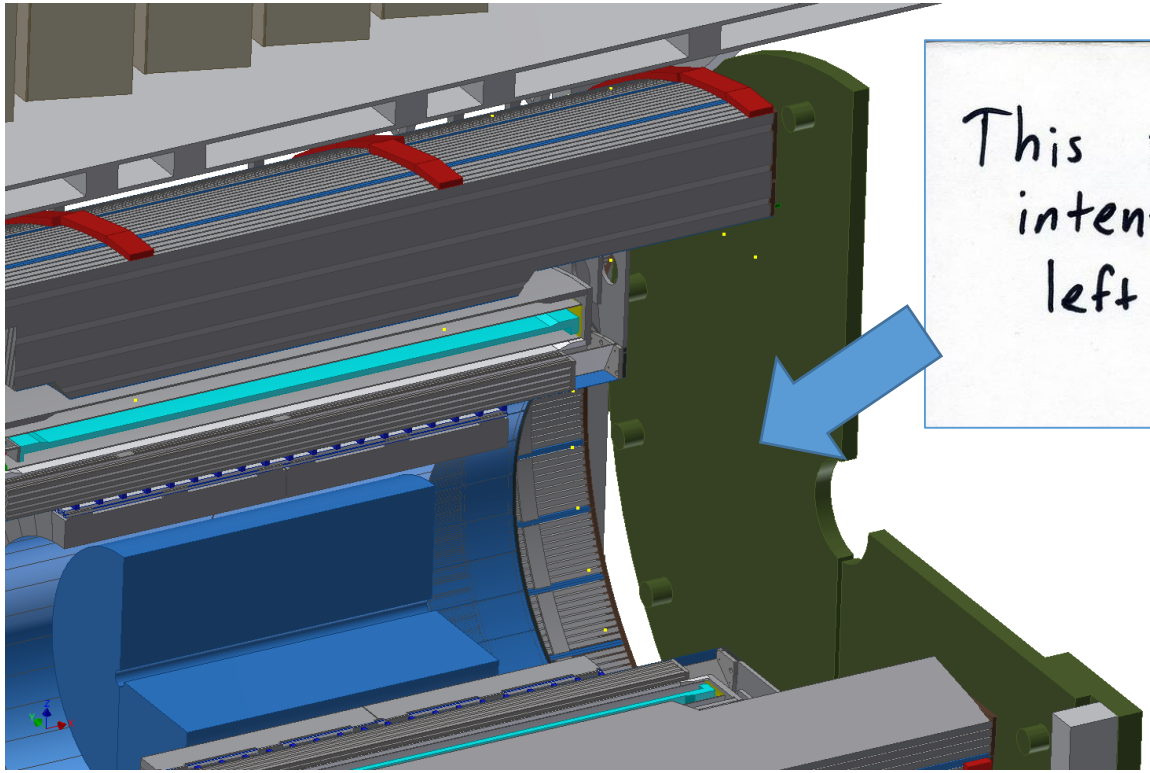
fsPHENIX:

A Detector Evolution for the Study of Nucleon Spin Structure and Cold Nuclear Matter at RHIC



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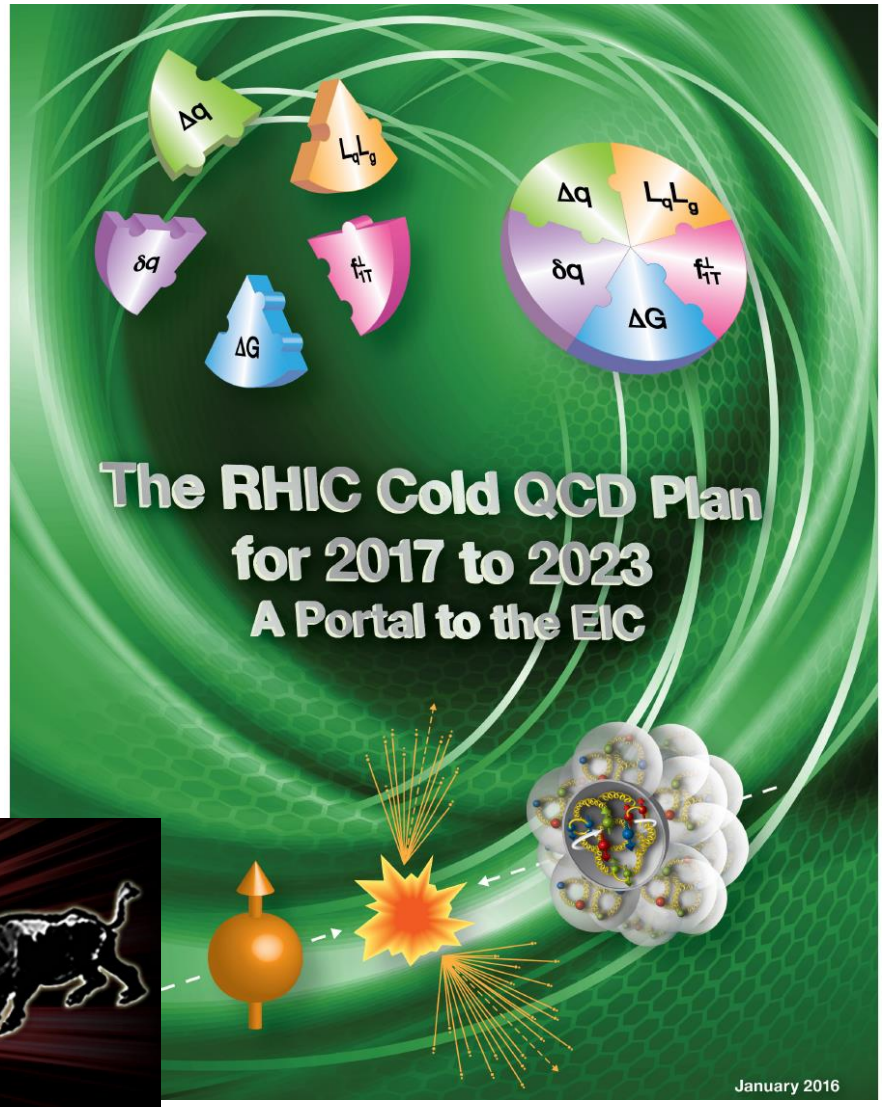
STATE

Outline

- The RHIC Cold QCD Plan
  - Physics opportunities in spin and CNM
- Forward Physics in RHIC's future
- sPHENIX and the fsPHENIX concept
- Conclusions

RHIC Cold QCD Plan

- Requested by DOE, submitted Feb 2016
  - Subject of RBRC workshop
- Lays out a comprehensive set of important measurements to be made on the road to an EIC



http://arxiv.org/abs/1602.03922

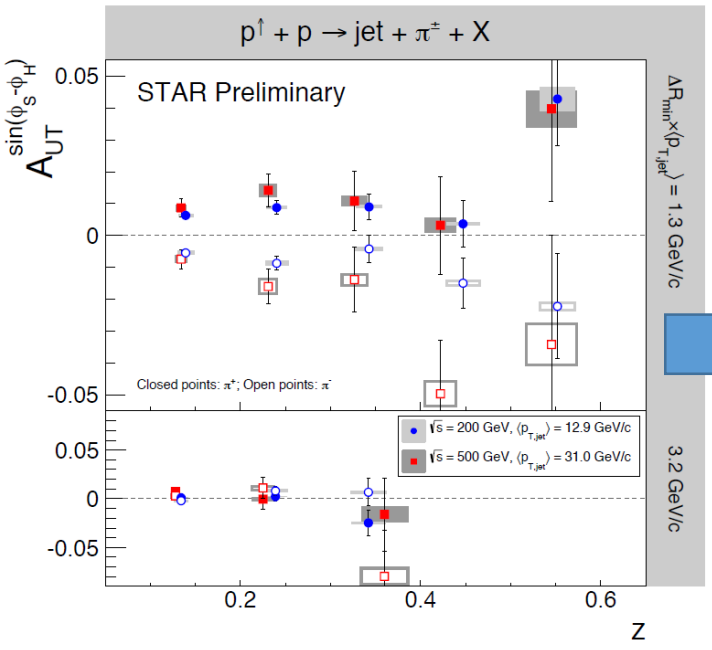
Physics Goals From Cold QCD Plan

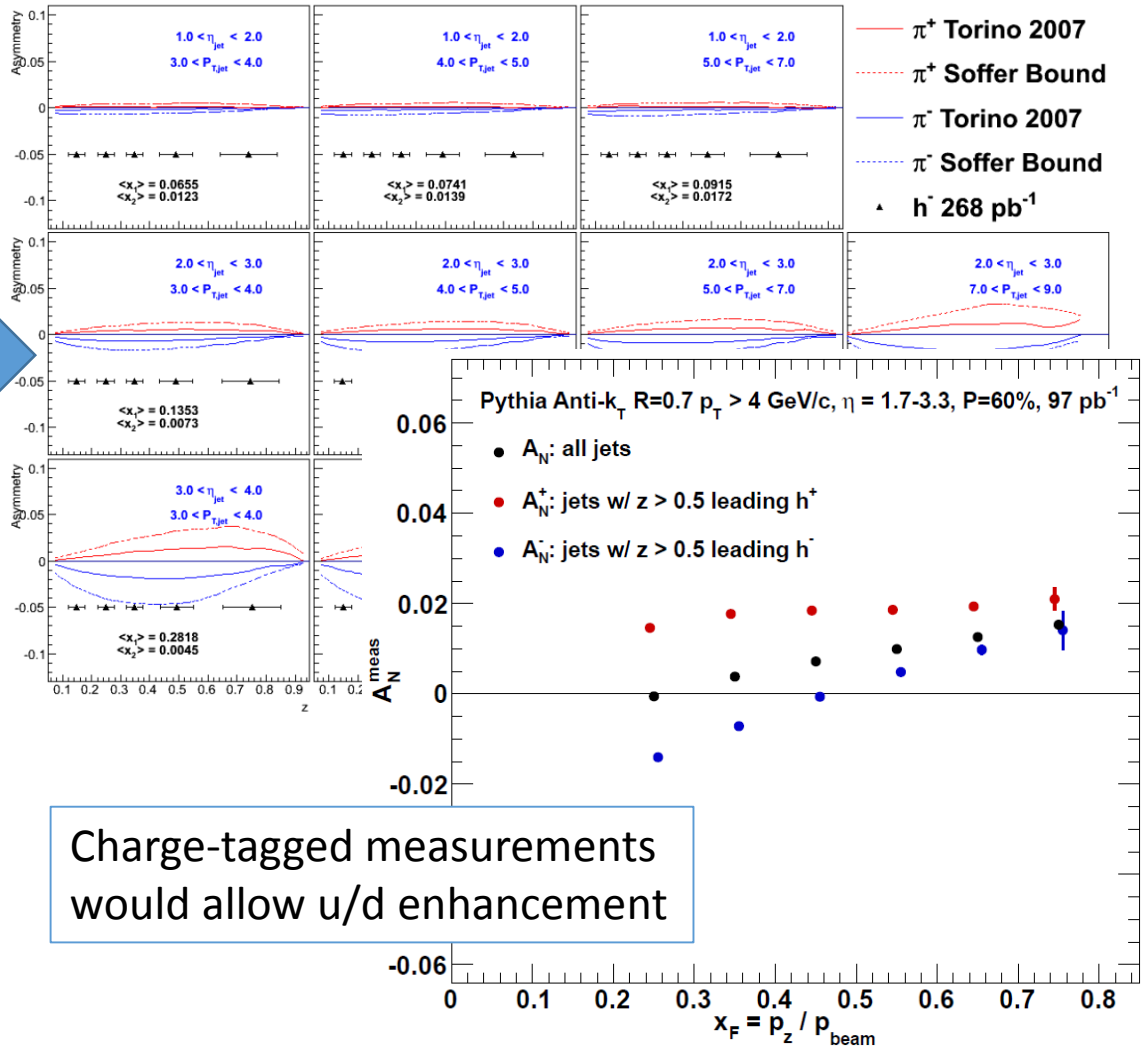
- **Key Physics Measurements**:
  - **Jets in polarized p+p (510 GeV):**
    - Kinematics limited in p+p 200 (transverse), better kinematic reach at 510 GeV
    - Jet A_N, angular distribution in jets (h^- good proxy for π^- w/o PID)

For many of these measurements RHIC offers *unique* capabilities

  - **DY and Direct Photons in p+A:**
    - Measurements of saturation, A-scan required
  - **Diffraction in polarized p+p (200 GeV):**
    - A_{UT} from single-diffractive events (pol. proton breaks up).
  - **Ultraperipheral Collisions in p+Au:**
    - p-shine (unpolarized): gluon impact parameter distribution via J/Ψ
    - Au-shine (polarized): access GPD E_g via J/Ψ production (A_{UT})
      - Set the scale for a program to measure GPD E_g at the EIC

Jets and Polarized Jet Structure



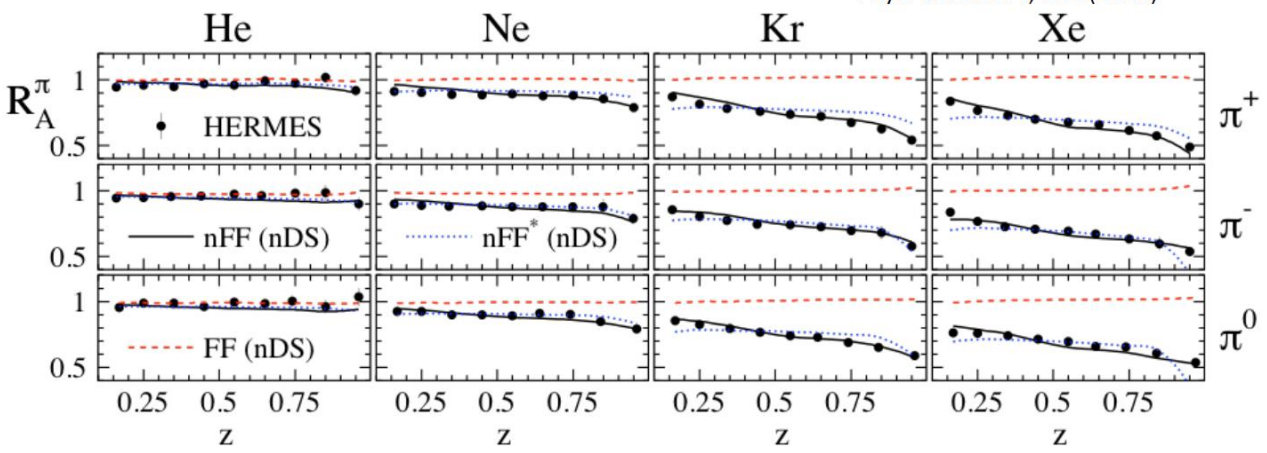


Future high luminosity measurements will allow detailed differential study of spin-dependent fragmentation

Charge-tagged measurements would allow u/d enhancement

Nuclear Fragmentation Functions

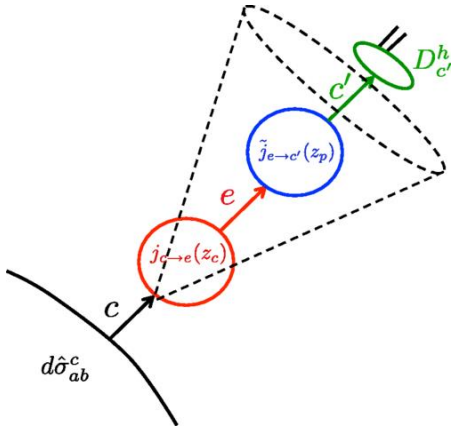
Phys. Lett. B577, 37 (2003)
Phys. Lett. B684, 114 (2010)

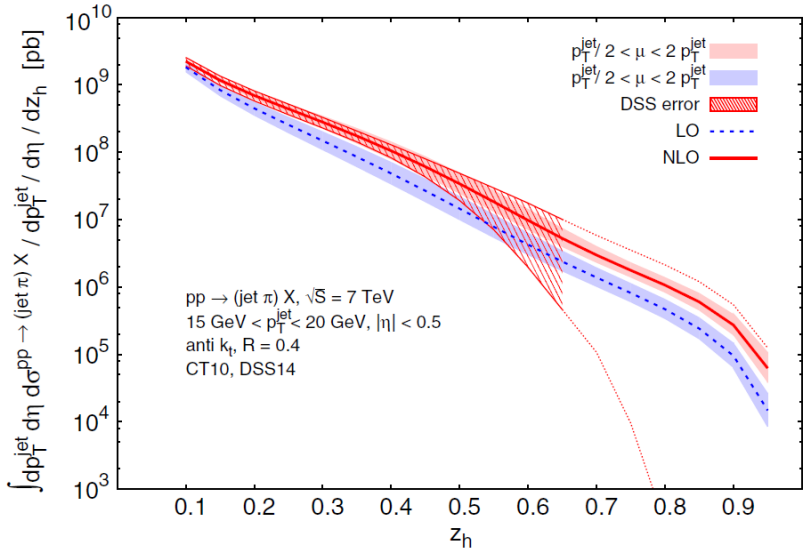


Hadron production in e+A suppressed compared to e+p

Kaufmann, Mukherjee and Vogelsang
Phys.Rev.D 92 5, 054015

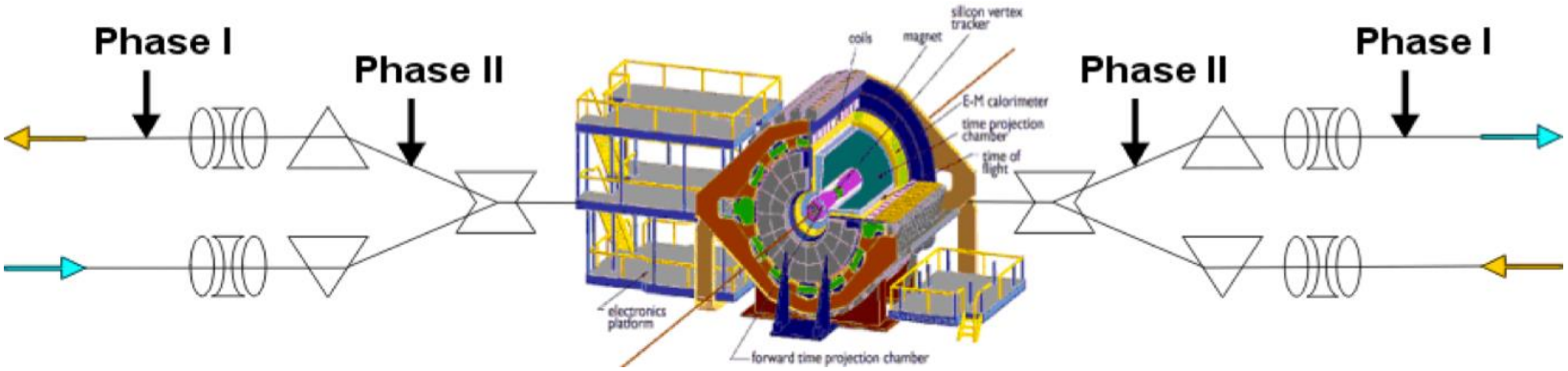
Access fragmentation functions (FF) through p+p(A) -> (jet *h*) X

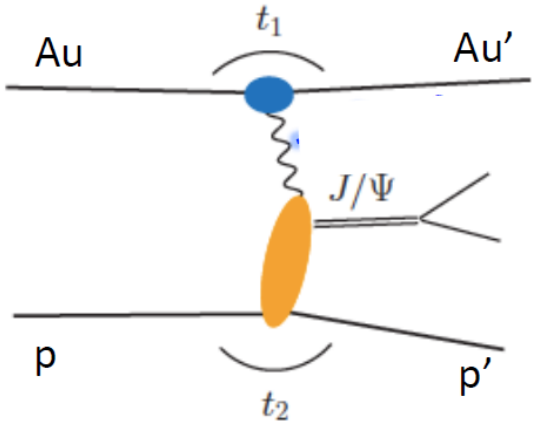




Diffraction/UPC

Data taken in 2015/17 by STAR will elucidate the diffractive contribution to A_N a RHIC.





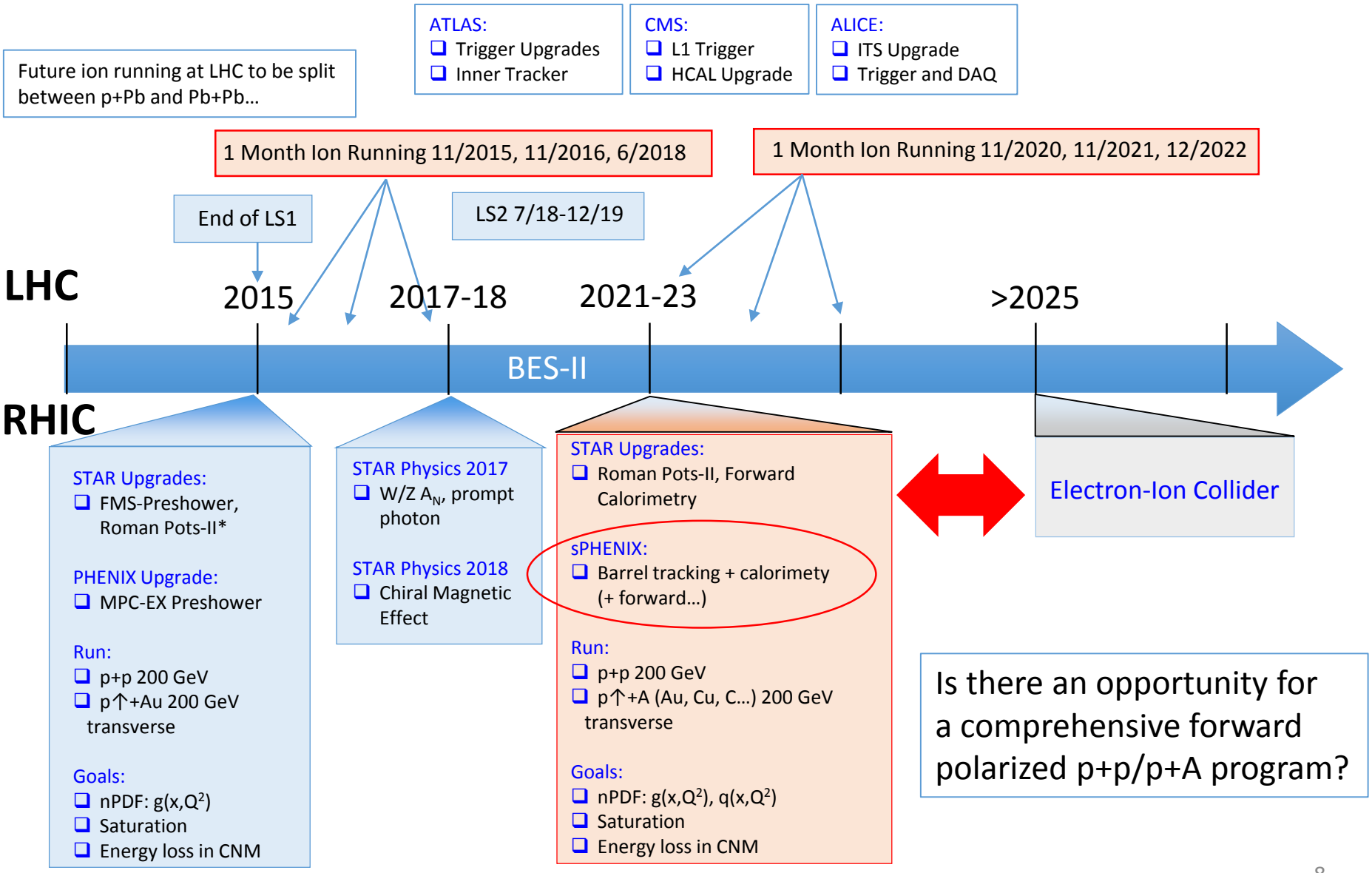
$$A_{UT}(\tau,t) \sim \frac{\sqrt{t_0 - t}}{m_p} \frac{\mathrm{Im}(E * H)}{|H|} \qquad t = \frac{M_{J/\Psi}^2}{s}$$

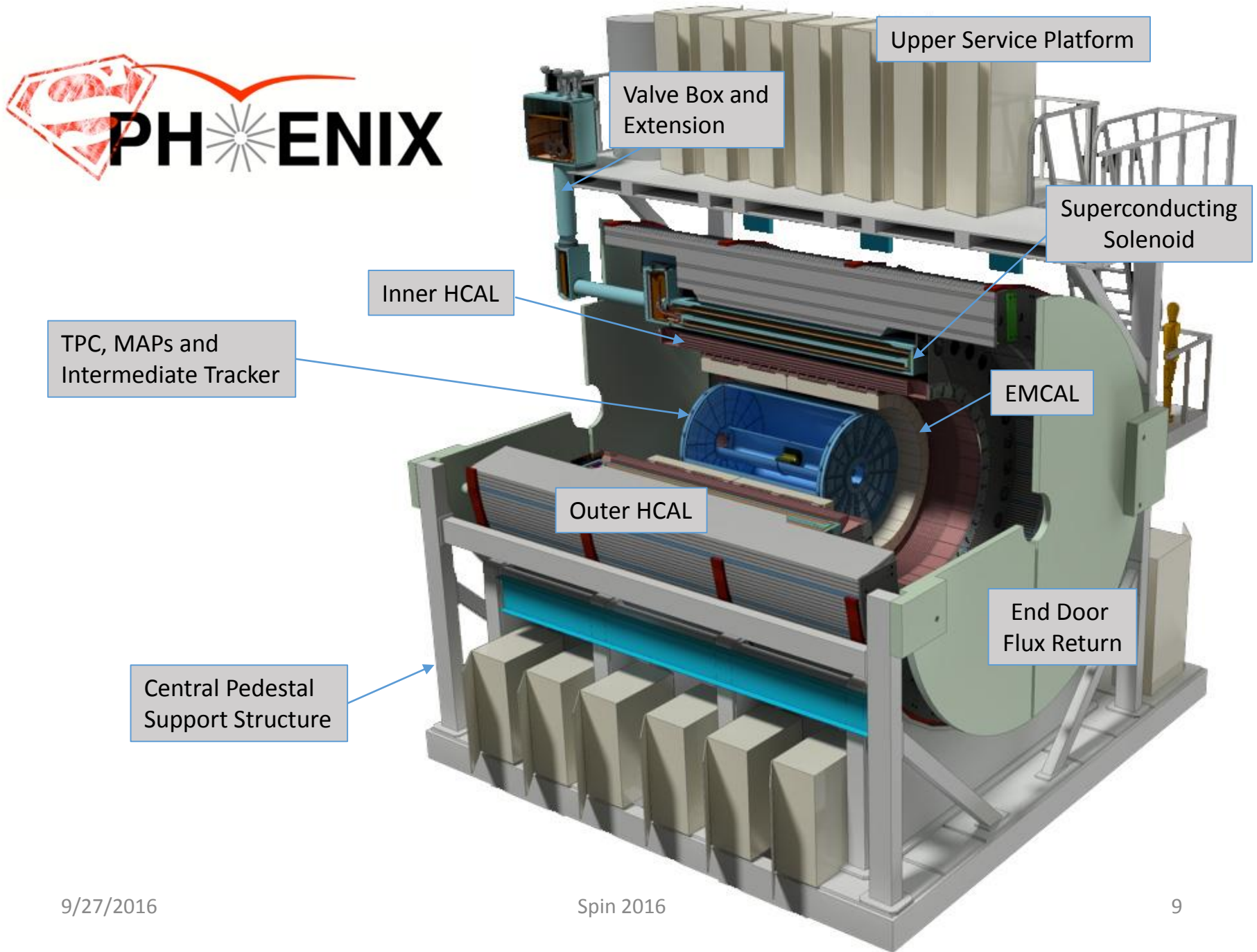
UPC collisions in p+A will allow study of:

- The gluon spatial distribution in nuclei ("proton shine")
- The gluon helicity flip Generalized Parton Distribution (GPD) E_g ("A-shine")

Requires Roman Pots, good t-acceptance and high luminosity

A Timeline for the LHC and RHIC

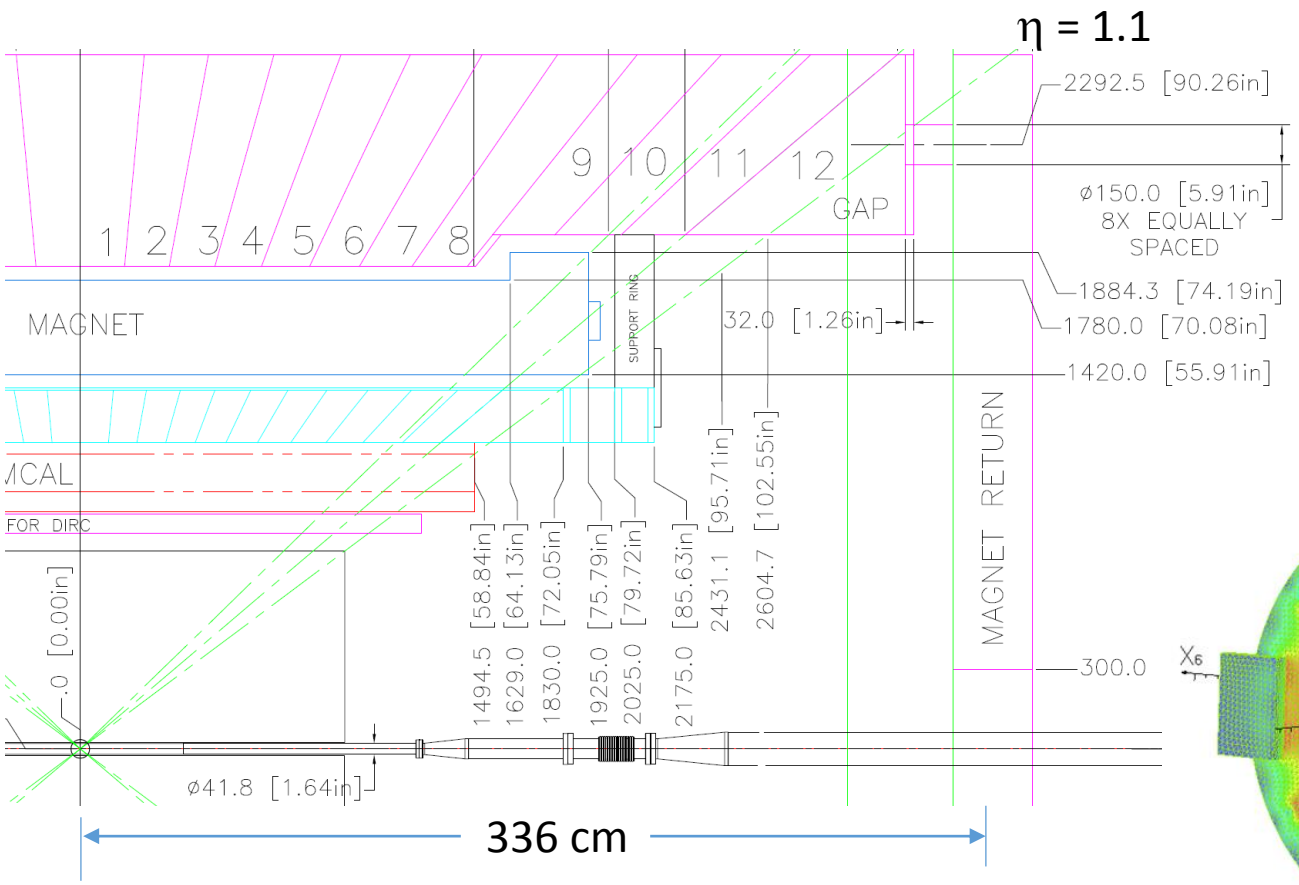



Upper Service Platform
Valve Box and Extension
Superconducting Solenoid
Inner HCAL
TPC, MAPs and Intermediate Tracker
EMCAL
Outer HCAL
End Door Flux Return
Central Pedestal Support Structure

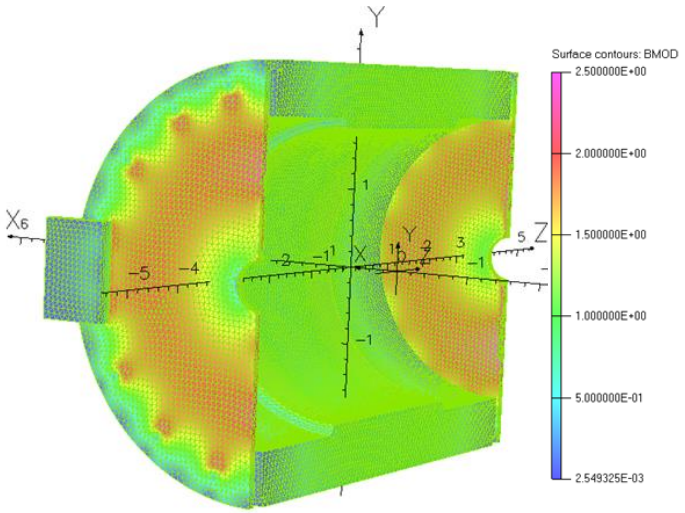
The PHENIX Detector Design

- **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…)

Current sPHENIX Magnet Design



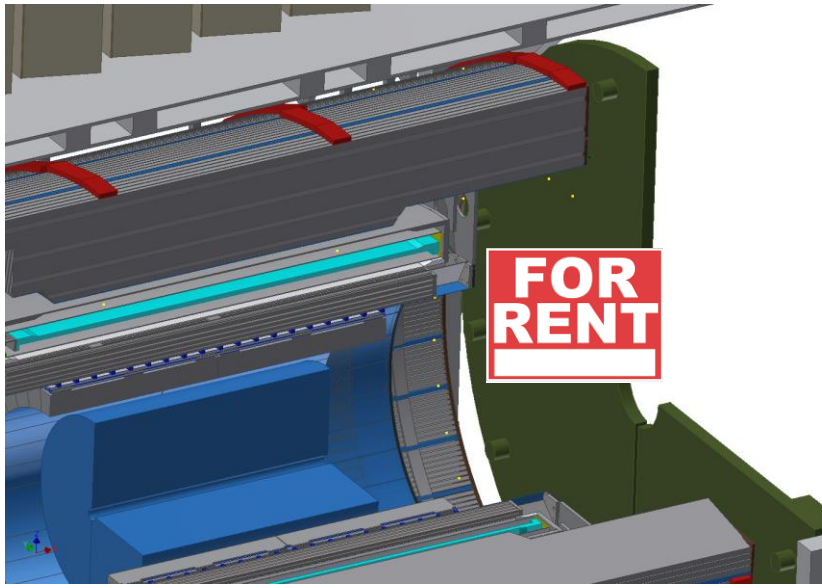
OPERA calculations show that a flux return only 10cm thick should be OK.



Current sPHENIX design well-suited to forward instrumentation!

A New Possibility – fsPHENIX!

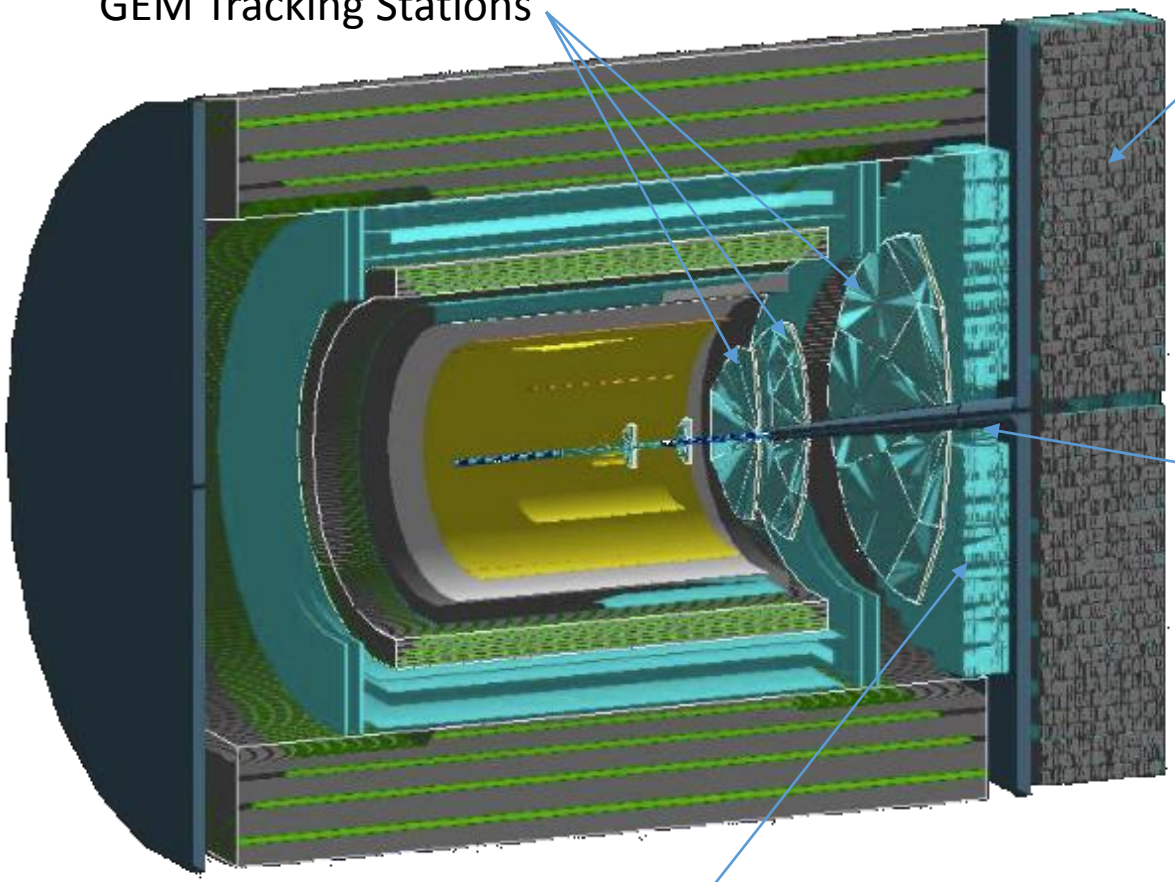
- The sPHENIX plug door is compatible with a forward detector suite!
- Implement “forward sPHENIX”:
  - GEM trackers and FEMC in magnetic field volume
    - PHENIX EMCal (PbSc) -> FEMC
  - FHCAL outside plug door
    - Plug door could be as thin as ~10cm
  - Magnetic field shaper piston
  - Roman Pots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



fPHENIX

Pb/Sc sandwich hadronic calorimeter (NEW)
10 x 10 x 100 cm^3 towers
$(1.2 < \eta < 4.0)$

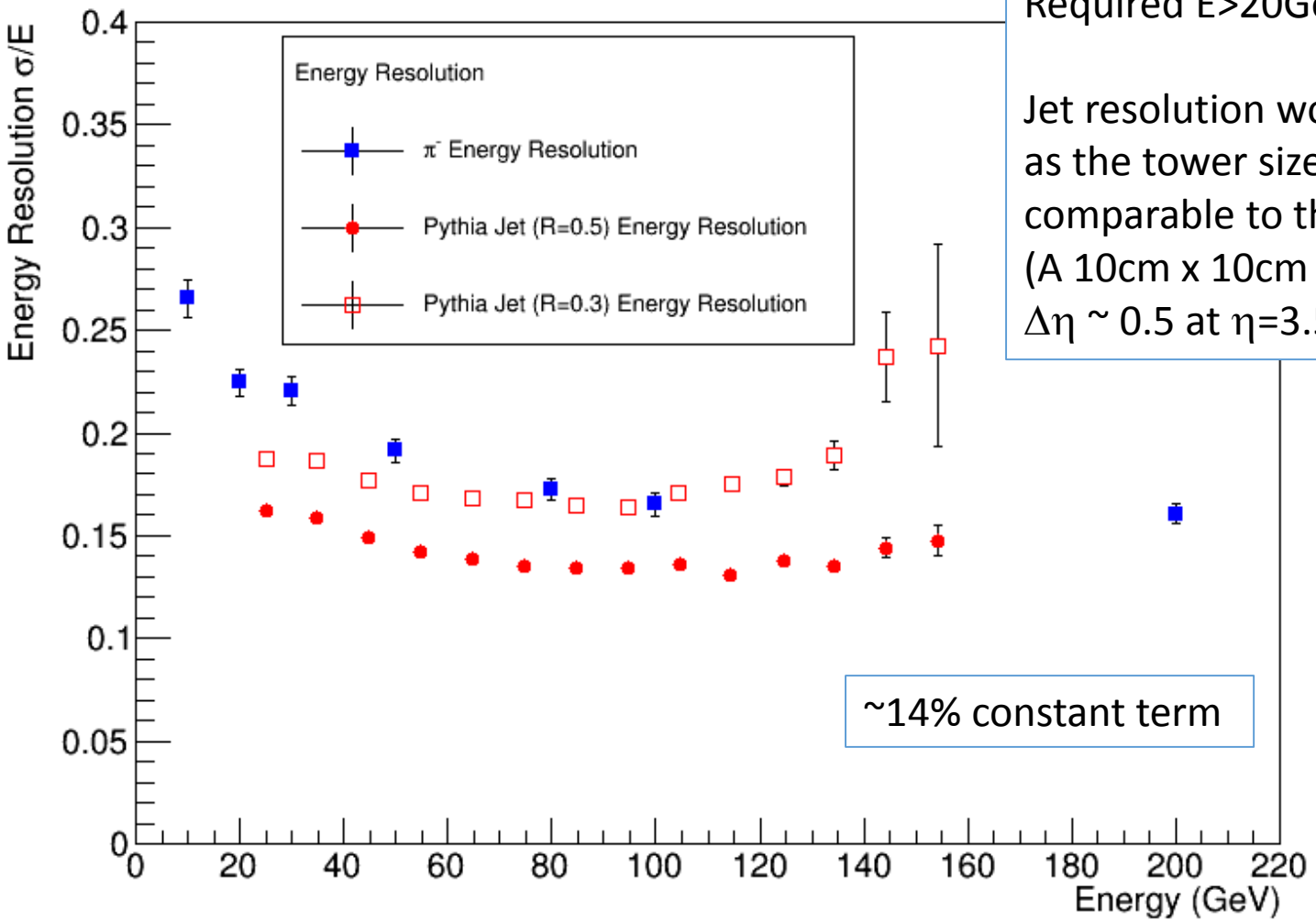
GEM Tracking Stations



20x20 array of
2.2 x 2.2 x 18 cm^3
PbW (PHENIX MPC)
crystals with 10x10
square hole
(300 crystals
total)
$3.0\text{-}3.3 < \eta < 4.0$

PHENIX PbSc modules (5.5 x 5.5 x 33 cm^3) organized in groups of four modules (3152 modules or 788 groups of 4)
$(1.4 < \eta < 3.0\text{-}3.3)$

Jet Energy Resolution



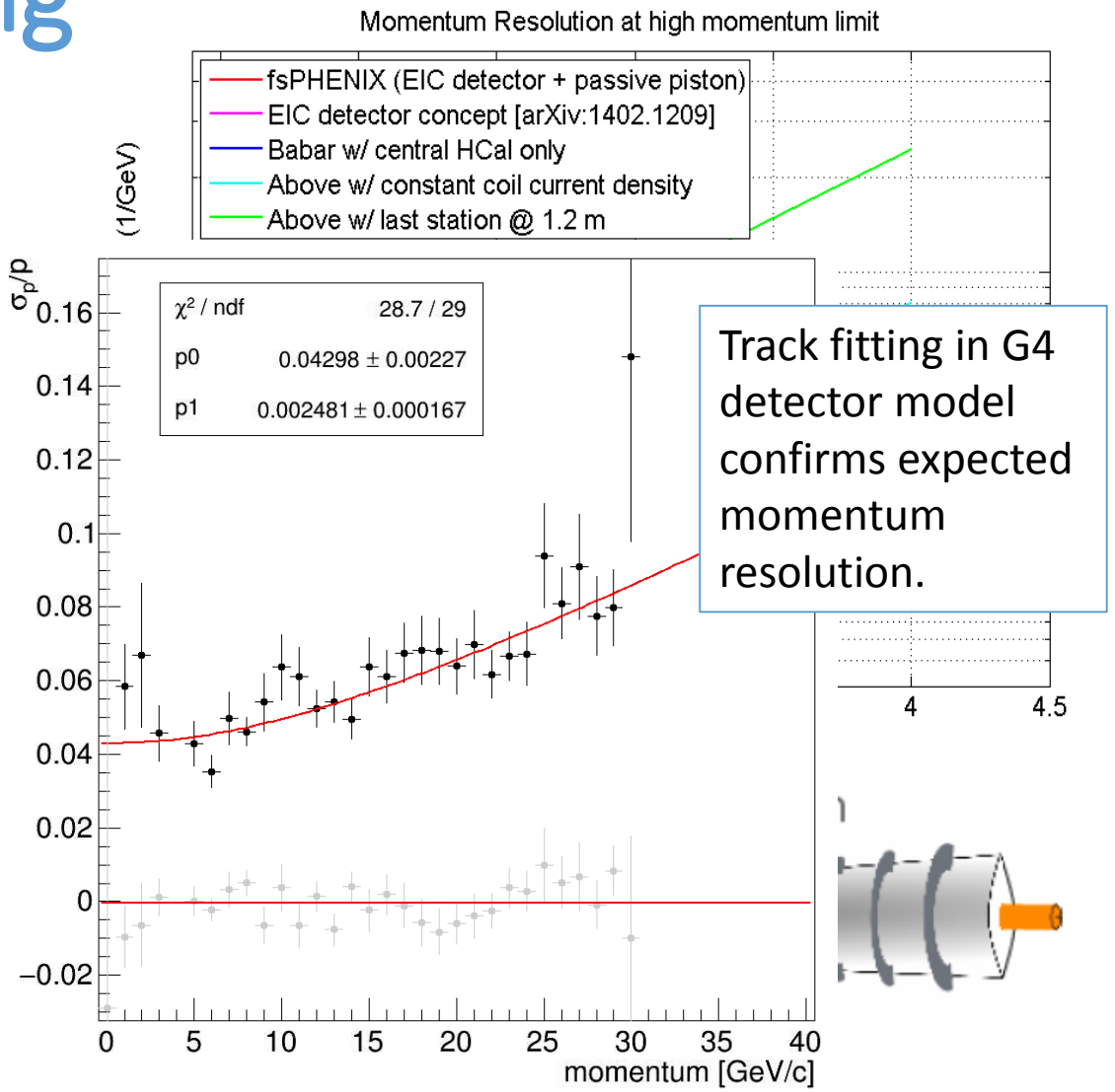
Jets from 510 GeV Pythia8, using jet trigger, jet energy is correlated with pseudorapidity. Required E>20GeV, p_T>5GeV.

Jet resolution worsens at high η as the tower size gets comparable to the cone size. (A 10cm x 10cm FHCAL tower is $\Delta\eta \sim 0.5$ at η=3.5.)

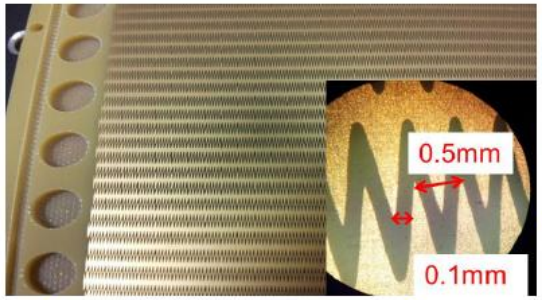
~14% constant term

Forward Tracking

- Large area GEM tracking stations at z=120, 150, 275cm ($1.45 < \eta < 4.0$)
  - Space left between ST1 and 2 for future PID
- Additional passive field shaper piston to enhance field shape for improved momentum resolution at high η.



Forward GEM Trackers



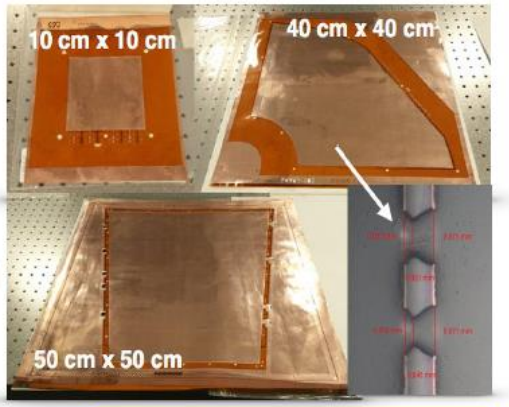
NIM A 811 (2016) 30-41

Florida Institute of Technology (FIT)

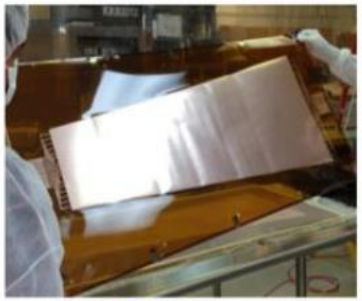
- Recently submitted a results of their large area (~1 m) triple-GEM detector to NIM A for publication.
- Successfully used zig-zag readout as a means to maintain good sp atial resolution while reducing number of readout channels needed
- σ_φ = 193 μrad

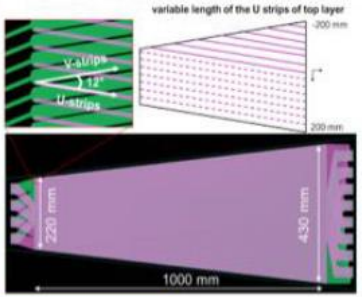
Temple University (TU)

- Have been working with US company Tech-Etch towards commercializing la rge-area GEM foils.
- Recently published results of electrical and geometrical foil quality



NIM A 802 (2015) 10-15





NIM A 808 (2016) 83-92

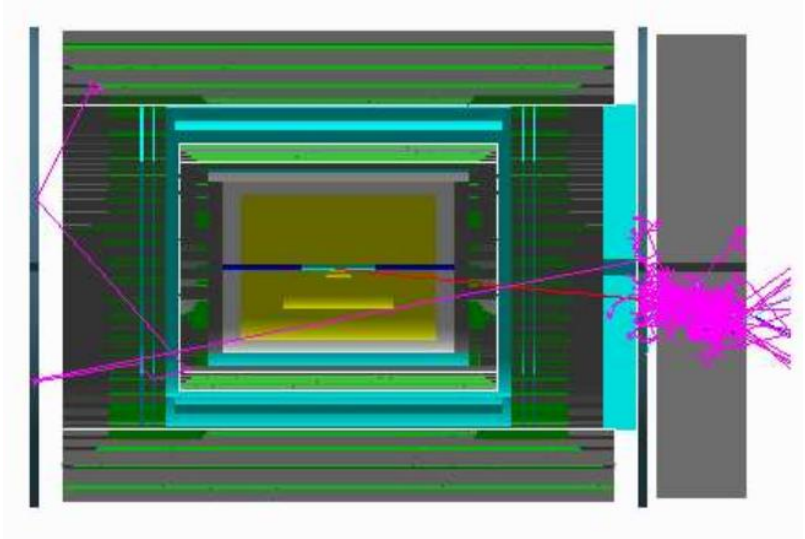
University of Virgina (UVa)

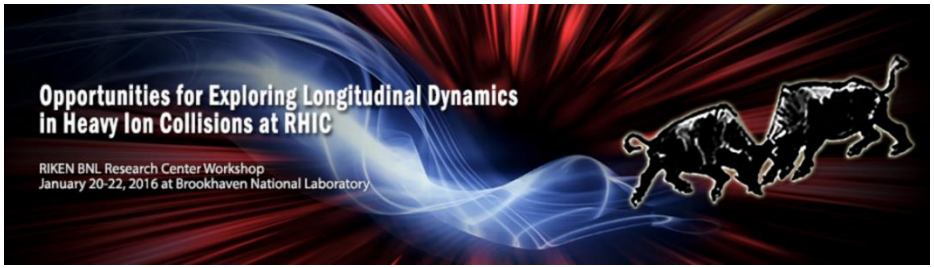
- Recently published results on their large-area (~1 - m)/ light weight triple GEM detector
- The detector successfully implemented 2D stereo -angle (U-V strips) readout
- σ_r = 550 μm, σ_φ = 60 μrad

Strong tie-ins with existing EIC R&D efforts!

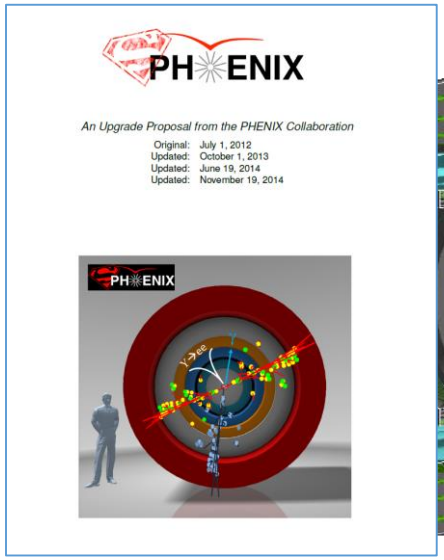
What About Heavy Ions?

- Extended coverage for <u>both</u> calorimetry and tracking.
  - $-1.1 < \eta < 4.0$
- Opportunity to extend the study of longitudinal dynamics in HI collisions:
  - No new data since PHOBOS/BRAHMS
  - State-of-the-art hydro fails to explain PHOBOS high rapidity – hydro needs to know longitudinal dynamics!
  - Particle correlations over a wide rapidity range could shed light on the *very initial* stages of a HI collision



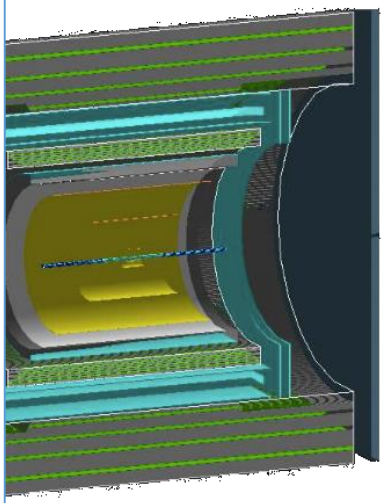


A Detector Evolution



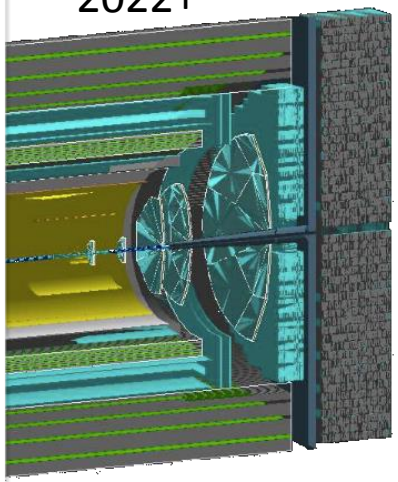
arXiv:1501.06197

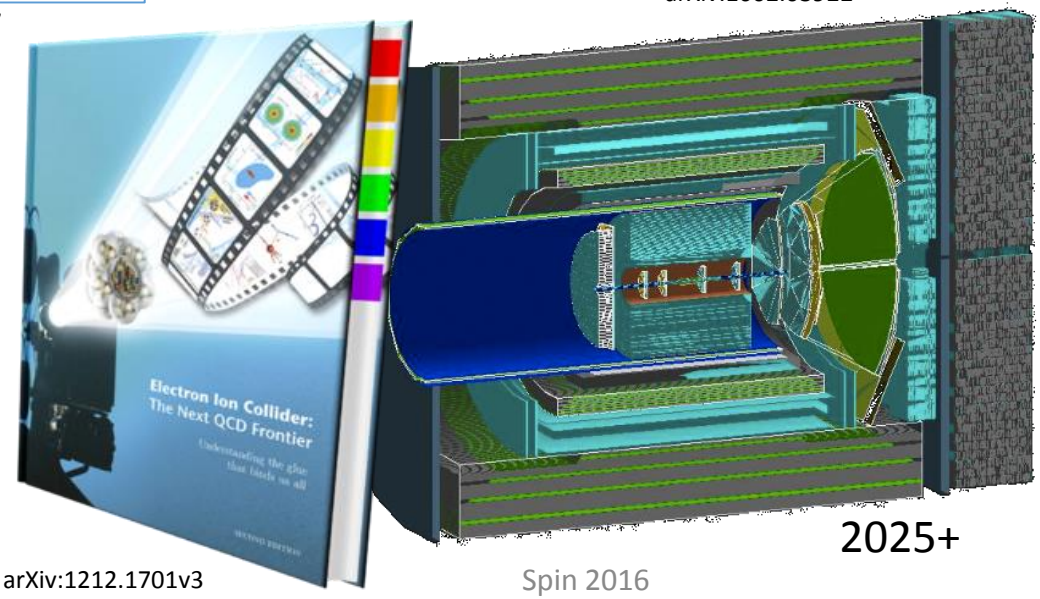
2021-2022



arXiv:1602.03922

2022+





2025+

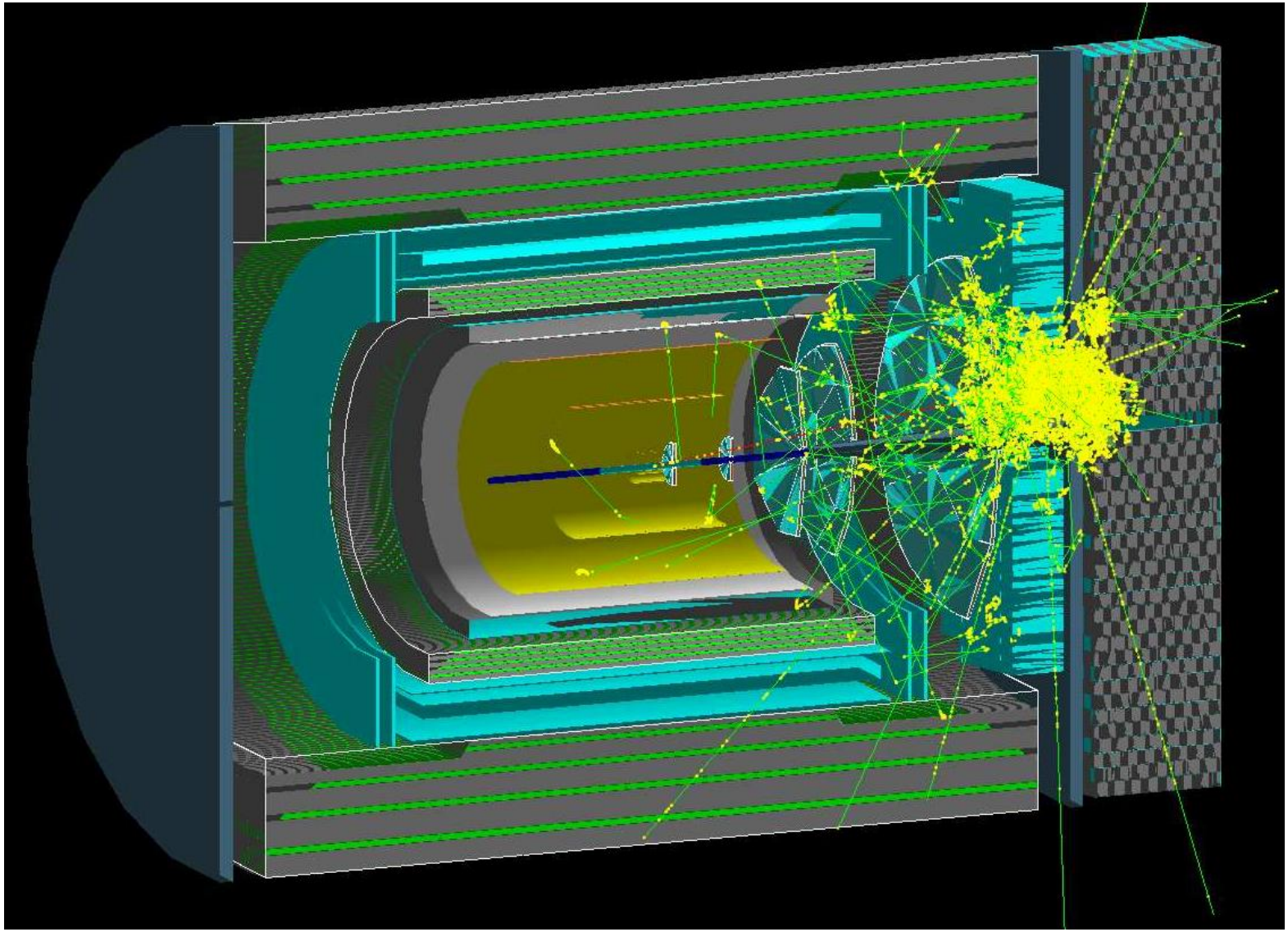
The forward detectors for fsPHENIX could be re-used for an EIC detector!

arXiv:1212.1701v3

Conclusions

- There is a wealth of unexplored physics in the forward region at RHIC!
- sPHENIX is a major new project that will make available probes of the Quark Gluon Plasma with unprecedented precision.
- An option for additional forward instrumentation added to sPHENIX (fsPHENIX) is being actively explored.
  - Extend the sPHENIX physics program to include p+p/p+A as well as longitudinal dynamics in HI collisions
  - Substantial re-use of existing detector systems for calorimetry
  - Tie-ins with EIC R&D as well as re-use of equipment for future EIC detector
  - A “Cold QCD” Topical Group recently formed in sPHENIX
  - Pushing towards a new fsPHENIX LOI in 2017

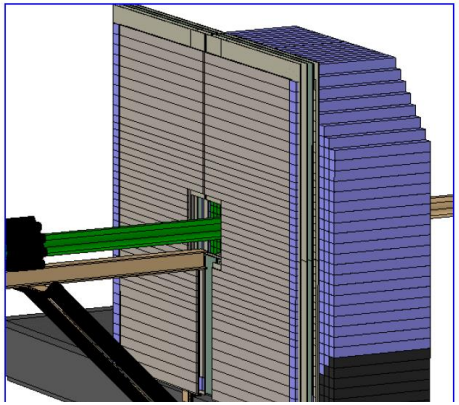
No longer left blank…



BACKUP

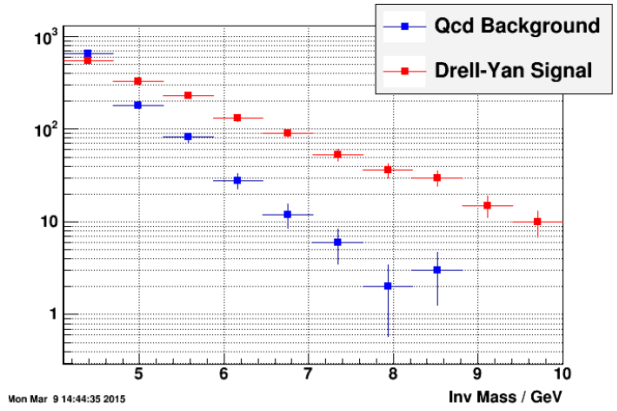
Forward Physics with STAR

- The existing (or soon to exist) STAR detector already has significant forward capabilities:

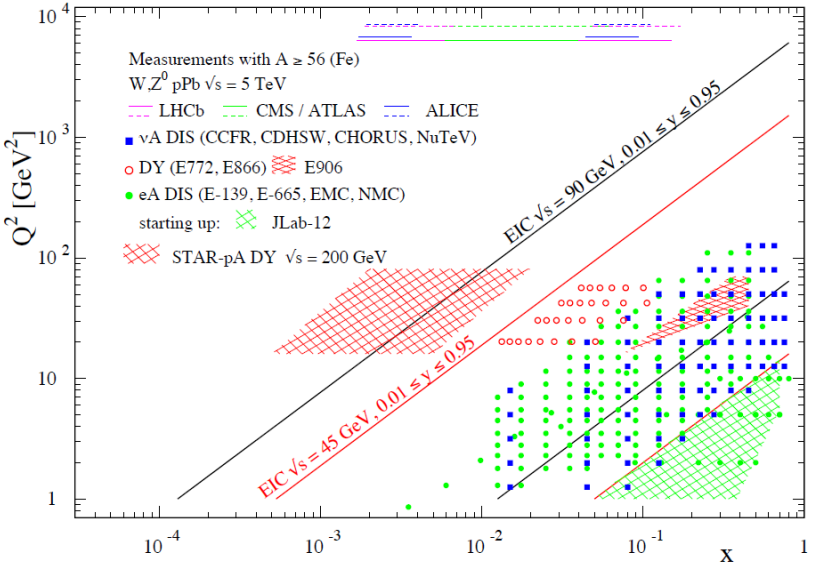


FMS (EMCal) and preshower in place

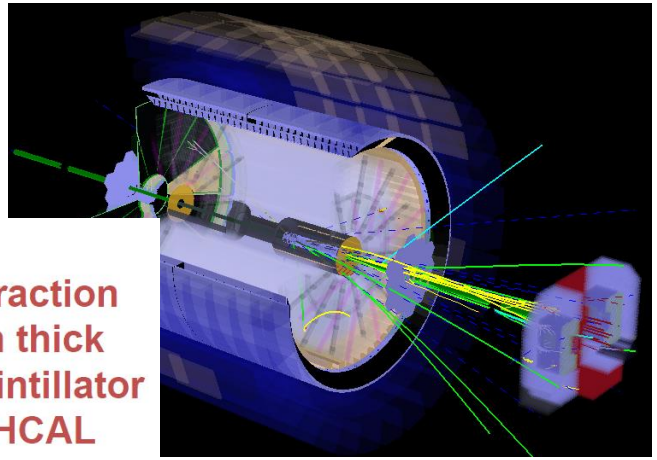
Additional post-shower planned for Run-17; enables DY -> e^+e^- measurements



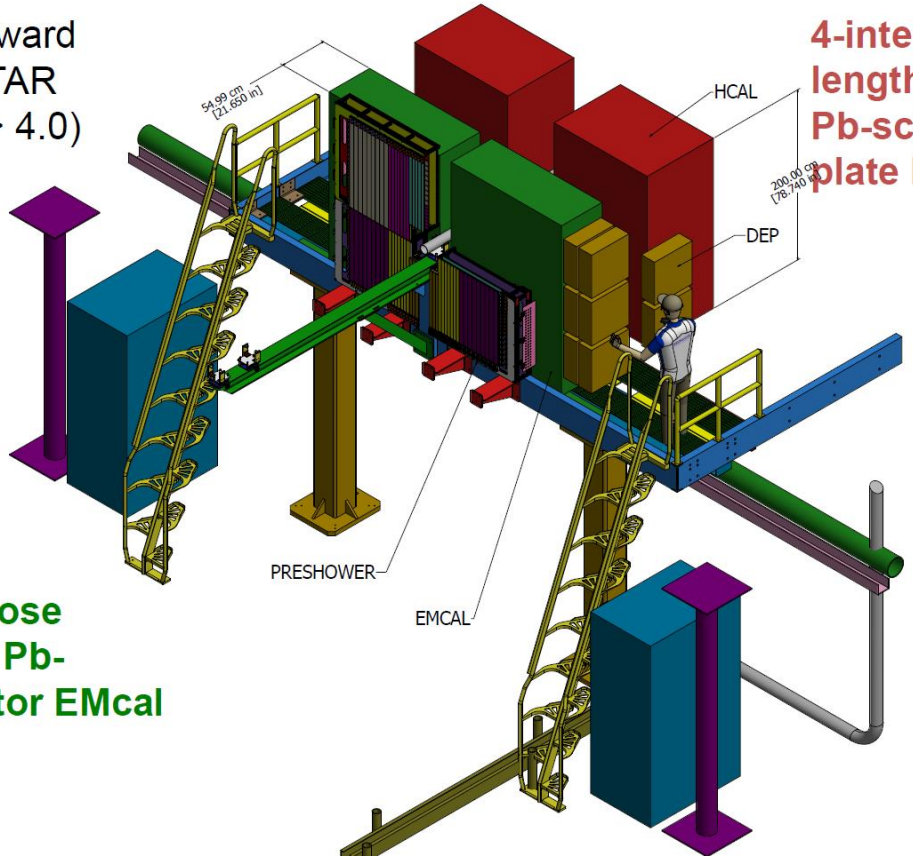
Coverage for nPDFs extended even compared to EIC!



STAR 2020+



Install in forward region at STAR (2.3 > eta > 4.0)



4-interaction length thick Pb-scintillator plate HCAL

Re-purpose PHENIX Pb-scintillator EMcal

Similar physics calls for similar instrumentation….

Lots of opportunities for collaboration between STAR and fsPHENIX!

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Tracking:

Silicon mini-strip detector 3-4 disks at z ~70 to 140 cm
Each disk has wedges covering full 2π range in ϕ
and 2.5-4 in η (other options still under study)