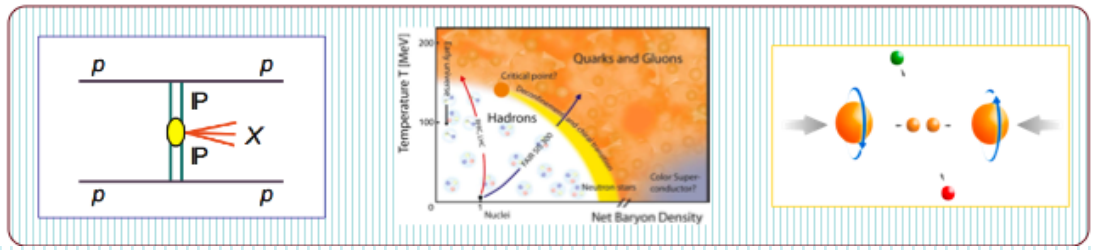
STAR Physics Program

STAR Beam Use Requests for Run13 and Run14

Nu Xu

for the STAR Collaboration



Outline

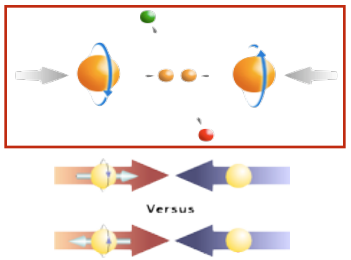
1) Introduction

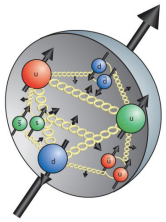
2) Selected Recent Results
   - Spin Physics Results
   - Results from 200 GeV Au+Au Collisions
   - Results from BES Phase I (BES-I)

3) Run12 Status

4) BUR for Run13 and 14

STAR Physics Focus



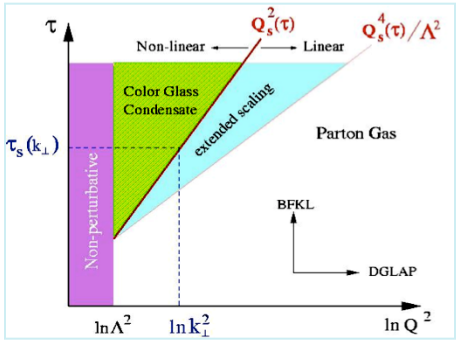


Polarized *p+p* Program

- Study ***proton intrinsic properties***

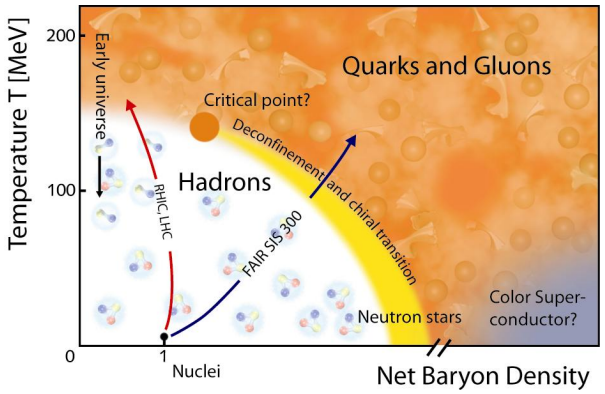
Carl's Talk

STAR Decadal Plan + *2020 -* **eRHIC** (eSTAR)



Small-x Physics Program

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



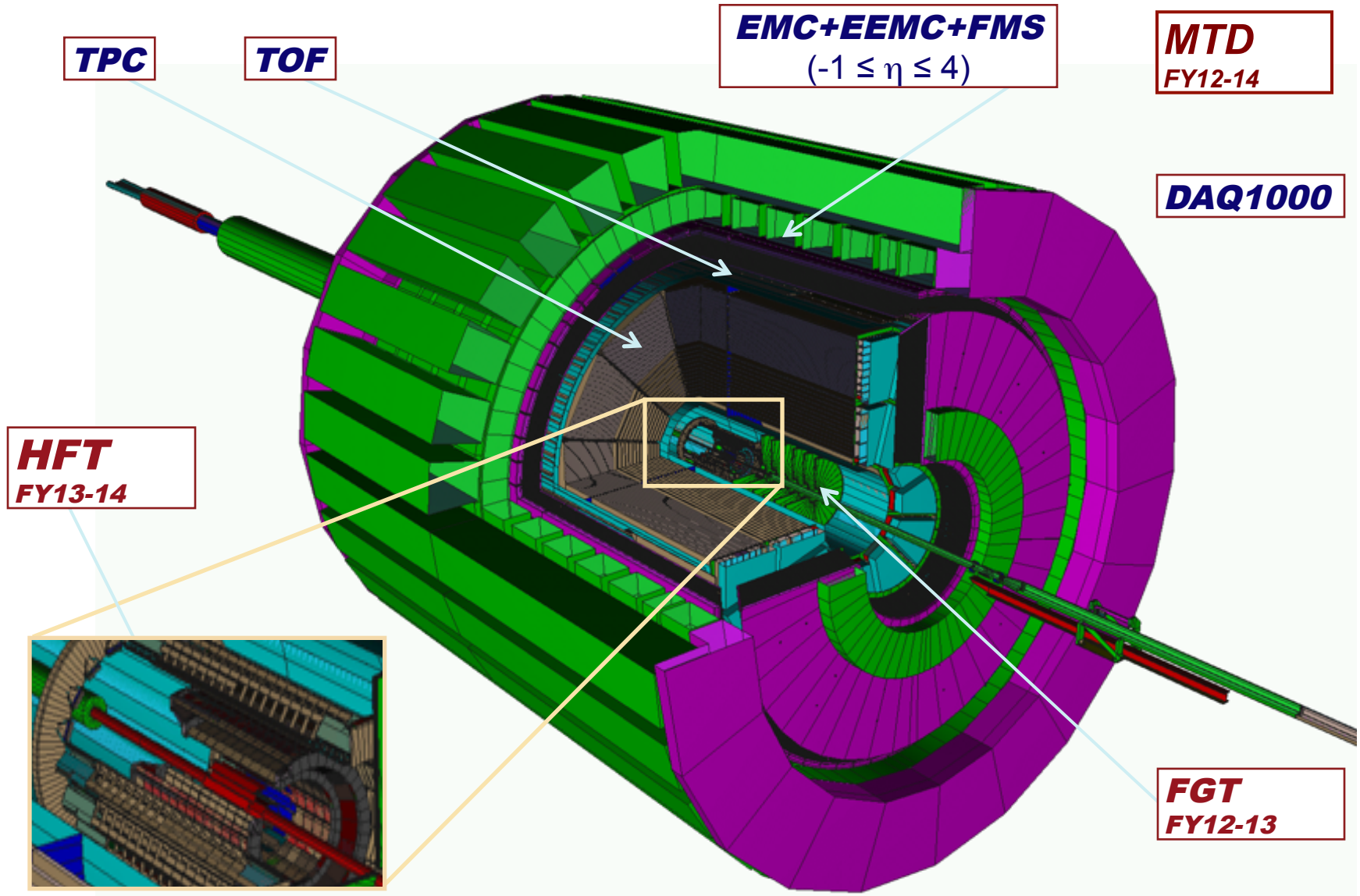
1) At 200 GeV at RHIC

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

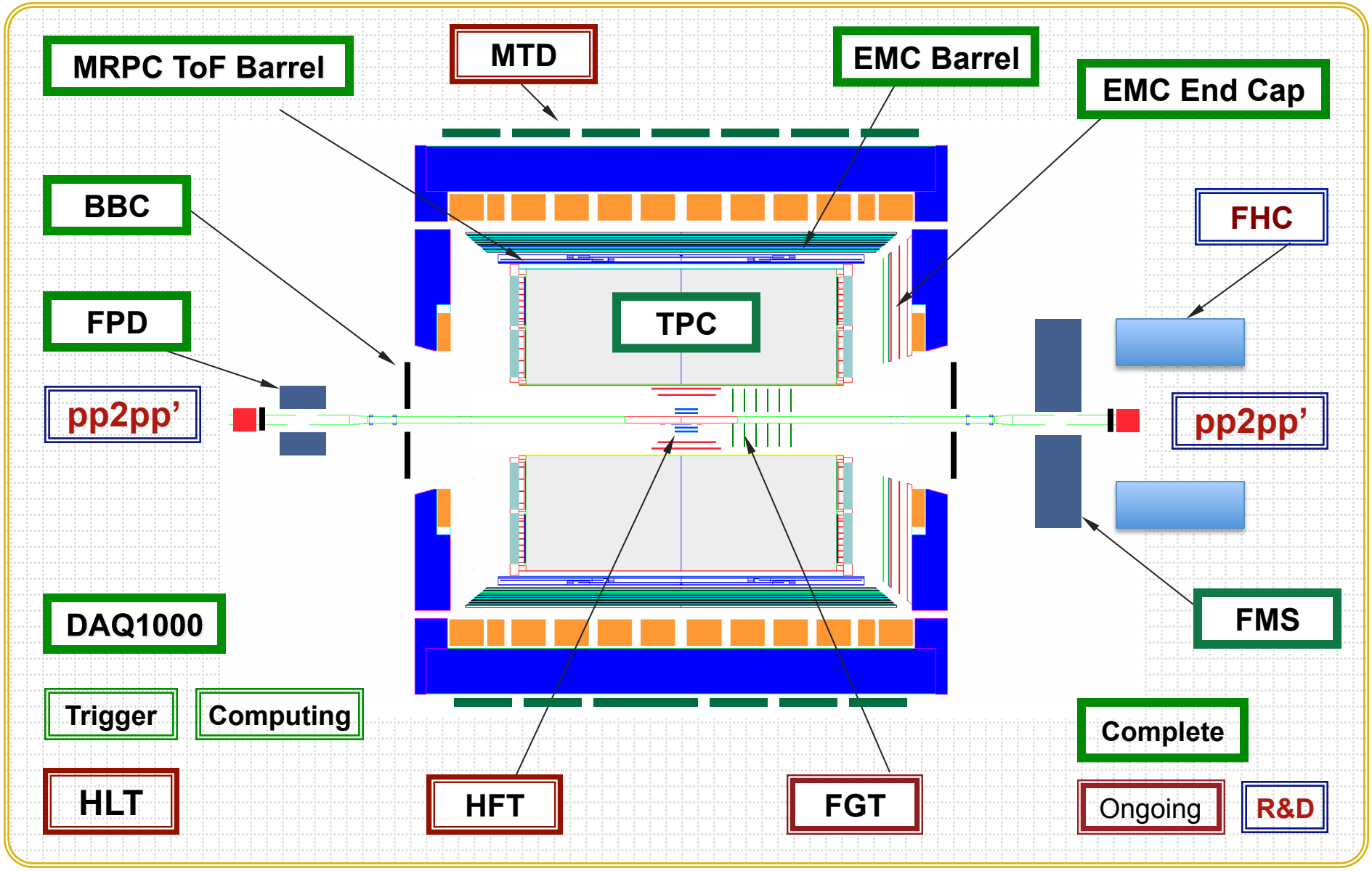
2) RHIC Beam Energy Scan (BES)

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

STAR Detectors *Fast and Full azimuthal particle identification*



STAR Experiment



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	Excellent PID in full azimuthal acceptance
FGT	14/24 Quadrants Run 12 Complete Run 13	Forward-y $W^{\pm}$ for flavor separated quark and anti-quark polarization
HFT	Engineering Run 13 Complete Run 14	(a) Precision hadronic ID for charm and Bottom hadrons (b) Charm and Bottom hadron energy loss and flow
MTD	Partial Run 12, 13 Complete Run 14	(a) High p_T muon trigger (b) Quarkonia states, e-μ correlation
	Beyond Run 14	Carl's talk

STAR Detector Configurations

	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**	

➔ **Large coverage, excellent particle ID, 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 physics in high rapidity regions, Carl's talk**

STAR BUR for Runs 13 and 14

Run	*	Beam Energy	Time	System	Goals
13	3	$\sqrt{s}$ = 510 GeV	4 days	$p_{\uparrow}\, p_{\uparrow}$	σ_{TOT}, A_N, A_{NN}, A_{SS}, Exclusive Central Production
	1		10 weeks	$p_{\rightarrow}\, p_{\rightarrow}$	i) $W^{\pm}$ A_L: P^2*L= 50 pb^{-1} ii) di-jets A_{LL}: P^4*L= 15 pb^{-1}
	2	$\sqrt{s_{NN}}$ = 200 GeV	4 weeks	Au + Au	i) MTD e-μ correlation, 2 nb^{-1} (280M central events) ii) HFT engineering run
14	1	$\sqrt{s_{NN}}$ = 200 GeV	10 weeks	Au + Au	i) HFT & MTD heavy flavor, 10 nb^{-1}(500M M.B.) ii) Fixed-target data taking
	2	$\sqrt{s}$ = 200 GeV	5 weeks	$p_{\rightarrow}\, p_{\rightarrow}$	i) Heavy ion reference data L= 40 pb^{-1} (500M M.B.) ii) Δg, L= 40 pb^{-1}

Run 13: 20 cryo-week. 510pp: 55% polarization

Run 14: 20 cryo-week. 200pp: 65% polarization

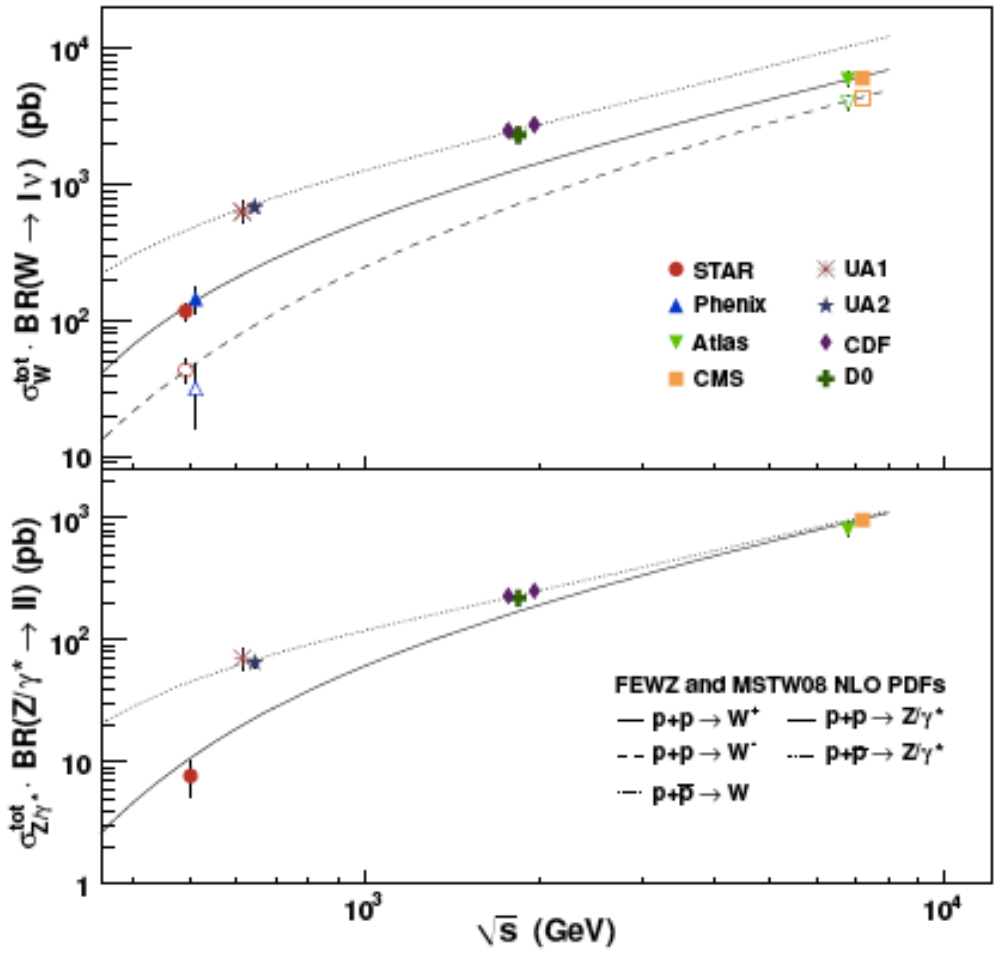
* Physics priorities

2) Selected Results:

(1) Spin Physics Results

W and Z/Υ* Production at $\sqrt{s}$ = 500 GeV

STAR Run9: PRD**85,** 92010 (2012)

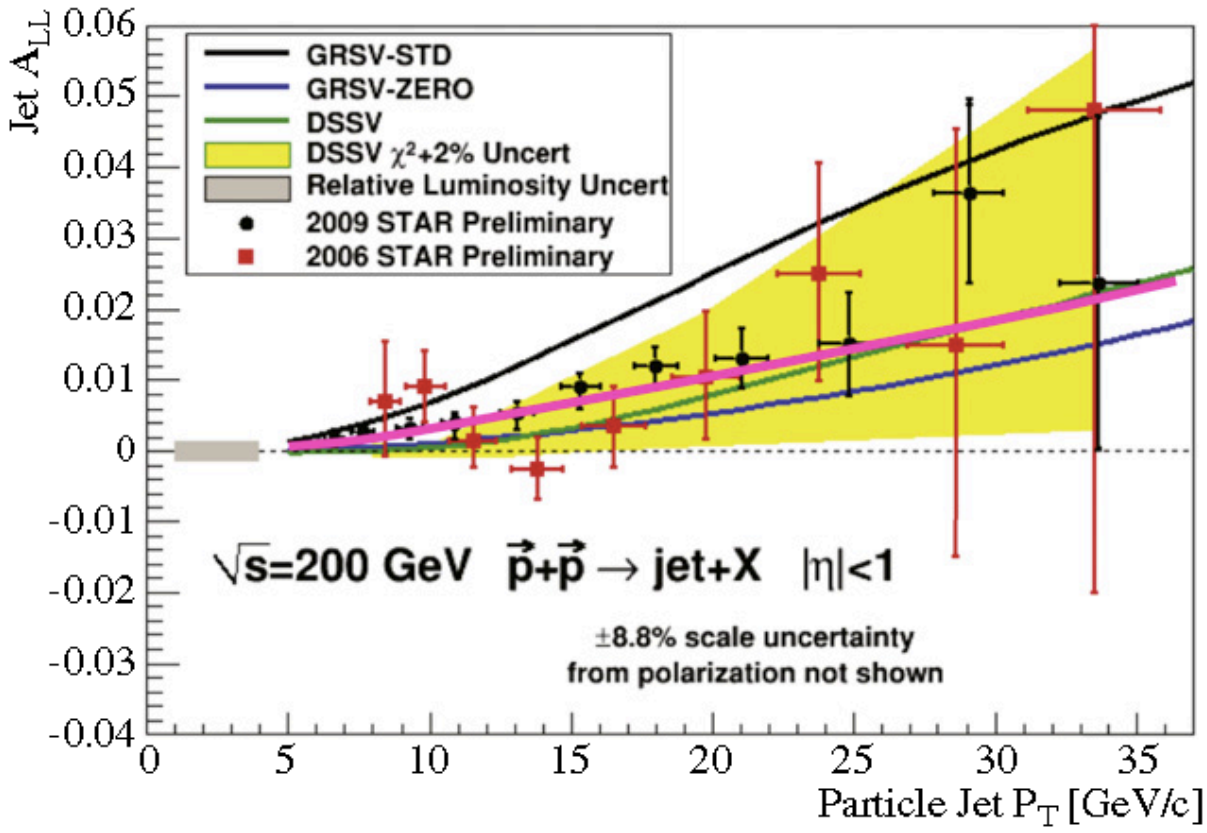


p+p collisions at $\sqrt{s}$ = 500 GeV

1) Results from NLO QCD models are consistent with STAR new data

2) Future high statistics W data important for flavor asymmetry of the sea quark study

STAR A_{LL} from 2006 to 2009



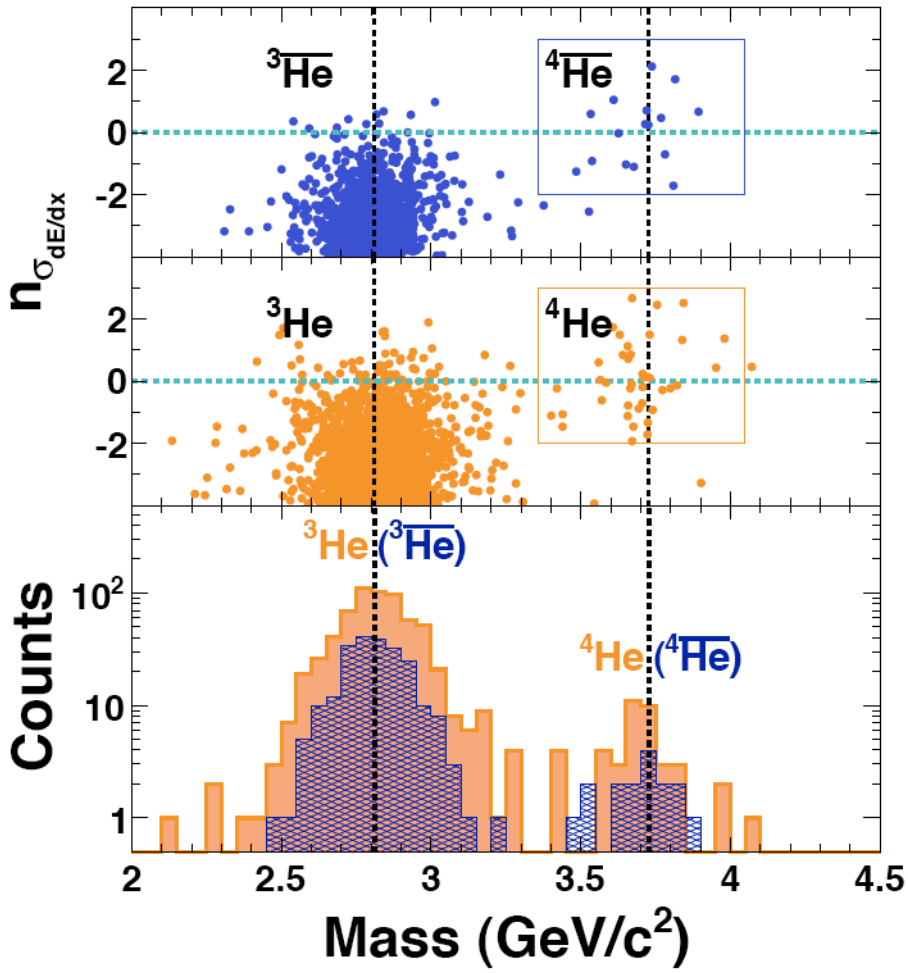
2009 STAR A_{LL} measurements:

- Magenta line: new fit with STAR Run9 results
- Results fall between predictions from DSSV and GRSV-STD

2) Selected Results:

(2) Results from $\sqrt{s_{NN}}$ = 200 GeV

Particle Identification at STAR (TPC + TOF + HLT)



- Clean Identification: TPC and ToF

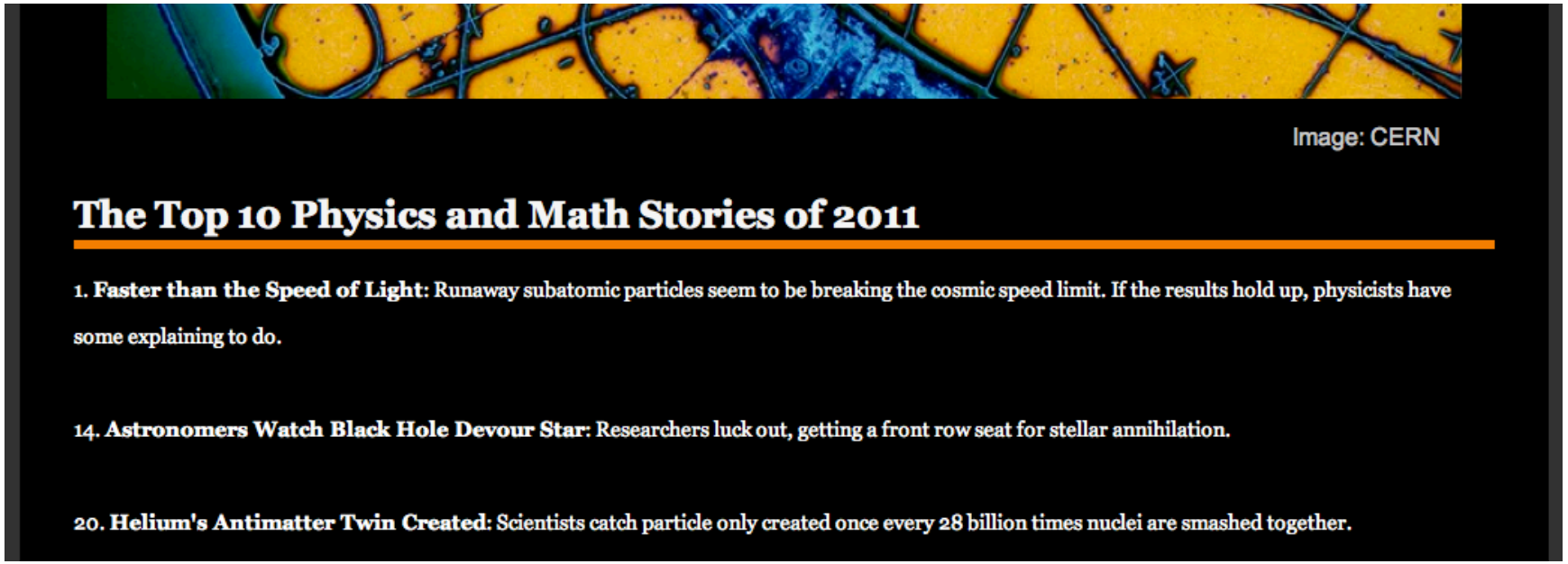
$$m^2 = p^2\left(1/\beta^2 - 1\right)$$

- China-US: Time of Flight (ToF) Detector

- High Level Trigger

Nature (2011) DOI: doi:10.1038/nature10079 || **STAR Experiment**
Received 14 March 2011 | Accepted 04 April 2011 | Published online 24 April 2011

$\bar{\alpha}$: Top-100 Physics and Math Science in 2011

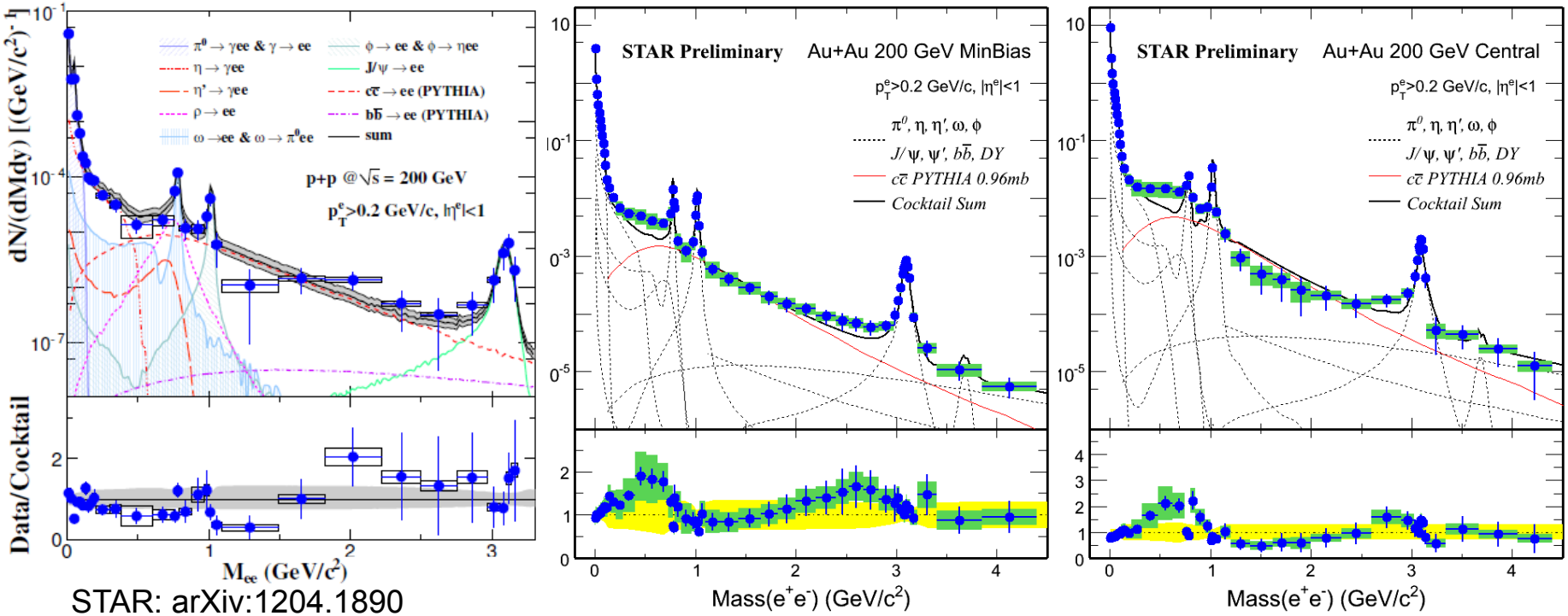


Discovery Magazine:http://discovermagazine.com/photos/19-top-100-stories-of-2011

Since last PAC meeting we have published: 3 PRL; 1 PRD; 1 PLB; 5 PRC papers including high-p_T PID, HF, strangeness enhancement in HI, W production cross sections.

STAR Di-electron Program

$\sqrt{s}$ = 200 GeV **p+p** **Au+Au MinBias** **Au+Au Central**

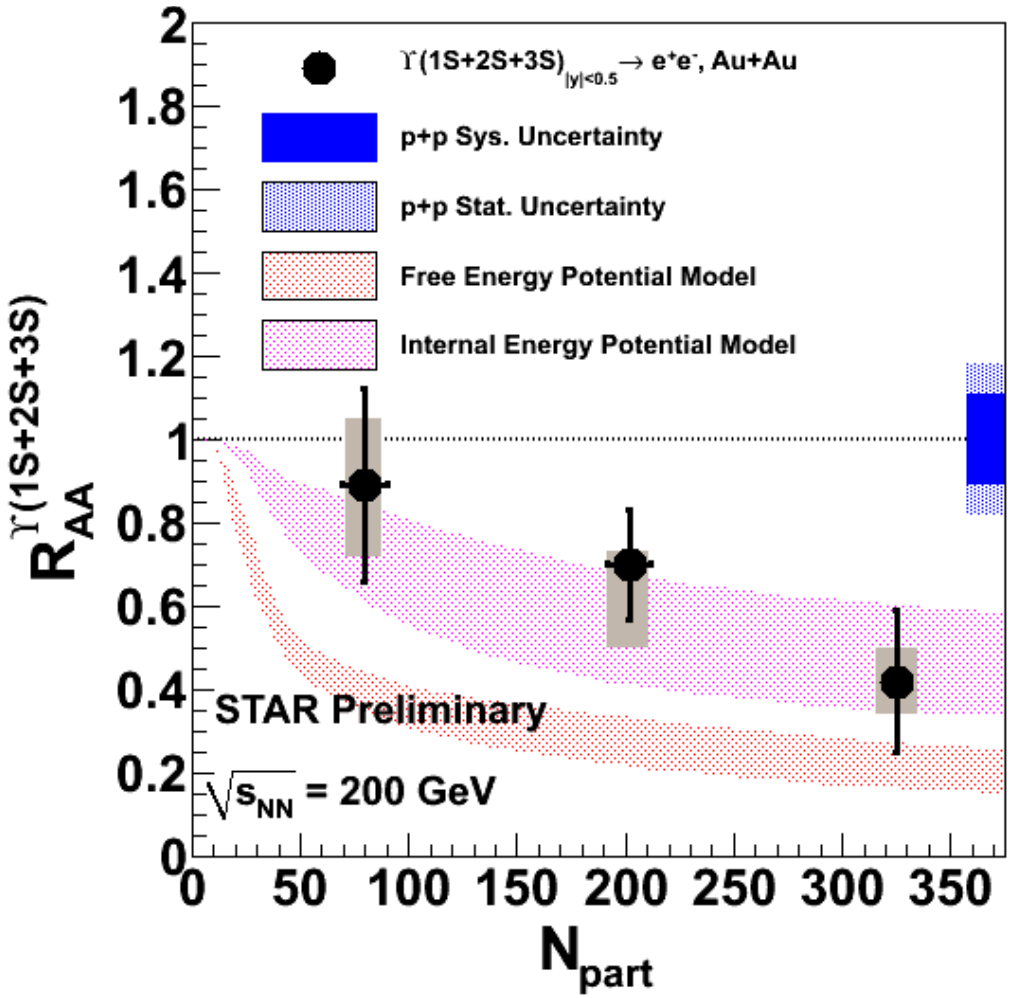


STAR: arXiv:1204.1890

1) Direct radiation, penetrating-bulk probe, **new to STAR**!
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.

Υ(1S+2S+3S) R_{AA}

$\sqrt{s_{NN}}$ = *200* GeV Au+Au collisions



1) STAR: Triggered events

2) The result is consistent with the scenario that all Upsilon excited states are melted in central Au + Au collisions at RHIC

*M.Strickland and D. Bazow, NPA 879, 25 (2012).

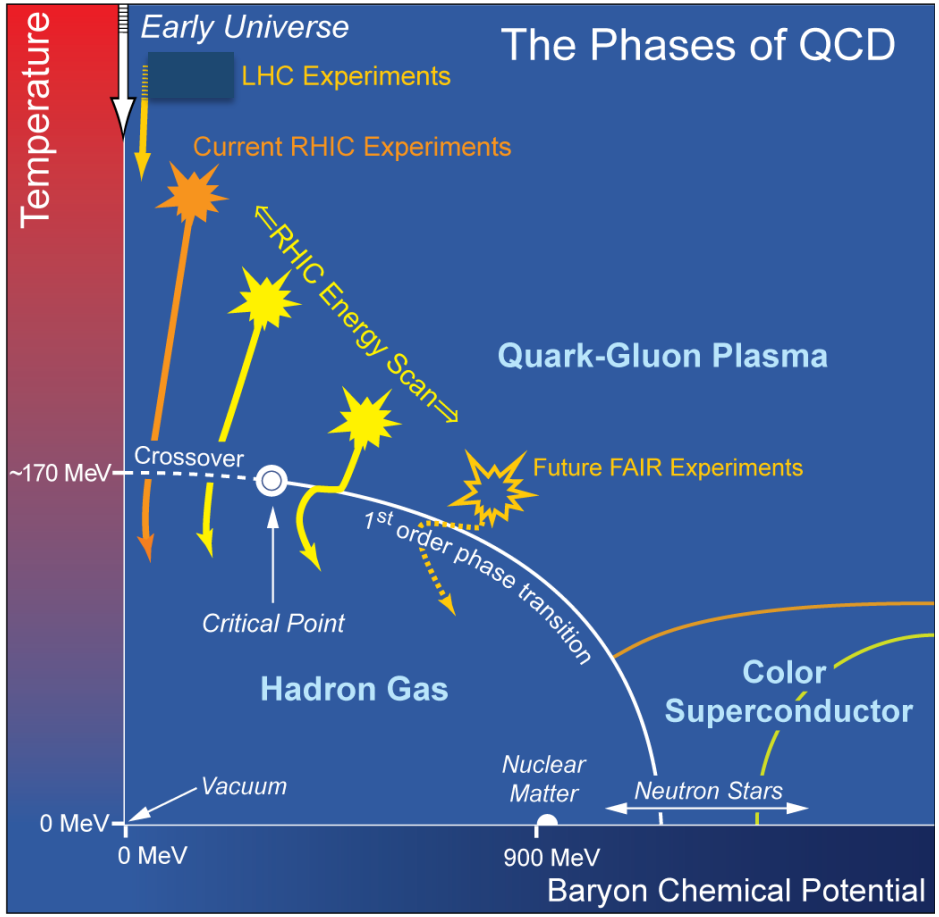
2) Selected Results:

(3) RHIC Beam Energy Scan (BES-I)

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

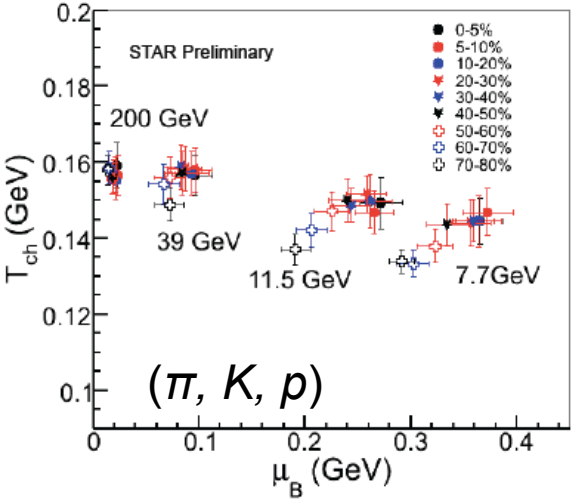
- http://drupal.star.bnl.gov/STAR/starnotes/public/sn0493

- arXiv:1007.2613

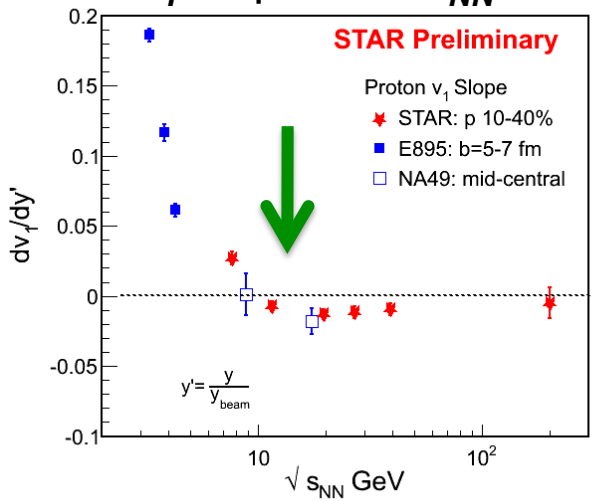
RHIC BES-I Au+Au Dataset

	Runs	Events(10^6)	$\sqrt{s_{NN}}$ (GeV)	μ_{B^*} (MeV)
1	10	130	39	112
2	11	70	27	156
3	11	36	19.6	206
4	10	12	11.5	316
5	10	5	7.7	420
6	**12***	--	**5**	550

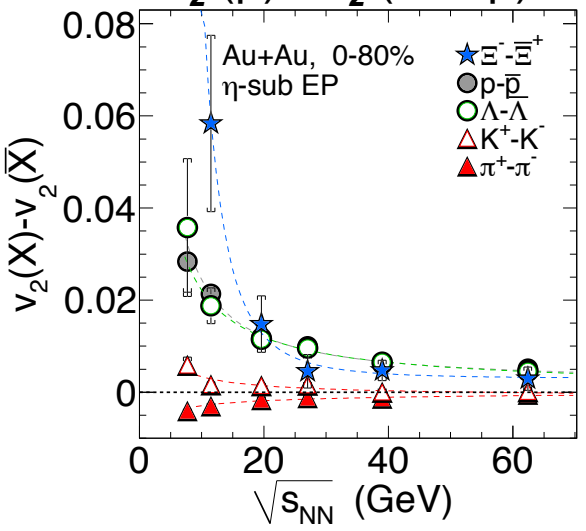
Chemical freeze-out



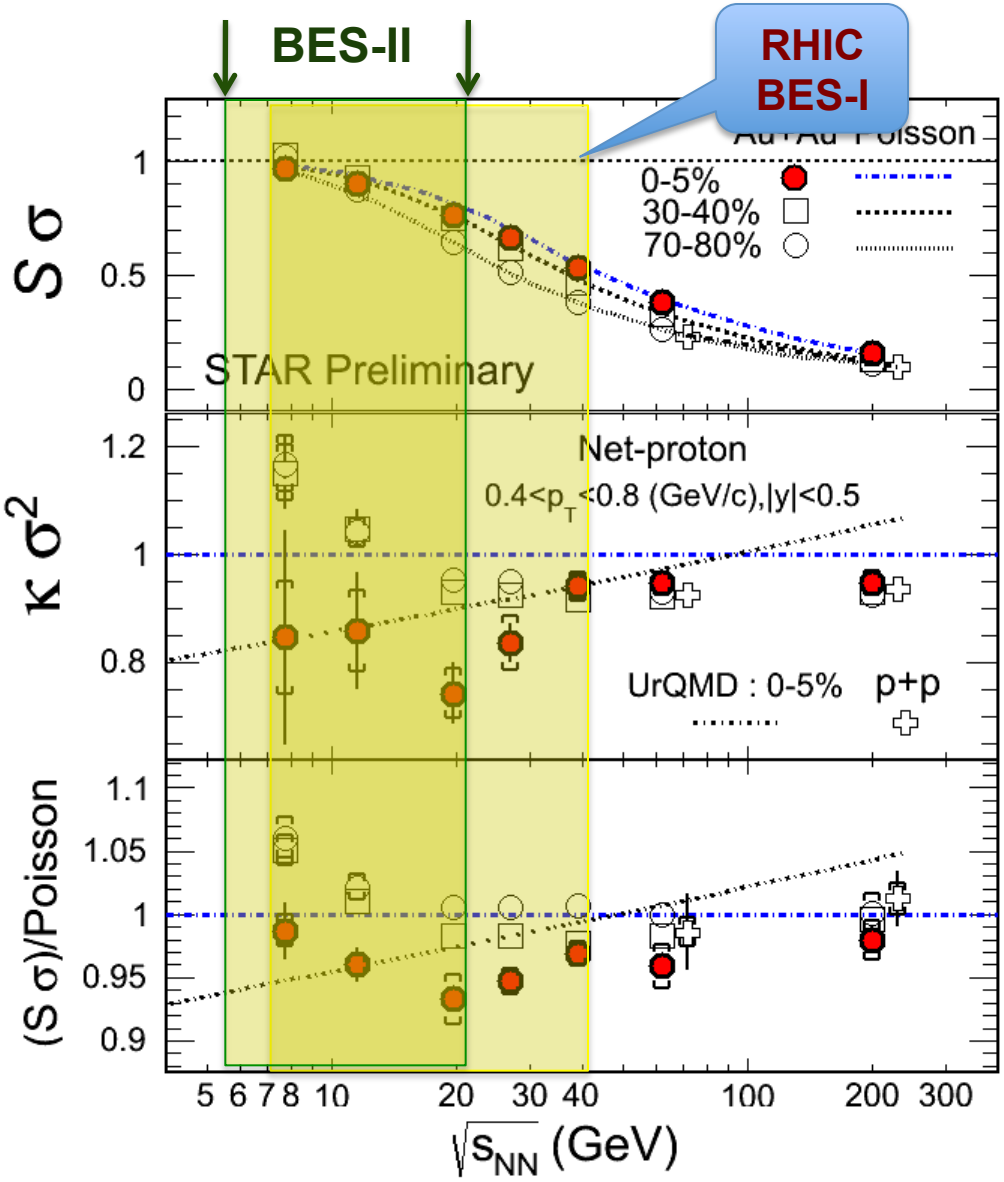
v_1 slope vs. $\sqrt{s_{NN}}$



v_2 (p) - v_2 (anti-p)



Net-proton Higher Moment



RHIC BES-I key findings:

1) Changes around $\sqrt{s_{NN}}$ = 20 GeV Au+Au collisions:

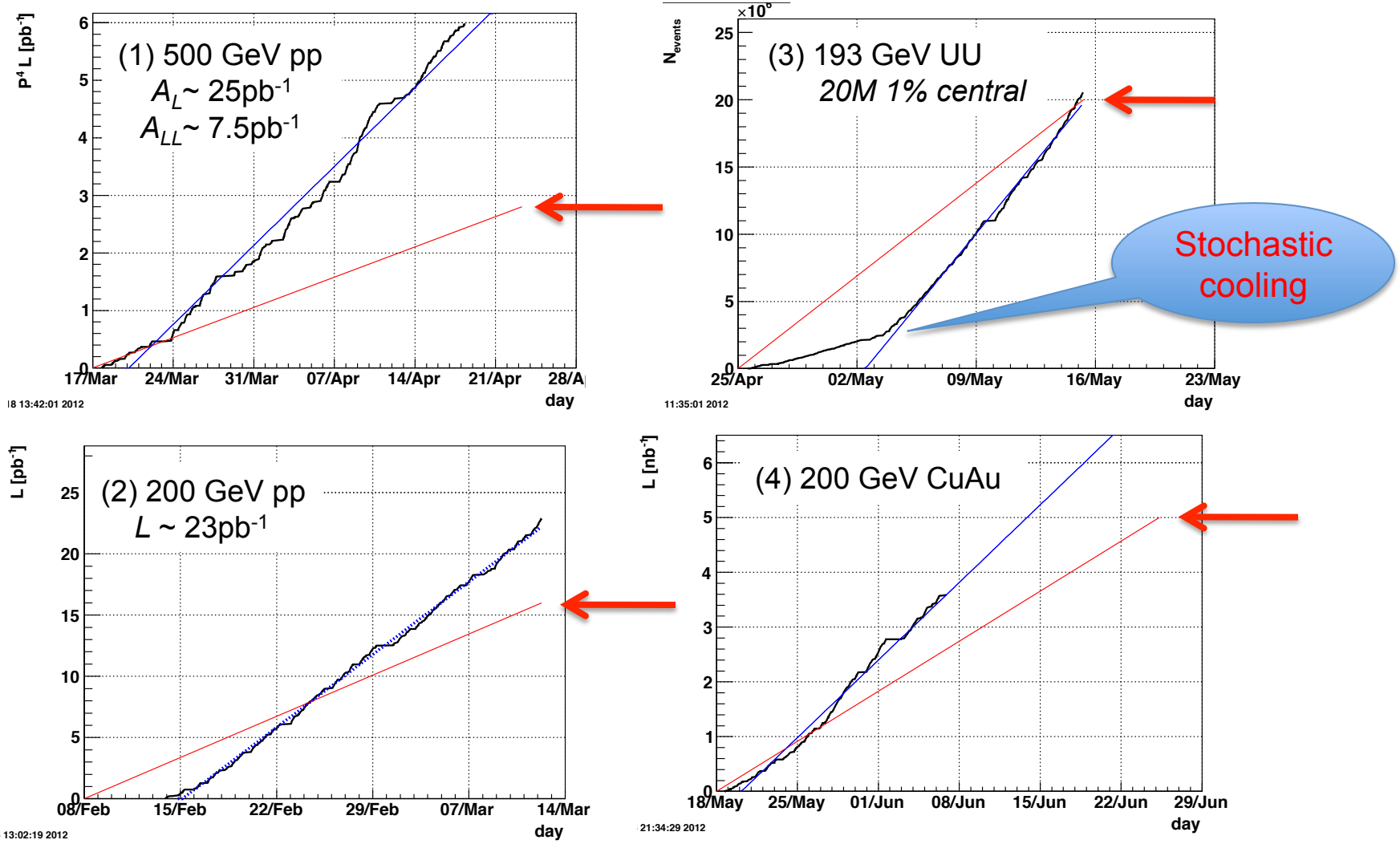
- **higher moments**
- **v_2 ϕ-meson drops**
- **charge correlations**
- **v_1 slope change sign**
-
- more in Carl's talk

2) Need higher statistics for collisions at $\sqrt{s_{NN}}$ < *20 GeV*

BES-II: focus on $\sqrt{s_{NN}}$ = 5-20 GeV

3) Run12 Status

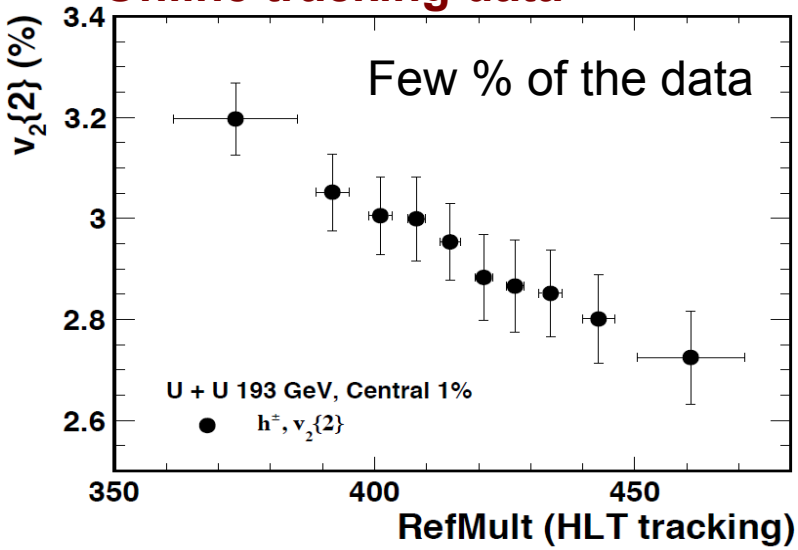
Run12: Integrated Luminosities



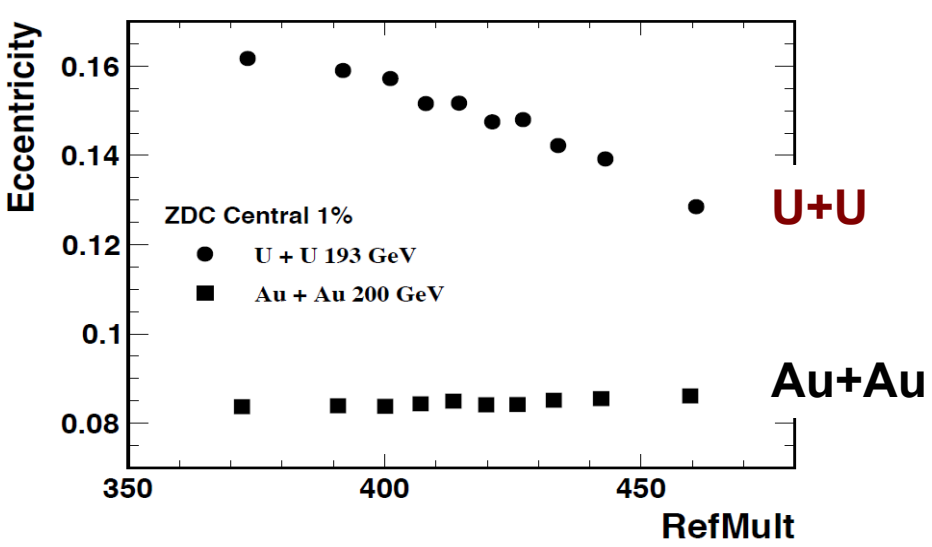
← STAR's goals in Run12

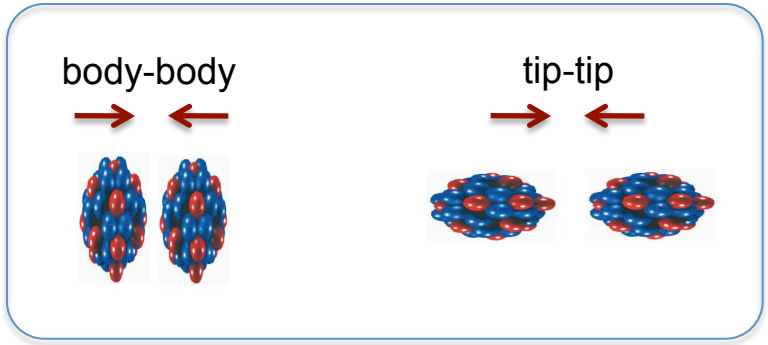
$\sqrt{s_{NN}}$ = 193GeV U+U Collisions

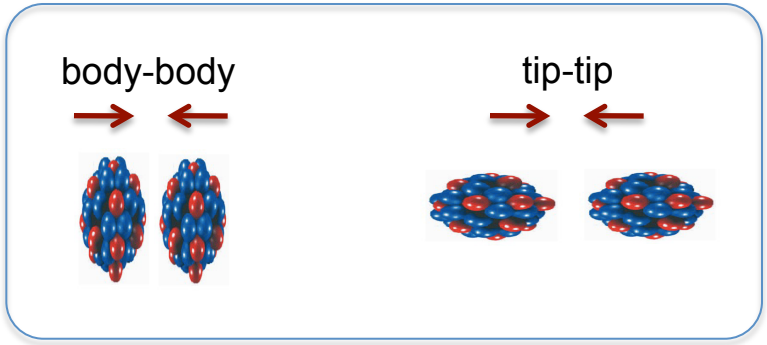
Online tracking data



Simulations

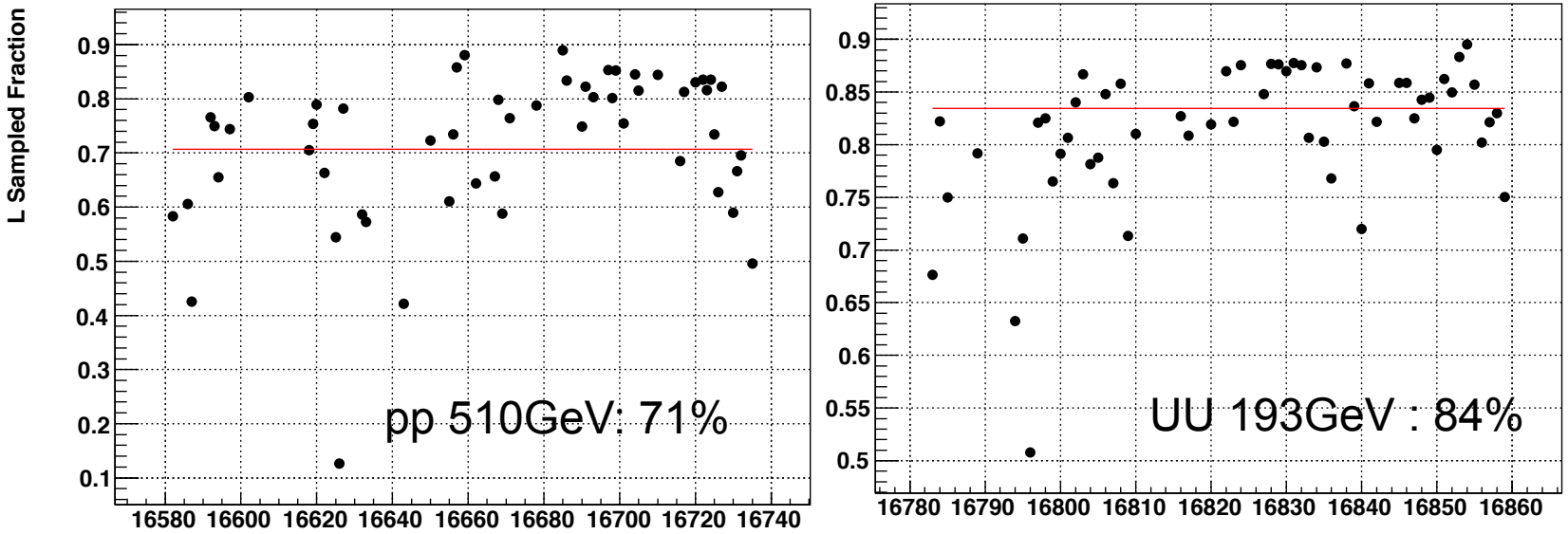






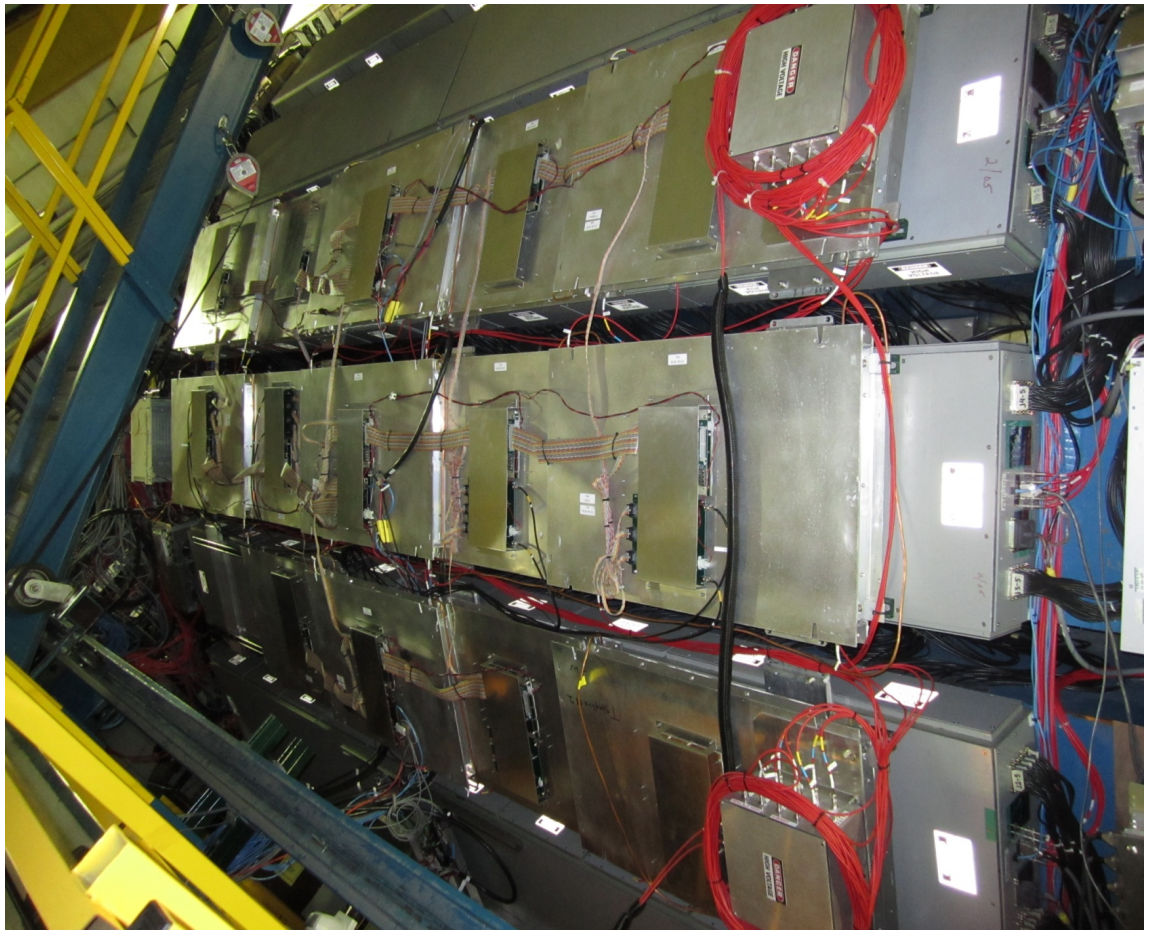
U+U Collisions: (1) test CME with small external B-field
(2) test v_2 at 30% higher density
(3) test path-length dependence of R_{AA}

Data Taking Efficiency



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

STAR-MTD



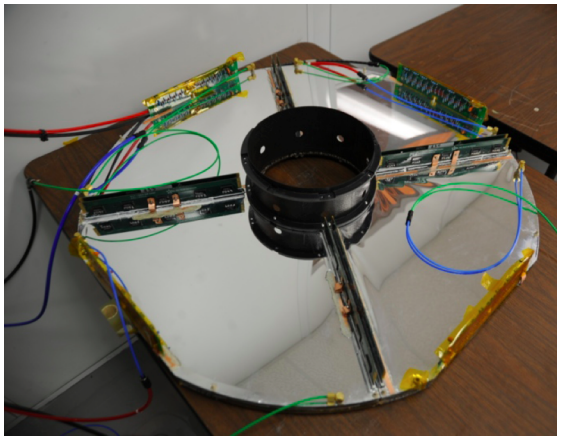
1) MTD timing resolution:
   Δt ~ 100 ps
   consistent with proposal

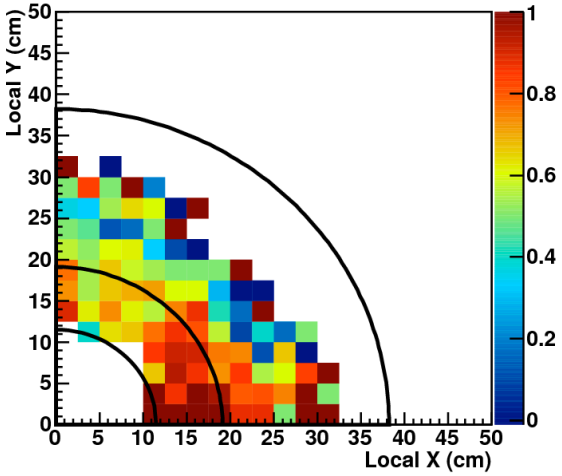
2) **Run12**: 12/118(~10%)

3) **Run13**: 50/118 (~43%)

4) **Run14**: complete

STAR: Forward GEM Tracker





1) FGT works, 14/24 quadrants installed

2) Working on:
   - Fine tune on HV, gas mixture are ongoing
   - Tracking software

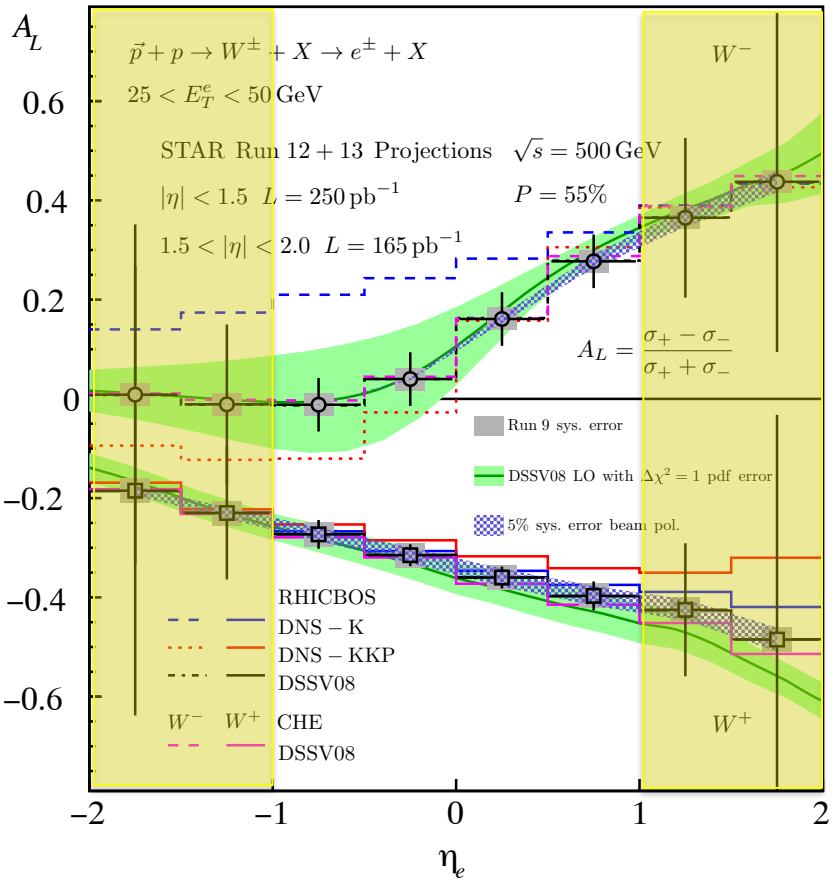
Run13: complete FGT

4) Beam Use Request for Run13, Run14

and

e-cooling for Beam Energy Scan-II

Quark Flavor Measurements: W±



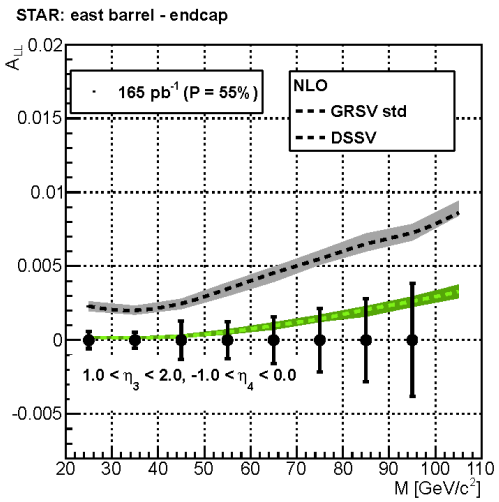
Run13 Request:

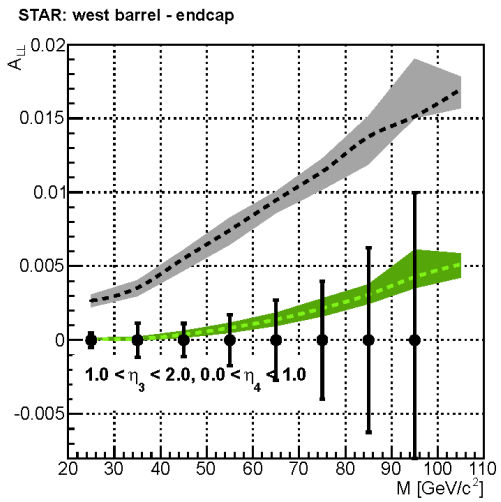
- 10-week 510 GeV p+p

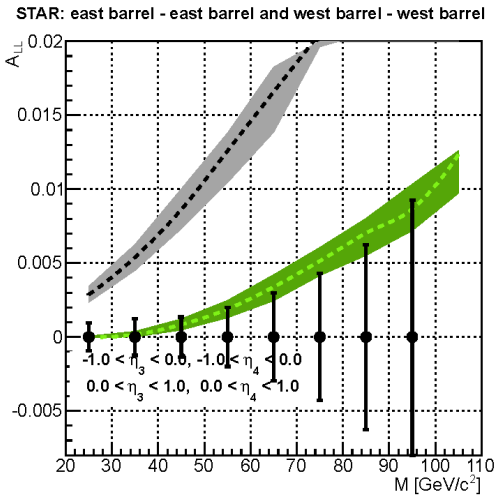
$W^{\pm}$ A_L: $P^2*L = 50\ pb^{-1}$

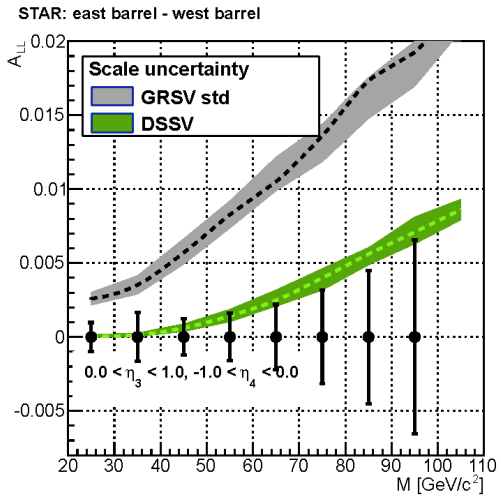
1) Precision measurements require **large luminosity** and **high polarization** at RHIC!
2) Projections: (a) |η| ≤ 1.5, Run12 + 13; (b) 1.5 ≤|η| ≤ 2, FGT, Run13

Di-Jets: Projected Sensitivity at 510GeV









$$x_1, x_2 = \frac{M}{\sqrt{s}} \exp\left(\pm \frac{\eta_3 + \eta_4}{2} \right)$$

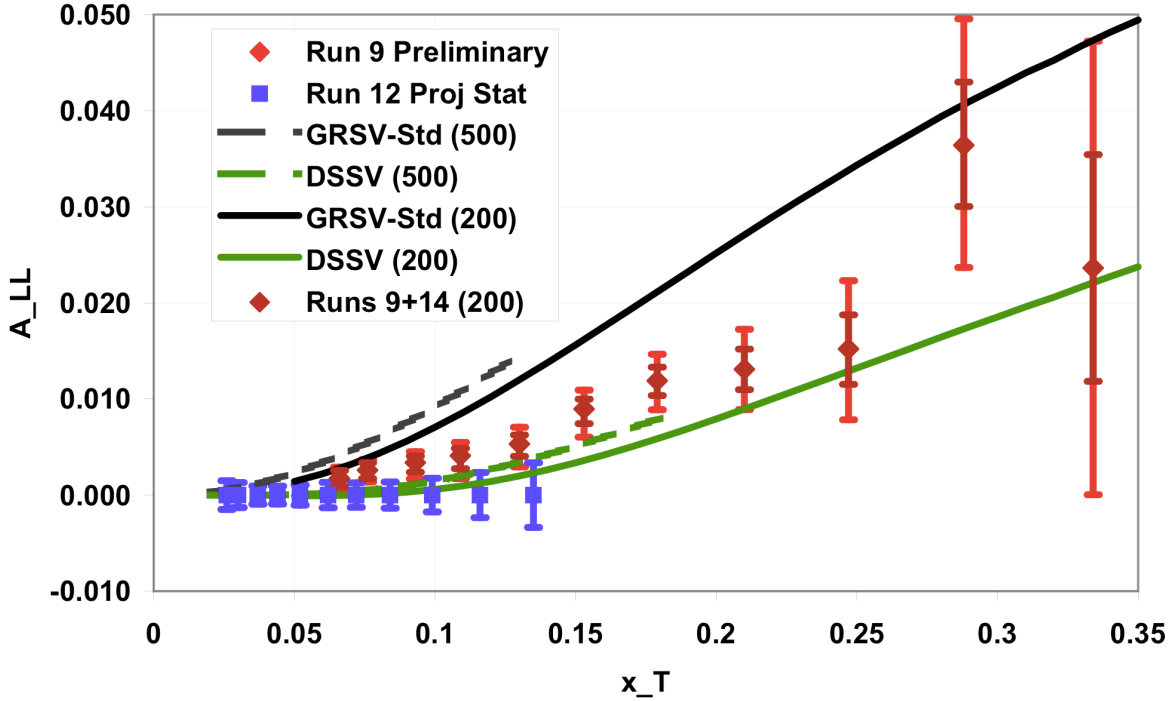
- Higher energy accesses lower x_g
- Expect smaller A_{LL}
- Uncertainties shown are purely statistical

Run13: 165 pb^{-1} @ P = 55%

di-jets A_{LL}: P^4*L= 15 pb^{-1}

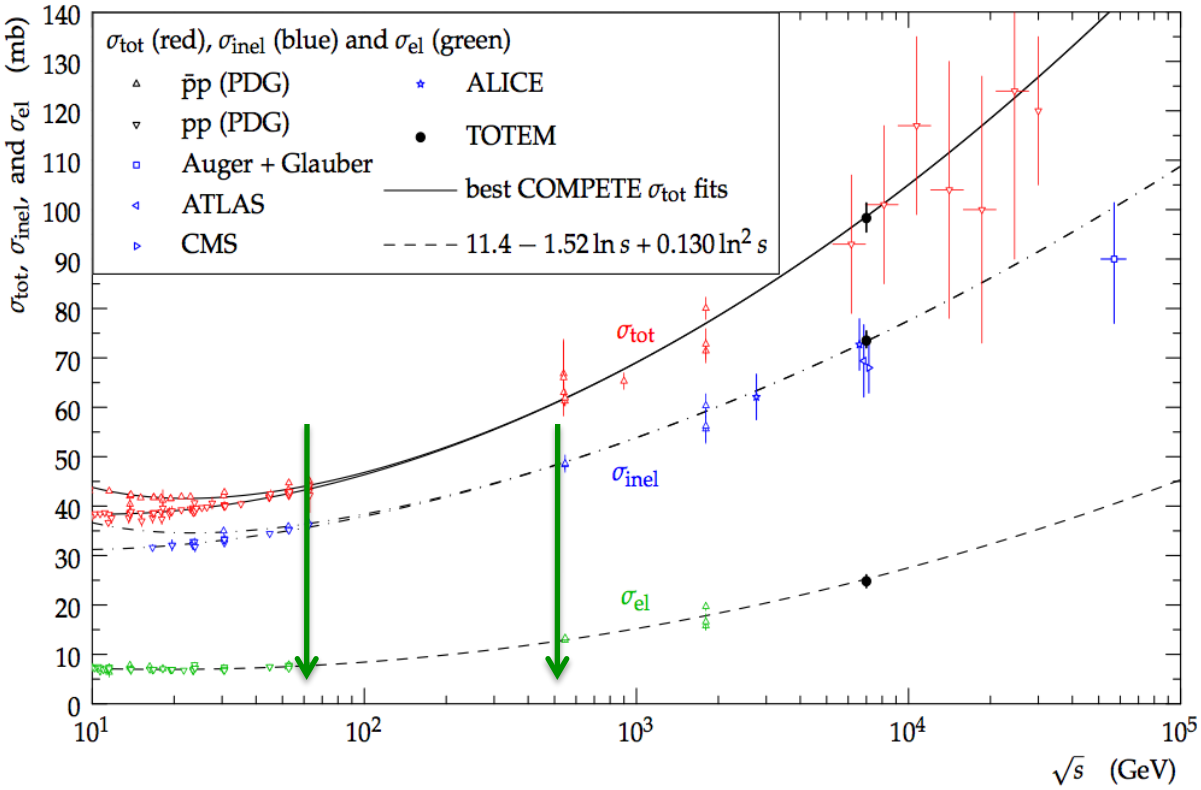
Expected Inclusive Jet A_{LL} Precision

Run9+Run14



- Run14 will provide a very useful complement to Run9
- During Run14, further reduce the 200 GeV uncertainties compared to Run9 by:
  - A factor of ~2 for jet p_T >~ 12 GeV
  - A factor of ~sqrt(2) for jet p_T <~ 12 GeV

Run13: 20x10^6 pp2pp Collisions

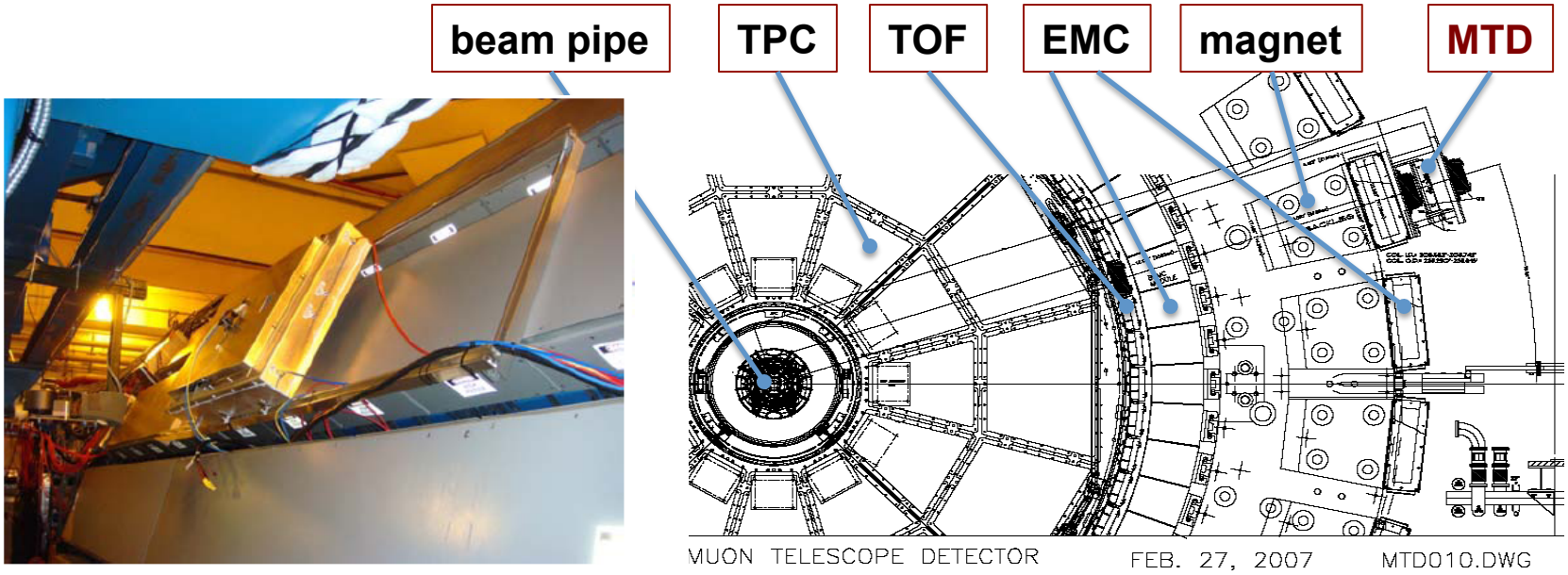


1) Four-day pp2pp data taking at the beginning of Run13. Minimize effects on other physics programs at RHIC. Request: 20x10^6

2) First data $\boldsymbol{\sigma_{TOT}}$, for example, at √s = 510 GeV with the Roman Pots and a large dataset of Exclusive Central Production

Run9, √s = 200 GeV pp2pp results are ready for submission to PLB

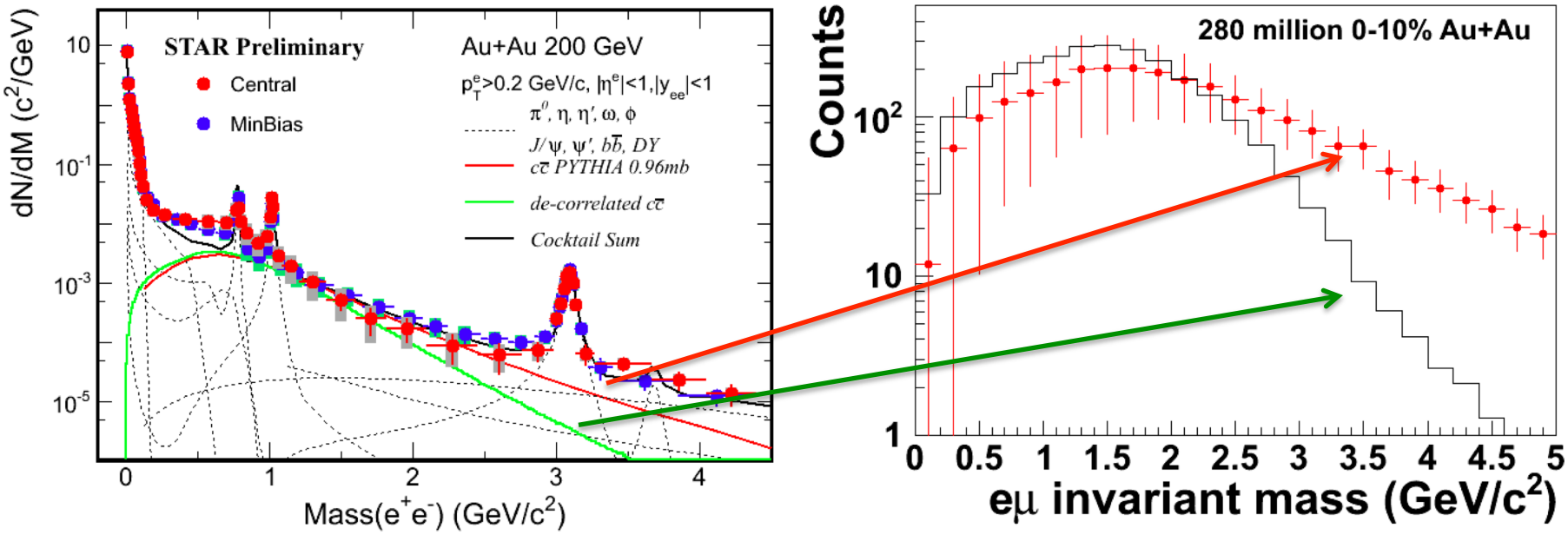
STAR: Muon Telescope Detector



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 ~ $10^{2\text{-}3}$
3) For high p_T muon trigger, heavy quarkonia, light vector mesons, B→J/Ψ+X
4) China-India-STAR collaboration
5) **Run13**: 43% MTD will be ready

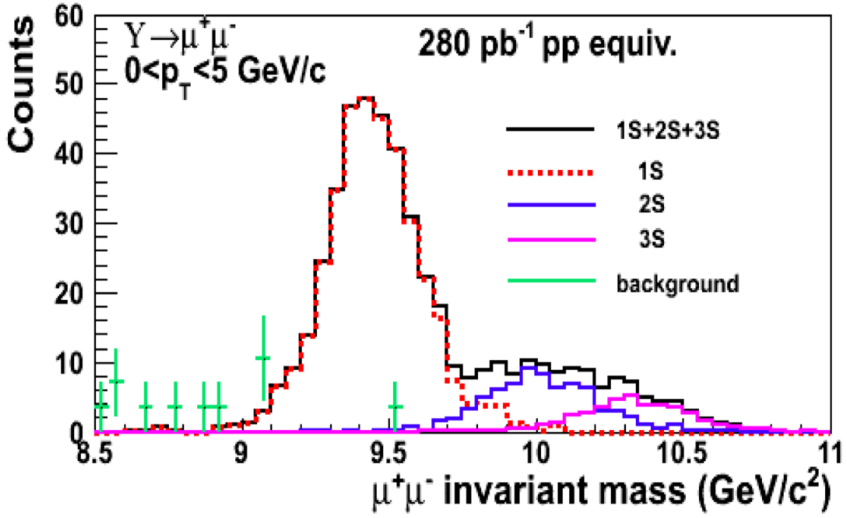
Run13 MTD: HF e-μ Correlations

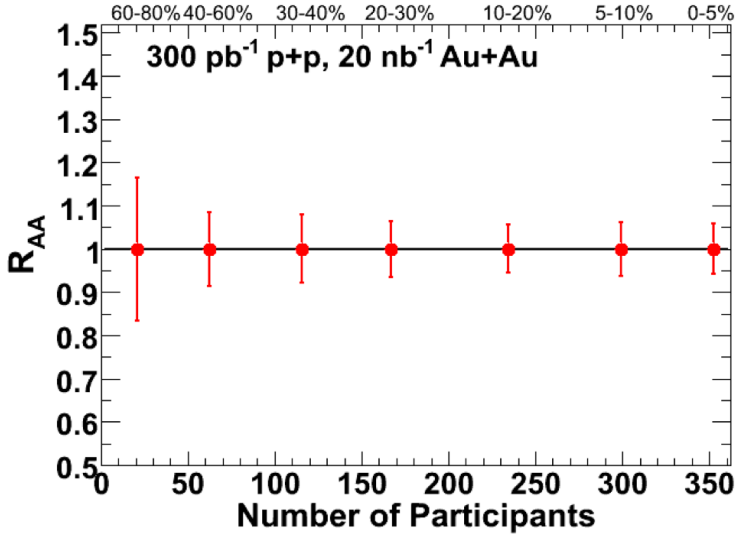


Run13: Four-week Au+Au collisions allow us:

1) Utilize the partially installed MTD to measure the e-μ correlations
2) Commissioning HFT in real HI environment, assure the success in Run14

MTD: Run14 and Beyond

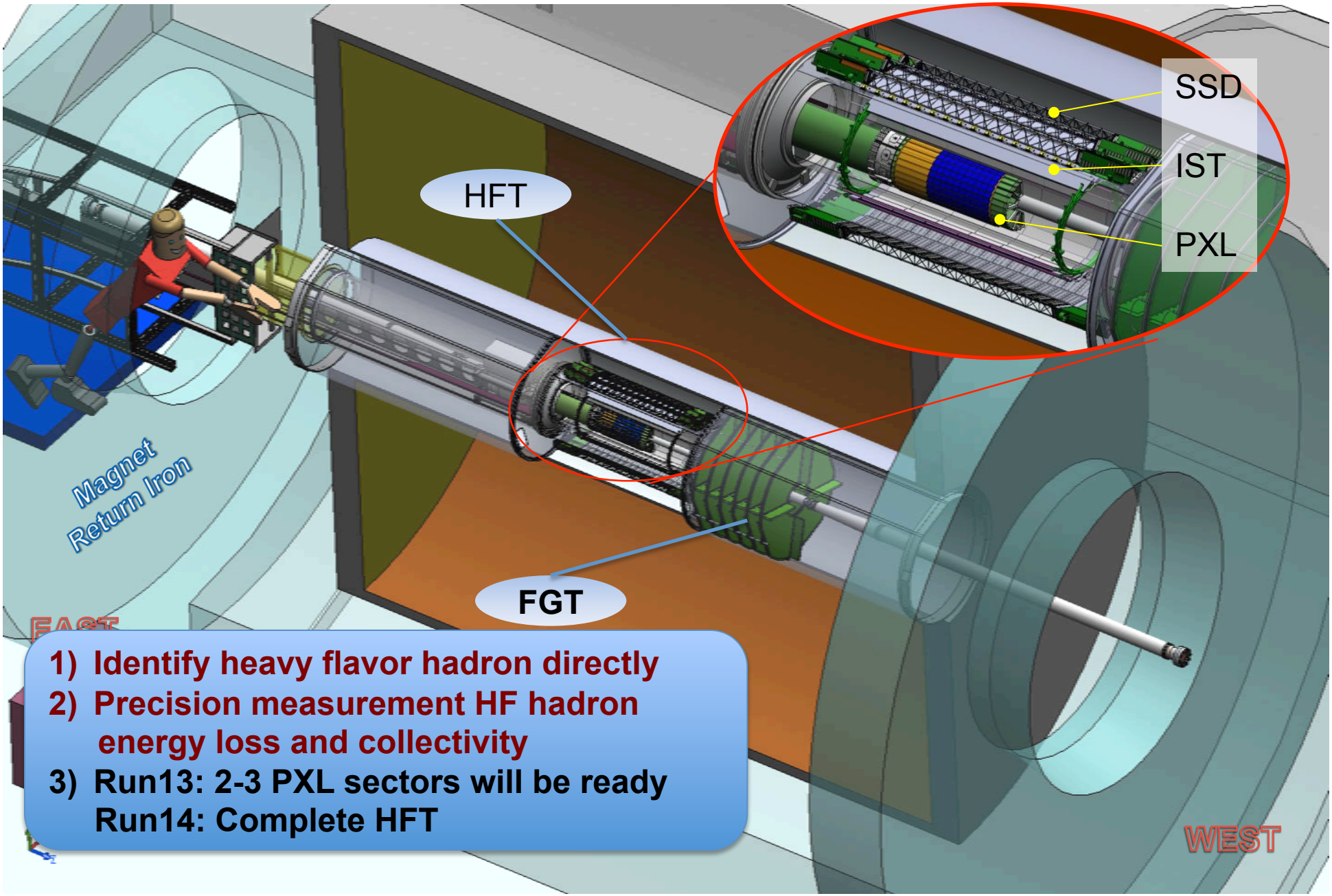




1) **Upsilon at RHIC:** unique, no regeneration, only initial production
2) **MTD at STAR:** Υ => $\mu\mu$, unique, no Bremsstrahlung tails, clean separation of the excited states

STAR multi-year program to accumulate sufficient luminosity

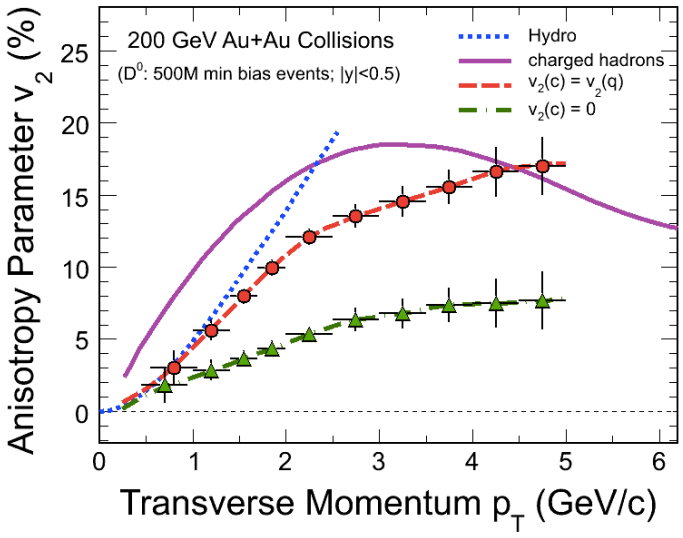
Heavy Flavor Tracker at STAR

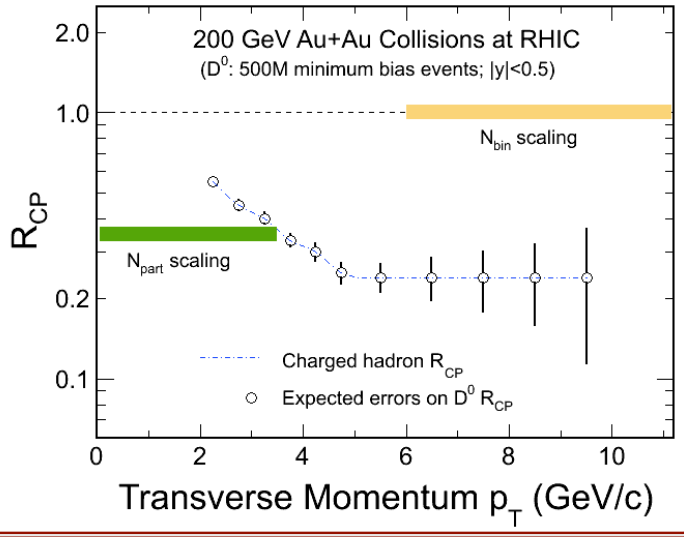


1) Identify heavy flavor hadron directly
2) Precision measurement HF hadron energy loss and collectivity
3) Run13: 2-3 PXL sectors will be ready
   Run14: Complete HFT

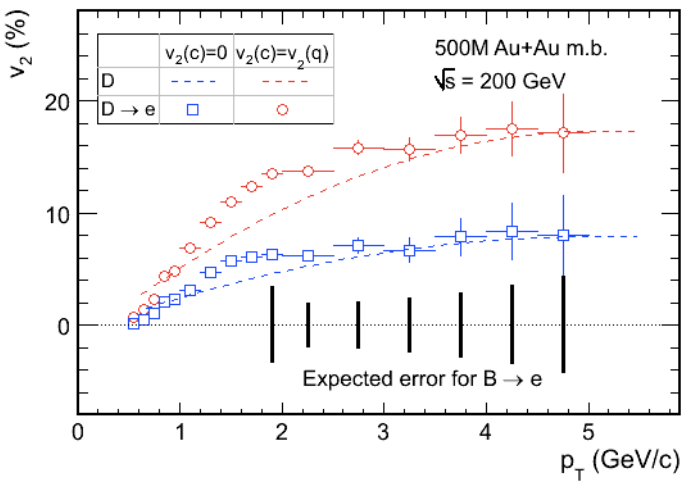
Run14: Physics Goals for HFT

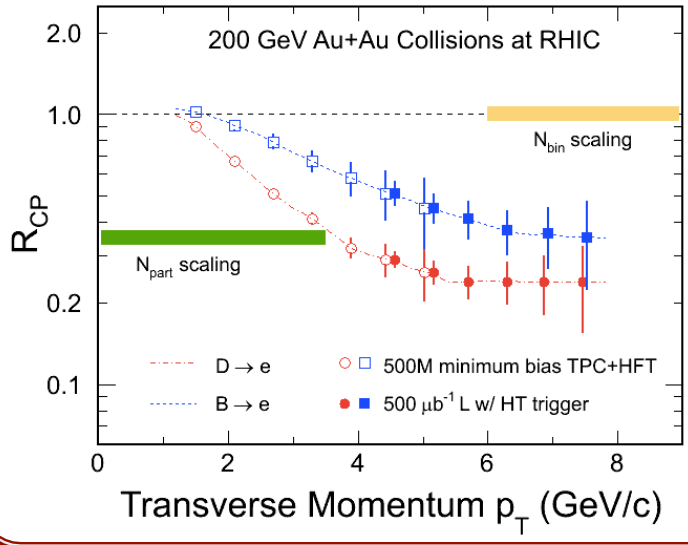
D^0 mesons



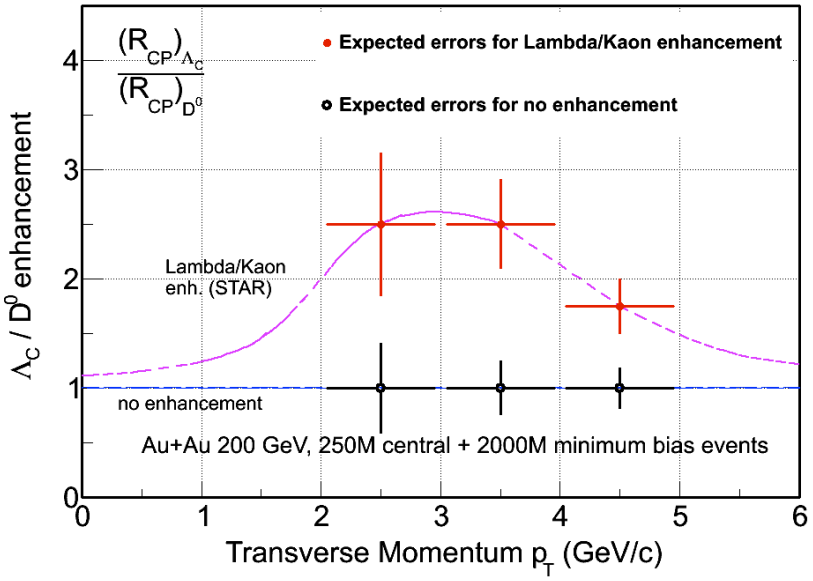


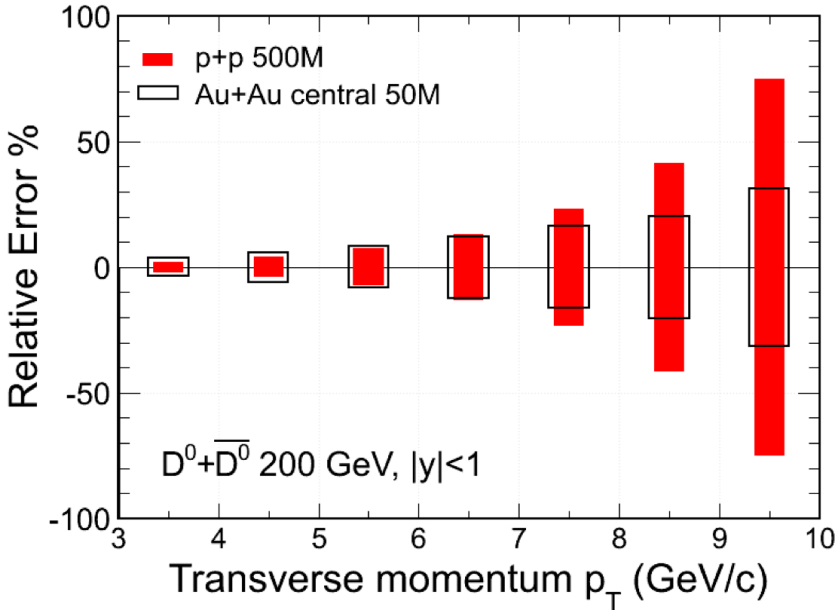
HF decayed electrons





HF Physics: Run14 and beyond





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

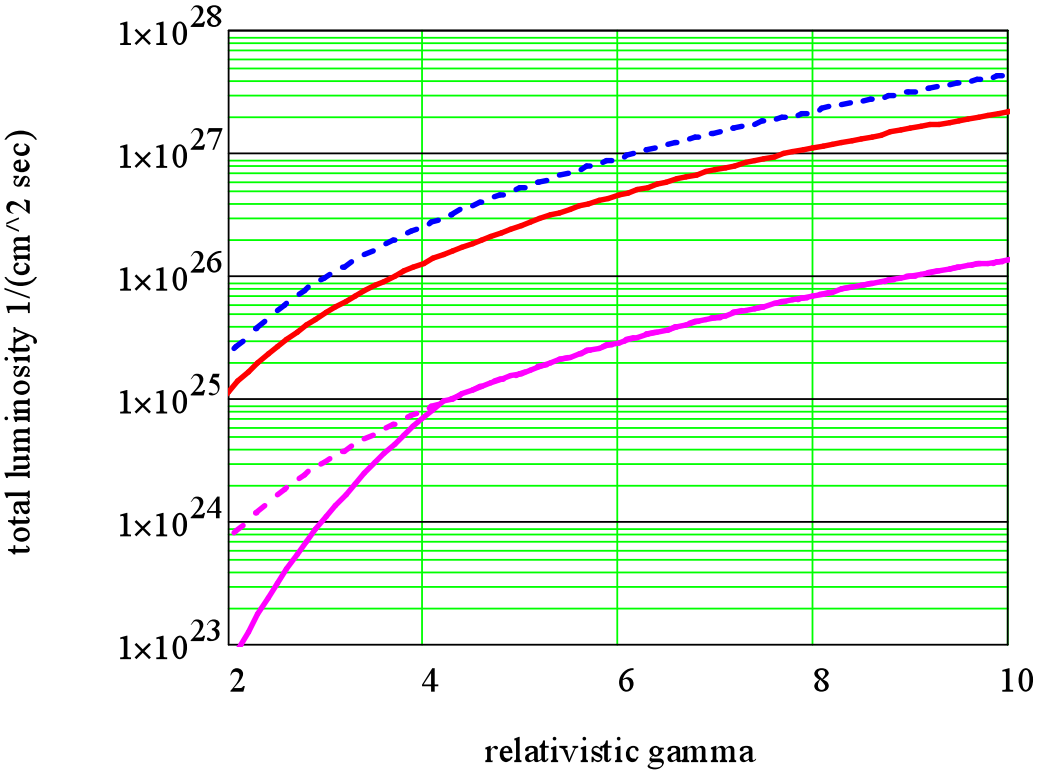
- Hadro-chemistry with charm
- Meson vs. baryon effect with charm hadrons

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

e-cooling at RHIC for BES-II

A. Fedotov, W. Fischer, private discussions, 2012.

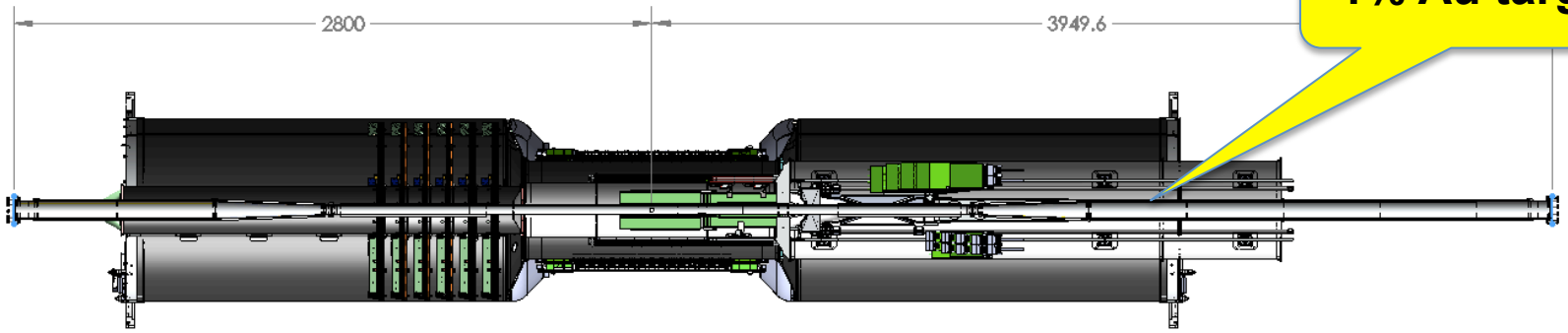
Fermi Lab Pelletron



$\sqrt{s_{NN}}$ (GeV)	~ 5	~ 20
Increasing factor*	3-5	10

- Request install the e-cooling device in FY13
- BES-II data taking in 2015 - 2017

Fixed-Target Mode



Collider mode $\sqrt{s_{NN}}$ (GeV)	Fixed-target mode $\sqrt{s_{NN}}$ (GeV)	Fixed-target mode μ_B (MeV)
19.6	**4.5**	585
15	**4.0**	625
11.5	**3.5**	670
7.7	**3.0**	720
5	**2.5**	775

1) Fixed-target data taking will be concurrently with collider mode. It can be done parasitically at the beginning of each filling.
2) Need CAD to install the 1% gold target.

Summary

STAR has been very effective and productive:

1) TOF, HLT, DAQ1k upgrades successfully completed.
   FGT, **MTD** and **HFT** upgrades are all on track.

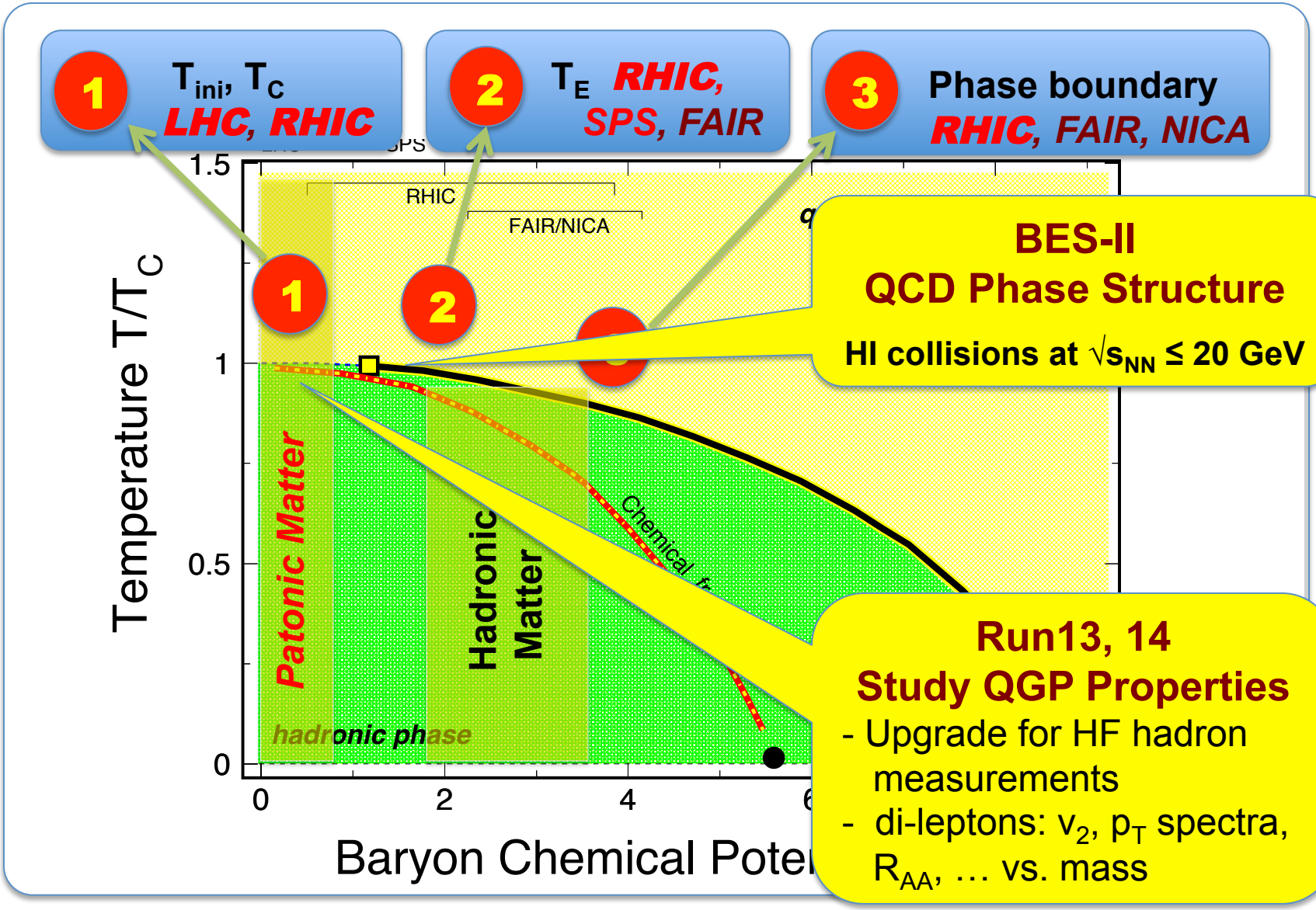
2) 200 GeV Au+Au collisions:
   - Large acceptance di-electron program started
   - Upsilon suppression vs. centrality

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

4) Spin Physics
   - First $W^{\pm}$ A_L and cross section results published
   - di-jet A_{LL} analysis in progress

5) Run12: High statistics, high quality data collected
   - pp 200GeV, 510GeV; UU 193GeV; CuAu 200GeV; AuAu 5GeV

BES-I,II: (5, 7.7, 11.5, 15.5, 19.6, 27, 39, 62.4, 200 GeV)



Runs13 & 14 Request

1) **Spin Physics (polarized p+p collisions)**
   - **$W^{\pm}$ A_L at both mid-y and forward-y (2013)**
   - σ_{TOT} and DPE at 510 GeV (2013)
   - Δg measurements at 200 GeV* (2014)

     * Reference data for heavy ion programs

2) **Heavy Ion Physics (Au+Au collisions)**
   - Physics with partial MTD and HFT engineering run (2013)
   - **Physics run with HFT+MTD (2014)**

3) **Install e-cooling for BES-II ($\sqrt{s_{NN}} \leq 20$ GeV)**

   Important item in STAR decadal plan

STAR BUR for Runs 13 and 14

Run	*	Beam Energy	Time	System	Goals
13	3	$\sqrt{s}$ = 510 GeV	4 days	$p_{\uparrow}\, p_{\uparrow}$	σ_{TOT}, A_N, A_{NN}, A_{SS}, Exclusive Central Production
	1		10 weeks	$p_{\rightarrow}\, p_{\rightarrow}$	i) $W^{\pm}$ A_L: P^2*L= 50 pb^{-1} ii) di-jets A_{LL}: P^4*L= 15 pb^{-1}
	2	$\sqrt{s_{NN}}$ = 200 GeV	4 weeks	Au + Au	i) MTD e-μ correlation, 2 nb^{-1} (280M central events) ii) HFT engineering run
14	1	$\sqrt{s_{NN}}$ = 200 GeV	10 weeks	Au + Au	i) HFT & MTD heavy flavor, 10 nb^{-1}(500M M.B.) ii) Fixed-target data taking
	2	$\sqrt{s}$ = 200 GeV	5 weeks	$p_{\rightarrow}\, p_{\rightarrow}$	i) Heavy ion reference data L= 40 pb^{-1} (500M M.B.) ii) Δg, L= 40 pb^{-1}

Run 13: 20 cryo-week. 510pp: 55% polarization

Run 14: 20 cryo-week. 200pp: 65% polarization

* Physics priorities