Overview EIC detector planning

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Outline

- Part I
  - Overview of physics channels: Requirements
  - Open questions: Inclusive / Exclusive measurements
  - Conceptual detector layout
- Part II
  - Simulations tools
  - Detector R&D topics
- Part III
  - Organization
  - Milestones / Timescale / Needs

Overview of physics channels: 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)

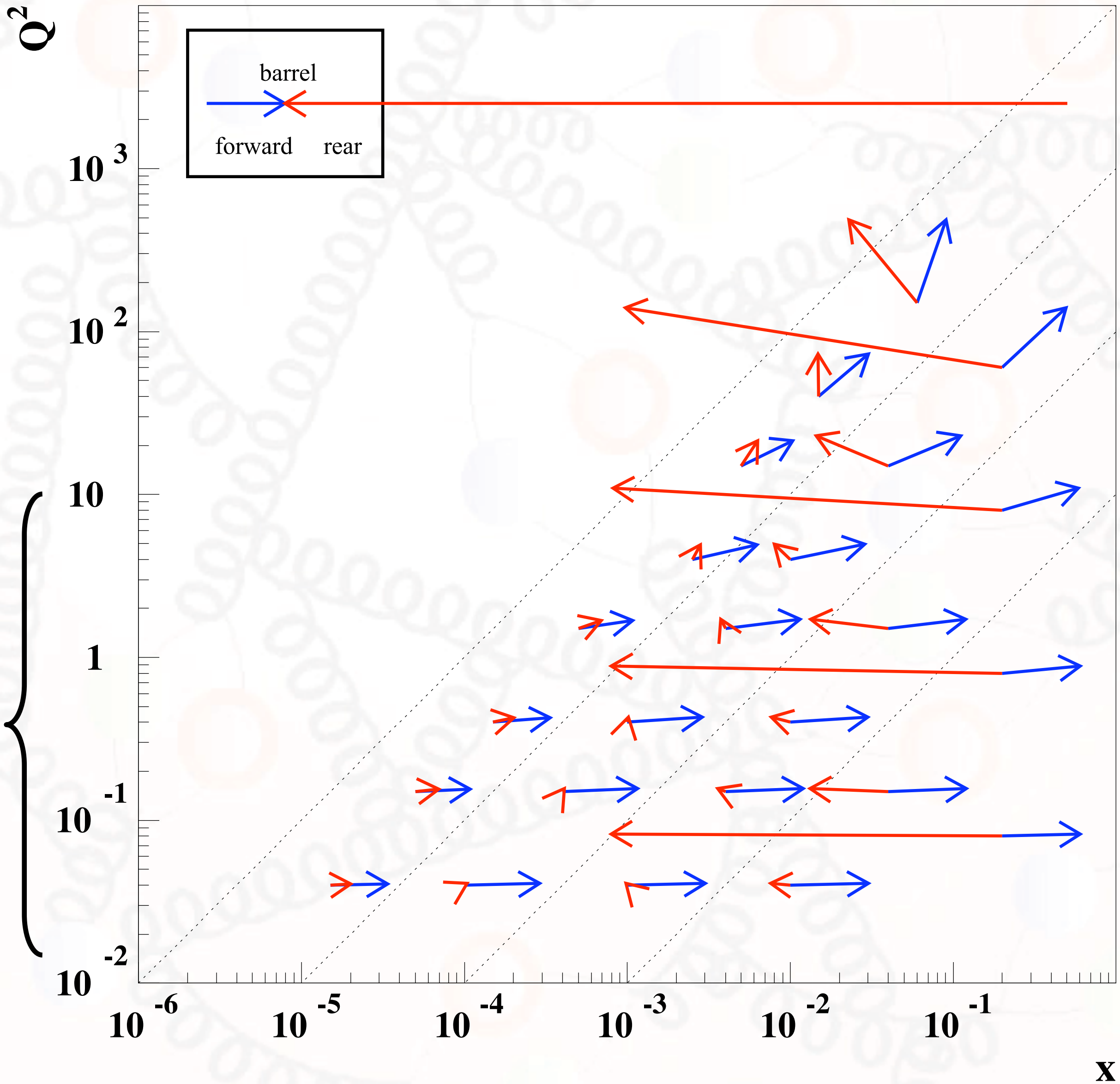
Forward acceptance: Tracking and calorimetry

Overview of physics channels: 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

Overview of physics channels: Requirements

- 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)

Overview of physics channels: Requirements

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

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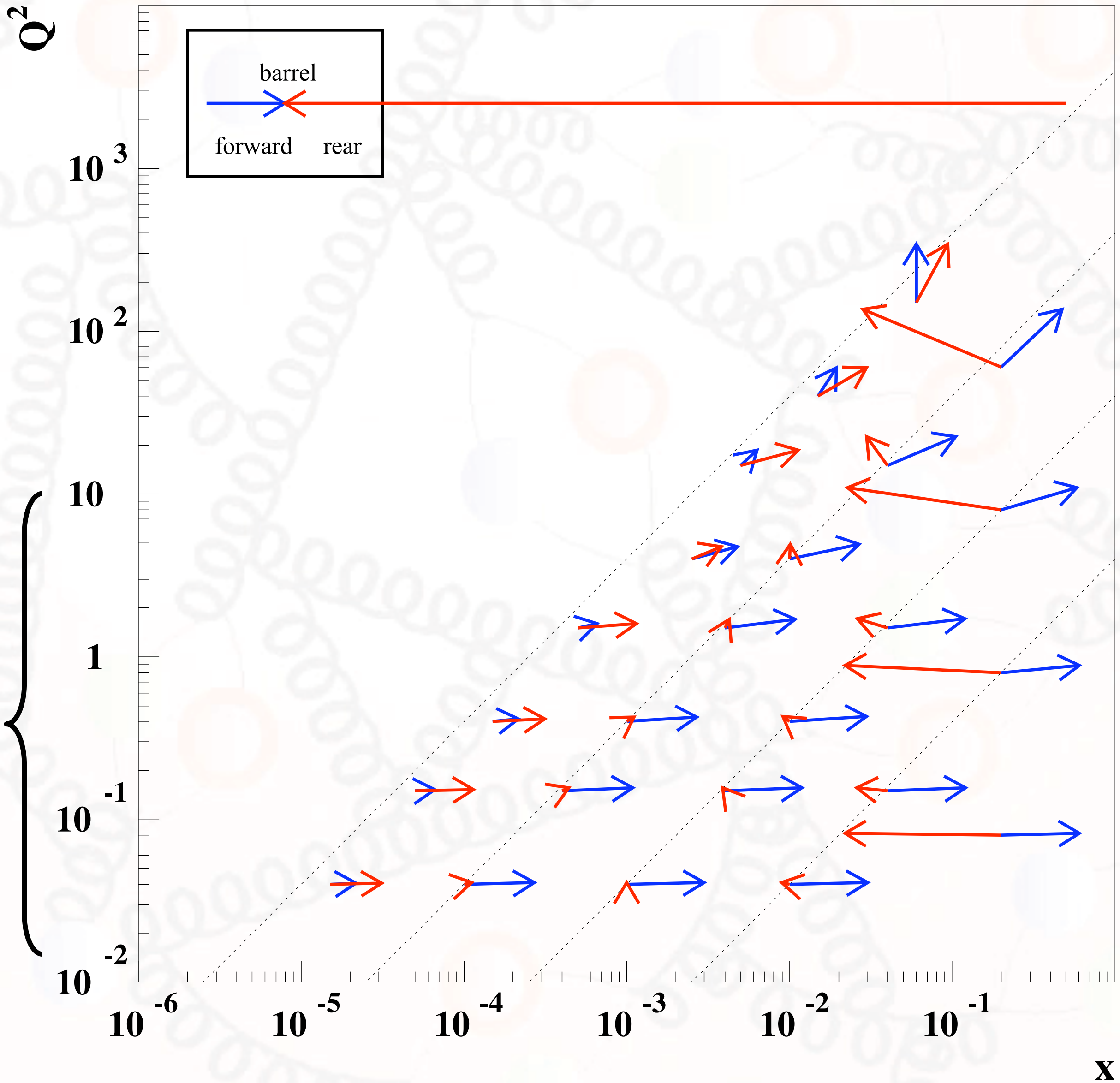


- High-x-high Q^2: Electron predominantly in barrel/forward direction (High energy) and current jet in forward direction (High energy)

Open questions: Inclusive/Exclusive measurements

- Inclusive measurements: ep/eA
    - Kinematic reconstruction through electron or hadron final state in what phase space region?
    - Kinematic reconstruction of eA using hadronic final state at high-x?
    - Use tracking for kinematic reconstruction besides calorimetry, in particular at very low energies?
    - Resolution requirements and systematic requirements on inclusive observables?
    - Phase space coverage for electron and hadron final state?
    - e/h separation at very low energy requires more than just calorimetry - How can this be achieved? TRD in addition to calorimetry (pre-shower detector / long. & trans. segmen.)
    - Optimal magnetic field?

Open questions: Inclusive/Exclusive measurements

- Semi-inclusive / Exclusive measurements
  - Define phase space coverage for final state particles
  - Resolution requirements and systematic requirements on observables to be measured
  - Particle ID requirements incl. momentum coverage
    - Distribution of different final state particles, i.e. momentum and angular distribution
    - Particle ID systems:
      - TOF / dE/dx does not give enough coverage in momentum
      - RICH versus DIRC (RICH allows wider momentum coverage)
  - Forward instrumentation:
    - Once topological requirements are clear, identify where we need tracking and calorimetry - Impact on machine lattice?

Open questions: Inclusive/Exclusive measurements

- General
  - Up to what point can we define a detector regardless of linac-ring and ring-ring option in case of eRHIC? What detector design aspects will critically depend on this choice?
    - Impact: Very forward (h) detection and rear (e) detection systems
  - Up to what point can we define a detector regardless of eRHIC vs. eLIC? What aspects of the detector design aspects will critically depend on this choice?
    - Rate requirements on detectors and DAQ
    - Background due to very different bunch spacing (High intensity bunches inside detector volume)
    - Impact: Very forward (h) detection and rear (e) detection system
  - What is the lowest electron beam energy for which a reliable reconstruction at low-x can be achieved? What is the efficiency?
    - Requires detection systems beyond calorimetry only

Open questions: Inclusive/Exclusive measurements

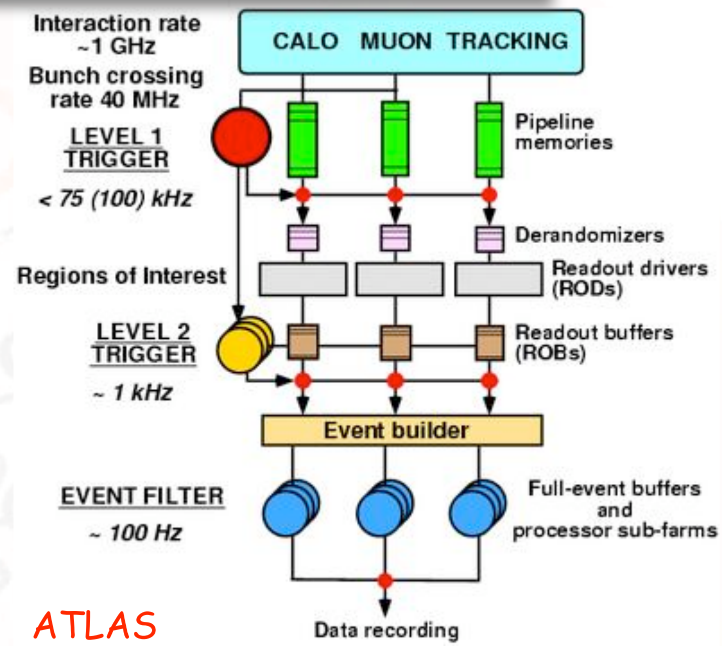
- General
  - Staging of detector: Start with inclusive measurements followed by additions (Particle-ID) for exclusive measurements, keeping in mind that several inclusive measurements can be achieved at lower luminosity
  - To what extend can the detector field be changed / modified from a conventional solenoidal field to accommodate beam transport in IR region and spin aspects?
  - Luminosity measurement, in particular eA?
  - Local polarimetry

Conceptual detector layout

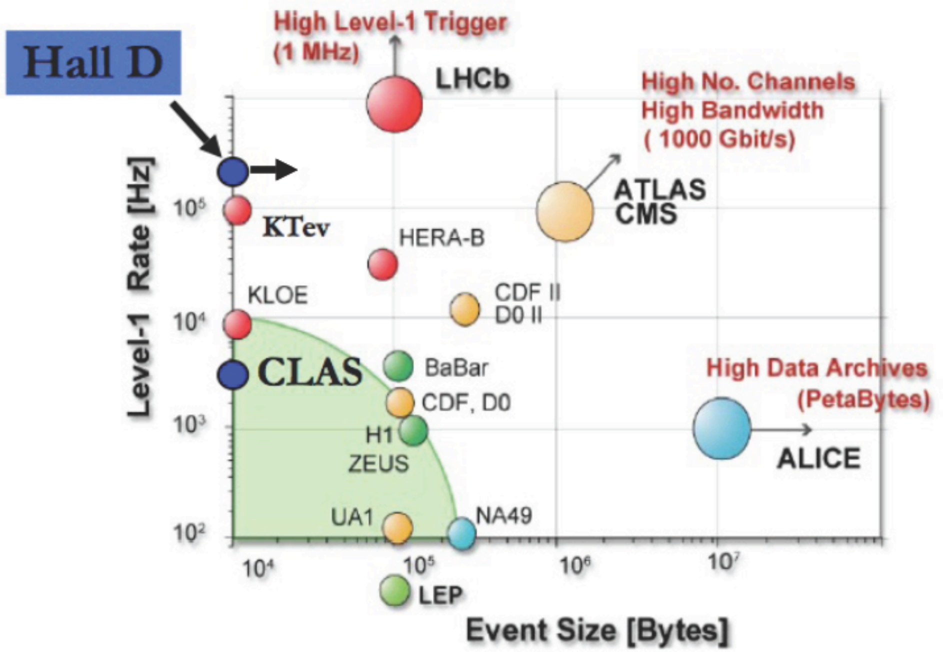
- Detector specifications (1)
  - Tracking over wide acceptance range operating in high-rate environment - Contribute to reconstruction of event kinematics besides calorimetry in particular at very small energies
  - Calorimetry over wide acceptance range (e/h separation critical): Transverse and longitudinal 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)

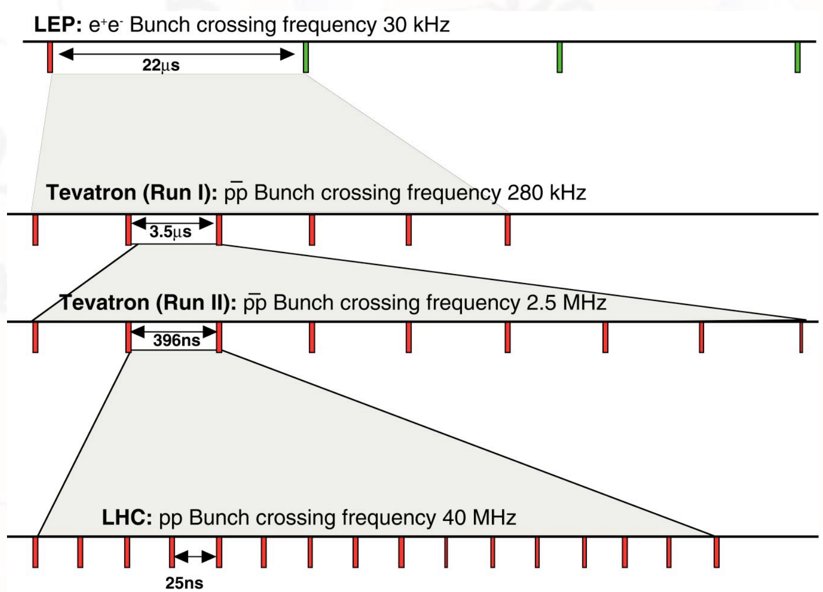
Conceptual detector layout

- 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



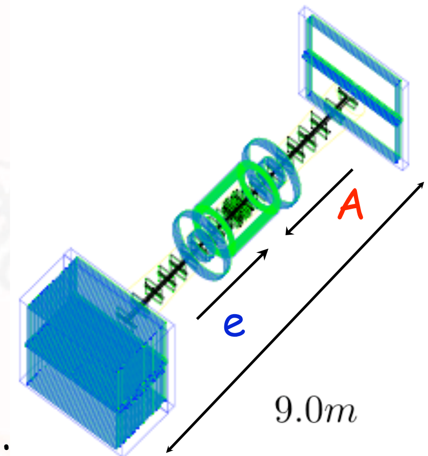
ATLAS



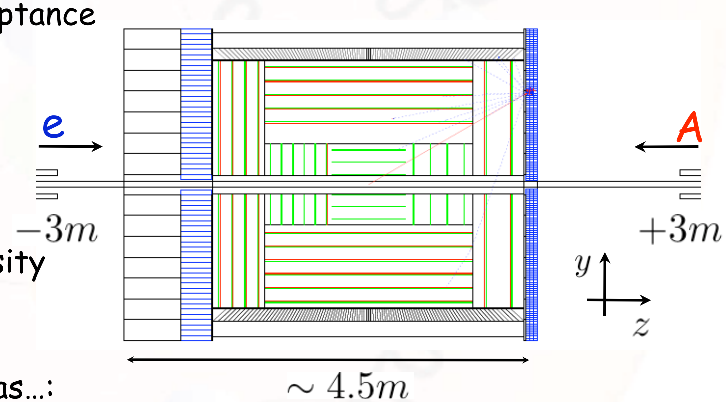


Conceptual detector layout

- 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



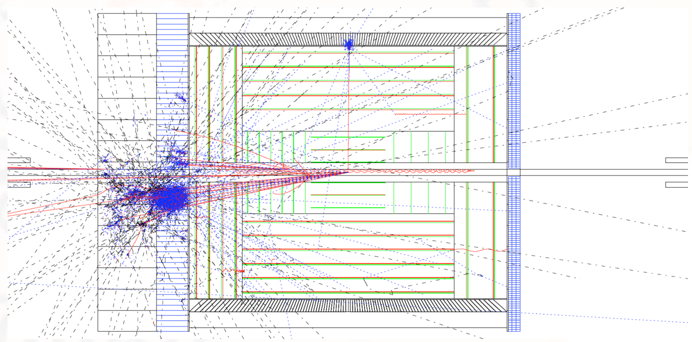
  - Design 2: General purpose (unpolarized/polarized ELECTRon-A):
    - Compact central detector (Solenoidal magnetic field) with specialized forward/rear tagging detectors/spectrometers to extend central detector acceptance
    - Required machine element-free region: approx. ±3m



  - 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

Simulation tools

- MC generators
  - Existing for both unpolarized and polarized ep
  - Various exclusive physics channels needs some work still
  - eA - Some progress from BNL group - Urgently needed!
- Detector simulation and reconstruction framework
  - Completely standalone GEANT3 based detector simulation incl. basic energy and momentum reconstruction exists in CVC repository (Only HELIX fitting - No pattern recognition): ELECTRA incl. documentation: http://starmac.lns.mit.edu/~erhic/electra/
  - Move eventually from GEANT3 to GEANT4



Detector R&D topics

- EIC detector R&D topics
  - Calorimetry: Compact, high resolution, e/h separation
  - Tracking: High-rate, low dead material, high occupancy (Forward direction)
  - Forward/Rear instrumentation: Compact, high radiation environment
  - Magnetic field configuration: Combination of solenoid and dipole-type configuration
  - DAQ/Trigger system: Multi-level trigger system
  - Background: Synchrotron radiation absorber and shielding

- Profit from and/or join existing world-wide detector R&D efforts
  - LHC detector experience (e.g. radiation-hard silicon detector, ROSE collaboration)
  - Micro-pattern R&D collaboration - RD51 Collaboration (BNL/MIT/Yale joined this effort)
  - LHeC collaboration on detector issues
  - Profit from LC detector R&D efforts (e.g. silicon-tungsten calorimetry)
  - Other efforts at: EUDET, JLab, GSI, SuperB@KEK

Detector R&D topics

- 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!

Detector R&D topics

- 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.

Detector R&D topics

- 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.

Detector R&D topics

- 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.

Detector R&D topics

- DAQ / Trigger System (I)

  - Goal:

    Multi-level trigger system including development of trigger algorithms for efficient rare process and DIS-e trigger selection (In particular for very low electron energies)

  - Issue:

    To efficiently select rare processes next to minimum-bias trigger may require the use of tracking at the trigger level.

Detector R&D topics

- 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.

Detector R&D topics

- 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.

Detector R&D topics

- 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

    Understand the requirements for dedicated particle-ID systems in addition to calorimetry for efficient e/h separation, in particular at very low electron energies (low-x region)

  - Issue:

    Efficient K/π separation over a large range of momenta is an essential ingredient for flavor tagging of the foreseen EIC physics program.

Detector R&D topics

- Development of precision auxiliary techniques
  - Goal:

    Precision luminosity measurement (absolute and relative) - Bremsstrahlung measurement
  - Issue:

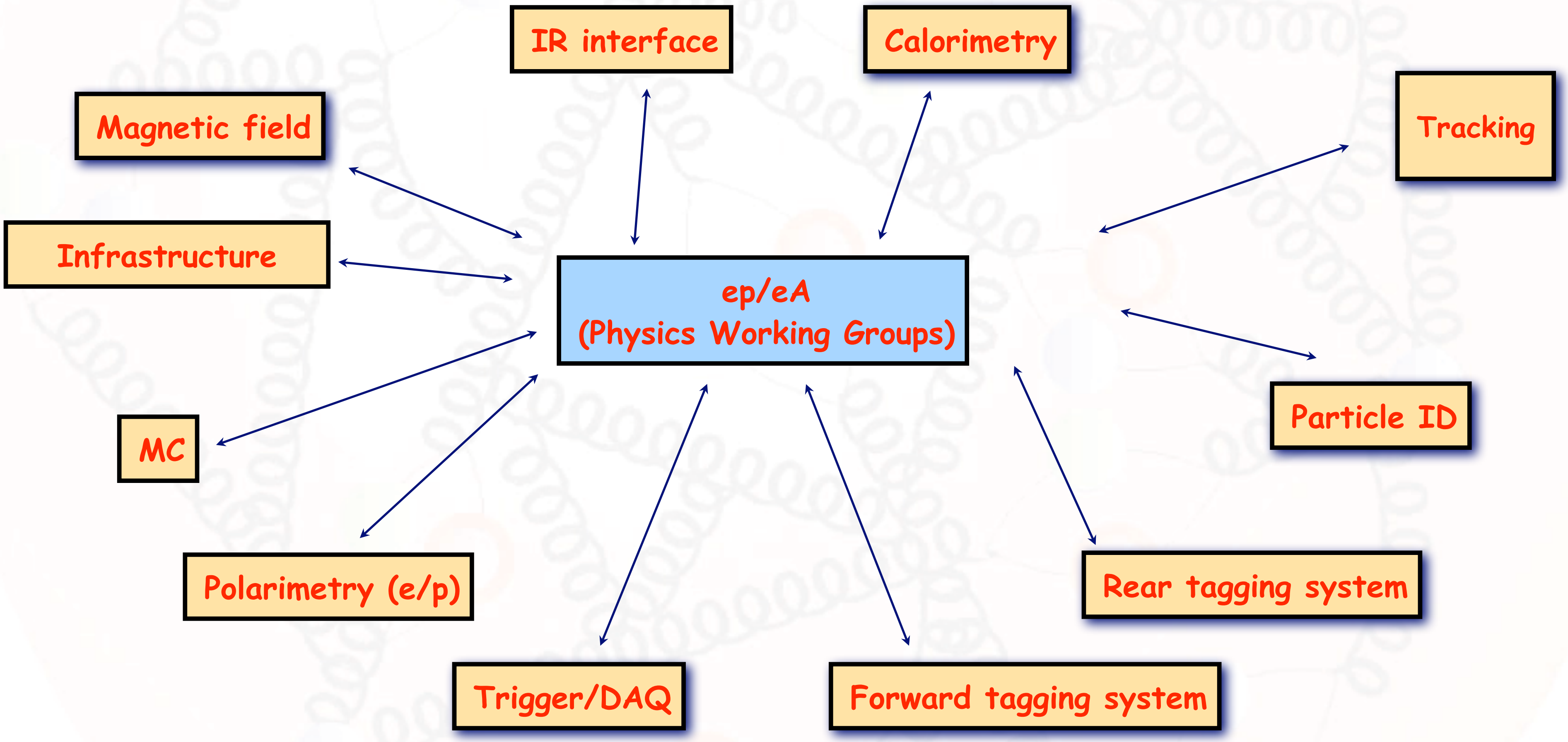
    Precision luminosity measurements are a must for absolute cross section measurements. Are the techniques developed at DESY sufficient?

Organization

- EIC Detector WG
  - Organize regular bi-weekly (phone) and monthly (BNL/MIT/JLab) meetings
  - Use existing mailing list more and more
  - WWW-page documentation and collection of material linked to MIT-EIC WWW-page
  - For now, a larger formal structure is not necessary yet, until the requirements and strategy has been worked out
  - Work with eA and ep WG to clearly define requirements for inclusive / exclusive measurements
  - Compile list of ongoing world-wide detector R&D efforts
  - Eventually organize dedicated EIC detector R&D workshop

Organization

: Several participating institutes chaired by 2 conveners



Milestones / Timescale / Needs

- Important: In order to keep a team of people focused to work out further the EIC physics case and an EIC detector design, clear milestones have to be defined, which have to end up in a formal proposal:
  - Window of opportunity for new initiatives starting ~2015
  - Define staging / upgrade of an EIC detector (Inclusive to Exclusive measurements)
  - Focus on one detector
  - Required: Site selection (BNL versus JLab) and realization (R-L versus R-R) to ensure leadership of both BNL and JLAB / Reviewed by international accelerator committee
  - Develop firm cost basis
  - Prepare and present a proposal along with preparation for next NSAC long-range plan
  - Proposal provides a basis to attract non-US institutions

Milestones / Timescale / Needs

- Timescales
  - Work towards the goal to start construction: ~2015 - CD3 required
  - Therefore: Prepare and present CD0 proposal by ~2012
  - This will allow to keep a community focused and motivated to work on EIC over the next couple of years (BNL/JLab groups plus University groups)
- Needs
  - Dedicated detector group at BNL/JLab (Senior leader besides postdoc and staff members who share their time with existing experimental efforts)
  - University groups: Postdoc and staff members who share their time with existing experimental efforts
  - Requires support from DOE