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SpecMAT
Spectroscopy in a Magnetic Active Target

Riccardo Raabe

KU Leuven, Instituut voor Kern- en Stralingsfysica

Argonne NATIONAL LABORATORY

ReA Solenoidal Spectrometer Projects

Si arrays, active targets, and beyond

24 March 2017, Physics Division, Argonne National Laboratory

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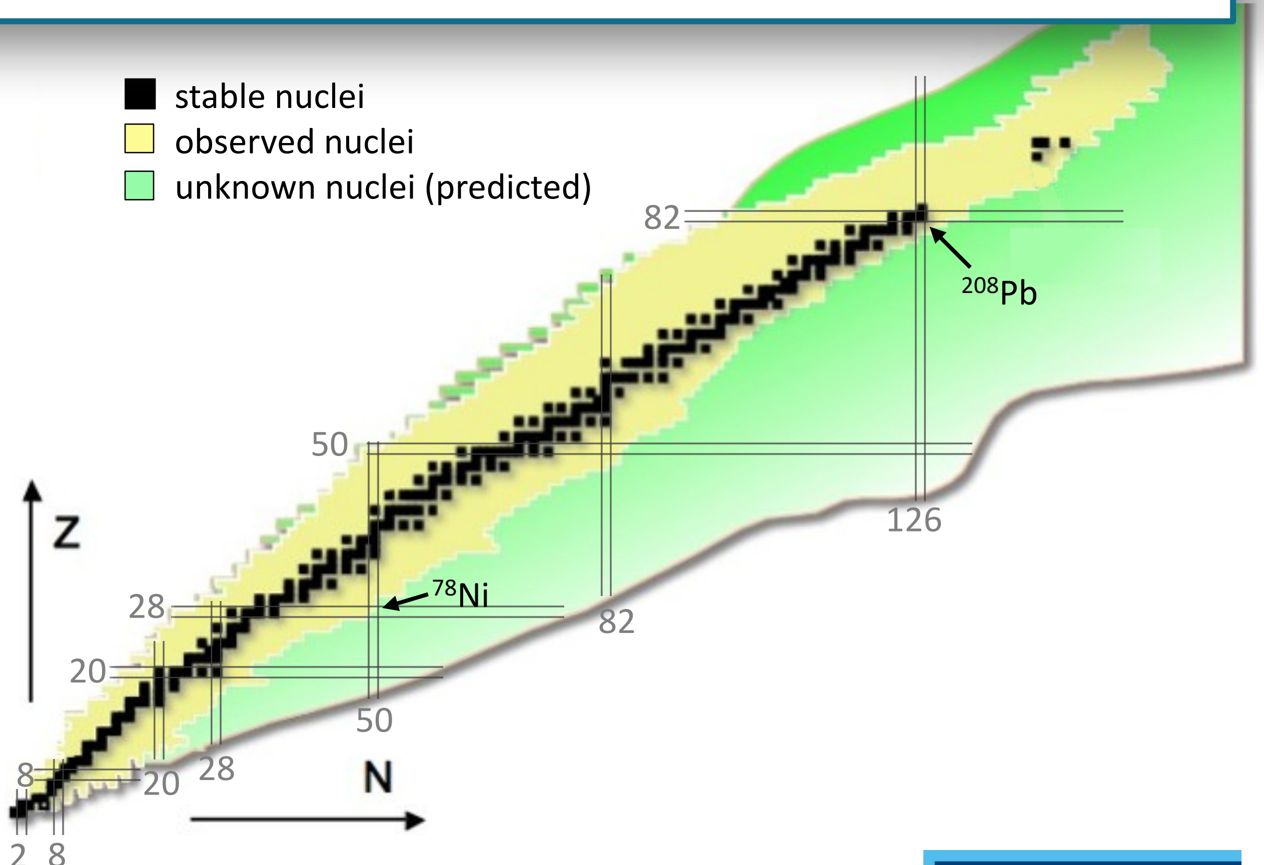
The physics (motivation)

- What are the **forces driving the shell structure in nuclei and how do they change** in nuclei far from stability?
- What remains of the **Z = 28 and N = 50 "magic numbers"** in ^{78}Ni?
- Do we understand **shape coexistence in nuclei**, and what are the mechanisms controlling its appearance?

Changes in nuclear structure far from stability

- Shell evolution towards ^{78}Ni
- Shape coexistence "west" of ^{208}Pb



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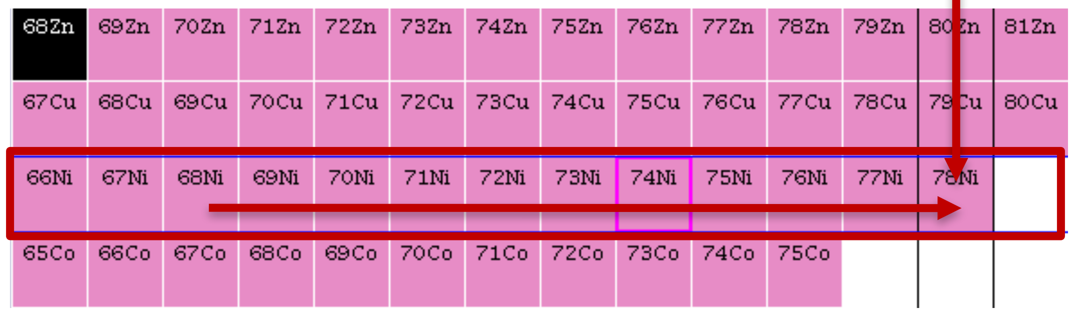
Shell evolution towards ^{78}Ni

- Migration of $\pi f_{7/2}$, $\pi f_{5/2}$ as $\nu g_{9/2}$ is filled (tensor interaction)



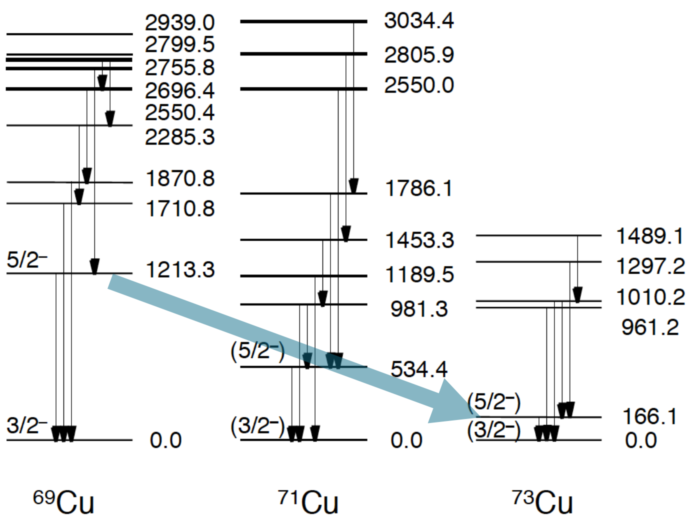


FIG. 4. Energy level systematics for ^{69,71,73}Cu. Energies are given in keV. The data for ^{69}Cu are taken from Ref. [18].

S. Franchoo et al., PRL 81 (1998) 3100

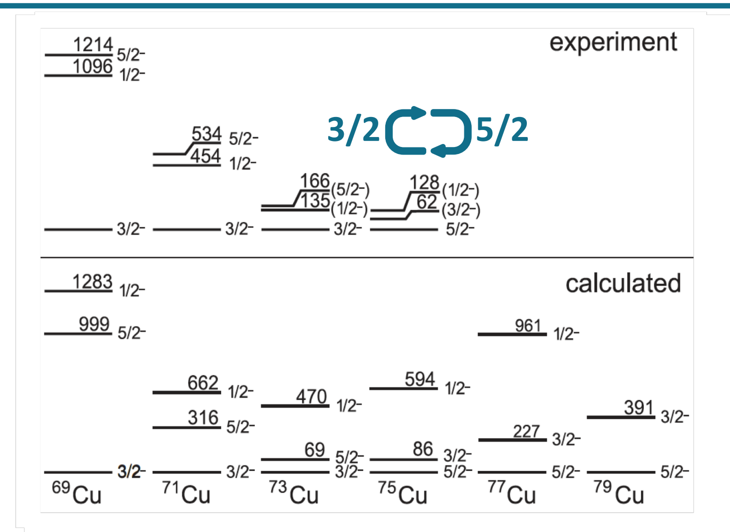


FIG. 3. Energy of the lowest levels from experiment [2,5,6] compared to large-scale shell-model calculation [25].

K. Flanagan et al.,
PRL 103 (2009) 142501

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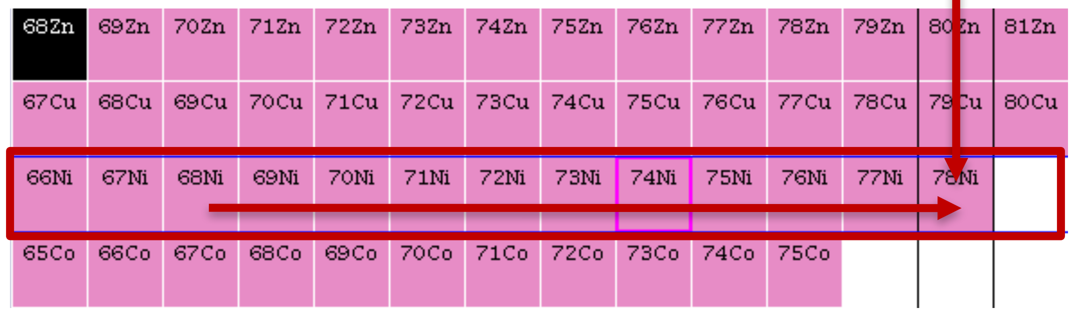

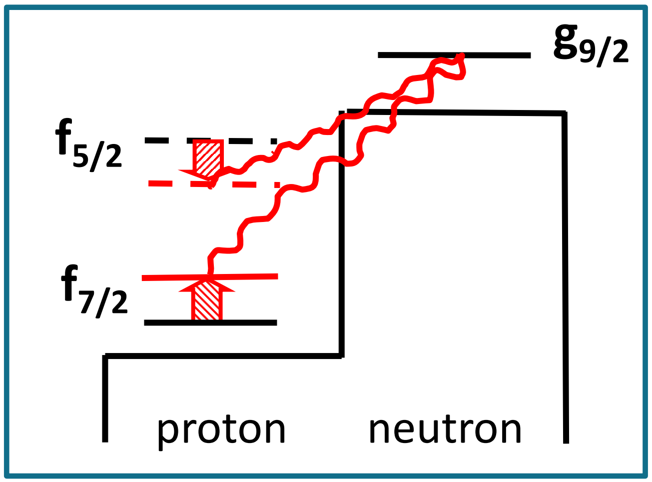

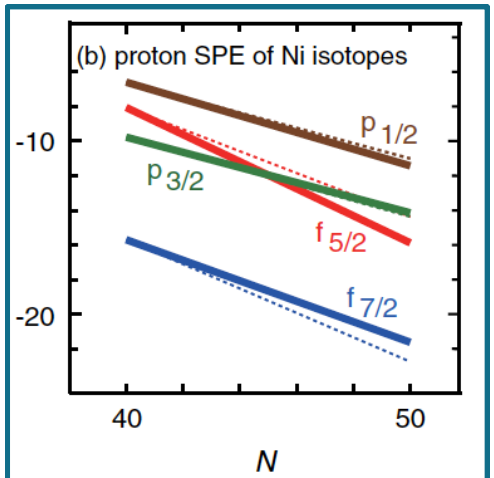

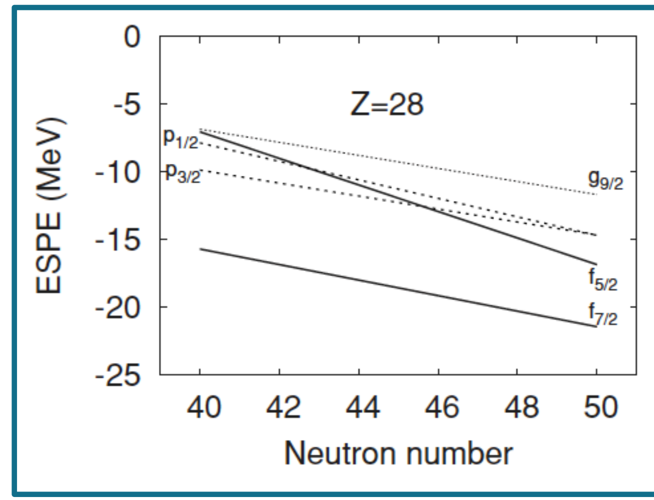

T. Otsuka, et al., PRL 104 (2010) 012501

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

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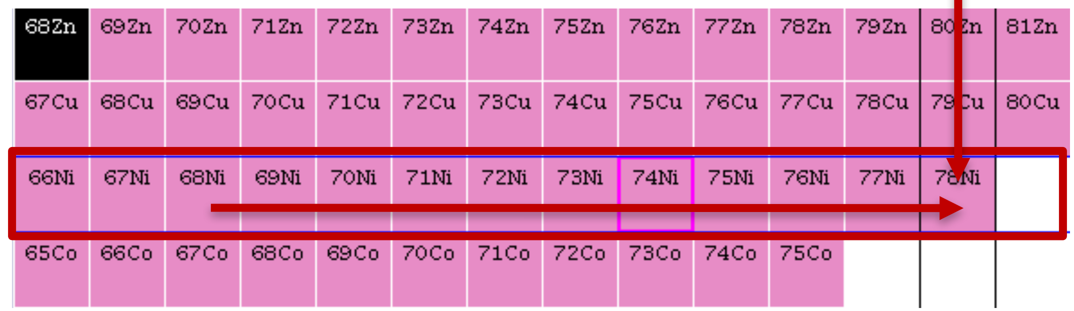
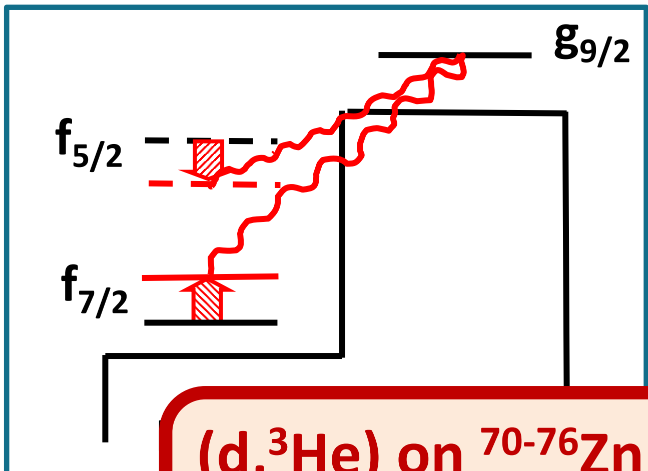
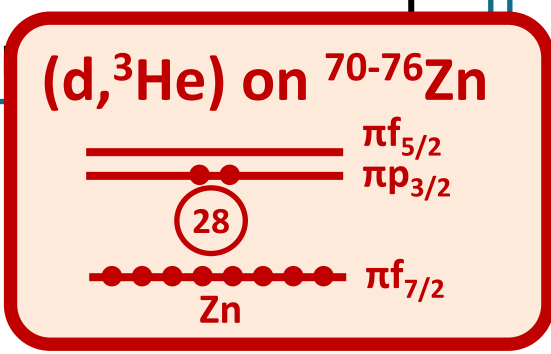
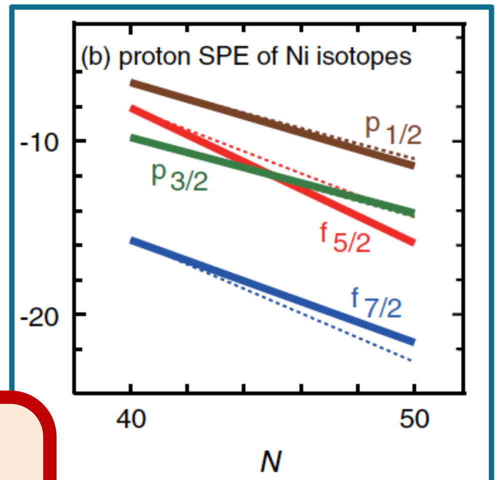
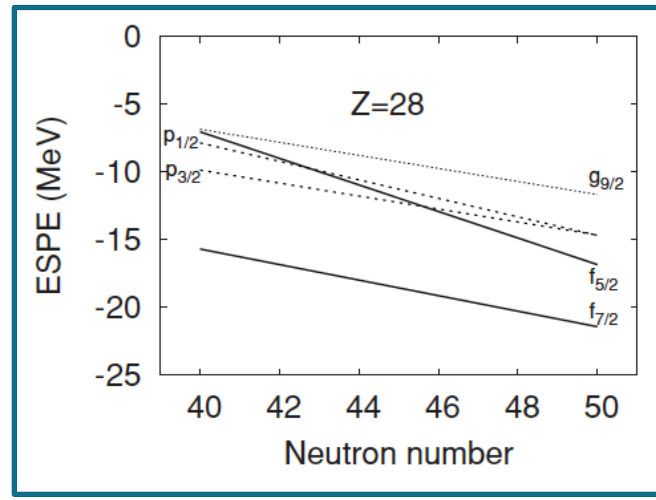








T. Otsuka, et al., PRL 104 (2010) 012501



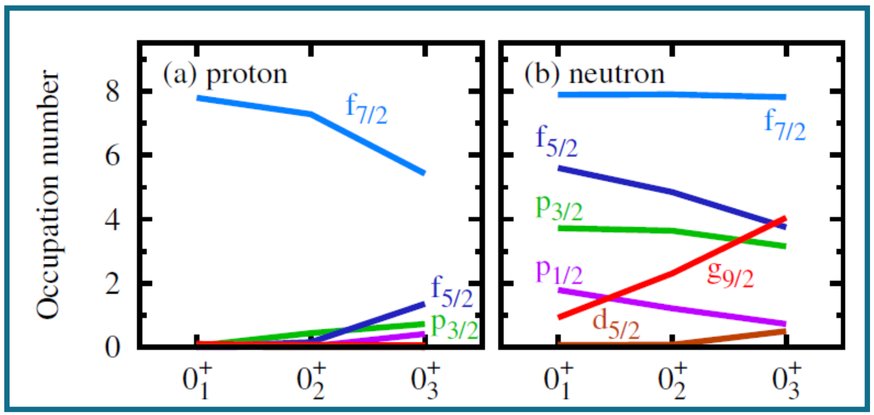
K. Sieja, F. Nowacki, PRC 81 (2010) 061303(R)

Single-particle and deformation

PHYSICAL REVIEW C **89**, 031301(R) (2014)

Novel shape evolution in exotic Ni isotopes and configuration-dependent shell structure

Yusuke Tsunoda,[1] Takaharu Otsuka,[1,2,3] Noritaka Shimizu,[2] Michio Honma,[4] and Yutaka Utsuno[5]
[1]*Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*
[2]*Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*
[3]*National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824, USA*
[4]*Center for Mathematical Sciences, University of Aizu, Ikki-machi, Aizu-Wakamatsu, Fukushima 965-8580, Japan*
[5]*Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan*
(Received 19 September 2013; revised manuscript received 25 November 2013; published 17 March 2014)



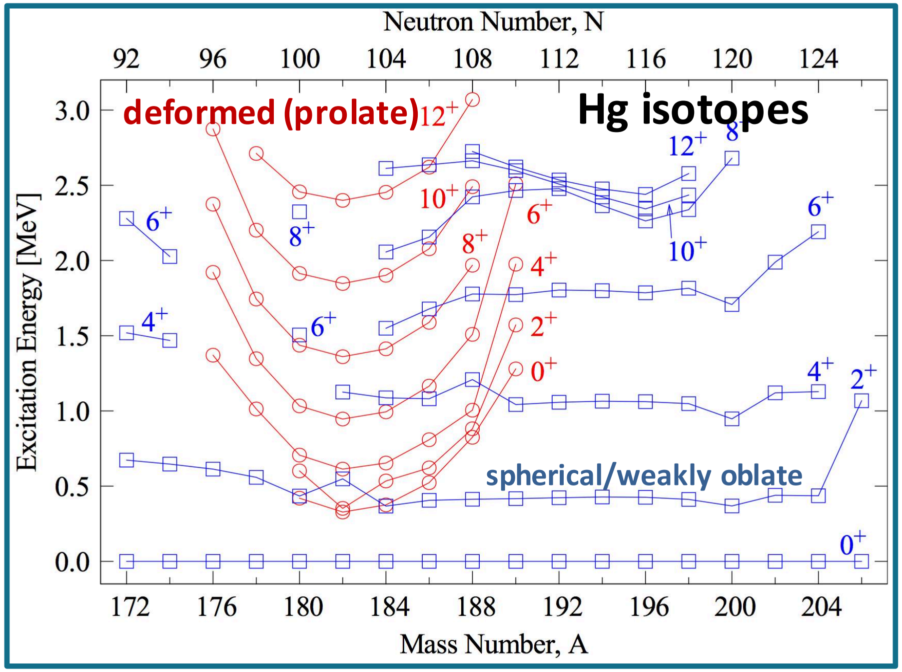
^{68}Ni

"Type II" shell evolution

- Deformation can induce changes in occupancy…
- which, through the tensor interaction, modifies the gaps between shells

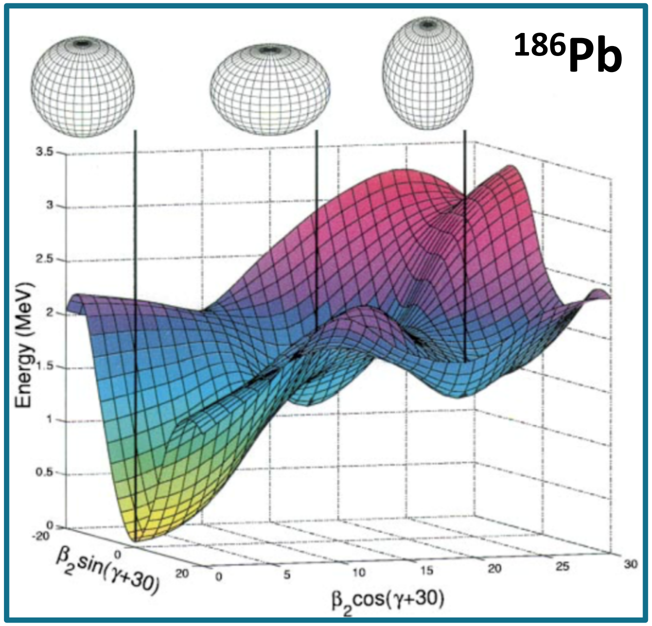
Shape coexistence "west" of ^{208}Pb

- States characterised by different shapes appear at low excitation energy
- Example: n-deficient Pb region
  ^{186}Pb triple-shape coexistence
  Hg nuclei: "parabolic intrusion" at mid-shell



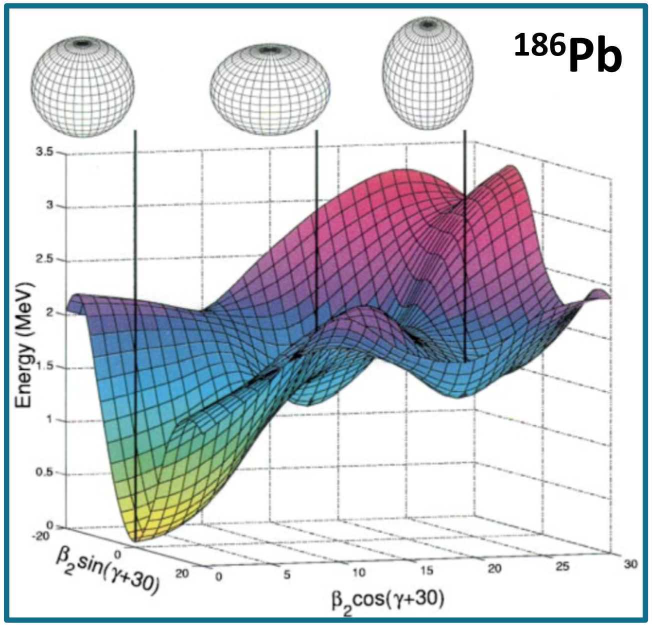
Data: NNDC
Original figure in R. Julin et al., J. Phys. G 27 (2001) R109

A. Andreyev et al., Nature 405 (2000) 430



Shape coexistence “west” of ^{208}Pb

A. Andreyev et al., Nature 405 (2000) 430



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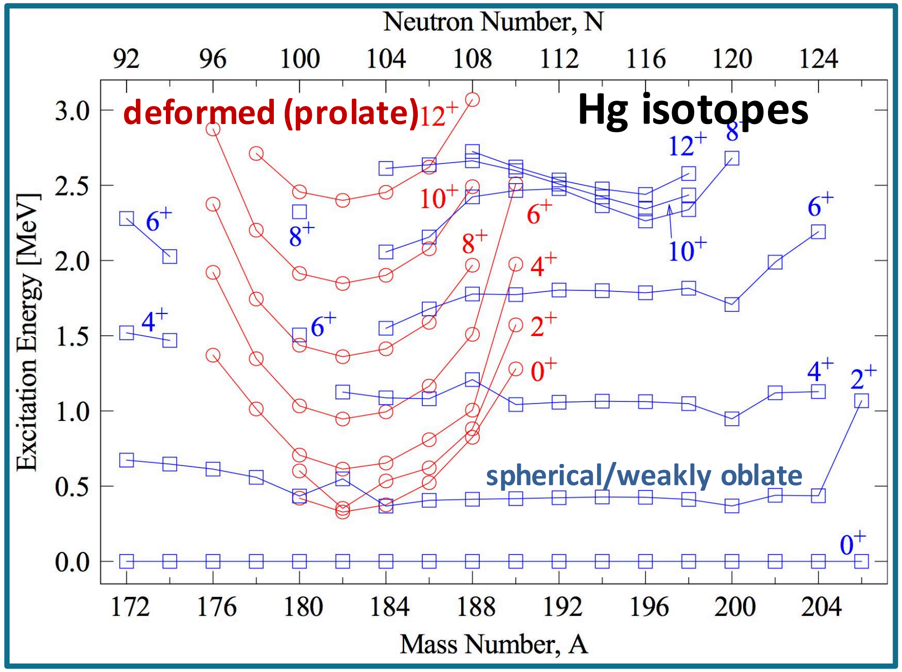

Data: NNDC, figure courtesy of Liam Gaffney
Original figure in R. Julin et al., J. Phys. G 27 (2001) R109

(d,p) and (p,d) transfers on ^{184,185g,185m}Hg (possibly ^{182}Hg), ^{188}Pb, ^{196}Po

Problem: density of states

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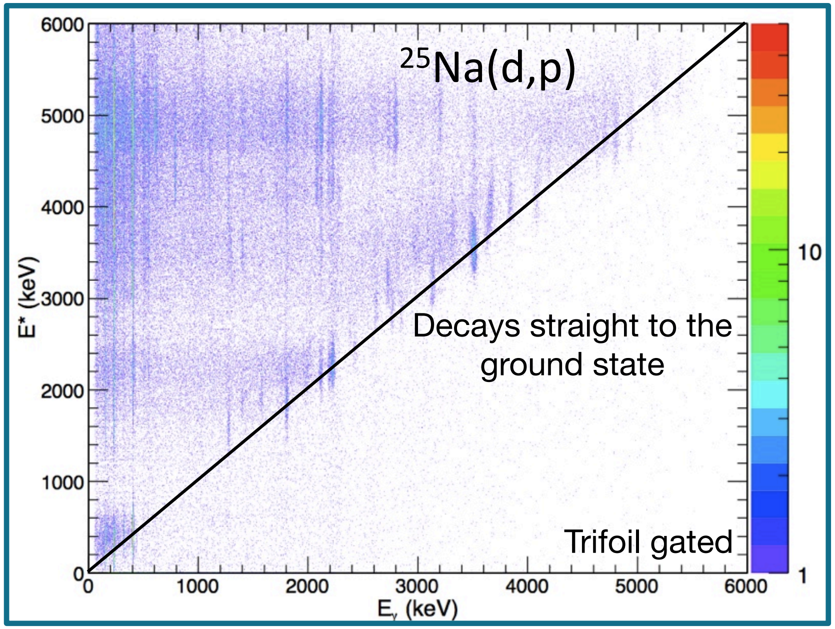
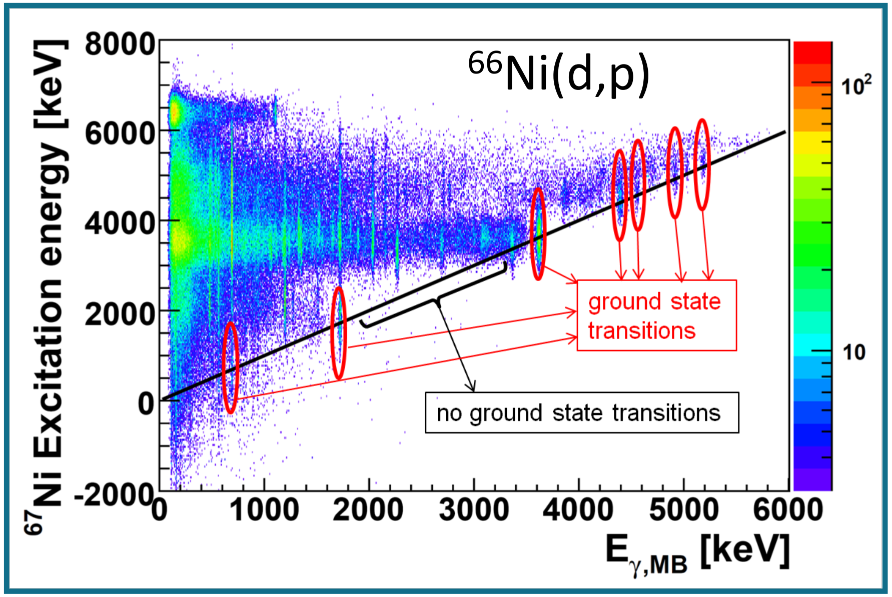
Importance of γ-ray detection

- Transition probabilities
- Energy resolution from coincidences
- Build the decay scheme



G. Wilson et al., PLB 759, 417 (2016)



J. Diriken et al., PLB 736, 533 (2014)
J. Diriken et al., PRC 91, 054321 (2015)

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Method: active target + γ-ray array

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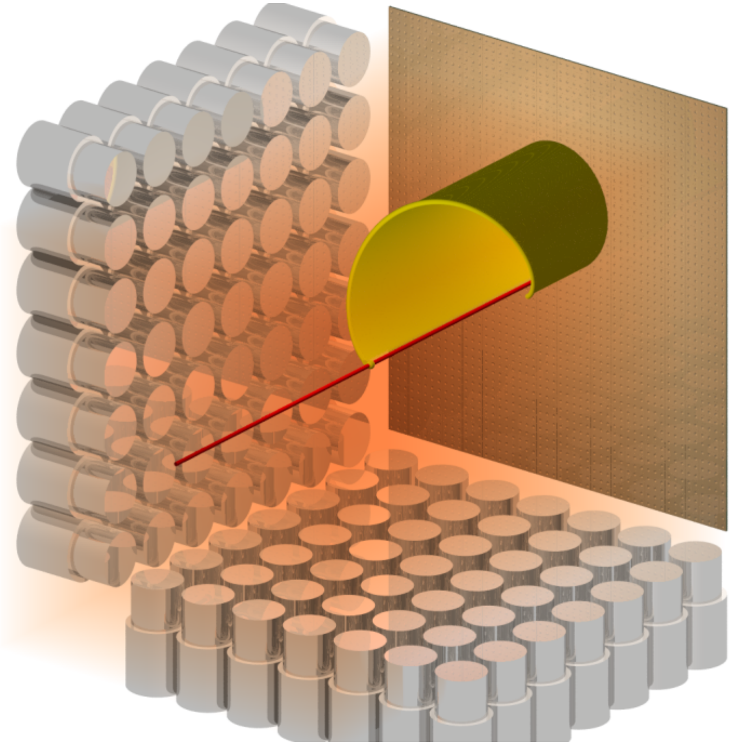
Challenges

- Resolution
- Efficiency

→ Choices

- Active target
- Magnetic field parallel
  to beam direction
  to confine emitted particles
  and minimize material
- + γ-ray detection



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Challenges for γ-ray detection

- Good resolution and efficiency
- Placement in a magnetic field
- Possible use of digital electronics
- Budget

→ Scintillation crystals ($LaBr_3$ or $CeBr_3$)

→ Silicon photomultipliers (SiPMs)

→ Compact design

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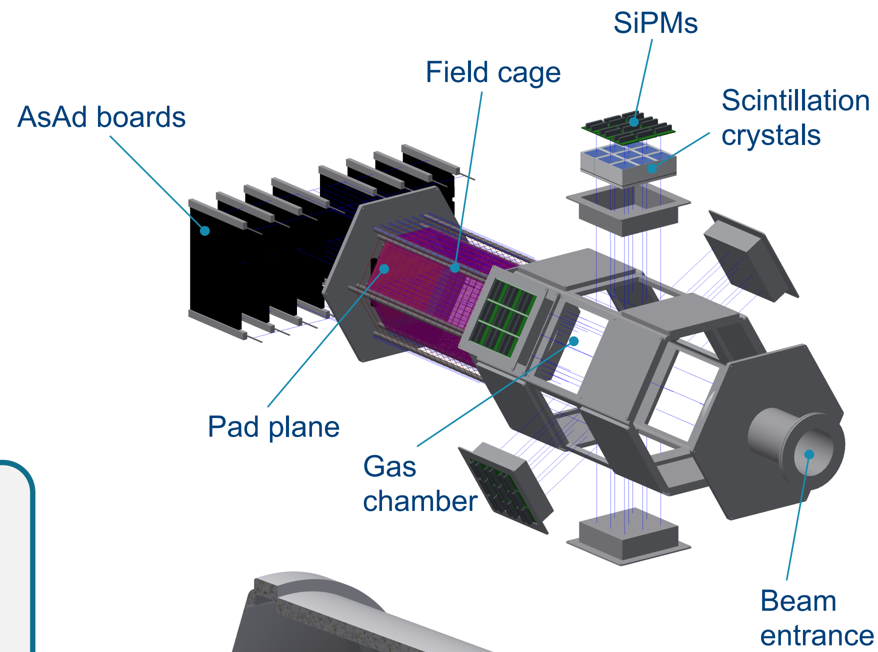
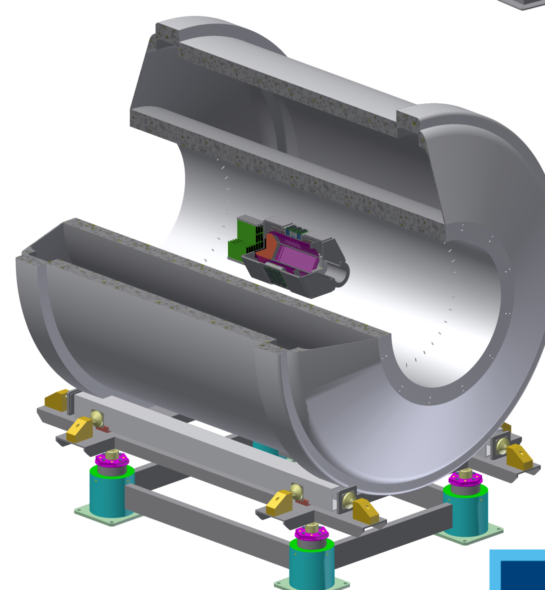
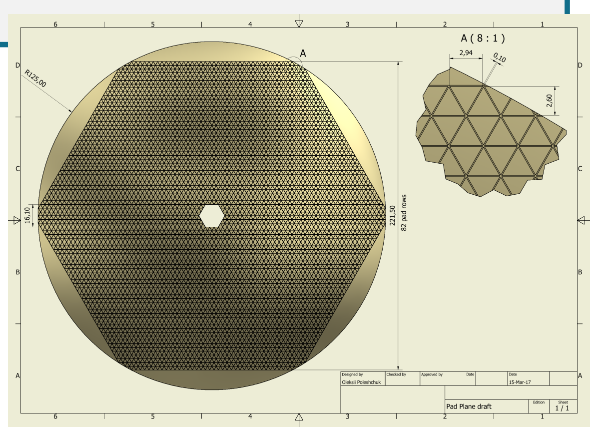
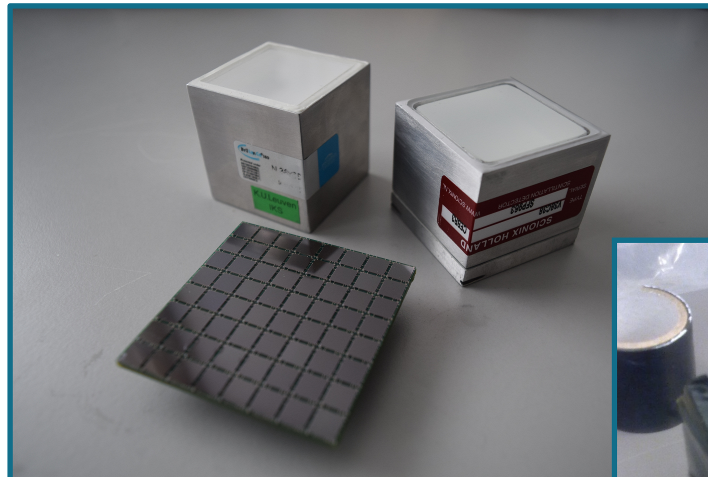


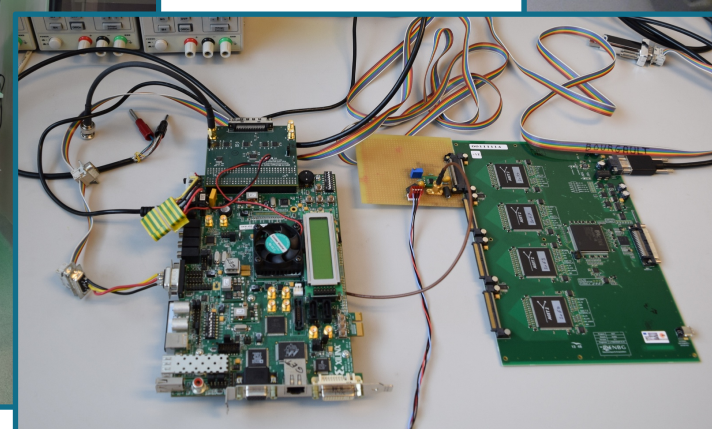




Characterising the scintillation crystals

- Test resolution against
  - SiPMs
  - Digital electronics
  - Magnetic field
- Optimise efficiency
  - validate results of simulations





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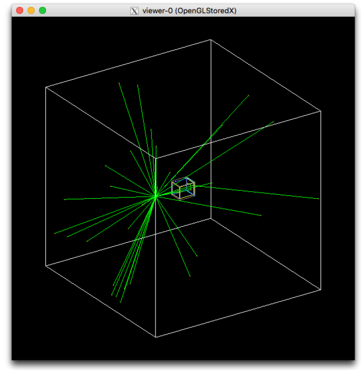
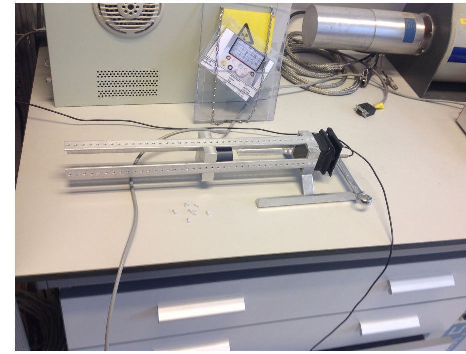
Efficiency

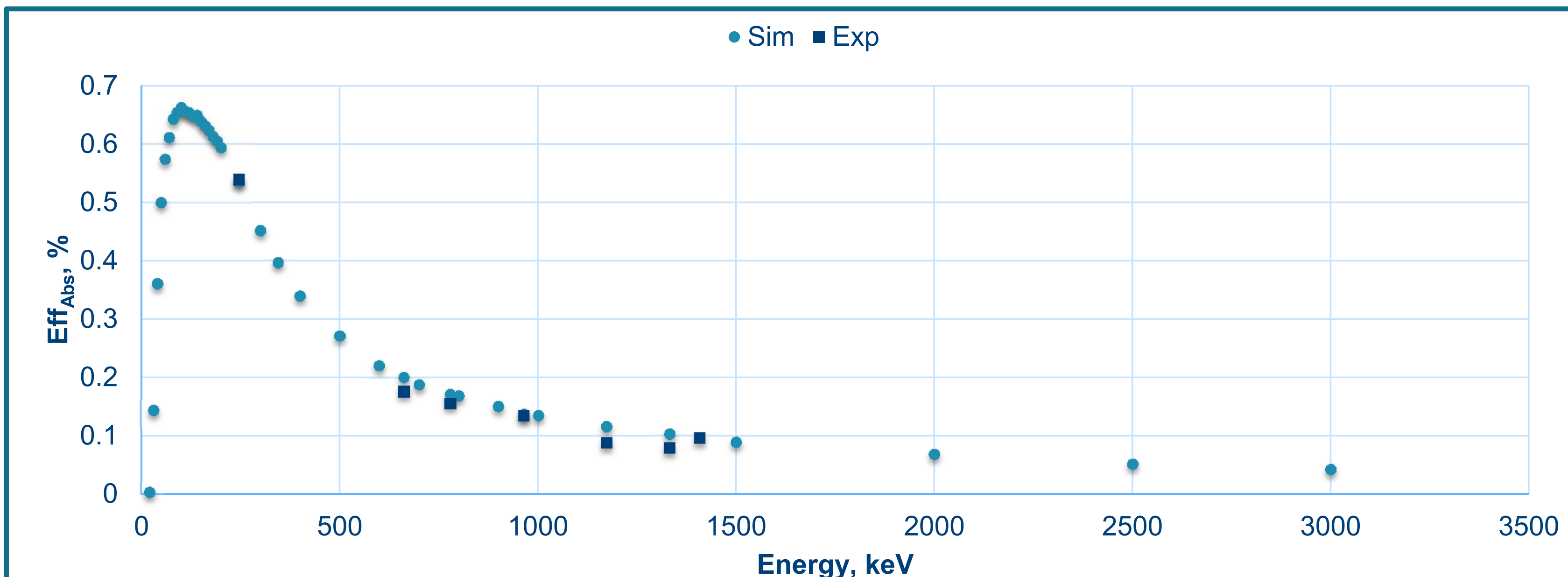
Work of J.A. Swartz, O. Poleshchuk

- 1.5”x1.5”x1.5” $CeBr_3$ at 120 mm

→ Simulation under control







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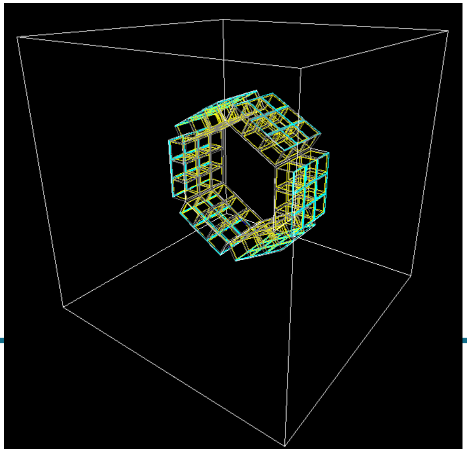
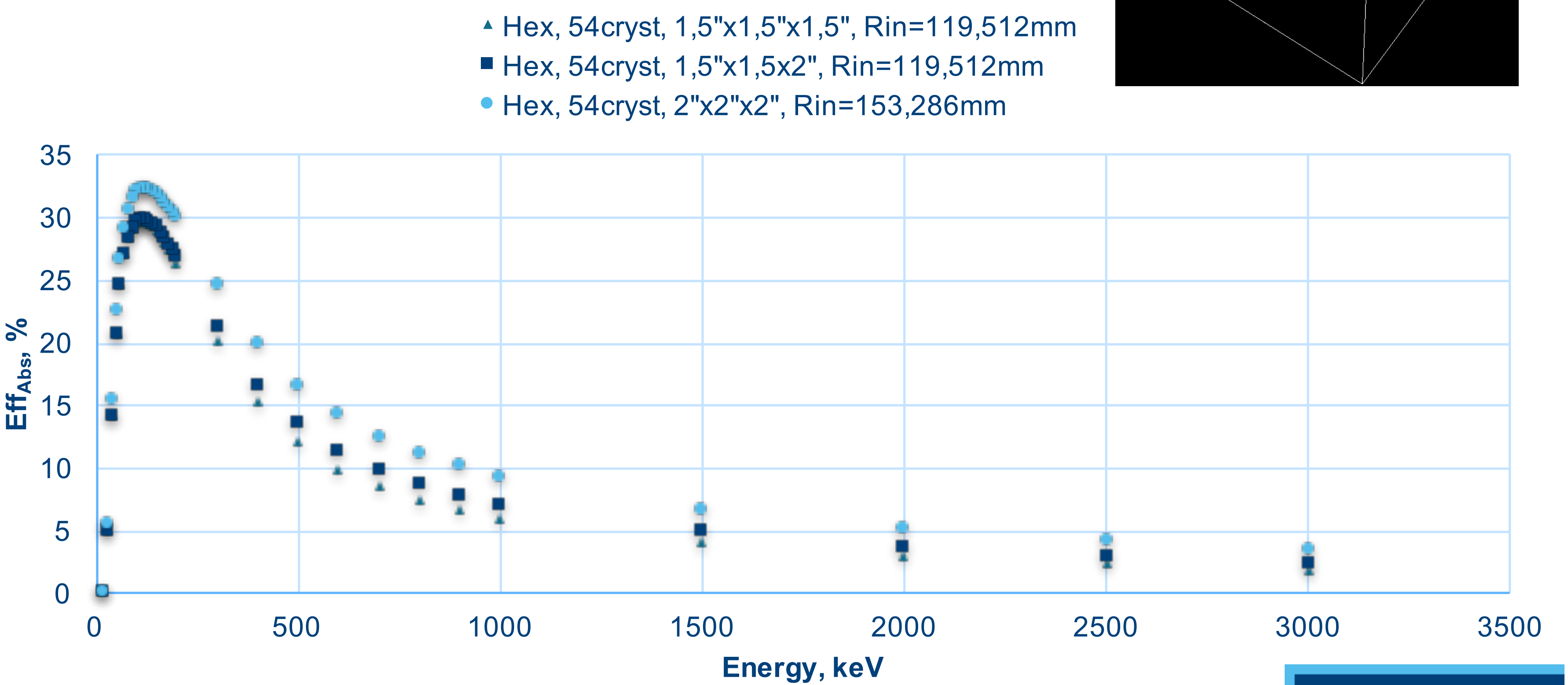
Efficiency

Work of J.A. Swartz, O. Poleshchuk

- Detector size

→ the bigger the better

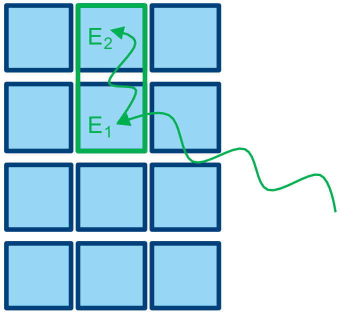




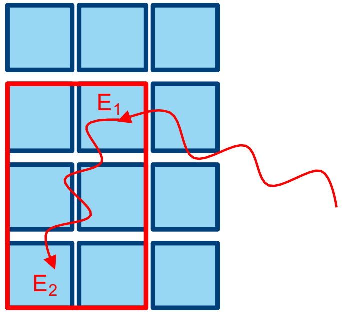
Efficiency

Work of J.A. Swartz, O. Poleshchuk

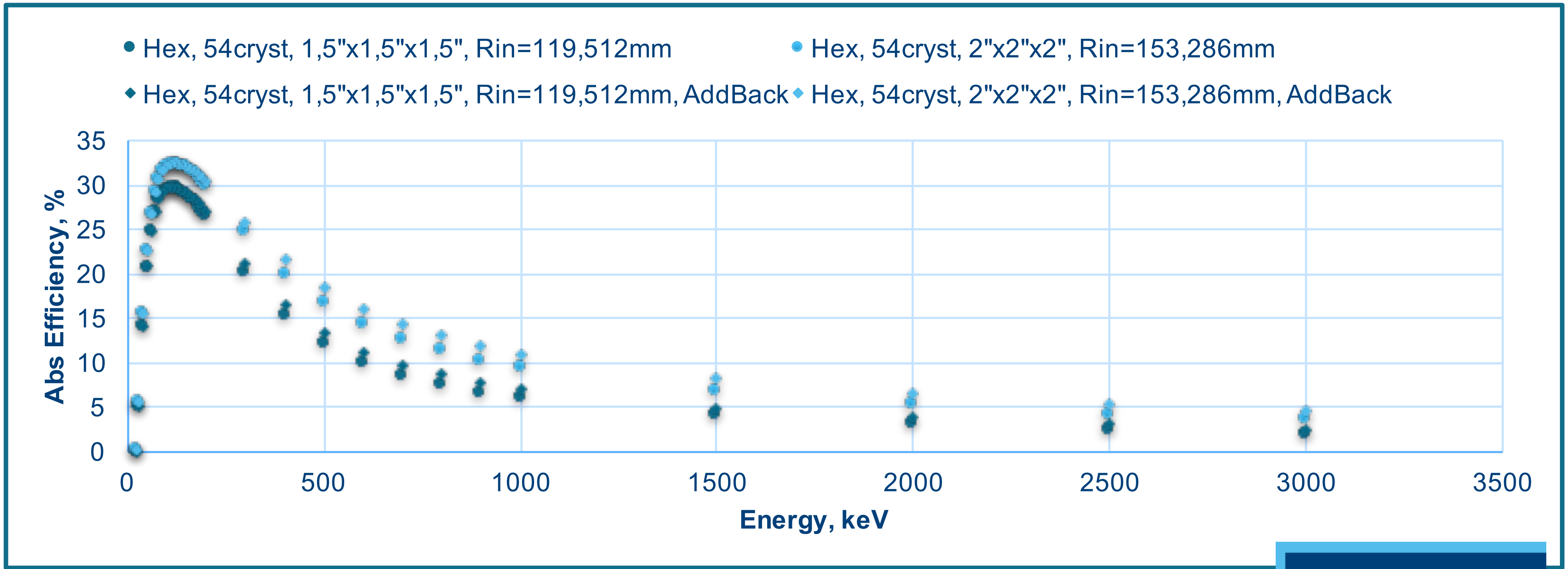
- Add-back
  only neighbouring crystal
- Understand from count rate
  if other addback possible



E_1 and E_2 replaced by $E_{AddBack} = E_1+E_2$



E_1 and E_2 remain unchanged



Resolution

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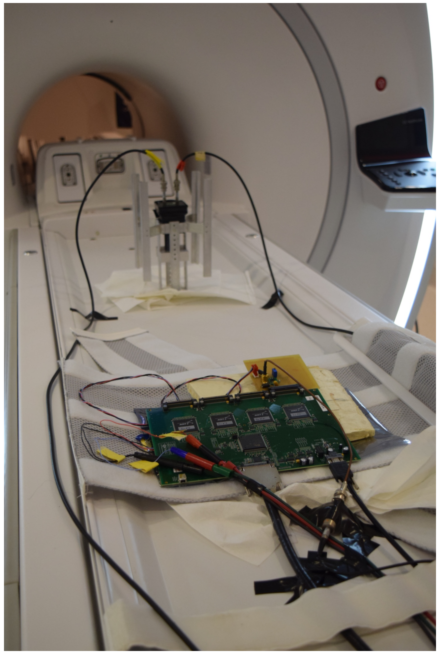
Work of J.A. Swartz, O. Poleshchuk

Tests in 3T-magnetic field at the UZ Leuven

- 1,5"x1,5"x1,5" $LaBr_3$ and $CeBr_3$ crystals
- C-series SiPM array
- Analog, Standard digital (CAEN) and GET system

	DAQ	Analogue	CAEN	GET
Detector	B-field	No field	No field	No field
$CeBr_3$+SiPM	No field	5.3 %	5.7 %	6.0 %
$CeBr_3$+SiPM	3T	5.3 %	5.6 %	6.0 %
$LaBr_3$+SiPM	No field	3.5 %	3.7 %	4,2 %
$LaBr_3$+SiPM	3T	3.5 %	3.9 %	4.2 %



→ No measurable effect of the magnetic field
→ Resolution worse (≈1%) through use of SiPMs and digital electronics

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Status – Conclusions

- Scintillation detectors purchased, delivery within 8 months
- Chamber design in full progress
- GET electronics (2000 channels) acquired
- First version pad plane and assembly by end 2017
  tests in Legnaro or Catania
- Measurements in 2018 (?)

Thanks to the SpecMAT team!

A. Arokja Raj, M. Babo, S. Ceruti, T. Marchi, O. Poleshchuk, M. Renaud, H. De Witte, J. Yang

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