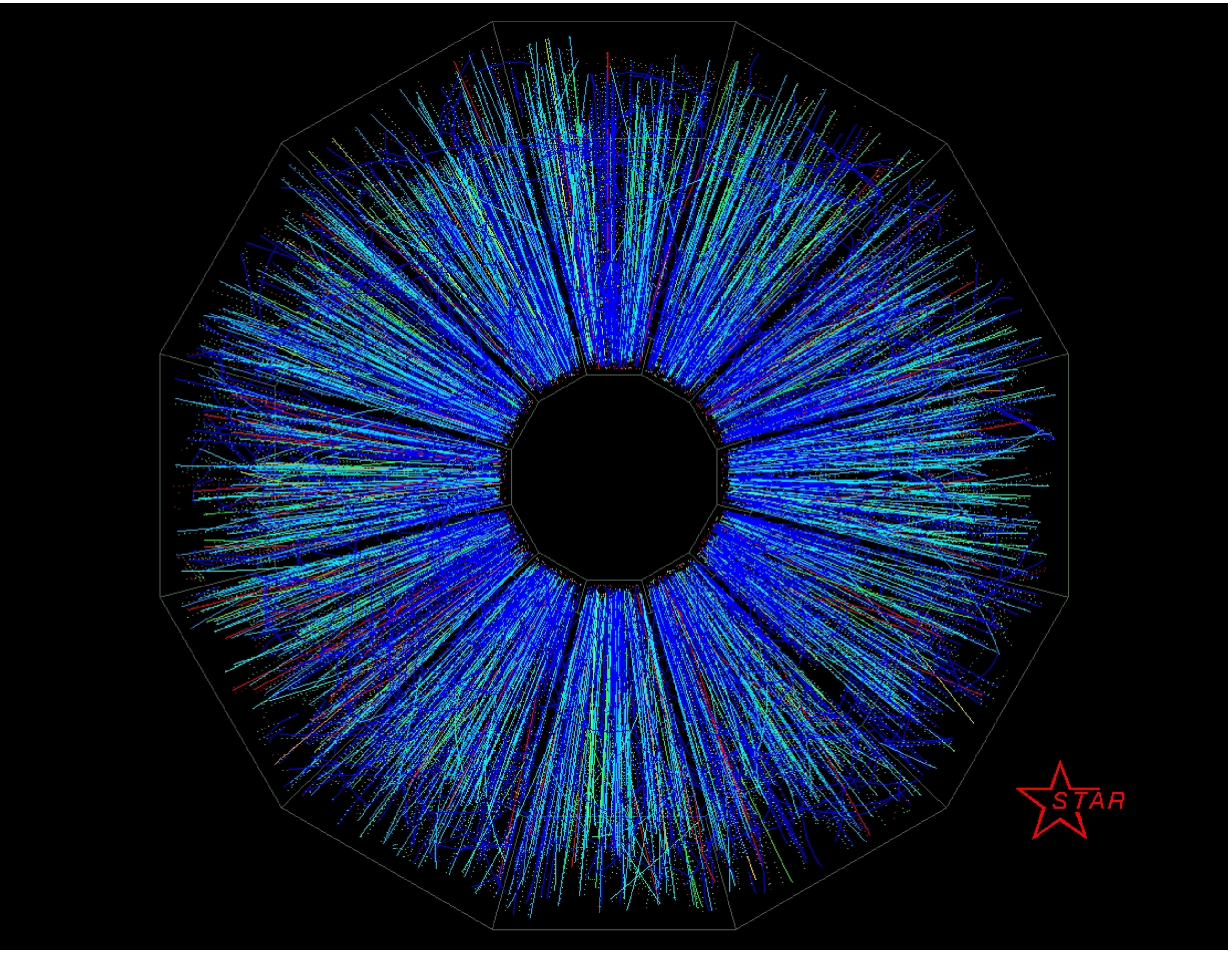
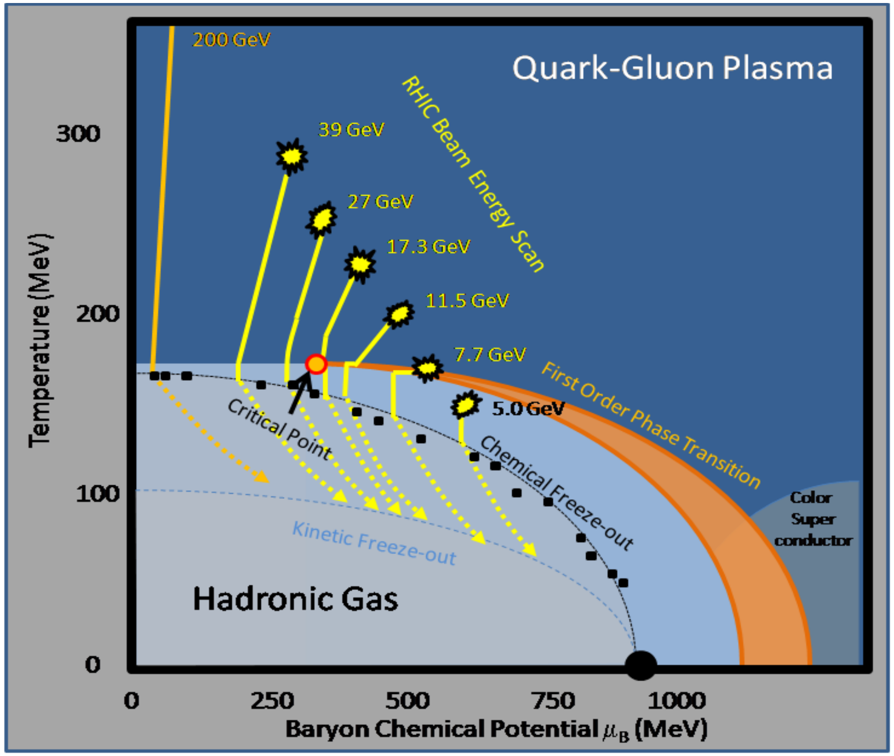
STAR Decadal Plan



James Dunlop for the STAR Collaboration

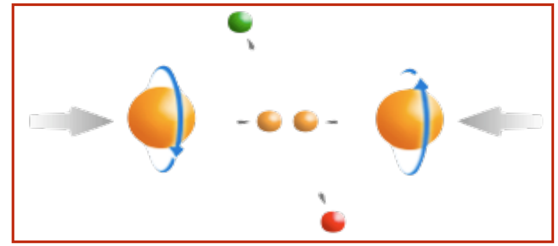
RHIC: Exploring QCD in detail

Hot QCD Matter

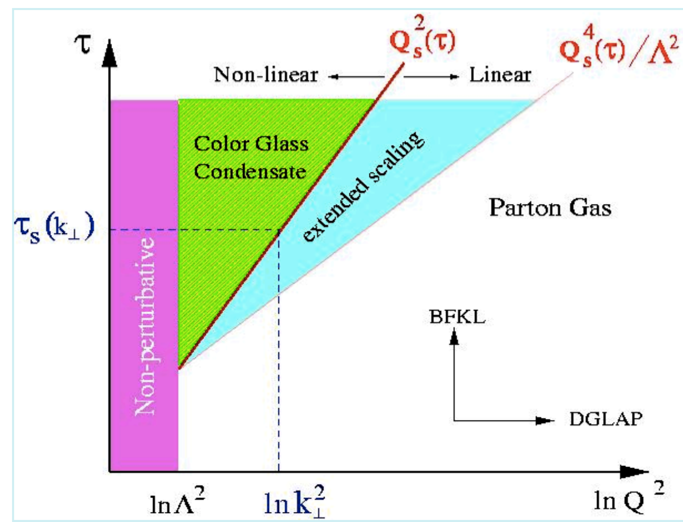


Properties of the sQGP in detail
Mechanism of Energy Loss:
weak or strong coupling?
Is there a critical point, and if so, where?
Novel symmetry properties
Exotic particles

Partonic structure



Spin structure of the nucleon
How to go beyond leading twist and colinear factorization?

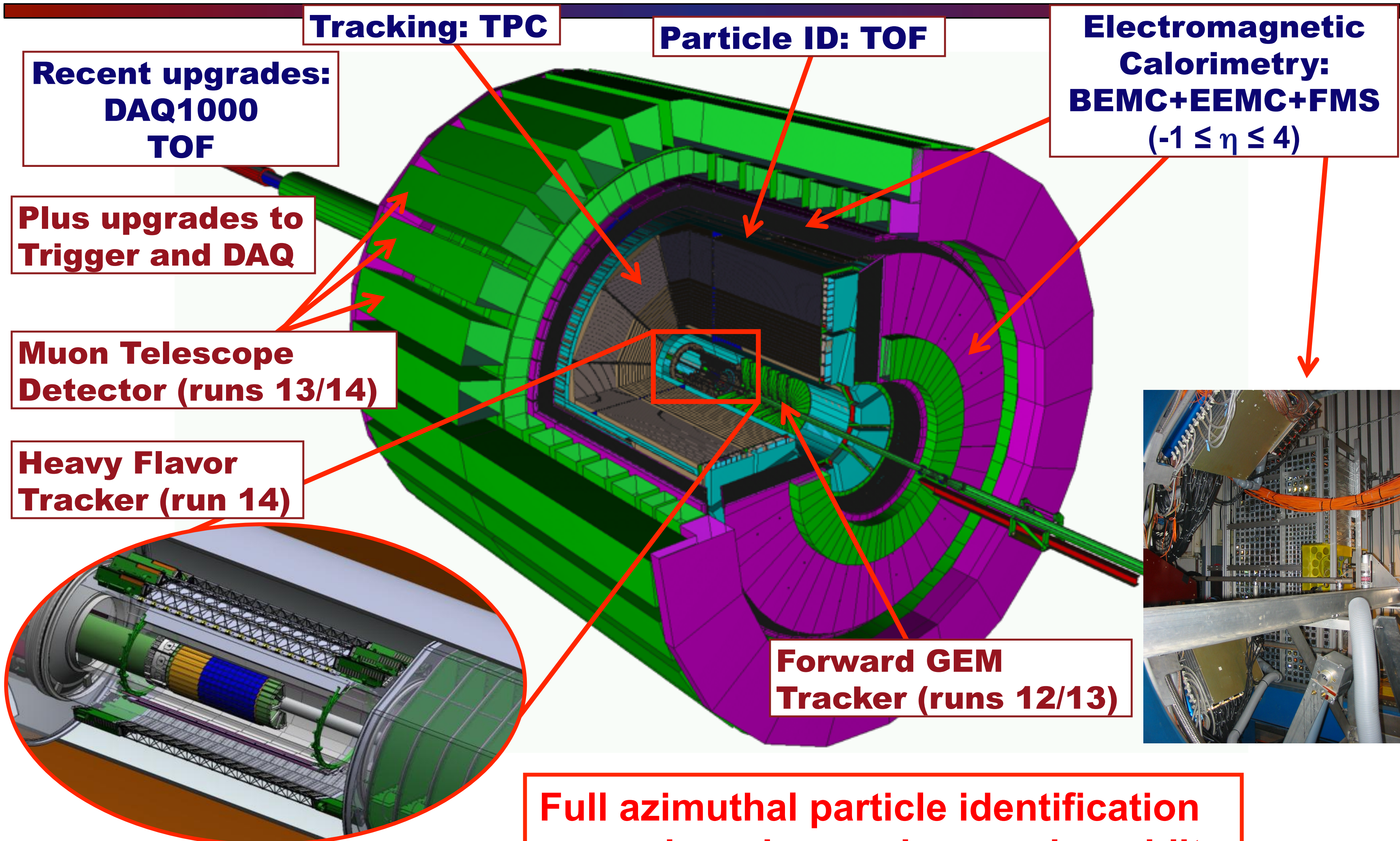


What are the properties of cold nuclear matter?

How to explore QCD: from hot to cold

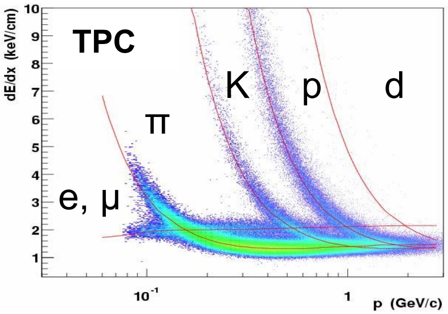
- Hot QCD matter: high luminosity RHIC II (fb^{-1} equivalent)
  - Heavy Flavor Tracker: precision charm and beauty
  - Muon Telescope Detector: e+μ and μ+μ at mid-rapidity
  - Trigger and DAQ upgrades to make full use of luminosity
  - Tools: jets combined with precision particle identification
- Phase structure of QCD matter: Energy Scan Phase II
  - Fixed Target to access lowest energy at high luminosity
  - Low energy electron cooling to boost luminosity for $\sqrt{s_{NN}}$<20 GeV
  - Inner TPC Upgrade to extend η coverage, improve PID
- Cold QCD matter: high precision p+A, followed by e+A
  - Major upgrade of capabilities in forward direction
  - Existing mid-rapidity detectors well suited for portions of e+A program

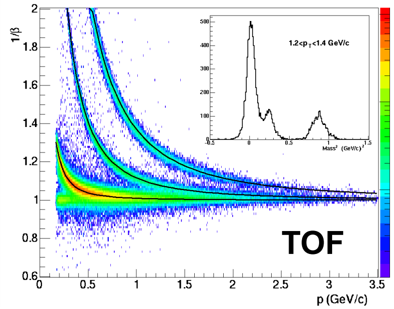
STAR: A Correlation Machine



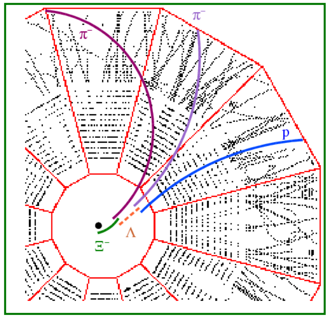
Full azimuthal particle identification over a broad range in pseudorapidity

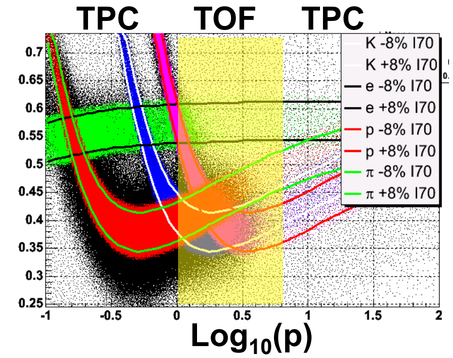
Particle Identification in STAR



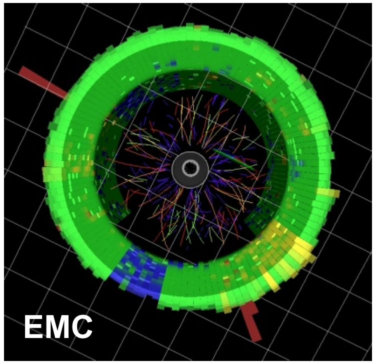


Charged hadrons

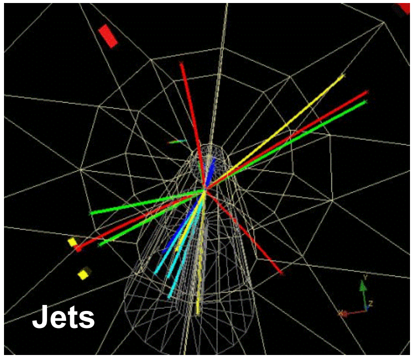




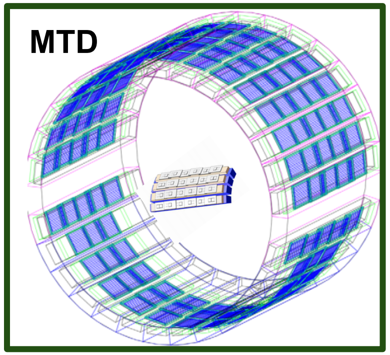
Hyperons & Hyper-nuclei



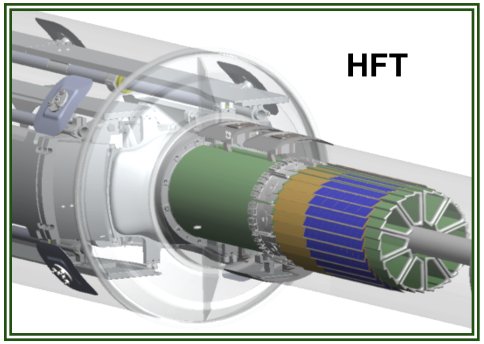
Neutral particles



Jets & Correlations



High p_T muons



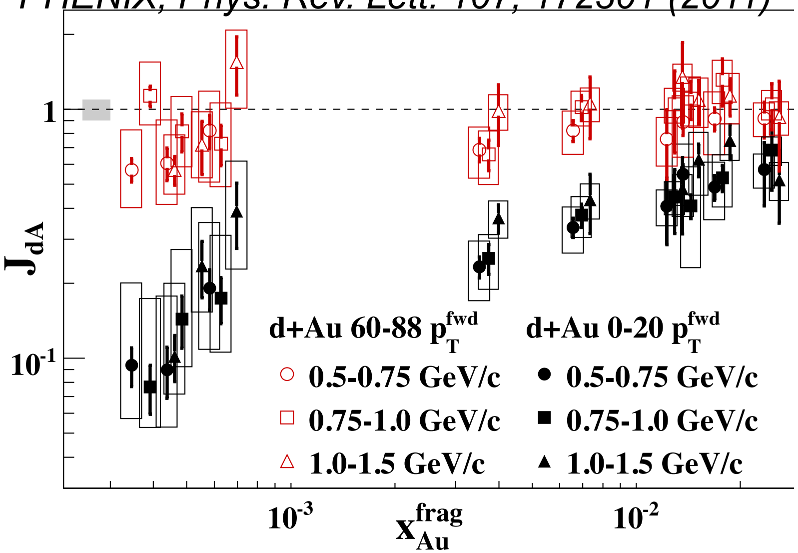
Heavy-flavor hadrons

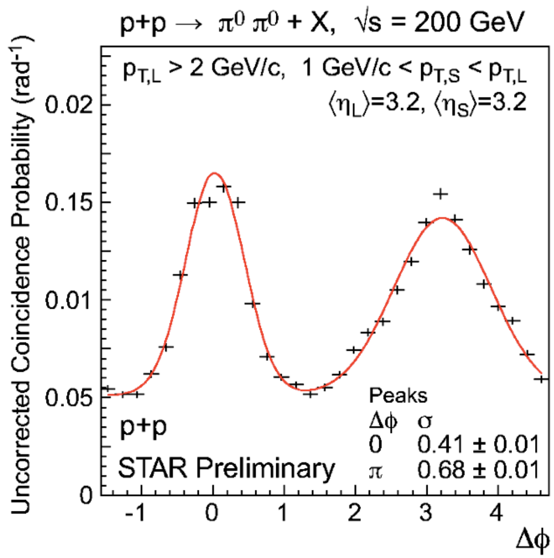
Multiple-fold correlations among the identified particles!
Nearly perfect coverage at mid-rapidity

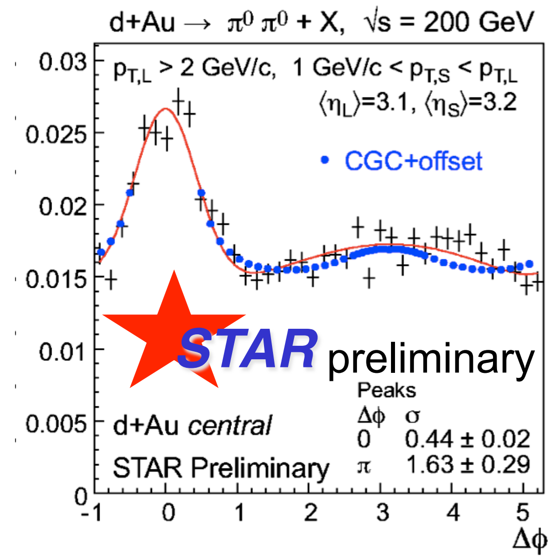
What are the properties of cold nuclear matter?

Is there evidence for saturation of the gluon density?

PHENIX, Phys. Rev. Lett. 107, 172301 (2011)





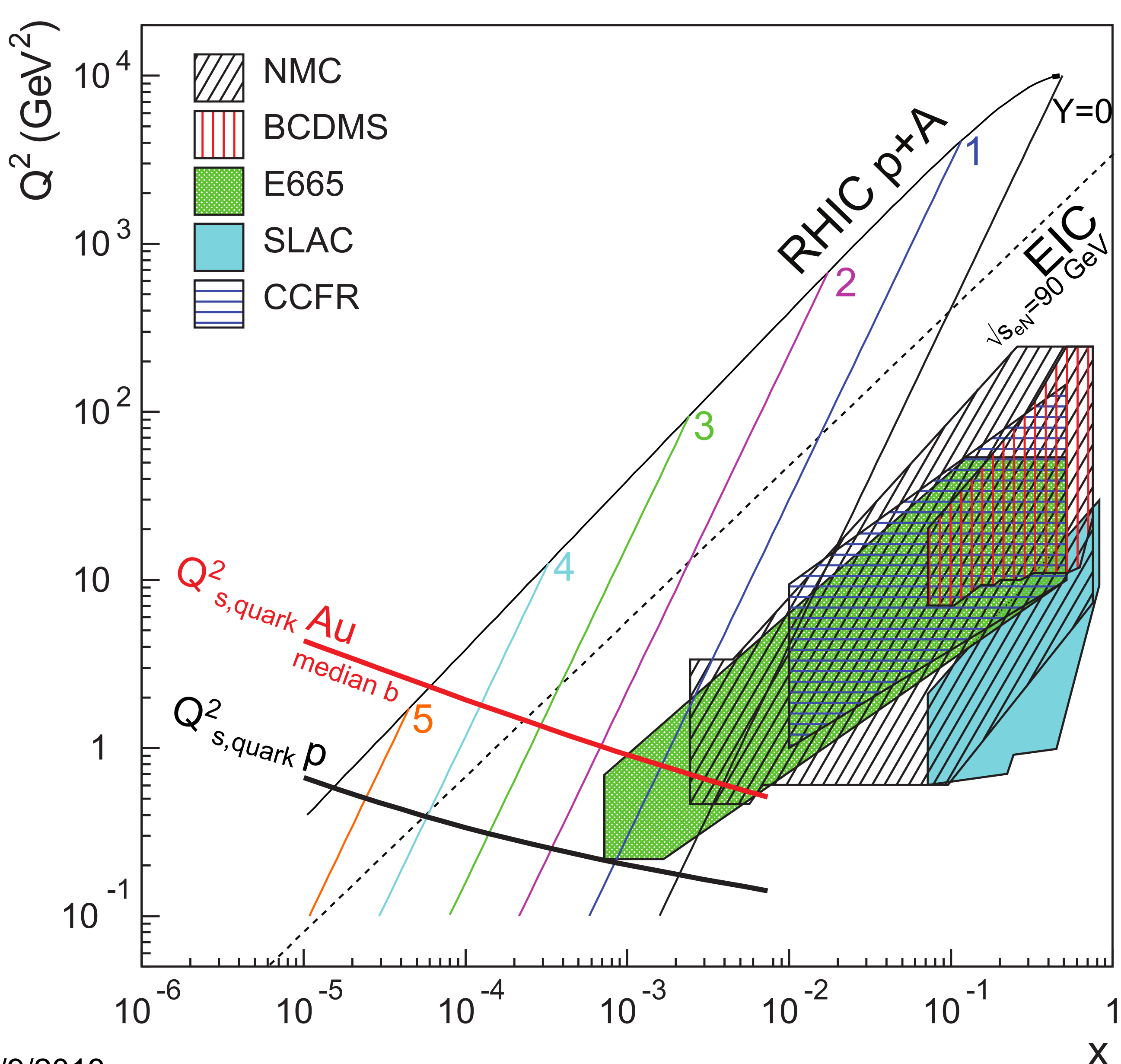


- RHIC may provide **unique access to the onset of saturation**
  - Complementarity: LHC likely probes **deeply saturated regime**
- Future questions for **p+A**
  - What is the gluon density in the (x,Q^2) range relevant at RHIC?
  - What role does saturation of gluon densities play at RHIC?
  - What is Q_s at RHIC, and how does it scale with A and x?
  - What is the impact parameter dependence of the gluon density?

Upgrades to both STAR and PHENIX to extend observables (focus on EM)

Timescale: medium-term (~2017+)

p+A: Where to measure?

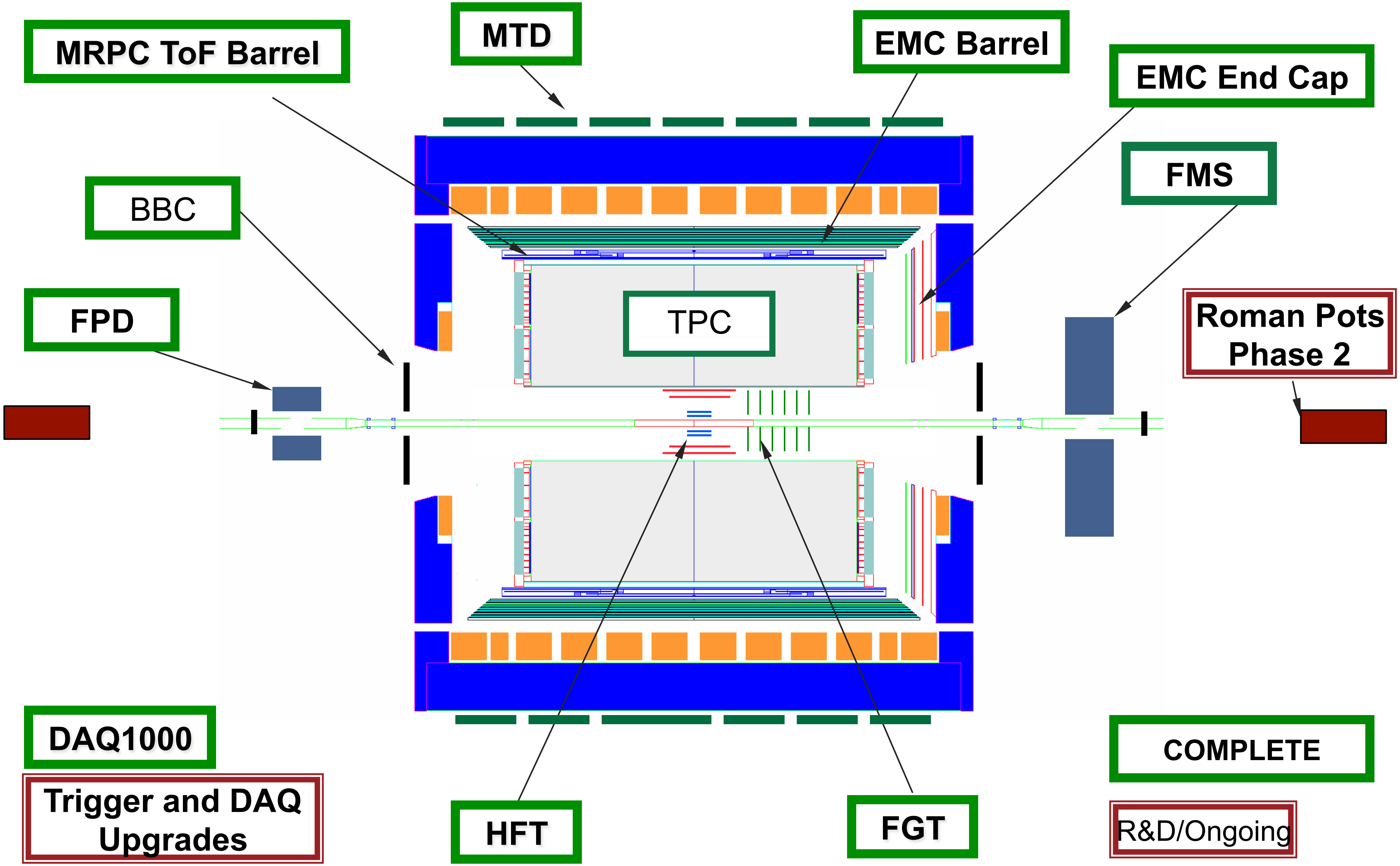


Most promising at RHIC energies:
y ~ 3-4
Q^2 ~ few GeV^2

N.B. Lines only schematic, kinematic control limited in p+A
From 2->2 parton scattering, many sources of smearing

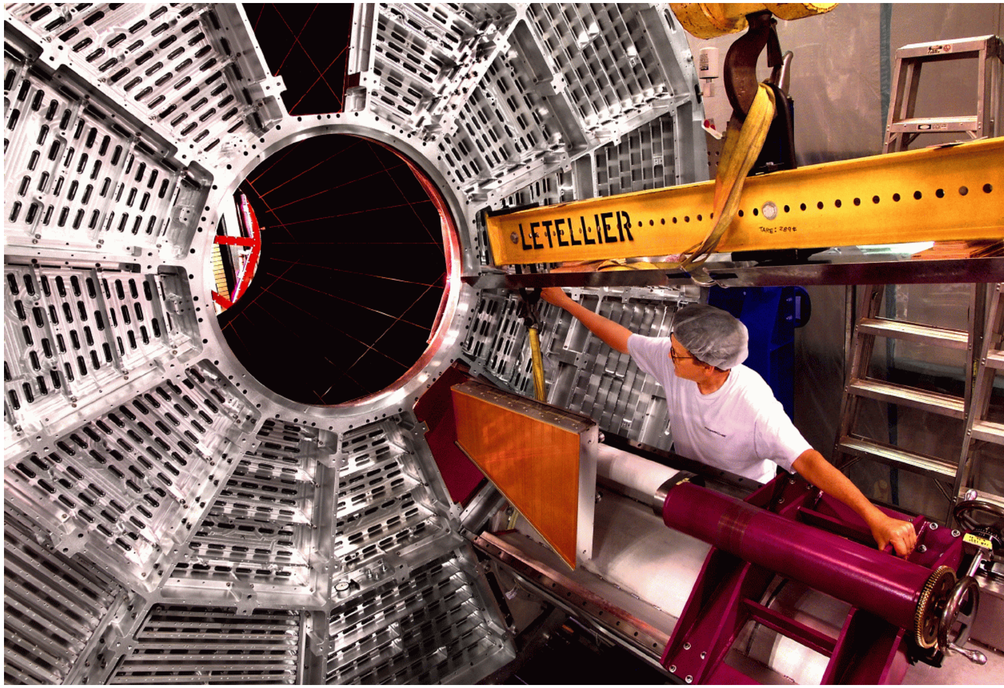
LHC mid-y
~ RHIC y=4

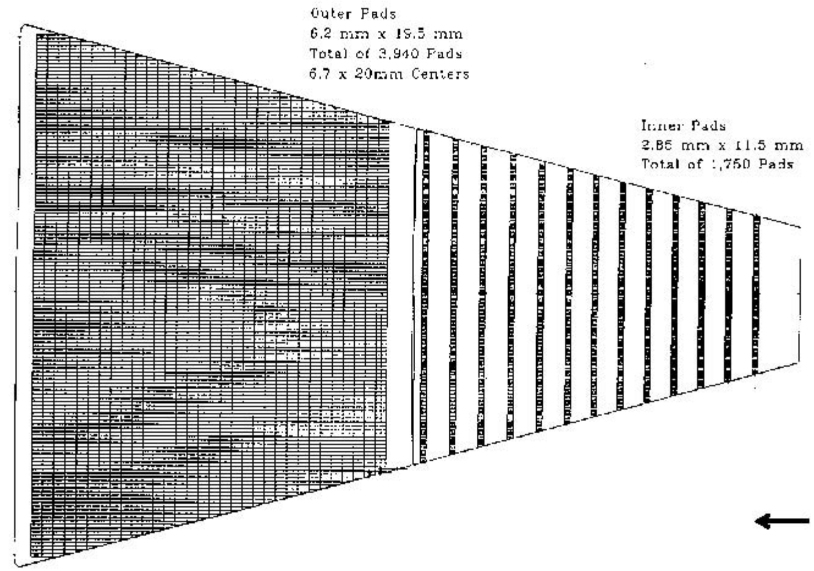
STAR Experiment as of 2014

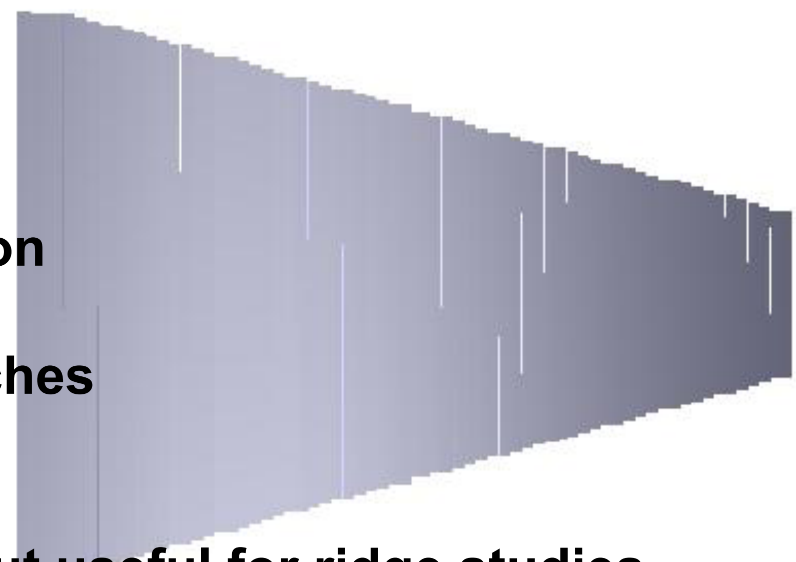


STAR

Inner TPC Upgrade







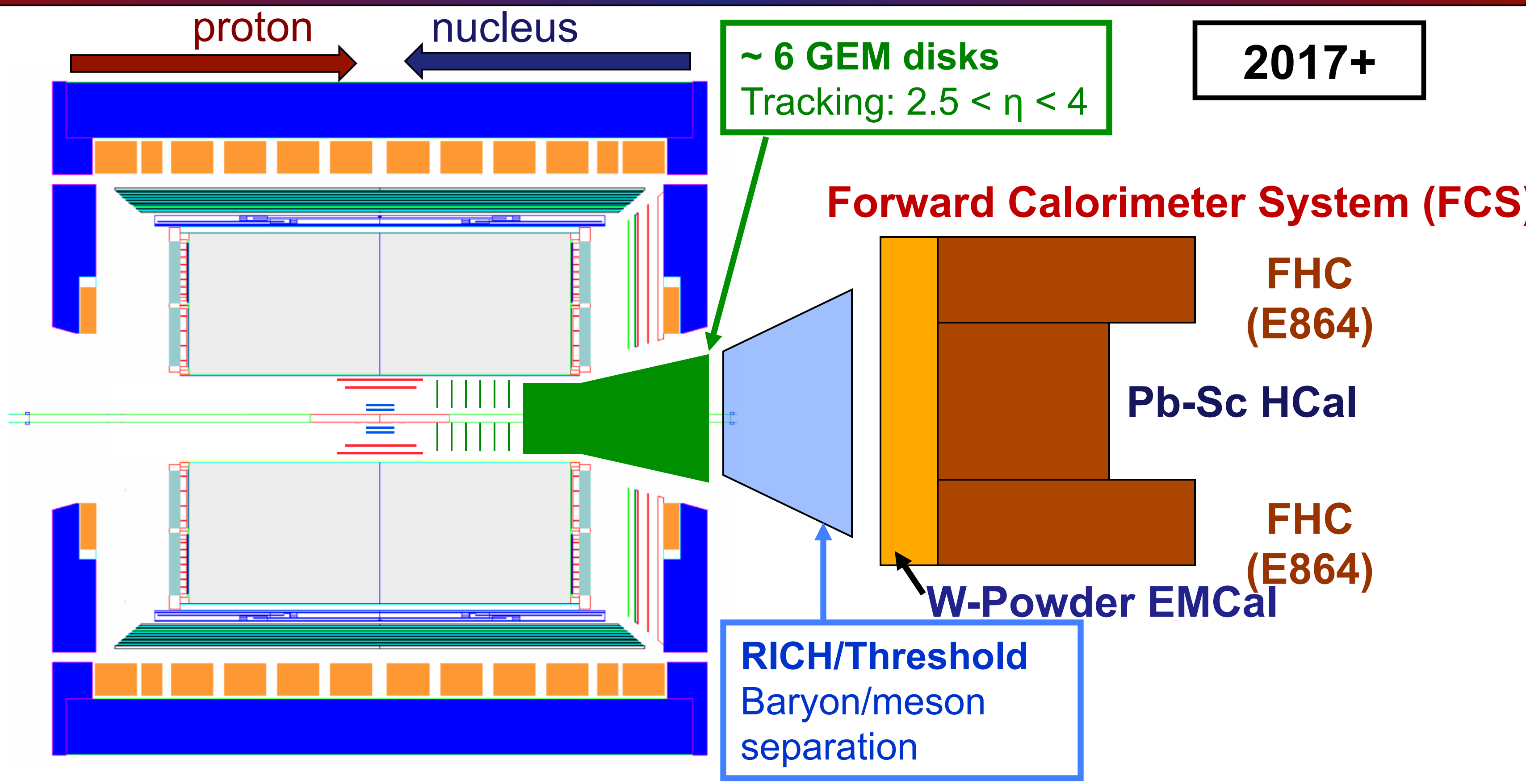
Better tracking and dE/dx PID capability

η 1.0-1.7 region -- broad physics impact on

- **transverse spin physics program**
- **hyperon and exotic particle searches**
- **high p_T identified particles**
- **BES Phase II+**

Not as forward as most useful for p+A, but useful for ridge studies

Forward Instrumentation Upgrade



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

Some planned p+A measurements

- Nuclear modifications of the gluon PDF
  - Correlated charm production
- Gluon saturation
  - Forward-forward correlations (extension of existing π^0-π^0)
    - *h*-*h* } Easier to measure
    - π^0-π^0
    - γ-*h* } Easier to interpret
    - γ-π^0
  - Drell-Yan
    - Able to reconstruct x_1, x_2, Q^2 event-by-event
    - Can be compared directly to nuclear DIS
    - True 2 → 1 provides model-independent access to $x_2 < 0.001$
- What more might we learn by scattering ***polarized* protons off nuclei**?

- **Forward-forward correlations and Drell-Yan** are also very powerful tools to unravel the **dynamics of forward transverse spin asymmetries** – **Collins vs Sivers effects, TMDs or Twist-3, …**

Plans for Forward Upgrade

Calorimeter:

1) EM: Pb-glass (FMS) augmented by Tungsten SPACAL
   1) Smaller Moliere radius for better 2-γ separation
   2) Keep high E resolution
2) Hadron calorimetry for e/h discrim., jet reconstruction

Very Forward GEM Tracker (VFGT)

1) Likely GEM-based
2) Details of the design depend on experience with FGT

Particle Identification

RICH problematic with accessible p_T resolution

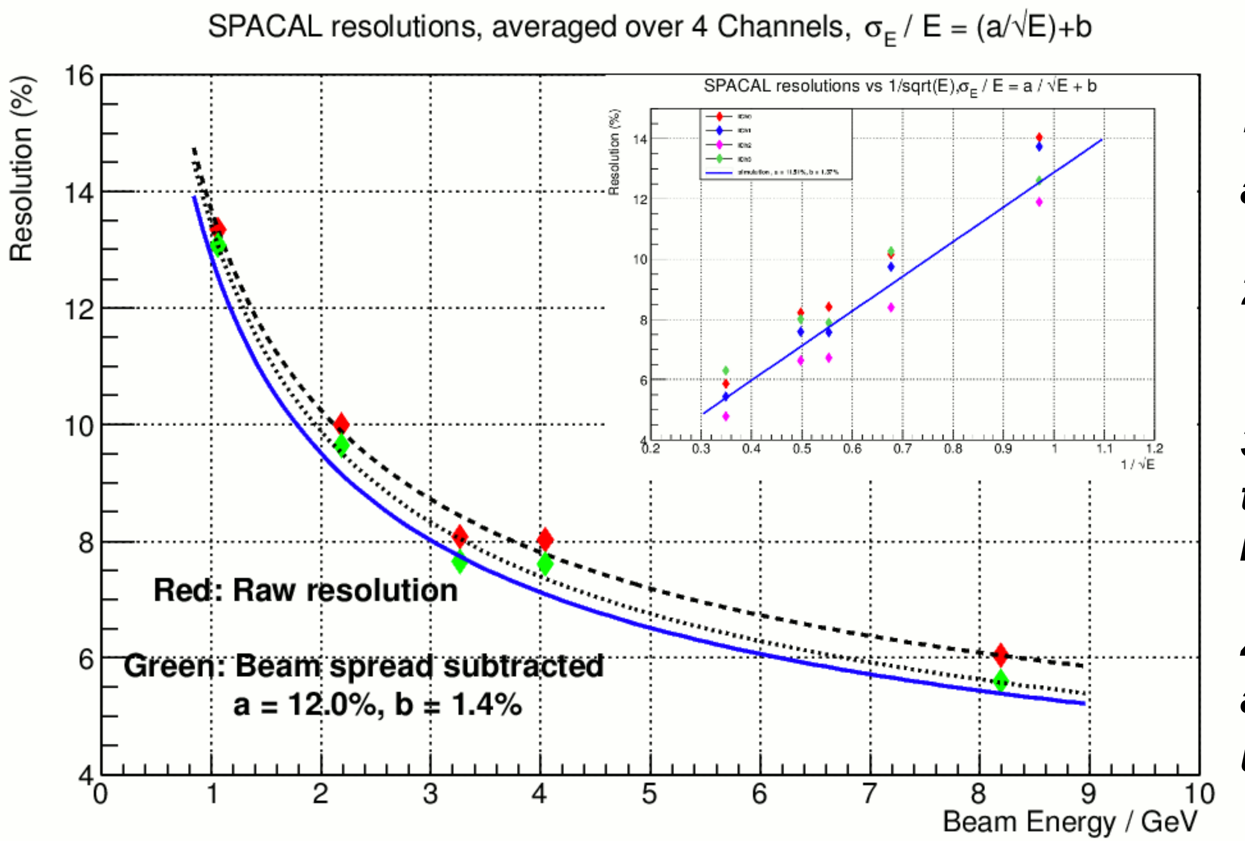
Threshold Cerenkov detector under consideration

Detector will not be included in initial upgrade

Schedule: proposal this year, construction start 2015+

Ready for data 2017 at the earliest

Calorimeter: SPACAL works



Also measured:

1.Uniformity of response across the towers.

2. Energy resolution with and without mirror.

3. Perform scans along the towers with electrons and muons.

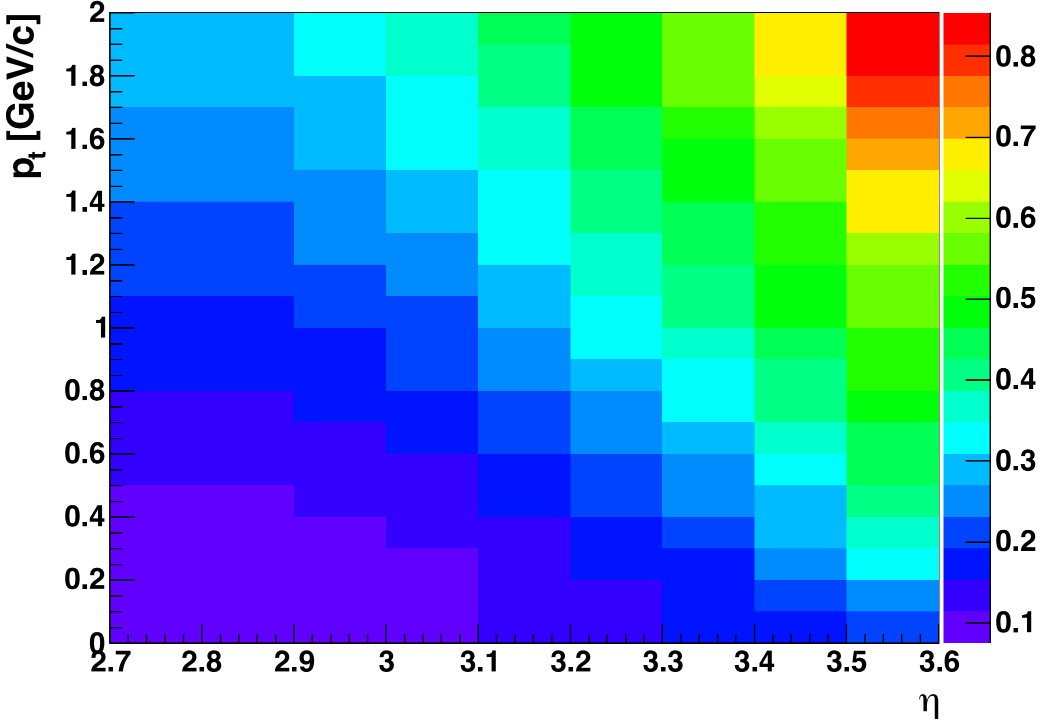
4. Estimated effects of attenuation and towers non-uniformities on resolution.

Viable EMC detector technology developed through EIC R&D
A prototype hadron calorimeter module will be built in 2013

Tracking: proof of principle

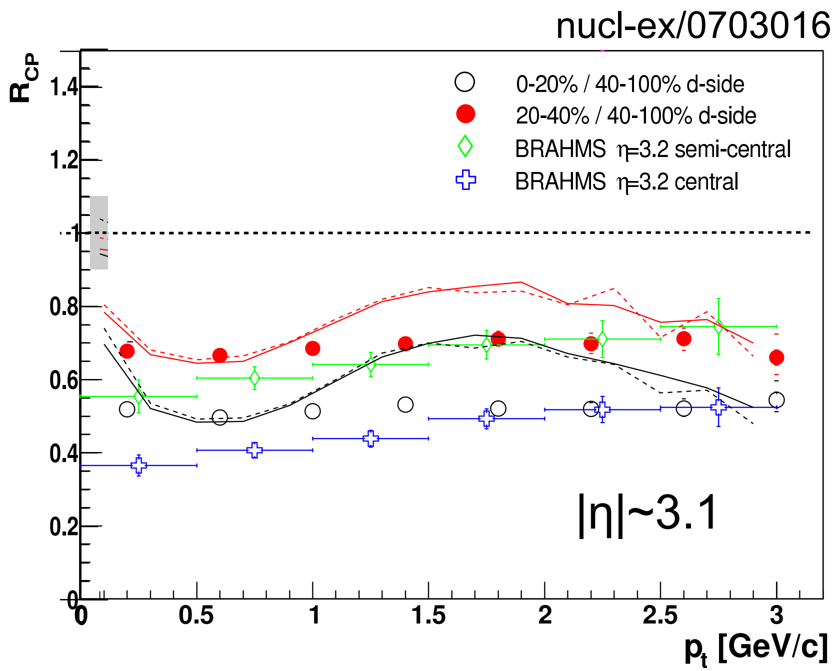
P_t Resolution in STAR Forward TPC

J. Putschke, Thesis



Charged hadron R_{cp} at |η|~3.1

nucl-ex/0703016



STAR magnetic field allows for moderate p_T resolution in forward direction
e.g. FTPC, position resolution ~100 μm
Some added momentum resolution can be garnered from radial magnetic field at poletip

Likely insufficient for RICH particle identification, but sufficient for charge sign discrimination in Drell-Yan: detailed simulations underway

Summary

Major upgrade of capabilities in forward direction envisioned

- Full calorimetry (EM+Hadronic)
- Modern tracking technology to make most of existing magnetic field

Timescale: 2017+

(BTW: Roman Pots Phase 2 have program in p+A, so engineering needs to take this into account)

Strong set of measurements to be made, complementary to and supporting those at a future EIC

From this workshop: what specific measurements should we optimize for in design?

Backup