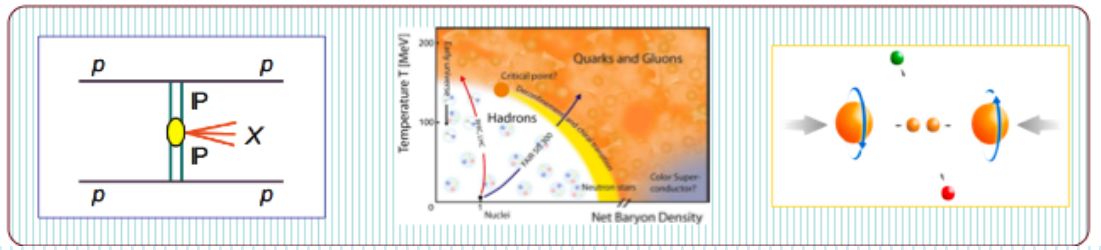
STAR Physics Program

STAR Beam Use Requests for Run14 and Run15

Nu Xu

for the STAR Collaboration



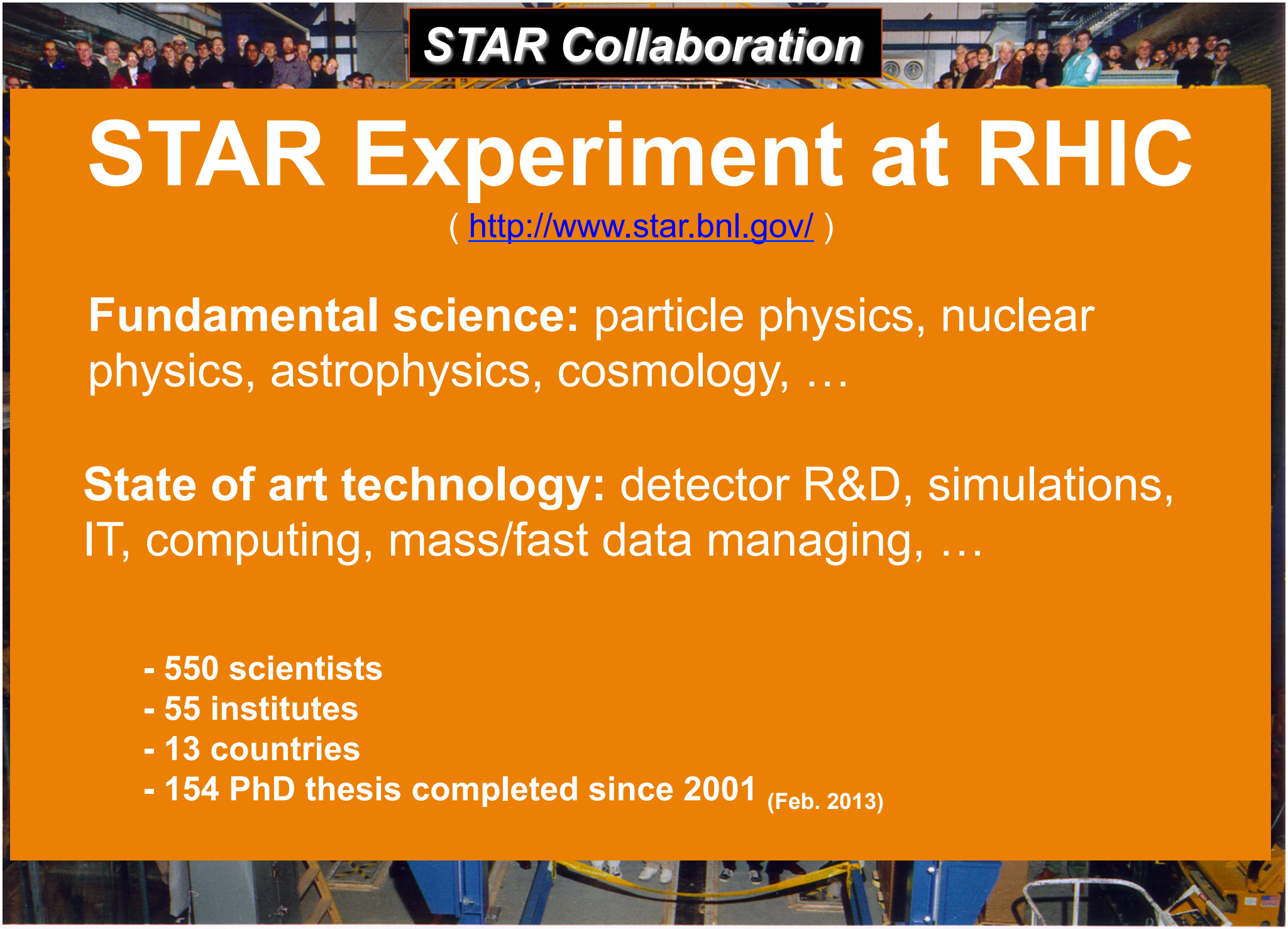
Outline

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



STAR Experiment at RHIC

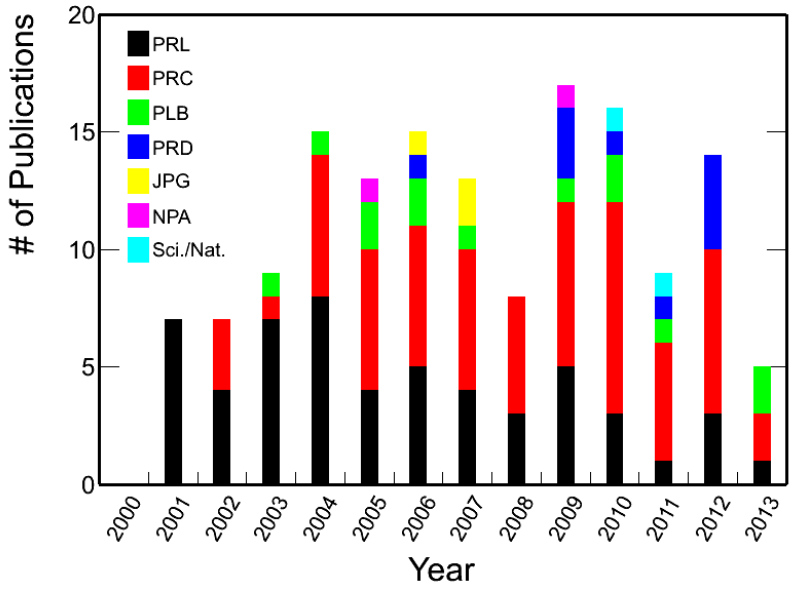
(http://www.star.bnl.gov/)

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**
- **154 PhD thesis completed since 2001** **(Feb. 2013)**

STAR Publications



Citations summary

Generated on 2013-06-04

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

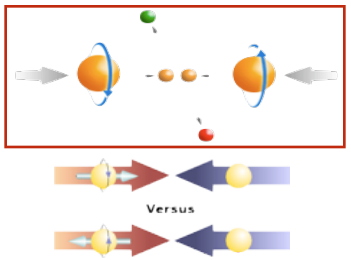
Citation summary results	Citeable papers	Published only
Total number of papers analyzed:	148	145
Total number of citations:	15,681	15,680
Average citations per paper:	106.0	108.1
Breakdown of papers by citations:		
Renowned papers (500+)	5	5
Famous papers (250-499)	10	10
Very well-known papers (100-249)	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 [?]	62	62

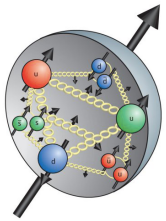
2012-2013: 12 published & 7 submitted in referee process

Citations: 15681 (June 4th, 2013)

Average citation/paper: 106

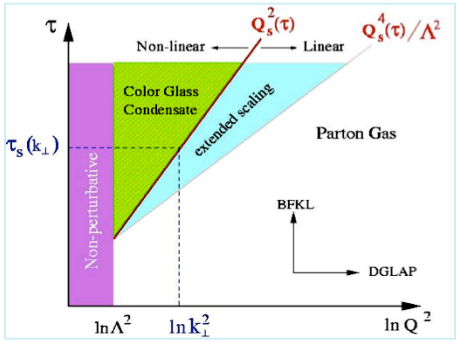
STAR Physics Focus





Polarized *p+p* Program

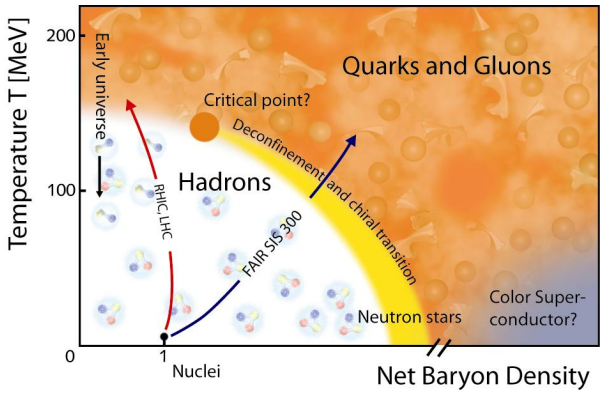
- Study ***proton intrinsic properties***



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

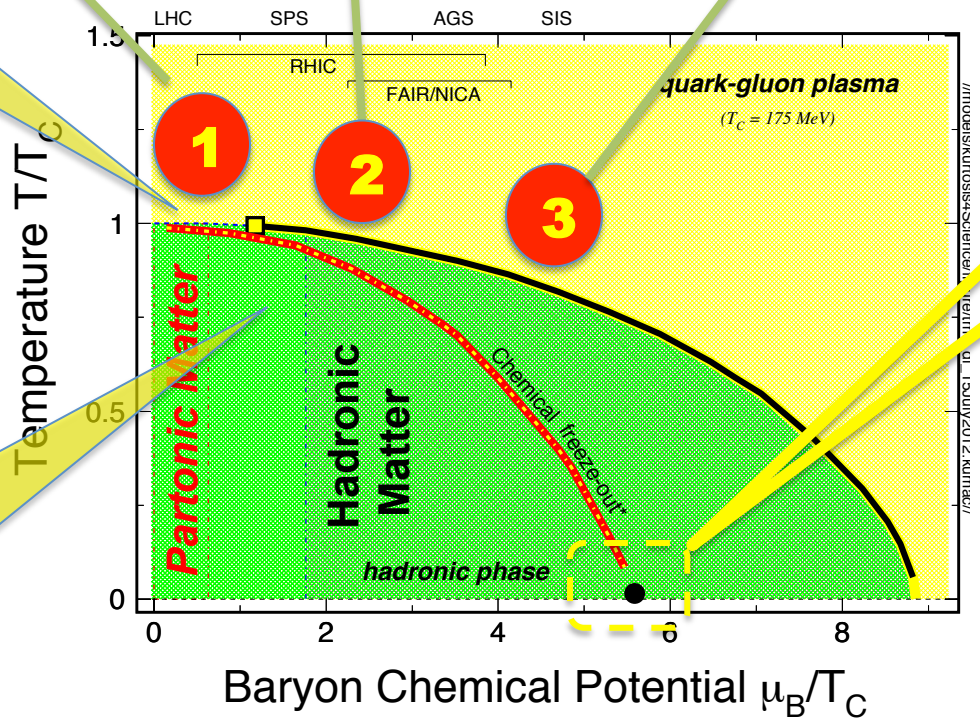
Exploring the QCD Phase Structure

1 T_{ini}, T_C **LHC, RHIC**

2 T_E **RHIC, SPS**

3 **Large μ_B NICA, FAIR**

LHC+RHIC
sQGP properties
$\sqrt{s_{NN}}$ ~ 0.1 - 5 TeV

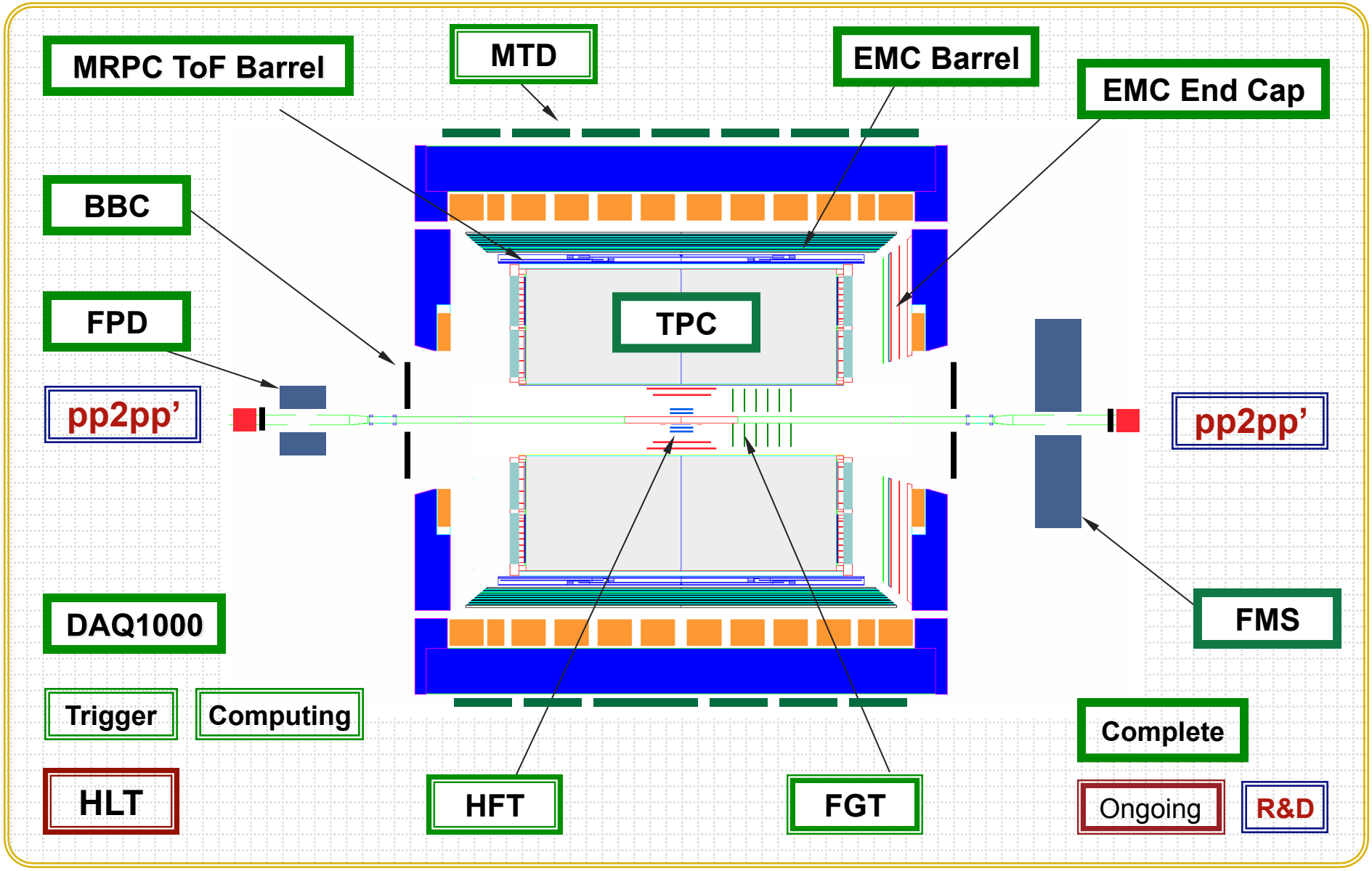


Future eRHIC
Cold nuclear matter properties
e + ion collisions

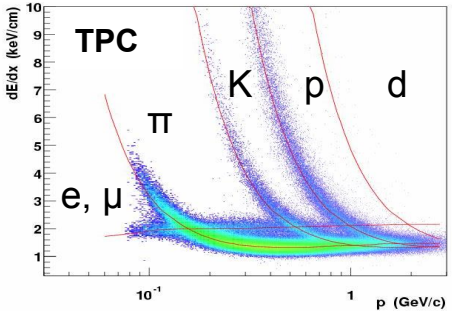
RHIC BES-II
QCD phase structure and critical point
$\sqrt{s_{NN}} \leq$ 20 GeV

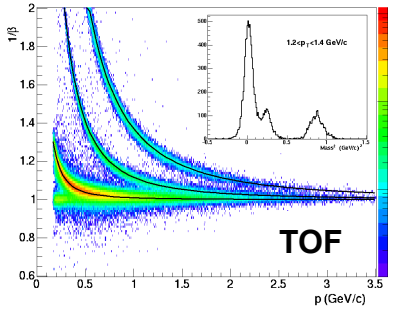
Emergent properties of QCD matter

STAR Experiment

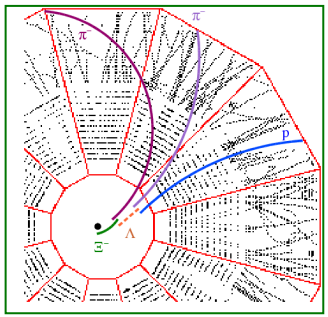


Particle Identification at STAR

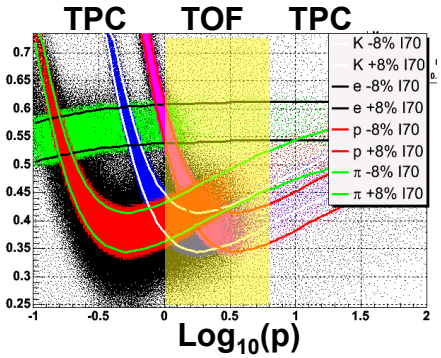


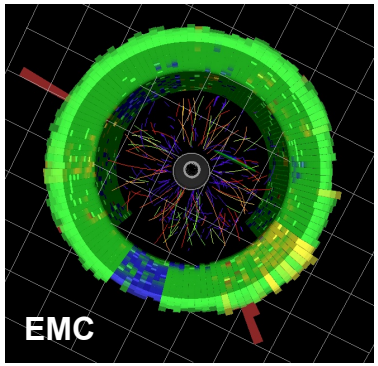


Charged hadrons

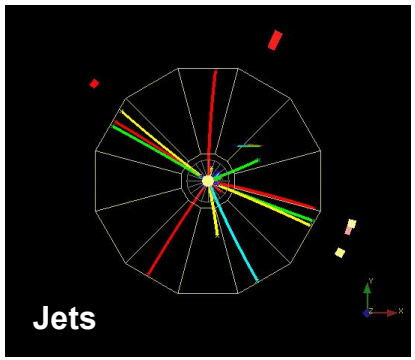


Hyperons & Hyper-nuclei

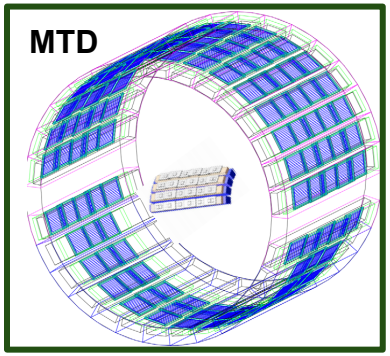




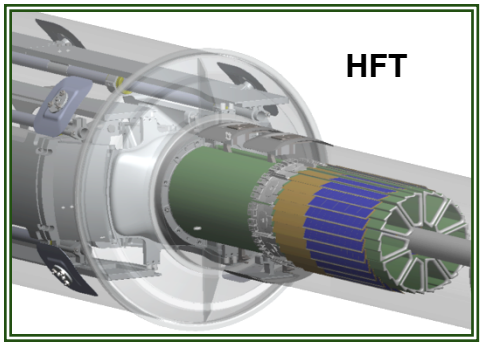
Neutral particles



Jets & Correlations



High p_T muons

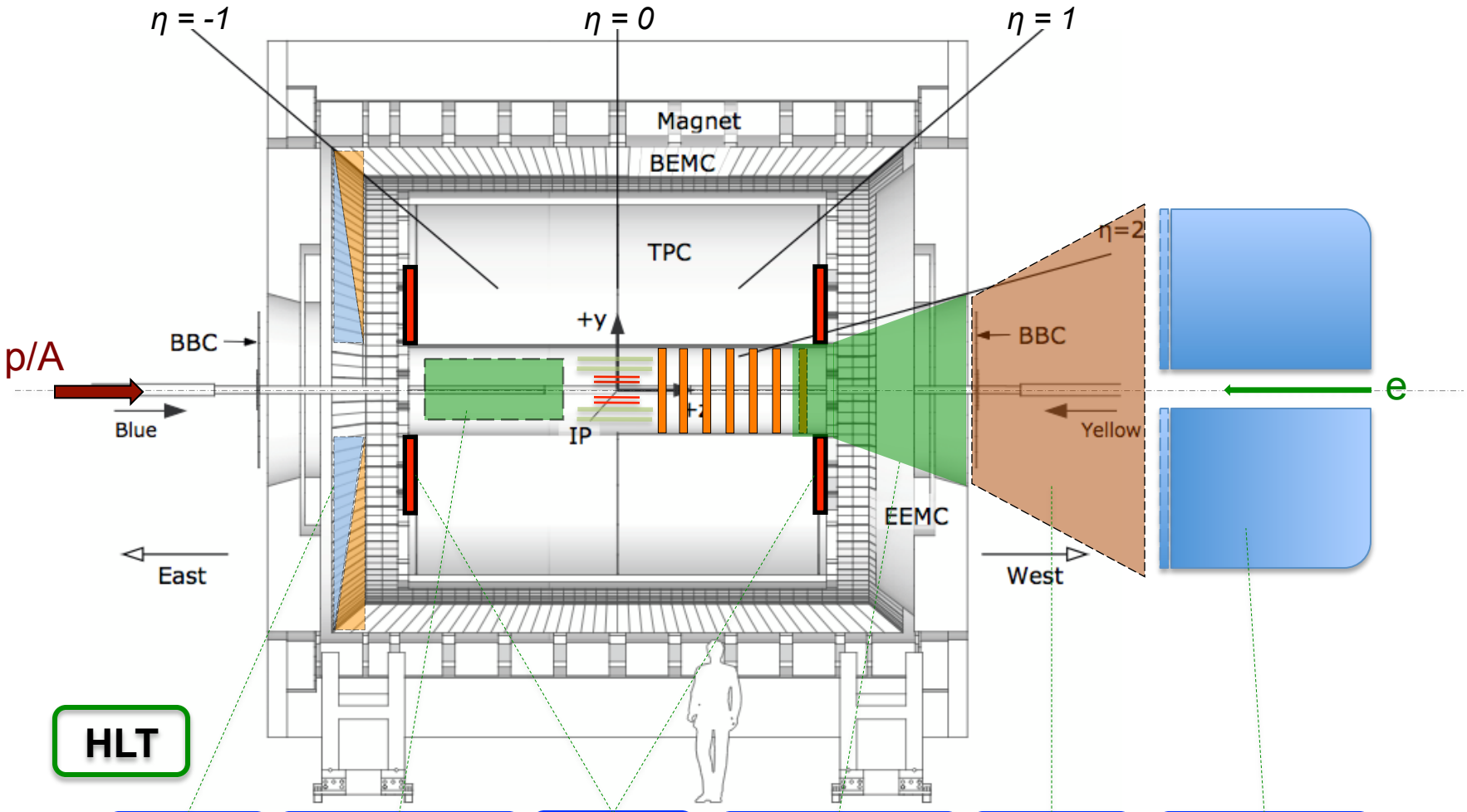


Heavy-flavor hadrons

Multiple-fold correlations for the identified particles!

STAR Forward Upgrade Plan (2018)

MTD | BEMC | TPC | HFT | TOF | EEMC | FGT



HLT

EMCal | Tracking | iTPC | Tracking | PID | EM/HCal

STAR Detector System

	Period	Detectors	Physics
	2001-2010	**TPC**	*u, d, s*
	2010	TPC + TOF	*u, d, s + dilepton*
	2013	TPC + TOF + MTD	*u, d, s, c, b + dilepton*
	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, and *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 the BNL management

STAR BUR for Runs 14 and 15

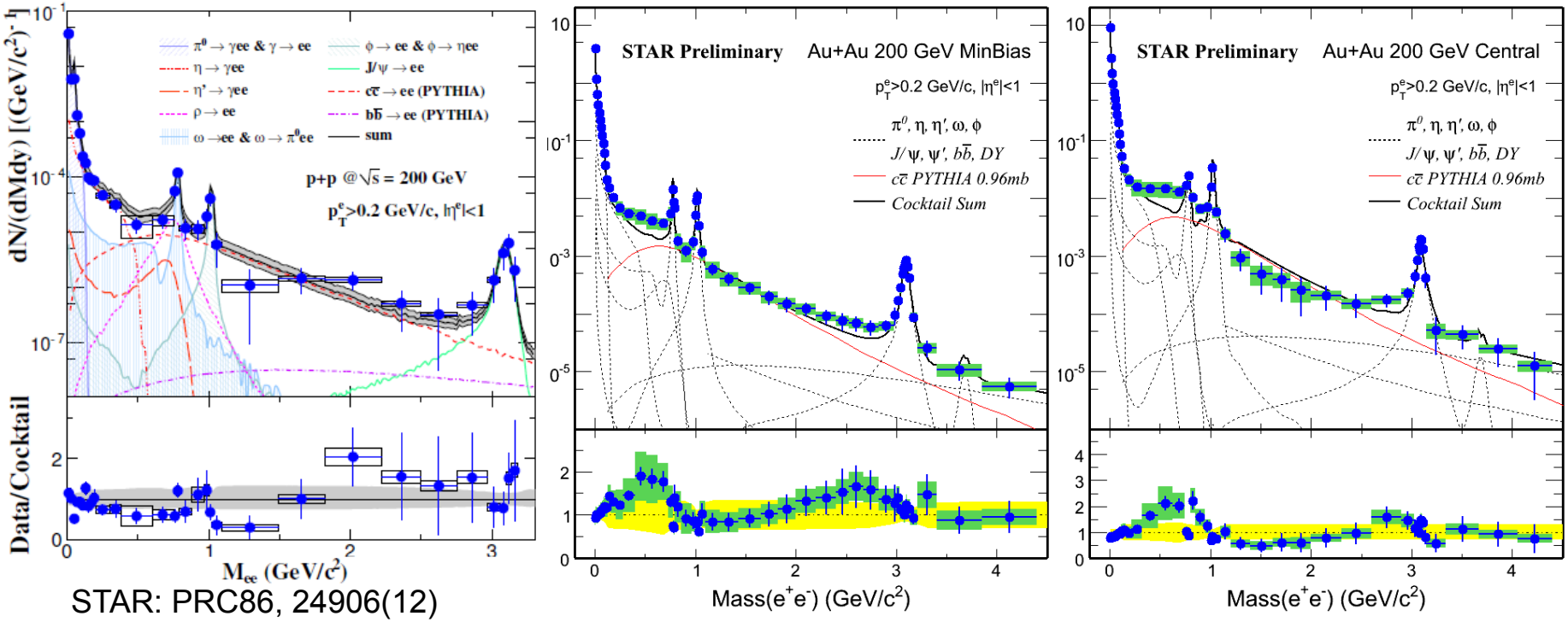
Run	*	Beam Energy	Time	System	Goals
14	2	$\sqrt{s_{NN}}$ = 15 GeV	3-week	Au + Au	1) 150M M.B. events for CP search 2) Fixed-target data taking[3]
	1	$\sqrt{s_{NN}}$ = 200 GeV	14-week	Au + Au	HFT & MTD heavy flavor hadron measurements L=10 nb^{-1}, 1000M M.B.
15	1	$\sqrt{s}$ = 200 GeV	12-week	1) p + p 2) $p_{\uparrow} + p_{\uparrow}$ (6-week) 3) $p_{\rightarrow}$ $p_{\rightarrow}$ (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 $\Delta g(x)$ L=50 pb^{-1}, 60% pol.
	2	$\sqrt{s_{NN}}$= 200 GeV	5-week	$p_{\uparrow}$ + 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 GeV **p+p** **Au+Au MinBias** **Au+Au Central**



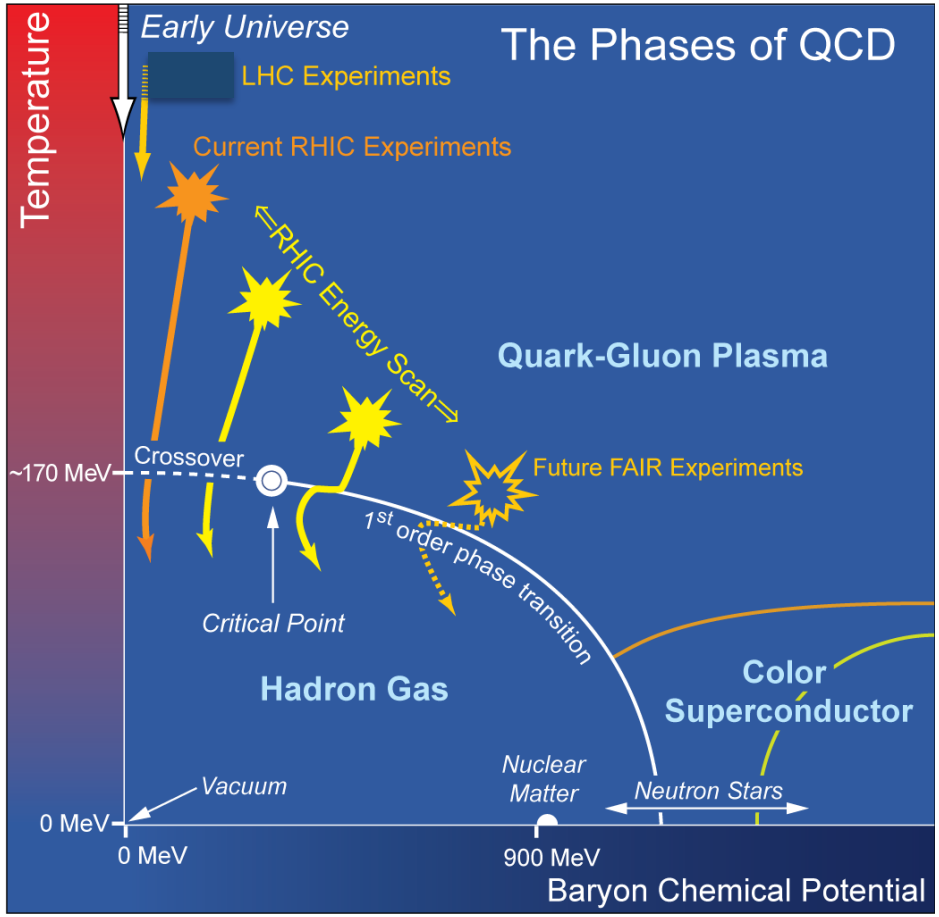
STAR: PRC86, 24906(12)

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

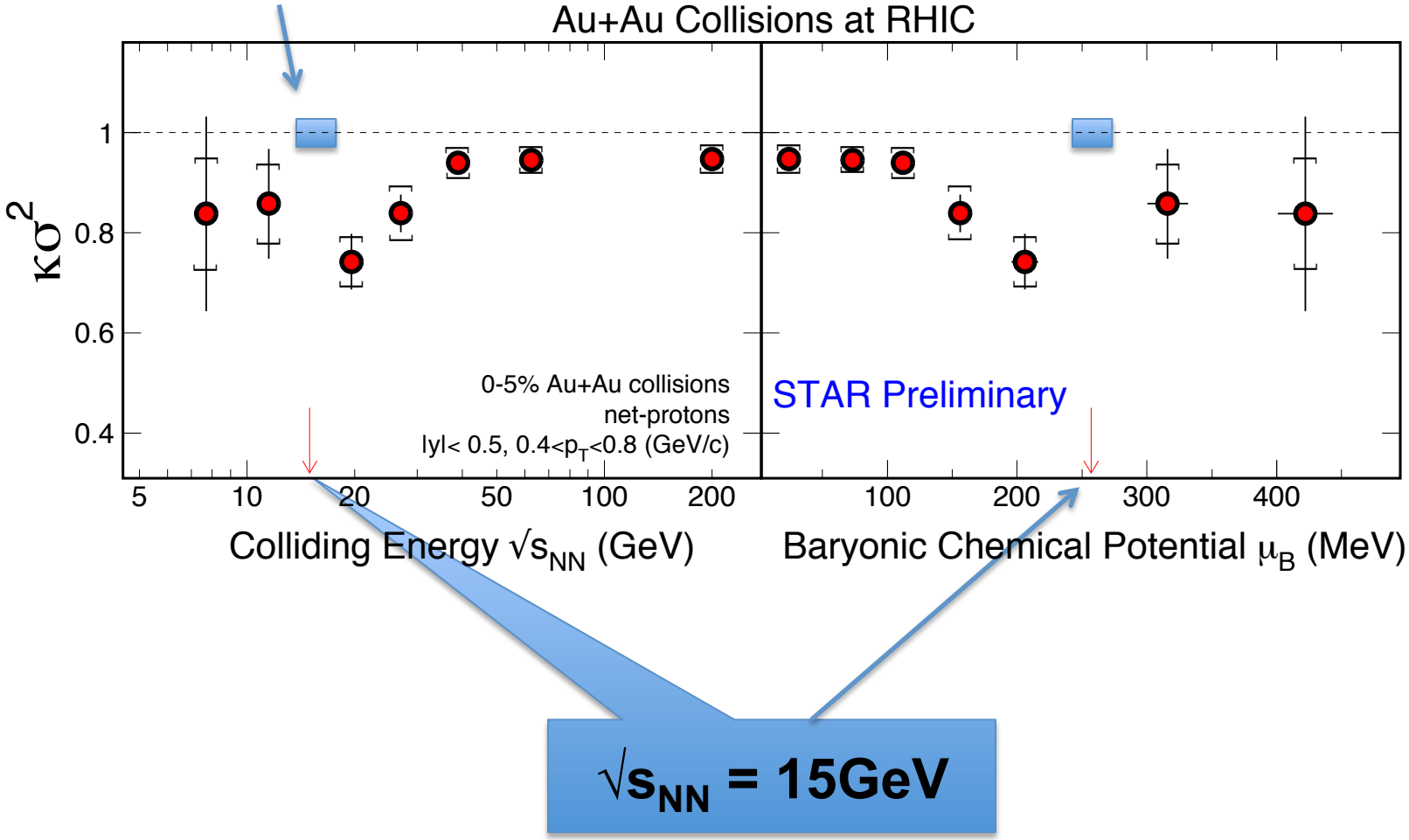
(4) v_2 - NCQ scaling
partonic vs. hadronic dof

(5) Fluctuations
Critical point, correl. length

Published 2 papers and 6 are coming

Net-proton Higher Moment

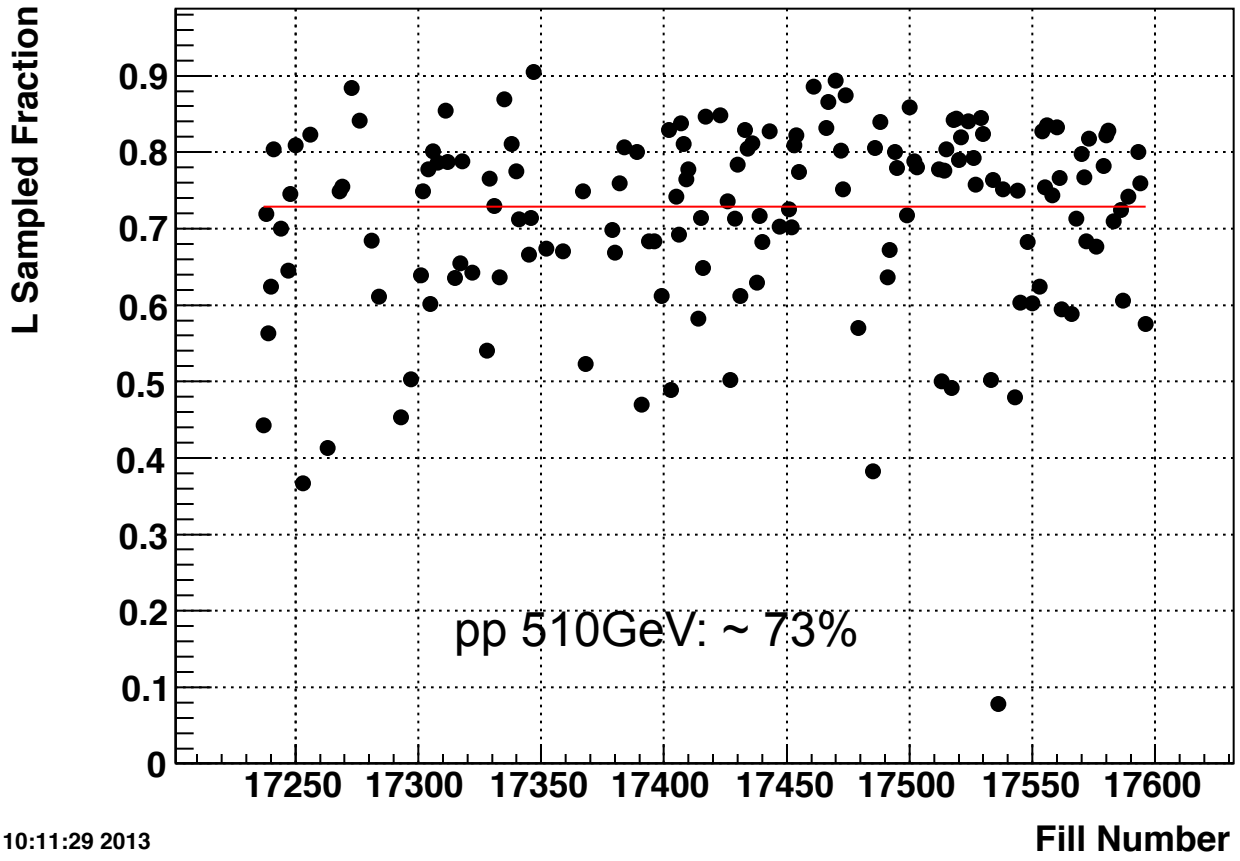
Expected statistical error from Run 14



The timely 15GeV AuAu data will be useful

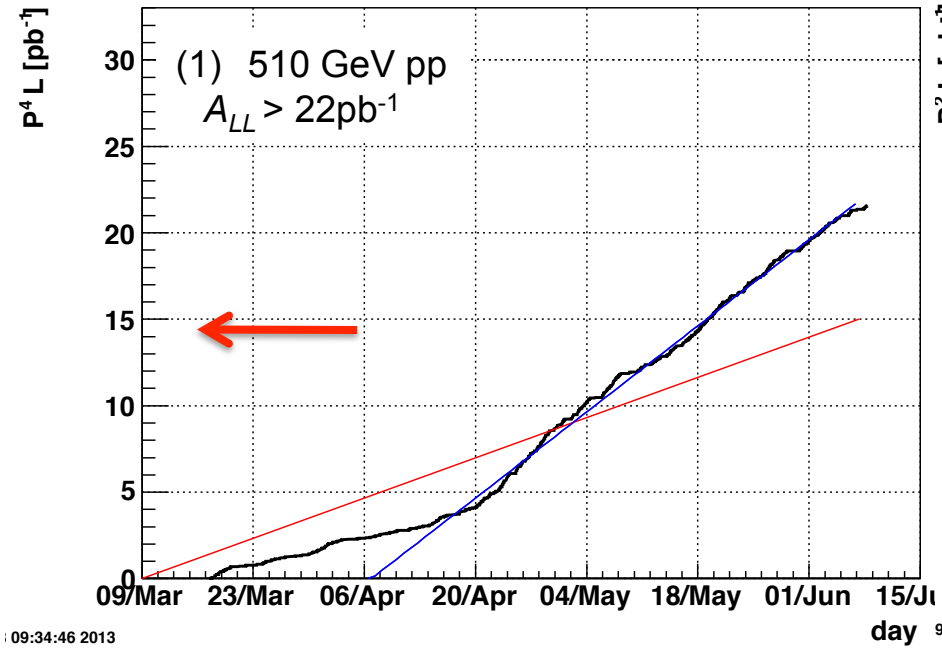
1) physics case; 2) future BES-II efforts

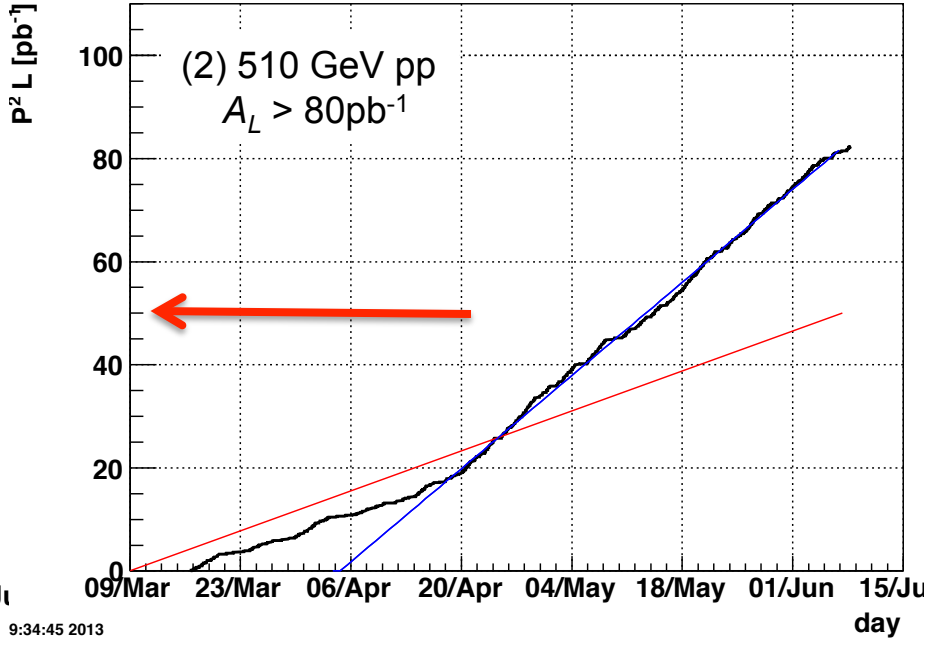
Data Taking Efficiency



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

Run 13: Integrated Luminosities

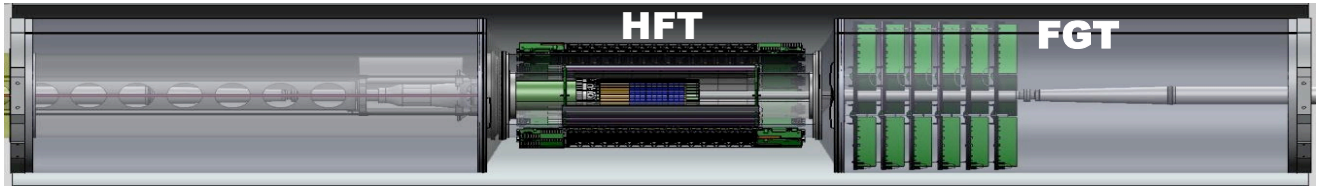


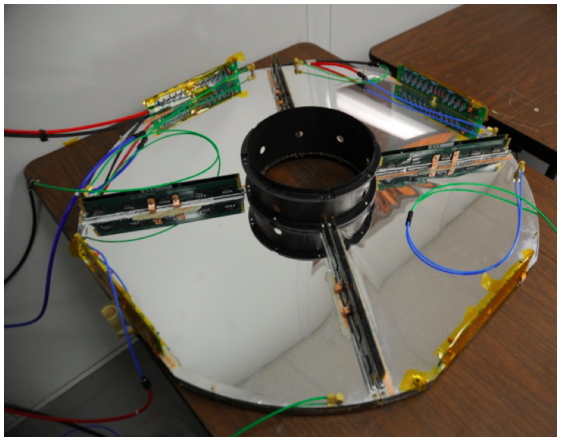


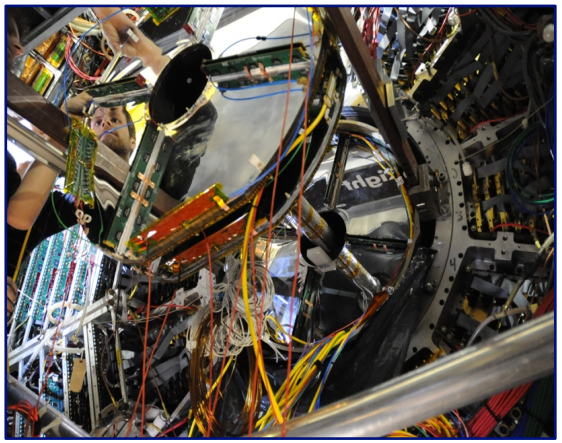
	2012	2013
P^{4}L	6 pb^{-1}	> 22 pb^{-1} (15 pb^{-1})
P^{2}L	23 pb^{-1}	> 80 pb^{-1} (50 pb^{-1})

← STAR's goals in Run 13

Forward GEM Tracker (FGT)

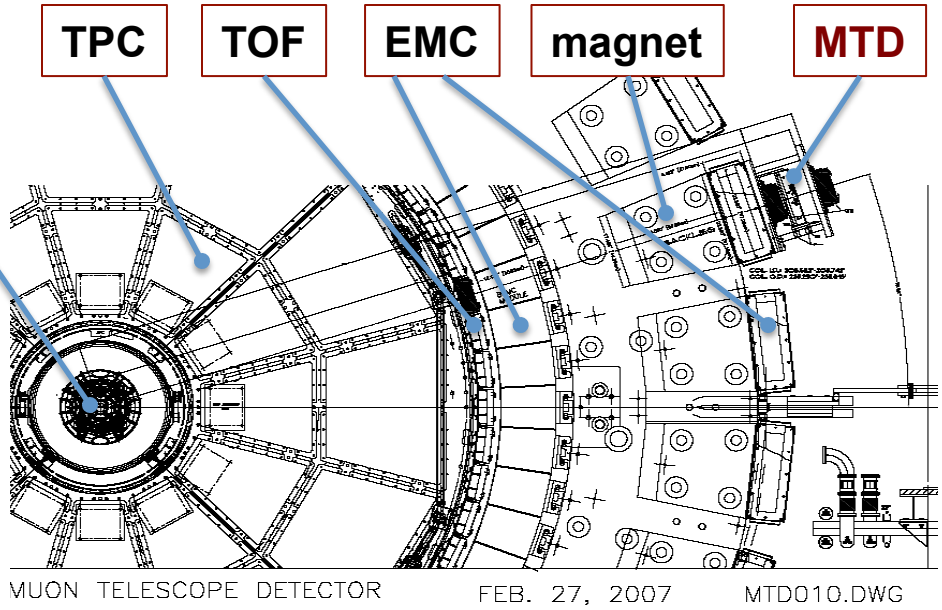






FGT: all quadrants were installed in Run 13 and their performance is under study.

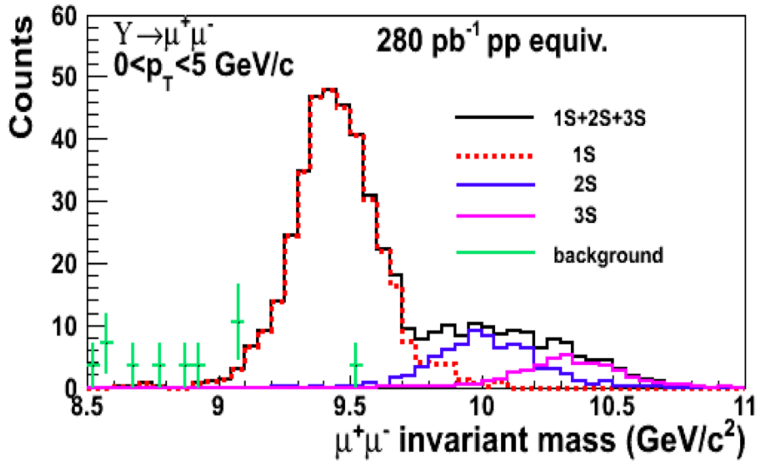
Muon Telescope Detector (MTD)

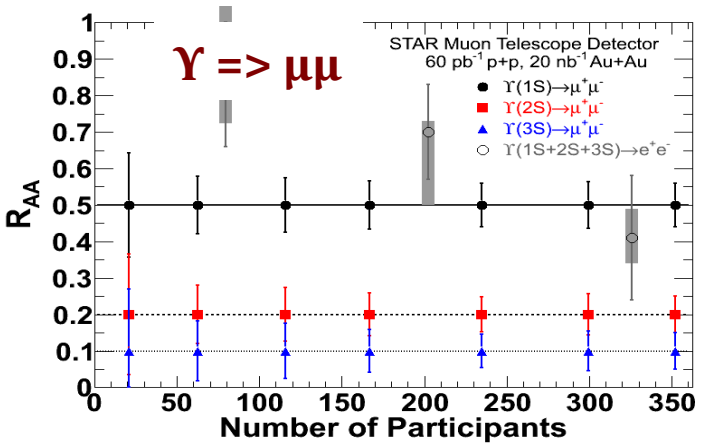


Muon Telescope Detector (MTD) at STAR:

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

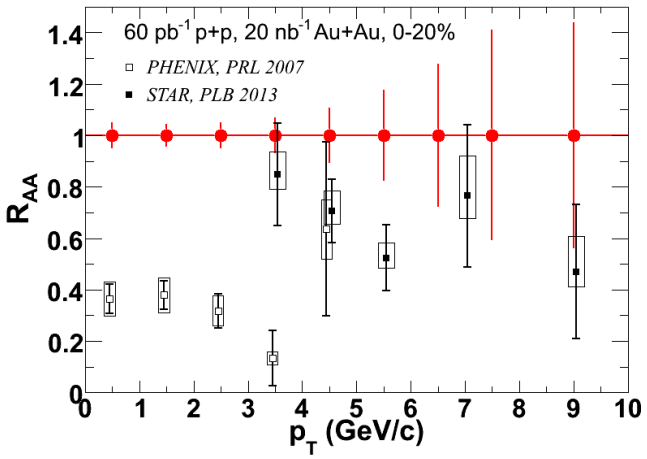
MTD: Run14 and Beyond





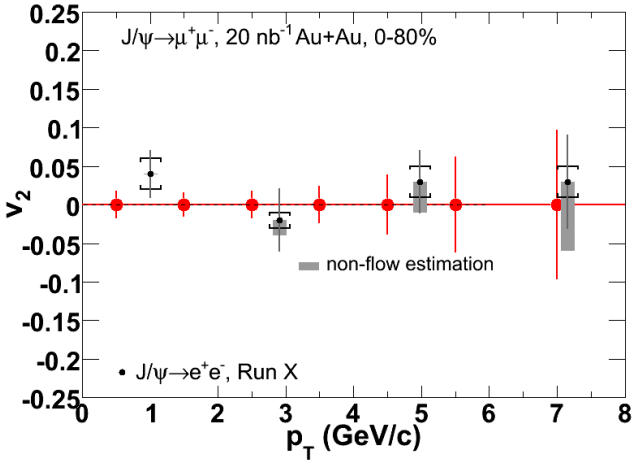
1) **Upsilon at RHIC:** unique, no regeneration, only initial production

2) **MTD at STAR:** Υ => μμ, no Bremsstrahlung tails, clean separation of the excited states

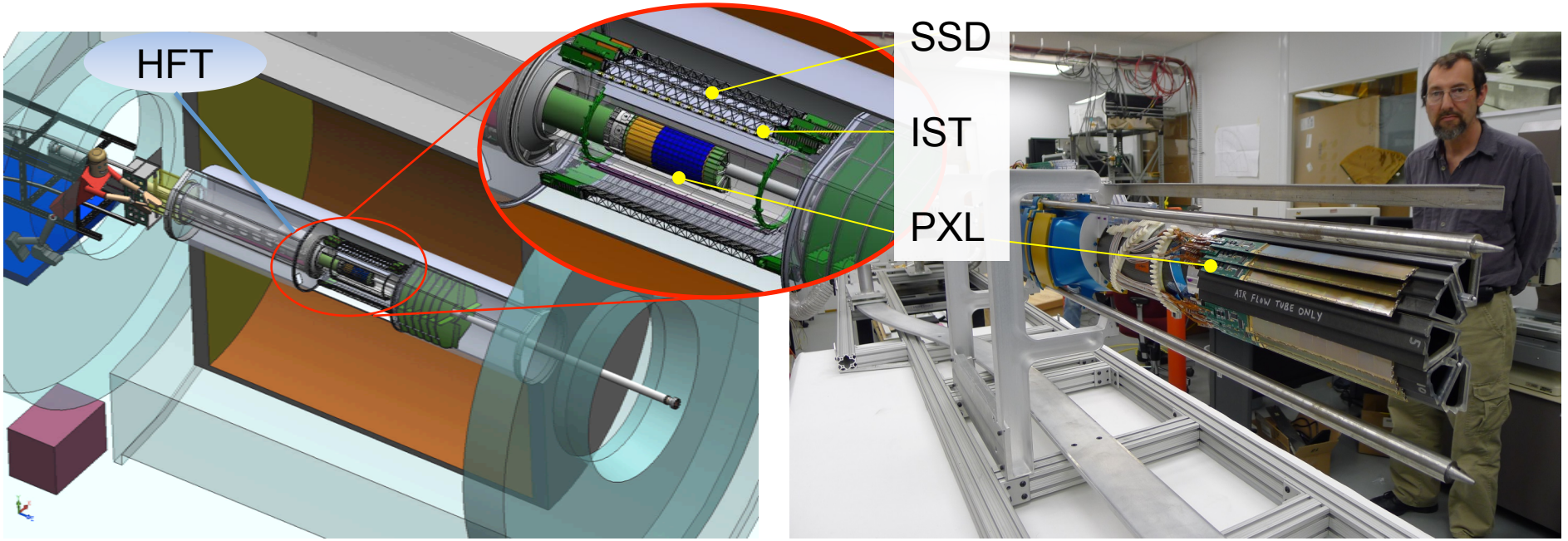


J/ψ

R_{AA} and v_2

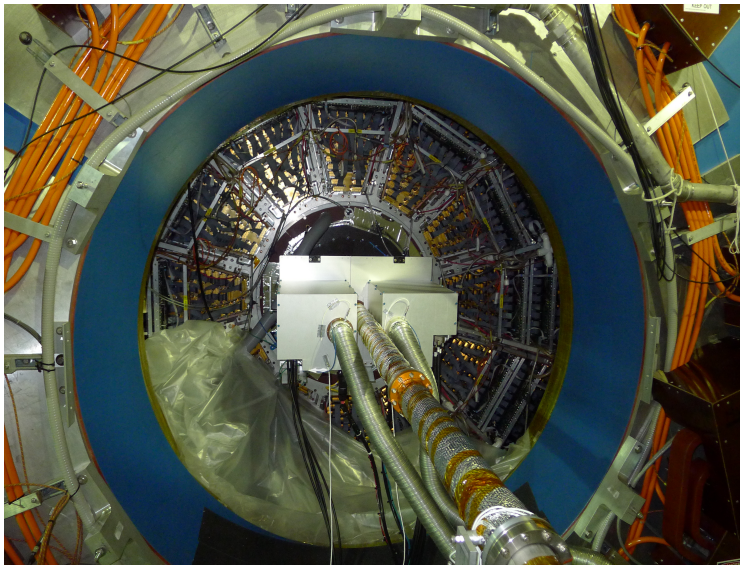


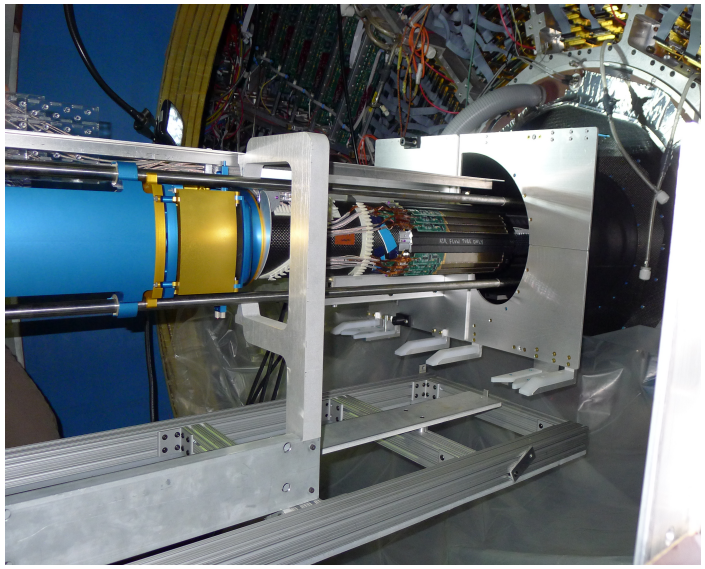
Heavy Flavor Tracker (HFT)

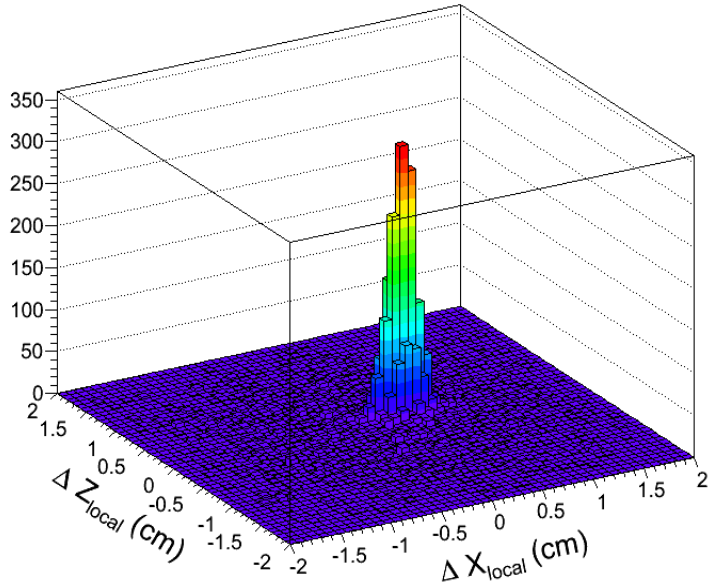


1) Engineering run: 3 sectors installed on May 8, 2013
2) The PXL system has been integrated in STAR trigger & DAQ system
3) First application of MAPs technology in the collider environment

STAR HFT Commissioning



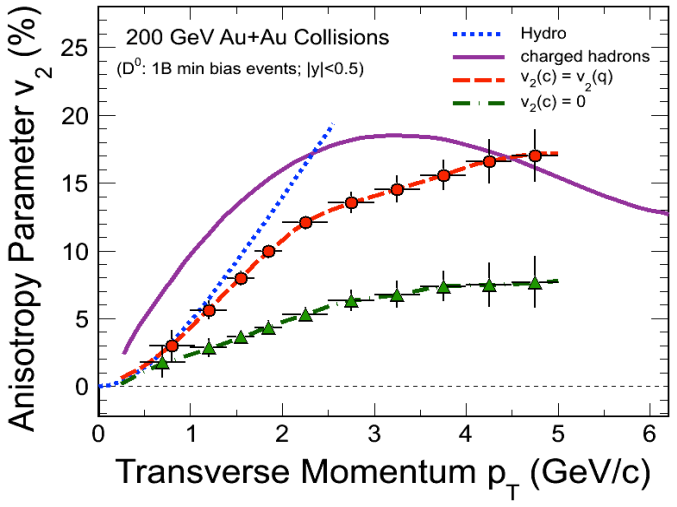


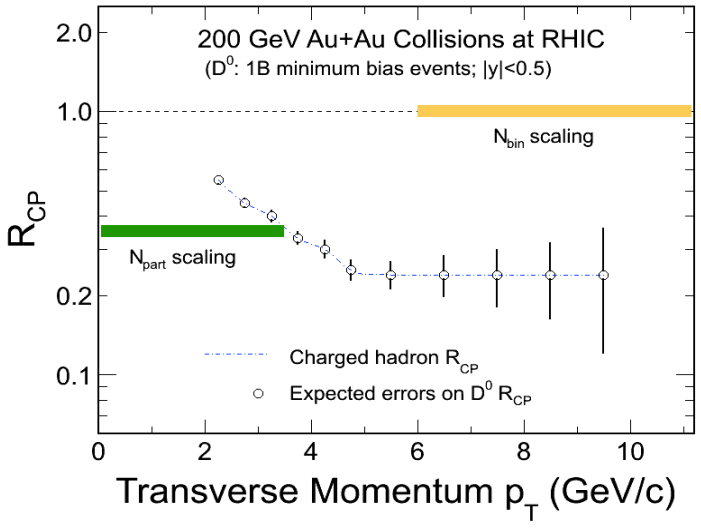


1) HFT designs worked
2) Lessons learned on mechanical, settings, latch-up and stability. Several issues have been resolved.
3) First tracking results: TPC-PXL correlation expected TPC resolutions (~1-2 mm)

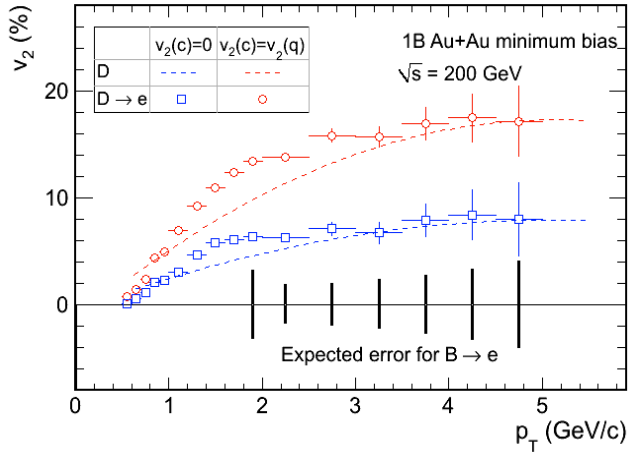
Run14: Physics Goals for HFT

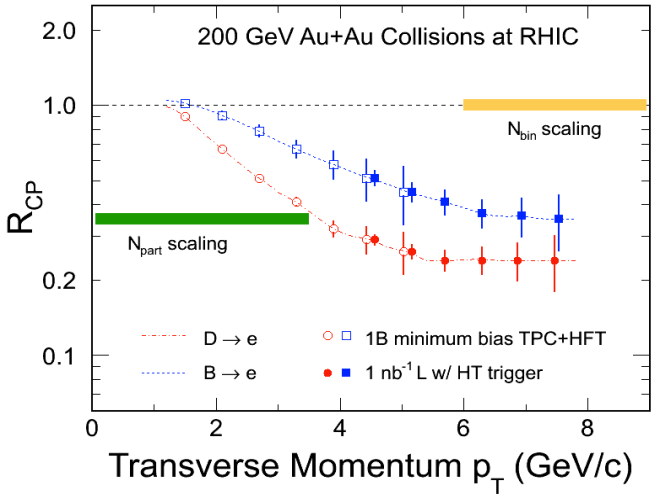
D^0 mesons



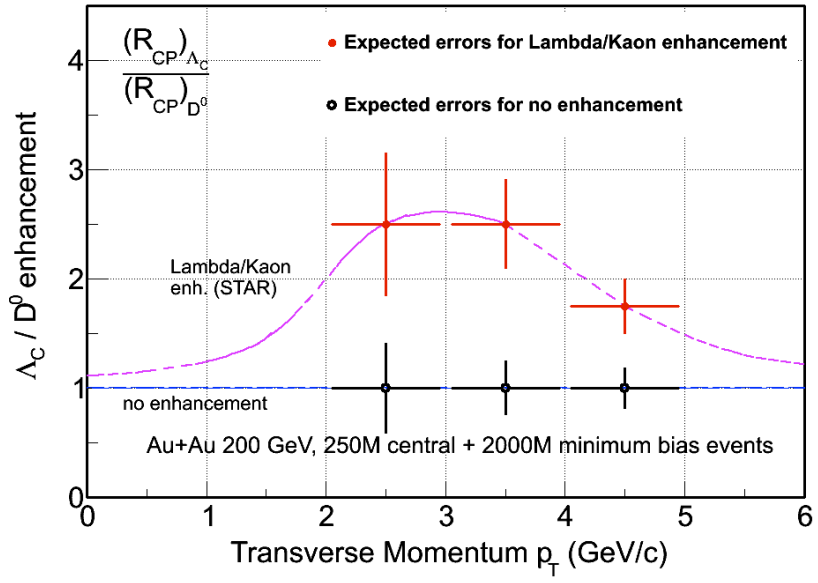


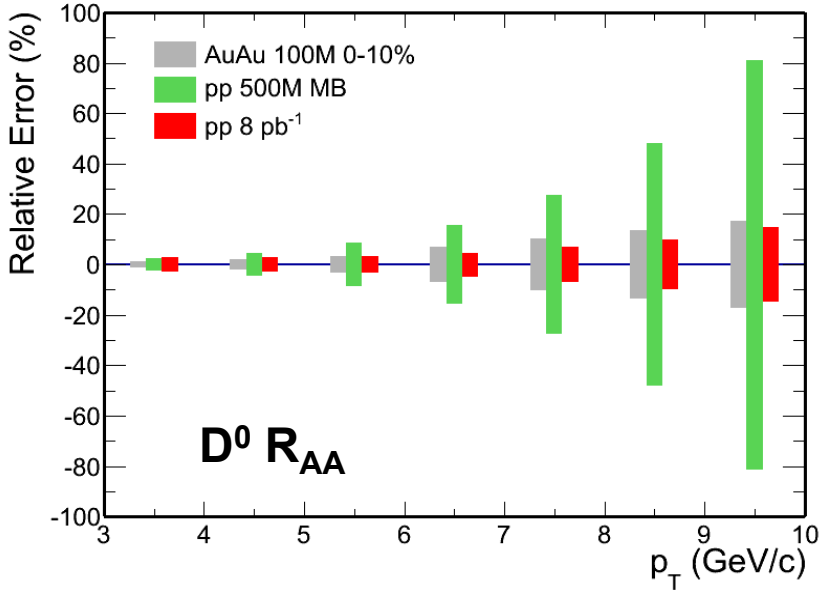
HF decayed electrons





HF Physics: Beyond Run14





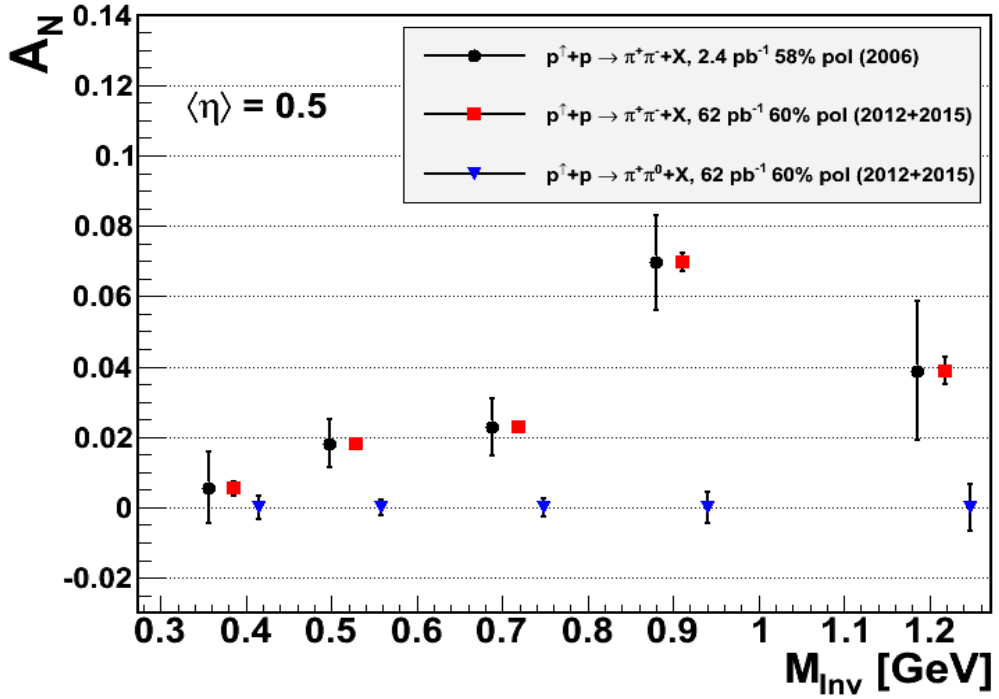
Λ_c: lowest charm baryon state, $c\tau \sim 60\mu m$

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

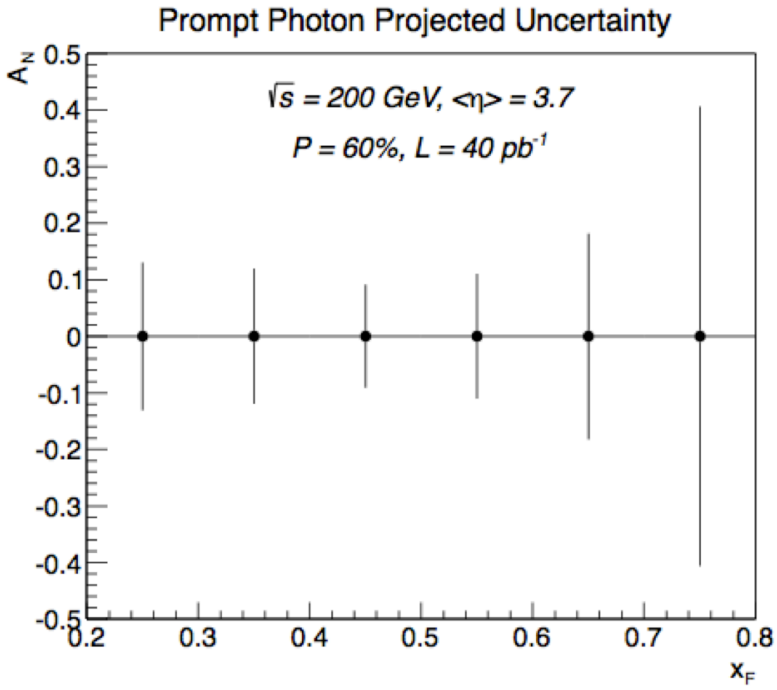
STAR multi-year physics program with the heavy flavor measurements requires high statistics data from ***both p+p and heavy ion*** collisions

Transverse Polarized pp Collisions

Collins Mechanism



Sivers/Twist-3

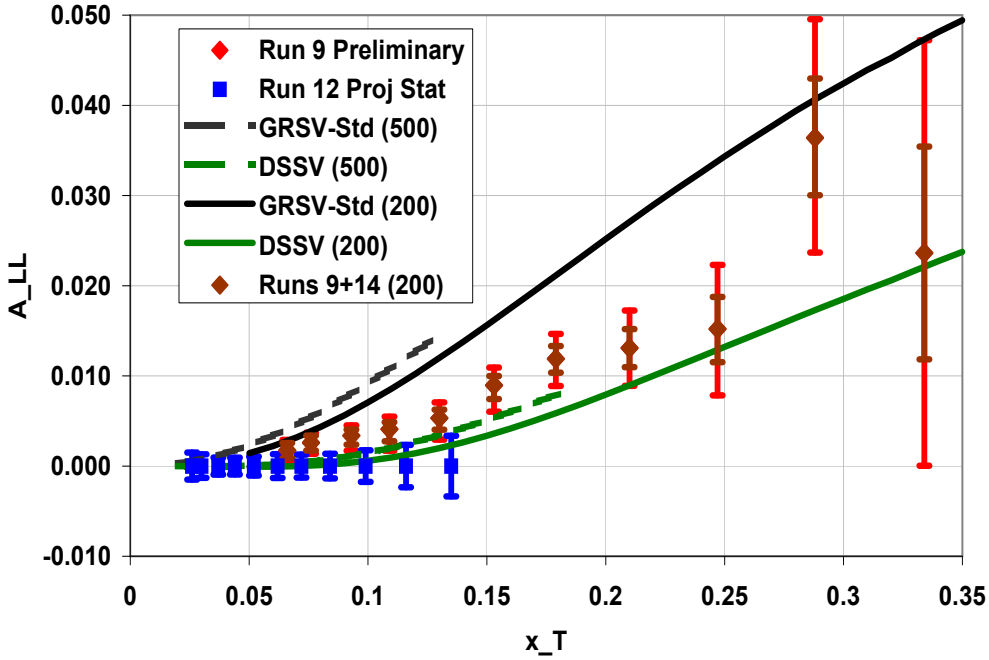


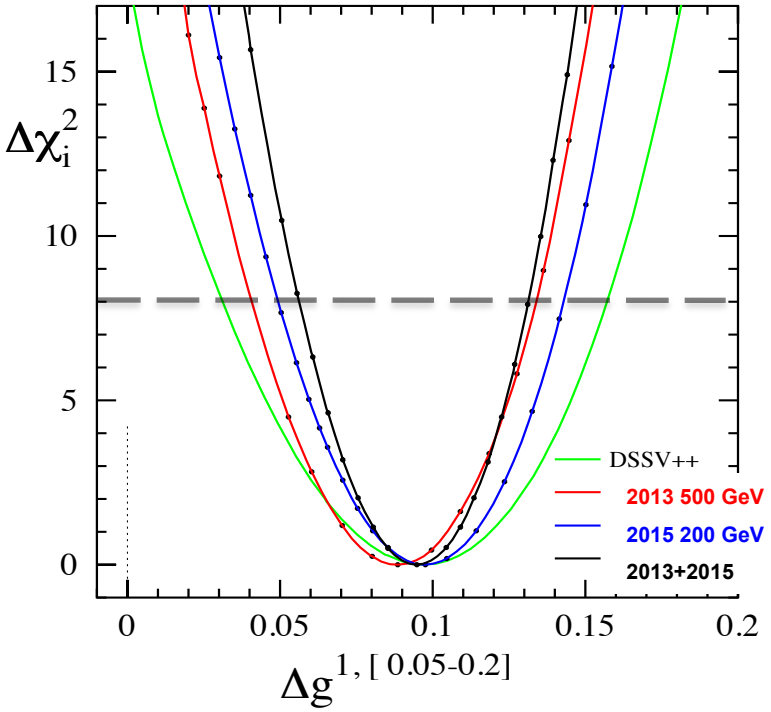
SSA measurements:

- **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



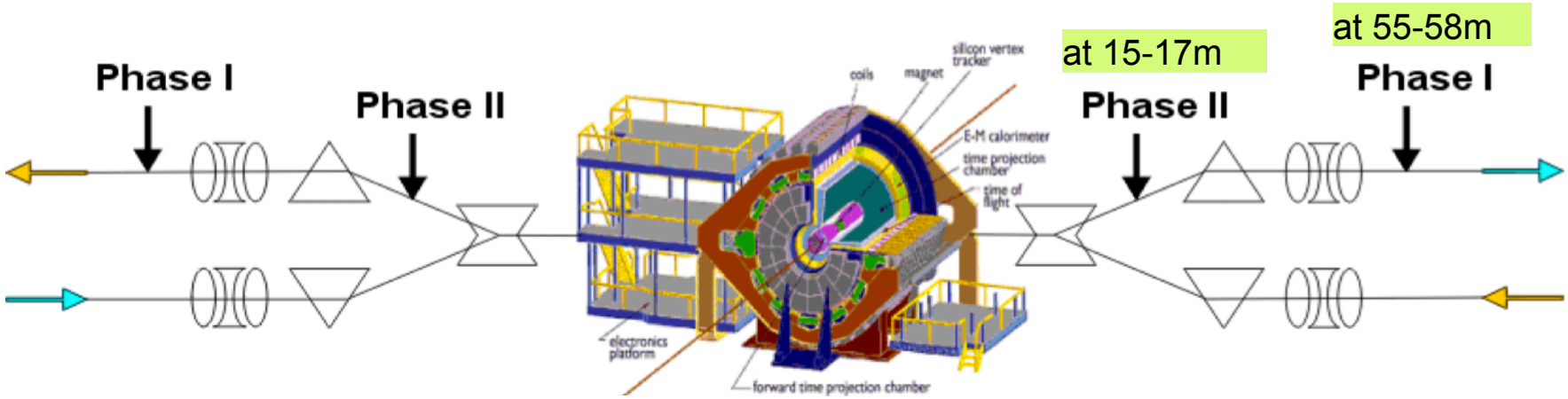


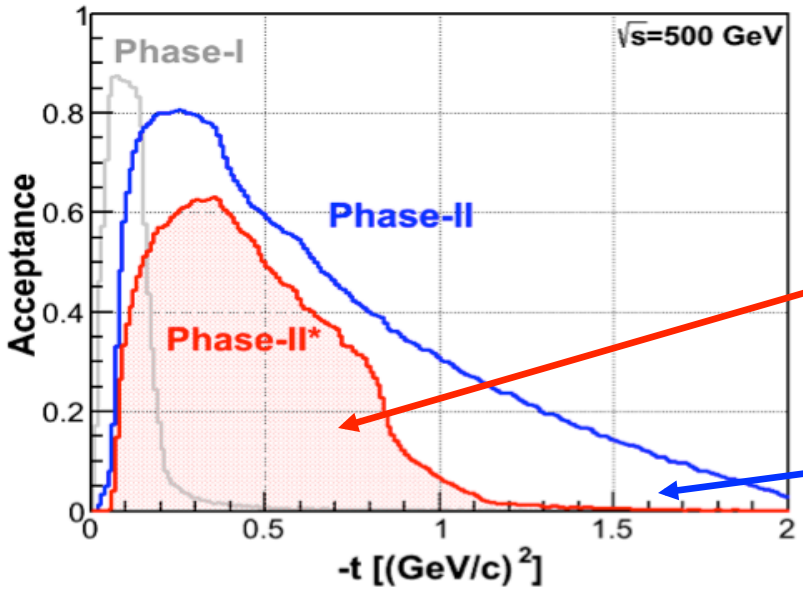
Data ≤ 2009 yield a significant non-zero Δg(x): $\int_{0.05}^{0.2} dx\Delta g \sim 0.1 \pm^{0.06}_{0.07} @\ 10\ \mathrm{GeV}^2$

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

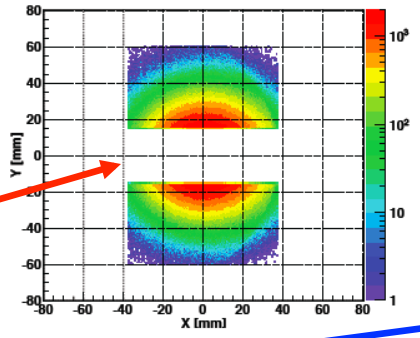
$$\int_{0.05}^{0.2} dx\Delta g \sim 0.1 \pm^{0.06\rightarrow 0.03}_{0.07\rightarrow 0.035} @\ 10\ \mathrm{GeV}^2$$

Forward Proton Tagging Upgrade

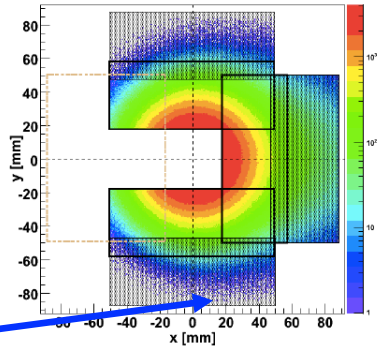




Phase-II: 1st step



full Phase-II

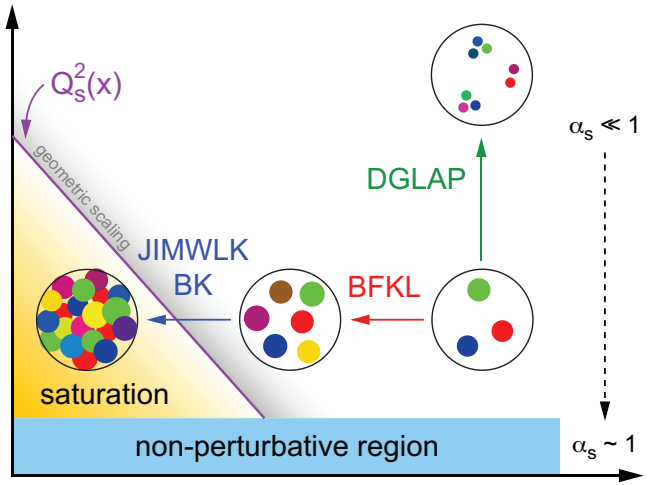


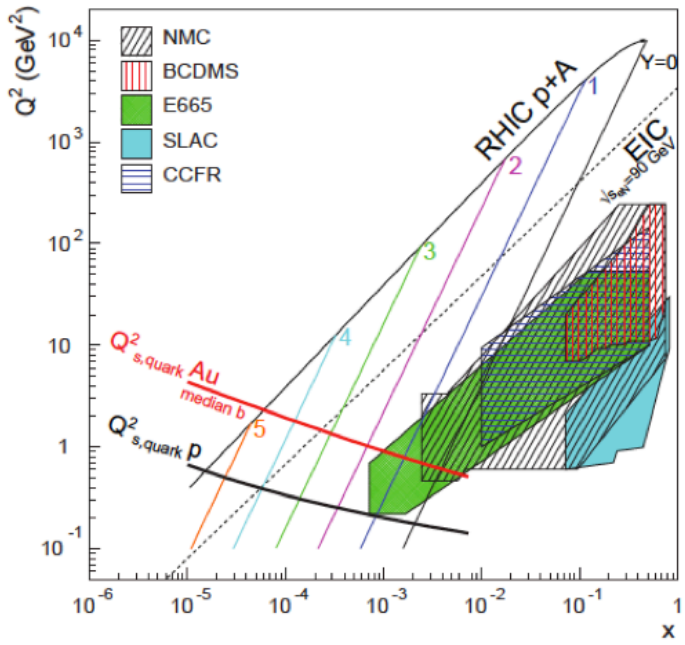
Follow PAC recommendation: data taking co-currently with other programs

Upgrade Phase-I ➔ Phase-II at a modest cost

p↑ + A Collisions at RHIC

Studying Saturation Through Spin

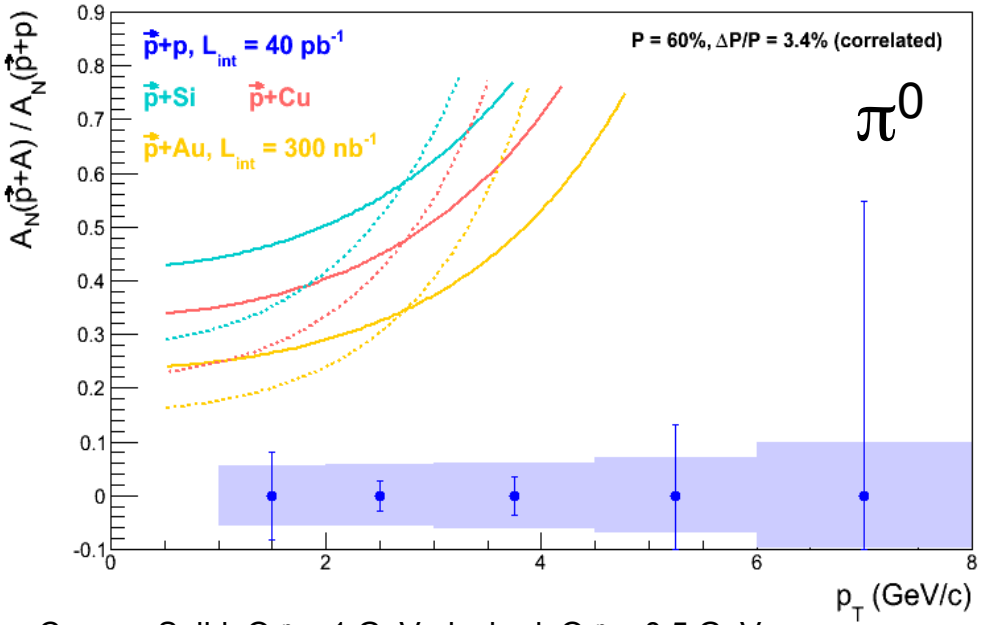




- Very unique RHIC possibility ***p↑+A***
- Synergy between CGC based theory and transverse spin physics
- Suppression of A_N in ***p↑+A*** provides sensitivity to Q_s

arXiv:1106.1375 & arXiv:1201.5890

STAR: projection for p↑A Run 15



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

Summary

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:
   $\sqrt{s_{NN}} \geq 39$ GeV: partonic // $\sqrt{s_{NN}} \leq 11.5$ GeV: hadronic dominant

4) Run13: High statistics, high quality data collected
   - 510 GeV

5) 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 GeV	3-week	Au + Au	1) 150M M.B. events for CP search 2) Fixed-target data taking(3)
	1	$\sqrt{s_{NN}}$ = 200 GeV	14-week	Au + Au	HFT & MTD heavy flavor hadron measurements L=10 nb^{-1}, 1000M M.B.
15	1	$\sqrt{s}$ = 200 GeV	12-week	1) p + p 2) $p_{\uparrow} + p_{\uparrow}$ (6-week) 3) $p_{\rightarrow}$ $p_{\rightarrow}$ (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 $\Delta g(x)$ L=50 pb^{-1}, 60% pol.
	2	$\sqrt{s_{NN}}$= 200 GeV	5-week	$p_{\uparrow}$ + 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
- $p^{\uparrow}$+Au: Saturation physics