# An eRHIC Detector: Design Consideration and its Realization by Means of Detector R&D

*Klaus Dehmelt*[1]

[1]Stony Brook University, Dept. of Physics & Astronomy, Stony Brook, NY 11794-3800, USA

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eRHIC is a proposed high luminosity, polarized Electron Ion Collider, which would make use of the existing RHIC infrastructure. eRHIC is a collider with the possibility of using the two existing upgraded IP detectors and a dedicated eRHIC detector. This detector has to be designed making use of present knowledge and experience gained from the HERA detectors, but has to be adapted such that it is able to cope with the EIC physics program. The following will give an overview of the detector design, its IR and presently ongoing R&D activities for making technology choices towards such a detector.

## 1 Introduction

An Electron-Ion Collider (EIC) will be best suited for answering compelling questions in Quantum Chromodynamics (QCD). The EIC will be able to quantitatively probe the universality of strong color fields in electron-ion collisions. It will help to establish the existence of a saturation regime, will explore non-linear QCD, as well as measuring the momentum and space-time structure of glue.

The EIC will also play a vital role in determining answers for spin physics related questions with polarized electron-proton collisions. It will do so by precisely imaging the sea-quarks and gluons and thus determining spin, flavor, and the spatial structure of the nucleon. It will determine the quark and gluon contributions to the proton at last.

The eRHIC design requires a dedicated detector design that will be differing in various aspects from detectors such as ePHENIX, eSTAR, or an ELIC detector.

## 2 Detector Requirements

A detector has to be developed that can cope with the opportunities an EIC can deliver. Such a detector must be multi-purpose, i.e., one detector that is able to perform inclusive ($eh \to e'X$), semi-inclusive ($eh \to e'h'X$), as well as exclusive ($eh \to e'\pi p$) deep inelastic scattering (DIS) measurements, where $eh$ can be either $ep$ or $eA$ collisions.

The detector must also be able to handle collisions with varying beam energies and therefore varying $eh$ kinematics. It is anticipated that $\frac{E_h}{E_e}$ varies between 1 and 65, in contrast to HERA, where it varied between 17 and 34, with a fixed electron-energy of 27 GeV.

The impact on the detector configuration can be seen in terms of the various final state conditions: for inclusive DIS reactions the scattered lepton goes more and more into the original

beam direction when increasing its initial energy. High $Q^2$ events will be detected with the central detector. Low $Q^2$ events will have only small scattering angles and close to the original beam energy. One therefore needs a small angle, forward electron tagger. Moreover, the tracker has to be low-mass with a high resolution, covering a wide angular acceptance.
Semi-inclusive DIS reactions have a signature in hadrons that go from very forward to central and even backward directions, when the lepton energy increases. A good particle identification is required over the entire detector.
Exclusive DIS reactions require the measurement of decay products from $\rho - \phi - J/\psi$ particles, which will appear from very forward to central to even backward directions with increasing lepton beam energy.

## 3 Design Interaction Region

Due to the desired high luminosity at eRHIC the interaction region (IR) is designed to have a $\beta^* = 5$ cm and a field-free region of $l^* = 4.5$ m and a crossing angle of 10 mrad. This is required to achieve a luminosity of up to $10^{34}$ cm$^{-2}$ s$^{-1}$.
The crossing angle will be combined with the *crab-crossing* technique so that a maximum overlap of the crossing bunches can happen. High gradient large aperture $Nb_3Sn$ focusing magnets are planned for and a field-free region will be arranged where the electrons pass through the hadron triplet magnets.
The integration with the detector allows an efficient separation and registration of low angle collision products. Last but not least, a gentle bending of the electron-beam out of the the IR will avoid the synchrotron radiation impact in the detector.

## 4 Detector Concept

The generic detector concept for a dedicated eRHIC detector is shown in Fig. 1. It will be

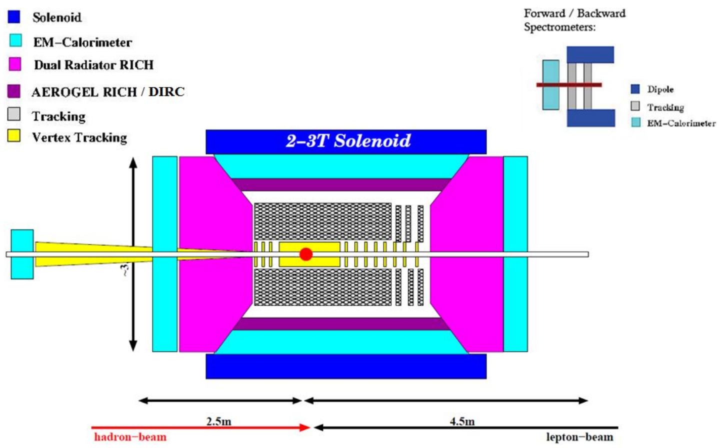


Figure 1: Concept for a dedicated eRHIC detector.

asymmetrically surrounding the IR and will consist of vertex tracking, barrel and forward

tracking, particle identification detectors and electromagnetic calorimeters. All is embedded in a solenoid, which is foreseen to deliver a magnetic field of 2-3 T. This detector concept is based on providing maximum hermecity.
The detector is planned to also have the least amount material so that multiple scattering and bremsstrahlung is avoided to the highest degree. A radiation length scan in a *GEANT4*-simulation is shown Fig. 2.

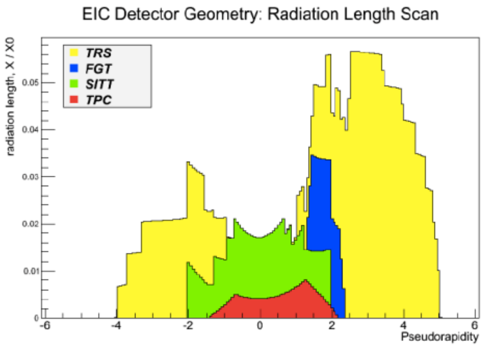


Figure 2: Radiation length distribution for a dedicated eRHIC detector.

## 4.1 Tracking-Vertex

For a vertex detector it is foreseen to make use of a Si-VTX device which is based on the MAPS-technology [1]. This technology is in an advanced R&D stage, mainly pursued by the IPHC group in Strasbourg/France. It found already use in the STAR-HFT, CBM, ALICE, to name a few.
The barrel will be equipped with four double sided layers at distances of 2.5/5.0/7.5/15.0 cm, subdivided in ten sectors in $\phi$. The rapidity coverage should be at least $|\eta| = 1$. A dual sided readout with 60 µs readout time per column would result in a radiation length of 0.5 % per layer based on 5 µm Si and will have an excellent vertex resolution of better than 5 µm.
In the forward direction at least four single sided disks are foreseen, spaced in $z$ from 20 cm. The radial extension makes from 3 to 12 cm with 19 respectively 75 µm pixel-size. The radiation length per layer is expected to be 0.3 %.

## 4.2 Tracking-Barrel and Forward

For the barrel tracking a Time Projection Chamber (TPC) with Micro Pattern Gas Detectors (MPGD) is a preferred technology. It provides low mass, particle identification ability e/h via dE/dx and the has a rather good position resolution in conjunction with pattern recognition.
Present MPGD-R&D is ongoing with the most promising technology being the Gas Electron Multiplier (GEM [2]) and Micro Mesh Gas Detectors (Micromegas [3]). Both offer transverse $\sigma_r < 150$ µm and longitudinal $\sigma_z < 300$ µm position resolution.
Forward tracking detectors are foreseen similar to the very small angle tracker (VSAT) in COMPASS or the Forward GEM Tracker at STAR.

### 4.3 Particle identification

The particle identification PID options for a dedicated eRHIC detector are manifold. In the barrel region one could deploy a combination of a TPC with dE/dx in conjunction of a Cerenkov detector with gaseous radiator, a detector of internally reflected Cerenkov light (DIRC [4]), time of flight detector (ToF) of the next generation with 10 ps time resolution [5], Aerogel as proximity focused Cerenkov detector plus ToF, proximity focused Cerenkov detector with liquid radiator, and/or electromagnetic calorimetry detectors (EmCal) In the forward region one is not as spatially constrained as in the barrel region. Therefore a combination of a Cerenkov detector with gaseous radiator and CsI-GEM photodectors plus tracking, ToF, and EmCal detectors would be suitable. In the very forward region EmCal detectors could be used.

### 4.4 Electromagnetic Calorimetry

In the backward as well in the barrel region PWO-crystal calorimeters are considered because of their good resolution and small Molière radius which enables them to provide good $e/\pi$-separation. It also gives the possibility to measure the scattered lepton from the *eh*-collision which is an important aspect for the measurement in Deep Virtual Compton Scattering (DCVS). In the forward direction the requirements are less demanding and one could think about the use of sampling calorimeters made out of scintillating fibers and tungsten powder. Preshower might find an application in form of the Si-W technology as proposed for the PHENIX MPC-EX detector.

## 5 Summary

The eRHIC is one of the possible EIC options and will be considering eSTAR, ePHENIX, and a dedicated eRHIC detector. This particular detector will be able to cover all EIC physics aspects and will have much more stringent requirements as previous detectors at HERA. There is a vast number of R&D activities that this detector will make use of: Tracking R&D efforts for the vertex, forward, and the barrel region, as well as for PID and calorimetry. All these aspect are going hand-in-hand with R&D efforts for various other detector projects. Furthermore, the Brookhaven National Lab has announced a generic detector R&D program for an EIC [6].

## References


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