Exclusive Study of Deuteron Electrodisintegration near Threshold

B.E. Norum

For the Hall A Collaboration

Defining problem for Nuclear Physics:

"Heavy hydrogen was chosen as the first to be examined because the diplon has a small mass defect and also because it is the simplest of all nuclear systems and its properties are as important in nuclear theory as the hydrogen atom is in atomic theory."

-- J. Chadwick and M. Goldhaber, "A nuclear Photo-effect: Disintegration of the Diplon by γ-rays," Nature 134 (18 Aug. 1934) 237.

PAC 14 Few-Body Workshop:

- Key question: "Can few-body systems be understood in terms of a 'Standard Model' for nuclear physics with only nucleon degrees of freedom?"

- First requirement: "Precise and complete tests of the 'Standard Model' need to be carried out experimentally."

- Experimental opportunity: "Threshold deuteron electro-disintegration."

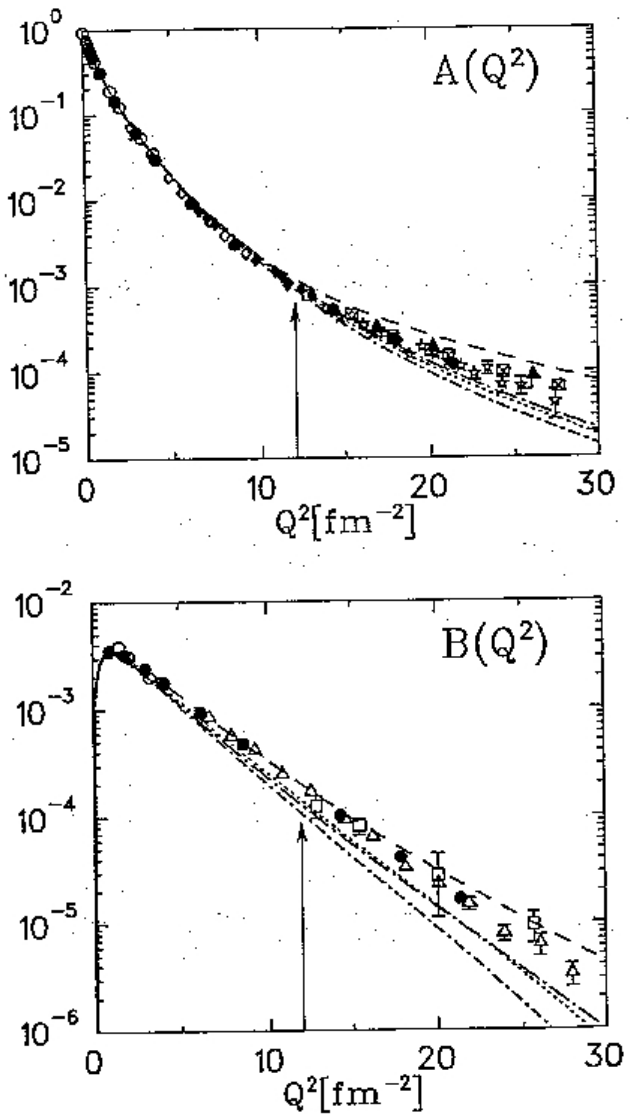
PAC 29:

"Conditionally approve for 16 days in Hall A"

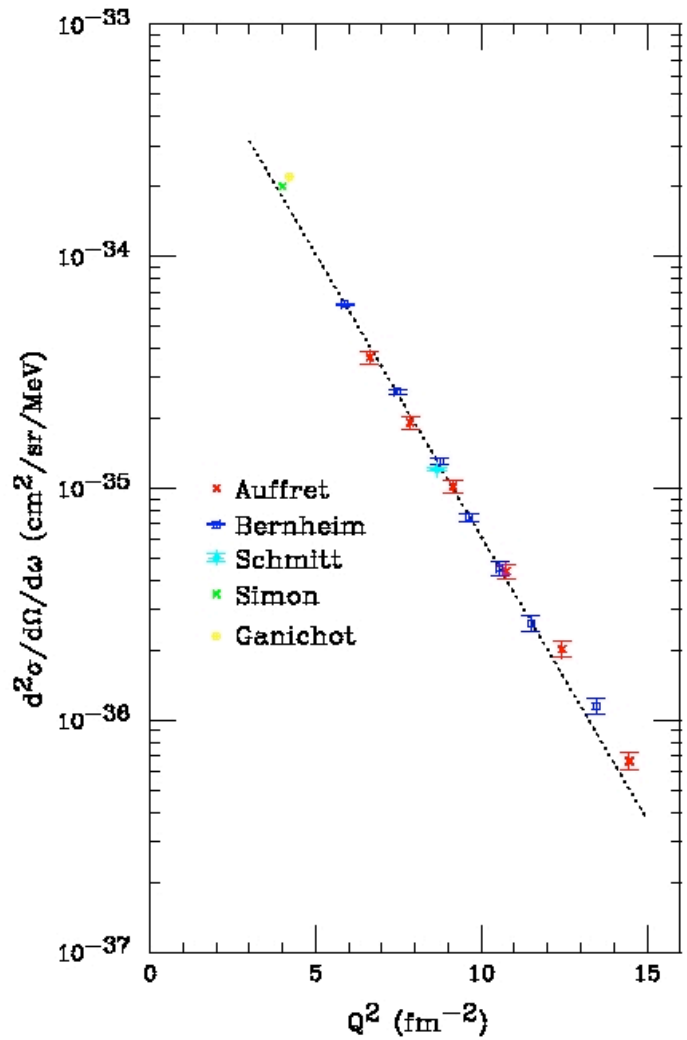
"The experimenters should demonstrate that this experiment can be run within a factor of two of the stated luminosity."

Isn't the deuteron understood by now?

Elastic electron scattering:



Electro disintegration at threshold:



Elastic scattering consistent with theory at few percent level

→ useful for normalization

Threshold electrodisintegration data shown integrated over θ_p

Apparent discontinuity (~30% level) near $Q^2 \sim 12\ fm^{-2}$.

<u>What happens with d(e,e'p)n?</u>

TH-Darmstadt [von Neumann-Cosel *et al.*, PRL 88 (2002) 202304]

$Q^2 = 0.1\ fm^{-2}$

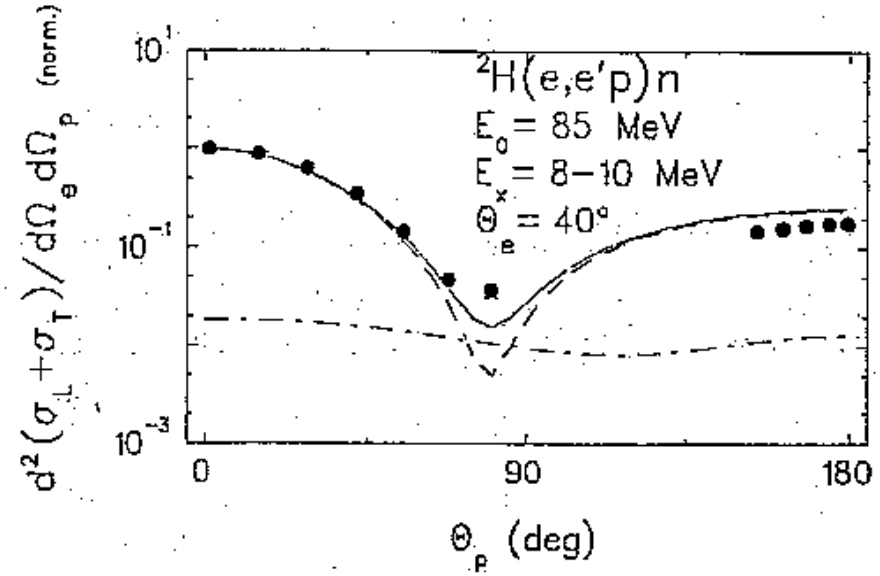
$E_{np} < 10$ MeV

$\sigma_L + \sigma_T$

$\sigma(\theta_p = 0) \square 10 \times \sigma(\theta_p = 180^o)$

$\rightarrow \sigma(\theta_p < 45^o)$ dominates $\int d\theta_p$

40-45% difference near $\theta_p = 180^o$

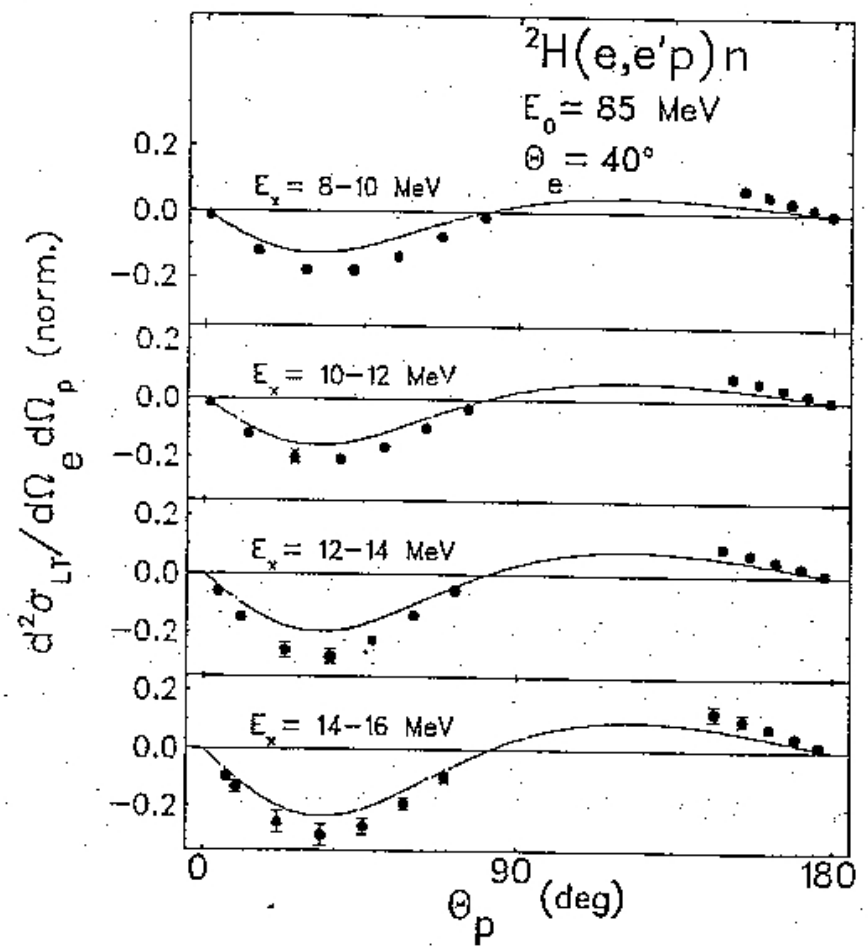


Solid line is full calculation of Arenhovel *et al.*

σ_{LT}

30% difference at 35°

100% difference at 145°



Scientific Motivation:

To study the electrodisintegration structure functions near threshold as well as their evolution with Q^2 and E_{np}

-- **IV/IS and IC contributions studied via σ_L and f_L**

-- **Relativistic effects studied via f_{LT}**

-- **MEC effects studied via σ_T and f_T**

-- **Nuclear models and FSI studied via f'_{LT}**

Why focus on threshold?

1. Fewer multipoles required for description

2. Non-nucleonic effects more pronounced

3. Protons emitted in narrow cone

   → simultaneous out-of-plane measurement of all 5 structure functions

4. Elastic channel measured simultaneously

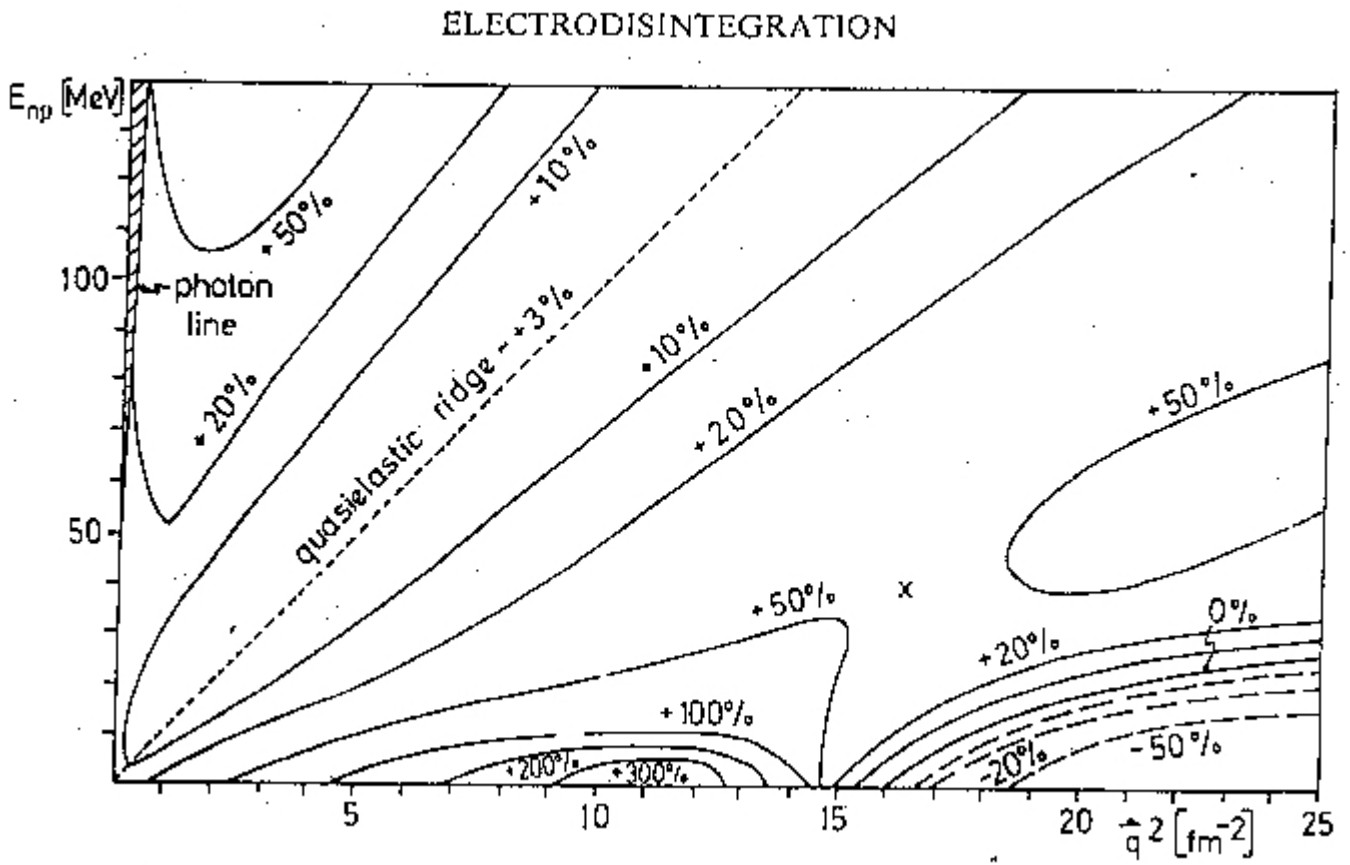
   → normalize electrodisintegration cross sections

   → good measure of $A(Q^2)$ /$B(Q^2)$

Choice of kinematics:

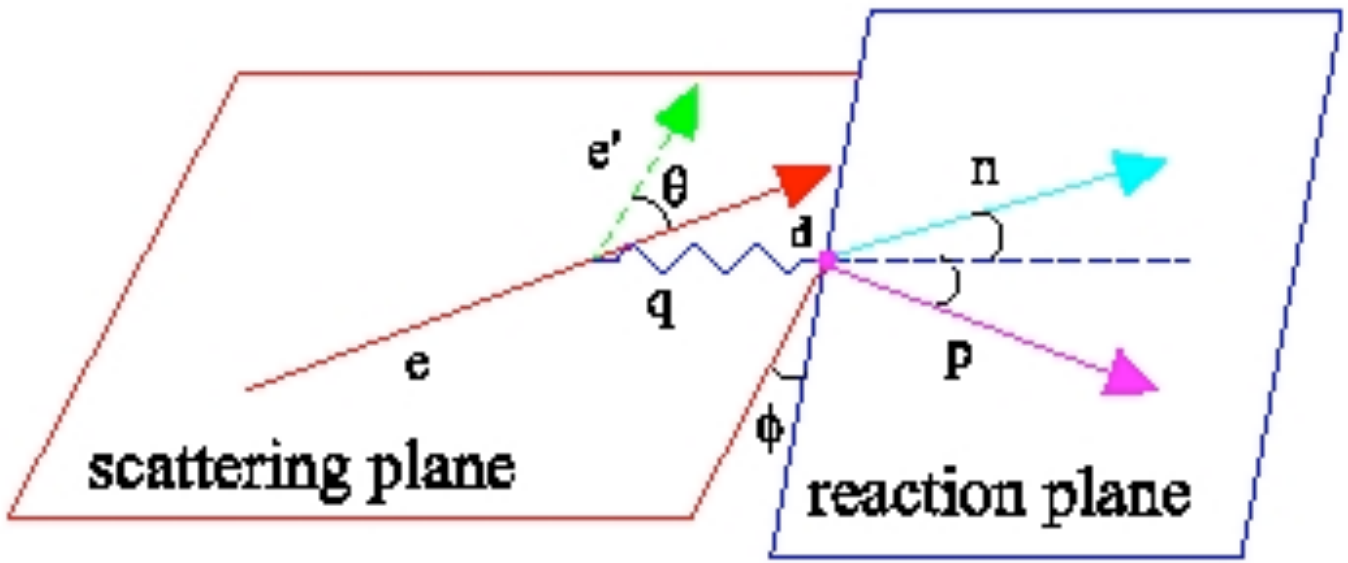
-- Maximize sensitivity to interference terms & non-nucleonic degrees of freedom

-- ratio of relativistic contribution to nucleonic contribution



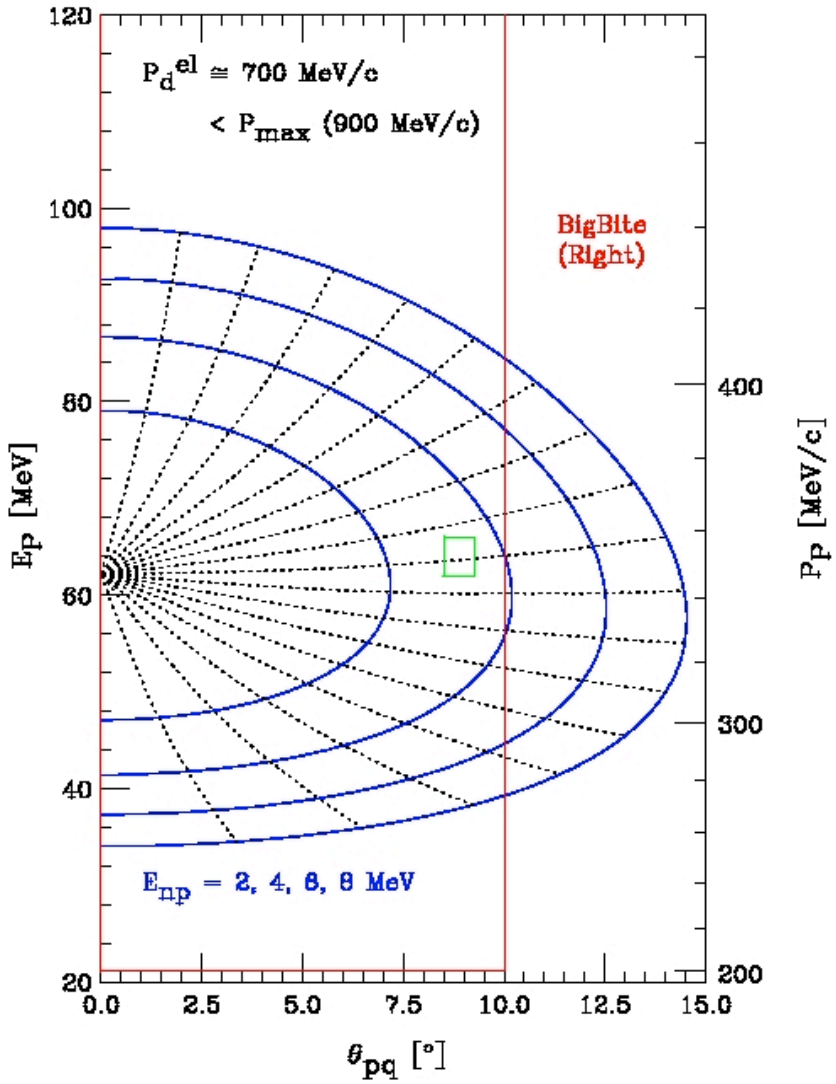
Experimental Conditions:

$E_e\left[GeV\right]$	$\theta_e^{HRS}\left[^\circ\right]$	$Q^2\left[fm^{-2}\right]$	$\left\langle\theta_p\left[^\circ\right]\right\rangle$	ε_L
3.20	12.5	12.0	72.8	0.976
0.55	90.0	12.0	37.3	0.344

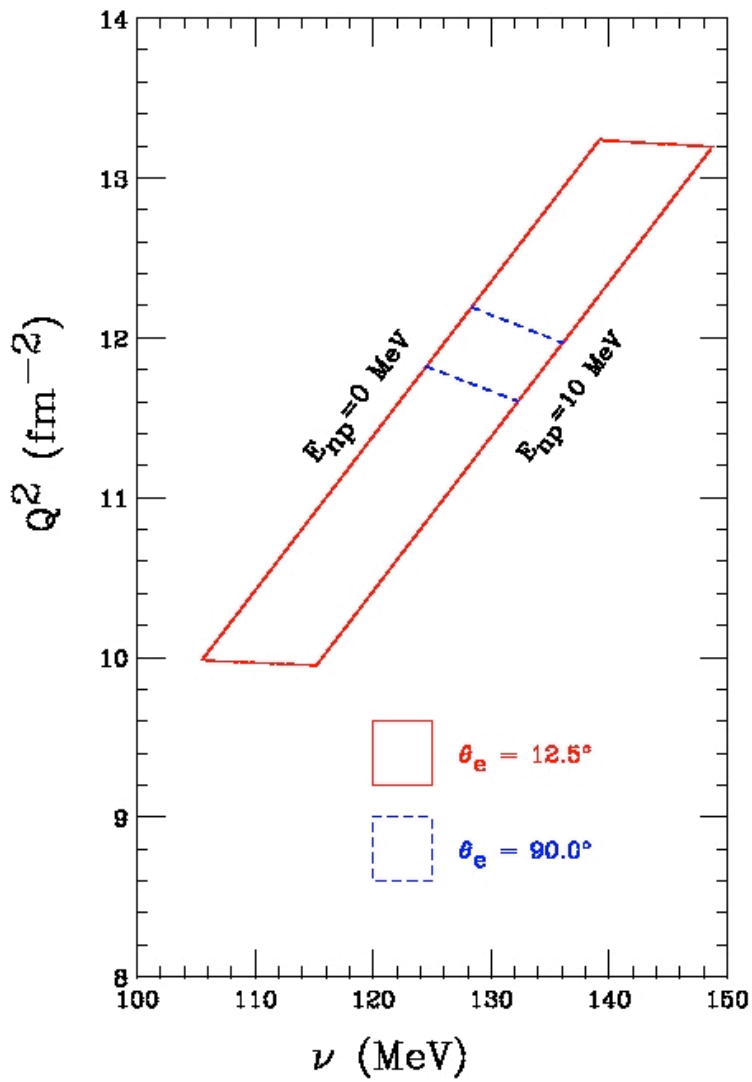


Kinematic Coverage:

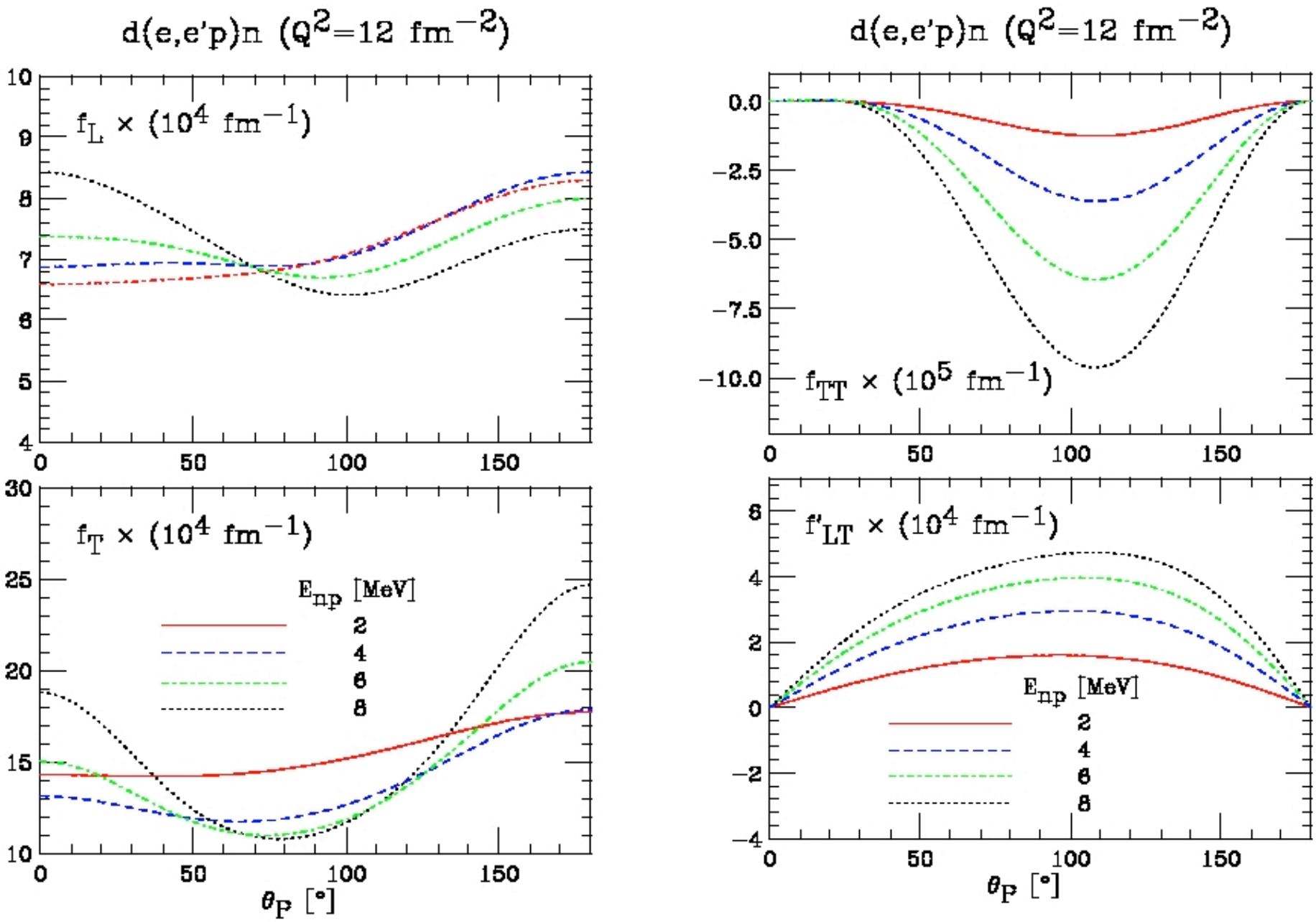
BigBite acceptance



Q^2 dependence of f_{LT}



Structure function dependences:



Longitudinal/Transverse Separation:

-- ε_L range (0.34 - 0.98) reasonable

-- $\vec{q}$ defined by HRS measurement of e'

-- elastic scattering measures BigBite alignment

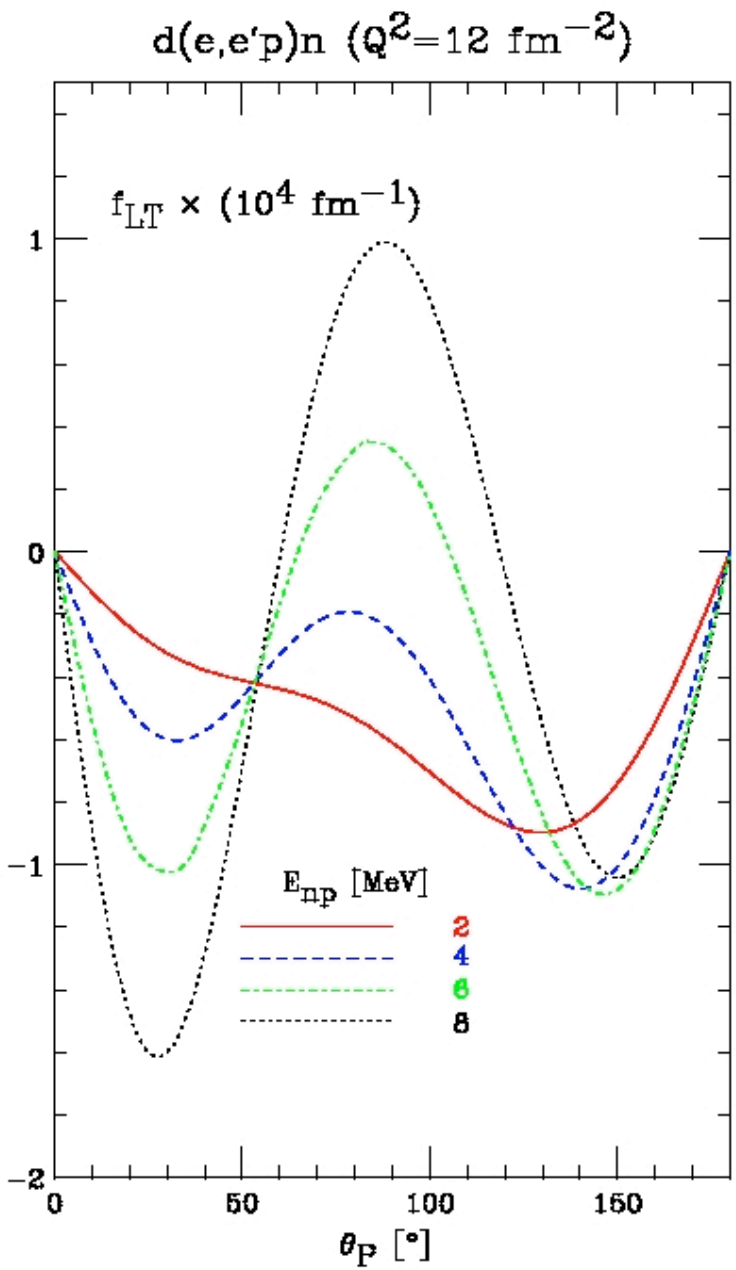
-- $\Delta Q^2 \square \ \sigma_{Q^2}$ and $\Delta W \square \ \sigma_W$

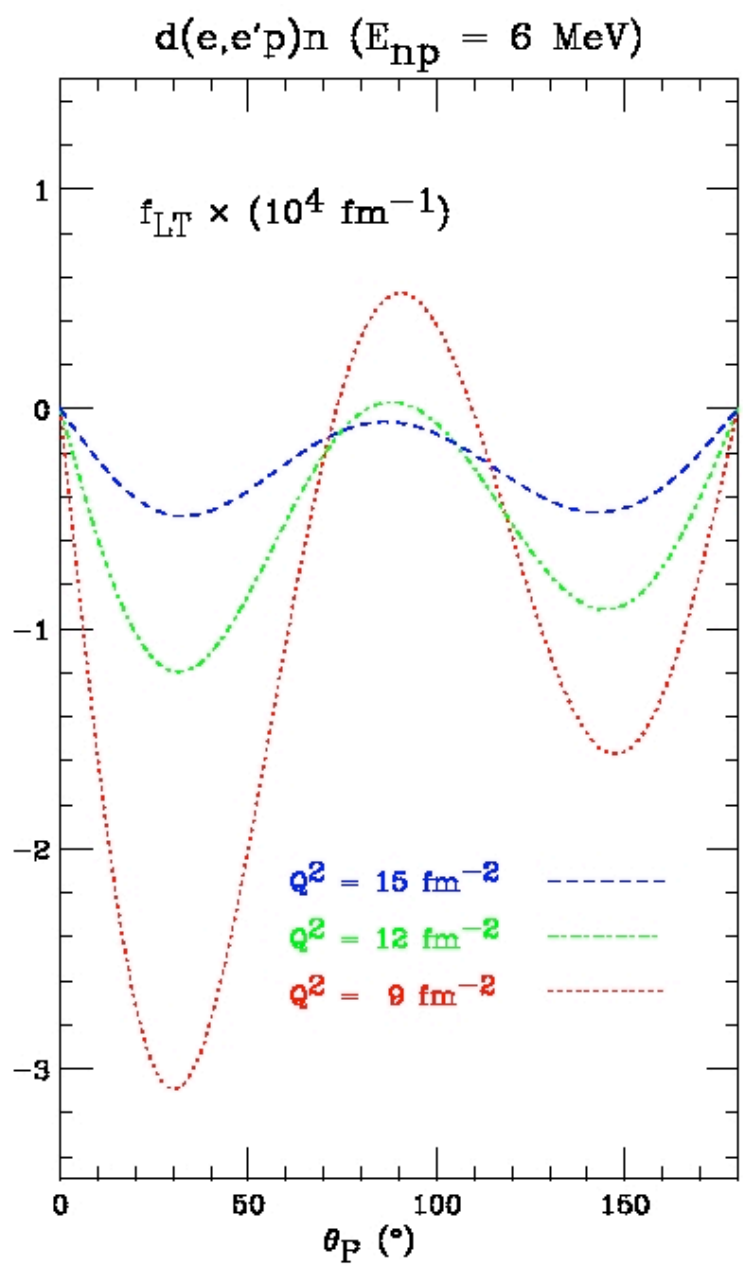
-- $f_{\mu\mu'}\left(Q^2, W\right)$ is slowly varying function of Q^2 and W

-- $d\left(e,e\right)d$ fixes lower W edge; calibrates ν

-- $P_p - \theta_{pq}$ "rings" monitor acceptances

f_{LT} Structure function:



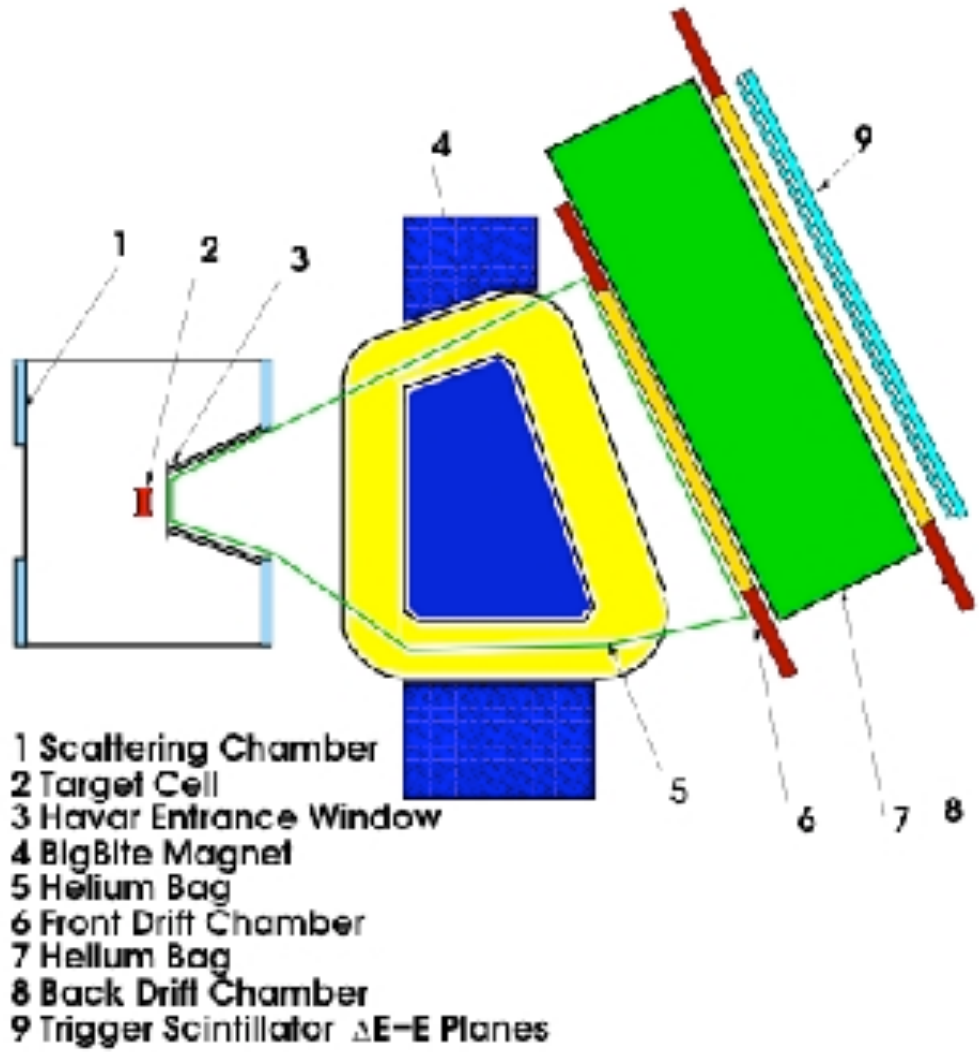


Experimental Configuration:

Target: Liquid D_2; 6 cm long; from threshold π^0 experiment

HRS: Scintillators turned off to restrict momentum acceptance

BigBite: From π^0 experiment



BigBite Singles rates:

Principal concern singles rates in wire chambers

GEn with $L = 0.5\times10^{37}$ $e\cdot$nucleons/cm^2/s saw 20 MHz dominated by low energy photons

→ 75% track reconstruction efficiency

→ detection efficiency effects

This experiment will use $L = 6.0\times10^{37}$

→ must reduce by factor of about 6

- shielding
- short target with relatively thin windows
- helium bags
- higher thresholds

Experiment less sensitive

-- **relative measurement with respect to** $d(e,e)d$

-- **photons populate chambers uniformly → uniform effect on efficiencies**

-- **restricted kinematics of events of interest constrains track reconstruction**

Experimental configuration parallels $p(e,e'p)\pi^0$ **measurement**

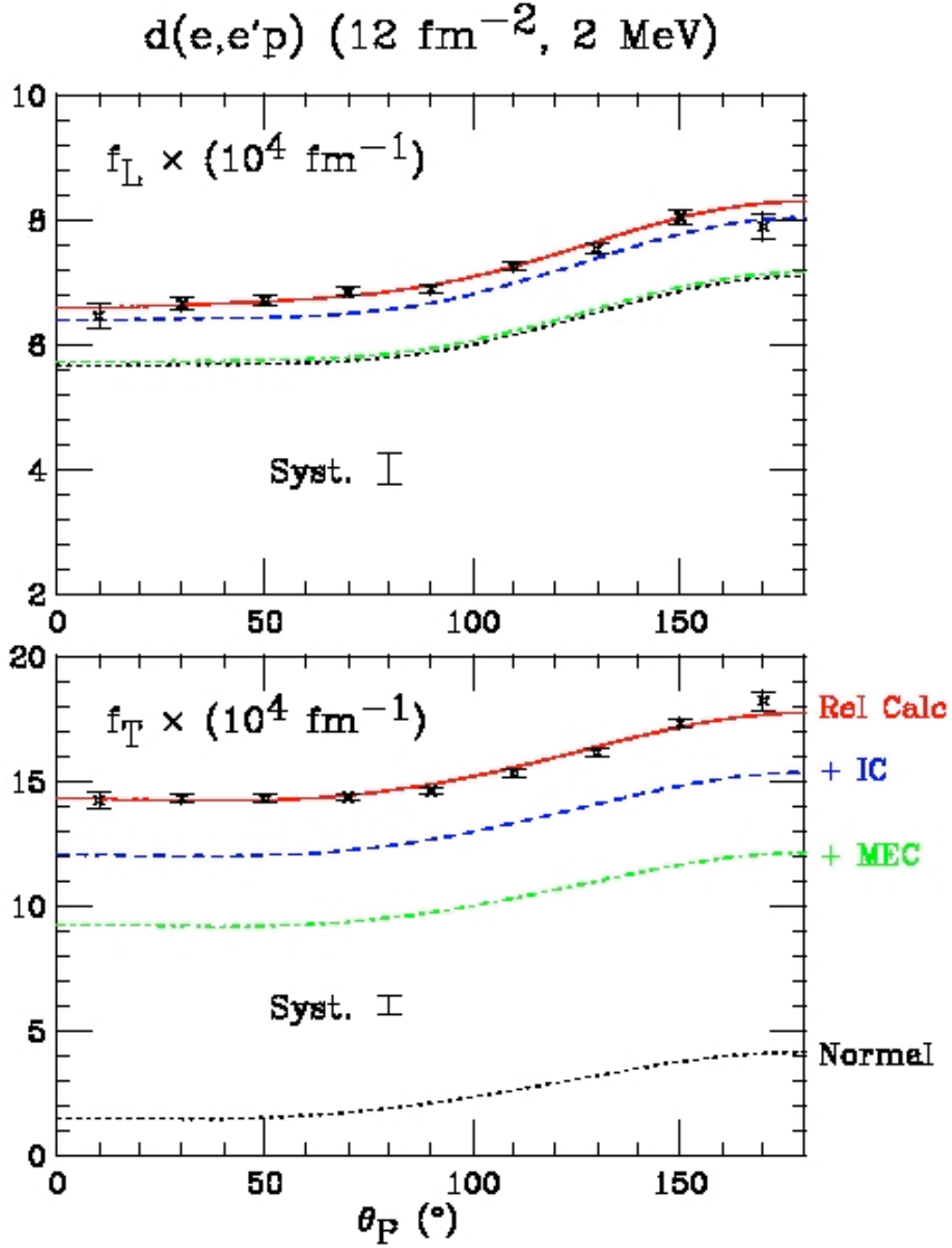
Beam Time Request:

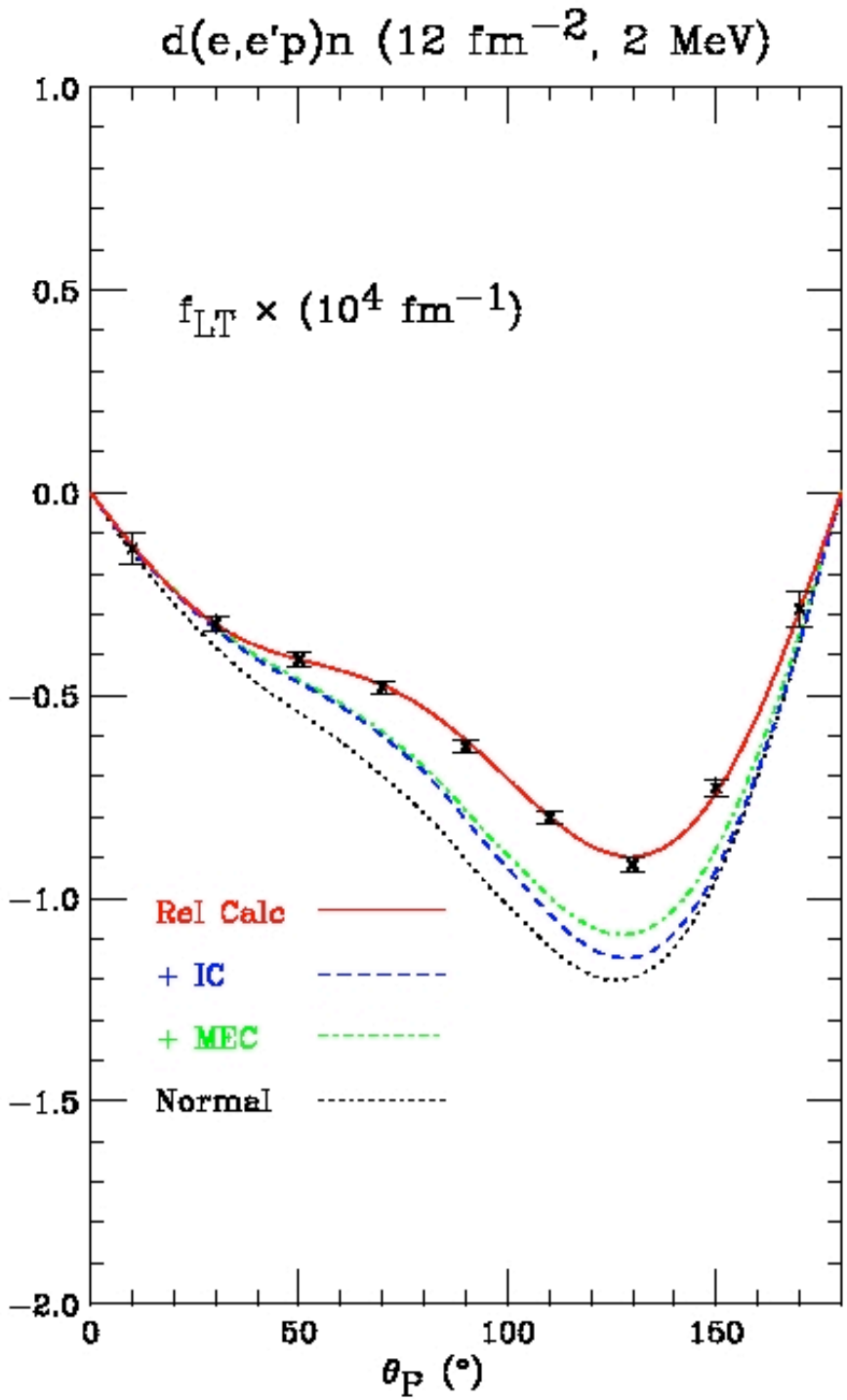
-- polarized 15 μA beam

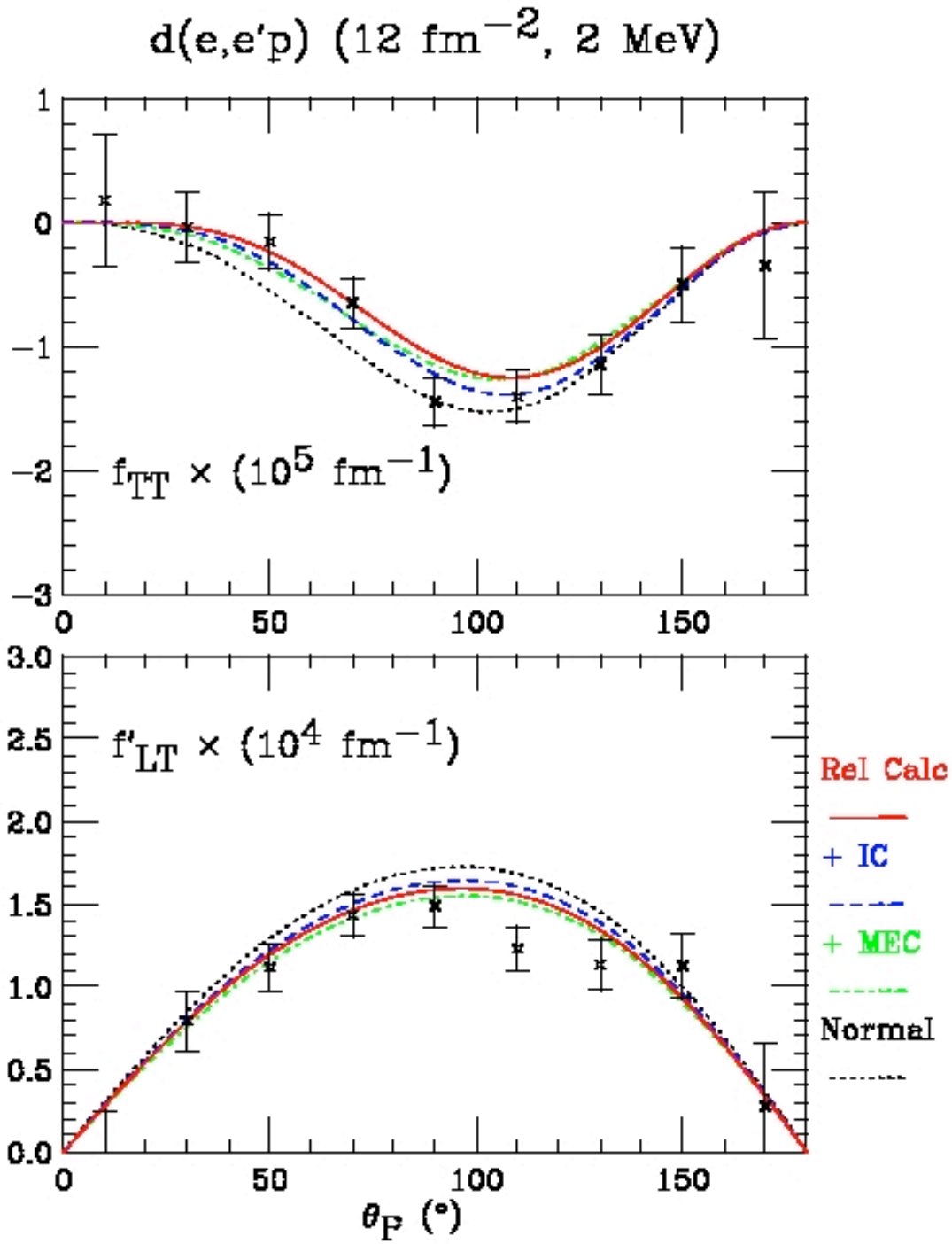
-- 6 *cm* liquid D_2 target; liquid H_2 for calibration

$E_e\left[GeV\right]$	$\theta_e^{HRS}\left[^\circ\right]$	$\theta_p^{BB}\left[^\circ\right]$	$T\left[days\right]$
3.20	12.5	67.8	4
3.20	12.5	77.8	4
0.55	90.0	32.3	2
0.55	90.0	42.3	2
Rates studies			2
Setup			4
Total			18

Results:


d(e,e'p) (12 fm^{-2}, 2 MeV)
$f_L \times (10^4$ fm$^{-1})$
Syst.
$f_T \times (10^4$ fm$^{-1})$
Syst.
Rel Calc
+ IC
+ MEC
Normal
θ_P (°)


d(e,e'p)n (12 fm^{-2}, 2 MeV)
$f_{LT} \times (10^4$ fm$^{-1})$
Rel Calc
+ IC
+ MEC
Normal
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
50
100
150
θ_P (°)


d(e,e'p) (12 fm^{-2}, 2 MeV)
$f_{TT} \times (10^5$ fm$^{-1})$
$f'_{LT} \times (10^4$ fm$^{-1})$
θ_P (°)
Rel Calc
+ IC
+ MEC
Normal

<u>Summary:</u> We propose the first simultaneous measurement of all 5 structure functions $\left(f_L, f_T, f_{LT}, f_{TT},\right.$ and $\left.f'_{LT}\right)$ for $d\left(\vec{e}, e' p\right)n$ near threshold using an HRS and BigBite spectrometer -

-- $Q^2 = 12\ fm^{-2}$

-- E_{np} from threshold to 8 MeV

IV/IS and IC effects to be studied via σ_L and f_L

Relativistic effects to be studied via f_{LT}

MEC effects to be studied via σ_T and f_T

Nuclear models & FSI to be studied via f_{TT} and f'_{LT}

Normalization via σ_L and σ_T from $d\left(e,e\right)d$