$^{10}B(\alpha,p)^{13}C$ and $^{10}B(\alpha,d)^{12}C$

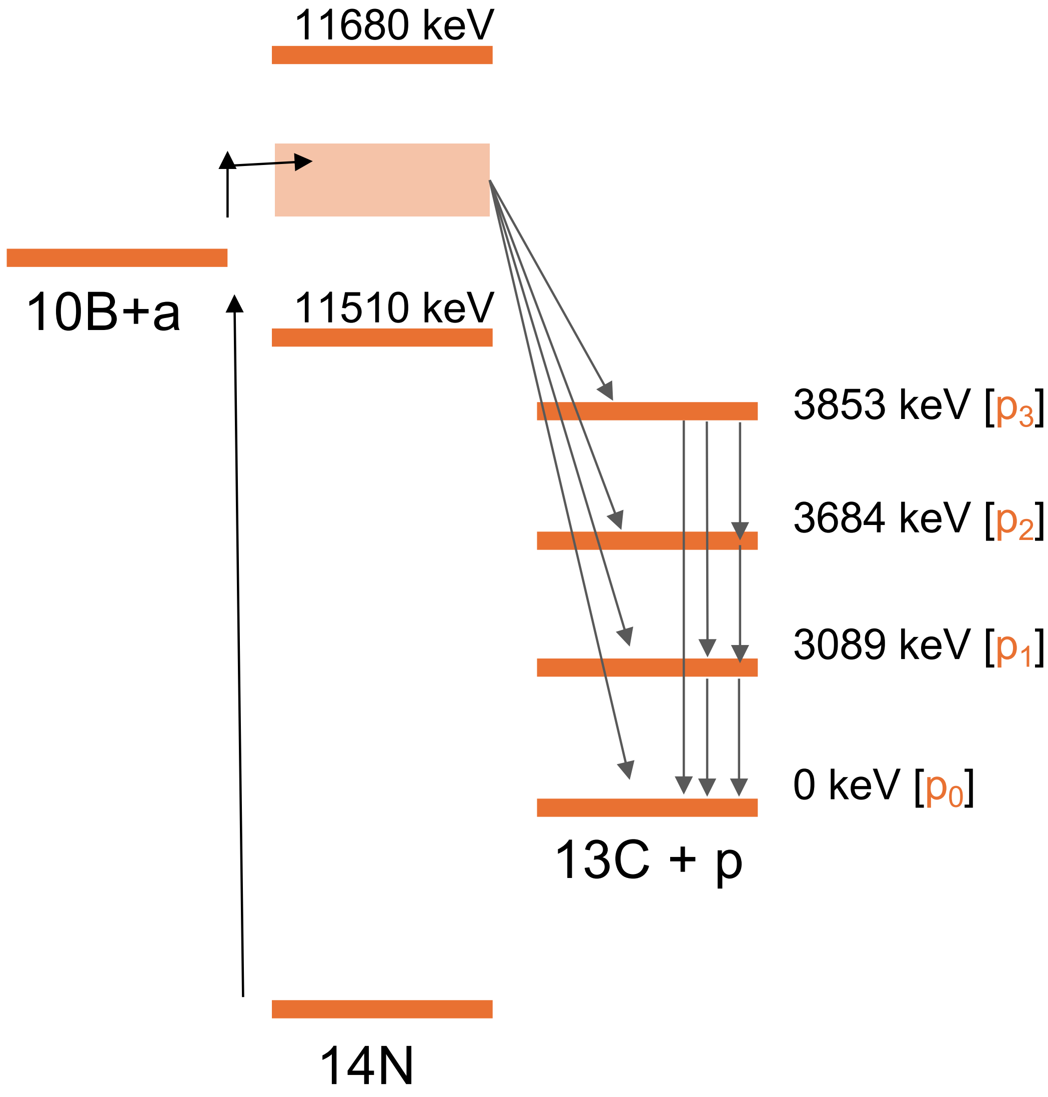
Jamie Jones

Goal…

Measure cross-sections for **$^{10}B(\alpha,p_x)$** and **$^{10}B(\alpha,d)$** at energies of astrophysical interest (**$E_{cm} < 285$ keV**)

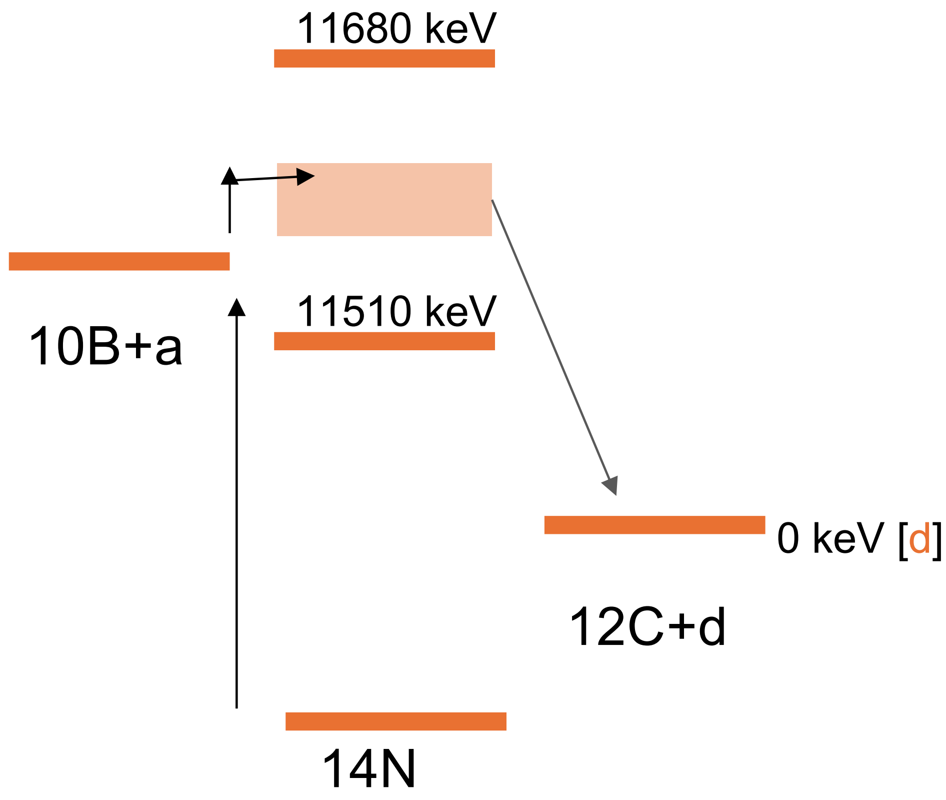
$^{10}B(a,p)^{13}C$

- Reaction Q-Value: 4061.55 keV
- @ E_{beam} = 400 keV
- ^{14}N dexcites via p emission
    - ^{13}C left in 4 possible states



$^{10}B(a,d)^{12}C$

- Reaction Q-Value: 1339.8 keV
- @ E_{beam} = 400 keV
- ^{14}N dexcites via d emission
  - Ground state



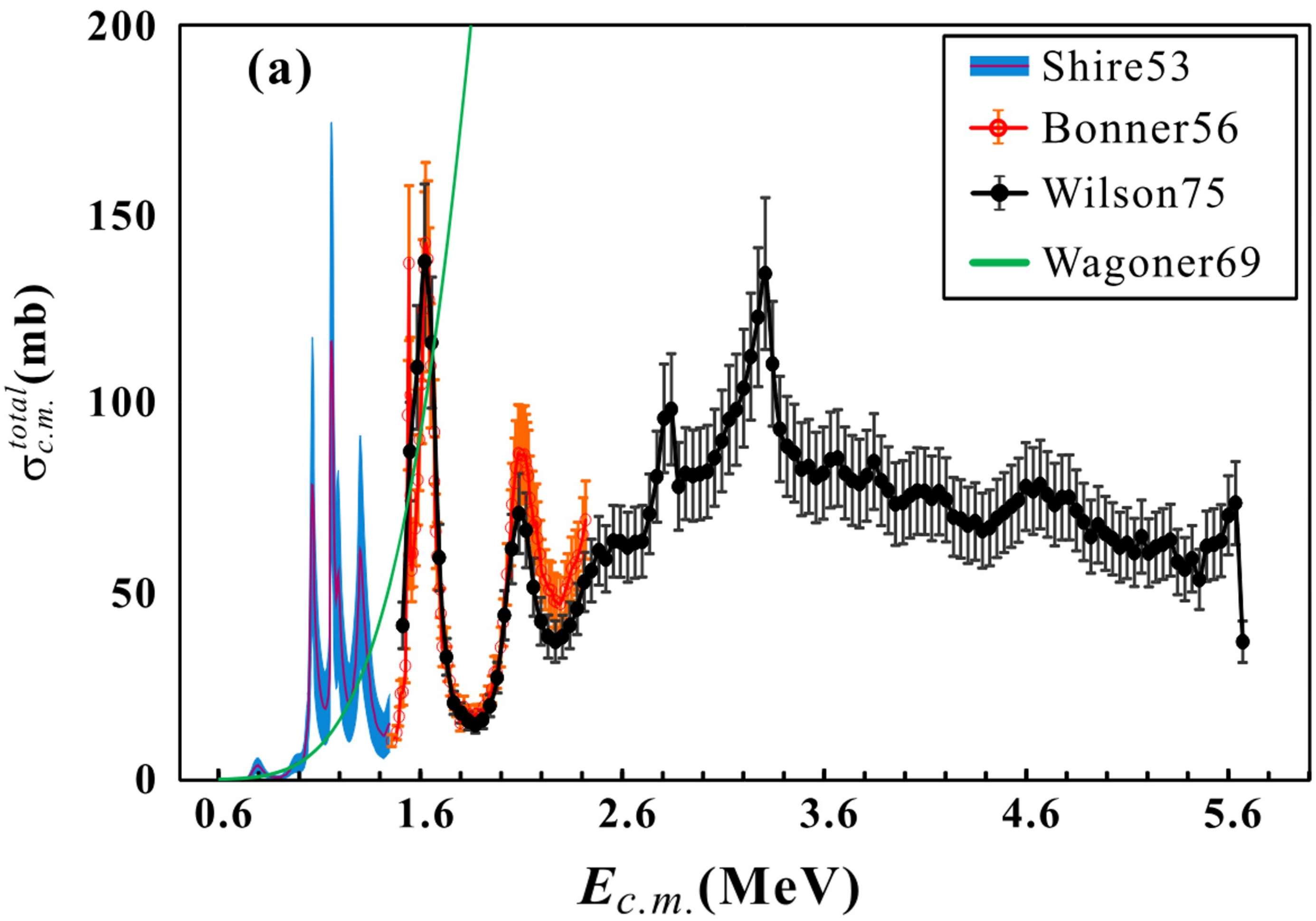
$^{10}B(\alpha,p_0)^{13}C$

- Re-evaluation of old data: **Zhang** et al. (2018)

- All E_{cm} > 700 keV

- No excited states

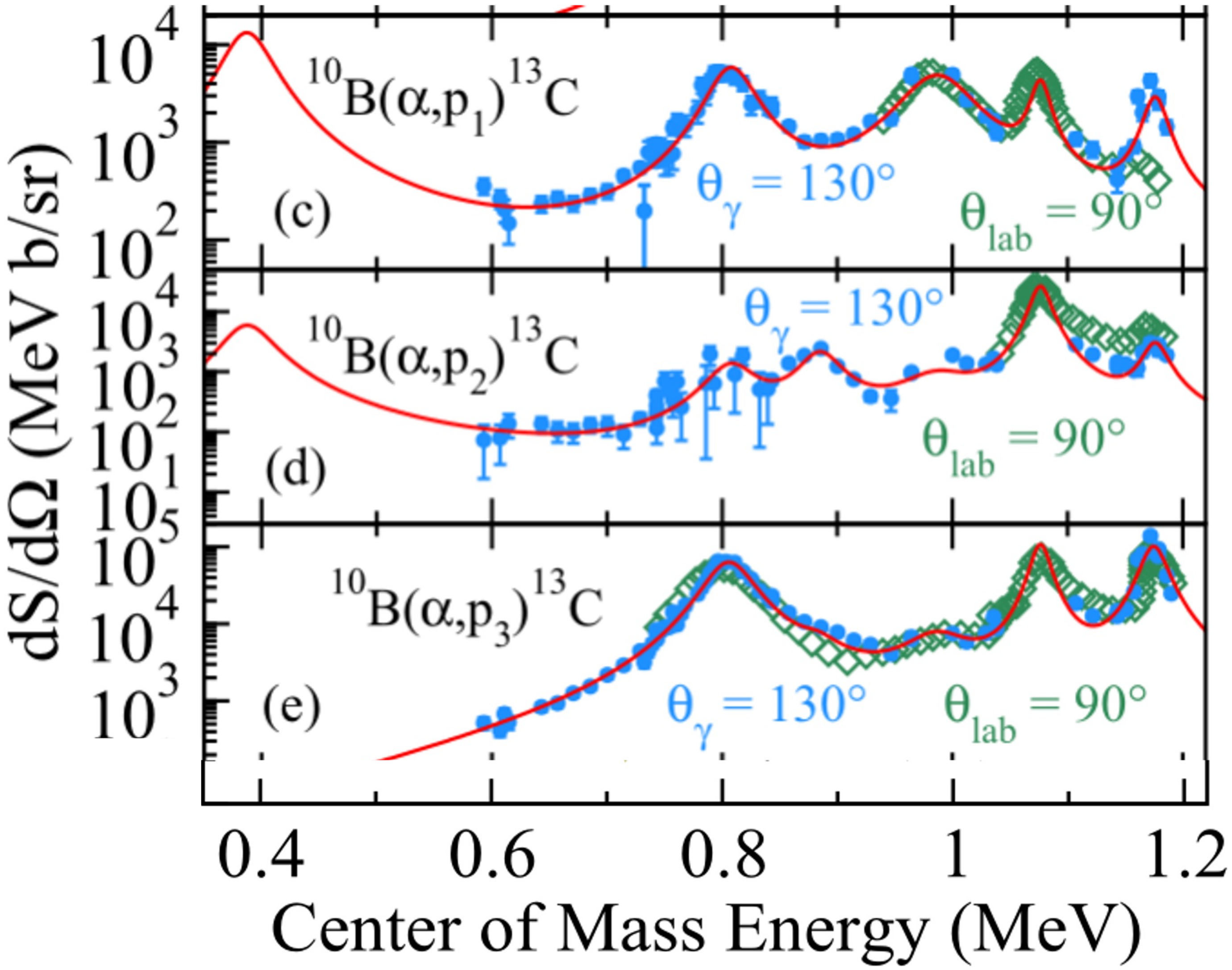
- No deuteron channel



Zhang, L. Y., He, J. J., Wanajo, S., Dell'Aquila, D., Kubono, S., & Zhao, G. (2018). New Thermonuclear 10B(α,p)13C Rate and Its Astrophysical Implication in the νp-process. *The Astrophysical Journal*, *868*(1), 24. https://doi.org/10.3847/1538-4357/aae479

$^{10}B(\alpha,p_{1,2,3})^{13}C$

- **Liu** et al. (2020)
- Excited states of ^{13}C
- E_{cm} > 600 keV
- R-Matrix
  - Predicts sub-threshold contribution

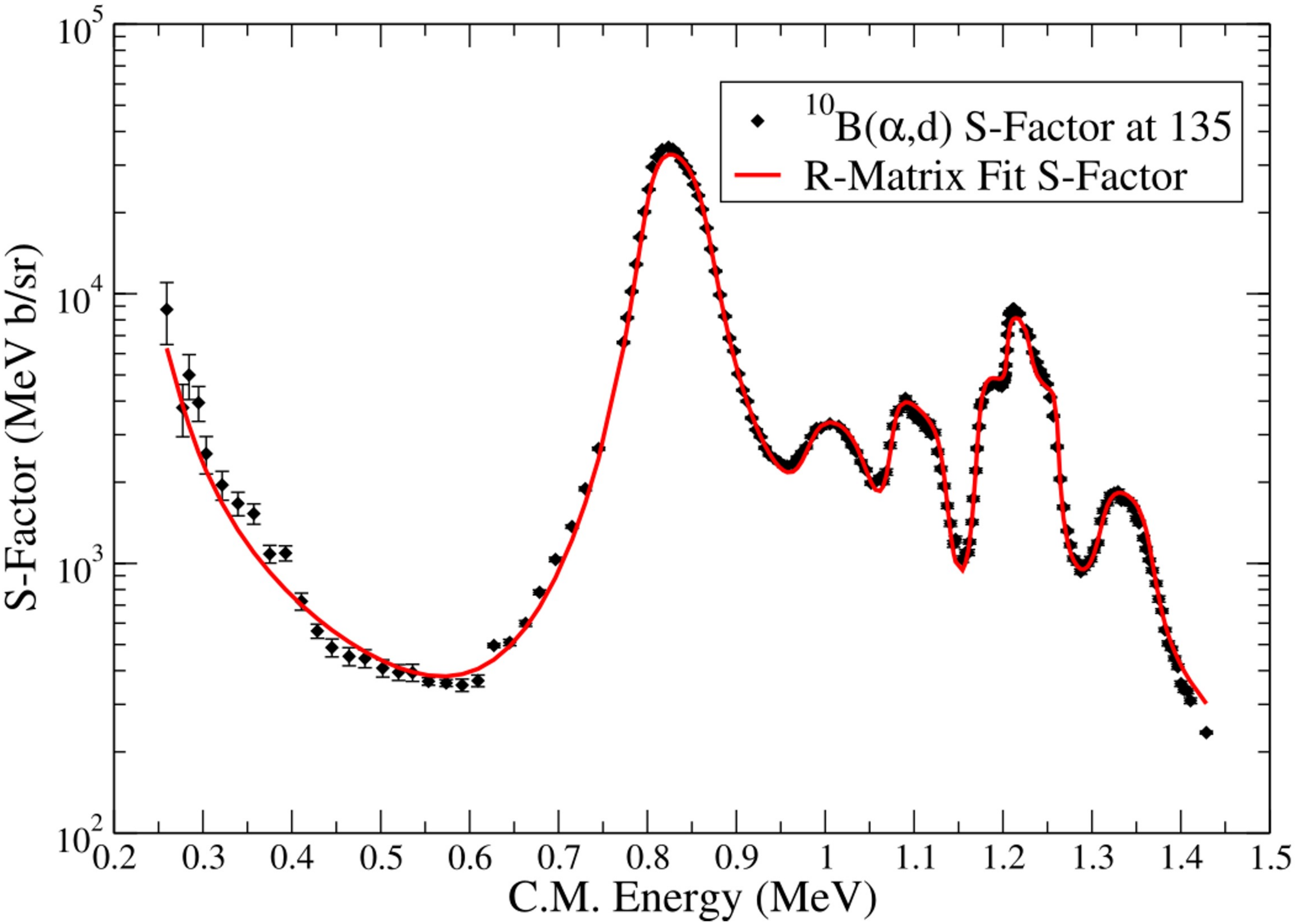


Liu, Q., Febbraro, M., deBoer, R. J., Aguilar, S., Boeltzig, A., Chen, Y., Couder, M., Görres, J., Lamere, E., Lyons, S., Macon, K. T., Manukyan, K., Morales, L.,(2020). Low-energy cross-section measurement of the B10(α,n)N13 reaction and its . . .. *Physical Review. C*, *101*(2).

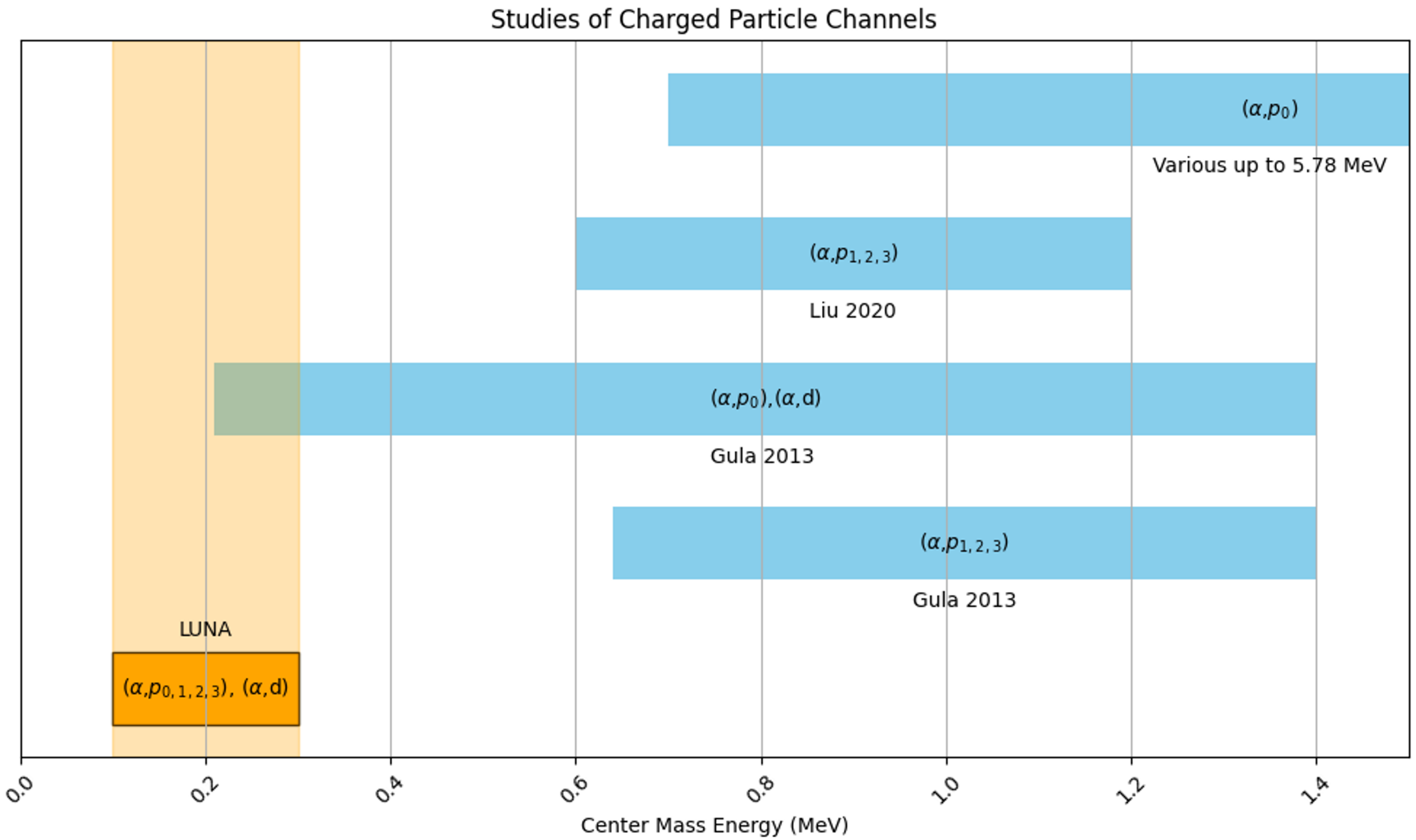
- **Gula** et al (2023)

- E_{cm} > 210 keV (p_0 and d)

- E_{cm} > 640 keV ($p_{1,2,3}$)



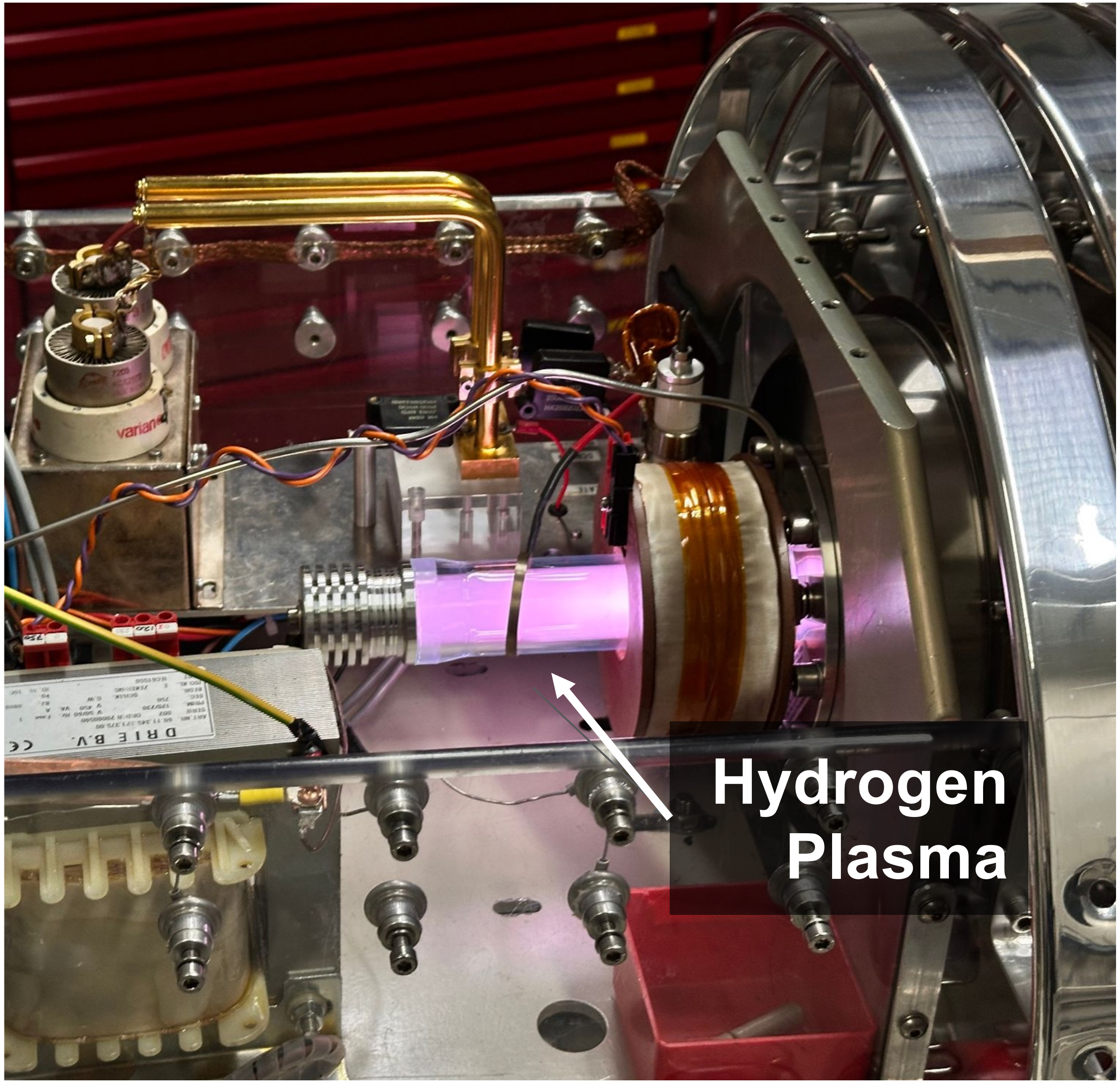
Gula, A., deBoer, R. J., Aguilar, S., Arroyo, J., Boomershine, C., Frentz, B., Görres, J., Henderson, S., Kelmar, R., McGuinness, S., Manukyan, K. V., Moylan, S., Robertson, D., Seymour, C., Shahina, N., Stech, E., Tan, W., Wilkinson, J., & Wiescher, M. (2023). B10 +α reactions at low



Studies of Charged Particle Channels
(α,p_0)
Various up to 5.78 MeV
(α,$p_{1,2,3}$)
Liu 2020
(α,p_0),(α,d)
Gula 2013
(α,$p_{1,2,3}$)
Gula 2013
LUNA
(α,$p_{0,1,2,3}$), (α,d)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Center Mass Energy (MeV)

LUNA 400 kV

- E_{beam} : 50 - 400 keV
- Current: 100 - 200 uA
- Precision: 0.3 keV
- Stability: 5 eV/hr
- Proton and Alpha beam



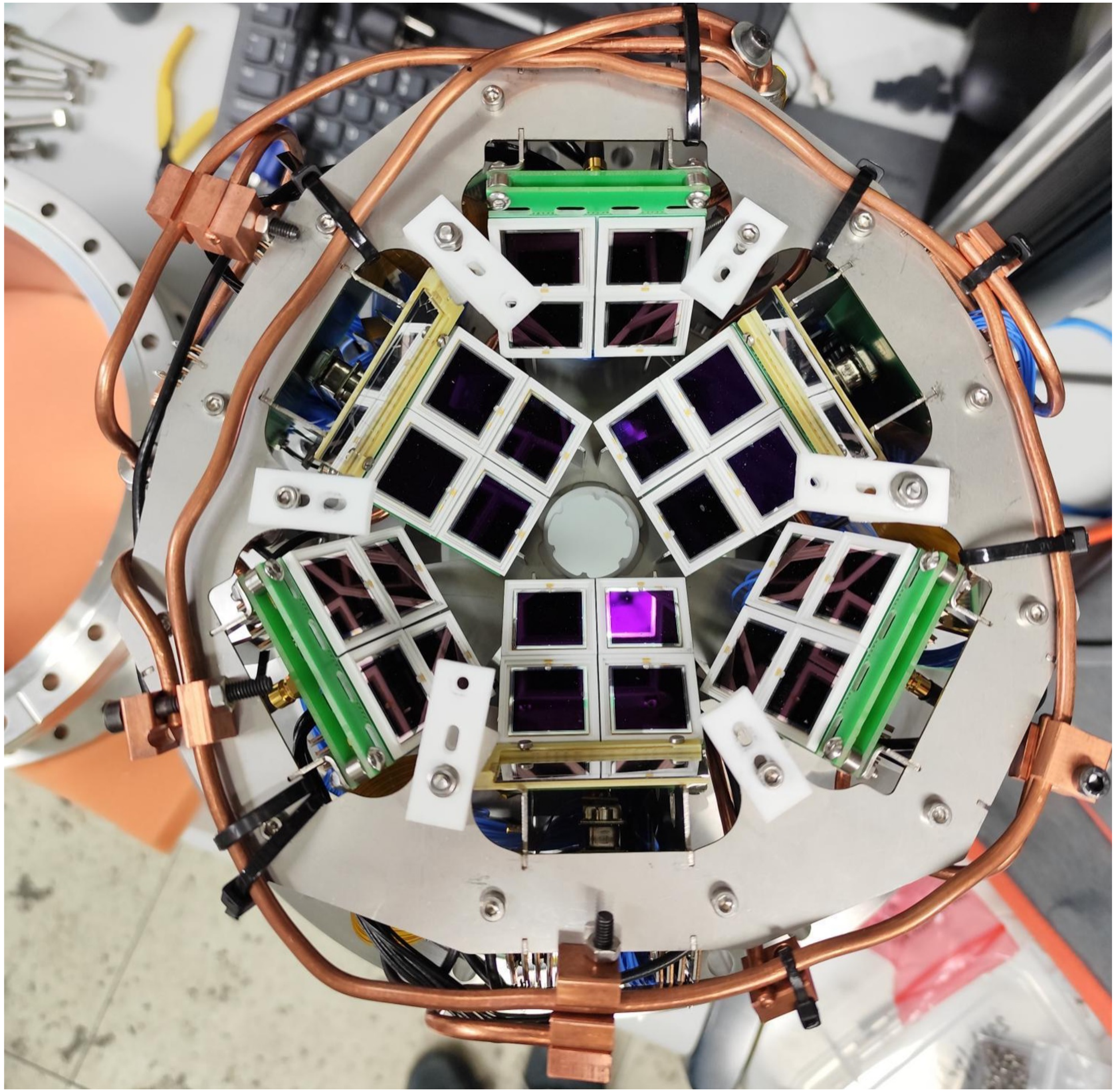
Experimental options

ELDAR (Carlo Bruno's ERC)

- Detection Angles:

  -100°, 105°, 122°, 135°, 151°

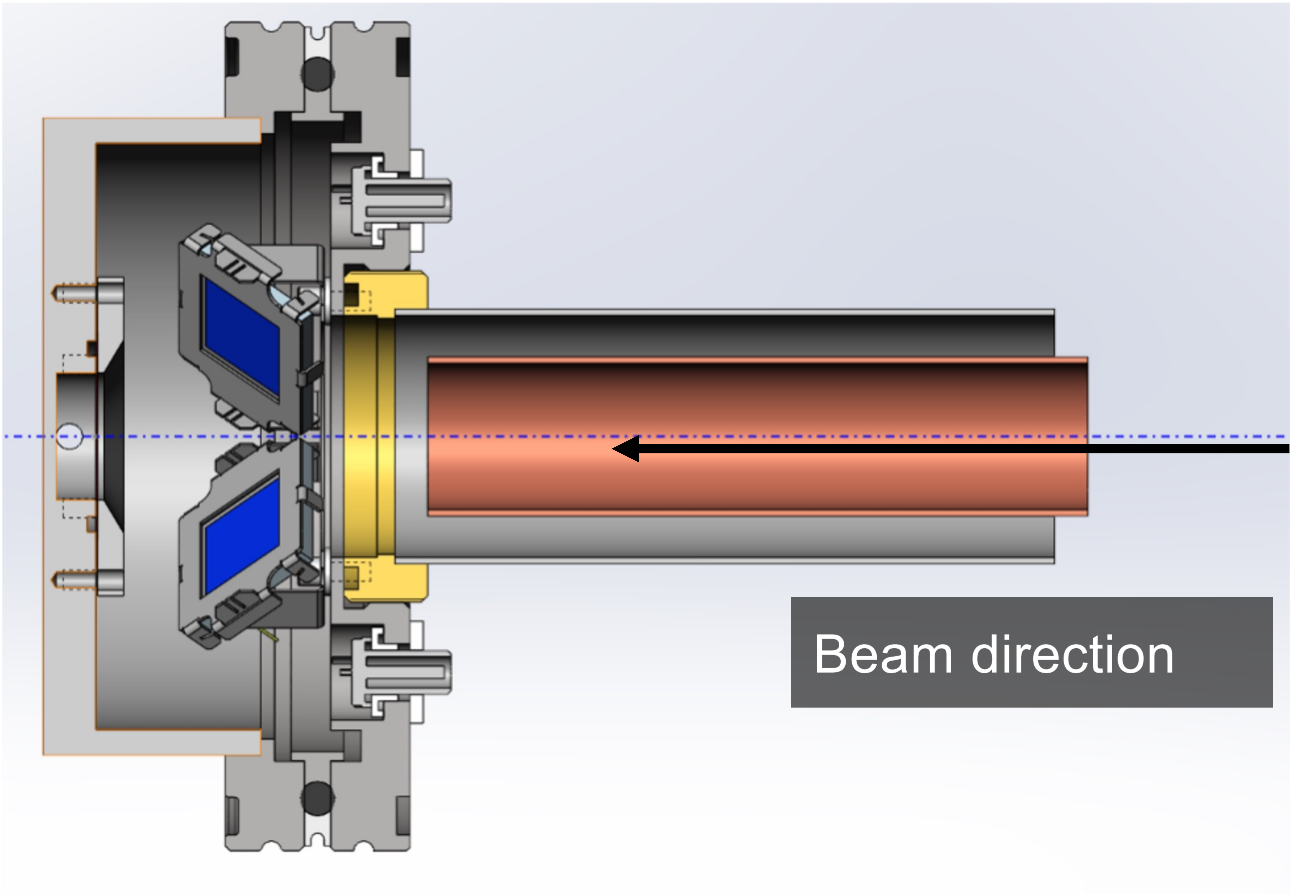
- 15% geometric efficiency
- 24 Si detectors (18x18mm^2 each)
- 3 MSPADs (4 ch each) at 100°
- 72 channels (p+n,n+n)



Experimental options

NUCLEAR

- New, small chamber
- 135°
- ~9% geometric efficiency
- 4 18x18mm^2 Pin Diodes
- Room for a Gamma/Neutron Detector
- We have multiple target chambers



Experimental options

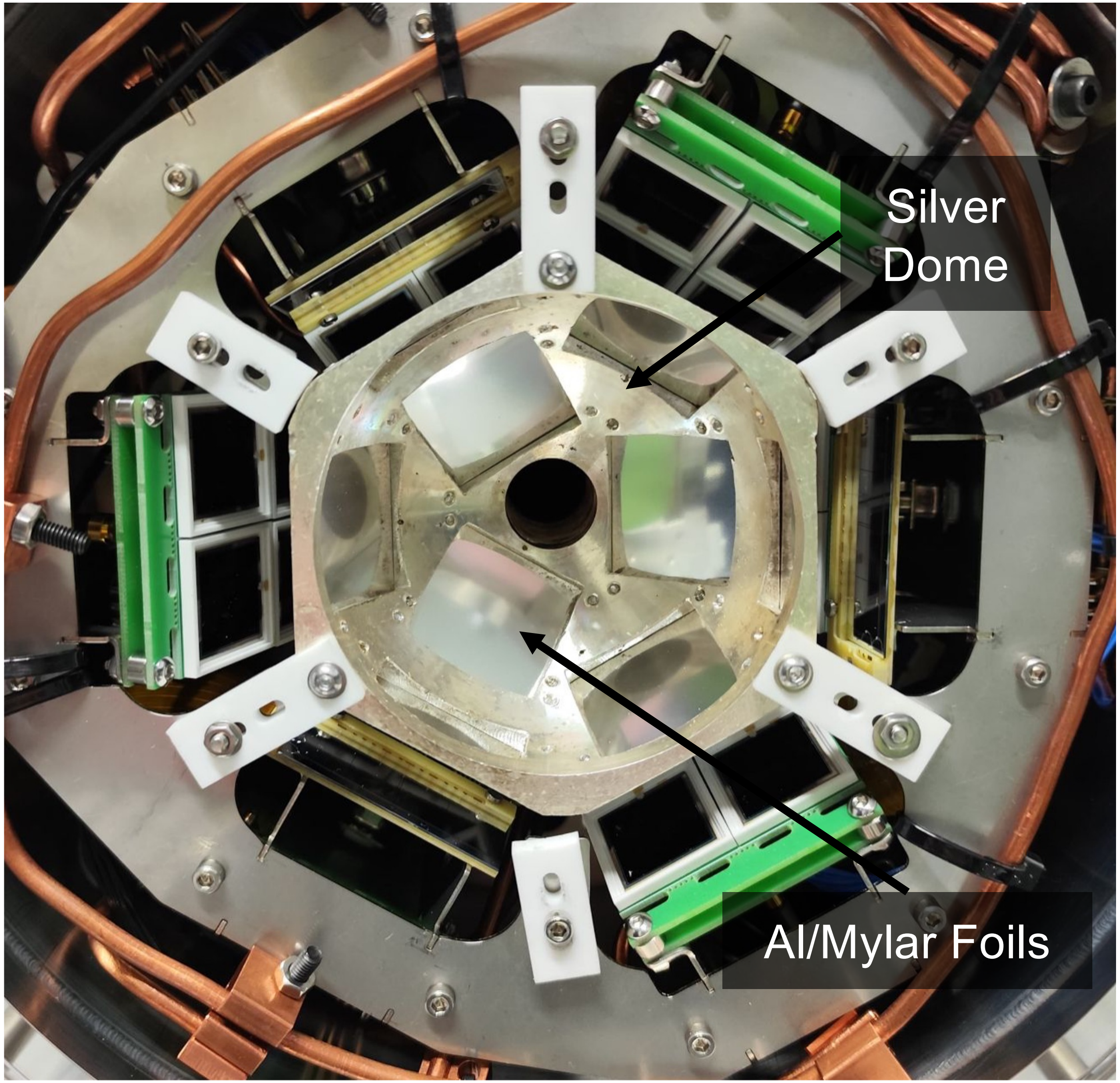
ELDAR (Carlo Bruno's ERC)

Advantages

- Angular distribution
- Larger efficiency (~6pp)

Disadvantages

- Many Mylar foils to mount
- Not quick to solve issues



Experimental options

NUCLEAR

Advantages

- Measure both charged and neutral channels simultaneously
- Simpler set-up

Disadvantages

- lower geometric efficiency
- No angular distribution

Challenges….

*"Typically, targets survived between **1–2 C** of charge deposition from the helium beam before being gradually degraded by **10–30%**."*

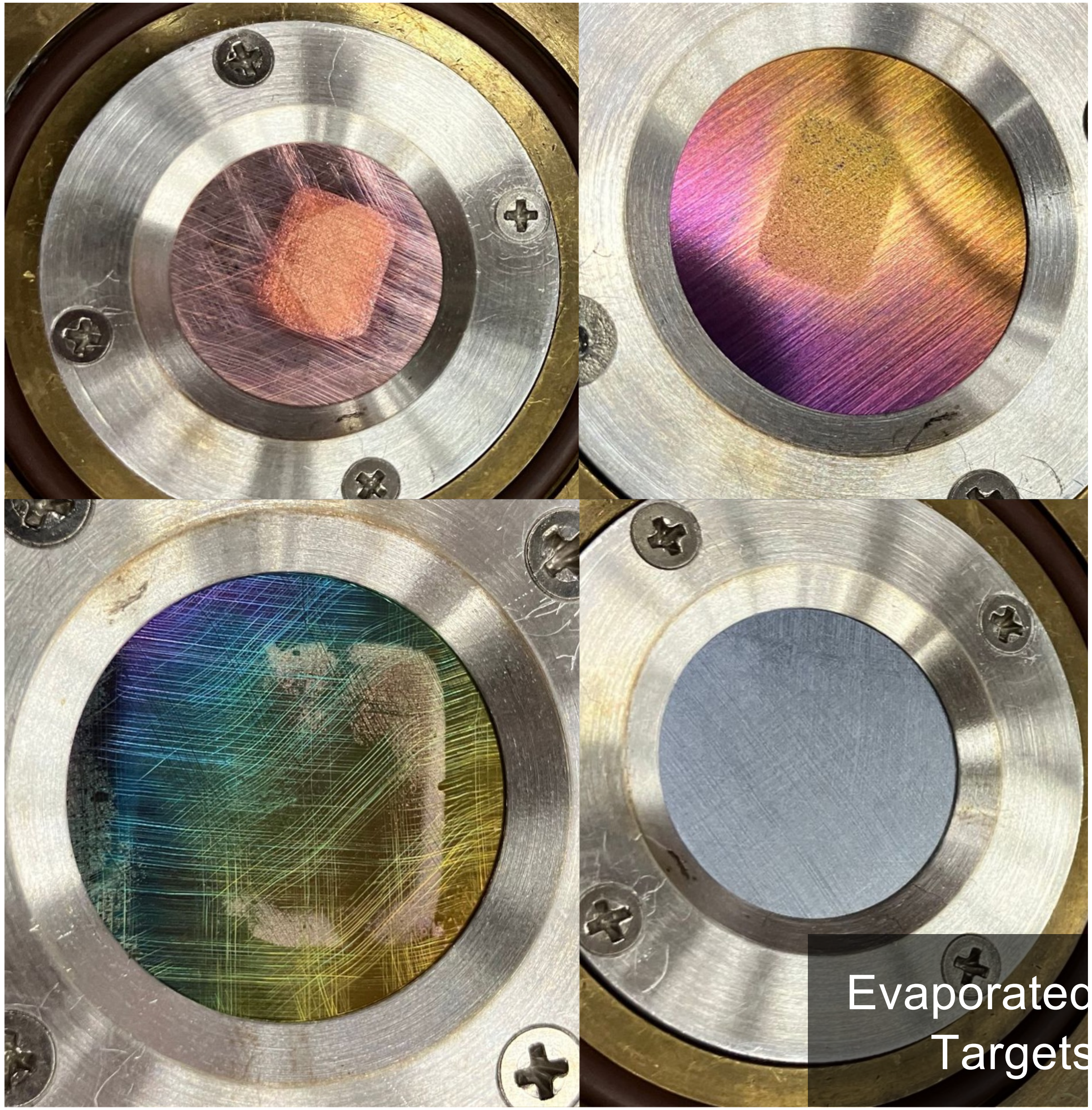
- Gula et al

Note: E_{beam} = 300 - 1400 keV

Evaporated Target

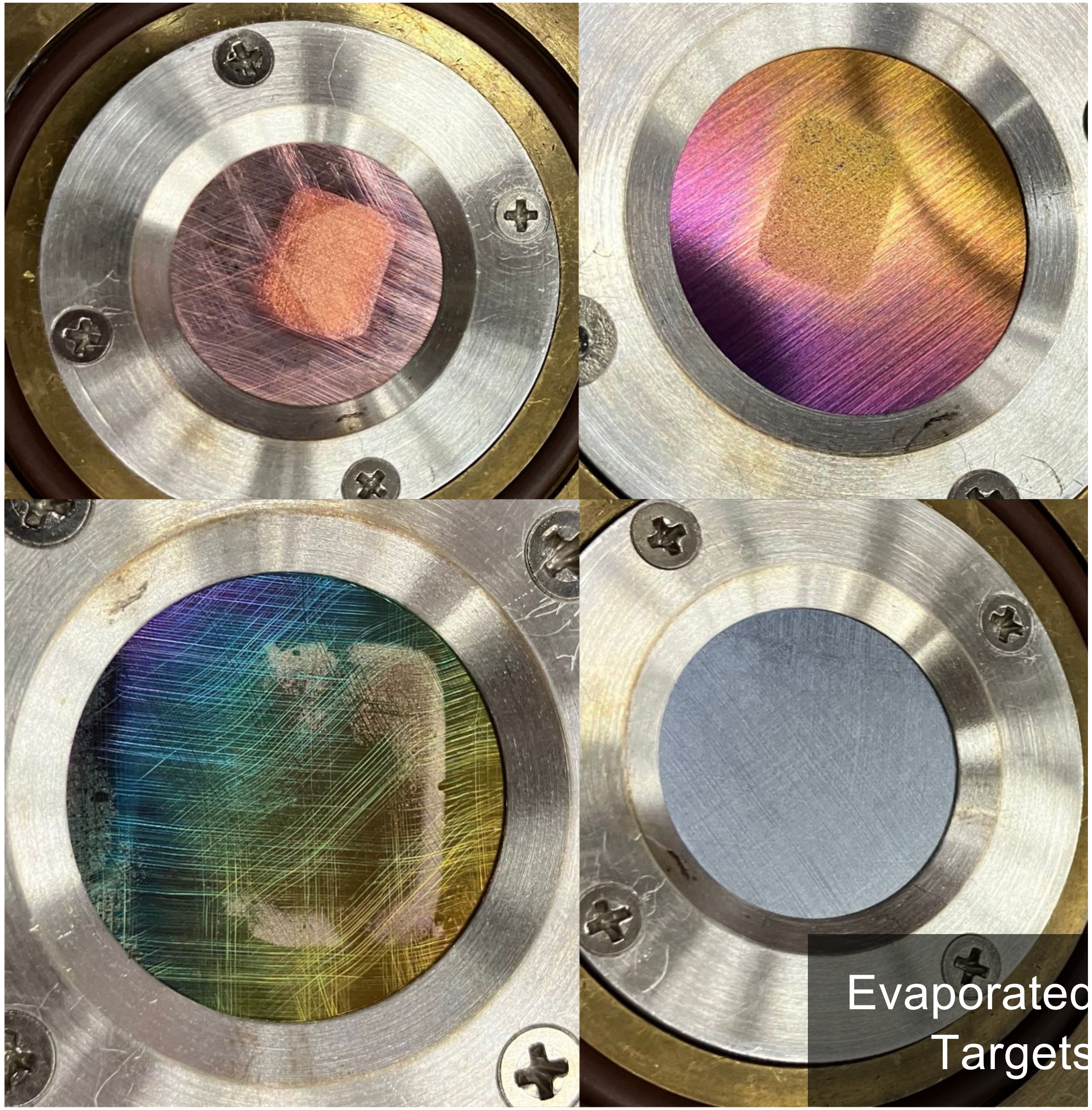
Number of targets

- 100 - 200 uA beam current
- 1 - 2C reached in a few hours
- 25 - 100 +



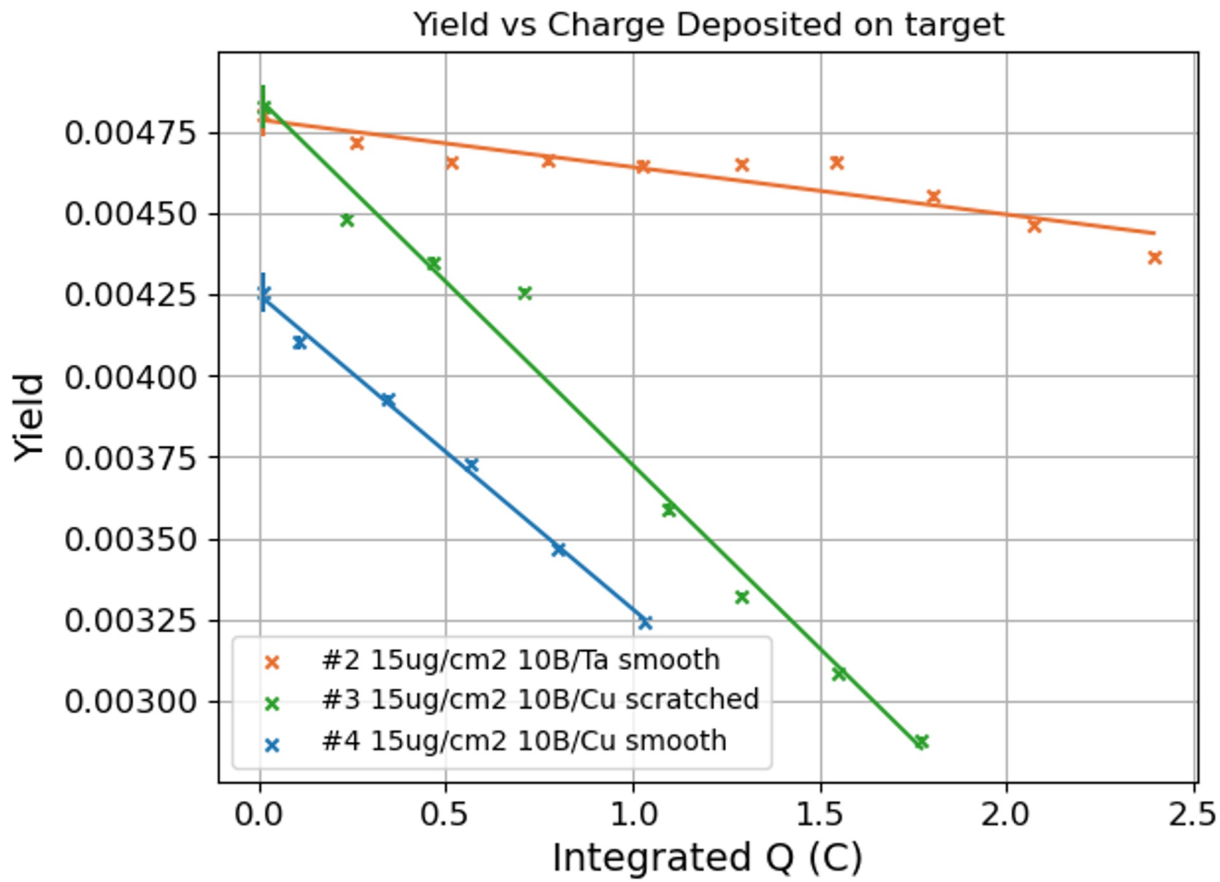
Targets

- Evaporated
  - Notre Dame, ATOMKI
- Implanted
  - UK NIBC (Surrey, $^{10}B^{19}F_3$), Dresden
- Coated (Sputtered)
  - Magtec ($^{10}B_4{}^{12}C$)



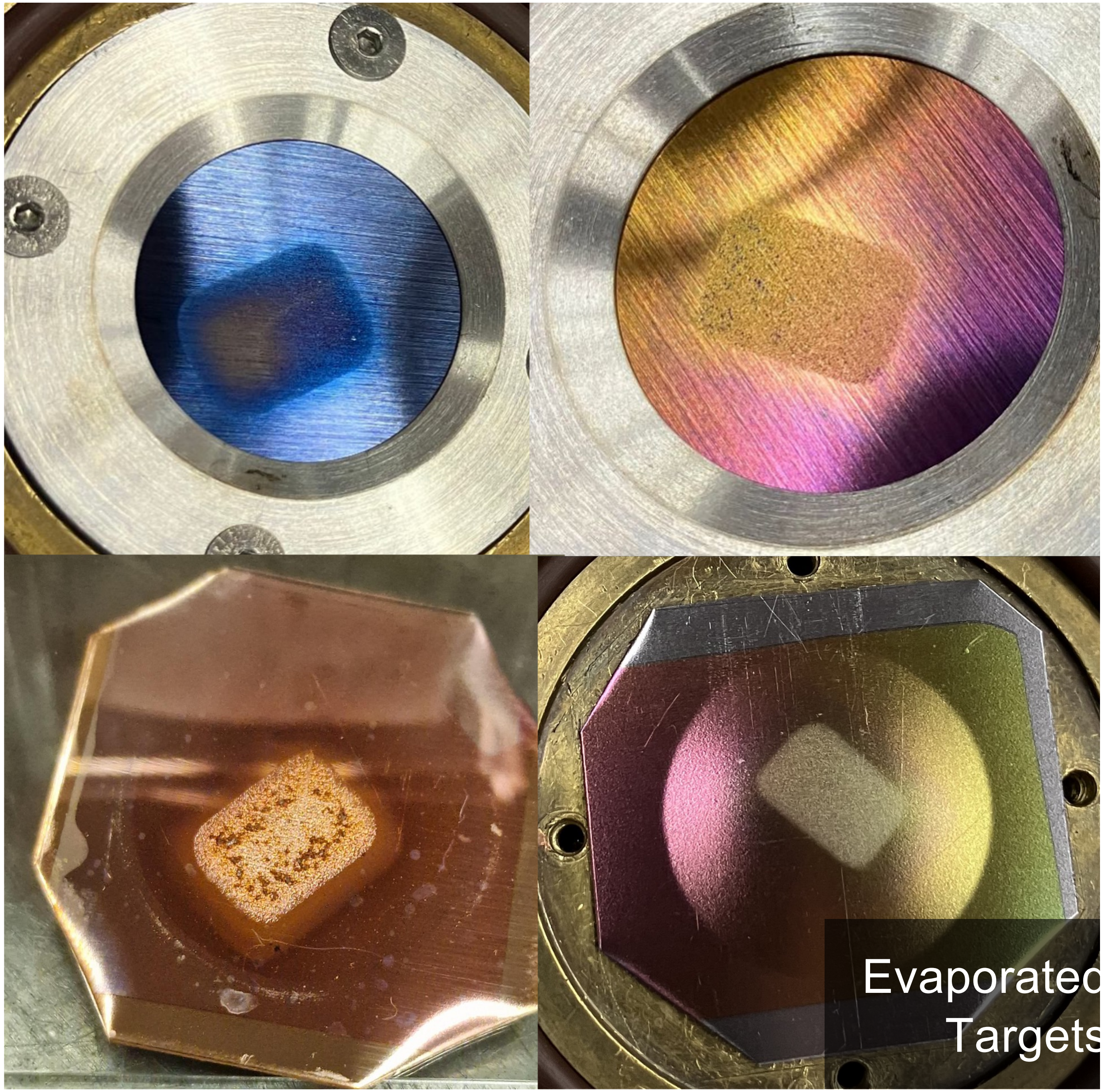
Notre Dame tests

- Alpha beam deterioration
  - —>
  - 10-30% drop in yield over 1- 2 C
  - Confirms Gula's results
- Nominal thicknesses not reliable (10% difference)
- 20-30% difference also observed in deterioration



….But

- E_{beam} >> 400 keV
- Limited runs at 400 keV
- Intensity: 25 - 100 uA
  - Typical 70 uA
- More data needed!



LUNA May beamtime

- 26th May - 8th June
- Using NUCLEAR chamber
- Durability tests @ E_a= 400 keV
- Hopefully Measure target thicknesses
- Possibly Start data taking

Thank you