2nd Electron Ion Collider Workshop
March 15-17, 2004
Jefferson Lab

Lattice /Detector Integration for Target Fragmentation, Diffraction, and other Low-*t* Processes

Charles Hyde-Wright
Old Dominion University
Chyde@odu.edu

Forward Tagging

- Electron-Ion collider offers unique opportunities for tagging particles emitted in the forward direction at very low momentum transfer:
  - Target Fragmentation in DIS
  - Recoil proton or nucleus in exclusive DVCS and Deep Virtual meson production
  - Spectator tagging in Quasi-Free reactions N(e,e’)X:
    - D(e,e’p)X, D(e,e’n)X
  - Zero degree electron scattering for tagging of Quasi-Real photons.

ELIC Baseline Design

- 5 GeV/c (electron) $\otimes$ 50 GeV/c proton
  - Luminosity $L = 10^{34}/\mathrm{cm}^2/\mathrm{s}$
- Nuclear beams ^{A}Z,
  - Magnetic rigidity $K = A\,P / (Ze) = 50$ GV/c
  - N=Z nuclei, $P_A = (A/2)\,P = (25\ \mathrm{GeV/c})\,A$
  - Luminosity $L_A = L\,A^2/Z^4$
- Crab crossing at 100 mrad
- Longitudinal & Transverse momentum spread
  - $\sigma_\perp = \sigma_{||} = 3\cdot 10^{-4}$
  - Longitudinal acceptance $\delta P = 0.3\%$
  - Transverse Beam Stay Clear??

Zero degree electron scattering

- Singles rates dominated by Bremsstrahlung e Z → e Z γ
  - Ion beam Radiation Length : $X_0\ ({}^{A}Z^{Z+}) = [A/Z^2]\ 7\cdot 10^{25}\ /\mathrm{cm}^2$
  - Tagging rate

$$d\Phi_\gamma = \frac{dk_\gamma}{k_\gamma}\frac{L_e}{X_0}$$

$$\int_{0.5}^{0.95} \frac{d\Phi_\gamma}{dk_\gamma}\frac{dk_\gamma}{k_\gamma} = 10^8\, Hz @ L = 10^{34}$$

- (e,e’x) Coincidence rates dominated by quasi-real photon true coincidences
- Tagging spectrometer (extended ‘C’ magnet) for first dipole on one IP
  - $0.5 < k_\gamma / E_e < 0.95$ (photon)
  - $0.05 < E_e' < 0.50$ (scattered electron)

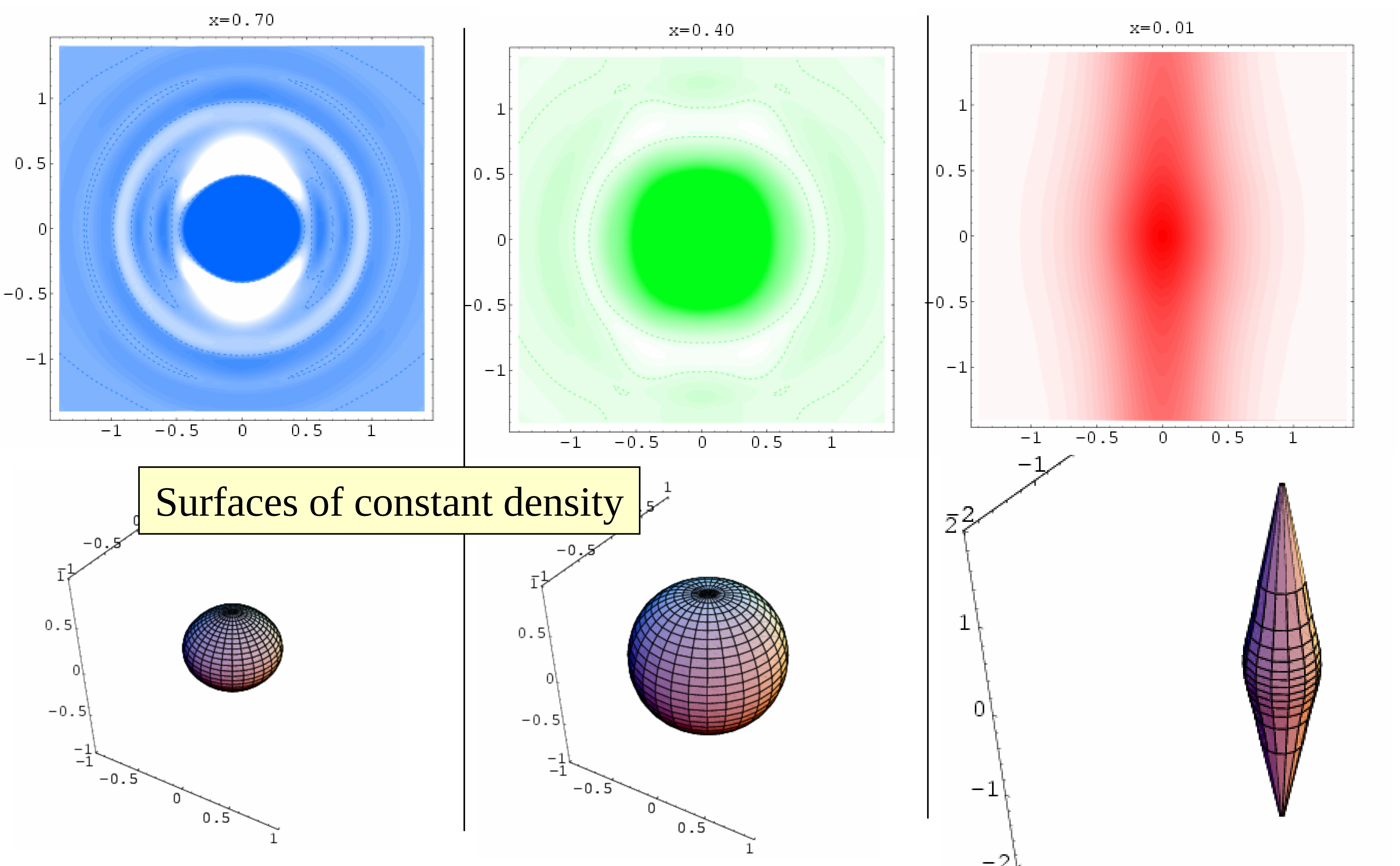
Hadron Beam tagging

- DVCS: $ep \rightarrow ep\gamma$
    - Form 3D image of proton as a function of quark wavelength
    - Size = [1fm] $\ln(1/x)$ = 5 fm at $x=0.01$
    - ELIC, $x > 0.01$ for $Q^2 > 5\text{GeV}^2$
- Proton recoil
    - $P' = P(1-x)$, resolve shift xP from beam momentum P
    - $P_\perp$, resolve 0.2GeV/$\ln(1/x)$ = 40 MeV/c at $x=0.01$
        - $P_\perp / P > 10^{-3} = 3\sigma$ at IP
    - x>3E-3 separated (=0) in first 100m
    - Require 2cm radius aperture in all elements
    - Require 2 x 10cm drift space before and after each dipole.
    - Pperp2 Emmitance = 0.2mr = 15 MeV/c

Phase Space Densities (Wigner Distributions) of Quarks inside the Proton, for Short, Medium, and Long wavelength quarks.

Scale is 1 fm ≈ r.m.s. charge radius of proton. Wavelength ≈ *h/(Mx)*

Courtesy, X. Ji, UMd



Surfaces of constant density

DVCS: Recoil proton tagging in lattice

- Ring acceptance $x < 0.003$
- Tag protons with $x > 0.003$
  - Trackers (Si…), 2 cm I.d., 4 cm. O.d. just after and just before each dipole in first few dipoles of ring.
    - Resolve (1-x)P and $P_{\perp}$.
  - Compact detectors, with 1m drift space.
  - Roman Pot Design (reinsertion after fill)?
  - Lattice apertures should accommodate larger acceptance.
  - Expanded magnet aperture for detectors inside magnets.

N* decay veto

- Resolve e p → e p γ from
- e p → e N* γ → e N π γ
    - π has long. momentum (m/M)P = P/7
    - π has typical transverse momentum m
        - $\theta = 7m/P = 20$ mr
    - π^0 2 photon opening angle = 7m/P = 20 mr
    - Fine grained calorimetry in front of FF Quad.
    - Recoil neutron $\theta = 7m/(6P) = 0.3$ mr → ZDC
    - Recoil proton P+ = (6/7) P
        - 133 mrad bend in Crab crossing dipole.

Neutron Detection

- Detect neutrons at zero degrees
  - Nuclear beam momentum AP/Z = 50 GeV
  - P = 25 GeV per nucleon
  - Aperture
    - θ = 200 MeV/ P
    - = 200 MeV/25 GeV = 8mrad
    - Aperture = 2.4 cm at final focus quad (3m). =
    - Hadron Calorimeters (20 cm length) before final focus
  - Roman Pot design needed between crab crossing dipole and final focus quad
    - Aperture 2 cm at 6 m → angle>3 mrad
  - 3 cm at 10m ZDC

Deuterium Quasi-Free

- Deuteron
  - Magnetic rigidity K = 50 GeV=AP/Z
  - P = 25 GeV/nucleon
- Spectator proton
  - K’ = 25 GeV
  - Lattice transport should allow detection of these protons.
- Deuteron bends 100 mr in crab crossing dipole.
- Proton will bend 200 mr!!
  - Need a C-magnet tagging spectrometer design or tracking detectors inside magnet.
  - Point-to-point focus with post-IP quadrupole

Nuclear Quasi-Free

- Beam rigidity = K = AP/Z
- ${}^{A}Z(e,e'\,{}^{A-1}Z)X$,   [quasi-free on neutron]
  - Magnetic Rigidity of daughter
    - $K(A-1)/A<K$
- ${}^{A}Z(e,e'\,{}^{A-1}[Z-1])X$
  - Magnetic Rigidity of daughter
  - $K\,Z\,(A-1)/[(Z-1)A] > K$

Tracking needed at both large and small radius in first dipoles

Nuclear Decay fragments

- Quark fragmentation, measure nuclear temperature:
- Evaporation neutrons near 0-deg
- Evaporation protons at rigidity P <AP/Z

Conclusions

- First few elements in lattice should be designed with thought to detection of forward fragments
- Compact detectors near 0deg can enhance physics program.