EIC detector R&D plans

Rolf Ent
(JLab)

Bernd Surrow
(MIT)

Outline

- Physics requirements
- Kinematics reconstruction
- R&D detector plans
- Discussion

Physics requirements

- Polarized ep physics
  - Precision measurement of g^p_1 over wide range in Q^2
    - Extraction of gluon polarization through DGLAP NLO analysis
    - Extraction of strong coupling constant
  - Precision measurement of g^n_1 (neutron) (Polarized ^{3}He)
  - Photoproduction measurements
  - Electroweak structure function g_5 measurements
  - Flavor separation through semi-inclusive DIS
  - Target and current fragmentation studies

Inclusive measurement - electron (Low x) and hadronic final state (High x) over wide acceptance range

In addition: p tagging in forward direction

Jet production and small-angle e tagger

Hermetic detector configuration / e^- and e^+ Missing energy measurement

K/π separation - particle ID - Heavy flavor - Secondary vertex reconstruction and J/Psi (Forward muons)

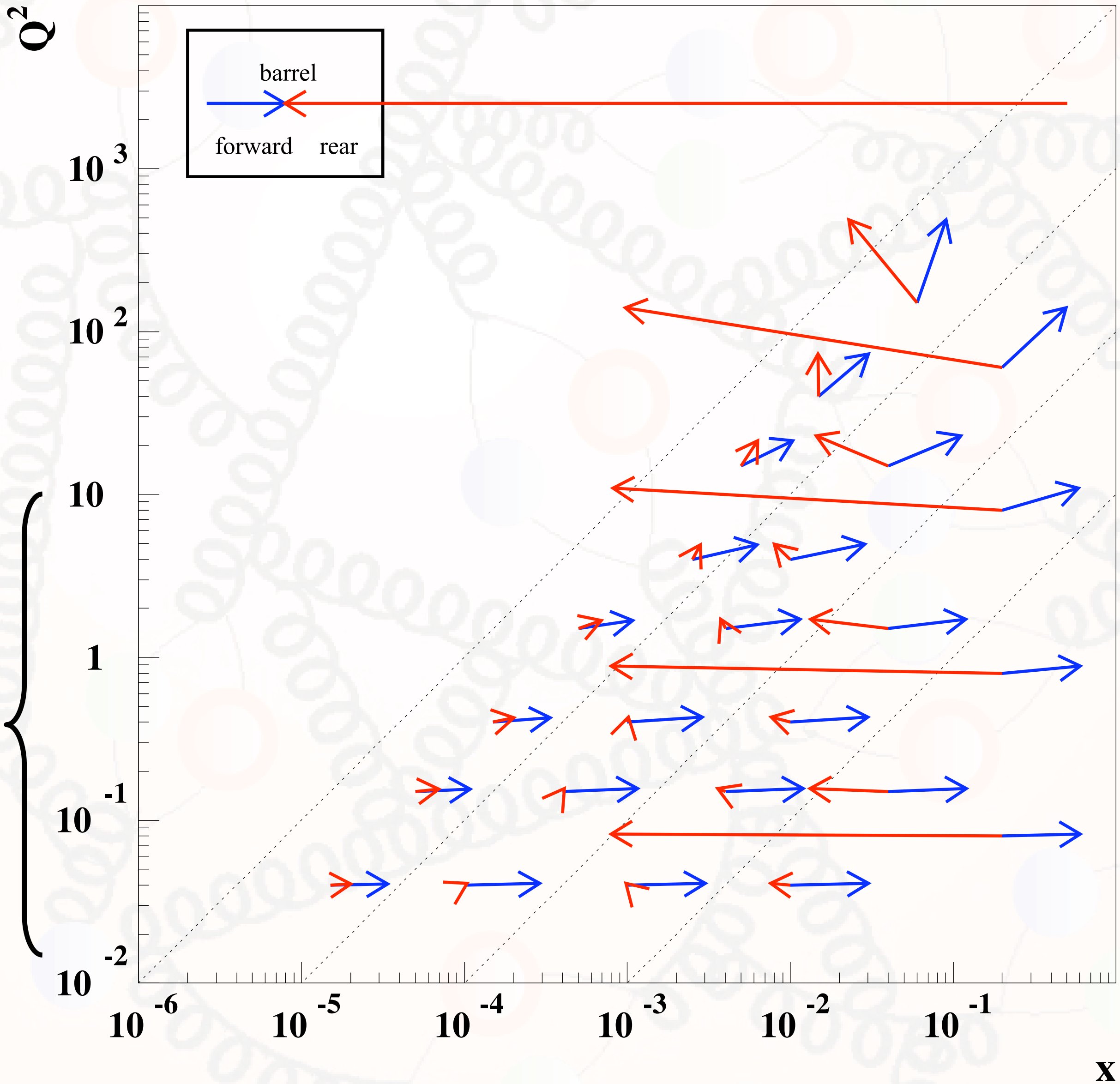
Forward acceptance: Tracking and calorimetry

Physics requirements

- Unpolarized ep/eA physics
  - Precision measurement of F_2 at low x: Transition from hadronic to partonic behavior — Inclusive measurement involving electron at small polar angles (≈10mrad)
  - Precision measurement of the longitudinal structure function F_L — Inclusive measurement involving electron (Low x) - Variable √s
  - Precision measurement of F_2 at high x — Inclusive measurement (hadronic final state in forward direction): Good forward acceptance
  - Measurement of diffractive and exclusive reactions — Forward p tagging system
  - DVCS — Forward p tagging system - photon/electron discrimination Variable √s and positrons
  - Precision measurement of eA scattering — Similar to ep case at low x - High x: Forward acceptance - careful study necessary!
  - Nuclear fragments / Centrality measurement — Forward acceptance

Kinematics reconstruction

- Event kinematics (10GeV electron on 250GeV proton)



- Low-x-low Q^2: Electron and current jet (low energy) predominantly in rear direction

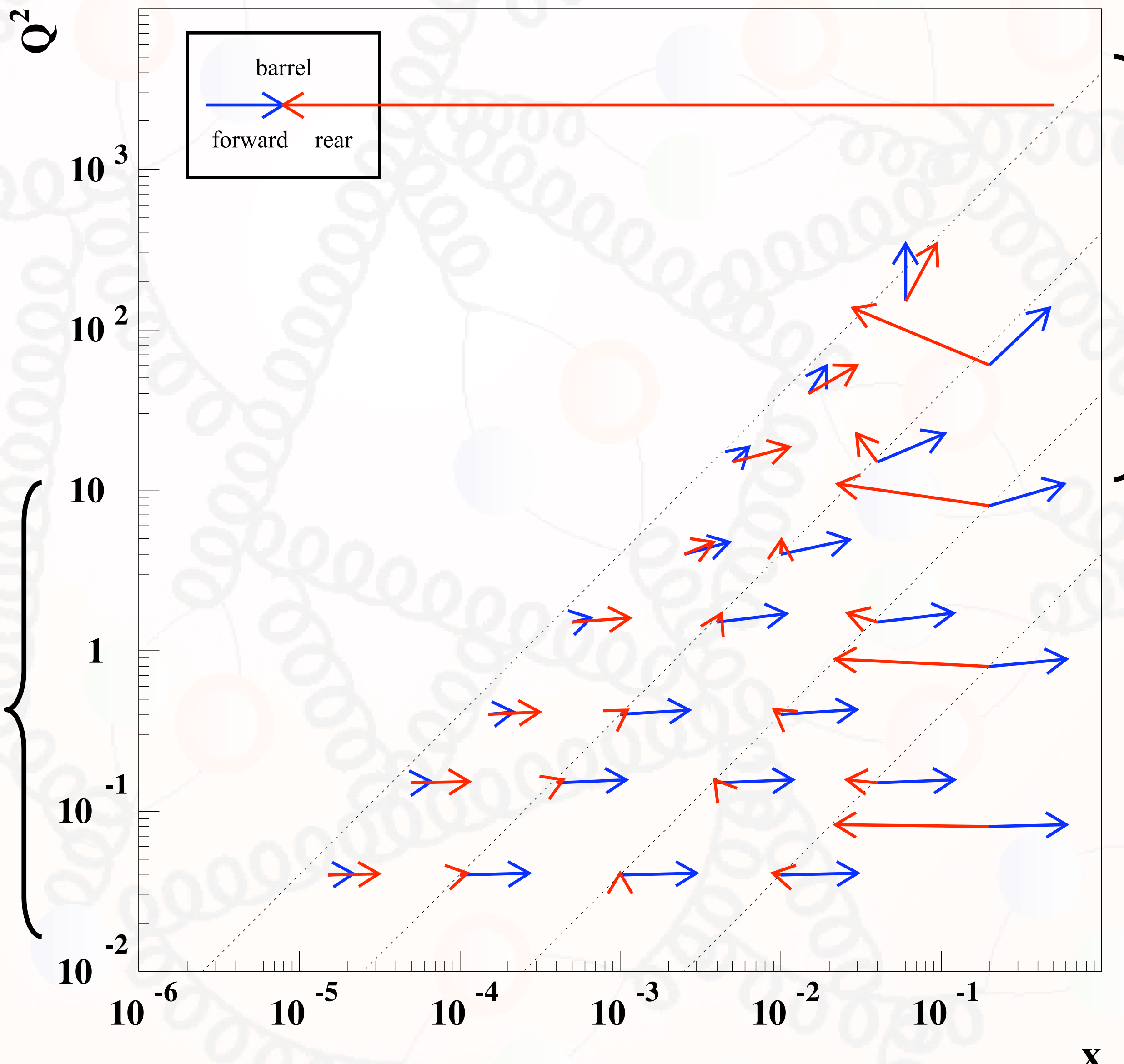
- High-x-low Q^2: Electron in rear and current jet (High energy) in forward direction

- High-x-high Q^2: Electron predominantly in barrel/forward direction (High energy) and current jet in forward direction (High energy)

Bernd Surrow

Kinematics reconstruction

- Event kinematics (10GeV electron on 100GeV/n A)



- Low-x-low Q^2: Electron and current jet (low energy) predominantly in rear direction
- High-x-low Q^2: Electron in rear and current jet (High energy) in forward direction
- High-x-high Q^2: Electron predominantly in barrel/forward direction (High energy) and current jet in forward direction (High energy)

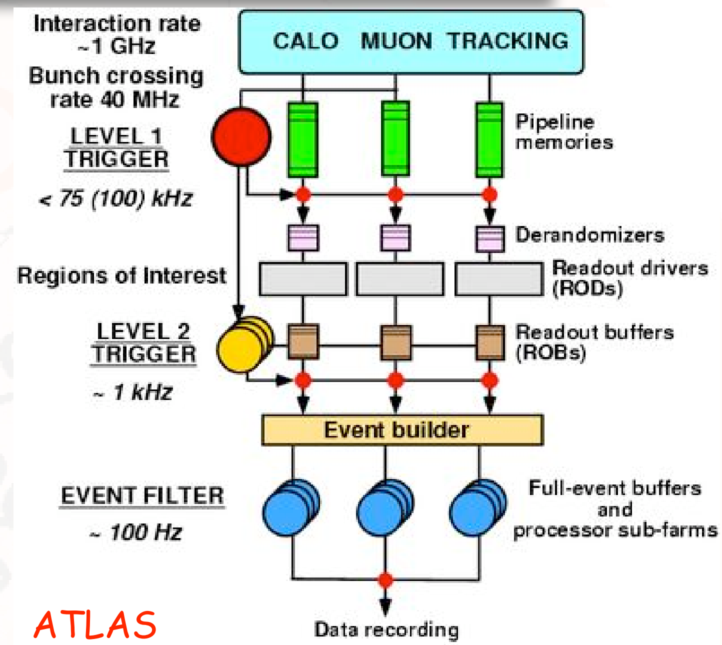
R&D detector plans

Detector specifications (1)

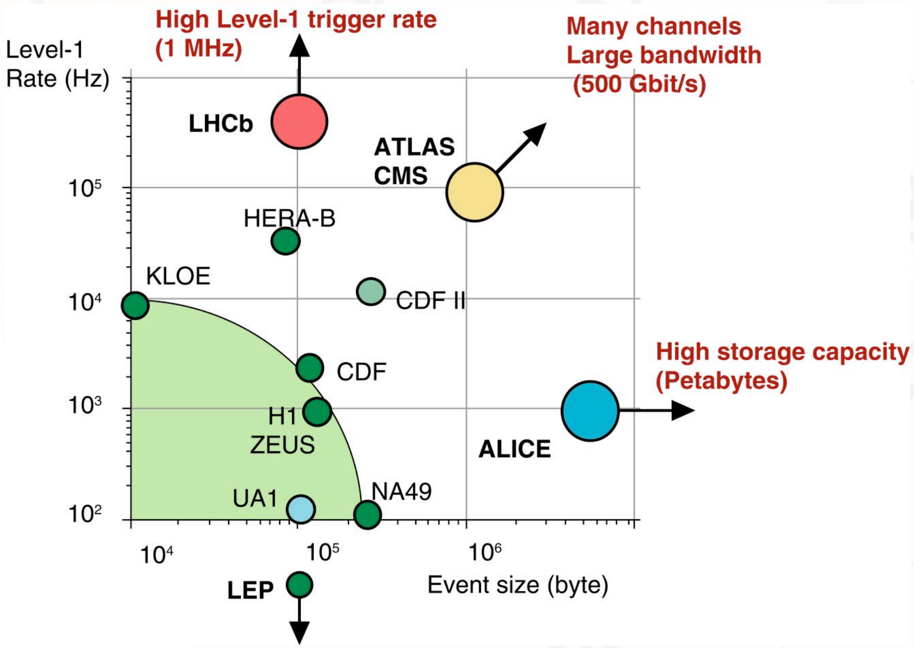
- Tracking over wide acceptance range operating in high-rate environment - Contribute to reconstruction of event kinematics besides calorimetry in particular at very small energies
- Calorimetry over wide acceptance range (e/h separation critical): Transverse and longitudinal segmentation (Track-calorimeter cluster matching essential)
- Specialized detector systems
  - Zero-degree photon detector (Control radiative corrections and luminosity measurement)
  - Tagging of forward particles (Diffraction and nuclear fragments) such as...:
    - Proton remnant tagger
    - Zer0-degree neutron detector
- Particle ID systems (K/π separation), secondary vertex reconstruction and muon system (J/Psi)

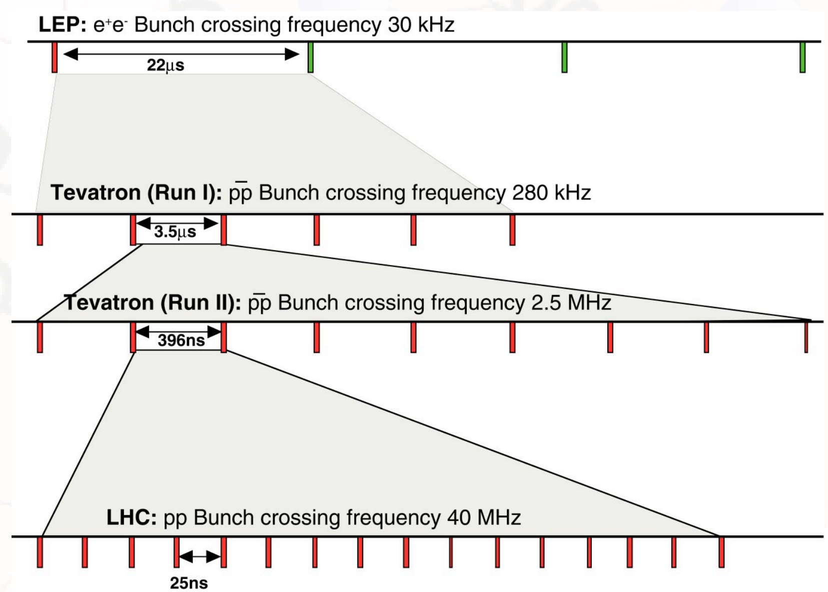
R&D detector plans

- Detector specifications (2)
  - High-rate rate requirement
  - Background rejection: Timing requirements e.g. calorimetry timing essential to reject beam related background
  - Trigger: Multi-level trigger system involving calorimetry and fast tracking information to enhance data sample for rare processes over inclusive ep/eA and photoproduction



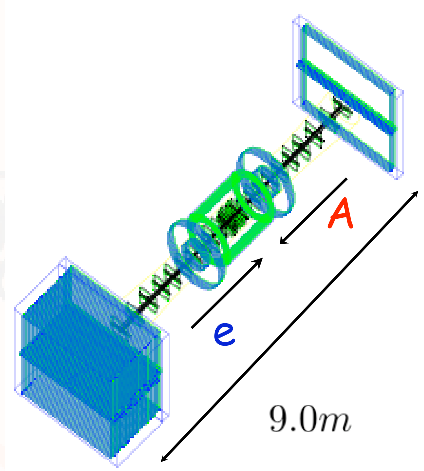
ATLAS



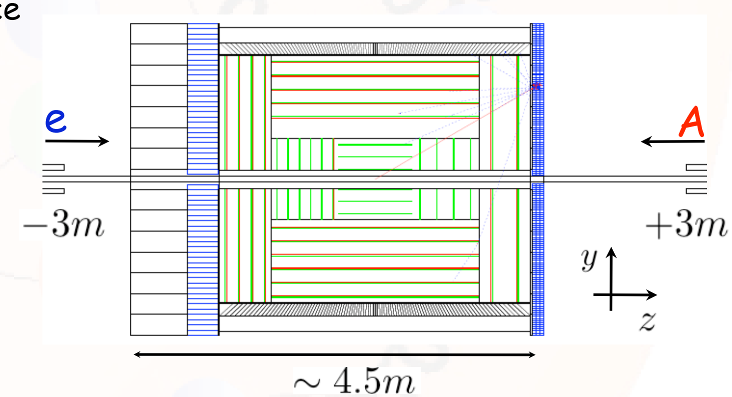


R&D detector plans

- General considerations
  - Design 1: Forward physics (unpolarized eA MPI Munich group):
    - Specialized detector system to enhance forward acceptance of scattered electrons and hadronic final state
    - Main concept: Long inner dipole field (7m)
    - Required machine element-free region: approx. ±5m



  - Design 2: General purpose (unpolarized/polarized ELECTRon-A):
    - Compact central detector (Solenoidal magnetic field) with specialized forward/rear tagging detectors/spectrometers to extend central detector acceptance
    - Required machine element-free region: approx. ±3m



  - Detector sub-systems in both design concepts:
    - Zero-degree photon detector (Control radiative corrections and luminosity measurement)
    - Tagging of forward particles (Diffraction and nuclear fragments) such as...:
      - Proton remnant tagger / proton spectrometer
      - Zer0-degree neutron detector

R&D detector plans

- Tracking
  - Goal:
    Development of cost-effective and compact high rate tracking system (radius < 1 m) over full acceptance, with high-speed readout capability. Promising possibility: silicon and triple-GEM (cost effective) type tracking detectors.
  - Issue:
    Cost-effective solution for inner tracking detector is essential. This may provide a low cost solution!
  - Cost estimate:
    - Labor: 4 FTE Years
    - M&S: $350k
    - Total: $1050k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Calorimetry
  - Goal:
    Development of compact EM calorimetry in rear and barrel direction (e.g. Si-W), which provides efficient e/h separation for energies as low as ~1GeV.

    Develop compact hadron calorimeter system in forward direction only.
  - Issue:
    Compactness of calorimetry has direct impact on inner-most machine elements.
  - Cost estimate:
    - Labor: 3 FTE Years
    - M&S: $300k
    - Total: $840k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Forward and Rear small-angle detector instrumentation

  - Goal:
    Development of low-angle e tagging system (Low Q^2, photo production)

    Development of large acceptance tagging of forward diffractive events in ep/eA scattering and forward energy flow (With tracking stations using either beam magnets and/or dedicated very forward spectrometer systems) / Forward neutron tagging / Tagging of elastic scattered p/A system

  - Issue:
    Large fraction of physics of interest depends on auxiliary small-angle detection systems. Conceptual design of main detector is intrinsically intertwined with capabilities of forward and rear small-angle instrumentation.

  - Cost estimate:
    - Labor: 4 FTE Years
    - M&S: $400k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Magnetic field configuration
  - Goal:
    Development of optimized field configuration from combined accelerator and detector point of view
  - Issue:
    Balance a solenoid-type in central and dipole-type in forward/rear direction against other magnetic field choices, such as a toroidal design.
  - Cost estimate:
    - Labor: 3 FTE Years
    - M&S: \$0k
    - Total: \$420k

$$\mathrm{Total} = (\mathrm{FTE} \cdot \$100k + \mathrm{M\&S}) \cdot 1.4$$

R&D detector plans

- DAQ / Trigger System (I)
  - Goal:
    Multi-level trigger system including development of trigger algorithms for efficient rare process and DIS-e trigger selection.
  - Issue:
    To efficiently select rare processes next to minimum-bias trigger may require the use of tracking at the trigger level.
  - Cost estimate:
    - Labor: 3 FTE Years
    - M&S: $250k
    - Total: $770k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- DAQ / Trigger System (II - ELIC only)
  - Goal:
    Development of high-speed DAQ/Trigger system for very small bunch crossing time.
  - Issue:
    Need to i) prove that one can pipeline data to handle 0.5 GHz RF frequency; ii) Prove >2,000 rejection of hadronic background capability at trigger level; iii) develop GHz level ultra-fast digitization capabilities and verify timing; iv) Develop multi-processing data acquisition to achieve 5 kHz, 150 MB/s (CLAS achieved 8 kHz, 30 MB/s); v) Simulate data rates in detectors and electronics; vi) Study how to further improve to 1.5 GHz RF frequency.
  - Cost estimate:
    - Labor: 10 FTE Years
    - M&S: $700k
    - Total: $2380k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Development of precision high-energy polarimetry
  - Goal:
    Develop a new scheme to perform 1% high-energy ion polarimetry
  - Issue:
    Conceptual studies of novel techniques to allow for order 1% ion polarimetry are a must of precision spin sum rule measurements at the EIC.
  - Cost estimate:
    - Labor: 3 FTE Years
    - M&S: $250k
    - Total: $770k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Background
  - Goal:
    Development of main absorber and collimation system for synchrotron radiation background
    Development of algorithms an/or detector capabilities to limit beam gas background from high-intensity beam operation in particular for very small bunch crossing time operation
  - Issue:
    Maximum luminosity of EIC physics program is directly related to the possibility to reduce/solve known backgrounds.
  - Cost estimate:
    - Labor: 2 FTE Years
    - M&S: $0K
    - Total: $280k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Final focus superconducting magnet for proton lattice (ELIC only)
  - Goal:
    Balance design option of 1.2 meter long magnet with 6.2T field (for 12σ aperture) against 1.5 meter long magnet with 4.9T field.
  - Issue:
    Final focus SC magnets directly affect final luminosity. Preliminary design and feasibility aimed to study risk associated with first option.
  - Cost estimate:
    - Labor: 2 FTE Years
    - M&S: $200K
    - Total: $560k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Particle identification
  - Goal:
    Development of detection system for efficient K/π separation for semi-inclusive DIS studies (e.g. RICH detector) to maintain compact detector system
  - Issue:
    Efficient K/π separation over a large range of momenta is an essential ingredient for flavor tagging of the foreseen EIC physics program.
  - Cost estimate:
    - Labor: 3 FTE Years
    - M&S: $250K
    - Total: $770k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

R&D detector plans

- Development of precision auxiliary techniques
  - Goal:
    Precision luminosity measurement (absolute and relative) – Bremsstrahlung measurement
  - Issue:
    Precision luminosity measurements are a must for absolute cross section measurements. Are the techniques developed at DESY sufficient?
  - Cost estimate:
    - Labor: 2 FTE Years
    - M&S: $250K
    - Total: $630k

$$\text{Total} = (\text{FTE} \cdot \$100k + \text{M\&S}) \cdot 1.4$$

Concluding remarks

: Several participating institutes chaired by 2 conveners