Super BigBite Monte Carlo

Seamus Riordan
University of Massachusetts, Amherst
sriordan@physics.umass.edu

December 10, 2012

Outline

- Needs and Overview of framework
- Physics generators
- Analysis
  - Resolution studies
  - Detailed acceptance studies
- Future Work

G_E^n, G_M^n, A_1^n, G_E^p Simulation

Basis:

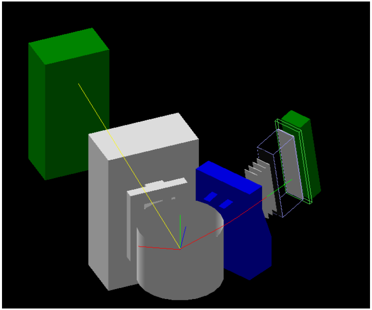
- Both G_E^n, G_M^n, A_1^n have similar hardware configurations
  - BigBite + GEMs + Cerenkov + shower/preshower
  - 48D48 and HCal
- FFs all use elastic or QE nucleon scattering - similar reconstruction needs

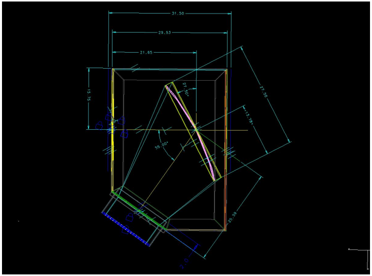
Needs:

- Given a realistic field map - what is the momentum resolution for various configurations?
  - High precision field propagation, multiple scattering effects in detailed geometry
- What is the acceptance given new placement of 48D48 for G_E^n, latest Cerenkov design?
- How do inelastic backgrounds contribute?

Components Included

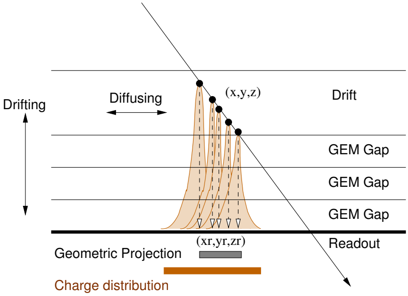
- BigBite and 48D48 Magnet
- Realistic BigBite field
- LH_2/LD_2 cryotargets, ^3He glass cells
- Vacuum scattering chamber
- GEMs
- Calorimeters
- Cerenkov



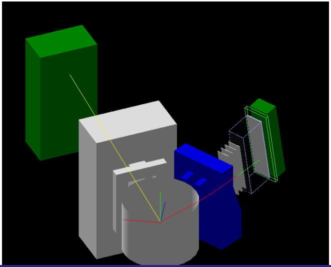


Sensitive Detector Elements

- GEM material/design from SBS GEM tracking sim
- Gas ionization layer sensitive detector for hits
- Hits taken as points - only from primary track, no background
- Assume 70 μm detector res.

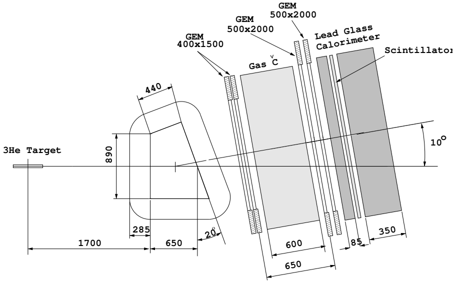


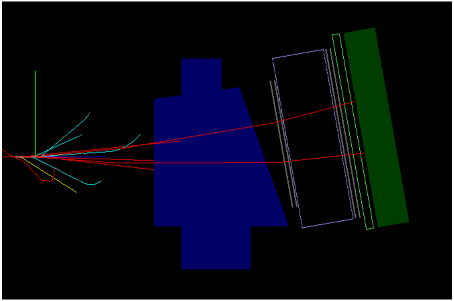
- Calorimeters are dead absorbers, no showering, no smearing
- Acts as "trigger" for each arm



GEM Configurations I

G_E^n/G_M^n Proposal





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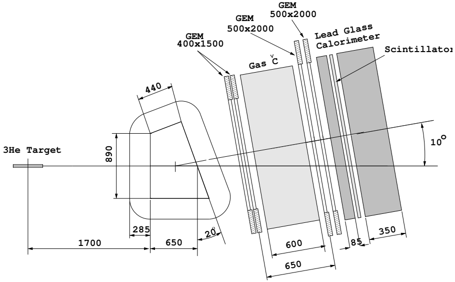
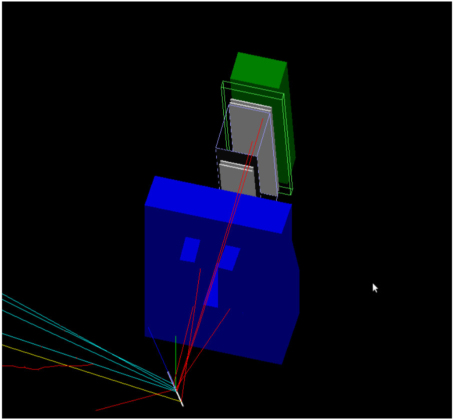
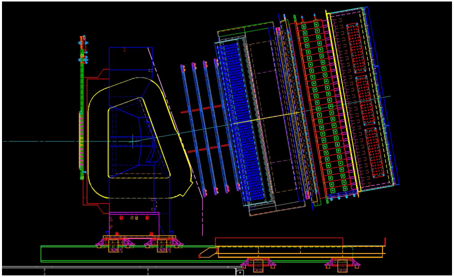
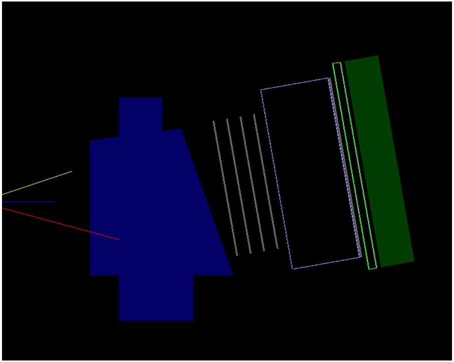




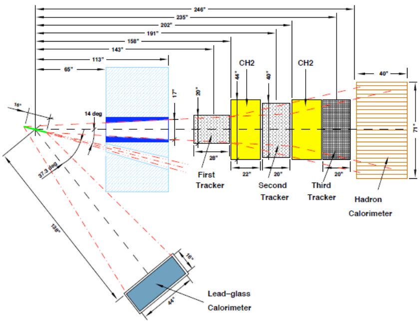
GEM Configurations II

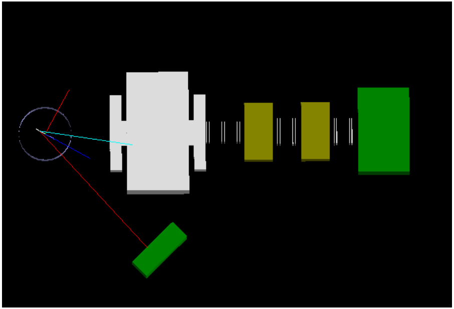
G_E^n, G_M^n, A_1^n New Frame





GEp-V Configuration





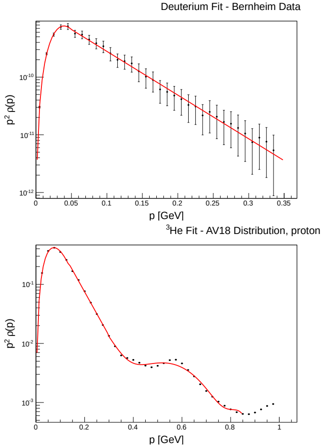
Implemented Generators

Written

- *eN* elastic, quasielastic
  - Use momentum distribution smearing from D and ^{3}He
  - Kelly and E02-013 for FFs
- Parameterized *eN* inelastic from Christy/Bosted
  - Include single pion production from simple model
- DIS from CTEQ distributions

Nice to include someday:

- Wiser $\pi^{\pm,0}$ production (have ported to C)
- Internal/external radiative effects



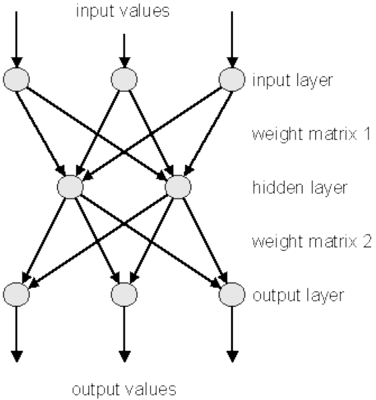
Resolution Studies - Overview

Determine resolution given BigBite field map (thanks V. Nelyubin!)

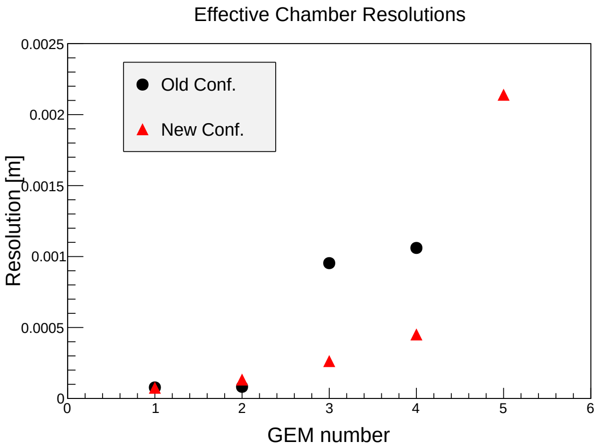
- G_E^n and G_M^n configurations (different magnet distances, targets)
- Both GEM configurations
- Effects of Cerenkov, scattering chamber, target

To speed up analysis, maps determined from neural network

- ROOT now contains multi-layer models which use ntuples
- Don't have to consider implementing specific forms
- Relatively fast fitting
- Details Wednesday!



Effective GEM Resolutions

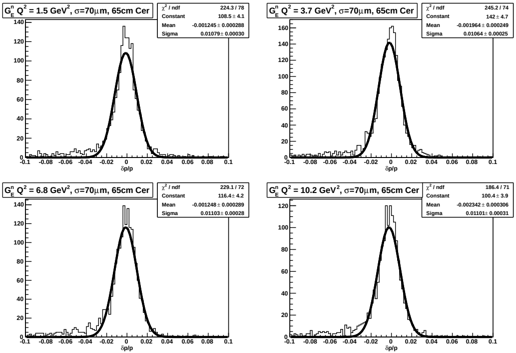


- With high resolution, multiple scattering contributes and must be accounted for
- Weight chambers in minimum χ^2 with effective resolutions

Resolution Results - G_E^n Momentum

- Training data results for various configurations

G_E^n *Conf*	$\delta p/p$ for Q^2 [%]			
	1.5 GeV^2	3.7 GeV^2	6.8 GeV^2	10.2 GeV^2
proposal	1.3	1.4	1.4	1.3
new conf	1.2	1.1	1.1	1.2



Resolution Results - G_E^n, in plane

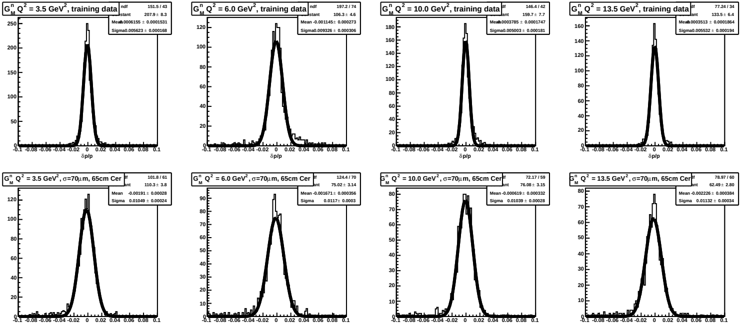
- Training data results for various configurations

$G_E^n Conf$	$\delta\theta$ for Q^2 [mrad]			
	1.5 GeV^2	3.7 GeV^2	6.8 GeV^2	10.2 GeV^2
Proposal	4.5	3.8	3.5	3.4
New conf	4.4	3.5	3.5	3.5
$G_E^n Conf$	δv_z for Q^2 [cm]			
	1.5 GeV^2	3.7 GeV^2	6.8 GeV^2	10.2 GeV^2
Proposal	0.9	0.9	0.8	0.7
New conf	0.8	0.7	0.6	0.7

- θ and v_z training data was roughly half width of full resolution data

Resolution Results - G_M^n

G_M^n *Conf*	$\delta p/p$ for Q^2 [%]			
	$3.5\ \mathrm{GeV}^2$	$6.0\ \mathrm{GeV}^2$	$10.0\ \mathrm{GeV}^2$	$13.5\ \mathrm{GeV}^{2}*$
New conf	1.1	1.2	1.2	1.1
No cer	1.0	1.0	1.0	1.1
No cer, no targ	0.9	0.8	1.0	1.0



* Updated G_M^n, $Q^2 = 13.5\ \mathrm{GeV}^2$ point

Rate Results - G_E^n

Kin	Cut factor	Quoted Rate [Hz]	Prop conf [Hz]
1.5 GeV^2	1.0	29.7	37.9
3.7 GeV^2	2.0	1.01	1.00
6.8 GeV^2	3.0	0.049	0.053
10.2 GeV^2	4.0	0.006	0.007

Kin	New conf [Hz]	1 m Cer [Hz]
1.5 GeV^2	35.0	35.4
3.7 GeV^2	0.98	0.99
6.8 GeV^2	0.053	0.050
10.2 GeV^2	0.007	0.006

- Proposal $\rightarrow$ new conf has 48D48 distance 1.6 $\rightarrow$ 2.8 m
- With plausible cuts on data, reproduce rates quoted in plots

Rate Results - G_M^n

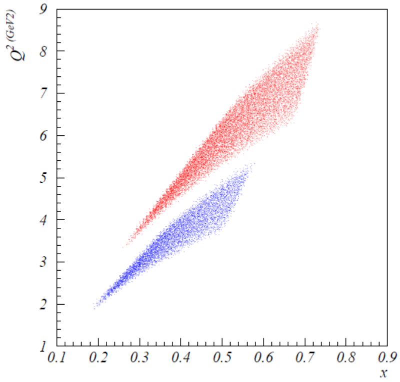
Kin	Quoted Rate [Hz]	MC New Conf [Hz]
3.5 GeV^2	50.0	56.6
4.5 GeV^2	10.0	10.2
6.0 GeV^2	0.73	0.74
8.5 GeV^2	0.26	0.29
10.0 GeV^2	0.21	0.30
12.0 GeV^2	0.043	0.051
13.5 GeV^2	0.010	0.012
New 13.5 GeV^2	-	0.058

- Rates agree very well with Kelly param. and what was used for the G_M^n proposal

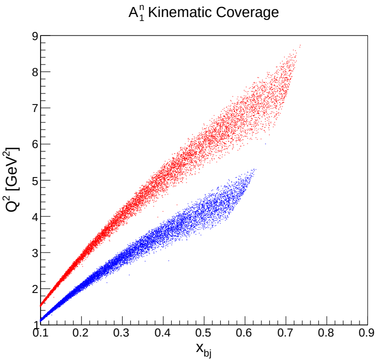
Acceptance for A_1^n

- Just used 1-arm neutron FF setup

Proposal



New MC



Rate Results - A_1^n

$E = 6.6$ GeV

x	Prop [Hz]	CTEQ [Hz]	B/C [Hz]
0.60	1.3	5.9	8.2
0.56	8.0	7.2	9.3
0.52	12.0	10.2	12.3
0.48	17.0	12.8	15.4
0.44	23.0	20.5	19.0
0.40	30.0	24.9	24.4
0.36	30.0	34.3	30.8
0.32	17.0	46.0	35.3

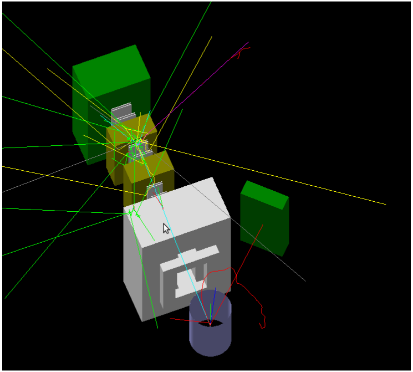
$E = 8.8$ GeV

x	Prop [Hz]	CTEQ [Hz]	B/C [Hz]
0.71	0.5	1.0	1.7
0.67	1.7	1.4	2.2
0.63	2.9	2.2	2.9
0.58	4.1	3.3	4.5
0.54	6.4	5.5	5.9
0.49	8.2	6.8	8.7
0.45	8.8	10.8	11.3
0.40	6.2	15.4	14.3

Rate Results - G_E^p-V

Q^2 [GeV^2]	Rate [Hz]
5	1060
8	485
12	65

- Resolutions are with constant dipole field
- Training data and realistic data comparable - not sure how accurate these are



Q^2	5 GeV^2	8 GeV^2	12 GeV^2
δp (%)	0.4	0.3	0.3
$\delta\theta$ (mrad)	2.3	1.5	0.9
δv_z (cm)	0.5	0.2	0.2

Further Work

Analysis

- Momentum resolution propagated to reconstructed variables
- Inelastic contamination

Coding:

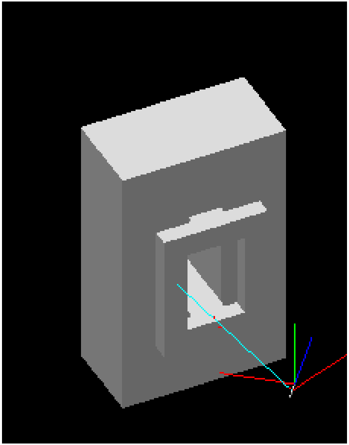
- Radiative effects
- Add in Wiser code for $\pi^{\pm,0}$
- Shower responses
- Cerenkov responses

Summary

- Resolution studies for GEMs show resolutions within proposal needs with new configuration
- Rates are near proposal expectations and allow for small changes in placement and sizes of hardware
- Inelastic studies are underway

BACKUP SLIDES

- Used older design for coil
- Aperture 48 in $\times$ 18.5 in $\times$ 48 in ($H \times W \times D$)



Components - Target

- Used tubes filled with gas/cryo and endcaps
- Values from Hall A NIM or G_E^n thesis

G_E^n

Material	GE180
l	0.55 m
r	0.953 cm
t_{wall}	1.6 mm
t_{cap}	0.126 mm

G_M^n

Material	Aluminum
l	10 cm
r	3.2 cm
t_{wall}	0.18 mm
t_{dcap}	71 μm
t_{ucap}	102 μm

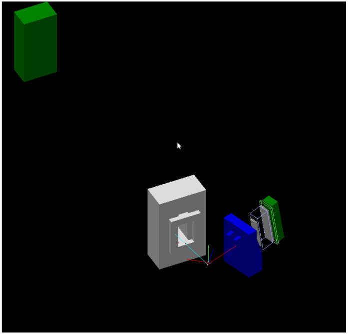
Components - Scattering Chamber

- Used simplified scattering chamber
- $R = 1.036$ m, window 0.33 mm thick (too thin?), Aluminum

Components - Calorimeters

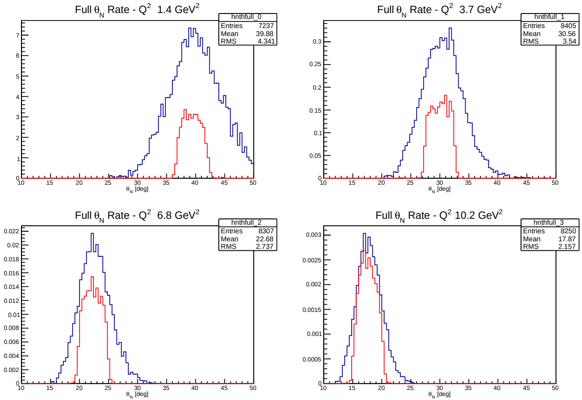
- Calorimeter from standard BigBite setup and CDR
- Dead absorber - no showering
- Sensitive detectors - record hit time and position

BigBite Shower		HCal	
h	229.5 cm	h	330 cm
w	59.5 cm	w	165 cm



Rate Results - G_E^n Acceptance

- Black is QE neutron inclusive, red is coincidence
- Acceptance not matched well for G_E^n for θ and ϕ - was taken into account in rates
- Maybe some room for tuning?



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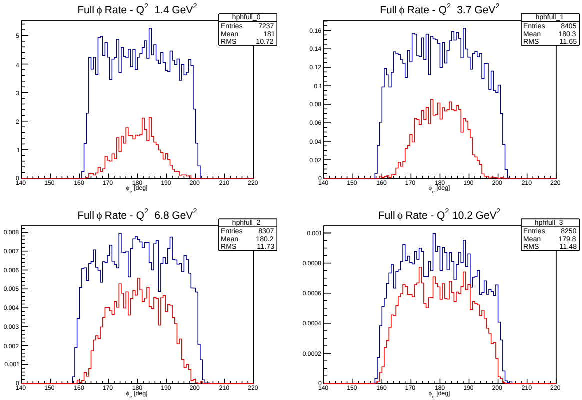
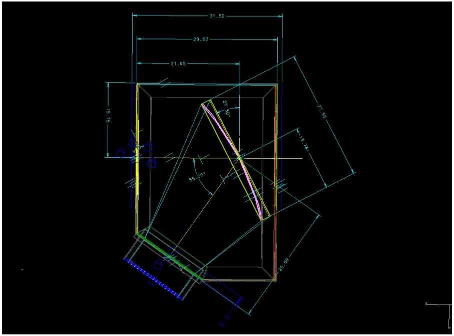


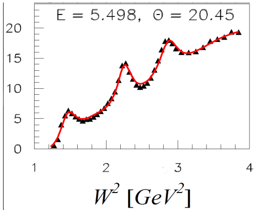
Cerenkov

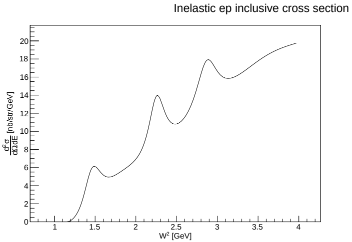
- Cerenkov just a gas box with flat mirror - no light collection
- Mirror 1 mm acrylic
- Entrance (exit) windows 0.1 (0.2) mm Al
- Gas is C4F8O, 1 atm



Inelastic Generators

- Previous inelastic rates were given by MAID parameterization - got both σ and A, but limited in Q^2
- Worked in Christy/Bosted inclusive parameterization of *ep* and *en* data
- Use simple single pion decay model, assume Δ contributes for $\pi^{+/-}$,π^0 rates

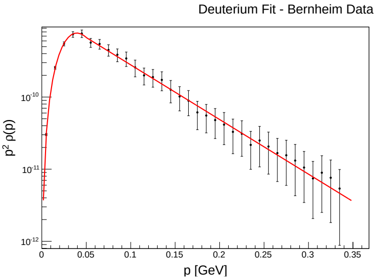


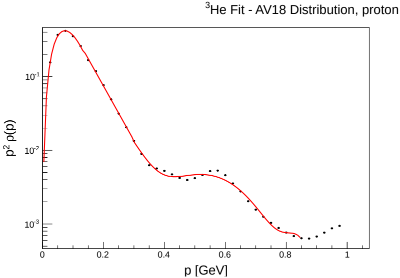


- Reproduce plots in the papers well
- C code is available if anyone else needs it

QE Generator

- QE rates given by
  - Nucleon momentum distributions - just use simple smearing
  - Kelly parameterization for G_E^p, G_M^p, G_M^n, E02-013 parameterization for G_E^n





- Dumbly sample these distributions
- No offshell effects