Measurment of the Neutron's Electric Form Factor G_E^n via Doubly Polarized, Quasi-Elastic Scattering at Jefferson Lab

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Outline

- Overview
- From $\vec{d}(\vec{e}, e'n)p$ to G_E^n
- Experimental Setup
- Results

Overview

Jlab Experiment E93-026 (*Gen01*):

* Measurement of *Electric* Form Factor of Neutron G_E^n

  $Q^2 = 0.5\,GeV^2$ *and* $Q^2 = 1.0\,GeV^2$

  Hall C, August − December 2001

* Quasi-Elastic Scattering off Deuteron

  polarized e^- beam, polarized d target

  $d \approx n + p$, inside frozen ND_3

* Asymmetry Measurement

  detect scattered e^- and neutron in coincidence

  Jlab standard HMS *and custom n detector*
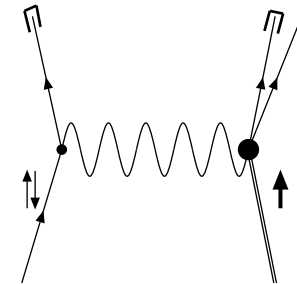
	Electric	Magnetic
Proton	1	2.79
Neutron	0	-1.91

Nucleon Form Factors at $Q^2 = 0$

Gen01 Collaboration

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Virginia Polytechnic Institute & State University, Vrije Universiteit of Amsterdam,
Yerevan Physics Institute*

From $\vec{d}(\vec{e}, e'n)p$ to G_E^n

Unpolarized:

$$\left(\frac{d\sigma}{d\Omega}\right) = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \times \left[\frac{G_E^2 + \tau G_M^2}{1 + \tau} + 2\tau G_M^2 \tan^2 \frac{\theta_e}{2}\right]$$

$$\tau = \frac{Q^2}{4M^2} \quad h = \text{beam helicity}$$

Polarized:

$$\left(\frac{d\sigma}{d\Omega}\right)^{pol} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \times \left[\Sigma + h \, \mathcal{P}_{\text{target}} \, \Delta\right]$$

$$\Delta \; \sim \; \cos\theta^* \, G_M^2 + \; G_E \, G_M \sin\theta^* \cos\phi^*$$

Measurement via Vector Asymmetry

$$A^V = \frac{\Delta}{\Sigma} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

for quasi-free,
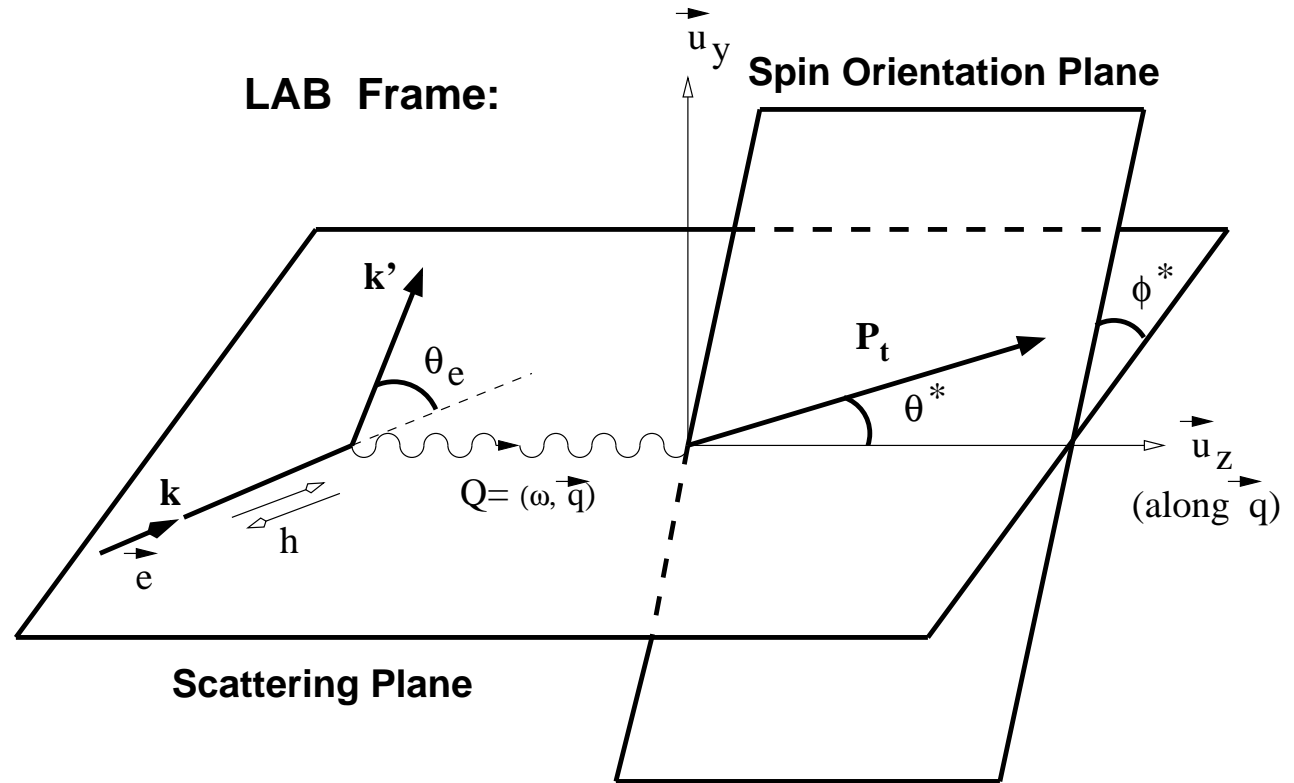
$\mathcal{P}_{\text{target}} \perp \vec{q}$
$(\theta^* = 90^o)$
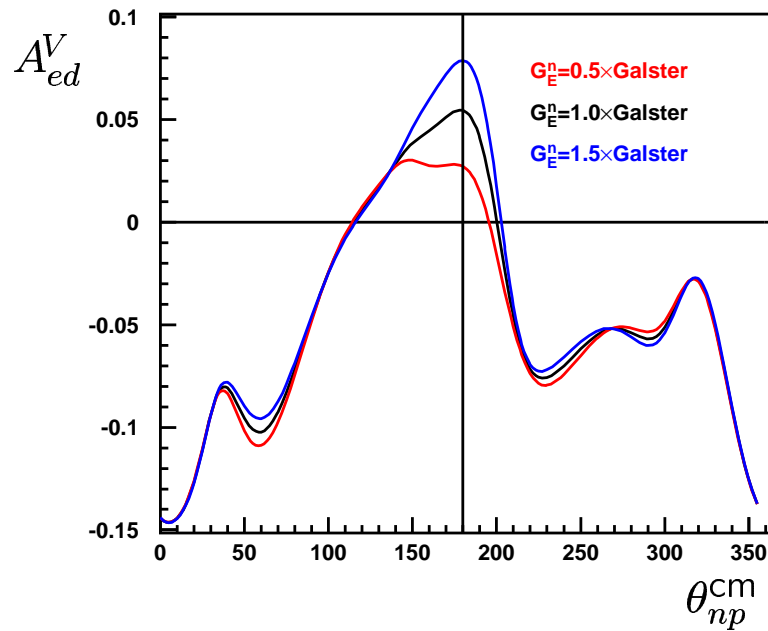
and

$\mathcal{P}_{\text{target}}$ in scattering plane
$(\phi^* = 0)$,

LAB Frame:

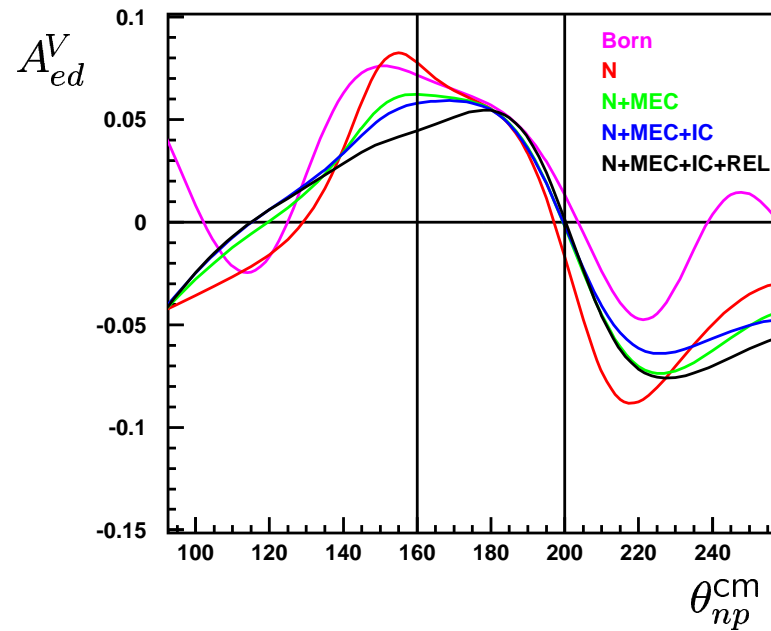$\vec{u}_y$ **Spin Orientation Plane**

Scattering Plane

k'

θ_e

k

$Q = (\omega, \vec{q})$

h

e

P_t

θ^*

ϕ^*

$\vec{u}_z$

(along $\vec{q}$)

$$A^V = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{\Delta}{\Sigma} = \frac{-2\sqrt{\tau(1+\tau)}\,\tan\frac{\theta_e}{2}\,G_E\,G_M}{G_E{}^2 + \tau[1 + 2(1+\tau)\tan^2\frac{\theta_e}{2}]\,G_M{}^2}$$

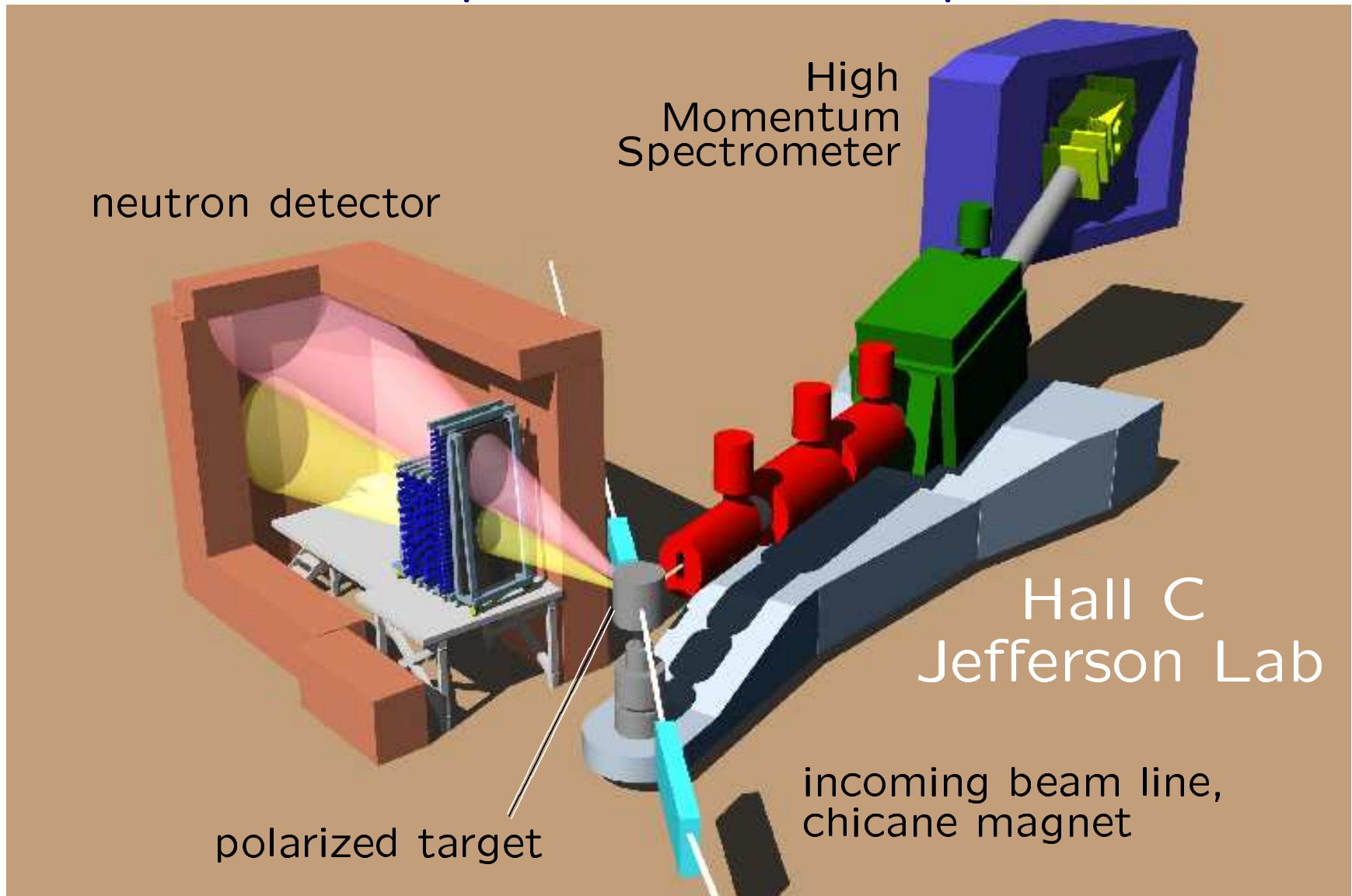# Benefits of this Approach

Maximize Sensitivity to G_E^n

A_{ed}^V

$G_E^n = 0.5 \times$ Galster

$G_E^n = 1.0 \times$ Galster

$G_E^n = 1.5 \times$ Galster

$\theta_{np}^{\mathrm{cm}}$

Minimize Model Dependence

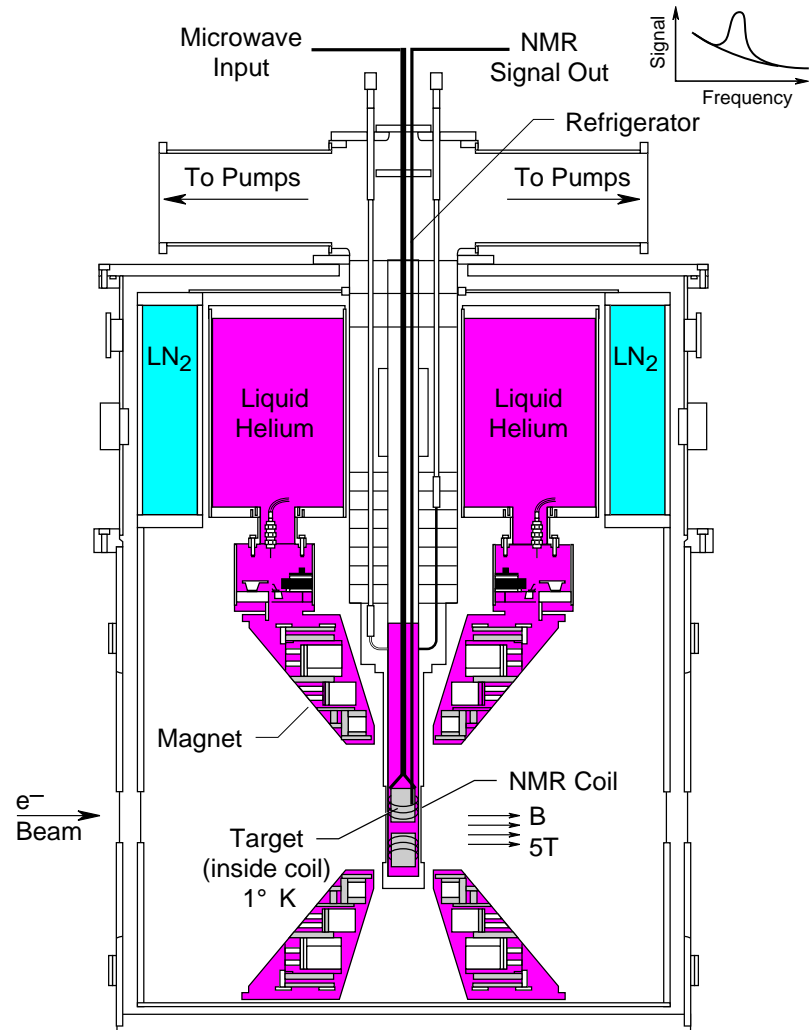A_{ed}^V

Born

N

N+MEC

N+MEC+IC

N+MEC+IC+REL

$\theta_{np}^{\mathrm{cm}}$

and: Asymmetry Measurement

Experimental Setup

Target

* frozen ND_3
* ^{4}He evaporation refrigerator
* $5T$ polarizing field
* dynamic nuclear polarization driven by microwaves
* remotely movable insert

Neutron Detector

* segmented scintillator

  high rate: $\sim 100 kHz$

* 2 proton VETO layers,
  6 conversion layers

  142 elements total

* vertically extended for
  symmetric p^+ acceptance

* phototubes at both ends

  horizontal position

  2 vertical elements for calibration
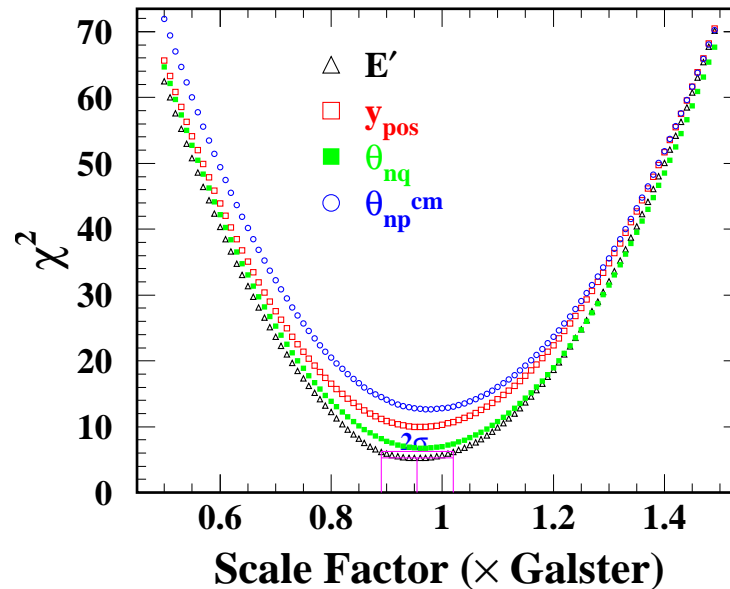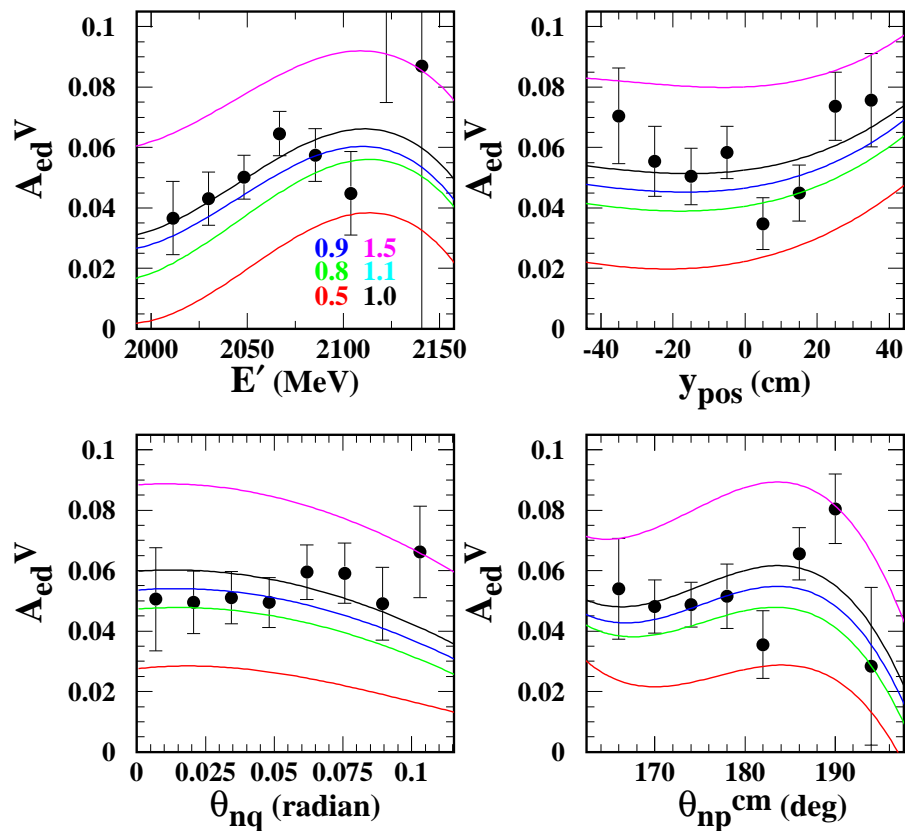
* provides 3 space coords,
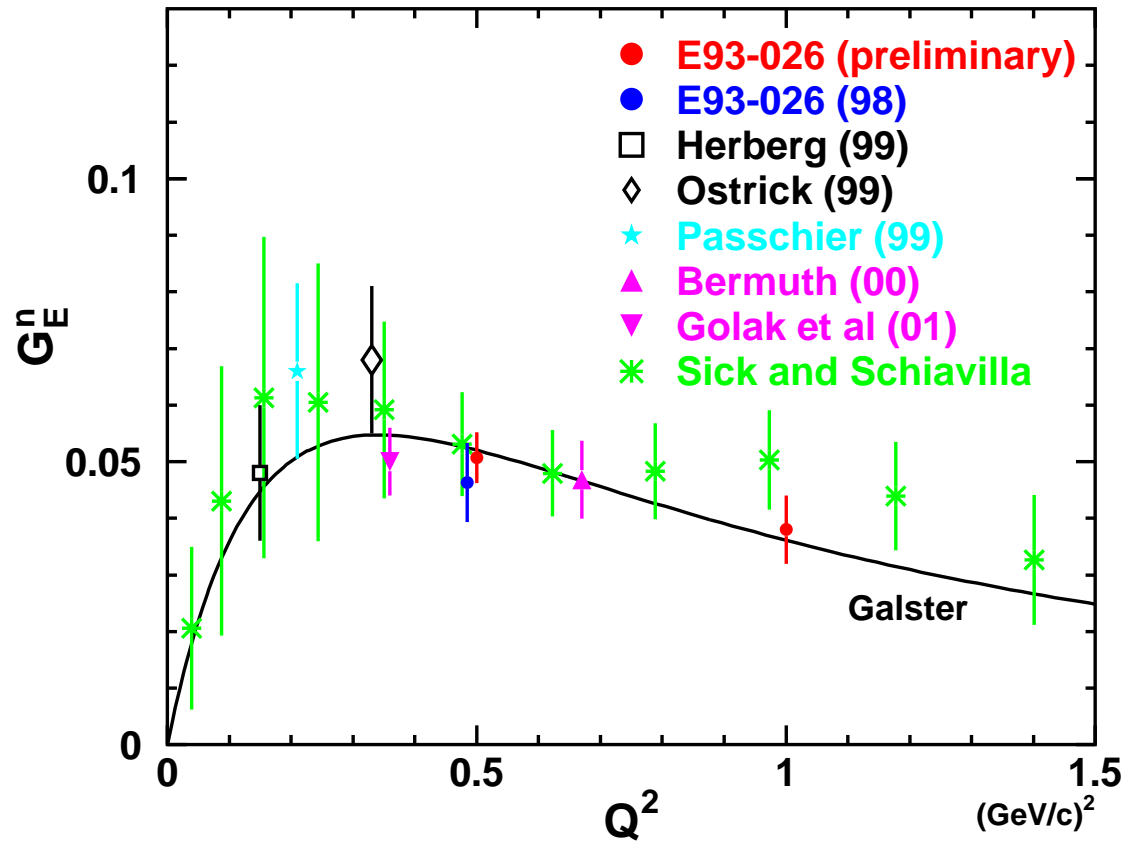 time and energy
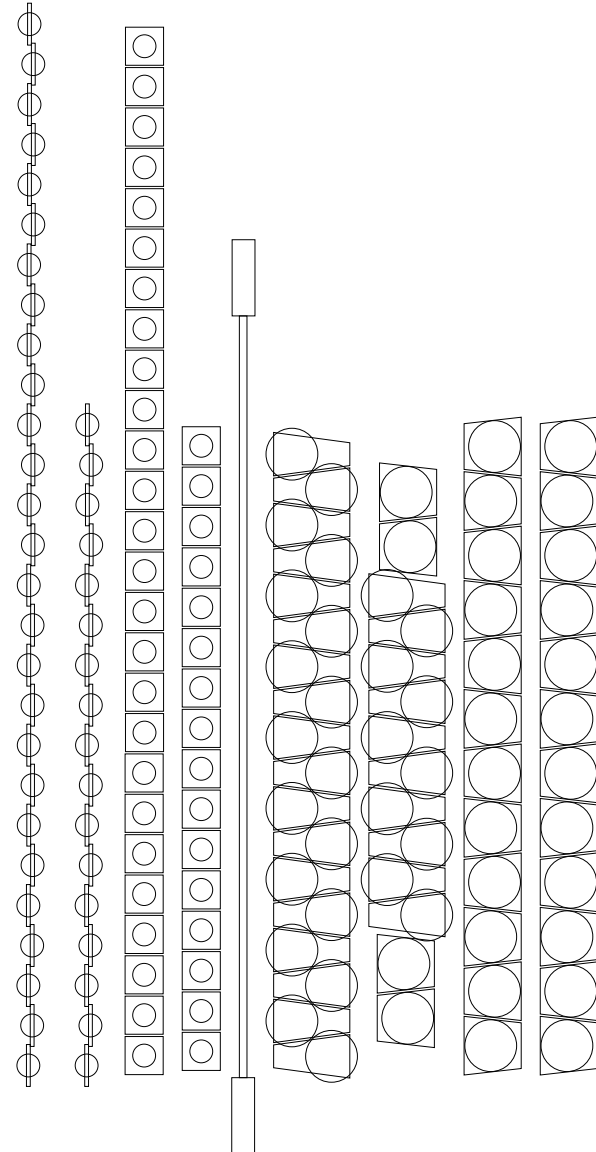
Neutron Detector — Rear View

Data and MC Comparison — Rates
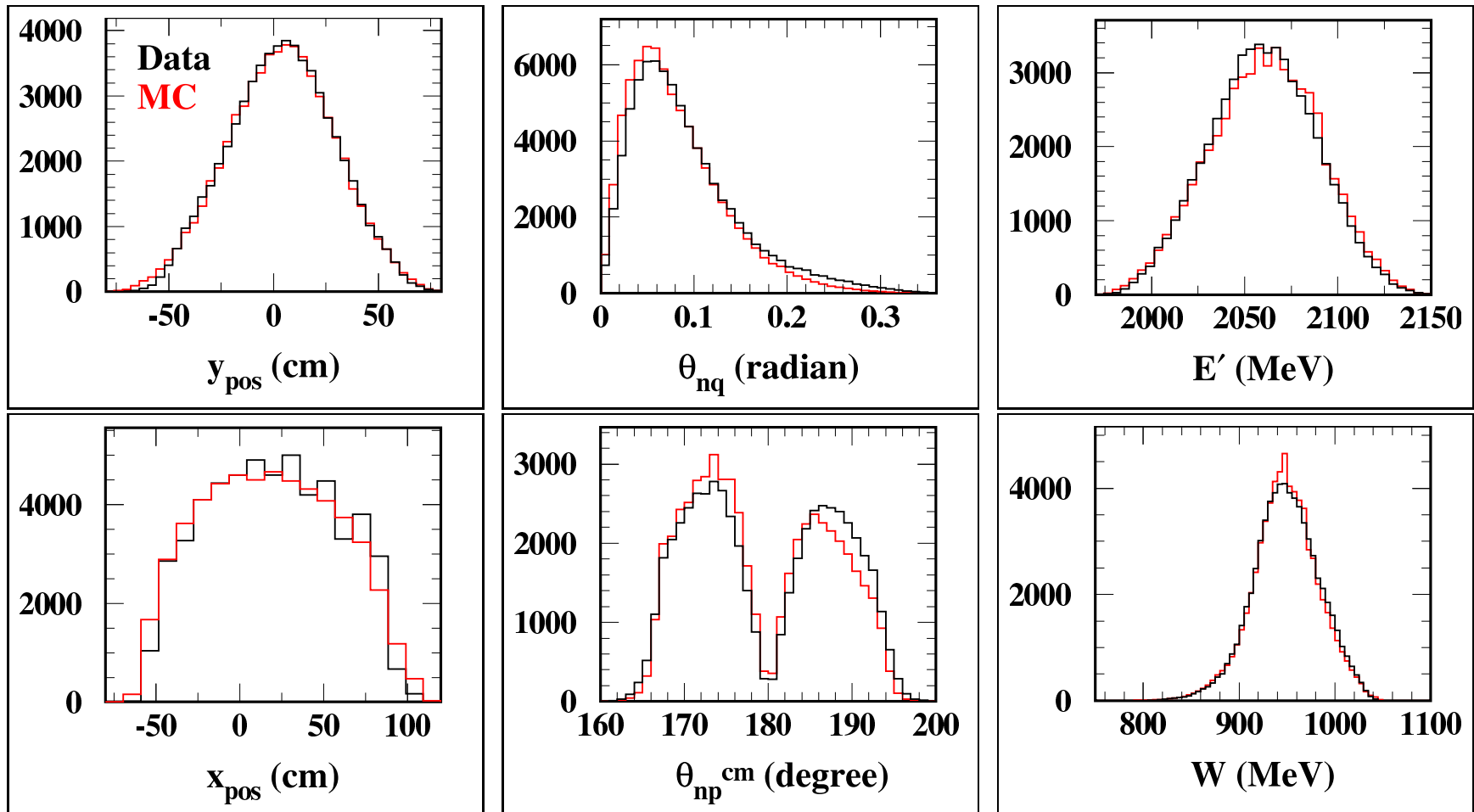
Extracting G_E^n from A_{ed}^V

Results

Systematic Errors (incl)

$\mathcal{P}_{target}$	3-5 %
f	3 %
cuts	2 %
kinematics	2 %
G_M^n	1.7 %
$\mathcal{P}_{beam}$	1-3 %
other	1 %
total	**6-8 %**