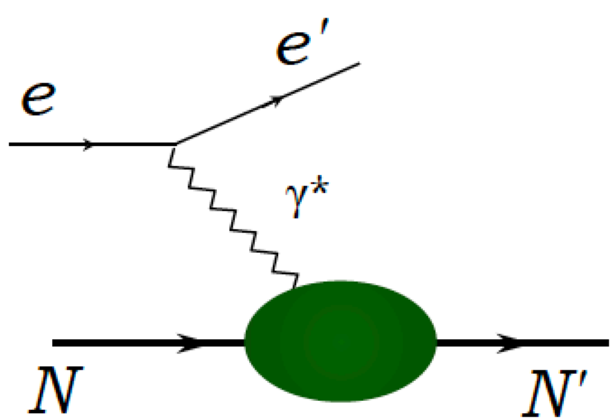
# RECAP

- Nucleon elastic form factors (transverse q distributions: charge and magnetisation)
- Hadron internal structure (quarks bound together to give a hadron)
- Deep inelastic scattering: partons are quarks!

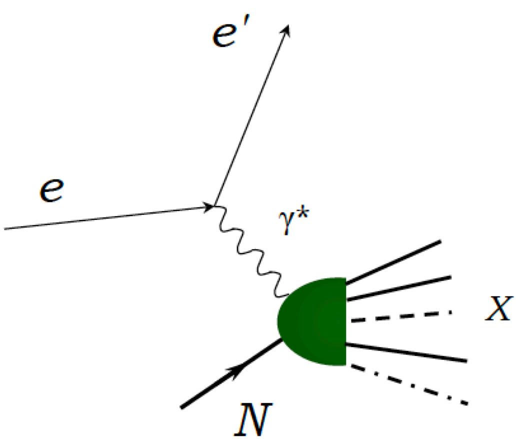
QCD is responsible for such a rich phenomenology!

## Electron scattering: a reminder of terminology

**Elastic scattering**: initial and final state is the same, only momenta change.



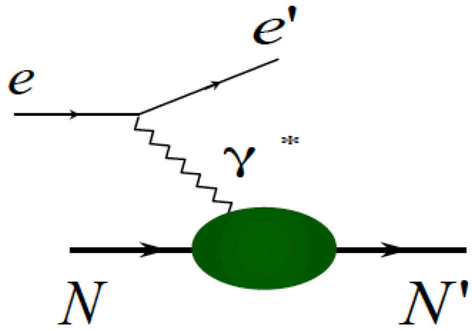

**Deep inelastic scattering (DIS)**: state of the nucleon changed, new particles created.

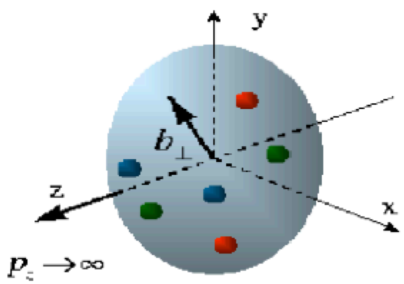


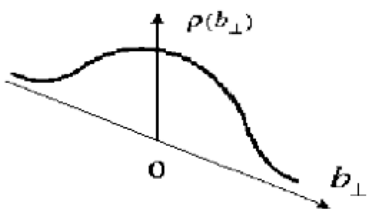
# The 2D spatial image

Lepton (eg: electron, neutrino) scattering off a nucleon reveals different aspects of nucleon structure.

## Elastic Scattering



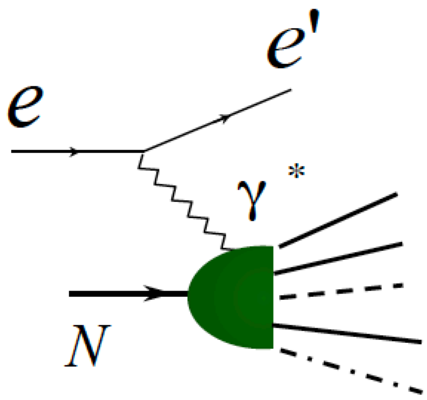



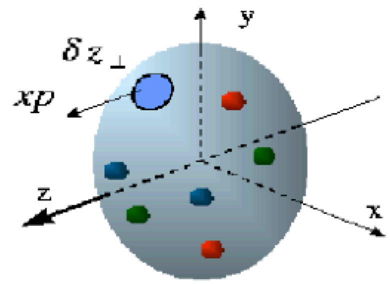



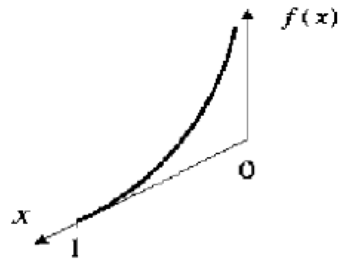

Cross-section parameterised in terms of Form Factors (Pauli, Dirac, axial, pseudo-scalar) → Transverse quark distributions: charge, magnetisation.

# A dynamical image

## Deep Inelastic Scattering




First experimental evidence of partons inside a nucleon

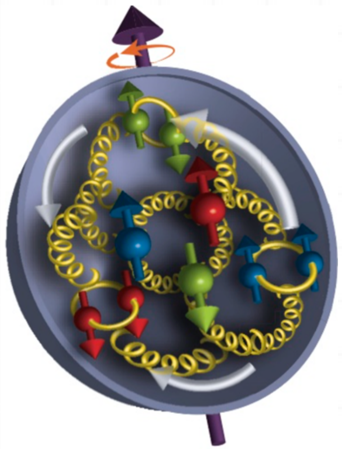
Cross-section parameterised in terms of polarised and unpolarised Structure Functions

→ Longitudinal momentum and helicity distributions of partons

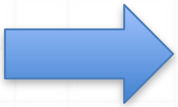
# What are we missing?

- We discovered that (nearly) massless quarks and gluons make up the nucleon and that QCD governs their interactions.
- We had hoped to find out how quarks and gluons and their interactions give rise to the characteristics of the nucleons.
  - Spin
  - Mass
  - Bulk
- We also hoped that we would be able to find out how NN interactions work in terms of QCD.
  - How nuclear forces arise.
  - How nuclear characteristics come about
- We were able to do this kind of things with EM and atoms.
- So far we have failed..

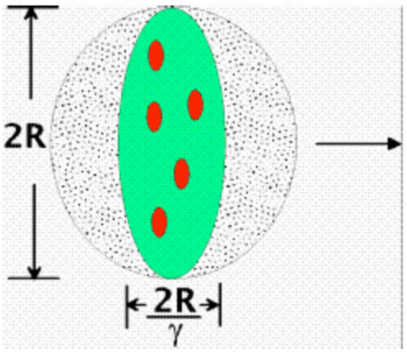
# Limits of Longitudinal Information



infinite
momentum
frame



What we know

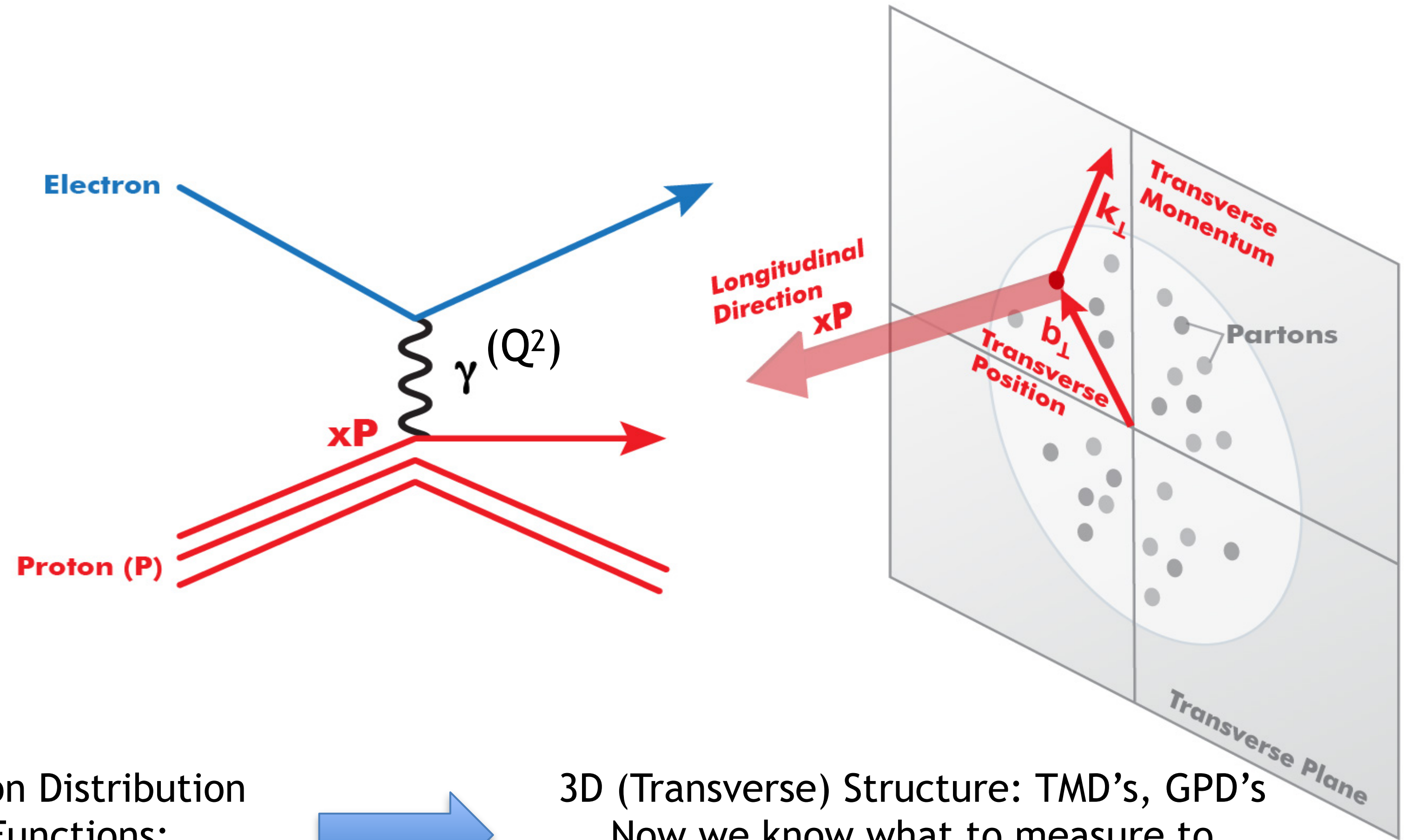



What is the quark and gluon structure of the proton?
-orbital motion?
-color charge distribution?
-how does the mass come about?
-origin of nucleon-nucleon interaction?

Parton frozen transversely. Framework does not incorporate any transverse information.

But this was the only way to define quark-gluon structure of proton in pQCD.

# Progress in pQCD Theory (~1980-~2010)

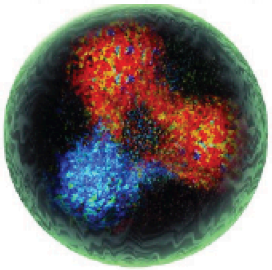



Parton Distribution Functions: Longitudinal only

3D (Transverse) Structure: TMD's, GPD's
Now we know what to measure to understand the 3D structure of nucleons

Transverse Momentum Dependent Distributions (TMD): $k_t$
Generalized Parton Distributions (GPD): $b_t$

# Images of nucleon

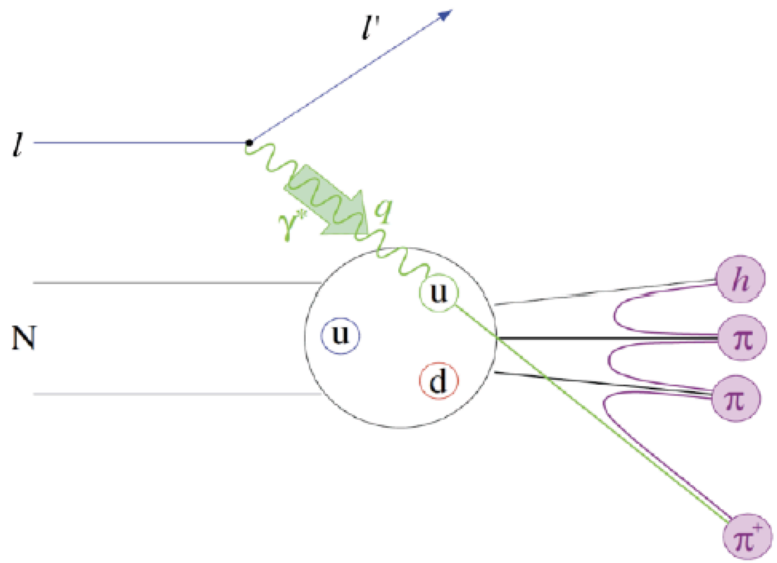


*Wigner function:*
*full phase space parton distribution of the nucleon*

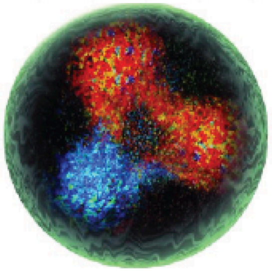
$$\int d^2 b_T$$

Transverse Momentum Distributions (TMDs)

* Semi-inclusive DIS



# Images of nucleon



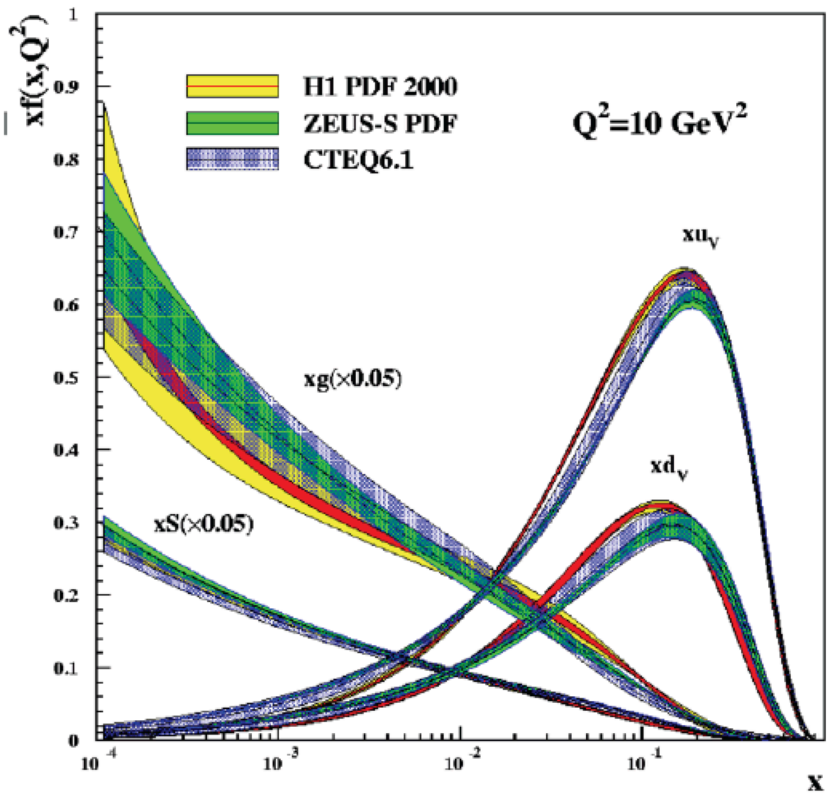
*Wigner function: full phase space parton distribution of the nucleon*

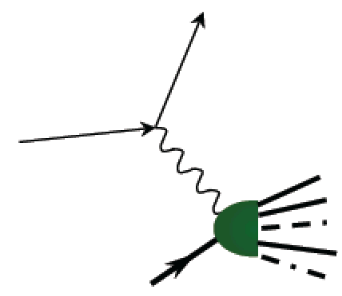
$\int d^2 b_T$

Transverse Momentum Distributions (TMDs)

$\int d^2 k_T$

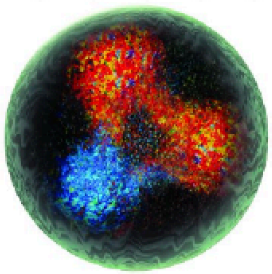
Parton Distribution Functions (PDFs)



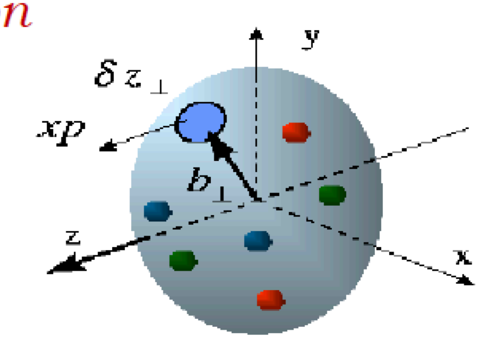



✱ Deep Inelastic Scattering

# Images of nucleon



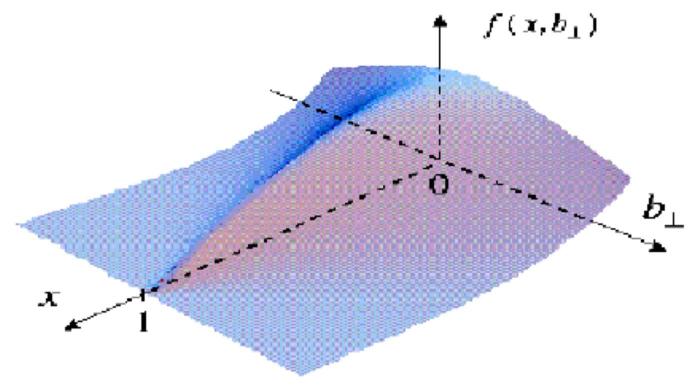
*Wigner function:*
*full phase space parton*
*distribution of the nucleon*




$$\int d^2 k_T$$

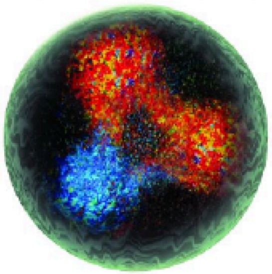
Generalised Parton
Distributions (GPDs)

- relate, in the infinite momentum frame, transverse position of partons ($b_\perp$) to longitudinal momentum ($x$).




✱ Deep exclusive reactions, e.g.: Deeply Virtual Compton Scattering, Deeply Virtual Meson production, ...

# Images of nucleon

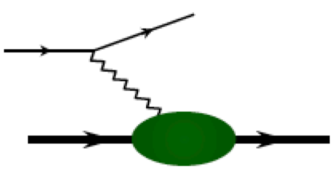


*Wigner function:*
*full phase space parton distribution of the nucleon*

$\int d^2 k_T$

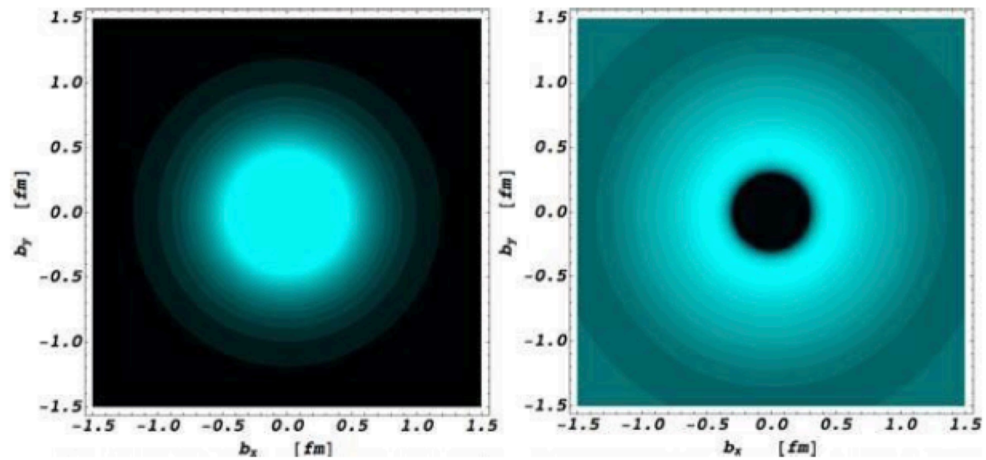
Generalised Parton Distributions (GPDs)

$\int dx$



Form Factors
$eg$: $G_{E,}$ $G_M$

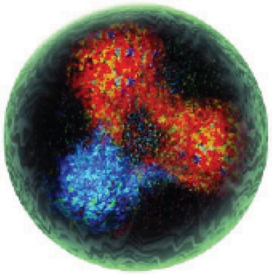
Fourier Transform of electric Form Factor: transverse charge density of a nucleon




proton neutron

*C. Carlson, M. Vanderhaeghen*
*PRL 100, 032004 (2008)*

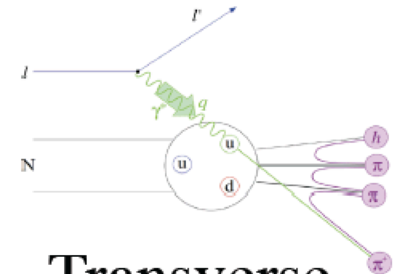
# Images of nucleon



*Wigner function: full phase space parton distribution of the nucleon*

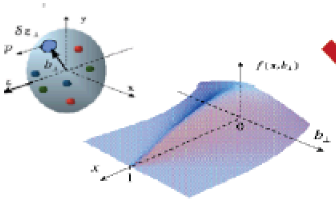
$\int d^2 k_T$

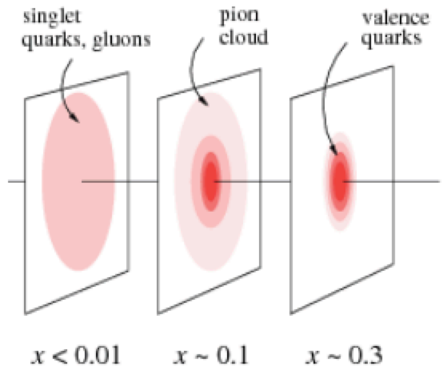
$\int d^2 b_T$




Transverse Momentum Distributions (TMDs)

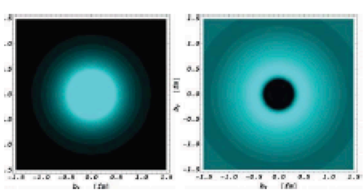
Generalised Parton Distributions (GPDs)






$\int dx$

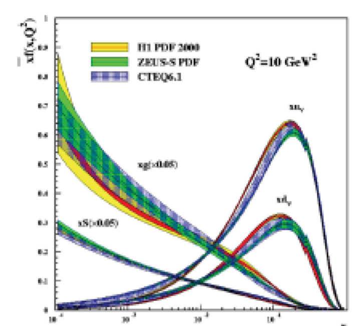
$\int d^2 k_T$



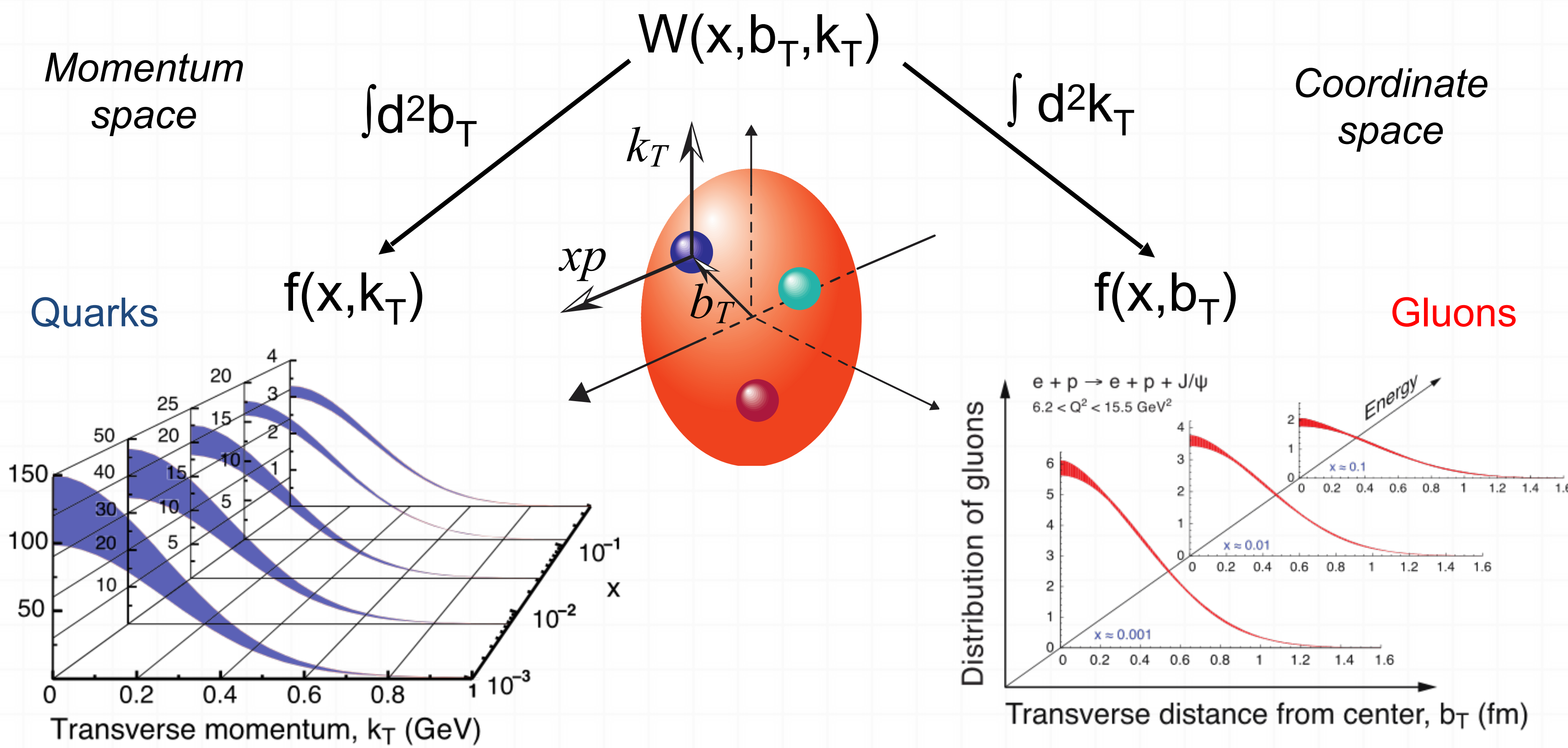
Form Factors

*eg*: $G_{E,}$ $G_M$

Parton Distribution Functions (PDFs)



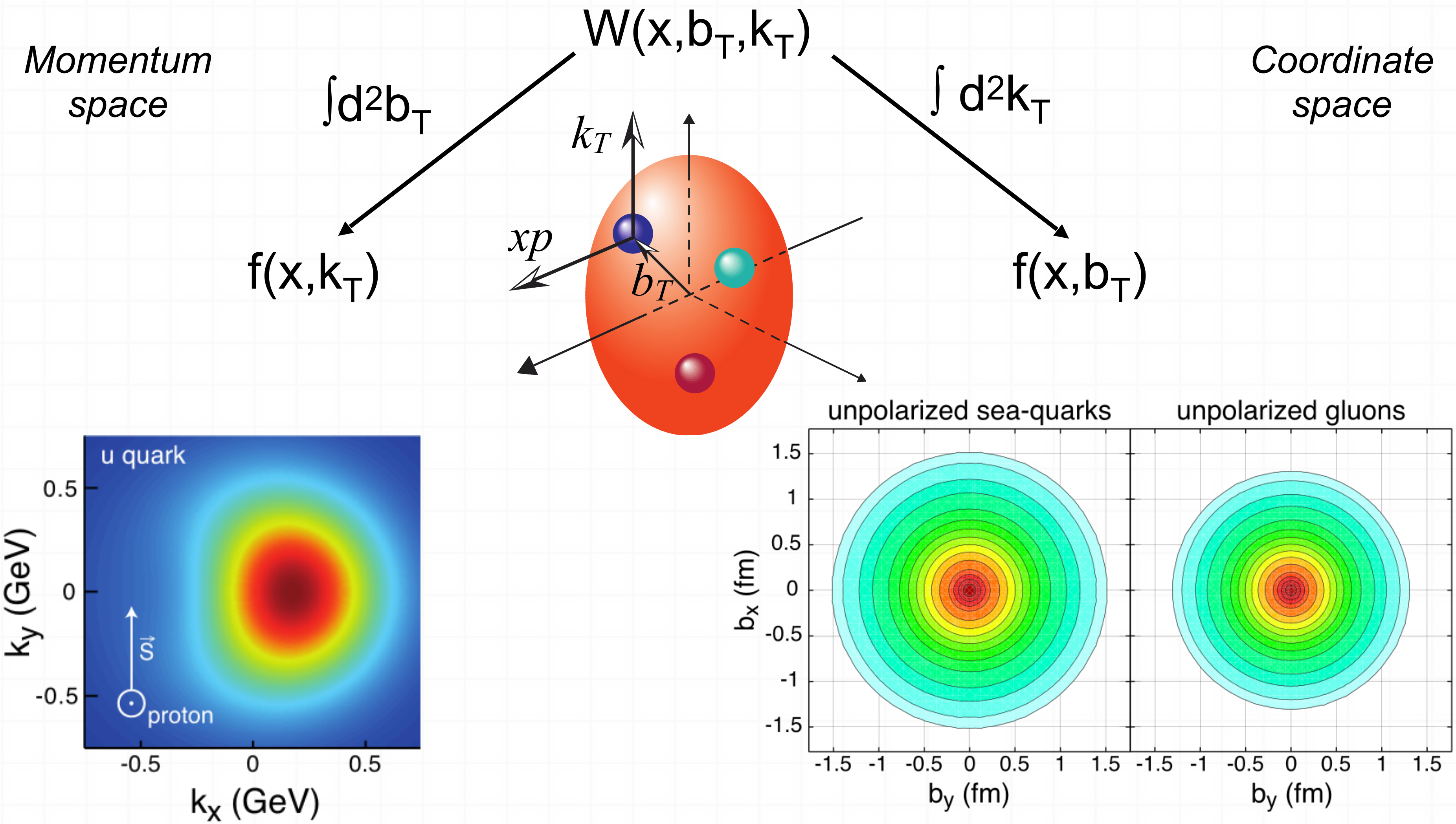
# 3D Imaging of Quarks and Gluons




Spin-dependent 3D momentum space images from semi-inclusive scattering

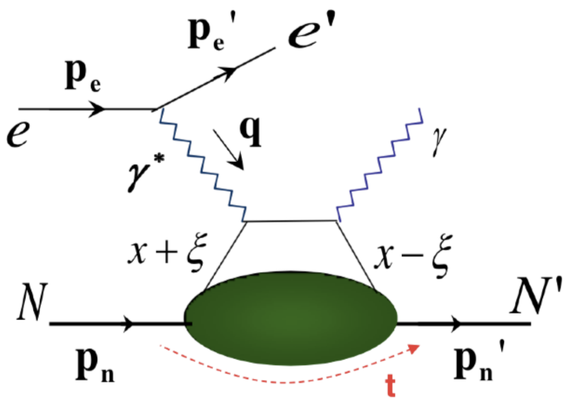
Spin-dependent 2D (transverse spatial) + 1D (longitudinal momentum) coordinate space images from exclusive scattering

# 3D Imaging of Quarks and Gluons




Position $r \bullet p$ → Orbital Motion of Partons

# Deeply virtual Compton Scattering (DVCS)




- $Q^2 = -q^2 = -(p_e - p_e')^2$

  $q$: four-momentum transfer to the struck quark

- $t = (p_n - p_n')^2 \qquad \nu = E_e - E_e'$

  $t$: quantifies change in four-momentum of the nucleon

- Bjorken variable $x_B = \dfrac{Q^2}{2p_n \cdot q}$

In the Bjorken limit (high Q2, high ν) and low t

- Generalised Bjorken variable:

$$\xi \cong \frac{x_B}{2 - x_B}$$

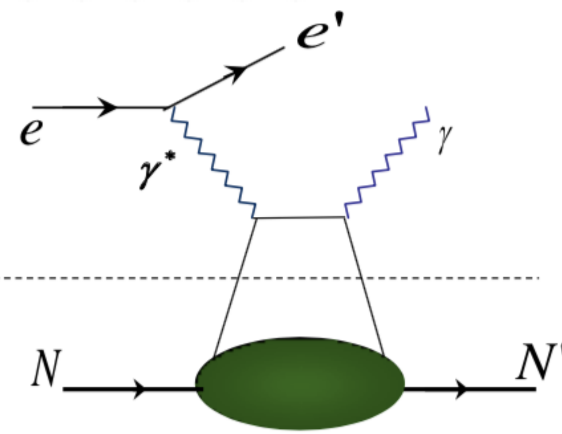
- $x+\xi$ and $x-\xi$ :

initial and final longitudinal momentum of struck quark, as a fraction of nucleon momentum

**Factorisation:** allows to separate the "hard"-scattering of electron off a quark from the "soft" part of the interaction inside the nucleon.

"hard" interaction: perturbative calculation

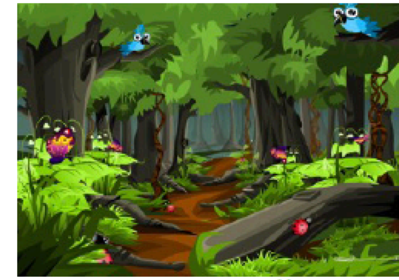
"soft" interaction: parameterised by GPDs




***Only valid for high $Q^2$!***

$$E_q, \widetilde{E}_q, H_q, \widetilde{H}_q \ (x, \xi, t)$$ Four for each quark-flavour $q$

# Experimental paths to GPDs

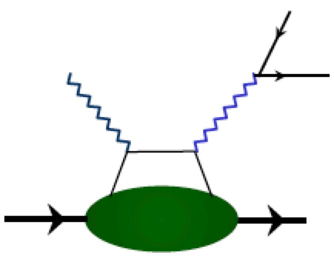


cliparts.co

Accessible in *exclusive* reactions, where all final state particles are detected.

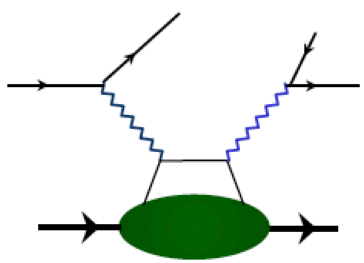
Trodden paths, or ones starting to be explored:

- Deeply Virtual Compton Scattering (DVCS)
- Deeply Virtual Meson Production (DVMP)
- Time-like Compton Scattering (TCS)
- Double DVCS



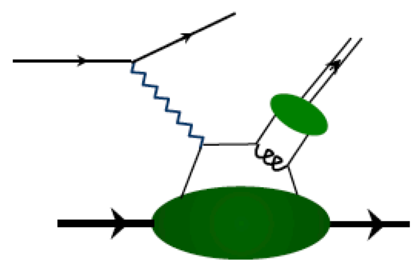
**TCS**

*Virtual photon time-like*

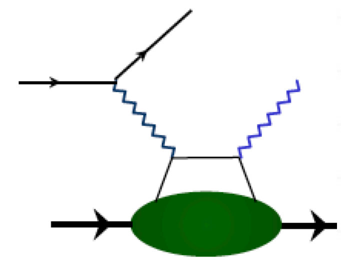


**DDVCS**

*One time-like, one space-like virtual photon*



**DVMP**



**DVCS**

*Virtual photon space-like*

# On-going efforts to map out GPD &n TMD @ Jefferson Lab

## CLAS12

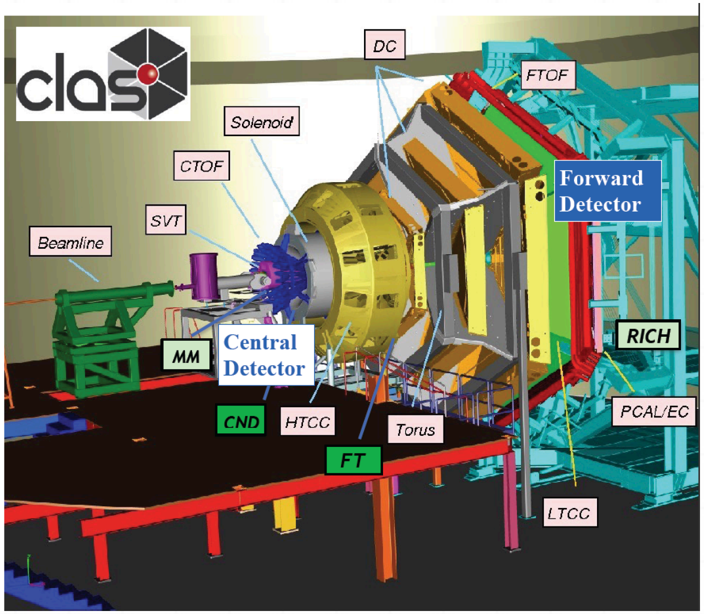
**Design luminosity**
L ~ $10^{35}$ cm$^{-2}$ s$^{-1}$

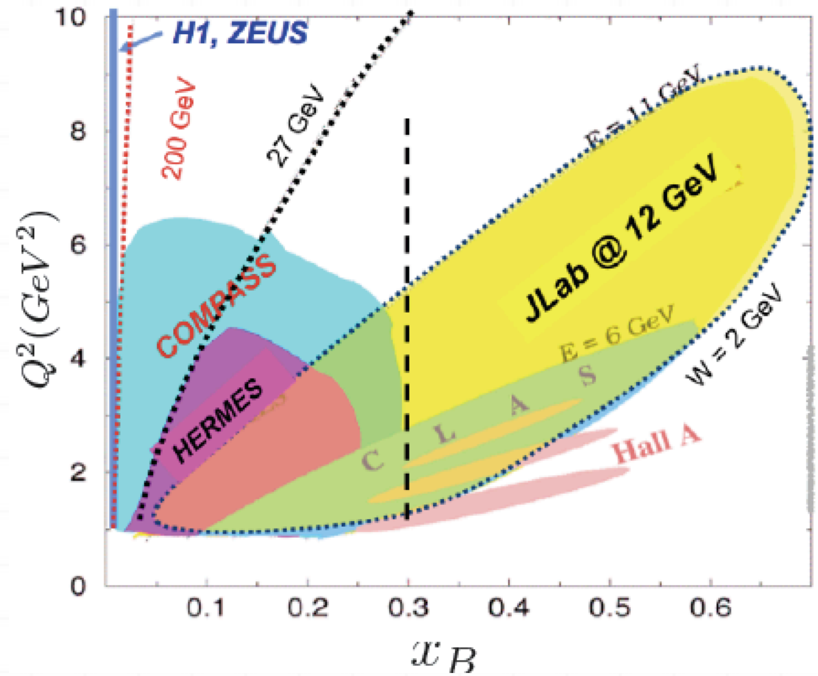
**High luminosity & large acceptance:**
Concurrent measurement of exclusive, semi-inclusive, and inclusive processes

**Acceptance for photons and electrons:**
- $2.5^{o} < \theta < 125^{o}$

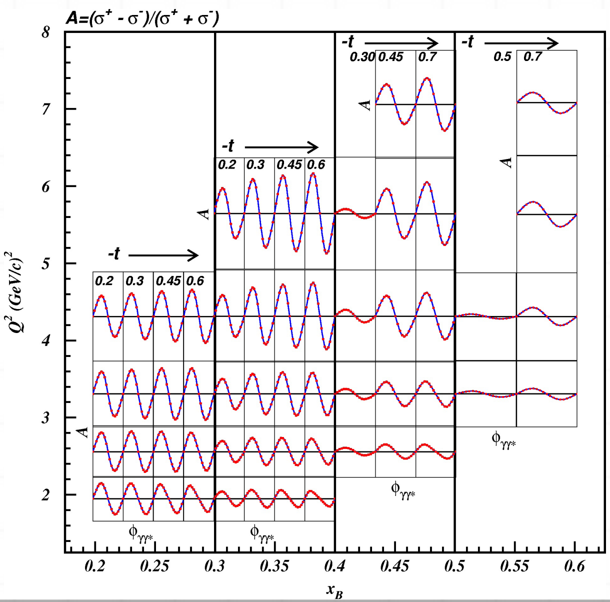
**Acceptance for all charged particles:**
- $5^{o} < \theta < 125^{o}$

**Acceptance for neutrons:**
- $5^{o} < \theta < 120^{o}$



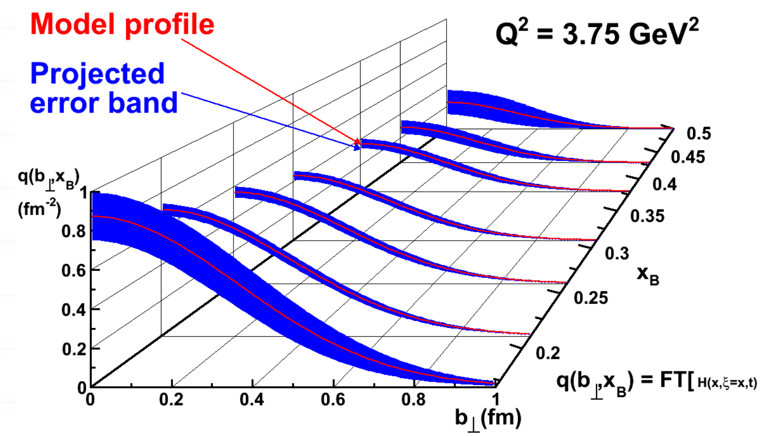




Projection for Proton BSA DVCS ALU




CLAS12 Projection for GPD H(x,ξ,t) extraction

**Projection for the Nucleon transverse profile**



# The Nucleon Spin Puzzle

- What contributes to nucleon spin?

- 1980's: European Muon Collaboration (EMC) measures contribution of valence quarks to proton spin to be ~ 30 %. Subsequent deep inelastic scattering (DIS) experiments confirm.

Where is the rest? → **Proton spin crisis!**

***Quark spin***: extracted from helicity distributions measured in polarised DIS.

***Gluon spin and OAM***: measurements of DIS and polarised proton collisions indicate gluon spin $\Delta G$ contribution is very small, although in a different decomposition.

$$J_N = \frac{1}{2} = \frac{1}{2}\Sigma_q + L_q + J_g$$

***Quark orbital angular momentum (OAM)***: can be accessed, in Ji's decomposition, via **GPDs**, which contain information on total angular momentum, $J_q$.

**Caveat:**

*In Ji's decomposition of nucleon spin, the gluon spin and OAM terms cannot be separated.*

# GPDs and nucleon spin

$$J_N = \frac{1}{2} = \frac{1}{2}\Sigma_q + L_q + J_g$$

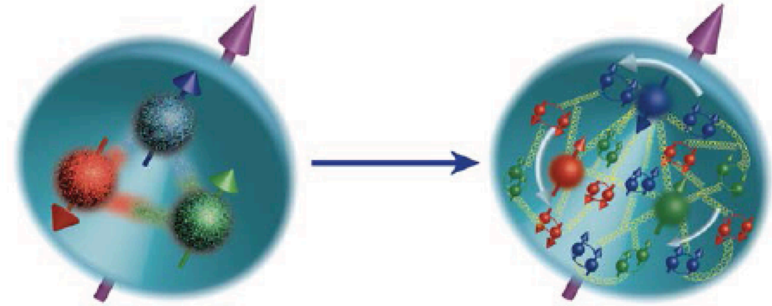
- Ji's relation: $J^q = \frac{1}{2} - J^g = \frac{1}{2}\int_{-1}^{1} x dx \left\{ H^q(x,\xi,0) + E^q(x,\xi,0) \right\}$

Second Mellin moments of the GPDs contain information on the total angular momentum carried by quarks.

Note that the contribution from GPD $H$ is given by the quark momentum, already known from PDFs:

$$2J^q = \int_0^1 \mathrm{d}x\, x[q(x) + \bar{q}(x)] + \int_{-1}^{+1} \mathrm{d}x\, x E^q(x,0,0)$$

# Nucleon Spin: An emergent phenomena



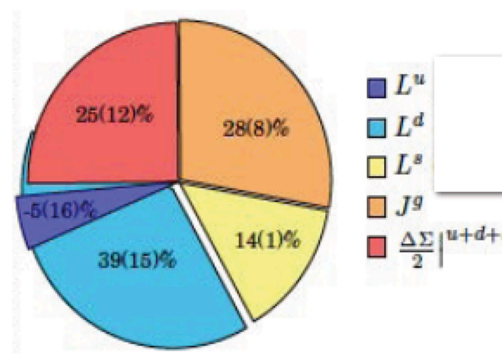
"Helicity sum rule"

$$\frac{1}{2}\hbar = \frac{1}{2}\underbrace{\Delta\Sigma}_{\text{quark contribution}} + \underbrace{\Delta G}_{\text{gluon contribution}} + \sum_q \underbrace{L_q^z + L_g^z}_{\text{orbital angular momentum}}$$

(25 +/- 3%) + (25+/-25%) + ????

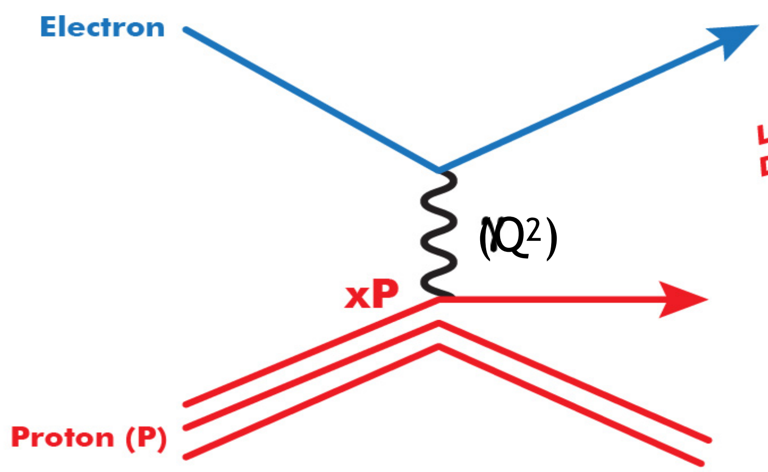
**RECENT: Spin on the Lattice:**

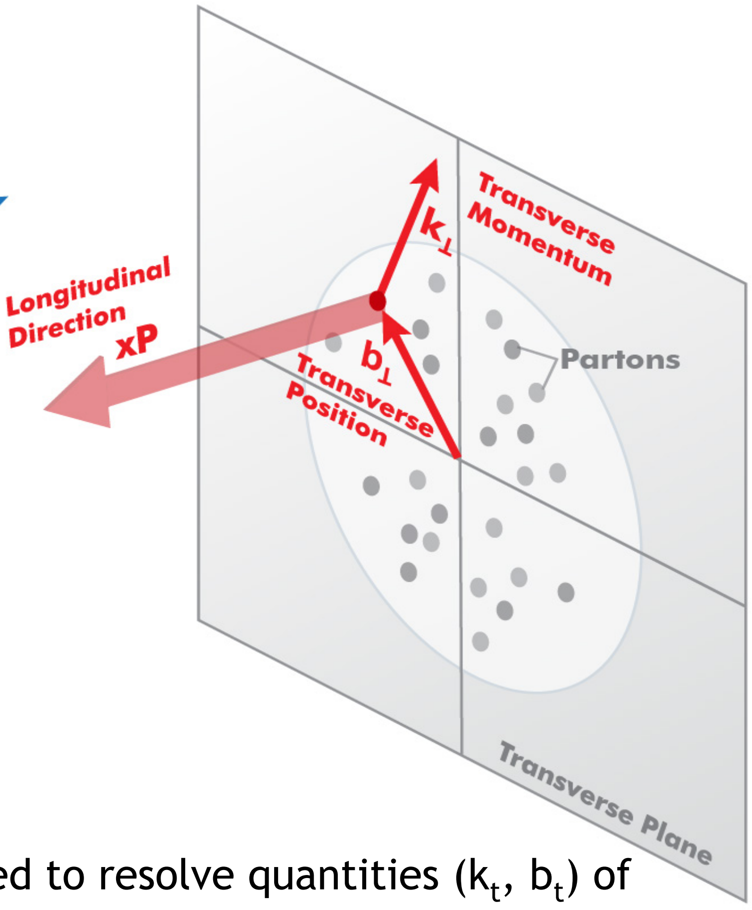
- **Gluon's spin contribution on Lattice: $S_G = 0.5(0.1)$**
  Yi-Bo Yang et al. PRL **118**, 102001 (2017)
- **$J_q$ calculated on Lattice QCD:**
  χQCD Collaboration, PRD91, 014505, 2015



# Experimental Challenge of the EIC

$Q^2 = sxy, \quad s = 4E_eE_p$



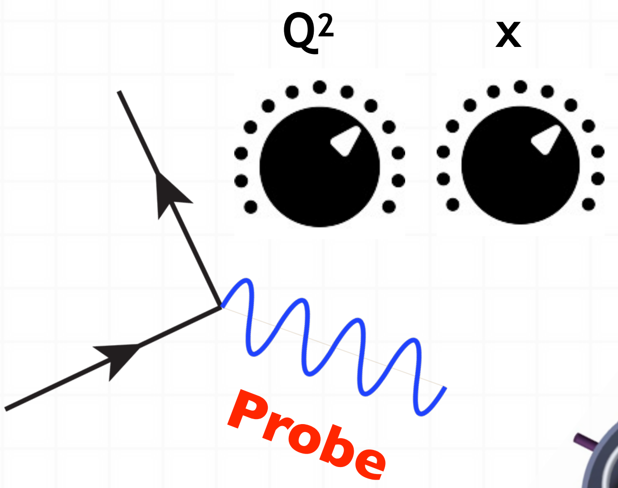




Need high beam energies to resolve partons in nucleons
$Q^2$ needs to be up to ~1000 $GeV^2$

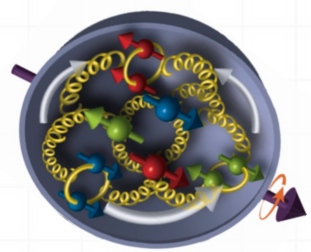
Need to resolve quantities ($k_t$, $b_t$) of order a few hundred MeV in the proton
Limits proton beam energy
High Luminosity needed

Electron-Ion Collider: Cannot be HERA or LHeC: proton energy (TeV) too high

# Parameters of the probe

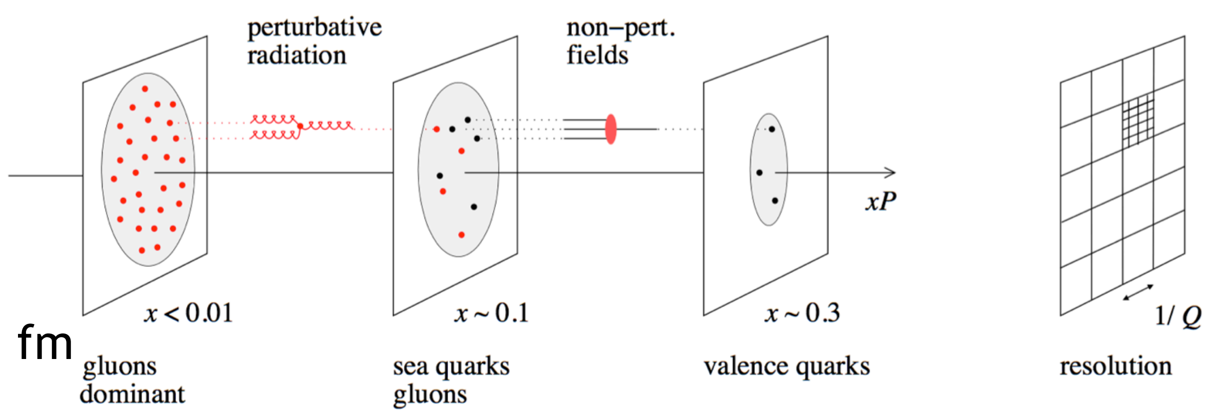



Ability to change **x** projects out different configurations where different dynamics dominate



Ability to change **Q²** changes the resolution scale

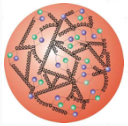
$Q^2 = 400\ GeV^2 \Rightarrow 1/Q = .01\ fm$



# Where EIC Needs to be in x (nucleon)

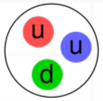
Saturation Regime: Needs to be Accessed via Ions (see later)

Collective Regime



Many-body Regime

Few-body Regime




$10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ 1 X (for proton)

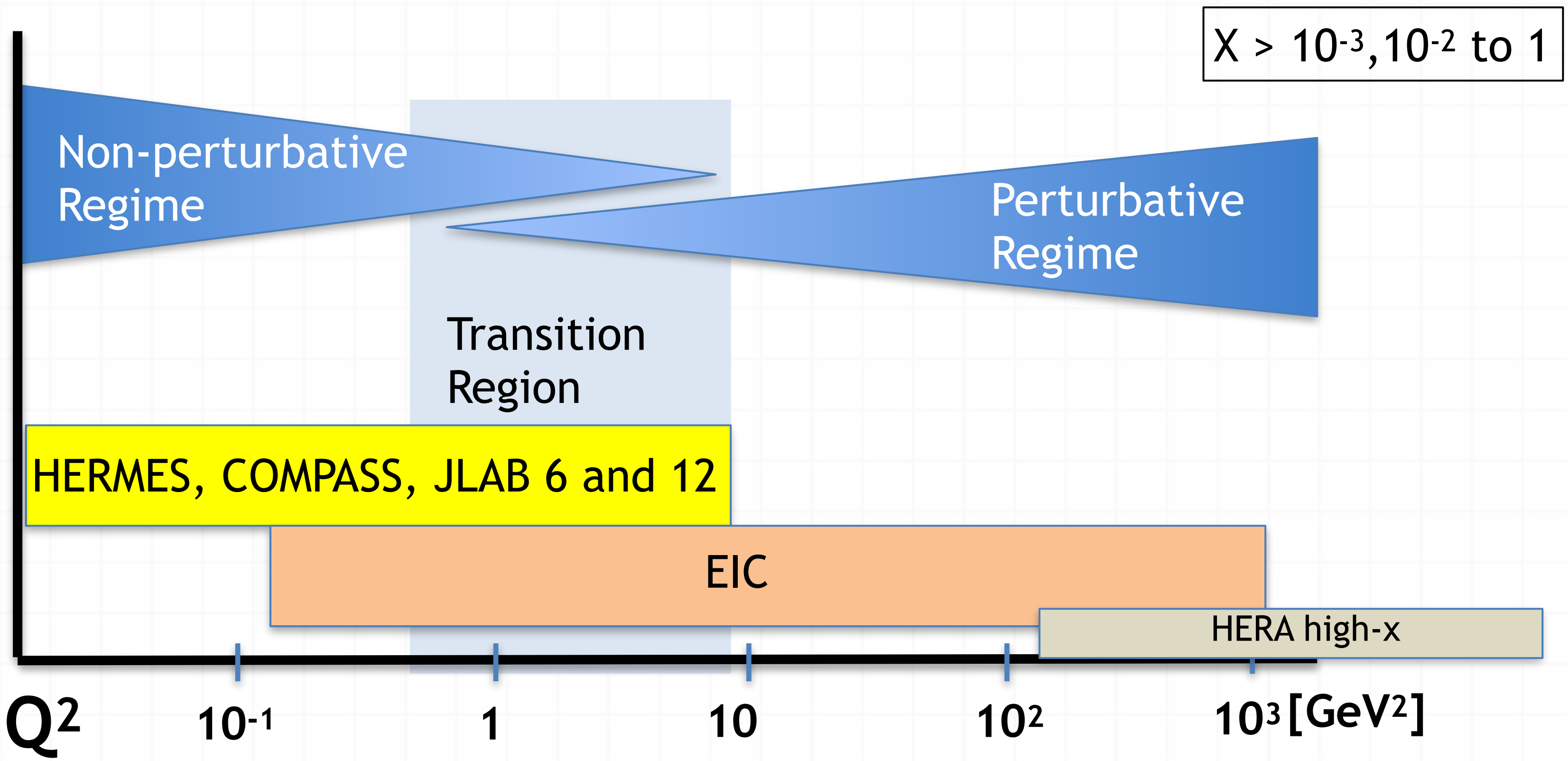
QCD Radiation Dominated
(Studied at HERA)

Hadron Structure Dominated

Main interest for EIC Nucleon/Nuclear Program

Spin,TMD,GPD...

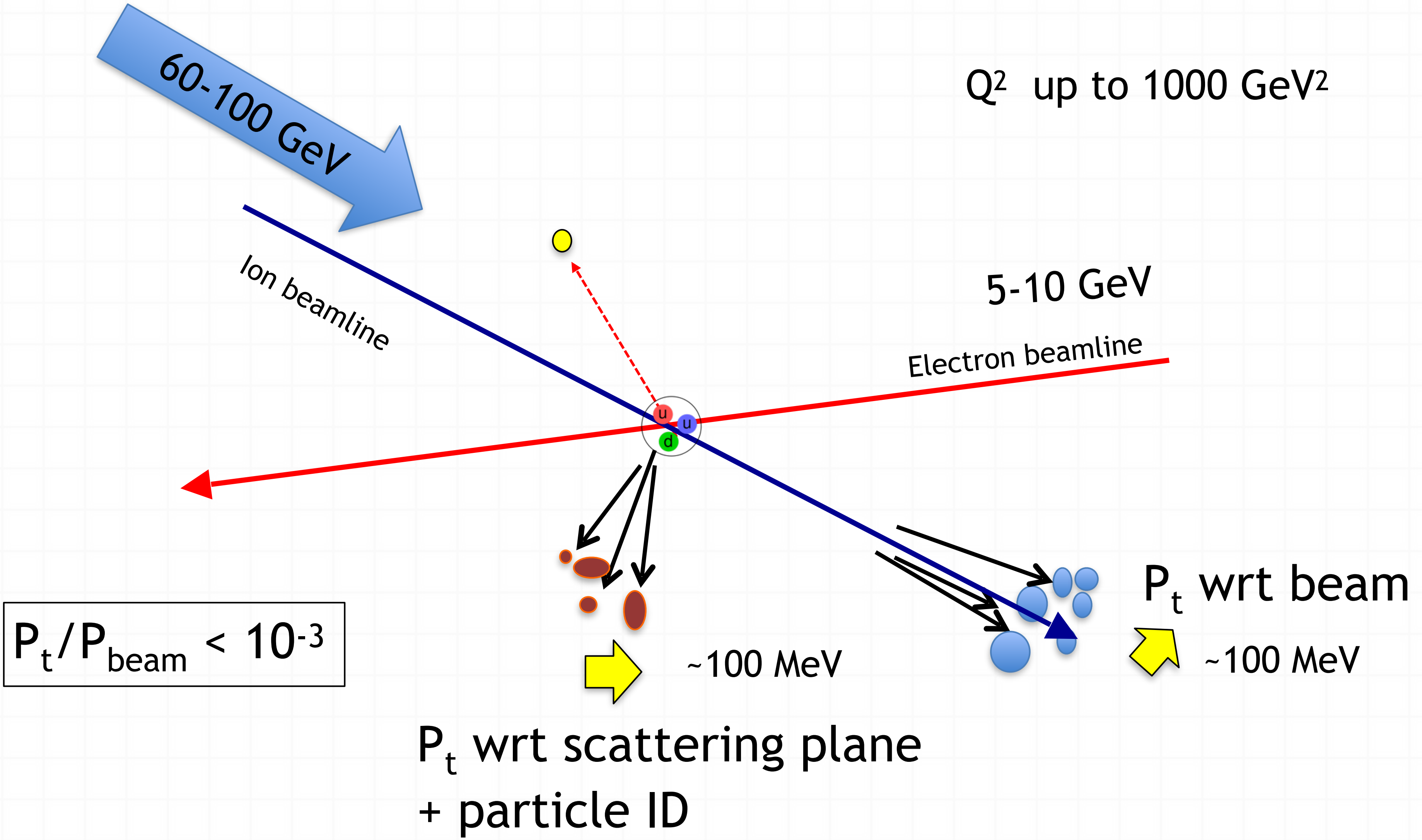
# Where EIC needs to be in $Q^2$



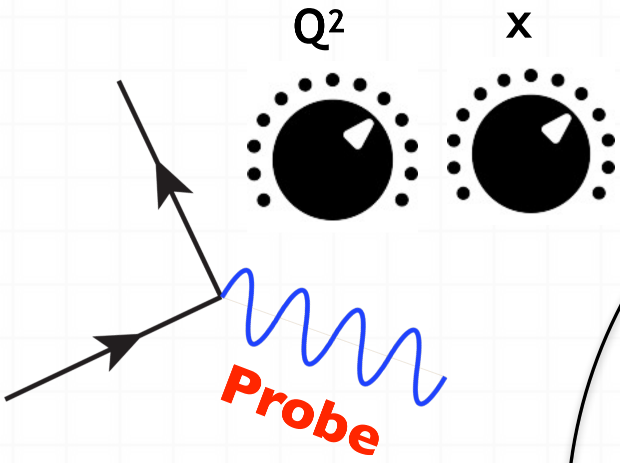

- Include non-perturbative, perturbative and transition regimes
- Provide long evolution length and up to $Q^2$ of ~1000 $GeV^2$ (~.005 fm)
- Overlap with existing measurements

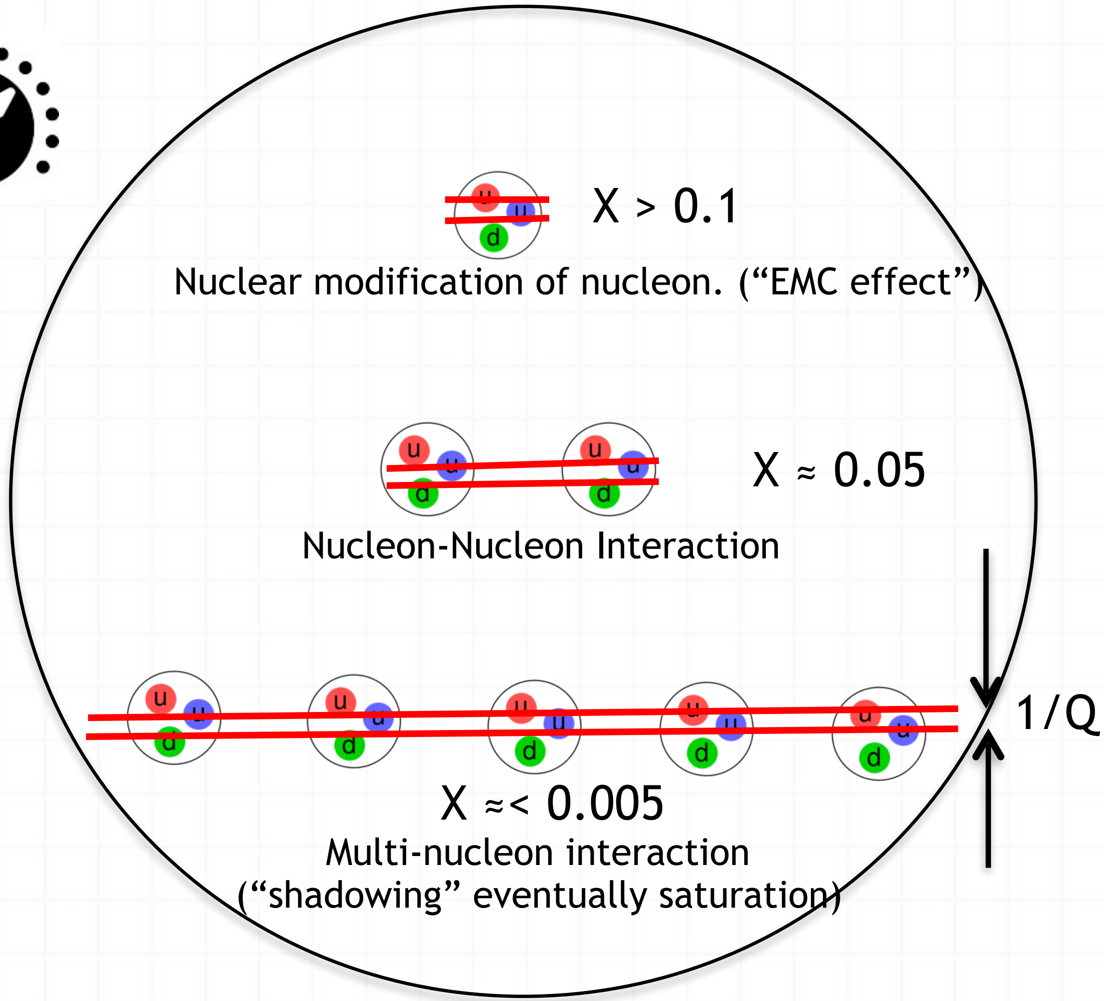
Disentangle Pert./Non-pert., Leading Twist/Higher Twist

# Measuring $k_t$ and $b_t$



# Parameters of the Probe (Nuclei)

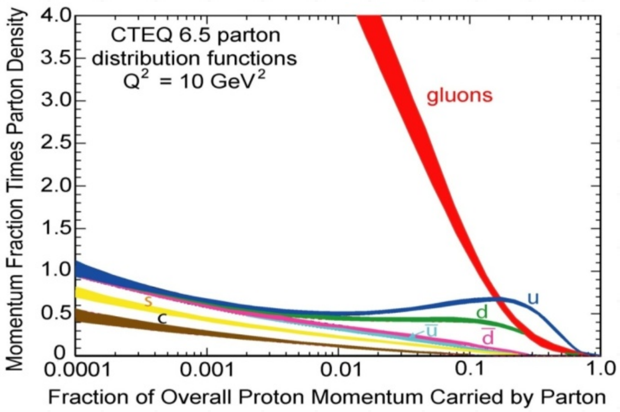


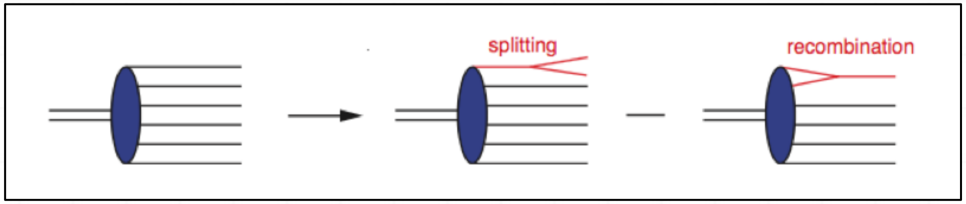

Probing the nucleon interaction in the nuclei

Note: the x range for nuclear exploration is similar to the nucleon exploration

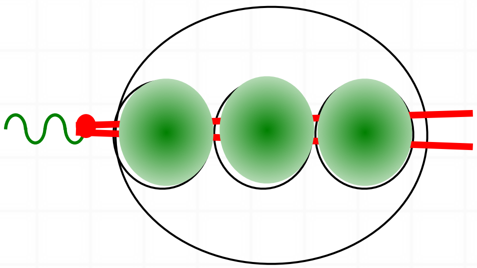
# QCD at Extremes: Parton Saturation



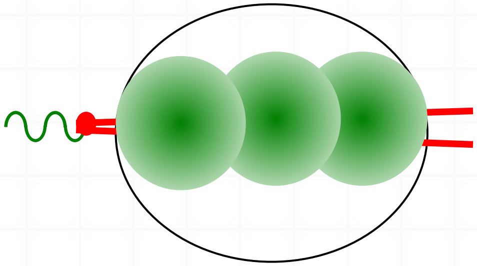

HERA discovered a dramatic rise in the number of gluons carrying a small fractional longitudinal momentum of the proton (i.e. small-x).




This cannot go on forever as x becomes smaller and smaller: parton recombination must balance parton splitting.
i.e. Saturation—unobserved at HERA for a proton. (expected at extreme low x)

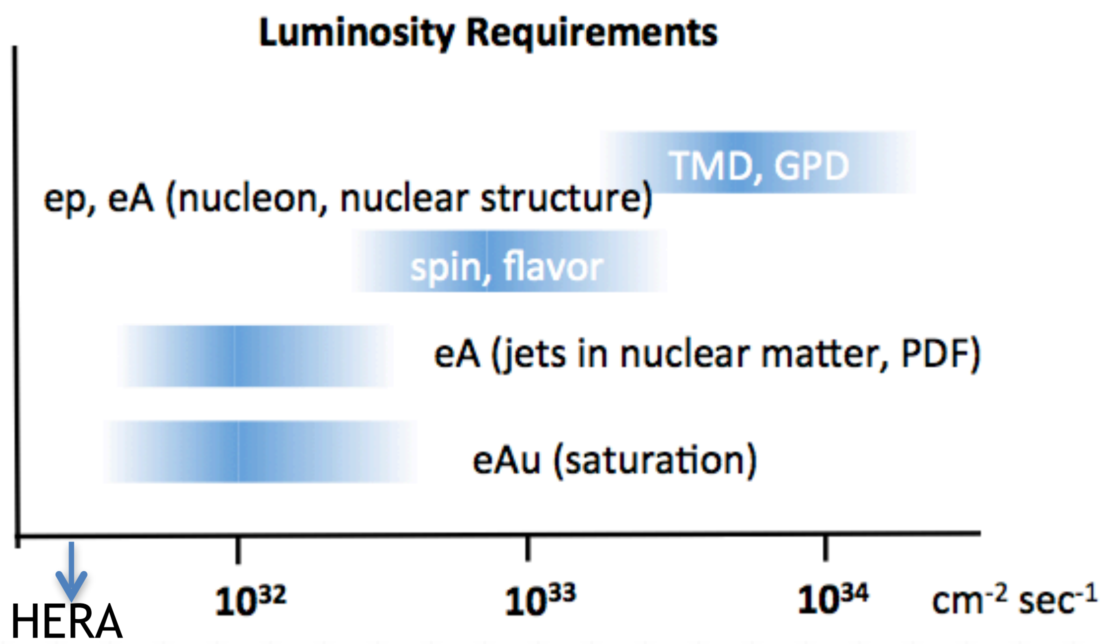


In nuclei, the interaction probability enhanced by $A^{1/3}$



Will nuclei saturate faster as color leaks out of nucleons?

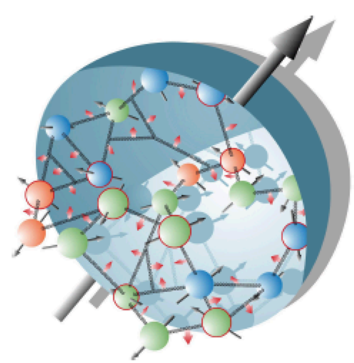
# Luminosity/Polarization Needed




Polarizaton

Understanding hadron structure cannot be done without understanding spin:

- polarized electrons and
- polarized protons/light ions

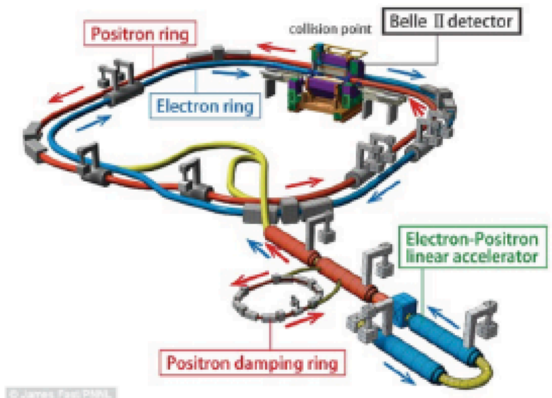


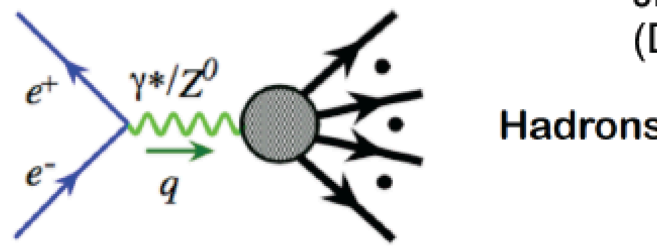
Central mission of EIC (nuclear and nucleon structure) requires high luminosity and polarization (>70%).

# Why Electron- Ion scattering ? Hard probes

Jianwei Qiu (DIS2018)

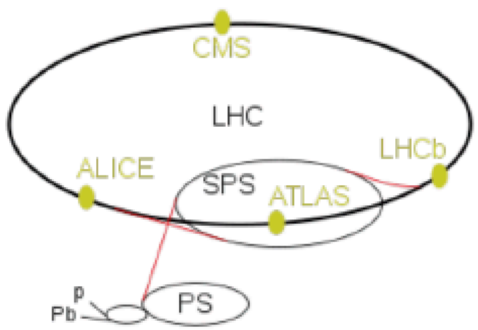
❑ **Lepton-lepton collisions:**

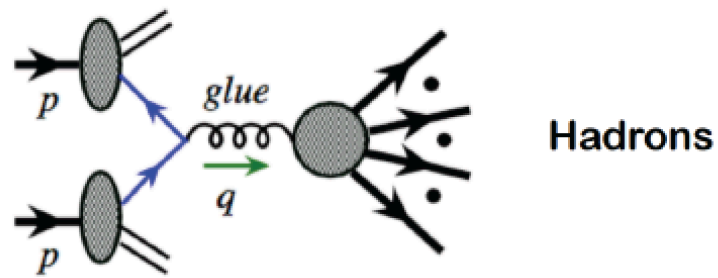



✧ No hadron in the initial-state
✧ Hadrons are emerged from energy
✧ Not ideal for studying hadron structure

❑ **Hadron-hadron collisions:**



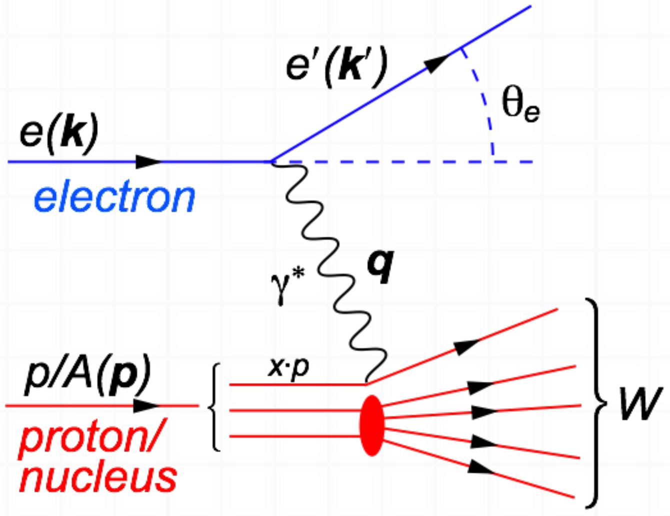




✧ Hadron structure – motion of quarks, …
✧ Emergence of hadrons, …
✧ Initial hadrons broken – collision effect, ..

❑ **Lepton-hadron collisions:**

Hard collision without breaking the initial-state hadron – spatial imaging, …

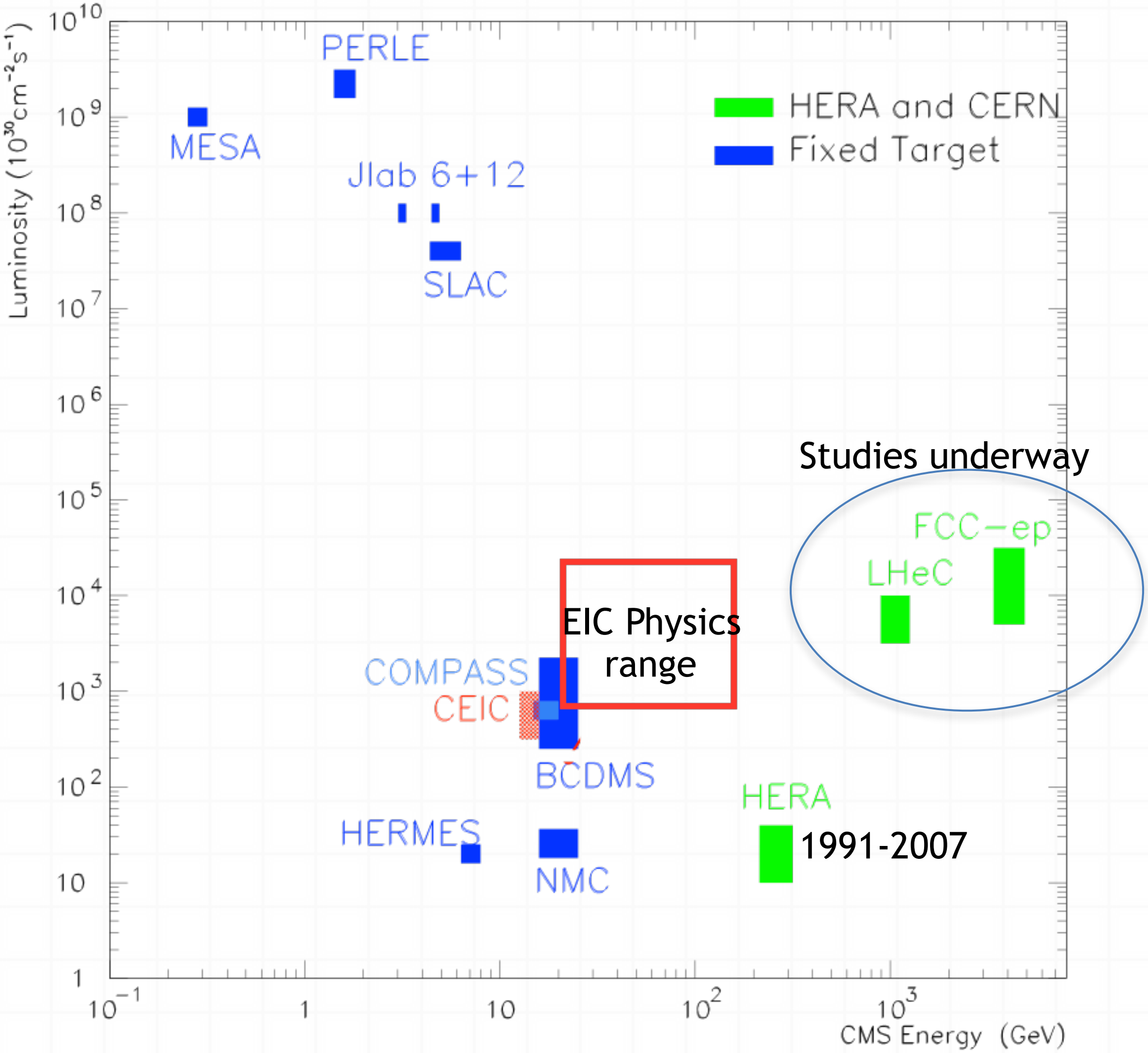
# Electron Ion Collider (EIC)




- Electron Ion Collider (EIC)
  - It is a Deep Inelastic Scattering Collider
  - Point-like probe interacts with p/A
  - Science aims of the EIC
    - Probe Nuclear and Nucleon Structure
    - Laboratory for Quantum Chromo Dynamics.
    - Search for certain types of BSM particles (e.g. Leptoquarks)

Which aims play the primary role depends on the parameters of the EIC, such as the center-of-mass energy, luminosity, etc.

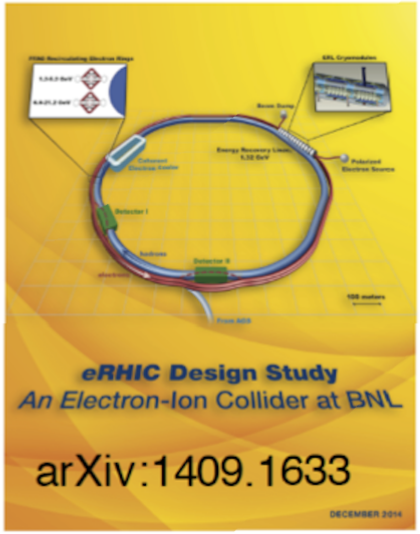
# Past, Existing and proposed DIS Facilities




US EIC will be a unique facility

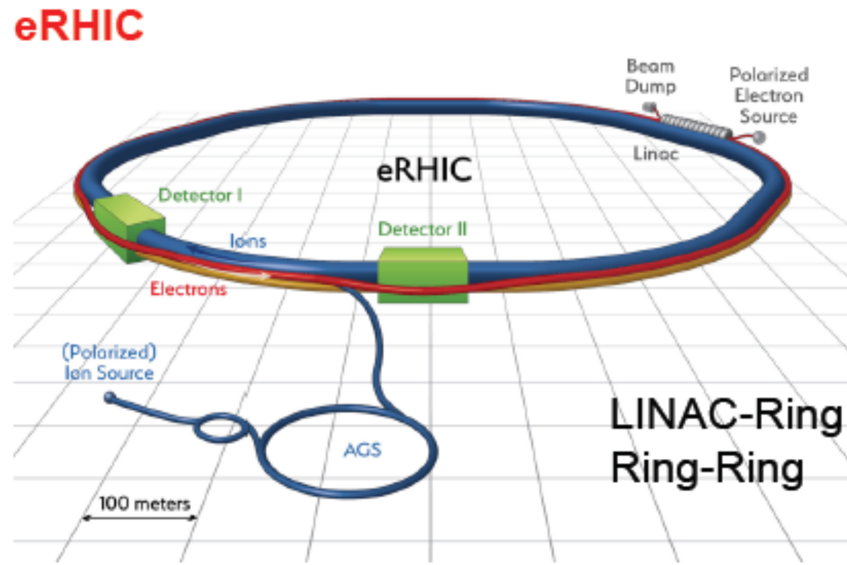
No other machine, existing or planned can address the physics of interest satisfactorily

# Options for EIC




**eRHIC**

arXiv:1409.1633
Energy range:
e-: 15-20 GeV
p: 100-250 GeV
W: 40-120 GeV





MEIC Design Summary

**January 20, 2015**

**Author List**

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**Author Institutions**

[1]Thomas Jefferson National Accelerator Facility (JLab), Newport News, VA 23606 USA

[2]Deutsches Elektronen-Synchrotron (DESY), 22607 Hamburg, Germany

[3]Sci. & Tech. Laboratory Zaryad, Novosibirsk, Russia

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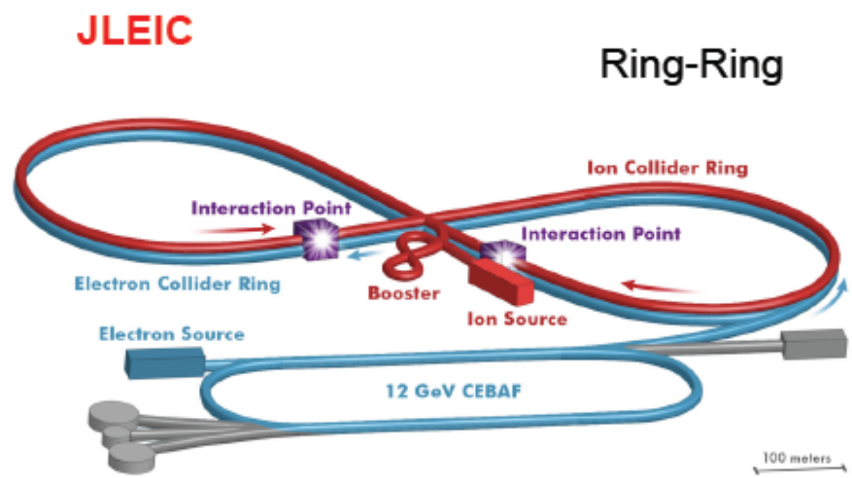
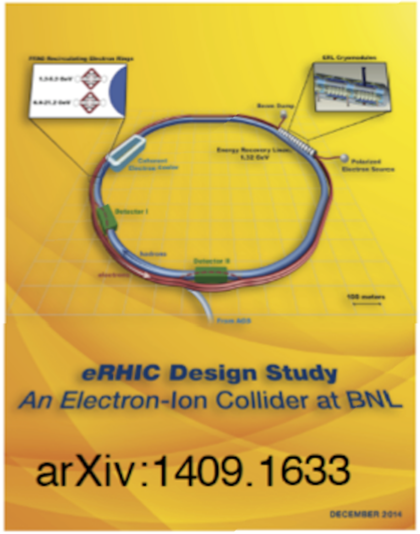
**JLEIC**

arXiv:1504.07961
Energy range:
e-: 3-12 GeV
p : 40-100/400 GeV
W: 20-65/140 GeV



# Options for EIC

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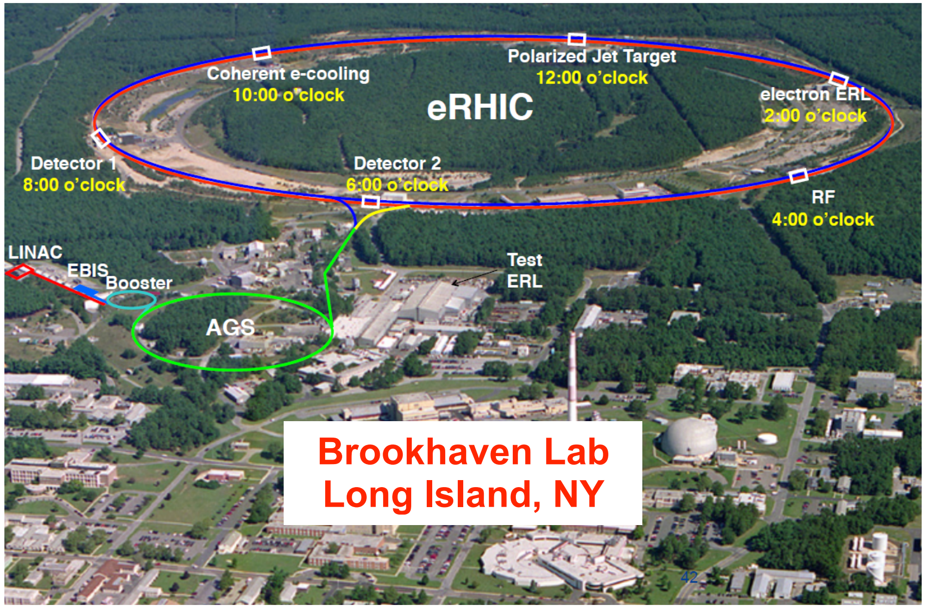


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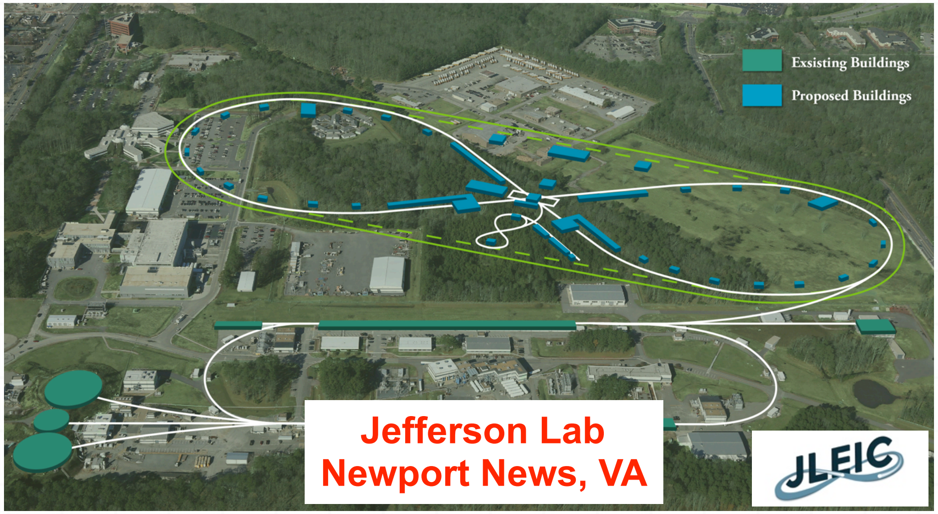

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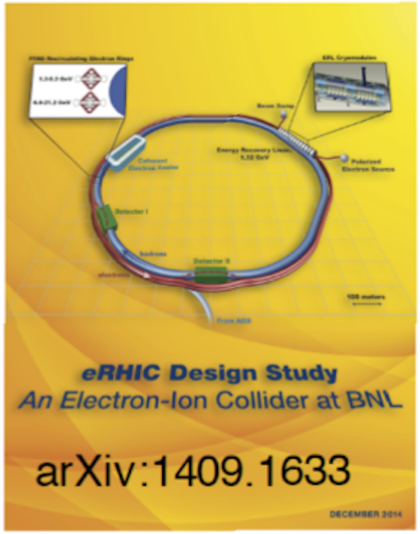


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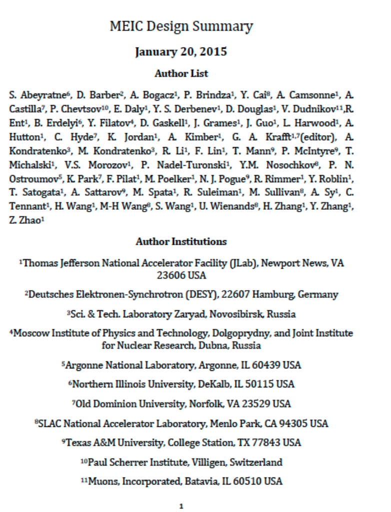

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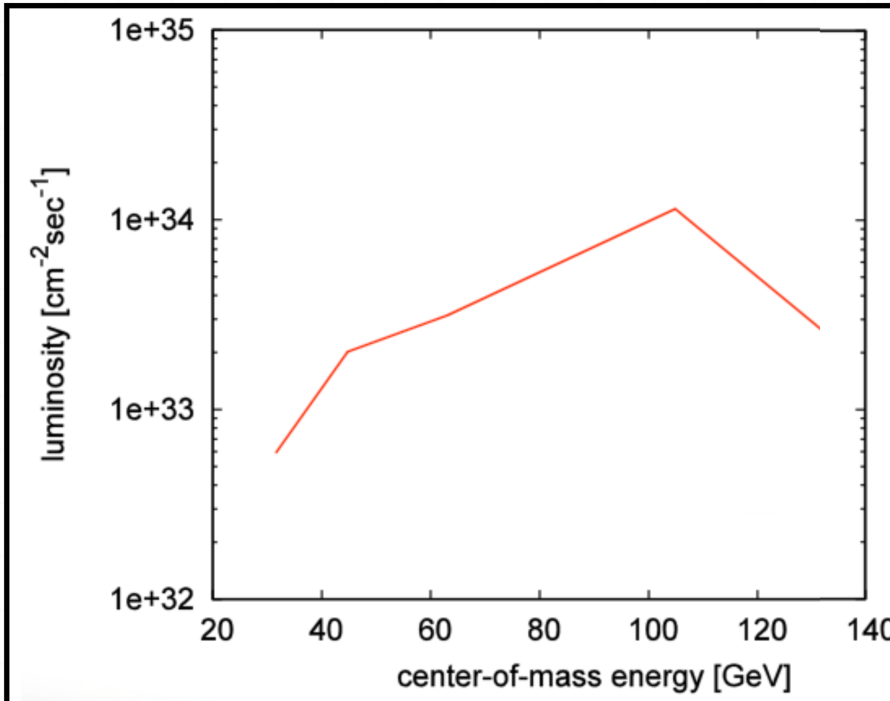
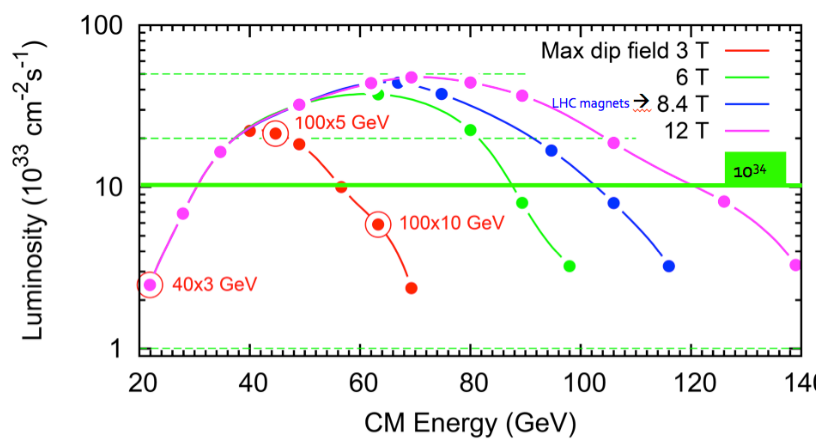



Luminosity vs. center-of-mass energy



# EIC Parameters and Realization Plans

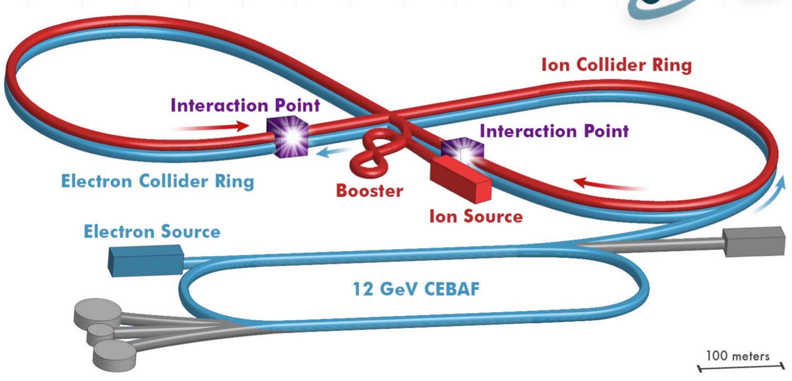
- US EIC Machine design aims from the EIC Whitepaper
  - Highly polarized (~70%) electron and nucleon beams.
  - Ion beams from deuterons to the heaviest nuclei (uranium or lead).
  - Variable center of mass energies from ~20 - ~100 GeV, upgradable to ~140 GeV.
  - High luminosity: ~10 $^{33-34}$ $cm^{-2}$ $s^{-1}$
  - Possibility of having more than one interaction region.

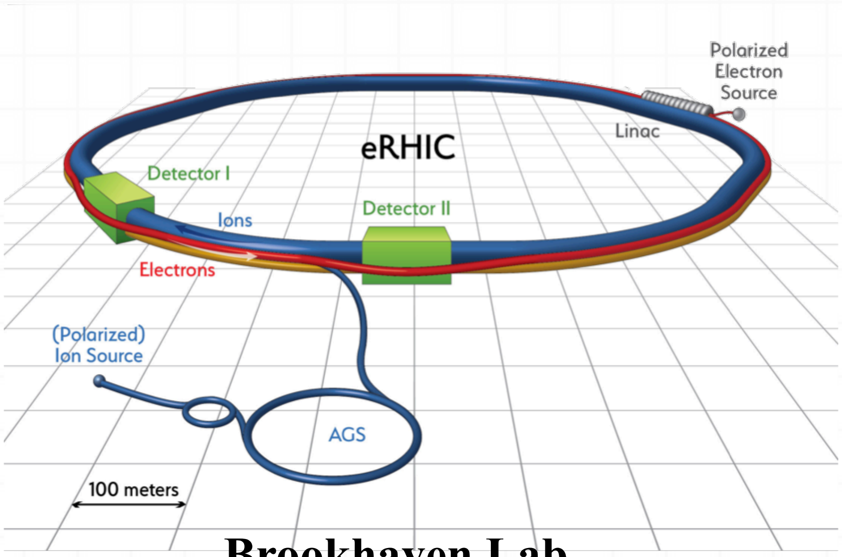
- Two proposed realization plans
  - Jefferson Lab: building on the existing 12 GeV CEBAF. JLEIC Design.
  - BNL: building on the existing RHIC. eRHIC Design.
  - Recent review of acc. R&D

- Similar performances, cost according to LRP assessment

- US EIC will likely be down-selected from one of these proposals

**Jefferson Lab**

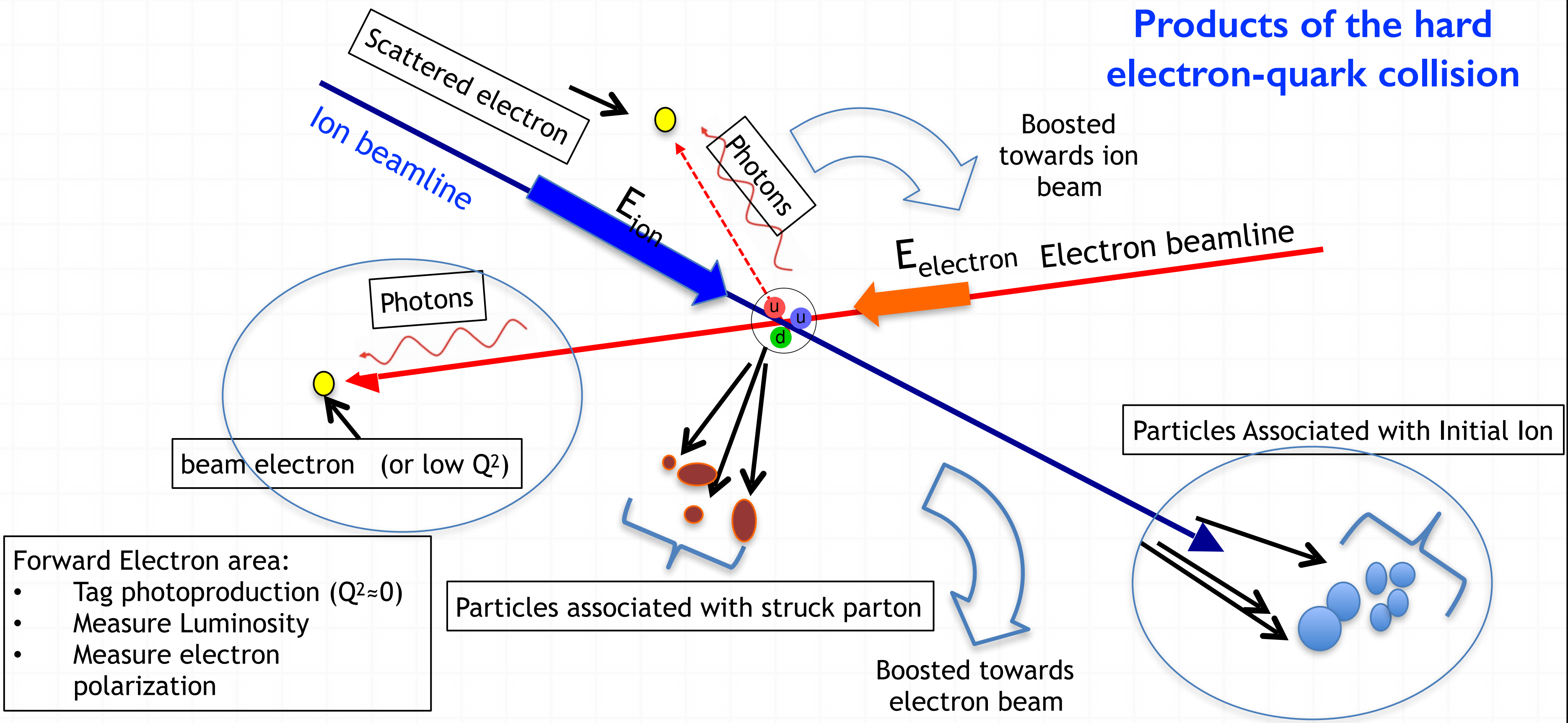



**Brookhaven Lab**

# EIC detection requirements

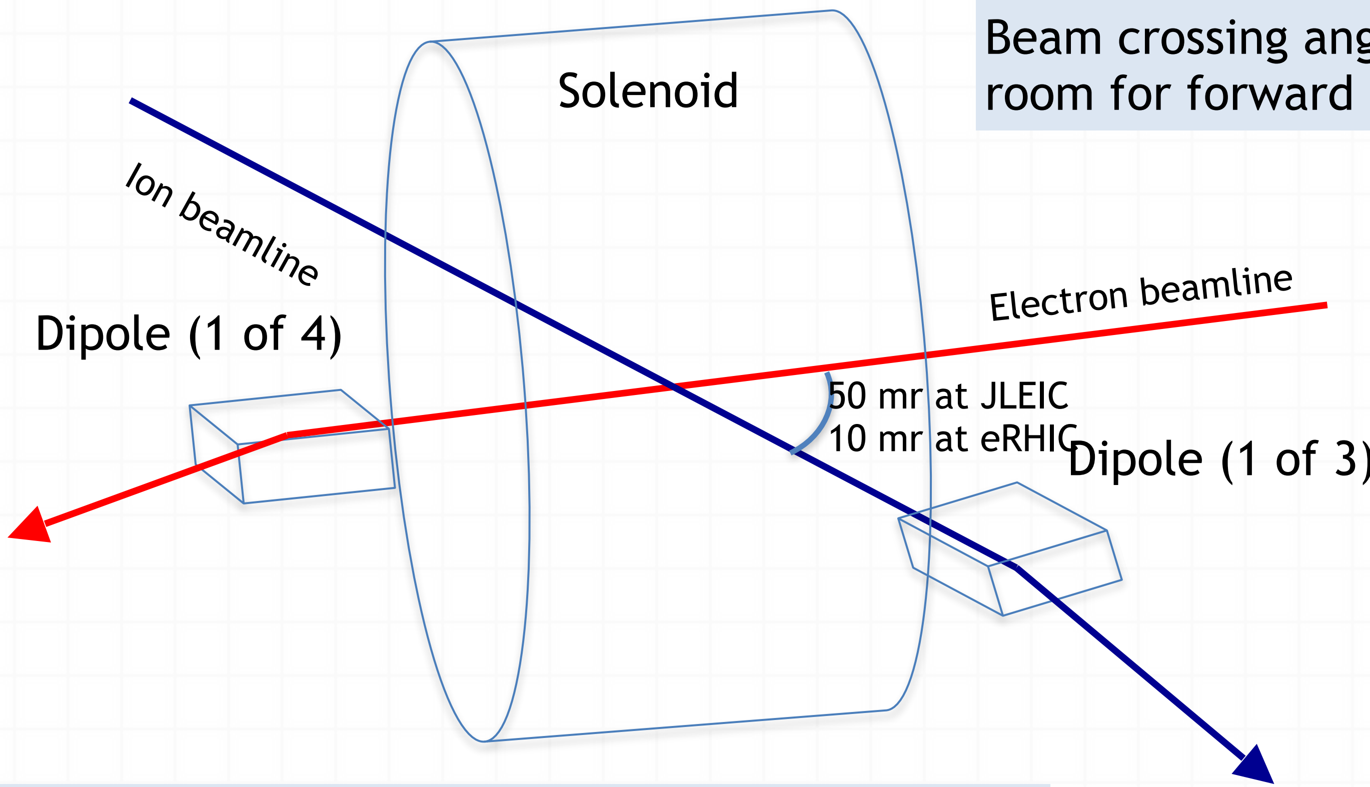
Aim of EIC is nucleon and nuclear structure beyond the longitudinal description




- Particles associated with struck parton must be identified and measured: **PId essential!**
- Asymmetric collision energies will boost the final state particles in the ion beam direction: **Detector requirements change as a function of rapidity**
- For EIC, particles of the "target remnant" is as important as the struck parton: **aim for ~100% acceptance and good resolution**

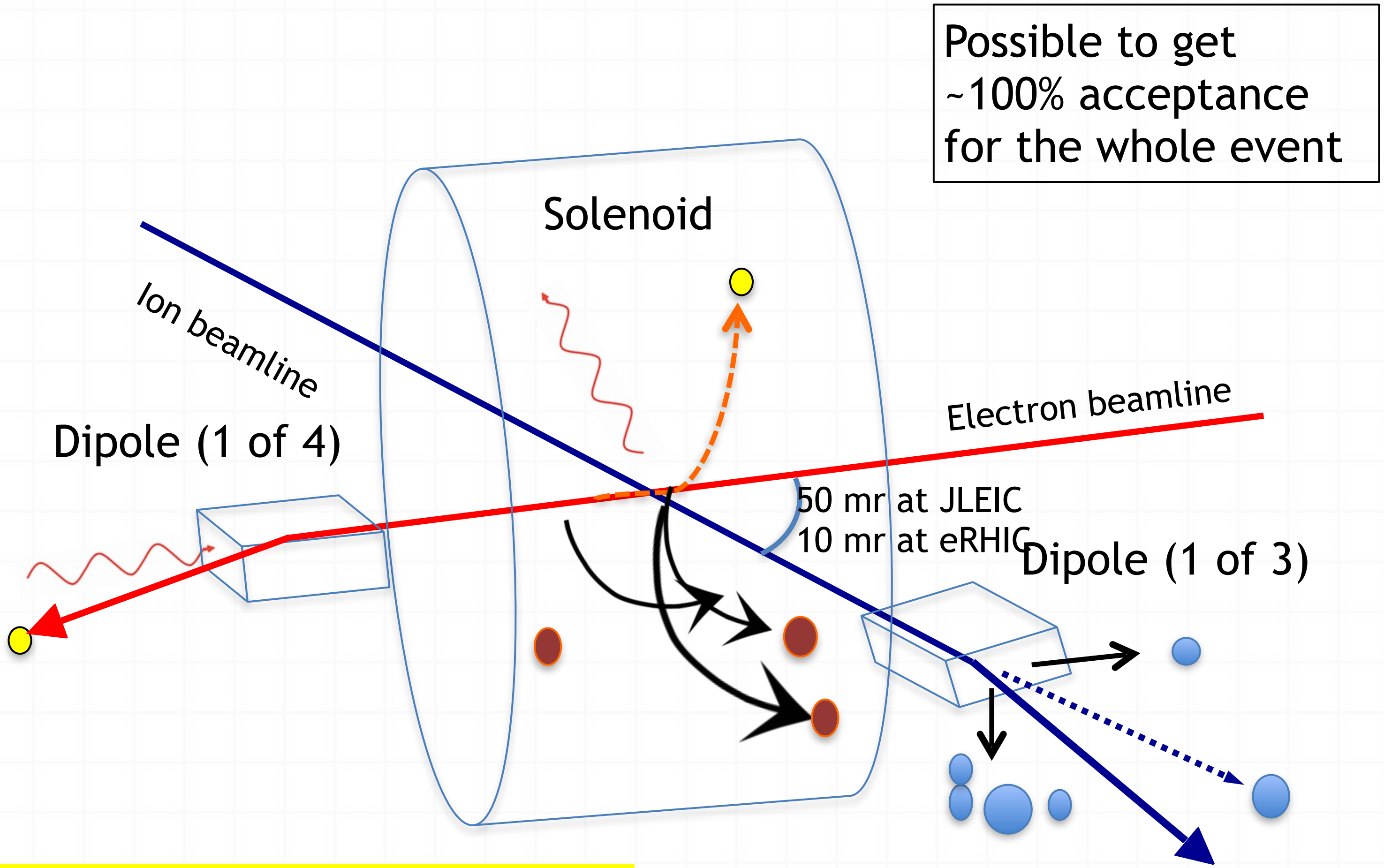
# Interaction Region concept

Beam crossing angle creates room for forward dipoles



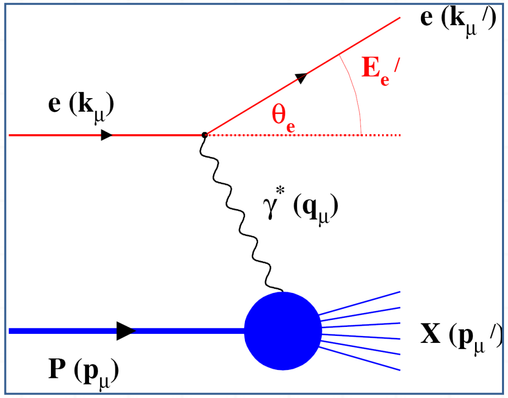

Dipoles analyze the forward particles
and create space for detectors in the forward direction

# Interaction Region concept

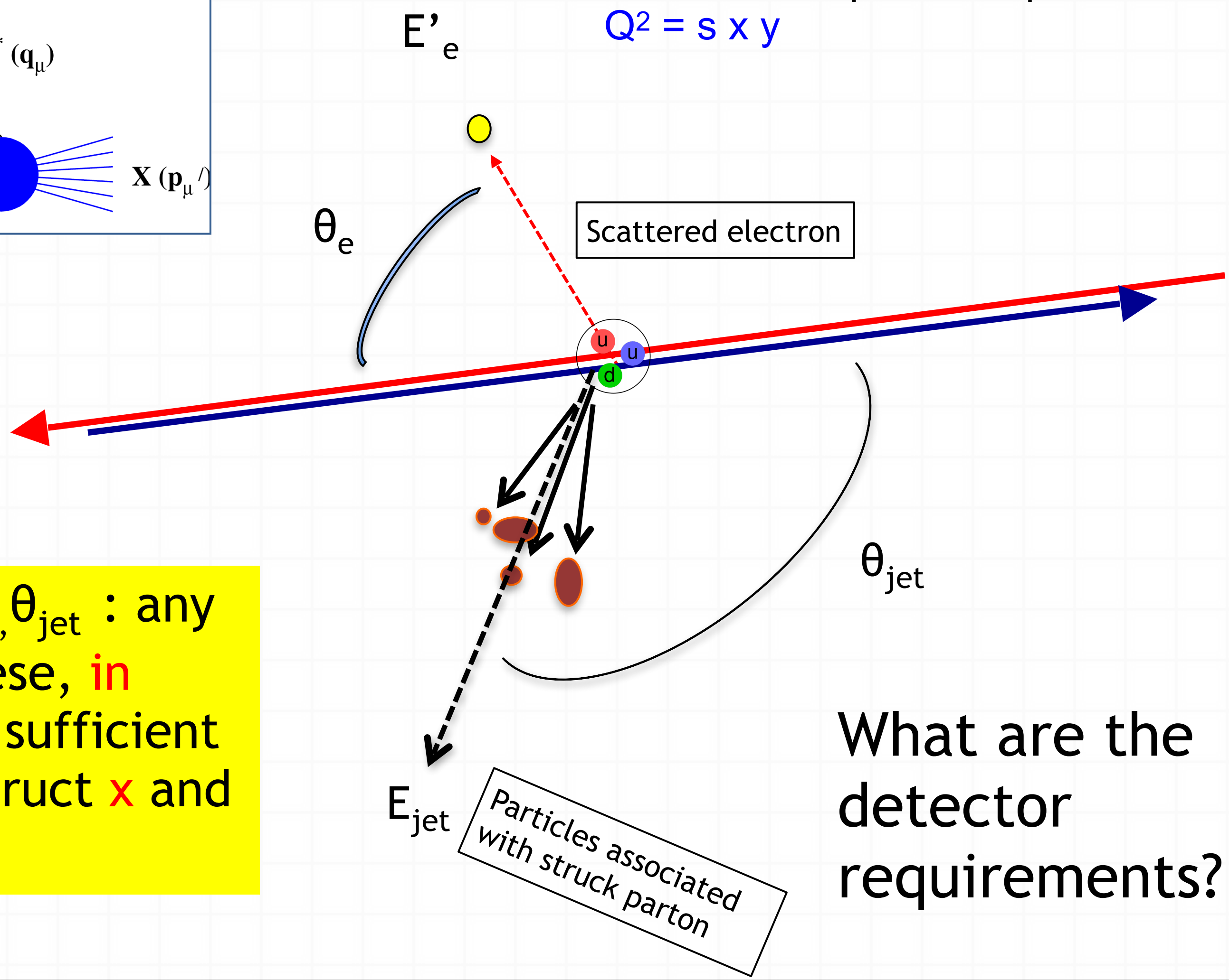



Total acceptance detector (and IR)

# EIC Central Detector



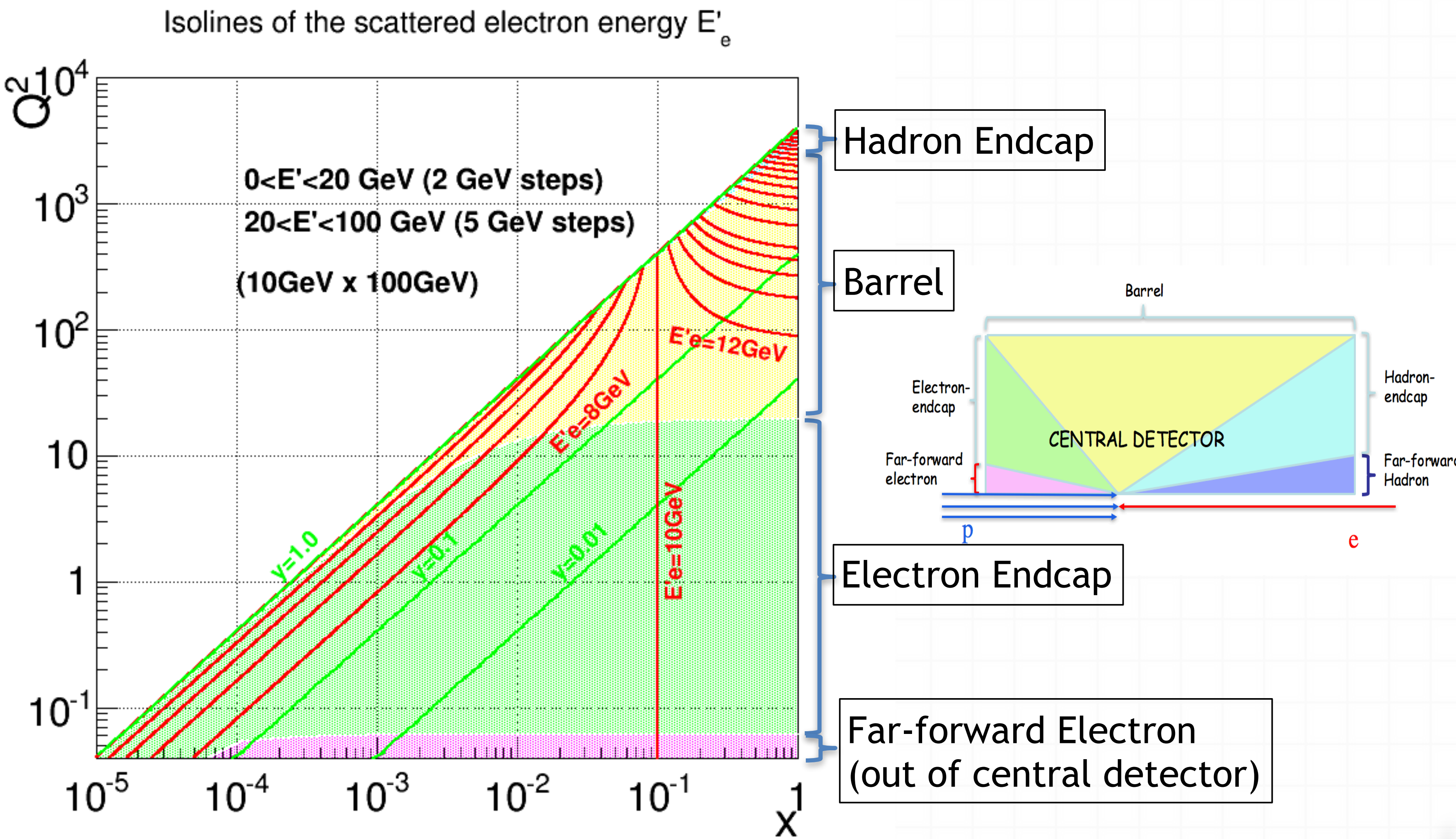

$Q^2$ → Measure of resolution (~θ)
y → Measure of inelasticity (ν/$E_{beam}$)
x → Measure of momentum fraction ($Q^2$/2Mν) of the struck quark in a proton
$Q^2 = s\ x\ y$



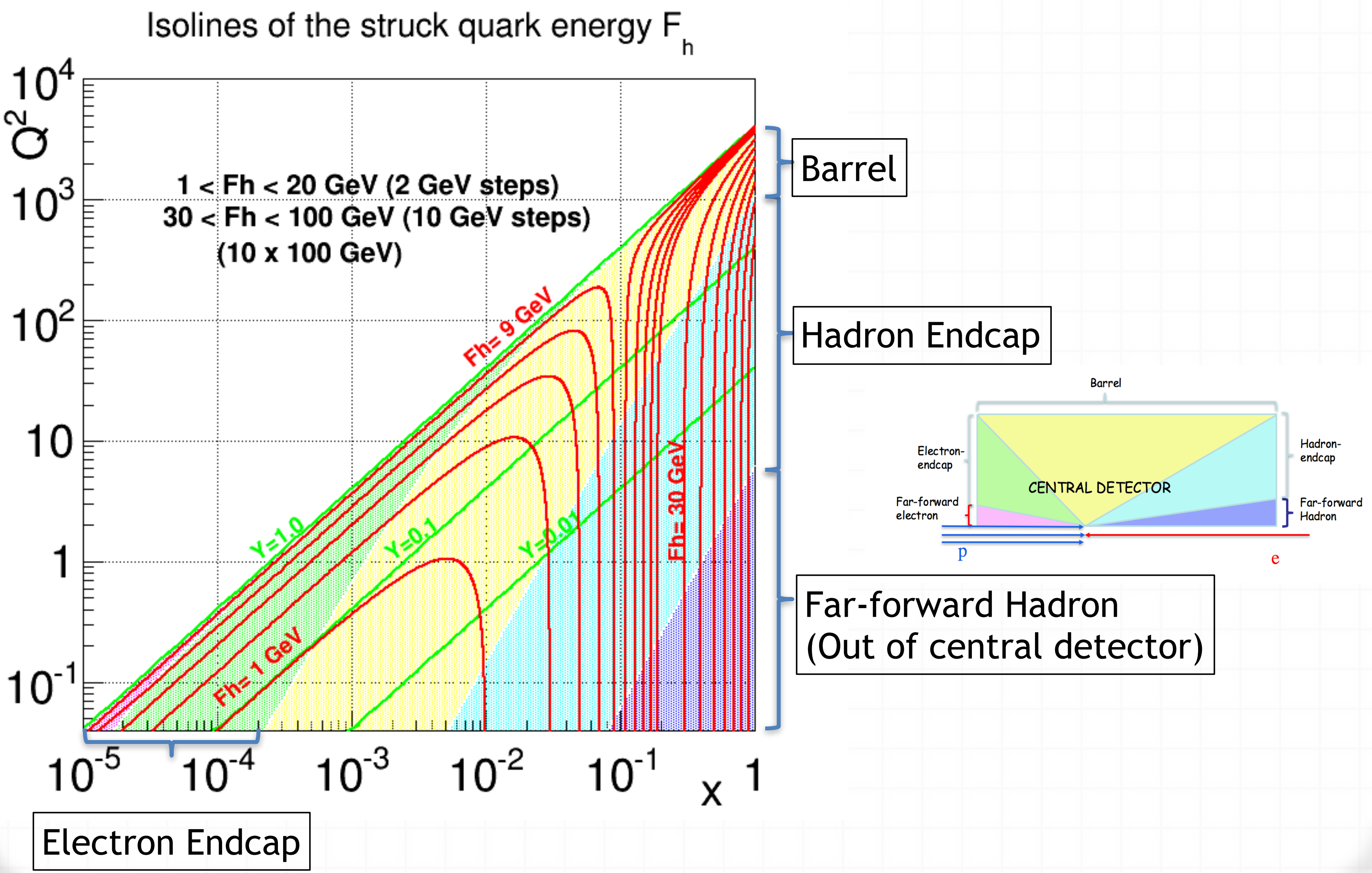

$E'_e, \theta_e, E_{jet}, \theta_{jet}$ : any two of these, in principle, sufficient to reconstruct x and $Q^2$.

What are the detector requirements?

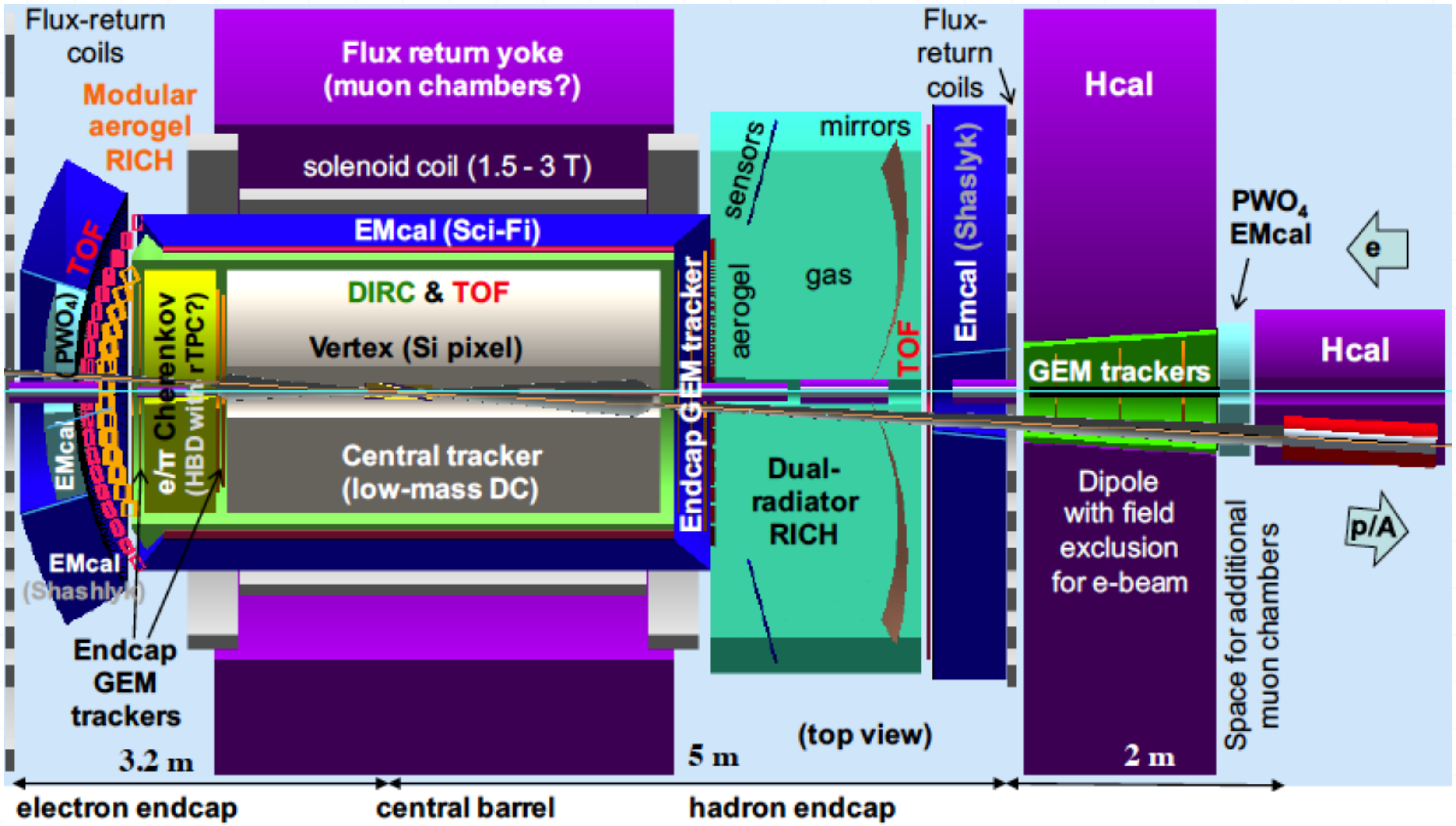
# Electron detection



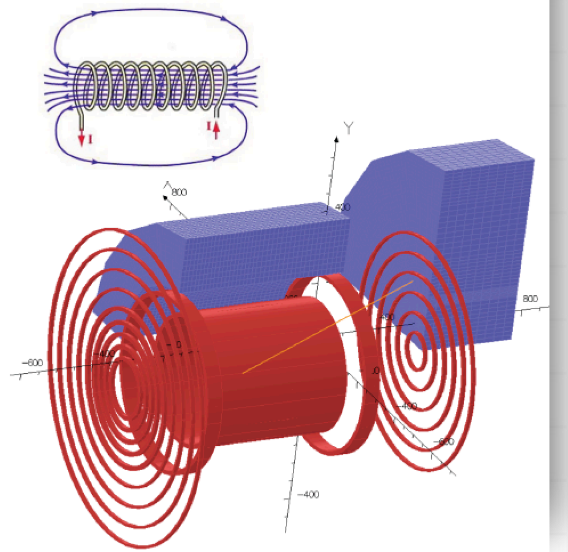
# Quark (Jet) detection



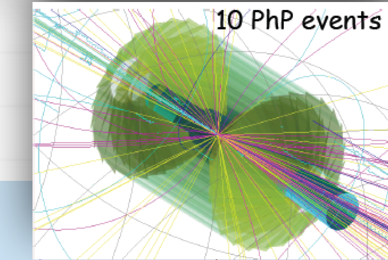
# Current JLEIC concept

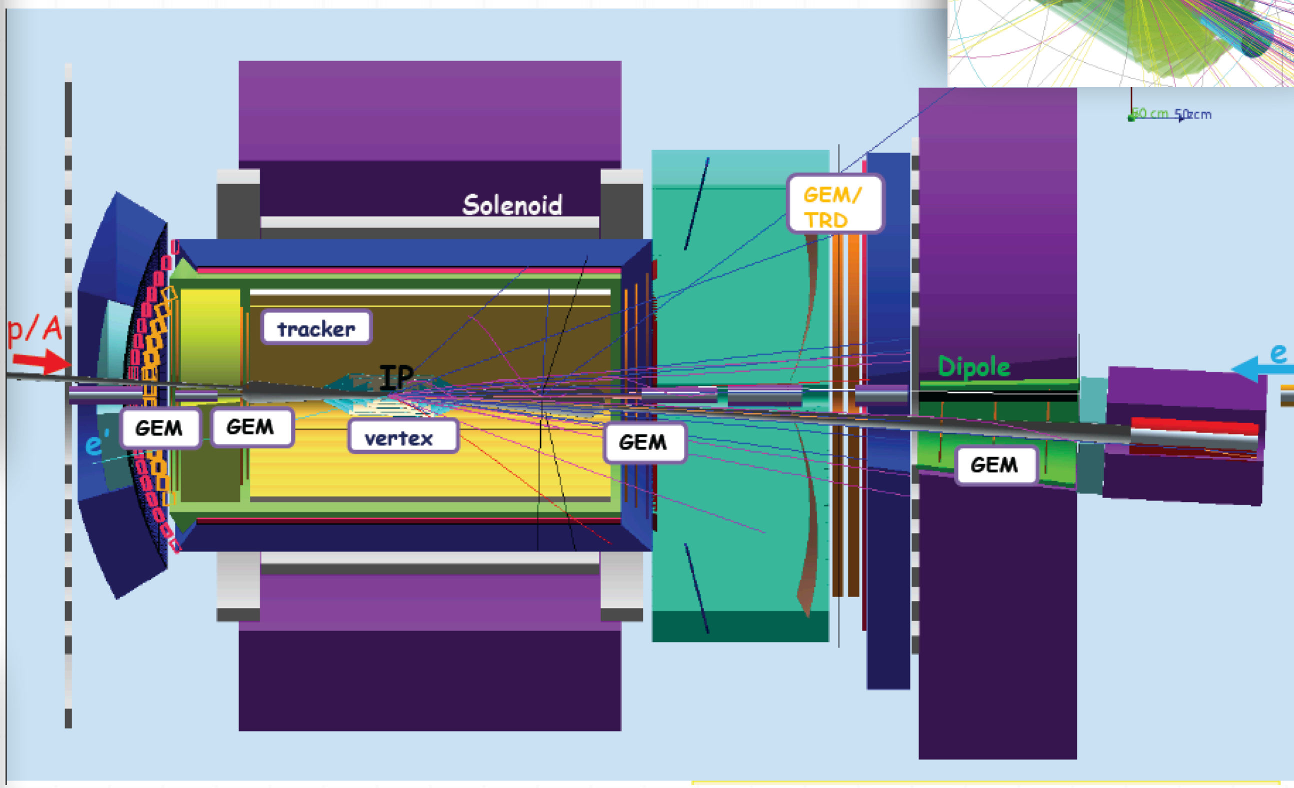


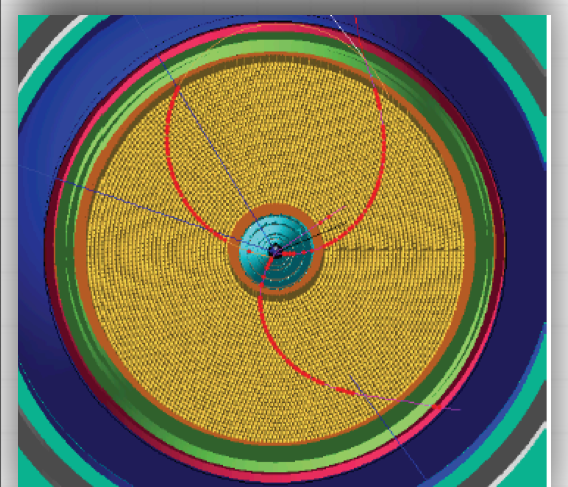
- around Interaction point
- Strong homogeneous field (1.5-3) Tesla



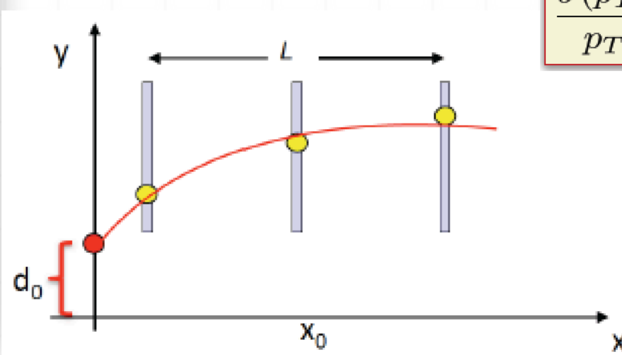
# JLEIC trackers



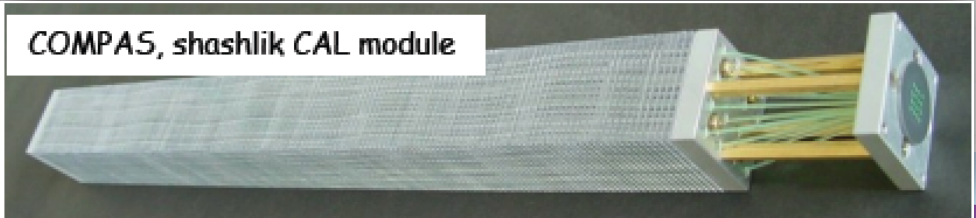



JLEIC tracker design with straws

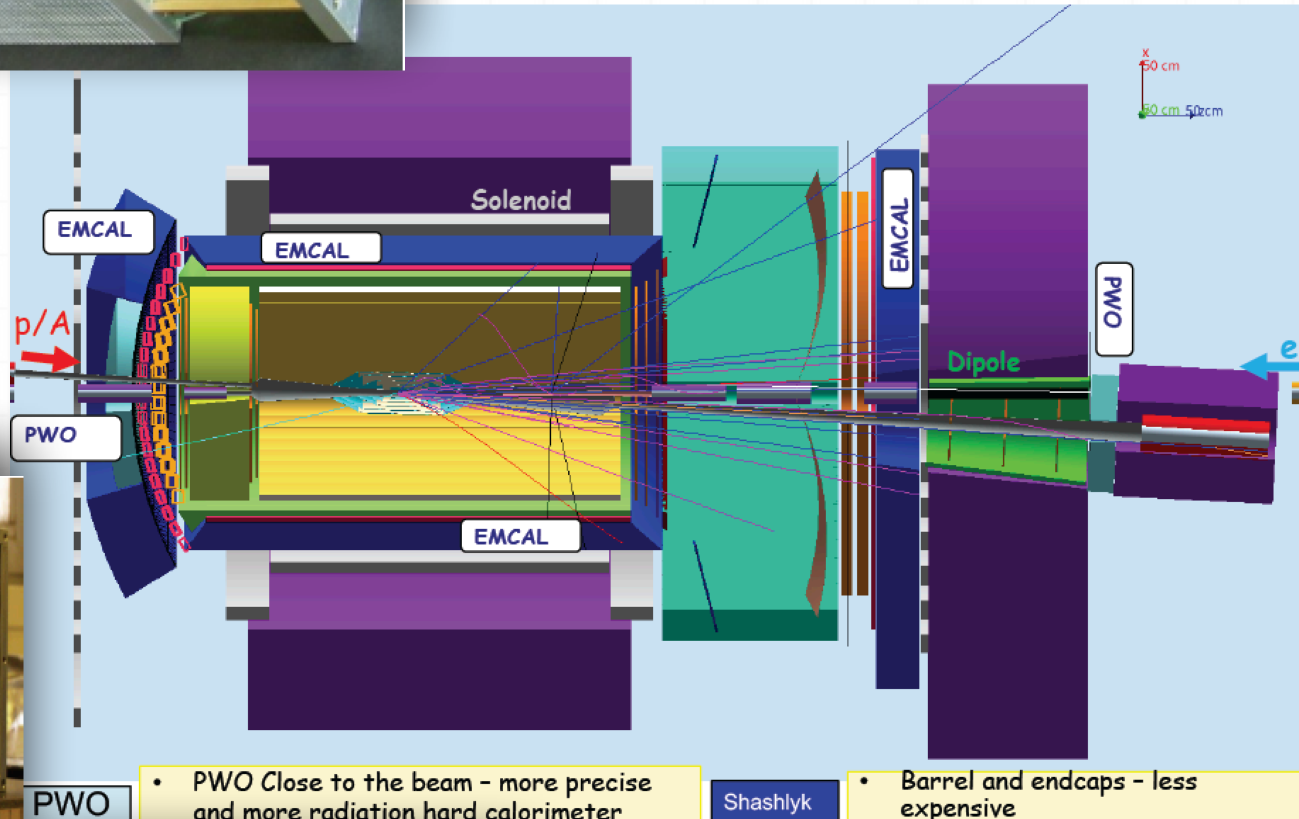



$$\frac{\sigma(p_T)}{p_T}^{meas} = \frac{\sigma(x) \cdot p_T}{0.3BL^2}\sqrt{\frac{720}{N+4}}$$

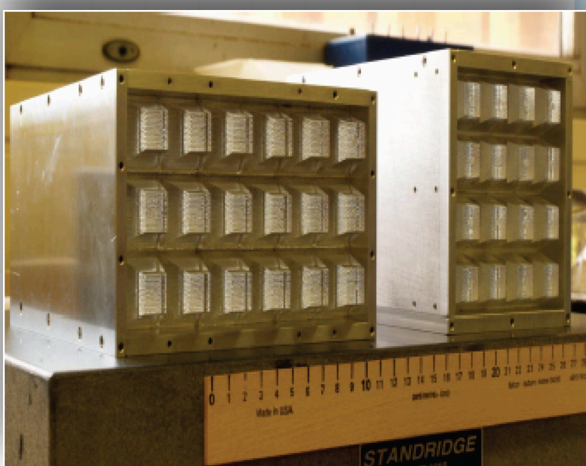
$p_t$ ~ 1-10 GeV
B =3T
N~50
$\sigma_x$~100μm
L~1m
for 10GeV ~0.4%



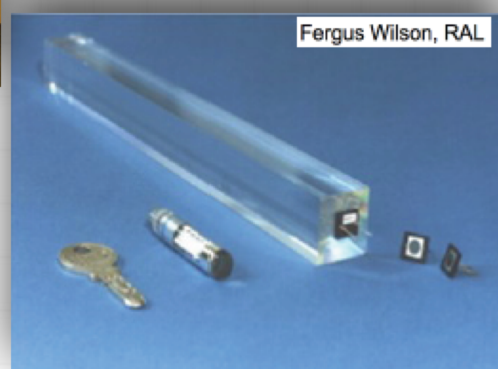

# JLEIC Calorimetry




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

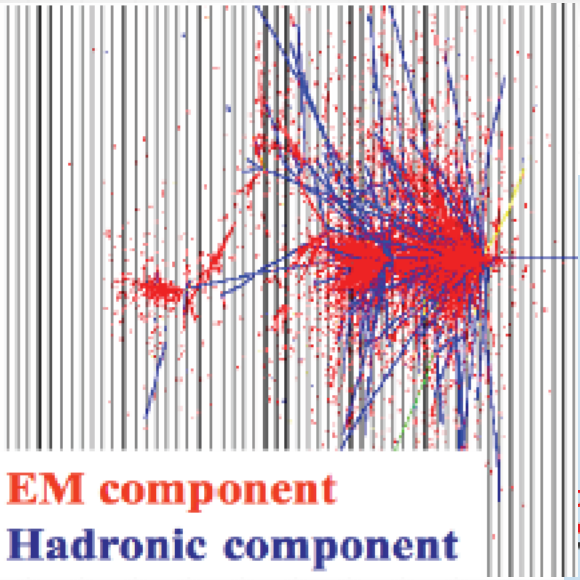


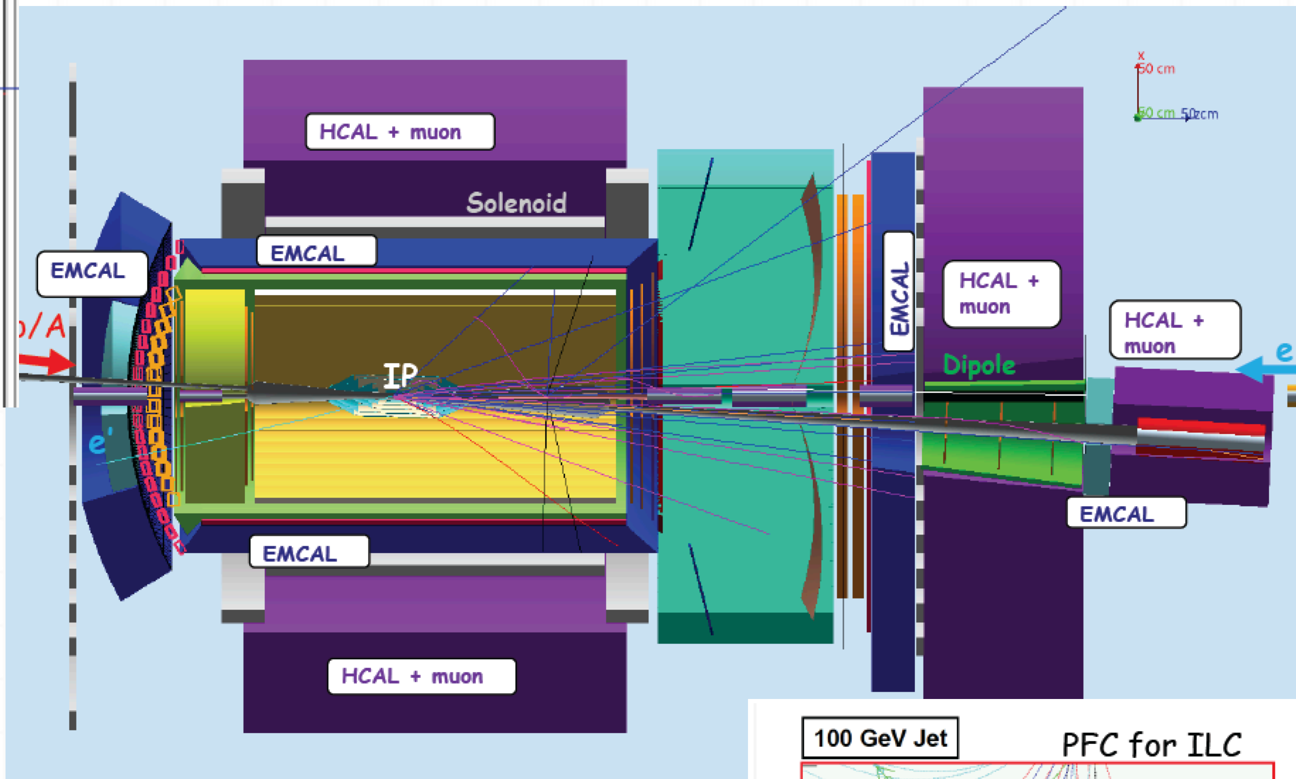
**W powder + Sci-fibers**
- Resolution ~12%/√E




**$PbWO_4$**
- Excellent energy resolution:
  (1-3) %/√E(GeV) + 1%
- large experience (CMS, PANDA, …)

# JLEIC Calorimetry



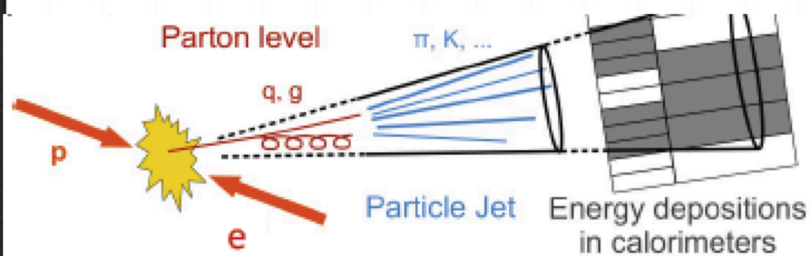




## ZEUS Hcal:

$$electrons: \frac{\sigma}{E} = \frac{18\%}{\sqrt{E}} \oplus 2\%$$

$$hadrons: \frac{\sigma}{E} = \frac{35\%}{\sqrt{E}} \oplus 2\%$$

## Jets



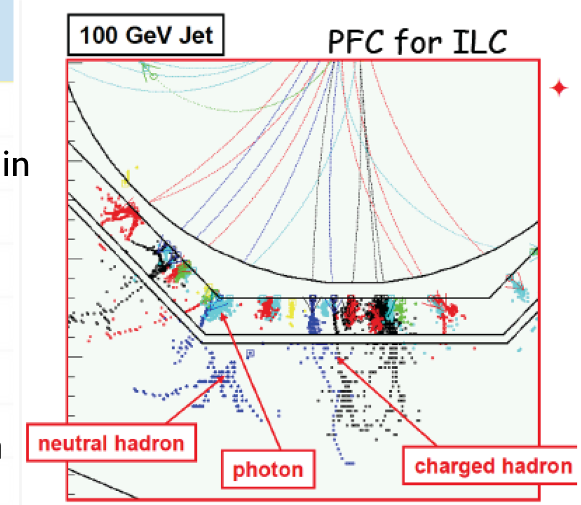

**Flow calorimeter**

-charged particles measured in tracker

-Photons in ECAL: : $\sigma_E/E$~2-10%/$\sqrt{E}$

-Neutral hadrons (ONLY) in HCAL =>

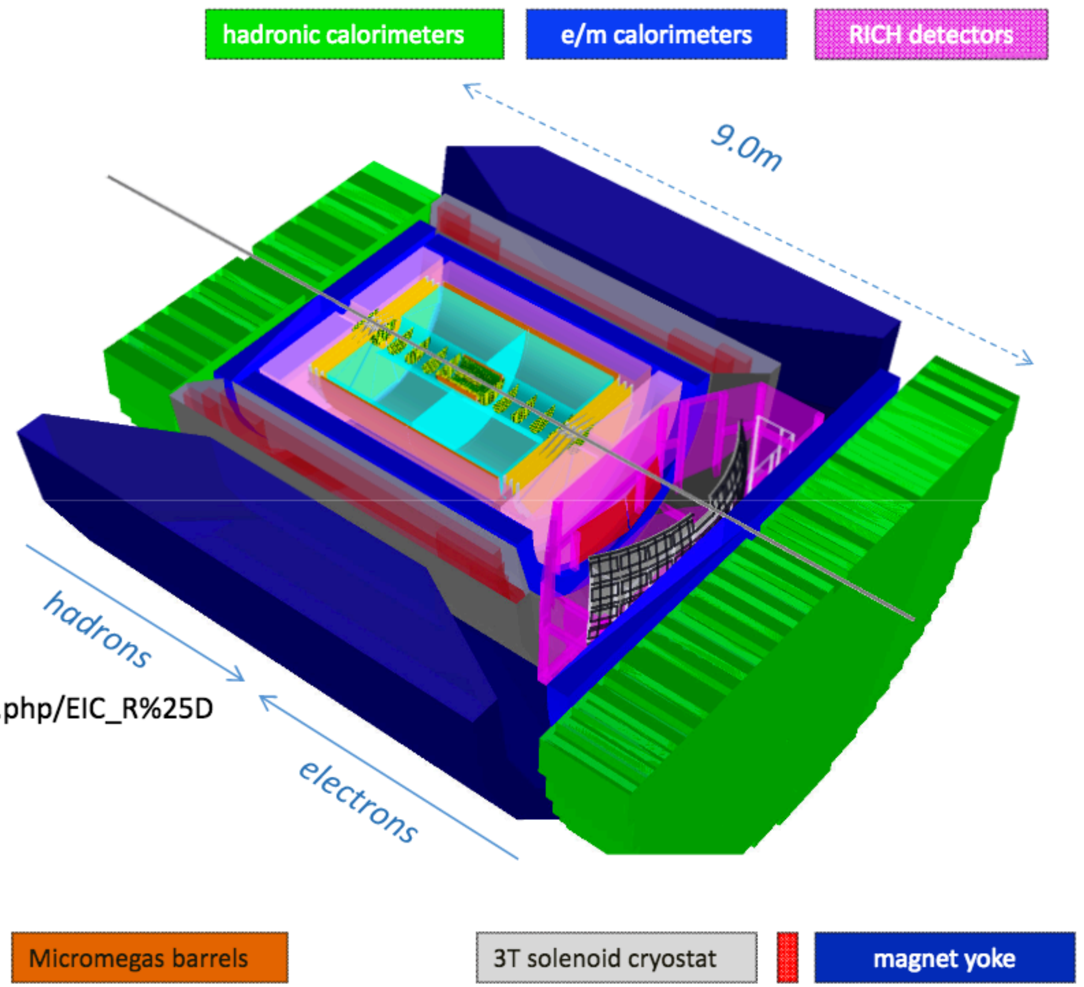
**Only 10 % of jet energy from HCAL**



# BNL reference detector BEAST

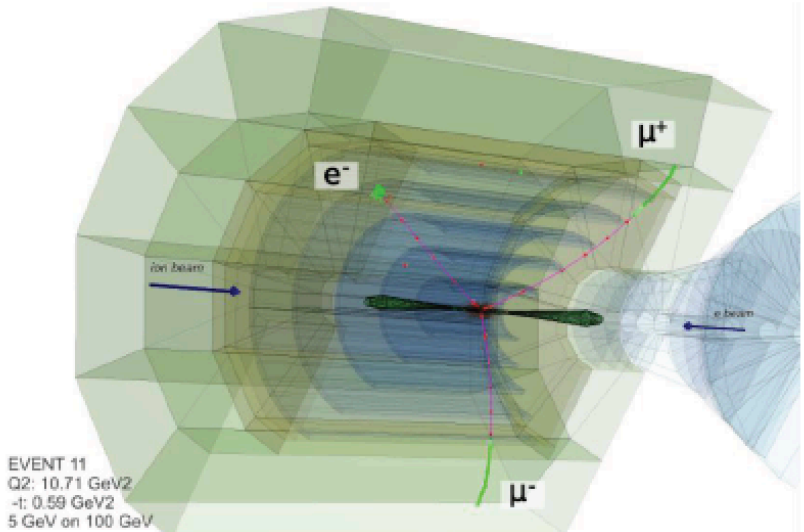
- BeAST: Brookhaven eA Solenoidal Tracker
- Hermetic coverage
- Tracking and e/m calorimetry in the range $|\eta| < 3.5$
- Active R&D for detector components

https://wiki.bnl.gov/conferences/index.php/EIC_R%25D



# TOPSiDE (EIC detector concept )

Jose Repond




| Particles in jets | Fraction of energy | Measured with | Resolution [$\sigma^2$] |
|---|---|---|---|
| Charged | 65 % | Tracker | Negligible |
| Photons | 25 % | ECAL with 15%/√E | $0.07^2\ E_{jet}$ |
| Neutral Hadrons | 10 % | ECAL + HCAL with 50%/√E | $0.16^2\ E_{jet}$ |
| Confusion | If goal is to achieve a resolution of 30%/√E → | | **$\leq 0.24^2\ E_{jet}$** |

18%/√E

Factor of 2 better then previously achieved

- All silicon tracking
- Imaging calorimetry
- Ultra-fast silicon

**Of the order of 55 –80 M readout channels for EMCAL and HCAL:**

Silicon pixels with an area of 0.25 cm$^2$
Total area about 1,400 m$^2$

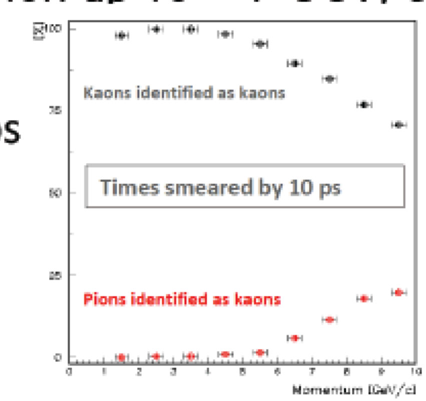
**Needed for 5D *Concept* (Measure E, x, y, z, t)**

Implement in calorimeter and tracker for Particle ID (π-K -p separation)

Resolution of 10 ps→ *separation up to ~ 7 GeV/c*

Current status:

Best timing resolution about 27 ps



# EIC detectors readout system

**Vertex detector** → primary and secondary vrtx(s)
Silicon pixels, e.g. MAPS
**Central tracker** → Measure charged track momenta
Drift chamber, TPC + outer tracker or Silicon strips
**Forward tracker** → Measure charged track moment
GEMs, Micromegas, or Silicon strips, MAPS

**Particle Identification** → pion, kaon, proton separation
Time-of-Flight or RICH + dE/dx in tracker
**Electromagnetic calorimeter** → Photons (E, angle), identify electro
Crystals (backward), Shashlik or Scintillator/Silicon-Tungsten
**Hadron calorimeter** → Measure charged hadrons , neutrons and KL0
Plastic scintillator or RPC + steel

## Options for EIC readout

### Traditional (triggered) DAQ

- All channels continuously measured and hits stored in short term memory by the FEE
- Channels participating to the trigger send (partial) information to the trigger logic
- Trigger logic takes time to decide and if the trigger condition is satisfied:
  - a new 'event' is defined
  - trigger signal back to the FEE
  - data read from memory and stored on tape
- **Drawbacks:**
  - only few information form the trigger
  - Trigger logic (FPGA) difficult to implement and debug
  - not easy to change and adapt to different conditions

# EIC detectors readout system

**Vertex detector** → primary and secondary vrtx(s)
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Crystals (backward), Shashlik or Scintillator/Silicon-Tungsten

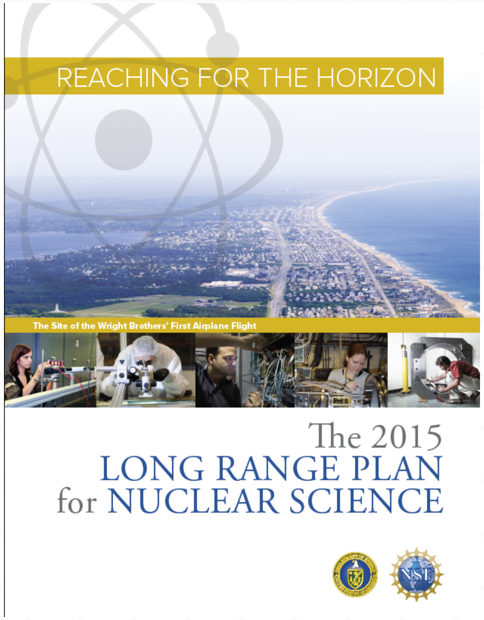
**Hadron calorimeter** → Measure charged hadrons , neutrons and KL0
Plastic scintillator or RPC + steel

## Options for EIC readout

### Streaming readout

* All channels continuously measured and hits streamed to a HIT manager (minimal local processing) with a time-stamp
* A HIT MANAGER receives hits from FEE, order them and ship to the software defined trigger
* Software defined trigger re-aligns in time the whole detector hits applying a selection algorithm to the time-slice
    * the concept of 'event' is lost
    * time-stamp is provided by a synchronous common clock distributed to each FEE
* **Advantages:**
    * Trigger decision based on high level reconstructed information
    * easy to implement and debug sophisticated algorithms
    * high-level programming languages
    * scalability

# The Electron Ion Collider project

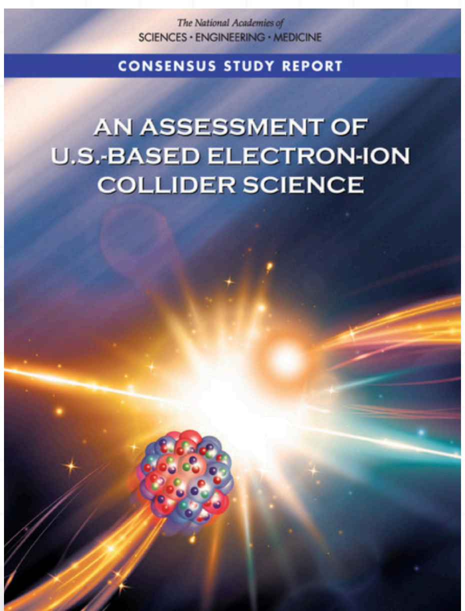



- **The 2015 Long Range Plan for Nuclear Science**

Nuclear Science Advisory Committee (NSAC) and American Physics Society – Division of Nuclear Physics (APS-DNP) partnered to tap the full intellectual capital of the U.S. nuclear science community in identifying exciting, compelling, science opportunities

## Recommendations:

- …
- Gluons…generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain…. These can only be answered with a powerful new electron ion collider (EIC). **We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.**
- …




- **In July 2018 the National Academy of Science endorsed unanimously EIC Science**

### NAS Committee Statement of Task

from DOE/NSF to NAS (End of 2016)

The committee will assess the scientific justification for a U.S. domestic electron ion collider facility, taking into account current international plans and existing domestic facility infrastructure. In preparing its report, the committee will address the role that such a facility could play in the future of nuclear physics, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics.

# Assignments (pick two)

- Discuss the limitation of Rosembluth separation in extracting GE in elastic electron scattering
- Calculate the ratio of proton/neutron magnetic moment within the Quark Model and compare to the experimental value
- Describe the kinematic variables of DIS and discuss their physical meaning
- Which parton degrees of freedom are accessible in TMD and GPD, respectively?
- Decompose the spin of the proton in its elementary contributions and discuss how it can be derived using GPDs
- Discuss the physical meaning of '*parton saturation*' and in which kinematic conditions is expected to be observed
- Why EIC aims to detect final state particles with 100% acceptance?
- Describe the kinematic of the scattered electron in EIC and implications on its detection
- Advantages/disadvantages of streaming read-out vs triggered

For any questions, further discussion or request of clarifications: **battaglieri@ge.infn.it**