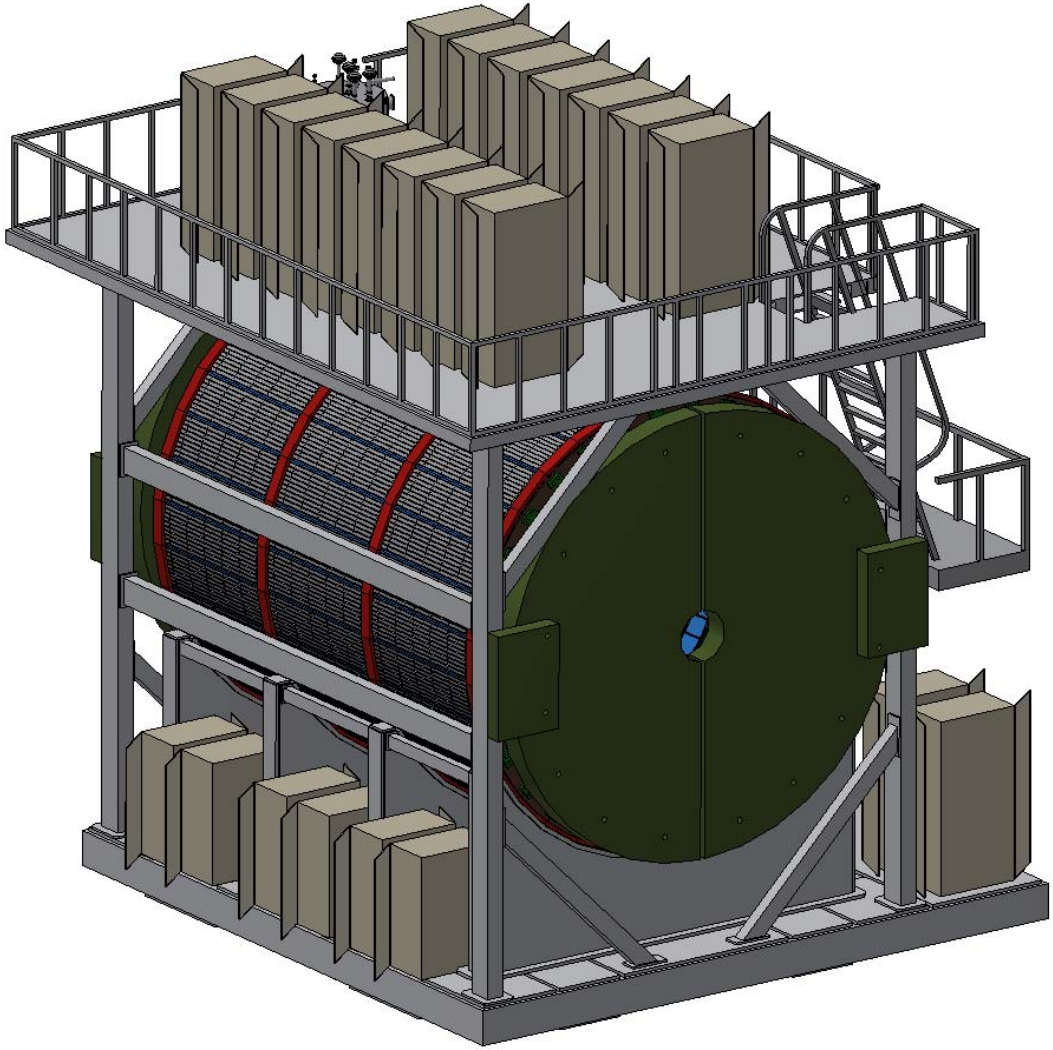
Capabilities and Plans



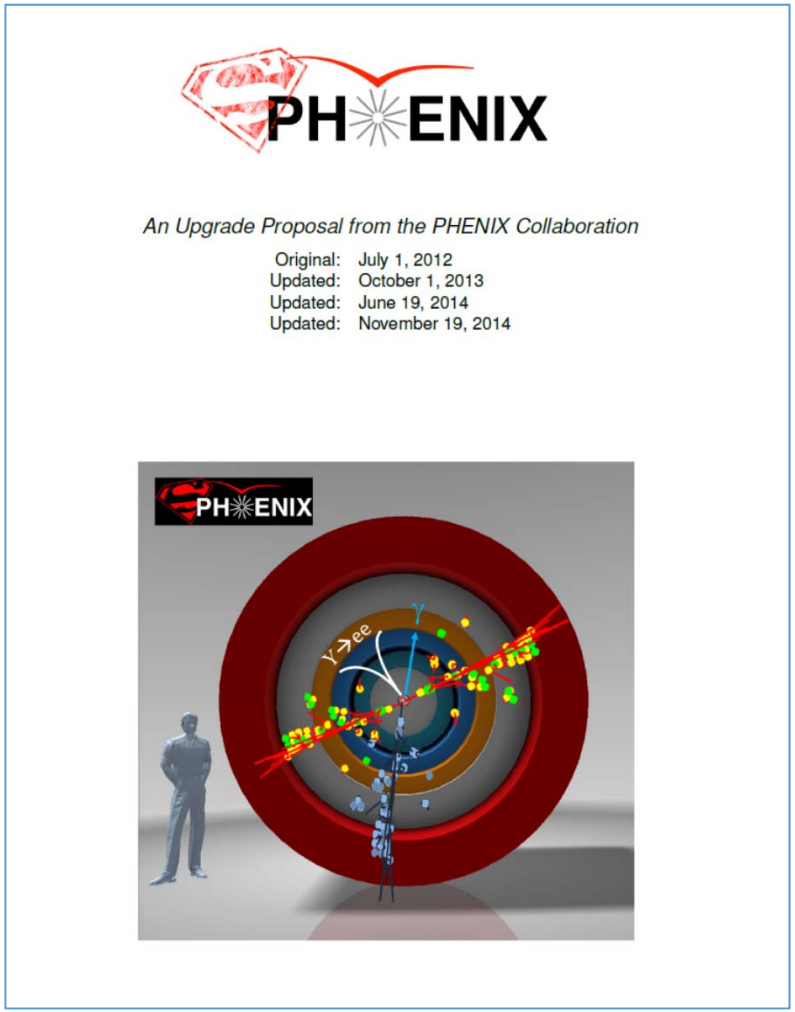
J. Lajoie

Iowa State University

Introduction, Physics and Concept

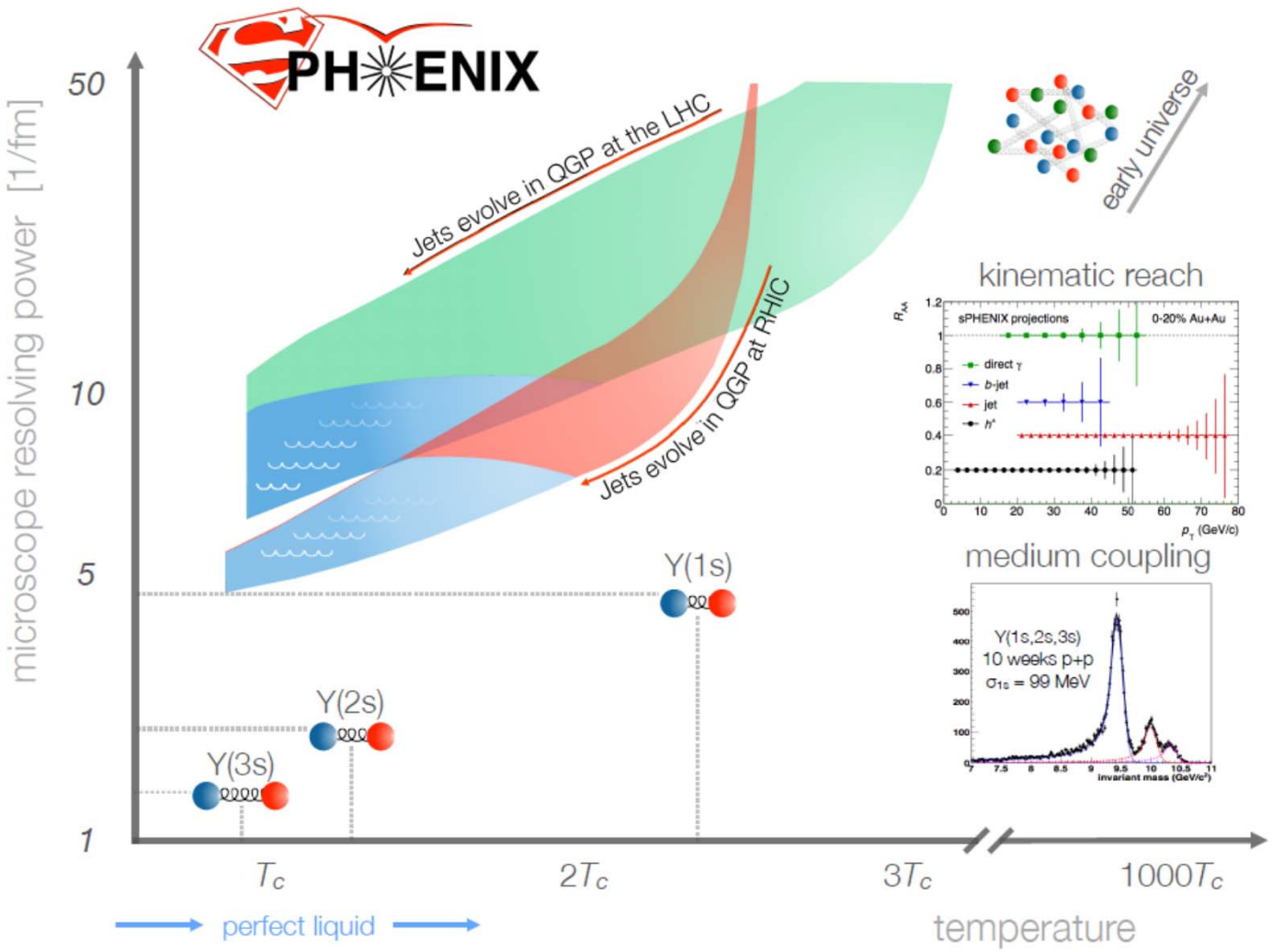
- Physics Goals
- sPHENIX Overview
- fsPHENIX

Extensive additional information available in PHENIX proposal.



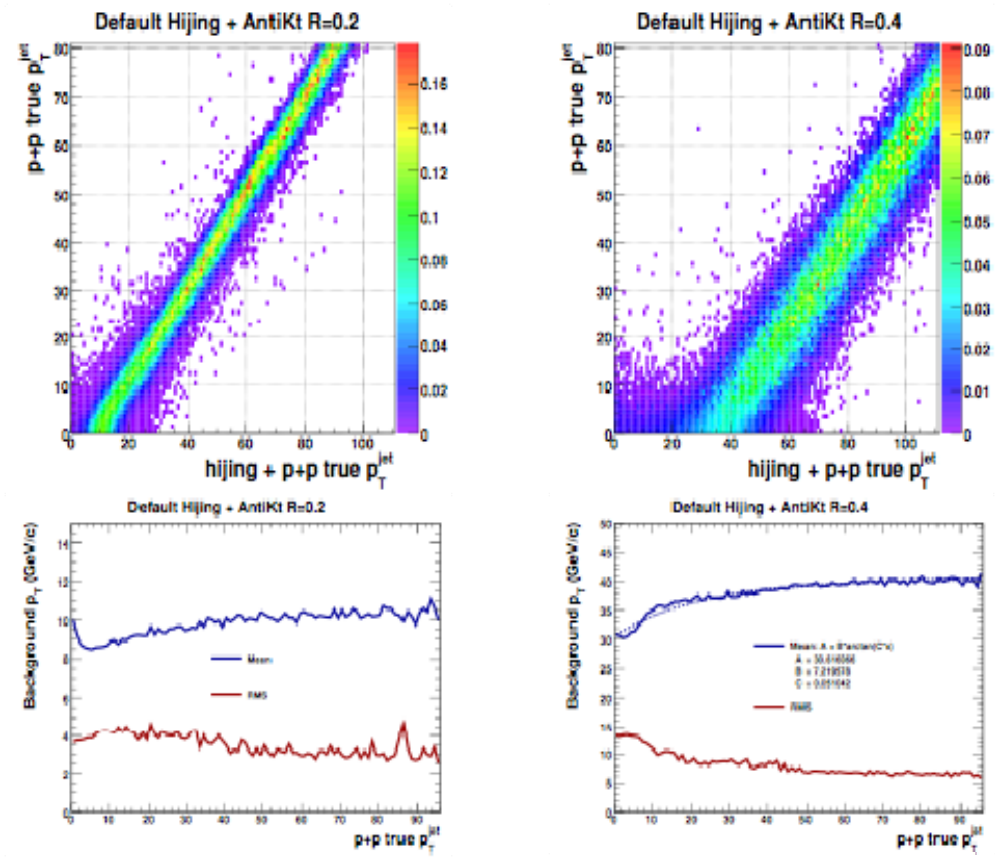
arXiv:1501.06197

Jets as a Probe



The Challenge of Heavy Ions

- Underlying event (UE) adds energy to measured jets in heavy ion collisions
- Fluctuations in UE degrade jet energy resolution
- At lower p_T fluctuations in UE can appear to be jets—"fake" jets

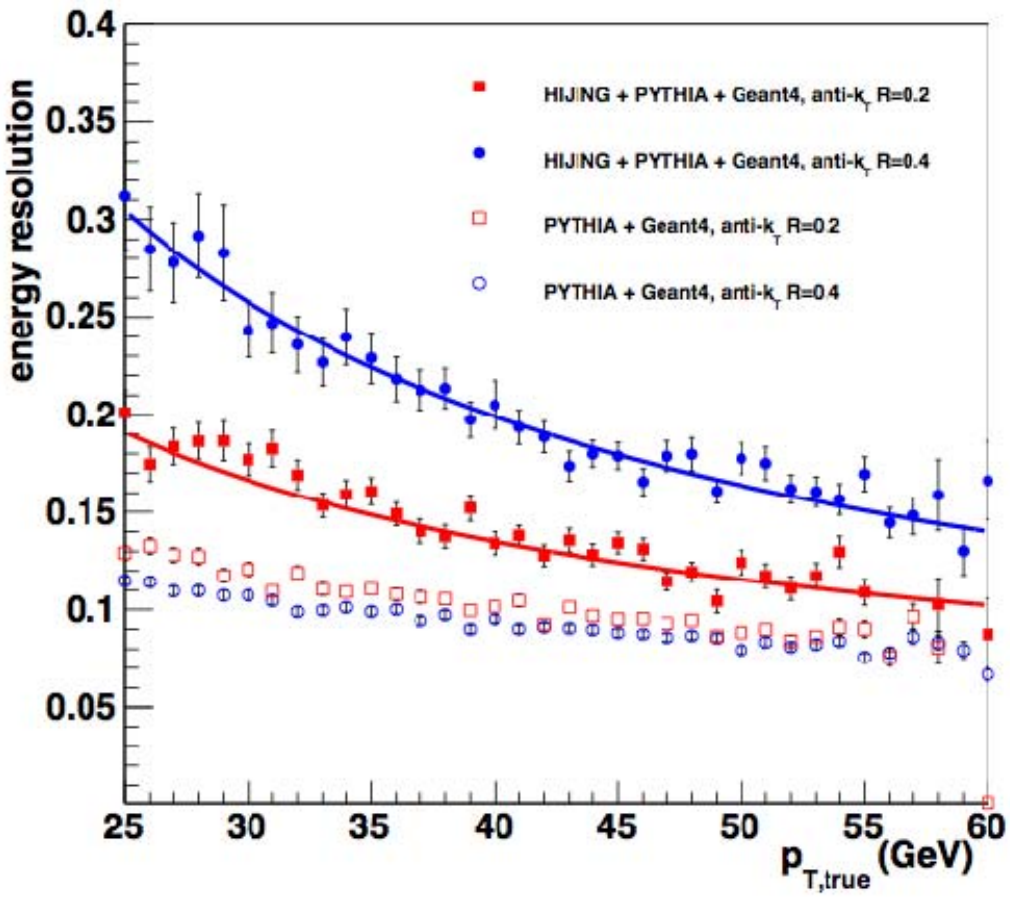


R = 0.2, b = 4.4fm
Σ background ~ 10 GeV
background RMS ~ 3.5GeV

R = 0.4, b = 4.4fm
Σ background ~ 40 GeV
background RMS ~ 7 GeV

Jet Energy Resolution – Au+Au

PYTHIA events embedded into central HIJING events



lines: p+p resolution $\oplus$ UE smearing

7 GeV for R = 0.4

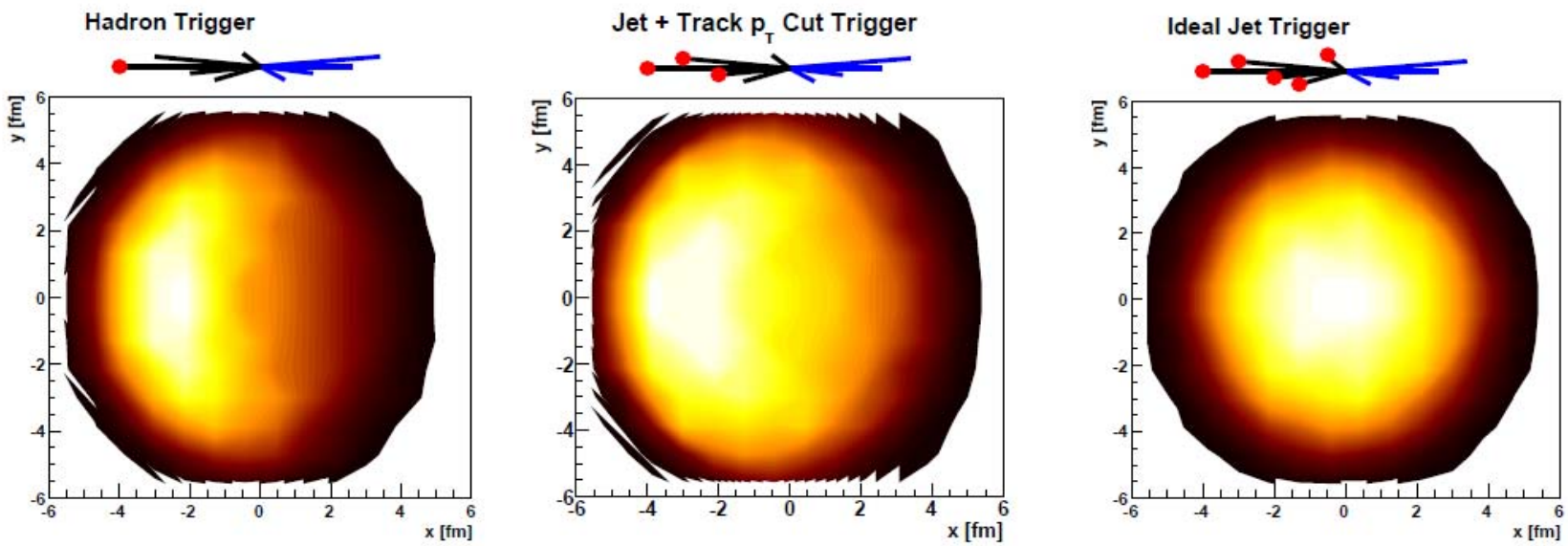
3.5 GeV for R = 0.2

underlying event determines jet performance in AA

Biases in Jet Measurements

how do jet measurement correlate with where the jet originates?

calc: T. Renk

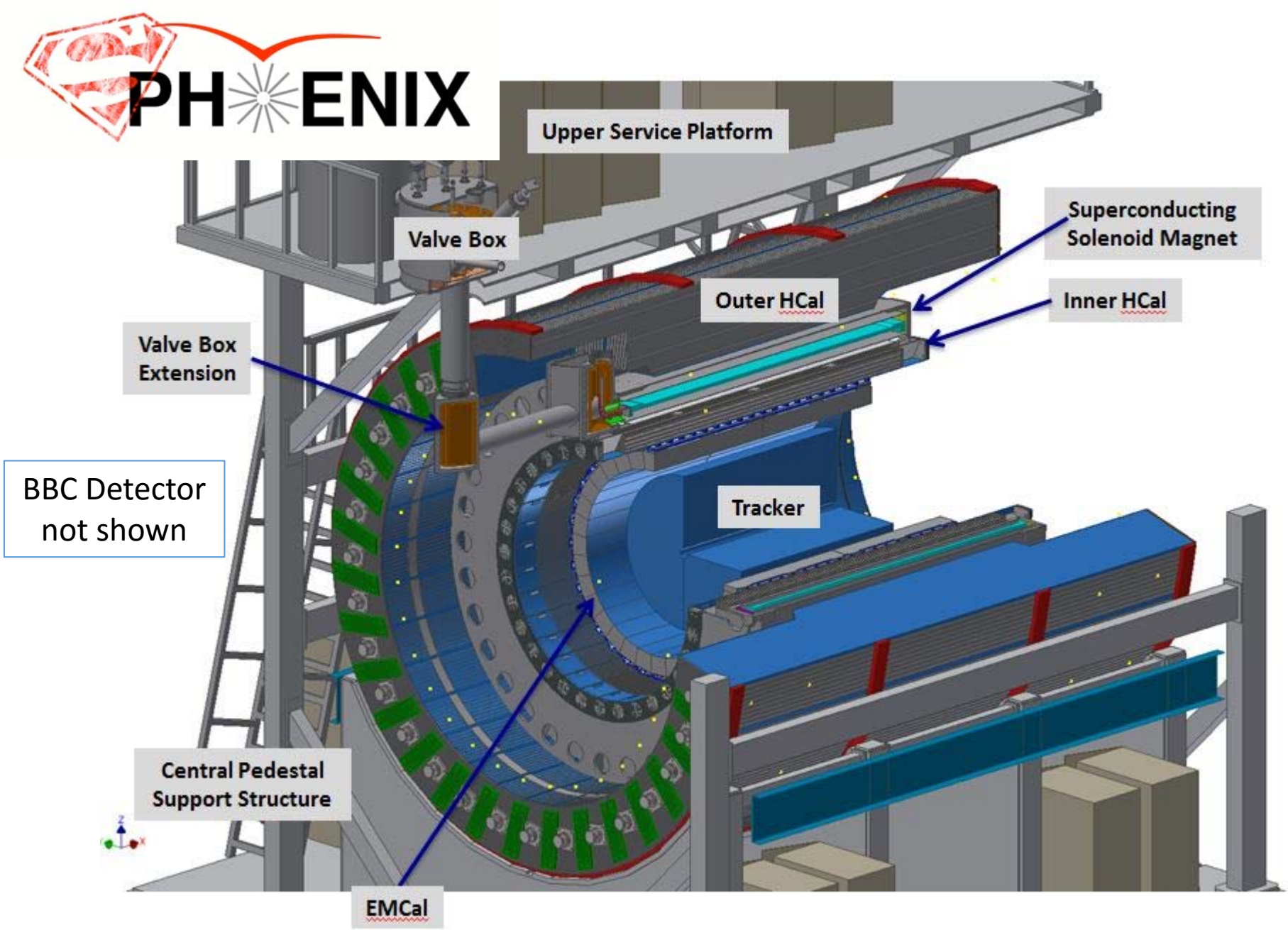


STAR →

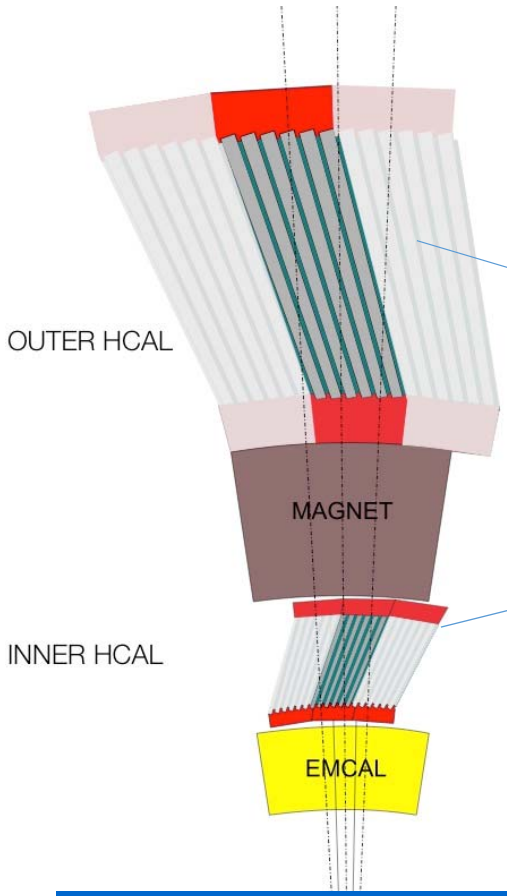
← sPHENIX

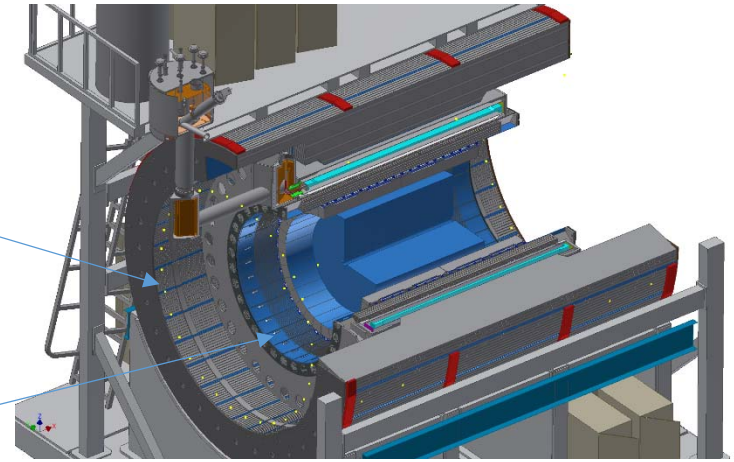
The sPHENIX Detector Concept

- **Uniform acceptance** $|\eta|<1.1$ and $0<\phi<2\pi$
- **Superconducting solenoid -** high resolution tracking
  - Acquired the BaBar solenoid!
- 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, low cost, do not require high voltage, are physically small
- **Common readout electronics** in the calorimeters
- **15 kHz recorded** in A+A allows for large unbiased data sample
- **High resolution tracking** within an 80 cm radius
- Utilization of infrastructure in an **existing experimental hall** (cranes, rails, beam pipe, power, network…)


PHENIX
Upper Service Platform
Valve Box
Superconducting Solenoid Magnet
Outer HCal
Inner HCal
Valve Box Extension
BBC Detector not shown
Tracker
Central Pedestal Support Structure
EMCal

HCAL Reference Design

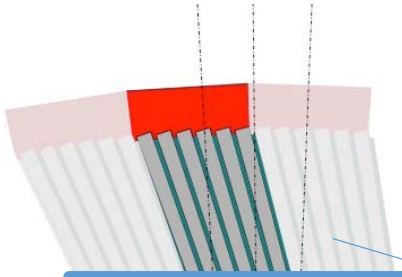


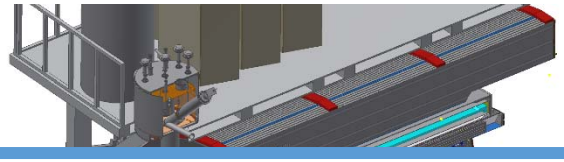


- Outer HCAL ≈3.5λ_I
- Magnet ≈1.4X_0
- Inner HCAL ≈1λ_I
- EMCAL ≈18X_0≈1λ_I

- 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
  - $\sigma_E/E < 100\%/\sqrt{E}$ (single particle)
- SiPM Readout

sPHENIX HCAL Description





OUTER HCA

INNER HCA

Why a "tilted plate" design?

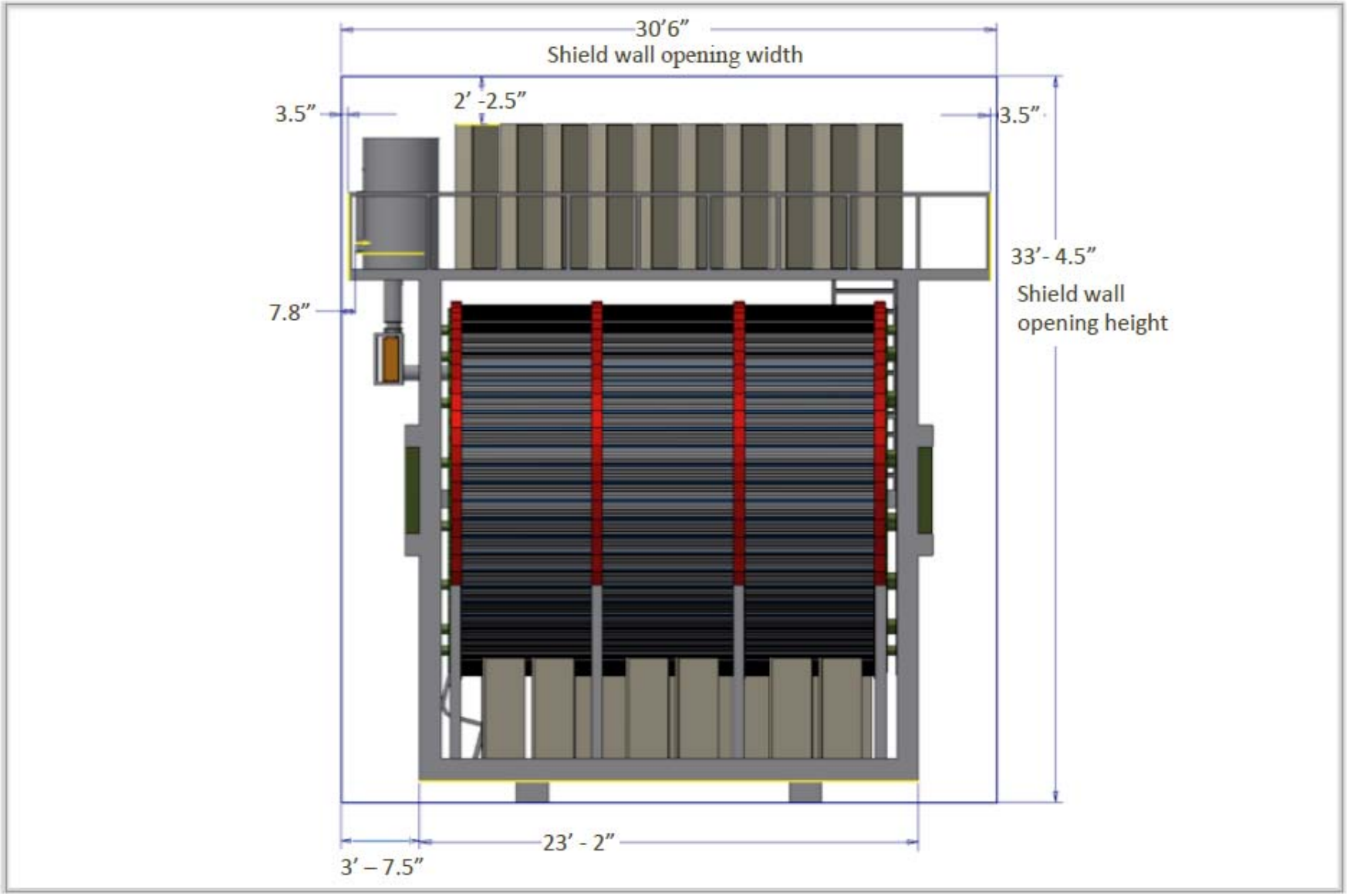
- Size limitations set by existing 1008 interaction hall lead us to integrate the flux return and the outer HCAL.
  - Requires longitudinally contiguous steel sections
  - Design consistent with requirements for a hermetic detector
    - Variation of a tile calorimeter design
  - Minimizes engineering challenges
- Adequate performance for the sPHENIX physics goals.

- Magnet ≈1.4X_0
- Inner HCAL ≈1λ_I
- EMCAL ≈18X_0≈1λ_I

- $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$
- 2 x 24 x 64 readout channels
- HCal $\sigma_E/E < 100\%/\sqrt{E}$ (single particle)

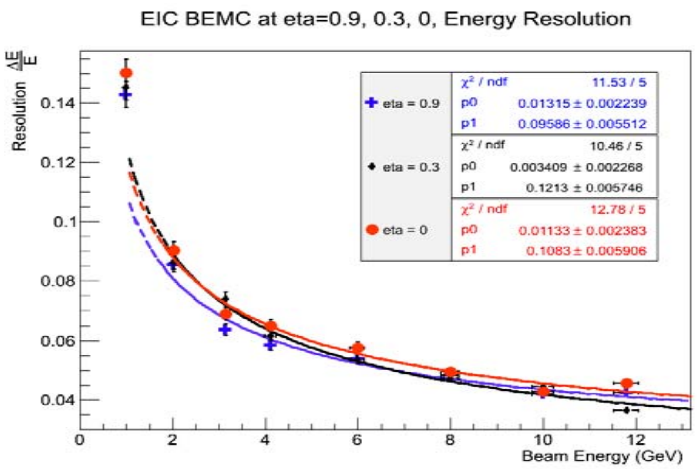
- SiPM Readout

Detector Size and Shield Wall

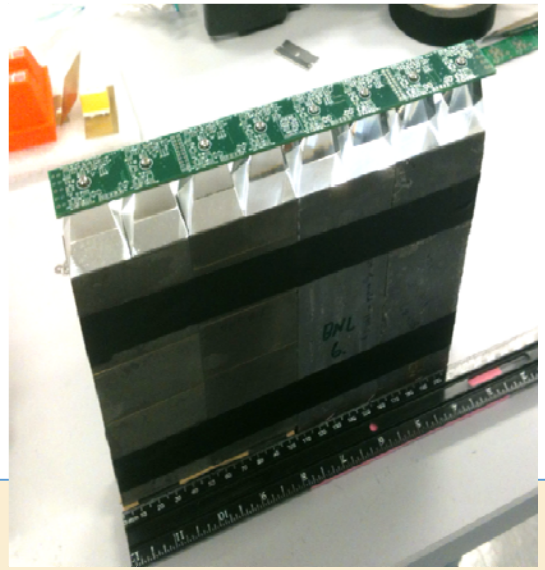


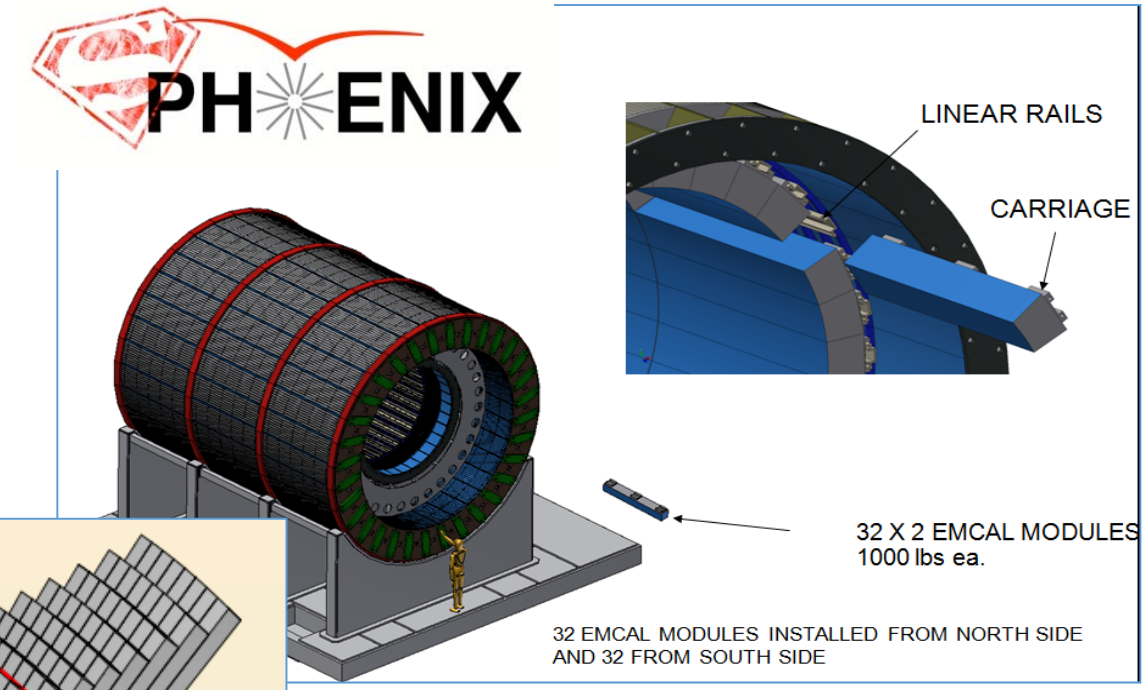
Electromagnetic Calorimeter

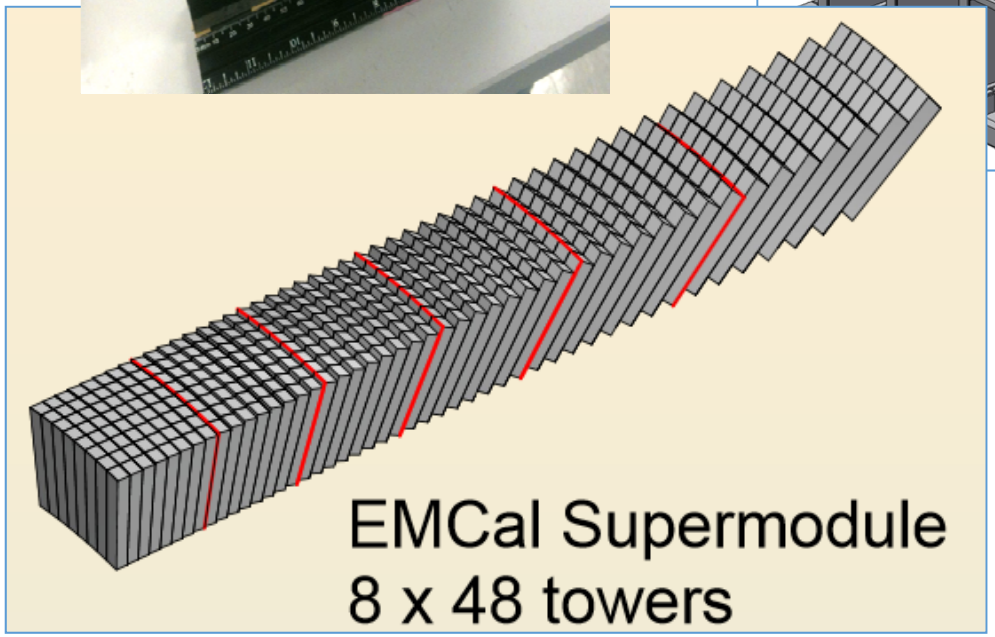
- Tungsten-scintillating fiber SPACAL
- Radiation length of ≈7 mm allows it to be inside the solenoid where only the material of the tracker is in front of it
- Beam tested by UCLA group
- Development of projective geometry which could improve e/π separation needed for the Upsilon measurements
- Readout on inner radius of EMCAL with 4 3x3 mm SiPM's
- On-detector electronics limited to preamps, bias control and temperature monitoring



1D Projective Reference Design







- Efforts to produce towers of spacal modules using UCLA-developed design is ongoing at UCLA, UIUC and Tungsten Heavy Powder
- Work supported in part by RHIC and EIC R&D

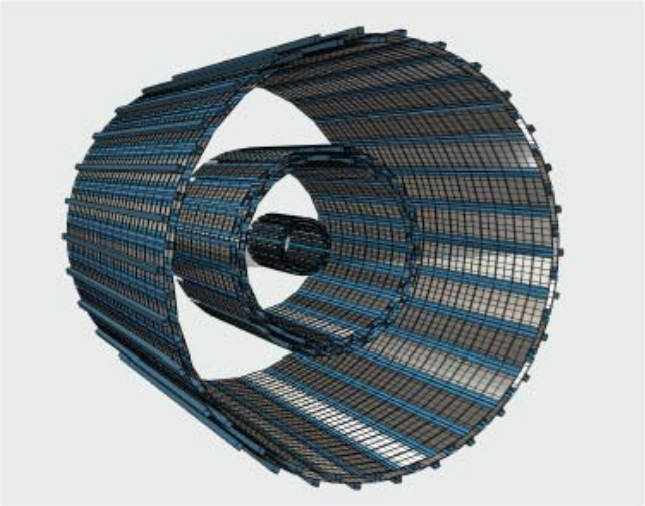
Ultimately need to build ~25k towers

Tracking – Options and Issues

All Si Tracker option

Si tracker

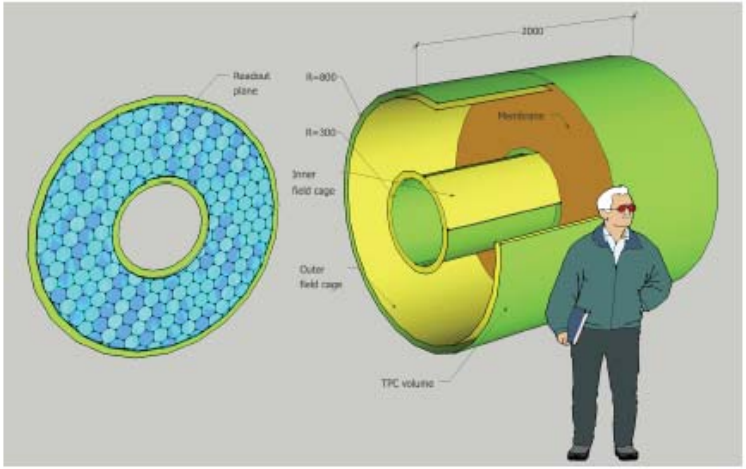
- 7 layers strips and pixels
- Achieves design goals of pattern recognition and 100 MeV mass resolution on Upsilon states
- Total thickness $\approx 0.1X_0$



2 Pixel Layers + Compact TPC option

TPC + inner Si layers

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

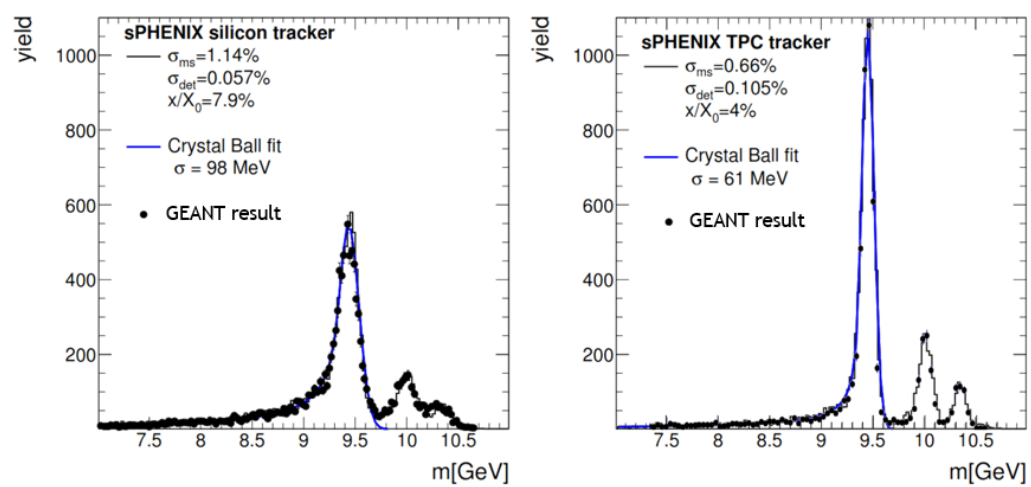


Inner pixel layers could be re-used from PHENIX VTX or MAPS pixels as in the ALICE upgrade

Tracking Requirements

- Physics program accomplished via two toughest constraints:
  - Mass resolution sufficient to resolve Upsilon States.
    - $\boldsymbol{\sigma_m < 100\ \frac{MeV}{c^2}\ @\ m \approx 9\ \frac{GeV}{c^2}}$ ← Outer Tracking
  - DCA Resolution sufficient for tagging heavy flavor secondary vertices.
    - $c\tau(D) = 123\ \mu m;\ \ c\tau(B) = 457\ \mu m$ ← Inner Vertex
    - $\boldsymbol{\sigma_{DCA} < 100\ \mu m}$

Both options can meet the performance requirements with very different technical challenges!

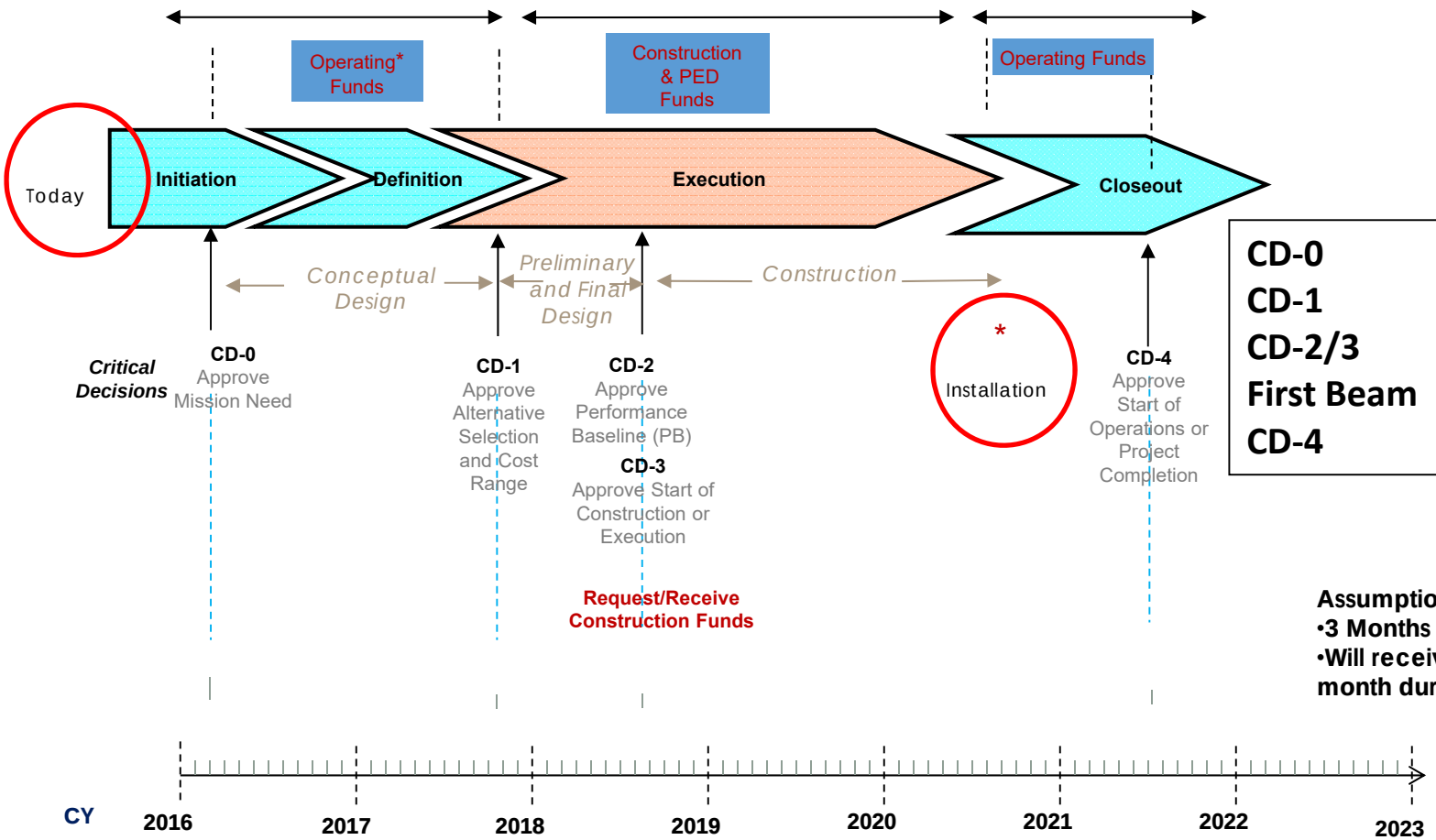


Recent sPHENIX Calendar

• sPHENIX Proposal submitted to DOE	Fall 2012
• DOE Science Review	July 2014
• Internal Rev of SC-magnet	Dec 2014
• Internal Rev of Decommissioning and Installation	Jan 2015
• Internal Rev of HCal	Feb 2015
• BaBar magnet arrives at BNL	Feb 2015
• Internal Rev of Calorimeter Electronics	Mar 2015
• DOE Science Review	April 2015
• New RHIC Collaboration formation Workshop	Jun 2015
• Internal Rev of EMCal	Aug 2015
• NPP Director's Cost and Schedule Rev	Nov 2015
• 1st Meeting of new "sPHENIX" Collaboration	Dec 2015

Many internal reviews and a successful DOE Science Review

DOE Critical Decision Scenario

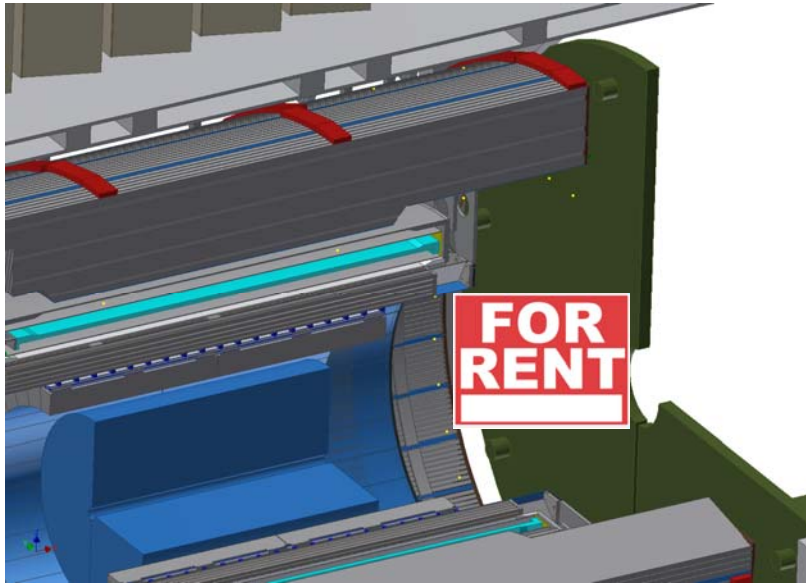


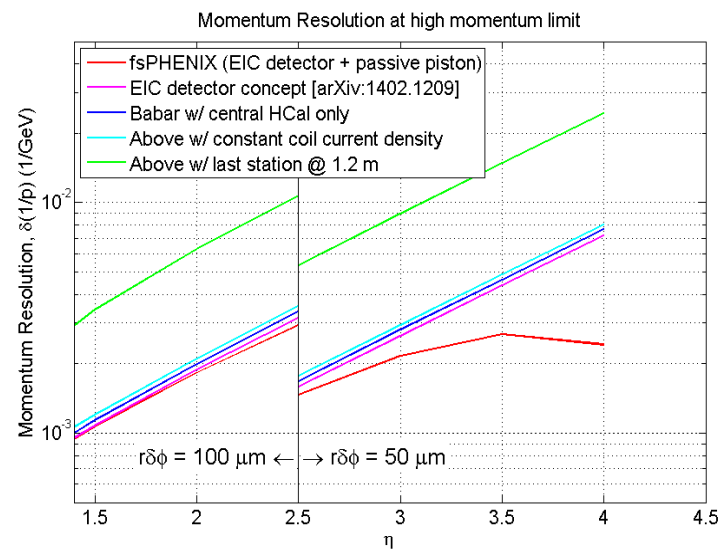
CD-0	**Apr 2016**
CD-1	**Nov 2017**
CD-2/3	**Jul 2018**
First Beam	**Jan 2022**
CD-4	**Jan 2023**

Assumption:
- **3 Months CR**
- **Will receive 1/12 per month during CR**

A New Possibility – fsPHENIX!

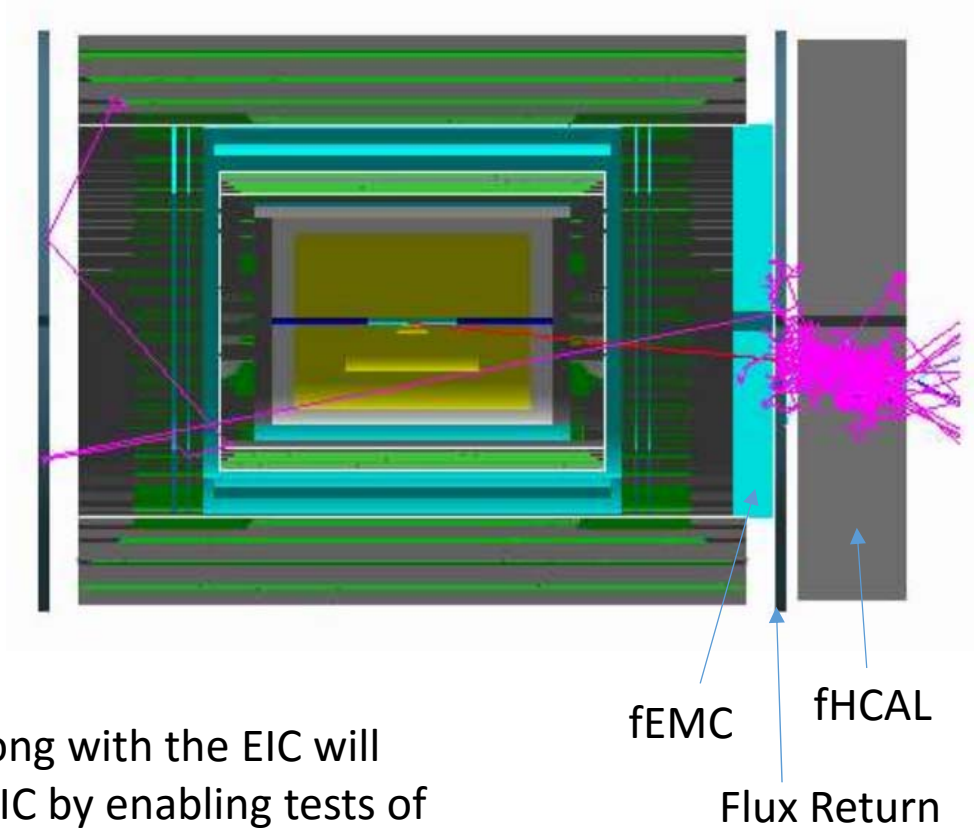
- The sPHENIX plug door is compatible with a forward detector suite (1.1< η <4.0)!
- Implement "forward sPHENIX":
  - GEM trackers and FEMC in magnetic field volume
    - PHENIX EMCal -> FEMC
  - FHCAL outside plug door
    - Plug door could be as thin as ~10cm
  - Roman Pots in beamline
  - Magnetic field shaper piston
  - Fits in 4.5m eRHIC space constraint





fsPHENIX – A Wealth of New Physics

- Additional instrumentation in the forward region will make available important and exciting new physics on the road to the EIC!
  - p+p – jet asymmetries, diffraction and SSA's, …
  - p+A - nFF's, saturation, DY, UPC's,…

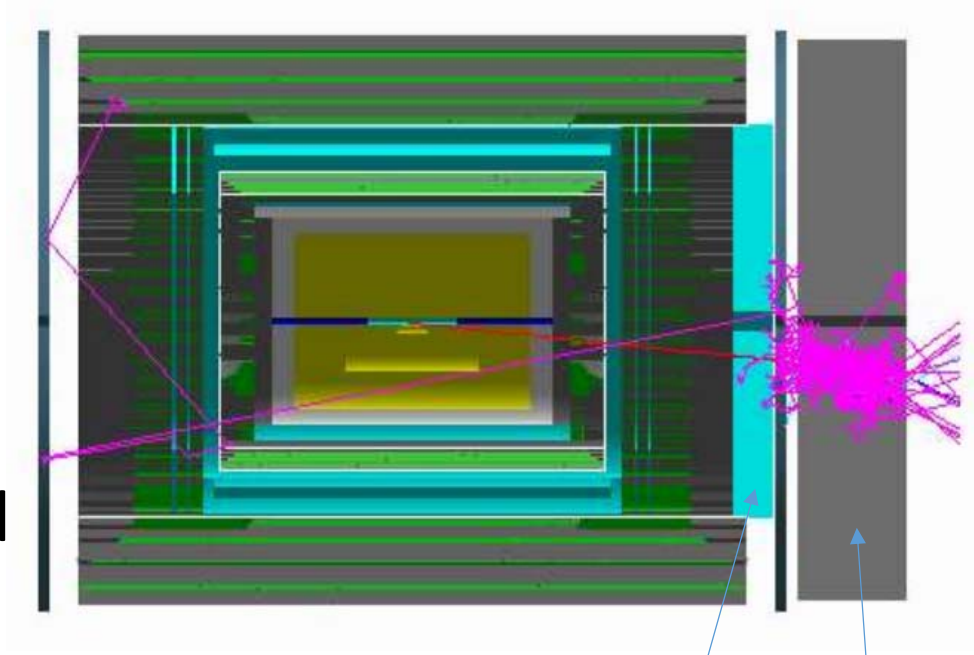


The availability of these measurement along with the EIC will substantially <u>enhance</u> the impact of the EIC by enabling tests of factorization and evolution for a variety of observables.

Draft of RHIC Cold QCD Plan released for comment, to be submitted to DOE soon.

What About Heavy Ions?

- Extended coverage for <u>both</u> calorimetry and tracking.
  - $-1.1 < \eta < 4.0$



- Opportunity to extend the study of long. dynamics in HI collisions
  - Energy flow, particle correlations, jet correlations, event plane correlations, …

- Broadens the physics reach of sPHENIX!

Conclusions

- sPHENIX is a major new project that will make available probes of the Quark Gluon Plasma with unprecedented precision.
  - How does a partonic shower propagate and evolve in the medium?
  - What are the relevant degrees of freedom in the plasma at different scales?
- A reference design for sPHENIX exists, development continues with key technology choices still to be made.
- An option for additional forward instrumentation (fsPHENIX) is being actively explored.
  - Extend the sPHENIX physics program to include p+p/p+A as well as longitudinal dynamics in HI collisions