BG merging and reconstruction efficiency

Task-force report

S. Stepanyan (JLAB)

April 28, 2020

Results of old studies

- Charged particle multiplicities as a function of beam current (luminosity scan runs)
  - Spring RG-A inbending – 4301, 4302, 4303, 4305 and 4307 with 2 nA, 10 nA, 30 nA, 50 nA and 75 nA, respectively
  - Fall RG-A inbending – 4893, 4895, 4887, 4888, 4903, and 4900 with 2 nA, 4 nA, 10 nA, 25 nA, 45 nA, and 60 nA, respectively
  - Fall RG-A outbending – 5443, 5444, 5453, and 5543 with 5 nA, 20 nA, 40 nA, and 50 nA, respectively
  - Engineering FT-OFF inbending – 2284, 2301, 2302, 2317, 2346, and (2326, 2327) with 20 nA, 10 nA, 50 nA, 15 nA, 75 nA, and 125 nA, respectively
  - RG-K FT-ON outbending – 5681, 5682, 5683, and 5684 with 10 nA, 20 nA, 30 nA, and 45 nA, respectively
  - 5684 had a different trigger file, not clear whether that will be a problem
  - RG-k FT-OFF outbending – 5875, 5877, 5879, 5886, and 5885 with 5 nA, 10 nA, 30 nA, 60 nA and 75 nA, respectively
  - RG-B inbending – 6226, 6227, 6224(5), and 6299 with 5 nA, 15 nA, 35 nA and 50 nA, respectively

(%/nA)	RG-B, Winter-Spring 2019	Spring e- inbending	Fall e- inbending	Fall e- outbending	Eng. Run FToff e- inb.	RG-K FT-ON, outbanding	RG-K FToff, 6.5 GeV, outbanding
α –positives	0.4	0.46	0.49	0.27	0.49	0.33	0.325
α –negatives	0.41	0.38	0.48	0.34	0.46	0.44	0.151
α –positives, PID	0.48	0.6	0.63	0.37	0.55	1 (prot)	1.05 (prot.)
α –negatives, PID	0.51	0.59	0.66	0.45	0.55	0.7 (e-)	0.93 (e-)

- A normalized yield of physics reactions, for FD so far, (Nick, Joseph, FX)
- BG merging with low luminosity beam data and MC (Veronique, Josh, Joseph)

Summary: inefficiency $\approx 0.45\%/nA$ (the same for FD and CD)

Conclusions from year ago

- Efforts to improve the reconstruction efficiency must continue using 2 nA beam date merged with beam background (Veronique, Raffaella, Nathan, Stepan …)
- Regardless of the success with the software developments, we still will be left with significant losses of event reconstruction efficiency that must be properly corrected for each physics reaction
- The efficiency losses are physics reaction (kinematics, topology …), and individual track angle and momentum dependent
- More studies with final calibrations and reconstruction algorithms will be needed to determine all dependencies. *Note: background effects 3-momentum reconstruction and that cannot be corrected with traditional momentum corrections*
- The simulation is the main method to correct for inefficiency for a given physics reaction
- The beam background merging with the simulated event using data from random trigger samples has to be fully validated
- The validation of background merging method can be done (should be done) by comparing the yields of high rate physics reactions from low luminosity (5(2) nA) runs without and with merged beam background

Goal

Develop and validate GEMC based software for beam background merging with MC event to properly account for track/particle reconstruction efficiency and accuracy in CLAS12.

Charge

- ✓ Develop a software for merging hits in fADCs and TDCs in CLAS12 detectors associated with physics (GEMC or exp. data) and the beam background (from the random trigger) events
- ✓ Develop software for filtering out hits in fADCs and TDC associated with beam background using random trigger events
- study the dependence of a particle detection efficiency and 3-momentum accuracy on the kinematics of particles and topology of physics events using experimental data with different luminosities (normalized yields, invariant and missing mass distributions)
- validate background merging procedure by comparing above dependencies with results obtained from merged samples of MC and low luminosity data
- document the work

Members

- S. Stepanyan (PI)
- M. Ungaro (core)
- V. Ziegler (core)
- H. Avagyan (core)
- N. Markov (external)
- V. Burkert (external)
- R. De Vita (external)

Documentation

- Background files and software tools

Old studies

- Summary of Spring 2019 studies of luminosity scan runs (Stepan)
- Old studies with 2 nA data merged with 50 nA BG (Stepan)
- Background Merging Validation (Joseph)

https://clasweb.jlab.org/wiki/index.php/Hall-B_Task_Forces_2020#tab=BG_Merging__26_Efficiency

Where we are with the software development (Raffaella)

- software release for RG-A pass1, 6.5.3, GEMC 4.3.2 supports DC and FTOF (4.4.0 will supports all the detectors), see https://clasweb.jlab.org/wiki/index.php/Background_files_and_software_tools
- the random trigger BG filtering and merging tools ready in a branch of the main software repository and will go in a release whenever validation is done –

  https://github.com/JeffersonLab/clas12-offline-software/tree/bgMerging

- the beam background (BG) merging with data is ready for all detectors, detector selection is a command line argument

```
****************************************
*      PROGRAM USAGE : by OptionParser    *
****************************************


     Usage : bgMerger -b [background file] -i [input data file] -o [merged file]


   Options :
        -d : list of detectors, for example "DC,FTOF,HTCC" (default = DC,FTOF)
        -n : maximum number of events to process (default = -1)
```

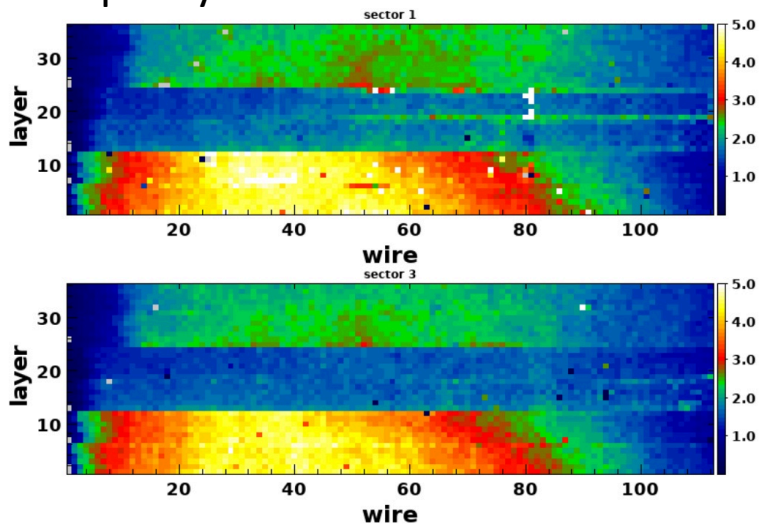
Example:

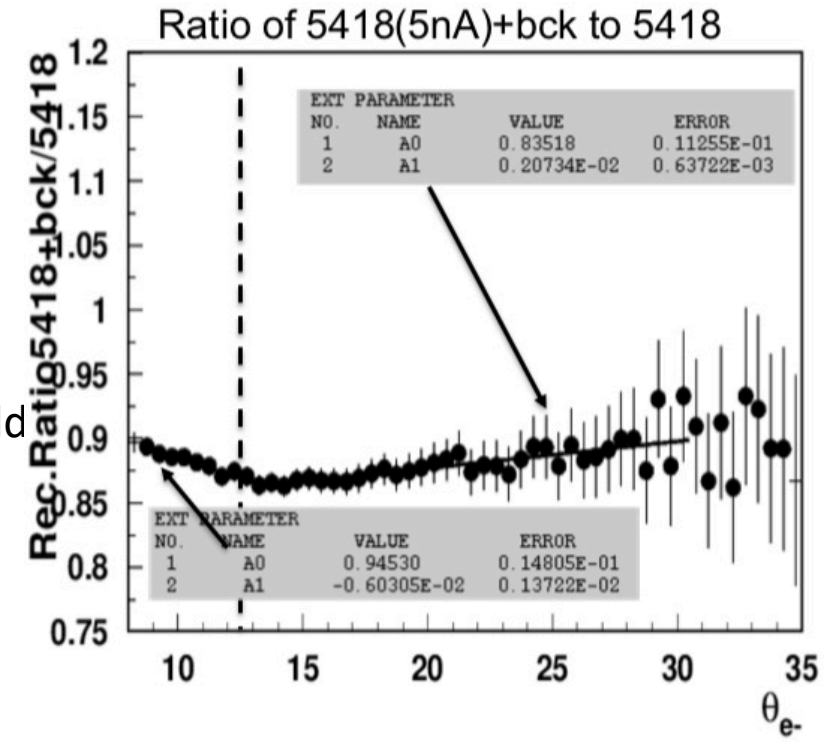
```
bgMerger -b bgfile.hipo -i eventfile.hipo -d "DC,FTOF,ECAL,HTCC" -o mergedfile.hipo
```

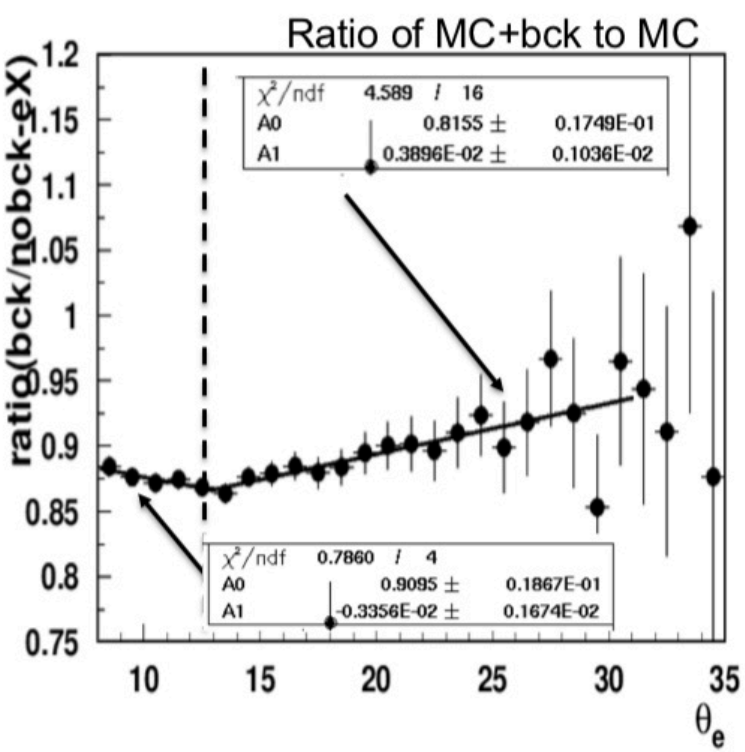
- low luminosity data merged with high luminosity background was done for different list of detectors for RG-A fall 2018 inbending data set
- random trigger events have also been skimmed for the outbending data set and the same tests done for inbending can start for the outbending set as soon data processing starts
- beam BG files and the low luminosity data merged with BG can be found at- /volatile/clas12/users/devita/bgmerging

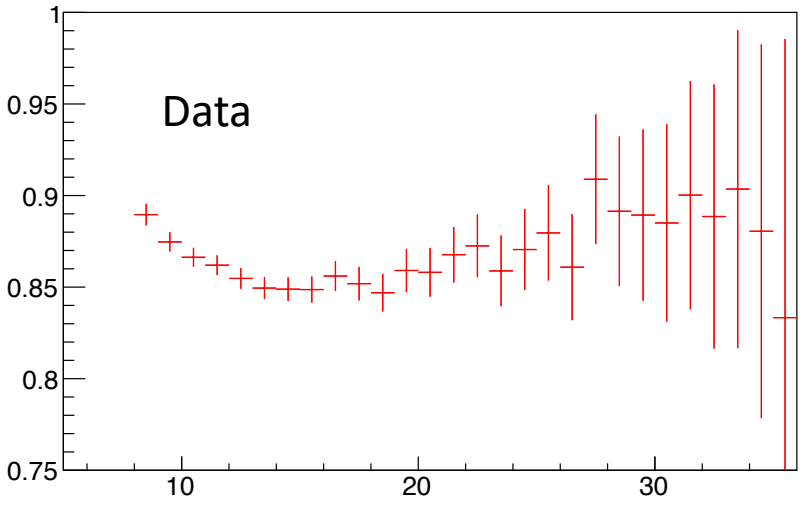
Inclusive electrons, data vs MC merging (Harut, Nick)

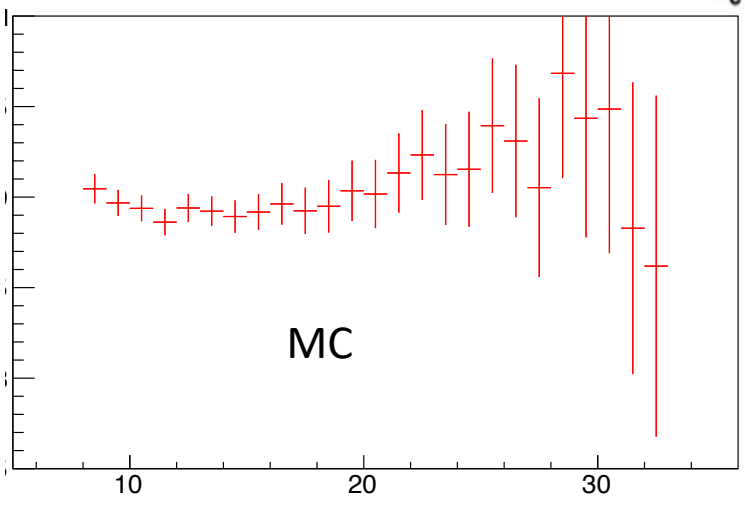
- Two independent studies:
  - data files are the same
  - MC uses SIDIS event generator (top) and a generator based inclusive cross section parametrization (bottom)
- the basic features are similar in the data and MC, and in both studies. But, devil in the details, differences must be understood – could be the difference of kinematical dependences in generators?
- the shape of the dependence, deep in efficiency around 13 degrees, agrees with DC R1 occupancy



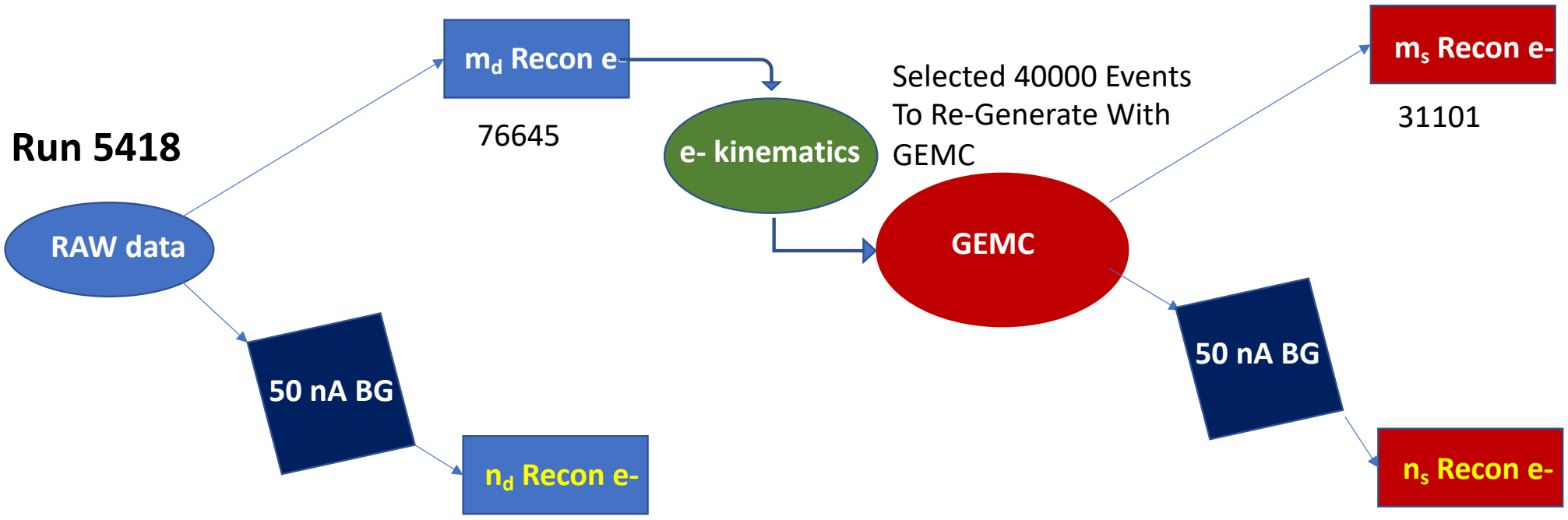








Inclusive electrons, data vs. MC merging (Joseph)



$$\frac{n_d}{m_d} \propto \frac{n_s}{m_s}$$

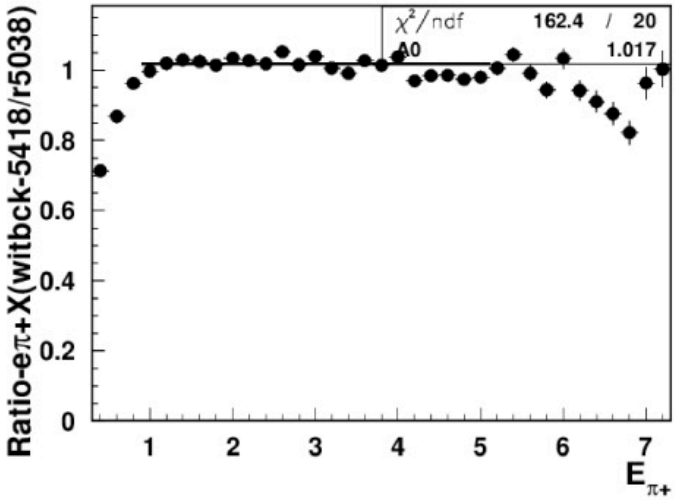
$$\frac{n_d}{m_d} = 0.88$$

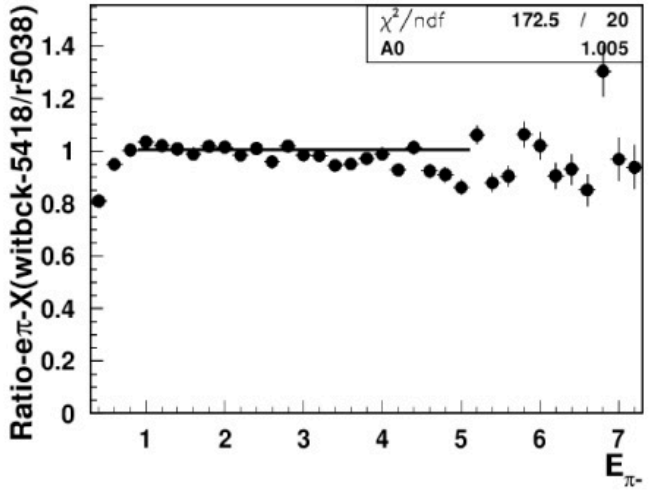
$$\frac{n_s}{m_s} = 0.91$$

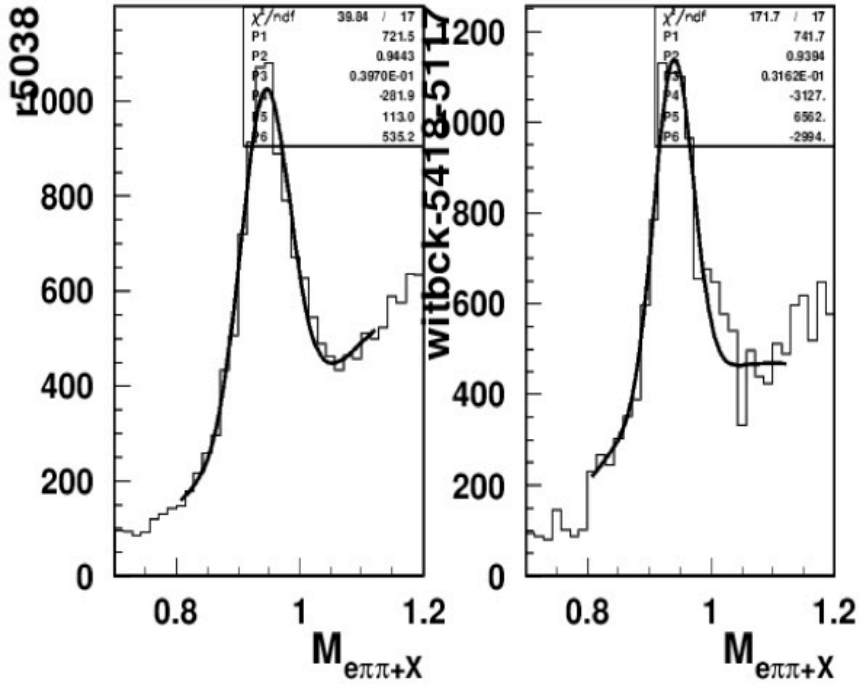
Numbers agree with previous studies – kinematic dependences have not been studies yet

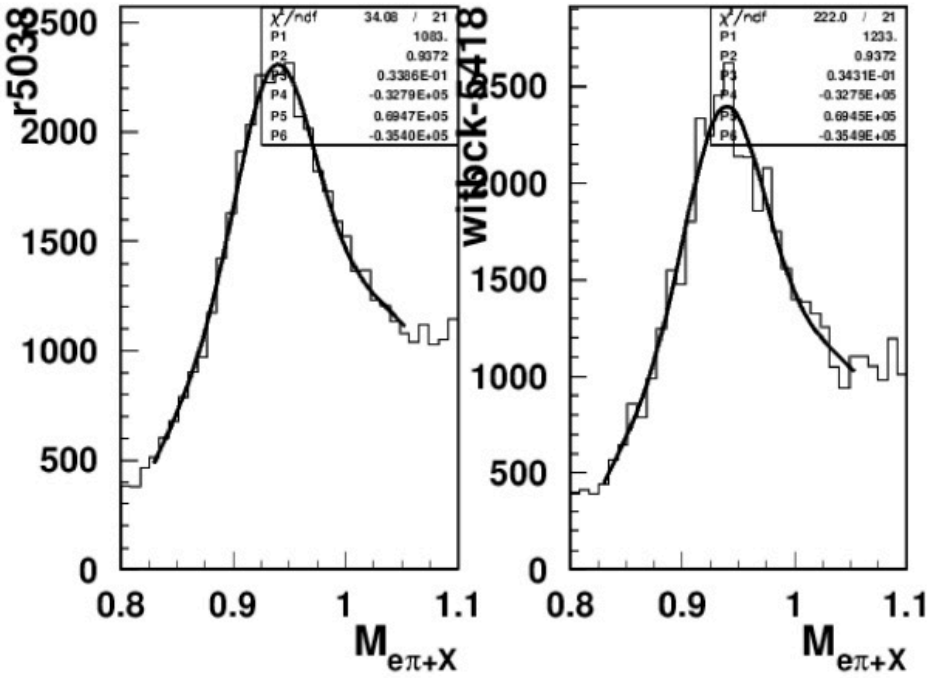
Single and double pion electroproduction (Harut)

- Comparison of 5 nA data with 40 nA merged BG (5418) with a 45 nA data (run 5038)
- Efficiency and the missing mass resolution of eπ and eππ final state
- Good agreement in the resolution the energy dependence of the efficiency has some issues at low pion momenta (< 1 GeV)









FD angular resolutions vs luminosity

Beam energy from polar angles:

$$\frac{E_{\text{beam}}}{M} = \frac{1 - \tan\theta_p \tan\theta_e/2}{\tan\theta_p \tan\theta_e/2}$$

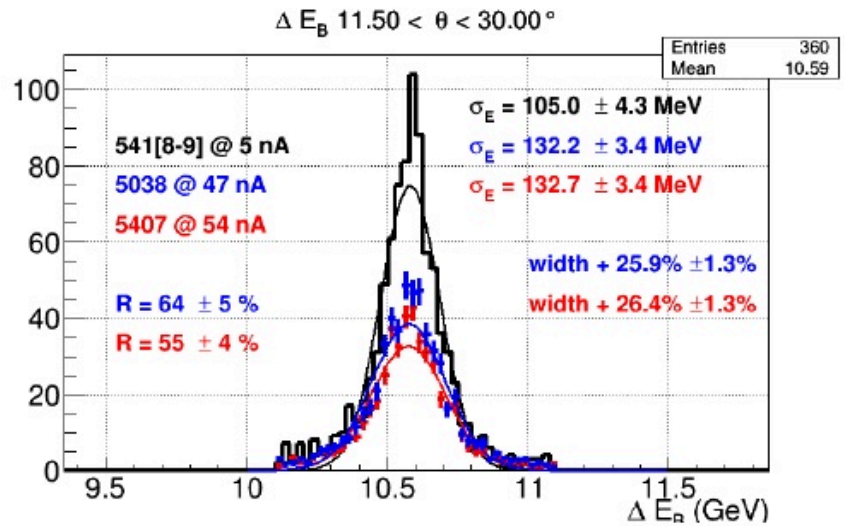
Propagate polar angle resolution from reconstructed beam energy resolution

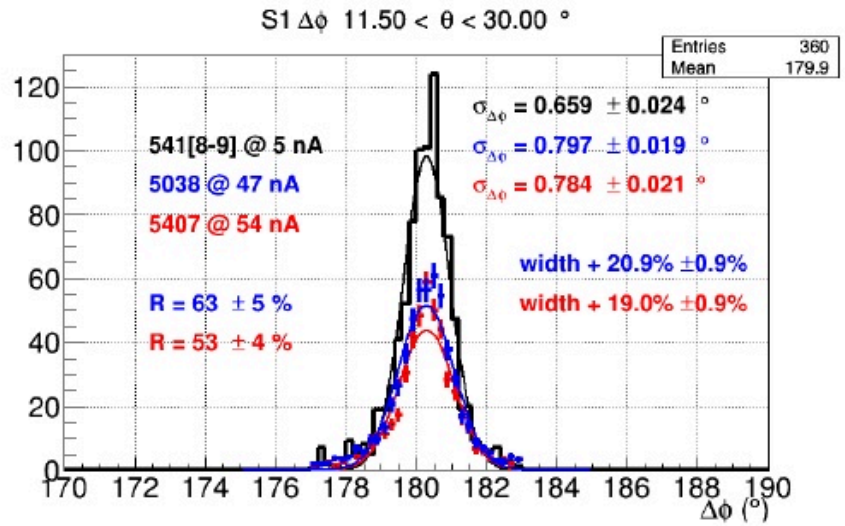
$$\langle\theta_e\rangle = 13^\circ \quad , \quad \langle p_e\rangle = 8.1 \text{ GeV}$$
$$\langle\theta_p\rangle = 35^\circ \quad , \quad \langle p_p\rangle = 3.2 \text{ GeV}$$
$$\Longrightarrow \quad \Delta\theta_p/\Delta\theta_e \approx 3.5$$

$$\frac{1}{M}\Delta E_b = \left[\frac{\partial E_b}{\partial\theta_e} \oplus \frac{\Delta\theta_p}{\Delta\theta_e}\frac{\partial E_b}{\partial\theta_p}\right]\Delta\theta_e$$

Results:

I_{beam}	ΔE_{beam}	$\Delta\theta_e(^\circ)$	$\Delta\theta_p(^\circ)$	widening
5 nA	105 MeV	0.06	0.21	ref
47 nA	130 MeV	0.075	0.2625	+25%
54 nA	135 MeV	0.078	0.273	+30%





FD Normalized rates 5 nA vs 45 nA

Ratio of FD rates consistent between elastic and radiative elastic ✓
5038 ratio 67 to 70% $\Longrightarrow$ eff(single)=82%
5407 ratio 56 to 58% *i* $\Longrightarrow$ eff(sigle)=75%

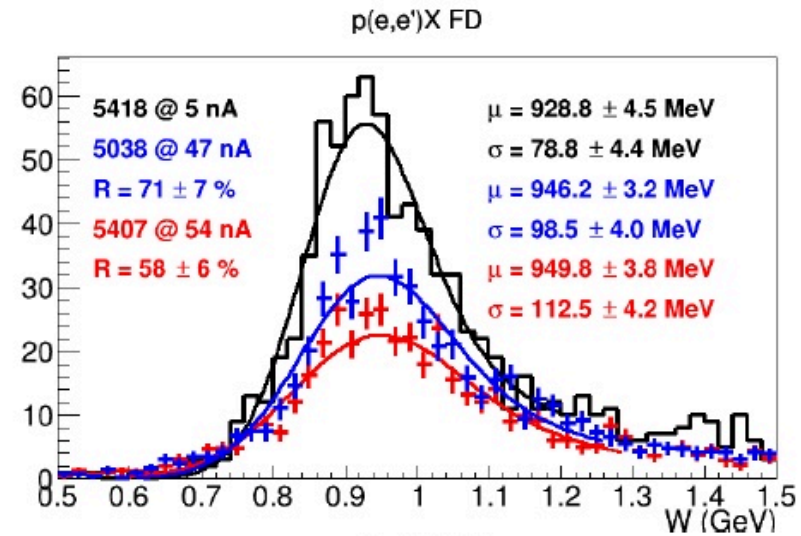
Degraded fit results: dispersion of the underlying distributions per sector ✗

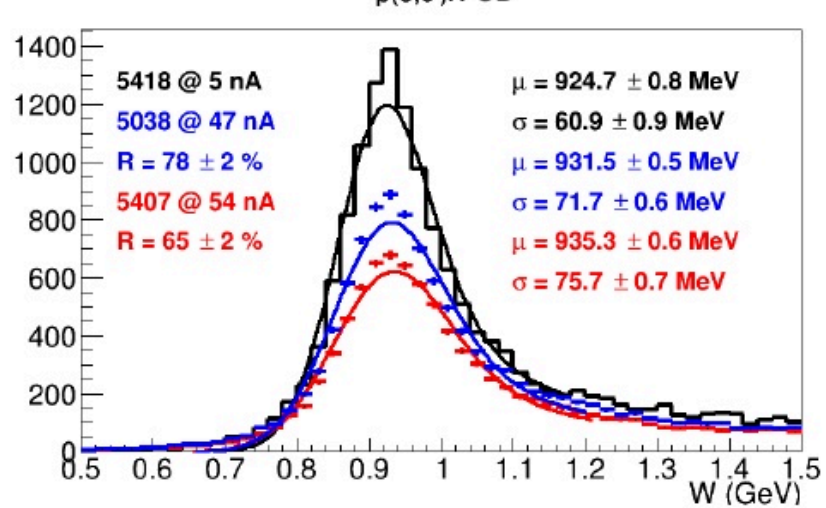
$\rightarrow$ need additional luminosity scan data

Forward Detector efficiency: ratio of rates worse than CD. Overall CD efficiency already low (?)

$$W^2 \approx M^2 + 2M\left(E - E'\right) - EE'\theta^2$$
$$2W\Delta W \approx \left[2M + E\theta_e^2\right]\Delta E' \oplus \left[EE'\theta_e\right]\Delta\theta_e$$

I_{beam}	ΔW	$\Delta\theta_e$	Δp_e	+wide
5 nA	79 MeV	0.06°	0.5%	ref
47 nA	98.5 MeV	0.075°	0.7%	+40%
54 nA	112.5 MeV	0.078°	0.8%	+60%





Summary of elastic studies

FD resolutions:

I_{beam}	$\Delta\theta_e$	+wide	$\Delta\phi_e$	+wide	Δp_e	+wide	ΔE_b	ΔW
5 nA	0.06°	ref	0.6°	ref	0.5%	ref	105 MeV	79 MeV
47 nA	0.075°	+25%	0.8°	33%	0.7%	+40%	130 MeV	98.5 MeV
54 nA	0.078°	+30%	0.8°	33%	0.8%	+60%	135 MeV	112 MeV

CD resolutions:

I_{beam}	$\Delta\theta_p$	+wide	$\Delta\phi_p(°)$	+wide	$\Delta p_p(GeV)$	+wide
5 nA	0.4 °	ref	0.6-0.8°	ref	?	ref
47 nA	0.4 °	0% ?	0.7-0.9°	12-16%	?	?
54 nA	0.4 °	0% ?	0.7-0.9°	12-16%	?	?

Efficiencies from ratios of absolute rates:

I_{beam}	Eff FD×FD	Eff FD	Eff FD×CD	Eff CD
47 nA to 5 nA	67 to 70%	82%	77%	88%
54 nA to 5 nA	56 to 58%	75%	63%	79%

Efficiencies somewhat lower than in inclusive studies, could be efficiency for protons lower than electrons?

Summary

- Software for beam background merging with the data and MC event is ready, undergoing validation
- Work done in the past few weeks by Raffaella, Harut, Nick, FX, Joseph suggests that the existing software is very close to reproducing charged-particle reconstruction efficiency and 3-momentum resolution in the CLAS12 FD
- The statement “very close” can be quantified as 3% - 5% differences between different studies and various dependencies
- To advance in understanding these differences, aside from more studies and comparison results, analysis of luminosity scan data as it has been done in the past is necessary. We expect data will be available soon
- To complete the software development for BG merging in MC, the following should happen
  - implement different time shifts for fADCs and TDCs in GEMC
  - tuning the DC TDC smearing parameters in GEMC
  - tuning the intrinsic wire inefficiency function in GEMC
  - GEMC release with merging for all detectors and to run on outside of JLAB (OSG …)
- While still some work in front of us for full validation, the software is ready for users to start using it, testing on different physics reactions, kinematic domain, with different event generators – more studies will always help