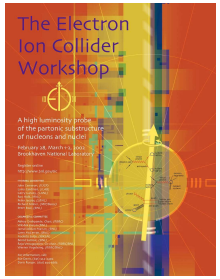
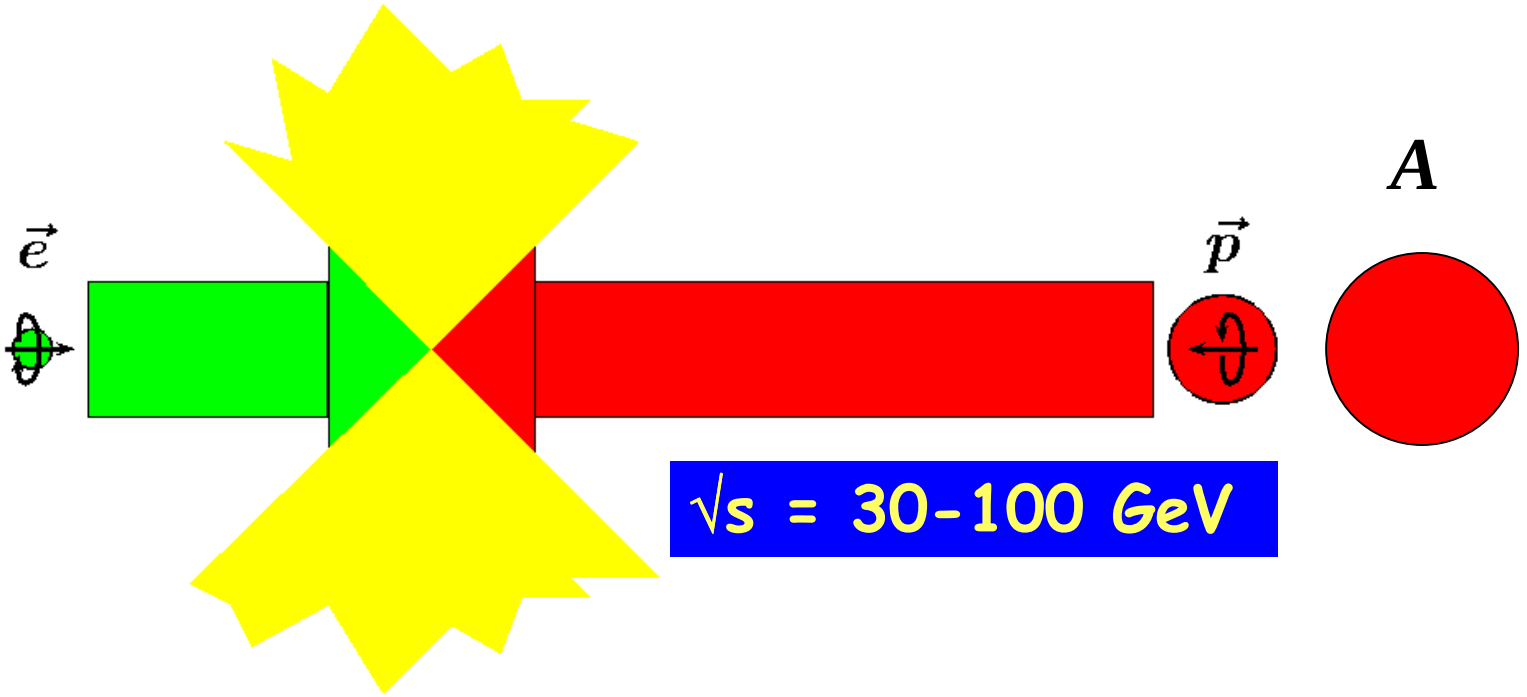


Towards a Detector for eRHIC



Abhay Deshpande
May 29, 2003

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Kinematics: Deep Inelastic Scattering

[1]

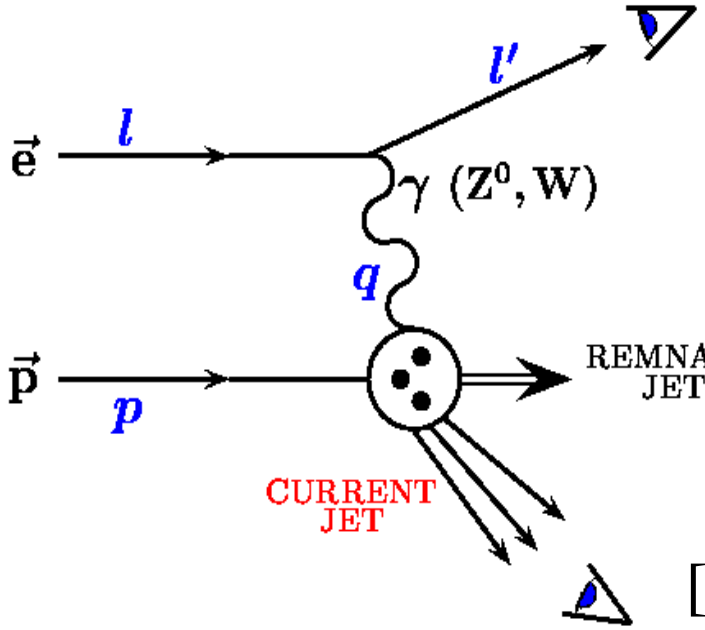
$$Q^2 = -q^2 = sxy$$

$$x = \frac{Q^2}{2p \cdot q}$$

$$y = \frac{p \cdot q}{p \cdot l}$$

$$s = 4E_e E_p$$

$$W = (q + p)^2$$

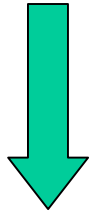


[3]

[2]

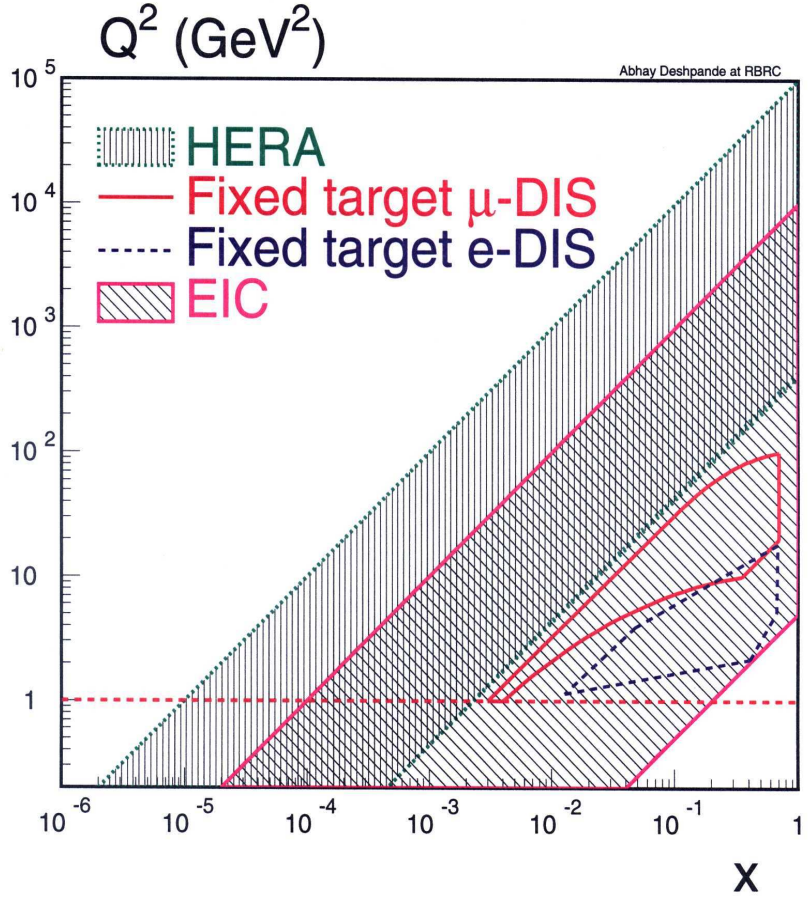
Inclusive: observe only outgoing electron → [1]
Semi-inclusive: [1] + current fragments → [2]
Exclusive: [2] + target fragments → [3]

Low lumi



High lumi

EIC vs. DIS Facilities (I)



~70% beam polarizations!

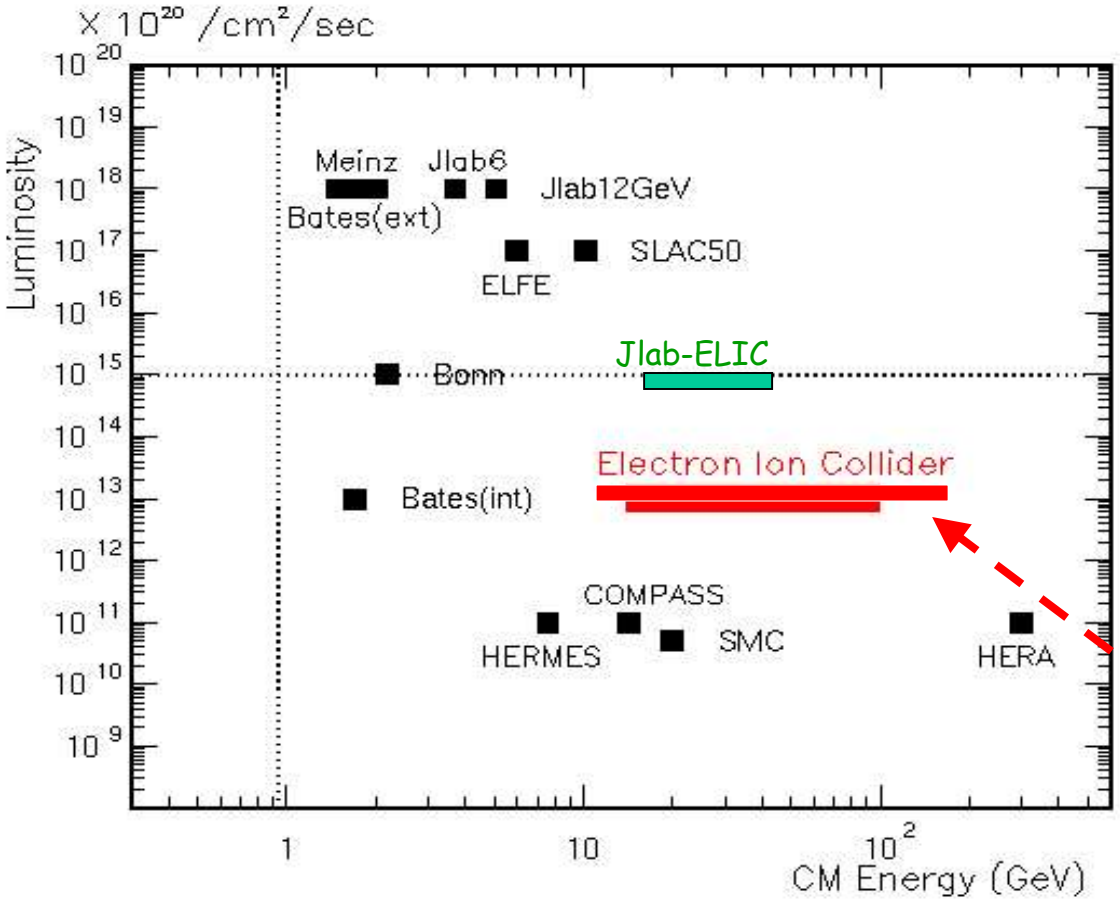
- New kinematic region
- Collider geometry

- E_e = (2)5–10 GeV
- $E_{p/A}$ = 30 – 250/100 GeV
- Sqrt(s) = 20 – 100/65 GeV

- Kinematic reach of EIC
  x = 10^{-5} → 0.7
  Q^2 = 0 → 10^5 GeV

- High Luminosity
  L ~10^{33} cm^{-2} sec^{-1}
  Minimum goal… [1],[2]
  but can we go beyond? [3]

EIC vs. Other DIS Facilities (II)



Variable beam energy

Variable hadron species

Hadron beam polarization

Large luminosity

325 GeV p beam ?

130 GeV A beam?

Scientific Frontiers Open to eRHIC

- **Nucleon Structure:** polarized & unpolarized e-p/n scattering
  - -- Role of quarks and gluons in the nucleon
  - -- Spin structure: polarized quark & gluon distributions [1,2]
  - -- Unpolarized quark & gluon distributions [1,2]
  - -- Correlation between partons → hard exclusive processes leading to Generalized Parton Distributions (GPD's) **[3]**

- **Nuclear structure:** unpolarized e-A scattering
  - -- Role of quarks and gluons in nuclei
  - -- e-p vs. e-A physics in comparison [1,2]

- **Hadronization in nucleons and nuclei** & effect of nuclear media
  - -- How do partons knocked out of nucleon in DIS evolve in to colorless hadrons? [2,**3**]

- **Partonic matter under extreme conditions** → Highest possible Sqrt(s)
  - -- e-A vs. e-p scattering; study as a function of A [1,2]

Probably at mid/hi x, low Q^2!

Heaviest beam and push ion beam energy?

Unpolarized DIS e-p at eRHIC

- Large(r) kinematic region already covered at HERA but additional studies at EIC are possible & desirable
- Will enable precision physics:
  - -- He3 beams → neutron structure → d/u as x→0, dbar(x)-ubar(x) [1]
  - -- precision measurement of $\alpha_S(Q^2)$ [1]
  - -- flavor separation (charm and strangeness) [2]
  - -- precision gluon distribution in x=0.001 to x=0.6 [1,2]
  - -- slopes in $dF_2/d\ln Q^2$ [1]
  - -- photo-production physics [1]
  - -- exclusive reaction measurements [2,3]
    pion structure function measurements….
  - -- nuclear fragmentation region measurements [2]

Polarized DIS at eRHIC

- Spin structure functions g_1 (p,n) at low x, high precision [1]
  -- g_1(p−n): Bjorken Spin sum rule better than 1% accuracy
- Polarized gluon distribution function $\Delta G(x,Q^2)$ [1,2]
- Precision measurement of $\alpha_S(Q2)$ from g_1 scaling violations [1]
- Polarized structure function of the photon from photo-production [1]
- Electroweak structure function g_5 via $W^{+/-}$ production [1]
- Flavor separation of PDFs through semi-inclusive DIS [2]
- Deeply Virtual Compton Scattering (DVCS) → Generalized Parton Distributions (GPDs) [3]
- Transversity [2]
- Drell-Hern-Gerasimov spin sum rule test at high ν [1]
- Target/Current fragmentation studies [2,3]
- … etc….

Electron-Ion Physics: Highest Sqrt(s) Paramount

- Statistical accuracies of measurements with 2 or three nuclei calculated (Ca, C, Sn, Pb) [1]
- Systematic uncertainty studies dearly needed
- High parton density nuclear media:
  Many theoretical models and predictions exist [1]
- Quantitative comparisons with expected uncertainties on measurements at eRHIC and those theoretical predictions still needs to be done.
  --Needs communication by experimentalists with some of the theorists (Raju, Dima, McLerran, Jamal etc.)

10 GeV e on 325 GeV p/130 GeV A

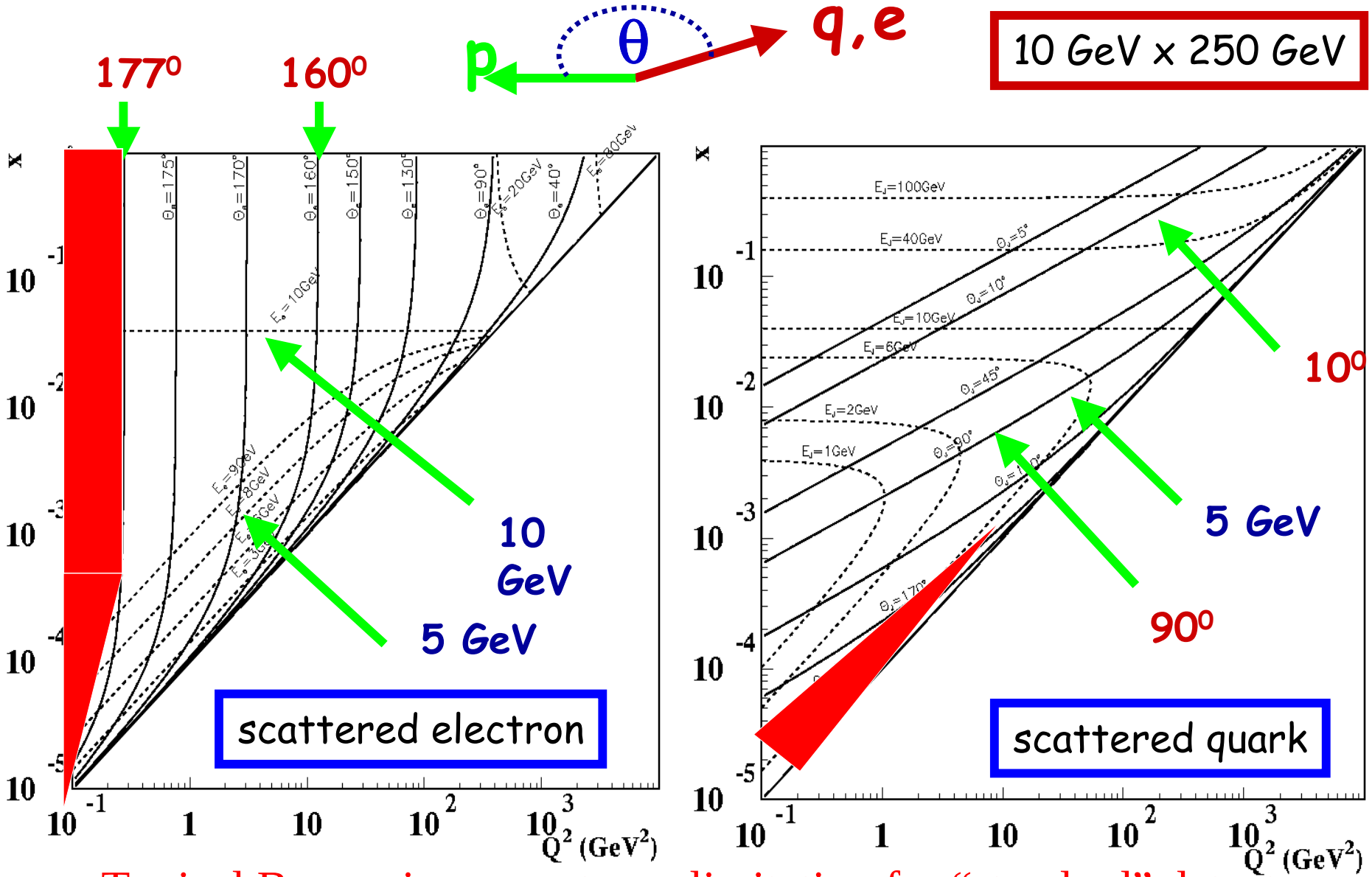
Experimental Variables at the EIC

- Scattered electrons to measure kinematics of DIS
- Scattered electrons at small (~zero degree) angles to tag photo-production events
- Central hadronic final state for kinematics, jet measurements, quark flavor tagging, fragmentation studies….
- Central hard photon and particle/vector meson detection (DVCS)
- Zero angle photon measurement to control radiative corrections and in e-A physics to tag nuclear de-excitations
- Missing E_T for neutrinos in final state (W physics)
- Tagging forward nuclear fragments
- Tagging forward particles for diffractive physics & target depedence

From accelerator side:

- Variable energies
- Polarized beam species: p, d, He
- Unpolarized heavy ion beams
- High luminosity

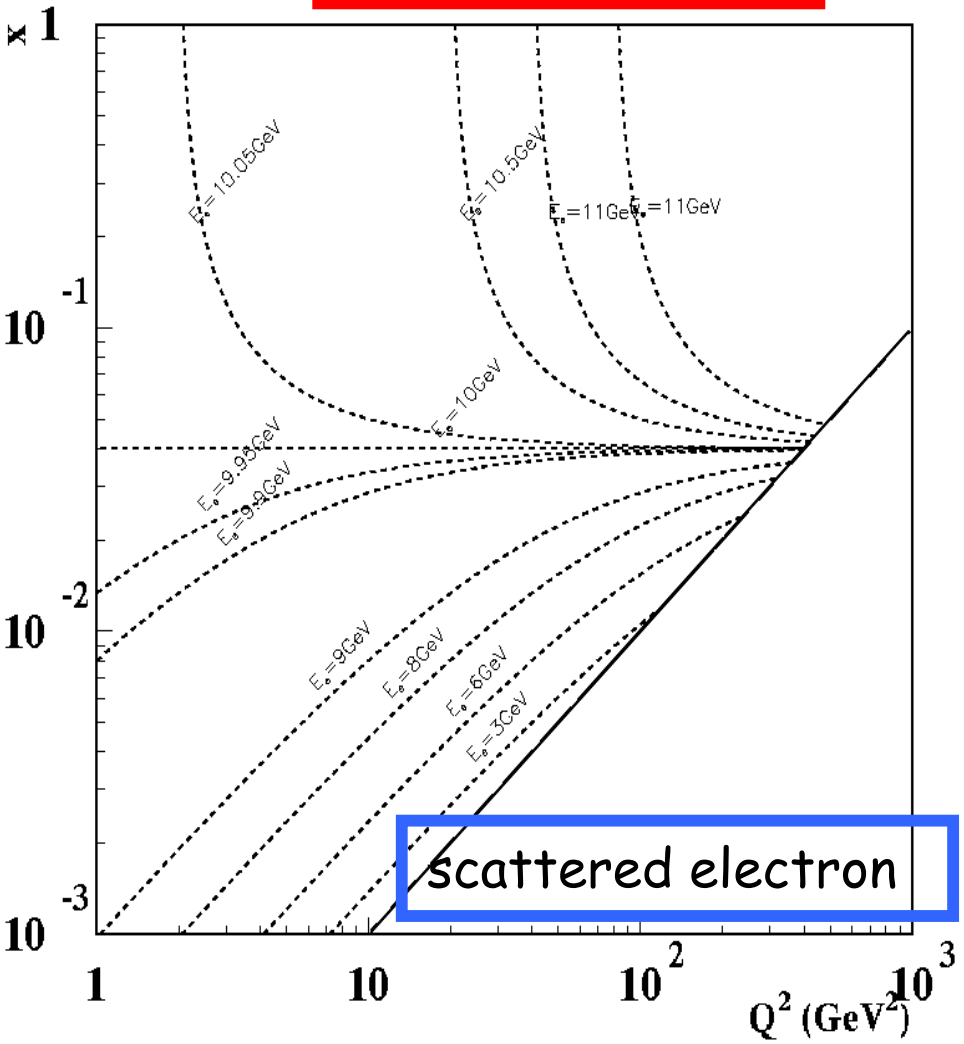
Kinematics of electron and quark

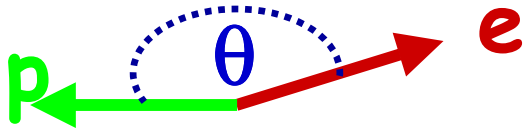


Typical Beam pipe acceptance limitation for “standard” detectors

Electron kinematics:detail

10 GeV x 250 GeV





HERA (H1/ZEUS):

Electron method: $\Delta x/x \sim \Delta E/(y.E)$

→ limited by calorimeter resolution

Hadron method (Jacquet-Blondel or Sigma method)

→ limited by noise in calorimeter, reach scales with E_{noise}/E_{beam}

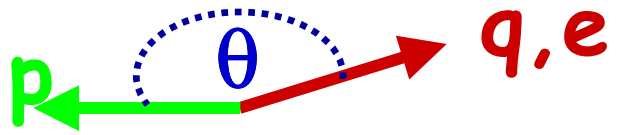
EIC:

→ Measure electron energy with tracker (<20 GeV in large region) $\Delta p/p \sim 0.005\text{-}0.0001$ .p **(2-4T!)**

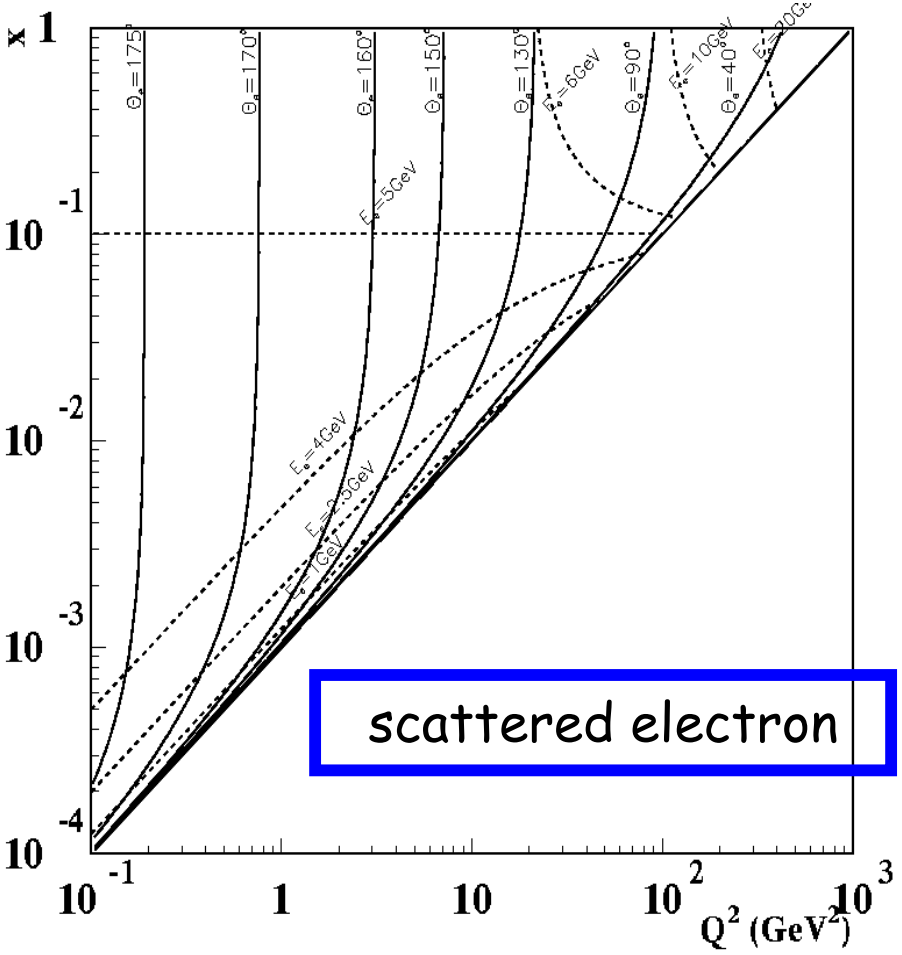
→ Low noise calorimeter (crystals/ spacal)

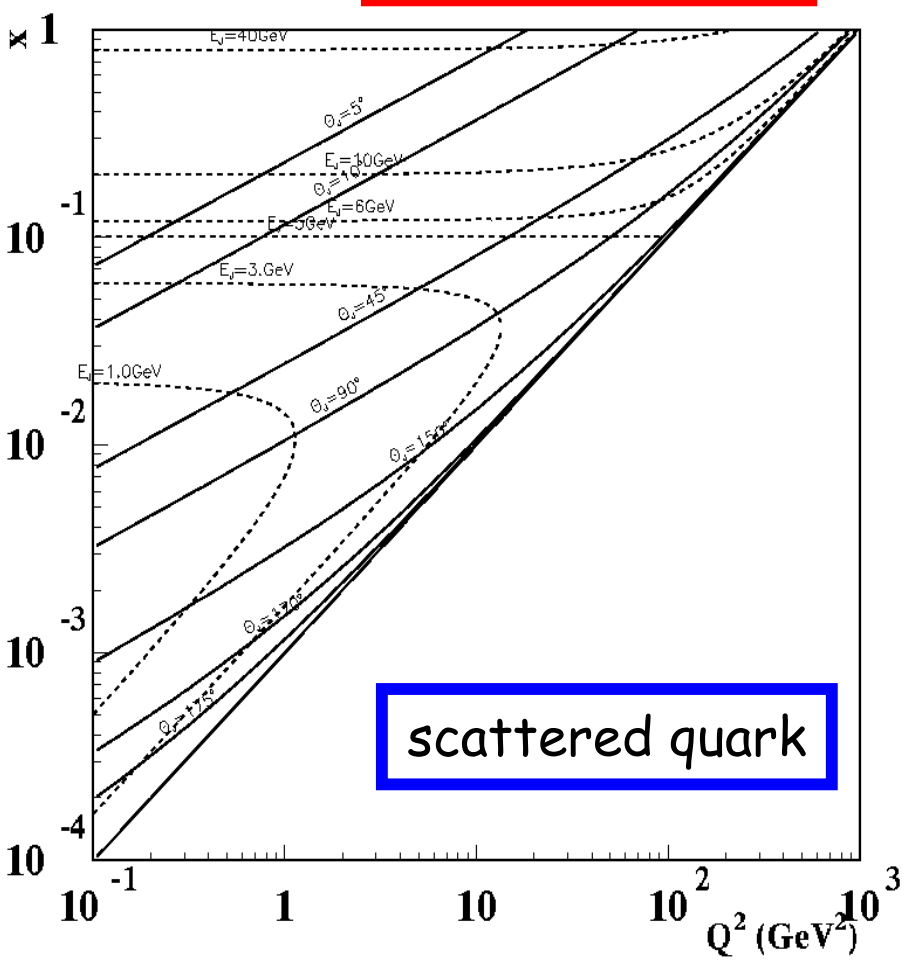
Effect of magnet on beam?

Kinematics of electron and quark



5 GeV x 50 GeV





Beam energy ratio different: Hadronic & EMCal will have to flexible

Acceptances for “ZEUS/H1” Like Detectors

For lepton facing EM showers:

250 x 10

SELECTION:

- $Q^2 > 1$ GeV^2
- $0.1 < y < 0.9$
- E_e > 3-5 GeV

Assumes electron kinematics reconstruction Using electron and hadron method.

Most polarization studies included detector Studies.

For hadronic systems: hadrons/jets

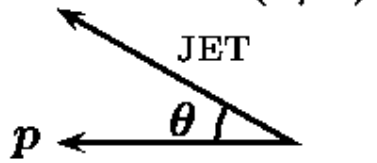
250 x 10

SELECTION:

- $5 < Q^2 < 100$ GeV^2
- $0.3 < y < 0.85$
- $p_T^{\mathrm{JET}} > 5$ GeV
- $|\eta_{\mathrm{LAB}}^{\mathrm{JET}}| < 2.8$

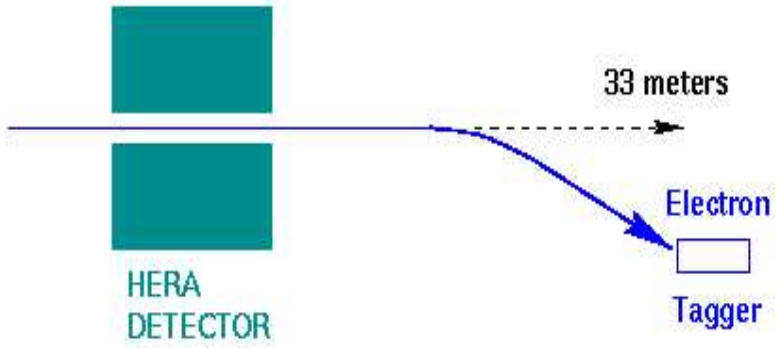
DETECTOR EFFECTS INCLUDED

$$\eta = -\ln\tan(\theta/2)$$



Existing Forward Electron Tagger Idea

Drell-Hearn-Gerasimov Sum Rule



Electron Tagger:

$$Q^2 \approx 10^{-6} - 10^{-2} GeV^2$$

$$\sqrt{s} \approx 25 - 85 GeV$$

Inclusive Photoproduction measurement

- DGH sum rule:

$$\int_{\nu_{th}}^{\infty} \frac{d\nu}{\nu} (\sigma_{\uparrow\downarrow}^{\gamma p} - \sigma_{\uparrow\uparrow}^{\gamma p})(\nu) = -\frac{4\pi^2 \alpha \kappa^2}{2m_p^2}$$

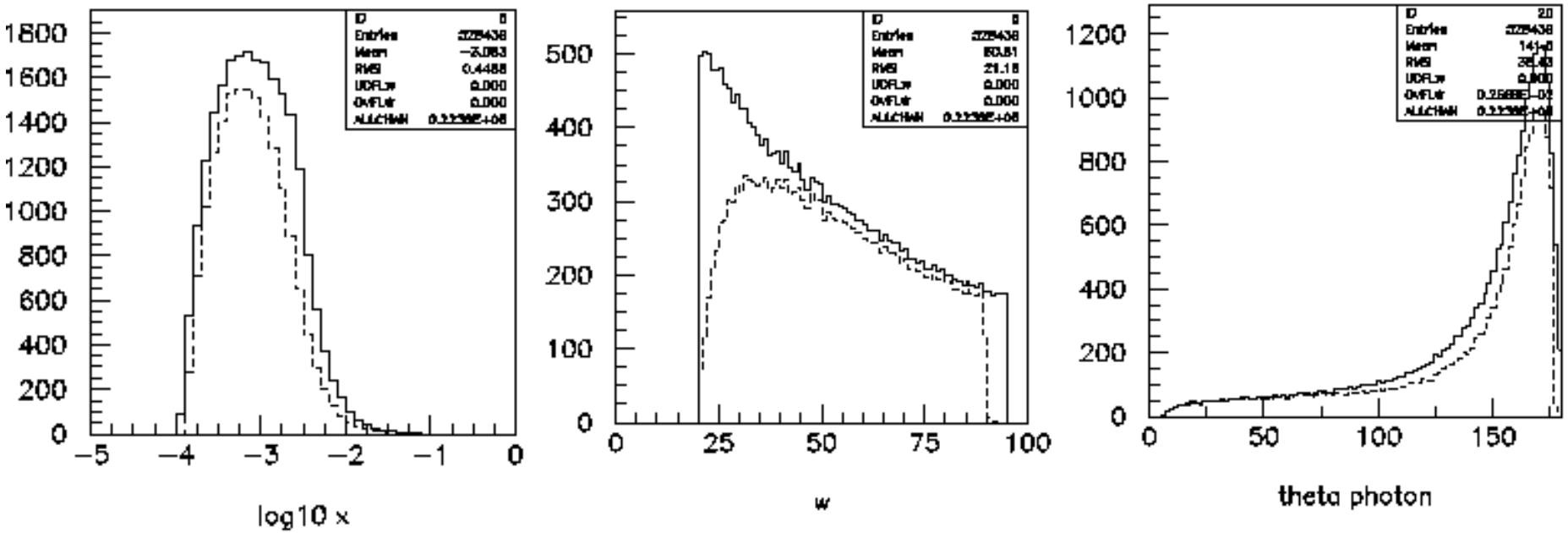
- At EIC ν range: GeV-few TeV range
- Although contribution to integral is small: explore energy dependence of cross-section.
- Complementary to JLAB, MAMI Experimental effort

DVCS & Roman Pots….

Virtual photon + proton → real photon (any vector meson…) + proton

A. Sandacz

10 x 250 GeV

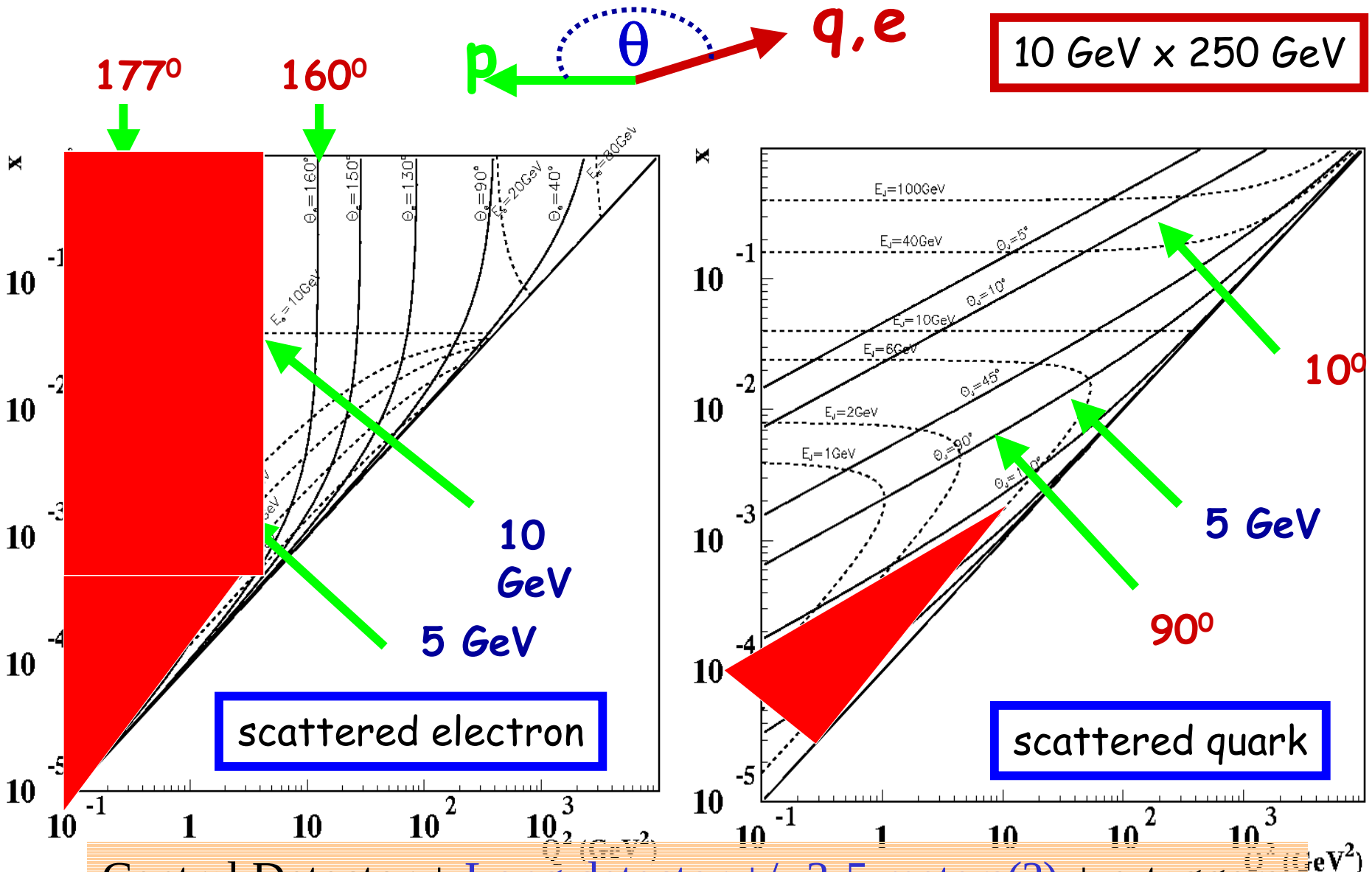


$Q^2 > 1$ GeV^2
$20 < W < 95$ GeV
$0.1 < |t| < 1.0$ GeV^2

Full curve: all events
Dashed curve: accepted events
$Q^2 > 1$ GeV^2: 50K events/fb^{-1}

What beam divergences/emitances should we assume?

New Low x detector Ideas: HERA-III, A. Caldwell et al.



Summary

- **Luminosity?**
  -- Beyond goal minimum? – Inclusive vs. Exclusive physics
  -- Addition of new collaborators
- **Beam Energy and species?**
  -- Variable beam energies & species
  -- 325/130 p/A GeV possible?

- **Polarization: 70% each beam**

- **Experimental IR:**
  -- Effect of solenoid?
  -- Element free zone → x-y dimension (+/- 5cm) and z(+/-2m) direction
  -- Flexibility of detector/design for central vs. forward acceptances
  -- Can we have two parallel beam lines: one moves in and out?

Summary: Detector issues

- Detector ideas and requirements are still preliminary…. Work has begun to define more accurately the requirements for each physics measurement

  --Present element free zone will be given to the physicists as a starting point.
- Standard ZEUS/H1 like detector is a MINIMUM acceptance and performance requirement (scale dimensions with Sqrt(s), as a starting point.
- Added capabilities: forward taggers for electron, roman pots for hadronic systems
- If Luminosity can be increased by factors of 10-100, it would help the exclusive measurements & significant interest might develop from Jlab community

No matter what happens, we should proceed with a realistic, optimistic and ambitious scenario.