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Electron capture of ^{8}B into highly excited states in ^{8}Be. INTC: P-482

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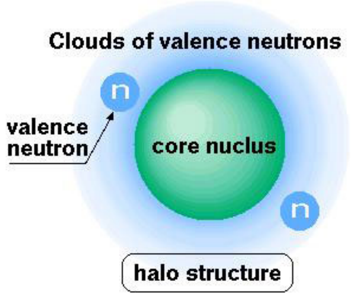
ISOLDE

Halo Nuclei – Reaction & β-decay

Halo Nuclei



- Weakly bound (easy to break-up)
- Easy to polarise (large B(E1) low energy strenght)
- Suffer lower Coulomb barrier
- Higher transfer probability

→ good cases to be studied in Reaction experiments
As was done for ^{11}Li, ^{11}Be, ^{6}He

IS616@HIE-ISOLDE, D. Pietro et.al., Reaction mechanisms in collisions induced by a ^{8}B beam close to the barrier : effects of halo structure on reaction dynamics

The ^{8}B proton halo is not as extended as the neutron halos (p-wave & Coulomb barrier)
Reaction experiments; Coulomb dissociation at higher energy, or proton capture on ^{7}Be, are good at probing the structure at larger distances from the core.

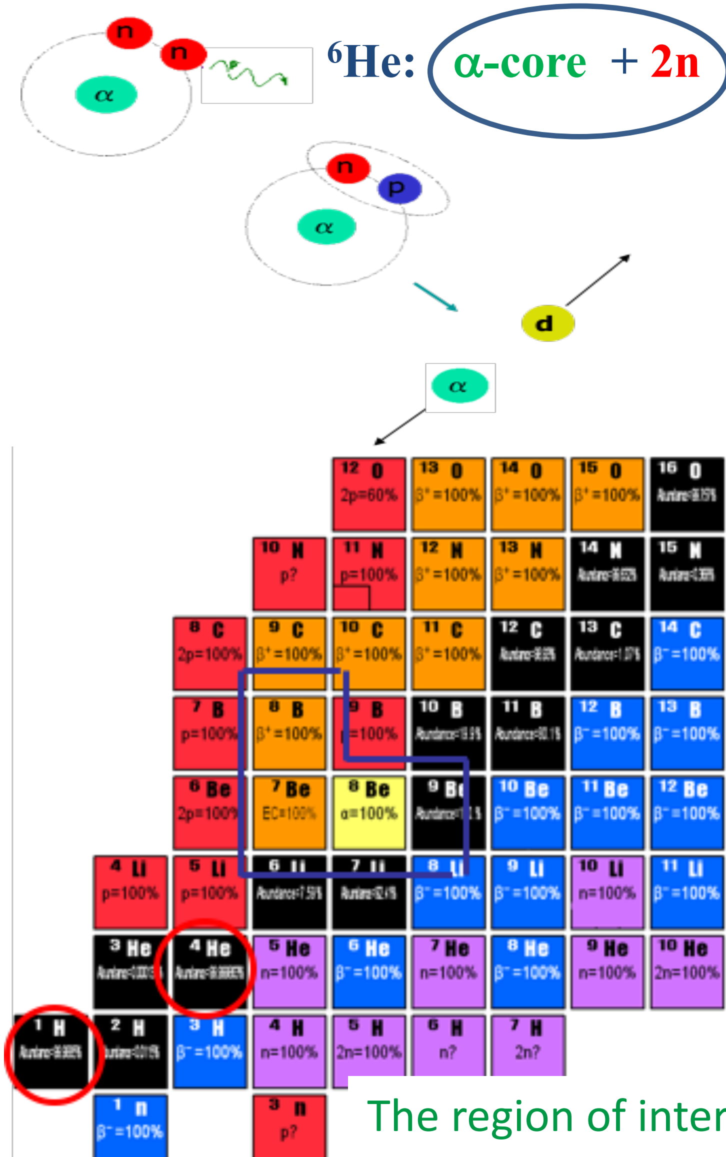
A complementary approach is β-deacy

- **In beta decay we probe the complete wave function,**
- **we are sensitive to the structure at smaller distances,**
- **we can identify the largest part of the beta-strength**

^{8}B a proton halo nuclei?

20 years ago: ^{6}He a 2n halo → localized decay in the 2n-halo → **d + alpha**

^{6}He: α-core + 2n



First observation of beta-delayed deuteron emission
K. Riisager et.al. Phys Let B235 (1990) 30

ISOLDE-3: IP-42

24h for 147 coincidencies → branching 2.8 10^{-6}

^{8}B as p-halo nuclei → ^{7}Be + p

Here the situation is the opposite: we localize the main strength of the decay to the core and the halo-p constitutes the non-decaying spectator;

$$\mathcal{O} \mid c+h\rangle = \mathcal{O}(\mid c\rangle \mid h\rangle) = (\mathcal{O} \mid c\rangle) \mid h\rangle + \mid c\rangle(\mathcal{O} \mid h\rangle)$$

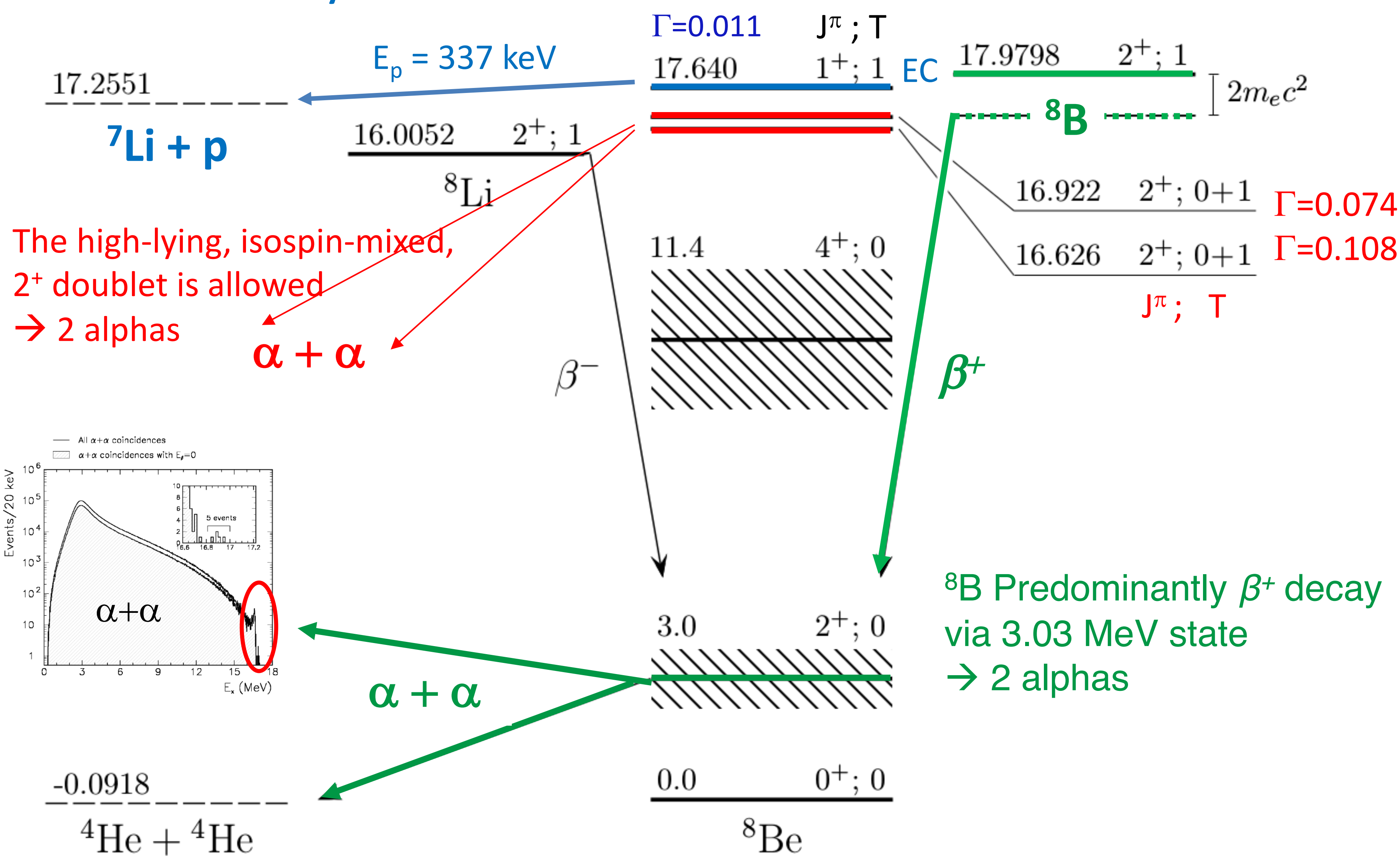
The decay through the 1^{+} level is described by the first term thus the strength can be estimated from the known decay of the ^{7}Be core nucleus.

T. Nilsson et al., Hyperfine Int. 129 (2000) 67

The region of interest enclosed in violet and the decay products red -rings

^{8}B: Decay modes

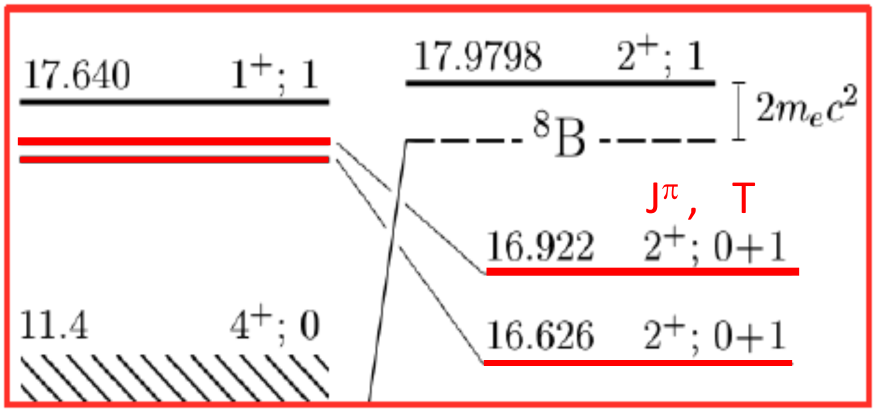
The 1$^+$ at 17.640 MeV accessible only via EC



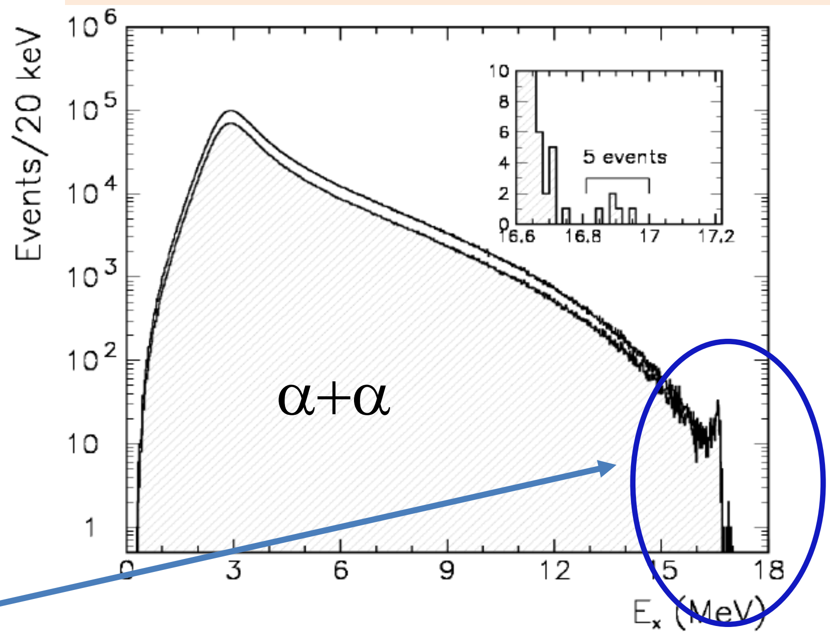
The 2^+ doublet

The decay of ^{8}B into the 16.626 MeV state has been observed several times.

The decay (mainly EC) into the 16.922 MeV state, however, was first seen in our JYFL experiment.



O. Kirsebom et al., Phys. Rev. C 83 (2011) 065802



Expected ratio of decay rates assuming zero GT strength to T=1 component

$$\frac{r_{16.9}}{r_{16.6}} = 2.4\times10^{-2}$$

Consistent with the 5 to 180 events seen

Measurement of the beta-feeding to both members of the 2^+ doublet will allow to determine the Gamow-Teller and Fermi matrix elements of BOTH states for the first time

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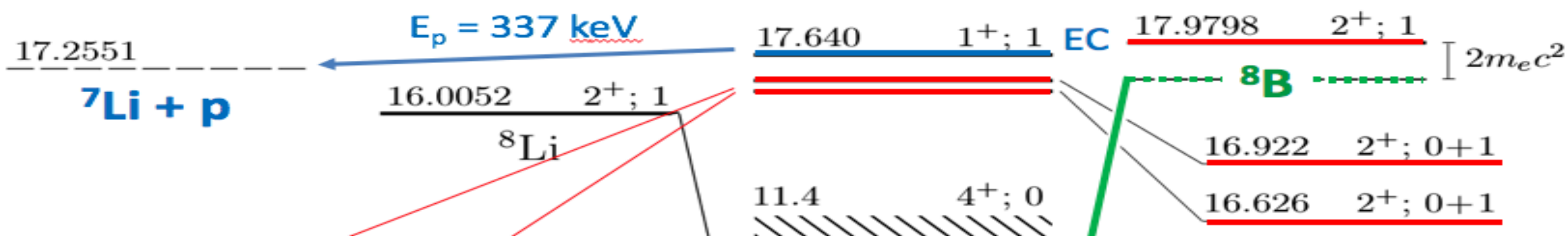
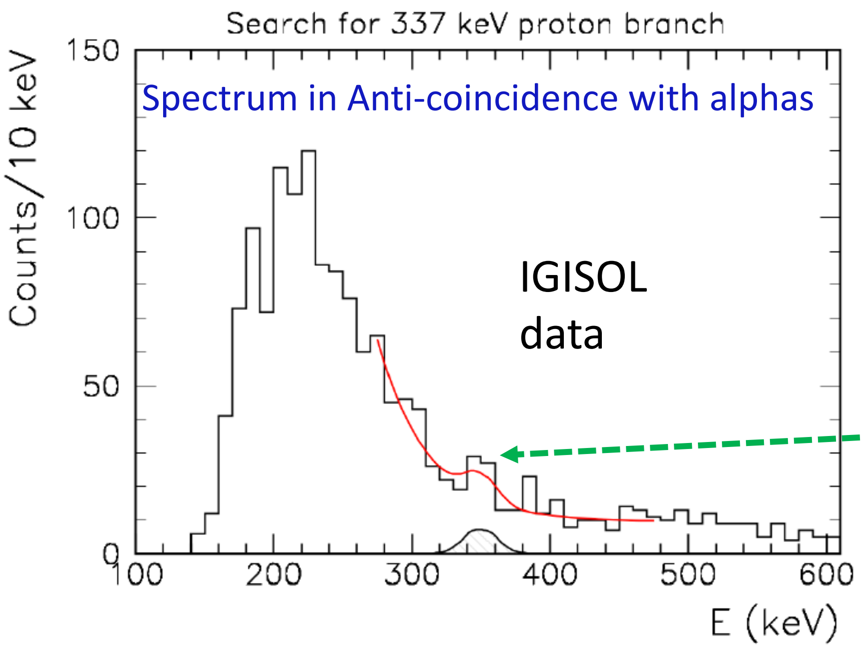
β-delayed proton emission

The 1⁺ at 17.640 MeV accessible only via EC





M.J.G. Borge et al., J. Phys. G 40 (2013) 035109

To look for the 337-keV proton hidden in alpha & beta response is a very challenging task;

Theoretical branching ratio based on the *p-halo spectator + ^{7}Be core - decay* $2.3\ 10^{-8}$

Experimental upper limit from IGISOL $2.6\ 10^{-5}$

Lacking 3 order of magnitude in sensitivity

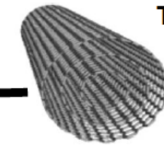
The Background is primarily from

- Multiple scattering of beta particles
- Cosmic muons (observed in beam-off run)

^{8}B production @ ISOLDE

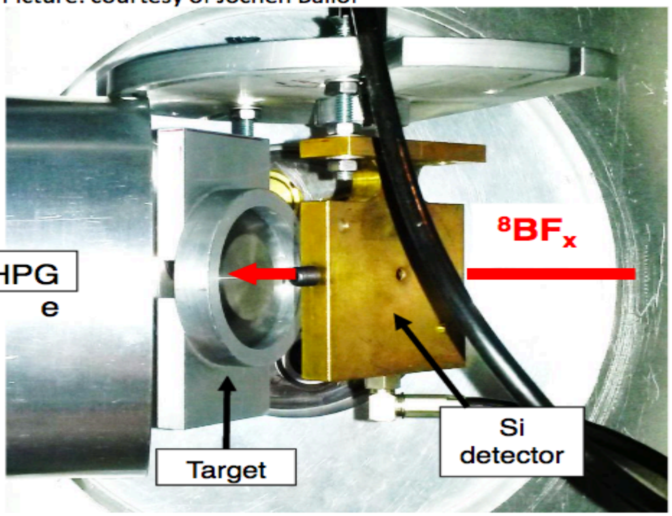
The average yield of ^{8}B in the JYFL experiment was 200/s.
Recent target development at ISOLDE has succeeded in producing a substantially higher yield:

Online measurements: #513

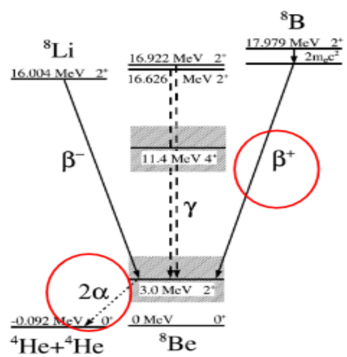


Target container with pellets of Multi Walled Carbon Nanotubes

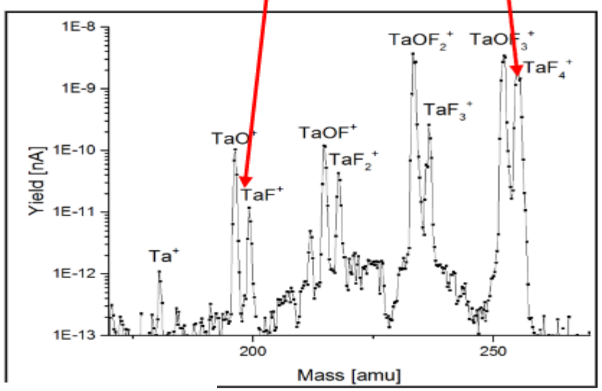
Picture: courtesy of Jochen Ballof



- Coincidence measurement of α and γ (from β^{+} annihilation)
- In addition: β^{+} and γ activity with tape station



Target	TaF^{+}	TaF_4^{+}
#499	0.6 pA	0
#513	190nA	1.6μA



Mass scan unit #470

20

Christoph.Seiffert@Cern.ch

- Yield of $^{8}BF_2^{+}$ of **2.8x10⁴ 1/μC**

C. Seiffert, contribution to the ISOLDE workshop 2015

This now allows to tackle the above two challenges in the ^{8}B decay @ ISOLDE

Experimental set-up @ IDS

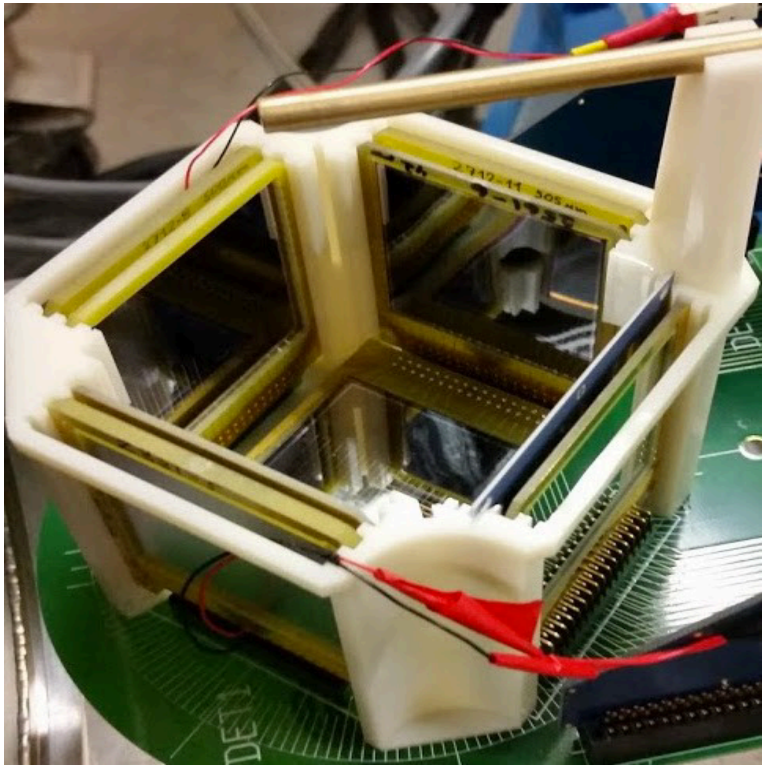
4x particle ΔE-E telescopes + 1x PAD in the bottom for further β coverage

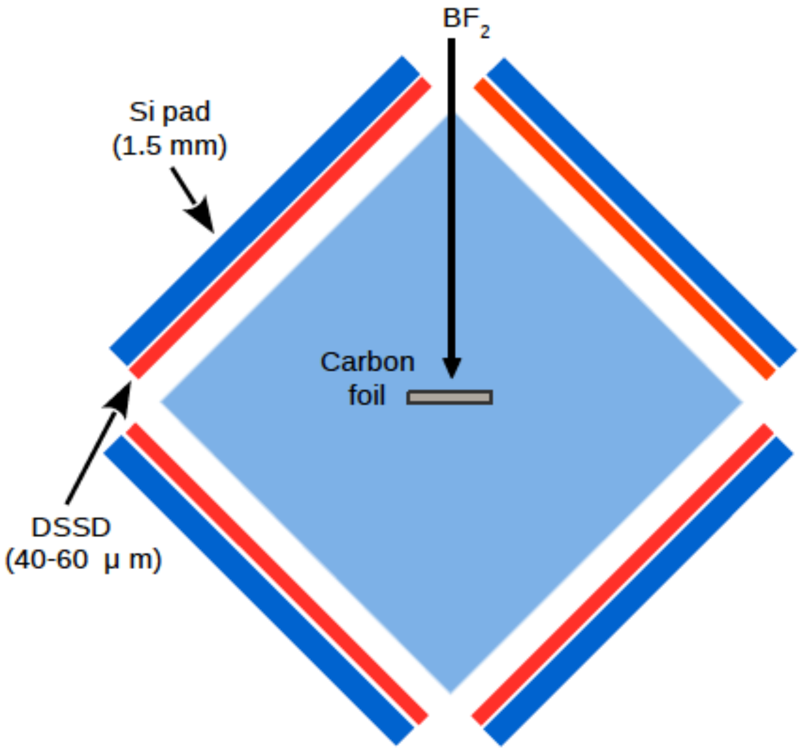
- ΔE: DSSDs 2x40 μm + 2x60 μm
- E: PADs 1500 μm

Highly segmented 1024 pixels of 3x3 mm

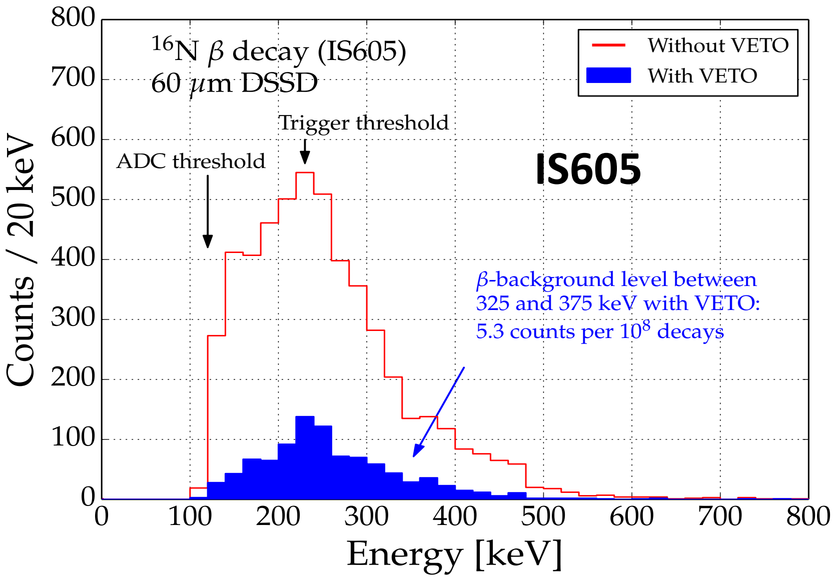
→ high many particle coincidence efficiency, high β-efficiency

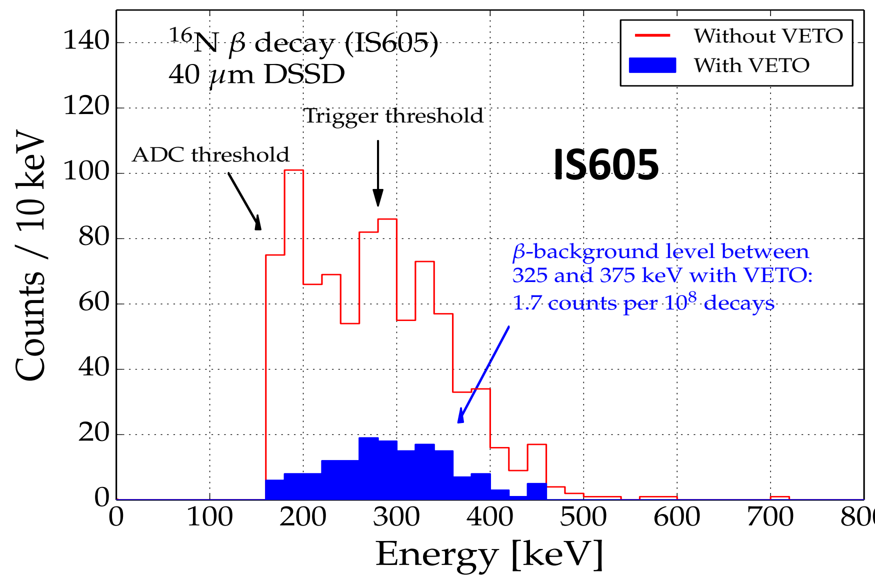
The same and tested Set-up of IS605

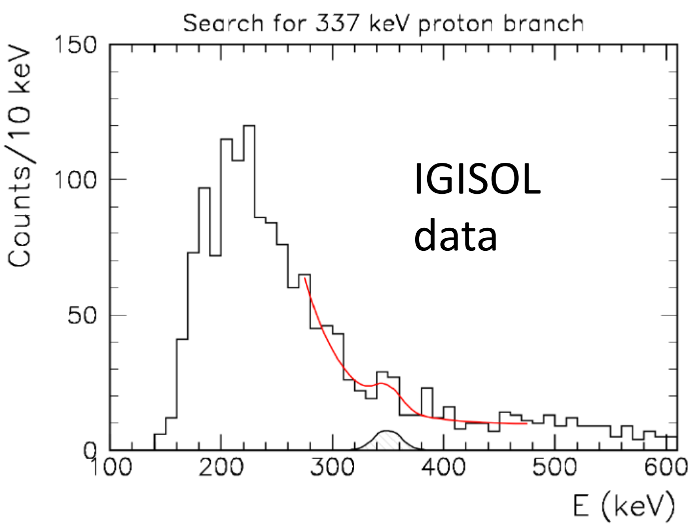




Experimental sensitivity (p-branch)





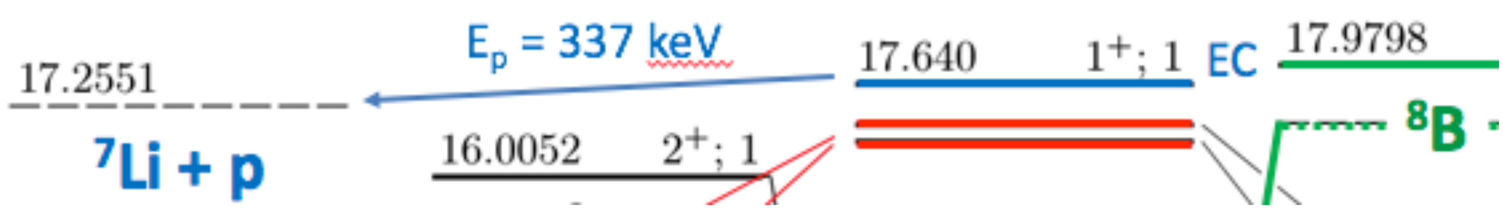


2/5 further reduction with 40 μm

By analyzing the ^{16}N data of IS605 (2016);

- **the cosmic background rate is sufficiently low,**
- **the beta rate in the 40 and 60 micron DSSDs is low**
- **Using the VETO condition we should reach a few 10^{-7} sensitivity in 6 shifts Not enough! →**

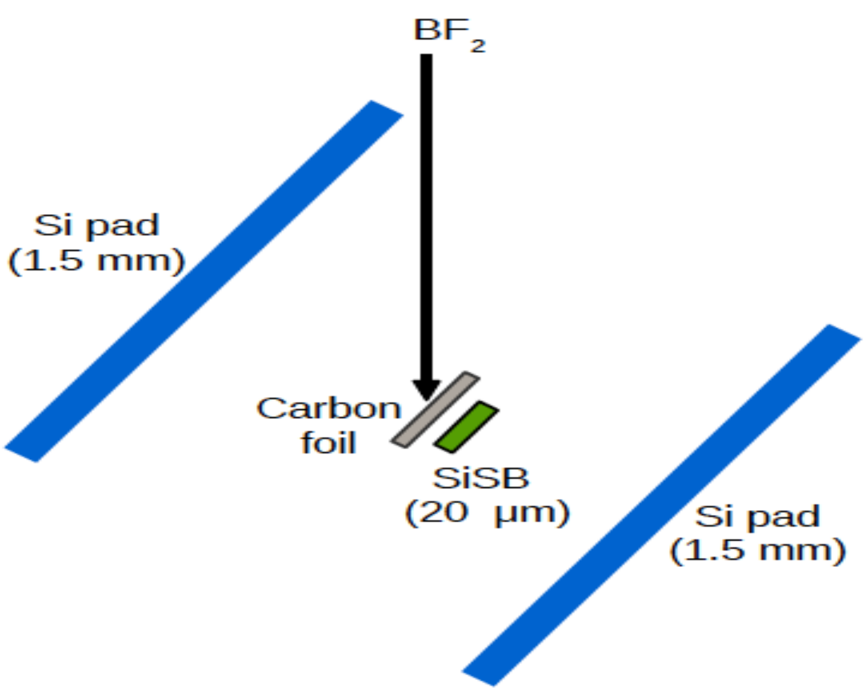
Experiment Run-2: β-delayed proton emission



The 17.640-MeV state is fed by EC (electron capture) → lack of a coincident charged particle to gate on → rely on other techniques;

1) **Thinner Si-dector 20 μm → minimize the beta and myon response**
2) **Thick Si surrounding → Anti-coincidence requirement will cut down unwanted events from the region of interest**
3) **Add magnetic separation?**

- **Thin 20 μm Small sized SiSB to reduce the noise level and better energy resolution**
- close proximity to the C-foil
- Thick pad detectors acting as anti-coincidence veto



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Summary & Beam request

The purpose of this experiment is to determine the beta strength to highly exited states in ^{8}Be;

- **→ explore the Halo wave function over the full radial range**
- **→ identify the unobserved ^{8}B delayed proton emission**

We ask for 15 shifts distributed over 2 runs:

6 shifts: Measurement using DSSD + pad telescopes
Based on the IGISOL data we should observe
~500 decays through the 16.9-MeV member of the 2^{+} doublet

Time to analyse the background before the 2nd experiment

9 shifts: Measurement using optimized set-up for detecting the 337 keV proton
to reach a sensitivity of 10^{-8}

Estimated beam time request is based upon an **implantation rate of 4.2 10^{4}** ions/s
(TAC: Yield 3e4 as BF^{+} , re-use existing target. Beam 1.6 μA Transmission 85%)

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Recent β-decay studies by the collaboration

Data taking completed, under analysis

IS605 ^{16}N

IS577 ^{31}Ar

I. Marroquin et al., Act. Phys. Pol. B47, 747 (2016).

Completed experiment

IS541 ^{11}Be

K. Riisager, et.al. Phys. Let. B732 (2014) 305-308

IS507 $^{20\text{-}21}Mg$

M. Lund et al., Phys. Lett. B750, 356 (2015).
M. Lund et al., Eur. Phys. J. A51, 113 (2015).
M. Lund et al., Eur. Phys. J. A52, 304 (2016).

IS476 ^{31}Ar

G. T. Koldste et al., Phys. Rev. C87, 055808 (2013).
G. T. Koldste et al., Phys. Rev. C89, 064315 (2014).
G. T. Koldste et al. Phys. Lett. B737, 383 (2014).

Related Publications by the Collaboration

n-halo in beta decay @ ISOLDE

6He: **First observation of beta-delayed deuteron emission**
K. Riisager et.al. Phys Let B235 (1990) 30
17F: **Beta-decay to the proton halo state in ^{17}F**
M.J.G.Borge et.al., Phys. Lett. B 317 (1993) 25
11Li: **Evidence of a new state in ^{11}Be observed in in the ^{11}Li decay**
M. Madurga, et.al. Phys. Lett B677, 255259, (2009)
11Be: **^{11}Be(βp), a quasi-free neutron decay?**
K. Riisager, et.al. Phys. Let. B732 (2014) 305-308.

Halo-nuclei at ISOLDE
T. Nilsson, G. Nyman and K. Riisager
Hyperfine Interactions 129 (2000) 67–81

Journal of Physics G: Nuclear and Particle Physics
ISOLDE Decay Station for decay studies of interest in astrophysics and exotic nuclei
Hans O U Fynbo[1], Oliver Kirsebom[2] and Olof Tengblad[3]
https://doi.org/10.1088/1361-6471/aa5e09