The Path through sPHENIX and fsPHENIX Toward an EIC Detector at eRHIC

KLAUS DEHMELT

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FOR THE PHENIX COLLABORATION

Stony Brook University | The State University of New York

PHENIX

Realization of EIC

- US Nuclear Science Community is considering
  - High energy
  - High luminosity
  - Polarized proton*–electron
  - Electron-Ion

  * and smaller ion

  } Collider **EIC**

- Two possible scenarios
  - eRHIC: add up to 21 GeV electron beam facility to existing RHIC facility
  - MEIC: add 20 – 100 GeV proton (up to 40 GeV/u ion) beam facility to existing CEBAF facility

The eRHIC

see V. Litvinenko WG7 (278)

- eRHIC design is based on
  - Using one of the two RHIC hadron rings
  - Adding and using a multi-pass Energy Recovery Linac ERL
  - Possibility to have more than one Interaction Region I.R.
- Existing RHIC accelerator complex would provide
  - Polarized protons up to E = 250 GeV
  - Fully stripped uranium ions up to 100 GeV/u
- ERL would provide
  - Polarized electrons up to E = 16 GeV (21 GeV)

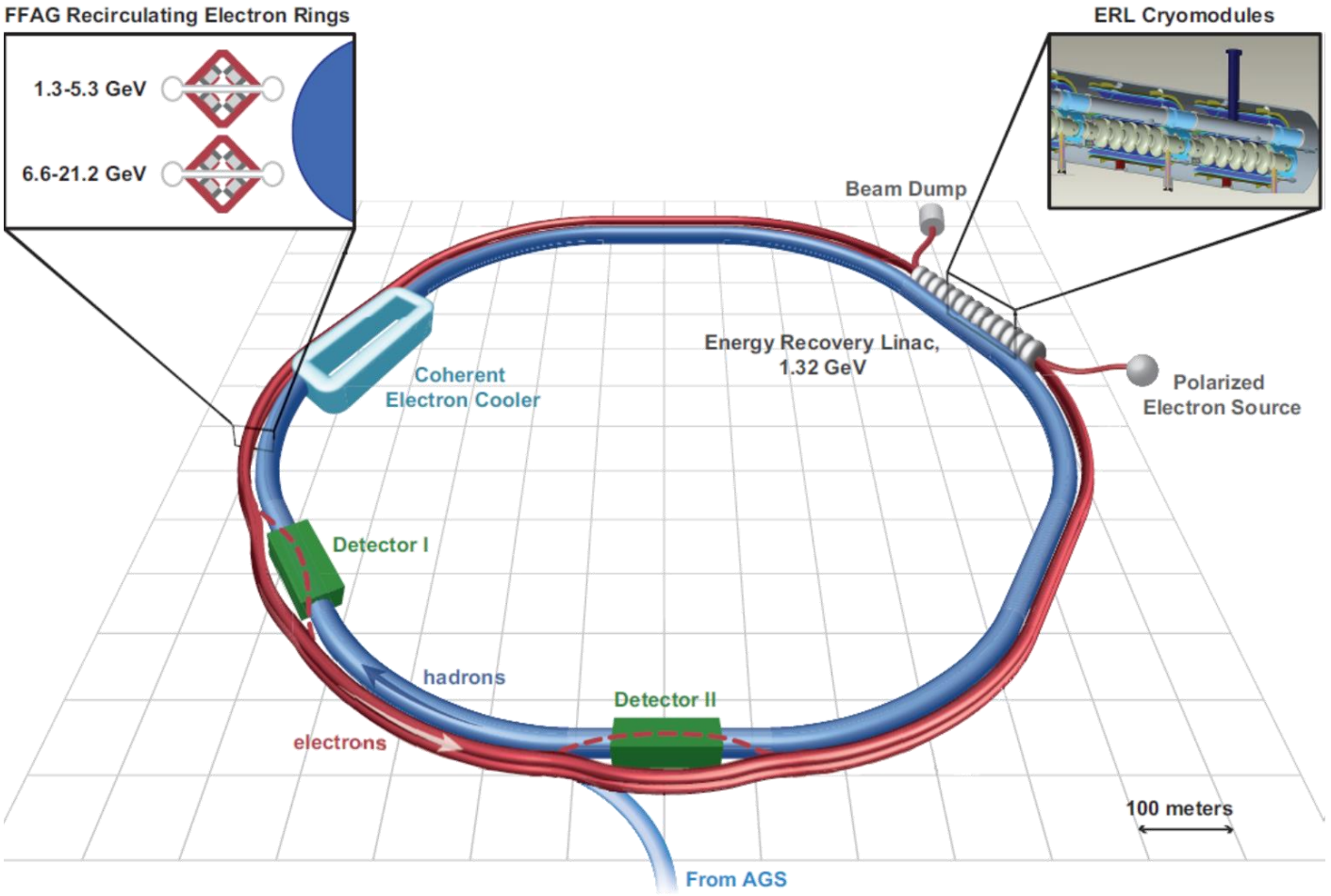
Up to $\sqrt{s}$=126 GeV (145 GeV) for polarized e-p collisions

Up to $\sqrt{s}$ = 80 GeV (91 GeV) for e-A (large A) collisions

$$10^{33} cm^{-2} s^{-1} \leq \mathscr{L} \leq 10^{34} cm^{-2} s^{-1} \left(\frac{\mathscr{L}}{2} \rightarrow \frac{\mathscr{L}}{3}\right)$$

The eRHIC

eRHIC design study arXiv:1409.1633



Day-1 eRHIC

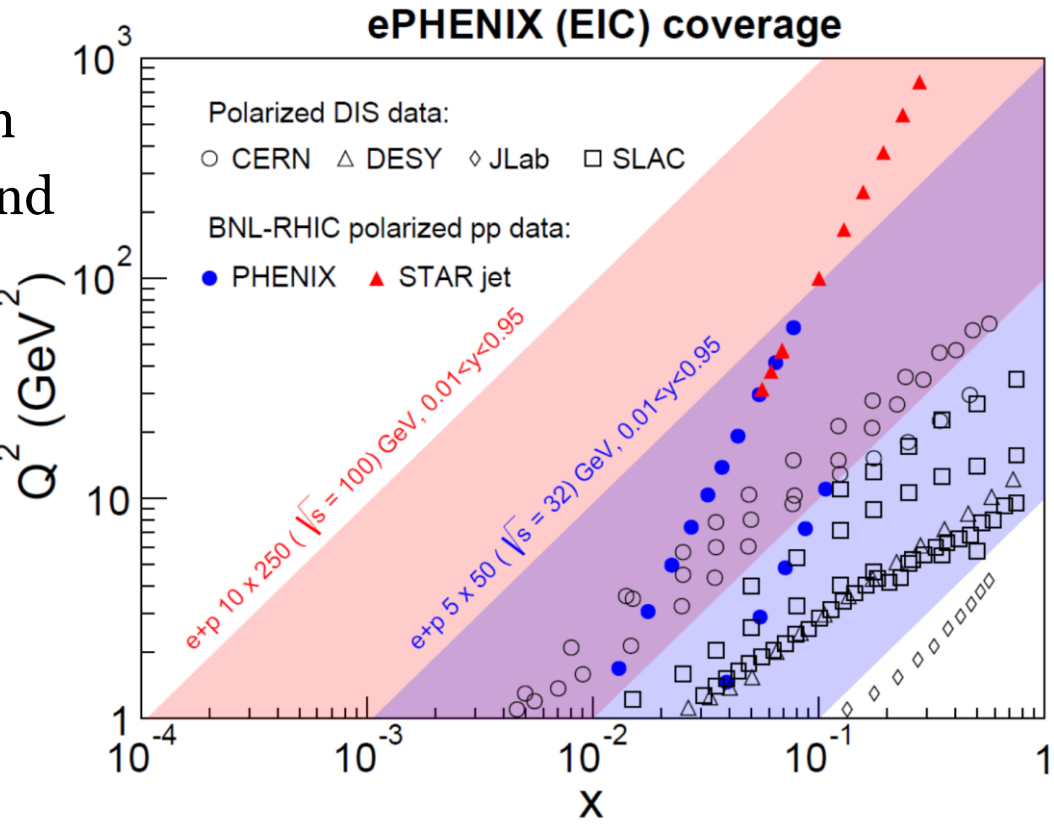
- Target is to provide eRHIC facility from day-1 with one high-luminosity intersection region
- Can take advantage of existing infrastructure in STAR and PHENIX experimental hall
- Day-1 eRHIC detector as successor of PHENIX built around the BaBar solenoid

Resources:

1. arXiv:1212.1701 - Electron Ion Collider: The Next QCD Frontier - Understanding the glue that binds us all
2. https://indico.bnl.gov/getFile.py/access?resId=0&materialId=11&confId=1483 - sPHENIX preConceptual Design Report
3. arXiv:1402.1209 - Concept for an Electron Ion Collider (EIC) detector built around the BaBar solenoid
4. arXiv:1409.1633 - eRHIC Design Study: An Electron-Ion Collider at BNL

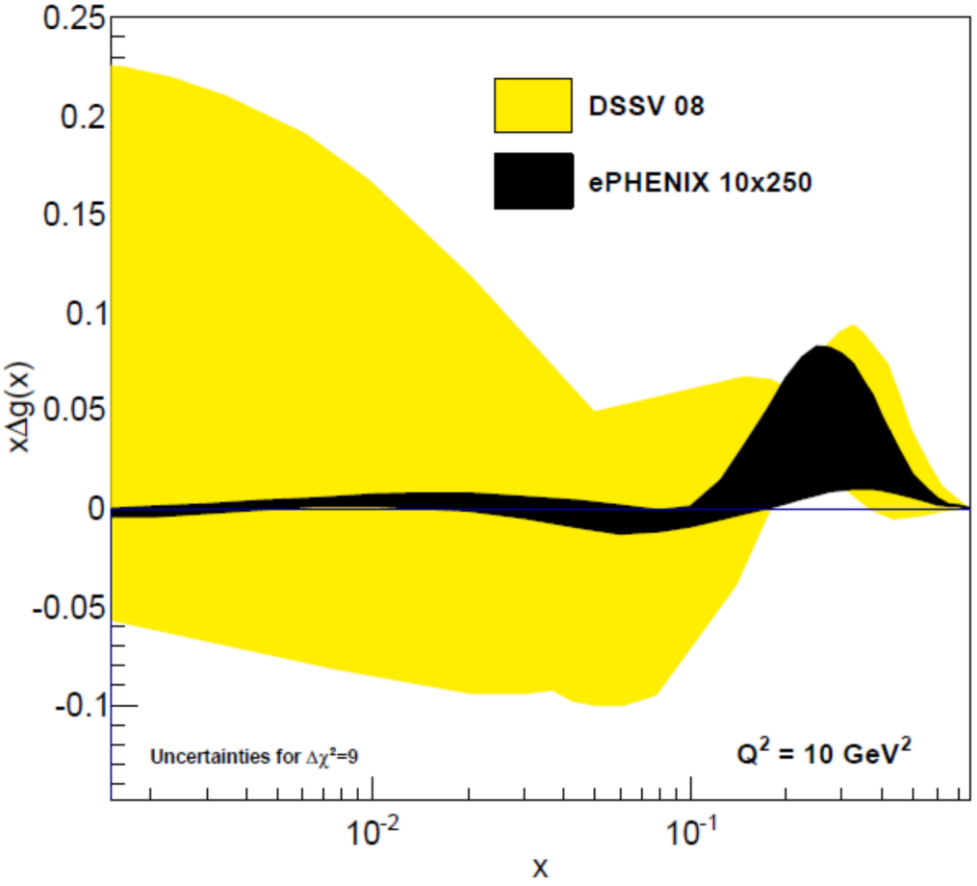
Physics Deliverables of Day-1 eRHIC Detector

- Longitudinal spin of the proton
- Transverse motion of quarks and gluons in proton
- Tomographic imaging of the proton
- Hadronization and its modification in nuclear matter
- QCD matter at extreme gluon density



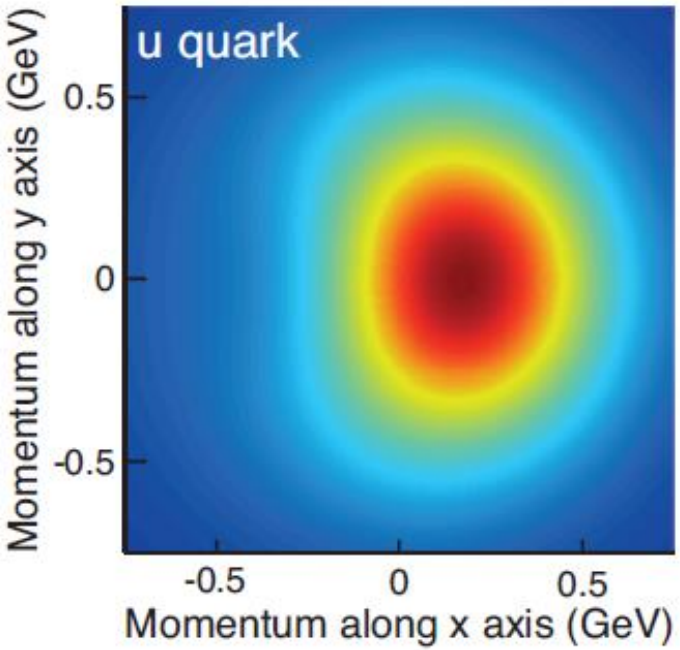
Spin Structure

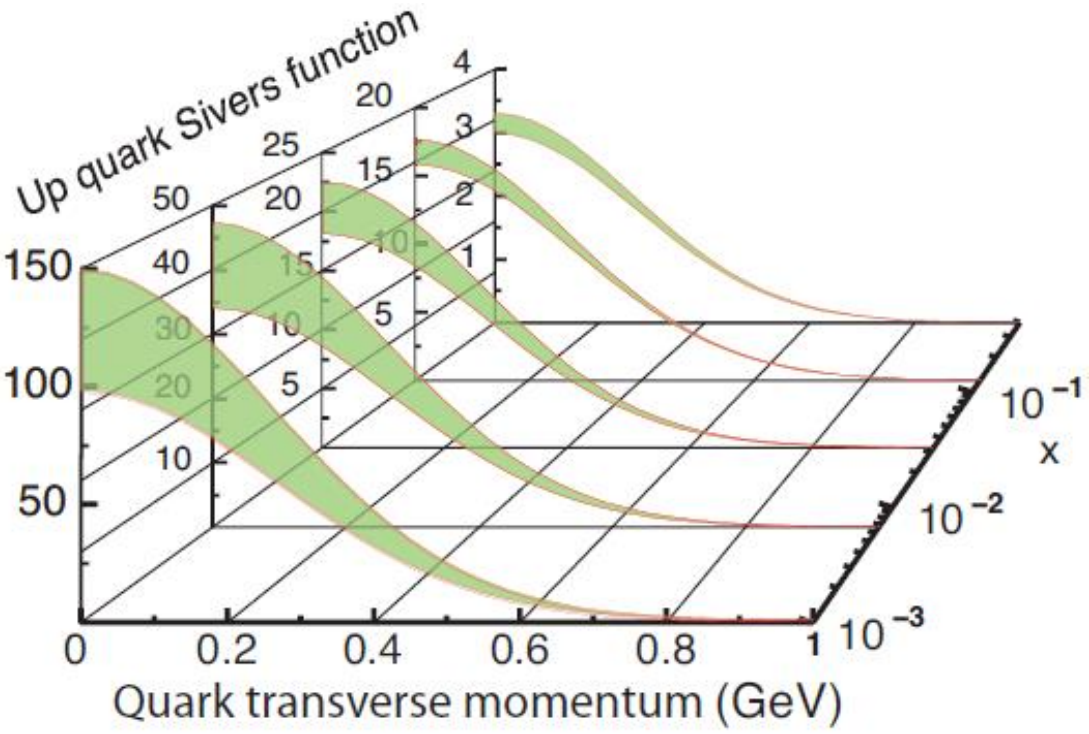
- Reduction in uncertainty on gluon longitudinal spin distribution



Transverse Motion

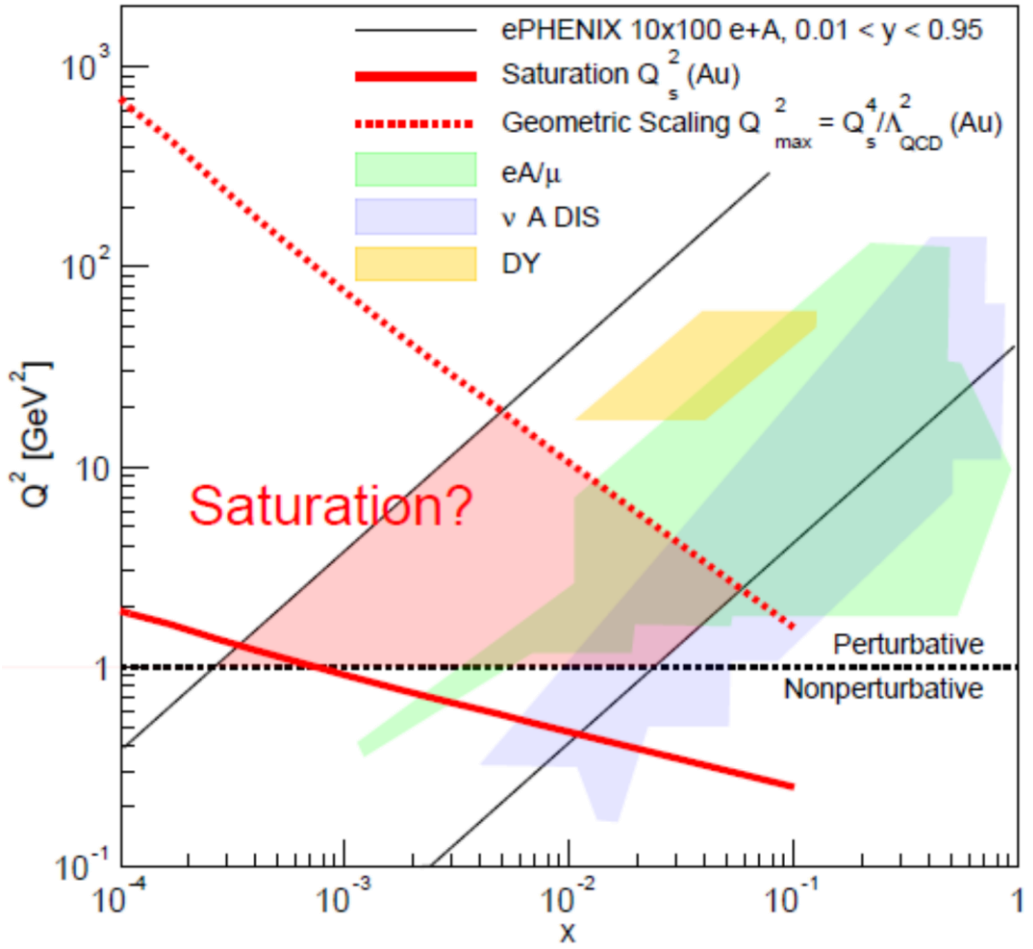
- Transverse momentum distribution of up-quark





QCD Matter at extreme Gluon Density

- Probing saturation effects



Detector Requirements

Electron-ID

- Electromagnetic Calorimetry and charged particle tracking
- Minimum material budget before EMCal
- Good energy and tracking resolution for E/p matching

Hadron ID

- In barrel acceptance: DIRC for $p_h < 4$ GeV/c;
  in hadron-going direction:
  Aerogel for lower momentum and
  gas RICH for higher momentum

Electron/Photon separation

- High granularity EMCal in electron-going direction

Resolution in x and Q^2

- High resolution EMCal and tracking in electron-going direction
- Good (tracking) momentum resolution for $E'_e < 10$ GeV in barrel
- Good (EMCal) energy resolution for $E'_e > 10$ GeV in barrel

Wide acceptance for Leptons and Photons in DVCS

- EMCal and tracking with good resolution for lepton and photon measurements covering $-4 < \eta < 4$

Scattered p in exclusive processes

- Roman pots in hadron-going direction

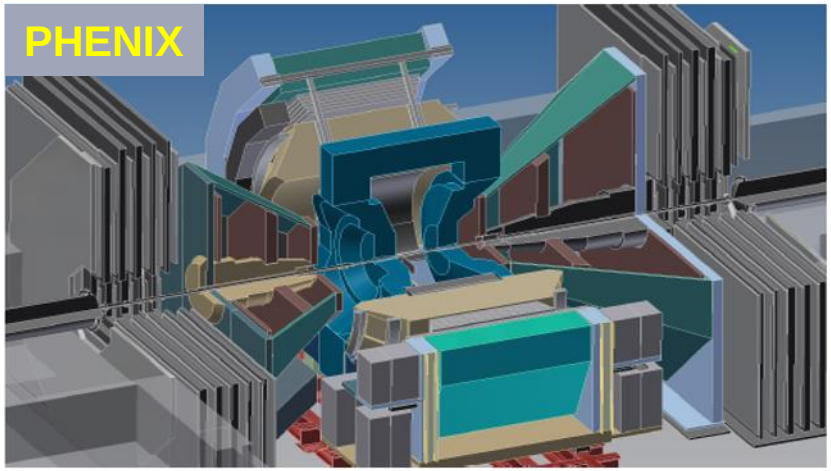
Rapidity Gap

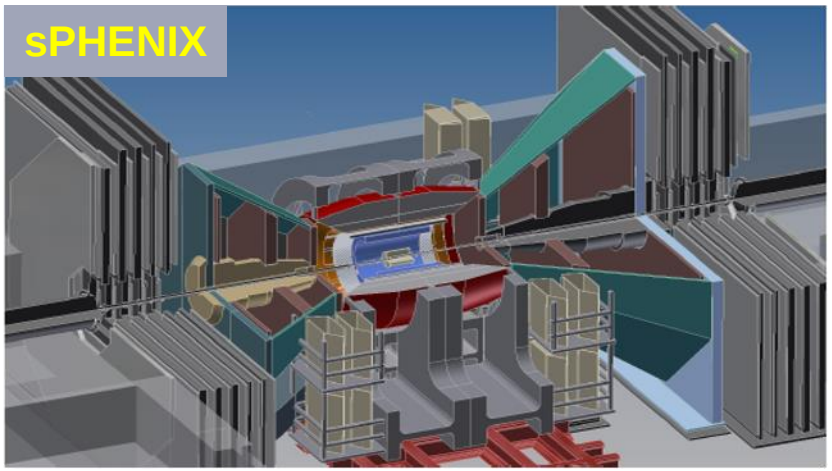
Hadronic calorimetry covering $-1 < \eta < 5$ and EMCal covering $-4 < \eta < 4$

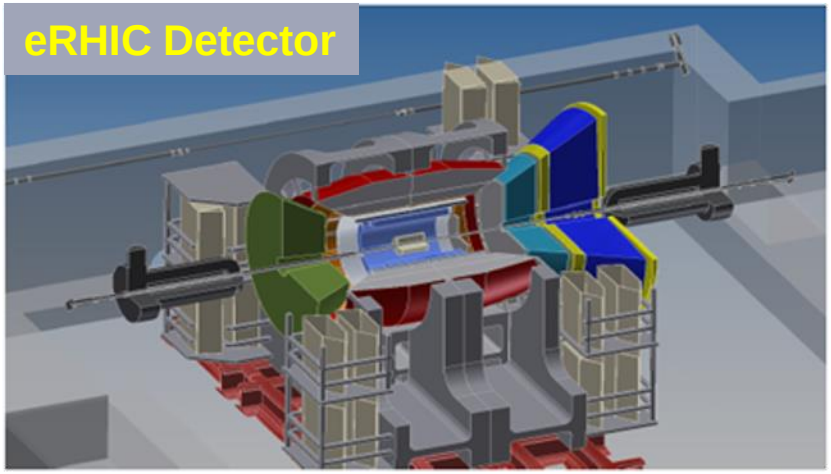
Forward ZDC

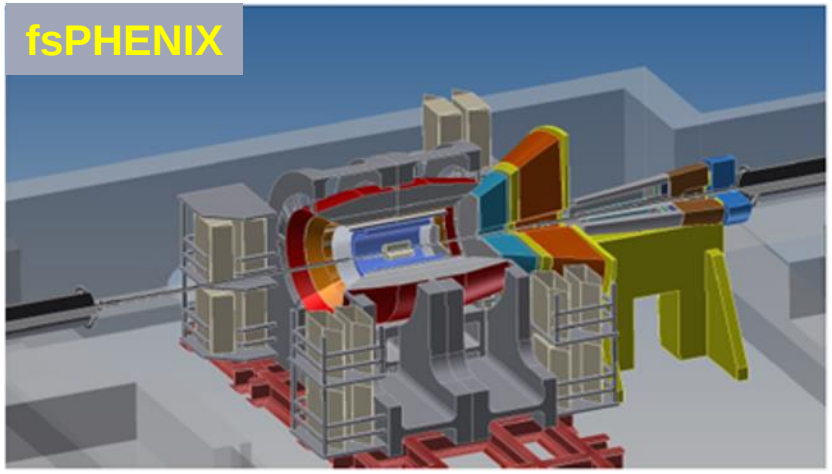
Zero-Degree calorimeter in hadron-going direction planned, in coordination with Collider Accelerator Department CAD

Close the Loop: s/fsPHENIX – eRHIC-Detector

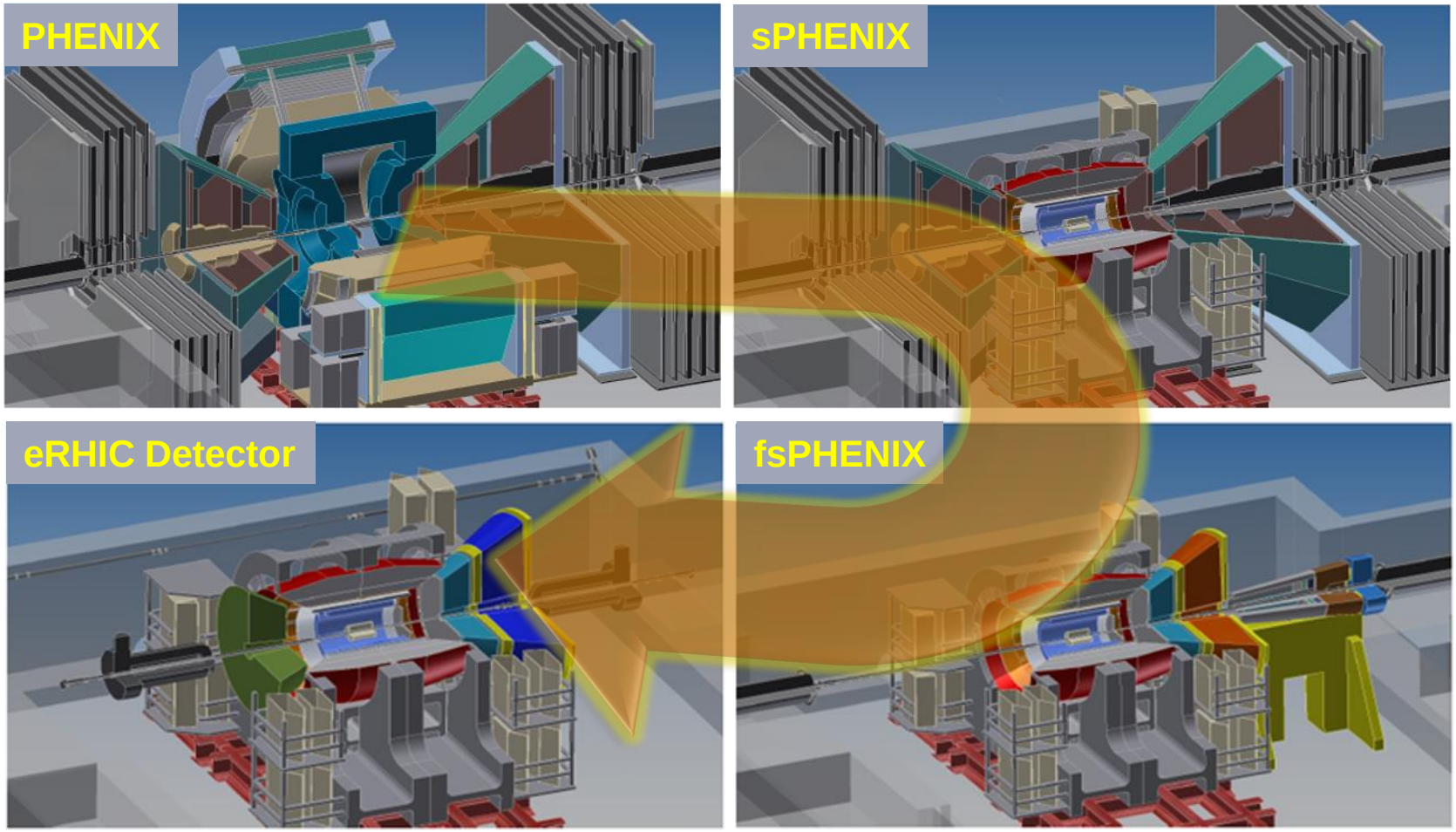








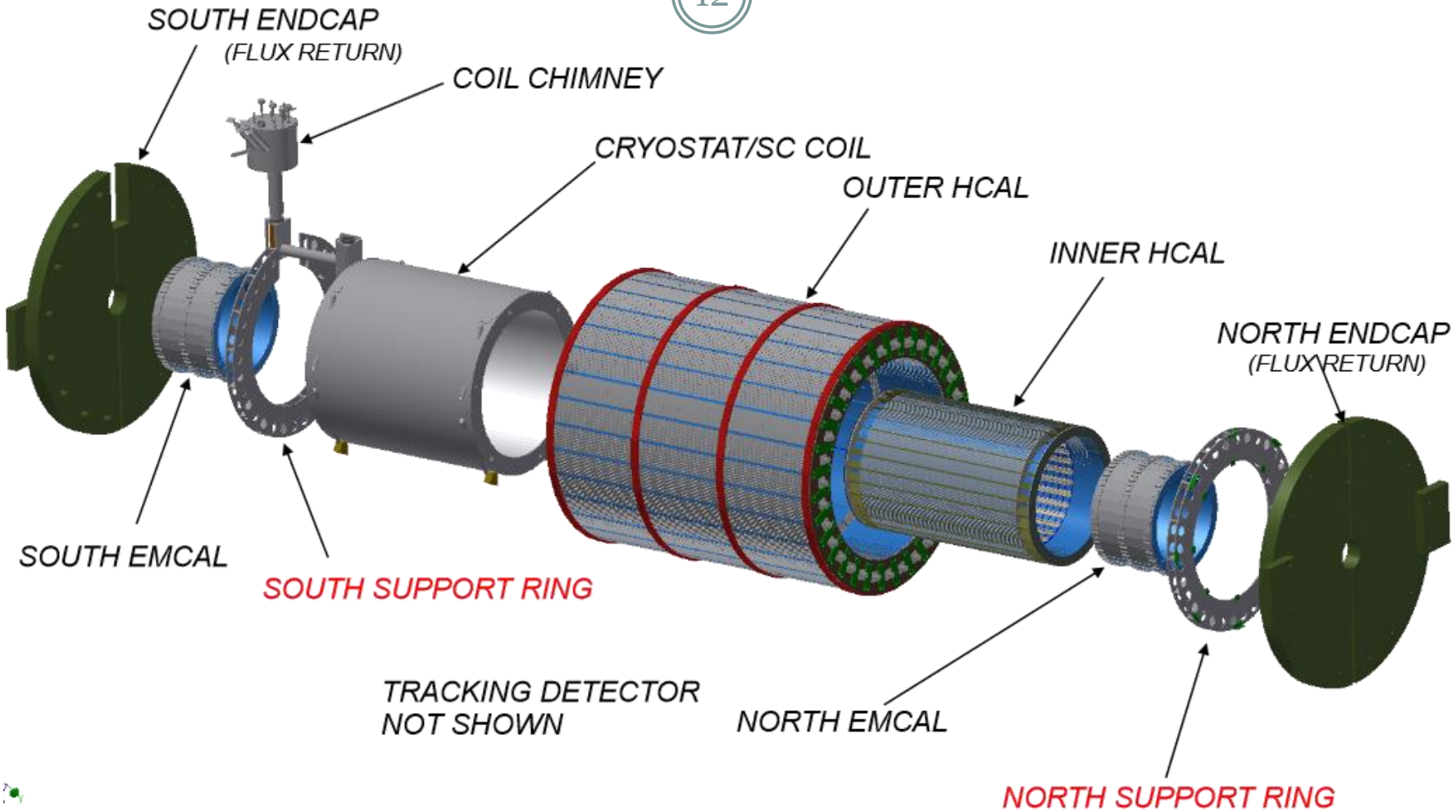
Close the Loop: s/fsPHENIX – eRHIC-Detector



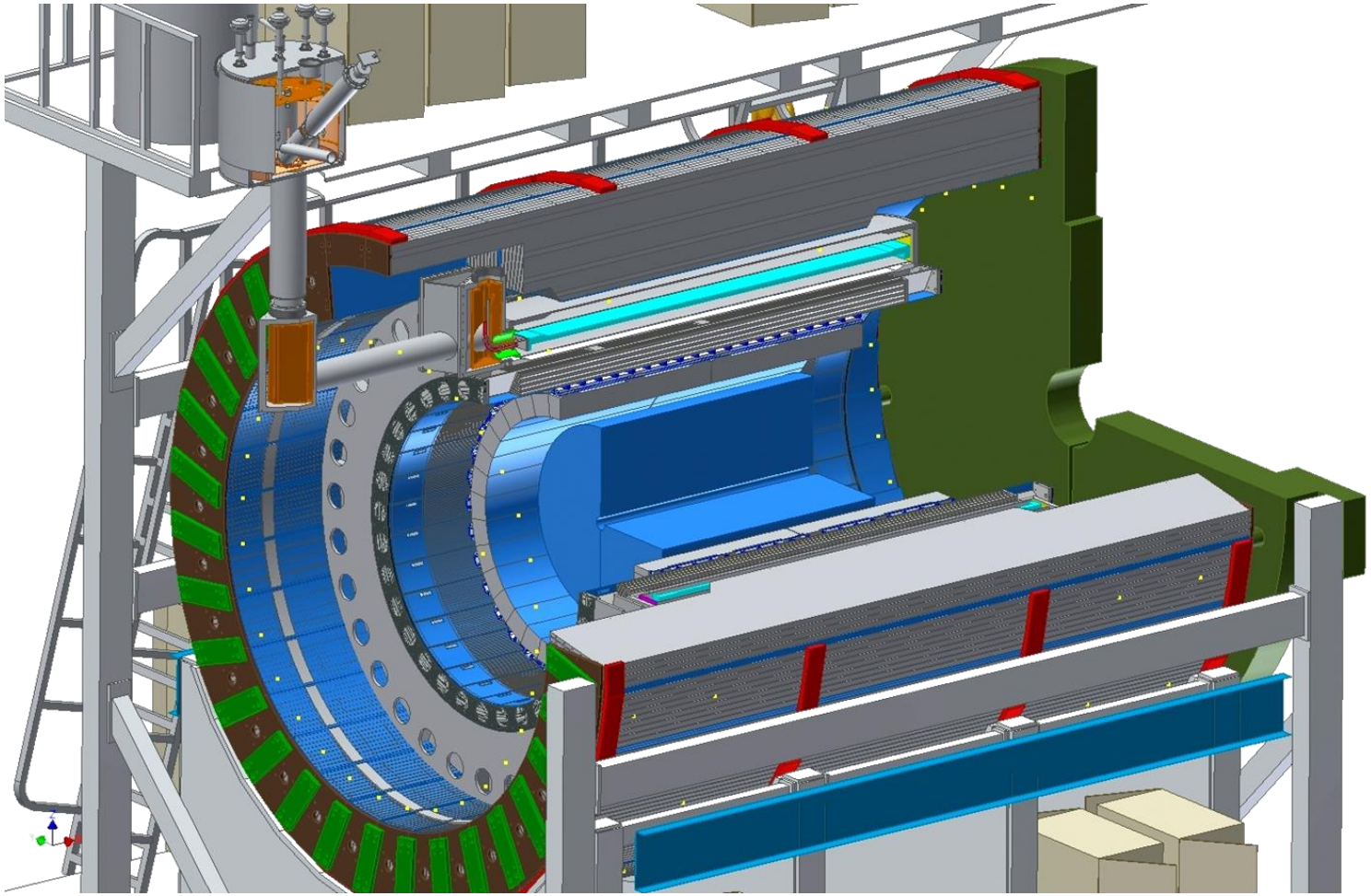
sPHENIX

Centered around BaBar magnet. Moved across the continent from SLAC to BNL.

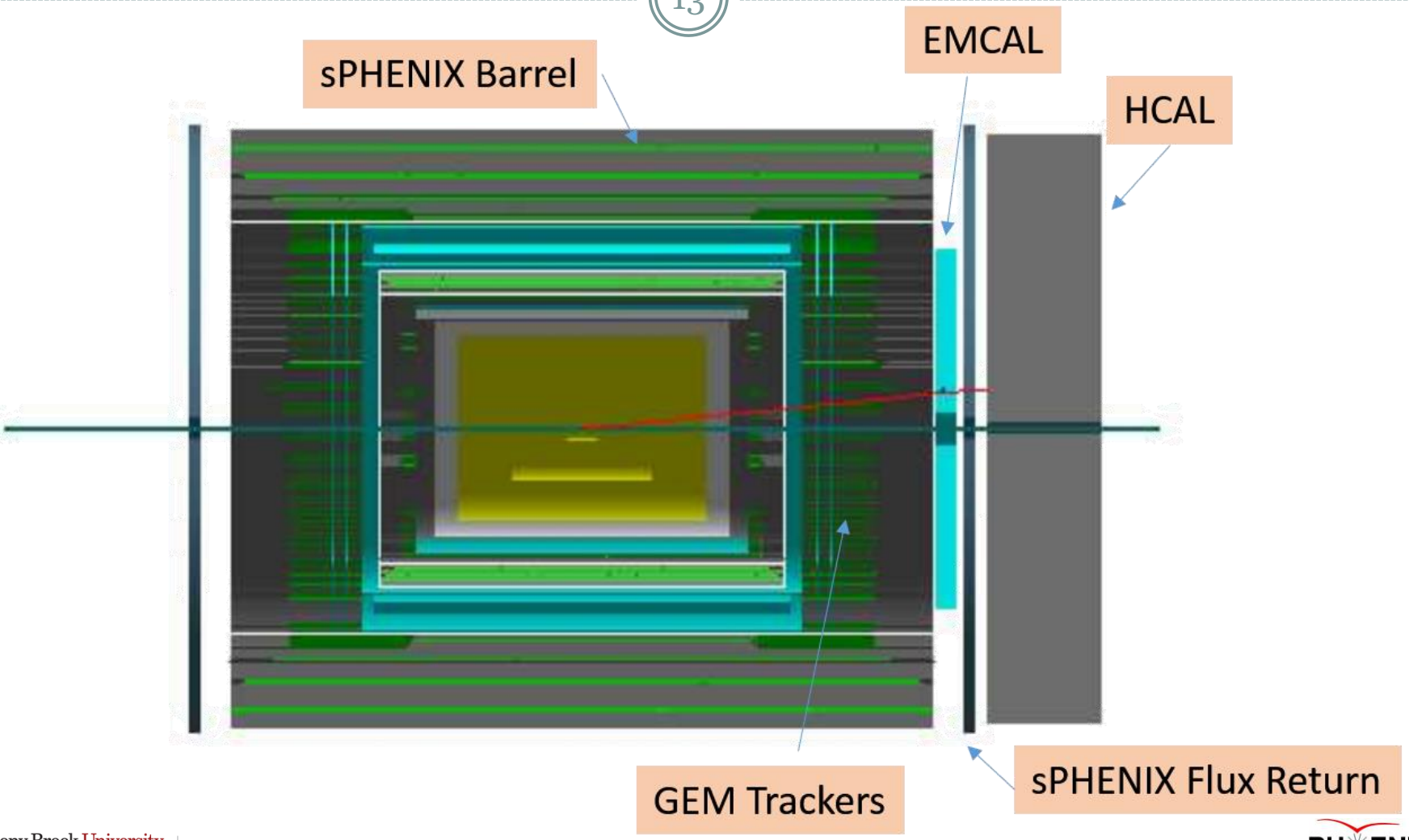
sPHENIX


SOUTH ENDCAP
(FLUX RETURN)
COIL CHIMNEY
CRYOSTAT/SC COIL
OUTER HCAL
INNER HCAL
NORTH ENDCAP
(FLUX RETURN)
SOUTH EMCAL
SOUTH SUPPORT RING
TRACKING DETECTOR
NOT SHOWN
NORTH EMCAL
NORTH SUPPORT RING

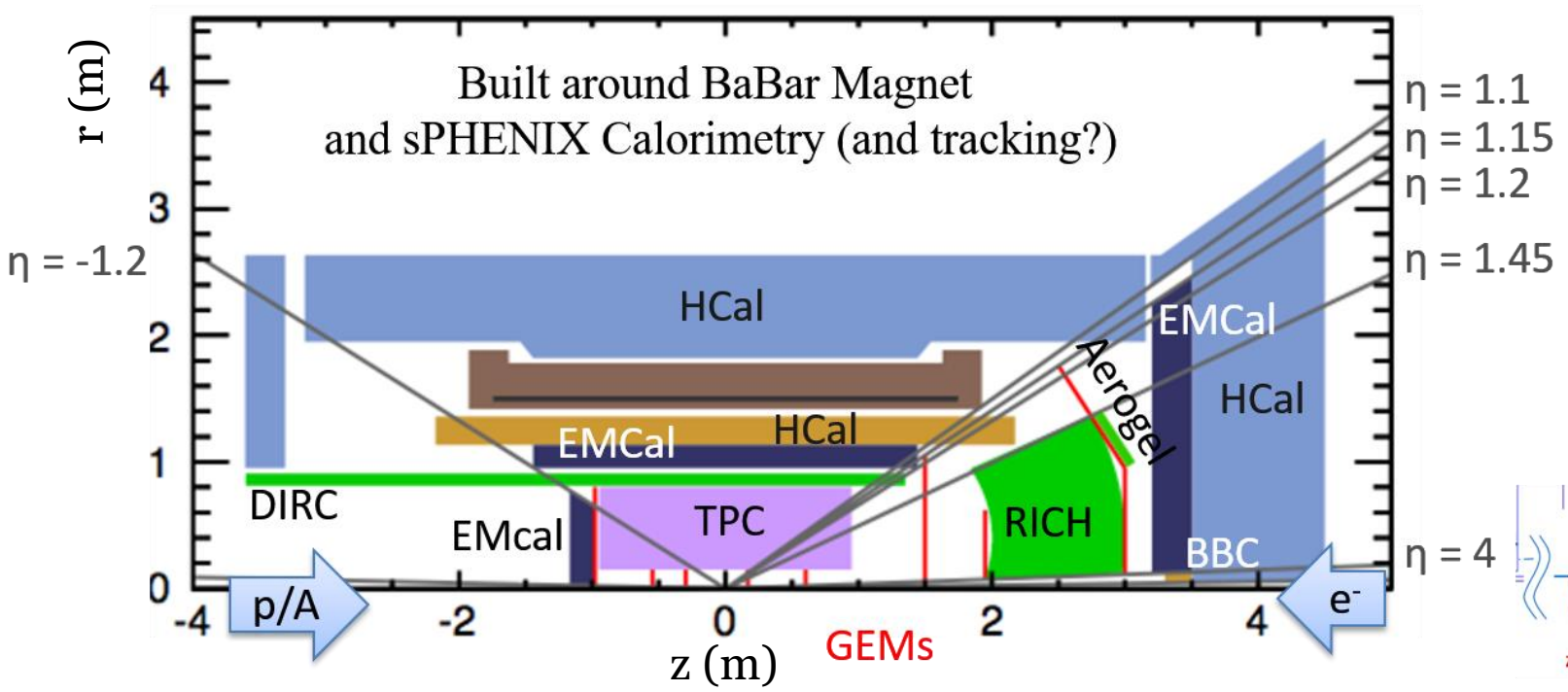
sPHENIX



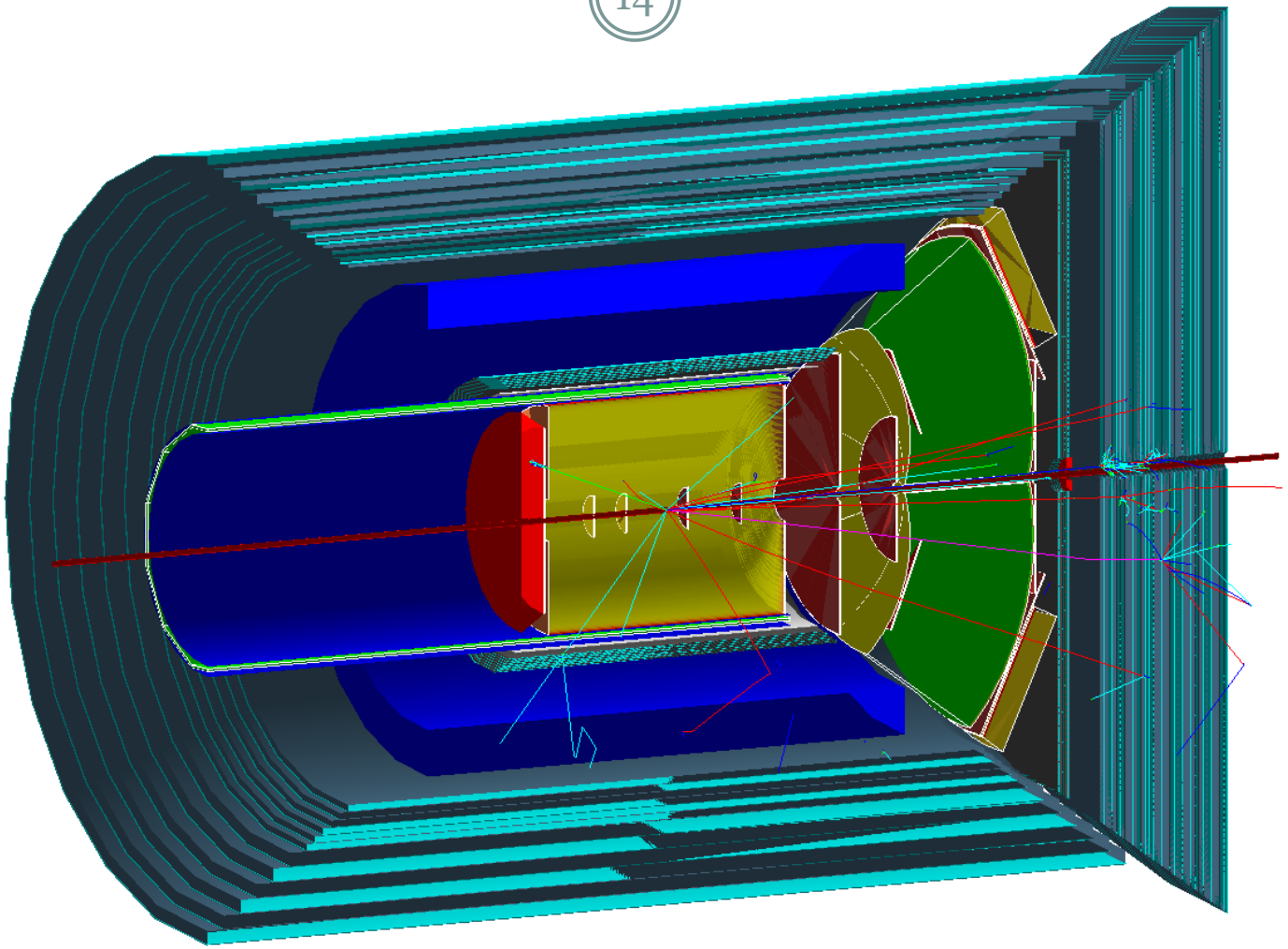
fsPHENIX


sPHENIX Barrel
EMCAL
HCAL
GEM Trackers
sPHENIX Flux Return

Day-1 eRHIC Detector

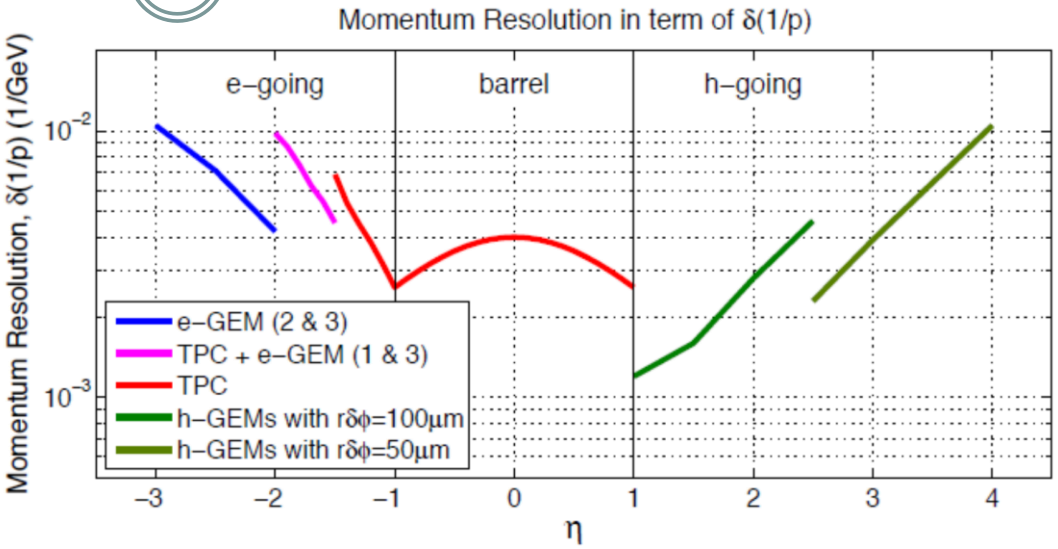


Day-1 eRHIC Detector



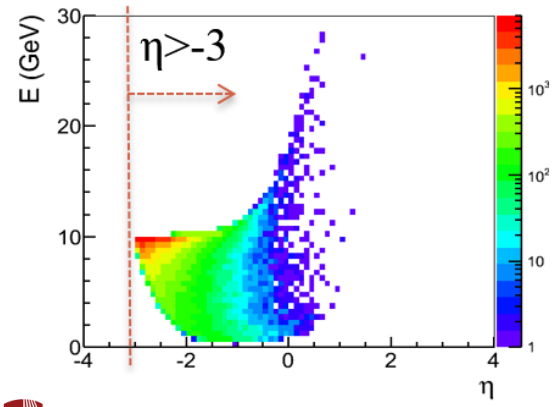
Tracking Performance

- Tracking within magnetic field

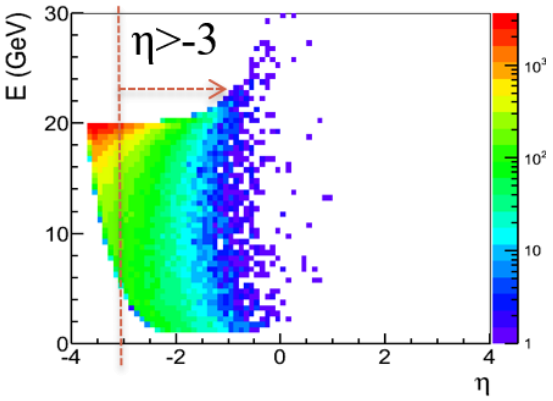


$Q^2 > 1\ GeV^2$

10 x 250 GeV

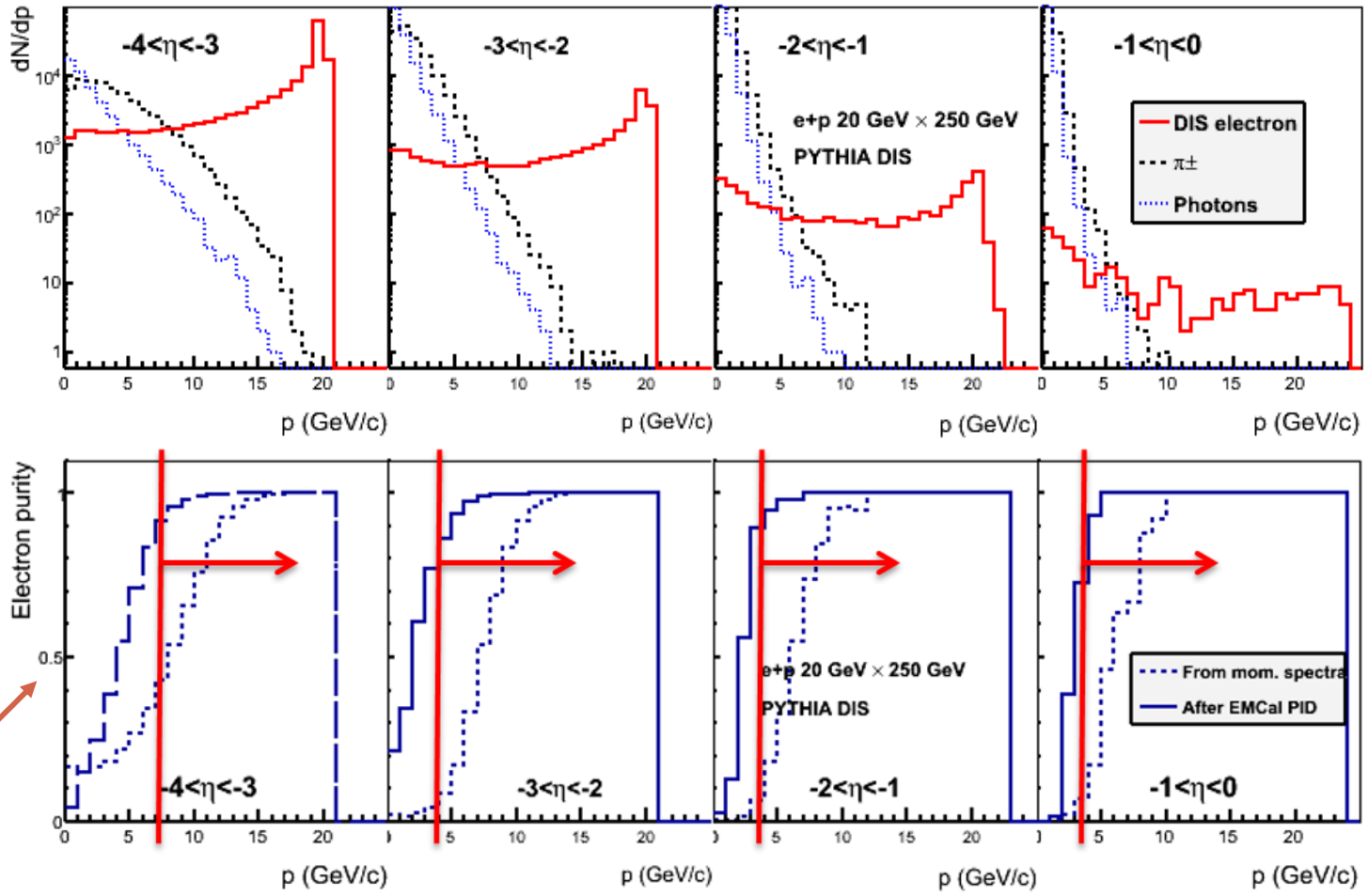


20 x 250 GeV

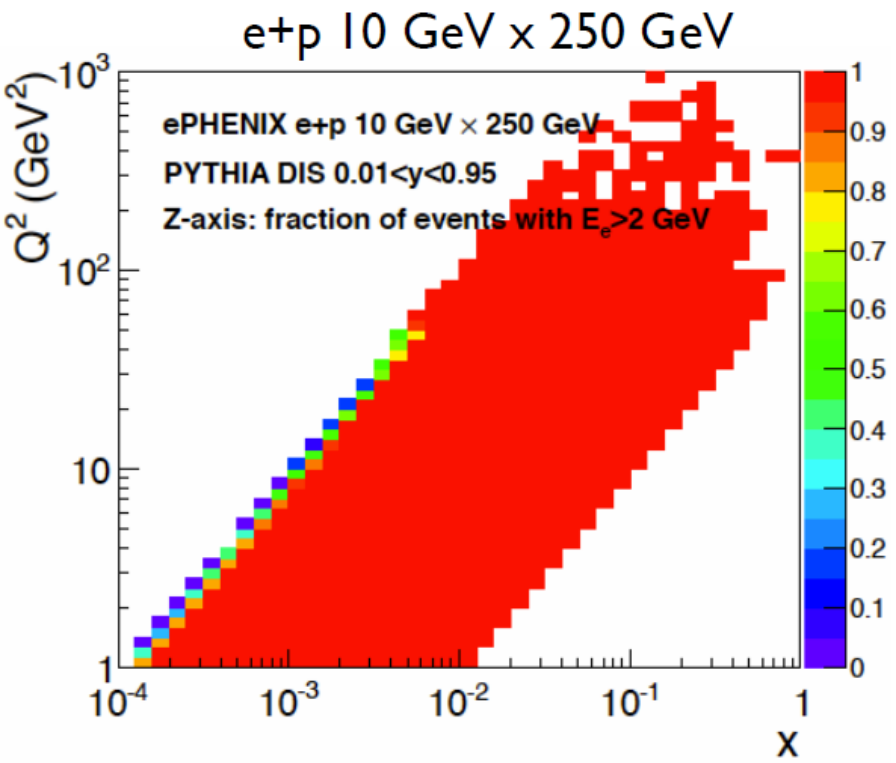


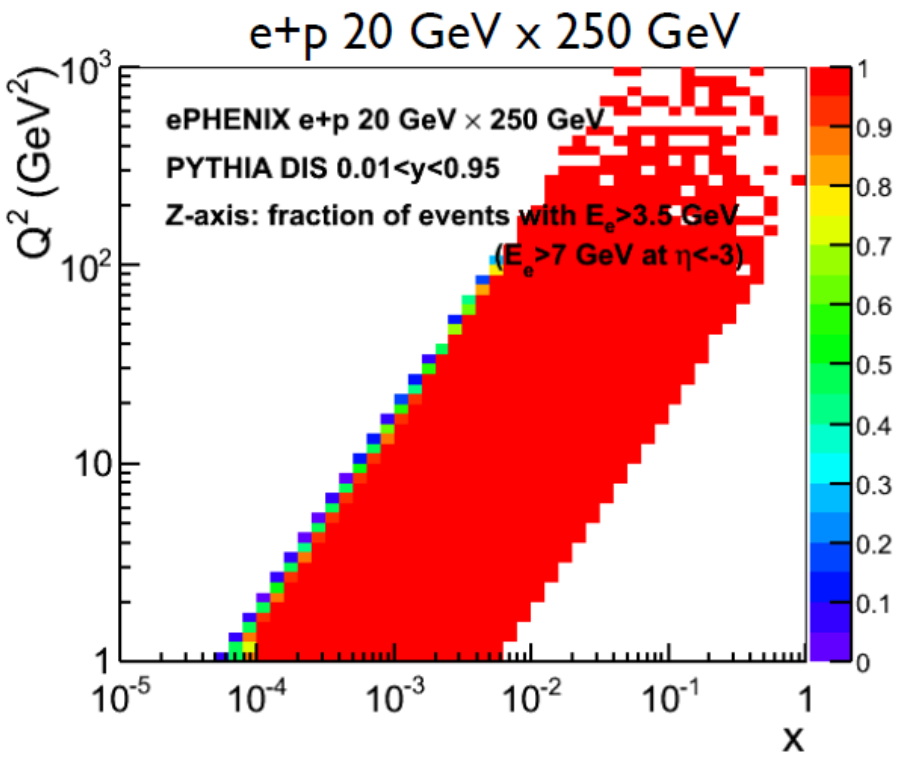
For 20 GeV electron beam: need to get down to η = -4

Electron ID


dN/dp
-4<η<-3
-3<η<-2
-2<η<-1
-1<η<0
e+p 20 GeV × 250 GeV
PYTHIA DIS
DIS electron
π±
Photons
p (GeV/c)
Electron purity
From mom. spectra
After EMCal PID
no E/p

Electron ID

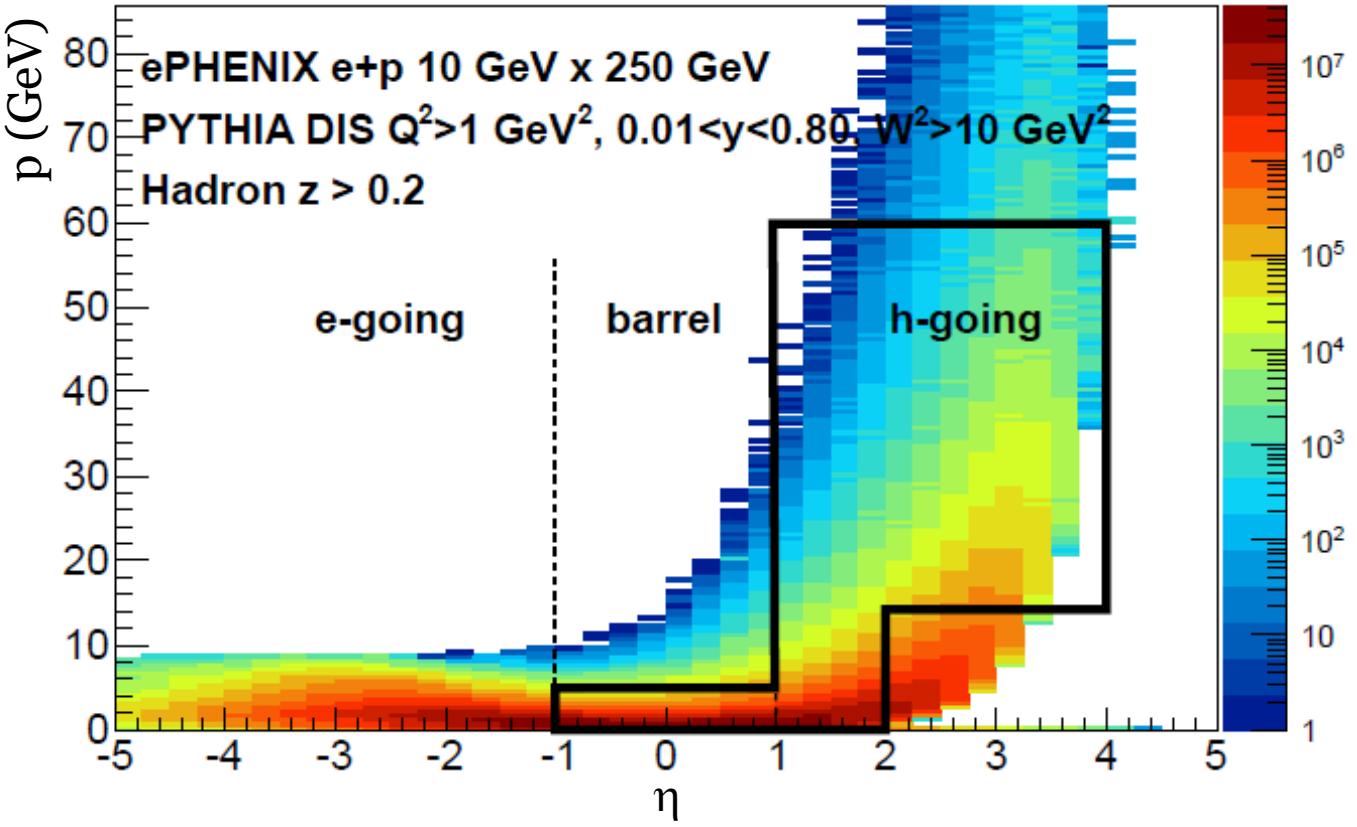




Only minor reduction in x-Q^2 space

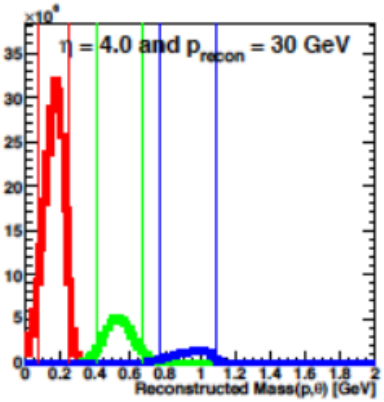
Hadron ID

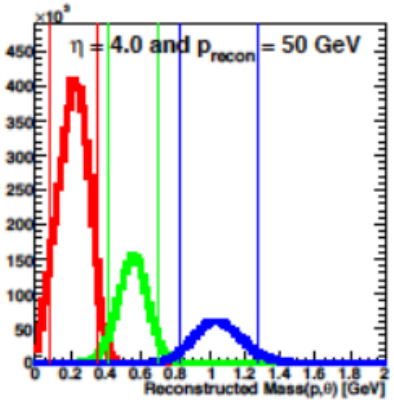
- Quark helicity – TMD – Hadronization

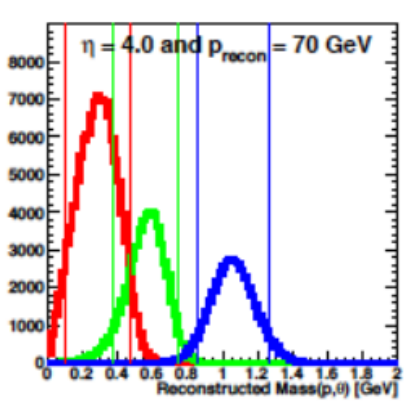


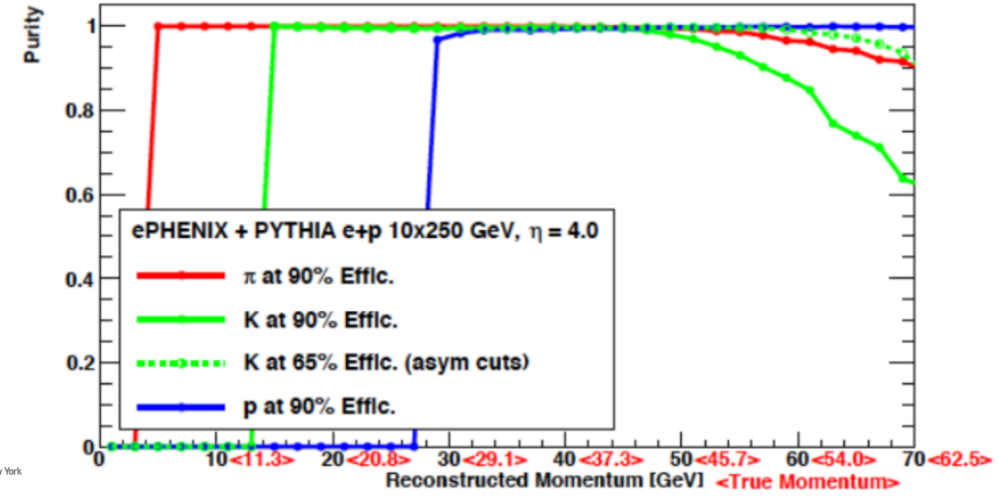
Hadron ID

- PID capabilities: η=4 and up to p=70 GeV (*)





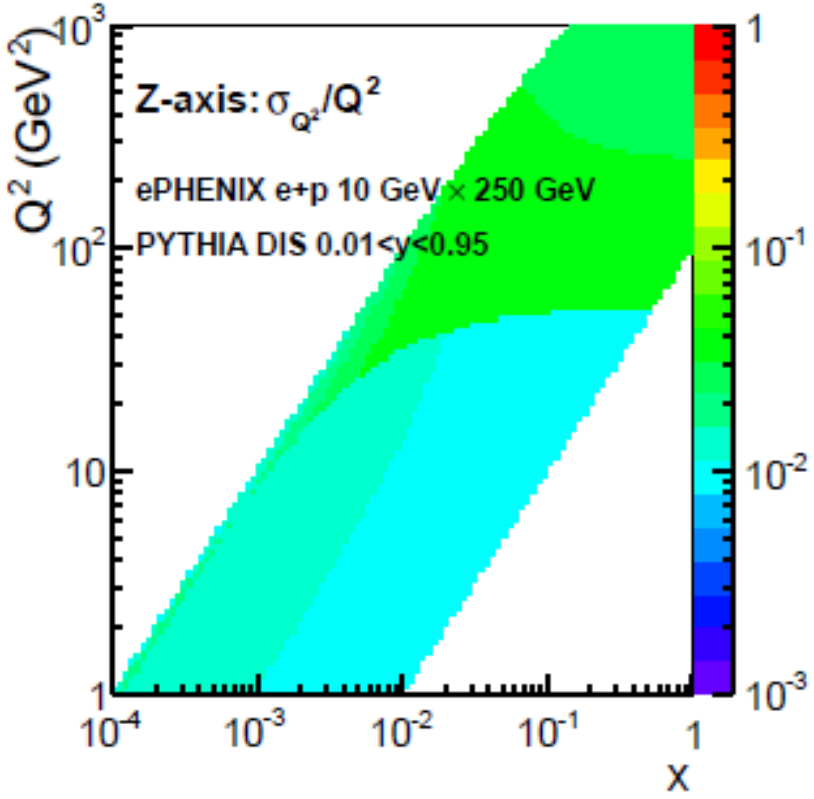


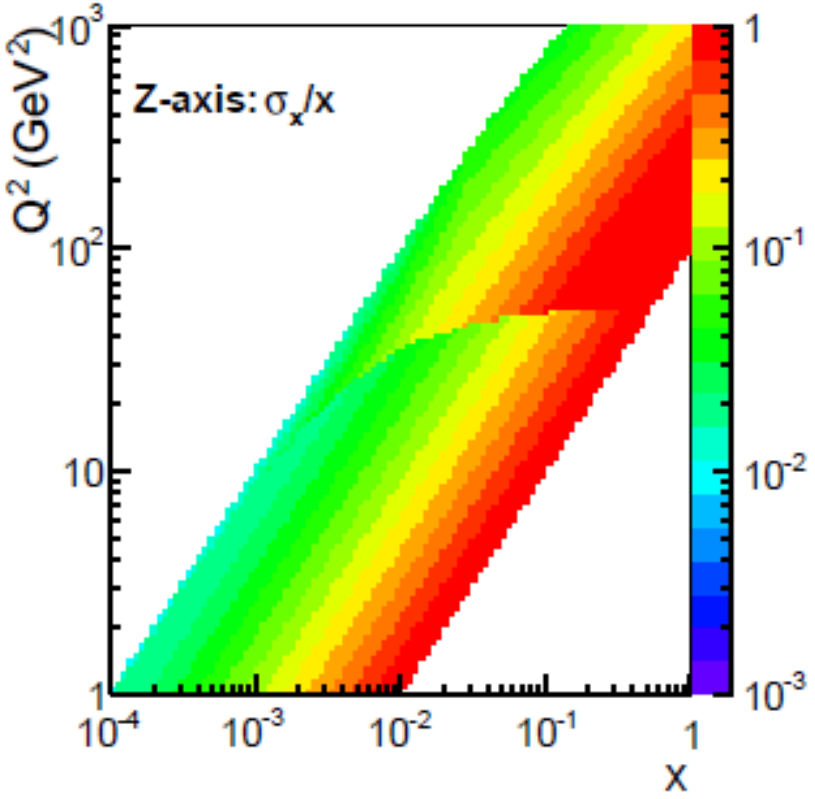


(*)

Resolution in x – Q^2

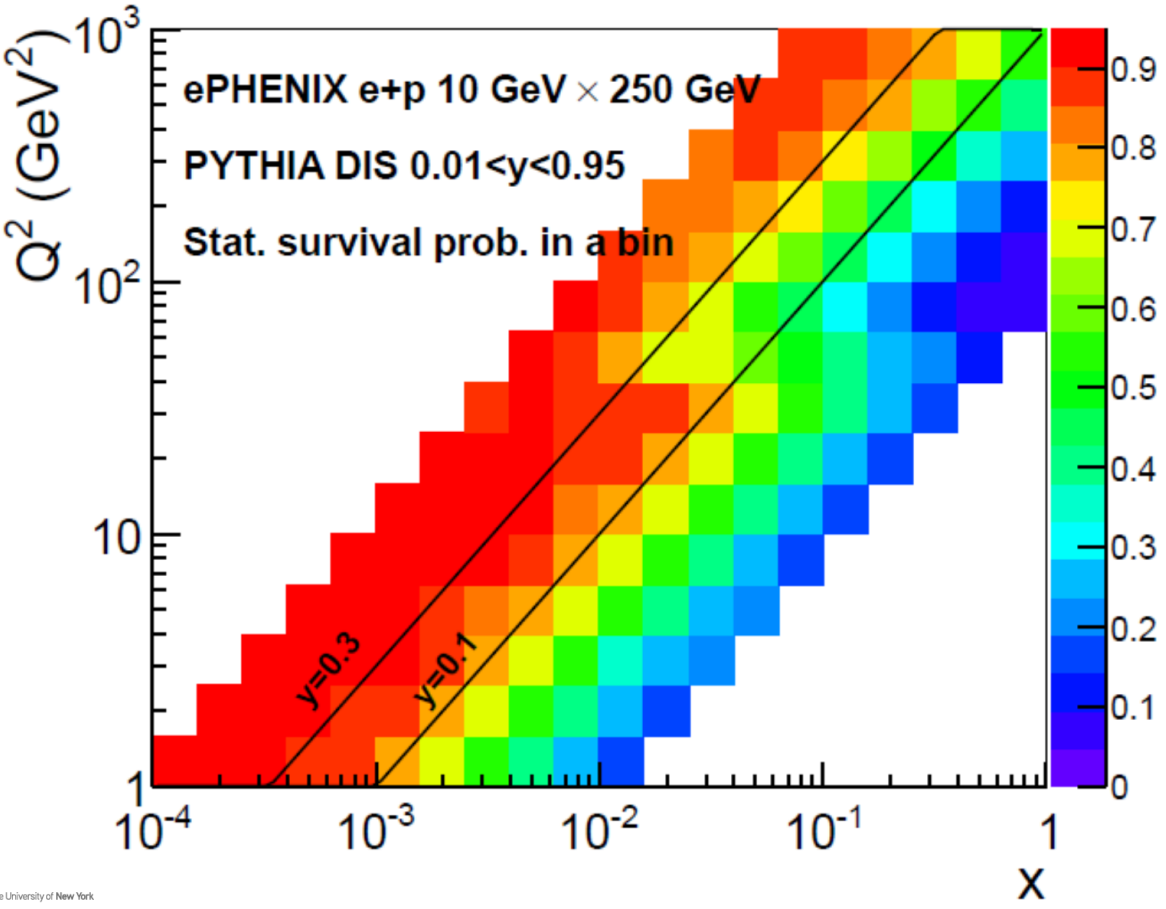
- Standard electron method





Resolution in x – Q^2

- Standard electron method




… to
be
continued …

Summary

- Many opportunities to study condensed matter of strong force from day-1
- Path through sPHENIX detector, with its focus on jets and hard probes in heavy-ion collisions, into eRHIC detector
- Additional capabilities supporting its focus on e+p and e+A collisions the sPHENIX detector in the existing PHENIX experimental hall
- Day-1 eRHIC detector
  - Full use of PHENIX upgrades to sPHENIX and Forward sPHENIX with additional specific modifications for EIC physics