University of Brighton

Nuclear Physics
Research Group

Neutron-rich A~100 nuclei studied at the University of Jyväskylä cyclotron facility

(interesting science with a cyclotron)

Alison Bruce

University of Jyväskylä

University of Brighton

Three large-scale accelerators:

The K130 cyclotron: isochronous cyclotron which can deliver an exceptionally large variety of heavy- and light-ion beams up to the energy of 130 Q^2/A MeV for use in research and applications

MCC30/15 cyclotron: a small cyclotron for production of 18-30 MeV protons and 9-15 MeV deuterons

1.7 MV Pelletron: dedicated facility for accelerator-based material physics

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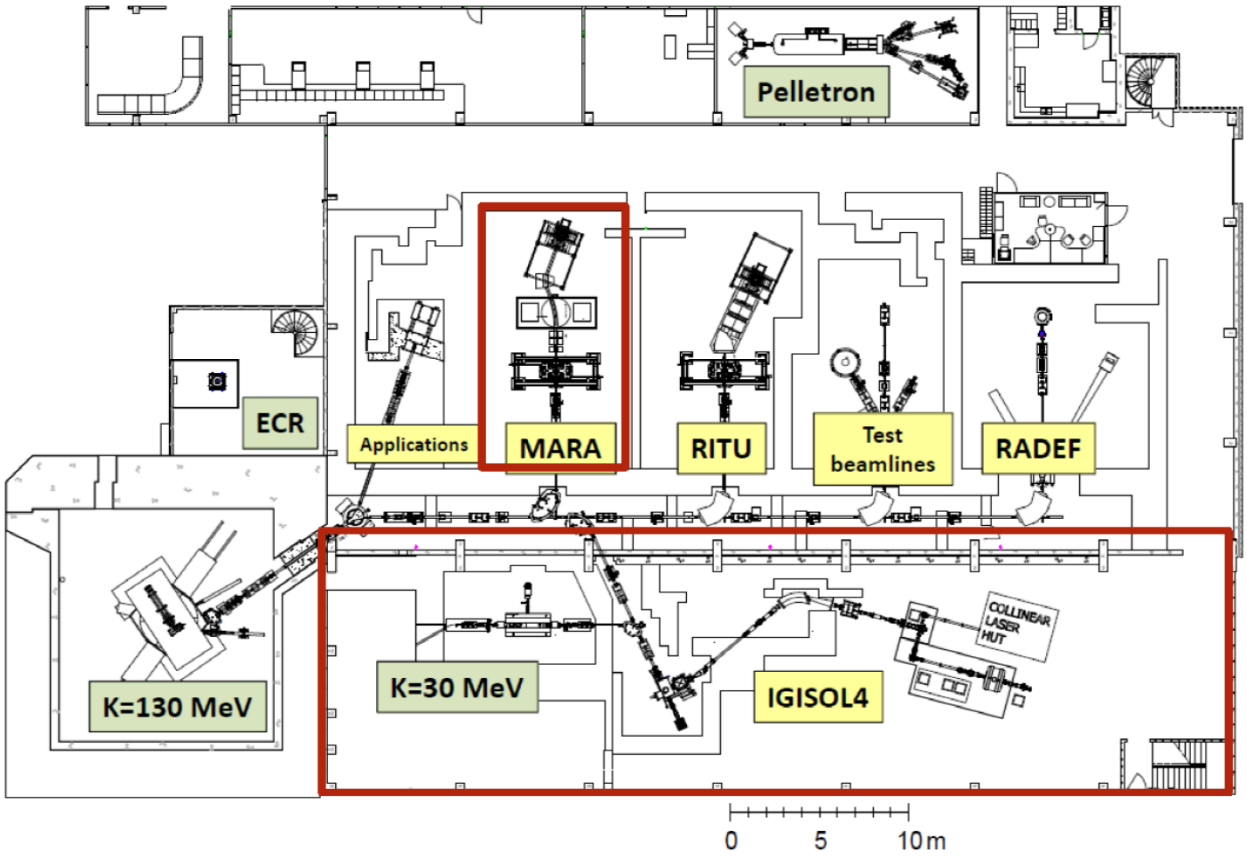
JYFL ACCLAB, ca. 2014



RADiation Effects Facility (RADEF), for studies of single-event effects (SEE) in electronics and for radiation hardness tests of materials, sensors and detectors with light ions and heavy-ion cocktail beams.

Artem Alikhanyan National Science Laboratory

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IBA Cyclone-18:

18 MeV cyclotron =>

low-energy nuclear science programme

(focus on what is done with low-energy beams at Jyväskylä)

So, what can you do with low-energy beams?

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One example is to use low-energy protons to induce fission

and study fission fragments

What's the physics?

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The shape is a basic property of the nucleus

oblate

spherical

prolate

Pretty fundamental, should be able to calculate and measure but still not known for many nuclei.

Where are we in the nuclear chart?

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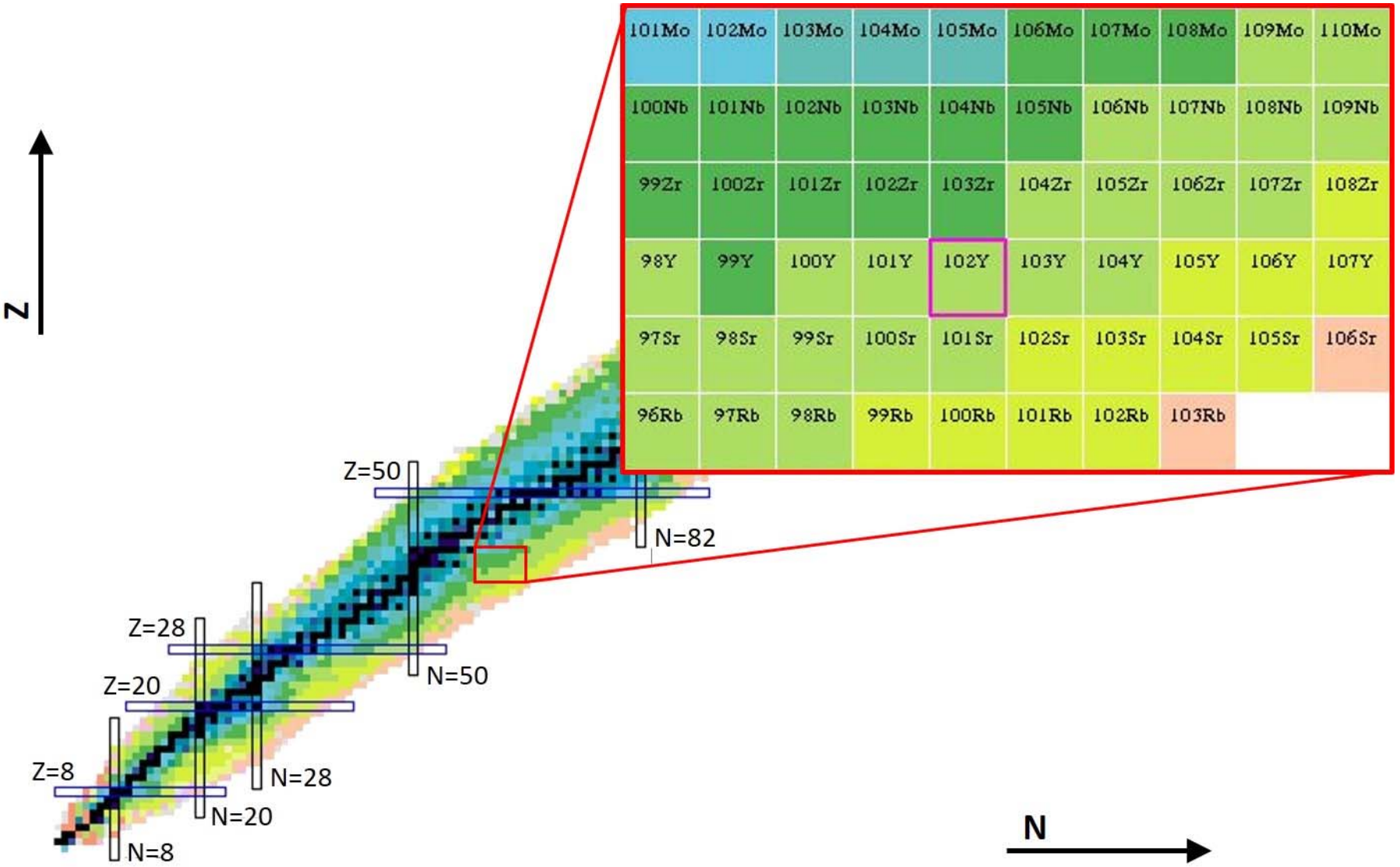

Source: http://www.nndc.bnl.gov/

^{102}Y shape calculations

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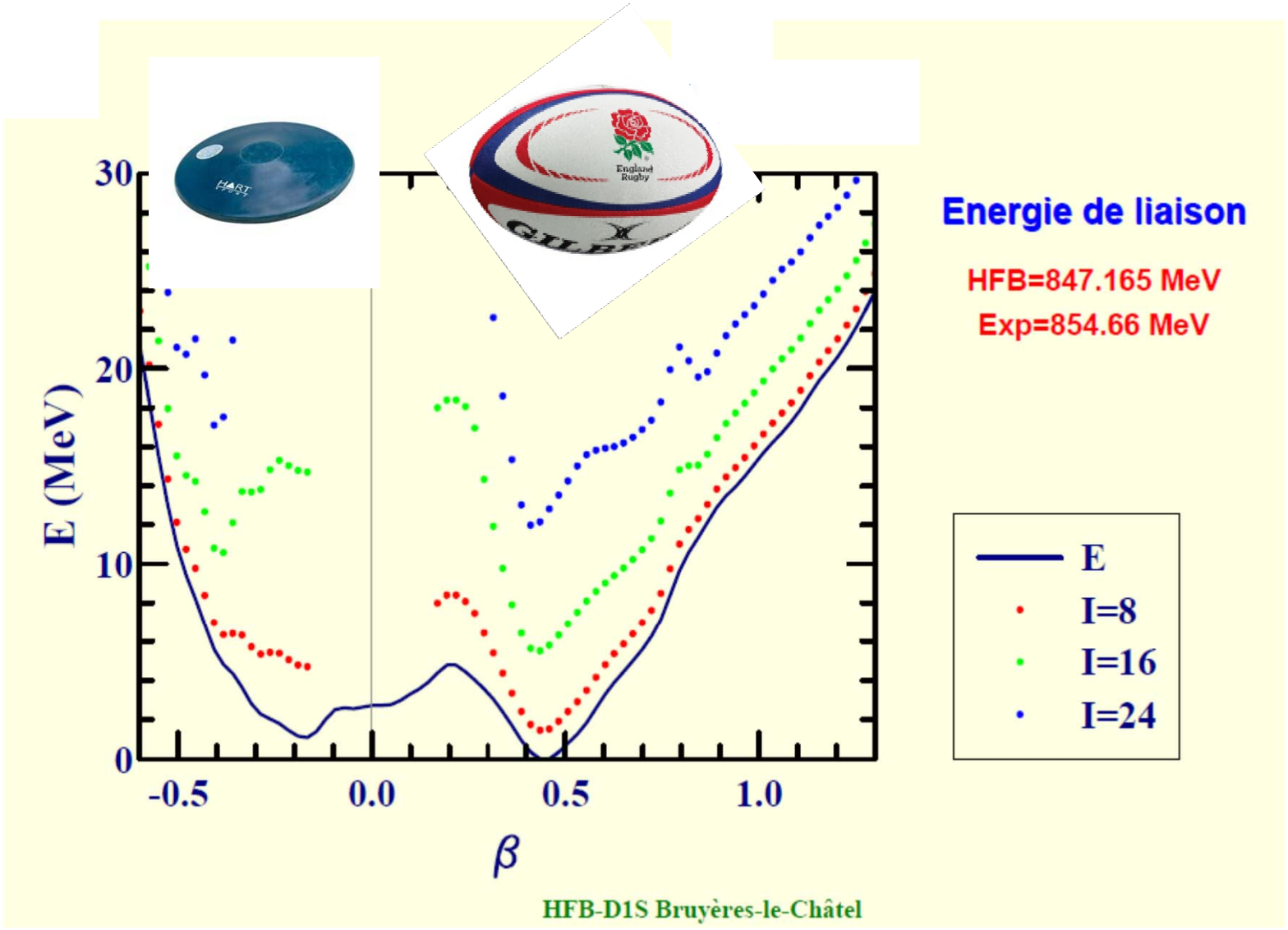

S.Hilaire, M.Girod http://www-phynu.cea.fr

Outline

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- Producing nuclei of interest
  - IGISOL facility
- Experimental setups
  - Laser spectroscopy
  - Penning traps
  - Post-trap spectroscopy setup
- What is possible?

Producing the nuclei

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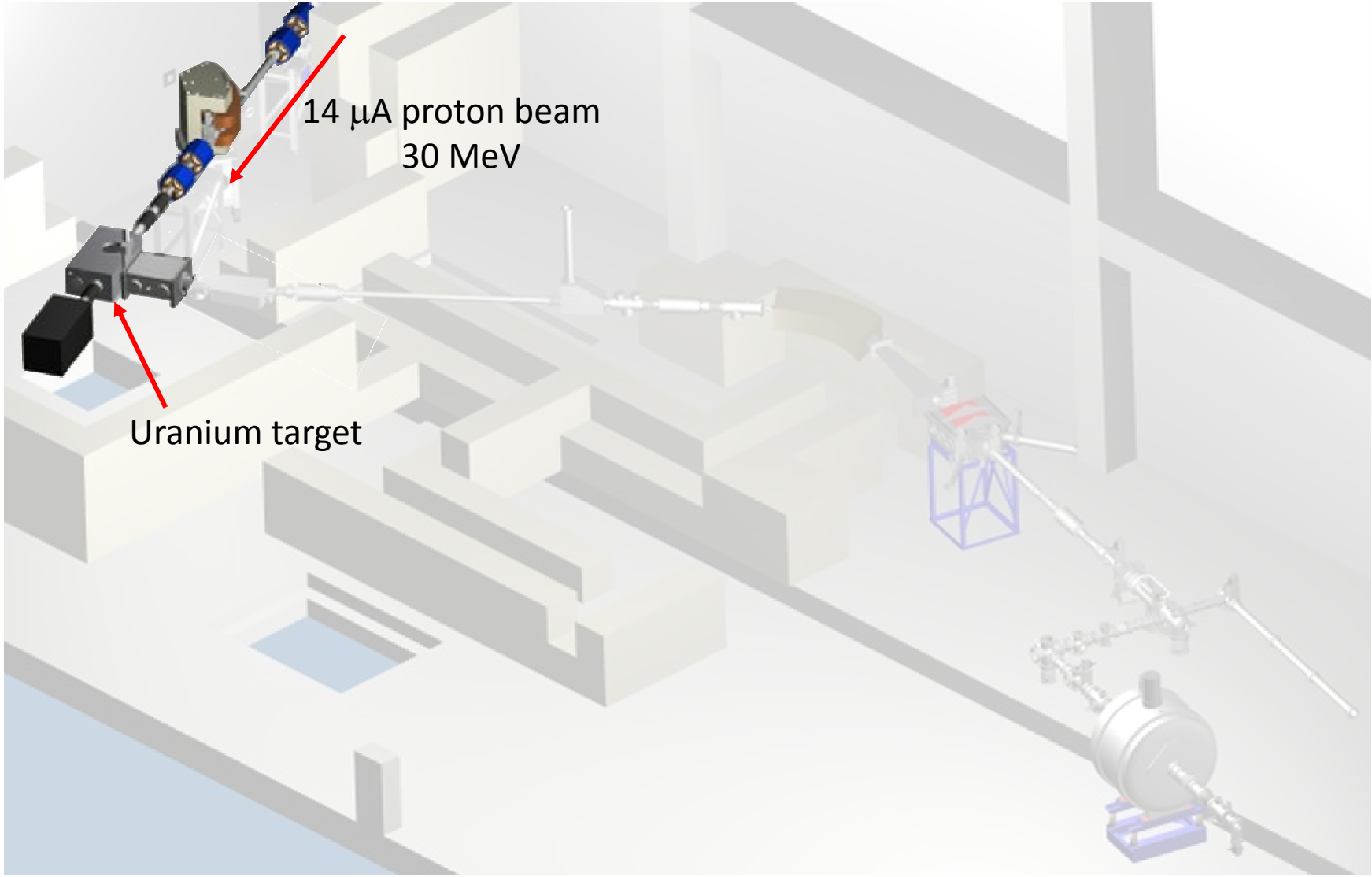

Source: https://www.jyu.fi/fysiikka/en/research/accelerator/igisol/igisol4.html

Separating the nuclei

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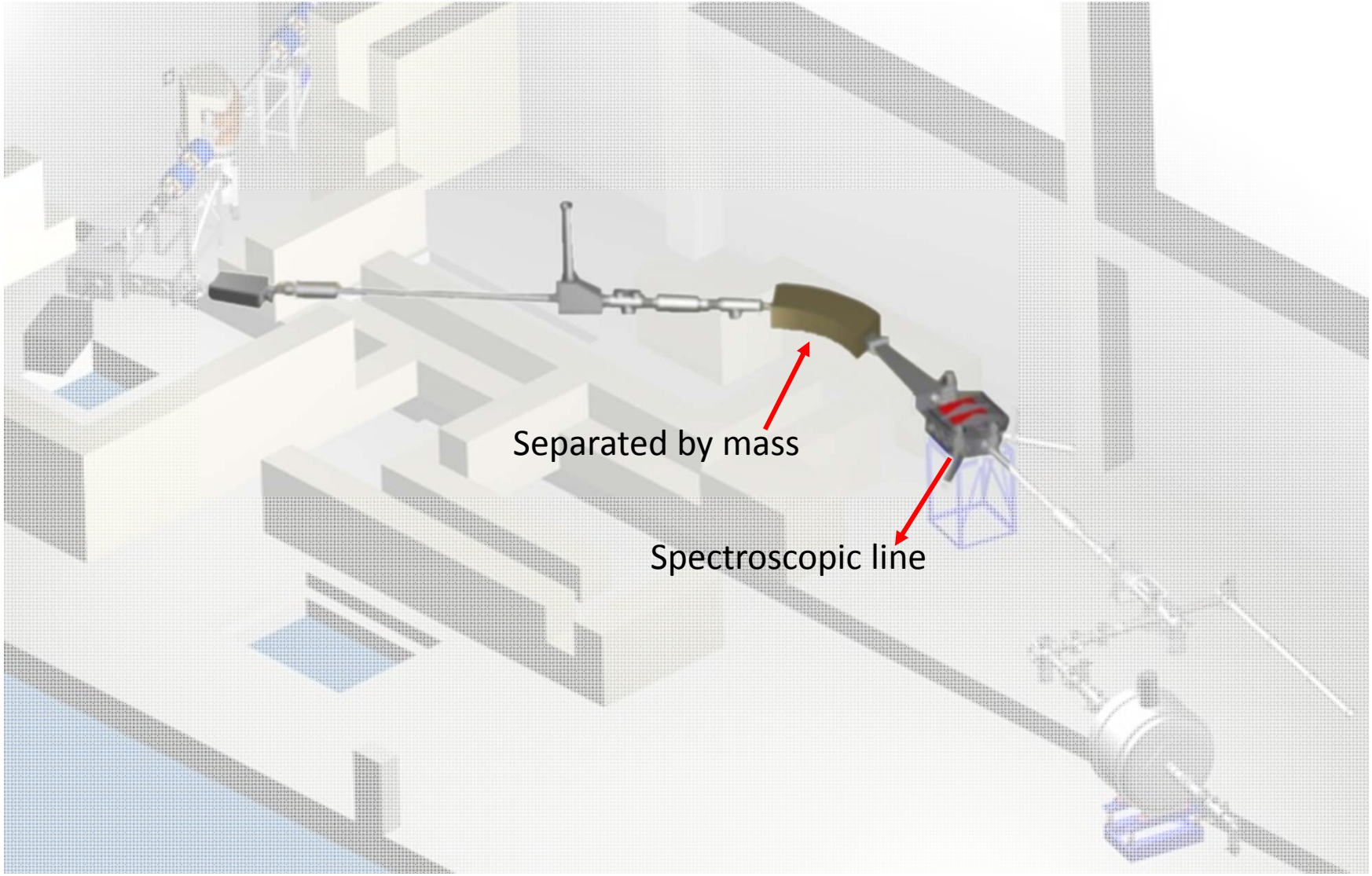

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Laser spectroscopy

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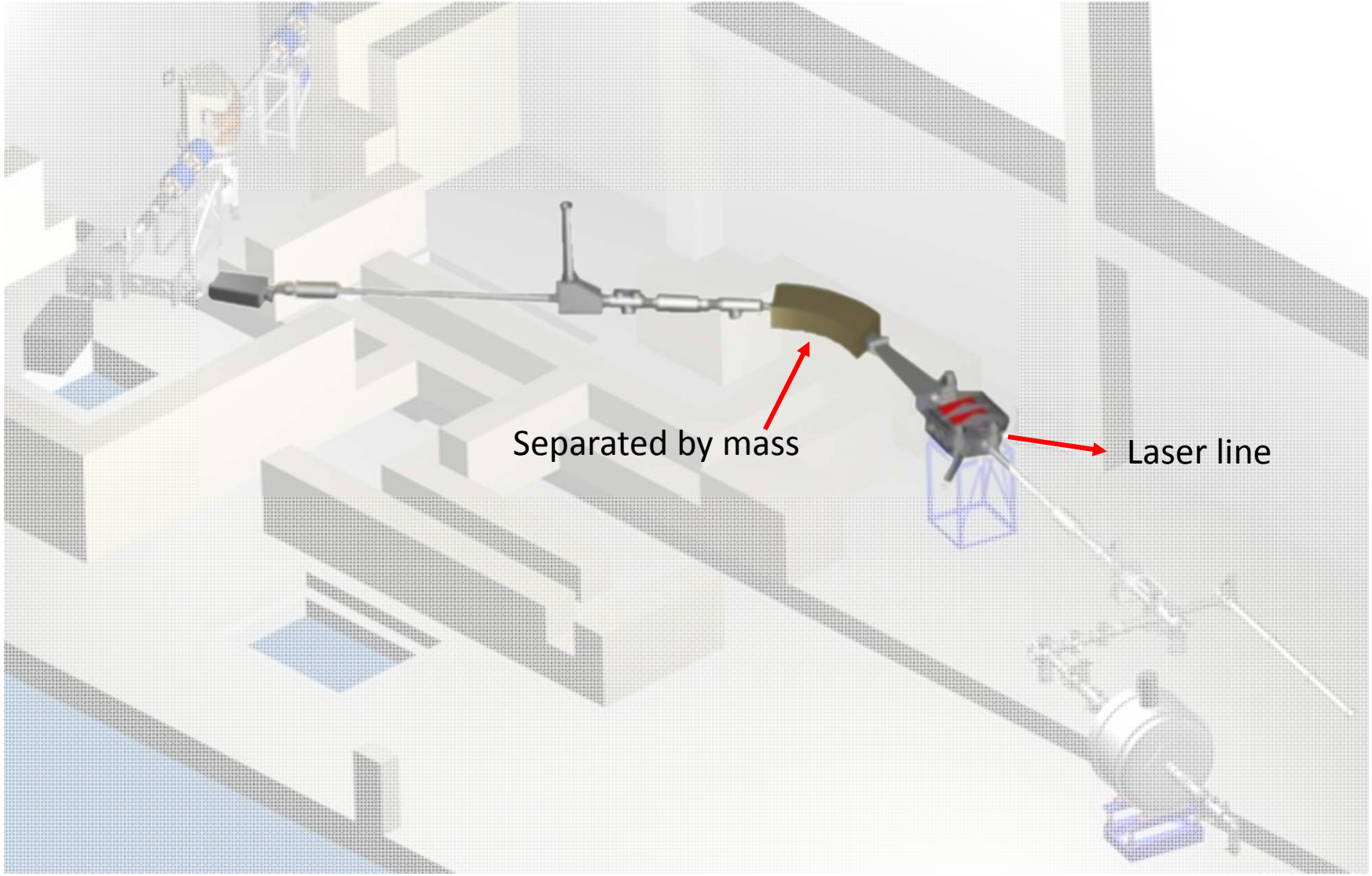

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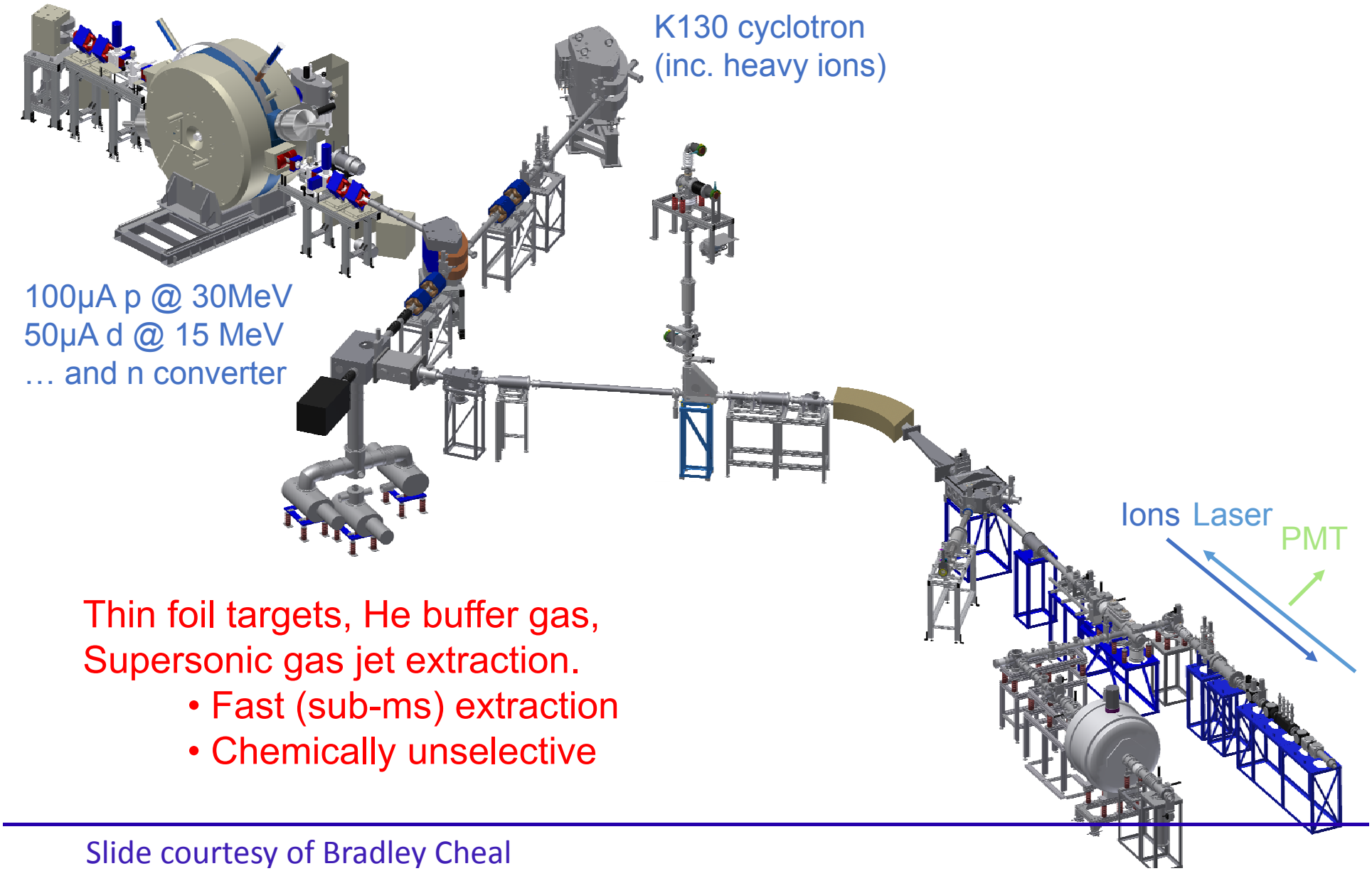
Laser spectroscopy

University of Brighton



Thin foil targets, He buffer gas,
Supersonic gas jet extraction.

- Fast (sub-ms) extraction
- Chemically unselective

Slide courtesy of Bradley Cheal

Laser spectroscopy

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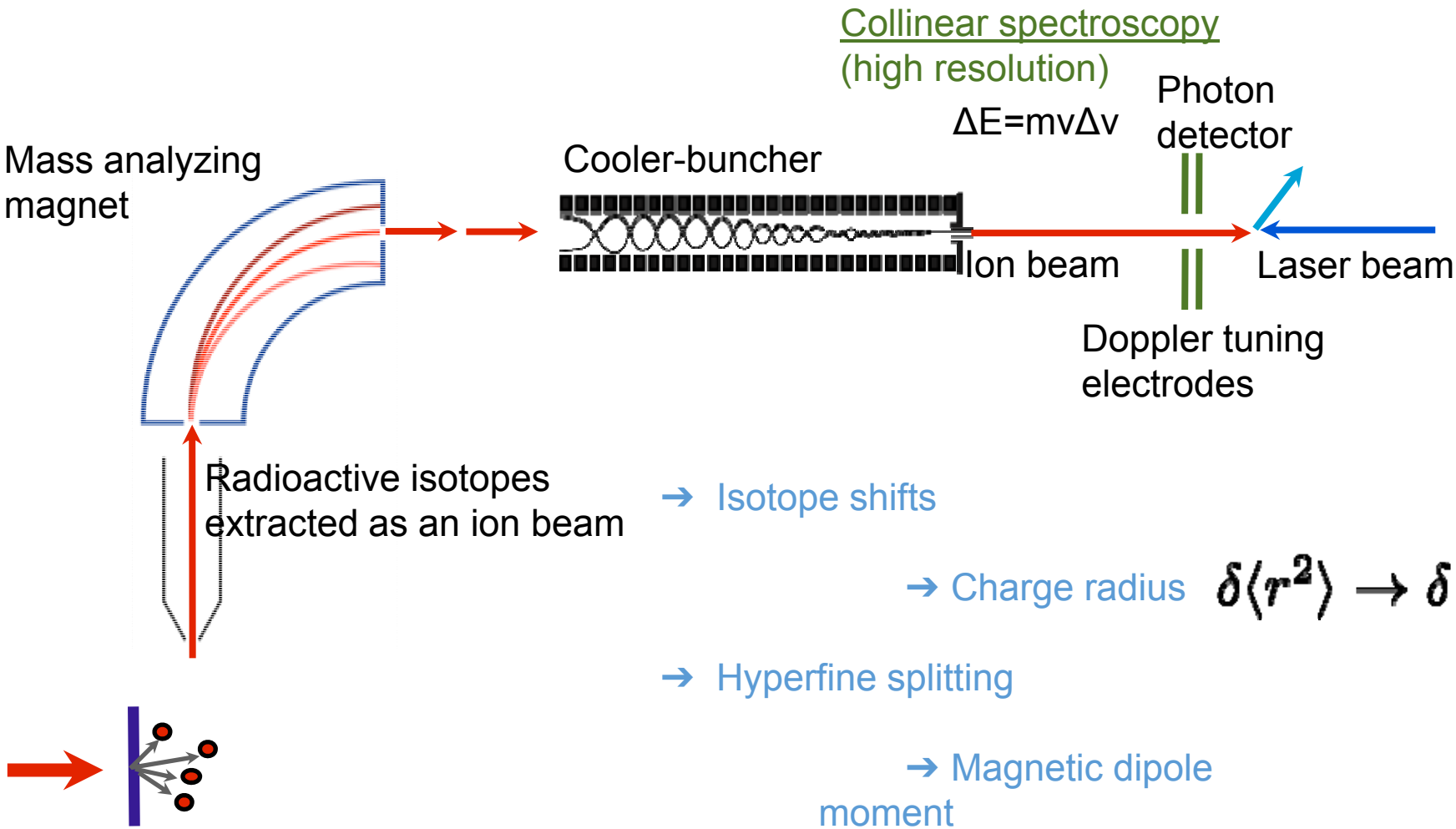

➔ Isotope shifts

➔ Charge radius $\delta\langle r^2\rangle \rightarrow \delta\langle\beta_2^2\rangle$

➔ Hyperfine splitting

➔ Magnetic dipole moment

➔ Electric quadrupole moment $Q_s \rightarrow \langle\beta_2\rangle$

➔ Nuclear spin

Slide courtesy of Bradley Cheal

Charge radii in the N=60 region

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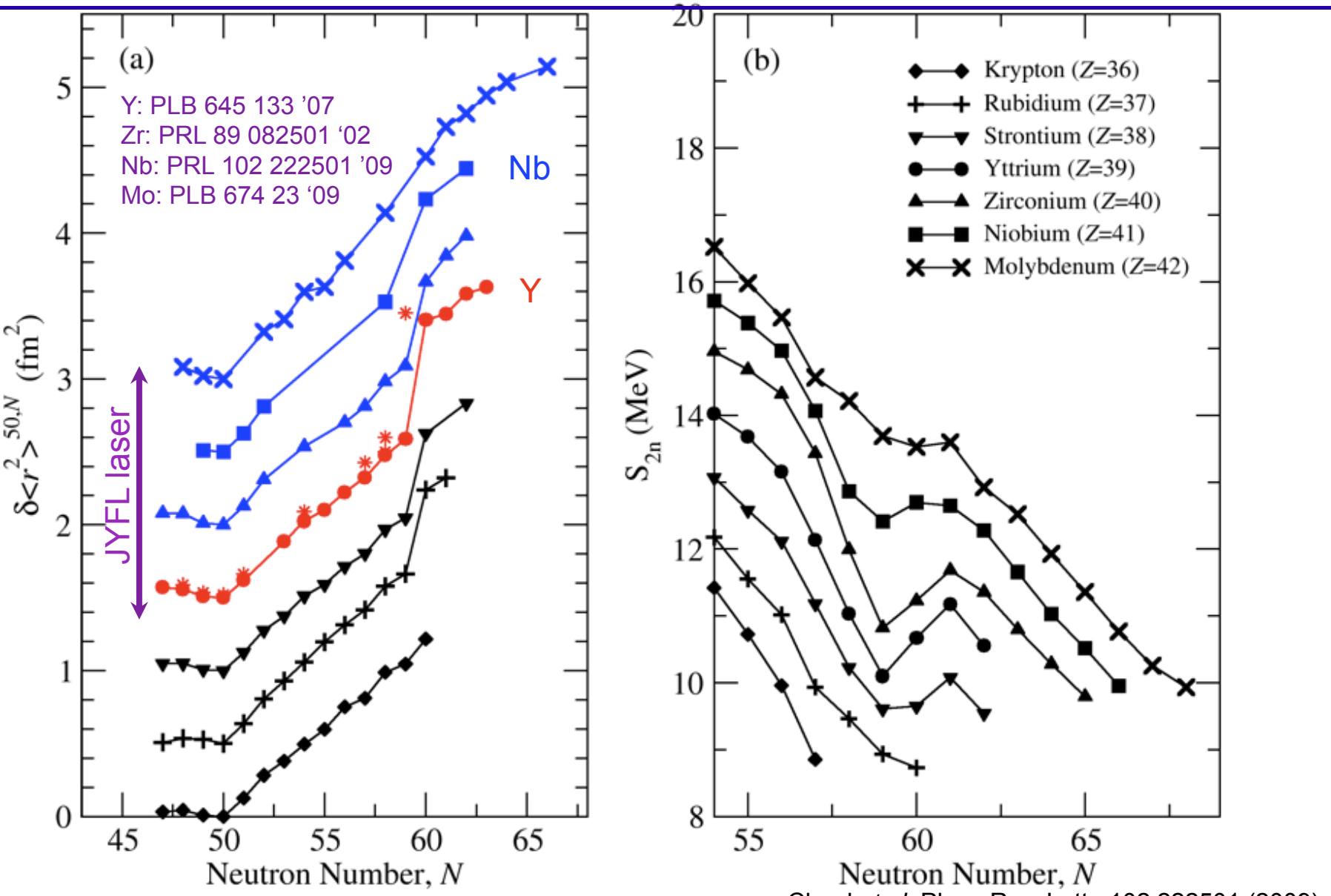

Slide courtesy of Bradley Cheal

Cheal *et al.* Phys. Rev. Lett. 102 222501 (2009)
Cheal *et al.* Phys. Lett. B 645 133 (2007)

Nuclear rigidity in yttrium

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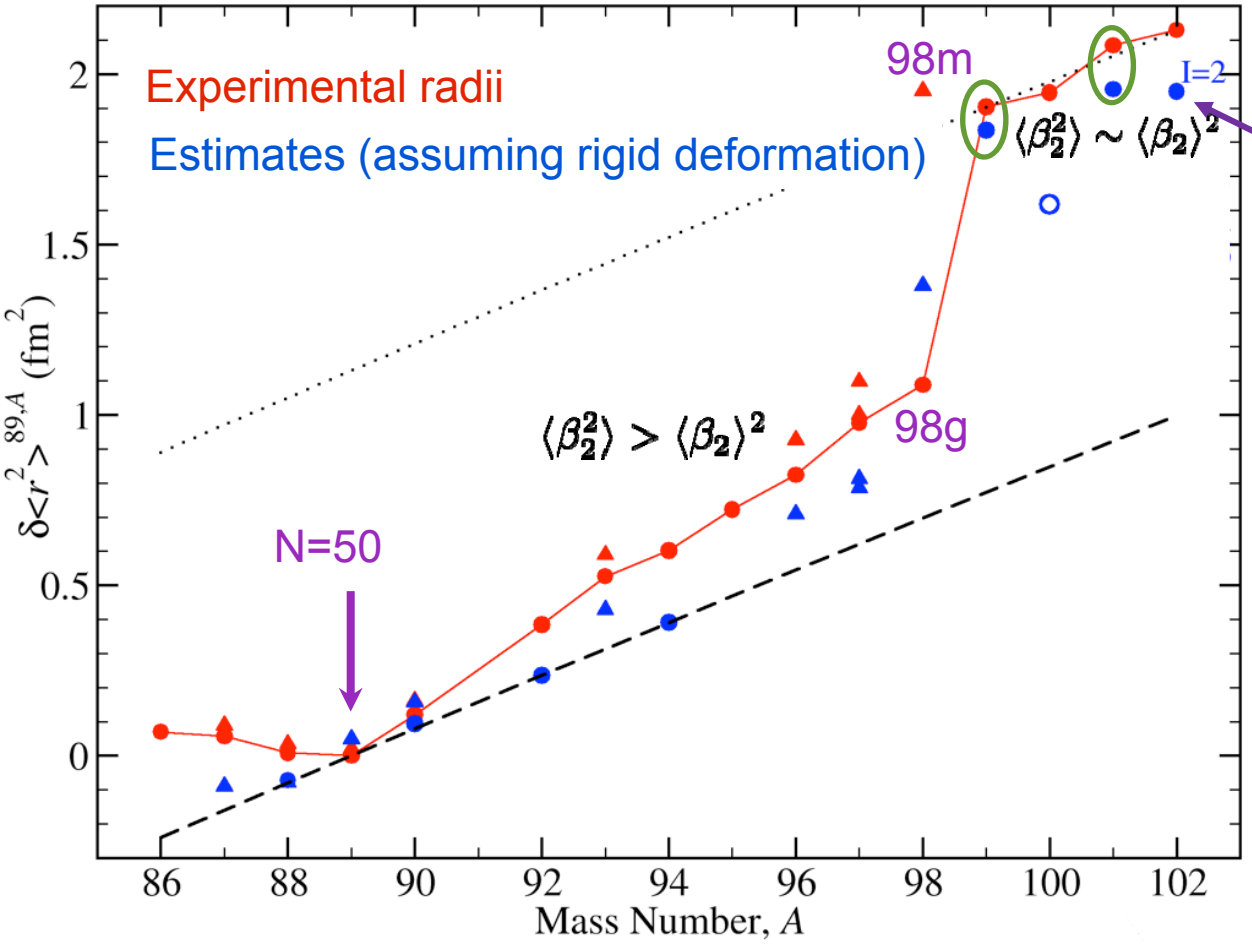
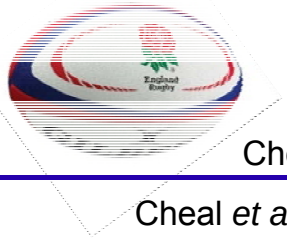


Problem here… but we're not really sure what is being measured as 2 states very close in energy



Cheal *et al.* Phys. Lett. B 645 133 (2007)

Cheal *et al.* Phys. Rev. Lett. 102 222501 (2009)

Slide courtesy of Bradley Cheal

^{102}Y beta decay

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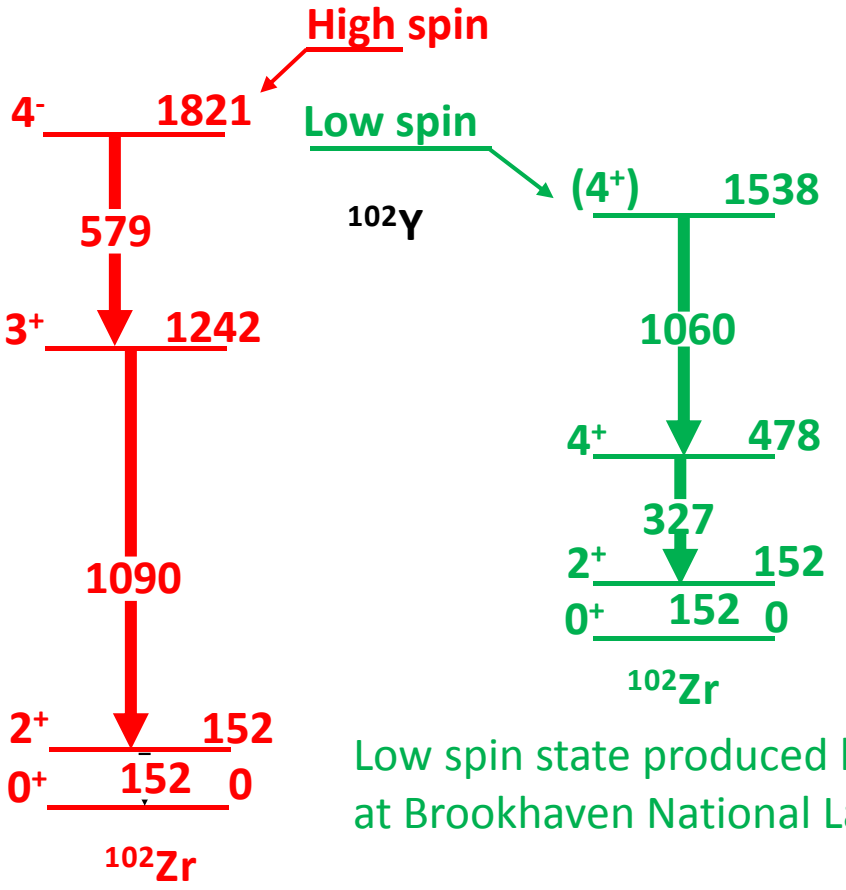

Gamma-ray energy (keV)	Gamma-ray intensities	
	Low spin state	High spin state
152	100(4)	79(10)
160	<1.1	8(8)
327	8.6(9)	42(3)
579	<1.1	28(3)
1060	29(3)	8(3)
1090	<1.3	33(3)

Low spin state produced by thermal fission of a ^{235}U target at TRISTAN facility at Brookhaven National Lab.

High spin state produced by thermal fission of a ^{235}U target using the JOSEF recoil separator at the research reactor DIDO at Kernforschungsanlage Jülich, without the use of an ion source.

Source: J. C. Hill et al., Phys. Rev. C 43, 2591 (1991)
K. Shizuma et al., Phys. Rev. C 27, 2869 (1983)

^{102}Y beta decay

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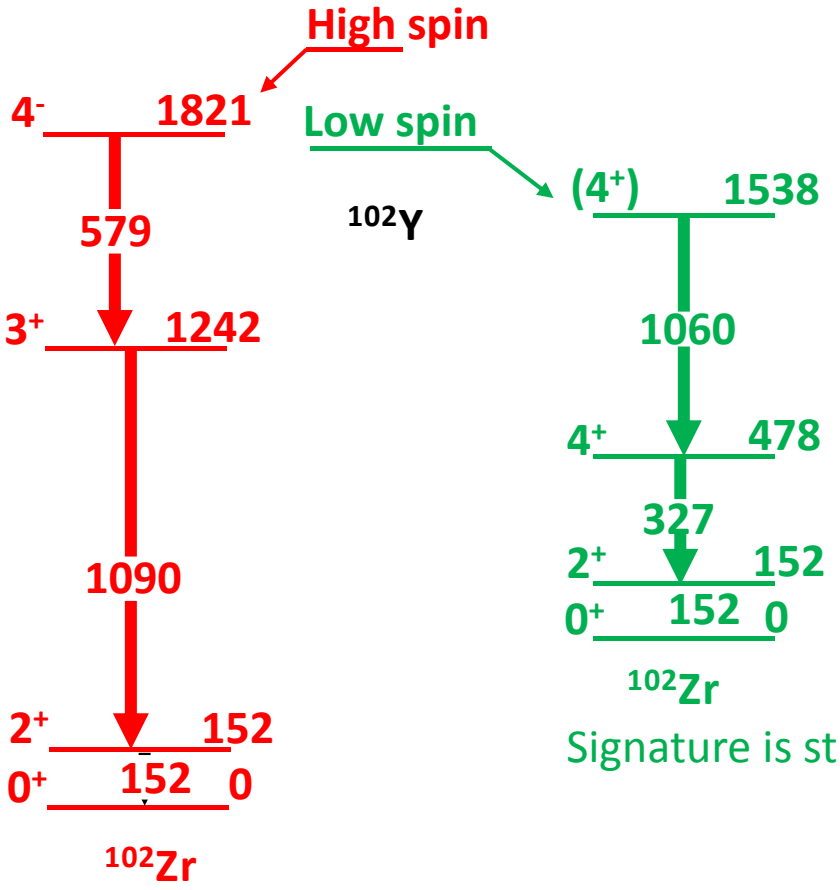

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Penning traps

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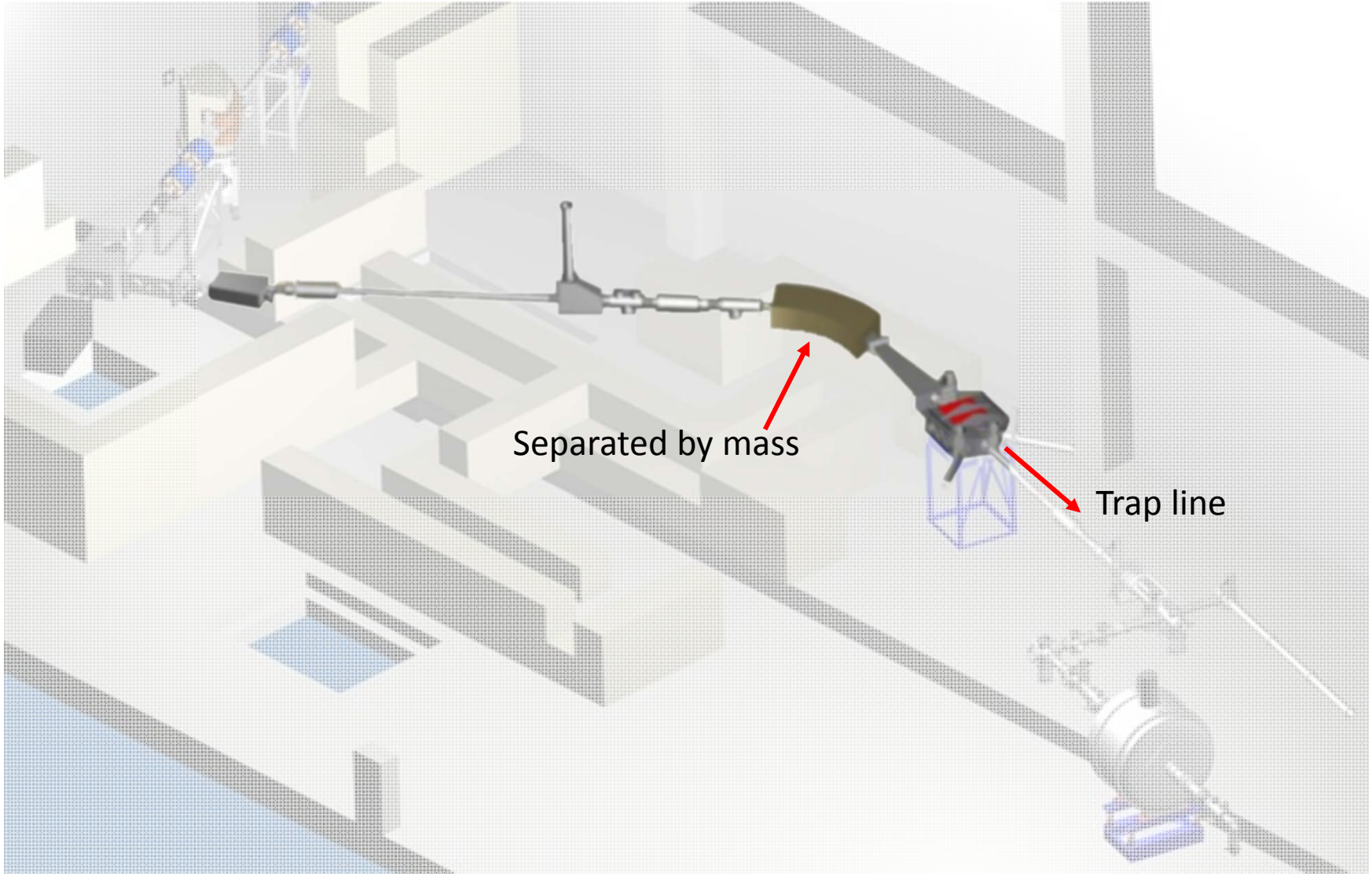

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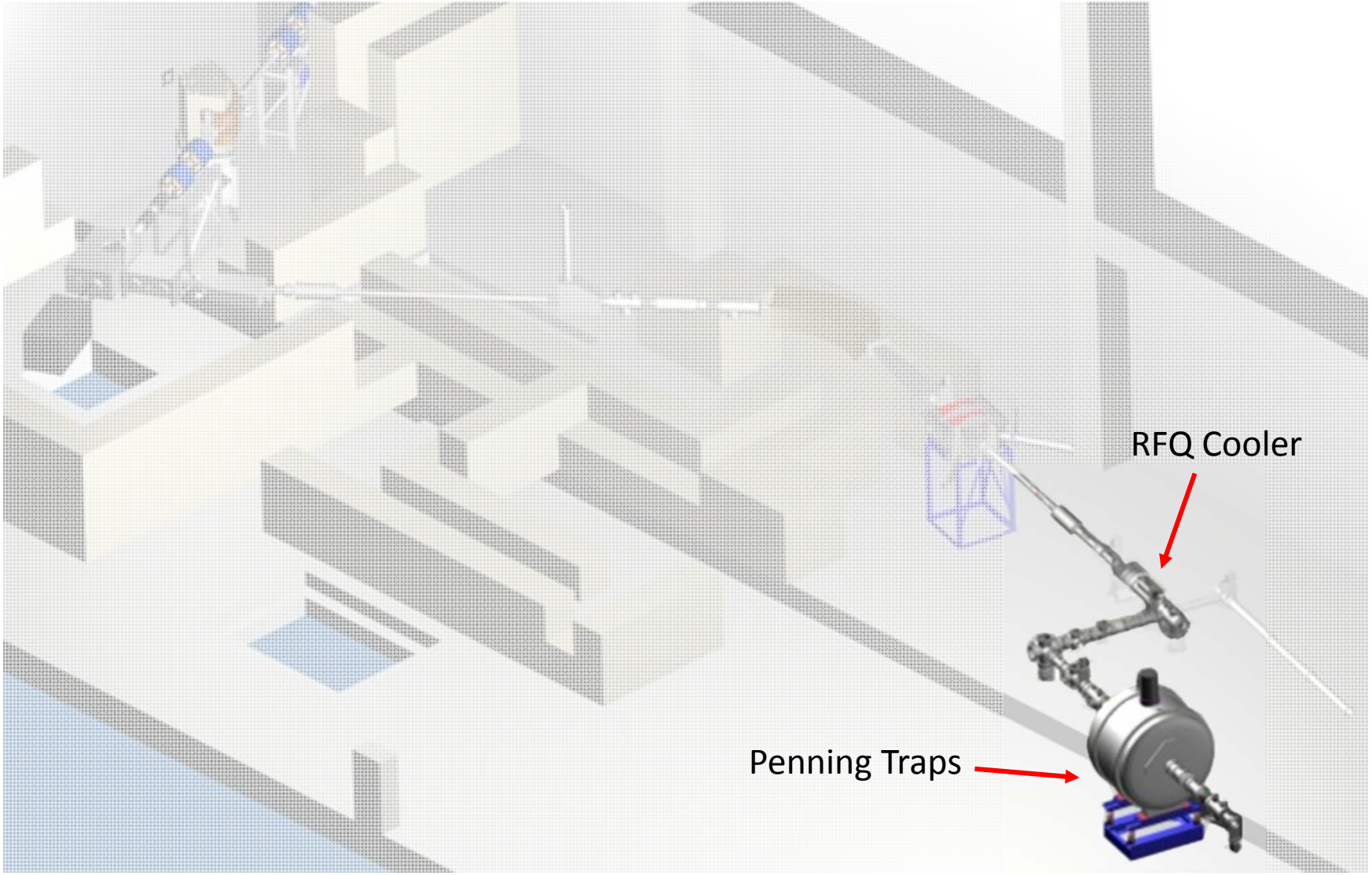

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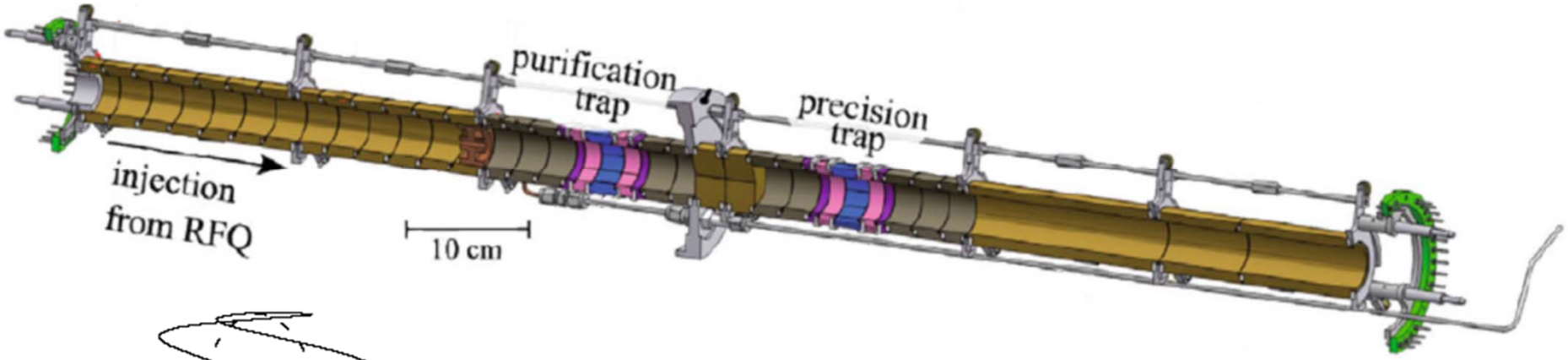

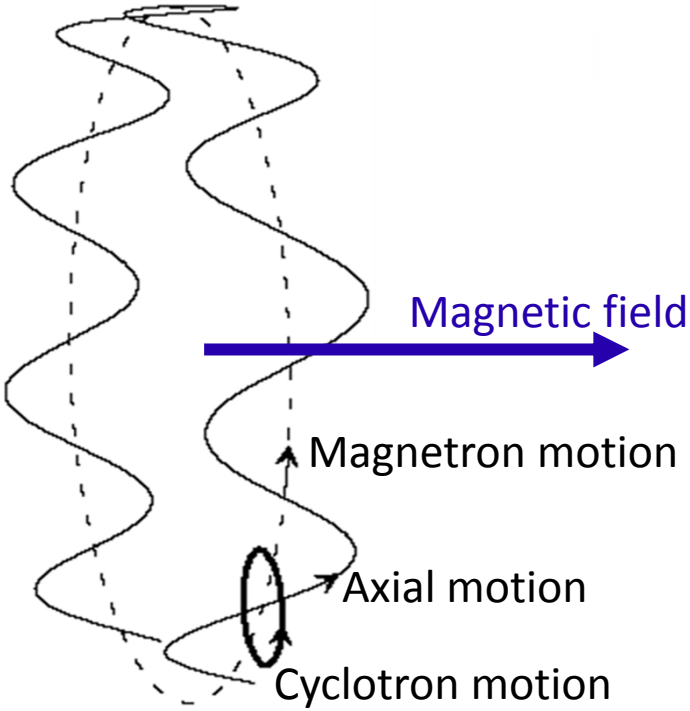

Magnetron motion: Mass independent

Cyclotron motion: Mass dependent

Source: T. Eronen et al., Eur. Phys. J. A 48, 1 (2012)

Penning traps

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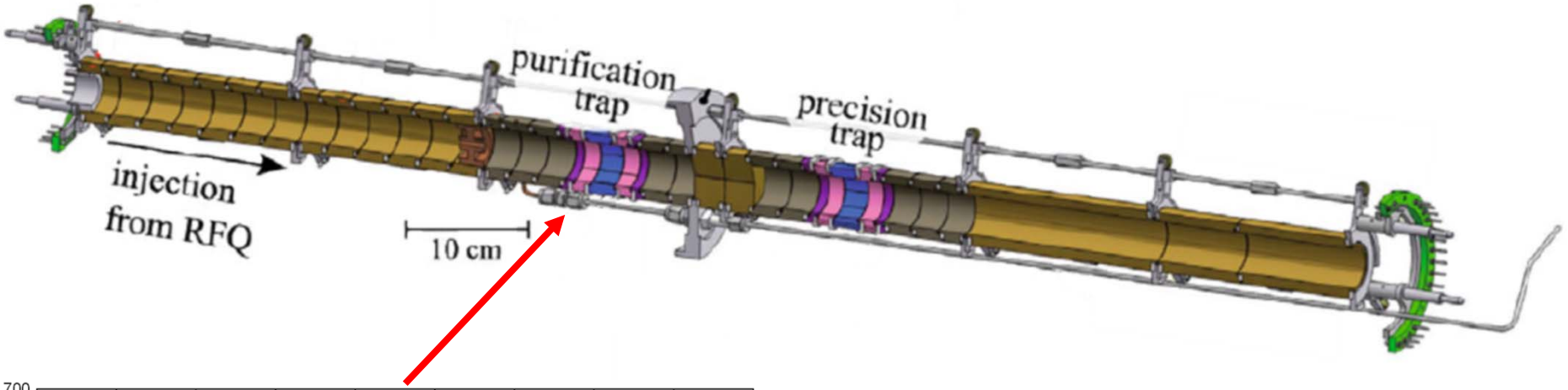

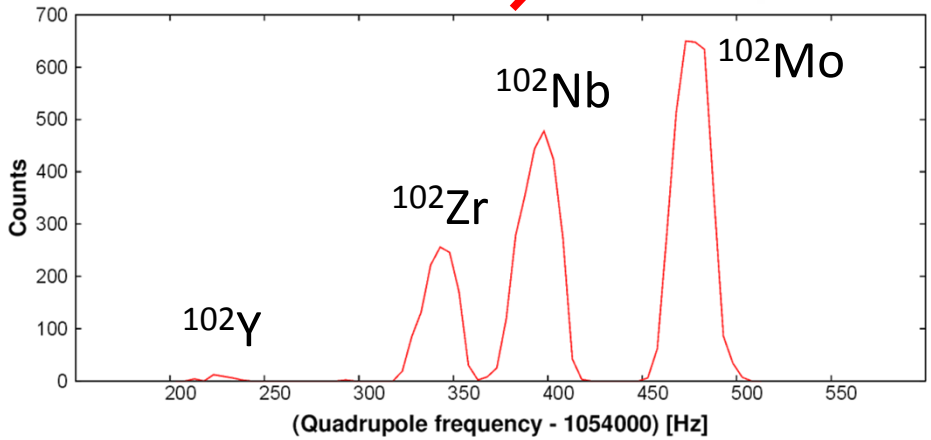

Primary beam: 14 μA ≈ 9×10^{13} protons/s

^{102}Y after traps: ~1 ion/s

Penning traps

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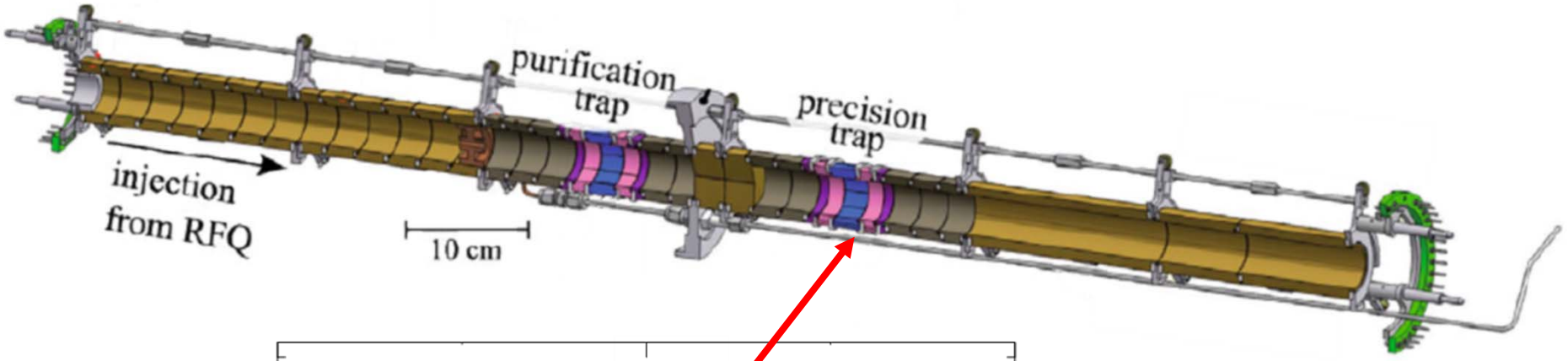

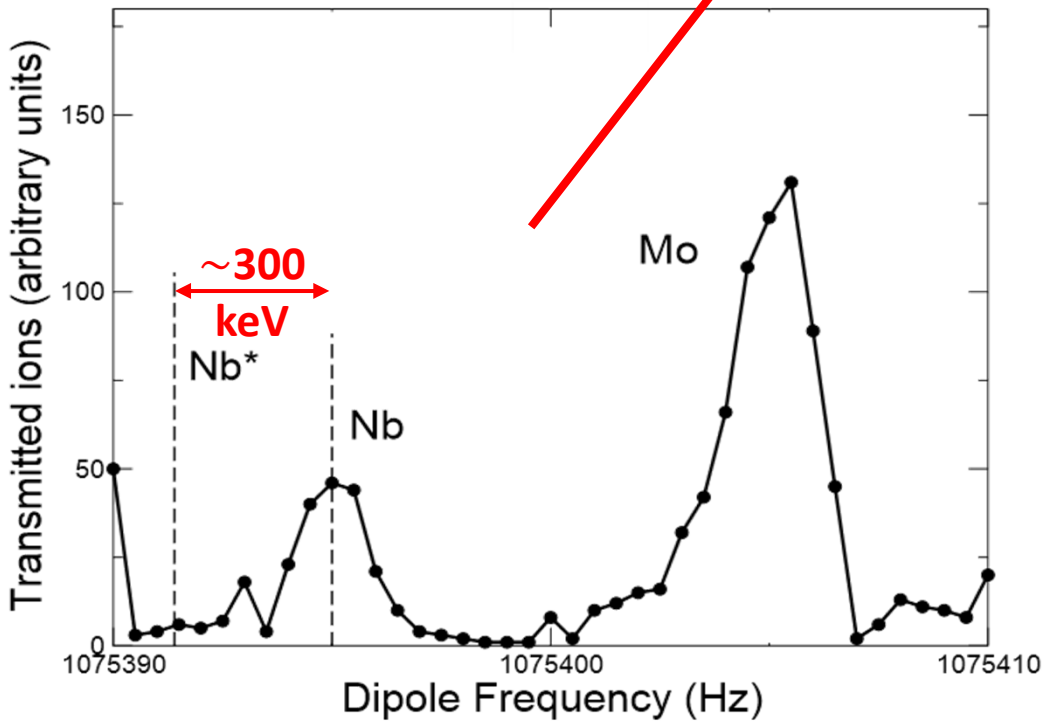

Post-trap spectroscopy

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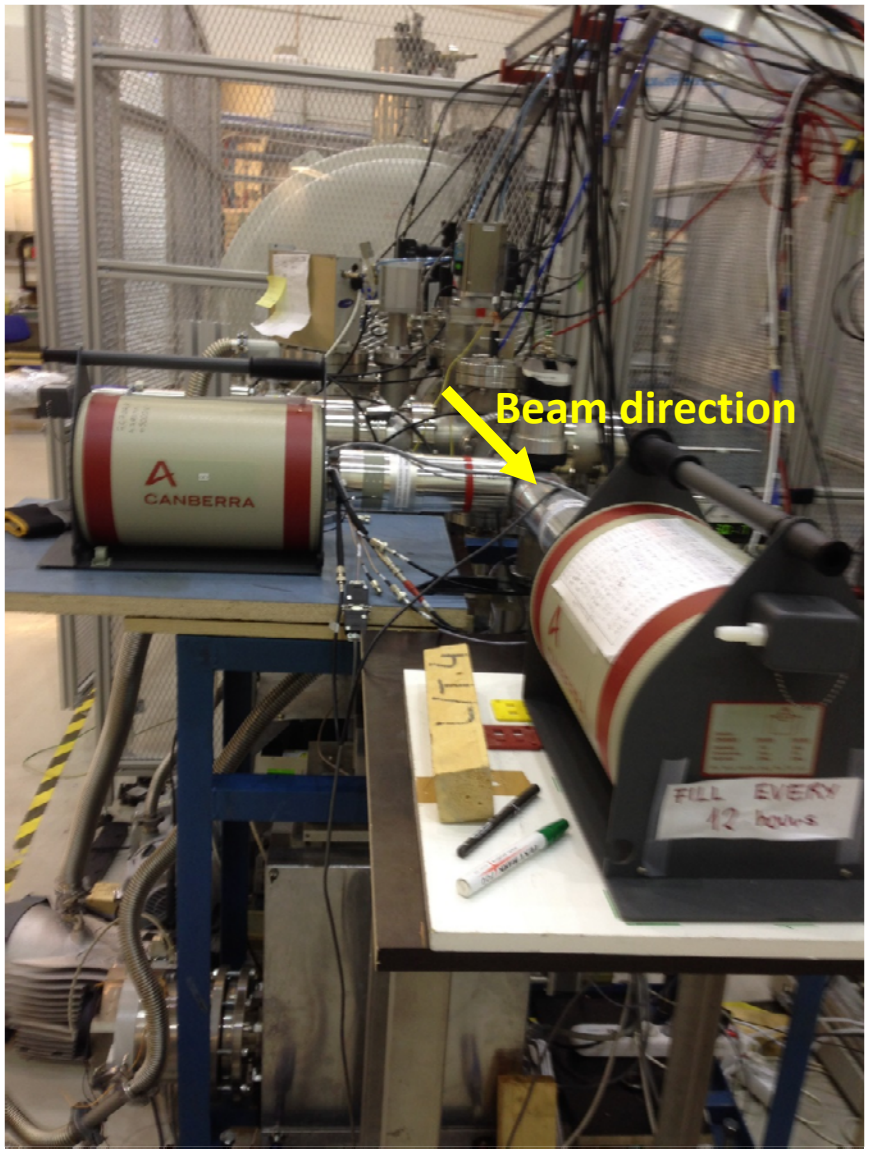

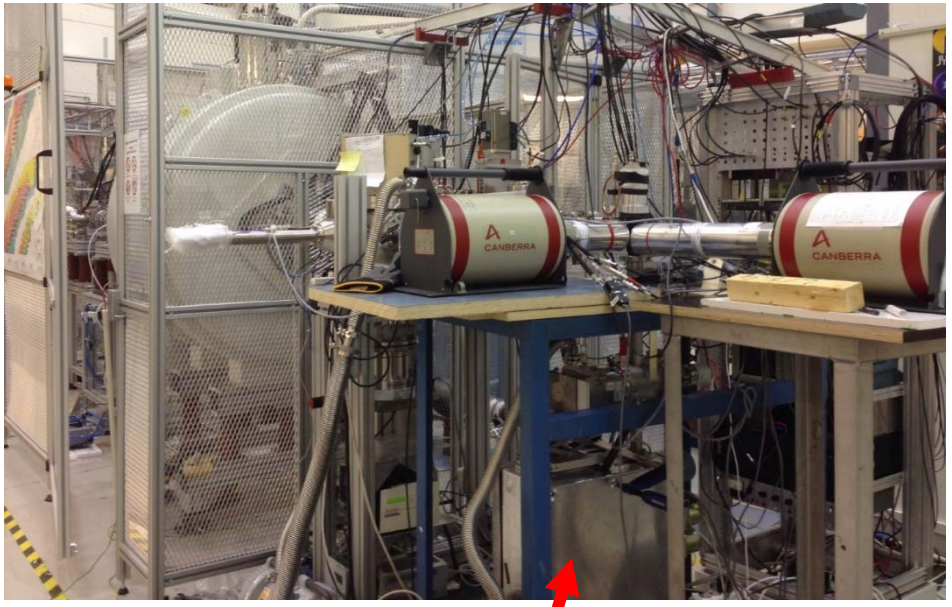

Tape station – moves about every 60 s

Test with ^{100}Nb decay into ^{100}Mo

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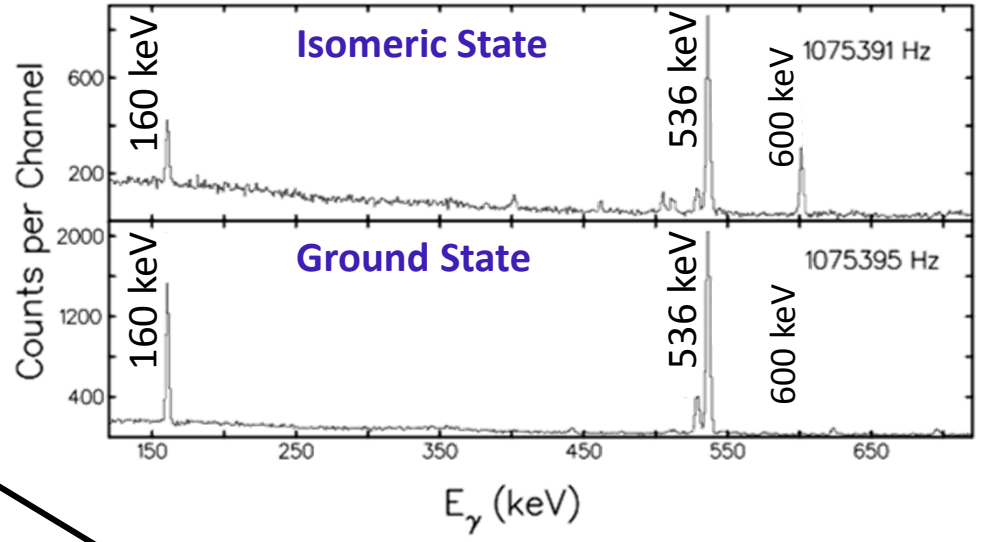

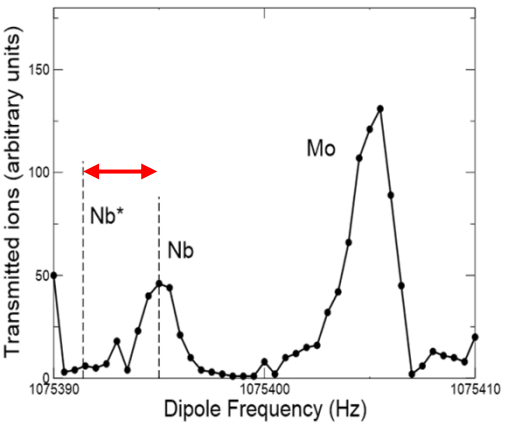

Source: C. Rodríguez-Triguero, PhD Thesis, University of Brighton, 2013

^{102}Y beta decay

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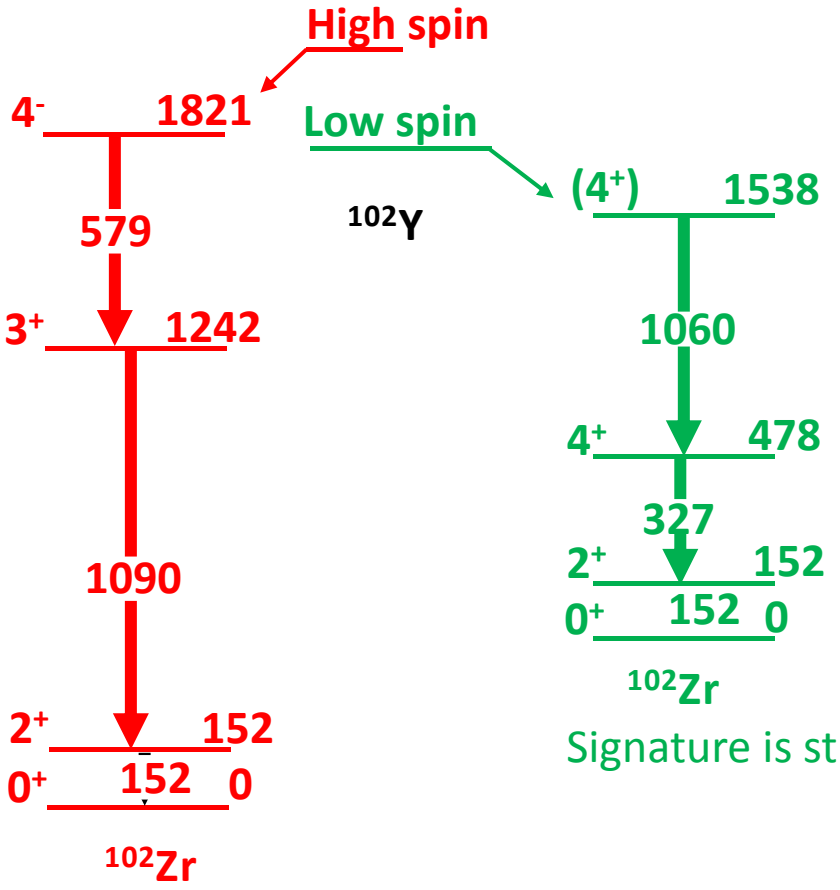

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Results inconclusive

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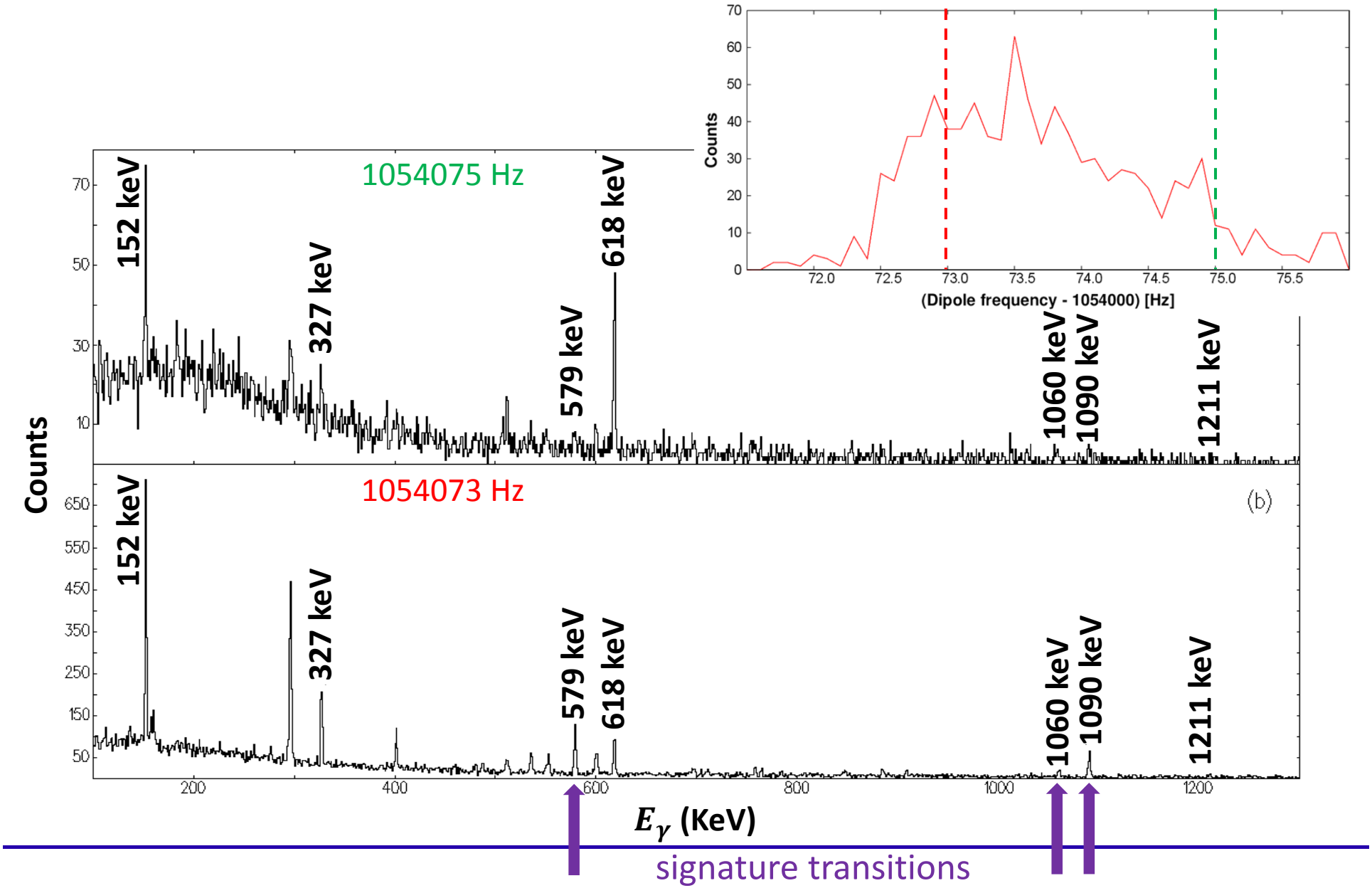

^{102}Y shape calculations

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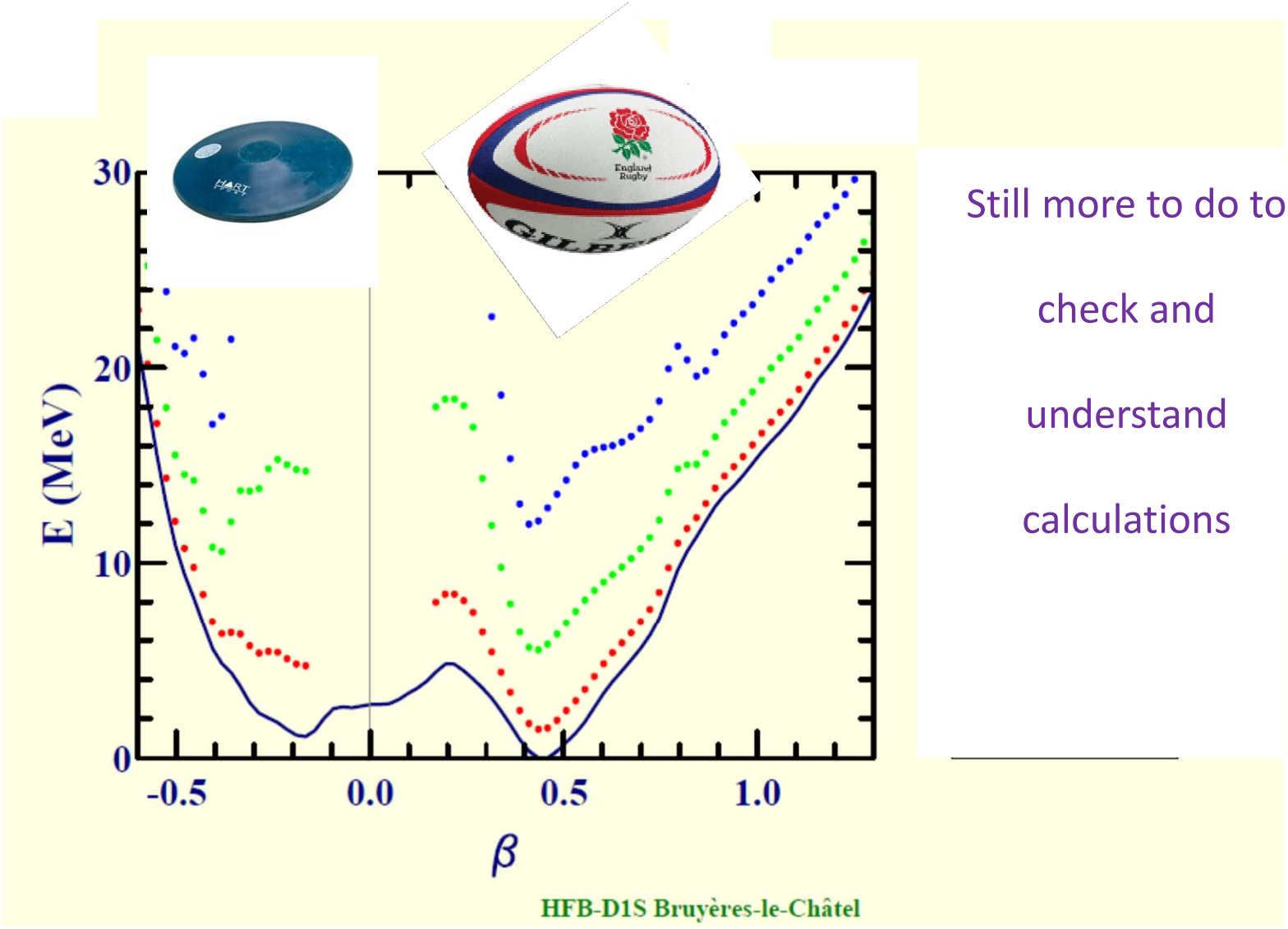

Still more to do to

check and

understand

calculations

S.Hilaire, M.Girod http://www-phynu.cea.fr

Artem Alikhanyan National Science Laboratory

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IBA Cyclone-18:

18 MeV cyclotron =>

low-energy nuclear science programme

(focus on what is done with low-energy beams at the IGISOL)

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Lots of exciting possibilities

IBA Cyclone-18:

18 MeV cyclotron =>

low-energy ... ence programme

(focus ... is done with low-energy beams ... the IGISOL)