MAPS at EIC?

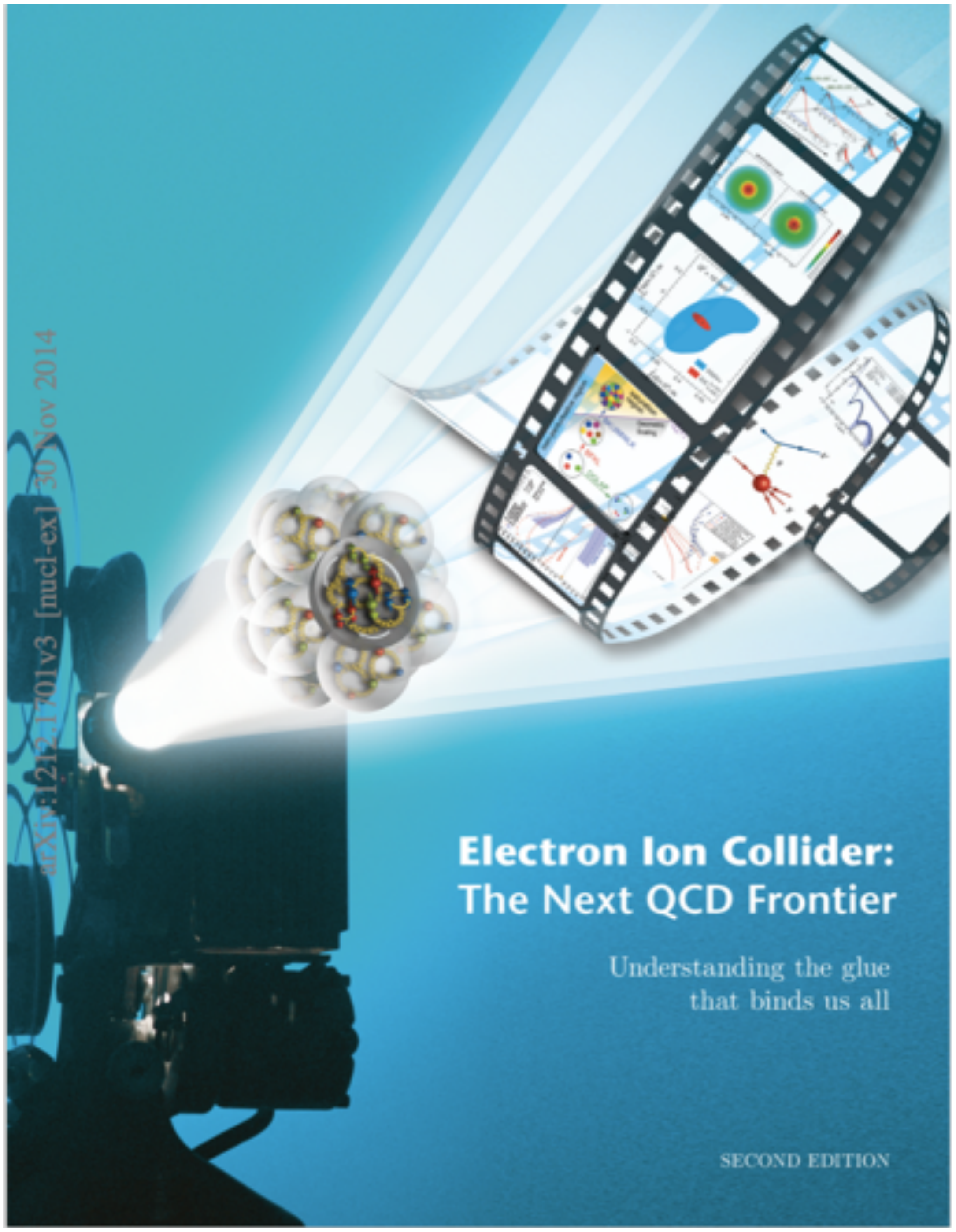
Ernst Sichtermann, LBNL

and *many* others:
Giacomo Contin,
Leo Greiner,
Jim Thomas,
Howard Wieman,
EIC friends

the errors and mistakes are of course mine.

EIC Users' Group Meeting
U.C. Berkeley, January 8, 2016

EIC Physics



coherent contributions from many nucleons effectively amplify the gluon density being probed.

The EIC was designated in the 2007 Nuclear Physics Long Range Plan as "embodying the vision for reaching the next QCD frontier" [1]. It would extend the QCD science programs in the U.S. established at both the CEBAF accelerator at JLab and RHIC at BNL in dramatic and fundamentally important ways. The most intellectually pressing questions that an EIC will address that relate to our detailed and fundamental understanding of QCD in this *frontier* environment are:

- **How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon?** How are these quark and gluon distributions correlated with overall nucleon properties, such as spin direction? What is the role of the orbital motion of sea quarks and gluons in building the nucleon spin?
- **Where does the saturation of gluon densities set in?** Is there a simple boundary that separates this region from that of more dilute quark-gluon matter? If so, how do the distributions of quarks and gluons change as one crosses the boundary? Does this saturation produce matter of universal properties in the nucleon and all nuclei viewed at nearly the speed of light?
- **How does the nuclear environment affect the distribution of quarks and gluons and their interactions in nuclei?** How does the transverse spatial distribution of gluons compare to that in the nucleon? How does nuclear matter respond to a fast moving color charge passing through it? Is this response different for light and heavy quarks?

Answers to these questions are essential for understanding the nature of visible matter. An EIC is the ultimate machine to provide answers to these questions for the following reasons:

- A collider is needed to provide kinematic reach well into the gluon-dominated regime;
- Electron beams are needed to bring to bear the unmatched precision of the electromagnetic interaction as a probe;
- Polarized nucleon beams are needed to determine the correlations of sea quark and gluon distributions with the nucleon spin;
- Heavy ion beams are needed to provide precocious access to the regime of saturated gluon densities and offer a precise dial in the study of propagation-length for color charges in nuclear matter.

The EIC would be distinguished from all past, current, and contemplated facilities around the world by being at the intensity frontier with a versatile range of kinematics and beam polarizations, as well as beam species, allowing the above questions to be tackled at one facility. In particular, the EIC design exceeds the capabilities of HERA, the only electron-proton collider to date, by adding a) polarized proton and light-ion beams; b) a wide variety of heavy-ion beams; c) two to three orders of magnitude increase in luminosity to facilitate tomographic imaging; and d) wide energy variability to enhance the sensitivity to gluon distributions. Achieving these challenging technical improvements in a single facility will extend U.S. leadership in accelerator sci-

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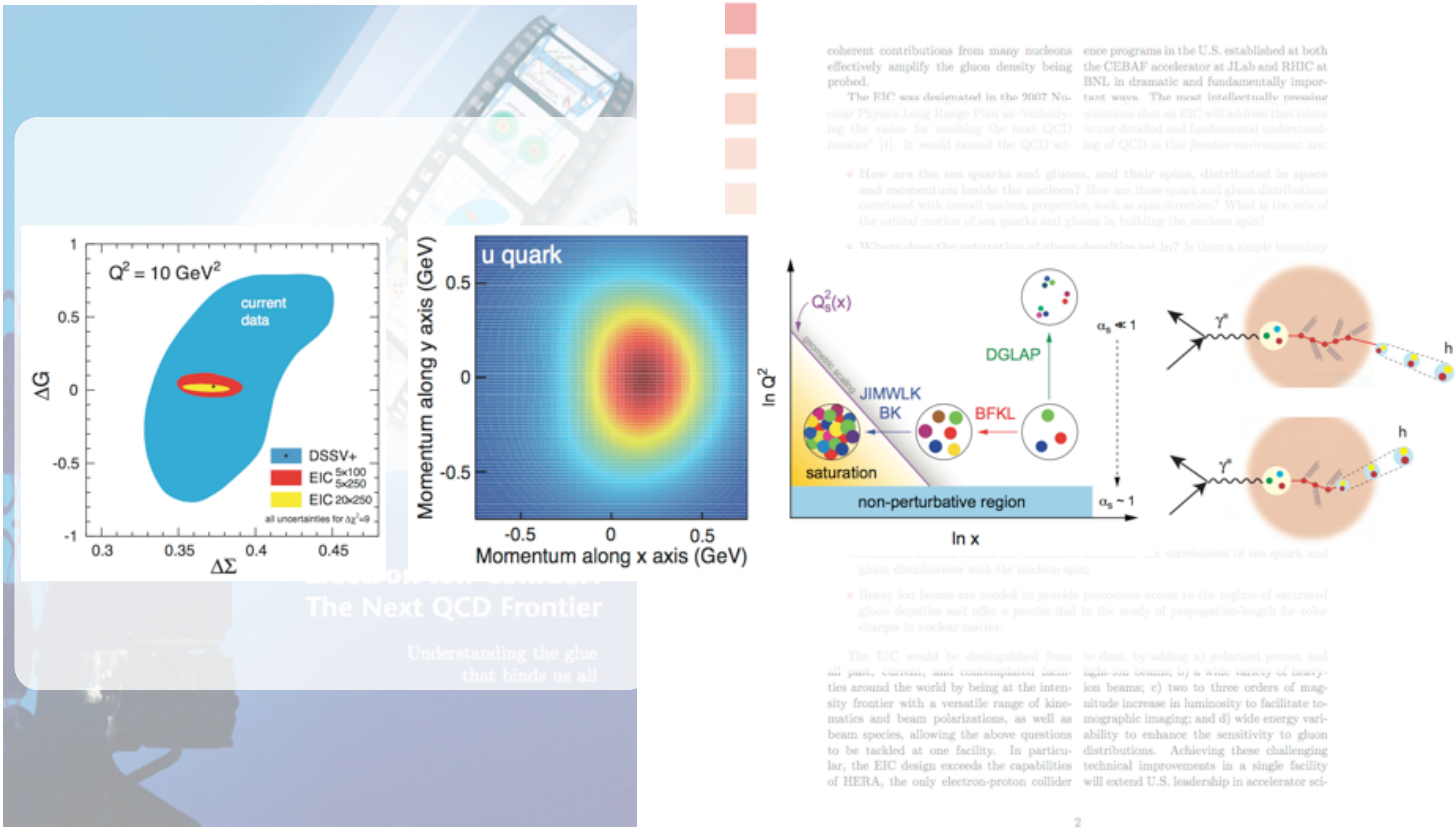
ArXiv:1212.17010

EIC Physics



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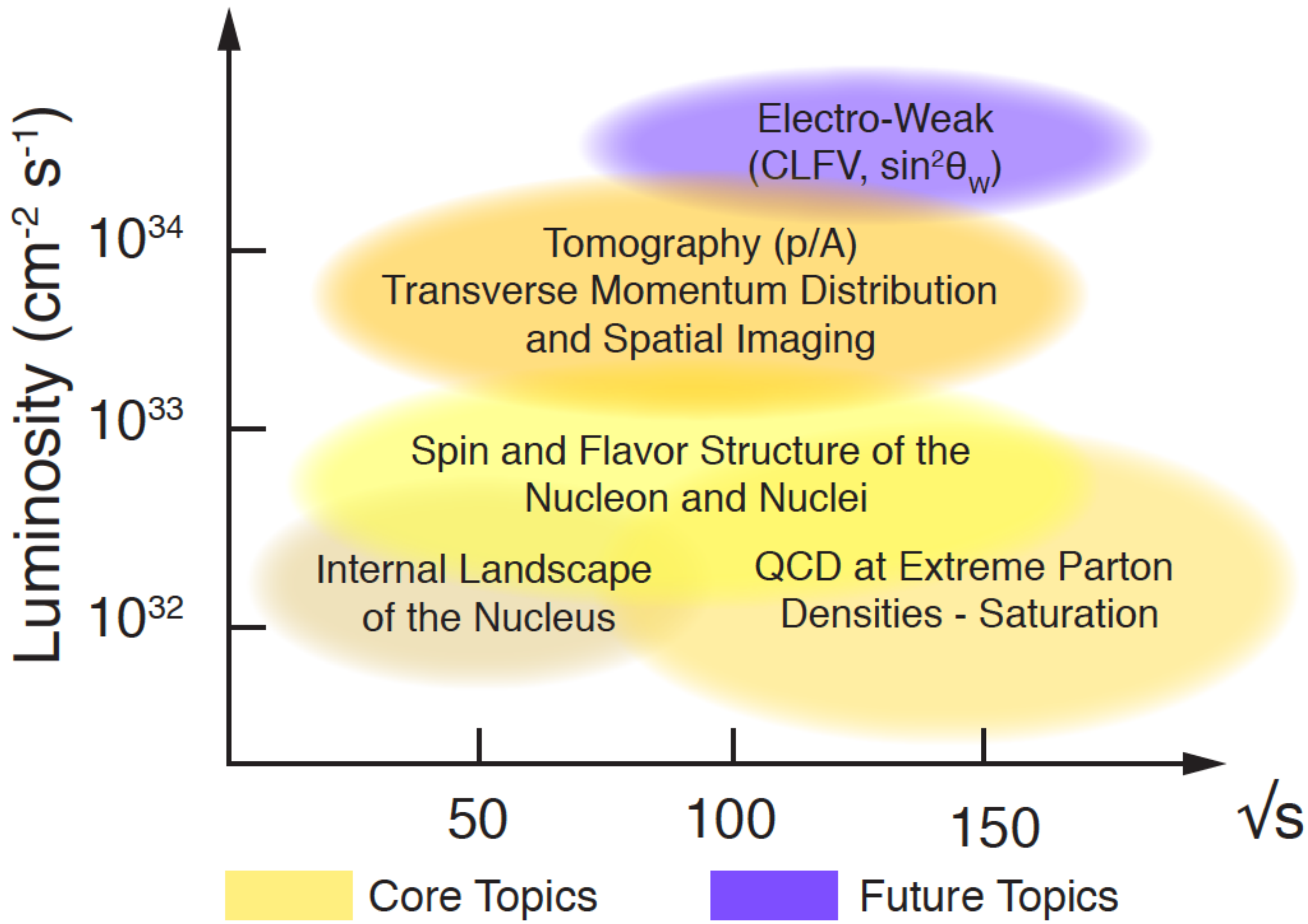
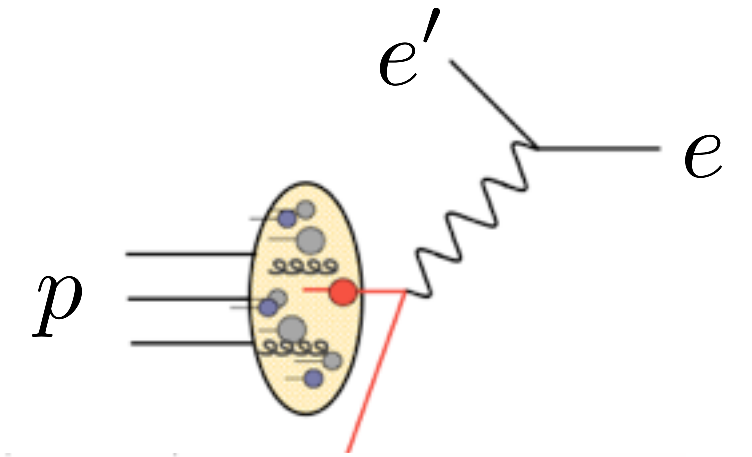
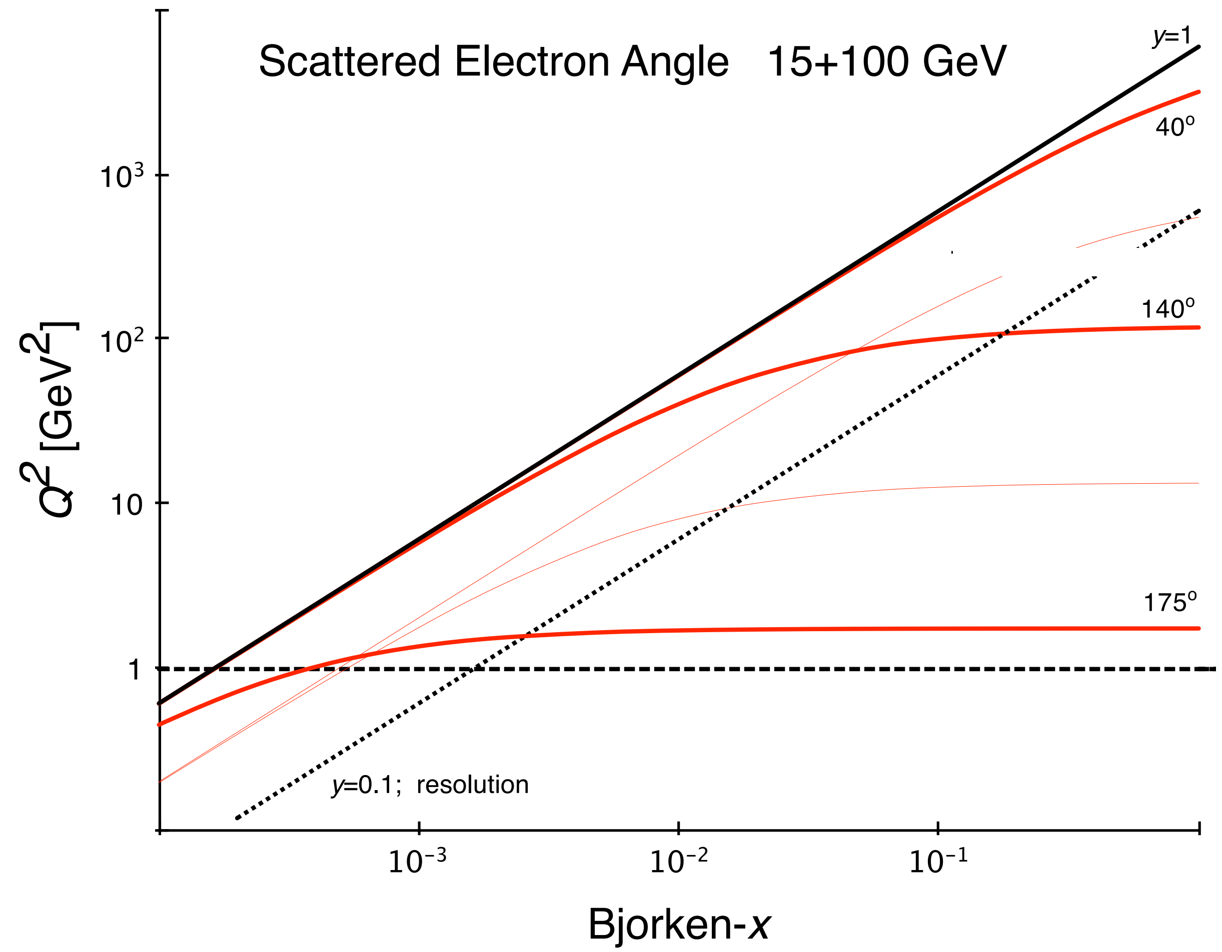
EIC Physics

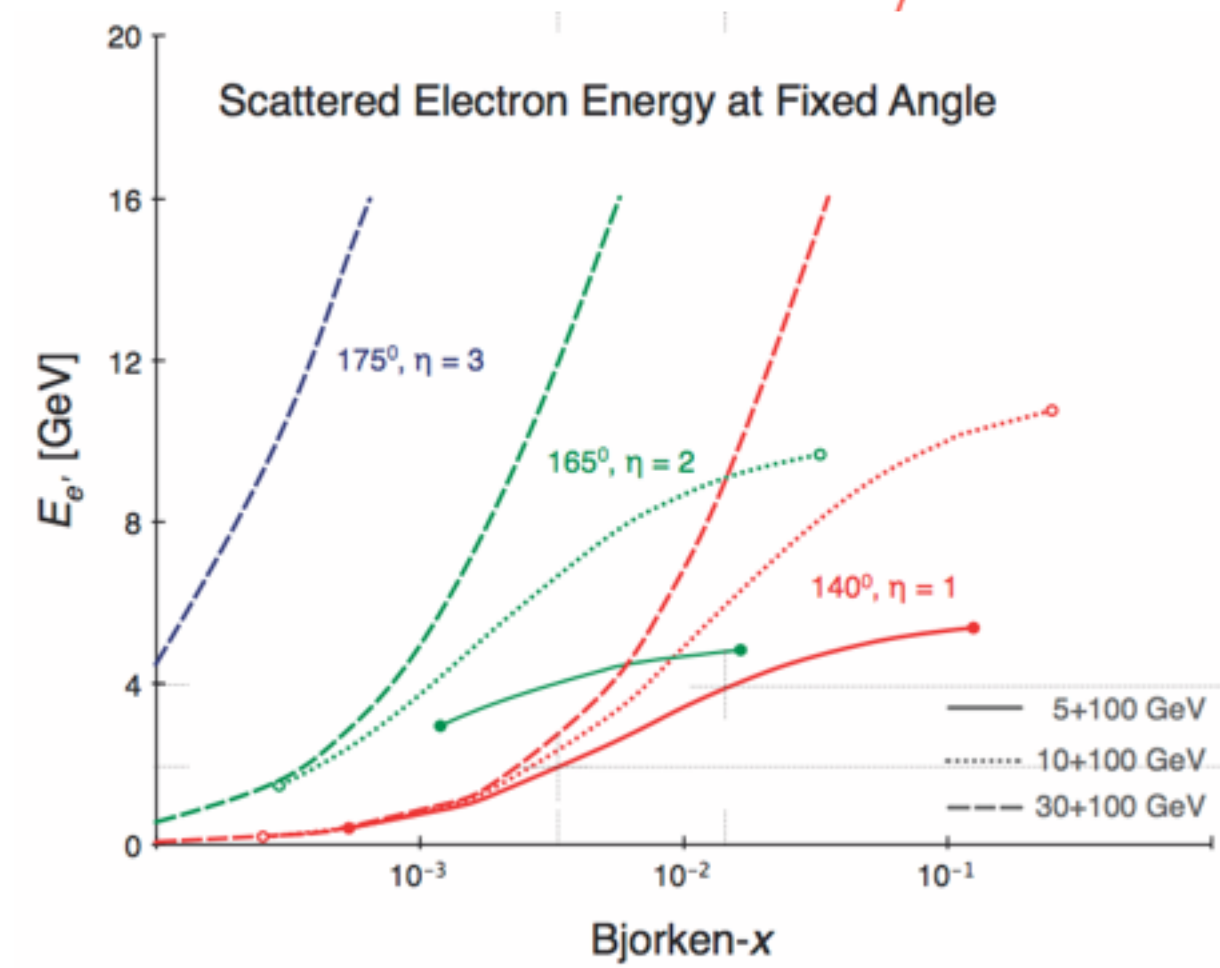


implies a need for *moderate* to *high*-$\sqrt{s}$,
asymmetric beam energies,
inclusive, semi-inclusive, exclusive observables

EIC Kinematics







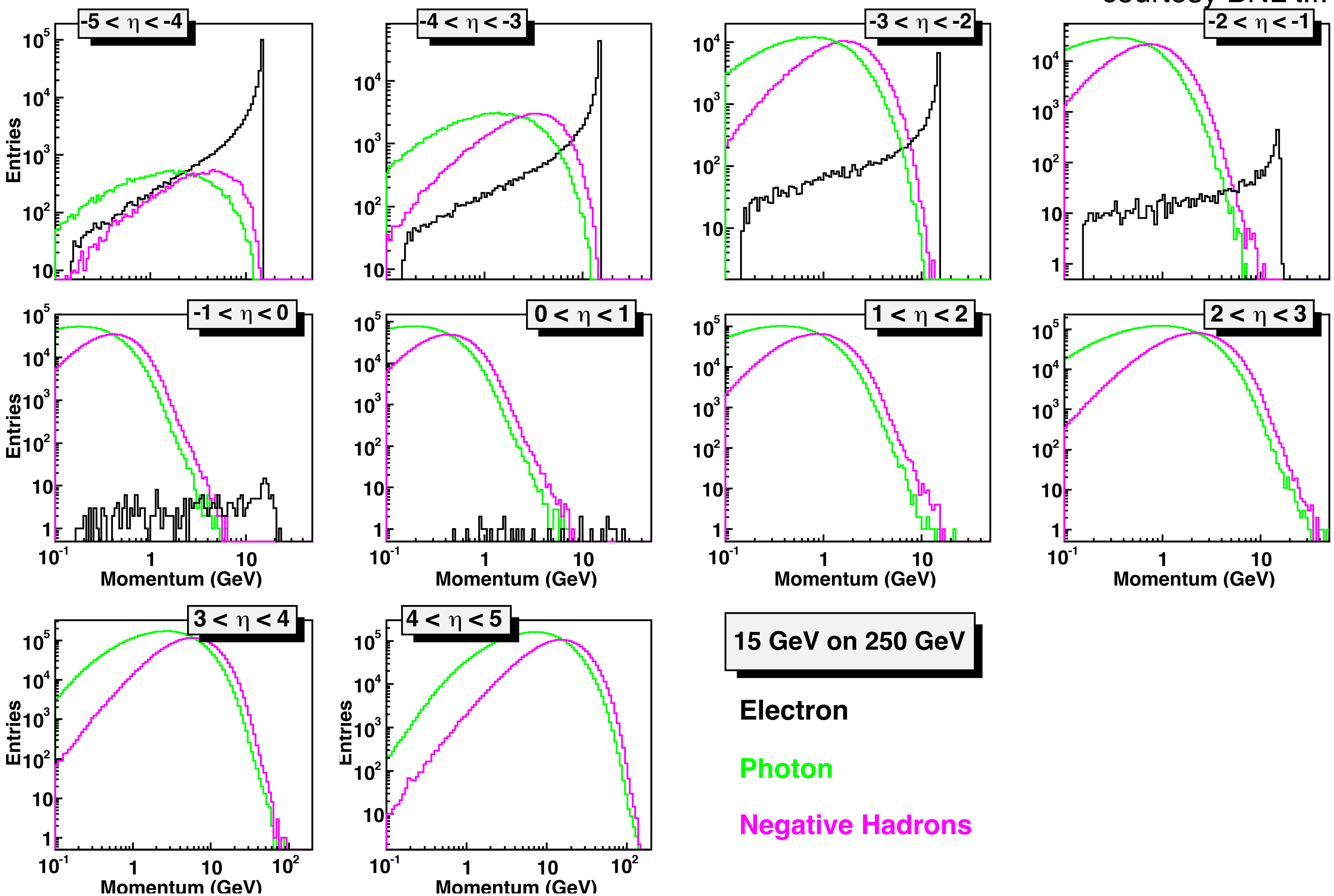
necessitates instrumentation at *backward* angles w.r.t. the hadron beam (HERA convention)

x-resolution typically behaves as 1/*y*

low-x scattered electrons have *low* energies

EIC electron identification

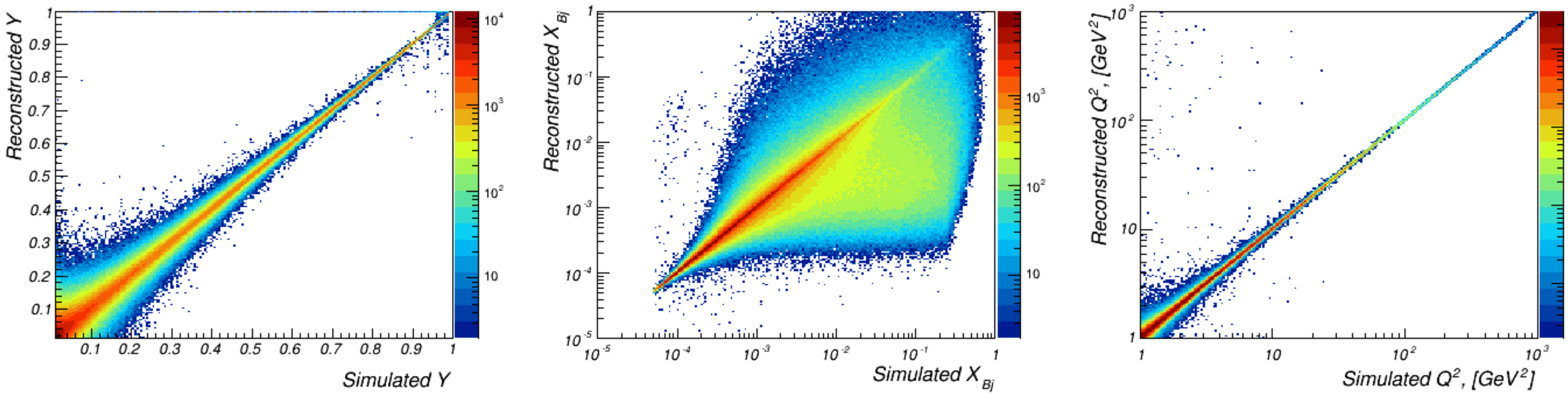
courtesy BNL t.f.



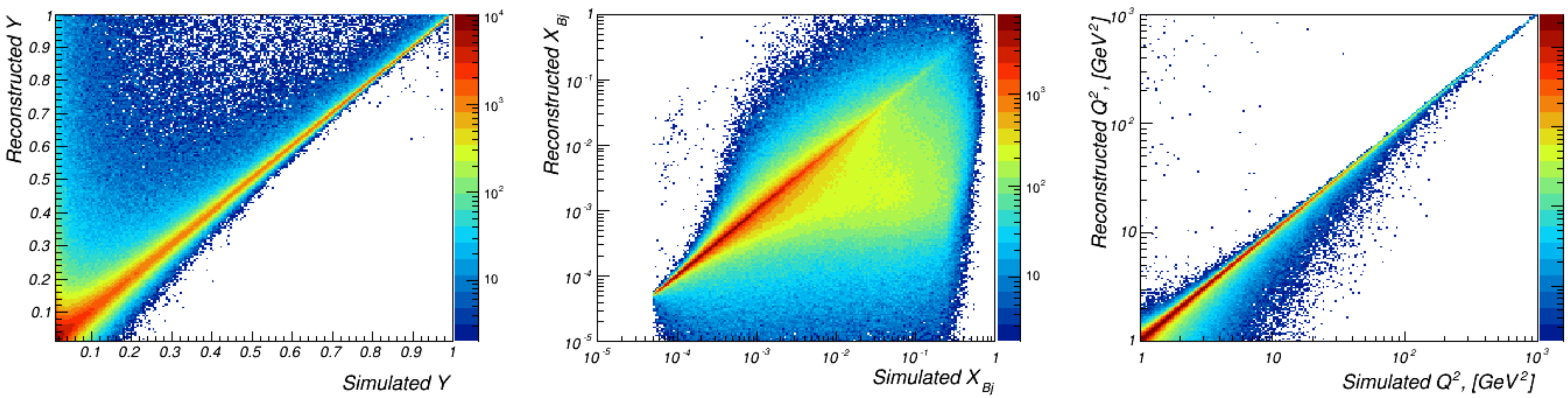
photon rejection - same tracking and EMCal acceptance,
hadron rejection - charge and E/p.

EIC bremsstrahlung

Pythia-based GEANT+tracking simulations for 20x250 GeV collisions without bremsstrahlung:



Pythia-based GEANT+tracking simulations for 20x250 GeV collisions, including bremsstrahlung in BeAST:



Courtesy BNL t.f. See Elke Aschenauer and/or Alex Kiselev's talks earlier this week.

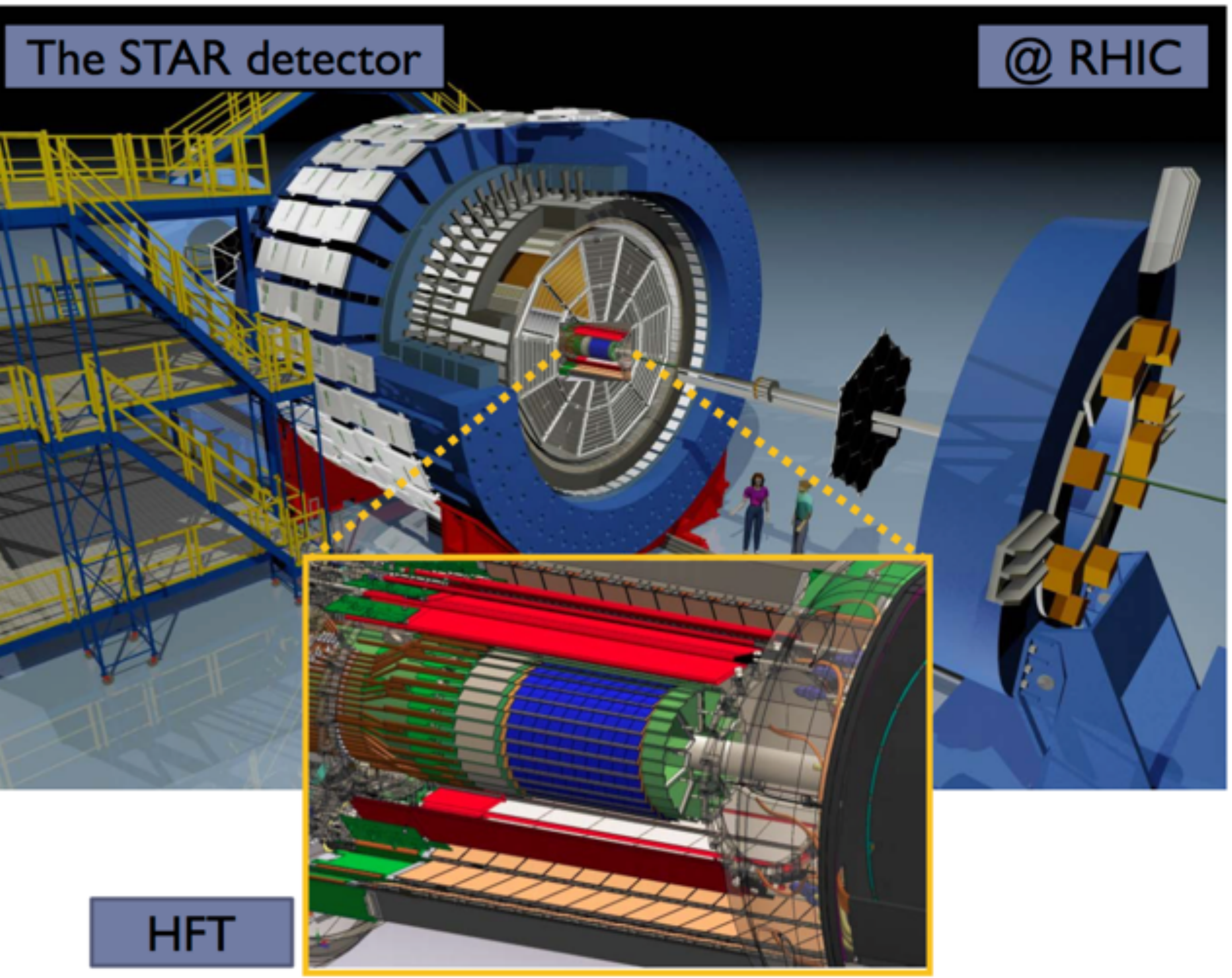
Necessity for *thin* tracking in the electron-going direction on day-1

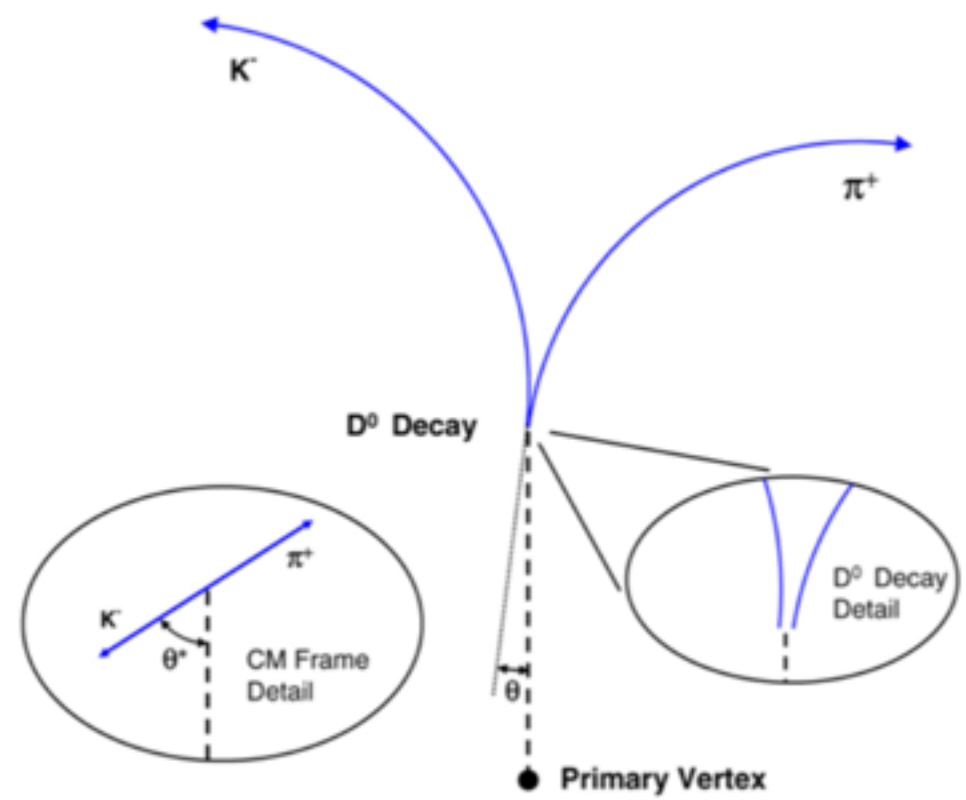
MAPS in the real-world

STAR HFT-PXL

Extend the measurement capabilities in the *heavy flavor* domain, good probe to QGP:

- Direct topological reconstruction of charm hadrons (small cτ decays, e.g. $D^0 \rightarrow K\ \pi$)





Method: Resolve displaced vertices (~120 µm)

200 GeV Au+Au collisions @ RHIC

- $dN_{ch}/d\eta$ ~ 700 in central events

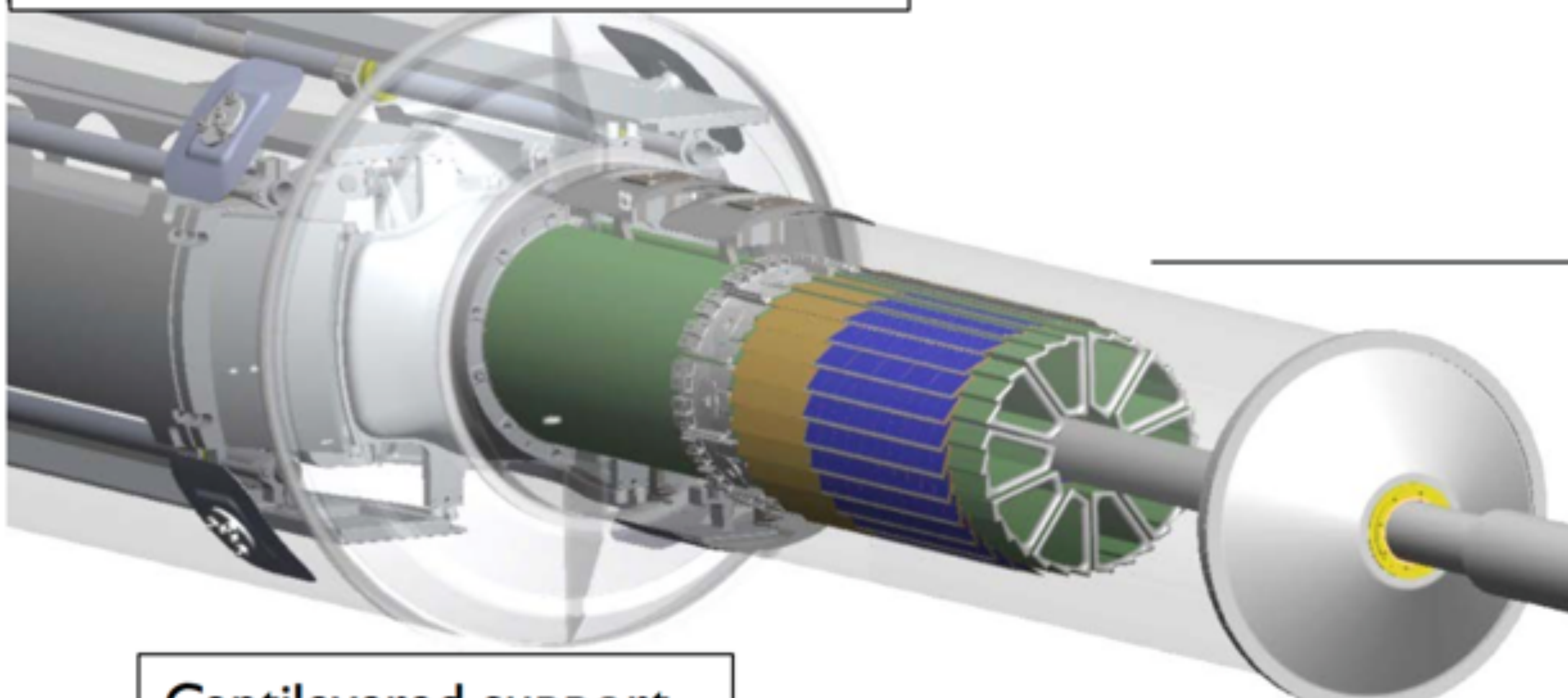
First large scale MAPS based vertex detector at a collider experiment.

STAR HFT-PXL

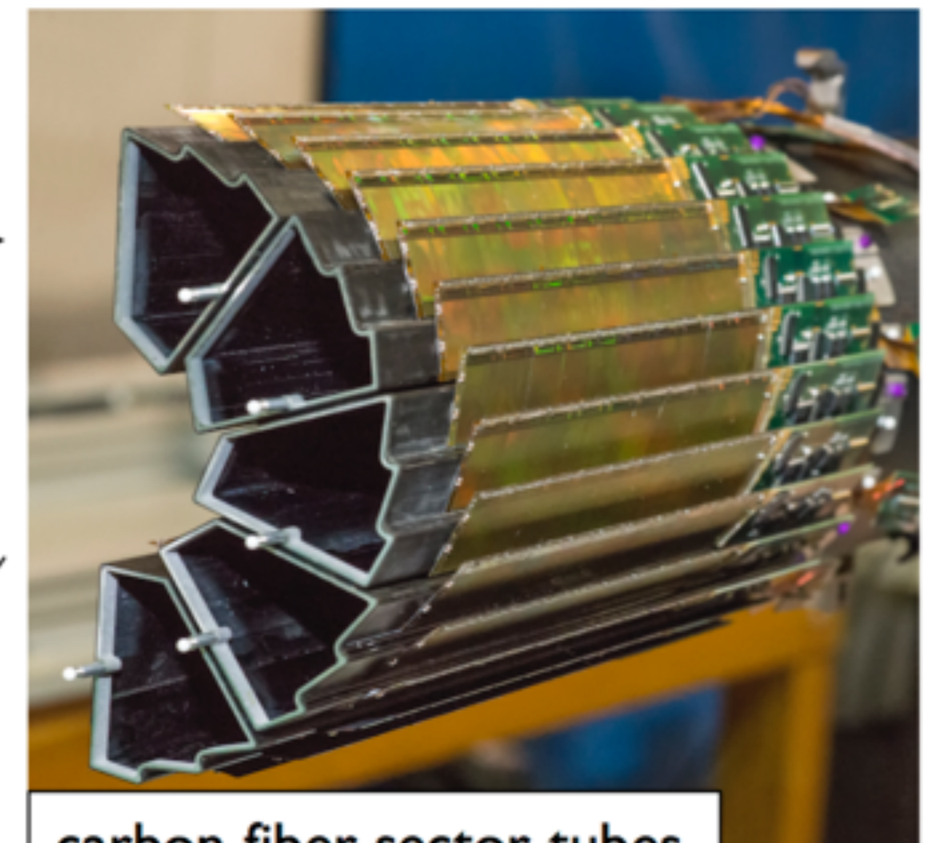
Mechanical support with kinematic mounts (insertion side)

10 sectors total
5 sectors / half
4 ladders / sector
10 sensors / ladder

Highly parallel system



Cantilevered support



carbon fiber sector tubes (~ 200 μm thick)

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

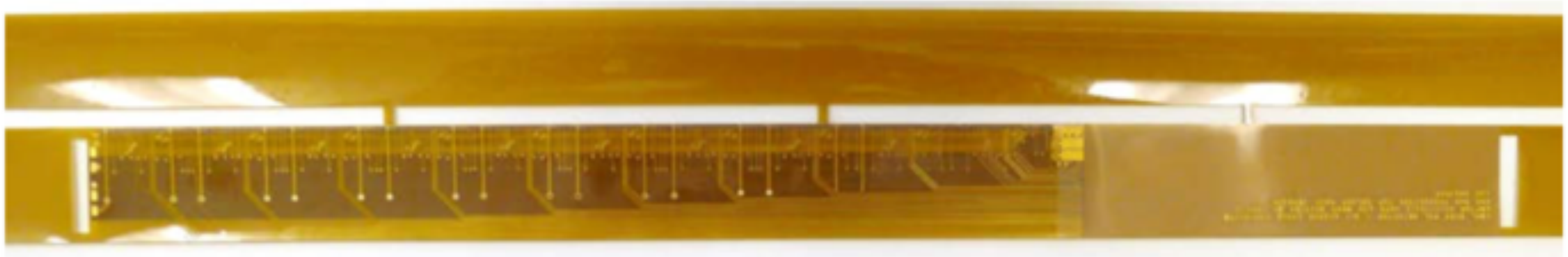
Courtesy G. Contin (STAR), QM2015

STAR HFT-PXL

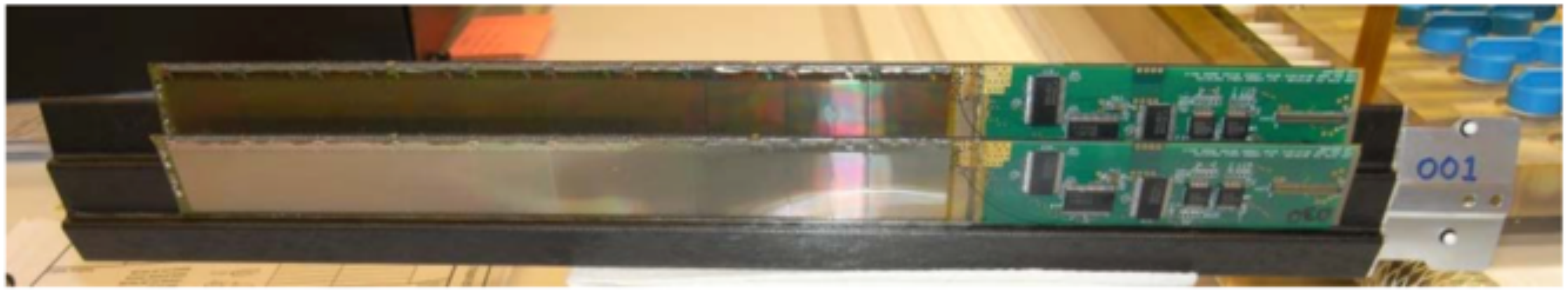
- Thinned Sensor
  - 50 μm
  - 0.068% X_0

- Curved sensor
- 40-60% yield after thinning, dicing and probe testing

- Flex Cable
  - Aluminum-Kapton
  - two 32 μm-thick Al layers
  - 0.128% X_0
    - *Copper* version → 0.232% X_0



- Carbon fiber supports
  - 125 μm stiffener
  - 250 μm sector tube
  - 0.193% X_0



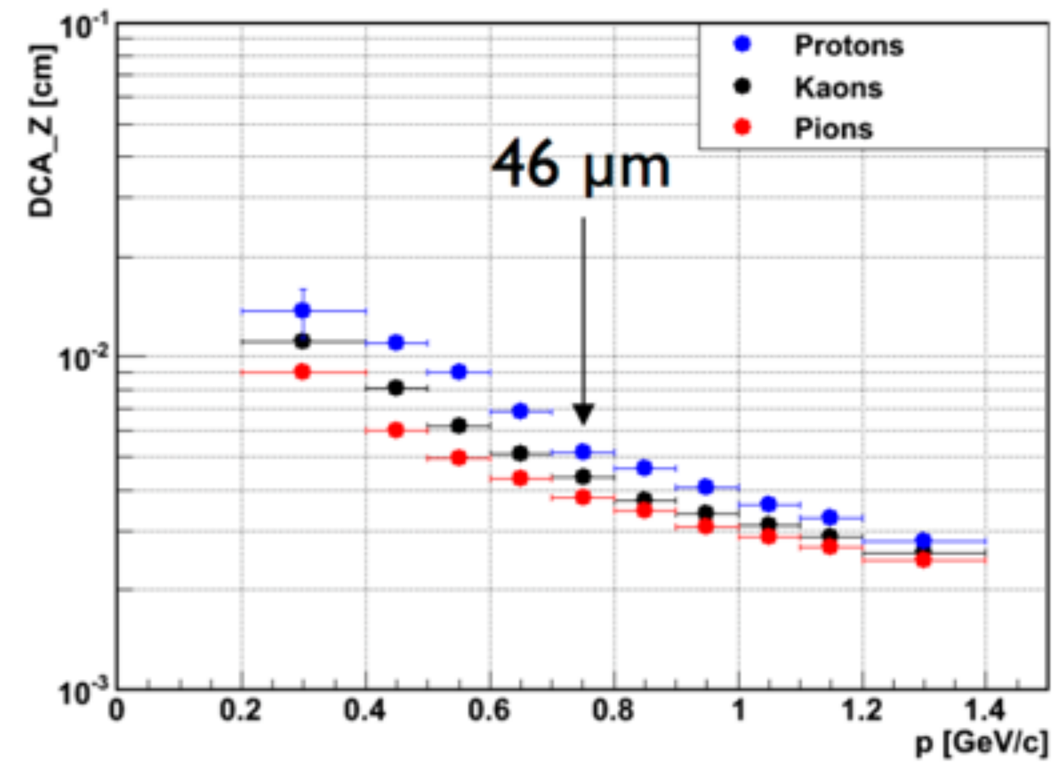
- Cooling
  - Air cooling: negligible contribution

- **Total material budget on inner layer: 0.388% X_0**

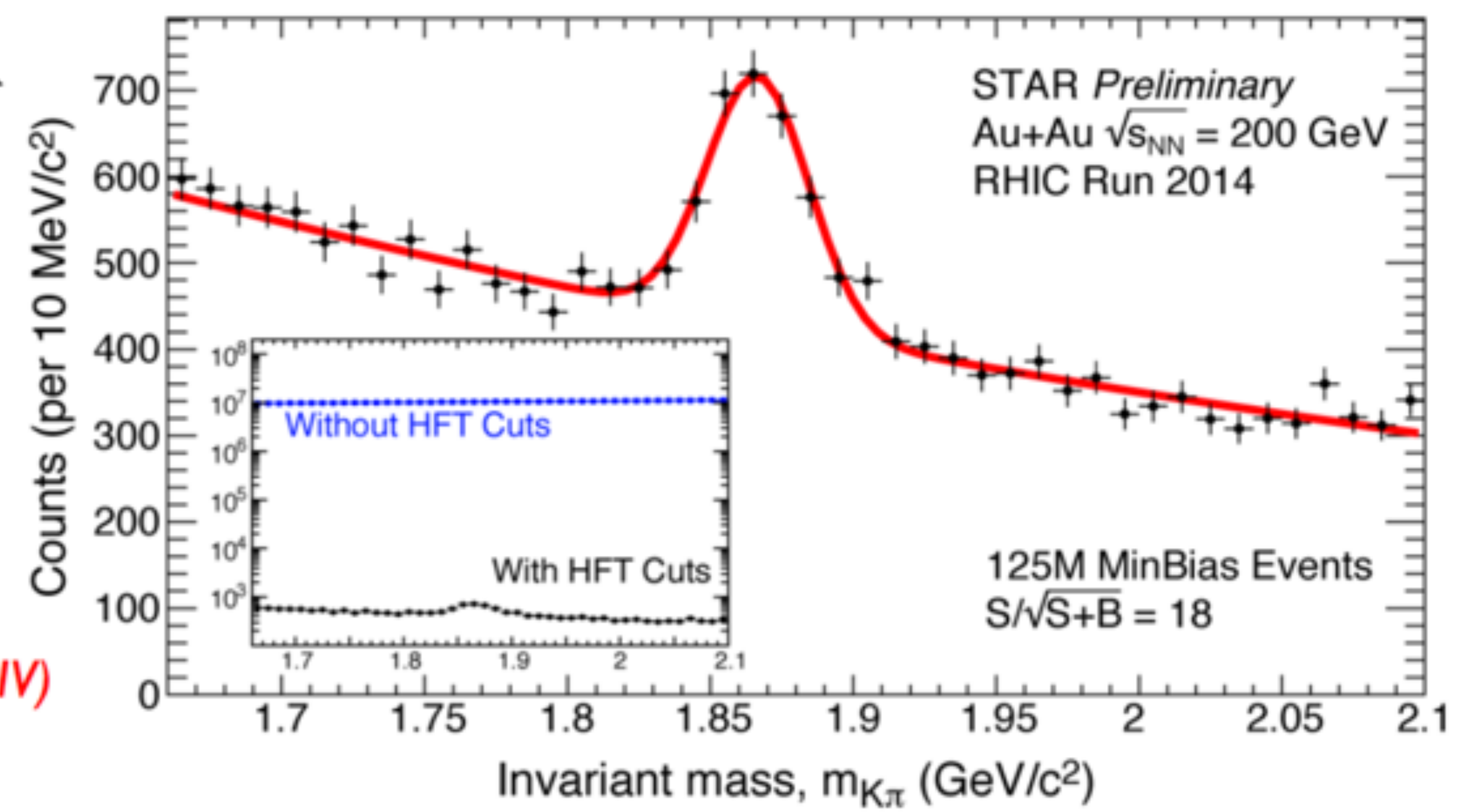
(0.492% X_0 for the Cu conductor version)

STAR HFT Initial Results

- DCA pointing resolution
  - Design requirement exceeded: 46 μm for 750 MeV/c Kaons for the **2 sectors** equipped **with aluminum cables on inner layer**
  - ~ 30 μm for p > 1 GeV/c
    - From 2015: all sectors equipped with aluminum cables on the inner layer



***$D^0 \to K\pi$ production** in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions (partial event sample)*

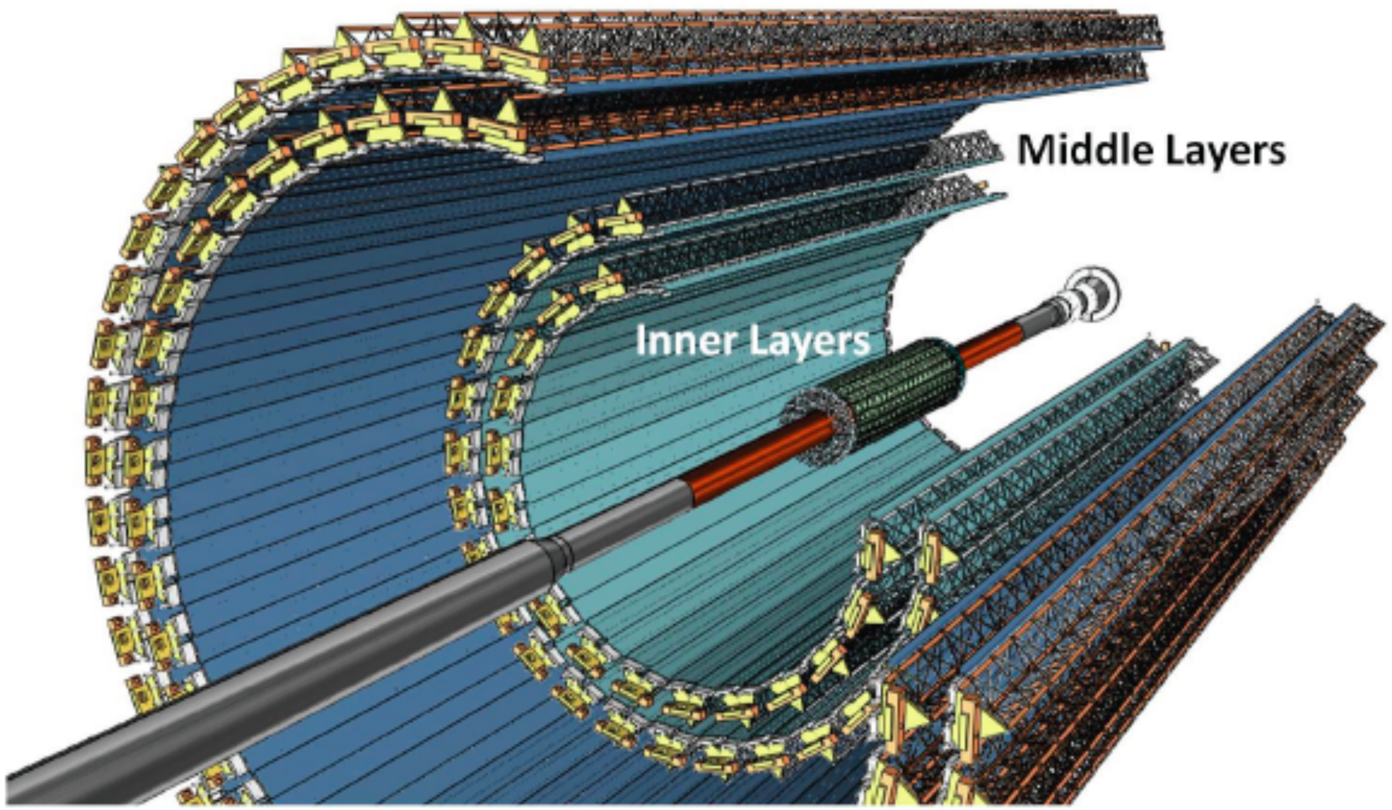


- Physics of D-meson productions
  - See QM15 contributions by:
    - G. Xie (*Sept. 28th - Open HF and Strangeness II*)
    - M. Lomnitz (*Sept. 29th - Collective Dynamics I*)
    - Md. Nasim (*Sept. 29th - Open HF and Strangeness IV*)

First large scale MAPS based vertex detector at a collider experiment.

MAPS in near-term future

ALICE ITS Upgrade



- 7 layers
- 10 m^2 of silicon
- Installation in early 2019
- X/X_0 ~ 0.3% (inner layers)
- X/X_0 ~ 0.8% (outer layers)

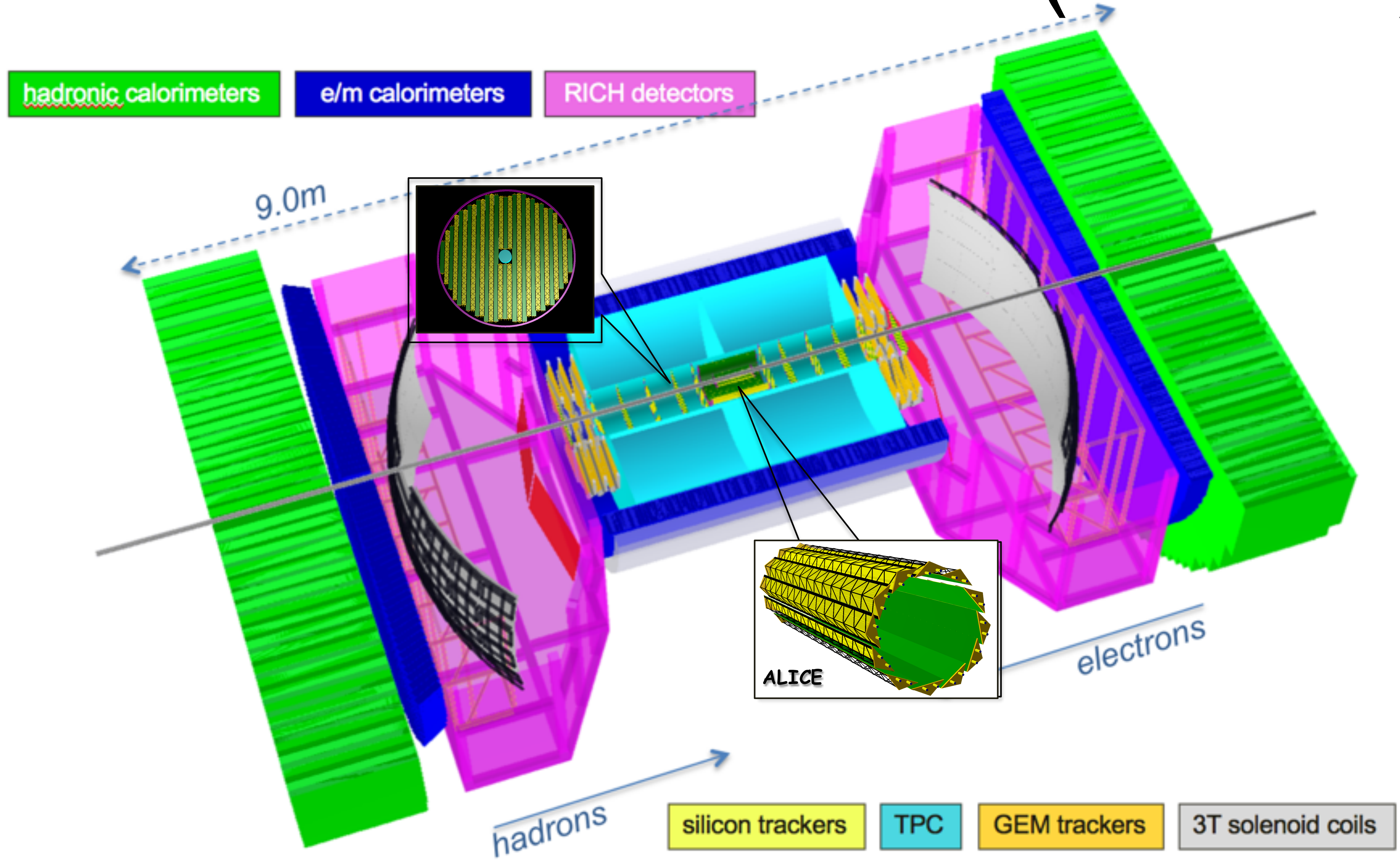
Anticipated use of CERN-developed MAPS sensors, ALPIDE:

Dimensions: 15mm x 30mm
Pixel pitch: 28µm x 28µm
Integration time: 8-10µs
Power consumption: 39mW/cm^2

TDR: http://iopscience.iop.org/0954-3899/41/8/087002/

MAPS at EIC?

eRHIC Model Detector (BeAST)

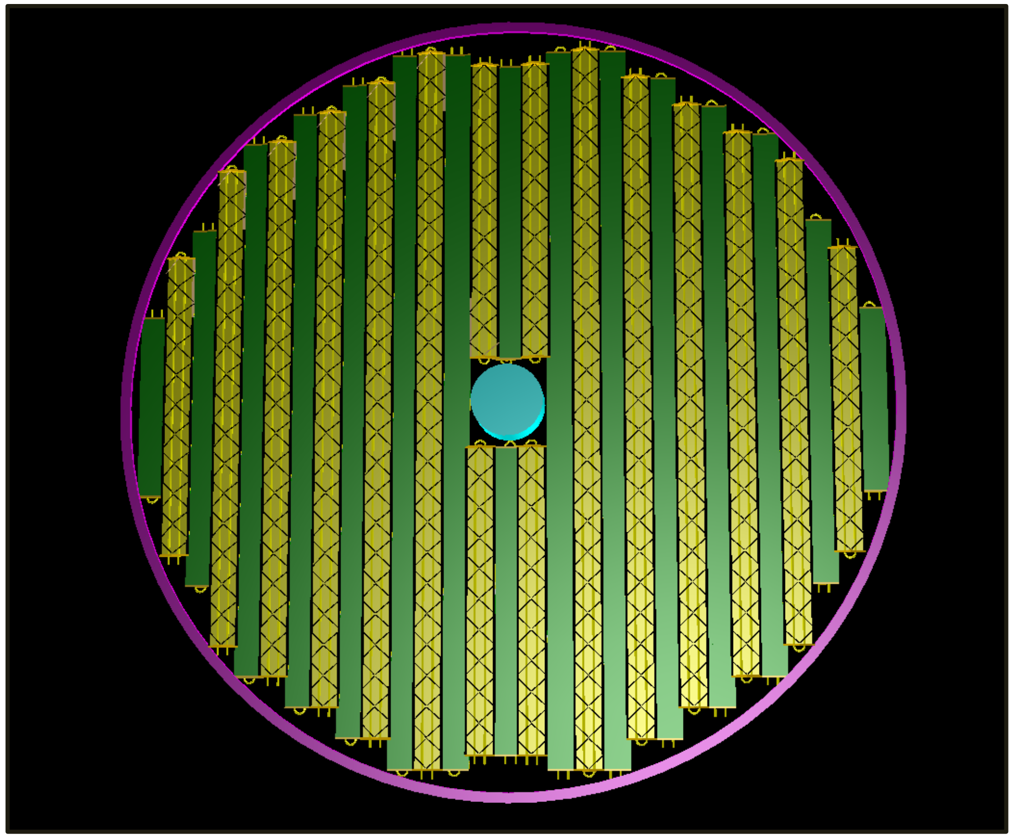


E.C. Aschenauer, A. Kiselev, et al.

MAPS-based Si; minimize bremsstrahlung, resolutions, and also vertexing.

MAPS at EIC - Requires R&D

BeAST



ALICE MFT

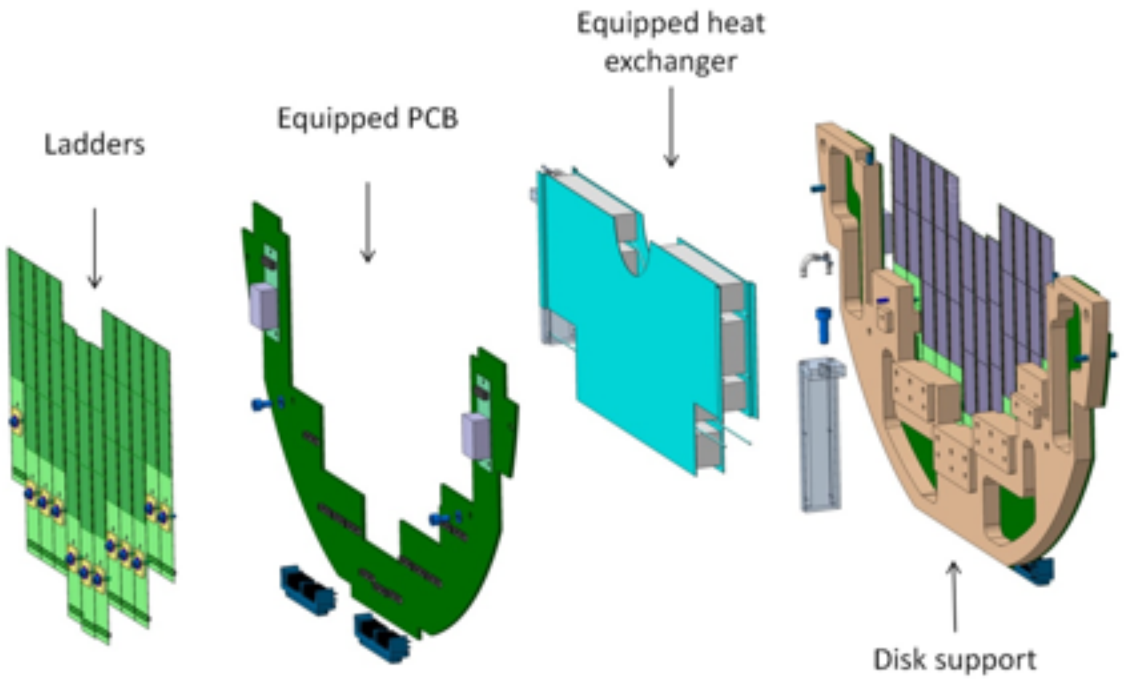


Figure 3.8: MFT half-disk layout (exploded view).

Clear *need* for R&D:

- develop a *realistic* disk configuration,
- sensor R&D, e.g. integration time, pixel size,
- suitability for other EIC detector design concepts (fields),

and that's just a start. Actual mechanics, read-out, …

MAPS@EIC - LBL *start* on R&D

- *Simulations* and *calculations* to quantitively address: *viability*
  - disk configuration(s),
  - services,
  - sensor specifications and development needs, if any,
    sampling rate, pixel size

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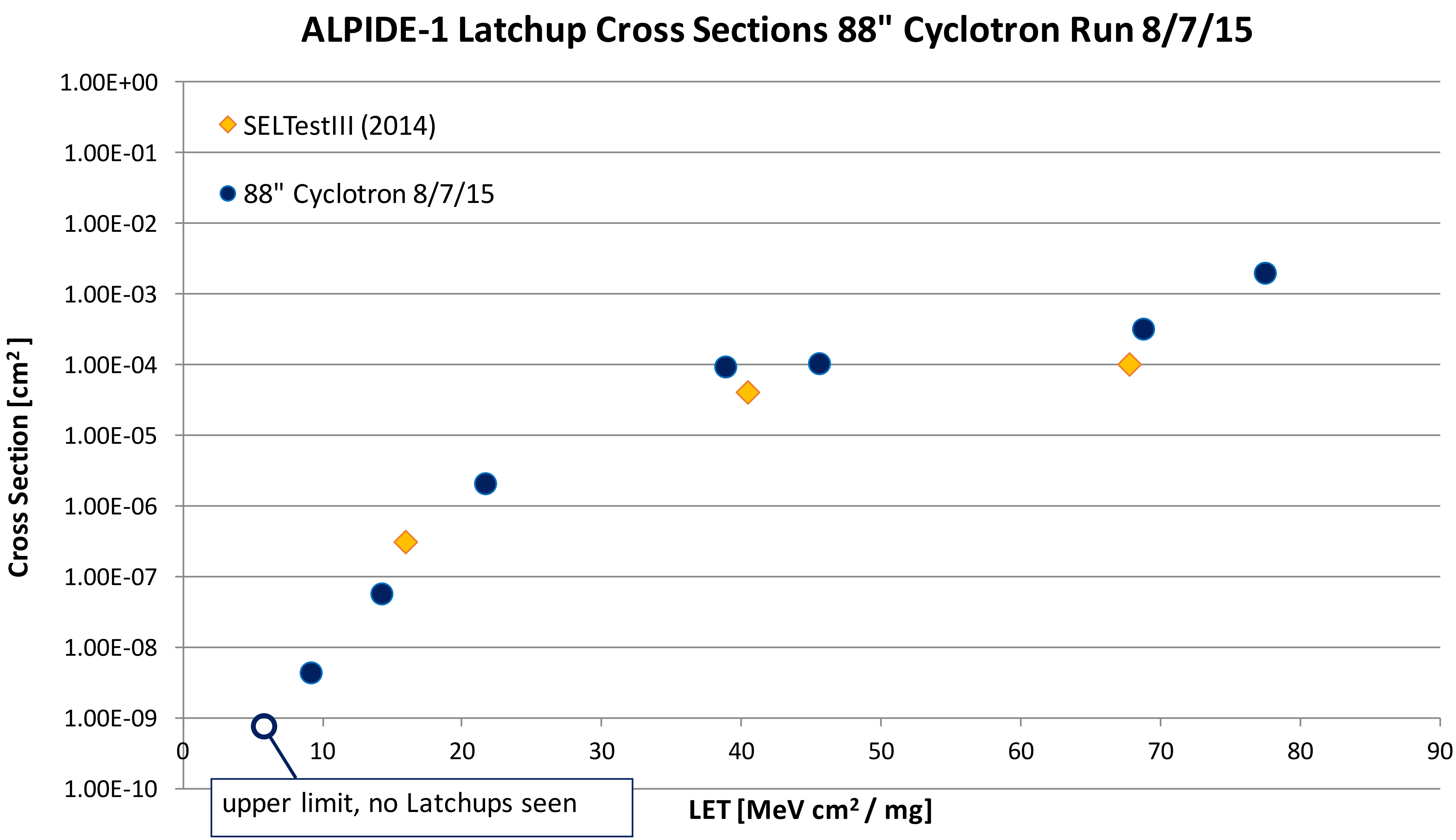
long lead-time

- Iterative development of low-mass cables
  - ultimate goal is a *new* production partner for *aluminum* conductor cables,
    besides CERN and Institute at Kharkov Ukraine,
  - contact with and build on prior work with the Hughes Circuits Inc,

- Continued ~engagement with MAPS sensor development, for ALICE (ALPIDE)

ALPIDE-1 latch-up measurements



Joanna Szornel, Elad Michael, Fernando Torales Acosta, Leo Greiner, Barbara Jacak
the LBNL 88” cyclotron and its staff

MAPS at EIC? - Closing Comments

- STAR-HFT is a the first large-scale MAPS-based vertex detector in an experiment
  - a number of unique characteristics; rapid and reproducible insertion/extraction
  - a decade, or more, in R&D (multiple generations of sensors, mechanics, …)

- ALICE-ITS will be the next generation,
  - a number of unique characteristics as well; *scale*, to name one.

- Aspects of a natural fit for MAPS at EIC *on day-1*,

- *Lots* of work ahead,
  - we are enthusiastic to have made a small start on investigating the possibility,
    student contributions already, and soon also on simulations,
    postdoc opening: http://inspirehep.net/record/1409874
    with partial support from generic EIC R&D funds

- Look forward to more realistic (forward) tracking conceptual designs.