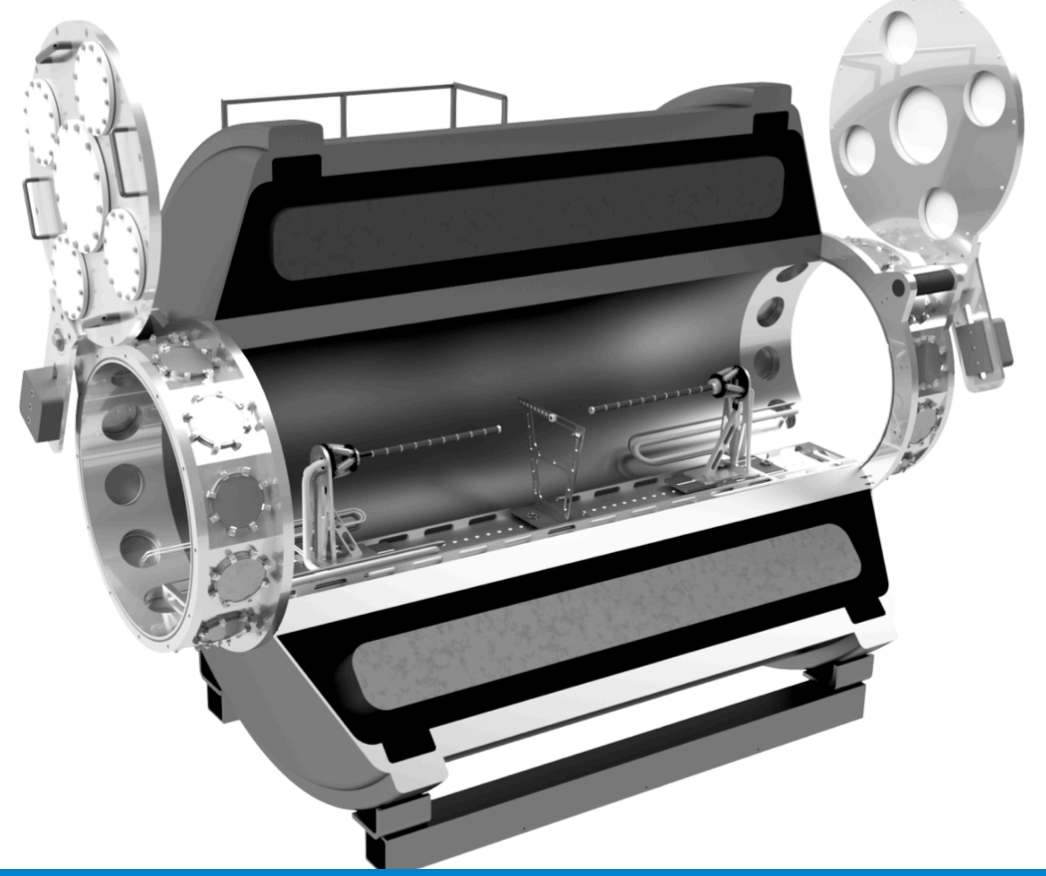


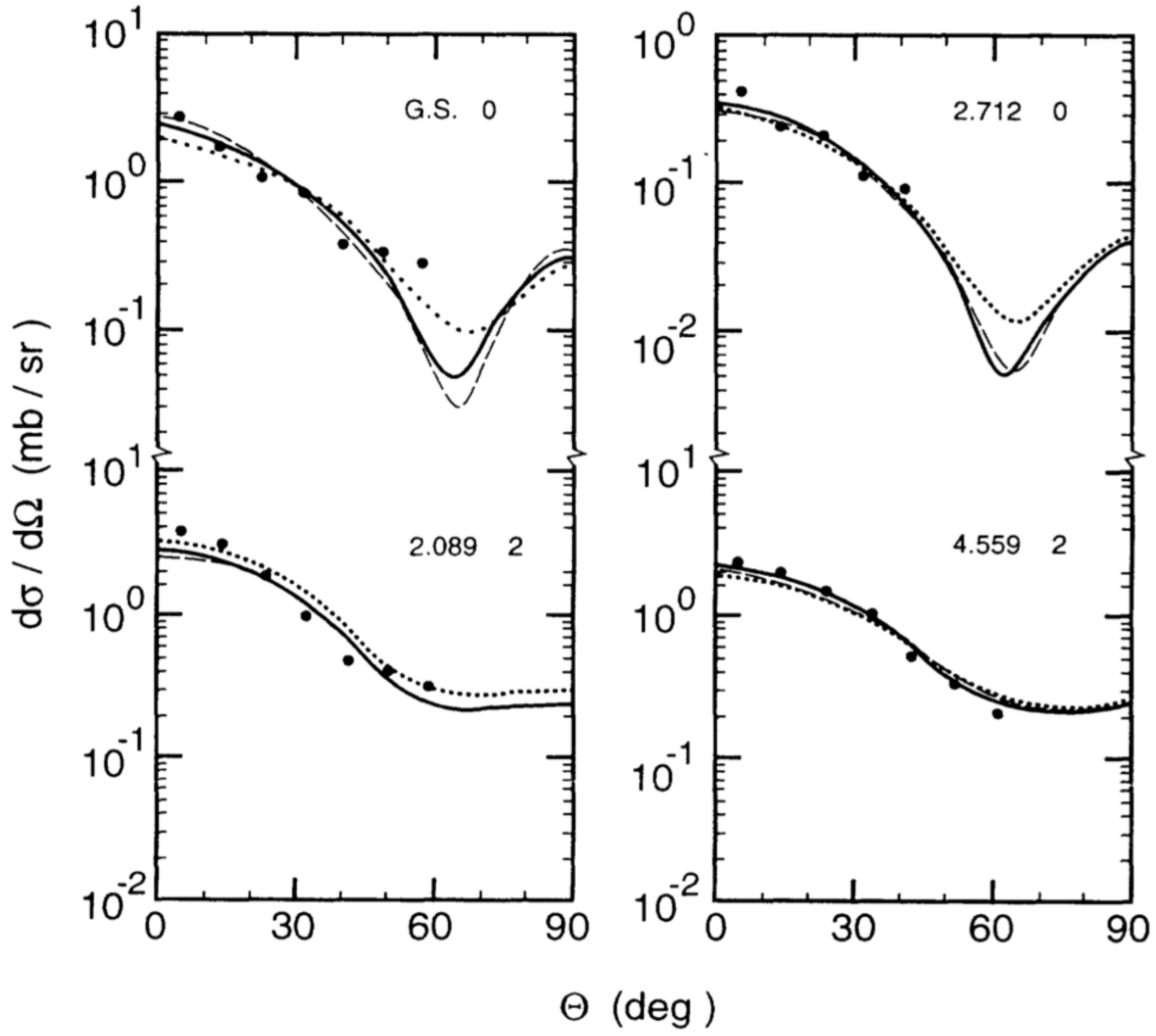
Study of the $^{10}Be(t,p)^{12}Be$ reaction with the SOLARIS spectrometer

Alicia Muñoz-Ramos, Y. Ayyad, B. P Kay, H. Alvarez-Pol, and the SOLARIS collaboration

ARIS conference, Avignon, France, June 2023

Overview

- *Structure of ^{12}Be*
- *Why revisit with the (t,p) reaction?*
- *Challenges of inverse kinematics*
- *Solution? SOLARIS*
- *Preliminary results*
- *Future work*



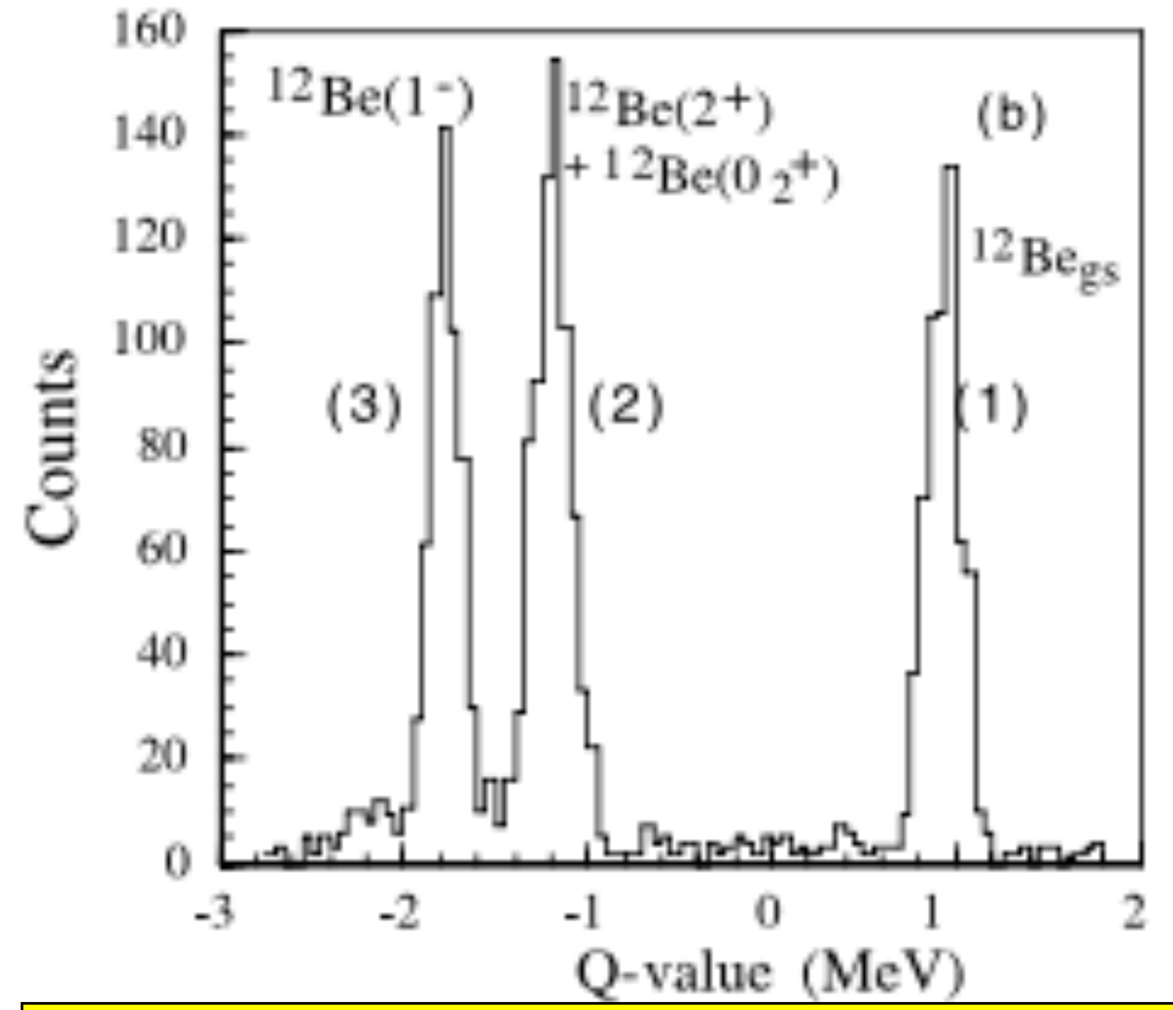
Fortune et al., Phys. Rev. C ***50*** *(1994) 1355-1359*

^{12}Be so far

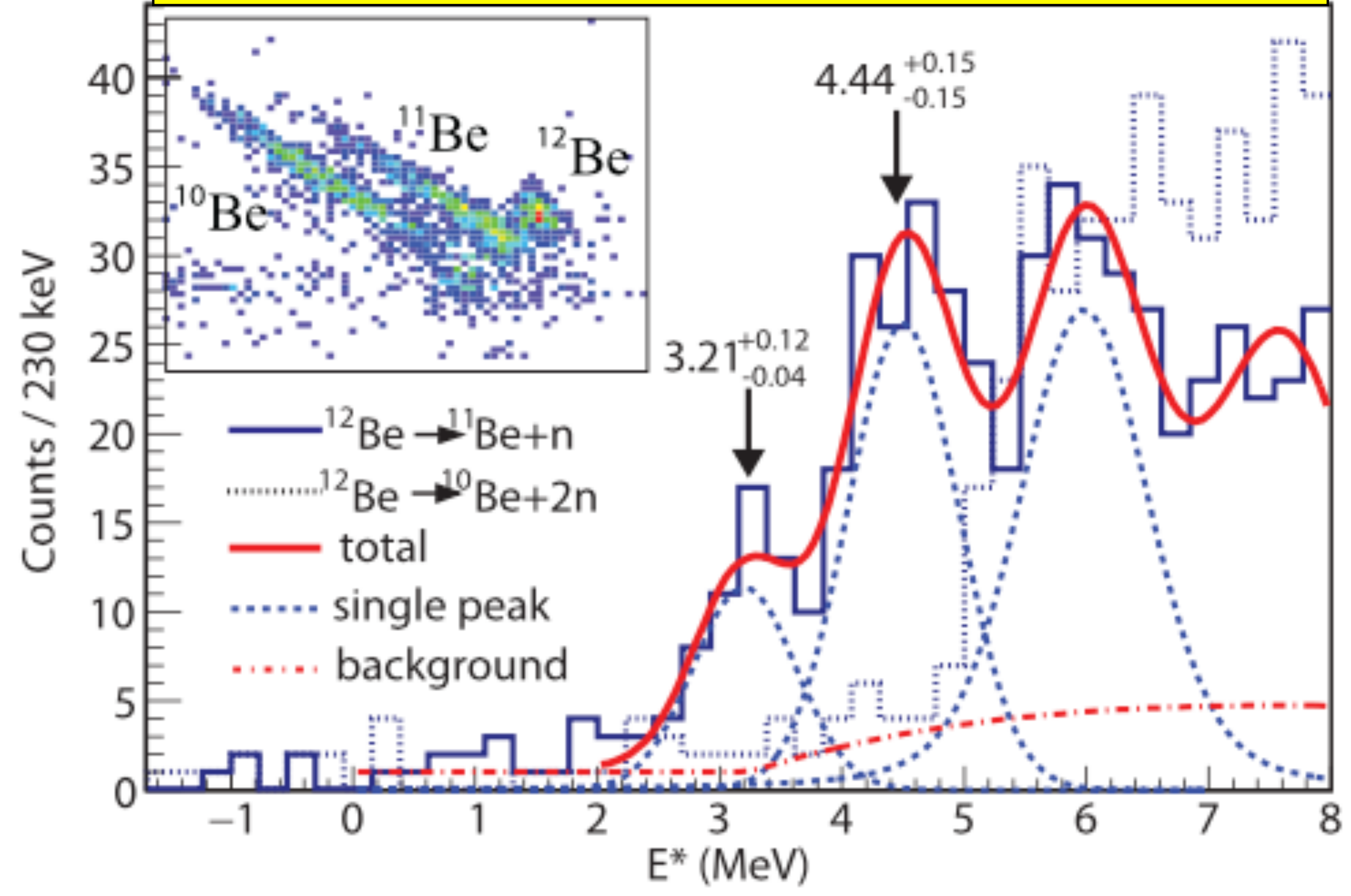
- *Several low-lying bound states known from a variety of studies*
- *Recent measurements of (d,p), but still some ambiguity as to assigment/structure of some states*
- *Past (t,p)-reaction studies done at lower energies + background from target*

E (MeV)	J^{π} (lit.)[a]
0.0	0^+
2.109	2^+
2.251	0^+
2.715	1^-
3.21	(0^-)
4.412	(2^-)
4.580	$(2^+,3^-)$
5.0	–
5.724	$(4^+,2^+,3^-)$
6.02	–
6.275	–

S_n



*R. Kanungo et al., Phys. Lett. B **682** (**2010**) 391-395*



*J. Chen et al., Phys. Rev. C **103**, L031302 (**2021**)*

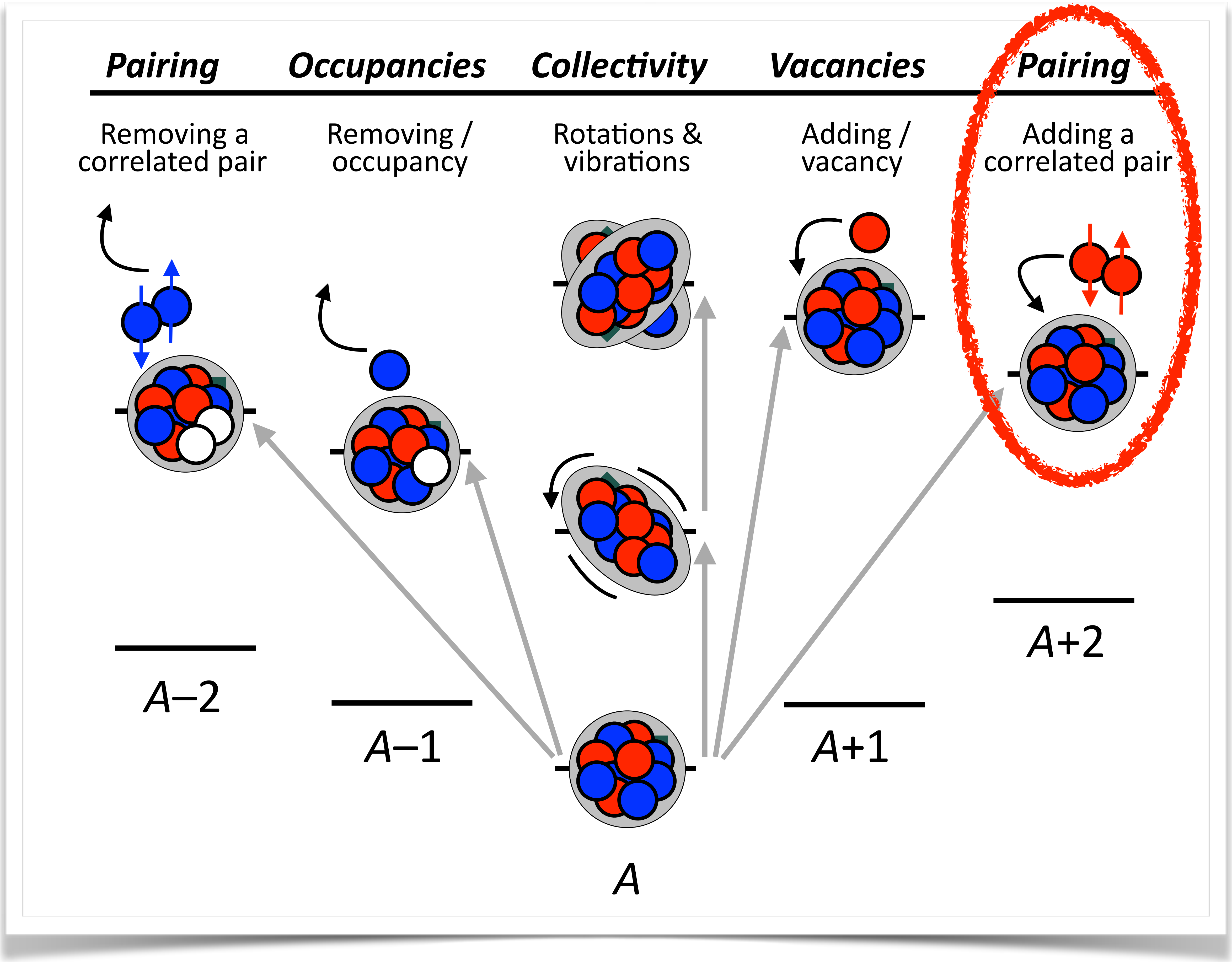
(Top) States below threshold
(below) States above threshold

Direct Reactions

~10 MeV/u (3-20 MeV/u)

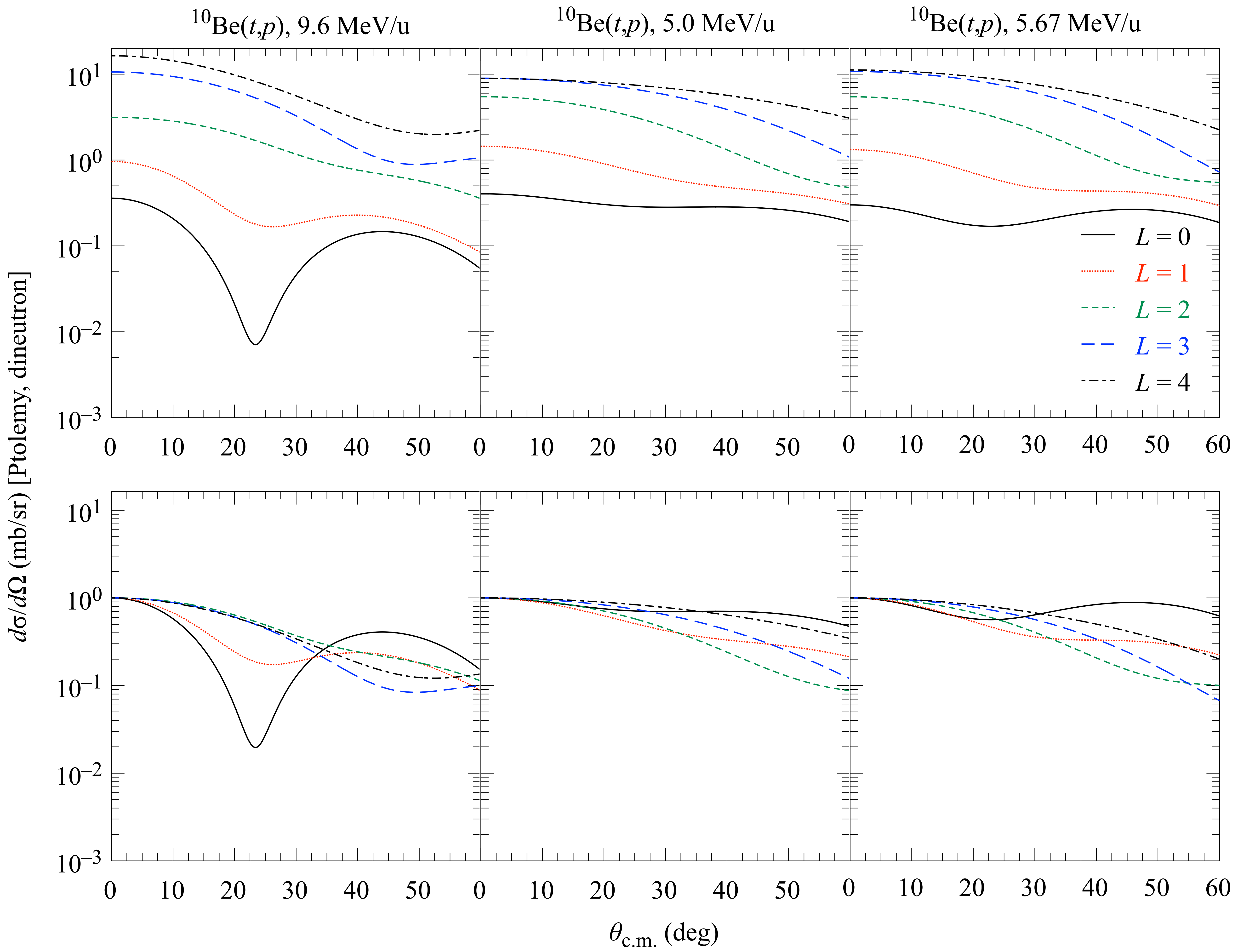
Reactions used as a tool for nuclear structure and astrophysics:

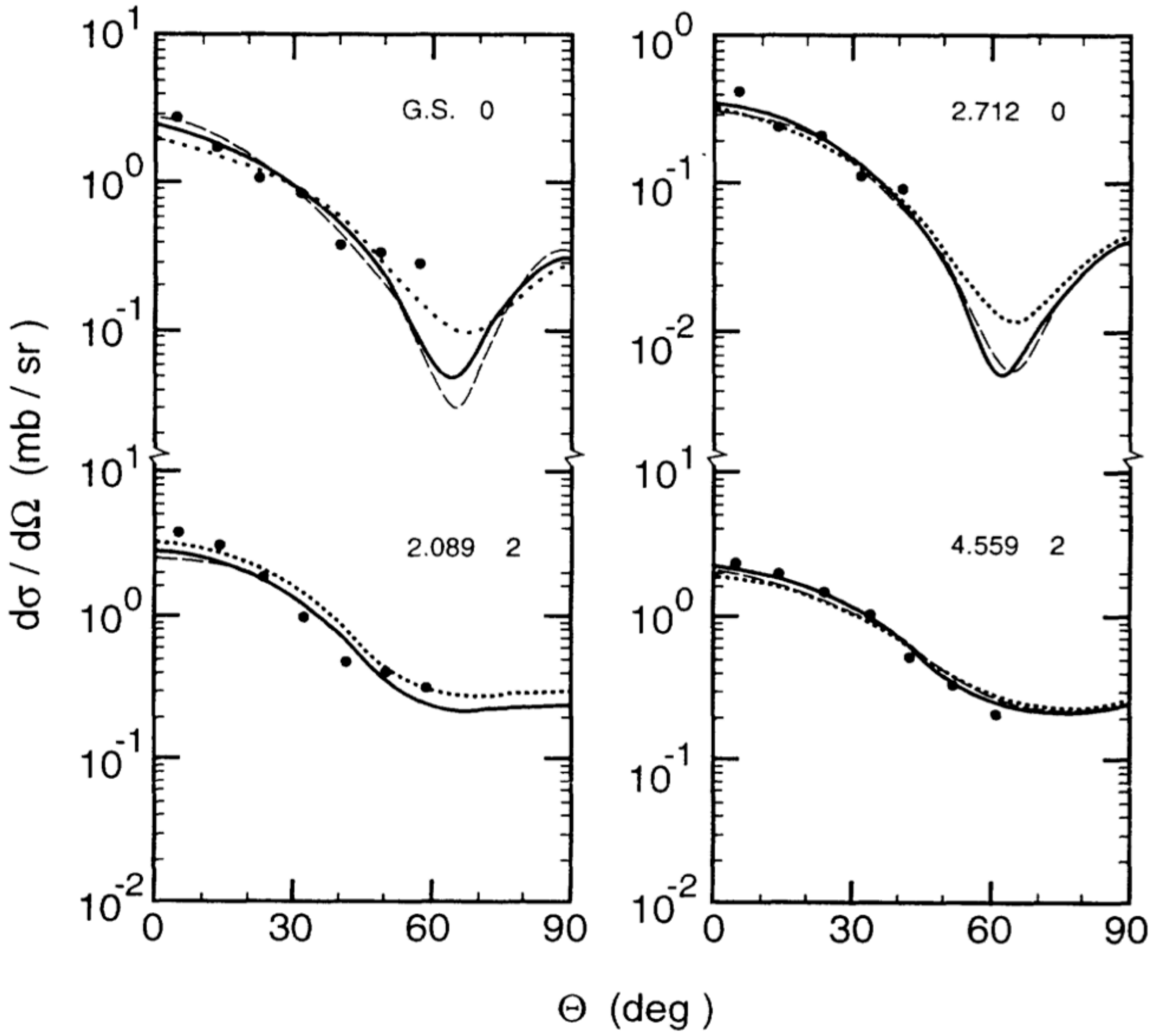
- *Selectively populate states, determine E, j^{π}*
- *Inelastic, single-nucleon, two-nucleon*

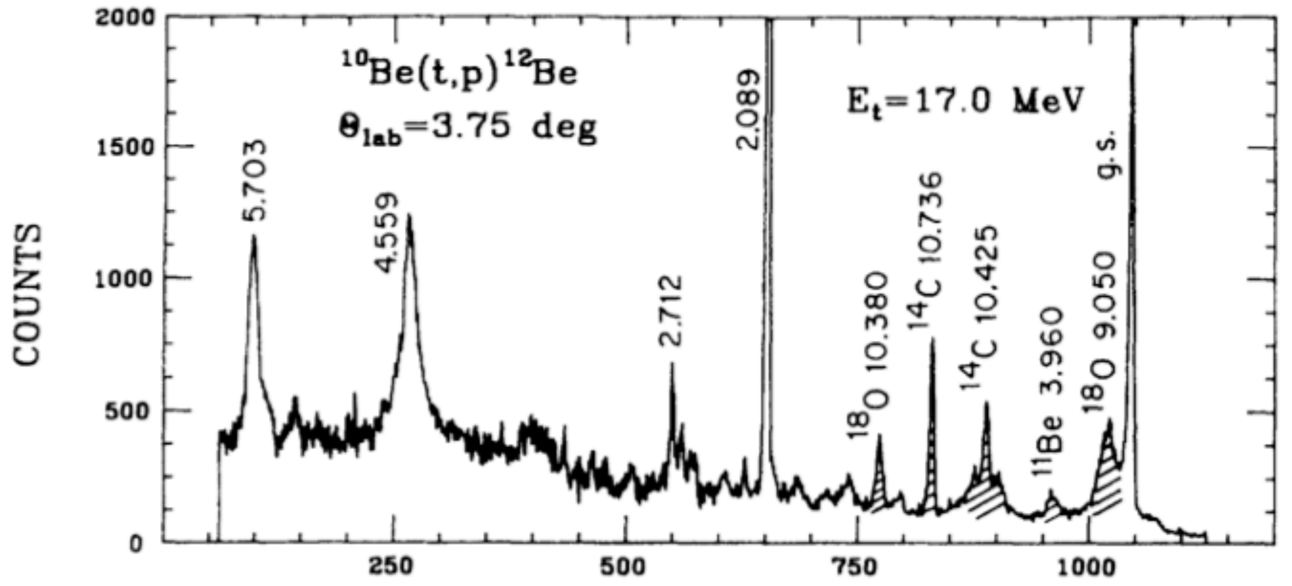


Why repeat the (t,p)?

Famous result of Fortune et al., done at lower energies around 5-5.7 MeV/u, angular distributions are broad with less features … some advantages to higher energy … plus, in theory a background-free measurement (removing target complications [though others remain])





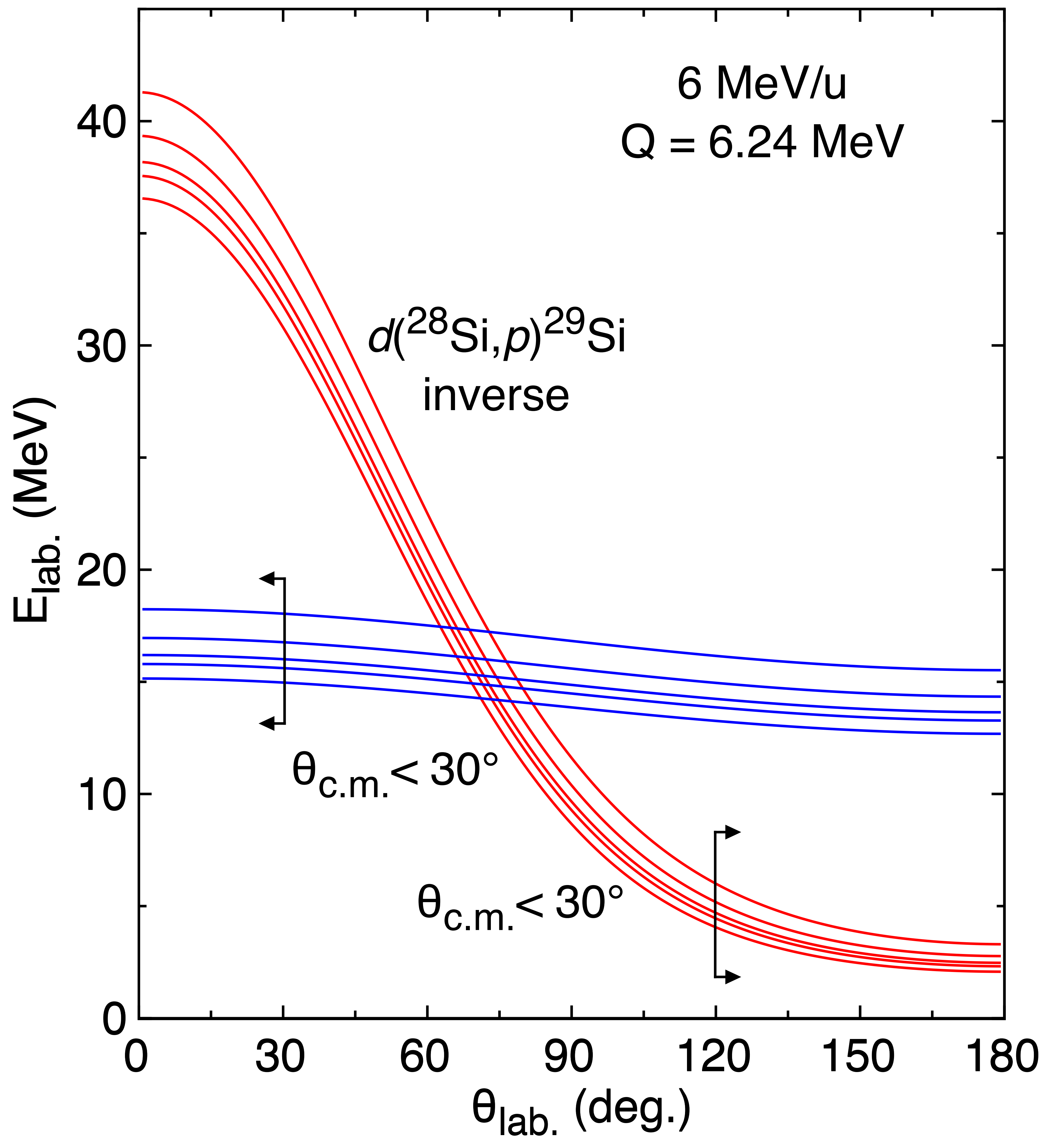


Challenge of inverse kinematics

When compared to normal/forward kinematics, inverse kinematics suffers from:

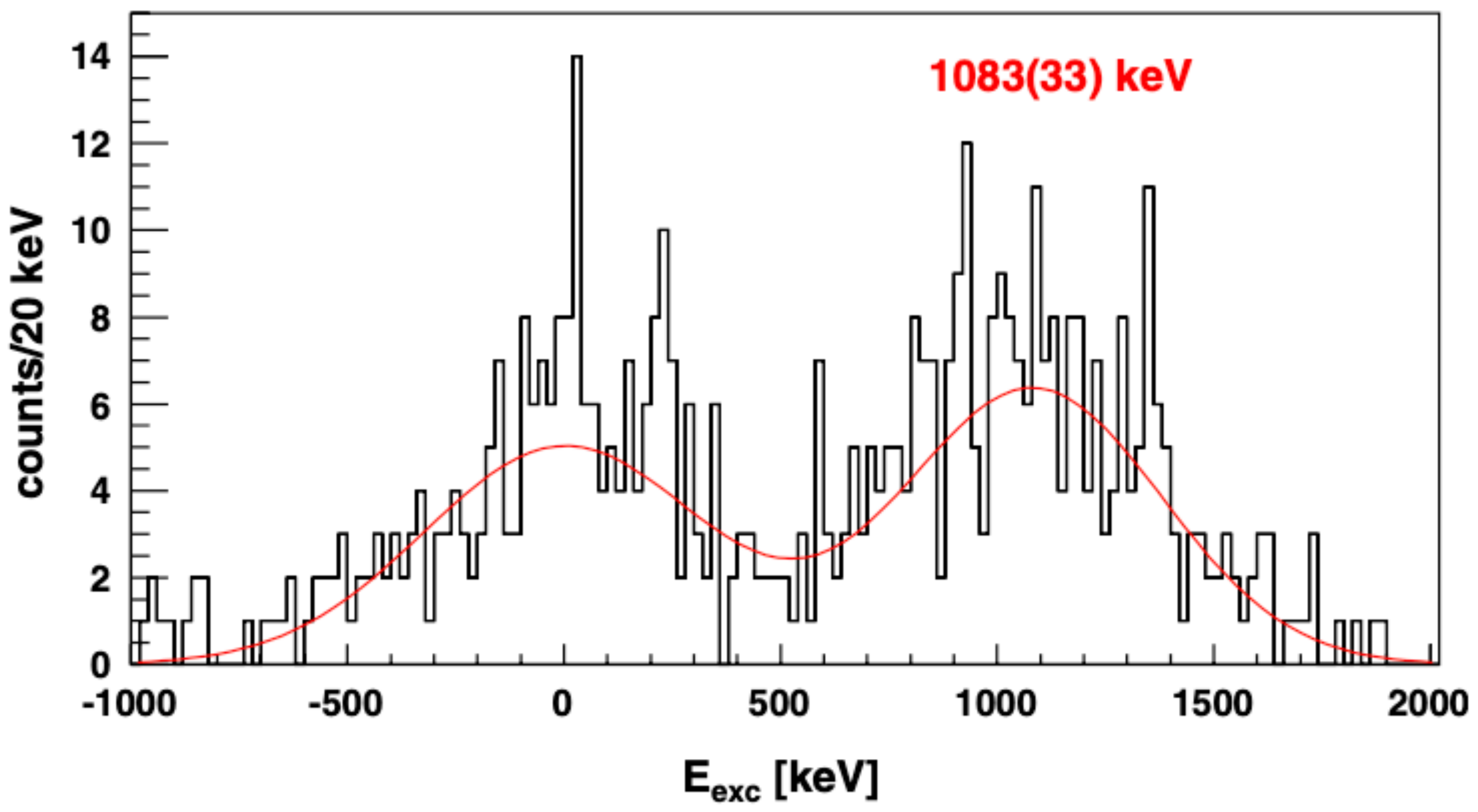
- *Much* ***lower energy*** *outgoing ions, challenges for E-ΔE techniques*
- *Much stronger* ***energy dependence*** *with respect to laboratory angle*
- *A factors of 2-3* ***kinematic compression*** *at forward c.m. angles*
- *… and beams many* ***orders of magnitude weaker***

The result is typically very poor Q-value resolution of 100s of keV FWHM



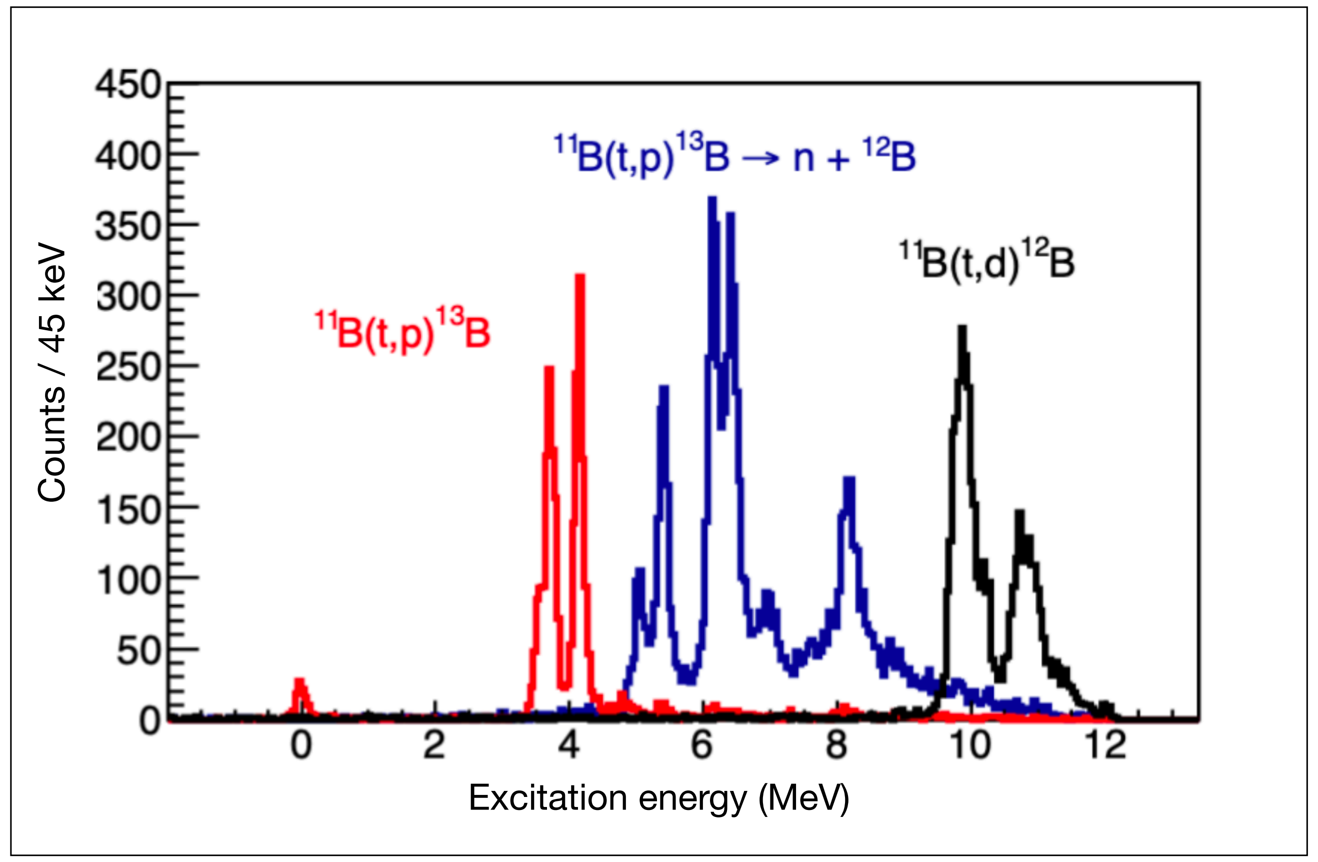
The challenge with inverse kinematics

For examples (very few of which exist)

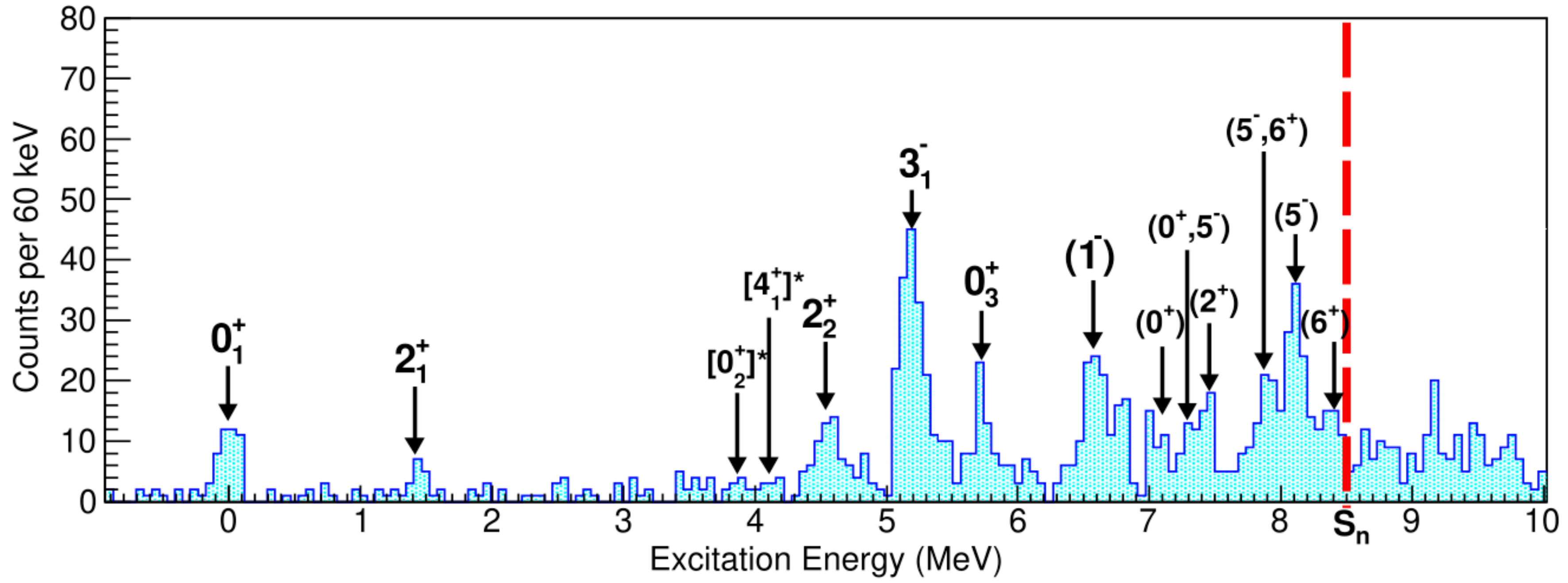


Wimmer et al., Phys. Rev. Lett. ***105****, 252501 (****2010****)*

Pioneering measurement of Wimmer et al. using TREX and Miniball to study the ^{30}Mg(t,p)^{32}Mg reaction



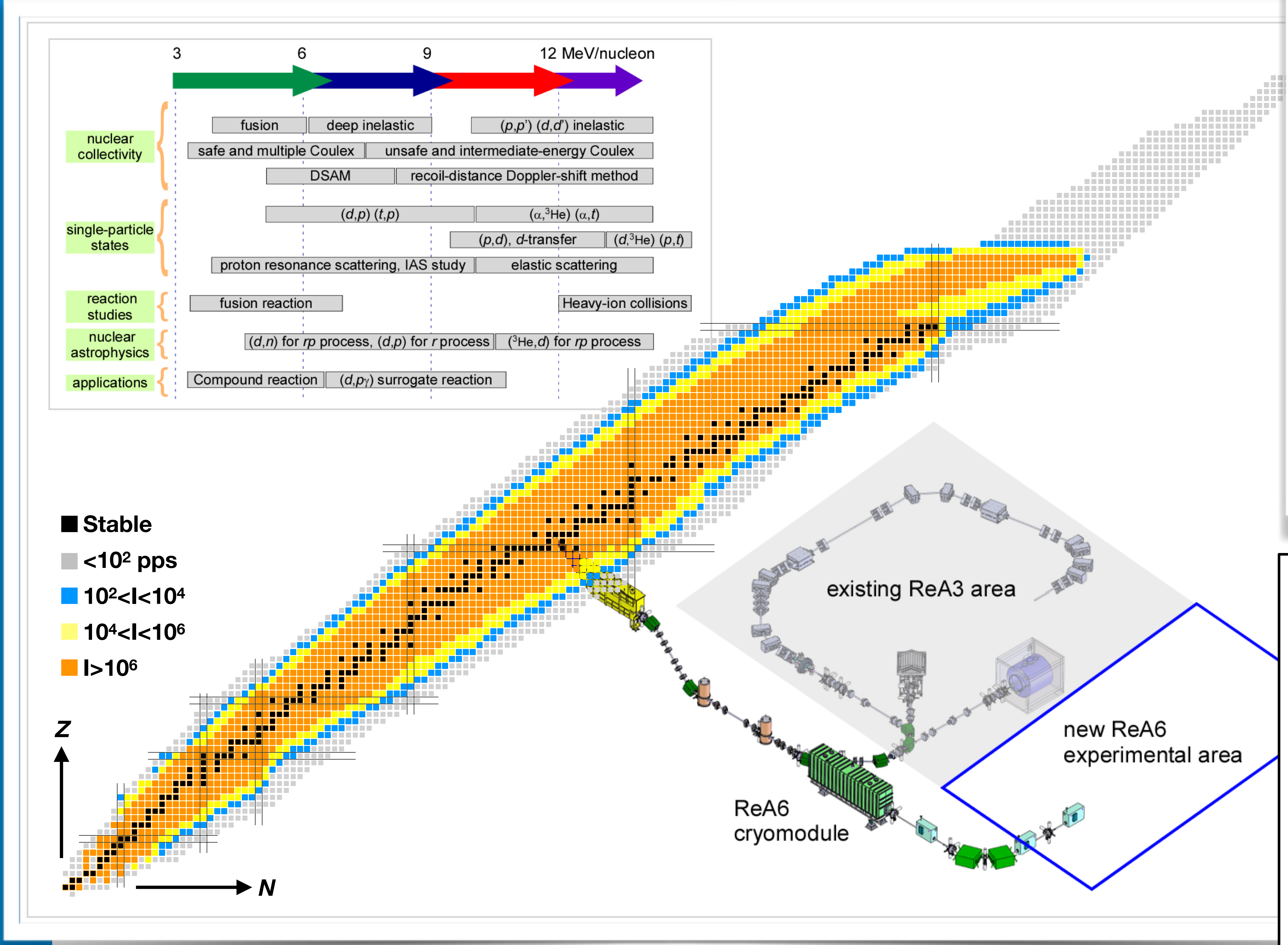
Kuvin et al., unpublished

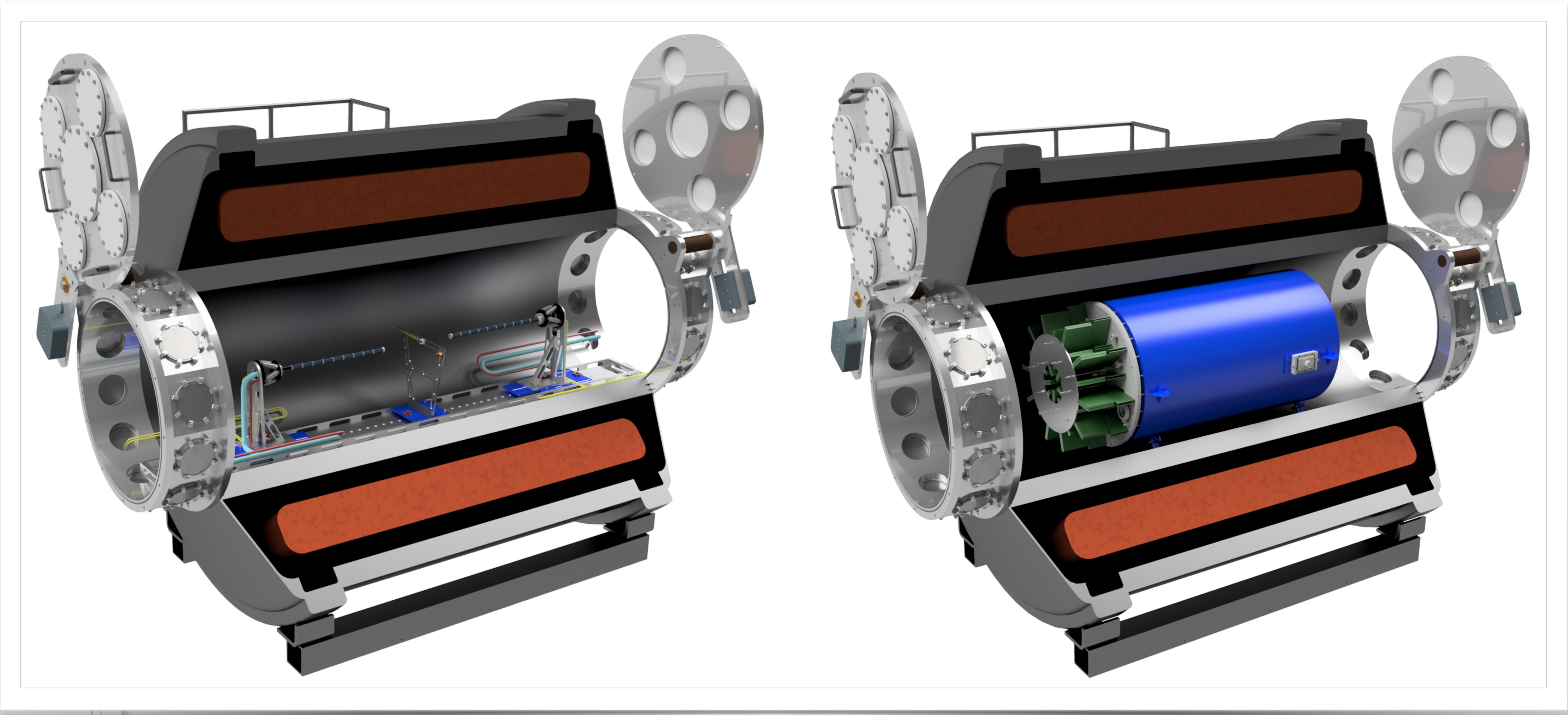


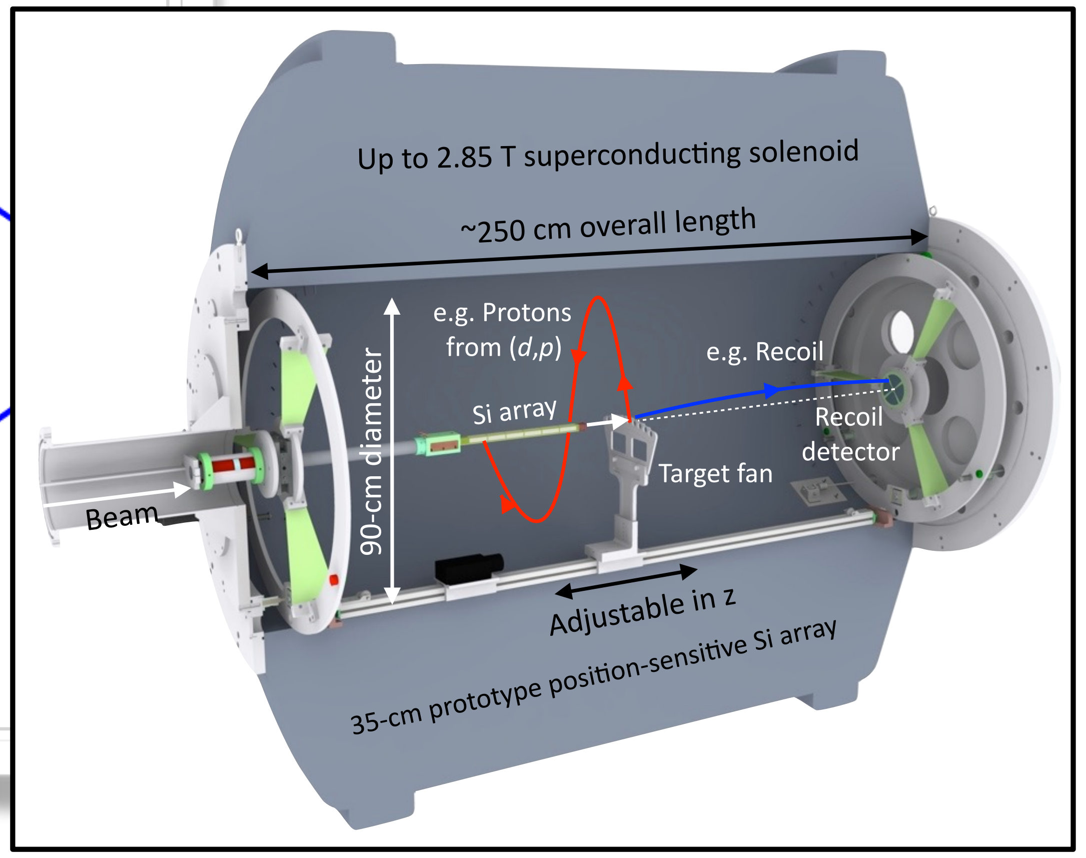
McNeel et al., Phys. Rev. C ***103****, 064320 (****2021****)*

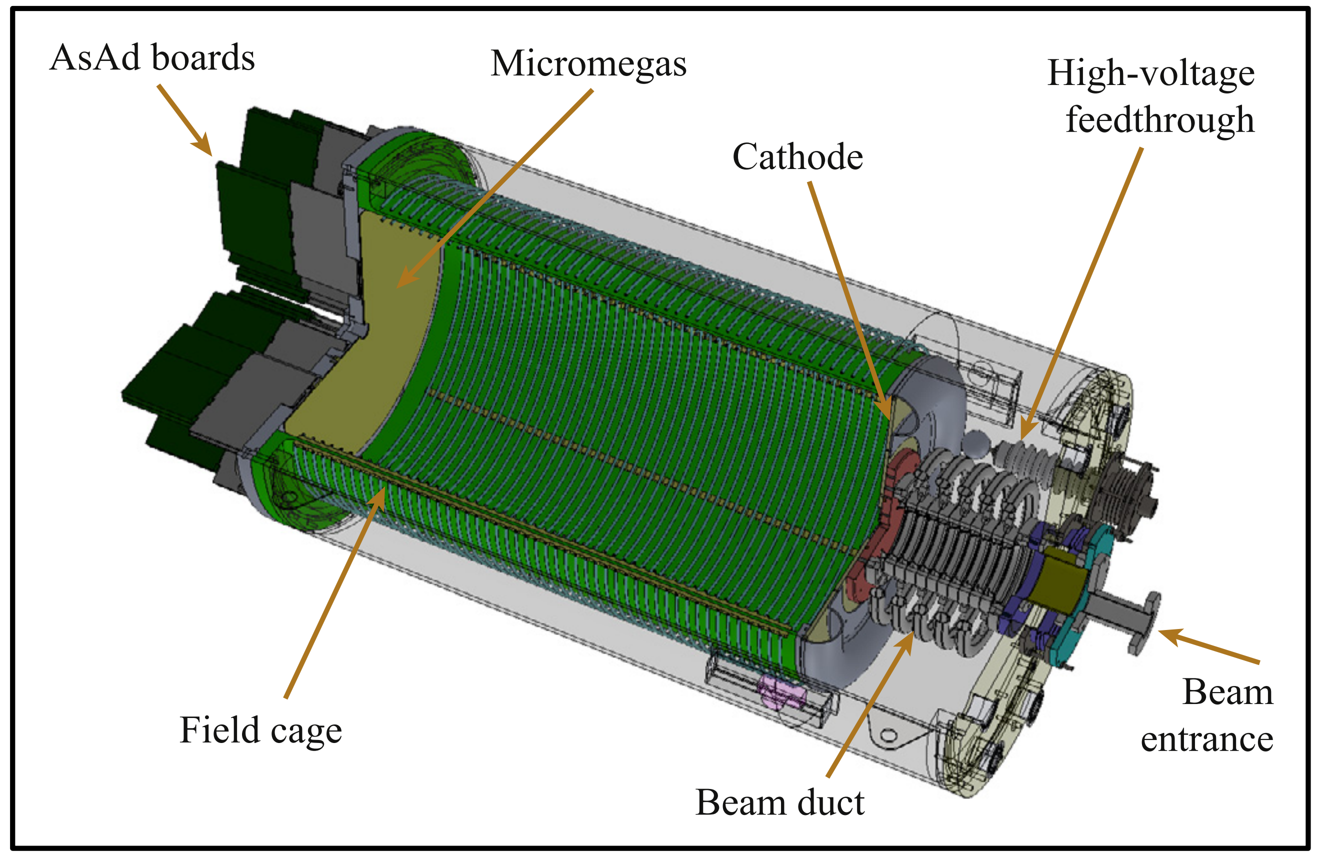
(Top) Example of the ^{11}B(t,p) reaction in HELIOS (below) and the ^{26}Mg(t,p) reaction

Solution? SOLARIS



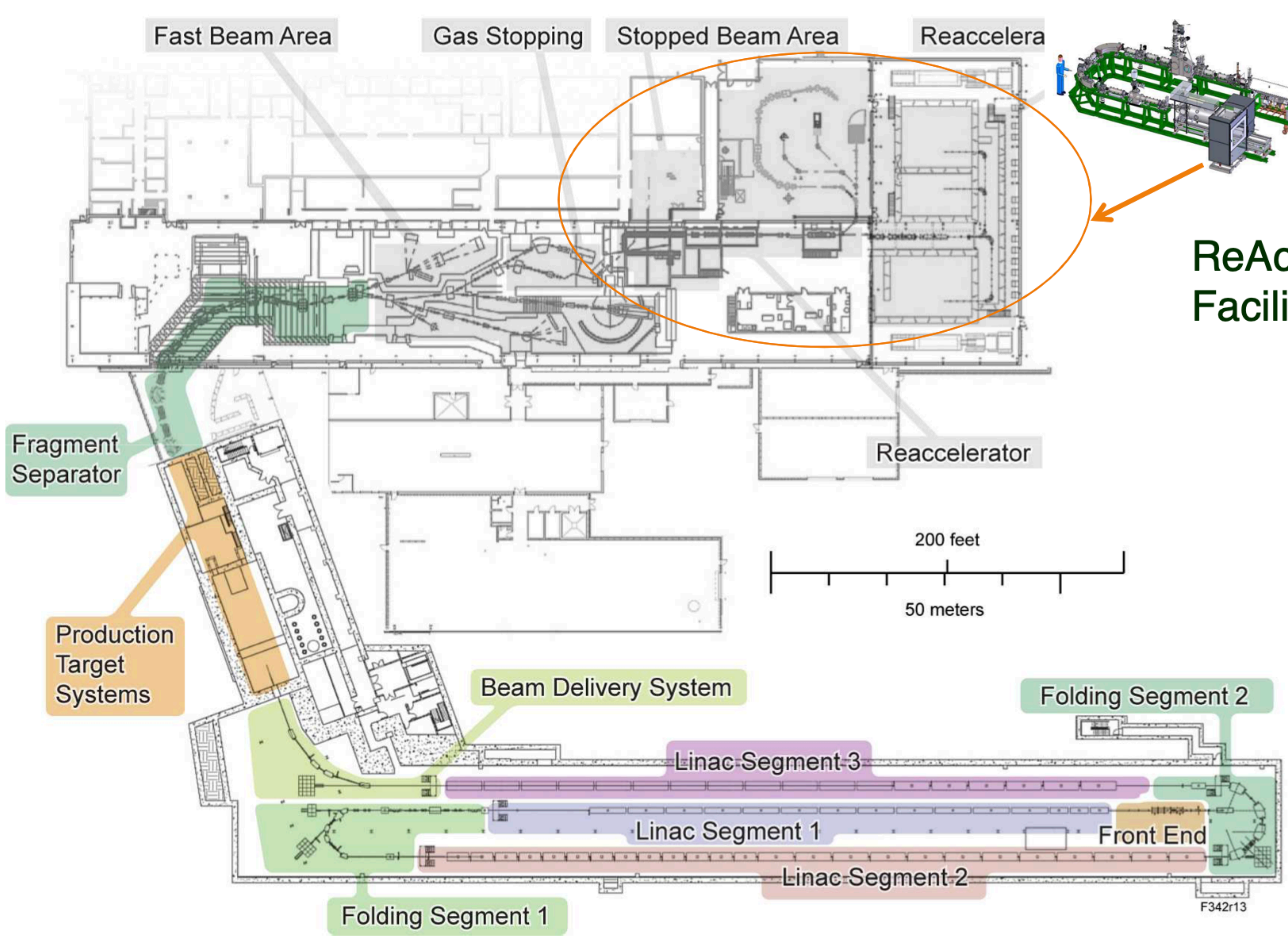


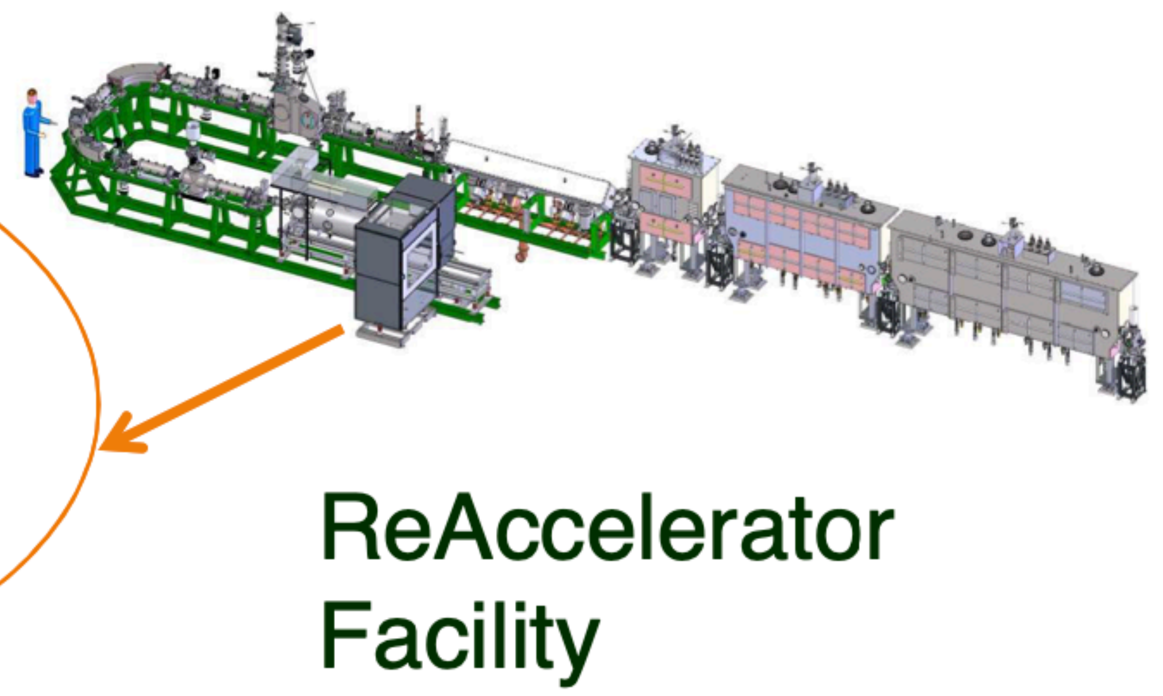




A dual-mode solenoidal spectrometer to exploit the full dynamic range of the ReA facility at FRIB

FRIB Accelerator Complex Subsystems



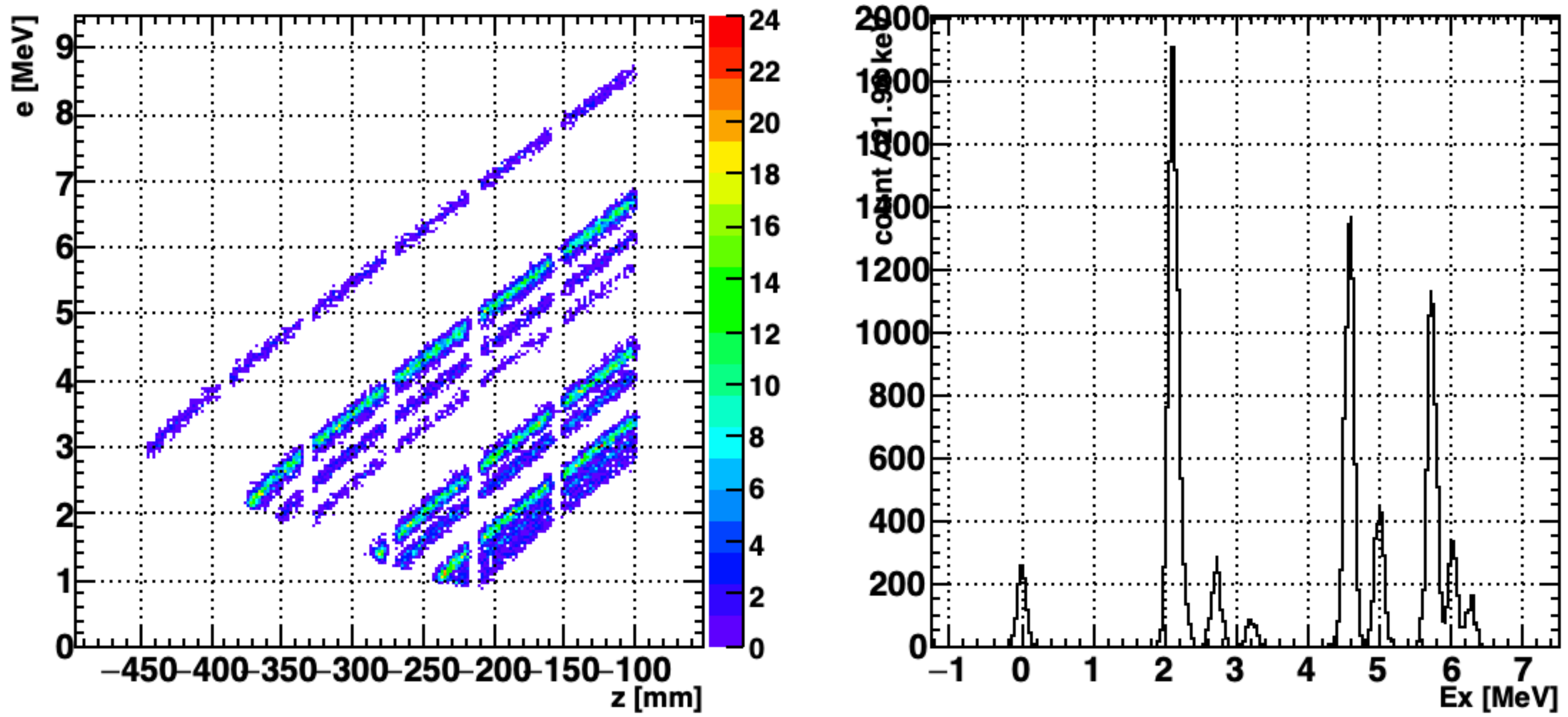


Golden opportunity in 2021:

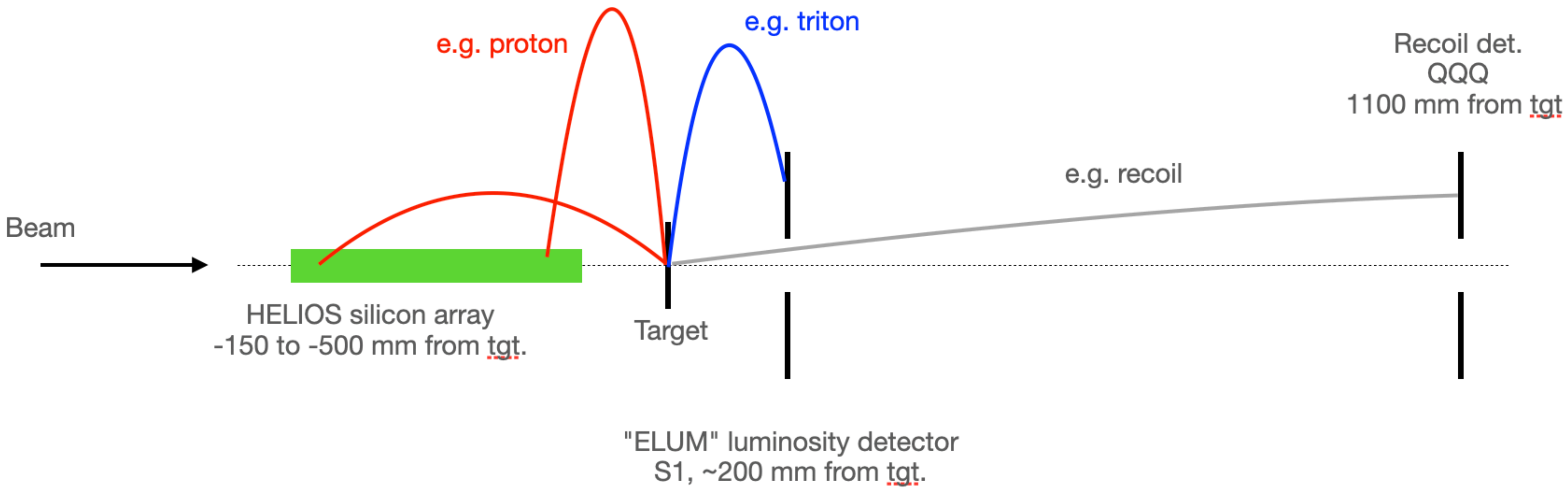
- *Before FRIB started, NSCL stopped*
- *ReA in "standalone" mode*
- *^{10}Be isotope by PSI*

Physics

$^{10}Be(t,p)$ @ 9.6 MeV/u

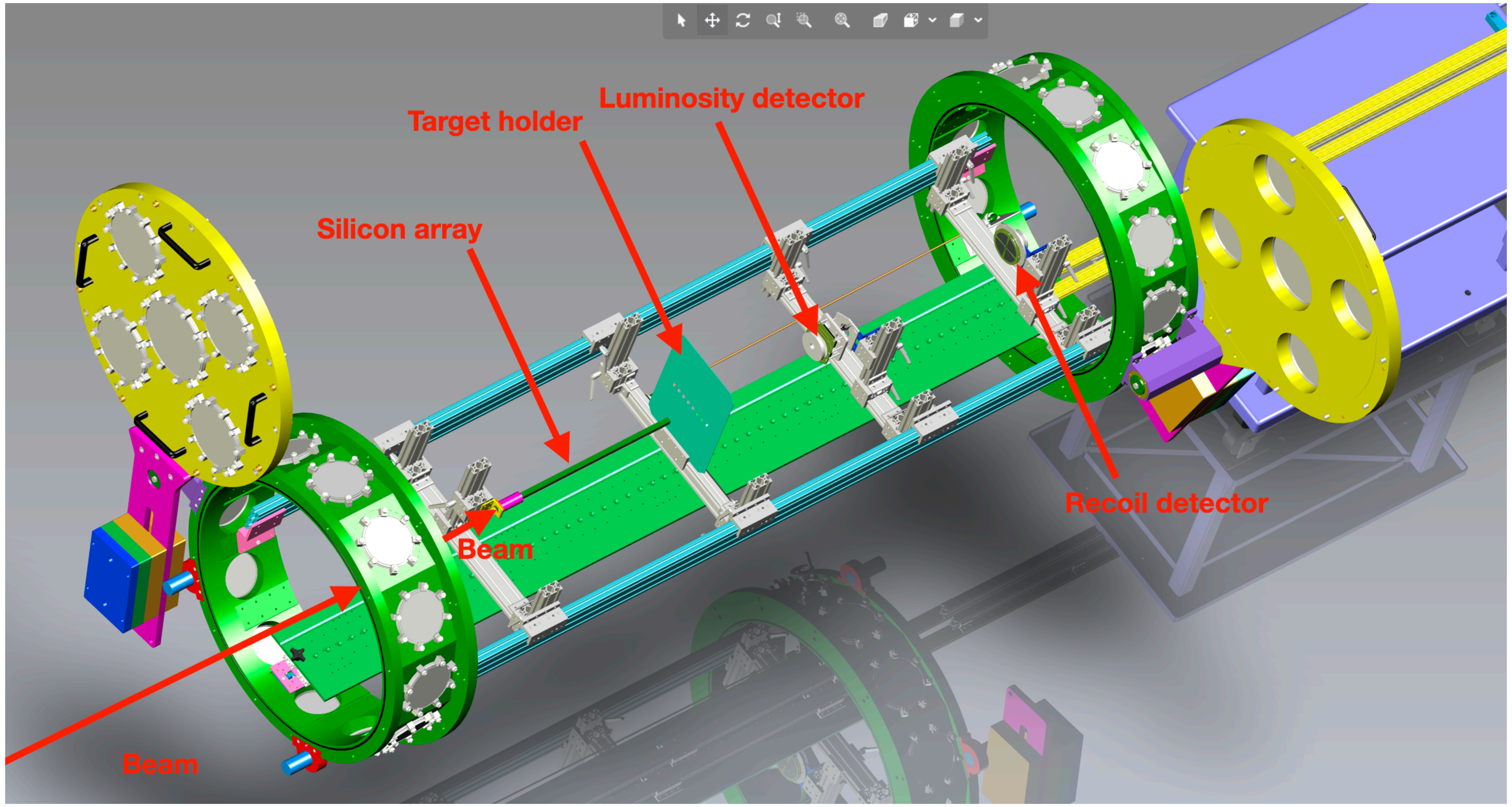


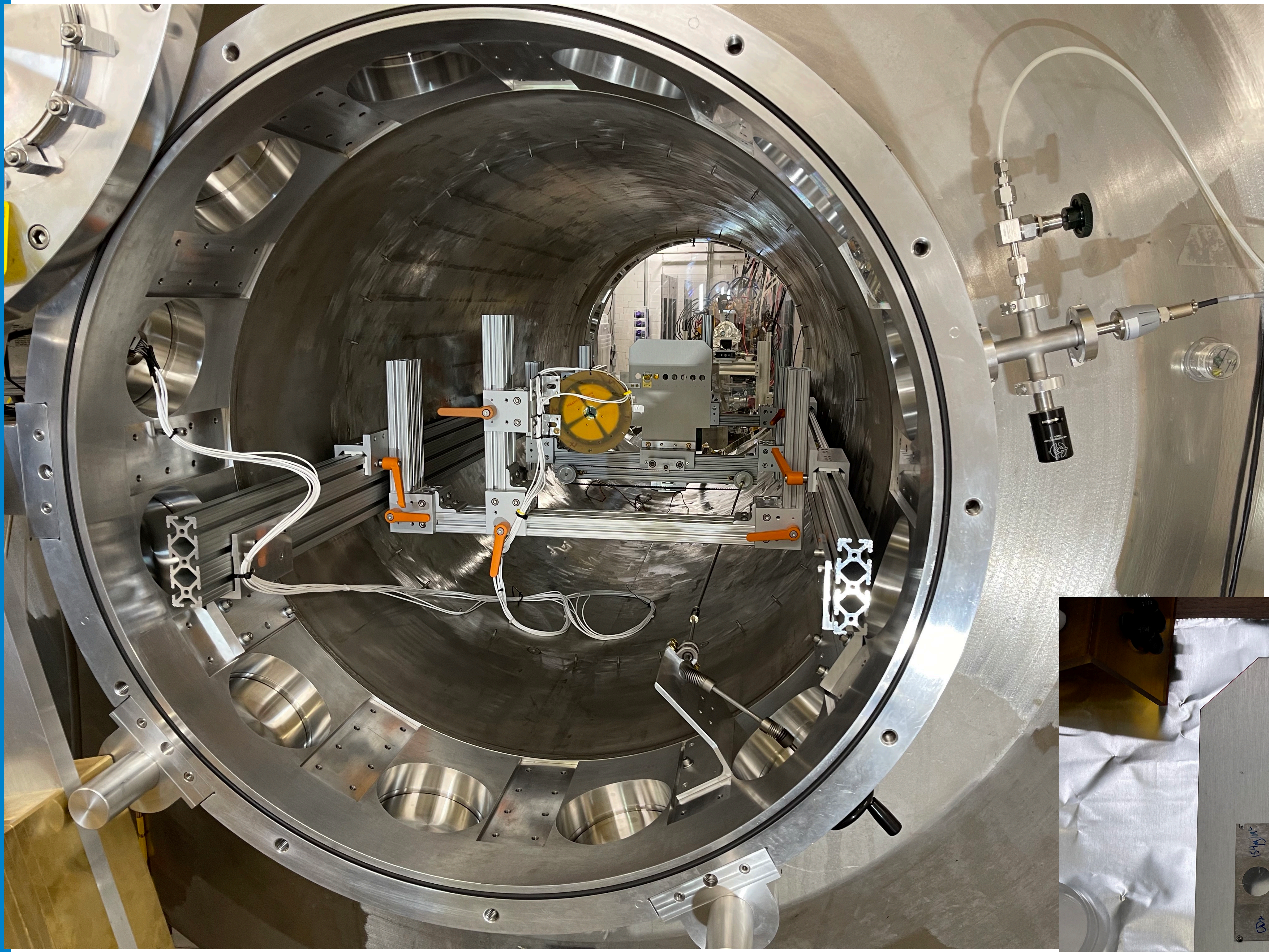
$$E_{lab} = E_{cm} - \frac{1}{2} m V_{cm}^2 + \left(\frac{m V_{cm}}{T_{cyc}} \right) z$$

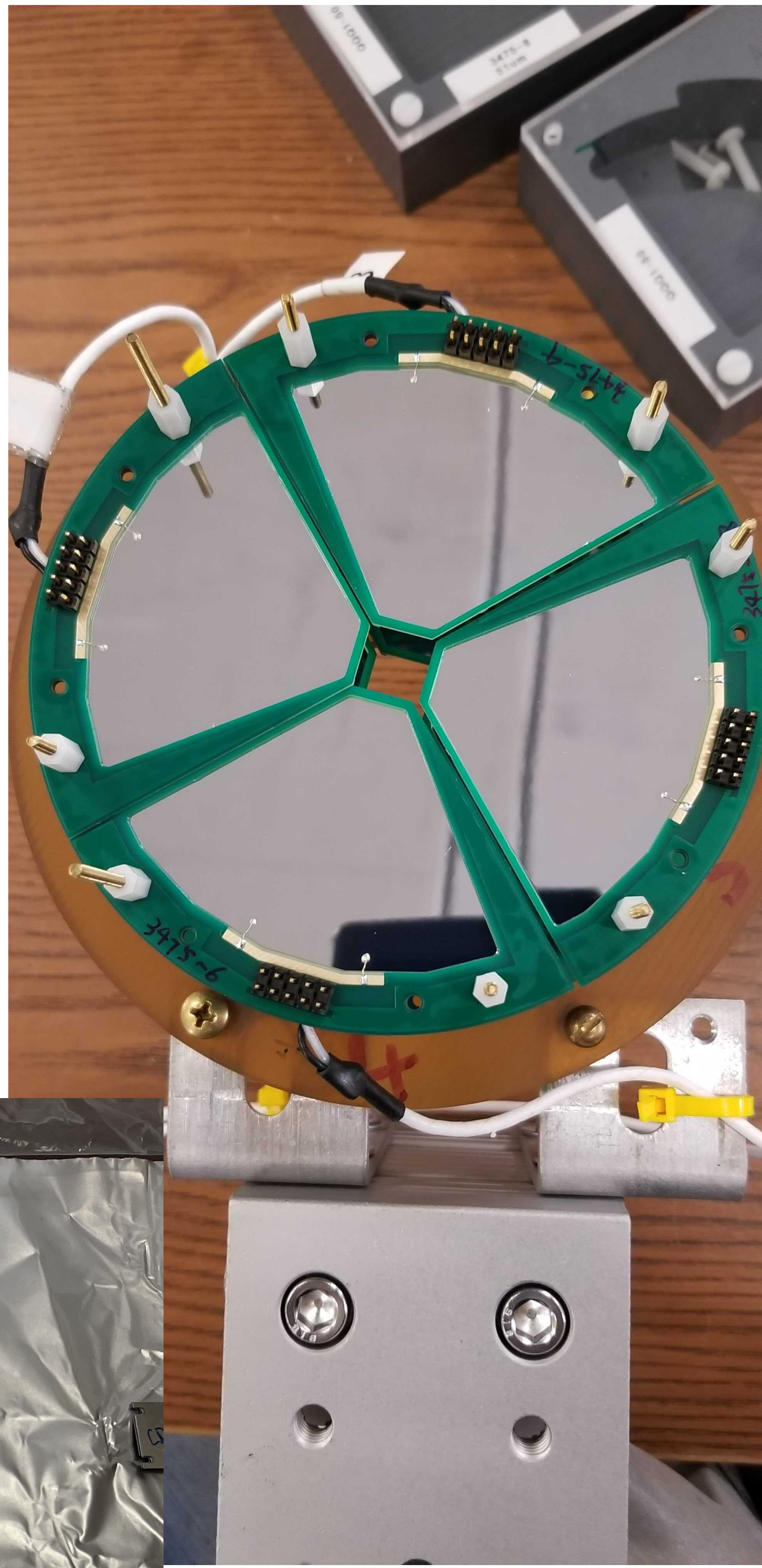


Using SOLARIS

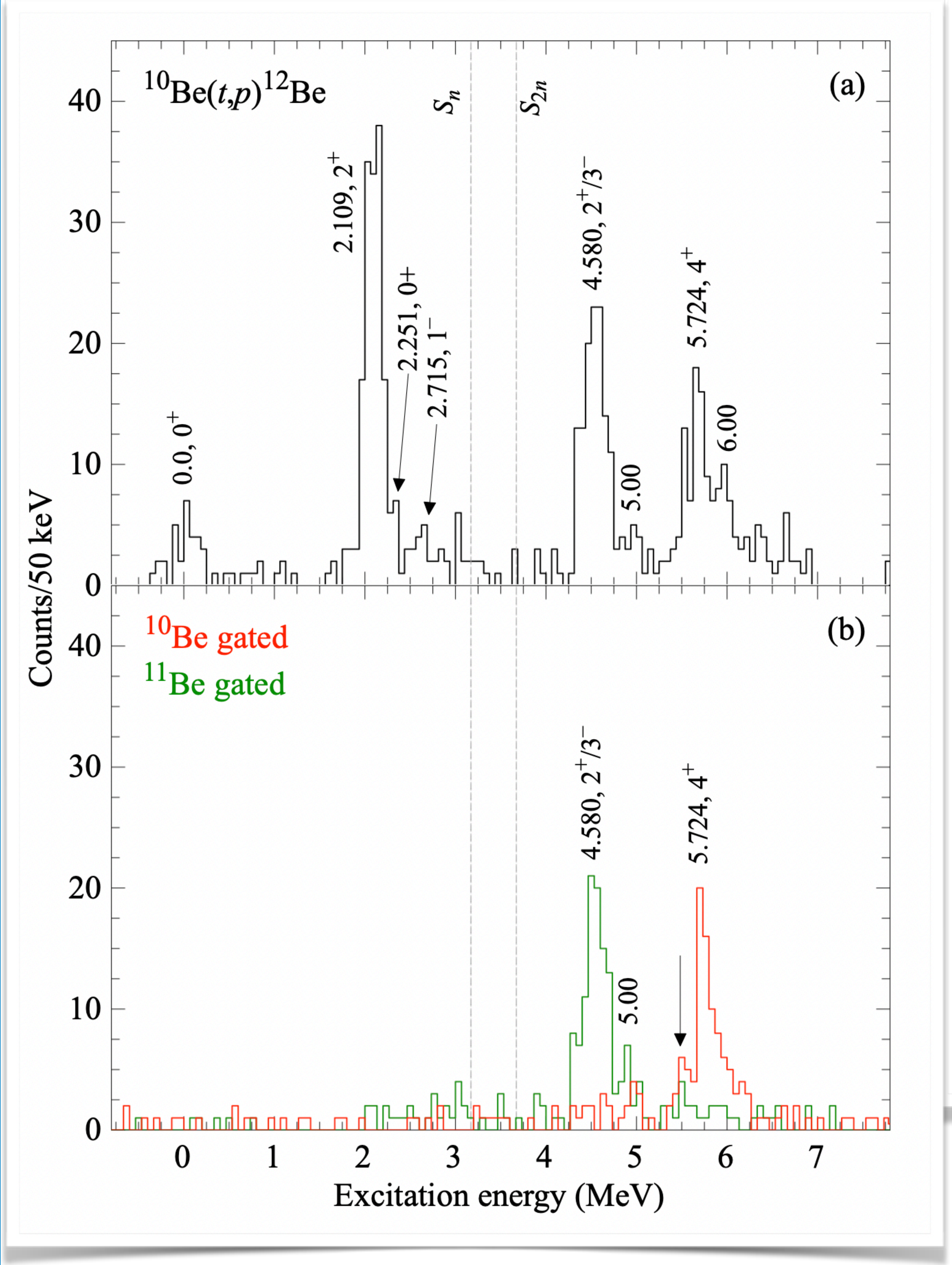
- ^{10}Be beam at **9.6 MeV/u** on titanium tritide target (2-5 $\mu g/cm^2$!!)
- Helios Si-array for protons
- Recoil detection: annular Si detectors
- B field of 3T
- Q-value resolution ~150 keV FWHM

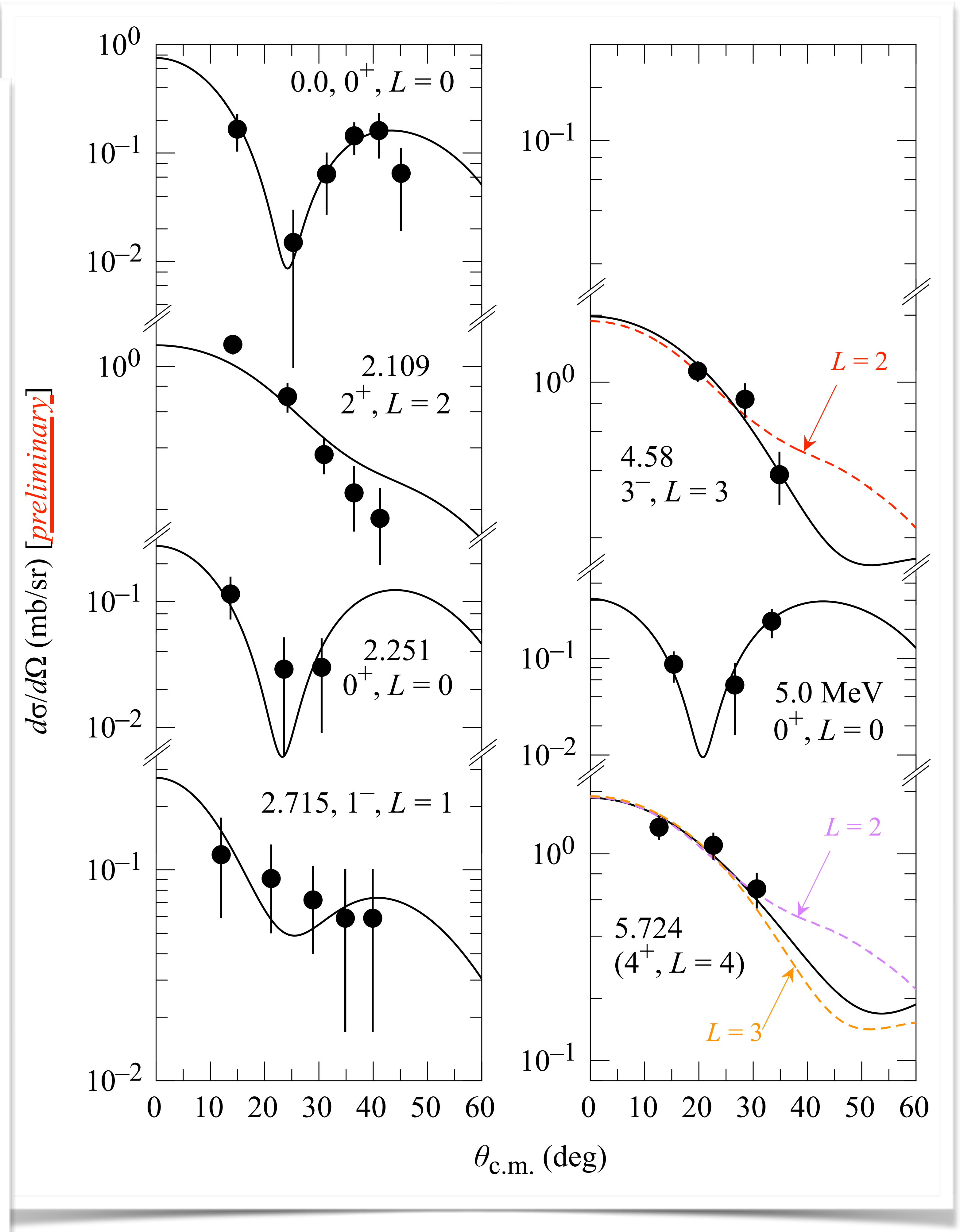






Preliminary results

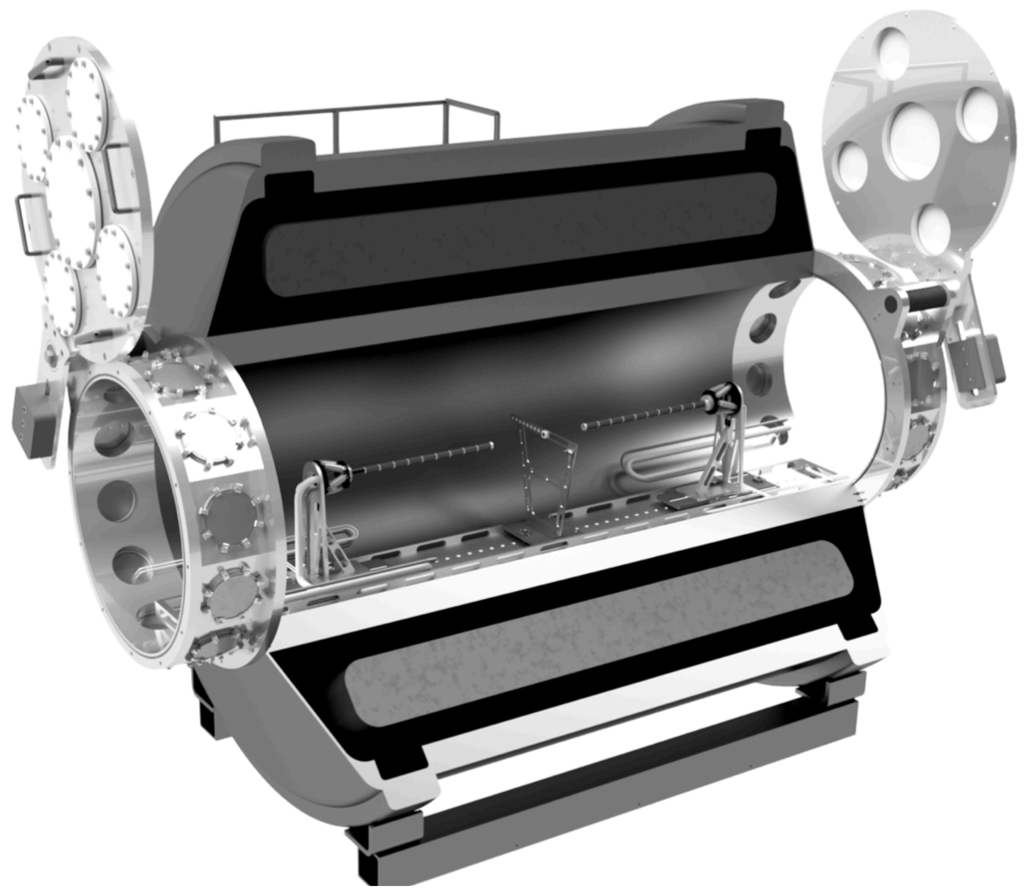


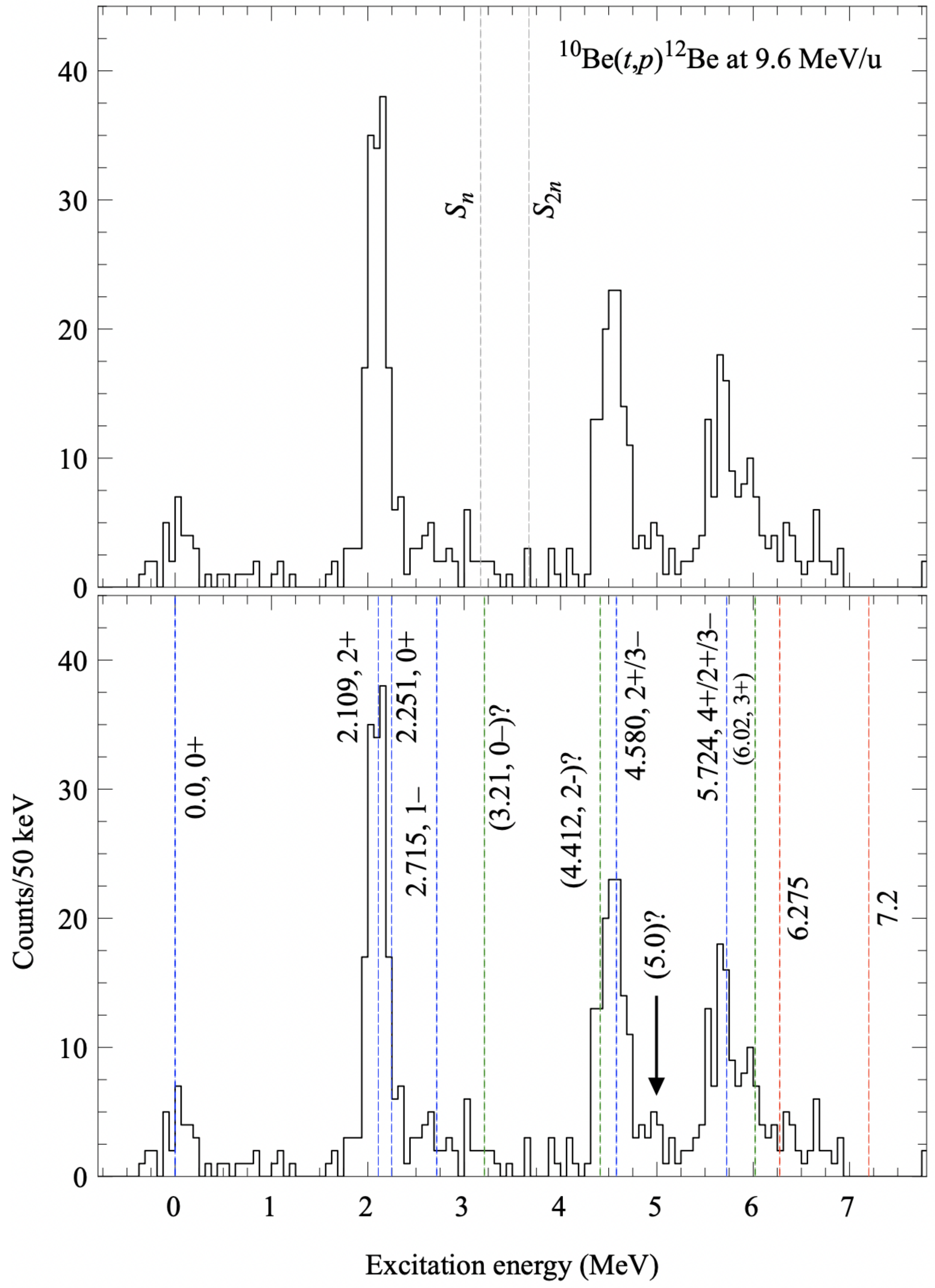


- *Limited statistics (very [effectively] thin target), but also very low background*
- *Confirm previous results from (t,p), below S_n/S_{2n} (2nd 0^+ challenging to fit)*
- *Possibly confirm the long speculated 3^- at 4.6 MeV is consistent with a 3^- (but could be doublet)*
- *Clear strength at 5.0 MeV, with shape compatible with 0^+ (3rd 0^+ predicted to be weak and at around ~5 MeV)*
- *The 5.724 MeV state must be 4^+, some strength at 6.0 MeV and at 6.275 MeV*

Conclusions

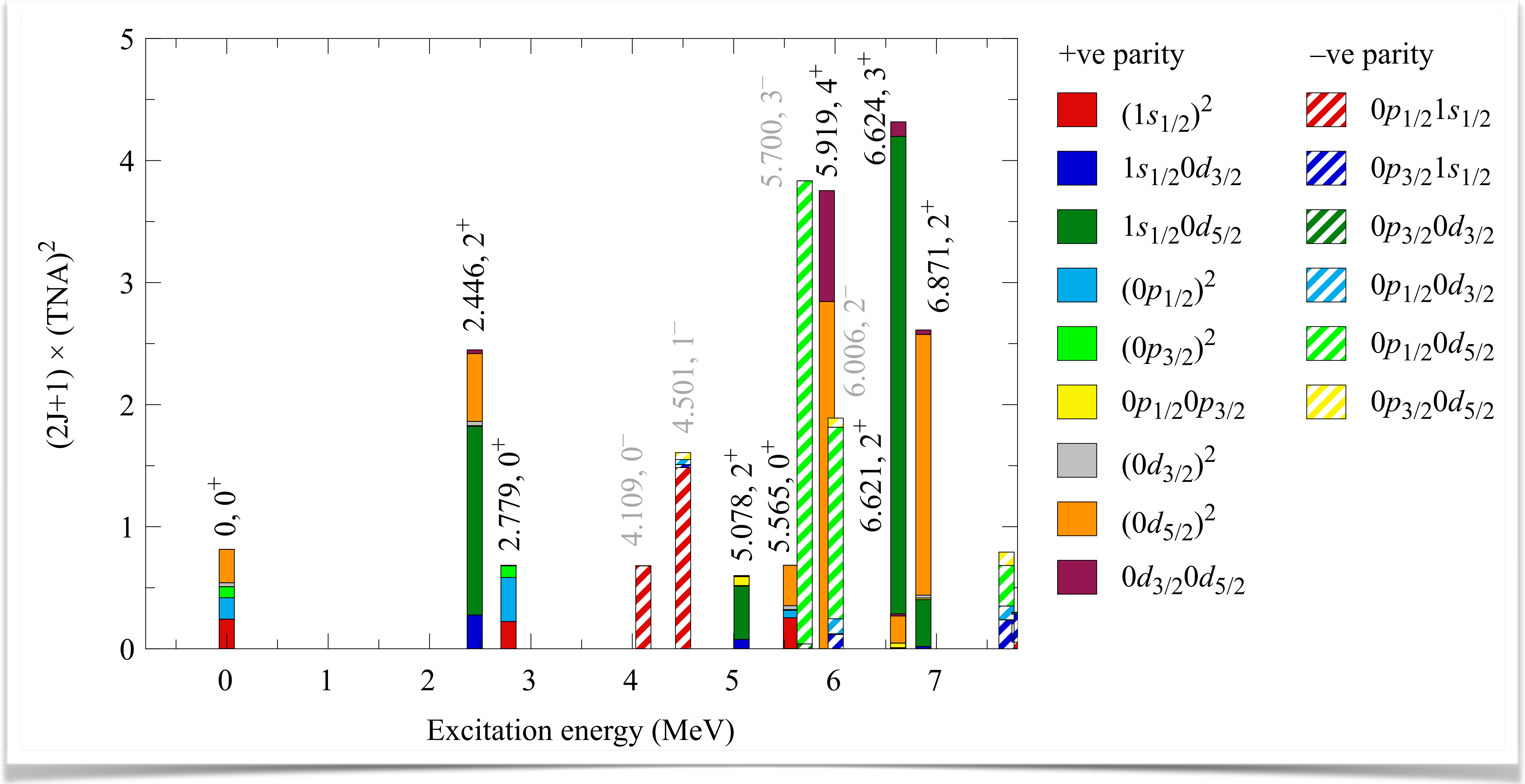
1. *Powerful demonstration of ReA and SOLARIS*
2. *Agreement with previous results from (t,p) below S_n*
3. *Possibly confirmation of 3^- at 4.6 MeV*
4. *Clear strength at 5.0 MeV with compatible shape with 0^+*
5. *Some strength at 3.2 MeV and significant strength at 6.0 MeV and 6.275 MeV*



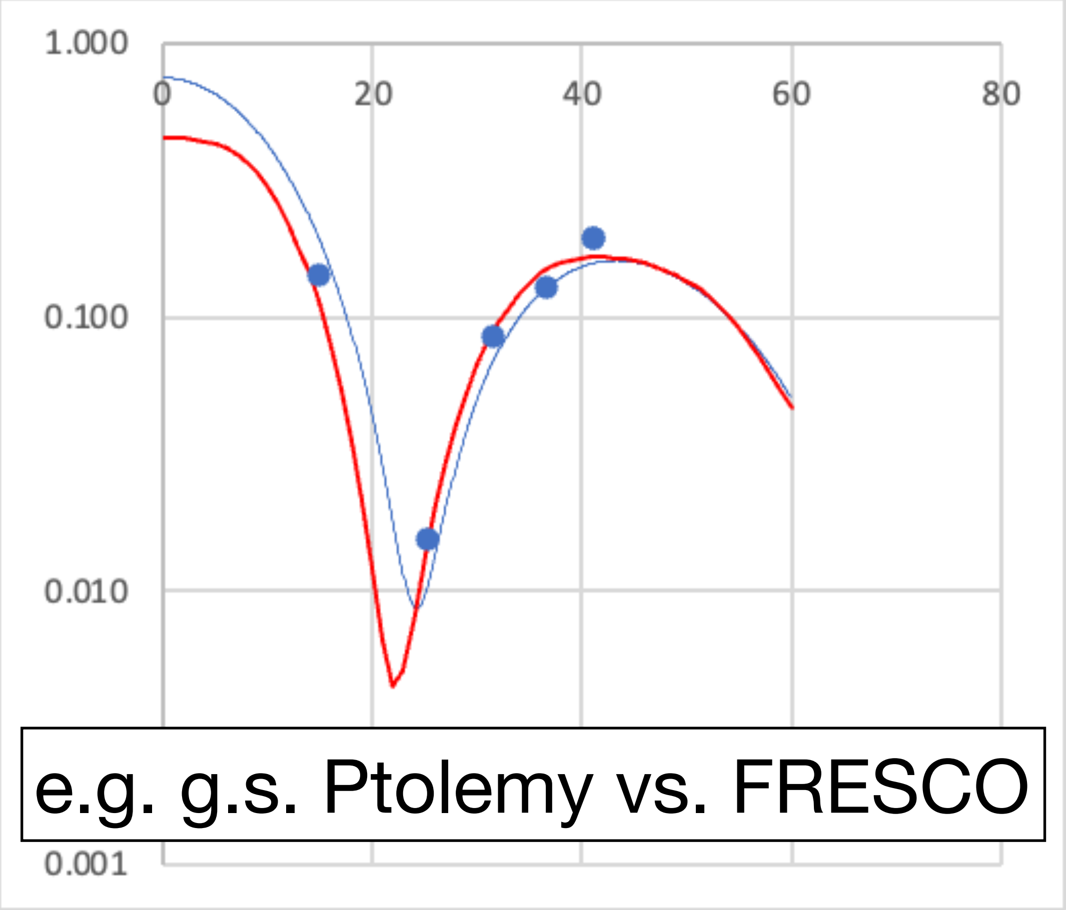


Future work

- *Full DWBA (Fresco) analysis with shell-model two-nucleon amplitudes*
- *Future ^{14}C in ATLAS*
- *^{9}Li(t,p) run at CERN by Y. Ayyad et al.*
- *The study of ^{11}Be(d,p) at CERN complements this work*



Two-nucleon amplitudes (YSOX, curtesy of Alan Wuosmaa [UConn]) and FRESCO calculations (B. Alex Brown, UoM)



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USC Universidade de Santiago de Compostela
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