STAR

Status and Physics Opportunities of STAR Heavy Flavor Tracker and Muon Telescope Detector Upgrades

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for the STAR Collaboration

BIRMINGHAM SQM 2013

BERKELEY LAB

Office of Science
U.S. DEPARTMENT OF ENERGY

Outline

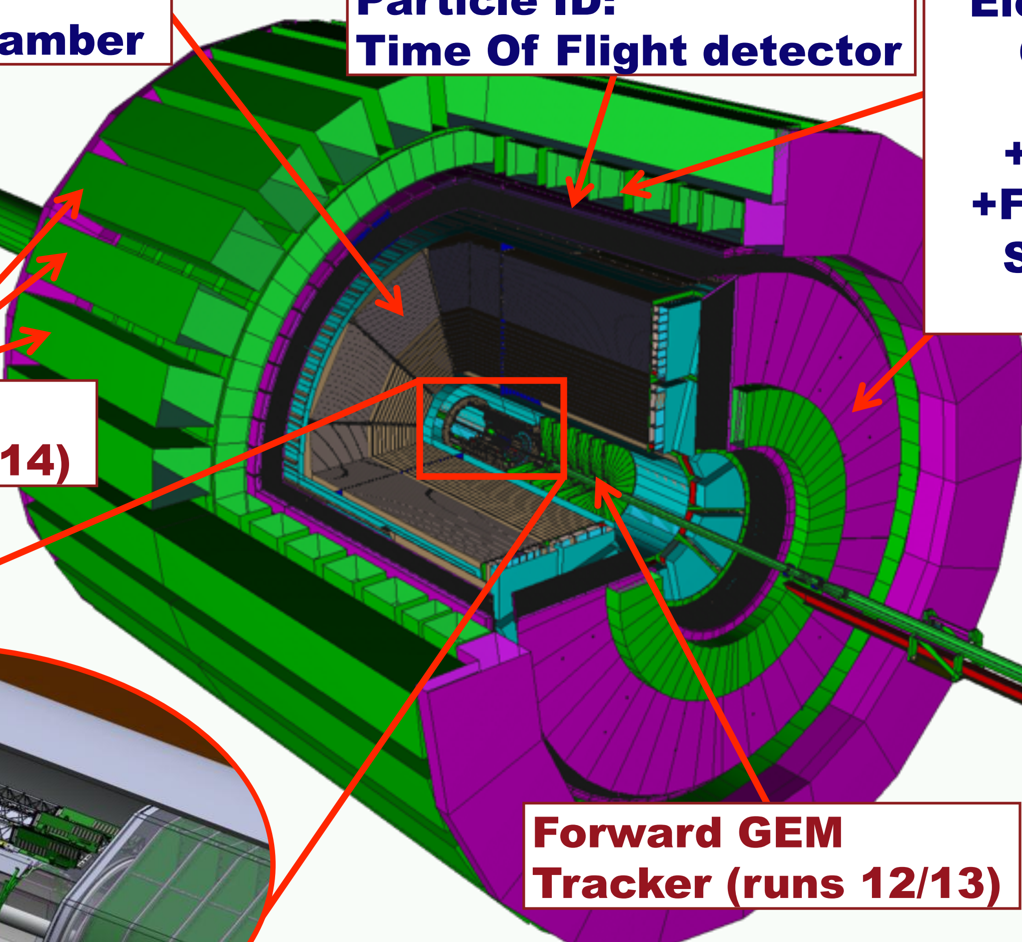
- STAR detector overview
- New physics direction for STAR heavy ion program
- Heavy Flavor Tracker and Muon Telescope Detector
  - Physics motivation
  - Design
  - Status and performance
- RHIC run plan
- Summary

STAR Detector Overview

Tracking & dE/dx:
Time Projection Chamber

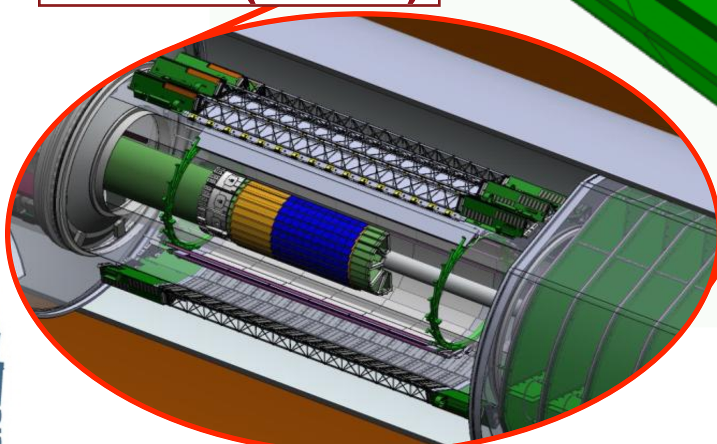
Particle ID:
Time Of Flight detector

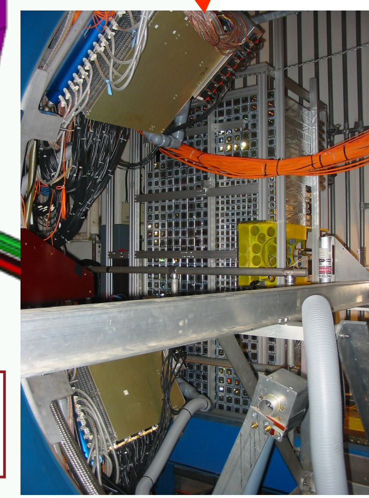
Electromagnetic Calorimetry:
Barrel EMC
+Endcap EMC
+Forward Meson Spectrometer
($-1 \leq \eta \leq 4$)



Muon Telescope Detector (runs 13/14)

Heavy Flavor Tracker (run 14)





Forward GEM Tracker (runs 12/13)

- Full azimuthal particle identification at middle rapidity

New Physics Direction for STAR Heavy Ion Program

- Heavy flavor
  - $m_{b,c} >> T_C, \Lambda_{QCD}, m_{u,d,s}$
  - Early produce
  - Conserve in total number
  - Less influenced
  - Good probe to QGP
- Thermal di-lepton
  - QGP signal
  - Probing the temperature of the medium

Heavy flavor → Open heavy flavor → HFT

Heavy flavor → Heavy quarkonium → MTD

Thermal di-lepton → MTD

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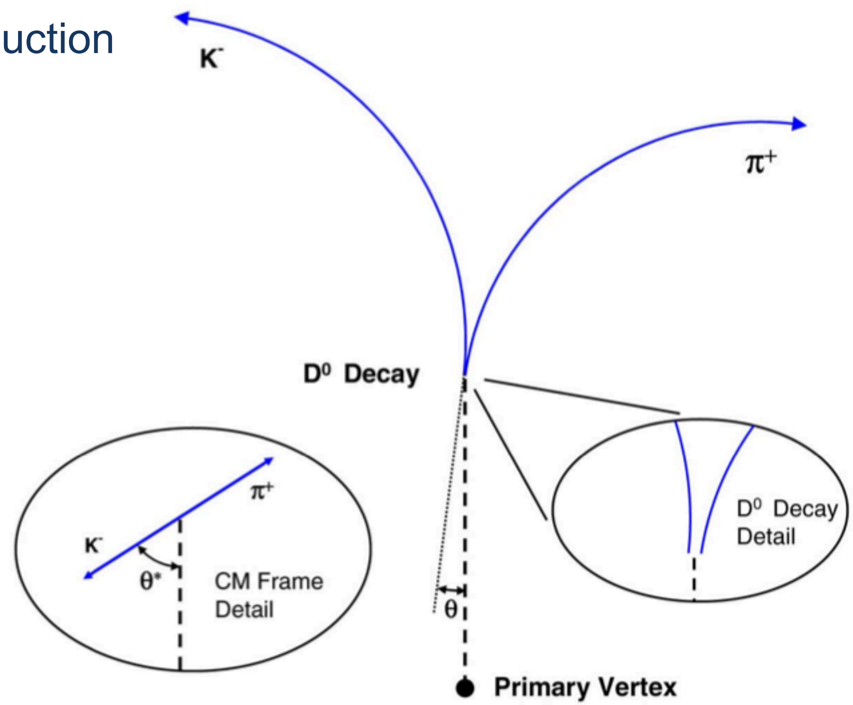
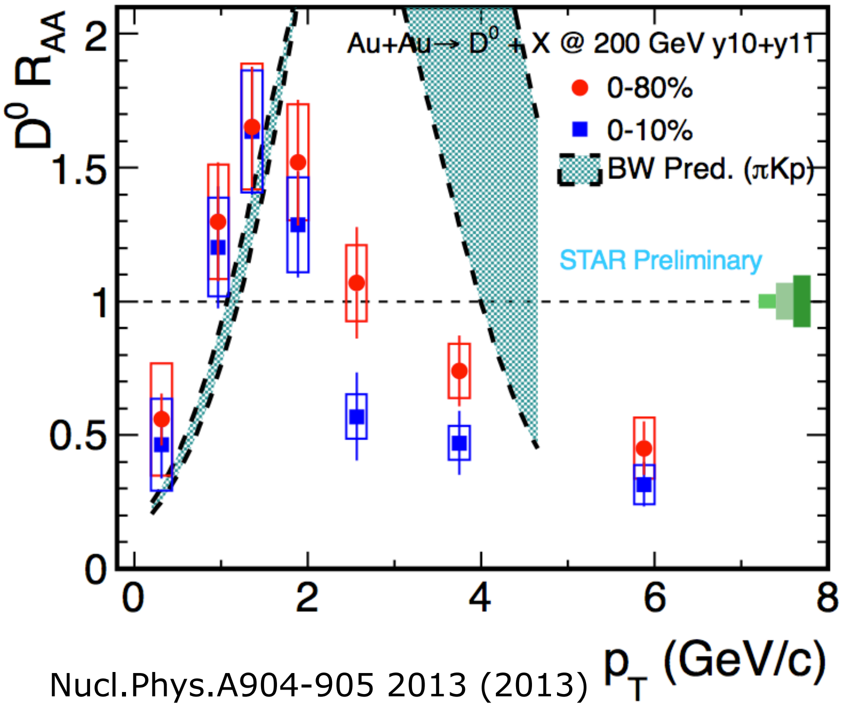
HFT Physics Motivation

- HFT can be used to study heavy flavor production by the measurement of displaced vertices
  - $D^0 \rightarrow K^- \pi^+$
    - BR = 3.83 %   cτ ~ 120 μm
  - $\Lambda_c^+ \rightarrow p\, K^- \pi^+$
    - BR = 5.0 %   cτ ~ 60 μm
  - B mesons → J/ψ + X   or   e + X
    - cτ ~ 500 μm



- Total charm yield → base line for charmonium suppression & coalescence
- R_{CP}, R_{AA} of charm and bottom → energy loss in QGP
- Charm (D^0) flow → thermalization?
- $c\bar{c}$ ($D^0 \overline{D^0}$) angular correlation → interaction with the medium
- Λ_c^+ / D^0 → test coalescence model

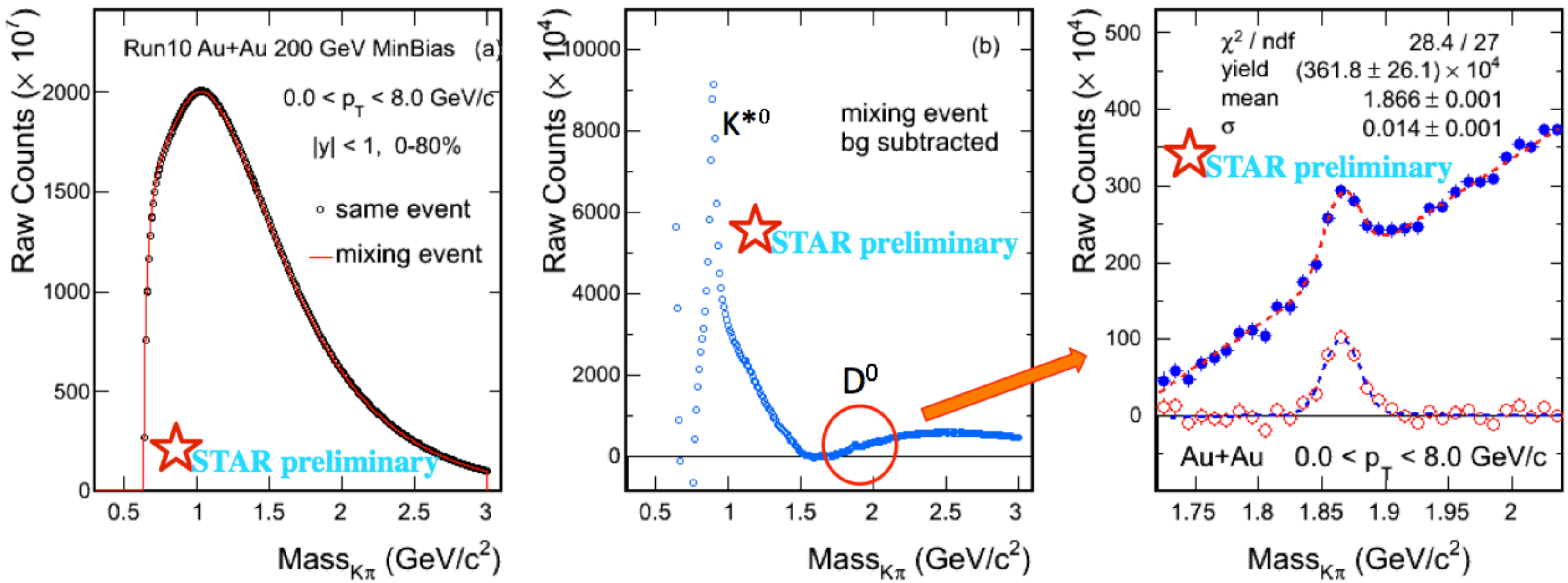
Charm Yield, R_{CP} and R_{AA}



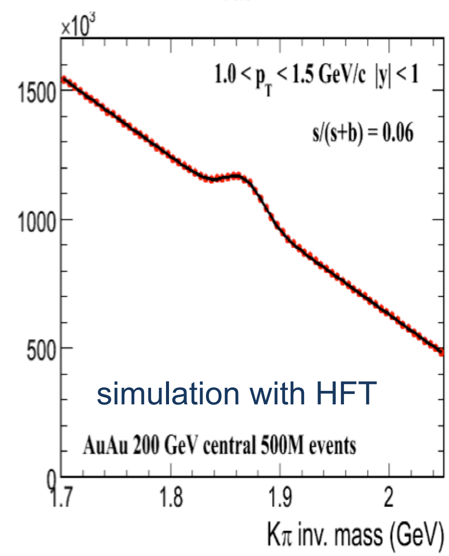
Nucl.Phys.A904-905 2013 (2013) 639c-642c

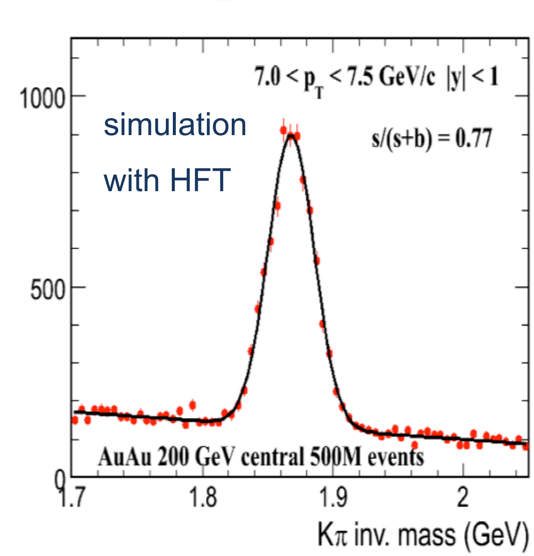
- Total charm yield → base line for charmonium suppression & coalescence
- R_{CP}, R_{AA} → energy loss mechanism, QCD in dense medium

Charm Yield, R_{CP} and R_{AA}

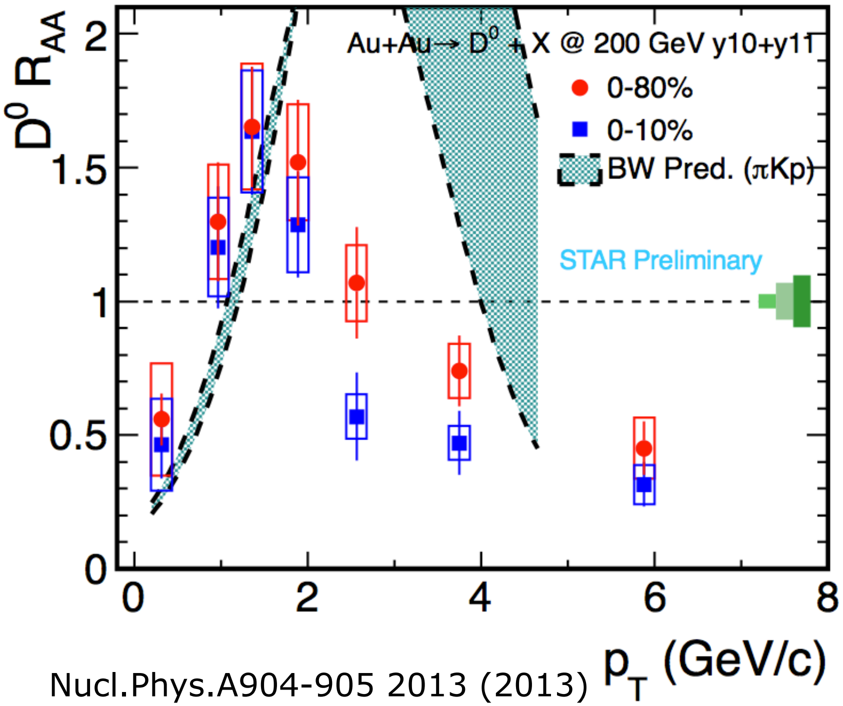


- Large combinatorial background using primary tracks to reconstruct D^0
- Much better S/B ratio with displaced vertex from HFT





Charm Yield, R_{CP} and R_{AA}



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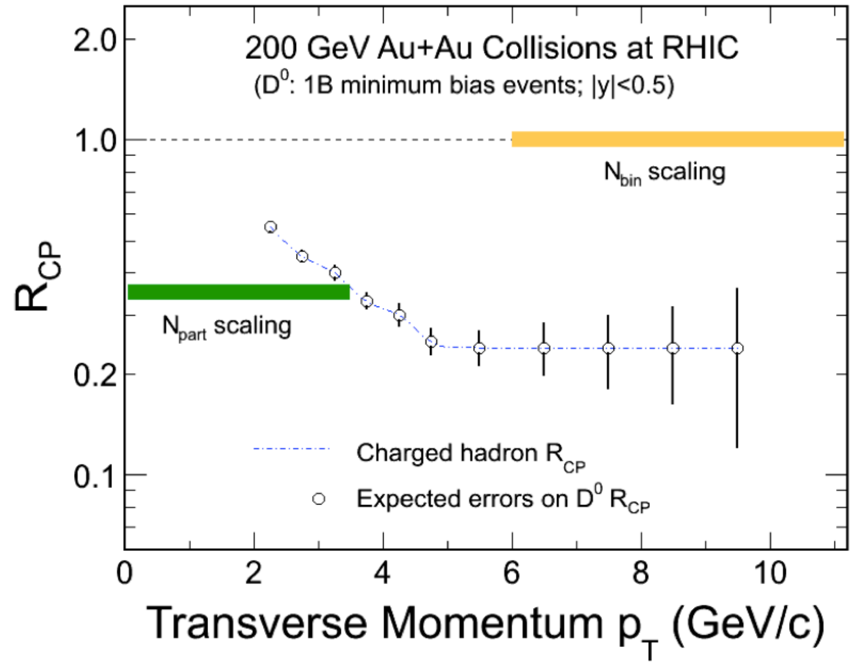
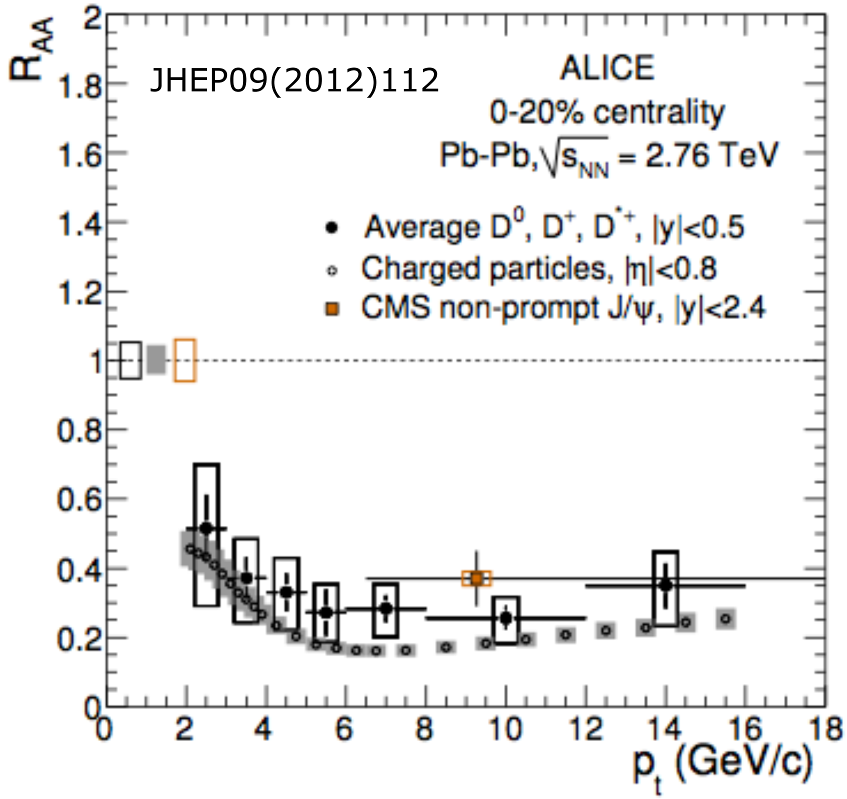
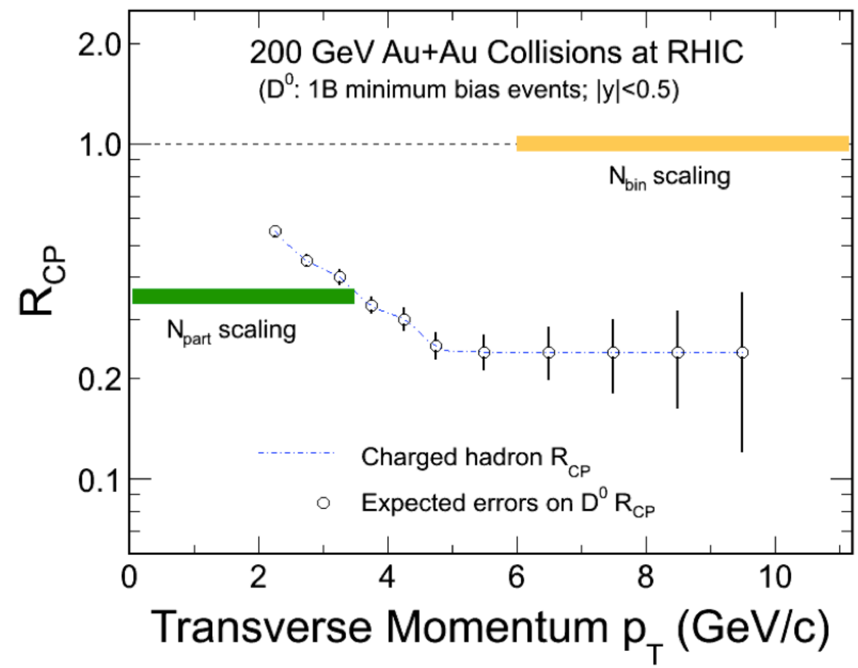


STAR projection with HFT

- Much better precision with HFT than current STAR measurement
- Low radiation length enable reconstruction of D^0 with p_T starting from 0, enabling charm total cross section measurement.

Charm Yield, R_{CP} and R_{AA}

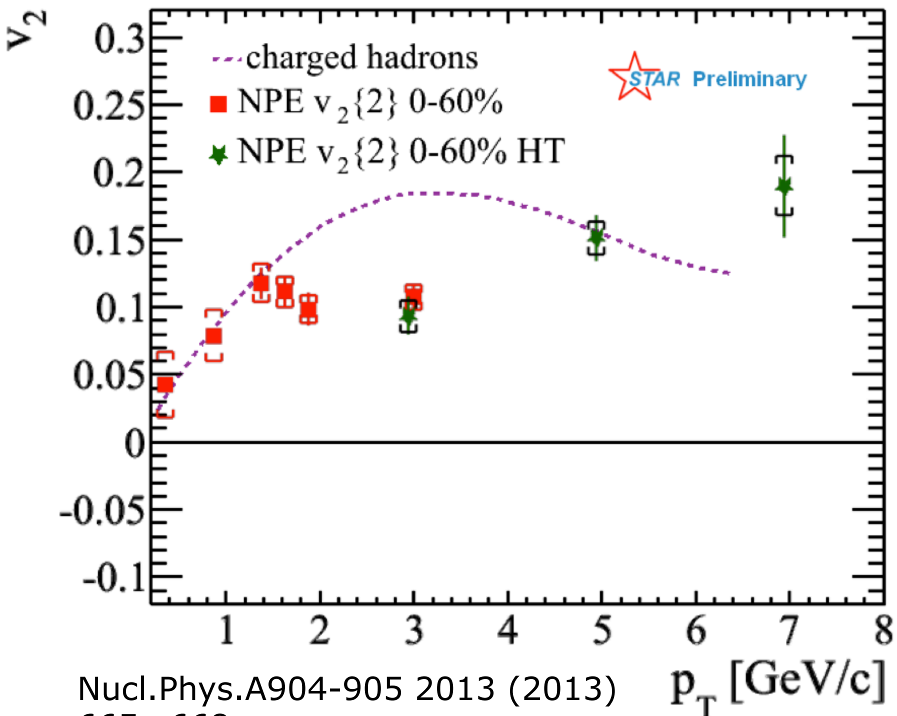




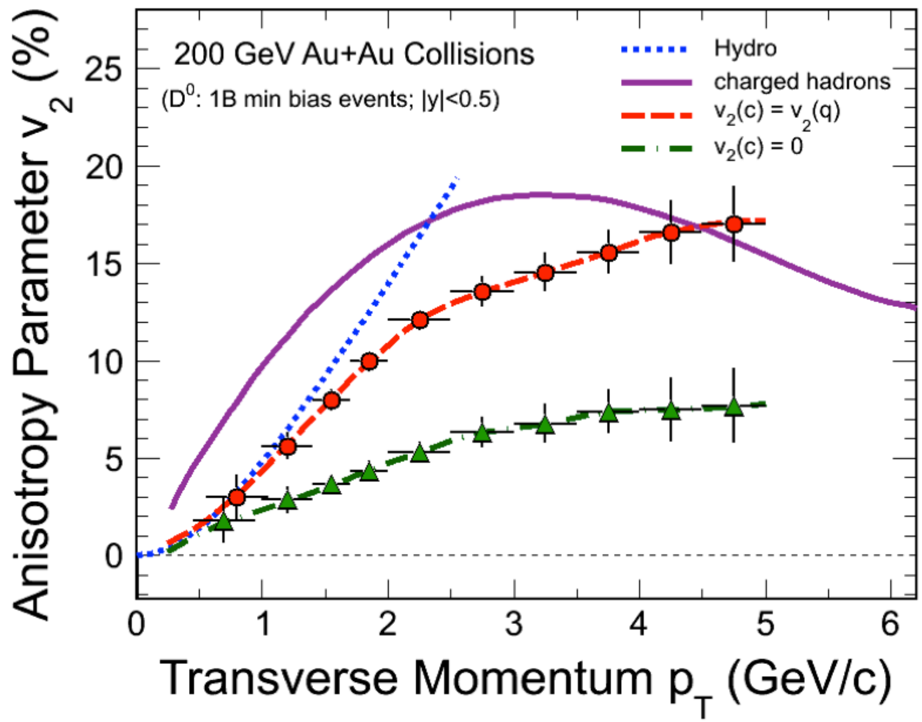
STAR projection with HFT

- Probe possible different medium property with different collision energy.
- Low radiation length enable reconstruction of D^0 with p_T starting from 0, enabling charm total cross section measurement.

Charm Flow



Nucl.Phys.A904-905 2013 (2013) 665c-668c

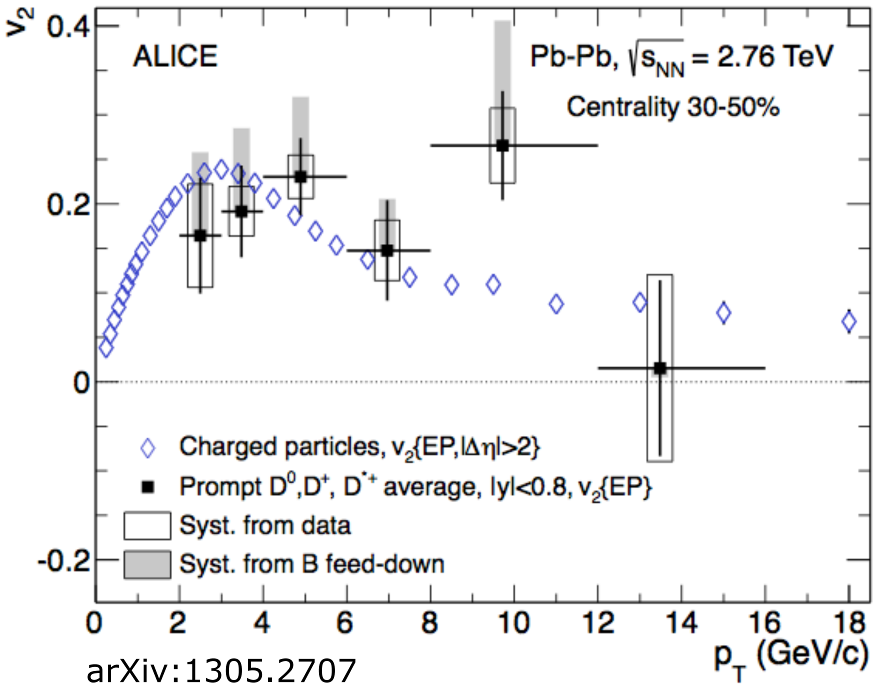


STAR projection with HFT

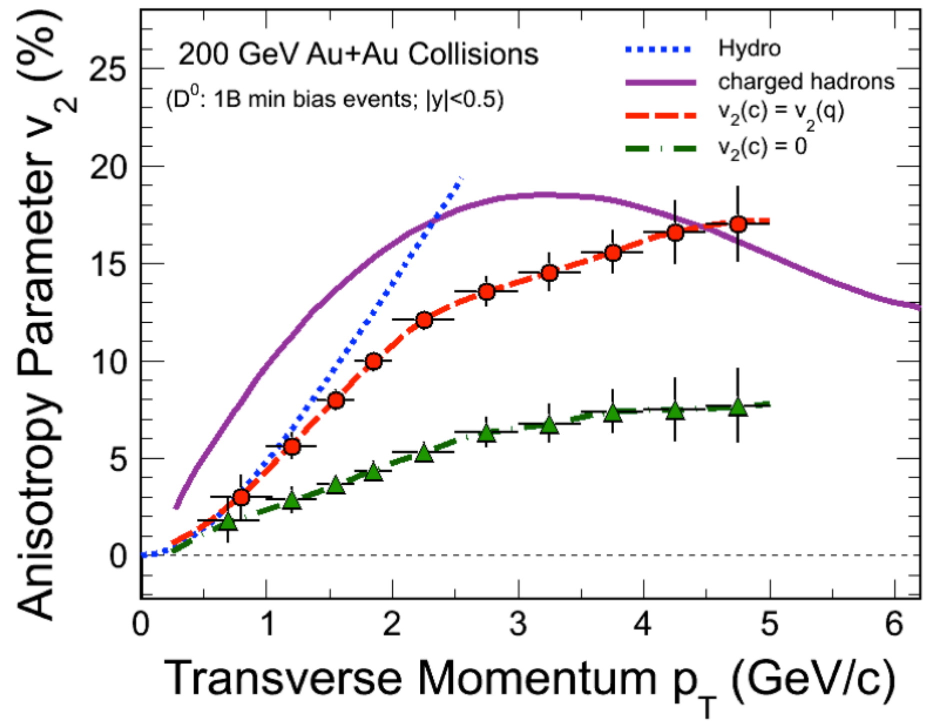
- Charm collectivity → light flavor thermalization?

- D^0 v_2 is a more direct measurement of charm flow than non-photonic electron v_2.
- With HFT STAR is able to measure D^0 v_2 at low p_T region, which is sensitive to charm flow.

Charm Flow



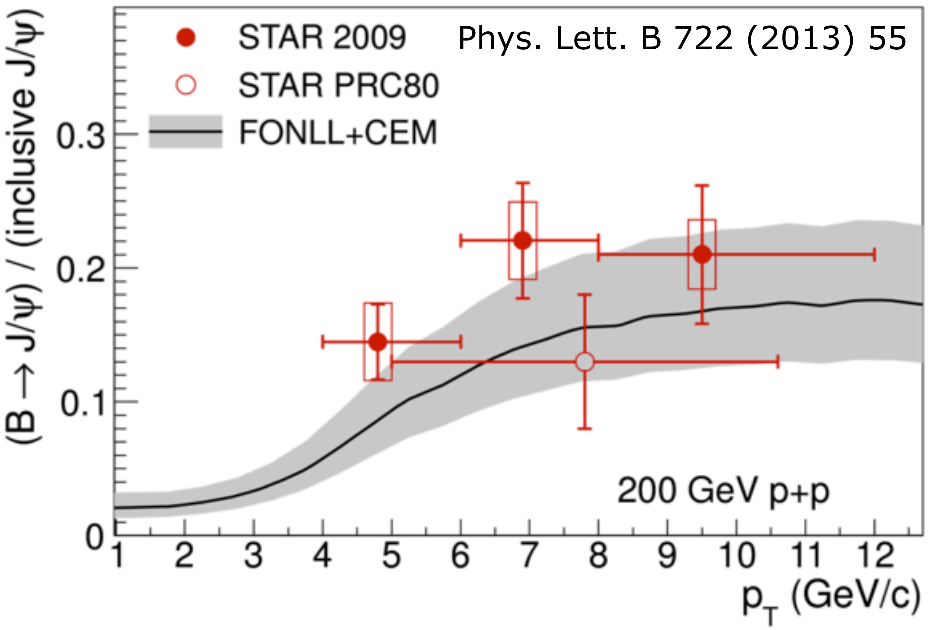
arXiv:1305.2707

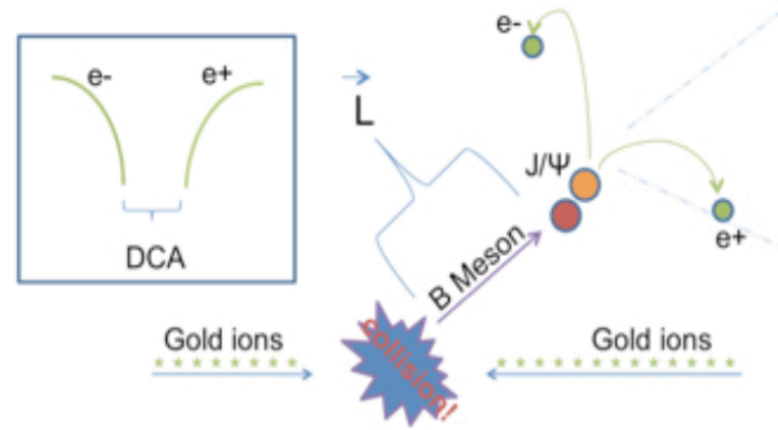


STAR projection with HFT

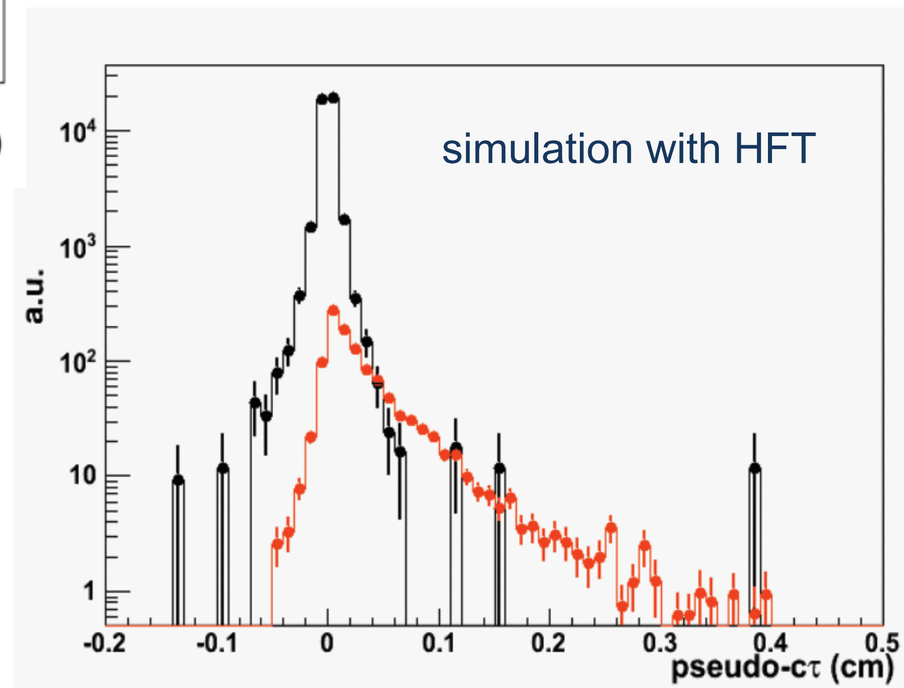
- Charm collectivity → light flavor thermalization?
- Measurements at both LHC and RHIC will explore the change of media properties with energy.

J/ψ from B meson

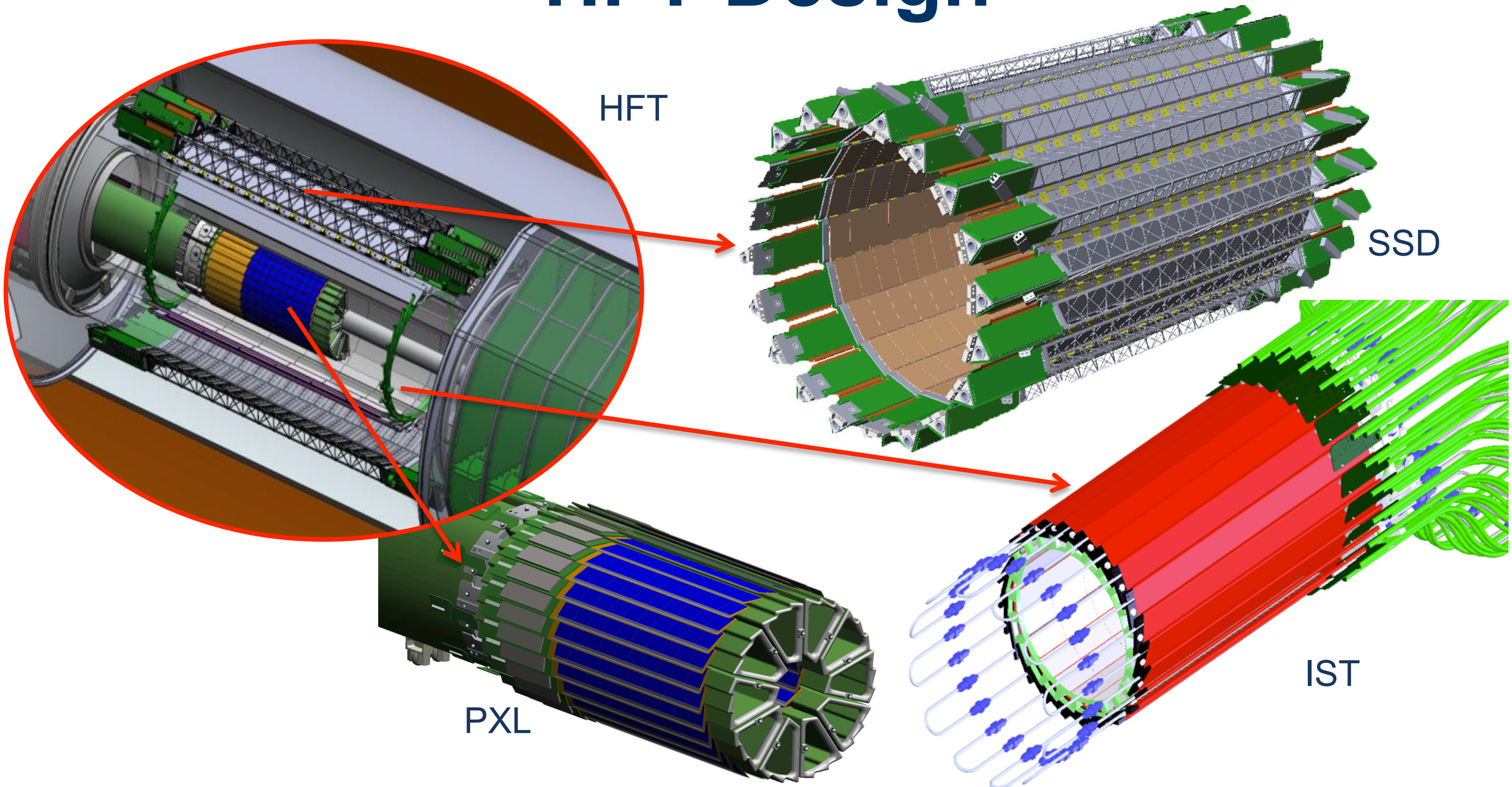




- Measured before through J/ψ-hadron correlation
  - only in pp collisions
  - large errors
- with HFT can be measured by displace vertex
- with MTD can also be measured through $\mu^+\mu^-$ channel



HFT Design

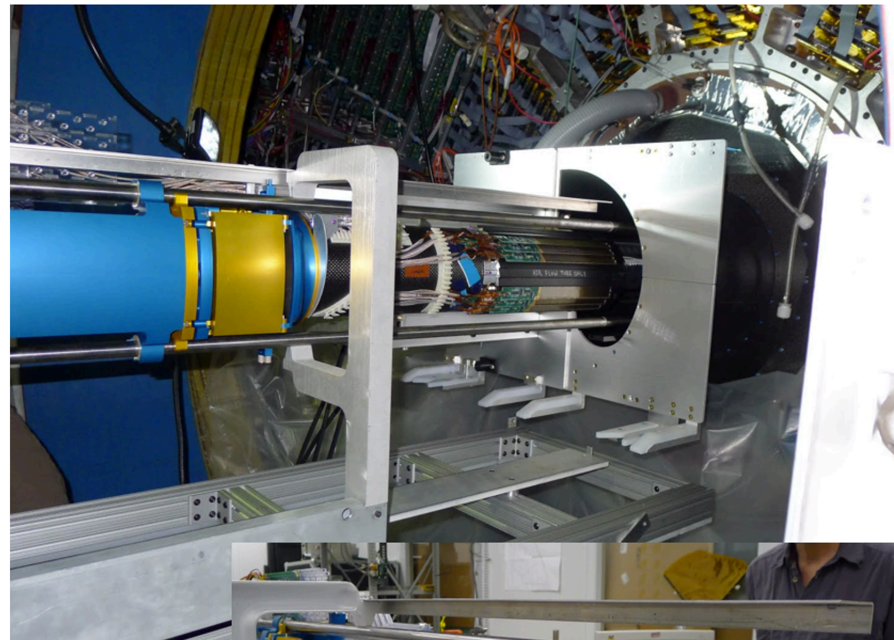


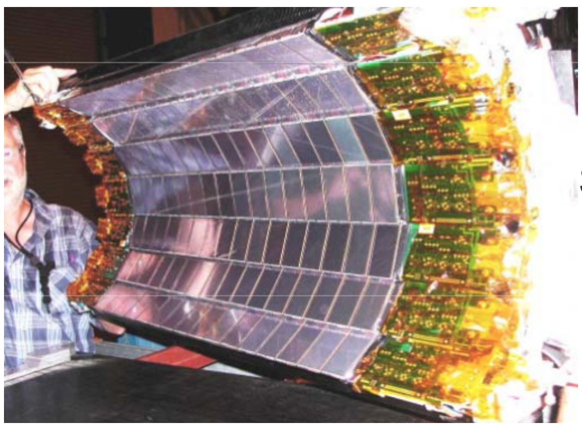
Sub detector	r (cm)	Sensitive units	$\sigma_{R\text{-}\varphi}$(μm)	σ_Z(μm)	X/X_0 (%)
Silicon Strip Detector	22	2 side strips with 95 μm pitch	20	740	1
Intermediate Silicon Tracker	14	600 μm x 0.6 cm strips	170	1800	<1.5
PIXEL	2.5/8	18 μm pixel pitch	12	12	0.4/layer

HFT Status

- Engineering run for PXL prototype (3 out of 10 sectors) finished
  - installed on May 8, 2013
    - within 12 hours
  - first PXL data in daq file on May 10
  - 78 M events taken with PXL
- full system to be installed in 2014

PXL prototype insertion



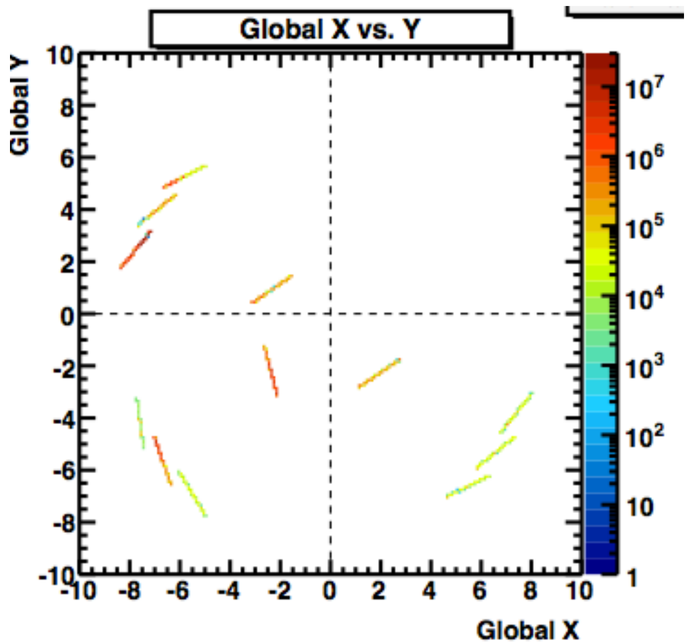


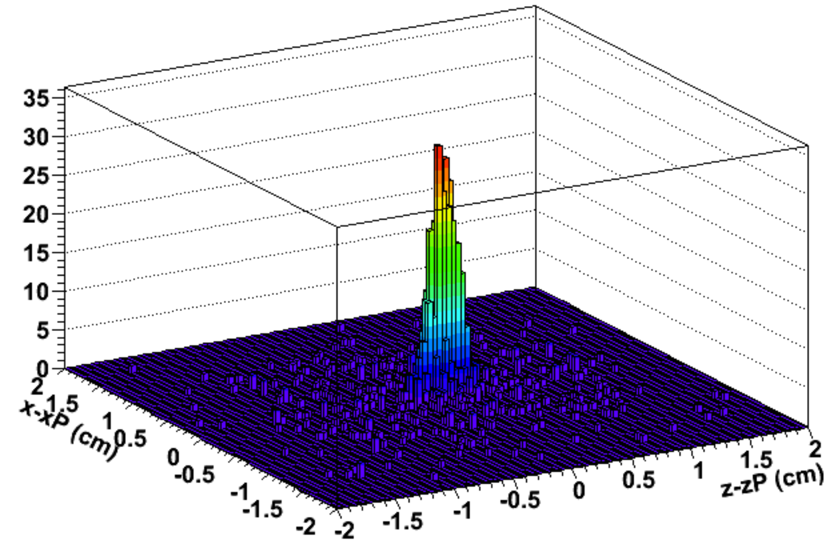
SSD part

IST ladder

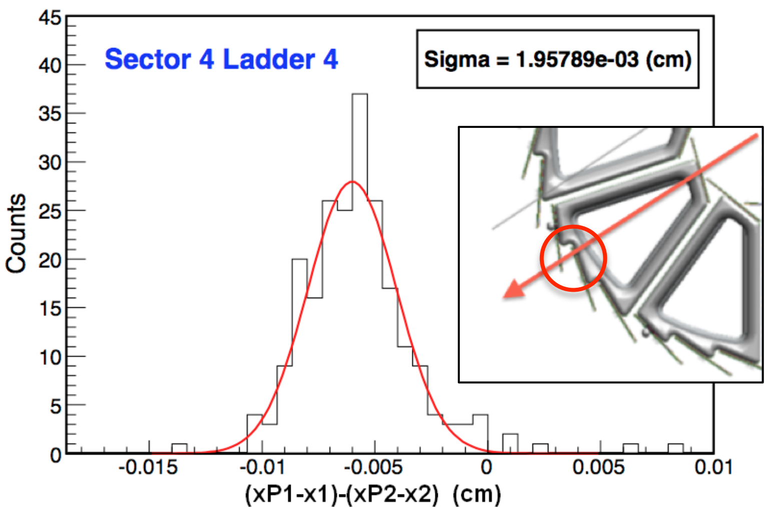
PXL prototype half

PXL Performance





- 2D correlation between measured pxl hit and TPC track projection on a sensor



- Double difference of hit and track projection positions between 2 overlapping sensors
- Single sensor resolution = 20 / √2 = 14 microns

  ~ 12 microns resolution of designed goal

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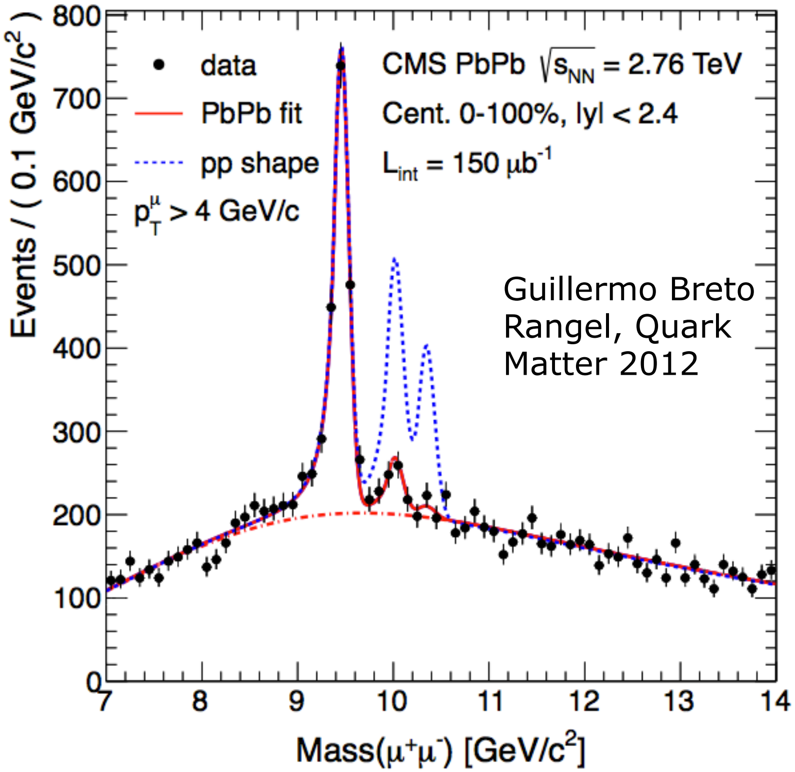
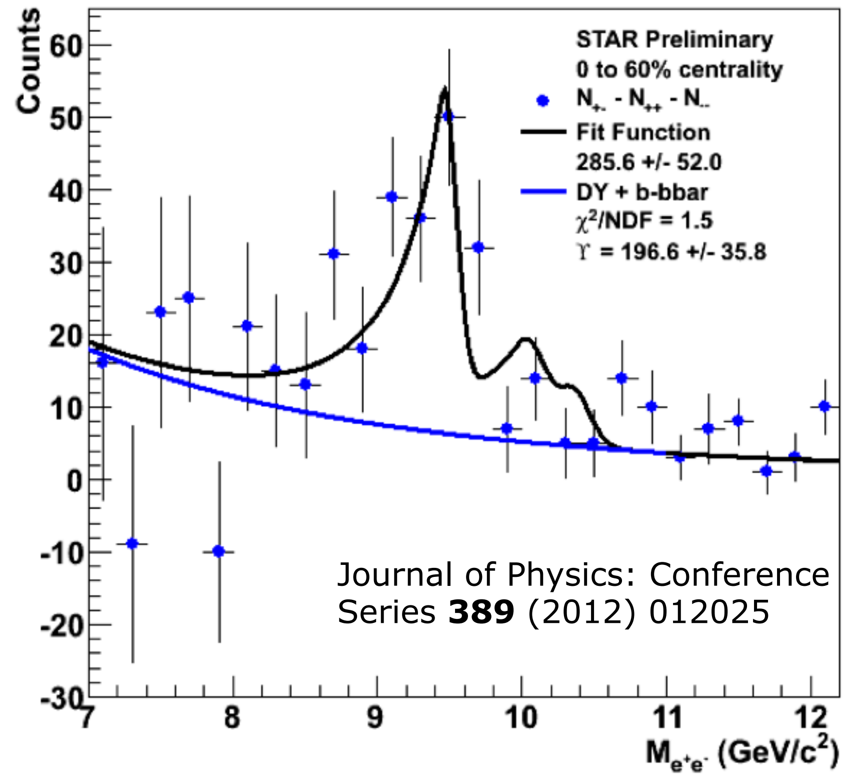
MTD Physics Motivation

- di-muon pairs from
  - QGP thermal radiation
  - quarkonia
  - light vector mesons
  - Drell-Yan production
- single muons from
  - heavy flavor hadrons

- advantages over electrons:
  - no γ conversion
  - much less Dalitz decay contribution
  - less affected by radiative losses in the detector materials
  - trigger capability in Au+Au

Different Υ states



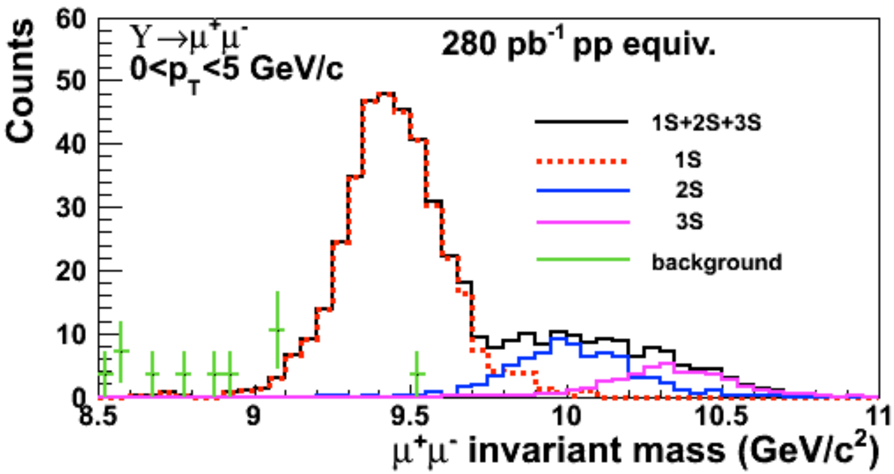


$q\bar{q}$	T/T_c
Υ(1S)	2.31
$\chi_b(1P)$	1.13
Υ(2S)	1.10
$\chi_b(2P)$	0.83
Υ(3S)	0.75

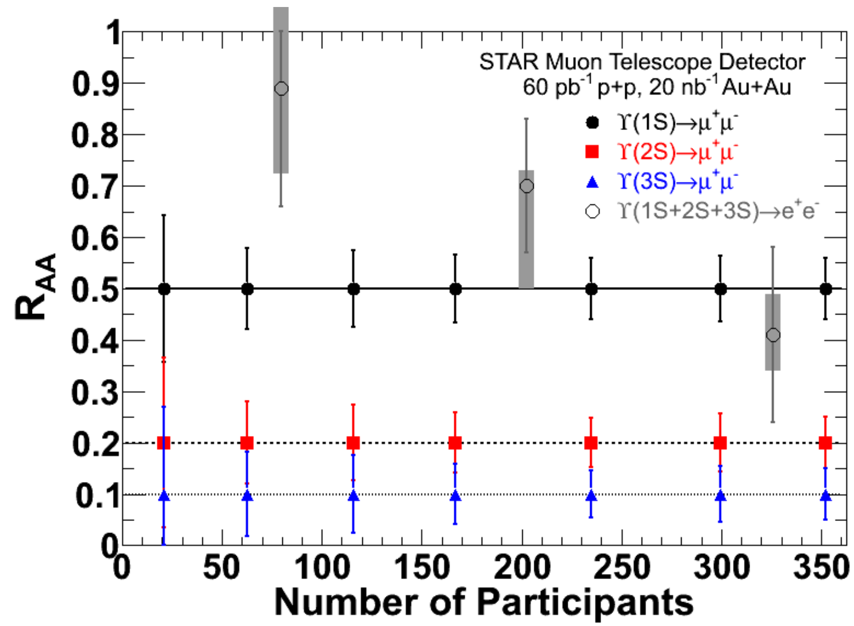
S. Digal, P. Petreczky, and H. Satz, *Phys Rev. D 64,094015 (2001)*

- Sequential suppression of different Υ states can be used as a QGP thermometer
- Di-muon channel is less affected by bremsstrahlung energy losses, enabling separating different Υ states.

Different ϒ states



simulation with MTD



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- Sequential suppression of different ϒ states can be used as a QGP thermometer
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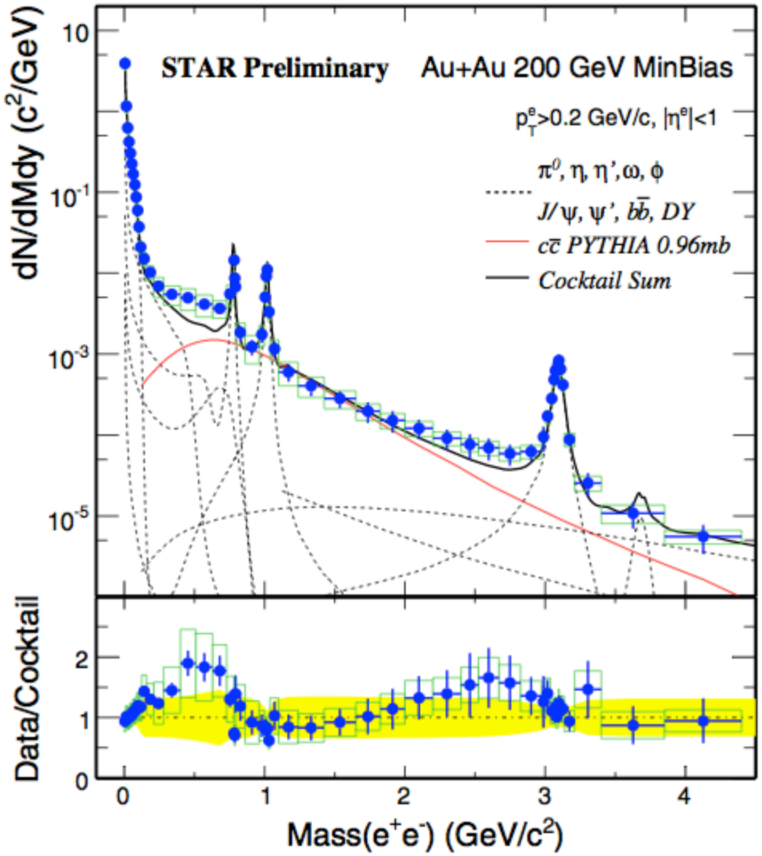
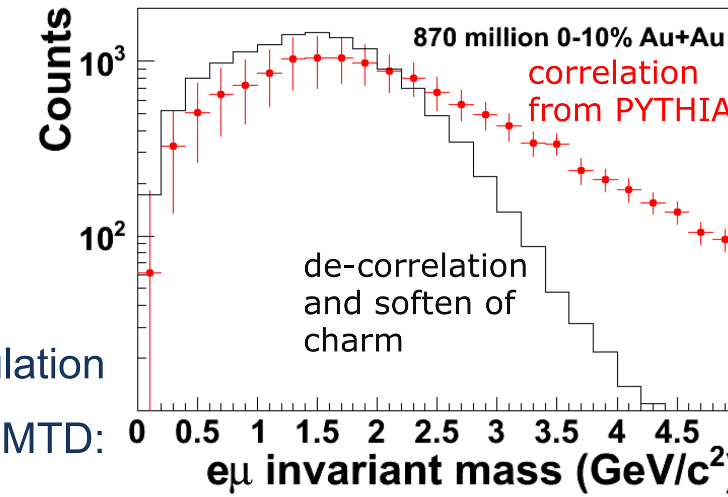
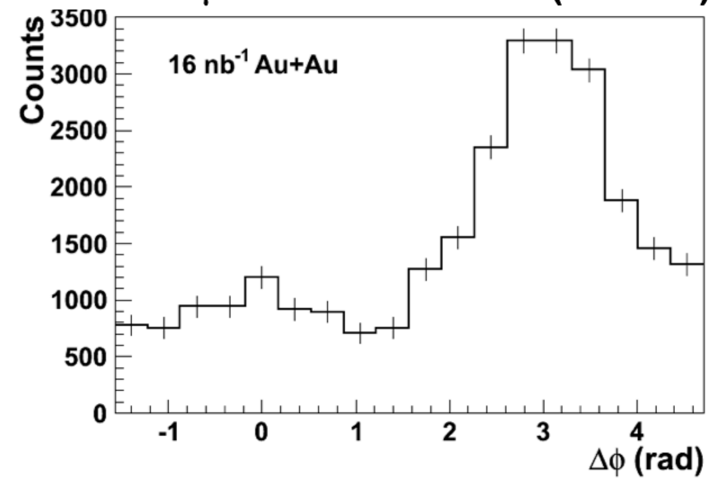
e-μ Correlation



J. Phys. G: Nucl. Part. Phys. 38 124134 (2011)

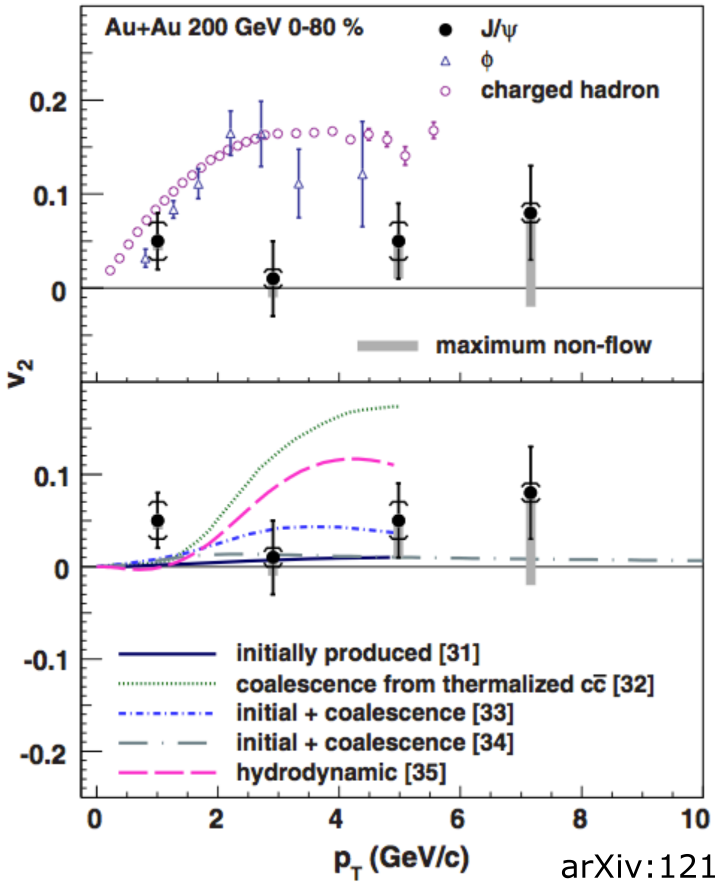
simulation with MTD:





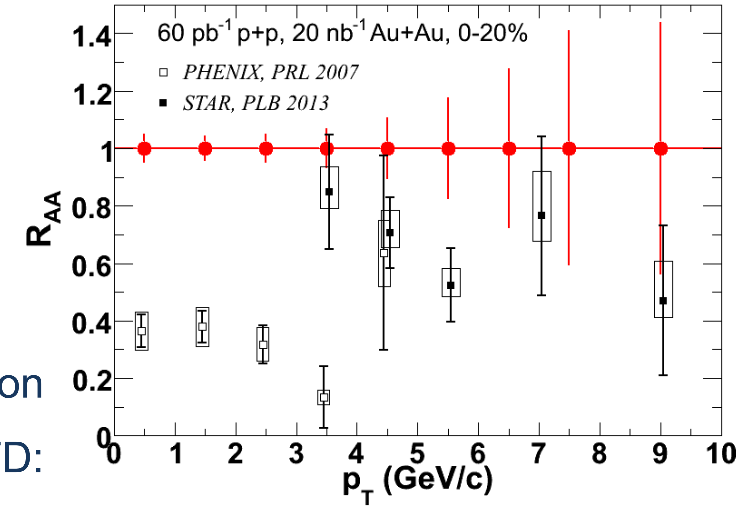
- e-μ correlation → $c\bar{c}$ correlation → charm interaction with the medium
- subtract $c\bar{c}$ contribution from di-lepton → Thermal production → medium thermometer

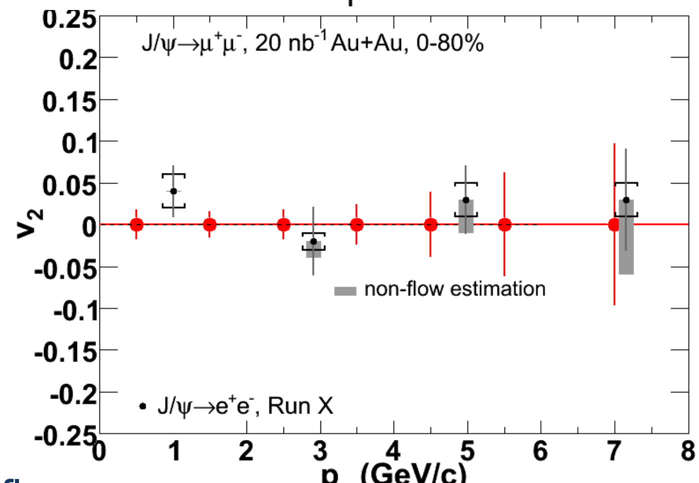
J/ψ R_{AA} and Flow



arXiv:1212.3304

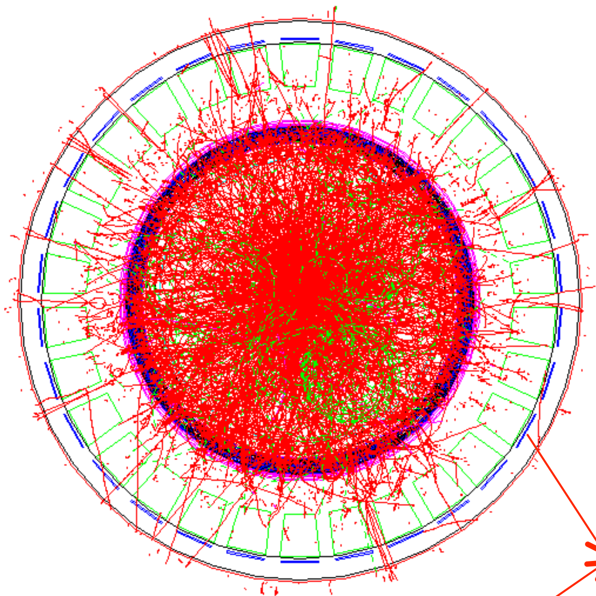
simulation with MTD:



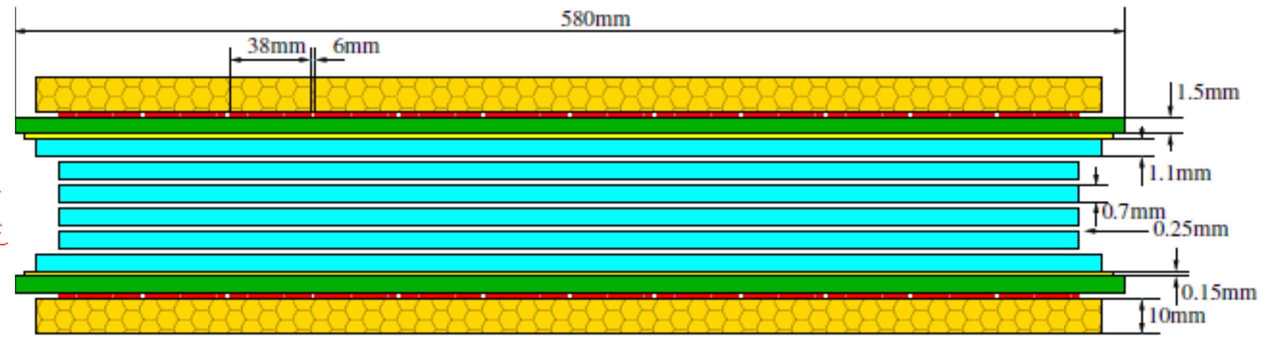


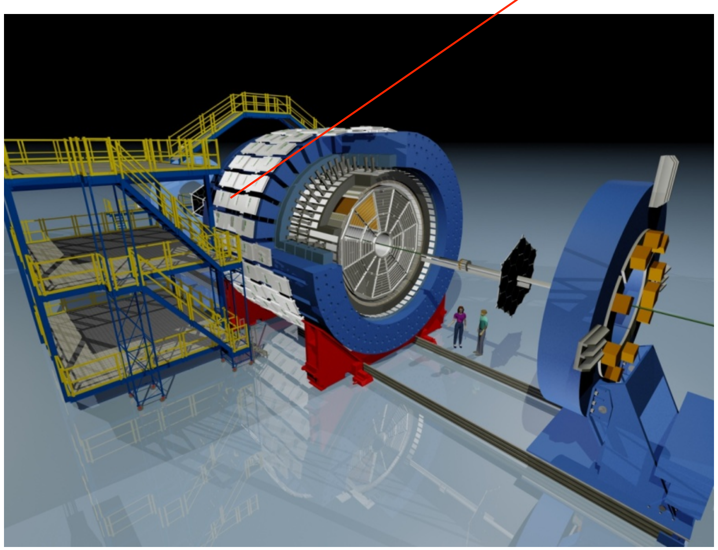
- R_{AA} & v_2 ⇒ J/ψ production mechanism & charm flow
- $\mu^+\mu^-$ channel
  - Trigger capability for low p_T J/ψ
  - lower background

MTD Design



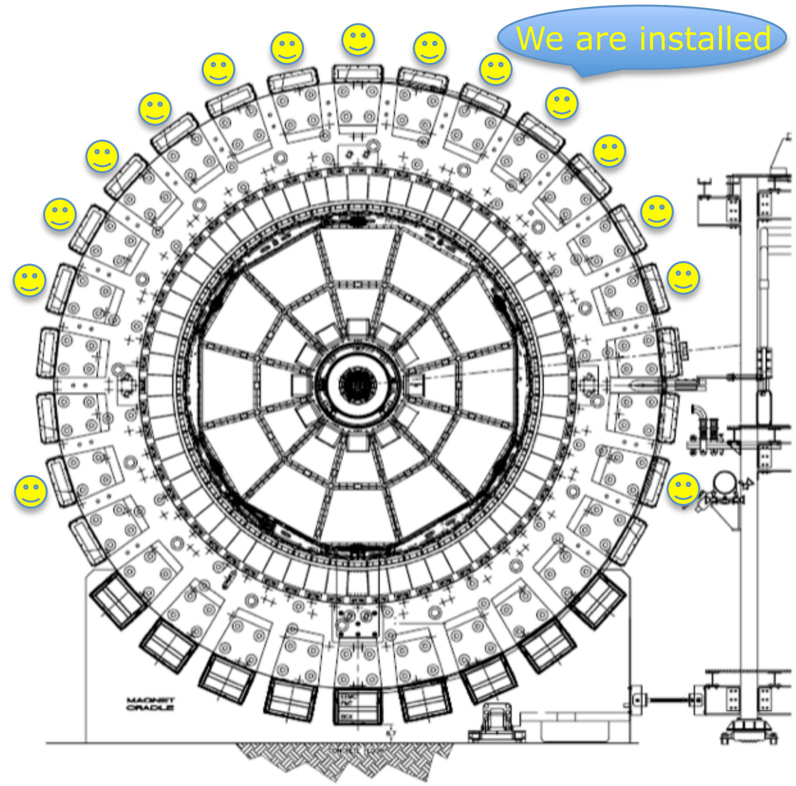
MTD





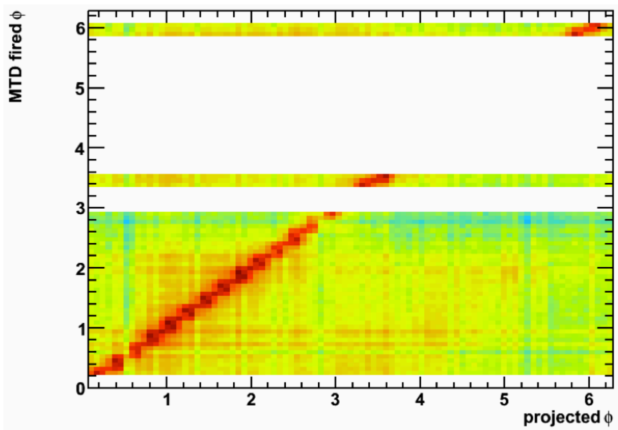
- Multi-gap Resistive Plate Chamber (MRPC):
    - gas detector, avalanche mode
- use the magnet iron bars as absorber and leave the gaps in-between uncovered
- Acceptance: 45% at $|\eta|<0.5$
- 118 modules, 1416 readout strips, 2832 readout channels
- Long-MRPC detector technology
- electronics same as used in STAR-TOF

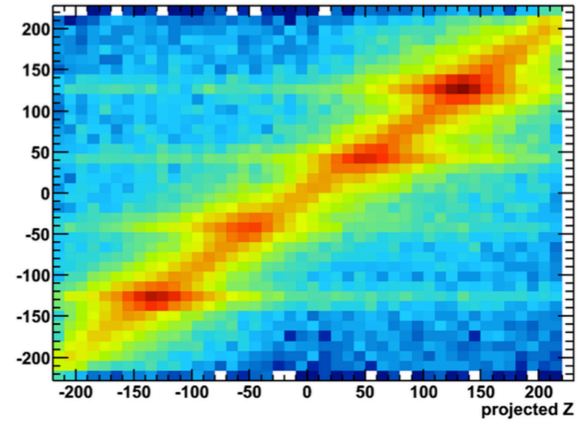
MTD Status



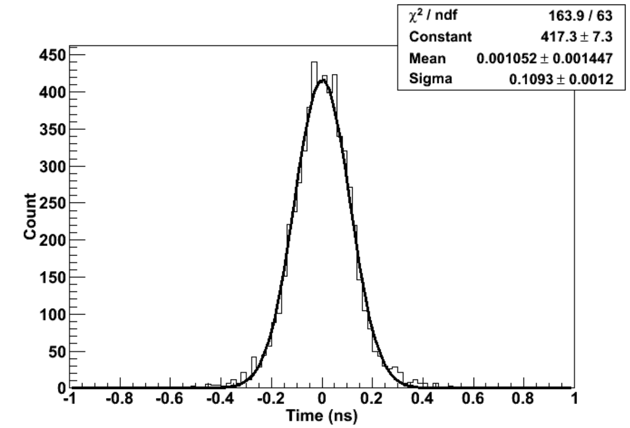
Proposed	Actual
10% installation for 2012	10% installation for 2012
43% for 2013	**63% for 2013**
80% for Run 14	100% for 2014
Finish 2014	

MTD Performance

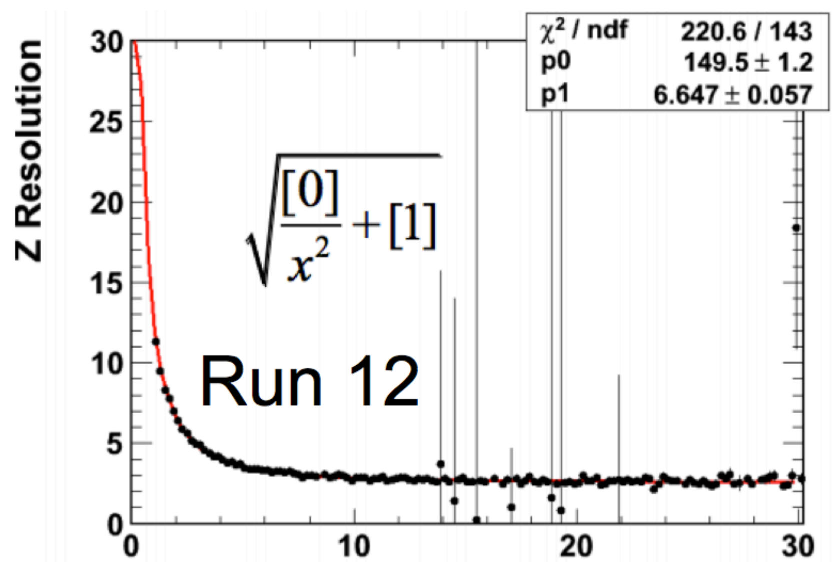




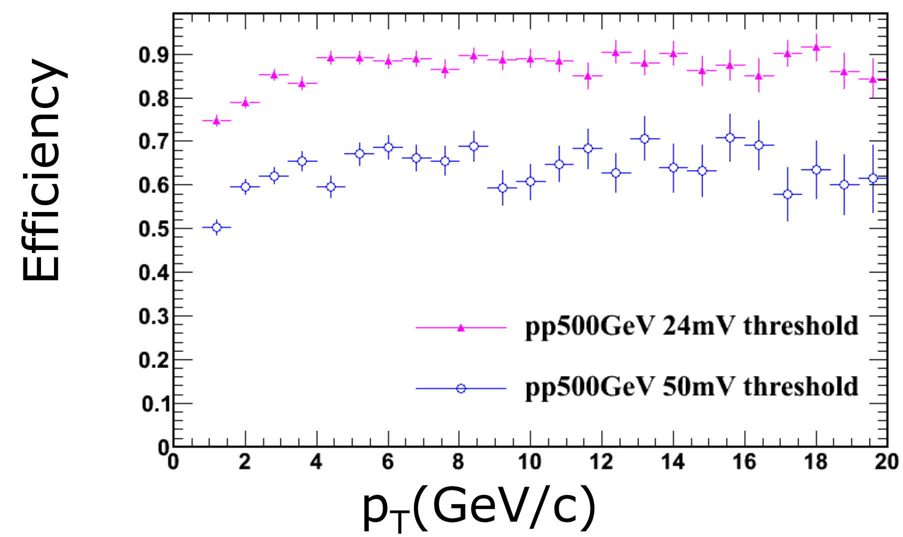
- MTD hit – TPC track projection correlation



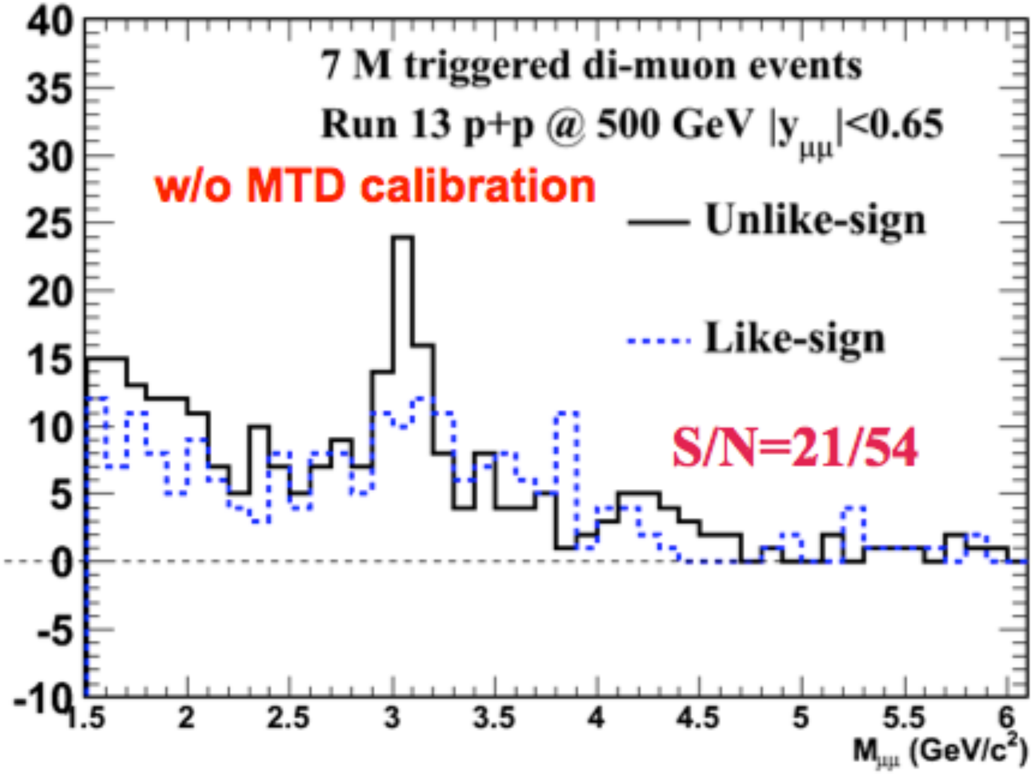
- Time resolution measured with cosmic data: 96 ps

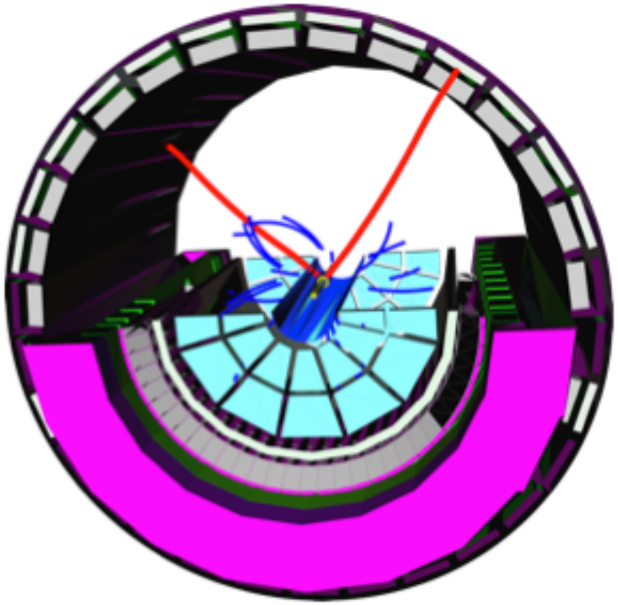


Intrinsic space resolution 2.6 cm



J/ψ from Di-muon Trigger





One di-muon trigger event

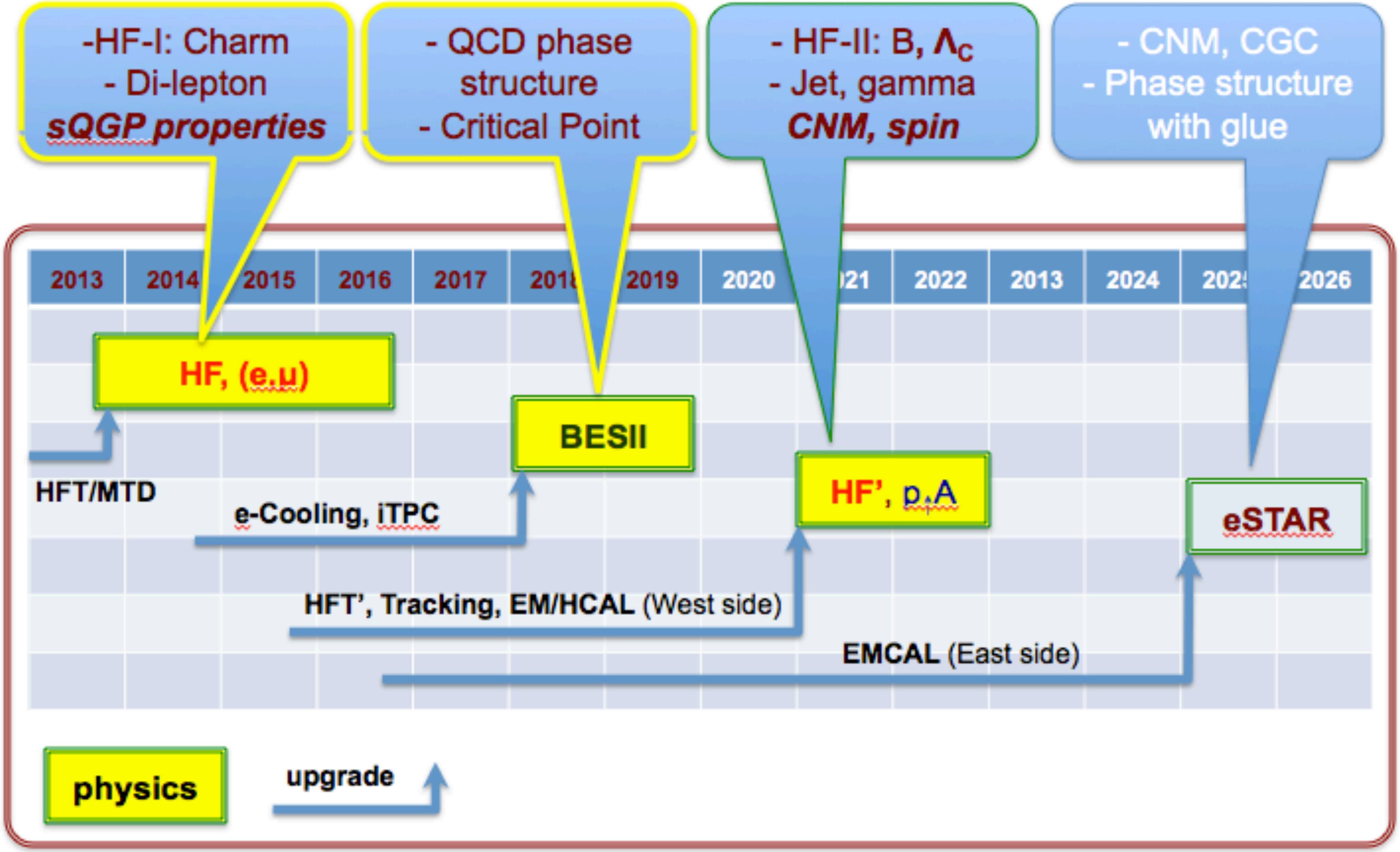
- J/ψ from Di-muon Trigger with only 7 M events, out of 120 M in total from Run 13.
- without time calibration, which will further suppress background

RHIC Run Plan

Run	Energy	Time	System	Goal
14[1]	$\sqrt{s_{NN}}$=200GeV	14-week	Au+Au	HFT & MTD heavy flavor measurements, $\mathcal{L}$=10 nb^{-1}, 1000M M.B.
	$\sqrt{s_{NN}}$=15GeV	3-week	Au+Au	1) Collect 150M M.B. events for CP search 2) Fixed-target data taking[3]
15[2]	$\sqrt{s_{NN}}$=200GeV	5-week	p+Au	Study saturation physics, pA-ridge and heavy ion reference, $\mathcal{L}$=300 nb^{-1}
	$\sqrt{s}$=200GeV	12-week	1) p+p	1) Heavy ion reference data $\mathcal{L}$=90 pb^{-1}, 500M M.B.
			2) transverse 6 weeks	2) Study transversity, Sivers effects $\mathcal{L}$=40 pb^{-1}, 60% pol.
			3) longitudinal 6 weeks	3) Study $\Delta g(x)$ $\mathcal{L}$=50 pb^{-1}, 60% pol.

- STAR Beam User Request, endorsed by RHIC PAC.
- Focus on 200 GeV AA, pA, and pp collisions for heavy ion programs with new upgrades.

RHIC Run Plan



Summary

- STAR is conducting two major upgrades for heavy ion program:
  - HFT for heavy flavor measurements
  - MTD for muon detection
- These upgrades will enable or enhance a rich set of physics programs:
  - open and closed heavy flavor measurements, a clear probe to the QGP phase
  - thermal radiation, QGP thermometer
- The combination of HFT and MTD, together with the existing mid-rapidity subsystems, will make STAR the best suited detector to carry out the mission of studying the hot QCD matter properties.
- Construction of both detectors are going well
  - technical run for PXL prototype just finished successfully
  - 63 % of MTD installed, with desirable performance
- Both detectors will be finished for Run 14.
- New physics results with them will greatly enhance our understanding of QGP created at RHIC.

Thank you

☺