The (d,p) reaction on ^{132}Sn*

Is it possible/plausible/pursuable at ISOLDE with ISS?

ISS workshop, July 2020

The ISS collaboration and friends (B. P. Kay, C. R. Hoffman, T. L. Tang [Argonne],
A. O. Macchiavelli [Berkeley], Y. Ayyad, J. Chen [FRIB] et al.)

*This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract Numbers DE-AC02-06CH11357

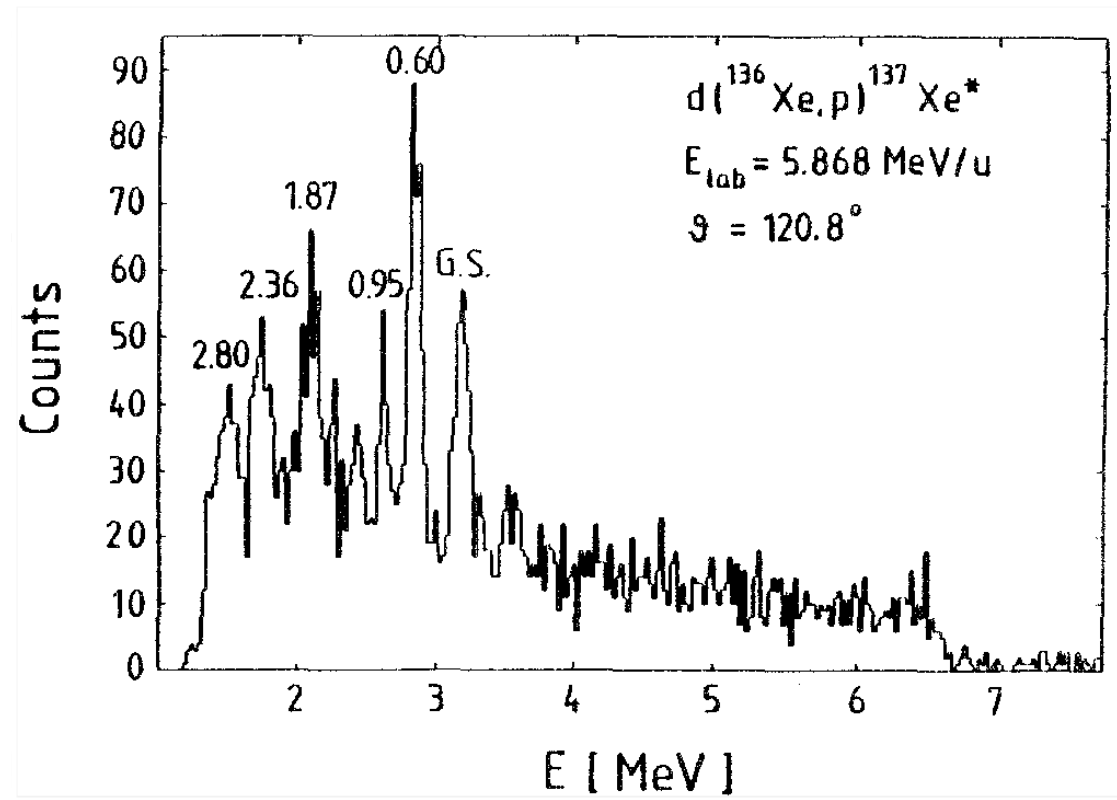
History

The $^{132}Sn(d,p)^{133}Sn$ **reaction** has been front and center in motivating the development of facilities (10 MeV/u RI beams), techniques, and instrumentation for 30+ years. It was central to the development of the solenoidal-spectrometer technique.

Investigation of the (*d*, *p*)-reaction on ^{136,132}Xe in inverse kinematics ⋆

G. Kraus[1], P. Egelhof[1], H. Emling[1], E. Grosse[1], W. Henning[1], R. Holzmann[1], H.J. Körner[2], J.V. Kratz
R. Kulessa[4], Ch. Schießl[2], J.P. Schiffer[5], W. Wagner[2], W. Walus[4], and H.J. Wollersheim[1]

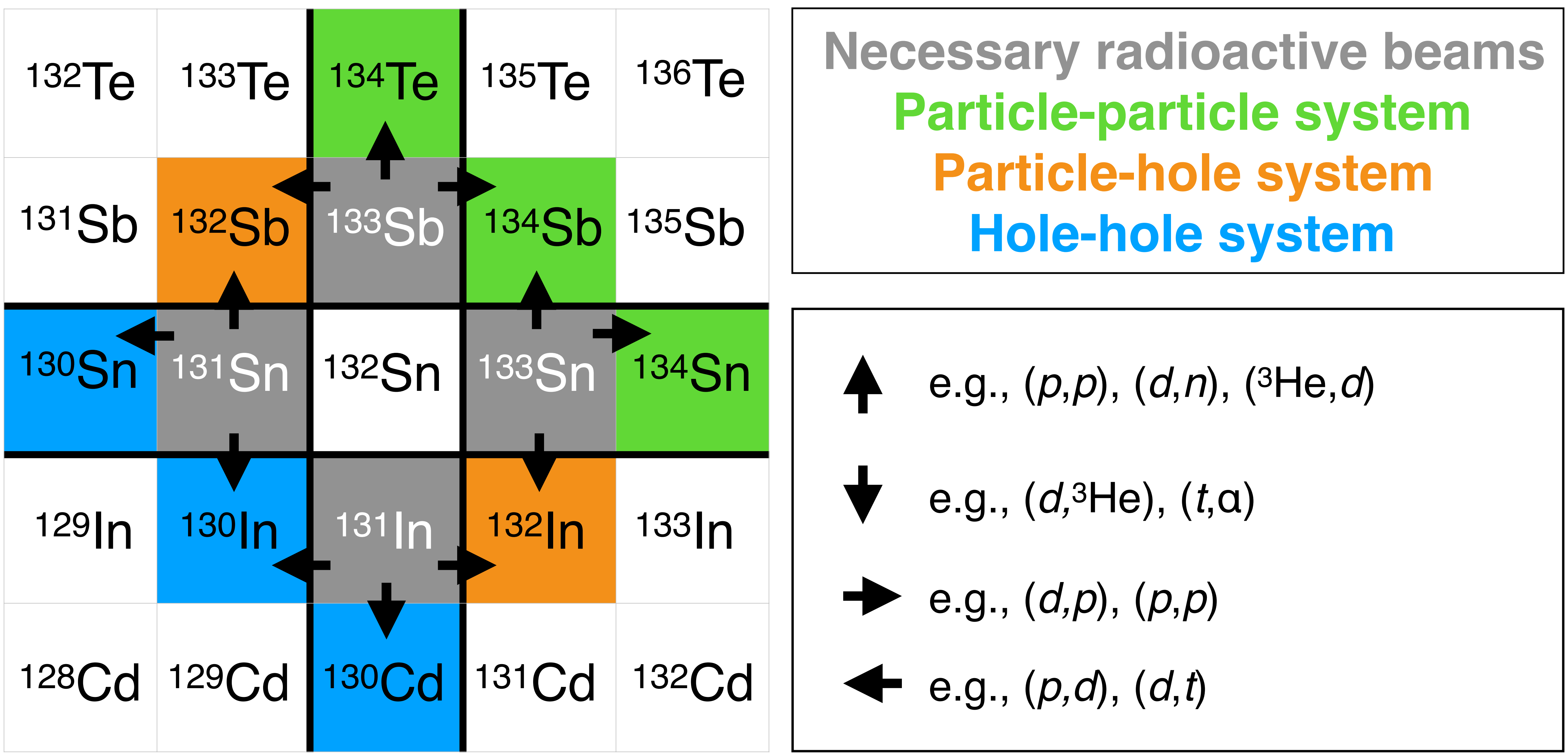
Of particular interest are investigations of single-nucleon transfer reactions near doubly-magic nuclei, as for instance the determination of single-particle energies and matrix elements of the two-body residual interaction in the vicinity of ^{132}*Sn* (N = 82, Z = 50), and of inelastic scattering studies of low-lying collective states.



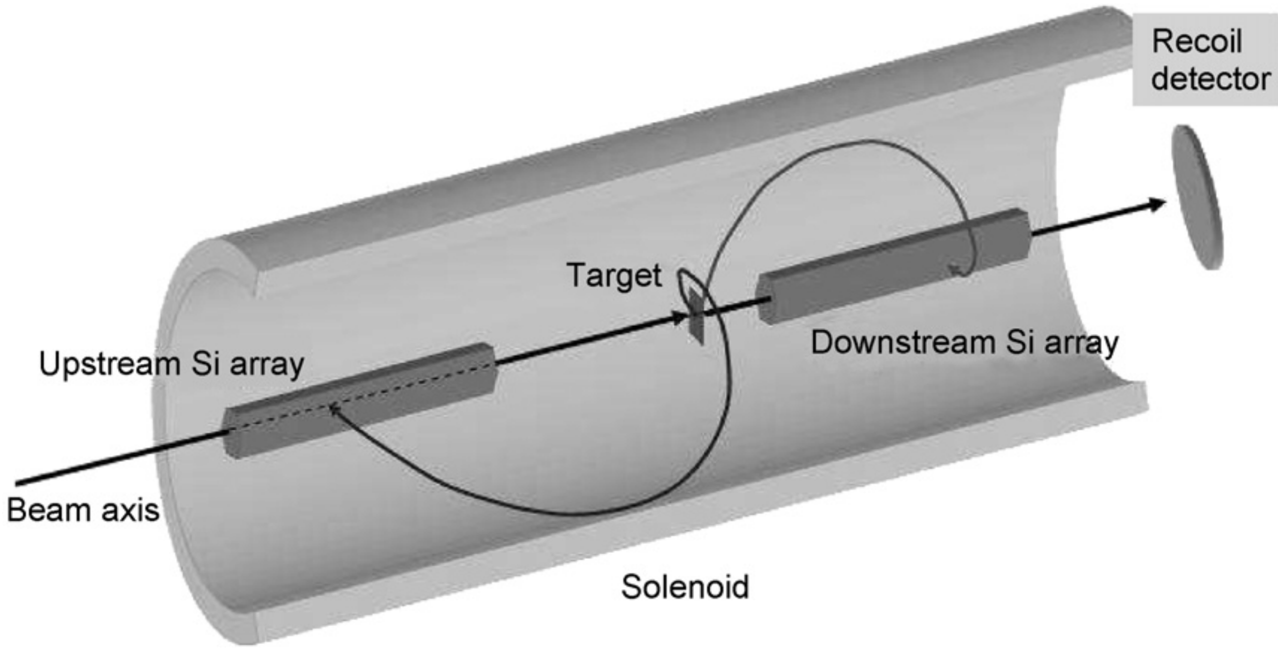
G. Kraus, P. Egelhof et al., Z. Phys. A **340**, 339 (1991)

History

The **$^{132}Sn(d,p)^{133}Sn$ reaction** has been front and center in motivating the development of facilities (10 MeV/u RI beams),

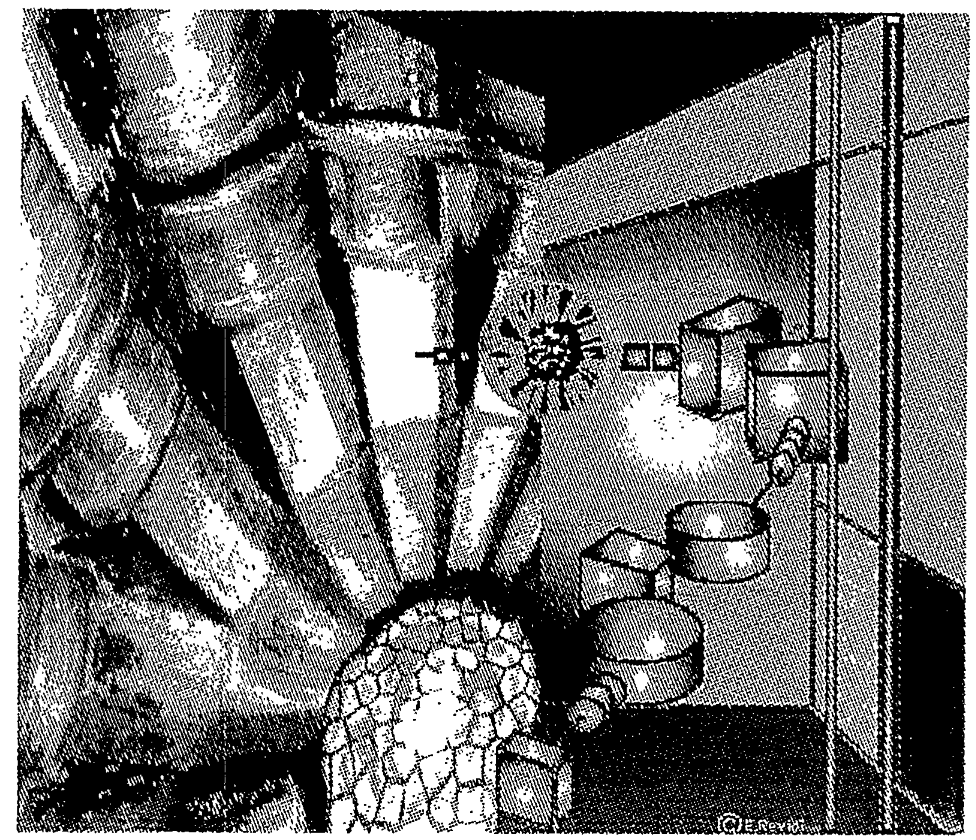


J. P. Schiffer and W. W. True, Rev. Mod. Phys. **48**, 191 (1976)



J. P. Schiffer, in Workshop on the Experimental Equipment for an Advanced ISOL Facility, edited by C. Baktash, I. Y. Lee, and K. E. Rehm, Lawrence Berkeley National Laboratory Report No. LBNL-43460, 1999.

Experimental Equipment for an Advanced ISOL Facility

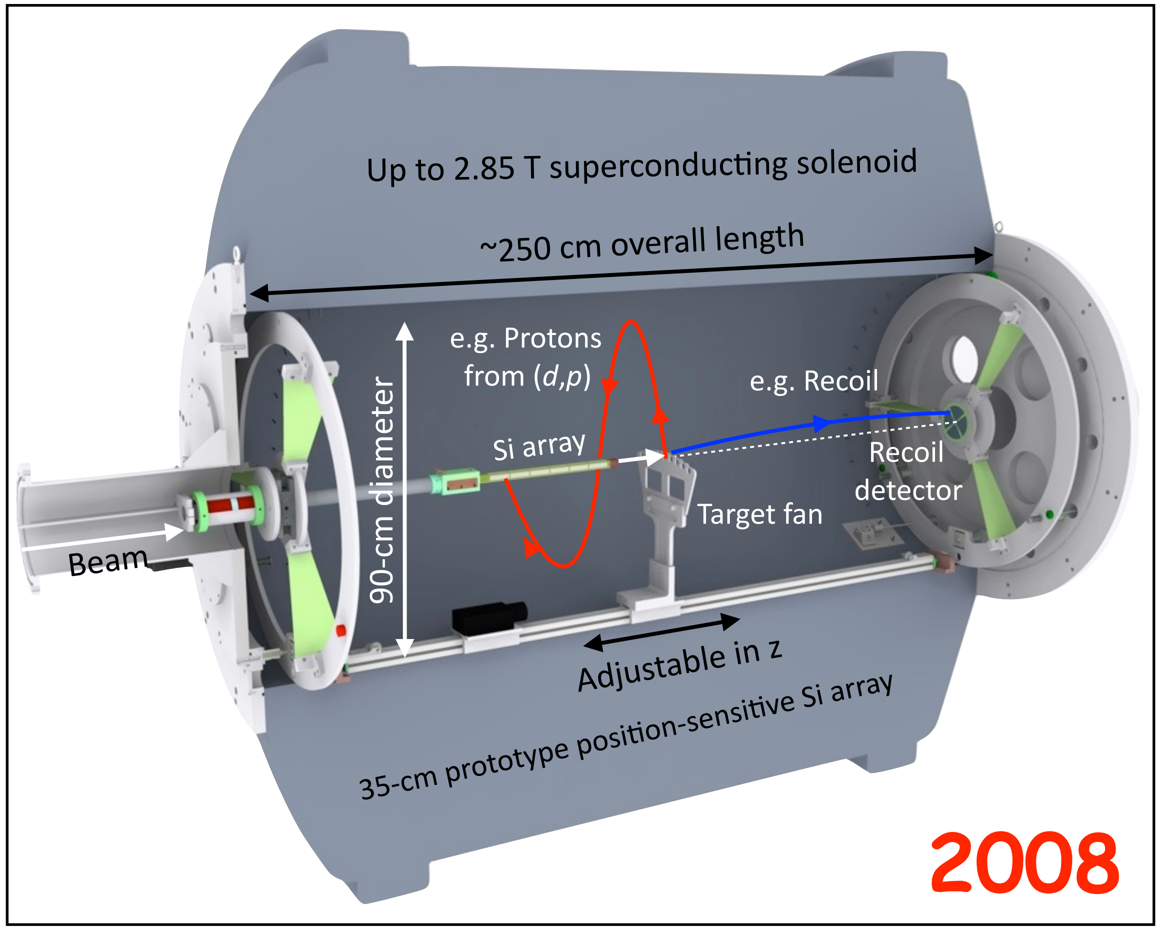


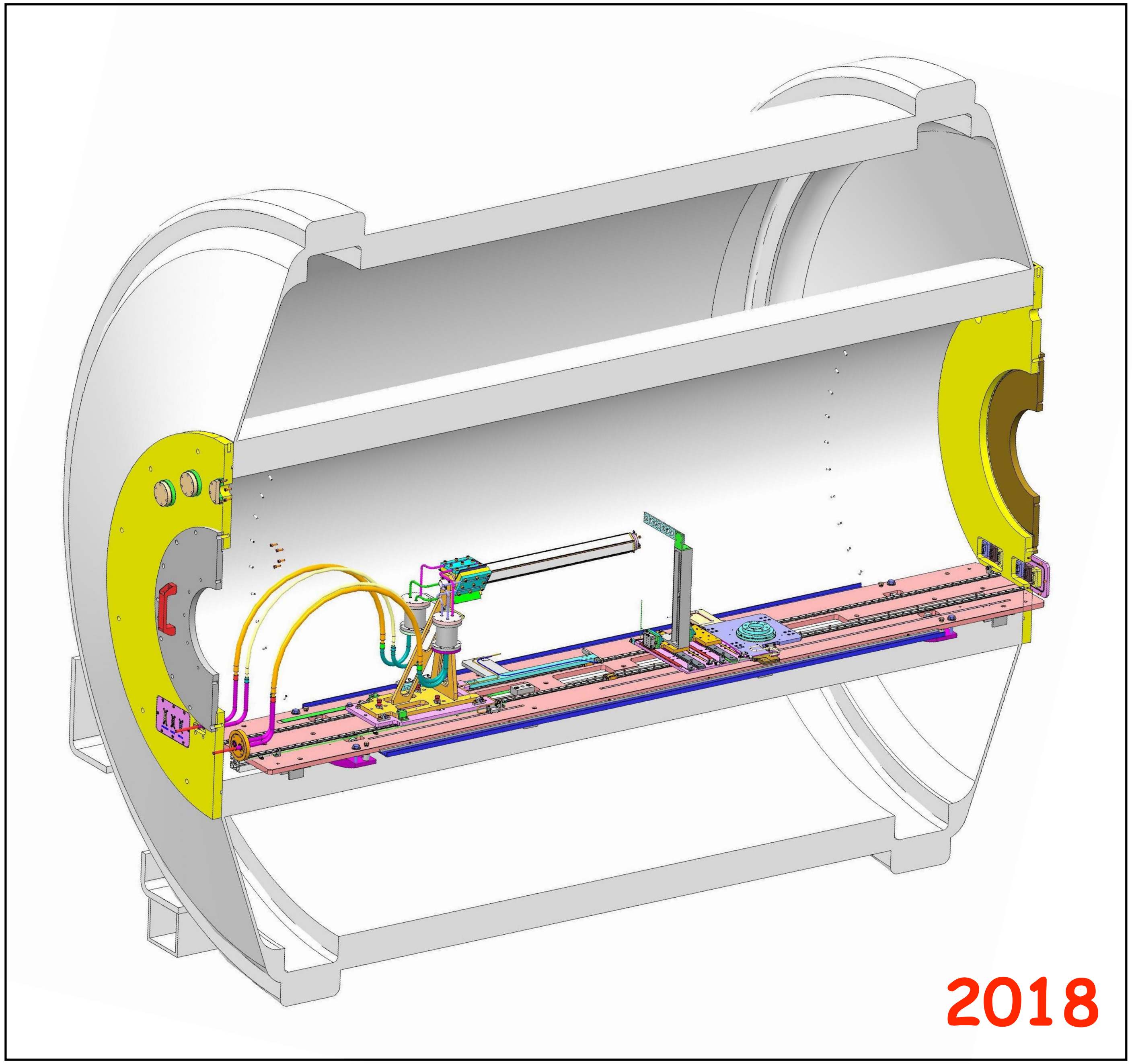
March 1999

a) Solenoidal Geometry

A magnetic solenoid with its axis oriented along the beam direction could serve as a very large-acceptance magnetic spectrograph for low-energy light particles from inverse reactions such as $d(^{132}\mathrm{Sn},p)^{133}\mathrm{Sn}$. In this case the protons of interest are emitted in the backwards hemisphere with energies of 1-10 MeV. The particle energy measurements are done via silicon detector barrels surrounding the beam axis. This type of magnetic spectrograph deserves further study.

Development of the technique/instrum.

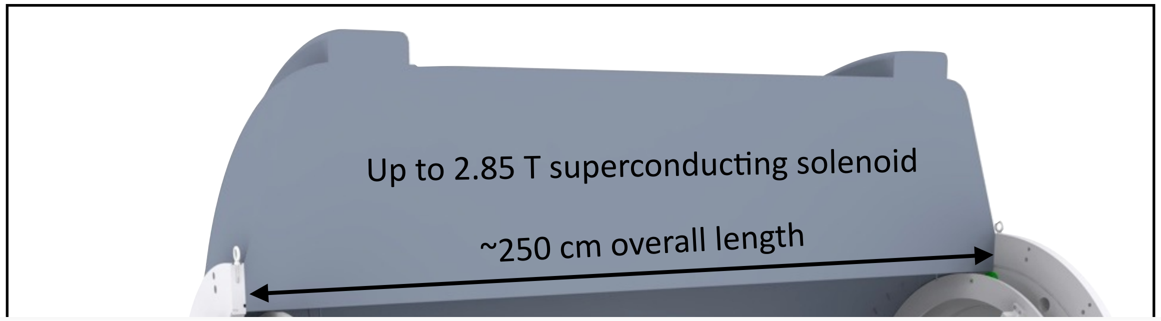




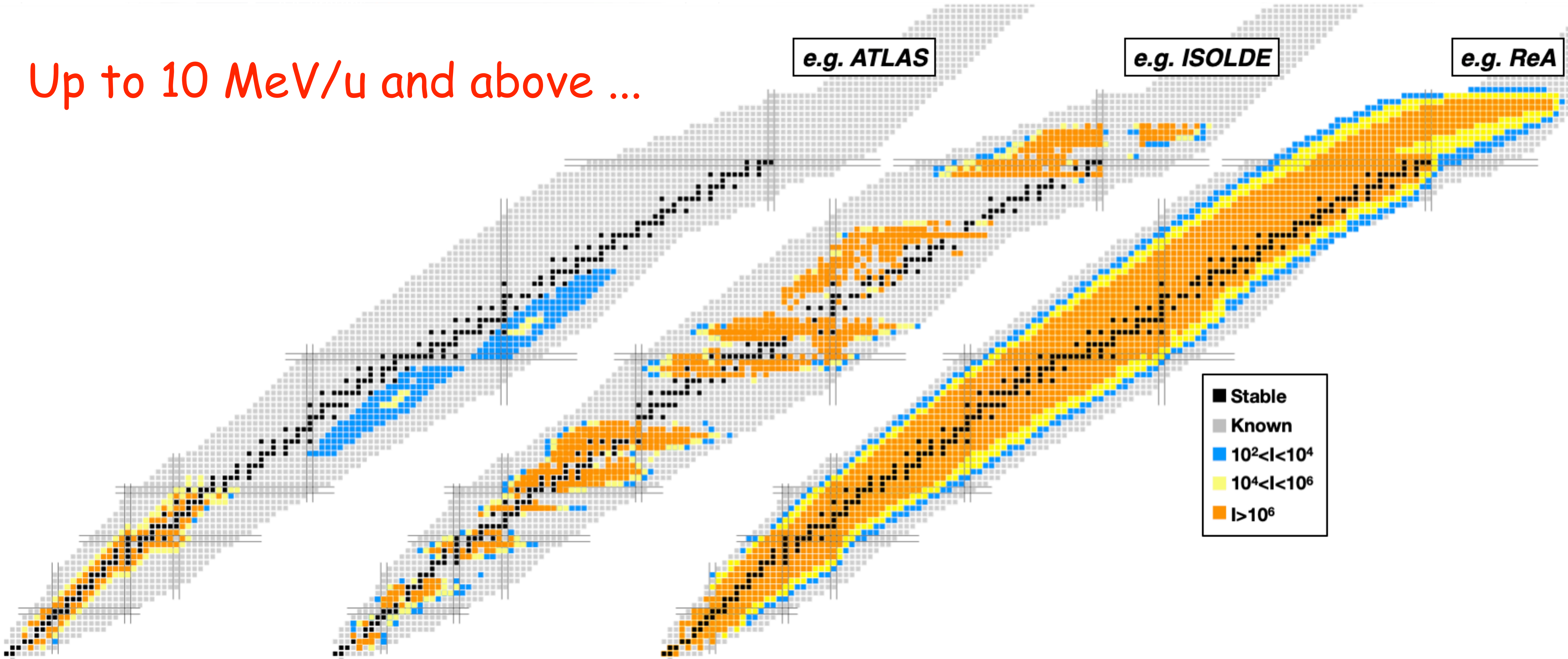
A. H. Wuosmaa, J. P. Schiffer et al.,
Nucl. Instrum. Methods Phys. Res. A **580**, 1290 (2007)

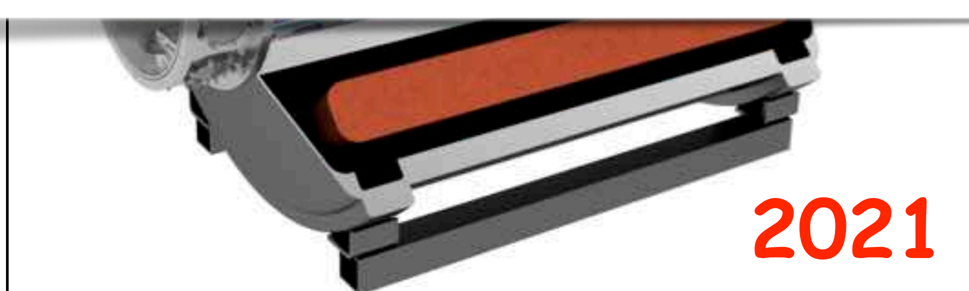
Development of the technique/instrum.

… and facilities



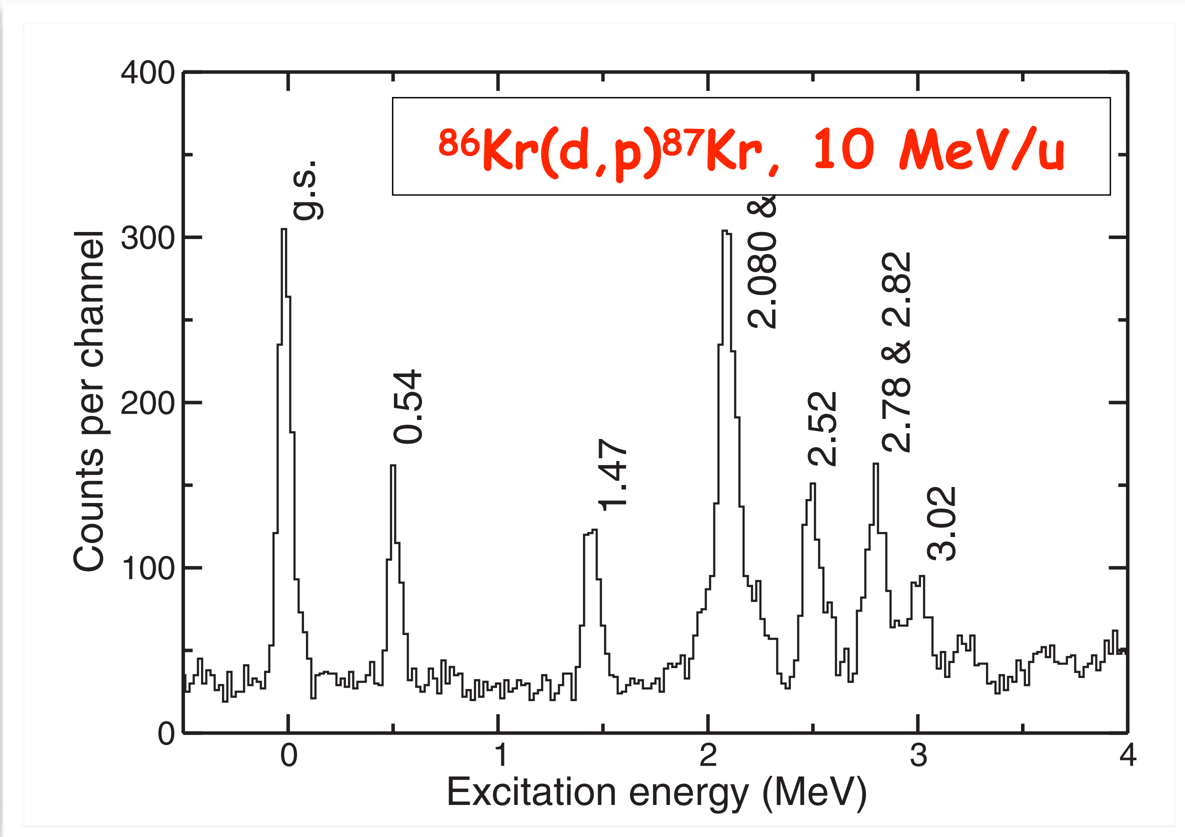
Up to 10 MeV/u and above …

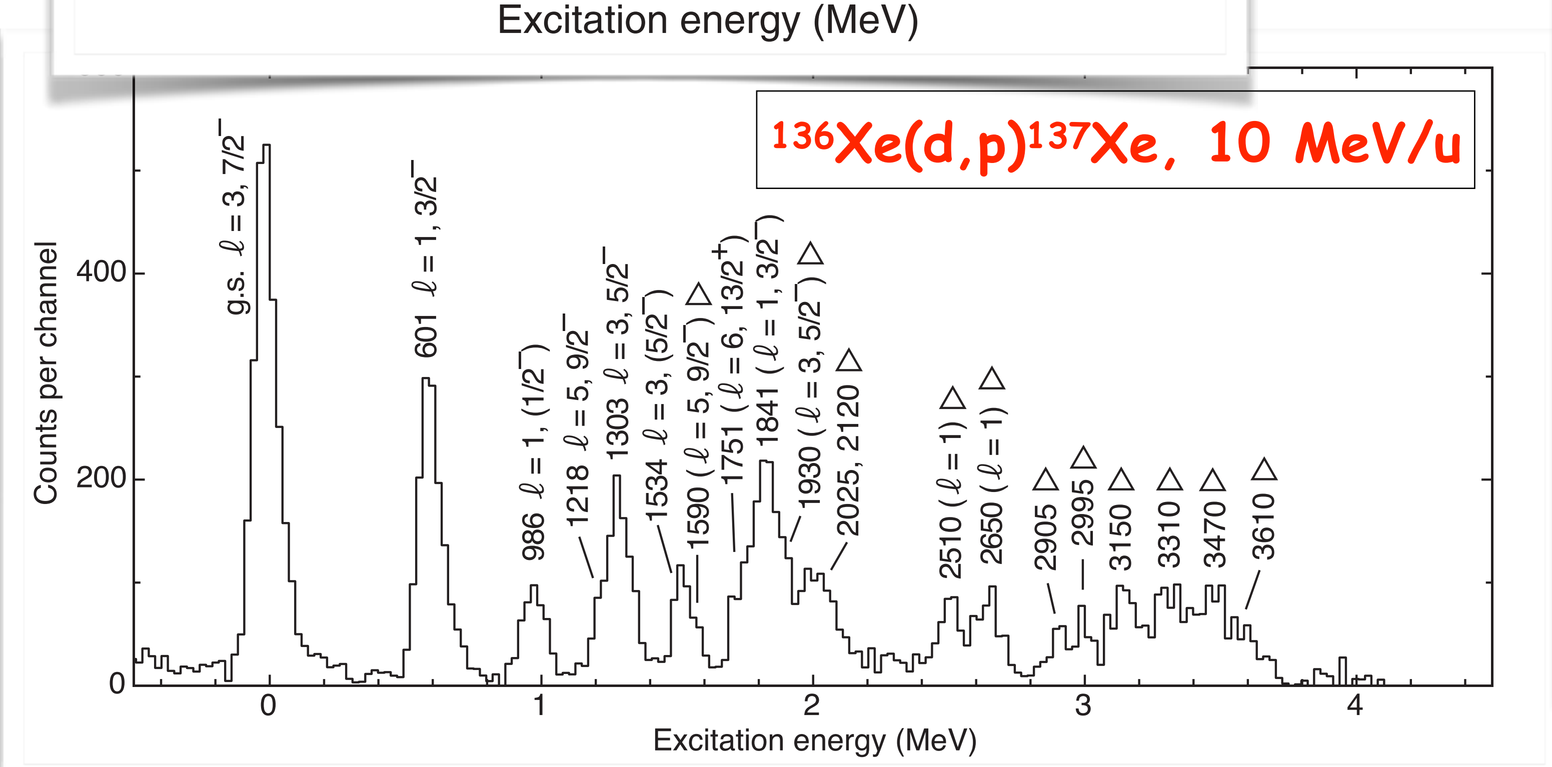


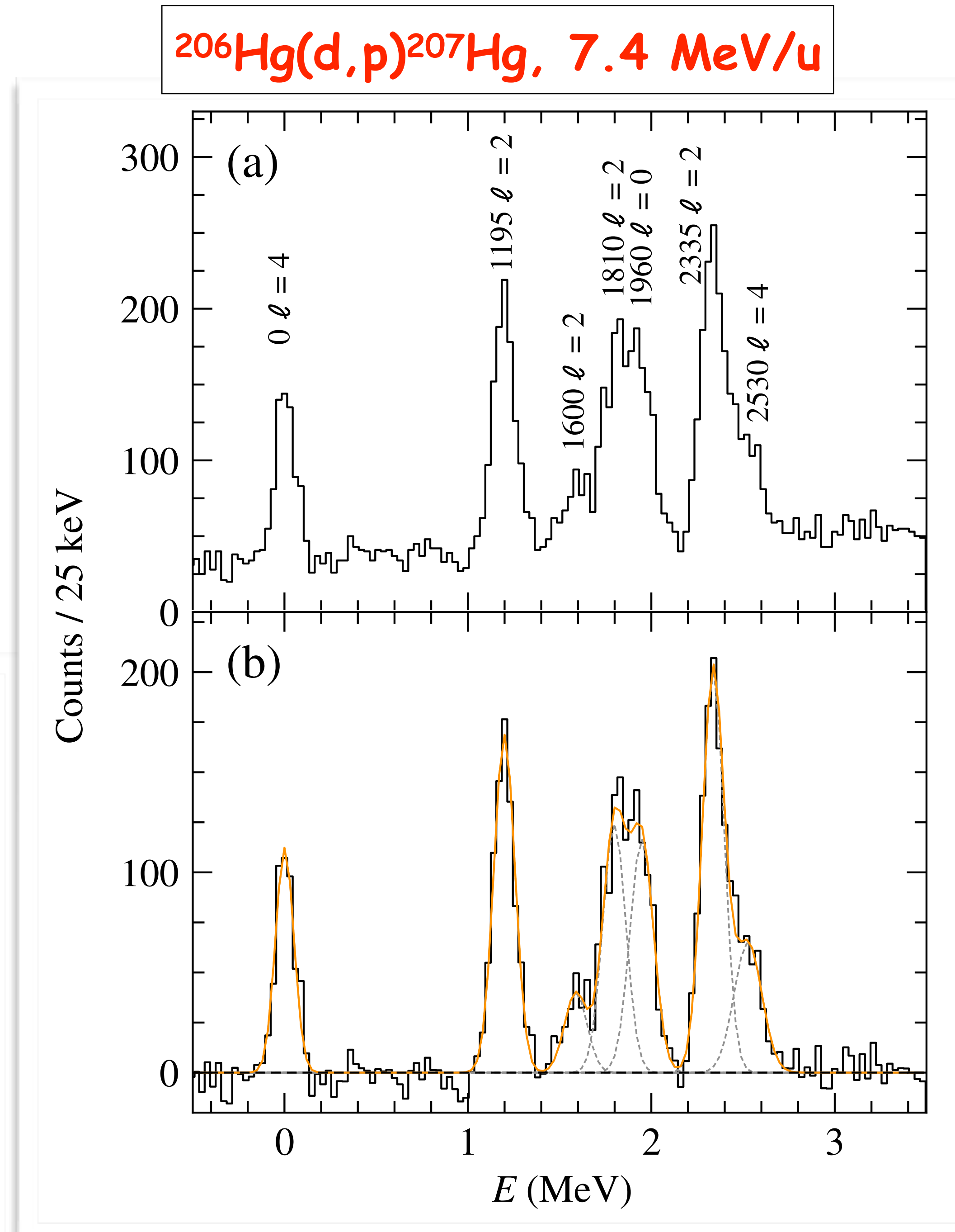


A. H. Wuosmaa, J. P. Schiffer et al.,
Nucl. Instrum. Methods Phys. Res. A **580**, 1290 (2007)

(Pertinent) Examples







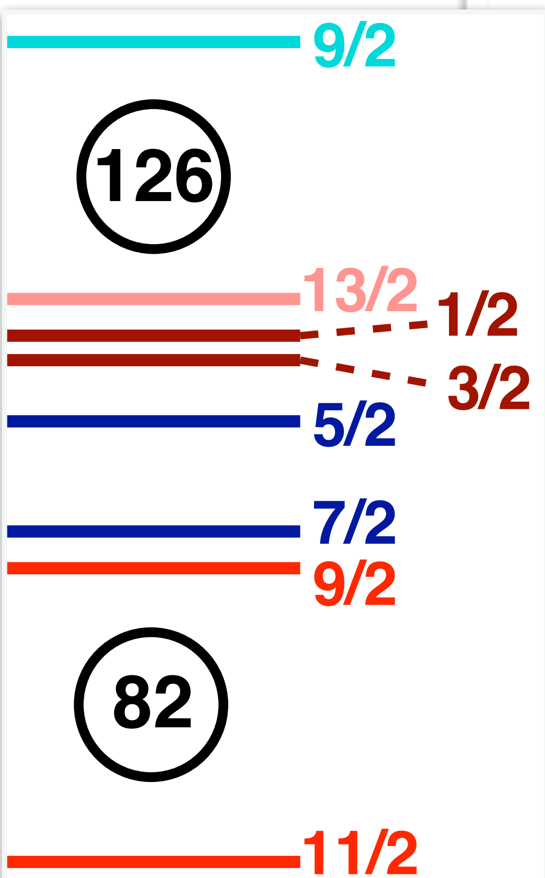
BPK, J. P. Schiffer et al., Phys. Rev. C **84**, 024325 (2011)

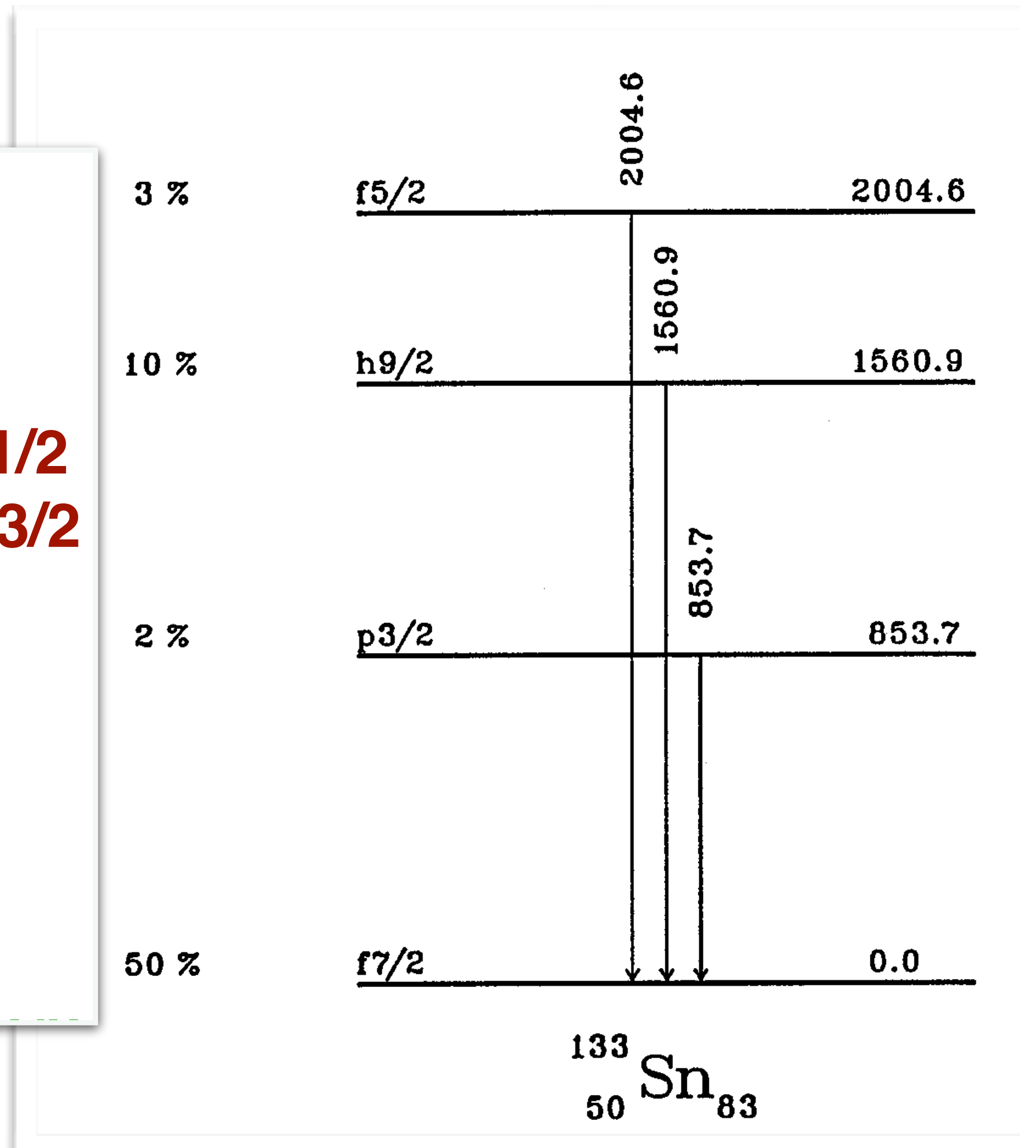
D. K. Sharp, BPK et al., Phys. Rev. C **87**, 014312 (2013)

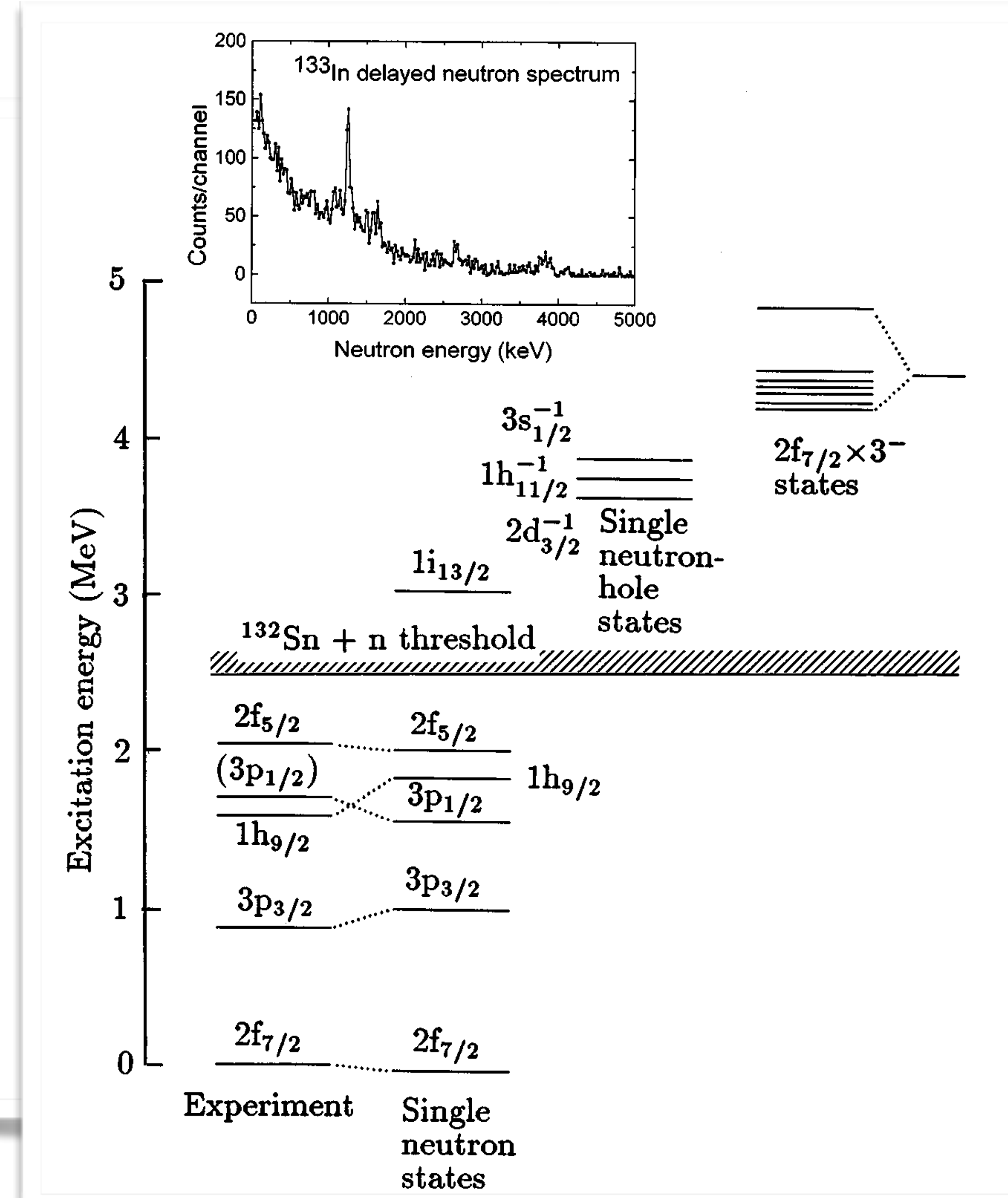
T. L. Tang, BPK et al, Phys. Rev. Lett. **124**, 062502 (2020)

In the meantime, ^{133}Sn

Excited states in ^{133}Sn identified via decay studies (numerous other works too)



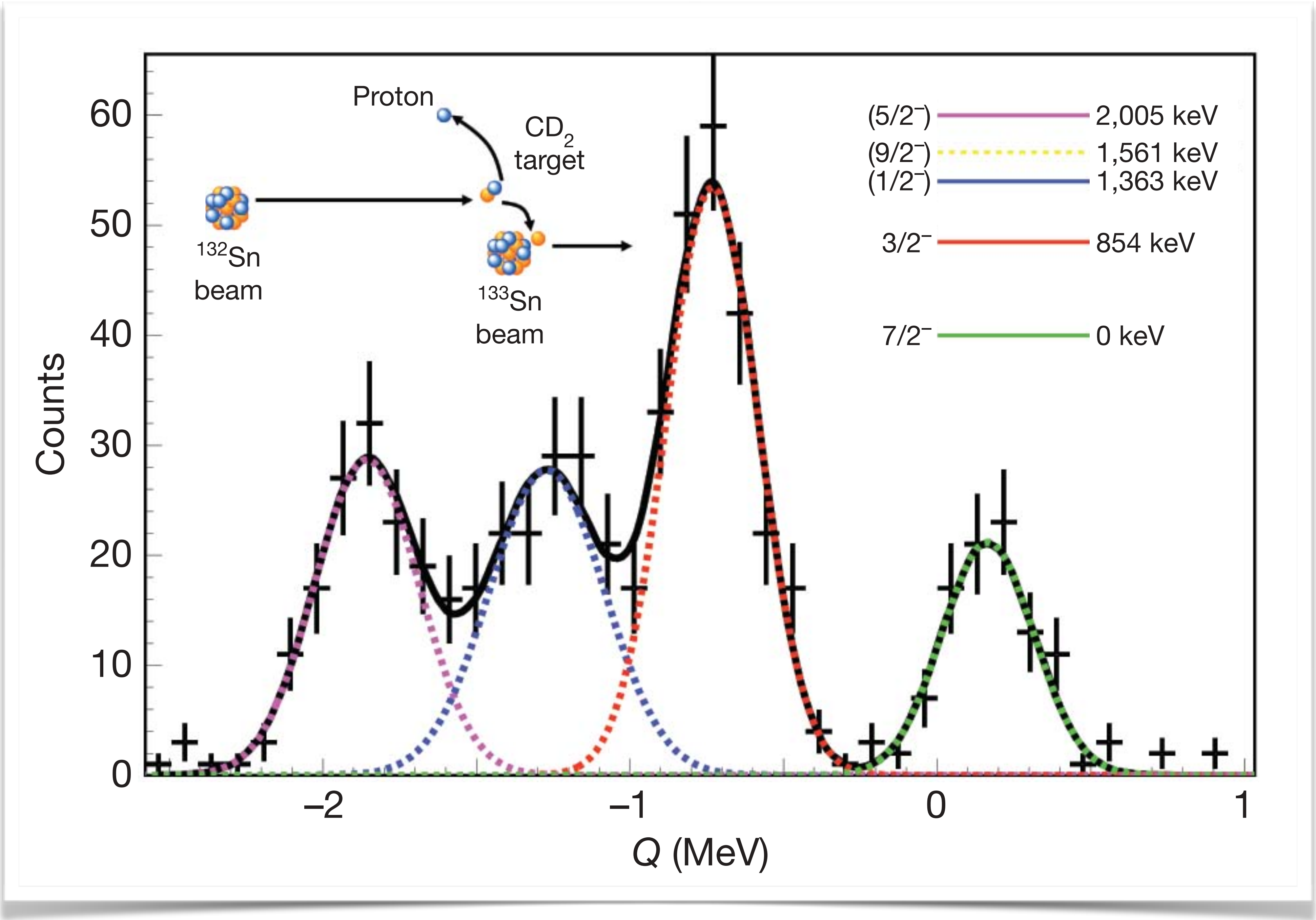




P. Hoff, P. Baumann et al., Phys. Rev. Lett. **77**, 1020 (1996)

The Oak Ridge measurements

The famous work by K. Jones et al. at Oak Ridge ...



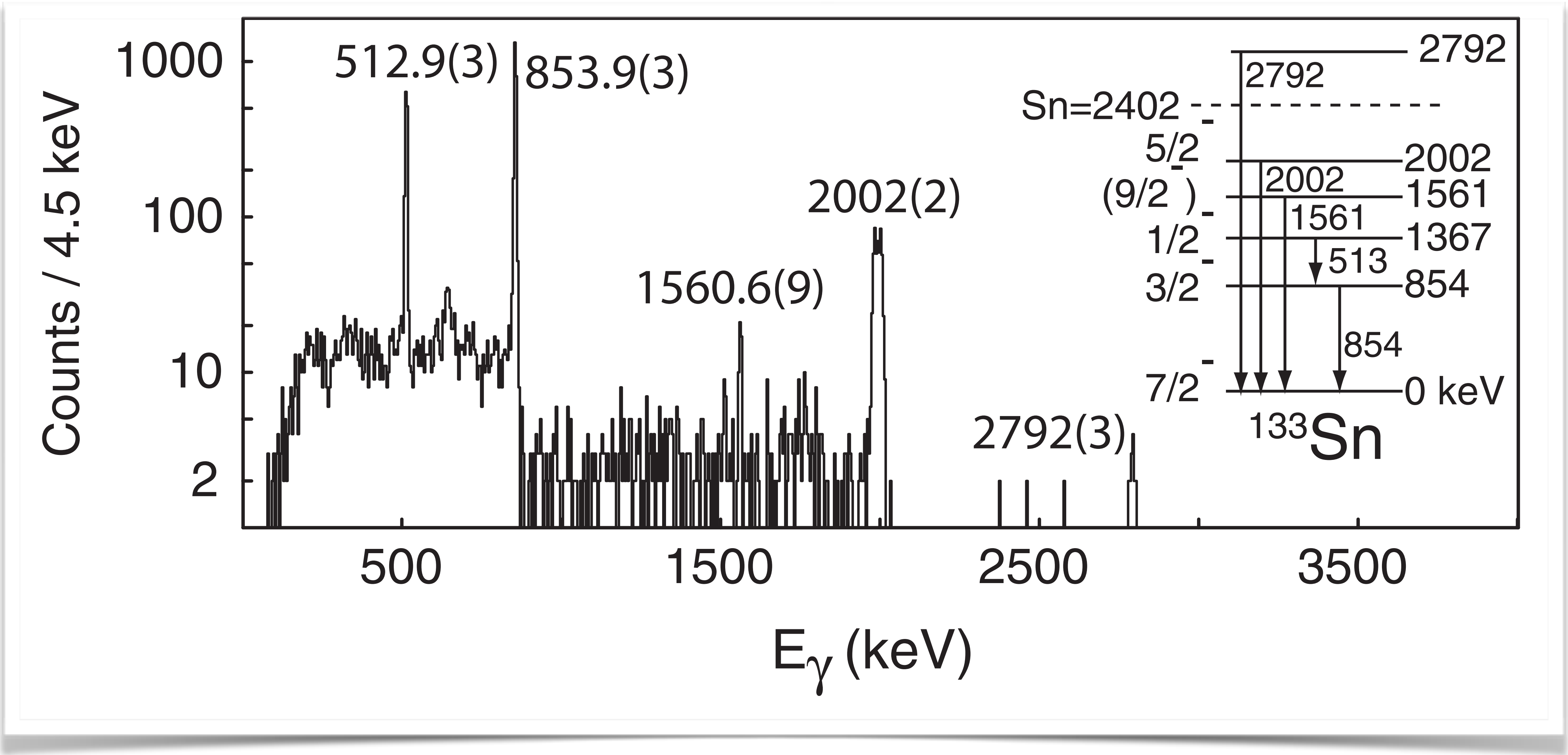
- 4.77 MeV/u beam
- >90% purity
- 160 μg/cm² target
- Varying intensity
- ORRUBA setup

Missing 9/2⁻, 13/2⁺ state (cross section, sub-barrier) and note extremely low Q value

K. L. Jones, A. S. Adekola et al., Nature **465**, 454 (2010)

The Oak Ridge measurements

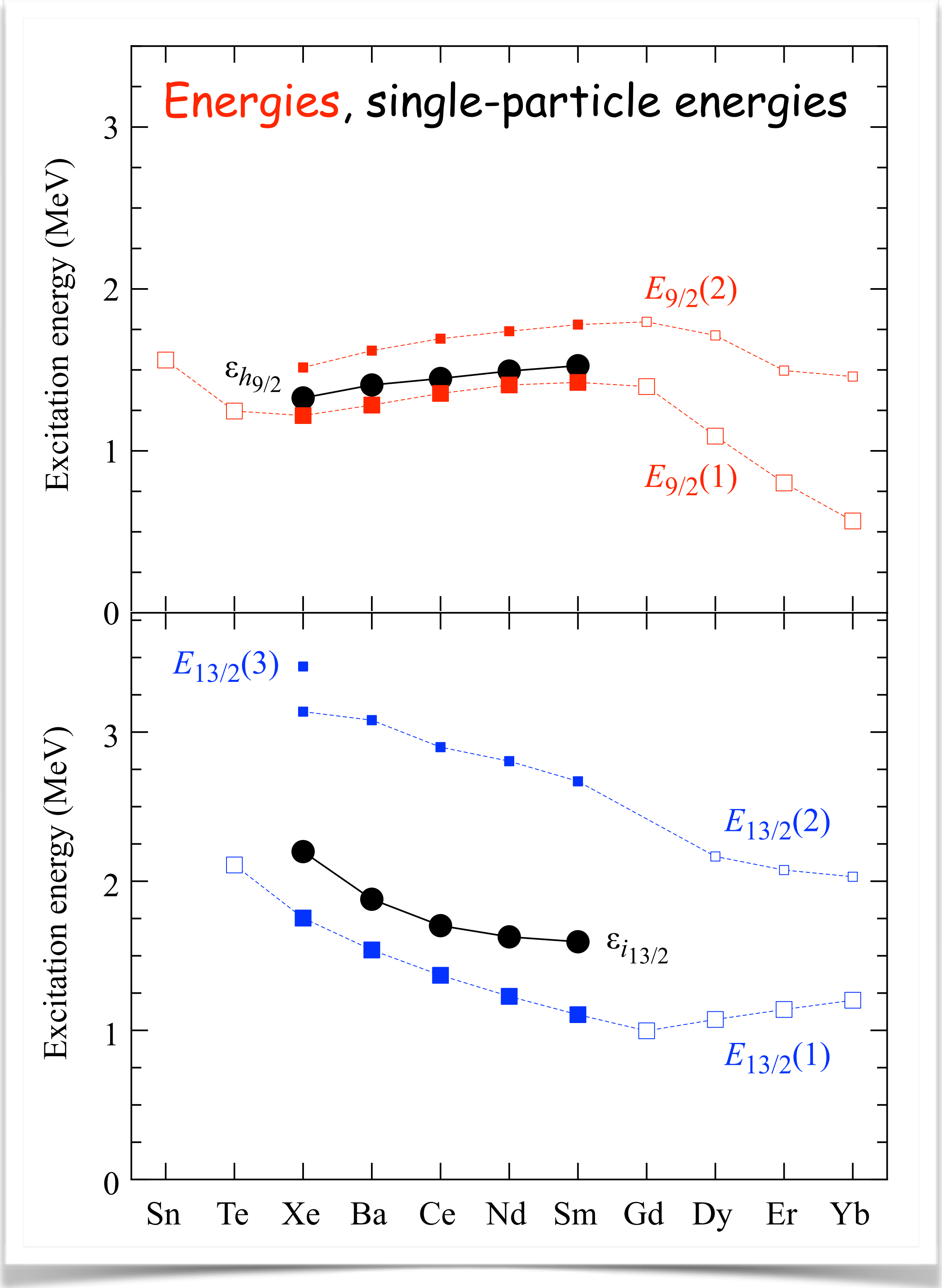
... and J. M. Allmond ...

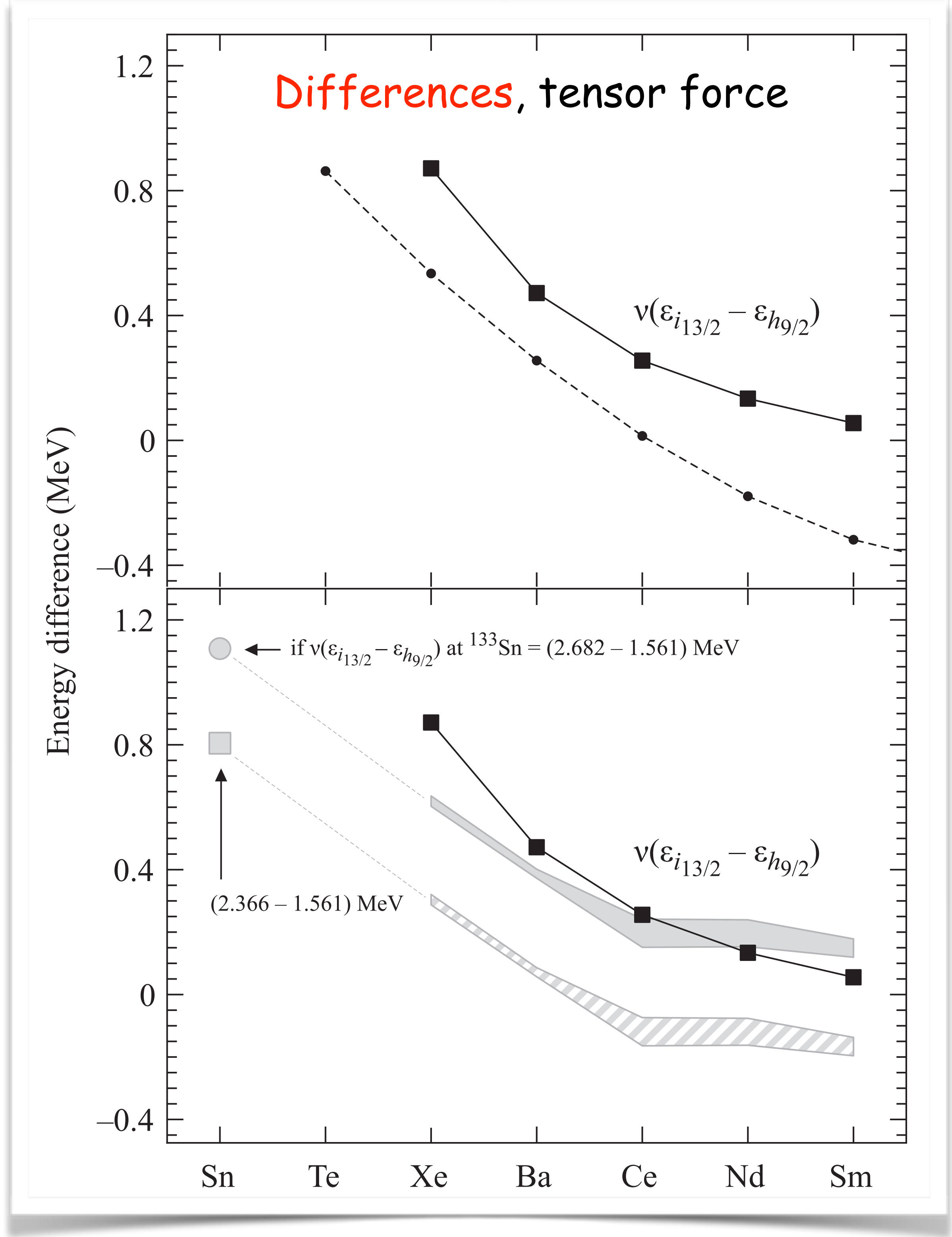


Exploiting the power of the (^{9}Be,^{8}Be→2αγ) [but $p_{3/2}$ (j>) preferentially populates j<, e.g., $h_{9/2}$ over $h_{11/2}$, and $i_{11/2}$ over $i_{13/2}$] ... still a missing 13/2+ state

J. M. Allmond, A. E. Stuchbery et al., Phys. Rev. Lett. **112**, 172701 (2014)

Where is the 13/2⁺?

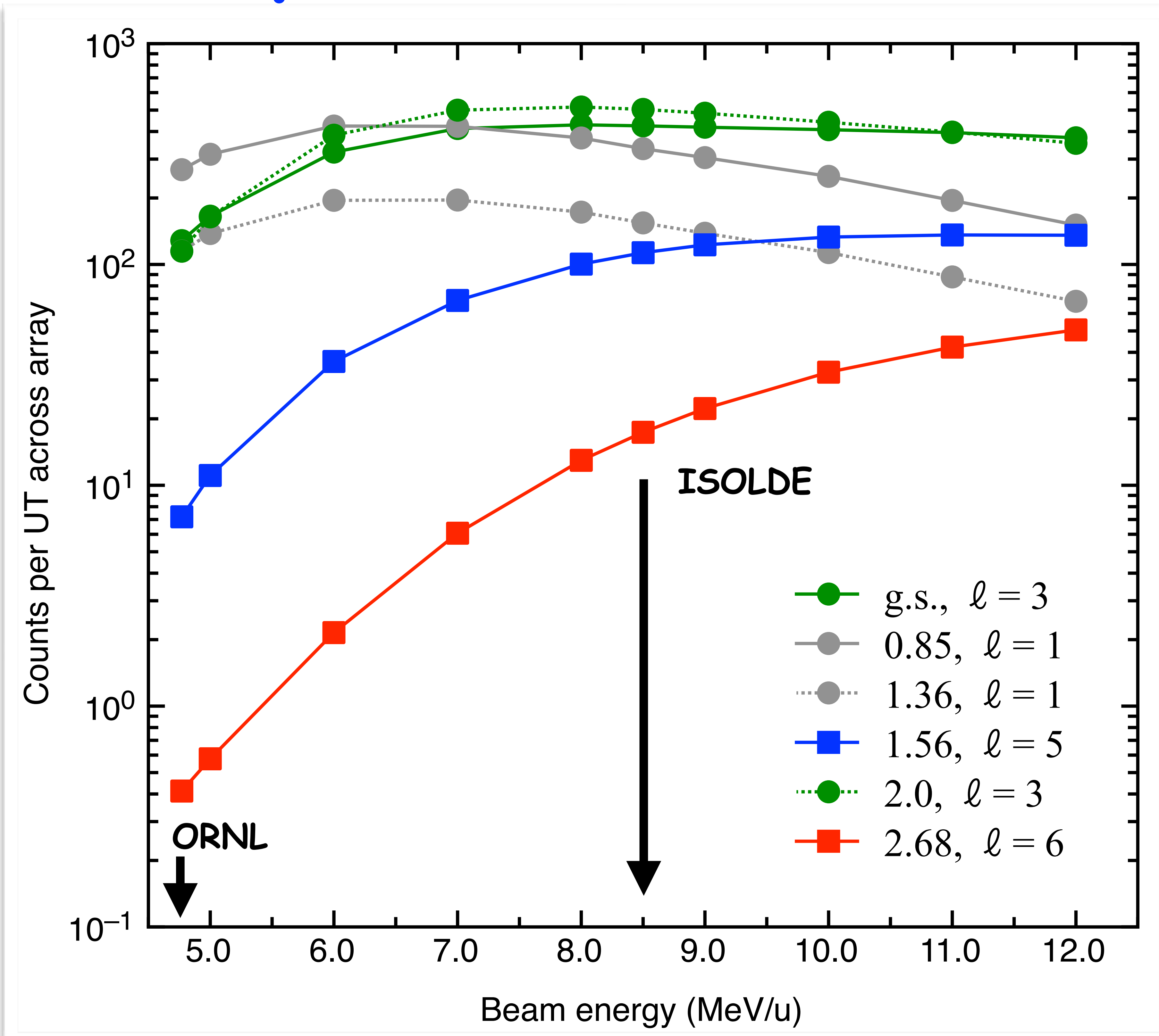




Most likely at around **2700 keV** in excitation energy (S_n = 2402 keV)

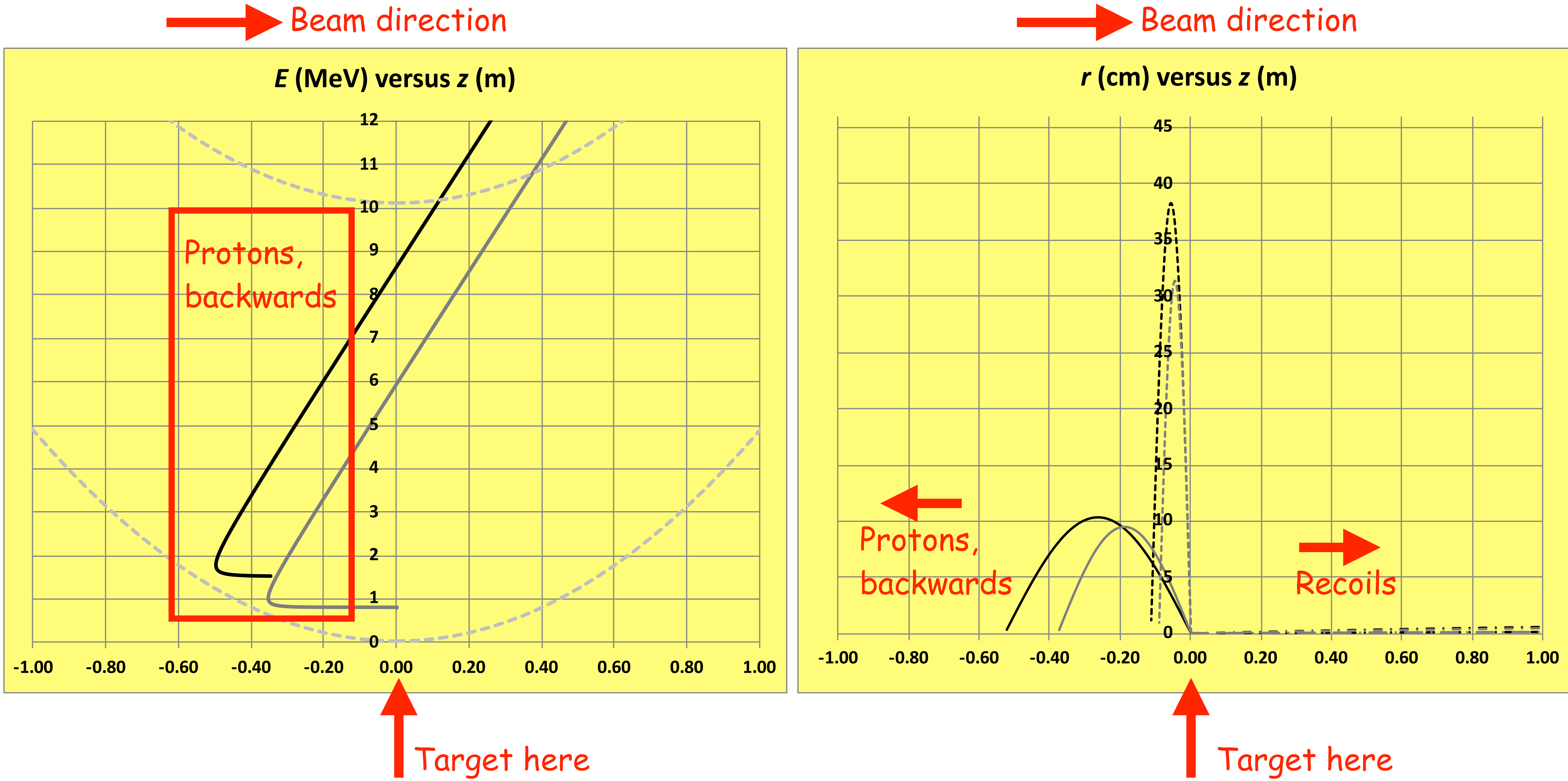
R. Talwar, BPK et al., Phys. Rev. C **96**, 024310 (2017)

Is it possible at ISOLDE?



Assuming 200 μg/cm², **1×10⁵ pps**, 10-40° c.m. (10-35° for l=6) @ 70% geometrical efficiency, S=0.6 for standard OMP parameters in DWBA using Ptolemy. 1 UT = 8 hrs.

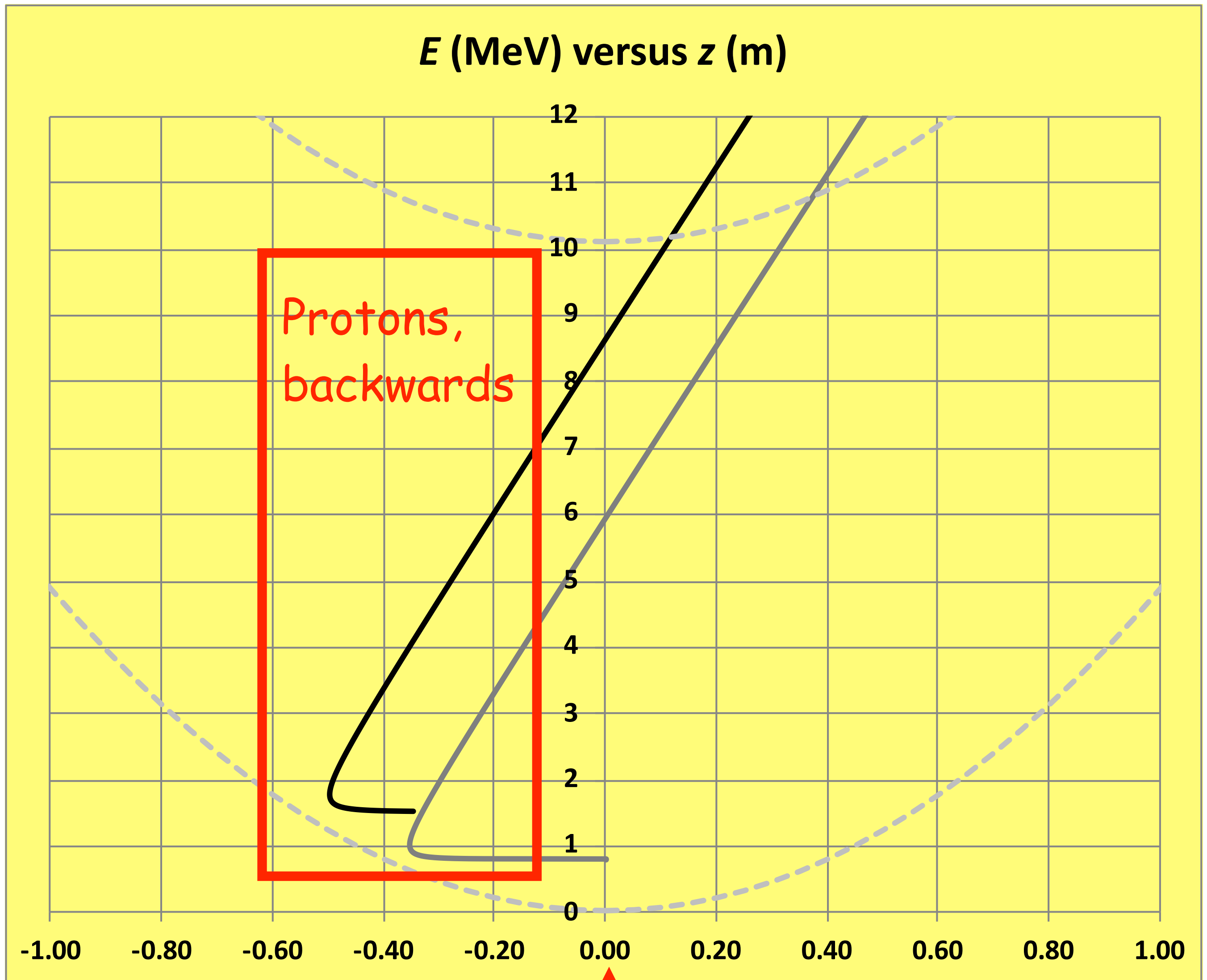
Is it possible at ISOLDE?



Assuming 200 μg/cm², 1×10⁵ pps, 10-40° c.m. (10-35° for l=6) @ 70% geometrical efficiency, S=0.6 for standard OMP parameters in DWBA using Ptolemy. 1 UT = 8 hrs. 2 T, 50-cm long array

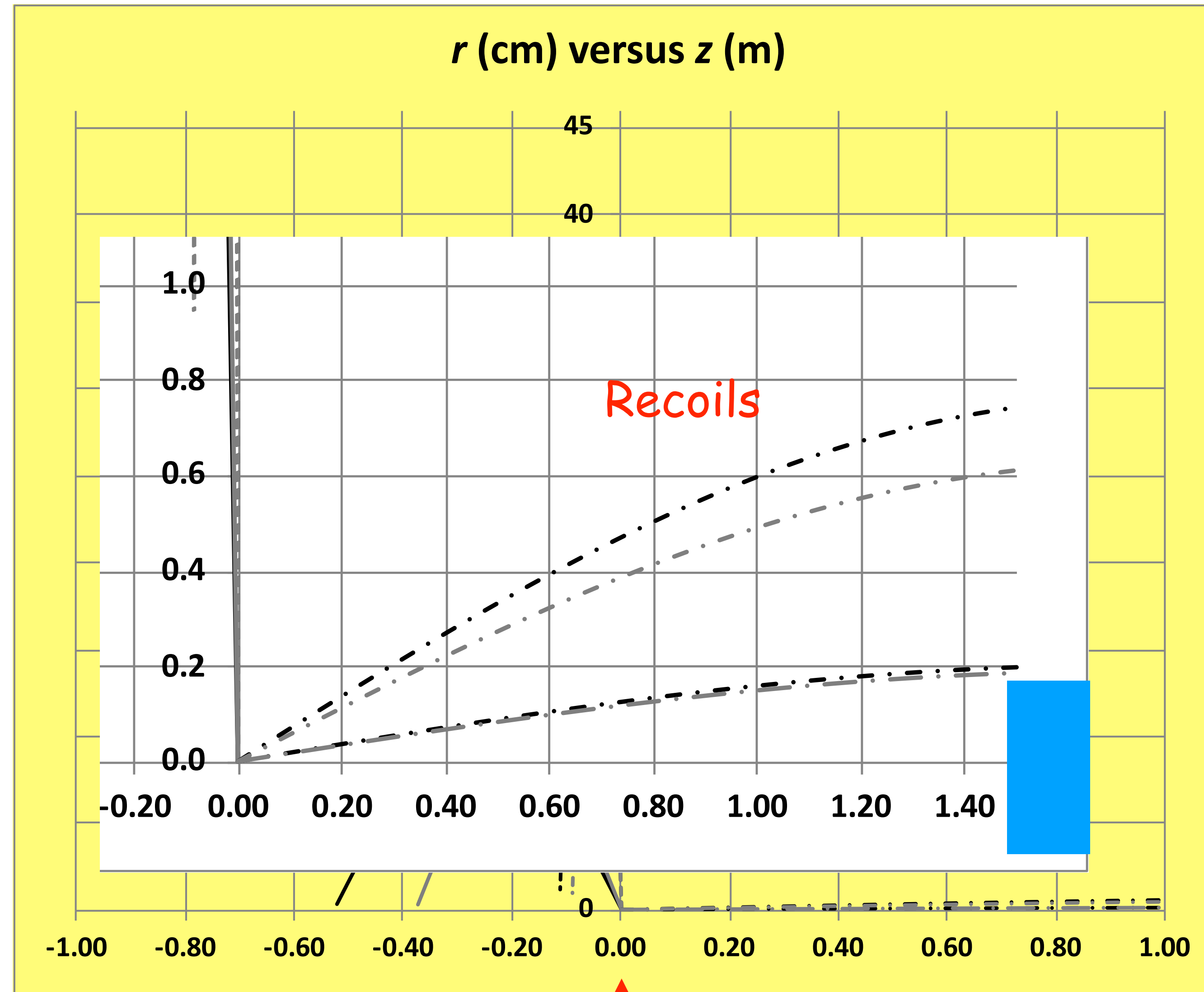
Is it possible at ISOLDE?

Beam direction



Target here

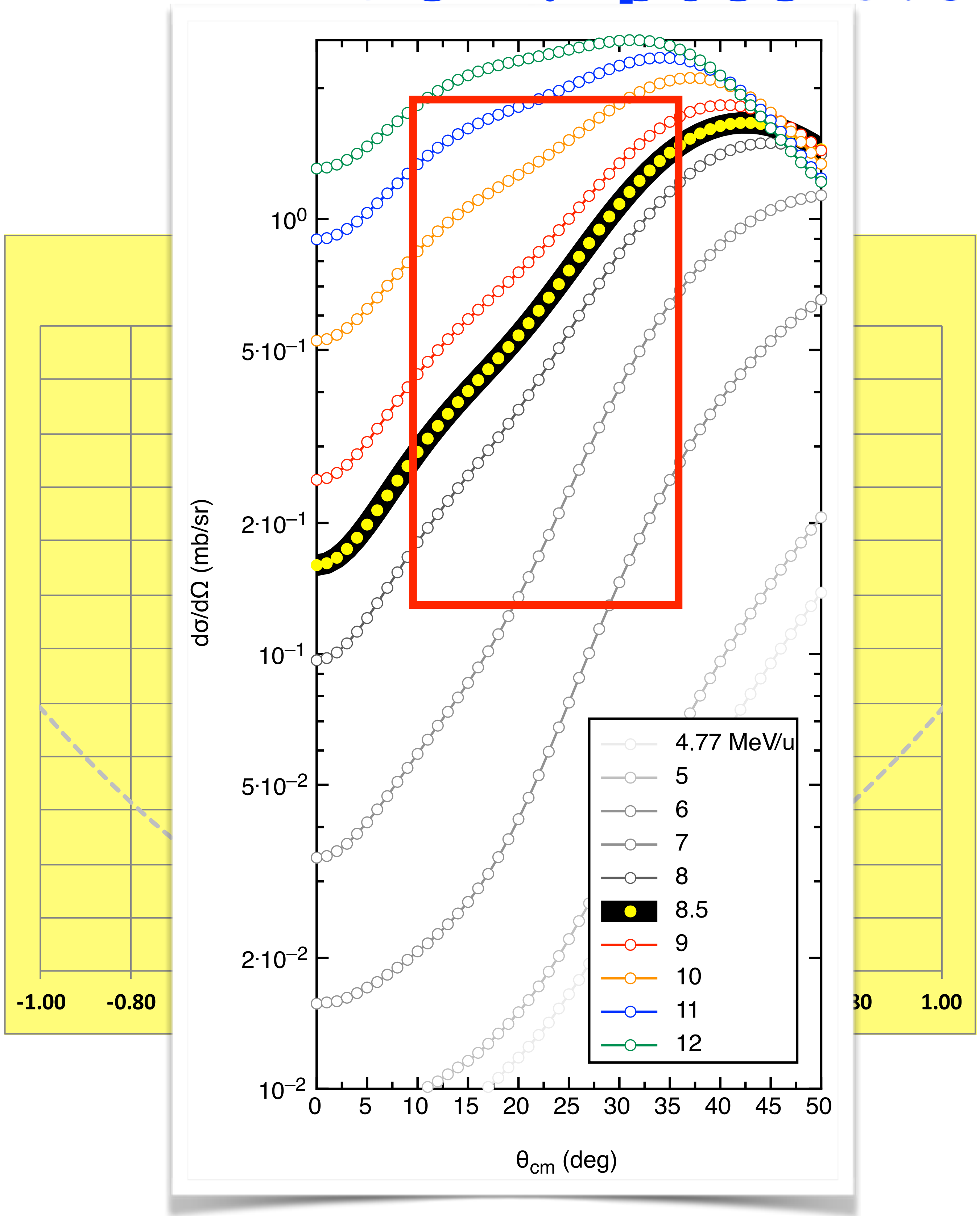
Beam direction

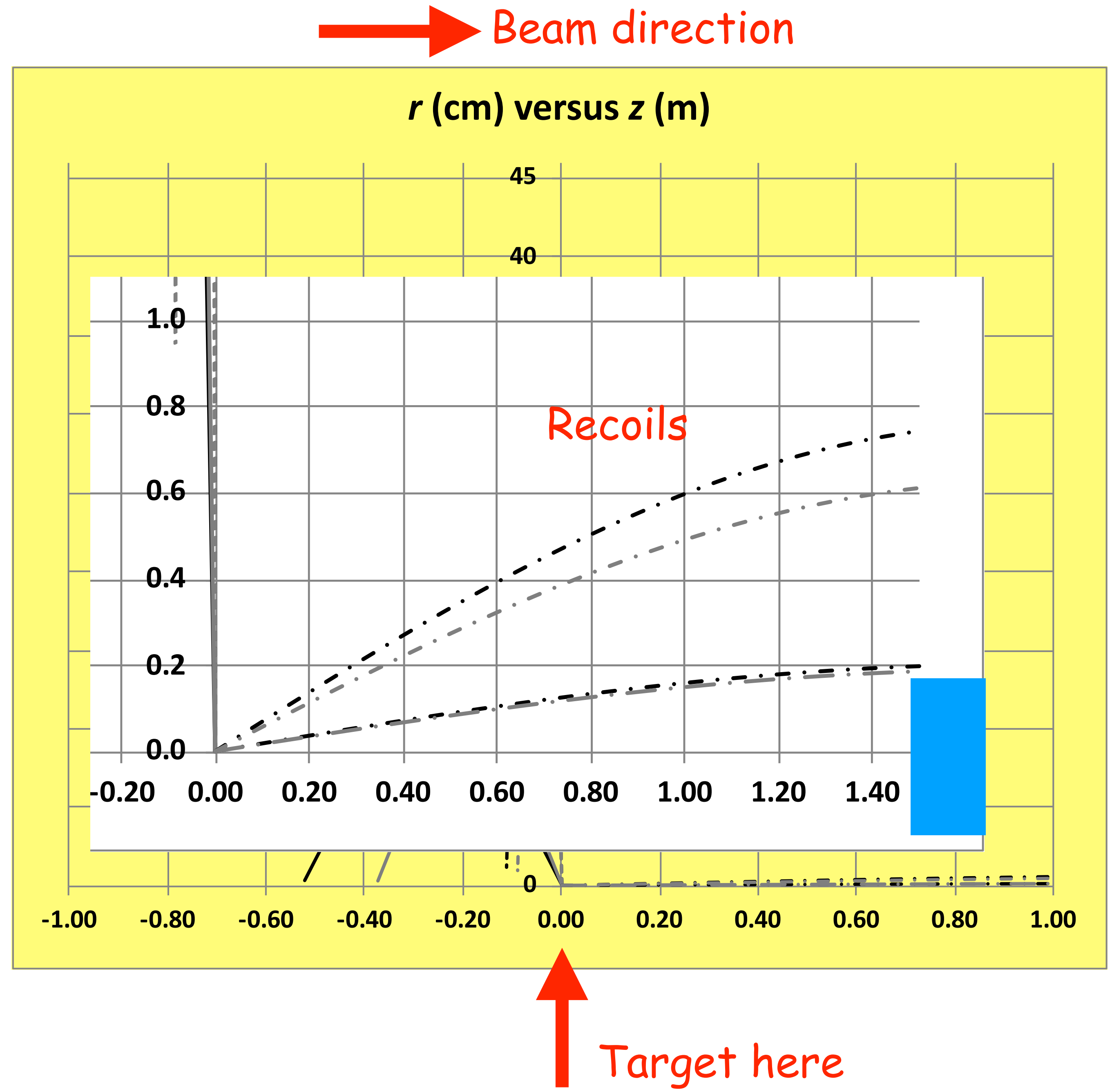


Target here

Assuming **200 μg/cm²**, **1×10⁵ pps**, **10-40° c.m.** (10-35° for l=6) @ **70%** geometrical efficiency, S=0.6 for standard OMP parameters in DWBA using Ptolemy. 1 UT = 8 hrs. 2 T, 50-cm long array

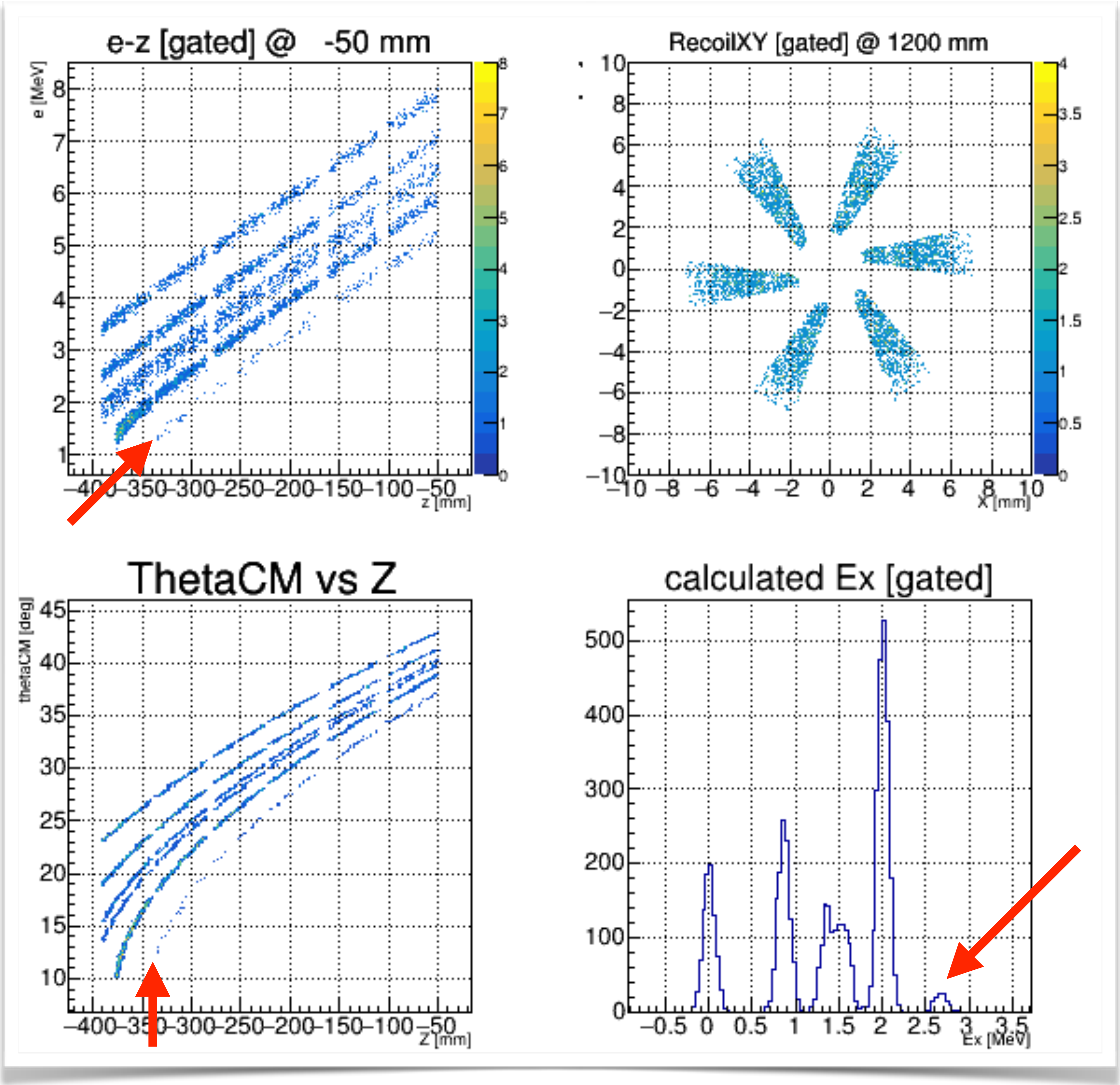
Is it possible at ISOLDE?





Assuming 200 μg/cm², 1×10⁵ pps, 10-40° c.m. (10-35° for l=6) @ 70% geometrical efficiency, S=0.6 for standard OMP parameters in DWBA using Ptolemy. 1 UT = 8 hrs. 2 T, 50-cm long array

Simulation



e-z [gated] @ -50 mm
e [MeV]
z [mm]
RecoilXY [gated] @ 1200 mm
X [mm]
ThetaCM vs Z
thetaCM [deg]
Z [mm]
calculated Ex [gated]
Ex [MeV]

Conclusion

It is possible/plausible/pursuable at ISOLDE with ISS, though limited by the beam energy (higher at Argonne, probably at ReA), but the intensity and purity are likely excellent cf. other facilities

Likely not possible elsewhere in next 3-5 years

Recoil detection explored, is likely possible based on experience at Argonne

The cross section for l=6 are just possible, unlike for Hg case (where we had lower MeV/u, higher Z)

Would be the clear determination of all s.p. levels outside ^{132}Sn

It also raises an obvious question about ^{134}Te(d,p) -- many have considered, and trying elsewhere (Oak Ridge, Argonne)

Notes for Liam and David

- Which direction in the laboratory are ejectiles emitted? Backwards
- Do you require recoil detection? Yes (No)
- Specific targetry requirements? No
- Absolute or only relative cross sections required? Relative (abs. preferred)
- Other ancillary detectors? "ELUM"