# Study of NN Short Range Correlations in the XEM2 Experiment

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For the Light ions for the EIC Summer School

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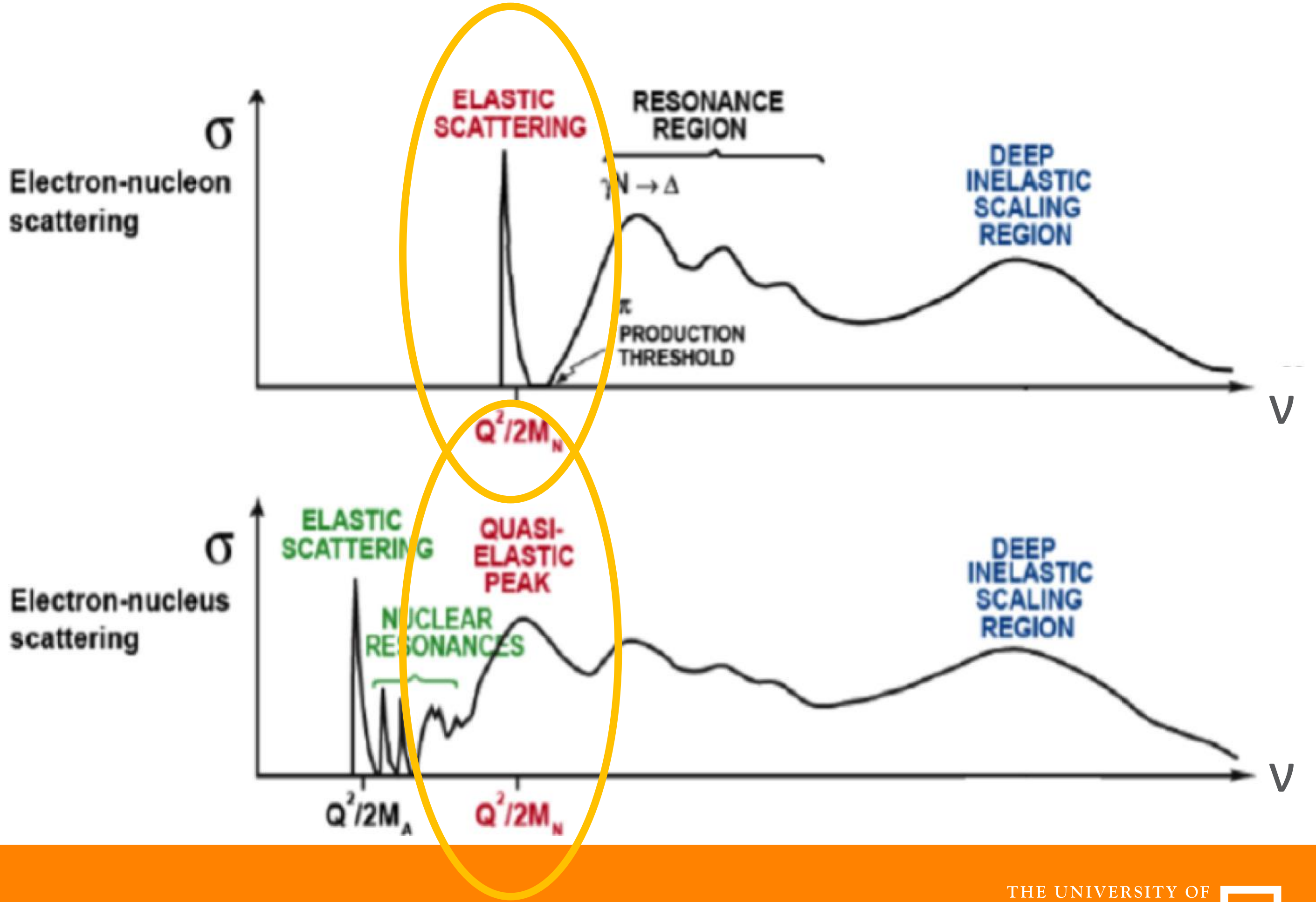
# Scattering Processes

- This experiment will be focused on Quasi-Elastic (QE) Scattering
  - Can be interpreted as scattering from the entire nucleon within the nucleus



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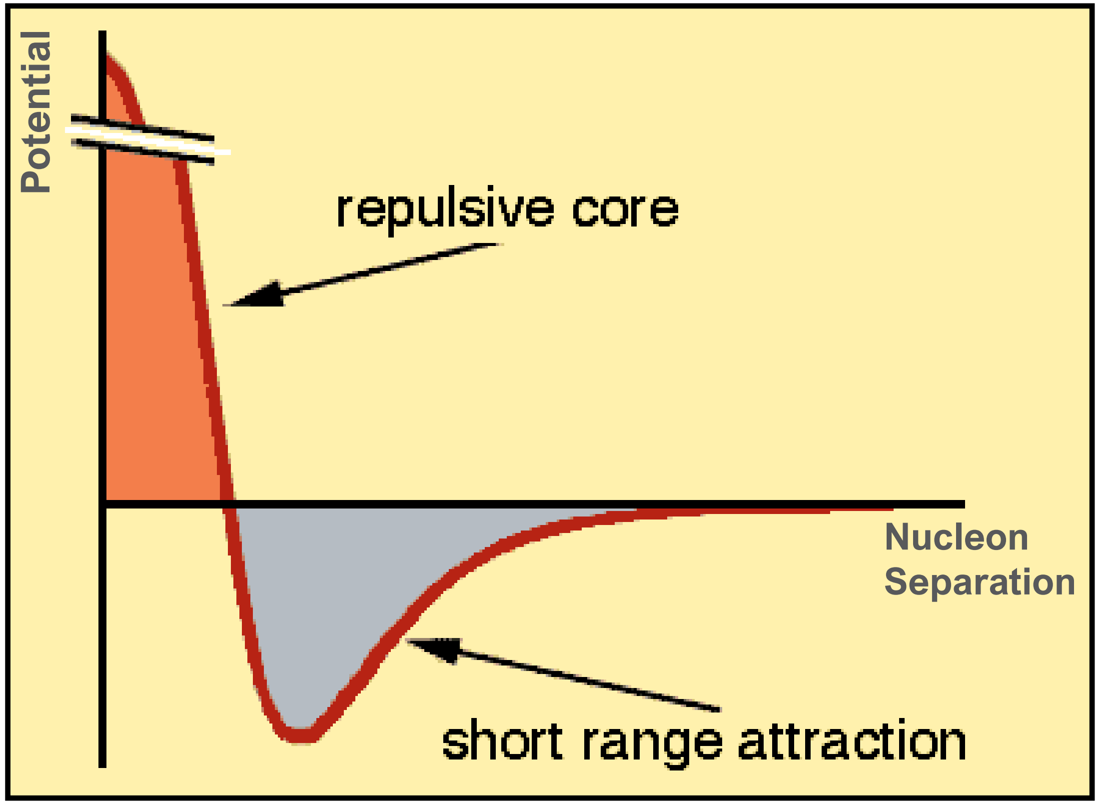
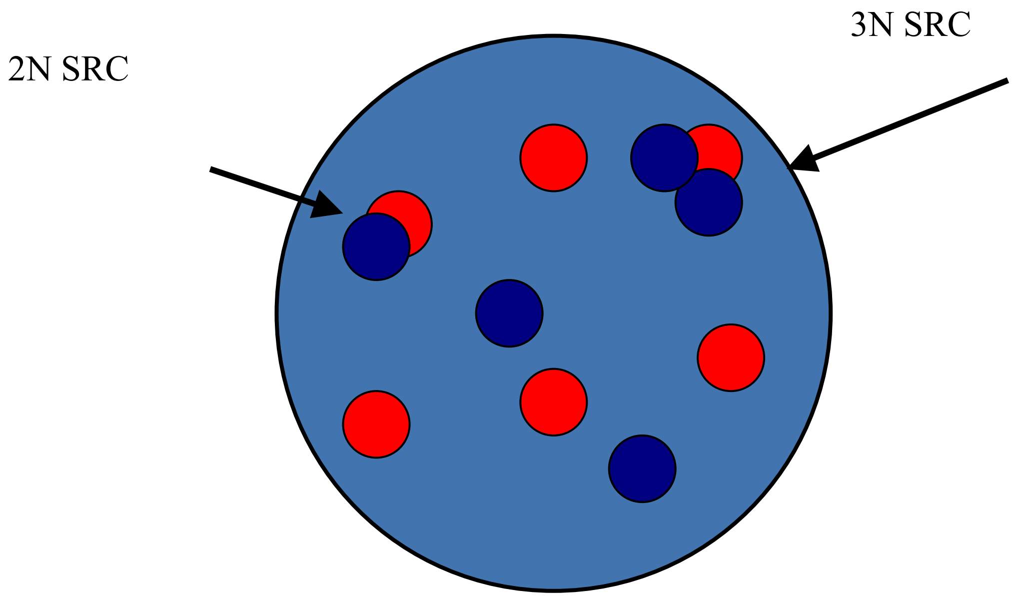
# The NN Short-Range Correlation (SRC) Picture




High momentum nucleons

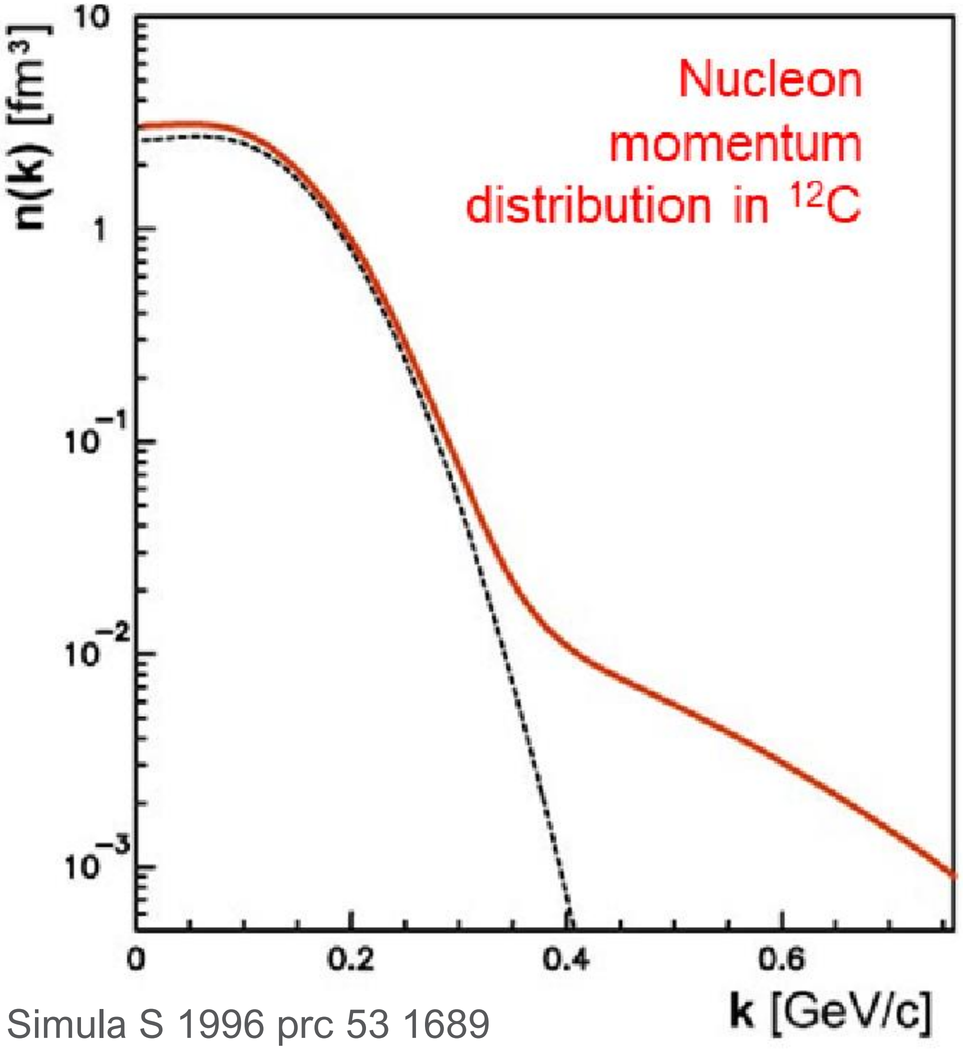
→ Short Range Correlations

Were studying the high momentum component of the nuclear wave function

Picture credit: Nadia Fomin

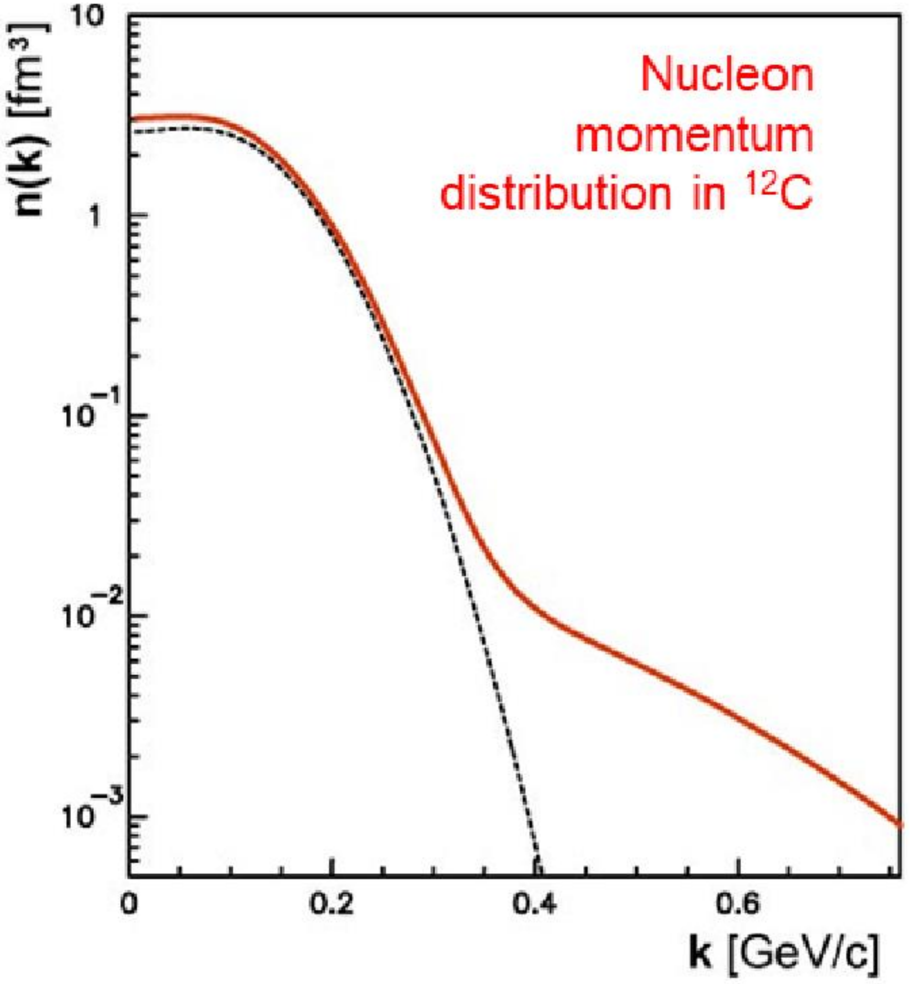
# The nucleon momentum distribution

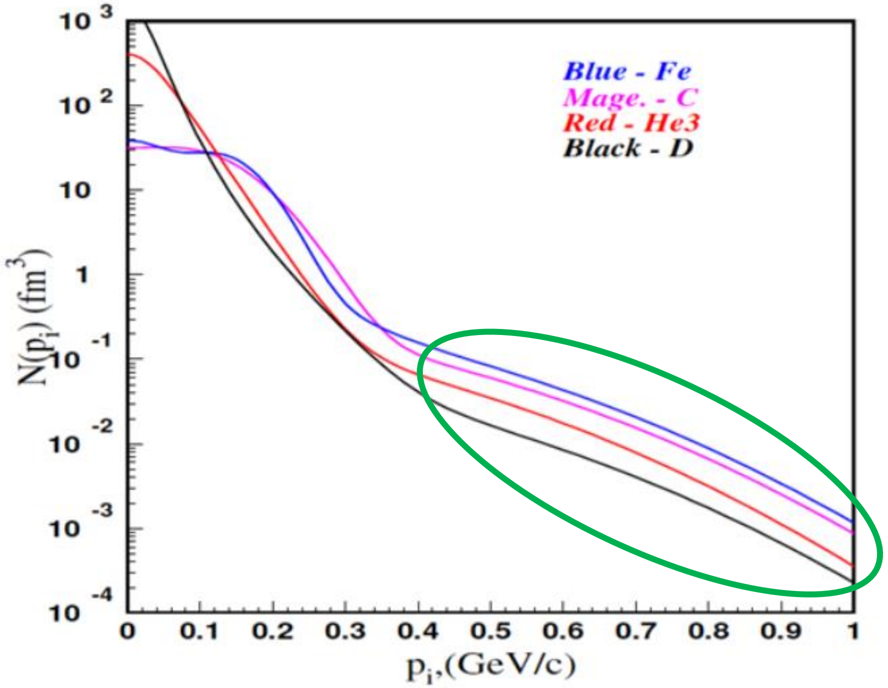
- Early Mean-Field models of the nucleus couldn't account for the "observation" of a tail in the distribution at high momentum
  - Nucleons were "observed" above the Fermi momentum
  - Where do these high momentum nucleons come from??




Credit: Degli Atti C C and Simula S 1996 prc 53 1689

# The nucleon momentum distribution




Credit: Degli Atti C C and Simula S 1996 prc 53 1689



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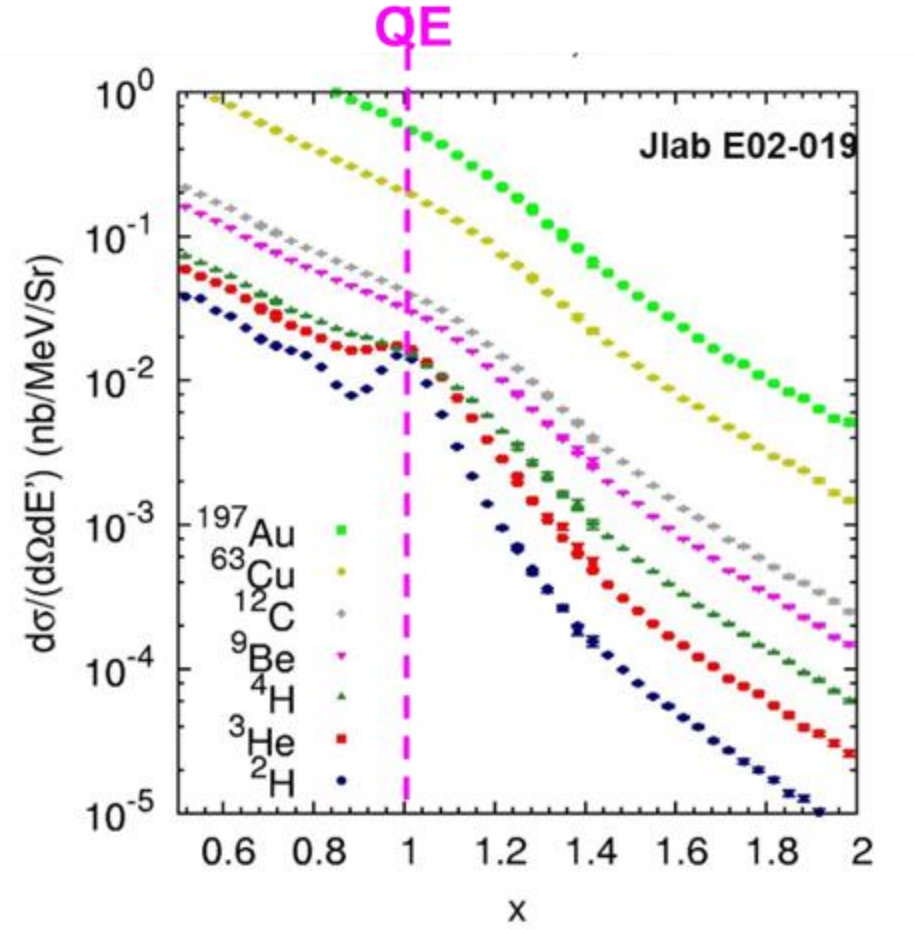
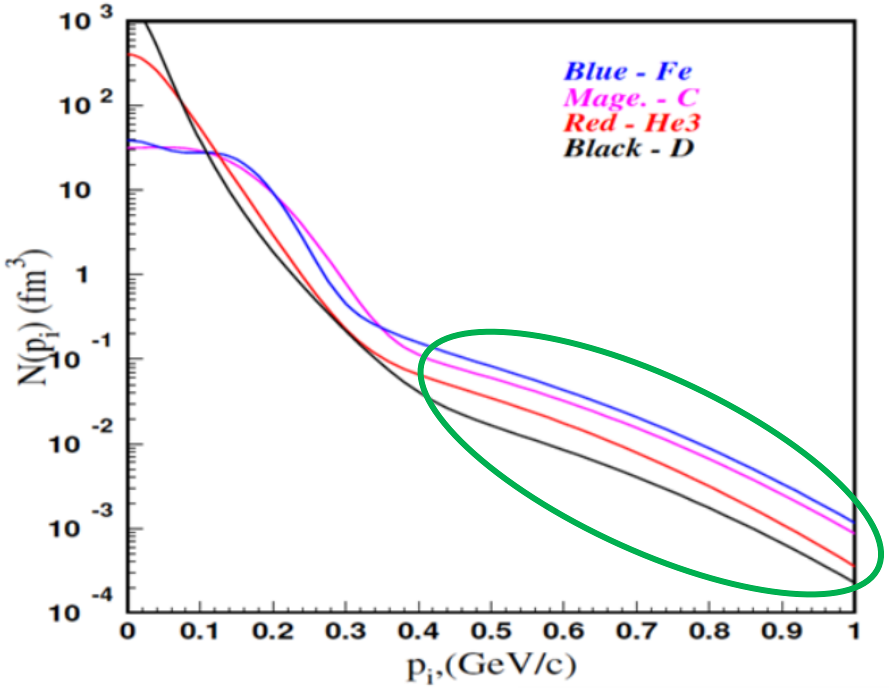
# The nucleon momentum distribution




Credit: Degli Atti C C and Simula S 1996 prc 53 1689



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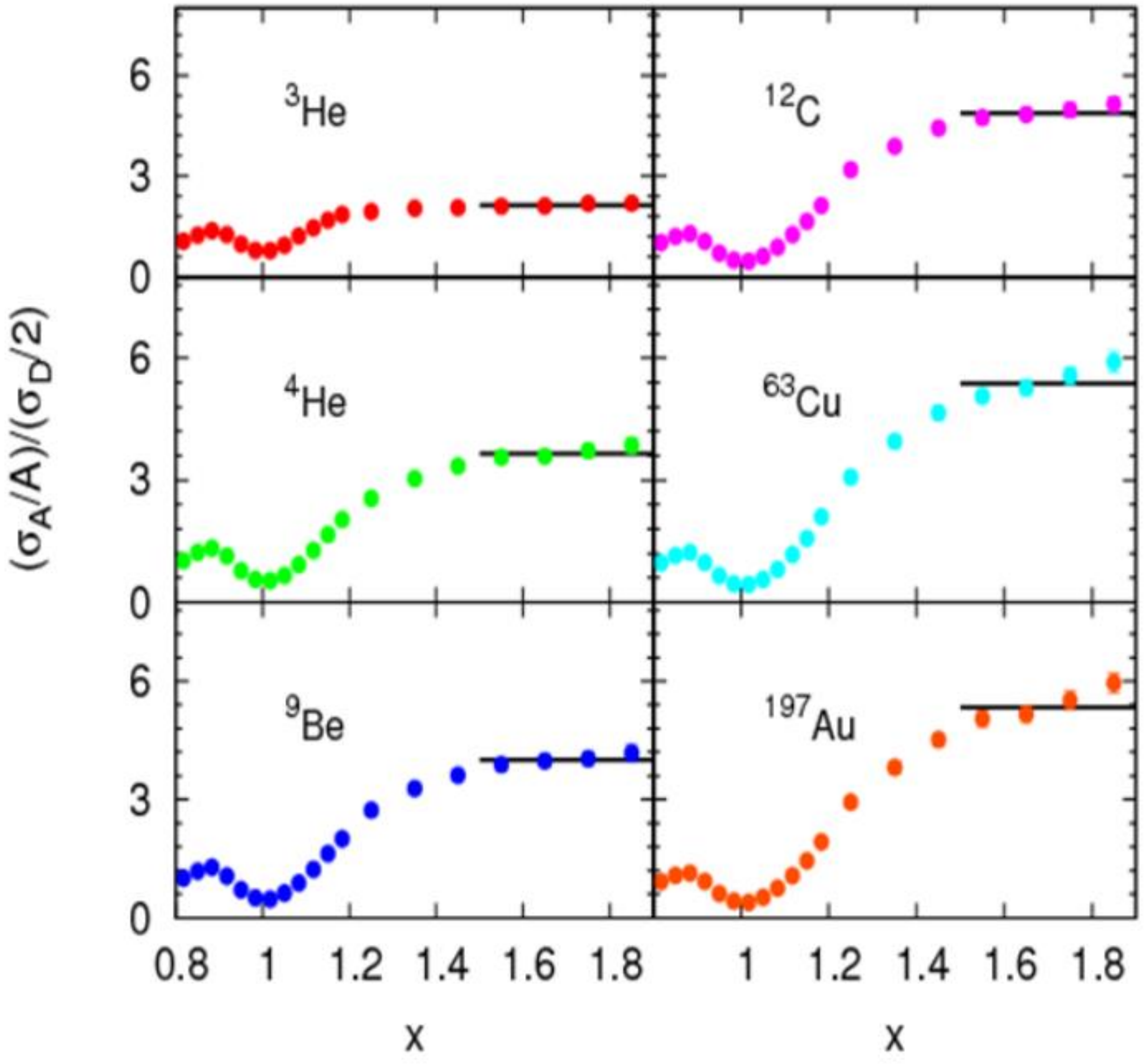
# 2N SRC data

- In the region x > 1, these plateaus have been observed
- The value of this plateau is the magnitude of $a_2$.
- $a_2$ can also be interpreted as the abundance of 2N SRCs relative to Deuteron.




Fomin N et al. 2012 Phys. Rev. Lett. 108 092502



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# SRC Expansion

- We can expand the cross section in terms of scattering cross sections for each SRC order:

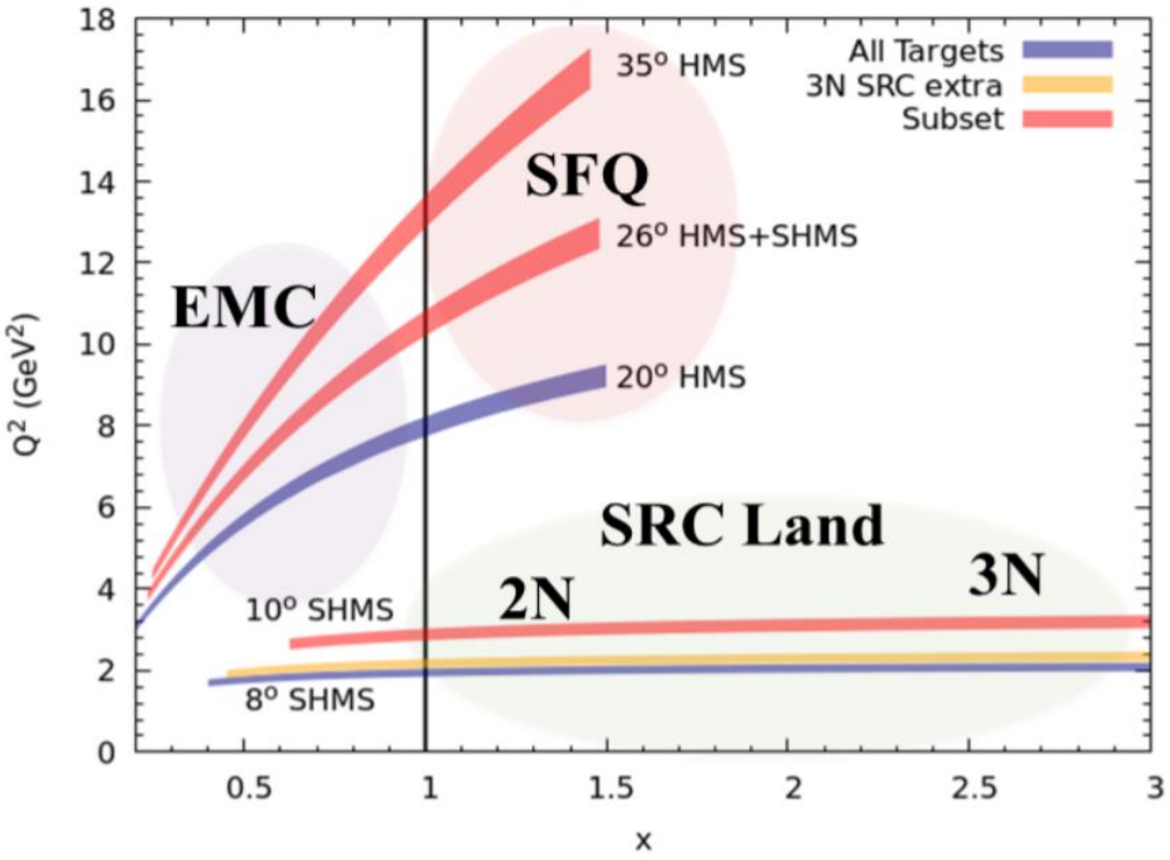
$$\sigma(x,Q^2) = Aa_1\sigma_1(x,Q^2) + \frac{A}{2}a_2\sigma_2(x,Q^2) + \frac{A}{3}a_3\sigma_3(x,Q^2) + \dots$$

- $\sigma_n$ is the scattering cross-section from a nucleon that's part of an SRC group of size $n$
- $a_n$ is the ratio of the scattering cross sections from a nucleus of mass A to that off the simplest nucleus of mass n
- $a_n$ represents the abundance of each nN SRC group. In the case of 2N: $a_2(A) = \frac{2}{A}\frac{\sigma_A}{\sigma_D}\Big|_{x\in plateau}$

# XEM2 Details – Hall C

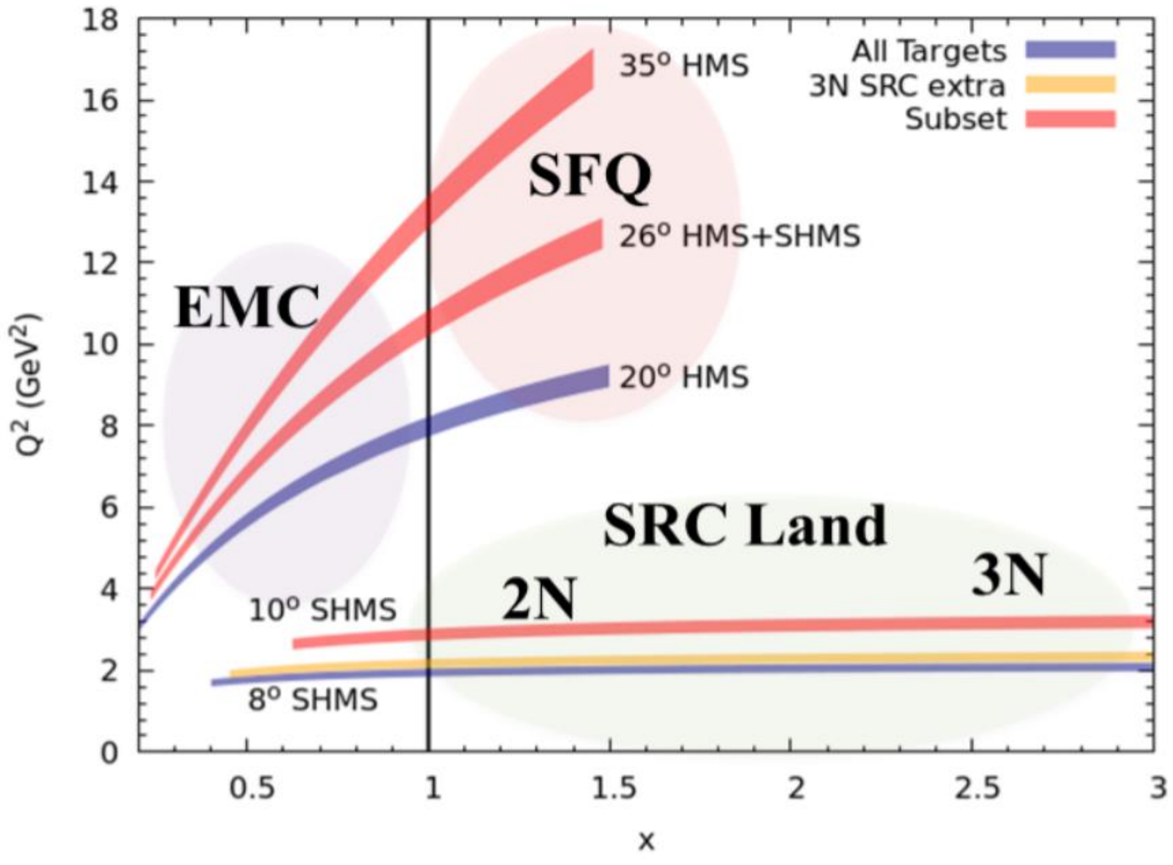
- Ran concurrently with Experiment E12-10-008 (Detailed Studies of the nuclear dependence of F2 in light nuclei) using HMS

- Data was taken for SRC experiment in SHMS and EMC experiment in HMS were taken SIMULTANEOUSLY
  - Some data was taken using both spectrometers simultaneously.
- For SRCs ALL targets were measured at 8 deg,
  - Only a subset was measured at 10 deg.



# XEM2 Details

| Previously measured targets | NEW targets |
|---|---|
| $^{3}$He | $^{10}$B |
| $^{4}$He | $^{11}$B |
| $^{9}$Be | $^{6}$Li* |
| $^{12}$C | $^{7}$Li* |
| $^{63}$Cu | $^{48}$Ti |
| $^{197}$Au | Sn* |
| $^{40}$Ca | $^{232}$Thor |
| $^{48}$Ca | $^{58}$Ni |
| $^{54}$Fe | $^{64}$Ni |
| Al | Ag |



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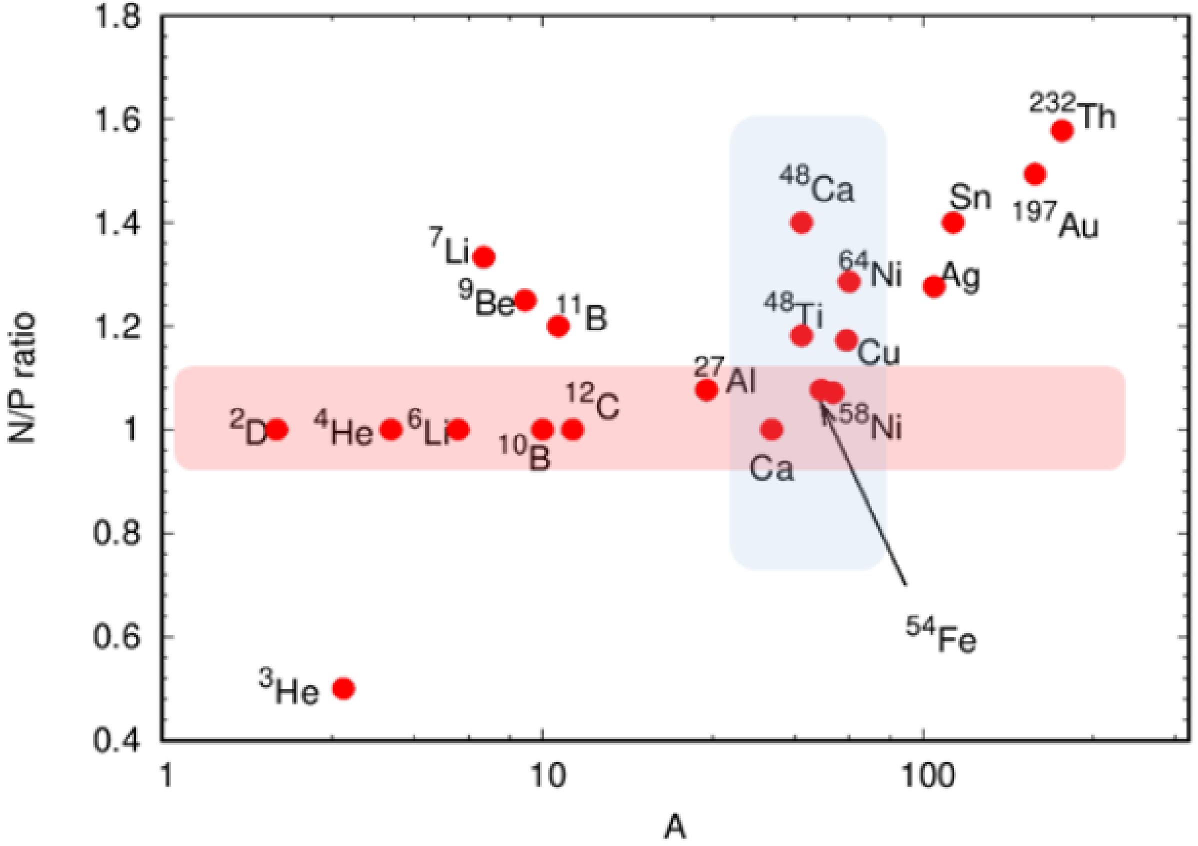
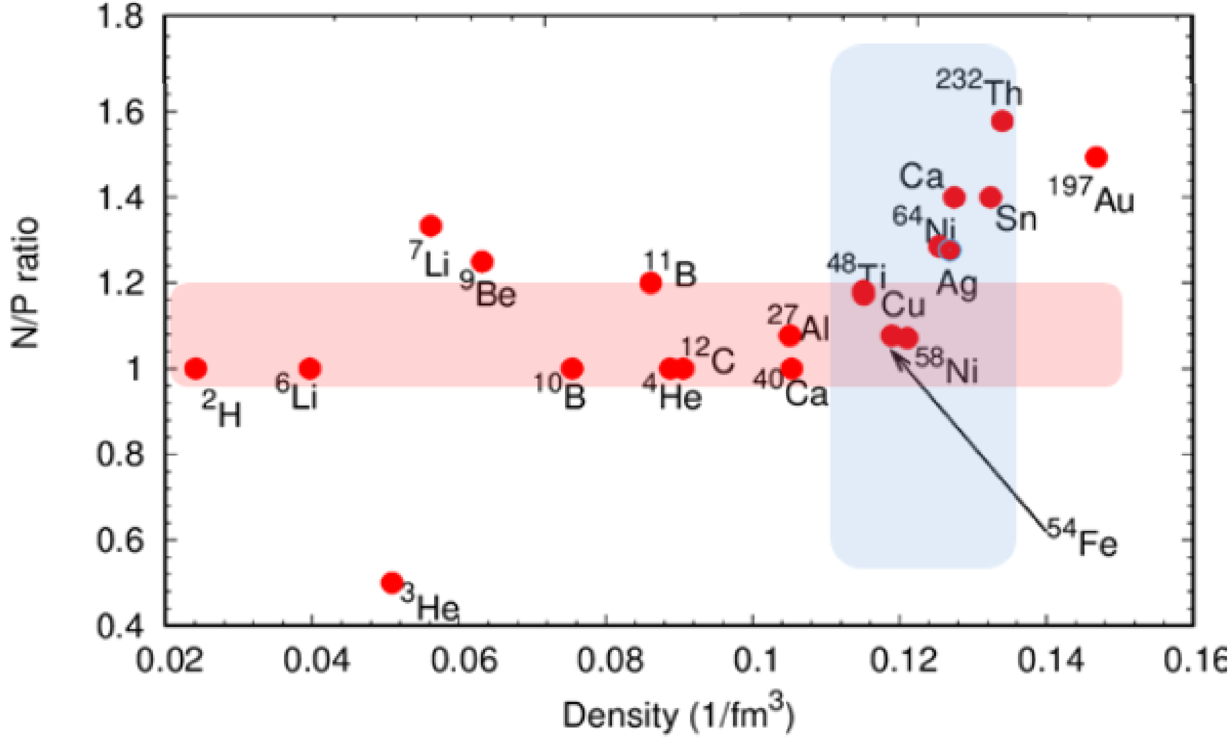
# Targets




Picture credit: Nadia Fomin

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# Detector Calibrations & Corrections

- Beam energy calibration
- Beam Current Monitor (BCM) Calibrations
- Reference Time Cuts
- Timing window cuts
- Cherenkov Calibrations
- Calorimeter Calibrations
- Hodoscope Calibrations
- Drift Chamber
- Momentum & Angle Offsets
- Boiling Correcctions
- Coulomb Corrections
- Hodoscope Cuts

- Detector Efficiency
  - Cherenkov
  - Calorimeter
  - Beam current monitor
- Electronic Dead Time Efficiency
- Computer Dead Time Efficiency
- Multi-Track reconstruction
- Target deformations

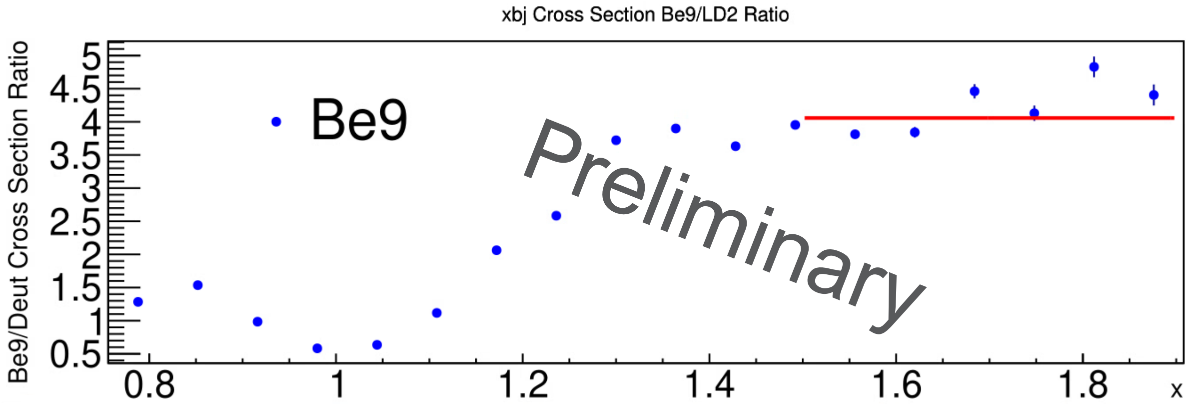
# Born Cross Section

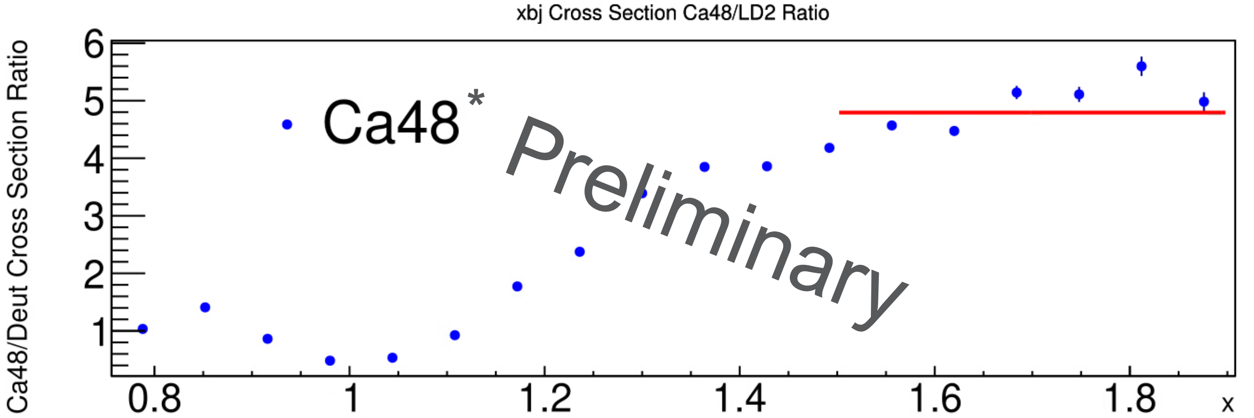
- This is the actual cross section that we will use to take our ratios

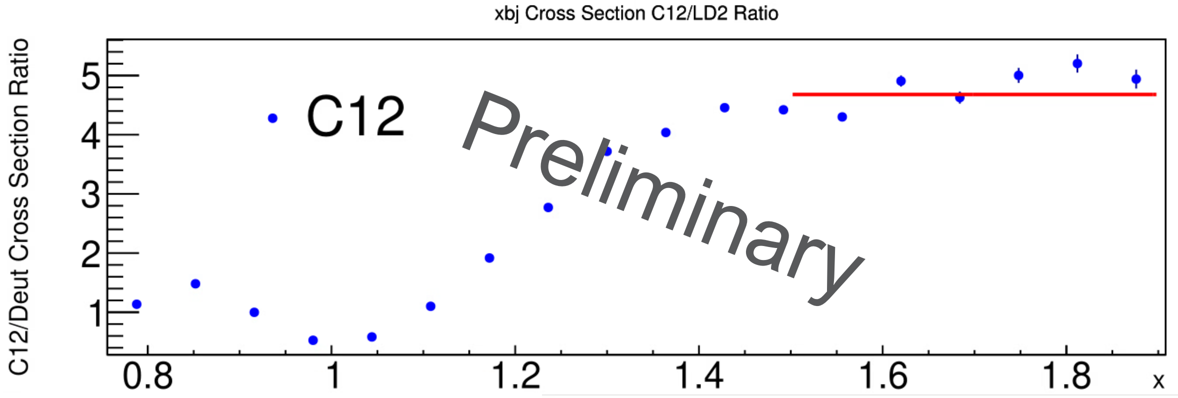
$$\sigma_{Born}(x, Q^2) \equiv \frac{Y_{data}}{Y_{MC}} \cdot \sigma_{Born}^{Model}$$

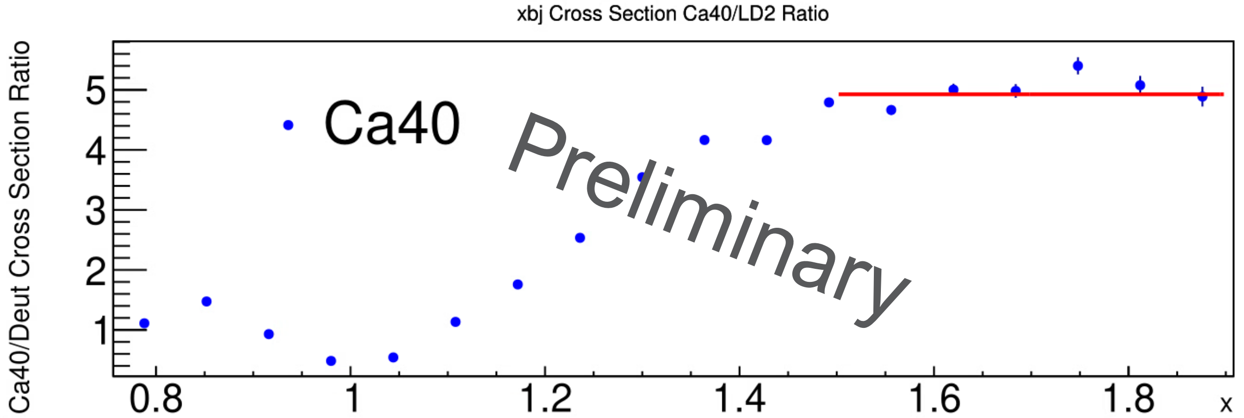
- $Y_{data}$ will be extracted from our data
- $Y_{MC}$ will be extracted from a Monte Carlo simulation of our spectrometer weighted by the radiated cross section model
- CURRENTLY we ONLY have statistical uncertainties.

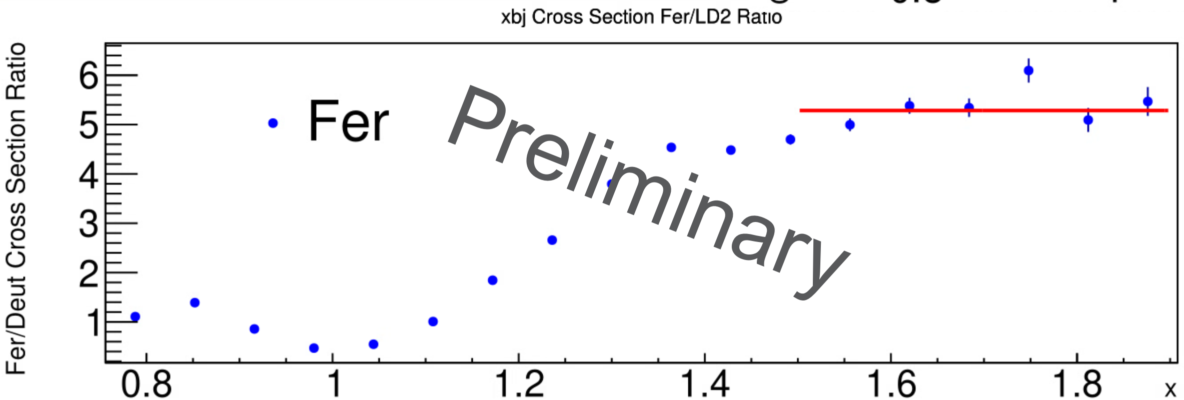
# XS Ratios (9.2 GeV 8°) - old



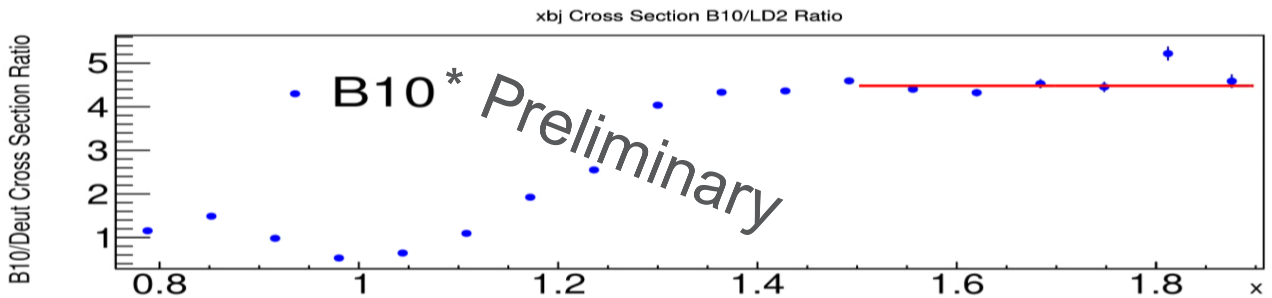



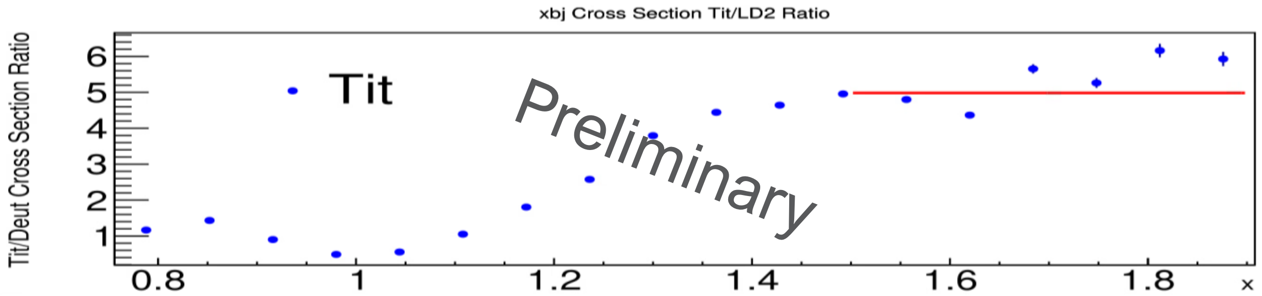



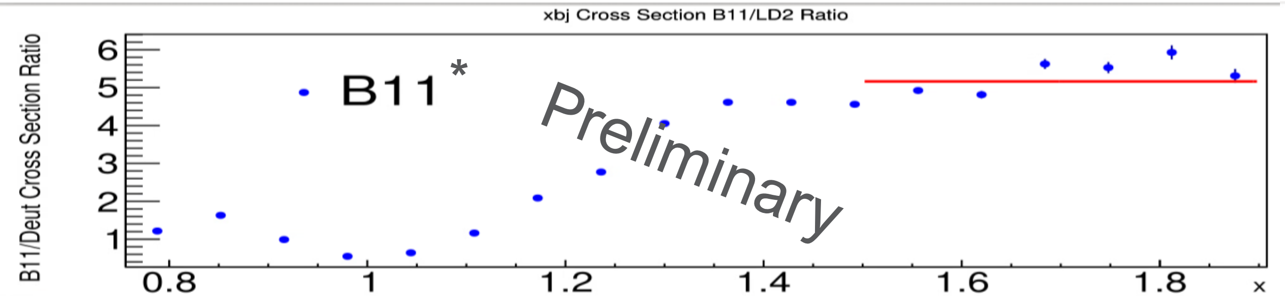



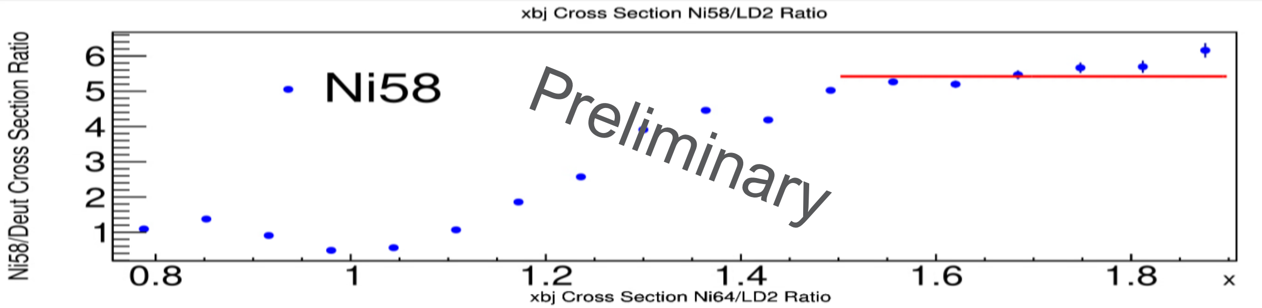



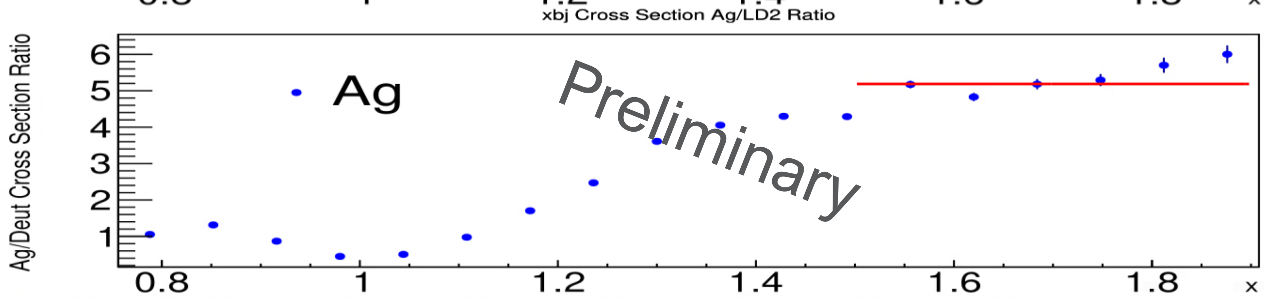
# XS Ratios (9.2 GeV 8°) - new

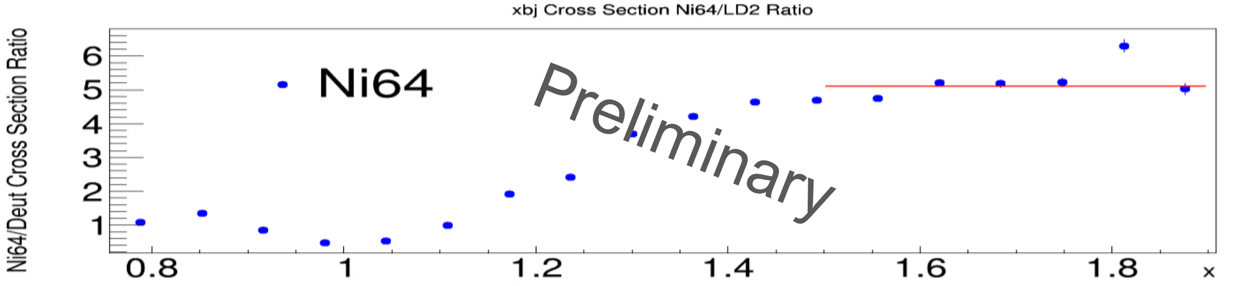


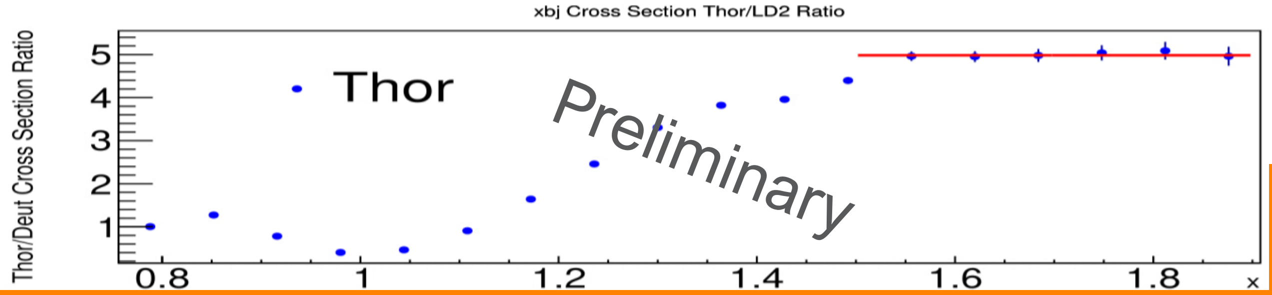



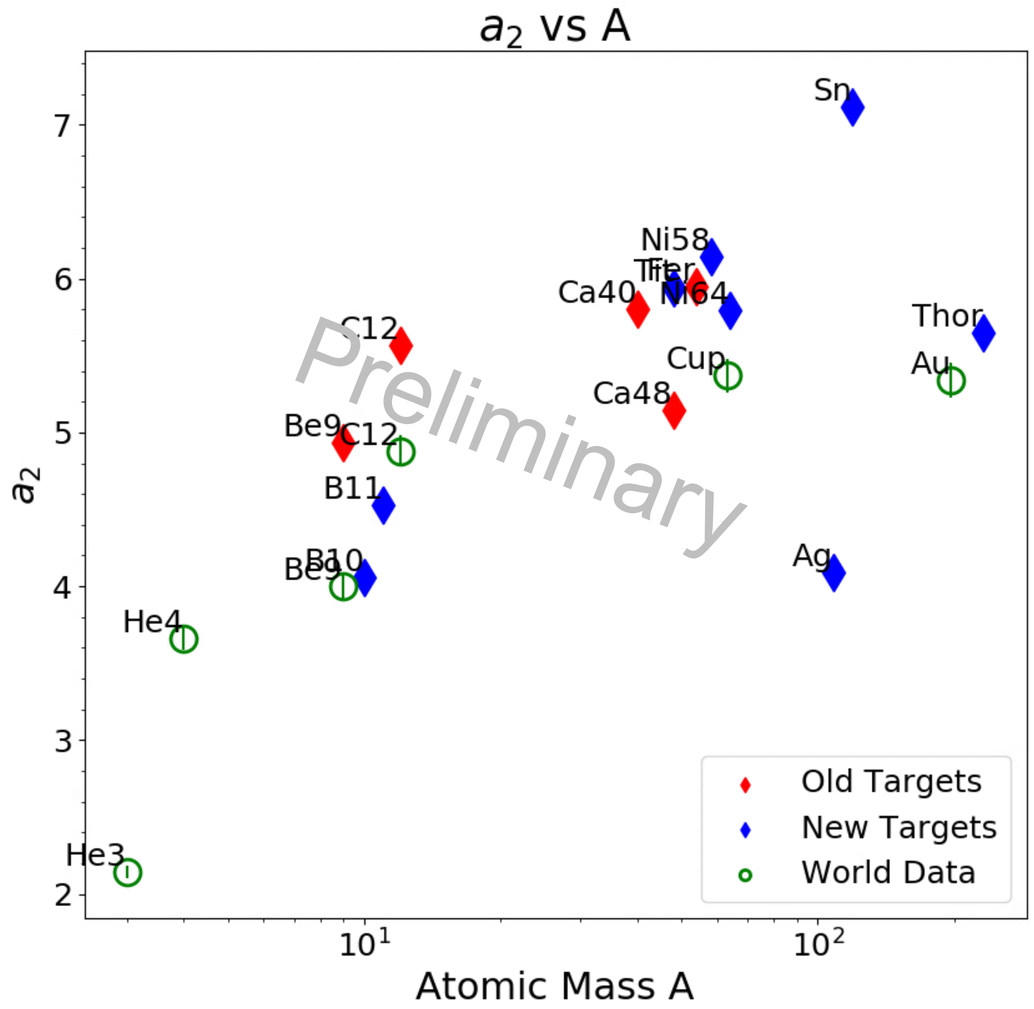



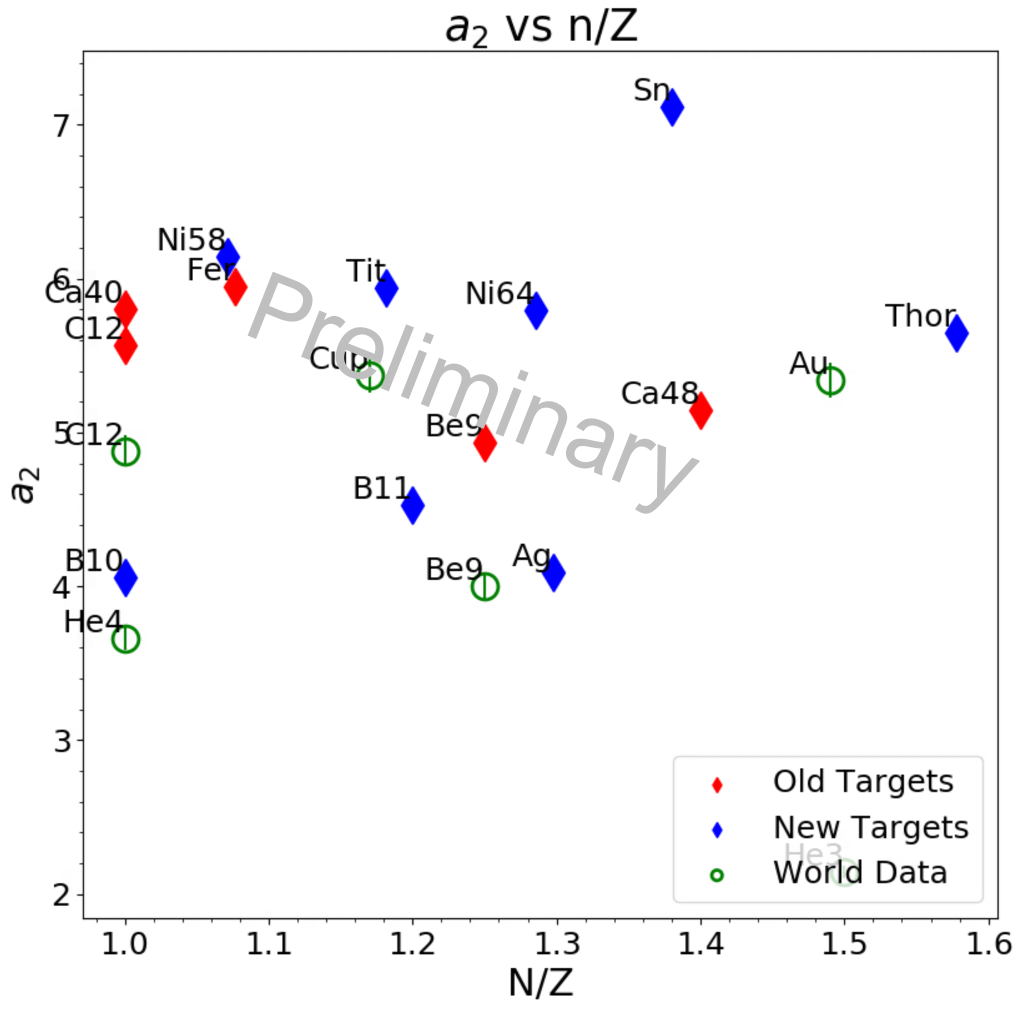



# Nuclear Dependences: $a_2$ vs A & $a_2$ vs N/Z



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# Thanks

**Spokespeople**:
- John Arrington (LBL), Nadia Fomin (UTK) & Dave Gaskell (JLab)

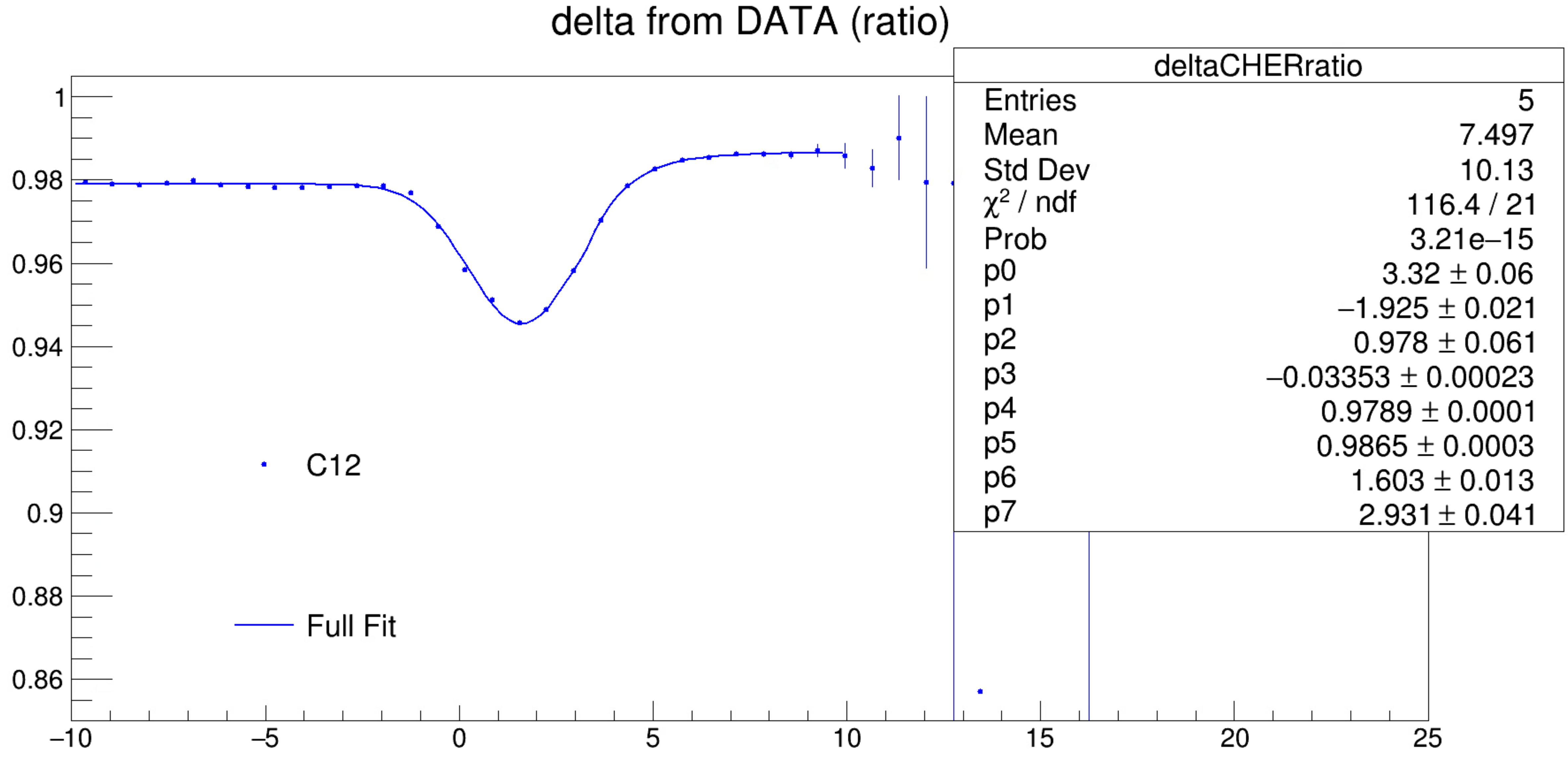
**Graduate Students**:
- Cameron Cotton (UVA), Abishek Karki* (MSU), Casey Morean* (UTK), Ramon Ogaz (UTK), Abhyuday Sharda (UTK), Sebastian Vasquez (UCR), Zoe Wolters (UNH), Jordan O'Kronley (UTK)

**Other Collaborators**:
- Burcu Duran (NMSU), Miguel Arratia (UCR), Dipangkar Dutta (MSU), Shujie Li (LBL), Dien Nguyen (UTK), Nathaly Santiesteban (UNH), Xiaochao Zheng (UVA), Tyler Hague (JLab)

**DOE award:** DE-SC0013615

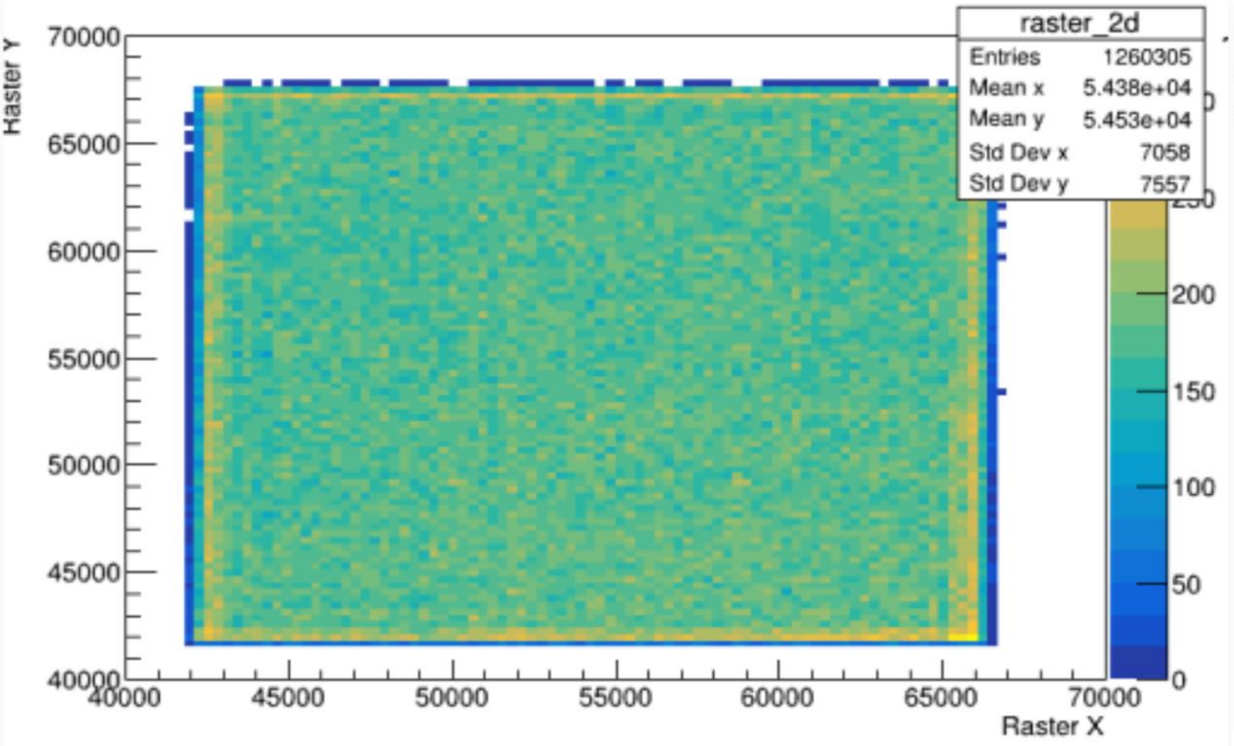
* Graduated

# Cherenkov Detector Efficiency

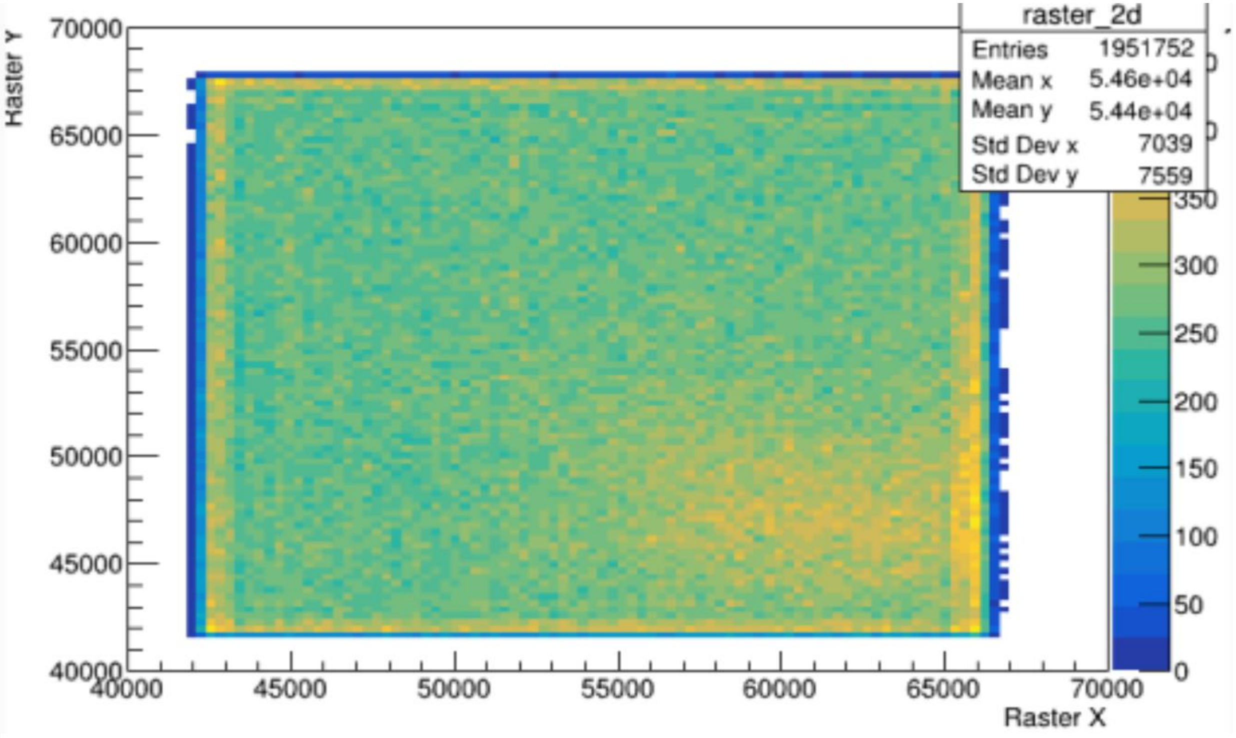


# Li target Melting

**Before**



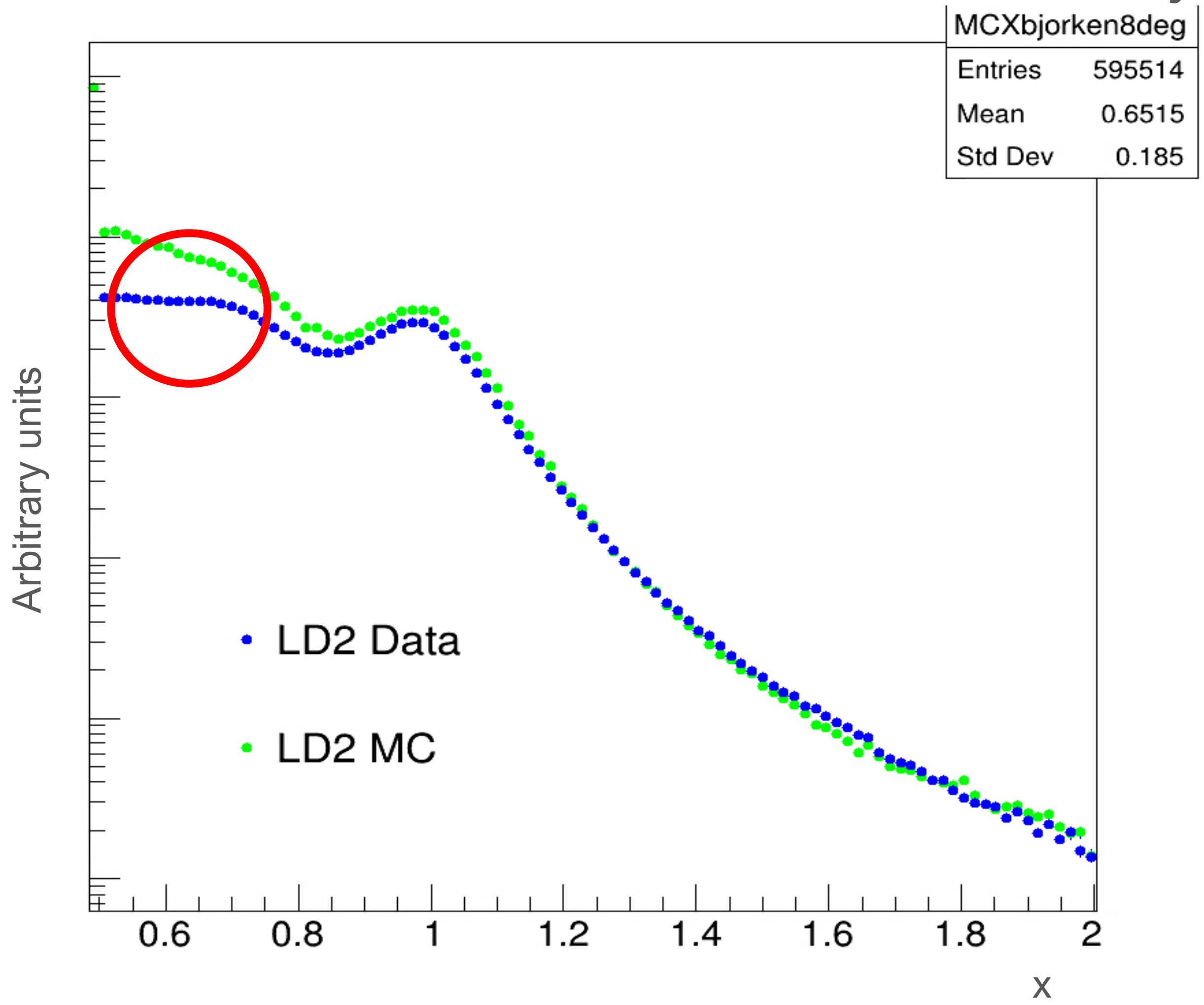

**After**

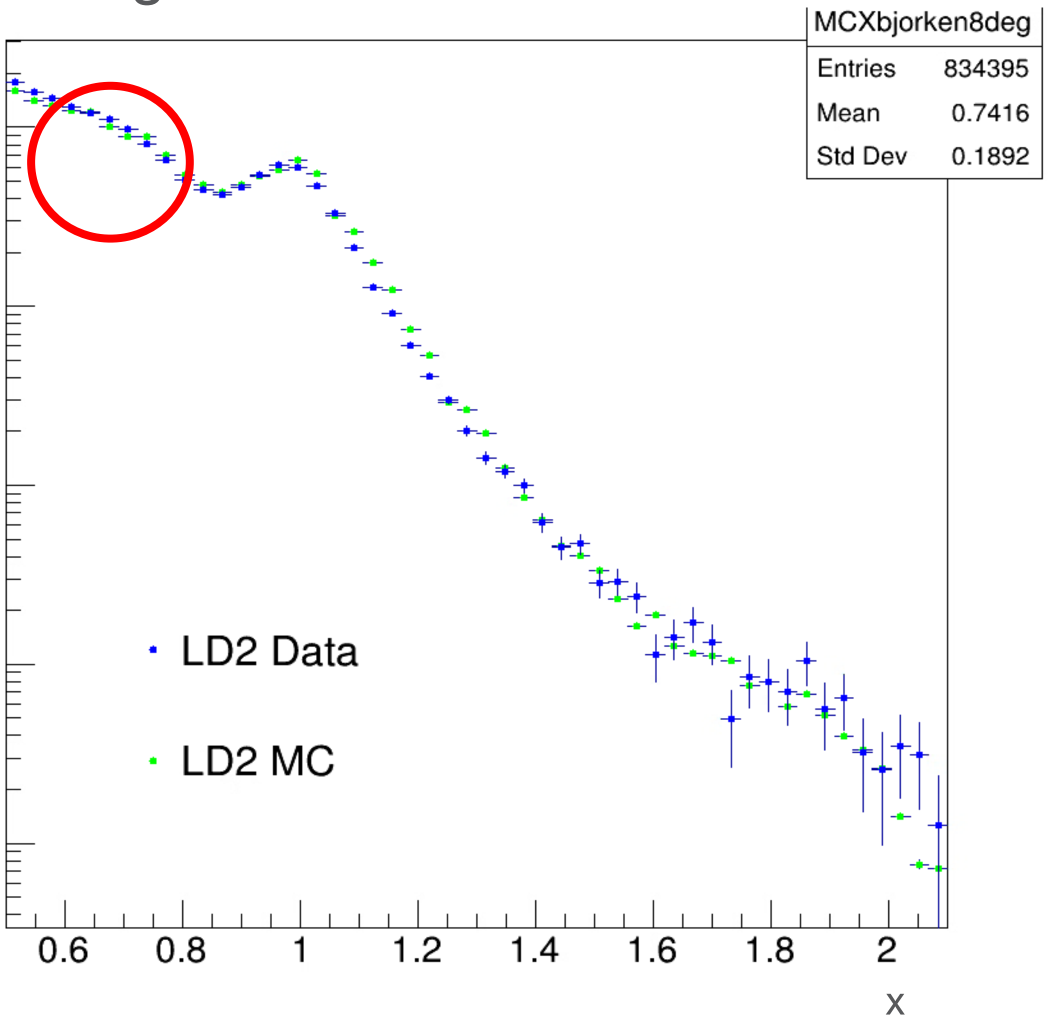



Uneven raster distribution suggests target deformation from melting

# Hodoscope geometric configurations

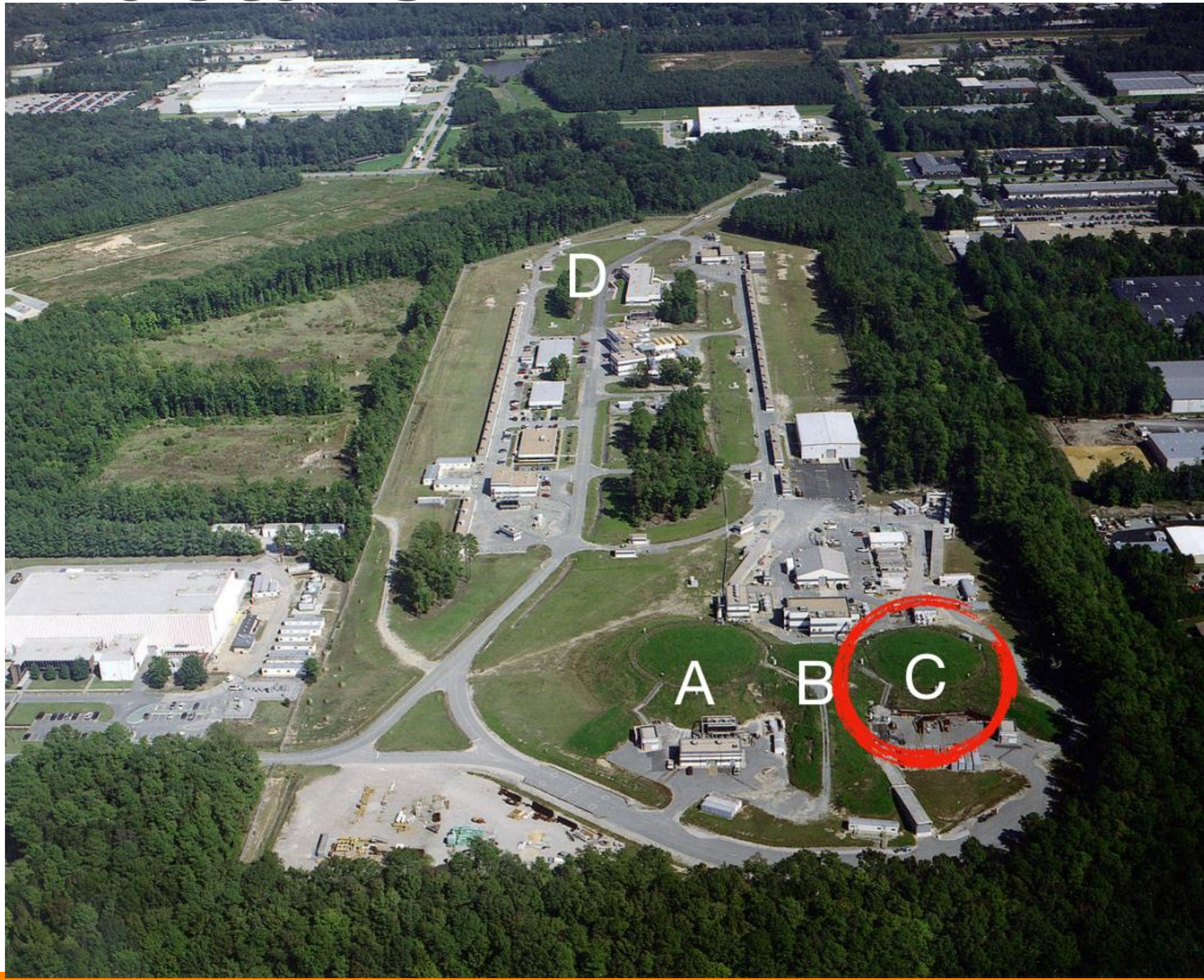
Turning off a section of the detector where we don't expect any x > 1 events in order to increase DAQ efficiency at high x



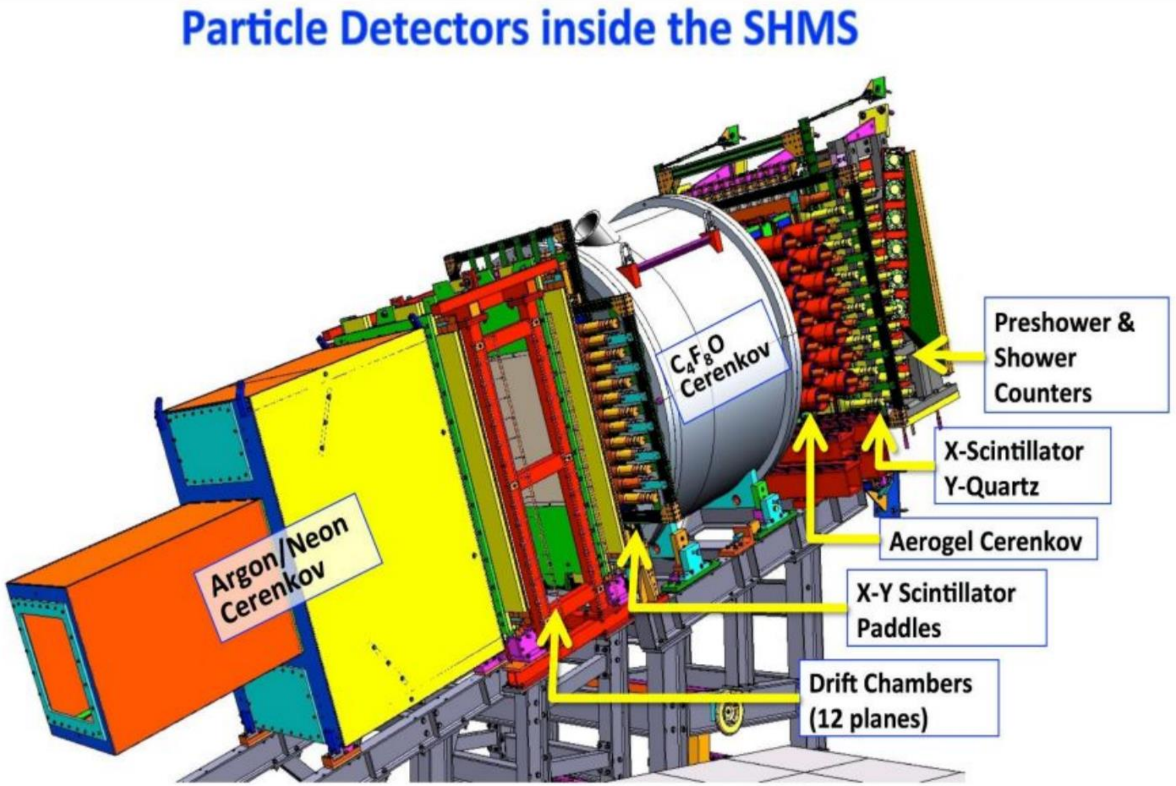
# Jefferson Lab & Beam details

- Jlab delivers up to 70 uA of electrons at a frequency of 249.5 MHz
- Energy of the beam delivered is up to 11 GeV
- Beam size is about 600 um in diameter



# Experimental Setup (SHMS)

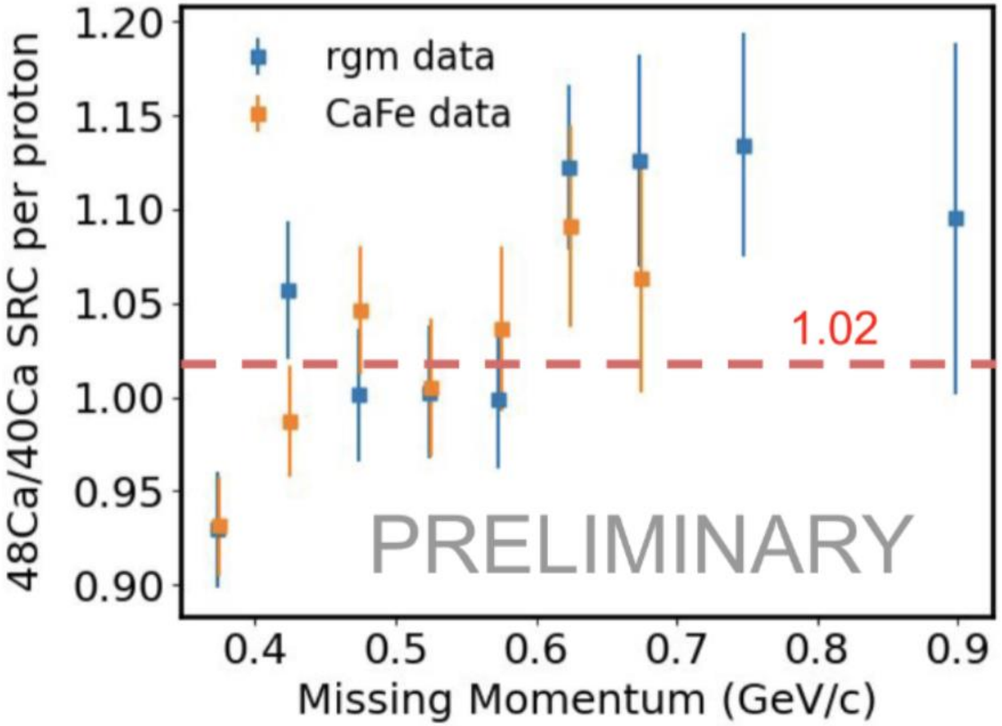
- **Noble Gas Cherenkov**: Particle ID
- **Drift Chambers**: Tracking
- **Hodoscope (Scintillator Paddles)**: Primary Trigger
- **Heavy Gas and Aerosol Cherenkov**: UNUSED
- **Calorimeter**: Energy



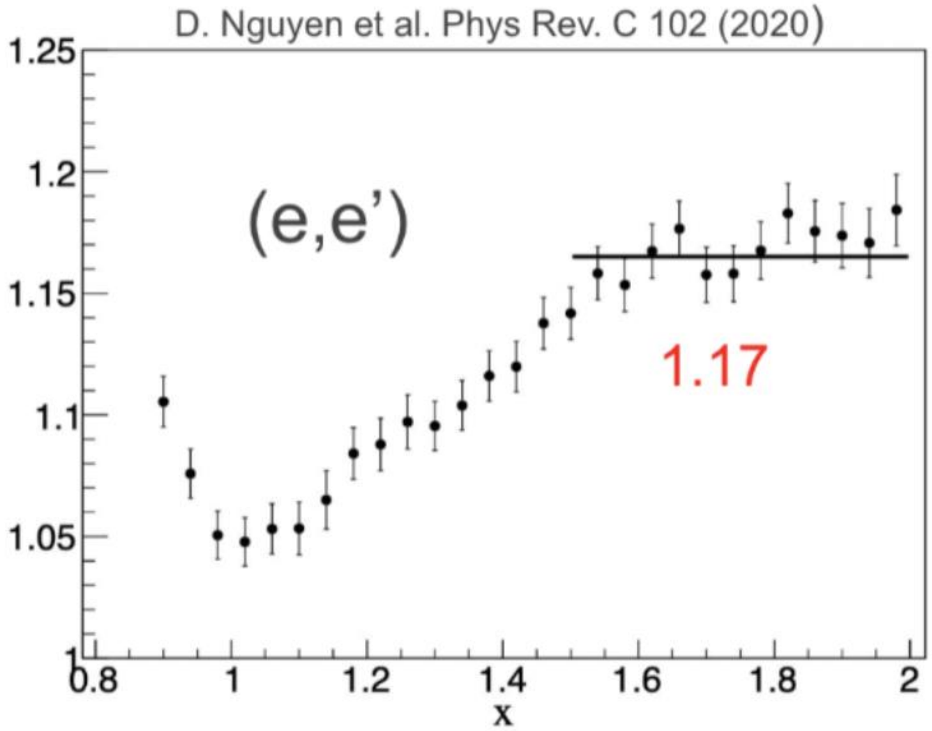

- Credit: Burcu Duran

# First Look at Nuclear Dependences

- Inclusive vs Exclusive Experiments



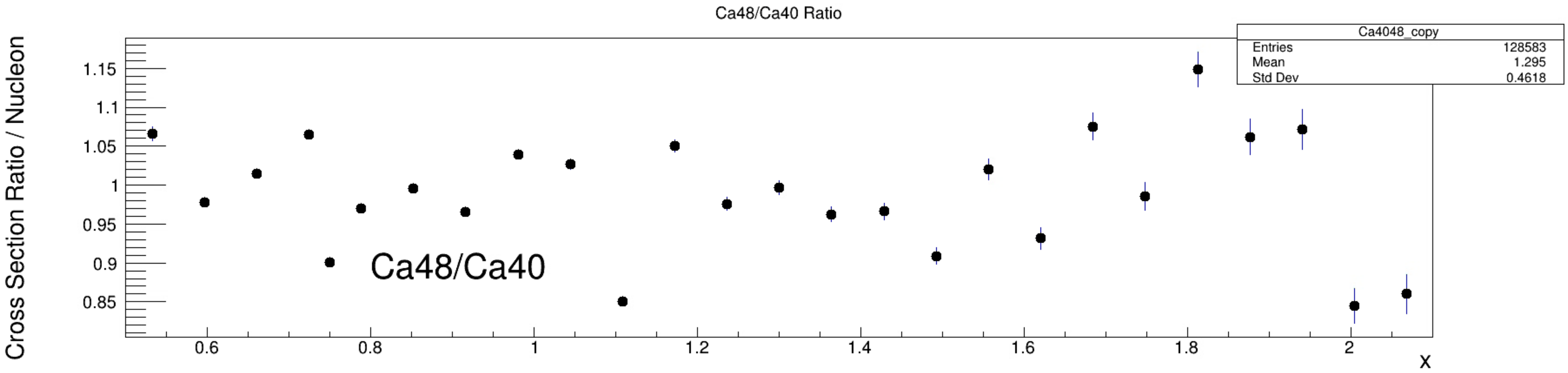

$$\frac{\sigma(^{48}\mathrm{Ca})}{\sigma(^{40}\mathrm{Ca})}$$



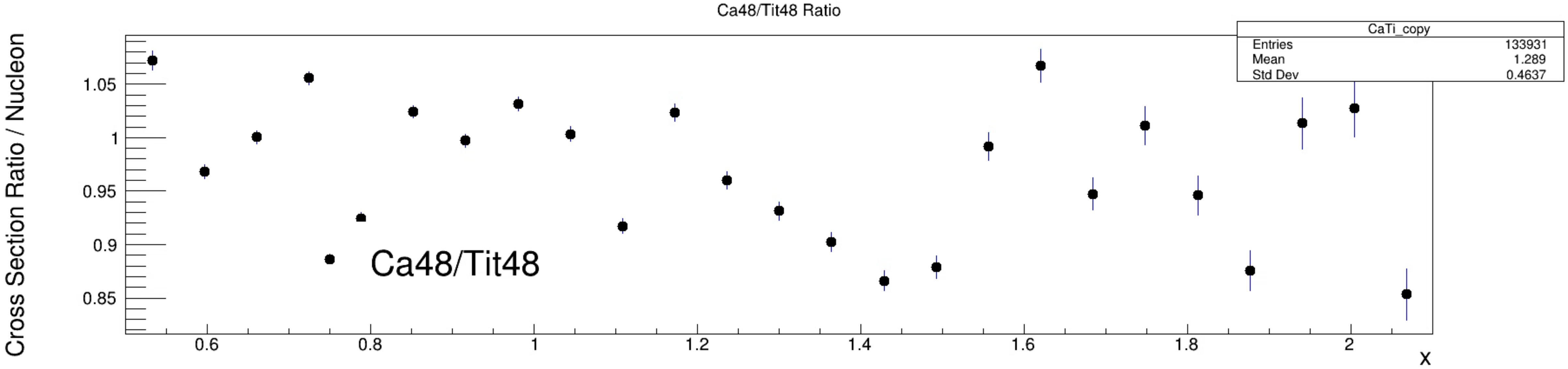

Weinstein L, Cohen E and Higinbotham D The CaFe Experiment: Short-Range Pairing Mechanisms in Heavy Nuclei Proposal to Jefferson Lab PAC 44

# Next steps, issues

- Hodoscope configurations Simulations
  - Geometric cut to exclude low x particles
- Melting/damaged targets
  - Lithium & Tin
- Target contamination
- Optics
- Systematic Errors



Ca48/Ca40 Ratio
Ca4048_copy
Entries 128583
Mean 1.295
Std Dev 0.4618
Cross Section Ratio / Nucleon
Ca48/Ca40
x

Ca48/Tit48 Ratio
CaTi_copy
Entries 133931
Mean 1.289
Std Dev 0.4637
Cross Section Ratio / Nucleon
Ca48/Tit48
x