High Q^2 measurement of G_M^p/G_M^p

?????????

Brian Quinn / Carnegie Mellon Univ.
(with Bogdan Wojtsekhowski / JLab)

Exclusive Reactions Workshop May 22/07

Magnetic form factor of the neutron up to 8 GeV^2

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Technique: Quasi-elastic scattering from the deuteron

Measure: $R \equiv \dfrac{\text{d(e,e'n)}}{\text{d(e,e'p)}}$

$$R \approx \frac{\left.\frac{d\sigma}{d\Omega}\right|_n}{\left.\frac{d\sigma}{d\Omega}\right|_p} \rightarrow \frac{\eta \frac{\tau/\epsilon}{1+\tau} \sigma_{Mott} (G_M^n)^2}{\left.\frac{d\sigma}{d\Omega}\right|_p}$$

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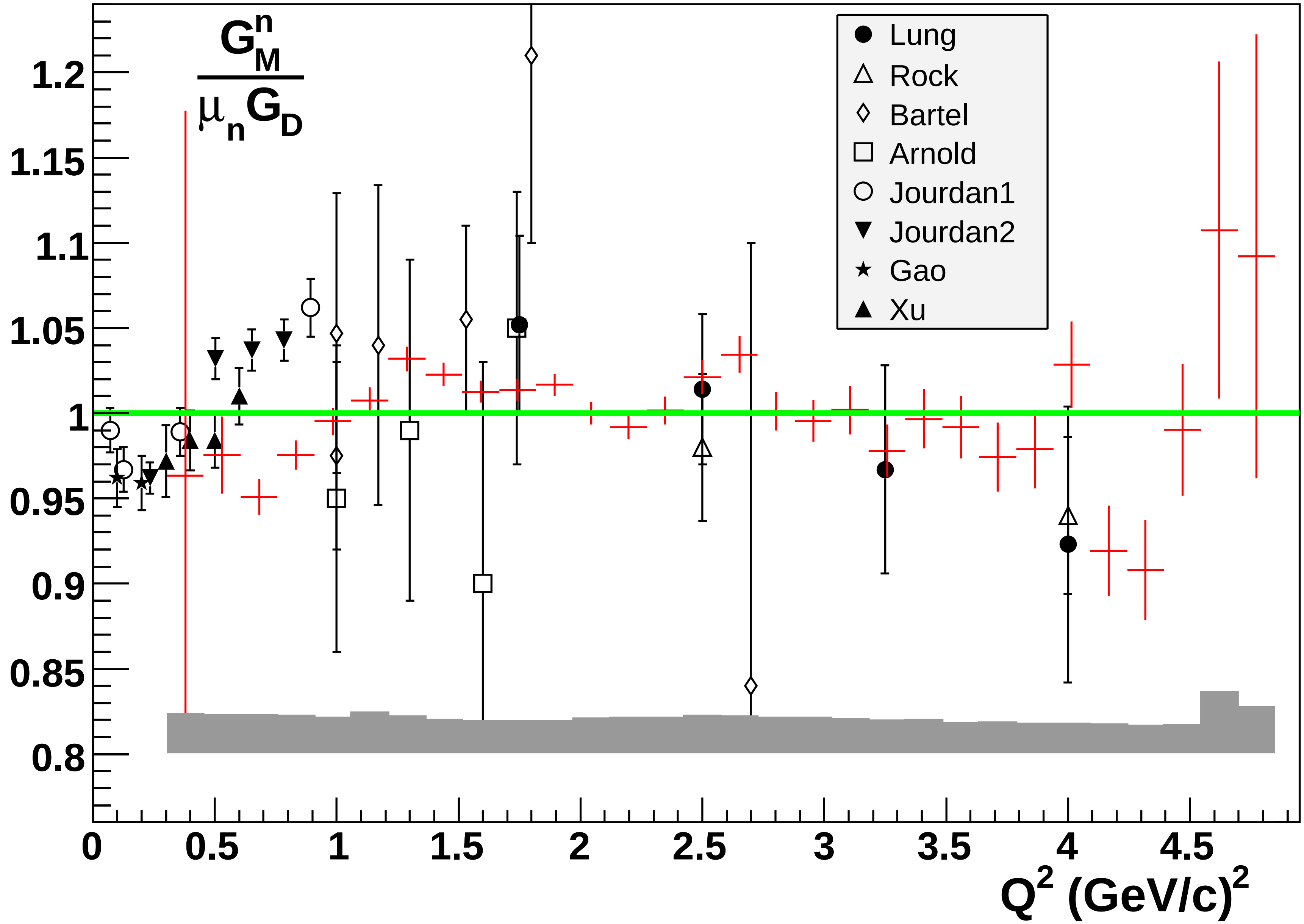
Calibration: **H(e,e'p)** **H(γ,π^+n)**

Physics Motivation

- Probe nucleon structure
- Evolution from non-perturbative to perturbative description
- Test Lattice QCD structure predictions
- Constrain generalized parton distributions

Selected World Data



Red points: Lachniet et al. CLAS (e5) Preliminary

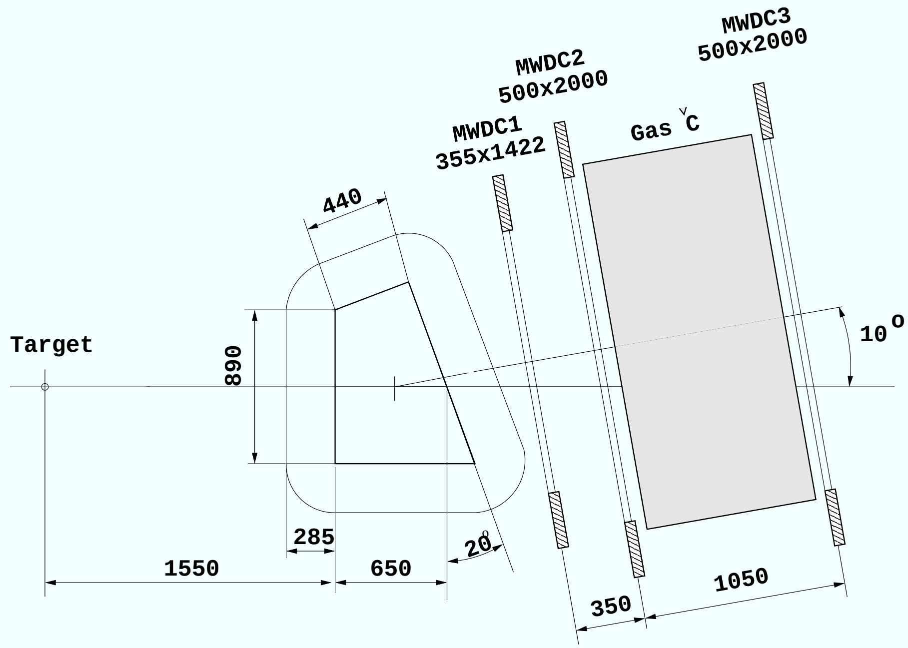
Kinematics

Q^2 $(GeV/c)^2$	E_{beam} (GeV)	θ_e	θ_N	E' (GeV)	P_N (GeV/c)
3.5	4	37.5°	29.2°	2.1	2.65
4.5	4	49.5°	22.4°	1.6	3.2
6	5	48.1°	19.5°	1.8	4.0
8	6	$52.^\circ$	15.5°	1.7	5.1

Apparatus

Big Bite spectrometer

Electron arm (and π^+ for H(γ, π^+)n calibration)



Reconfigured for higher momentum running.

$\approx$ **50 msr acceptance**

$<$**0.75 % momentum resolution**

$<$**.5 mr angular resolution**

“BigHAND” Hall A *Nucleon* Detector

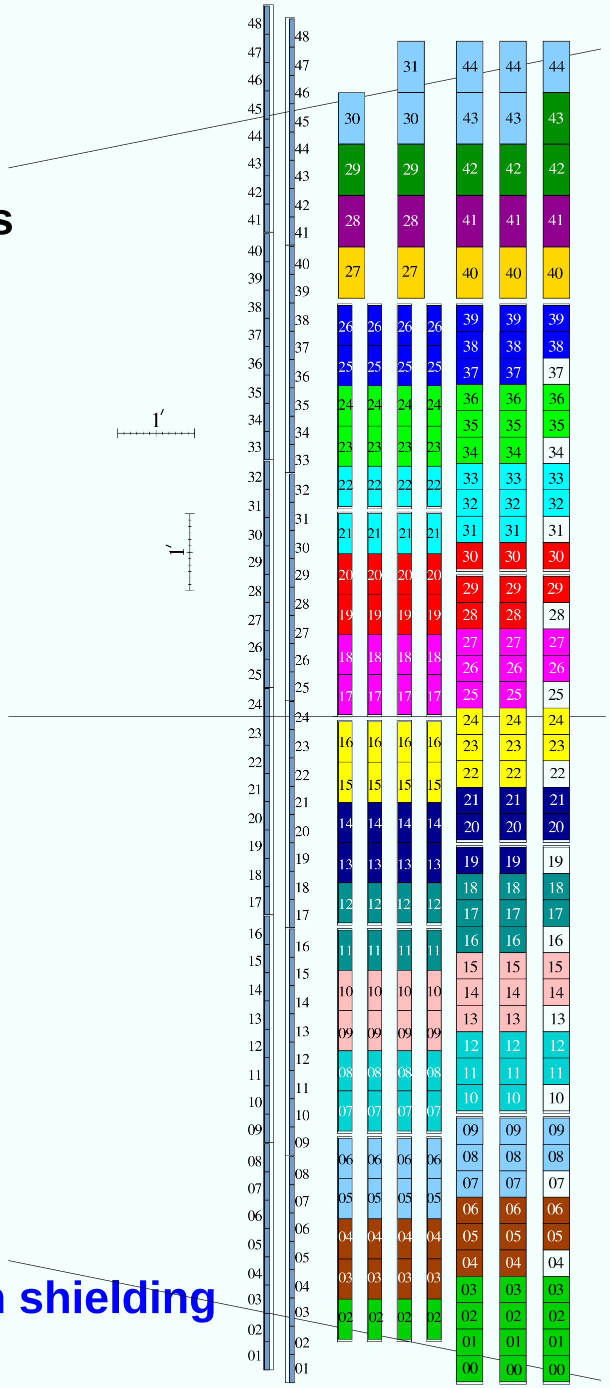
(neutron and proton arm)

244 scintillator bars in 7 layer with $\frac{1}{2}$” iron converters

Two veto layers with 2” lead and 1” iron shields

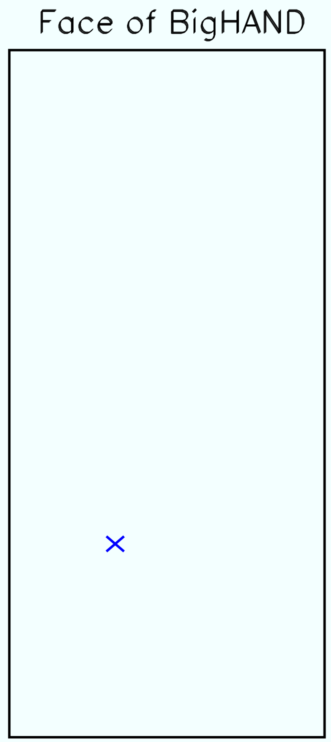
$\mathrm{L}_{\mathbf{flight}} = 17$ m

Time Resolution ≈ 0.35 ns



Nucleon identification complicated by hadronic interactions in shielding

Enhance neutron/proton identification with large aperture magnet on nucleon flight path



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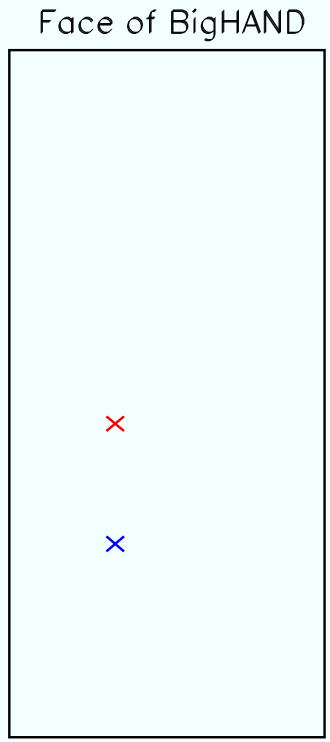

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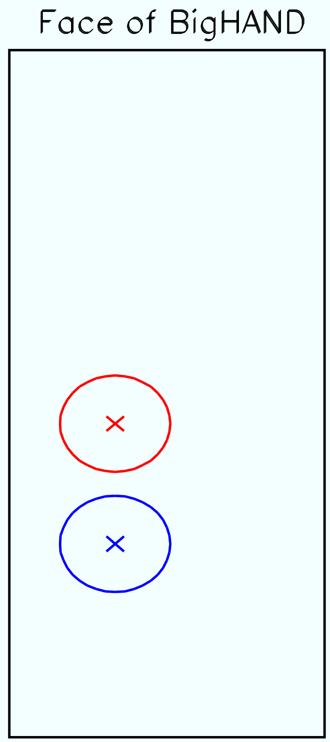

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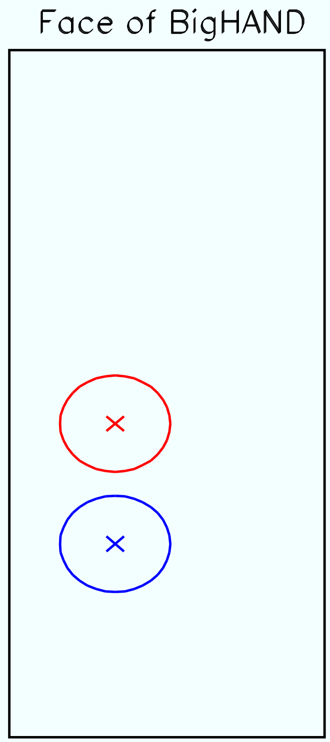

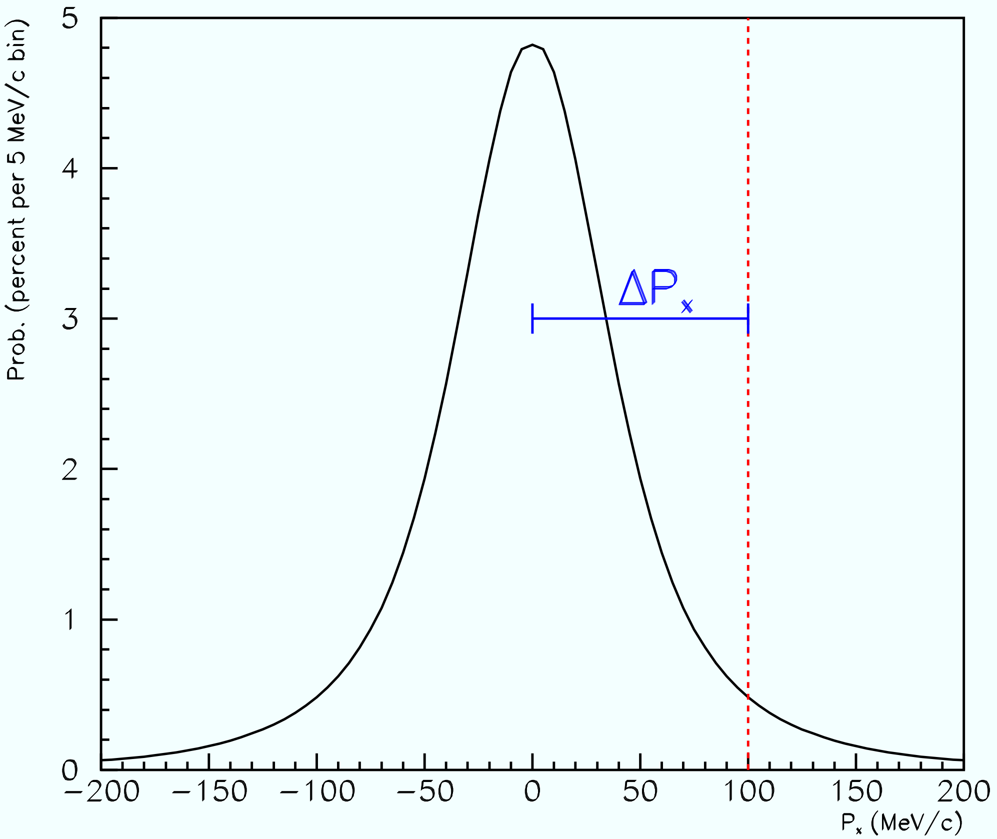

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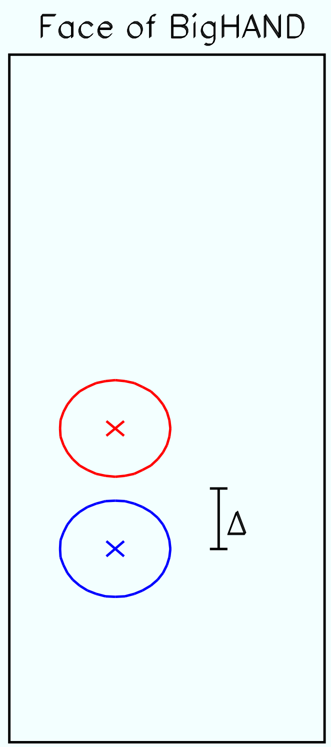
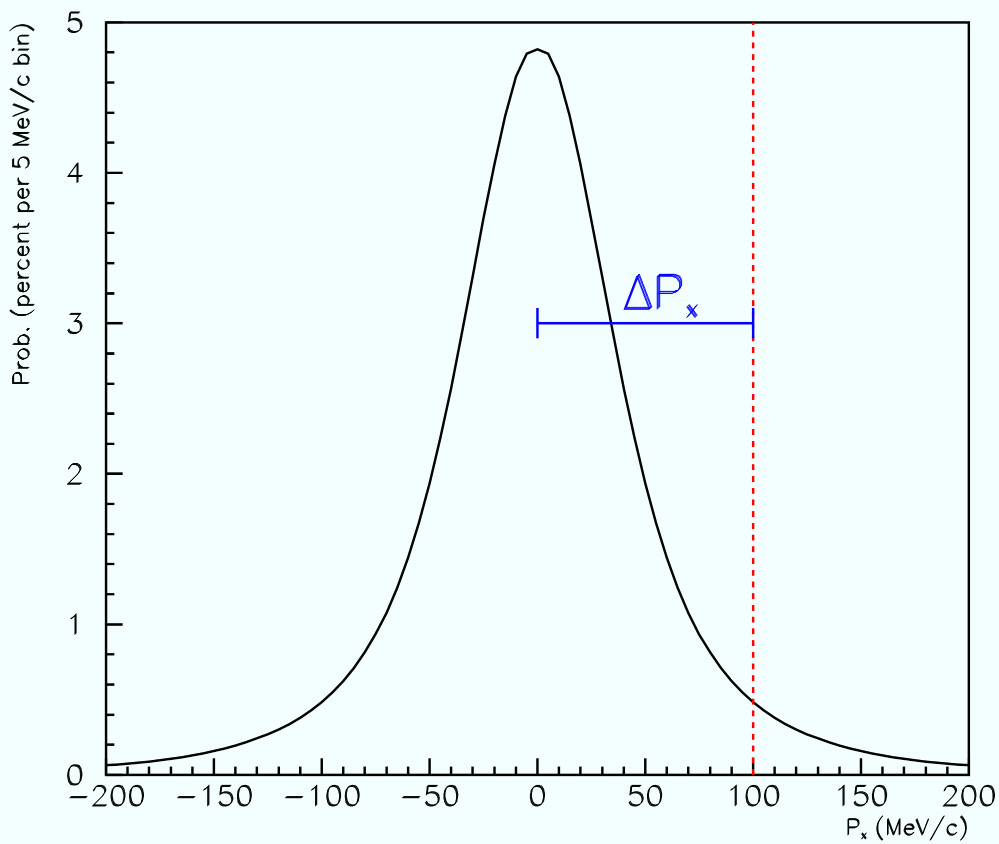




Choose $\Delta P_x = 100$ **MeV/c**

95% **probably postion will be shifted by less than**

$\Delta = \frac{\Delta P_x}{|\vec{q}|}$**Lflight**

Deflect proton by ≈ 200 **MeV/c for clean PID.** $\Rightarrow$ $\int Bdl \approx .66$ **Tm**

Input for rate estimates

Luminosity (electron-nucleon): $\mathcal{L} = 10^{37}$ **/cm^2/s**

Quasi-elastic cross sections: Scaled Dipole (G$_E^p$,G$_M^p$,G$_M^n$), Galster(G$_E^n$)

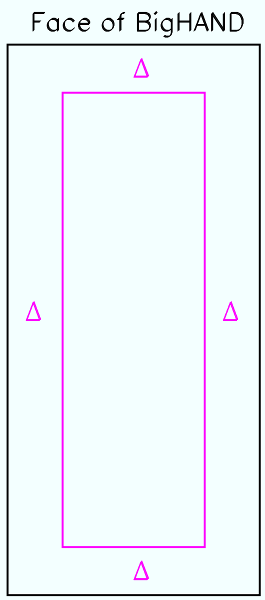
75% n-efficiency

80% p-efficiency

80% live-time

75% tracking efficiency

Combined BigBite/BigHAND acceptance model with 'safety' buffer at edge of BigHAND acceptance



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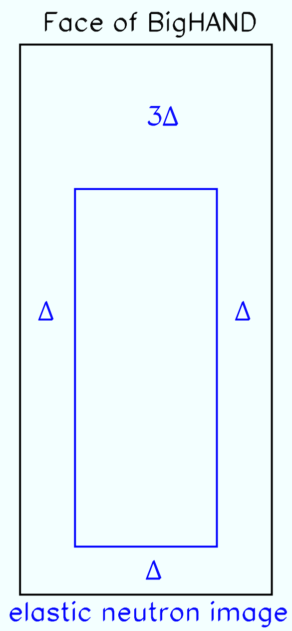
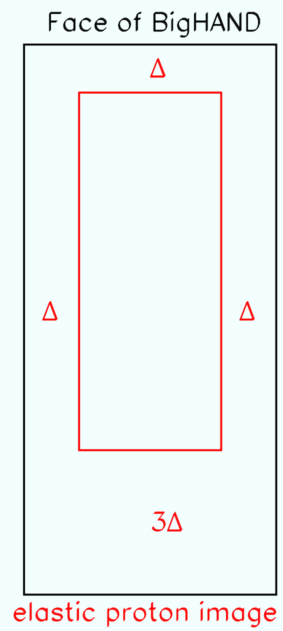




For H(γ, π^+n) calibration:

6% Cu radiator ($\mathcal{L} = 0.25 \times 10^{37}$/cm^2/s)

Counting rule scaling for (γ, π) $s^7 \frac{d\sigma}{dt} \approx 0.5 \times 10^7$ **GeV^{14} $\frac{\text{nb}}{\text{GeV}^2}$ (at $90°$):**

Empirical angular distribution: $\frac{1}{(1-\cos\theta^*)^5(1+\cos\theta^*)^4}$ **(actual $\theta^*_{\gamma,\pi} = 93°,\ 110°,\ 99°,\ 123°$)**

Bremsstrahlung end-point method with E$_{\gamma_{\text{min}}}$ chosen to give P$_\pi$ at least 1.5% above maximum possible pion momentum from ($\gamma, 2\pi$).

$$\int_{E_{\text{min}}}^{E_e} \Gamma dk = 0.0030,\ 0.0043,\ 0.0030,\ 0.0026$$

for Q$^2 = 3.5,\ 4.5,\ 6,\ 8$ (GeV/c)^2

Rate Estimates

(Counts per hour)

Q^2 (GeV/c)^2	3.5	4.5	6	8
E_{beam} (GeV)	4	4	5	6
d(e,e'p)	4400	2600	1125	275
d(e,e'n)	1675	1025	440	112
H(e,e'p)	8775	5250	2250	555
H(γ, π^+n)	800	1240	331	150

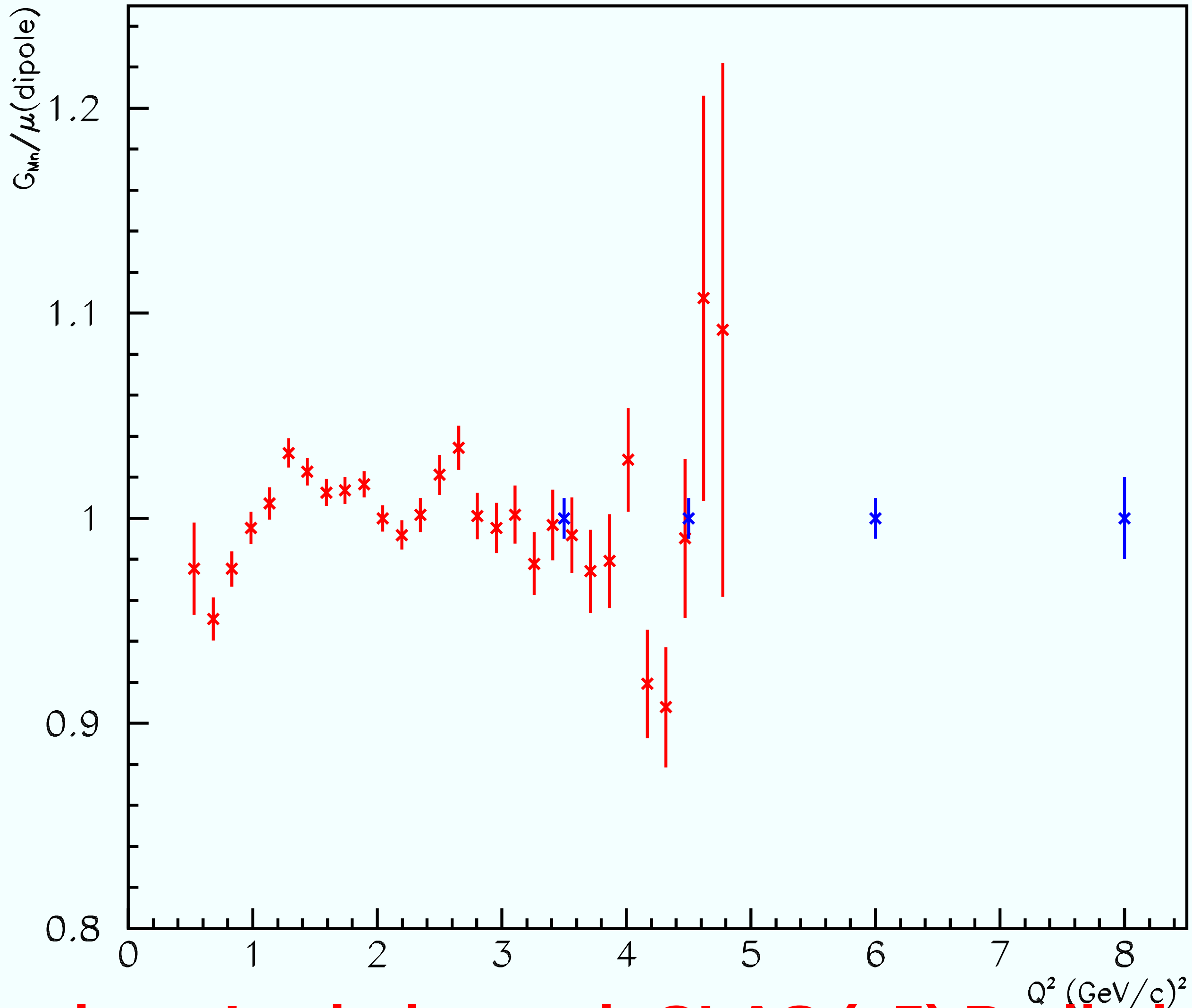
Possible beam allocation (Hours)

(Straw man)

Q^2 (GeV/c)^2	3.5	4.5	6	8
E$_{beam}$ (GeV)	4	4	5	6
d	24	24	48	96
H no radiator (e,e'p) and (γ, π^+n)	12	12	24	36
H with 6% Cu rad H(γ_R, π^+n)	24	24	48	72

Total:444 Hours. Gives 1% (or better) statistical error on measurement and calibration

(Fractional err on G$_M^n$ = half of fractional error on cross section ratio, R.)



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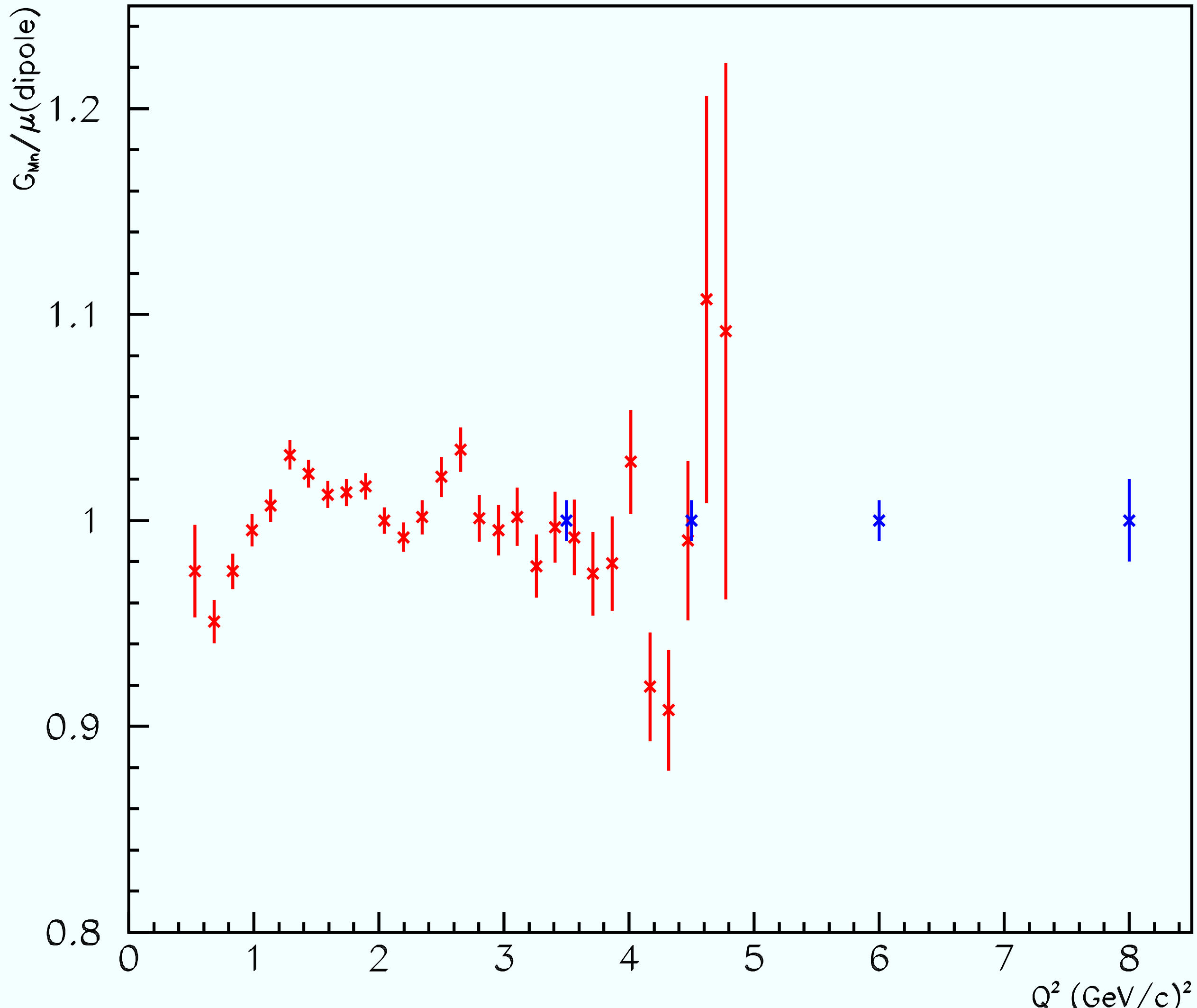
Blue points: Projected error

assuming 1% (and 2% at Q$^2 = 8$ (GeV/c)^2)



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Conclusion

Promising experiment for near-term extension of Q^2 coverage of $G_{\mathbf{M}}^{\mathbf{n}}$.