# XEM2 EMC Update

## Hall C Winter Collaboration Meeting 2026

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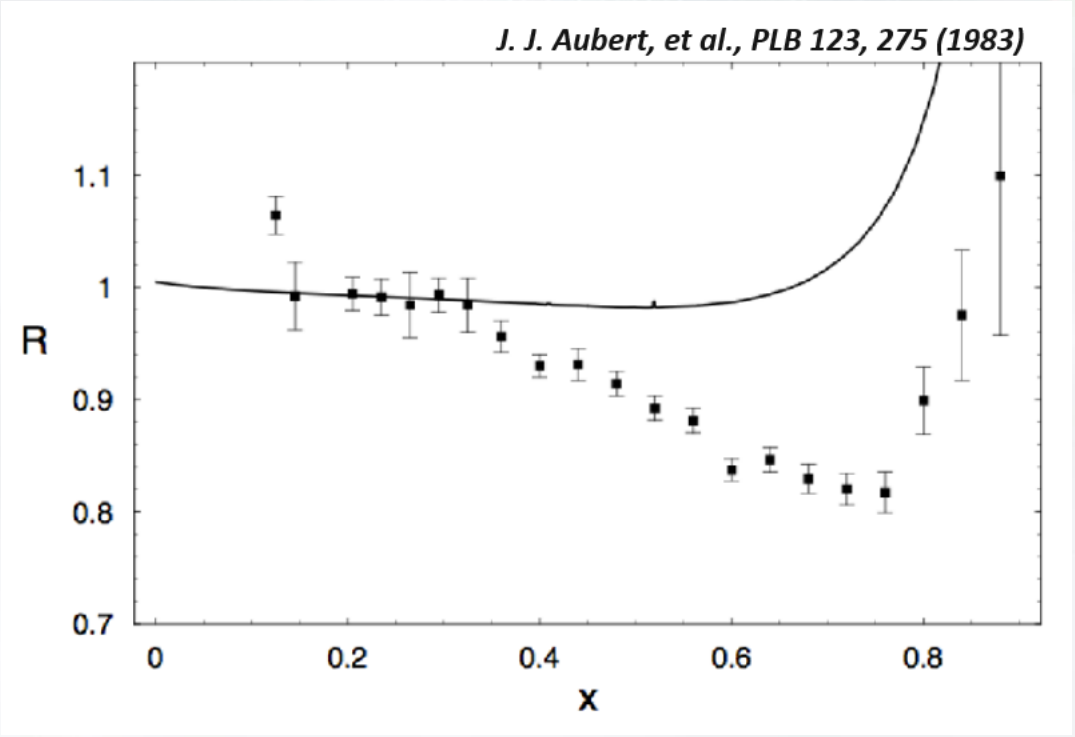
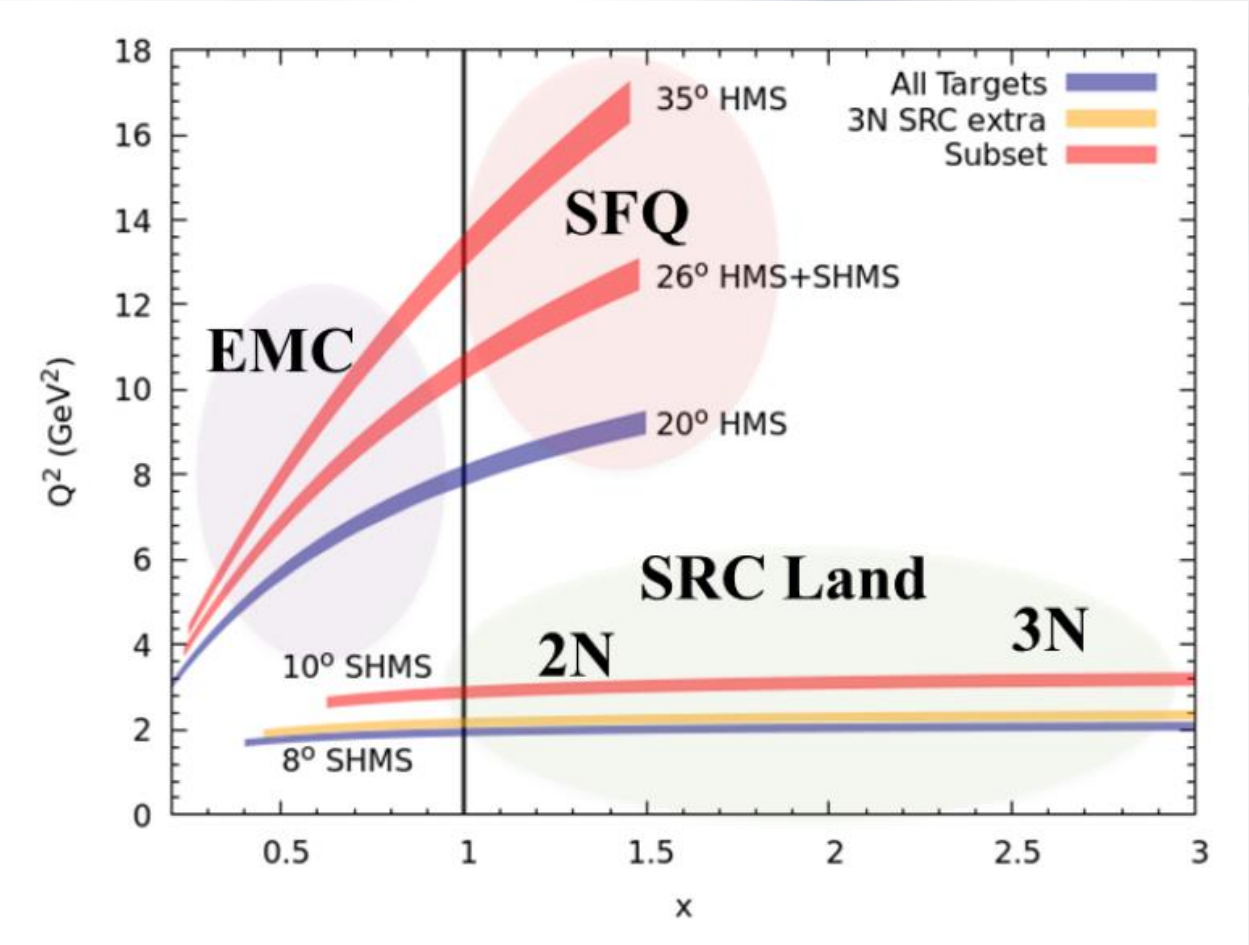
# The EMC Effect

- First seen by the European Muon Collaboration (EMC)
  - Assumed that the ratio of two nuclear targets would be unity + Fermi smearing
  - Intended to use this “property” as a check of luminosity
  - When checking this, a stark deviation that couldn’t be explained by luminosity was seen
- Kicked off many studies to better characterize this behavior
- The “strength” of the EMC effect is typically described as the slope of the data in the region 0.3<x<0.7

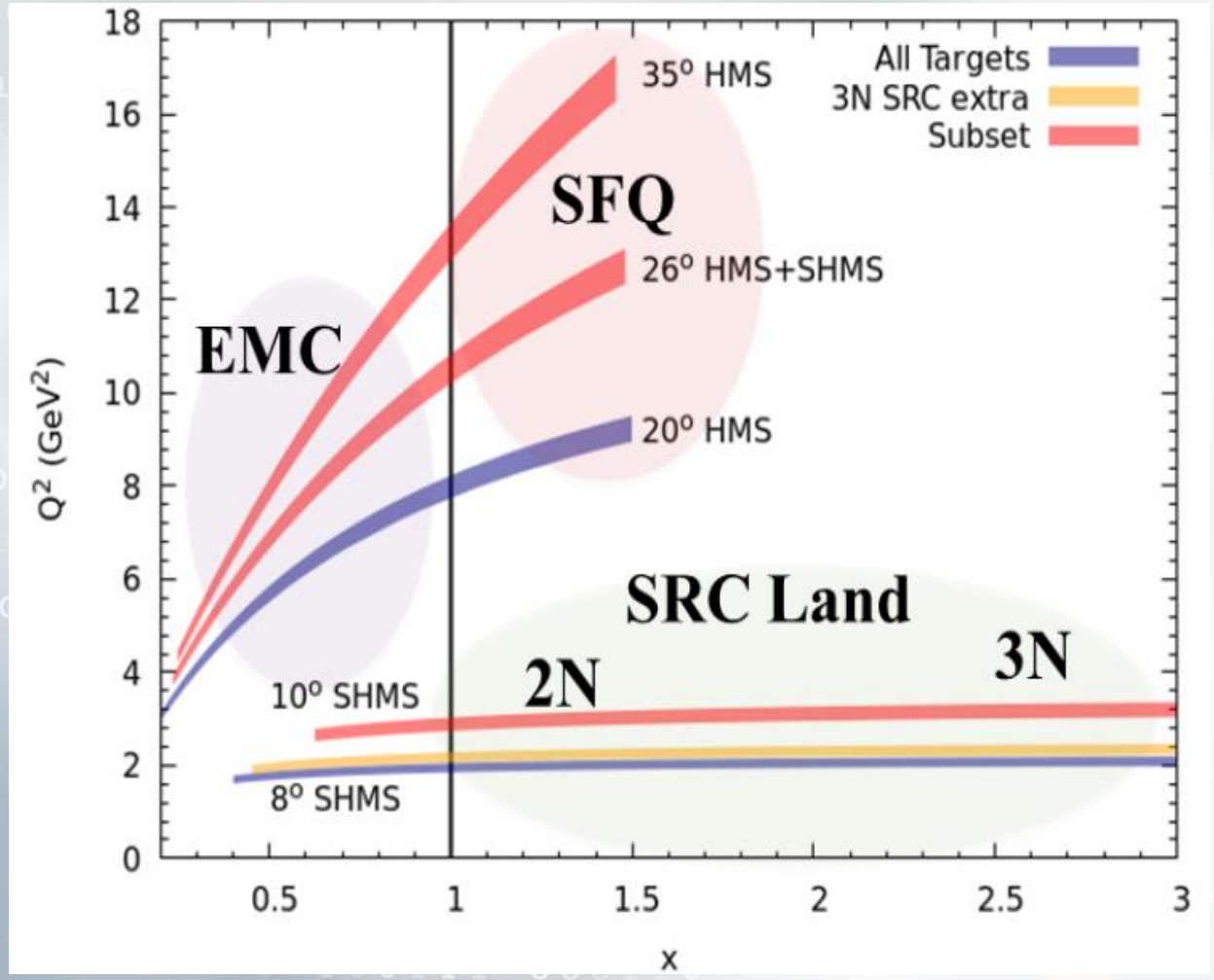


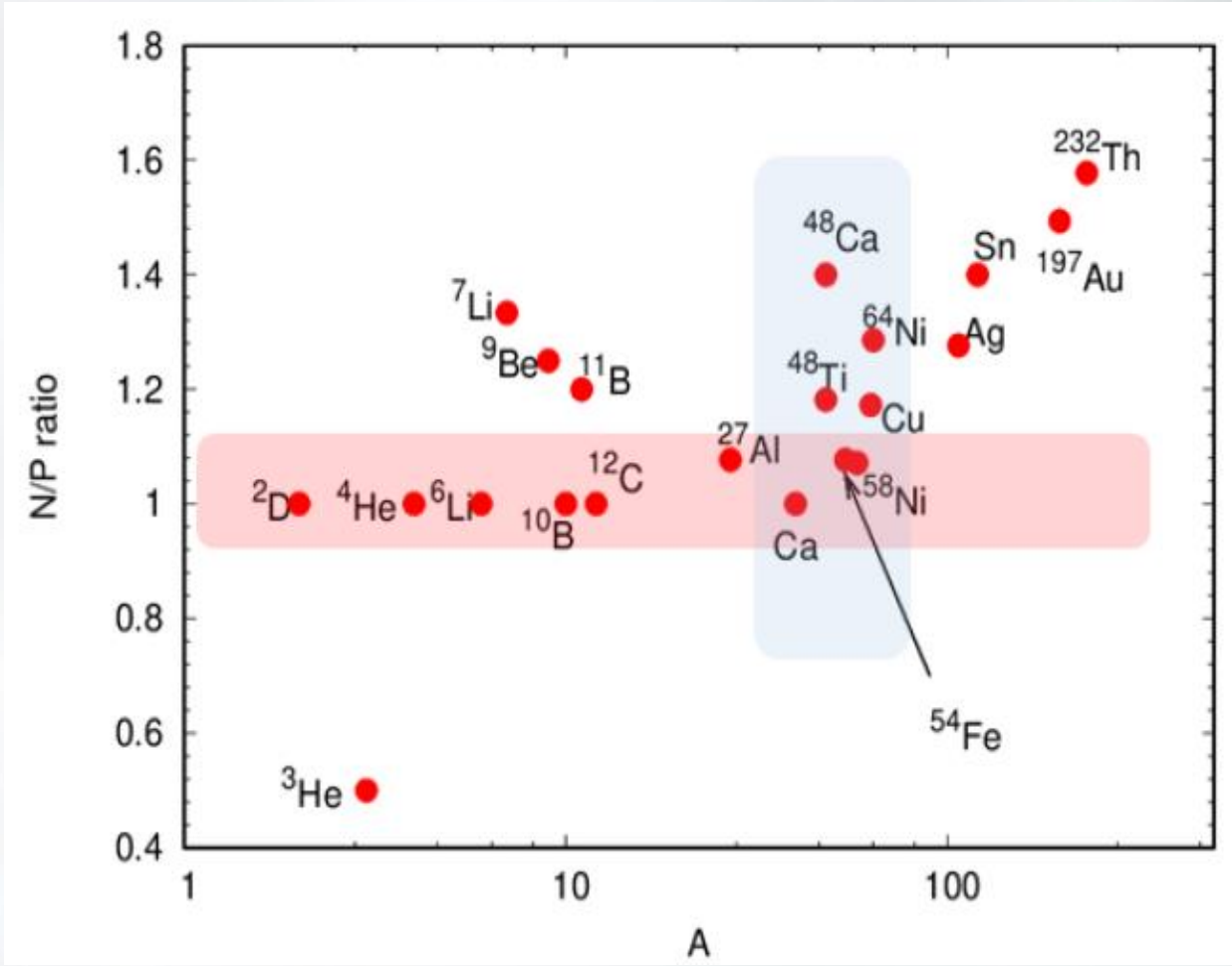
# XEM2 Experiments

- E12-06-105: (SHMS)
  - Studies of Short Range Correlations (SRCs)
  - Super fast quarks
- E12-10-008: (HMS)
  - Studies of the EMC effect



# Experimental Landscape



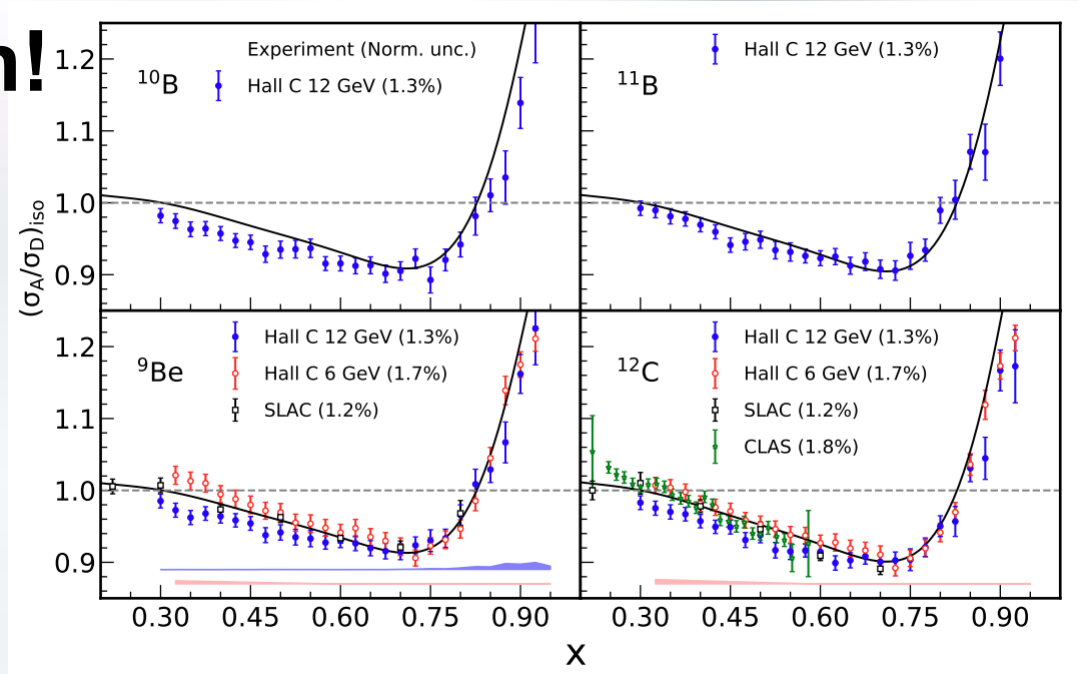



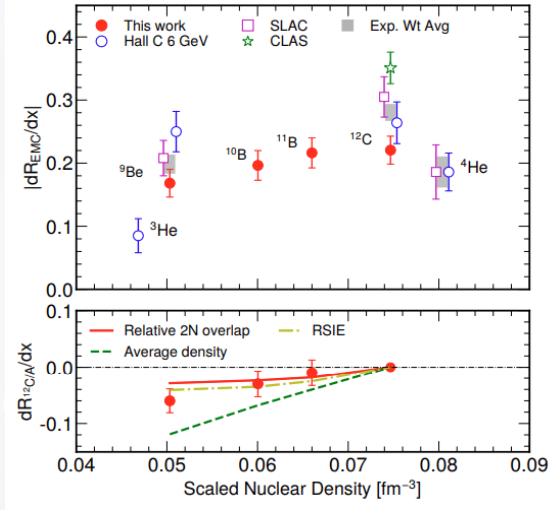
# Current Status

- 3 students graduated *so far*
  - Abishek Karki
  - Casey Morean
  - Cameron Cotton
  - *Who's next?*
- 1 Publication from commissioning data
  - A. Karki *et al.* First Measurement of the EMC Effect in $^{10}$B and $^{11}$B. *Phys. Rev. C* (2023).
- *Lots* of analysis underway

# Commissioning Run Publication!

- First study of EMC effect in Boron 10 and 11
- Data recorded with SHMS at 21° with three momentum settings (3.3, 4.1, and 5.0 GeV)
- Carbon and Beryllium have approximately 2σ smaller effect than previous measurements
  - No clear cause at the moment
  - More data coming from production run
  - Beryllium difference at low x may be due to reduced radiated quasi-elastic tail contributions

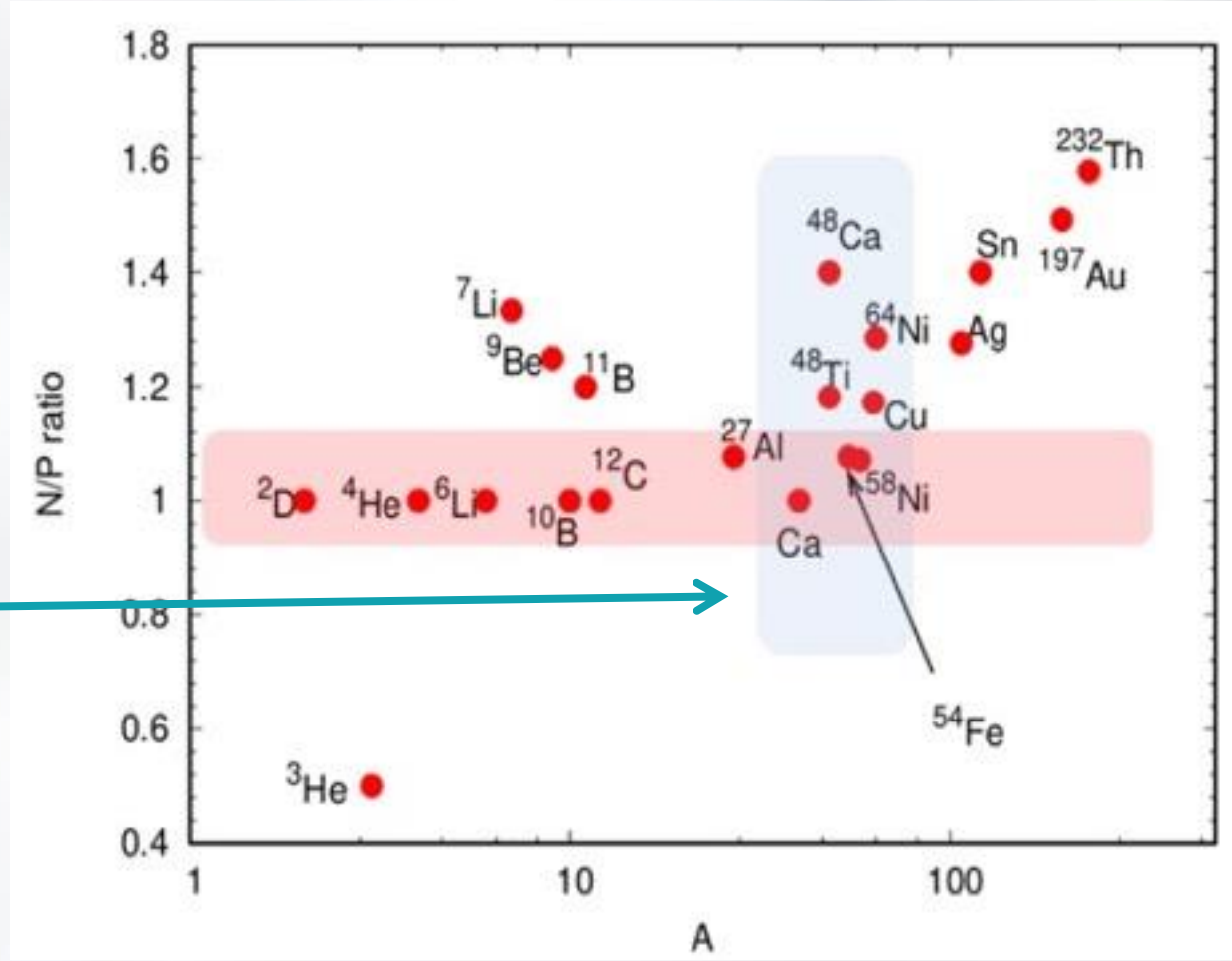



A. Karki *et al.* First Measurement of the EMC Effect in $^{10}$B and $^{11}$B. *Phys. Rev. C* (2023).

# First Production Data Thesis!

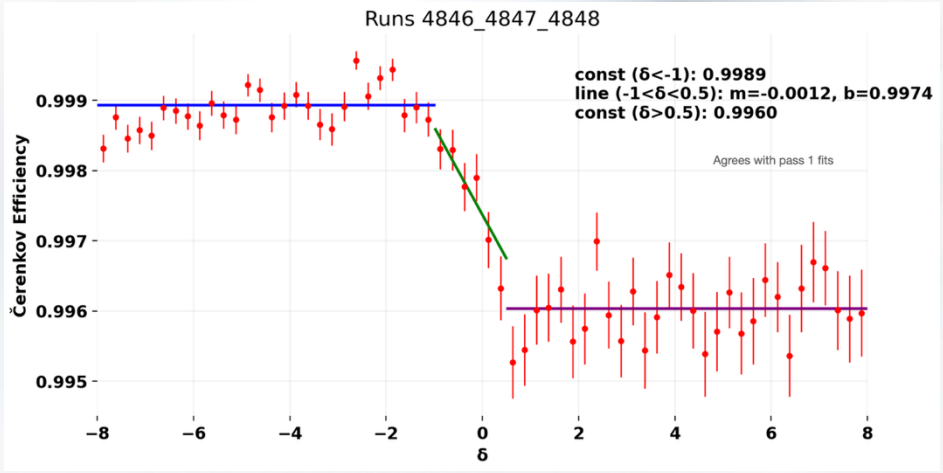
- Dr. Cameron Cotton – University of Virginia
  - First Measurement of the Isospin-Dependence of Nuclear Structure Functions at 12 GeV Jefferson Lab
- HMS data at 20°
  - 0.18<x<1
  - Many momentum settings
- Focus on targets with similar mass number A but varying N/Z ratios
  - Looking at the blue band



# Systematics Studies

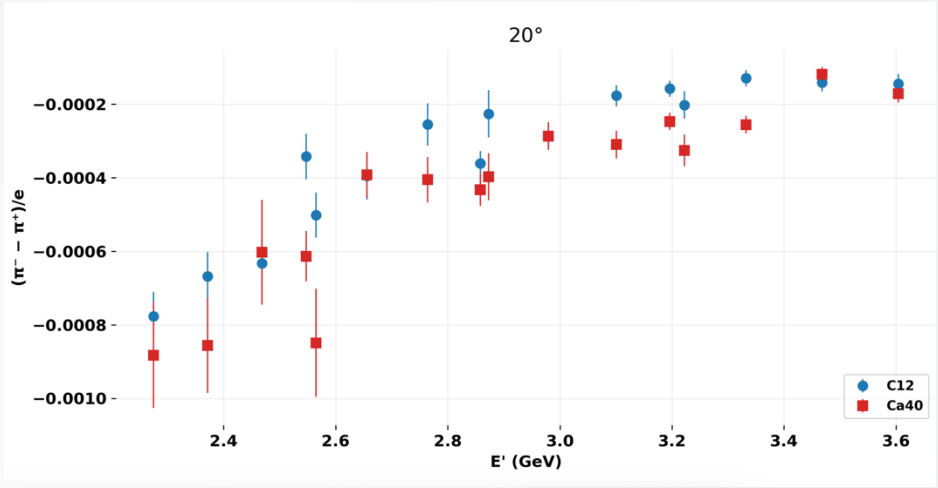
# Cherenkov Efficiency

- The Cherenkov efficiency is delta dependent
- The fit is almost a step function



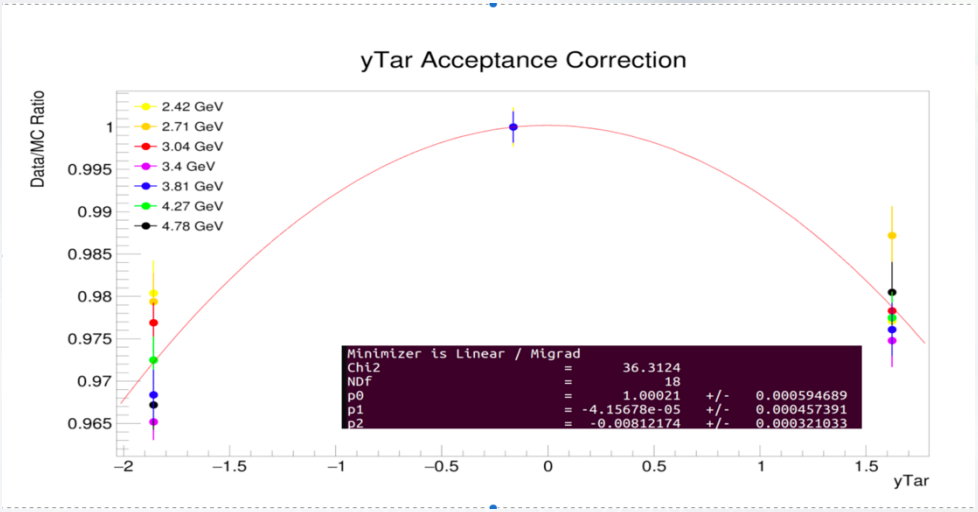

# Pion Contamination

- Pion production is charge asymmetric
- We need to quantify this to ensure that the charge symmetric background is sufficient
- The relative asymmetry is at most ~0.15%



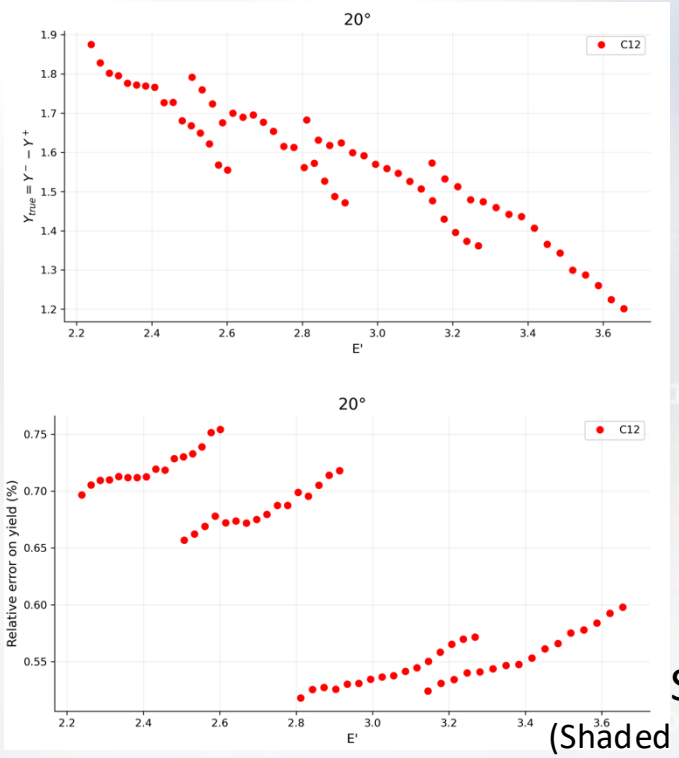
# $y_{tar}$ Acceptance Correction

- Monte Carlo simulation of the acceptance of the spectrometer is imperfect
- Best practice is to use the same target material at several ytar locations to fit a correction
- Here we use our aluminum target for a central ytar point and the two cell walls of the aluminum dummy cryo-target for the up/down-stream ytar points
- There is a clear central momentum dependence to this correction
  - Currently, we ignore this dependence
  - Studying this further is in the queue



# Charge-Symmetric Background

- Reverse polarity runs used to measure charge symmetric process production
- CSB contributions grow smaller with increasing E', leading to smaller uncertainty contributions




# Target Thickness

- Studies are being made into the uncertainty on target thicknesses
- Some solid target uncertainties are complicated by impurities

Deuterium Target

| Error | Value | Uncertainty | drho/rho |
|---|---|---|---|
| Temperature | 22 K | 200 mK | 0.3% |
| Pressure | 26 psia | 2 psia | 0.02% |
| Equation of state | | | 0.3% |
| Length measurement | 100 mm | 0.26 mm | 0.26% |
| Target contraction | 99.6% | 0.1% | 0.1% |
| Beam position | 0 | 1 mm | 0.2% |
| Total | | | 0.546% |

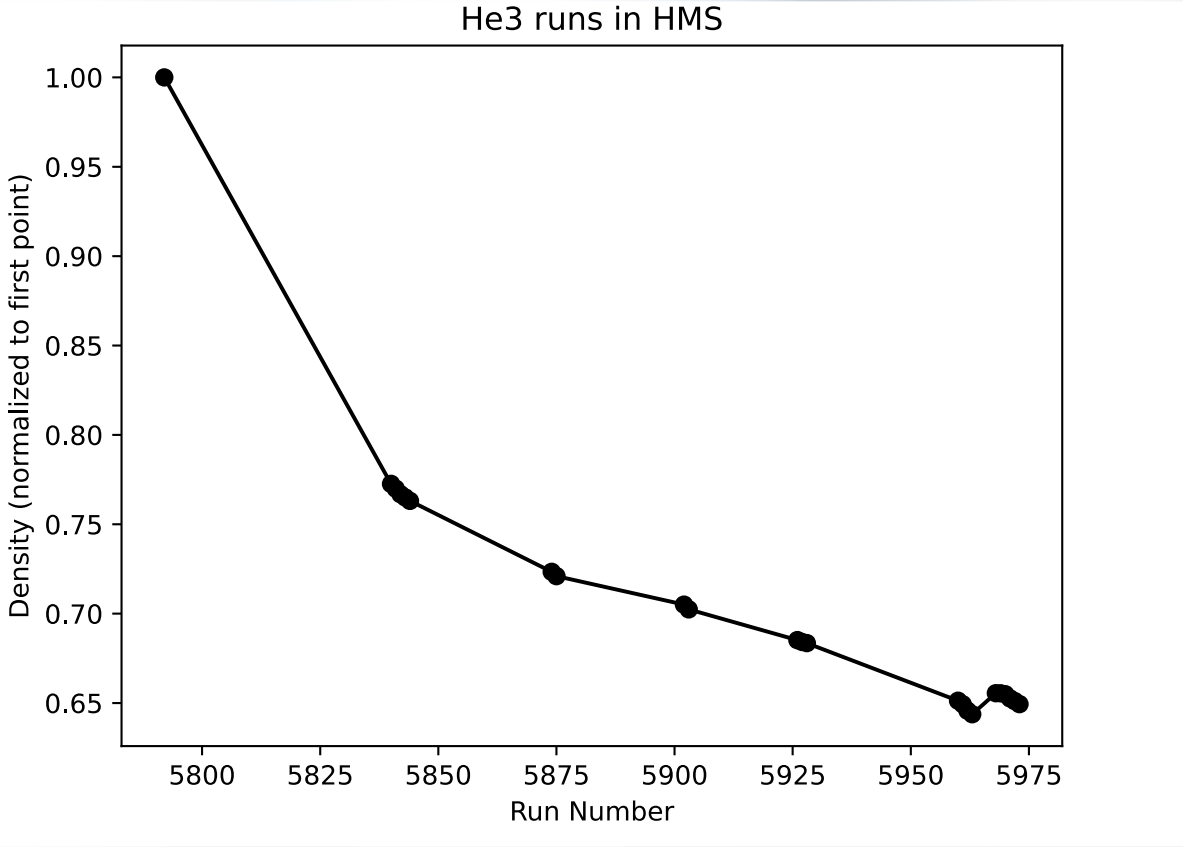
Solid Targets
(Shaded have known impurities)

| Target | Relative uncertainty in thickness (%) |
|---|---|
| $^{6}$Li | 0.356 |
| $^{7}$Li | 1.181 |
| $^{9}$Be | 0.304 |
| $^{10}$B | 0.463 |
| $^{11}$B | 0.416 |
| $^{12}$C | 0.315 |
| $^{27}$Al | 0.217 |
| $^{40}$Ca | 0.382 |
| $^{48}$Ca | 0.314 |
| $^{48}$Ti | 0.340 |
| $^{54}$Fe | 0.272 |
| $^{58}$Ni | 0.166 |
| $^{63}$Cu | 0.318 |
| $^{64}$Ni | 0.192 |
| $^{108}$Ag | 0.379 |
| $^{197}$Au | 0.148 |
| $^{232}$Th | 0.244 |

# Problems to Overcome

# Helium 3 Target Leaking

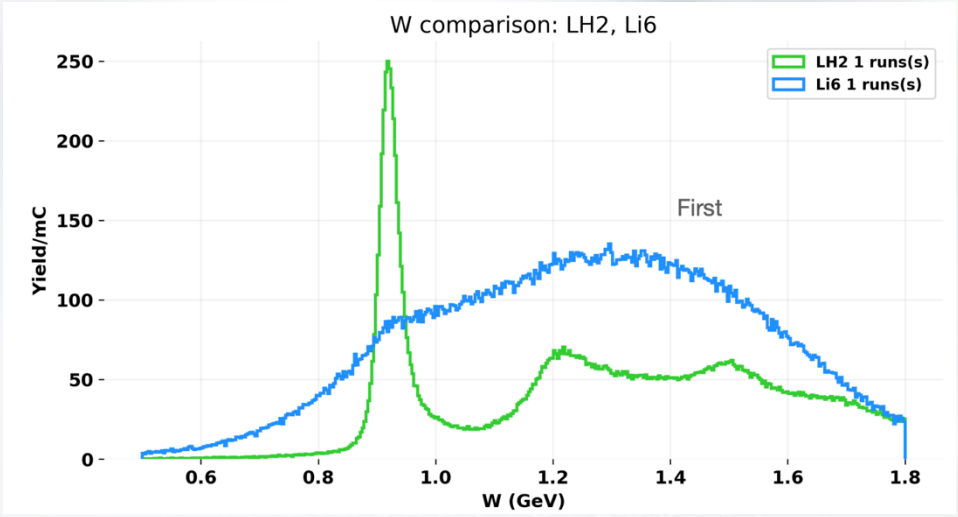
- Early after the second target ladder was installed, a leak was discovered in the $^3$He target
- Around half of the target thickness was lost
- Abhyuday (UTK) has been hard at work to characterize the target thickness over time
  - A non-negligible fraction of our data was taken while the target was actively leaking
  - Will lead to a time-dependent target thickness correction
  - Will require an additional systematic uncertainty to account for this correction

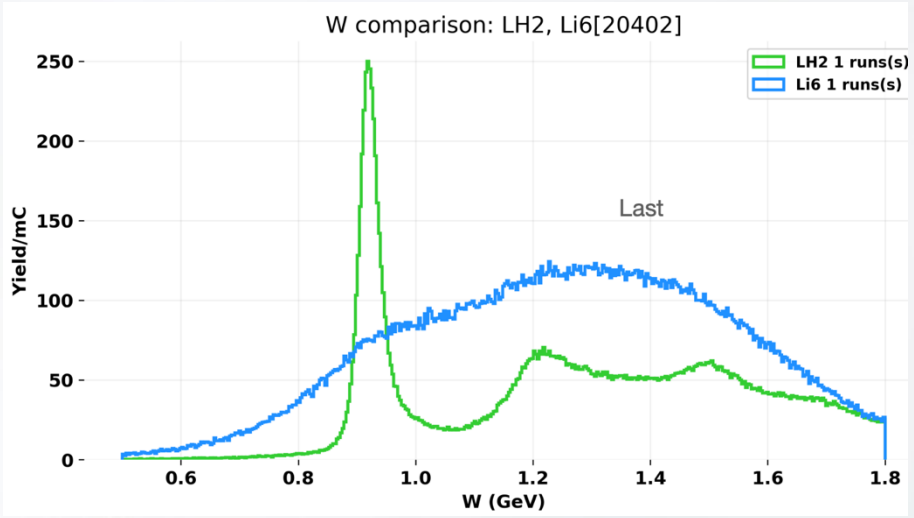



Plot courtesy of Abhyuday Sharda (UTK)

# Mineral Oil Contamination of Lithium Targets

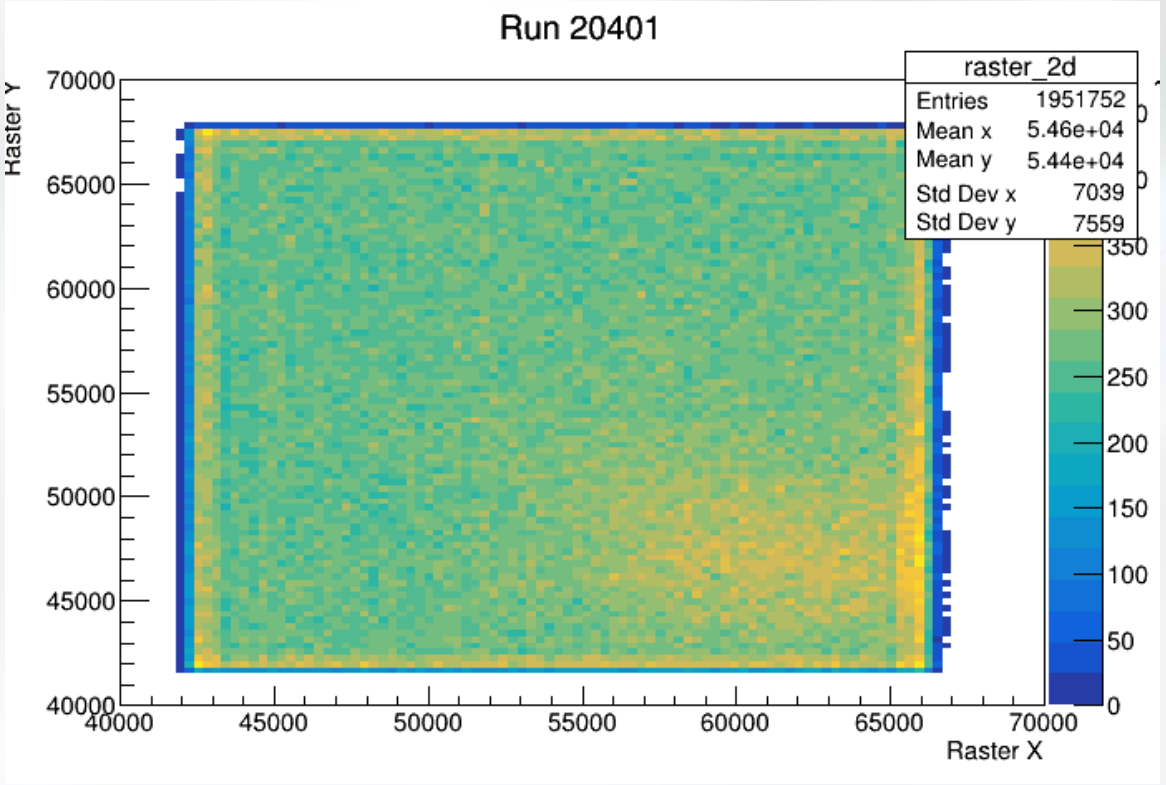
- An enhancement has been seen in the lithium targets near the proton mass in the W spectra
- Comparing it to the hydrogen spectrum, it does appear to be in the correct location
- It appears that this is mineral oil that was used in target production that did not fully burn off
- This contaminates the data and must a subtraction procedure needs to be developed
- The mineral oil used was “white” mineral oil with a chemical structure of $C_{15}H_{16}O_6$

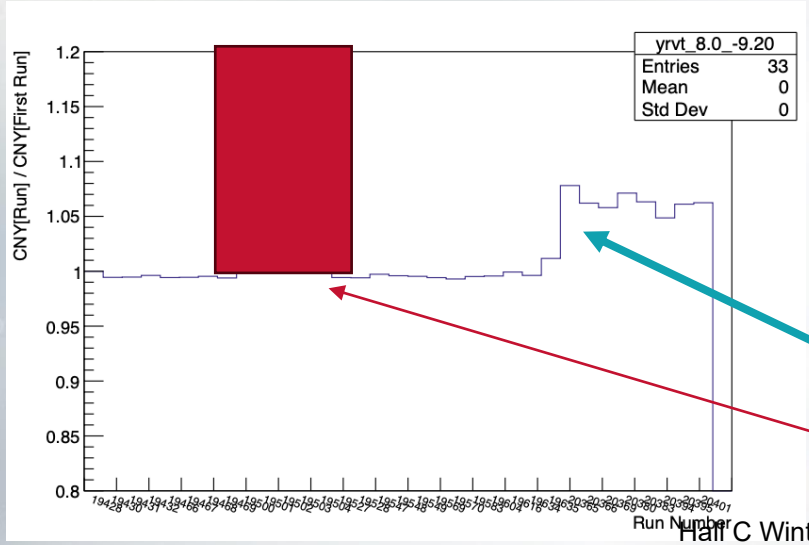


# Lithium Target Melting and the Tin Disappearing Act

- Partway through the run period, a “hot spot” appeared on the $^{6}$Li, $^{7}$Li, and Sn targets
  - The tin target was not on the target ladder and not found after the run
- Investigation found no issues with the raster
  - That is, it is a target effect, not a beam position effect
- It seems that we partially melted the target causing a buildup of excess material forming a hot spot



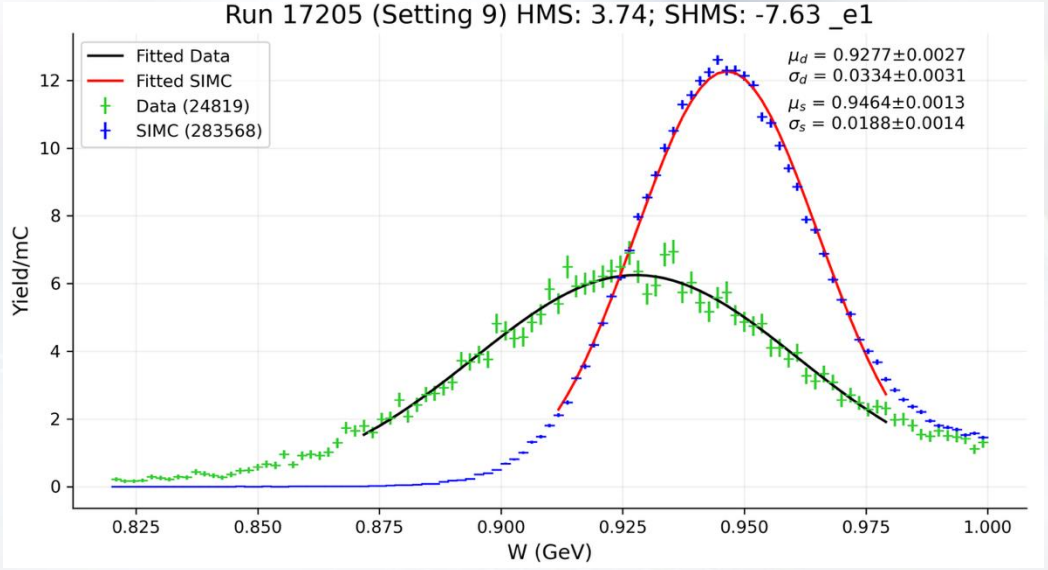

Charge Normalized Yield v. Run normalized to first run

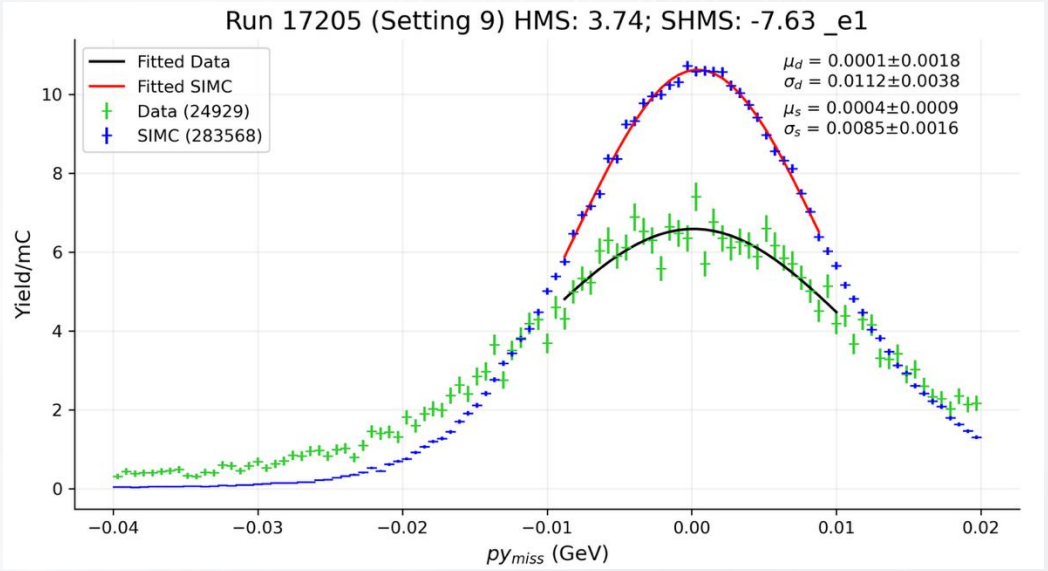
Yield jump just as hot spot appears in data!

Nothing to see here… (red herring easily explainable by configuration changes)

# Spectrometer Offsets

- Angle and momentum offsets are applied per spectrometer are calculated using elastic coincidence runs and singe-arm runs
- The offsets are used to align the elastic peak as compared to simulation
- To the right is the peak before (top) and after (bottom) offsets are applied
- We are still investigating that offsets calculated from single-arm elastics are different from coincidence
- Further, excluding settings where the SHMS is saturated prevents the HMS angle offset from converging



# What is left?

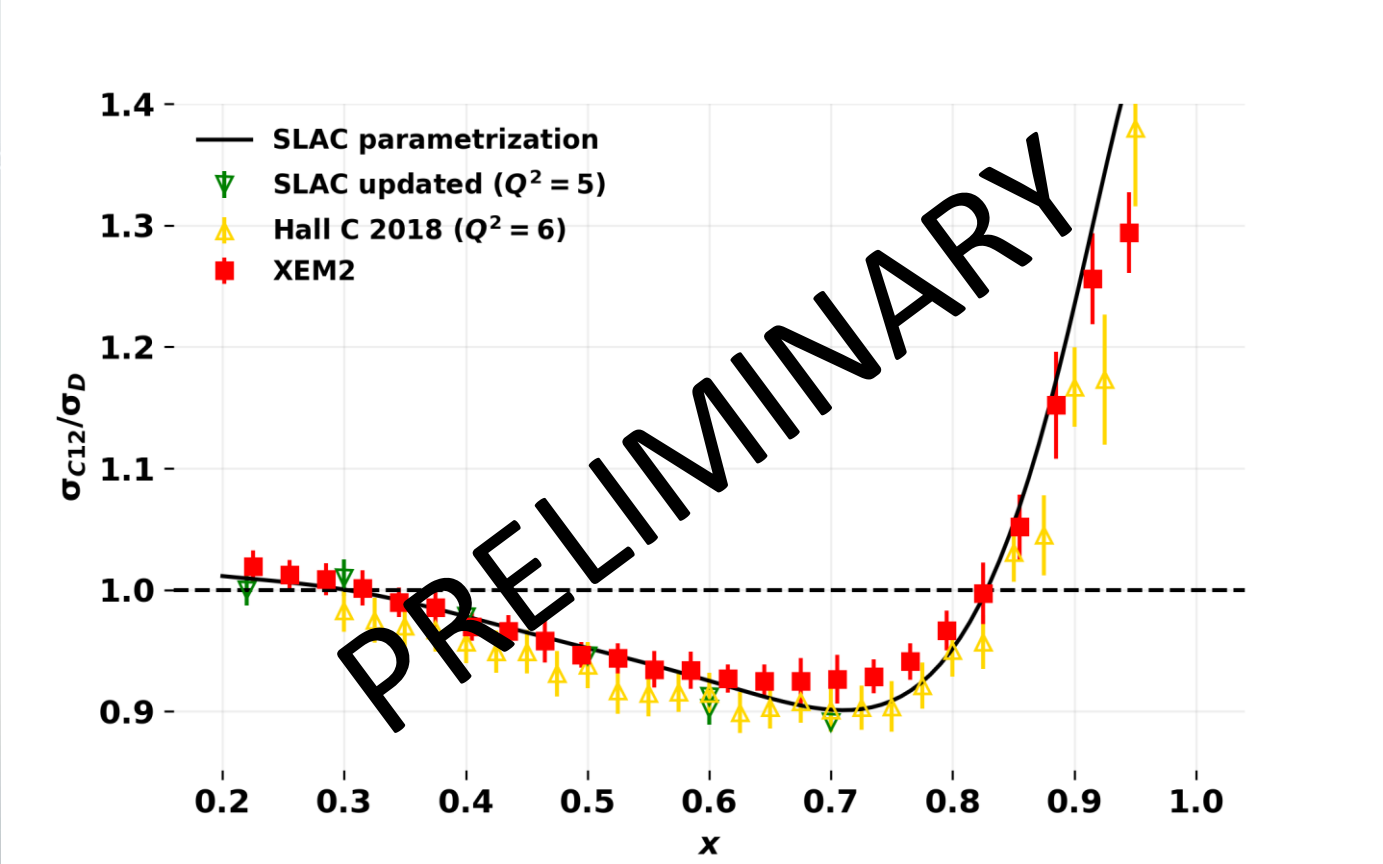
# Studies and Analyses Ongoing and in the Queue
**(in no particular order)**

- Mineral oil subtraction from Lithium targets
  - Results in a hydrocarbon contribution to the data
  - Hydrogen peak is visible
  - Currently do not have a subtraction procedure
- Spectrometer Offsets
  - Calculated offsets vary based on SHMS delta using coincidence data
  - Omitting coincidence data where the SHMS is saturated prevents HMS angle offset from converging
- Electronic Deadtime
  - SHMS EDTM study is underway, HMS study is in the queue
- Full analysis of 26° and 35° data
  - Both have been looked at for data quality
  - 20° data has been focus so far

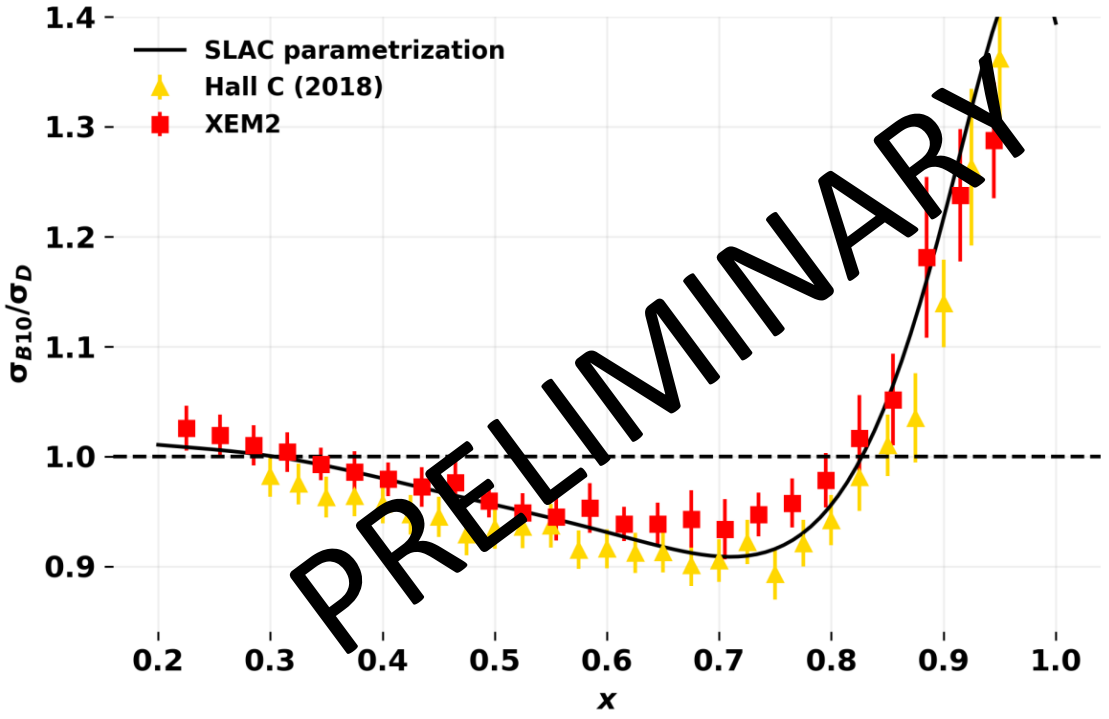
# Preliminary Results

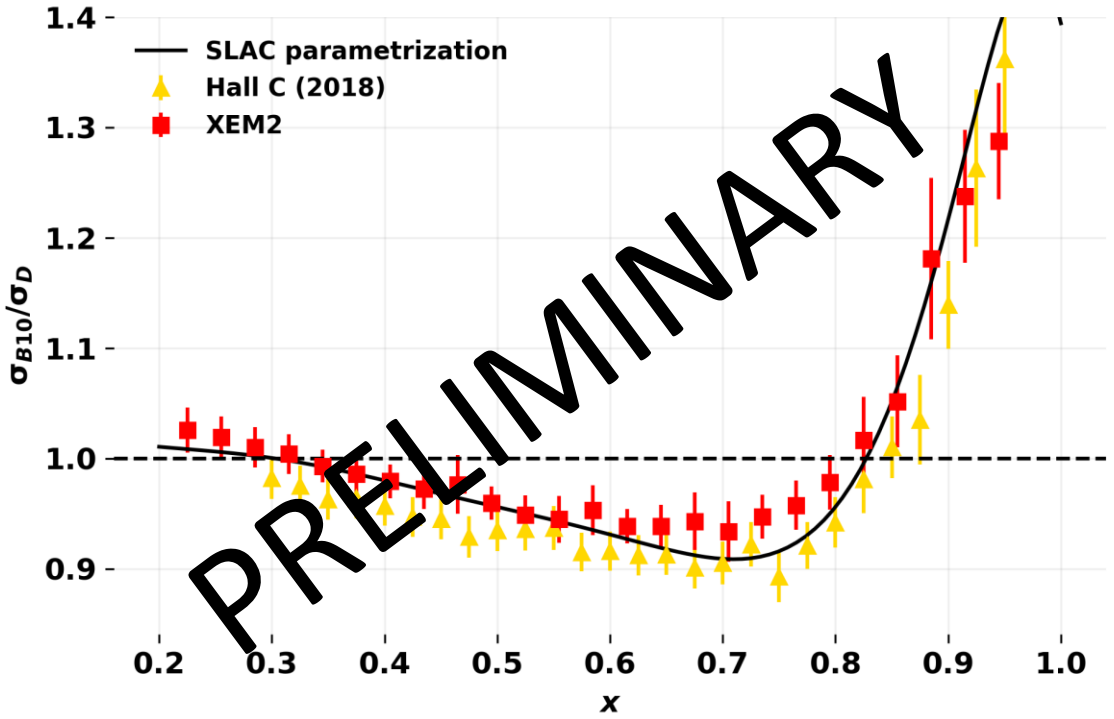
*Plots include rough estimations of systematics and are still undergoing cross checks

# Carbon

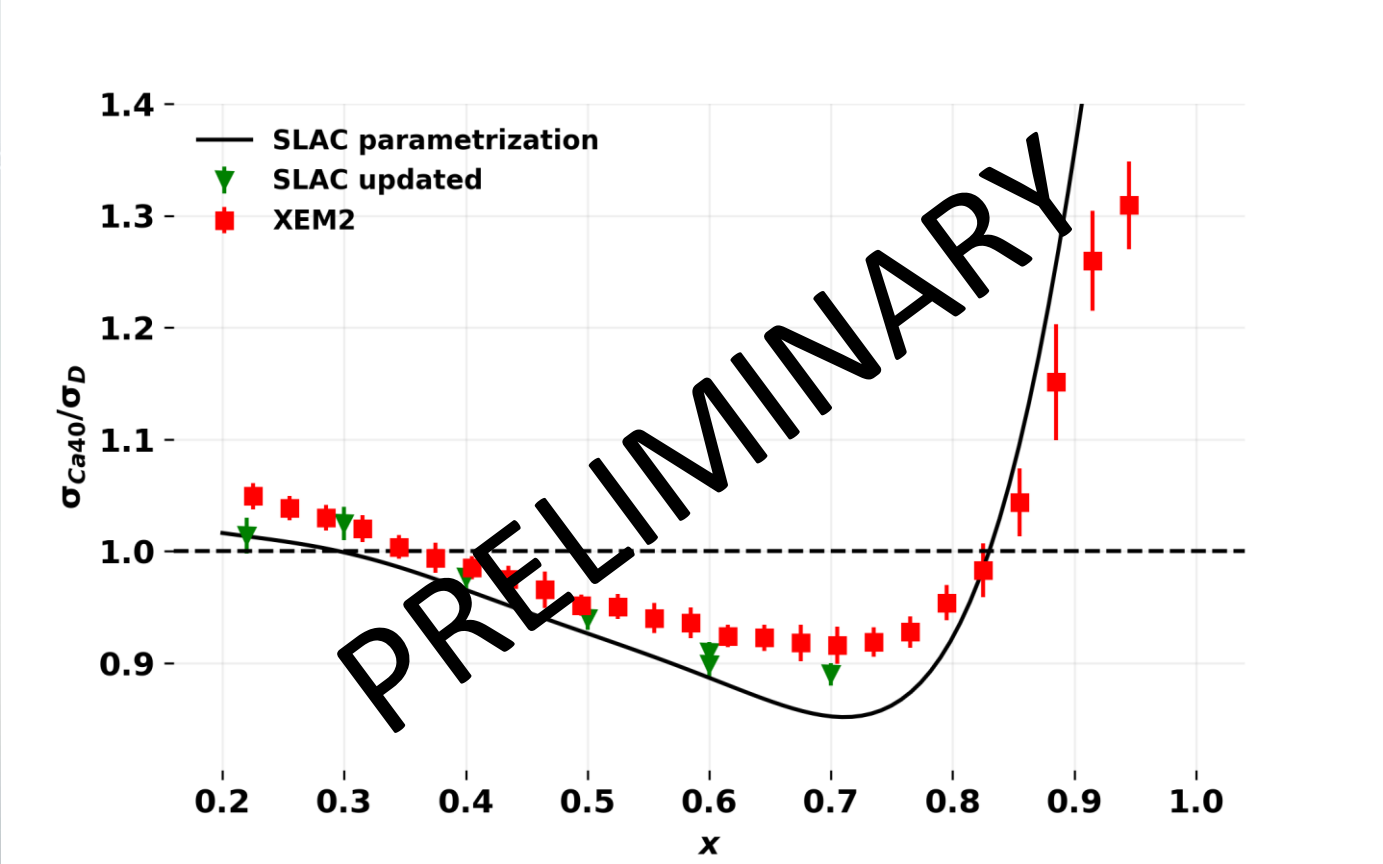

SLAC parametrization
SLAC updated ($Q^2 = 5$)
Hall C 2018 ($Q^2 = 6$)
XEM2
PRELIMINARY
$\sigma_{C12}/\sigma_D$
1.4
1.3
1.2
1.1
1.0
0.9
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
$x$

# Boron 10 and 11

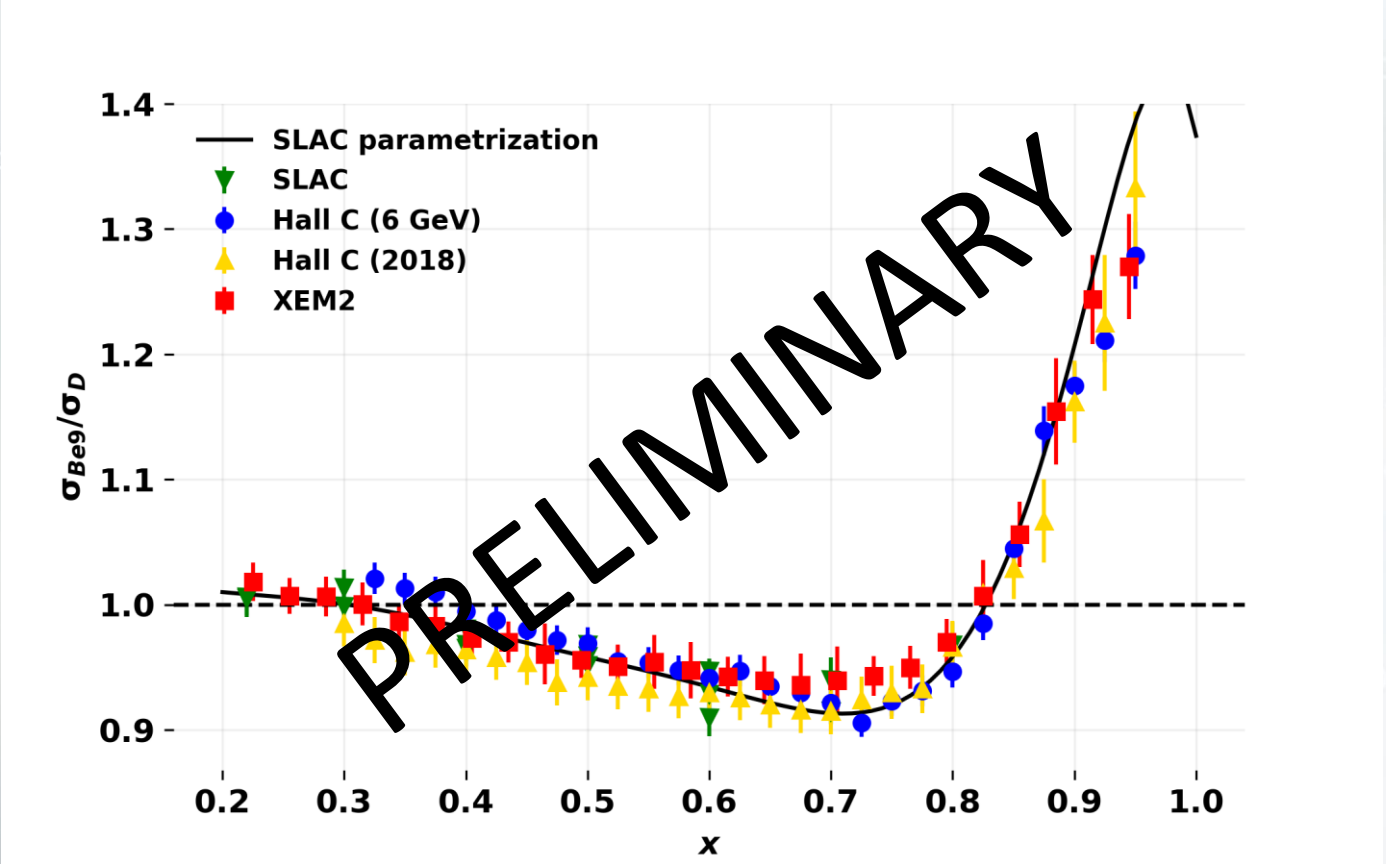


# Calcium 40


SLAC parametrization
SLAC updated
XEM2
PRELIMINARY
$\sigma_{Ca40}/\sigma_D$
1.4
1.3
1.2
1.1
1.0
0.9
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
x

# Beryllium 9


SLAC parametrization
SLAC
Hall C (6 GeV)
Hall C (2018)
XEM2
PRELIMINARY
$\sigma_{Be9}/\sigma_D$
1.4
1.3
1.2
1.1
1.0
0.9
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
x

# Acknowledgement


Spokespeople:
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* = Graduated/Escaped

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# QUESTIONS?

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