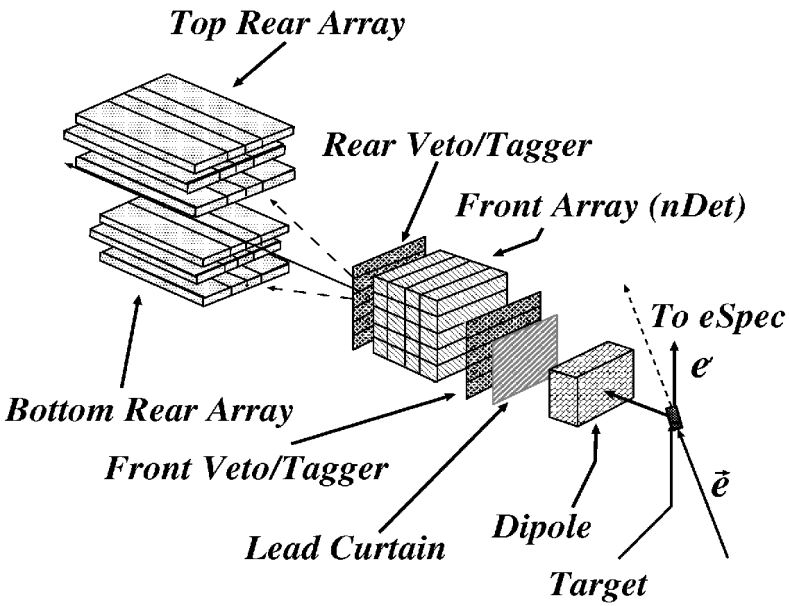
# Measurement of $G_{en}$ at High Momentum Transfer

Andrei Semenov *(University of Regina)*

# General Idea




## Recoil polarimetry from the QE $d(\vec{e},e'\vec{n})p$ reaction

- Secondary scattering in polarimeter with analyzing power $A_y$
- Dipole field permits access to both components of polarization vector
- Ratio of polarization components gives $(G_{en}/G_{mn})$ ratio
- Analyzing power $A_y$ and beam polarization cancel in the ratio
- Small systematics
- Insensitivity to FSI, MEC, IC, and choice of NN potential for d wavefunction

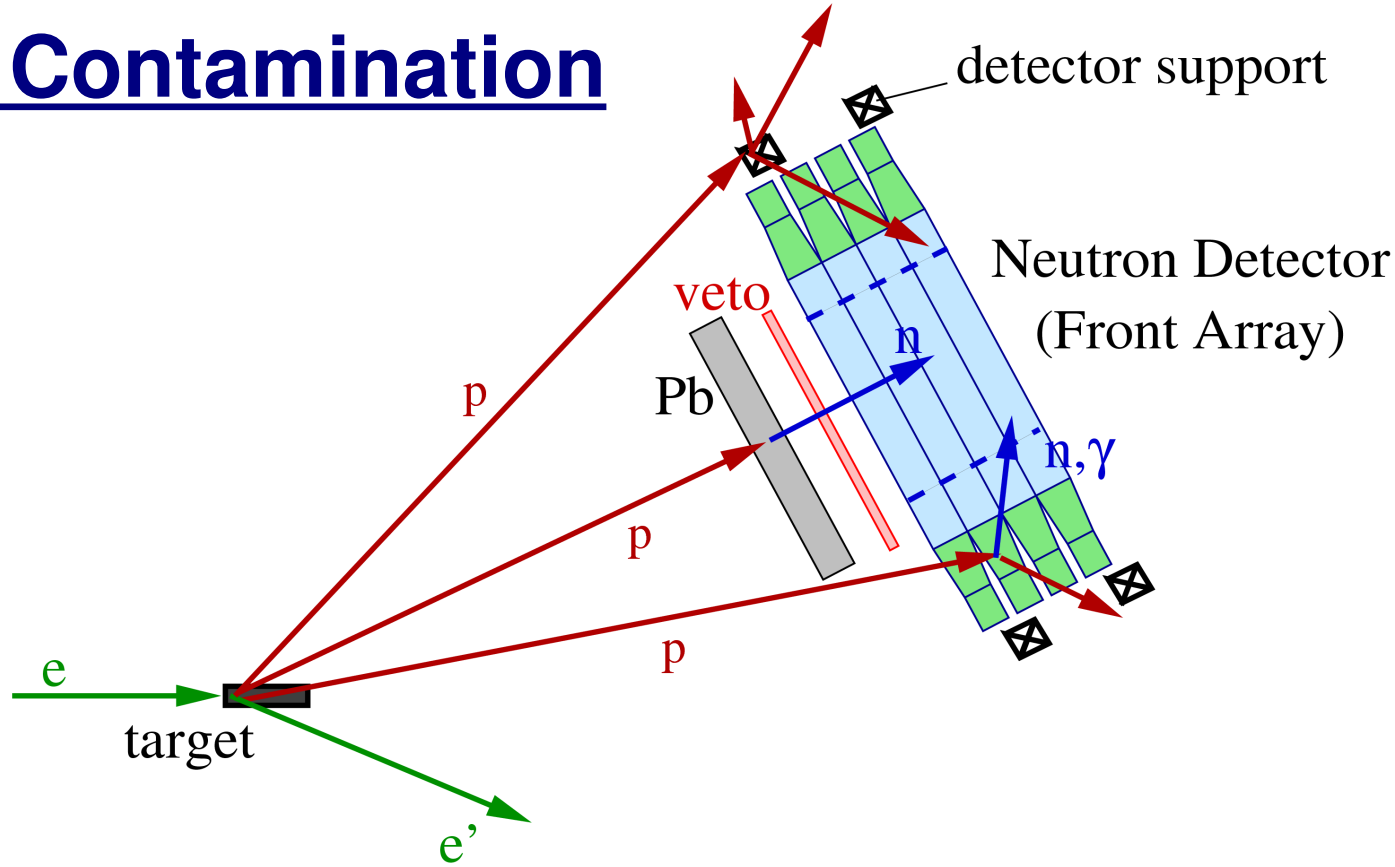
## Alternative: Target asymmetry from polarized 3He target

# Selection of kinematics

| $Q^2$ $(GeV/c)^2$ | E0 (GeV) | $\theta_e$ (deg) | $P_e$ (GeV/c) | $\theta_n$ (deg) | $P_n$ (GeV/c) | MCEEP Rate [80uA & 40-cm LD2] |
|---|---|---|---|---|---|---|
| 2.18 | 2.2 | 58.60 | 1.035 | 28.0 | 1.881 | |
| 3.95 | 4.4 | 36.53 | 2.288 | 28.0 | 2.901 | |
| 5.22 | 6.6 | 26.31 | 3.815 | 28.0 | 3.602 | |
| 6.15 | 8.8 | 20.51 | 5.515 | 28.0 | 4.116 | |
| **6.88** | **11.0** | **16.79** | **7.330** | **28.0** | **4.511** | **50.4 Hz** |
| 6.81 | 8.8 | 22.32 | 5.165 | 26.0 | 4.475 | 25.4 Hz |
| 6.79 | 6.6 | 34.20 | 2.975 | 22.0 | 4.464 | 7.4 Hz |

**Compared to 6.6-GeV beam, the use of 12-GeV beam gives rate increase of about factor 7 and figure-of-merit increase of factor 2.5**

# Proton Contamination

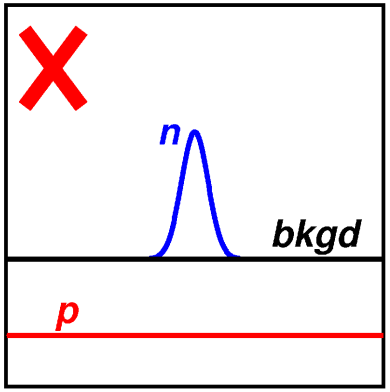


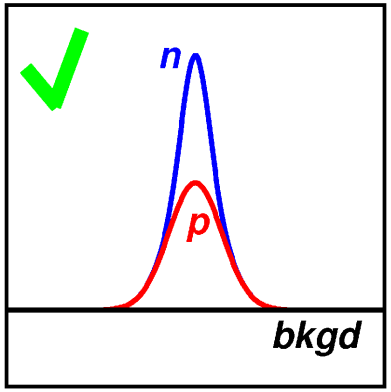

- Pb(p,n) charge-exchange reaction in the lead shielding

- Scattering and inelastic interactions of protons in "side materials" [viz., light guides, PMTs (including housing and magnetic shielding), cables, and detector support construction]

# Why proton contamination is a problem?

- QE proton polarization together with depolarization in the secondary reaction contributes to the false asymmetry (for measurements with $^3$He target, not-polarized flux of protons dilutes the measured target asymmetry)
- For deuteron target and selected kinematics, flux of QE protons is about **2 times** higher than flux of QE neutrons => **small efficiency of proton "pickup" leads to visible distortion of the result**
- Proton contamination correlated with the "good" signal in both Electron Spectrometer and Neutron Detector



# What to do?

✘ Minimize material around (Hardly possible)

✘ Do not use part of the Neutron Detector volume OR use it as a "side veto" (Reduced statistics + Neutrals)

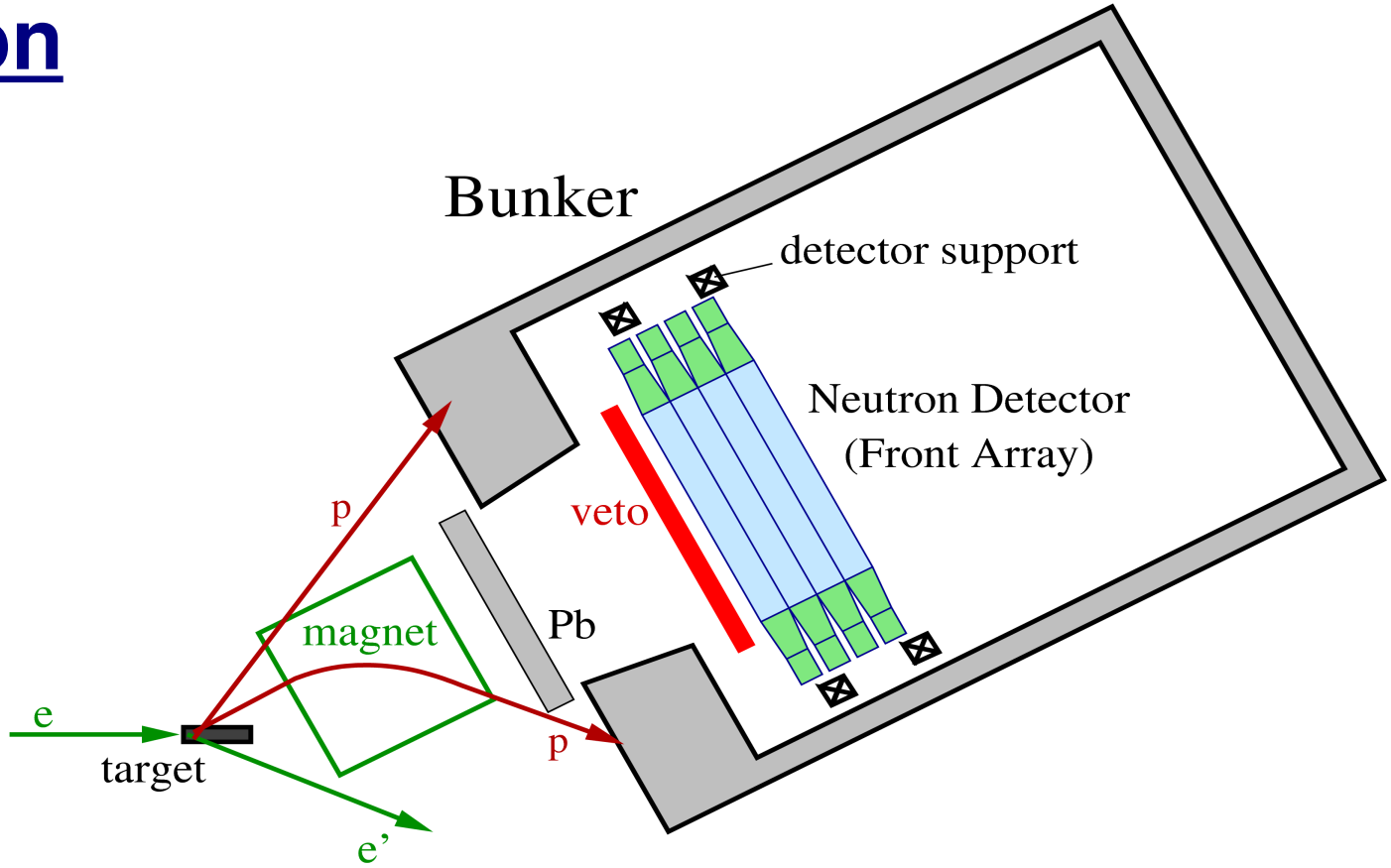
✘ Ignore (Distortion of the reported $G_{en}$ result)

● Use restriction on the kinematics of the secondary scattering (Polarization transfer experiments only)

● Detailed simulation and correction of the result (Additional uncertainty)

✓ REMOVE PROTONS

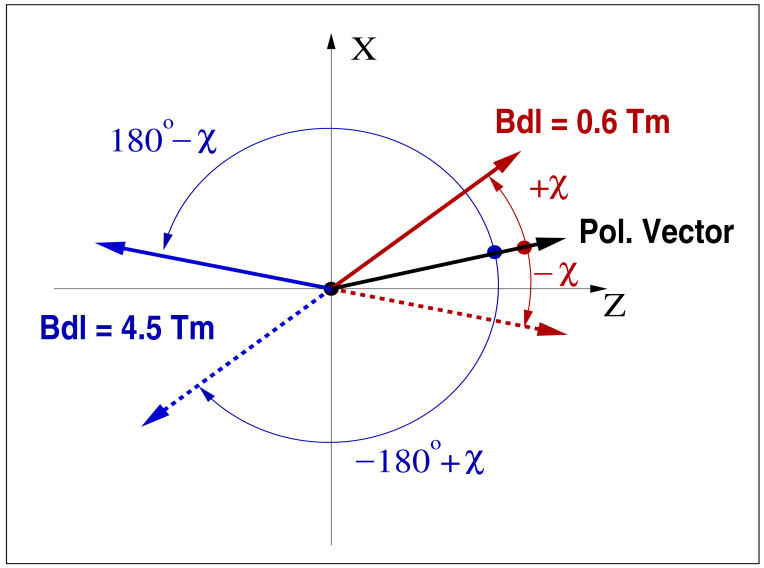
# Solution



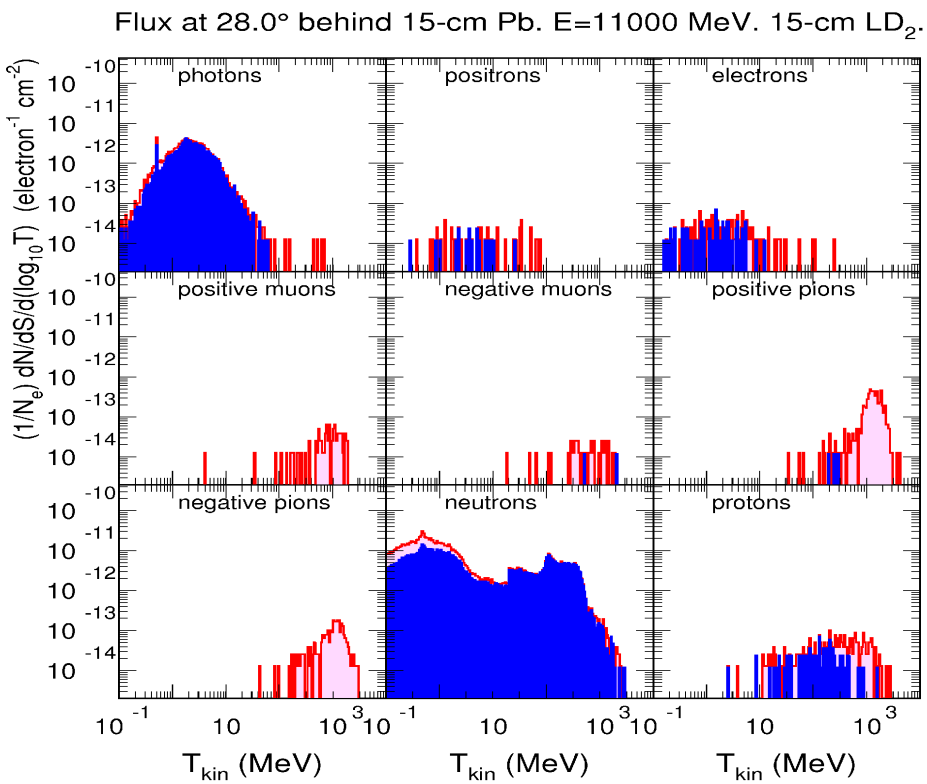

- **Protect Neutron Detector with bunker**

- **Using magnet, sweep QE protons away from the face of lead shielding => the field should be strong enough**

# High Magnetic Field



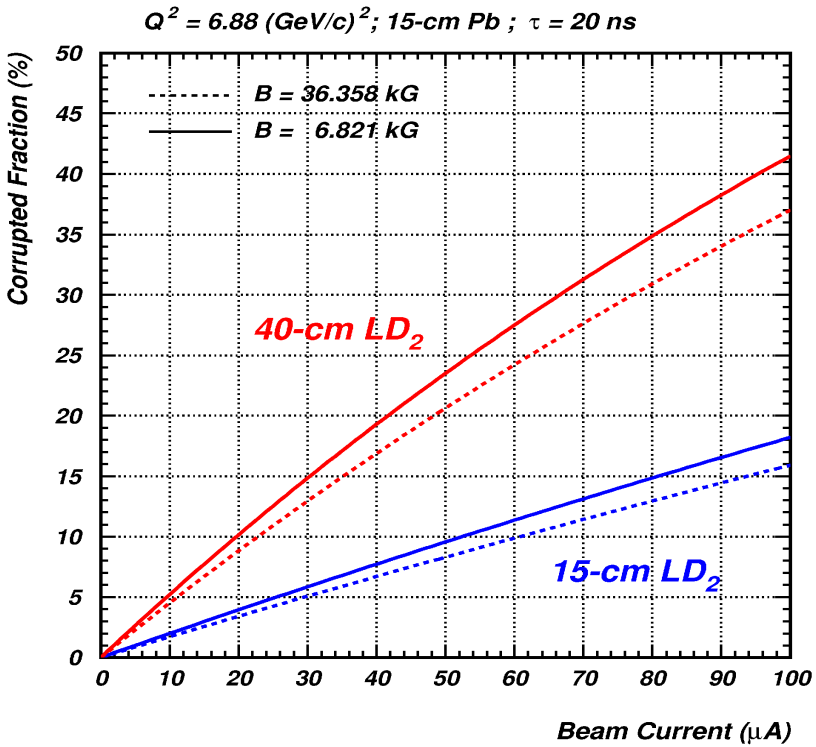

## "Optimal precession" requirement




GEANT 3
+ DINREG
+ GCALOR

# Load of Detectors

Event loss because accidental neutron hit in neighbour 5 detectors during 20-ns window




Expected Veto detector load:

- about 38 kHz per detector with High magnetic field
- about 454 kHz per detector with Low magnetic field

# Analyzing Power

No direct data exist

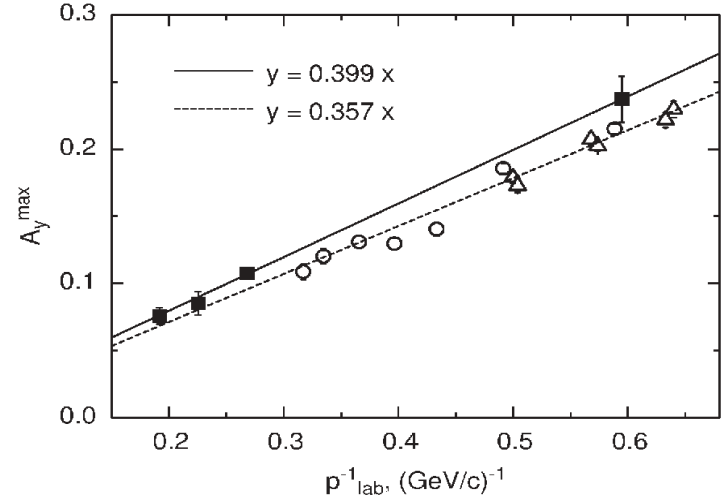



Fig. 5. Momentum dependence of $CH_2$- and C-data. Solid squares—current data, open circles— Ref. [4], open triangles— Ref. [5]. Solid line—fit of $CH_2$-data, dashed line—fit of C-data.

From Jlab E93-038:

$A_y$ = 14.4% for $P_n$ (lab)= 1.45 GeV/c

Scale according to *NIM A538 (2005) 431*:

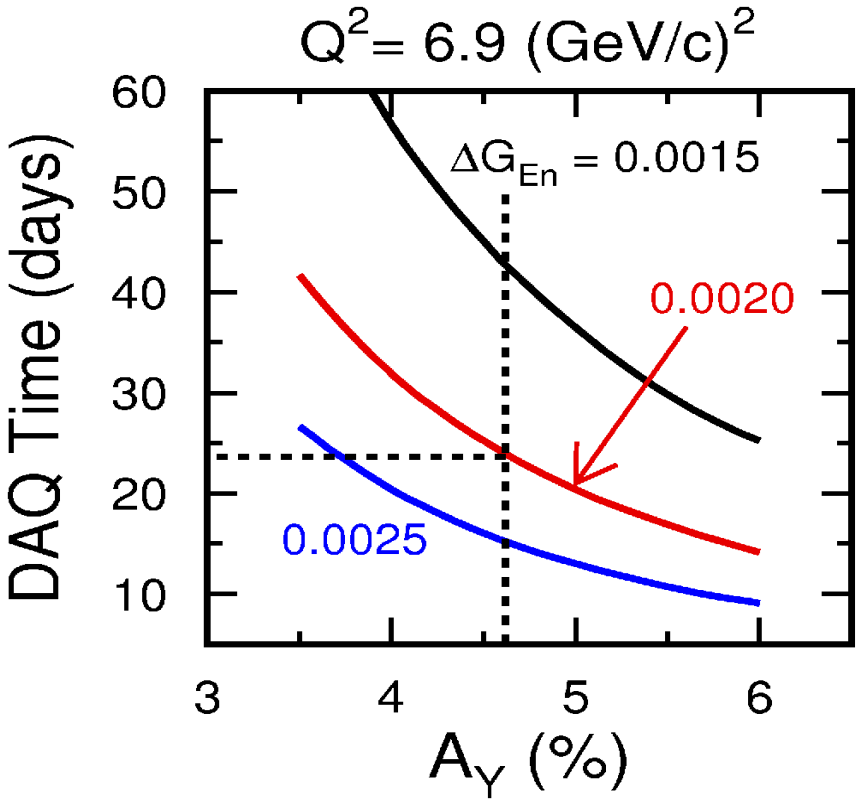
(for proton scattering on $CH_2$)

$A_y \sim 1 / P_p(\text{lab})$ or $A_y \cdot P_p(\text{lab}) = \text{const}$

Our best estimation for $P_n$ = 4.51 GeV/c:

**$A_y$ = 4.6 %**

# Uncertainties




**It's doable! But...**

# Simulation of inelastic events

Method

Generated invariant mass W spectra for d(e,e'n)p and d(e,e'nπ) events *separately* using the GENGEN simulation code

Normalized simulated spectra to measured W spectra for d(e,e') scattering near the quasielastic peak and into the inelastic regime from SLAC E133 [S. Rock et al., PRD 46, 24 (1992)]

Simulating quasielastic and inelastic events *simultaneously* for an e-n *coincidence* experiment is a very difficult problem [hence, the normalization to measured data]. Jim Kelly stated this would be a highly non-trivial problem [thus, we should believe this is, indeed, a difficult problem !!]. For now, will demonstrate efficiency of suppression of inelastic events with appropriate cuts.

# SLAC E133 kinematics

| $E_e$ [GeV] | $\theta_e$ [deg] | $E_{e'}$ [GeV] | $Q^2$ [(GeV/c)$^2$] | $T_n$ [GeV] | $\theta_n$ [deg] |
|---|---|---|---|---|---|
| 9.750 | 10.0 | 8.422 | 2.450 | 1.328 | 45.1 |
| 12.571 | 10.0 | 10.447 | 3.99 | 2.124 | 38.5 |
| 15.736 | 10.0 | 12.544 | 6.00 | 3.192 | 32.8 |
| 17.307 | 10.0 | 13.523 | 7.11 | 3.784 | 30.5 |
| 18.482 | 10.0 | 14.230 | 7.99 | 4.252 | 28.9 |
| 21.005 | 10.0 | 15.680 | 10.01 | 5.325 | 26.1 |

for elastic e-n scattering

# GENGEN simulation code

Used to perform kinematic acceptance-averaging and calculation of FSI/MEC/IC corrections for E93-038

Event generator for d(e,e'n) and d(e,e'nπ)

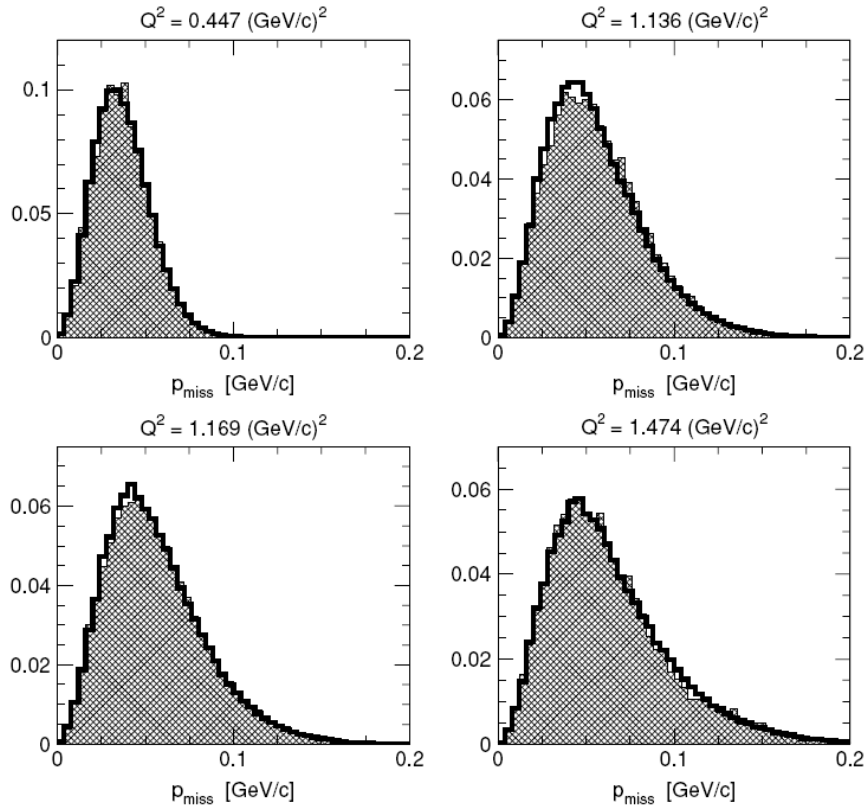
HMS acceptance

Charybdis spin transport

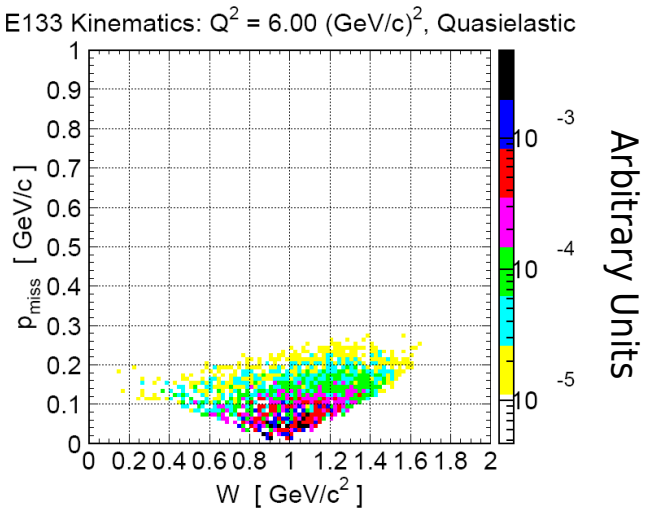
NPOL acceptance and interactions (front-to-rear scattering)

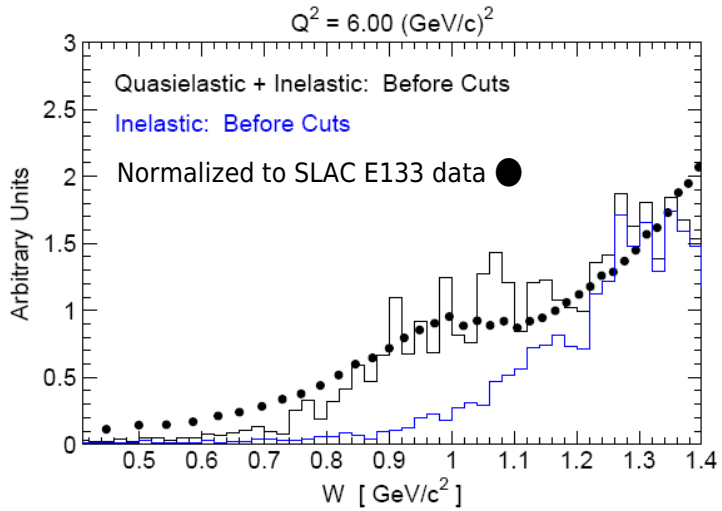
Good agreement with experimental distributions

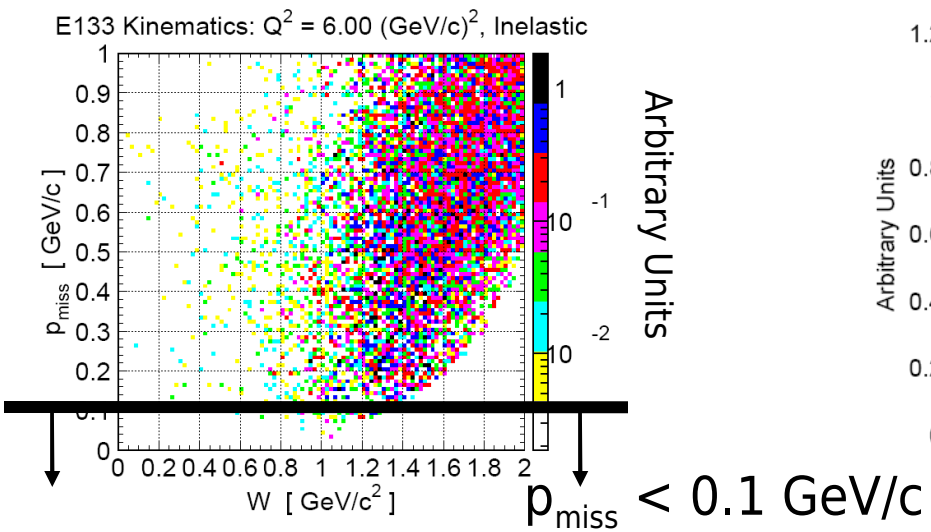
*example*

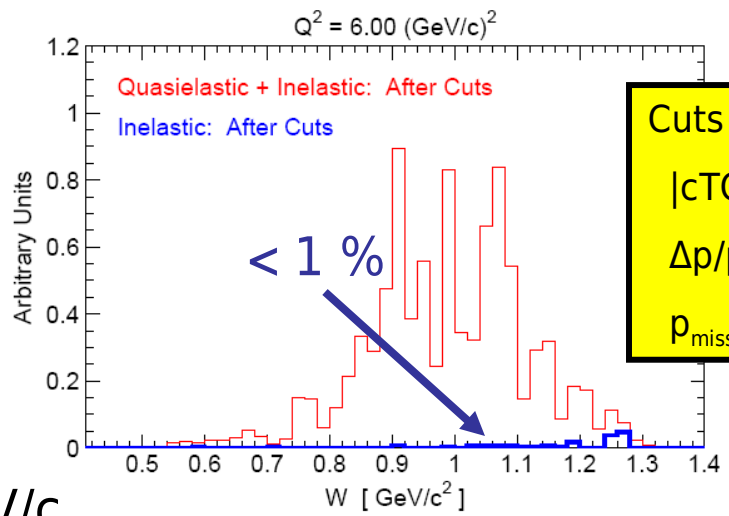


# E133 kinematics at $Q^2$ = 6.00 $(GeV/c)^2$



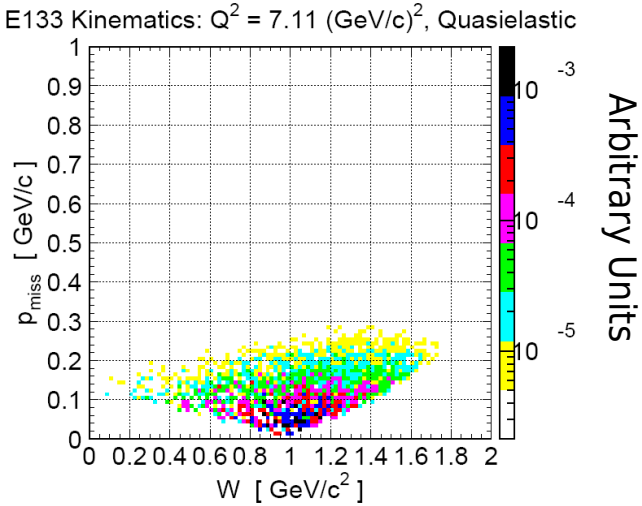

Cuts :

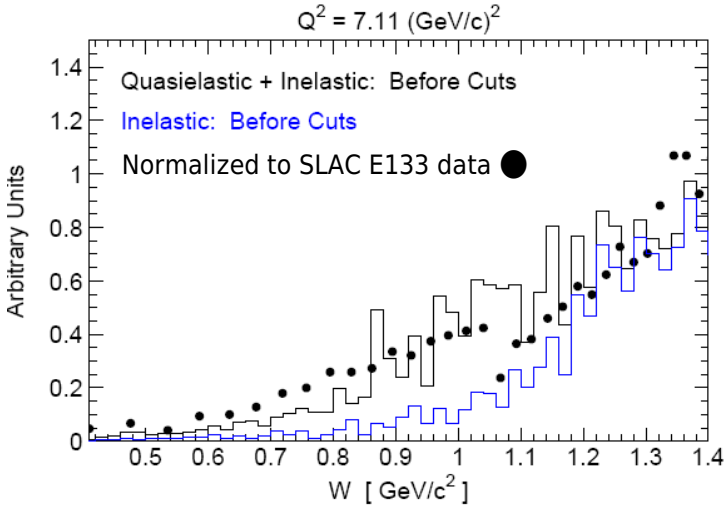
$|cTOF| < 1$ ns

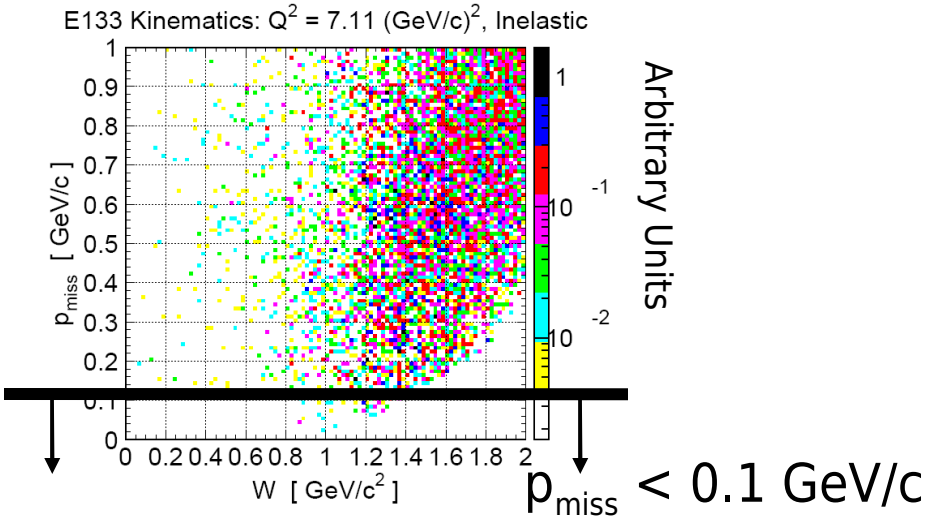
$\Delta p/p = -3/+5$ %

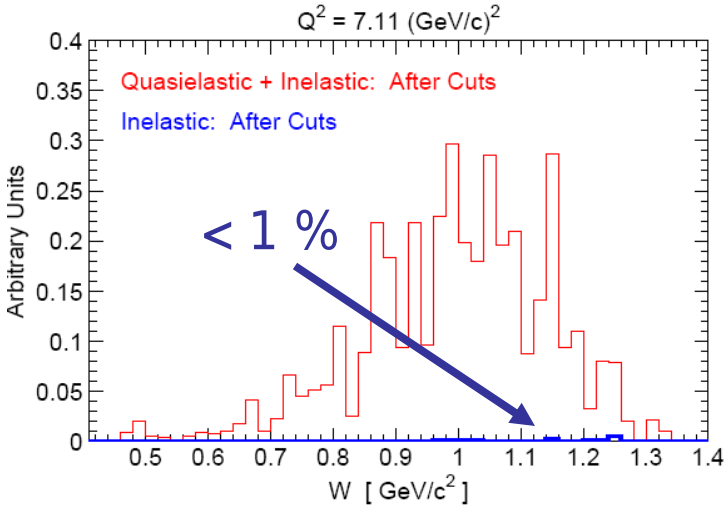
$p_{miss} < 0.1$ GeV/c

# E133 kinematics at $Q^2 = 7.11\ (GeV/c)^2$

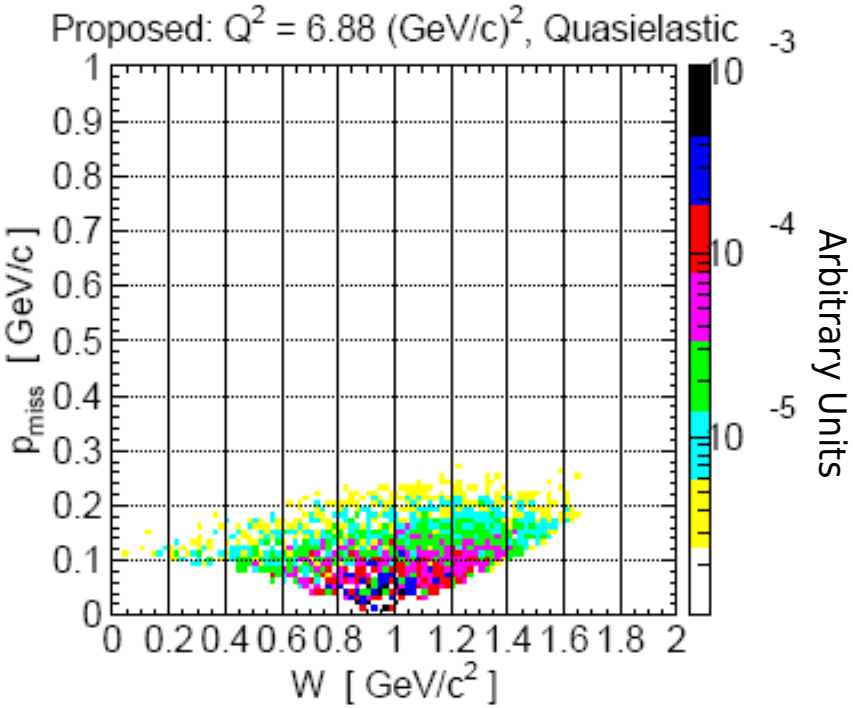


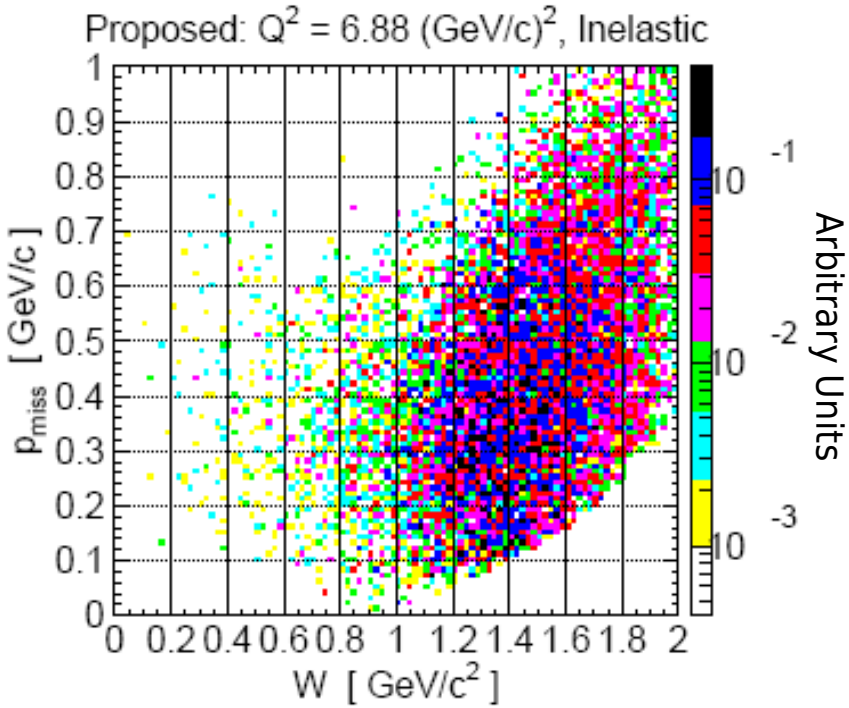



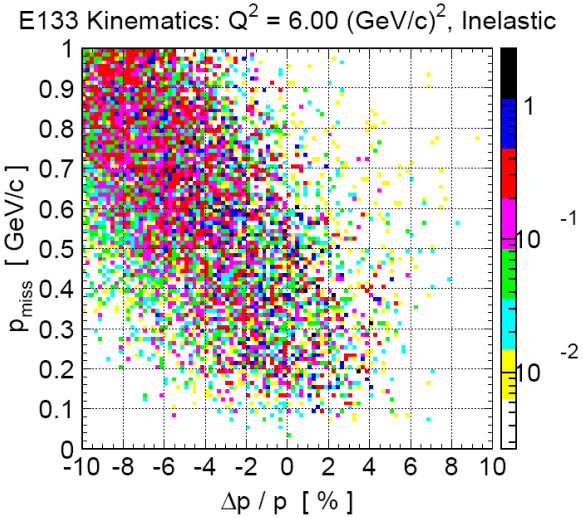
# JLab proposed at $Q^2 = 6.88\ (GeV/c)^2$

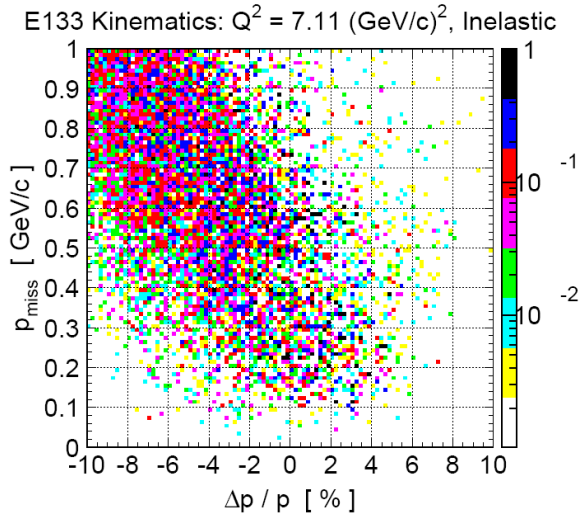


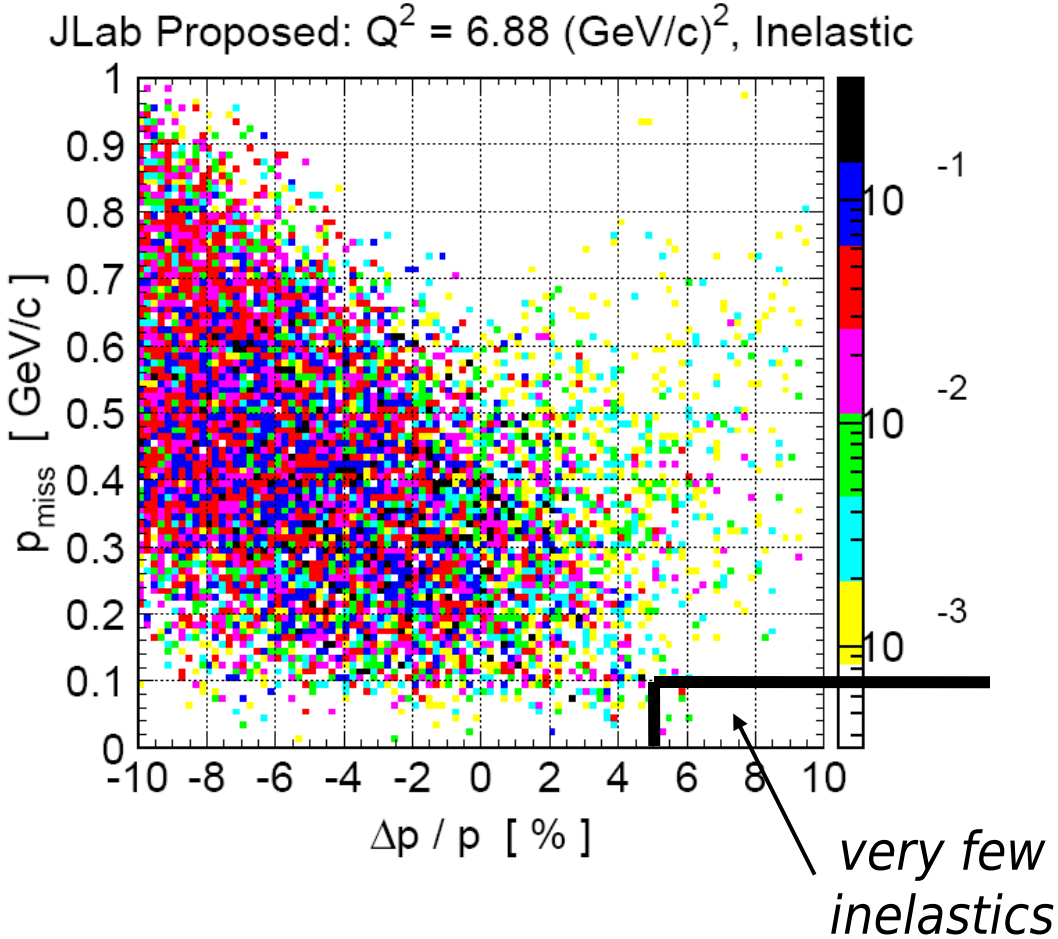




Tight $p_{miss} < 0.1$ GeV/c cut should select most quasielastics while rejecting most inelastics

# Opening the Δp/p cut to -3/+20 % ?



# CONCLUSIONS:

- ✔ Smaller angular acceptance of SHMS (compared to Big Byte) is greatly compensated with higher SHMS rate ability and advantageous kinematics available in Hall C
- ✔ **Measurement of $G_{en}$ via polarization transfer at $Q^2 = 7\ (GeV/c)^2$ is doable**
- ✔ Very careful analysis of background is important
- ✔ **Cross-check of Gen results from different experimental techniques is absolutely needed**