STAR Upgrade Plans and Physics Outlook

RHIC&AGS Users Meeting, June 25-28 2013, BNL

Zhenyu Ye

for the STAR collaboration

(1) Department of Physics, University of Illinois at Chicago, USA

(2) College of Physical Science & Technology, Central China Normal University, China

STAR

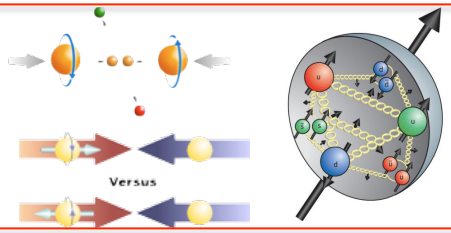
UIC The University of Illinois at Chicago

Office of Science U.S. DEPARTMENT OF ENERGY

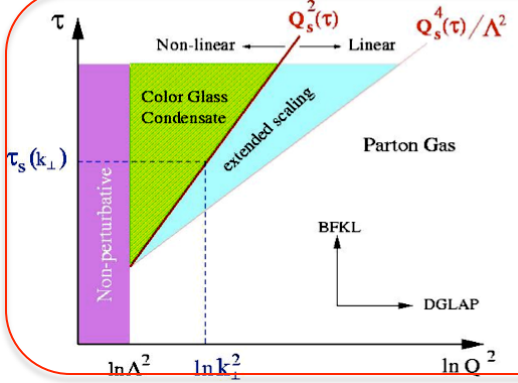
Outline

- Introduction
- On-going upgrades and physics goals
  - Heavy Flavor Tracker
  - Muon Telescope Detector
- Middle- and longer term plans
  - Forward upgrades
  - eSTAR for eRHIC
- Summary

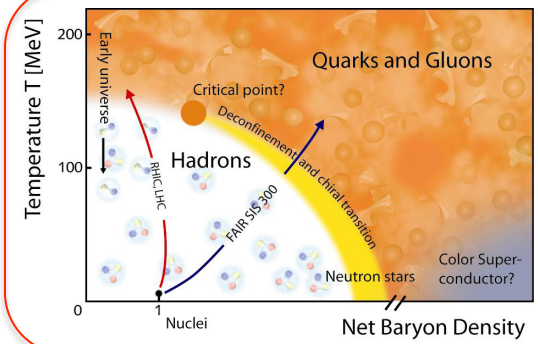
STAR Physics Focus



Polarized p+p Program:
proton intrinsic properties, QCD



Small-x Physics Program
low-x properties, initial conditions
search for CGC
elastic and inelastic process in pp2pp



1) At 200 GeV at RHIC
- medium properties, EoS
- pQCD in hot and dense medium

2) RHIC Beam Energy Scan (BES)
- search for the QCD critical point
- chiral symmetry restoration

STAR Decadal Plan

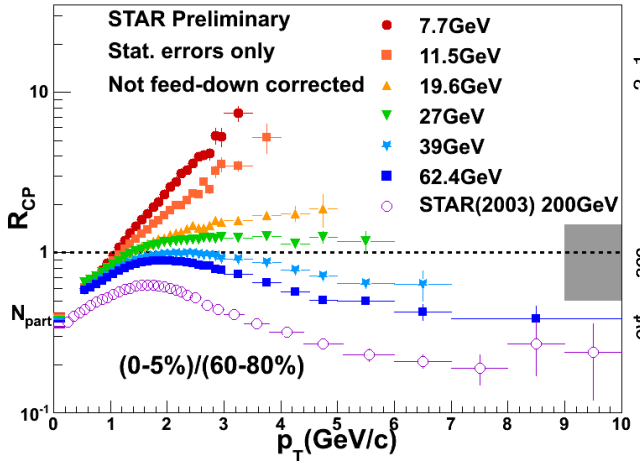
STAR Decadal Plan:

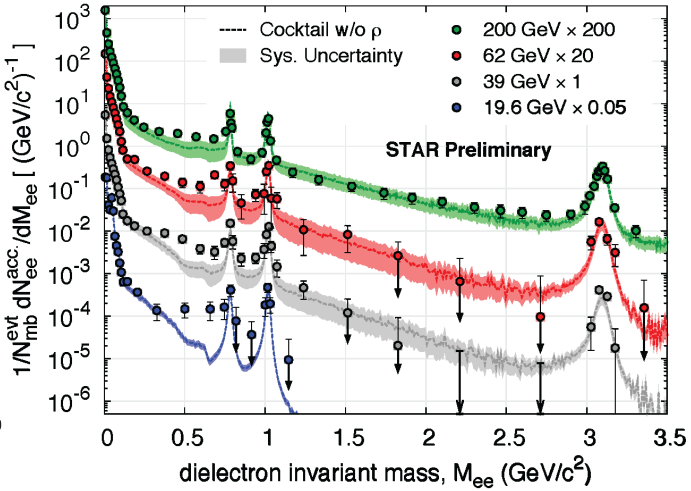
http://www.bnl.gov/npp/docs/STAR_Decadal_Plan_Final[1].pdf

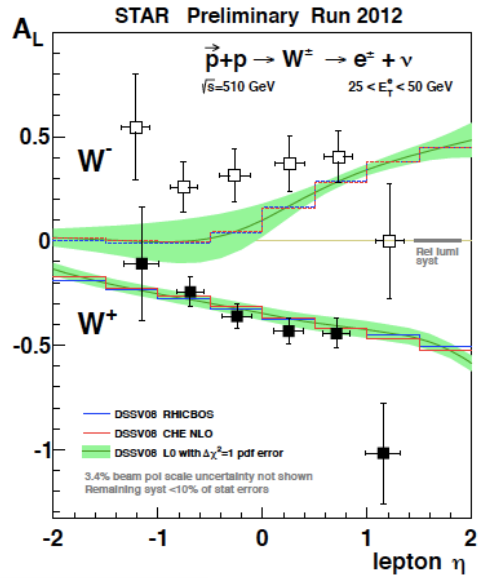
(1) Properties of the sQGP
(2) Mechanism of energy loss
(3) Is there a critical point, and if so, where?
(4) Novel symmetry properties
(5) Exotic particles
(6) Spin structure of the nucleon
(7) How to go beyond leading twist and collinear factorization?
(8) What are the properties of cold nuclear matter?

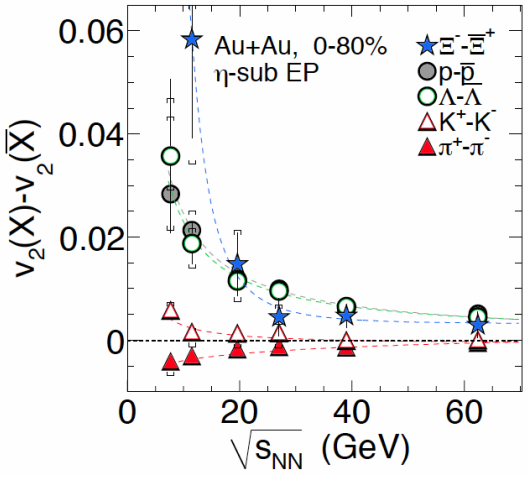
Emergent properties of QCD matter

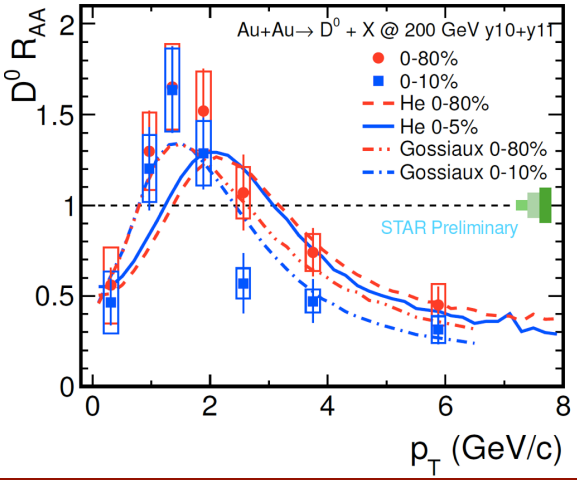
New STAR Results

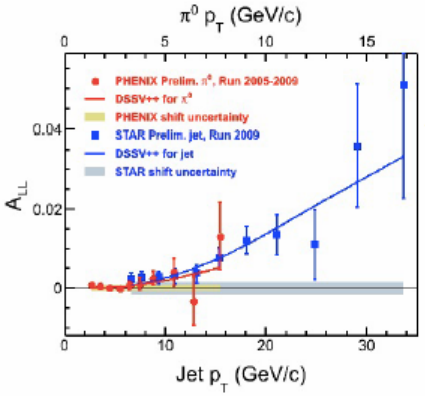


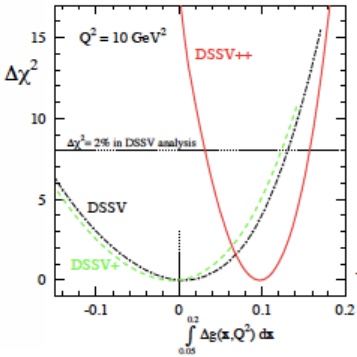












J.Stevens "Summary of Recent STAR Results" and other STAR talks this week

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STAR Detector in 2013-2014

Recent Upgrades:
DAQ1000, TOF, FGT

Tracking + PID: TPC

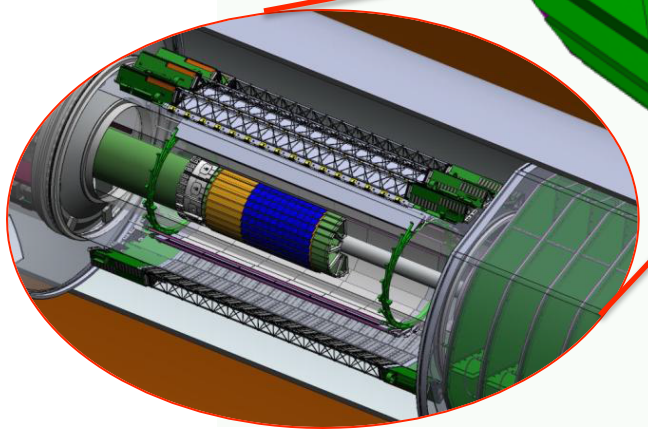
PID: TOF

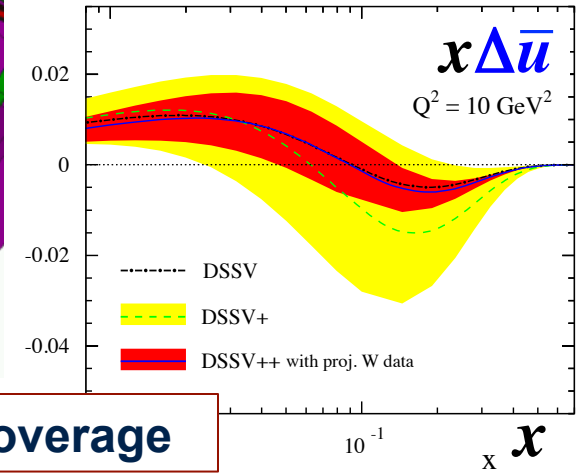
BEMC+EEMC+FMS (-1≤η≤4)

Muon Telescope Detector
(run 13/14)

Heavy Flavor Tracker
(run 14)

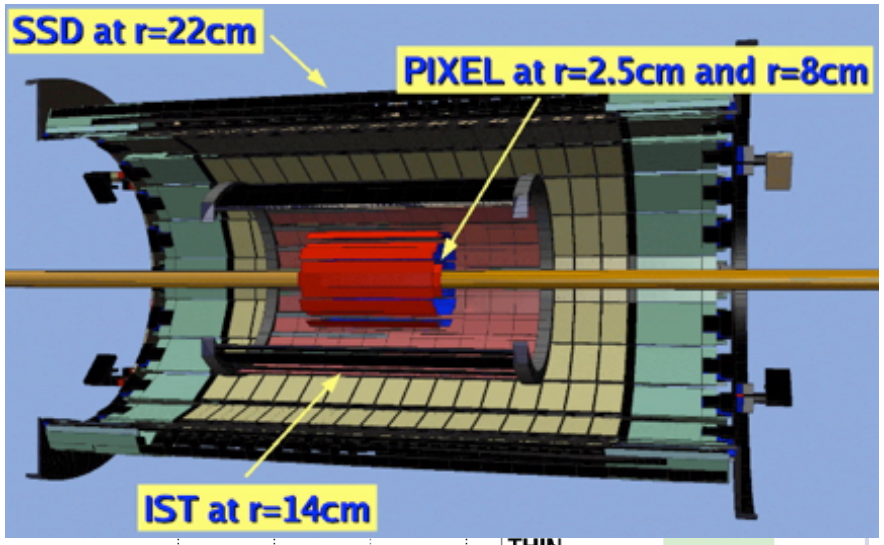
Forward GEM Tracker
(run 12/13)

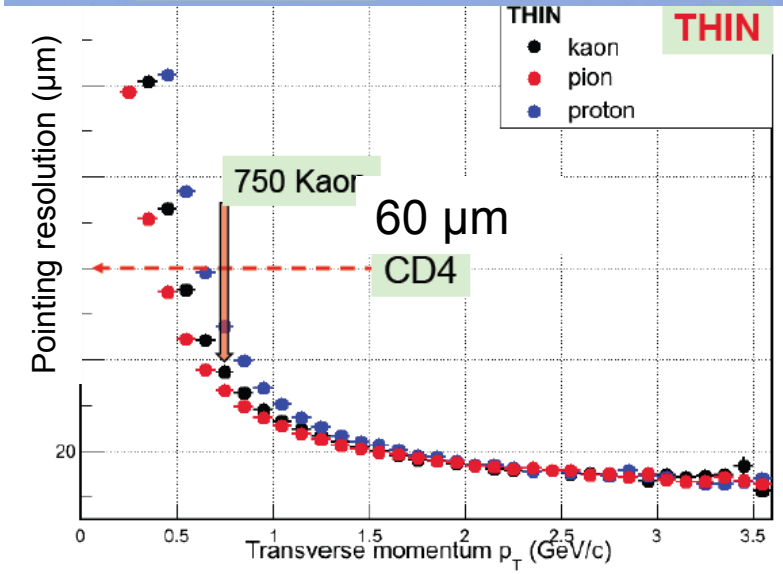




Excellent mid-rapidity Tracking+PID with full azimuthal coverage

Heavy Flavor Tracker - HFT





On-going DOE MIE since 2010

Detector	Radius (cm)	Hit Resolution R/φ - Z (μm)	Radiation length
SSD	22	20 / 740	1% X_0
IST	14	170 / 1800	<1.5 %X_0
PXL	8	12 / 12	~0.4 %X_0
	2.5	12 / 12	~0.4% X_0

PXL

- two layers of Monolithic Active Pixel Sensors with 20.7x20.7 μm pitch, 400M channels
- installation/repair ~12h while STAR rolled in
- delivering ultimate pointing resolution allowing for direct topological identification of c/b

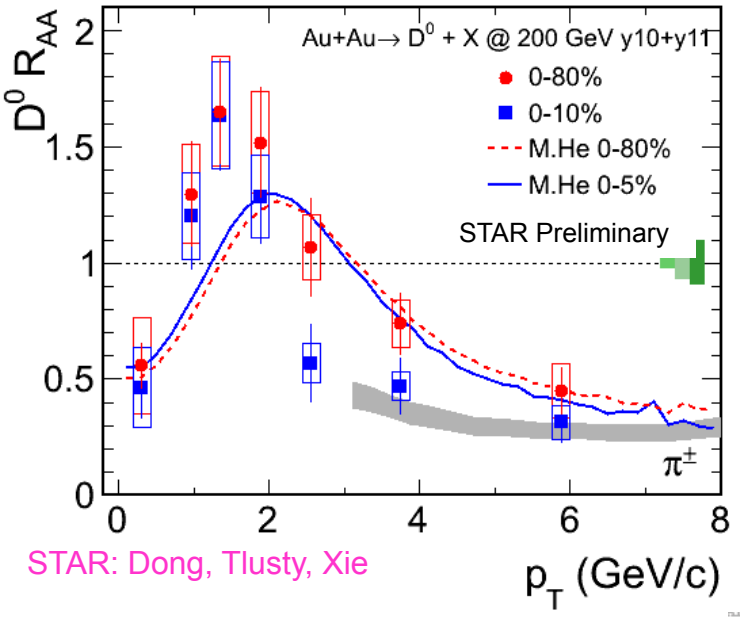
IST

- one layer of single-sided mini-silicon strip detector guiding tracks from SSD to PXL

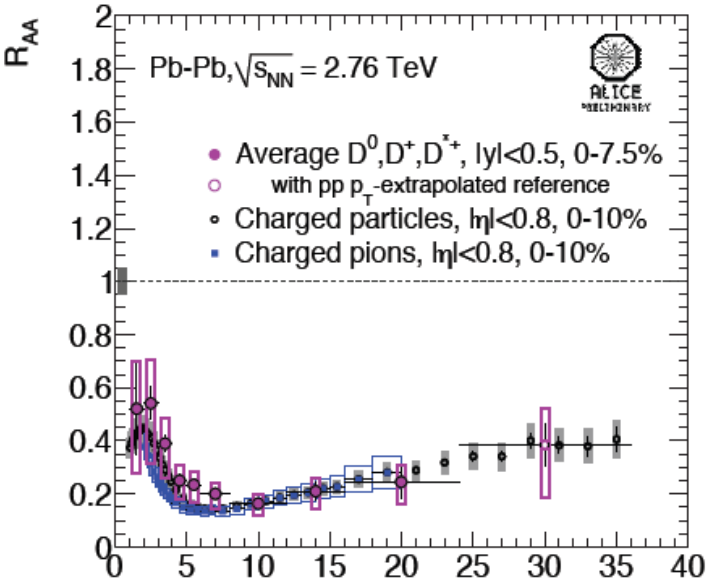
SSD

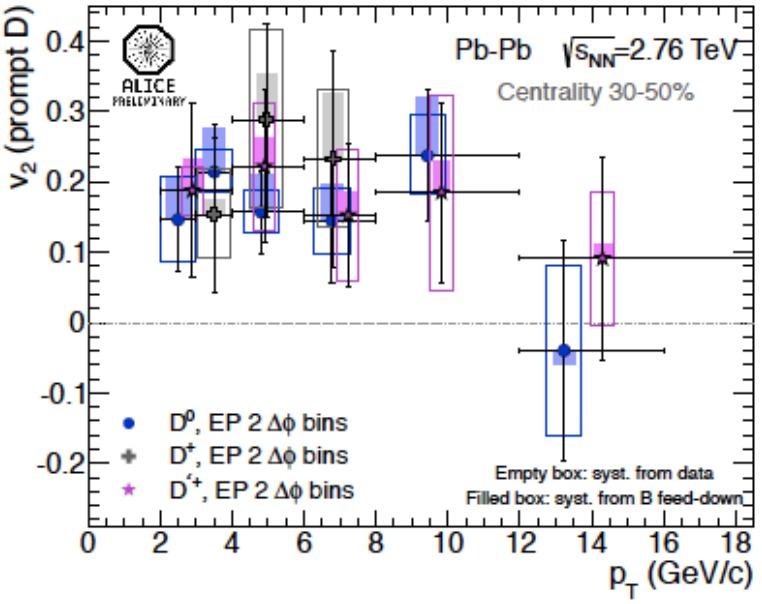
- existing single layer of double-sided silicon strip detector with electronic upgrade

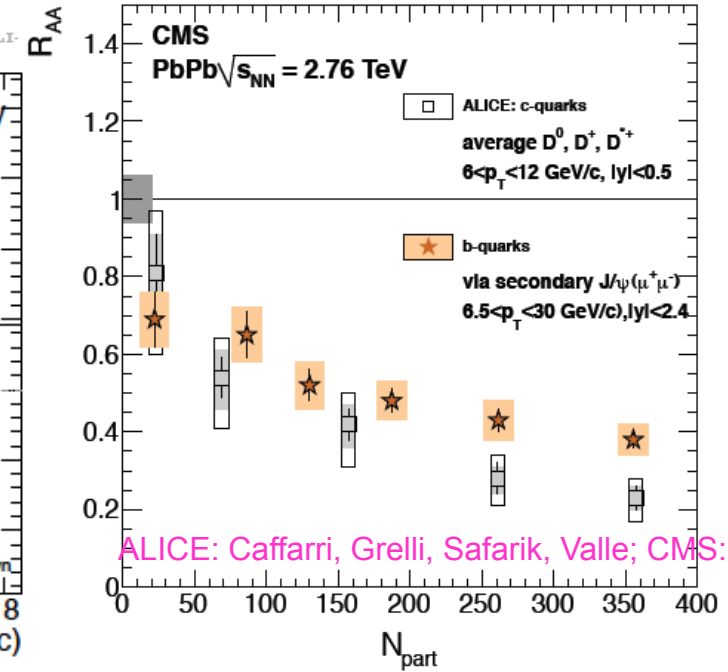
Open heavy flavor results in A+A



STAR: Dong, Tlusty, Xie

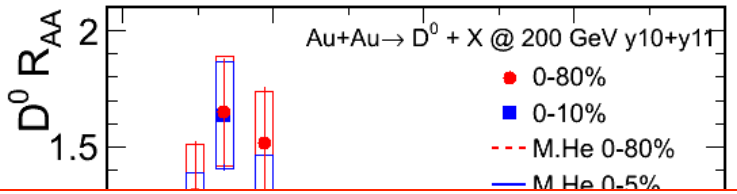


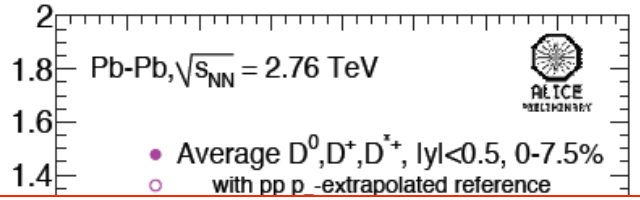




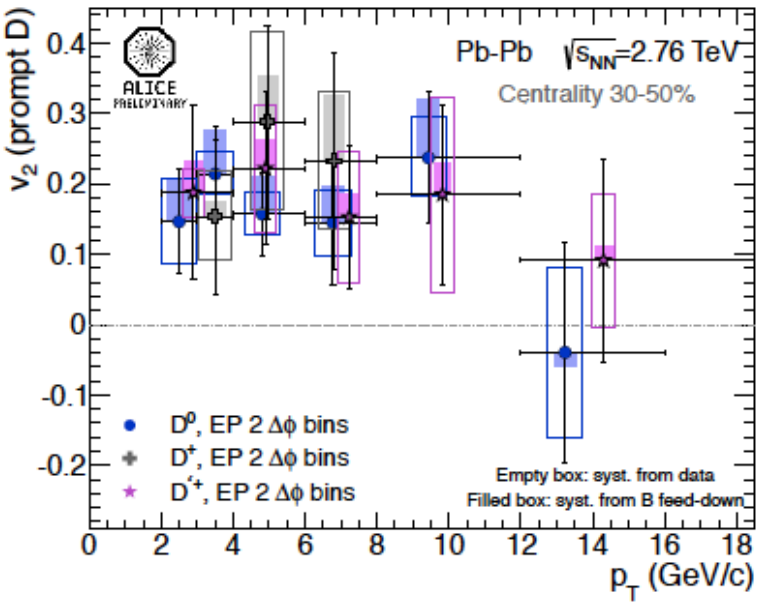
ALICE: Caffarri, Grelli, Safarik, Valle; CMS: Mironov, Jo

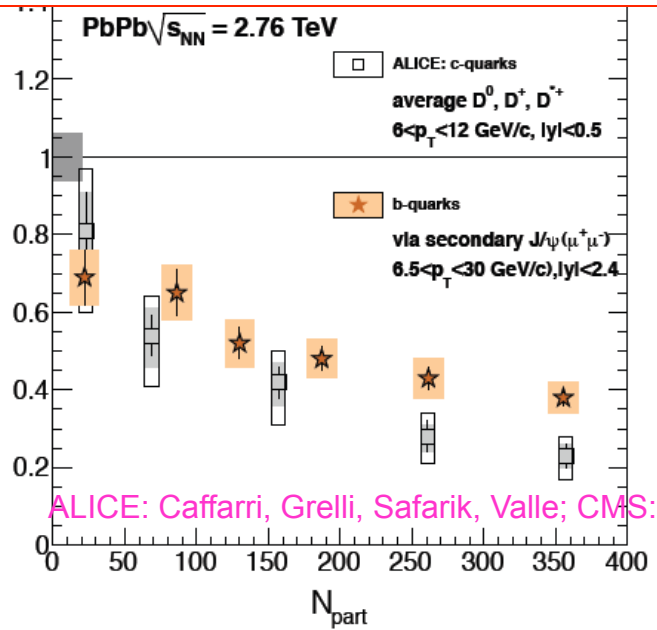
Open heavy flavor results in A+A





- **Significant charmed hadron, B hadron suppression observed. $R_{AA}(D) \sim R_{AA}(\pi) \leq R_{AA}(B \rightarrow J/\psi)$**
- **D meson flows** (High precision measurements of electron, muon R_{AA} and v_2 also reported by ALICE, ATLAS, and STAR)
- **Need more precise measurements to study color charge and/ or flavor dependence of energy loss**

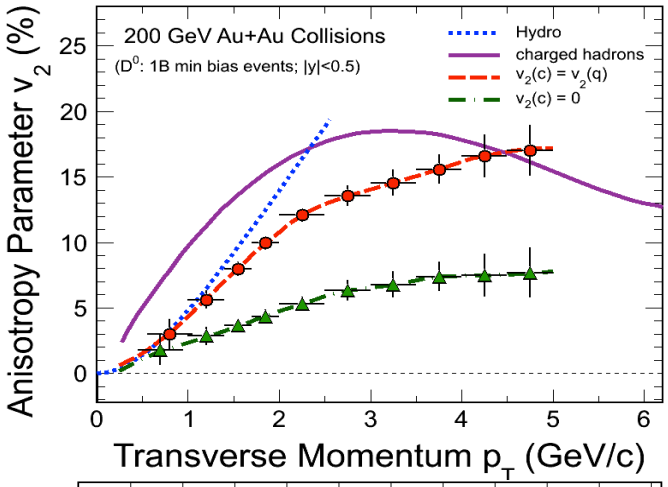


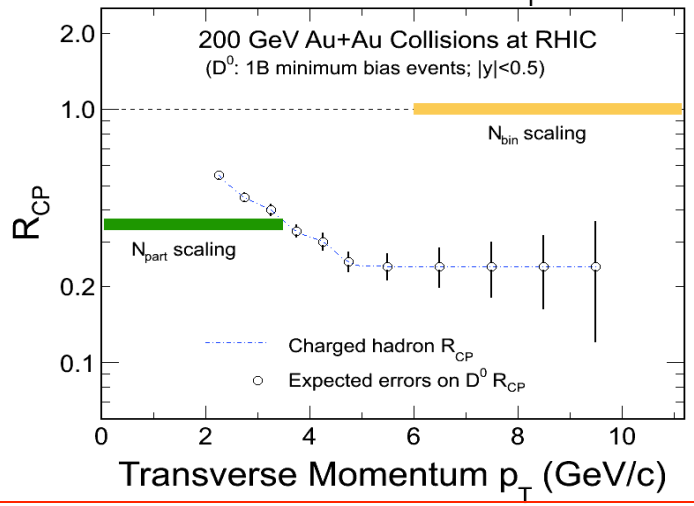


ALICE: Caffarri, Grelli, Safarik, Valle; CMS: Mironov, Jo

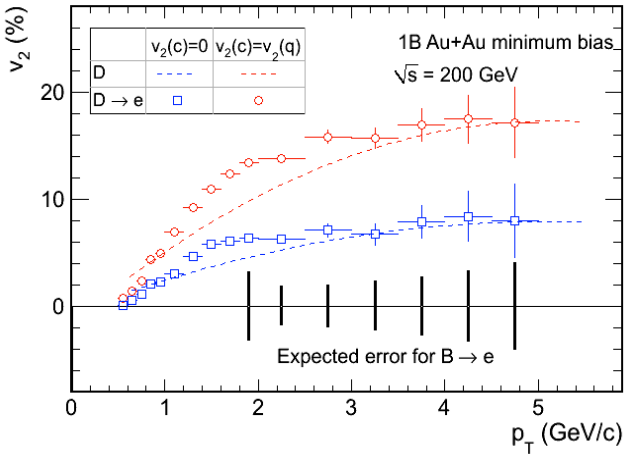
(Projected) HFT Physics Goals – 2014+

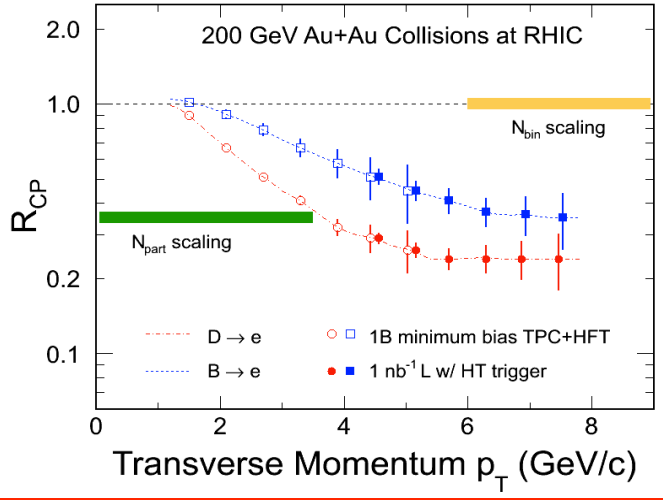
D^0 mesons





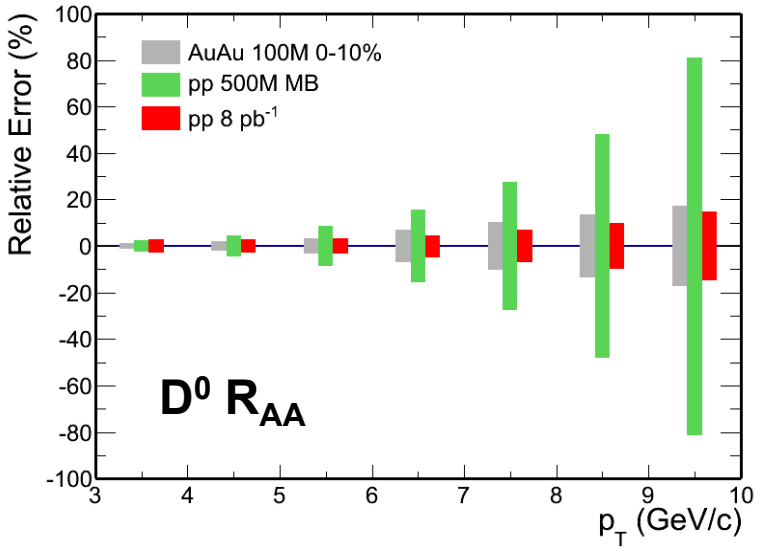
HF decayed electrons

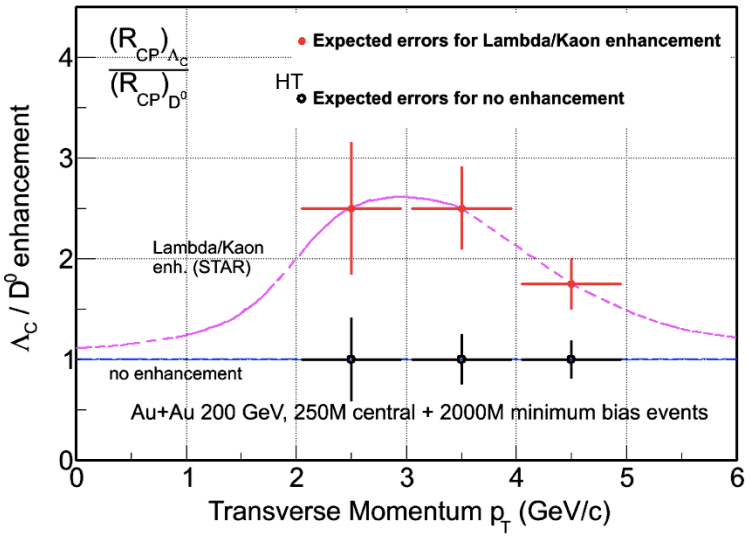




unique high precision at low p_T -> medium thermalization, total charm production

(Projected) HFT Physics Goals – 2014+



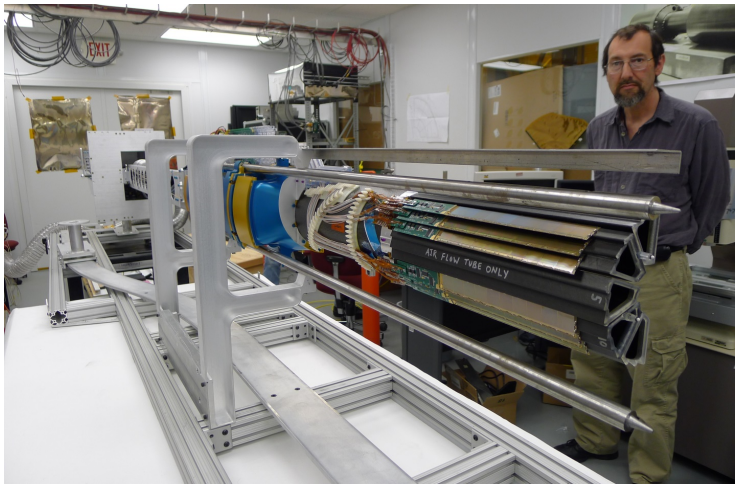


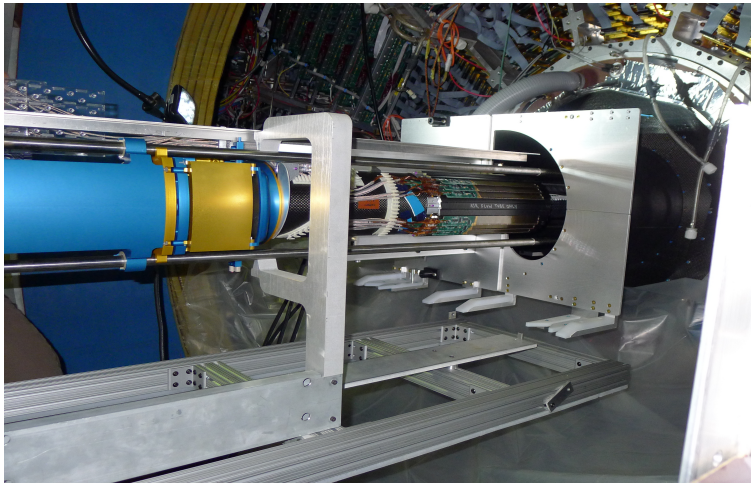
STAR multi-year physics program with the heavy flavor measurements requires high statistics data from both p+p and heavy ion collisions

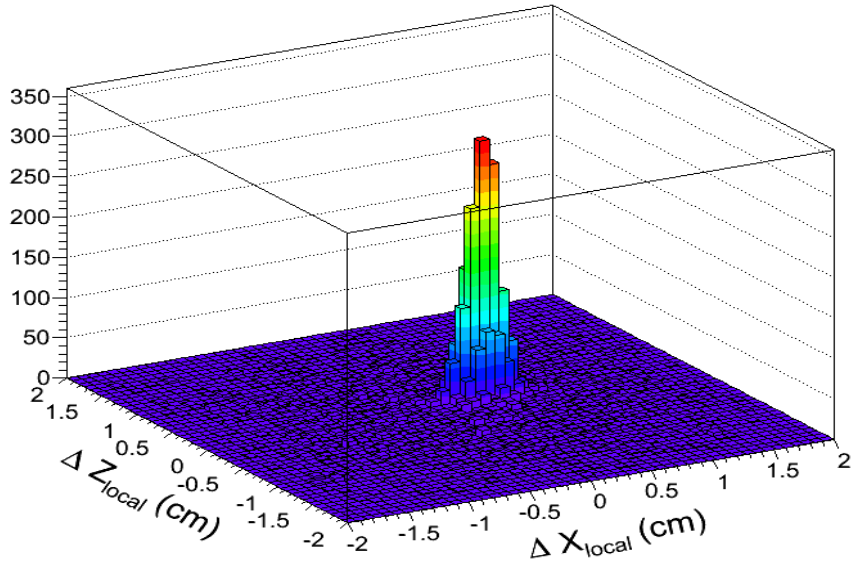
Λ_c: lowest charm baryon state, $c\tau \sim 60\mu m$

- First measurement of charm baryon in heavy ion collisions
- Hadro-chemistry with charm
- Meson vs. baryon effect with charm hadrons

HFT Engineering Run in 2013





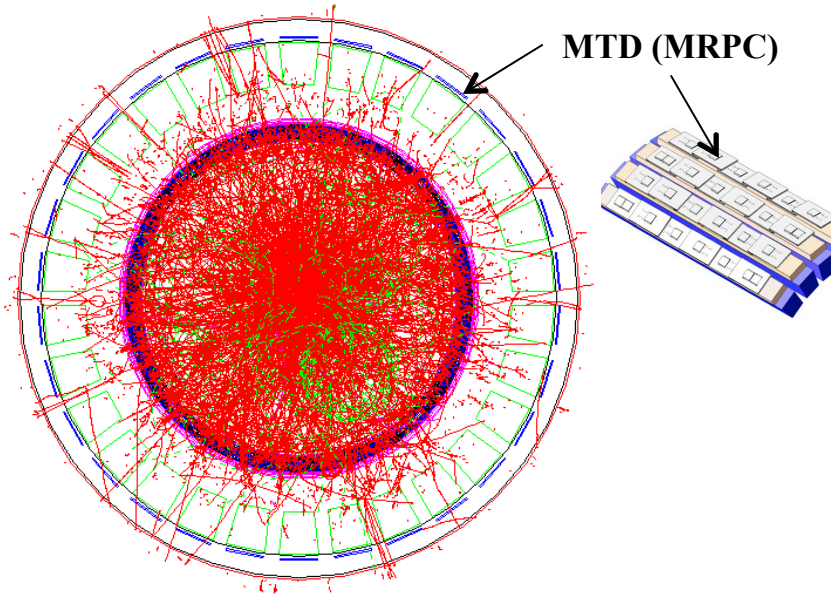


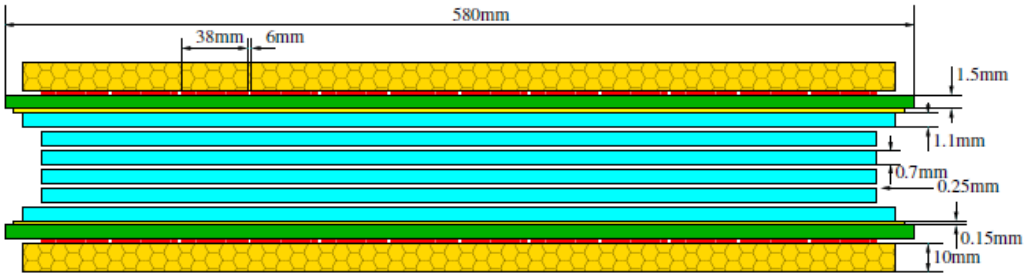
3 out of 10 PXL sectors successfully installed and took data in dedicated low luminosity runs in 2013

- design works, successful integration in STAR
- lessons learned on mechanical, operation settings, latch-up and stability, etc
- First results: TPC-PXL correlation match expected TPC resolution (~1-2 mm)

Full HFT starts data taking in 2014

Muon Telescope Detector - MTD



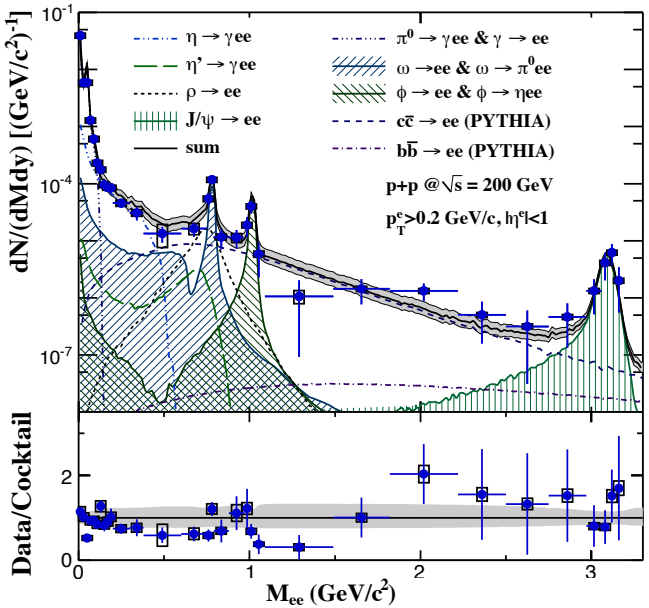


- Multi-gap Resistive Plate Chamber:
  - Gas detector, avalanche mode
- Electronics same as STAR-TOF
- Acceptance: 45% at $|\eta|<0.5$
  - Covers the magnet iron bars with gaps in-between uncovered

R&D since 2007; Construction since 2010
Significant contribution from China, India

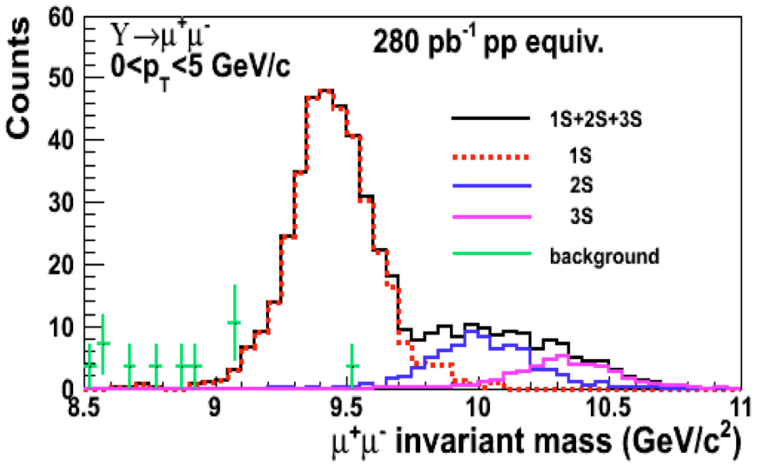
MTD Physics Motivation

- Di-muon pairs from QGP thermal radiation, $c\bar{c}$, quarkonia, light vector mesons in QGP
- Single muon from semi-leptonic decay of open heavy flavor. Unique: e-mu correlation for heavy flavor at low pT -> medium.
- No photon-conversion, much less Dalitz decay background contribution, and less radiative energy loss in detector than electrons -> excellent mass resolution.

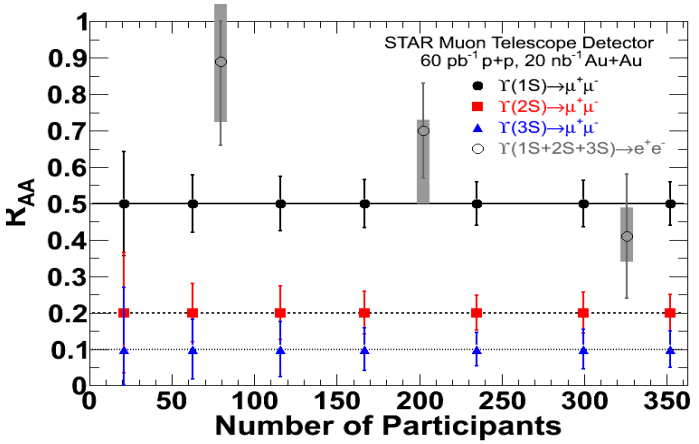


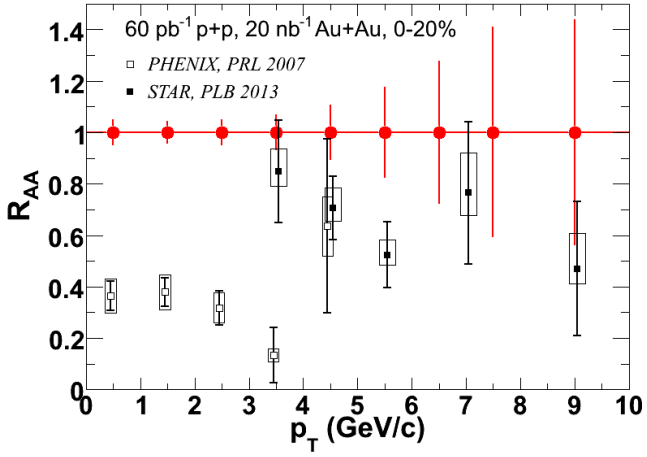
2013 DOE Early Career Research Program awarded to Lijuan Ruan "Mid-rapidity Di-lepton Measurements at RHIC with the Muon Telescope Detector at STAR"

Quarkonia from MTD



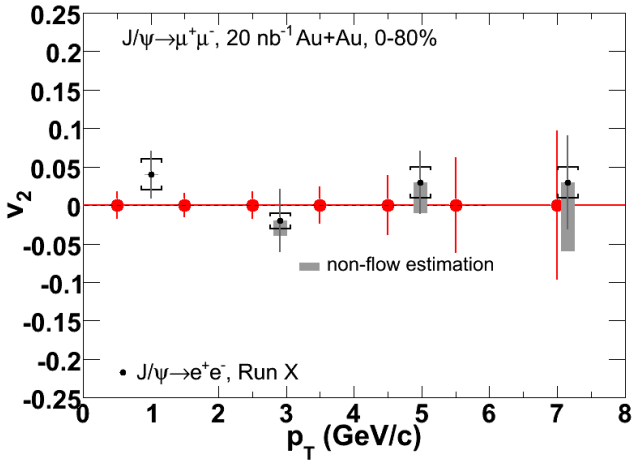
Υ => μμ





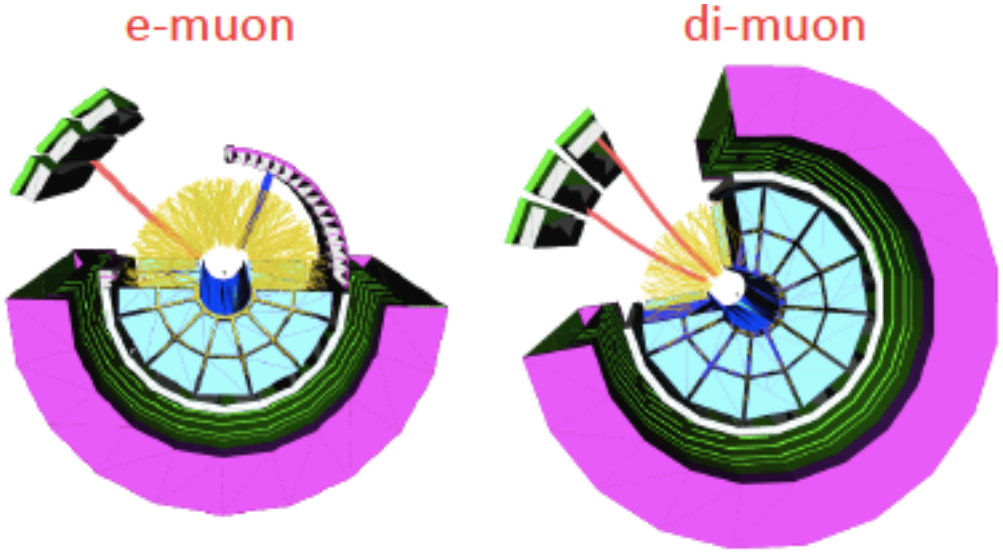
J/ψ

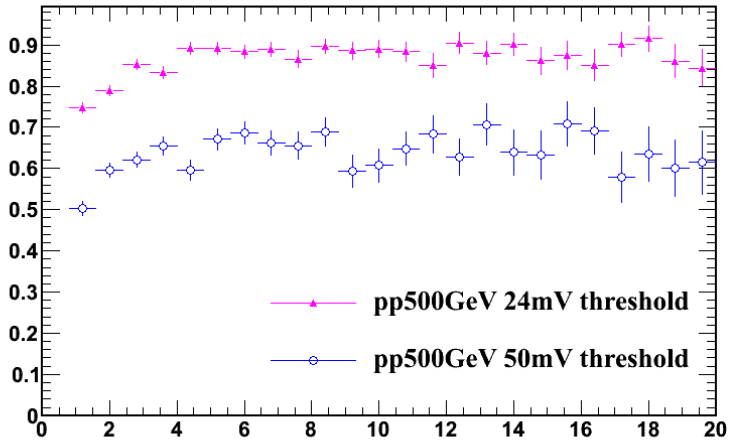
R_{AA} and v_2

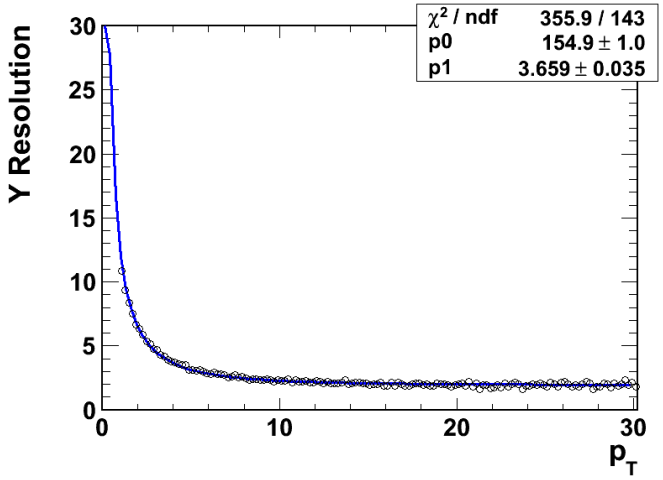


1) **Upsilon at RHIC:** unique, no regeneration, only initial production
2) **MTD at STAR:** Υ => μμ, no Bremsstrahlung tails, clean separation of the excited states

MTD Performance in 2012-2013

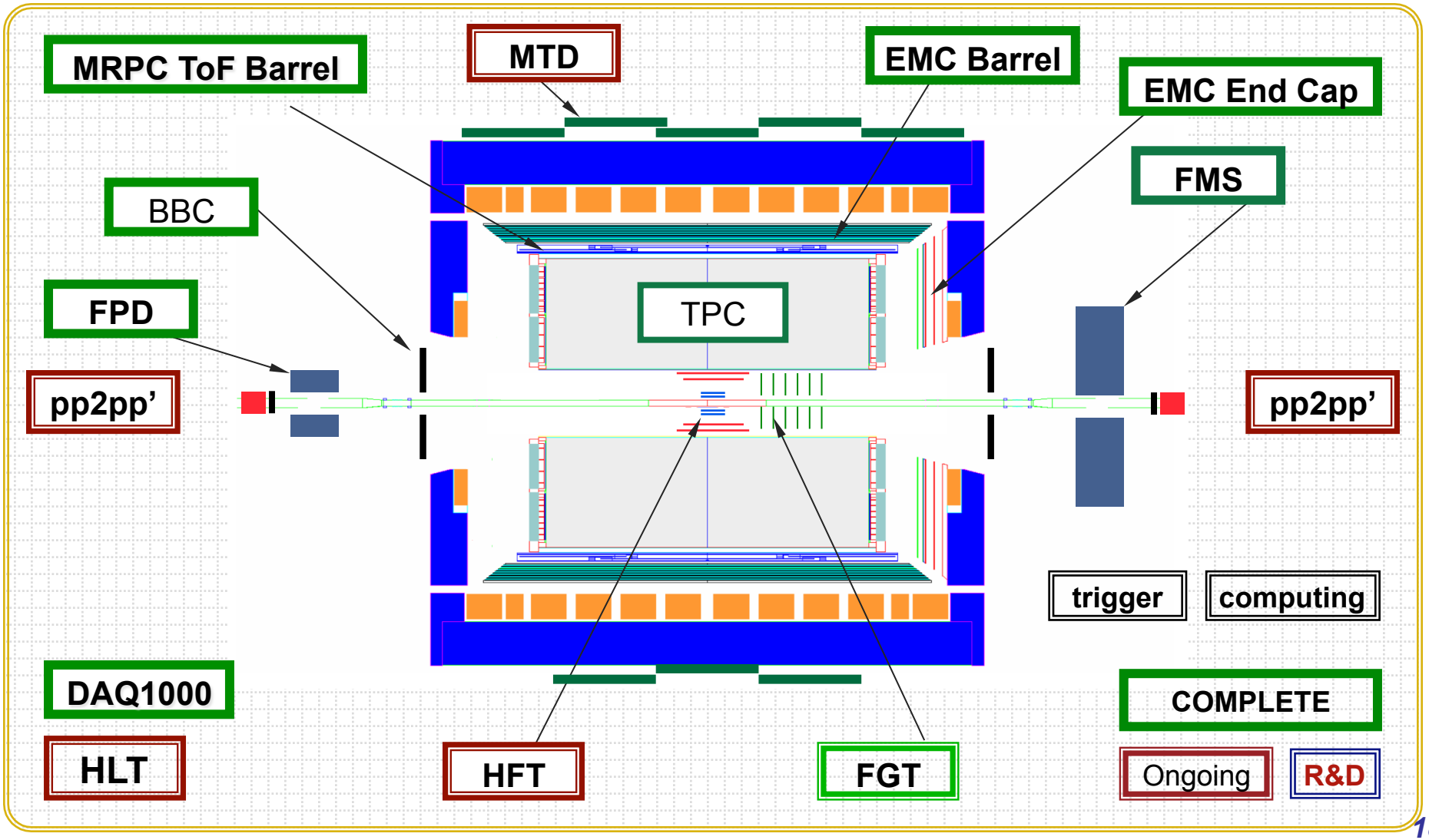




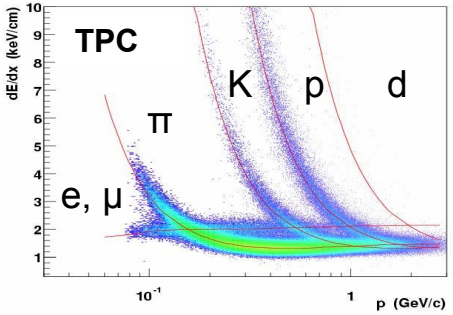


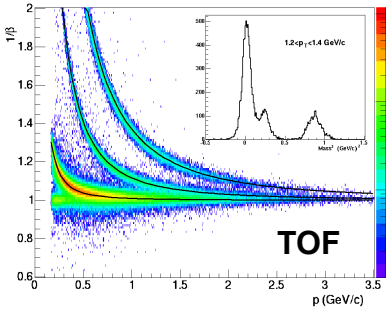
- Status and plan:
  2012–10%; 2013–63%; 2014–100%
- Commissioned single muon, di-muon and e-mu triggers (event display for Cu+Au collisions)
- Optimized threshold settings, ~90% efficiency
- Achieved stable operation conditions

STAR Detector in 2014+

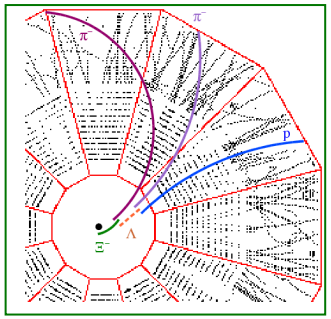


Particle Identifications in 2014+

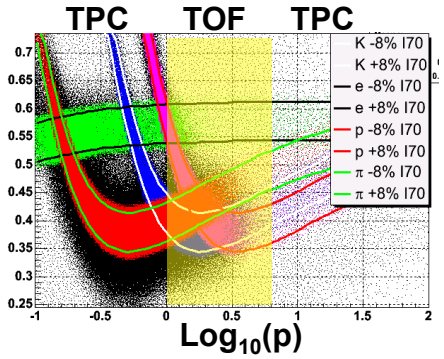


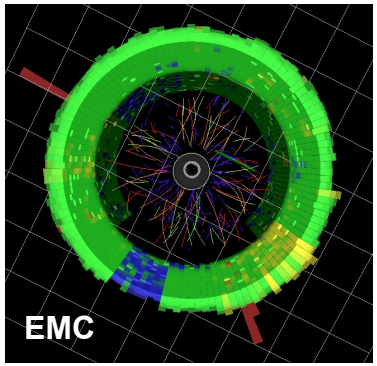


Charged hadrons

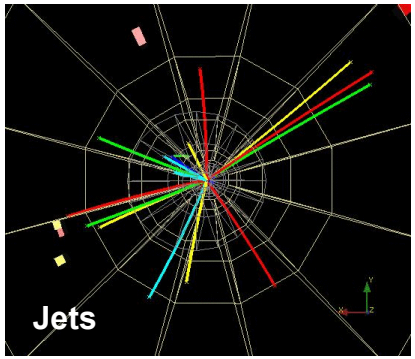


Hyperons & Hyper-nuclei

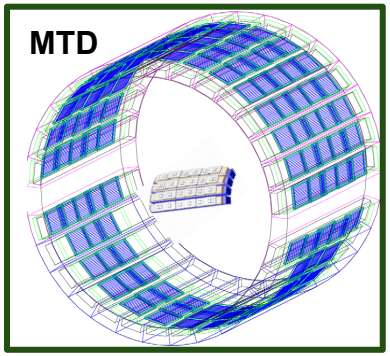




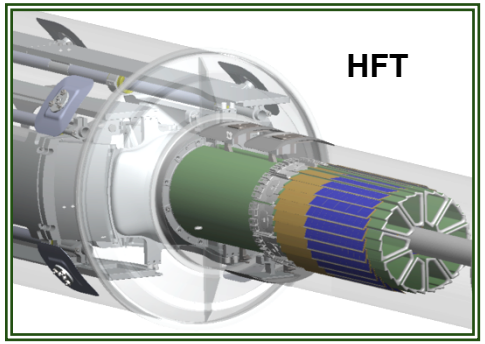
Neutral particles



Jets & Correlations



High p_T muons



Heavy-flavor hadrons

Multiple-fold correlations for identified particles!

STAR Decadal Plan

(1) *Properties of the sQGP

(2) *Mechanism of energy loss

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

(4) ***Novel symmetry properties**

(5) *Exotic particles

(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?

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To answer those questions one needs Beam Energy Scan Phase II, polarized *p+p, p+A, e+p, e+A* collisions & a upgraded STAR detector!

Outline

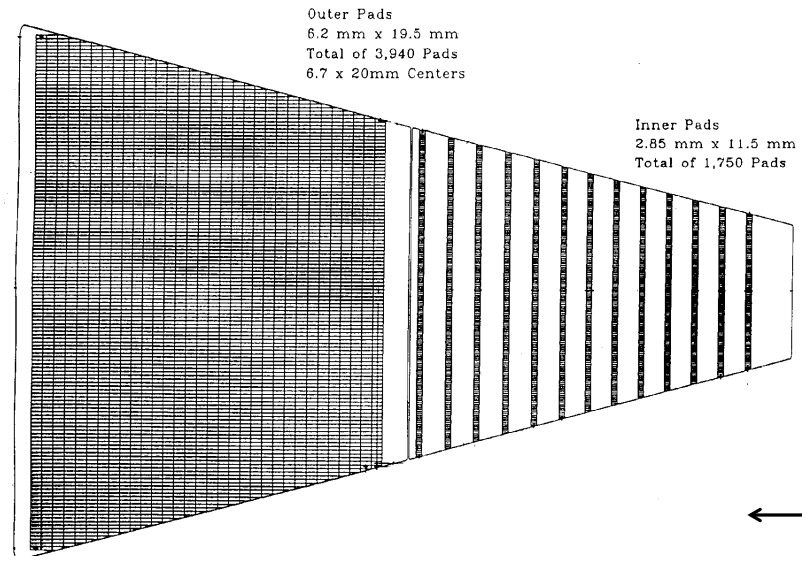
- Introduction
- On-going upgrades and physics goals
  - Heavy Flavor Tracker
  - Muon Telescope Detector
- Middle- and longer term plans
  - Forward upgrades
  - eSTAR for eRHIC
- Summary

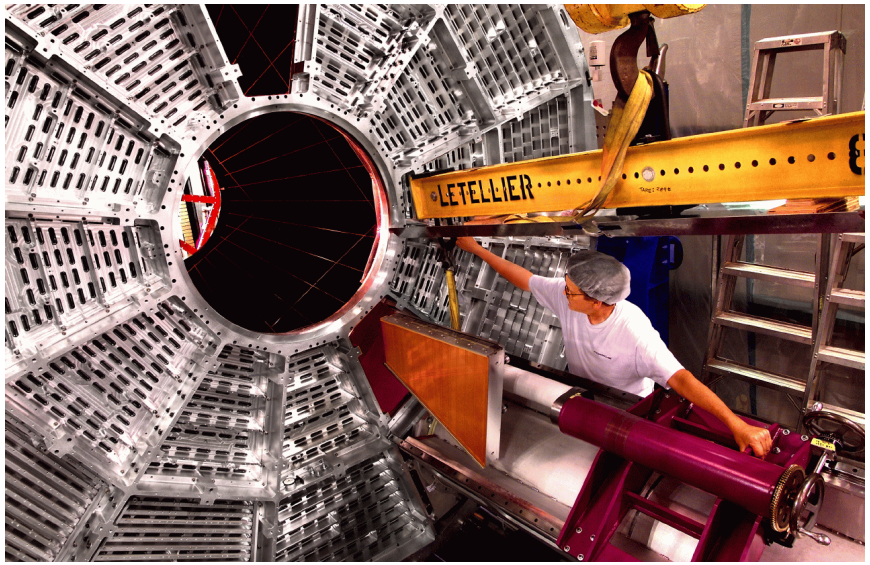
Middle-Term (2016+) Plan

- **Detector Upgrades:**
  - **TPC Inner Sector Upgrade**
  - **Forward EM+Had Calorimeter System**
  - **GEM or Si tracking in the very forward region**
  - **PID Detector – Meson/Baryon separation**
- **Physics Focuses:**
  - **Beam Energy Scan Phase II program**
  - **Forward photon/electron/jet(leading hadron)**
  - **p+p -- transverse spin dynamics (transversity function and Collins FF, twist-3)**
  - **pp/pA -- Drell-Yan, h-h, gamma-h correlations (initial conditions, gluon saturation)**
  - **AA -- Forward HQ NPE R_{AA} and eta dependence**

TPC Inner Sector Upgrade (iTPC)

- Current pad plane layout with 13 rows and gaps
  - only 13 maximum possible points
  - only reads ~20% of possible gas path length
    - Inner sectors essentially not used in dE/dx
- Essentially limits effective acceptance to |η|<1





TPC Inner Sector Upgrade (iTPC)

Fill all inner sector with active pads -> better tracking and dE/dx PID for |h|=1.0-1.7 region, broad impact on

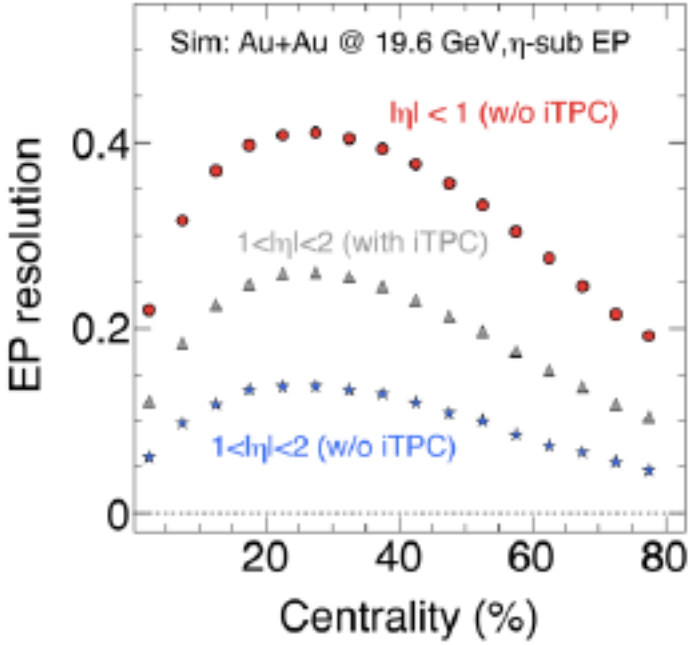
transverse spin physics

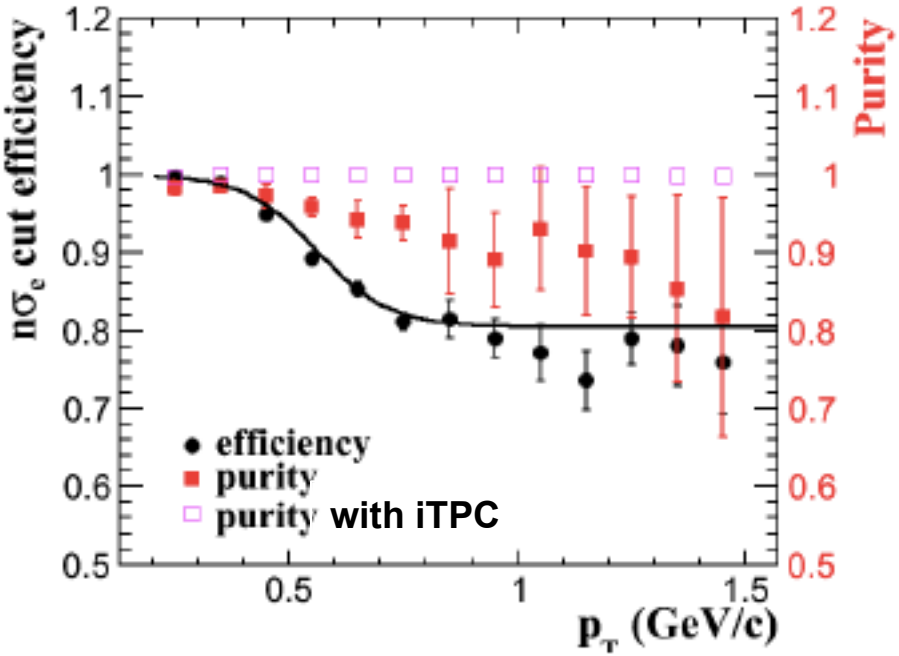
hyperon and exotic particle searches

high p_T identified particles

iTPC Upgrade:

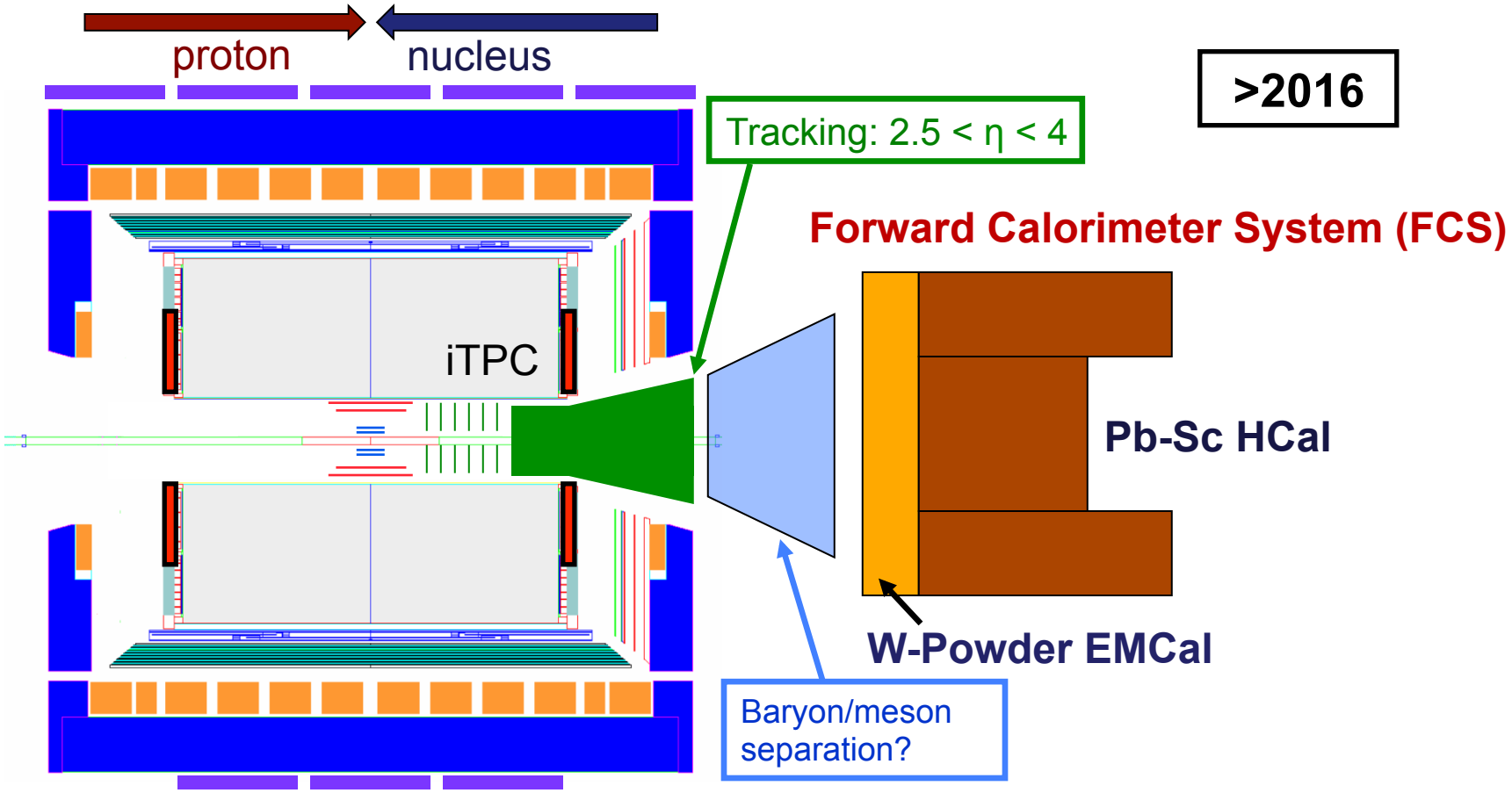
1. **MWPC (SDU/SINAP)**
2. **Mechanics (LBL/BNL)**
3. **Electronics (BNL/ALICE)**
4. **Schedule 2017**





Essential for both BESII and eSTAR physics

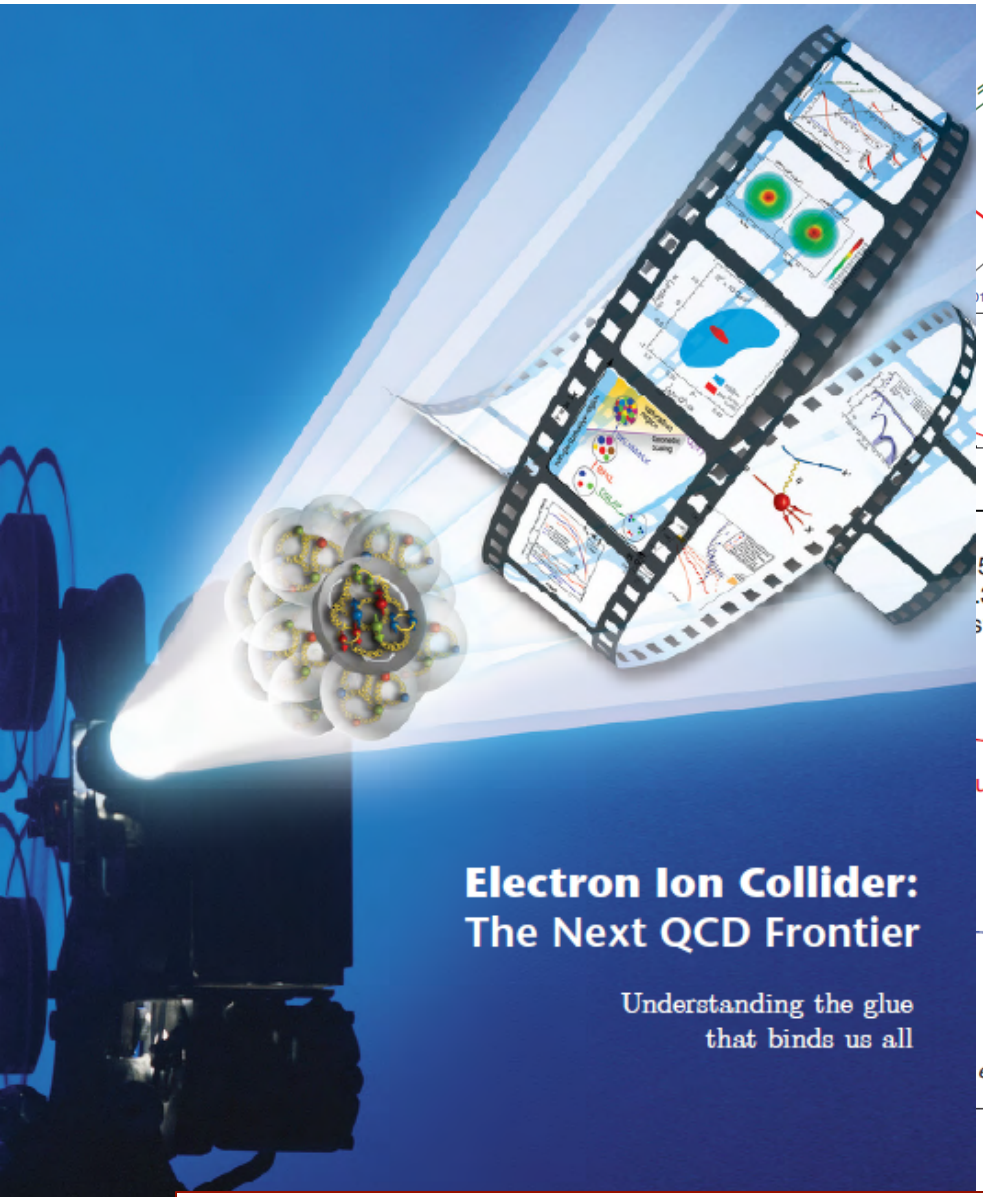
STAR forward instrumentation upgrade

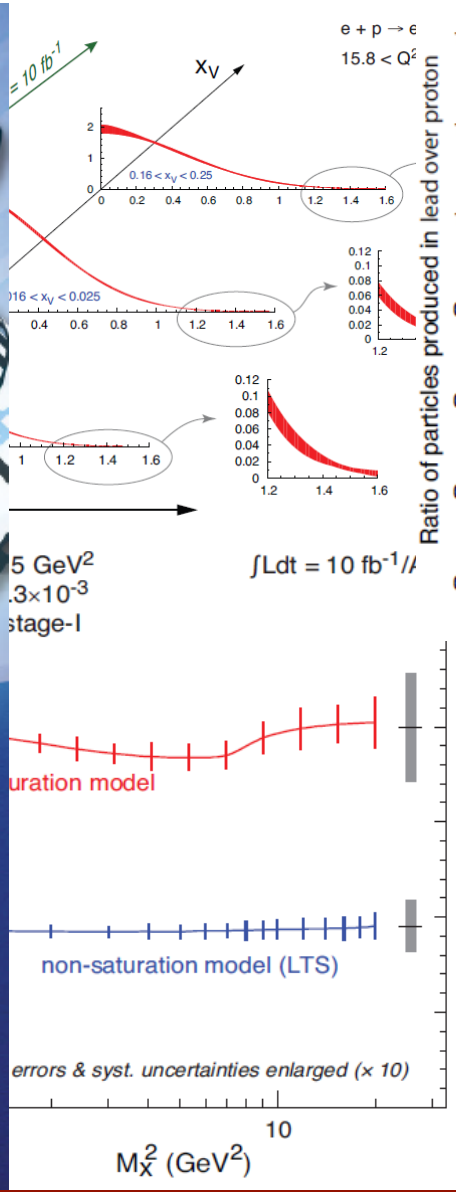


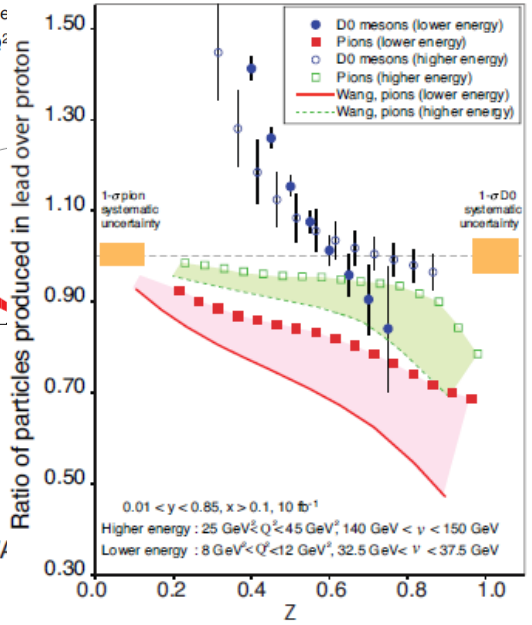
- **Forward instrumentation optimized for p+A and transverse spin physics**
  - **Charged-particle tracking**
  - ***e/h* and γ/π^0 discrimination**
  - **Baryon/meson separation**

L. Eun "STAR Forward Upgrade" on Tuesday

Physics Deliverables (EIC whitepaper)



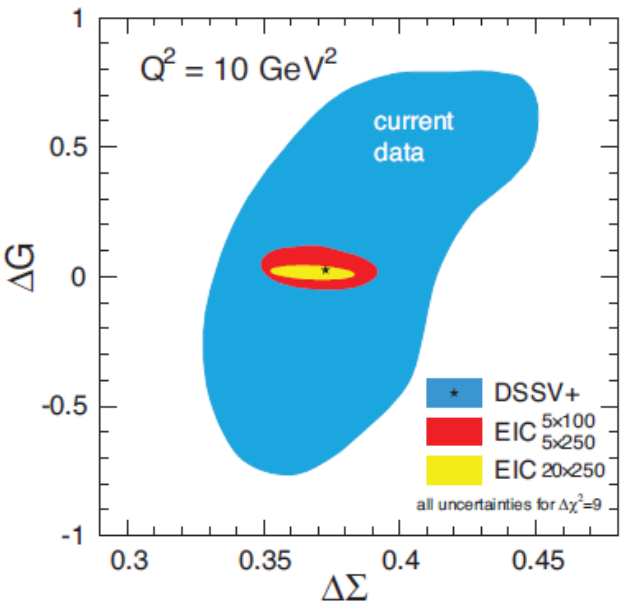


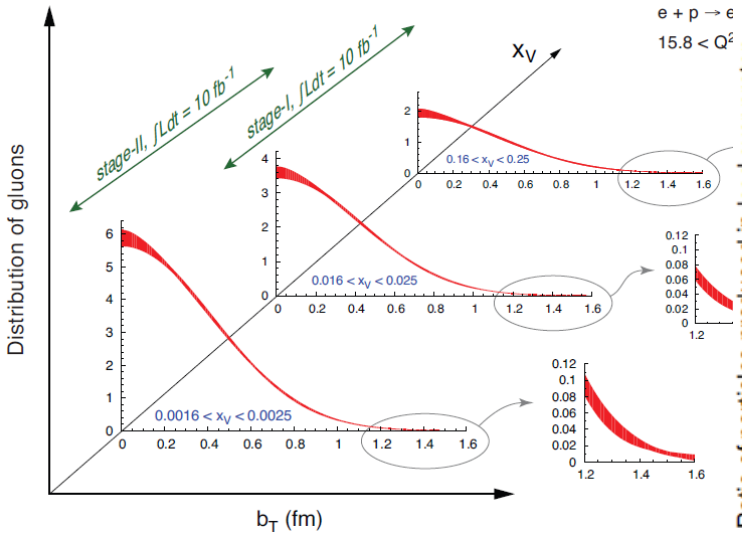


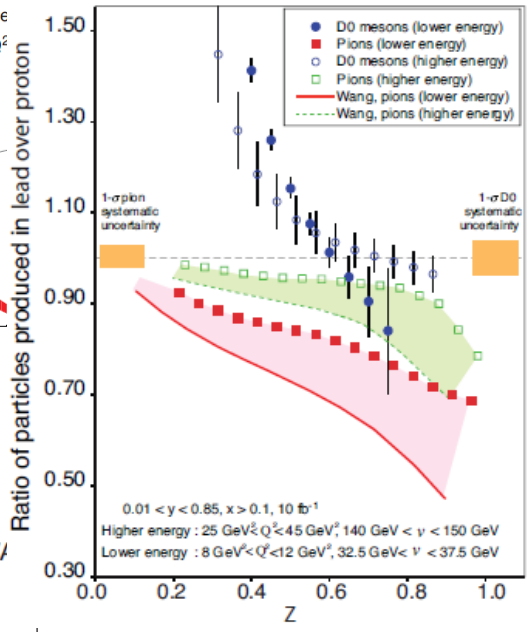
1. Proton Spin
2. Motion of partons
3. Imagining
4. Dense Gluonic QCD matter
5. Quark Hadronization

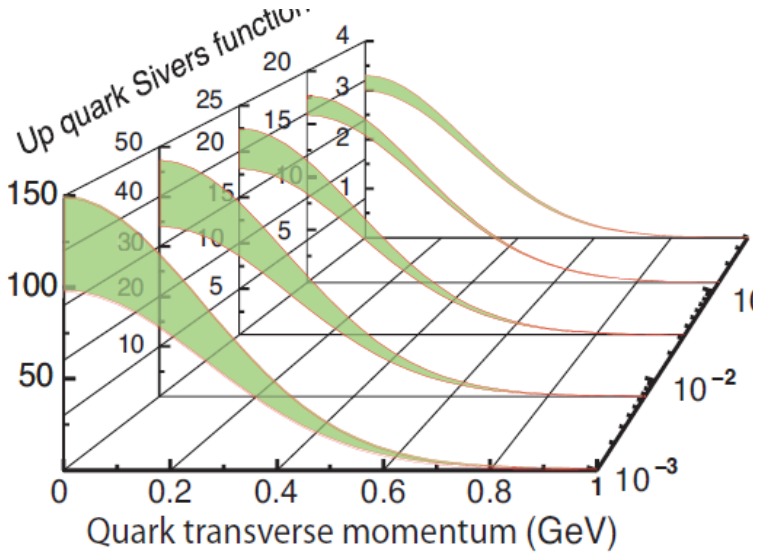
T.Ullrich "The Electron Ion Collider Physics Program" on Wednesday

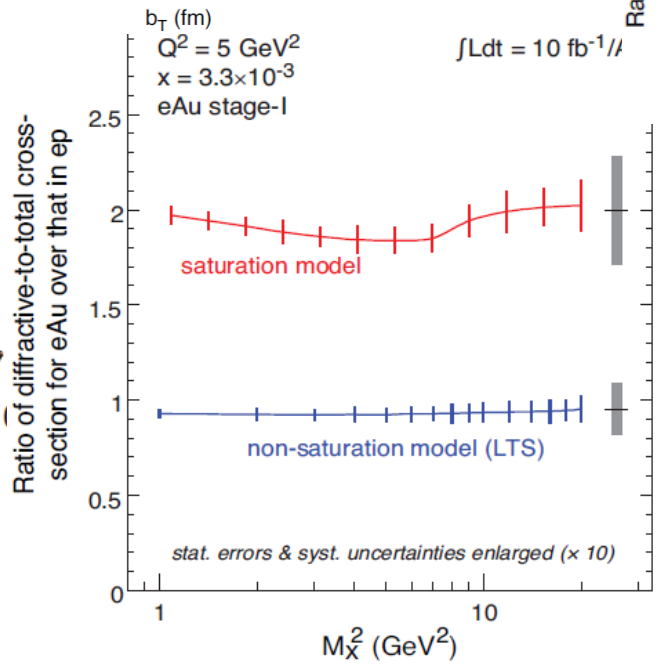
Physics Deliverables (EIC whitepaper)











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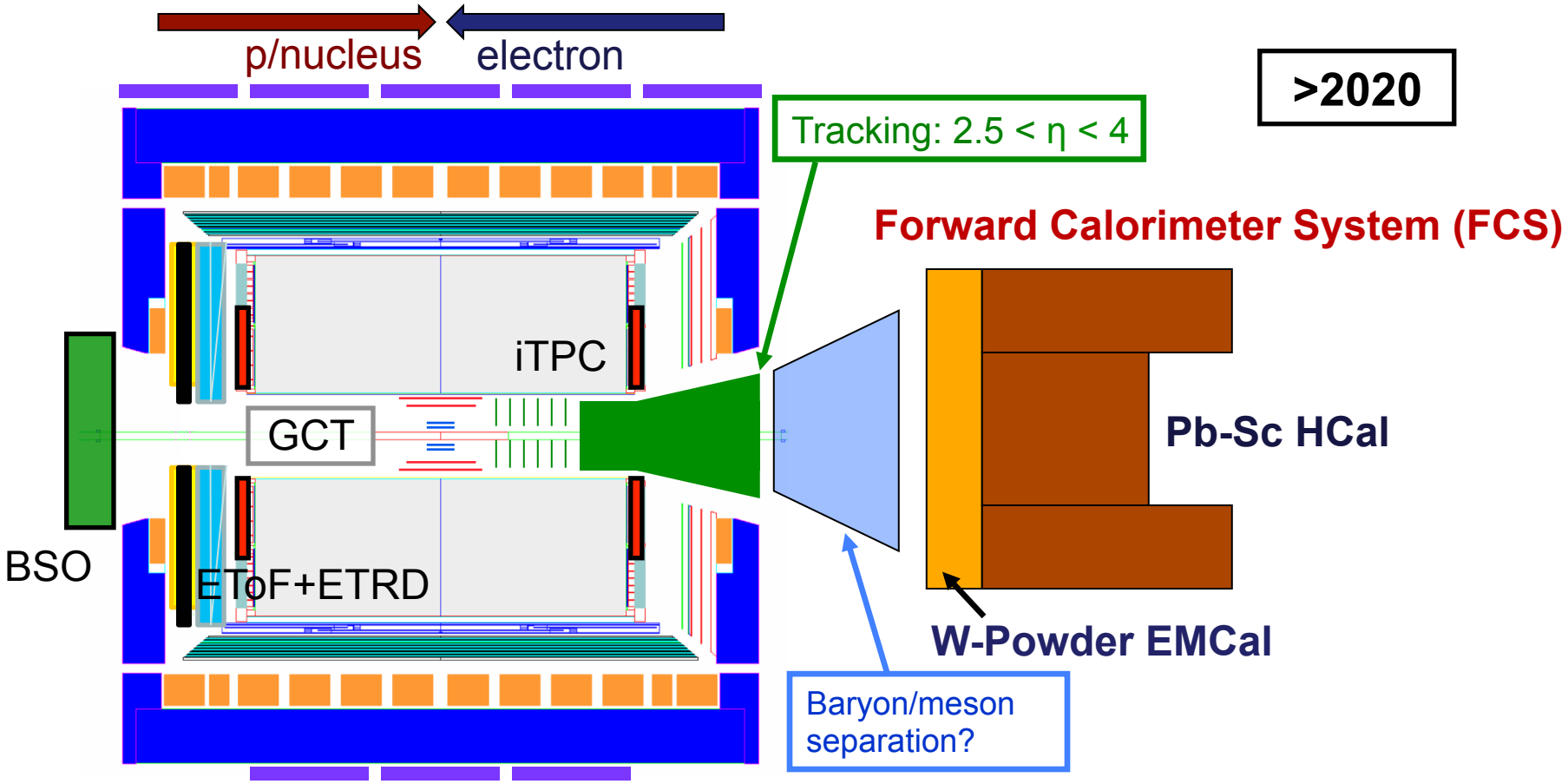
STAR forward instrumentation upgrade



eSTAR specific upgrades:
GCT: low mass tracking
EToF: e, *π*, *K* identification,
ETRD: electron ID and hadron tracking
BSO: 5 GeV, 10 GeV electron beams

- Forward instrumentation optimized for p+A and transverse spin physics
  - Charged-particle tracking
  - *e*/*h* and γ/π^0 discrimination
  - Baryon/meson separation

E. Sichtermann "eSTAR Upgrades" on Tuesday

Forward and eSTAR R&D Plans

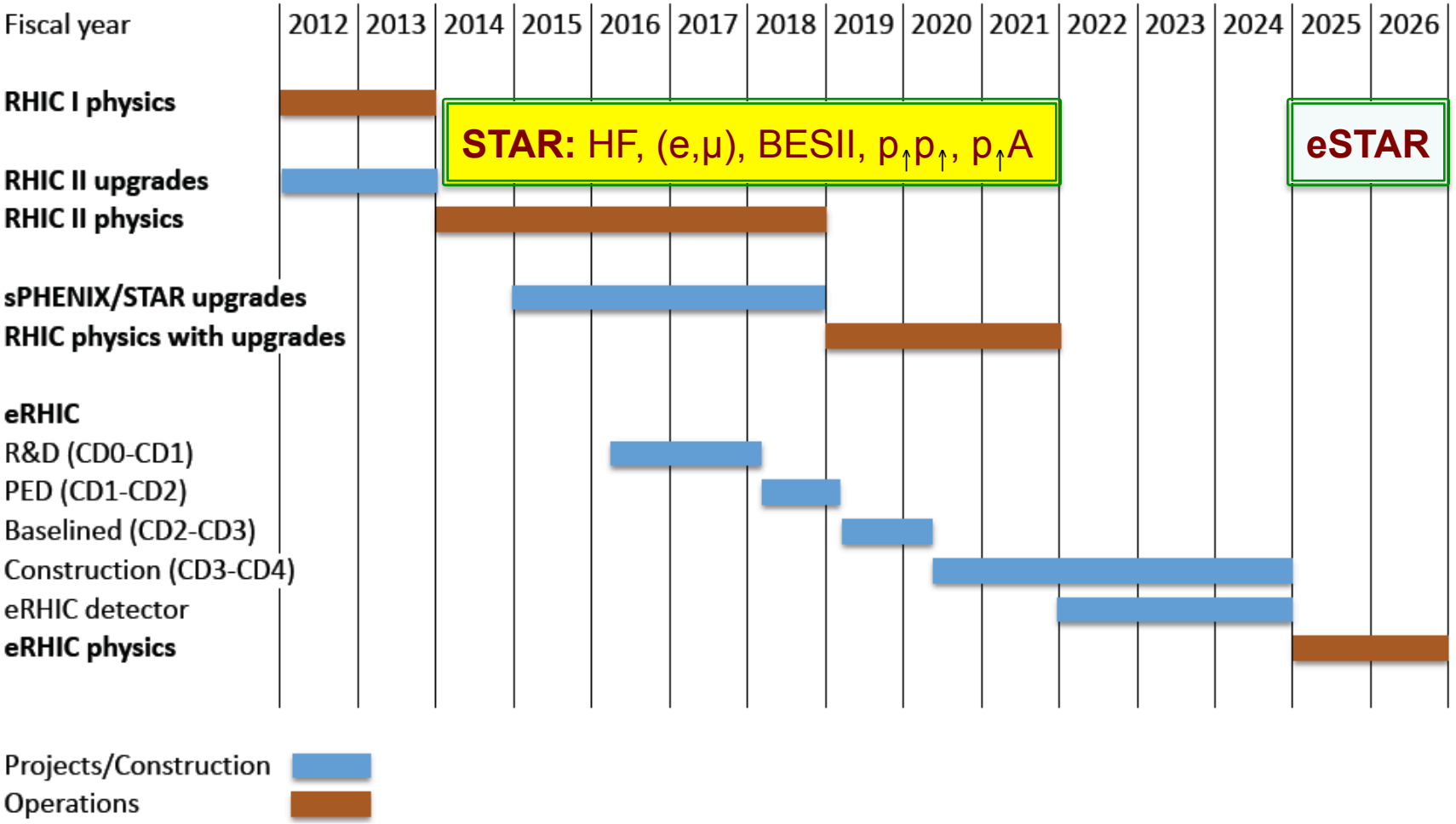
- Map the physics cases from EIC whitepaper to eSTAR
- Possible R&D projects:
  1. Tracking (hadron side, pA/pp, eSTAR)
  2. Calorimetry (hadron side, pA/pp, eSTAR)
  3. Tracking+eID (electron side, eSTAR)
  4. End-Cap TOF (electron side, eSTAR)
  5. Very forward electron ID (electron side, eSTAR)
  6. Roman Pots II (pA/pp, eSTAR)
- On-going Simulation of feasibilities
- Discuss with CAD and EIC TF on IR design and detector R&D
- eSTAR LOI by Sep 30, 2013.

Build on the successful current detector. Evolution Not Revolution!

Summary

1) STAR at RHIC: Dedicated facility/Detector for studying matter with QCD degrees of freedom:
   - **Properties of QGP**
   - **Sea quark and gluon contributions to nucleon spin**
2) Near Future: HFT, MTD
   - **Heavy flavor production, collectivity and energy loss**
   - **Resonance-Medium interaction, Chiral symmetry restoration**
3) Middle term: BES-II, forward upgrades (~2016)
   - **QCD critical point, phase boundary, transition to eSTAR**
4) Longer term: eSTAR (~2020)
   - **Partonic structures of nucleon and nuclei**
   - **Dynamical evolution from cold nuclear matter to hot QGP**

Upgrade Plan (now - 2025)



A fruitful future ahead of (e)STAR and (e)RHIC!