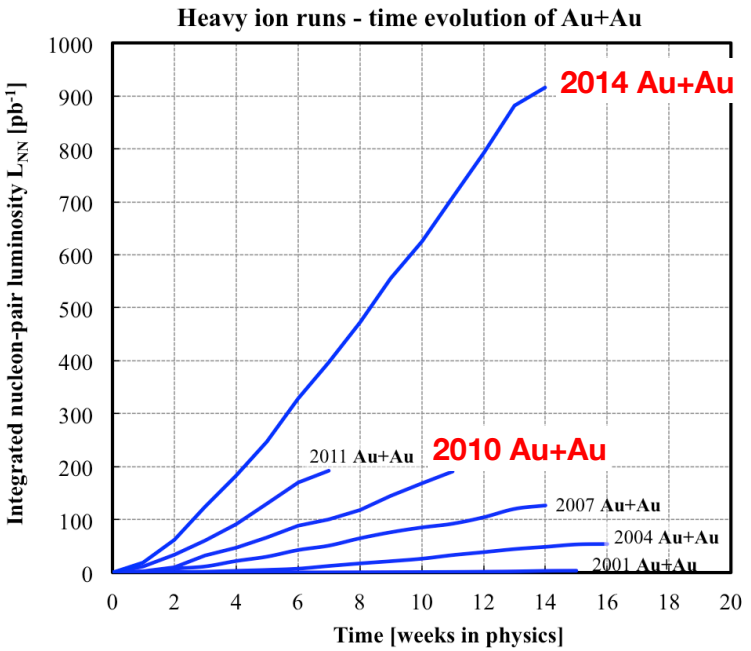
sPHENIX Calorimeter Design and Jet Performance

John Haggerty

Brookhaven National Laboratory

Fifteen years of RHIC experiments

- RHIC data taking from 2001-2015 has produced large data sets in too many collision energies and species to fit on one page see http://www.rhichome.bnl.gov/RHIC/Runs/ for the full range of collision species and energies
- During that period, accelerator upgrades (particularly stochastic cooling) gave us increased luminosity and extended our physics reach
- **sPHENIX** is conceived as a **second generation experiment** building on what has been learned at RHIC and taking advantage of technological progress since the RHIC experiments were proposed in 1992

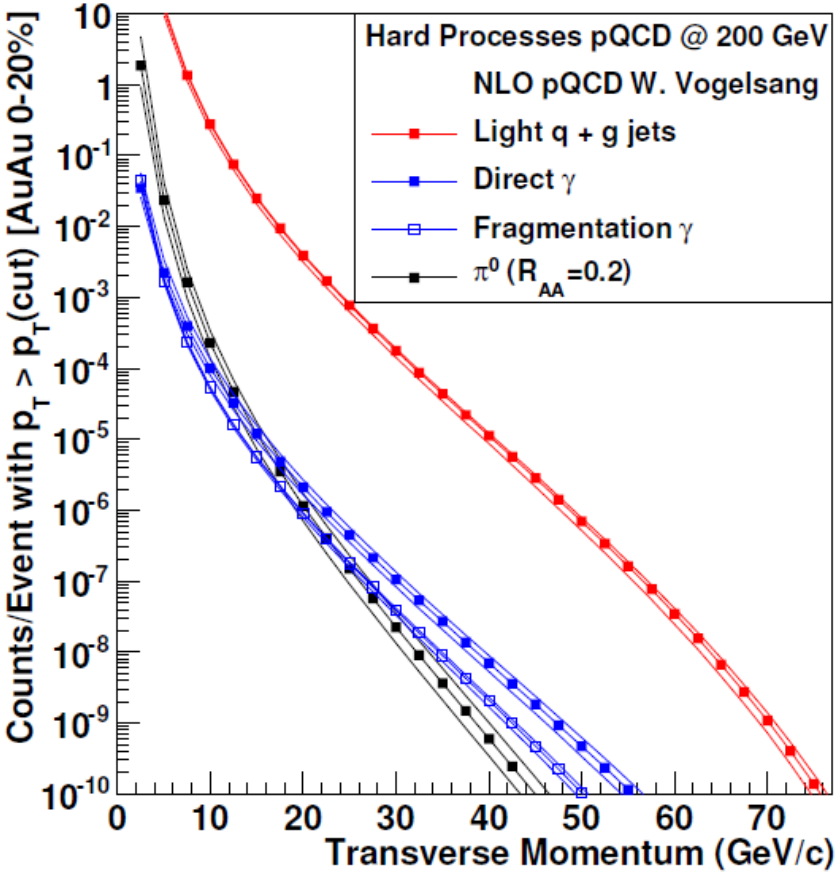


sPHENIX objectives

- Complete the picture of evolution and coupling strength from the initial high temperature through expansion and cooling to the transition scale and below
- Fragmentation of partons measured with jets and the melting of the Upsilon states are the probes
- Direct photons and high p_T hadrons measured with high statistics due to high rates and large acceptance

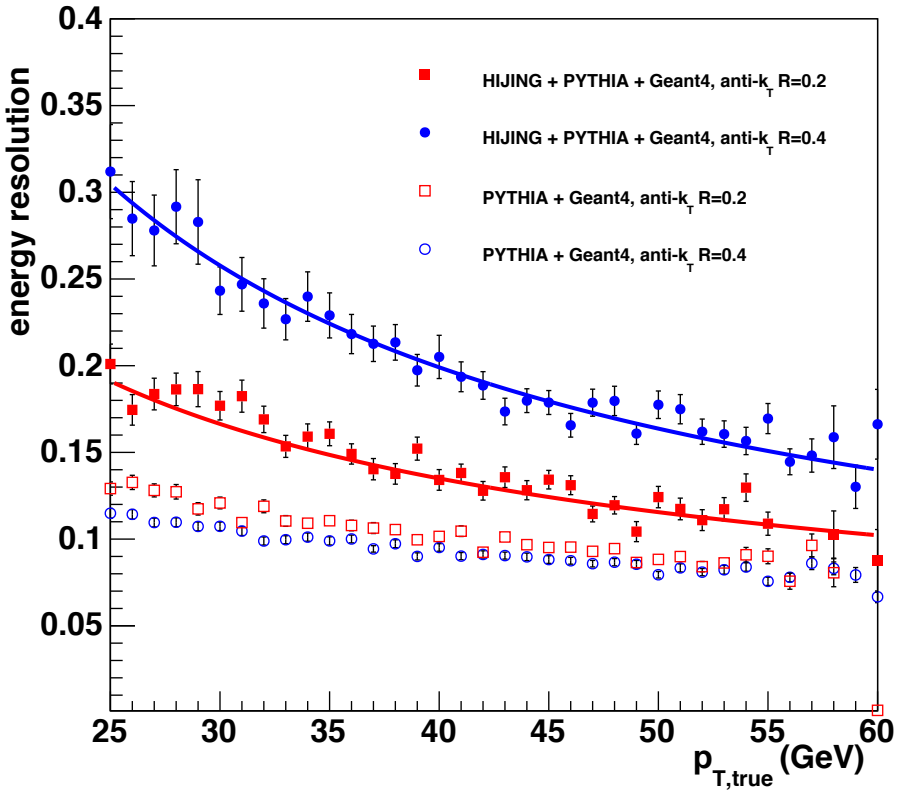
Jets at RHIC

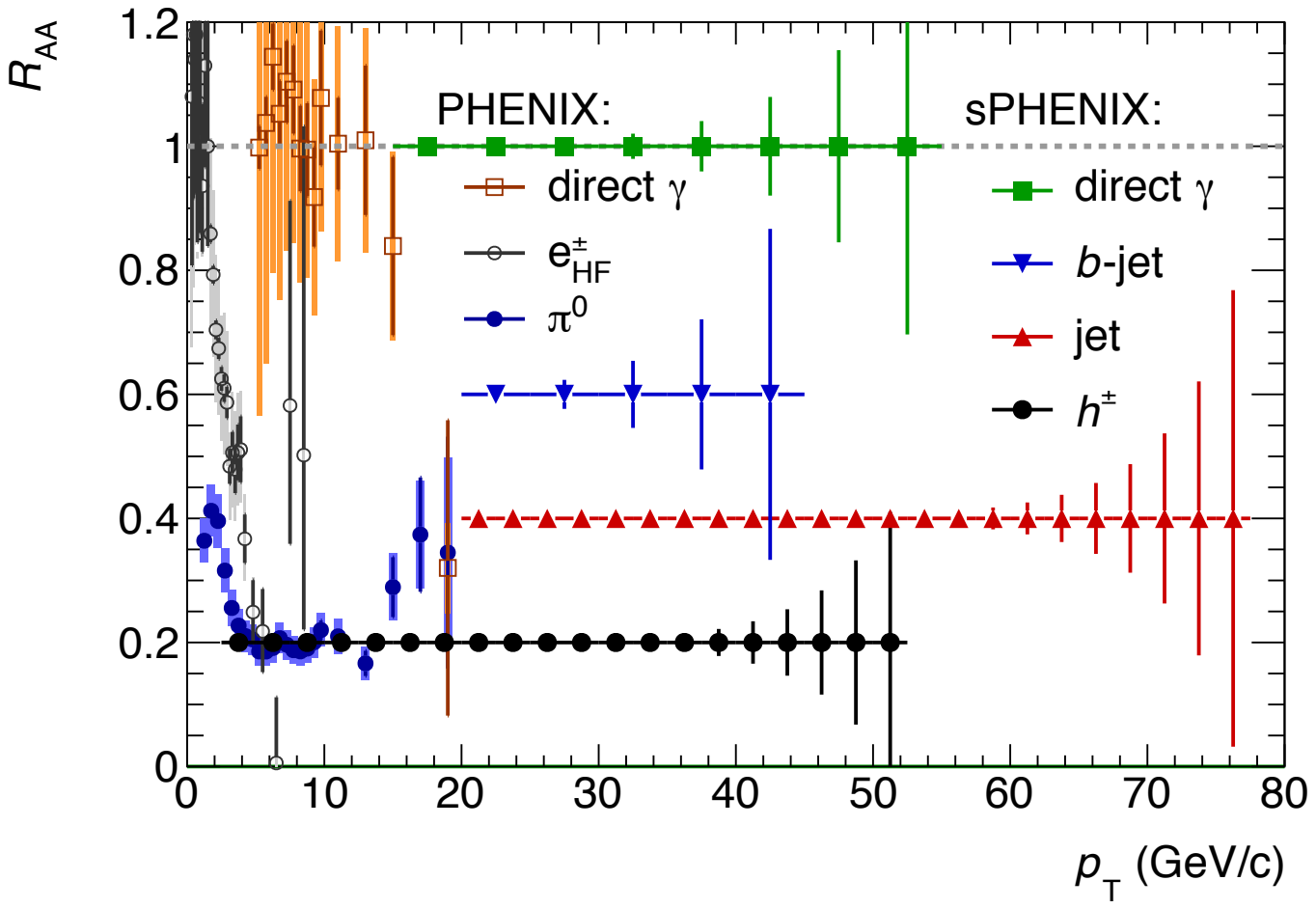
- Design to collect 100 billion minimum bias Au+Au events in one year run
- High statistics jet measurements
  - 10^7 jets above 20 GeV
  - 10^6 jets above 30 GeV
  - 10^4 direct photons above 20 GeV
- Large statistics for γ+jet, b-tagged jets and more



Jets in A+A

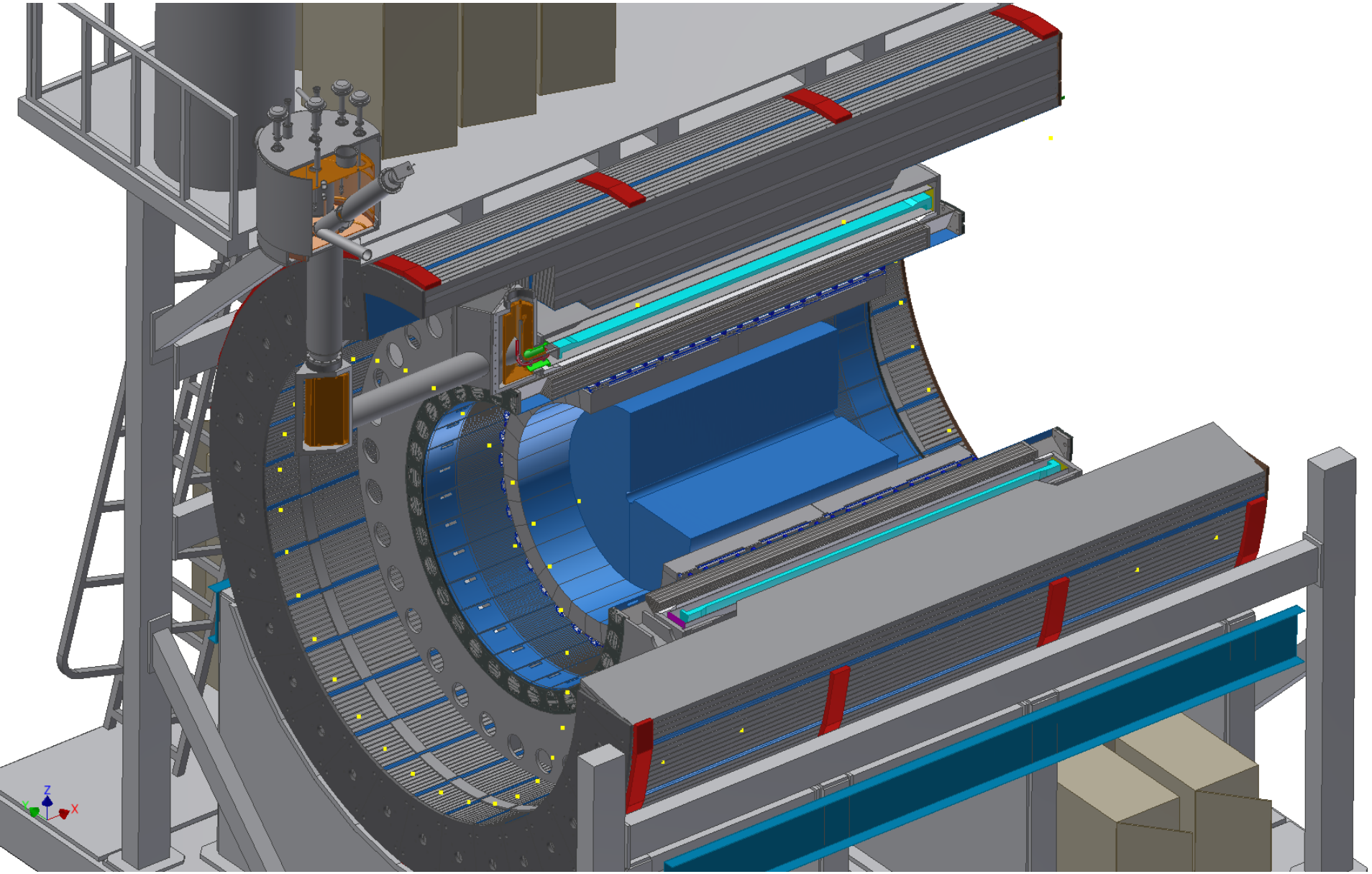
- Effective jet energy resolution has an important contribution from fluctuations in underlying event
- Fluctuations in underlying event can create “fake jets”
- Procedure has been developed to unfold
  - Hanks et al. *Phys. Rev.*, C86:024908, 2012
- Ongoing simulation work to assure the proposed detector can achieve the needed performance

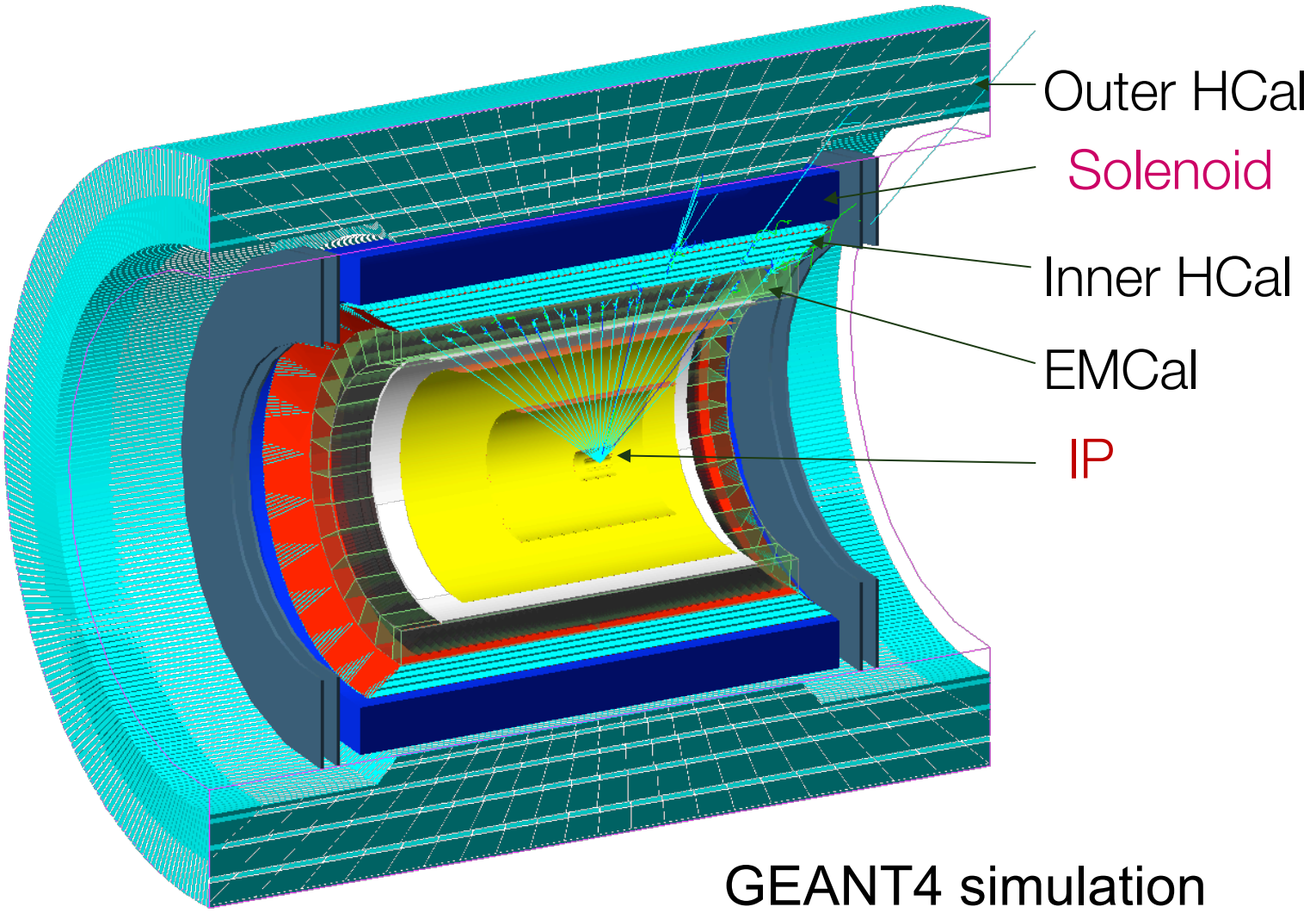



R_{AA}
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
p_T (GeV/c)
PHENIX:
direct γ
$e^{\pm}_{HF}$
π^0
sPHENIX:
direct γ
b-jet
jet
$h^{\pm}$

The sPHENIX detector concept

- **Uniform acceptance** $-1<\eta<1$ and $0<\phi<2\pi$
- **Superconducting solenoid** enabling high resolution tracking
- Compact **electromagnetic calorimeter** allowing fine segmentation at a small radius
- **Hadronic calorimeter** doubling as flux return
- **Solid state photodetectors** that work in a magnetic field, have low cost, do not require high voltage, are physically small
- **Common readout electronics** in the calorimeters
- **15 kHz recorded** in AA allows for large unbiased data sample
- Utilization of infrastructure in an **existing experimental hall** (cranes, rails, power, network…)

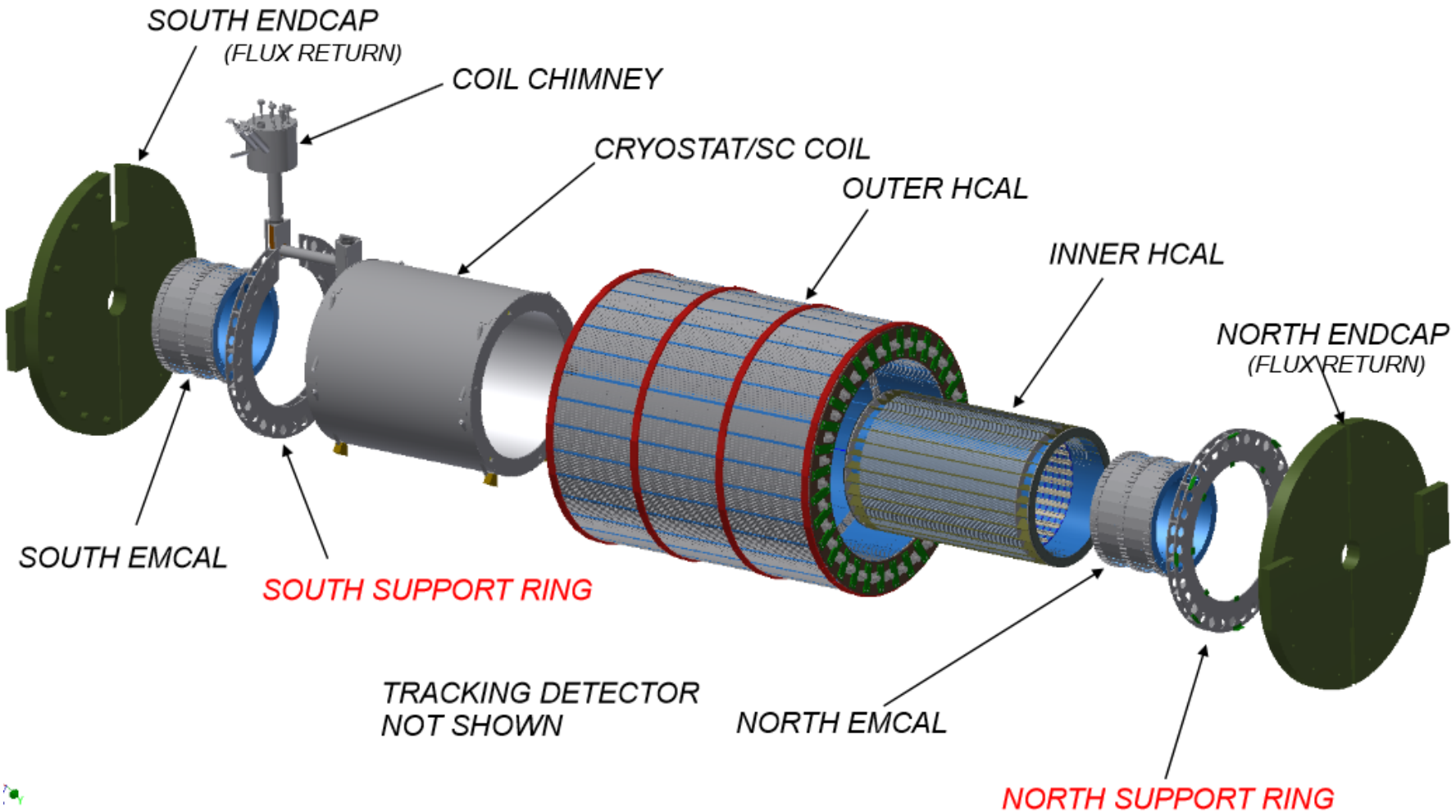




GEANT4 simulation

https://github.com/sPHENIX-Collaboration

Putting it all together

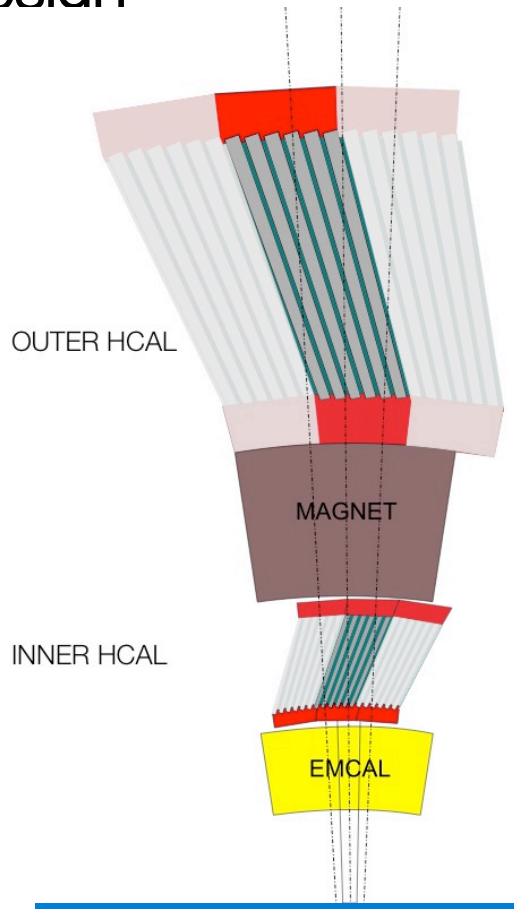


Magnet

- BaBar magnet secured from SLAC after SuperB canceled, arrived at BNL in February 2015
- Preparation for low power cold test this year
- Well suited to our needs without compromises
  - 1.5 T central field
  - 2.8 m diameter bore
  - 3.8 m long
  - $1.4X_0$ coil+cryostat

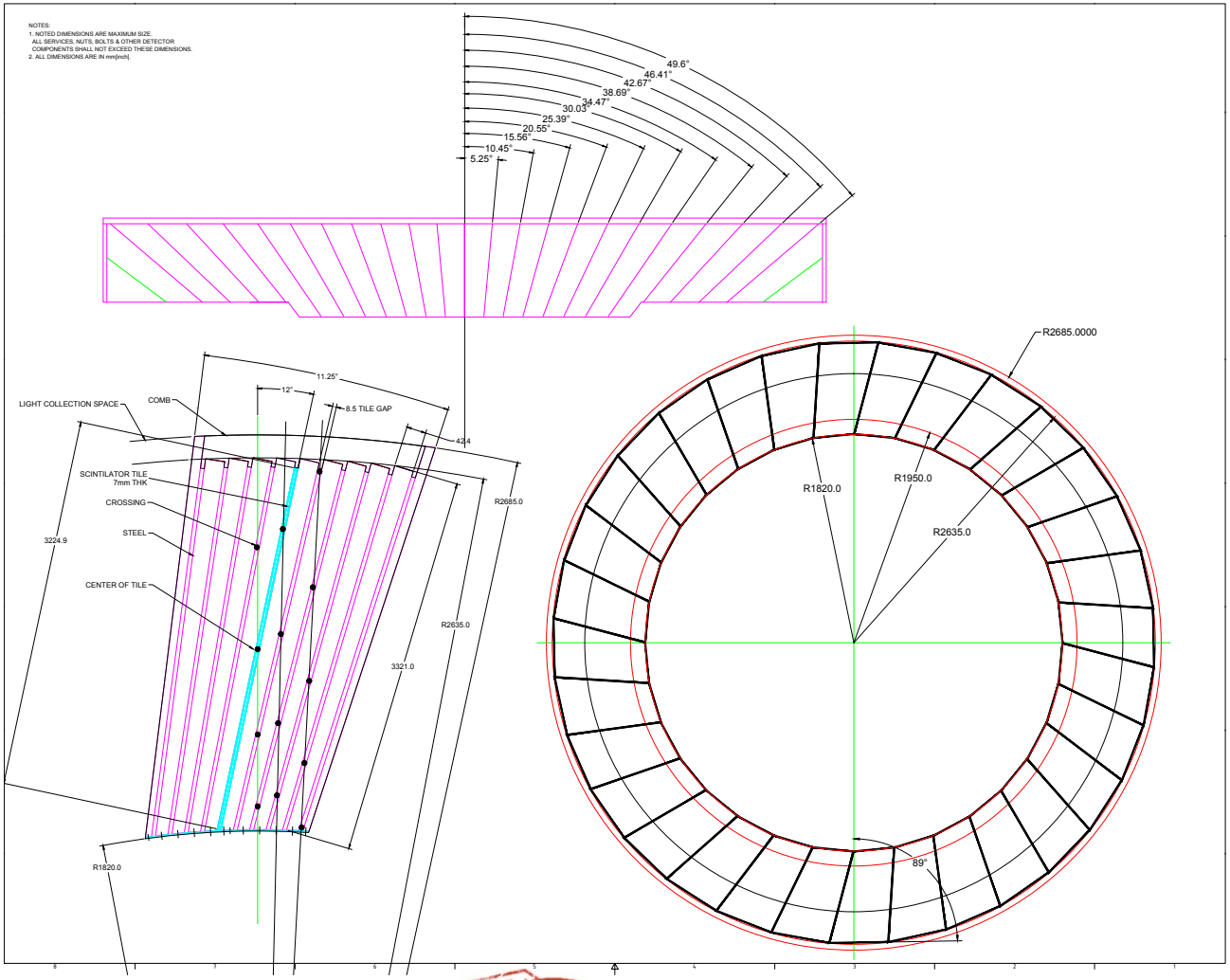
Calorimeters reference design

- 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)



- 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



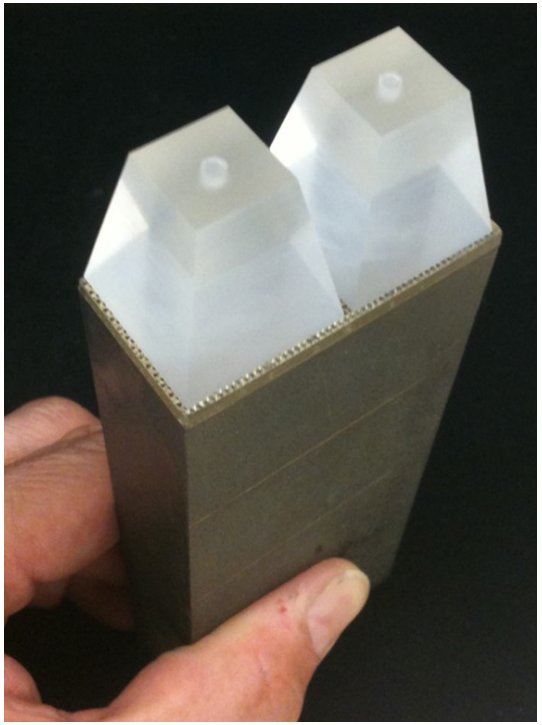
PHENIX

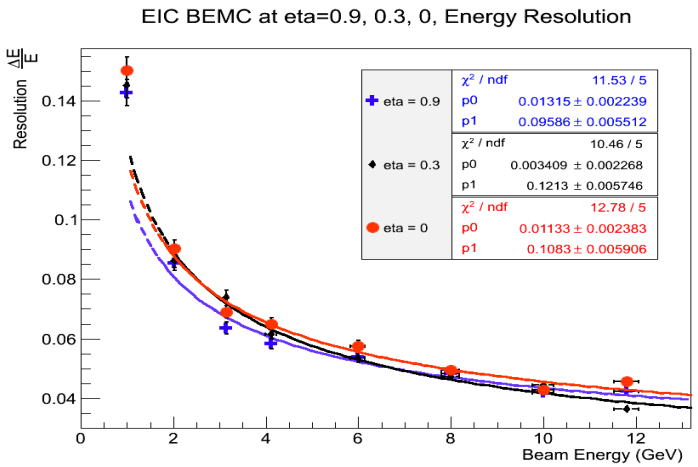
HCAL scintillator

- 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

EMCAL

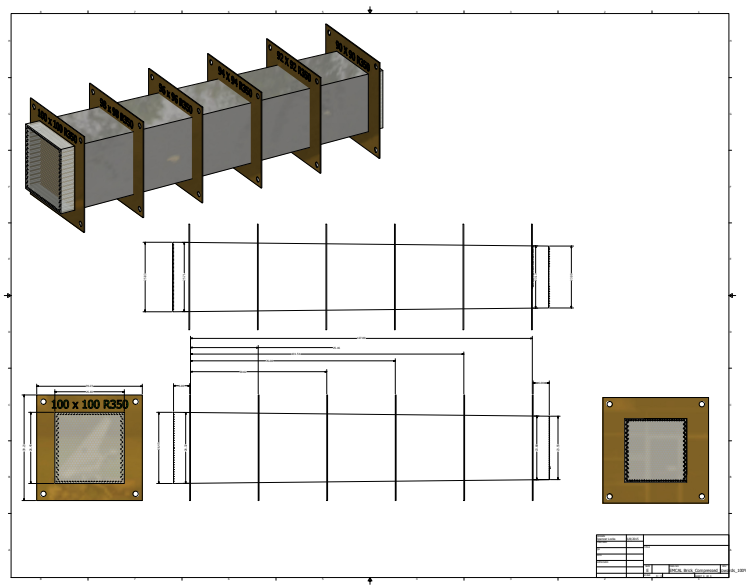
- R&D is going forward at BNL, UIUC, and UCLA on a tungsten-fiber SPACAL developed at UCLA
  - We believe we need 2D projectivity to achieve the e/π separation needed for the Upsilon measurements
  - Beam tests to validate concept
- Readout on inner radius of EMCAL with 4 3x3 mm SiPM's
- On-detector electronics limited to preamps, bias control and temperature monitoring

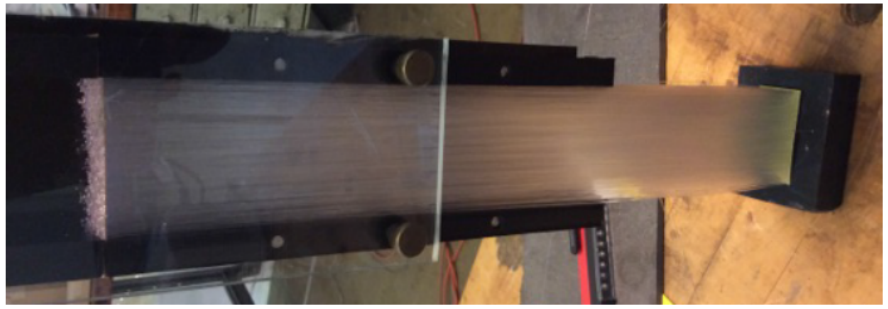




Tsai, T-1018

EMCAL module design



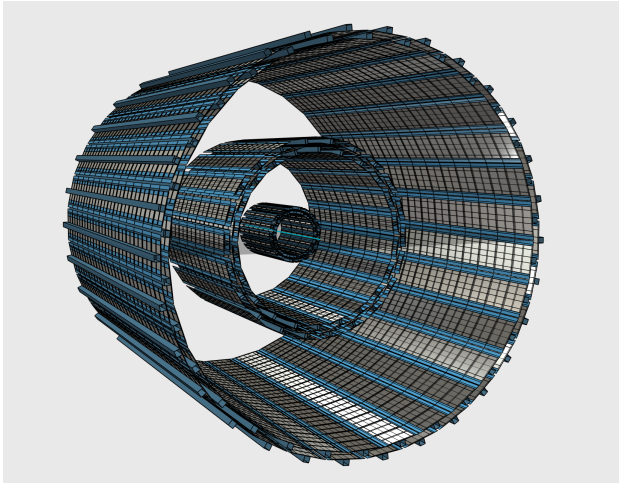


- Fibers threaded through screens
- Filled with tungsten powder and epoxy
- Final density more than half of pure tungsten
- Moliere radius ~2.3 cm

Tracking options compared

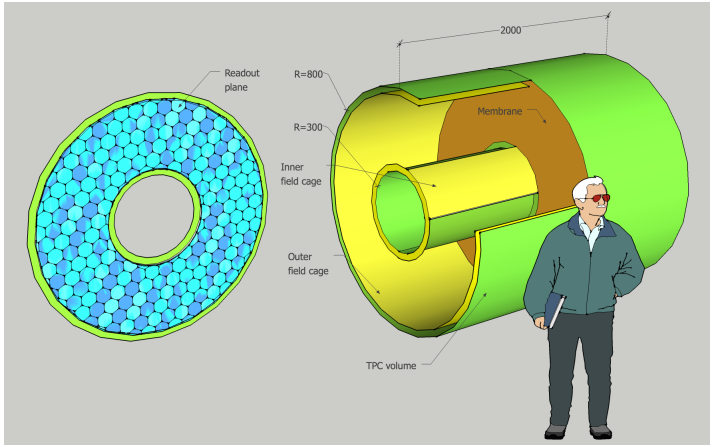
Si tracker reference design

- 7 layers strips and pixels
- Achieves design goals of pattern recognition and100 MeV mass resolution on Upsilon states
- Total thickness ~10%X_0

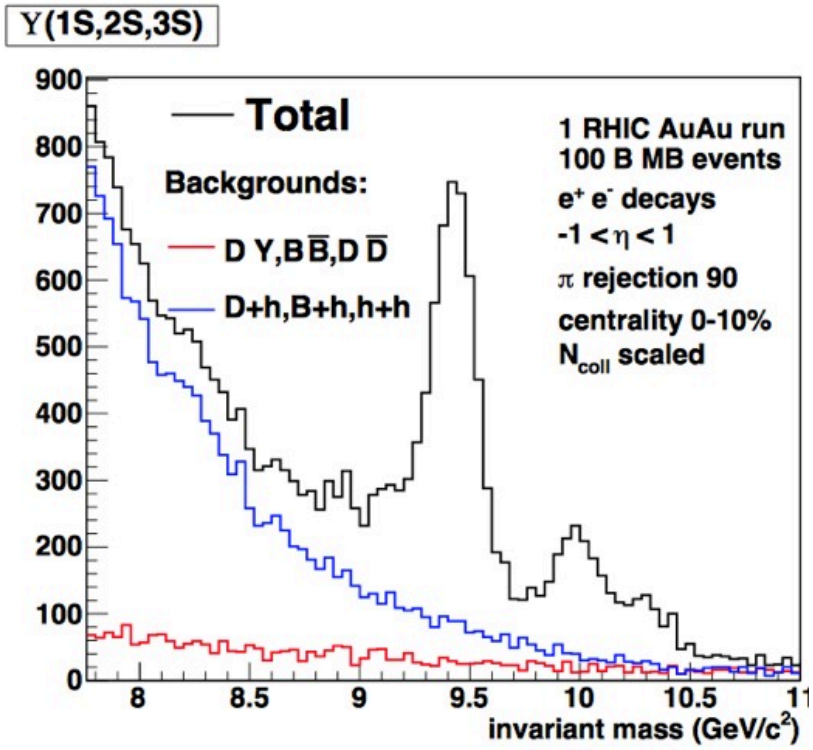


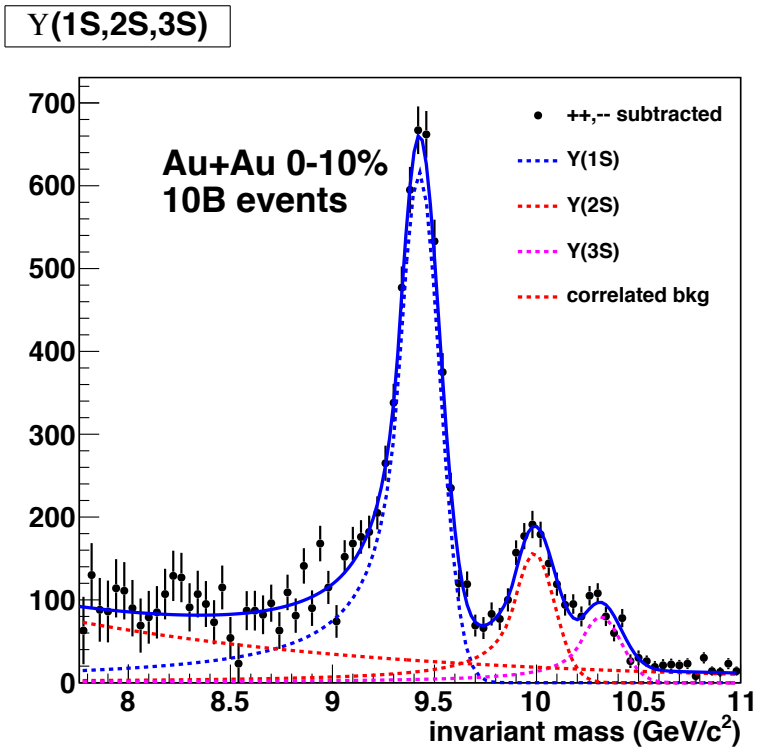
TPC + inner Si layers

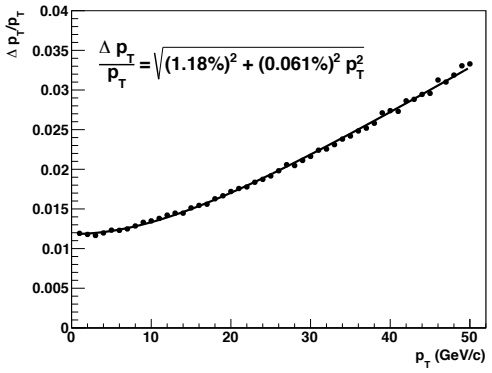
- 80 cm outer radius TPC
- Inner Si detector
- TPC electronics following from ALICE upgrade



Upsilon performance in Au+Au



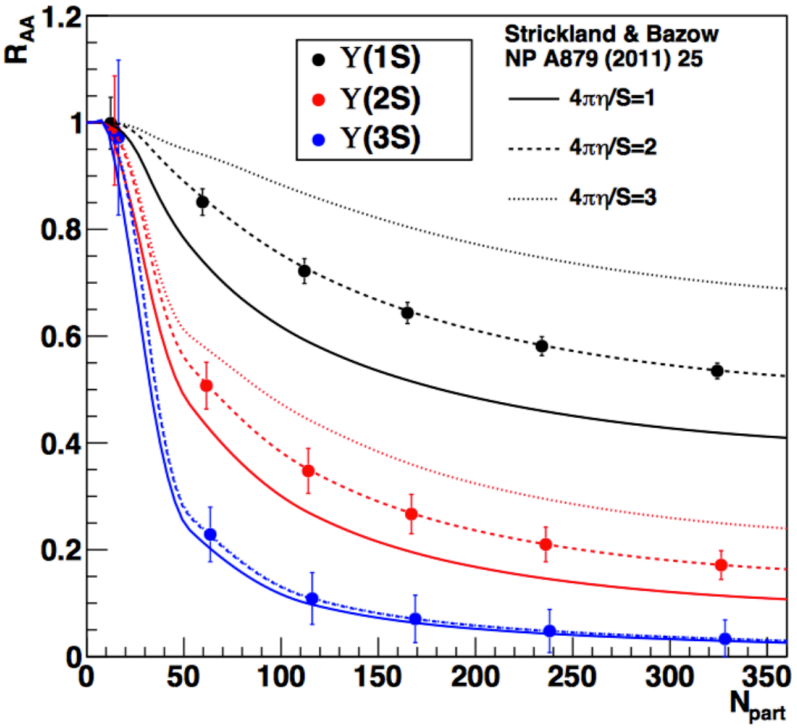




100 MeV mass resolution in reference design

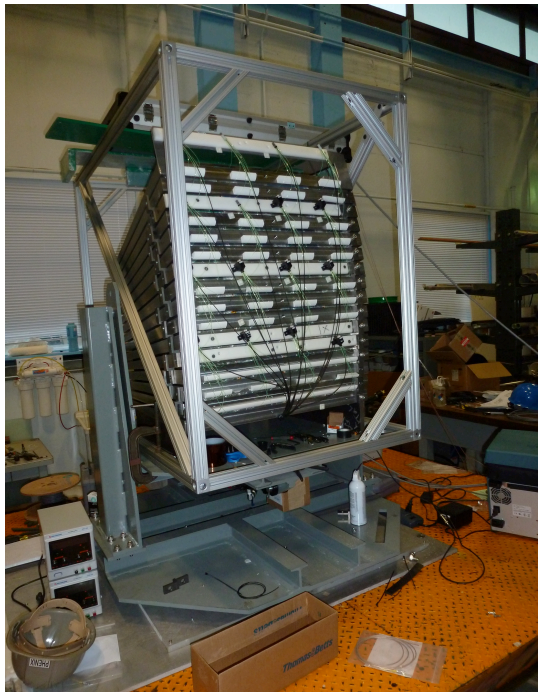
Nuclear modification projections for Upsilons

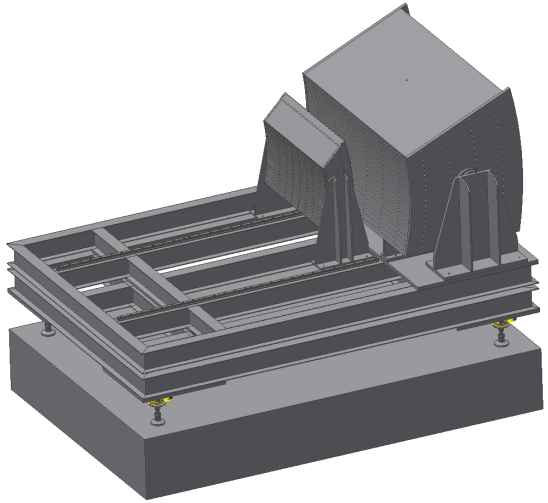
- With
  - 10 weeks p+p
  - 22 weeks Au+Au
- Yield and s/b scaled to match model suppression



R&D, work in progress

- We have had one beam test at Fermilab of an early version of our calorimeter design in February 2014
- Second prototype planned for April 2016 for all three calorimeter sections
- Low power cold test of magnet being prepared
- Radiation damage tests of SiPM's
- Development of manufacturing techniques for the SPACAL
- Finite element analysis of structure
- New digitizers being developed at Nevis
- Exploration of tracking options





Status and next steps

- DOE panel accepted science case at a reviews completed May 2015
- sPHENIX is an integral part of the BNL plan after a final PHENIX run in 2016; project planning ongoing
- Design, simulation, R&D, prototyping all moving forward rapidly
- BNL Associate Laboratory Director convened a workshop to form a new collaboration in June 2015, and the first collaboration meeting is Dec 10-12, 2015 at Rutgers
  - http://www.lehigh.edu/~rjr215/NewRhicDetector1stColab.html
- More information:
  - http://www.phenix.bnl.gov/phenix/WWW/publish/documents/sPHENIX_proposal_19112014.pdf
- See the many sPHENIX posters at this conference