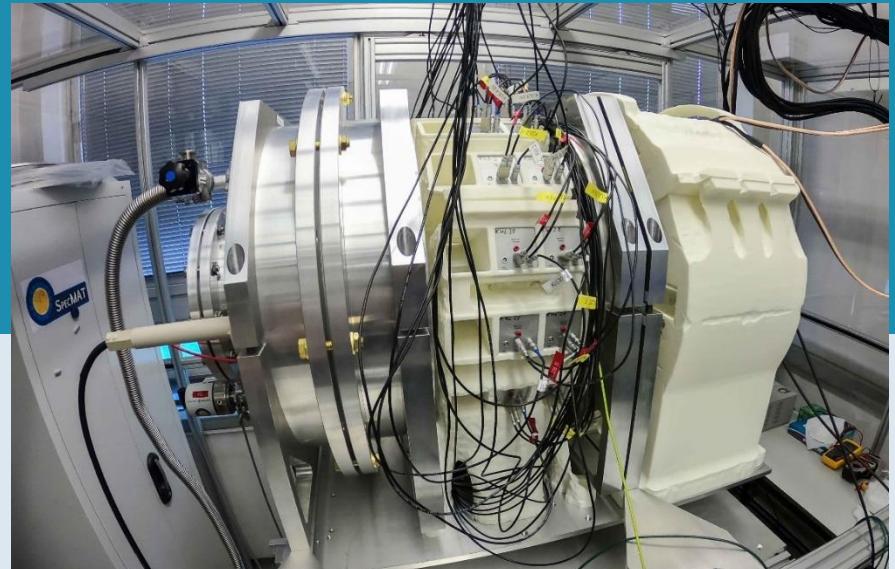


The SpecMAT active target

Oleksii Poleshchuk

ISOLDE Workshop and Users meeting

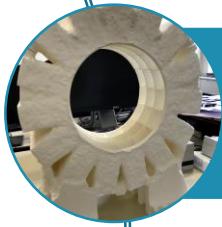
26 November 2020



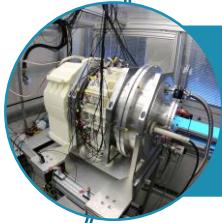
Outline



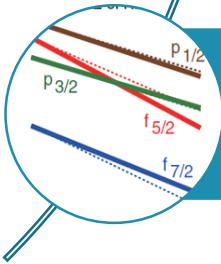
The SpecMAT active target



Characterisation of the
SpecMAT scintillation array

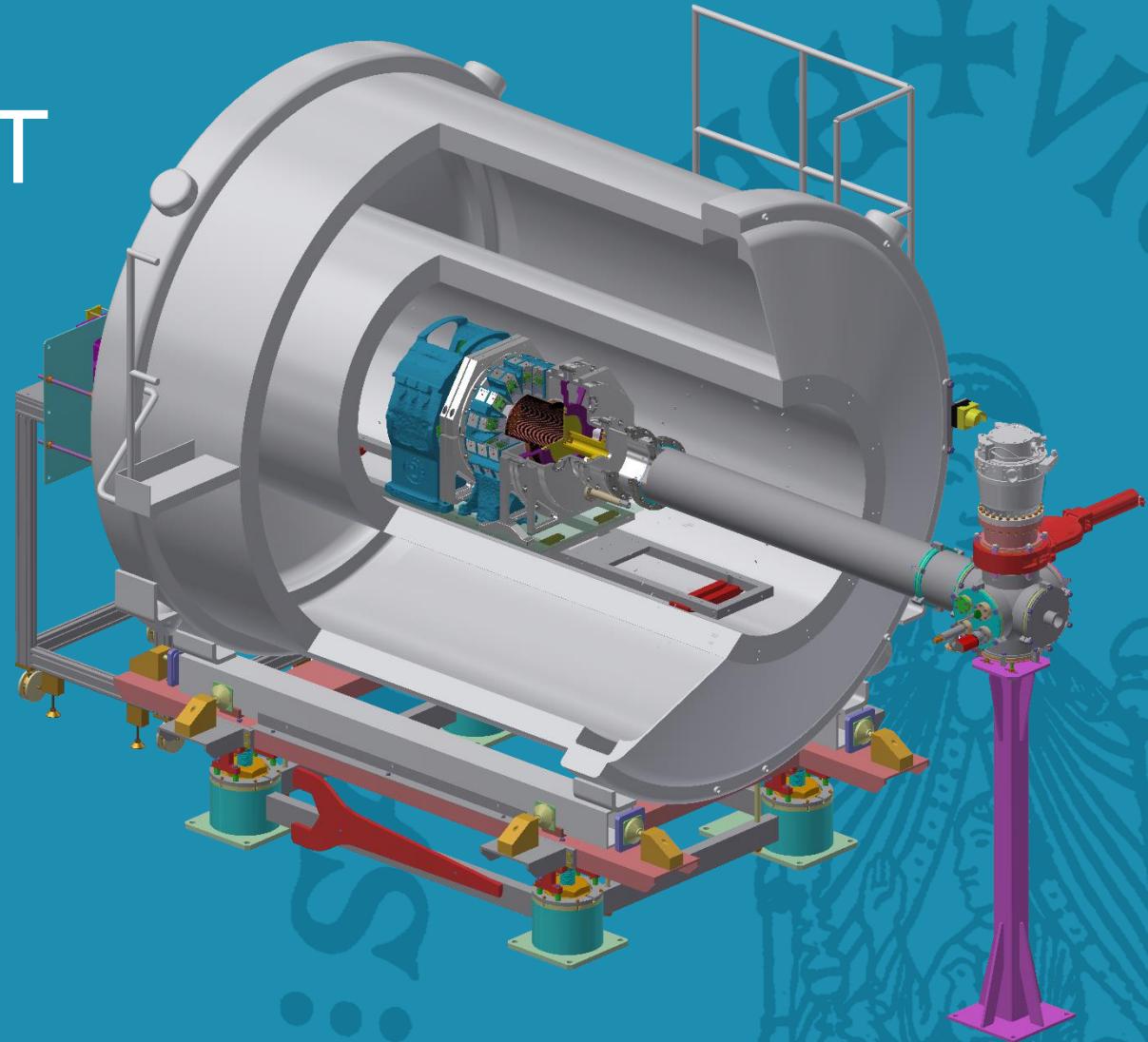


Characterisation of SpecMAT



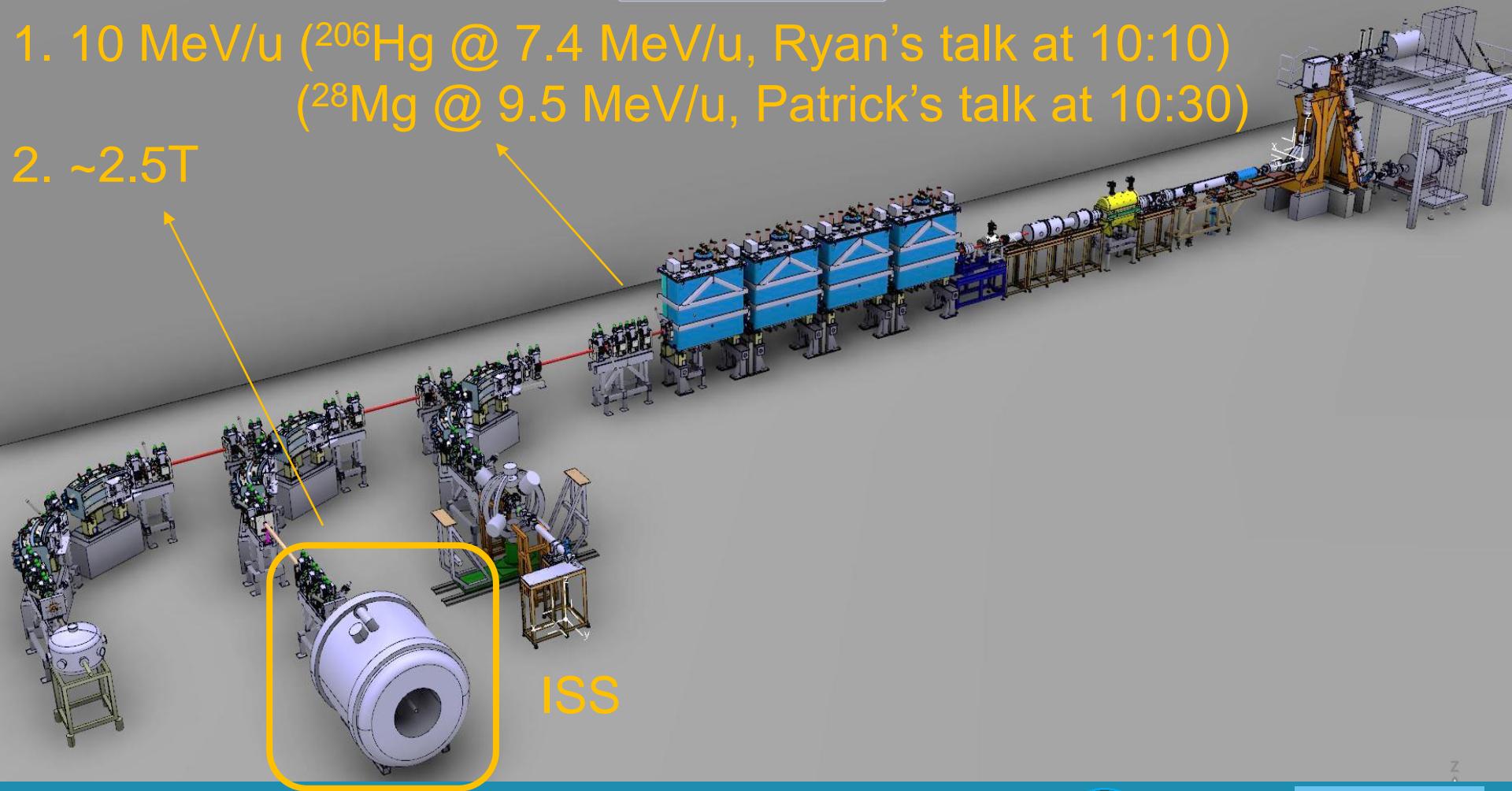
Shell evolution in $^{69-75}\text{Cu}$

The SpecMAT active target



1. 10 MeV/u (^{206}Hg @ 7.4 MeV/u, Ryan's talk at 10:10)
(^{28}Mg @ 9.5 MeV/u, Patrick's talk at 10:30)

2. ~2.5T

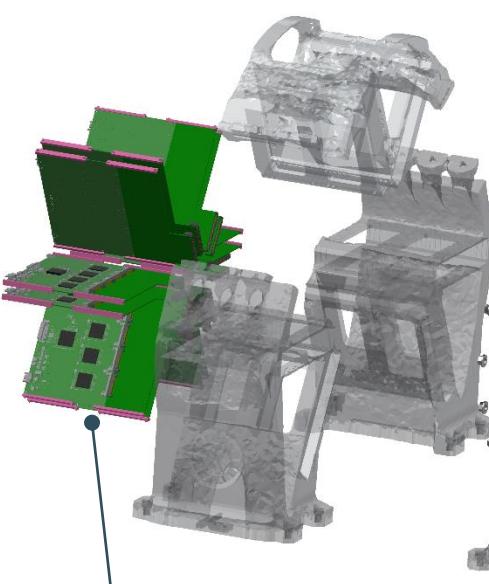


45 CeBr₃
48×48×48mm
scintillation
detectors

Field cage
homogeneous
electric field ~2%

Cathode
up to -32kV

Beam entrance
window
3-12 μm

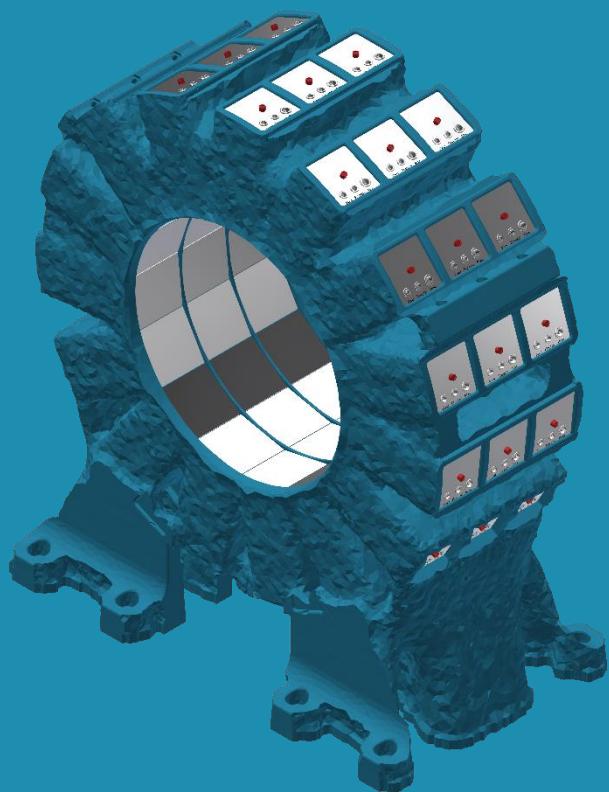


Readout electronics
1-100MS/s 12bit
3072+256 channels

MICROMEGAS detector
2916 channels

Gas chamber
up to 1 atm
min wall thickness 3mm

The CeBr₃ scintillation array

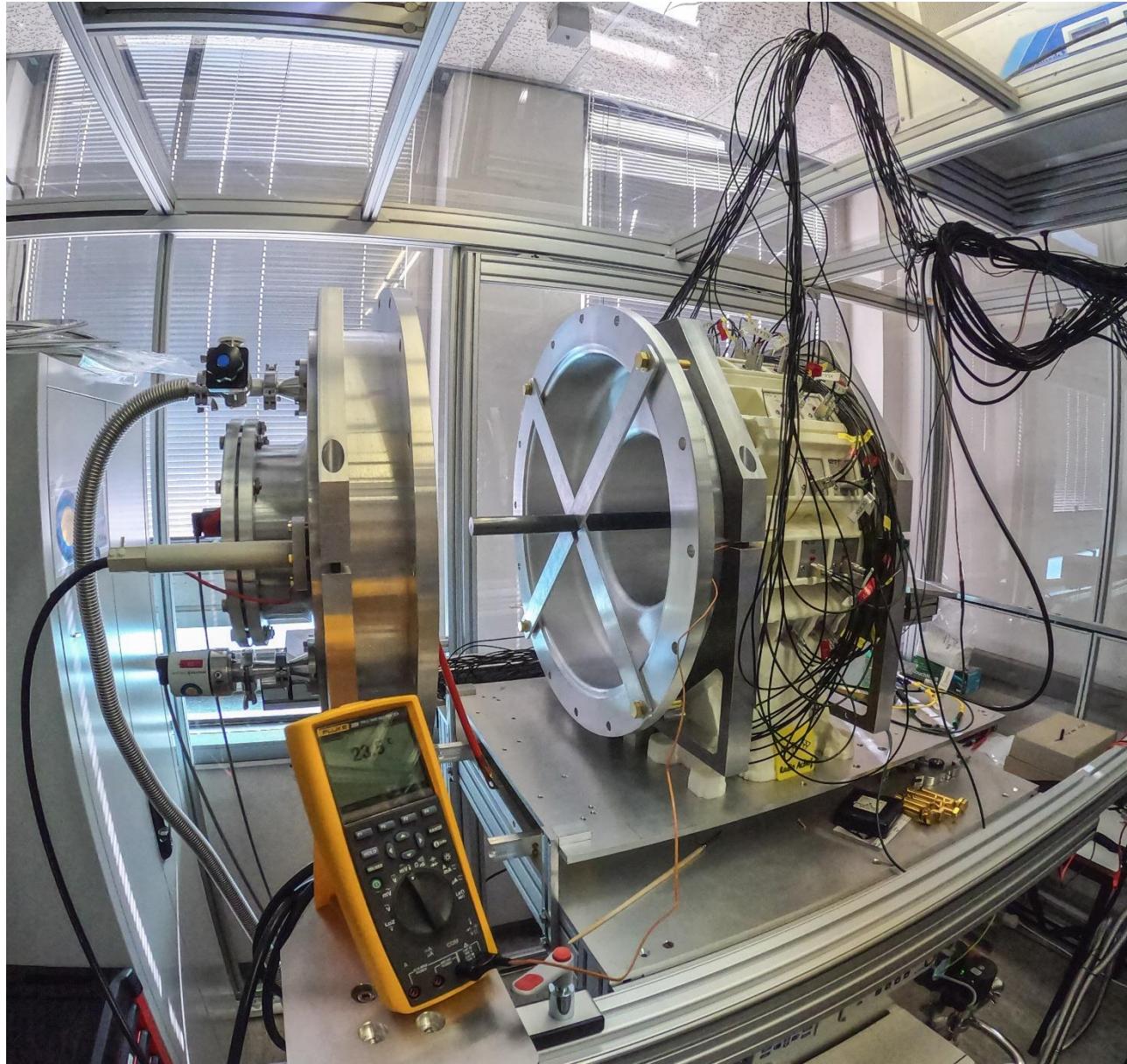


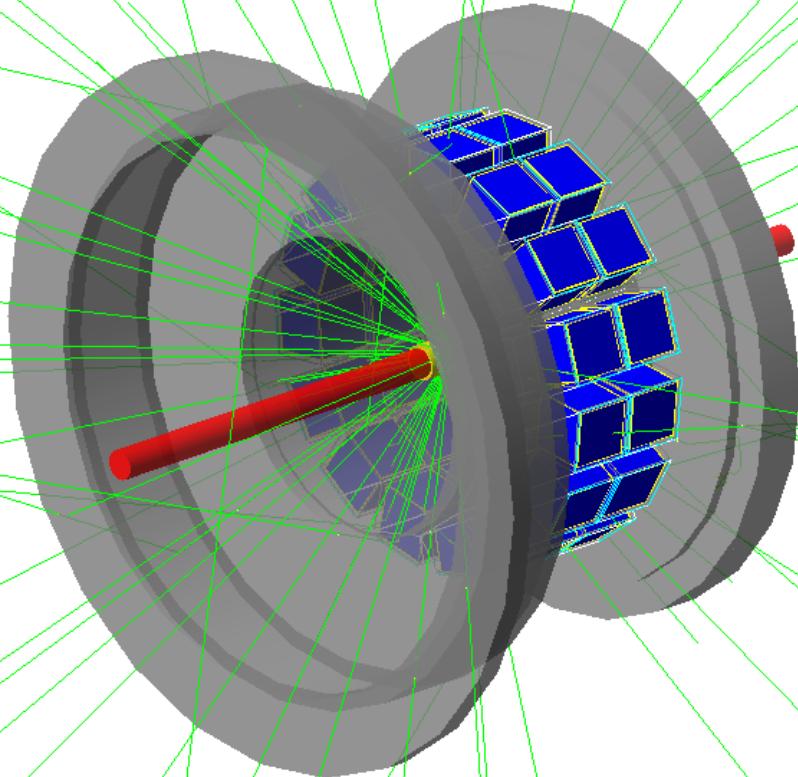


+10 detectors (from 10.2020)

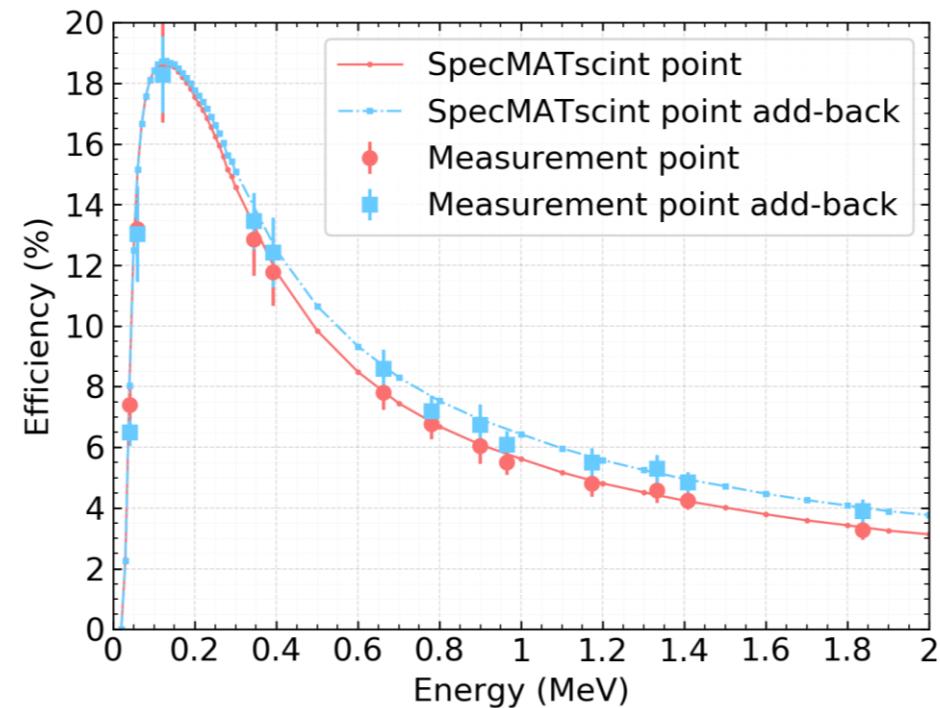
=

40 CeBr₃

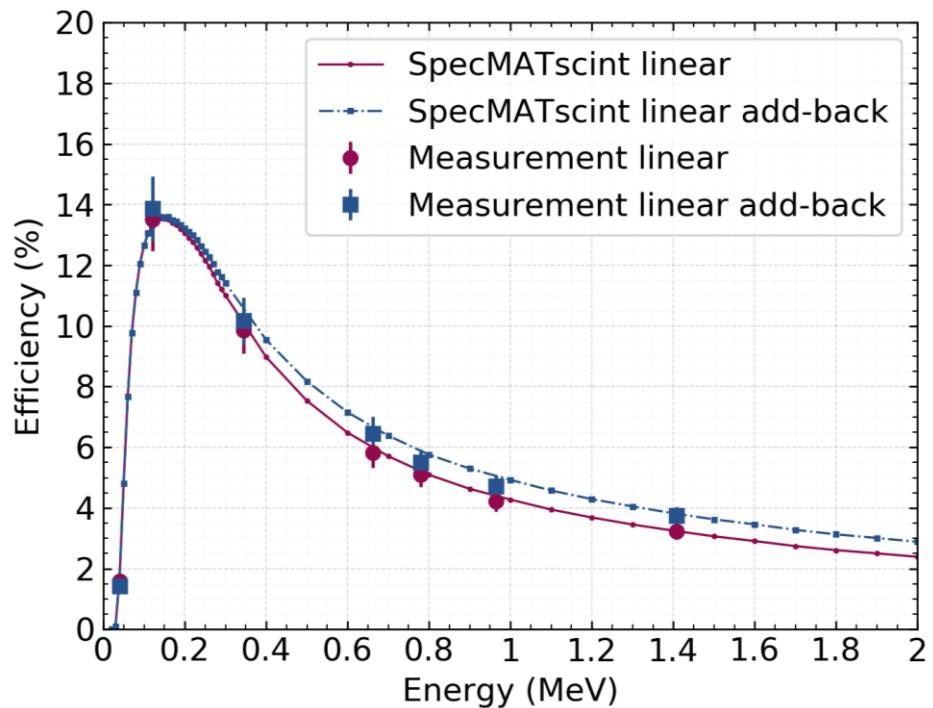




Point source



Linear source

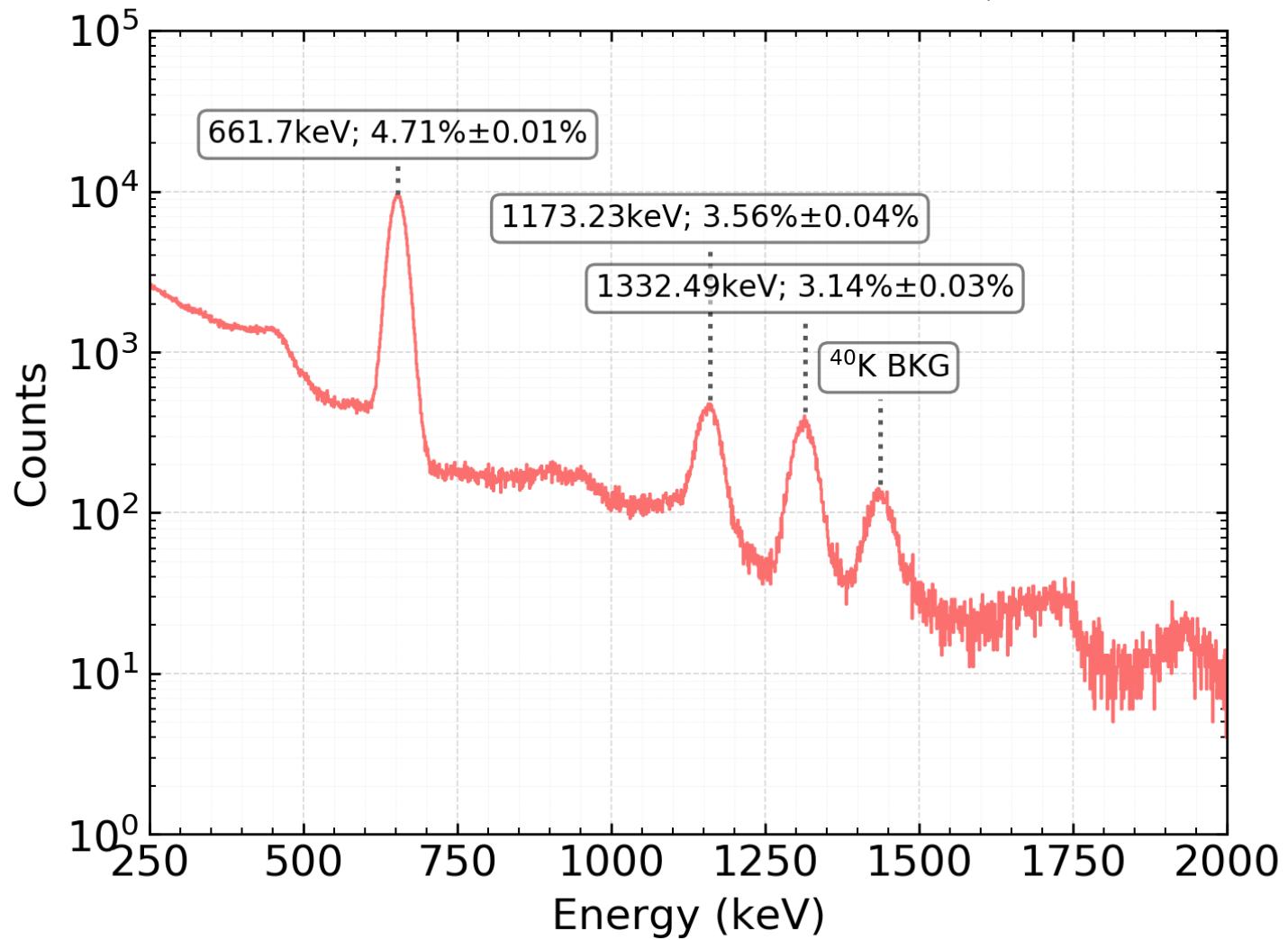


Max efficiency

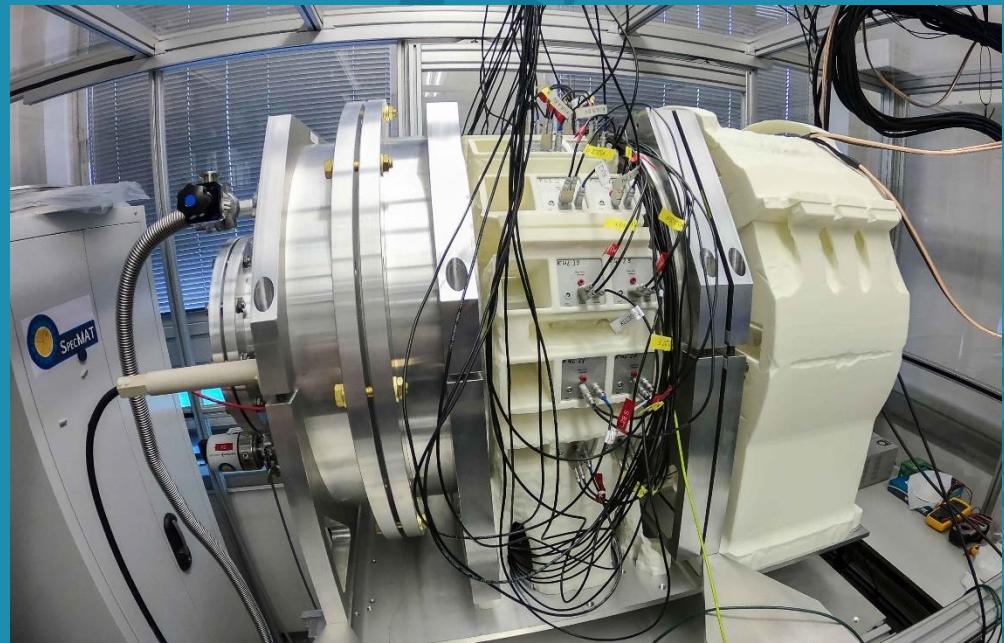
Experiment average efficiency

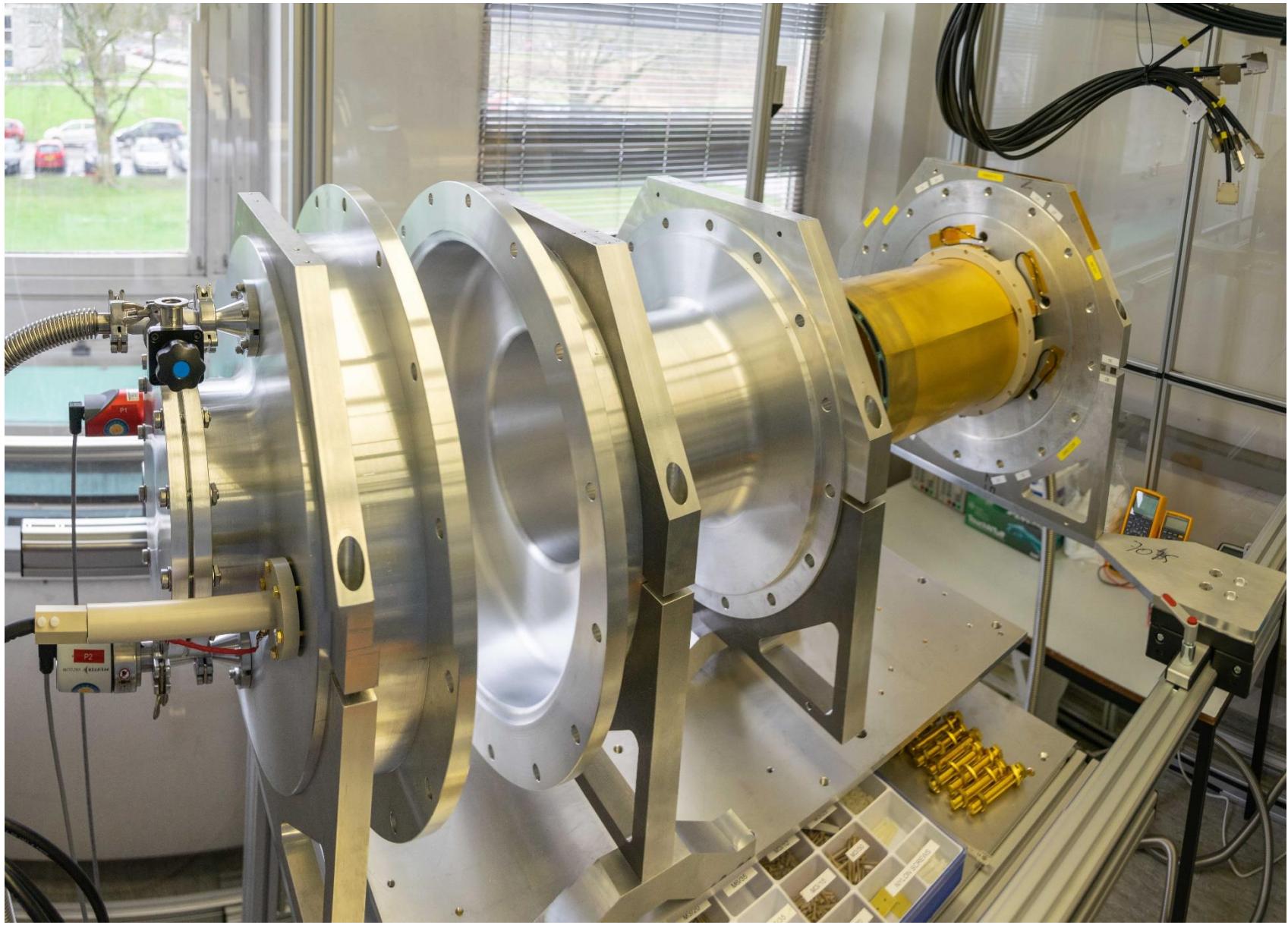
Cumulative spectrum

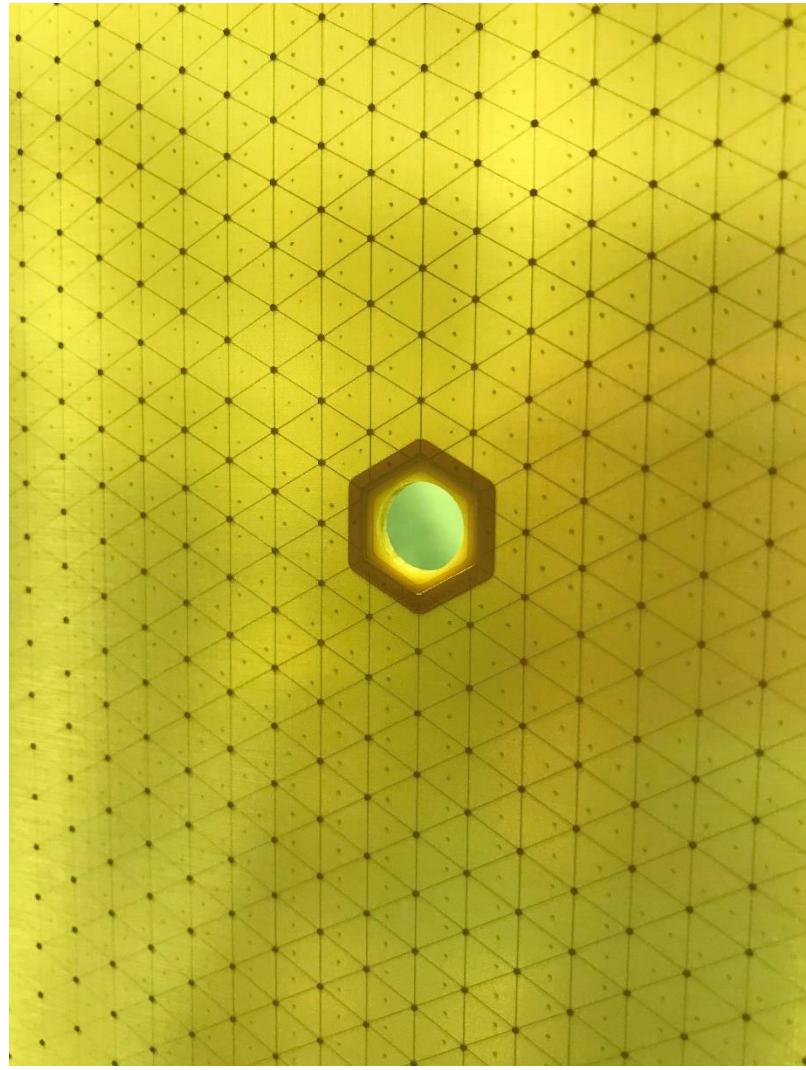
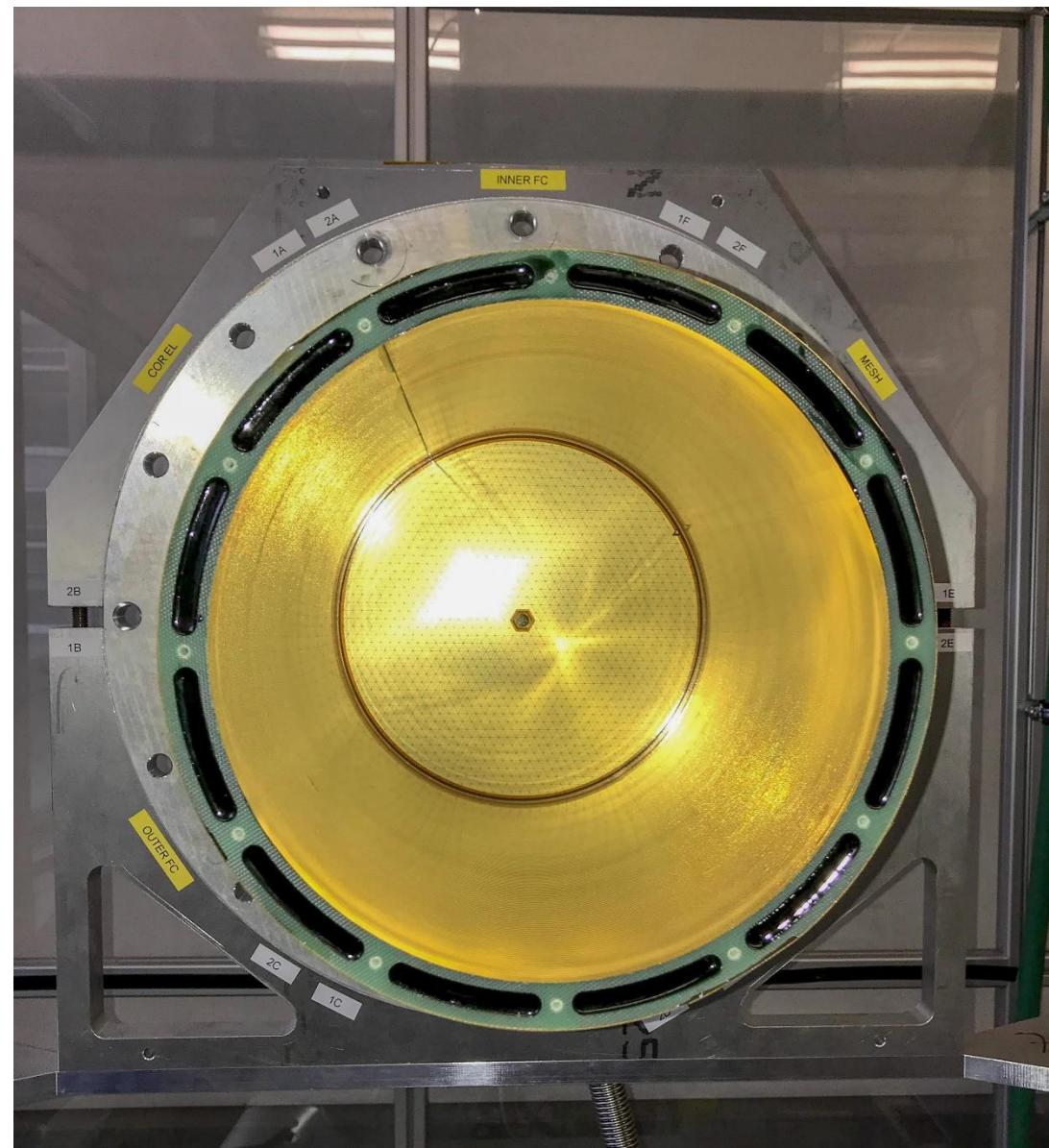
Measurement, no Geant4 !



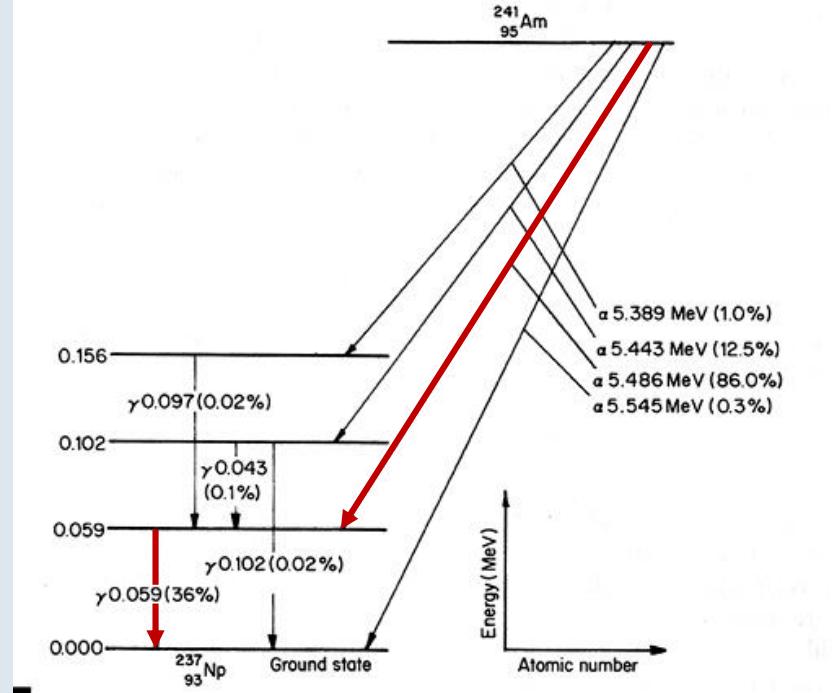
TPC data and its correlation with gamma-rays







Calibration with a 3-alpha source in $\text{Ar}(95\%) \text{CF}_4(5\%)$ @ 400mbar

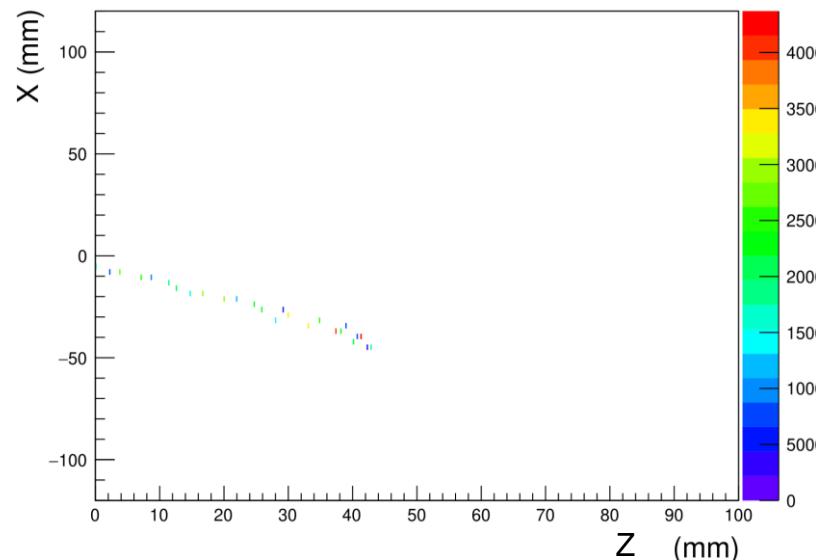
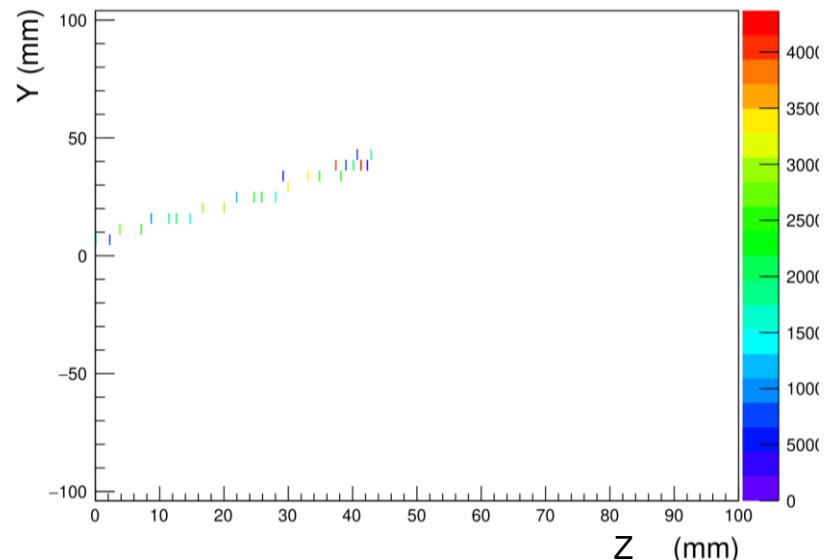
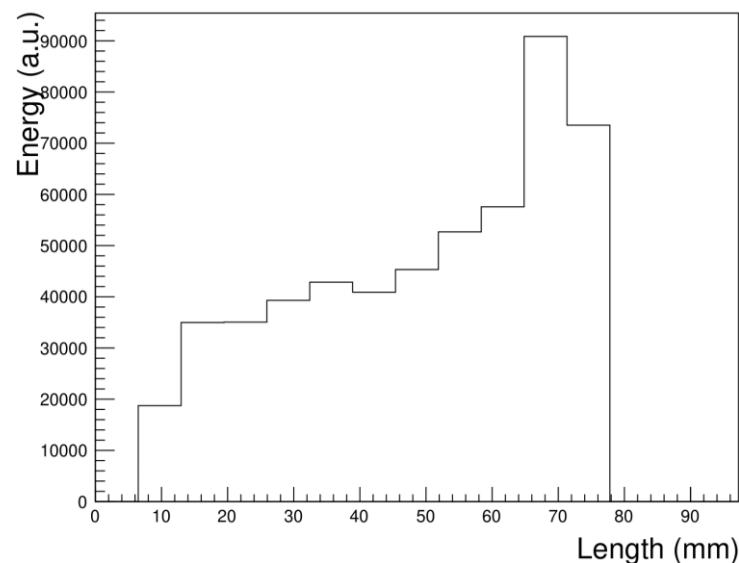
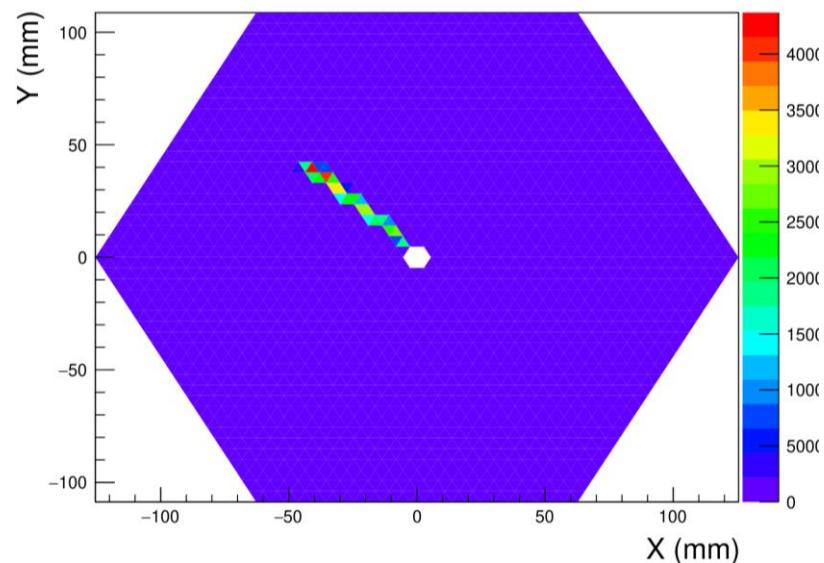


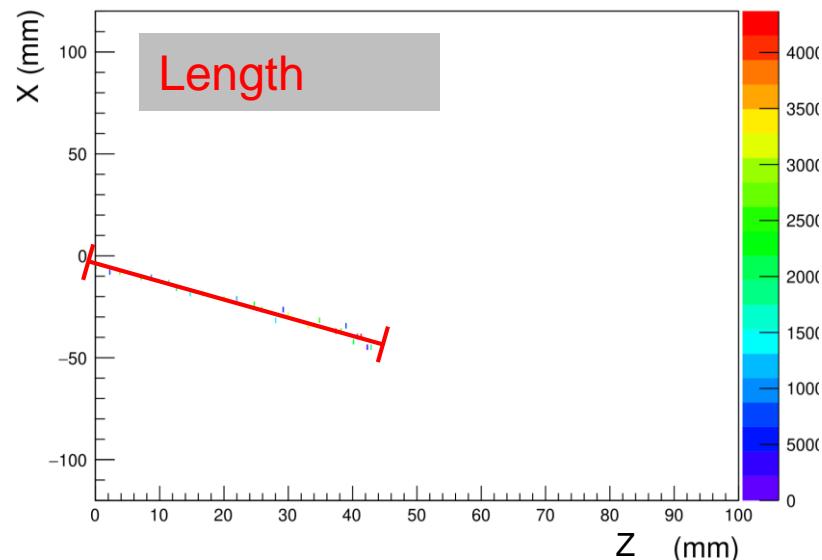
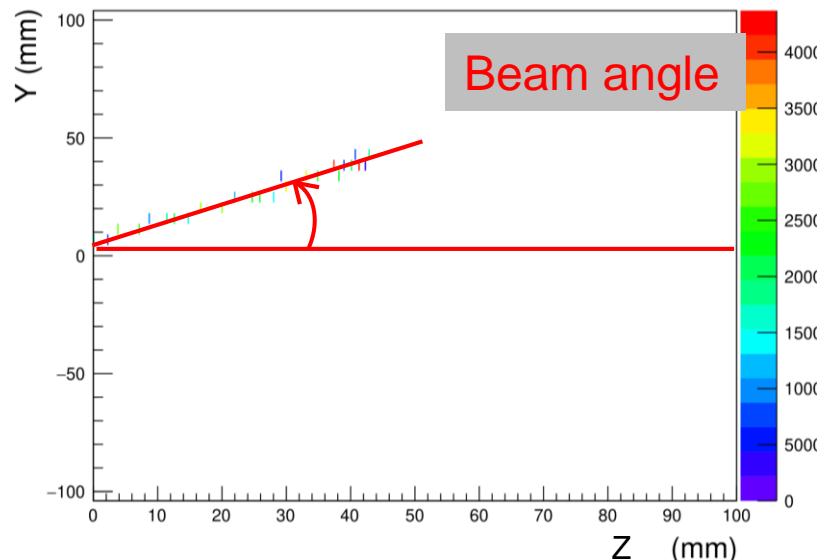
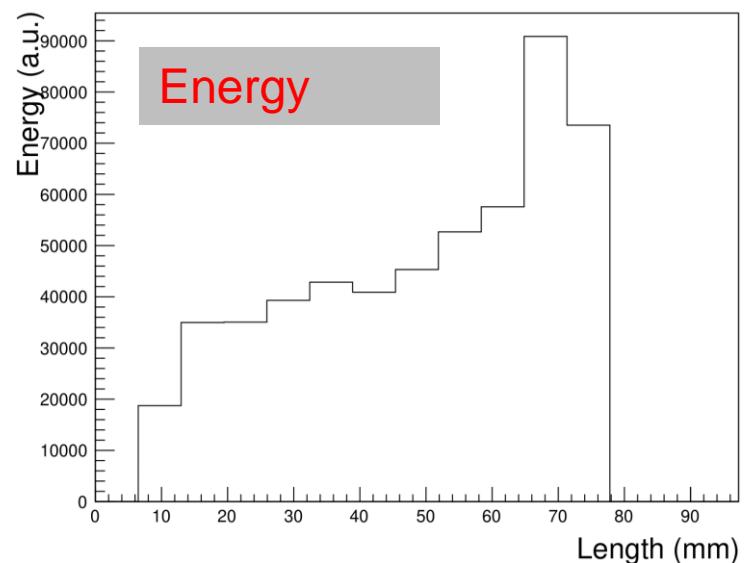
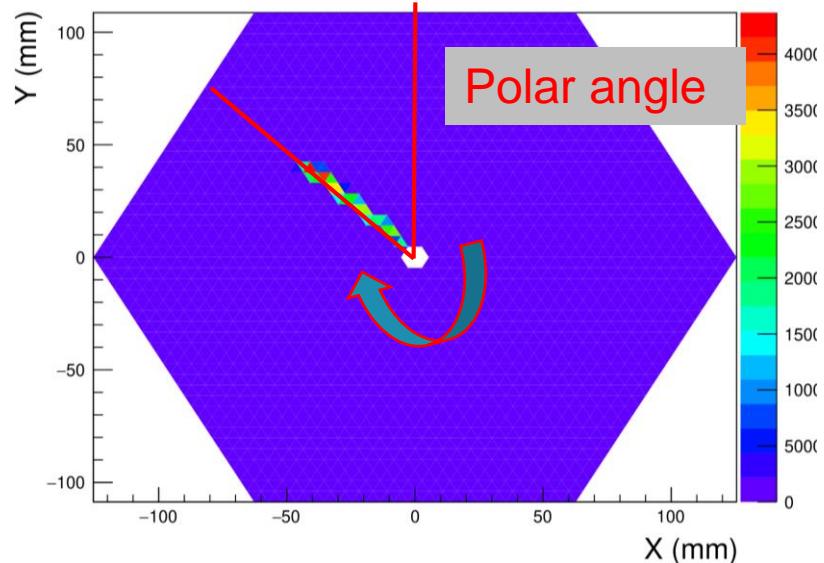
[physicsopenlab.org]

Measurement, no Geant4 !

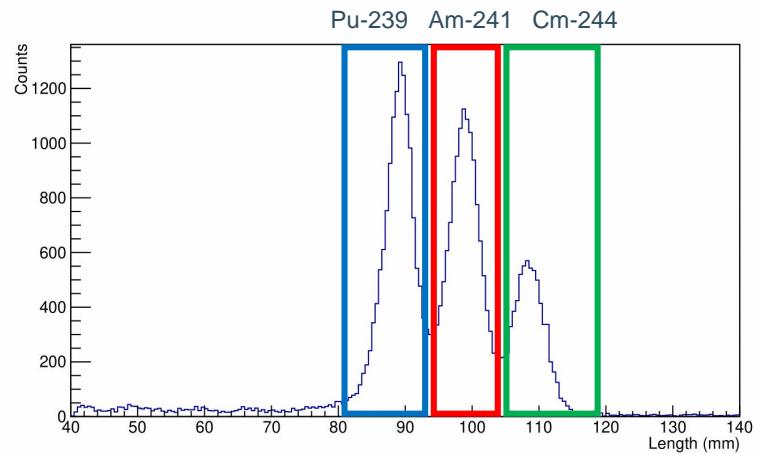
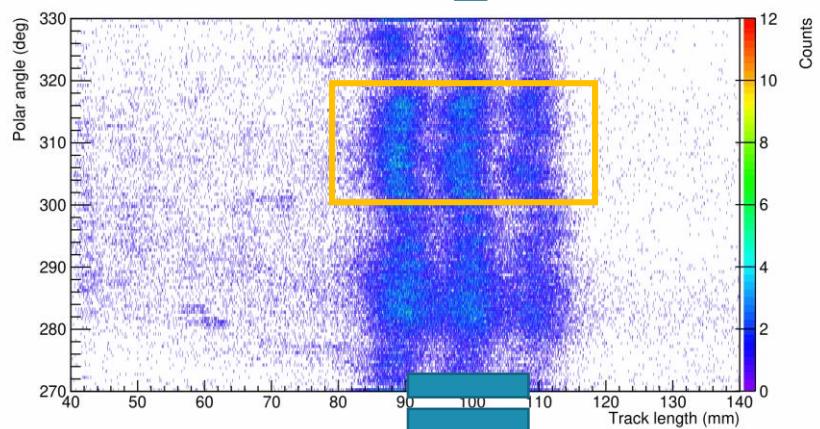
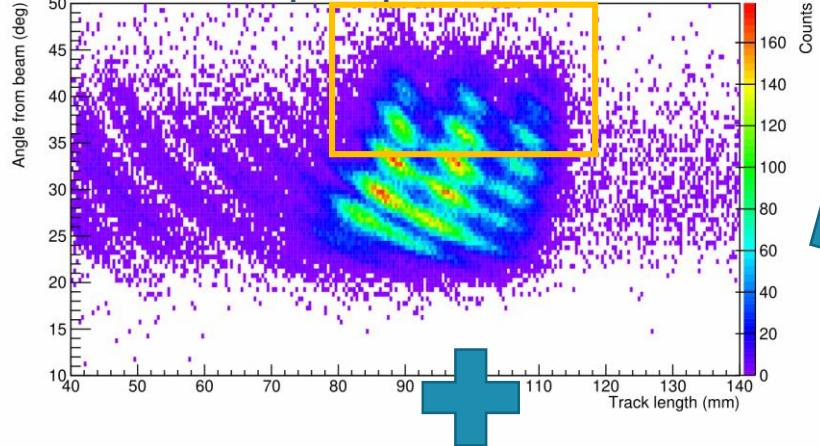


European Research Council
Established by the European Commission

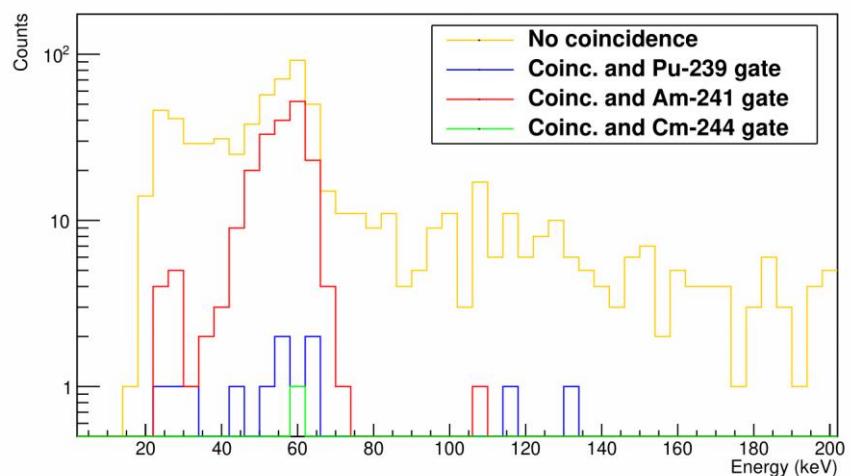
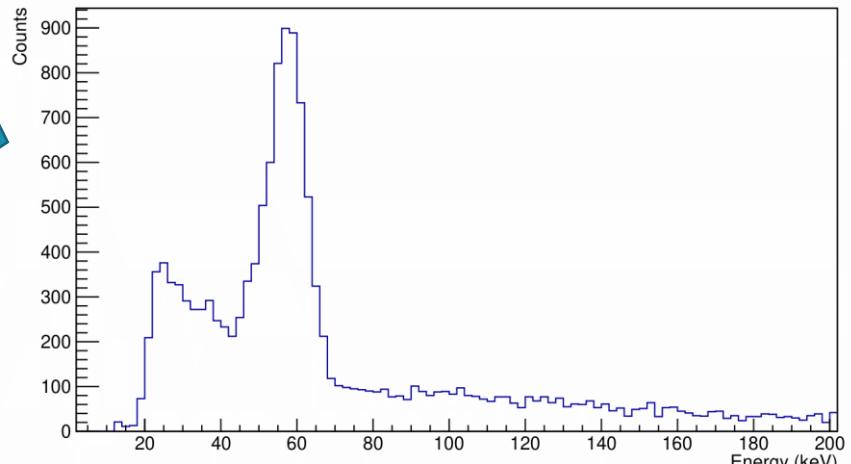




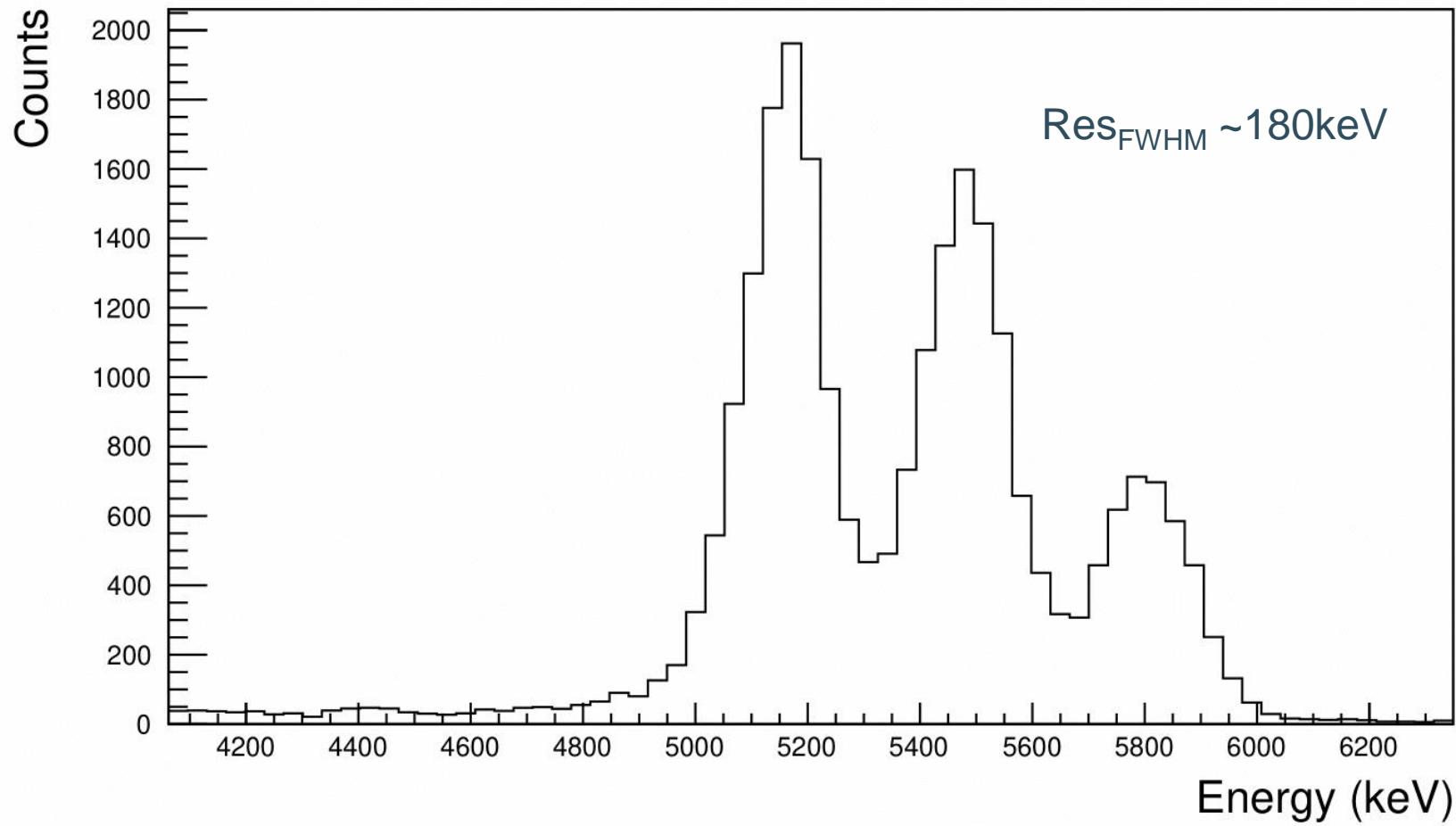
Alpha particles



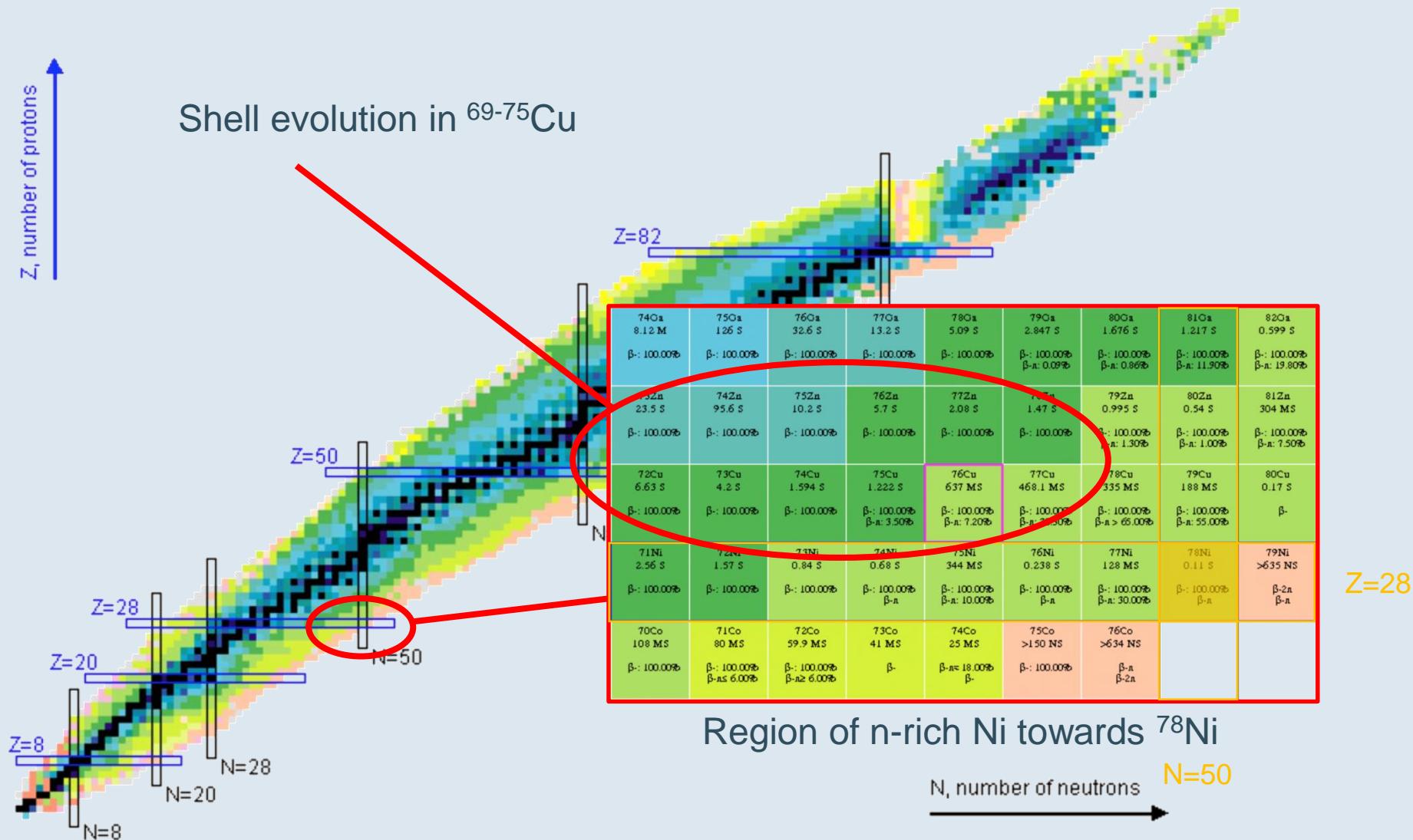
Gamma-rays



CalibSpectrum



Physics case for an on-line experiment



Physics motivation

Experimental observations

VOLUME 81, NUMBER 15

PHYSICAL REVIEW LETTERS

12 October 1998

Beta Decay of $^{68-74}\text{Ni}$ and Level Structure of Neutron-Rich Cu Isotopes

S. Franschoo, M. Huyse, K. Kruglov, Y. Kudryavtsev, W. F. Mueller, R. Raabe, I. Reusen, P. Van Duppen, J. Van Roosbroeck, L. Vermeeren, and A. Wöhr*

Instituut voor Kern- en Stralingsfysica, University of Leuven, B-3001 Leuven, Belgium

K.-L. Kratz and B. Pfeiffer

Institut für Kernchemie, University of Mainz, D-55099 Mainz, Germany

W. B. Walters

Department of Chemistry, University of Maryland, College Park, Maryland 20742
(Received 12 May 1998)

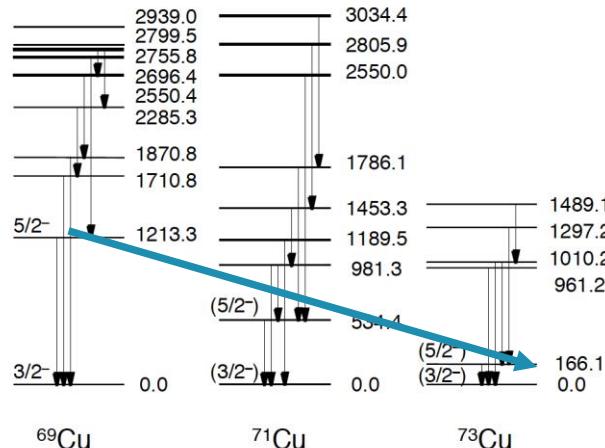


FIG. 4. Energy level systematics for $^{69,71,73}\text{Cu}$. Energies are given in keV. The data for ^{69}Cu are taken from Ref. [18].

PRL 103, 142501 (2009)

PHYSICAL REVIEW LETTERS

week ending
2 OCTOBER 2009**Nuclear Spins and Magnetic Moments of $^{71,73,75}\text{Cu}$: Inversion of $\pi 2p_{3/2}$ and $\pi 1f_{5/2}$ Levels in ^{75}Cu**

K. T. Flanagan,^{1,2} P. Vingerhoets,¹ M. Avgoulea,¹ J. Billowes,³ M. L. Bissell,¹ K. Blaum,⁴ B. Cheal,³ M. De Rydt,¹ V. N. Fedoseev,⁵ D. H. Forest,⁶ Ch. Geppert,^{7,8} U. Köster,¹⁰ M. Kowalska,¹¹ J. Krämer,⁹ K. L. Kratz,⁹ A. Krieger,⁹ E. Mané,³ B. A. Marsh,⁵ T. Materna,¹⁰ L. Mathieu,¹² P. L. Molkanov,¹³ R. Neugart,⁹ G. Neyens,¹ W. Nörtershäuser,^{9,7} M. D. Silverstov,^{13,16} O. Serot,¹² M. Schug,⁴ M. A. Sjoedin,¹⁷ J. R. Stone,^{14,15} N. J. Stone,^{14,15} H. H. Stroke,¹⁸ G. Tungate,⁶ D. T. Yordanov,⁴ and Yu. M. Volkov¹³

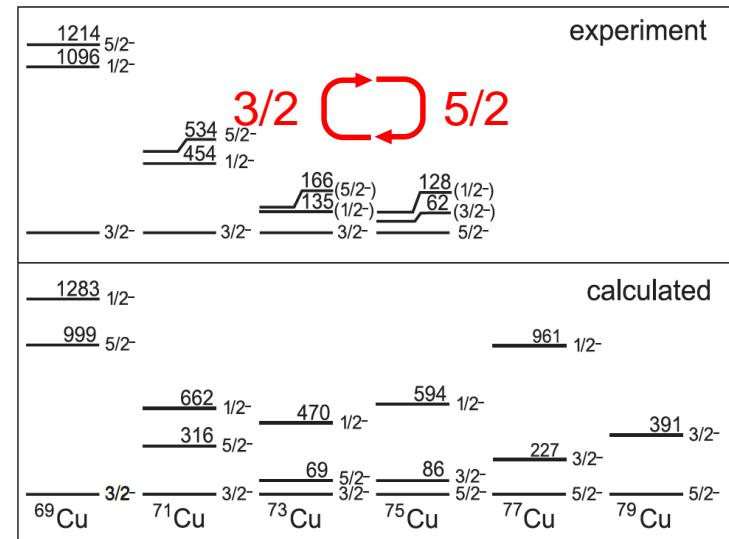


FIG. 3. Energy of the lowest levels from experiment [2,5,6] compared to large-scale shell-model calculation [25].

Physics motivation

Theoretical explanations

PRL 95, 232502 (2005)

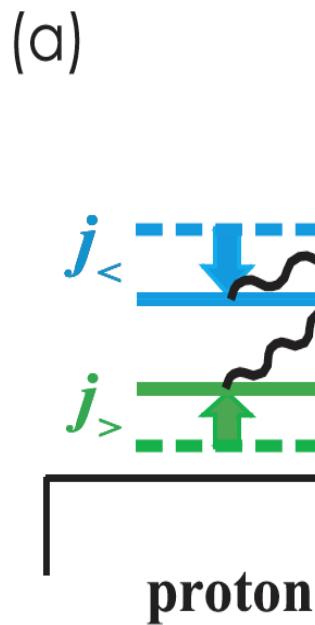
PHYSICAL REVIEW LETTERS

week ending
2 DECEMBER 2005

Evolution of Nuclear Shells due to the Tensor Force

Takaharu Otsuka,^{1,2,3,*} Toshio Suzuki,⁴ Rintaro Fujimoto,¹ Hubert Grawe,⁵ and Yoshinori Akaishi⁶¹Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan²Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan³RIKEN, Wako-shi, Saitama 351-0198, Japan⁴Department of Physics, Nihon University, Sakurajosui, Setagaya-ku, Tokyo 156-8550, Japan⁵GSI, D-64291, Darmstadt, Germany⁶KEK, Oho, Tsukuba-shi, Ibaraki 305-0801, Japan

(Received 22 February 2005; published 30 November 2005)



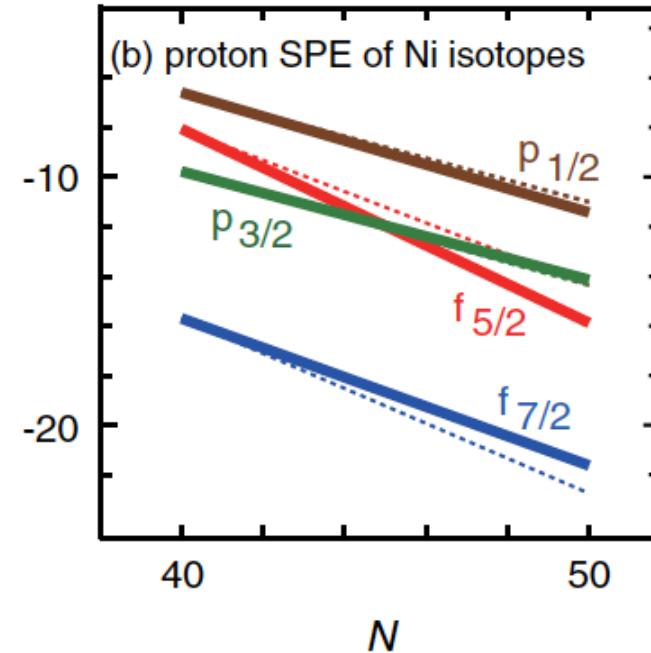
PRL 104, 012501 (2010)

Selected for a Viewpoint in Physics
PHYSICAL REVIEW LETTERSweek ending
8 JANUARY 2010

Novel Features of Nuclear Forces and Shell Evolution in Exotic Nuclei

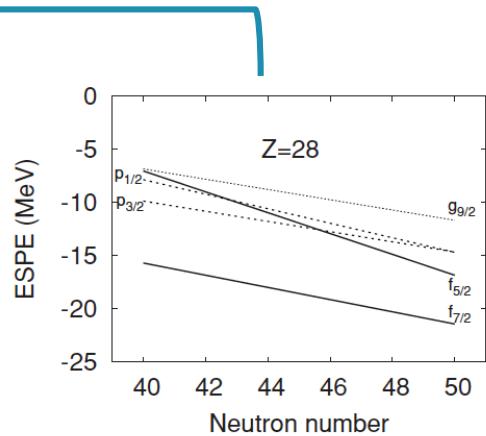
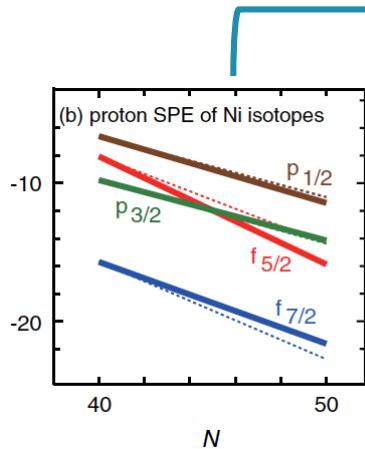
Takaharu Otsuka,^{1,2} Toshio Suzuki,³ Michio Honma,⁴ Yutaka Utsuno,⁵ Naofumi Tsunoda,¹Koshiroh Tsukiyama,¹ and Morten Hjorth-Jensen⁶¹Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan²Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan³RIKEN, Wako-shi, Saitama 351-0198, Japan⁴Center for Mathematical Sciences, University of Aizu, Tsuruga, Ikkimachi, Aizu-Wakamatsu, Fukushima 965-8550, Japan⁵Japan Atomic Energy Agency, Tokai, Ibaraki, 319-1195 Japan⁶Department of Physics and Center of Mathematics for Applications, University of Oslo, N-0316 Oslo, Norway

(Received 29 September 2009; published 4 January 2010)



Comparison of ESPE

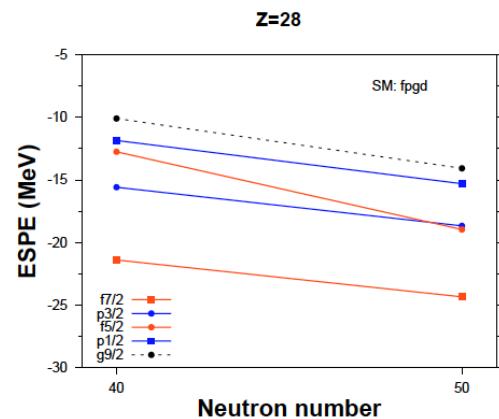
Theory



T. Otsuka, *et al.*,
PRL, 104, 012501 (2010)

K. Sieja, F. Nowacki,
PRC, 81, 061303(R) (2010)

Experiment



P. Morfouace,
PhD thesis (2014)

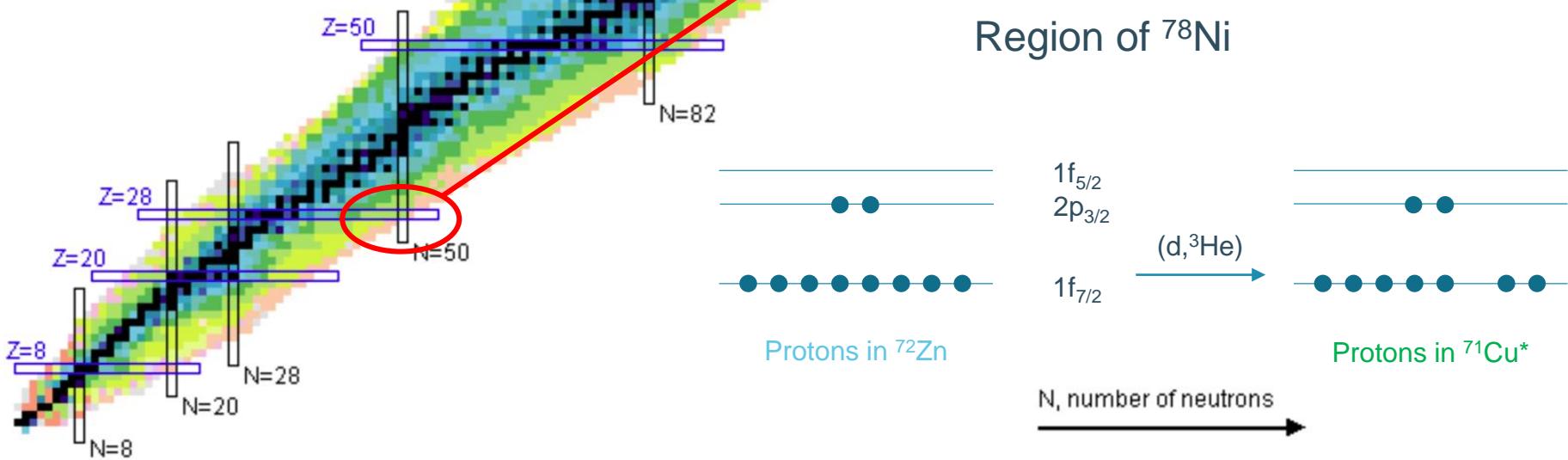
Experimental observations beyond ^{71}Cu are needed to determine $1\text{f}_{7/2} - 1\text{f}_{5/2}$ spin-orbit splitting and map the Z=28 gap!

Transfer reactions!

Shell structure of odd Cu isotopes via nucleon transfer reactions on Zn:

- $^{70}\text{Zn}(\text{d}, ^3\text{He})^{69}\text{Cu}$
- $^{72}\text{Zn}(\text{d}, ^3\text{He})^{71}\text{Cu}$
- $^{74}\text{Zn}(\text{d}, ^3\text{He})^{73}\text{Cu}$
- $^{76}\text{Zn}(\text{d}, ^3\text{He})^{75}\text{Cu}$

^{70}Zn 21.14 M β^- : 99.59% β^- : 0.41%	^{71}Zn STABLE 39.892% β^- : 100.00%	^{72}Zn 14.10 H β^- : 100.00%	^{73}Zn 4.86 H β^- : 100.00%	^{74}Zn 8.12 M β^- : 100.00%	^{75}Zn 1.26 S β^- : 100.00%	^{76}Zn 32.6 S β^- : 100.00%	^{77}Zn 13.2 S β^- : 100.00%	^{78}Zn 5.09 S β^- : 100.00%	^{79}Zn 2.847 S β^- : 100.00% β^- : 0.09%	^{80}Zn 1.9 S β^- : 100.00% β^- : 0.86%	^{81}Zn 1.217 S β^- : 100.00% β^- : 11.90%	^{82}Zn 0.599 S β^- : 100.00% β^- : 19.80%
^{69}Zn 56.4 M β^- : 100.00%	^{70}Zn 22.3 E+17 Y 0.4% β^- : 23-	^{71}Zn 2.45 M β^- : 100.00%	^{72}Zn 46.5 H β^- : 100.00%	^{73}Zn 23.5 S β^- : 100.00%	^{74}Zn 95.6 S β^- : 100.00%	^{75}Zn 10.2 S β^- : 100.00%	^{76}Zn 5.7 S β^- : 100.00%	^{77}Zn 2.08 S β^- : 100.00%	^{78}Zn 1.47 S β^- : 100.00%	^{79}Zn 0.746 S β^- : 100.00% β^- : 1.70%	^{80}Zn 561.9 MS β^- : 100.00% β^- : 1.00%	^{81}Zn 303.5 MS β^- : 100.00% β^- : 7.50%
^{68}Cu 30.9 S β^- : 100.00%	^{69}Cu 2.65 M β^- : 100.00%	^{70}Cu 44.5 S β^- : 100.00%	^{71}Cu 19.4 S β^- : 100.00%	^{72}Cu 6.63 S β^- : 100.00%	^{73}Cu 4.1 S β^- : 100.00%	^{74}Cu 1.594 S β^- : 100.00%	^{75}Cu 1.224 S β^- : 100.00%	^{76}Cu 0.638 S β^- : 100.00%	^{77}Cu 468.1 MS β^- : 100.00% β^- : 7.20%	^{78}Cu 335 MS β^- : 100.00% β^- : 30.30%	^{79}Cu 241.0 MS β^- : 100.00% β^- : 55.00%	^{80}Cu 0.17 S β^- : 100.00%
^{67}Ni 21 S β^- : 100.00%	^{68}Ni 29 S β^- : 100.00%	^{69}Ni 11.4 S β^- : 100.00%	^{70}Ni 6.0 S β^- : 100.00%	^{71}Ni 2.56 S β^- : 100.00%	^{72}Ni 1587 MS β^- : 100.00%	^{73}Ni 842 MS β^- : 100.00%	^{74}Ni 507.7 MS β^- : 100.00%	^{75}Ni 331.8 MS β^- : 100.00%	^{76}Ni 234.7 MS β^- : 100.00%	^{77}Ni 158.4 MS β^- : 100.00%	^{78}Ni 122.2 MS β^- : 100.00%	^{79}Ni 43.0 MS β^- : 100.00%
^{66}Co 209 MS β^- : 100.00% β^- : 2-a	^{67}Co 329 MS β^- : 100.00% β^- : 2-a	^{68}Co 99 MS β^- : 100.00%	^{69}Co 180 MS β^- : 100.00% β^- : 2-a	^{70}Co 14 MS β^- : 100.00%	^{71}Co 80 MS β^- : 100.00% β^- : 3.60%	^{72}Co 57.3 MS β^- : 100.00% β^- : 4.00%	^{73}Co 40.5 MS β^- : 100.00% β^- : 4.90%	^{74}Co 31.4 MS β^- : 100.00% β^- : 18.00%	^{75}Co 26.5 MS β^- : 100.00% β^- : 16.00%	^{76}Co 21.7 MS β^- : 100.00% β^- : 3-a	^{77}Co 13.0 MS β^- : 100.00% β^- : 3-a	



What can be measured

Shell structure of odd Cu isotopes via nucleon transfer reactions on Zn:

- $^{70}\text{Zn}(\text{d}, ^3\text{He})^{69}\text{Cu}$
- $^{72}\text{Zn}(\text{d}, ^3\text{He})^{71}\text{Cu}$
- $^{74}\text{Zn}(\text{d}, ^3\text{He})^{73}\text{Cu}$
- $^{76}\text{Zn}(\text{d}, ^3\text{He})^{75}\text{Cu}$



$1f_{5/2}$



$1f_{7/2}$



$1d_{3/2}$

Protons in ^{76}Zn

$(\text{d}, ^3\text{He})$



$1f_{7/2}$



$1d_{3/2}$

Protons in $^{75}\text{Cu}^*$

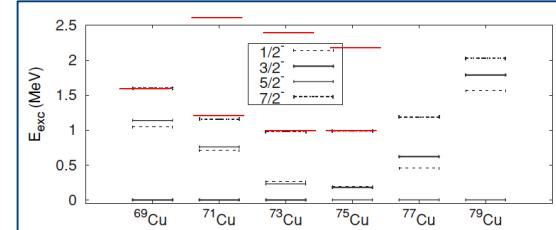
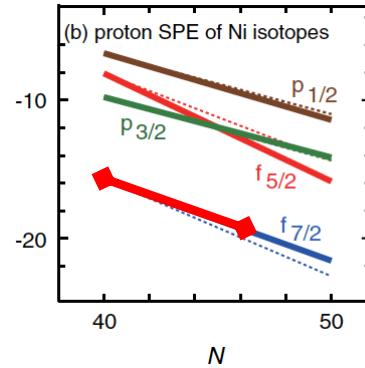


FIG. 2. Low-lying levels in copper isotopes resulting shell model calculations.

T. Otsuka



What can be measured

Shell structure of odd Cu isotopes via nucleon transfer reactions on Zn:

- $^{70}\text{Zn}(\text{d}, ^3\text{He})^{69}\text{Cu}$
- $^{72}\text{Zn}(\text{d}, ^3\text{He})^{71}\text{Cu}$
- $^{74}\text{Zn}(\text{d}, ^3\text{He})^{73}\text{Cu}$
- $^{76}\text{Zn}(\text{d}, ^3\text{He})^{75}\text{Cu}$



$1f_{5/2}$



$1f_{7/2}$



$1d_{3/2}$

Protons in ^{76}Zn

$(\text{d}, ^3\text{He})$



$1f_{5/2}$



$1f_{7/2}$



$1d_{3/2}$

Protons in $^{75}\text{Cu}^*$

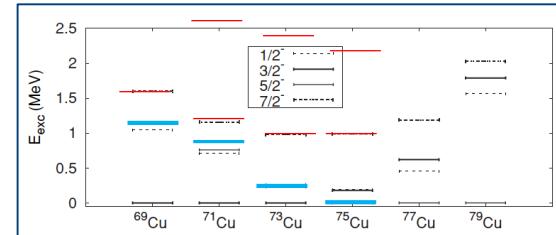
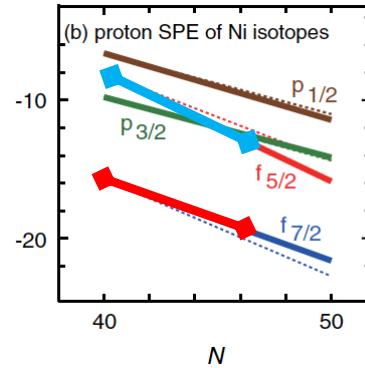


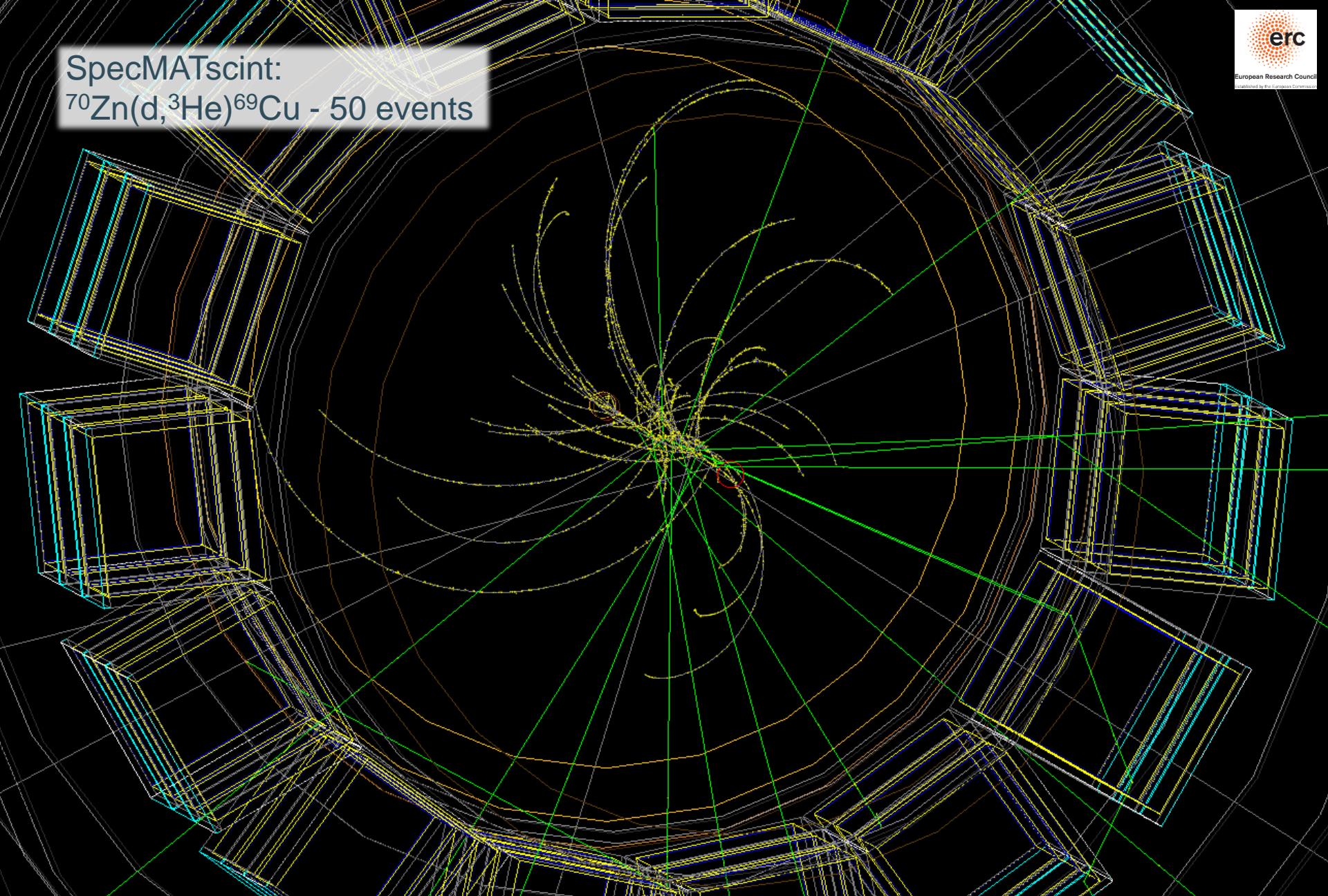
FIG. 2. Low-lying levels in copper isotopes resulting shell model calculations.

T. Otsuka



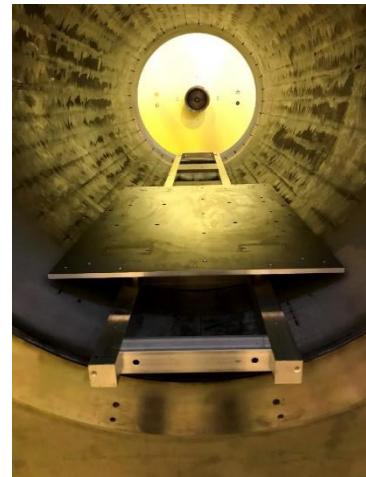
SpecMATscint:

$^{70}\text{Zn}(\text{d}, ^3\text{He})^{69}\text{Cu}$ - 50 events



Summary

- ✓ The SpecMAT active target was assembled.
 - ✓ With some parts successfully tested in ISS.
 - ✗ Some of the arrived parts (MICROMEGAS + suppl. electronics) has low production quality → require repair.
- ✓ The scintillation array was characterised.
- ✓ The TPC was characterised.
- ✓ A working set of simulations.
- ✓ We are looking towards an experimental campaign



Thank you for your attention!