Tagged Deep Inelastic Scattering

Exploring the Sullivan Process

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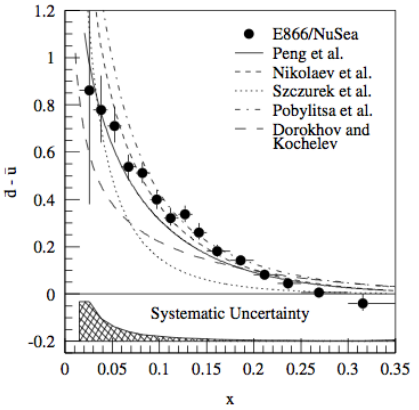
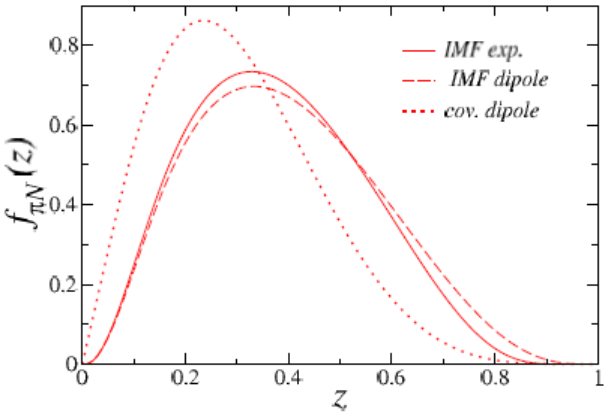
Overview

- The Tagged Deep Inelastic Scattering proposal would seek to run in Hall A using SBS and a new recoil proton detector to measure DIS in the target fragmentation kinematics
- The kinematics of choice, in e+p→e'+p'+X for example, would isolate target fragmentation processes, by which the proton fluctuates to a virtual π^0-p pair and the hard scattering takes place between the electron and pion
- The TDIS rate will be a convolution of the fragmentation function, describing the meson component of the nucleon, and the structure function of the meson
  - By making measurements of e+p→e'+p+X and e+D→e'+p+p+X, we would plan to examine the charged and neutral pion structure function

Meson component of the nucleon

- We believe that the nucleon wave function has important contributions from meson-baryon states
  - The $\bar{d}$ - $\bar{u}$ imbalance seen by E866 at low x can be explained using a meson cloud model
- But there is little direct experimental probes of the contributions





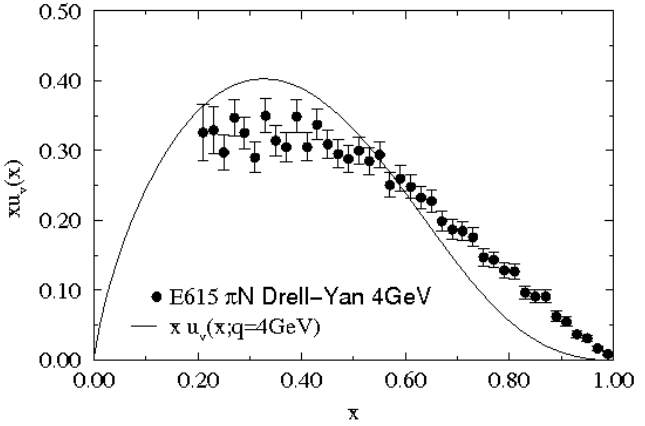
Pion structure function extractions

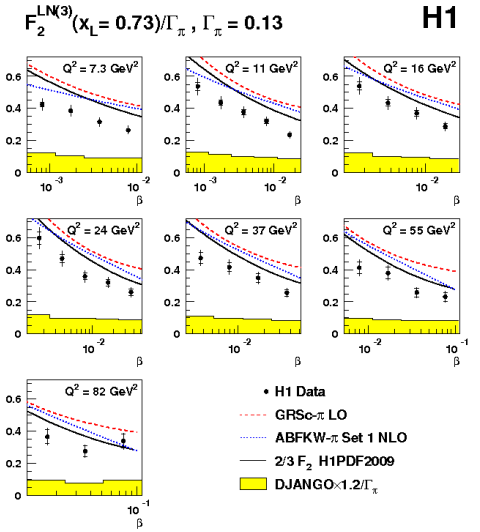
- E615 extracted the pion structure function from Drell-Yan muon production in π-N scattering

  J. S. Conway, et al., PRD 39, 92 (1989).

- H1 extracted pion structure functions at low x_π and high Q^2 by detecting leading neutrons

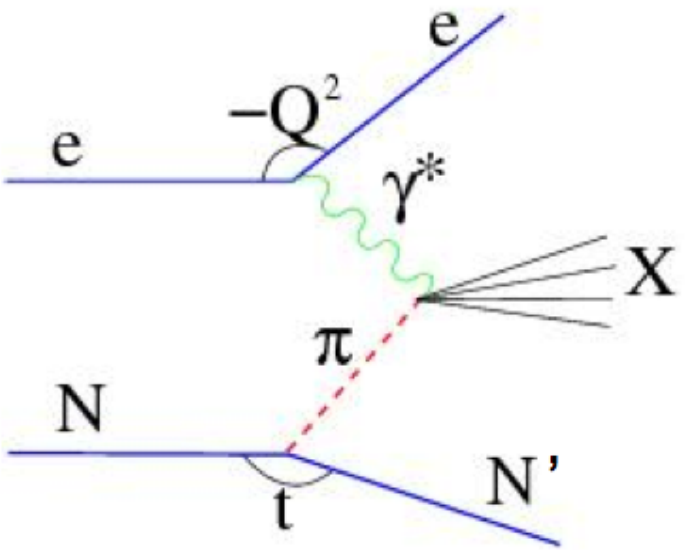
  C. Adloff et al., Eur. Phys. J. C6, 587 (1999).





DIS via the Sullivan process

- Sullivan process: scattering from a nucleon which has fluctuated into a meson-baryon pair
  - Splitting function depends on the longitudinal and transverse momentum of the meson
  - DIS on virtual pion
- To extrapolate to the pion pole, |t| must be small



A Model of Spectator Tagging

- Consider the process e+n→e'+p+X, starting with the neutron at rest
- Following Holtmann *et al.* (Phys.Lett. B **338** (1994) 363) and Speth and Thomas (Adv.Nucl.Phys. **24** (1998) 83) the cross-section for the Sullivan process can be factorized as:

$$\frac{d\sigma(en \to e' p' X)}{dx_{Bj}\, dQ^2\, d\bar{z}\, dp_T^2} = f_{p\pi/n}(\bar{z}, p_T^2)\,\sigma_\pi(x_{Bj}/(1-\bar{z}), Q^2)$$

where $\bar{z}$ is the longitudinal momentum fraction of the recoil proton, and p_T is the transverse momentum of the recoil proton

  - Longitudinal and transverse momenta are defined with respect to the virtual photon in the neutron rest frame

Other kinematical variables

- Other variables are defined similar to what we used in LOI05-001.
  - p initial baryon 4-momentum
  - p' final baryon 4-momentum
  - $z = 1 - \bar{z}$ Longitudinal momentum fraction of the pion

$$q = k - k' \qquad \nu = E - E'$$

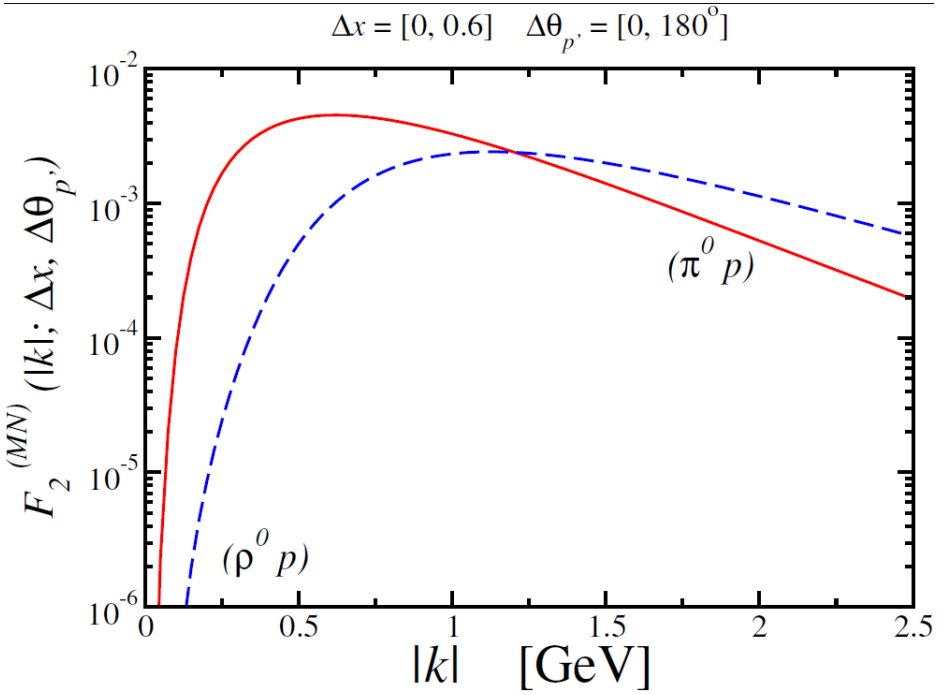
$$Q^2 = -q^2 = 4\,E\,E'\sin^2\frac{\theta_e}{2} \qquad x_{Bj} = \frac{-q^2}{2p\cdot q} = \frac{Q^2}{2M_N\nu}$$

$$p_\pi = p - p' \qquad \bar{z} = \frac{p'\cdot q}{p\cdot q} = 1 - z$$

$$t = p_\pi^2 \qquad x_\pi = x_{Bj}/z$$

e+p→e'+p+X & e+D→e'+p+p+X

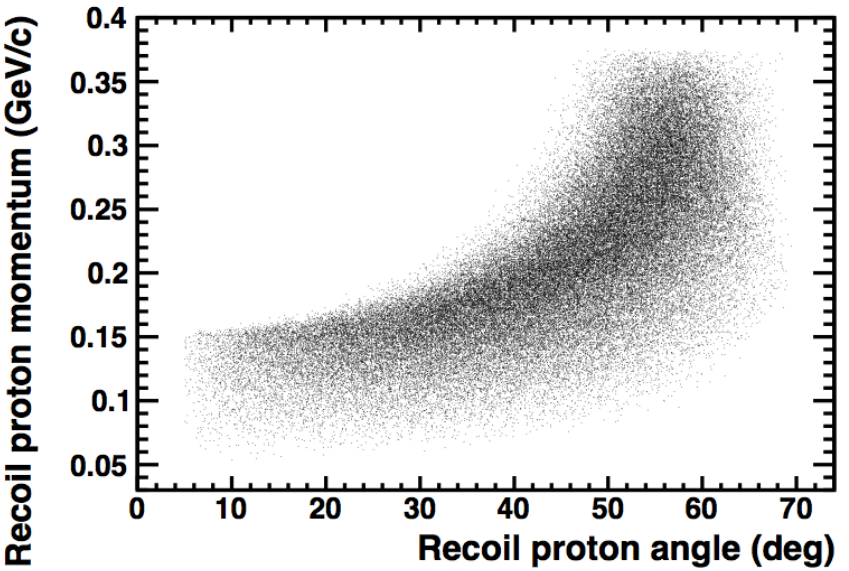
- Detecting a recoil proton from e+p scattering probes processes like $p \rightarrow p+\pi^0$ followed by DIS from the π^0
- There are contributions from other neutral hadronic exchanges including Pomeron exchange, depending on kinematics
- The charged pion exchange in $e+D \rightarrow e'+p+p+X$ has less contribution from Pomeron and Reggeon processes



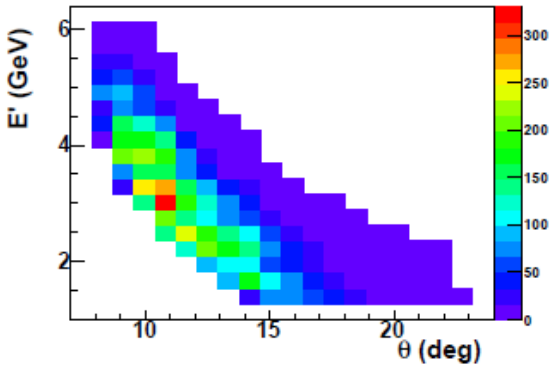
Recoil proton momentum

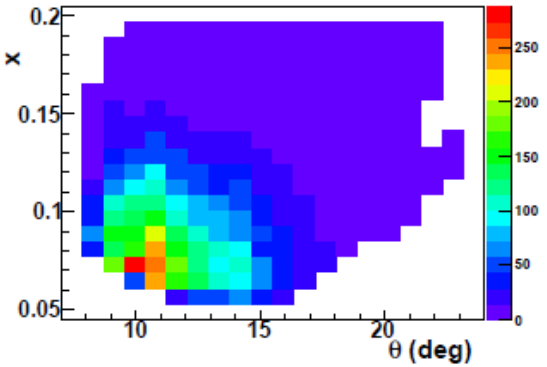
Kinematics of recoil protons

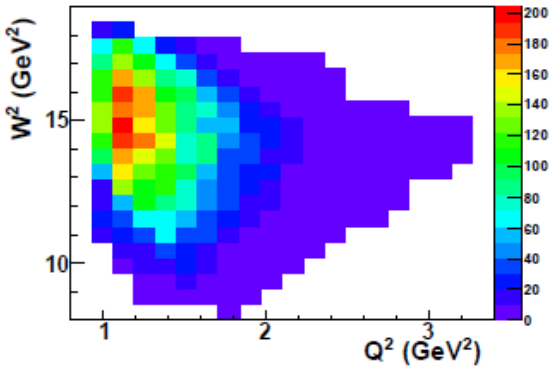
- The recoil protons from the low-t fragmentation tend to have modest momenta (50-400 MeV/c) and angles between 10º and 60º
  - Cuts in this model: $5º<\theta_e<20º$, $0.05<z<0.15$

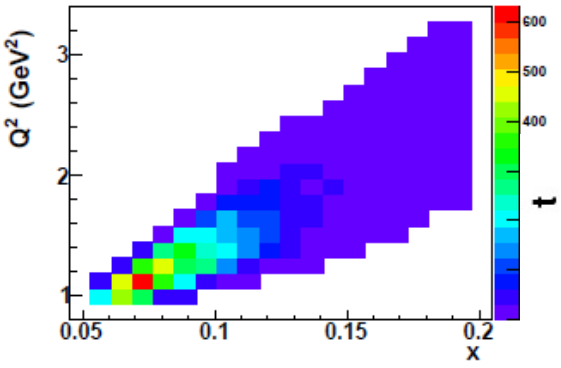


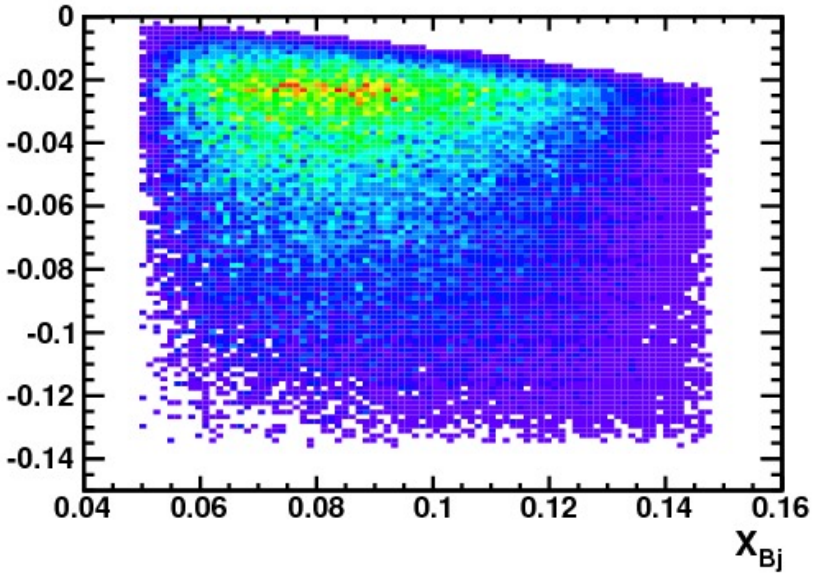
Electron and pion kinematics





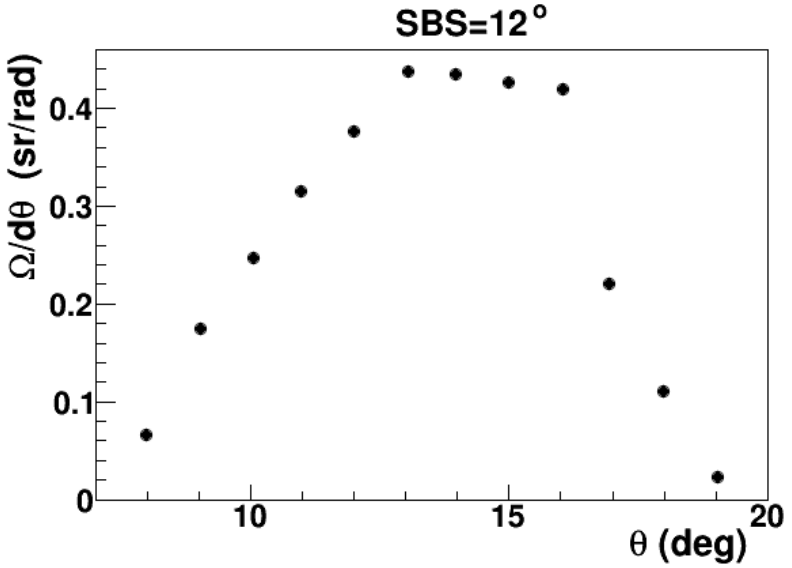






Experimental concept

- Scattered electrons detected in SBS+LAC
  - SBS acceptance for 12deg setting is a reasonable match to the electrons of interest



- 50μA (25 μA) beam current at 11 GeV incident on a thin 40 cm long "soda straw" H2 (D2) target at 77K and 1 atm

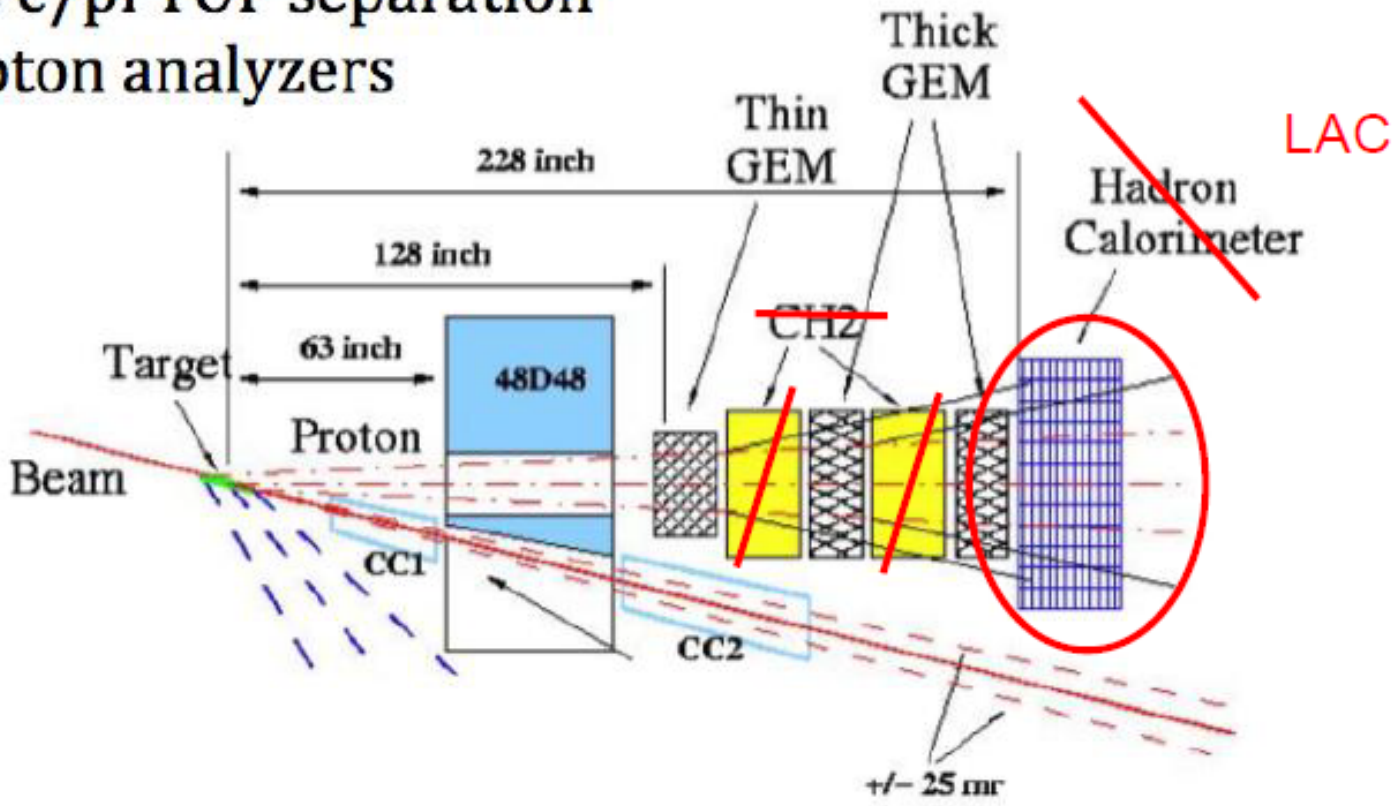
  $L \sim 10^{37}$

- Recoil (and spectator) protons detected in RTPC surrounding the target, similar to BoNuS
  - Solenoidal magnet helps reduce Moller backgrounds and momentum analysis

SBS + LAC

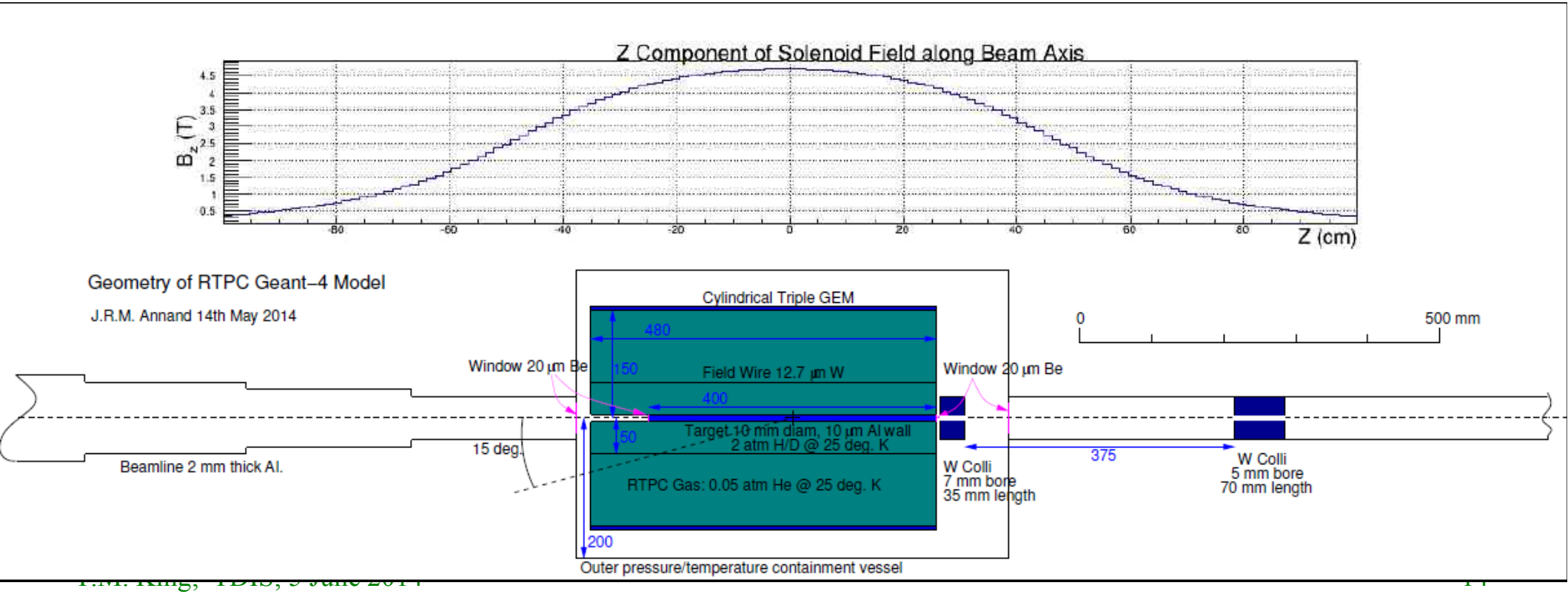
Using the SBS for electron detection:

- Replace Hadron Calorimeter with LAC (2.17 m x 4 m)
  - Similar sizes (5.5 m^2 vs 8.7 m^2)
  - Place the LAC as far back as possible to match the solid angle.
    - Improves angular resolution
    - Improves e/pi TOF separation
- Remove CH2 proton analyzers



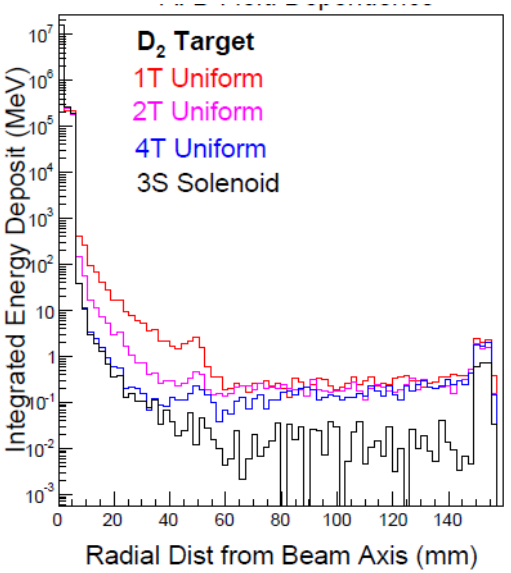
Recoil detector for TDIS in Hall A

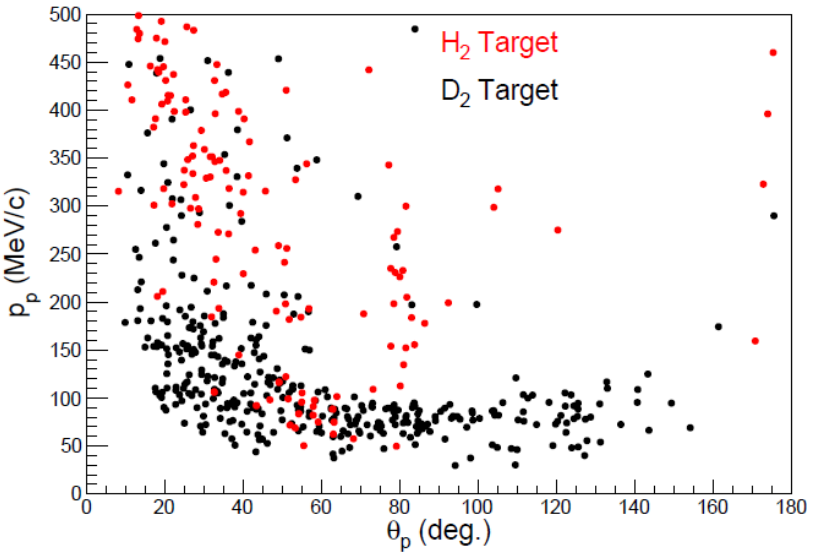
- Planning to use the UVa S3 superconducting solenoid
  - 400mm warm bore, 152.7 cm length, Peak field of 4.7 T at the center
- RTPC will be ~40 cm long
  - Inner radius of 5cm for active region, outer radius of 15 cm with 3-layer GEM and pad readout



Backgrounds

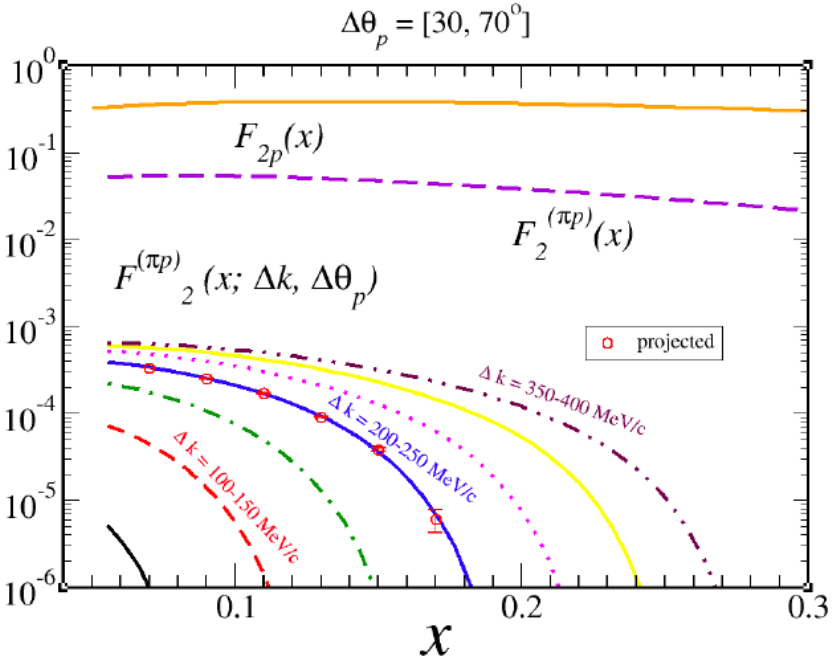
- Moller electrons should be largely confined within the inactive core of the detector
- Photonuclear processes will produce protons with similar kinematics to the recoil protons, but tend toward higher mometum and lower angle in the proton case





Projected measurement

- The conditional structure function $F^{(\pi p)}_2$ versus x_{Bj} for several momentum bins is shown compared to the F^p_2
- Estimates of the measurement precision for 10 days running are shown for one of the momentum bins



Summary

- The Tagged DIS experiment would be a new technique for probing the meson content of the nucleon and for exploring the meson structure functions
- This could be the beginning of a program using recoil tagging to look at other processes, and could complement other experiments at the lab
  - pion form factors
  - DVCS
  - Detection of lambda to measure the kaon contribution to the proton?
- Ideas are continuing to develop following the workshop “Exploring Hadron Structure with Tagged Structure Functions” held here last January 16-18