RG-M update

Stuart Fegan (on behalf of many others)

CLAS12 International Workshop, Paris, France, March 23rd, 2023

Run Group-M (RGM) Experiment

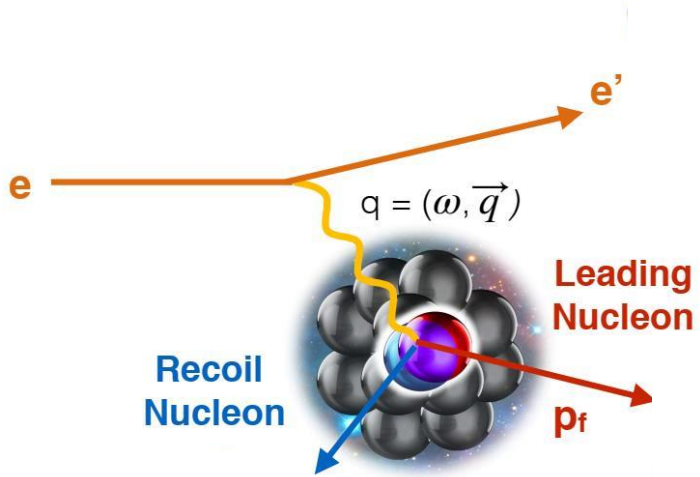
- Completed November 2021 - February 2022
- Electron scattering off nuclear targets over several energies
- 2, 4 and 6 GeV on D, He, C, Ar, Ca (40 and 48) and Sn
- 1 GeV running on Oxygen TBA

*fraction of the RGM group who ran in person

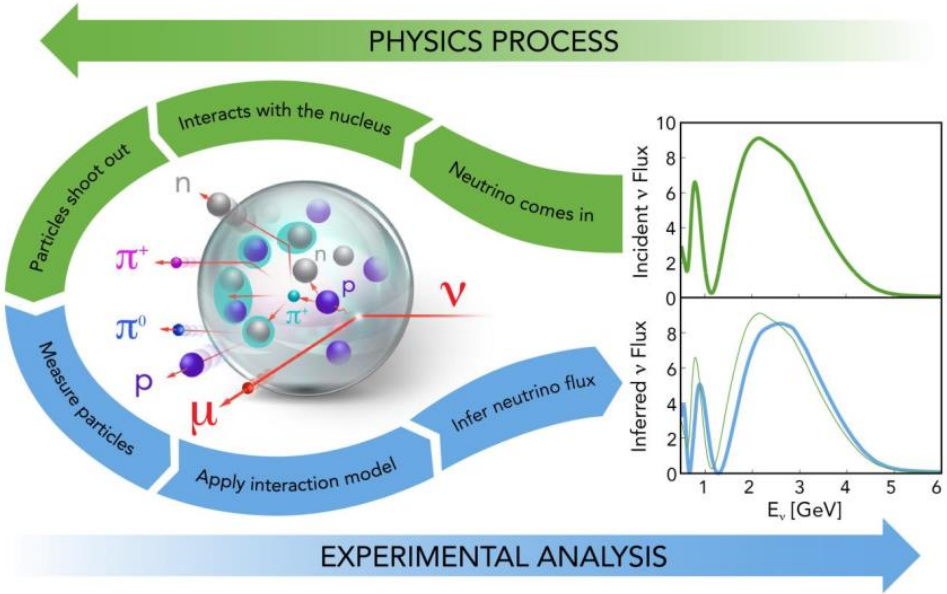
*fraction of the RGM group who ran remotely

Run Group-M Proposals

Short Range Correlations (E12-17-006A)



Electrons for Neutrinos ($e4\nu$) (E12-17-006)



- (e,e') inclusive
- (e,e'N)
- (e,e'NN)

Calibrations and Alignments

- All alignments and nearly all calibrations are done for RG-M in-bending
- Out-bending has some ongoing issues with DC calibrations
- Proposal is to move forward with RG-M in-bending
- In-bending contains all SRC and some e4nu data

Clas12 Analysis software

- Developed software to work w/ clas12root framework standardize CLAS12 cuts across analyzers
- Allows analyzers to focus on physics

Modular cuts, turn on/off, vary strength of cut

```
clasAna.setEcalSFCuts();
clasAna.setEcalEdgeCuts();
clasAna.setPidCuts();
clasAna.setVertexCuts();
clasAna.setVertexCorrCuts();
clasAna.setDCEdgeCuts();

clasAna.setVzcuts(-6,1);
clasAna.setVertexCorrCuts(-3,1);
```

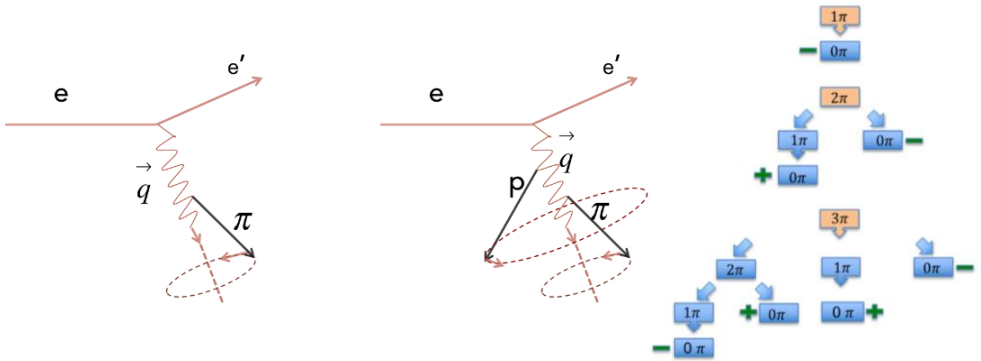
Using clas12root classes (applies cuts on left)

```
auto electrons = clasAna.getByPid(11);
auto protons = clasAna.getByPid(2212);
```

Side remark: clas12root has been a tremendously useful software offering a very low learning curve and much reliability for CLAS12 analysis. It usually takes people less than one week to get started who have had zero experience. We are very happy ;)

Clas12 Software for e4nu

- e4nu activities started as a CLAS6 data mining project
- Significant code base to support these analyses, much of which can be reused on RGM data



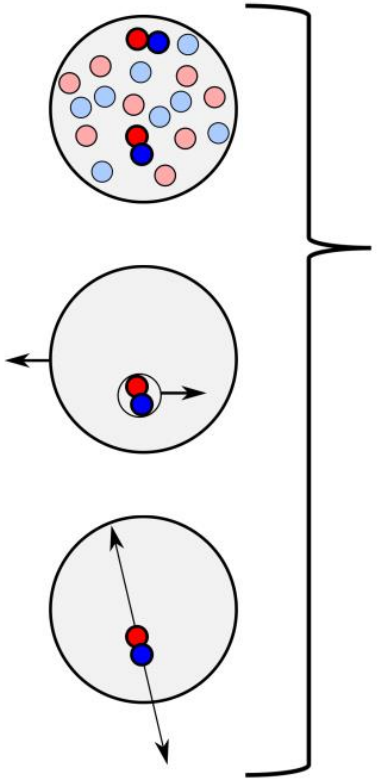
- Comparison with neutrino event generators (Genie) often performed after conversion to standard formats used in the neutrino physics community
- Clas12root codes have been developed to convert hipo files to commonly used neutrino experiment formats

Components of the SRC

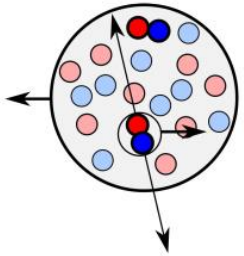
Pair Abundance

Center of Mass Motion

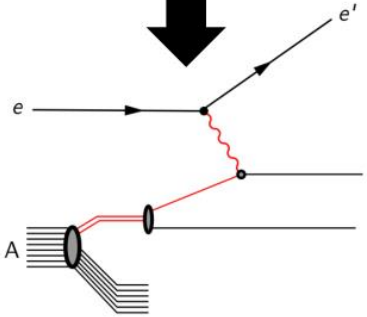
Pair Interaction



SRC Component of the Wave-Function



SRC Cross Section

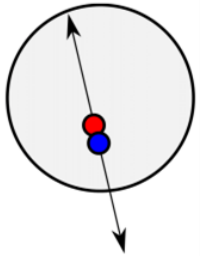


RG-M intends to answer all aspects of SRC pair formation

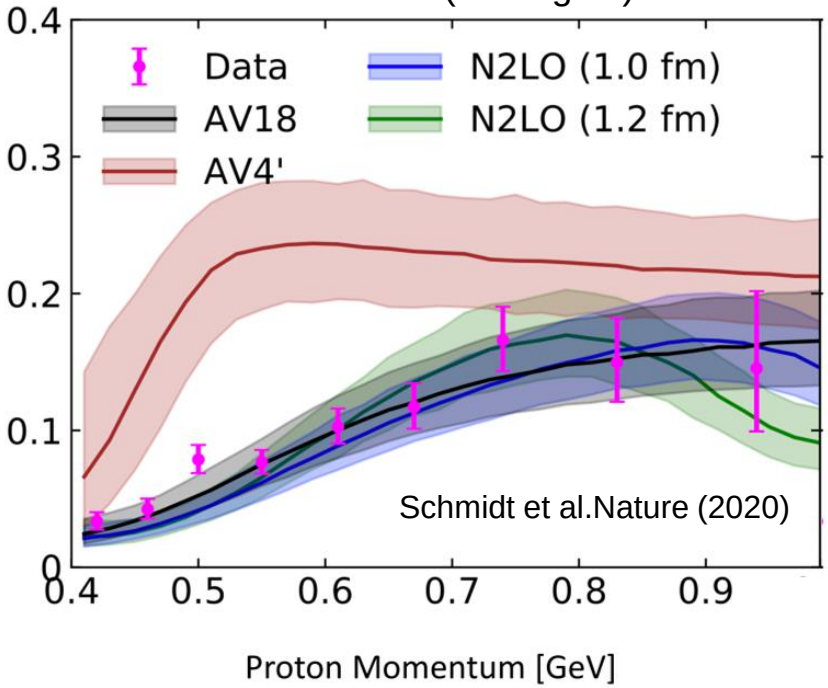
Analysis and near term paper goals

- Scale (Q2) independence of SRC observables
  - Mature analysis, just needs publishable quality data set
- Center of Motion analysis
  - Need data from other targets cooked, analysis and simulation framework mature
- Scalar to tensor Transition analysis
  - Requires (e,e’pn)/(e,e’p) ratio which requires a CND neutron veto
  - Ongoing efforts to develop a general CND neutron veto algorithm (more later)

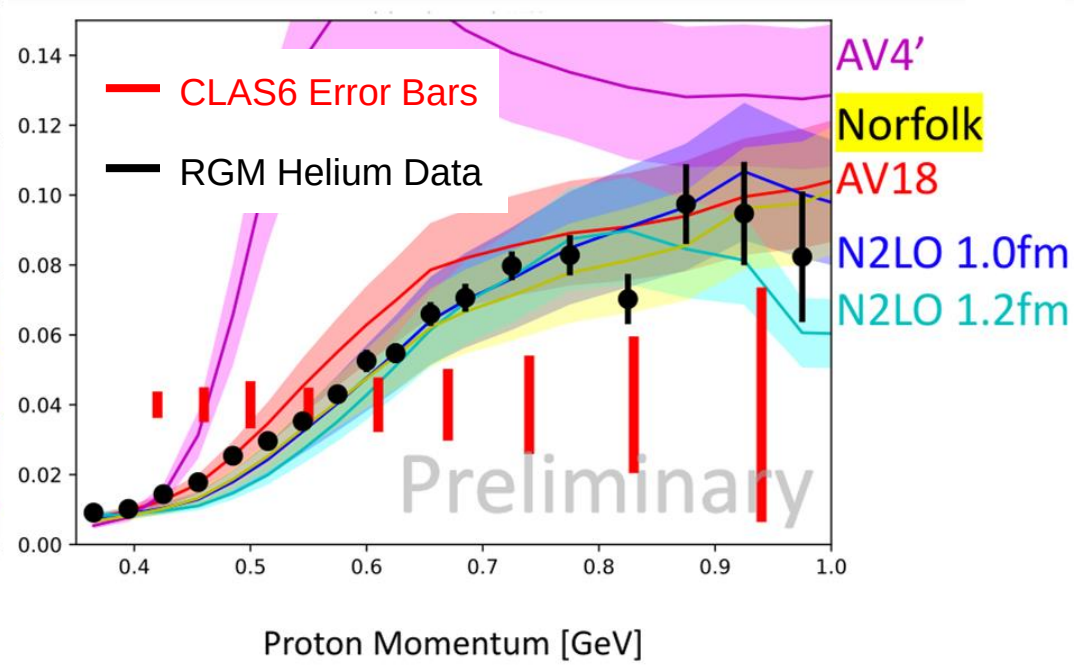
Pair Interaction



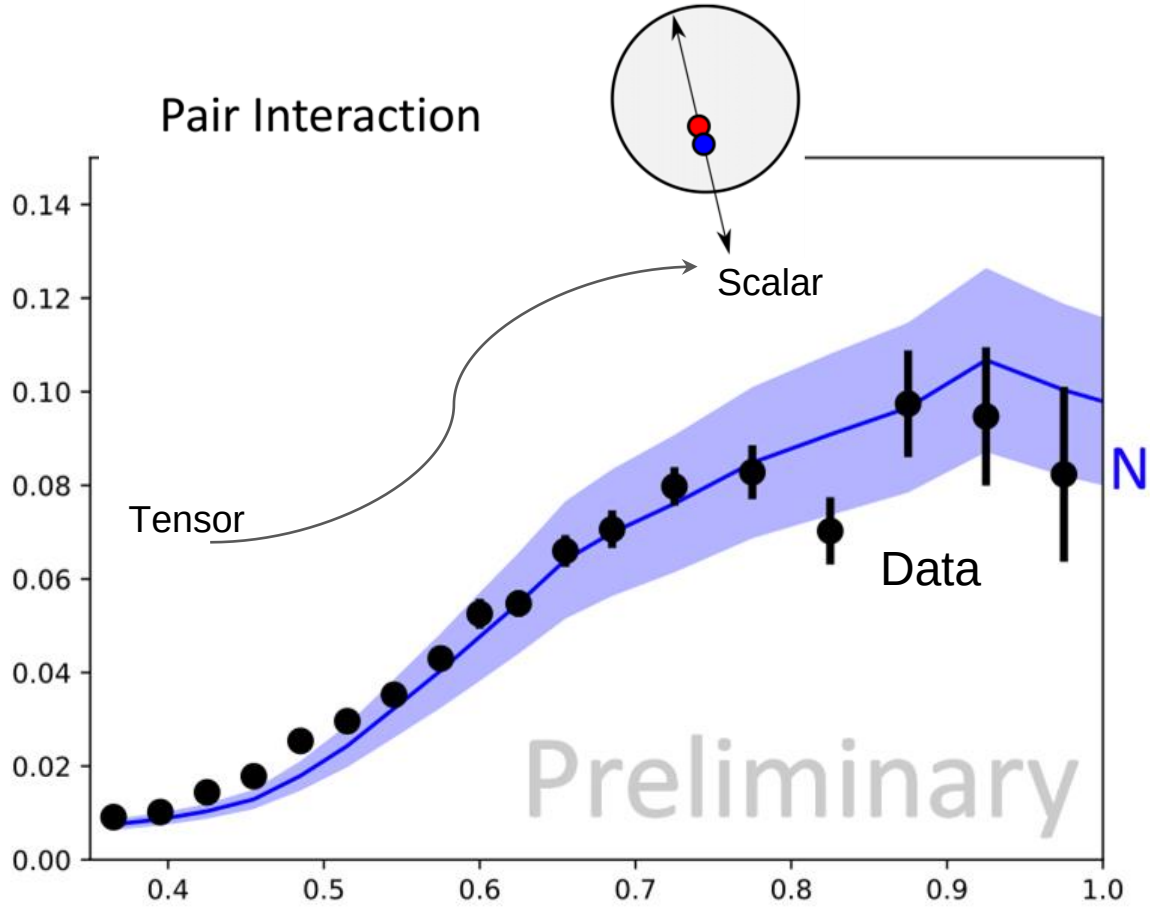
CLAS6 Data (All targets)



RG-M Preliminary

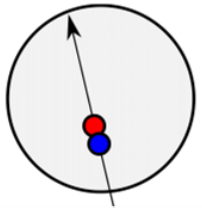


$$\frac{\mathrm{He}\,(e,e'pp)}{\mathrm{He}\,(e,e'p)}$$



With only a partial fraction of one target cooked.
We can already have resolution to distinguish between different theoretical models

Scale independence of Pair Interaction



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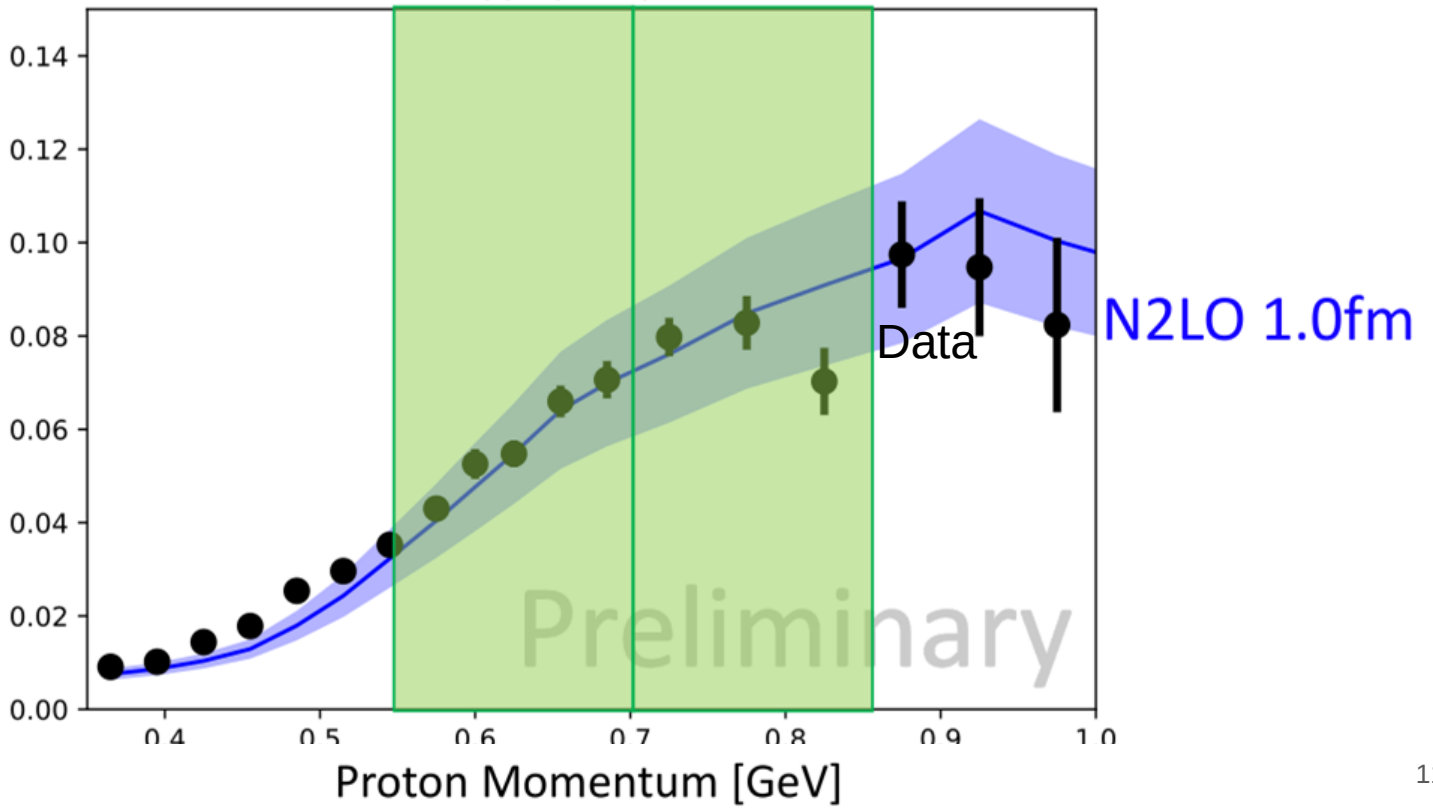
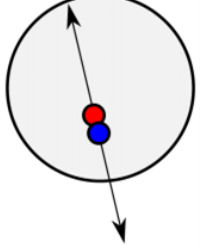
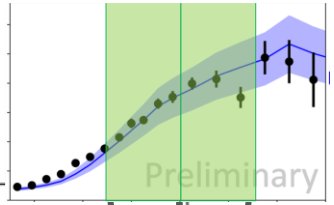
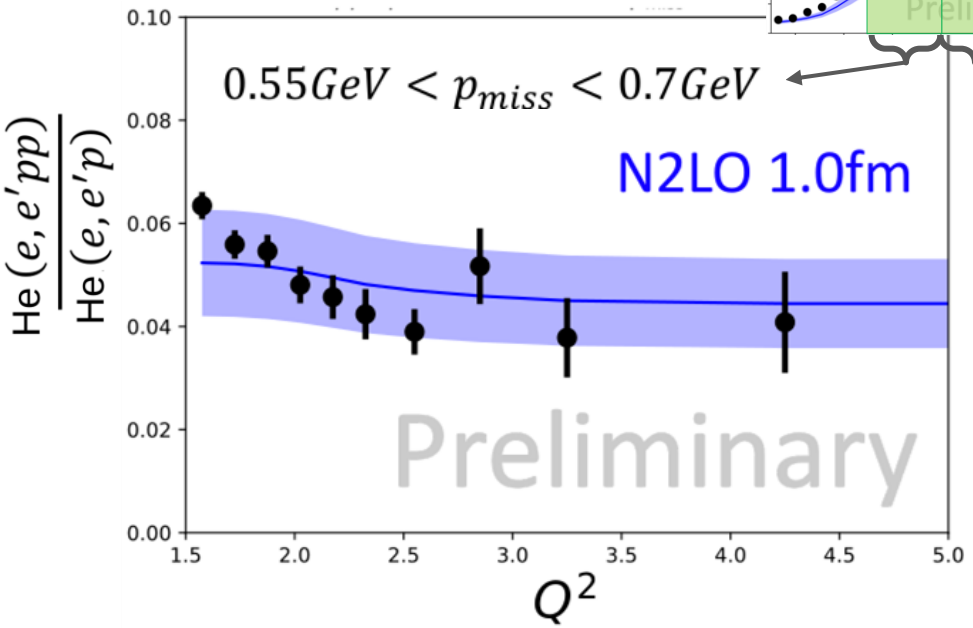
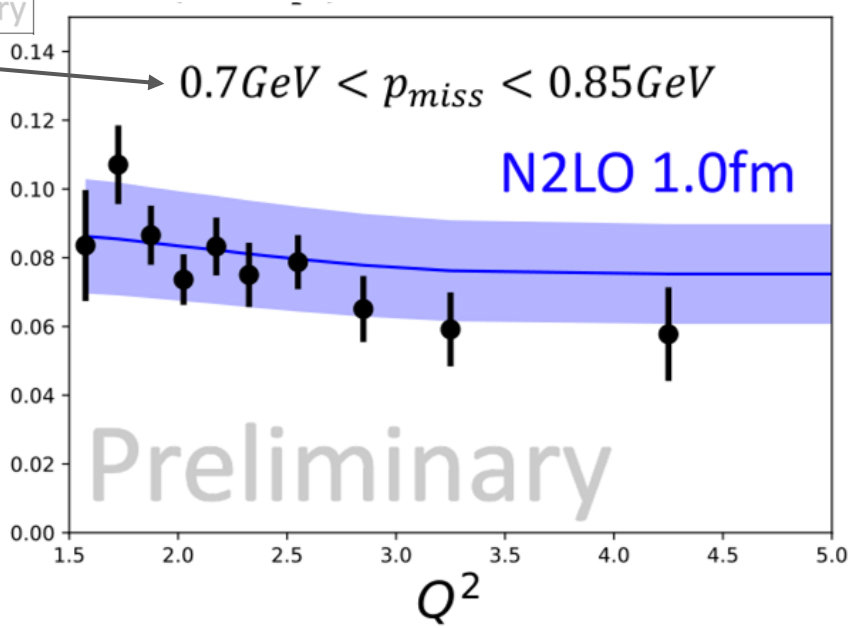


Scale independence of Pair Interaction

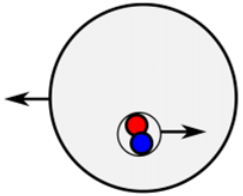




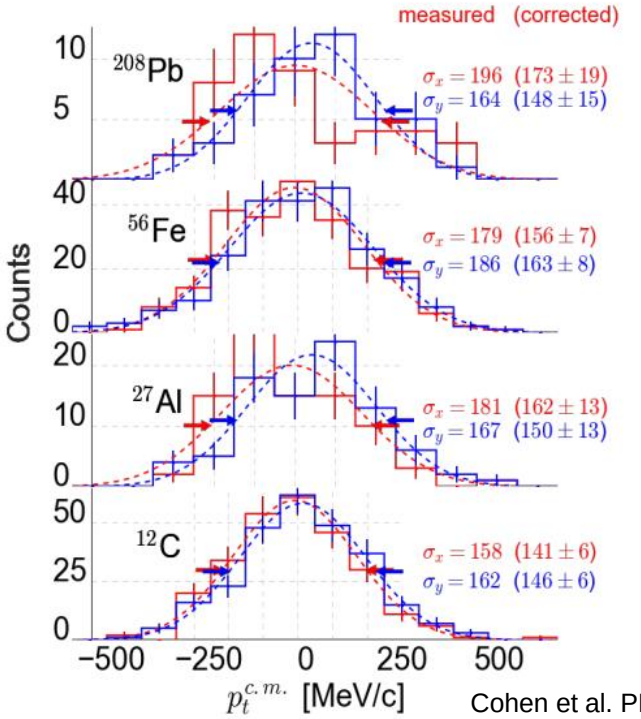




Center of
Mass Motion

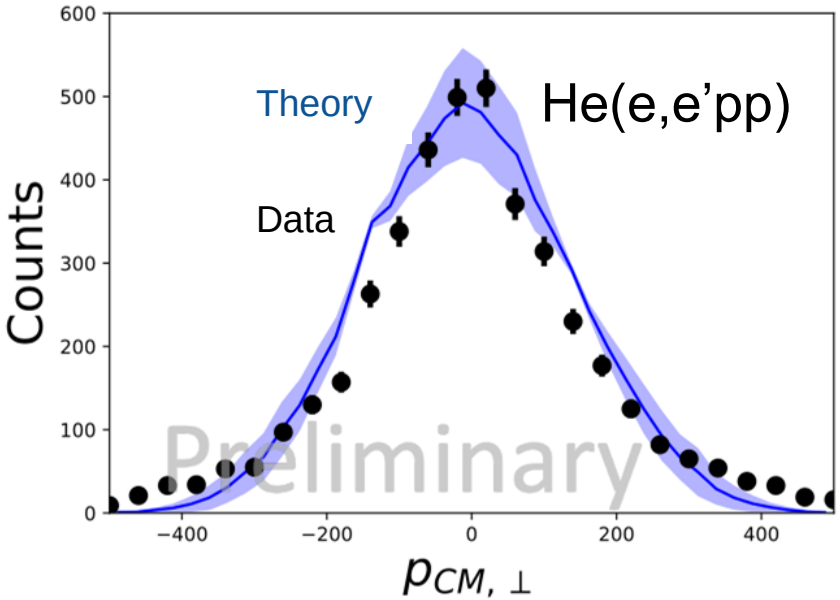


CLAS6 Data



Cohen et al. PRL(2018)

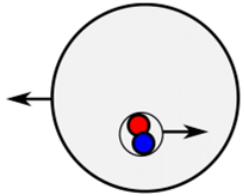
RG-M Data

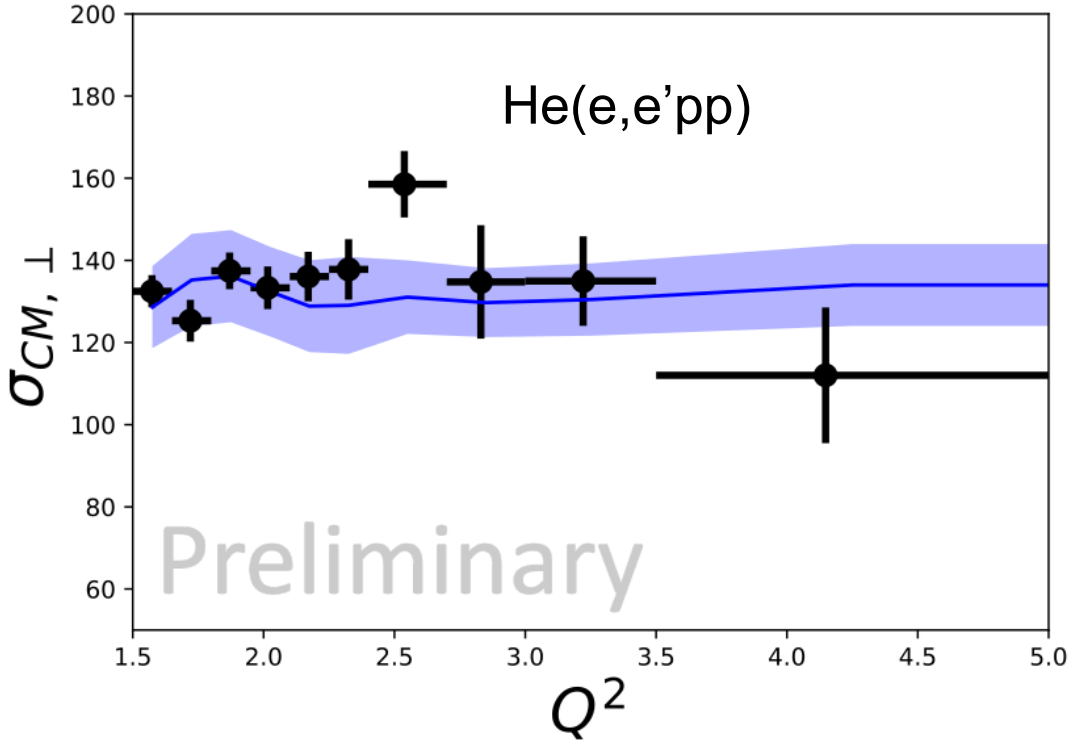


100's of counts (CLAS6) -> 1k's of counts RG-M
We can begin to extract more accurate COM parameters

Scale independence of

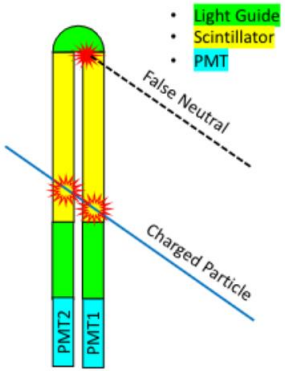
Center of
Mass Motion

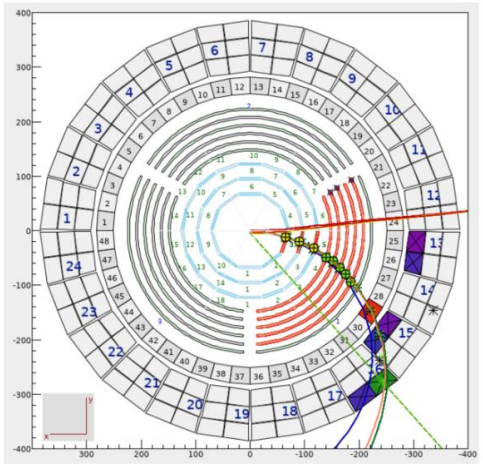


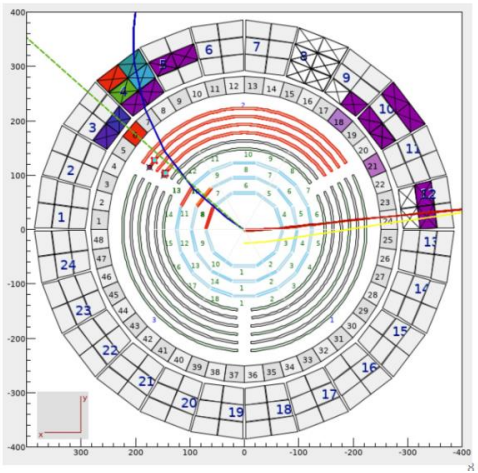


CND Veto

- Developing a general neutron veto for CND
- Testing/training on MC and Data sets
- Approaching with various machine learning algorithms
- See Erin Seroka’s talk on developing a neutron veto algorithm with ML



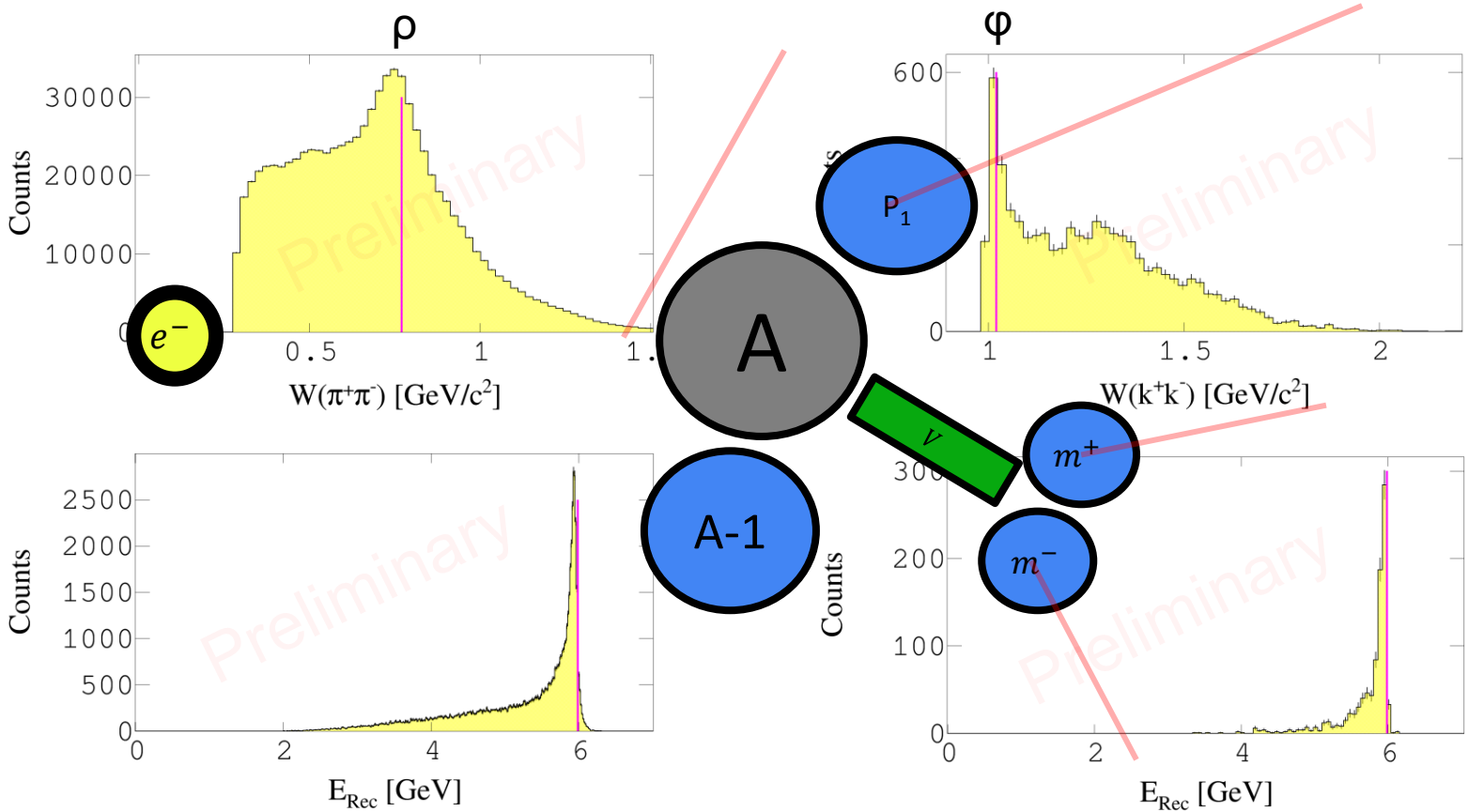




e4nu Analysis

- Recall Rhidian Williams' talk for examples on ongoing e4nu analysis
- Beam energy reconstruction on various multi-particle final states
- Test limits of lepton-nucleus interaction models used in neutrino physics event generators

$He(e, e'pV)X$ @ E = 6.0 GeV



Conclusion

- RG-M alignment and calibrations are finished for in-bending
- Several analysis are very mature and only require fully cooked datasets
- Developing CND veto algorithm is key to unlocking all neutron observables
  - most recoil neutrons are in CND (we can do lead neutrons which go into ECAL)
- Started to characterize phase space of where we expect to see 3N - SRC’s
- e4nu analyses ongoing and will provide new constraints to event generator models needed for next generation experiments (e.g. DUNE)
- looking forward to fully cooked data!