Nuclear Physics Working Group Summary Report

M. H. Wood, Canisius College

November 16, 2018

Conferences

Since July 2018 meeting, there were 27 presentations.
Invited – 6 (5 approved)
Contributed 6 (5 notified)
General – 13 (5 notified)
Poster – 2 (1 notified)

Active Reviews

- **Neutral pion electroproduction ratios off C, Fe, and Pb to D**, T. Mineeva et al. (Analysis review)
- **Validation of neutrino energy estimation using electron scattering data**, L. Weinstein et al. (analysis review)
- **First exclusive Deeply Virtual Compton Scattering measurement off bound nucleon in ^{4}He,** M. Hattawy et al. (Collaboration review)
- **EMC Effect and Correlated Nucleons: When One Plus One is not Two**, B. Schmookler (submitted to Nature Physics)
- **Measurement of Transparency Ratios for Protons and Neutrons,** M. Duer et al. (submitted)

PAC46

E12-17-006 Approved with A rating

- Electrons for Neutrinos: Addressing Critical Neutrino- Nucleus Issues
- Exclusive Studies of Short Range Correlations in Nuclei using CLAS12

08:30 - 10:10

Nuclear Physics Working Group - I

Convener: Dr. Michael Wood (Canisius College)

08:30 **NPWG Business/Scheduling Discussion** *20'*
Speaker: Dr. Michael Wood (Canisius College)
Material: **Slides**

08:50 **BAND: Installation and Commissioning** *20'*
Speaker: Florian Hauenstein (Old Dominion University)
Material: **Slides**

09:10 **BAND: Readout and calibration plans** *20'*
Speaker: Efrain Segarra (MIT)
Material: **Slides**

09:30 **BAND: Laser calibration system** *20'*
Speaker: Jackson Pybus (MIT)

09:50 **EG2: Two-pion correlations** *20'*
Speaker: Antonio Radic (UTFSM)
Material: **Slides**

10:30 - 12:30

Nuclear Physics Working Group - II

Convener: Dr. Michael Wood (Canisius College)
Location: A110

10:30 **EG2: (e,e'pp)/(e,e'p) and new SRC event generator** *20'*
Speaker: Axel Schmidt (MIT)
Material: **Slides**

10:50 **E2a: PID, Calibration, and maps analysis note** *20'*
Speaker: Adin Hrnjic (MIT)
Material: **Slides**

11:10 **E2a: (e,e'pp) in 12C, 4He and 3He** *20'*
Speaker: Adin Hrnjic (MIT)

11:30 **E2a: (e,e'N) in 12C, 4He and 3He** *20'*
Speaker: Peninah Levine (MIT)

11:50 **E2a: Onset of SRC dominance from (e,e'p) and New event generator** *20'*
Speaker: Andrew Denniston (MIT)

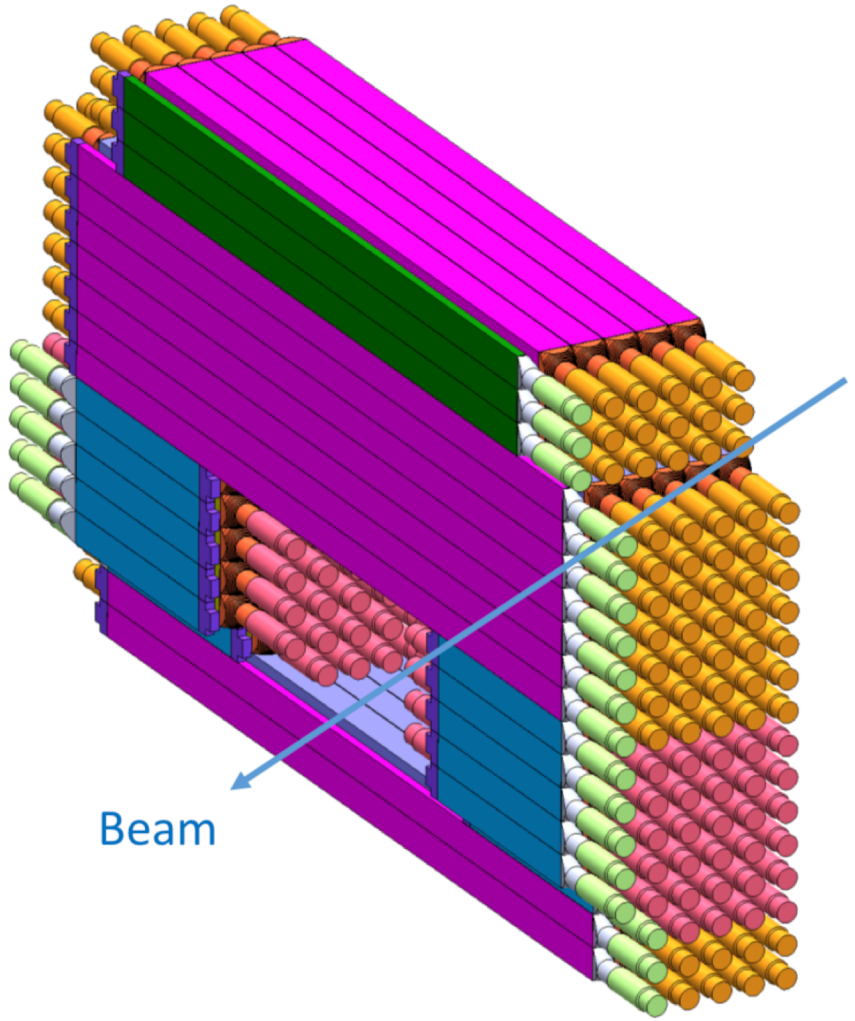
BAND Layout

Plastic scintillator detector

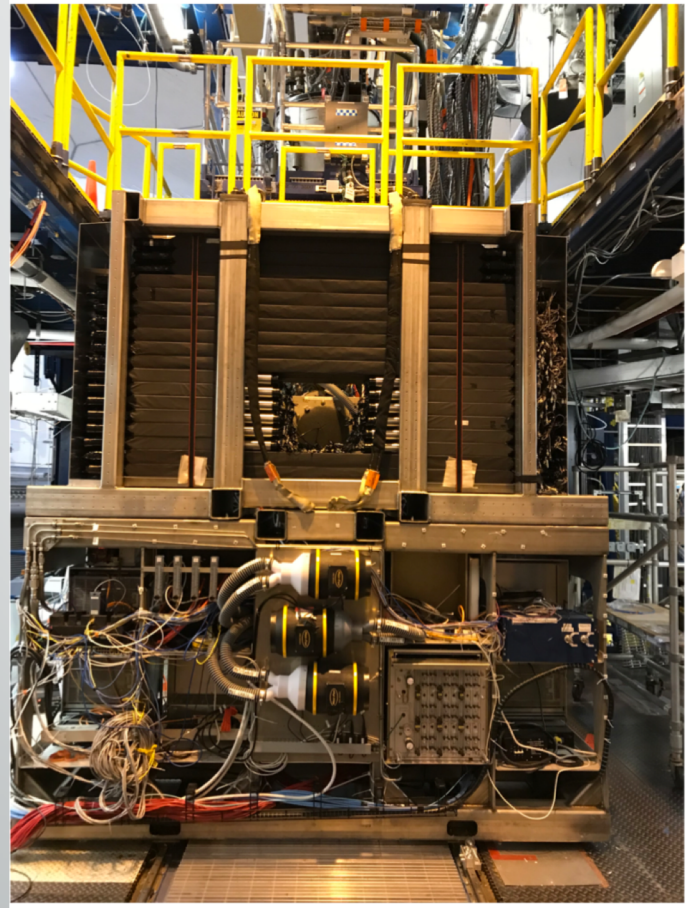
- Covers 160 to 170^{o}
- 40% neutron efficiency
- 116 7.2 x 7.2 cm^2 bars
  - two 2” PMTs per bar
  - 3 scintillator lengths (51, 164 and 202 cm)
  - BC-408 Scintillant
- Hole for beam line

Veto layer

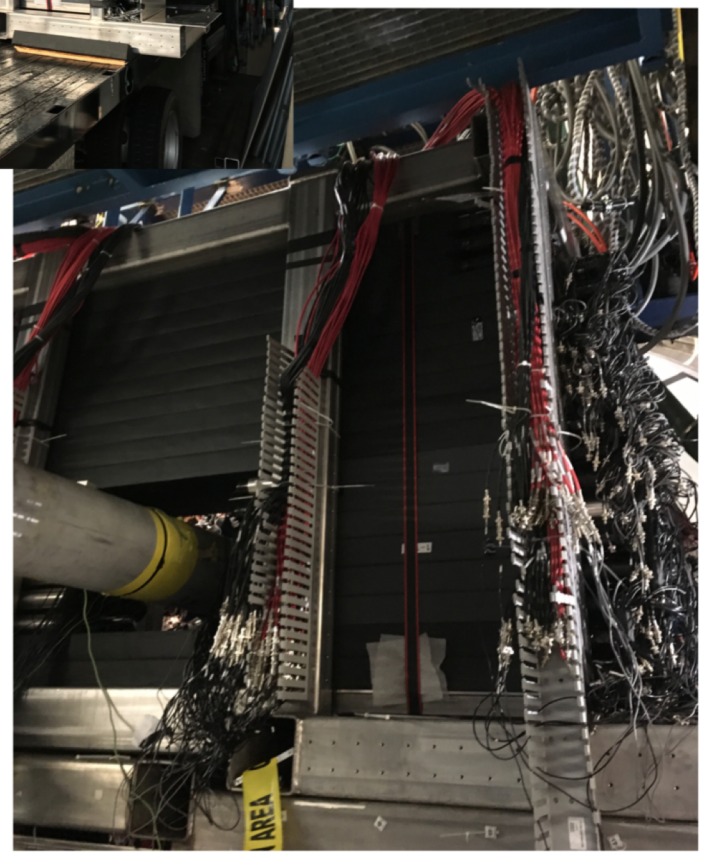
- 2 cm x 7.2 cm
- one 2” PMT per bar
- 24 PMTs



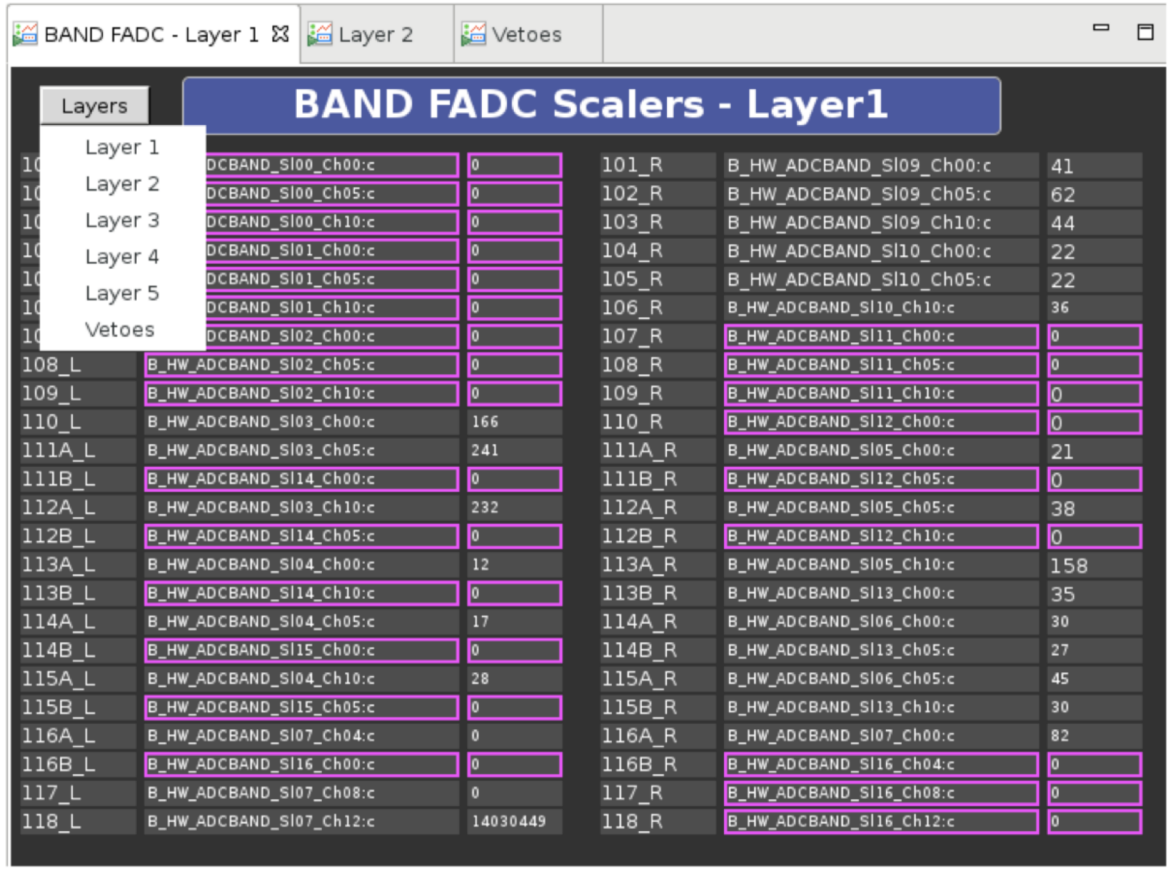
BAND in the Hall

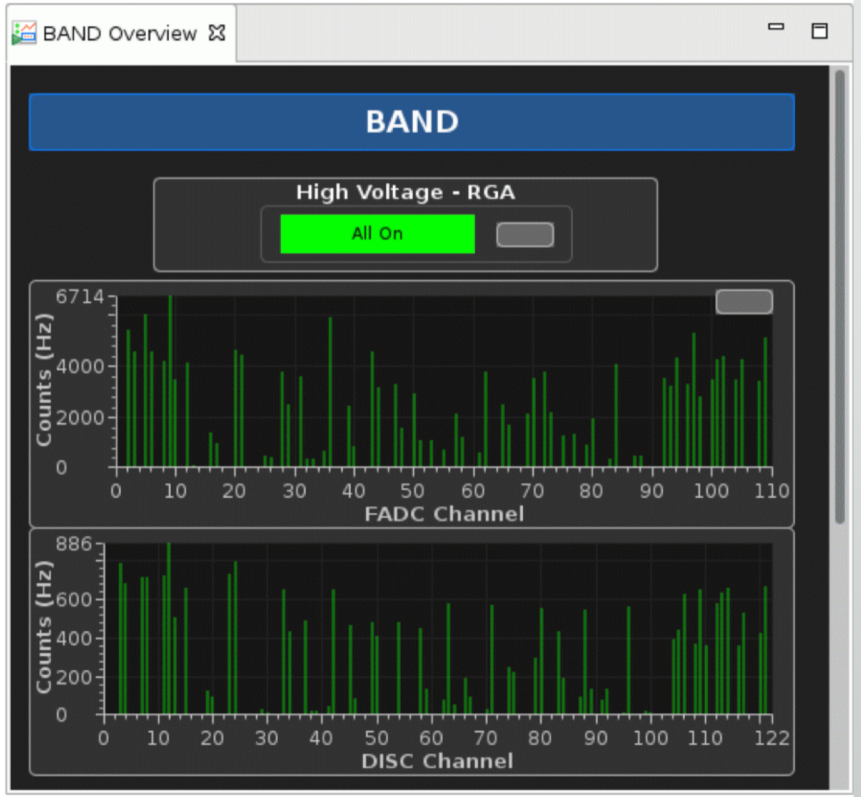


Transport to the hall



BAND Scaler GUIs

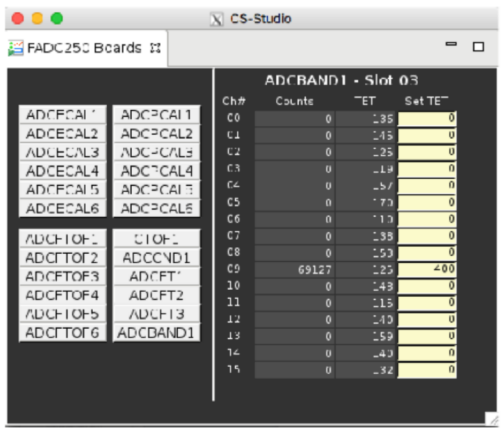


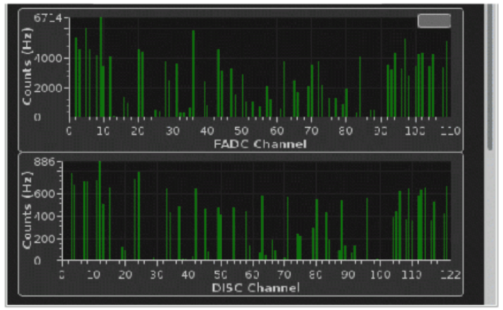


Summary

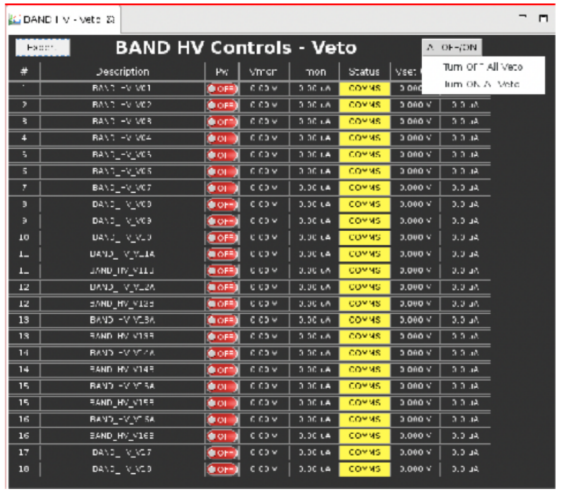
- Total of 116 scintillator bars (+ 24 vetos in BAND)
  - 58 long ones (2m and 1.6 m) + 12 Veto
  - 58 short ones (0.5 m) + 12 Veto
- BAND installed in the hall (without all Veto bars)
- ~40% cabled up for fall for background studies and commissioning
- Mapping files available for next year as well as fall
- Data available with standalone triggering on cosmics
- Readout of BAND with CLAS is available, tests in the next days

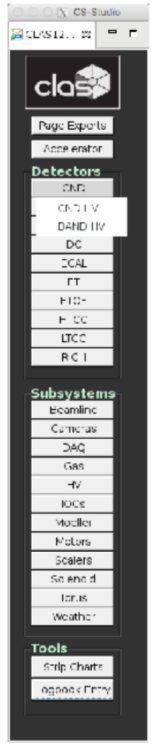
BAND Slow Control





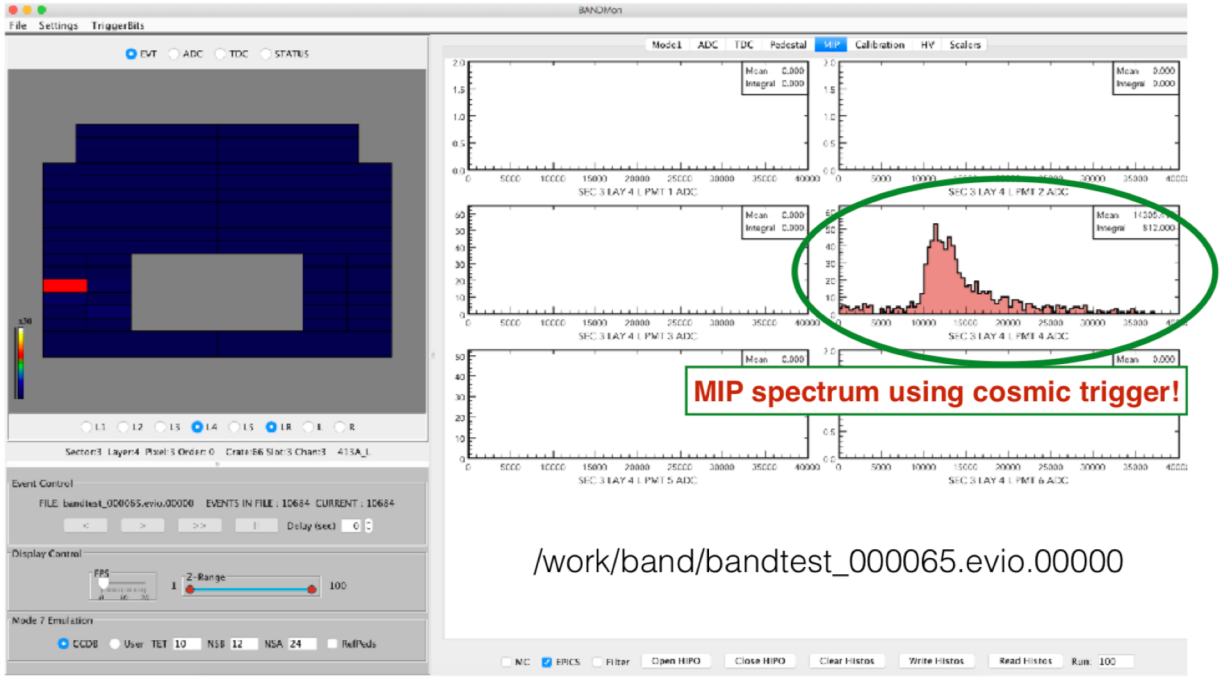
Developed by Nathan B.





Online Monitor Suite

Online monitoring software & structure developed by Cole Smith



/work/band/bandtest_000065.evio.00000

Calibrations we are aiming to finish during RG-A

- Cosmic gain-match
- Left-right time shifts
- Speed-of-light map
- Attenuation lengths
- Time-walk correction / resolution
- Threshold determinations
- Neutron efficiency
- Time-of-flight (global time) calibration
- Re-scattering
- Background measurement

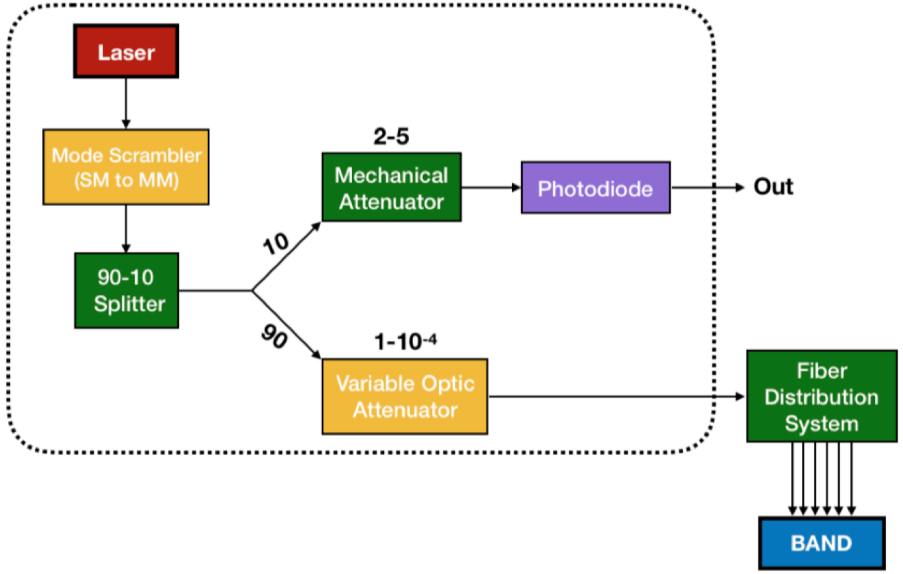
} Need LD_2 for (e,e'pn) exclusive

Laser Calibration

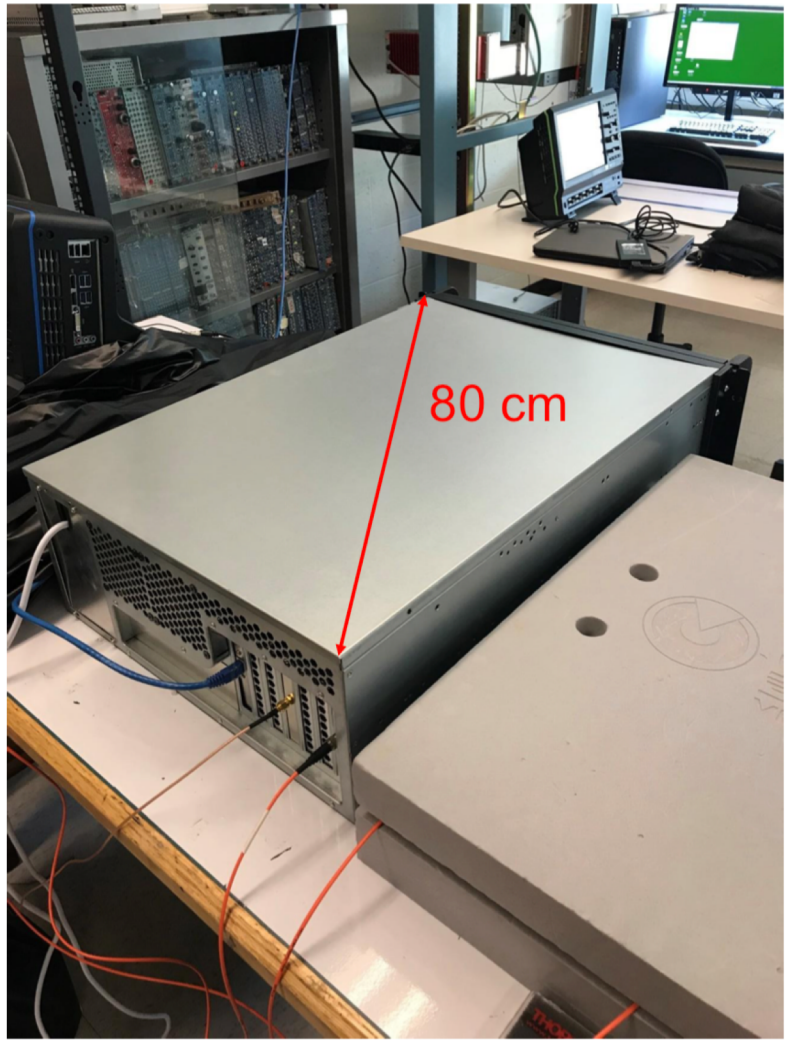
System Overview and Motivation

- System is intended for providing time-calibration for BAND detectors

- Controlled laser pulse of variable intensity
- Pulse split among 400 destinations
- Precise timing signal from internal photodiode
- Well-suited to determining amplitude-dependent time-response

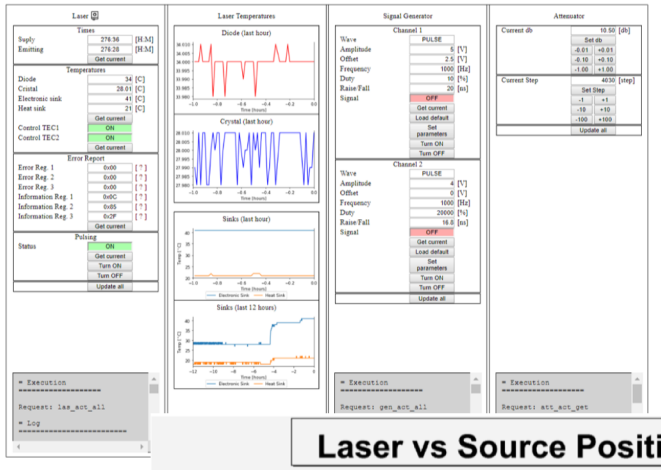


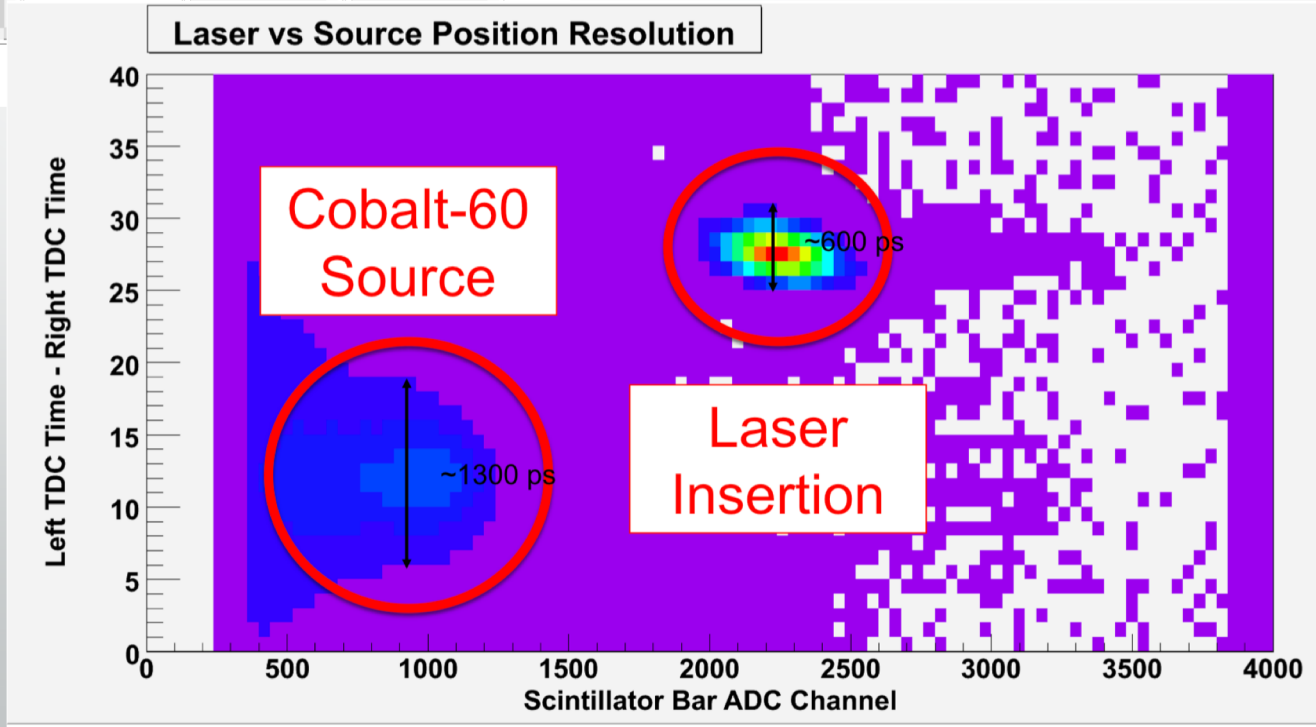
System Overview and Motivation



Web-Based Control System

- System controlled and monitored by Raspberry Pi, linked to online webpage providing:
  - Laser Driver Control
  - Signal Generator Control
  - Variable Attenuator Control
  - Temperature Monitoring





E2a: PID, Calibration, and Map Analysis Note

CLAS Nuclear Physics Working Group Meeting

Axel Schmidt

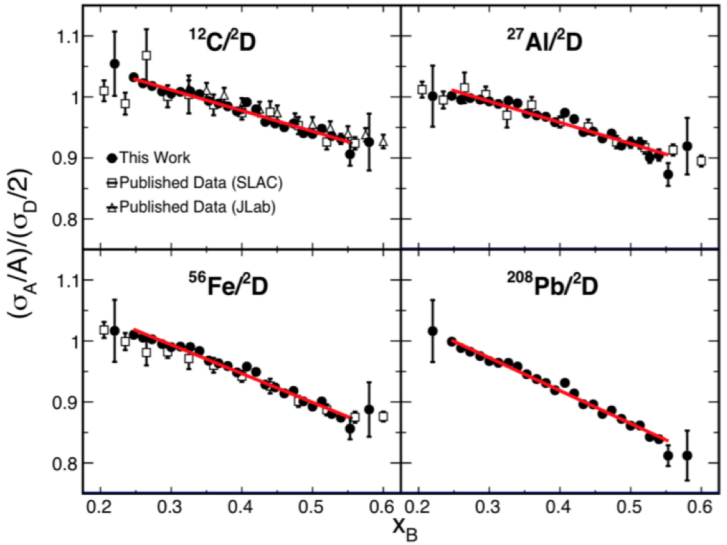
MIT

November 15, 2018

E2a offers new possibilities.

- Multiple beam energies
  - Great for electrons-for-neutrinos
- ^{3}He, ^{4}He targets
  - In range of ab initio calculations
  - ^{3}He is extremely asymmetric
- Overlap with EG2
  - Cross checks with C, Fe

Data mining has taught us a lot about short range correlations.



B. Schmookler et al., under peer review (2018)

EG2

- *pp* pairs are universally rare.
- *np* dominance in asym. nuclei
- Center of mass motion of pairs
- Connection to the EMC effect

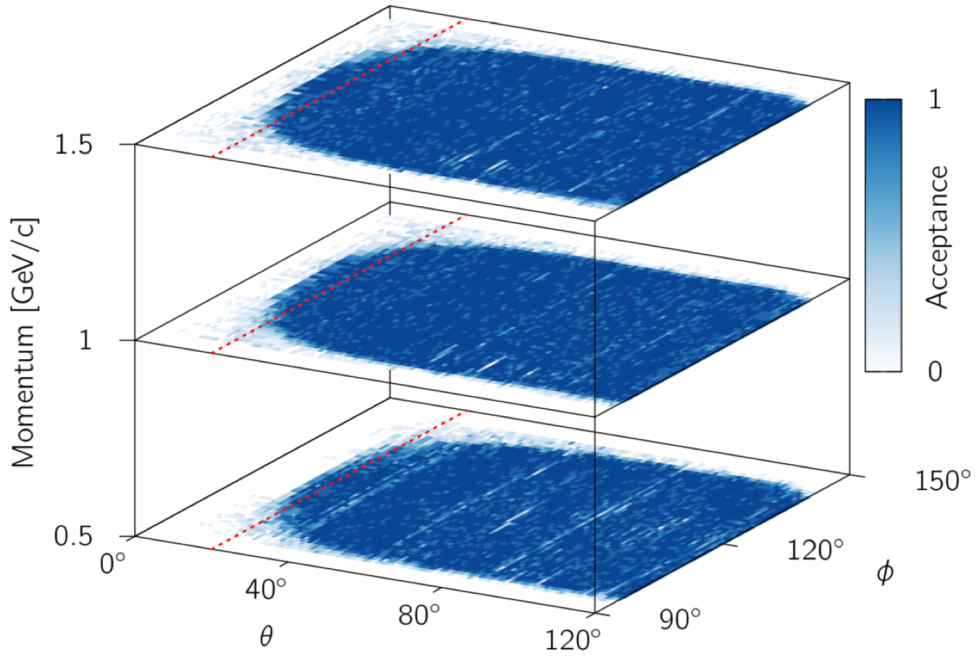
E2a Calibrations

Curating the work by W. Ingram, S. McLauchlan, R. Niyazov, D. Protopopescu et al.

- Particle ID
- Momentum Corrections
- Vertex Corrections
- Fiducial Cuts

Described in Mariana Khachatryan's analysis note

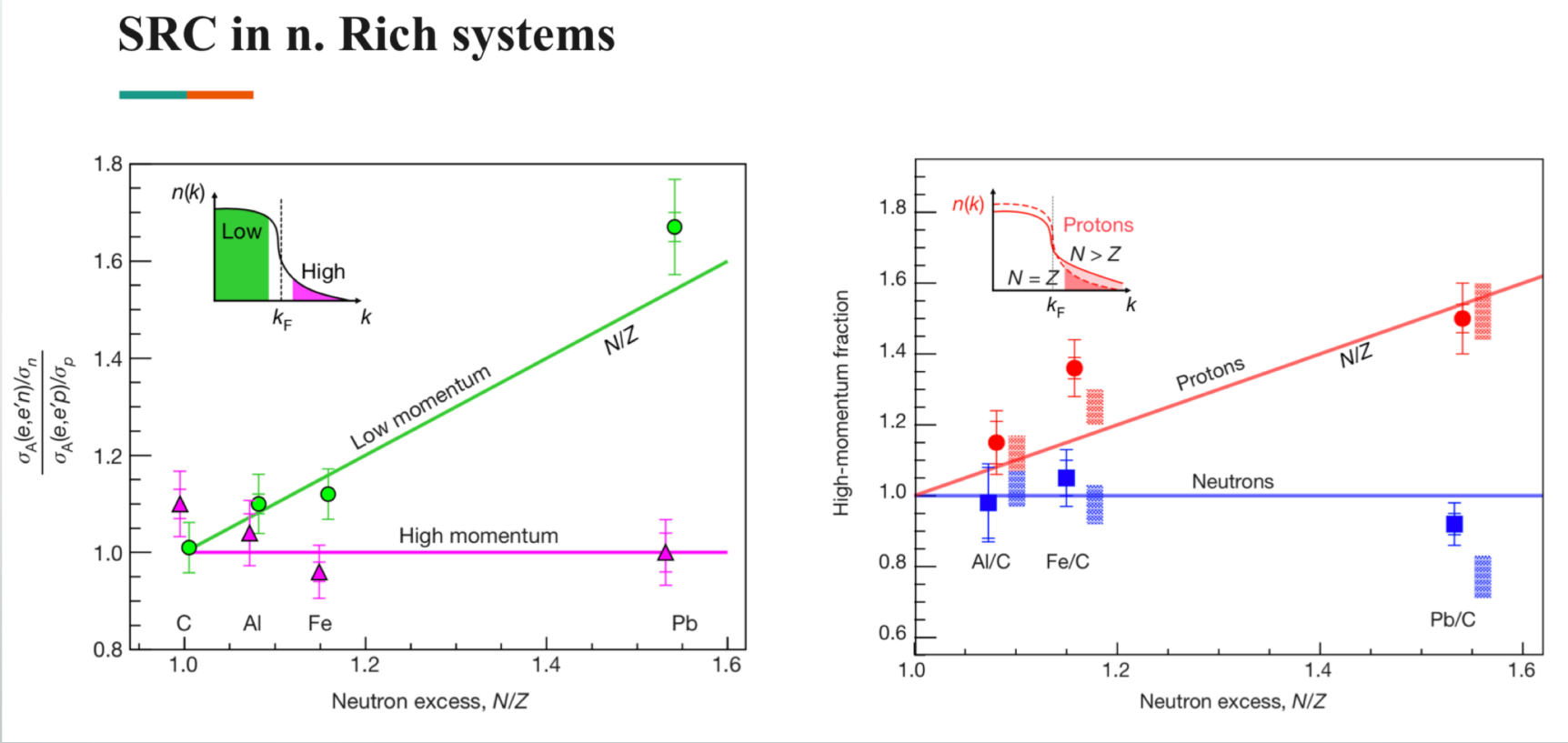
Detector acceptance by "Map"



Probing 2N-SRC via (e,e'N) reactions off ^{3,4}He and ^{12}C

Using E2a data

Peninah Levine
Nov. 15, 2018



A / ^{4}He (e,e'p) cross-section ratio

$$\frac{A(e,e'p)\cdot w/L/Z/T}{4He(e,e'p)\cdot w_{4He}/L_{4He}/Z_{He}/T_{He}}$$

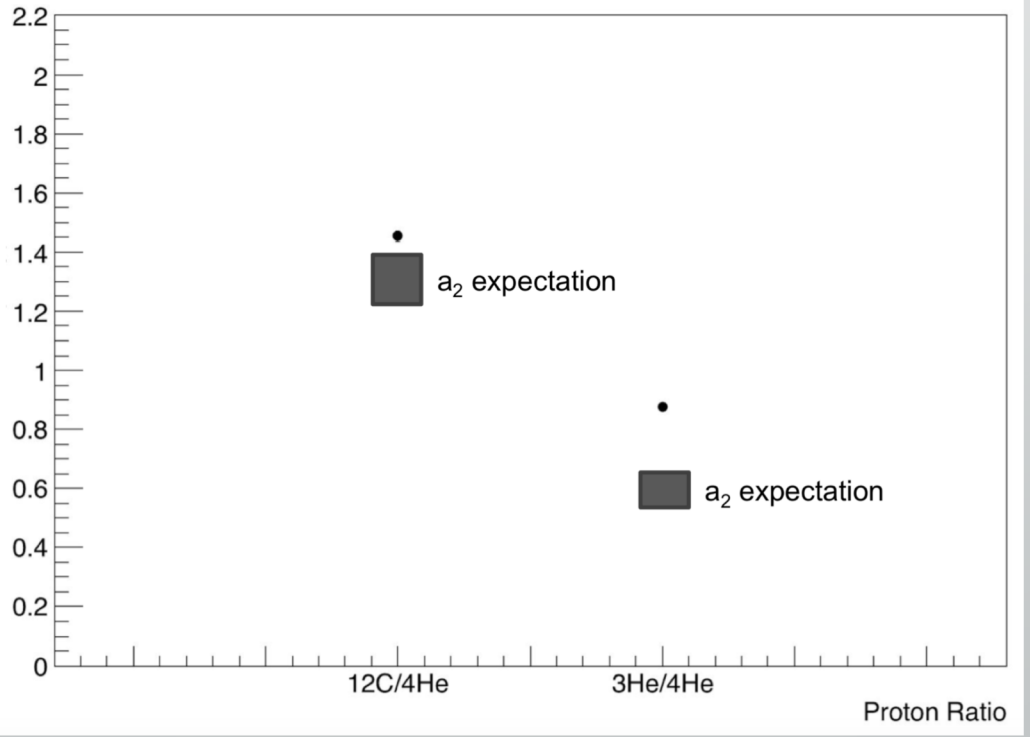
- Number of measured events
- 1 / Simulated_Efficiency
  Only for 12C/4He; From map; Applied even-by-event
- Integrated luminosity
- Number of protons in the nucleus
- Nuclear Transparency (^{4}He: 0.75; ^{12}C: 0.53)

A/^{4}He(e,e'n) also under investigation

A / ^{4}He (e,e'p)

Stat. uncertainties only

Sys. Uncertainties:
- luminosity (~2%)
- Transparency
- Cut sensitivity
- P_{miss} (in)dependence

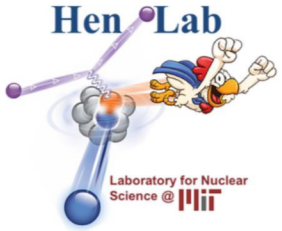


New Event Generator and Onset of SRC Dominance from (e,e'p)

ANDREW WILLIAM DENNISTON

MIT

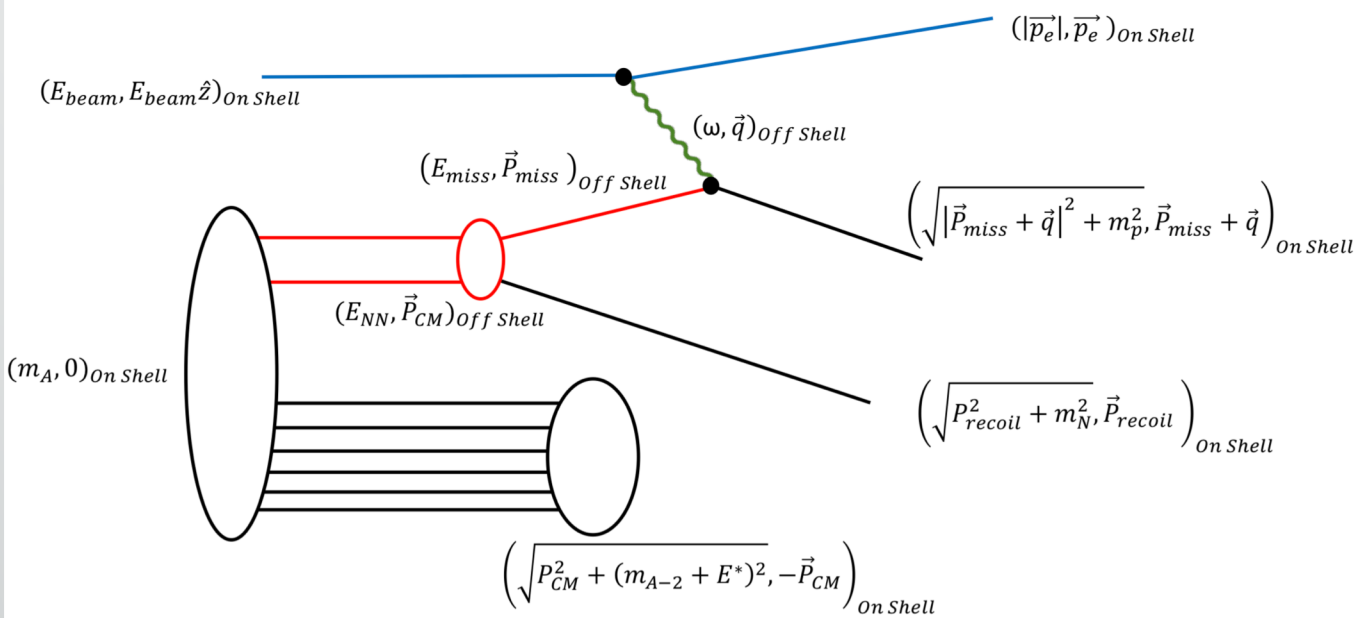
NOVEMBER 15, 2016



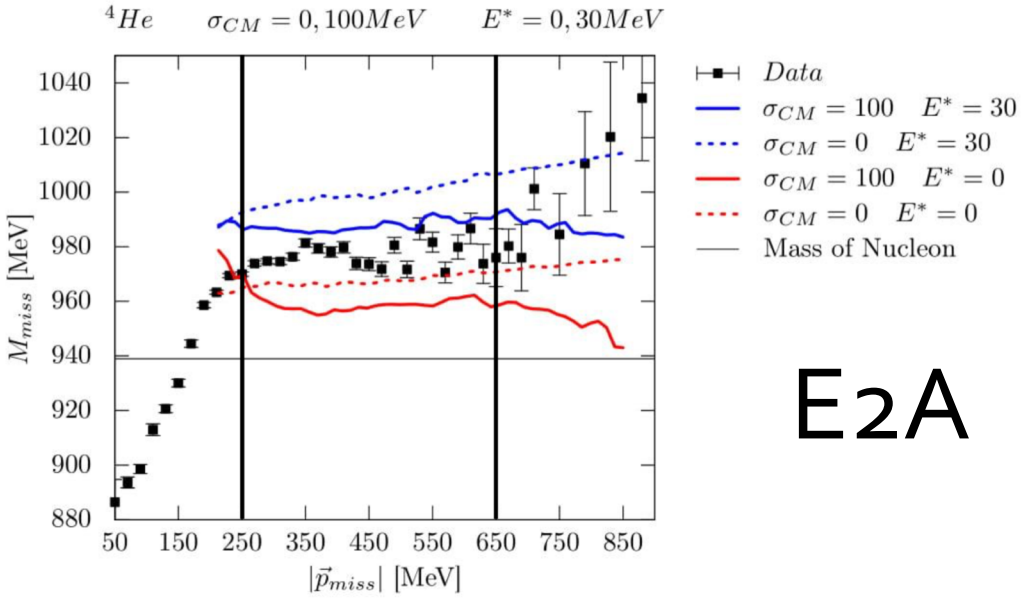
Overview

- New Event Generator
  - Quasi-elastic Scattering of SRC Pairs
  - Contact Formalism and Spectral Function
  - Generating events
- New Observable in Plateau of M_{miss}
  - Explaining M_{miss}
  - Comparing data to generator
  - Further work

Scattering electrons off SRC pairs



Generator and Experiment are Consistent for M_{miss}



E2A

EG2: $(e, e'pp)/(e, e'p)$ and new SRC event generator

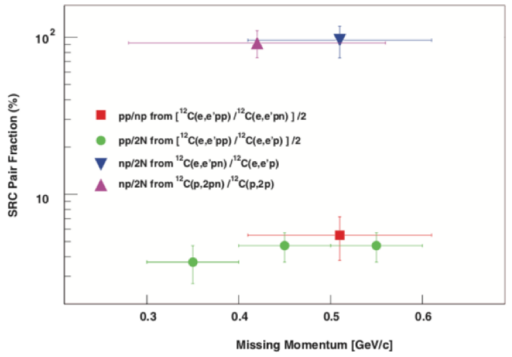
CLAS Nuclear Physics Working Group Meeting

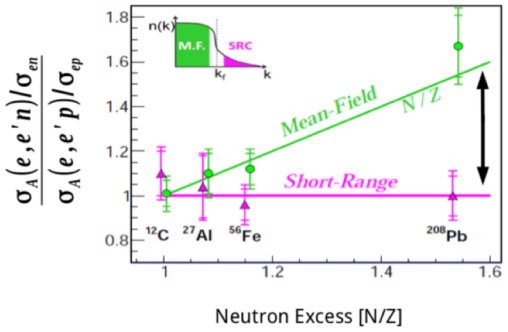
Axel Schmidt

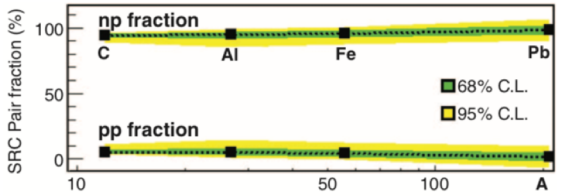
MIT

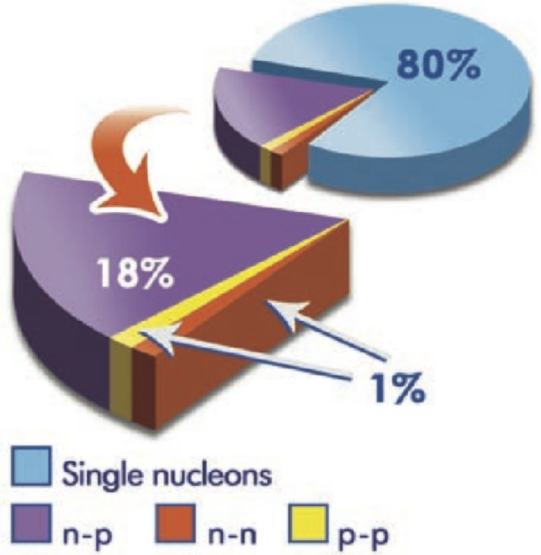
November 15, 2018

Short-range correlated pairs prefer to be *np* because of the tensor force.

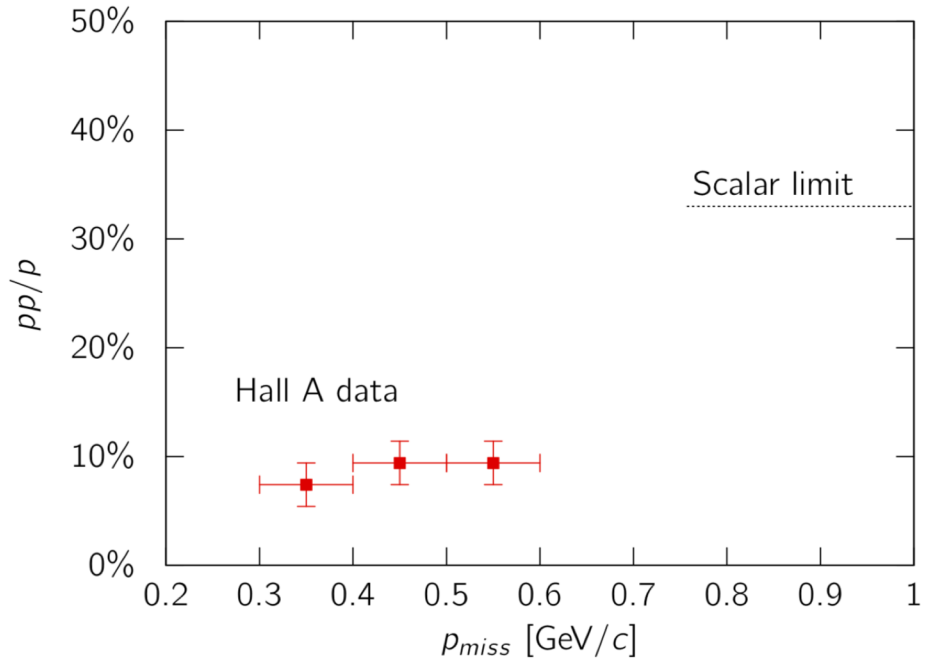




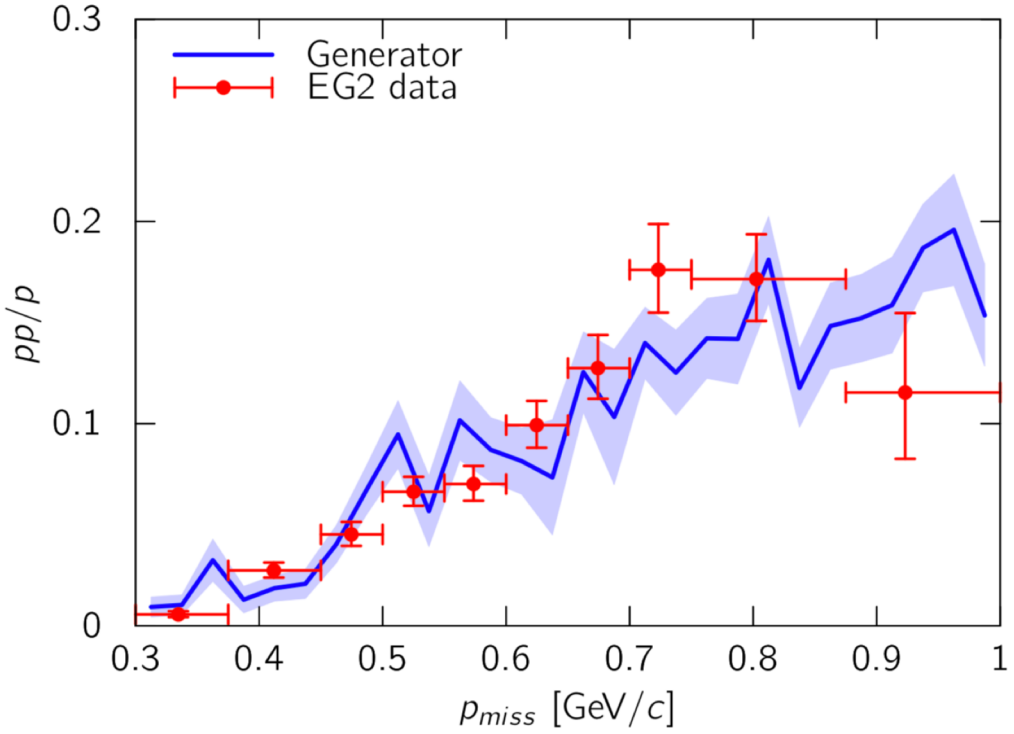




How does *np*-dominance evolve with momentum?



The generator can explain the pp/p ratio we measure.



1D and 2D Two Pion Correlations

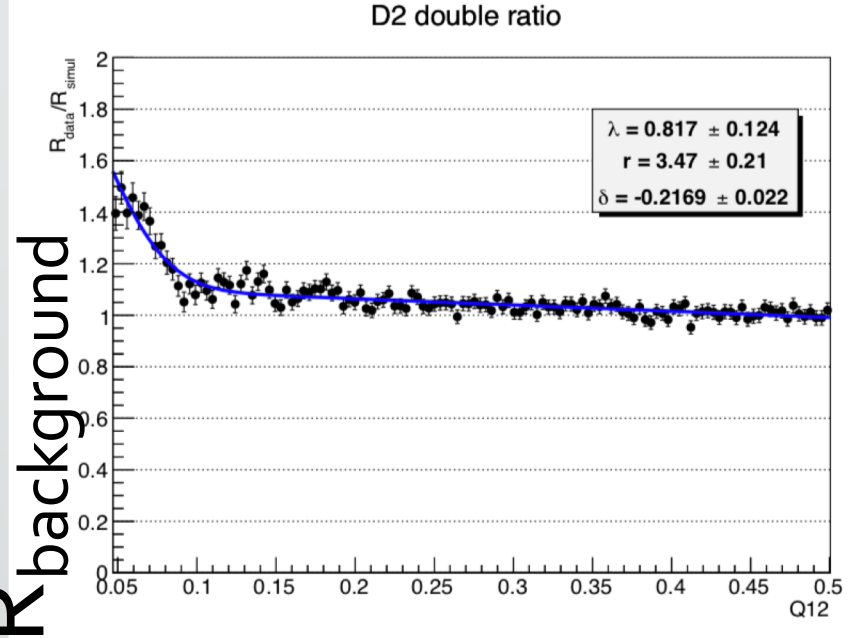
Results from EG2 experiment

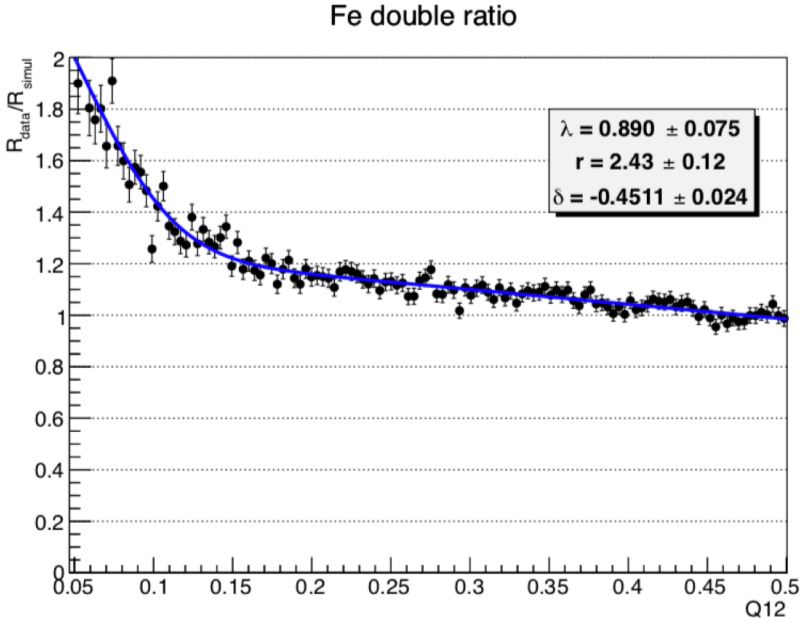
Antonio Radic

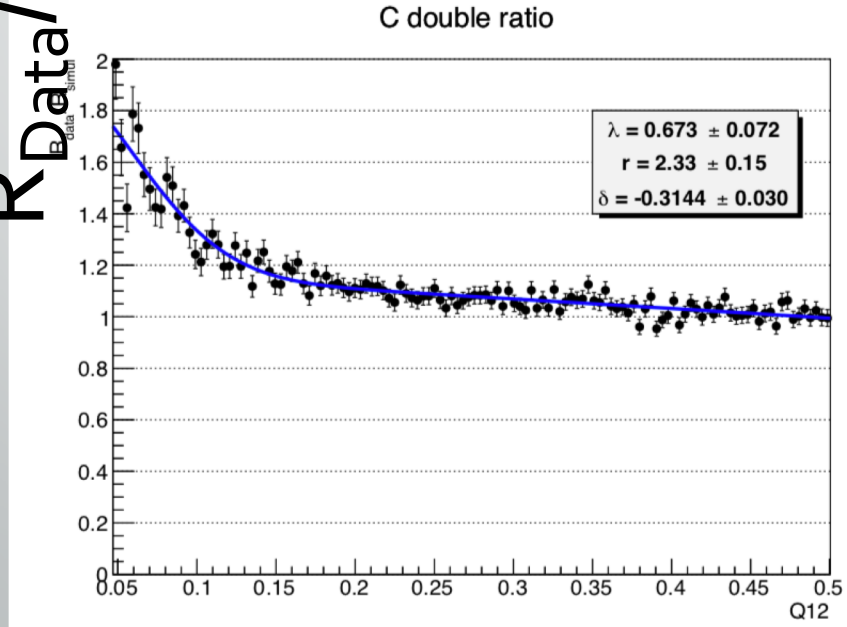
UTFSM

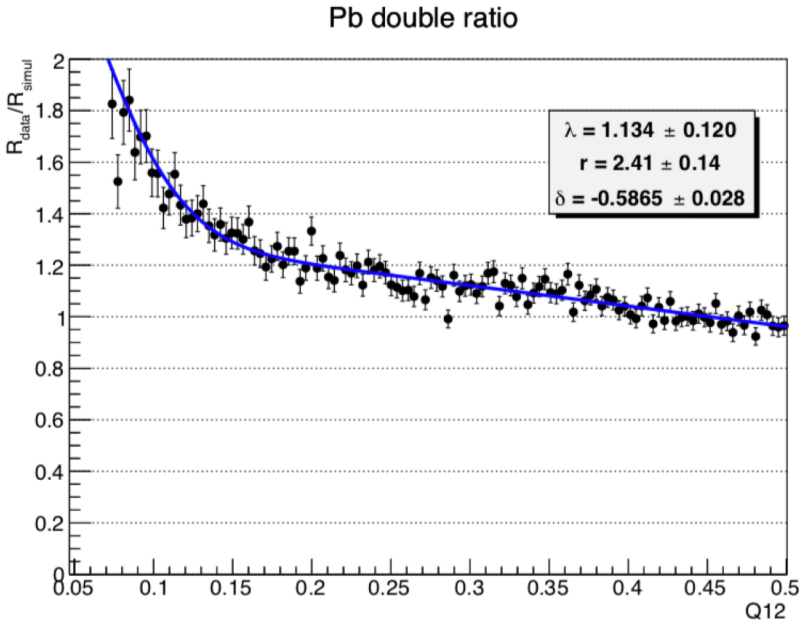
Bose-Einstein Correlation (BEC) arise from the interference between the symmetrized wave functions of identical bosons, in this case pions.
Using BEC it is possible to obtain information about the particle source or the emission duration

$R_{Data}/R_{background}$

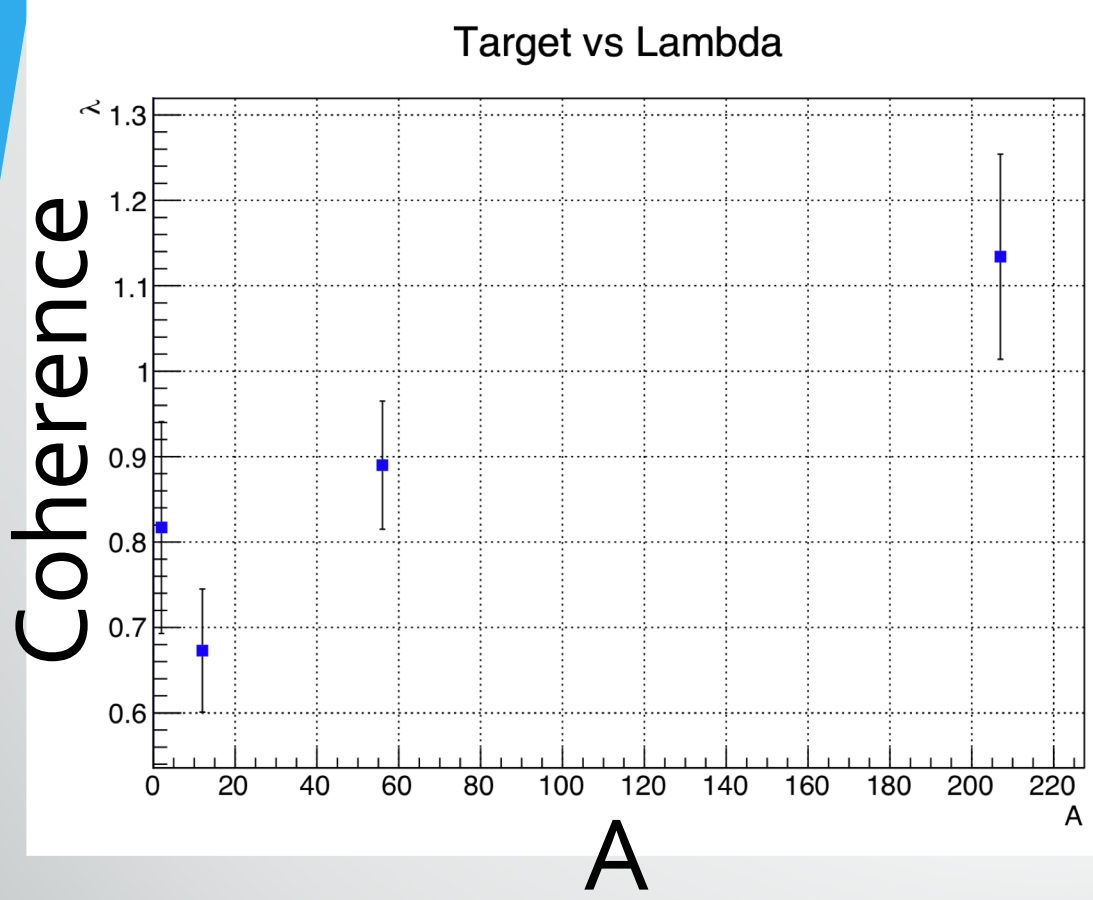


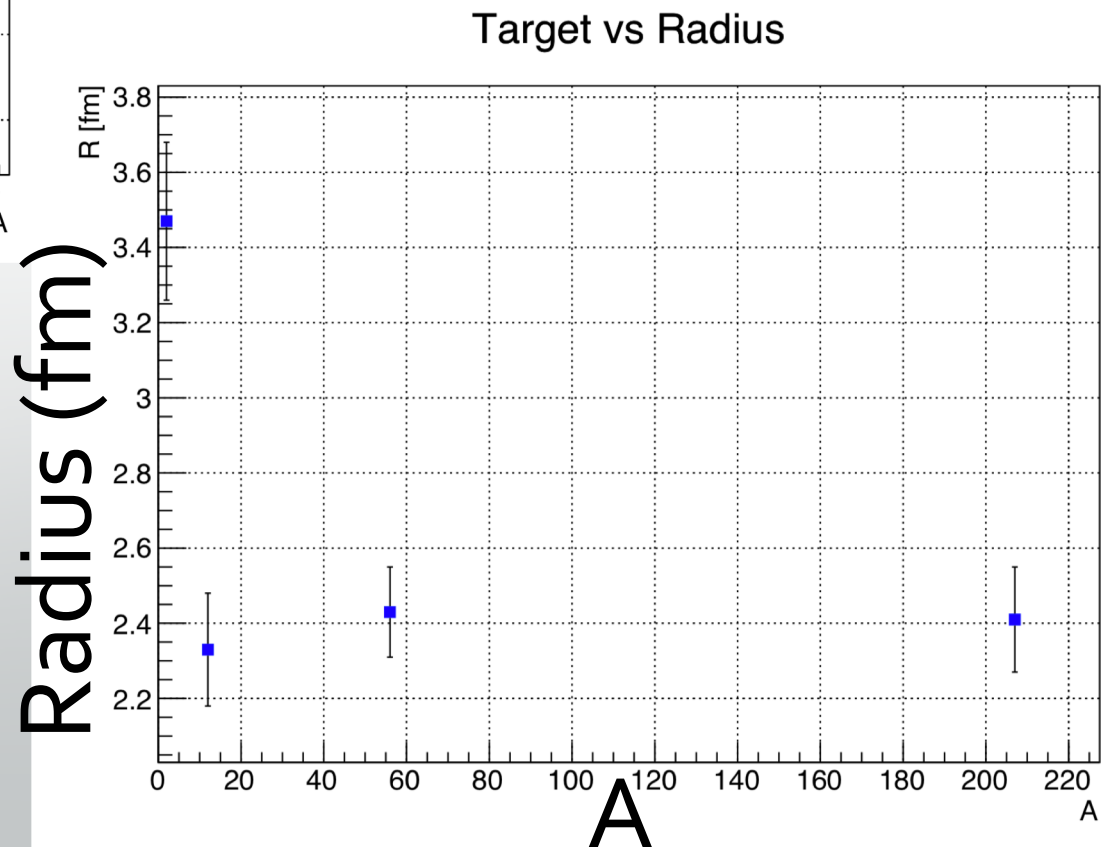






$$Q_{12} = \sqrt{-(p_1 - p_2)^2}$$


Target vs Lambda
λ
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0
20
40
60
80
100
120
140
160
180
200
220
A
Coherence
A


Target vs Radius
R [fm]
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0
20
40
60
80
100
120
140
160
180
200
220
A
Radius (fm)
A