The STAR Upgrade Program

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For the STAR collaboration

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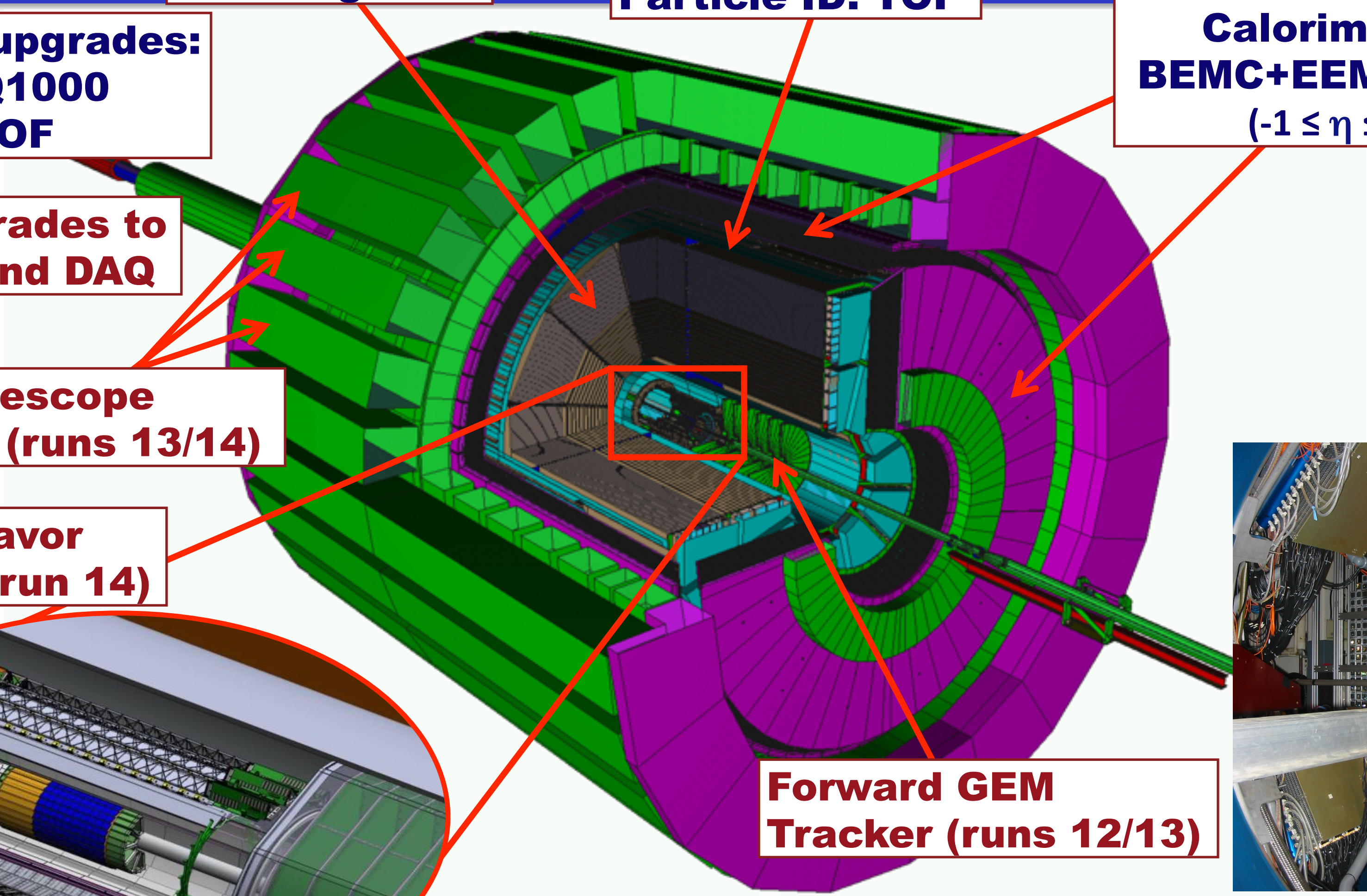
Overview

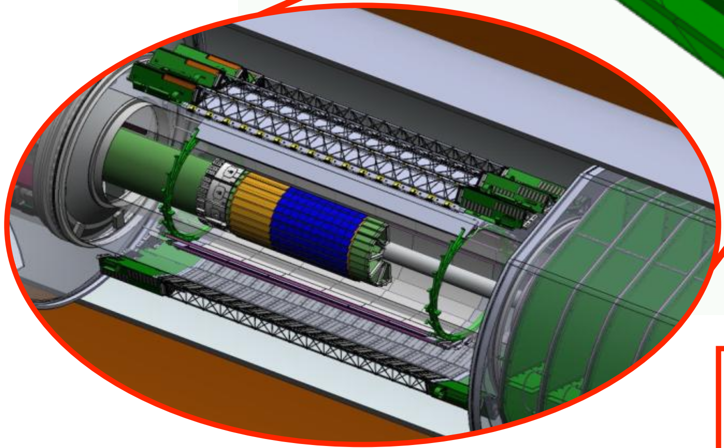
- Introduction
- Near Term Upgrades
  - *Muon Telescope Detector (MTD)*
  - Realization & Planned Physics from MTD
  - *Heavy Flavor Tracker (HFT)*
  - Realization & Planned Physics from HFT
- Future Plans (STAR decadal Plan)
  - iTPC
  - Forward upgrades for pA and eRHIC
- Status and Summary

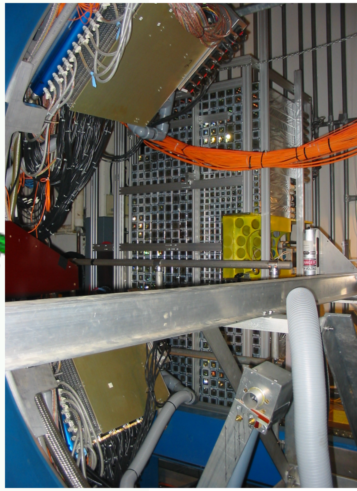
How to explore QCD: from hot to cold

- 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: Beam 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

STAR near term upgrades

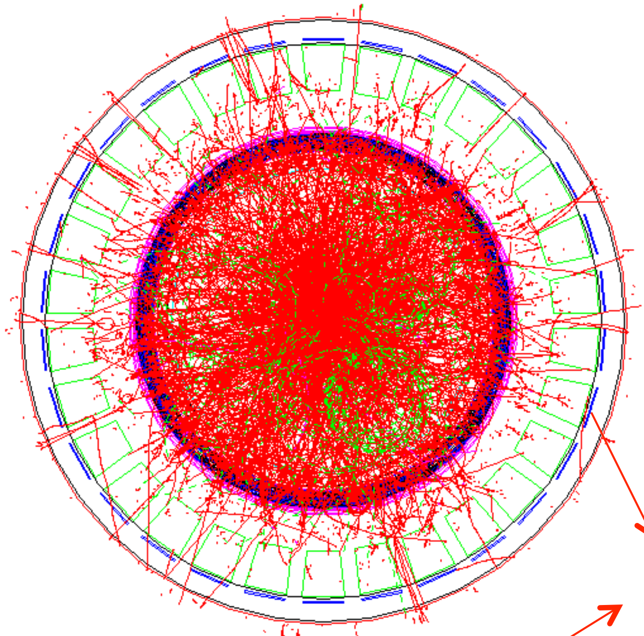
- Muon Telescope Detector (MTD)
  - Accessing muons at mid-rapidity
  - R&D since 2007, construction since 2010
  - Significant contributions from China & India
- Heavy Flavor Tracker (HFT)
  - Precision vertex detector
  - Ongoing DOE MIE since 2010
  - Significant sensor development by IPHC, Strasbourg

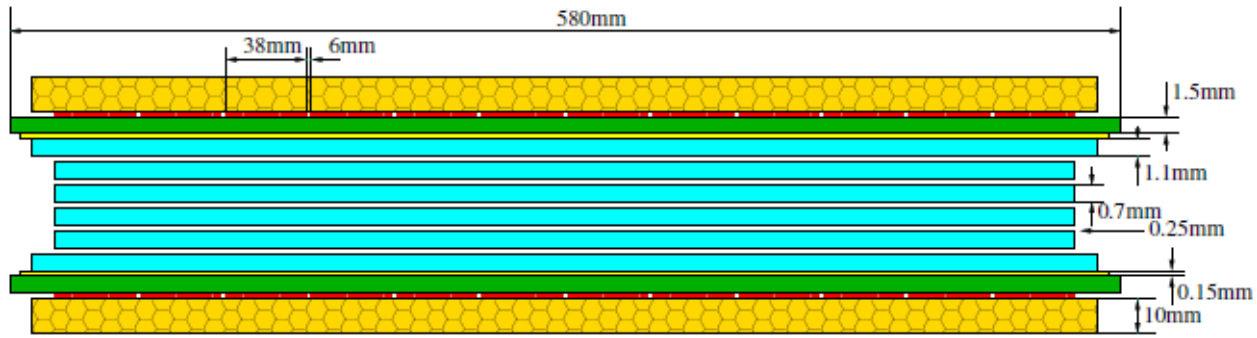
STAR-MTD physics motivation

The large area of muon telescope detector (MTD) at mid-rapidity allows for the detection of

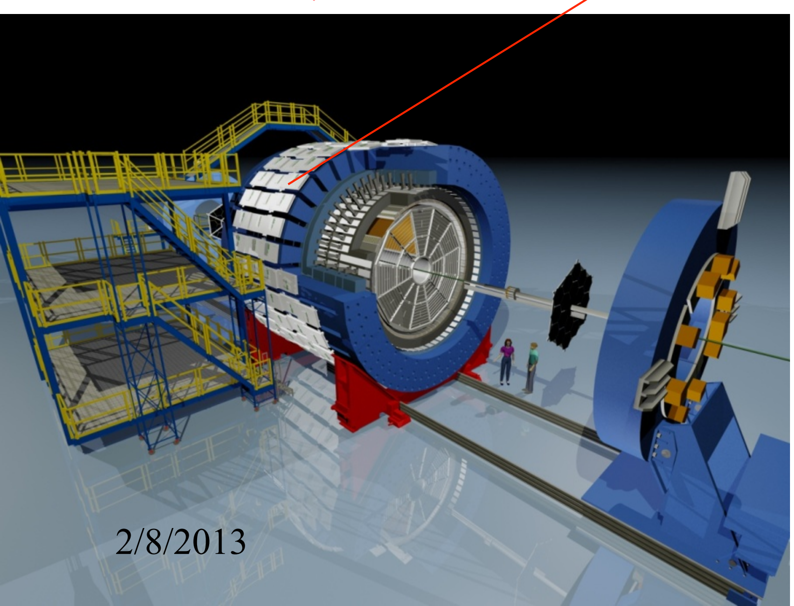
- Di-muon pairs from QGP thermal radiation, quarkonia, light vector mesons, resonances in QGP, and Drell-Yan production
- Single muons from the semi-leptonic decays of heavy flavor hadrons
- Advantages over electrons: no γ conversion, much less Dalitz decay contribution, less affected by radiative losses in the detector materials, trigger capability in Au+Au collisions
- Trigger capability for low to high p_T J/ψ in central Au+Au collisions and excellent mass resolution results in separation of different upsilon states
- e-muon correlation can distinguish heavy flavor production from initial lepton pair production

Concept of design of the STAR-MTD





MTD



Multi-gap Resistive Plate Chamber (MRPC): gas detector, avalanche mode

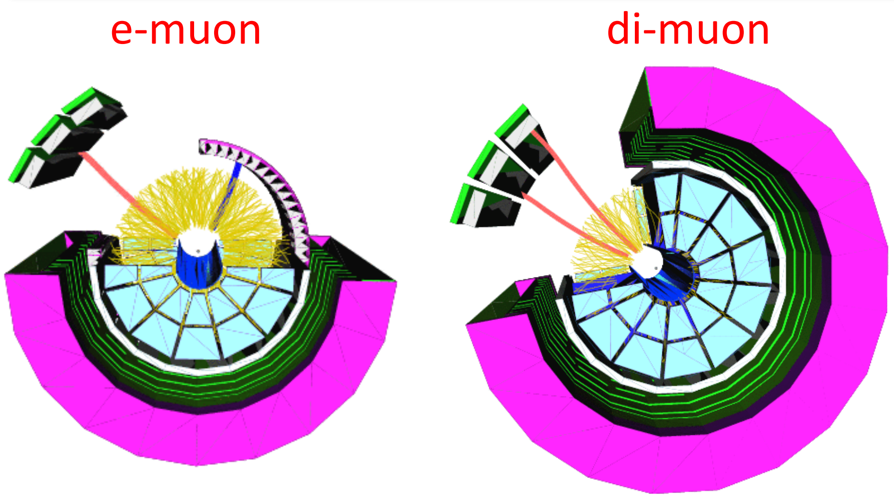
A detector with long-MRPCs covers the whole iron bars and leaves the gaps in-between uncovered. Acceptance: 45% at $|\eta|<0.5$

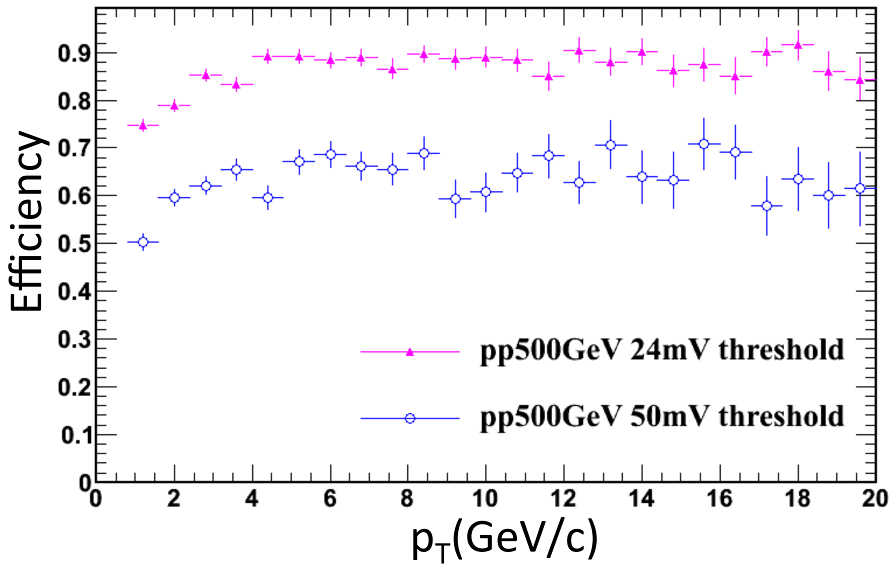
118 modules, 1416 readout strips, 2832 readout channels

Long-MRPC detector technology, electronics same as used in STAR-TOF

STAR-MTD

MTD Performance from Run 12

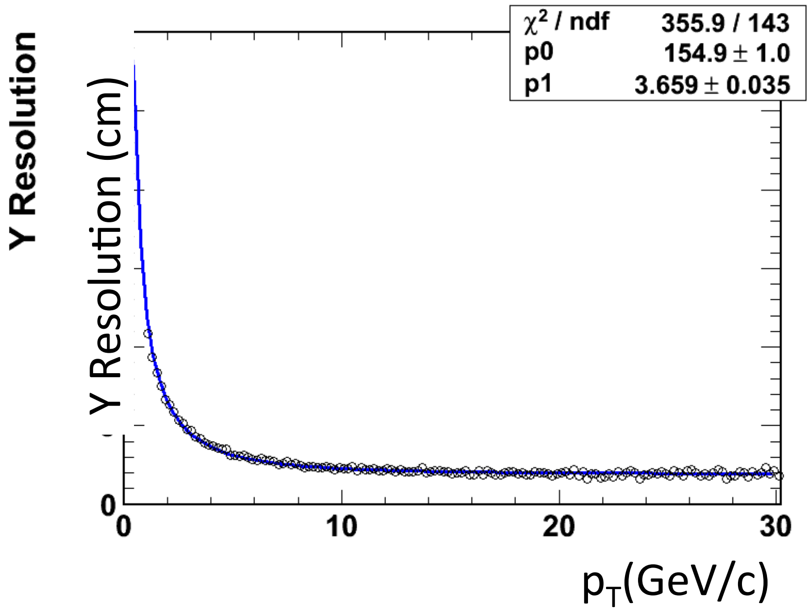




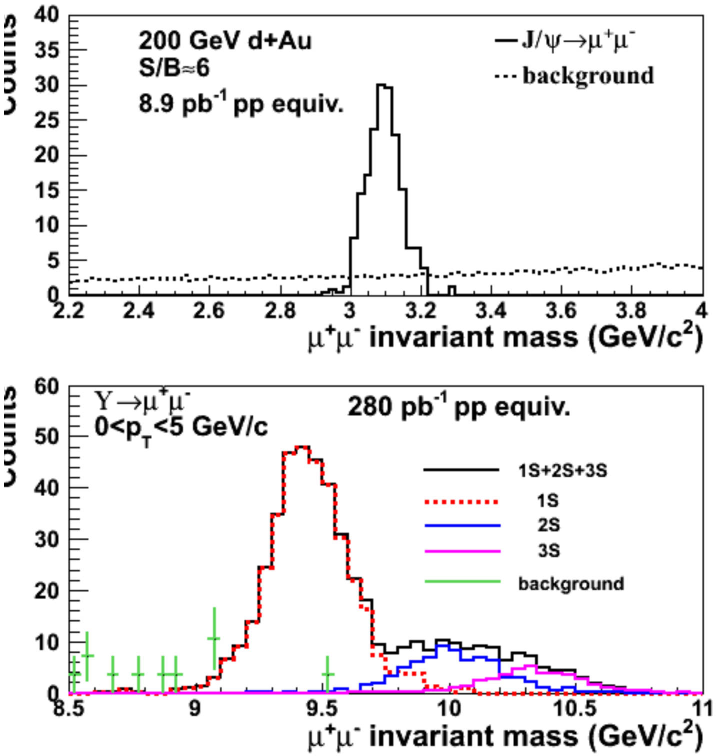
Commissioned e-muon (coincidence of single MTD hit and BEMC energy deposition above a certain threshold) and di-muon triggers, event display for Cu+Au collisions shown above

Determined the electronics threshold for the future runs, achieved 90% efficiency at threshold 24 mV

Intrinsic spatial resolution: 2 cm



Quarkonium from MTD

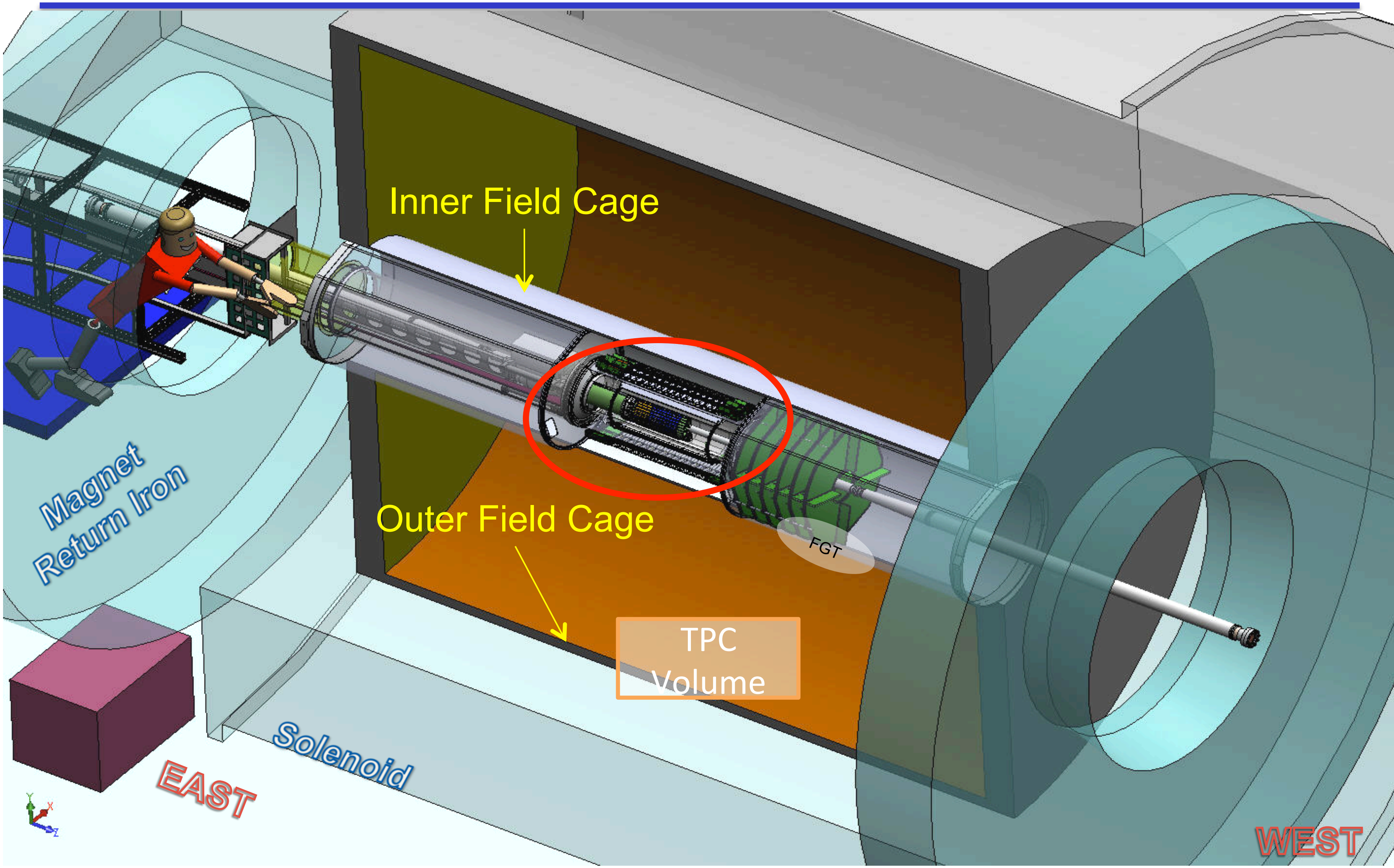


1. J/ψ: S/B=6 in d+Au and S/B=2 in central Au+Au collisions
2. Excellent mass resolution: separate different upsilon states
3. With HFT, study B→J/ψ X; J/ψ→$\mu\mu$ using displaced vertices

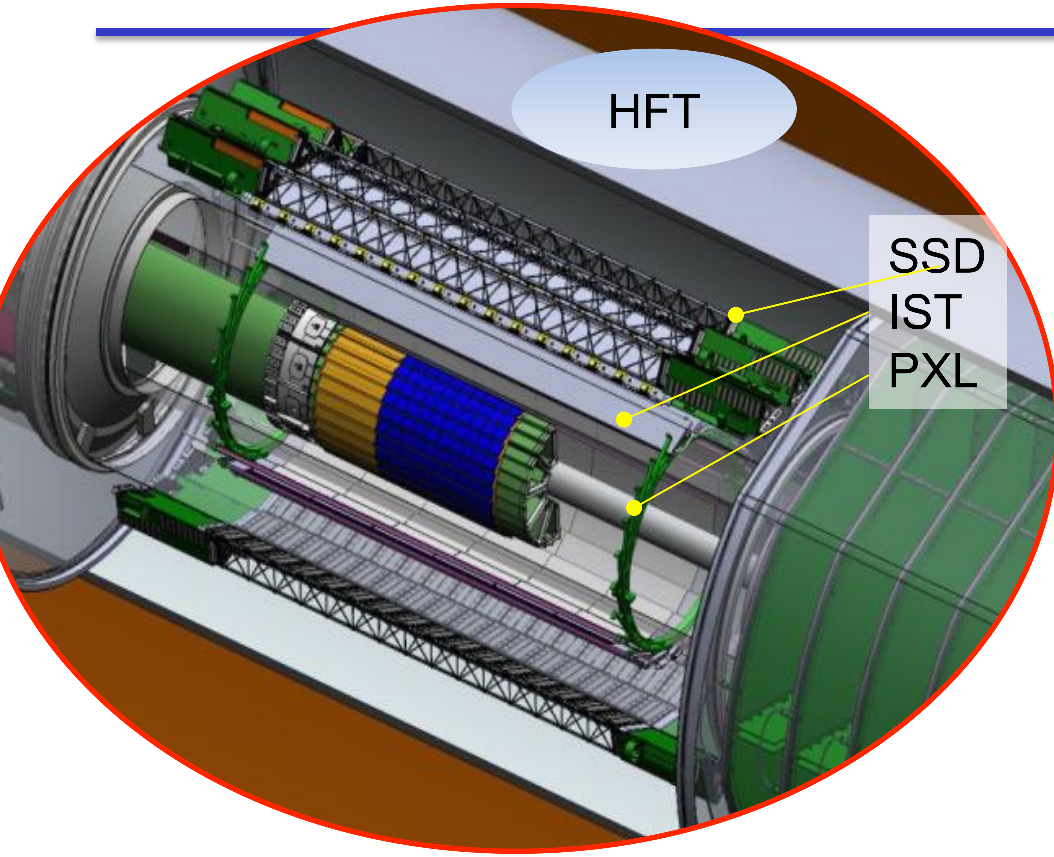
Heavy flavor collectivity and color screening, quarkonia production mechanisms:
J/ψ R_{AA} and v_2; upsilon R_{AA} …

Z. Xu, BNL LDRD 07-007; L. Ruan et al., Journal of Physics G: Nucl. Part. Phys. 36 (2009) 095001

Heavy Flavor Tracker (HFT)



Heavy Flavor Tracker (HFT)



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

PIXEL

- two layers
- 18.4x18.4 μm pixel pitch
- 10 sectors, delivering ultimate Pointing resolution that allows for direct topological identification of charm.
- New monolithic active pixel sensors (MAPS) technology

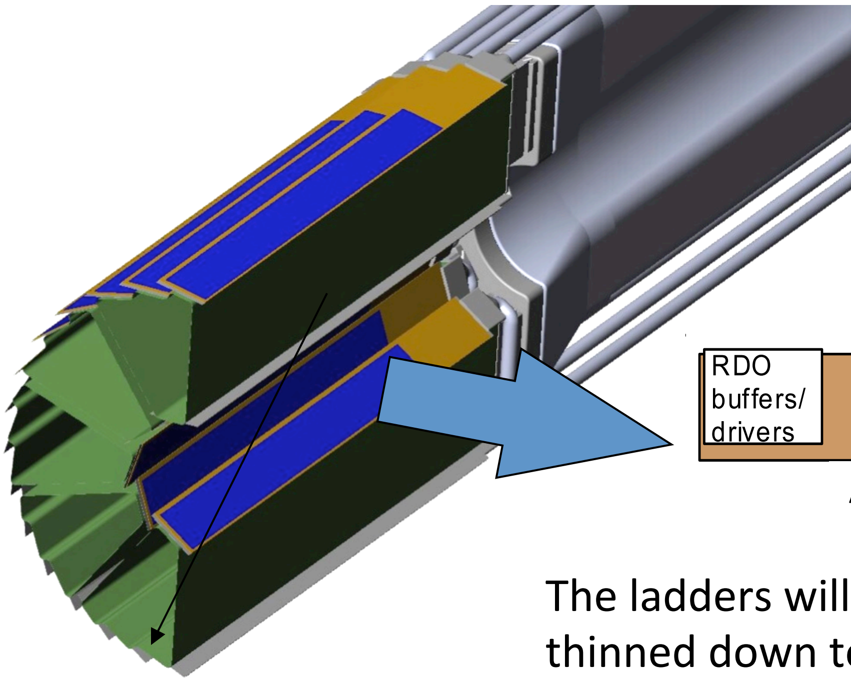
SSD

- Existing single layer detector, double side strips (electronic upgrade)

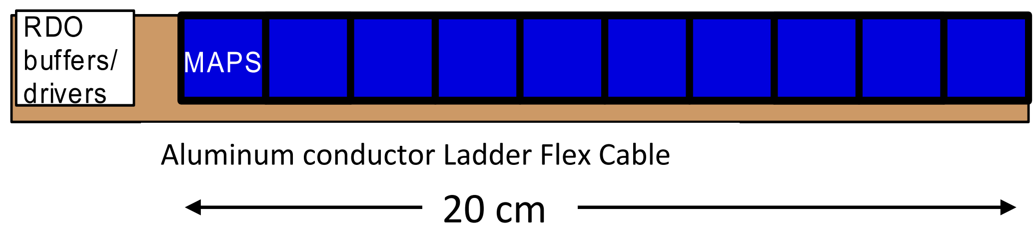
IST One layer of silicon strips along the beam direction (r-ϕ) , guiding tracks from the SSD to PIXEL detector. - **proven technology**

PXL Detector Design

Carbon fiber sector tubes (~ 200μm thick)



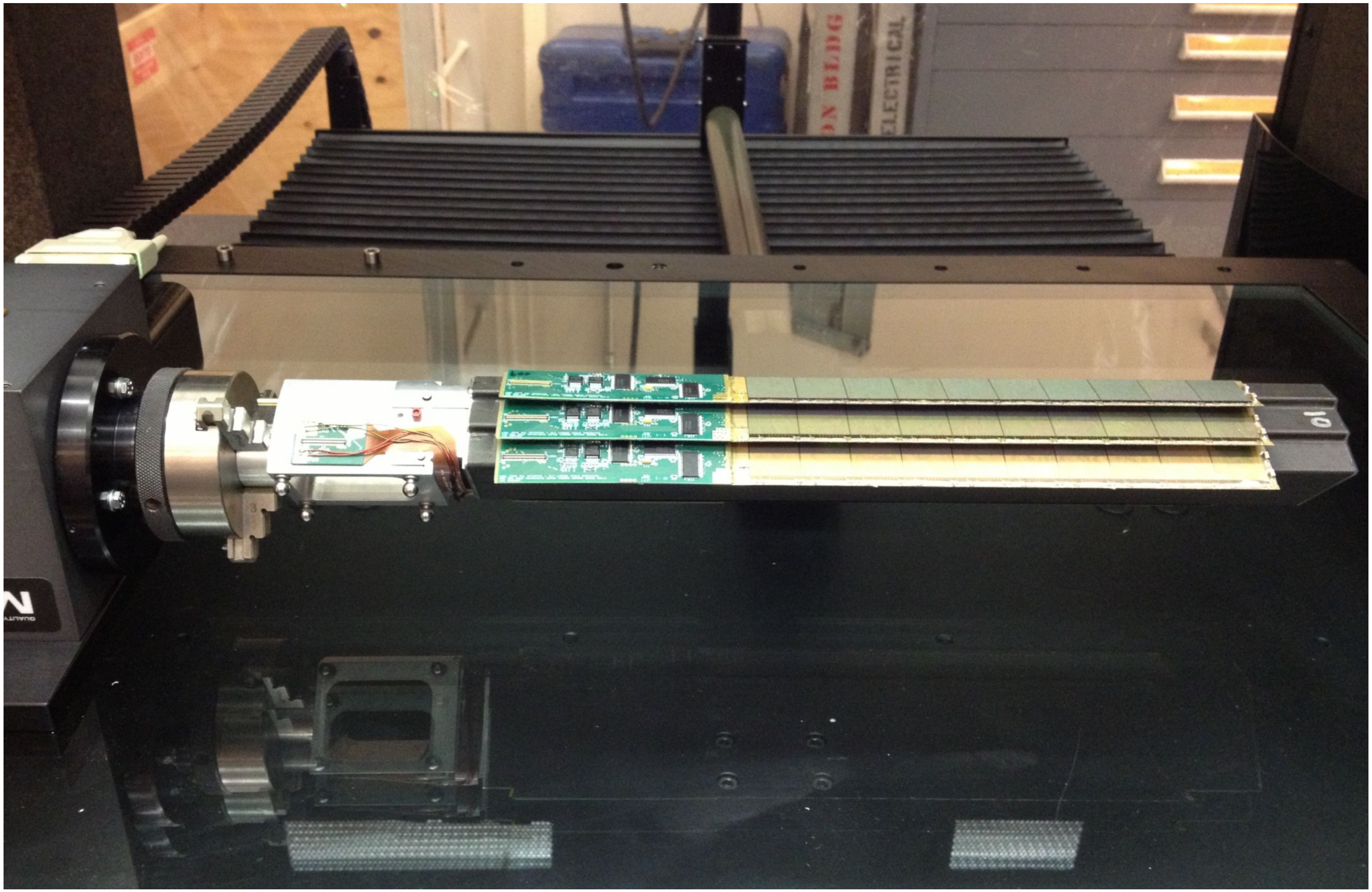
Ladder with 10 MAPS sensors (~ 2×2 cm each)



The ladders will be instrumented with sensors thinned down to 50 micron Si.

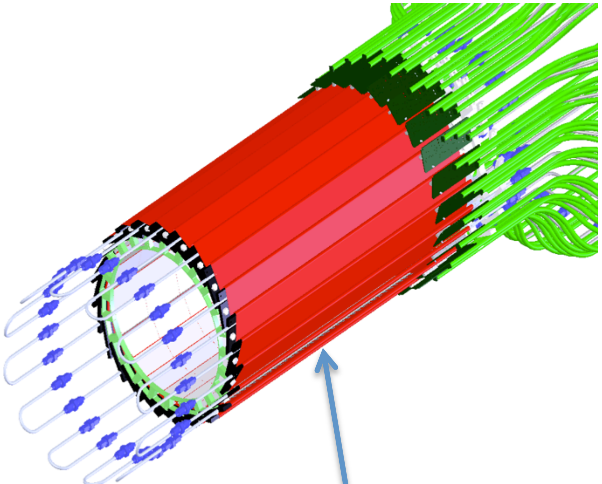
Novel rapid insertion mechanism allows effective exchanges and repairs (~12 h)
Precision kinematic mount guarantees reproducibility to < 20 microns

Production sector

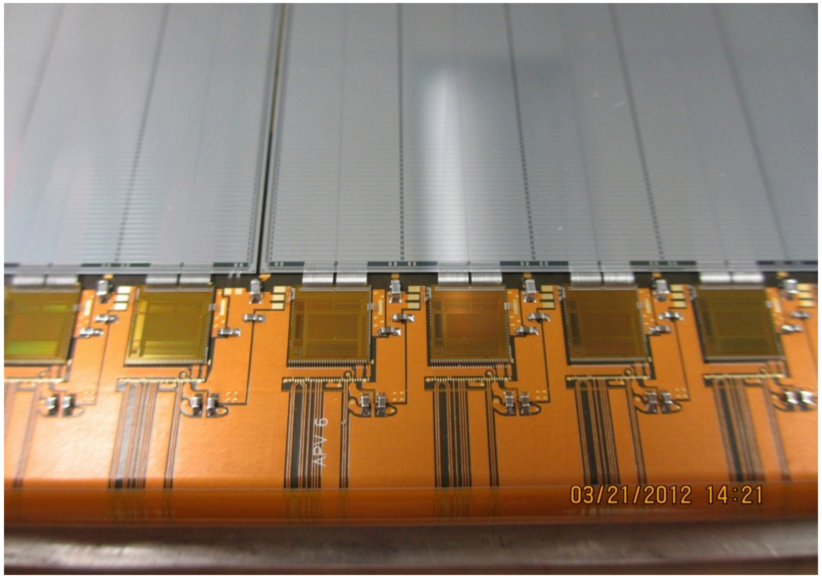


Production sector on metrology stage

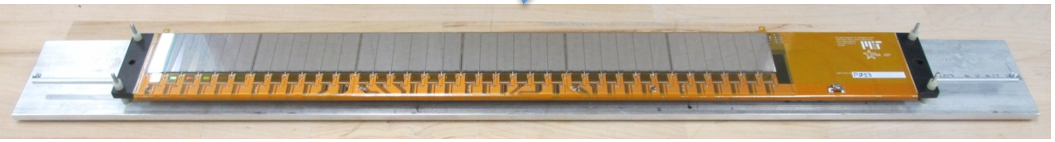
Intermediate Si Tracker



24 ladders, liquid cooling

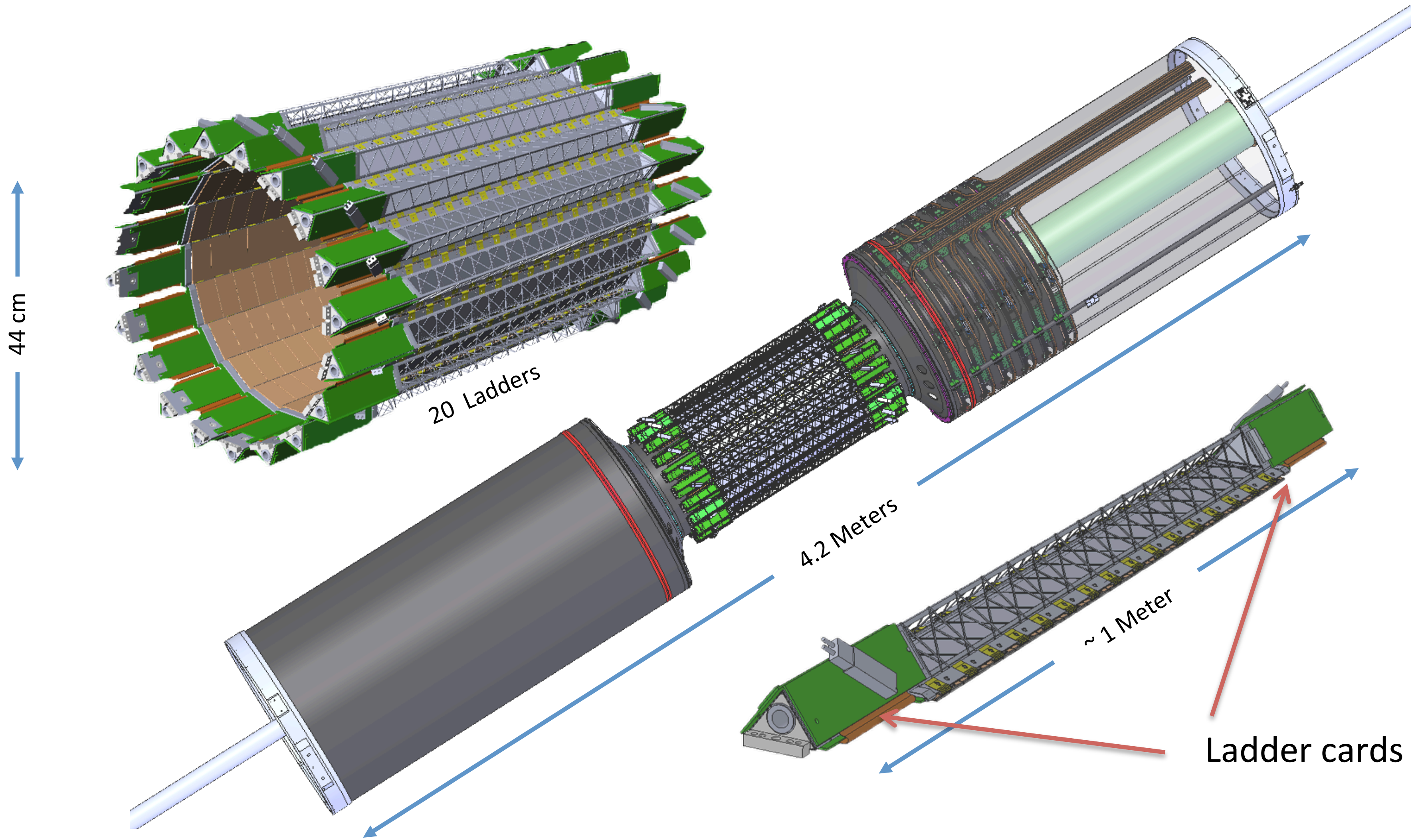


Details of wire bonding



Prototype Ladder
S:N > 20:1
>99.9% live and functioning channels

Silicon Strip Detector (SSD)



Physics of the Heavy Flavor Tracker at STAR

- Direct HF hadron measurements (p+p and Au+Au)

  (1) Heavy-quark cross sections: $D^{0\pm *}$, D_S, Λ_C , B, …

  (2) Both spectra (R_{AA}, R_{CP}) and v_2 in a wide p_T region: 0.5 - 10 GeV/c

  (3) Charm hadron correlation functions, heavy flavor jets

  (4) Full spectrum of the heavy quark hadron decay electrons

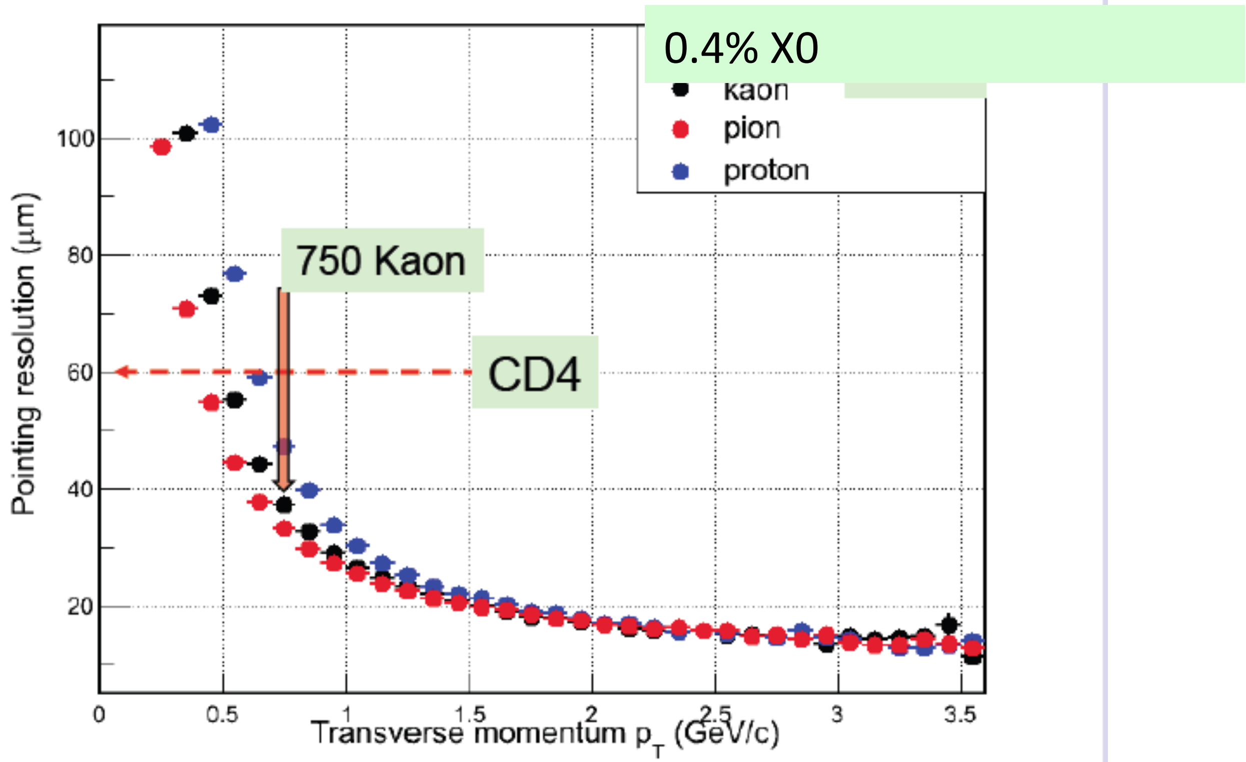
- Physics

  (1) Measure heavy-quark hadron v_2, heavy-quark collectivity, to study the medium properties e.g. light-quark thermalization

  (2) Measure heavy-quark energy loss to study pQCD in hot/dense medium e.g. energy loss mechanism

  (3) Analyze hadro-chemistry including heavy flavors

DCA resolution performance r-φ and z

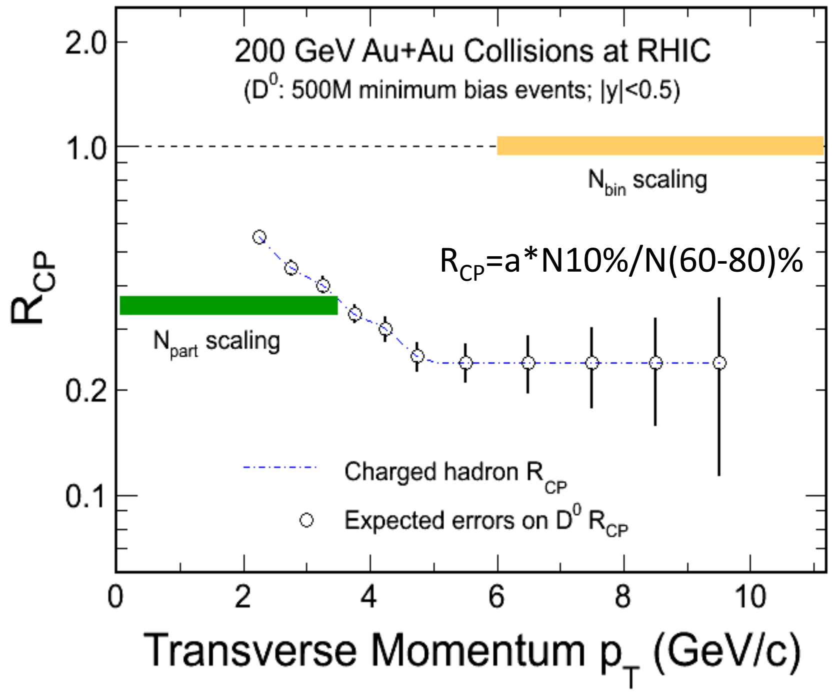


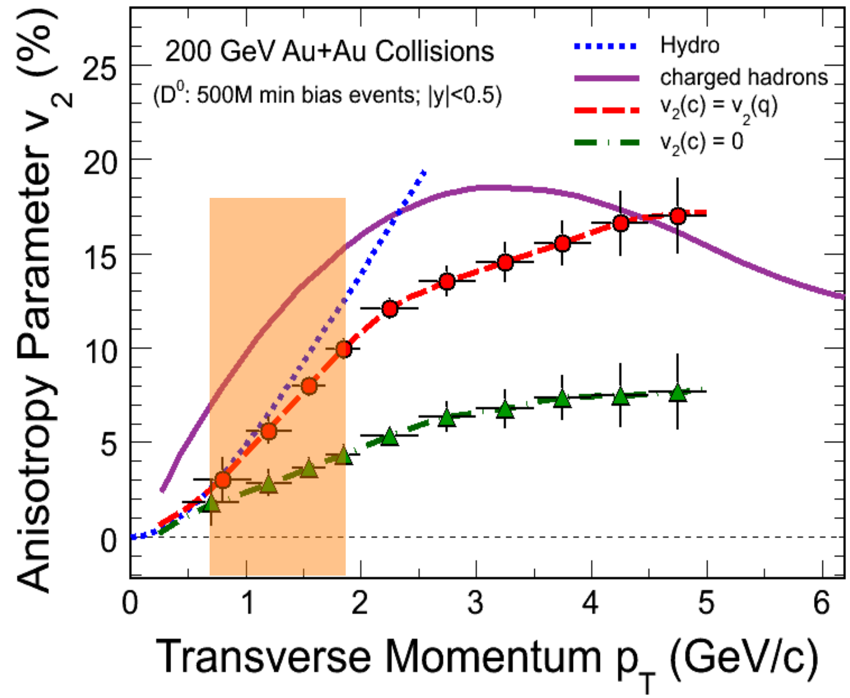
GEANT: Realistic detector geometry + Standard STAR tracking including the pixel pileup hits at RHIC-II luminosity

Goal with Al-based cable (Cu cable -> 55 micron for 750 MeV/c K)

Physics – Run-14,15 projections

STAR





Assuming D^0 R_{cp} distribution as charged hadron.

500M Au+Au m.b. events at 200 GeV.

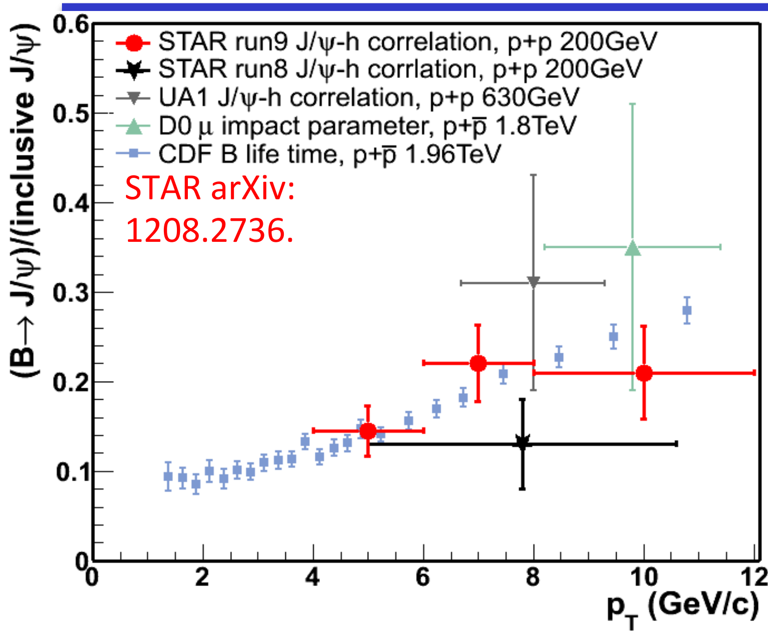
- Charm R_{AA} ⇨
Energy loss mechanism!
Color charge effect!
Interaction with QCD matter!

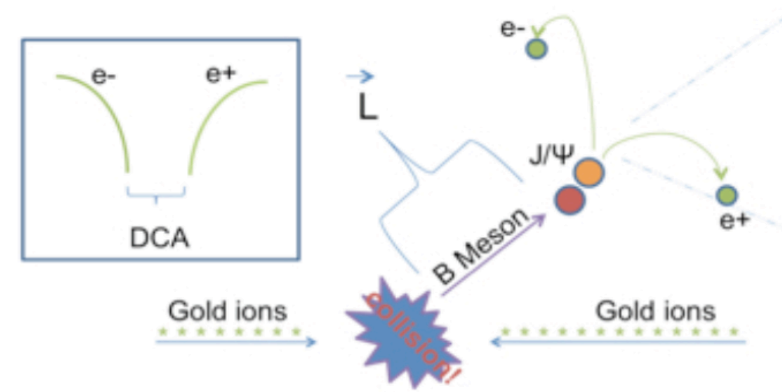
Assuming D^0 v_2 distribution from quark coalescence.

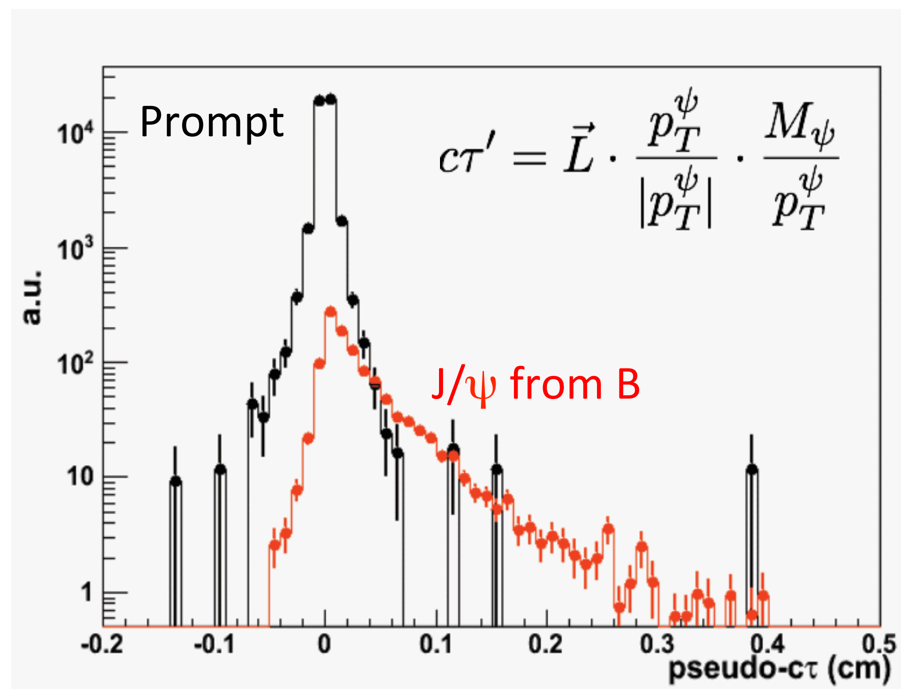
500M Au+Au m.b. events at 200 GeV.

- Charm v_2 ⇨
Medium thermalization degree
Drag coefficients!

B tagged J/ψ







- Current measurement via *J/ψ*-hadron correlation have large uncertainties.

- Combine **HFT+MTD** in di-muon channel
  - Separate secondary *J/ψ* from prompt*J/ψ*
  - Constrain the bottom production at RHIC

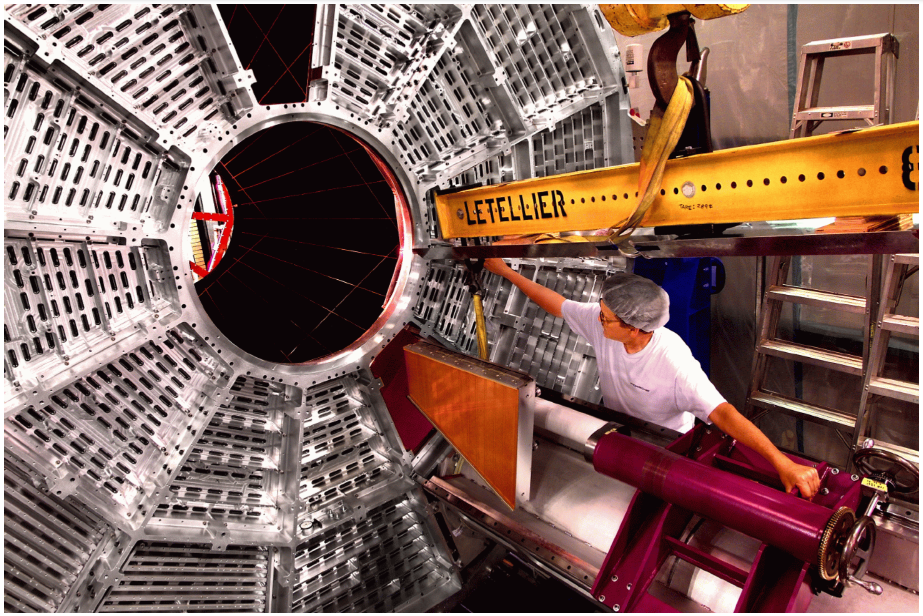
HFT project status

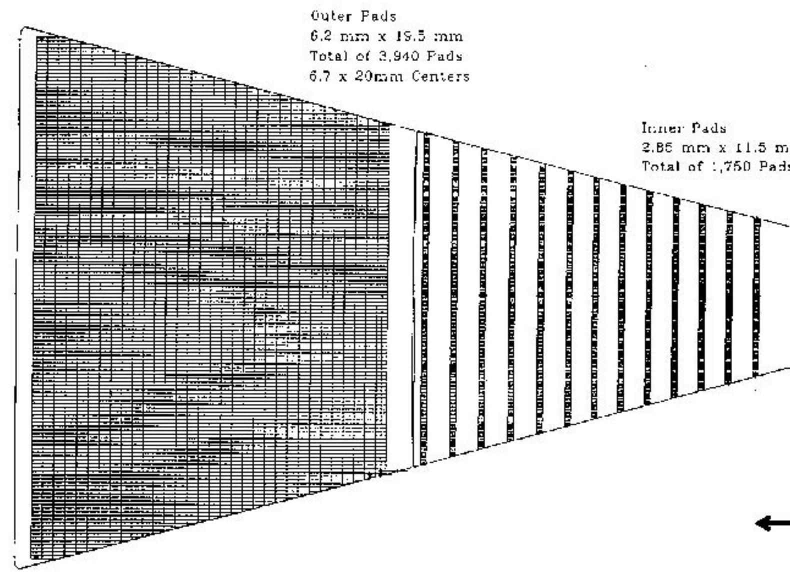
- HFT upgrade was approved CD-2/3 October 2011 and is well into fabrication phase
- All detector components have passed the prototype phase successfully
- A PXL prototype with 3+ sectors instrumented is planned for an engineering run and data taking in STAR in mid to end March
- The full assembly including PXL, IST and SSD should be available for RHIC Run-14, which is planned to be a long Au-Au run

Future Plans

- Beam Energy Scan II (Hui's talk Monday)
- Exploit pA physics
- Prepare STAR for eRHIC on 2020-2025 timescale (eSTAR)

Inner TPC Upgrade





Current pad plane layout. 13 rows and gaps.
Fill all inner sector with active pads.
Configuration still under discussion

Better tracking and dE/dx PID capability
η 1.0-1.7 region -- broad physics impact on

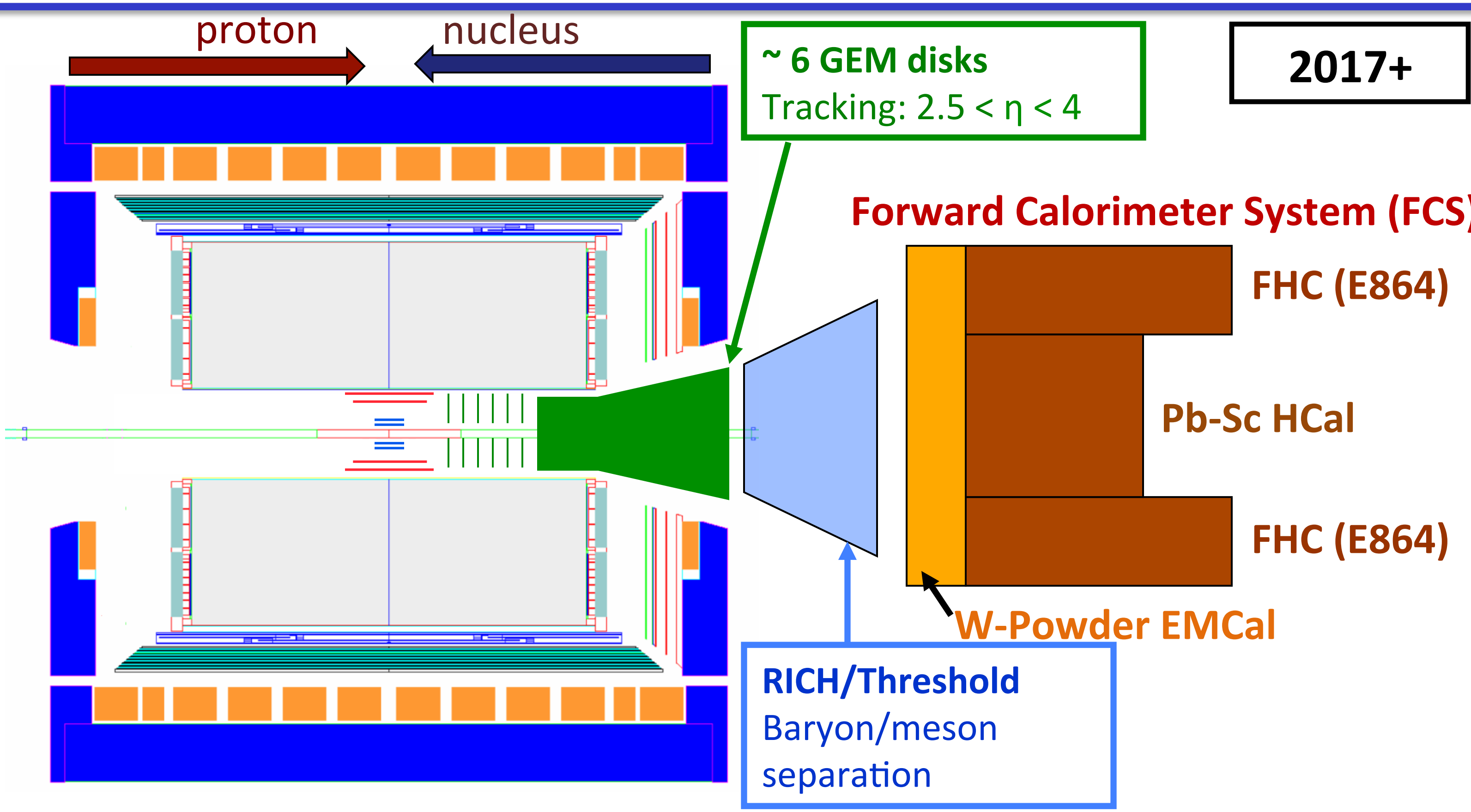
- **transverse spin physics program**
- **hyperon and exotic particle searches**
- **high p_T identified particles**
- **BES Phase II+**
- **Long range rapidity gap correlations.**

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 $x_2 < 0.001$
- ***polarized* protons off nuclei** can be studied at RHIC.

- **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, …**

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

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

Summary

STAR has an ongoing upgrade program that will enable significant physics measurements in 2013-1017

- Further high precision Heavy Flavor measurements will be carried out to explore the sQGP
- HFT upgrades will provide direct topological reconstruction for charm
- MTD will provide precision Heavy Flavor measurements in muon channels, and di-lepton measurements

Future upgrades for 2017+

- Enhanced TPC capabilities for BES II (and eSTAR)
- Forward Upgrades to exploit a p+A program
  - Full calorimetry (EM+Hadronic)
  - Modern tracking technology to make most of existing magnetic field
- Strong set of measurements to be made. Both complementary to, and supporting, those at a future eRHIC