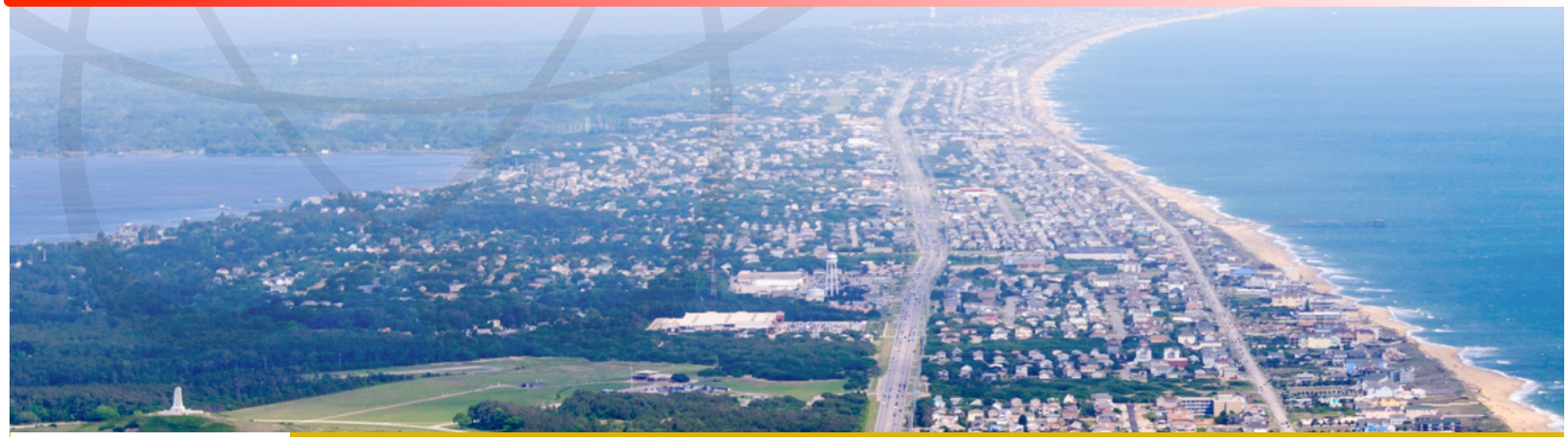
PHENIX

REACHING FOR THE HORIZON

Fulfilling RHIC's Scientific Mission with sPHENIX



Georgia State University

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RIKEN BNL Research Center

WWND 2016

Nuclear Science Long Range Plan Recommendations

RECOMMENDATION I

The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in this 2015 Plan is to capitalize on the investments made.

- *With the imminent completion of the CEBAF 12-GeV Upgrade, its forefront program of using electrons to unfold the quark and gluon structure of hadrons and nuclei and to probe the Standard Model must be realized.*
- *Expeditiously completing the Facility for Rare Isotope Beams (FRIB) construction is essential. Initiating its scientific program will revolutionize our understanding of nuclei and their role in the cosmos.*
- *The targeted program of fundamental symmetries and neutrino research that opens new doors to physics beyond the Standard Model must be sustained.*
- *The upgraded RHIC facility provides unique capabilities that must be utilized to explore the properties and phases of quark and gluon matter in the high temperatures of the early universe and to explore the spin structure of the proton.*

- RHIC:

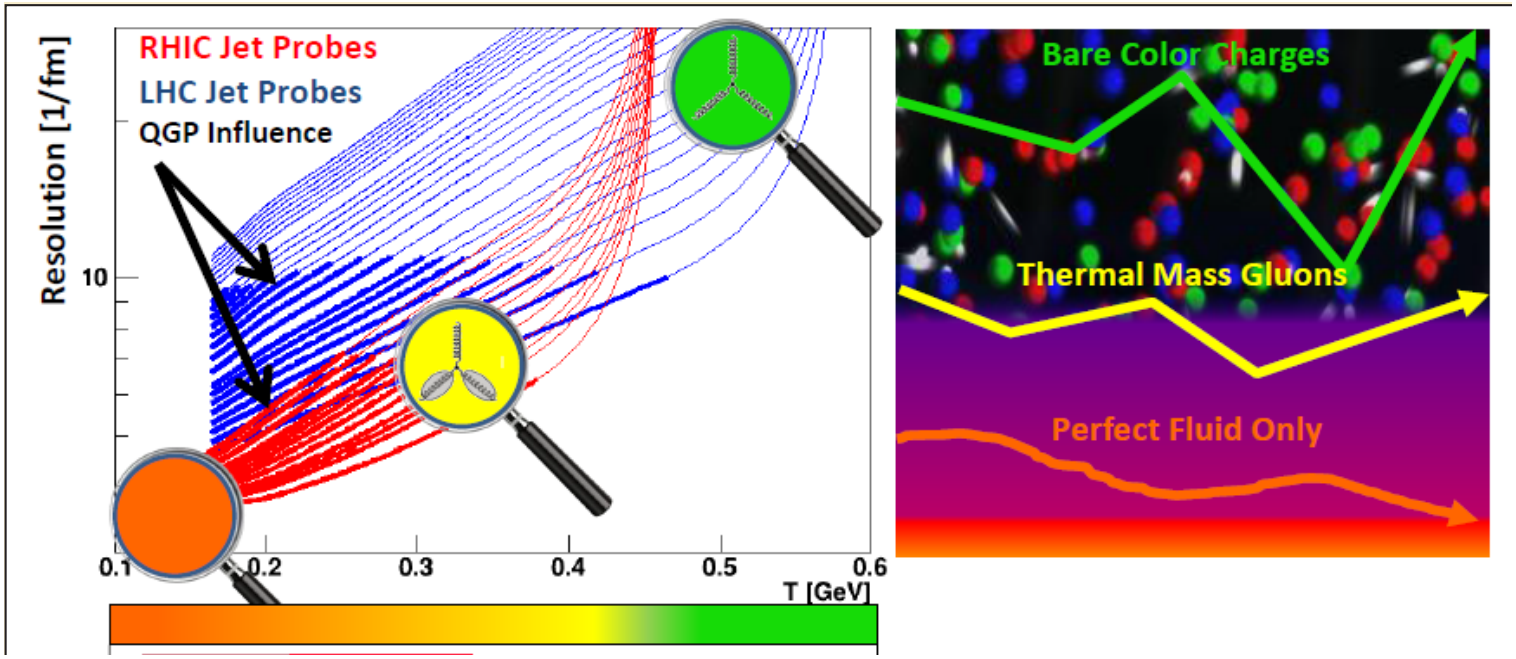
There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

…

New instrumentation at RHIC in the form of a state-of-the-art jet detector (referred to as sPHENIX) is required to provide the highest statistics for imaging the QGP right in the region of strongest coupling (most perfect fluidity) while also extending the kinematic reach at RHIC (as illustrated in Figure 2.13) to overlap that for jets at LHC energies. Upgrades to the LHC luminosities and detector and measurement capabilities are keys to providing a complete picture, as are new experimental techniques being developed to compare how light quark jets, heavy quark jets, and gluon jets “see” QGP.

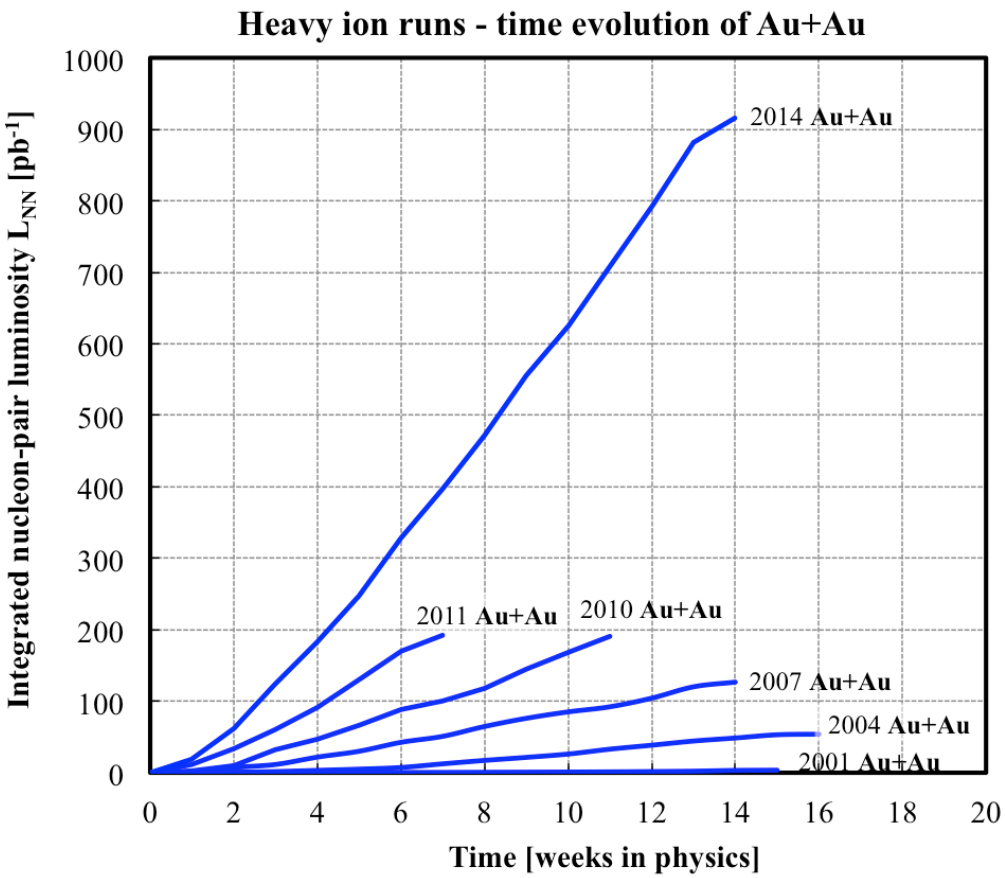
"Shorter and shorter length scales"

- Jet probes at RHIC energy spend more time in the QGP and have finer resolution



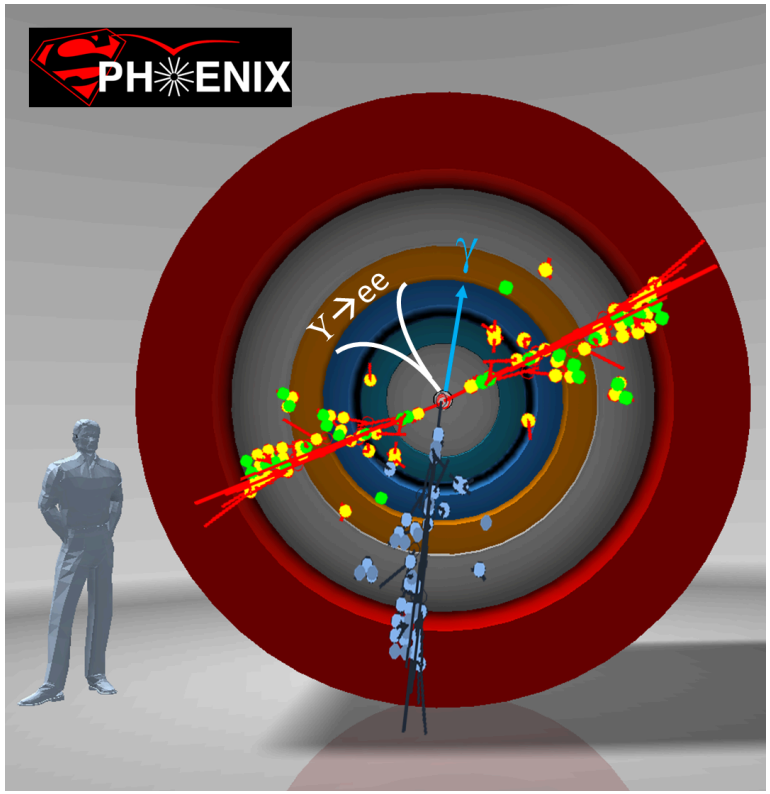
"Investments Made"

- Capitalize on 15+ years of accelerator developments at RHIC with a new detector to fully utilize the luminosity



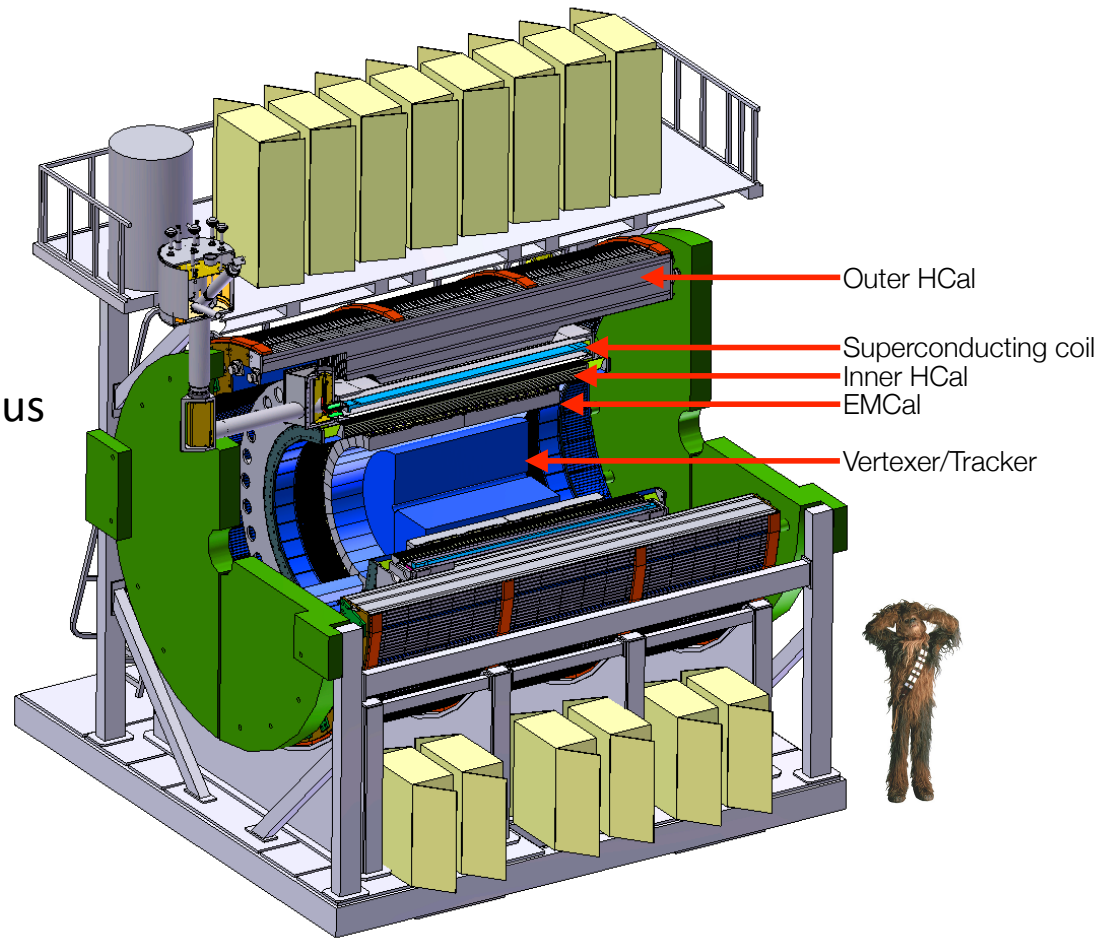
"State of the art jet detector"

- Uniform acceptance $-1<\eta<1$ and $0<\phi<2\pi$
- Superconducting solenoid enabling high resolution tracking
- Hadronic & electromagnetic calorimeter
- Solid state photodetectors
  - work in a magnetic field
  - have low cost
  - do not require high voltage
- Common calorimeter readout electronics
- 15 kHz recorded in AA allows for large unbiased MB data sample
- Utilization of infrastructure in an existing experimental hall



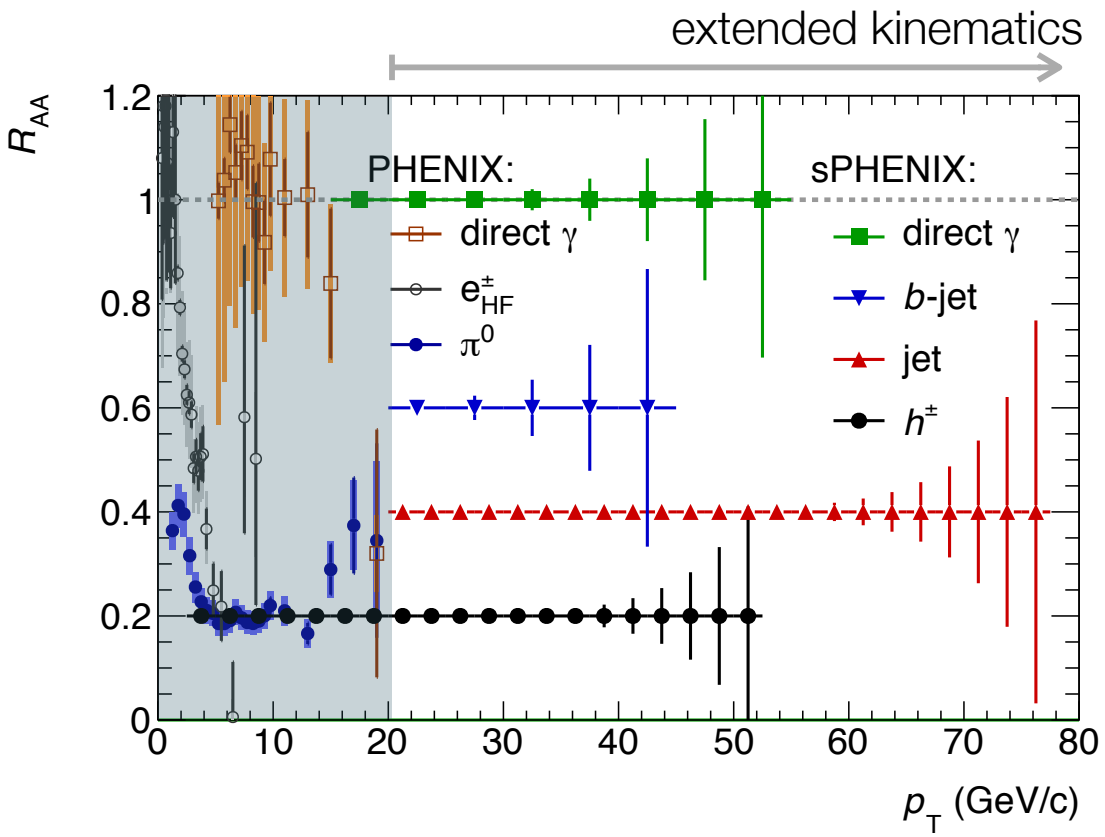
sPHENIX Detector Design

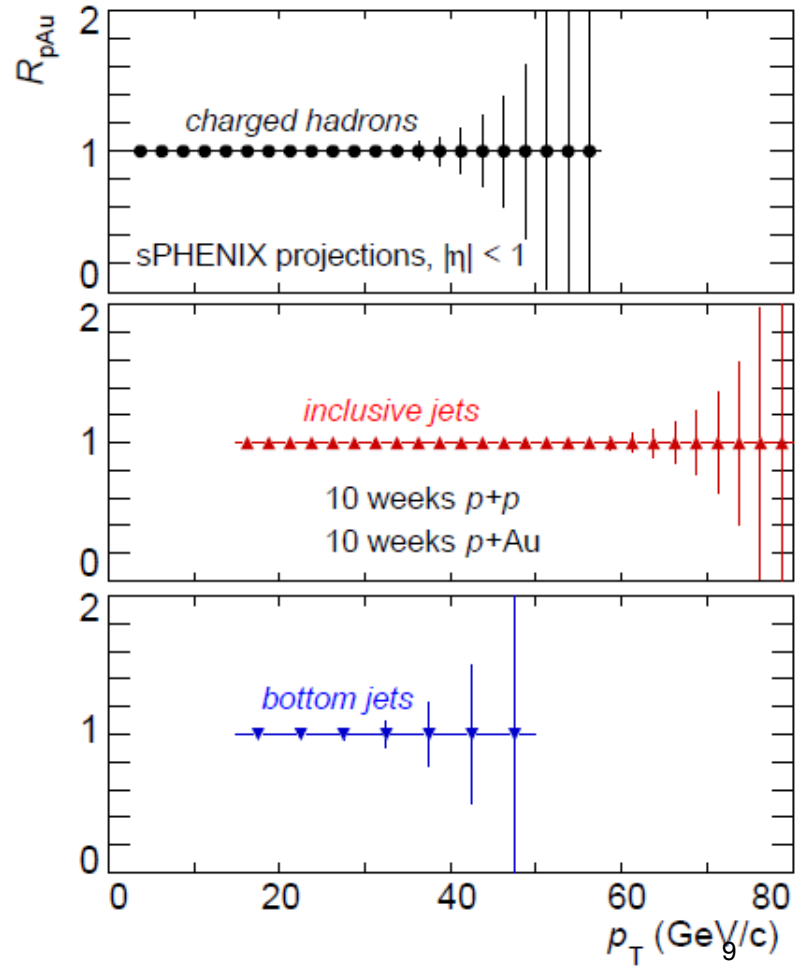
- Uniform acceptance
  - $-1<\eta<1$ and $0<\phi<2\pi$
- Superconducting solenoid
- Hadronic calorimeter doubles as flux return
- Compact electromagnetic calorimeter
  - fine segmentation at a small radius
- Solid state photodetectors
  - work in a magnetic field
  - have low cost
  - do not require high voltage
- Common calorimeter readout electronics
- 15 kHz recorded in AA allows for large unbiased MB data sample
- Utilization of infrastructure in an existing PHENIX experimental hall



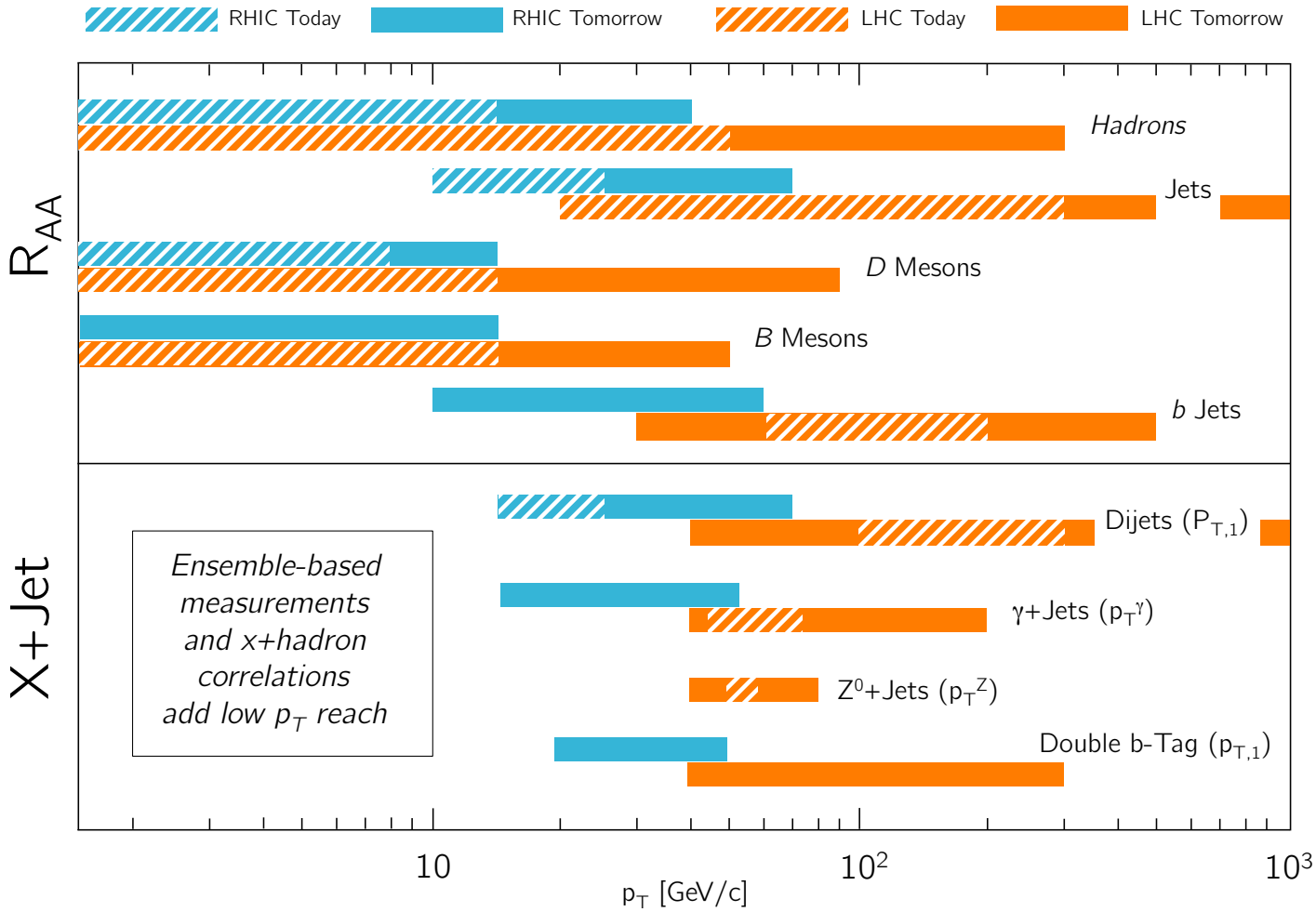
"Extending the kinematic reach"

- R_{AA} for photons, HF and jets extended to higher p_T





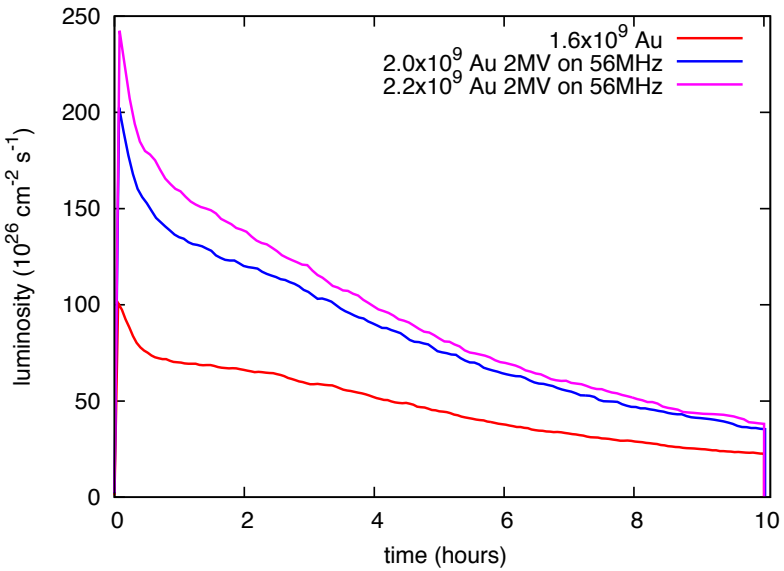
"Overlap with LHC"

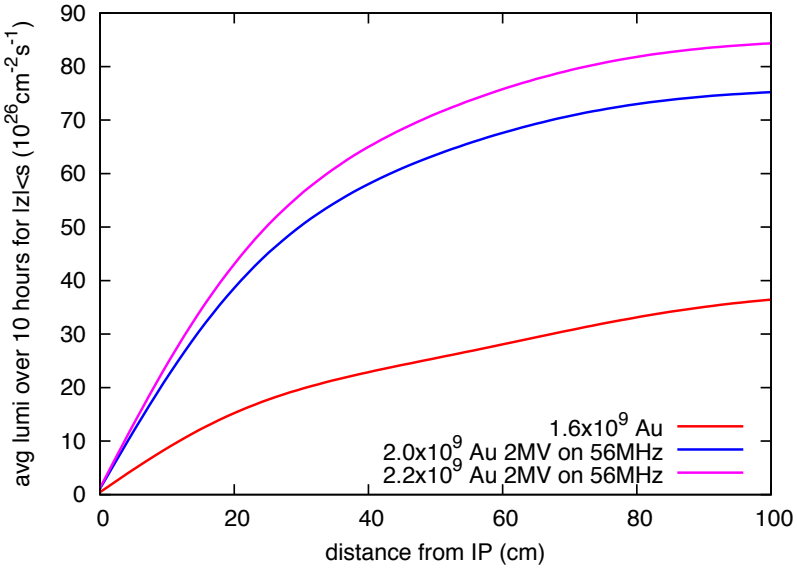


- Significant overlap achievable with next generation of RHIC-LHC jet measurements

"High Statistics"

Au+Au luminosity projections from BNL Collider-Accelerator Department
(2.5x RHIC Run-14 in |z| < 10 cm vertex cut)

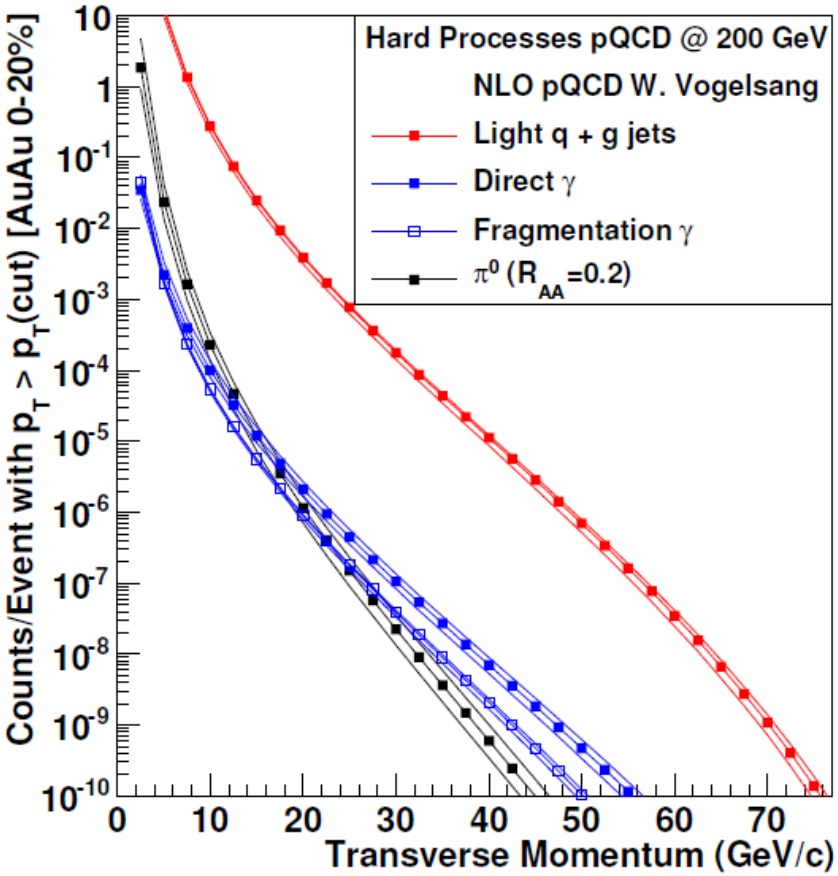




- In nominal one-year Au+Au run will be able to record 100 billion Au+Au minimum bias events (z<10cm)
- Rare triggers with the calorimeters expect to sample 0.6 trillion events
- PHENIX DAQ tested to 15 kHz

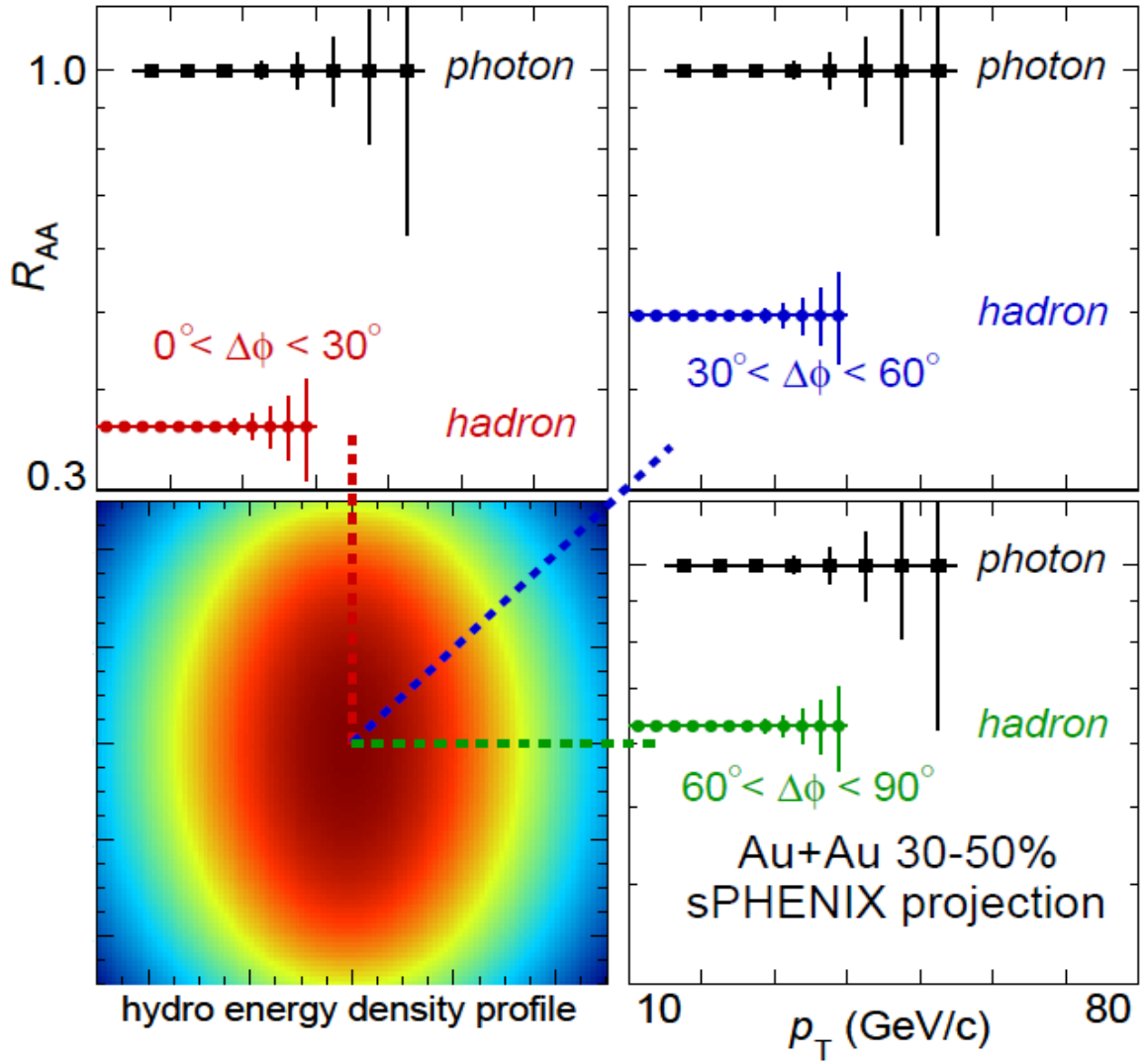
"High Statistics"

- High Statistics Jet measurements
  - 10^7 jets above 20 GeV
  - 10^6 jets above 30 GeV
  - 10^4 direct photons above 20 GeV
- Large statistics for
  - γ+jet
  - b-tagged jets
  - And more



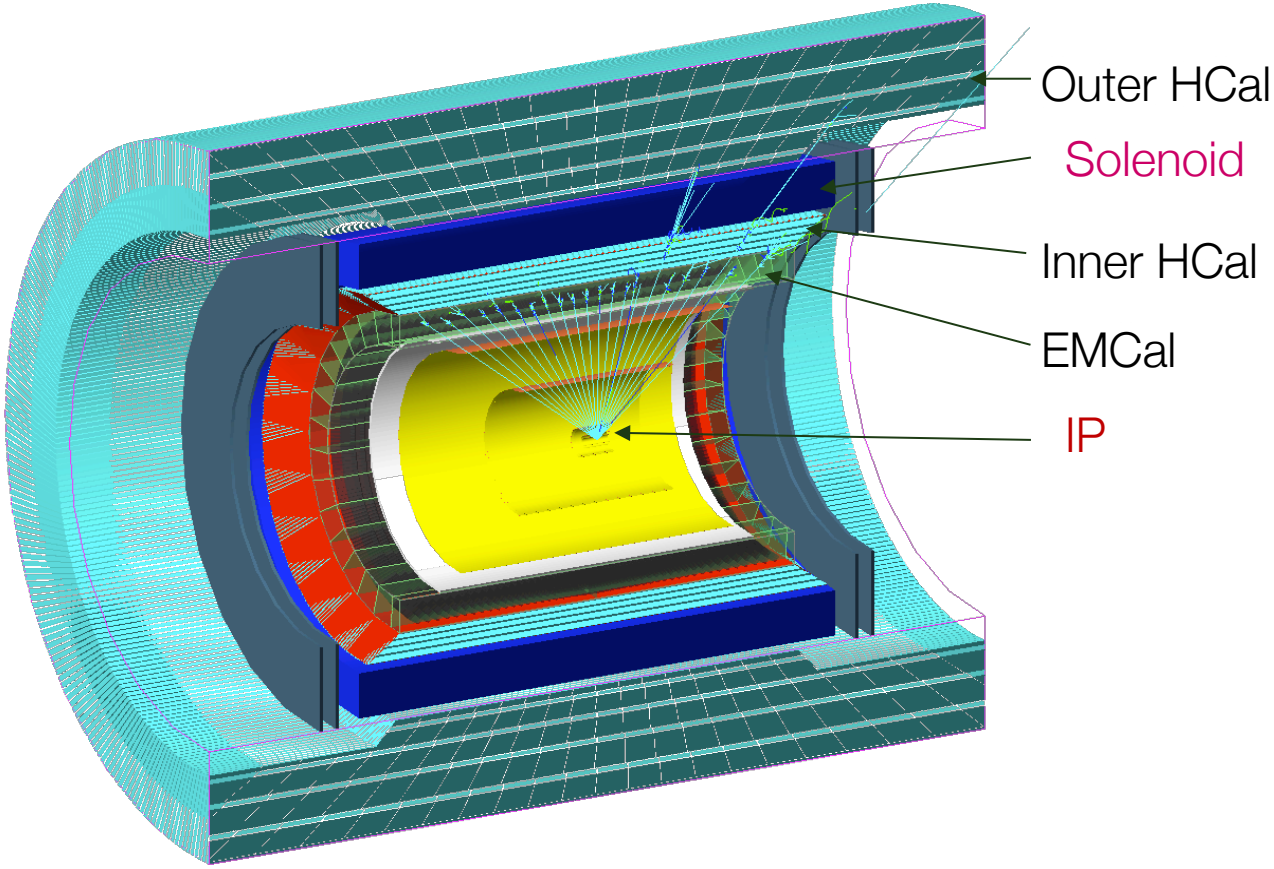
More Statistics = More Differential

- Pathlength studies
- Important constraints for models that describe inclusive R_{AA}



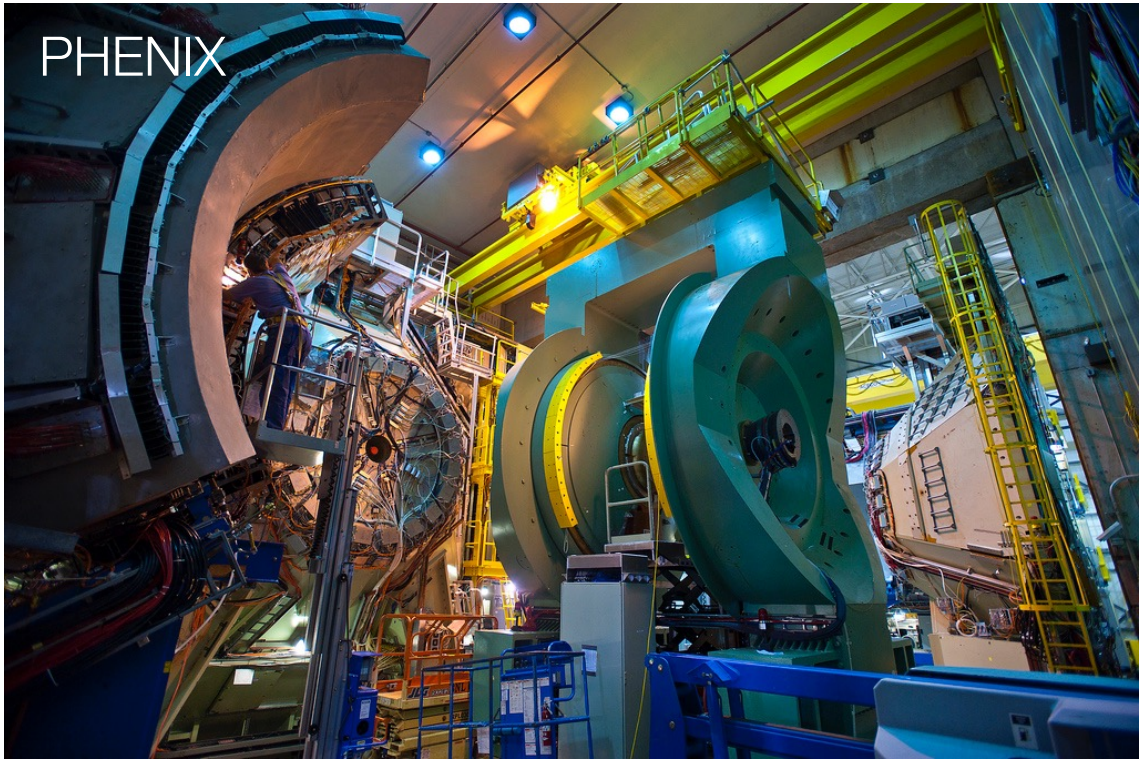
sPHENIX in GEANT World

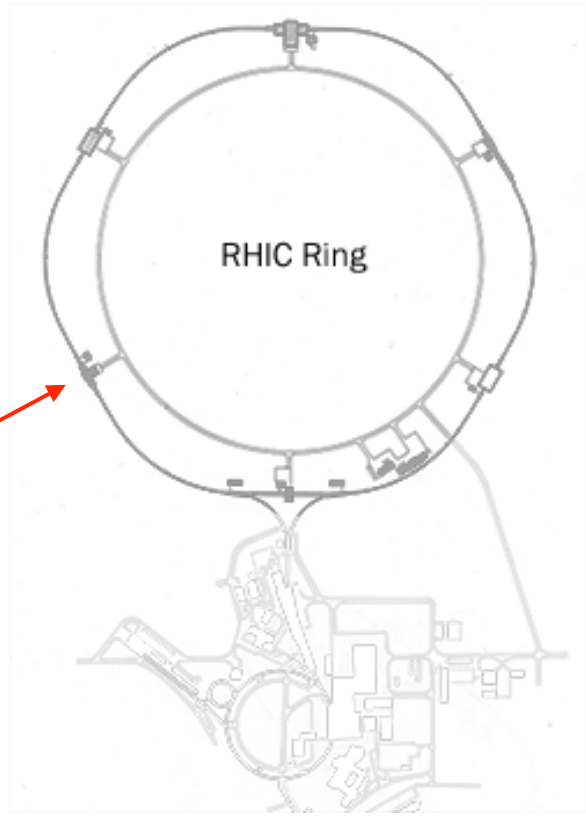
- Plots created with full GEANT4 simulation
- Calorimeter system shown here



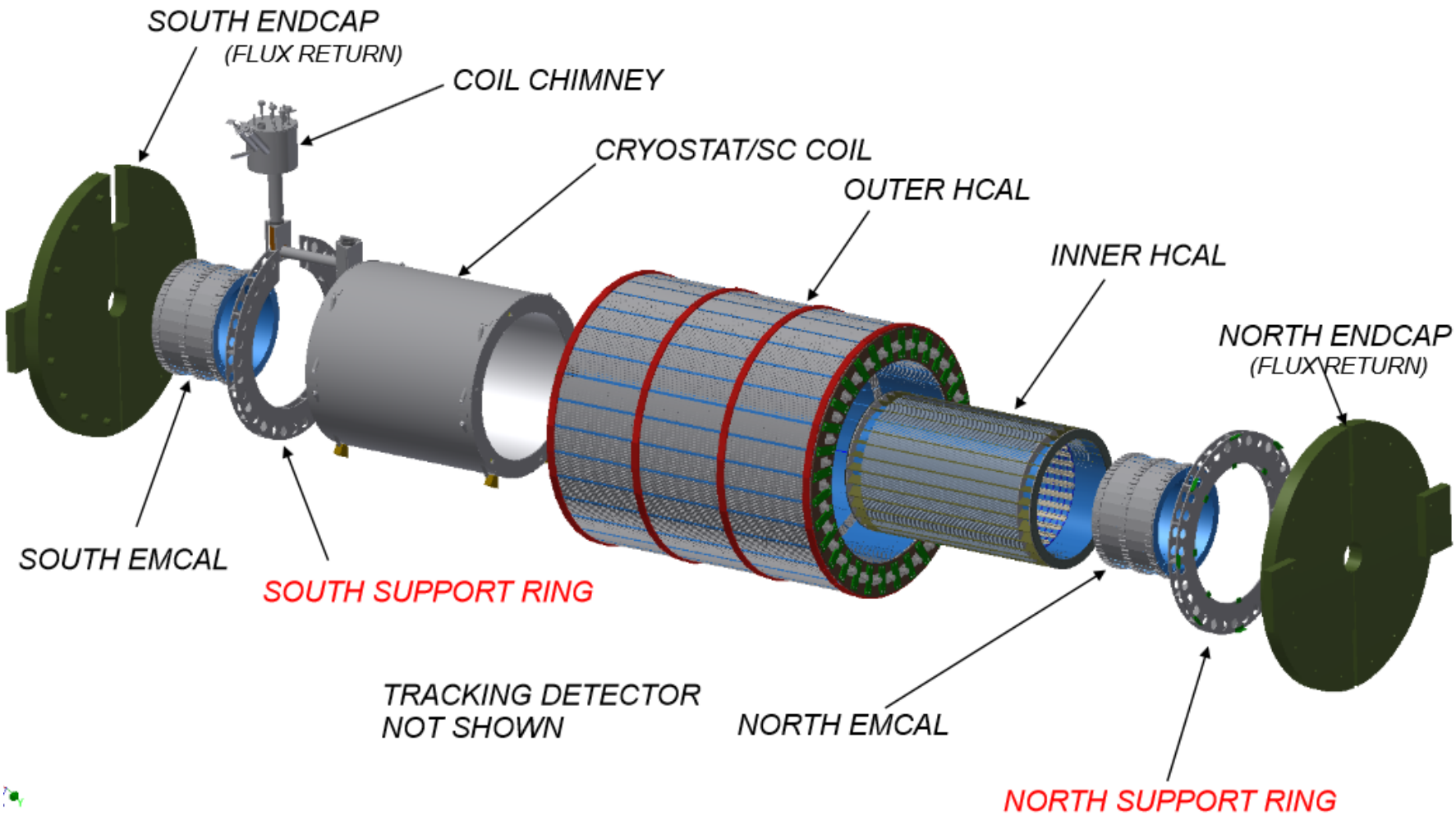
Where's it going to go?

- Run 16 200 GeV Au+Au and d+Au beam energy scan = Last year of PHENIX data taking





Putting it all together

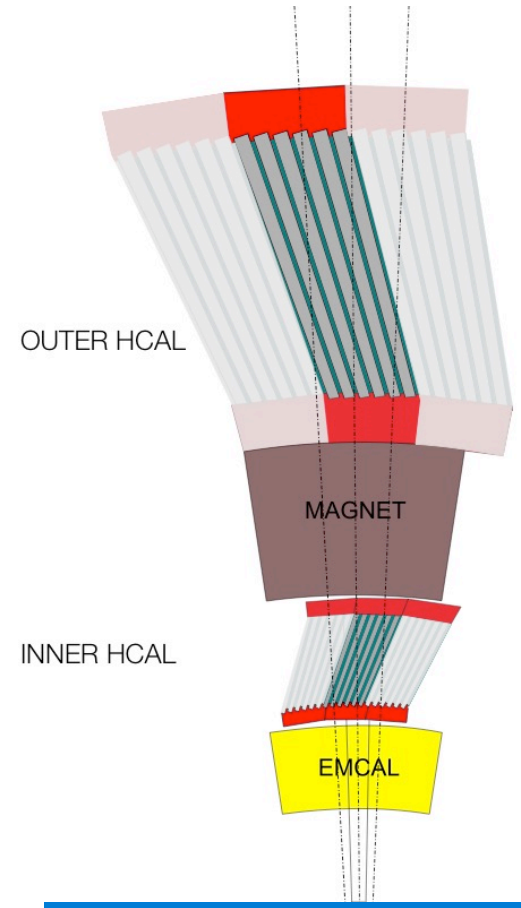


Magnet

- BaBar magnet fulfills our needs
  - 1.5 T central field
  - 2.8 m diameter
  - 3.8 m long
- ~ 1 year ago arrived at BNL
- Low power cold testing underway

Calorimeters reference design

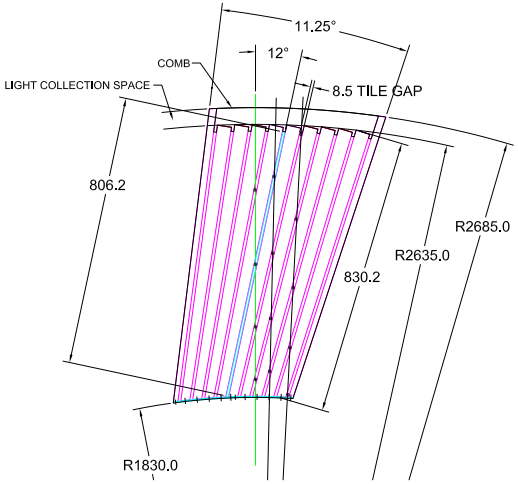
- EMCAL Tungsten-scintillating fiber
  - $\Delta\eta \times \Delta\phi \approx 0.025 \times 0.025$
  - 96 x 256 readout channels
  - EMCal $\sigma_E/E < 15\%/\sqrt{E}$ (single particle)
- HCAL steel and scintillating tiles with wavelength shifting fiber
  - 2 longitudinal segments.
  - An Inner HCal inside the solenoid.
  - An Outer HCal outside the solenoid.
  - $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$
  - 2 x 24 x 64 readout channels
  - HCal $\sigma_E/E < 100\%/\sqrt{E}$ (single particle)
- Readout with solid state photodetectors (silicon photomultipliers)
- Beam Tests
  - Feb 2014: earlier design
  - April 2016



- Outer HCAL $\approx 3.5\lambda_I$
- Magnet $\approx 1.4X_0$
- Inner HCAL $\approx 1\lambda_I$
- EMCAL $\approx 18X_0 \approx 1\lambda_I$

Outer HCal

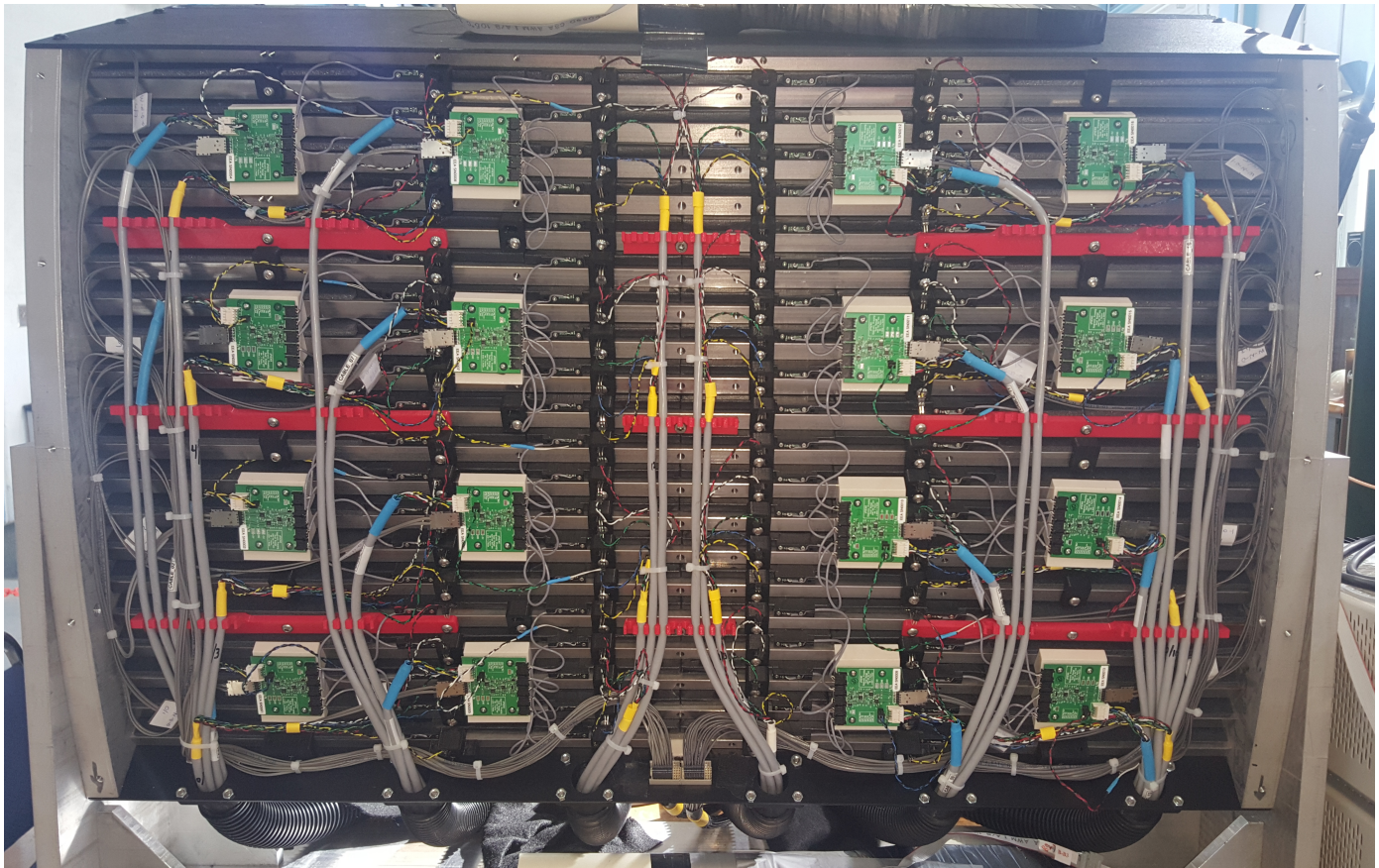
- 7 mm polystyrene with embedded 1 mm WLS fiber ala T2K
- Five tiles each with an SiPM ganged together in Φ to create a tower readout



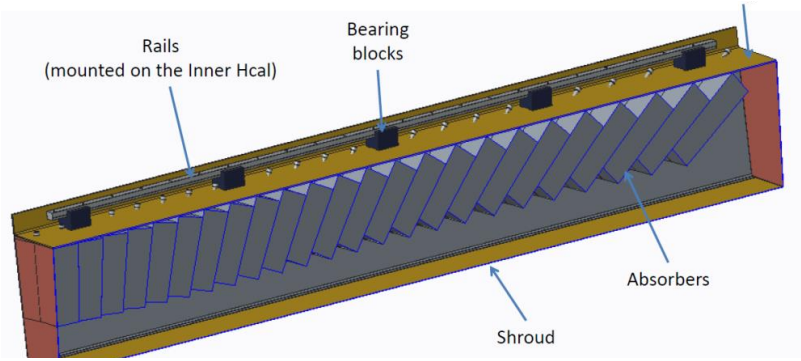
- Prototype for April

Inner HCal

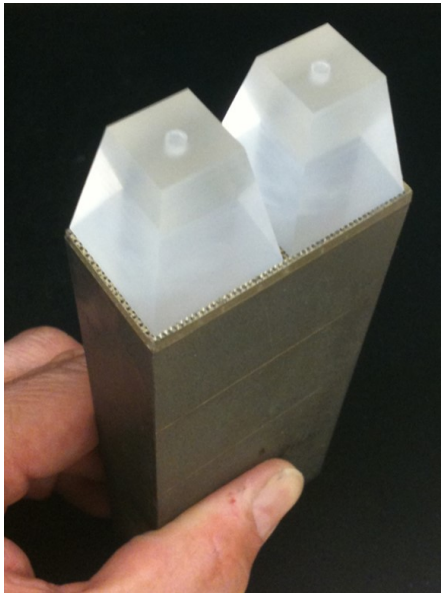
- Prototype fully assembled for April Test Beam
- Testing with Cosmics and LEDs

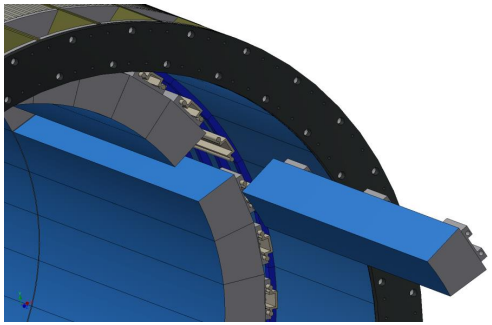


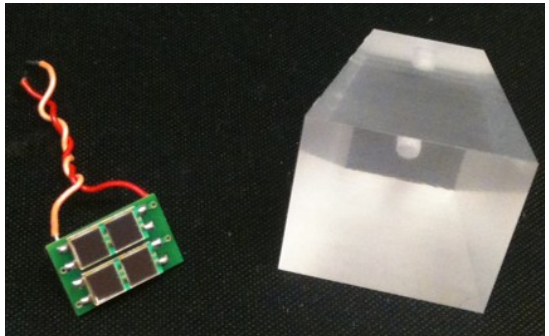
EMCal

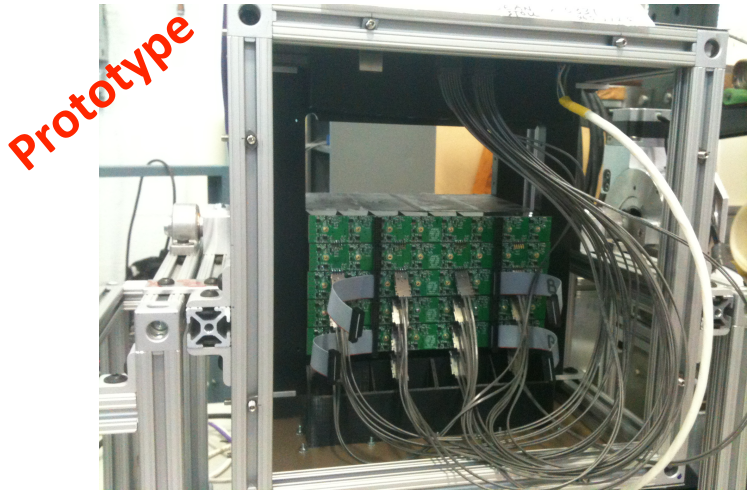


- Fibers threaded through screens
- Filled with Tungsten powder and epoxy
- Attach light guide
- Moliere radius ~2.3 cm
- 1D and 2D Projective modules being explored

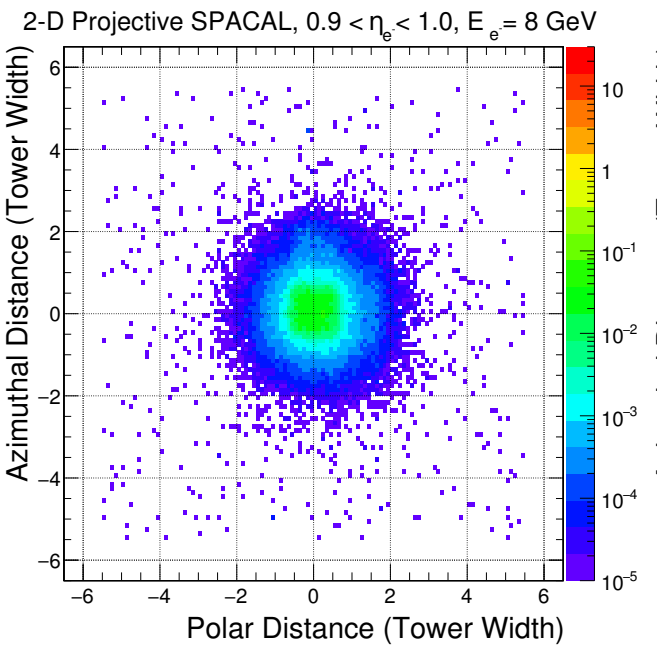




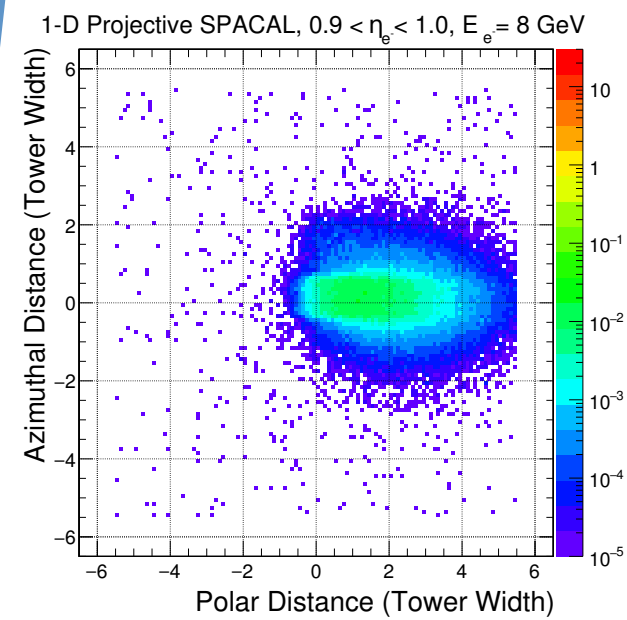


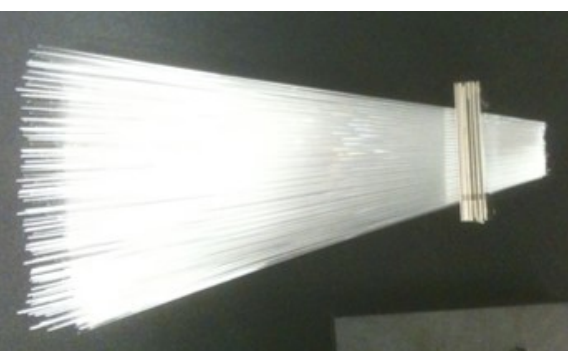


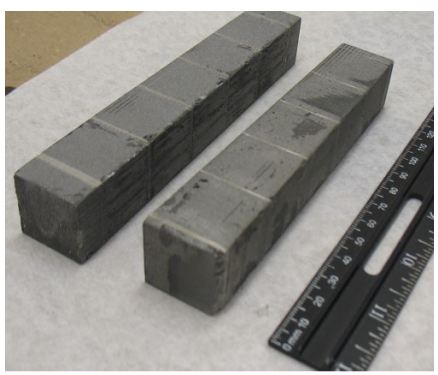
EMCal 1D vs 2D projective Modules

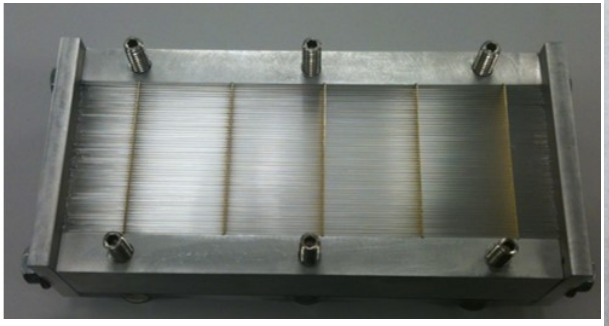


- 2D Projective improves e/π separation
- 1D Production process more established









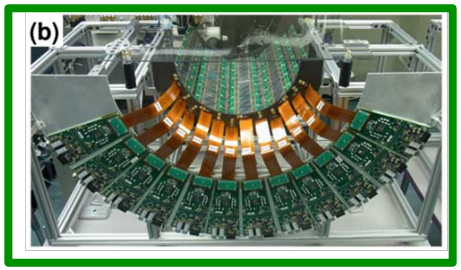
Excellent Tracker Required

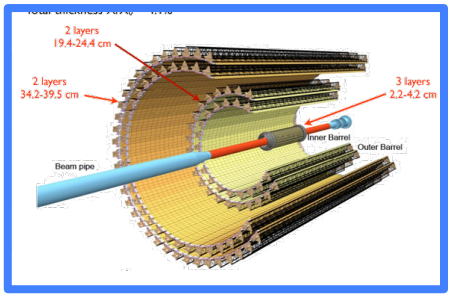
Physics Goal	Detector Requirement
Fragmentation Functions	Excellent Momentum Resolution: dp/p ~ 0.2%p to > 40 GeV/c
Jet Substructure	Excellent track pattern recognition
Distinguish Upsilon States	Mass resolution: $\sigma_M < 100$ MeV/c^2
HF jet tagging	Precise DCA resolution $\sigma_{DCA} < 100$ µm
High Statistics Au+Au 200 GeV	Handle multiplicity and full RHIC luminosity

- Detector options for the inner and outer technologies are being explored
  - Full simulations underway to evaluate physics performance of each
  - Evaluation of the needed and available resources

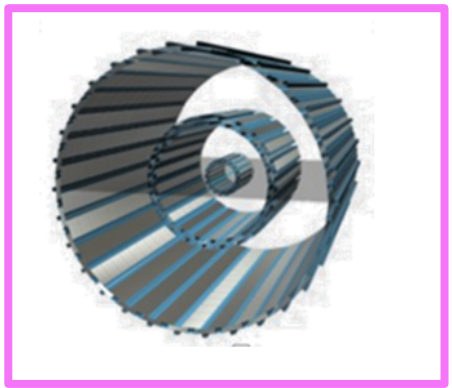
Tracking options

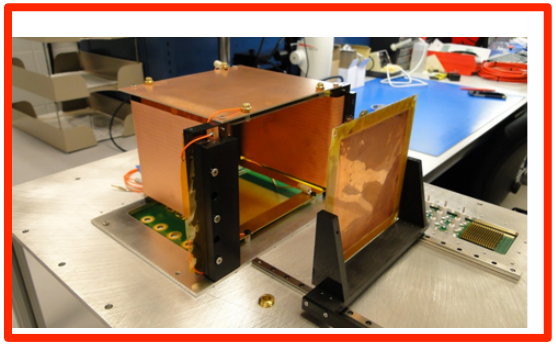
- Inner Tracker
  - Reuse PHENIX VTX Components
  - MAPS (ALICE ITS Upgrade)





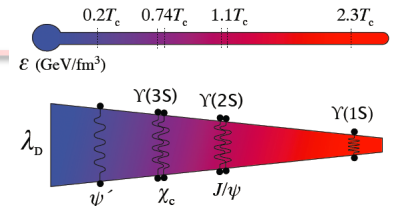
- Outer tracker
  - New (PHENIX like) Silicon Components
  - Compact TPC w/GEM readout (ALICE Upgrade)

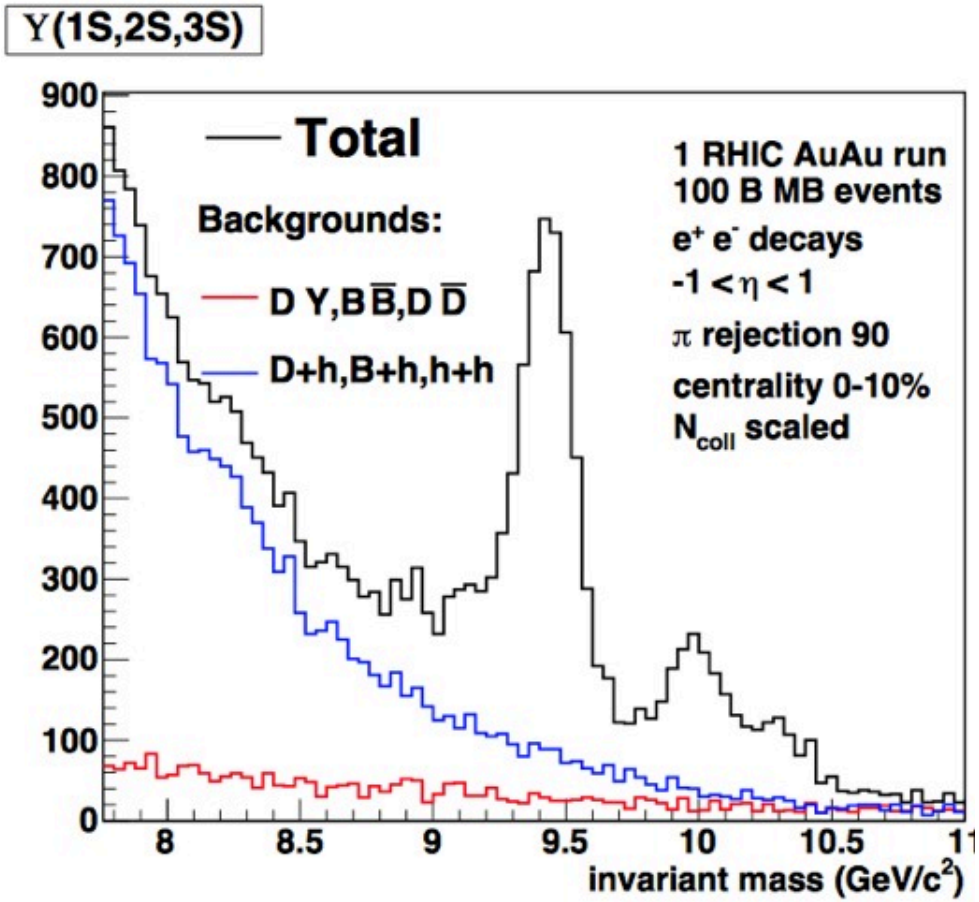


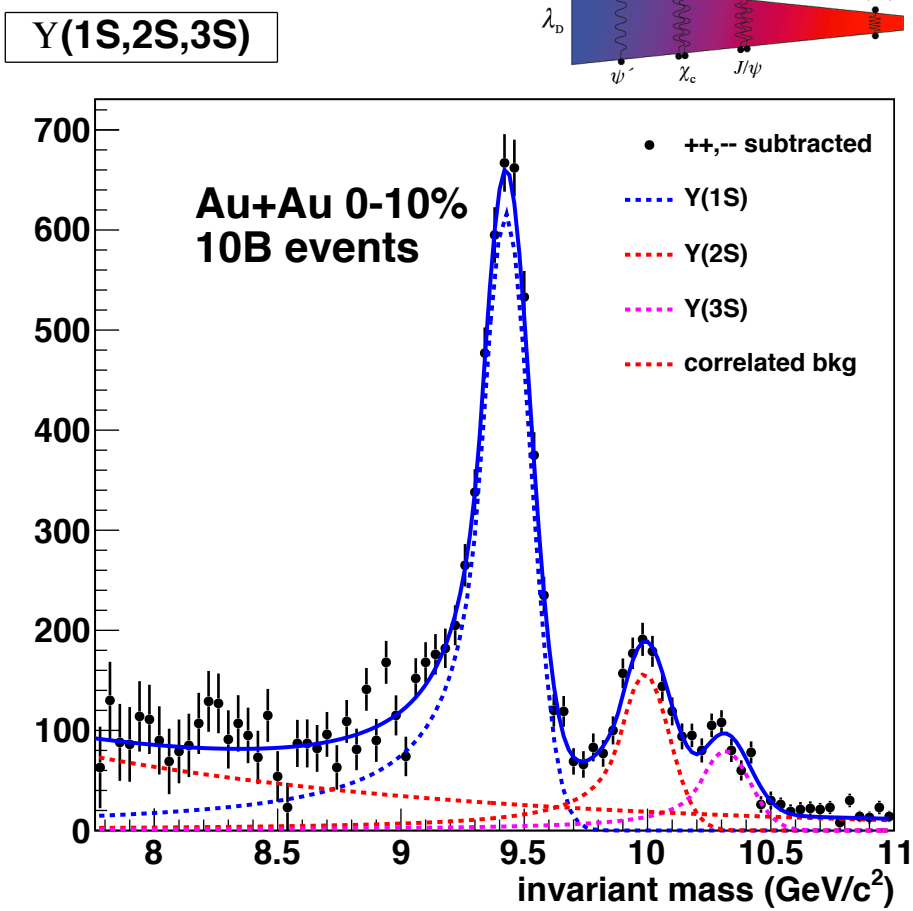


- Reference design is 7 layers of silicon
- Final decision after all options are fully evaluated

Upsilon performance in Au+Au

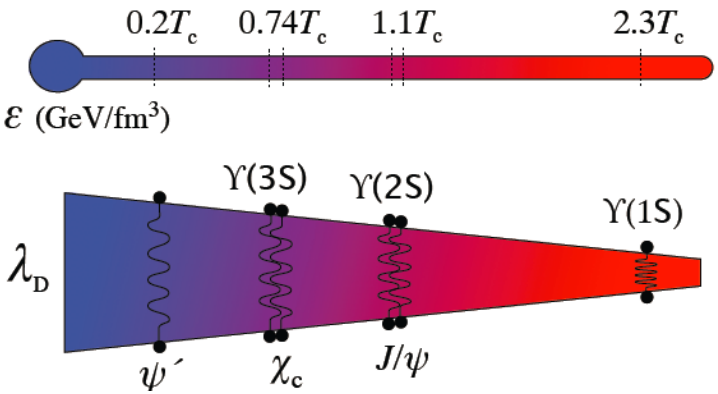




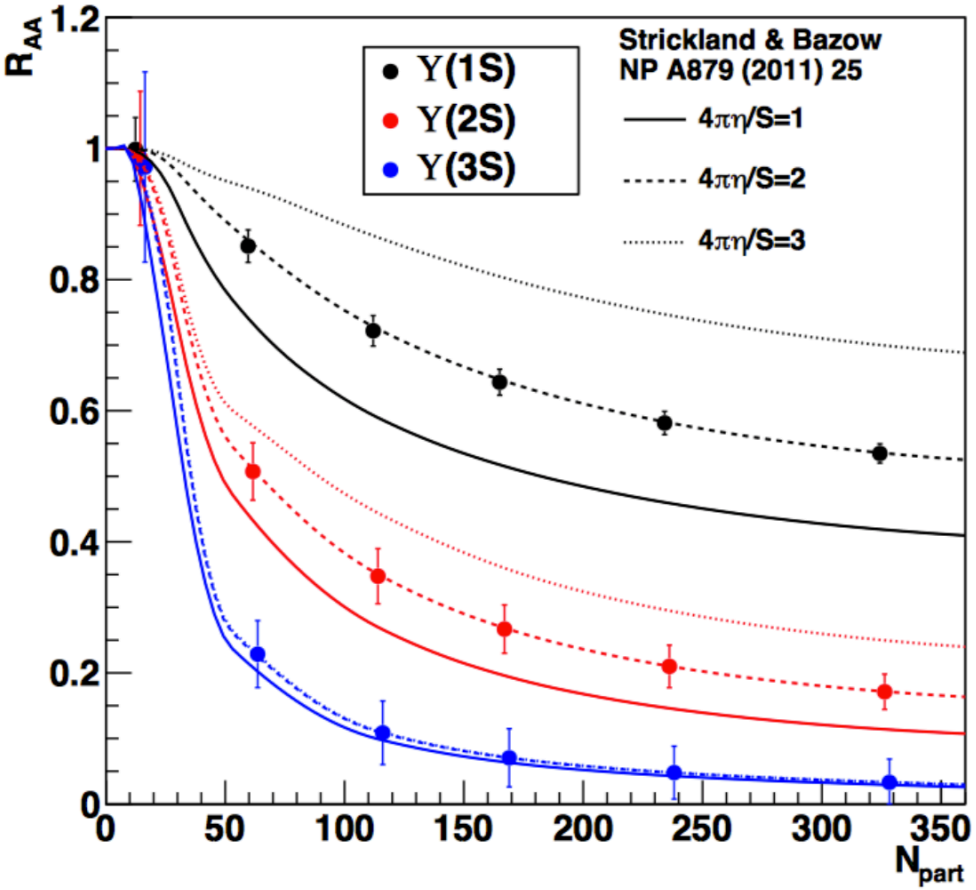


- PYTHIA normalized to PHENIX measured b and c cross-sections
- Combinatorial background removed with like sign or mixed events

Nuclear modification projections for Upsilons



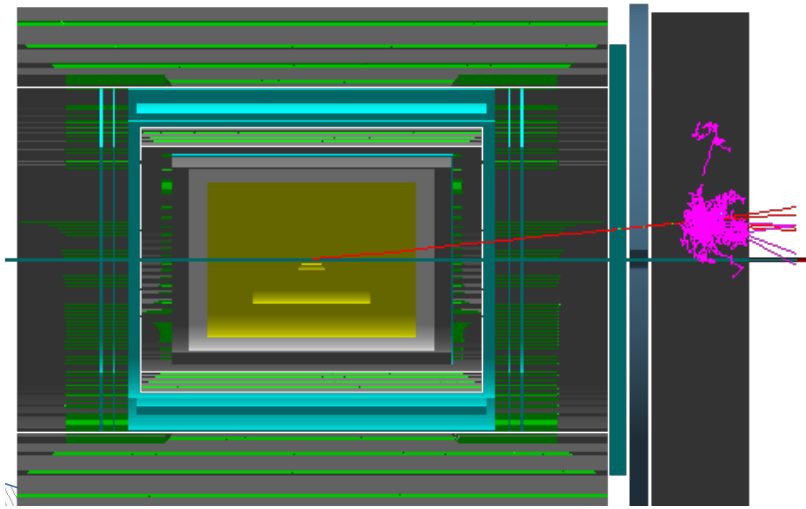
- With
  - 10 weeks p+p
  - 22 weeks Au+Au
- Yield and S/B scaled to match model suppression



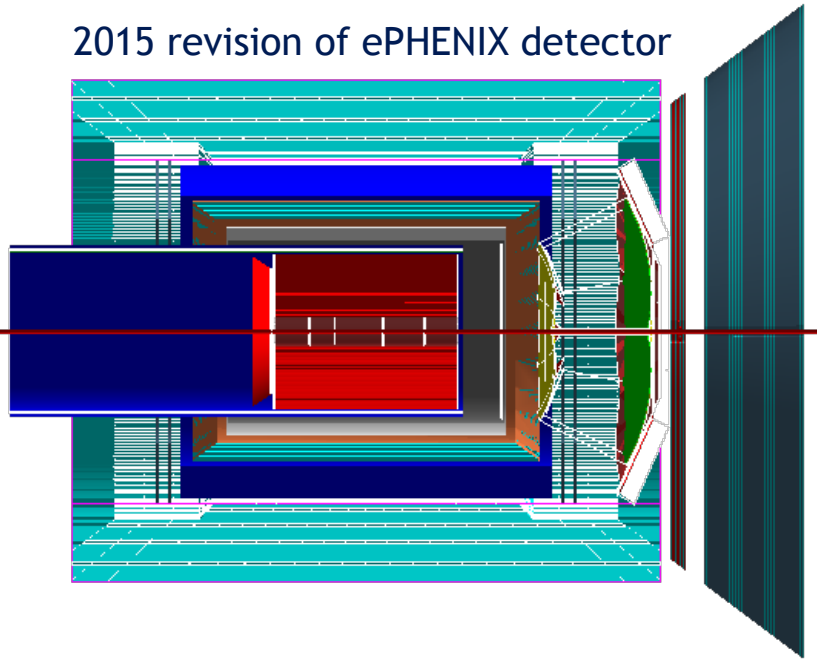
Looking Forward

- Toward future EIC
- Forward calorimeter simulations in same sPHENIX framework
- Regular fsPHENIX/EIC meetings ongoing

30 GeV/c pion shower in forward EMCal + HCal



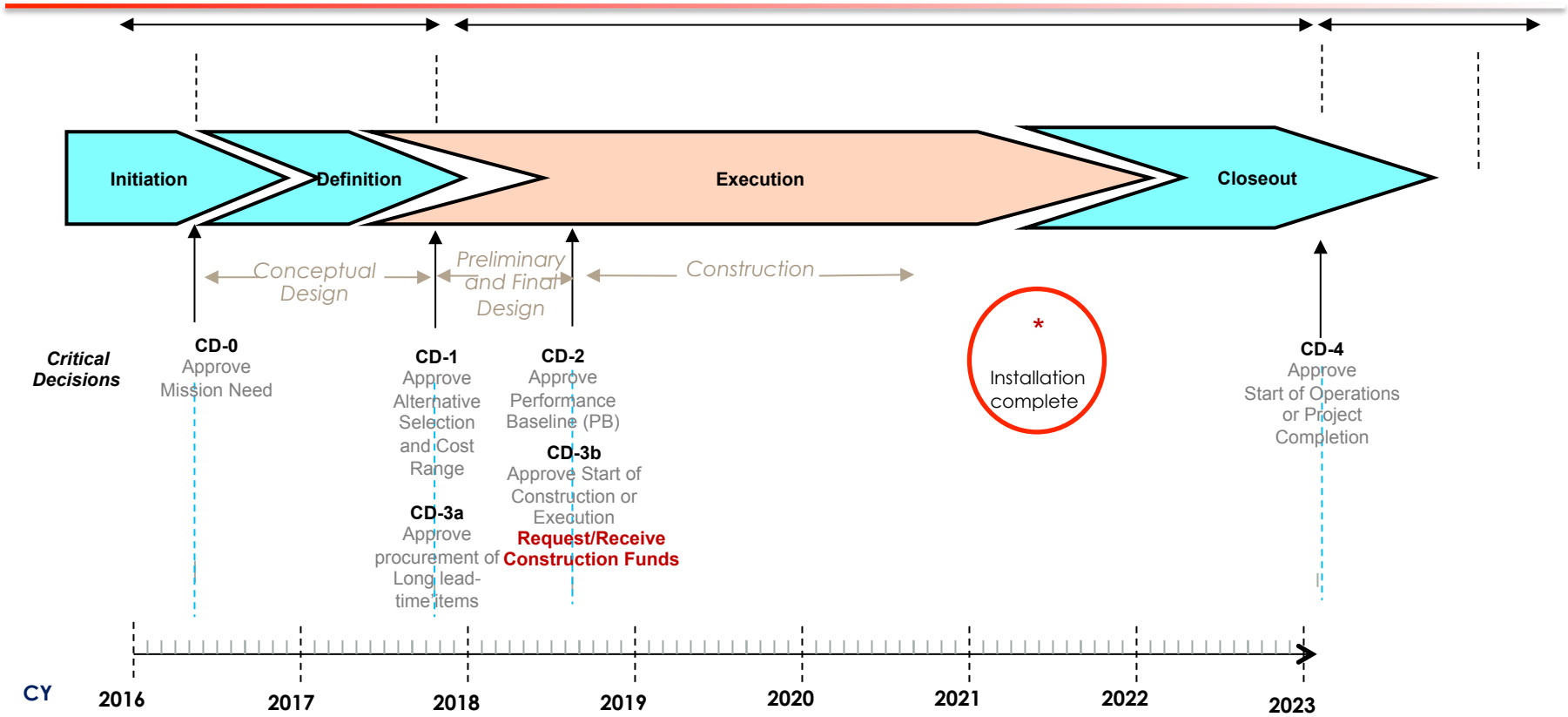
2015 revision of ePHENIX detector



Collaboration

- Dec 2015: Inaugural Collaboration Meeting at Rutgers
  - Bylaws approved
- Spokespersons elected (D. Morrison and G. Roland)
- Next Collaboration Meeting at BNL May 18-20, 2016

sPHENIX Timeline



CD-0	Apr 2016
CD-1/CD-3a	Nov 2017
CD-2/3	Jul 2018
Installation complete	Jun 2021
Ready for Beam	Jan 2022
CD-4	Jan 2023

- pCDR in November went very well
- No recommendations from May scientific review

Summary

- sPHENIX will allow high statistics measurements for jets and quarkonia at 200 GeV
- Scientific case for sPHENIX has been demonstrated
- Collaboration formed
- Design, Simulation, and R&D progressing rapidly
- Looking forward to start collecting data in January 2022
- More information:
  - http://www.phenix.bnl.gov/phenix/WWW/publish/documents/sPHENIX_proposal_19112014.pdf