STAR Physics Program

STAR Beam Use Request for Runs 11, 12

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for the STAR Collaboration

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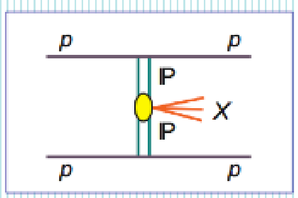
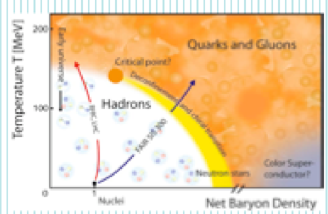
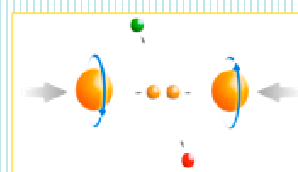
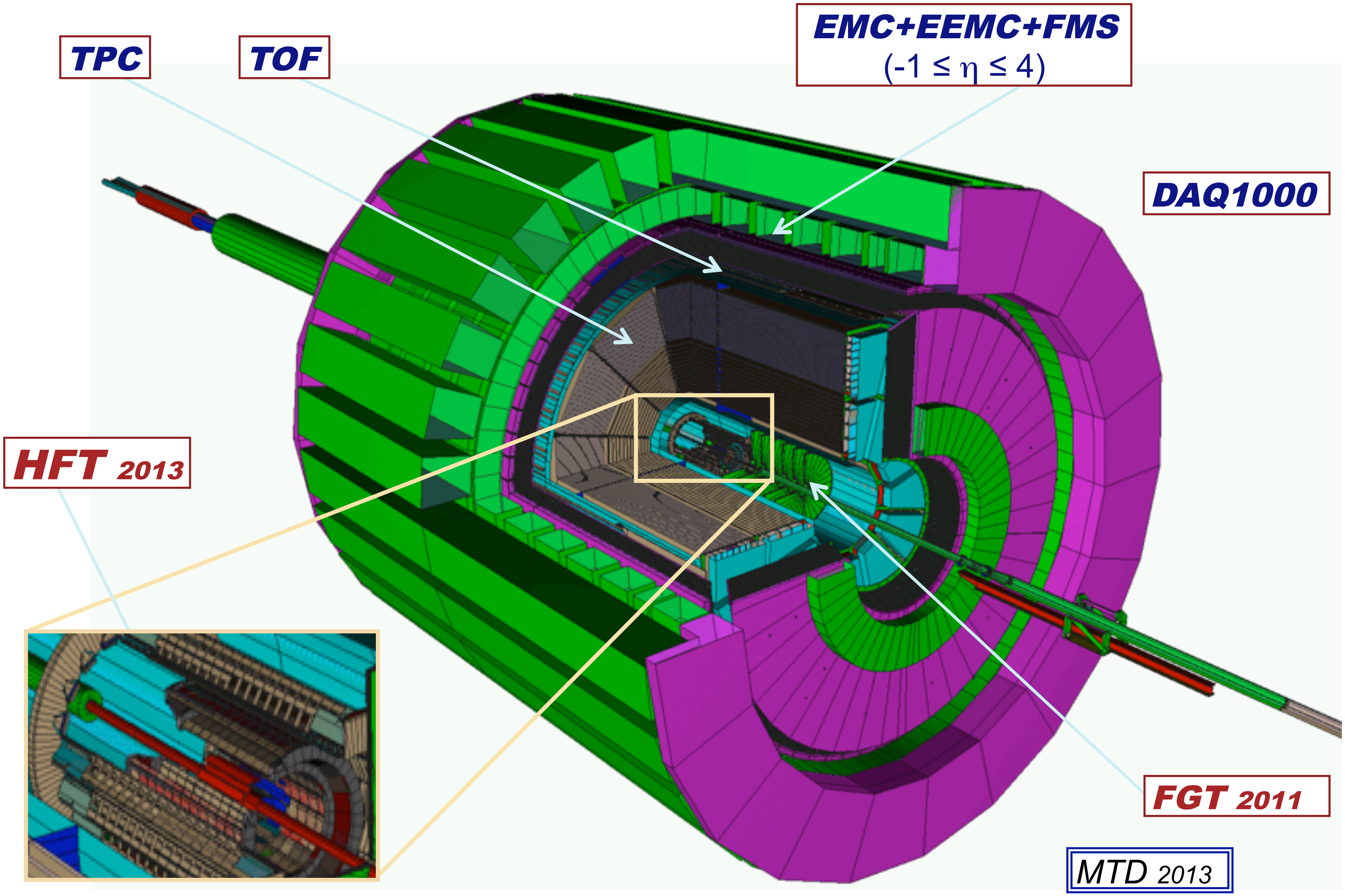


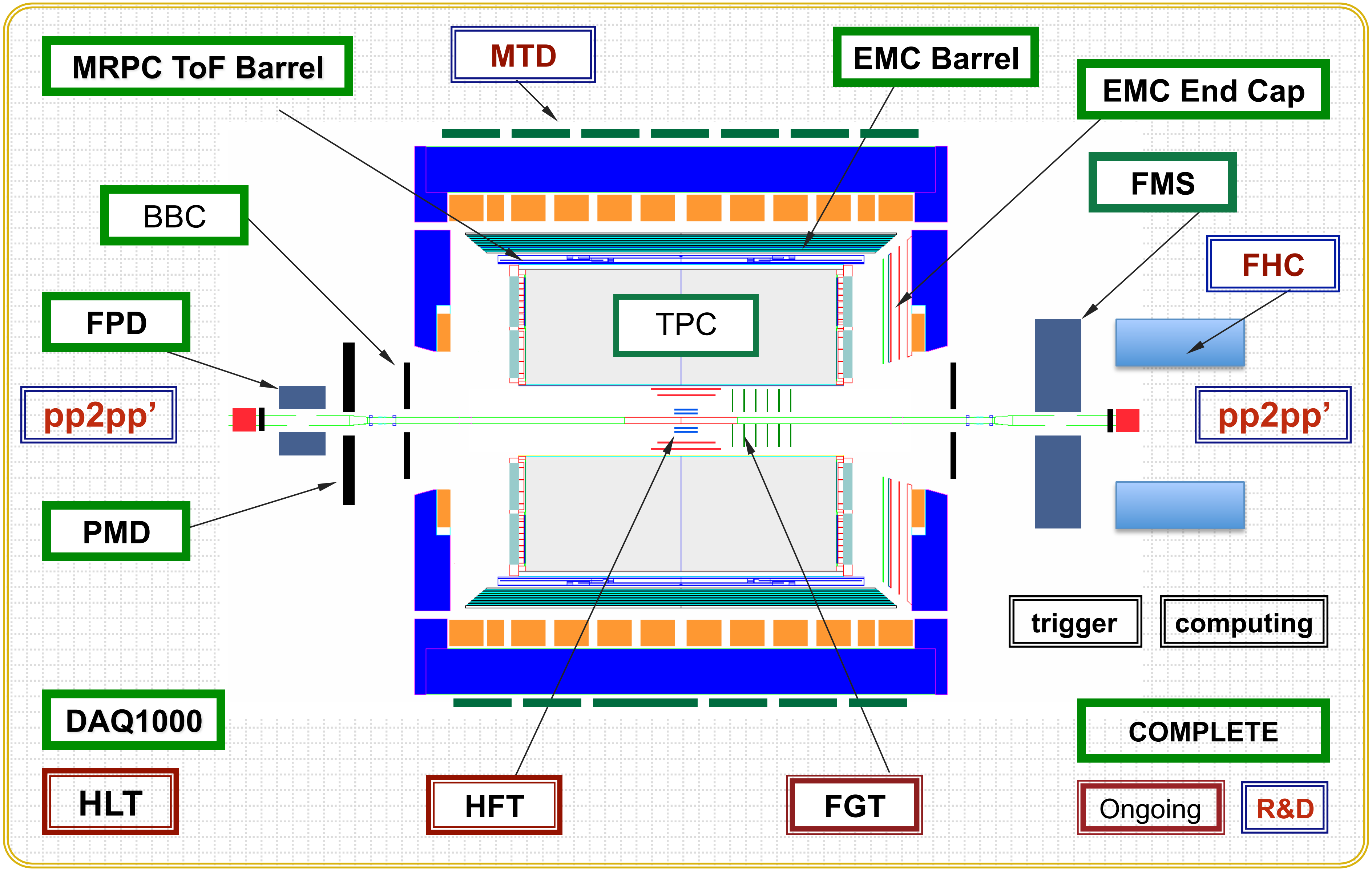




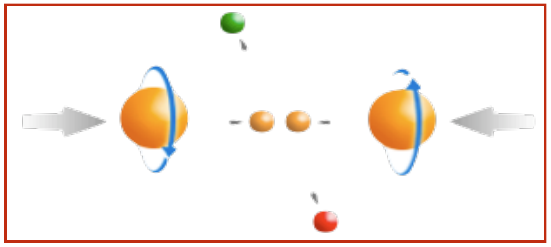
STAR Detectors *Fast and Full azimuthal particle identification*



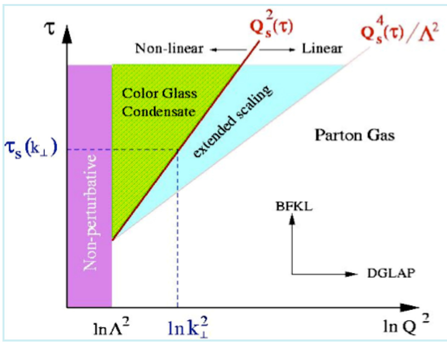
STAR Experiment



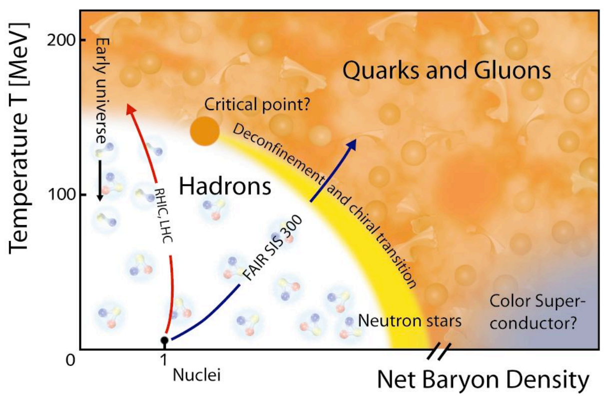
STAR Physics Focus



Polarized *p+p* program
- Study ***proton intrinsic properties***



Forward program
- Study low-x properties, search for ***CGC***
- Study elastic (inelastic) processes (pp2pp)
- Investigate ***gluonic exchanges***



1) At 200 GeV top energy
- Study ***medium properties, EoS***
- pQCD in hot and dense medium

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

STAR BUR for Runs 11 and 12

Run	Beam Energy	Time	System	Goal
11	$\sqrt{s_{NN}}$ = 18, 27 GeV*	2 weeks	Au + Au	100, 150M minbias
	$\sqrt{s_{NN}}$ = 200 GeV	4 weeks	U + U	200M minbias 200M central
	$\sqrt{s}$ = 500 GeV	5 weeks 6 weeks	$p_{\uparrow} p_{\uparrow}$ $p_{\rightarrow} p_{\rightarrow}$	trans. $P^2*L = 4\ pb^{-1}$ long. $P^2*L = 20\ pb^{-1}$
		1 week	$p_{\uparrow} p_{\uparrow}$	pp2pp at high β^*
12	$\sqrt{s}$ = 500 GeV	10 weeks	$p_{\rightarrow} p_{\rightarrow}$	long. $P^2*L = 50\ pb^{-1}$ $P^4*L = 15\ pb^{-1}$
	or		or	
	$\sqrt{s}$ = 200 GeV**		$p_{\uparrow} p_{\uparrow}$ $p_{\rightarrow} p_{\rightarrow}$	trans. $P^2*L = 8.5\ pb^{-1}$ long. $P^4*L = 4.3\ pb^{-1}$
	$\sqrt{s_{NN}}$ = 200 GeV	10 weeks	U + U or Au+Au***	$3.5\ nb^{-1}$ U+U or $5\ nb^{-1}$ Au+Au

* Request a CA-D test to determine the lowest possible collision energy at RHIC

** Request complete the Run 9 spin physics goals at $\sqrt{s}$ = 200 GeV

*** Depends on the out come of Run 11 U+U commissioning

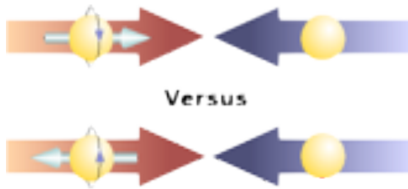
Selected STAR Spin Results

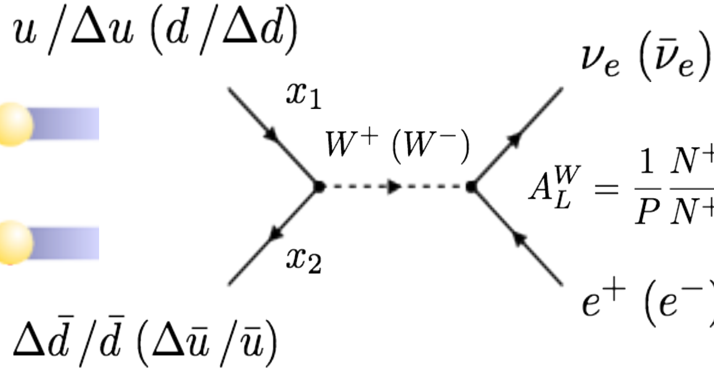
STAR W Program:

- Mid-rapidity W program ($-1<\eta<1$):
  BEMC and TPC
- Forward/Backward W program ($1<\eta<2$):
  EEMC and TPC / FGT (Installation in 2011, ready for Run 12)

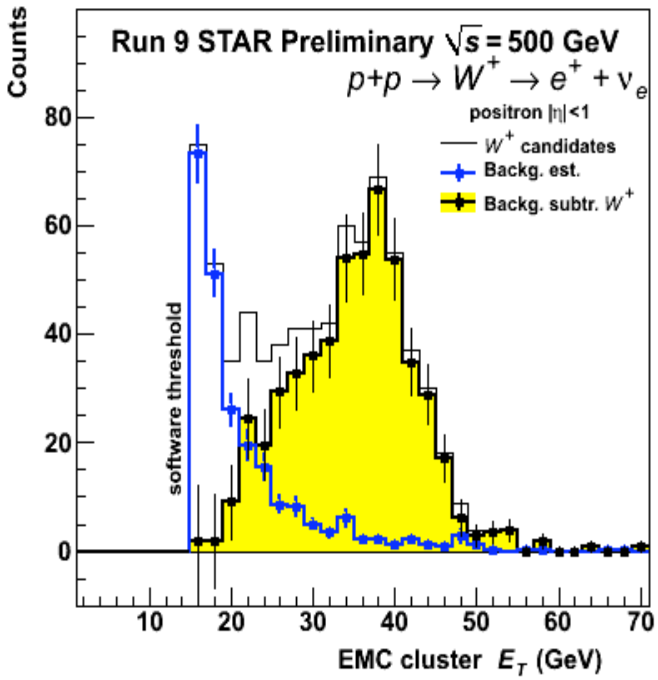
The First W Asymmetry Measurement

A_L determination





$$A_L^W = \frac{1}{P}\frac{N^+(W) - N^-(W)}{N^+(W) + N^-(W)}$$



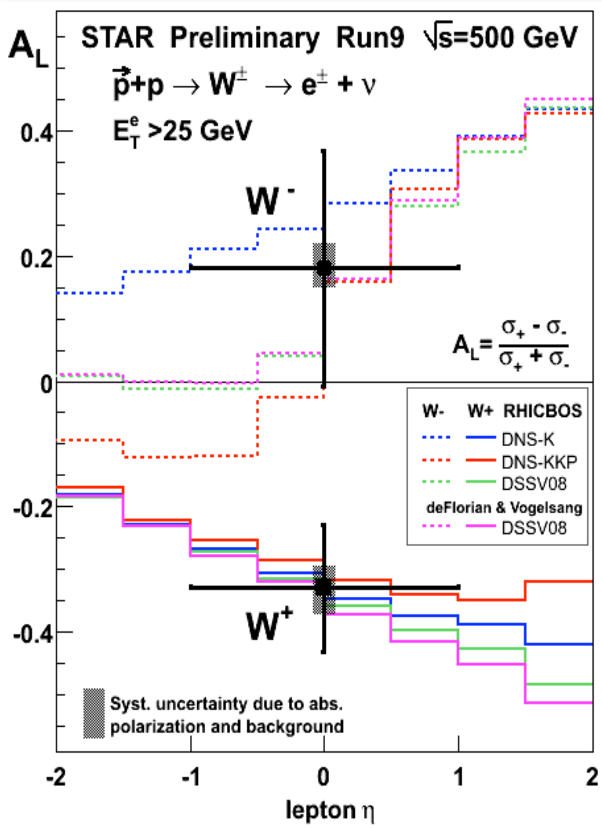
1) First measurement A_L via parity-violation in polarized proton-proton collisions.

2) W^+: Observe directly u quark polarization!

The First W Asymmetry Result

Parity-violating single-spin asymmetry A_L for W^+/W^-

$$A_L^{W^-} = \frac{1}{2}\left(\frac{\Delta\bar{u}}{\bar{u}} - \frac{\Delta d}{d}\right) \qquad A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta\bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$



STAR Preliminary Run 9 (p+p √s=500 GeV)

$$A_L(W^+) = -0.33 \pm 0.10(\text{stat.}) \pm 0.04(\text{syst.})$$

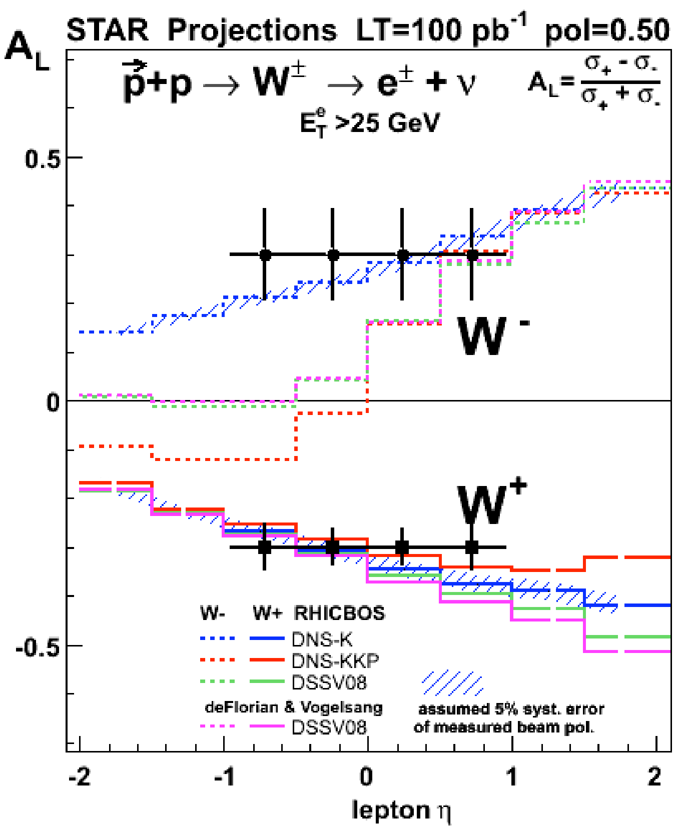
$$A_L(W^-) = 0.18 \pm 0.19(\text{stat.}) \,^{+0.04}_{-0.03}(\text{syst.})$$

1) TPC charge separation works up to $p_T \sim$ 50GeV
2) Measured asymmetries are in agreement with theory evaluations using polarized pdf's (DSSV) constrained by polarized DIS data.

Run 11: Spin Request for W

Parity-violating single-spin asymmetry A_L for W^+/W^-

$$A_L^{W^-} = \frac{1}{2}\left(\frac{\Delta\bar{u}}{\bar{u}} - \frac{\Delta d}{d}\right) \qquad A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta\bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$



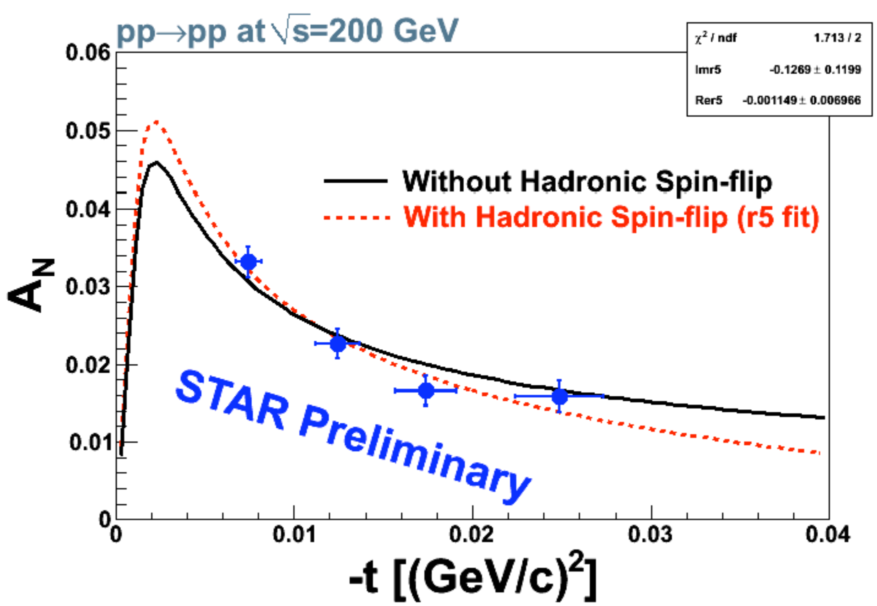
2) STAR Projection for A_L :
100 pb^{-1}
50% or better polarization

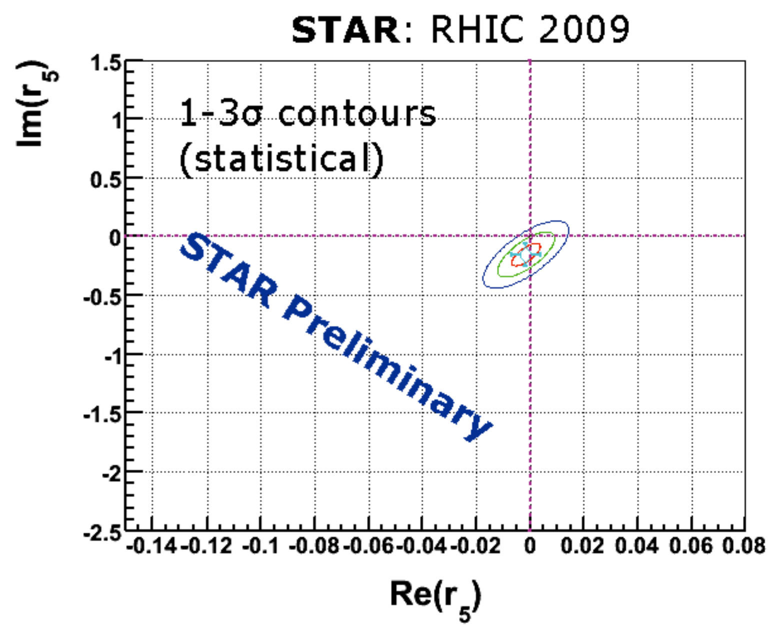
2) Significantly improve mid-y W statistics

STAR pp2pp Results

1) Central production: glueballs in Double Pomeron Exchange
2) Elastic scattering: hadronic spin-flip amplitude

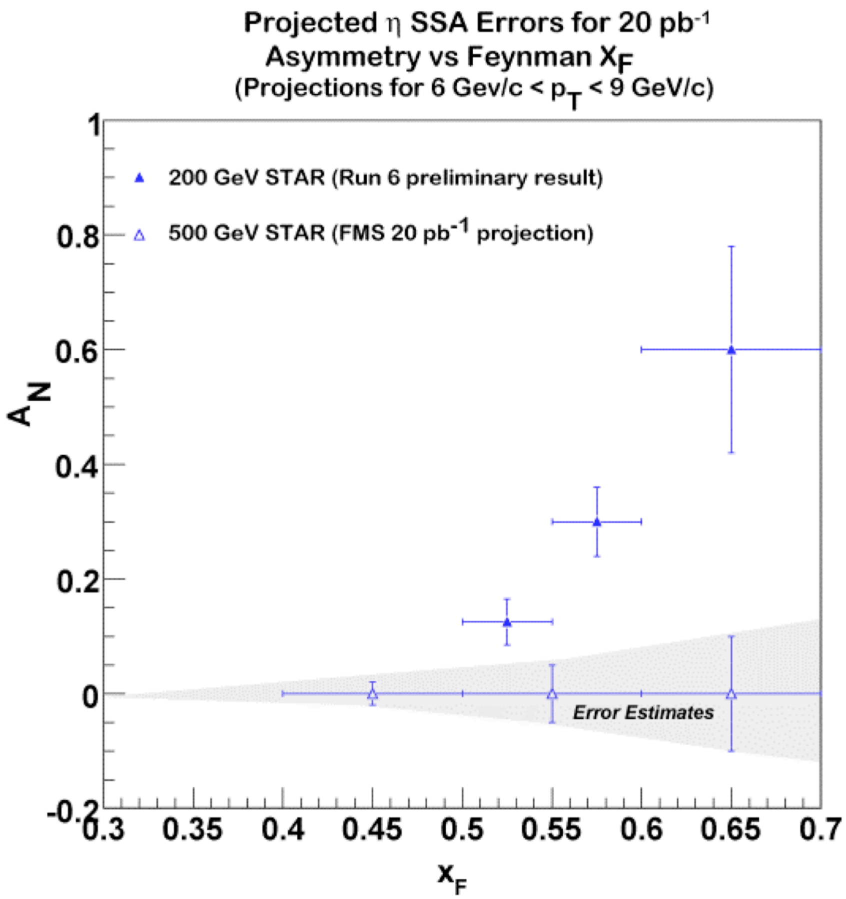
$$A_N(t) = \frac{\sigma^{\uparrow}(t) - \sigma^{\downarrow}(t)}{\sigma^{\uparrow}(t) + \sigma^{\downarrow}(t)} = C_1 \phi_{flip}^{em*} \phi_{non-flip}^{had} + C_2 \phi_{flip}^{had*} \phi_{non-flip}^{em}$$





The 200 GeV data limited sensitivity for spin flip. **In 500 GeV collisions, the *-t* range will be expanded to 0.15 (GeV/c)², more sensitive to different model predictions.**

Run 11: Transverse Spin Request



1) STAR preliminary results show that in 200 GeV p+p collisions, η-meson single spin asymmetry $A_N \sim 0.6$ at $x_F \sim 0.65$.

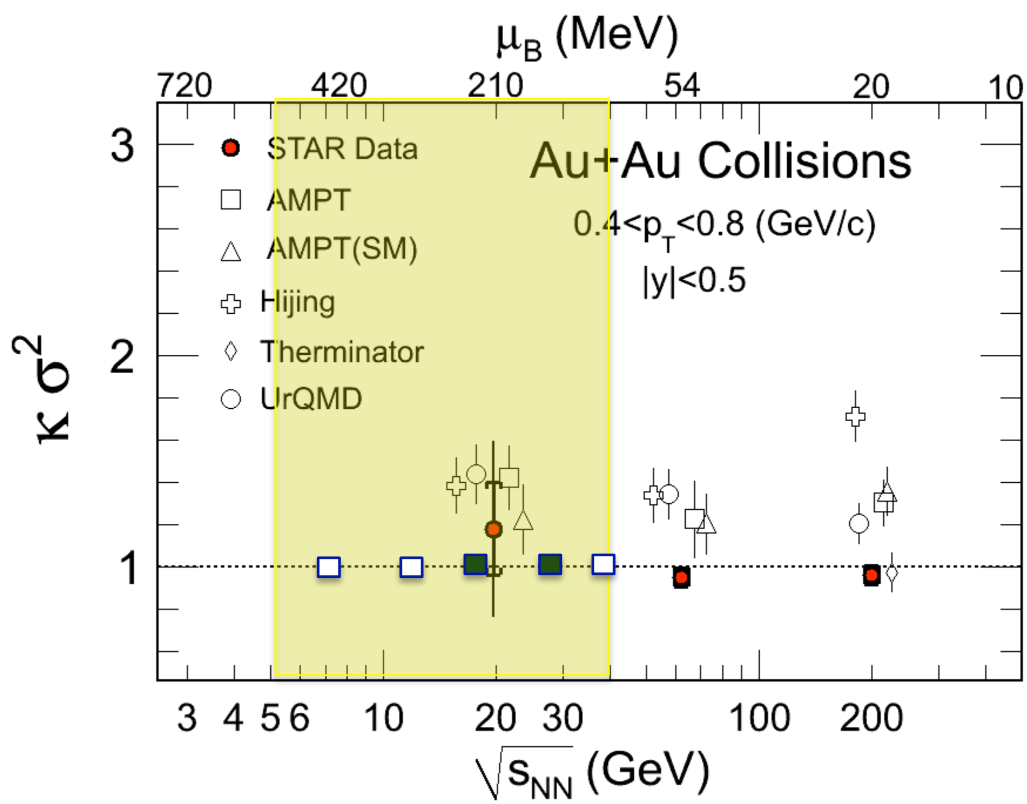
2) STAR will make a similar measurement for 500 GeV p+p collisions, with much greater precision.

3) **Run 11 request:** 20 pb^{-1} and polarization ~ 60%

Selected STAR Heavy Ion Results

Net-proton High Moments

STAR: 1004.4959, PRL



Estimated errors in Au+Au collision :

- Run 10: 7.7, 11.5, 39 GeV
- **Run 11: 18, 27 GeV**

1) STAR results* on net-proton high moments for Au+Au collisions at $\sqrt{s_{NN}}$ = 200, 62.4 and 19.6 GeV.

2) Sensitive to critical point**:

$$\left\langle (\delta N)^2 \right\rangle \approx \xi^2, \quad \left\langle (\delta N)^3 \right\rangle \approx \xi^{4.5}, \quad \left\langle (\delta N)^4 \right\rangle \approx \xi^7$$

3) Direct comparison with Lattice results**:

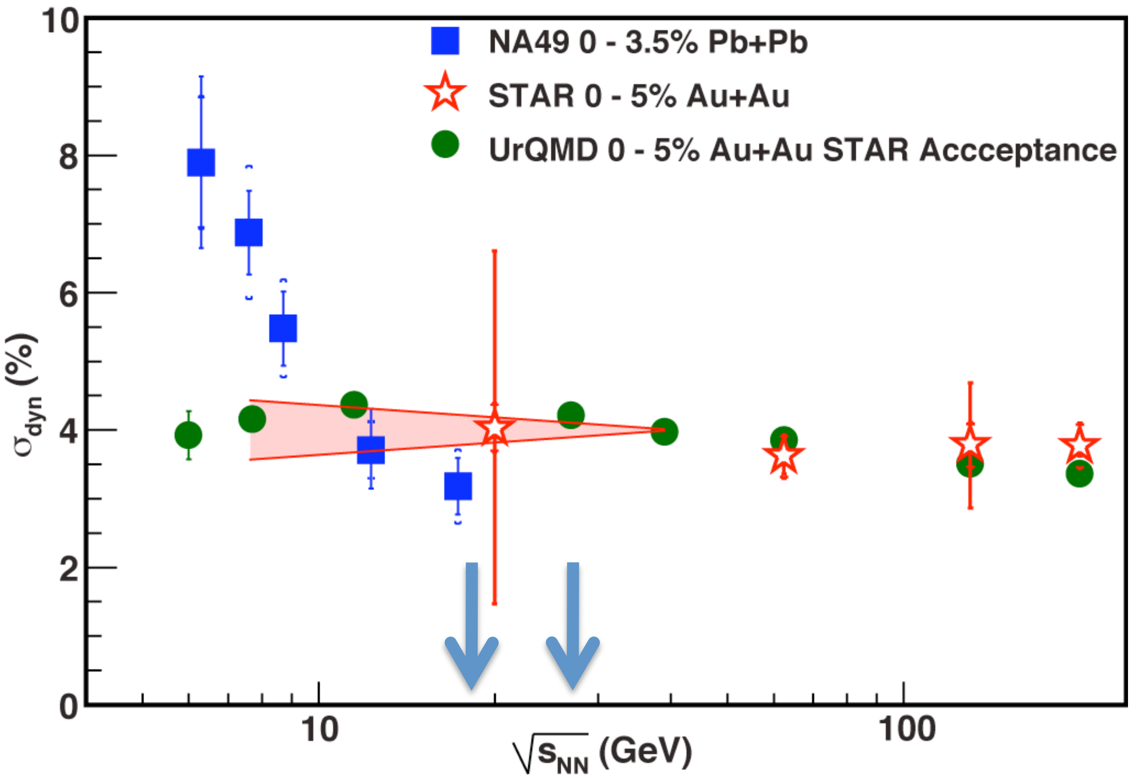
$$S*\sigma \approx \frac{\chi_B^3}{\chi_B^2}, \qquad \kappa*\sigma^2 \approx \frac{\chi_B^4}{\chi_B^2}$$

4) Extract susceptibilities and freeze-out temperature. An independent test on thermal equilibrium in HI collisions.

* STAR: 1004.4959, accepted by PRL.
** M. Stephanov: PRL,102, 032301(09).
*** R.V. Gavai and S. Gupta: 1001.2796.

Identified Particle Fluctuations

$(K^+ + K^-)/$
$(\pi^+ + \pi^-)$



<u>K/π fluctuations</u>

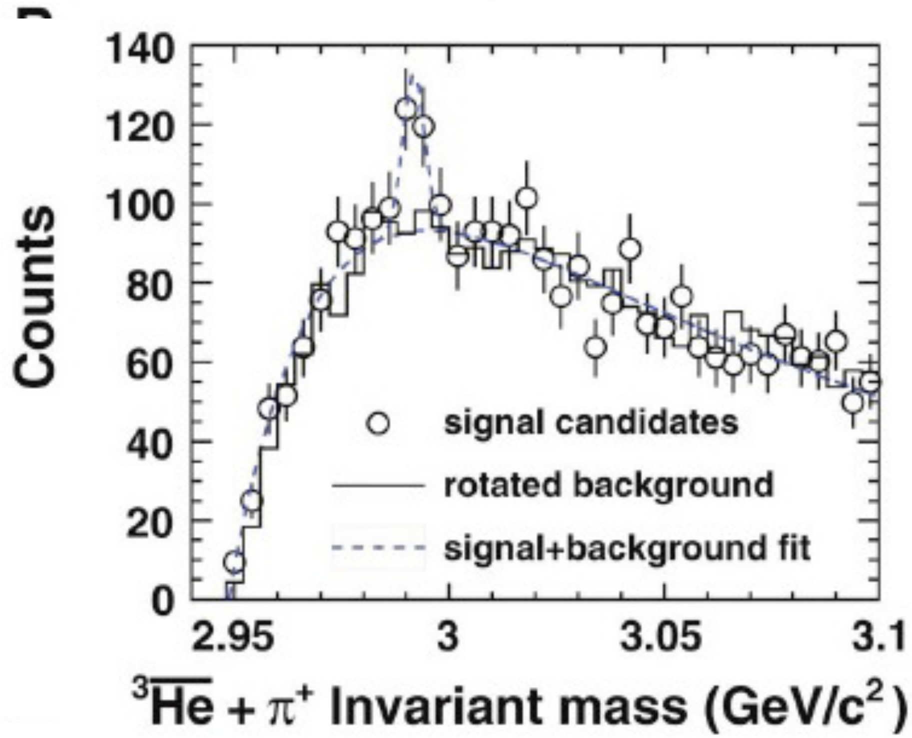
1) STAR: Full PID, large acceptance uniform over $\sqrt{s_{NN}}$
2) Accurate and differential measurements: error estimates from Run 10 data

First Observation of $^{3}_{\Lambda}\overline{H} \rightarrow {}^{3}\overline{He} + \pi^{+}$

Sciencexpress Research Article

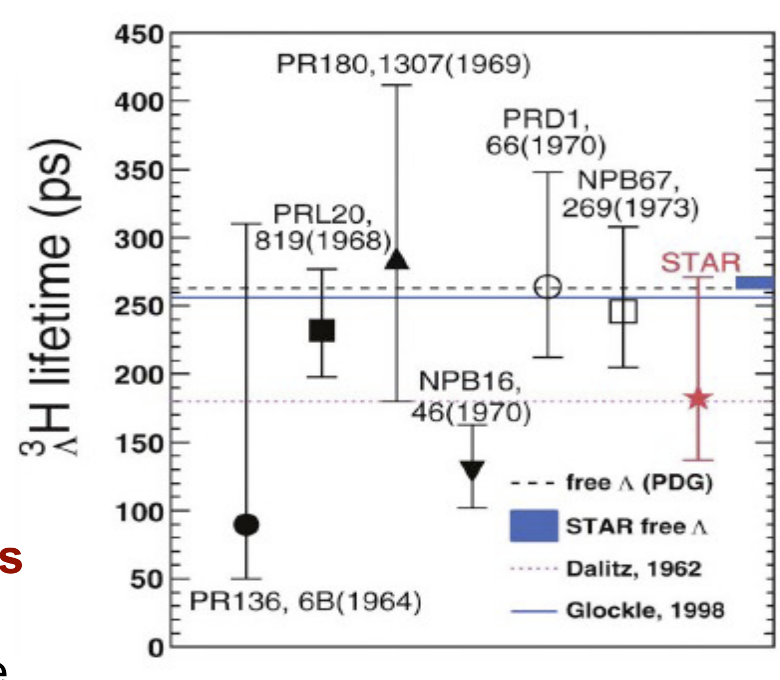
Observation of an Antimatter Hypernucleus

The STAR Collaboration*†



200 GeV Au+Au collisions at RHIC

- Equilibrium of s-quarks
- Thermal models (Stachel *et al*.)

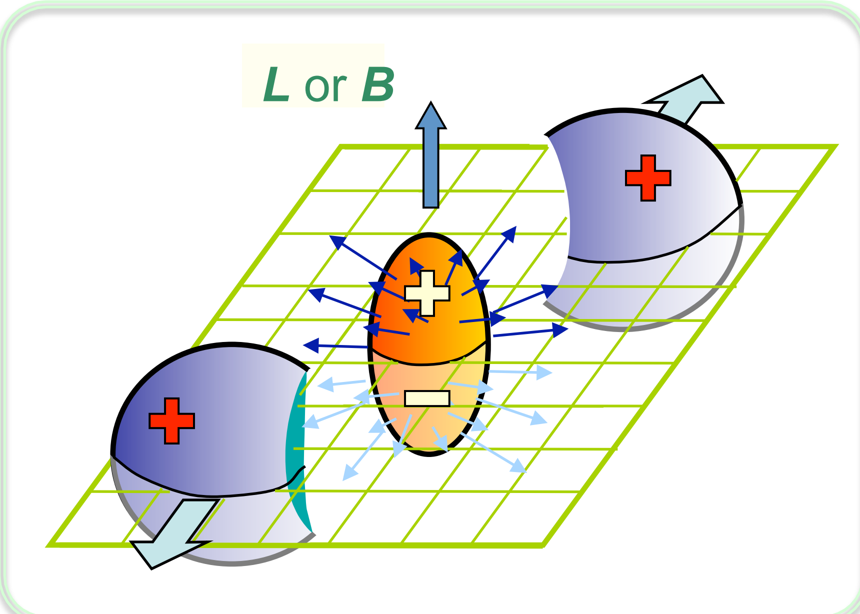


- First observation of **the anti-hypernucleus**
- Lower energy, higher baryon density.

Run 11 request: Beam energy dependence

Search for Local Parity Violation

in High Energy Nuclear Collisions

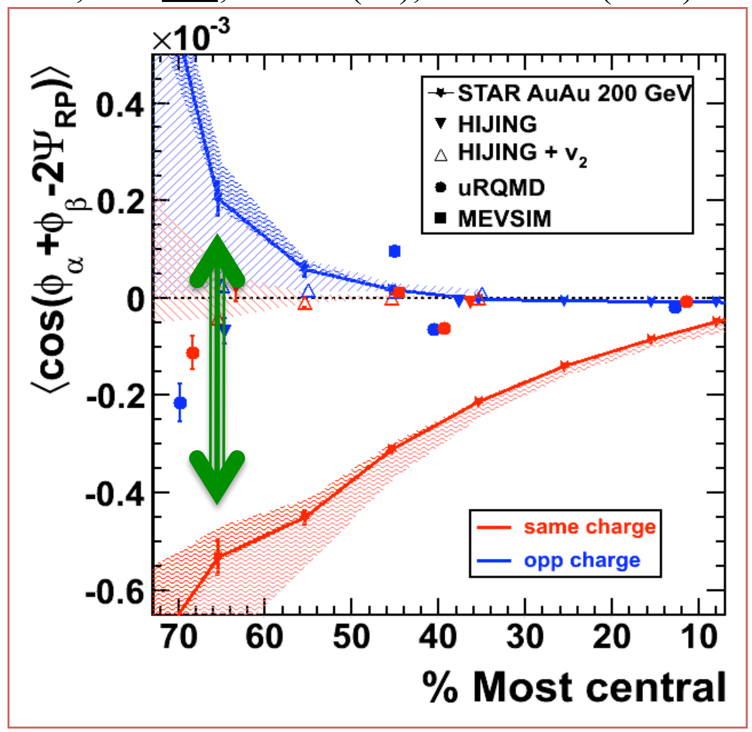


$$\left\langle \cos\left(\phi_\alpha + \phi_\beta - 2\Psi_{RP}\right)\right\rangle$$

Parity even observable

Voloshin, PR C62, 044901(00).

STAR; PRL**103**, 251601(09); 0909.1717 (PRC).



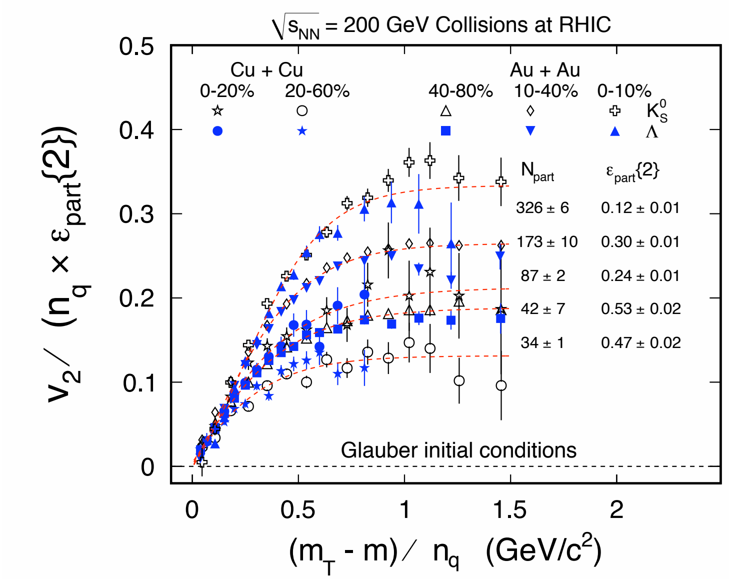
The separation between the same-charge and opposite-charge correlations.

- **Strong external EM field**
- ***De-confinement* and *Chiral symmetry restoration***

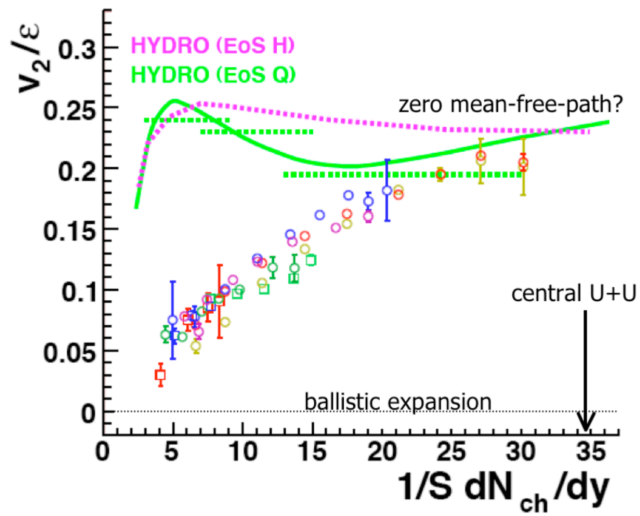
Run 11 requests:

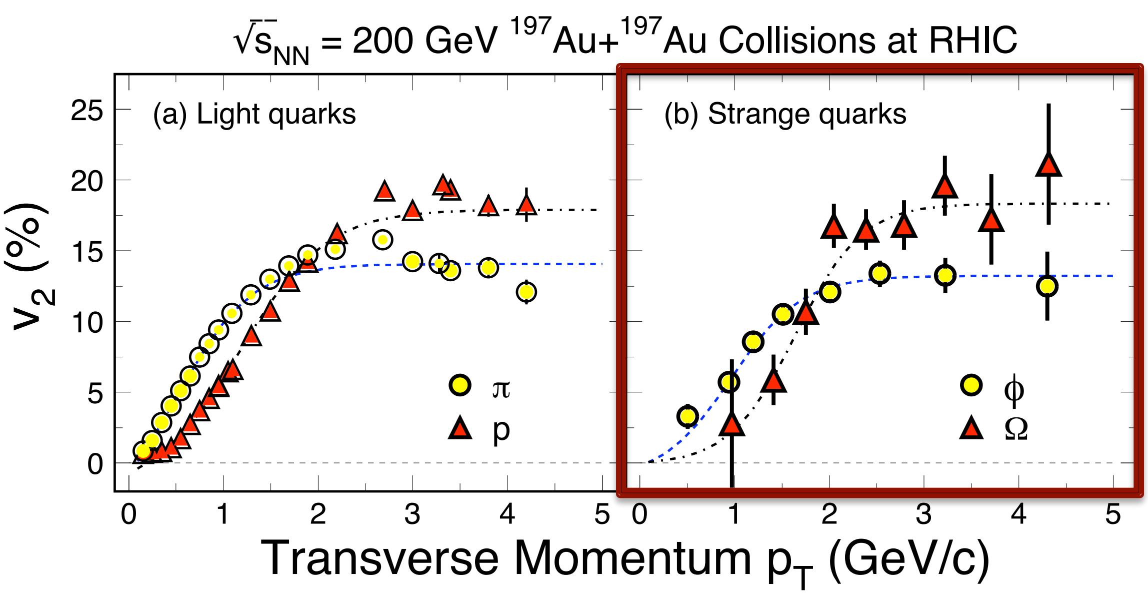
Beam Energy Dependence & U+U

Systematic Results on Collectivity



***STAR*:**
PRL **92**, 052302(04)
PRL **95**, 122301(05)
PRC ***77***, 54901(08)
PRC ***81***, 44902(10)





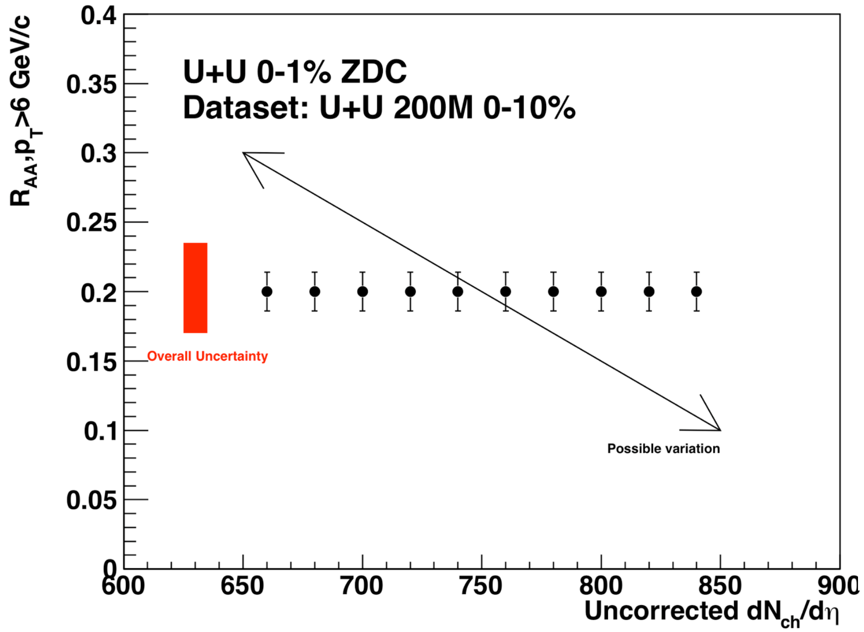
Results:

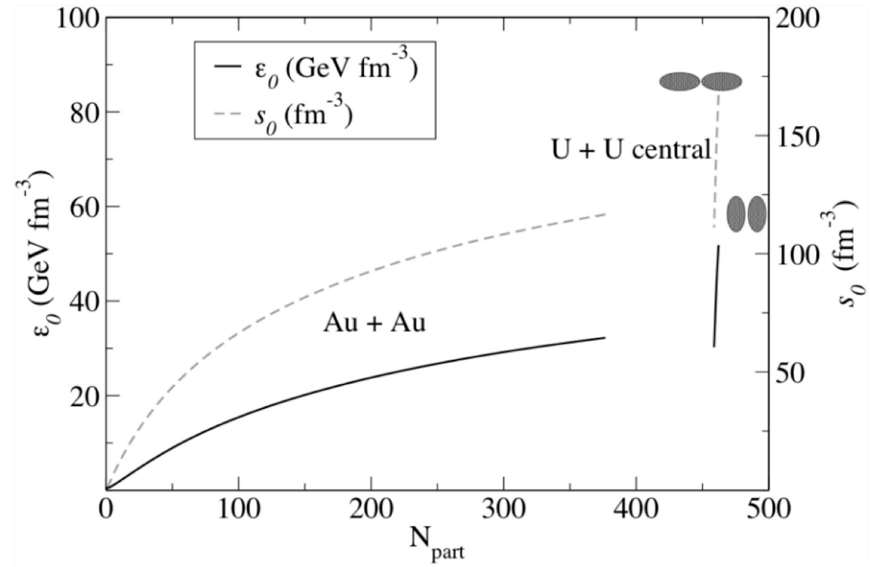
1) Partonic collectivity at RHIC
2) Number of constituent quark scaling – partonic degrees of freedom at play

➔ **Run 11 request**: UU collisions test the hydro limit, LPV, …

Run 11 Request U+U Collisions

U. Heinz et al, PRL **94**, 132301(05)

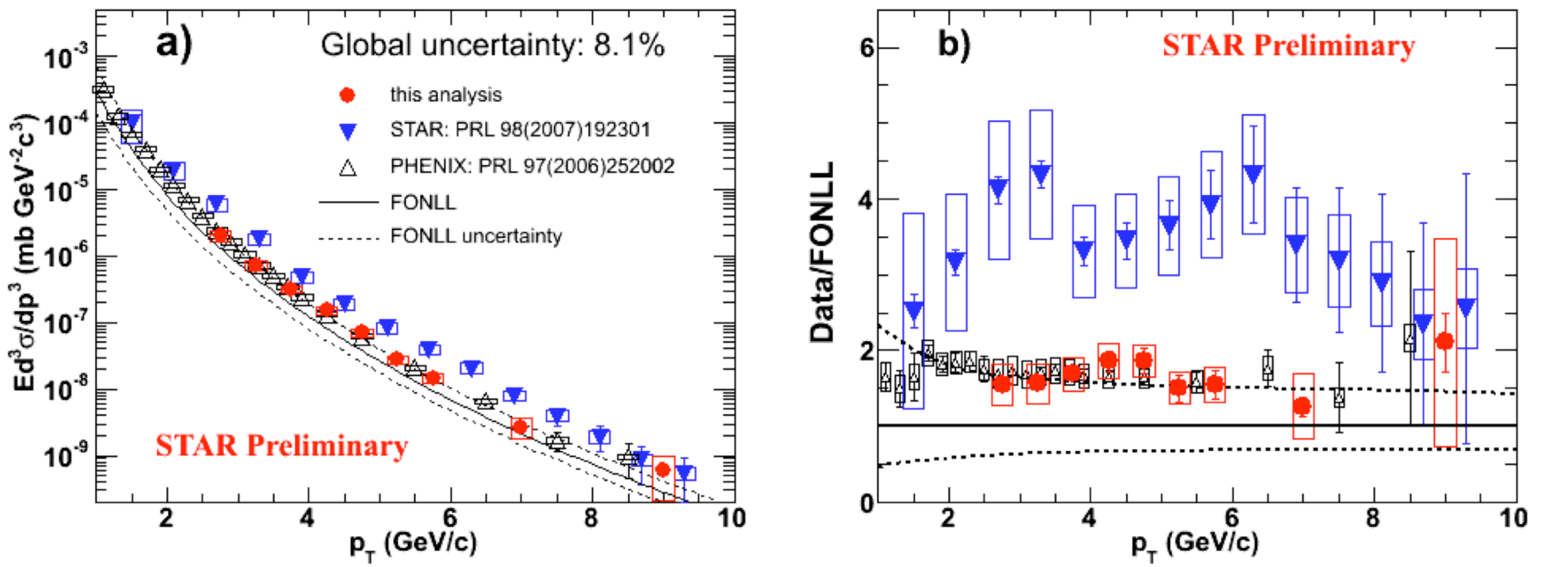




1) Significant increase in energy density for hydrodynamic studies
2) Prolate shape: path-length dependence of E_{loss} at much higher density
3) First run from EBIS likely to be moderate intensity.

Run 11 request: 200M MB and 200M central UU collisions.

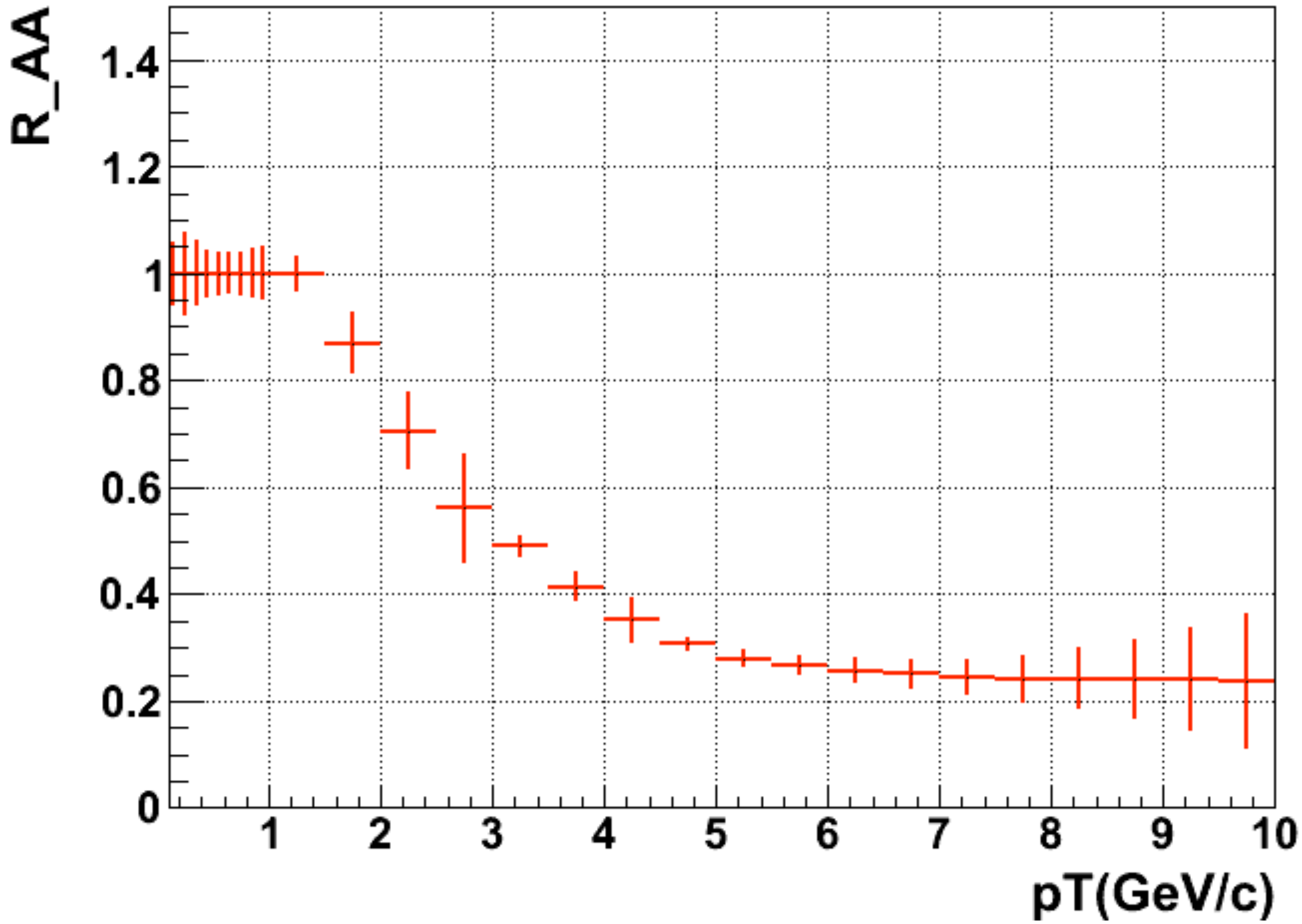
Status of NPE from p+p Collisions



STAR Heavy flavor decay electron (p_T > 2.5 GeV/c) differential cross section analysis:

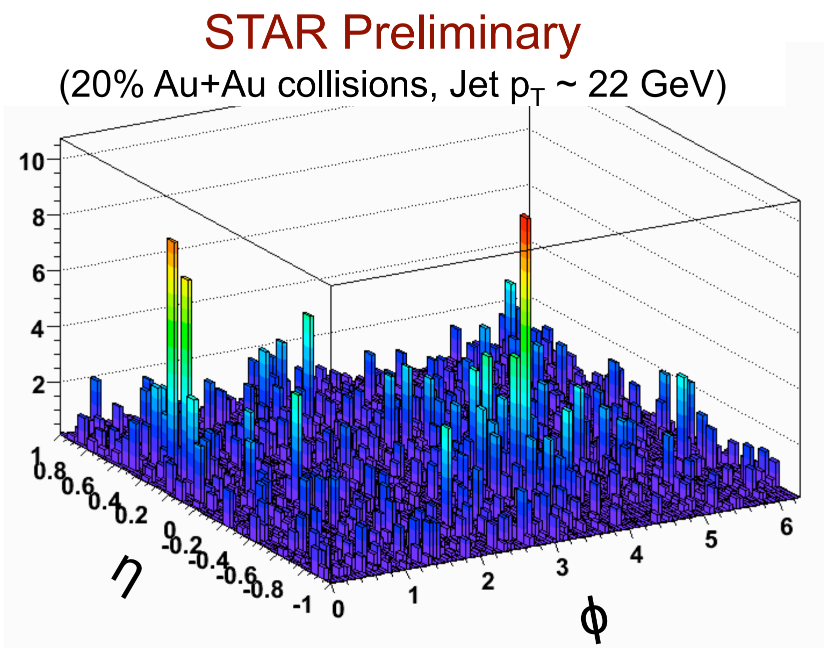
1) An error in the efficiency correction in 2003 data analysis identified.
2) New results from 2005 (SVT), 2006 (SVT) and 2008 (no SVT) are consistent.

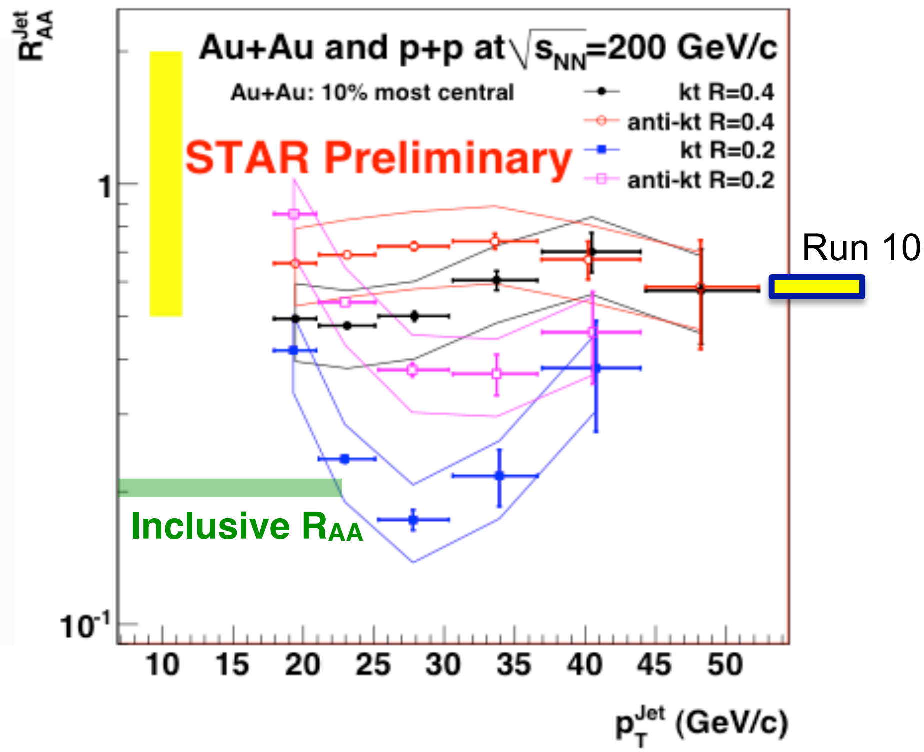
NPE R_{AA} Projection for Run 10



1) Run 8 data, scaled to Run 9 and 10 statistics
2) NPE measurement up to ~10 GeV/c.

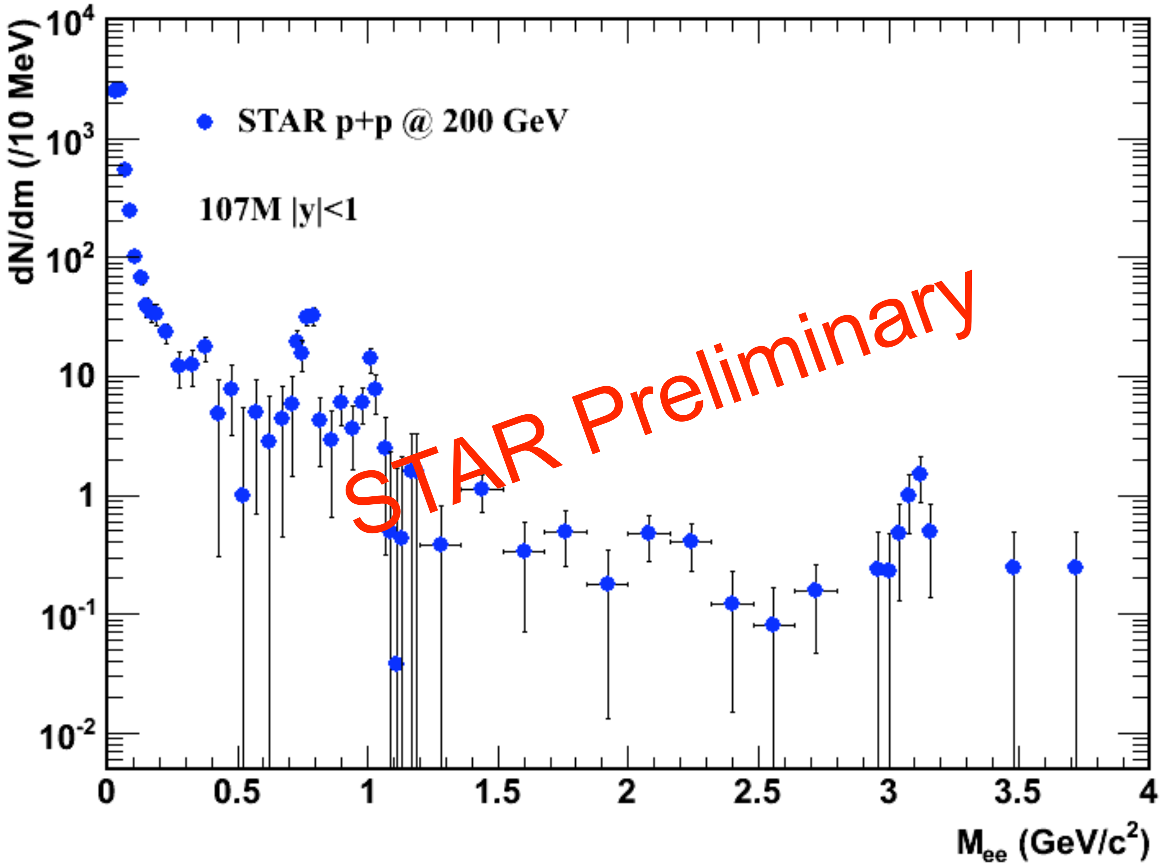
Status on Jet Reco. in A+A collisions





1) Jets are seen in Au+Au collisions, extended the kinematical reach to jet energies > 40 GeV in central Au+Au collisions at RHIC
2) We see a substantial fraction of jets - in contrast to x5 suppression for light hadron R_{AA}
3) Run 10 statistics: a factor of 40 increase

Di-lepton Program at STAR

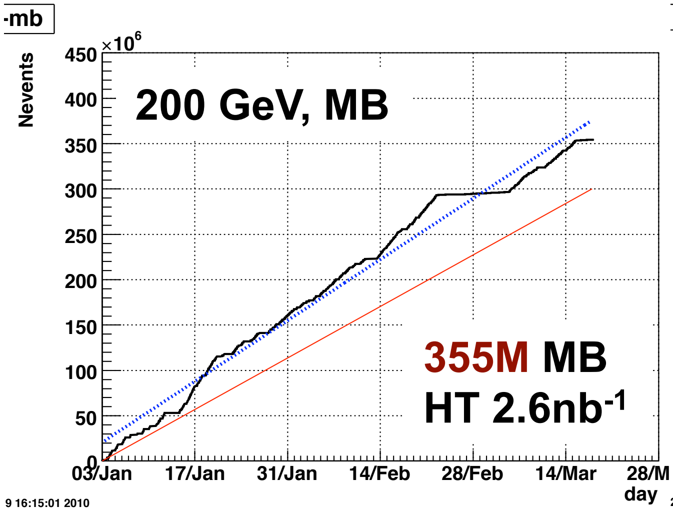


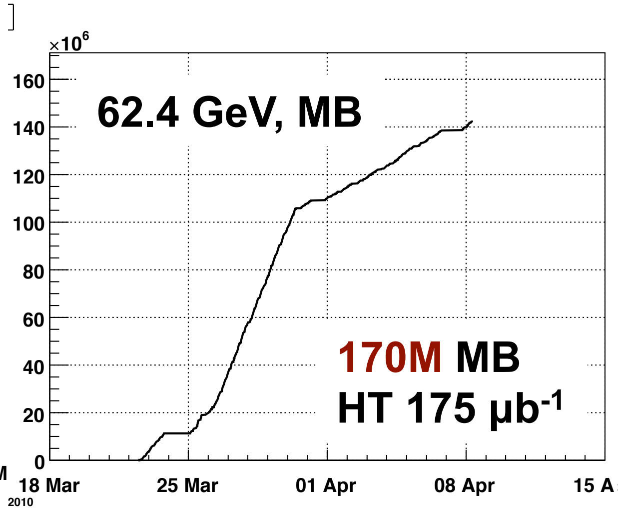
1) Run 9: 200 GeV p+p collisions, 75% TOF installed.
2) STAR will do the di-electron analysis for Au+Au collisions data from Run 10 with 100% TOF.
3) **Run 11 request**: 150M events from 27 GeV Au+Au collisions.

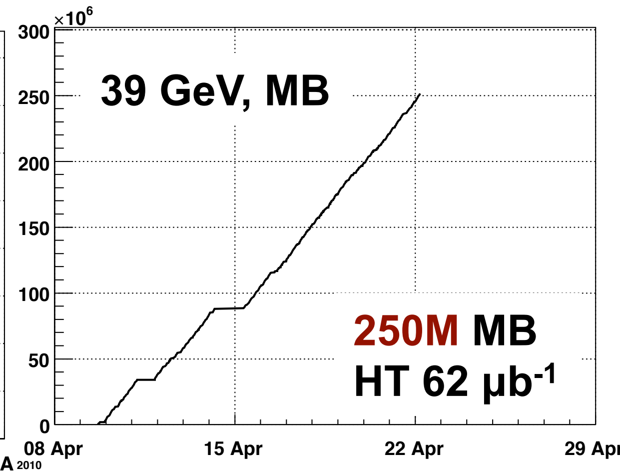
Results from Run 10

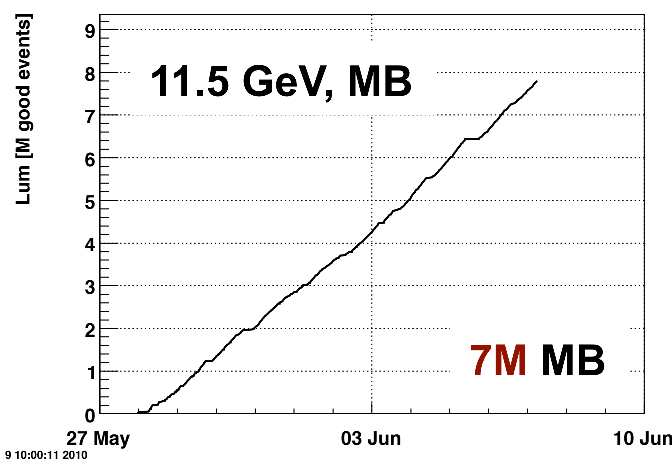
Run 10: 200, 62.4, 39, 11.5 7.7 GeV

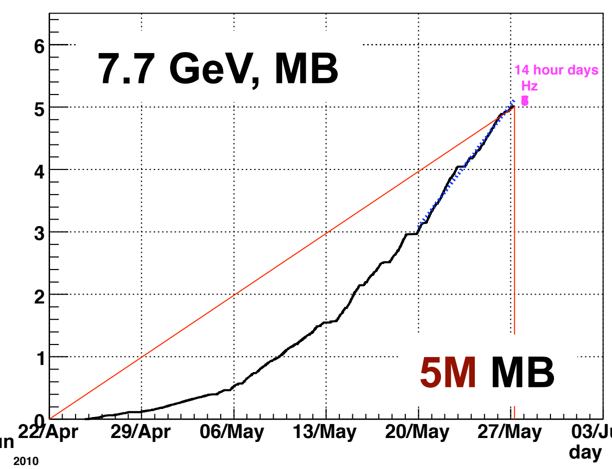
A great success, many thanks to CA-D!

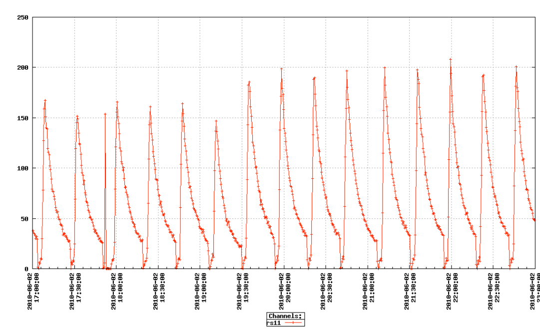






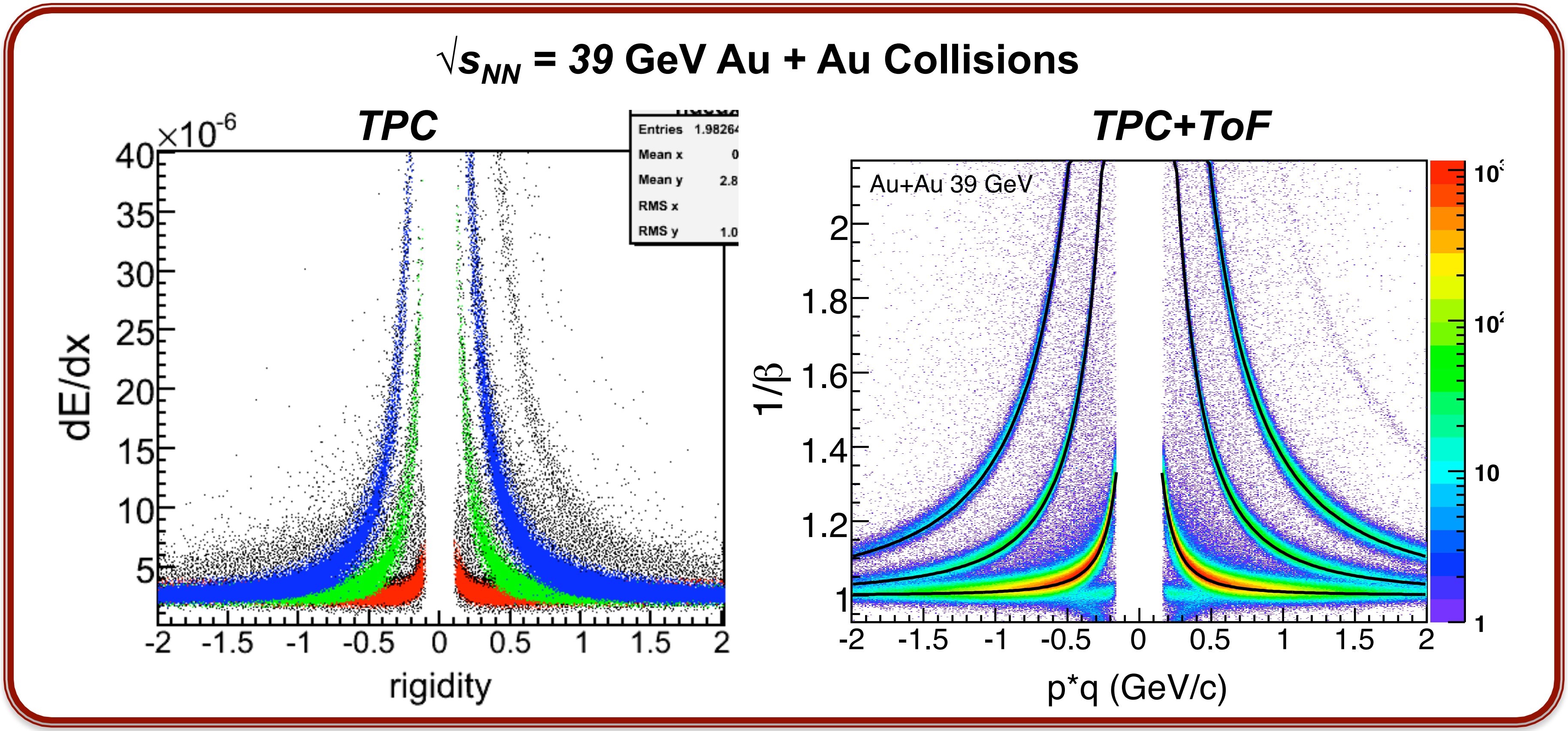






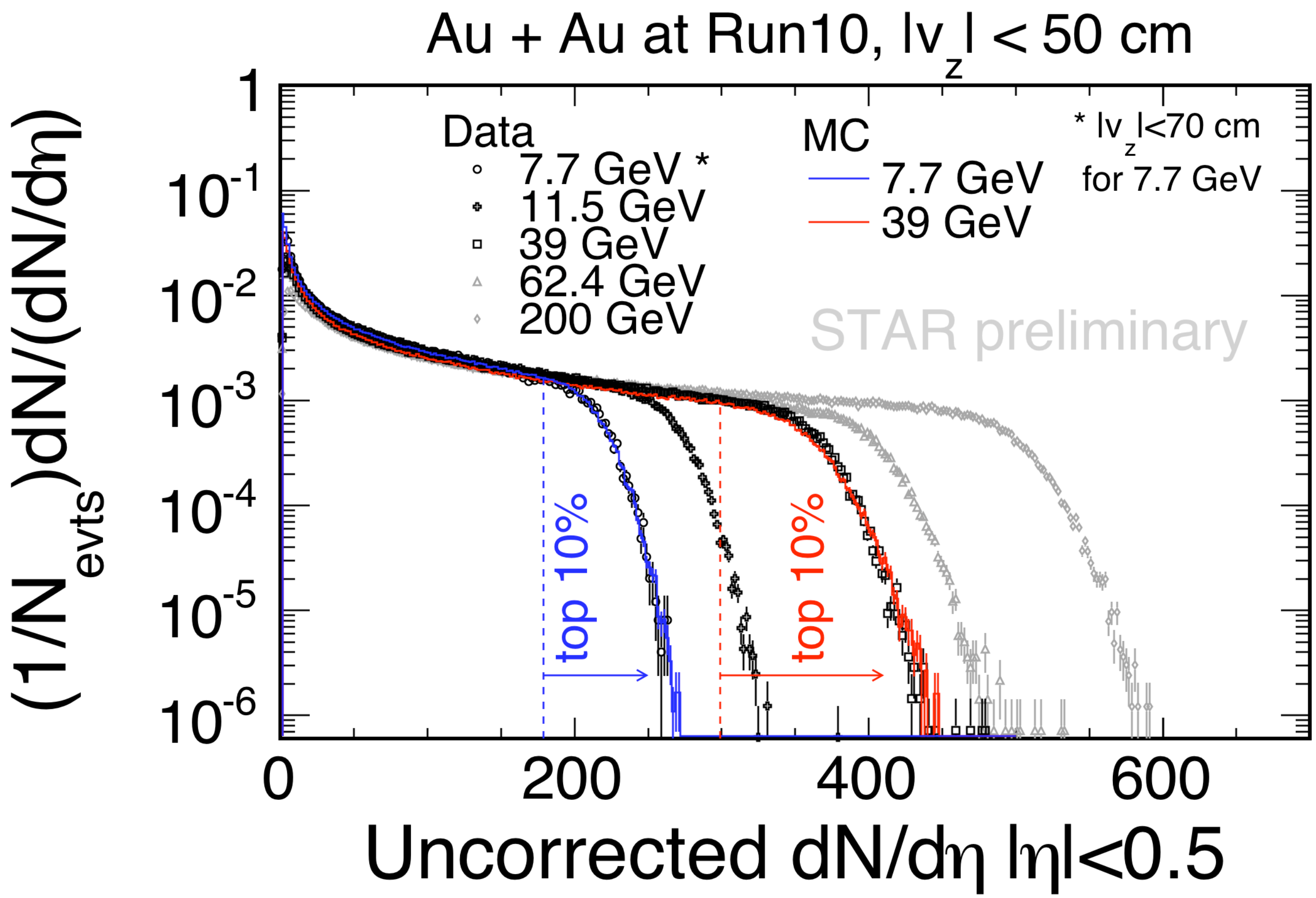
1) Successful run, all goals were reached or exceed
2) Many thanks to CA-D

Run 10 Performance



Beam Energy	Timing Resolution	Remarks
200 (GeV)	85 (*ps*)	At 39 GeV, using a new calibration scheme without information of start time from VPD, 87 *ps* of timing resolution has been achieved.
62.4 (GeV)	90 (*ps*)	
39 (GeV)	85 (*ps*)	

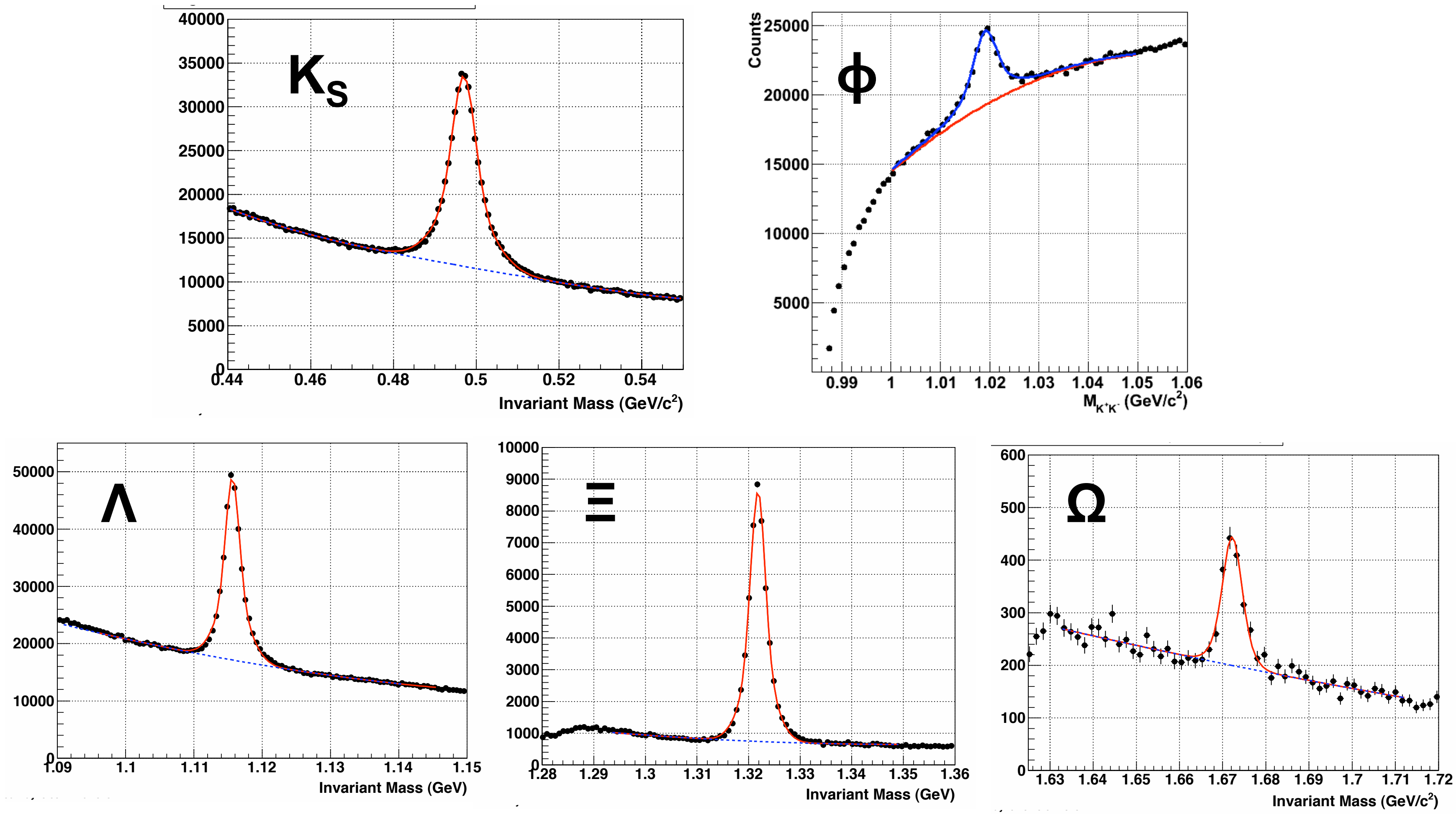
Collision Centralities



1) Collision geometries at different energies are under control
2) **Run 11 request**: 18 and 27 GeV Au+Au collisions

Particle Identification at STAR

$\sqrt{s_{NN}}$ = 39 GeV Au + Au Collisions



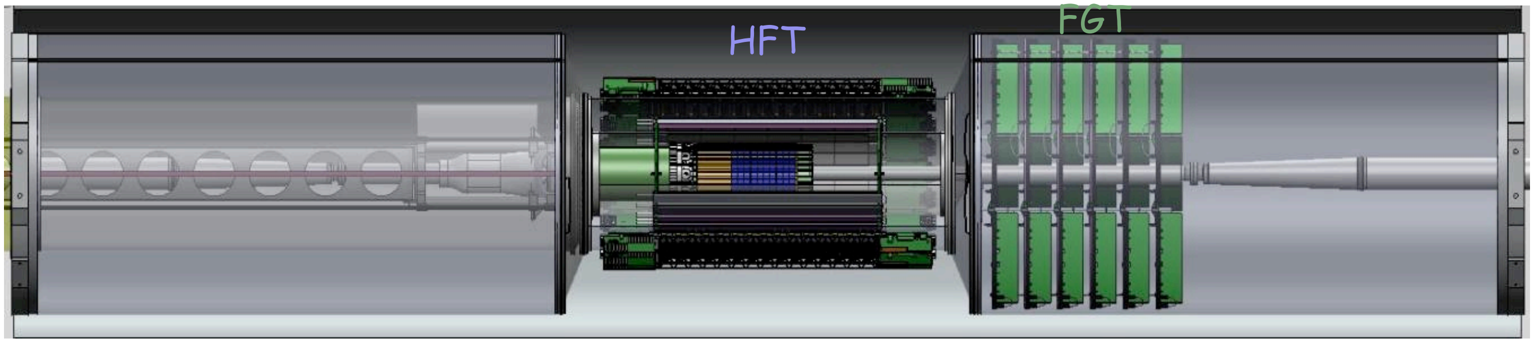
Invariant Mass (GeV)

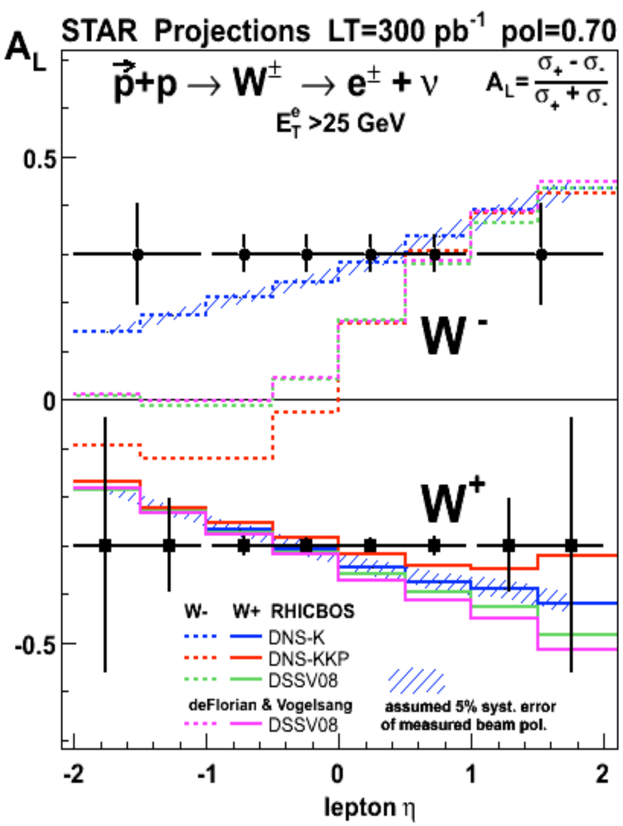
STAR Upgrades

STAR Upgrade Timeline*

Upgrade	Completion	Key Physics Measurements
FMS	Completed 2008	(a) Trans. Asymmetry at forward-y (b) CGC
TPC DAQ1000	Completed 2009	Minimal dead time, large data set
MRPC TOF	Completed 2010	Fast PID in full azimuthal acceptance
FGT	Summer 2011 Ready for Run 12	Forward-y $W^{\pm}$ for flavor separated quark polarization
HFT**	Summer 2013 Ready for Run 14	(a) Precision hadronic ID for charm and Bottom hadrons (b) Charm and Bottom hadron energy loss and flow
MTD	Summer 2013 Ready for Run 14	(a) High p_T muon trigger (b) Quarkonia states
pp2pp'	Summer 2014 Ready for Run 15	

Forward GEM Tracker

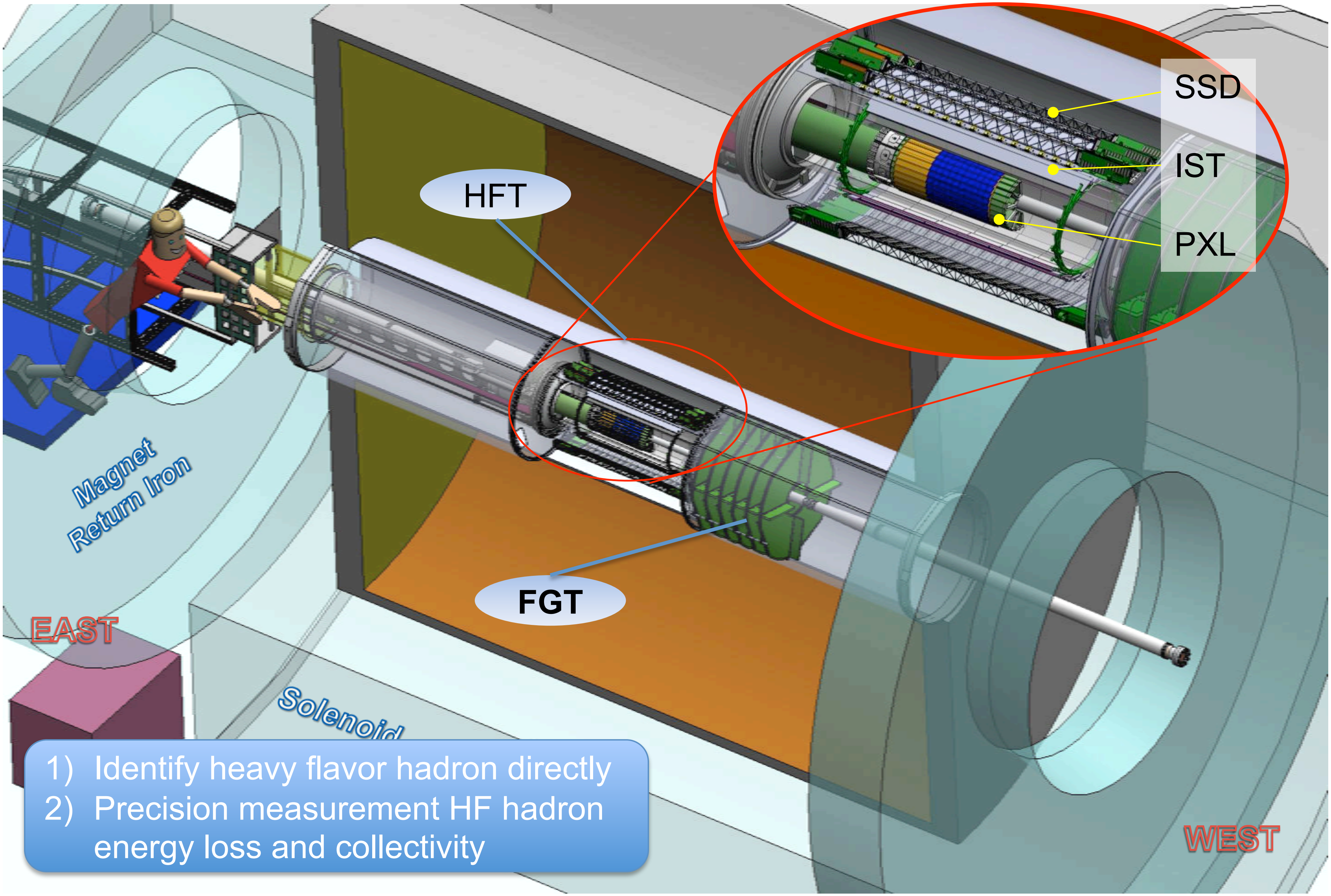




1) FGT: RHIC MIE project
2) Six light-weight triple-GEM disks
3) New mechanical support structure
4) Planned installation: Summer 2011

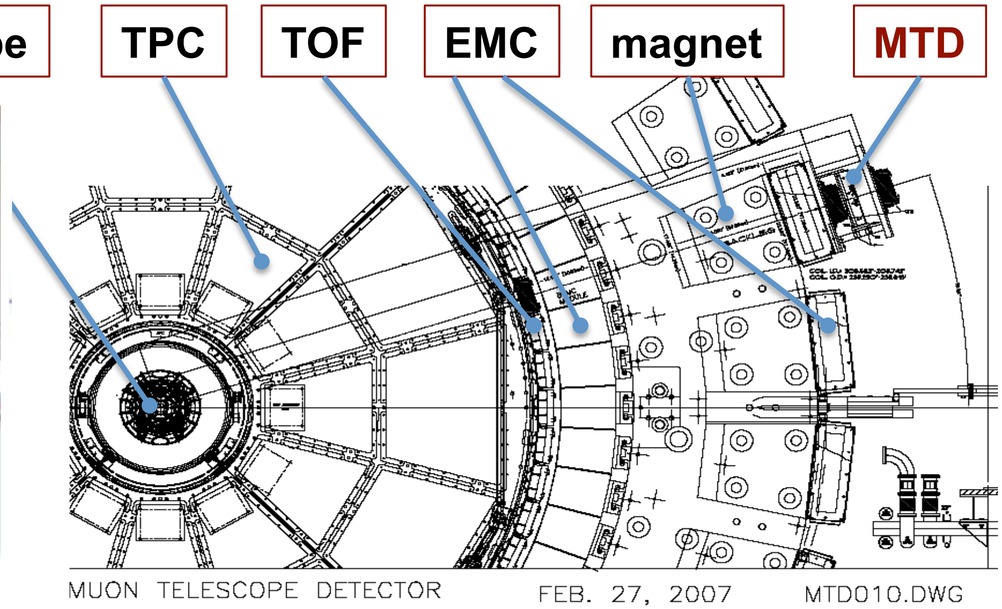
1) Full charge-sign discrimination at high-p_T
2) Design polarization performance of **70% or better** to collect at least 300pb^{-1}
3) **Ready for Run 12!**

Heavy Flavor Tracker at STAR



1) Identify heavy flavor hadron directly
2) Precision measurement HF hadron energy loss and collectivity

STAR: Muon Telescope Detector



Muon Telescope Detector (MTD) at STAR:

1) MRPC technology; μ_ε ~ 36%; cover ~45% azimuthally and |y| < 0.5
2) TPC+TOF+MTD: muon/hadron enhancement factor ~ 10^{2-3}
3) For high p_T muon trigger, heavy quarkonia, light vector mesons, B→J/Ψ+X
4) China-India-STAR collaboration: a proposal sub. to BNL 02/2010.

Summary

1) Spin Physics

- $W^{\pm}$ A_L at mid-y (2011) and forward-y (2012)
- Light meson A_N at forward-y (2011)
- DPE and hadronic spin-flip amplitude
- Δg measurements at 500 GeV (2012) and 200 GeV (2013)

2) Heavy Ion Physics*

- Complete BES at 18 and 27 GeV including di-electron program at STAR (2011)
- U+U collisions: hydro limit, LPV, path length dep. (2011)
- High luminosity AA collisions (2012)

* Request a CA-D test to determine the lowest possible collision energy at RHIC

STAR BUR for Runs 11 and 12

<table>
<tr><th>Run</th><th>Beam Energy</th><th>Time</th><th>System</th><th>Goal</th></tr>
<tr><td rowspan="4">11</td><td>$\sqrt{s_{NN}}$ = 18, 27 GeV*</td><td>2 weeks</td><td>Au + Au</td><td>100, 150M minbias</td></tr>
<tr><td>$\sqrt{s_{NN}}$ = 200 GeV</td><td>4 weeks</td><td>U + U</td><td>200M minbias
200M central</td></tr>
<tr><td rowspan="2">$\sqrt{s}$ = 500 GeV</td><td>5 weeks
6 weeks</td><td>$p_{\uparrow} p_{\uparrow}$
$p_{\rightarrow} p_{\rightarrow}$</td><td>trans. $P^2{*}L$= 4 pb^{-1}
long. $P^2{*}L$= 20 pb^{-1}</td></tr>
<tr><td>1 week</td><td>$p_{\uparrow} p_{\uparrow}$</td><td>pp2pp at high β^*</td></tr>
<tr><td rowspan="4">12</td><td>$\sqrt{s}$ = 500 GeV</td><td rowspan="3">10 weeks</td><td>$p_{\rightarrow} p_{\rightarrow}$</td><td>long. $P^2{*}L$= 50 pb^{-1}
$P^4{*}L$= 15 pb^{-1}</td></tr>
<tr><td>or</td><td colspan="2">or</td></tr>
<tr><td>$\sqrt{s}$ = 200 GeV**</td><td>$p_{\uparrow} p_{\uparrow}$
$p_{\rightarrow} p_{\rightarrow}$</td><td>trans. $P^2{*}L$= 8.5 pb^{-1}
long. $P^4{*}L$= 4.3 pb^{-1}</td></tr>
<tr><td>$\sqrt{s_{NN}}$ = 200 GeV</td><td>10 weeks</td><td>U + U or
Au+Au***</td><td>3.5 nb^{-1} U+U or
5 nb^{-1} Au+Au</td></tr>
</table>

* Request a CA-D test to determine the lowest possible collision energy at RHIC

** Request complete the Run 9 spin physics goals at $\sqrt{s}$ = 200 GeV

*** Depends on the out come of Run 11 U+U commissioning