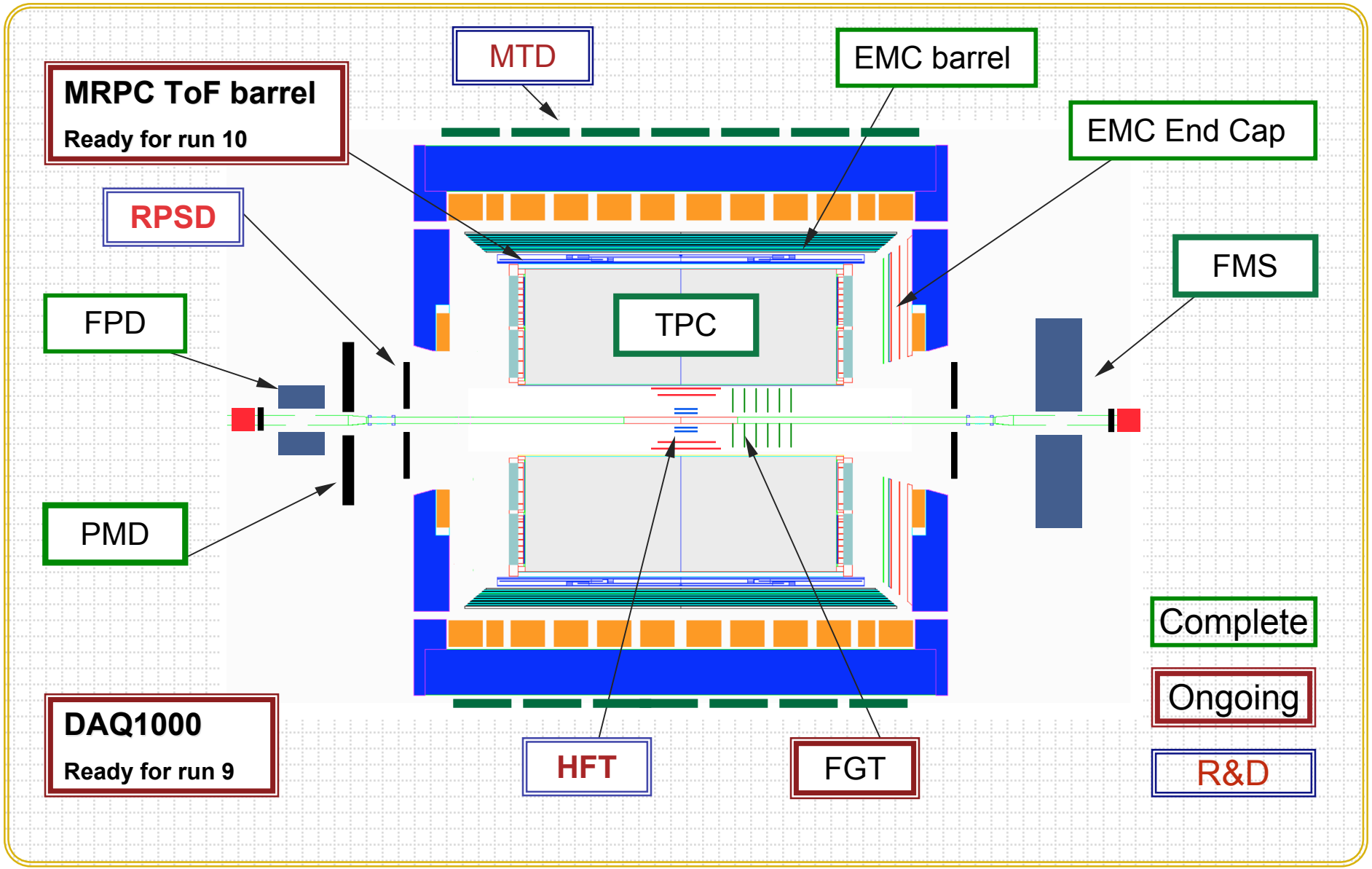




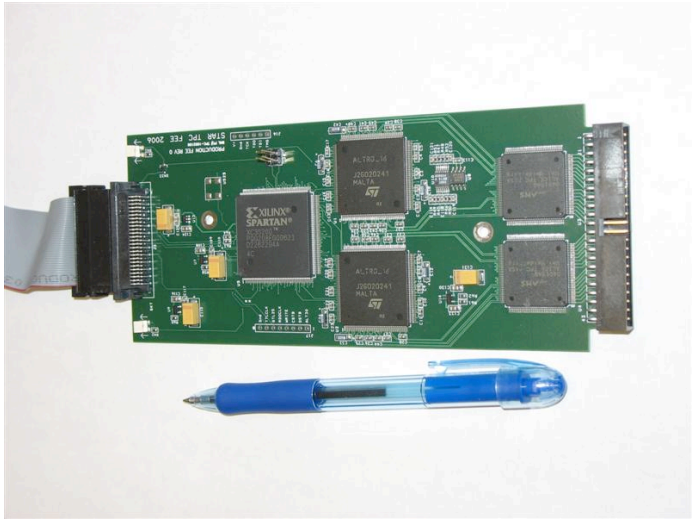
PID will be significantly extended using TOF

STAR Upgrades

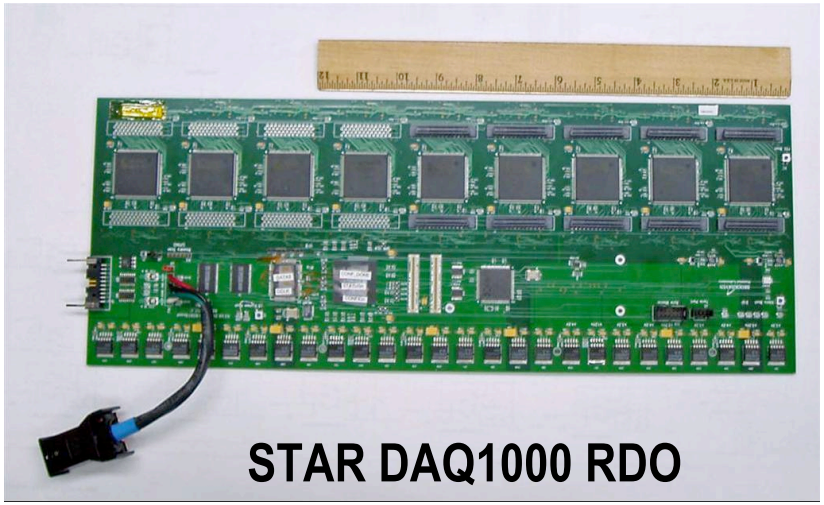
STAR Detector

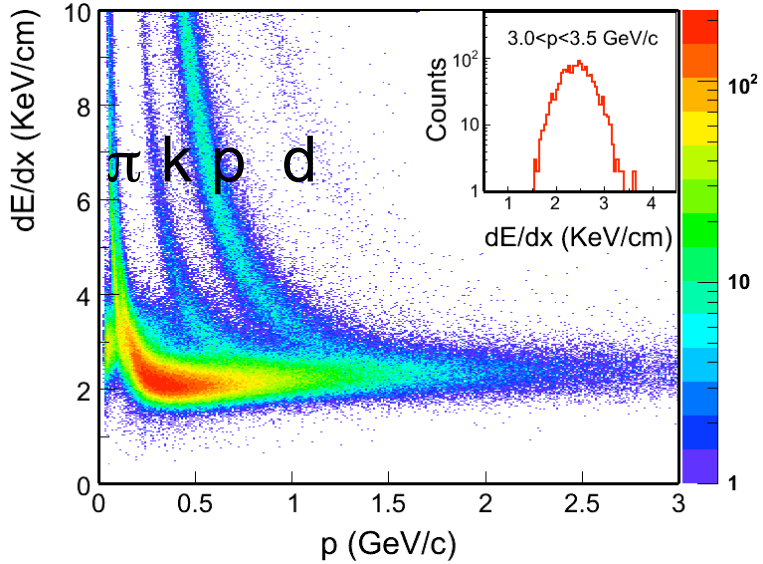


STAR DAQ1000



CERN/ALICE Altro chip development

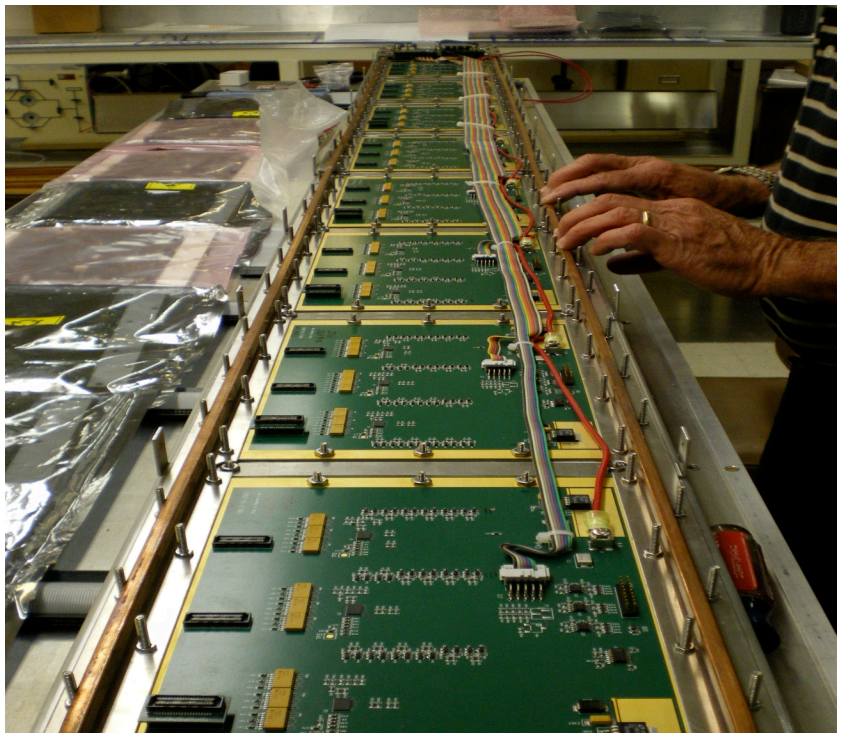


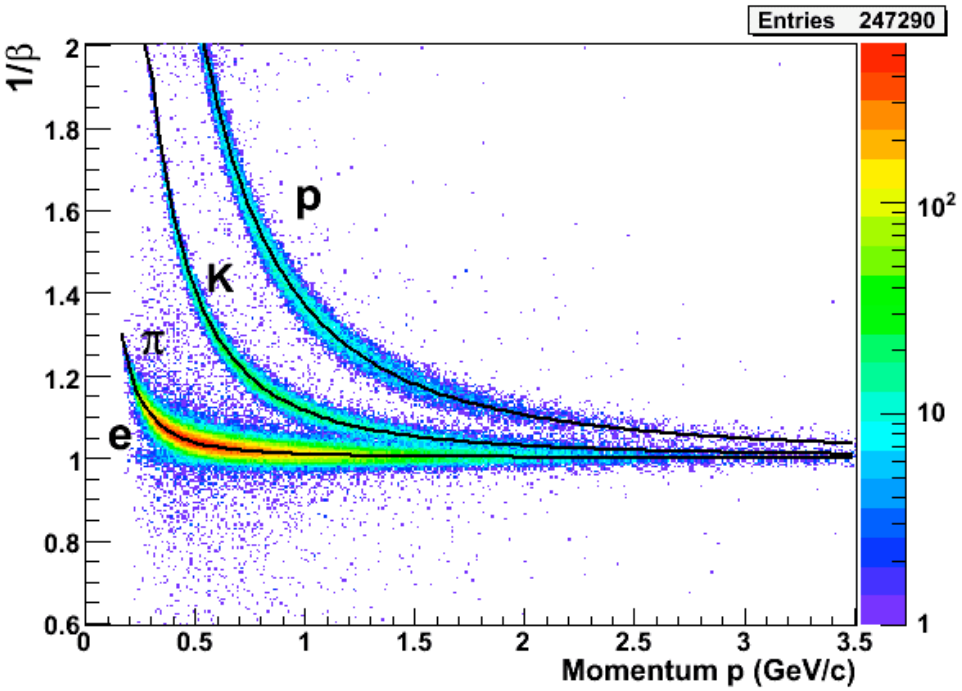


Run 8 tests:

- One sector of the TPC (1/24) instrumented with DAQ1000 electronics
- Routine operation for physics.
- Speed test: operated at 1 kHz with only 5-7% dead time
- Full TPC will be instrumented before Run 9

STAR MRPC ToF





Run 8 test:

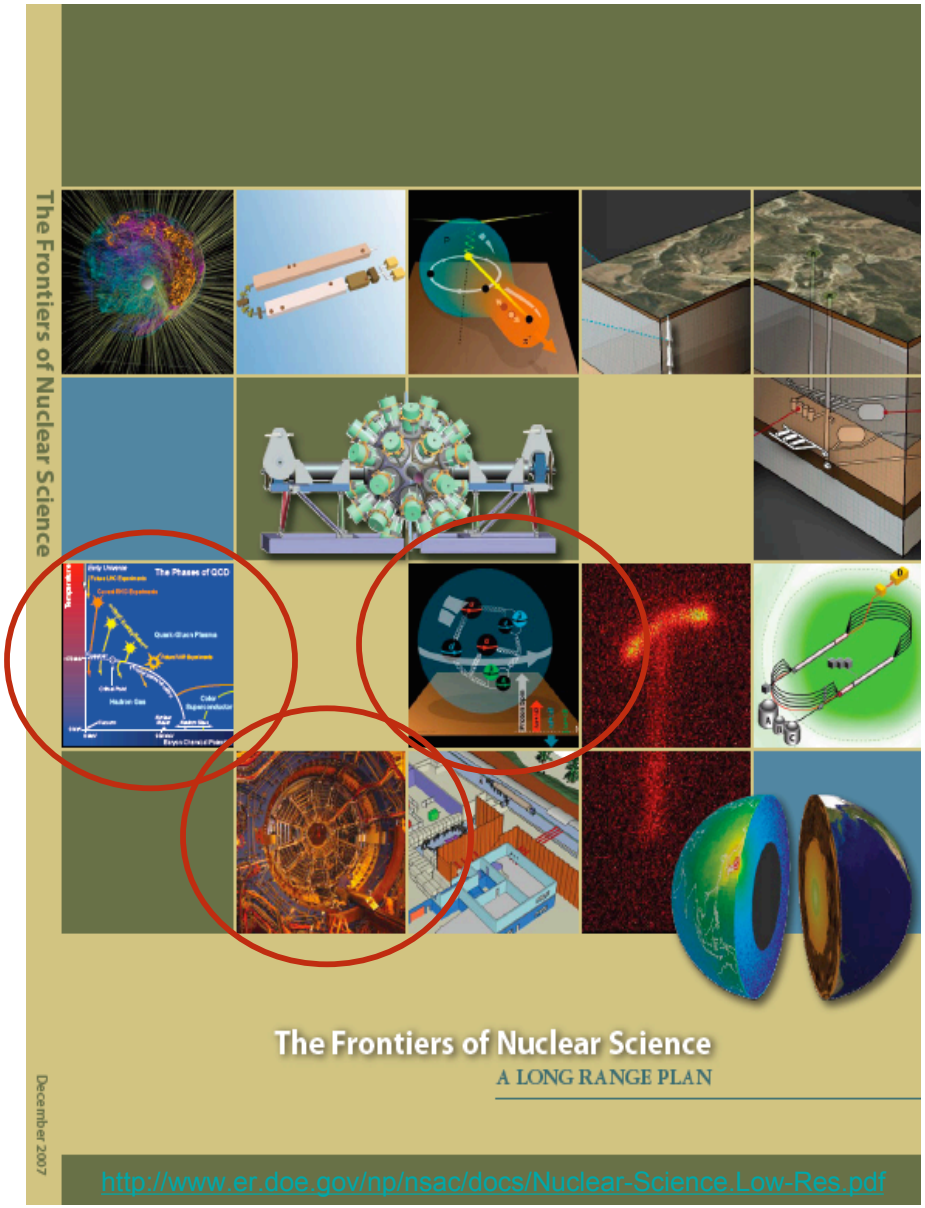
- Five trays of ToF system installed, commissioned, and used for physics
- Behind sector with DAQ1000 TPC electronics. Routine operation for physics.
- **90 (of 120) ToF trays to be installed for Run 9 and the full ToF (120) will be completed before Run 10**

STAR Upgrade Timeline

Upgrade	Completion	Key physics measurements
FMS	Completed 2008	(a)Transverse asymmetry at forward rapidity (b) CGC
TPC DAQ (DAQ1000)	Summer 2008 Ready for Run 09	Large data set, minimal dead time
MRPC TOF	Summer 2009 Full TOF ready for Run 10	Full PID in full azimuthal acceptance (90/120 trays will be used in Run 9) TOF capability is critical for the energy scan
FGT	Summer 2010 Ready for Run 11	Forward $W^{\pm}$ for flavor separated quark polarization
HFT	Summer 2011 Ready for Run 12	(a) Precision hadronic ID for Charm and Bottom hadrons (b) Charm and Bottom hadron energy loss and flow

1) Physics
2) Upgrades - technically driven schedule
3) Request for new measurements

The Frontiers of Nuclear Science



(I) **Systematically study the partonic medium properties at RHIC**

(II) **Search for QCD critical point**

(III) **Study proton intrinsic structure**

Run 9: 25 Cryo-week (scenario I)

STAR priorities for Runs 9 and 10:

(1) 200 GeV longitudinally polarized p+p ***- Δg(x)***

(2) Beam energy scan down to $\sqrt{s_{NN}}$ ~ 5-6 GeV

- Search for the QCD critical point

** C-AD transverse stochastic cooling test important!

Run	Energy (GeV)	System	Time	Goal
9	$\sqrt{s}$ = 200	$p_{\rightarrow}\ p_{\rightarrow}$	12 week	50 pb^{-1} P^4L 6.5 pb^{-1}
	$\sqrt{s}$ = 500	$p_{\uparrow}\ p_{\uparrow}$	2 week	Commissioning
	$\sqrt{s}$ = 200	$p_{\uparrow}\ p_{\uparrow}$	½ week	pp2pp
	** $\sqrt{s_{NN}}$ = 200	Au + Au	3 week	0.3B minbias, 0.5 nb^{-1}
	$\sqrt{s_{NN}}$ = 5	Au + Au	½ week*	Commisioning
10	$\sqrt{s_{NN}}$ = 39 – 6.1	Au + Au	14 week	1st energy scan
	$\sqrt{s_{NN}}$ = 5	Au + Au	1 week	Commisioning
	$\sqrt{s_{NN}}$ = 200	Au + Au	2 week	200M central
	$\sqrt{s_{NN}}$ = 200	Au + Au	1 week	50M central
	$\sqrt{s}$ = 200	$p_{\rightarrow}\ p_{\rightarrow}$	½ week	pp2pp
	$\sqrt{s}$ = 500 or 200	$p_{\uparrow}\ p_{\uparrow}$ or $p_{\rightarrow}\ p_{\rightarrow}$	4 ½ week	Spin studies

Run 9: 16 Cryo-week (scenario II)

Run	Energy (GeV)	System	Time	Goal
9	$\sqrt{s}$ = 200	$p_{\rightarrow}\, p_{\rightarrow}$	11 weeks	50 pb^{-1}, P^4L 6.5 pb^{-1}
	$\sqrt{s}$ = 200	$p_{\uparrow} p_{\uparrow}$	½ week*	pp2pp
10	$\sqrt{s_{NN}}$ = 39 – 6.1	Au + Au	12 weeks	1st energy scan
	$\sqrt{s_{NN}}$ = 5	Au + Au	1 week	Commissioning
	** $\sqrt{s_{NN}}$ = 200	Au + Au	3 ½ weeks	0.5B events, 0.5 nb^{-1}
	$\sqrt{s_{NN}}$ = 200	Au + Au	1 week	50M central
	$\sqrt{s}$ = 500	$p_{\uparrow} p_{\uparrow}$ or $p_{\rightarrow} p_{\rightarrow}$	5 weeks	Commissioning
	$\sqrt{s}$ = 200	$p_{\uparrow} p_{\uparrow}$ or $p_{\rightarrow} p_{\rightarrow}$	½ week	pp2pp

STAR priorities for Runs 9 and 10:

(1) 200 GeV longitudinally polarized p+p ***- $\Delta g(x)$***

(2) Beam energy scan down to $\sqrt{s_{NN}}$ ~ 5-6 GeV

- Search for the QCD critical point

** C-AD transverse stochastic cooling test important!

Global Fits with Inclusive RHIC Data

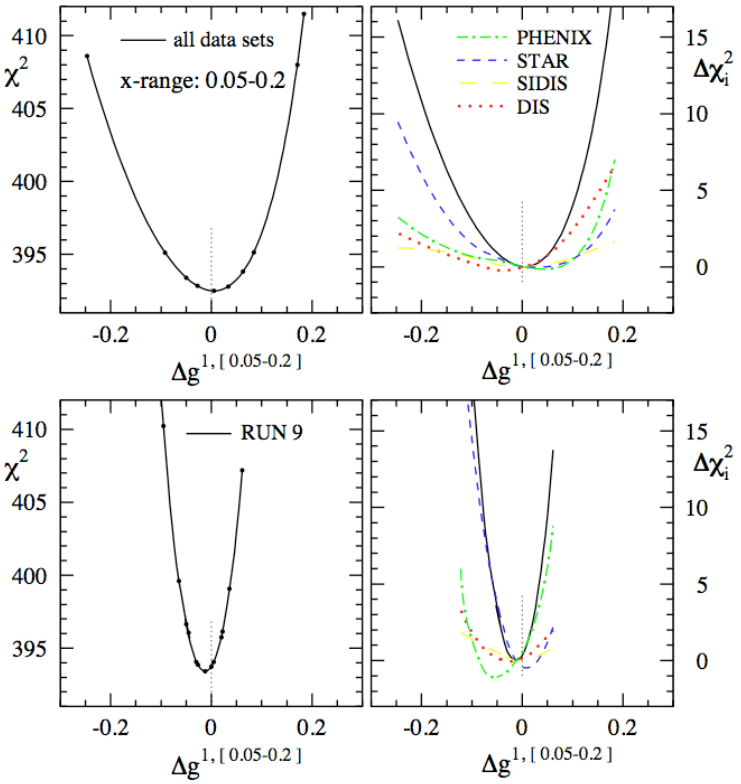
Goals for taking: Run 9 ~ 16* Run 6

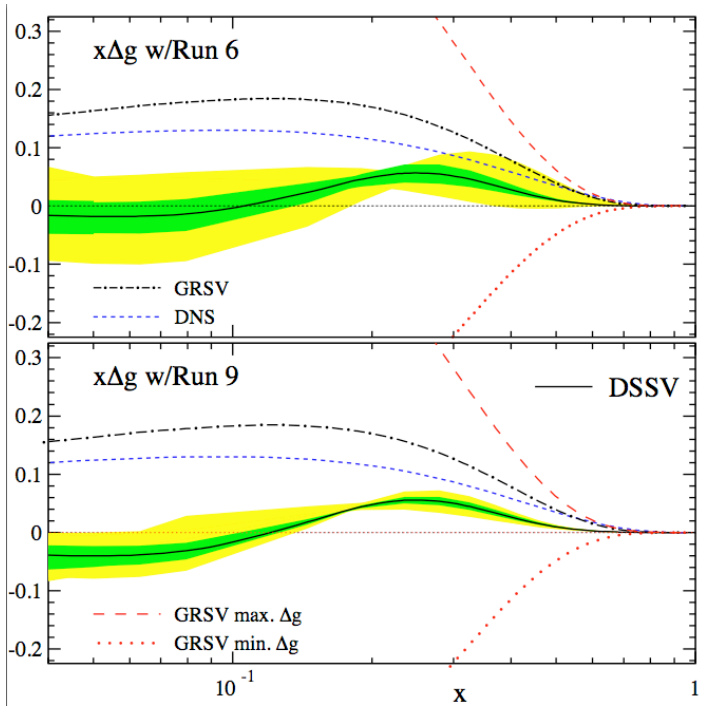
Run 9: STAR bottom line is to collect FoM: 6.5 pb^{-1}

inclusive jet, di-jets, γ-jet… analysis

Run 6

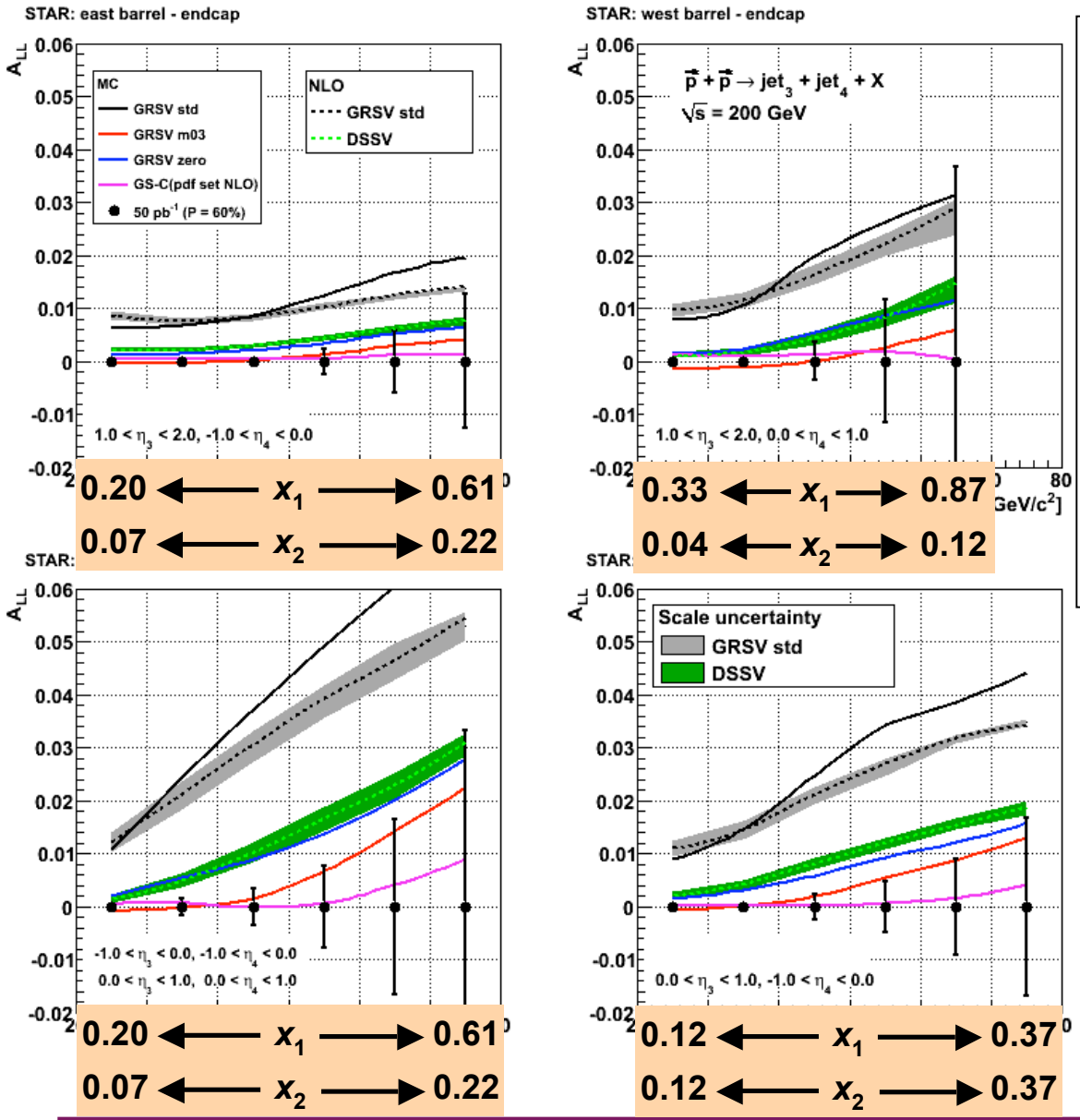
Run 9





de Florian et al, arXiv: 0804.0422

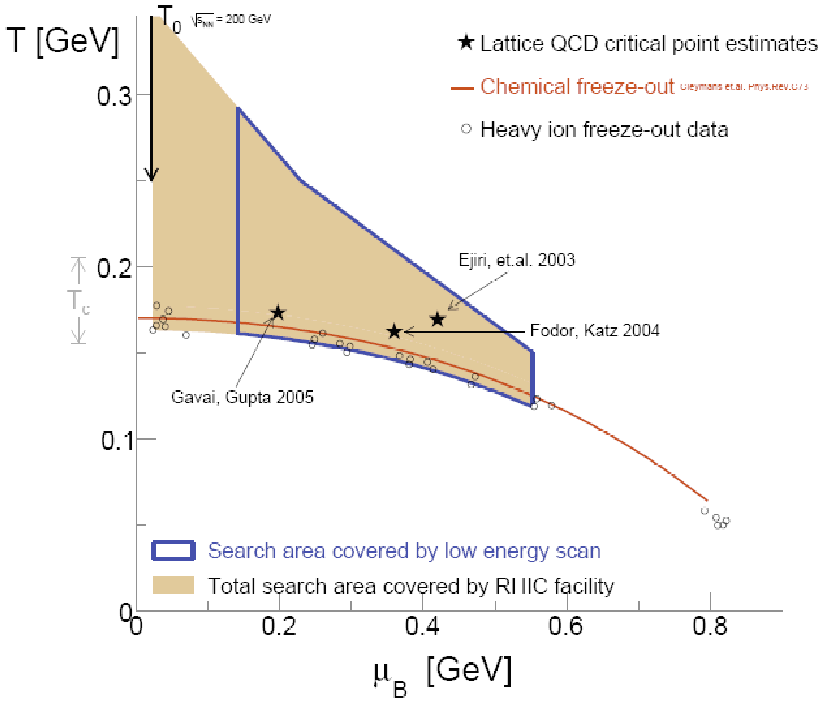
Di-jet Sensitivity in Run 9



- Di-jets provide **direct access to $\Delta g(x)$** in leading order
- Full NLO asymmetry calculations for di-jets are similar to LO estimates
- Sensitivity is shown for **FoM = P^4L = 6.5 pb^{-1}**
- Significant discrimination amongst allowed models

Significant contributions at 200 GeV from quark-gluon scattering with highly polarized quarks.

Search for QCD Critical Point



STAR Beam Use Request FY10

$\sqrt{s_{NN}}$ [GeV]	μ_B [MeV]	Rate [Hz]	Goal [Events]	Duration [Days]
5.0	550	0.5		7
6.1	491	1.4	1M	20
7.7	410	2.7	2M	20
8.6	385	4	2M	15
12.3	300	10	5M	15
17.3	229	25	10M	12
27	151	30	10M	7
39	112	50	10M	6

Key measurements:

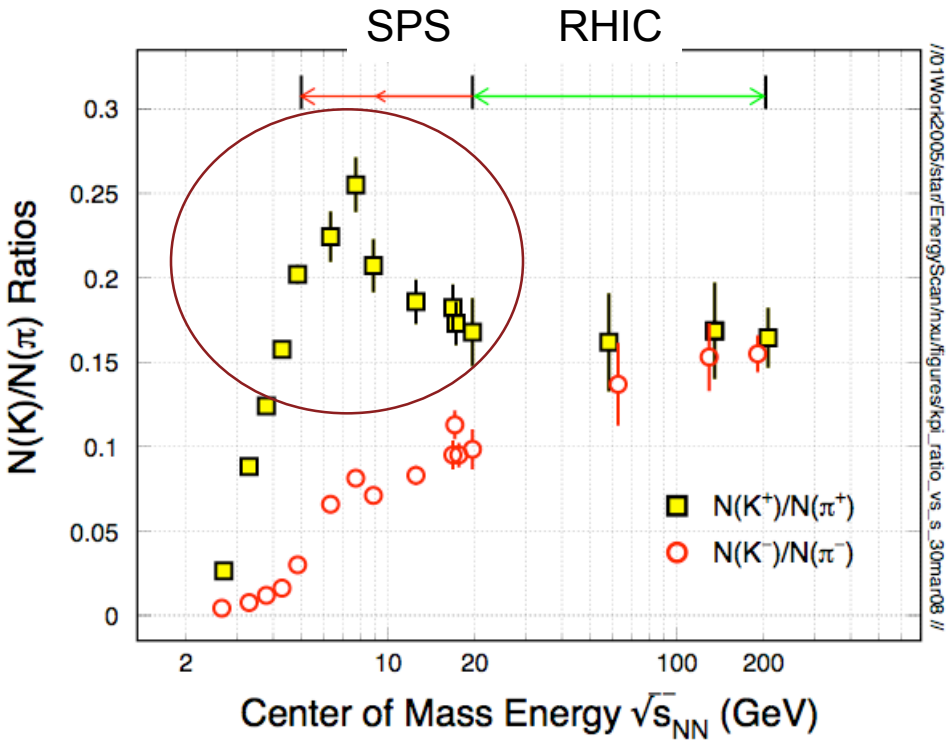
(1) All PID hadron spectra and v_2
(2) K/π, $\langle p_T \rangle$ … fluctuations

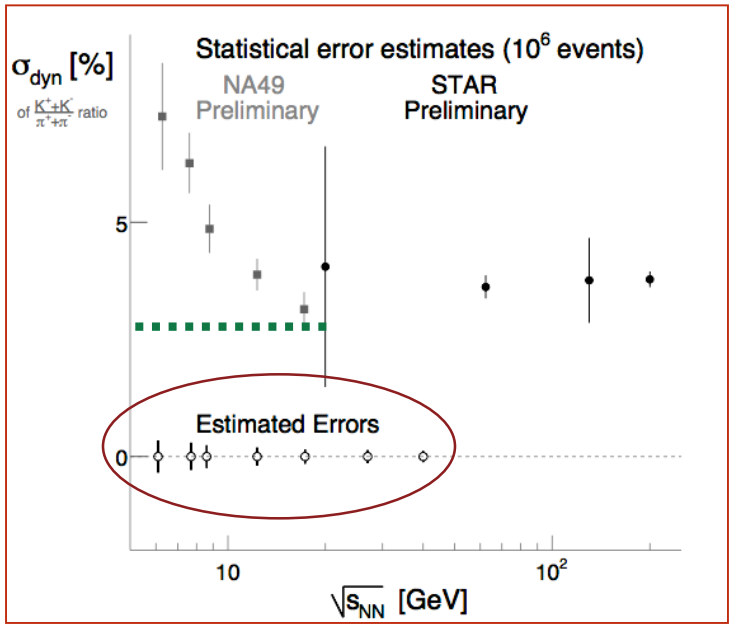
Strategy:

(1) From high to low energy, disappearance of high energy density phenomena (controlled experiment)

(2) Cover SPS range $\sqrt{s_{NN}}$ = 5 - 20 GeV, look for the onset of de-confinement

Observables and Advantages





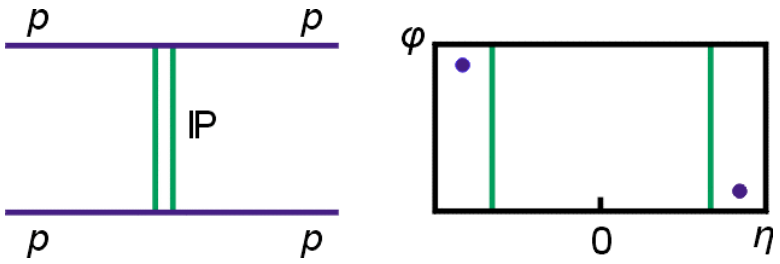
Torrieri

Advantages at STAR:

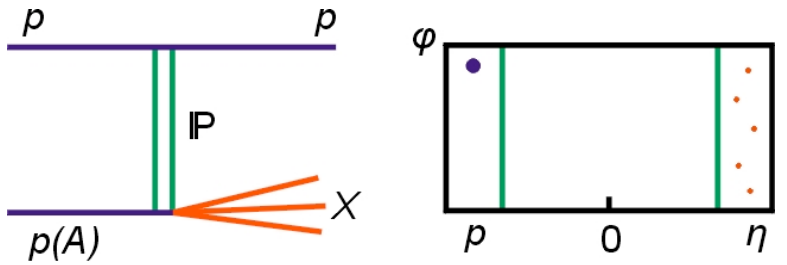
- Large acceptance: full azimuthal coverage and |y| < 1.0
- Clean particle identification: (TPC, ToF, EMC)
- Acceptance does ***not*** change with beam energy, systematic errors under control
- High potential for discovery

Tagged Forward Protons

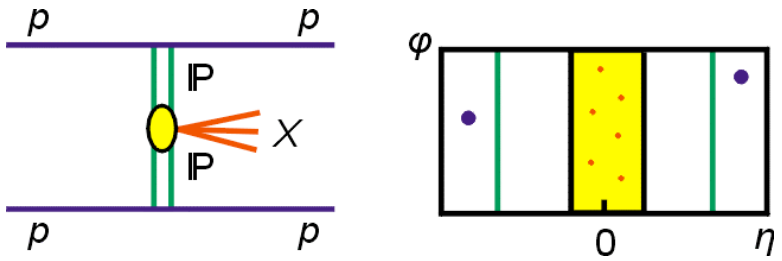
Elastic and Inelastic Processes



Elastic Scattering: Roman Pots only



Single Diffraction: RP + FMS or RP + BBC



For each proton vertex one has

t four-momentum transfer

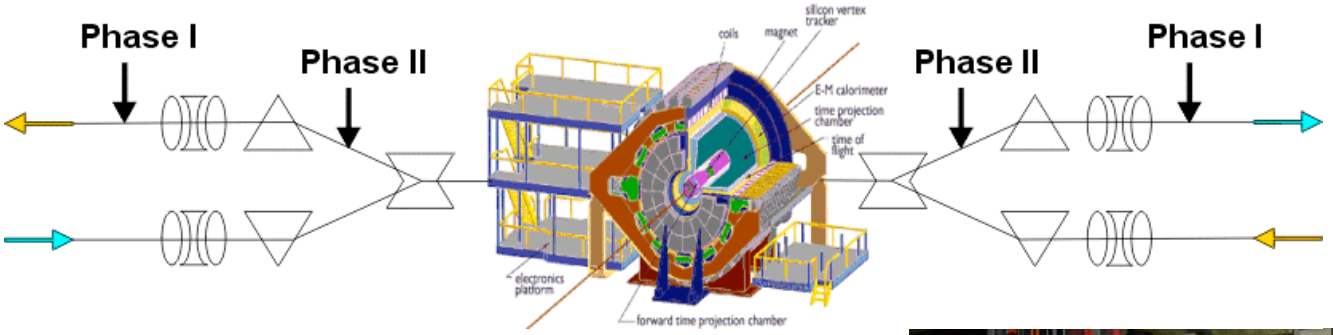
$\xi = \Delta p/p$ - proton momentum loss

M_X invariant mass

Central Production: RP + ToF; Tracks in the TPC ***full azimuthal acceptance***

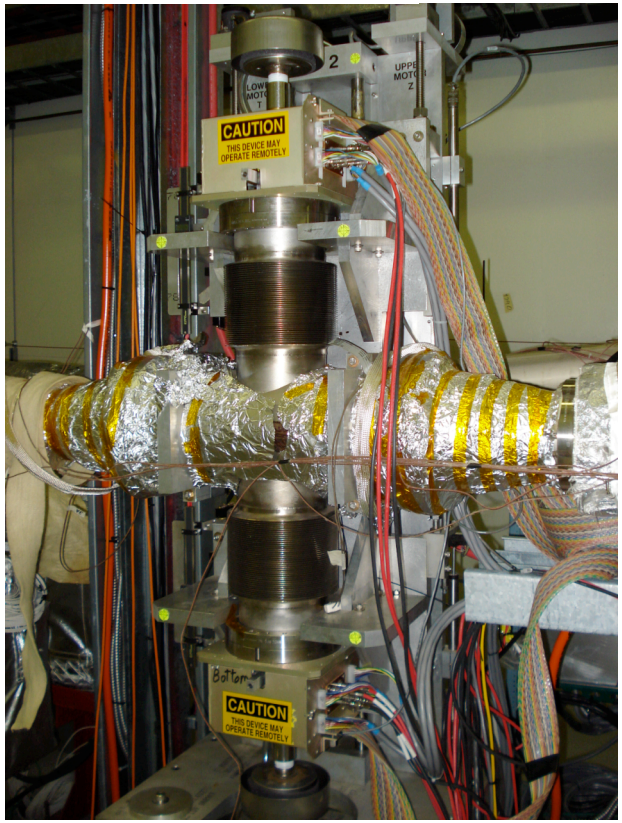
In terms of QCD, Pomeron exchange consists of the exchange of a color singlet combination of gluons. Hence, triggering on forward protons at high (RHIC) energies predominantly selects exchanges mediated by ***gluonic matter***.

Status of pp2pp



- Roman Pots (RP) were installed East and West of STAR (Phase I);
- pp2pp integrated into trigger and DAQ;
- Inserted pots into the beam pipe during last 2 hours of Run 8 (pp):
  - ***Triggered on elastic and inelastic coincidences in pp2pp RP***
  - ***No impact on background levels in STAR mid-rapidity detectors***

Phase II: Install RP between DX-D0 magnets, allowing to trigger on forward protons with standard tune, hence taking data with STAR without need for dedicated time.



pp2pp Plan for Runs 9 and/or 10

A dedicated ***1/2 -1 week run***, including setup of β^*=20m optics, and about 30 hrs of data taking will produce:

1. Elastic scattering:

- 100% acceptance for elastic scattering for $0.003 < |t| < 0.024$;
- ***40×10⁶*** elastic events: Δb=0.31 $(GeV/c)^{-2}$, $\Delta\rho$=0.01, $\Delta\sigma_{tot}$ = 2-3 mb;
- In eight t subintervals we shall have ~ ***5×10⁶*** events in each resulting in corresponding errors δA_n=0.0017, $\delta A_{nn}=\delta A_{ss}$=0.003.

2. DPE process: (luminosity 2×10^{29} $cm^{-2}sec^{-1}$)

- About ***1·10⁶*** events with the proton tag on each side, proton in either pot;
- ***3·10⁵*** DPE events with fully reconstructed proton momentum.

Runs 11 - 13 (30 cryo-week/yr)

Run	Energy (GeV)	System	Time	Goal	
11	$\sqrt{s}$ = 200	$p_\uparrow p_\uparrow$ or $p_\rightarrow p_\rightarrow$	6 week	20-30 pb^{-1}	
	$\sqrt{s}$ = 500	$p_\uparrow p_\uparrow$ or $p_\rightarrow p_\rightarrow$	15 week	150 pb^{-1}	FGT
	$\sqrt{s_{NN}}$ = 200	U + U	2 week	Commissioning	
12	$\sqrt{s_{NN}}$ = 200	Au + Au	12 week	0.5B minbias, 5 nb^{-1}	HFT
	$\sqrt{s_{NN}}$ = 39 - 5	Au + Au	13 week	2nd energy scan	
13	$\sqrt{s}$ = 200	$p_\uparrow p_\uparrow$ or $p_\rightarrow p_\rightarrow$	13 week	2B minbias, 100 pb^{-1}	
	$\sqrt{s}$ = 500	$p_\uparrow p_\uparrow$ or $p_\rightarrow p_\rightarrow$	12 week	300 pb^{-1}	

Run 11: (i) 1st measurement of flavor dependence of sea q/anti-q polarization in the proton at ***$\sqrt{s}$ = 500 GeV p+p collisions***

(ii) HFT engineering prototyping in ***$\sqrt{s_{NN}}$ = 200 GeV U+U collisions***

Run 12: ***Anticipating RHIC-II high luminosity***

(i) 1st HFT physics measurements of charm hadron $v_2(p_T)$ and $R_{CP}(p_T)$ in ***$\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions***

(ii) Focused energy-scan in the search for the QCD critical point. Prior accelerator development is crucial at ***$\sqrt{s_{NN}}$ = 5-6 GeV***

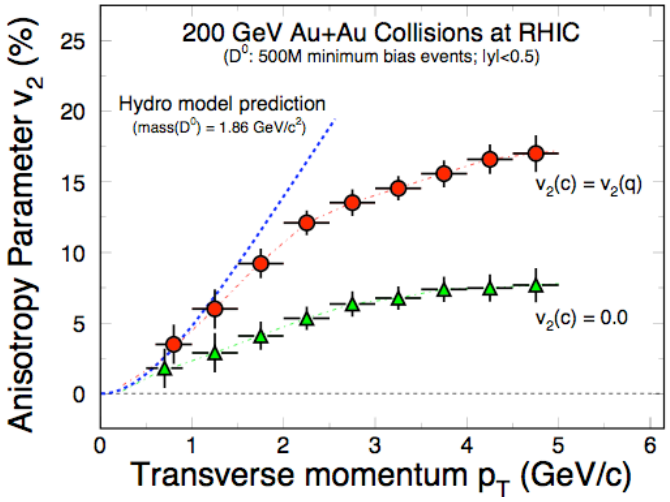
(iii) gamma-jet and quarkonia states measurements

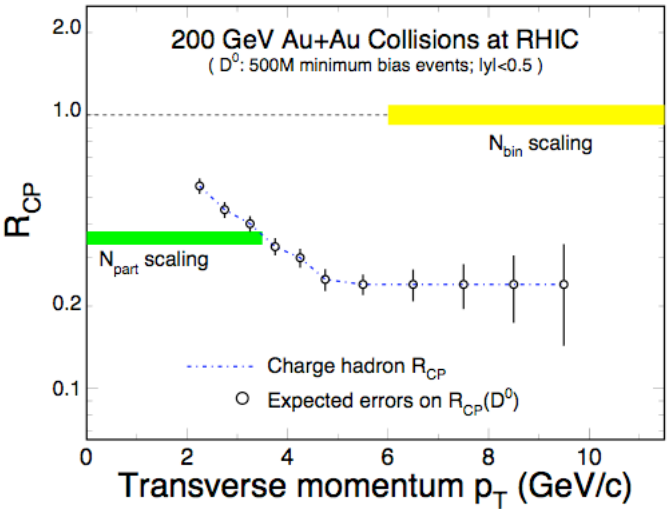
Run 13: (i) HFT physics reference measurement of charm hadron spectra in $\sqrt{s}$ = 200 GeV pp collisions; complete remaining ***$\sqrt{s}$ = 200 GeV*** spin milestones.

(ii) Measurement of the x dependence of W production at ***$\sqrt{s}$ = 500 GeV***

Future Physics Goals

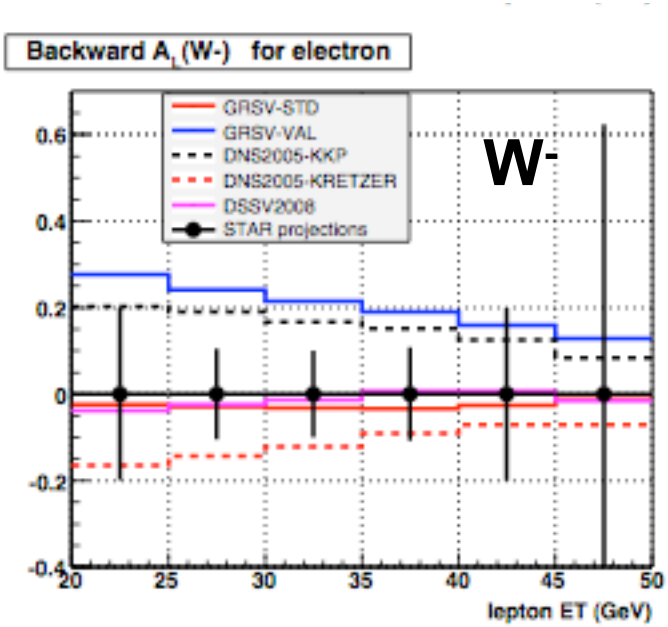
Heavy Flavor





$W^{\pm}$ Physics

L=300 pb^{-1}, pol.~ 70%



Plan to be accomplished
In Runs 11-13

Goals for Runs 9 and 10

(1) 200 GeV longitudinally polarized p+p

- Δg(x)

(2) Beam energy scan down to $\sqrt{s_{NN}}$ ~ 5-6 GeV

- Search for the QCD critical point

(3) **Top energy high statistics** Au+Au data set and ***transverse stochastic cooling*** test

(4) 500 GeV p+p collision

(5) pp2pp program

Summary

- Without high stat. 200 GeV $p_{\Rightarrow}+p_{\Rightarrow}$, we won't know ***Δg(x)***
- Without energy scan to 5 GeV, we won't find ***the QCD critical point***

STAR at the QCD Lab:

- Unique physics program
- National priorities
- Must be done in a timely fashion