Forward/Backward Tracking at EIC using MAPS Detectors

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Abstract:

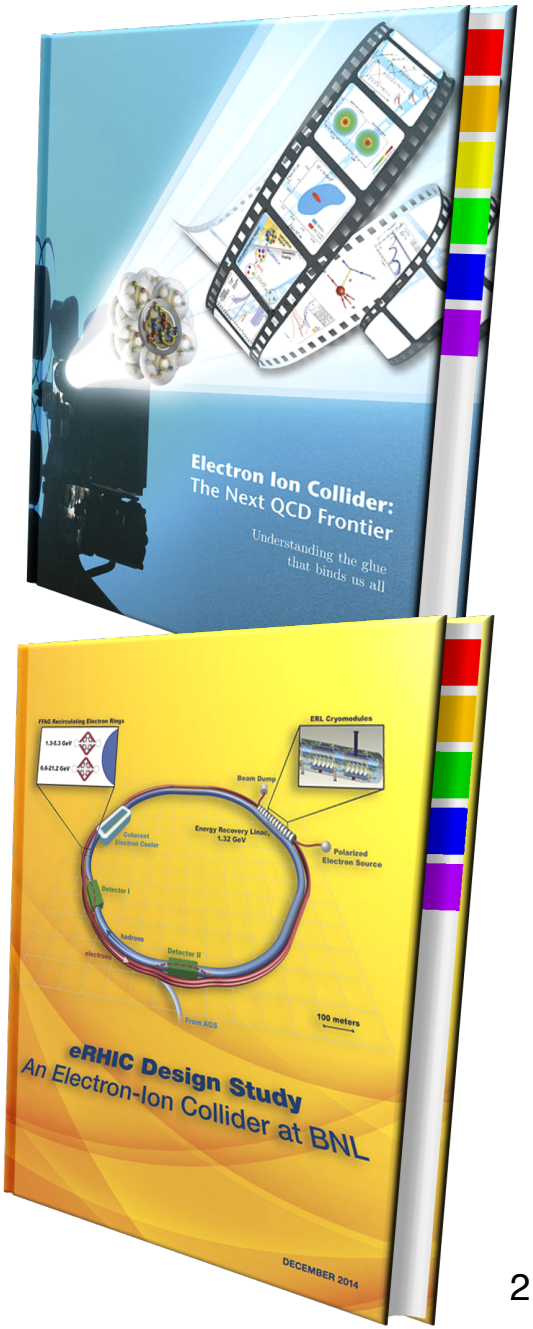
We propose to develop a concept for a backward (electron-going direction) tracking station near the collision vertex. We focus on detection of the scattered electron, as the precision of this measurement defines the kinematics of the collision. Disks of thinned-silicon sensors (MAPS) detectors will be laid out, including conceptual design for the arrangement of services, including cooling, power, and readout. We will perform simulations to specify layout and sensors optimized for high priority early physics measurements, and eventually determine whether a copy of the same tracker should be used in the hadron-going direction. We will also perform R&D on low-mass cabling utilizing aluminum traces.

EIC Physics - RNC

EIC science case - arXiv:1212.1701
arXiv:1409.1633

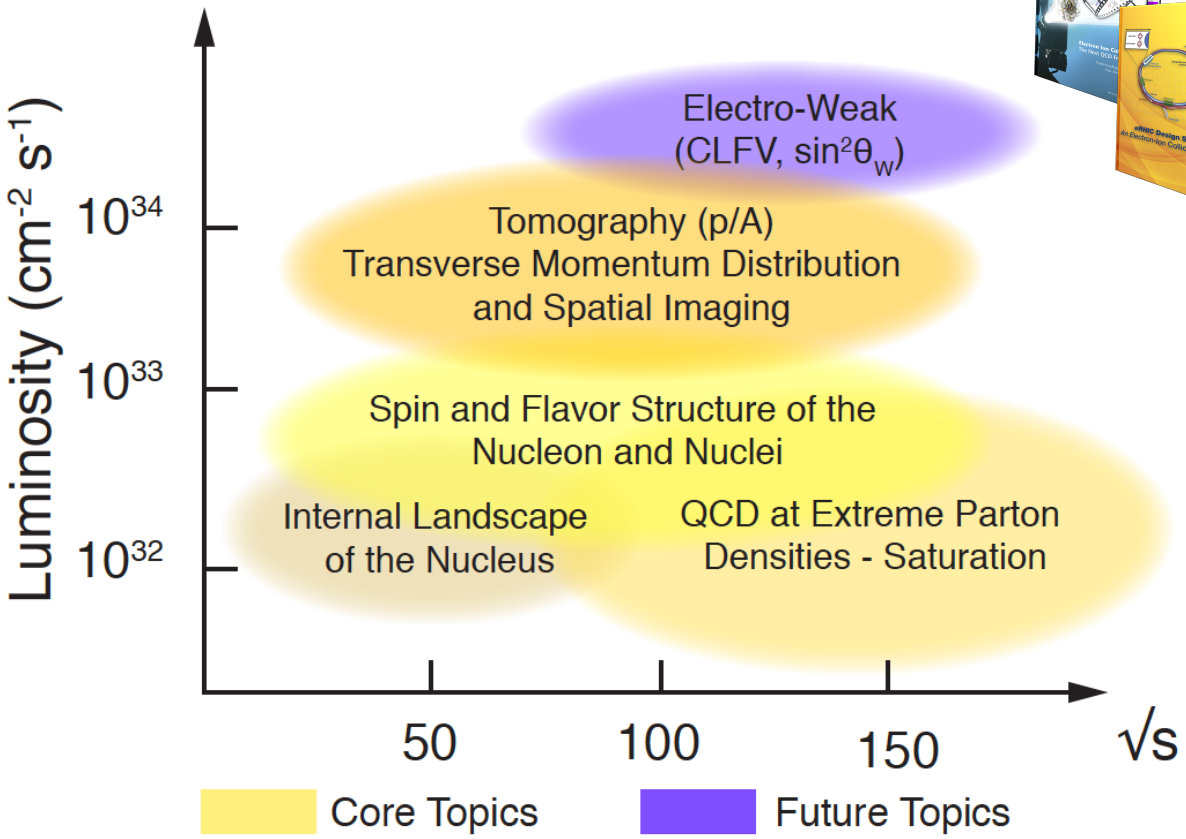
LBNL/RNC has contributed to both,
- spin physics case,
- eSTAR detector simulations,

Gluon-dense matter is the common theme of interests in RNC.



EIC Physics - RNC

Interest in *gluon-dense matter:*

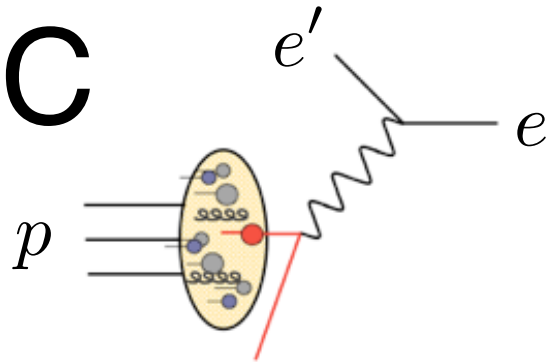


implies a need for *high*-√s,

observables $F_2(x,Q^2)$, $F_L(x,Q^2)$, $g_1(x,Q^2)$ at *low*-x

+ diffraction, dijets, heavy flavor, …

EIC Physics - RNC



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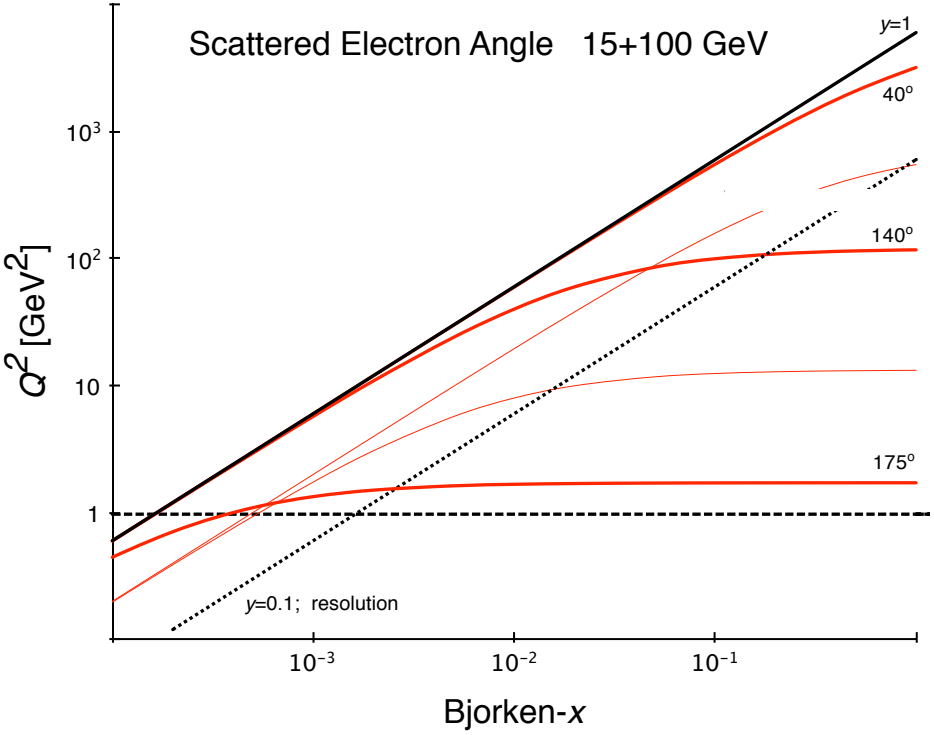
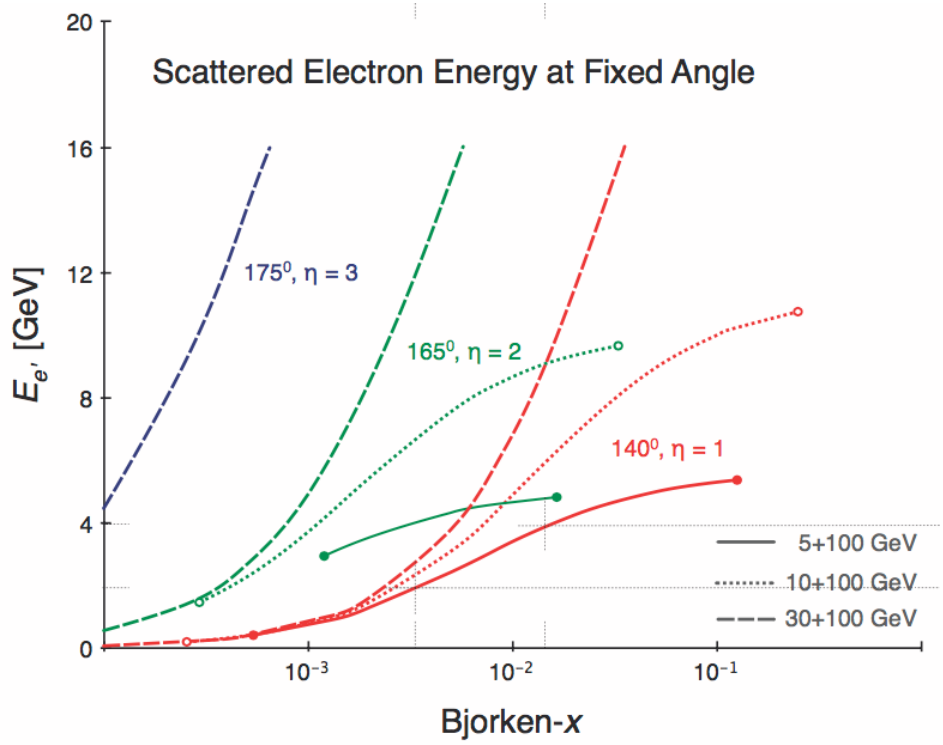


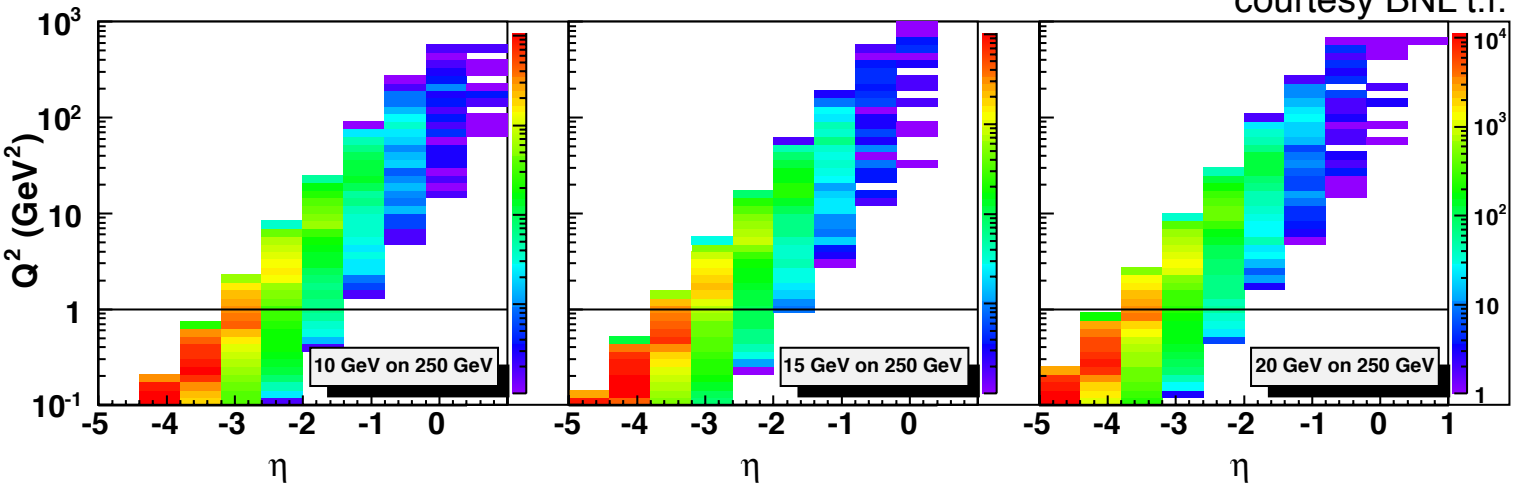


necessitates instrumentation at *backward* angles w.r.t. the hadron beam (HERA convention)

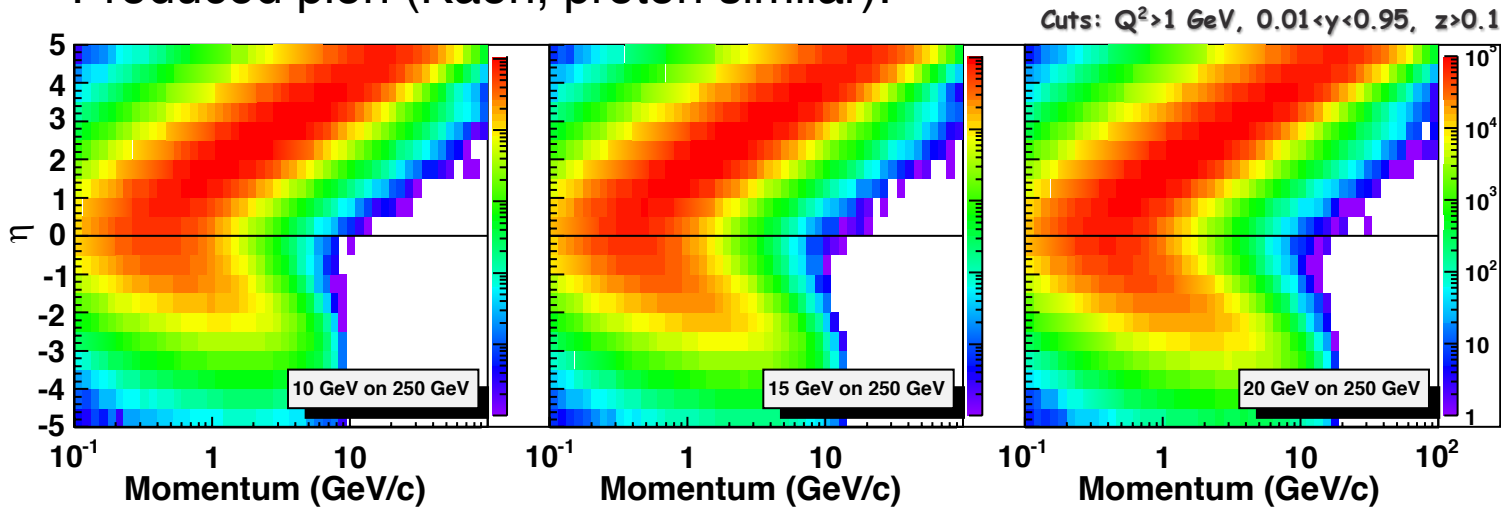
EIC - DIS particle distributions

Scattered electron:

courtesy BNL t.f.



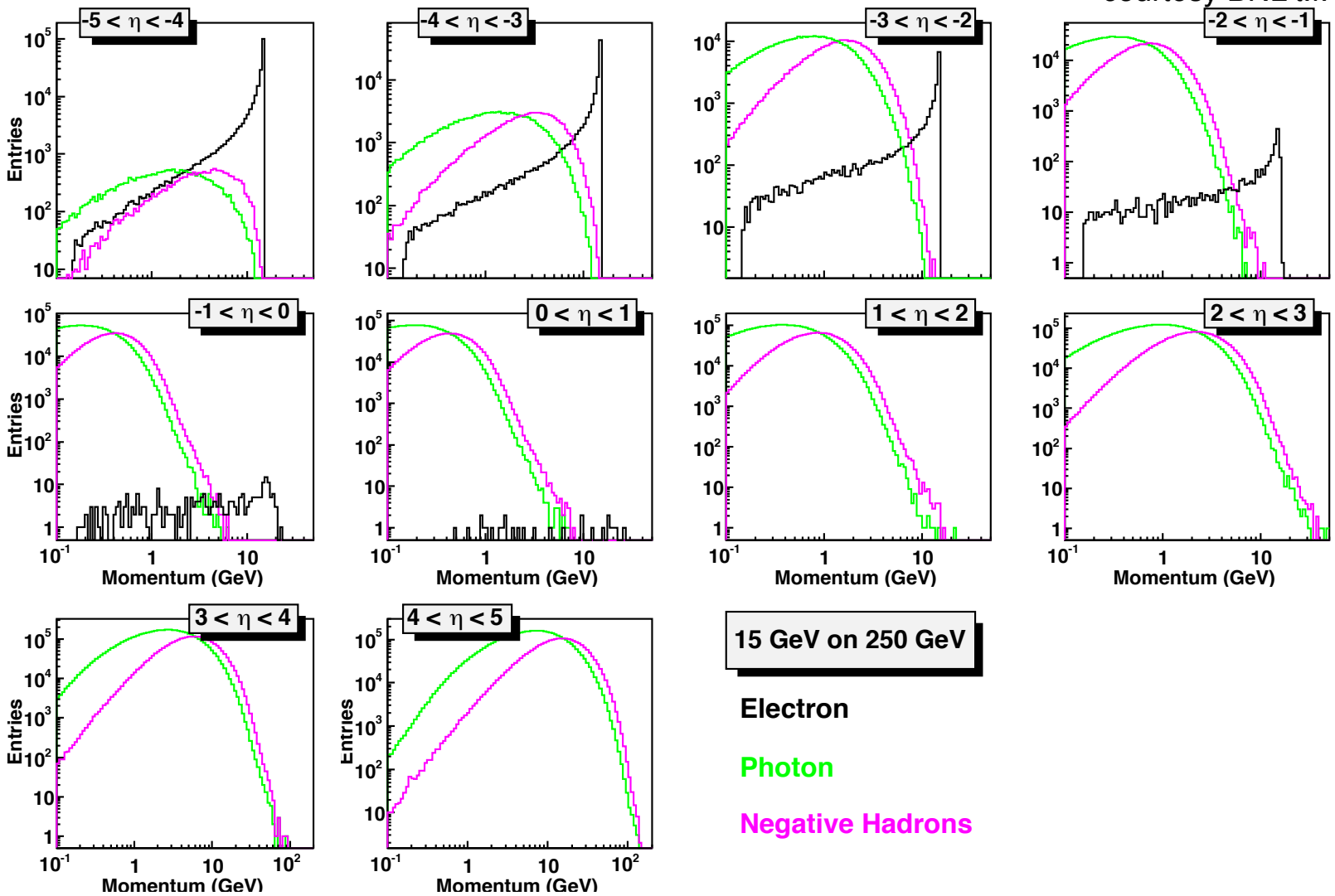
Produced pion (Kaon, proton similar):



drive acceptance, PID and other requirements.

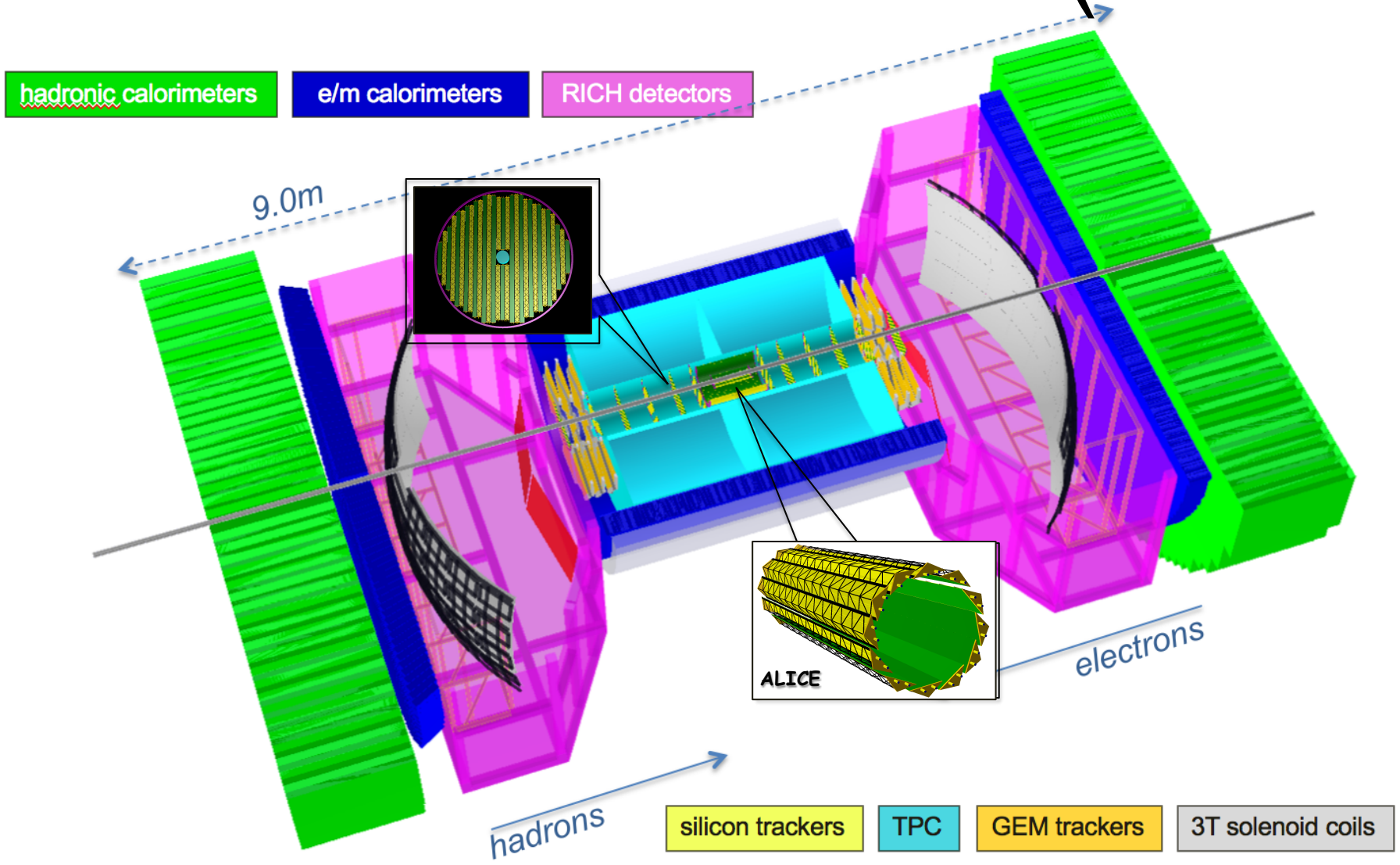
EIC - lepton PID

courtesy BNL t.f.



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

eRHIC - Model Detector (BeAST)



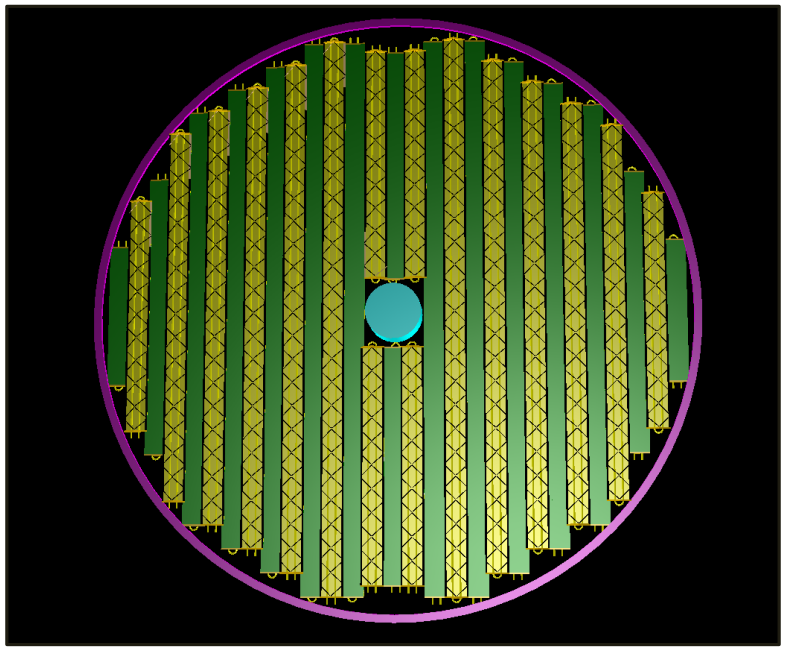
E.C. Aschenauer, A. Kiselev, et al.

MAPS-based Si; minimize bremsstrahlung, resolutions.

see e.g. talk by A. Kiselev at Temple tracking workshop.

eRHIC - MAPS disks

BeAST



ALICE MFT

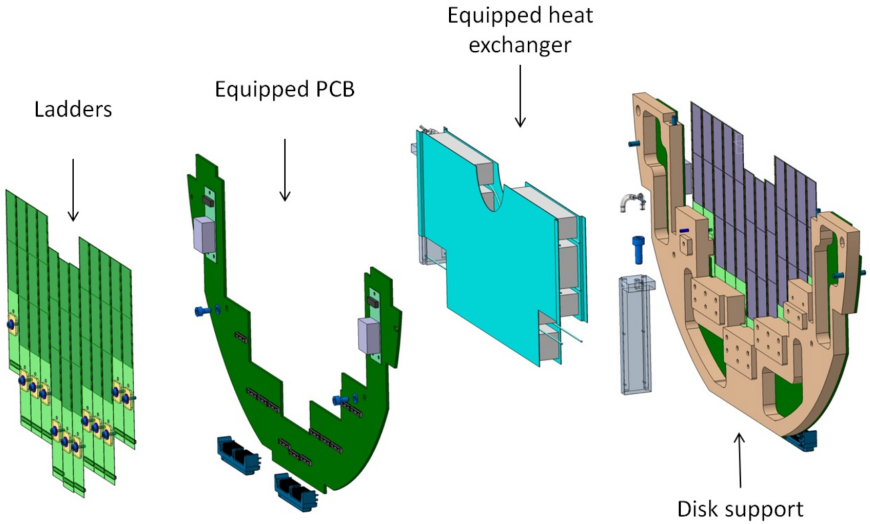


Figure 3.8: MFT half-disk layout (exploded view).

Clear *need* for R&D:

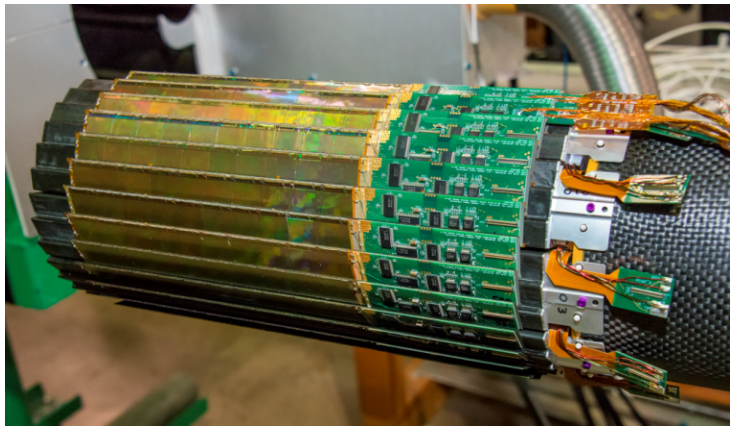
- develop a *realistic* disk configuration,
- sensor R&D, e.g. integration time, pixel size,
- suitability for other EIC detector design concepts,

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

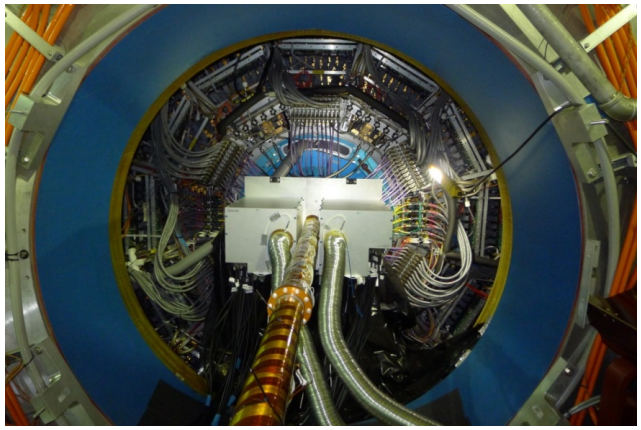
RNC - Selected Instrumentation

RNC - STAR PXL Detector

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



Detector-half



PXL inserted into STAR, cabled and working in 24 hours

- 356 M pixels on ~0.16 m^2 of Silicon
- 20 μm × 20 μm pixels.
- Low radiation length with X/X_0 of 0.4% on inner ladders.
- Air cooled.
- Full detector replacement in 12 hours.

RNC - STAR PXL Detector

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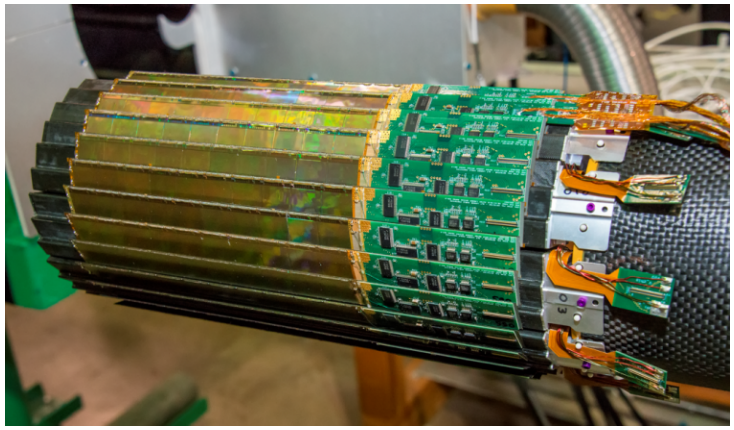
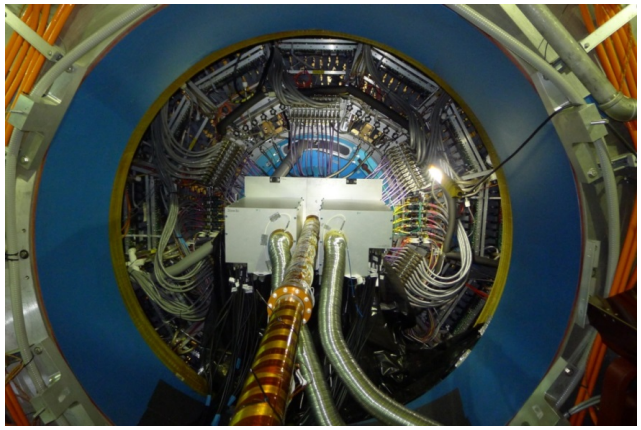


Detector-half



PXL inserted into STAR, cabled and working in 24 hours

<u>RNC scope</u>

Full simulation and optimization.

Full system design including R&D into MAPS sensors with IPHC Strasbourg.

Full construction including RDO electronics, firmware, software, commissioning and analysis.

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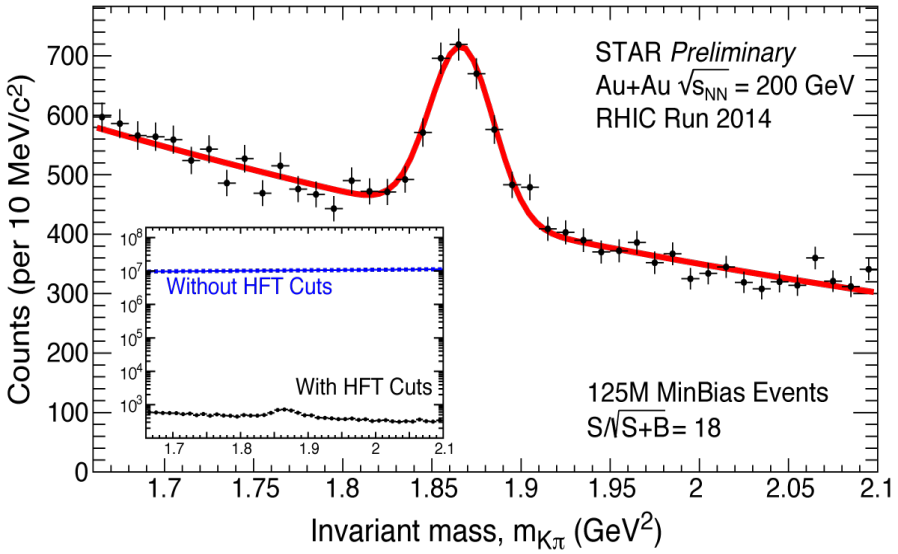

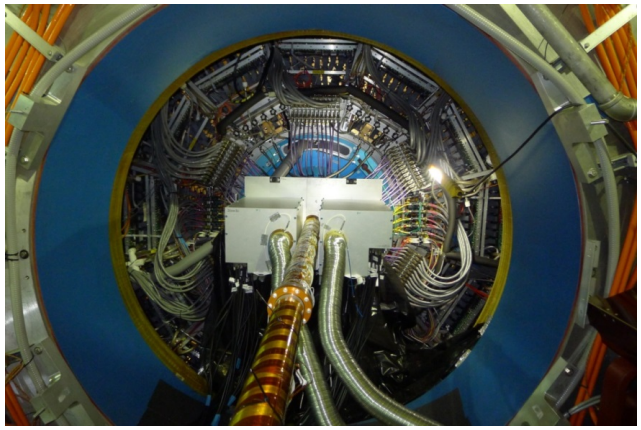

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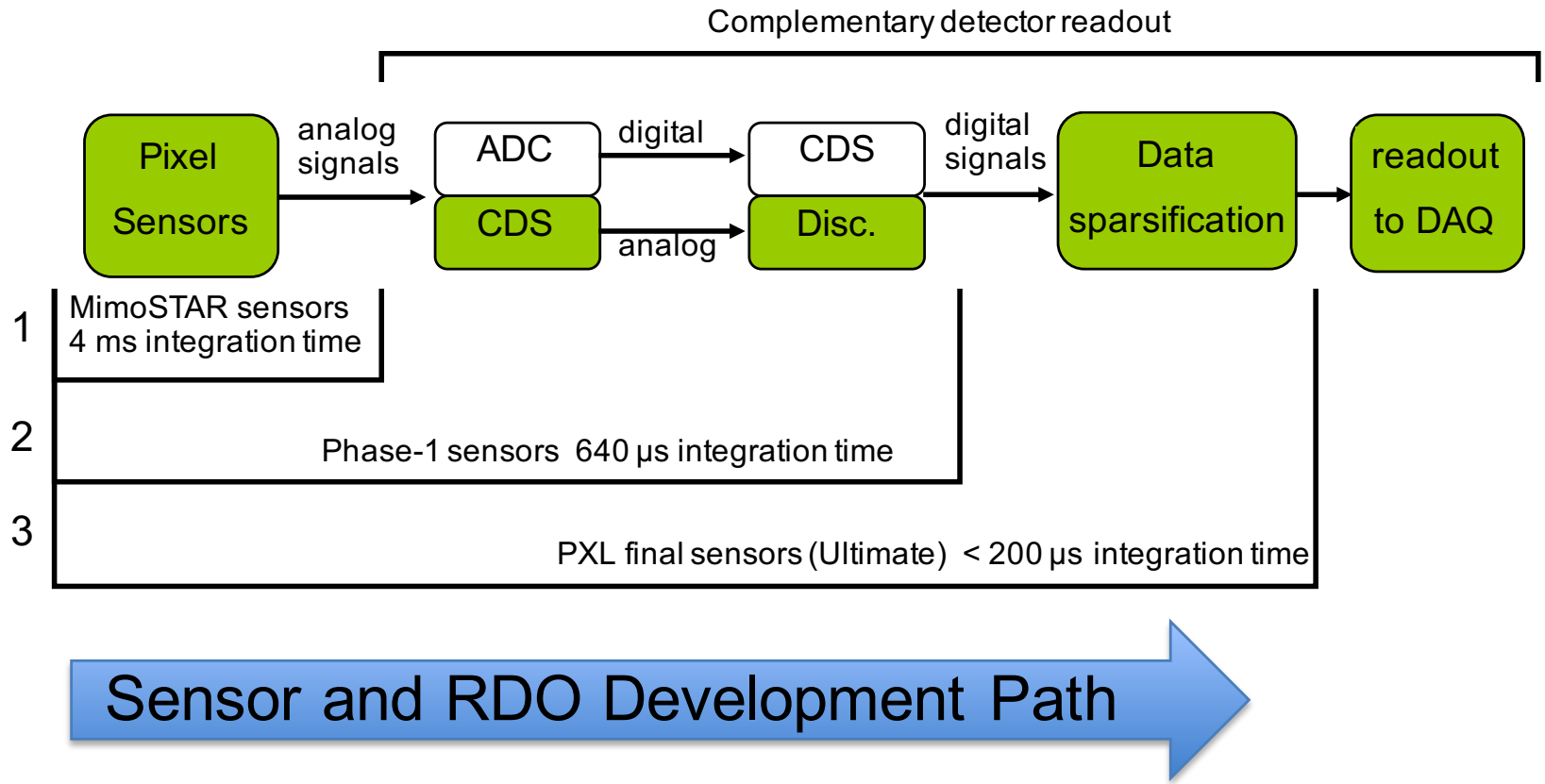
RNC - STAR PXL R&D

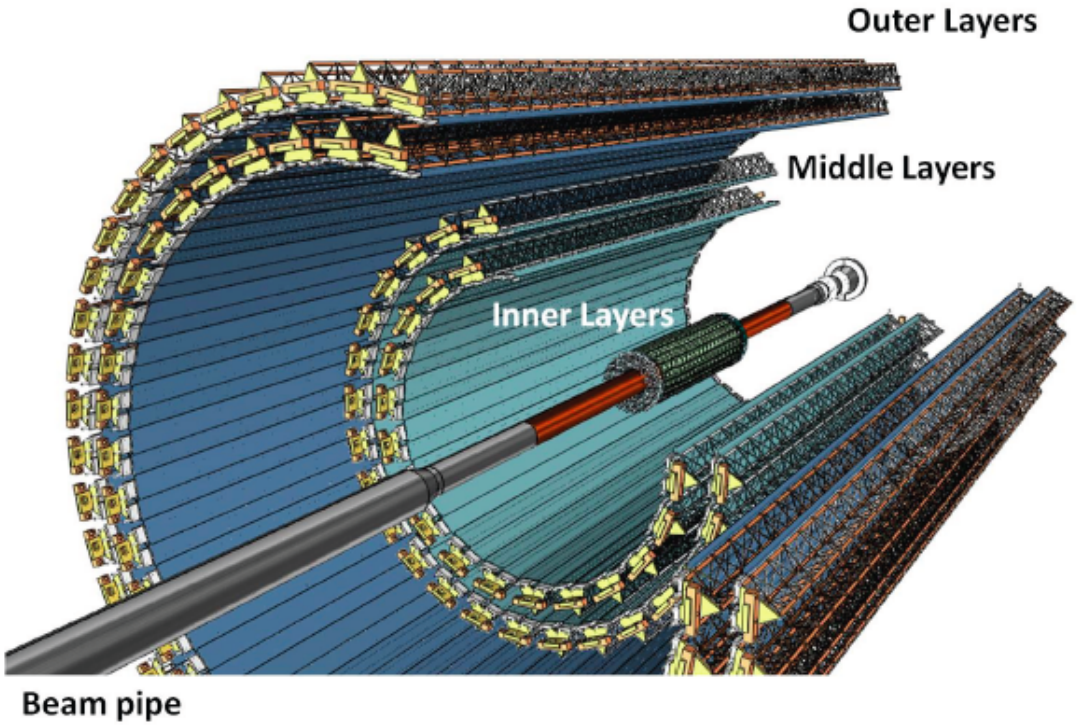
Comprehensive R&D effort, incl. sensor generation and RDO

>10 year collaboration with IPHC – PICSEL group

3 generation program with highly coupled sensor and readout development



RNC - 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

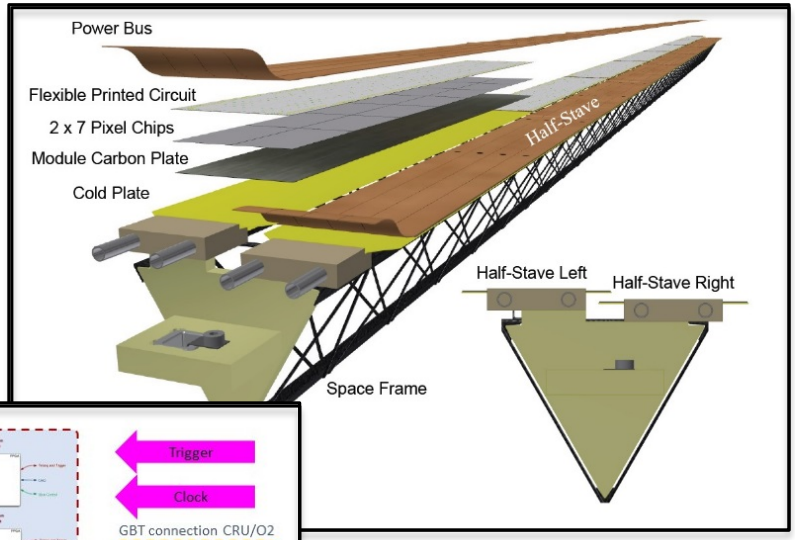
Power consumption: 39mW/cm^2

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

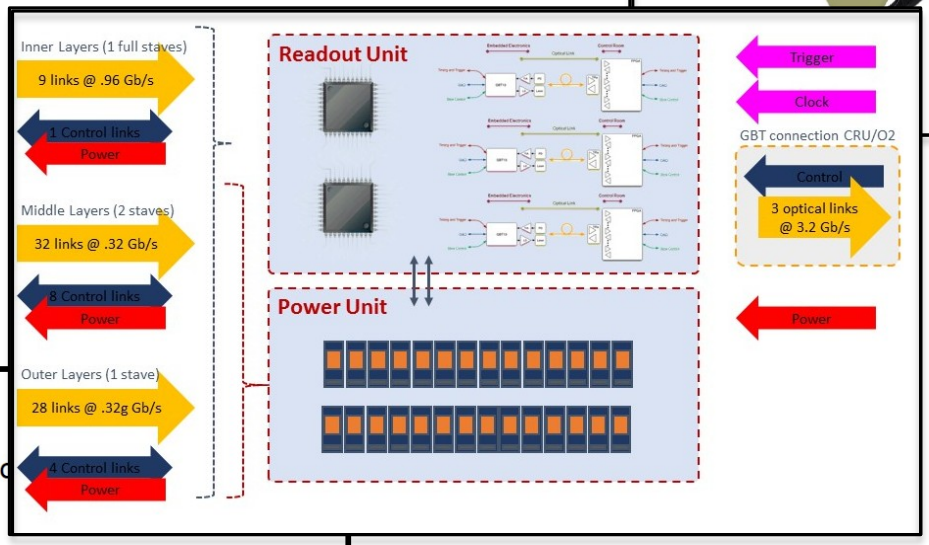
RNC - ALICE ITS Upgrade

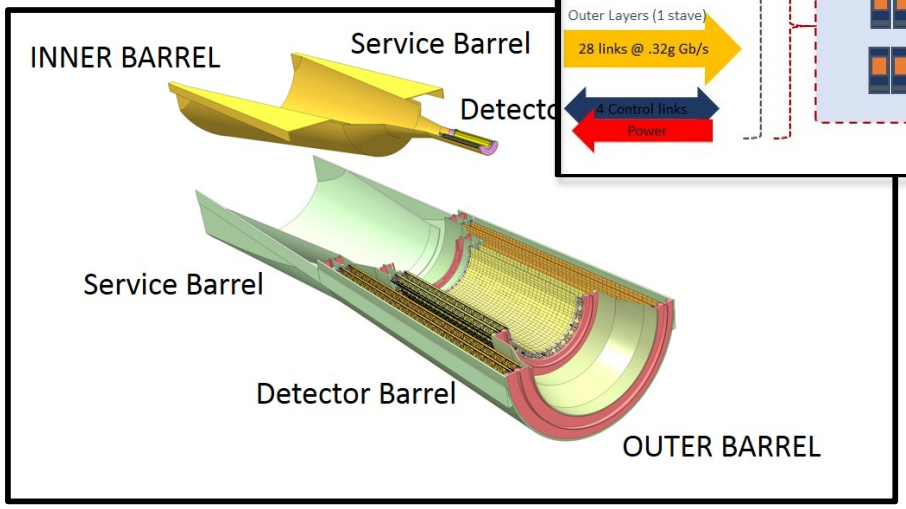
RNC scope:

middle layer staves



readout & power





mechanics (with LBNL engineering)

RNC - This EIC R&D proposal

RNC EIC R&D proposal

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

  Product: high-level sensor specifications and development needs
  conceptual design of a forward tracker for two or more field configurations

- 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,

  Product: uncertain - a 'must do' for the community as a whole.

RNC EIC R&D funding request

Request:

0.50 postdoc FTE; to work on R&D for sensor, services layout, and low-mass cable
0.25 postdoc FTE; to work on simulations

$20K for cable prototyping

5 trips at $1200/trip; to enable postdoc(s) to attend workshops and learn the BNL-developed EIC simulation framework.

Cost, including LBNL overheads:

$126,850 0.75 postdoc (for 1 year)

$ 25,844 M&S

$ 7,803 Travel

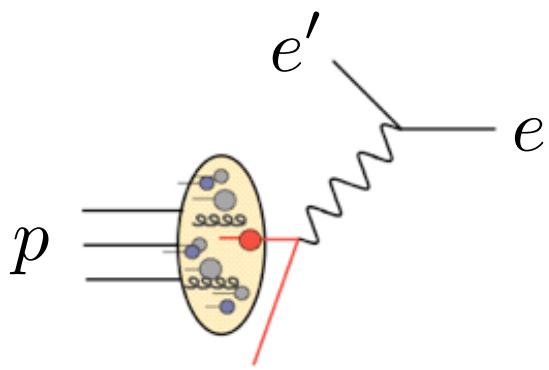
$160,497 Total

To *define* the angles, energies:

$$e = (0, 0, -E_e, E_e)$$

$$e' = (E'_e \sin\theta'_e, 0, E'_e \cos\theta'_e, E_e)$$

$$p = (0, 0, E_p, E_p)$$



Relevant invariants:

$$q = e - e' \qquad Q^2 = -(e - e')^2$$

Square of (4-)momentum transfer, ~resolution

$$x = \frac{Q^2}{ys}$$

Bjorken-x, ~parton mom. fraction

$$y = (q.p)/(e.p)$$

Fractional energy transfer

Resolutions (electron-method):

$$\frac{\delta Q^2}{Q^2} = \frac{\delta E'_e}{E_e} \oplus \delta\theta'_e \tan\frac{\theta'_e}{2}$$

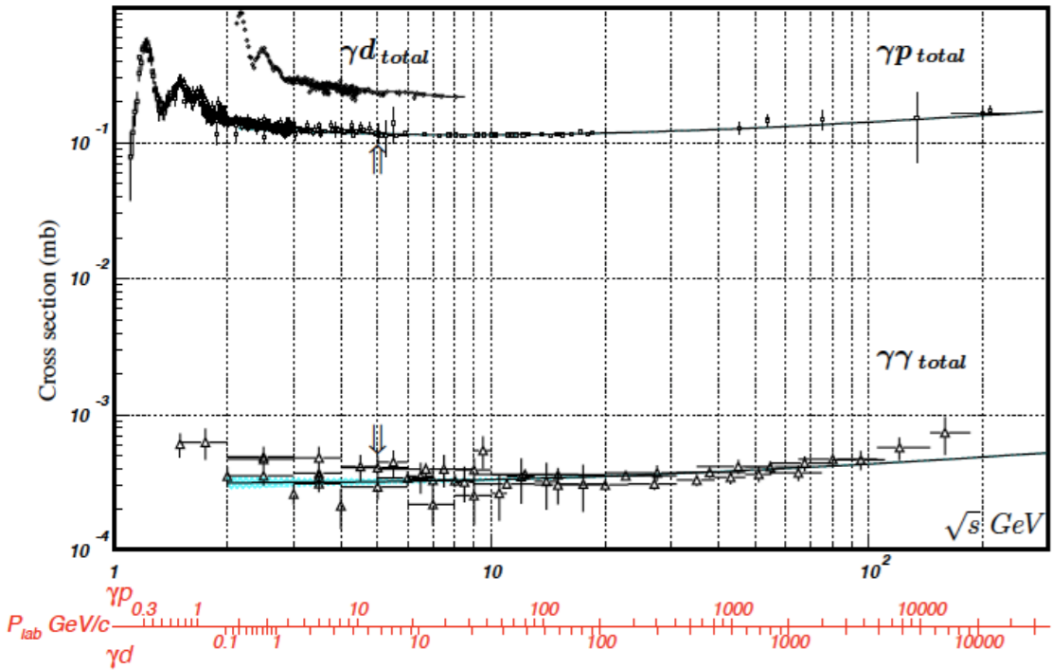
gets large near the beam region

$$\frac{\delta x}{x} = \frac{1}{y}\frac{\delta E'_e}{E_e} \oplus \left[\frac{x}{E_e/E_p - 1} - 1\right] \tan\frac{\theta'_e}{2}\delta\theta'_e$$

gets large at small *y*

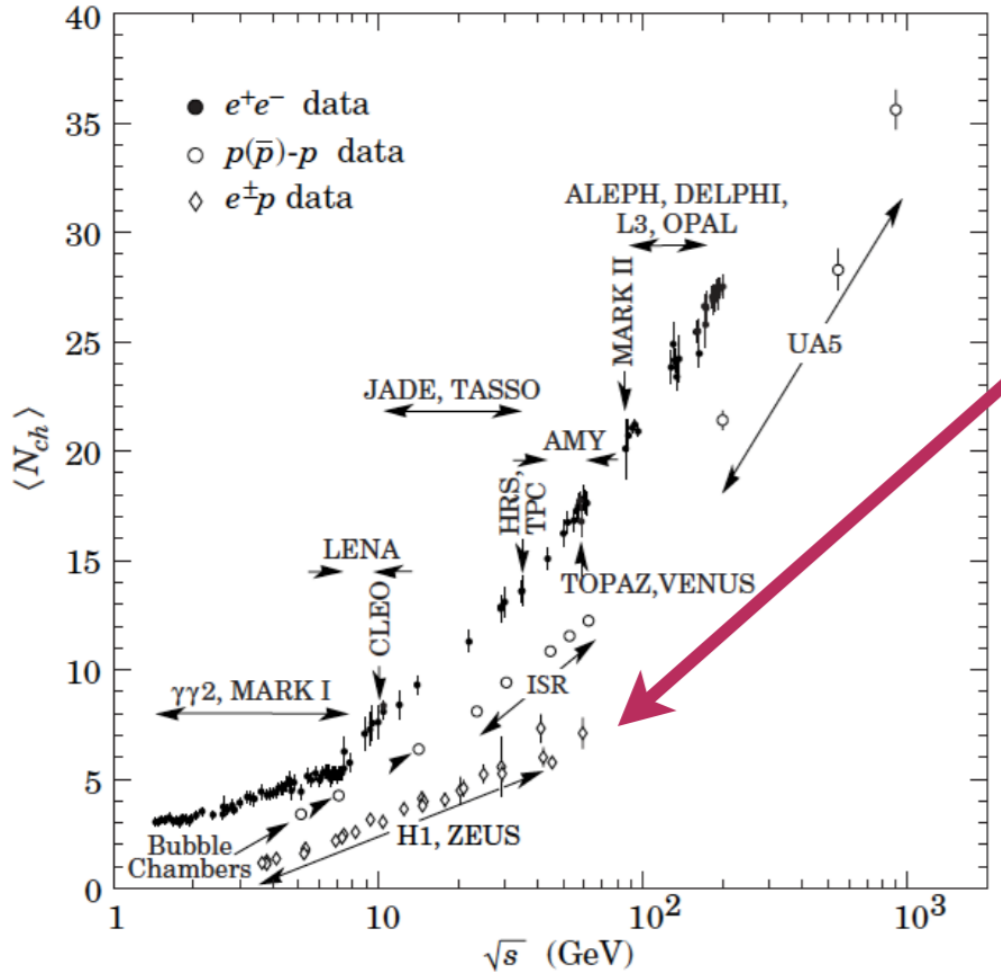
x, Q^2 can also be reconstructed from the “current jet”, hybrids - c.f. arXiv:hep-ex/9412004

Rates



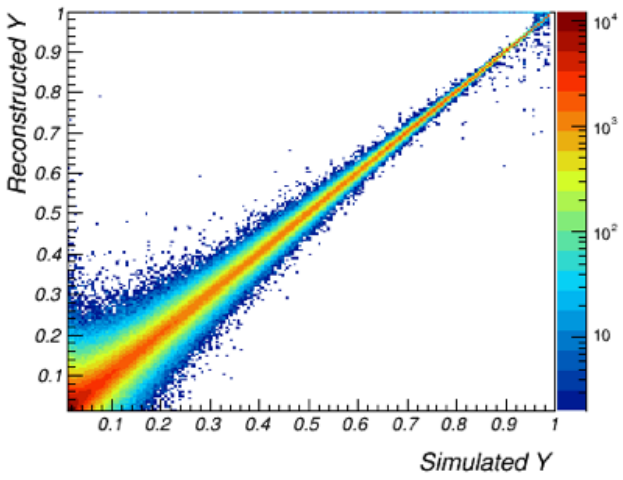
anticipate O(100kHz) rates

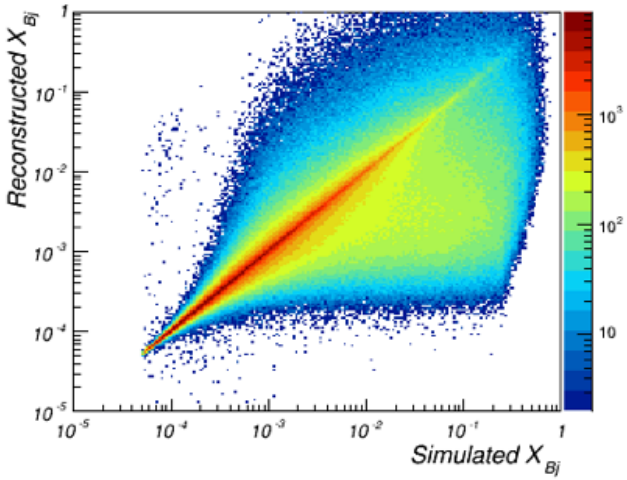
lower multiplicities than pA

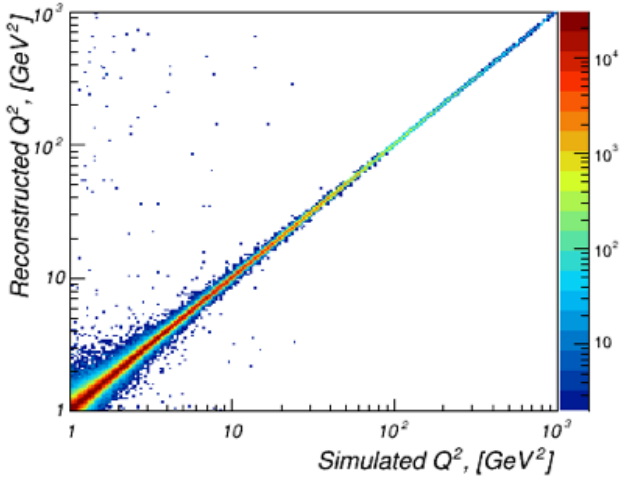


Simulations - radiation length

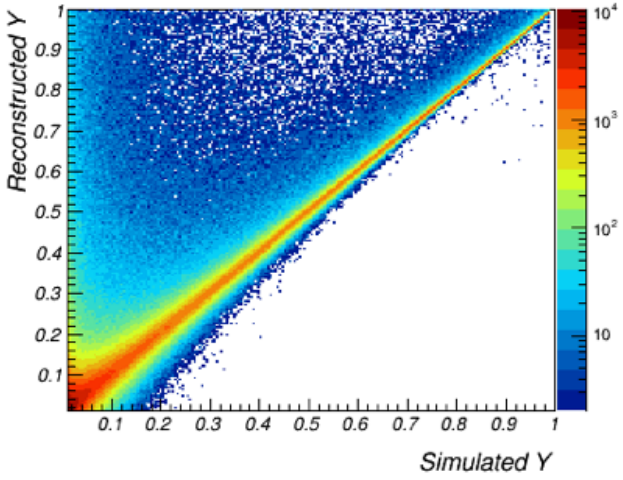
- {PYTHIA 20x250 GeV, NO bremsstrahlung} -> {GEANT} -> {Kalman filter track fit}

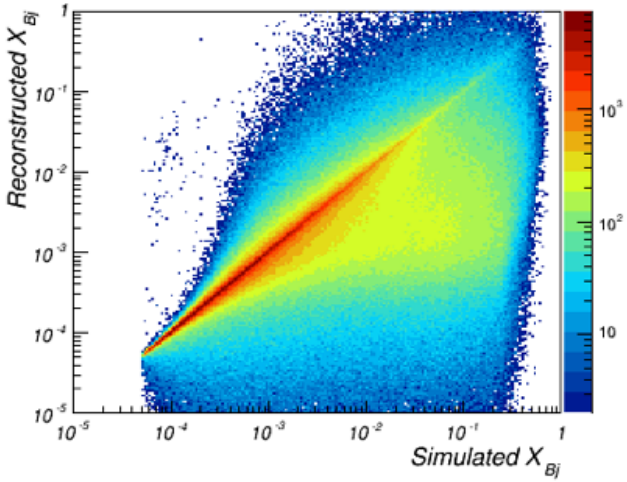


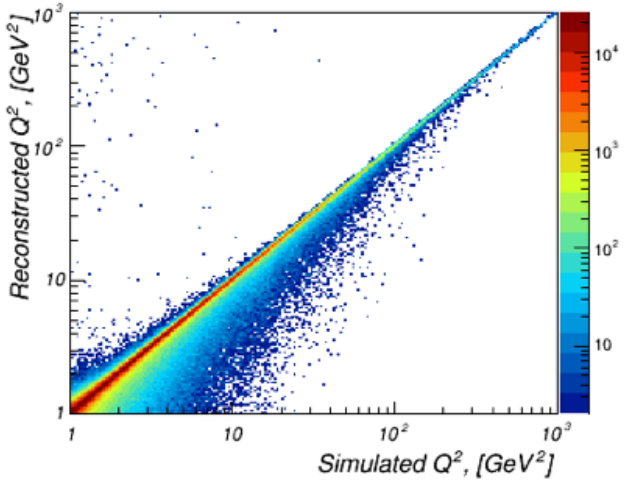




- same procedure; simulation WITH bremsstrahlung







-> looks good despite poor resolution at low Y and long bremsstrahlung tails

courtesy A.Kiselev

Simulations - resolution

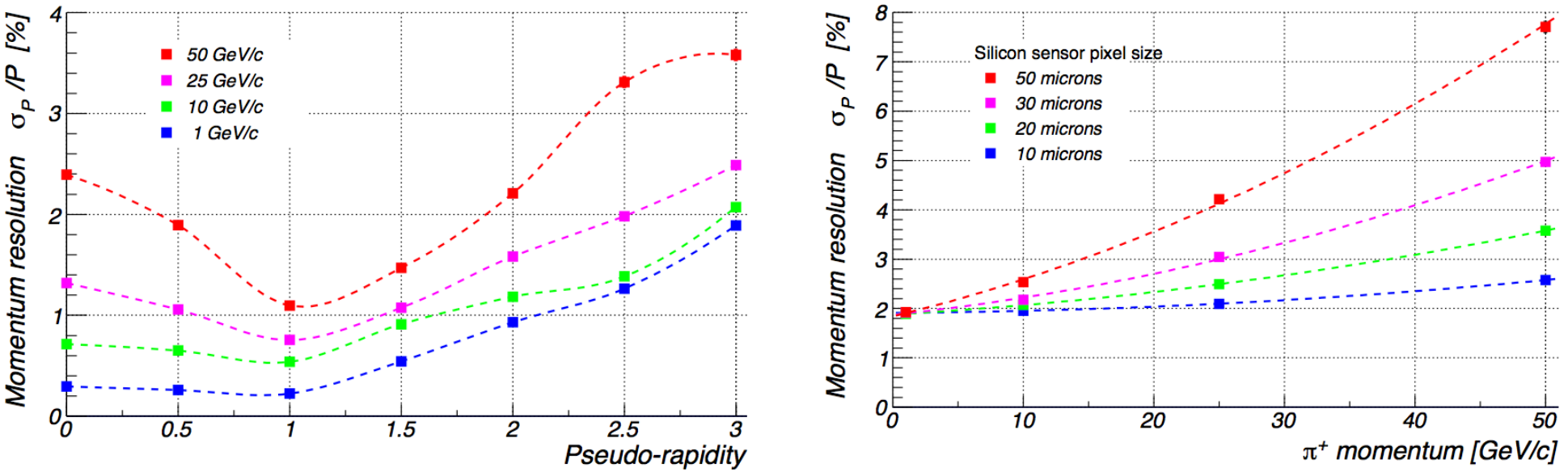
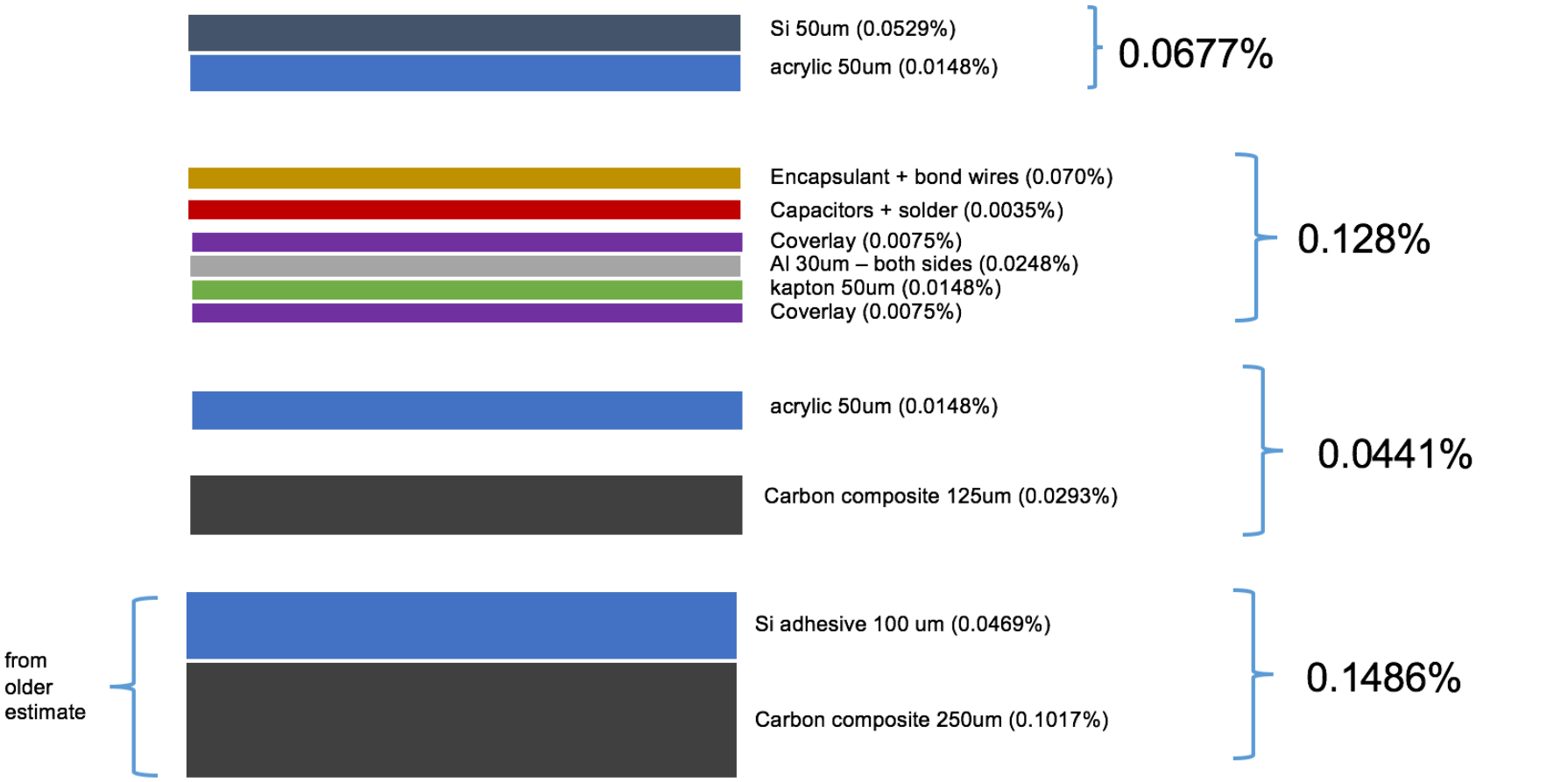


Figure 4-8: Left panel: expected momentum resolution of the baseline eRHIC detector as a function of pseudorapidity. Right panel: forward tracker momentum resolution at $\eta = 3$ vs secondary hadron momentum for various values of MAPS forward tracker pixel size.

HFT - radiation thickness

Radiation length in low mass area



NOTE: Does not include sector tube side walls

Total = 0.388%