STAR Experiment at RHIC

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for the STAR Collaboration

Nuclear Science Division
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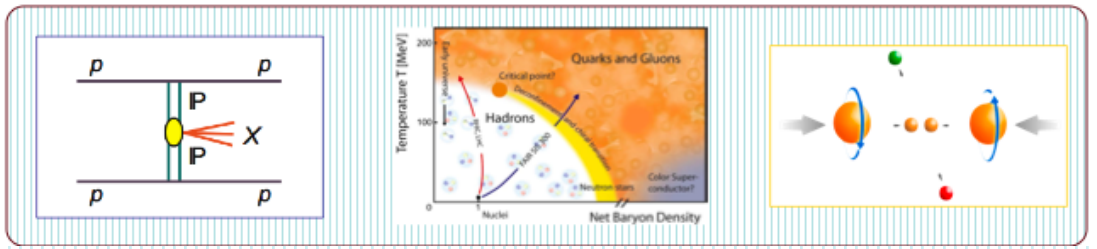


Outline

(1) Introduction
- Collaboration membership status
- Graduate students
- Publications and physics focus

(2) Run 11 performance and recent results

(3) *Decadal Plan* and *eSTAR Task Force*

(4) Ongoing upgrades and issues

STAR Collaboration Membership

STAR Membership:

U.S. Labs: Argonne, Lawrence Berkeley, Brookhaven

U.S. Universities: UC Berkeley, UC Davis, UCLA, Creighton, Indiana, UIC, Kent State, MSU, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale, MIT, Kentucky, Old Dominion, Houston

Brazil: Universidade de Sao Paulo, Universidade Estadual de Campinas

China: IOPP, USTC, Tsinghua U, SINAP, IMP, ShanDong U

Croatia: Zagreb U

Czech Republic: Institute of Nuclear Physics, Czech Technical U

France: *Institut de Recherches Subatomiques Strasbourg*, SUBATECH

Germany: Frankfurt

India: IOP, Jammu, IIT-Mumbai, Panjab U, Rajasthan, VECC

Poland: Warsaw U of Technology, Cracow group

Russia: MEPHI, JINR, IHEP, ITEP

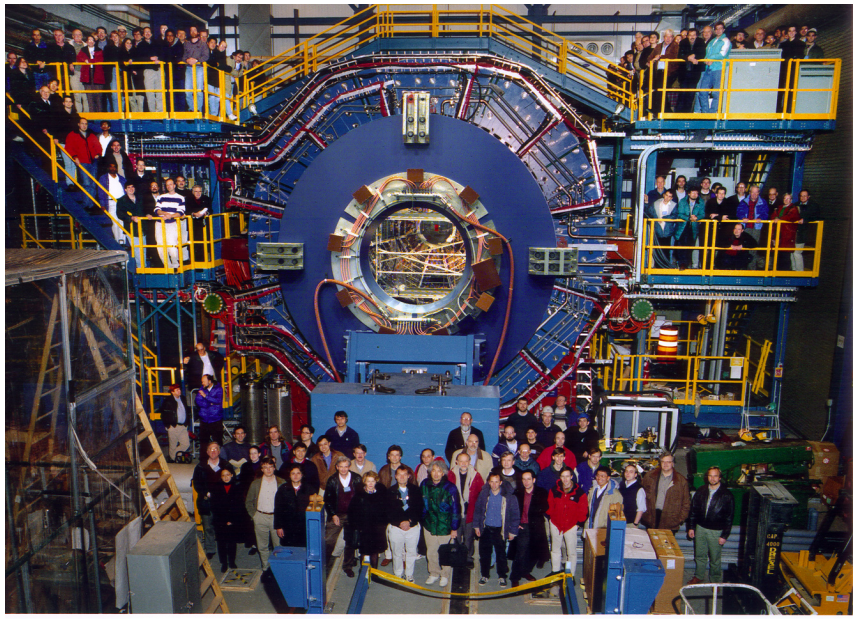
South Korea: Pusan National U, KISTI

1) 10 new institutes joined STAR since 2008
4 institutes left STAR since 2008 (LHC)

2) ~ 68% institutes are very active
~ 25% institutes are fairly active

3) New institutes have applied for membership:
(1) HIT, China: two-particle correlation
(2) GSI, Germany: Hypernuclear production

4) **New election**: May 18th Collaboration meeting



12 countries; 52 active institutes
~ *555* scientists and engineers
~ 396 scientific paper authors

Research topics at the QCD Lab:
- properties of sQGP & QCD critical point
- proton spin structure
- gluonic matter: CGC, DPE

List of degree recipients: *153 PhD and 21 other degrees awarded on STAR research to students at 36 institutions*

Jammu University
2009 Sunil Manohar Dogra
2009 Neeraj Gupta

Max-Planck-Institut
2005 Frank Simon
2004 Joern Putschke
2002 Markus Oldenburg
2000 [illegible]
1997 [illegible]

MS
2002

Oh
2009
2004
2004
2003
2002

Pa
2010
2008

Pu
2010
2008
2007
2006
2002

Ric
2010

US
2011
2009
2009
2007 [illegible]
2007 Yifei Zhang
2005 Xin Dong
2004 Shengli Huang
2004 Lijuan Ruan

IOP, Bhubaneswar
2010 Sadhana Dash
2007 R. Sahoo
2003 D. Misra
2005 A. Dubey

VECC
2008 P. Netrakanti
2007 D. Das
2005 S. Das

SUBATECH
2010 Artemios Geromitsos
2005 Magali Estienne
2004 Gael Renault
2003 Ludovic Gaudichet
2002 Javier Castillo
2000 Fabrice Retiere
2000 Walter Pinganaud

2009 Christine Nattrass
2008 Oana Catu
2007 Betty Abelev
2006 Sevil Salur
2005 Mark Heinz
2004 Jon Gans
2003 Haibin Zhang
2003 Michael Miller
2002 Matthew Horsley
2001 Manuel Calderon

IUCF
2008 Weihong He

SINAP
2010 Jian Tian
2010 Fu Jin
2009 Xinghua Shi
2009 Song Zhang
2008 Jin-Hui Chen

University of Birmingham
2010 Essam Elhalhuli
2009 Thomas Burton
2008 Anthony Timmins
2008 Leon Gaillard
2005 John Adams
2002 Matthew Lamont

UC – Los Angeles

2006 Thomas Henry

NIKHEF/Utrecht
2011 Ermes Braidot
2008 Federica Benedosso
2008 Martijn Russcher
2007 Yuting Bai
2007 Oleksandr Grebenyuk

MIT
2011 Matt Walker
2010 Tai Sakuma
2009 Alan Hofmann
2008 Julie Milane

Wayne State University
2010 Sarah LaPointe
2010 Muhammad Elnimr
2006 Ahmed Hamed
2005 Ying Guo
2005 Alexander Stolpovsky

Nucl. Physics Inst., Prague

LBNL
2008 Xiangming Sun
2007 Sarah Blyth
2007 Mark Horner
2003 Vladimir Morozov

LPP, JINR, Russia
2006 Alexei Zubanov

MEPhI, Moscow, Russia
2007 Sergei Timoshenko

University of Zagreb
2010 Nikola Poljak

153 Ph.D degrees
21 other degrees

(Since last review: 18)

STAR continues to do an excellent job of educating the next generation of physicists!

Blue = awarded 2010- 2011

STAR Publications

Total # of refereed publications: 138 !
- *Phys. Rev. Lett*: 53, *Phys. Rev*: 56, ***Science:* 1; *Nature:* 1** …

2010-2011: Total # of publications since last review: 14
- *Phys. Rev. Lett*: 4, *Phys. Rev*: 8, *PLB: 1; Nature: 1*
  and 4 manuscripts are in referee process.

Quark Matter Conference 2011:
4 + 2 plenary talks // 13 parallel talks // 28 posters

STAR is well focused and productive!

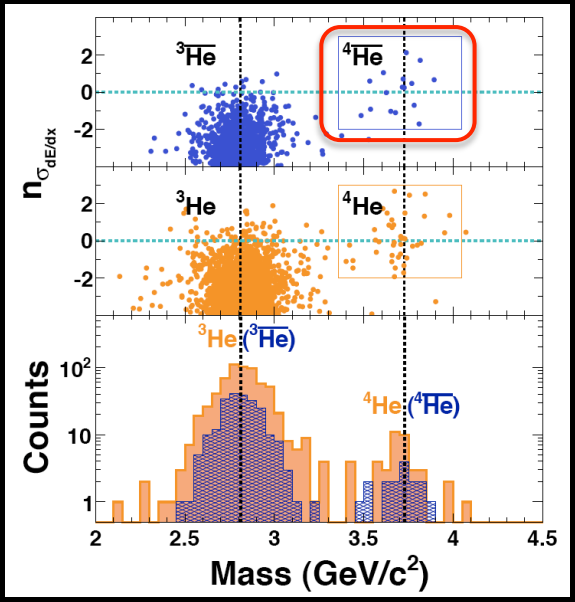
Antimatter Discoveries by STAR at RHIC

nature April, 2011

"Observation of the Antimatter Helium-4 Nucleus"

by ***STAR Collaboration***

Nature*, 473, 353(2011).*

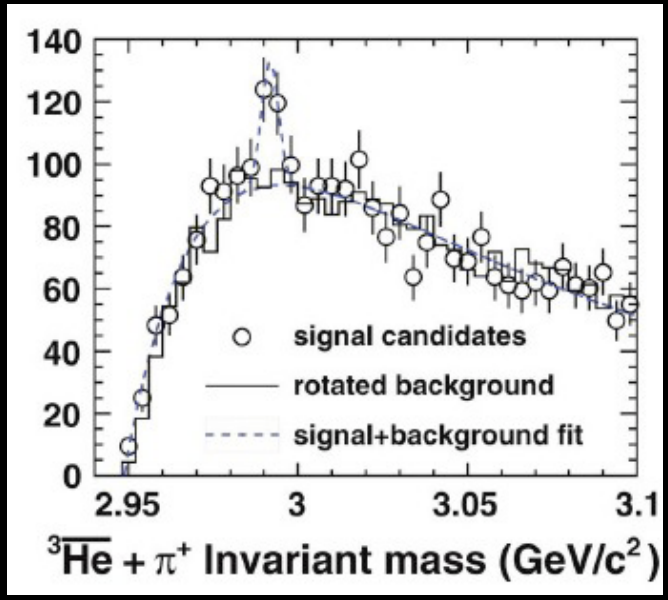


Science March, 2010

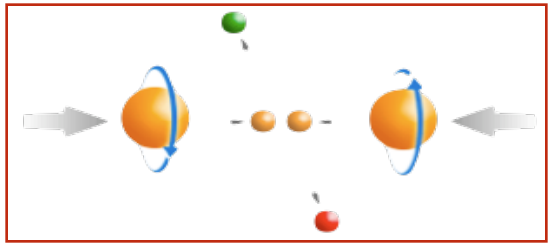
"Observation of an Antimatter Hypernucleus"

by ***STAR Collaboration***

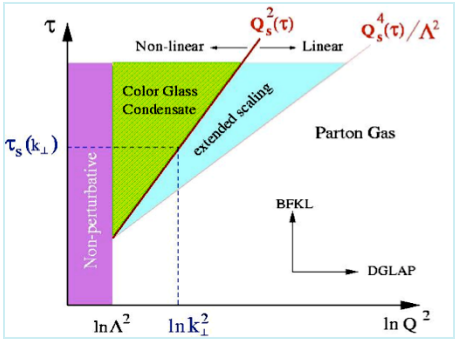
Science*, 328, 58(2010).*



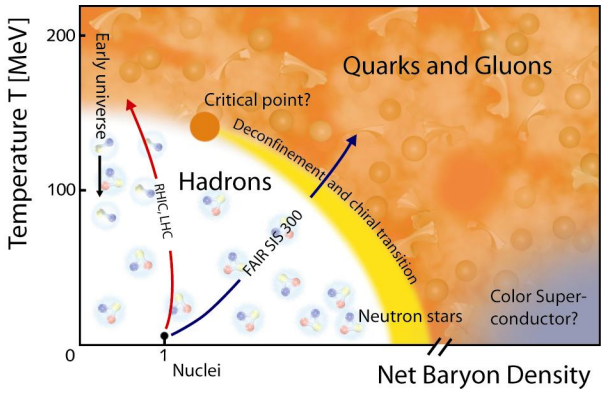
STAR Physics Focus



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



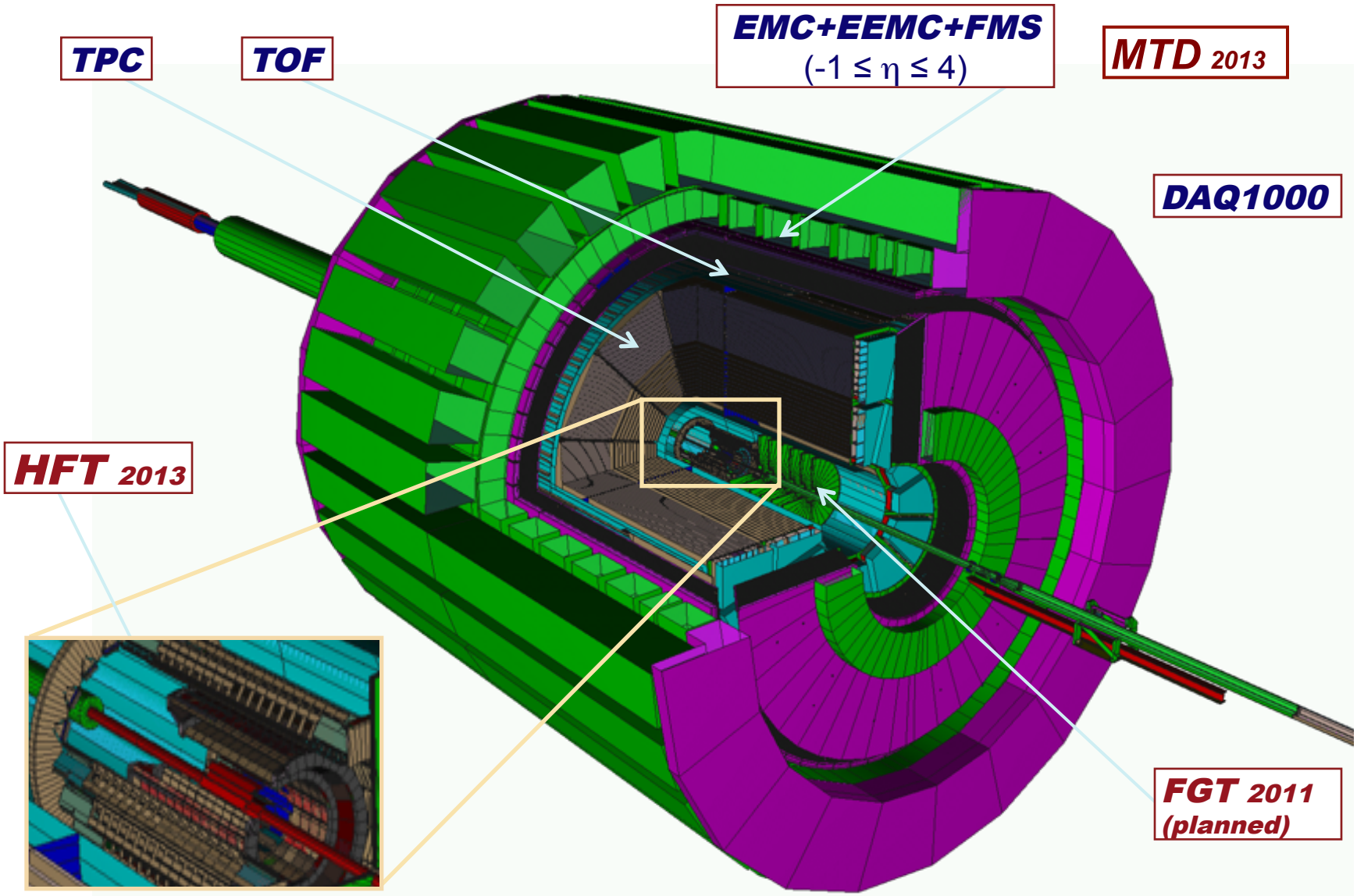
Forward program
- Study low-x properties, search for ***CGC***
- Study elastic (inelastic) processes (pp2pp)
- Investigate ***gluonic exchanges***



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

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

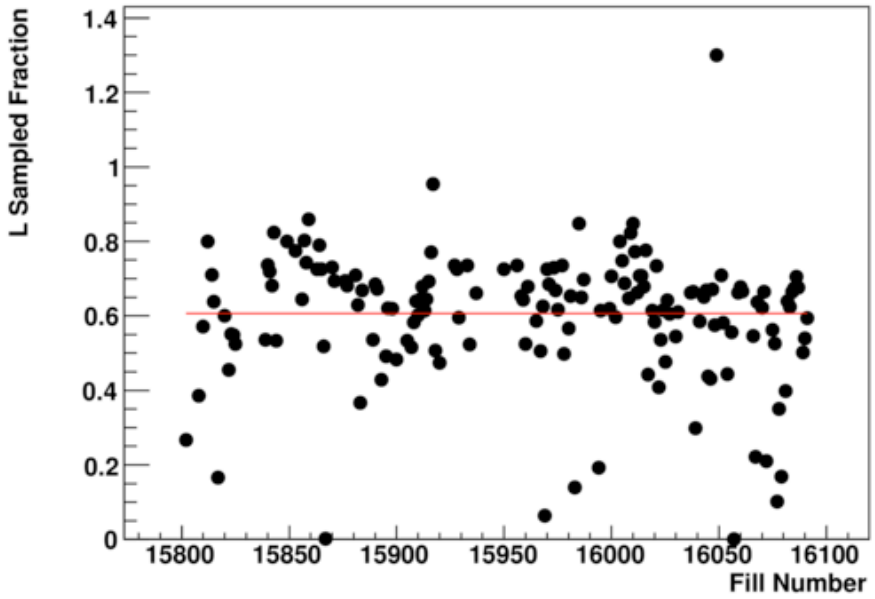
STAR Detectors *Fast and Full azimuthal particle identification*



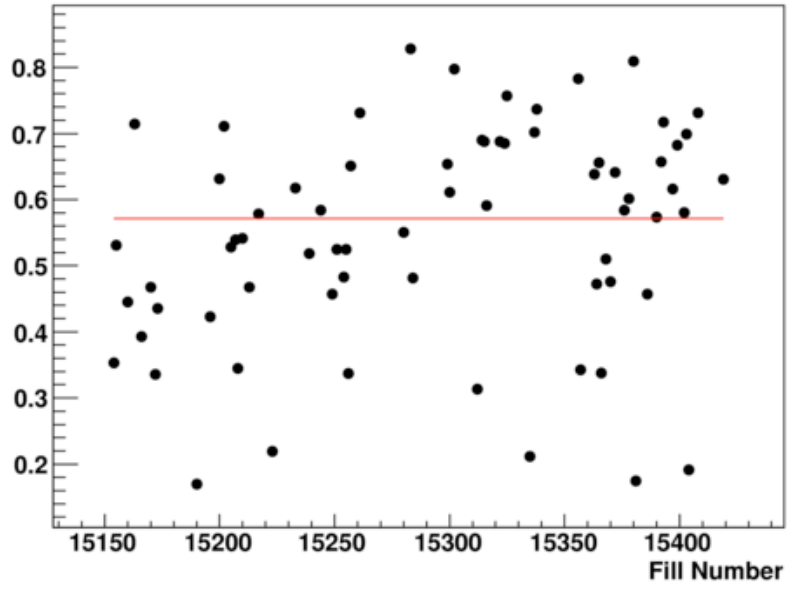
(2) Run 11 performance and recent physics results (selected)

STAR Efficiencies

200 GeV Au+Au Collisions



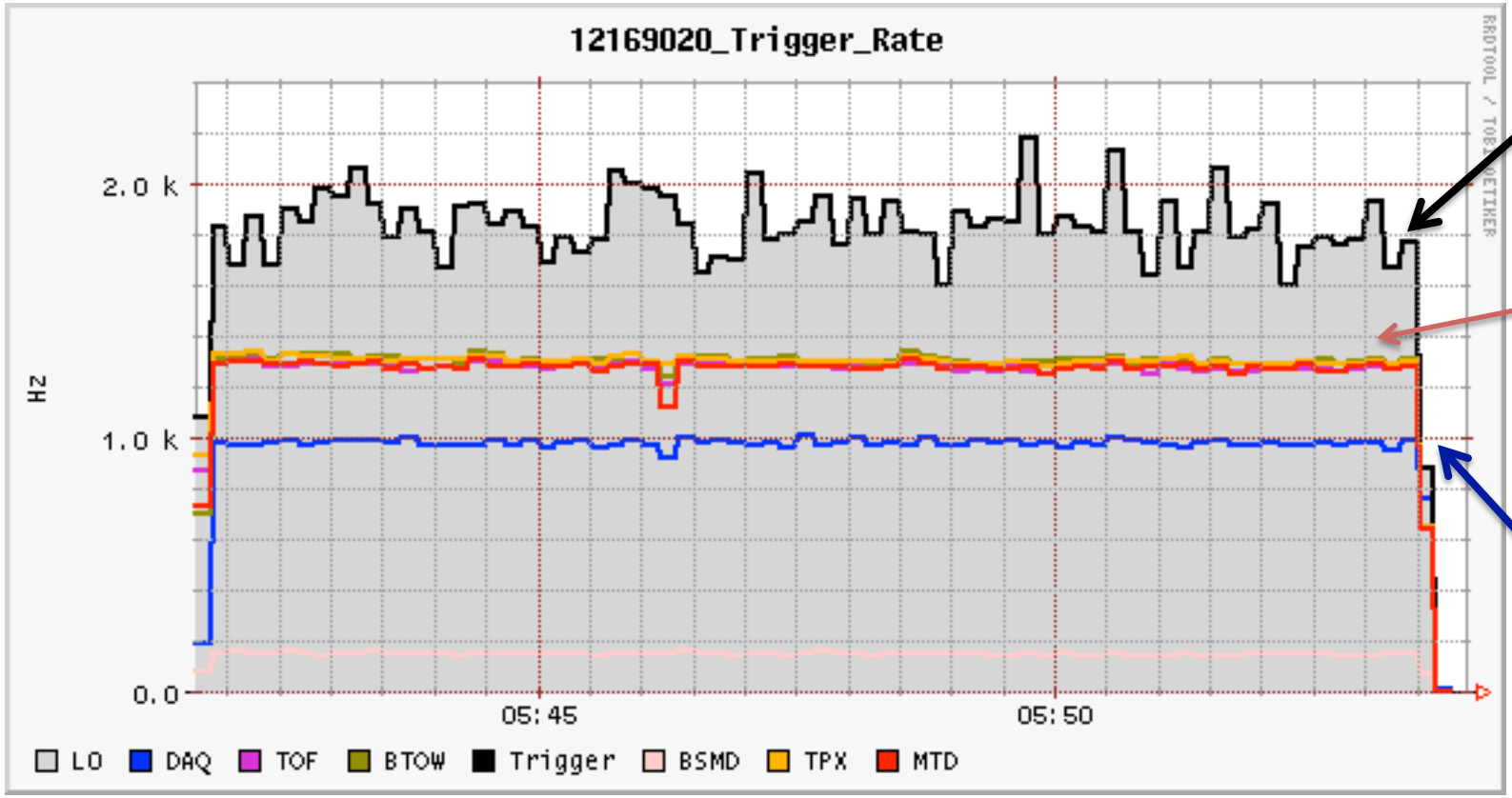
500 GeV p+p Collisions



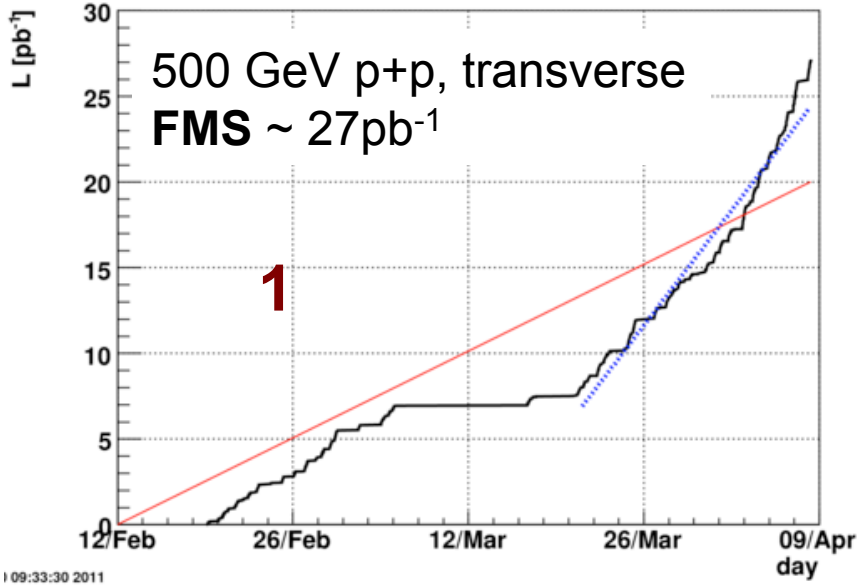
Average of Delivered luminosity samples is:
57% (pp 500) and 61% (AuAu200)

- includes: live time, turning on/off, problems, pedestals, commissioning …

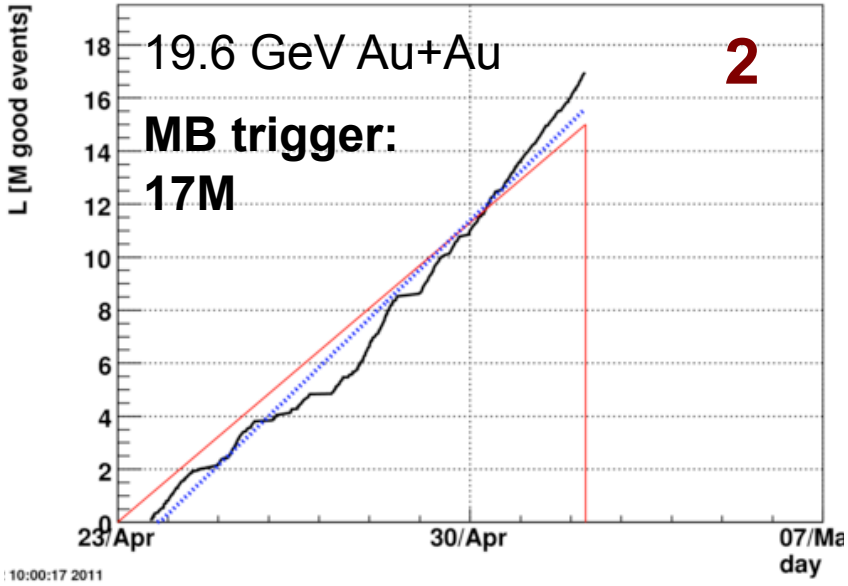
A Typical Run

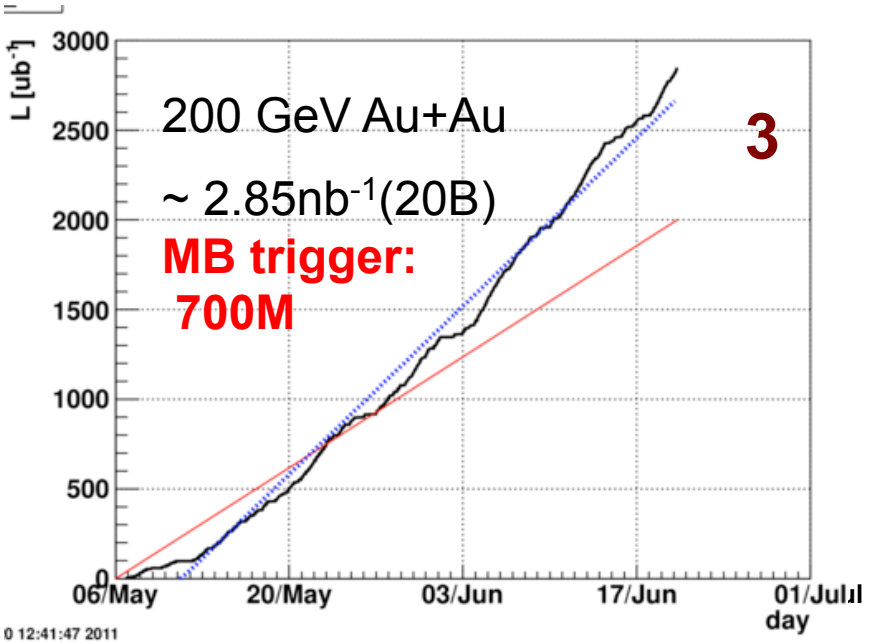


Run11: Integrated Luminosities



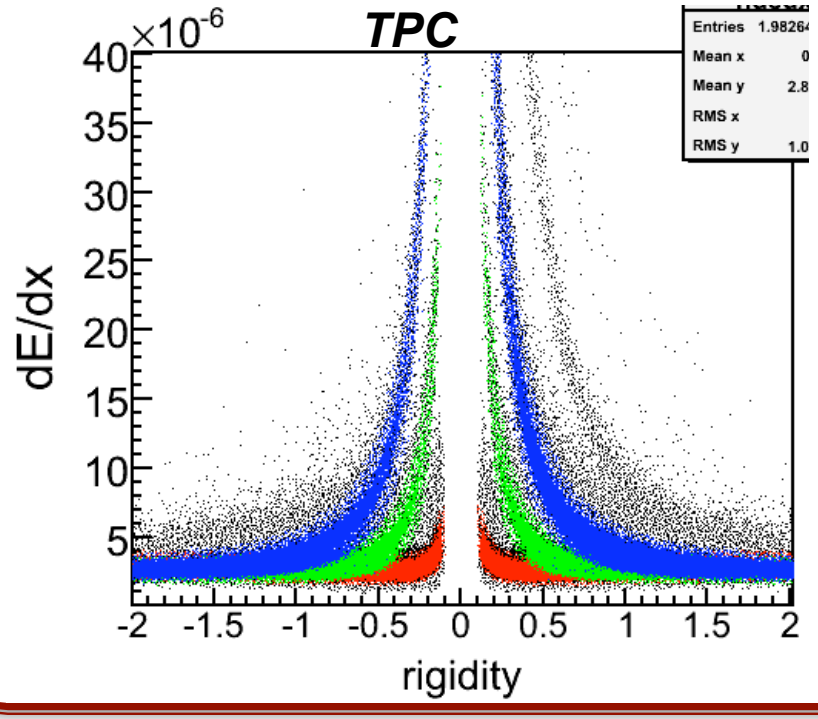
1) 500 GeV transverse p+p collisions
   - FMS, small-x
2) 19.6 GeV Au+Au collisions
   - critical point search
3) 200 GeV Au+Au collisions
   - di-electron and Upsilon
4) Taking data at 27 GeV

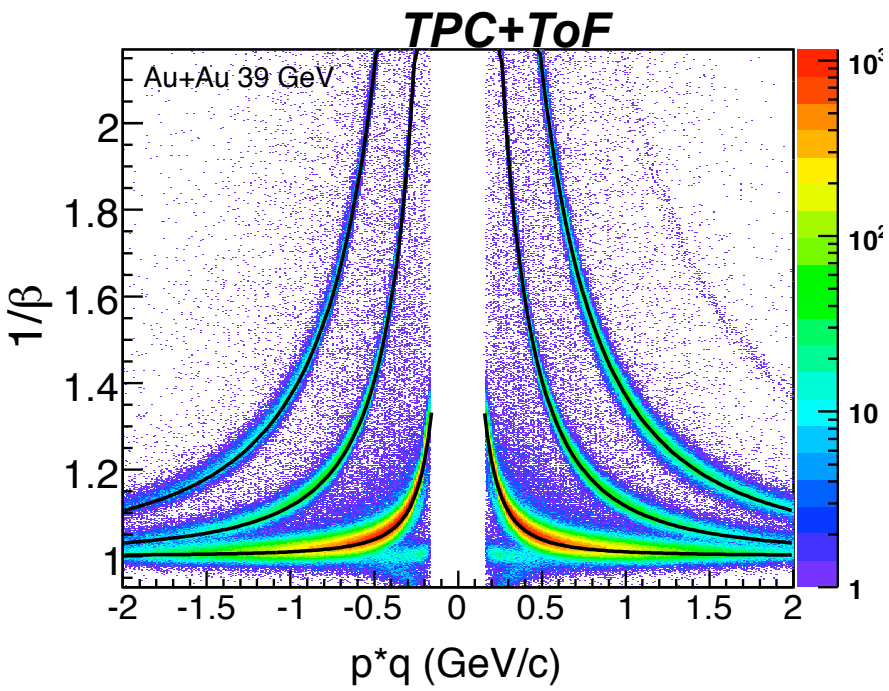




New TOF Performance

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

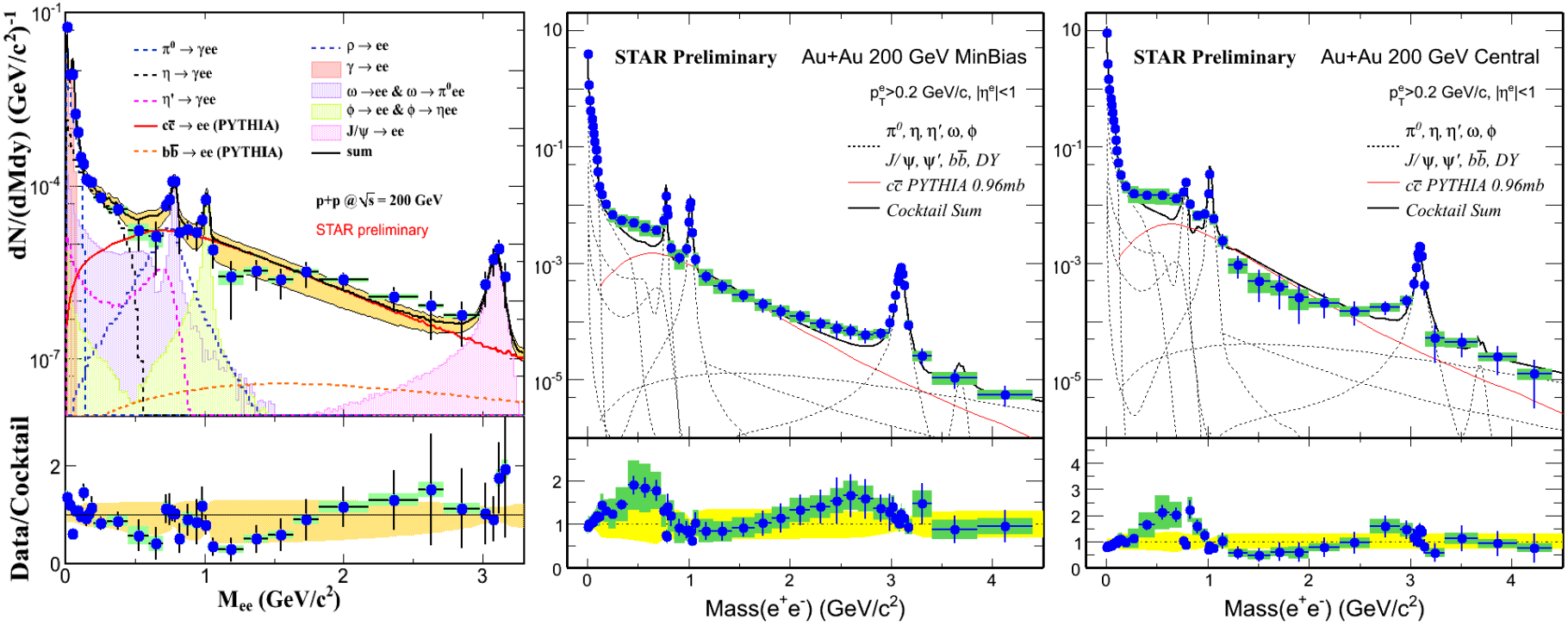




Beam Energy	Timing Resolution	Remarks
200 (GeV)	85 (*ps*)	At 39 GeV, using a new calibration scheme without information of start time from VPD, 87 *ps* of timing resolution has been achieved.
62.4 (GeV)	90 (*ps*)	
39 (GeV)	85 (*ps*)	
11.5 & 7.7 (GeV)	~ 80 (*ps*)	

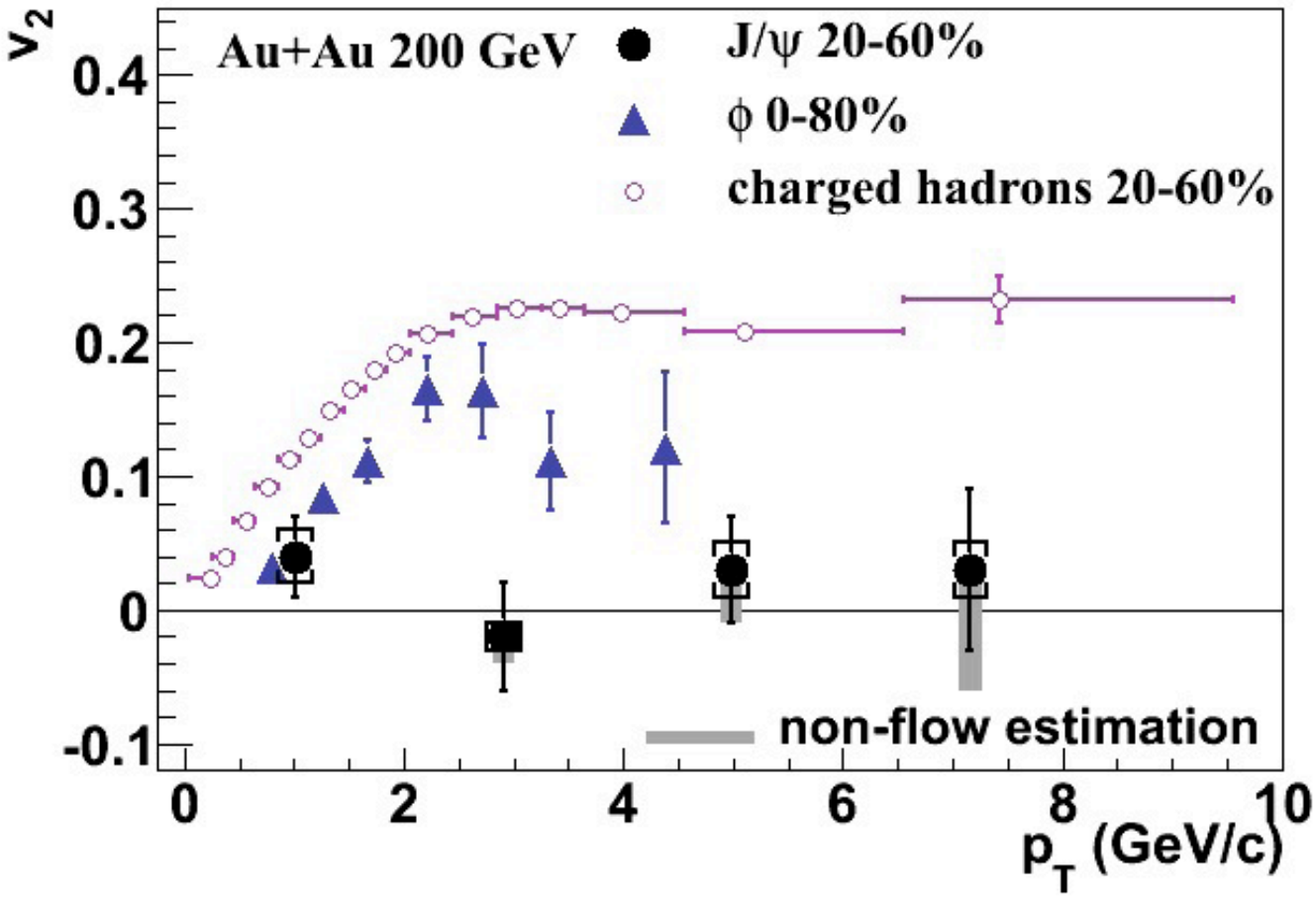
STAR Di-electron Program

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



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.

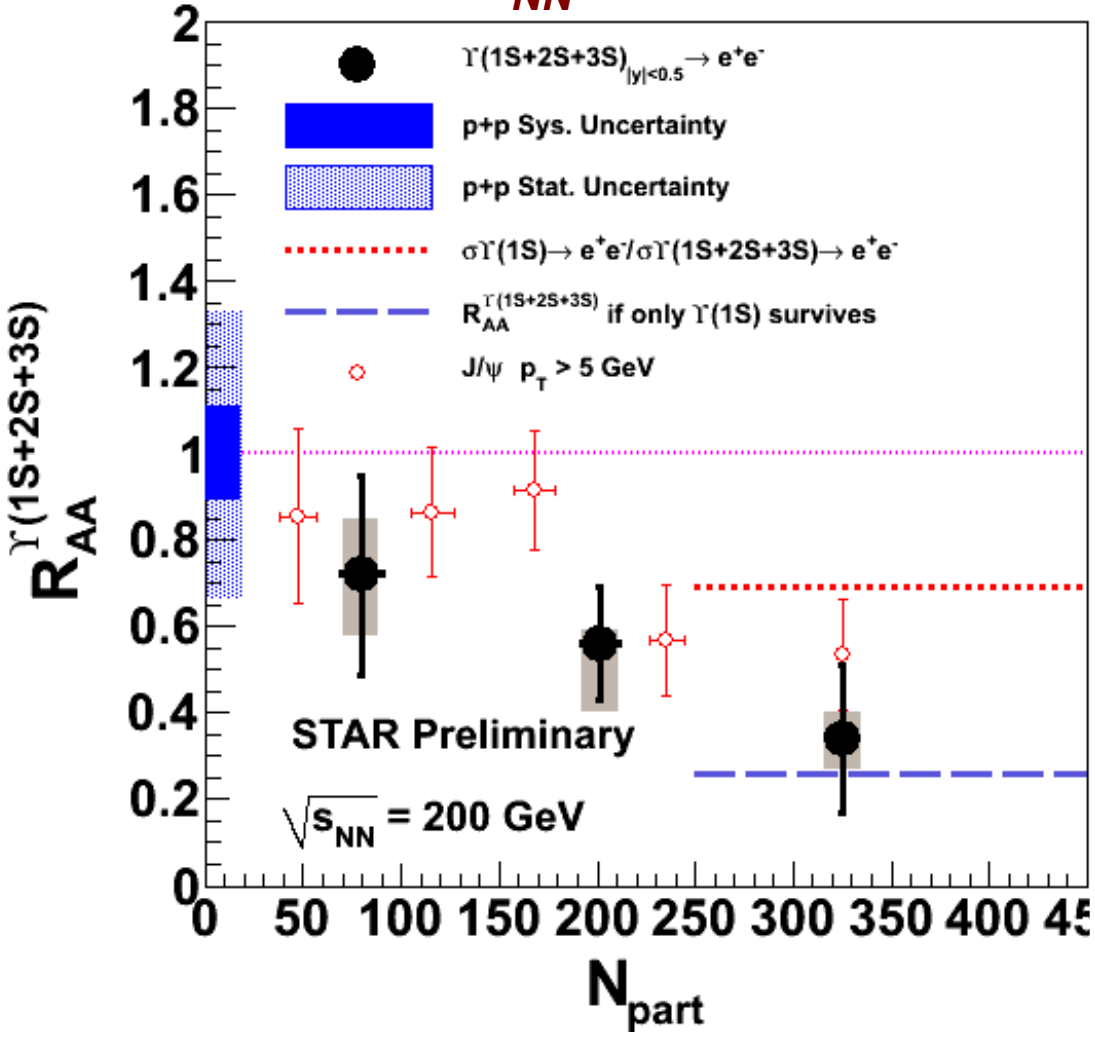
v_2 of J/ψ vs. p_T



1) STAR: **TPC + TOF + HLT**
2) $v_2^{J/\psi}(p_T) \sim 0$ up to $p_T = 8$ GeV/c in 200 GeV Au+Au collisions
3) Either ***c*-quarks do not flow** or **coalescence is not the dominant process for J/ψ production at RHIC.**

Υ(1S+2S+3S) R_{AA}

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



1) STAR Triggered

2) In central collisions, Υ(1S+2S+3S) is suppressed, 3σ away from R_{AA} = 1!

3) R_{AA} (0-60%)= 0.56±0.11 (stat)+0.02-0.14(sys)

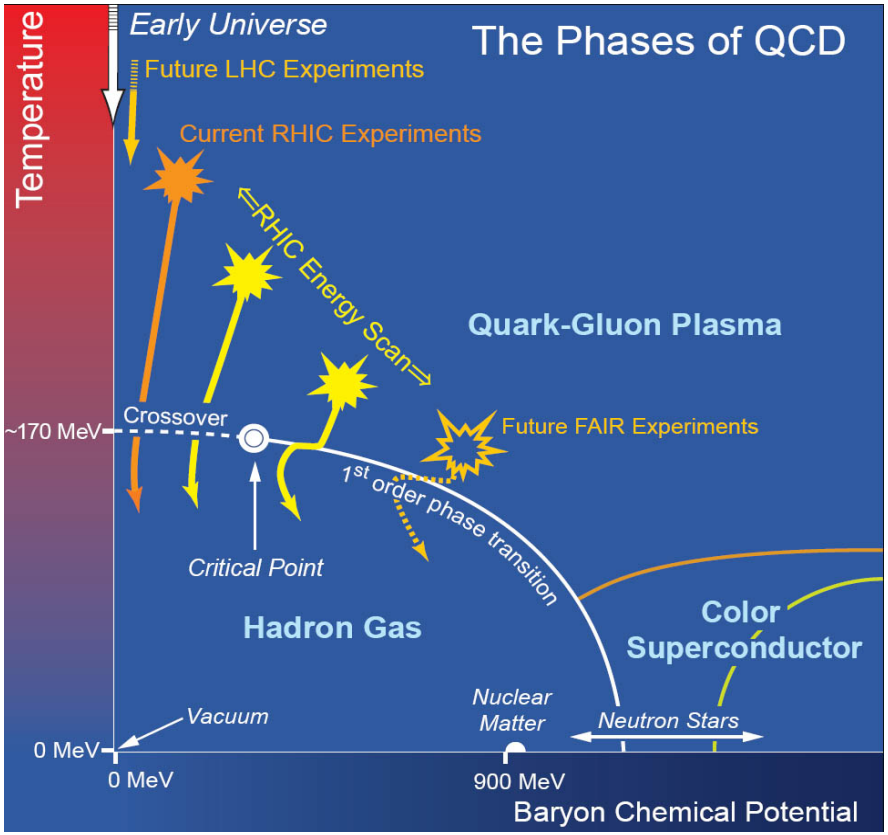
   R_{AA} (0-10%)= 0.34±0.17 (stat)+0.06/-0.07(sys)

Beam Energy Scan at RHIC

Motivations:

Signals of phase boundary

Signals for critical point



Observations:

(1) v_2 - NCQ scaling:
partonic vs. hadronic dof

(2) Dynamical correlations:
partonic vs. hadronic dof

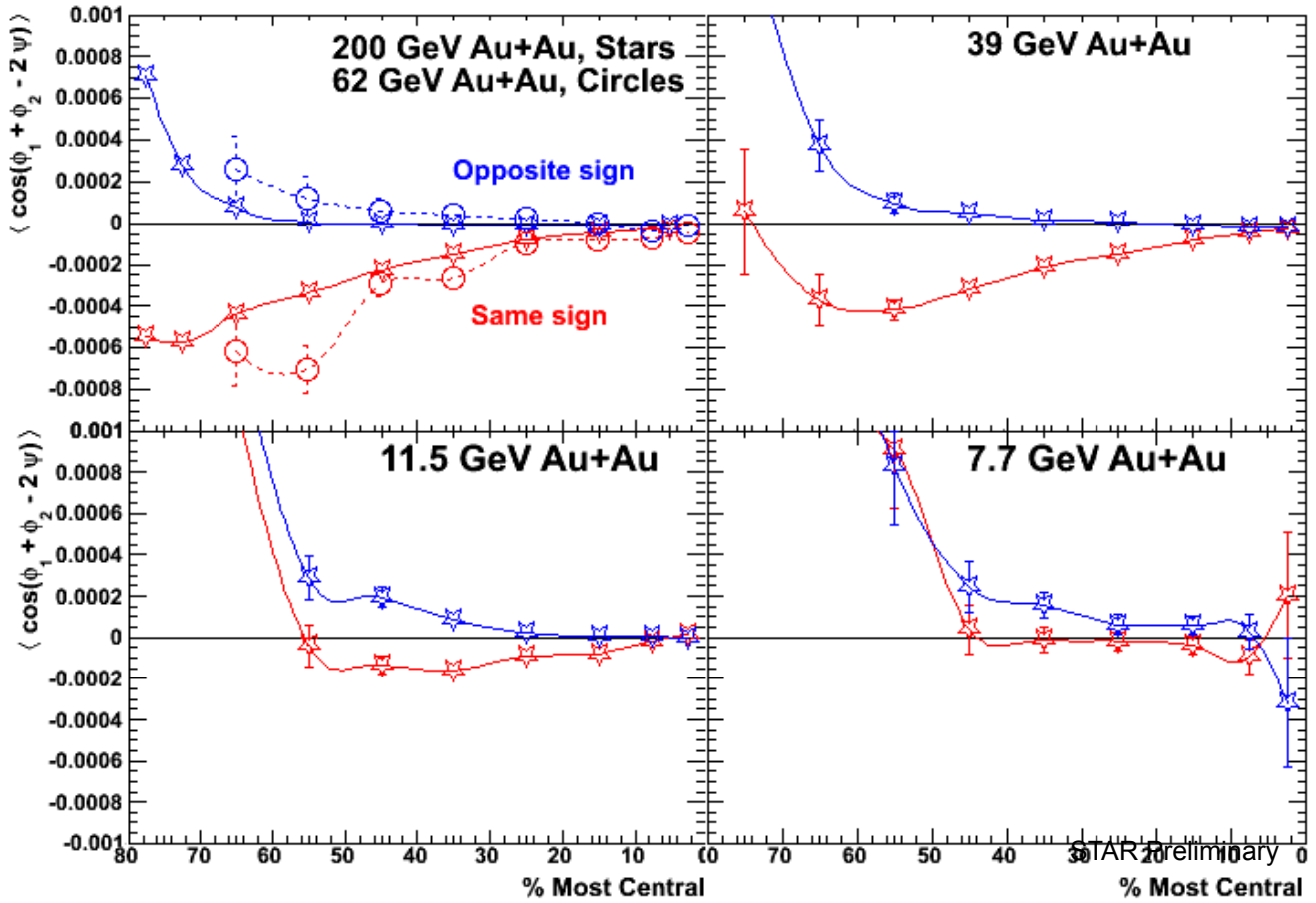
(3) Azimuthally HBT:
1st order phase transition

(4) Fluctuations:
Critical points

(5) Directed flow v_1
1st order phase transition

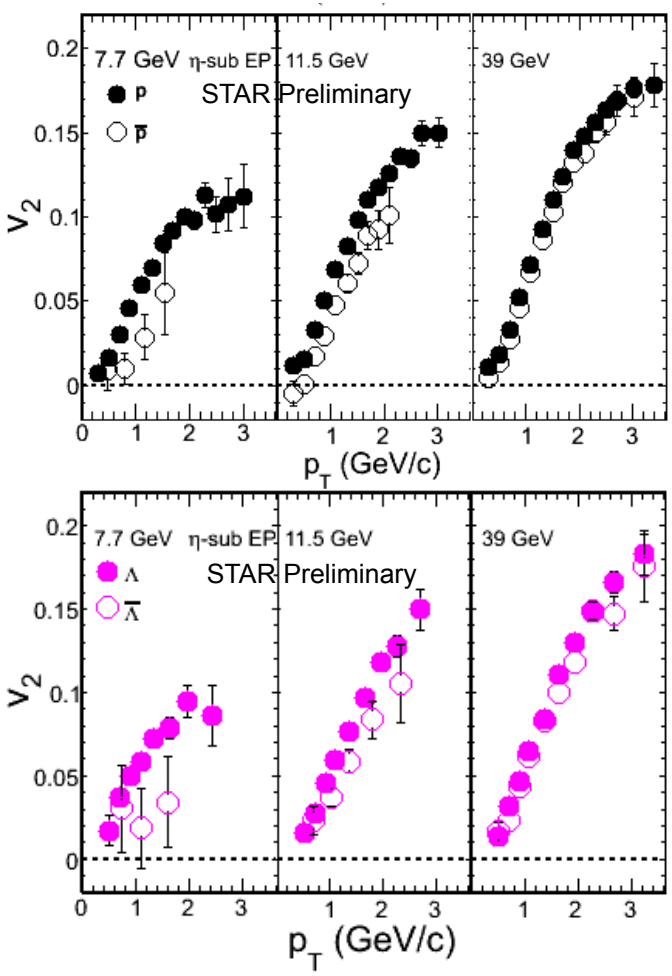
- http://drupal.star.bnl.gov/STAR/starnotes/public/sn0493
- *arXiv:1007.2613*

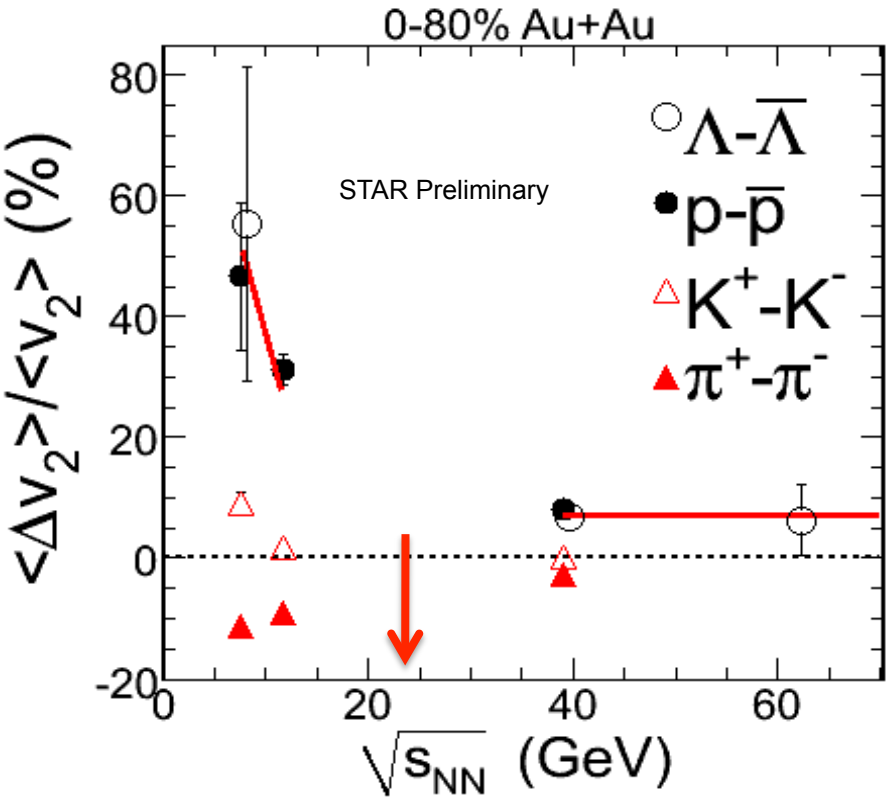
LPV vs. Beam Energy



1) Difference between same- and opposite-sign correlations decreases as beam energy decreases
2) Same sign charge correlations become positive at 7.7 GeV
3) Several different approaches in the collaboration

Particle and Anti-Particle v_2 vs. $\sqrt{s_{NN}}$

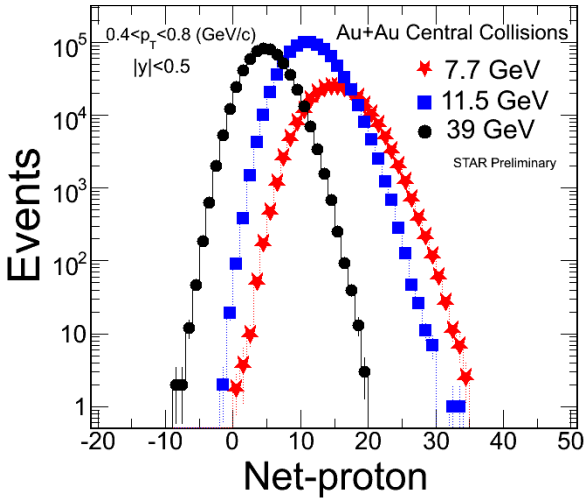


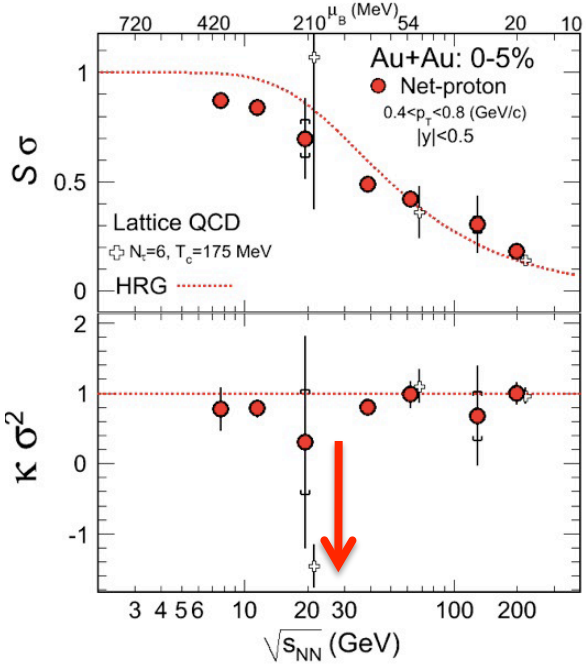


1) v_2(baryon) > v_2 (anti-baryon); $v_2(\pi^+) < v_2(\pi^-)$ at 7.7 GeV

2) We are taking data: 27 GeV Au+Au collisions

Higher Moments of Net-protons





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

2) Sensitive to critical point**:

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

3) Direct comparison with Lattice results**:

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

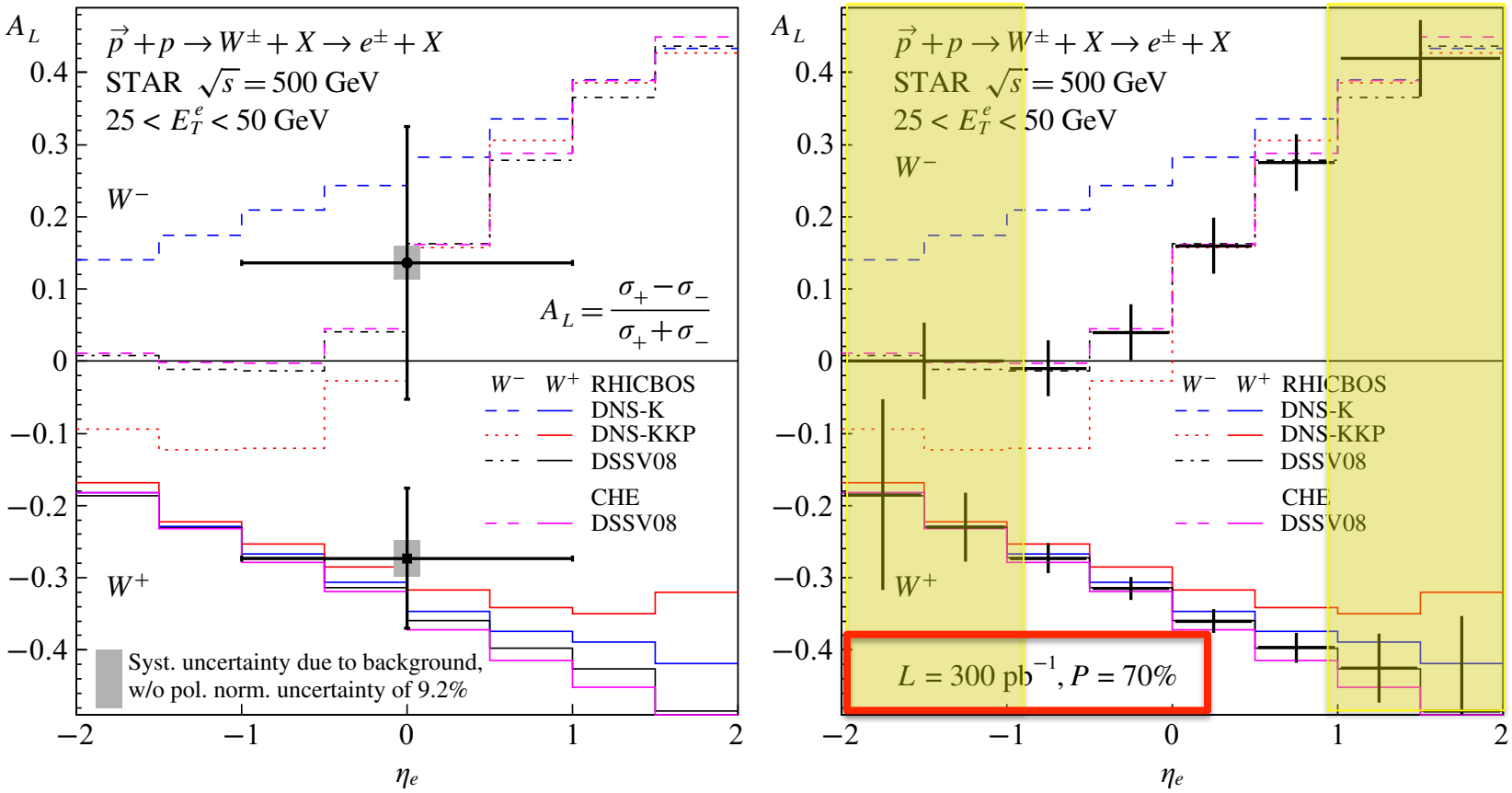
4) Extract susceptibilities and freeze-out temperature. An independent test on thermal equilibrium in HI collisions.

5) 17M good events at 19.6GeV collected in Run 11.

6) **We are taking data:** at 27 GeV Au+Au collisions

* STAR: 1004.4959, PRL 105, 22303(2010).
** M. Stephanov: PRL,102, 032301(09).
*** R.V. Gavai and S. Gupta: 1001.2796.

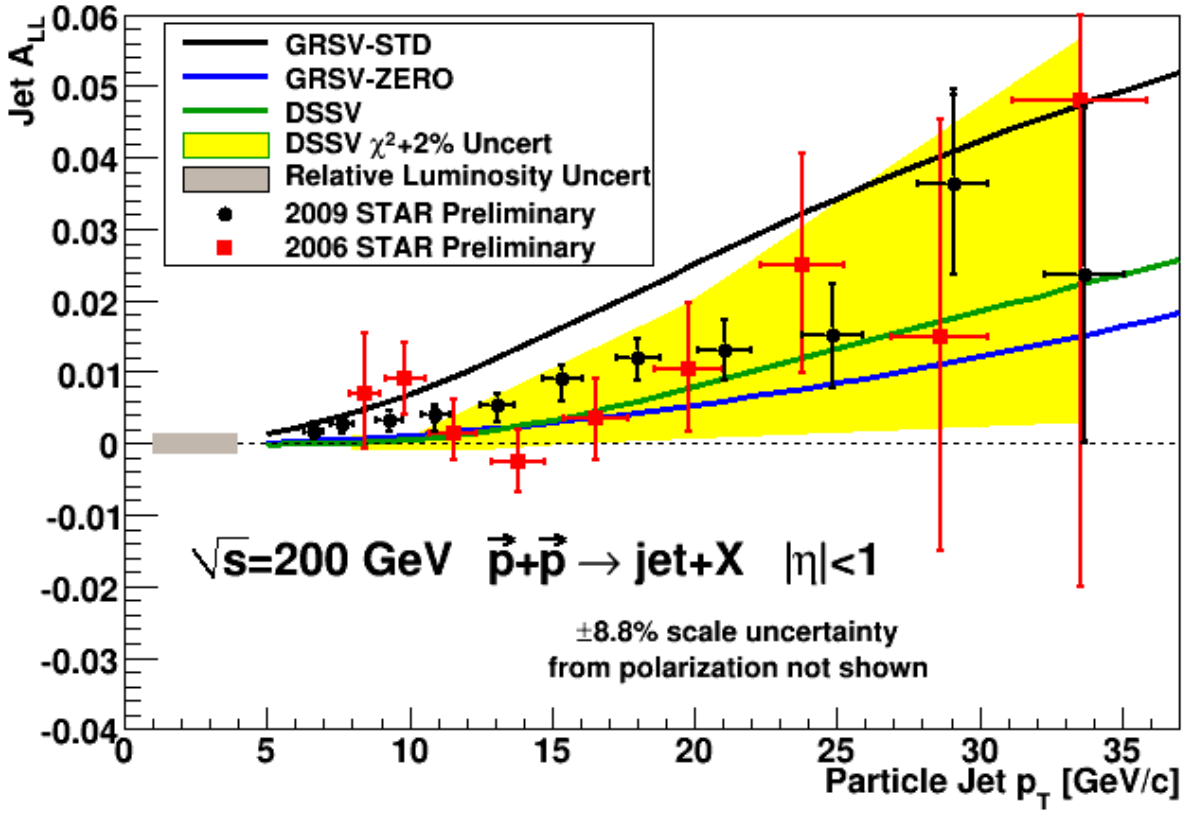
Quark Flavor Measurements: W±



1) Results* are consistent with model: **Universality of the helicity distr. Funct.**!
2) Combined results of Run 9 and Run 11 reduces the error ~ 0.63.
3) Precision measurements require **large luminosity**, **high polarization** at RHIC!

* STAR: Phys. Rev. Lett. **106**, 62002(2010).

STAR A_{LL} from 2006 to 2009

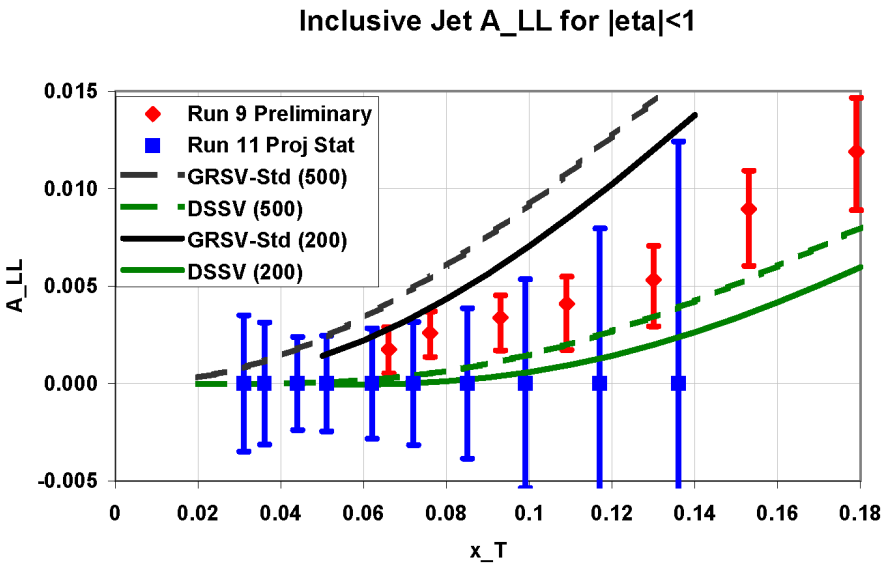


2009 **STAR** A_{LL} measurements:

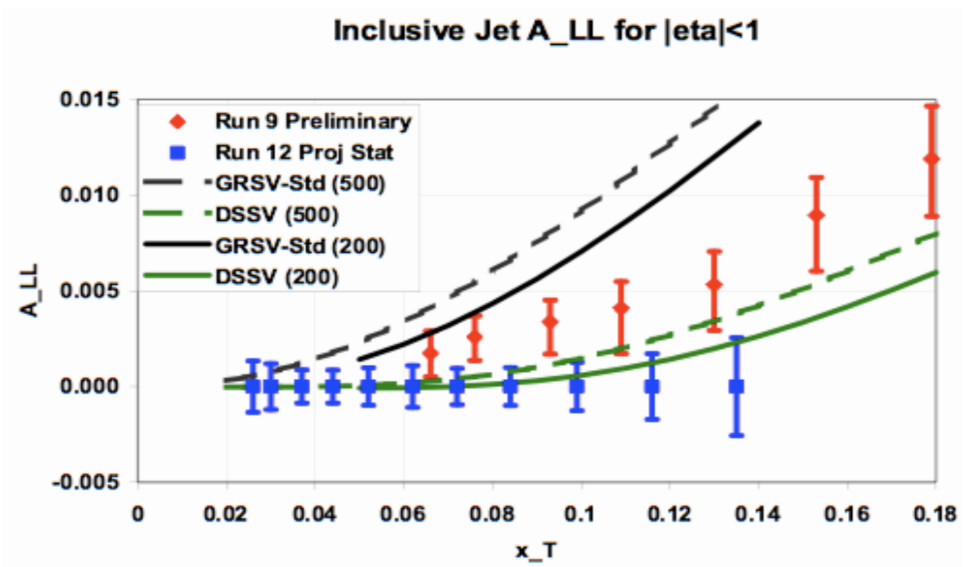
- **Results fall between predictions from DSSV and GRSV-STD**
- Precision sufficient to merit finer binning in pseudorapidity

Expected inclusive jet A_{LL} precision

Run 11



Run 12



- Run 12 will provide a very useful complement to Run 9
- During Run 13, we can further reduce the 200 GeV uncertainties compared to Run 9 by:
  - A factor of ~2 for jet p_T >~ 12 GeV
  - A factor of ~sqrt(2) for jet p_T <~ 12 GeV

Recent Results Summary

STAR has been very effective and productive:

1) **TOF, HLT, DAQ1k upgrades completed successfully**

2) **200 GeV Au+Au collisions**
   - Large acceptance di-electron program started
   - Upsilon suppression vs. centrality and high statistics J/ψ v_2
   - …

3) **Beam Energy Scan**
   - Systematic data of Au+Au collisions at 7.7/11.5/19.6/27/39/62.4GeV:
     See some interesting results and data analysis in progress.

4) **Spin Physics**
   - First $W^{\pm}$ A_L results (2009) published; di-jet A_{LL} analysis

5) **High statistics, high quality data have been collected**
   - pp 500 GeV FMS and low material Au+Au 200 GeV

(3) STAR Future Planning Activities

STAR Decadal Plan

Membership: Helen Caines, Hank Crawford, ***Jamie Dunlop*** (chair of heavy-ion task force), Olga Evdokimov, **Carl Gagliardi** (chair), Declan Keane, Thorsten Kollegger, Bedanga Mohanty, Ernst Sichtermann, ***Bernd Surrow*** (chair of spin task force), Thomas Ullrich, ***Flemming Videbaek*** (chair of upgrades), Wei Xie, Nu Xu, Zhangbu Xu

Issues discussed:

Science: ***Properties of QGP at RHIC; QCD critical point;***
Initial conditions; Proton helicity structure; Exotics

- Trigger development for the next 10 years (enhance rare probe capabilities)
- Additional detectors at the forward rapidity (pA, ep, eA)
- Maintain and upgrade the existing detectors
- New members for the collaboration

Status: Phase-I exercise completed by Nov. 2010.
Document has been submitted to BNL and discussed at last PAC.
Live document, discussions continuous, next update May 2012.

"For Scientific Discovery: ***Compelling physics, Cost effective, Community***"

eSTAR Task Force

Membership: Subhasis Chattopadhyay, Hank Crawford, Renee Fatemi, Carl Gargliardi*, Jeong-Hun Lee, Bill Llope, ***Ernst Sichtermann***, Huan Huang, Thomas Ullrich, Flemming Videbaek, Anselm Vossen, Wei Xie, Qinghua Xu, ***Zhangbu Xu***

Ex-officio: B. Christie, J. Dunlop, O. Evdokimov, B. Mohanty, B. Surrow, N. Xu

Charges: In order to prepare the experiment to complement the ongoing physics programs related to *AA, pA and pp collisions with a strong ep and eA program by an* additional electron beam and prepare the collaboration to participate in the US Nuclear Physics Long Range Planning exercises during 2012-2013, we establish the eSTAR Task Force. This task force will be in function during the next three years. The main charges for the task force are:

(1) Identify important physics measurements and assess their science impact during the eSTAR era (2017-2020). Prepare a white paper or an updated decadal plan including physics sensitivities and detailed R&D projects.
(2) With (1) in mind as well as the eRHIC interaction region design(s) and other constraints, identify and advise STAR Management on priorities for detector R&D projects within the collaboration.
(3) Engage the collaboration by organizing special *ep/eA* workshops, document the progress and report annually to the collaboration.
(4) Work with the STAR management and the EIC task force (setup by the BNL management) to strengthen the physics case(s) for eSTAR and a future EIC

(4) Ongoing upgrades and issues

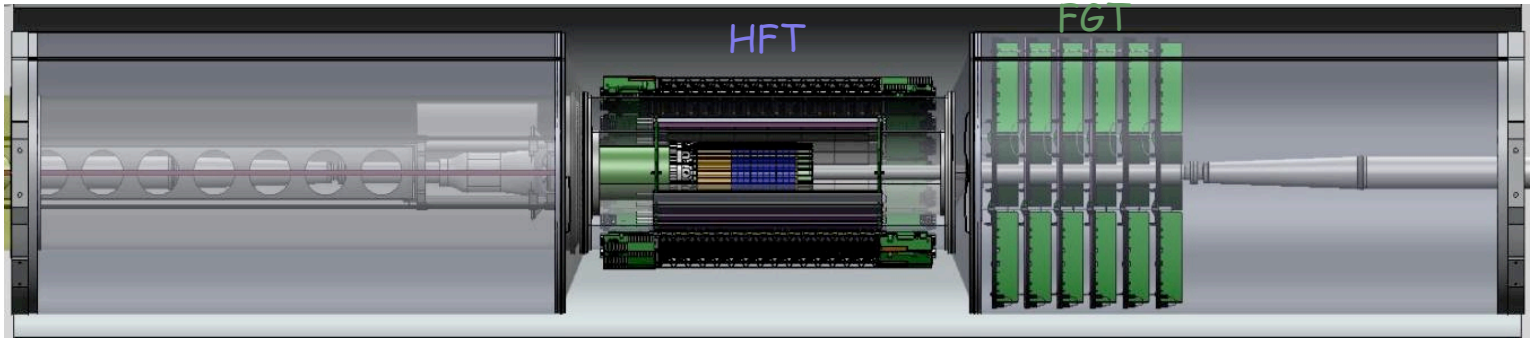
Compelling physics, Cost effective, Community

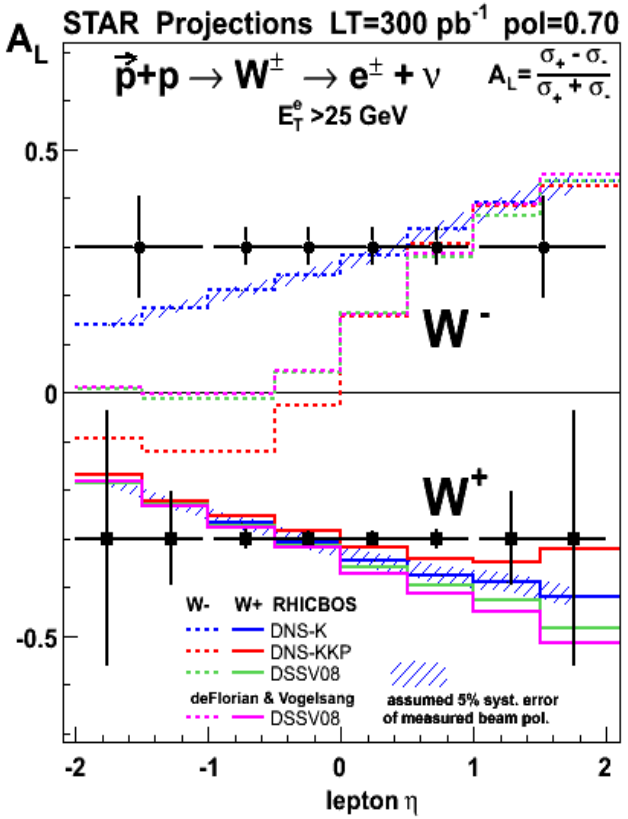
STAR Upgrade Timeline

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

*minimal configuration for Run 12 and completion before Run 13

Forward GEM Tracker





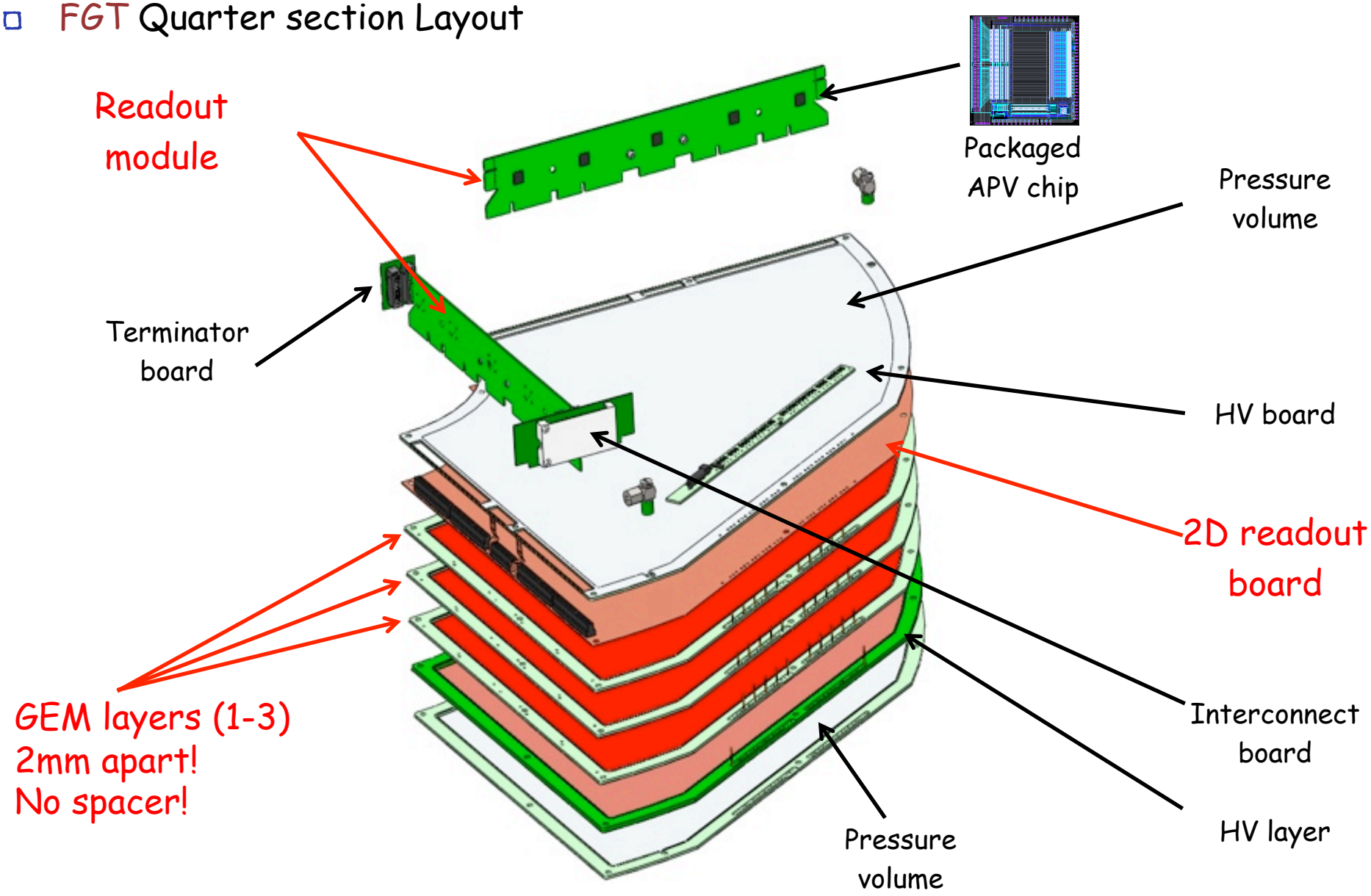
1) FGT: RHIC CE project
2) Six light-weight triple-GEM disks
3) New mechanical support structure
4) Planned installation: Summer 2011

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

*** minimal configuration**

FGT Quadrant

- FGT Quarter section Layout



FGT Schedule

I. Minimal configuration

1) Full FGT: 24 quarter sections / 6 disks (4 quarter sections per disk)
2) Minimal configuration: 4 disks with 3 quarter sections each, i.e. 50% of full FGT system (24 quarter sections)
3) 4 disks, i.e. 4 space points are required for proper charge-sign discrimination

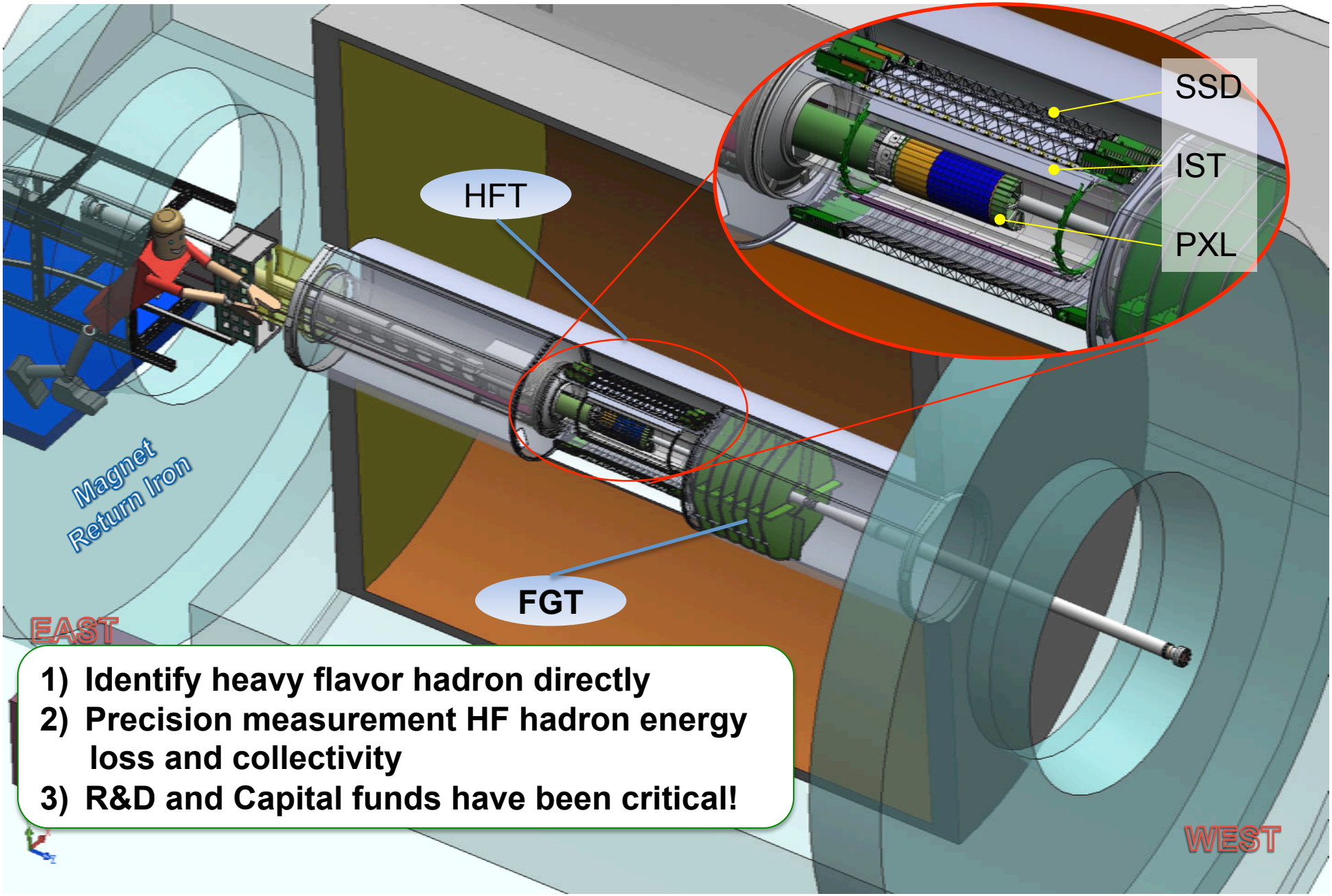
II. Schedule (draft)

1) July-September 2011: Quarter section assembly and testing
2) September 2011: Disk assembly and WSC integration
3) October 2011: Integration ESC / WSC / Beam pipe / Installation

Request RHIC cool down: January 1, 2012

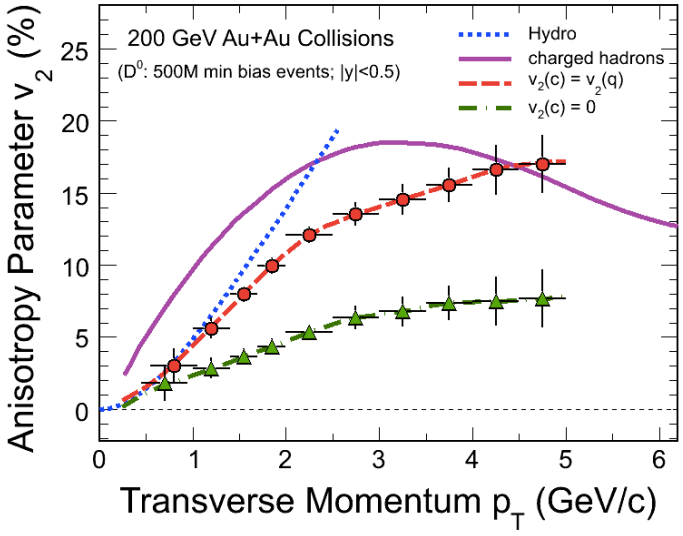
in order to install as many FGT disks as possible

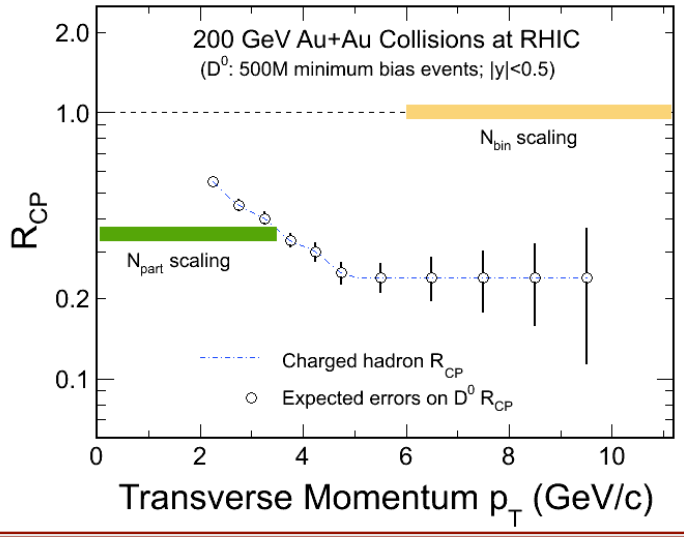
Heavy Flavor Tracker at STAR

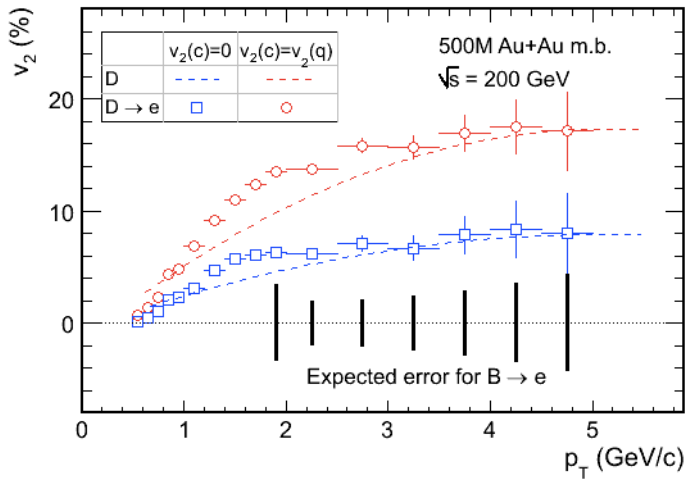


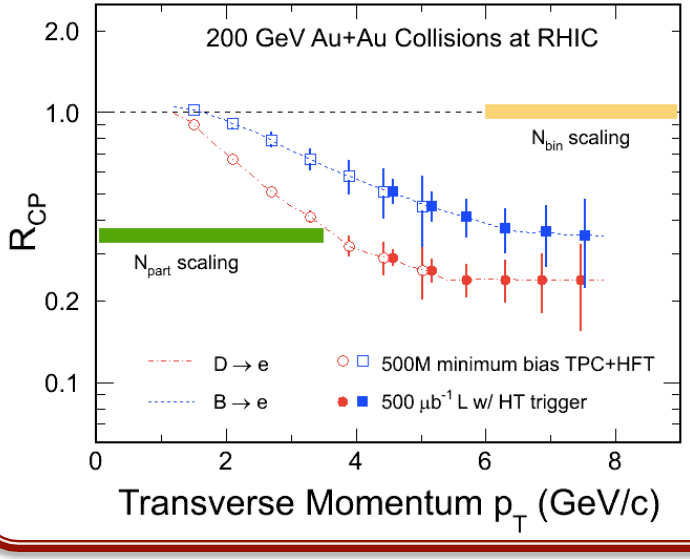
1) Identify heavy flavor hadron directly
2) Precision measurement HF hadron energy loss and collectivity
3) R&D and Capital funds have been critical!

Physics Goals for HFT





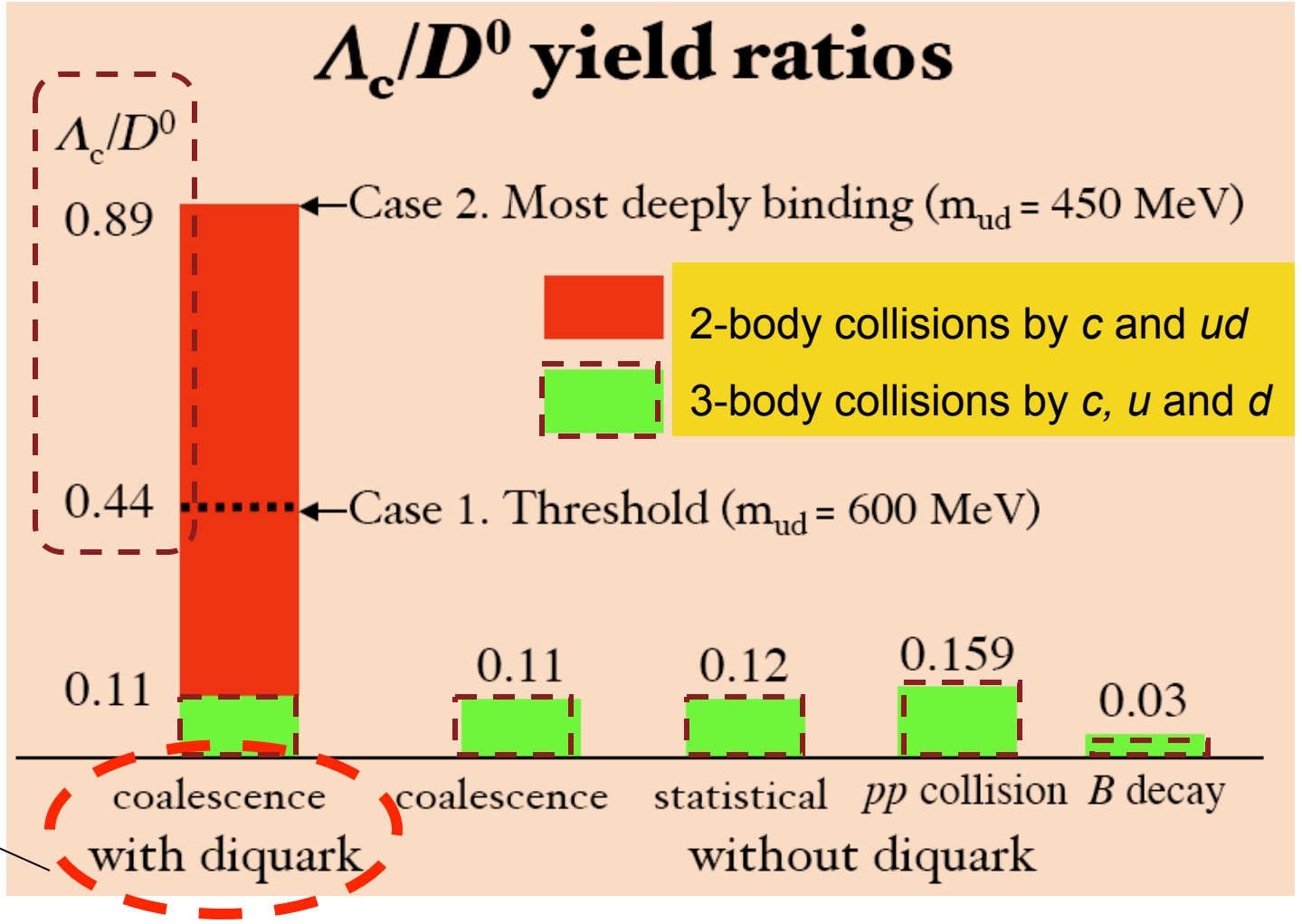




Charm Baryon/Meson Ratios

$\Lambda_c \rightarrow pK^-\pi^+$

$D^0 \rightarrow K^-\pi^+$

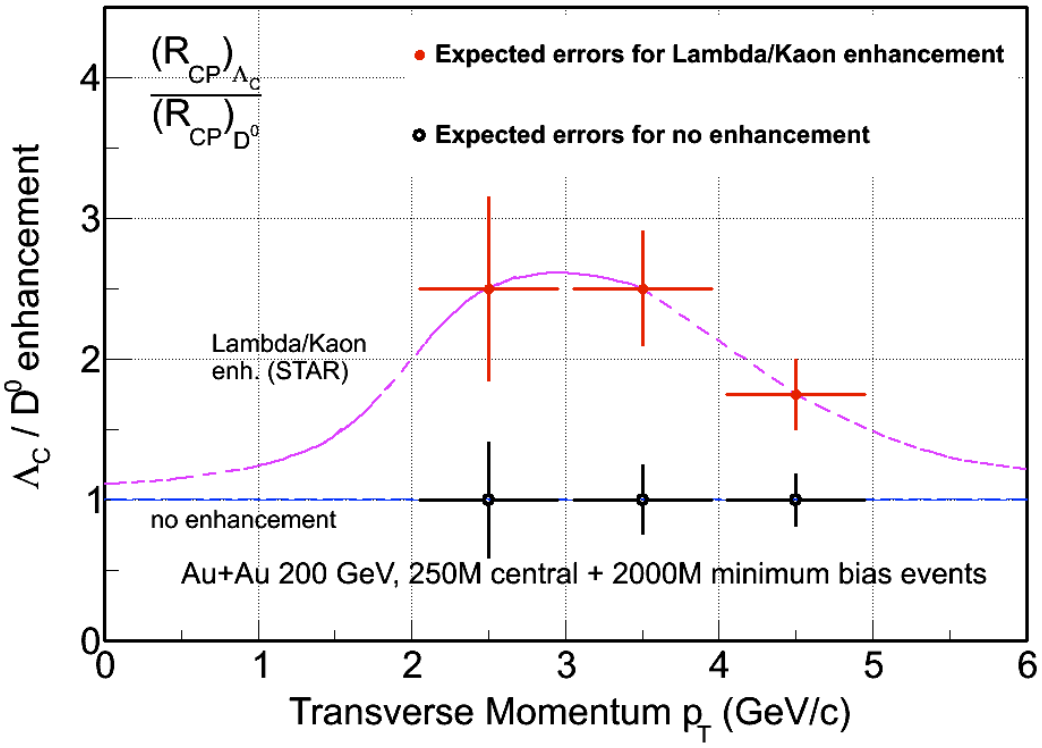


QGP medium

Key for the production mechanism for Charm hadrons and their chemistry

Y. Oh, *et al.*, PR**C79**, 044905(09);S.H. Lee, *et al.*, PRL**100**, 222301(08).

Heavy Flavor Physics

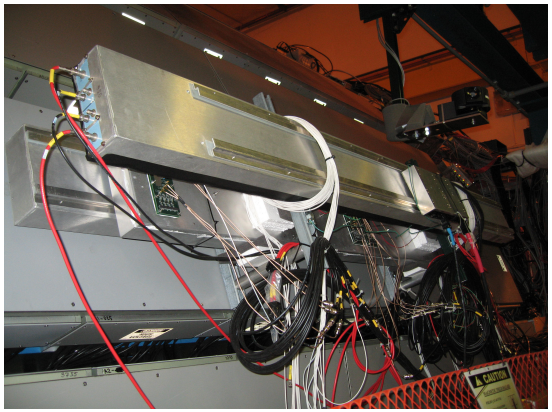


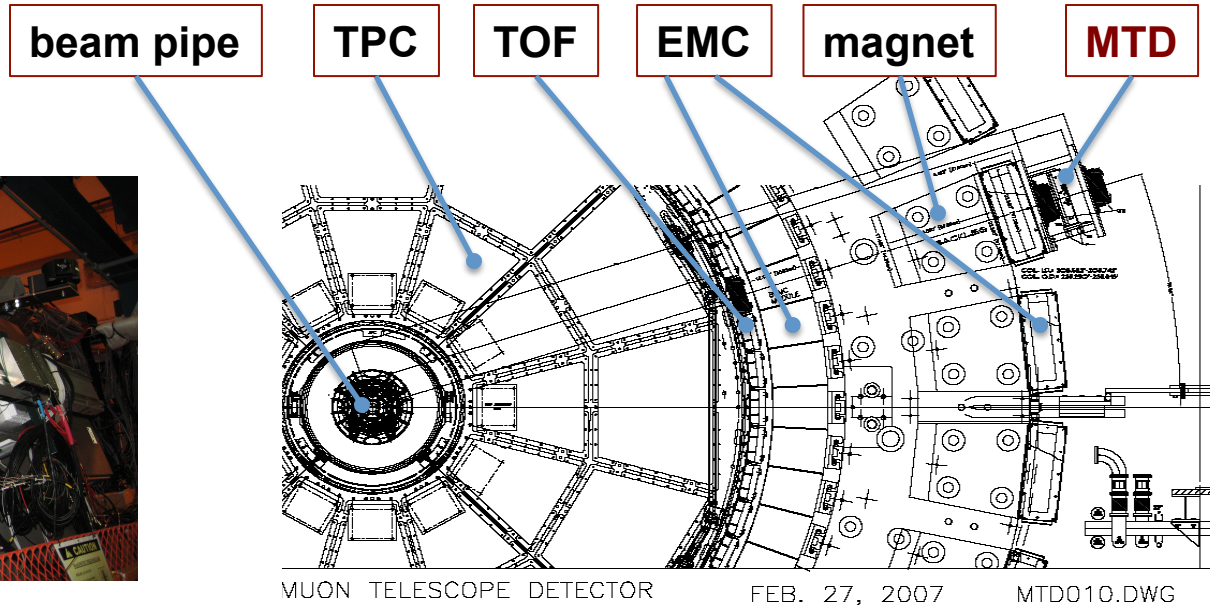
Λ_C: lowest charm baryon state, $c\tau \sim 60\mu m$

- Hadro-chemistry with charm

- Heavy flavor energy loss, meson vs. baryon effect

STAR: Muon Telescope Detector

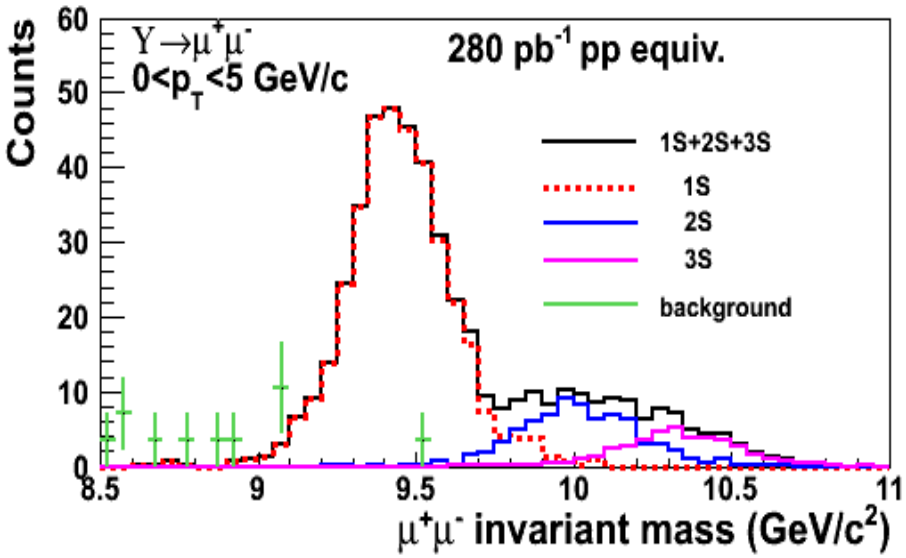


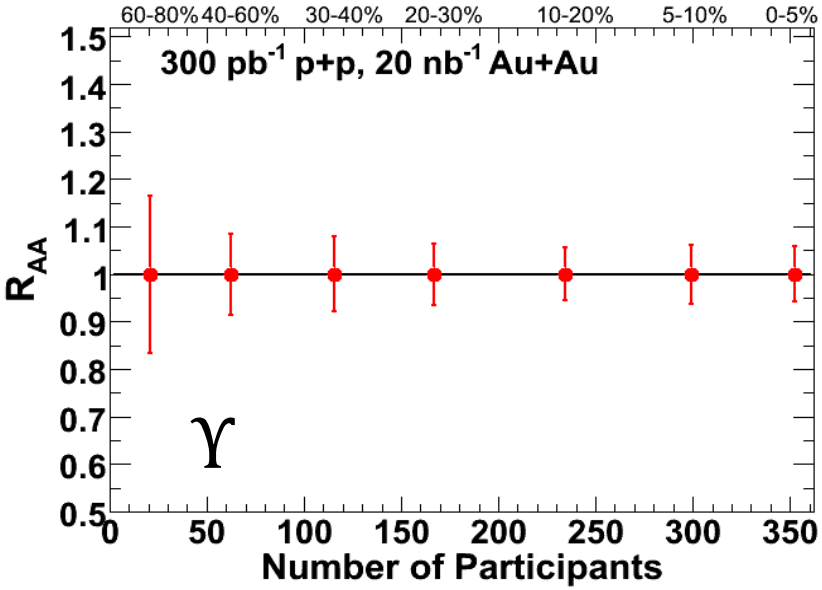


Muon Telescope Detector (MTD) at STAR:

1) MRPC technology; μ_ε ~ 45%; cover ~60% azimuthally and |y| < 0.25
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: build on the success of STAR MRPC TOF

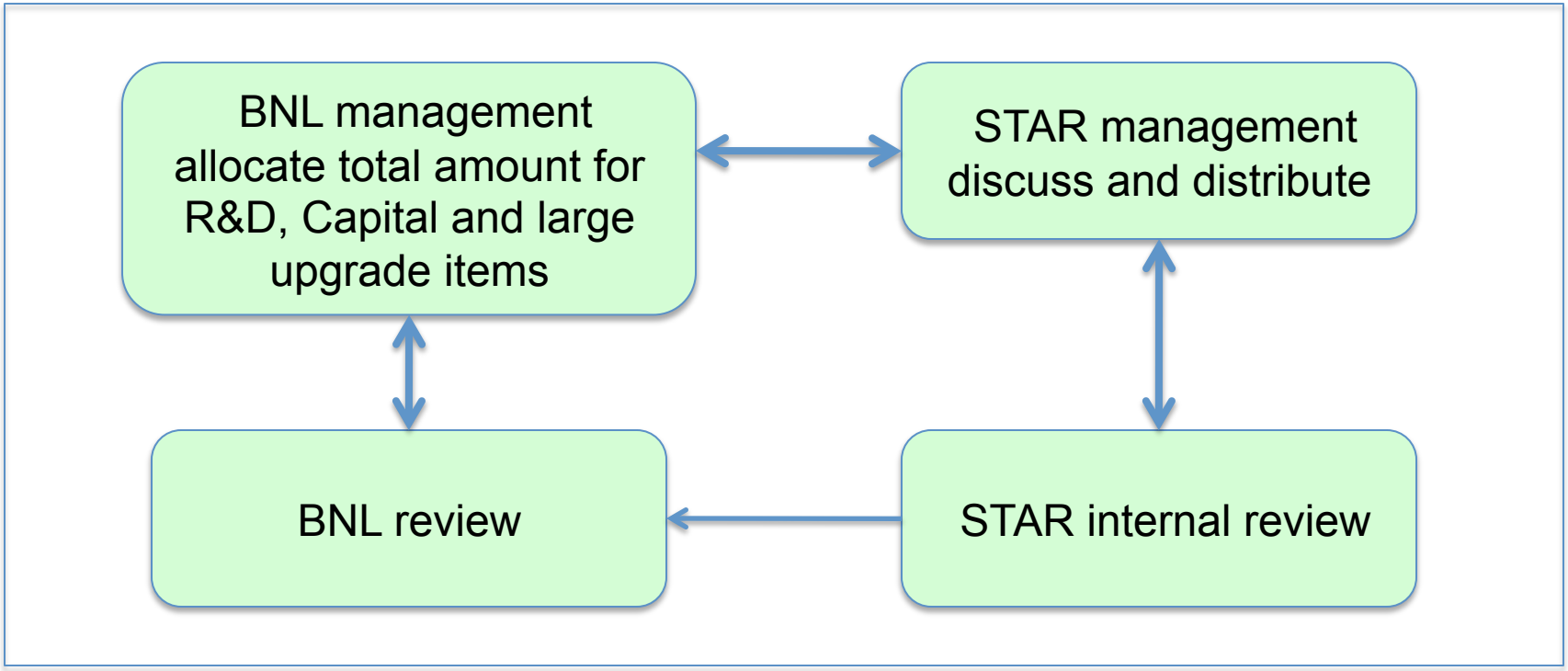
Study Medium Property Through ϒ





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

STAR Project Management



More support from university groups for operation activities, R&D efforts are needed

Summary

1) Recent upgrades (TOF, HLT) has provided STAR with new unique opportunities
2) The large acceptance of the mid-rapidity and the forward FGT, FMS provides rich opportunities in spin physics
3) BES runs are successful, systematic analysis emerging, final analysis may point to future BES program at RHIC
4) STAR has embarked on an evolving long term planning including transitions to eSTAR. The whole collaboration is involved
5) TPC issues: no sign of aging has seen
6) THE near term upgrades FGT, MTD and the HFT will ensure a vibrant new STAR physics program in to the mid-term era at RHIC
7) STAR management is working closely with BNL management on the on-going upgrade projects