Detector Team Update

28 March 2022

BaBar with all
outer HCal sectors

Progress on ECCE NIM Drafts

- Shared Overleaf projects exist for all planned ECCE NIM articles. (Ask respective owner for access.) Wherever available, preceding ECCE note imported into draft. ✓
- See ecce-paper-det-2022-01 for these files:
  - main.tex with options selected for consistent NIM-compatible style. ✓
  - authors-alphabetical.tex and affiliations.tex providing complete maintained lists. Will circulate for corrections. Other articles import refreshable copy via Overleaf and later can adjust first authors in static local copy. ✓
  - refs-ecce.bib for import for consistent cross-referencing of other ECCE articles within this same NIM collection. ✓
  - Thanks to all who helped develop the NIM drafts so far.

ECCE Detector Team Updates

- See ECCE document database with links to Overleaf projects for all NIM drafts:
  - https://docs.google.com/spreadsheets/d/1Nuke_bu3tKajKQoNEF50UzSZk2IpTMqrs2Xk5KjaduE/edit#gid=0
- This session, status of 3 ECCE detector-focussed NIM Drafts:
  - ecce-paper-det-2022-01: Design of overall ECCE detector
  - ecce-paper-det-2022-02: Design and performance of ECCE calorimetry systems
  - ecce-paper-det-2022-03: Design and performance of ECCE tracking systems
- Next session: status of ECCE physics NIM drafts
- Following session: status of 3 ECCE computing NIM drafts
  - ecce-notes-comp-2021-01: ECCE computing plan (note evolving in situ to preserve internal comments)
  - ecce-paper-comp-2022-01: Deep learning-based lepton identification for ECCE
  - ecce-paper-comp-2022-02: AI-assisted optimization of ECCE tracking systems

Status of 3 Detector-focussed NIM Drafts

- ecce-paper-det-2022-01: Design of overall ECCE detector
  - proposal imported and re-formatted for consistent NIM A style
  - adjusted to read like technical note, rather than “proposal”
  - cites all other ECCE articles in NIM collection
  - polishing and proofreading continue, 31 pages
  - Timescale ~2 weeks
- ecce-paper-det-2022-02: Design and performance of ECCE calorimetry systems
  - previous note imported, re-formatted, polishing underway
  - Timescale ~2 weeks
- ecce-paper-det-2022-03: Design and performance of ECCE tracking systems
  - previous note imported, re-formatted, polished, 10 pages
  - Timescale ~1 April (see accompanying slides)

ecce-paper-det-2022-01

ECCE

Design of the ECCE Detector for the Electron Ion Collider

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1. Introduction

The physics program at the Electron-Ion Collider (EIC) – planned for construction at Brookhaven National Laboratory (BNL), in close partnership with the Thomas Jefferson National Accelerator Facility (TJNAF) – will be the culmination of decades of research into the quark and gluon substructure of hadrons and nuclei, and provide scientific opportunities well into the next three decades. The EIC will address a broad set of questions, described in a 2018 report by the National Academies of Science (NAS) [1]:

- While the longitudinal momenta of quarks and gluons in nucleons and nuclei have been measured with great precision at previous facilities – most notably CEBAF at JLab and the HERA collider at DESY – the full three-dimensional momentum and spatial structure of even a proton has yet to be fully elucidated, particularly including spin, which requires the separation of the intrinsic spin of the constituent particles from their orbital motion.
- These studies will also provide insight into how the mutual interactions of quarks and gluons generate the nucleon mass and the masses of other hadrons. The nucleon mass is one of the single most important scales in all of physics, as it is the basis for nuclear masses, and thus the mass of essentially all of visible matter.
- The density of quarks and gluons which carry the small-est x, the fraction of the nuclear momentum (or that of its constituent nucleons), can grow so large that their mutual interactions enter a non-linear regime in which elegant, universal features emerge in what may be a new, distinct state of matter characterized by a "saturation momentum scale". Probing this state requires high energy beams and large nuclear size (A), and will answer longstanding questions raised by the heavy ion programs at RHIC and the LHC.

To carry out this ambitious physics program, the EIC requires a comprehensive experimental program carefully designed to extract all of the physics from the scattering of electrons off of hadrons and nuclei. An ideal EIC detector must measure nearly every particle emerging from the interaction point, including its direction, its momentum, as well as its identity. Each of these aspects of the EIC physics program, and how a single comprehensive detector system could address them, was studied by the EIC scientific community and led to the community-authored "Yellow Report" [2]. The report also identified a set of detector performance requirements that flow down from the physics requirements of the EIC science program articulated in the NAS report:

- The outgoing electron must be distinguished from other produced particles in the event, with a pion rejection of 10^3 — 10^4 even at large angles, in order to characterize the kinematic properties of the initial scattering process. These include the momentum fraction of the struck target constituent (x) and the squared momentum transfer (Q^2).
- A large-acceptance magnetic spectrometer is needed to measure the scattered electron momentum, as well as those of the other charged hadrons and leptons. The magnet dimensions and field strength should be matched to the scientific program and the medium-energy scale of the EIC. This requires a nearly 4π angular aperture, and the ability to make precisely measurements of the sagitta of its curved trajectory, to measure its momentum down to low-p_t, and its point of origin, to distinguish particles from charm and bottom hadron decays.
- A high-purity hadron particle identification (PID) system, able to provide continuous (e/π) and (K/π) discrimination out to the highest momentum (60 GeV), is important for identifying particles containing different light quark flavors.
- A hermetic electromagnetic calorimeter system, with matching hadronic sections, is required to measure neutral particles (particularly photons and neutrons) and, in tandem with the spectrometer, to reconstruct hadronic jets

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Design and Simulated Performance of Calorimetry Systems for the ECCE Detector at the Electron Ion Collider

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1. Introduction

We describe the design and performance the calorimeter systems used in the ECCE detector design[1] to achieve the overall required performancec cost effectively with judicious attention to technical risks.

2. Calorimeter Design

The ECCE calorimeters are designed with the Yellow Report requirement imposed by the corresponding physics in mind. Consequently, particular focus was placed on an excellent electron detection with the broadest possible pseudorapidity (η) coverage. Driven by these concerns, we chose homogeneous electromagnetic calorimeters (ECals) for the electron end cap and the barrel region, while a highly granular shashlik sampling calorimeter was chosen in the hadron going direction. The gaps between these calorimeters in η were minimized by reducing the support structures for the inner most detectors and even adapting a projective design for the barrel ECal.

For the hadronic calorimeters (HCals) the ECCE consortium has identified no physics process which would benefit from an HCal in the electron end cap within the first years of data taking. Thus our baseline design does not contain an HCal in this direction and instead the sPHENIX plugdoor will serve as magnet flux return. A similar design as used for the STAR forward calorimeter [2] has been identified as a possible upgrade for the future in this region. For the barrel we propose to reuse the existing outer HCal from the sPHENIX collaboration, which is currently under construction at BNL [3]. This rather shallow HCal surrounding the BABAR magnet will be complemented by an instrumented steel support frame that holds the barrel ECal. Despite its limited depth, the IHCAL will be able to serve as calibration point before the magnet. In the hadron going direction we propose to construct a new longitudinally separated HCal in order to capture the rather collimated hadrons going in this direction with the best possible energy resolution. In this region we also envision an upgrade in the future with an inlay of a Dual read-out calorimeter replacing parts of the newly constructed forward ECal and HCal after 5-7 years of running.

The $\eta - \varphi$ coverage of the envisioned detectors according to the latest GEANT4 implementations for all ECal (left) and HCal (right), can be found in Figure 1. The figure also shows that all calorimeters cover the full azimuth ($0 < \varphi < 2\pi$).

The performance of the above described calorimeters strongly depends on the detector material budget, as early material interactions can deteriorate the reconstruction performance. A special focus here is put on the ECals where excess material of the inner detectors could quickly add up to several radiation lengths X/X_0. Thus, the material of all inner detector systems

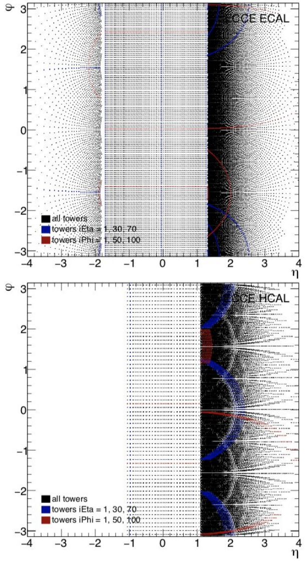

Figure 1: $\eta - \varphi$ coverage of the ECCE ECals (left) and HCals (right), where the positions of all calorimeter tower centers are plotted in black. For illustration, 3 rows and 3 columns of constant eta or phi index in the detector are depicted in blue or red, respectively.

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Design and Simulated Performance of Tracking Systems for the ECCE Detector at the Electron Ion Collider

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from -3.5 to 3.5 with full azimuthal coverage. Key tracking performances which include the tracking momentum resolutions, transverse Distance of Closet Approach (DCA_{2D}) resolutions, and the angular resolutions projected at the particle identification detectors will be presented.

Keywords: ECCE, Electron Ion Collider, Tracking

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1. ECCE tracking detector overview

The ECCE central detector[1] is a cylindrical detector covering $|\eta| \leq 3.5$ and the full azimuth angle. It is designed to reuse the former BaBar superconducting solenoid to contain a barrel tracking system, one hadron endcap tracking subsystem and one electron endcap tracking subsystem.

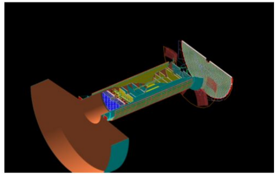

Figure 1: ECCE tracking detector side view in GEANT4 simulation.

As shown in Figure 1, the primary components of the ECCE tracking detector reference design are as follows.

Silicon Tracking system The Monolithic Active Pixel Sensor (MAPS) based siliocn vertex/tracking system consists of three components:

Silicon Barrel The silicon barrel detector consists of three vertex layers close to the beam pipe, two middle layers to provide the central track sagitta measurements. All layers use the ITS-3 type sensors with pixel pitch at 10 μm and an average material budget per layer of $0.05\% X_0$. The detector mechanical stricture design will be imported from the EIC eRD104 and eRD111 studies.

Siliocn Hadron Endcap The silicon hadron endcap detector consists of 5 disks, which provide precisely measured space points for charged particle tracking in the forward pseudorapidity region. This detector will enhance the capability to determine the decay vertex of long decayed particles and measure the majority of charged particle in the asymmetric $e+p$ and $e+A$ collisions. The technology for the silicon disk assembly is ITS-3 silicon sensor with pixel pitch at 10 μm. The detector mechanical strcture design will be imported from the EIC eRD104 and eRD111 studies.

Silicon Electron Endcap The silicon electron endcap detector consists of 4 disks to provide precise measurements of charged tracks, especially electron tracks, in the backward psedurapidity region. The reduction of number of disks in the electron endcap is to accommodate the integration needs from the electron electromagnetic calorimeter. The technology for the silicon disk assembly is ITS-3 silicon sensor with pixel pitch at 10 μm. The detector mechanical structure design will be imported from the EIC eRD104 and eRD111 studies.

Gas Tracking system All gas tracking layers in ECCE will be based on μRwell technology. μRWELL is a single-stage amplification Micro Pattern Gaseous Detector (MPGD) that is a derivative of Gas Electron Multiplier (GEM) technology. It features a single kapton foil with GEM-like conical holes that are closed off at the bottom by gluing the kapton foil to a readout structure to form a microscopic *well* structure. The technology shares similar performances with a GEM detector in terms of rate capability, while providing a better spacial resolution than GEM. Furthermore, compared to GEMs, μRWELL presents the advantages of flexibility, more convenient fabrication and lower production costs. These make it an ideal candidate for large detectors. Large area μRwell foils have been developed and manufactured at CERN. The Korean collaboration is expected to acquire this technology under a technology transfer agreement from CERN and manufacture the μRwell foils for ECCE gas detectors. The same Korean collaboration has experience in large area micro pattern gas detector foil fabrication, having worked successfully with CERN to manufacture GEM foils for CMS GEM detectors.

In ECCE μRwell layers will form three barrel tracking layers further out from the beam-pipe than the silicon layers. The barrel gas tracker layers include Two inner barrel μRwell layers, as well as a single outer barrel μRwell layer. All μRwell detectors will have 2D strip based readout. The strip pitch for all 3 layers will be 400 μm.