JLab **EIC** Detector(s)

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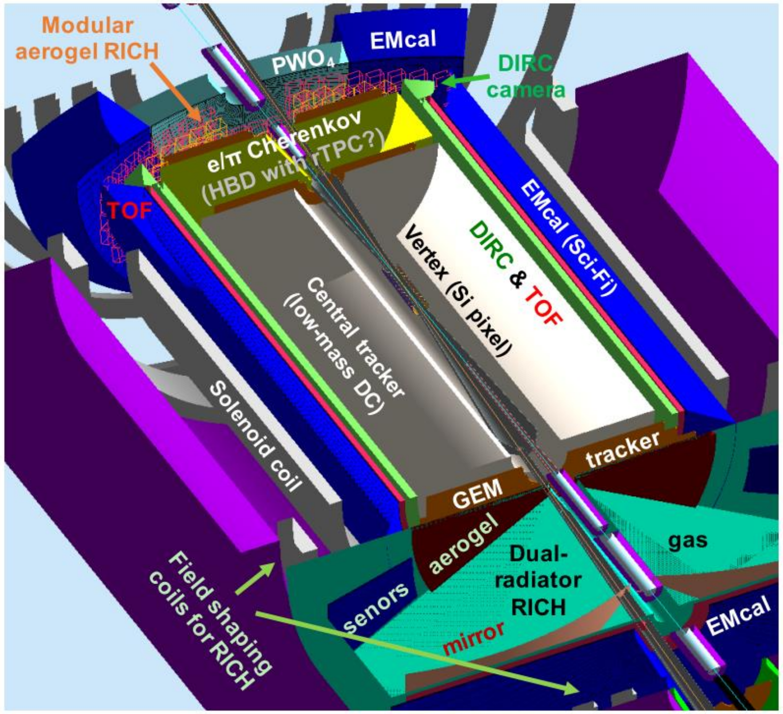
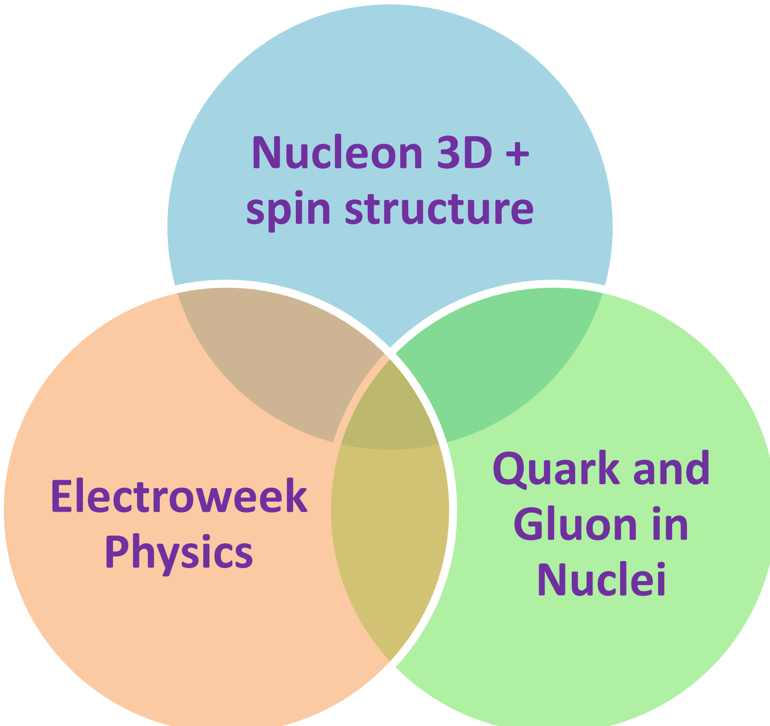
INFN Roma e Istituto Superiore di Sanità

Incontro EIC-INFN / Genova / 17 Gennaio 2017

- **Requisiti e concetti generali**
- **Spazio delle fasi**
- **Spettrometro centrale**
- **Regioni in avanti**

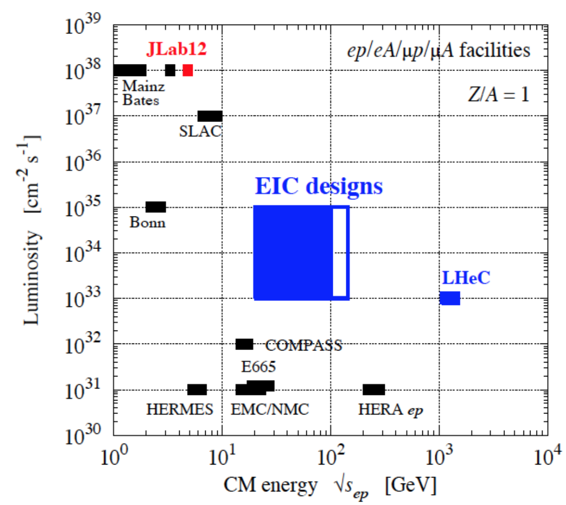


EIC Physics and Requirements

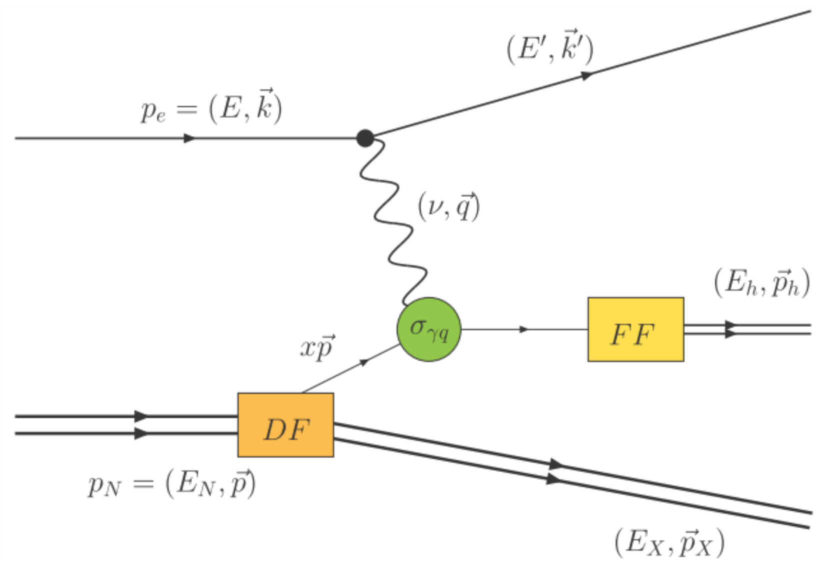


- Electron (and positron) and ion beams from proton to Pb/U
- Polarization (e, p, d, ^{3}He) >70%, e-polarimetry precision down to 1% for e
- Luminosity up to ≈10^{34}/(cm s)
- CM energy large and variable (20-100 GeV)
- Reach very low $x \approx 10^{-4}$

- Inclusive, Seminclusive and Exclusive reactions
- Good Particle ID (for hadrons and leptons)
- Vertex Resolution down to 0.1 mm
- Momentum Resolution (down to ≈100 MeV ≈1%)



Particles Detection and Kinematics Reconstruction

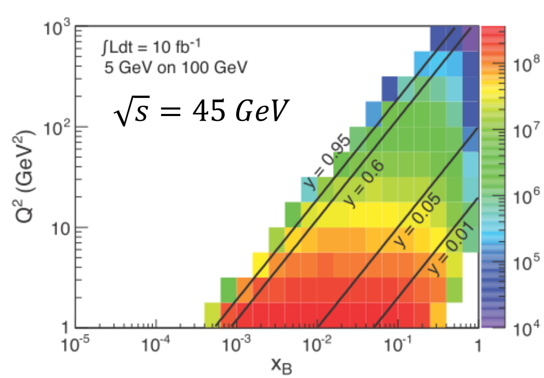


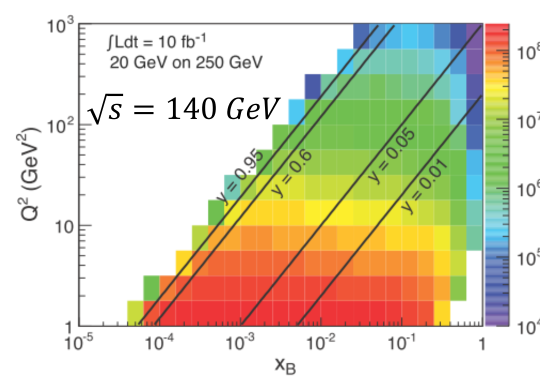
- Detect three types of particles:
  - Scattered electron (central and forward)
  - Hadron(s) (jet) associated with struck parton (mainly central)
  - Hadron(s) associated with initial ion (mainly forward)

Need to measure:
$\vec{k}', M_h, \vec{p}_h, \vec{p}_X$ (and M_X)

JLEIC at first IP: ~**100% acceptance** for all final state particles, and measure them with good resolution.

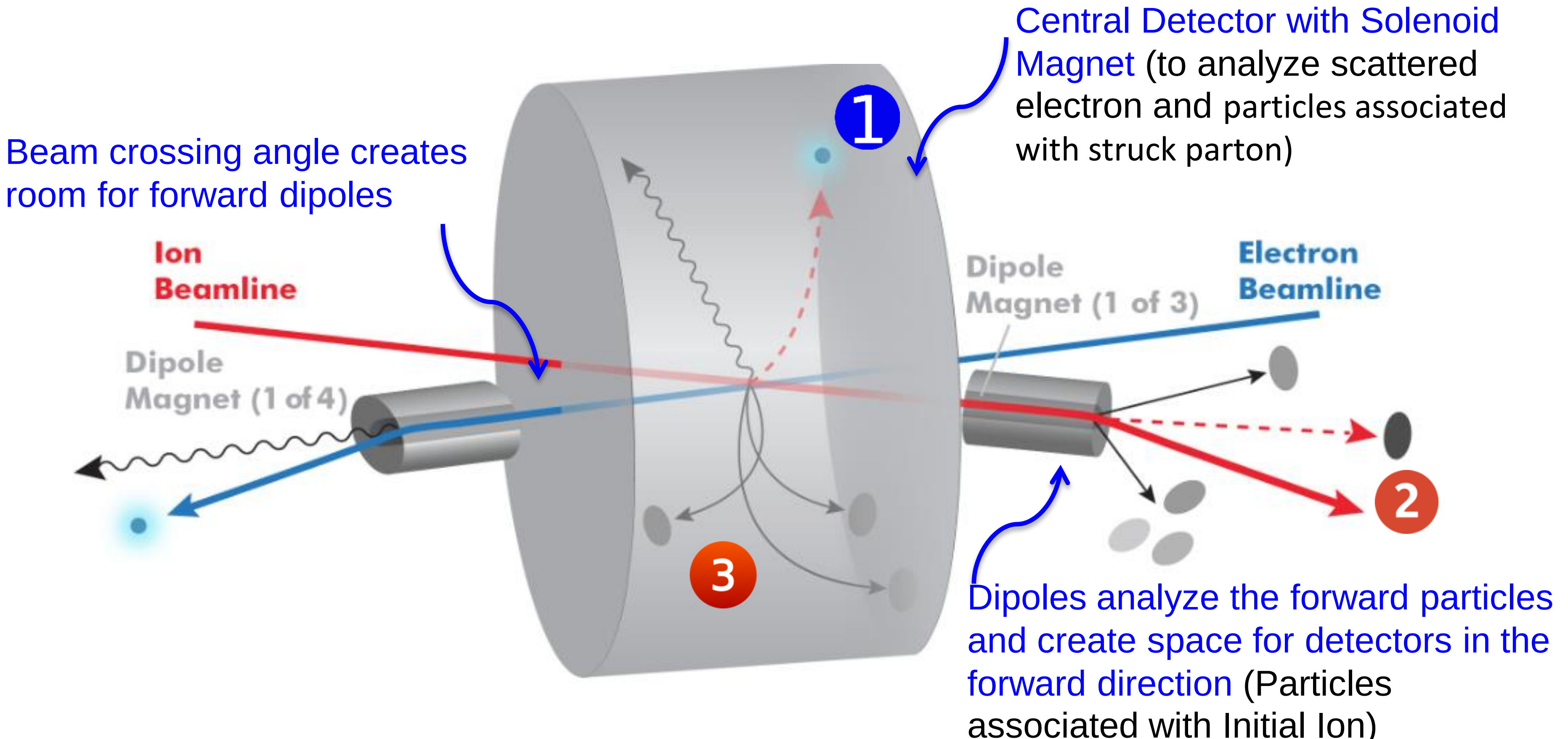
Reconstruct:
Q^2 : spatial scale
x : mom. fraction of the parton
y : inelasticity
$(Q^2 = s \cdot x \cdot y)$





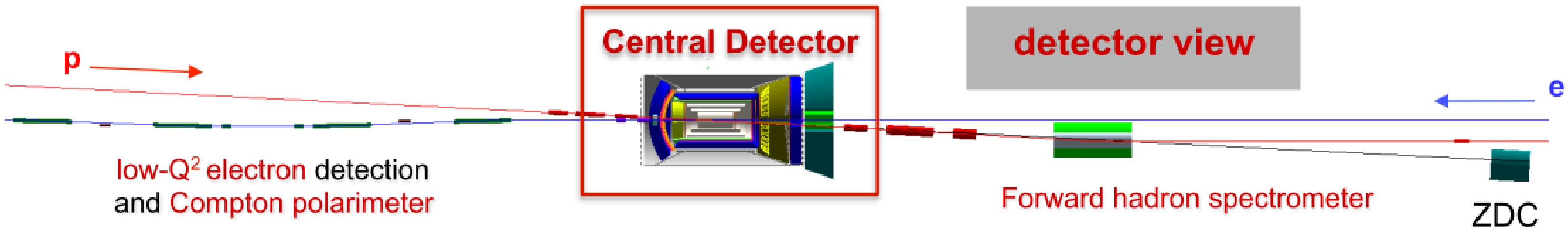
1st Interaction Region (=IP1) Concept @JLEIC

- The goal is to get **~100% acceptance** for all final state particles, and measure them with **good resolution**.
- Experimental challenges:
  a) beam elements limit forward acceptance,
  b) central Solenoid not effective for forward particles



Adapted from R. Yoshida

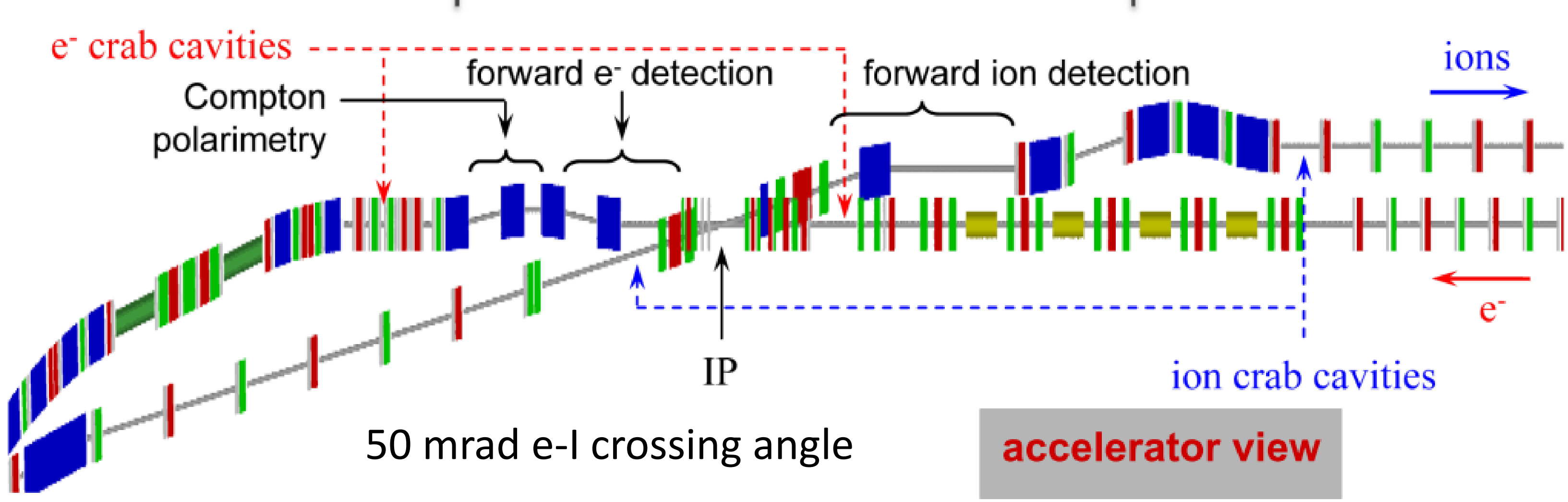
Detectors in JLEIC IP1



Extended detector: 80m

30m for multi-purpose chicane, 10m for central detector, 40m for the forward hadron spectrometer

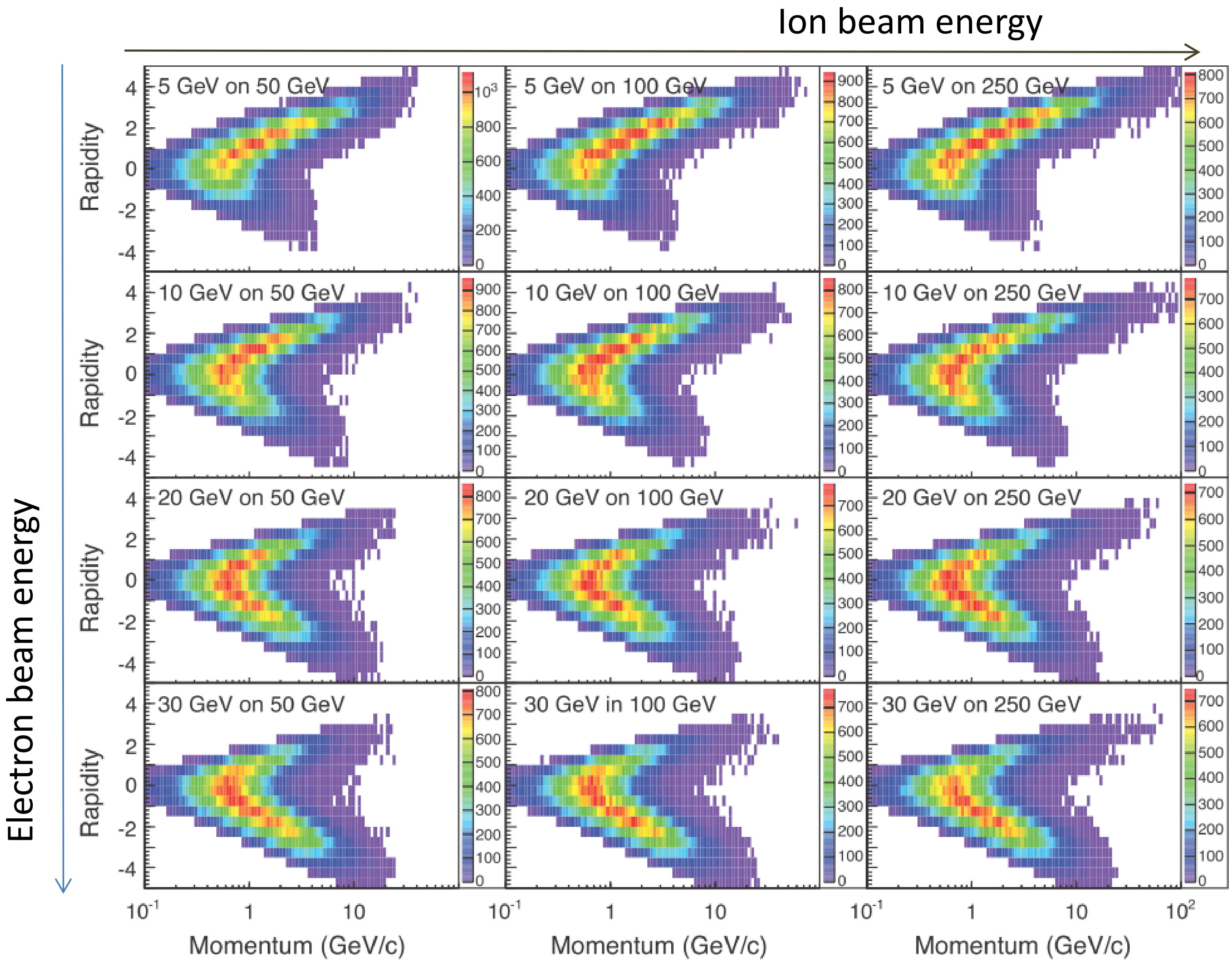
fully integrated with accelerator lattice



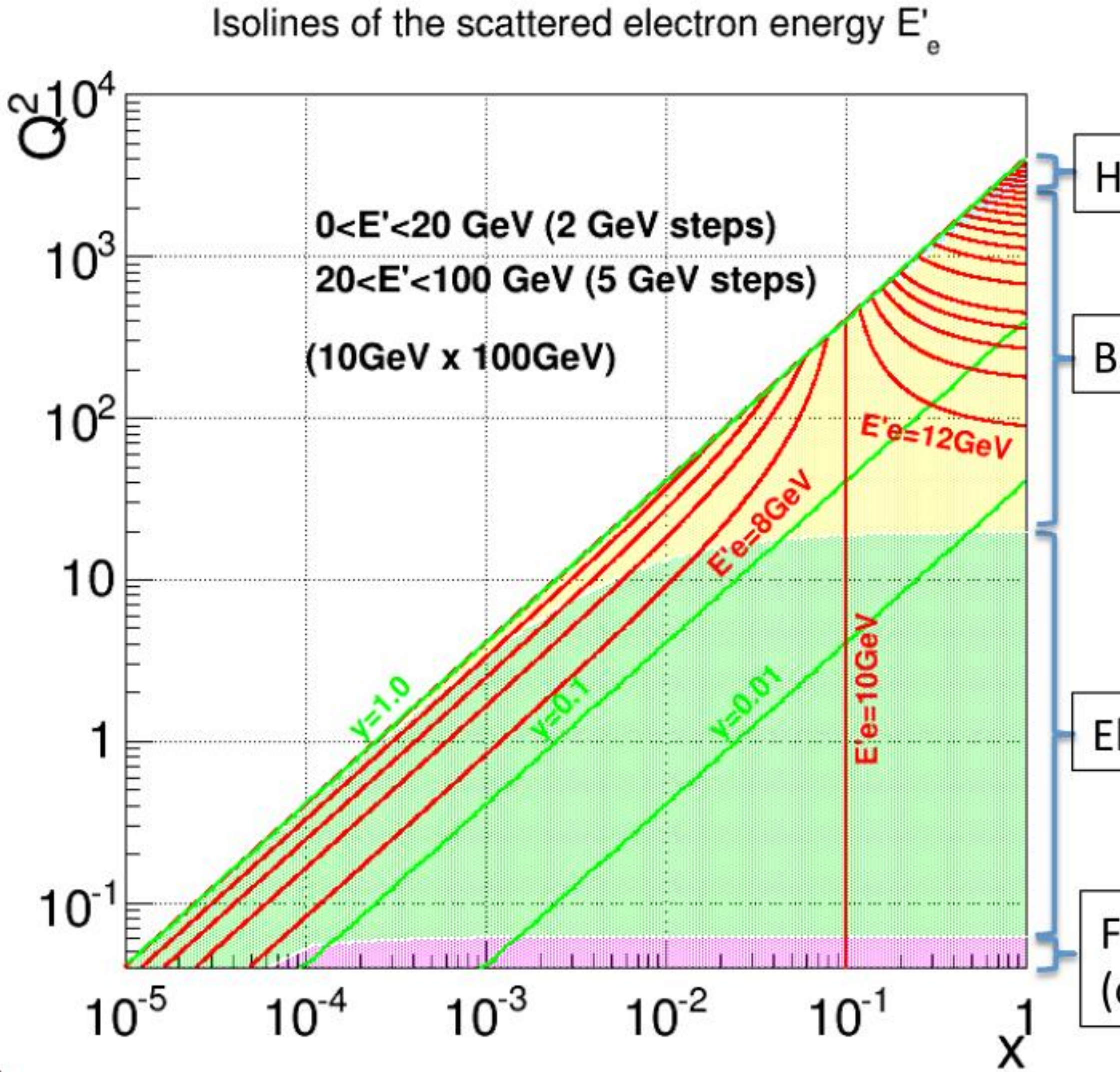
- GEANT4 detector model developed, simulations in progress

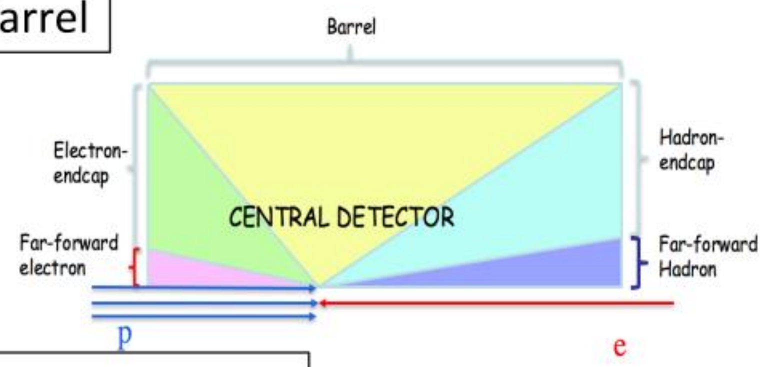
Adapted from M. Diefenthaler / JLEIC Coll.Meet. Oct/2016

Pion kin. distribution, non excl. reactions

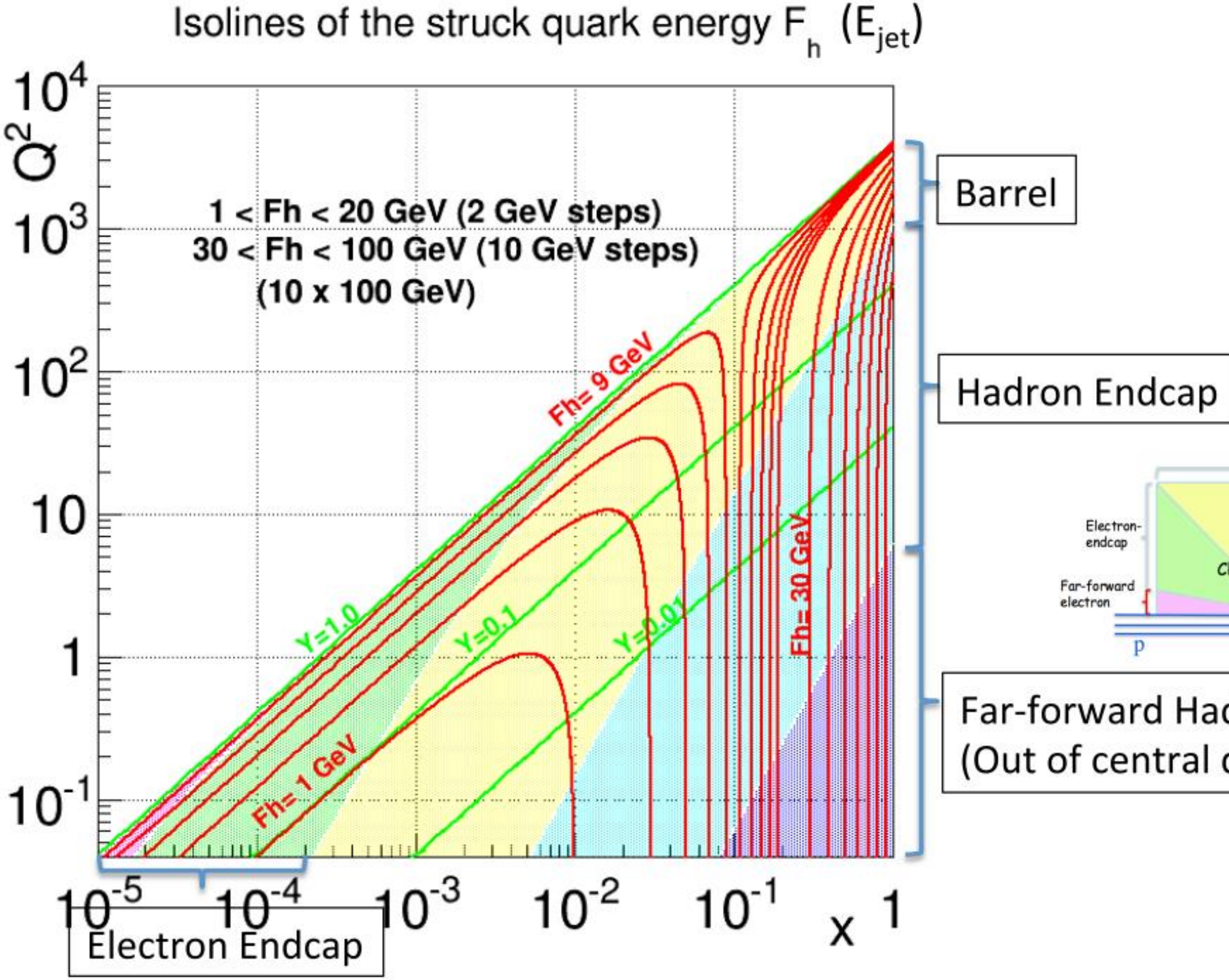


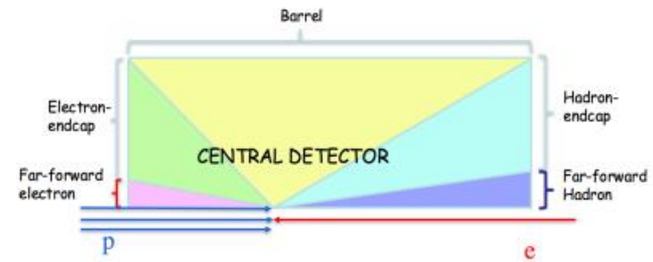
electrons


Isolines of the scattered electron energy E'e
0<E'<20 GeV (2 GeV steps)
20<E'<100 GeV (5 GeV steps)
(10GeV x 100GeV)
E'e=12GeV
E'e=8GeV
E'e=10GeV
y=1.0
y=0.1
y=0.01
Q2
x
Hadron Endcap
Barrel
Electron Endcap
Far-forward Electron
(out of central detector)

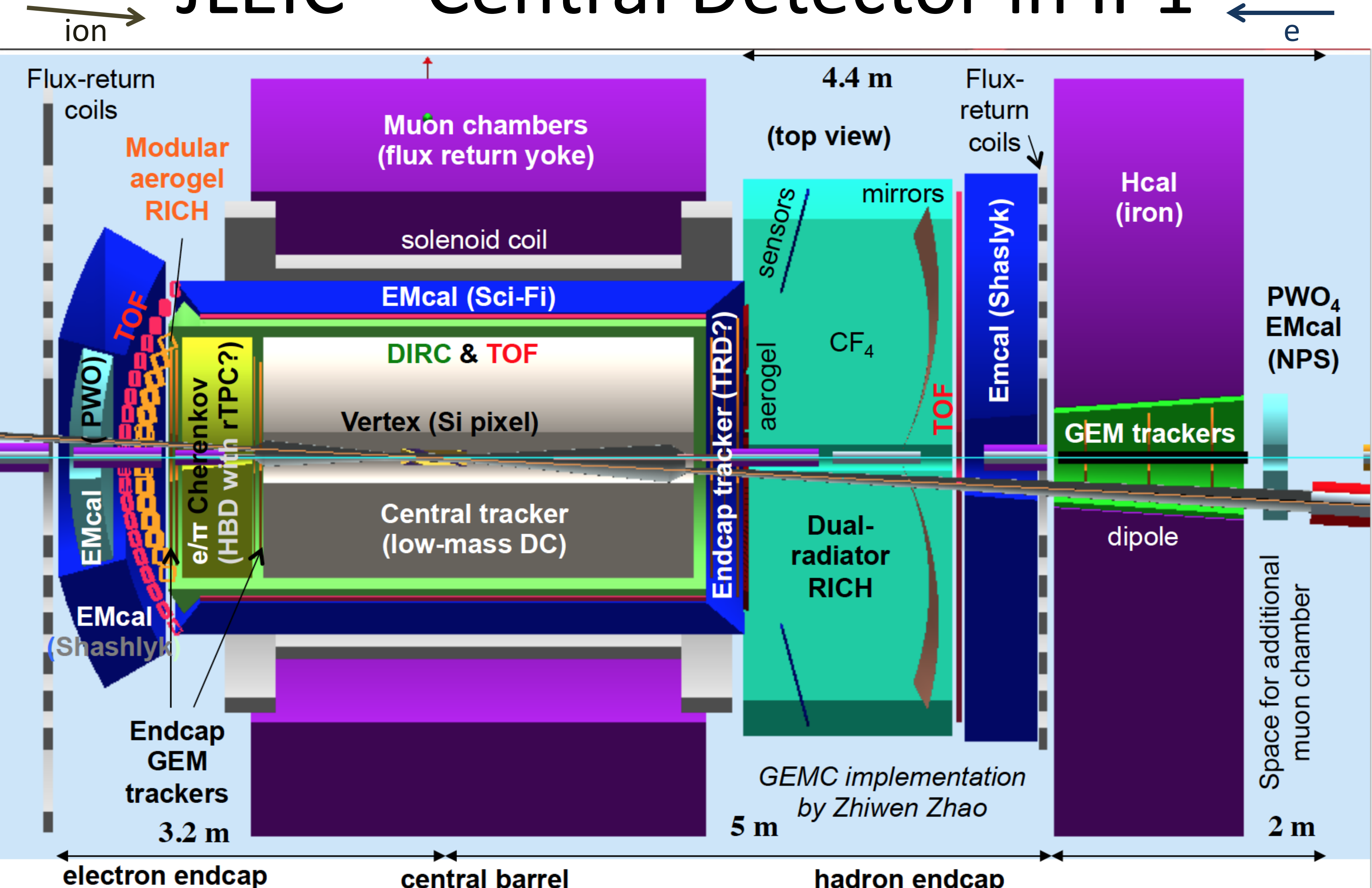

Barrel
Electron-
endcap
Hadron-
endcap
CENTRAL DETECTOR
Far-forward
electron
Far-forward
Hadron
p
e

hadron


Isolines of the struck quark energy F_h (E_{jet})
1 < Fh < 20 GeV (2 GeV steps)
30 < Fh < 100 GeV (10 GeV steps)
(10 x 100 GeV)
Fh= 9 GeV
Fh= 1 GeV
Fh= 30 GeV
Y=1.0
Y=0.1
Y=0.01
Q^2
x
Barrel
Hadron Endcap
Far-forward Hadron
(Out of central detector)
Electron Endcap


Barrel
Electron-
endcap
Hadron-
endcap
CENTRAL DETECTOR
Far-forward
electron
Far-forward
Hadron
p
e

JLEIC – Central Detector in IP1

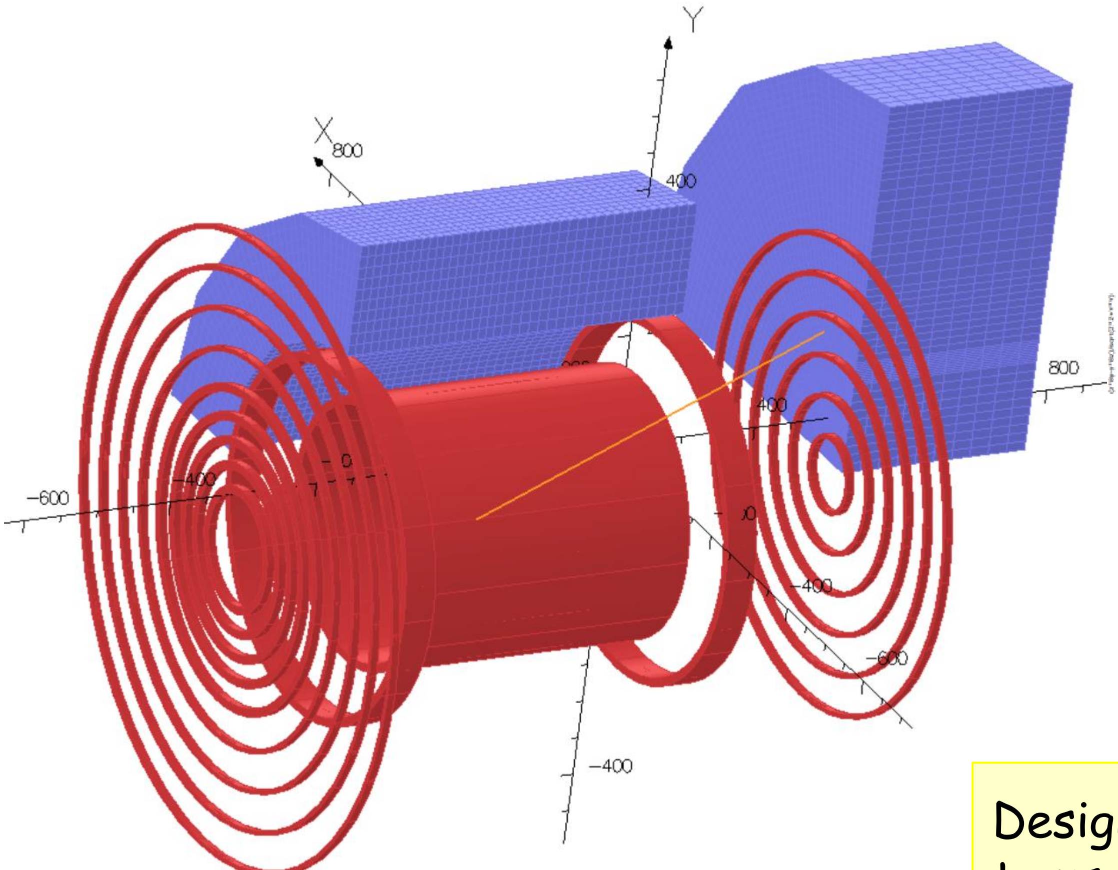


Magnet (Solenoid)

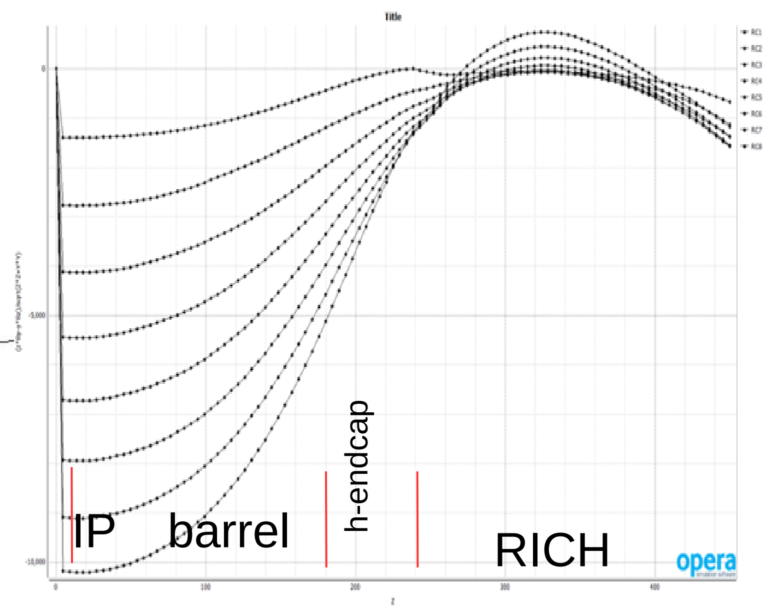
1. Reuse 1.5 T magnet from CLEO or BaBar

By Paul Brindza

2. New design 3(1.5)T solenoid



minimize the magnetic field
at hadron-endcap
(dual-radiator RICH region)



Design of a new solenoid could allow to use dual-radiator RICH in endcap.

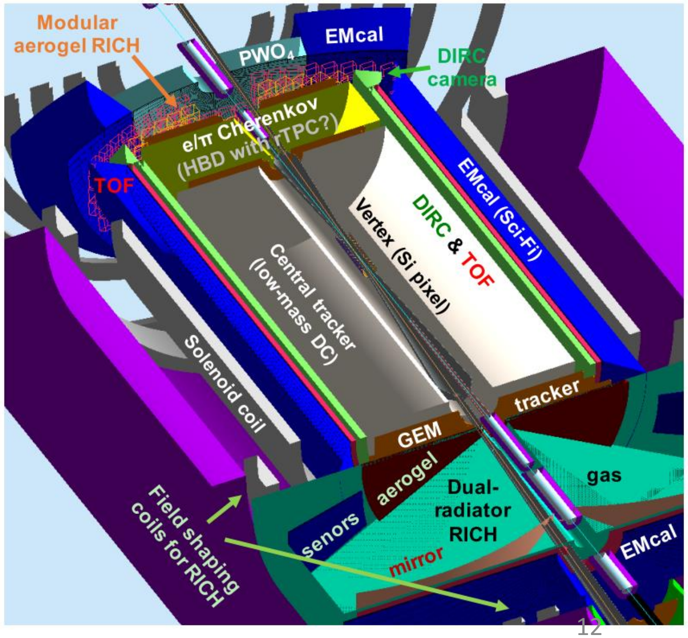
From Yulia Furletova / JLEIC – March - 2016

Tracking

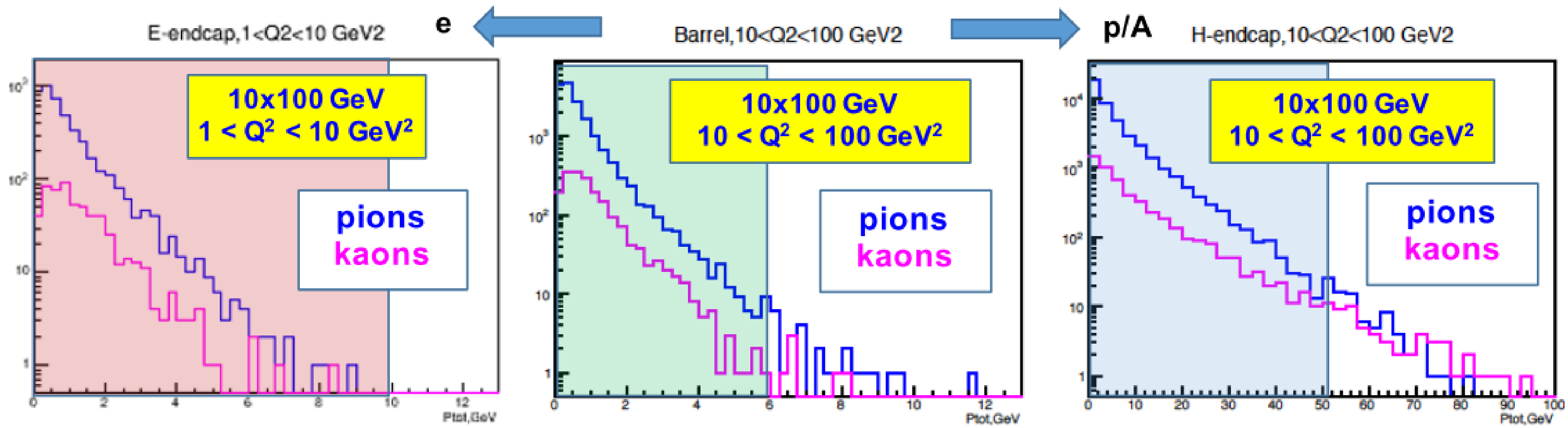
- Vertex:
  - Resolve secondary vertex (e.g. b and c quarks with lenght 100-500 um)
  - stand-alone measurement for low-Pt particles
  - dE/dx for P-ID
  - ➢ Si trackers (pixels) need high segmentation and low material budget ⇨ eRD18 on Monolithic Active Pixel Sensor (from STAR)
- Barrel (low material budget, relatively fast):
  - Spatial resolution $\approx 0.25 \text{ mm} \rightarrow \frac{\Delta p_t}{p_t} \approx 10^{-4}$
  - Limited low energy hadron separation by dE/dx
  - Low Mass Drift Chambers (KLOE LMDC ?)
- Endcaps (need high granualirity and radiation hardness)
  - Spatial resolution ≈ 0.05 mm
  - Two R&D (eRD3 and eRD6) ongoing (including large GEM and cylindrical MicroMegas, low material budget Chromium-GEM, commercial company producing GEM)

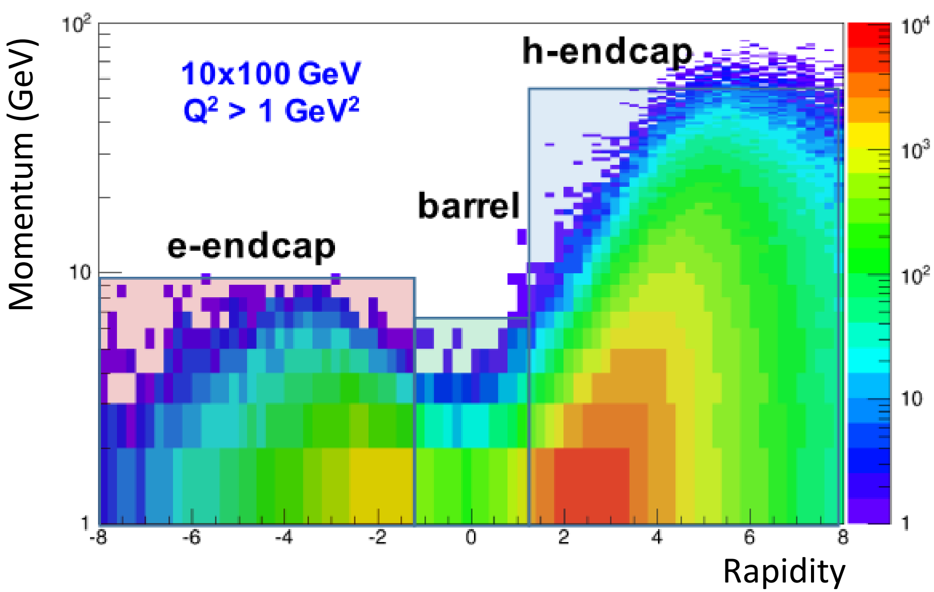
EM-Calorimetry

- Energy position and time of electron shower and hadron preshower
- Barrel:
  - Sampling (Shashlyk) scintillation + WLS (rad. hard. ?)
  - High Res. Sampling: Tungsten Powder + Scintillation fibers from UCLA (eRD1)
- Endcaps:
  - Sampling (Shashlyk) as before
  - PWO4 crystals (good rad. hard); supplier issue, crystal QA test → eRD1



hadron-ID (eRD14)





Hadron ID beneficial for many physics case, expecially in the high-momentum tails:

- SIDIS
- 3D tomography
- Diffraction/gluon saturation
- Open charm

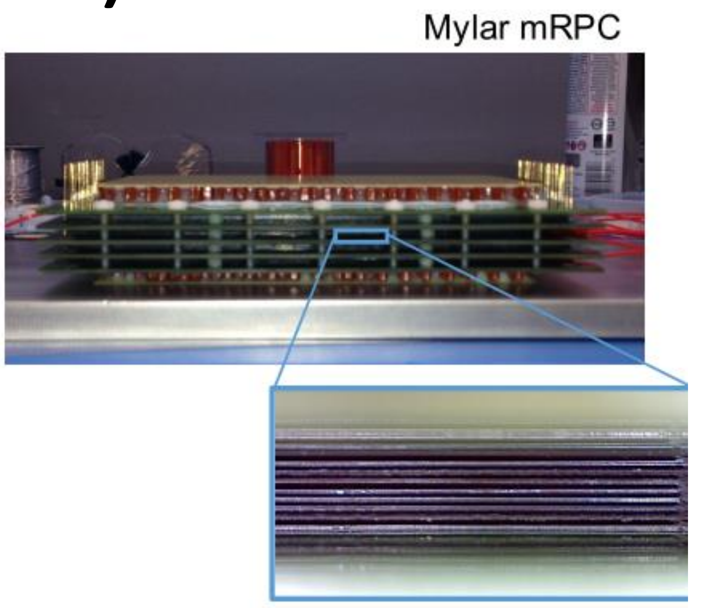
Technology options:

- e-endcap: TOF and aerogel RICH
- h-endcap: TOF and gas+aerogel RICH
- Barrel: TOF & DIRC

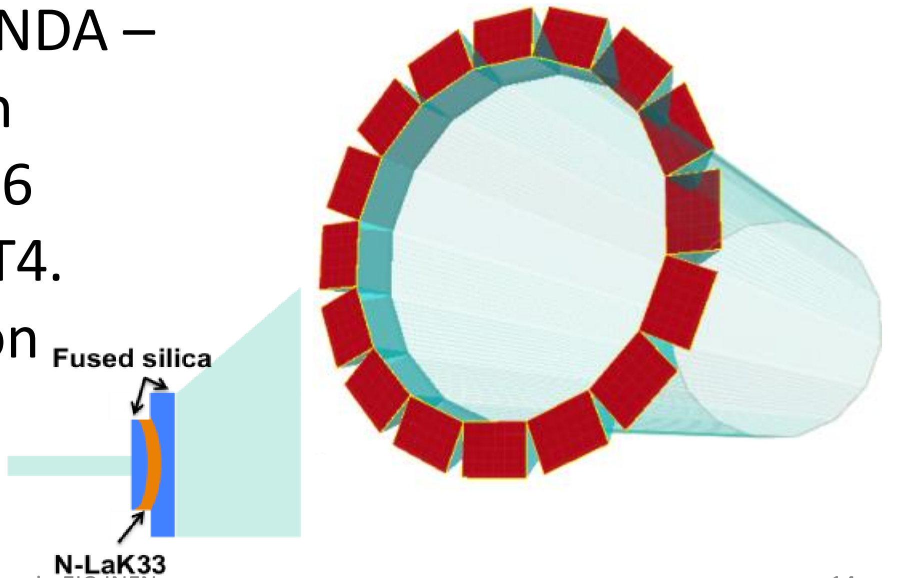
Adapted from P. Nadel-Turonski (ANL– July 2016)

h-PID (eRD14)

- Low Momenta:
  - TOF (everywhere) based on mRPC, π/K separation up to p=3.5 (e-endcap), 2 (barrel), 4 (h-endcap) GeV (assuming 30 ps sigma); R&D toward 10 ps, manufacturing optimization

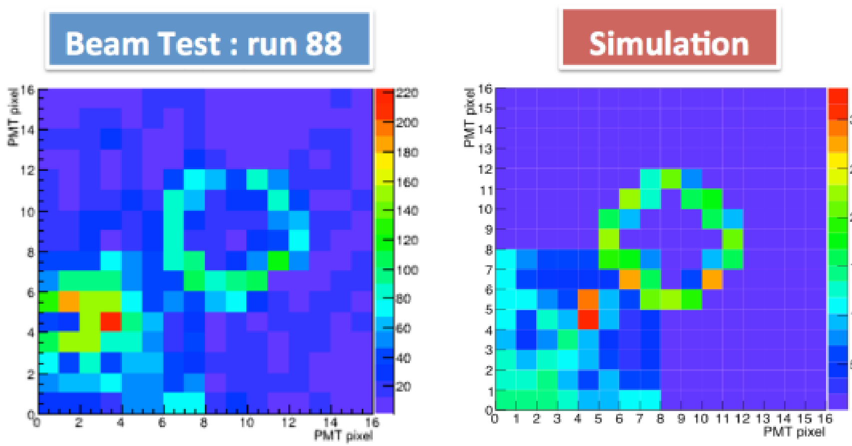


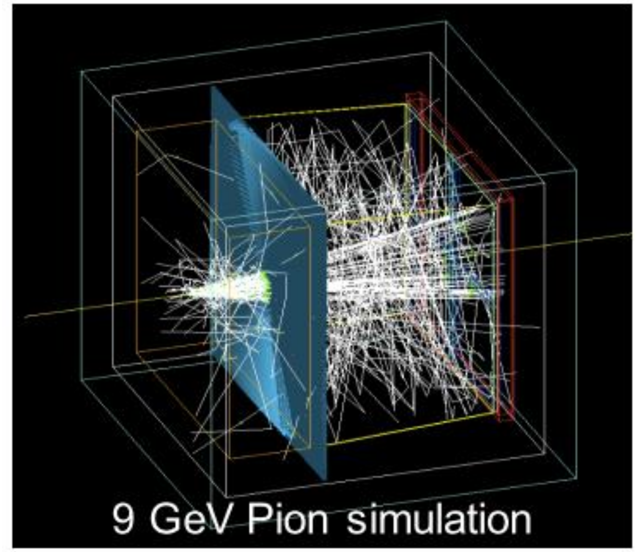
- Medium momenta:
  - DIRC (barrel); synergy with PANDA – 3 layer lens and exploit time in reconstruction; 4.3σ in π/K at 6 GeV/c demonstrated in GEANT4. MonteCarlo, test and validation ongoing



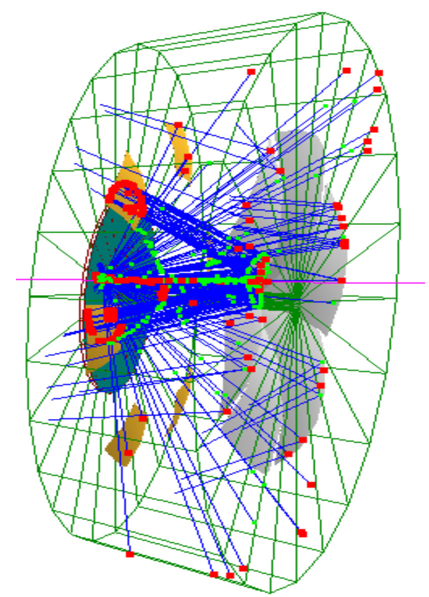
h-PID – RICH - (eRD14)

- Medium momenta:
  - Modular RICH (e-endcap): very compact assembly with aerogel + Fresnel lens; nees high res. Photon detector (≈2 mm)





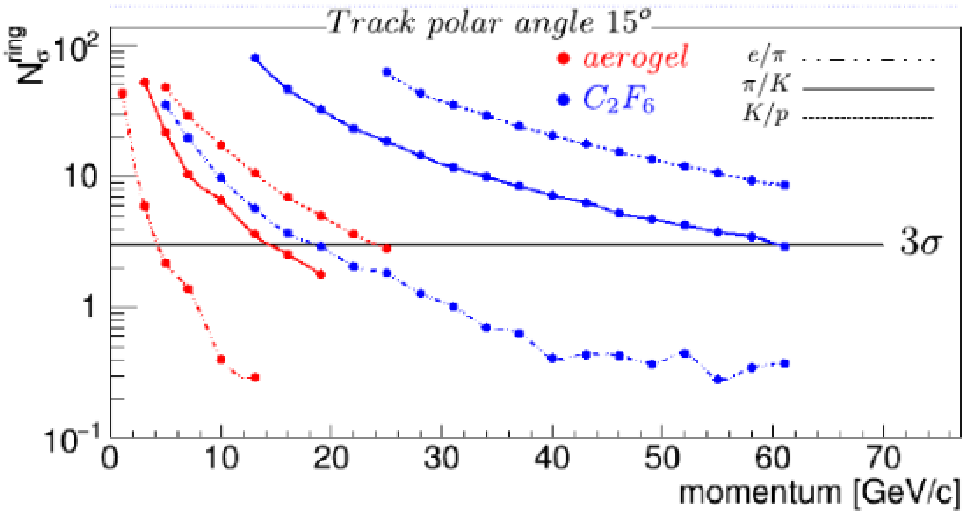
- Medium-High momenta:
  - Dual radiator RICH (h-endcap): aerogel and C_xF_y gas, up to 60 GeV/c π/K 3σ separation; focusing mirror, curved detector surface, need to operate in magnetic field – detailed simulation



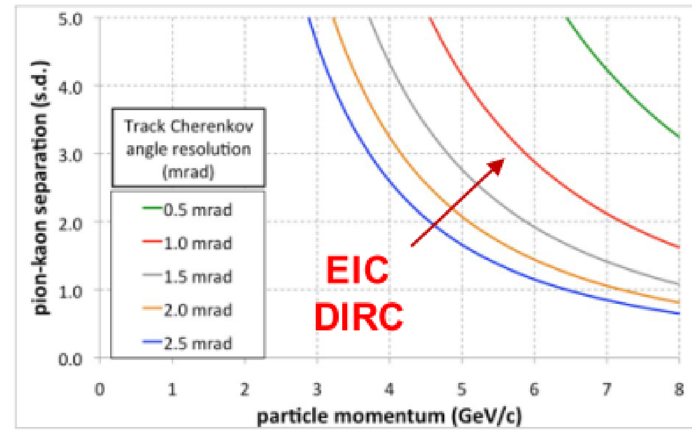
Effort to identify cost-effective photosensor solution for DIRC, mRICH, dRICH

h-ID (eRD14) Performance

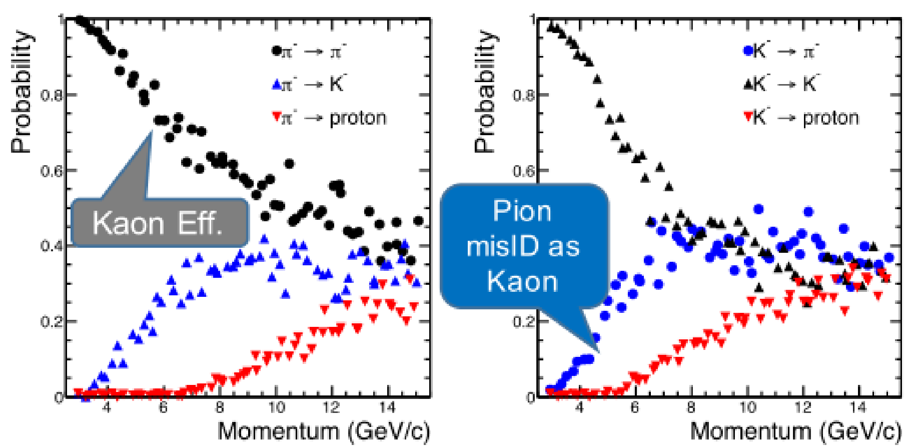
h-endcap: dual-radiator RICH (dRICH)



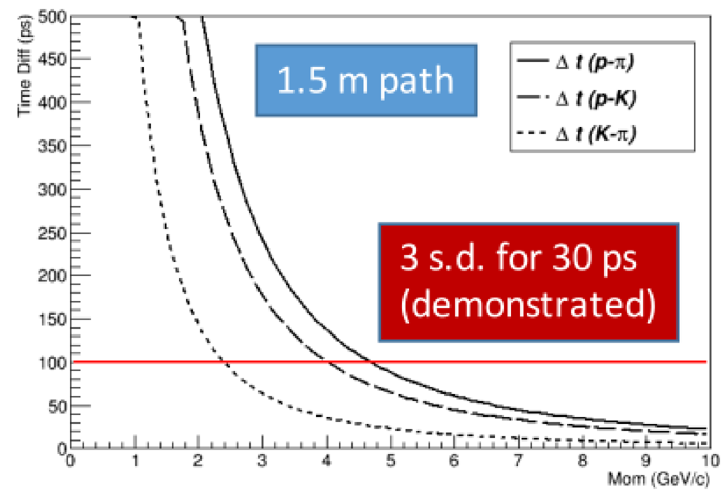
barrel: high-performance DIRC



e-endcap: modular aerogel RICH (mRICH)

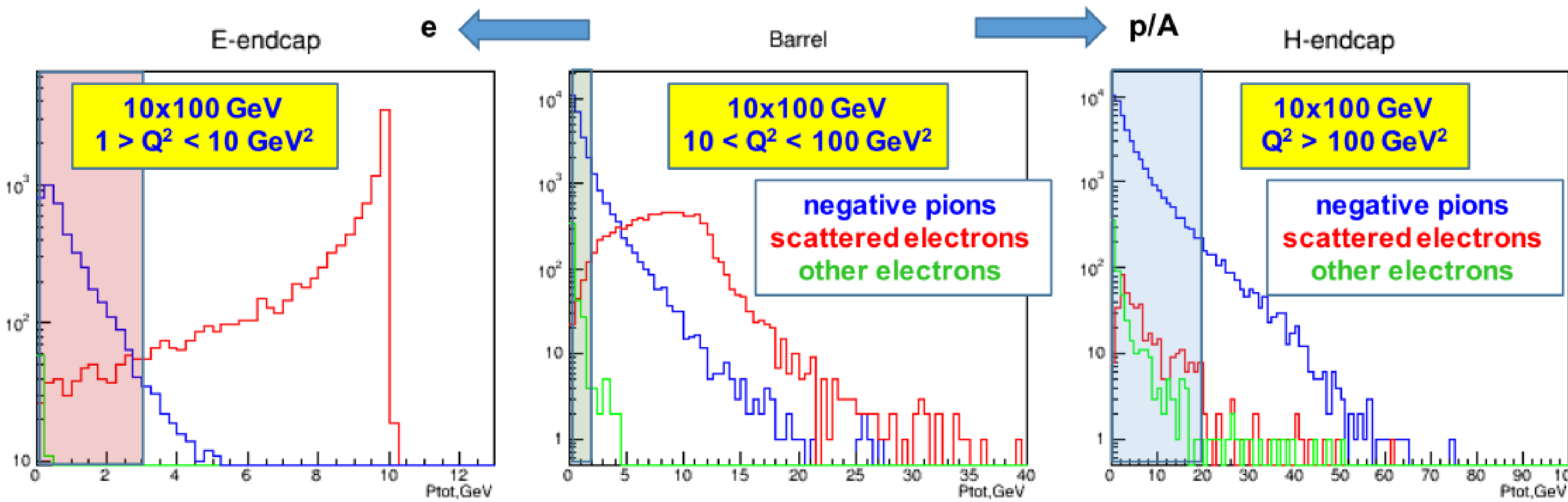


High-resolution mRPC TOF



From P. Nadel-Turonski (ANL– July 2016)

e-ID (eRD14)



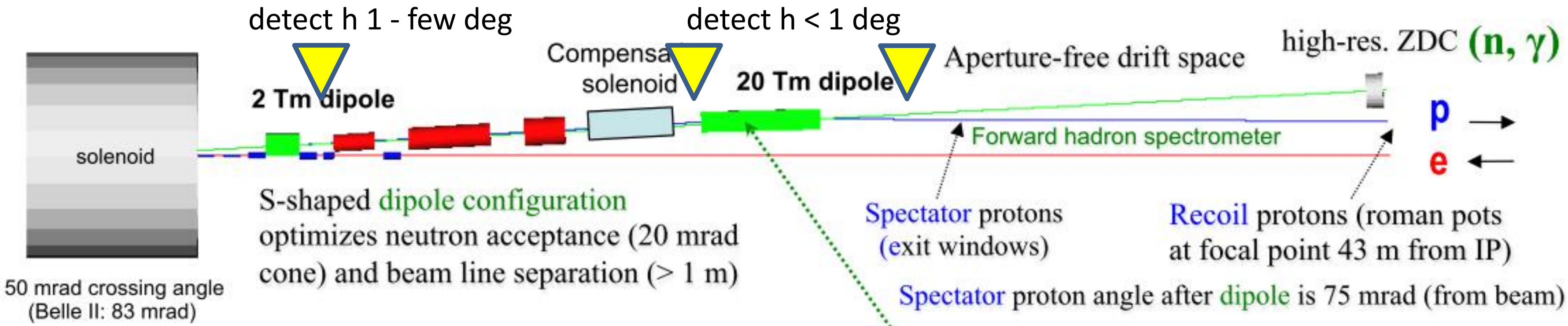
- Basic e/pi ID is provided by the EM cal (but only about 1:100 pion suppression)
- The Cherenkov detectors developed by eRD14 provide **supplementary e/pi ID**
- **h-endcap**: needed for all momenta. dRICH can cover up to 20 GeV
- **e-endcap and barrel**: needed for low momenta. DIRC and mRICH can cover up to about 2 GeV

- In the future, R&D on dedicated e/pi systems could follow
- **e-endcap**: Fast e/pi Cherenkov based on the PHENIX HBD, but in a reversed configuration (also possible radial TPC)
- **h-endcap**: a TRD could replace some of the GEM trackers

- Collaboration with eRD6?

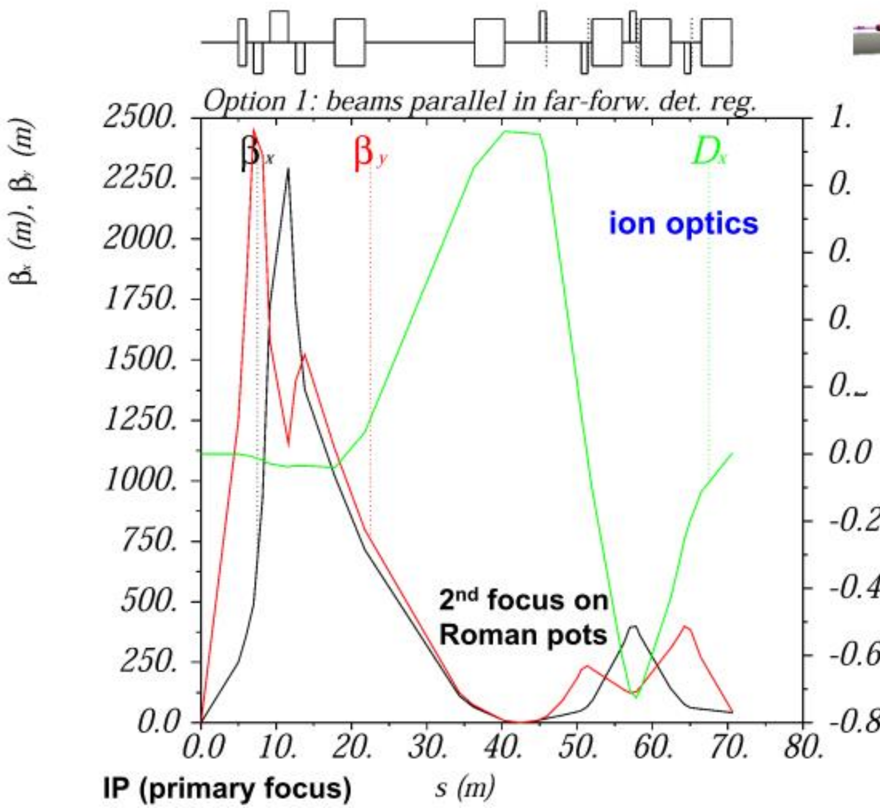
From P. Nadel-Turonski (ANL– July 2016)

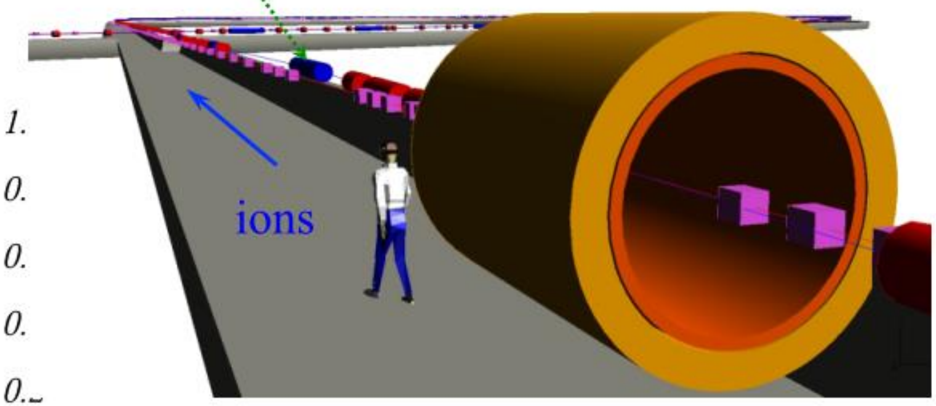
JLEIC forward hadron spectrometer



S-shaped dipole configuration optimizes neutron acceptance (20 mrad cone) and beam line separation (> 1 m)

Spectator proton angle after dipole is 75 mrad (from beam)

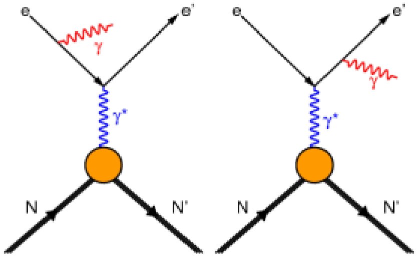




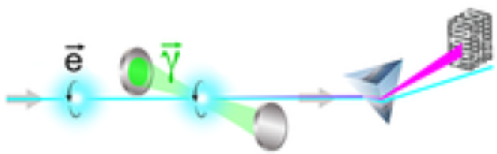
- Large 20 Tm dipole provides excellent resolution
- Large *dispersion* and small *beam size* at secondary focus ensure good acceptance for recoil protons
- Large quadrupole apertures (1 / *max* beam energy) give good acceptance for hadronic and nuclear fragments, charged and neutral (high res. ZDC).

Adapted from R. Yoshida

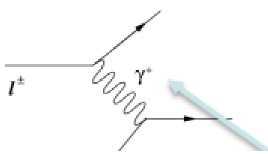
JLEIC forward electron region



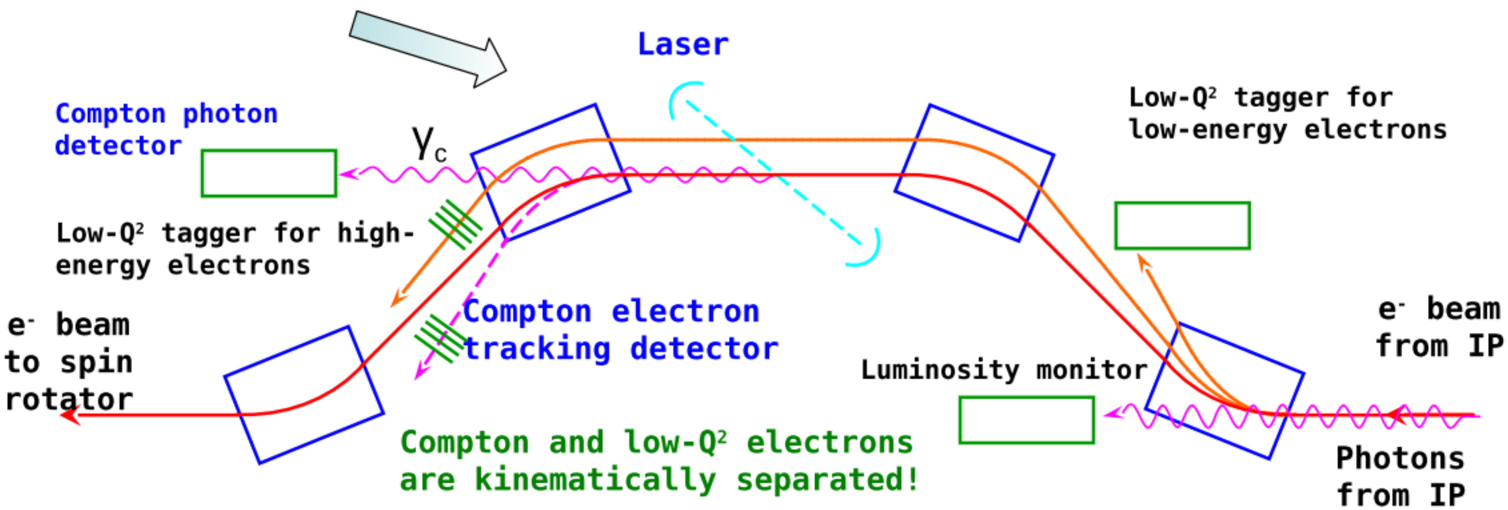
Bethe-Heitler process to monitor luminosity
(photons collinear to electron beam)



Electron-beam polarization measurement
by Compton scattering



Tagging electrons for photo-production
(scattered electron moving in the beam direction)



Dose rate 7-25 krad/h

Adapted from R. Yoshida

JLEIC Second Interaction Point

- 1^{st} IP (white paper): focuses on single particle reconstruction and identification
- 2^{nd} IP: compact and focuses on calorimetry- jets

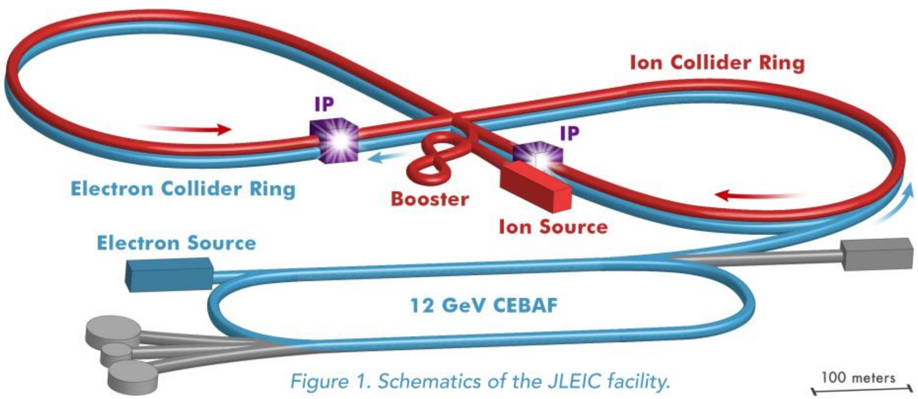
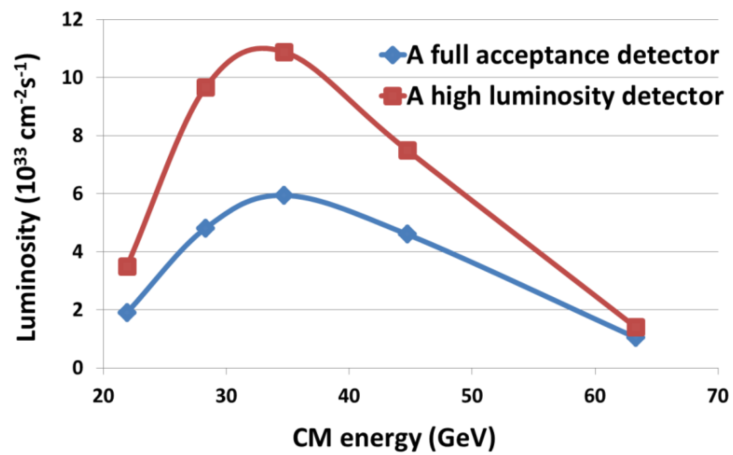
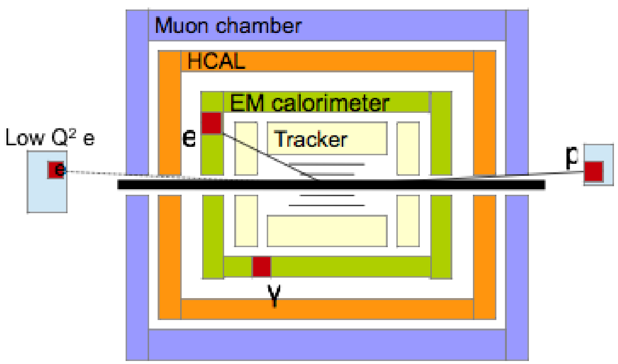


Figure 1. Schematics of the JLEIC facility.



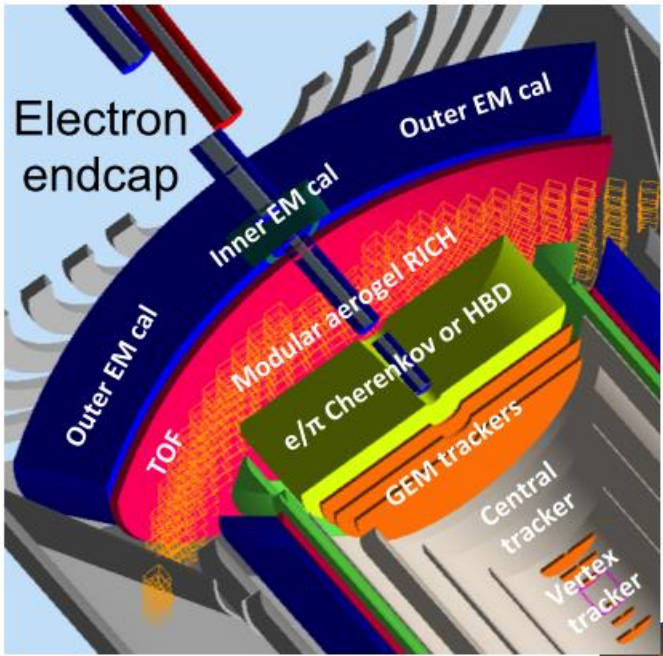
?

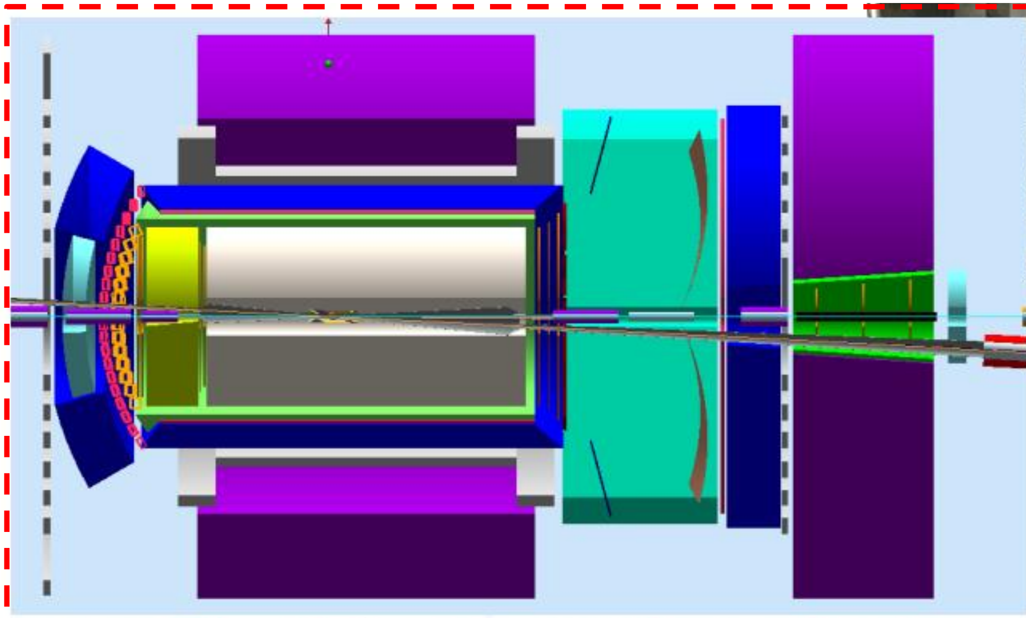


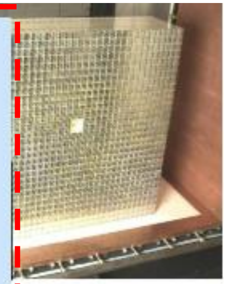
- *Combine results for precision measurements*
- *Increase scientific productivity*
- *Cross-checks on discoveries and important physics results*

Adapted from Yulia Furletova

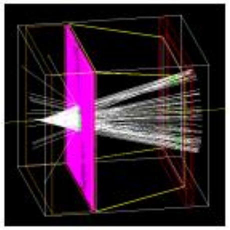
Conclusione



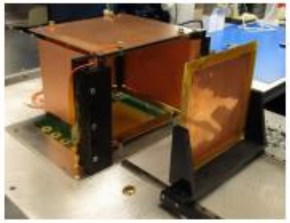




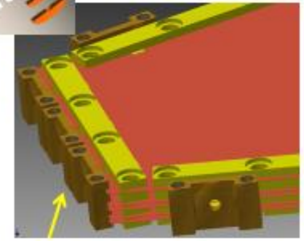
eRD1 – PWO_4 small-angle EMcal



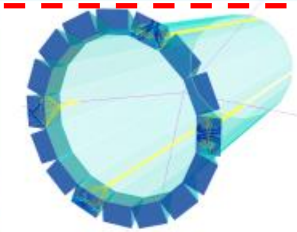
eRD14 – modular aerogel RICH



eRD6 – HBD/TPC?



eRD3 & eRD6 – GEM trackers

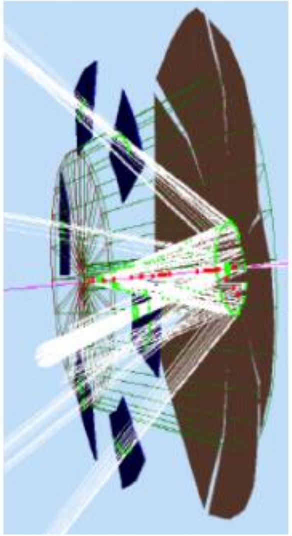


eRD14 – DIRC

eRD14 – MRPC TOF

eRD14 – photosensors

eRD14 – dual-radiator RICH



… verso una definizione consolidata;
ancora molto spazio per nuovi contributi e idee
(non solo di hardware)

Adapted from M. Diefenthaler / JLEIC Coll.Meet. Oct/2016