Quarkonium and Heavy Flavor in sPHENIX

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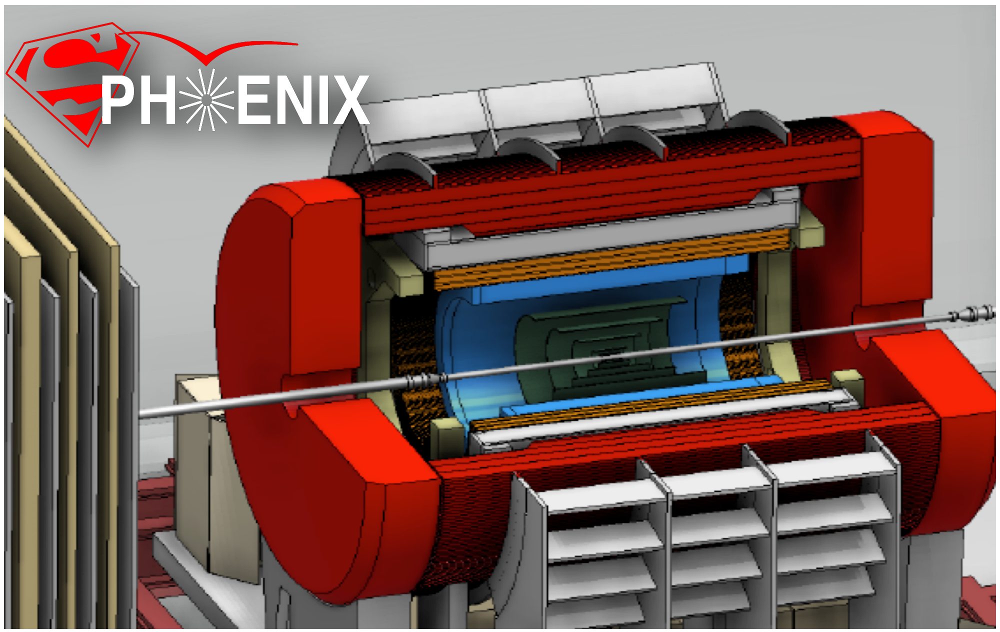
sPHENIX proposal available at
http://www.phenix.bnl.gov/phenix/WWW/publish/documents/sPHENIX_proposal_19112014.pdf

Outline

- Detector Configuration
- Expected Performance for
  - Upsilon
  - Open Heavy Flavor
- Planned Operation

sPHENIX Physics Program

sPHENIX goal is to probe the QGP near 1–2 T_c and over a broad ranges of scales in the region of strongest coupling



- Jet inclusive spectra
- γ-jet correlations
- Heavy flavor jets

In this talk

- Separated ϒ(1S), ϒ(2S), ϒ(3S) suppression

Knobs to Turn & Questions to Explore at RHIC

Temperature dependence of the QGP (**beam energy variation**)

Can we observe the strongest coupling near T_c definitively

Time dependence of the QGP by virtuality variation (**hard process Q^2**)

How do the parton shower and medium evolve together?

Length scale within the QGP by interaction hardness (**interaction Q^2**)

What are the inner workings? (quasiparticles, fields, modes)

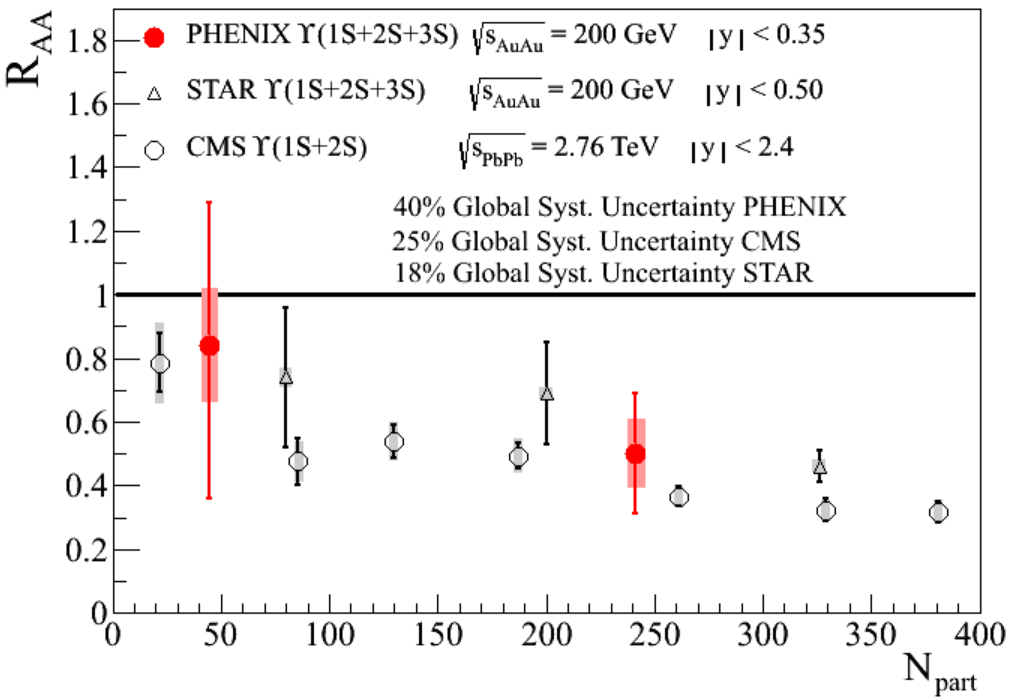
sPHENIX Run Plan

- Two years of physics running 2021 and 2022 with 30-cryo week runs
- 20 weeks Au+Au @ 200 GeV
- 10+ weeks p+p @ 200 GeV [comparable baseline statistics]
- 10+ weeks p+Au @ 200 GeV [comparable baseline/new physics stats]
- If we just record Au+Au minimum bias events (no trigger bias), in 20 weeks with current RHIC performance and PHENIX livetime, we can record <u>100 billion events within |z| < 10 cm</u> [optimal for silicon tracking]

Note this is not sampled, but <u>recorded</u>.

Quarkonium and HF at RHIC

Current RHIC & LHC Picture

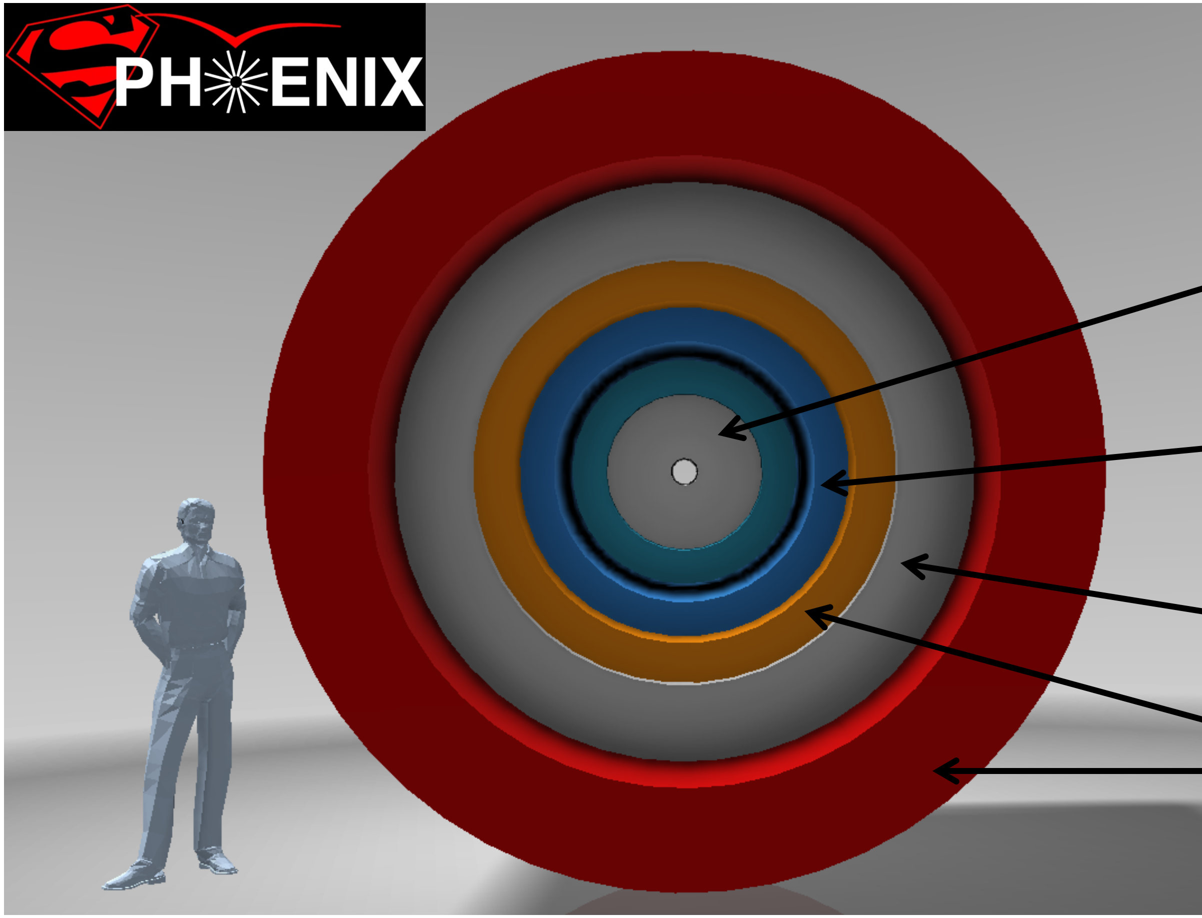


- PHENIX and STAR provided an excellent measurement of charmonium production
- New heavy flavor measurements will be coming in the next 2-3 years with upgraded detectors
- Bottomonium measurement challenging with current detectors since cross section at RHIC is small and momentum resolution doesn't allow separation of states

sPHENIX Concept

- Uniform Acceptance $|\eta|<1$ $\Delta\phi=2\pi$
- Superconducting magnet enabling high resolution tracking
- Hadronic calorimeter doubling as flux return
- Reuse of PHENIX silicon vertex detector adding 3 additional outer layers: two at ~45 and one 80cm
- Compact electromagnetic calorimeter to allow fine segmentation at a small radius
- High data acquisition rate capability ~ 10 kHz

sPHENIX Detector



Coverage $|\eta| < 1.1$

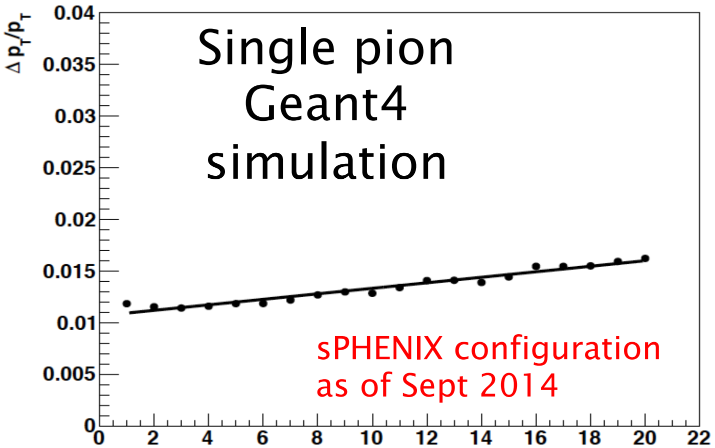
All silicon tracking
Heavy flavor tagging

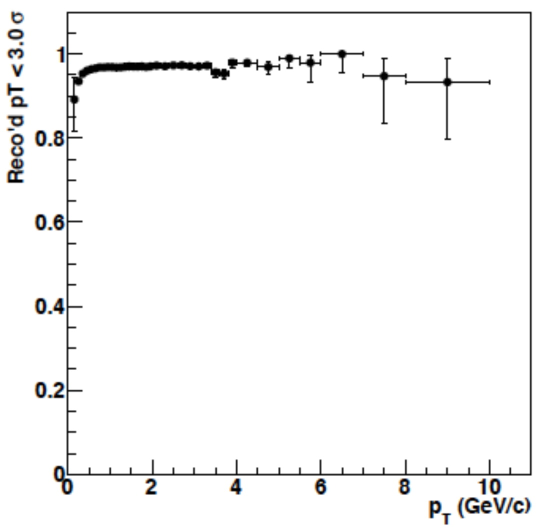
SPACAL EmCal
12%/sqrt(E) resolution

BaBar Magnet 1.5 T

Two longitudinal
Segment Hcal
5 interaction lengths

sPHENIX Tracking Performance





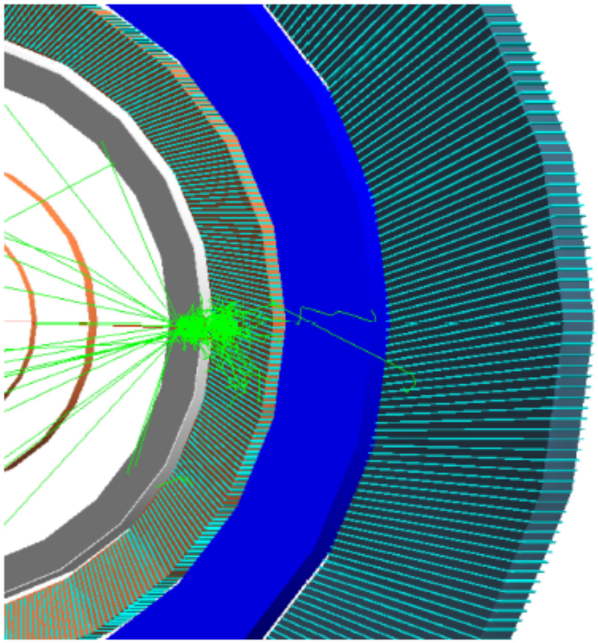
- Single pion momentum resolution in the sPHENIX spectrometer

$$\frac{\sigma_{p_T}}{p_T} = 1\% + 0.027\% \times p_T(GeV)$$

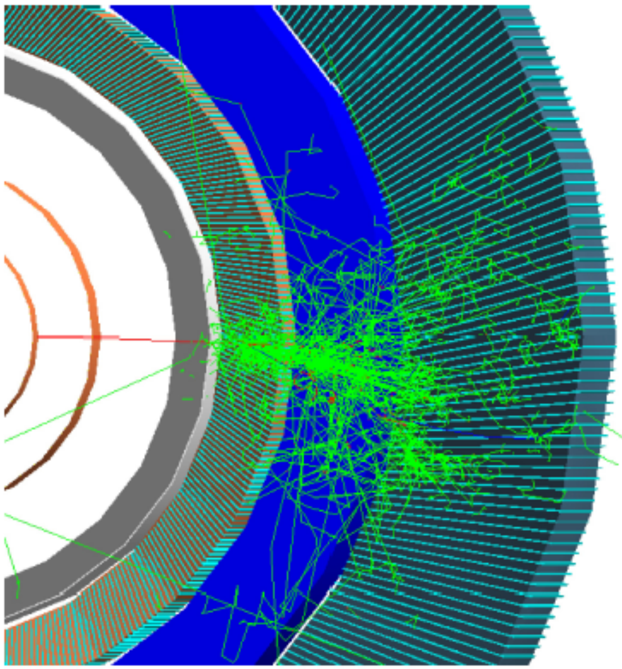
- Efficiency for pions embedded in 0–10% Hijing events is 97% for $p_T > 2$GeV

Electron Pion Separation

10Gev electron



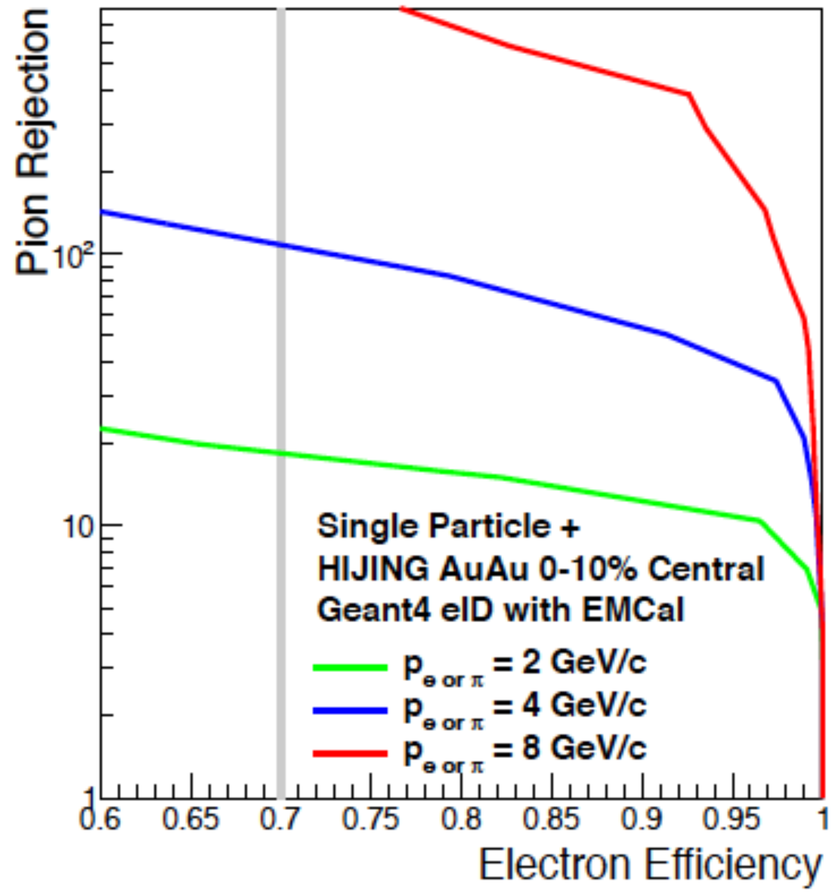
10Gev pion



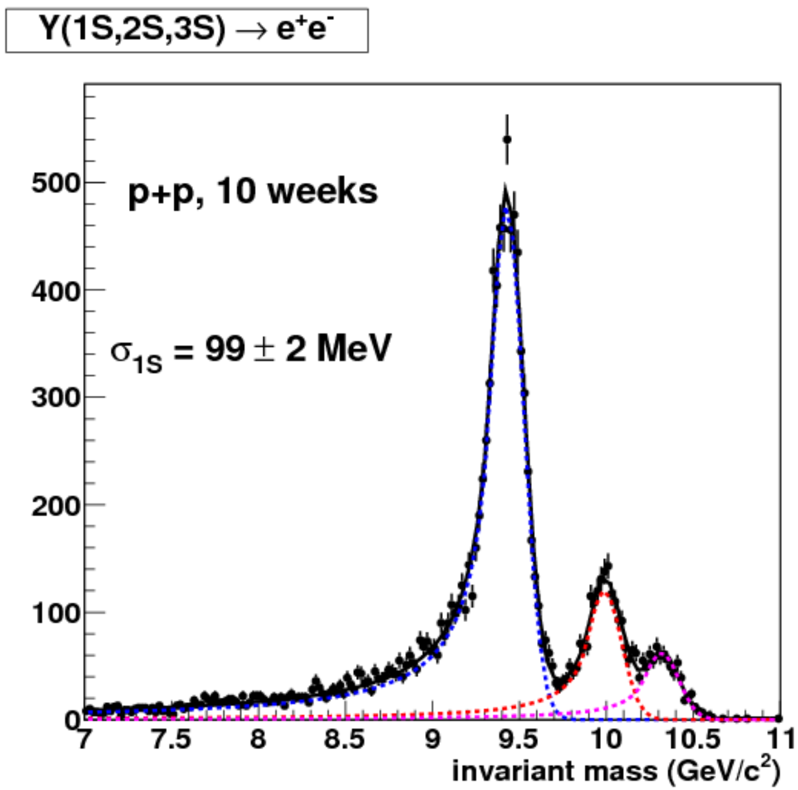
- Electron deposit most of the energy in EmCal (grey) while pion start showering in the inner HCal

Electron-id in Au-Au Collisions

- PID selection cuts:
  - E-p matching
  - leaked energy veto in inner Hcal
- Solid performance in 0-10% most central Au-Au at 4GeV/c:
  - factor of 100 pion rejection
  - 70% electron reconstruction efficiency



Υ in p-p Collisions

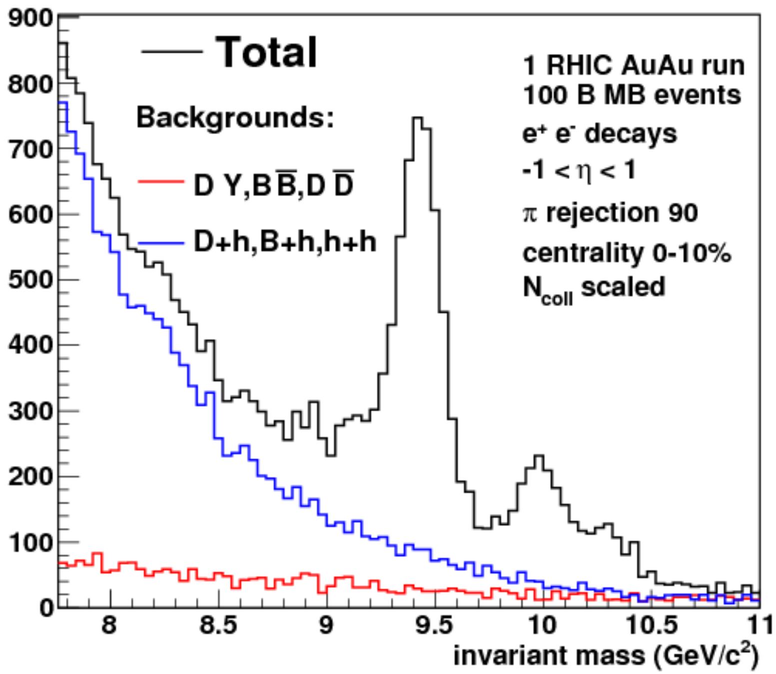


Revised design has improved mass resolution of 99MeV

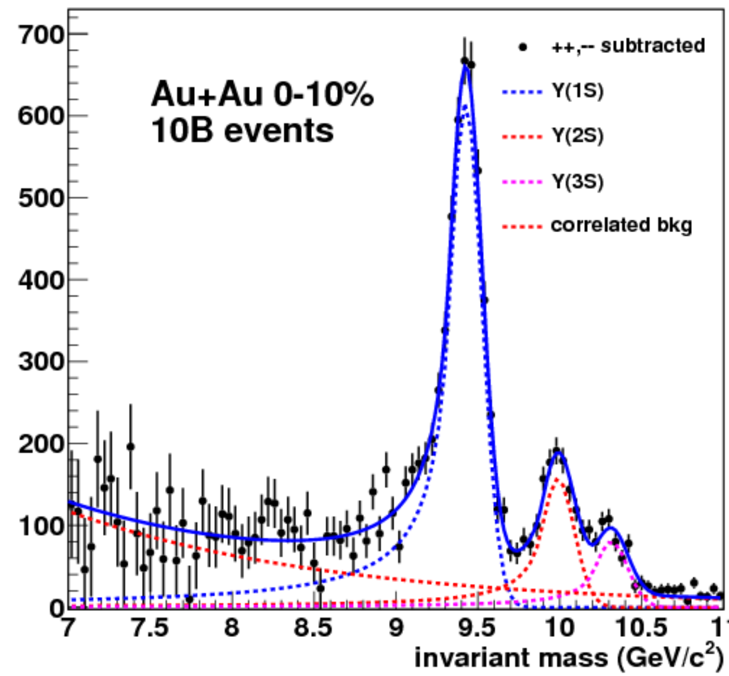
Expected Upsilon yield in 10 weeks of sPHENIX p-p data taking

Υ Measurement in AuAu Collisions

Opposite sign e^+e^- invariant mass

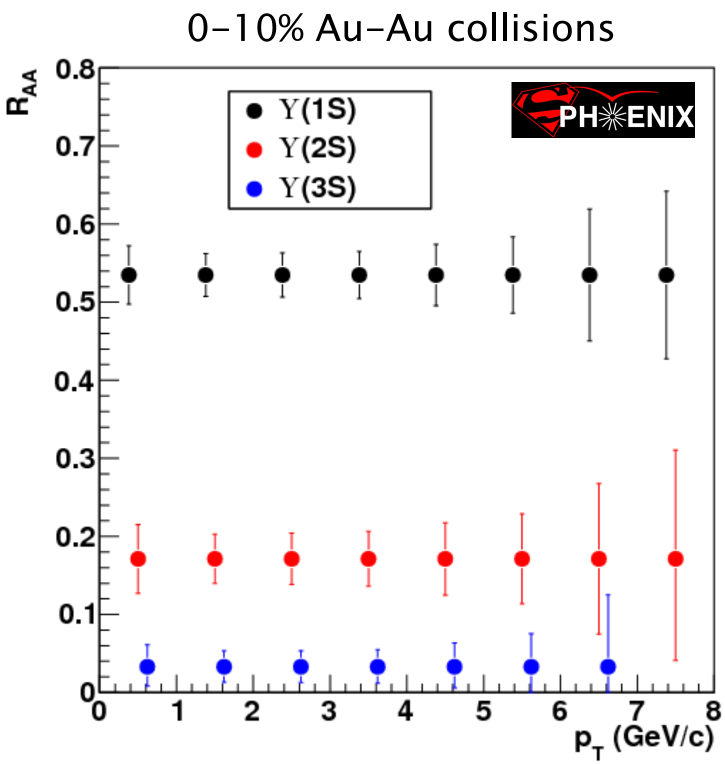


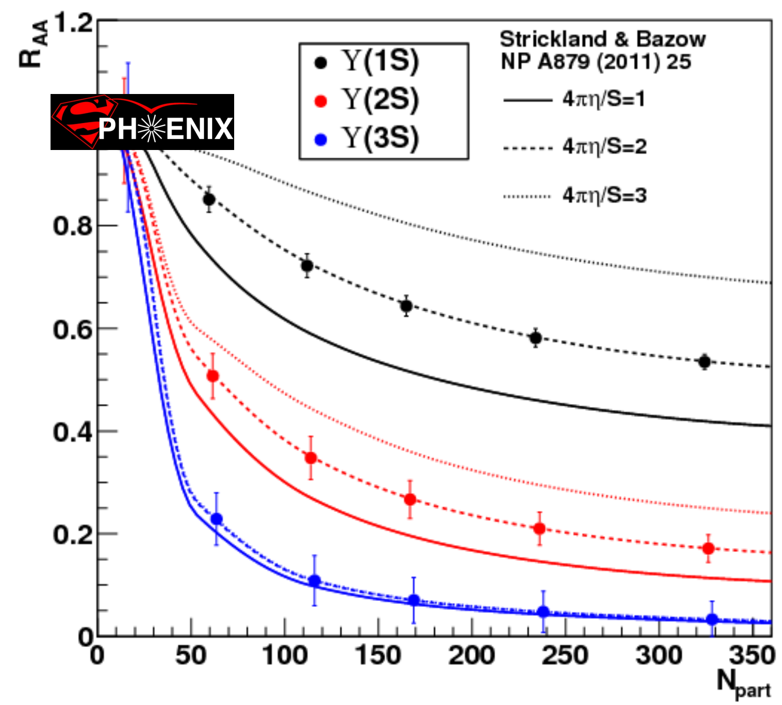
After same sign subtraction



- Yield in 10B 0-10% Au-Au events, assuming factor of 90 pion rejection and 70% electron reconstruction efficiency

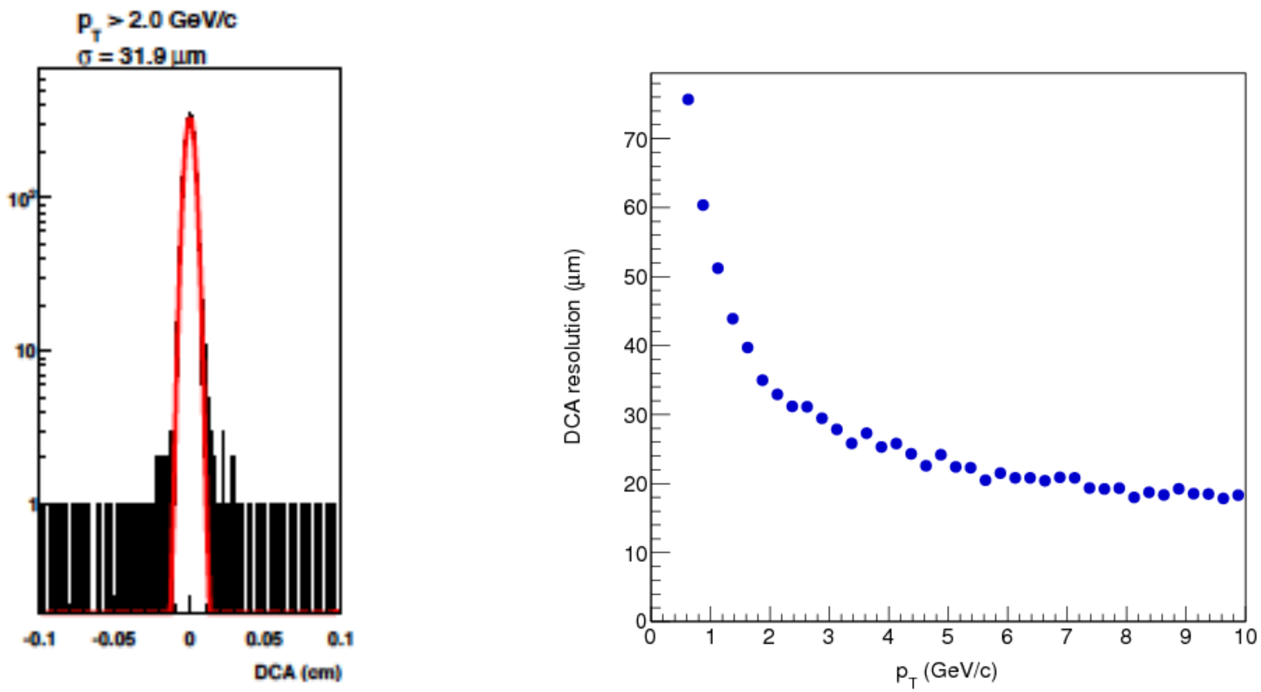
Upsilon RAA vs pT and centrality





Stringent constraint to theoretical models over different length scales

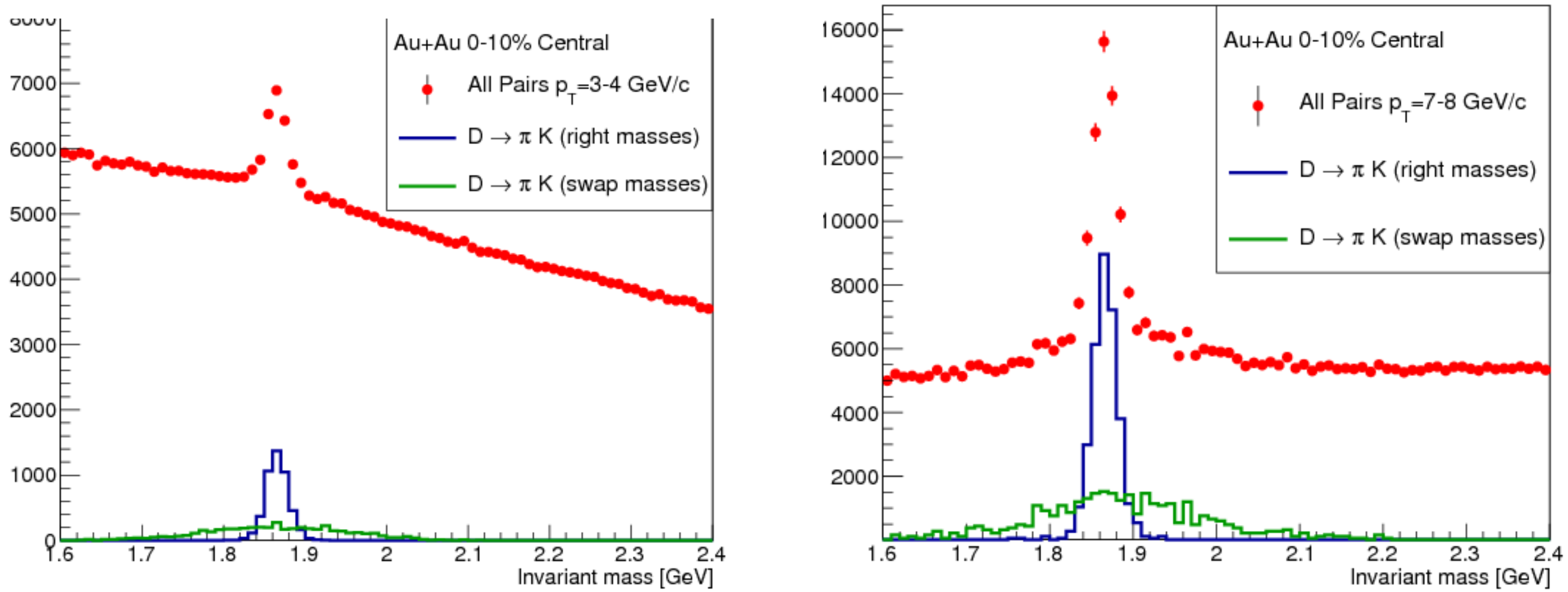
DCA resolution in Au–Au collisions



- sPHENIX performance for 2-D **Distance of Closest Approach** DCA to the primary vertex in 0-10% centrality

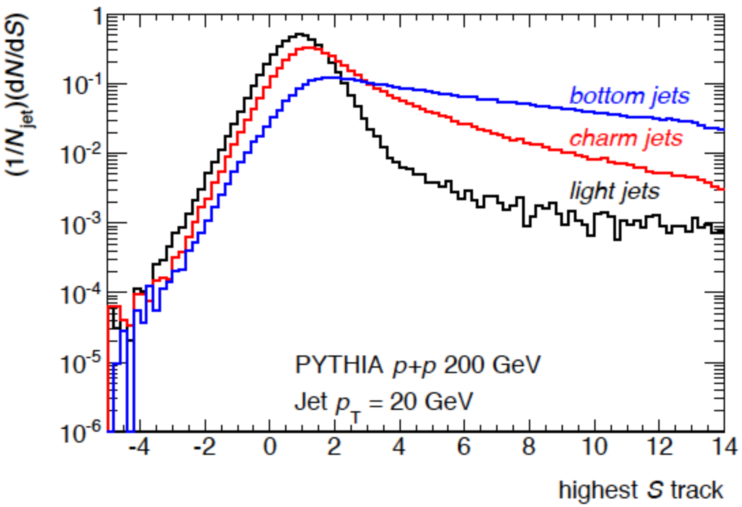
  ➡ **resolution expected to be <30μ for p_T>3GeV**

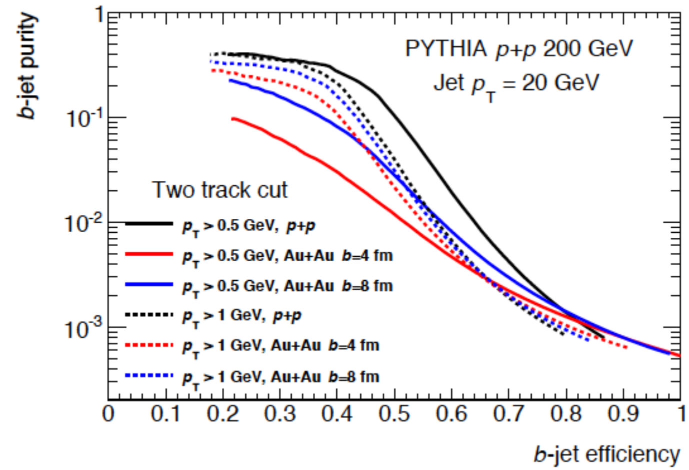
$D^0 -> k\pi$



- Invariant mass of all large DCA charged particle pairs assuming one is a pion and one is a kaon. Included are correlated and uncorrelated backgrounds
- Planning to use D^0 to tag charm jets and make measurements of charm jet fragmentation functions

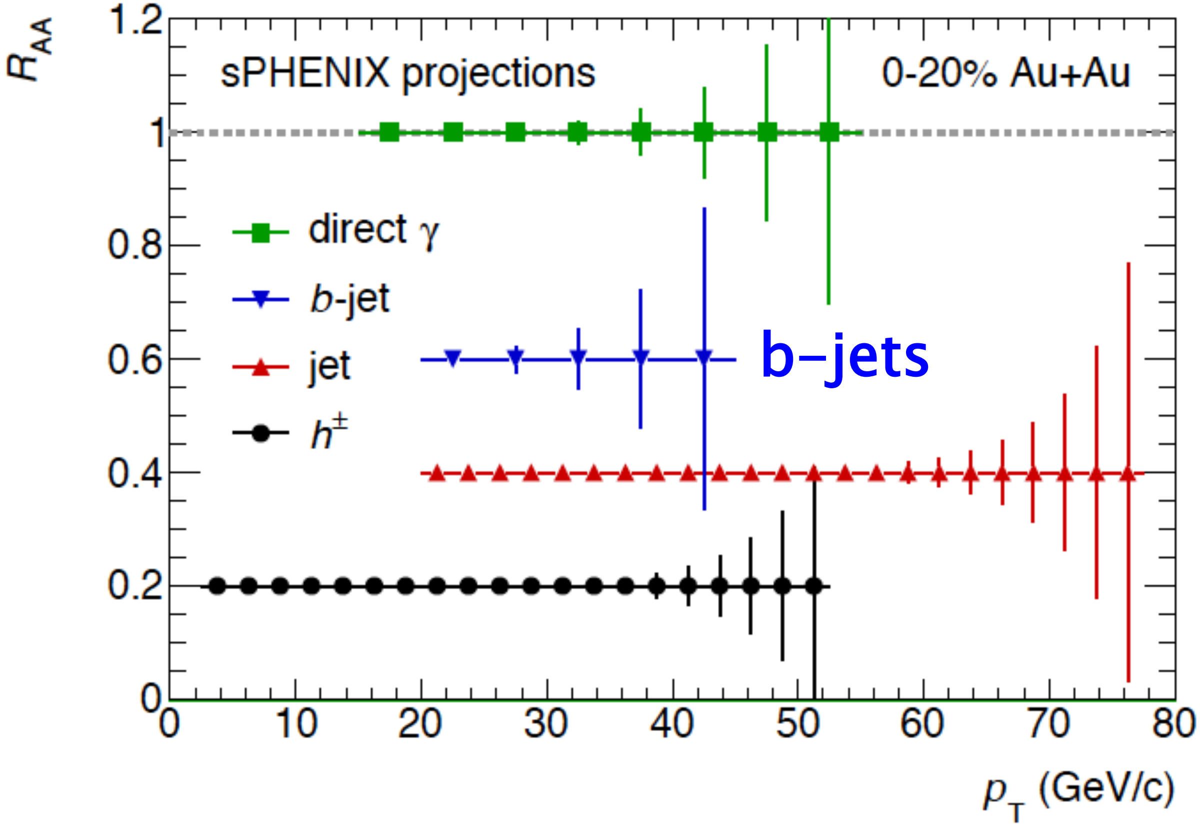
Heavy Quark Jets





- sPHENIX explored b-jet tagging through requiring a least two large DCA tracks in the jet
- Fast simulation using parameterized detector response shows reasonable efficiency vs purities can be achieved in p_T=20GeV jets.

Other R_{AA} Projections



Statistical uncertainties assume:

- B–jet tagging efficiency of 50%
- 22 weeks Au–Au data taking
- 10 weeks p–p data taking

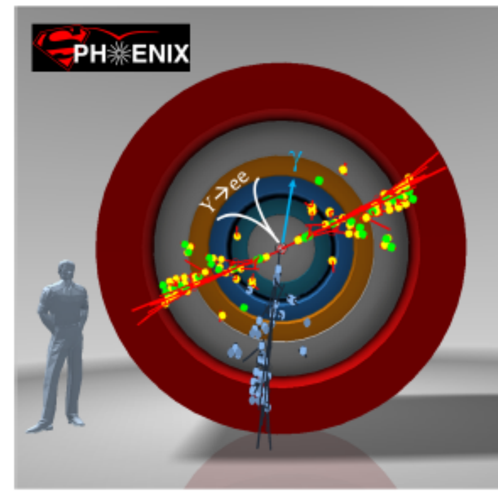
Conclusions

- sPHENIX detector is optimally designed to probe the the QGP near critical temperature and in the region of strongest coupling
- New capabilities to measure bottomonium and bottom jets at RHIC providing a broad program complementary to LHC.
- The unique combination of lever arm and precision from LHC and sPHENIX will provide a stringent constraint of key QGP properties

PHENIX

An Upgrade Proposal from the PHENIX Collaboration

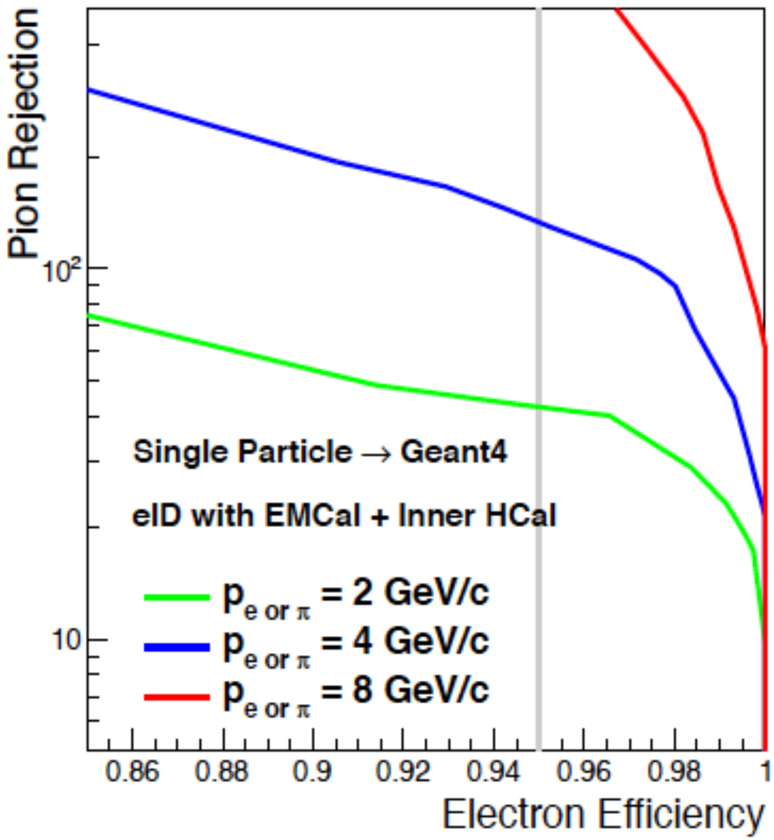
Original: July 1, 2012
Updated: October 1, 2013
Updated: June 19, 2014
Updated: November 19, 2014



http://www.phenix.bnl.gov/phenix/WWW/publish/documents/sPHENIX_proposal_19112014.pdf

Backup

Electron-id in p-p Collisions

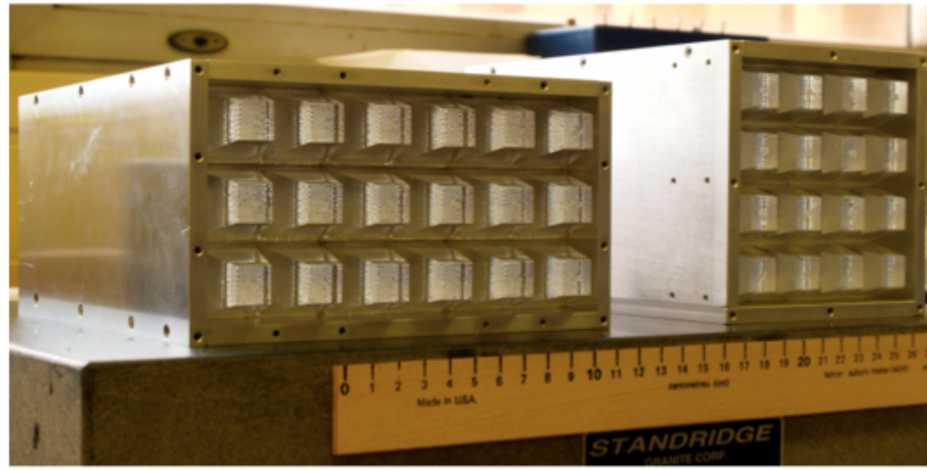


- Efficiency near central rapidity
- Proposed e-id cuts provide 95% electron efficiency and a rejection factor of ~150 for charged pion at 4GeV

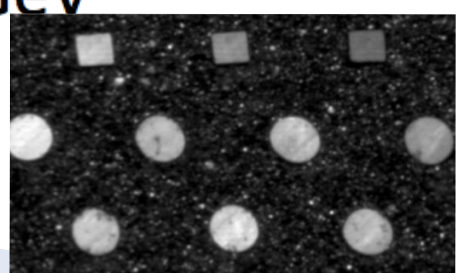
EMCAL SPACAL OPTION

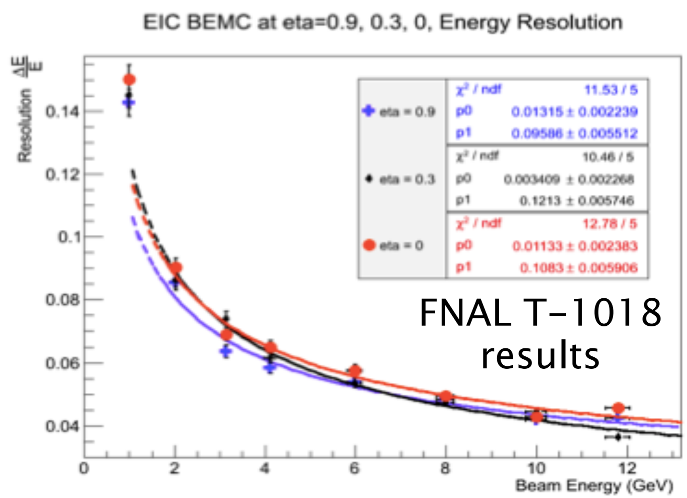
tungsten scintillating fiber calorimeters

- 18 X_0 deep
- 2.3 cm R_M ≈ cell size
- 256x96 = 24,576 channels
- Sampling fraction ≈ 2%
- Resolution ≈ 12%/√E
- ≈ 500 pe/GeV



SPACAL prototypes (Tsai)

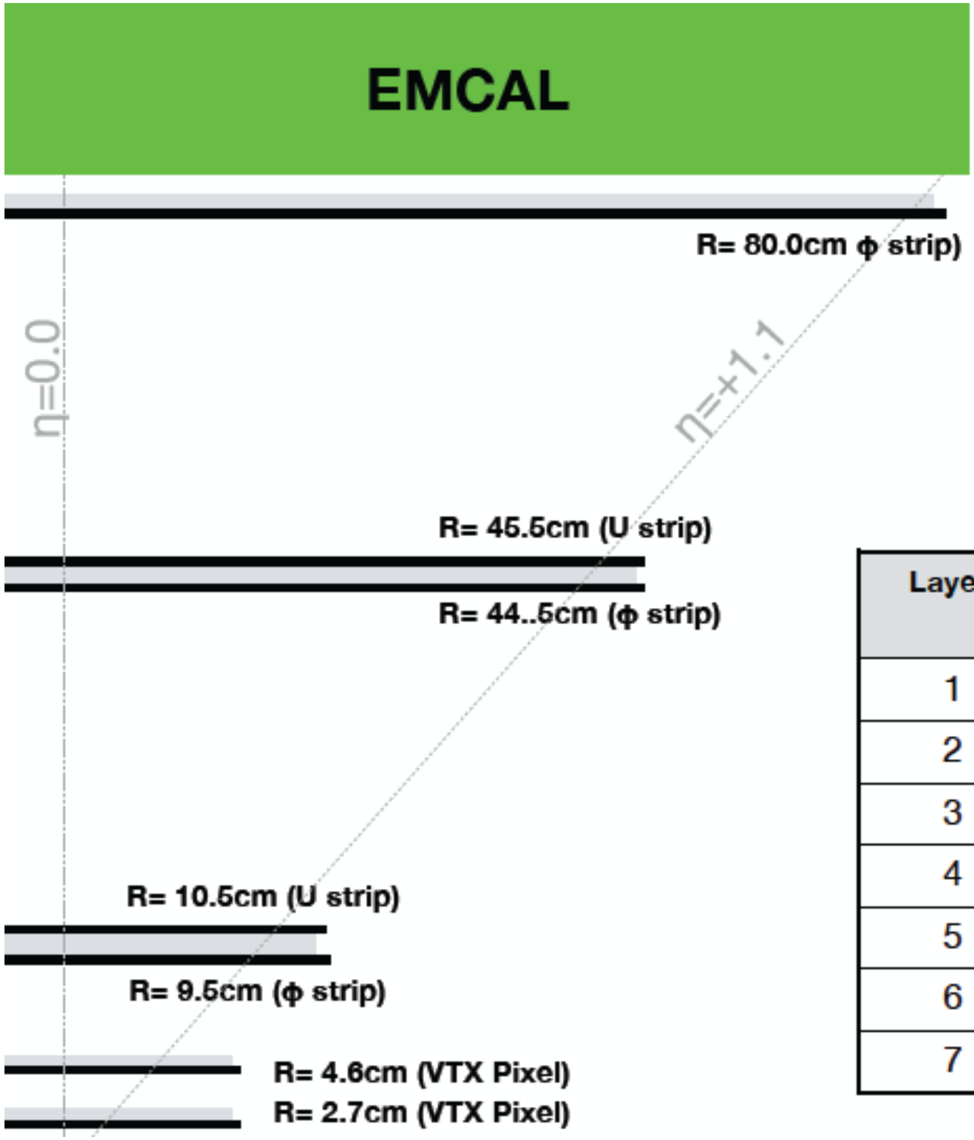




FNAL T-1018 results

PHENIX

Silicon Tracking Layers

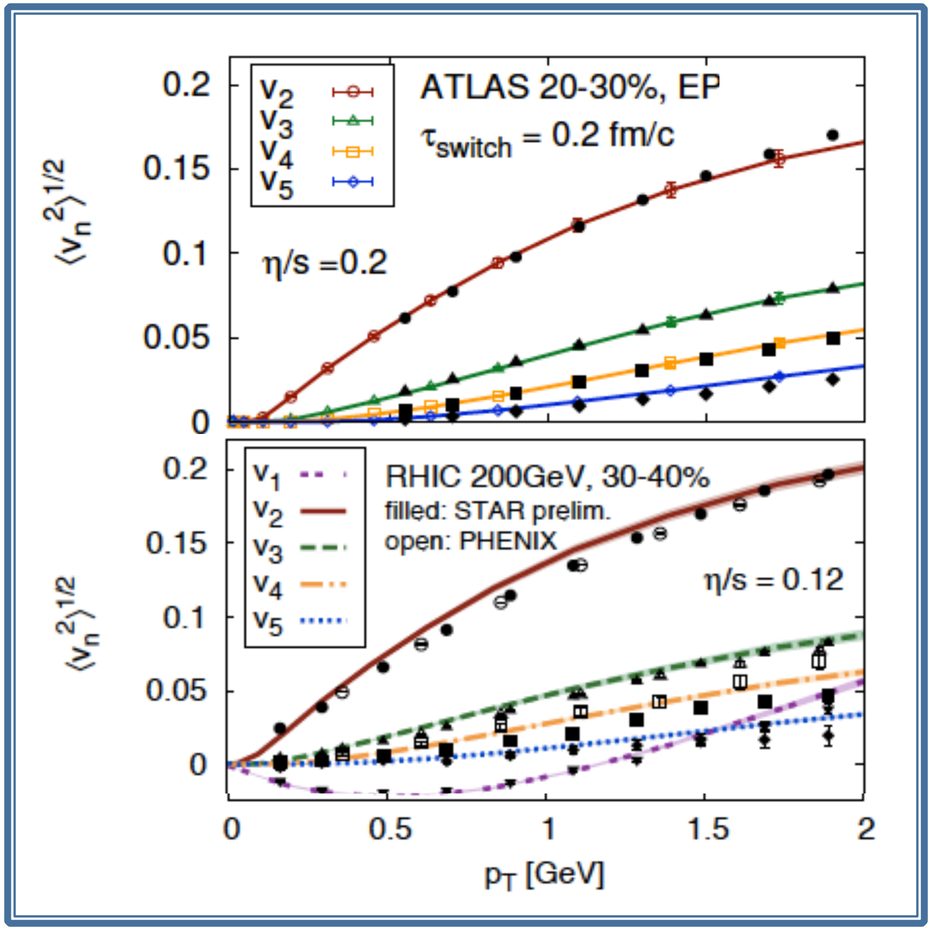


Extended radial reach for **improved resolution**

Shared support for outer tracking momentum and pattern recognition layers for **material budgeting**

Layer	ϕ pitch (um)	z pitch (mm)	Thickness (%)
1	50	0.425	1.3
2	50	0.425	1.3
3	60	8	2.7
4	*240*	*2*	
5	60	8	2.0
6	*240*	*2*	
7	60	8	2.0

Indications of Stronger Coupling at RHIC



There are indications that the QGP is most strongly coupled as created at RHIC

What are the underlying changes in QGP properties near the transition?

Calculation from Bjoern Schenke