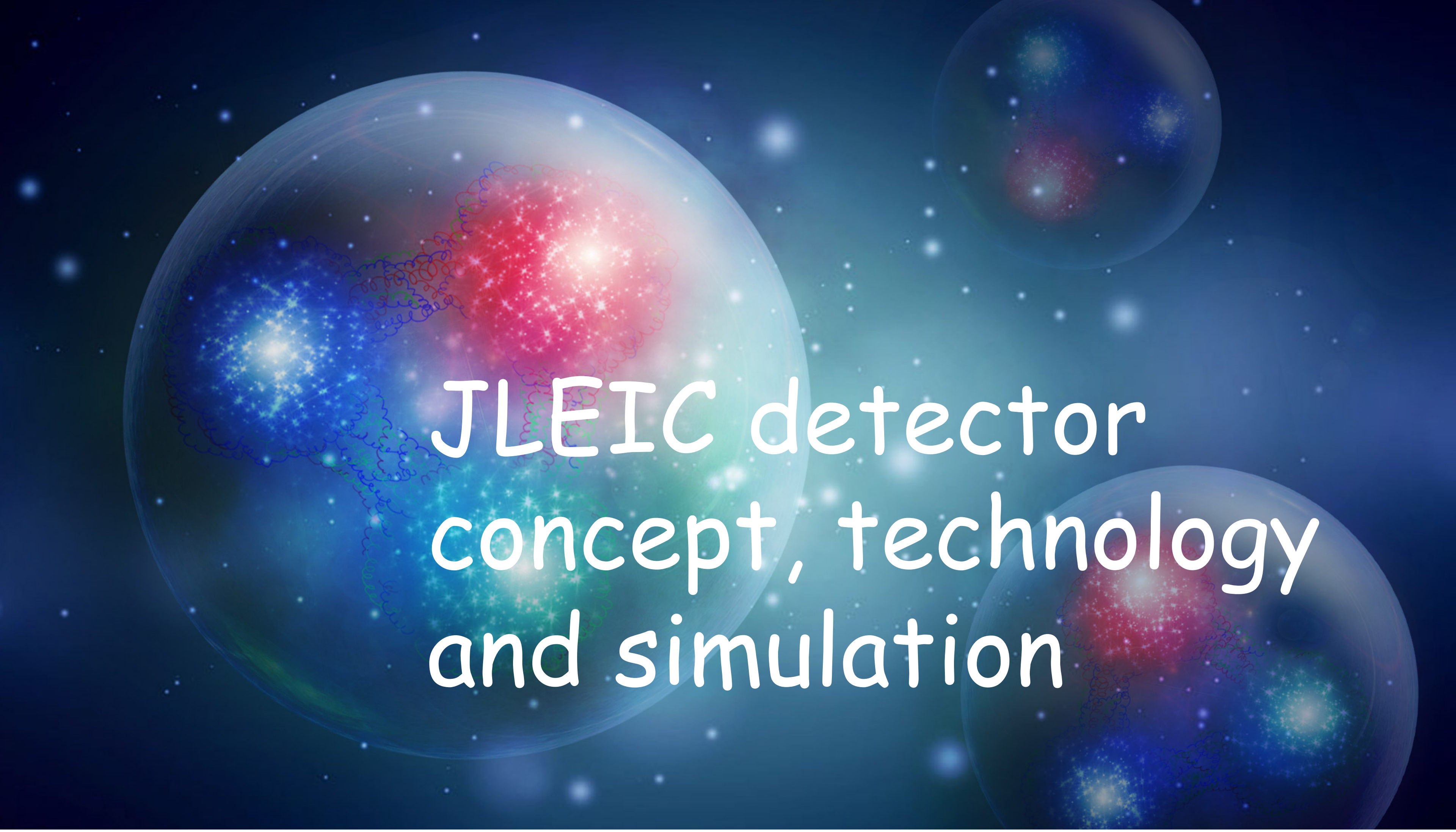


# JLEIC detector concept, technology and simulation

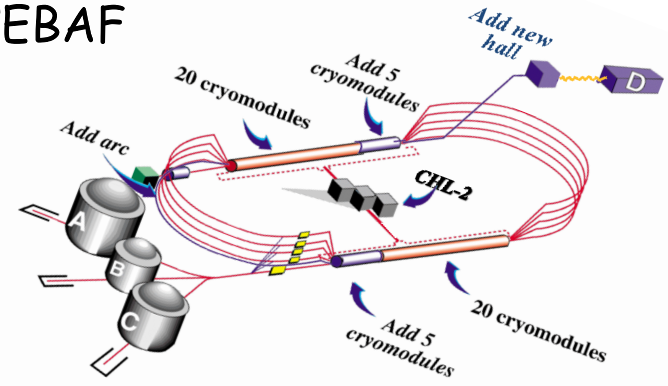
Yulia Furletova, on behalf of JLEIC detector/software working group

JLAB UG, June 18-20, 2018

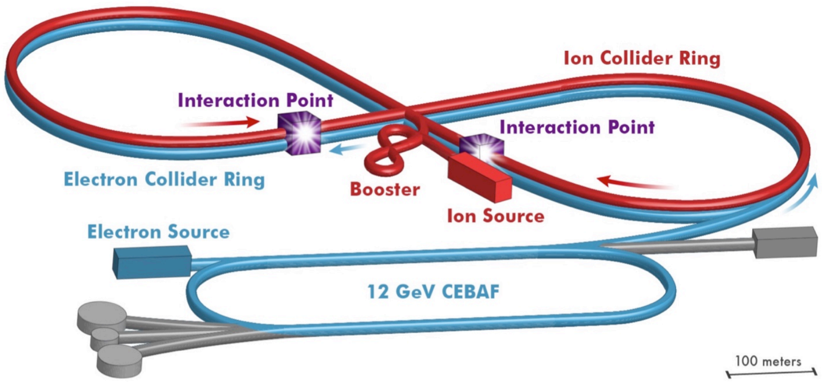
U.S. DEPARTMENT OF ENERGY   JSA   Jefferson Lab

# From CEBAF to Electron-Ion Collider

CEBAF

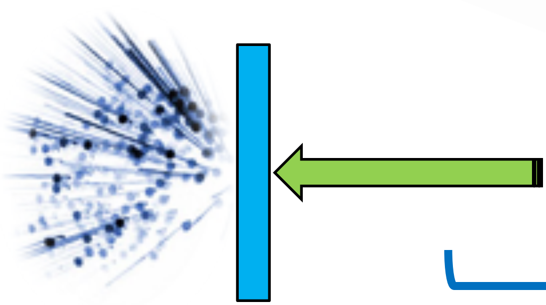


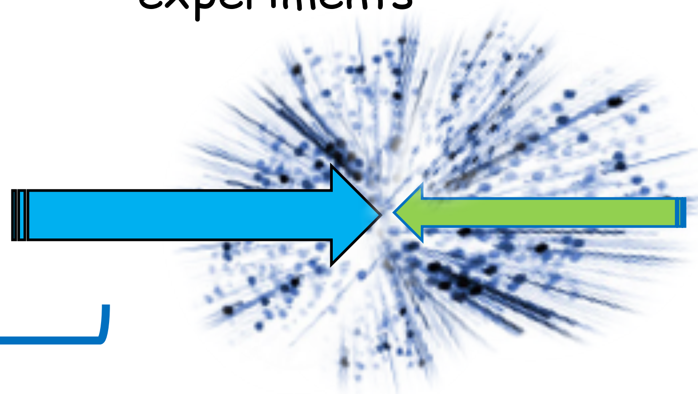

Electron-Ion Collider




Fixed target experiments

Collider experiments

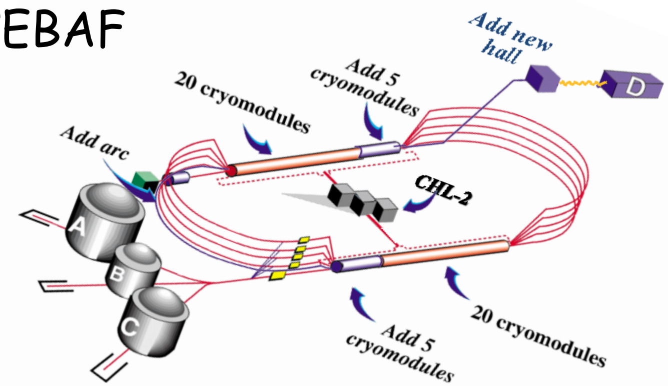




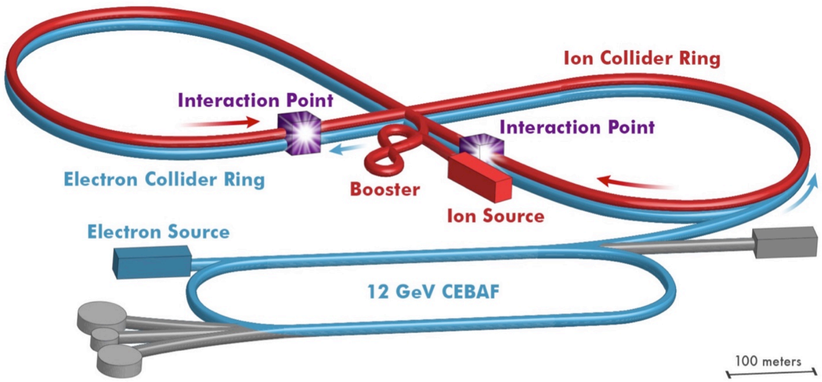
What unifies us all?

# From CEBAF to Electron-Ion Collider

CEBAF

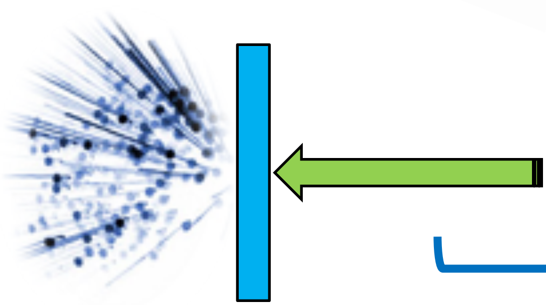


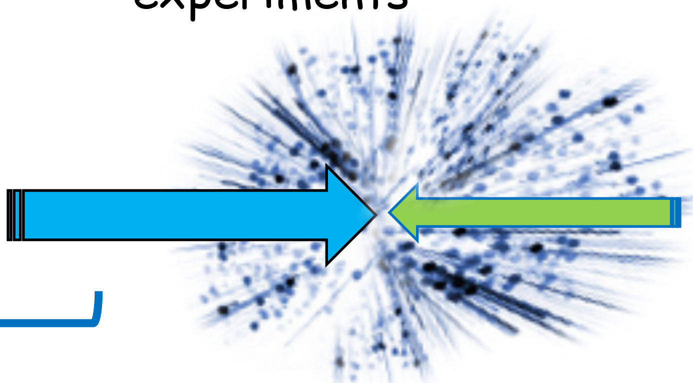

Electron-Ion Collider




Fixed target experiments

Collider experiments

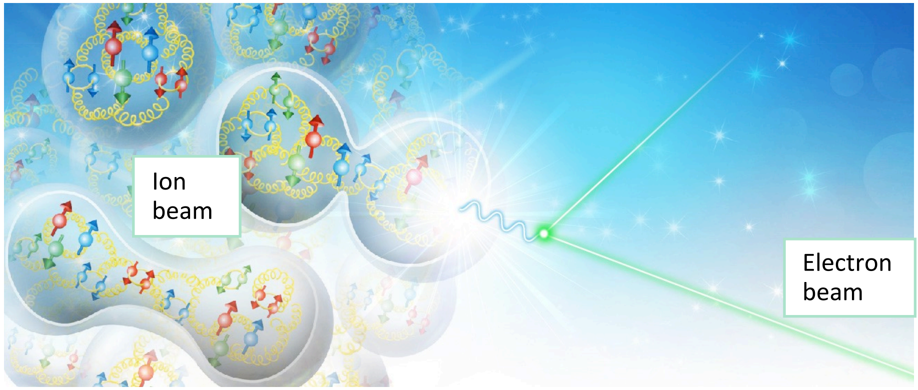




The strong connection between the science program at JLab and the EIC

Structure of hadrons (3D imaging), Nuclear dependence, etc..

# DIS: Many complementary probes in a single facility




✓ **Inclusive**

e+p/A -> e' + X

Analyze only scattered electron (modern Rutherford experiment)

✓ **Semi-inclusive**

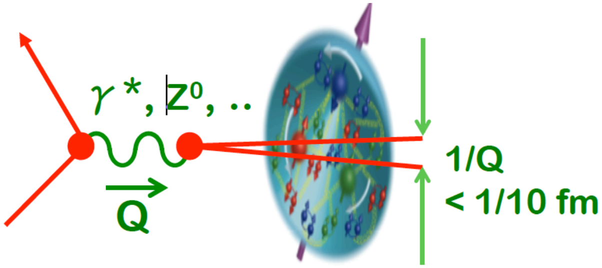
e + p/A -> e' + h ($\pi$,K,p, jet, ...) + X

Detect scattered electron in coincidence with hadrons/jets (much cleaner then in h-h collisions)

✓ **Exclusive**

e + p/A -> e' + h ($\pi$,K,p, jet, ...) + p'/A'

Detect everything, including scattered proton/nucleus ( or fragments)

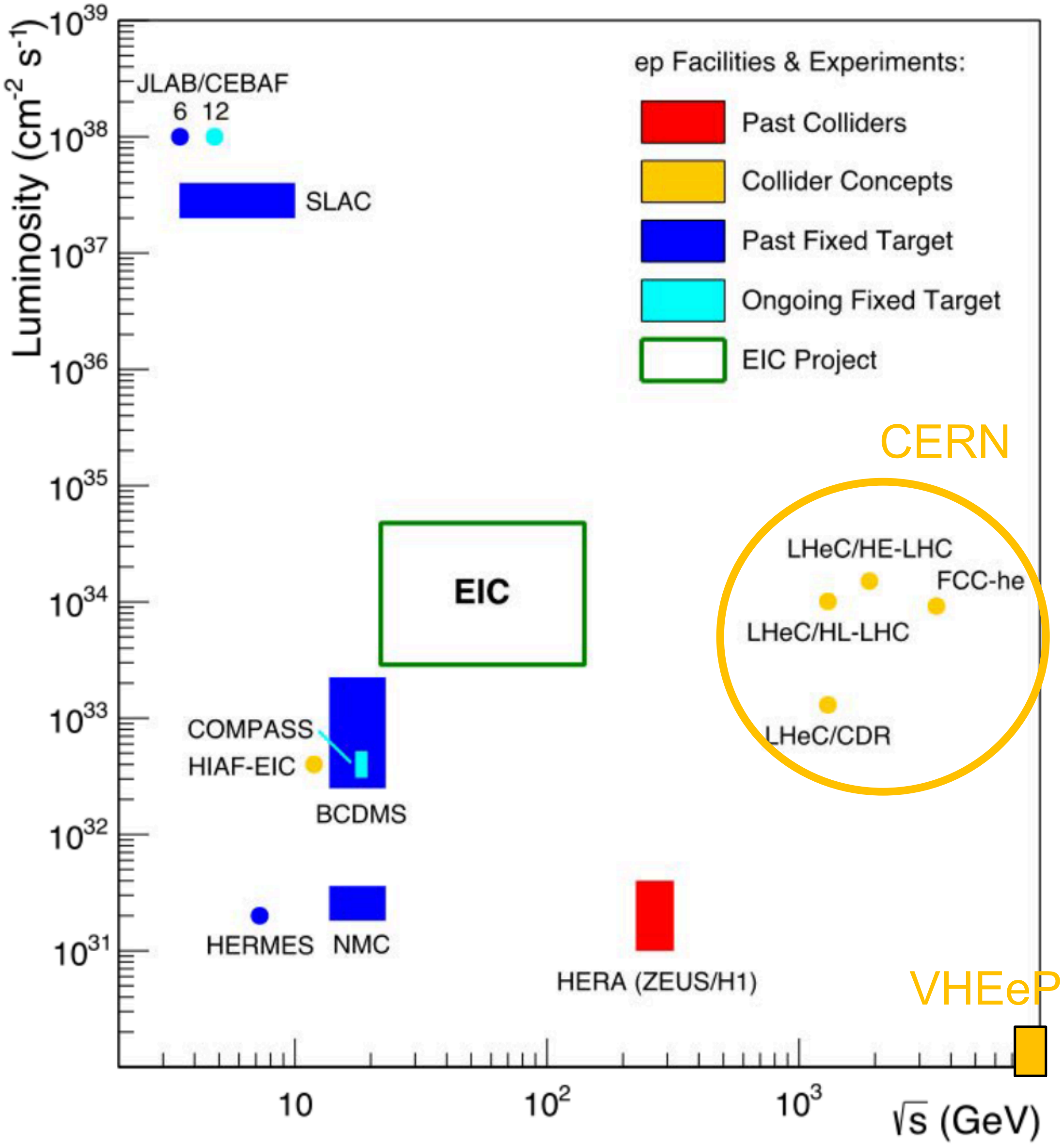



From 12 GeV to EIC:

Imaging -> Markus Diehl
Tagged physics -> Tanja Horn
GPDs -> Charles Hyde
QCD in nuclei -> Christian Weiss
Color propagation -> Taisiya Mineeva
.....

# Past, existing and proposed DIS facilities

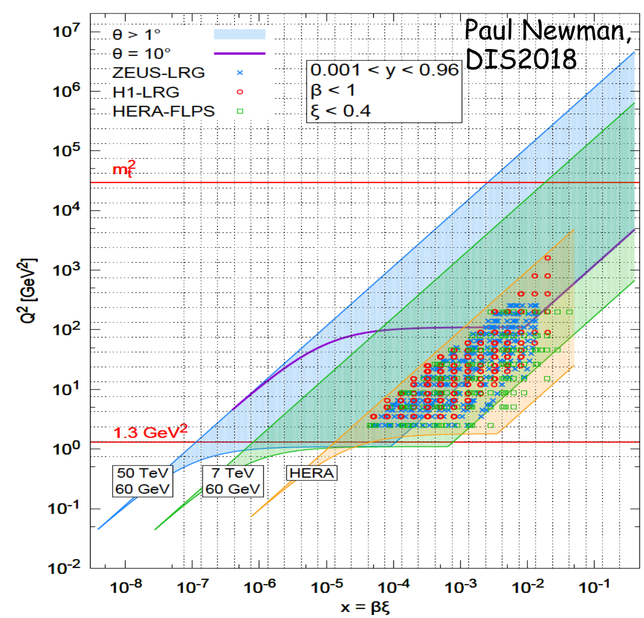
DIS2018




All DIS facilities in the world.

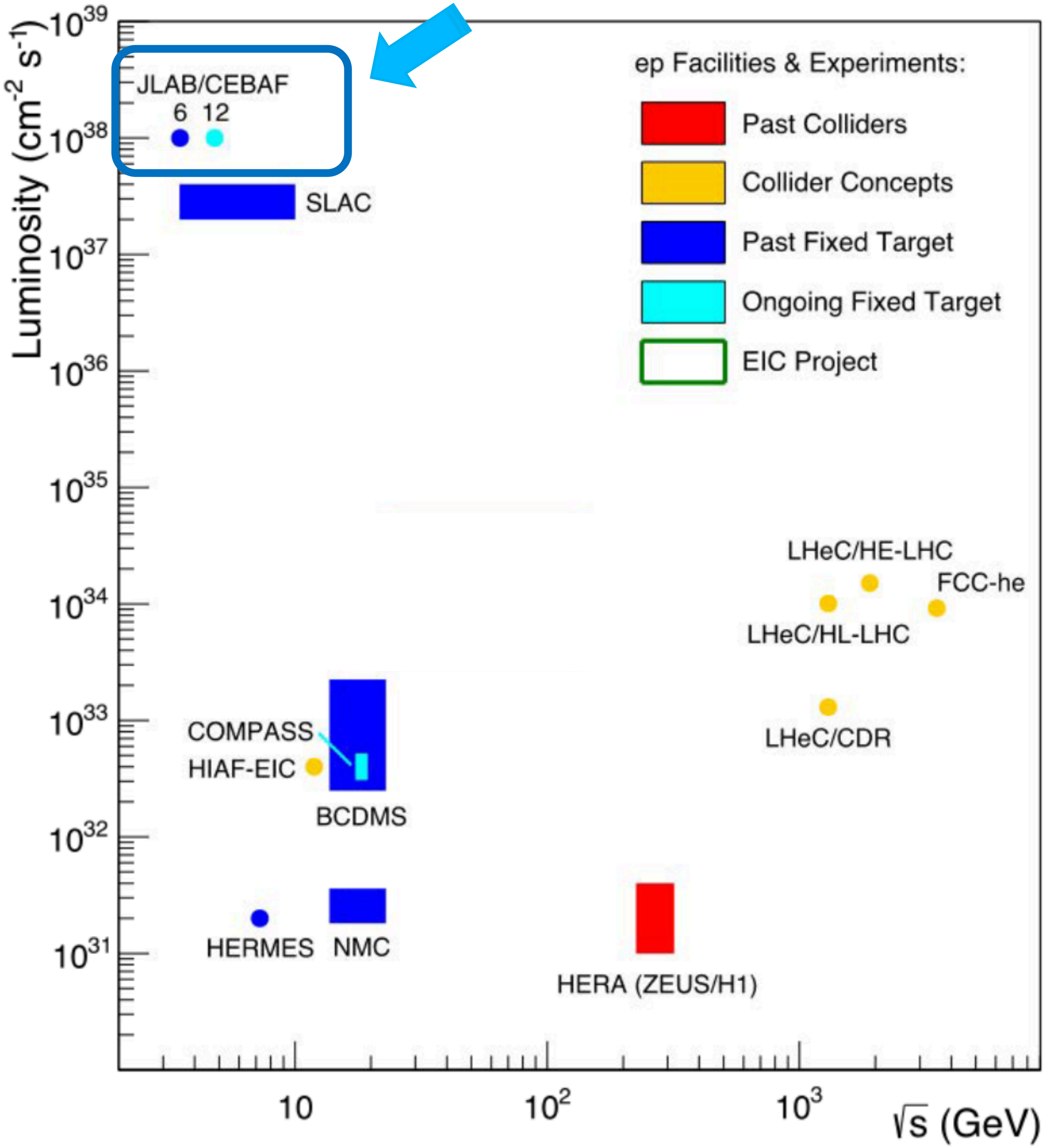
CERN is pioneering a high energy frontier:

- Beyond the Standard Model physics
- Higgs coupling
- Very low-x (saturation?)



# Past, existing and proposed DIS facilities

DIS2018

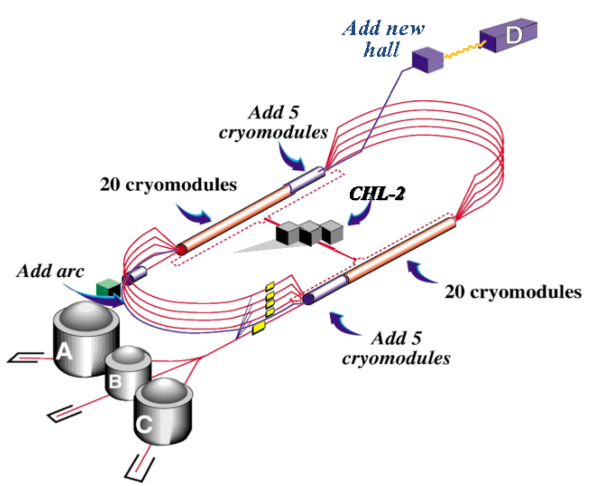



BUT for …

- ✓ 3D imaging of hadrons,
- ✓ nuclear or collective effects,
- ✓ hadron properties (mass, spin)

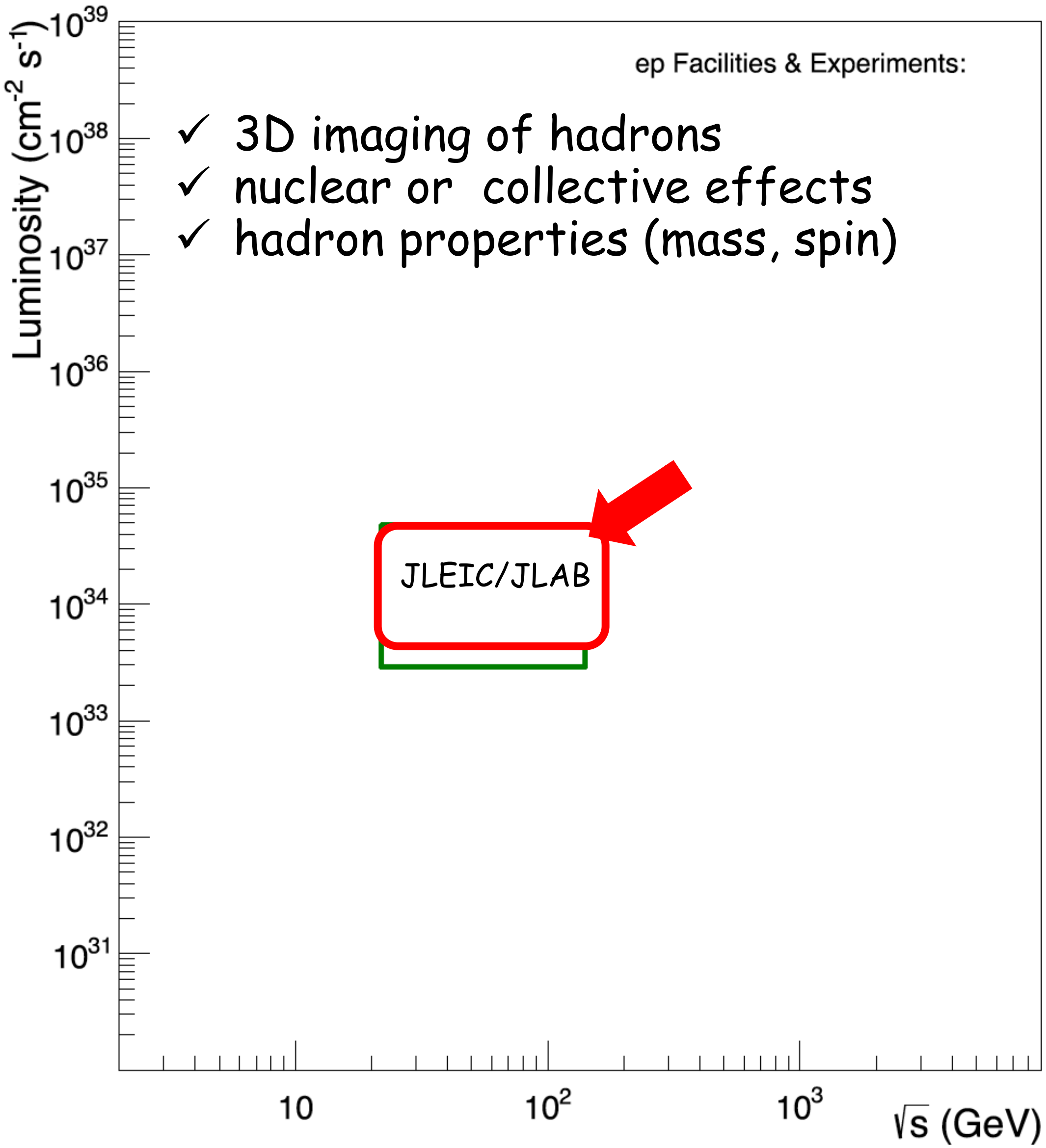
we need a high luminosity.

The existing DIS facility with a highest luminosity in the world is here at JLAB/CEBAF!



# Past, existing and proposed DIS facilities



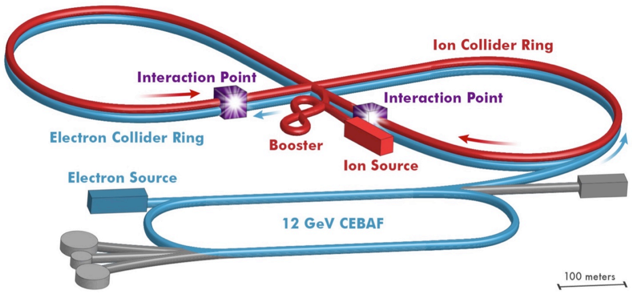



However,
if we ask for:

- Highest luminosity & wide reach in $\sqrt{s}$
- polarized lepton & hadron beams
- nuclear beams

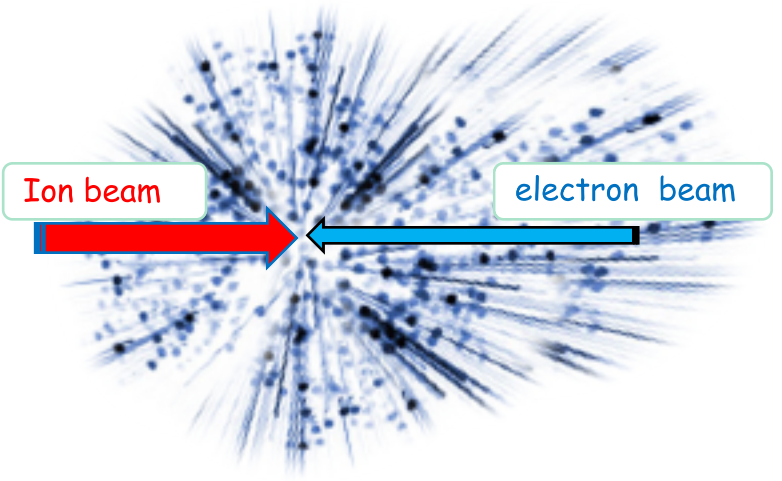
JLEIC will be a unique facility.

No other machine, existing or planned can address the physics of interest satisfactorily.



# Detector design for JLEIC

Collider experiments




-Total acceptance coverage ($4\pi$) including far-forward/rear detection

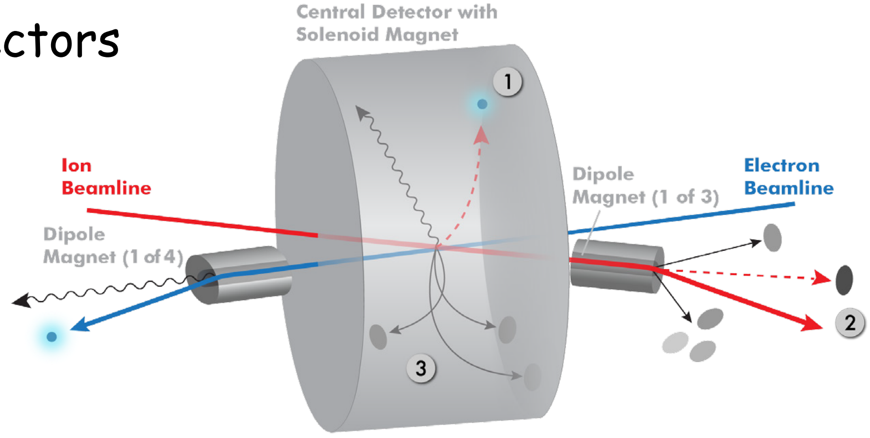
-Integration with accelerator

-High precision measurements:

- statistics (~100fb$^{-1}$/measurement )
- minimize systematic uncertainties (<1%)

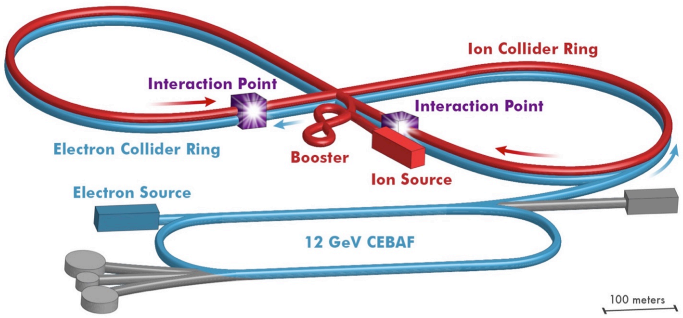
-Advanced detector technology:
High resolution tracking and vertex detectors
High energy resolution calorimeter
Particle identification ,etc..

-Minimize background

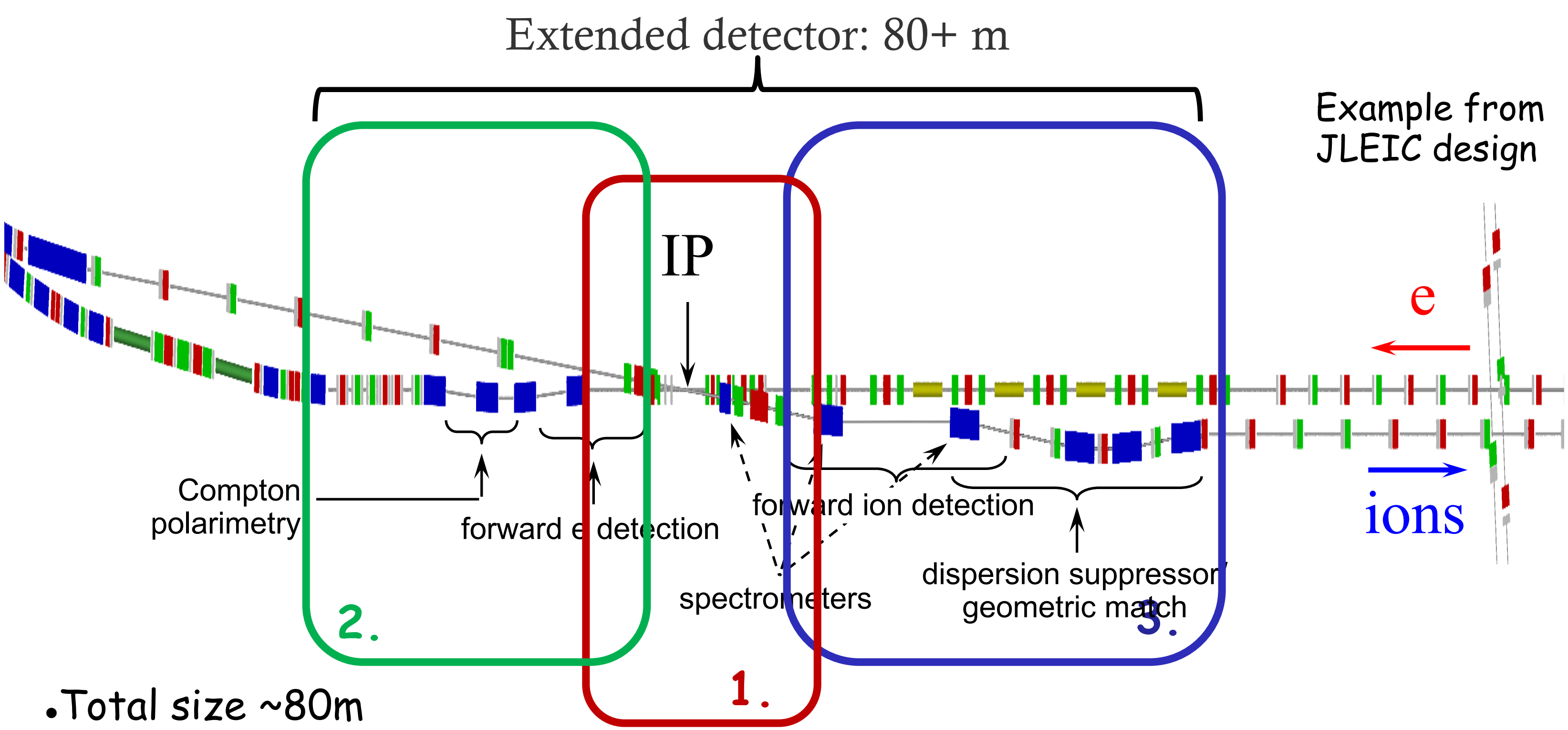


# Integration with accelerator

- IP placement to reduce a background
  - synchrotron radiation
  - beam gas events
  - neutrons
- Crossing angle (50mrad) to create a room for forward detection



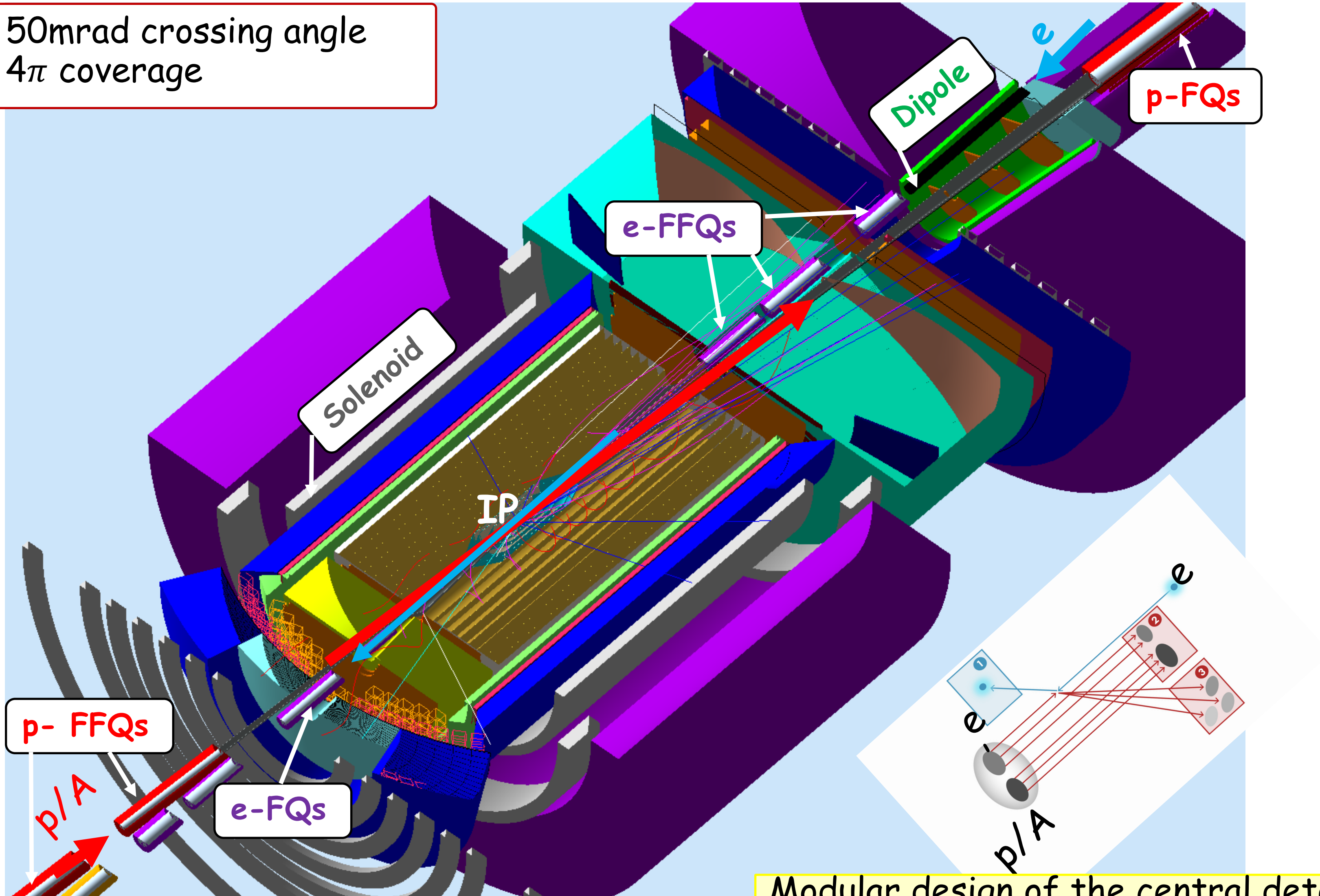

Example from JLEIC design




- Total size ~80m
1. Central detector ~10m
2. Far-forward electron detection ~30m
3. Forward hadron spectrometer ~40m

# EIC Central detector (top view)

- ✓ 50mrad crossing angle
- ✓ 4π coverage




Modular design of the central detector
GEMC simulation in docker

# GEMC with docker

## Getting started

1. Install Docker

2. Run container

   ***docker run -p 6080:6080 -v /my/data/dir:/data -it --rm electronioncollider/jleic:1.0.*** *4*

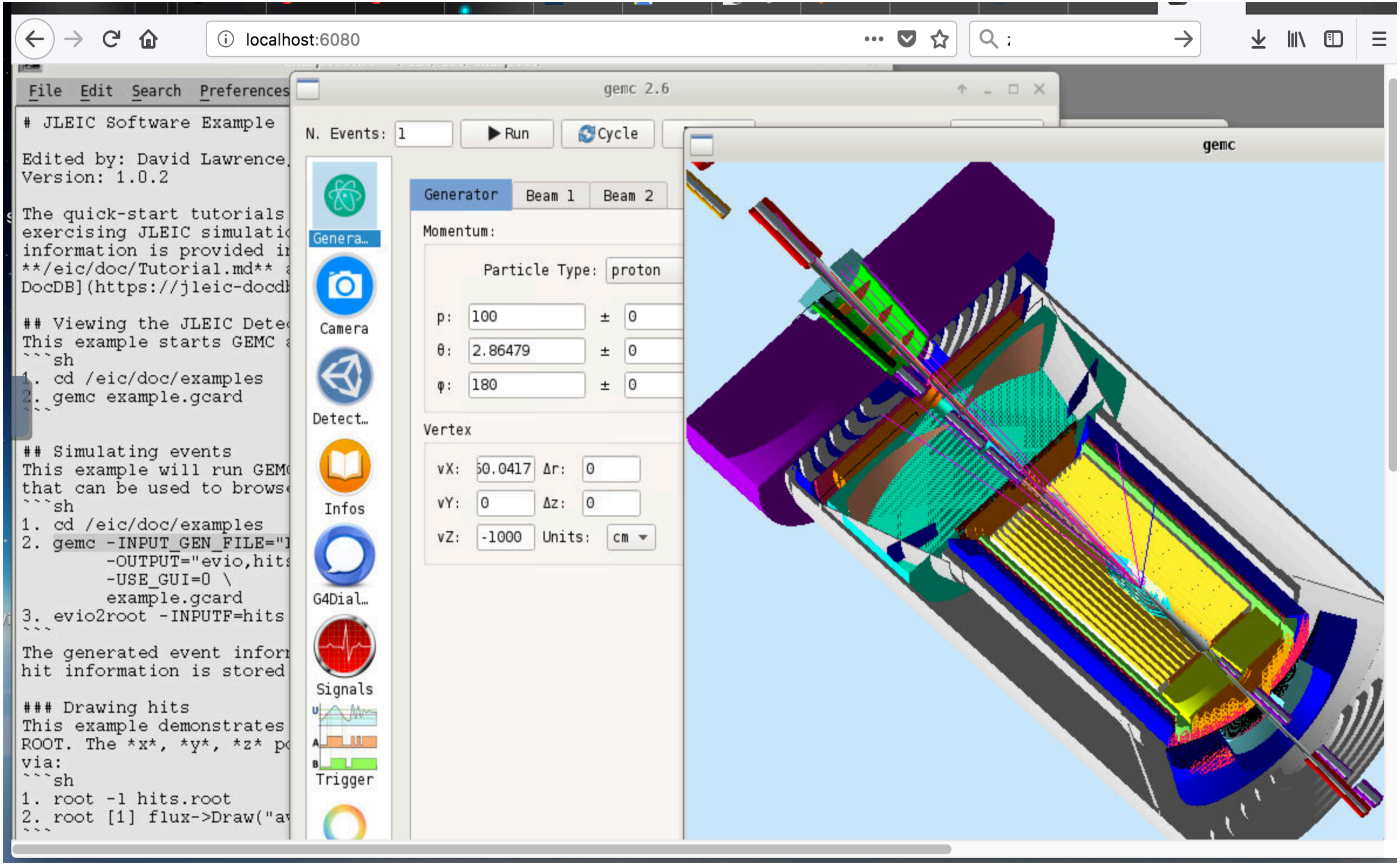
3. Point browser to:

   ***http://localhost:6080***

For tests on ifarm:
> singularity shell shub://electronioncollider/jleic:1.0.4

requires :
> setenv https_proxy https://jprox.jlab.org:8082
> module load singularity-2.5.1

# GEMC with docker



# GEMC with docker:README

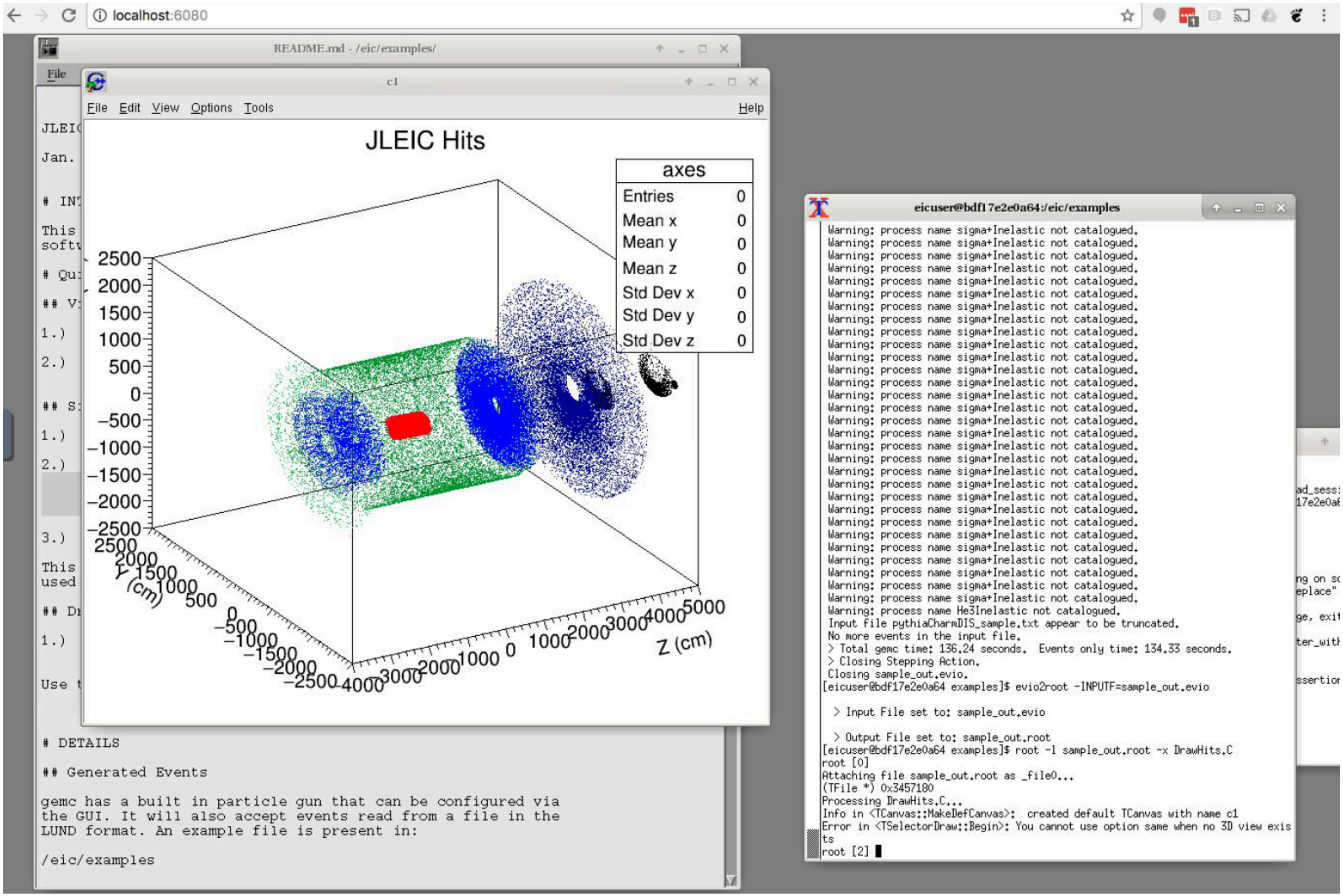
```
JLEIC container example README

Jan. 31, 2018  David Lawrence


# INTRODUCTION

This provides an example for exercising JLEIC simulation
software in this container.

# Quick Start

## View Geometry

1.)  cd /eic/doc/examples

2.)  gemc example.gcard


## Simulate events

1.)  cd /eic/doc/examples

2.)  gemc -INPUT_GEN_FILE="LUND,pythia-sample.lund" \
          -OUTPUT="evio,sample_out.evio" \
                  -USE_GUI=0 \
                  example.gcard

3.)  evio2root -INPUTF=sample_out.evio

This should produce a file sample_out.root that can be
used to browse and plot data.
```

Event generator (LUND file)

Geometry

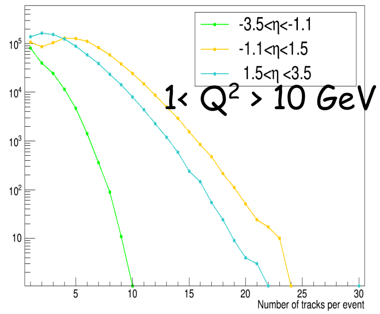
Output file with hits

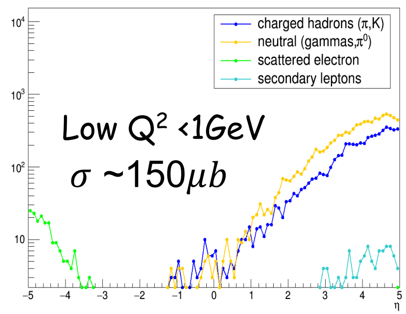
# GEMC with docker (hits)

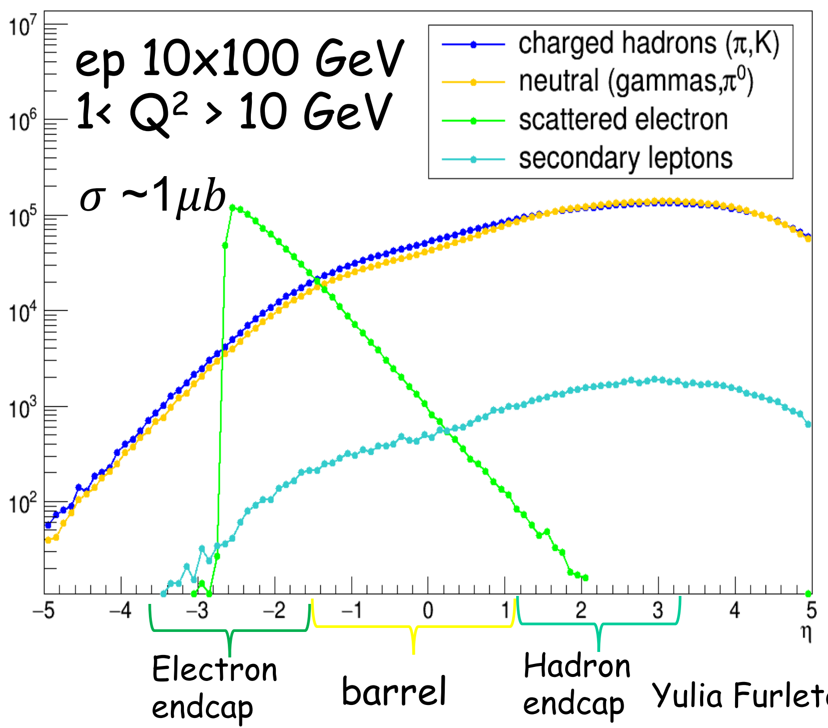


# Tracking detectors

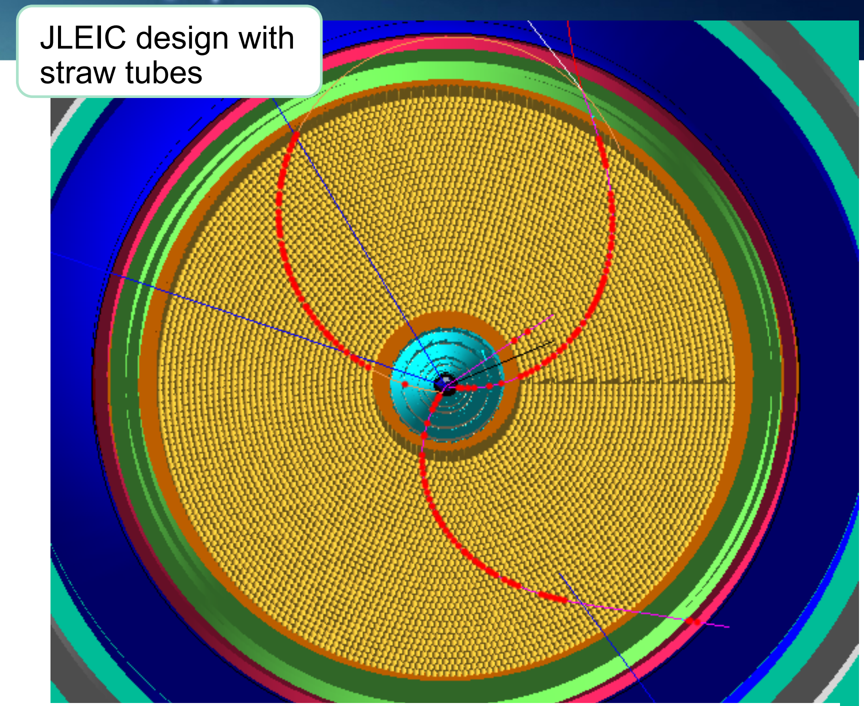
- Several options for central tracking: (TPC, straw tubes, Drift chambers, Si)
- At EIC, momentum resolution below few % is required

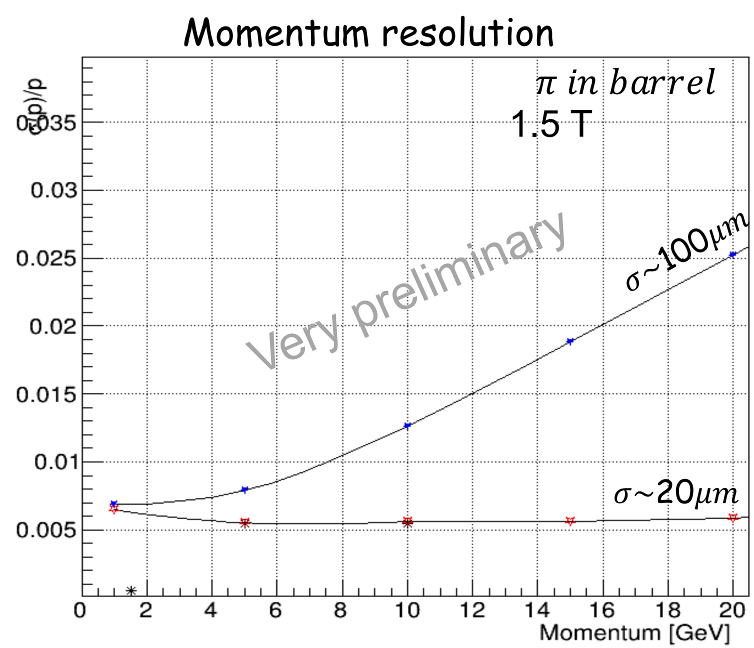



Yulia Furletova

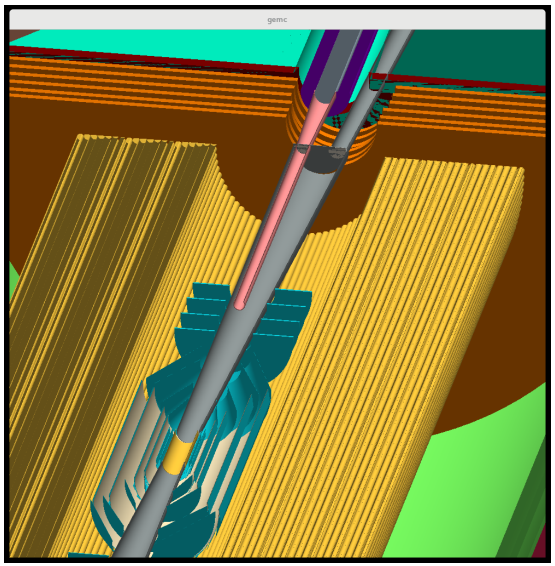


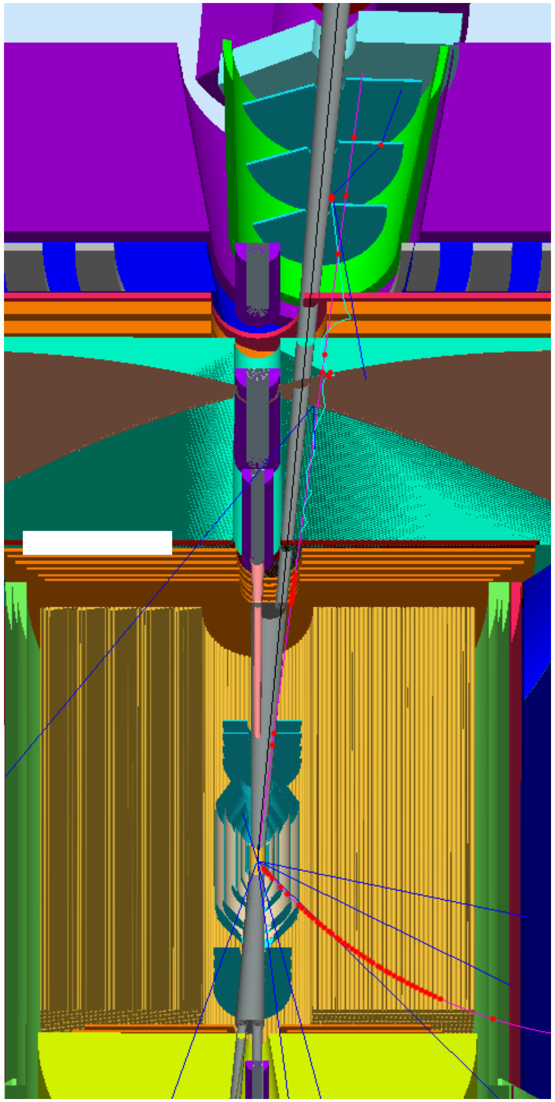

Yulia Furletova

# Tracking

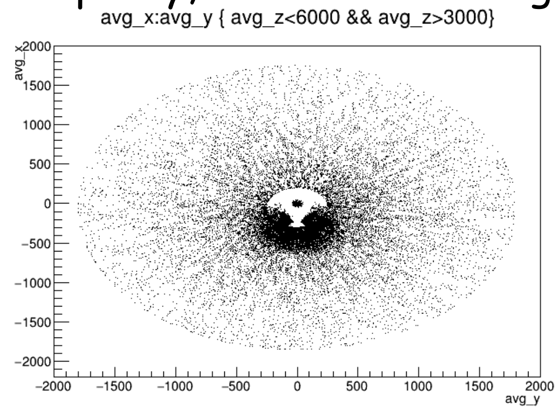
Vertex detector
(MAPS, DEPFET,DS Si)
- Number of layers, granularity
- Endcaps



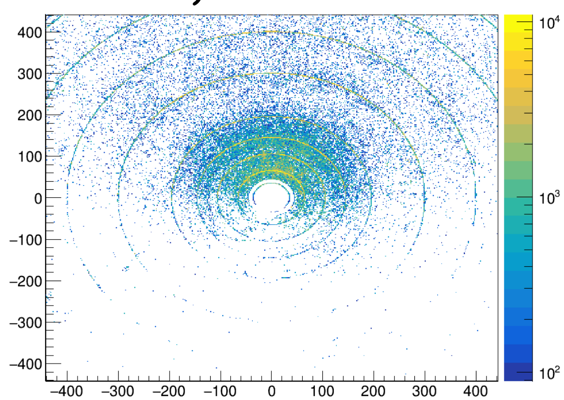

Forward Dipole at JLEIC to improve momentum reconstruction

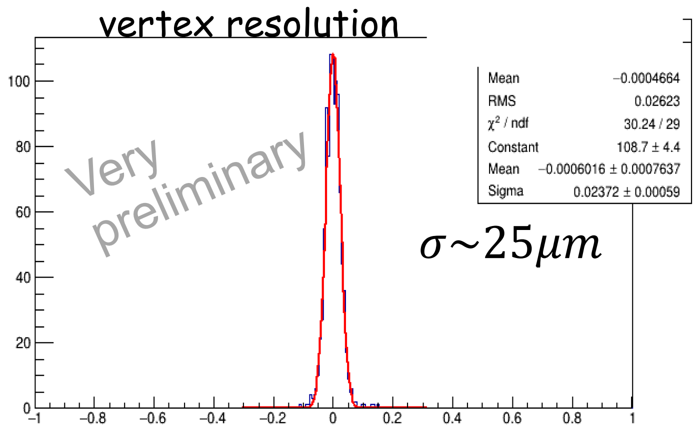


Occupancy, detector coverage




Occupancy with background (here with synchrotron radiation)






$\sigma \sim 25\mu m$

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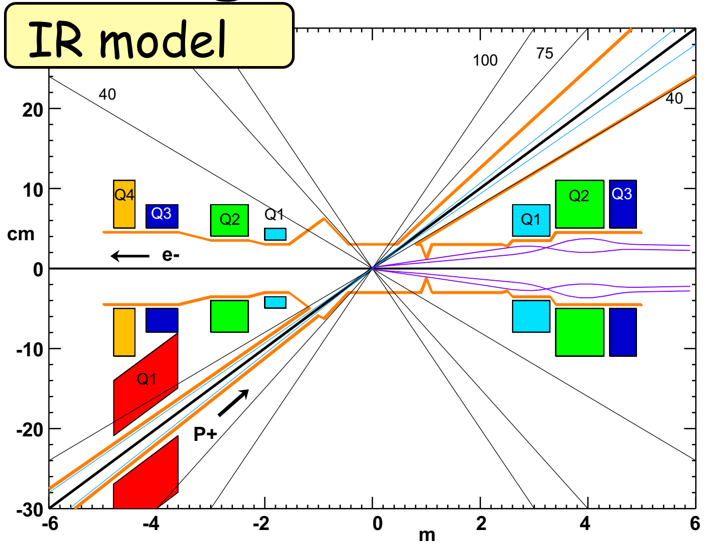
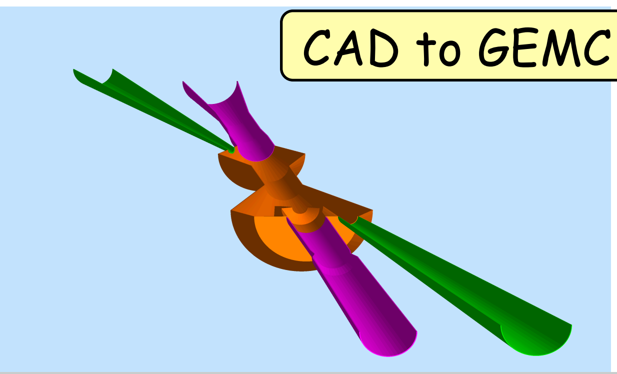
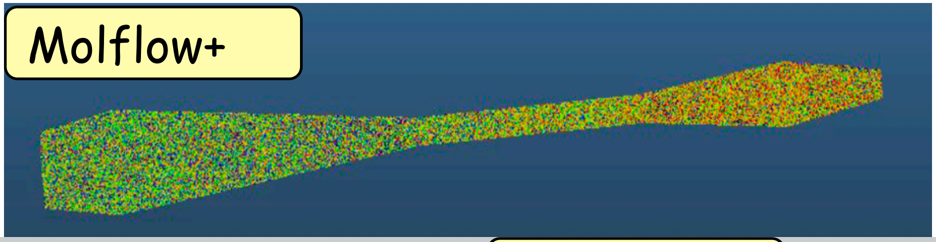
# Background and IR design

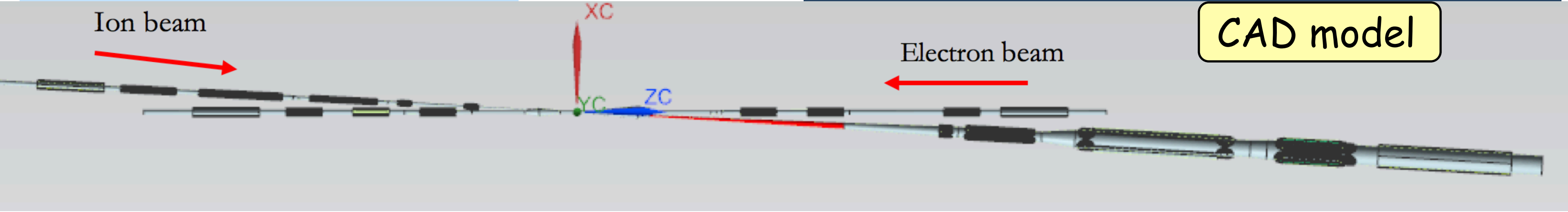
eRD21 L. Elouadrhiri et al. (JLab), C. Hyde (ODU), M. Sullivan (SLAC)



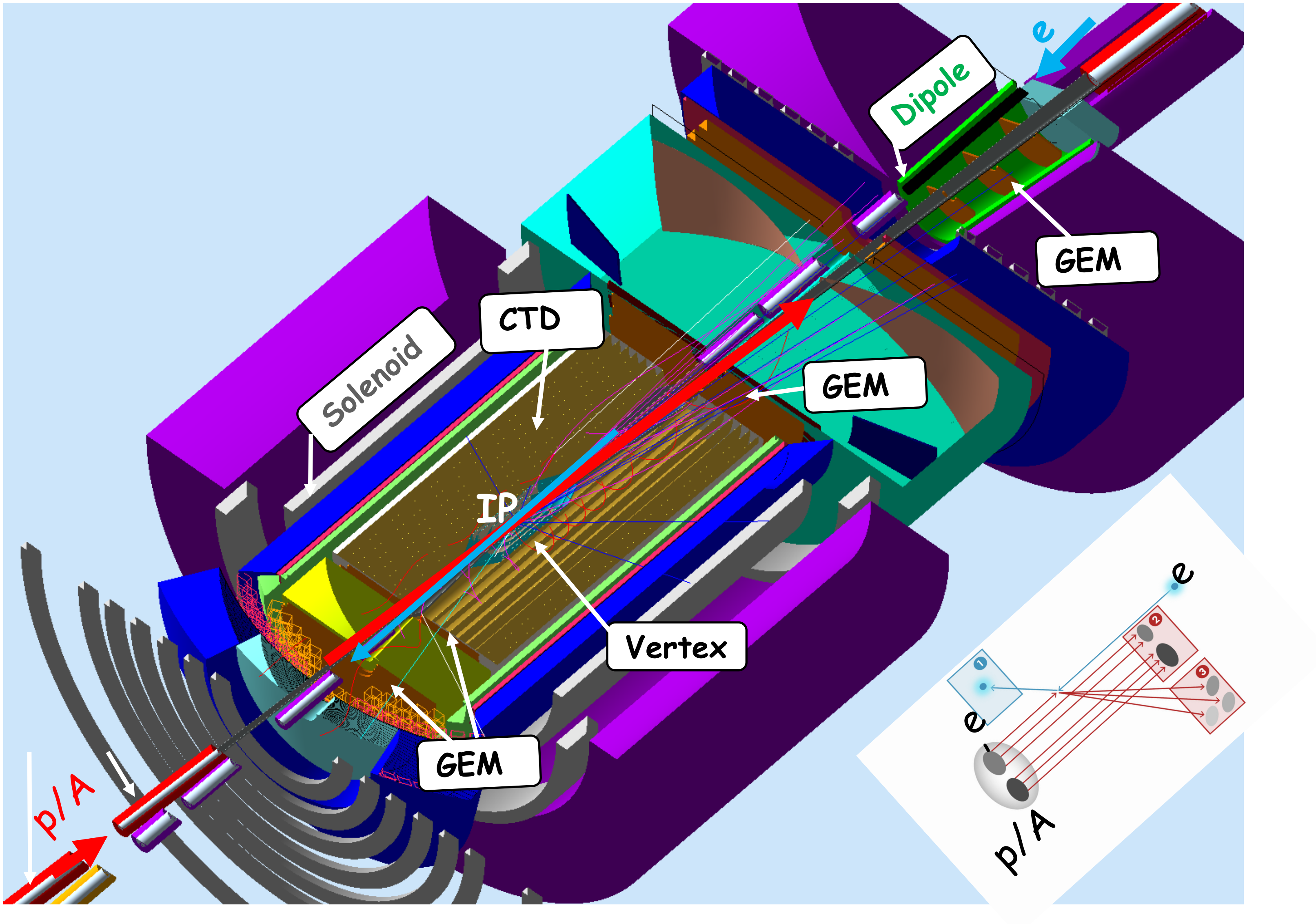

- Minimum multiple scattering in the beam pipe material
- Synchrotron radiation collimation
- The CAD model has been updated with the latest electron beam transport requirements
- Added water cooling channel to the central vacuum chamber
- CAD to GEMC
- Molflow+ simulations for vacuum evaluation



# Tracking



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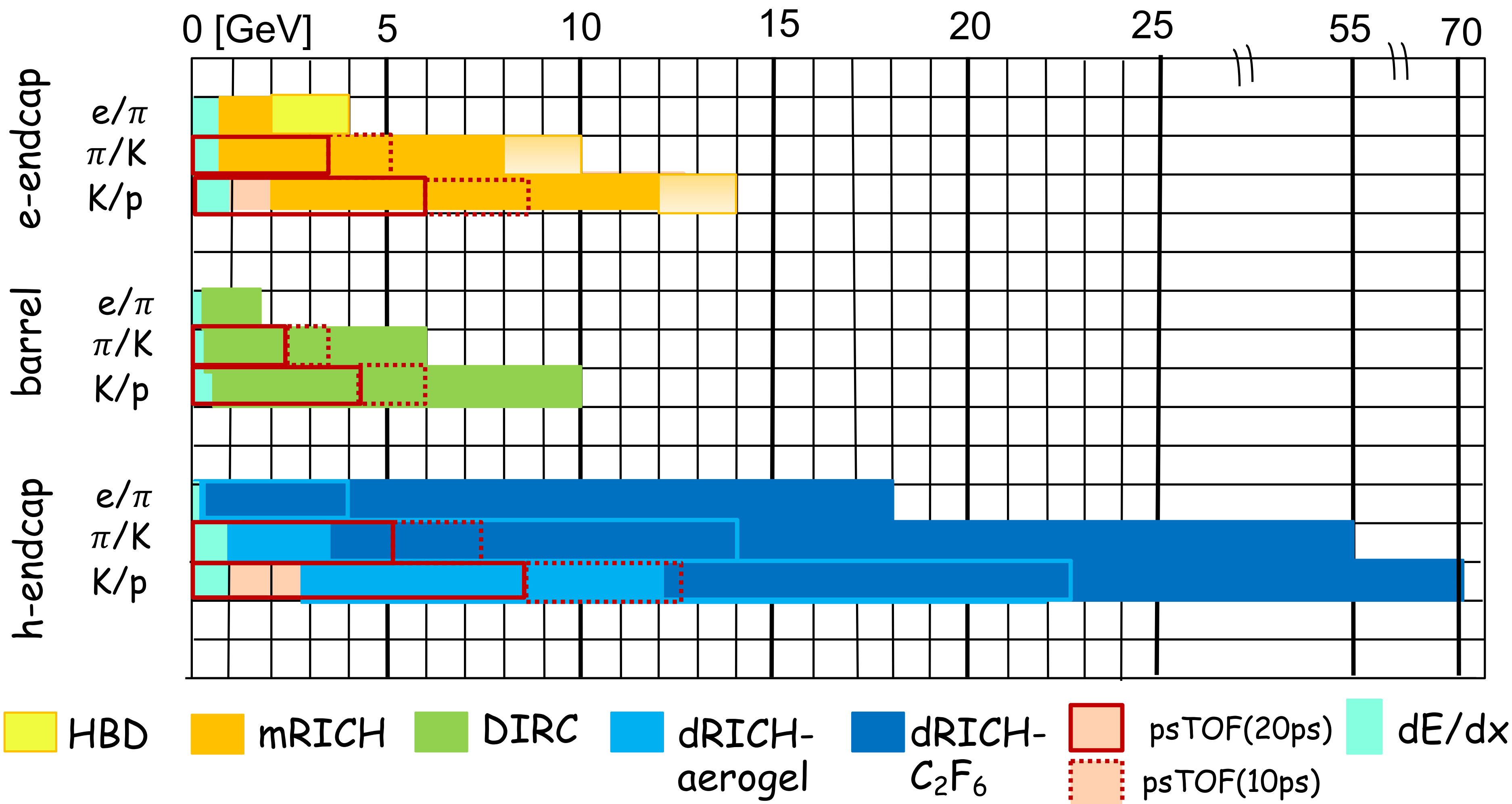
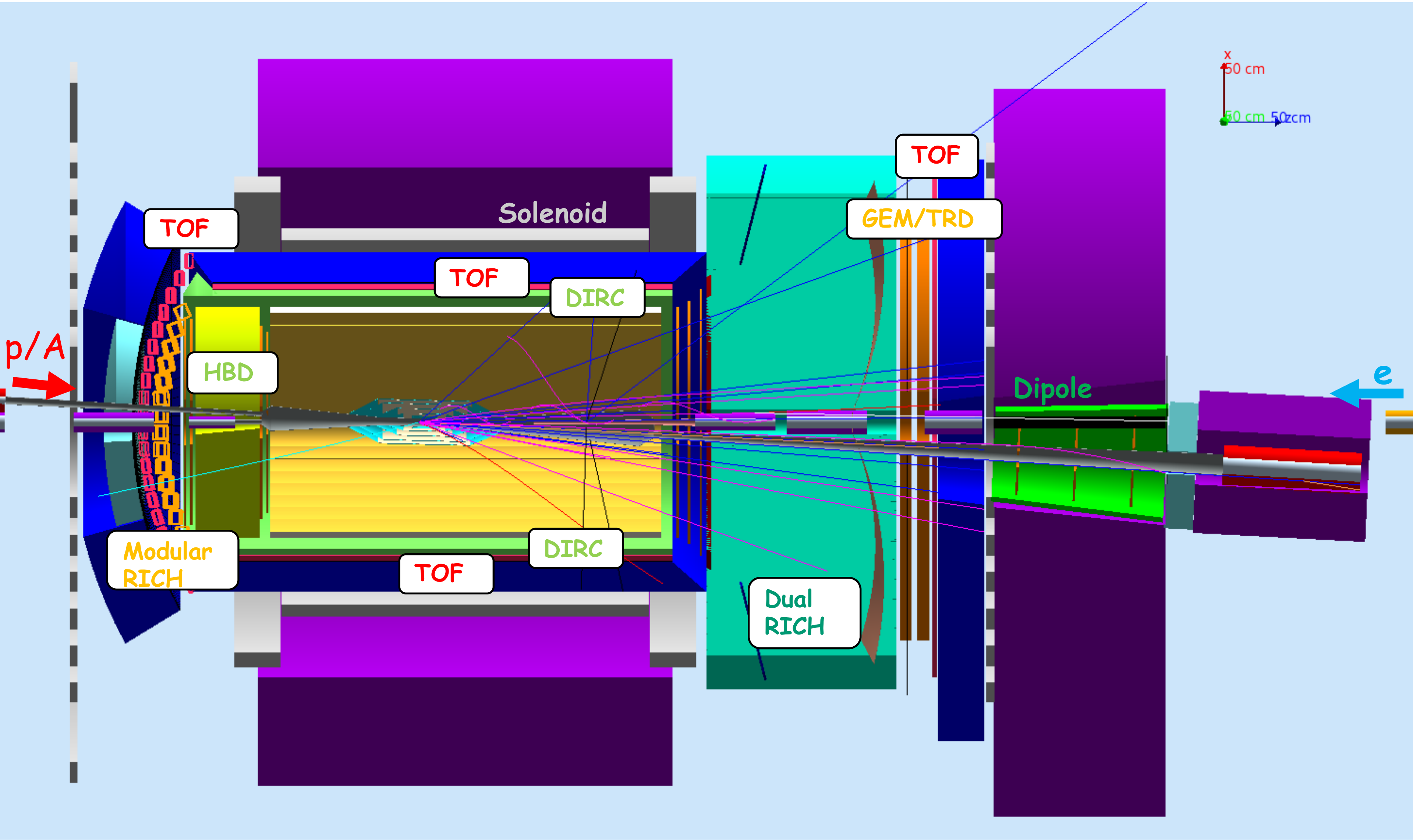
# Individual hadrons (π, K, p): Cherenkov, TOF

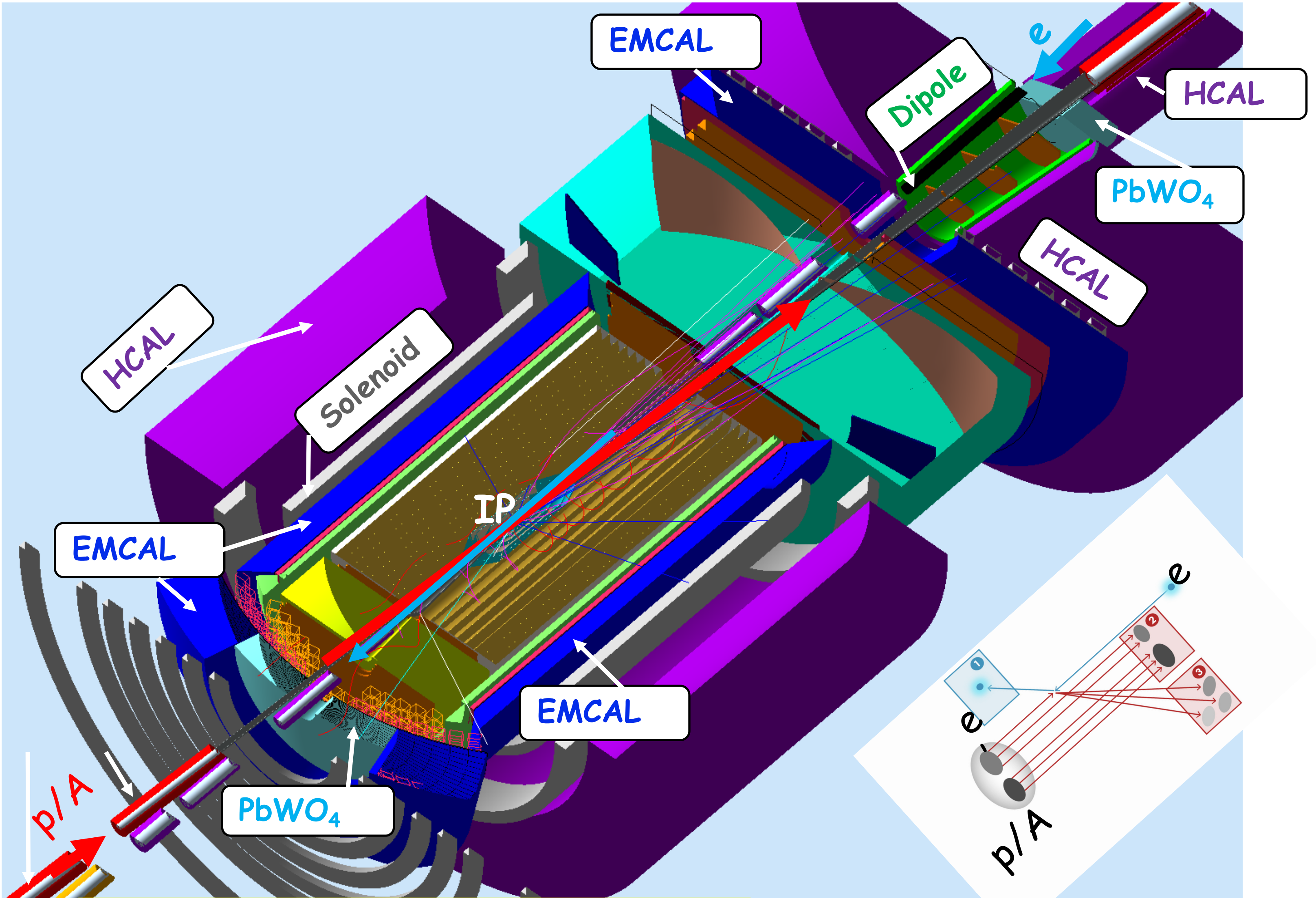



** Here, electron/hadron separation only from Cherenkov detectors is shown. Main e/h rejection is done by calorimeters (+TRD).

# JLEIC central detector( top view) /PID



# Calorimeter



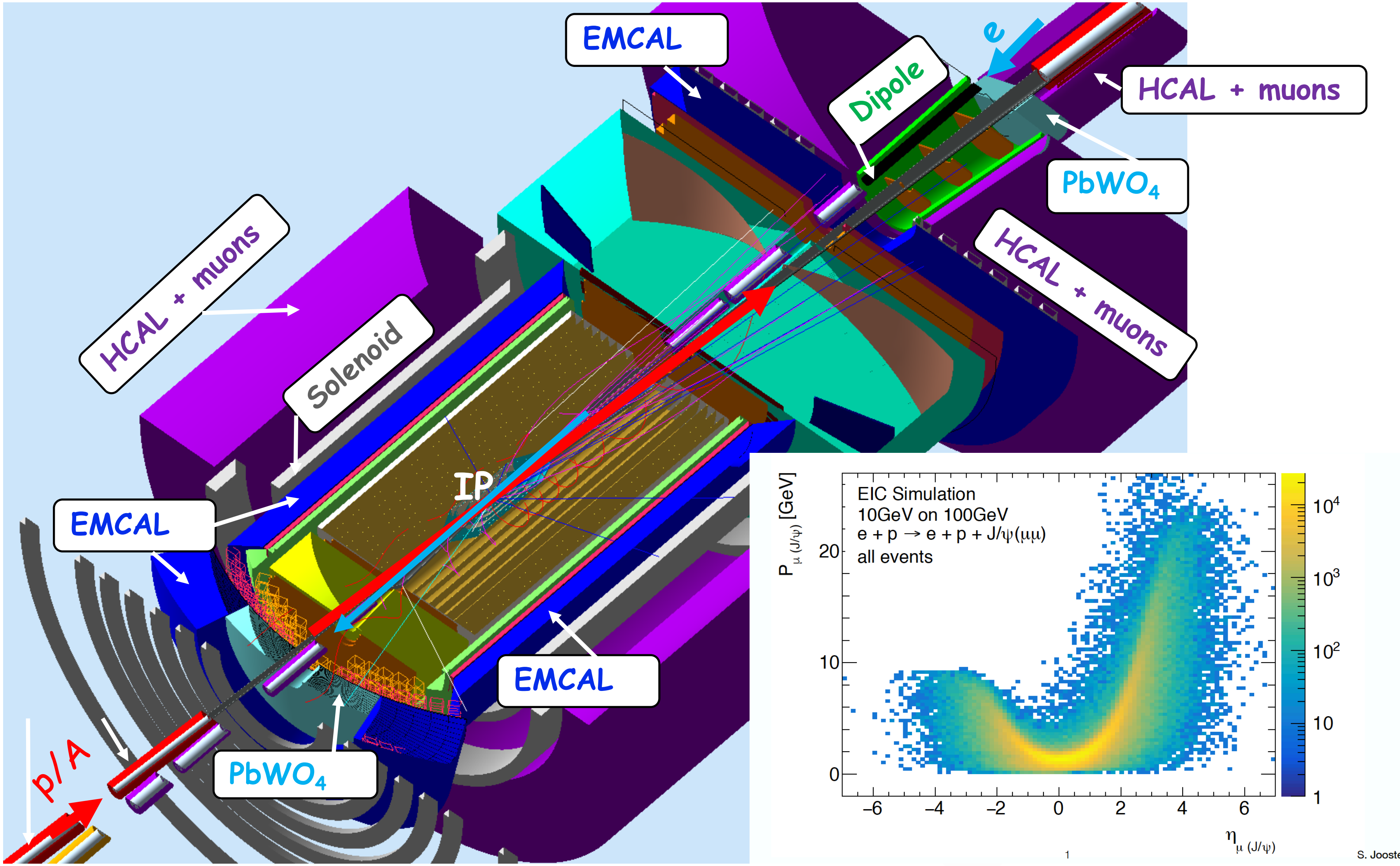

PbWO$_4$

- PbWO$_4$ Close to the beam – more precise and more radiation hard calorimeter

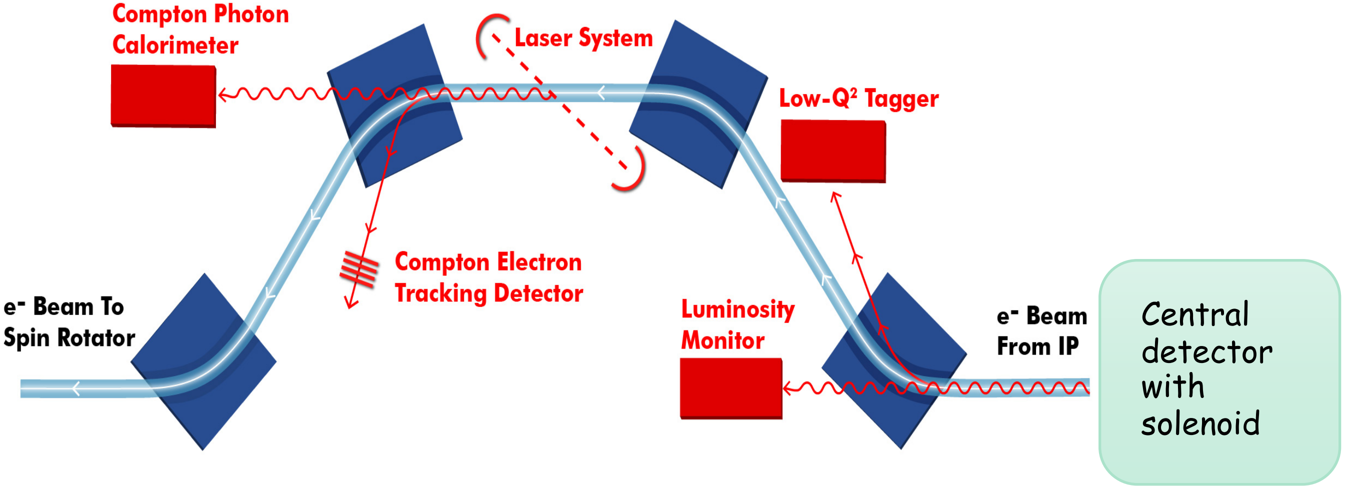
Shashlyk

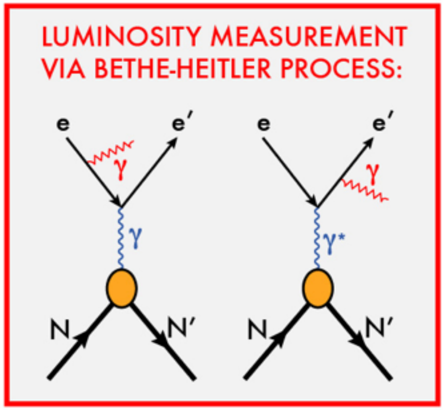
- Barrel and endcaps – less expensive

# Muon detection



# Chicane for Electron Far-Forward Area



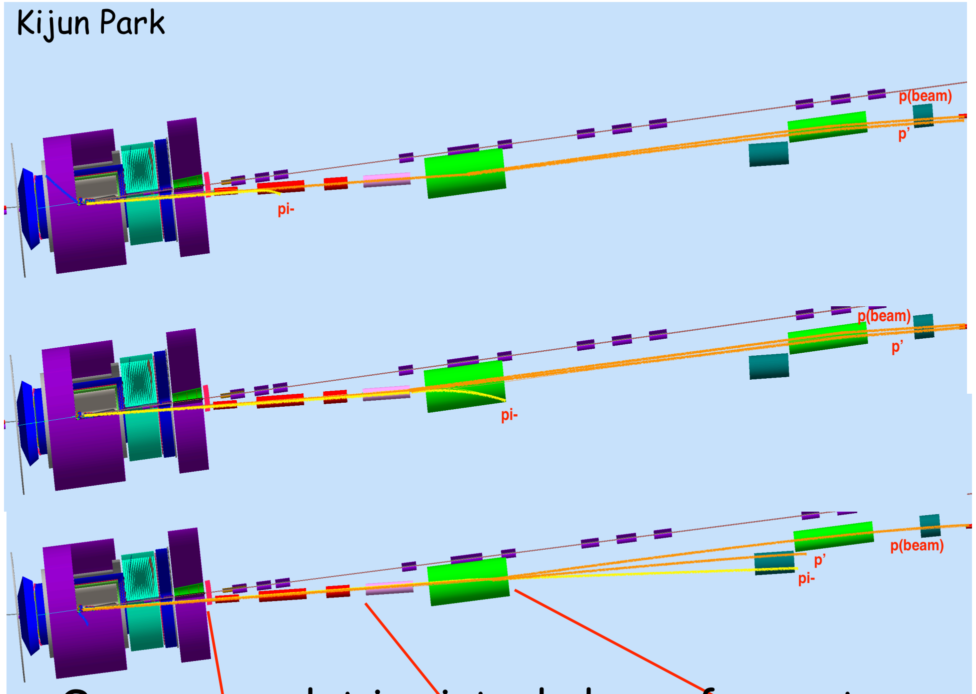




- **Low Q2 tagger**
  - ✓ For low $Q^2$ electrons
- **Luminosity monitor:**
  - ✓ Luminosity measurements via Bethe-Heitler process
  - ✓ First dipole bends electrons
  - ✓ Photons from IP collinear to e-beam
- **Polarization measurements (similar to JLAB/Hall-A/C chicane)**
  - ✓ First two Dipoles compensate each other
  - ✓ The same polarization as at IP
  - ✓ Minimum background and a lot of space.
  - ✓ Measurements of both Compton photons and electrons

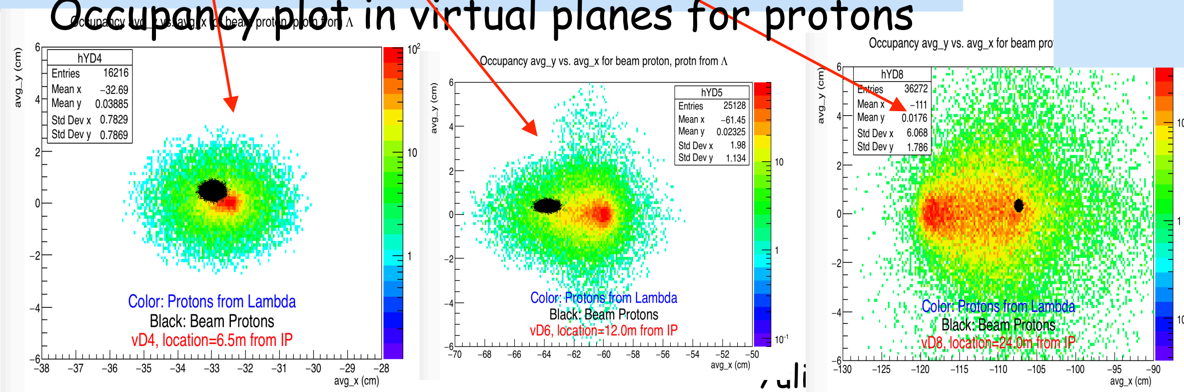
# Far-forward ion direction area

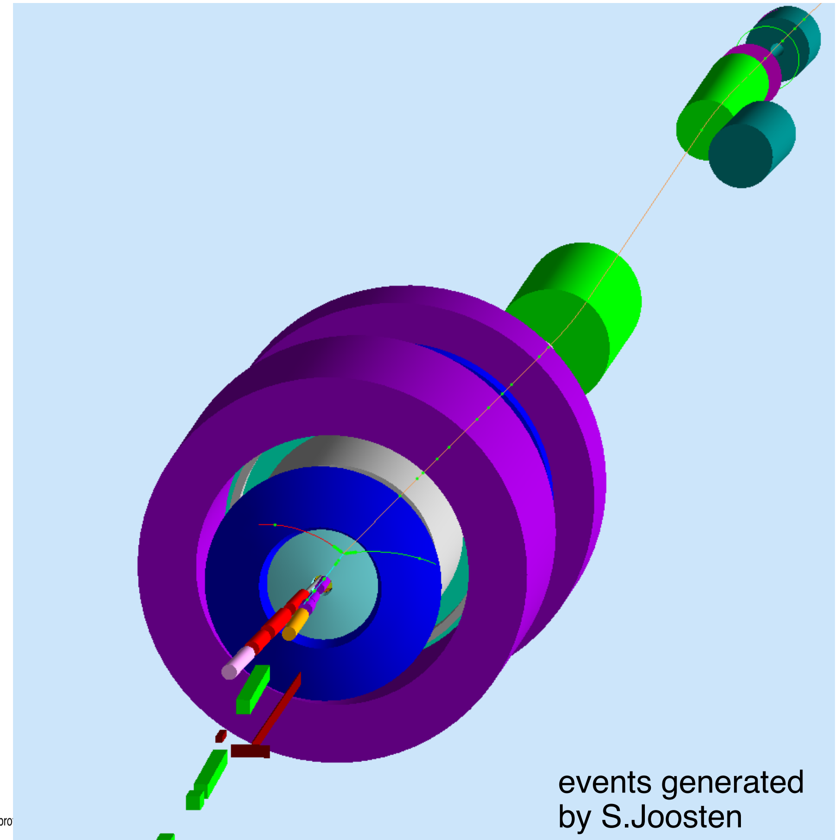
- Tracking for Tagged DIS events
- $\Lambda$ -> p+ $\pi$
- Exclusive J/$\psi$

Kijun Park




Occupancy plot in virtual planes for protons

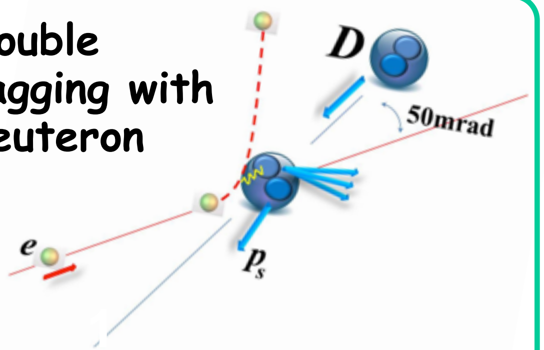


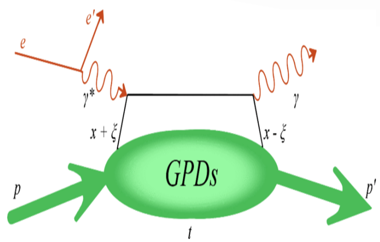
events generated by S.Joosten

# Far-forward ion direction area

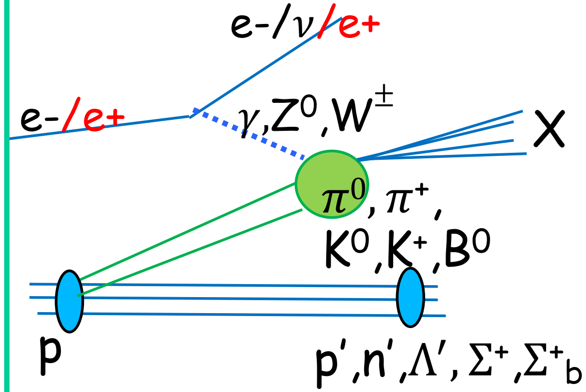
**Double tagging with deuteron**

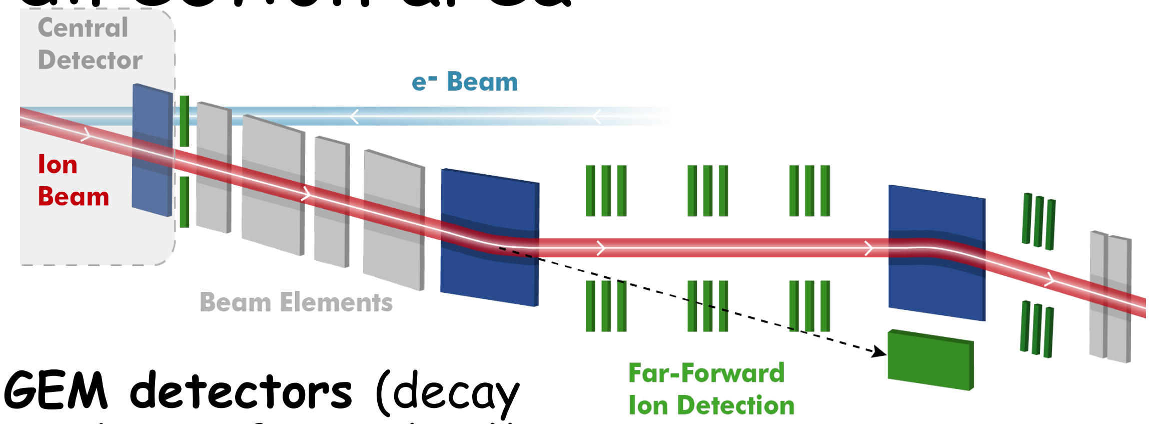



**DVCS / Diffraction**

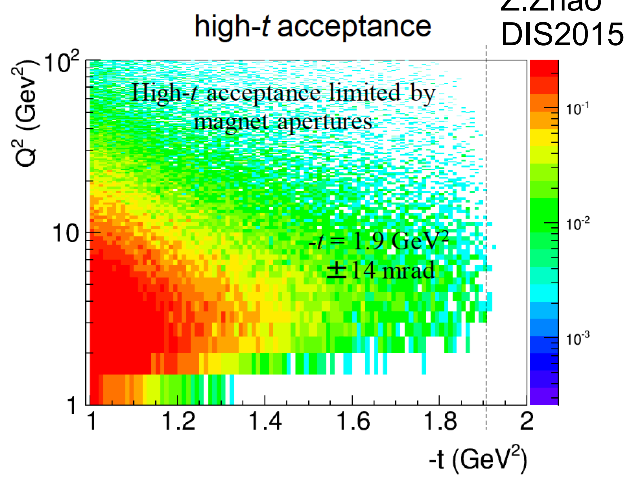


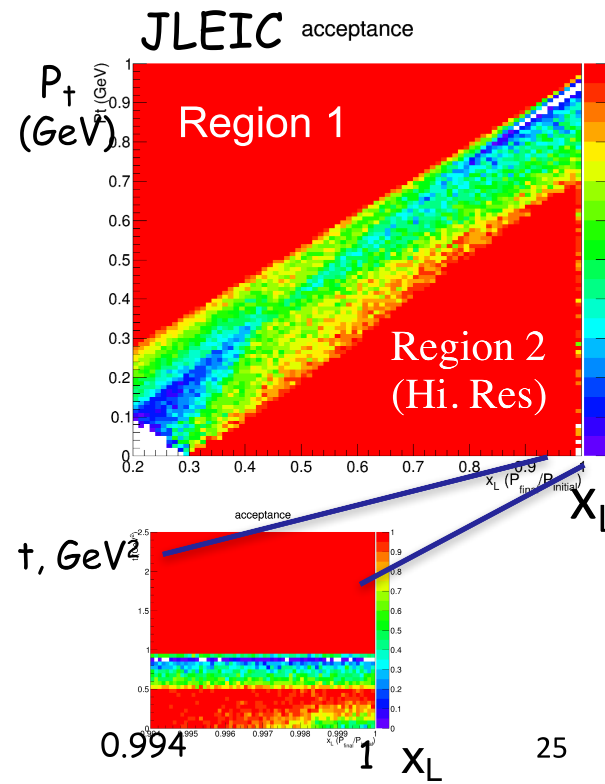

**Pion/Kaon structure**




- **GEM detectors** (decay products of $\Lambda', \Sigma$ $(\pi, K)$)
- **Roman-pots** for (p)-tagging
- **Zero degree calorimeter** for (n)-tagging
- **Double tagging**



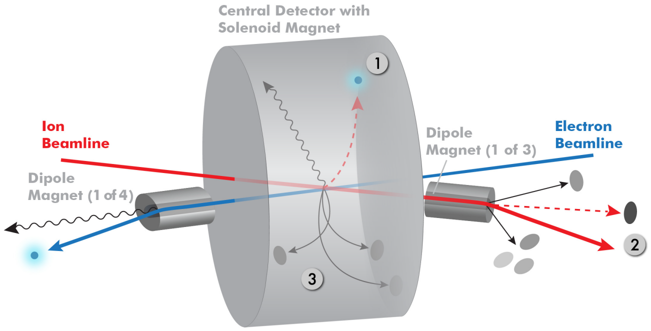



# JLab and User involvement in EIC R&D

| | |
|---|---|
| • Calorimeter Consortium | |
| - PbWO4 Crystal R&D (synergy with JLab/NPS) | CUA, Orsay, Giessen |
| • Tracking Consortium | Saclay, Temple, UVA |
| • Particle Identification Consortium | |
| - DIRC | ODU, CUA, GSI, … |
| - Dual RICH | Duke, INFN, W&M |
| - Modular RICH | INFN, … |
| - Sensors in high B field | USC, Jlab |
| • Compton Polarimetry Electron Detector | JLab, W&M (collaborating w Kansas) |
| • Software Consortium | JLab, ANL, SLAC, W&M.. |
| • GEM-Based TRD (new since 2017) | JLab, Temple, UVA |
| • Background Simulations (new since 2017) | JLab, UConn, SLAC, … |
| • Streaming readout Consortium (new, 2018 proposal) | SBU, INFN Genova,CUA, MIT, Jlab |

*List likely incomplete …*

# EIC UG working groups

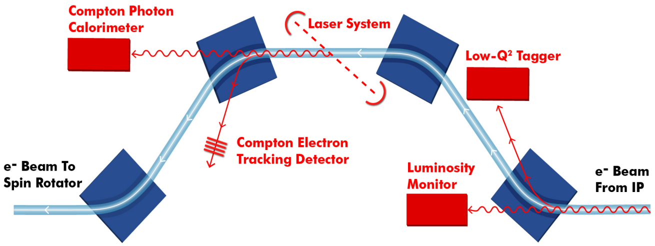



## EICUG IR / Luminosity Working Group

- interface between accelerator / IR design and the physics requirements
- proper implementation of the physics program in particular for forward / backward detection

Conveners:

- Accelerator / IR: C. Montag (BNL), **V. Morozov (JLab)**
- Physics: **C. Hyde (ODU),** A, Kiselev (BNL)

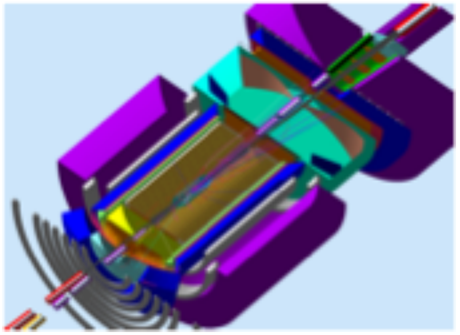



## EICUG Working Group on Polarimetry

- plan / develop the optimal methods and techniques for measuring the electron and ion beam polarization with high precision

Conveners

E.-C. Aschenauer (BNL), **D. Gaskell (JLab)**



## EICUG Software Working Group

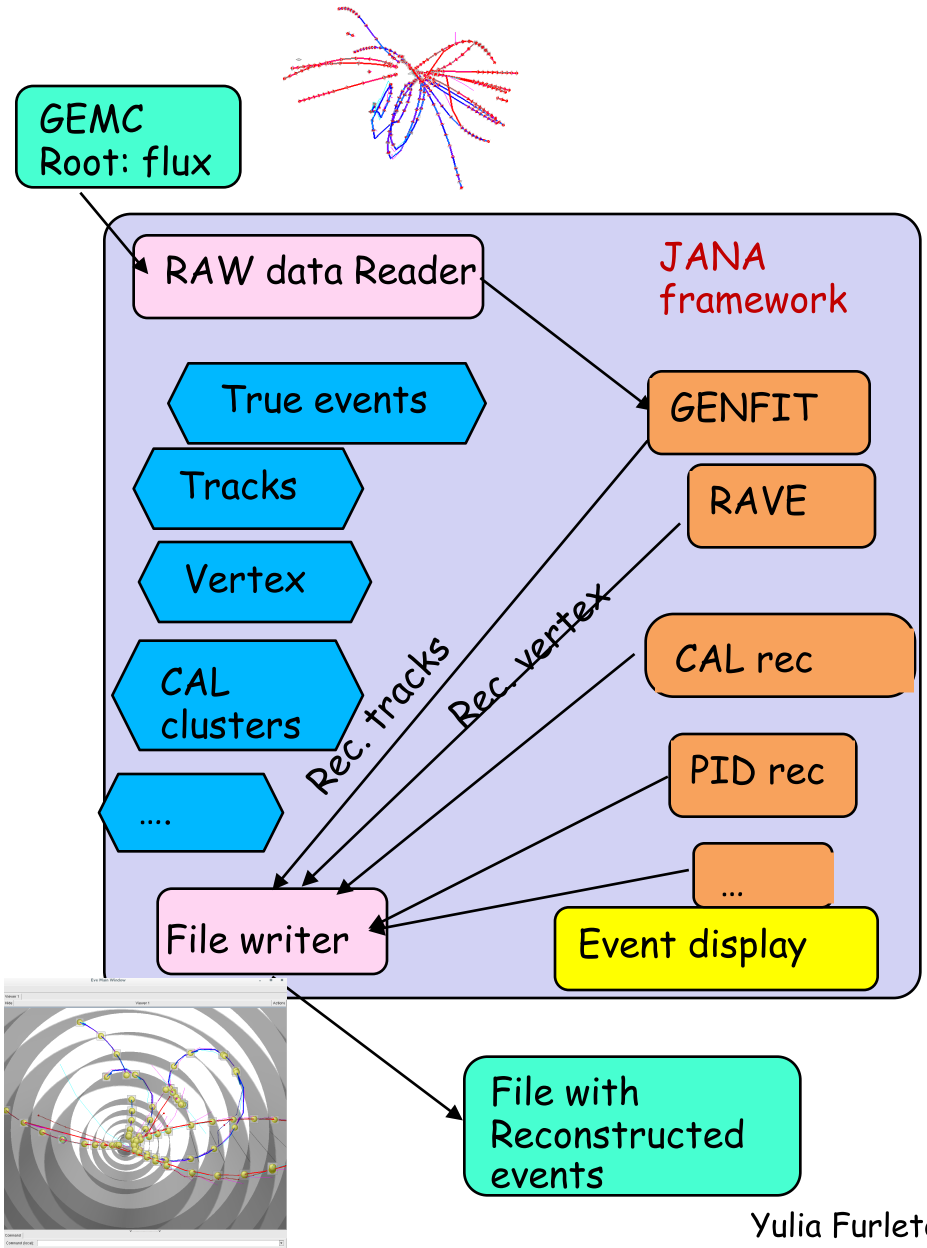
- simulations of physics processes and detector response to enable quantitative assessment of measurement capabilities and their physics impact

Conveners

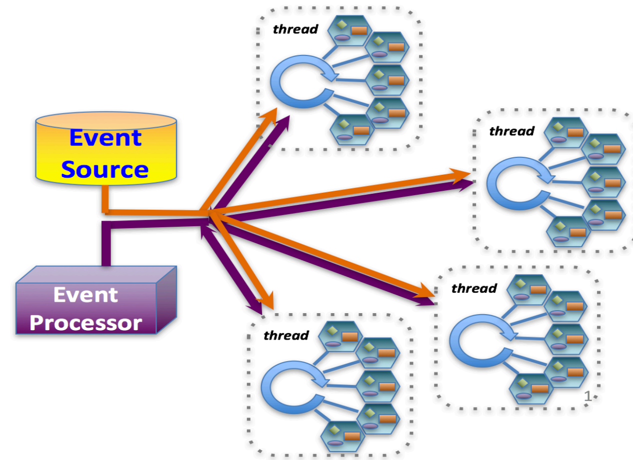
D. Blyth (ANL), **M. Diefenthaler (Jlab)**

# JANA based reconstruction (in progress)

David Lawrence




- ✓ *Modern C++, multi-thread framework*
- ✓ *An official framework in Hall-D*
- ✓ *first version of the event reconstruction toolkit of the EIC Software Consortium.*




- ✓ *Recommendation from EIC R&D advisory committee towards unifying the software of the various eRD projects into one environment.*
- ✓ *Database for simulated and reconstructed events ("HepSim" (ANL) … )*

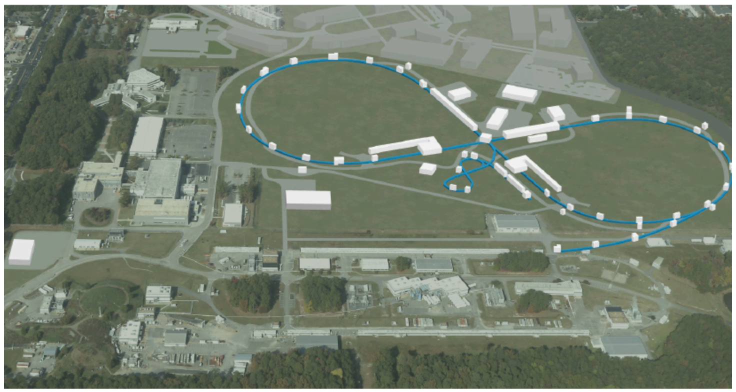
# Documentation series

JLEIC Documentation Series - 001

## Jefferson Lab Electron-Ion Collider (JLEIC): An Introduction to the Interaction Region and Detector Design

Authored by the JLEIC Detector and Interaction Region Study Group

Edited by: Rik Yoshida



JLEIC

The Jefferson Lab Electron-Ion Collider (JLEIC) is a proposed realization of the Elect
Collider (EIC), a new US-based facility with a versatile range of beam energies,
polarizations, and species, as well as high luminosity. The EIC is required to precisely
the quarks and gluons and their interactions, to explore the new QCD frontier of strong color fields in nucle
understand how matter at its most fundamental level is made. The EIC has been chosen as the highest prio
new construction for Nuclear Physics in the US.

LEVEL 0

**An Introduction to the Interaction Region and Detector Design** DocDB-doc-1

LEVEL 1

**Detector Requirements for Measurements at the Electron-Ion Collider** DocDB-doc-153

LEVEL 2

**Forward Electron Detection, Electron Beam Polarimetry, and Luminosity Measurements at JLEIC** DocDB-doc-55

**Particle Identification** (*in preparation*)

**EIC Calorimetry** DocDB-doc-154

https://jleic-docdb.jlab.org/cgibin/private/DocumentDatabase

# Documentation series

JLEIC Documentation Series - 001

## Jefferson Lab Electron-Ion Collider (JLEIC): An Introduction to the Interaction Region and Detector Design

Authored by the JLEIC Detector and Interaction Region Study Group

Edited by: Rik Yoshida

Thank you for your contributions!

## JLEIC Detector and Interaction Region Study Group

P. Brindza, A. Camsonne, M. Diefenthaler, L. Elouadrihiri, R. Ent, Y. Furletova, D. Gaskell, J. Hoskins (Manitoba), T. Horn (CUA), C. Hyde (ODU), G. Kalicy (CUA), C. Keppel, D. Lawrence, F. Lin, R. Montgomery (Glasgow), V. Morozov, P. Nadel-Turonski (Stony Brook), K. Park (HU), C. Ploen (ODU), P. Rossi, M. Sullivan (SLAC), M. Ungaro, G. Wei, C. Weiss, R. Yoshida, Z. Zhao (Duke), Y. Zhang

JLEIC

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**EIC Calorimetry**
DocDB-doc-154

https://jleic-docdb.jlab.org/cgibin/private/DocumentDatabase

# Summary

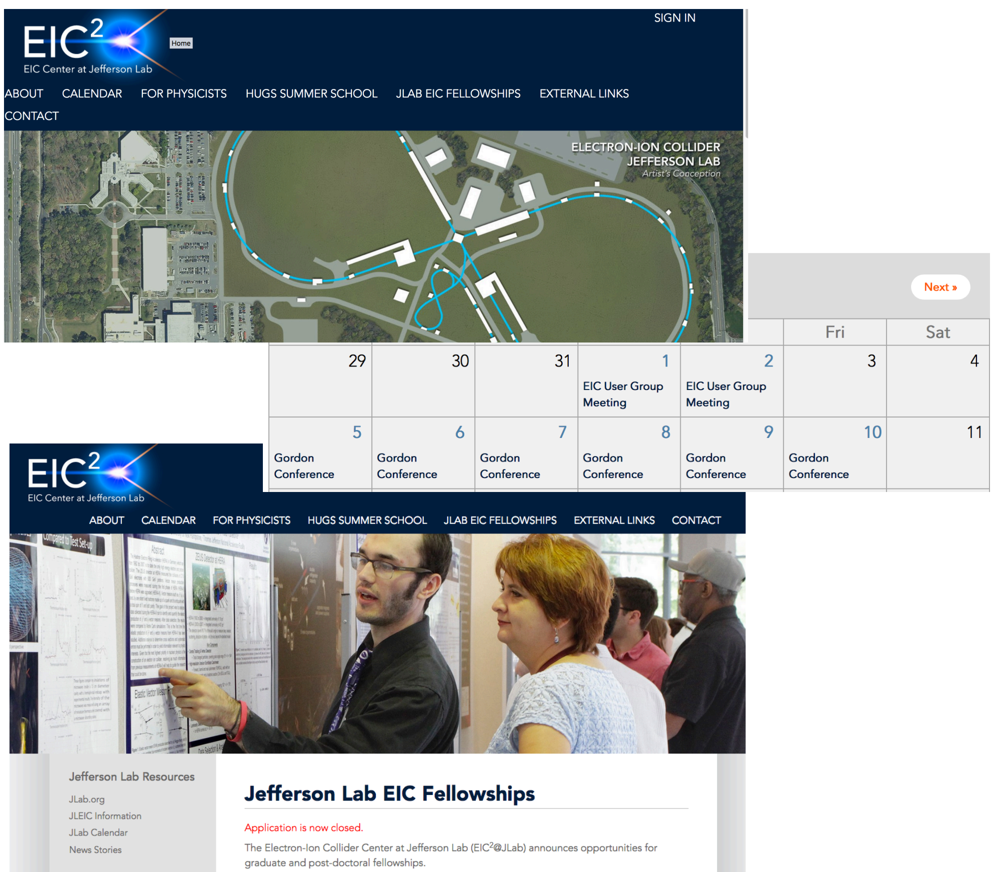
- Physics of nucleon and nuclear structure must drive the accelerator and detector design.
- JLEIC detector design is based on a *total* acceptance detector and particle identification concept. This means excellent forward/rear coverage in addition to the central coverage, as well as on identification of individual particle species.
- **Machine parameters**, **interaction region** and **detector design** must go hand in hand, paying close attention to the emerging **physics program** of the EIC (a good collaboration among Accelerator Physicists, Experimentalists, and Theoreticians)

# EIC Center at JLAB

eiccenter.org

The Electron-Ion Collider Center (EIC$^2$@JLab) is an organization to advance and promote the science program at a future electron-ion collider (EIC) facility. Particular emphasis is on the close connection of EIC science to the current Jefferson Lab 12 GeV CEBAF science program.

EIC$^2$
EIC Center at Jefferson Lab




Consolidates and connects EIC physics and detector development activities at(around) Jlab:

- ✓ Weekly meetings, ad-hoc meetings (workshops)
- ✓ Documentation
- ✓ LDRD,EIC Detector R&D activities
- ✓ HUGS summer school, visitors, etc..
- ✓ Graduate student and postdocs fellow program

➢ Contact person Rik Yoshida

# Join us now!

Subscribe to the Jlab-eic-news mailing list
Jlab-eic-news@jlab.org
https://mailman.jlab.org/mailman/listinfo/jlab-eic-news

**Tuesdays**: 12-1pm **Lunch** (CC-A110)

No talks, no agenda. Bring your lunch, your ideas, questions .. or just join and listen. Everyone's welcome!!!

**Wednesdays**: 2-4 pm **Detector, IR meeting** (CC-F324-325)

Detector design, detector technology, readout, simulation, reconstruction, …

**Fridays**: 9:30-11 am **General JLEIC meting** ( CC-F326-327)

General announcements, reports from conferences, physics topics, LDRD,etc.

# Conclusions

Electron-Ion Collider:
- NAS report
- DOE NP may move towards CD0 “shortly afterwards”
- EIC UG: a lot of international interest

Jefferson Lab is committed to EIC in all aspects:
- EIC Accelerator Proposal
- CEBAF 12 GeV Science leads naturally into EIC Science.
- Taking initiatives in developing EIC Science.
- Detector R&D involvements

EIC Accelerator and Detector are challenging:
- Jefferson Lab introducing many innovative concepts.
- Many opportunities for international collaboration.

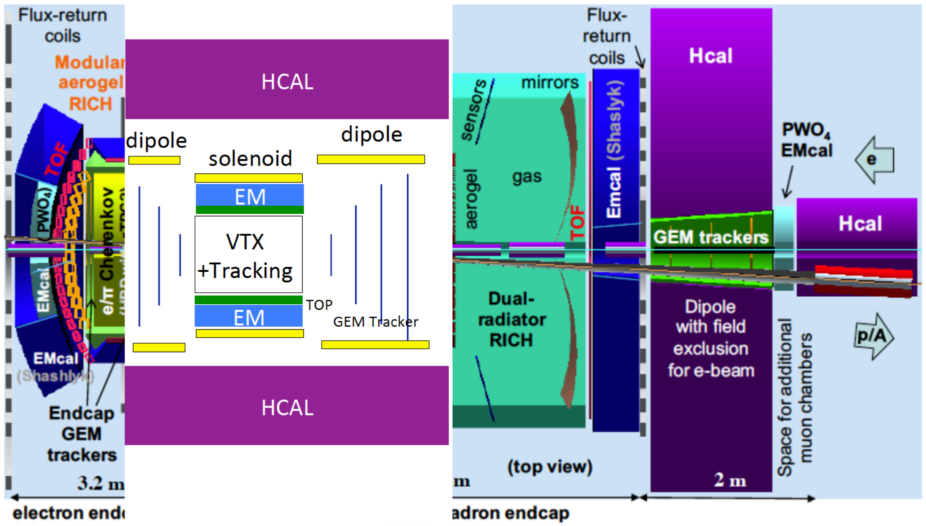
Thank you!

# BACKUP

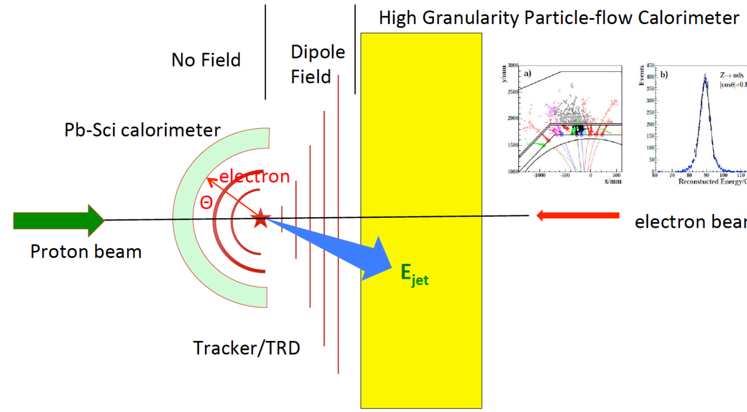
# EICUG Detector discussion meeting

at Temple U ( Nov 2017)

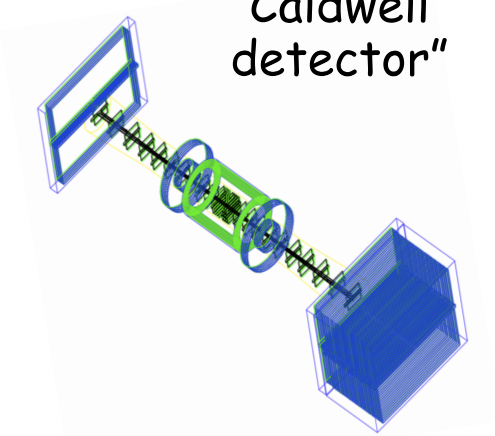
## Low-x, high-x detectors (R. Yoshida)




## Improvements for Jets (R. Yoshida)

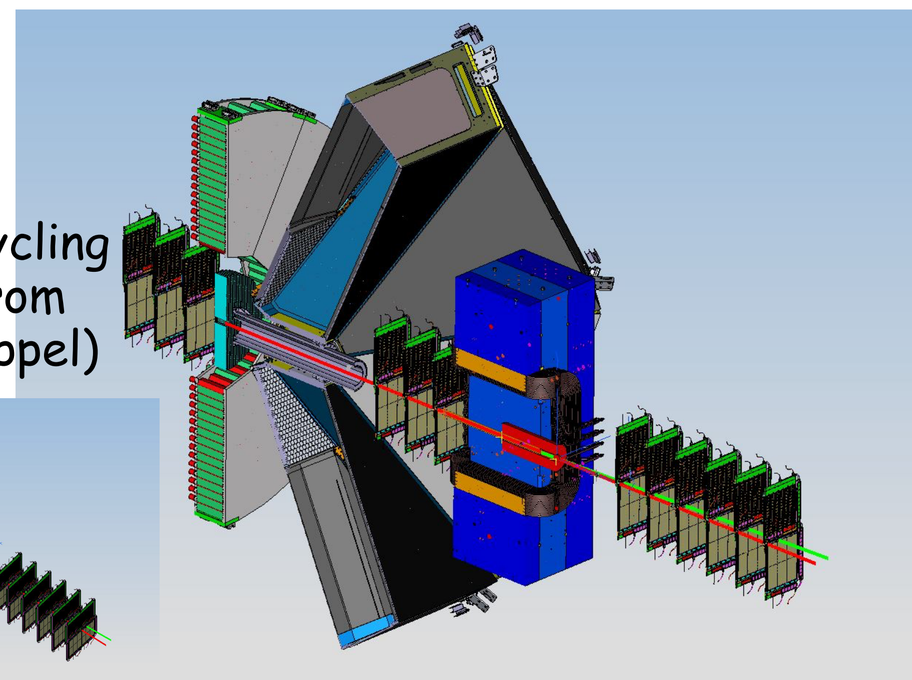


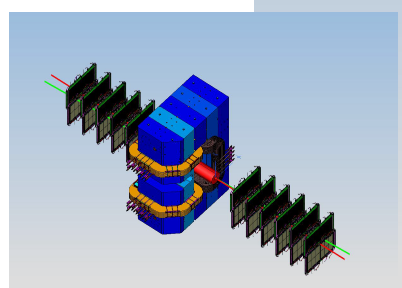

"Caldwell detector"



Particle flow detector concept (TOPSiDE) -> see Whitney Armstrong's talk

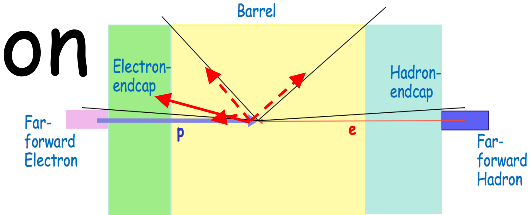
Magnet and Detector Upcycling Possibilities from Jlab (Thia Keppel)

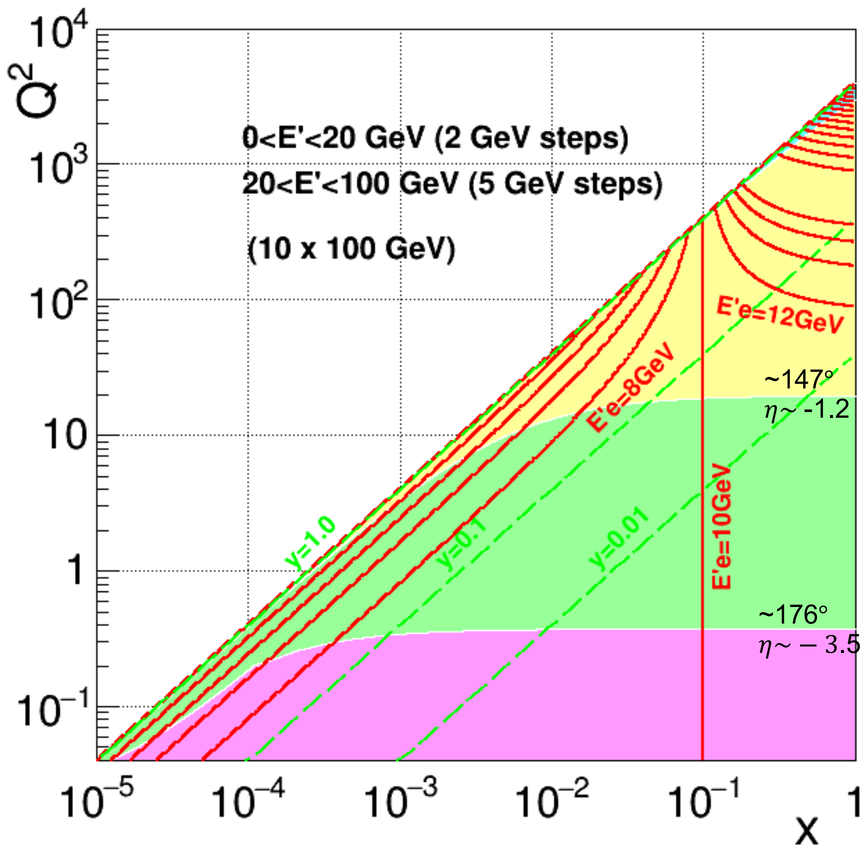


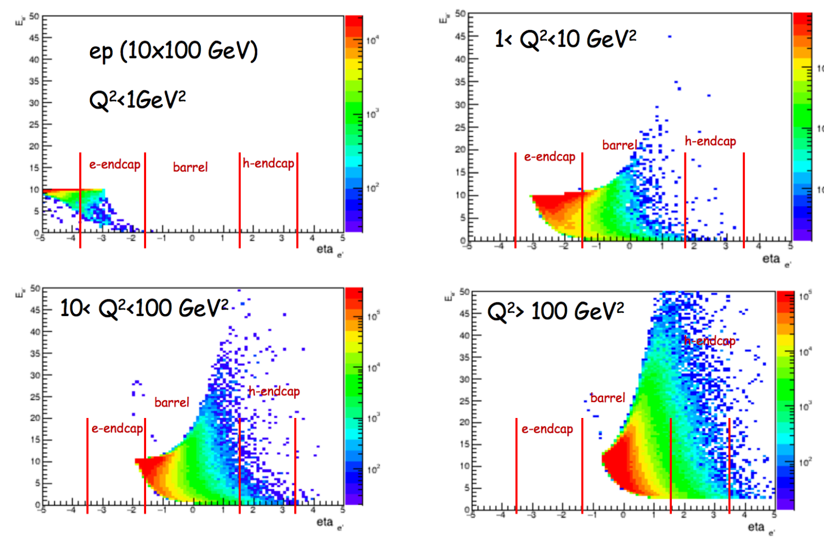


Yulia Furletova

# Event kinematic: scattered electron




$$Q^2_{\mathrm{EM}} = 2E_e E_{e'}\left(1+\cos\theta_{e'}\right),$$

$$y_{\mathrm{EM}} = 1-\frac{E_{e'}}{2E_e}\left(1-\cos\theta_{e'}\right),$$

$$x = \frac{Q^2}{4E_e E_{\mathrm{ion}}}\frac{1}{y}$$

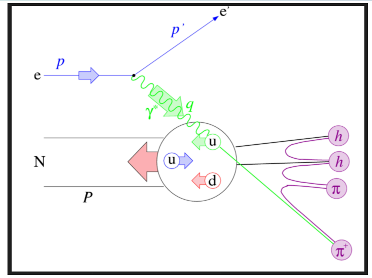
**Notes:**

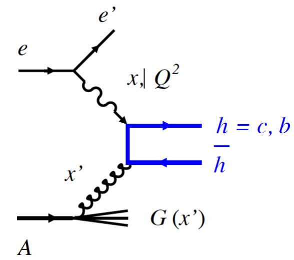
- Linear dependence on $E_{e'}$ of the $Q^2$
- This method could NOT be used for y < 0.1

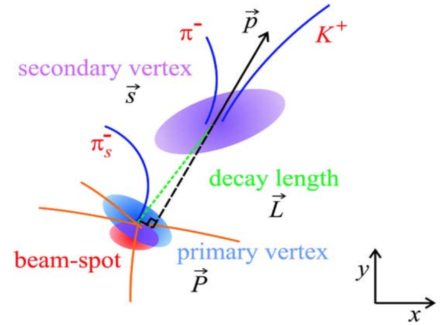
# PID and Vertex detectors

- Semi-inclusive DIS
- Charm/Beauty identification : access to gluons
  - exclusive decay ($D^0 \to K^- \pi^+$)
  - inclusive decays (D mesons-> K+X )
- Spectroscopy

- high combinatorial background

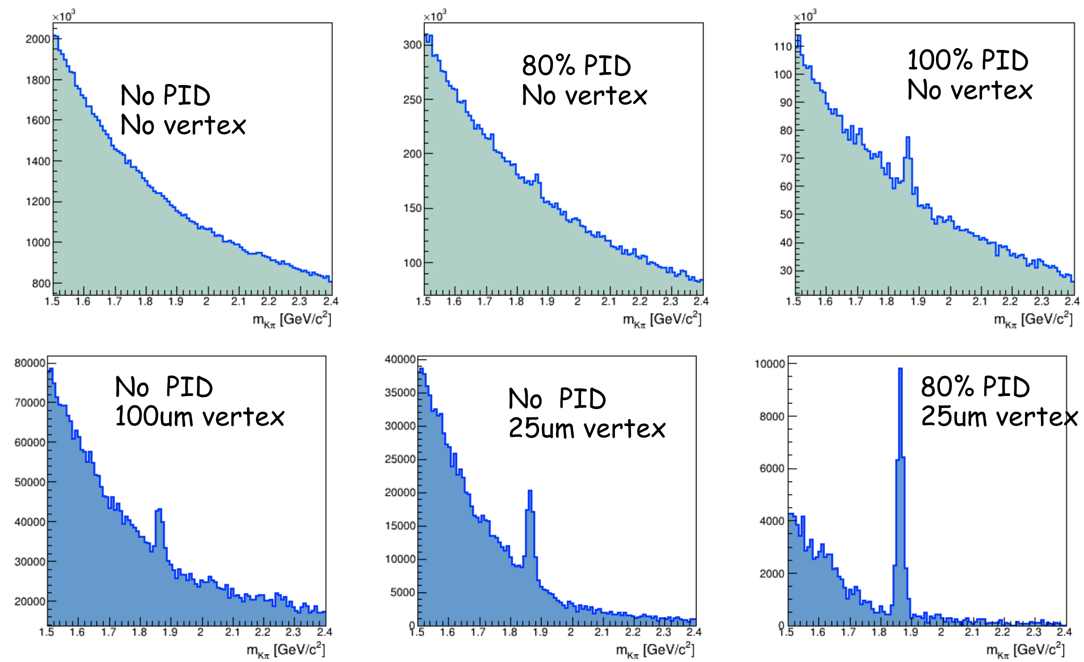


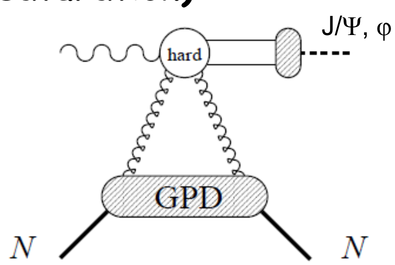

$D^0 \to \pi K$ mass spectrum
ep 10x100 GeV

> - Momentum
> - Particle identification (PID)
> - Vertex origin (high precision tracking and Vertex detector)



# Electron identification (e/hadron separation)

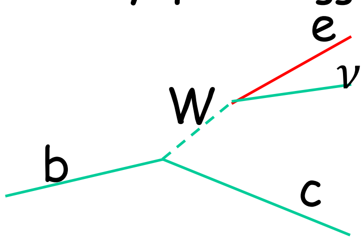
- GPD and Coherent Exclusive Diffraction (saturation)




Br ($J/\psi$->e+e- ) ~6%

Br ($J/\psi$->$\mu$+$\mu$- ) ~6%

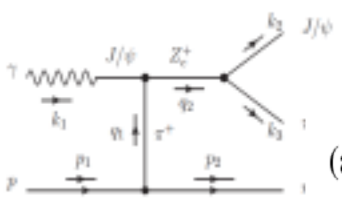
- Heavy quark tagging




Br ($D^{\pm}$->e+X ) ~16%

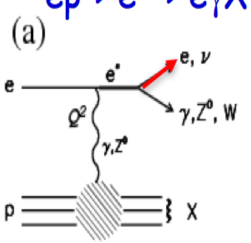
Br ($B^{\pm}$->e+$\nu$+$X_c$ ) ~10%

- Exotic spectroscopy

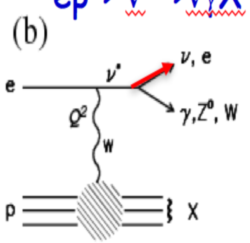



- Other BSM physics

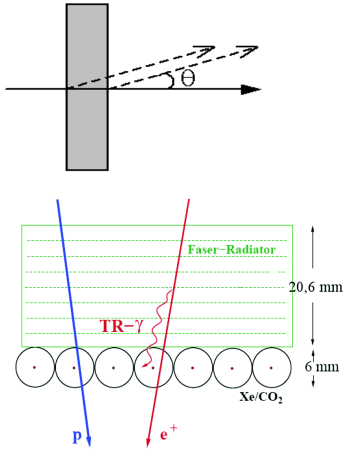
ep-> e*-> eγX

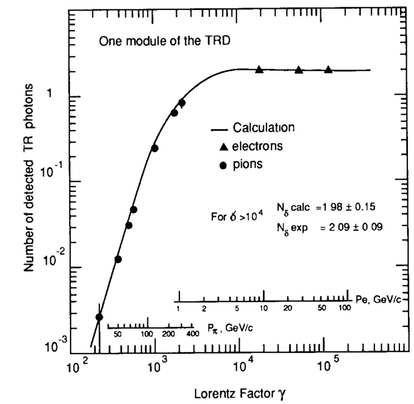



ep-> ν*->νγX



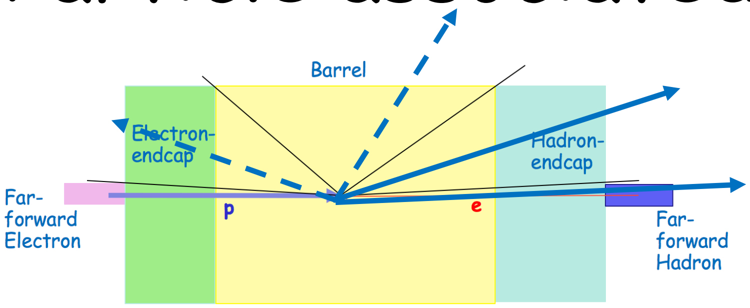

## Transition radiation




- Provides e/$\pi$ separation 1-100GeV
- It is a tracking device (could be combined with tracker)
- Provides also dE/dx high precision (heavy gas), could also work in a cluster counting mode.
- Depending on configuration provides additional e/$\pi$ rejection 10-100
- GEM/TRD detector R&D is ongoing

# Particle associated with struck quark




**All other methods of kinematic reconstruction require measurements of hadronic final states (particles associated with struck quark)**

*Double angle method*

$$Q^2_{\mathrm{DA}} = \frac{4E_e^2 \sin\gamma_h (1+\cos\theta_{e'})}{\sin\gamma_h + \sin\theta_{e'} - \sin(\theta_{e'}+\gamma_h)},$$

$$y_{\mathrm{DA}} = \frac{\sin\theta_{e'} (1-\cos\gamma_h)}{\sin\gamma_h + \sin\theta_{e'} - \sin(\theta_{e'}+\gamma_h)},$$

**Note:** Does not require measurements of scattered electron energy, but require a good knowledge of hadronic final state :

$$\cos\gamma_h = \frac{P^2_{T,h} - \left(\sum_h (E_h - p_{z,h})\right)^2}{P^2_{T,h} + \left(\sum_h (E_h - p_{z,h})\right)^2}$$

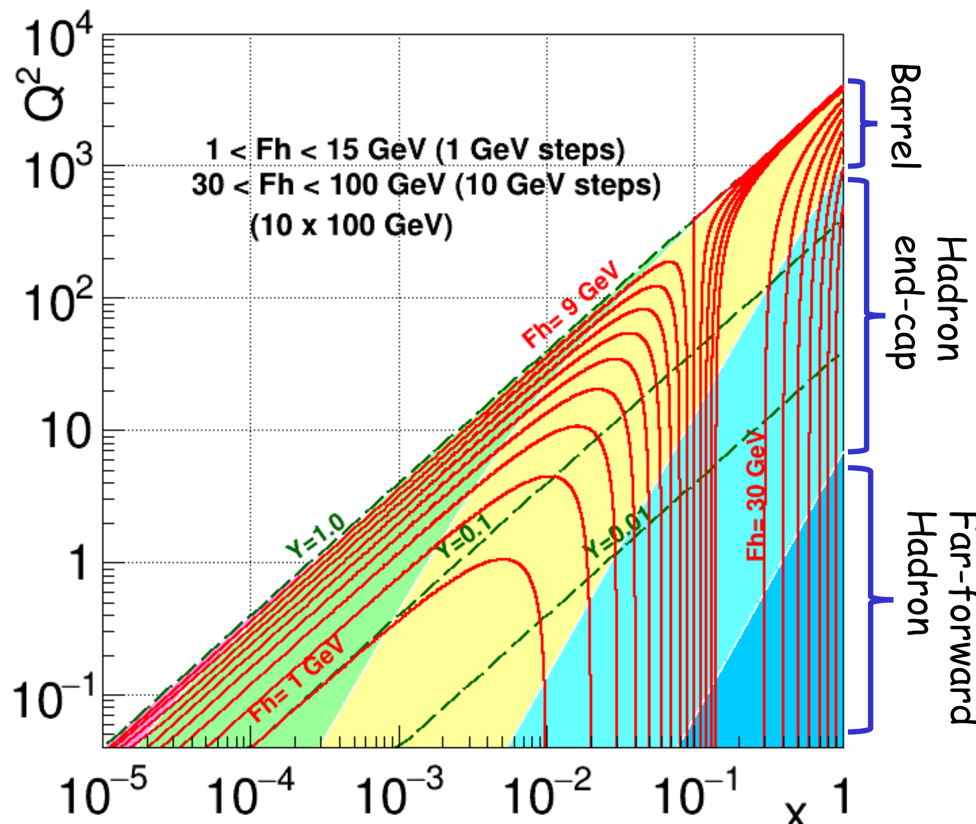
*Sigma method:*

$$y_{e\Sigma} = \frac{\Sigma_h (E_h - p_{z,h})}{E - P_z},$$

$$Q^2_{e\Sigma} = \frac{(E_{e'} \sin\theta_{e'})^2}{1-y}.$$

**Note:** Does not depend on initial electron beam energy, less influenced by a initial state radiation

Isolines of the struck quark Energy

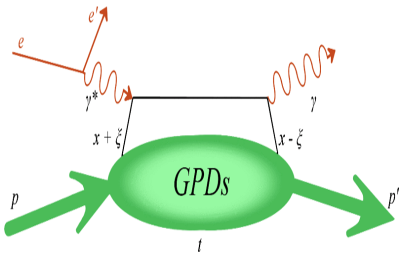



- Electron endcap : mostly low energy <10GeV
- Hadron end-cap and Far-forward hadron : high energy > 50GeV
- Hadron energy measurements at high-x refers to measurements of x

# EM Calorimeter

Electromagnetic Calorimeters measure EM showers and early hadron showers:
Energy, position, time

**Electrons:**
-scattered electron
-secondary electrons (decay products ($J/\psi$))
**Gammas:**
-DVCS process
azimuthal asymmetry




### PbWO$_4$ Crystal EM Calorimeter (at small angles, electron endcap)

-Tungsten glass, similar to CMS or PANDA
- Time resolution: <2 ns
- Energy resolution: <2%/√E(GeV) + 1%
- Cluster threshold: 10 MeV

- ✓ $4\pi$ coverage for EM calorimeter
- ✓ High performance EM calorimeter is need in the electron endcap where scattered electron **has low energy**
- ✓ **High granularity** in the forward going direction: high background from $\pi^0 \rightarrow \gamma\gamma$
- ✓ very good **e-identification and e/$\pi$ rejection**

### Sampling EM Calorimeter

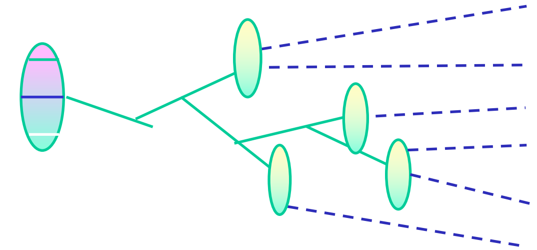
- **Shashlyk** (scintillators +absorber)
-WLS fibers for readout
-**Sci-fiber EM(SPACAL):**

- Compact W-scifi calorimeter, developed at UCLA
- Spacing 1 mm center-to-center
- Resolution ~12%/√E
- On-going EIC R&D

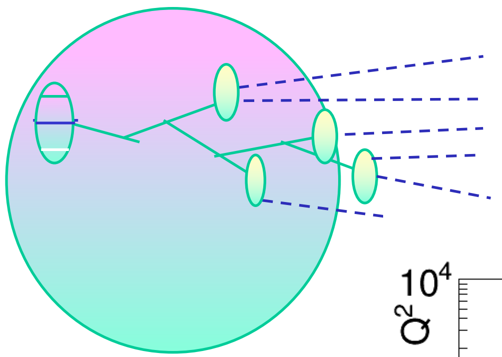
# Jets and neutral hadrons ($n, K^0_L$)

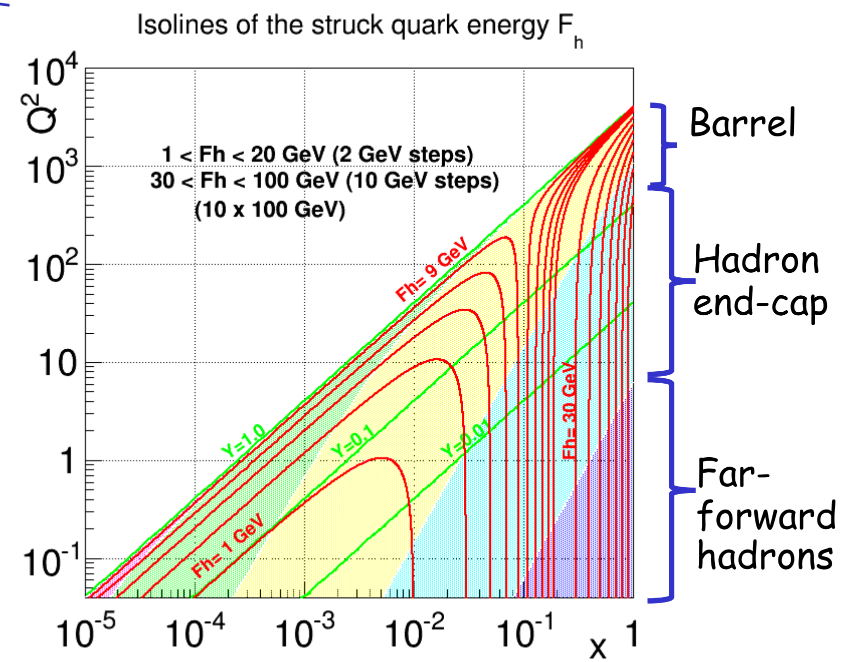
1) **Jets evolution and dynamics** ( jet == struck quark )

2) **Jets as a probe of partonic initial state**



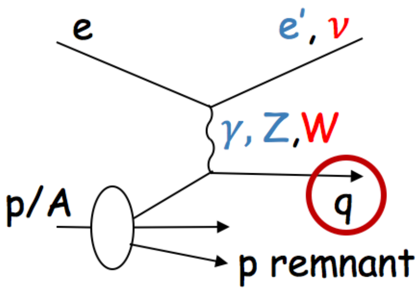
3) **Jets in medium**
**(cold nuclear matter)**
   - ✓ energy loss, quenching
   - ✓ broadening
   - ✓ multiple-scattering.






- $4\pi$ coverage for HCAL is required for CC DIS!
- High resolution calorimeter (energy measurements)
- High granularity to study subjet structure

# Charged Current DIS

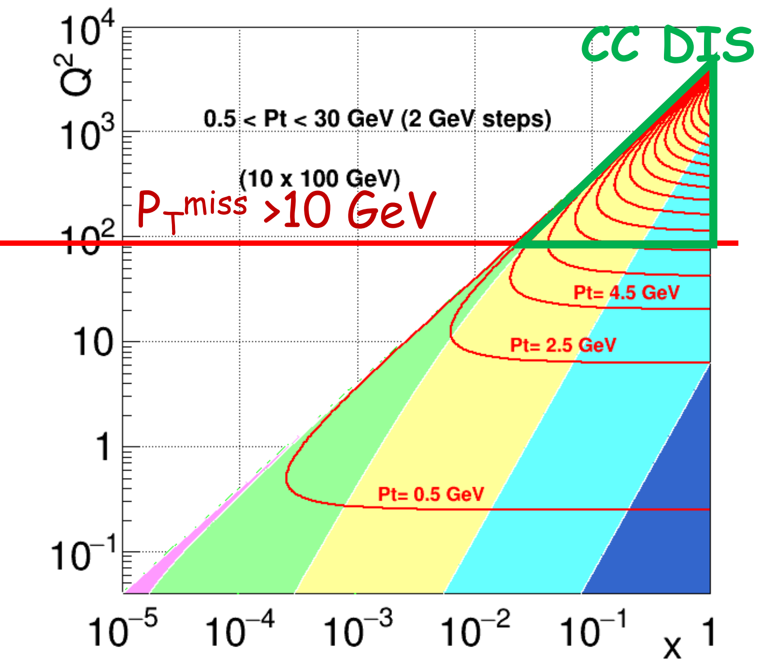


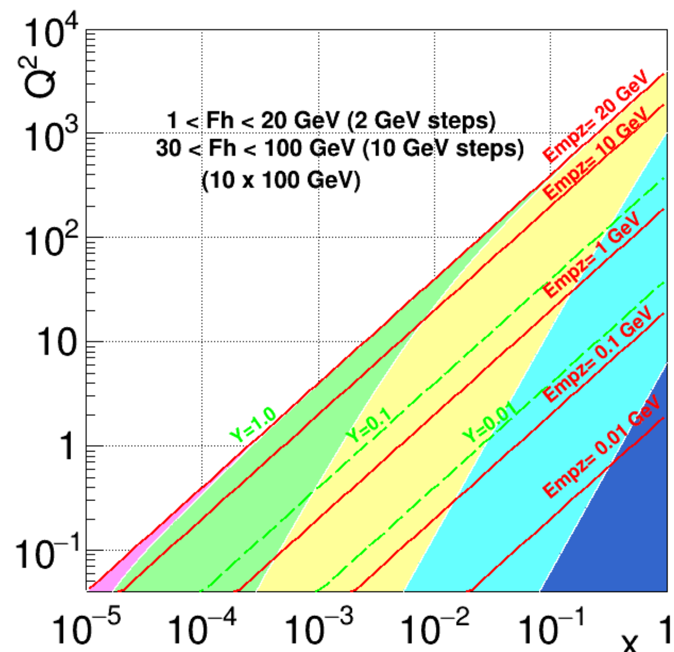

DIS kinematic will be reconstructed from hadronic final state only

d) Jacquet –Blondel method

$$y_{\mathrm{JB}} = \frac{1}{2E_e} \sum_h \left(E_h - p_{z,h}\right),$$

$$Q^2_{\mathrm{JB}} = \frac{1}{1 - y_{\mathrm{JB}}} \left[ \left( \sum_h p_{x,h} \right)^2 + \left( \sum_h p_{y,h} \right)^2 \right].$$



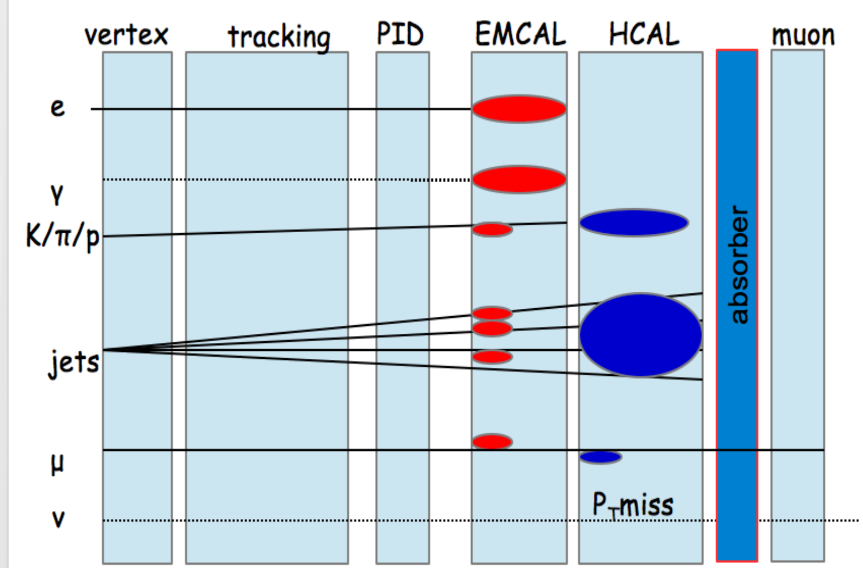




Note: poor resolution compare to other methods, but this is the only method for Charged Current DIS events!!!

# Particles associated with a struck quark

Limited number of "stable" final state particles:

- Gammas
- Jet/Jets
- Individual hadrons ($\pi^{\pm}$, $K^{\pm}$,p)
- Secondary electrons
- Muons (absorber and muon chamber)
- Neutrinos ( missing PT in EM+HCAL)
- Neutral hadrons (n,$K^0_L$) (HCAL)




Methods for PID (mass difference):

-dE/dx: (p<1GeV)
-Time-of-Flight: (p<3-6GeV)
-Cherenkov radiation: p < 5 (50) GeV)
-Transition radiation: (e/h separation) 1 < p < 100GeV

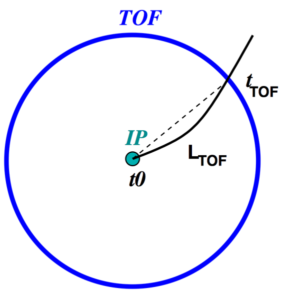
**Energy Loss Measurements dE/dx**

No extra detector required: use information from tracking/vertex detectors

- Limitation : p<1GeV
- Could be used for higher momentum due to he relativistic rise of the Bethe-Bloch curves
- Depending on available electronics a **cluster counting** method could be used to improve momentum coverage

# Individual hadrons ($\pi$, K, p)

## Time-of-flight (psTOF)

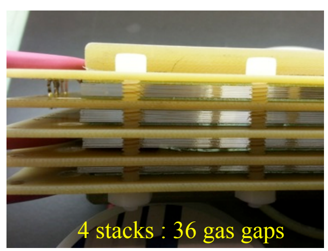



- **Limit in space** (barrel) => PID momentum limitation => could be improved by high precision timing measurements <10psec
- Radial space needed: ~10cm.

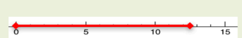
- **t0: self-determined =>** need to know a **vertex origination** to **measure L_TOF** precise (total particle length/curvature)

Multi-gap Resistive Plate Chamber (MRPC) R&D: achieved ~18 ps resolution with 36-105 μm gap glass MRPC

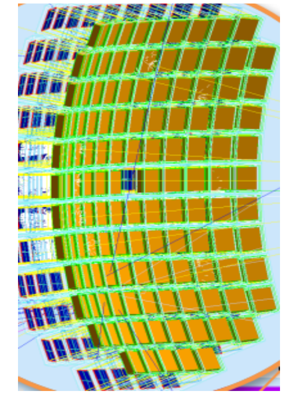
Barrel (1m) for 20ps (10ps):
$\pi$/K < 2.5 (3.5) GeV,
K/p < 4.2 (6) GeV
End-caps (4m):
$\pi$/K < 5 (7.3) GeV,
K/p < 8.5 (12.5) GeV




Mickey Chiu

| | | | |
|---|---|---|---|
| $\sigma_{tot}$=10 ps | 1m (Barrel) |  |  |
| $\sigma_{tot}$=10 ps | 4m (Hadron) |  |  |

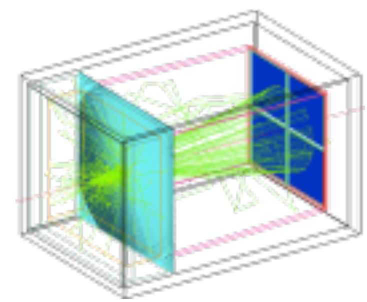
## Electron end-cap: Modular RICH

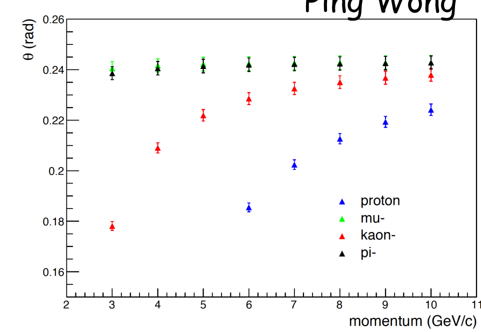


- Modular aerogel RICH: compact, using lens-based design to **reduce ring size and sensor plane area**

- Separation (3$\sigma$):
0.56 GeV < e/$\pi$ < 2 GeV ,
0.56 (2.0) GeV < $\pi$/K < 8 (10) GeV,
2.0 (3.8) GeV < K/p < 12 GeV

Ping Wong





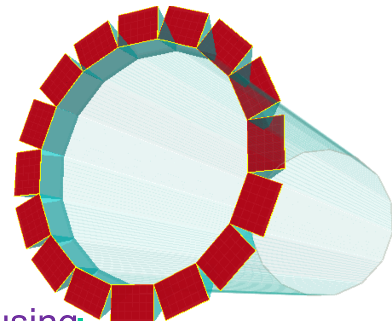

## Hadron blind detector (HBD)

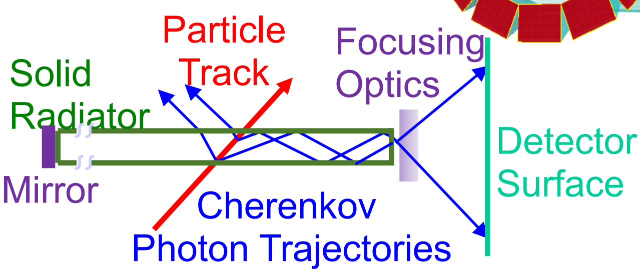
- Threshold cherenkov detector for e/$\pi$ separation
- Limited momentum coverage

# Individual hadrons ($\pi$, K, p)

## Barrel: DIRC

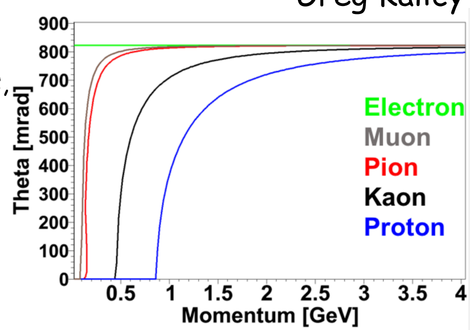
- radially compact (5 cm)






Greg Kalicy

Current design based on narrow synthetic fused silica bars arranged in 16 barboxes, coupled to solid prisms with custom made 3-layer lens, read out by arrays of MCP-PMTs.



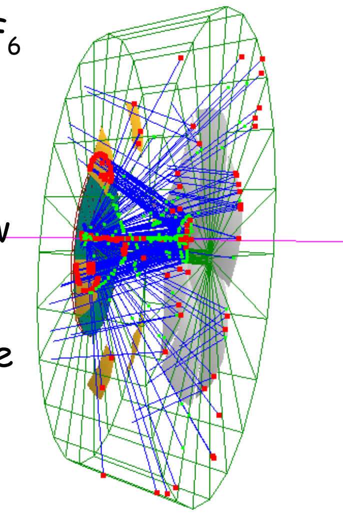

- Simulation for particle identification (3σ):

0.15 < e/π < 1.8 GeV
0.15 (0.45) < π/K < 6 GeV,
0.45 (0.8) < p/K < 10 GeV,

## Hadron end-cap: dual-radiator RICH

Alessio Del Dotto

- JLEIC design geometry constraint: ~160 cm length
- Aerogel in front, followed by $C_2F_6$
- Outward reflecting mirror
- Focal plane away from the beam, reduced background



- Sensitive to magnetic field=> New 3T solenoid minimized a field in RICH region
- Aerogel drives the detector to be solid state (e.g. SiPMs, LAPPDs)

- Particle identification:

| | |
|---|---|
| 0.003(0.8) < e/π < 4 GeV | 0.01 (3.48) < e/π < 18 GeV |
| 0.8 (2.84) < π/K < 14 GeV | 3.48(12.3) < π/K < 55 GeV |
| 2.84(5.4) < p/K < 22 GeV | 12.3 (23.4) < p/K < 70 GeV |