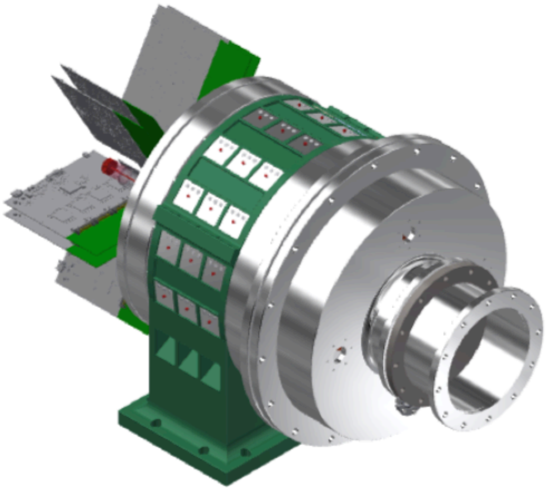
SpecMAT
Spectroscopy of exotic nuclei in a Magnetic Active Target

Riccardo Raabe
KU Leuven, Instituut voor Kern- en Stralingsfysica

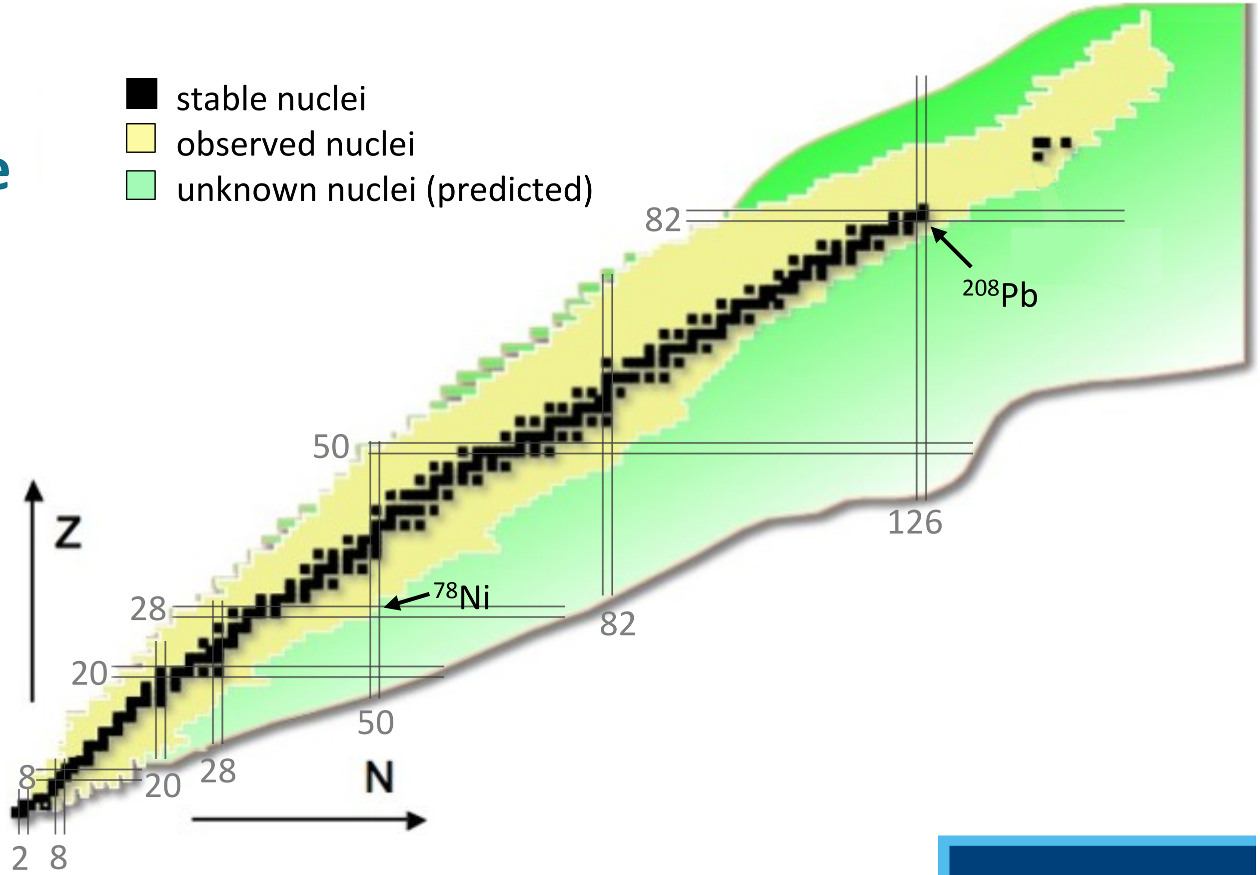


Physics goals

- 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?

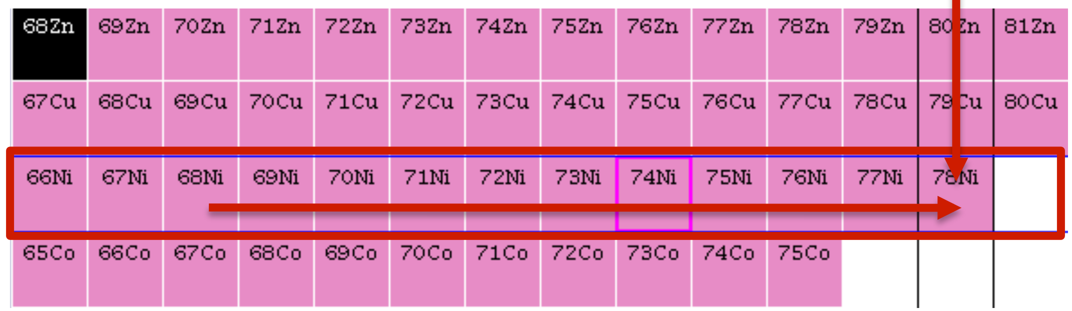
Changes in nuclear structure far from stability

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



Shell evolution towards ^{78}Ni

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



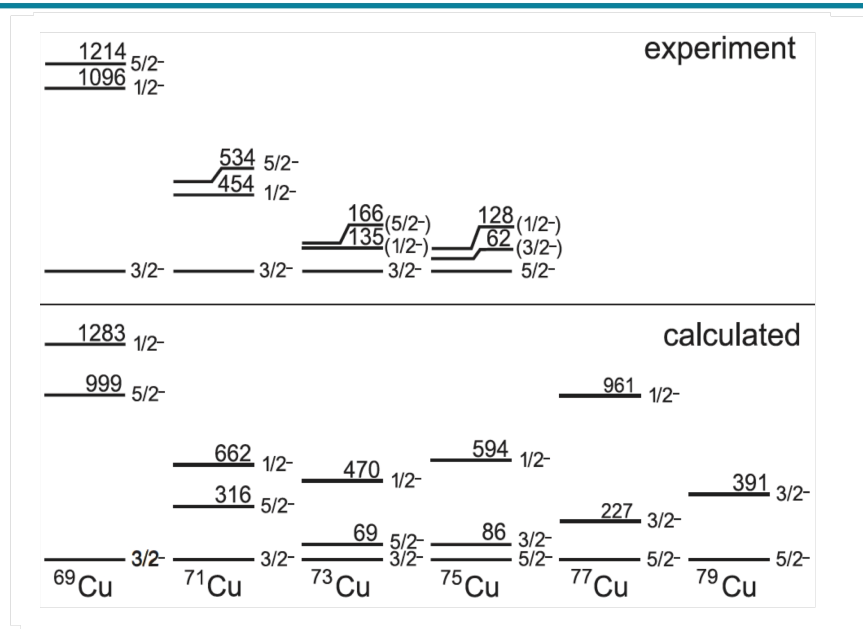


FIG. 3. Energy of the lowest levels from experiment [2,5,6] compared to large-scale shell-model calculation [25].

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

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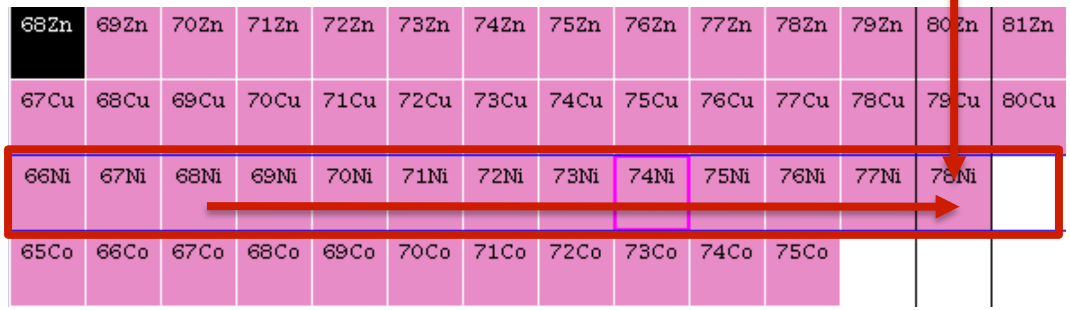

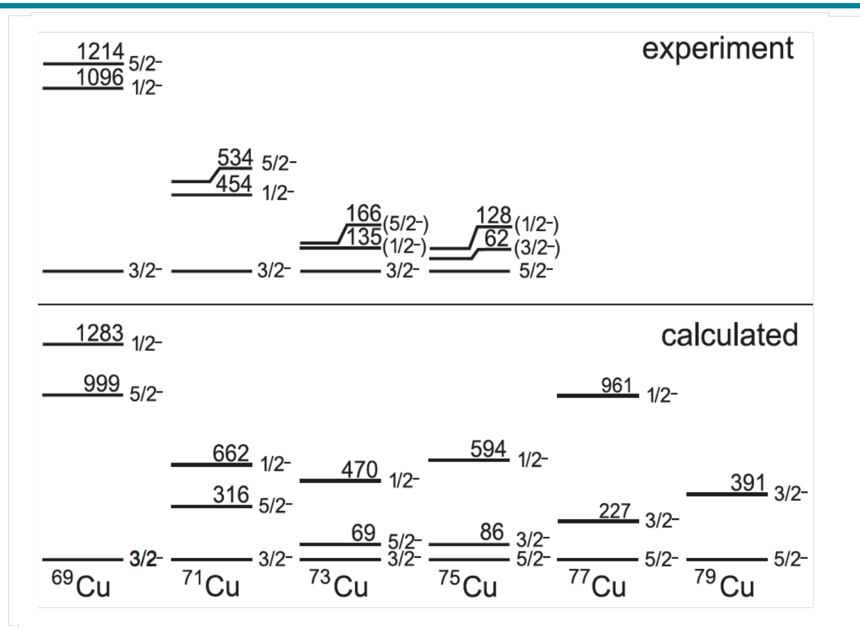

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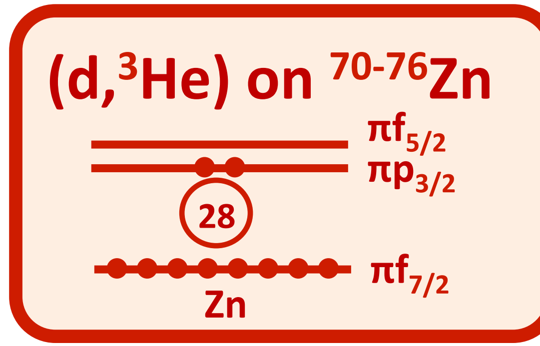
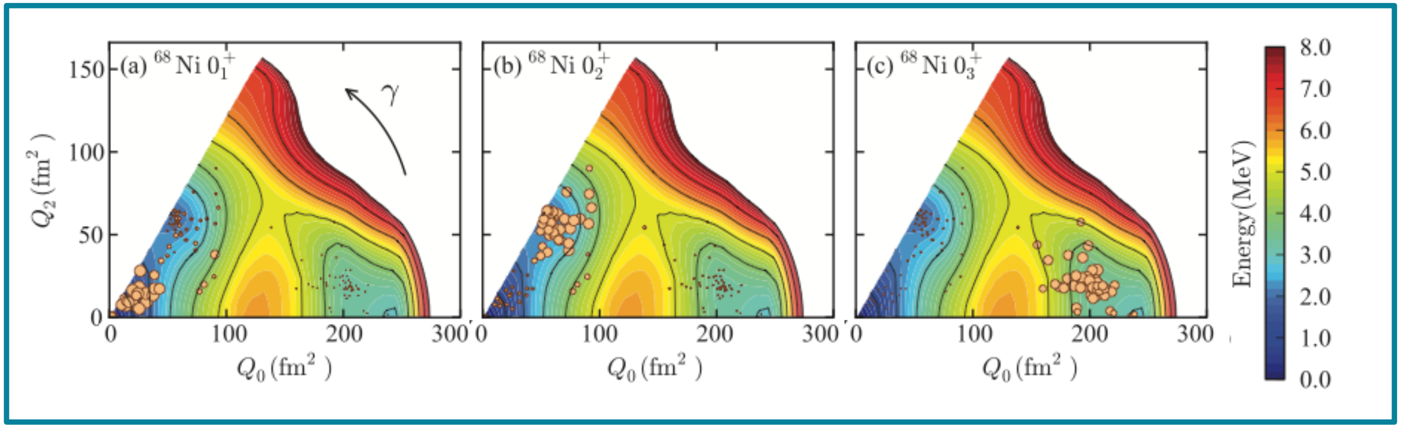
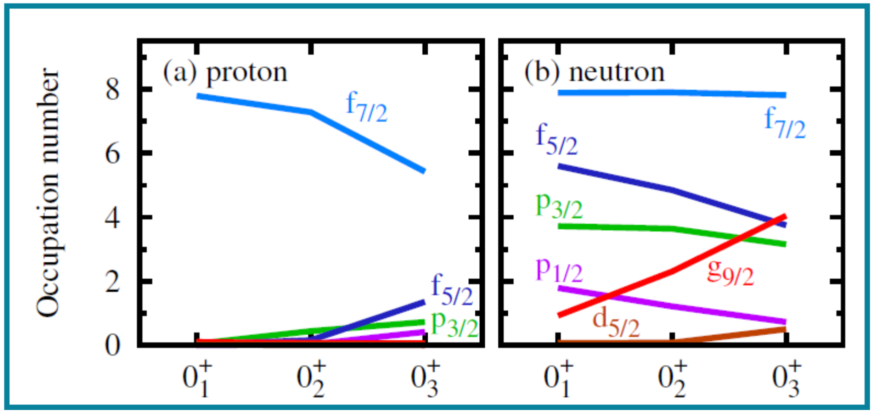


Shell evolution and shape coexistence

Y Tsunoda, T Otsuka et al., PRC 89 (2014) 031301

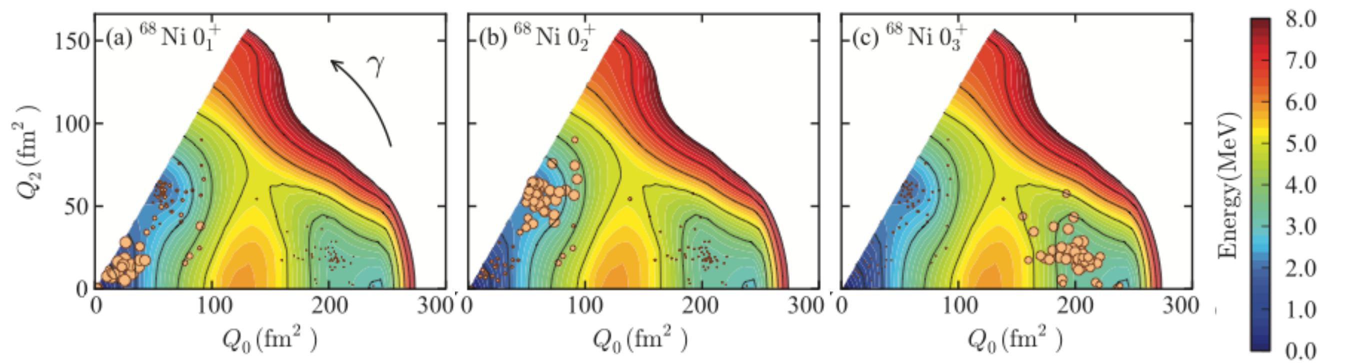


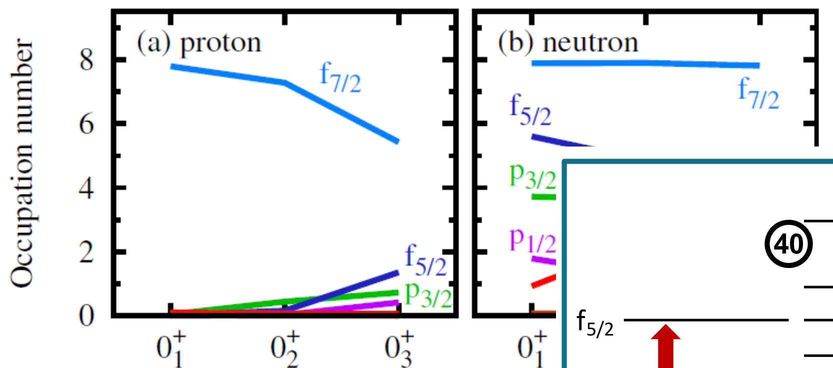


^{68}Ni

Shell evolution and shape coexistence

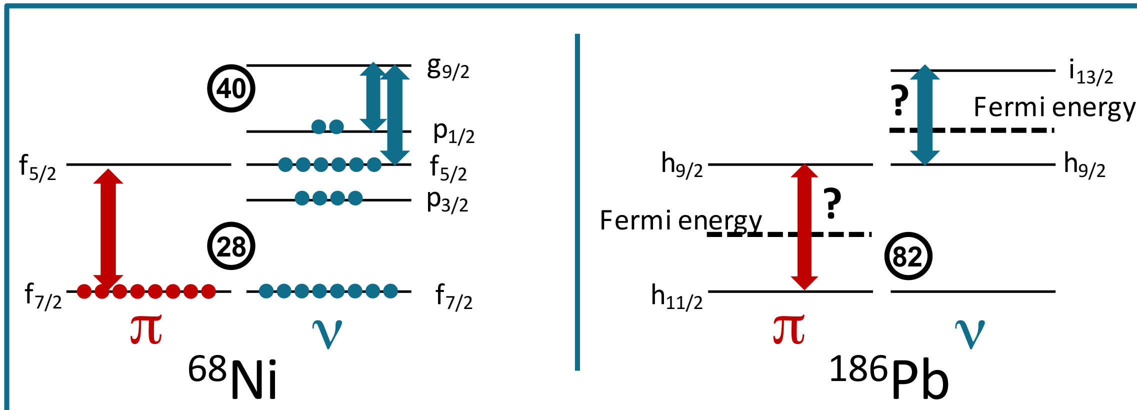
Y Tsunoda, T Otsuka et al., PRC 89 (2014) 031301





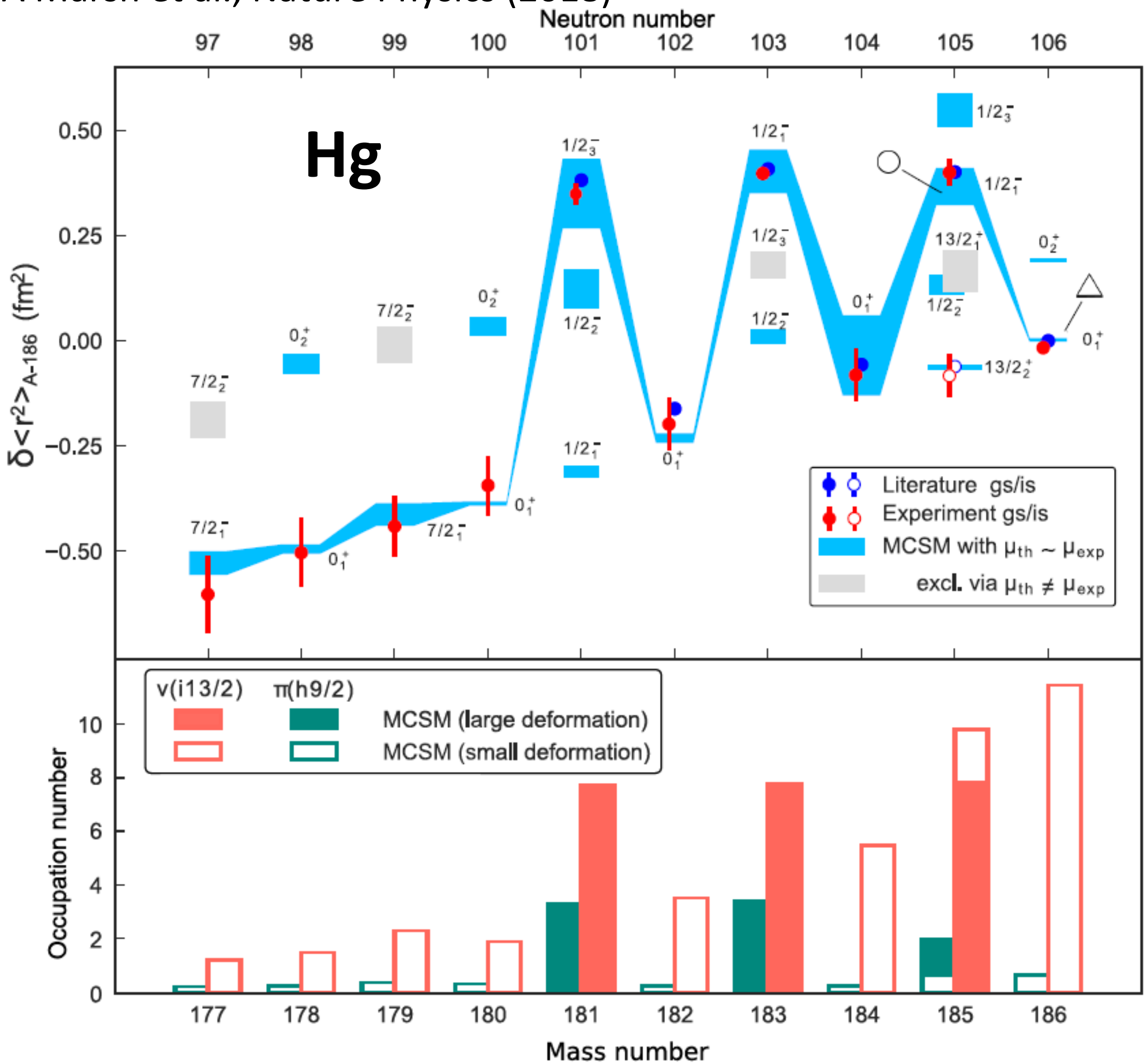
^{68}Ni

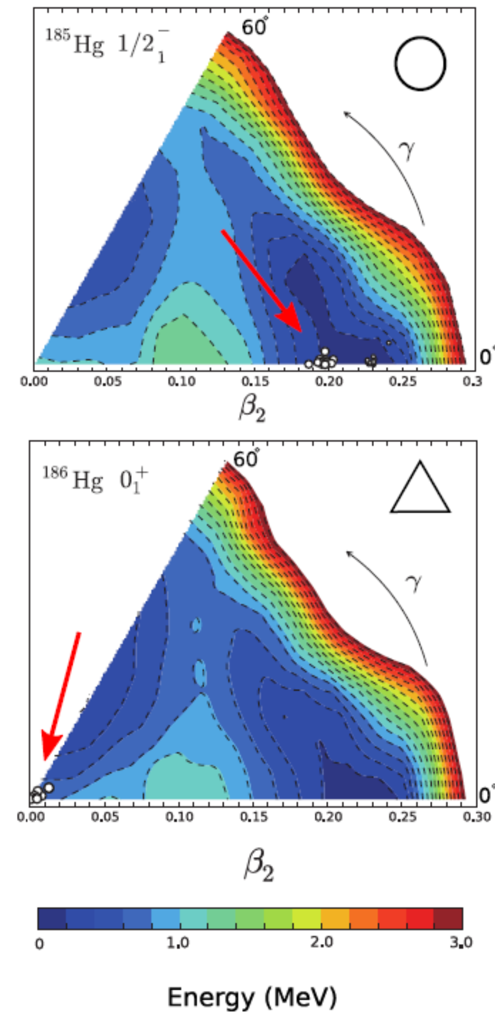
T Otsuka and Y Tsunoda, JPG 43 (2016) 024009



The n-deficient Pb region

B A Marsh et al., Nature Physics (2018)

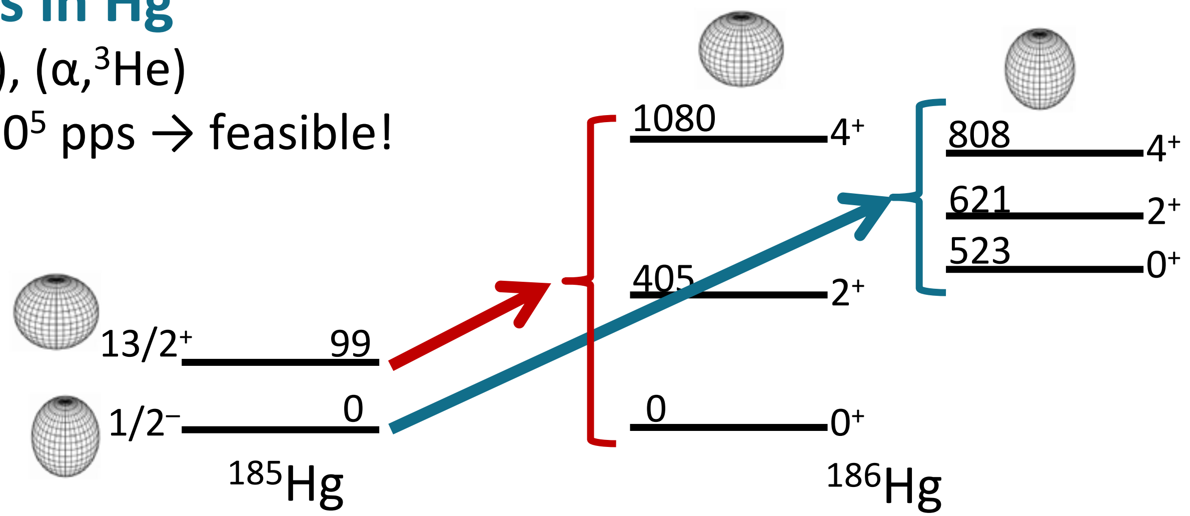


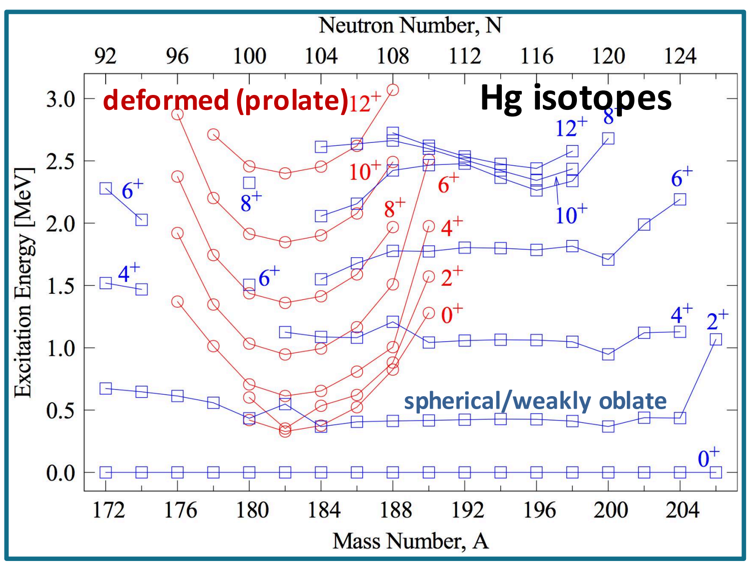


The n-deficient Pb region

Transfer reactions in Hg

- ^{185g,m}Hg (d,p), (p,d), (α,^{3}He)
- Beam intensity ≈ 10^5 pps → feasible!





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

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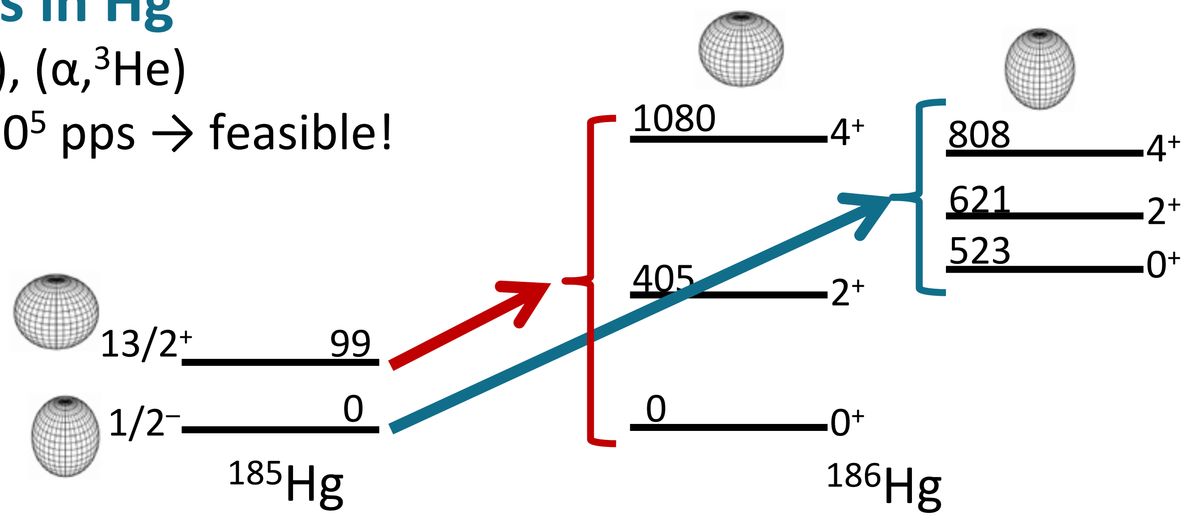
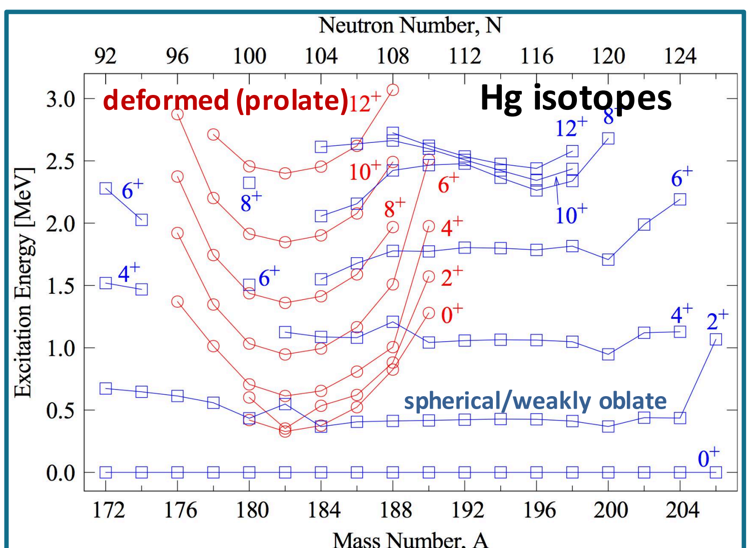




LOI I-195

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Investigating single-particle configurations in deformed Hg and Cd isotopes

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

Study of the Pigmy Dipole Resonance

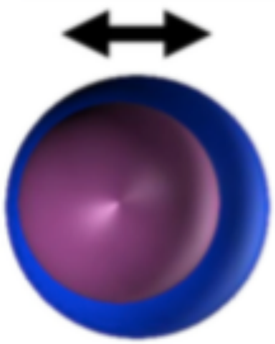
Low-energy dipole strength

- First observation in 1961
  γ rays from neutron capture
  G.A. Bartholomew, Annu. Rev. Nucl. Sci. 11 (1961) 259

- First use of "pygmy resonance" (PDR)
  J.S. Brzosko et al., Can. J. Phys 47 (1969) 2849

- Description as a collective excitation
  Mohan et al., Phys. Rev. C 3 (1971) 1740
  "Three-Fluid Hydrodynamical Model of Nuclei":
  Neutron excess oscillates against the N=Z core

- Different experimental probes
  to investigate the isospin nature of these states



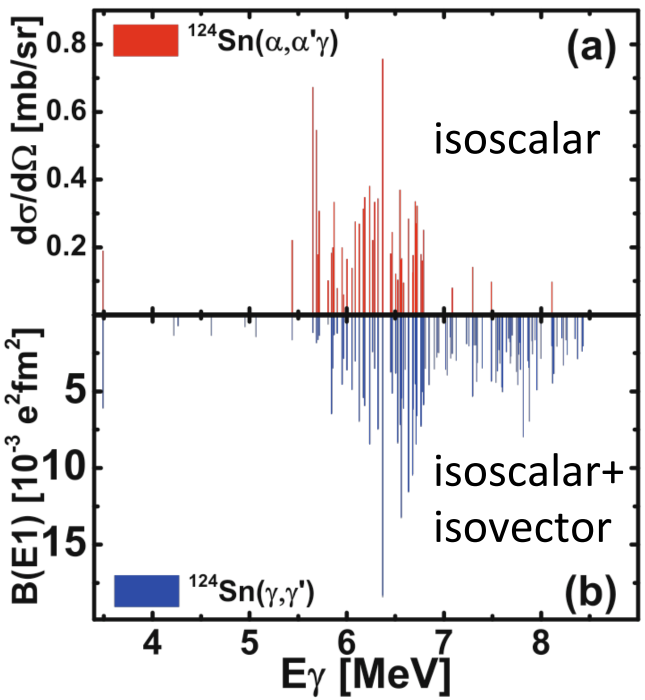
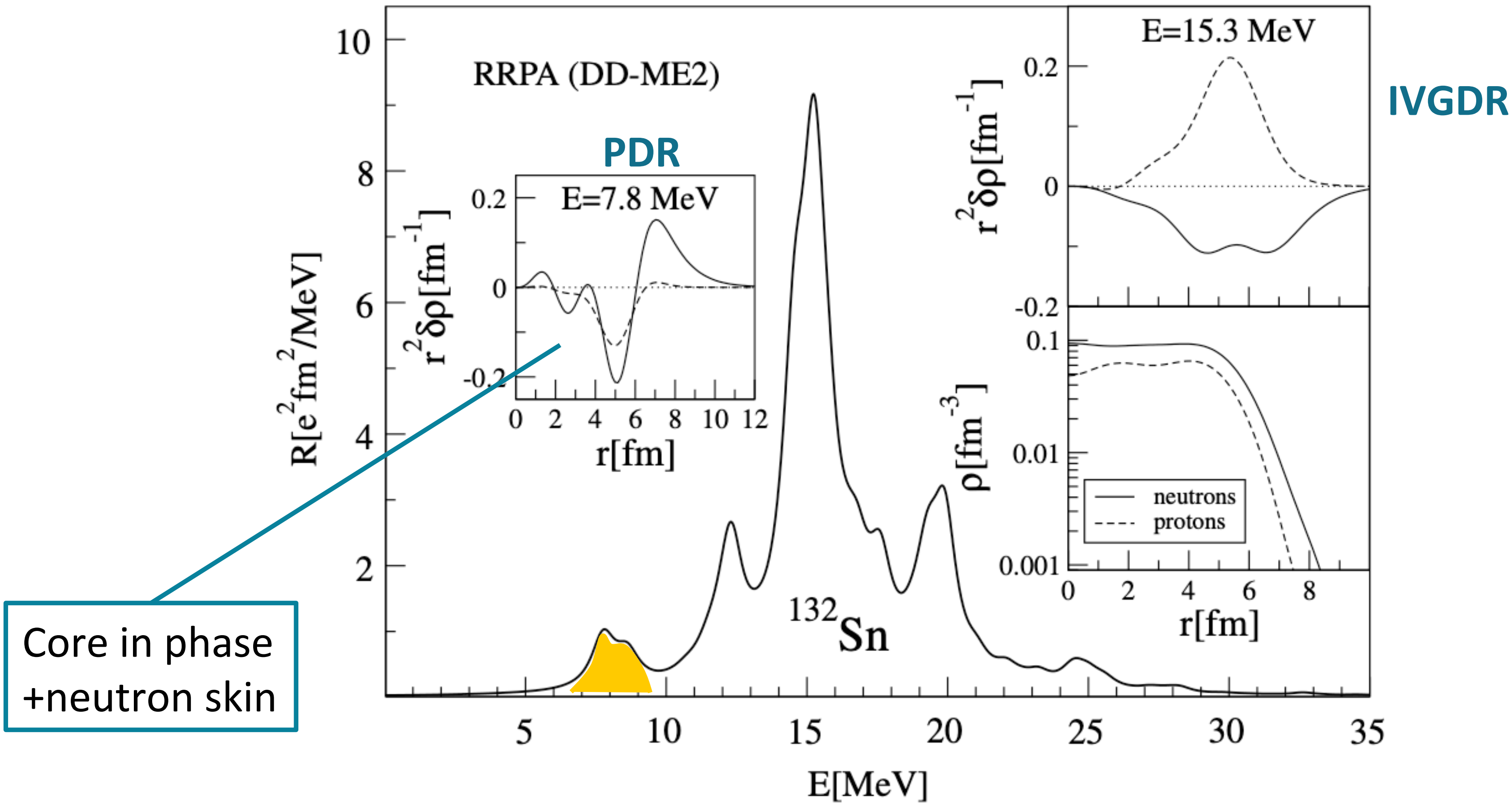


Figure A. Bracco et al., Eur. Phys. J. A 51 (2015) 99
Data from K. Govaert et al., Phys. Rev. C 57 (1998) 2229
and J. Endres et al., Phys. Rev. C 85 (2012) 064331

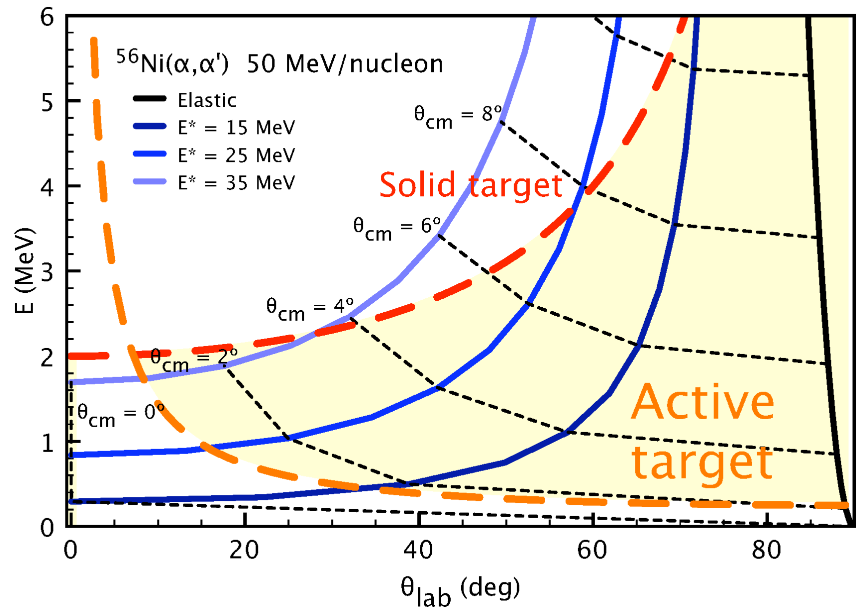
Study of the Pigmy Dipole Resonance

D. Vretenar et al., J. Phys. G 35 (2008) 014039



Study of the Pigmy Dipole Resonance

- Isoscalar probe:
  (α,α’) inelastic scattering
- SpecMAT:
  γ rays from decay of bound states



LOI I-194

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

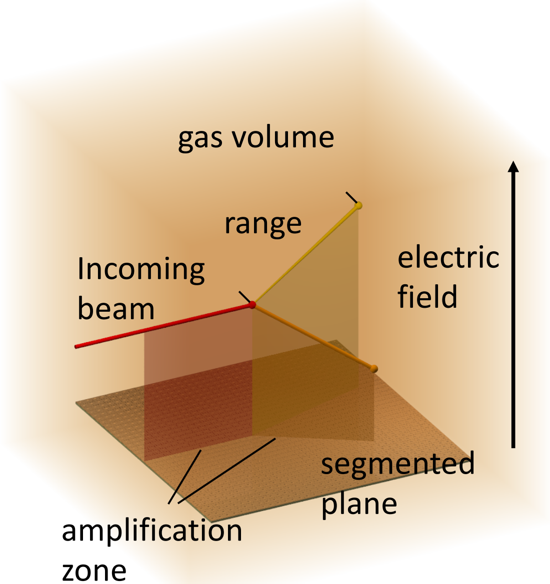
Study of the Pygmy Dipole Resonance using an Active Target

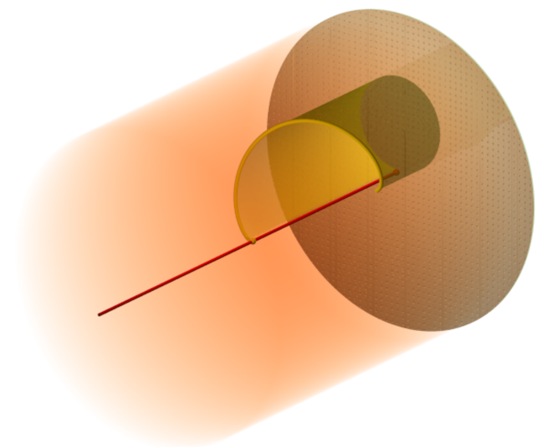
- Cases: ^{90}Sr, ^{194}Hg, ^{146,148,150}Gd
  ≈10 MeV/nucleon

The active-target method

Time-Projection Chamber (TPC)
+ gas is the target

- Full 3D track reconstruction
- High luminosity,
  keeping energy resolution
- Energy of stopped particles
  Particle identification
- Versatile:
  different gases, pressures, configurations
  ancillary detectors





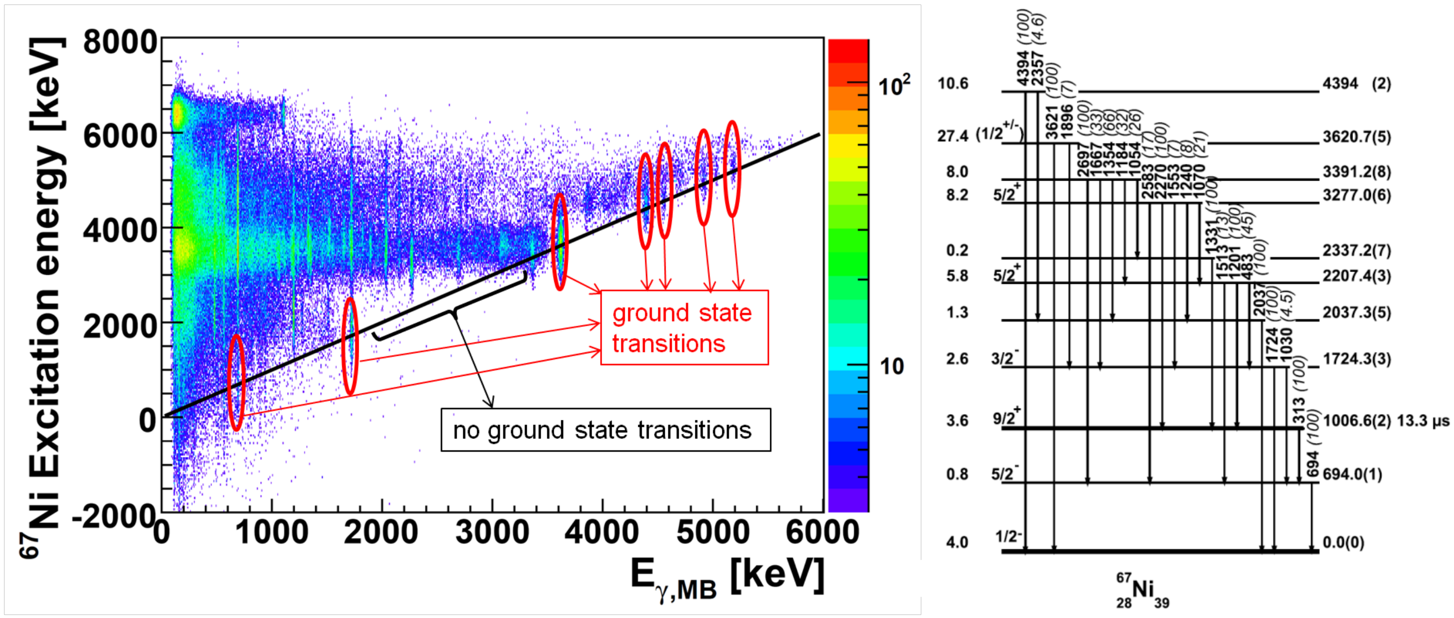
SpecMAT:
- Magnetic field parallel to the beam direction
- Drift field parallel to magnetic field

The active-target method

γ-ray detection

- $CeBr_3$ scintillators: good efficiency and resolution
- Si photomultipliers

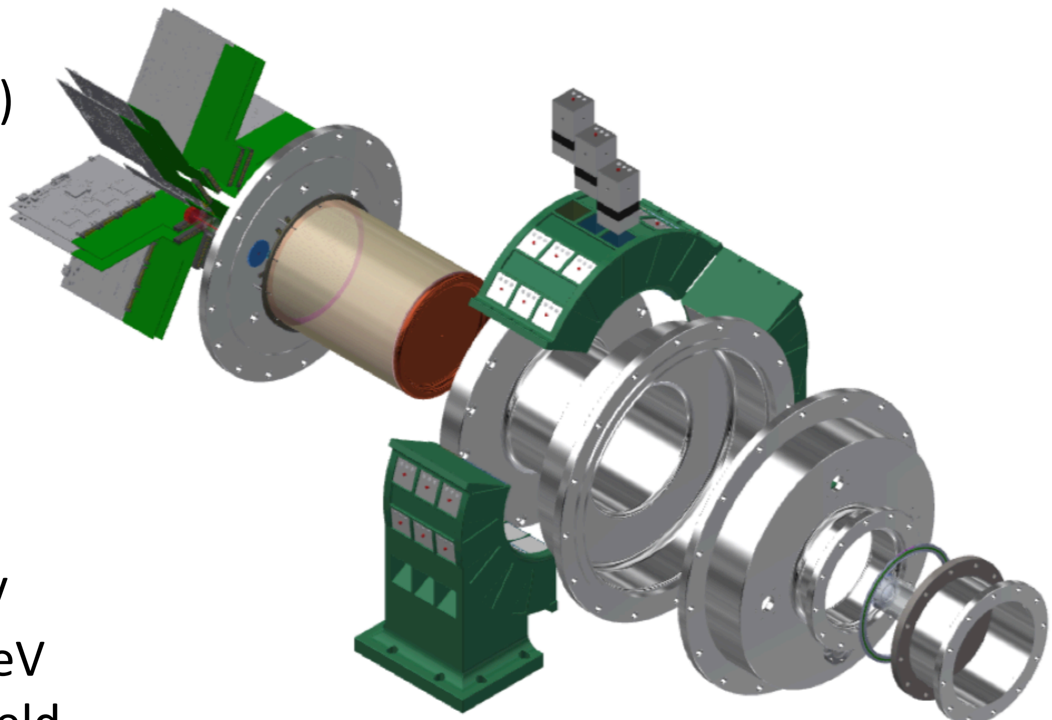
J. Diriken et al., PLB 736, 533 (2014)
J. Diriken et al., PRC 91, 054321 (2015)



Status

Design: O. Poleshchuk, KU Leuven

- GET Electronics (2048 channels): purchased and commissioned
- Pad plane and field cage designed in CERN (EP-DT-DD MPT) to be ordered shortly
- Chamber finalized and ordered
- Scintillators + SiPMs purchased, commissioning ongoing
  48x48x48 mm^3
  Photopeak efficiency 8% at 1 MeV
  Nominal resolution 3.9% at 661 keV
  No degradation in 3-T magnetic field



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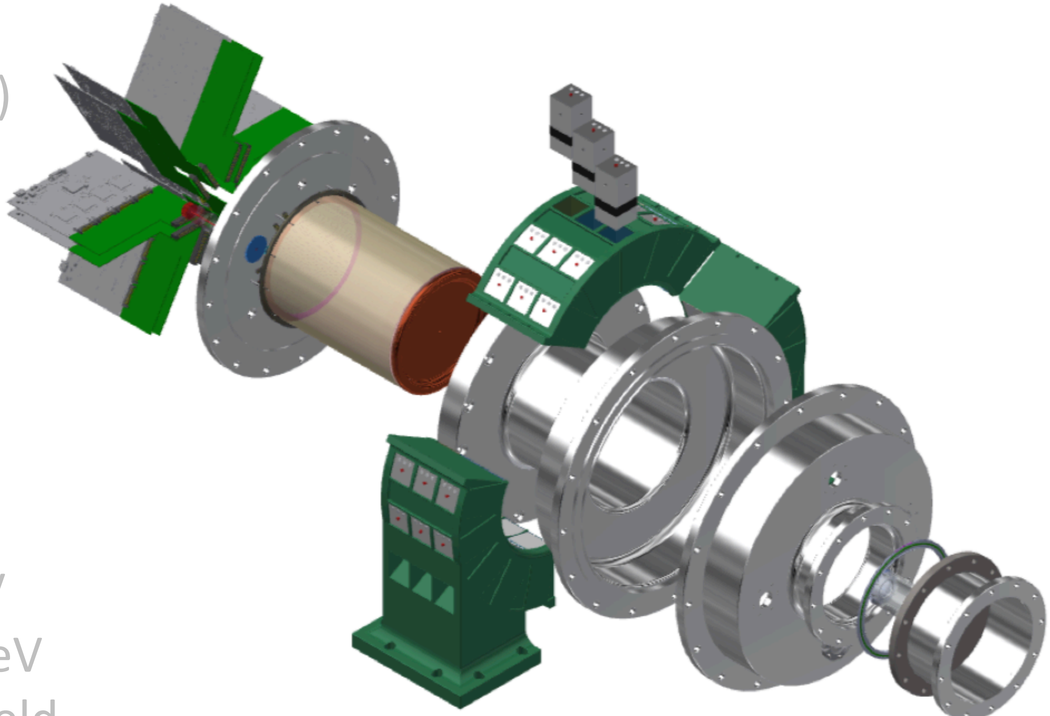

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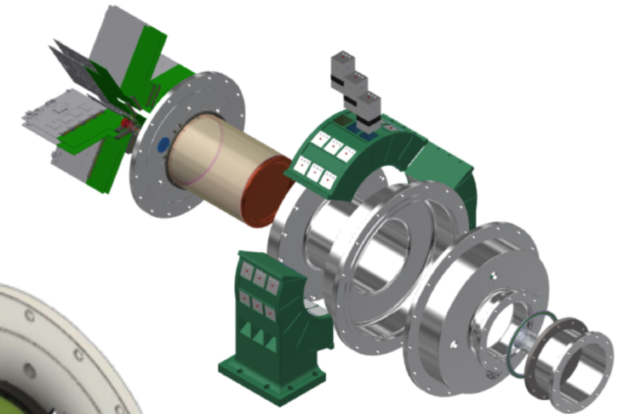

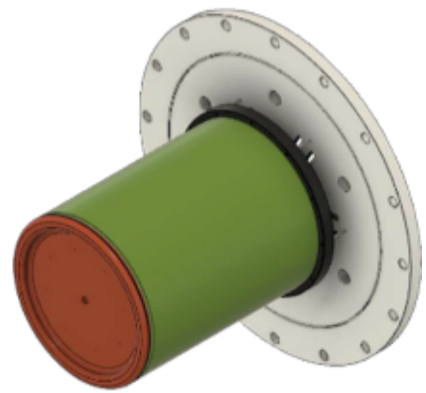

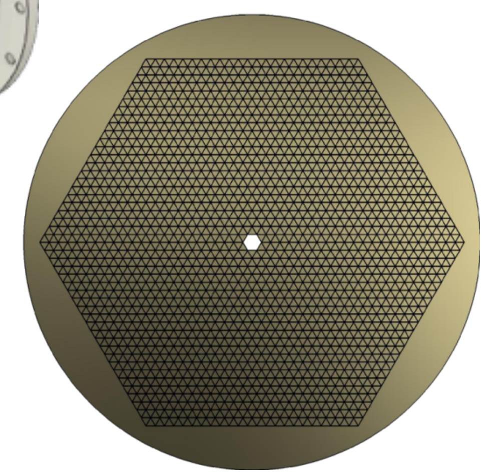

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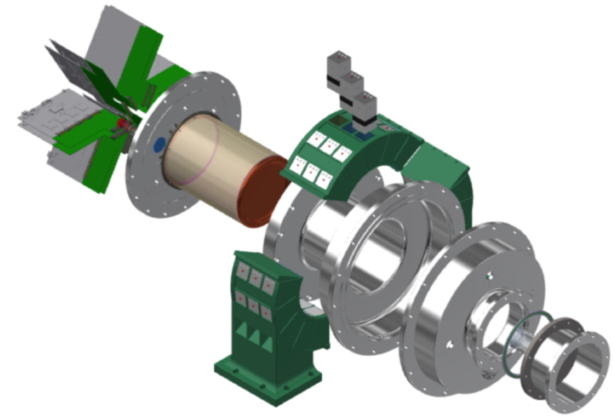

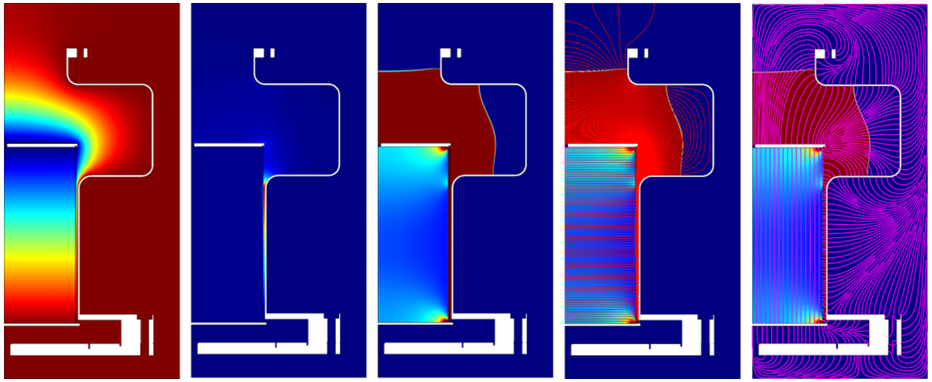

Simulations for:
electric field, mechanical stress, gas flow

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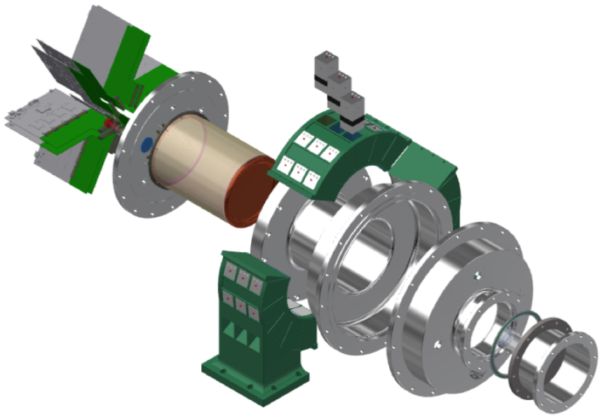

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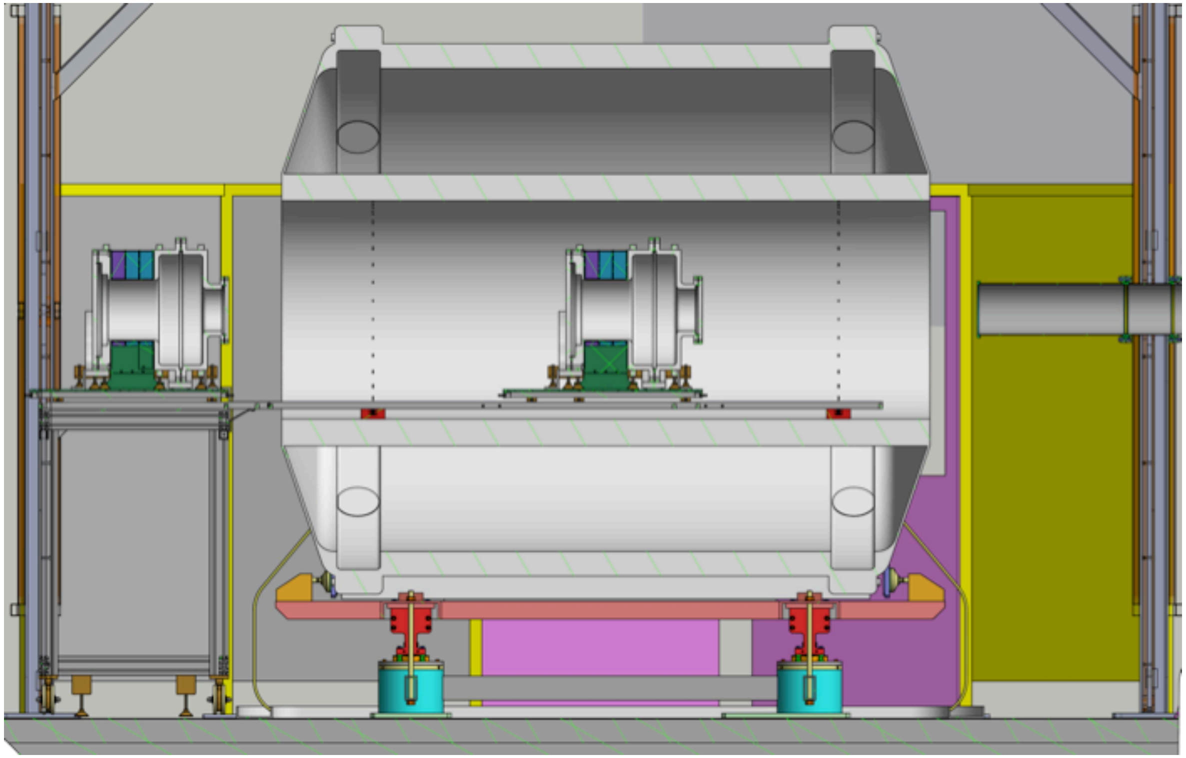
Installation

- Installation through a platform and rails from the back of the ISS
- Cables (8m) running to the electronics racks outside the cage



Planning

Spring 2019:
characterisation of the full system

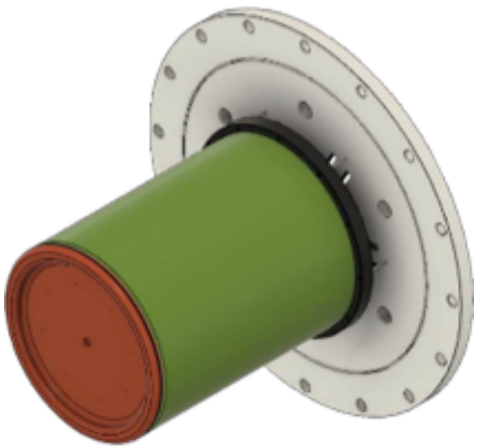
- Characterisation of the γ-ray array
- Leak tests of the detector chamber
- Commissioning of the gas control system
- Tests of the electric field cage
- Characterisation of particle tracks

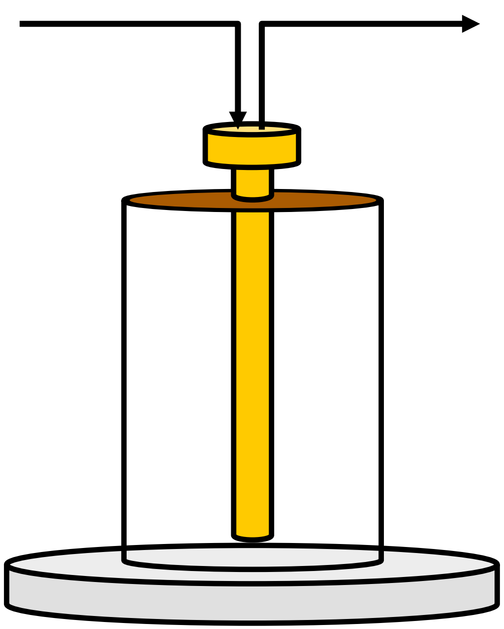
2019 Move to CERN

- Safety clearance
- Installation

Rare gases

- Main interest: ^{3}He
  spectroscopy of n-deficient nuclei
- (^{3}He,d) negative *Q*-value, backward angles
- (^{3}He,^{4}He) positive *Q*-value, forward angles
- Light recoils have very low energies!!





- Separated cylinder with rare gas
- Supporting structure, thin* foils??
- Equalized pressure

*** 3.6 µm mylar stops 350 keV deuterons and 900 keV alphas!**

Acknowledgements

Thanks to the SpecMAT team!

A. Arokja Raj, H. De Witte, A. Mentana, O. Poleshchuk, J. Refsgaard, M. Renaud, J. Yang

With us in the past: S. Ceruti, M. Babo, T. Marchi, C. Swartz

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