STAR Near Term Upgrades

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For the STAR Collaboration

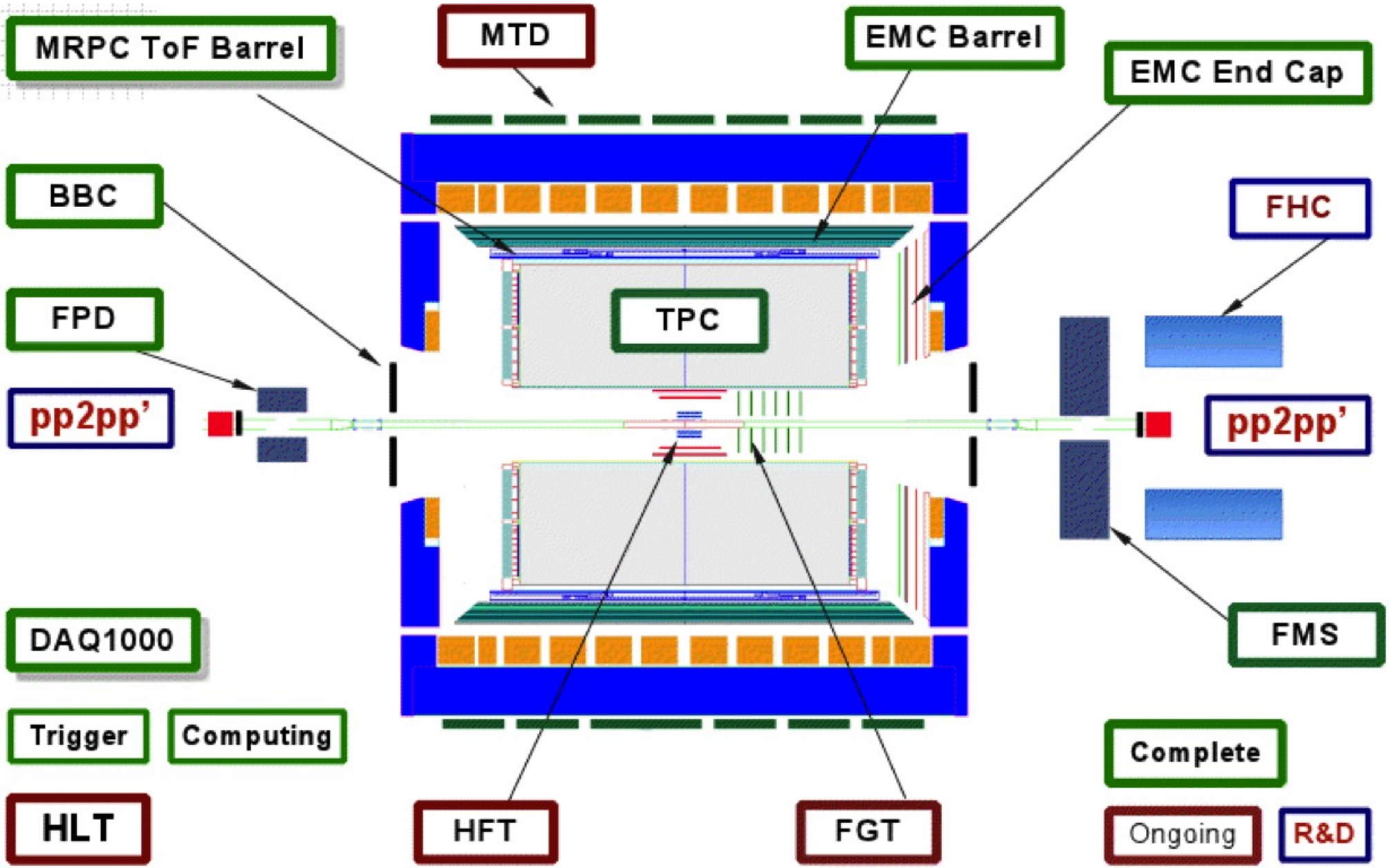
2012 RHIC & AGS Annual Users' Meeting

Office of Science
U.S. Department of Energy

Outline

- STAR current set up overview
- New physics direction for STAR heavy ion program
- Heavy Flavor Tracker and Muon Telescope Detector
  - Physics motivation
  - Design
  - Simulated performance
  - Status, schedule and performance
- Summary

STAR Current Set Up



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 GQP

Open heavy flavor → HFT

Heavy quarkonium → MTD

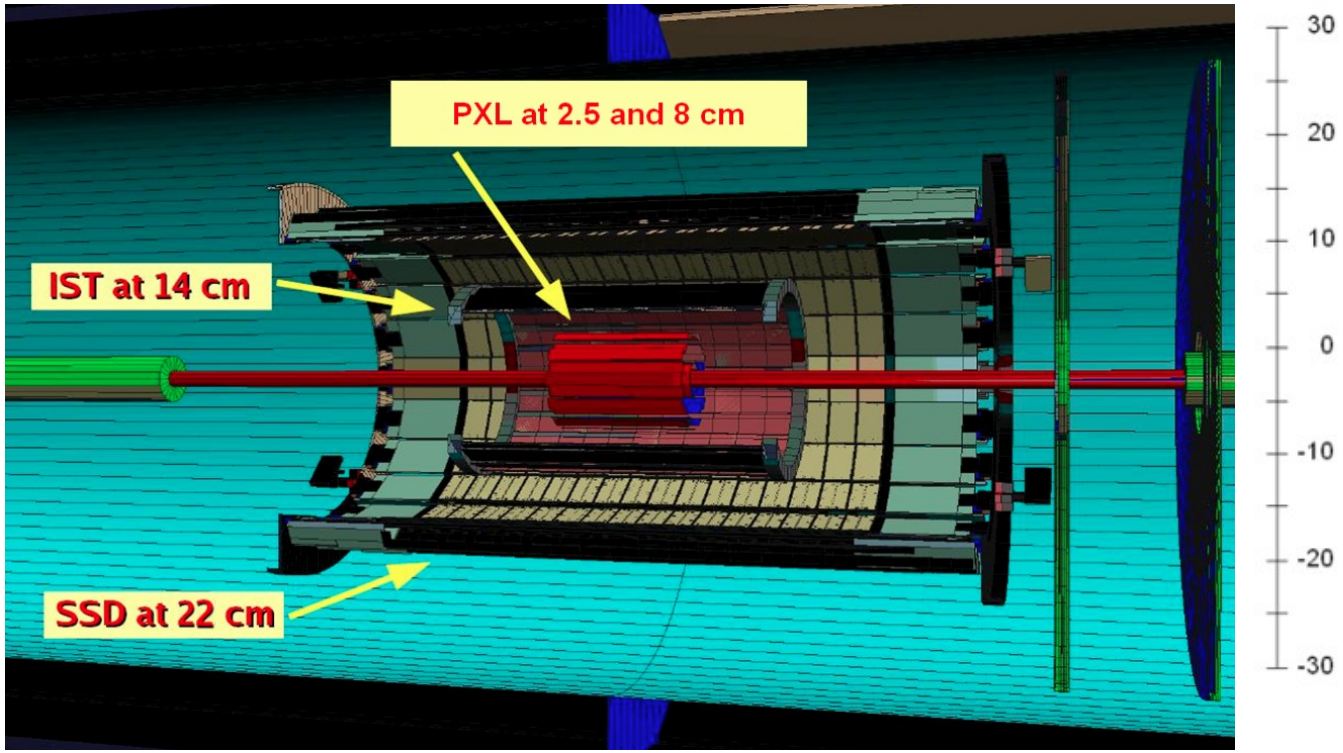
- Thermal di-lepton
  - Probing the temperature of the medium

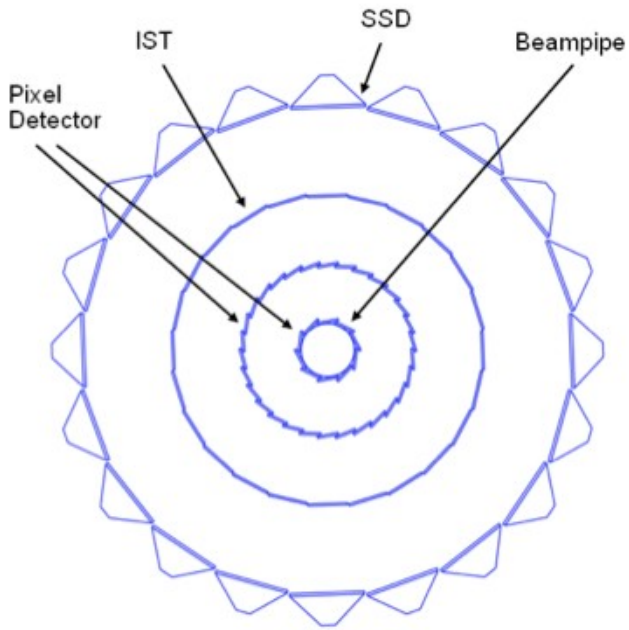
HFT Physics Motivation

- HFT can be used to study heavy flavor production by the measurement of displaced vertices
  - $D^0 \rightarrow K^-\pi^+$ BR = 3.83 % $c\tau \sim 120$ μm
  - $\Lambda_c^+ \rightarrow pK^-\pi^+$ BR = 5.0 % $c\tau \sim 60$ μm
  - B mesons → J/Ψ+X B mesons → e+X $c\tau \sim 500$ μm

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

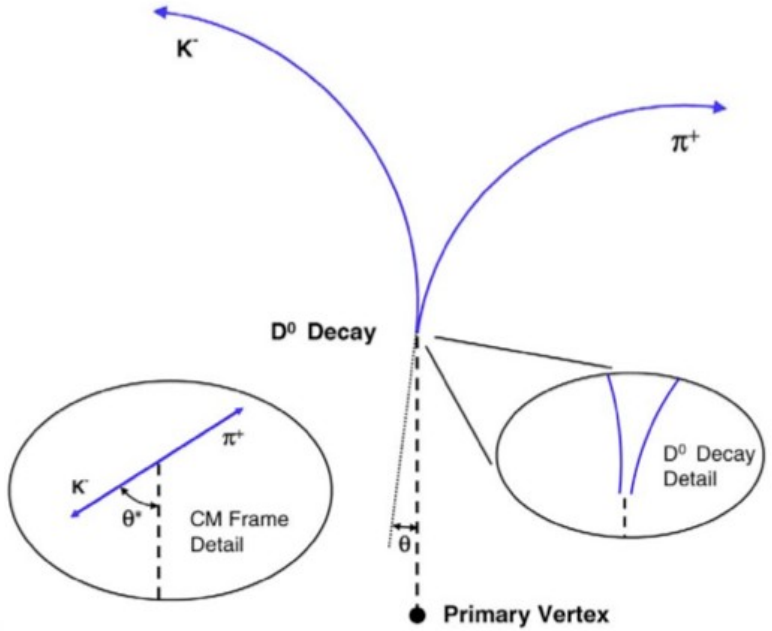
HFT Design

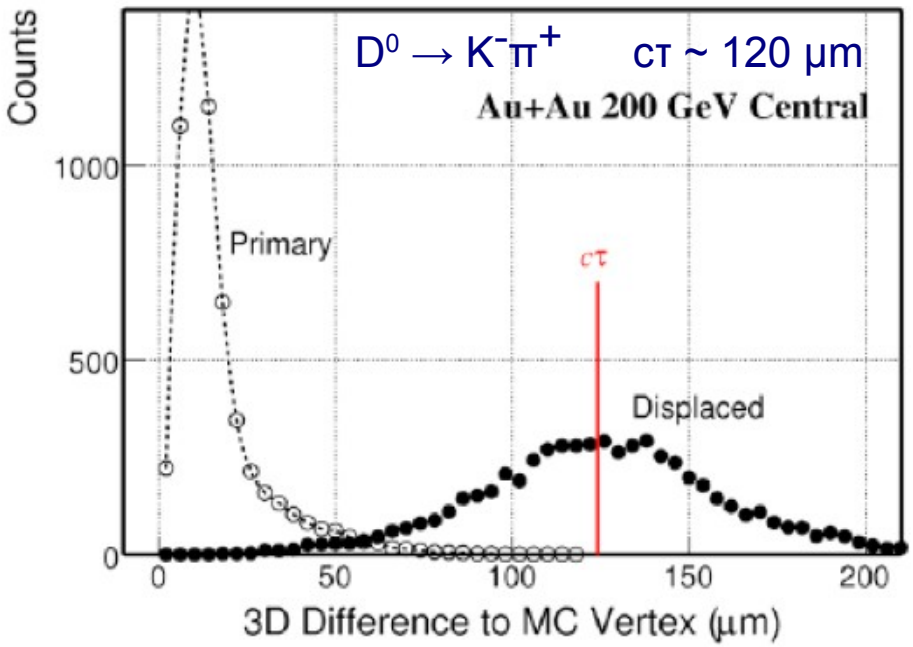


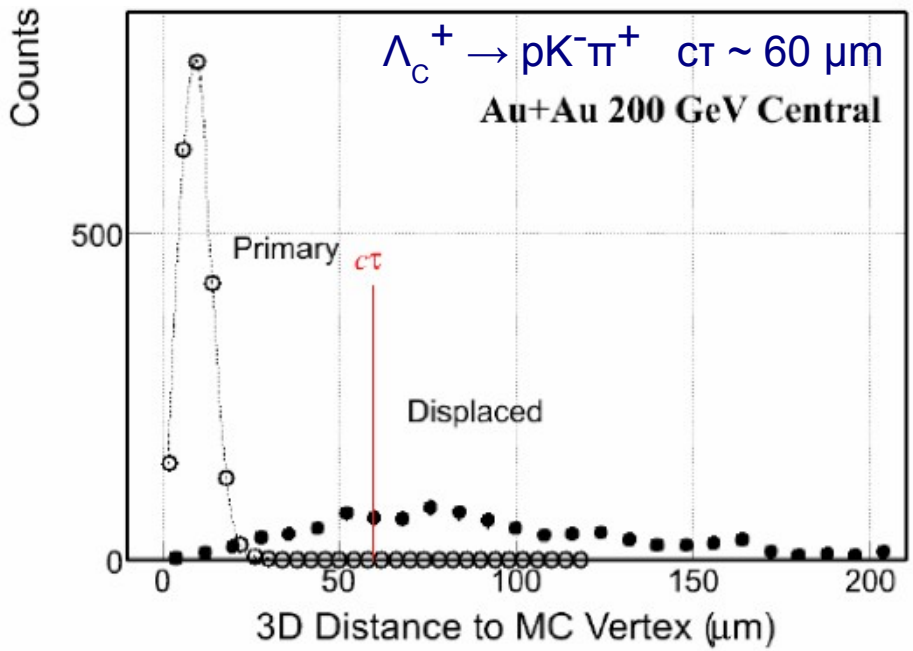


Sub detector	r (cm)	Sensitive units	$\sigma_{R-\varphi}$(μm)	σ_z(μm)	X/X_0 (%)
Silicon Strip Detector	22	2 side strips with 95 μm pitch	20	740	1
Intermediate Silicon Tracker	14	500 μm x 1cm strips	170	1800	<1.5
PIXEL	2.5/8	18 μm pixel pitch	12	12	0.4/layer

Displaced Vertex

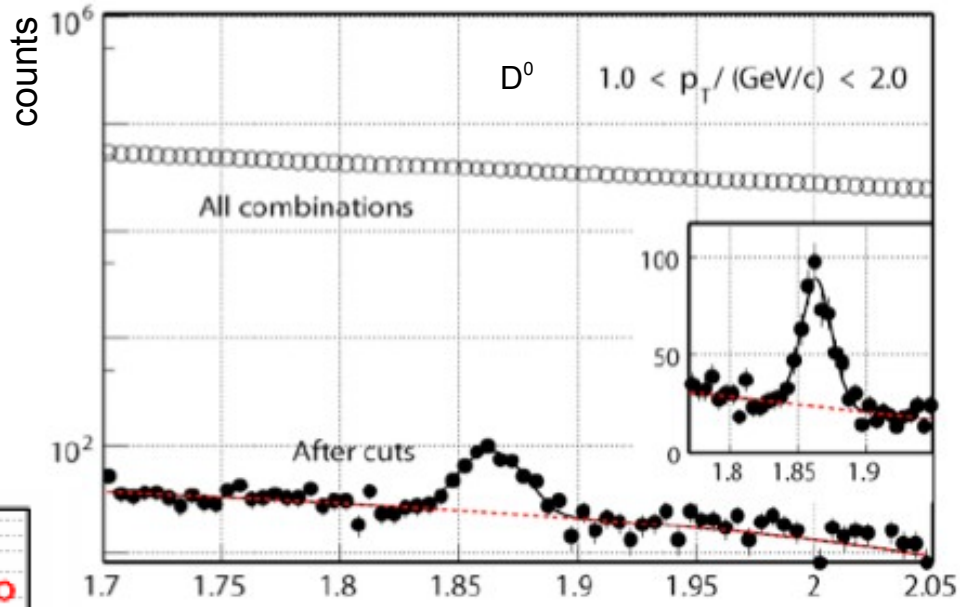


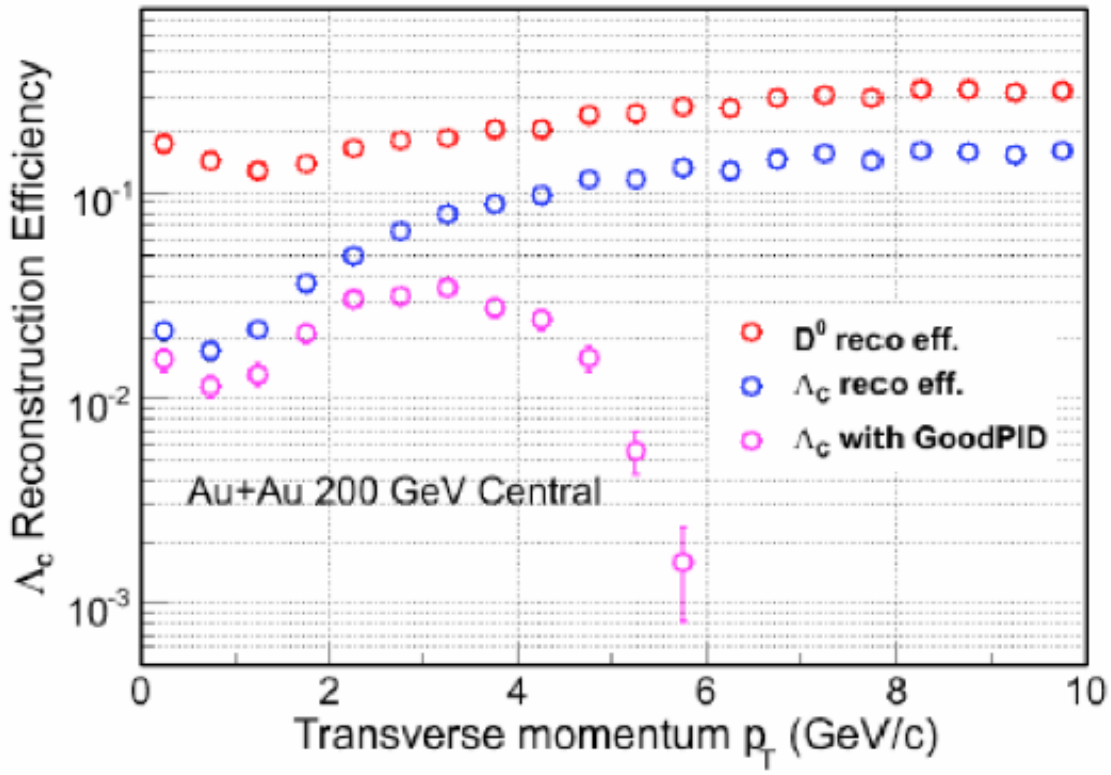


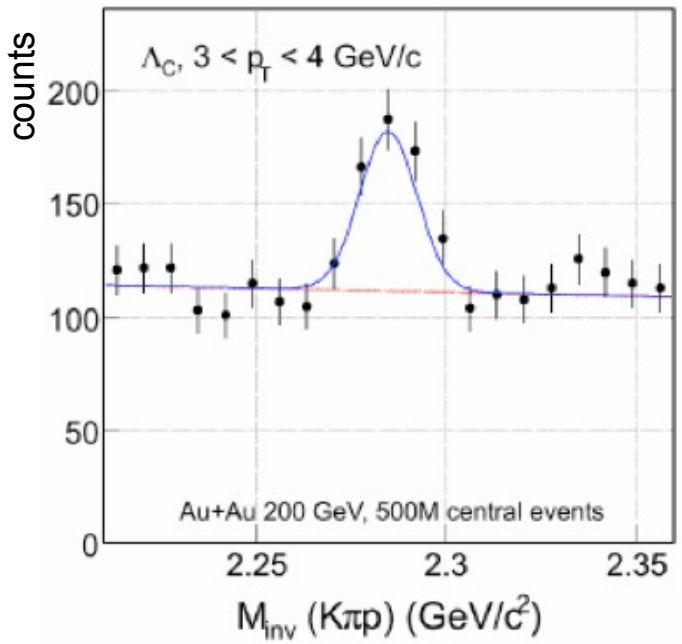


D^0, Λ_c Efficiency and Invariant Mass

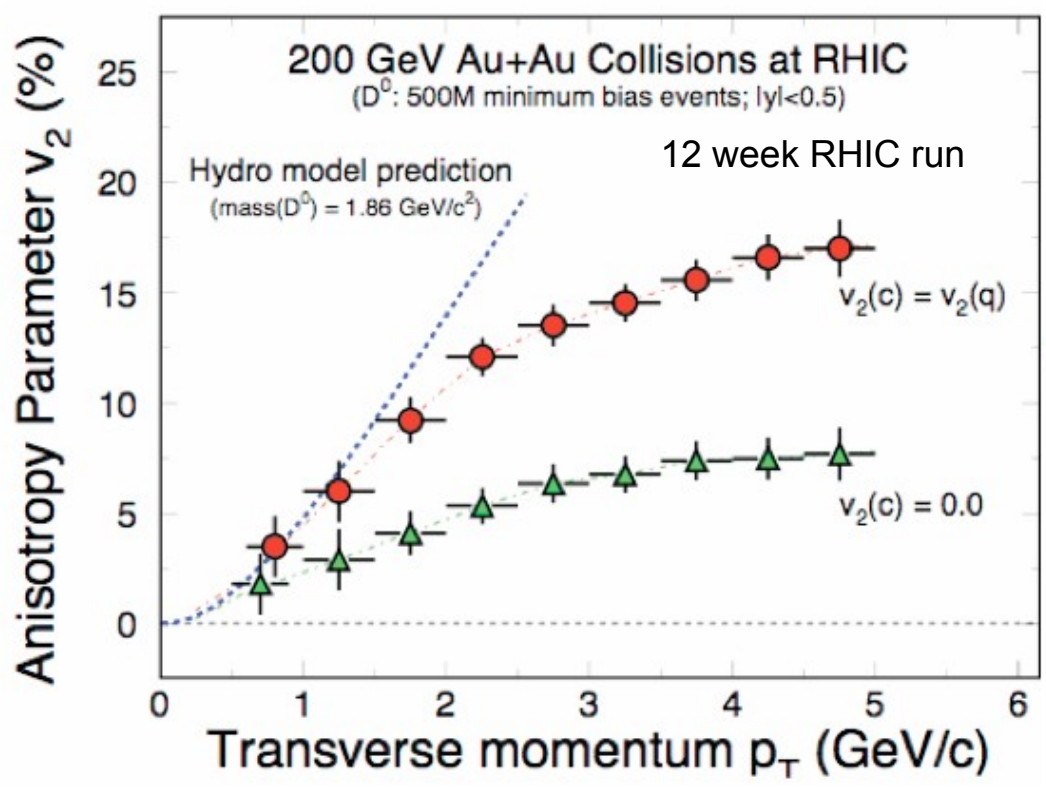
Greatly suppress the combinatorial background

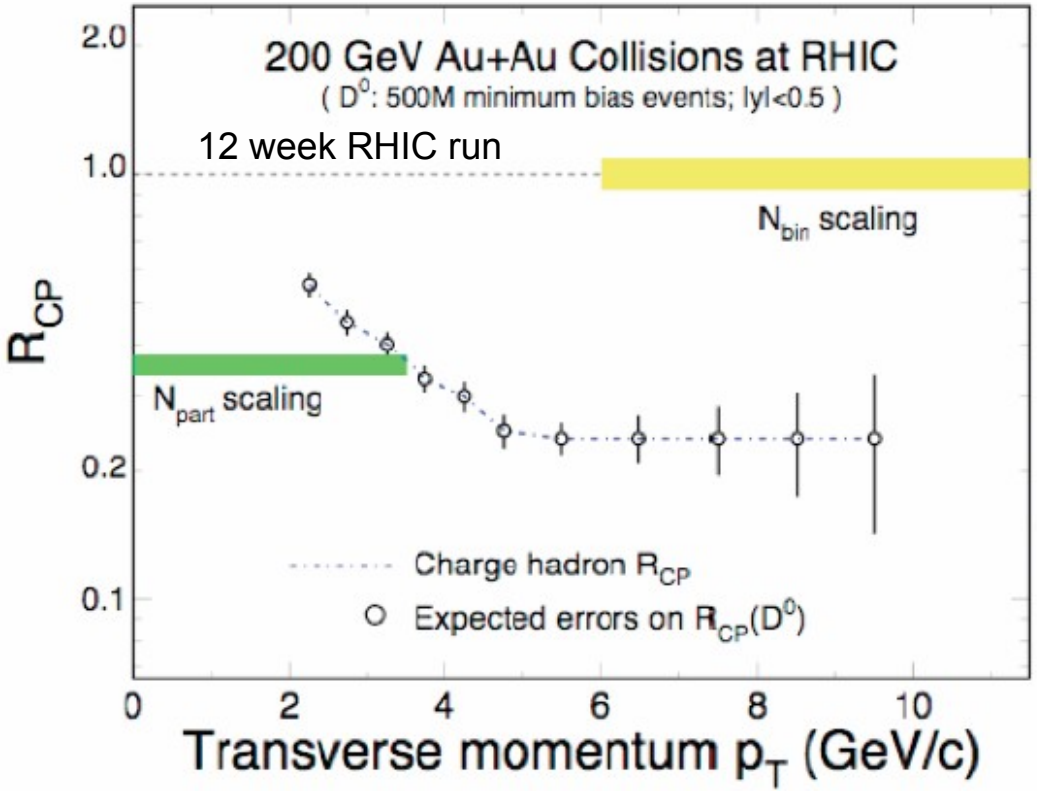






Error Estimation for D^0 v_2 and R_{CP}





Charm collectivity

↓

light flavor themalization?

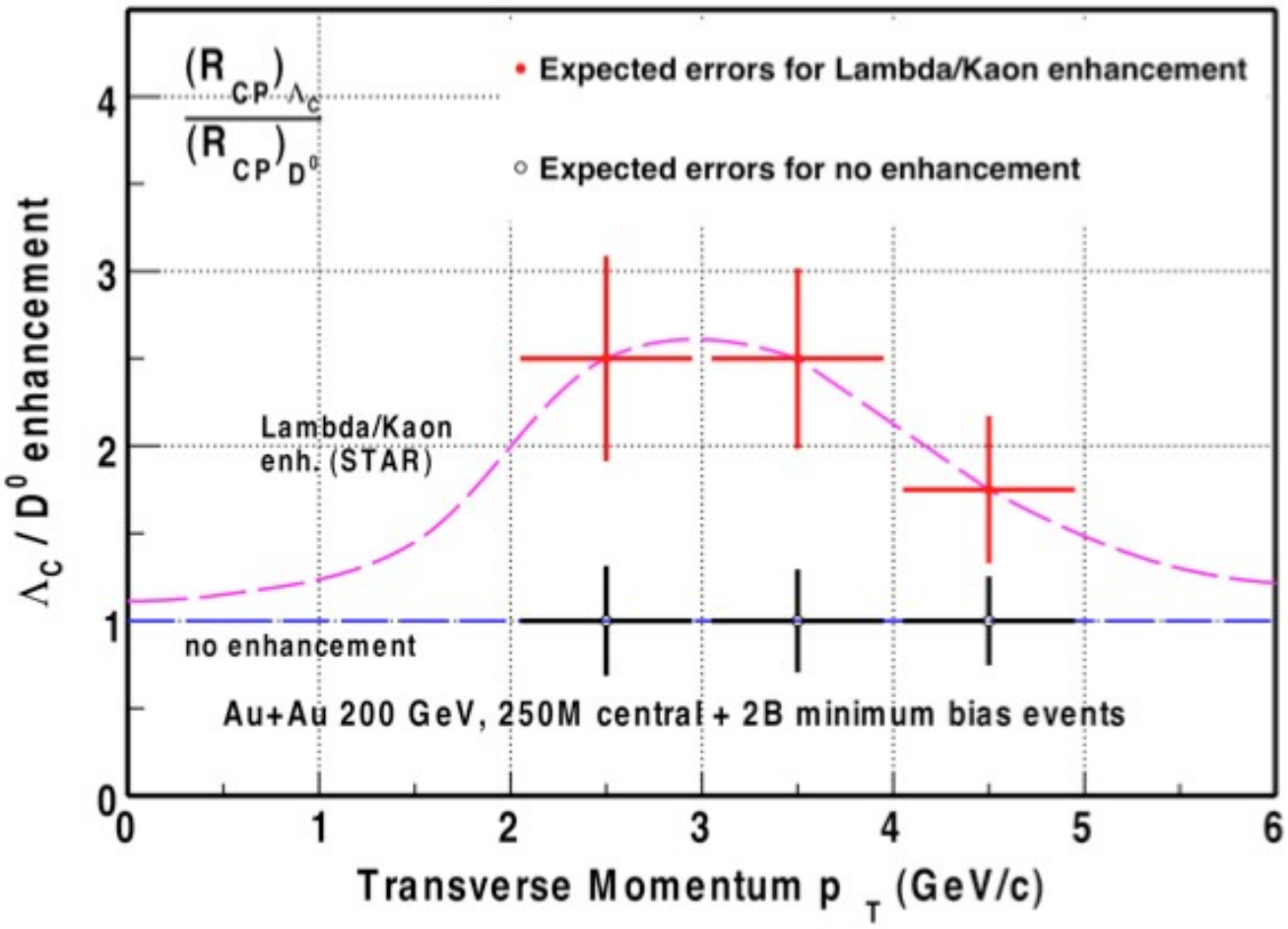
Charm energy loss

↓

energy loss mechanism,

QCD in dense medium

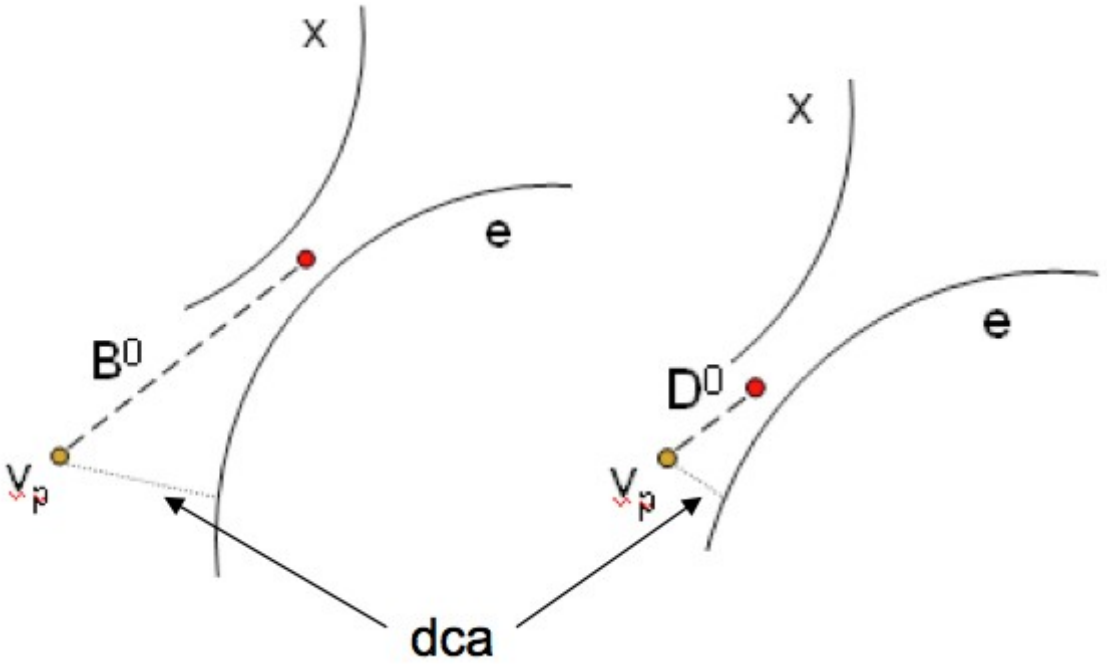
Error Estimation for Λ_c / D^0



Observation of an enhancement in baryon/meson ratio with light quarks is a support for quark coalescence model.

How about with heavy quarks?

Semi-leptonic Channels

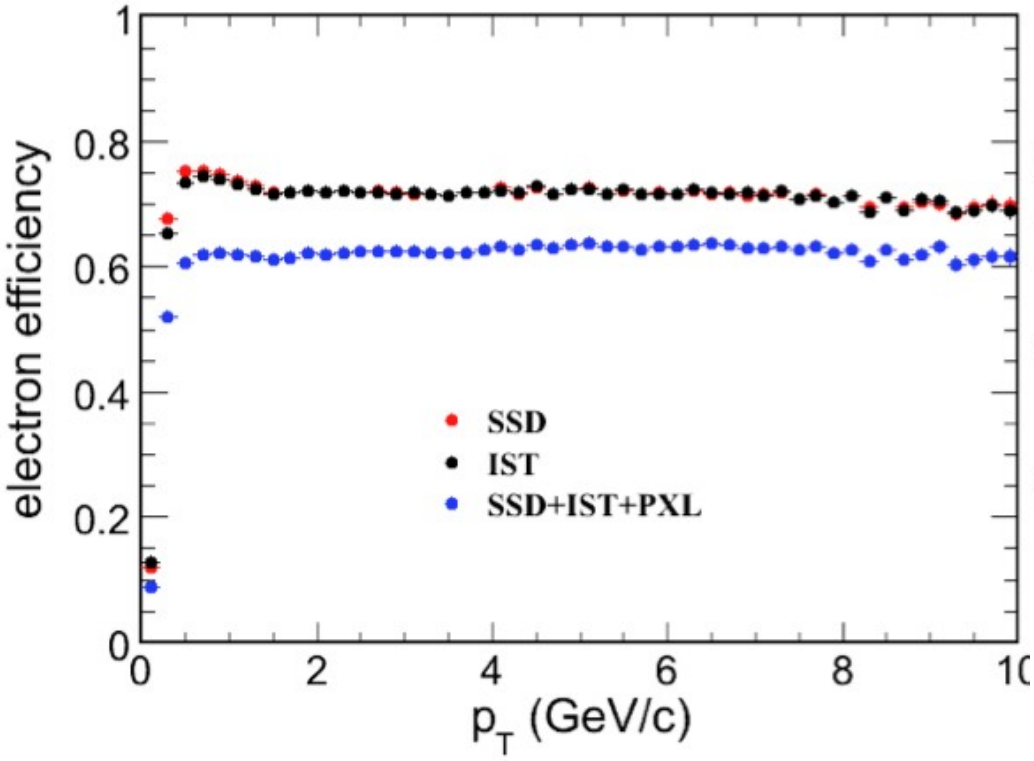


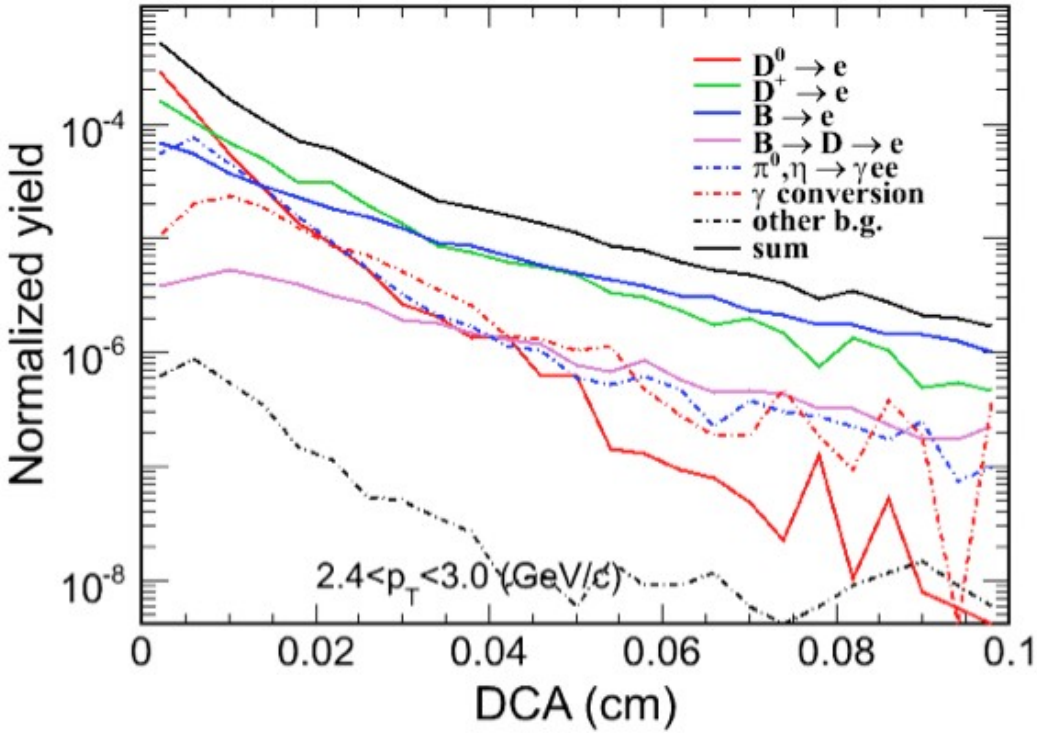
Longer life time → larger dca

Dca: Distance of Closest Approach

Particle	cτ(μm)	Mass(GeV)	Fragmentation Ratio $q_{c,b}$->X	Branching Ratio X -> e
D^0	123	1.865	0.54	0.0671
$D^{\pm}$	312	1.869	0.21	0.172
B^0	459	5.279	0.40	0.104
$B^{\pm}$	491	5.279	0.40	0.109

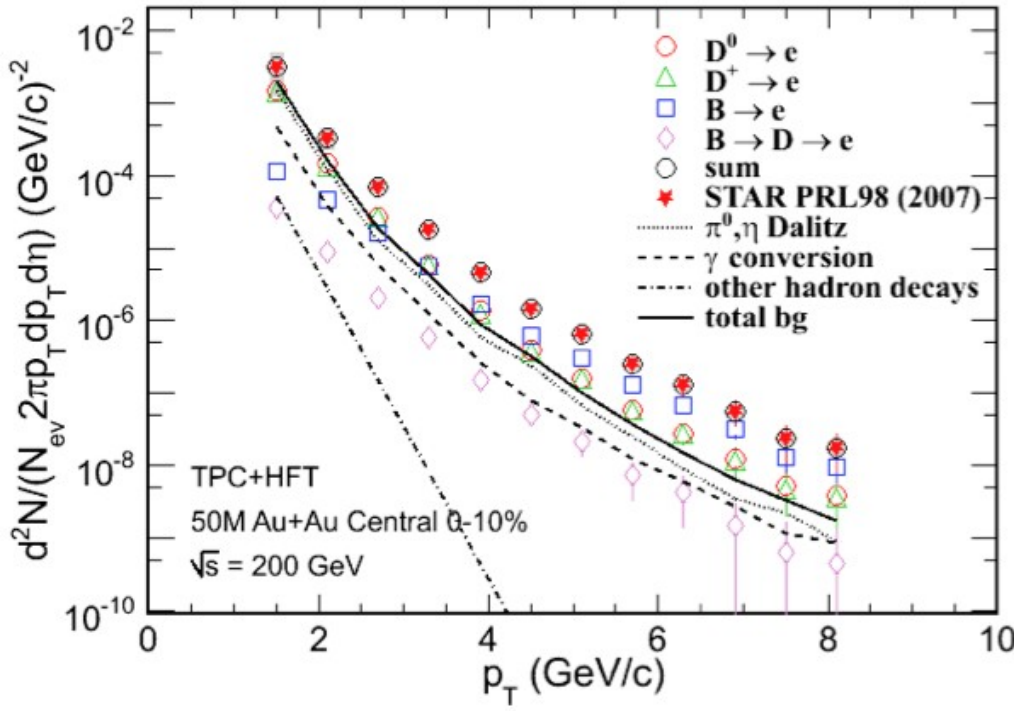
Electron Efficiency and DCA

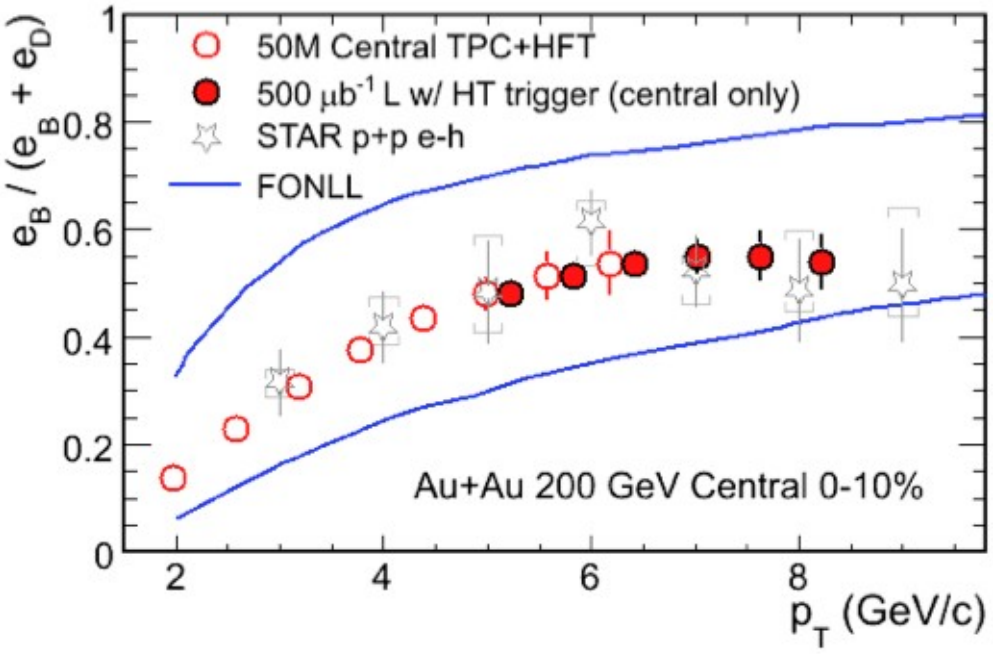




- ~60 % efficiency
- Dca can be used to fit yield from charm and bottom

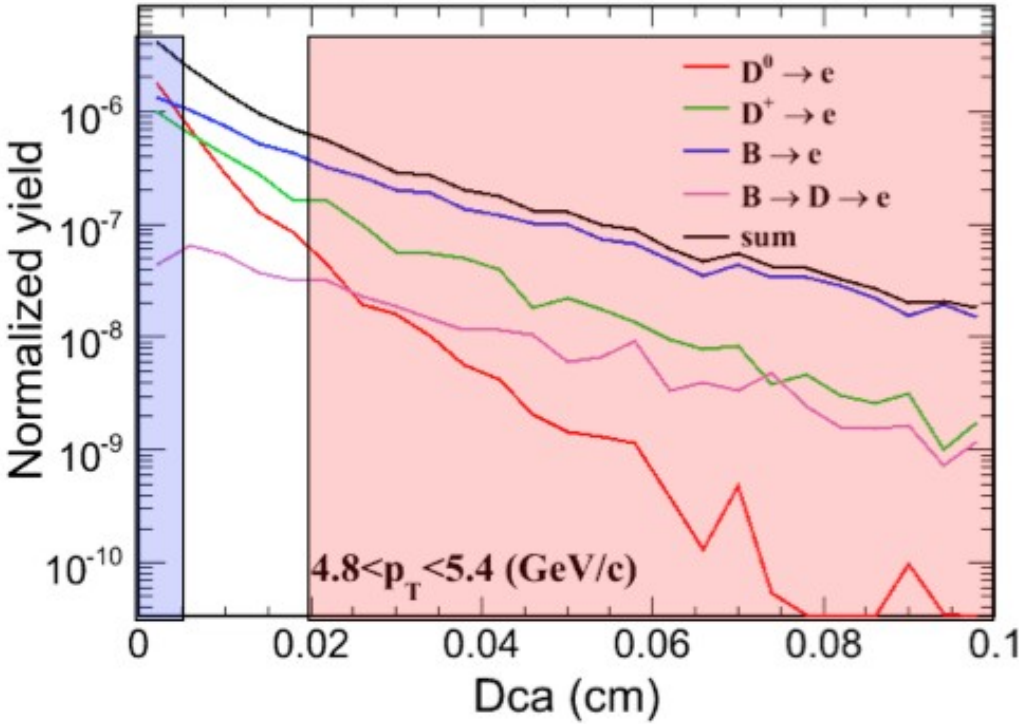
Error Estimation for p_T spectrum and B → e / NPE

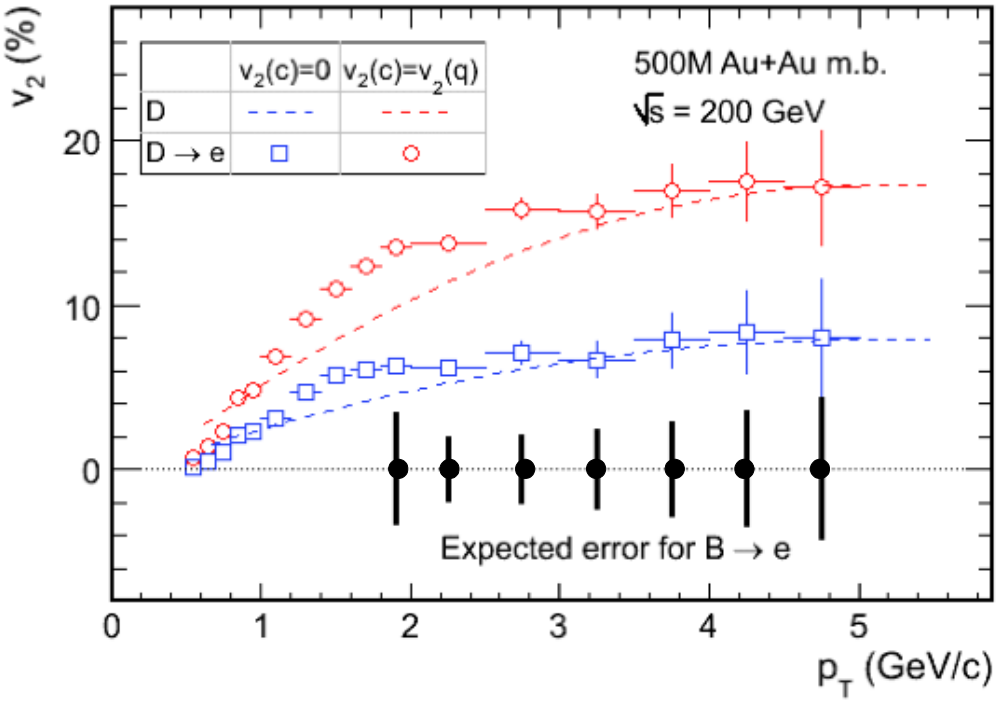




Non Photonic Electron (NPE) yield from charm and bottom can be measured separately by fitting dca distribution.

Error Estimation for v_2 of NPE from B and D



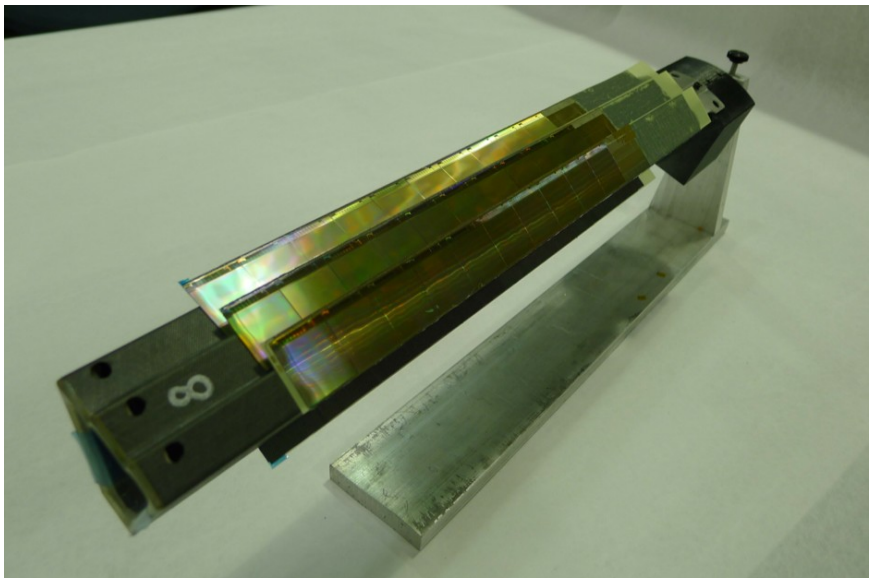


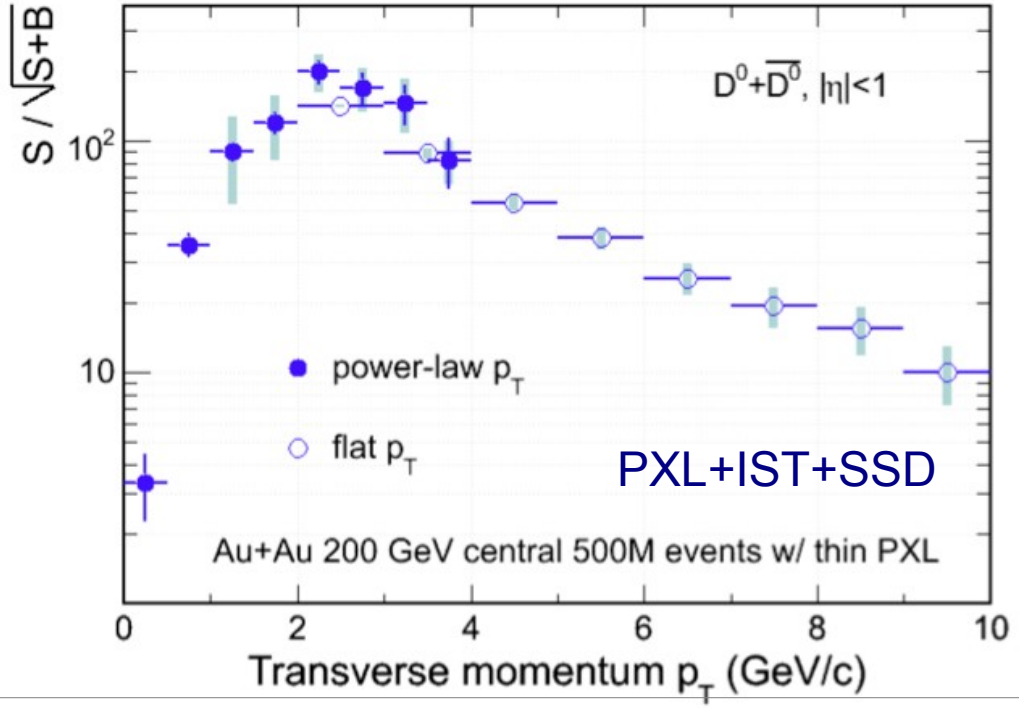
Case	Cut (cm)	e(D) eff. (%)	e(B) eff. (%)	r = e(B)/NPE
I	< 0.005	45.5	22.3	0.325
II	> 0.02	15.3	39.6	0.718

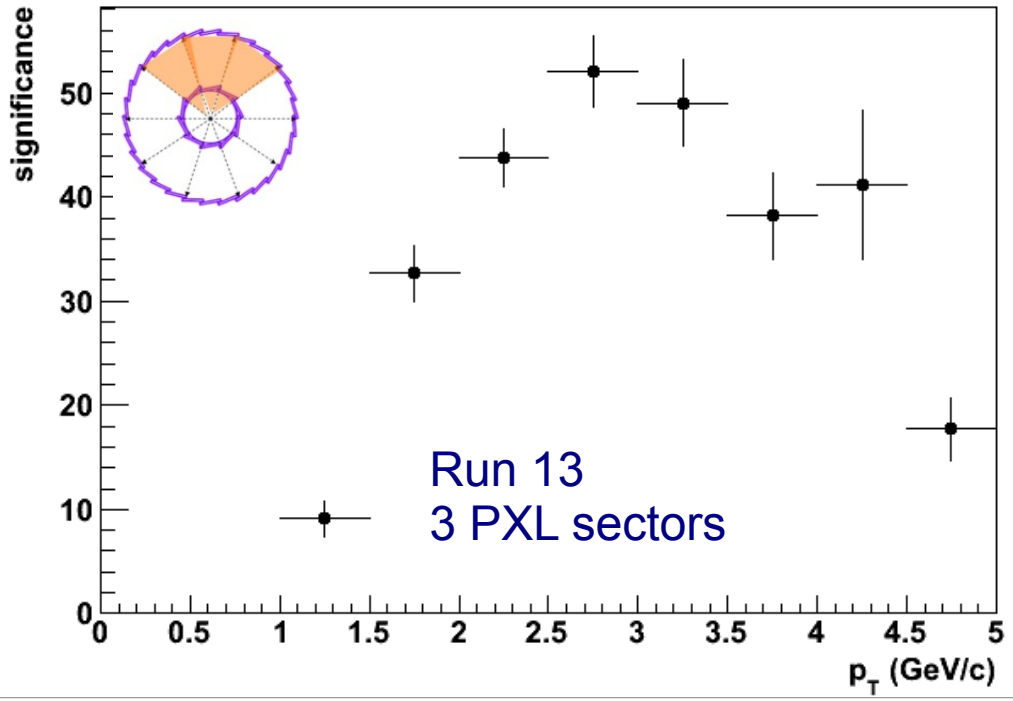
$r * v_2(B) + (1-r) * v_2(D) = v_2(NPE)$

Current Status and Plan

- Just begin constructing pixel sectors
- 0~4 pixel sectors out of 10 in Run 13, no SSD or IST
- technical run possible for some physics measurements, like D_0 R_{AA} and v_2
- The whole HFT (PXL+IST+SSD) expected to be finished in Run 14



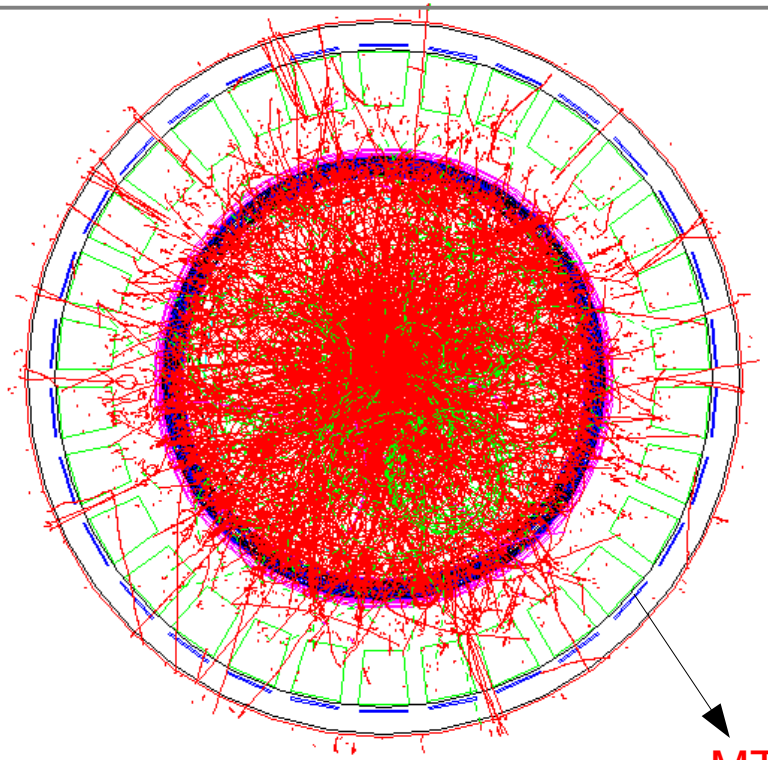




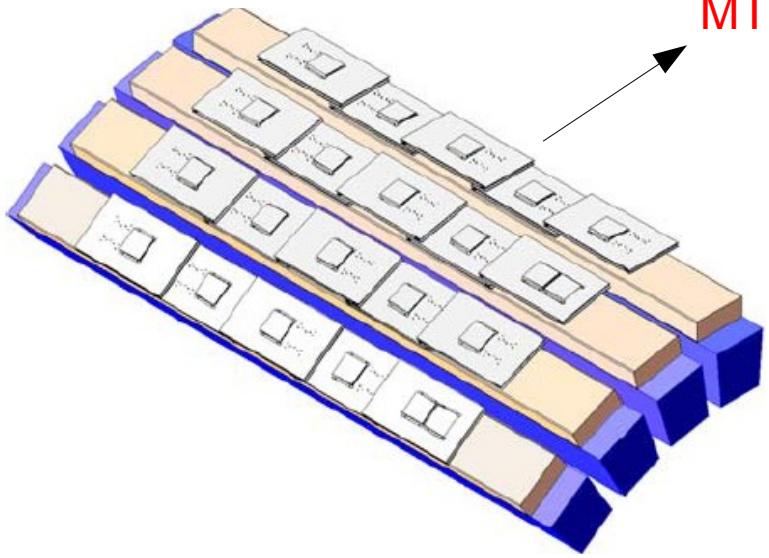
MTD Physics Motivation

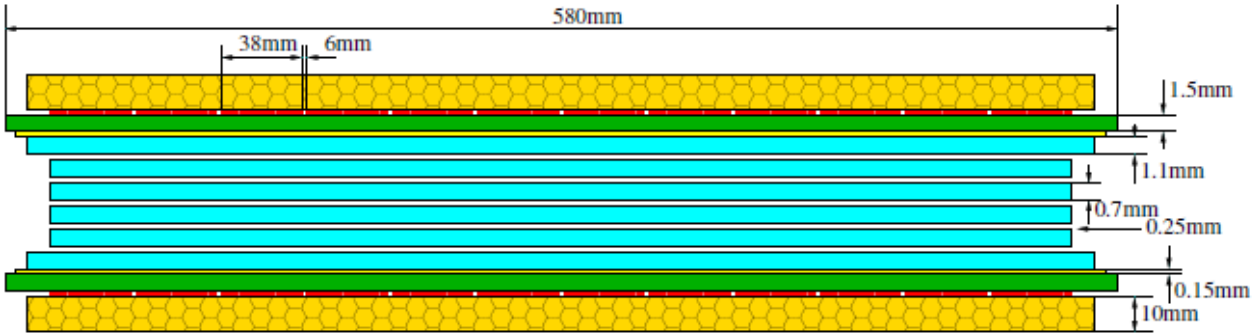
- Di-muon pairs
  - QGP thermal radiation, quarkonia (Y different states), light vector mesons, resonances in QGP, and Drell-Yan production
- Single muons
  - semi-leptonic decays of heavy flavor hadrons
- Electron muon correlation
  - Distinguish thermal and charm production in di-lepton
-
- Advantages of muons over electrons:
  - No γ conversion, much less Dalitz decay
  - Less radiative energy loss, better p_T and invariant mass resolution
  - Trigger capability from low to high p_T

MTD Design



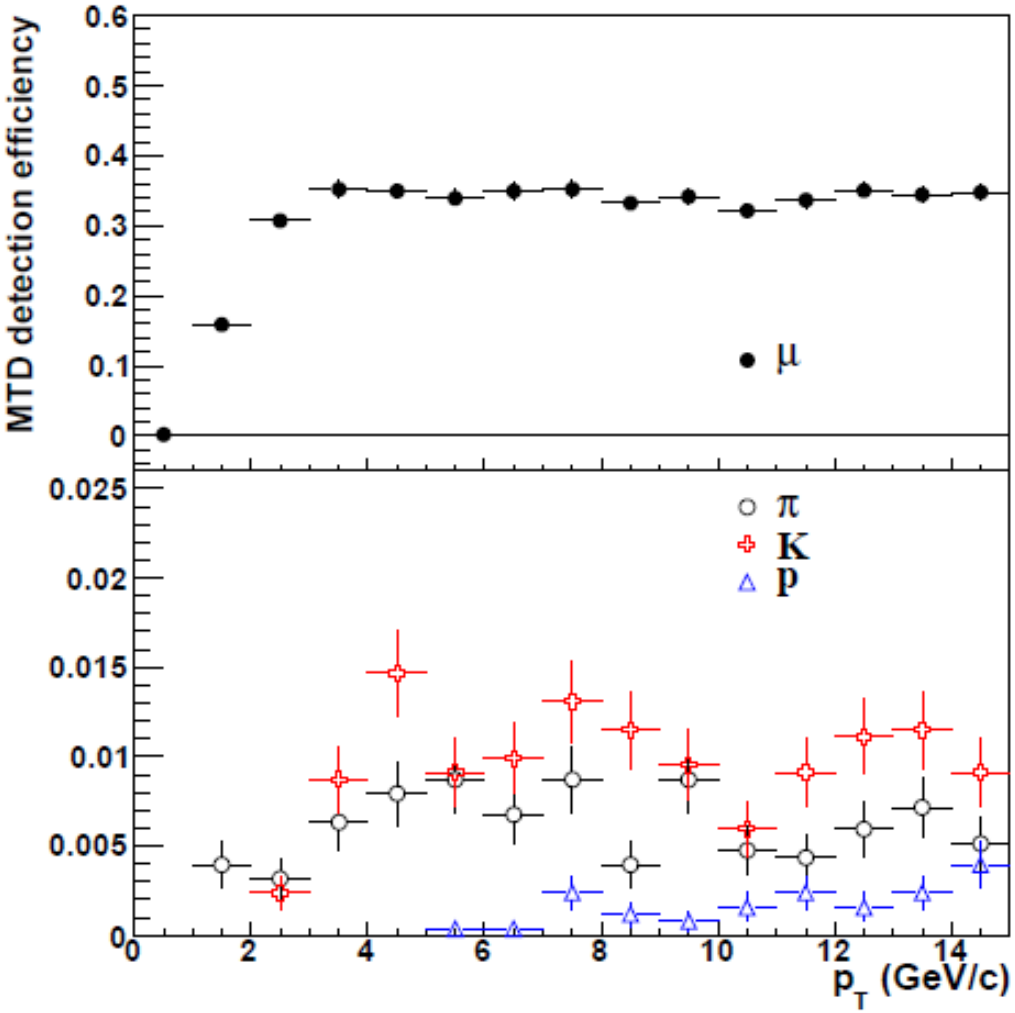
MTD

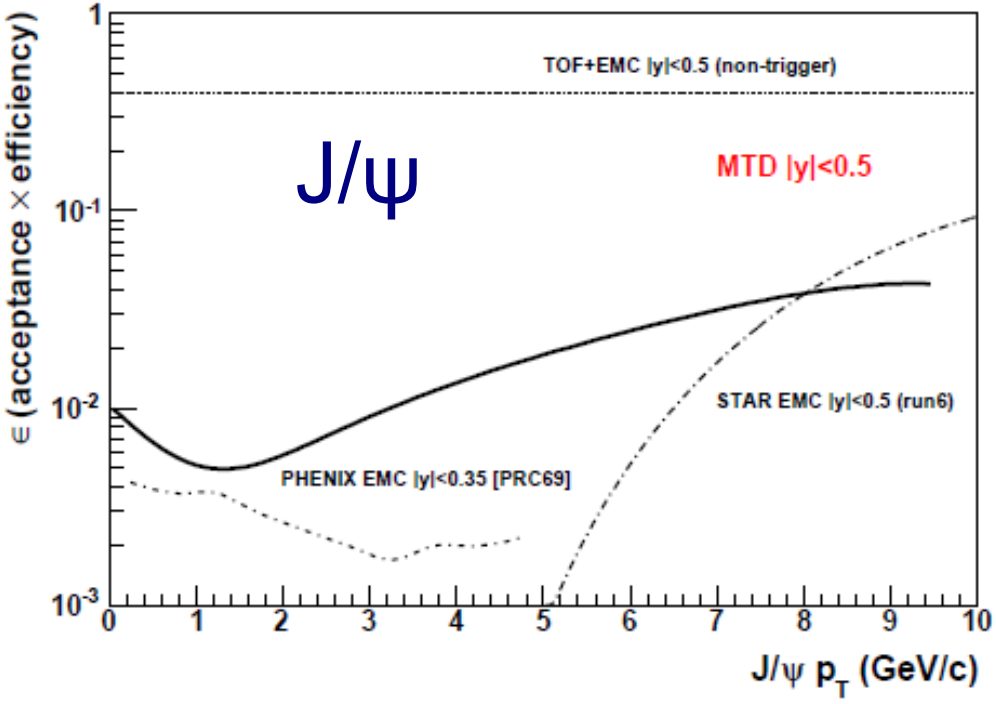




- Multi-gap Resistive Plate Chamber (MRPC): gas detector, avalanche
- Acceptance: 45% azimuth at $|\eta|<0.5$
- 118 modules, 1416 readout strips, 2832 readout channels
- electronics same as used in STAR-TOF

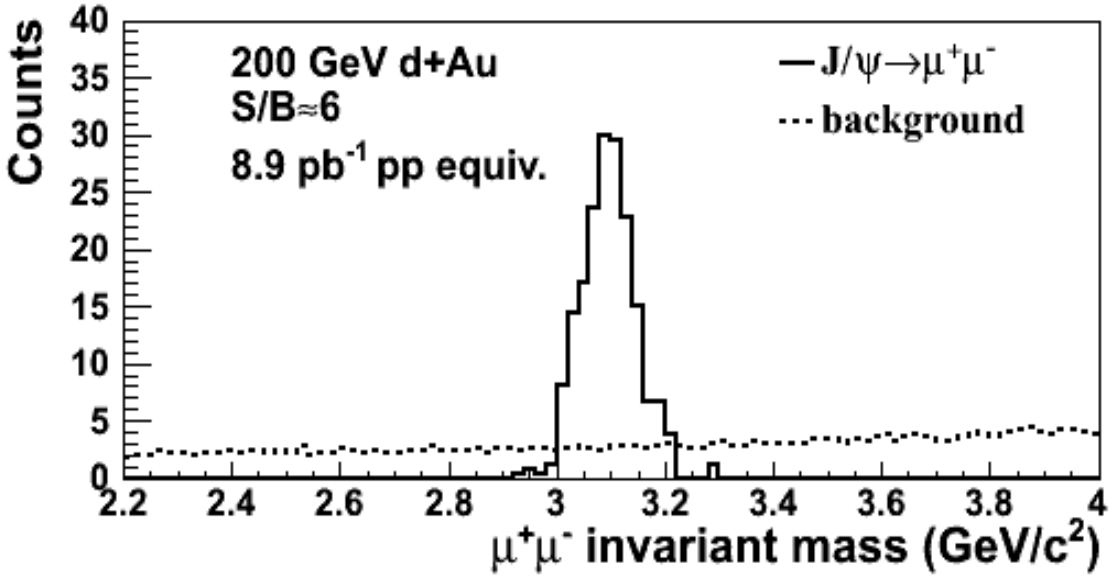
Efficiency Simulation



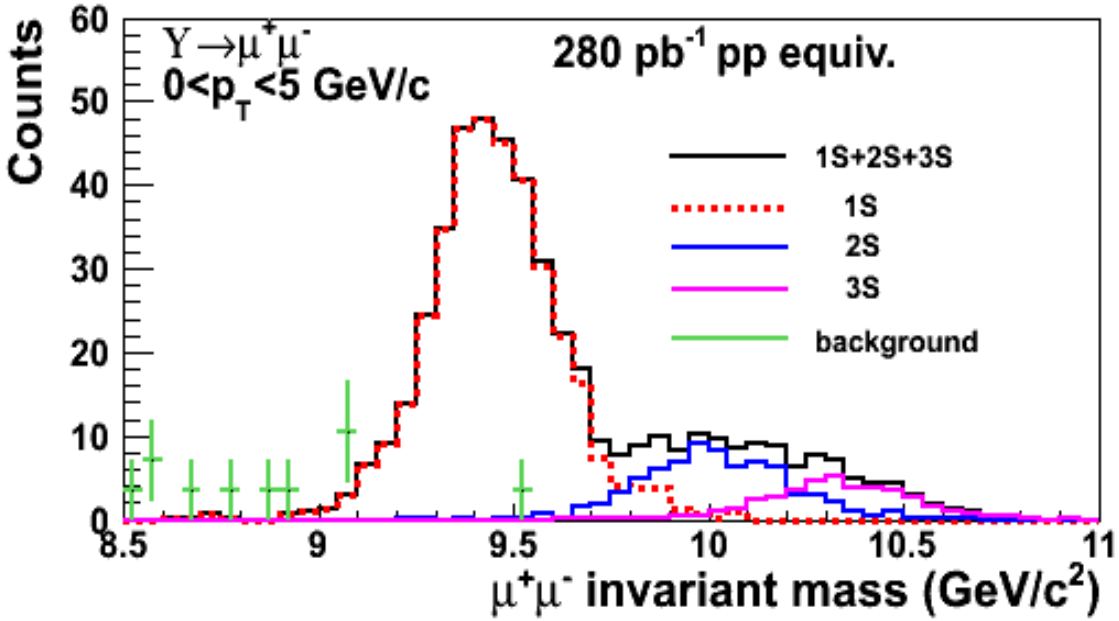


- muon-to-pion enhancement factor: 50-100
- muon-to-hadron enhancement factor: 100-1000 including track matching, tof and dE/dx

J/ψ and Υ with MTD



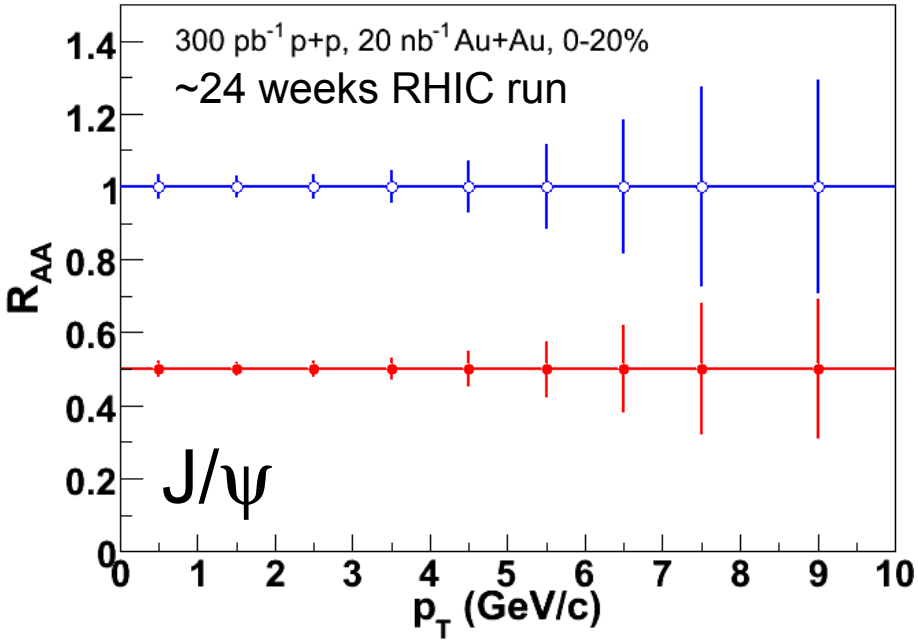
- Less background

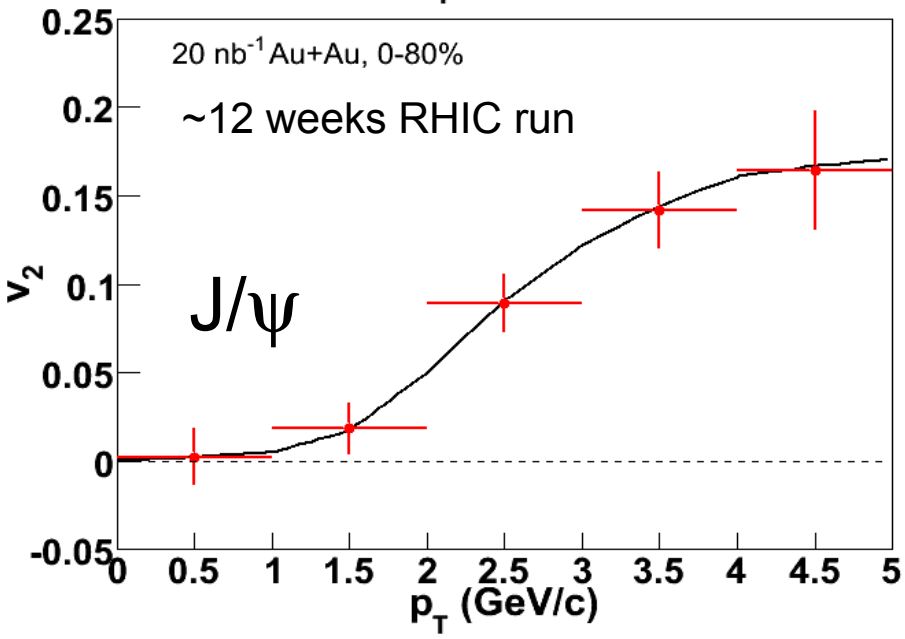


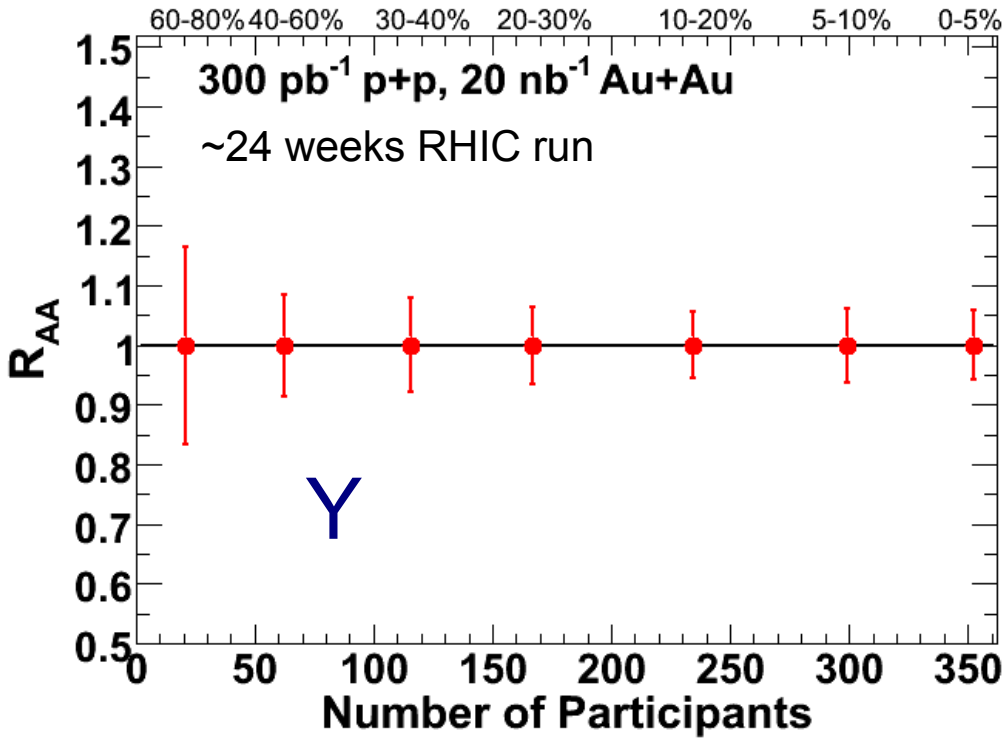
- better mass resolution, able to distinguish 3 different states.

Z. Xu, BNL LDRD 07-007;
L. Ruan et al., Journal of Physics G: Nucl. Part. Phys. 36 (2009) 095001

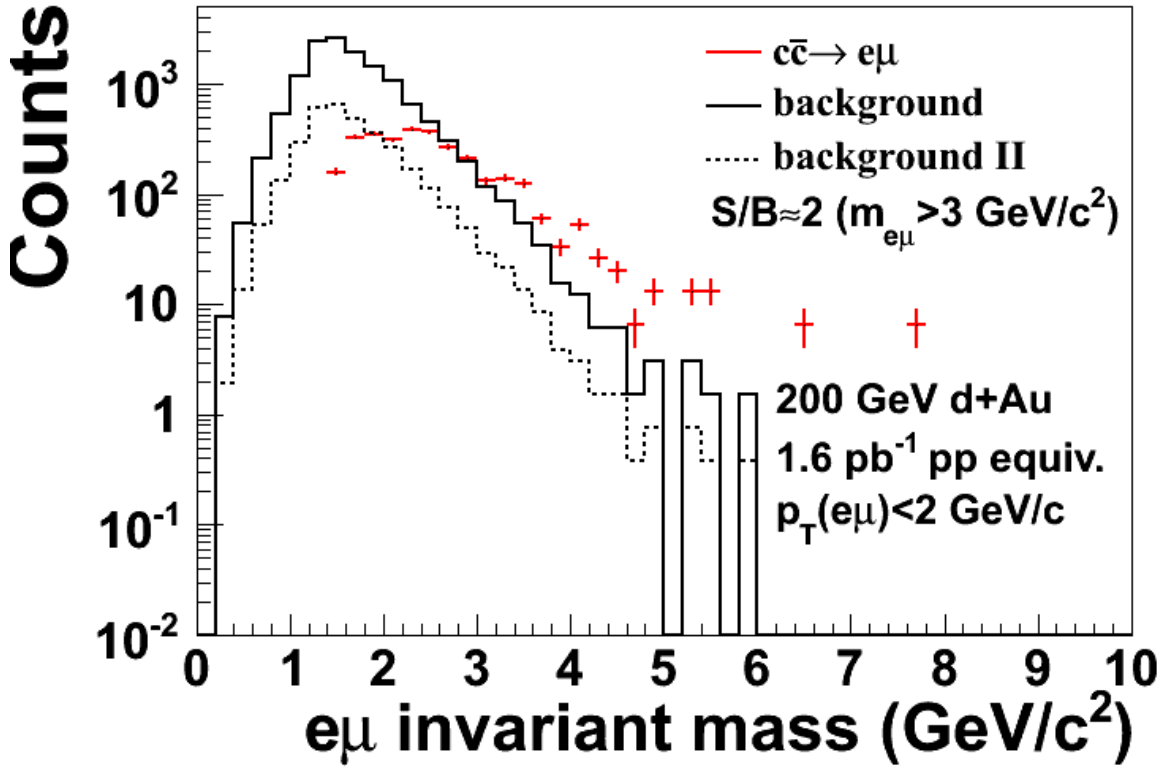
Error Estimation for J/ψ and Υ







Distinguish Thermal and Charm Production in Di-lepton



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L. Ruan et al., Journal of Physics G: Nucl. Part. Phys. 36 (2009) 095001

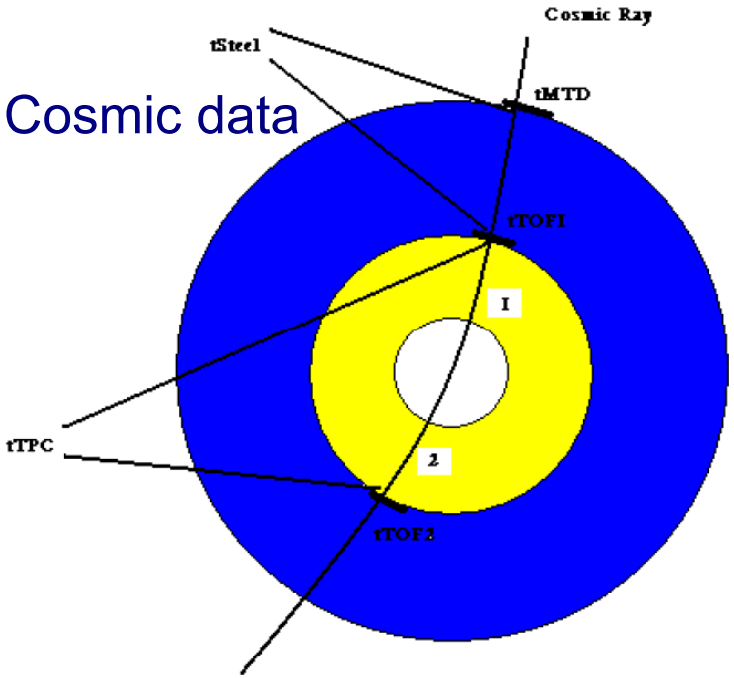
- Thermal production of di-lepton → temperature of the medium
- Thermal: e^+e^- and $\mu^+\mu^-$
- $c\bar{c}$: e^+e^-, $\mu^+\mu^-$ and $e^+\mu^-$, $e^-\mu^+$

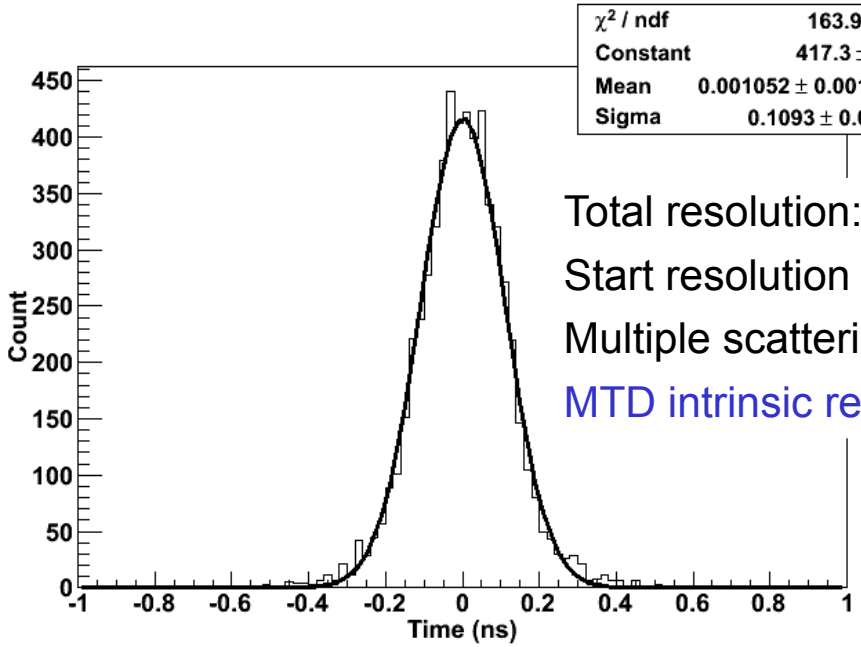
Current Status and Schedule

- Run 12, 13 trays, 10 % first look at electron muon correlation
- Run 13, 43 % J/ψ R_{AA}, v_2, Y R_{AA}, first look at different states
- Run 14, 80%
- Finish the project by Mar, 2014

Time and Position Resolution

Cosmic data



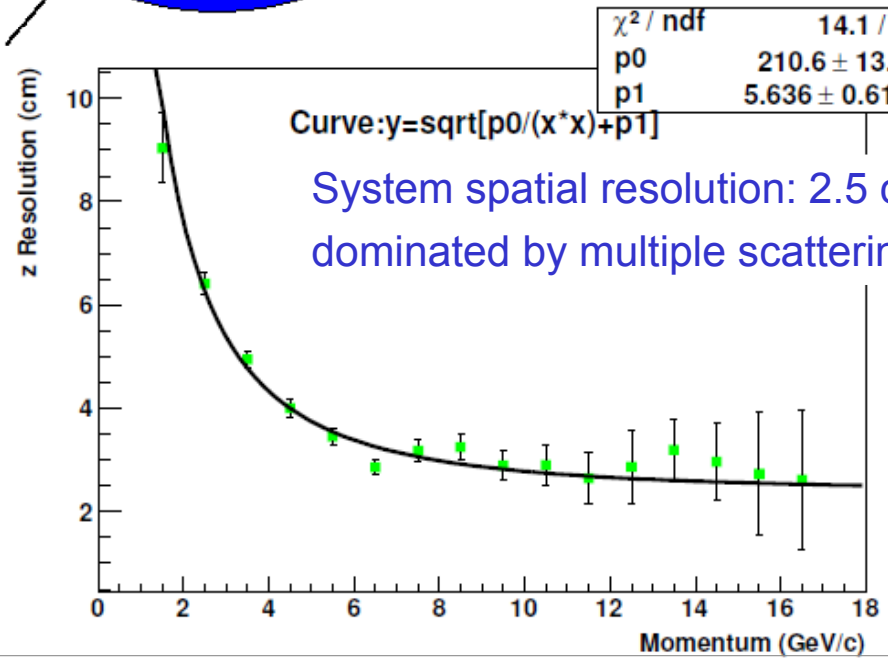


Total resolution: 109 ps

Start resolution (2 TOF hits): 46 ps

Multiple scattering: 25 ps

MTD intrinsic resolution: 96 ps



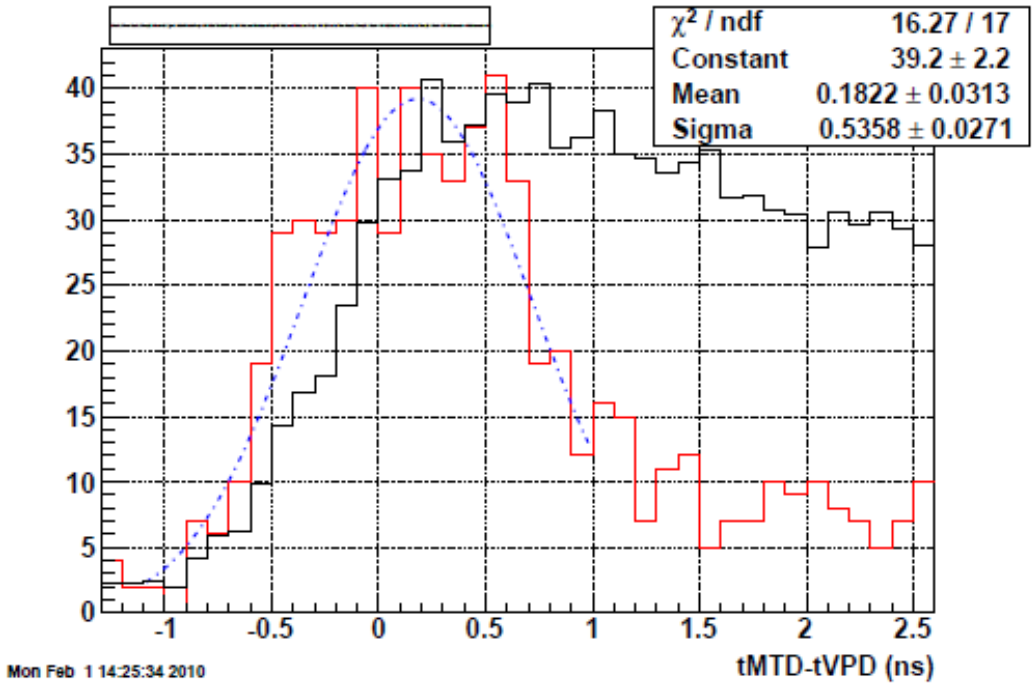
System spatial resolution: 2.5 cm,

dominated by multiple scattering

Trigger Rate

- RHIC II luminosity in terms of collision rate: 40 k Hz;
- Au+Au projection: based on Run 10 prototype performance.

trigger time window	double-hit rejection factor	dimuon L0 trigger rate
2 ns	50	800 Hz
1.5 ns	116	185 Hz
1 ns	509	80 Hz



Summary

- HFT
  - A rich set of physics programs including open and closed heavy flavor measurements will greatly enhance our understanding of QGP created at RHIC.
  - Technical prototype for Run 13, expect finishing for Run 14.

- MTD
  - Many interested physics studies will be enabled by a clear identification and trigger ability of muons, including QGP thermal radiation and quarkonia.
  - Desirable performance with trays installed, expect finishing in Run 14.

Thank You!
:-)