Summary of the discussion at ECT* Trento on Staged Realization of the EIC (eRHIC) in the WS on "Structure of Hadrons and Nuclei at the EIC" July 14-18, 2008

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Participants of the Workshop: List of names….

Discussion leader & Summary by
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The organizers (F. Gelis[CERN, Saclay], R. Venugopalan[BNL], W. Vogelsang[BNL], F. Yuan[LBL]) asked me to lead a discussion on the idea of Staged realization of the EIC. This was held on July 17, 2008. No slides were presented[1]. Only blackboards were used to draw schematic drawings and a collection of physics topics. Below is the result of collection of physics topics that we agreed ***as worth pursuing in the next few months to evaluate the case*** for the stage 1 of EIC, and hence the staged realization of the EIC. The proposal being discussed so far, is for RHIC only, and ***is very preliminary***.

I encourage the reader to send me comments. I apologize if the summary has mistakes, or misunderstandings: please send me corrections, I would be happy to fix them with acknowledgements. Eventually the workshop organizers will put this up as summary of the discussion.

Stage-1 realization of EIC, Concept:

Savings (in money & in time) from the stochastic cooling of the nuclear beams instead of the initially planned electron-cooling, seeded the notion of possibly using the savings to start the EIC physics program early with a "mini-EIC". The mini-EIC, then would be upgraded in to the full EIC as proposed and discussed in the wider Nuclear Physics community. This approach is now called the "Staged Development of the EIC". The collider concept was developed by V. Litvinenko et al from BNL's CAD, and was presented at the EIC meeting in Hampton University [1] and more recently at the RHIC-AGS User's meeting [2] by the BNL's Associate Lab director. The highlights are:

- A 2-or3-pass ERL could be constructed entirely within the existing RHIC tunnel, with no civil construction. The interaction region will be at IP2 or IP12.
- Electron beam energy of ~2 GeV may be possible. This would collide with the existing RHIC beams (250 GeV proton or 100 GeV nuclear beams).

[1] See the talk by A. Deshpande, July 14, in this workshop for the details of how the staged approach works schematically.

- Polarization of both the electron and hadron/light-nuclear beams possible.
- Luminosity 1-few times 10^{32} $cm^{-2}sec^{-1}$
- Resulting kinematics:
    - CMS Energy range Sqrt(S)_{ep}=20-45 GeV
    - For eA approx 10-28 GeV
- All (> 85%) of the parts of the Stage 1collider will be used in the full eRHIC within the RHIC tunnel.

Physics of Stage 1: The studies suggested/proposed at ECT* EIC meeting:

The x-Q2 regions overlaps with past fixed target polarized and un-polarized DIS experiments with polarized and un-polarized electron and muon beams at SLAC, CERN, DESY & FNAL. However, eRHIC-Stage-1 (eS1) would be the first exploration of matter in the same kinematic region with a collider geometry. Typically, in a fixed target experiment the impinging electron/muon beam and the target fragments go in the same direction and often the physics of the target and that associated with beam are difficult to separate (not enough pseudo-rapidity η separation). The studies proposed are meant to utilize this unique aspect of the collider vs. fixed target collision mode. A second unique aspect of this proposal is the fact that while past measurements have been made with different beams at different locations around the world, with different detectors, each of which had small x-Q^2 coverage. The advantage of the mini-EIC would be to have this region covered in one single collider greatly enhancing the ability to suppress systematic uncertainties of different measurements.

With very large beam energy asymmetries (2:250::E_e:E_p and 2:100::E_e:E_A), the scattered hadronic remnant goes in the very forward region (forward defined w.r.t. the hadron beam). The scattered electrons depending on the Q^2 (and x) of the collision are expected to populate a wider polar angle theta-prime. A detector that tries to capture most of the forward scatters, for example the detector proposed by Allen Caldwell et al [3] would be a good (minimal) design to start thinking about this.

Topics of potential physics of high impact to be studied in the next few months include (not in any order of priority or importance and note that some of them are not independent of each other):

Spin related measurements (mostly possible with polarized protons, deuterons and possibly Helium)

- Inclusive and semi-inclusive DIS **transverse e-N scattering**
    - Mini-EIC will allow measurements in **broad Q^2 range**
    - The above is crucial for measurements of transverse spin effects being discovered at HERMES, COMPASS and Jlab
    - First detailed study of Q^2 evolution of TMDs, which is not possible presently any where. This would be the first window in to this. The x access not being too different, (mid to large) this is a reliable region of

known (large) transverse spin effects and puzzles. (Author's note: this may be the most attractive physics program for this proposal, that will be unique and of high impact!). The need for large Q^2 arm in TMD measurements to study their evolution have been recently discussed in two recent overviews [6].

- A systematic study of target fragmentation including investigations of intrinsic charm/heavy-flavor quarks (see comments below related to this regarding luminosity and detector requirements).
- Inclusive and semi-inclusive DIS longitudinal e-N scattering
    - Spin structure function and its evolution $x >$ few x 10^{-3}
    - Polarized gluon from photon-gluon fusion
    - With appropriate detectors high x spin structure functions
    - Many aspects of higher-twist physics from the evolution of spin SF

With unpolarized beams of e and nuclei from H to U

A first window in to the DIS with nuclei will be possible with a collider geometry. This has significant value and impact based on some specific physics topics (see below) but also, and some might argue as being more important that, there is tremendous value toward learning how to do these experiments in the future e-A physics program at the EIC.

- With polarized and unpolarized beams study of intrinsic heavy flavor quarks (in particular: charm) has been emphasized by Stan Brodsky et al . A list of investigations possible with the mini-EIC were sketched out in two of his recent talks [4] at the EIC meeting at Stony Brook and the DIS2008 in London. To be investigated:
    - Would the luminosity a few x 10^{32} be enough?
    - Would it need a more comprehensive detector?
- First study of hard diffraction in e-A scattering to initiate the exploration of hard diffraction
    - Guidance for the future development of this program at higher energies allowing us to go deeper in the (expected) saturation region was of paramount importance, and emphasized as such.
- Detailed study of EMC effect over a wide kinematic x-Q2 region, in which perturbative QCD would work
    - Would be allowed with all species of nuclei Proton to Uranium (EBIS)
- Would settle the existing discrepancies between the NMC and E665 data sets in some of the crucial (not so small) x regions.
- EMC effect in nuclei has/may-have direct connections the physics of nuclear medium related suppression of colored probes observed in heavy ion collisions at RHIC. Precise knowledge and experimentation with different nuclei might be useful for the insights in to the behavior of nuclei in this intermediate to high x region.
    - This was dubbed as a study of *"partonic structure of nuclear forces"*
- Significant emphasis was given by some participants to the detailed study of the low A nuclei (deuteron, being called the ideal one).

- Deuteron with spin, also allows unique studies with polarization of the neutron and proton when the spectator in the collision is experimentally tagged.
- Detailed study of neutron final states as a function of $t = -Q^2$ GeV^2

What next?

- Initiate some of these studies in small groups
- Investigate the existence of potential show-stoppers for the measurements listed above
- If beam energy or luminosity parameters do not match the specific measurements listed above and some modifications are deemed necessary, that input should be given to the Collider Accelerator Division to investigate its feasibility. For examples questions that could potentially come up:
  - What would it take to go to 10^{33} in luminosity?
  - If found necessary, what would it take to go to 3-4 GeV in e beam energy?

A comment from concerned participants:

One of the issues not discussed in this note is the discussion about connections of EIC physics program to other subfields within Nuclear Science:, in particular the parity and symmetry violation studies with high luminosity nuclear and neutrino probes. This was a significant topic of discussion in the present ECT* workshop [5]. See presentations by M. Ramsey-Musolf and K. Kumar on July 16. Those measurements may become and the QCD program of the study of GPDs already is part of the EIC proposal. These two would be the **main drivers of high luminosity in the final EIC proposal** (NOT the mini-EIC). It was emphasized by all participants in the discussion, that those physics topics are of great importance, and even if one goes ahead with the Staged EIC approach, all machine design aspects of future luminosity upgrades to achieve ~ few x 10^{34} cm^{-2} sec^{-1} should be preserved. In other words**, the low-energy Stage 1 EIC can never be an "EIC-Lite",** it is ONLY a step towards the final EIC which will have high energy, high luminosity polarized hadron and nuclear beams as discussed in the wider NP community. The Stage 1 of the EIC should only be viewed as an opportunity to realize some of the planned EIC physics earlier, enabling the start of the physics program in near future.

References:

[1] V. Litvinenko, EIC Meeting at Hampton, Website and talk location
[2] S. Vigdor, RHIC Future Plans, Link to Symposium on Impact of RHIC on Nuclear Science
[3] A. Caldwell detector for forward physics at eRHIC, design link and reference
[4] S. Brodsky's talk link to EIC meeting at Stony Brook and DIS2008 program
[5] Links to Ramsey-Musolf and Kumar's presentations
[6] A. Bacchetta at the EIC Meeting in Hampton & M. Anselmino at Workshop on Transverse Spin Physics, PKU-RBRC Workshop in Beijing, July 2008. Link to websites.