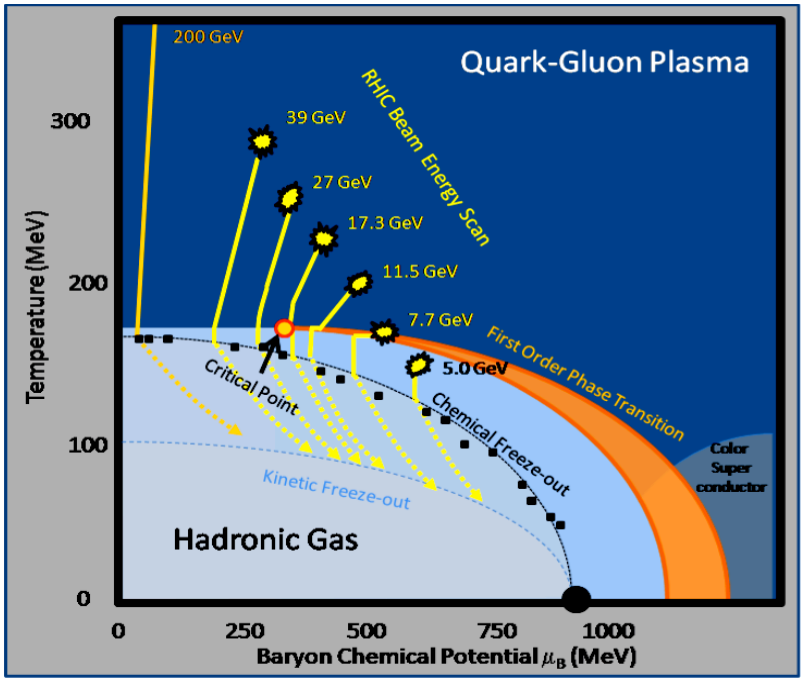
Prepare (e)STAR as an EIC detector

Zhangbu Xu (BNL)

- Physics Cases (EIC white paper)
- Kinematics and Acceptance
- Detector Configuration and Capabilities
  - Current STAR Configuration
  - Upgrades
- R&D Projects
- Simulations
- Summary

RHIC: eight key unanswered questions

Hot QCD Matter



1: Properties of the sQGP

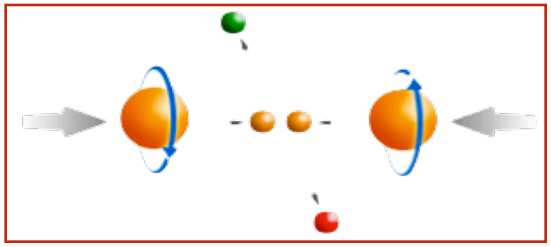
2: Mechanism of energy loss:
weak or strong coupling?

3: Is there a critical point, and if so, where?

4: Novel symmetry properties

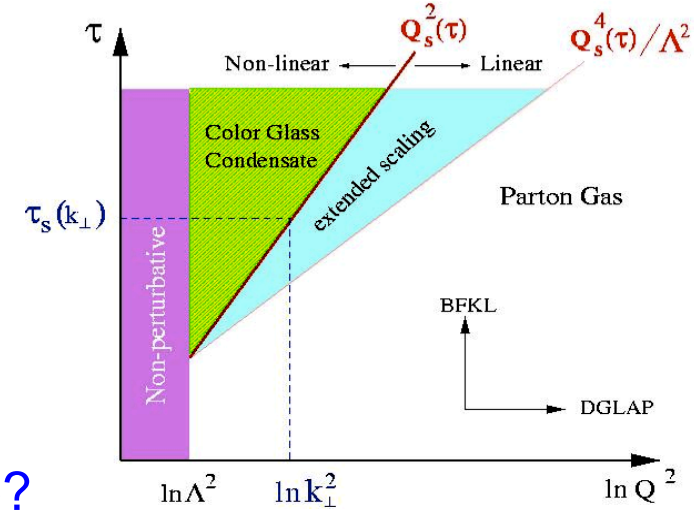
5: Exotic particles

Partonic structure



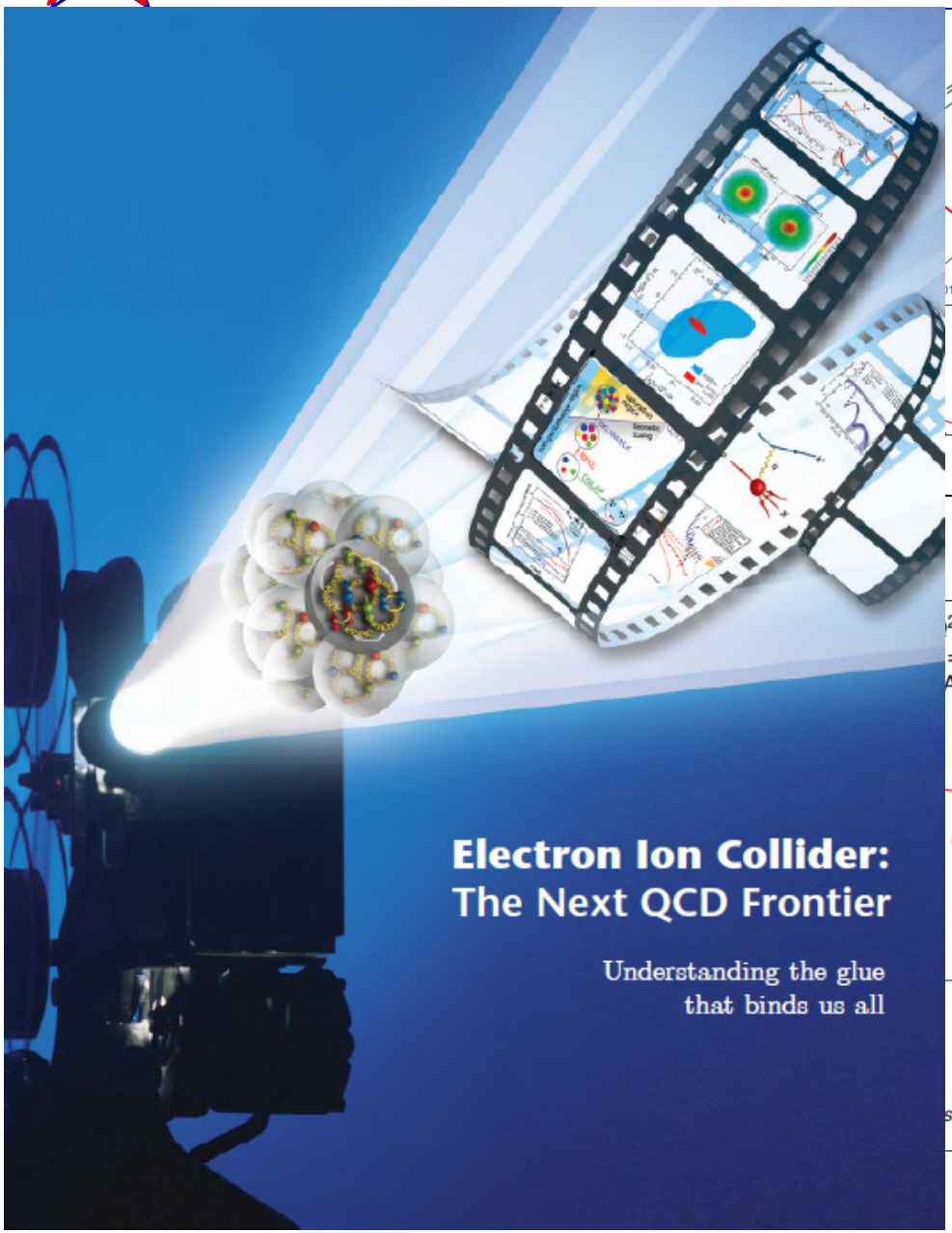
6: Spin structure of the nucleon

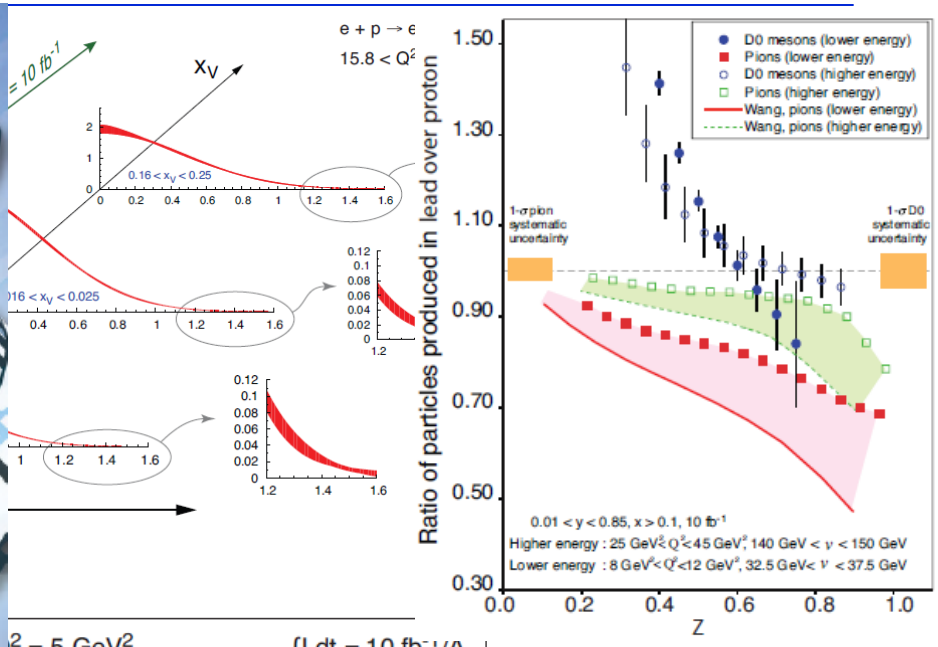
7: How to go beyond leading twist and collinear factorization?

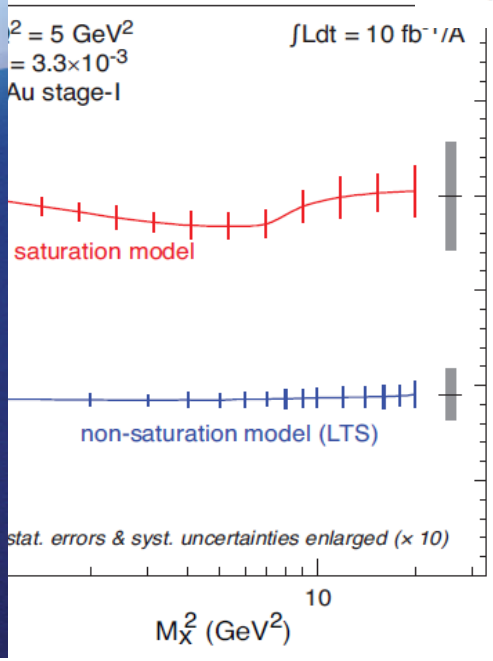


8: What are the properties of cold nuclear matter?

Physics Deliverables (EIC whitepaper)

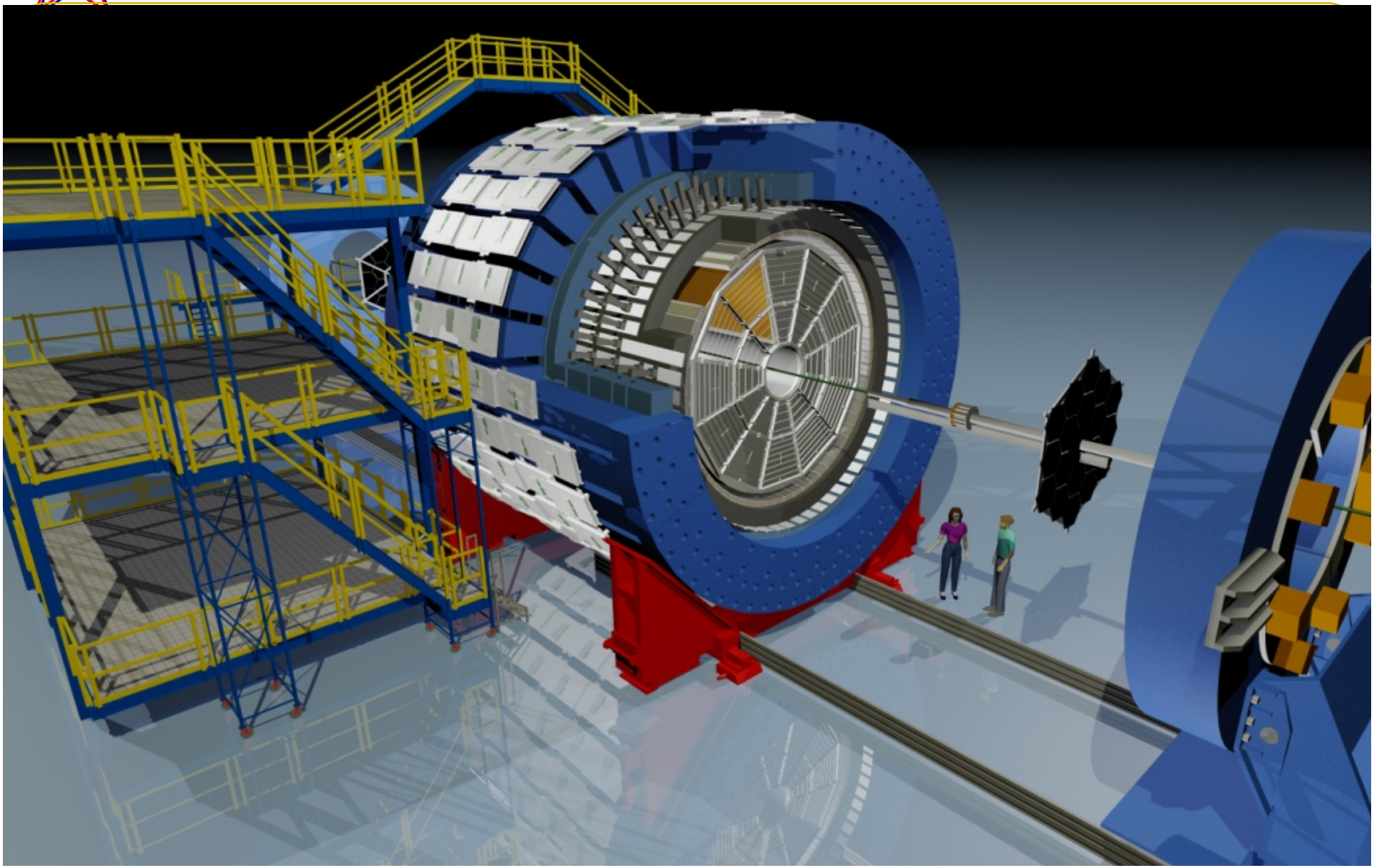






1. Proton Spin
2. Motion of partons
3. Imagining
4. Dense Gluonic QCD matter
5. Quark Hadronization

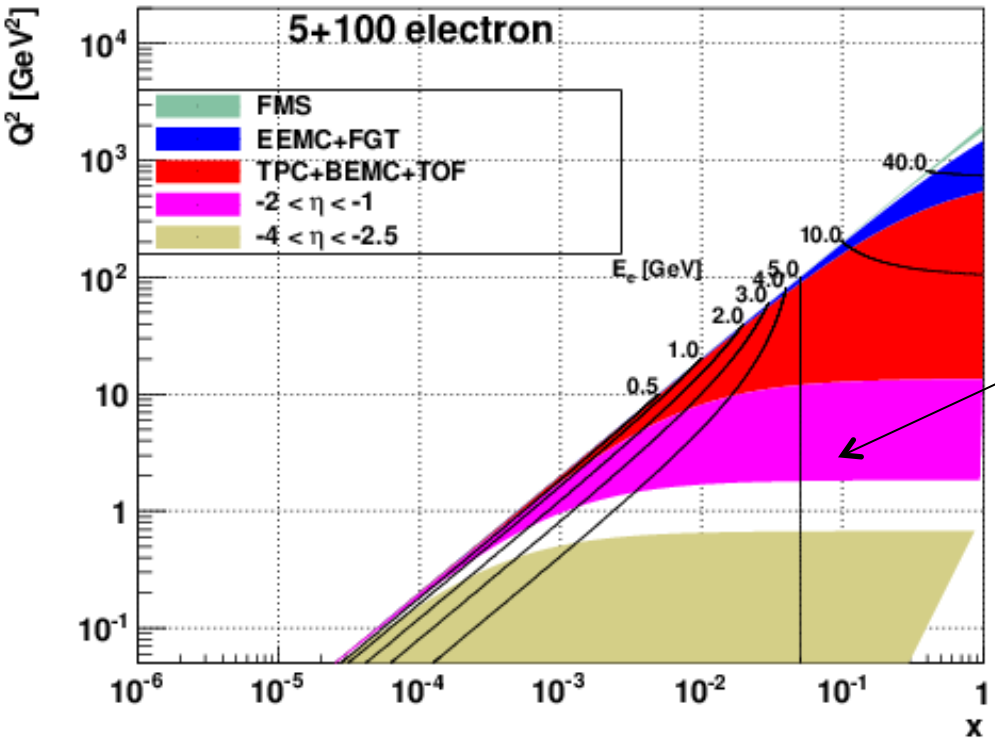
Current STAR Experiment



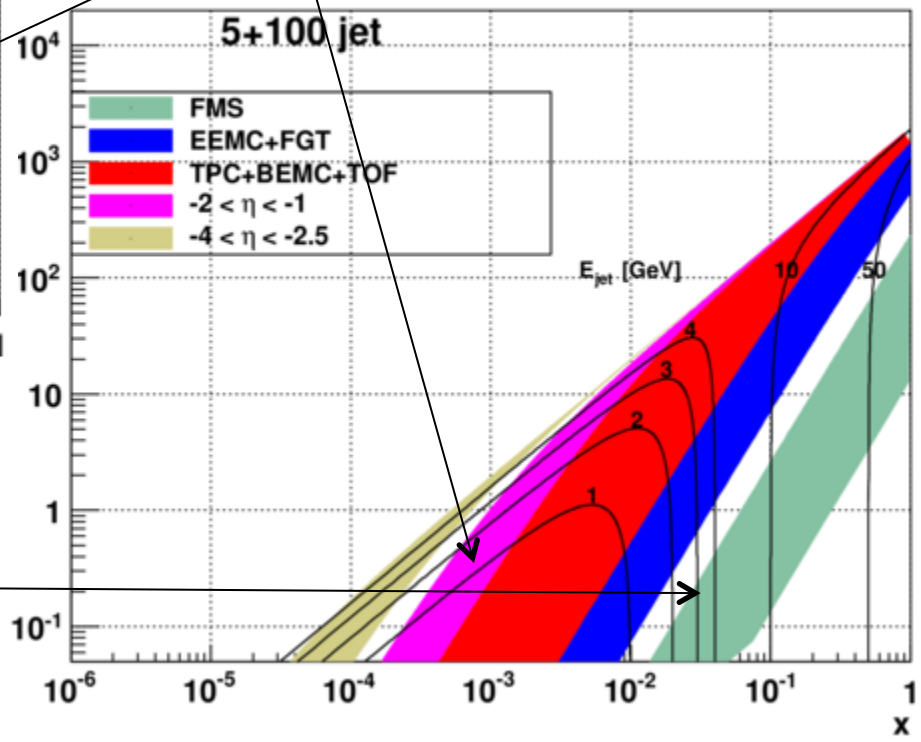
STAR Concept

- Large Coverage
- Low Material
- Electron and hadron ID with gas detector and TOF, EMC
- Extend this concept to hadron direction
  - GEM tracker (VFGT)
  - Forward Calorimetry
- Extend this concept to electron direction
  - Re-instrument inner TPC
  - TRD+TOF
  - Crystal Calorimeter (BSO)

DIS – eSTAR Kinematics

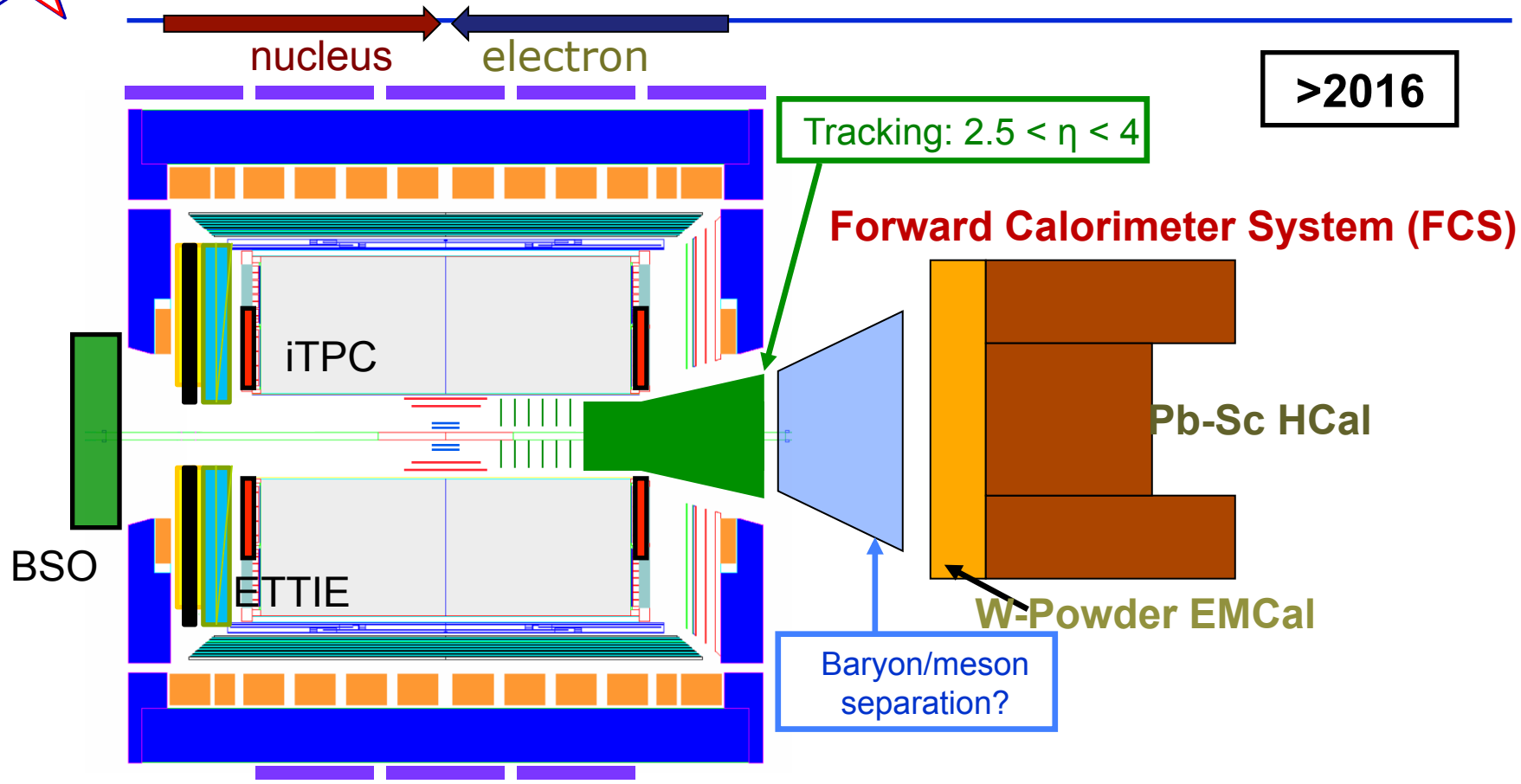


-2<η<-1
Electron side TPC Endcap upgrade
for electron PID and hadron tracking



Jets, hadrons (hyperons)

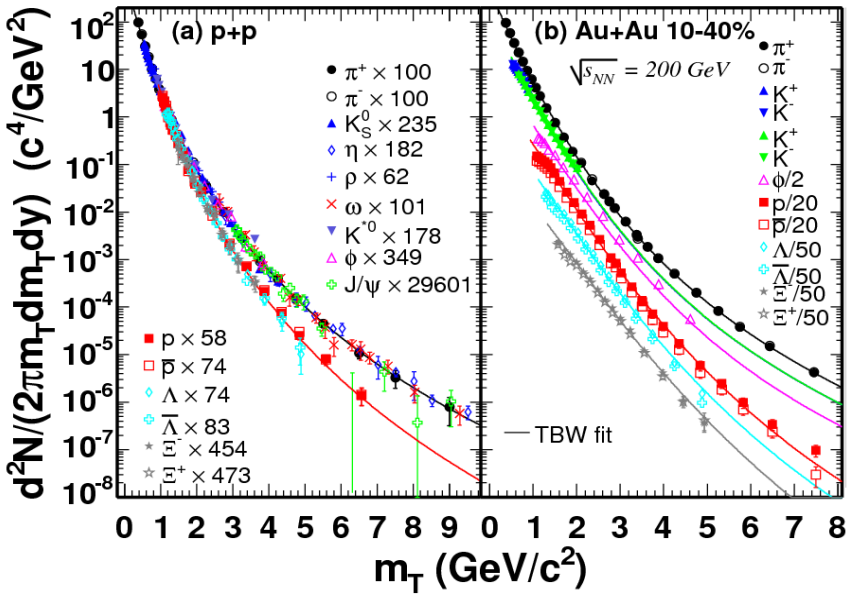
STAR forward instrumentation upgrade

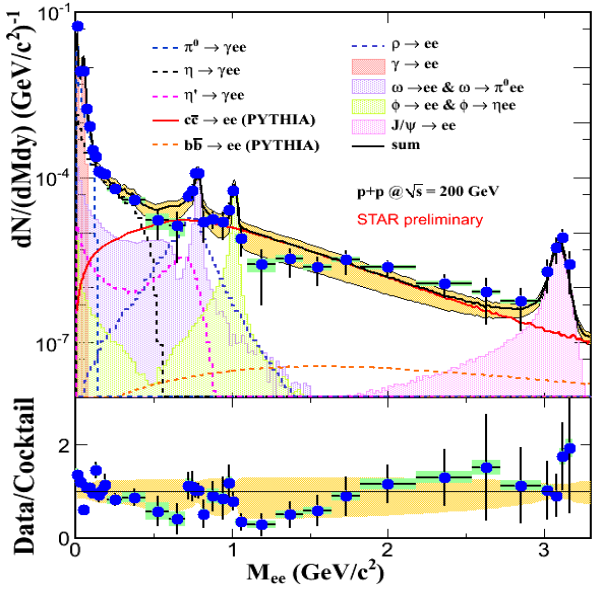


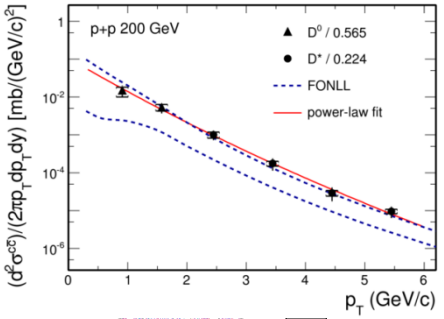
eSTAR specific upgrades:
ETOF: e, π, K identification,
ETRD: electron ID and hadron tracking
BSO: 5 GeV, 10 GeV electron beams
Re-instrument HFT

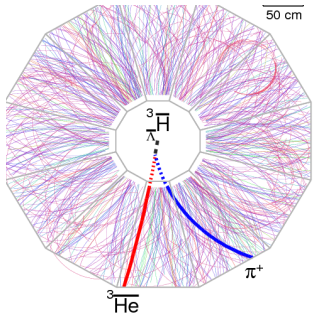
- **Forward instrumentation optimized for p+A and transverse spin physics**
  - **Charged-particle tracking**
  - ***e/h* and γ/π⁰ discrimination**
  - **Baryon/meson separation**

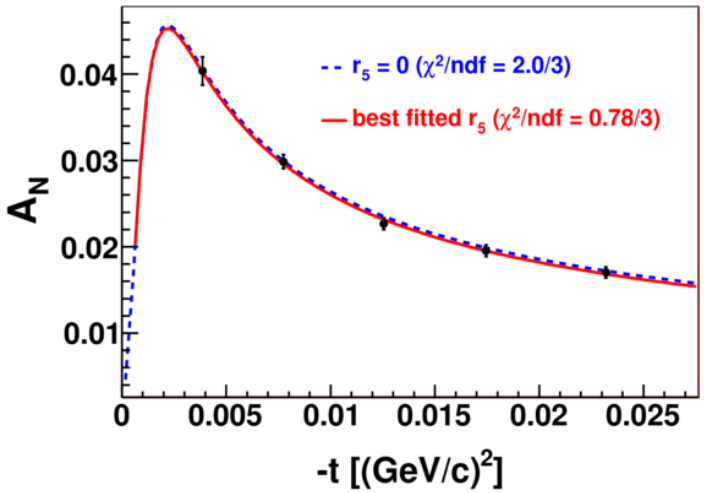
Proven STAR Capabilities

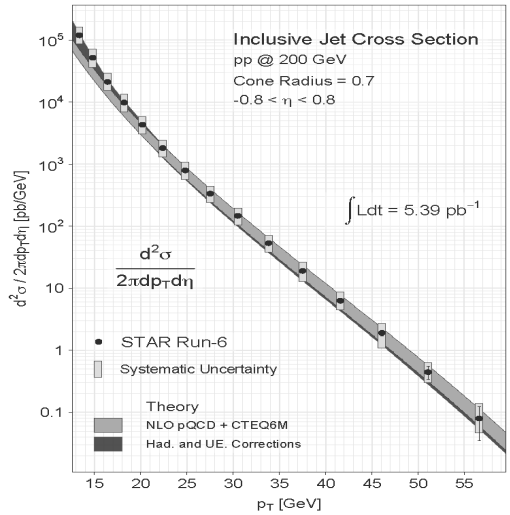


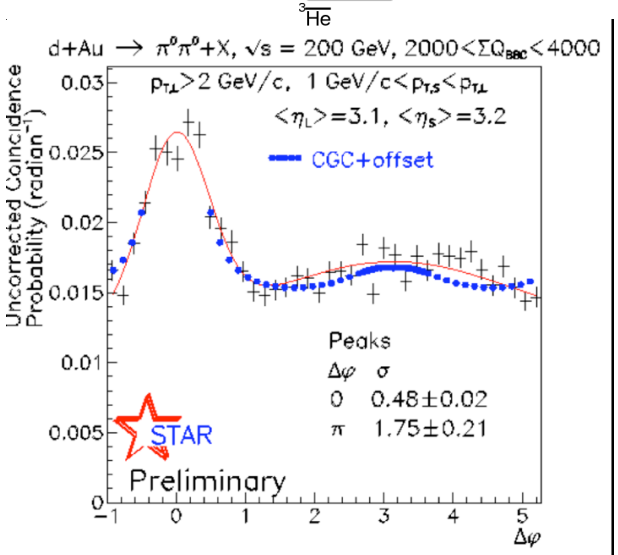




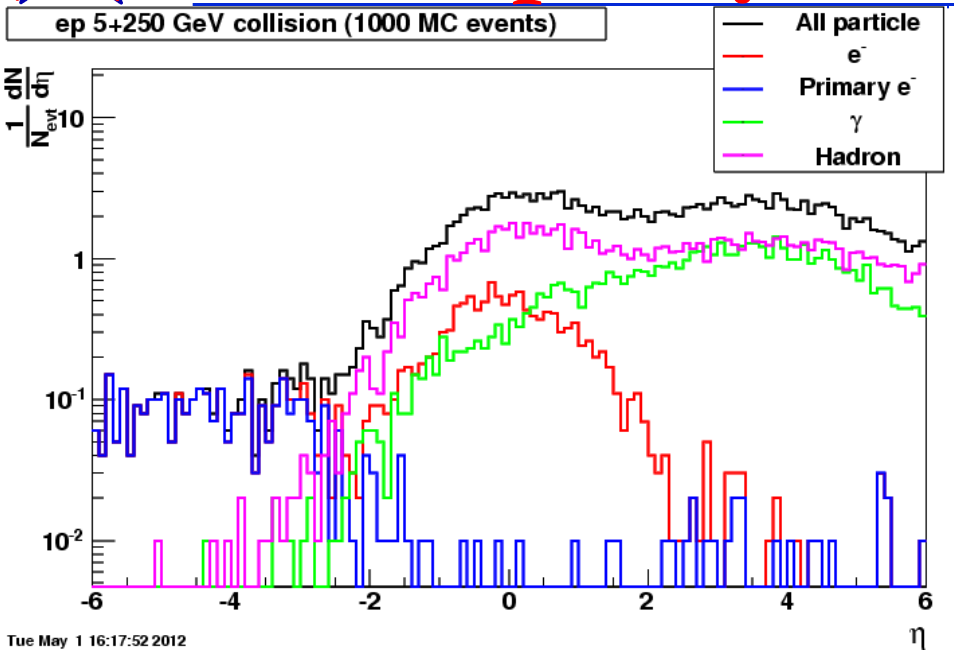


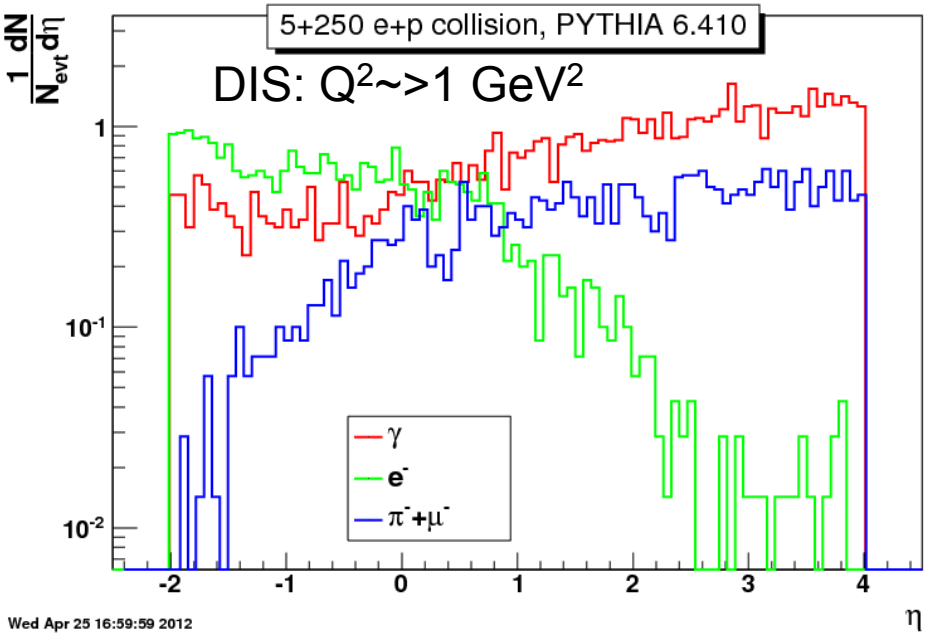






Occupancy and pile-up

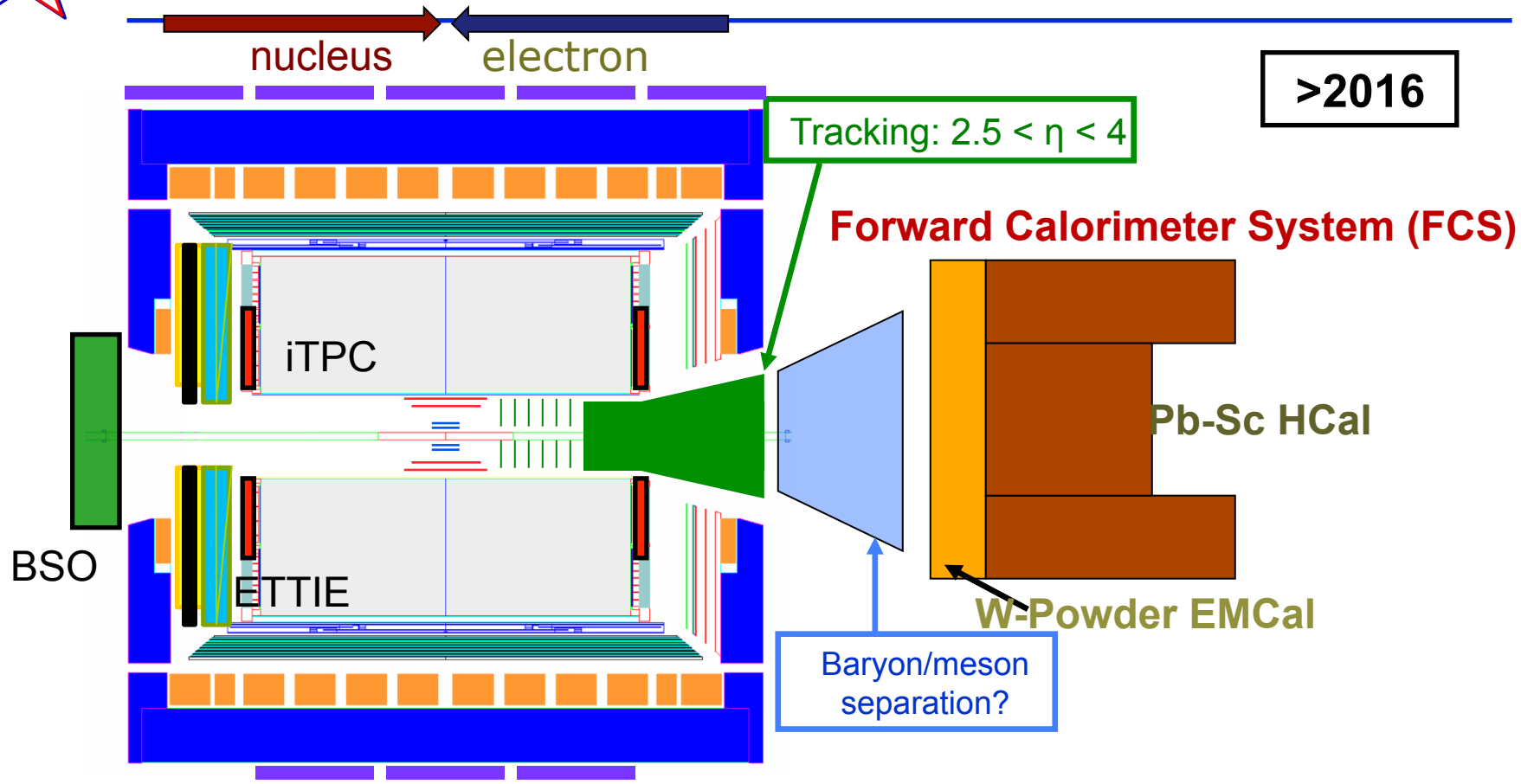




QED α=1/137 and low multiplicity ➔ an order of magnitude lower pile-up than RHIC

Beam species	Sqrt(s)	Peak Luminosity ($cm^{-2}s^{-1}$)	Cross section (cm^2)	Nch/dη	**Track density (dNch/dη MHz)**	Hit density impact hit finding	Space charge impact tracking
e+p	5x250	10^{34}	10^{-28}	0.7	**0.7**		
Au+Au	100x100	$5x10^{27}$	$7x10^{-24}$	161	**6**	Minor	Corrected to good precision
p+p	100x100	$5x10^{31}$	$3x10^{-26}$	2	**3**	Minor	Corrected to good precision
p+p	250x250	$1.5x10^{32}$	$4x10^{-26}$	3	**18**	Significant for inner	Corrected to acceptable

STAR forward instrumentation upgrade



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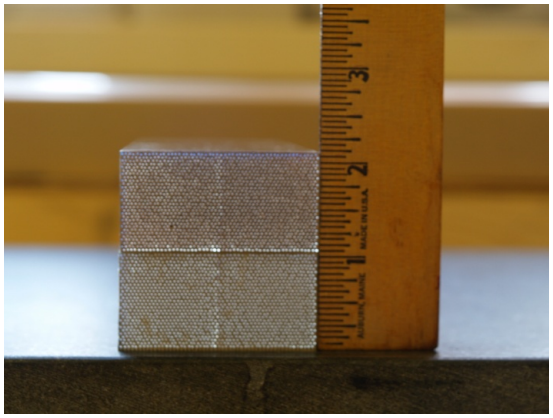
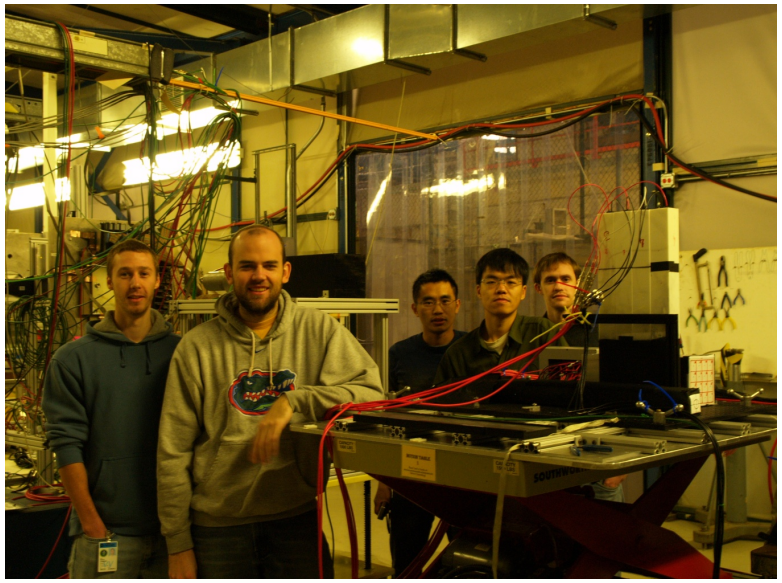
Calorimeter Test Beam and Simulations

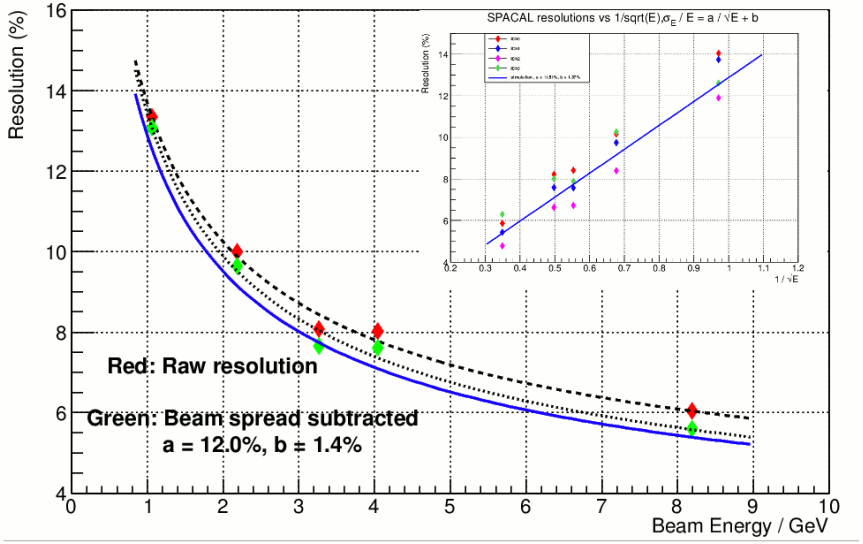


- Approved EIC R&D project from May 2011
- UCLA, TAMU, PSU
- Simulations on jets, photons and hyperons



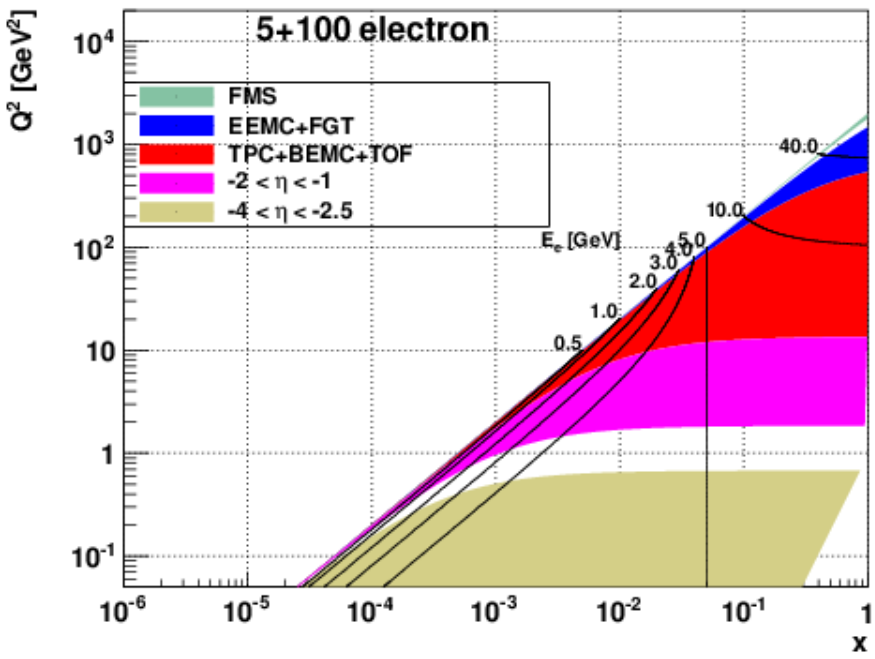
HAD Prototype for STAR

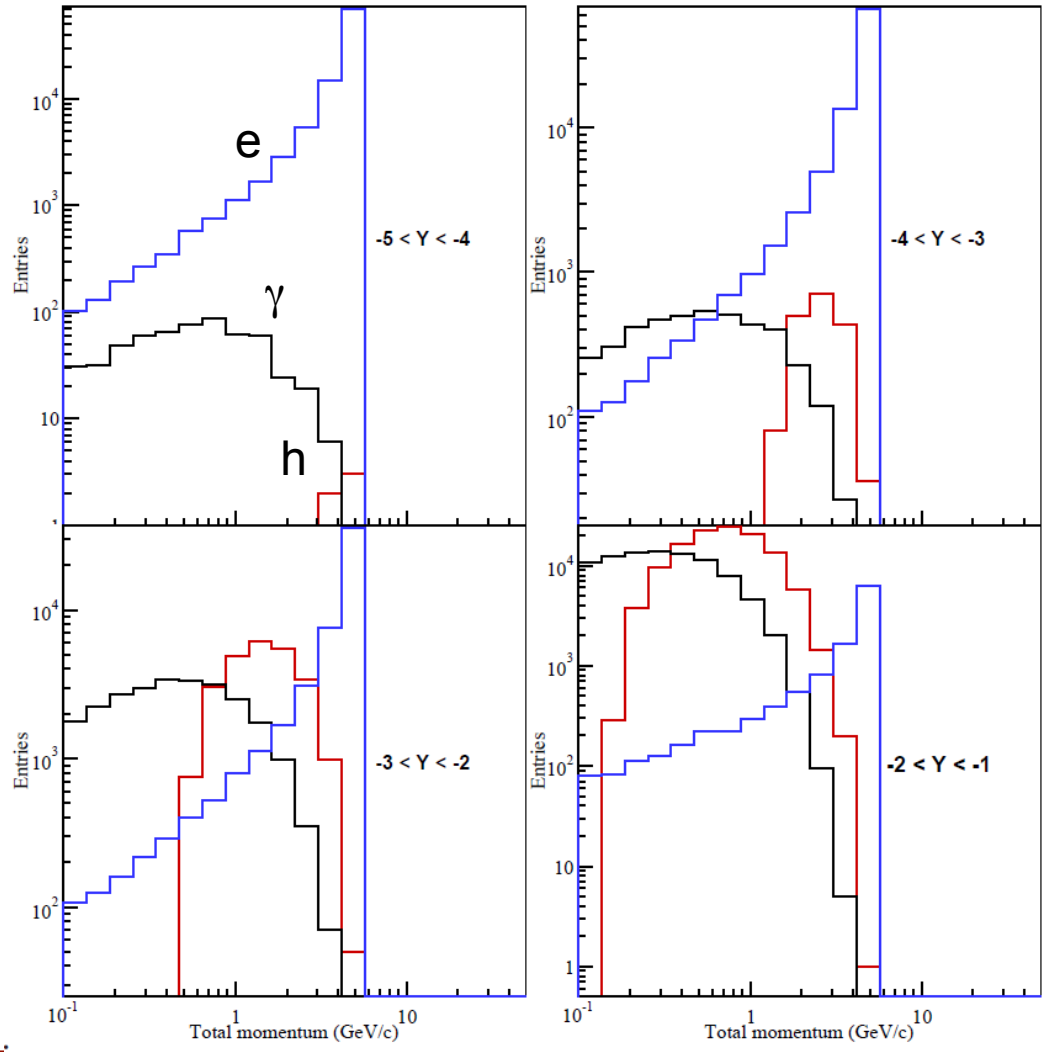
SPACAL resolutions, averaged over 4 Channels, $\sigma_E / E = (a/\sqrt{E})+b$



First Stage eRHIC electron/hadron PID

INT report (arXiv:1108.1713) Fig.7.18.





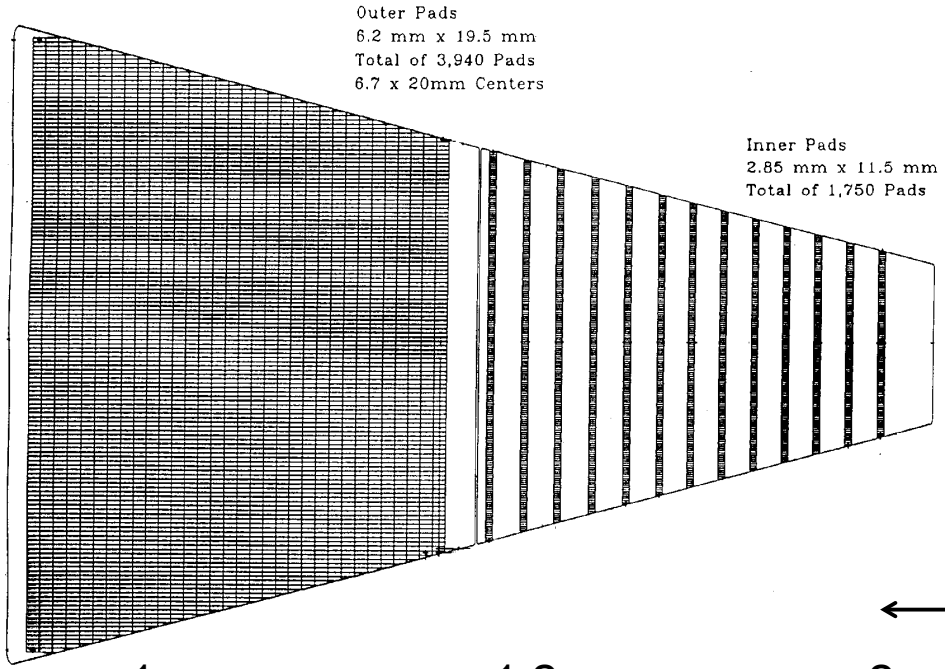
Electron coverage: 1>eta>-2.5

PID e/h: 1000

Low material: photon conversion

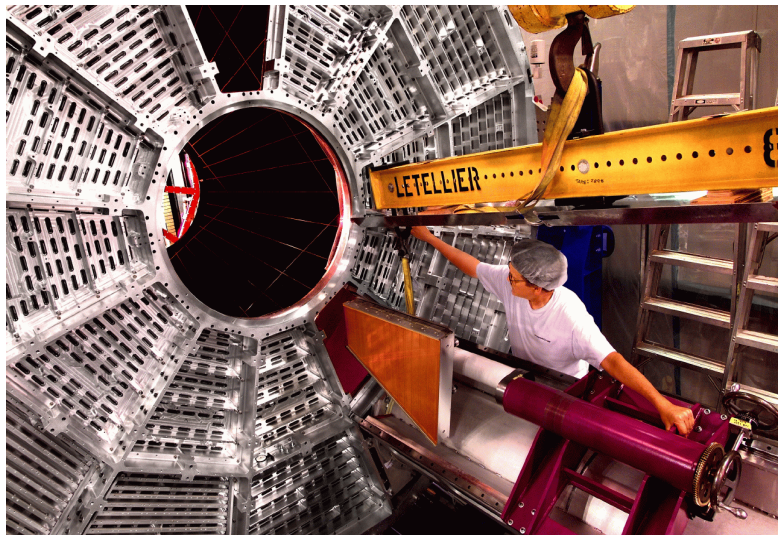
TPC Inner Sector Upgrade

- Staggered readout
  - Only 13 maximum possible points
    - Issues in Tracking: recognition and resolution
  - Only reads ~20% of possible gas path length
    - Inner sectors essentially not used in dE/dx
- Essentially limits TPC effective acceptance to $|\eta|<1$



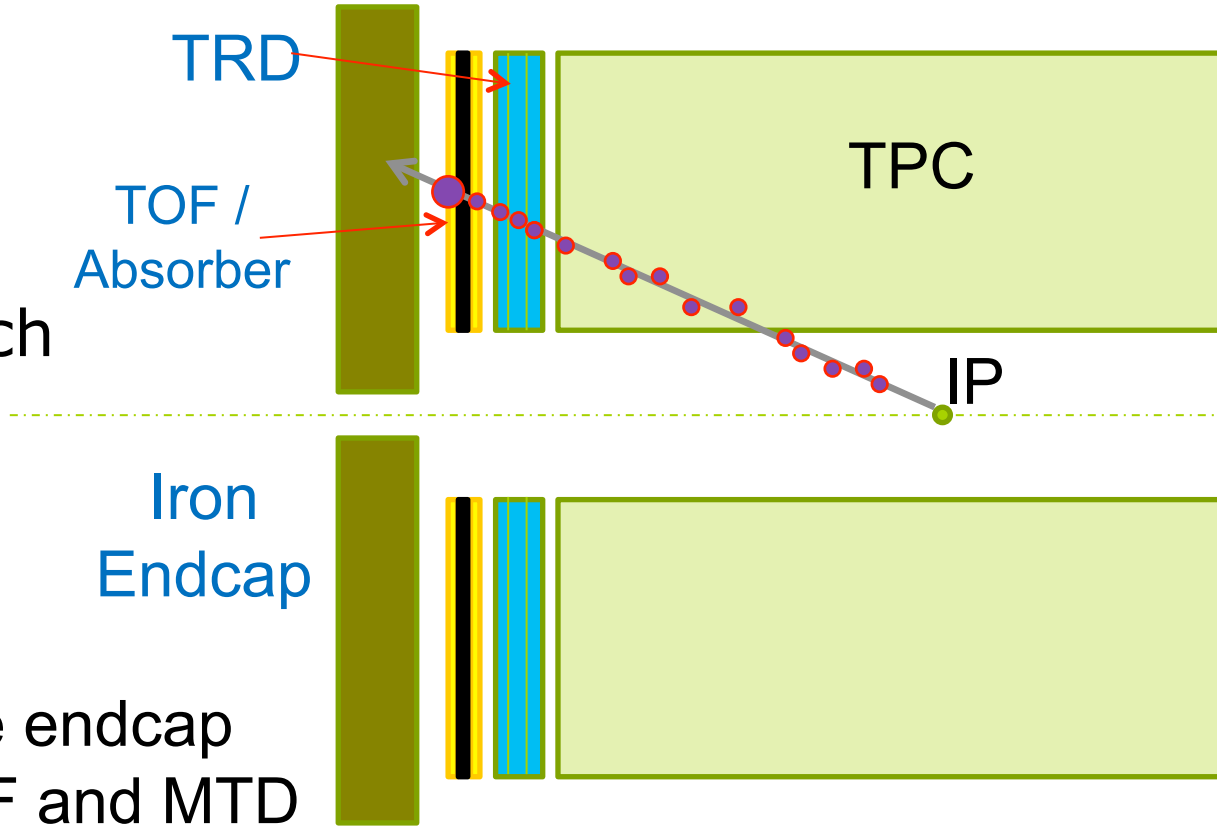
Inner TPC Upgrade:

1. MWPC (SDU/SINAP)
   ATLAS sTGC
   Chinese 973 project
2. Mechanics (LBL/BNL)
   Eric Anderson (PI)
3. Electronics (BNL/ALICE)
4. Schedule (2017)



TRD+TOF at Endcap (-2<η<-1)

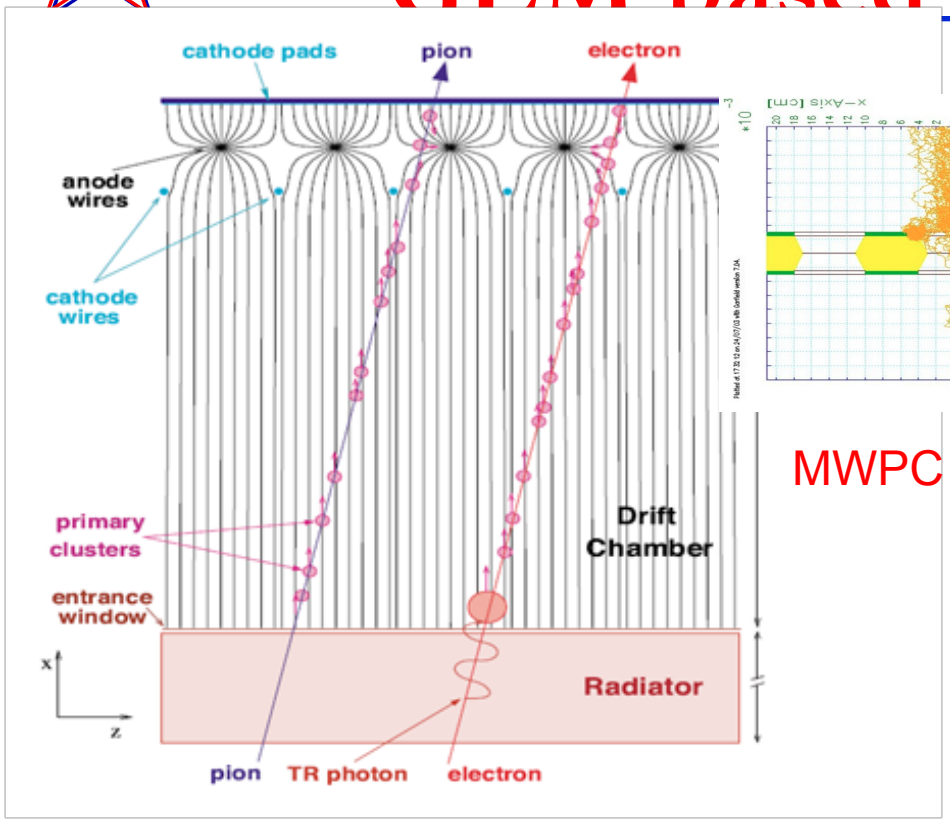
- Inner tracking
- TPC (endcap region):
  TRD +
  TOF/Absorber sandwich



Ming Shao (USTC)

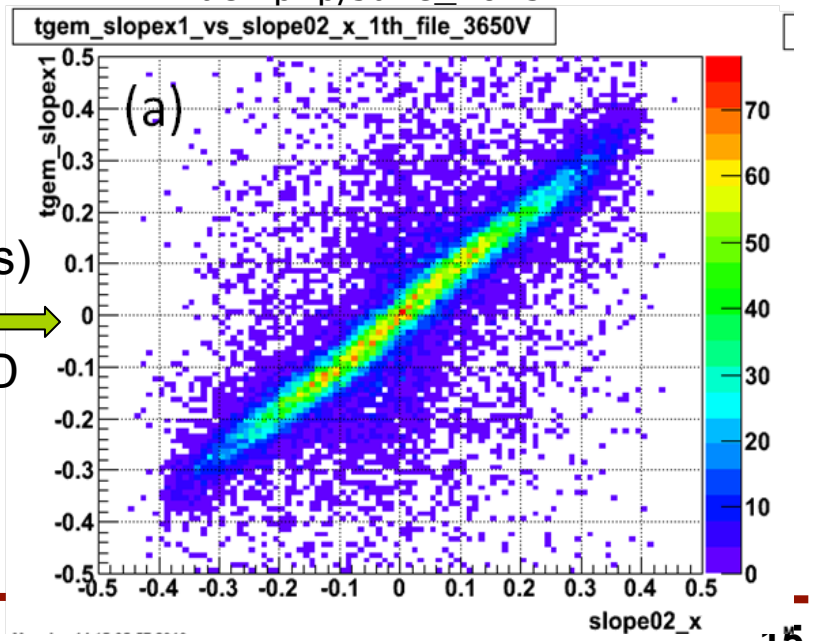
- Within <70cm space inside endcap
- TOF as start-time for BTOF and MTD
- TOF + dE/dx for electron ID
- TOF for hadron PID
- Extend track pathlength with precise points
- High-precision dE/dx (Xe+CO2) TRD

GEM based TRD – R&D



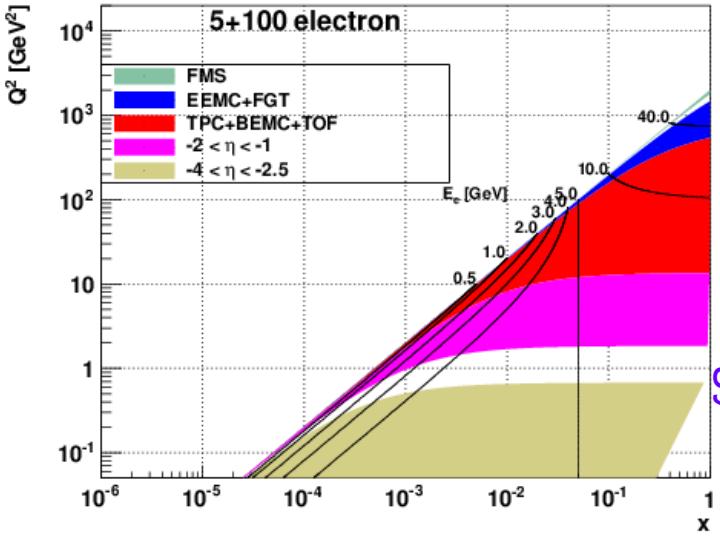
MWPC ➔ GEM

- Advantage
  - Few ion feedback to drift volume
  - High rate
  - Better position resolution
  - Less space charge effect
  - dE/dx
  - Drift along magnetic field
- EIC R&D support (BNL/USTC/IU/Yale)
- https://wiki.bnl.gov/conferences/index.php/June_2013

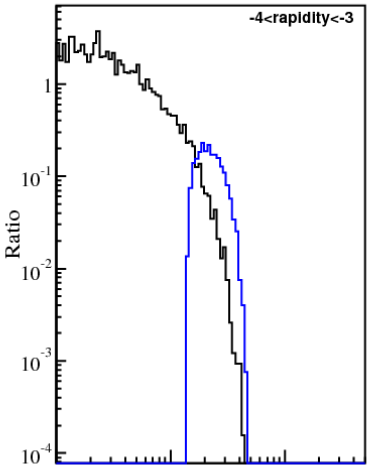


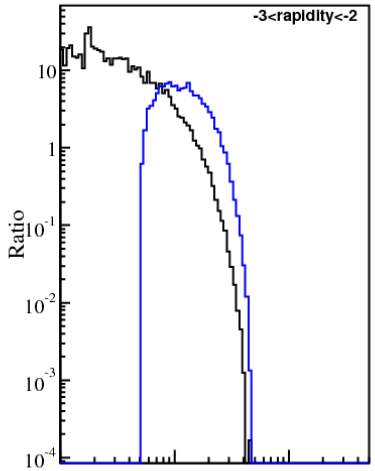
- Prototype TRD with miniDrift GEM (27 time bins)
- **Cosmic ray test results**
- Plan test beam at FermiLab with other EIC R&D projects in October (T1037)
- Setups at USTC and BNL

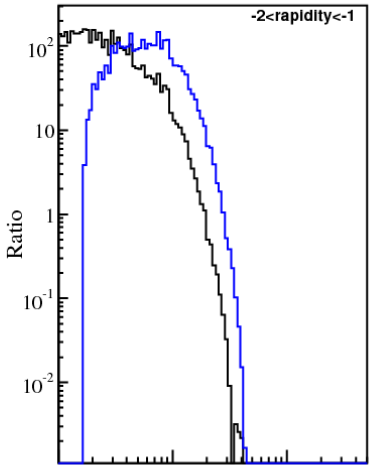
First Stage eRHIC electron/hadron PID



Electron Energy 5➔10 GeV

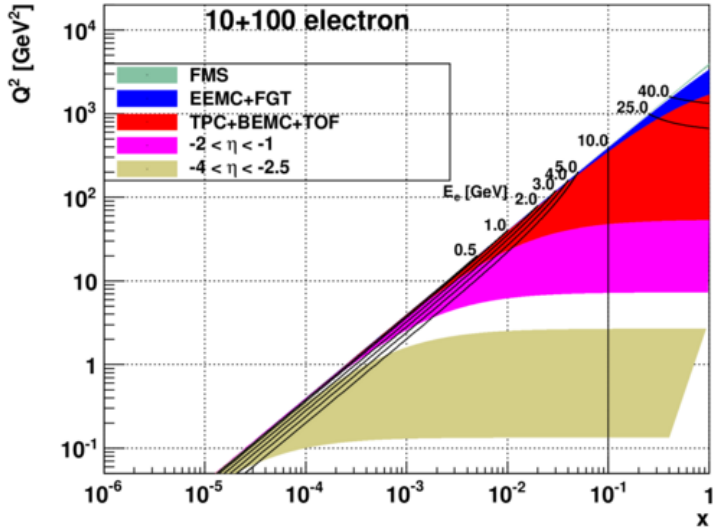


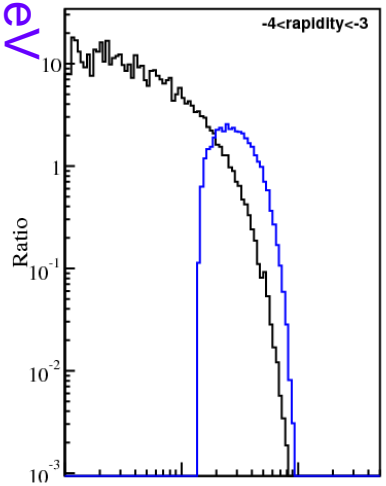


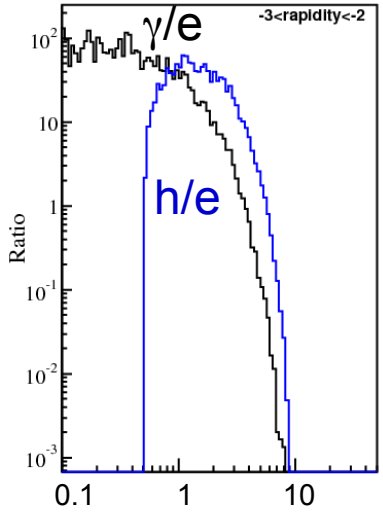


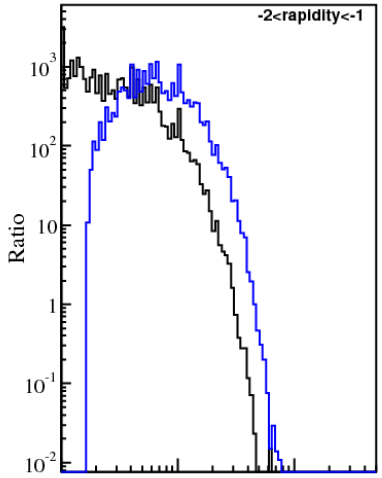
Momentum (GeV/c)

EIC task force



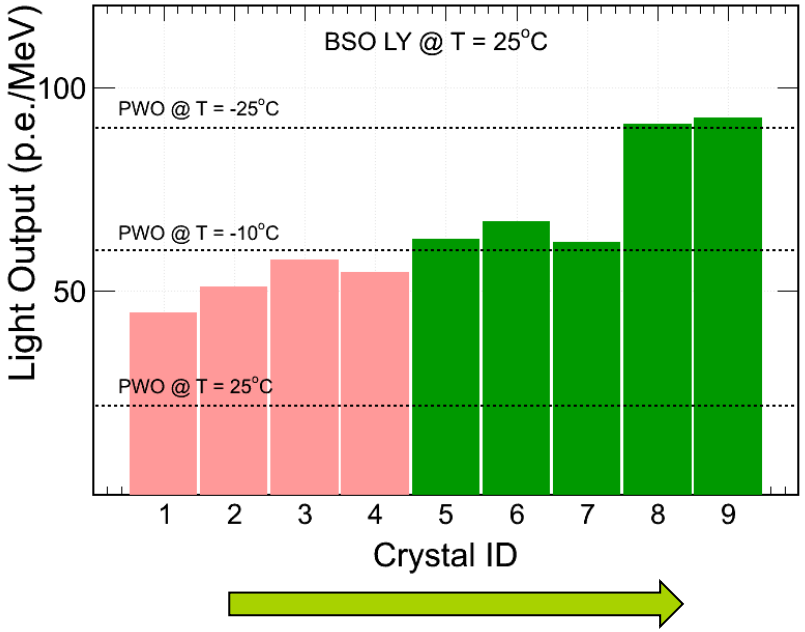






BSO Crystals for Forward Electron

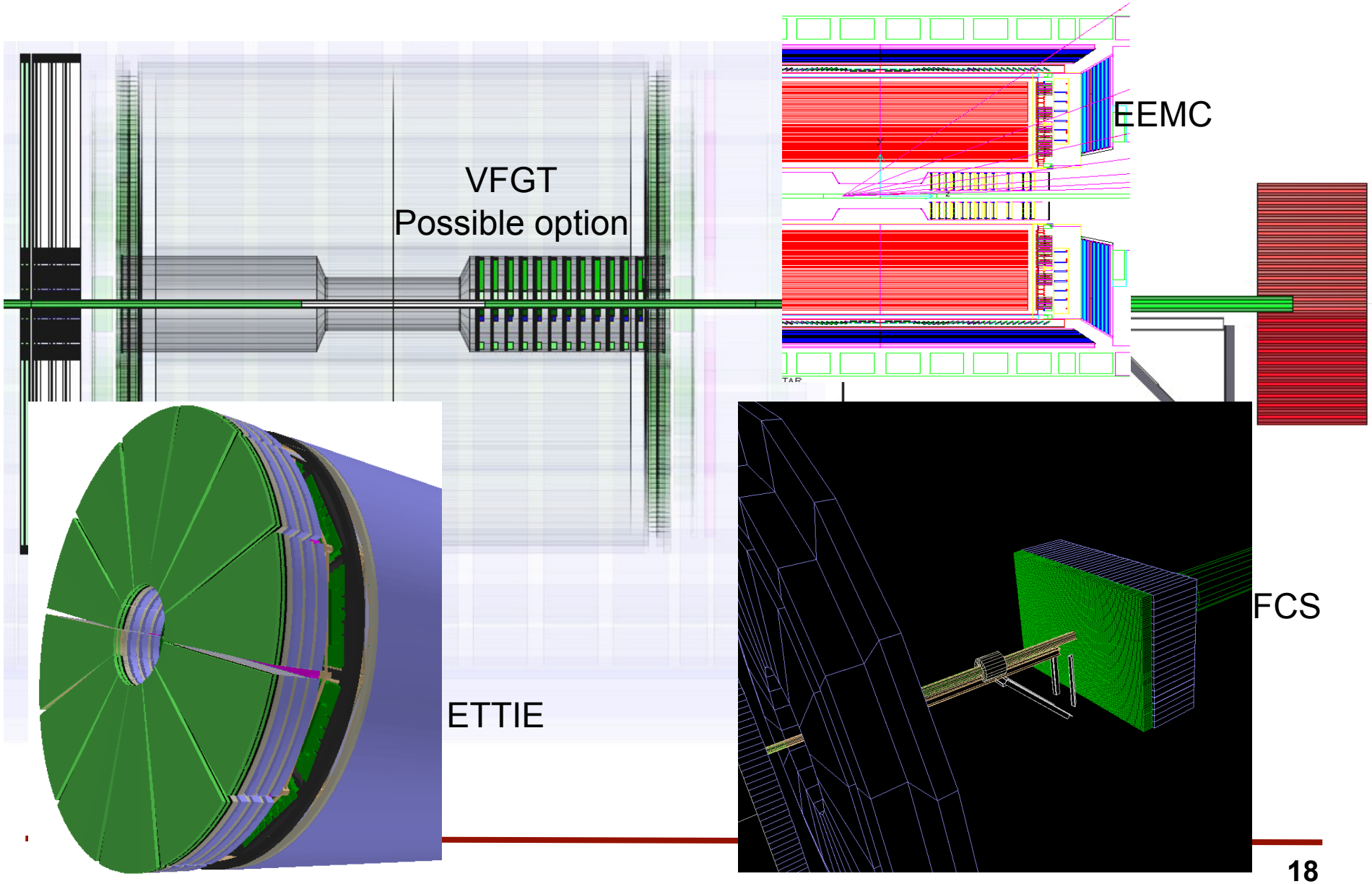
Crystal	Long_BSO	Short_BSO	Long_PWO	Short_PWO
ID	BSO_L	BSO_S	PWO-B	PWO-A
Size	20*20*200mm	Φ=25mm,L=30mm	25*25*220mm	30*30*45mm



Production Getting better over time

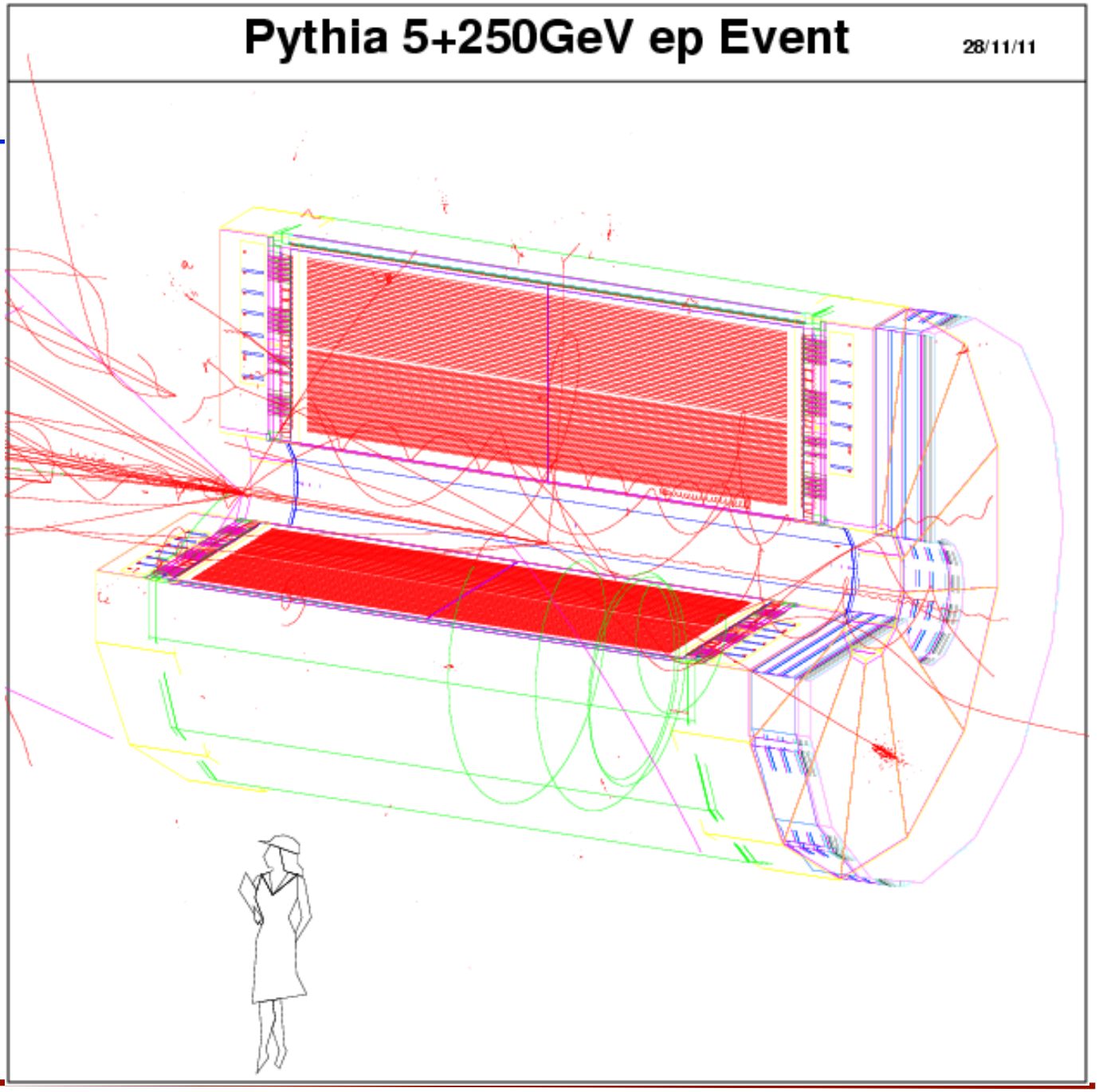
- **Very Forward Electron Detection (eta<-2.0)**
- BSO is produced by replacing Ge in BGO with Si, the material cost for BSO reduced by x3-4.
- Collaborators: USTC,SINAP,THU,UCLA
- Vendor: Shanghai SICCAS High Technology Coorporation (USTC/UCLA/SICCAS)
- **R&D proposal partially funded by BNL/DOE**

Simulation Geometry

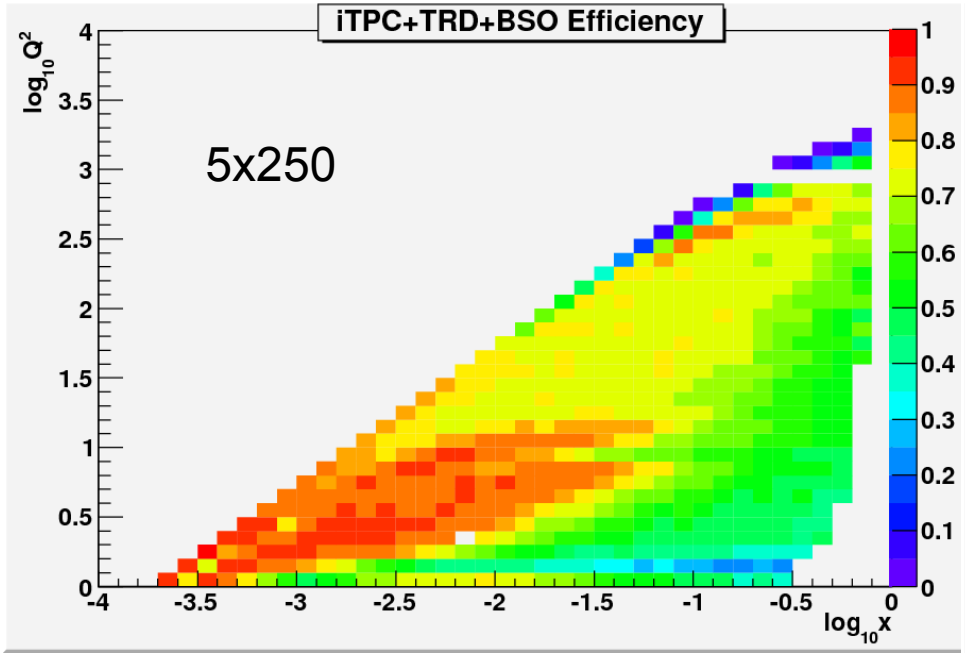


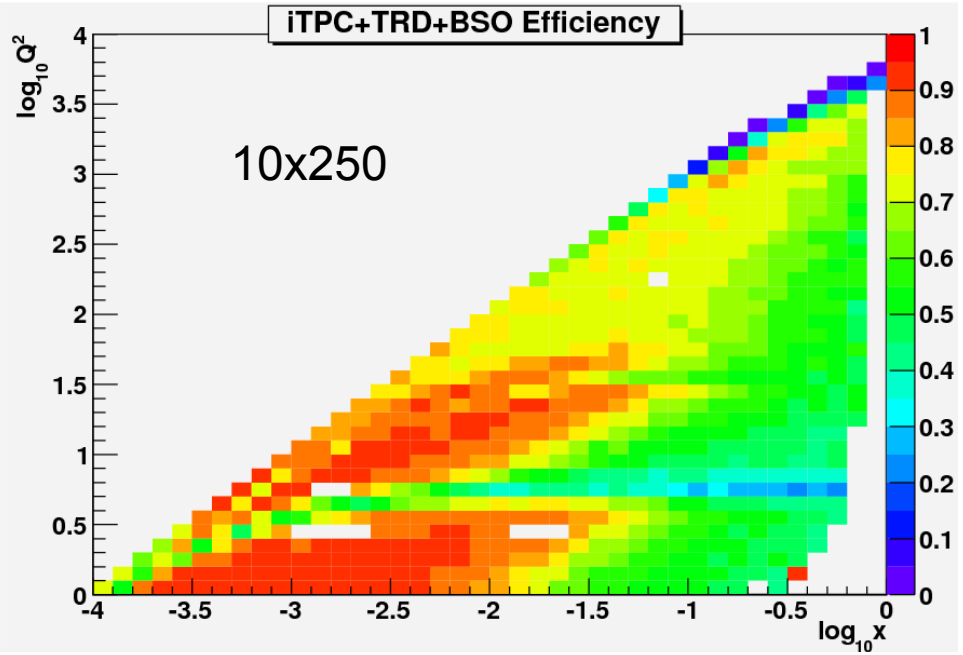
A Pythia Simulation Event

Only TPC and ETTIE are shown



eSTAR Acceptance



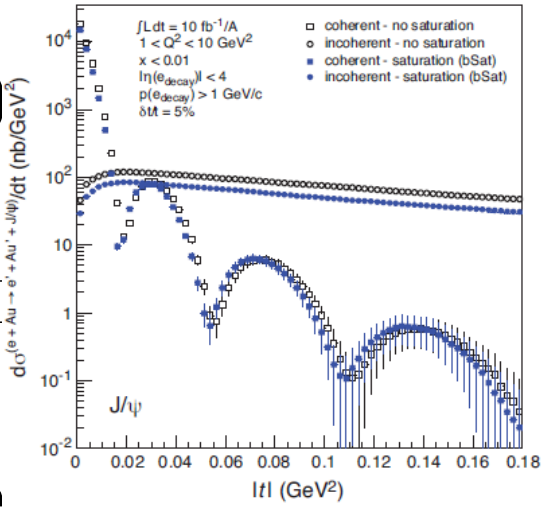


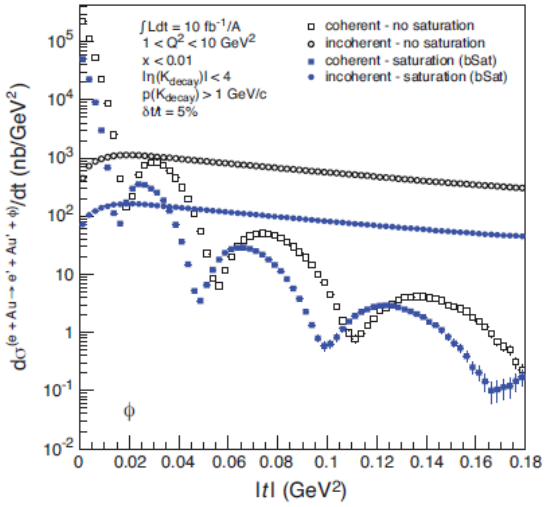
GEANT Simulation with eSTAR geometry
Inclusive Acceptance:
Scattered Electron in x-Q^2
TPC hits>15
BSO and TRD Efficiency assumed 90%

Physics Simulations in Progress

5(10)x250

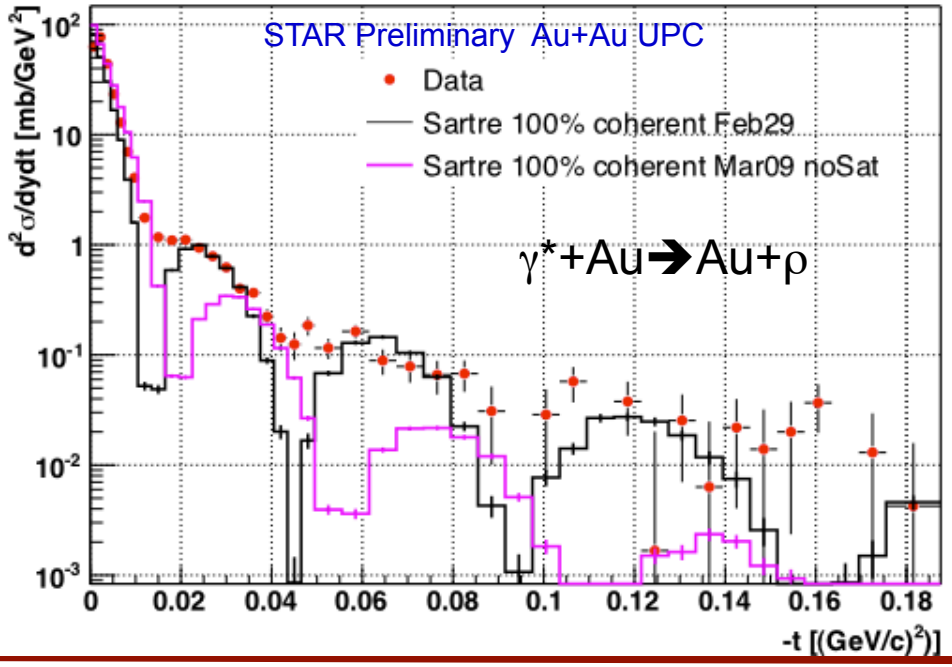
1. g_1 vs (x,Q^2), generator
2. Semi-inclusive with P





eA (ele

1. F_2, F_L 5(10)x50, 5x7
2. dϕ of di-hadron for
   photon direction (as z):
3. Semi-inclusive R(eA/ep
   (PYTHIA6.x)
4. J/Ψ exclusive (SARTRI



For event gene
https://wiki.bnl.gov/eic/in

Plans

- Continue to map the physics cases from EIC whitepaper to eSTAR
- Possible R&D projects:
  1. Tracking (hadron side, pA/pp)
  2. Calorimetry (hadron side, pA/pp)
  3. Tracking+eID (electron side, eSTAR)
  4. End-Cap TOF (electron side, eSTAR)
  5. Very forward electron ID (eSTAR)
  6. Roman Pots (pA/pp)
- Simulation of feasibilities
- Discuss with CAD and EIC TF on IR design and detector R&D

Summary

- eSTAR a possible option for first-stage EIC detector (Electron E<~10 GeV)
- Near-term upgrades for RHIC have optimized to be suitable for eRHIC (eSTAR)
- R&D projects and EIC simulation in progress
- LoI Writing Committee
- Inputs/helps from groups (theorists and experimental colleagues)

STAR: LOI for Transition to eRHIC

Membership of the committee: Elke Aschenauer, Jamie Dunlop, Renee Fatemi, Carl Gagliardi, Huan Huang, Ming Shao, ***Ernst Sichtermann****, Thomas Ullrich, Flemming Videbaek, Nu Xu, ***Zhangbu Xu****

*co-chair

Deadlines: Sept. 15: draft to the STAR Collaboration
Oct. 1: final document sent to the BNL management