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 $Q^2$
    - Inclusive measurement - electron (Low x) and hadronic final state (High x) over wide acceptance range
  - Extraction of gluon polarization through DGLAP NLO analysis
  - Extraction of strong coupling constant
    - In addition: p tagging in forward direction
  - Precision measurement of $g^n_1$ (neutron) (Polarized $^3$He)
    - Jet production and small-angle e tagger
    - Hermetic detector configuration / e$^-$ and e$^+$
    - Missing energy measurement
    - K/$\pi$ separation - particle ID - Heavy flavor - Secondary vertex reconstruction and J/Psi (Forward muons)
- Photoproduction measurements
- Electroweak structure function $g_5$ measurements
- Flavor separation through semi-inclusive DIS
- Target and current fragmentation studies

EIC Collaboration meeting
SUNY Stony Brook, Stony Brook, NY, December 07-08, 2007
Overview of physics channels: Requirements

- **Unpolarized ep/eA physics**
  - **Precision measurement of $F_2$ at low x**: Transition from hadronic to partonic behavior
  - **Precision measurement of the longitudinal structure function** $F_L$
  - **Precision measurement of $F_2$ at high x**
  - **Measurement of diffractive and exclusive reactions**
  - **DVCS**
  - **Precision measurement of eA scattering**
  - **Nuclear fragments / Centrality measurement**

Inclusive measurement involving electron at small polar angles ($\approx 10\text{mrad}$)
- Inclusive measurement involving electron (Low x) - Variable $\sqrt{s}$
- Inclusive measurement (hadronic final state in forward direction): Good forward acceptance
- Forward p tagging system
- Forward p tagging system - photon/electron discrimination Variable $\sqrt{s}$ and positrons
- Similar to ep case at low x - High x: Forward acceptance - careful study necessary!
- Forward acceptance
Overview of physics channels: Requirements

- Event kinematics (10 GeV electron on 250 GeV 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)
Event kinematics (10 GeV electron on 100 GeV/nucleon 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)
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 extent 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
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
    - Zero-degree neutron detector

- Particle ID systems (K/π separation), secondary vertex reconstruction and muon system (J/Psi)
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
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/](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!
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.
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.
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.
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 $K/\pi$ 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 $K/\pi$ separation over a large range of momenta is an essential ingredient for flavor tagging of the foreseen EIC physics program.
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
Several participating institutes chaired by 2 conveners

Organization

ep/eA (Physics Working Groups)

- IR interface
- Calorimetry
- Tracking
- Magnetic field
- Infrastructure
- MC
- Polarimetry (e/p)
- Trigger/DAQ
- Particle ID
- Rear tagging system
- Forward tagging system
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
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