eRHIC note # xxx

Implication of eRHIC IR Design for Experiments

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The eRHIC interaction region design presented by Steve Peggs at this week's workshop uses the DX magnet as a final bend to bring the electron beam into the interaction region.

We argue that this machine design, although it appears, at first glance, to maximize free space in the interaction regions, should be abandoned. An additional dipole magnet should be used to insert the electron beam – either with a vertical or horizontal bend. If properly designed, this second bend might even be an asset allowing magnetic analysis of forward charged particles, as pointed out by Bjorken.

Beam Fragment Measurement at RHIC

One of the recurrent themes at the workshop was the importance of measuring nuclear fragments at beam rapidity, specifically evaporation neutrons. Stan Brodsky, Malcolm Derrick, Krasny, and Bjorken emphasized this. An example of where this capability is useful is the tagging of coherent diffraction of a virtual photon off a gold nucleus. The absence (or small number of) evaporation neutrons would be used as a coherence tag. This is perhaps the only specific guidance on detector capability to come out of the discussion.

RHIC is designed to allow full acceptance measurement of evaporation neutrons at beam rapidity. We've built and are now operating – in all four experiments – zero degree calorimeters (ZDC's) to carry out these measurements. The most direct impact of this enterprise on the machine was the design of the vacuum chambers between DX and DO magnets. They are designed to allow the maximum free space for the ZDC's; taking into account all planned RHIC beam scenarios (i.e. p-A and A-A from injection to top energy) with a 6σ envelope and a fixed reserve.

The amount of material in front of the ZDC's was kept to a minimum. The resulting vacuum chamber design would have lead to a significant R.f. impedance (comparable to that of the r.f. storage cavities). To reduce the impedance we installed a wire mesh internal chamber, which is roughly conformal to the beams.

The eRHIC design would completely eliminate the possibility of beam rapidity neutron measurements for reasons given below. A modified eRHIC design, which alters less radically the RHIC beam orbits, may still compromise this investment in the ZDC vacuum chambers.

Finally, the ZDC's are at the limit of compactness for a hadron calorimeter (ref.1). They have 10cm transverse dimension (Tungsten with fiber sampling medium) and have uniform response to hadron showers (within 5%) to 1 cm of either edge of the detector. It is unlikely that another detector design could help alleviate the problem.

Fragmentation Neutron Acceptance

To see what is needed for a full acceptance neutron detector consider the emission spectrum of evaporation neutrons in the nucleus reference frame. If the neutron kinetic energy is E*<10 MeV, then their transverse momentum is bounded by

$$p_{\perp}^{\max} = \sqrt{2m_n E^*} \cong 140\,MeV/c\,.$$

In the lab frame

$$\vartheta^{\max} = \frac{p_t^{\max}}{(p_{beam} = 100GeV/u)} = 1.4 \text{ mrad}$$

The contribution to the neutron spot size from beam divergence is

$$\vartheta_{95\%} = \sqrt{\frac{\varepsilon_{\perp}}{6\pi\beta^*\gamma}} = \sqrt{\frac{20 \bullet \pi mm \bullet mrad}{6 \bullet \pi \bullet (2m) \bullet 100}}$$
$$= \sqrt{1.6} \bullet 10^{-1} mrad$$

In other words, it is only a 10% correction.

In the current RHIC lattice design, the neutron spot is well separated from the beam downstream of the DX magnet. The beam is deflected by 18 mrad in the DX magnet (Z_{bend} ~11.5m) whereas the ZDC's are located at z=18m's.

Proposed eRHIC Design

In the scheme proposed by Peggs, an electron beam of momentum, P_e = 10-15 Gev/c is brought into the collision region through DX also.

However, because the electron beam has lower rigidity by a factor

$$F = (10/100)(79/197) = 0.04 \quad ,$$

the magnetic field in DX has to be reduced by approximately this factor.

Under these conditions, the neutron beam fragments would not be separated from the beam trajectory and the zero degree calorimeters would be useless.

References:

1) for further details see the RHIC zdc home page at
http://www/rhic.bnl.gov/~swhite/zcal/index.html