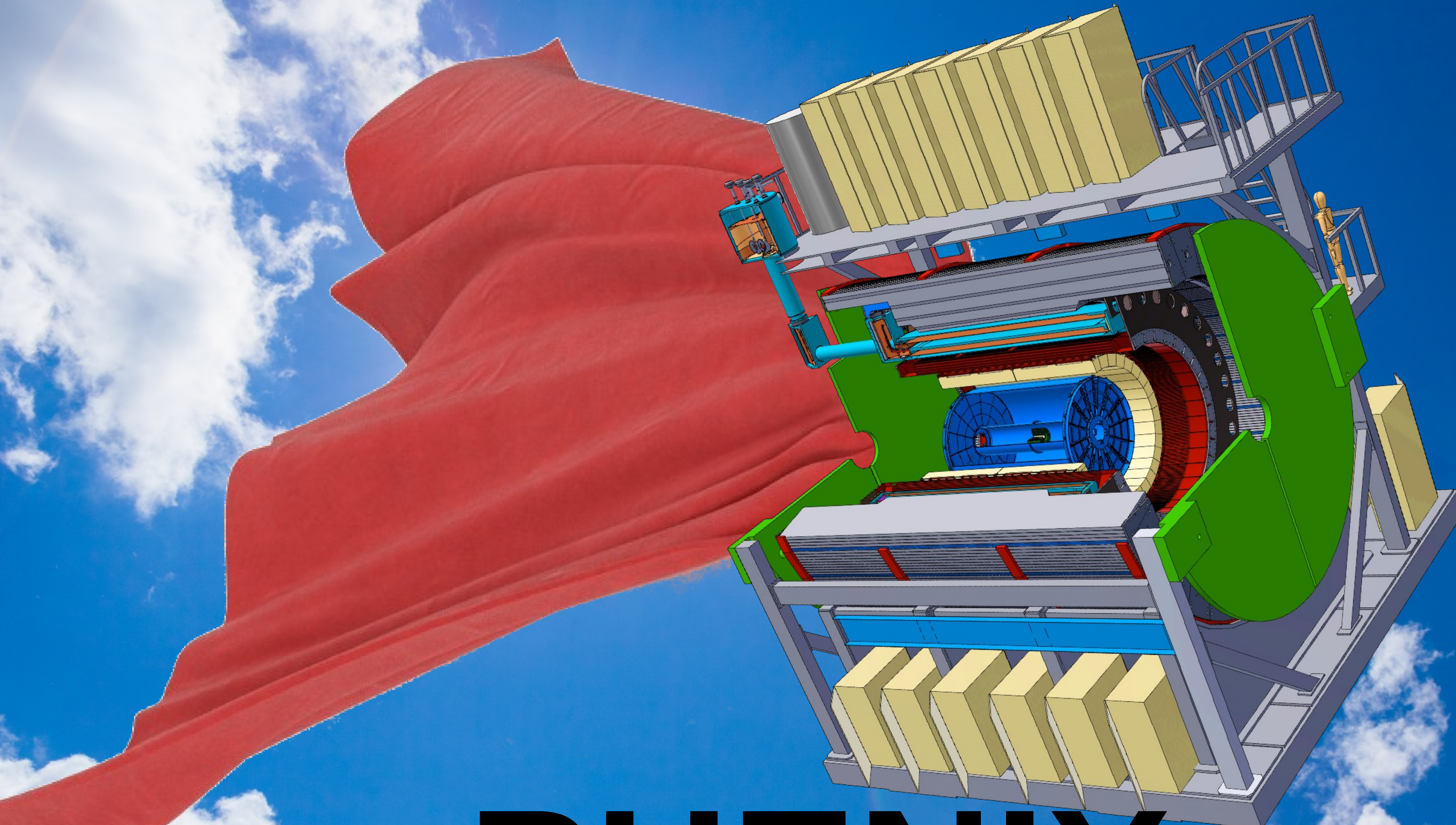


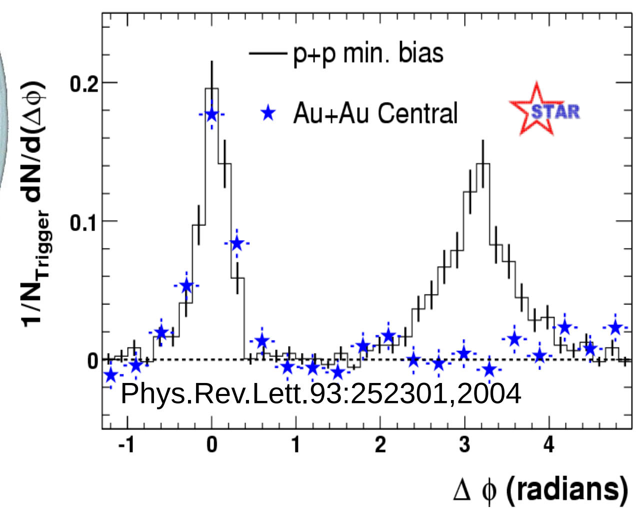
sPHENIX

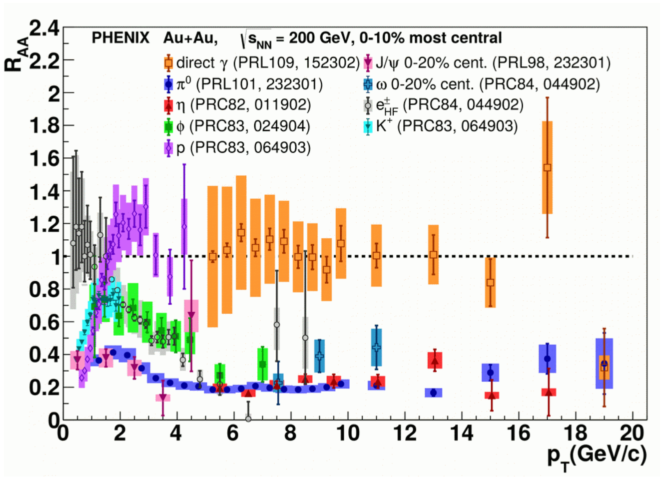
Christine Nattrass
For the sPHENIX Collaboration

Some of

What have we learned from RHIC

The QGP is the perfect liquid!



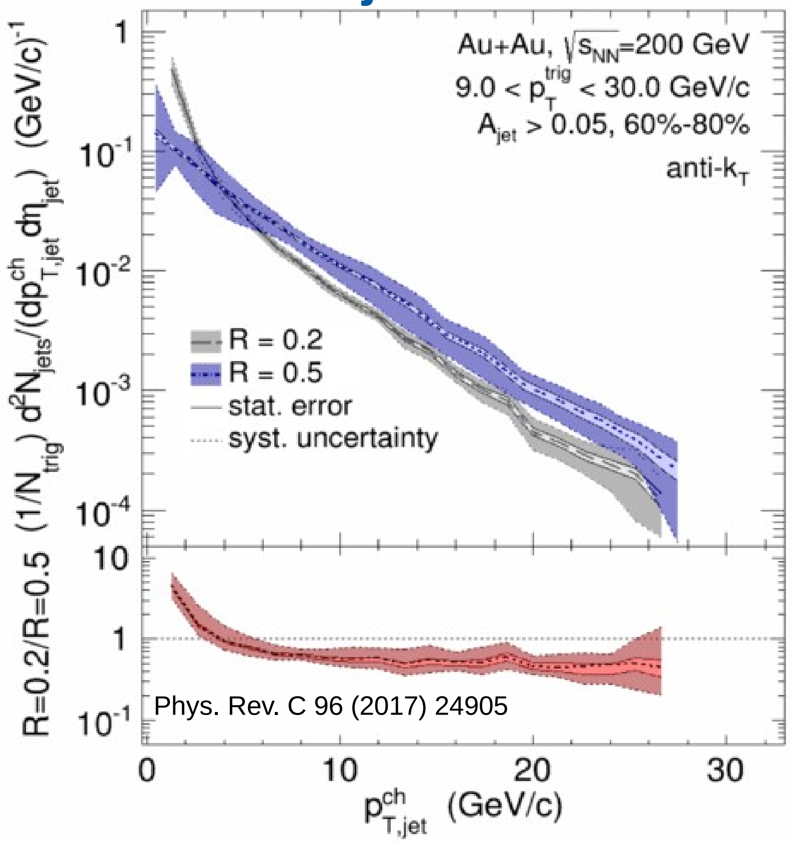


Jet quenching

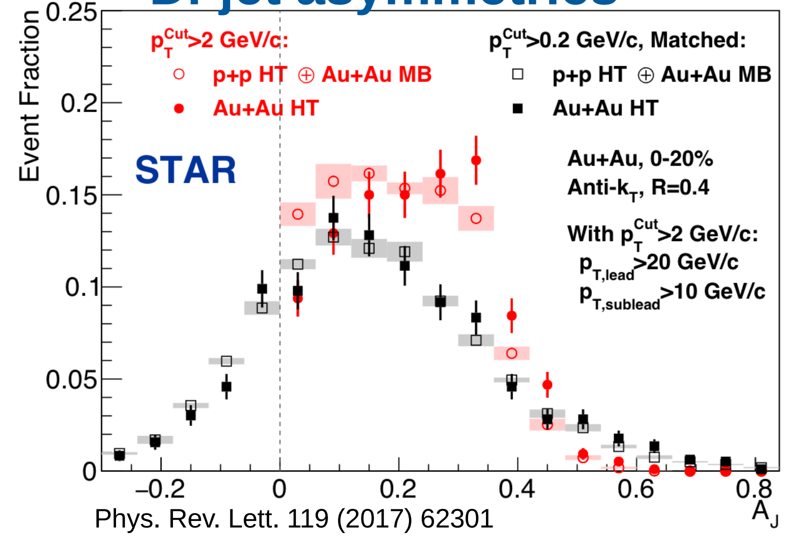
Some of

What have we learned from RHIC

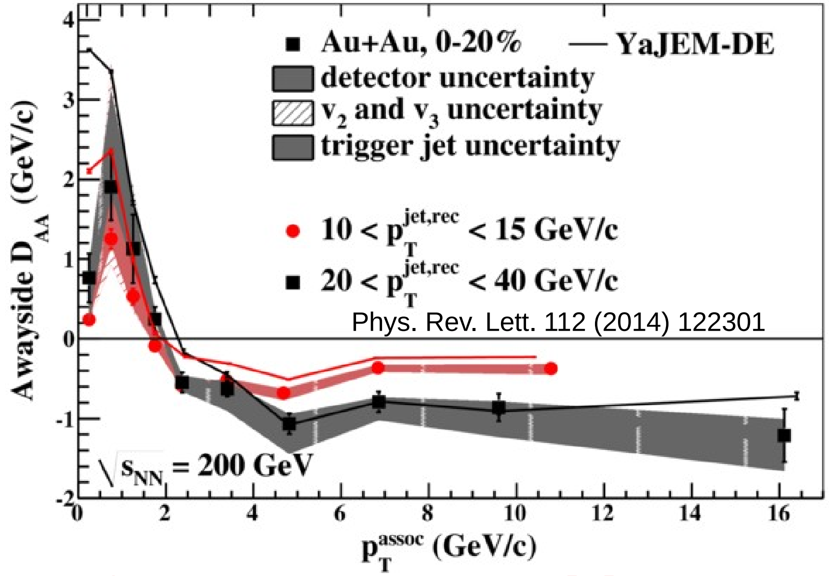
Hadron-jet correlations



Di-jet asymmetries



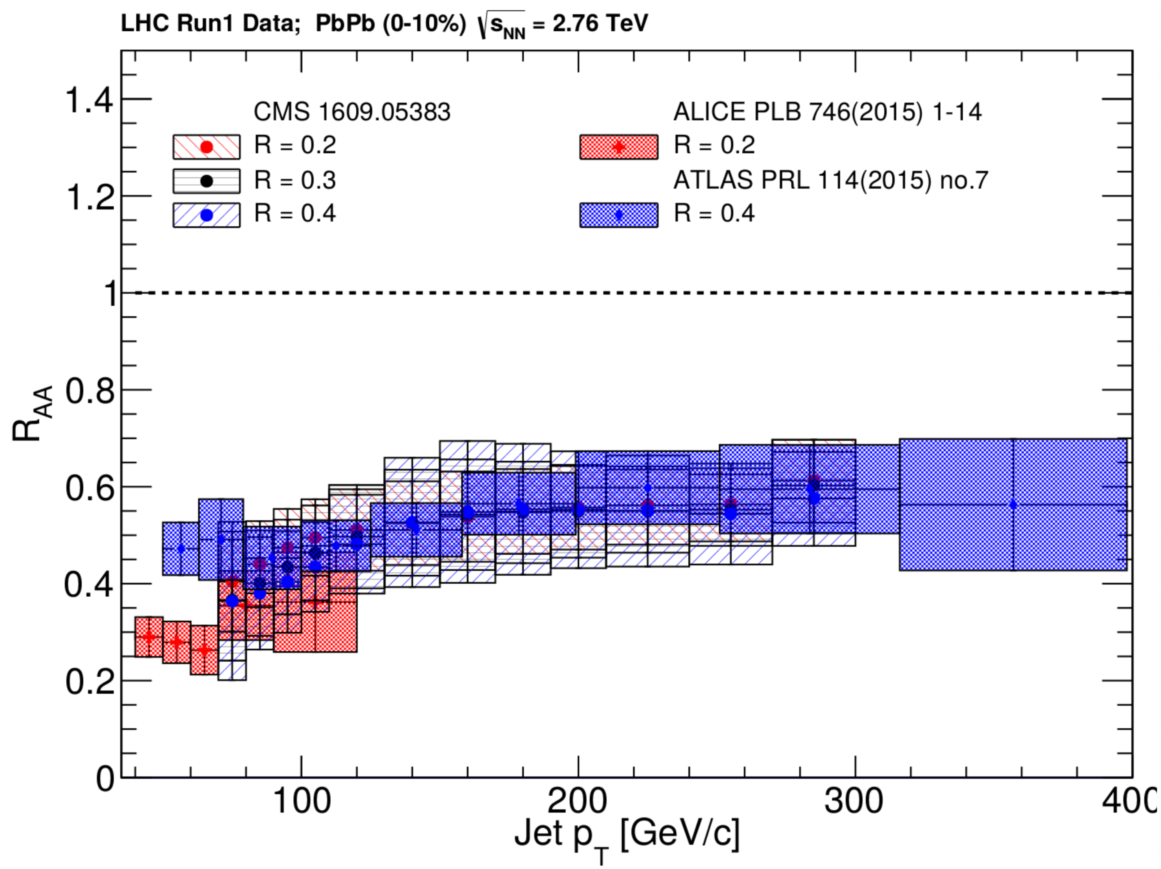
Jet-hadron correlations

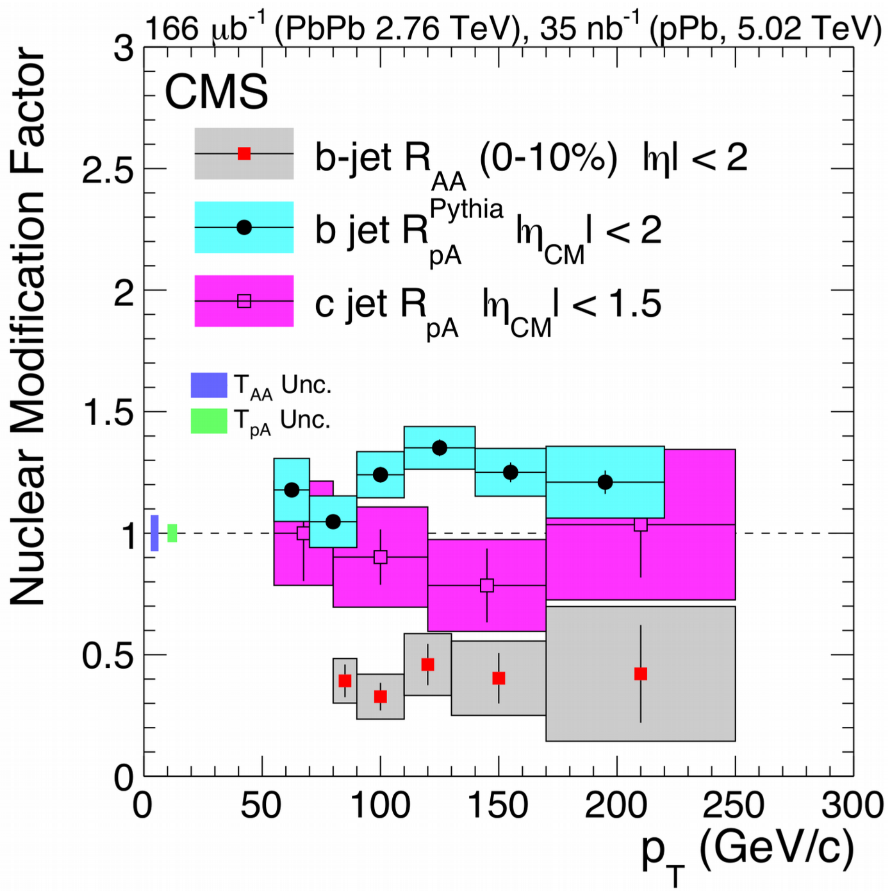


3 published measurements of reconstructed jets

What we haven't learned from RHIC Yet!

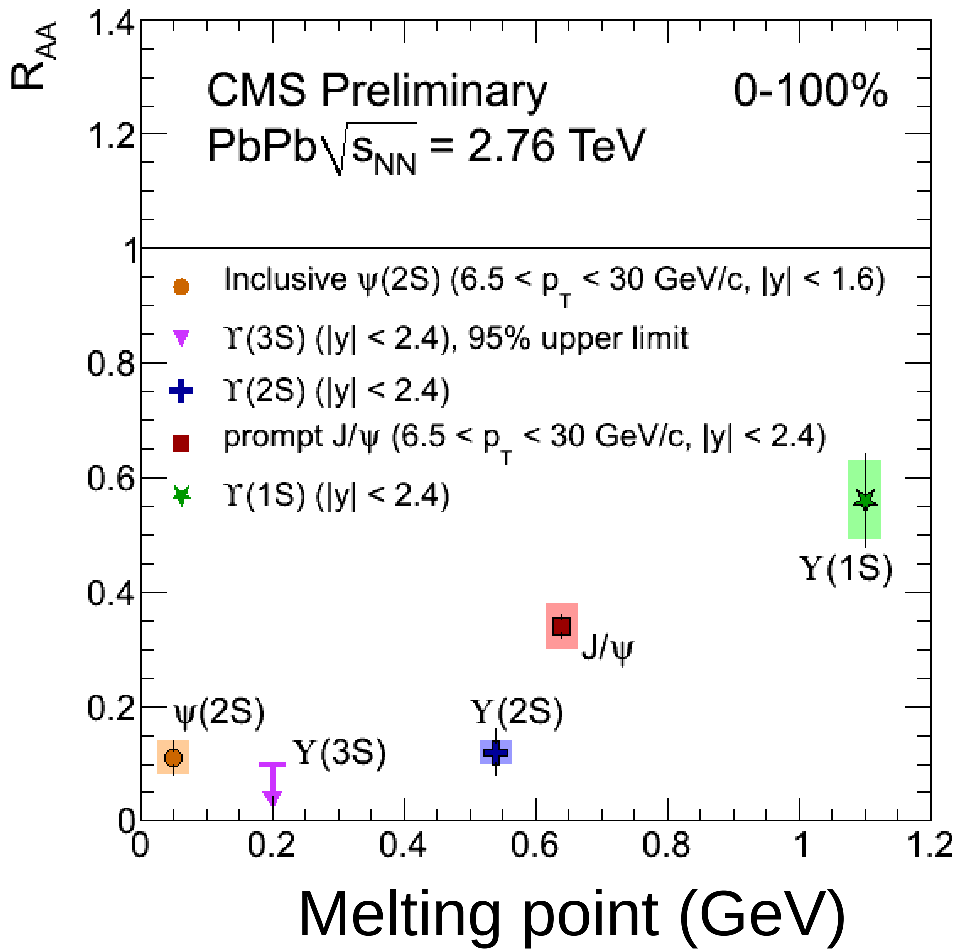
Jet R_{AA}

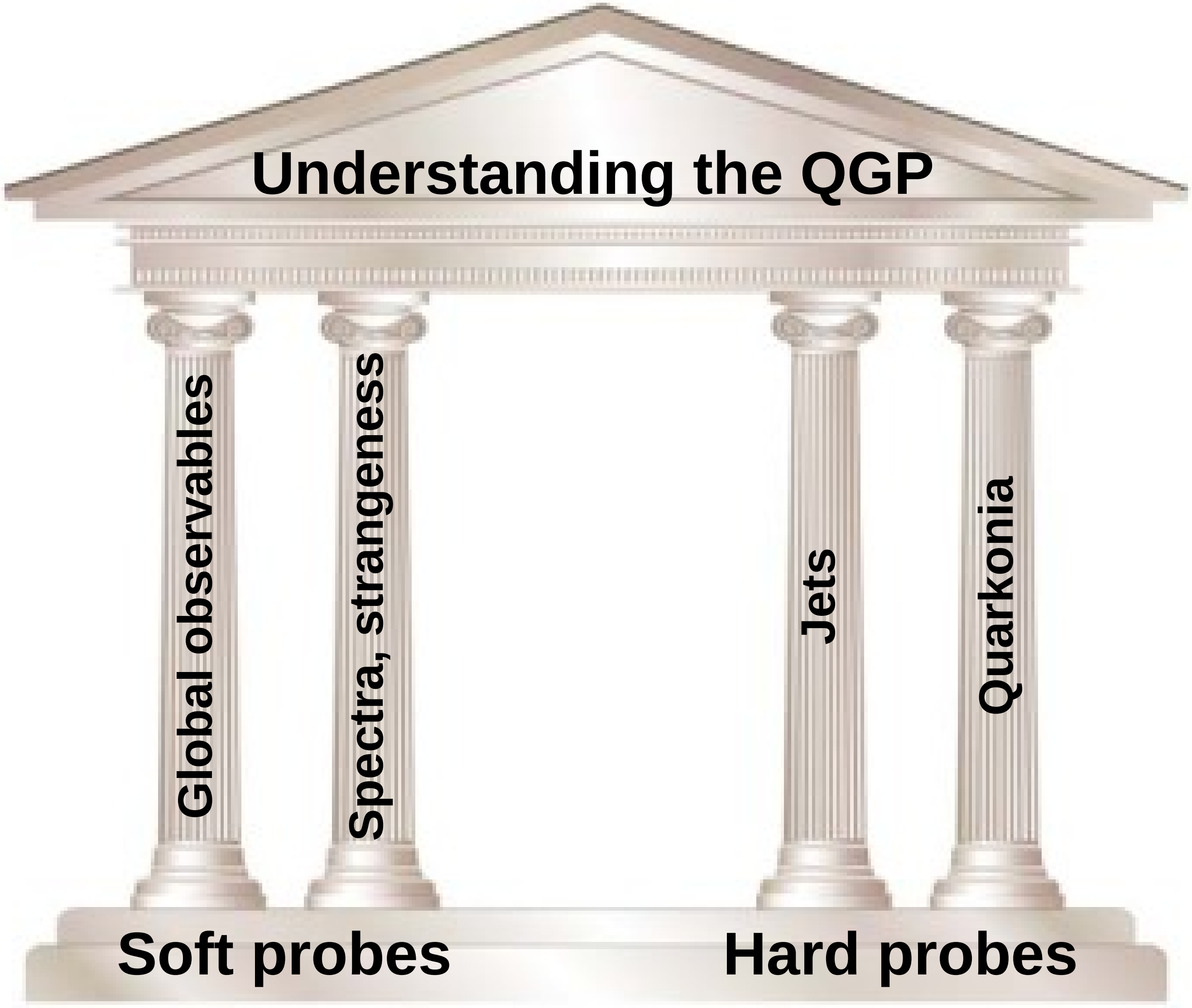




What we haven't learned from RHIC Yet!

Quarkonia



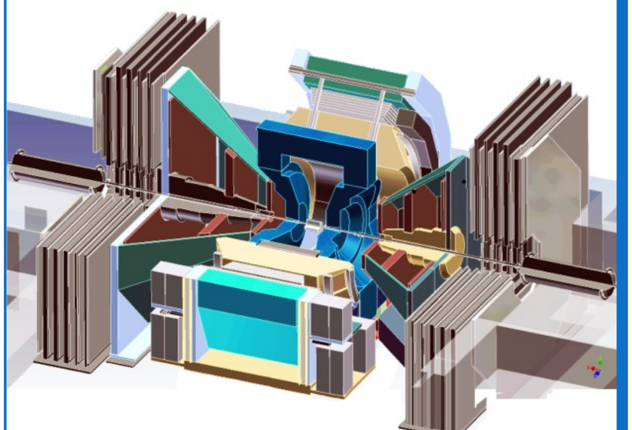

Understanding the QGP
Global observables
Spectra, strangeness
Jets
Quarkonia
Soft probes
Hard probes

Evolution of the PHENIX Interaction region

PHENIX experiment	sPHENIX	An EIC detector

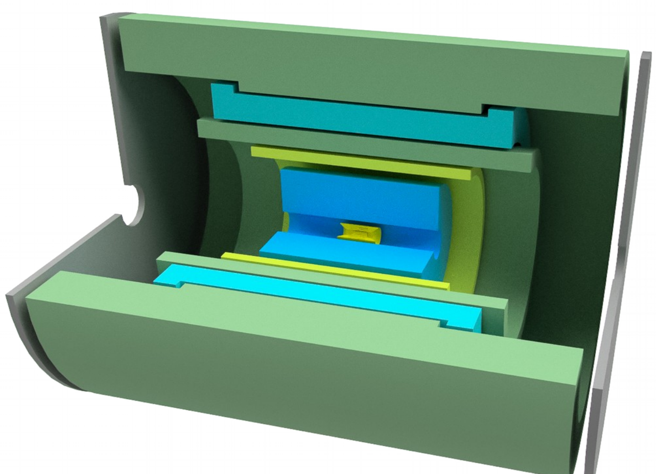
PHENIX experiment

- 16y+ operation
- Broad spectrum of physics (QGP, Hadron Physics, DM)
- 170+ physics papers with 24k citations
- Last run in this form 2016



sPHENIX

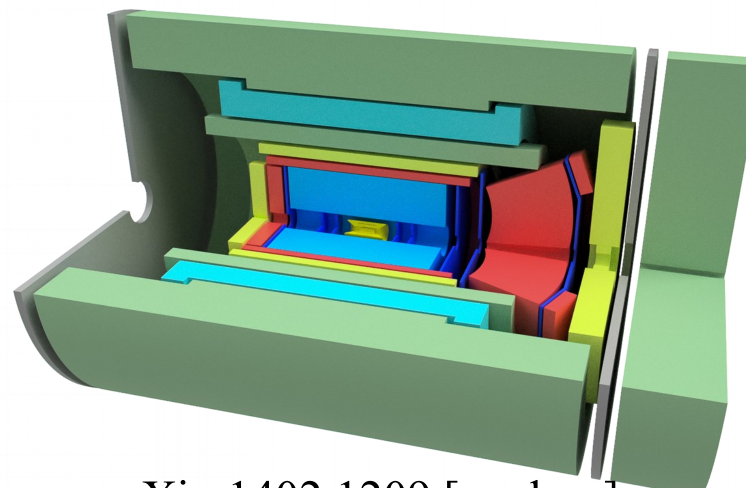
- Comprehensive central upgrade base on BaBar magnet
- Rich jet and HF physics program → nature of QGP
- Possible forward tracking, and calorimeter → Spin, CNM



arXiv:1501.06197 [nucl-ex]

An EIC detector

- Path of PHENIX upgrade leads to a capable EIC detector
- Large coverage of tracking, calorimetry and PID
- Update LOI this year, open to new collaborators/new ideas



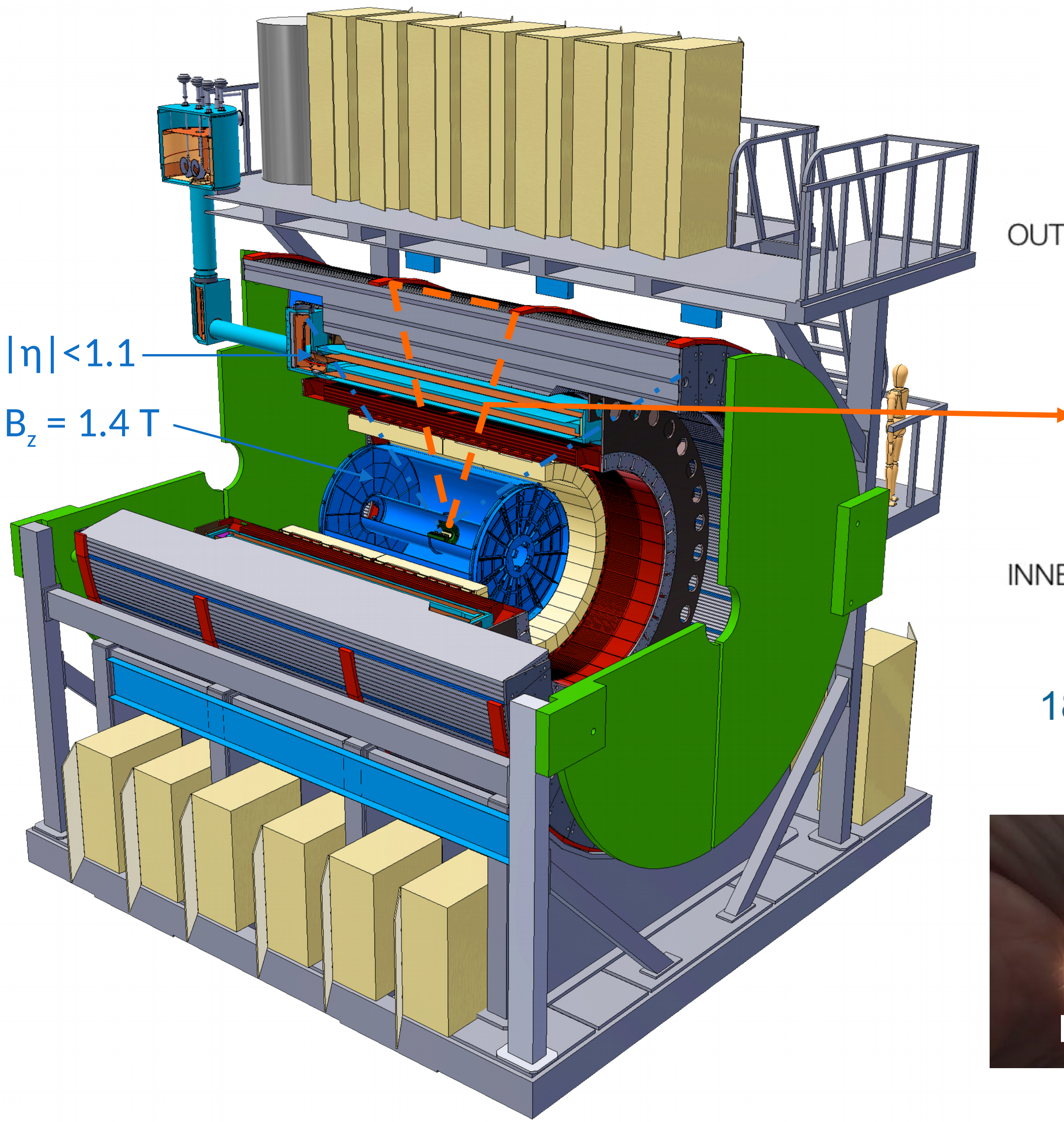
arXiv:1402.1209 [nucl-ex]

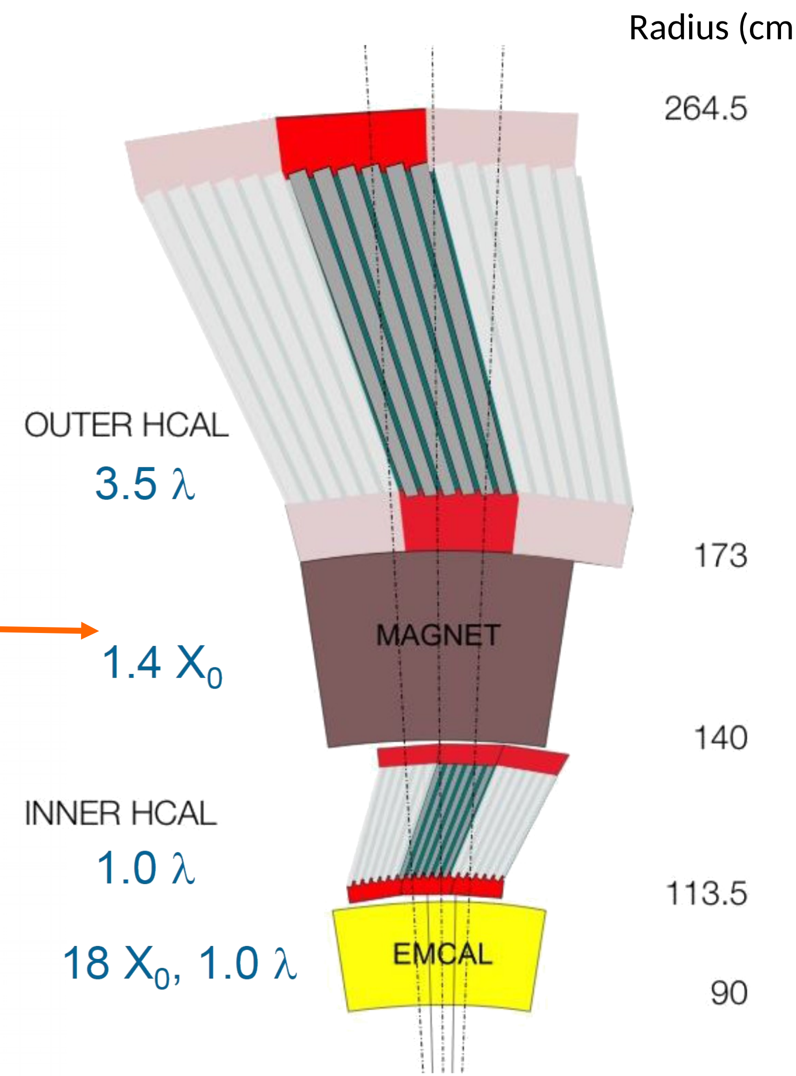
~2000 | 2017→2022, CD-0 @ 2016 | >2025 | Time

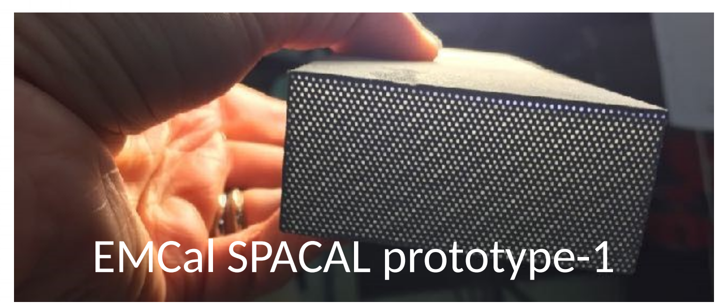
RHIC: A+A, spin-polarized p+p, spin-polarized p+A

EIC: e+p, e+A

SPHENIX Detector

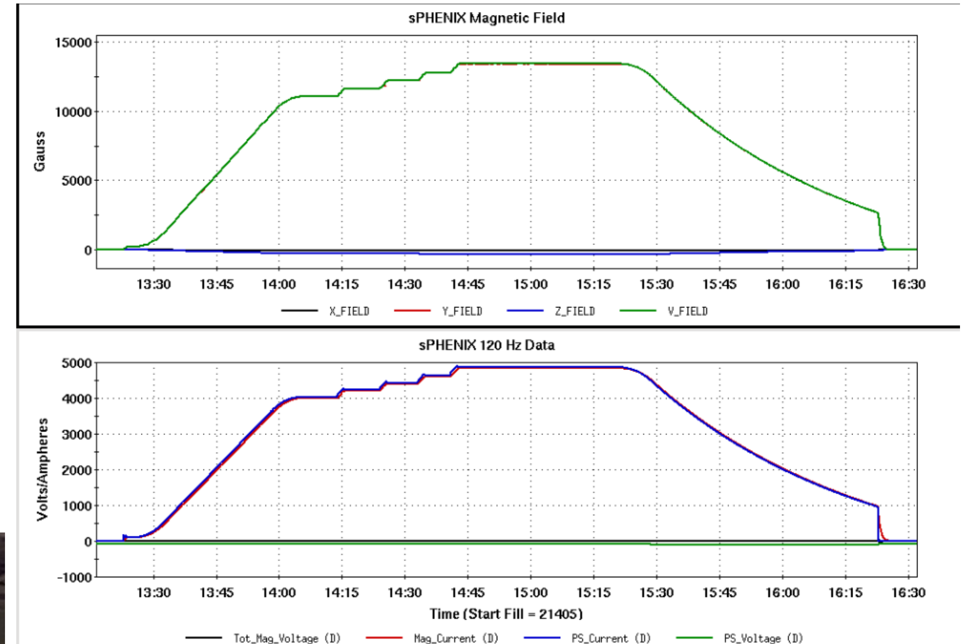


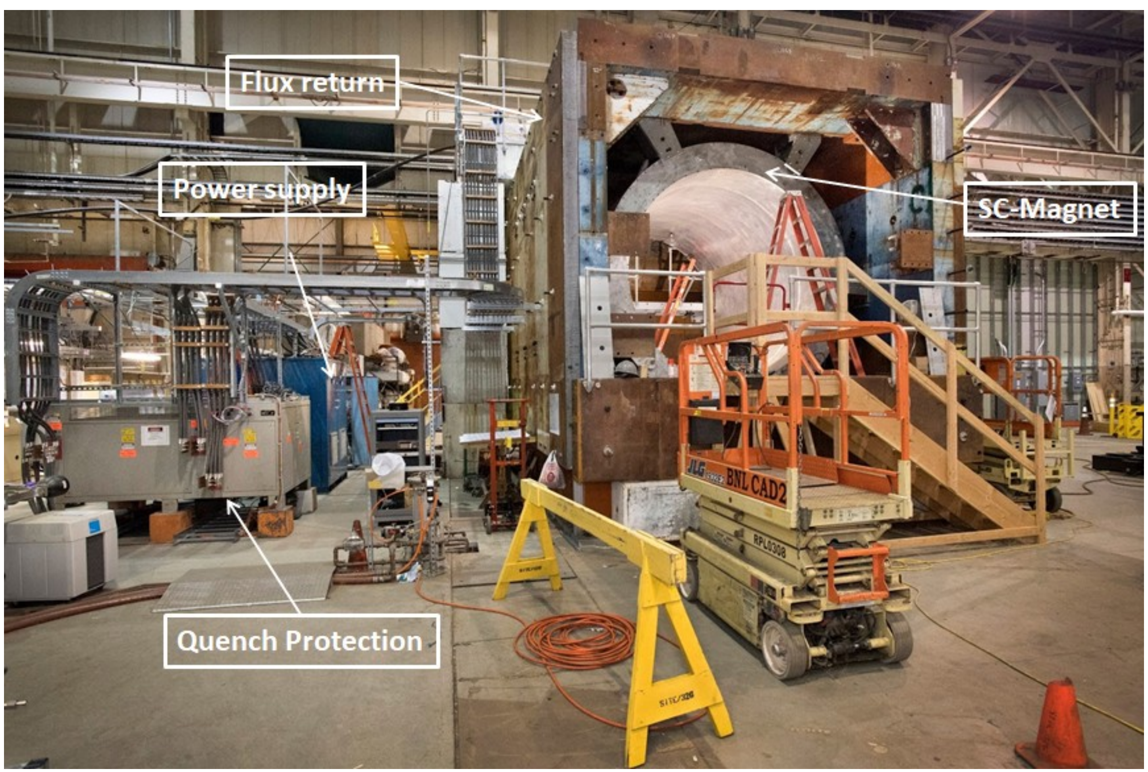




Super conducting magnet

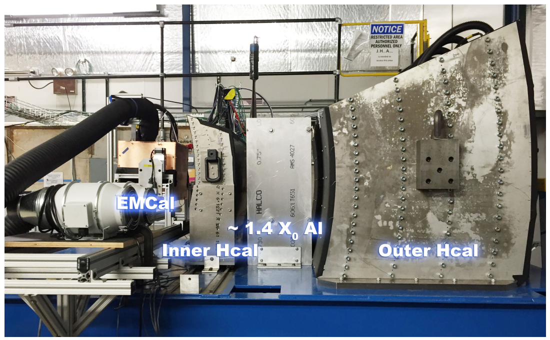
- 1.4 Tesla magnet, Φ = 2.8 m, L = 3.8 m
  Previously used in BaBar @ SLAC
- Moved to BNL in Feb 2015
- Successful cold low field test in 2016
- Full field test in February successful

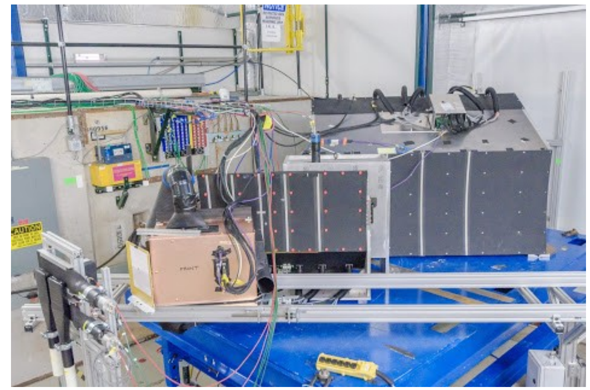




SC-Magnet Testing ramped the magnet to 105% Full Current twice. We held the magnet at the top current for ~ 40 minutes each time.
Conclusion: The magnet works to spec.
PS, control and quench protection system checks out.

Calorimeter beam tests





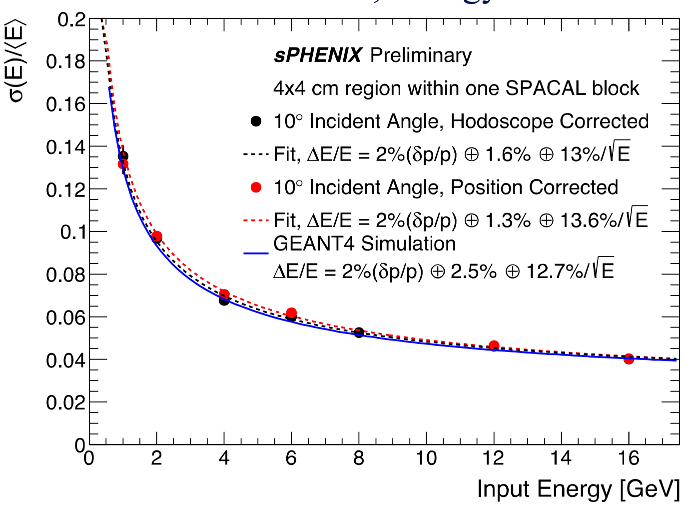
February 2014
Proof of principle

February 2016
η~0 prototype

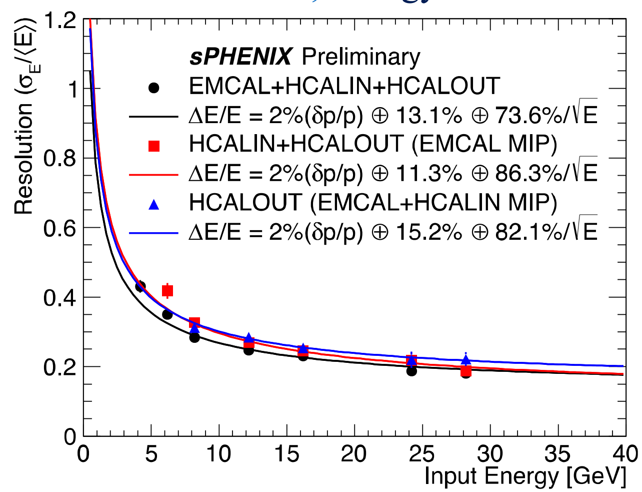
February 2017
η~0.9 prototype

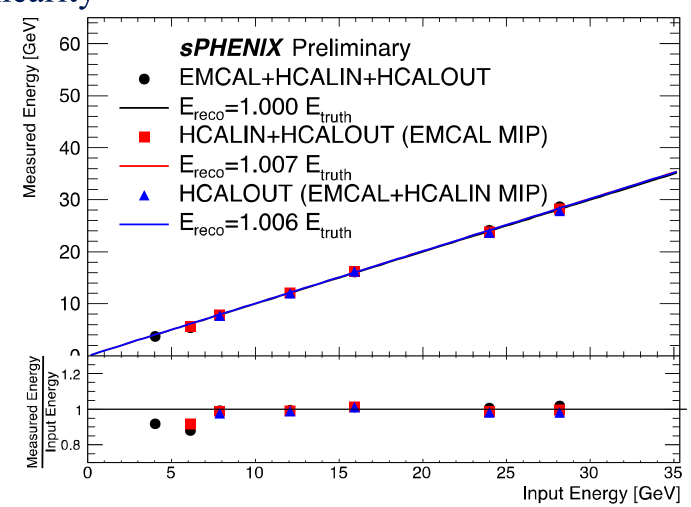
March - June 2017
Final η~0.9 prototype

Electron, Energy resolution

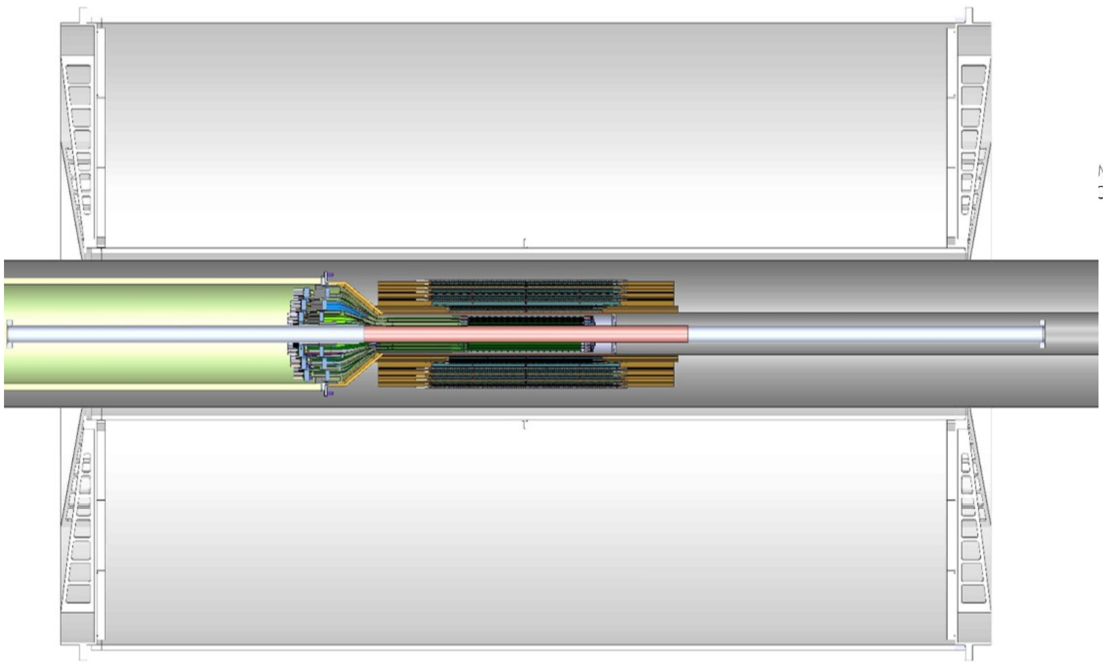


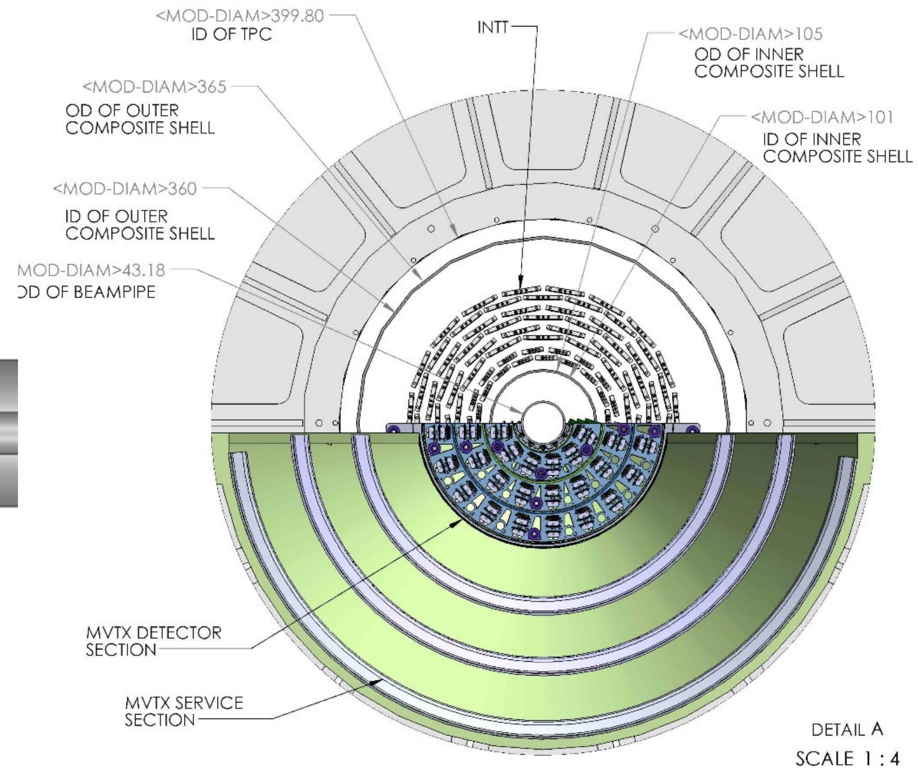
Pion, Energy resolution and linearity





Tracking detectors





Inner tracking:

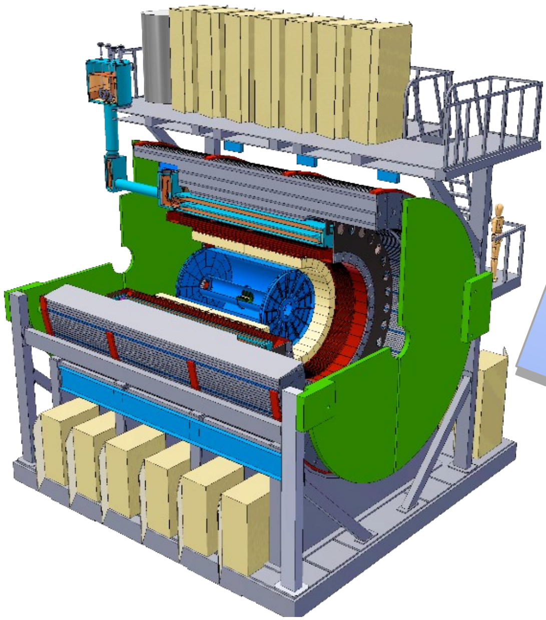
- **MVTX**: 30-um-pitch MAPS pixel sensors (3-layer)
  - Precision vertexing
- **INTT**: strip silicon sensors (4-layer)
  - Pattern recognition, timing
- DCA^{π}< 50um for p_T>1 GeV/c, <10 um for p_T>10 GeV/c

Outer tracking:

- **TPC**: gateless and continuous readout
- Low diffusion, high ion mobility Ne-CF_4 gas + Quad GEM + mini pads
- 1 Tbps DAQ, FPGA-based reduction, 100 Gbps data file rate
- $R\delta\Phi < 200$ um
- $\delta p/p < 2\%$ for p_T<10 GeV/c

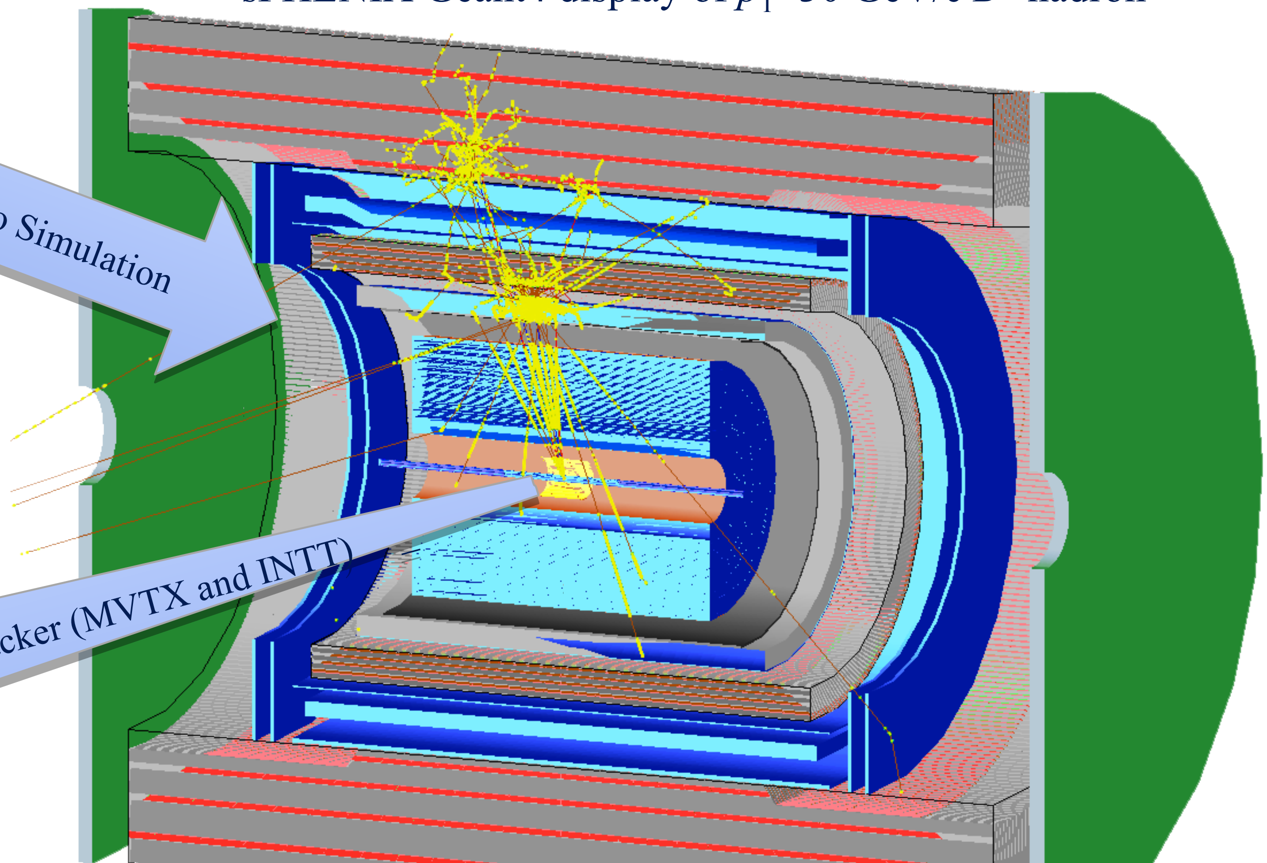
Full detector simulation + reconstruction

Open source @ GitHub : https://github.com/sPHENIX-Collaboration/

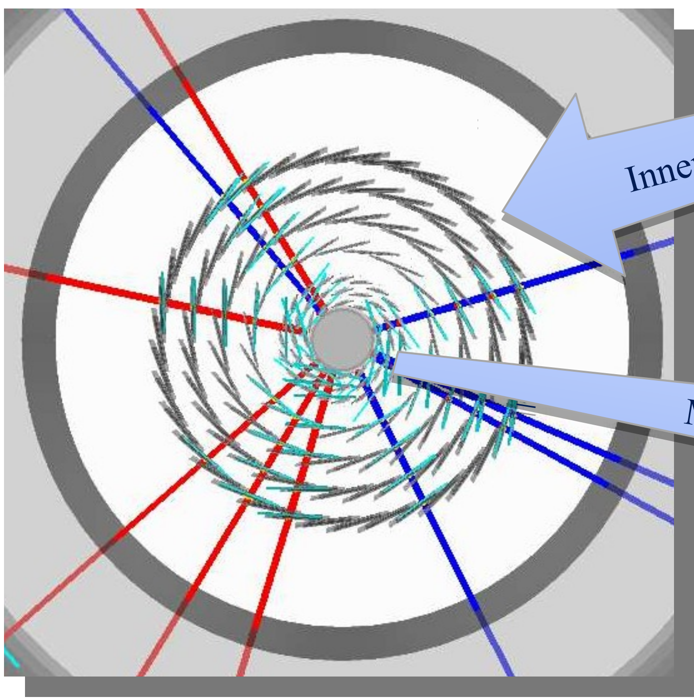


Design to Simulation

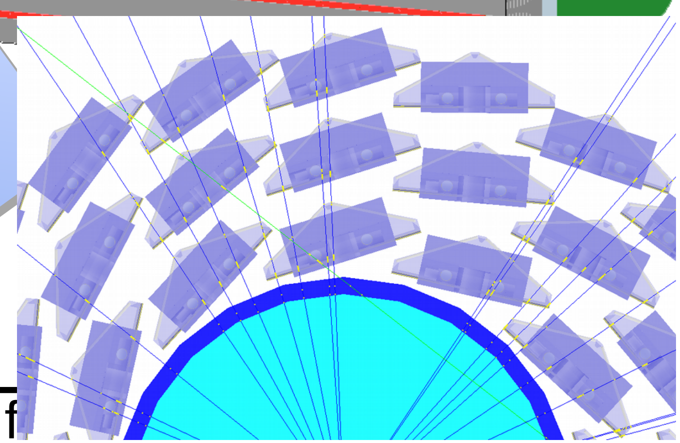
sPHENIX Geant4 display of p_T=30 GeV/c B^+-hadron



Inner tracker (MVTX and INTT)

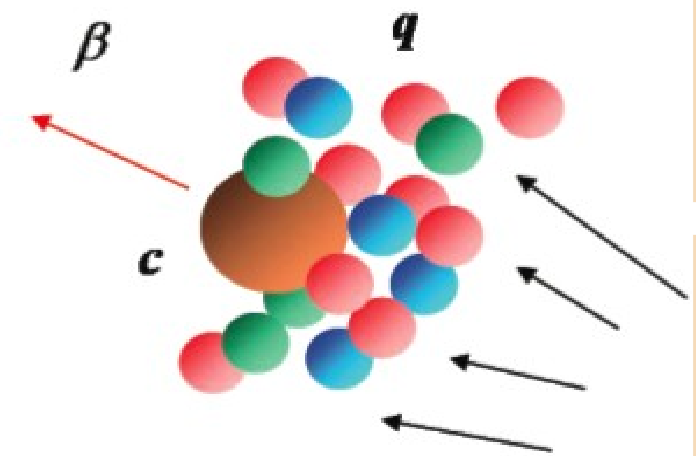


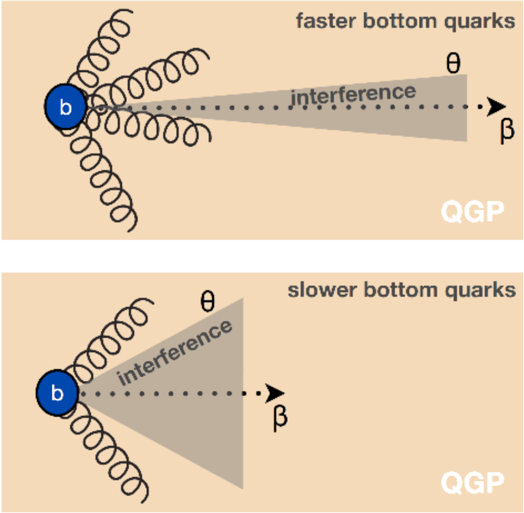
MVTX Ladders modeled in detail

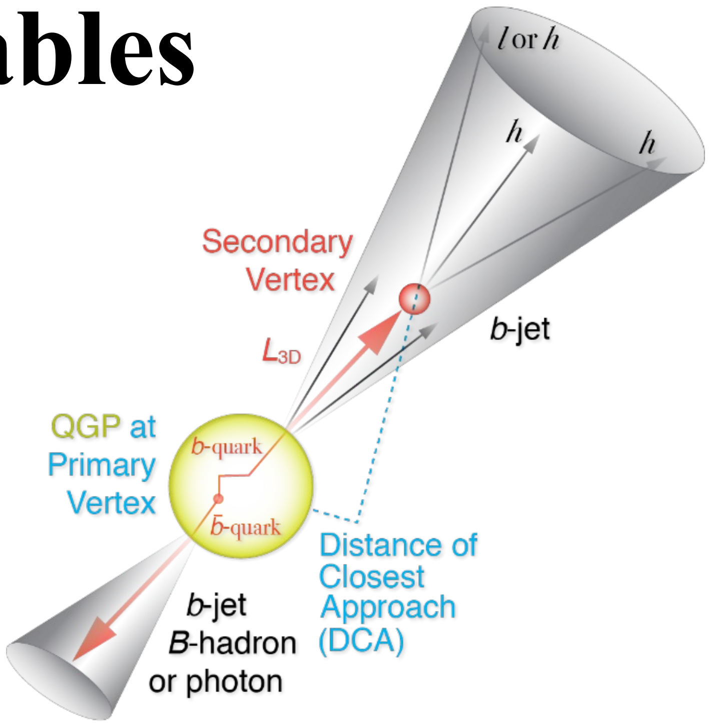



Heavy Flavor

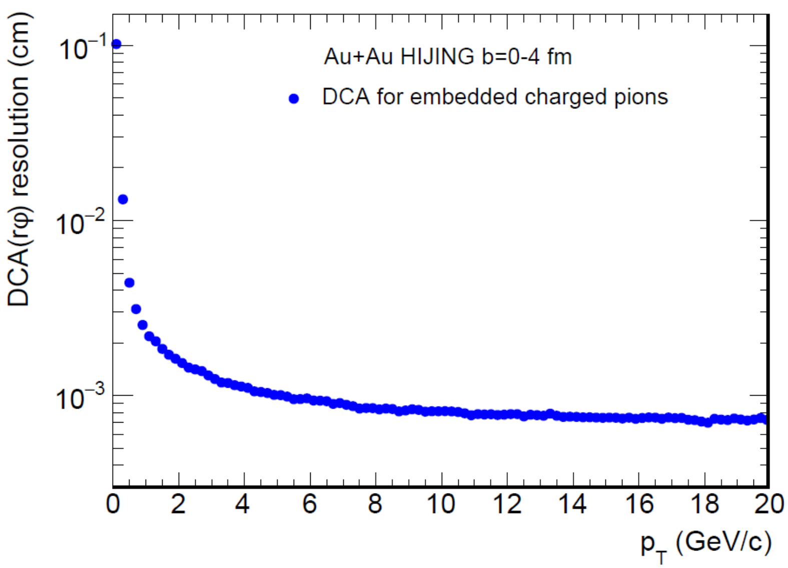
Open heavy flavor observables





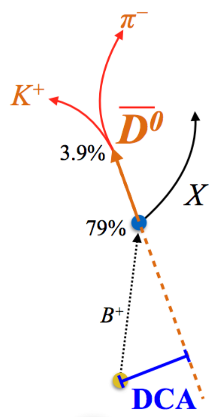


- Precision vertex tracker + High rate → Precision bottom observables
- *B*-meson @ Low p_T : diffusion of HF quark in QGP
- *b*-jet @ Higher p_T: differentiate collisional vs radiative energy loss

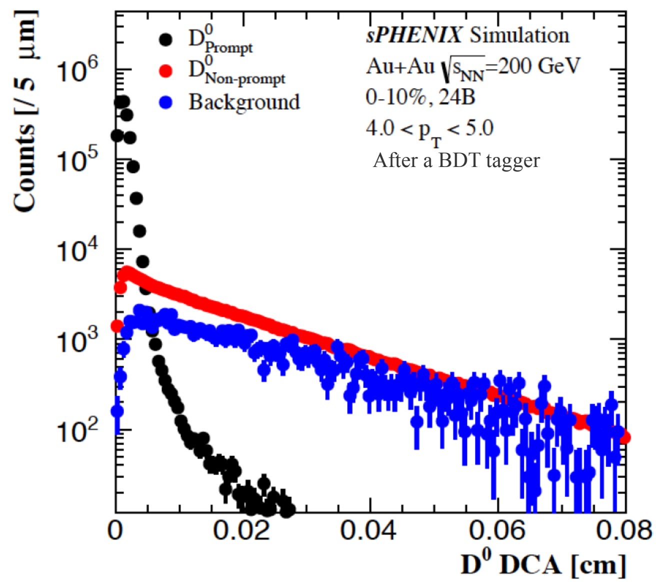


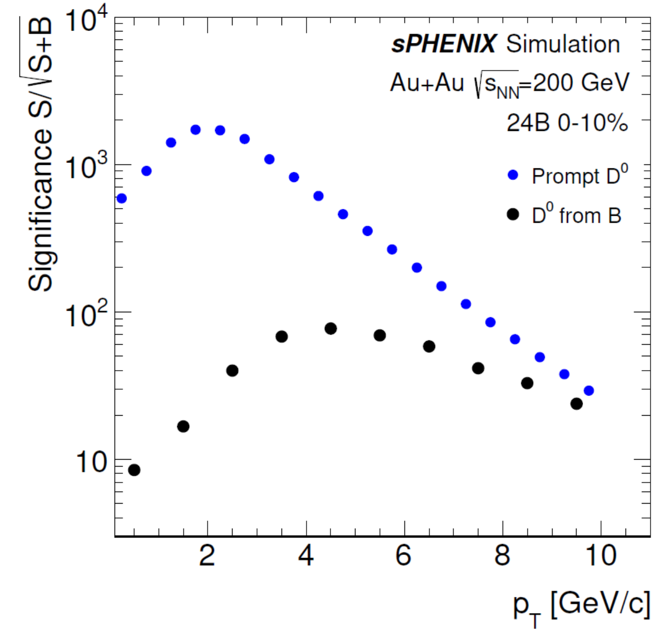
Precision open bottom meson

$B \rightarrow \overline{D}^0 + X$

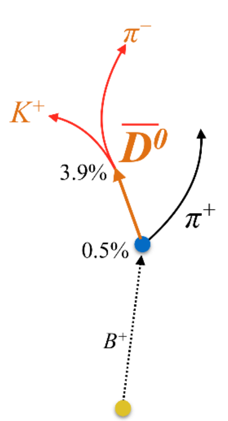


Prompt and non-prompt D-meson

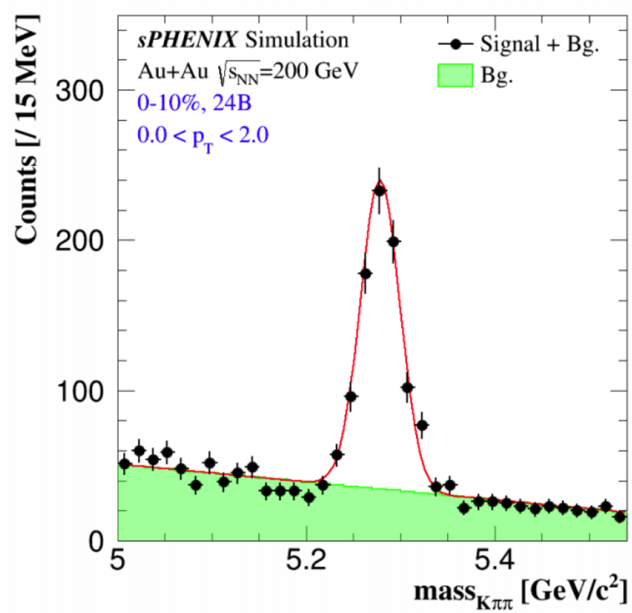




$B^+ \rightarrow \overline{D}^0 \pi^+$

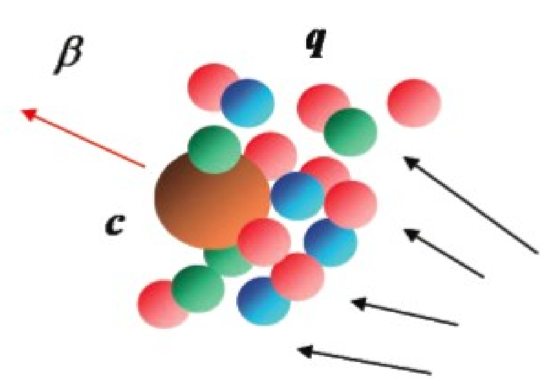


Exclusive $B^\pm$

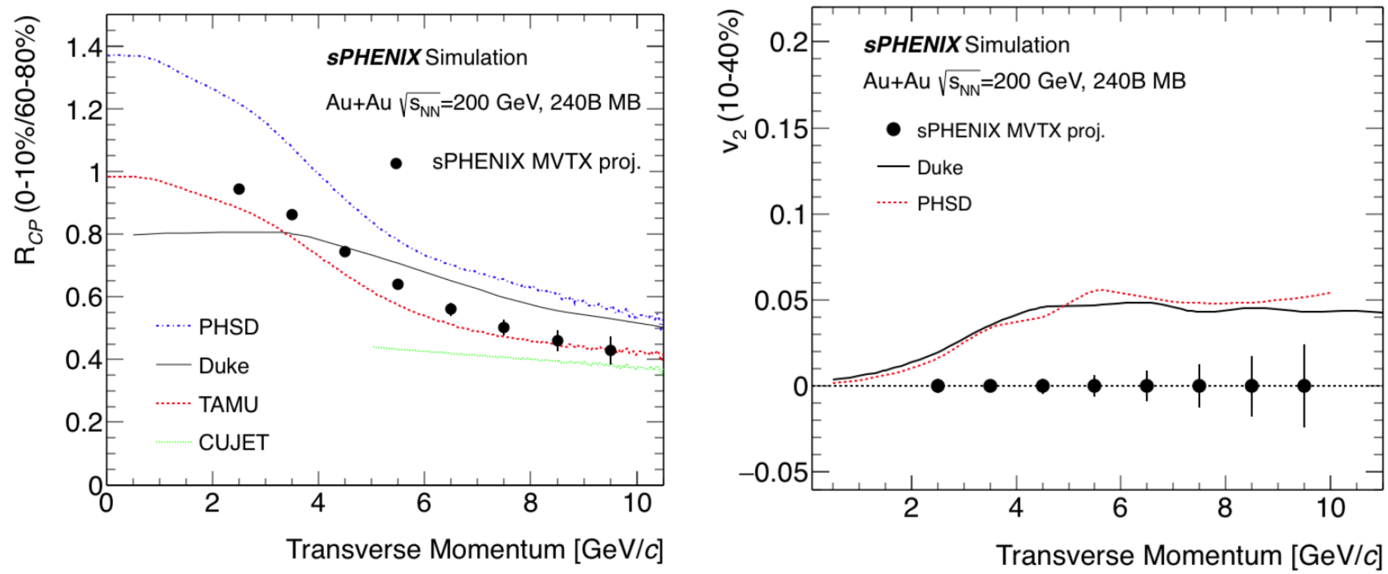


- 240 MB Au+Au collisions and high precision tracking allow accumulate high significance of HF-meson signals
- Measuring high statistics *B* meson via non-prompt D decay channel
- Exclusive *B* reconstruction too!

B-meson projections

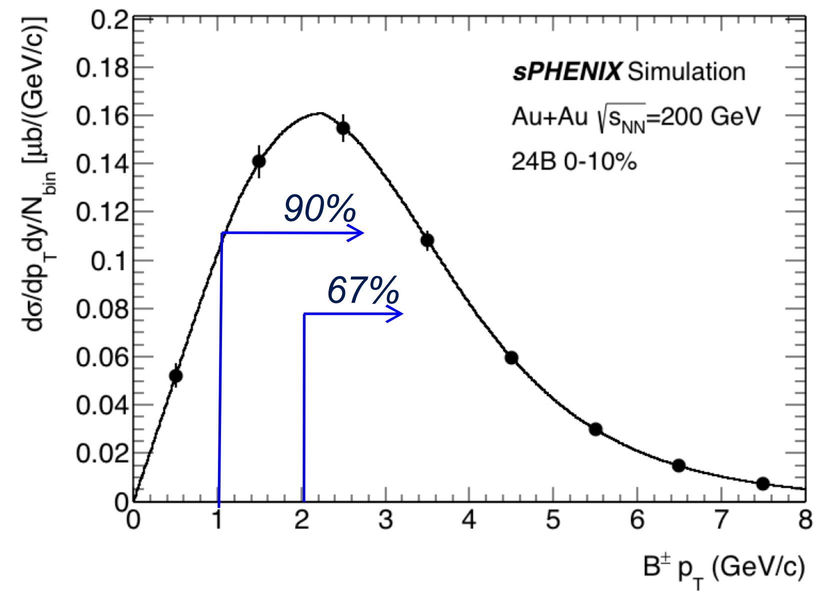


non-prompt *D*-meson and predictions for sPHENIX



- Bring high precision non-prompt-*D* suppression and flow to RHIC
- Determine the bottom quark collectivity → clean access to D_{HQ} at RHIC energy
- Broader program:
  - Total *b*-cross section for Upsilon program
  - Charm chemistry and HF hadronization
  - *D* fragmentation function with Jets

Exclusive $B^{\pm}$ in most central Au+Au

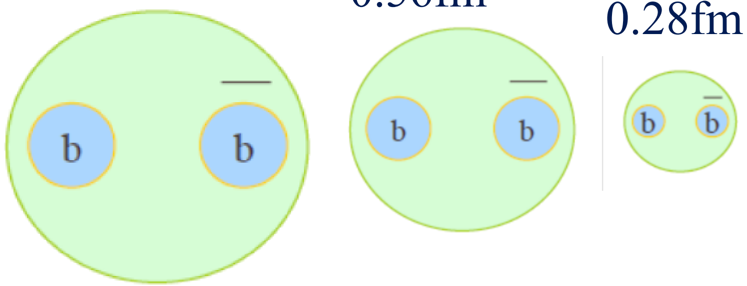


Upsilon spectroscopy

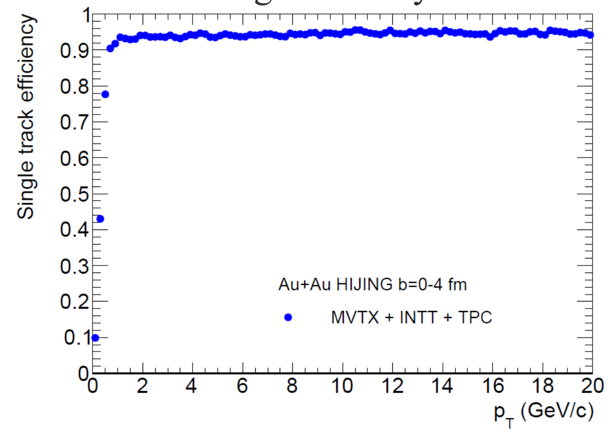
ϒ(3s)- 0.78fm

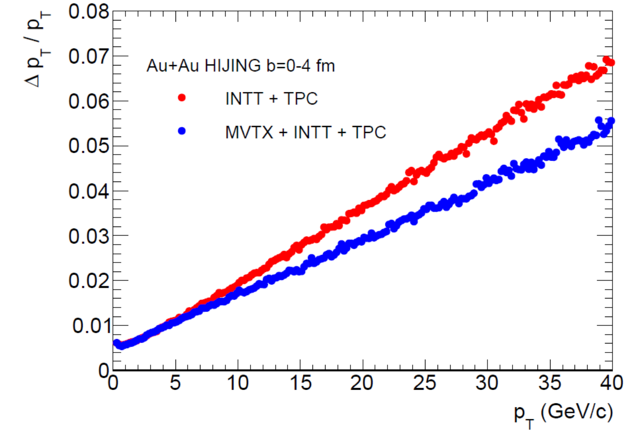
ϒ(2s) – 0.56fm

ϒ(1s) – 0.28fm

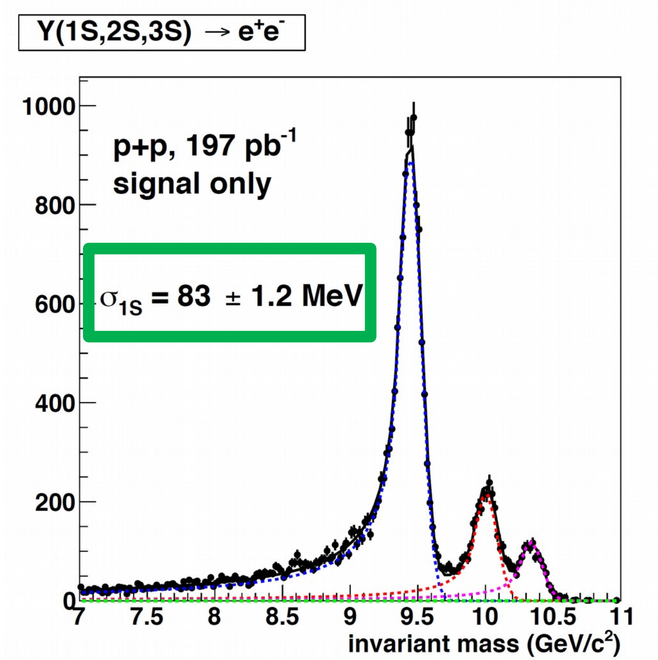


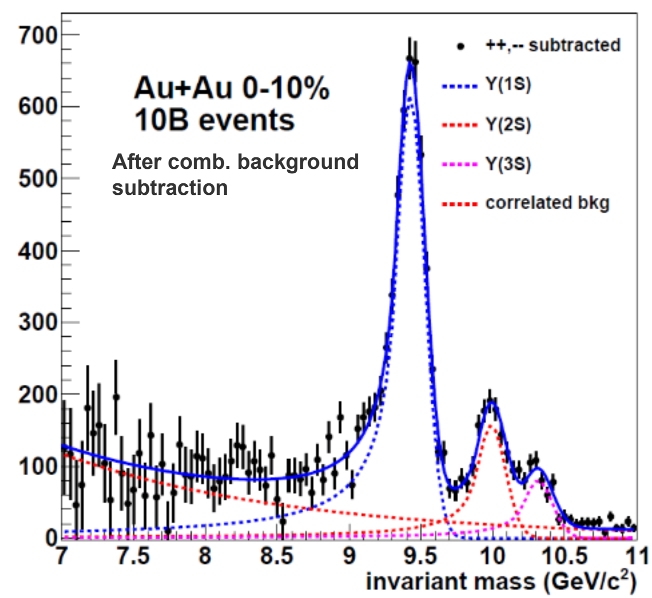
Tracking efficiency and transverse momentum resolution

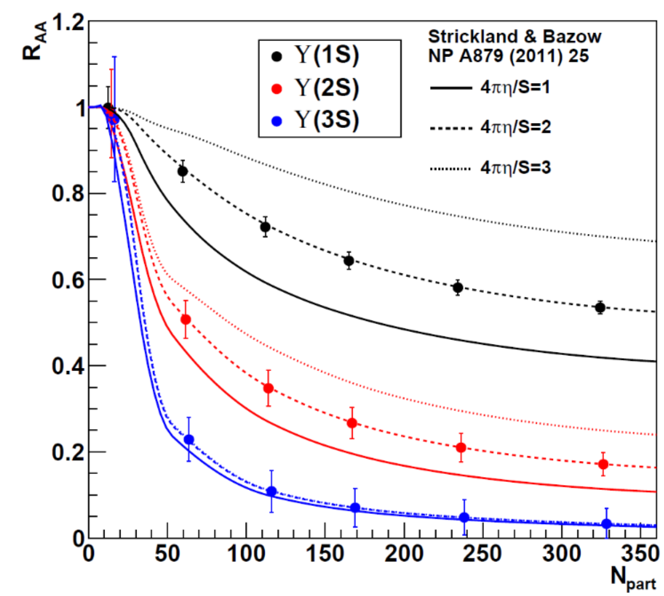




Precision tracking → Separated Upsilon states at RHIC → Probe of the QGP at distinct length scales.



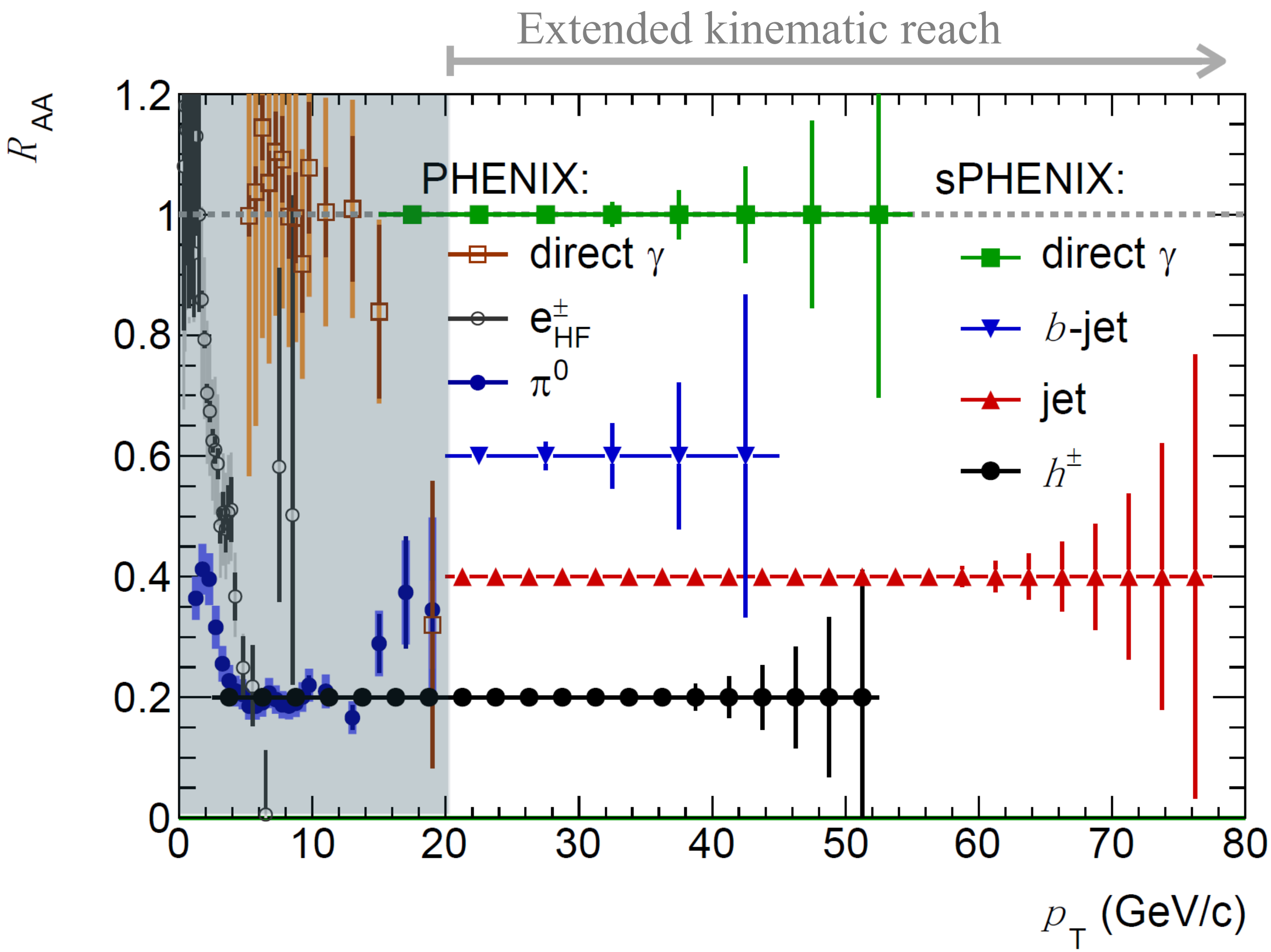


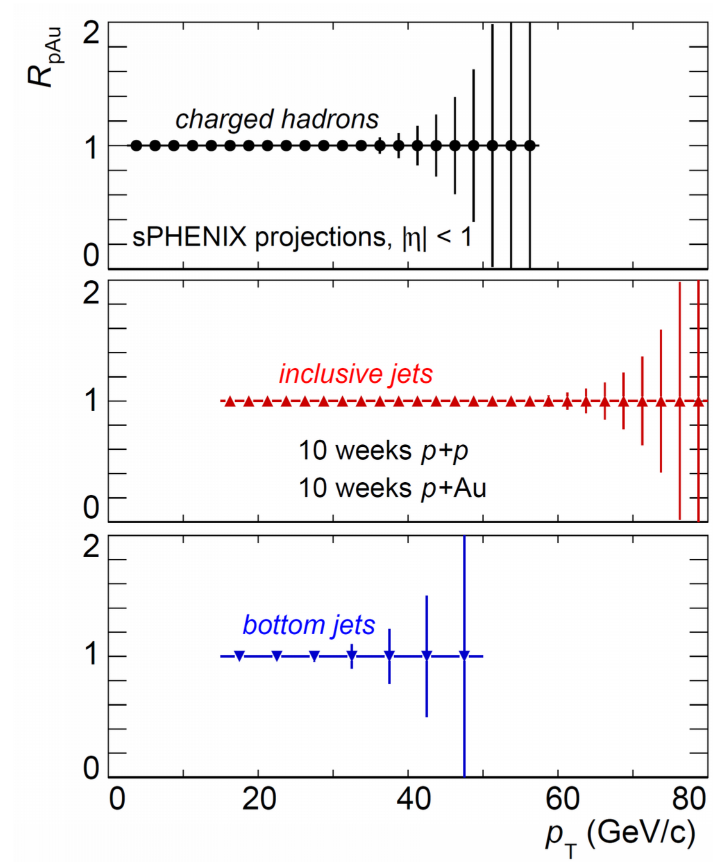


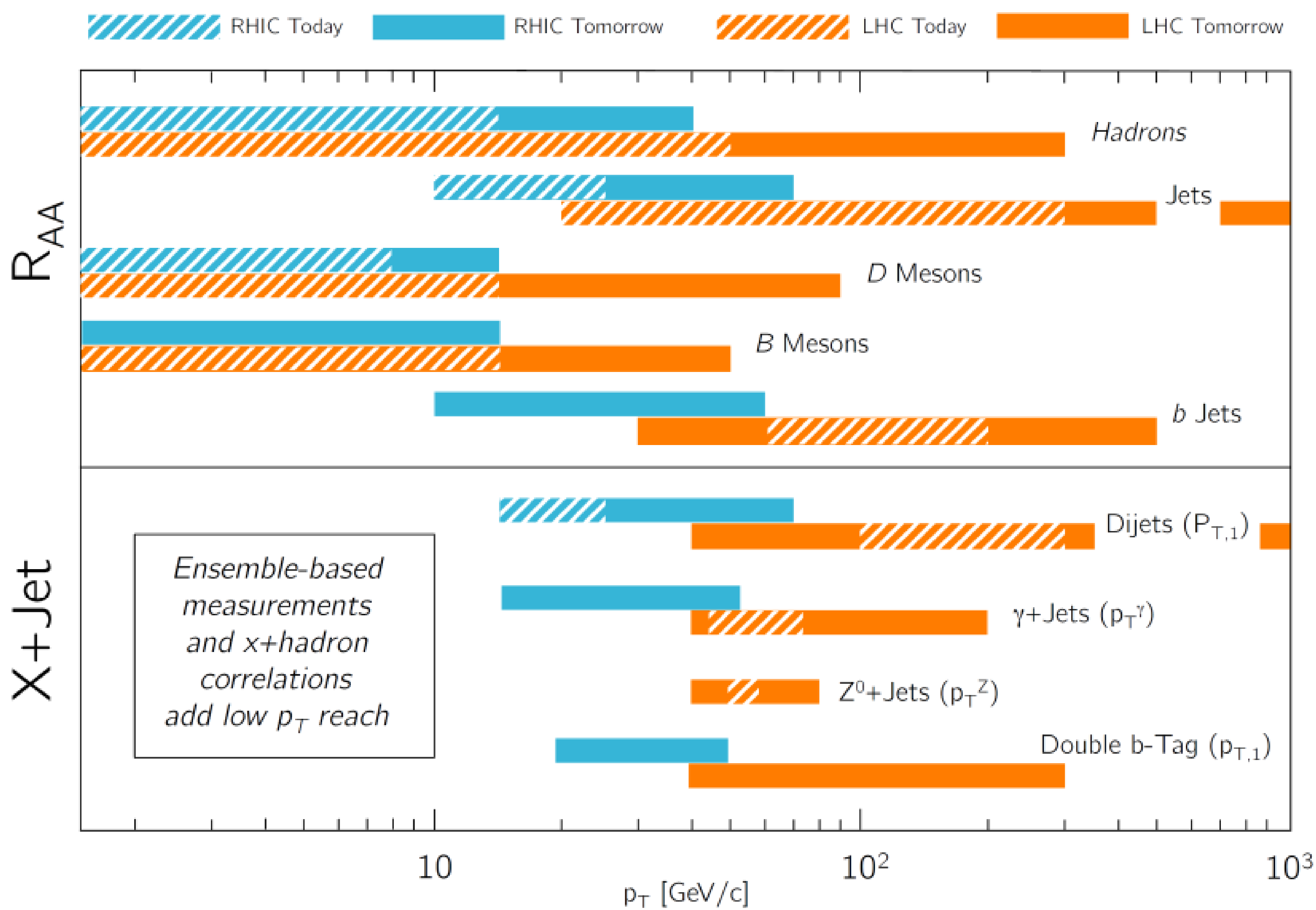

Jets

High statistics hard probes

High statistics data represents large extend in hard probes in jets, photon and hadrons

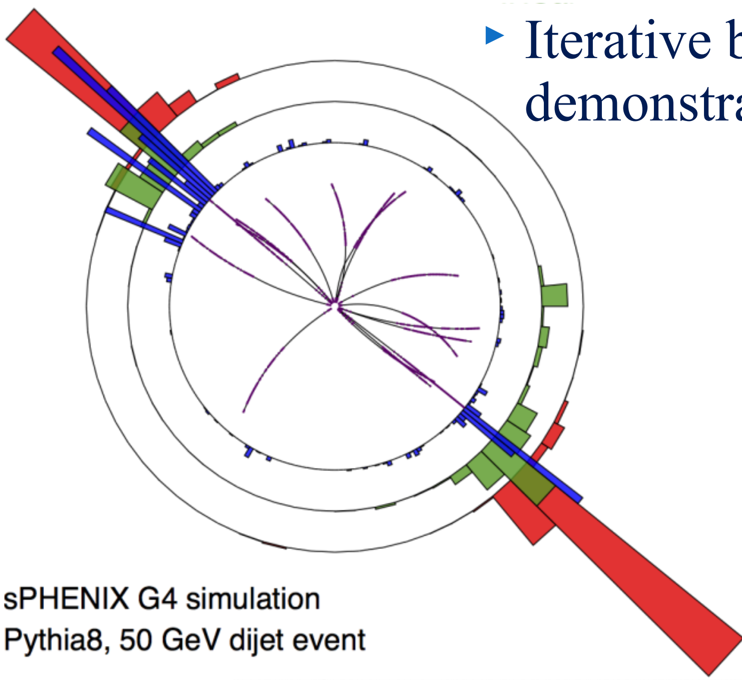




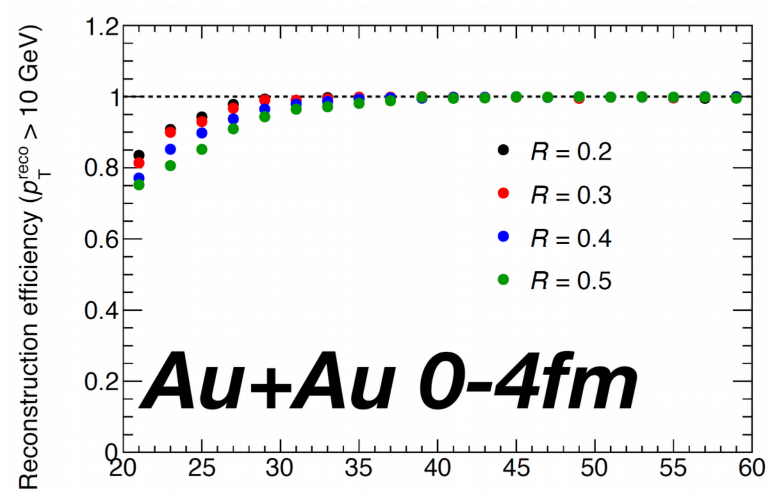

RHIC Today
RHIC Tomorrow
LHC Today
LHC Tomorrow
R_{AA}
Hadrons
Jets
D Mesons
B Mesons
b Jets
X+Jet
Dijets ($P_{T,1}$)
γ+Jets (p_T^{γ})
Z^0+Jets (p_T^Z)
Double b-Tag ($p_{T,1}$)
Ensemble-based measurements and x+hadron correlations add low p_T reach
10
10^2
10^3
p_T [GeV/c]

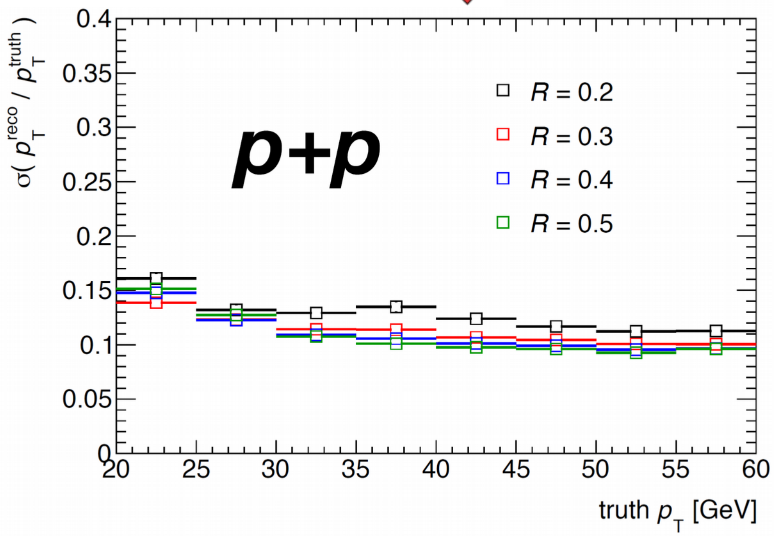
sPHENIX: calorimetry jet at RHIC

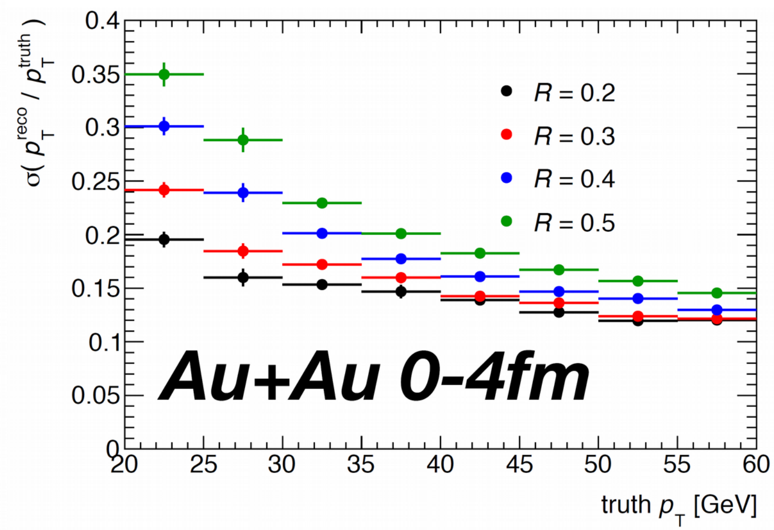
- Calorimetric triggering and measurement of jets
- Minimum bias to jet flavor and FF
- Iterative background subtraction [PRC 86 (2012) 024908] demonstrated in sPHENIX full event simulations



sPHENIX G4 simulation
Pythia8, 50 GeV dijet event

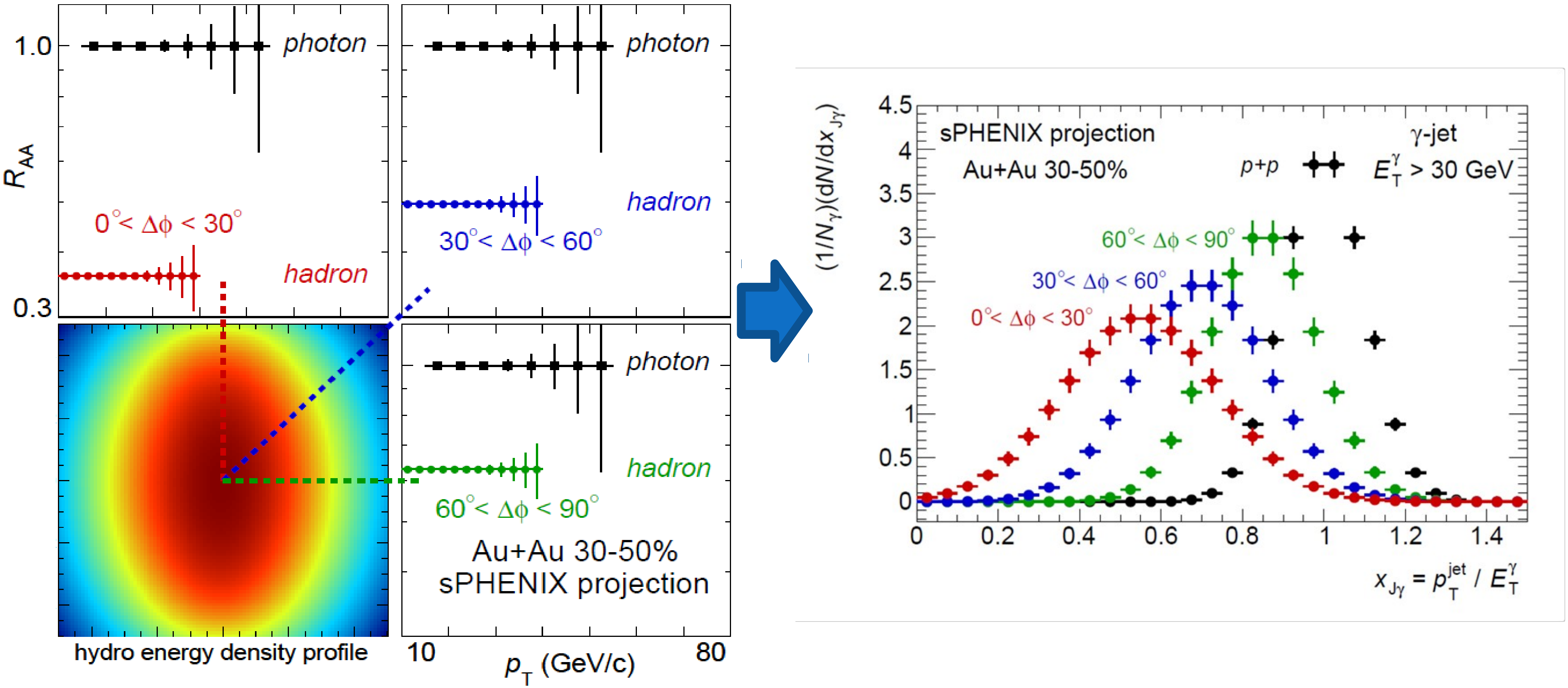






More differential measurement

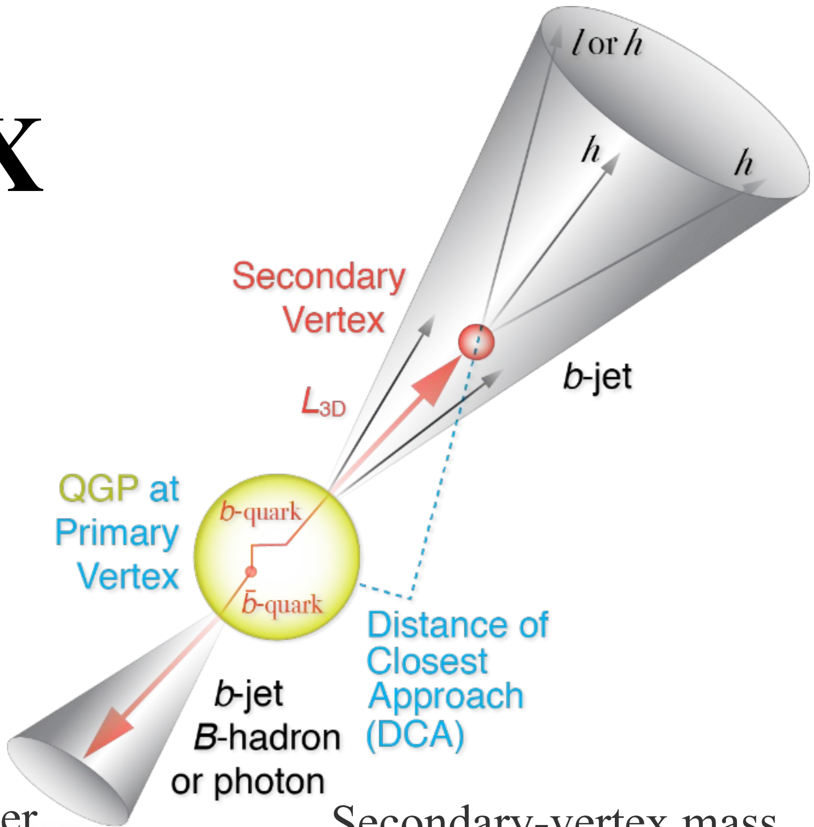
- High statistics also allows more differential measurements
- For example, path-length dependent studies via γ-jet transverse balance in correlation with event plane



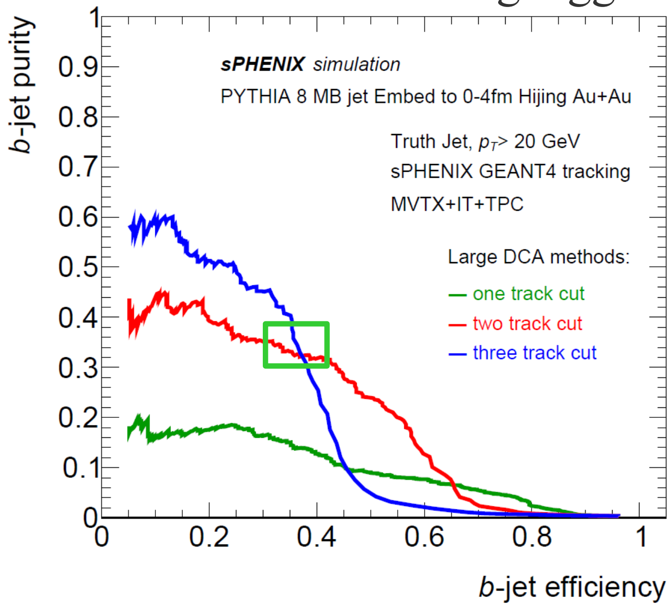

Heavy FlavorJets

b-jet tagging @ sPHENIX

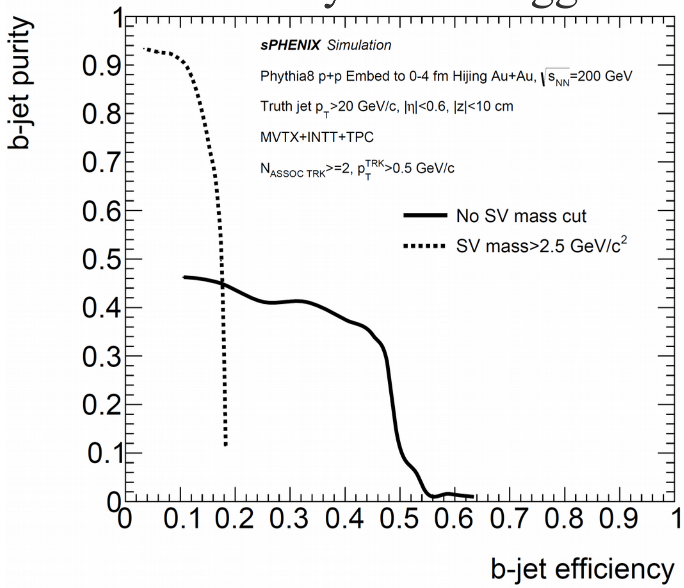
- Demonstrate b-jet capability: tagging algorithms evaluated using full detector HI simulation
- Reaching a promising working point in central Au+Au collisions



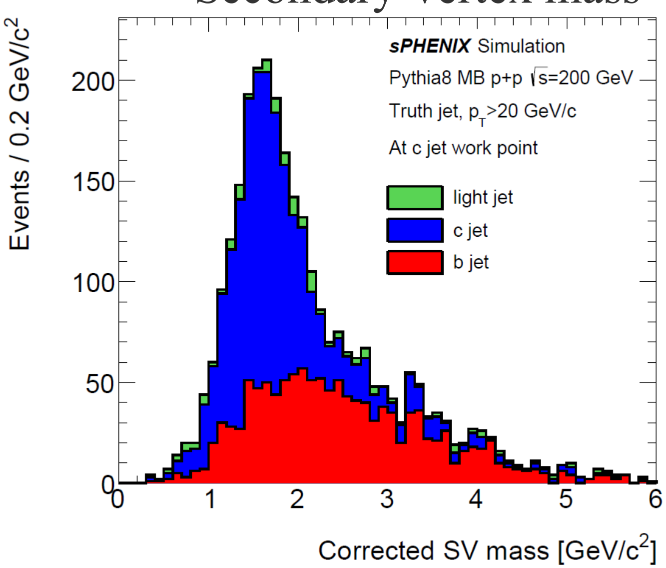
Track-counting tagger



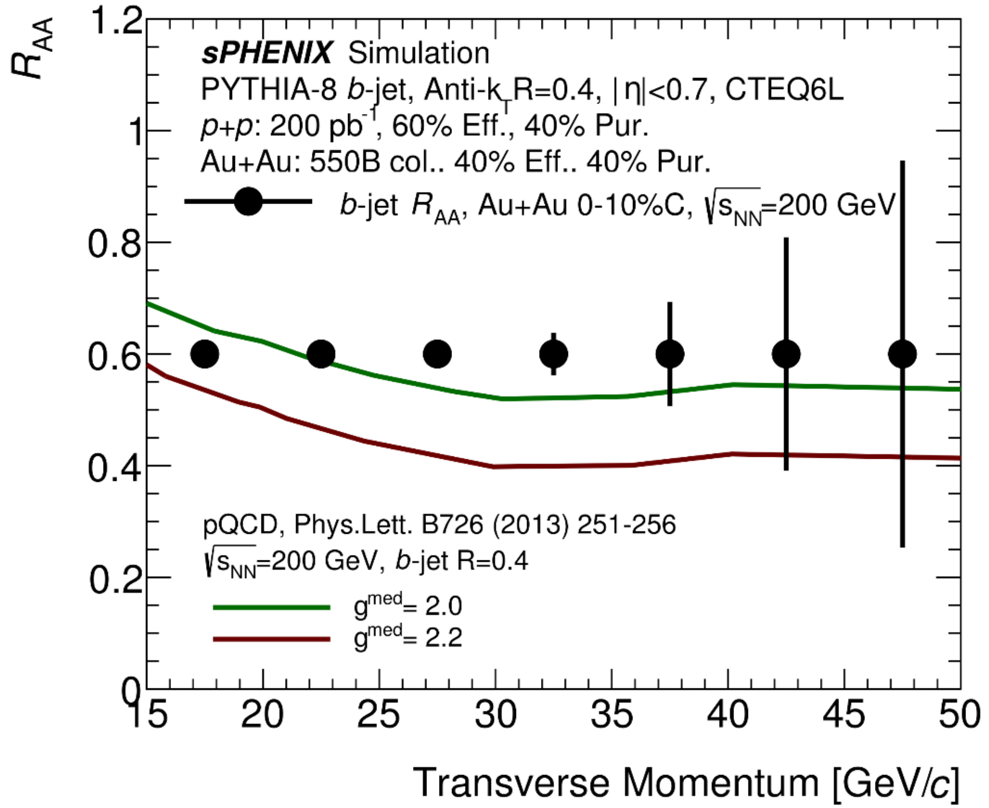
Secondary-vertex tagger

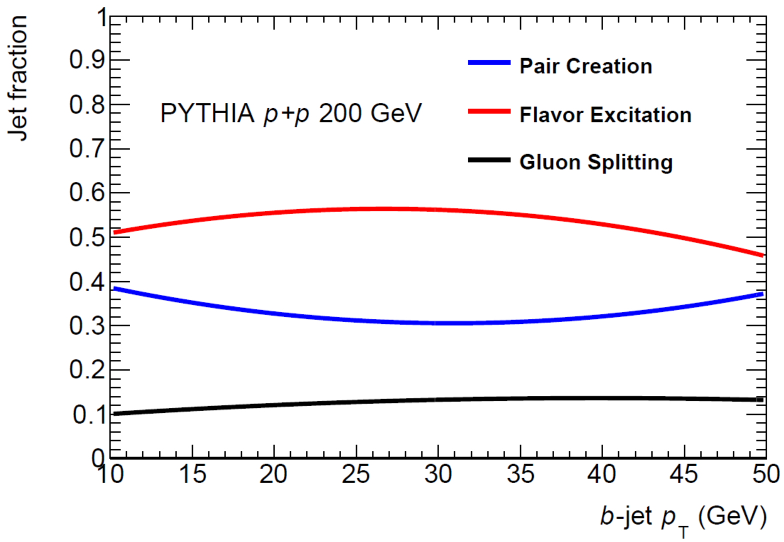


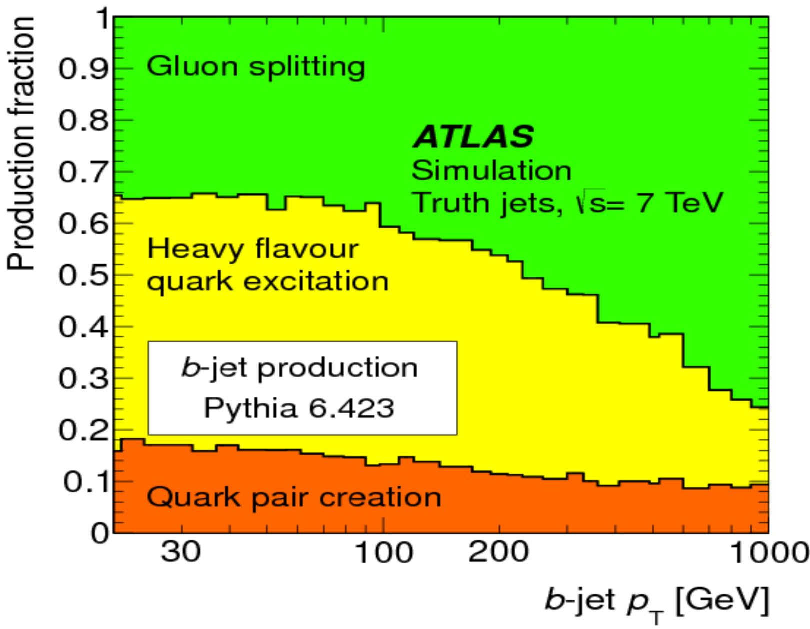
Secondary-vertex mass



Inclusive b-jet R_{AA} Performance







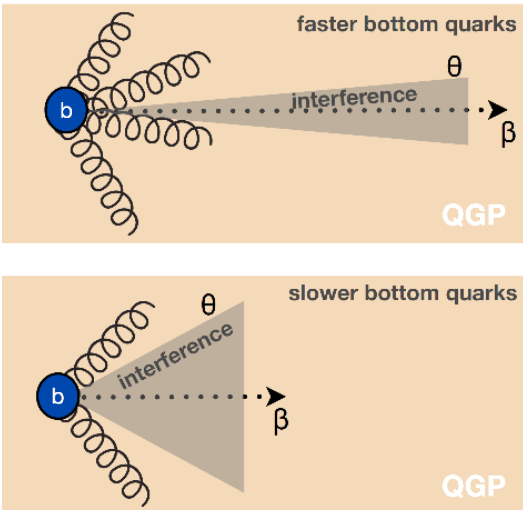
MVTX aiming first b-jet nuclear modification factor @ RHIC, covering ~15-40 GeV/c

- Mass dependence of parton energy loss
- Cleaner access to partonic kinematics

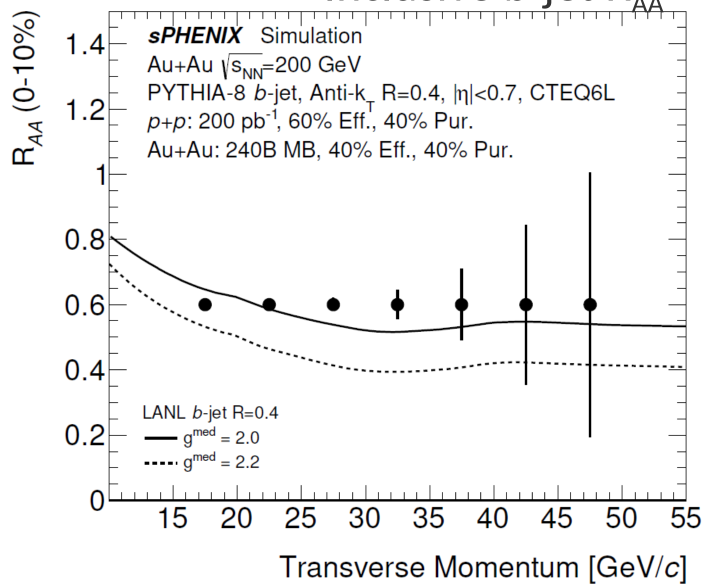
Uniqueness at RHIC (vs. LHC)

- Gluon splitting contribution is much less (~10%)

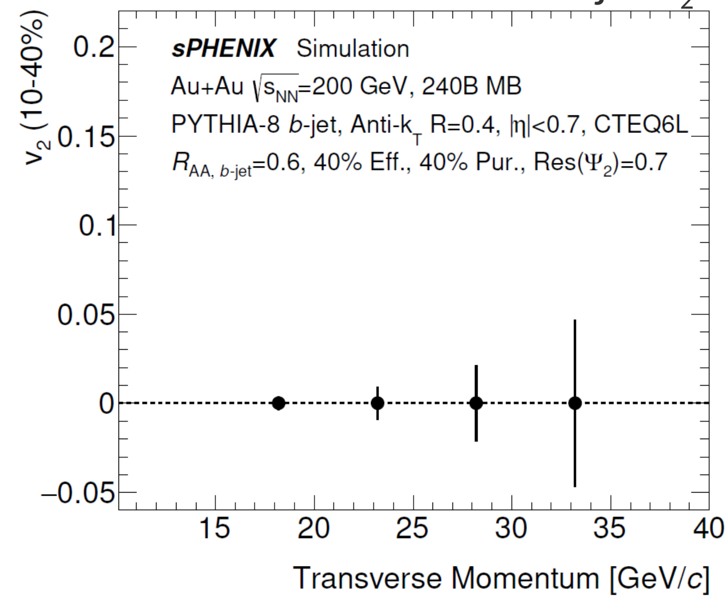
b-jet projection



Inclusive b-jet R_{AA}

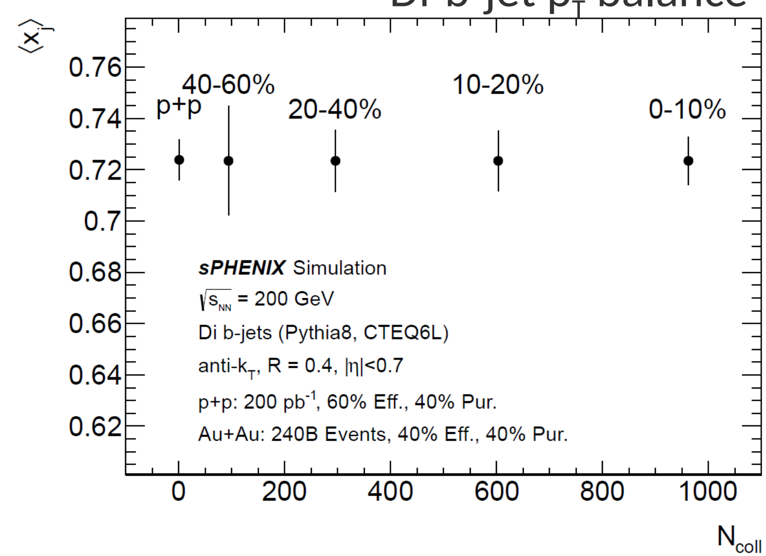


Inclusive b-jet v_2



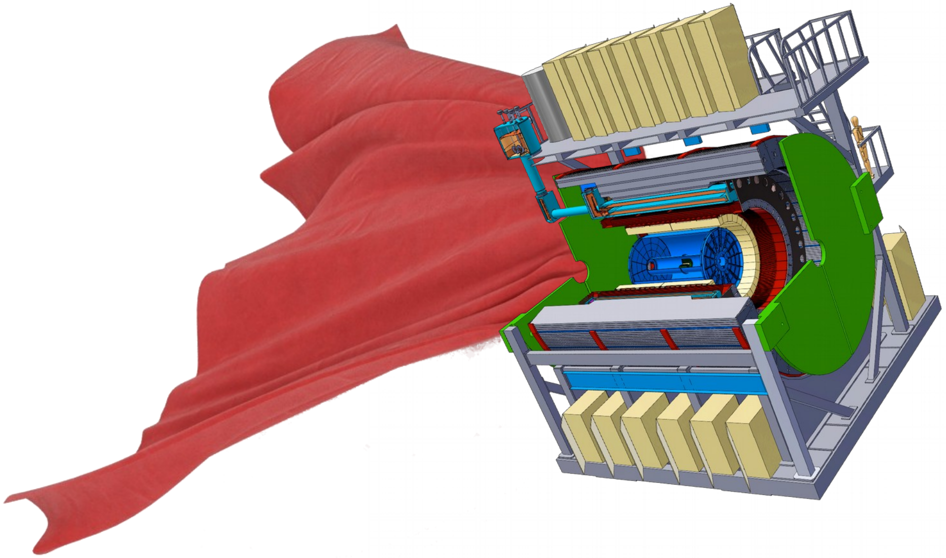
- Bring inclusive b-jet suppression and v_2 to RHIC
  - Covering jet p_T = 15-35 GeV/c
  - Strong constraints of high energy probe in QGP
- Broader opportunities on more differentiating observables
  - Di-*b*-jet and *b*-jet-*B*-meson correlations
  - *b*-jet substructures

Di-b-jet p_T balance

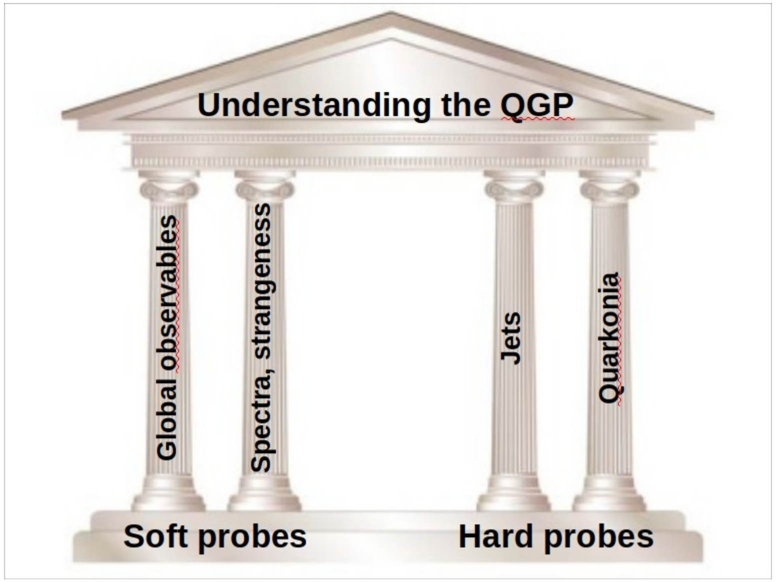


Summary

- Rich physics case
  - Precision jet and HF @ RHIC
  - Predictions on sPHENIX observables welcomed!
  - Completing scientific RHIC mission and connect to EIC



- Advanced design and many progress in detector R&D
  - CD-0 approved, in preparation for CD-1.
  - Data planned for 2023
- Growing collaboration
  - ~70 institutions with 9 new in the past year
  - Abundant opportunities to contribute



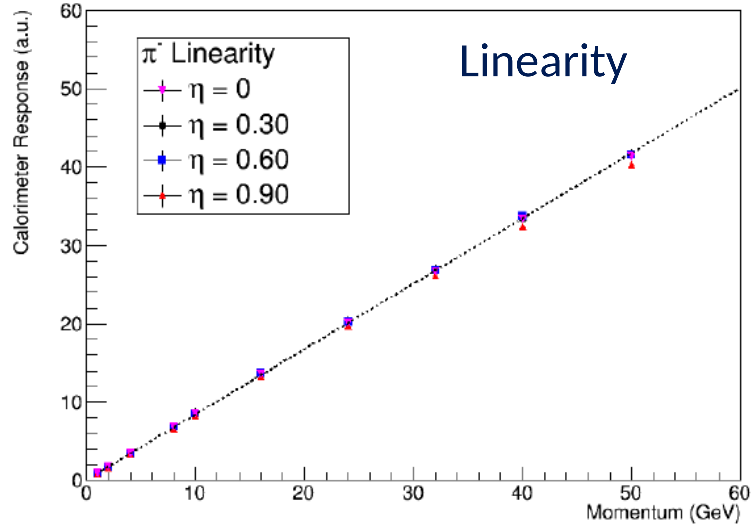
Welcoming more collaborators!

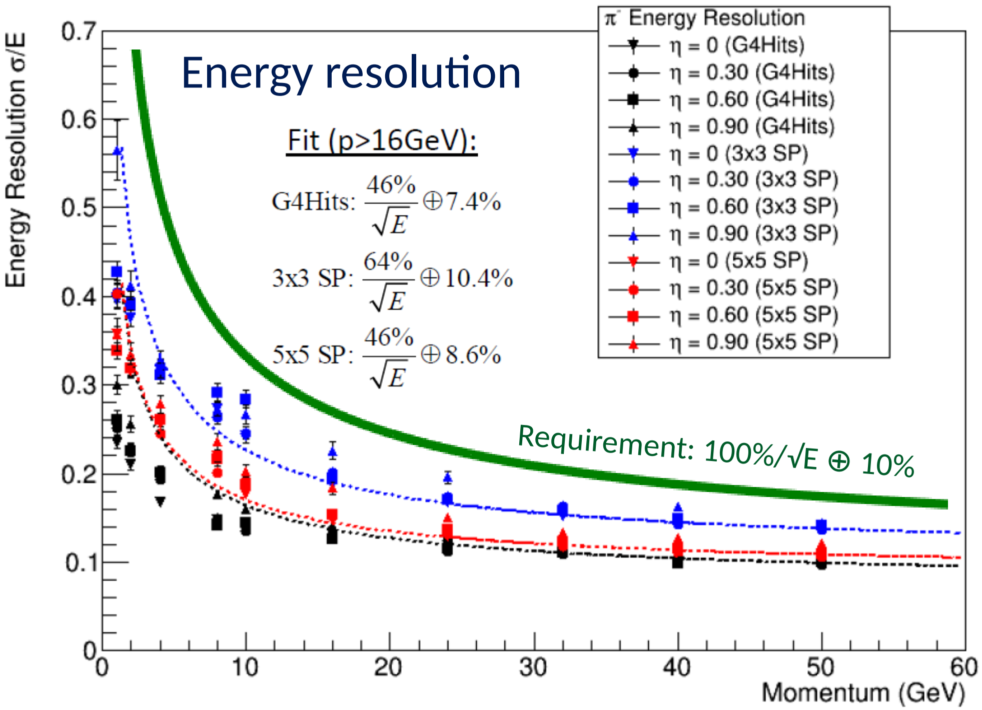
Established in Dec 2015
~70 institutions and growing

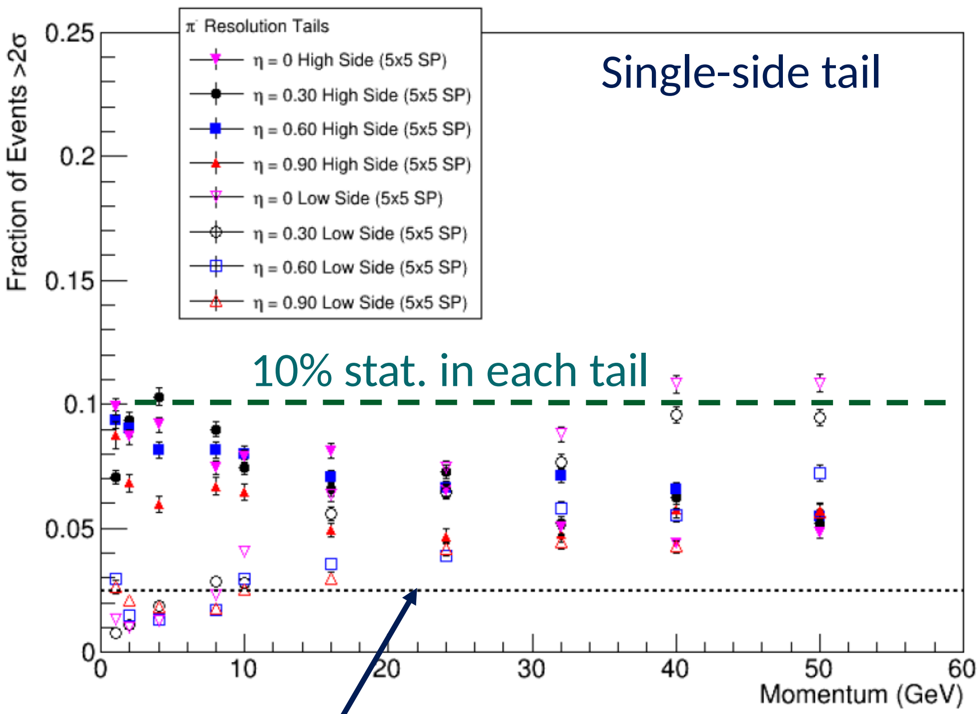
BACKUP

Performance : Single Hadron showers

- Single pion shower studied with clusters of digitized towers (3x3 and 5x5 clusters), which is compared with ideal sum of Geant4 hit in scintillator (label G4Hits)
- Energy resolution satisfied design goal.
  Tails <= 10%
- Refinement underway: time cut-off and light collection variations



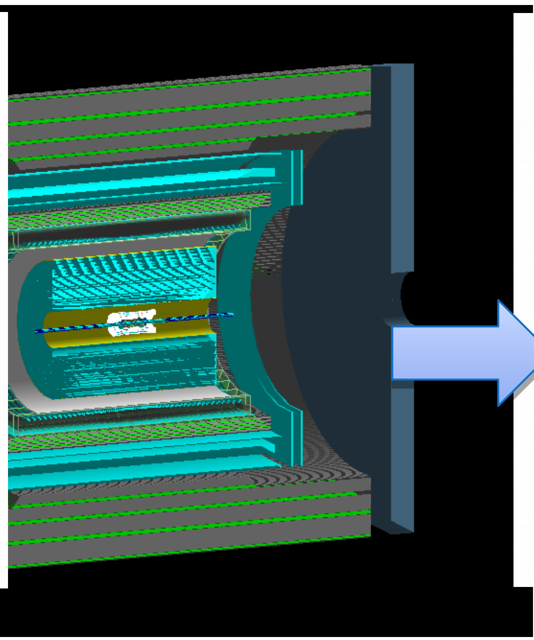


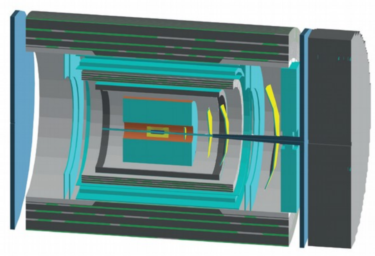


2.5% stat. in tails as expected from Gauss shape

Evolving upgrade concepts

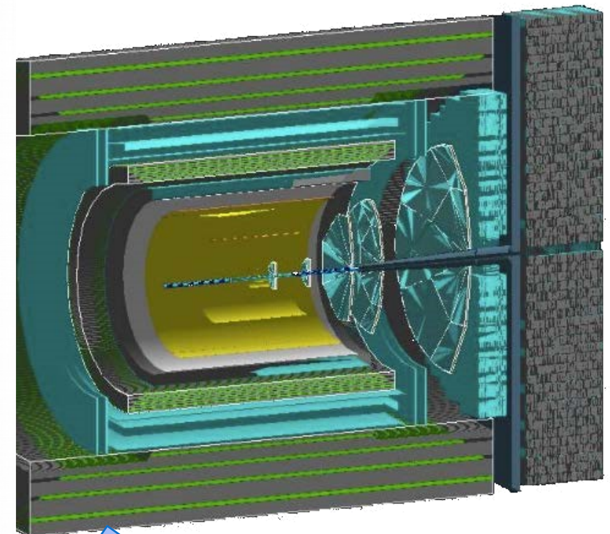
arXiv:1501.06197
CDR in preparation



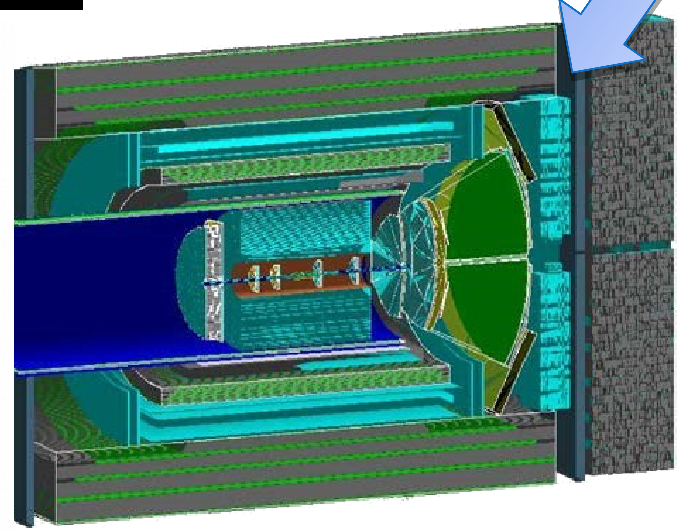

Letter of Intent for Forward Instrumentation at sPHENIX

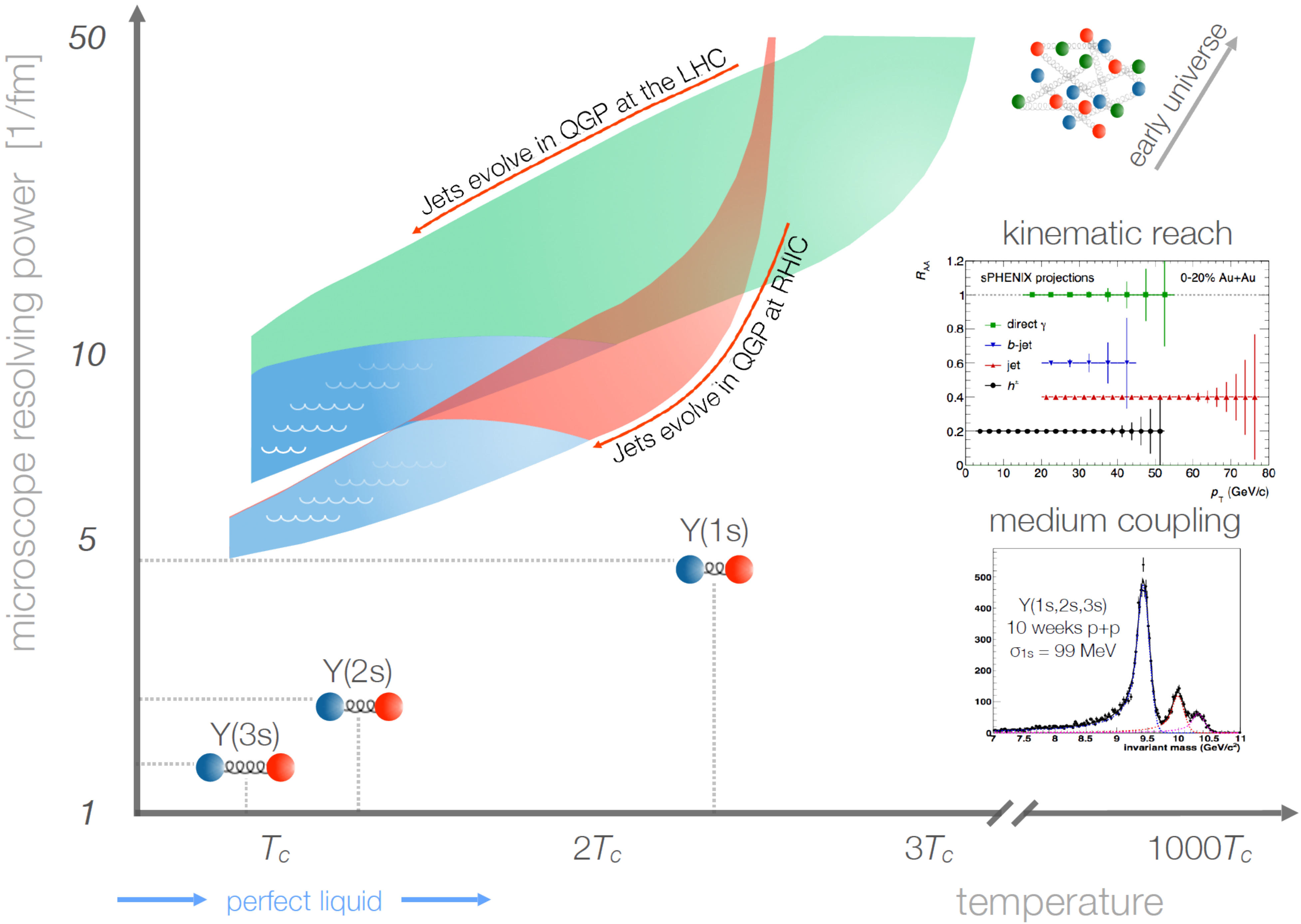
The sPHENIX Collaboration
June 1, 2017

To RHIC PAC 2017

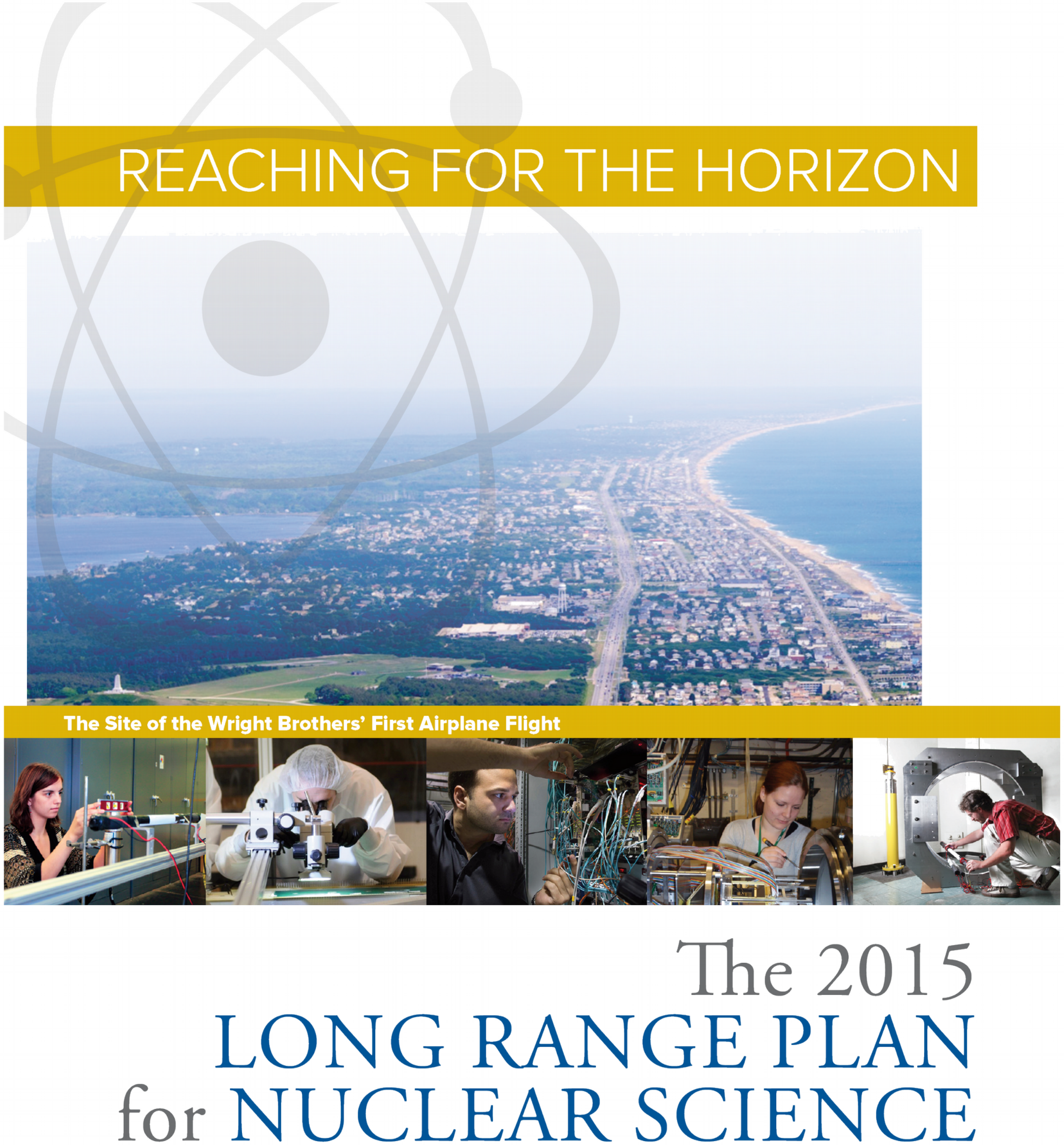


LOI/arXiv:1402.1209




microscope resolving power [1/fm]
50
10
5
1
Jets evolve in QGP at the LHC
Jets evolve in QGP at RHIC
early universe
kinematic reach
sPHENIX projections
0-20% Au+Au
R_{AA}
direct γ
b-jet
jet
$h^{\pm}$
p_T (GeV/c)
medium coupling
Υ(1s,2s,3s)
10 weeks p+p
σ_{1s} = 99 MeV
invariant mass (GeV/c²)
Υ(1s)
Υ(2s)
Υ(3s)
T_c
$2T_c$
$3T_c$
$1000T_c$
perfect liquid
temperature

Meeting the grand challenge



"To understand the workings of the QGP, there is no substitute for microscopy. We know that if we had a sufficiently powerful microscope that could resolve the structure of QGP on length scales, say a thousand times smaller than the size of a proton, what we would see are quarks and gluons interacting only weakly with each other. **The grand challenge for this field in the decade to come is to understand how these quarks and gluons conspire to form a nearly perfect liquid."**