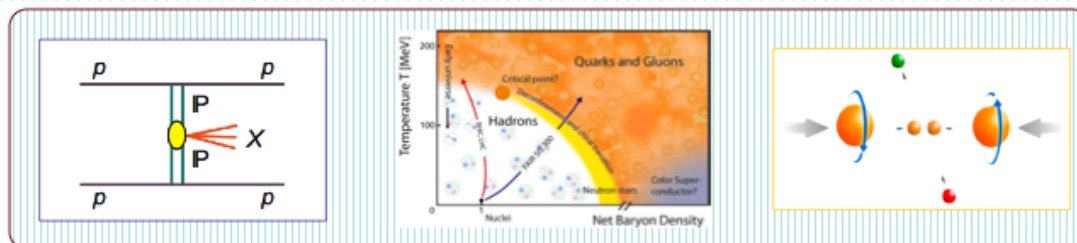


STAR Physics Program

STAR Beam Use Requests for Run14 and Run15

Nu Xu
for the STAR Collaboration



- 1) STAR Physics Program & Detector System
- 2) Selected Recent Results
 - Results from 200 GeV Au+Au Collisions
 - Results from Beam Energy Scan (BES-I)
- 3) Run13 Status
- 4) BUR for Run 14 and 15

A group of people, likely members of the STAR Collaboration, standing in front of a large industrial structure, possibly part of the RHIC accelerator.

STAR Collaboration

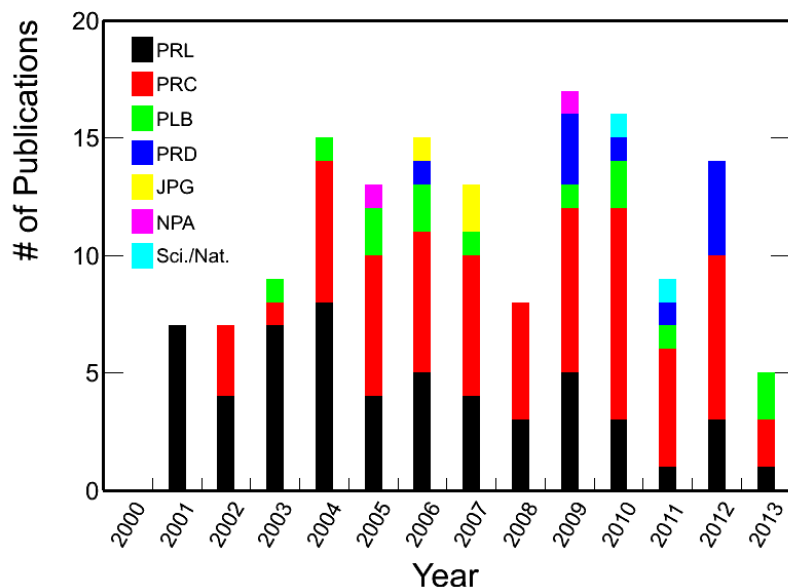
STAR Experiment at RHIC

(<http://www.star.bnl.gov/>)

Fundamental science: particle physics, nuclear physics, astrophysics, cosmology, ...

State of art technology: detector R&D, simulations, IT, computing, mass/fast data managing, ...

- 550 scientists
- 55 institutes
- 13 countries
- 165 PhD thesis completed since 2001 (May 2013)



Citations summary

Generated on 2013-06-04

148 papers found, 148 of them citeable (published or arXiv)

Citation summary results

Total number of papers analyzed:

Citeable papers

[148](#)

Published only

[145](#)

Total number of citations:

15,681

15,680

Average citations per paper:

106.0

108.1

Breakdown of papers by citations:

Renowned papers (500+)

[5](#)

[5](#)

Famous papers (250-499)

[10](#)

[10](#)

Very well-known papers (100-249)

[32](#)

[32](#)

Well-known papers (50-99)

[22](#)

[22](#)

Known papers (10-49)

[53](#)

[53](#)

Less known papers (1-9)

[24](#)

[23](#)

Unknown papers (0)

[2](#)

[0](#)

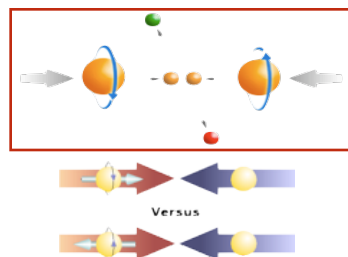
h_{HEP} index [7](#)

62

62

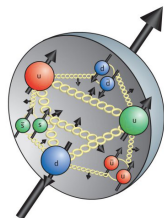
2012-2013: 12 published & 7 submitted in referee process
 Citations: 15681 (June 4th, 2013)
 Average citation/paper: 106

STAR Physics Focus



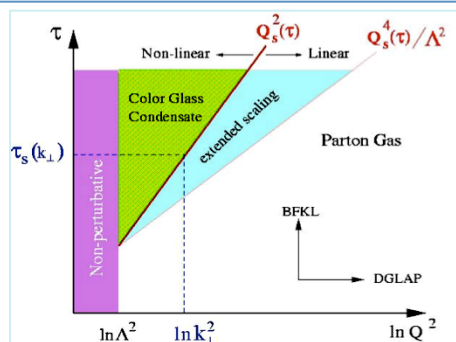
Polarized $p+p$ Program

- Study *proton intrinsic properties*



Small-x Physics Program

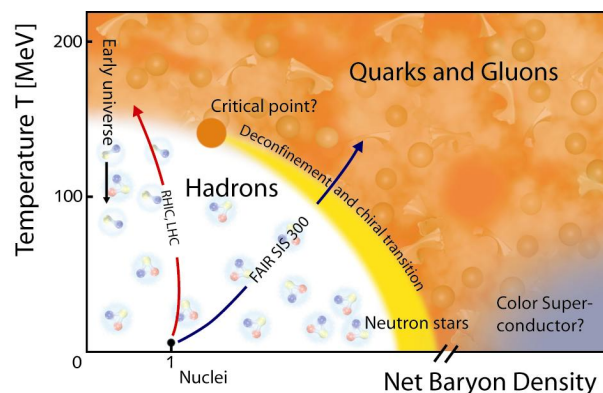
- Study low-x properties, initial condition, search for **CGC**
- Study elastic and inelastic processes in pp2pp



STAR
Decadal
Plan

+

eSTAR



1) At 200 GeV at RHIC

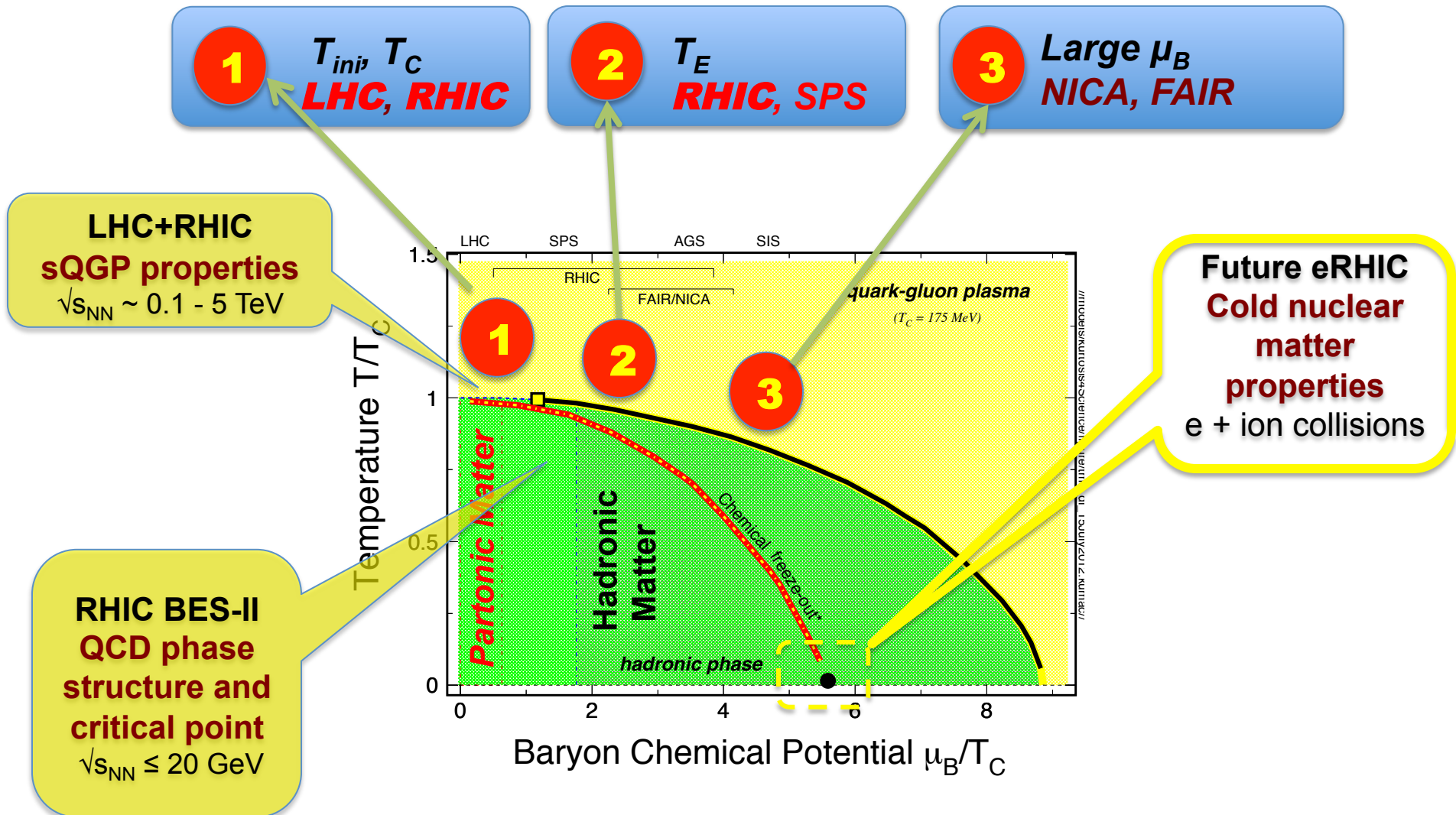
- Study *medium properties, EoS*
- pQCD in hot and dense medium

2) RHIC Beam Energy Scan (BES)

- Search for the **QCD critical point**
- Chiral symmetry restoration



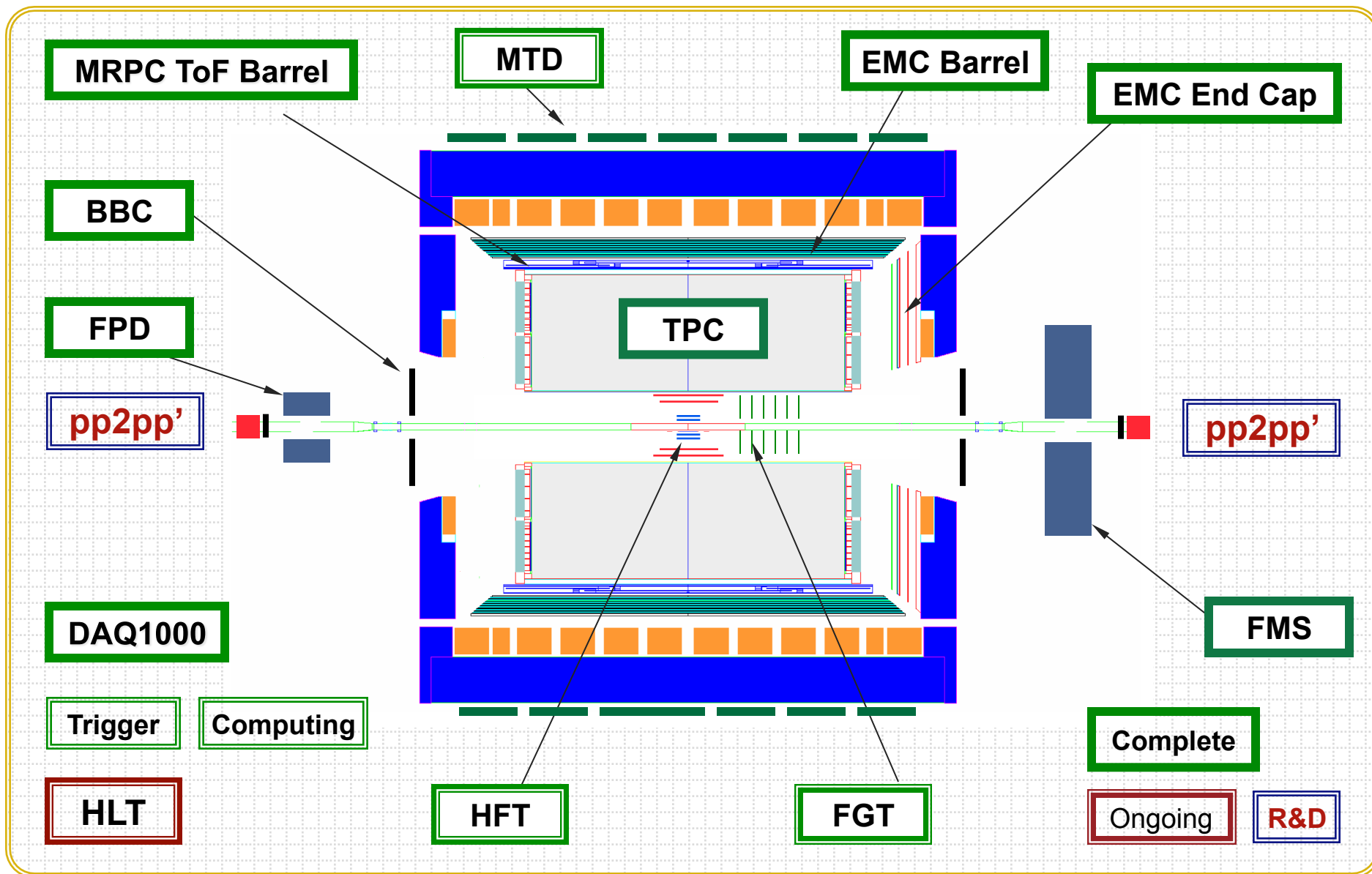
Exploring the QCD Phase Structure



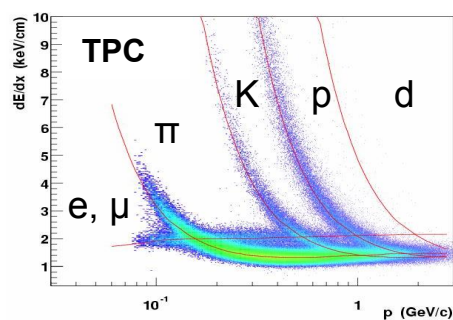
Emergent properties of QCD matter



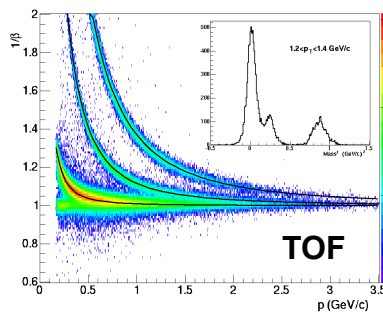
STAR Experiment



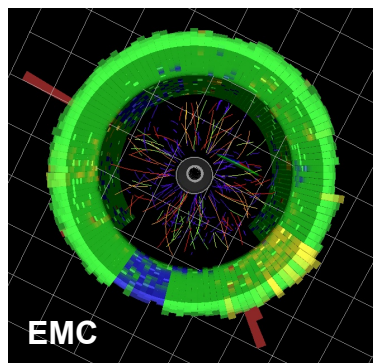
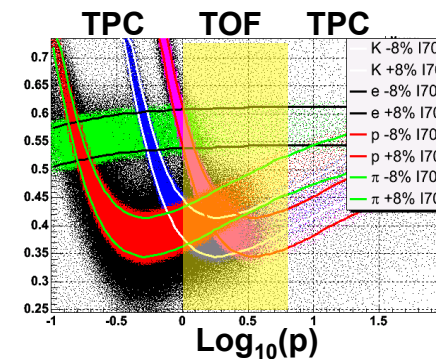
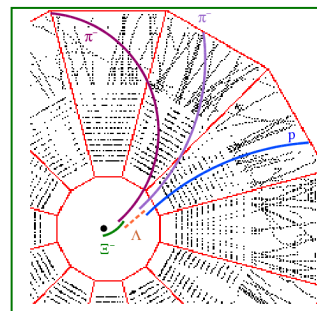
Particle Identification at STAR



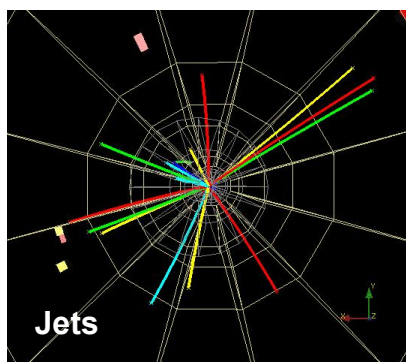
Charged hadrons



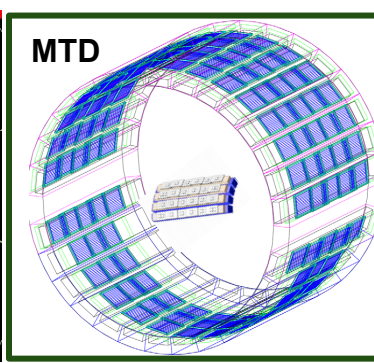
Hyperons & Hyper-nuclei



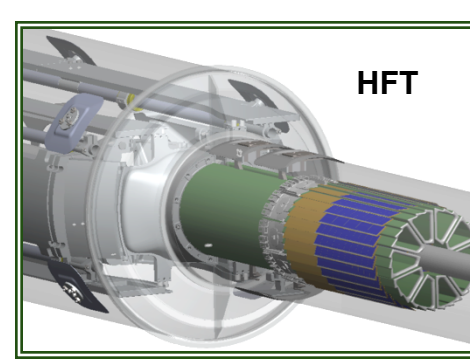
Neutral particles



Jets & Correlations



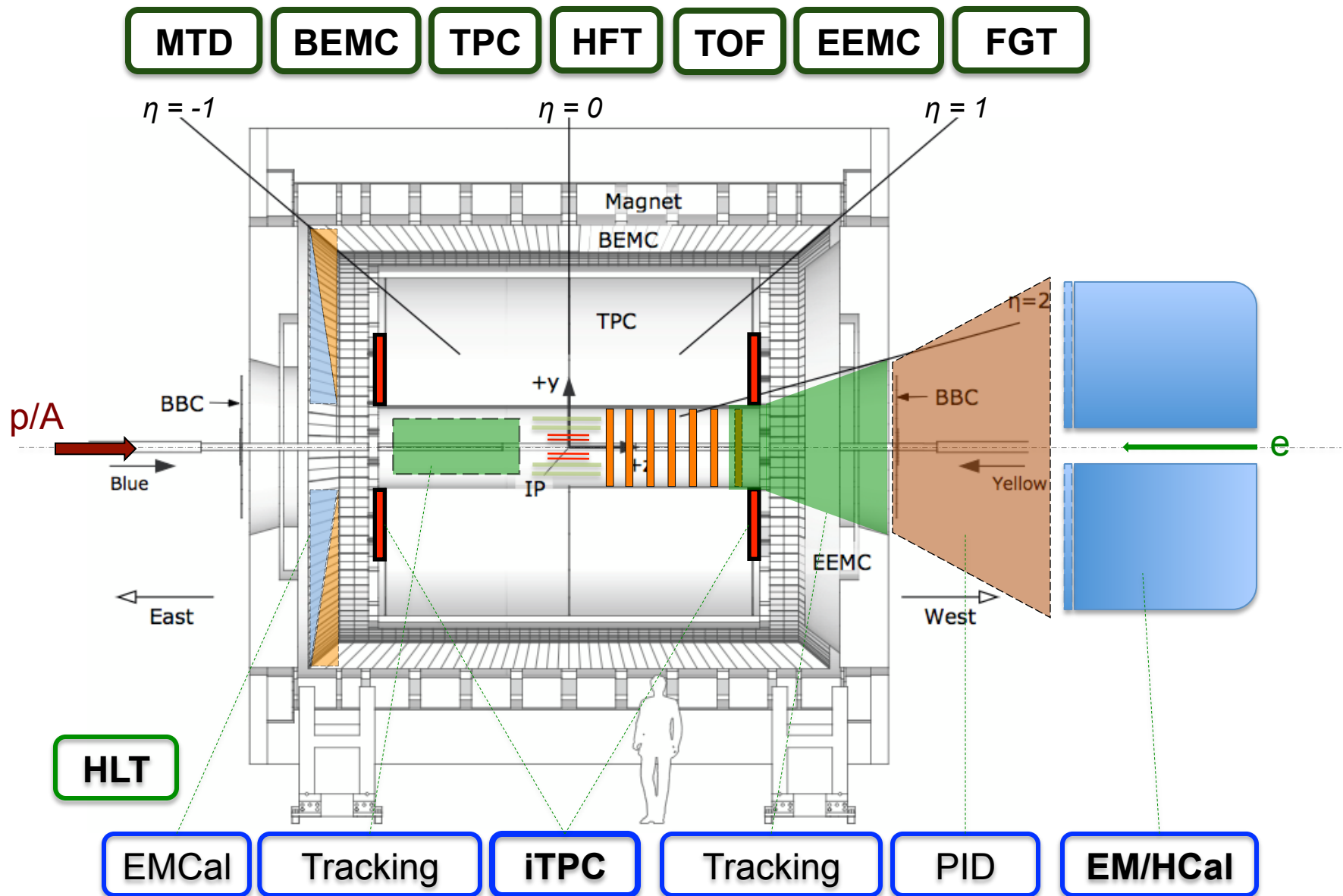
High p_T muons



Heavy-flavor hadrons

Multiple-fold correlations for the identified particles!

STAR Forward Upgrade Plan (2018)





STAR Detector System

	Period	Detectors	Physics
	2001-2010	TPC	<i>u, d, s</i>
	2010	TPC + TOF	<i>u, d, s + dilepton</i>
	2013	TPC + TOF + MTD	<i>u, d, s, c, b + dilepton</i>
	2014	TPC + TOF + MTD + HFT	

→ **STAR: Large coverage, excellent PID, fast DAQ**

- detects nearly all particles produced at RHIC
- multiple fold correlation measurements
- Probes: **bulk**, **penetrating**, **bulk-penetrating**

→ **STAR: Perfect mid-y collider experiment**

→ **STAR: Expanding into forward rapidity regions**



STAR: LOI for Transition to eRHIC

Membership of the committee: Elke Aschenauer, Jamie Dunlop, Renee Fatemi, Carl Gagliardi, Huan Huang, Ming Shao, ***Ernst Sichtermann****, Thomas Ullrich, Flemming Videbaek, Nu Xu, ***Zhangbu Xu****

*co-chair

Deadlines: Sept. 15: draft to the STAR Collaboration
Oct. 1: final document sent to BNL management

STAR BUR for Runs 14 and 15

Run	*	Beam Energy	Time	System	Goals
14	2	$\sqrt{s_{NN}} = 15 \text{ GeV}$	3-week	Au + Au	1) 150M M.B. events for CP search 2) Fixed-target data taking
	1	$\sqrt{s_{NN}} = 200 \text{ GeV}$	14-week	Au + Au	HFT & MTD heavy flavor hadron measurements L=10 nb ⁻¹ , 1000M M.B.
15	1	$\sqrt{s} = 200 \text{ GeV}$	12-week	1) p + p 2) p _↑ + p _↑ (6-week) 3) p _→ p _→ (6-week)	1) Heavy ion reference data L= 90 pb ⁻¹ , 500M M.B. 2) A _N , L= 40 pb ⁻¹ , 60% pol. 3) Study Δg(x) L=50 pb ⁻¹ , 60% pol.
	2	$\sqrt{s_{NN}} = 200 \text{ GeV}$	5-week	p _↑ + Au	Study saturation physics, pA-ridge and heavy ion reference L=300 pb ⁻¹

- 22 cryo-week.
- 15 cryo-week run, we request the top priority item for both runs.

* Physics priorities



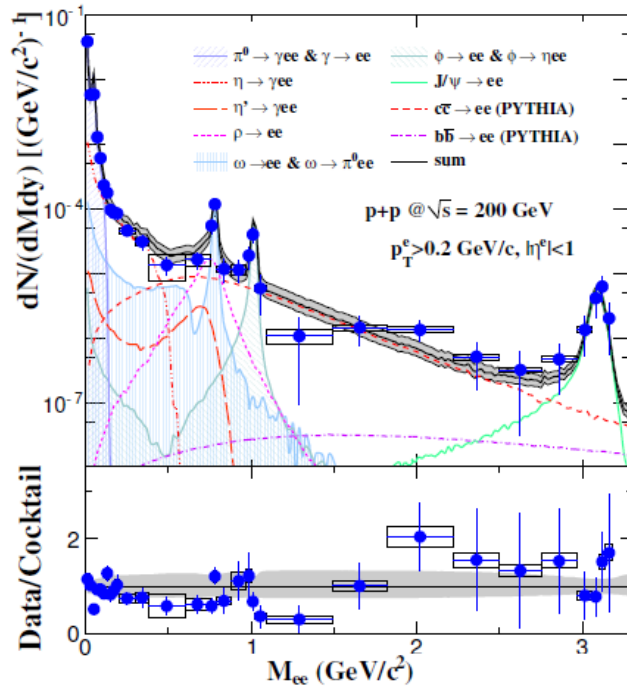
STAR Di-electron Program

$\sqrt{s} = 200 \text{ GeV}$

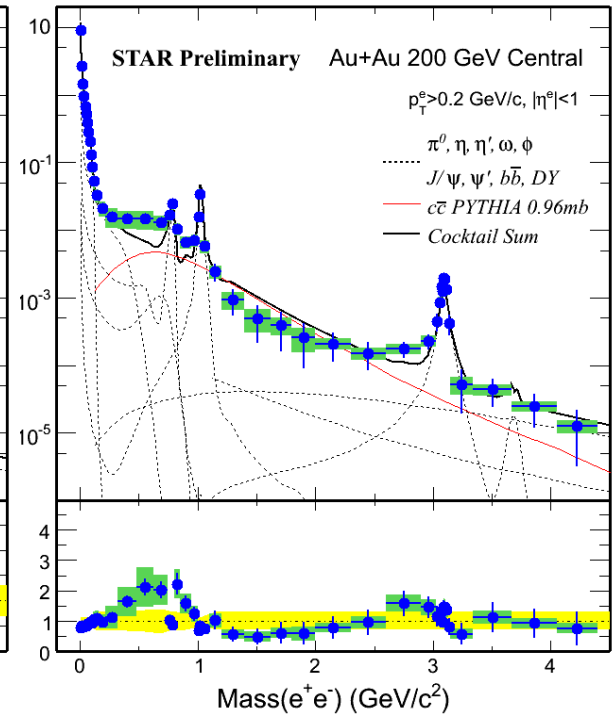
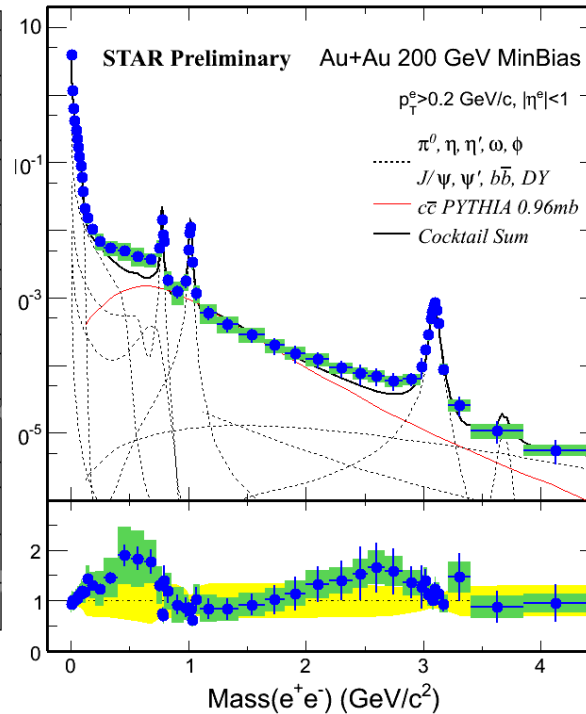
p+p

Au+Au MinBias

Au+Au Central



STAR: PRC86, 24906(12)



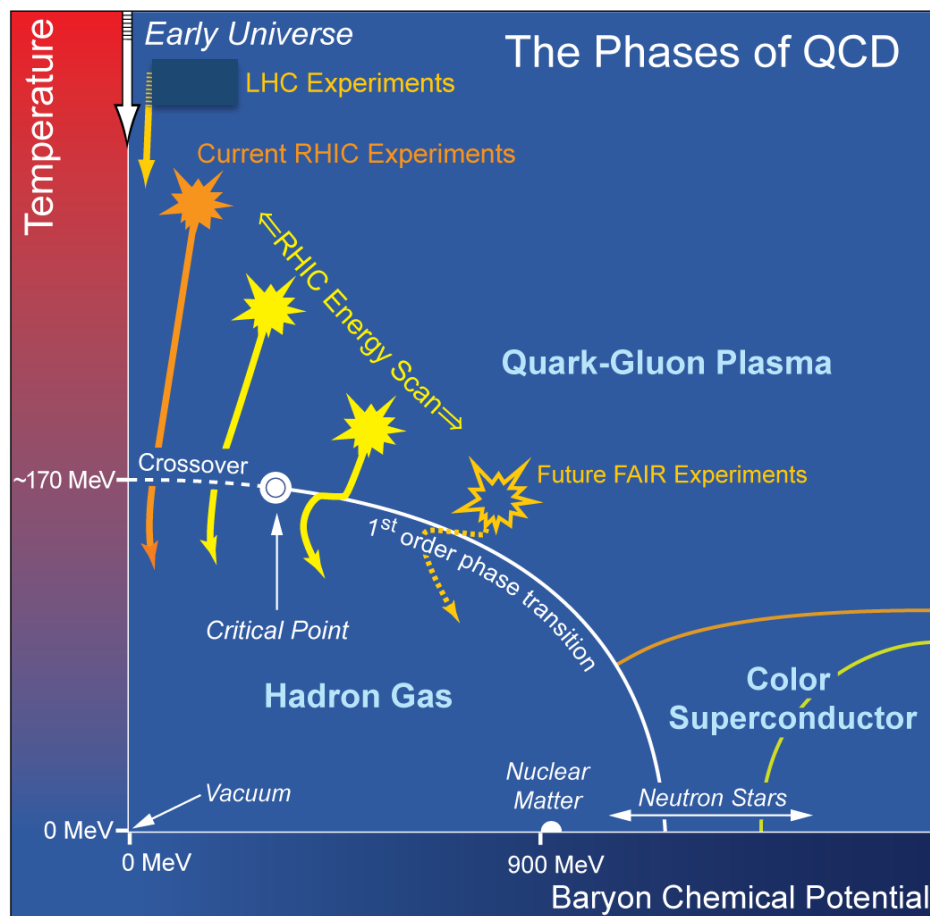
- 1) Direct radiation, penetrating-bulk probe.
- 2) Beam energy, p_T , centrality, mass dependence (8-10x more events):
 R_{AA} , v_2 , radial expansion, HBT, polarization, ...
- 3) HFT/MTD upgrades: key for the correlated charm contributions.



Beam Energy Scan at RHIC

Study QCD Phase Structure

- Signals of phase boundary
- Signals for critical point



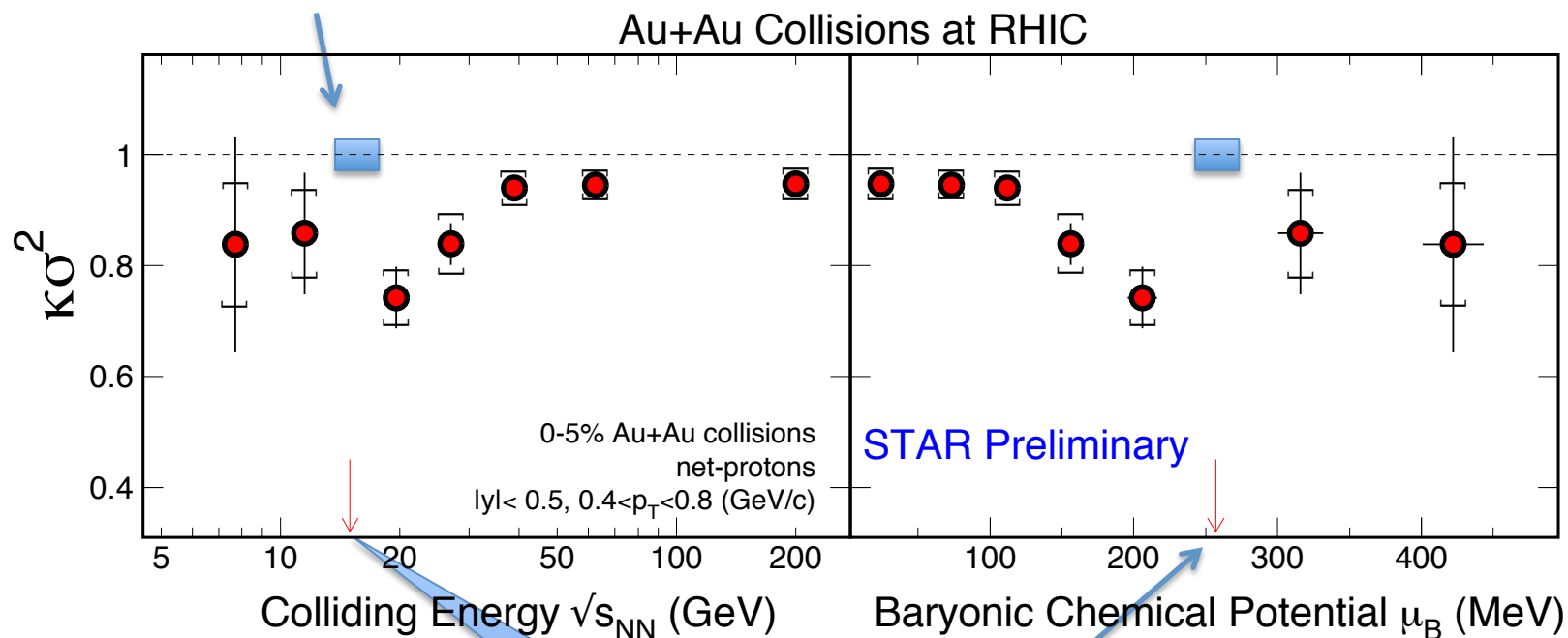
Observations:

- (1) **Azimuthally HBT**
1st order phase transition
- (2) **Directed flow v_1**
1st order phase transition
- (3) **Dynamical correlations**
partonic vs. hadronic dof
- (4) **v_2 - NCQ scaling**
partonic vs. hadronic dof
- (5) **Fluctuations**
Critical point, correl. length

Published 2 papers and 6 are coming

Net-proton Higher Moment

Expected statistical error from Run 14

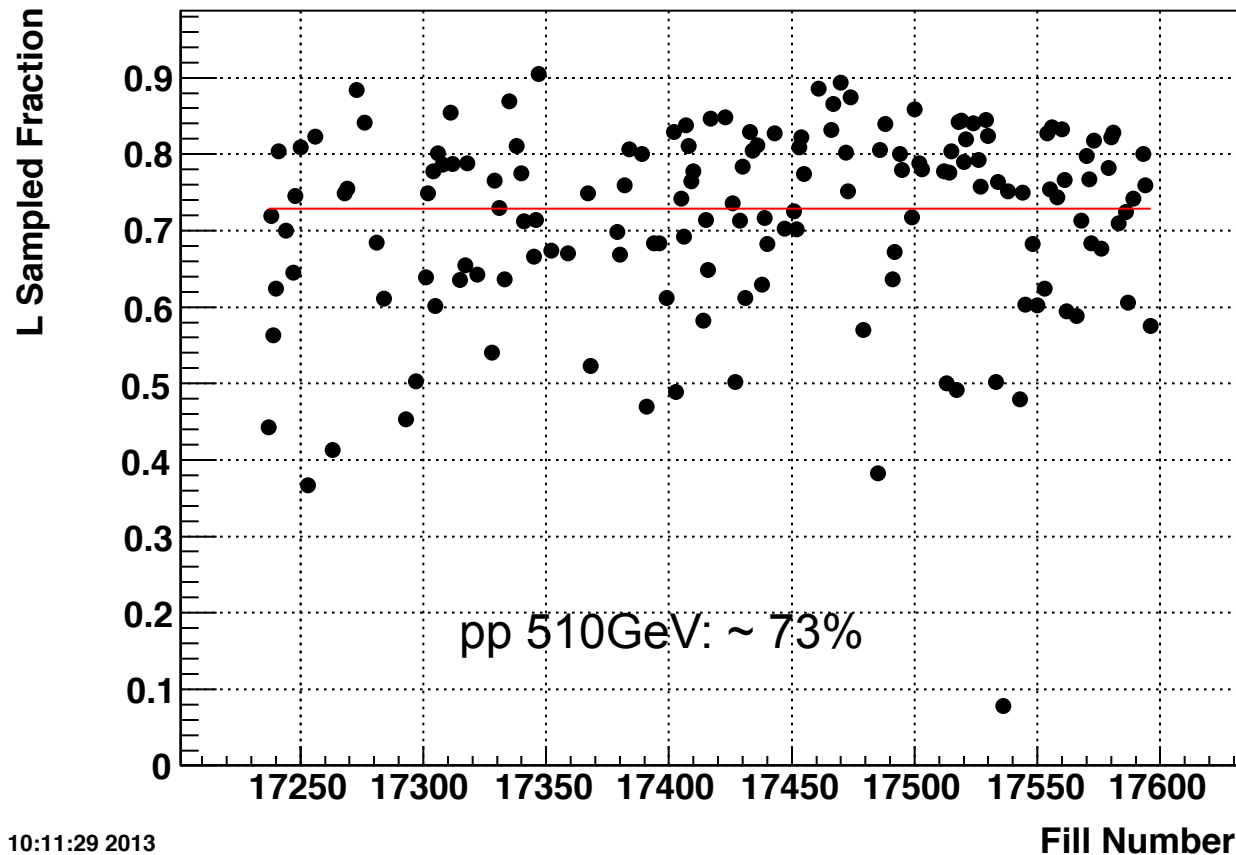


$\sqrt{s_{NN}} = 15\text{GeV}$

The timely 15GeV AuAu data will be useful

1) physics case; 2) future BES-II efforts

Data Taking Efficiency

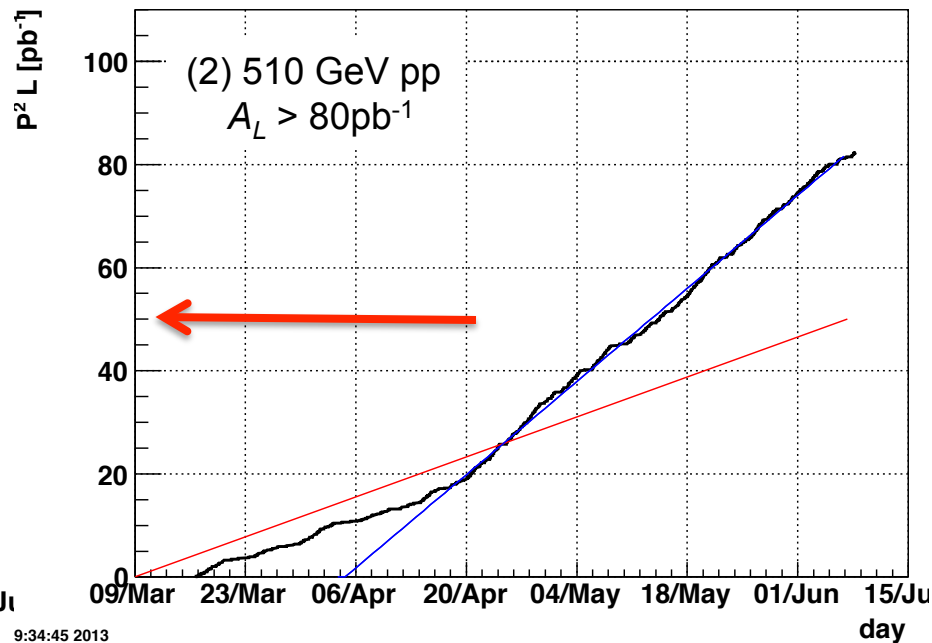
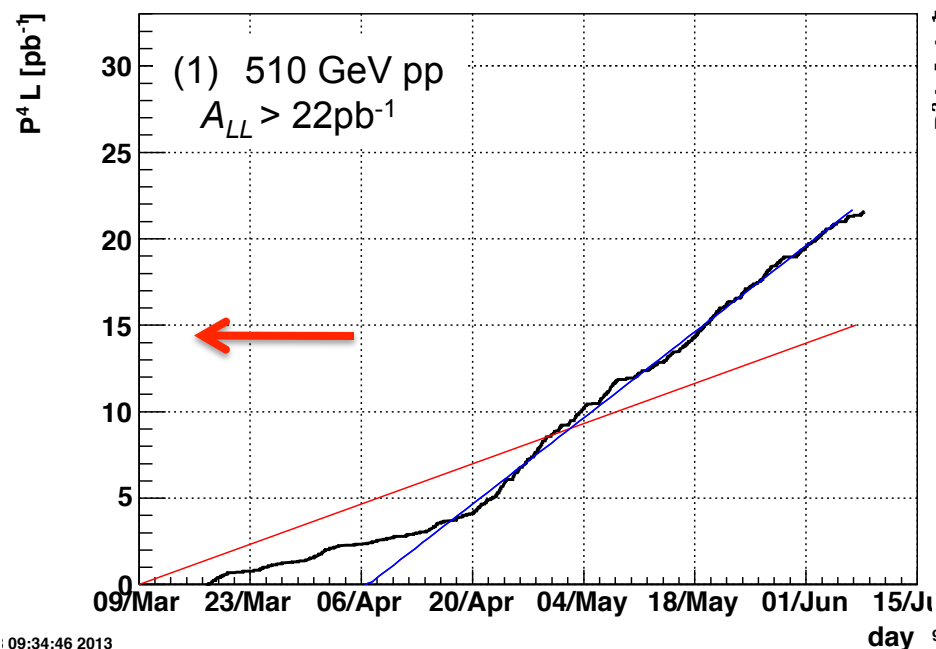


10:11:29 2013

STAR: By continuously improving DAQ/Trigger, Automated detector configurations, and Training shifters, we effectively utilize the beams provided by RHIC



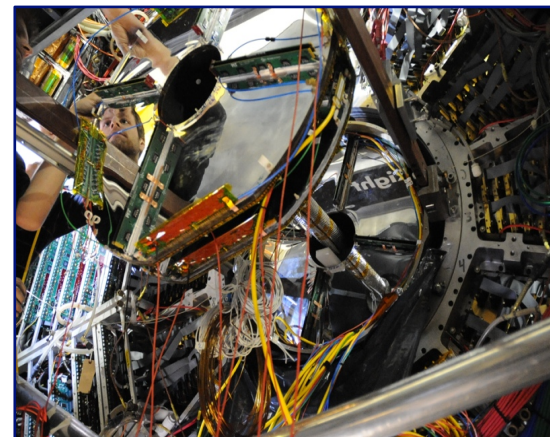
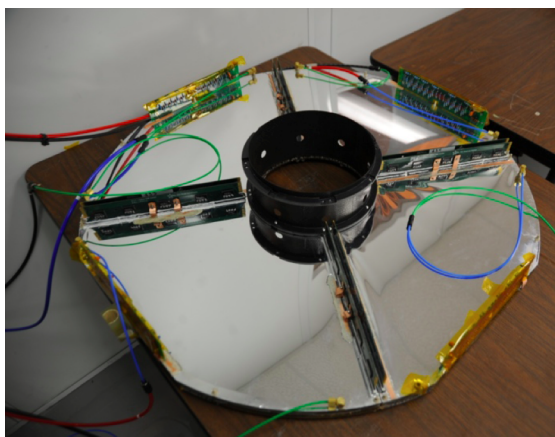
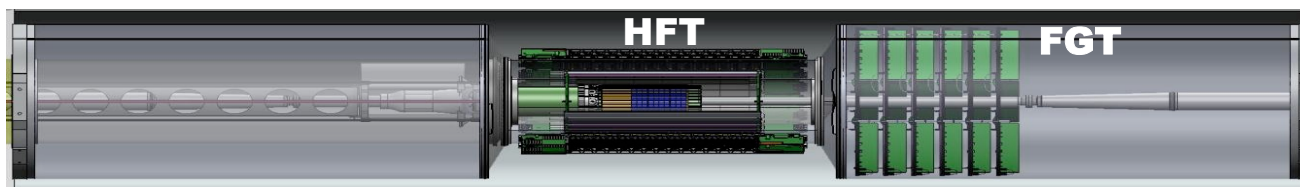
Run 13: Integrated Luminosities



	2012	2013
$P^4 L$	6 pb^{-1}	$> 22 \text{ pb}^{-1}$ (15 pb^{-1})
$P^2 L$	23 pb^{-1}	$> 80 \text{ pb}^{-1}$ (50 pb^{-1})

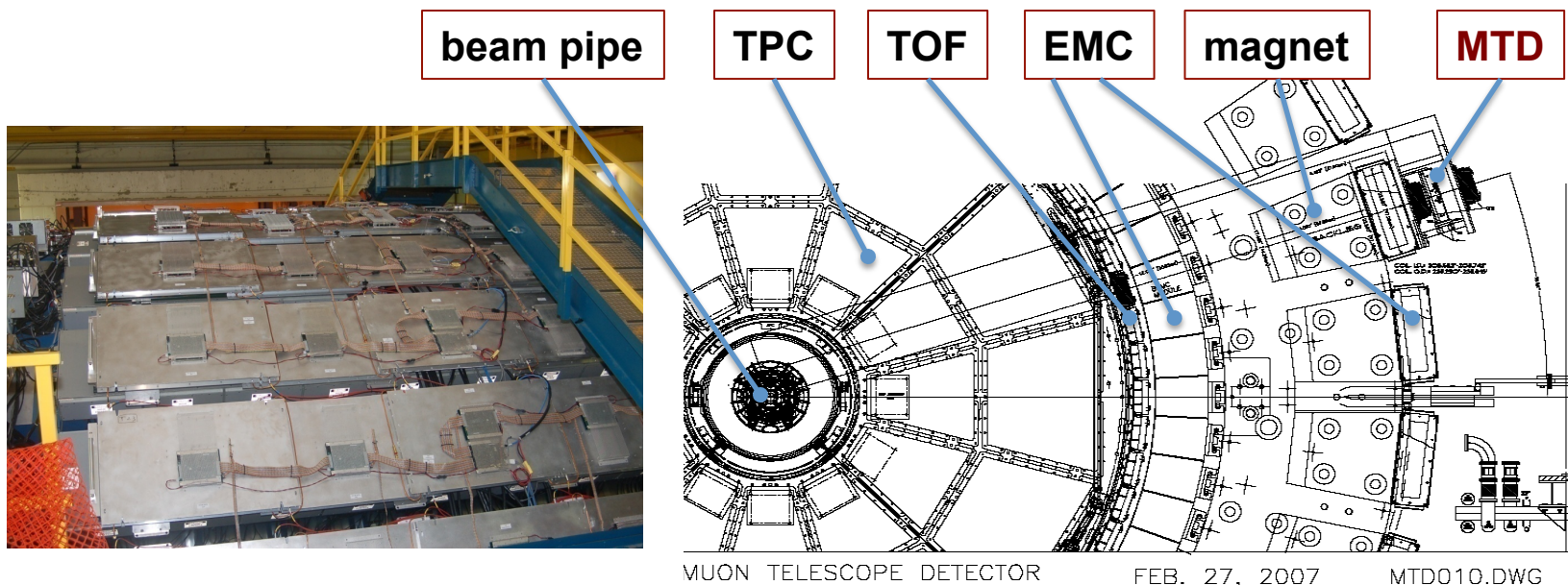
← STAR's goals in Run 13

Forward GEM Tracker (FGT)



FGT: all quadrants were installed in Run 13 and their performance is under study.

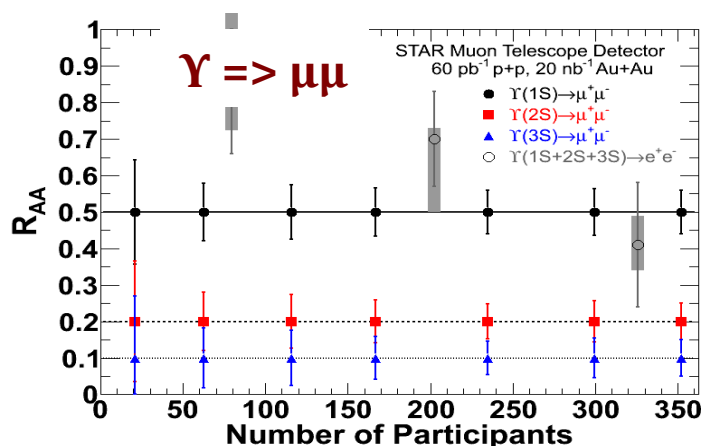
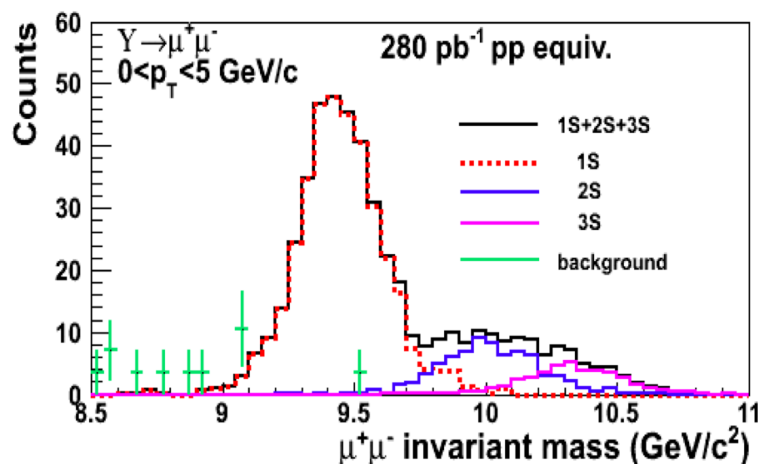
Muon Telescope Detector (MTD)



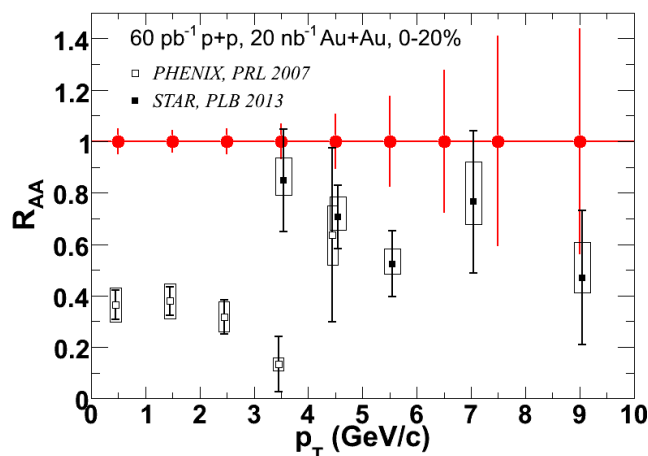
Muon Telescope Detector (MTD) at STAR:

- 1) MRPC technology; $\mu_{\epsilon} \sim 90\%$; cover $\sim 45\%$ azimuthally and $|y| < 0.5$
- 2) TPC+TOF+MTD: muon/hadron enhancement factor $\sim 10^{2-3}$
- 3) For high p_T muon trigger, heavy quarkonia, light vector mesons, $B \rightarrow J/\Psi + X$
- 4) China-India-STAR collaboration
- 5) **Run14**: Full MTD will be ready

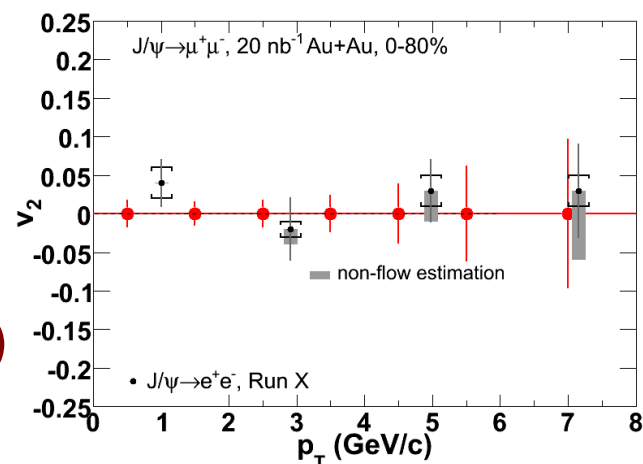
MTD: Run14 and Beyond



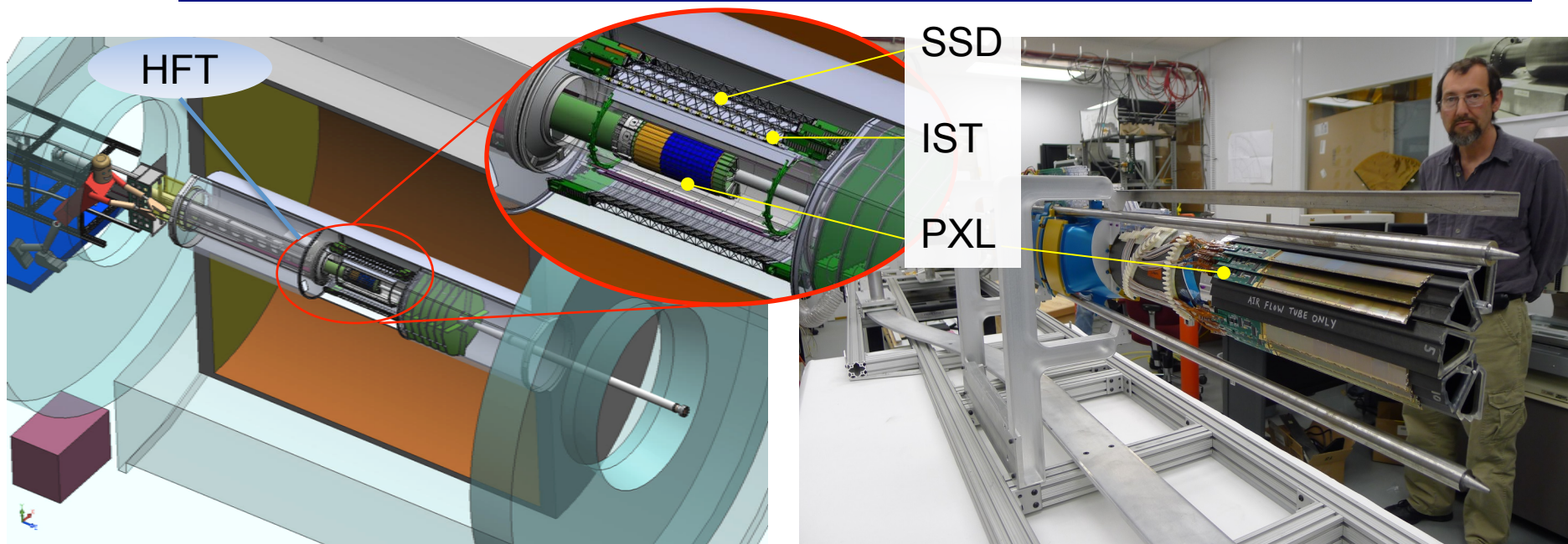
- 1) **Upsilon at RHIC:** unique, no regeneration, only initial production
- 2) **MTD at STAR:** $\Upsilon \Rightarrow \mu\mu$, no Bremsstrahlung tails, clean separation of the excited states



J/ψ
 R_{AA} and v_2
(low p_T region)

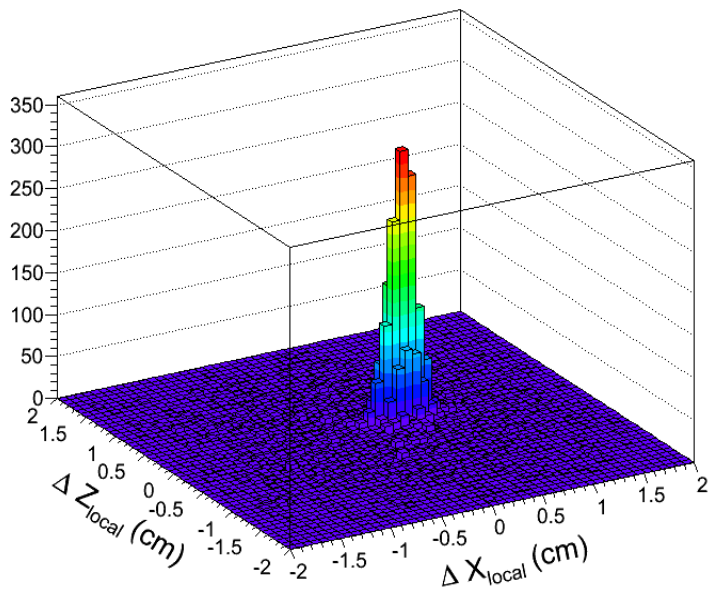
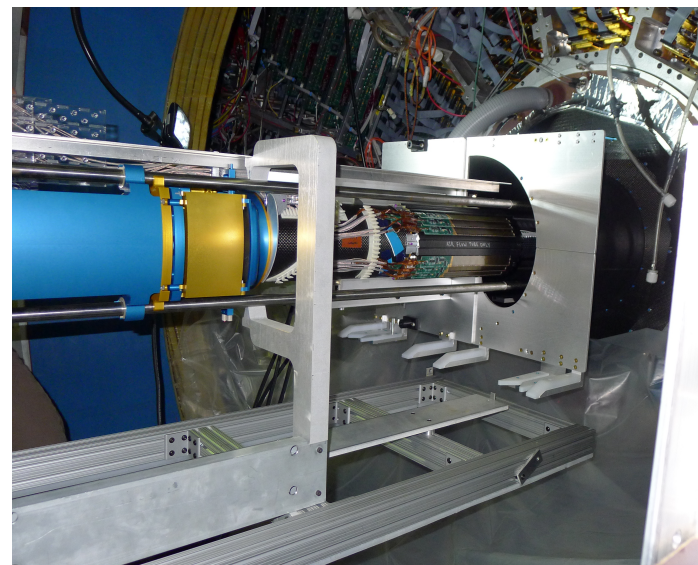
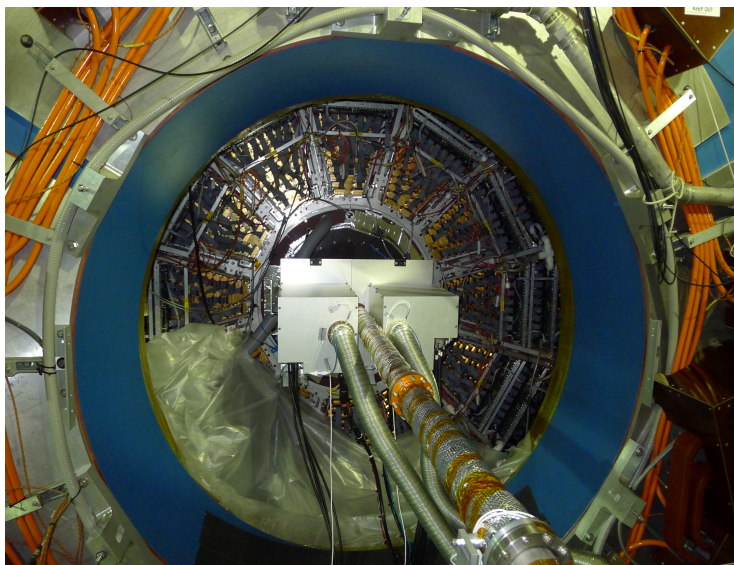


Heavy Flavor Tracker (HFT)



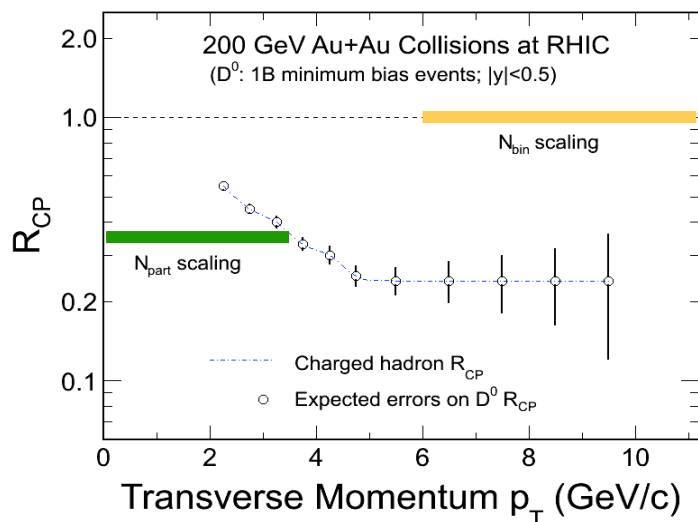
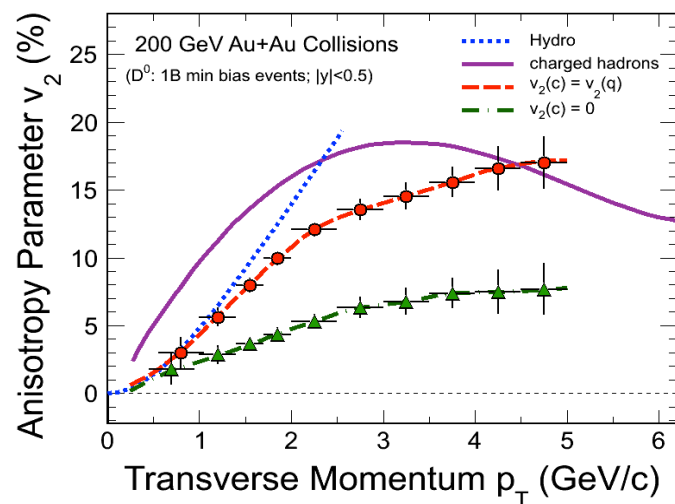
- 1) Engineering run: 3 sectors installed on May 8, 2013
- 2) The PXL system has been integrated in STAR trigger & DAQ system
- 3) First application of MAPs technology in the collider environment

STAR HFT Commissioning

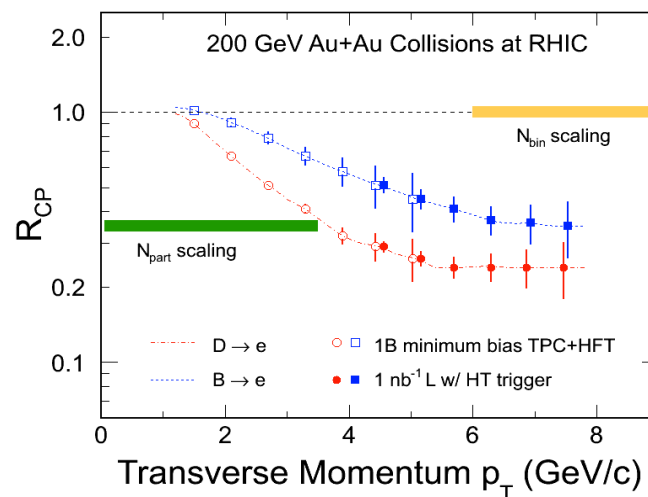
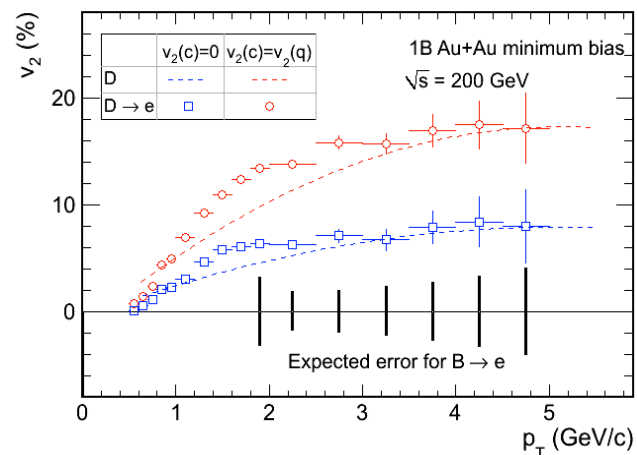


- 1) HFT designs worked
- 2) Lessons learned on mechanical, settings, latch-up and stability. Several issues have been resolved.
- 3) First tracking results: TPC-PXL correlation expected TPC resolutions ($\sim 1\text{-}2 \text{ mm}$)

D⁰ mesons

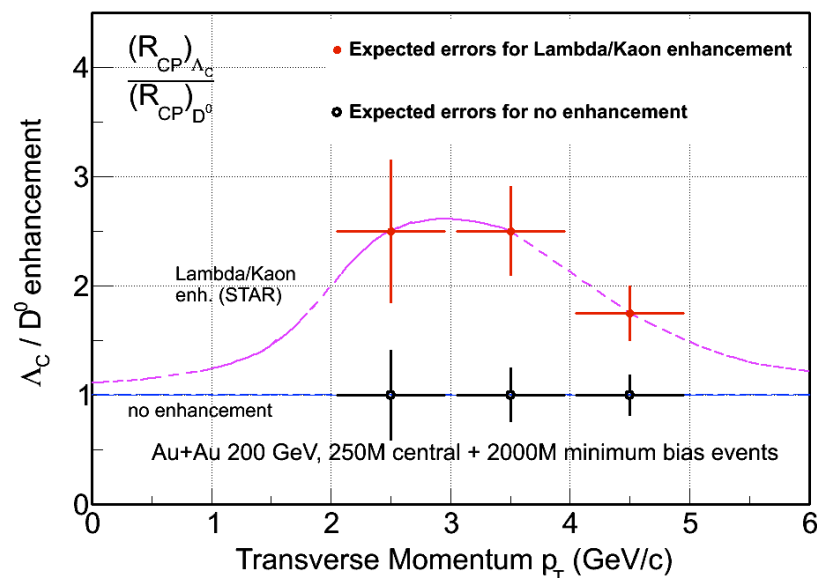


HF decayed electrons



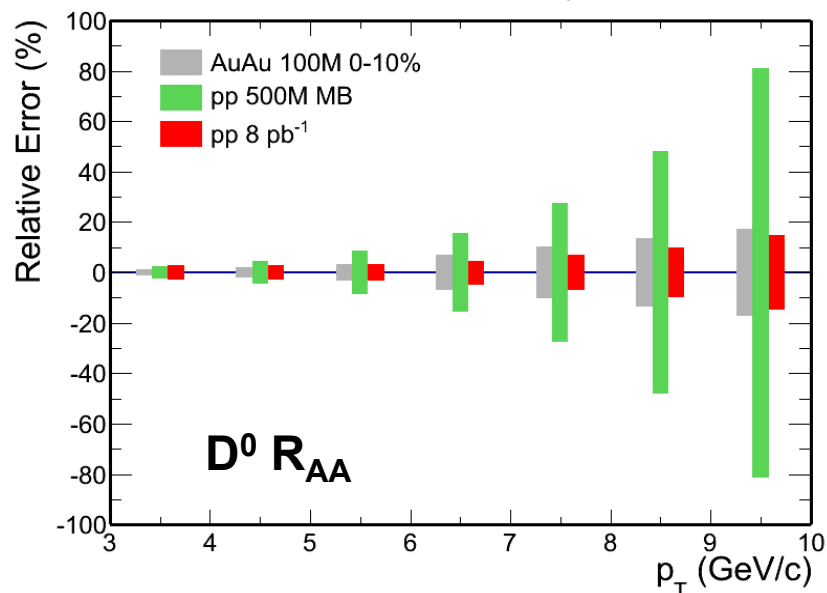


HF Physics: Beyond Run14



Λ_c : lowest charm baryon state,
 $\tau \sim 60\mu\text{m}$

- Hadro-chemistry with charm
- Meson vs. baryon effect with charm hadrons

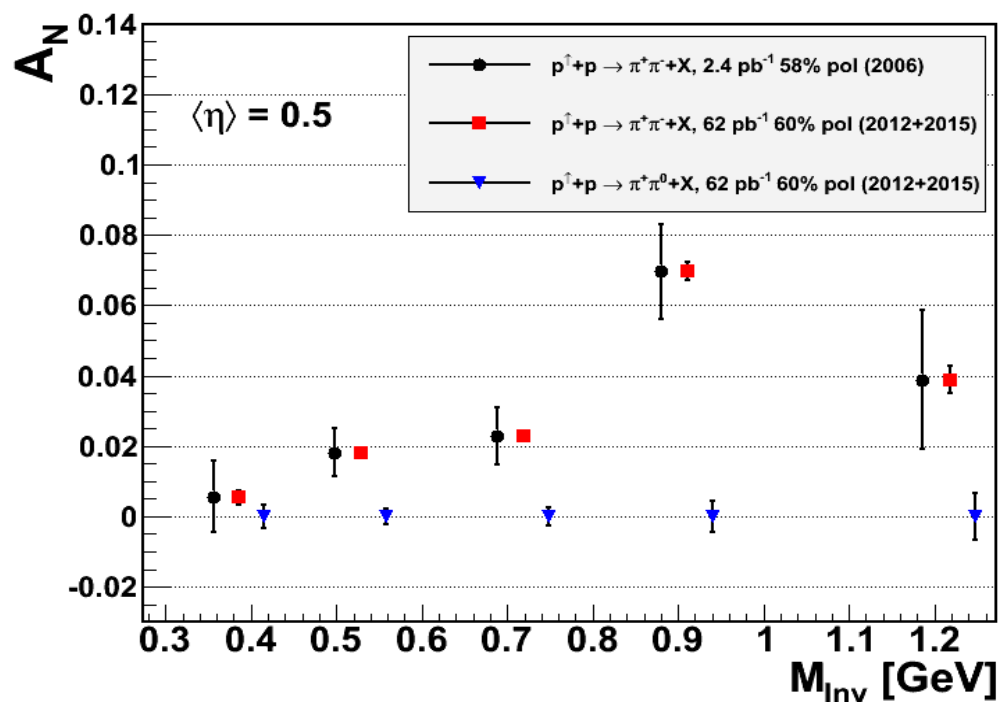


STAR multi-year physics program with the heavy flavor measurements requires high statistics data from **both *p+p* and heavy ion** collisions

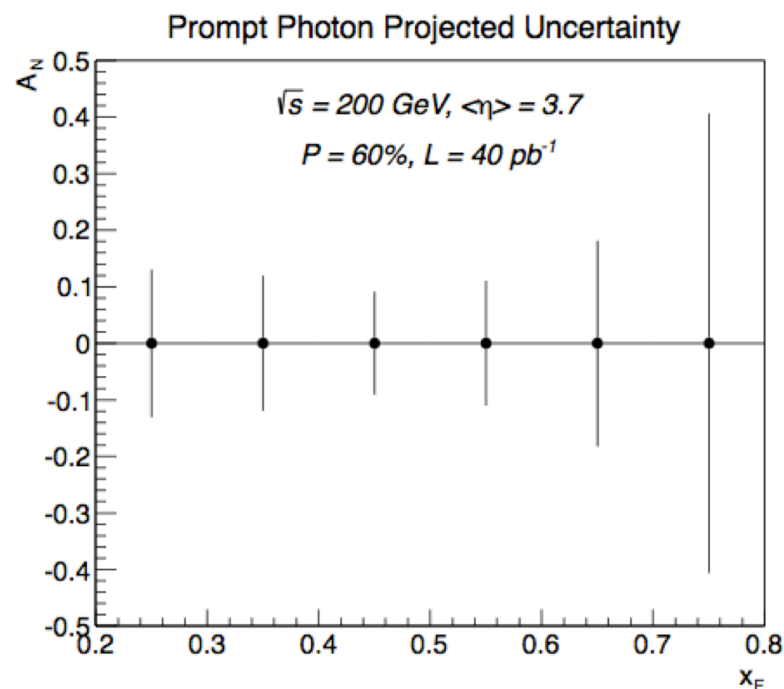


Transverse Polarized pp Collisions

Collins Mechanism



Sivers/Twist-3



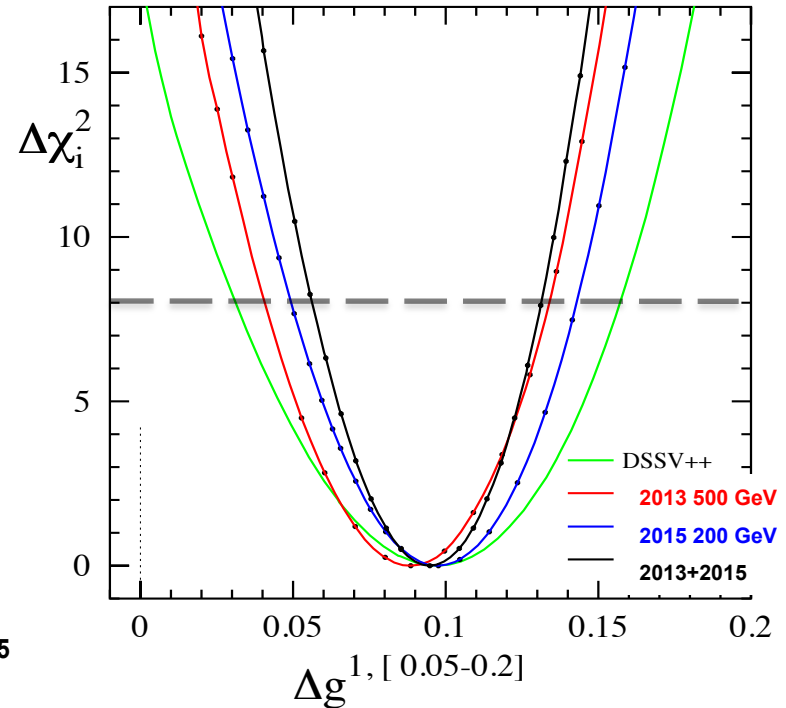
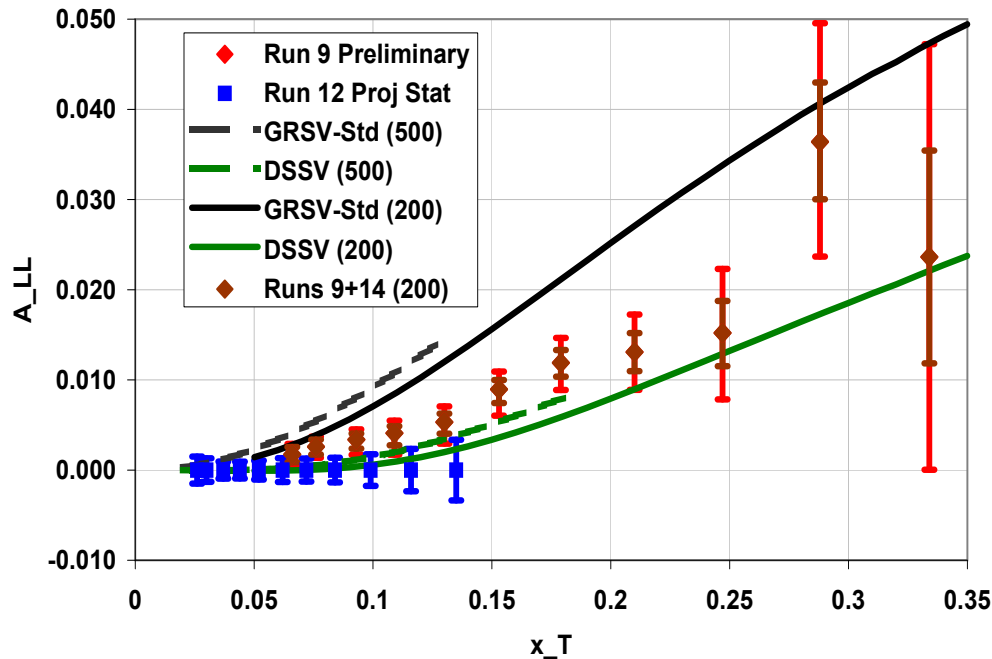
SSA measurements:

- **Mid-y:** Constrain Collins function and interference fragmentation function
- **Forward-y:** Prompt γ , require the pre-shower upgrade in front of the FMS



Longitudinally Polarized pp Collisions

Gluon contribution to the spin of the proton



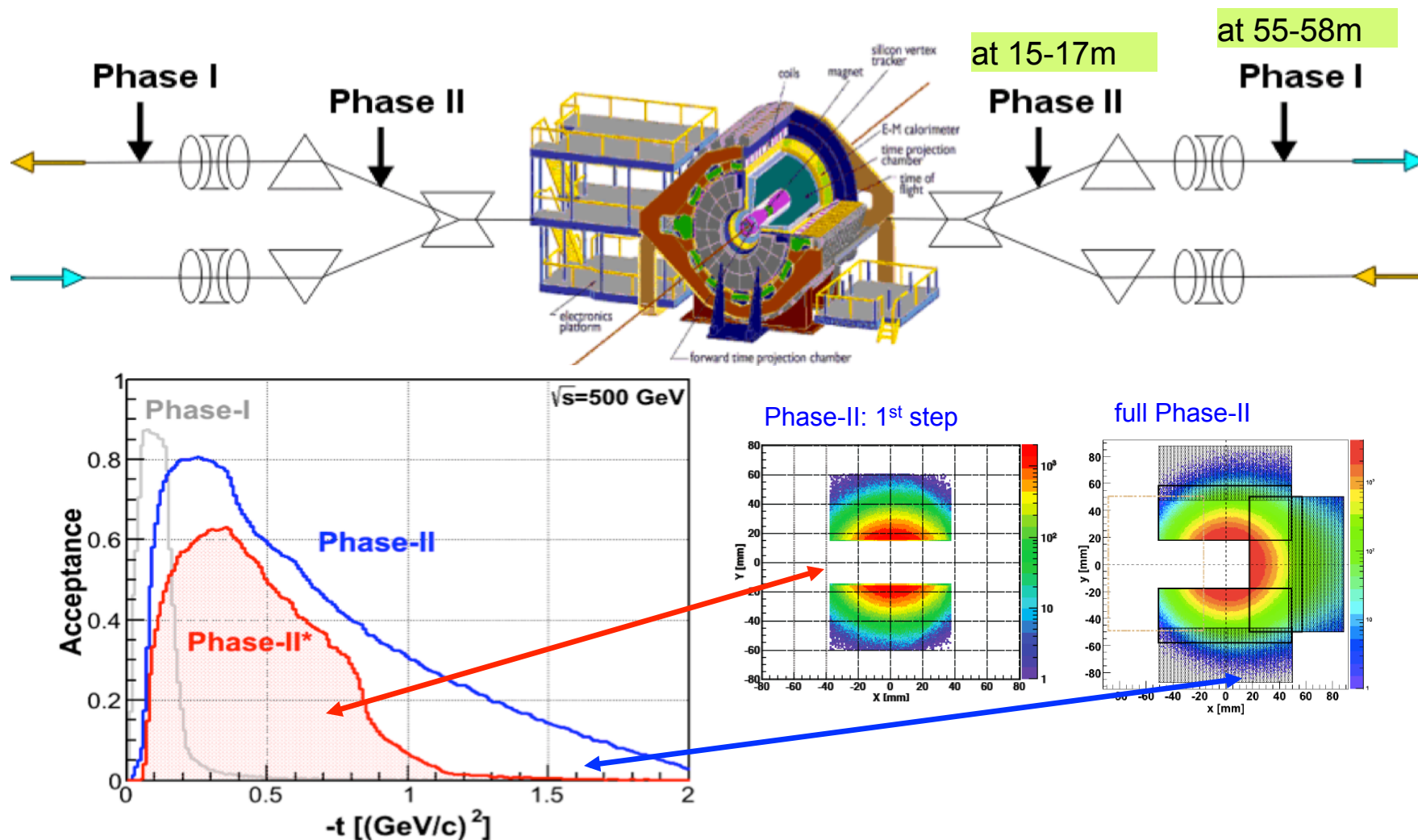
Data ≤ 2009 yield a significant non-zero $\Delta g(x)$: $\int_{0.05}^{0.2} dx \Delta g \sim 0.1 \pm_{0.07}^{0.06} @ 10 \text{ GeV}^2$

Combined data of 2012+13+15 will reduce the uncertainty by a factor of 2
=>

$$\int_{0.05}^{0.2} dx \Delta g \sim 0.1 \pm_{0.07 \rightarrow 0.035}^{0.06 \rightarrow 0.03} @ 10 \text{ GeV}^2$$



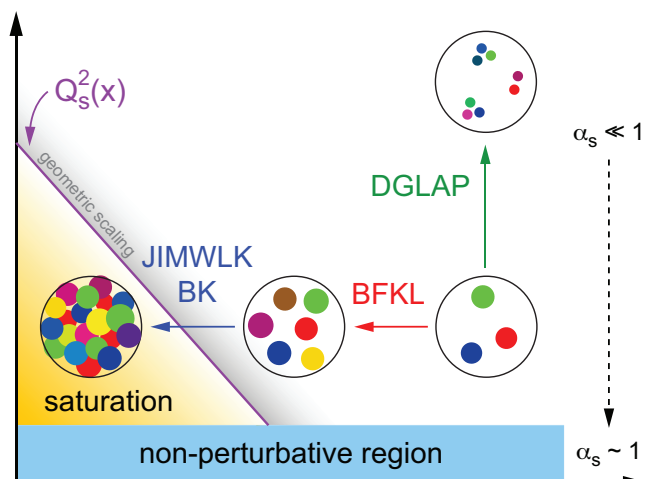
Forward Proton Tagging Upgrade



Follow PAC recommendation: data taking co-currently with other programs
Upgrade Phase-I → Phase-II, at a modest cost, for Run 15

$p^\uparrow + A$ Collisions at RHIC

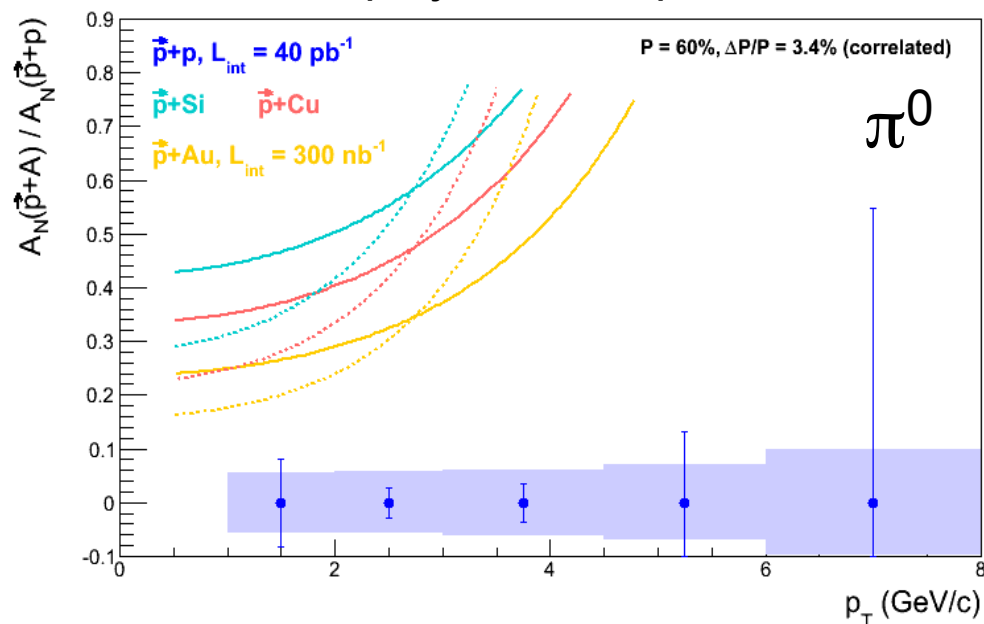
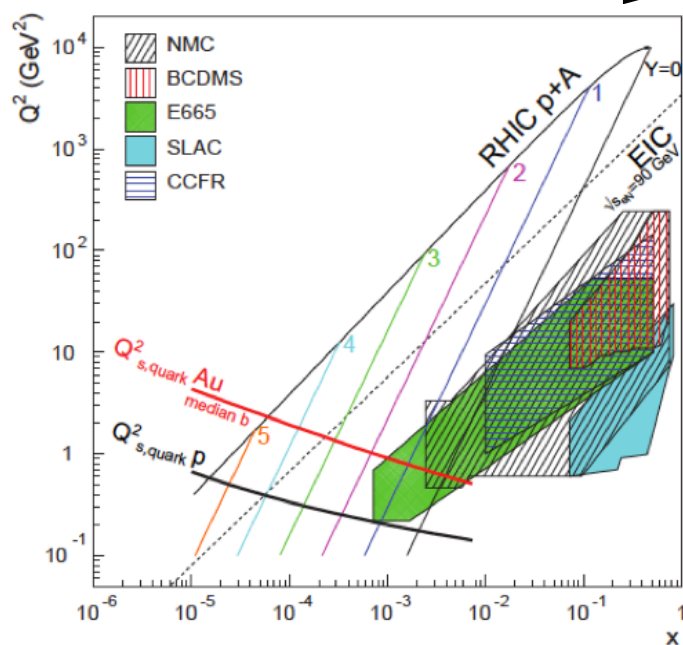
Studying Saturation Through Spin



- Very unique RHIC possibility $p^\uparrow + A$
- Synergy between CGC based theory and transverse spin physics
- Suppression of A_N in $p^\uparrow + A$ provides sensitivity to Q_s

arXiv:1106.1375 & arXiv:1201.5890

STAR: projection for $p^\uparrow A$ Run 15



Curves: Solid: $Q_s^p = 1$ GeV; dashed: $Q_s^p = 0.5$ GeV

STAR has been very effective and productive:

- 1) TOF, HLT, DAQ1k upgrades successfully completed.
FGT, MTD and **HFT** upgrades are all commissioned.
- 2) 200 GeV Au+Au collisions:
e.g. Large acceptance di-electron analysis
- 3) Beam Energy Scan Phase-I (BES-I)
 - Systematic analysis of Au+Au collisions at 7.7/11.5/27/19.6/39:
 $\sqrt{s_{NN}} \geq 39 \text{ GeV}$: **partonic** // $\sqrt{s_{NN}} \leq 11.5 \text{ GeV}$: **hadronic dominant**
- 4) Run13: High statistics, high quality data collected
- 510 GeV
- 5) Future: Build on mid-rapidity success:
Pushing **forward-upgrades for future** → **eSTAR/eRHIC**

STAR BUR for Runs 14 and 15

Run	*	Beam Energy	Time	System	Goals
14	2	$\sqrt{s_{NN}} = 15 \text{ GeV}$	3-week	Au + Au	1) 150M M.B. events for CP search 2) Fixed-target data taking
	1	$\sqrt{s_{NN}} = 200 \text{ GeV}$	14-week	Au + Au	HFT & MTD heavy flavor hadron measurements L=10 nb ⁻¹ , 1000M M.B.
15	1	$\sqrt{s} = 200 \text{ GeV}$	12-week	1) p + p 2) p _↑ + p _↑ (6-week) 3) p _→ p _→ (6-week)	1) Heavy ion reference data L= 90 pb ⁻¹ , 500M M.B. 2) A _N , L= 40 pb ⁻¹ , 60% pol. 3) Study Δg(x) L=50 pb ⁻¹ , 60% pol.
	2	$\sqrt{s_{NN}} = 200 \text{ GeV}$	5-week	p _↑ + Au	Study saturation physics, pA-ridge and heavy ion reference L=300 pb ⁻¹

- 22 cryo-week.
- 15 cryo-week run, we request the top priority item for both runs.

* Physics priorities



Runs 14 & 15 Requests

1) Run 14: 200 GeV Au+Au collisions

- Physics run with HFT+MTD (200 GeV)
heavy flavor hadrons, quarkonia, dileptons
- 15 GeV Au+Au collisions
search for QCD critical point

2) Run 15: polarized 200 GeV p+p/p+Au collisions

- p+p: Heavy ion reference data
- p+p: Spin physics
- p[↑]+Au: Saturation physics