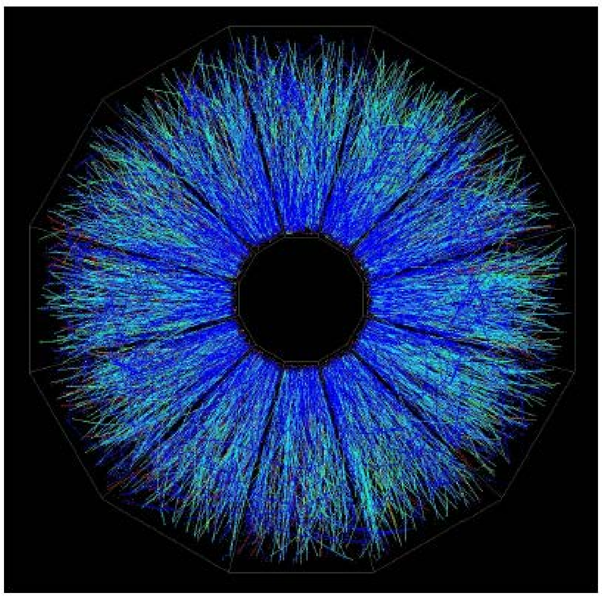
RHIC Beam Use Request
For Runs 17 and 18

The STAR Collaboration



May 26, 2016

Zhangbu Xu
(Brookhaven National Lab)

- Highlights
- Performance in run16
- BUR on Spin
  (sign change)
- BUR on Isobars
  (chiral effect)
- BUR on Au+Au @ 62GeV
  (Jet, NPE)
- BUR on Au+Au @ 27 GeV
  (global Lambda polarization)
- Summary

https://drupal.star.bnl.gov/STAR/starnotes/public/sn0657

Zhangbu Xu
(Brookhaven National Lab)

BUR charges

From: Mueller, Berndt
Sent: Tuesday, February 23, 2016 9:12 PM
To: Xu, Zhangbu; Morrison, David; Gunther M Roland; Yasuyuki Akiba; Takashi SAKO
Cc: Dunlop, James C
Subject: 2016 Beam Use Request

Dear Zhangbu, Takashi, Yasuyuki, Dave & Gunther:

I am writing to solicit the STAR beam use request for RHIC Run-17 and to request presentations from the RHIC collaborations at this year's PAC meeting, which is scheduled to be held on June 16+17, 2016.

Following the recommendations of the 2015 PAC, we anticipate the combination of a 510 GeV polarized p+p run and a 200 GeV run of a suitable isobar pair. Following current guidance from DOE, we are planning for a 24 cryo-week run, but the beam use request should also consider options for shorter runs of 20 weeks and 15 weeks to allow flexibility in case of other budget scenarios. The beam use request should be submitted no later than May 27 in order to allow the PAC members to study it in detail before the meeting.

In addition to the STAR/
from Runs 14 and 15, in
detectors. This is one of
update from the PHENI
sPHENIX collaboration
findings to the PAC.

Best regards
Berndt

<u>Future RHIC Run Plans:</u> The plan for RHIC runs before the BES-II has recently been refined to include independent runs in 2017 and 2018. The change is driven by the desire to permit a sufficiently long run with transversely polarized p+p collisions at 510 GeV in Run-17 (up to 19 cryo-weeks depending on budgetary constraints) to "test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic scattering" (NP Milestone HP13), and the plan to collide isobars ($^{96}Zr+^{96}Zr$ and $^{96}Ru+^{96}Ru$) at 200 GeV in Run-18 (13 cryo-weeks) as a critical test of the contribution from the possible Chiral Magnetic Effect to the various observed charge separation effects.

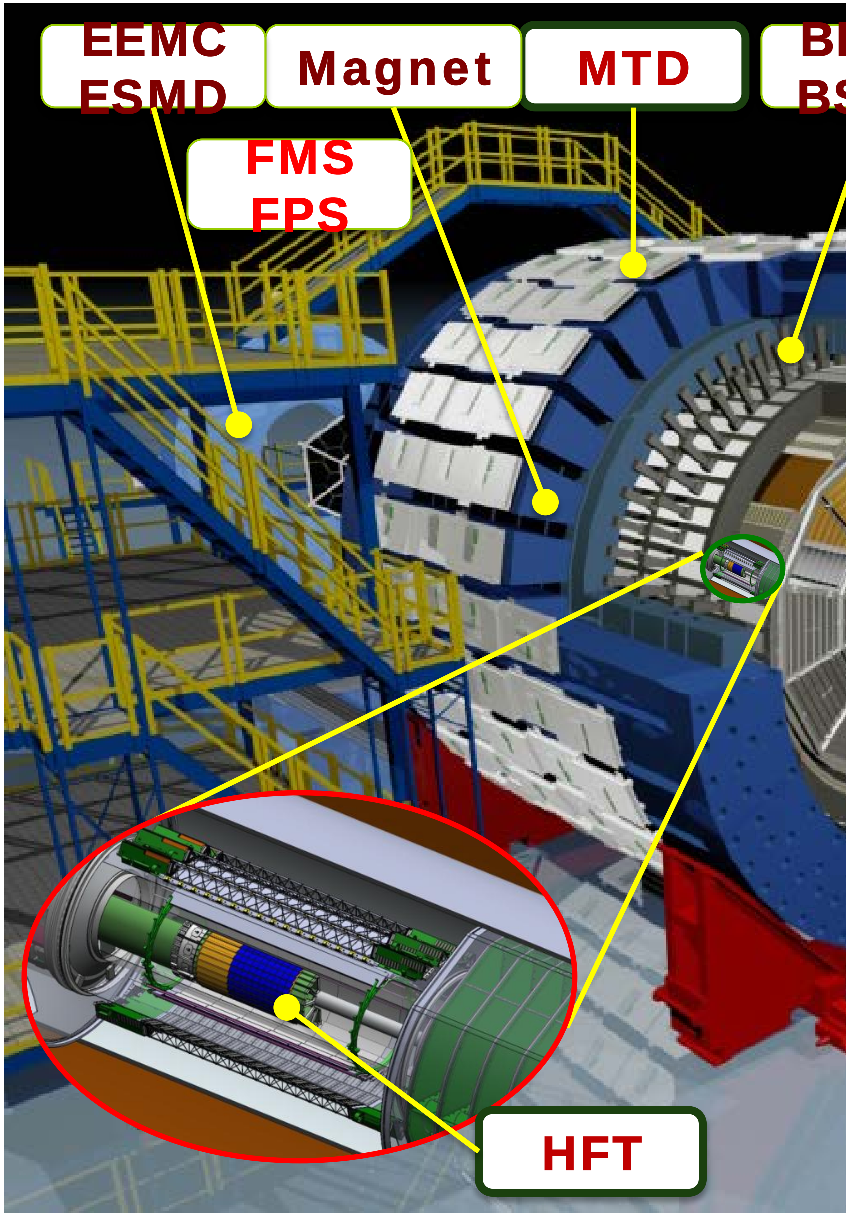
Executive Summary Table

Run	Energy	Duration	System	Goals	priority	Sequence
17	$\sqrt{s_{NN}}$=500 GeV	13-wk	Transverse p+p	A_N of $W^{\pm}$, γ, Drell-Yan, L=400 pb^{-1}, 55% pol	1	**1**
		1-wk	p+p	RHICf		**2**
		2-wk	CeC			
	$\sqrt{s_{NN}}$=62.4 GeV	4-wk	Au+Au	Jets, dileptons, NPE 1.5B MB	3	**3**
18	**$\sqrt{s_{NN}}$ =200 GeV**	**3.5-wk**	**Ru+Ru**	**1.2B MB**	**2**	**4**
	$\sqrt{s_{NN}}$=200 GeV	**3.5-wk**	**Zr+Zr**	**1.2B MB**	**2**	**5**
	$\sqrt{s_{NN}}$=27 GeV	**2-wk**	**Au+Au**	**>500M MB**	**3**	**6**

Options from guidance:
1) 24 cryo-weeks in run 17, 13 weeks in run 18
2) 19 cryo-weeks in run 17, 13 weeks in run 18
3) If only 15 weeks in run 17, all for pp500

STAR Detector System

15 fully functioning detector systems



NSAC RECOMMENDATION #I:
The upgraded RHIC facility provides unique capabilities that must be utilized to explore the properties and phases of quark and gluon matter in the high temperatures of the early universe and to explore the spin structure of the proton.

X10^3 increases in DAQ rate since 2000, most precise Silicon Detector (HFT 2014-16)

Highlights of Recent Results

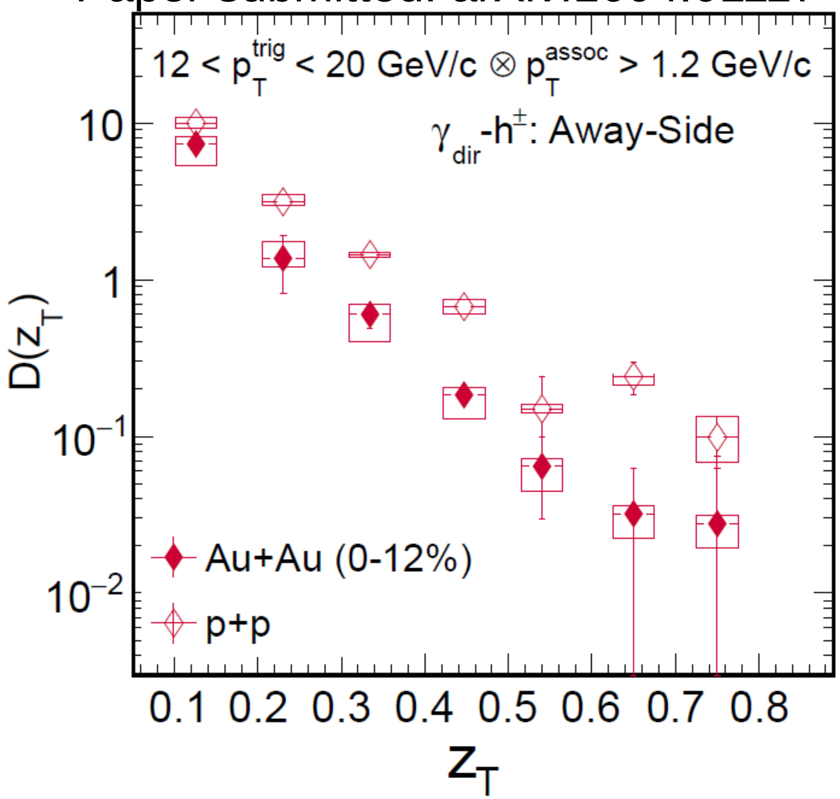
- Jets
- Heavy-Flavor
- Dileptons
- v_n
- Spin

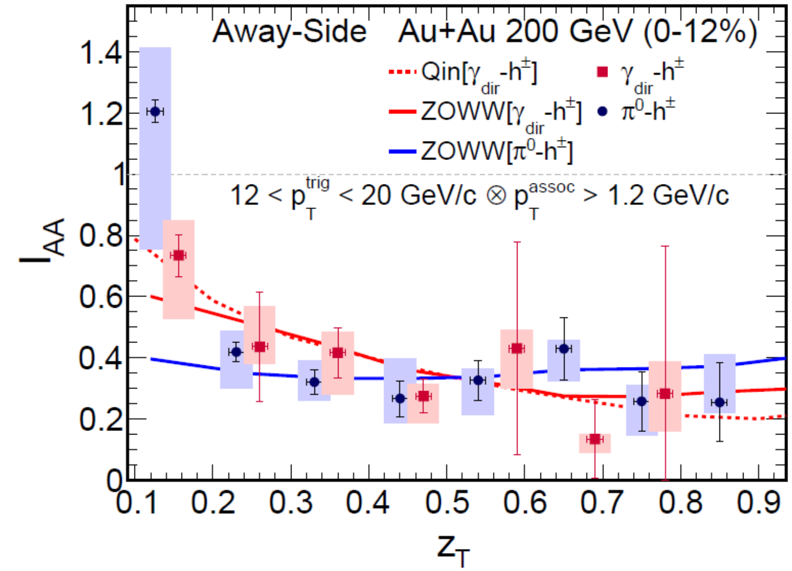
Experimental overview on run14/15: Frank Geurts (Rice)
BES-II (I): Helen Caines (Yale)

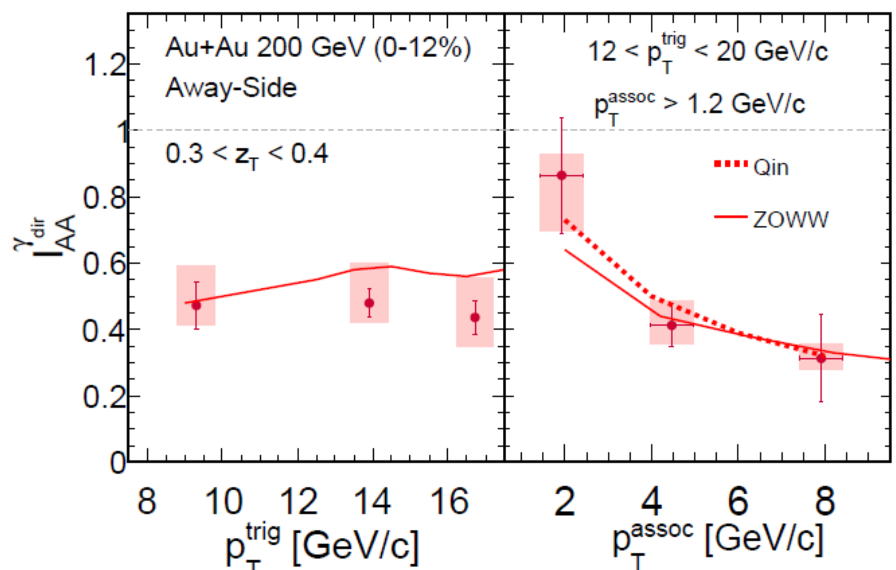
CME Task Force: Paul Sorensen (BNL)
Cold QCD Plan: Carl Gagliardi (TAMU)

γ-jet correlation

Paper submitted: arXiv:1604.01117

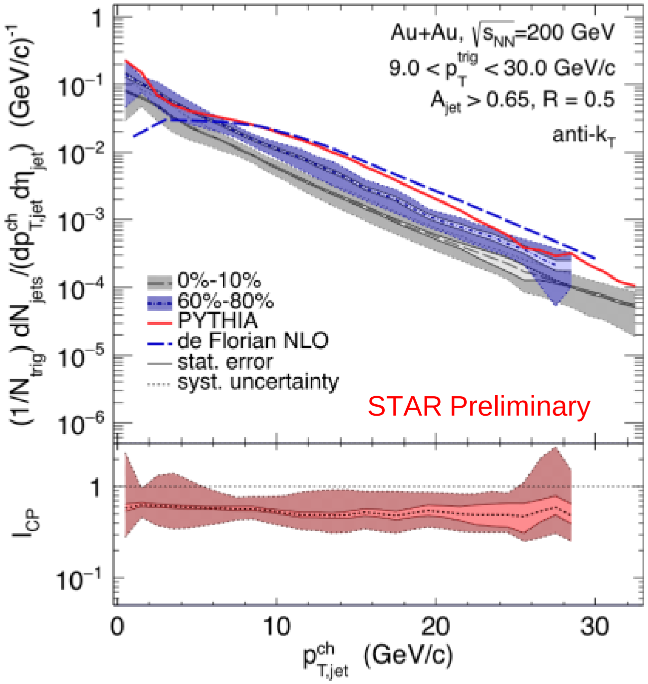


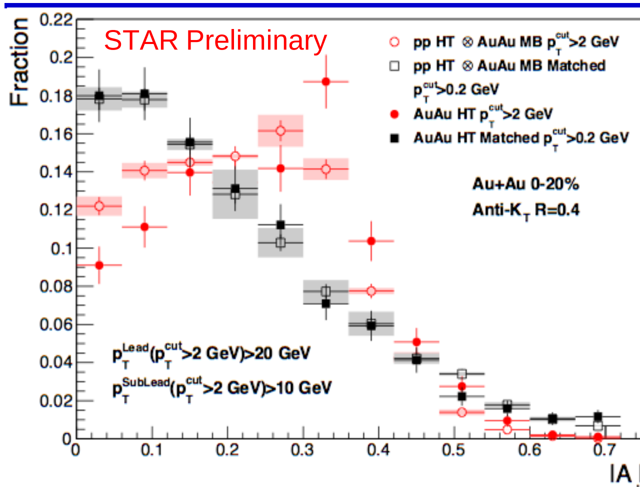


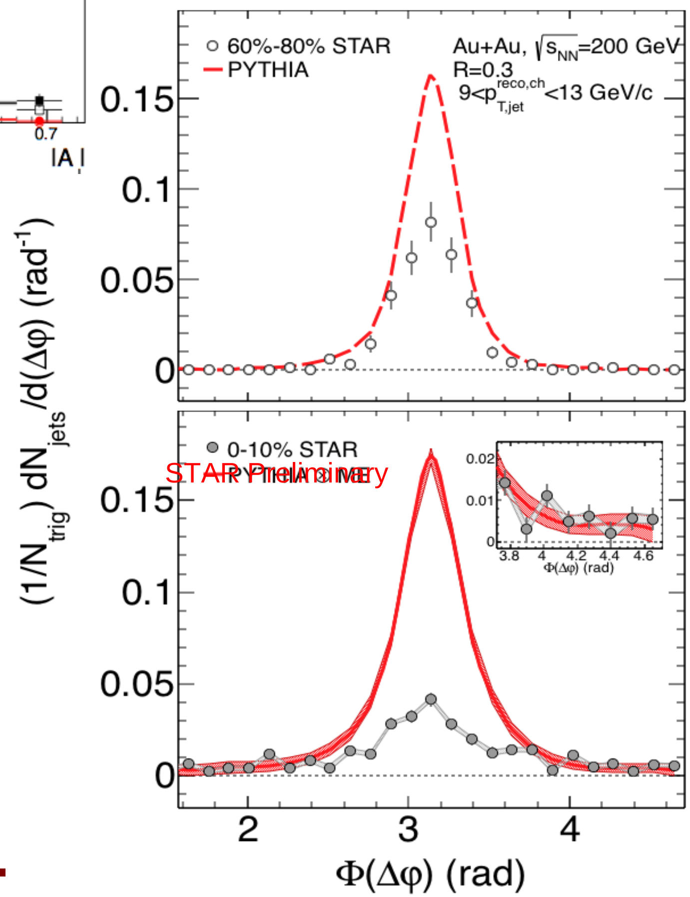


- Golden probe of Jet Energy Loss calibrated energy from γ for FF (Z_T)
- Cover large range of Z
- γ and π^0 triggered hadron I_{AA} similar
- Suppression independent of jet energy
- Lost energy reappear at low p_T

Semi-inclusive hadron jets

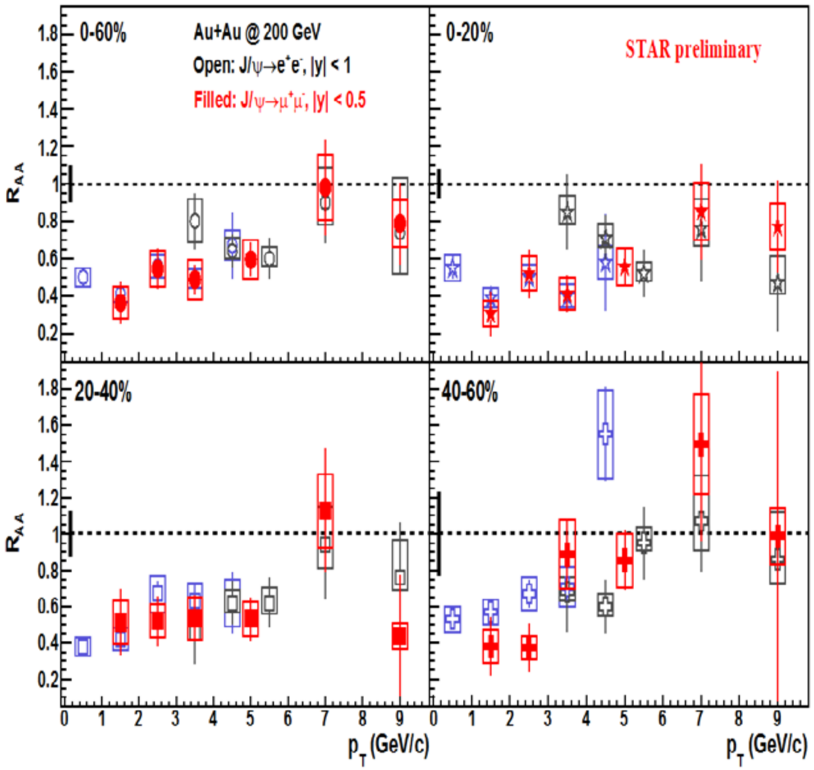


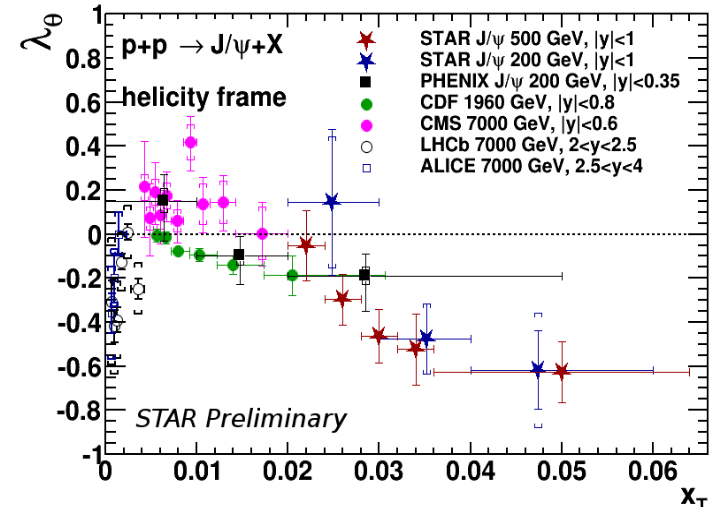


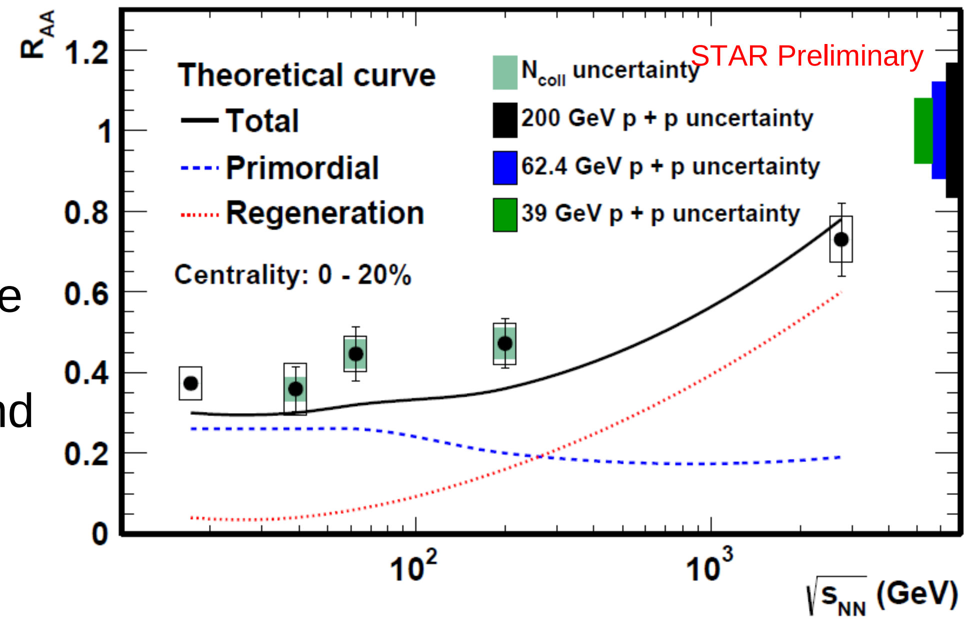


1. Reconstruction of semi-inclusive jet is successful to very low-pt using mix-event method
2. Energy loss is estimated to be ~3-5GeV for these jets; smaller than at LHC
3. Medium-induced radiation beyond 0.5 rad
4. Di-jet imbalance of Au+Au Aj similar to p+p only when low-p_T constituents are included
5. Significant broadening of h-jet correlation angle
6. No evidence for large-angle scattering of jets (maybe due to statistics)

Quarkonia production and probes

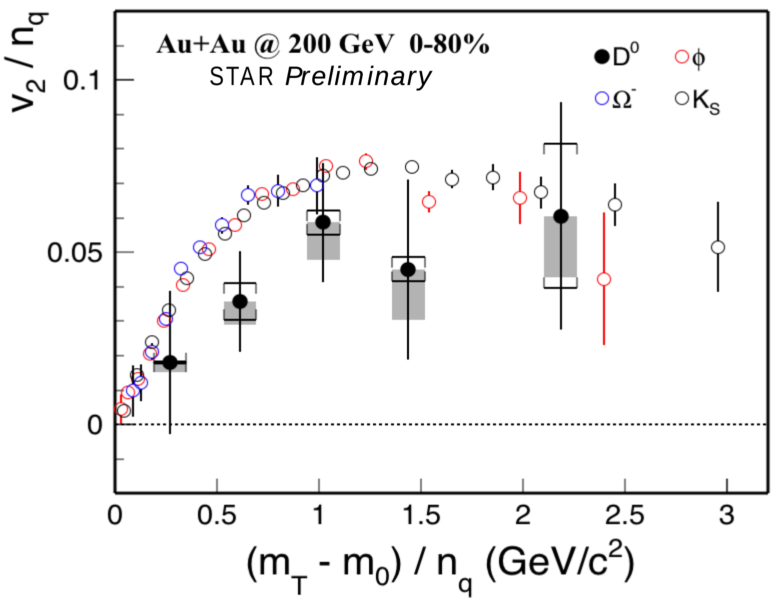


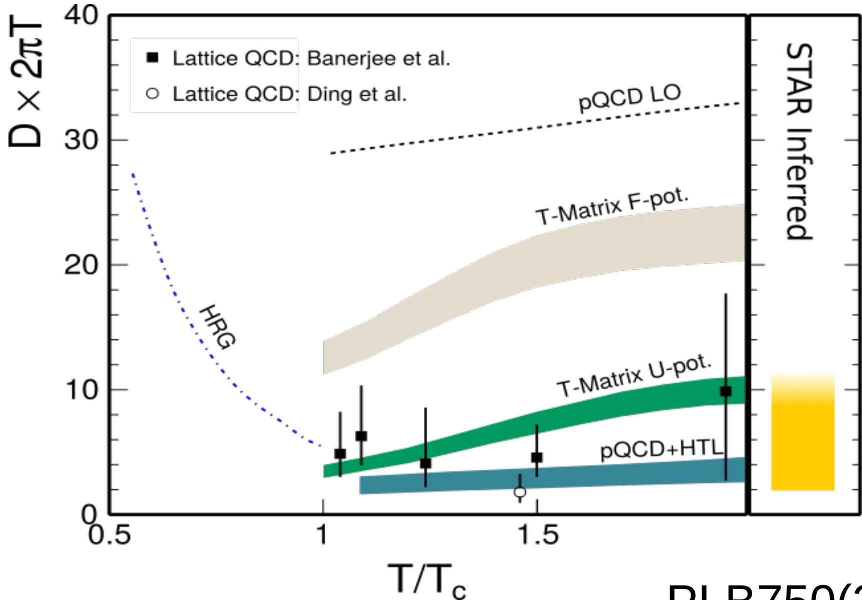




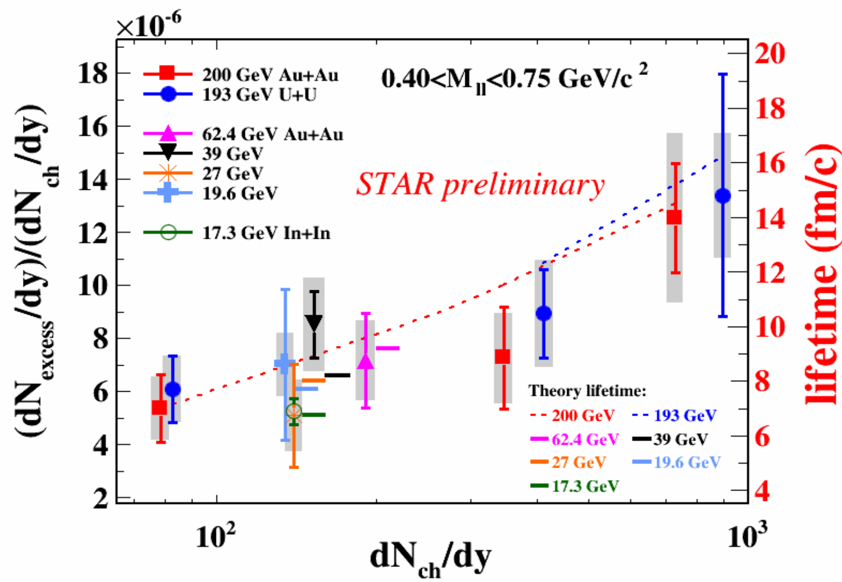
1. New MTD dataset covers whole p_T range with high statistics (x3 more data)
2. Polarization measurements in p+p extend to large X_T
3. Beam Energy dependence of J/ψ R_{AA}

(STAR QM15) Penetrating Probes





PLB750(2015)



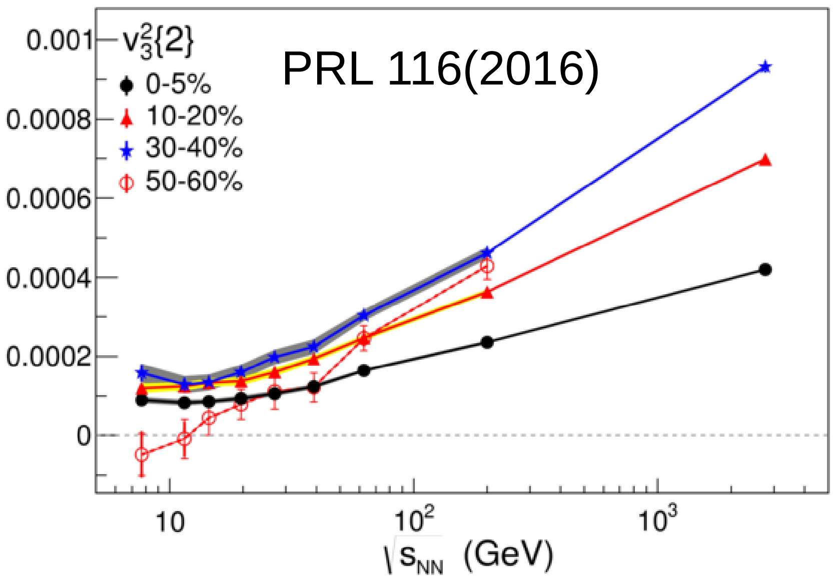
Brownian motion (diffusion) of heavy quarks

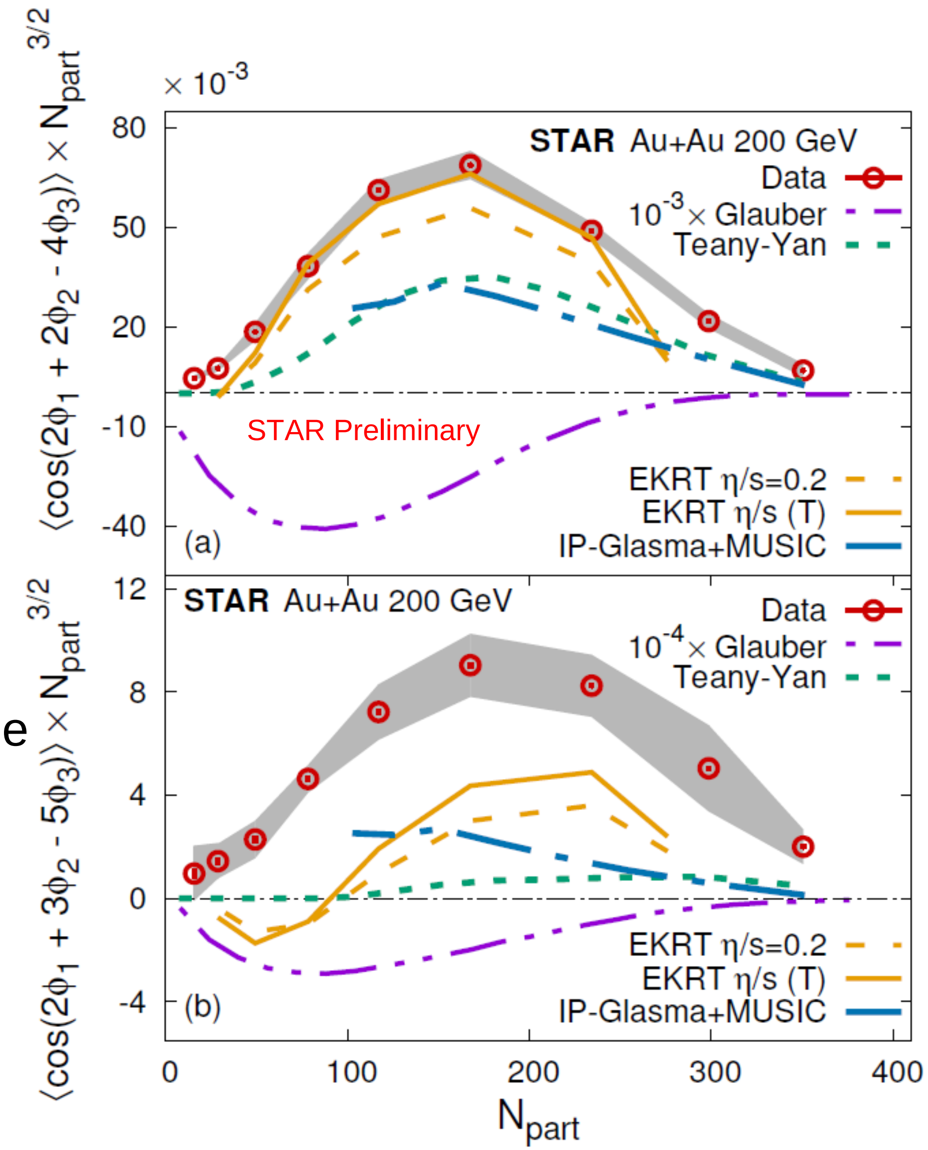
- Heavy Flavor Tracker (HFT) delivers its first results
- First result of quarkonia suppression from the Muon Telescope Detector (MTD)
- Charm flows at RHIC top energy
- Extracted diffusion coefficient compared to theory

Low-mass di-electron production

- Measured in many systems (Au+Au, U+U, p+p) and different energies (19.6, 27, 39, 62, 200 GeV)
- Quantifying how vector mesons evolve in the medium
- The yields probe timescale of collisions

Flows in nth order

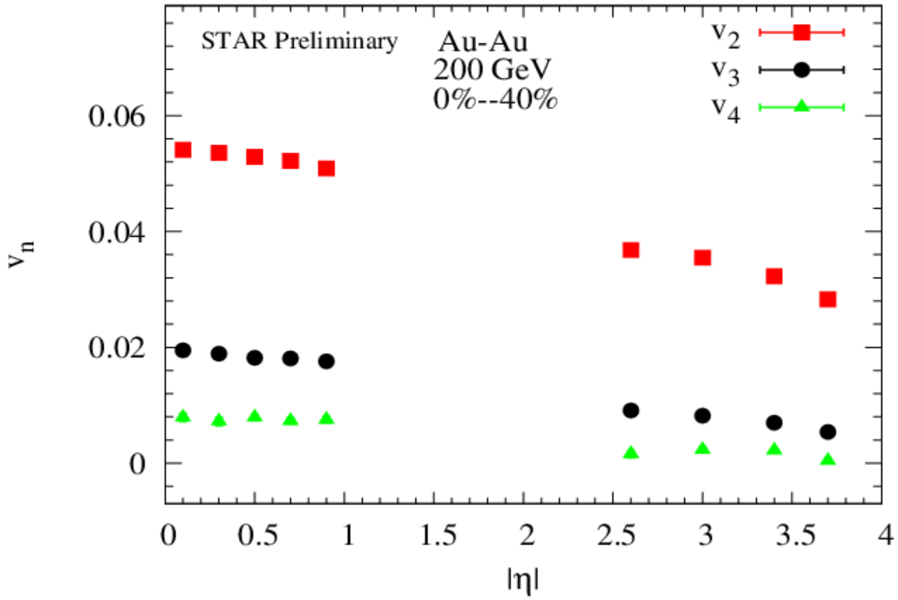




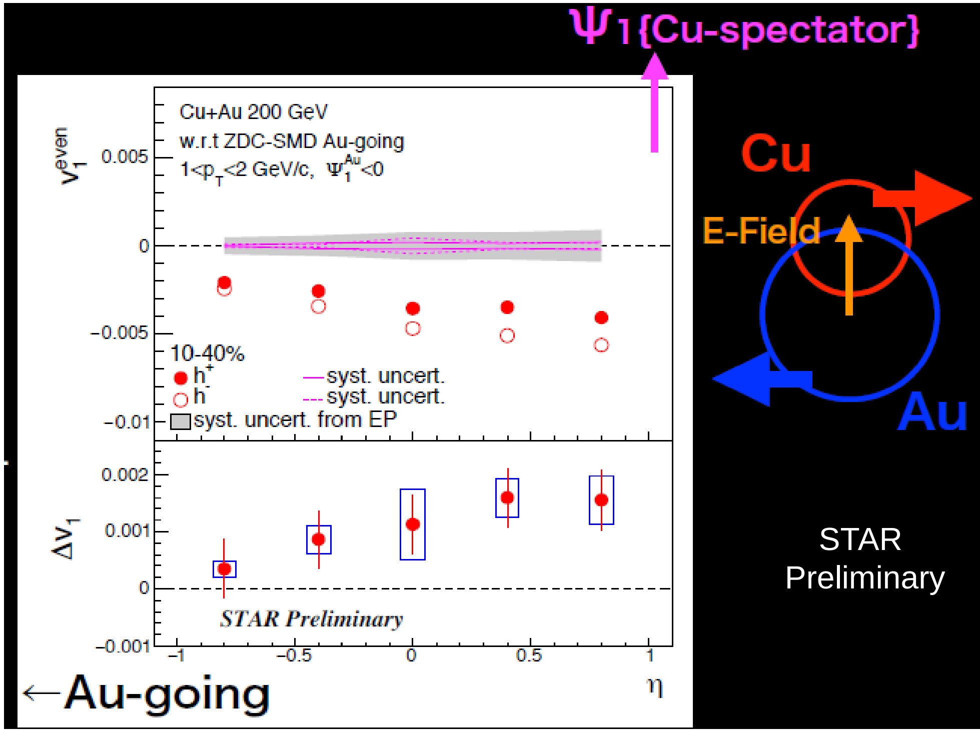
Higher harmonics sensitive to earlier stage
Study BES and small system size:
Turn OFF QGP?

Multiple-Harmonics sensitive to η/s

Flows in Rapidity



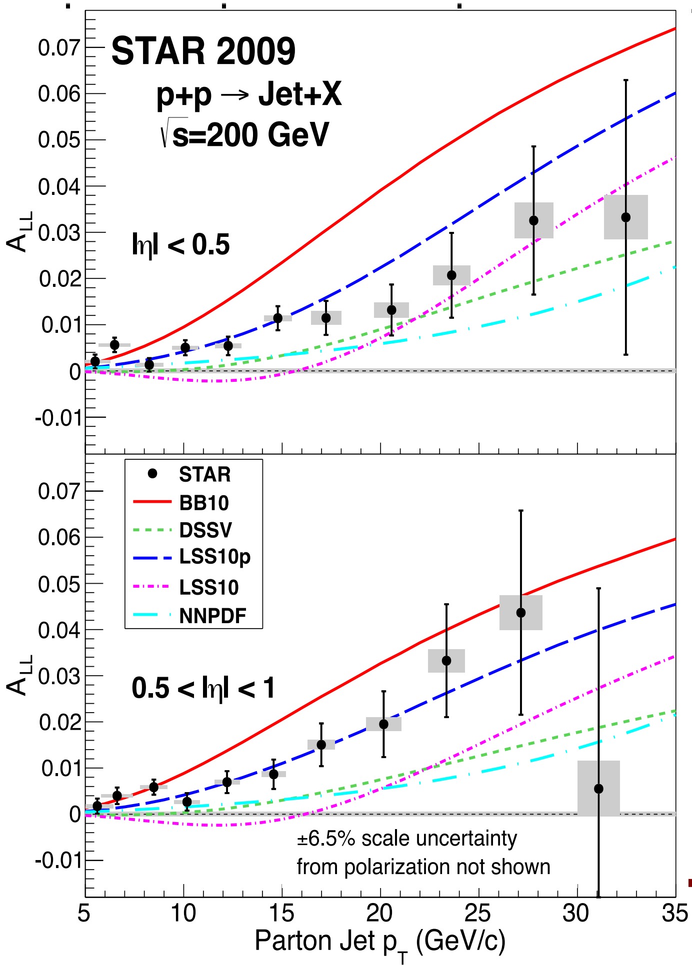
Flow (vn) vs rapidity:
η/s and initial stage;
baryon stopping at BES-II
(require upgrades)

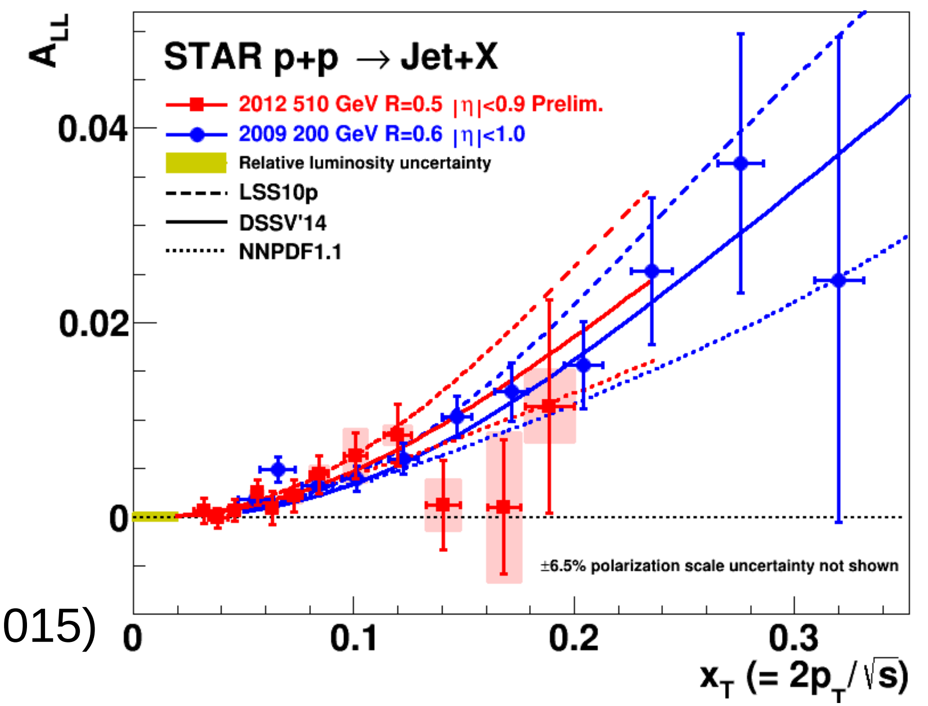


Flow in asymmetric collisions sensitive to the existence of E-field and quark content

NSAC Milestone (HP12)

Year	#	Milestone
2013	HP12 (update of HP1, met in 2008)	Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.

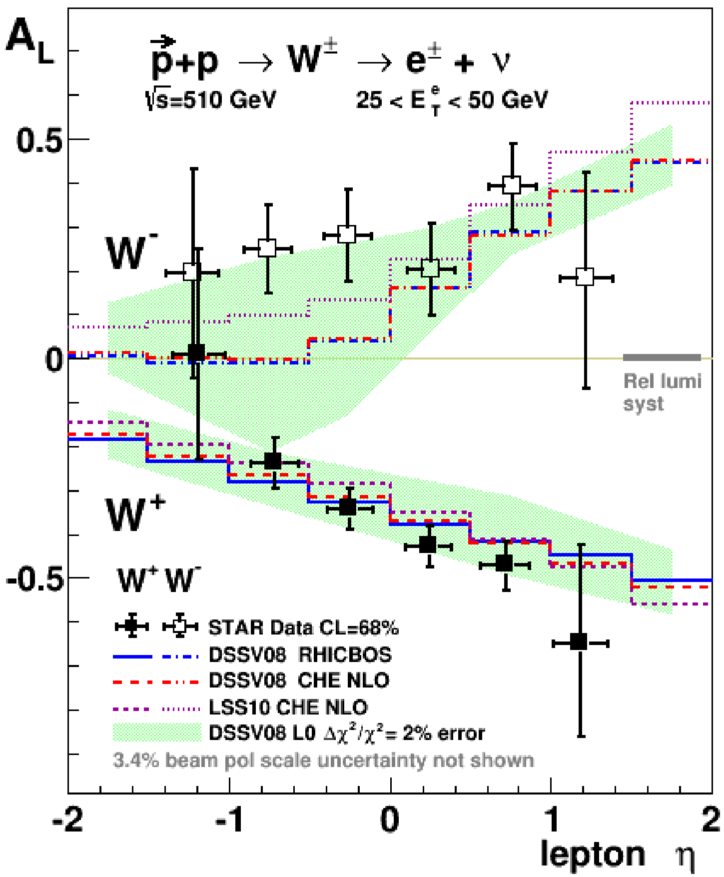


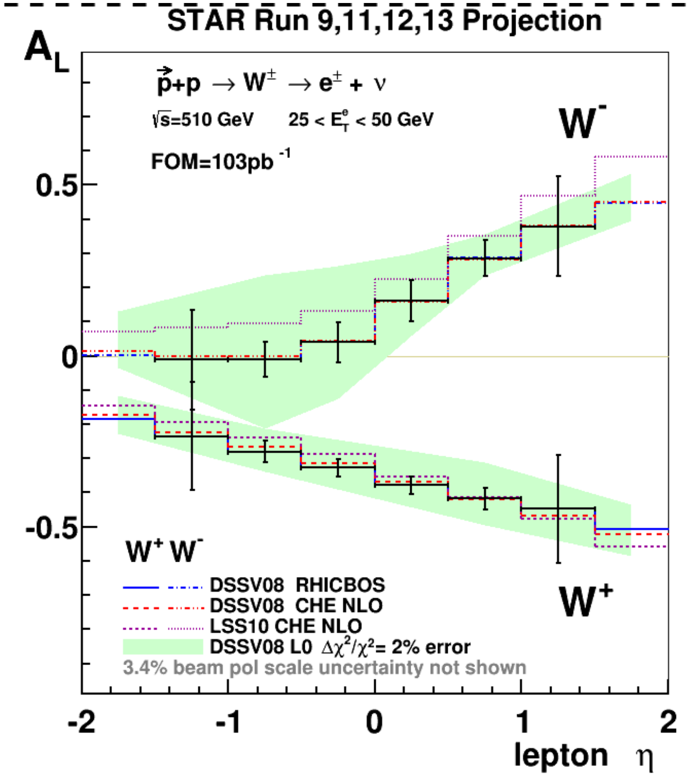


PRL 115 (2015)

NSAC Milestone (HP8)

Year	#	Milestone
2013	HP8	Measure flavor-identified q and contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.





PRL 113 (2014) + run13

First significant evidence that u and d anti-quark spin distributions are significantly different.

2015 BUR → RUN 16

Run	Energy	Duration	System	Goals	priority	Sequence
16	$\sqrt{s_{NN}}$=200 GeV	13-wk	Au+Au	Λ_c, D v_2, R_{AA}, Υ R_{AA} 10nb^{-1}, 2billion MB	1	1
	$\sqrt{s_{NN}}$=62 GeV	4-wk	Au+Au	1.5B MB (1B w/ HFT)	4	2
	$\sqrt{s_{NN}}$=19.6 GeV	1-wk	d+Au	100M MB	4	3
17	$\sqrt{s}$ = 510 GeV	11 wk	Transverse p+p	A_N of $W^{\pm}$, γ, Drell-Yan, L=360 pb^{-1}, 55% pol	2	1
	$\sqrt{s_{NN}}$=19.6 GeV	1-wk	p+p	400M MB	4	2
	$\sqrt{s_{NN}}$ =200 GeV	3-wk	Ru+Ru	1.2billion MB	3	3
	$\sqrt{s_{NN}}$=200 GeV	3-wk	Zr+Zr	1.2billion MB	3	4

In each scenario, the data requirements for STAR's two top priority scientific goals will be met. In no scenario can all the data needs for all programs be met in runs 16 and 17

Run 16 Heavy-Flavor Program

- Completion of DM12

2016	DM12 (new)	Measure production rates, high p_T spectra, and correlations in heavy-ion collisions at $\sqrt{s_{NN}}$ = 200 GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma.

DM12 uses the increase in RHIC luminosity that is part of the RHIC luminosity upgrade and associated detector upgrades to study rare particles with charm quarks, and possibly particles with bottom quarks, as a demanding way to learn how matter flow and energy loss are established in the partonic phase at RHIC.

Au-Au 200 GeV Highest Priority of STAR and PAC for Run-16

DOE Milestones for High Temperature/High Density Hadronic Matter

http://science.energy.gov/~/media/np/nsac/pdf/docs/perfmeasevalfinal.pdf

Run 16 proposed by STAR

Run	Energy	Duration	System	Goals	Priority	Sequence
16	$\sqrt{s_{NN}}$=200 GeV	13-wk	Au+Au	Λ_c, D v_2, R_{AA}, ϒ R_{AA} 10nb^{-1},2billion MB	1	1
	$\sqrt{s_{NN}}$=19.6 GeV	1-wk	d+Au	100M MB	2	2
	$\sqrt{s_{NN}}$=39 GeV	1-wk	d+Au	400M MB	2	3

PAC recommendation of 10 weeks of Au+Au; additional 2 floating weeks

Could have reached goals: 95 hours*10wk*3600seconds*600Hz=2B
Or we could have just scaled down our goals by 30%

RHIC Machine Efficiency not Luminosity key
STAR Operation and Optimization
- key to achieving this goal.

Presented at 01/19/2016 schedule meeting

Run16 schedule and main events

Run 16 plan based on 23.5 weeks cryo operation

and Fischer et.al. RHIC Collider Projections (FY 2016 – FY 2022), 19 April 2015

Today, June 15th

- 19 Jan, Begin cool-down to 4.5K
- 25 Jan, Beam in Yellow
- ~~22~~ 26 Jan, Beam in Blue
- ~~29 Jan~~, Feb 3, First Collisions
- ~~5~~ 7 Feb, Begin 10 week **√s=200 GeV/n AuAu** physics run
- 7 am March 18th, RHIC Operations halted for Blue ring Diode issue
- 7 pm April 6th, RHIC Operations resumed (19.5 days offline)
- Decision made to add 19.5 days to the AuAu running to account for the Diode related down time
- 9 May, End 10 week (+ 2 days) √s=200 GeV/n AuAu physics run
- 12 May, Begin 1 week **√s=200 GeV/n dAu** physics run
- 20 May, End ~1 week √s=200 GeV/n dAu physics run
- 21 May, Begin 1 week **√s=62 GeV/n dAu** physics run
- 27 May, End ~1 week √s=62 GeV/n dAu physics run
- 28 May, Begin 1.5 week **√s=19.6 GeV/n dAu** physics run
- 8 June, End 1.5 week √s=19.6 GeV/n dAu physics run
- 10 June, Begin 1 week **√s=39 GeV/n dAu** physics run
- 17 June, End 1 week √s=39 GeV/n dAu physics run
- 19 June, Begin ~7 day **Return to 200 GeV/n AuAu** physics run
- 27 June, End of 200 GeV/n AuAu physics run
- 27 June, begin cryo warm-up
- 1 July, Cryo warm-up complete, ***23.5 cryo weeks*** of operation

- February 7, start Au+Au physics run
- March 4, switching to run14 HFT firmware
- March 17, new online vertex implemented
- May 9, end of 1st 200GeV Au+Au run
  75% goal reached for HFT (open charm)
  90% goal reached for MTD (Quarkonia)
- May 12, begin d+Au Run
- June 19, begin 2nd Au+Au datataking

Schedule in Orange text not updated yet

See http://www.rhichome.bnl.gov/AP/RHIC2016/ for the Run Coordinator's detailed plan

Substantial Investments to reach our BUR goals

-- Many improvements since Run14

Open Charm (HFT) related: (MB events)

- Cables: Cu => Al Cable for HFT readout: up to x2 better S/B low-p_T D^0
- Refurbished PXL and SSD firmware: ~18% PXL dead in Run-14
  SSD improves tracking 10% (20% for Ds)

Overall factor of 3.6 improvement for D^0

- Vertex Cut quality improvement (~15%)
- Pile-up protection study w/o 30% more data volume and 10% worse efficiency
  optimize protection (10%)
- Re-populate TPC ASIC and RDO, DAQ software optimization, online disk and network, +50% faster readout speed, reduced deadtime
- Bring up detector at RHIC Flattop and detector ramp down for beam dump
  Run 16: 7 (5) minutes vs Run 14: 9 (11) minutes

Quarkonia (MTD) related: (triggered/luminosity)

- High-Level Trigger dedicated to online dimuon selection
- Express stream of Upsilon candidates x10 reduction
- Reduce monitoring triggers to minimum required

Setbacks in First few weeks of run16

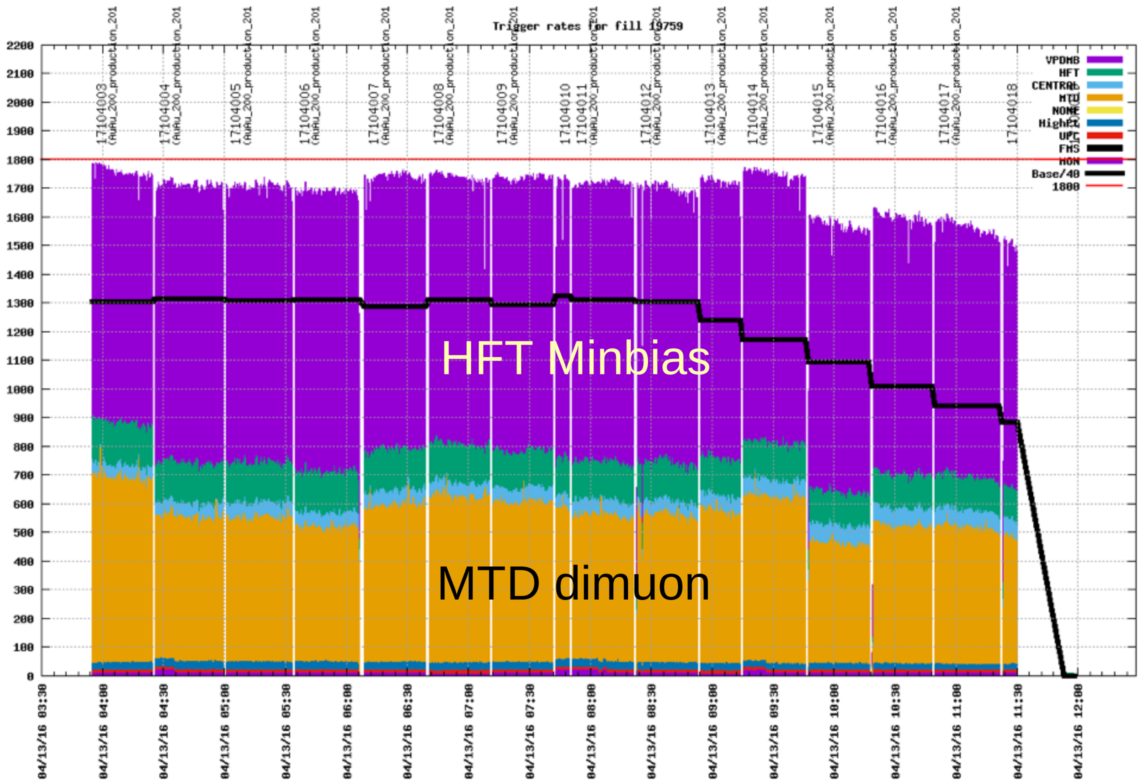
1. Online Vertex Selection Efficiency (-5-10%)
   A version of hardware has been commissioned during the first 5 weeks, final implementation in March 16.
   improve efficiency 17%

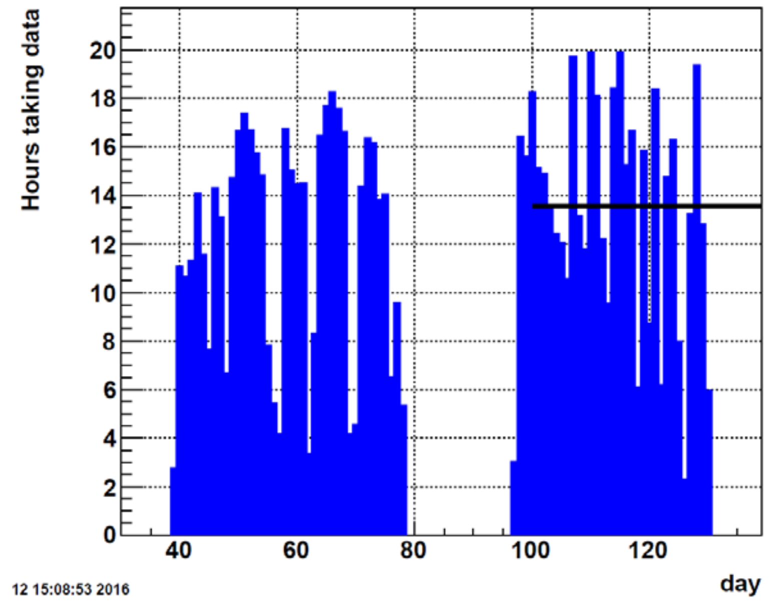
2. Uptime (-15%)
   Run 14 over 95 DAQ hours per week (110 CAD hours)
   Run 16 about 85 DAQ hours per week (94 CAD hours)
   April 6 after CAD Diode Fix, **95 DAQ hours (107 CAD hours)**

3. HFT readout Firmware (-20%)
   Low efficiency due to incorrect time latch
   Affects data from first 3 weeks
   A report assembled by a Detector Operation Task Force

4. RHIC Machine Diode Failure (March 18-April 6)
   Repaired and came back more efficient (Thanks!)

Typical Data-taking Mode





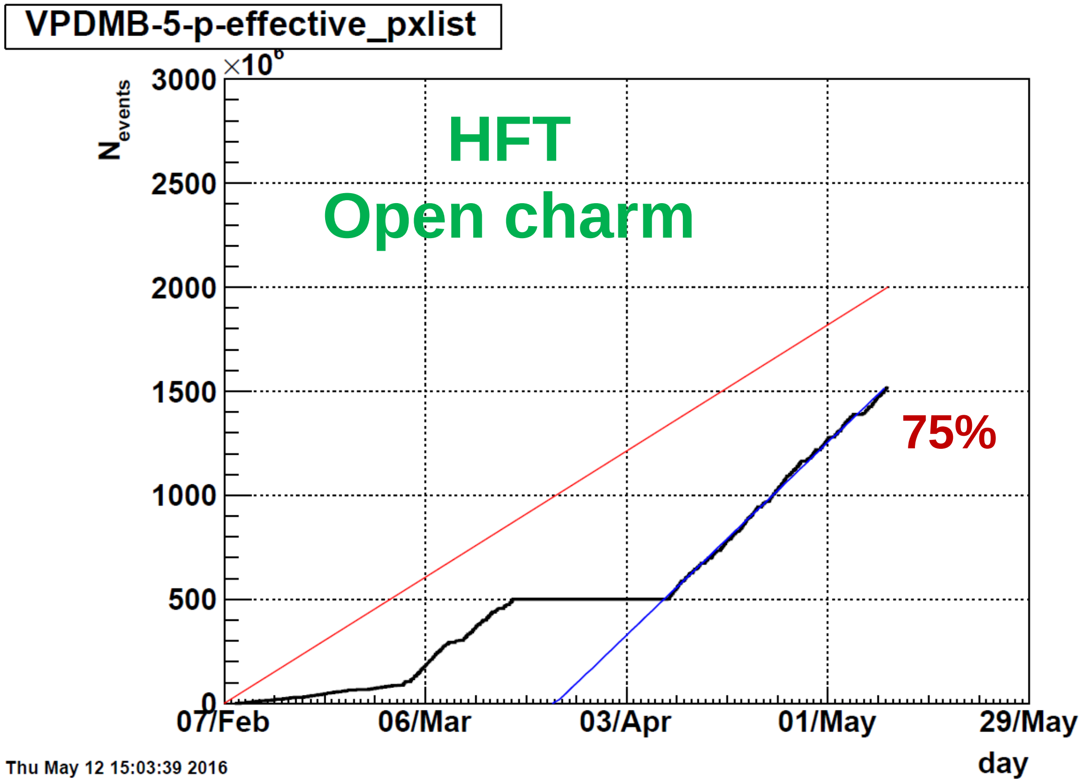
Average 13.5 DAQ hours/day

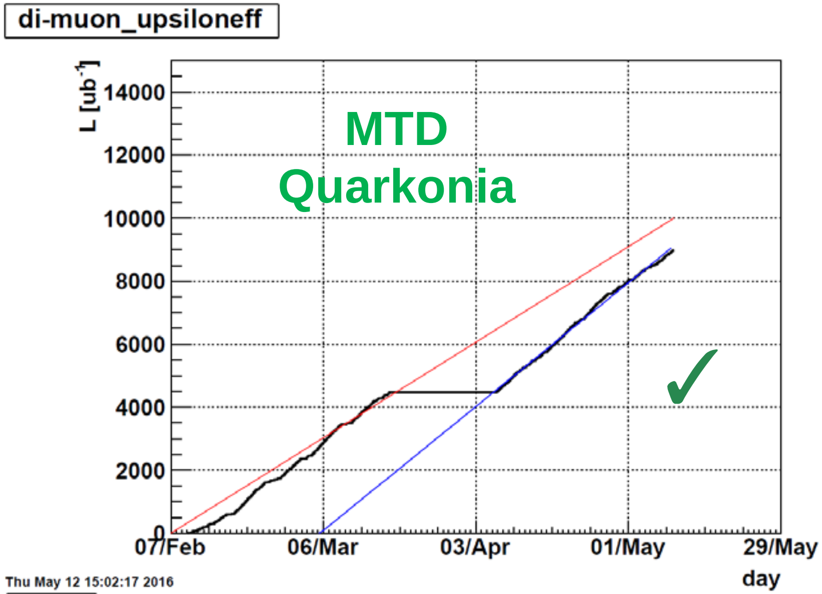
Designed and implemented by Jeff Landgraf.
Linked from Trigger versioning page
http://online.star.bnl.gov/RTS/plots/storedPlots.php

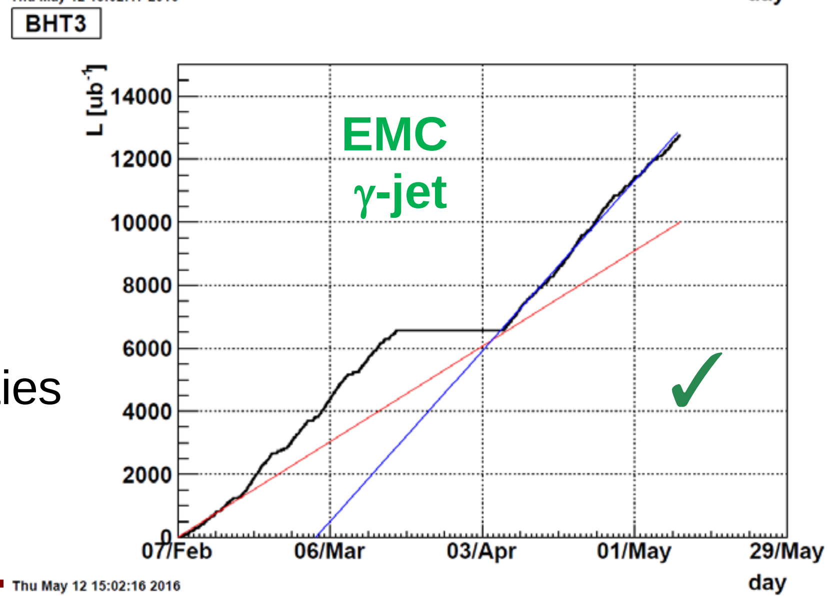
Last 4 weeks' performance:
95 hours*8.3wk*3600seconds*700Hz=2B

Excellent Machine Performance after Diode Repair

Au+Au Dataset Goals







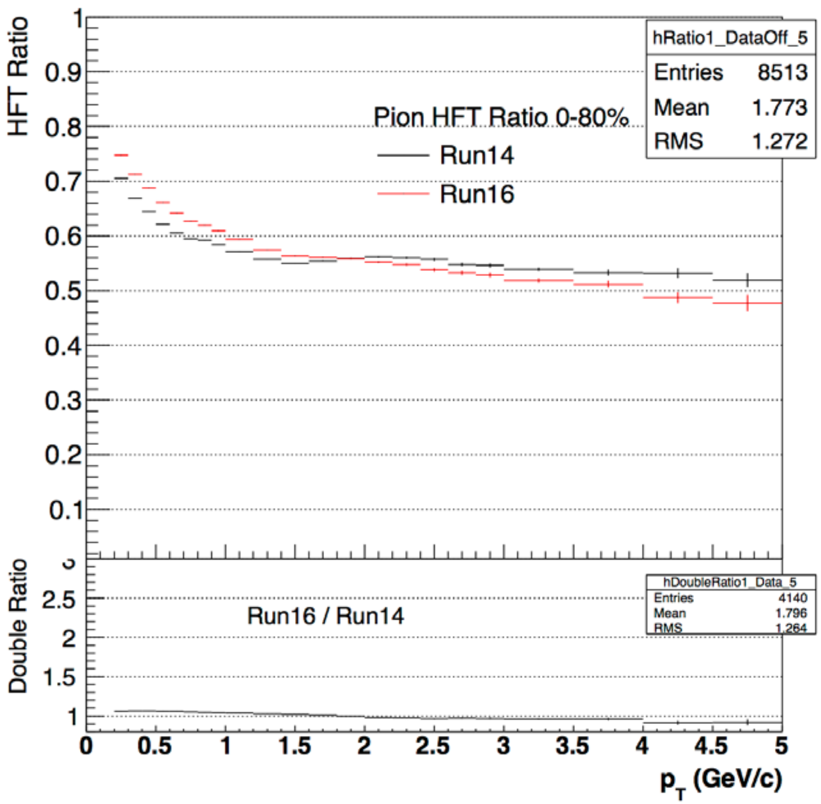
1. Minbias goal is about 75%,
   one more week of Au+Au to reach >90%
2. Quarkonium (ϒ) and γ-jet integrated luminosities (mostly) reach our goals.

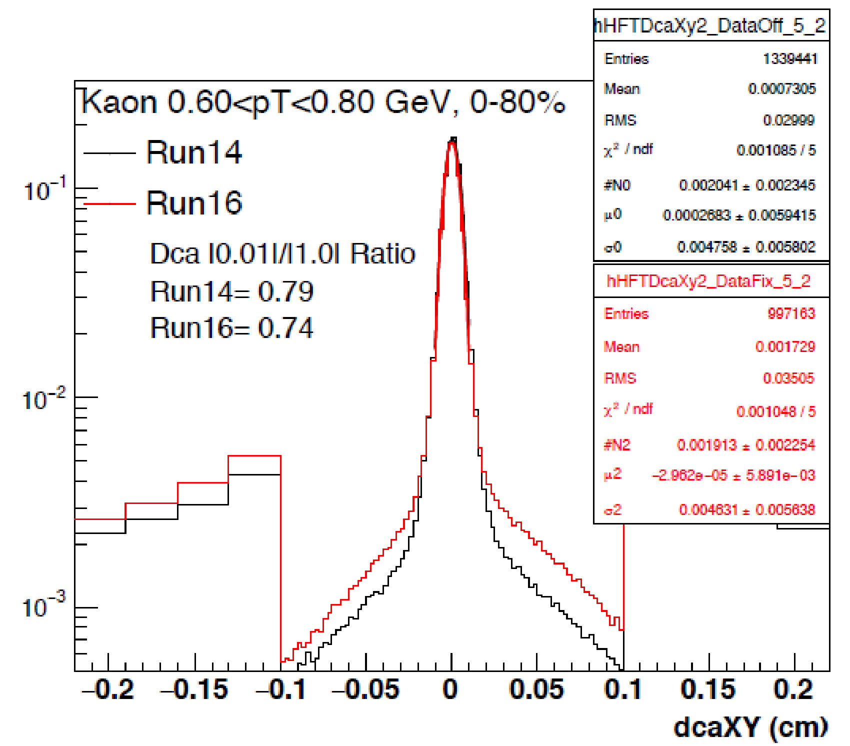
HFT Preliminary Performance (Run 16)

With preliminary calibrations, Run16 HFT matching efficiency and DCA resolution show a comparable or slightly better performance w.r.t Run14

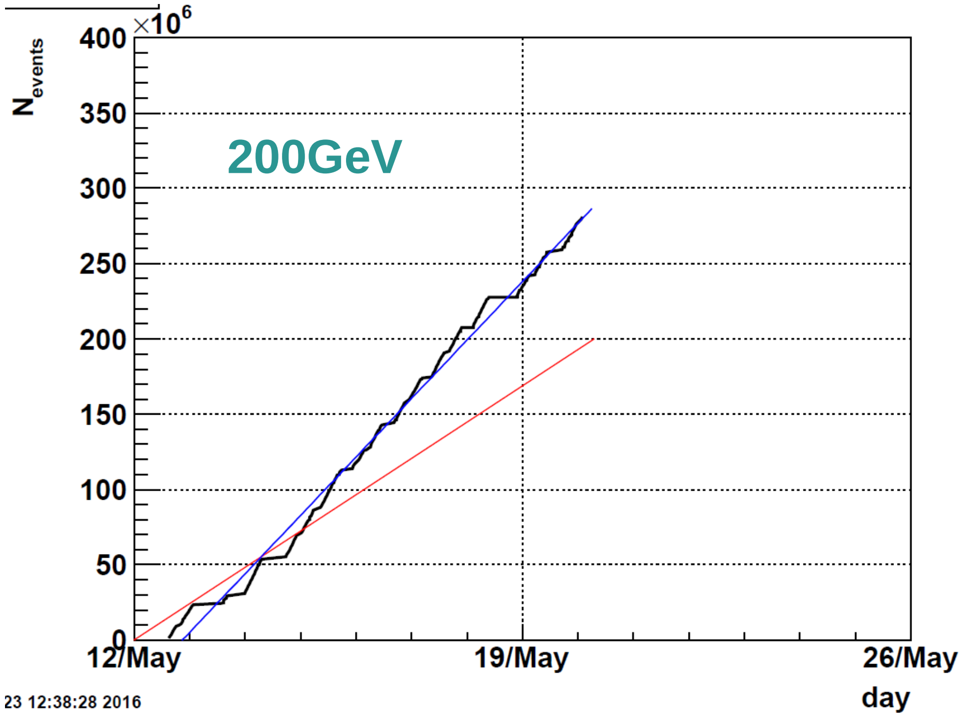
➡ different luminosity level

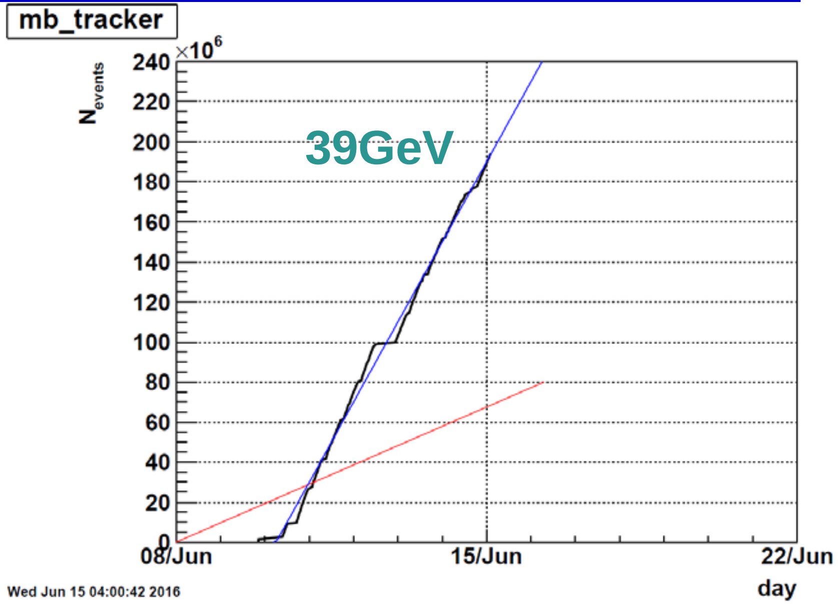
➡ different trigger setup for pileup protection

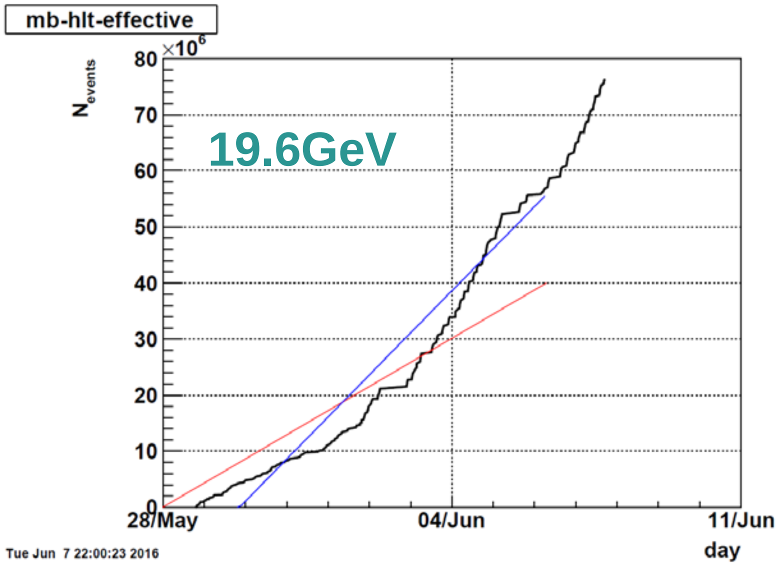




d+Au goals and projections







Goals mostly achieved (200,62.4,39,19.6 GeV);
Because of the Nbin = 7.5 in d+Au Minbias
in comparison with p+p.
Better primary vertex resolution,
Expect comparable D^0 signals in d+Au to that
from the p+p dataset in run15 with best HFT
performance

BUR Executive Summary Table

Run	Energy	Duration	System	Goals	priority	Sequence
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		2-wk	CeC			
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	$\sqrt{s_{NN}}$=200 GeV	**3.5-wk**	**Zr+Zr**	**1.2B MB**	**2**	**5**
	$\sqrt{s_{NN}}$=27 GeV	**2-wk**	**Au+Au**	**>500M MB**	**3**	**6**

Options from guidance:

1) 24 cryo-weeks in run 17, 13 weeks in run 18
2) 19 cryo-weeks in run 17, 13 weeks in run 18
3) If only 15 weeks in run 17, all for pp500

Run 17 Spin Program BUR and Projections

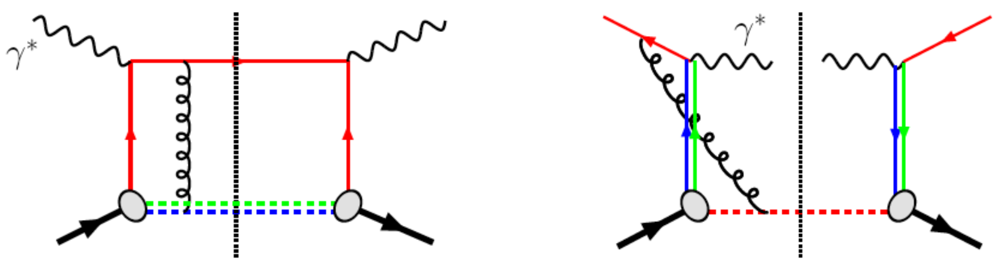
In this Beam Use Request the STAR Collaboration presents four compelling and prioritized scientific programs for the 2017 and 2018 RHIC runs.

STAR's **highest scientific priority** is the first significant measurement of the sign change of the Sivers function, as compared to the value measured in semi-inclusive deep inelastic scattering experiments, through measurements of single spin asymmetries in $W^{+/-}$, Z, direct photon and Drell-Yan production in transversely polarized $\sqrt{s}$ = 500 GeV p+p collisions. This measurement will also shed light on the size and nature of the evolution of these transverse momentum dependent distributions. The sign change measurement is a fundamental test of QCD and is being pursued by other experiments, making a timely measurement imperative. We therefore request **13 weeks of 500 GeV p+p running in Run17.**

Year	#	Milestone
2015	HP13 (new)	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering.

NSAC Milestone (HP13)

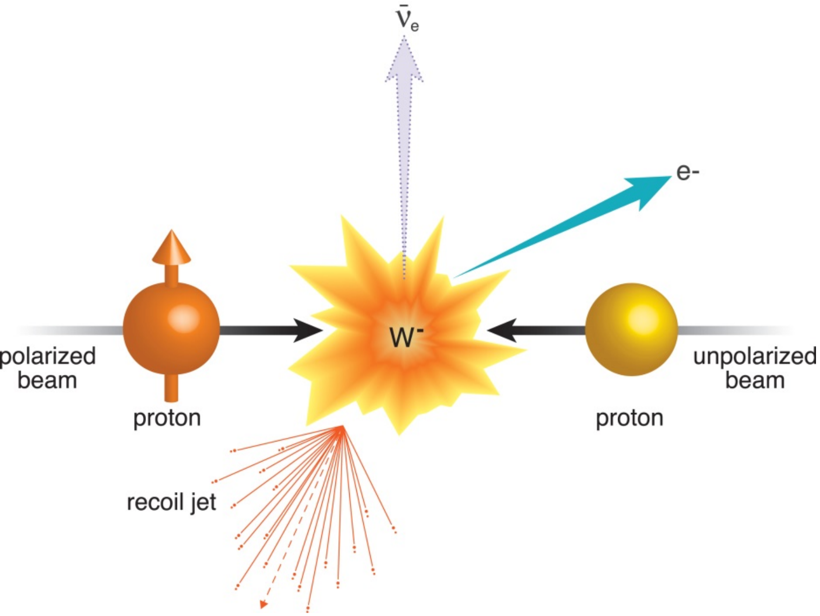
Year	#	Milestone
2013 ✓	HP8	Measure flavor-identified q and $\overline{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013 ✓	HP12 (update of HP1, met in 2008)	Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
2015	HP13 (new)	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering.

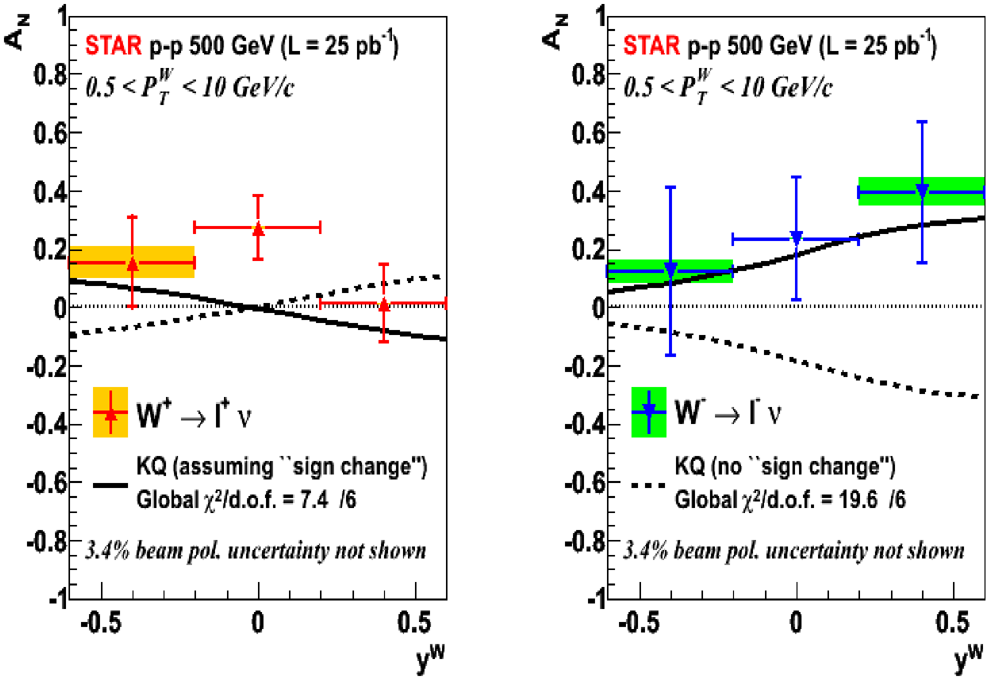


A_N of $W^{\pm}$,γ, DY in pp 500 are all sensitive to the Sivers sign-change. STAR can access all three world-class measurements in the proposed 2017 Run – **Significant discovery potential before 2020!**

Measure QCD interaction sign and TMD evolution

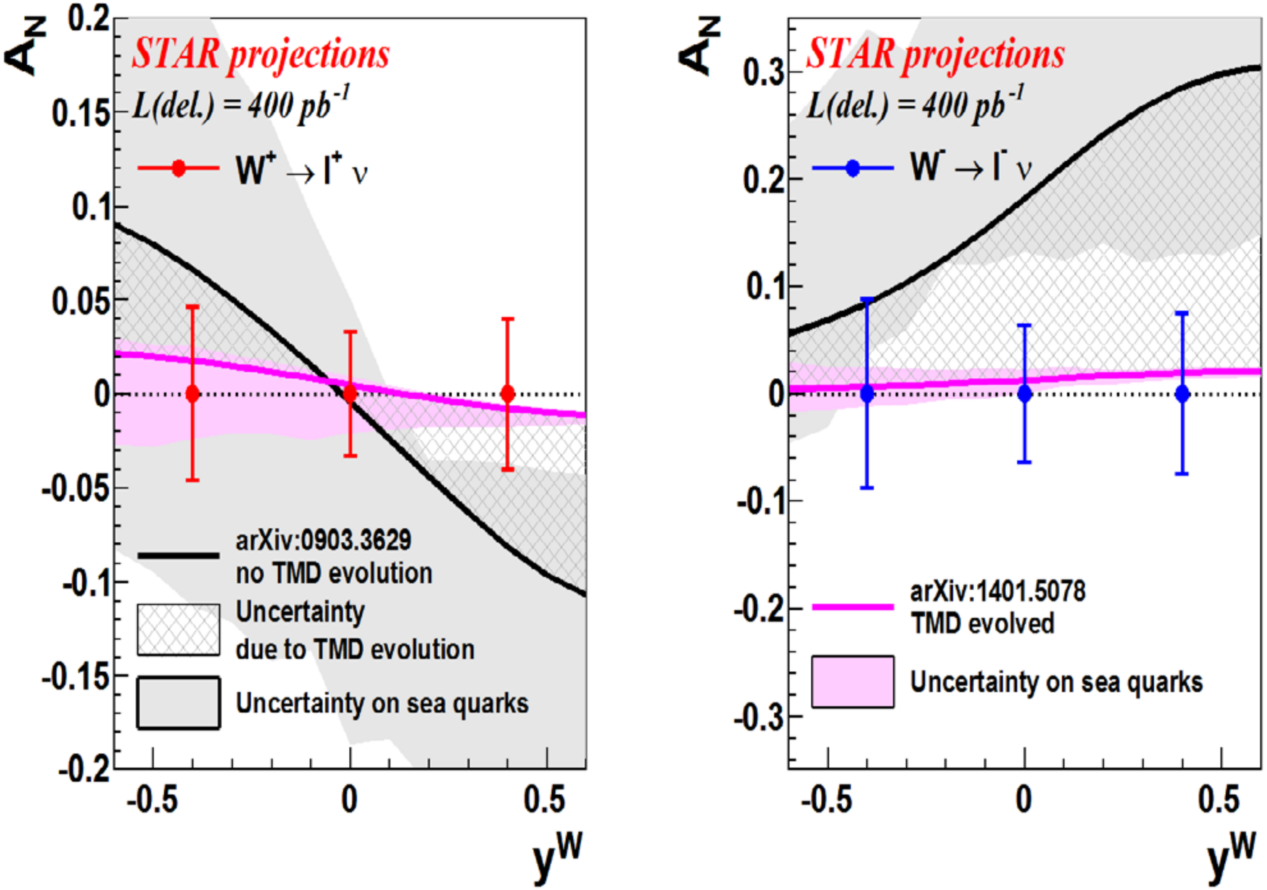
More in-depth discussions this afternoon:
See C. Gagliardi's talk





How to measure certain color interactions are repulsive and others attractive:
A View of the Colorful Microcosm Within a Proton (foundation for run 2017)
https://www.bnl.gov/rhic/news2/news.asp?a=1824&t=pr
STAR paper Phys. Rev. Lett. **116**, 132301 (2016), Editors' Suggestion

Run 17 Projection $W^{\pm}$ A_N



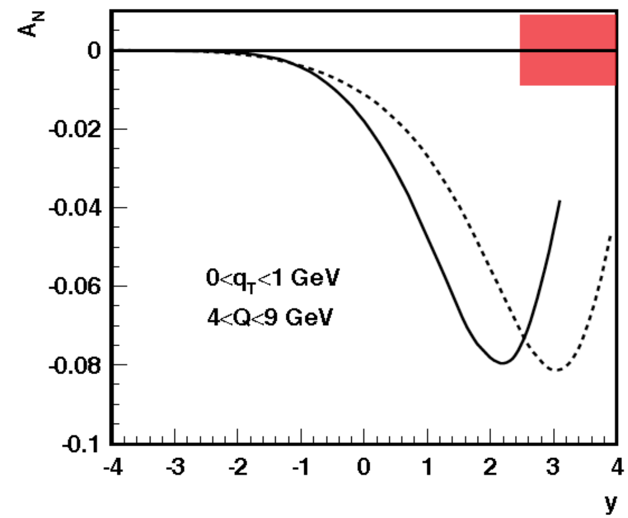
First measurement of sign change (a big deal)

Quantifying TMD evolution

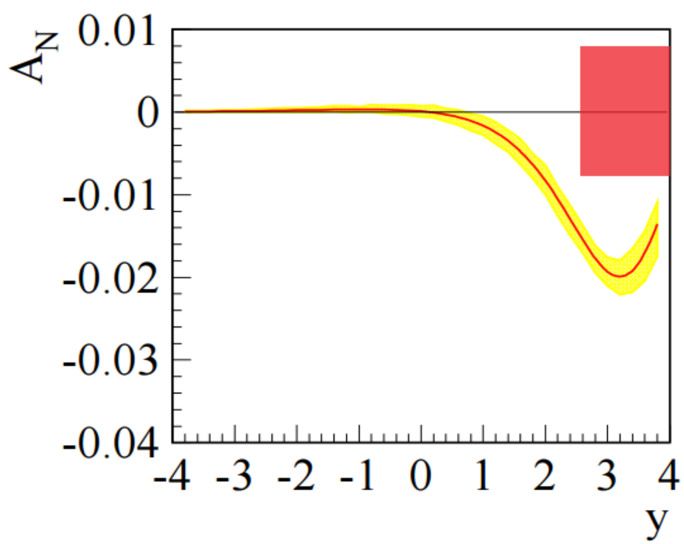
Constraint sea quark Sivers

Another TMD Observable: Drell-Yan e^+e^-

The orange square: achievable statistical precision for A_N DY asymmetry with 400 pb^{-1}



the theoretical prediction for the Sivers asymmetry A_N as a function of *DY* lepton-pair rapidity at $\sqrt{s}$=500 GeV, **before any TMD evolution is applied.**



Same evolution scheme as in W-Boson

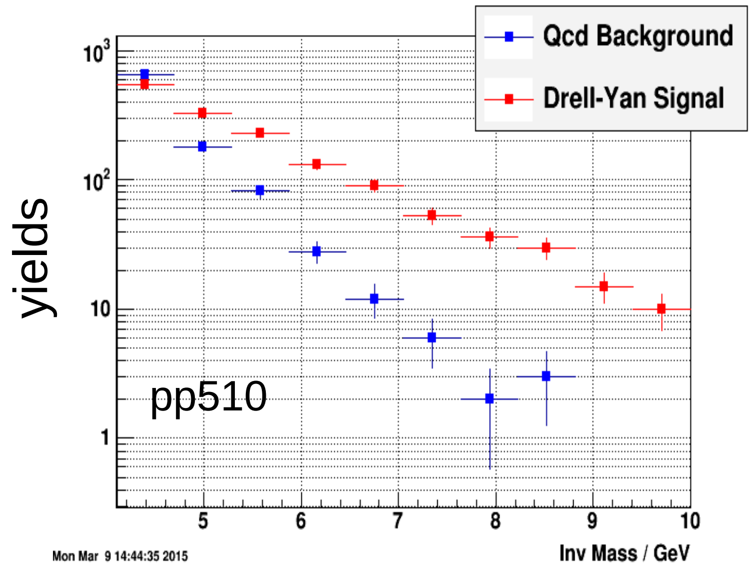
Theoretical predictions for DY for $0 < p_T < 1$ GeV and $4 < Q < 9$ GeV **after TMD evolution is applied**. The yellow bands represent the uncertainties for the asymmetry.

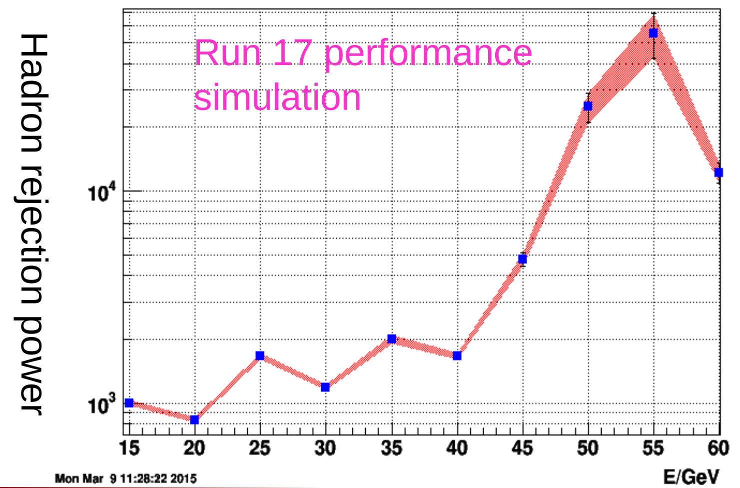
QCD background rejection: Drell-Yan e^+e^-

Add post-shower (run 17) to refurbished Pb-Glass FMS and scintillator pre-shower detector (run 15).

Simulate response of detector package to pions and electrons, collecting energy deposited in 3 pre-shower layers, FMS tower and post-shower layer.

Use multivariate analysis techniques to achieve hadron rejection powers of 800-14,000 for hadrons of 15 to 60 GeV while maintaining 90% electron detection efficiency.

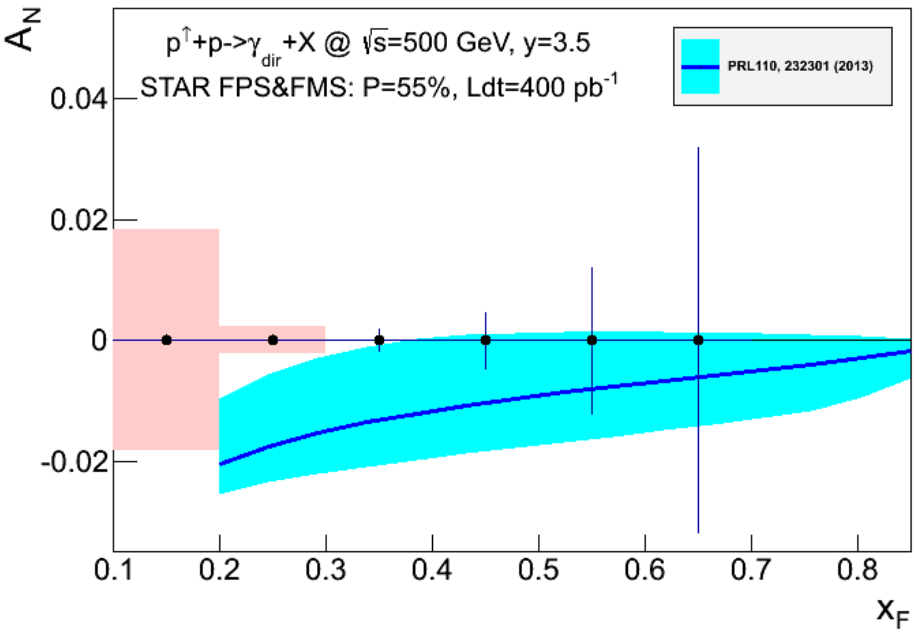




Twist-3 Observable: Direct photon A_N

Measurements of twist-3 observables explore the consistency between TMD and Collinear Twist-3 formalism.

Statistical and systematic uncertainties for the direct photon A_N after background subtraction compared to theoretical predictions for $\sqrt{s}$ = 500 GeV.



Summary of Sivers Function Tests Planned for STAR

	$A_N(W^{+/-},Z^0)$	$A_N(DY)$	$A_N(\gamma)$
Sensitive to Sivers fct. sign change through TMDs	Yes	Yes	No
Sensitive to Sivers fct. sign change through Twist-3 $T_{q,F}(x,x)$	No	No	Yes
Sensitive to TMD evolution	Yes	Yes	No
Sensitive to sea quark Sivers function	Yes	Yes for $x \sim 10^{-4}$	No
Detector upgrade needed	No	Yes FMS post-shower	No
Biggest experimental challenge	Integrated luminosity	Background suppression Integrated luminosity	----

pp500 Operation mode for W-boson

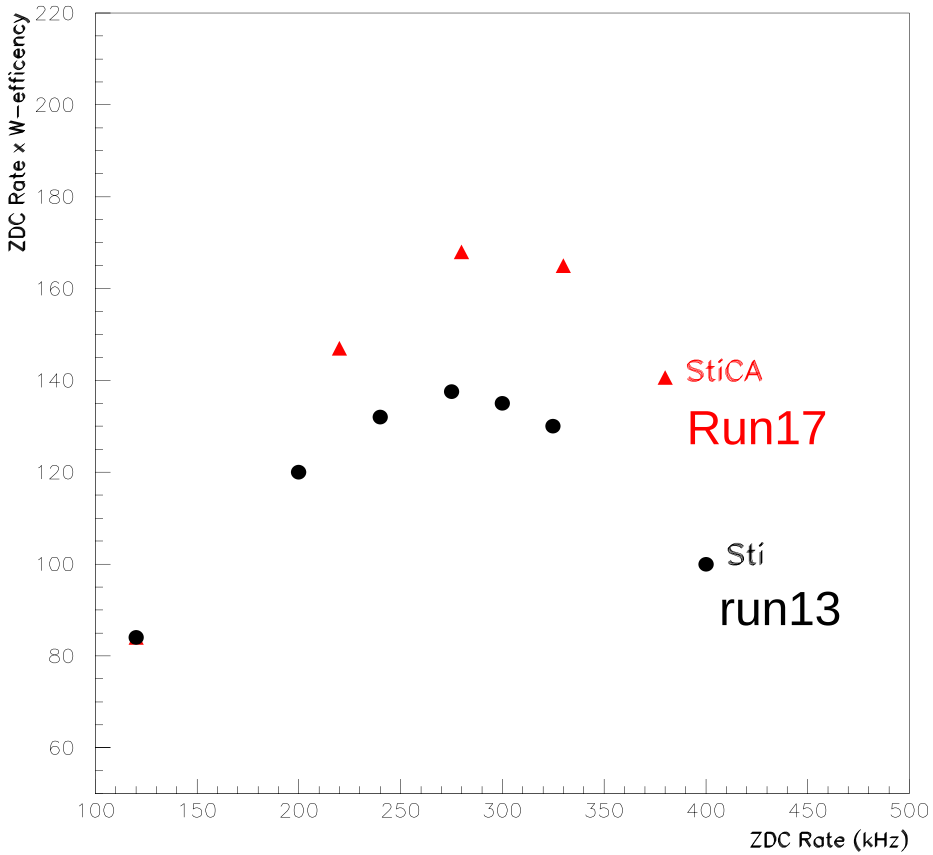
STAR TPC event pile-up affects tracking efficiency

The W-boson reconstruction efficiency was obtained from the data measured in 2011 to 2013 and with improved Tracking Algorithm.

The highest FoM is reached at a ZDC rate of 330 kHz corresponding to a luminosity of 1.5 x 10^{32} $cm^{-2}s^{-1}$.

Optimization of delivered luminosity with dynamic beta* squeeze.

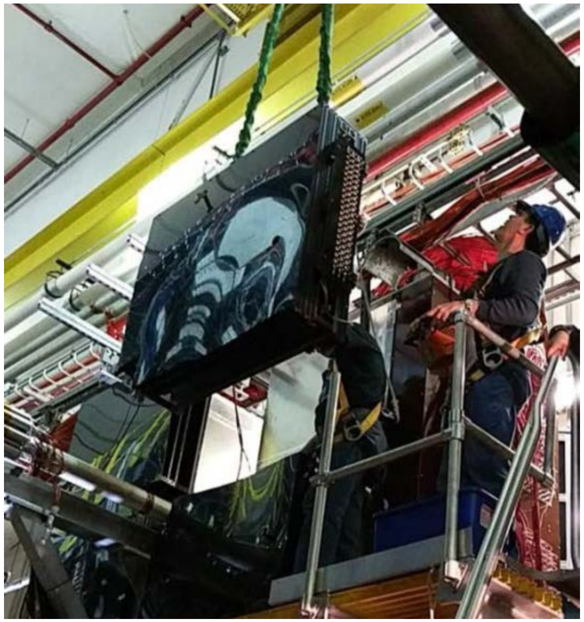
Requires 13 weeks to reach $400pb^{-1}$



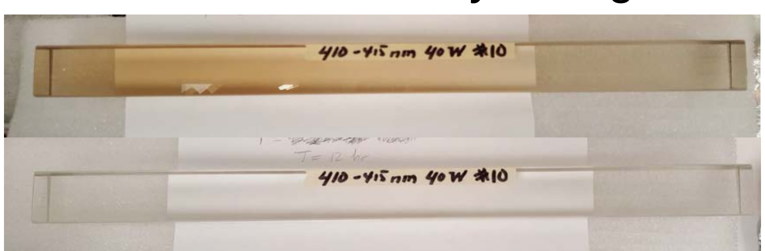
Forward Detector preparation for run 17

Forward Meson Spectrometer (FMS) + FMS Pre-shower + FMS Poster-Shower

Installation of pre-shower for run 15

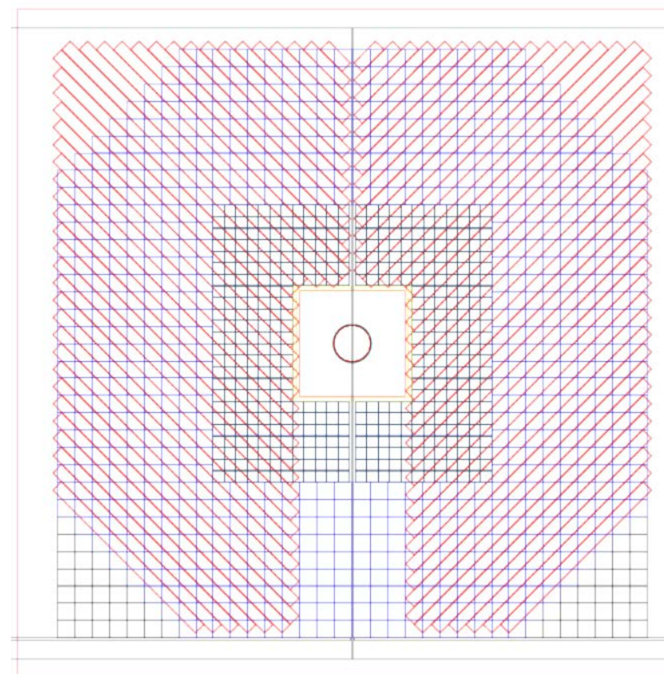


FMS radiation cure by UV lights



1. All three detector subsystems:
   existing FMS, Pre-shower
   Add new post-shower
2. Add UV lights to cure FMS radiation

https://drupal.star.bnl.gov/STAR/system/files/STAR.FMS_.Postshower.v2.pdf

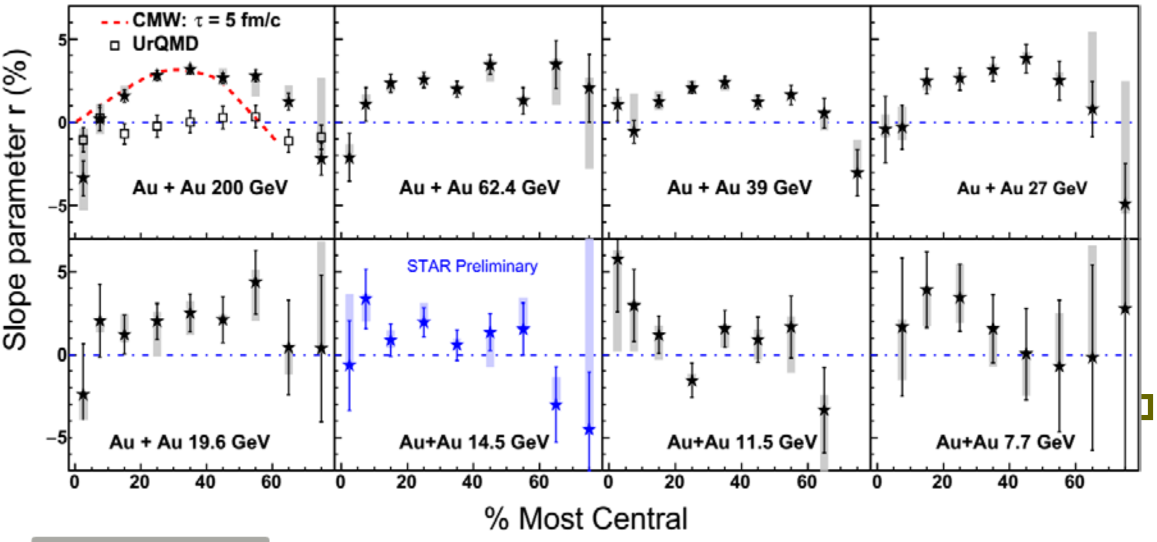


Isobar

Run	Energy	Duration	System	Goals	priority	Sequence
17	$\sqrt{s_{NN}}$=500 GeV	13-wk	Transverse p+p	A_N of $W^{\pm}$, γ, Drell-Yan, L=400 pb^{-1}, 55% pol	1	**1**
		1-wk	p+p	RHICf		**2**
		2-wk	CeC			
	$\sqrt{s_{NN}}$=62.4 GeV	4-wk	Au+Au	Jets, dileptons, NPE 1.5B MB	3	**3**
18	**$\sqrt{s_{NN}}$ =200 GeV**	**3.5-wk**	**Ru+Ru**	**1.2B MB**	**2**	**4**
	$\sqrt{s_{NN}}$=200 GeV	**3.5-wk**	**Zr+Zr**	**1.2B MB**	**2**	**5**
	$\sqrt{s_{NN}}$=27 GeV	**2-wk**	**Au+Au**	**>500M MB**	**3**	**6**

STAR's **second scientific priority** is to clarify the interpretation of measurements related to the chiral magnetic effect, chiral magnetic wave and chiral vortical effect. We therefore request **two 3.5 week runs in Run 18** with collisions of isobaric nuclei, Ruthenium-96 (Ru+Ru) and Zirconium-96 (Zr+Zr). Ru nuclei have an atomic charge of 44 compared to 40 for Zr. Ru+Ru collisions will therefore generate a magnetic field approximately 10% larger than Zr+Zr collisions while all else remains virtually fixed. Comparisons of charge separation in Ru+Ru and Zr+Zr collisions will isolate the magnetic field dependence of the observed charge separation thereby determining what fraction of those measurements are related to the chiral magnetic effect. These results will greatly advance our understanding of the chiral magnetic effect and have fundamental impact beyond the field of high-temperature QCD.

Results from Chiral Effects

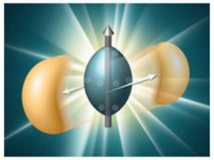


Editors' Suggestion

Observation of Charge Asymmetry Dependence of Pion Elliptic Flow and the Possible Chiral Magnetic Wave in Heavy-Ion Collisions

L. Adamczyk *et al.* (STAR Collaboration)

Phys. Rev. Lett. **114**, 252302 (2015) – Published 26 June 2015



A possible signature of chiral symmetry restoration, in the form of a chiral magnetic wave in the quark-gluon plasma, has been observed in heavy-ion collisions at RHIC.

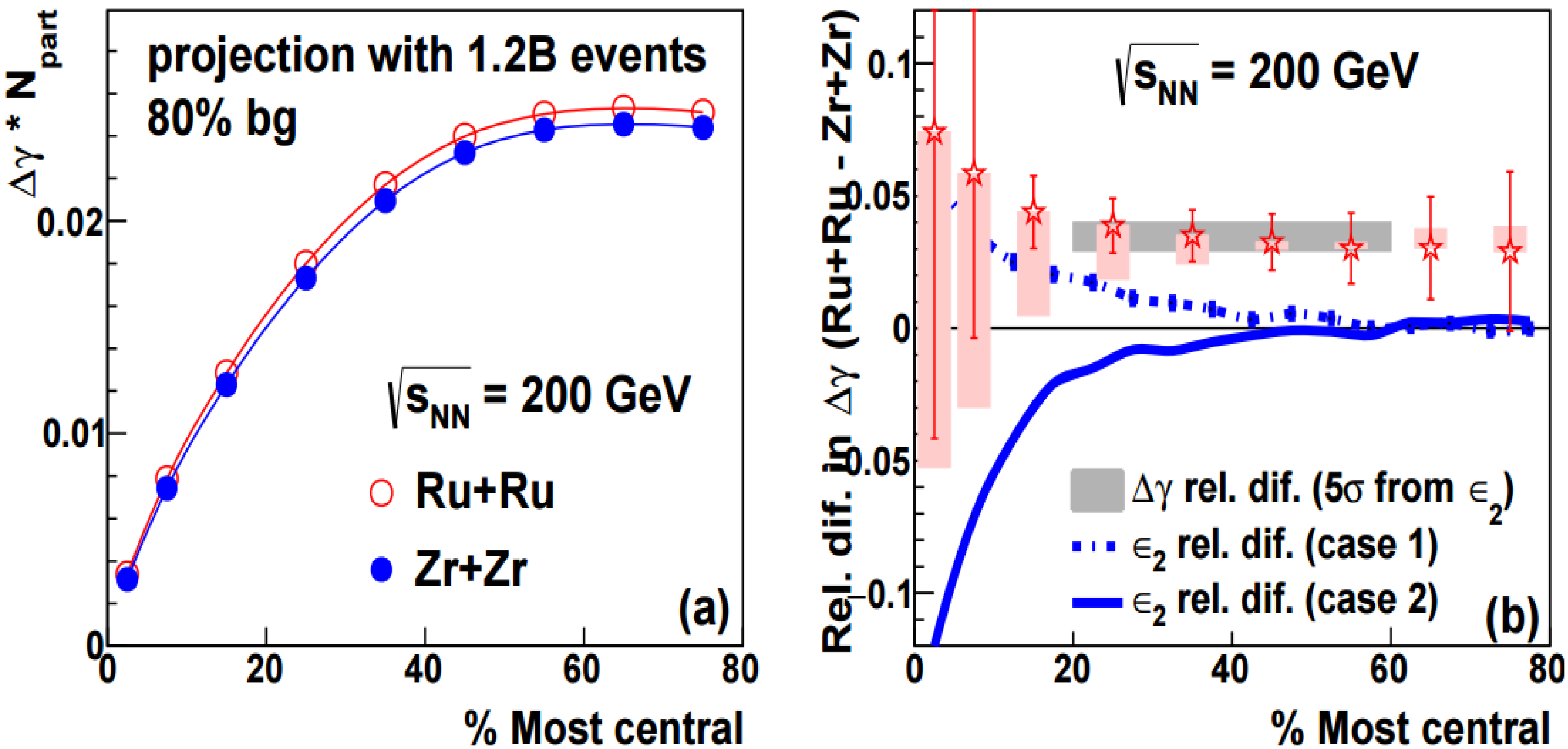
Show Abstract +

PRL on possible Chiral Magnetic Wave

More in-depth discussions this afternoon:
Talk by Paul Sorensen from CME Task Force

- We have published a few papers on possible Chiral Magnetic Effect and potential background
- U+U collisions
  Better understanding
- BES-I results on CME
  14.5GeV
- BES II with more statistics
- Chiral Magnetic Wave
  14.5GeV
- Chiral Vortical Effect

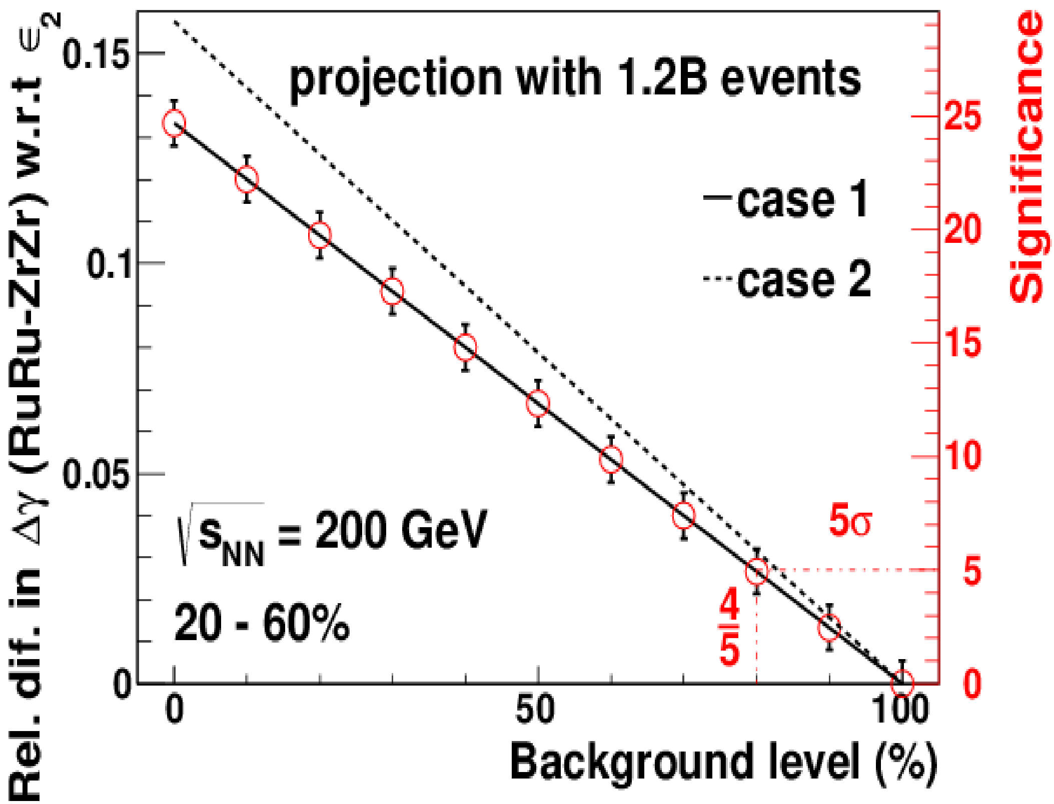
A decisive test with Isobars

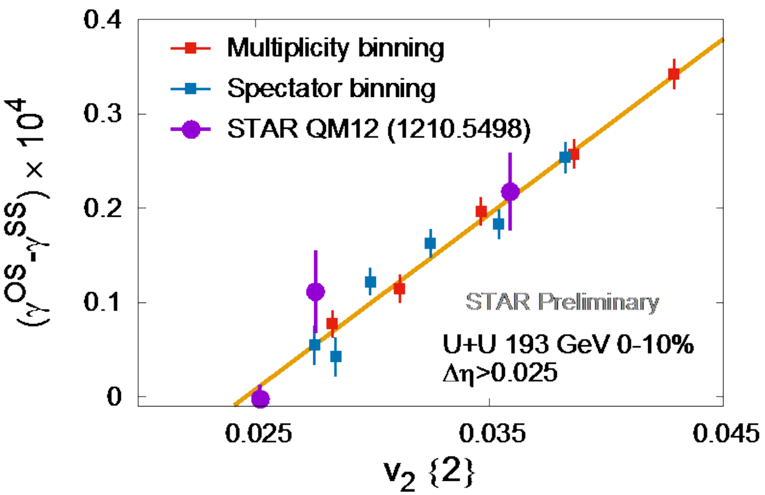


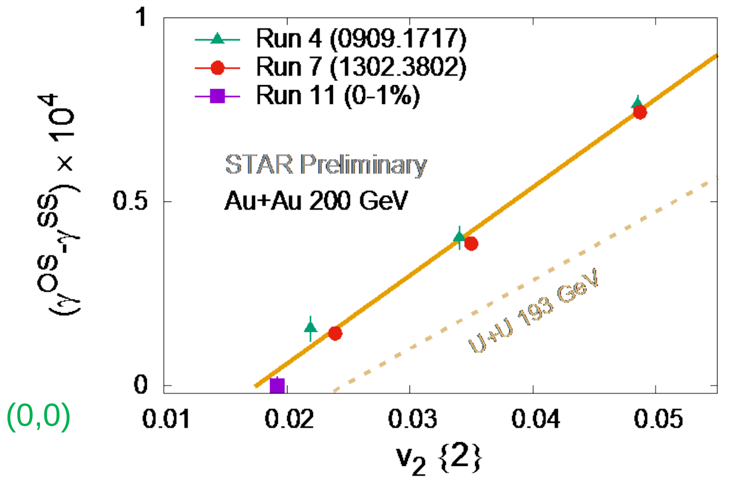
CAD was not able to locate enriched Ruthenium-96 source
Possible with the refurbished Oakridge Isotope Facility,
Run with natural abundance reduces luminosity by x5
Can reach 1.2 Billion events within 3.5 weeks of operation

Projections for Isobar

With 1.2B minbias events each species
5σ significance
if 80% observed correlation is background







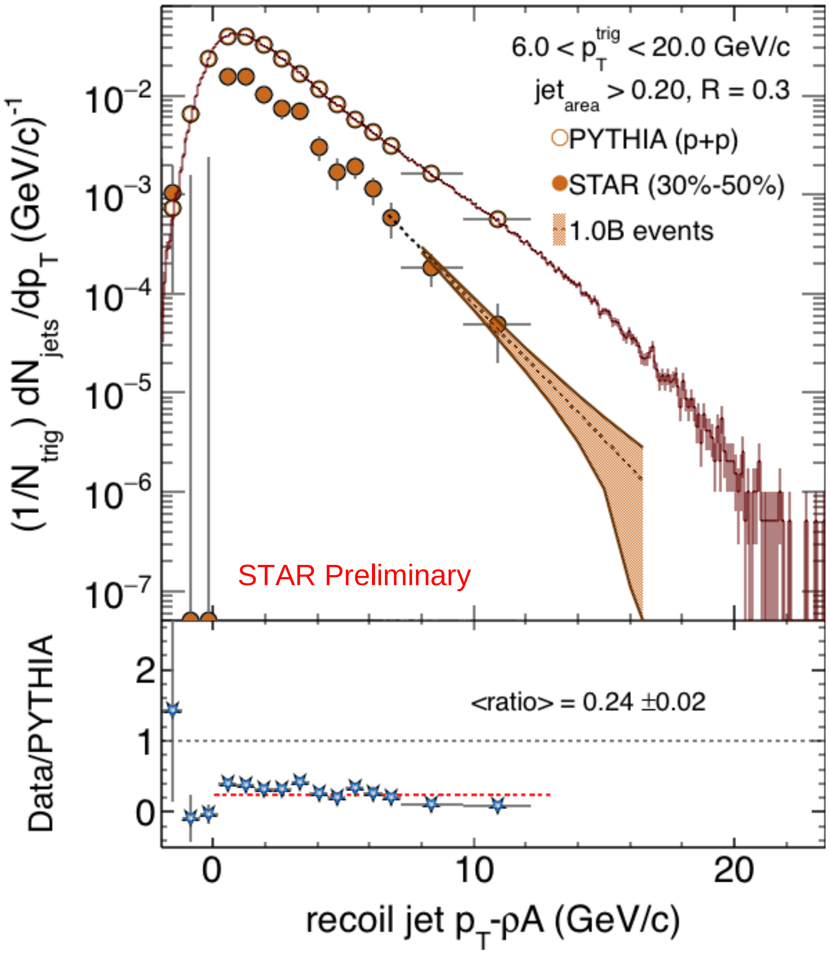
Au+Au at 62.4GeV

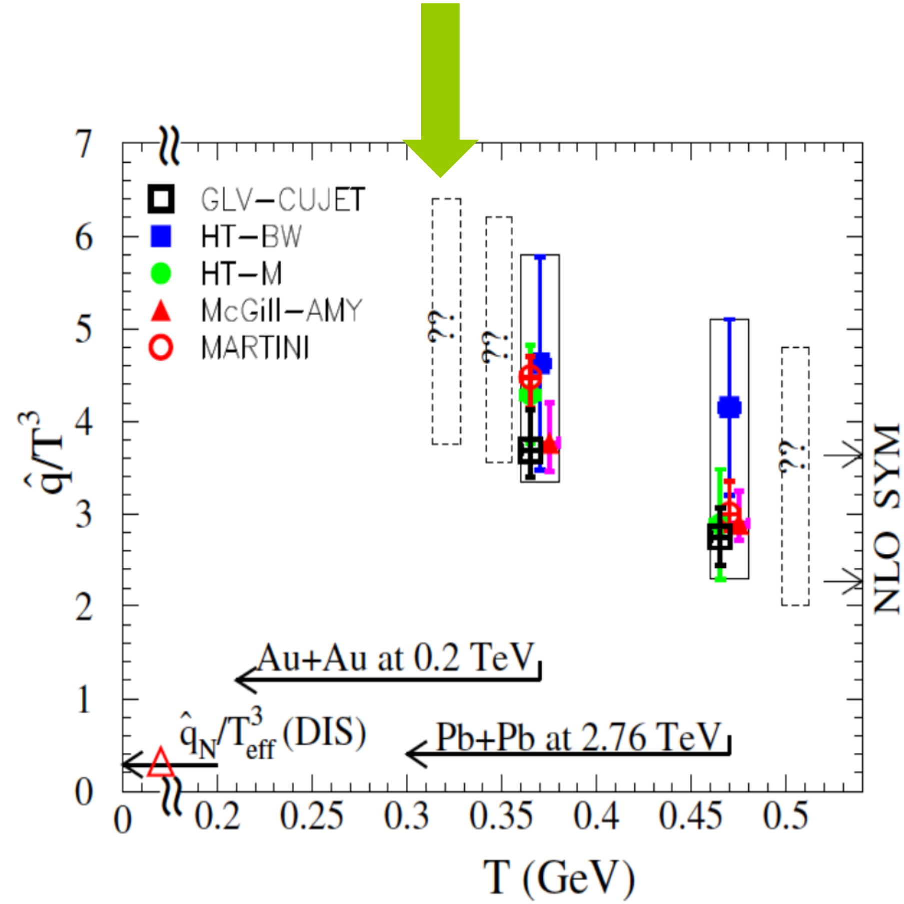
Run	Energy	Duration	System	Goals	priority	Sequence
17	$\sqrt{s_{NN}}$=500 GeV	13-wk	Transverse p+p	A_N of $W^{\pm}$, γ, Drell-Yan, L=400 pb^{-1}, 55% pol	1	**1**
		1-wk	p+p	RHICf		**2**
		2-wk	CeC			
	$\sqrt{s_{NN}}$=62.4 GeV	4-wk	Au+Au	Semi-inclusive Jets, dileptons, NPE, 1.5B MB	3	**3**
18	**$\sqrt{s_{NN}}$ =200 GeV**	**3.5-wk**	**Ru+Ru**	**1.2B MB**	**2**	**4**
	$\sqrt{s_{NN}}$=200 GeV	**3.5-wk**	**Zr+Zr**	**1.2B MB**	**2**	**5**
	$\sqrt{s_{NN}}$=27 GeV	**2-wk**	**Au+Au**	**>500M MB**	**3**	**6**

The first of these requests is driven by theoretical calculations suggesting that the partonic coupling to the medium is stronger when temperatures are close to the critical value. Results from Run 10 at 62.4 GeV provide tantalizing evidence that this is true, but the data are statistically limited. We therefore request a **4 weeks 62.4 GeV Au+Au run in Run 17** to significantly enhance the statistical precision of these results. Precise measurements of non-photonic electron v_2 will confirm that this enhanced coupling results in the partial thermalization of charmed quarks even at this low energy, while our semi-inclusive recoil jet studies will probe possible differences in the jet energy redistribution. Finally, measurements of direct (virtual) photons will improve our understanding of thermal photon production and their medium coupling.

Au+Au at 62GeV

Inclusive jet measurements

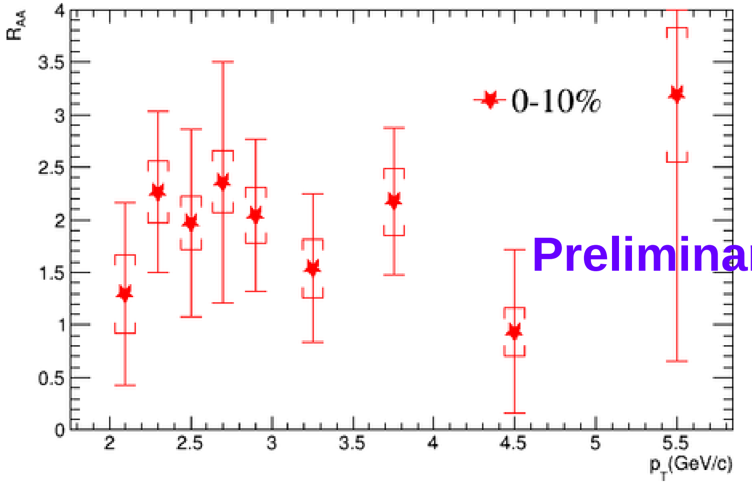




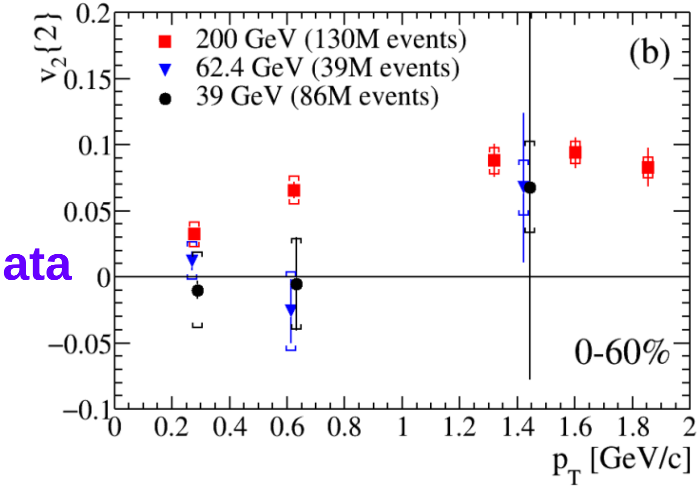
Au+Au at 62GeV helps establish the trend in temperature dependence

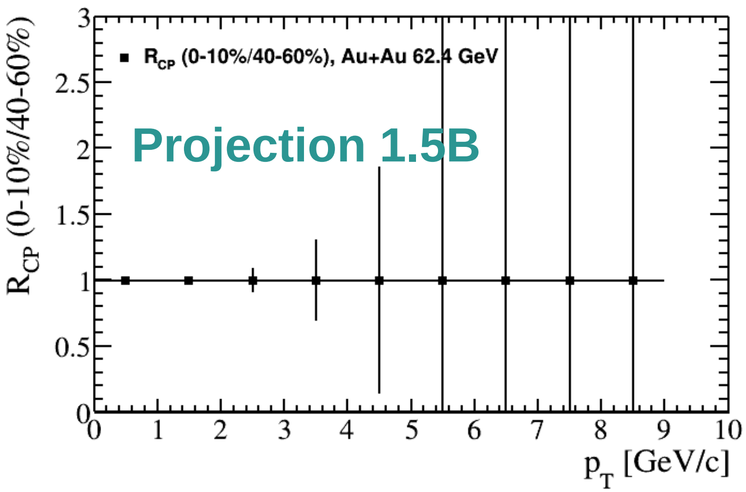
Resolving possible charm puzzle

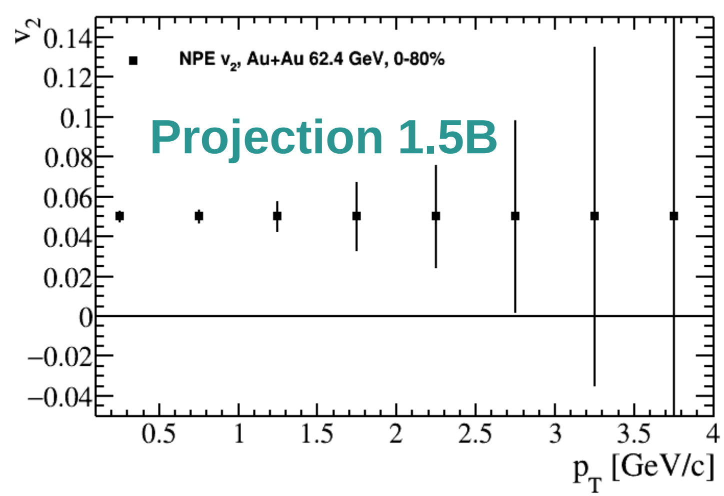
Large charm (NPE) suppression in Au+Au at 200GeV with large elliptic flow
Indication of enhancement in Au+Au at 62.4GeV with (~)zero elliptic flow



Preliminary data







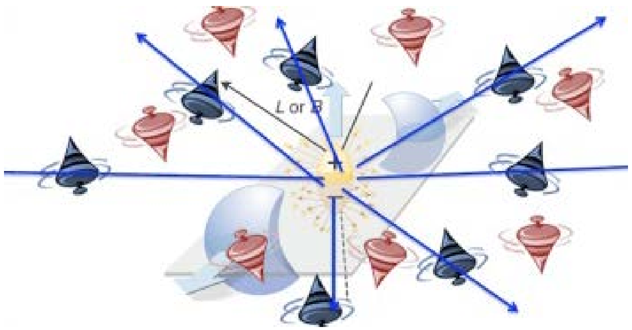
Au+Au at 27GeV

Run	Energy	Duration	System	Goals	priority	Sequence
17	$\sqrt{s_{NN}}$=500 GeV	13-wk	Transverse p+p	A_N of $W^{\pm}$, γ, Drell-Yan, L=400 pb^{-1}, 55% pol	1	**1**
		1-wk	p+p	RHICf		**2**
		2-wk	CeC			
	$\sqrt{s_{NN}}$=62.4 GeV	4-wk	Au+Au	Jets, dileptons, NPE 1.5B MB	3	**3**
18	**$\sqrt{s_{NN}}$ =200 GeV**	**3.5-wk**	**Ru+Ru**	**1.2B MB**	**2**	**4**
	$\sqrt{s_{NN}}$=200 GeV	**3.5-wk**	**Zr+Zr**	**1.2B MB**	**2**	**5**
	$\sqrt{s_{NN}}$=27 GeV	**2-wk**	**Au+Au**	**>500M MB**	**3**	**6**

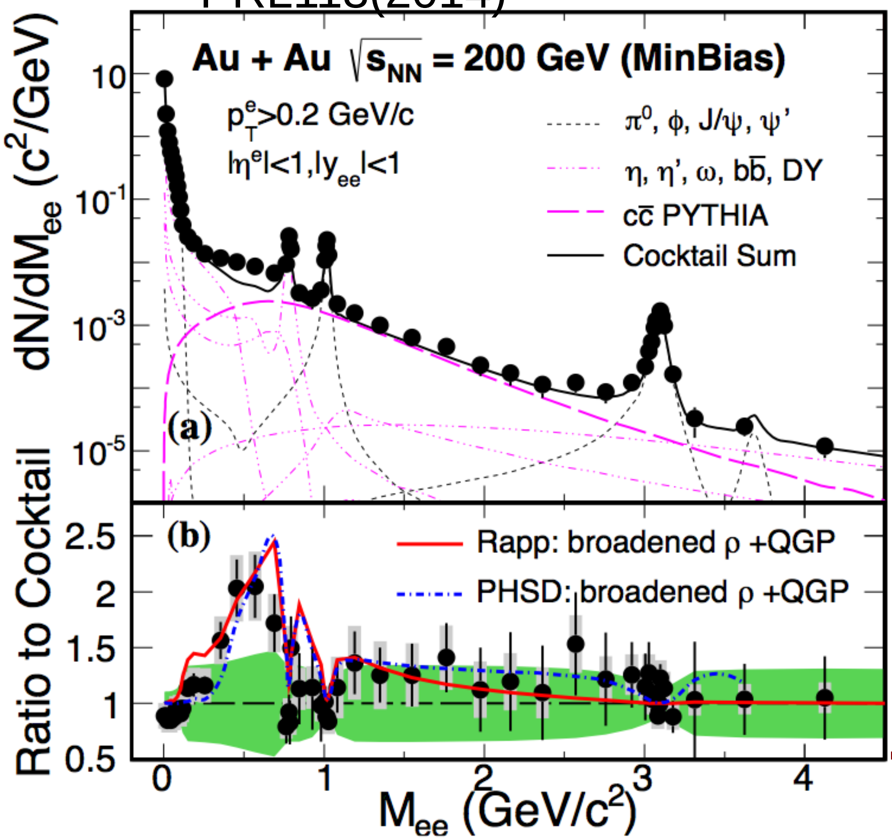
The second request is derived from STAR's recent report of the observation of the *global* polarization of hyperons (GPH) in non-central Au+Au collisions at energies below 40GeV. This is the first direct probe of the plasma vorticity, a fundamental characteristic of any fluid that must be quantified in order to understand the physics in detail. It also provides a measure of the magnetic field present over the evolution of the QGP. In addition to being of fundamental interest on their own accounts, these measurements provide critical context for recent high-profile studies of exotic phenomenon. In

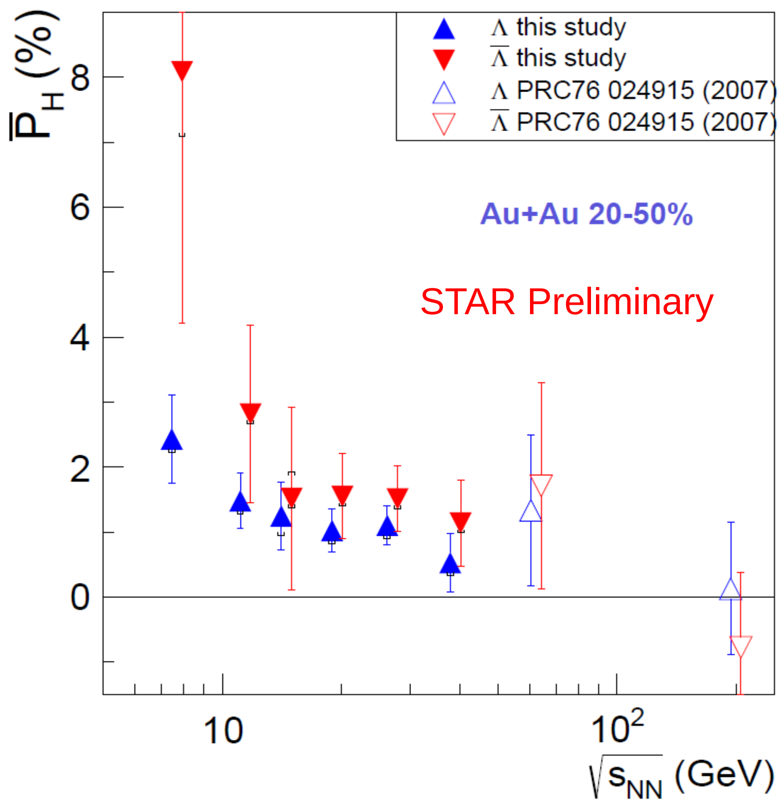
QCD phase transition is a chiral phase transition

1. Charge separation (14.5GeV)
2. Bulk charge dependence of $\pi^{\pm}$ v_2
3. Low-mass dilepton excess
4. Global polarization of hyperons



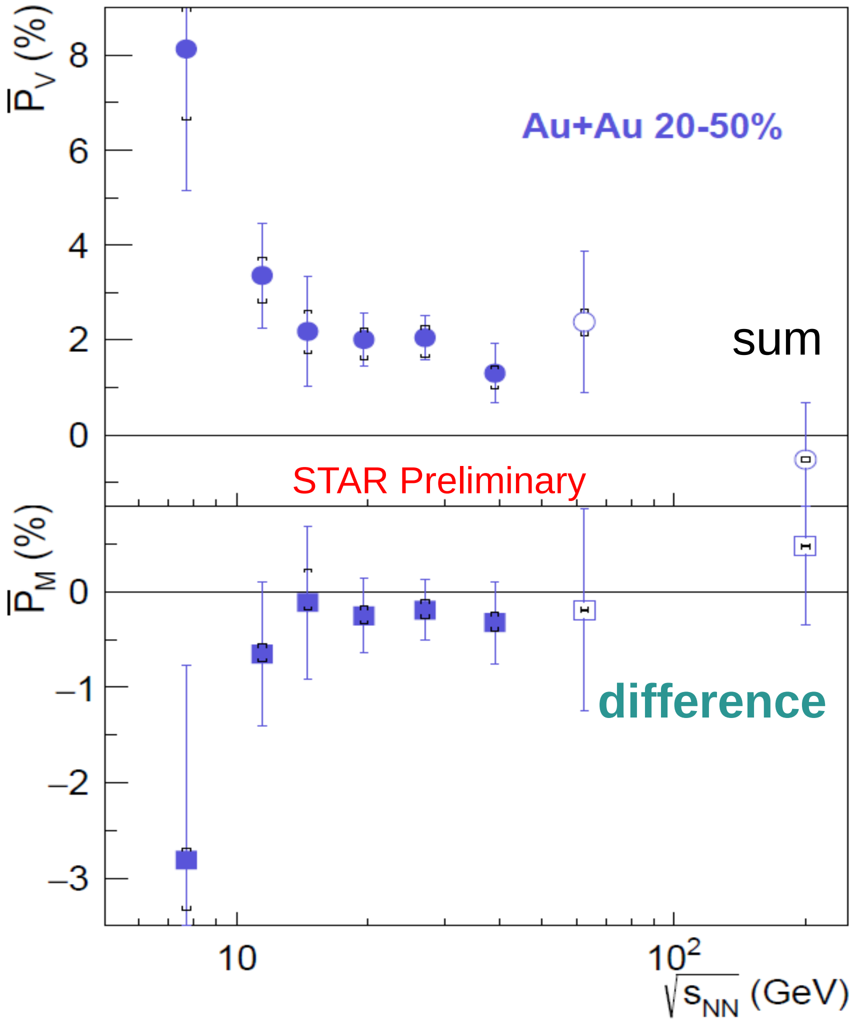
PRL113(2014)





QCD fluid responds to external field

- Current data not able to distinguish Lambda/AntiLambda polarization difference,
- (potentially) Direct measure of Magnetic Field effect
- **Need >x10 more data**

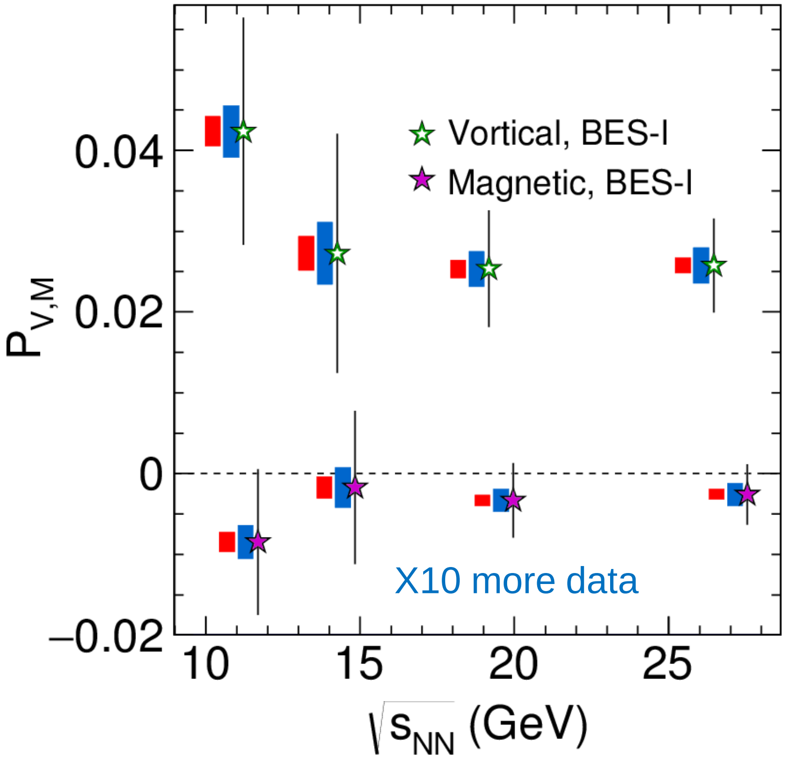


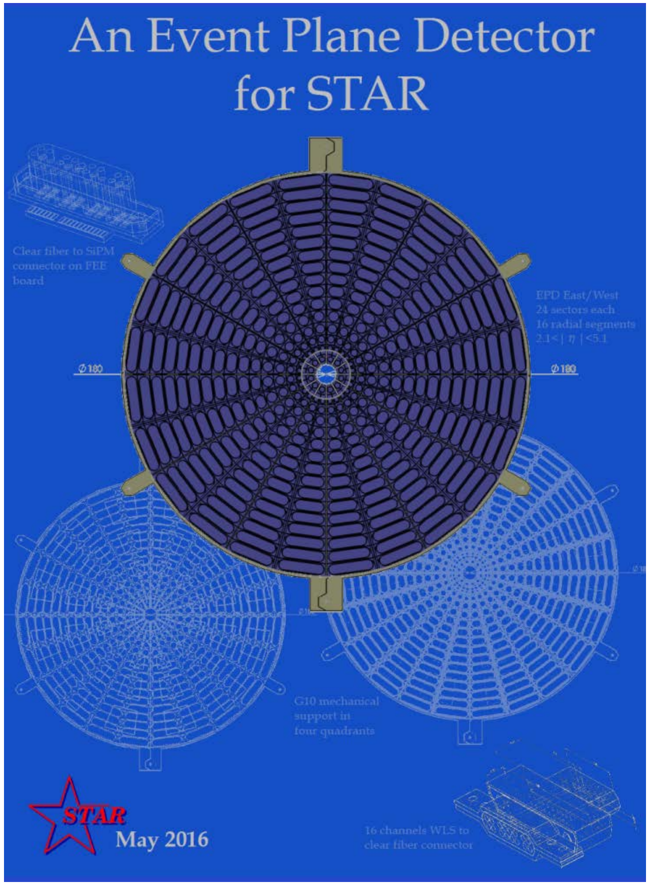
RHIC/AGS Users Meeting:
June 7 Xin-Nian Wang Polarization of Fermions in Vorticular Field
June 8 Issal Upsal Lambda Global Polarization

Request Au+Au 27GeV in run18 with EPD

https://drupal.star.bnl.gov/STAR/system/files/EPD_Construction_Proposal.pdf

- Clearly, very exciting development
- Signal and BES dependence need more data
- Request Au+Au 27GeV in run 18 with EPD or run17 without EPD, but earlier results
- To establish whether there is a difference
- Result will guide further studies in BES-II





Plan presented in 2011

Summary of the plan

	Near term (Runs 11-13)	Mid-decade (Runs 14-16)	Long term (Runs 17–)
Colliding systems	*p*+*p*, A+A	*p*+*p*, A+A	*p*+*p*, *p*+A, A+A, *e*+*p*, *e*+A
Upgrades	FGT, FHC, RP, DAQ10K, Trigger	HFT, MTD, Trigger	Forward Instrum, eSTAR, Trigger
(1) Properties of sQGP	Υ, $J/\psi \rightarrow ee$, m_{ee}, v_2	Υ, $J/\psi \rightarrow \mu\mu$, Charm v_2, R_{CP}, corr, Λ_c/D ratio, μ-atoms	*p*+A comparison
(2) Mechanism of energy loss	Jets, γ-jet, NPE	Charm, Bottom	Jets in CNM, SIDIS, *c*/*b* in CNM
(3) QCD critical point	Fluctuations, correlations, particle ratios	Focused study of critical point region	
(4) Novel symmetries	Azimuthal corr, spectral function	e-μ corr, μ-μ corr	
(5) Exotic particles	Heavy anti-matter, glueballs		
(6) Proton spin structure	W A_L, jet and di-jet A_{LL}, intra-jet corr, $(\Lambda+\bar{\Lambda})$ D_{LL}/D_{TT}		$\bar{\Lambda}$ D_{LL}/D_{TT}, polarized DIS & SIDIS
(7) QCD beyond collinear fact	Forward A_N		Drell-Yan, F-F corr, polarized SIDIS
(8) Properties of initial state			Charm corr, Drell-Yan, J/ψ, F-F corr, Λ, DIS, SIDIS

Measurements listed when they first become possible

Many will continue in future periods

Plan presented in 2011

Summary of the plan

	Near term (Runs 11-13)	Mid-decade (Runs 14-16)	Long term (Runs 17–)
Colliding systems	*p*+*p*, A+A	*p*+*p*, A+A	*p*+*p*, *p*+A, A+A, *e*+*p*, *e*+A
Upgrades	FGT, FHC, RP, DAQ10K, Trigger	HFT, MTD, Trigger	Forward Instrum, eSTAR, Trigger
(1) Properties of sQGP	Y, $J/\psi \rightarrow ee$, m_{ee}, v_2	Y, $J/\psi \rightarrow \mu\mu$, Charm v_2, R_{CP}, corr, Λ_c/D ratio, μ-atoms	*p*+A comparison
(2) Mechanism of energy loss	Jets, γ-jet, NPE	Charm, Bottom	Jets in CNM, SIDIS, *c*/*b* in CNM
(3) QCD critical point	**BES-I** Fluctuations, correlations, particle ratios	**BES-II** Focused study of critical point region	
(4) Novel symmetries	Azimuthal corr, spectral function	e-μ corr, μ-μ corr	
(5) Exotic particles	Heavy anti-matter, glueballs		
(6) Proton spin structure	W A_L, jet and di-jet A_{LL}, intra-jet corr, $(\Lambda+\bar{\Lambda})$ D_{LL}/D_{TT}		$\bar{\Lambda}$ D_{LL}/D_{TT}, polarized DIS & SIDIS
(7) QCD beyond collinear fact	Forward A_N		Drell-Yan, F-F corr, polarized SIDIS
(8) Properties of initial state			Charm corr, Drell-Yan, J/ψ, F-F corr, Λ, DIS, SIDIS

Measurements listed when they first become possible

Many will continue in future periods

RHIC has been adaptable to science needs

2010-13

BES-I

2014-16

BES-II

RHIC has been adaptable to science needs

2010-2013	2014	2015	2016	2017	2018	2019	2020		2022+
Au+Au p+p	Au+Au	p+p p+A	Au+Au d+Au	p+p Au+Au	Isobar Au+Au	Au+Au	Au+Au		Au+Au pp,pA
ΔG, QGP property	Charm flow	Ref. A_N	D_c, Λ_c Υ, Jets	Fc sign	CME, $\Lambda\uparrow$	Critical Point, Phase Transition			Jets, Υ forwardA_N
BES-I	200, 14.5	200	200- 19.6	500, 62.4	200, 27	BES-II 11-20	BES-II 7-11		200

BES-I **BES-II**

Expand to include several programs:
p+A in run 15,
pp500 in run17,
Isobar (Zr, Ru-96) in run 18
BES-II more compelling, detector and machine upgrades in 2018
Future high-luminosity jets and Upsilon in 2020+
3+1D hydrodynamics and Unique Cold QCD (DY) portal to EIC

Summary

- Successful run16 (thanks CAD)
- Compelling Heavy-Ion Programs for run 16 and run 18
  - Completion of Heavy-Flavor program for HFT+MTD
  - Decisive test of Chiral Magnetic Effect
  - Partonic coupling to QGP close to T_c
  - Quantifying the role of external field in Global Hyperon Polarization
- Compelling Spin Program in run17
  Three measurements related to TMD evolution and sign change
  (A_N $W^{+/-}$, γ, DY)
- Maintain track record in Results and Publications
- Preparation for BES II and beyond
  (3+1D hydro and Cold QCD)

Run	Energy	Duration	System	Goals	priority
17	$\sqrt{s_{NN}}$=500 GeV	13-wk	Transverse p+p	A_N of $W^{\pm}$, γ, Drell-Yan, L=400 pb^{-1}, 55% pol	1
	$\sqrt{s_{NN}}$=62.4 GeV	4-wk	Au+Au	Jets, dileptons, NPE 1.5B MB	3
18	$\sqrt{s_{NN}}$ =200 GeV	3.5-wk	Ru+Ru	1.2B MB	2
	$\sqrt{s_{NN}}$=200 GeV	3.5-wk	Zr+Zr	1.2B MB	2
	$\sqrt{s_{NN}}$=27 GeV	2-wk	Au+Au	>500M MB	3

1 Executive Summary

In this Beam Use Request the STAR Collaboration presents four compelling and prioritized scientific programs for the 2017 and 2018 RHIC runs.

STAR's **highest scientific priority** is the first significant measurement of the sign change of the Sivers function, as compared to the value measured in semi-inclusive deep inelastic scattering experiments, through measurements of single spin asymmetries in $W^{+/-}$, Z, direct photon and Drell-Yan production in transversely polarized $\sqrt{s}$ = 500 GeV p+p collisions. This measurement will also shed light on the size and nature of the evolution of these transverse momentum dependent distributions. The sign change measurement is a fundamental test of QCD and is being pursued by other experiments, making a timely measurement imperative. We therefore request **13 weeks of 500 GeV p+p running in Run17.**

STAR's **second scientific priority** is to clarify the interpretation of measurements related to the chiral magnetic effect, chiral magnetic wave and chiral vortical effect. We therefore request **two 3.5 week runs in Run 18** with collisions of isobaric nuclei, Ruthenium-96 (Ru+Ru) and Zirconium-96 (Zr+Zr). Ru nuclei have an atomic charge of 44 compared to 40 for Zr. Ru+Ru collisions will therefore generate a magnetic field approximately 10% larger than Zr+Zr collisions while all else remains virtually fixed. Comparisons of charge separation in Ru+Ru and Zr+Zr collisions will isolate the magnetic field dependence of the observed charge separation thereby determining what fraction of those measurements are related to the chiral magnetic effect. These results will greatly advance our understanding of the chiral magnetic effect and have fundamental impact beyond the field of high-temperature QCD.

Our **next scientific priorities** involve taking data at two beam energies that are lower than the nominal energies, but are not part of STAR's proposed Beam-Energy-Scan Phase-II (BES-II) program in 2019-2020 [1].

The first of these requests is driven by theoretical calculations suggesting that the partonic coupling to the medium is stronger when temperatures are close to the critical value. Results from Run 10 at 62.4 GeV provide tantalizing evidence that this is true, but the data are statistically limited. We therefore request a **4 weeks 62.4 GeV Au+Au run in Run 17** to significantly enhance the statistical precision of these results. Precise measurements of non-photonic electron v_2 will confirm that this enhanced coupling results in the partial thermalization of charmed quarks even at this low energy, while our semi-inclusive recoil jet studies will probe possible differences in the jet energy redistribution. Finally, measurements of direct (virtual) photons will improve our understanding of thermal photon production and their medium coupling.

The second request is derived from STAR's recent report of the observation of the *global* polarization of hyperons (GPH) in non-central Au+Au collisions at energies below 40GeV. This is the first direct probe of the plasma vorticity, a fundamental characteristic of any fluid that must be quantified in ordrer to understand the physics in detail. It also provides a measure of the magnetic field present over the evolution of the QGP. In addition to being of fundamental interest on their own accounts, these measurements provide critical context for recent high-profile studies of exotic phenomenon. In particular, the Chiral Vortical Effect (CVE) and Chiral Magnetic Effect (CME) are among the RHIC program's most exciting and visible topics today. However, they are nontrivial and require several conditions to be simultaneously met; "extraordinary claims require extraordinary evidence." GPH has nothing "chiral" or exotic about it. In a theoretically well-grounded way, it measures the average vorticity (ω) and field (B). Hence, GPH must be understood first, to put more "extraordinary" claims on firmer ground. A solid understanding of GPH and the magnetic field, however, requires the increased statistics available with a 2-week run at 27 GeV. While similar high-statistics measurements of GHP will eventually be performed in BES-II, the scientific impact of getting firm measures of vorticity and B much sooner is high, given the current intensity of research and attention on CME and CVE.

Table 1.1 and Table 1.2 summarize the above requests, along with our scientific priorities and proposed running sequence. We have considered two scenarios:

Scenario 1: 19 cryo-weeks for Run 17 and 13 cryo-weeks for Run 18 (Table 1-1)
Scenario 2: 24 cryo-weeks for Run 17 and 13 cryo-weeks for Run 18 (Table 1-2)

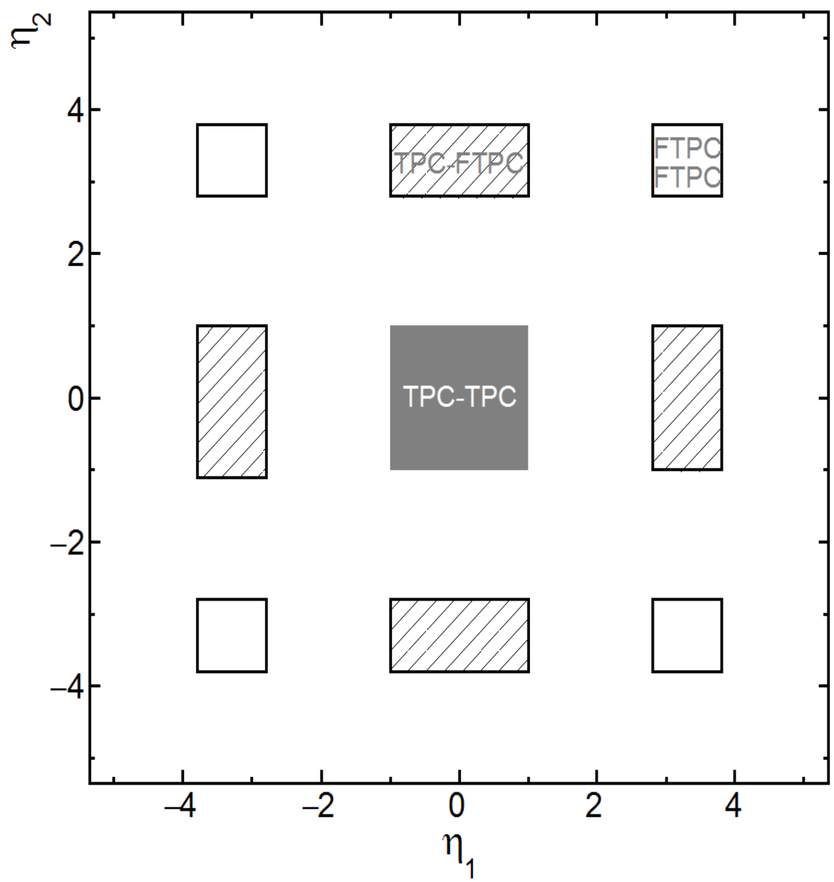
In this document we first present highlights from papers published since the last PAC meeting and on-going analyses. Next we summarize the analysis status of data from STAR's two recent upgrades, the Heavy Flavor Tracker (HFT) and the Muon Telescope Detector (MTD), and discuss the detector's performance in Run 16. In Sections 4 and 5, we detail the STAR Collaboration's compelling physics program driving our Run 17 and Run 18 beam-use request. Collection of these data will allow us to achieve our spin and relativistic heavy ion physics goals on a timescale consistent with the current intense international interest while utilizing RHIC beams effectively and taking full advantage of recent improvements in machine and detector capability. Finally, we outline the planned upgrades for Run 17 and 18 and the BES-II.

Run	Energy	Duration	System	Goals	priority	Seq
17	$\sqrt{s_{NN}}$=500 GeV	13-wk	Transverse p+p	A_N of $W^{\pm}$, γ, Drell-Yan, $\mathcal{L}$=360 pb^{-1}, 55% pol	1	1
		1-wk	p+p	RHICf		2
		2-wk	CeC			
18	$\sqrt{s_{NN}}$=200 GeV	3.5-wk	Ru+Ru	1.2B MB	2	3
	$\sqrt{s_{NN}}$=200 GeV	3.5-wk	Zr+Zr	1.2B MB	2	4
	$\sqrt{s_{NN}}$=27 GeV	2-wk	Au+Au	500M MB	3	5

Table 1.1: Scenario I: 19 cryo-weeks for Run 17 and 13 cryo-weeks for Run 18. All luminosities requested are actual sampled luminosity. See text for details about pp500 run conditions and optimizations.

Rapidity Coverage (BES-II)

TPC+fTPC (2001-2012)



TPC+iTPC+eTOF+EPD+FMS (2019--)