Nuclear Physics Working Group Summary Report

M. H. Wood, Canisius College

June 21, 2019

Conferences

Since March 2019 meeting, there were 18 presentations.
Contributed – 10, General – 7, Poster - 1

Active Reviews

- **Neutral pion electroproduction ratios off C, Fe, and Pb to D**,
  T. Mineeva et al. (analysis review, Round 2 responses to committee)
- **Validation of neutrino energy estimation using electron scattering data**,
  M. Khachatryan et al. (analysis review, Round 3)
- **Coherent DVπ^0P with CLAS EG6**, F. Cao et al. (analysis review completed)
- **Probing the strong nuclear interaction at neutron-star densities**,
  A. Schmidt et al. (ad hoc review -> collaboration-wide review)

Pre-Review Review

- **Charged Pion Color Propagation in Nuclei,** H. Hakobyan and R. Dupre.

Readiness Reports

RG-D and RG-E talks on June 19 during Collaboration Meeting

08:30 - 10:00

Nuclear Physics Working Group - I

Bluejeans link:https://bluejeans.com/7168882426

Convener: Dr. Michael Wood (Canisius College)

Location: A110

08:30 **NPWG Business** *10'*

Speaker: Dr. Michael Wood (Canisius College)

Material: Slides

08:40 **Constraining neutrino-nucleus interactions with electron scattering data** *20'*

Speaker: Mariana Khachatryan (ODU)

Material: Slides

09:00 **Update on BAND** *20'*

Speaker: Florian Hauenstein (Old Dominion University)

Material: Slides

09:20 **BAND Laser System** *20'*

Speaker: Andrew Denniston (MIT)

09:40 **CLAS12 Drift Chamber Calibration** *20'*

Speaker: Dr. Taya Chetry (Mississippi State University)

Material: Slides

10:30 - 12:00

Nuclear Physics Working Group - II

Bluejeans link:https://bluejeans.com/7168882426

Convener: Dr. Michael Wood (Canisius College)

Location: A110

10:30 **Neutron SRC** *20'*

Speaker: Dr. Igor Korover (NRCN)

Material: Slides

10:50 **Contact extraction from fitting** *20'*

Speaker: Axel Schmidt (MIT)

Material: Slides

11:10 **Charged Pion Hadronization Update** *20'*

Speakers: Dr. Hayk Hakobyan (UTFSM), Mr. Sebastian Moran (UTFSM)

Material: Slides

Update: Studies of neutrino energy reconstruction using electron scattering data

Mariana Khachatryan - ODU

Energy Reconstruction for QE reactions

(1) Cherenkov detectors:
- Detect: leptons & pions
- Miss: protons and neutrons

(2) Tracking detectors:
- Detect: Charged particles + π^0
- Miss: Neutrons and charged particles below threshold.

Use Lepton kinematics
Assuming QE interaction

$$E_{QE} = \frac{2M\varepsilon + 2ME_l - m_l^2}{2(M - E_l + |k_l|cos(\theta_l))}$$

ε-single nucleon separation energy
M- nucleon mass
m_l – outgoing lepton mass
k_l, E_l -lepton three momentum, energy
θ_l-lepton scattering angle

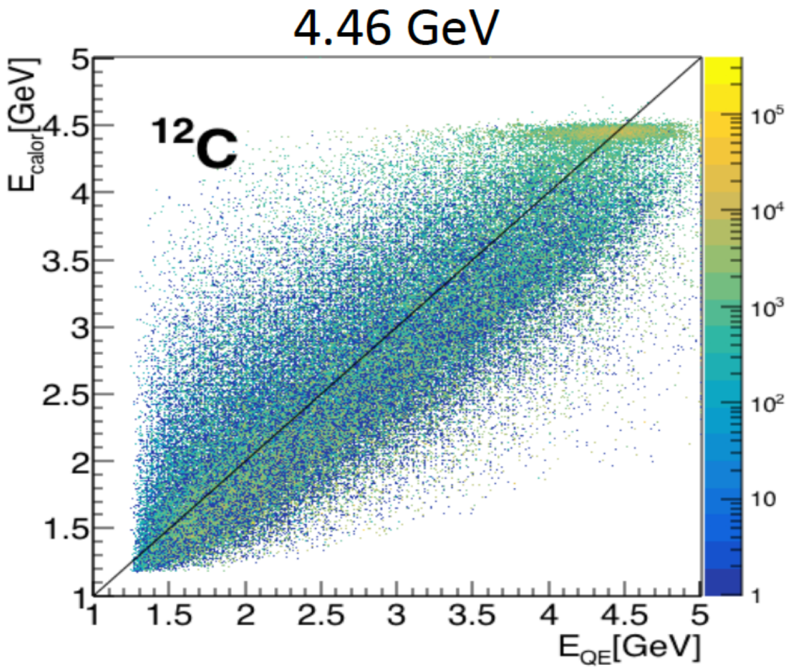
Use Final-State Calorimetry
Assuming low residual excitations

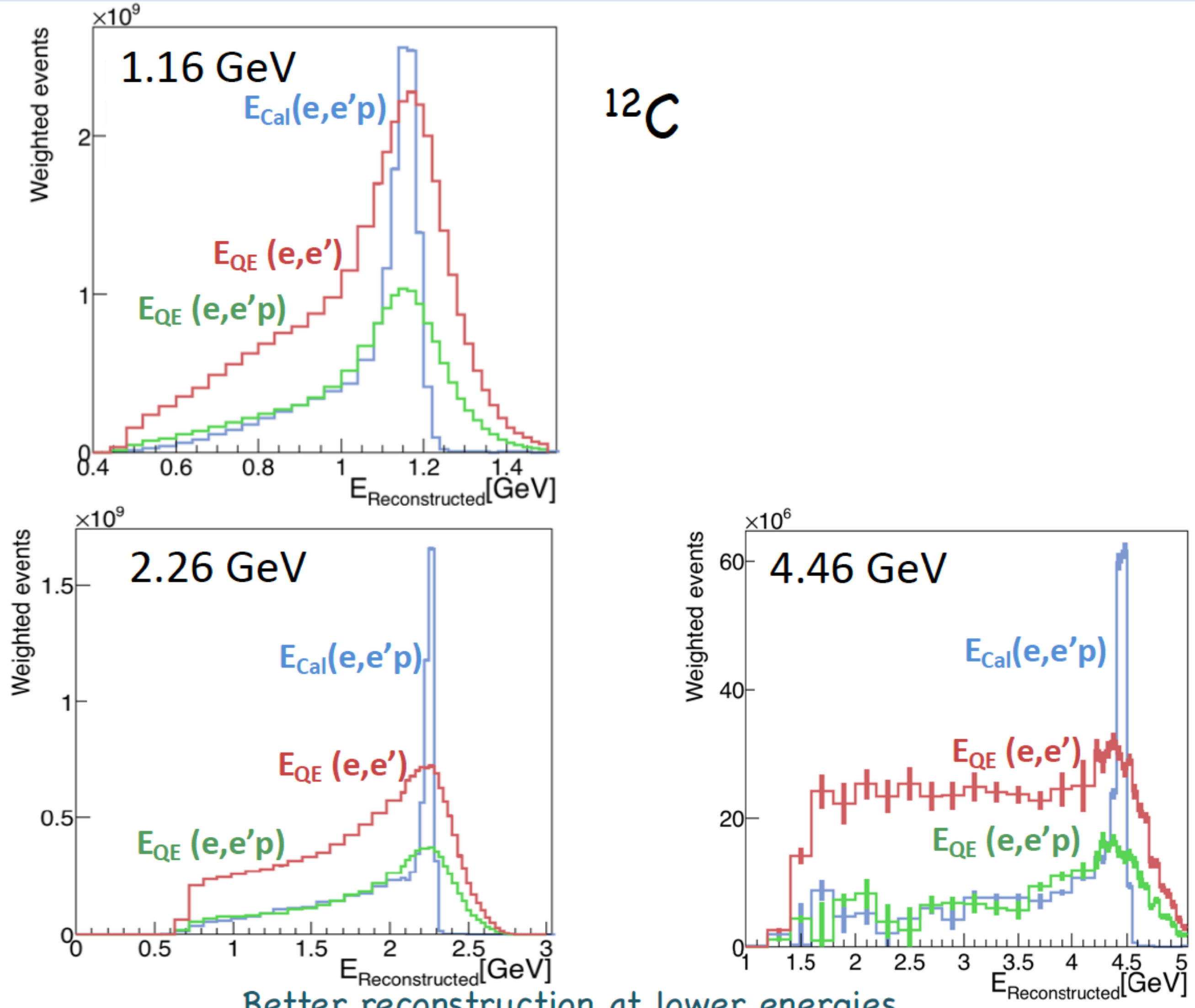
$$E_{Cal} = E_l + \sum T_p + \varepsilon + \sum E_\pi$$

T_p-kinetic energy of knock out proton
E_π-energy of produced meson

Large E dependence

Agreement between to methods doesn't imply correct energy reconstruction.





Better reconstruction at lower energies.

Summary

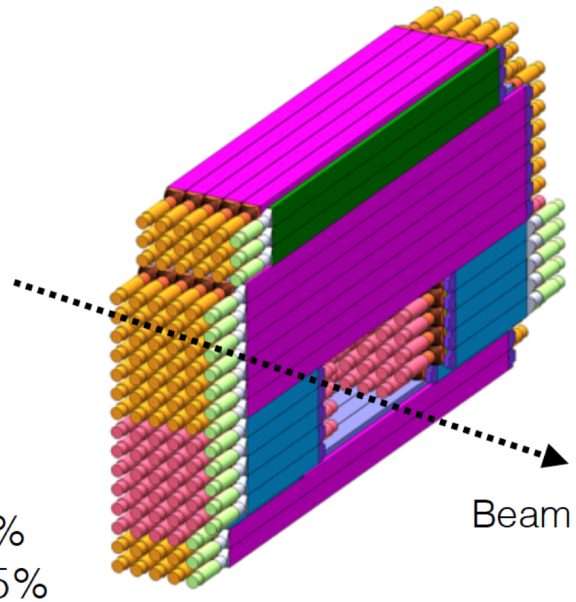
1. The first use of electron data to test neutrino energy reconstruction algorithms
   - select zero-pion events to enhance quasi-elastic signal
     - ✧ Subtract for undetected π and extra p.
   - just using scattered lepton (E_{QE})
     - ✧ used in Cherenkov-type neutrino detectors
   - total energy of electron plus proton (E_{Cal})
     - ✧ used in calorimetric neutrino detectors
2. Only 0.1-0.66 of events reconstruct to within 5% of the beam energy
   - better for lighter nuclei
   - improved by a transverse momentum cut
3. Added 1GeV analysis.
4. Analysis complete.
5. Update note for committee.
6. Anticipate paper submission soon.

BAND Detector Update

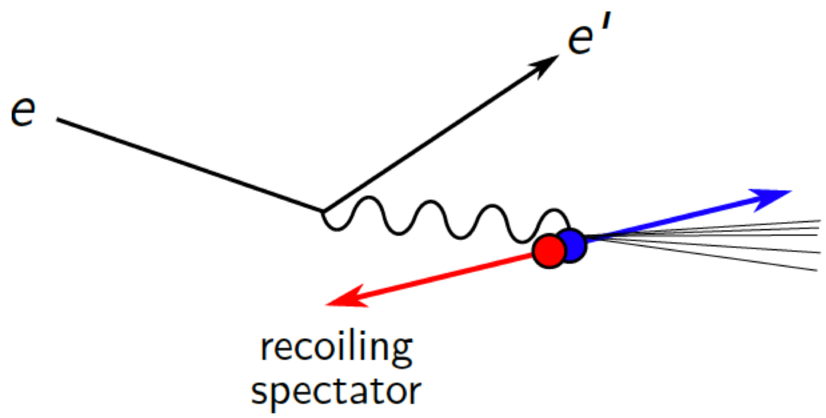
Florian Hauenstein,
Efrain Segarra,
Rey Cruz-Torres,
CLAS Collaboration Meeting
06/20/19

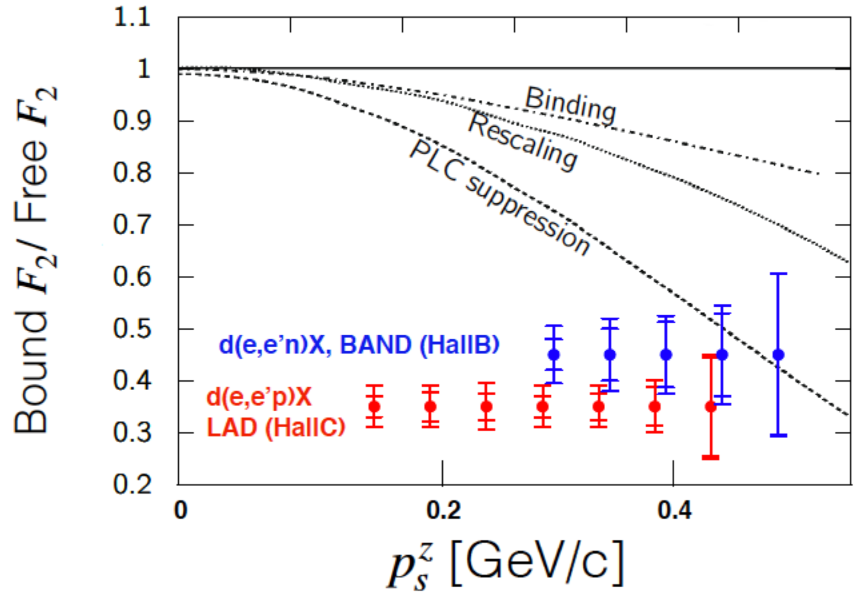
Overview of BAND

- 5 layers thick (36cm total) with veto layer (1cm thick)
- 140 scintillator bars
- Bar resolution < 200 ps
- 3 meters upstream of target
- 155° < θ < 176°, 200 msr
- Design neutron efficiency ~35% and momentum resolution ~1.5%
- Laser system for calibrations —> see Andrew's talk



Tagged DIS on Deuterium





- "Tag" interacting nucleon by measuring spectator
- How does the bound nucleon structure function depend on nucleon momentum?
- Explain the EMC effect

Base Level Calibrations

Cosmic Data

Source Data

Laser Data

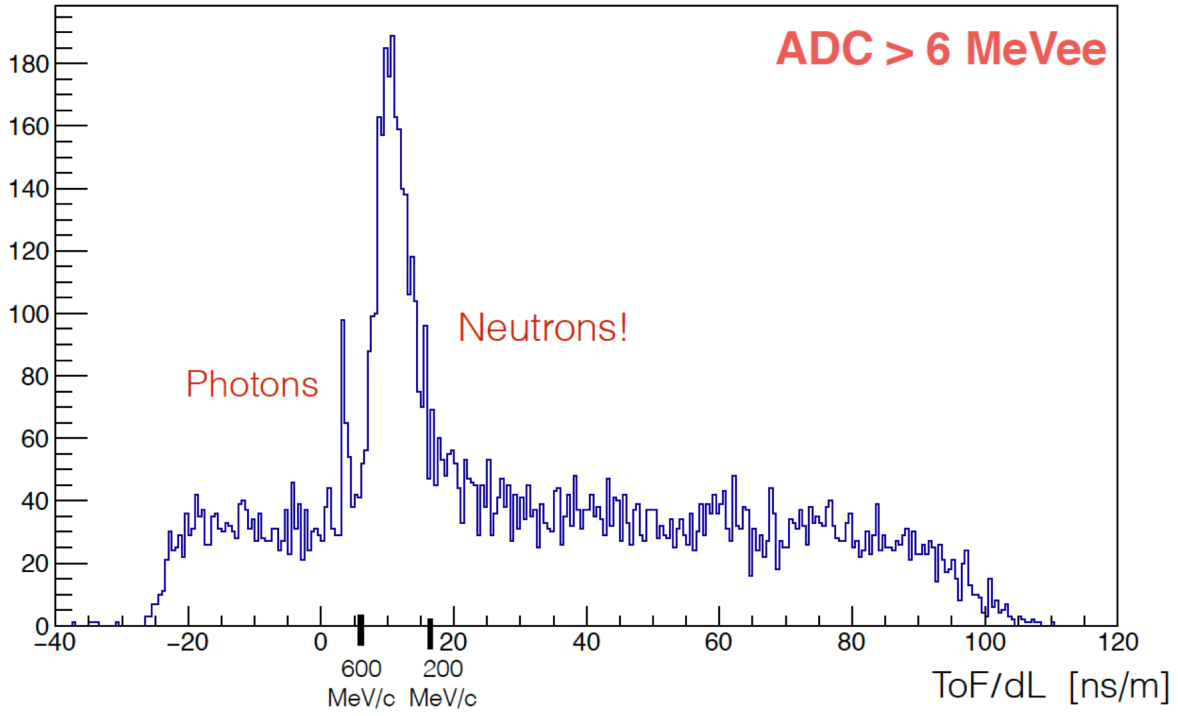
- HV Gains ✓
- ADC calibration ✓
- TDC/FADC phase offset ✓
- TDC time walk ✓
- Effective velocity ✓
- Bar attenuation ✓
- Timing offsets ✓

Prod Data

- Neutron efficiency
- Neutron momentum resolution

ToF/m Spectrum

One full day@50nA, DIS cuts, BAND neutral hits



BAND Simulations

- Stand-alone Geant4 simulation
  - CLAS12 via acceptance map (no detailed detector simulation)
  - Simple CLAS12 momentum resolution
  - Tagged DIS neutrons and accidental background neutrons
  - Check of analysis methods and routines

- Implementation work for GEMC
  - BAND
  - Upstream Beam pipe ✓
  - Micromegas electronic boxes
  - CTOF PMTs and shielding
  - CND PMTs and shielding

Summary and Outlook

- Tagged DIS measurements to explain EMC effect
- Finished first set of BAND calibrations
- Clear neutron signal in DIS kinematics
- S/B study to determine ADC cut
- Start implementing BAND and upstream components to GEMC

- Finishing of implementing BAND and other components to GEMC
- Developing analysis chain for physics channel with simulations
- **NEED** Fall 2019 low energy data for neutron efficiency and momentum resolution with

BAND Laser Calibration System

Andrew Denniston, MIT

Laser system to perform timewalk corrections has been implemented and gain monitoring.

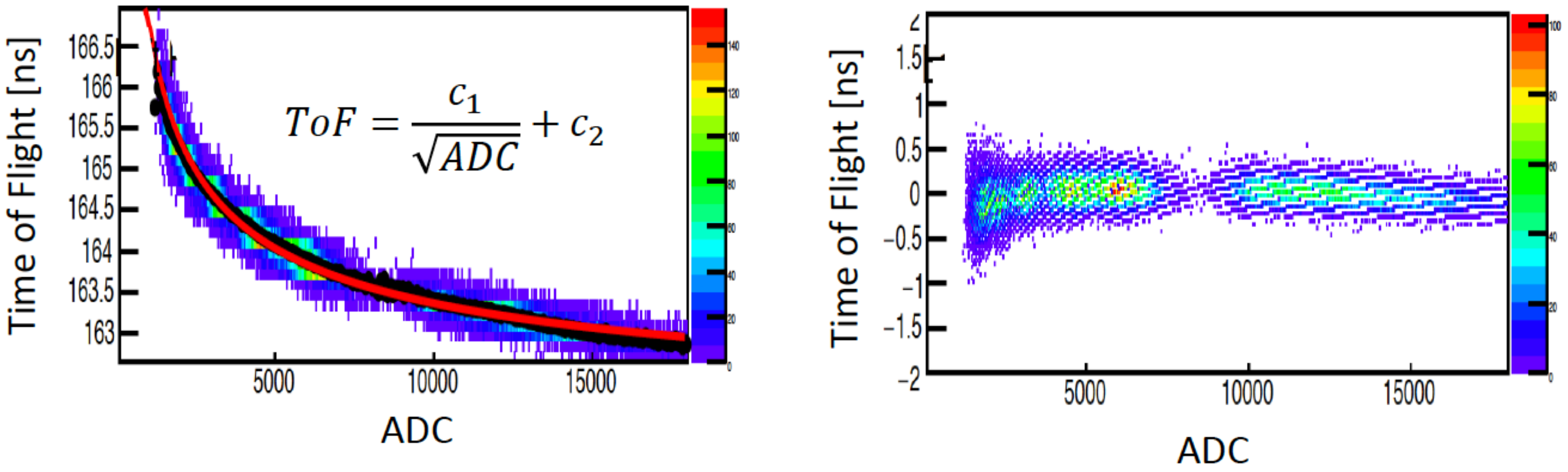
Developed at MIT and implemented on BAND.

Gain monitoring study has lead to switch of a slightly higher wavelength laser.

The upgraded system is being worked on at MIT and will be installed on BAND for the Fall run.

Time Walk Correction (BAND)

$$ToF = TDC_{mean} - ref$$



CLAS12 Drift Chamber Calibration: Updates

Taya Chetry
Mississippi State University
(For the DC Calibration team)

CLAS Collaboration Meeting
06/20/2019

DC Calibration Team

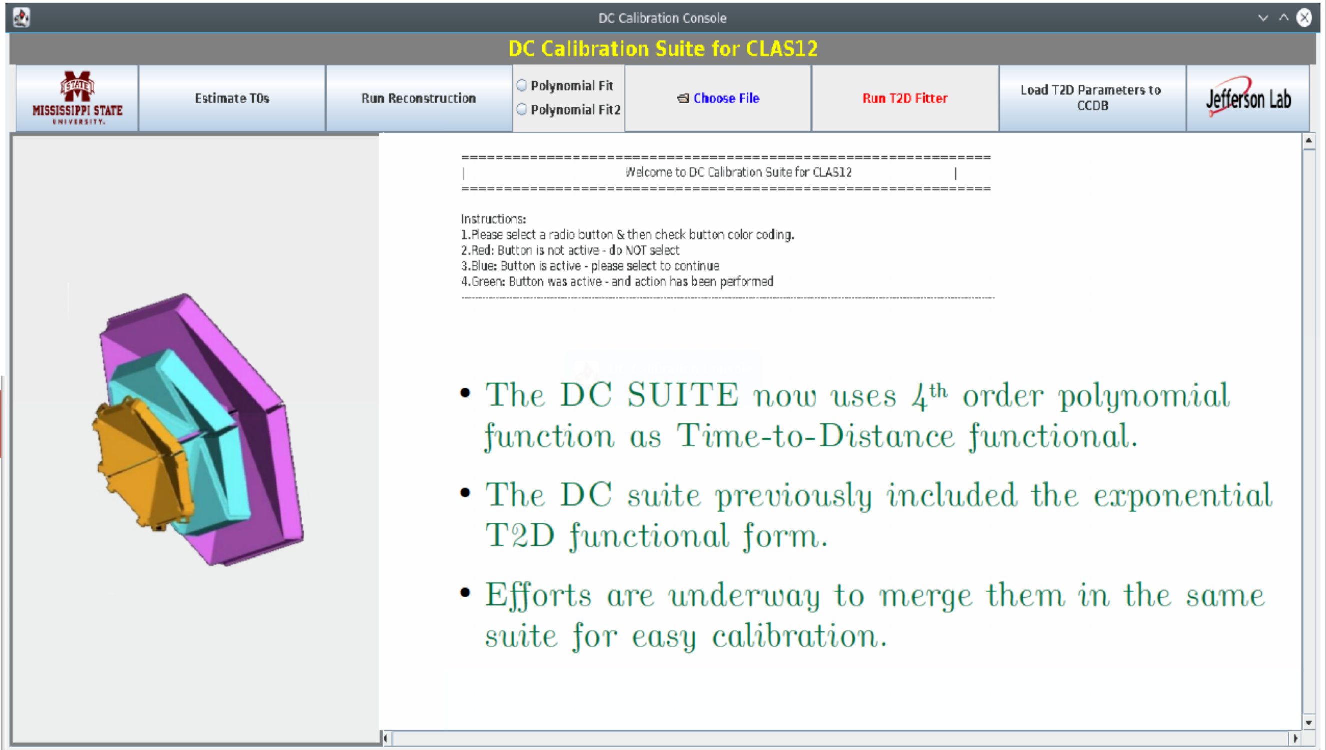
Group Leader
Mac Mestayer (Jlab)

Calibration Suite Optimization/Maintenance
Taya Chetry (MISS)

Calibrators
Dilini Bulumulla (ODU), Shirsendu Nanda (MISS)

Reconstruction
Veronique Ziegler (Jlab)

DC Calibration Console

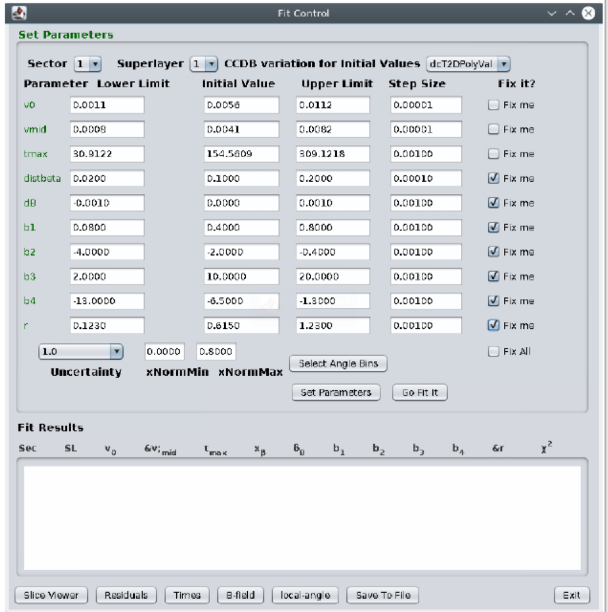


- The DC SUITE now uses 4^{th} order polynomial function as Time-to-Distance functional.
- The DC suite previously included the exponential T2D functional form.
- Efforts are underway to merge them in the same suite for easy calibration.

Understanding the parameters — Poly4

- Polynomial function:
  - t(x)=ax + bx^2 + cx^3 + dx^4

    where, x = trkDOCA
- There are 4 constraints used to solve:
  - Velocity at x = 0 is the saturated drift velocity, v0; so that v0 = 1/d
  - Inflection point at x=r is the parameter **r**. (maximum distance is referred as the dmax)
  - Velocity at the inflection point is the parameter **vmid**.
  - Time at dmax*cos(30-α) is **tmax**, where α is the local angle.



- The drift time is given by:

$$t = TDC - T_{start} - T_{flight} - T_{prop} - T_0 - T_{beta}$$

TDC time is corrected for trigger jitter and latency, flight time of the track, time of propagation of the signal along the wire to the readout, cable delay, and beta dependent time-walk correction

Show code →

Cook summary: 5038 (using exponential T2D functional)

Cook Level	μ (mean) [cm]						σ (resolution) [cm]					
V0	-0.011	-0.008	-0.004	0.0	-0.012	-0.014	0.038	0.036	0.036	0.038	0.039	0.039
V1	-0.013	-0.001	-0.004	-0.01	-0.018	-0.021	0.040	0.038	0.044	0.055	0.041	0.041
V2	0.006	-0.003	-0.005	-0.003	-0.022	-0.030	0.038	0.037	0.051	0.047	0.040	0.042
V3	-0.006	-0.006	-0.057	0.043	-0.024	-0.036	0.036	0.036	0.073	0.072	0.039	0.044
V1(Dilini)	-0.013	-0.003	-0.025	-0.029	-0.014	-0.016	0.040	0.037	0.038	0.048	0.035	0.036

Coatjava: 5.9.0; Hipo4

summary: 5038 (using 4^{th} order poly T2D function)

Cook Level	μ (mean) [cm]						σ (resolution) [cm]					
1	0.001	-0.001	-0.025	-0.019	-0.018	-0.000	0.042	0.046	0.082	0.082	0.050	0.048
2	0.034	0.034	0.020	0.021	-0.002	-0.003	0.043	0.045	0.041	0.046	0.051	0.048
3	-0.009	-0.001	0.020	0.021	-0.002	-0.003	0.042	0.042	0.041	0.046	0.051	0.048

- Slight improvement in the resolution (not really – compared to what we expect!)
- It is important to iterate (and learn as we repeat) and extract the best practices for the calibration using the new functional: in progress!

Summary

- New 4^{th} order polynomial time-to-distance function to better describe the data has been implemented in the calibration GUI.
- `t0` and `tmax` timelines for determining "When to calibrate".
- Sanity checks/iterations in progress for the optimal calibration parameters: "How to calibrate?"

Contact extraction from fitting

CLAS Nuclear Physics Working Group Meeting

Axel Schmidt

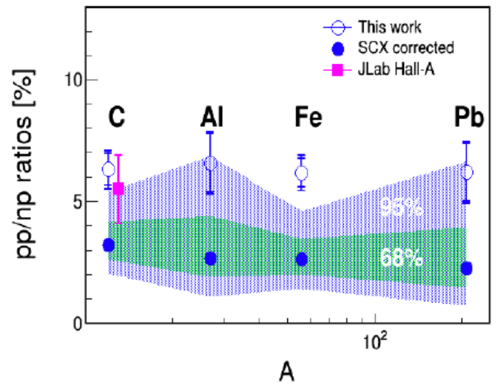
MIT

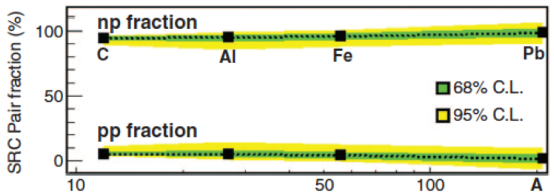
June 20, 2019

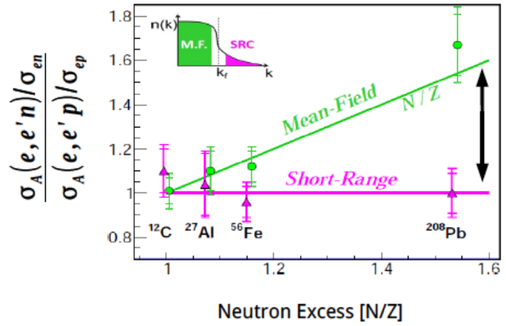
Several previous EG2 analyses have identified SRC pair break-up events.

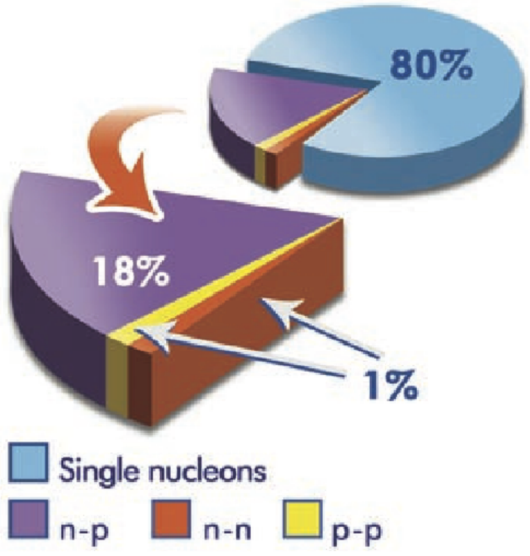
- Or Hen (2012):
  $(e, e'pp)/(e, e'p)$ confirms *np*-dominance in heavy nuclei
- Meytal Duer (2017):
  Direct confirmation of *np*-dominance by detecting neutrons in ECal
- Erez Cohen (2018):
  CM motion in *pp* pairs is Gaussian, $\sigma \approx 150$ MeV/c
- Igor Korover (*next talk!*):
  Detection of recoil neutrons in ToFs

SRC pairs are predominantly neutron-proton.



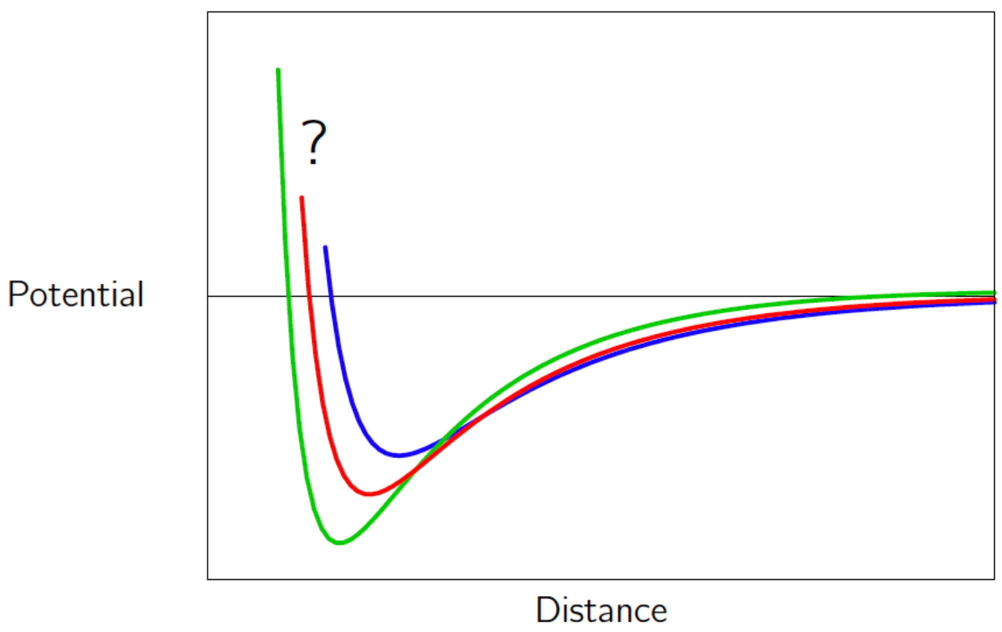






The NN interaction is poorly constrained at short-distance.

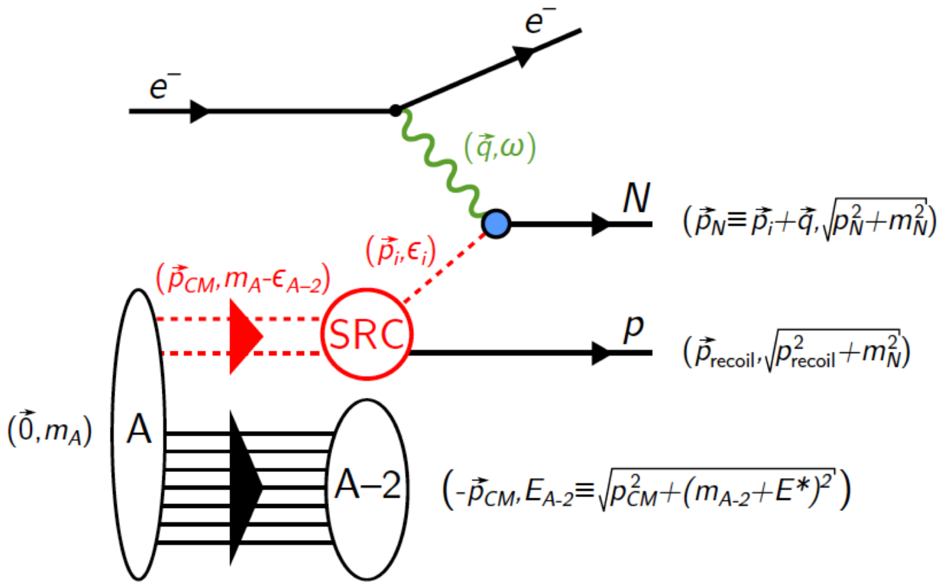
π-production complicates the interpretation of phase-shifts at high-momentum.



Generalized Contact Formalism:

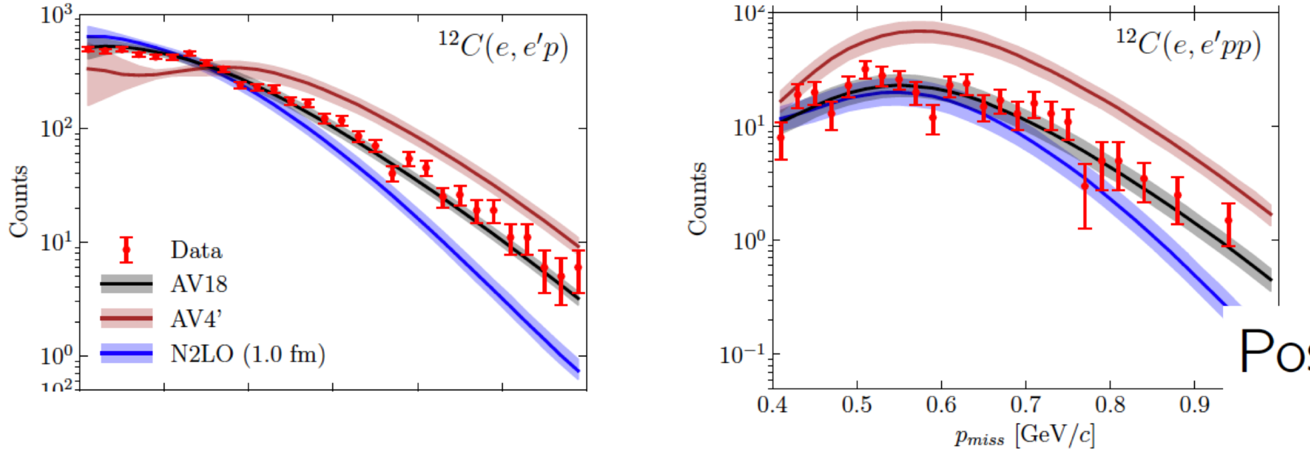
Use scale separation to calculate PWIA cross section

For pairs with high relative momenta:



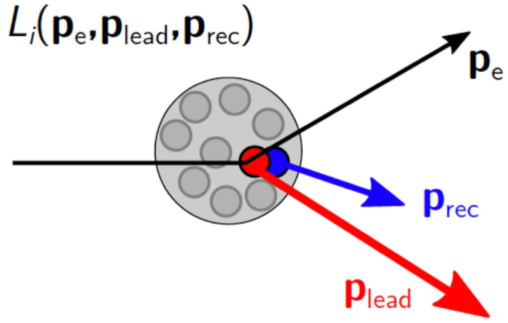
$$d\sigma \sim \sigma_{eN} \cdot n(\vec{p}_{CM}) \cdot \sum_{\alpha} C_\alpha |\tilde{\varphi}_\alpha(k)|^2$$

Missing momentum distribution



Possible approaches

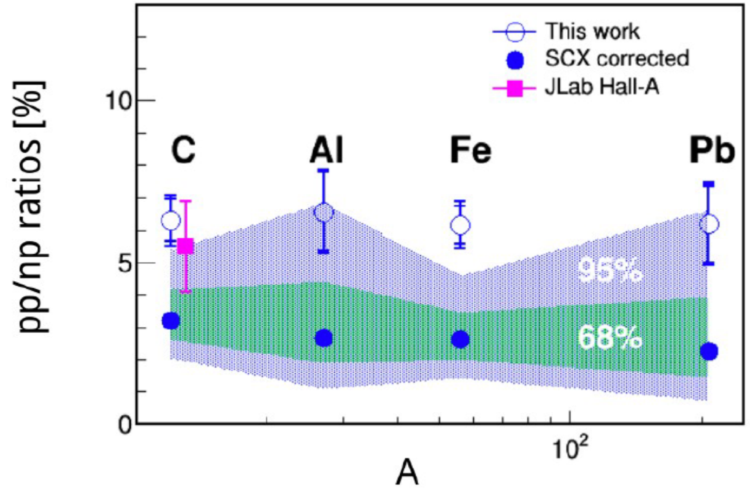
1. Compare several binned distributions
   - Run generator for each param. value
   - Which distributions?
   - Ignores full dimensionality
   - Limited by statistics
2. Unbinned Likelihood
   - Likelihood each event
   - Full dimensionality
   - The generator is the wrong tool



NN interaction study using C(e,e'pn) reaction at SRC kinematics

Igor Korover
NRCN & Tel Aviv University

Why to also study A(e,e'pn)/A(e,e'p)?



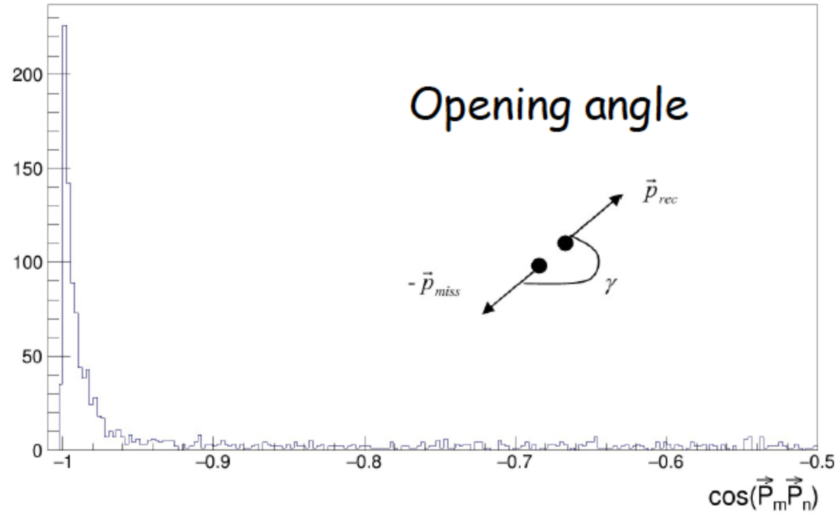
A(e,e'pn) → Small SCX correction

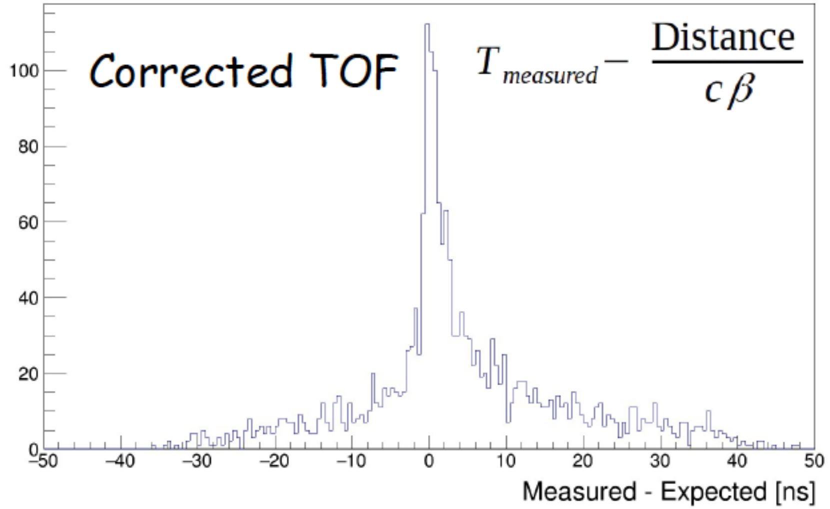
A(e,e'pp) → Large SCX correction

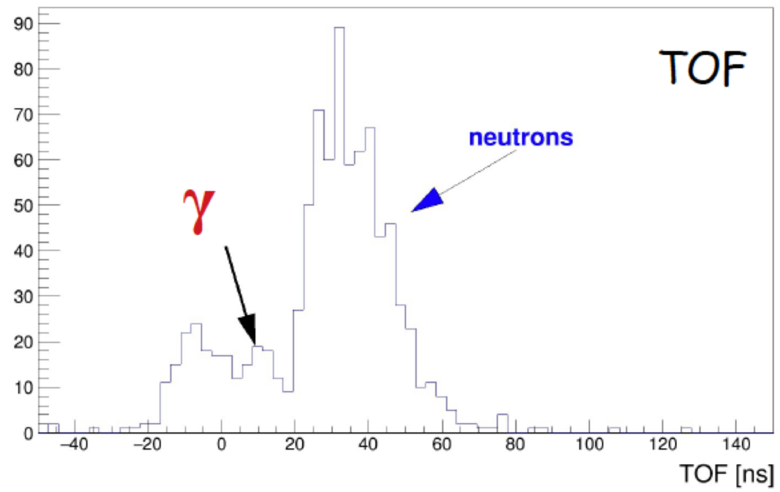
Identification of neutron candidates as neutrons

d(e,e'p)

Cuts:
- Vertex
- Vertex difference
- Missing Mass
- Leading Proton
- Missing Momentum
- Energy deposition





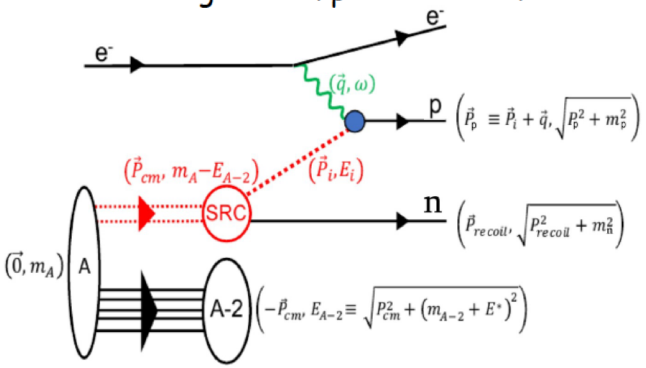


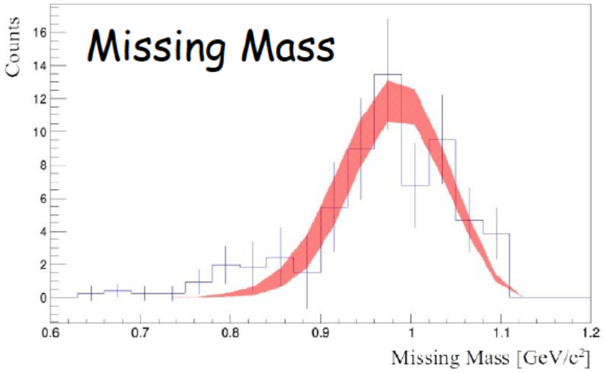
β – Calculated based on missing momentum

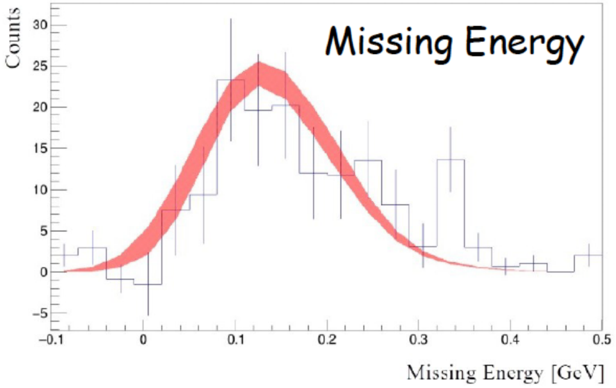
Comparison between the GCF

See Axel talk for details

Generator using the simple reaction mechanism







Summary

C(e,e'pn)/C(e,e'p) is complimentary to C(e,e'pp)/C(e,e'p) with less sensitive to the SCX correction.

Missing momentum dependence is consistent with the prediction of GCF model.

Analysis report will be submitted in the following weeks

Charged Pion Hadronization Update

CLAS Collaboration Meeting

(results of CLAS EG2 experiment)

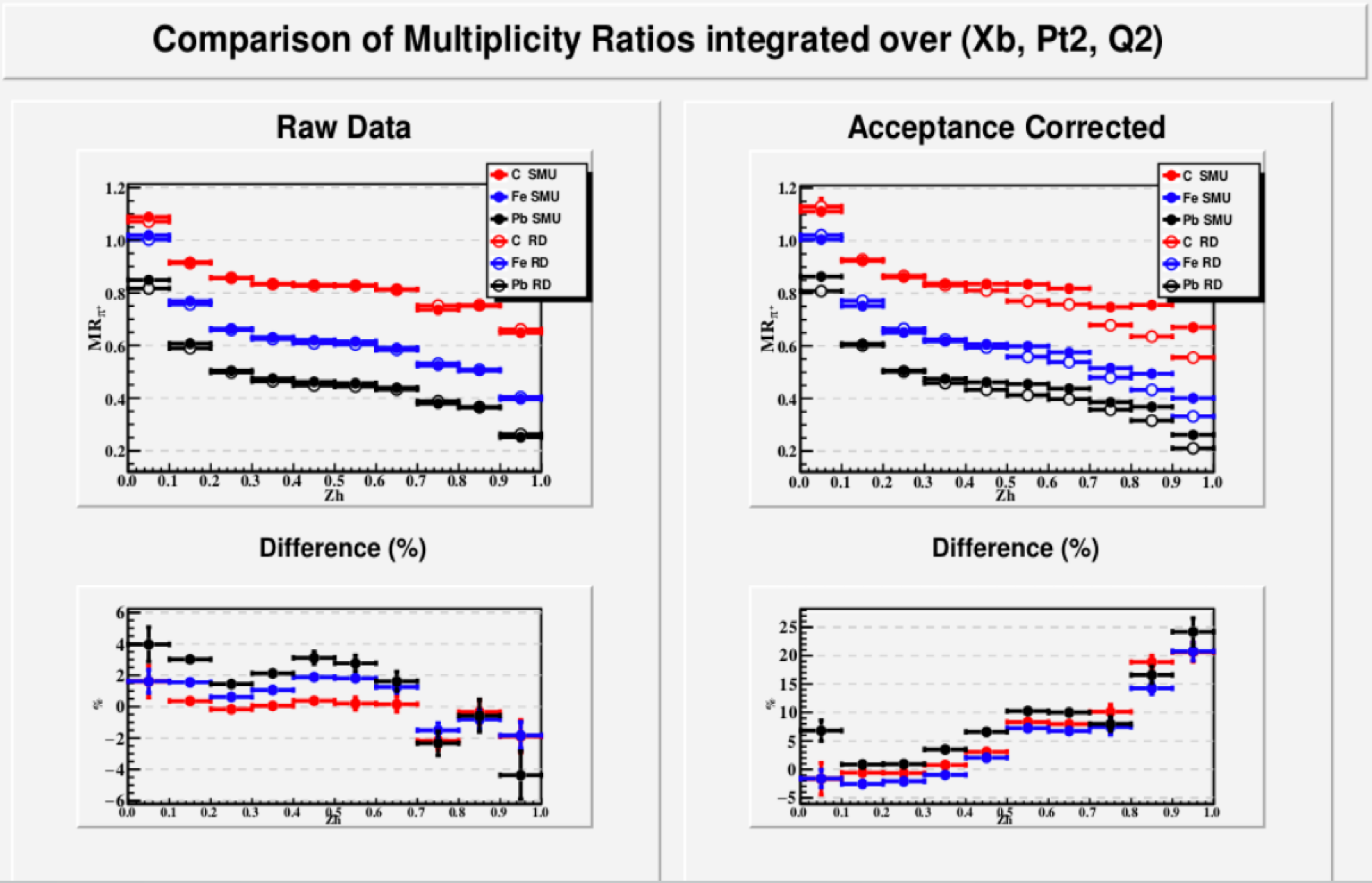
Sebastian Moran, Hayk Hakobyan and others

20th of June, 2019

Hadronic multiplicity ratio

$$R_M^h(z,\nu,p_T^2,Q^2,\phi) = \frac{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_A}{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_D}$$

Disagreement between two independent analysis done Santa María University group (SMU) and by Raphael Dupré (RD).



List of observations/suggestions from the committee

8.

- Apply the same vertex cuts in the simulations. Study the absence of the Y-vertex offset in part of SMU simulations.

- In SMU analysis use tighter timing cuts in TOF PID for pions with P < 2.7 GeV

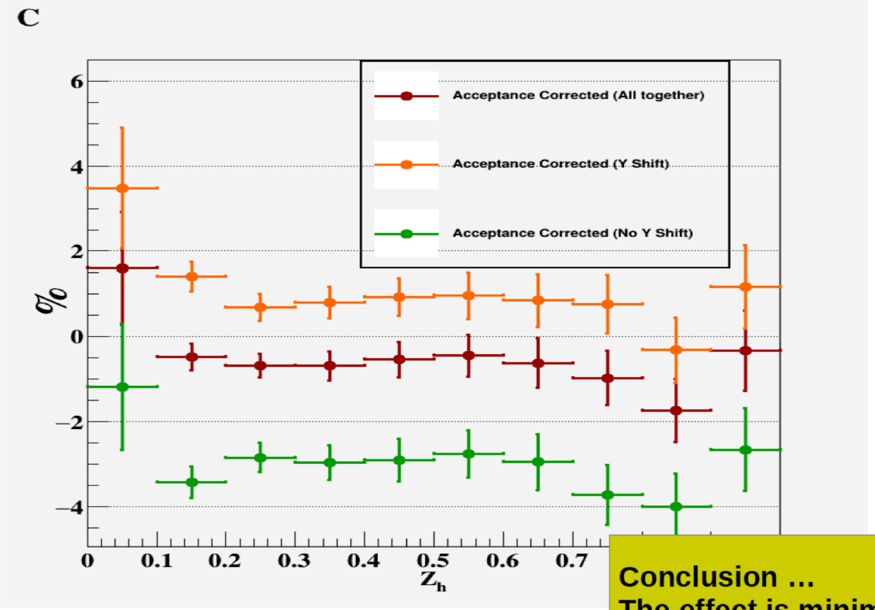
- In the PID for high momentum pions (P > 2.7 GeV) understand the difference between Chereckov counter method (SMU) versus TOF (RD).

- Find the differences in the overall acceptance. Make a comparison of the generated events between the two analyses. Compare the different parameters in the Pythia input.

- Study the number of simulation bins dependence on final analysis.

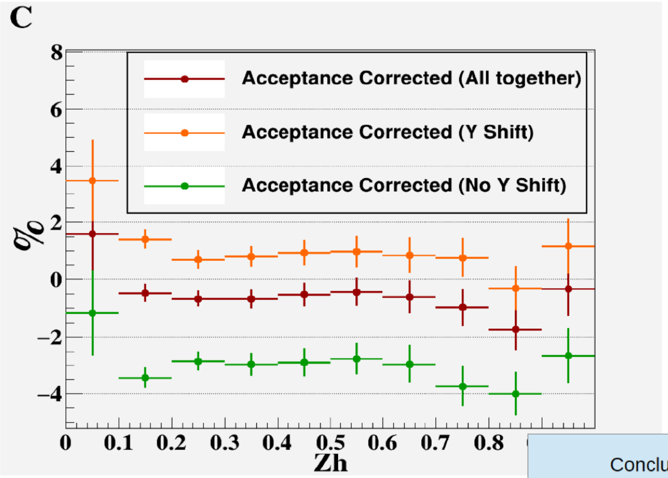
14.

Effect of this new cuts for positive pions in the Acceptance for **SMU** analysis:



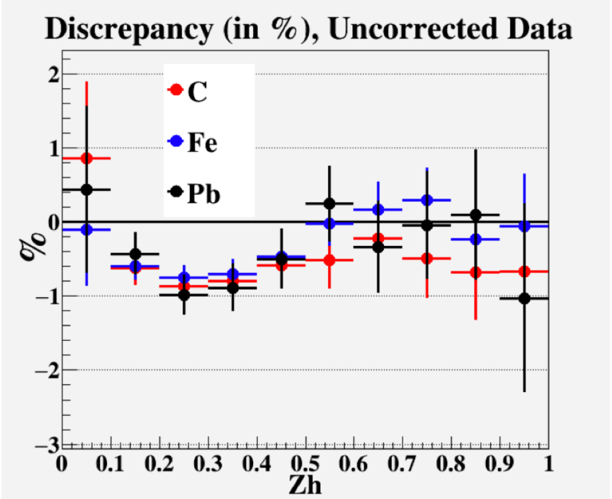
Conclusion …
The effect is minimal

Effects of the acceptance, for **SMU** only, in the Multiplicity Ratio, for the Accepta
done with the three set of simulations, for each target separately:



Conclusio
this changes th
but is not the main
discrepancy c

Now, if in **SMU** analysis used the T.O.F method for all P, without making the distinction at P=2.7, and also the cuts in ΔT for P < 2.7 are tighter, so it takes only the peak, the discrepancy between both analysis decreases:

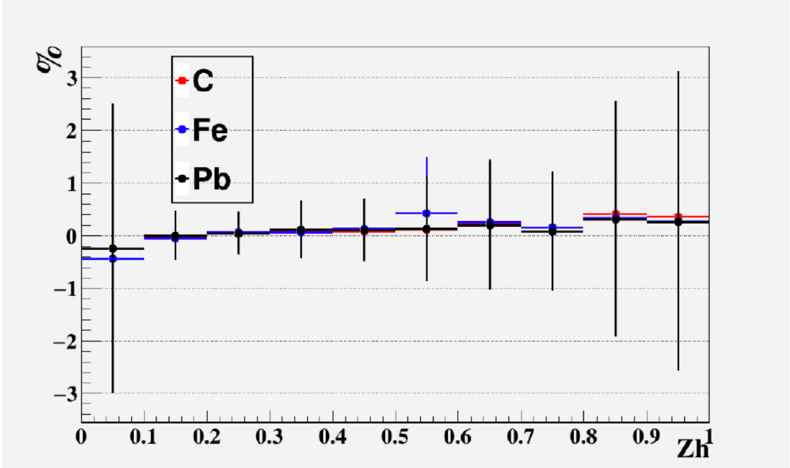


Both Analysis agreed within ~1% difference at data level

28.

The difference between the MR with the acceptance performed With the Z shift and without it is plotted here:

Difference in the Multiplicity Ratio, when the Z shift is applied or not in the simulation

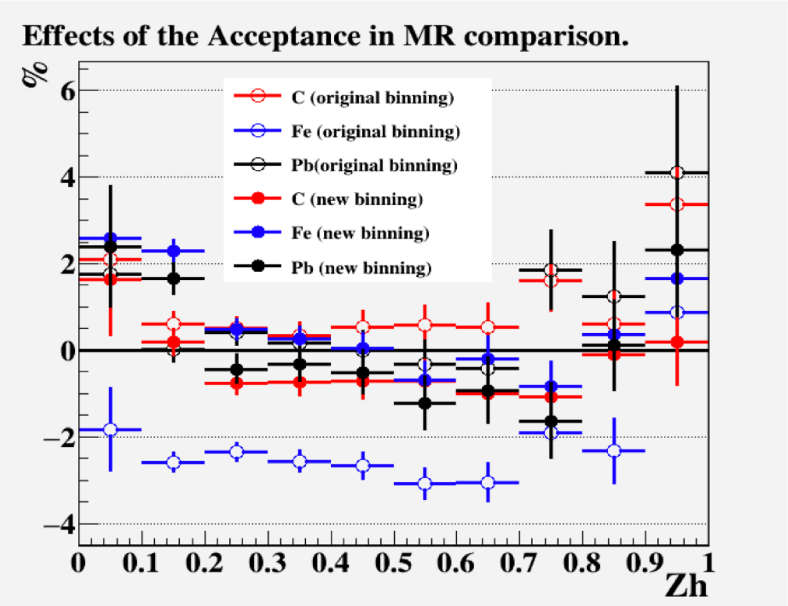


(No_shift – Shift) / Shift *100

For RD case it doesn't matter if the Z shift is applied or not in the simulation

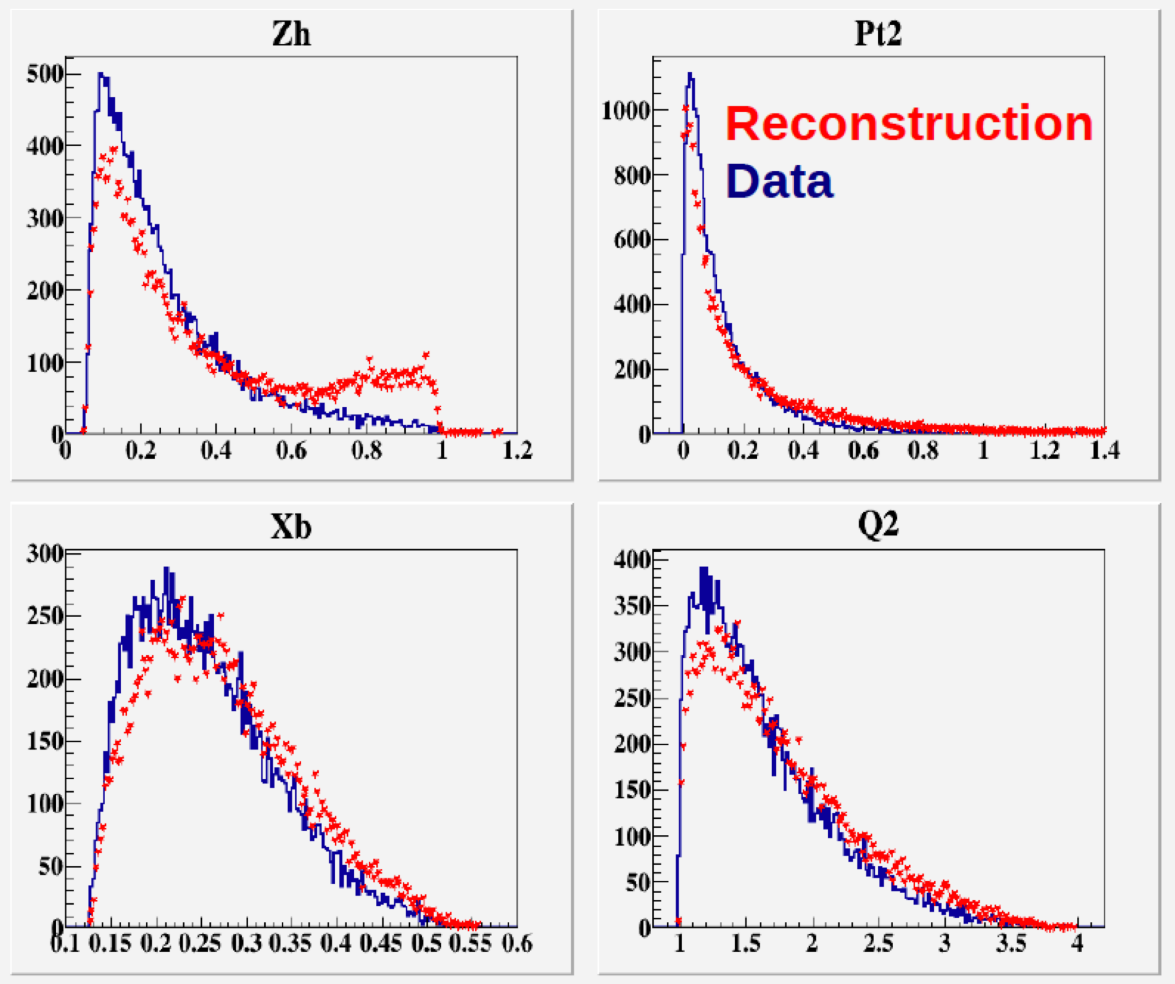
31.

The comparison between both cases, old binning (equal width) and this new binning (variable width), **<u>just for SMU case</u>**:

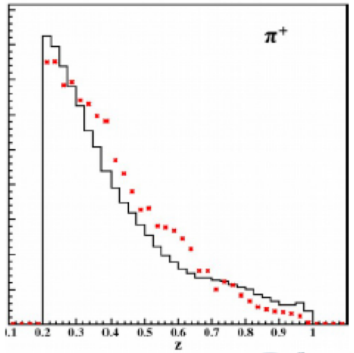


The new choice of binning mainly put the acceptance effect down, but the most clear effect is in Iron, now behaves like the other targets.

5. Comparison between Data and Reconstruction, for SMU analysis.



Zh, RD case



The mayor difference with RD is at high Zh

Thesis Archives

Not related to NPWG, but M. Wood has taken the job of maintaining the Hall B thesis archives.

https://www.jlab.org/Hall-B/general/clas_thesis.html

Please send thesis topics for work in progress as well as completed theses.

Thanks to Reinhard Schumacher for his 10+ years building and maintaining the archives.