Studies of the atomic nuclei by the MAGISOL collaboration at ISOLDE and HIE-ISOLDE

IDS Isolde Decay Station: ^{8}B beta decay
SEC Scattering Experiment Chamber: ^{15}C+^{208}Pb → elastic & break-up

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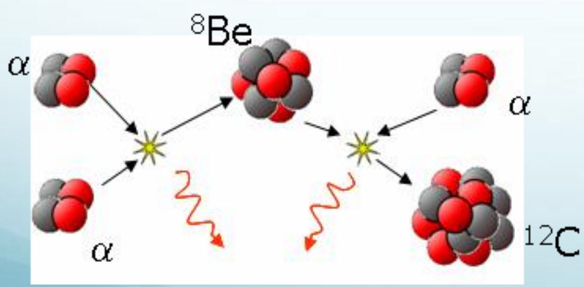
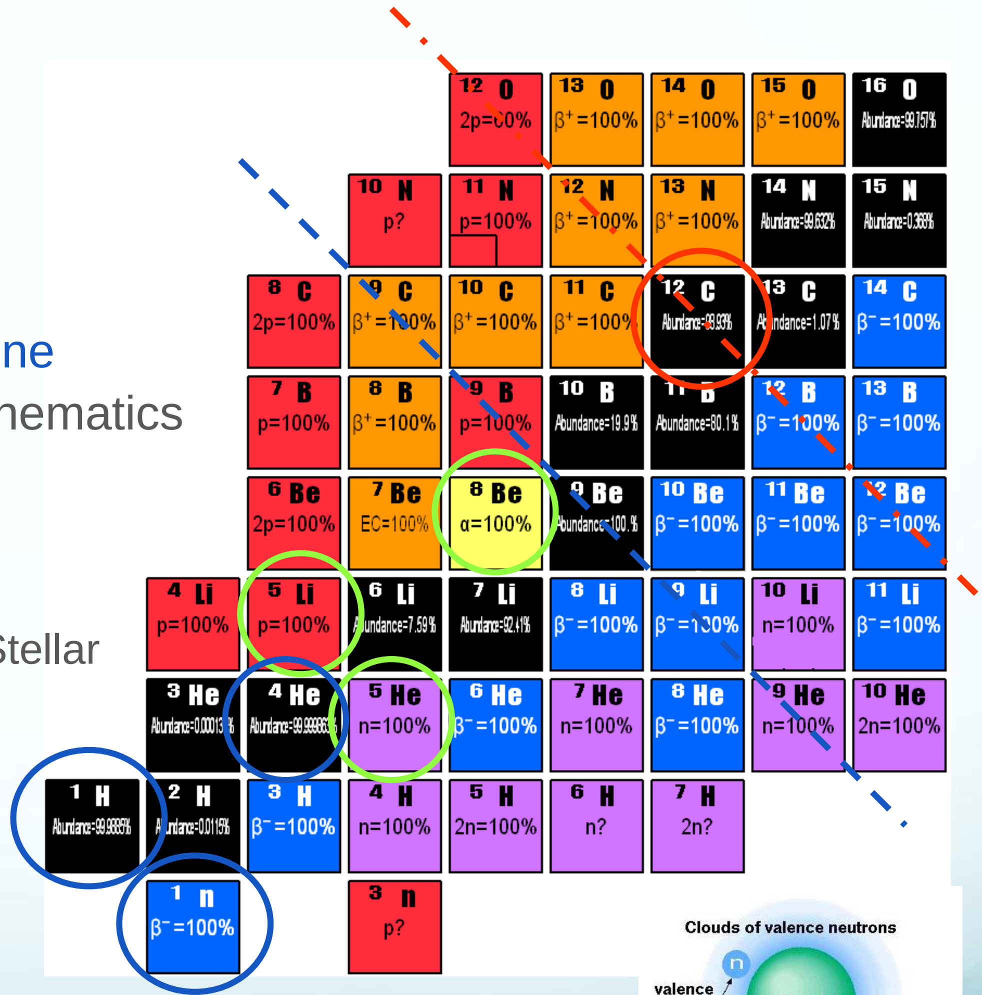
MAGISOL

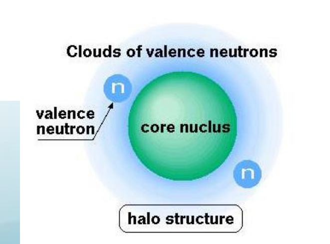
Madrid -- Aarhus -- Göteborg

Light Nuclei & Nuclear Structure

- "Exact" A-body calculations possible
  - Shell-model states
  - Molecular-cluster states
- We can cover from drip-line to drip-line
- Break-up mechanism not fixed by kinematics
  - Sequential?
  - Direct?
- Crucial for bridging the
  - A=5 and A=8 gaps in Big Bang and Stellar nuclear synthesis.





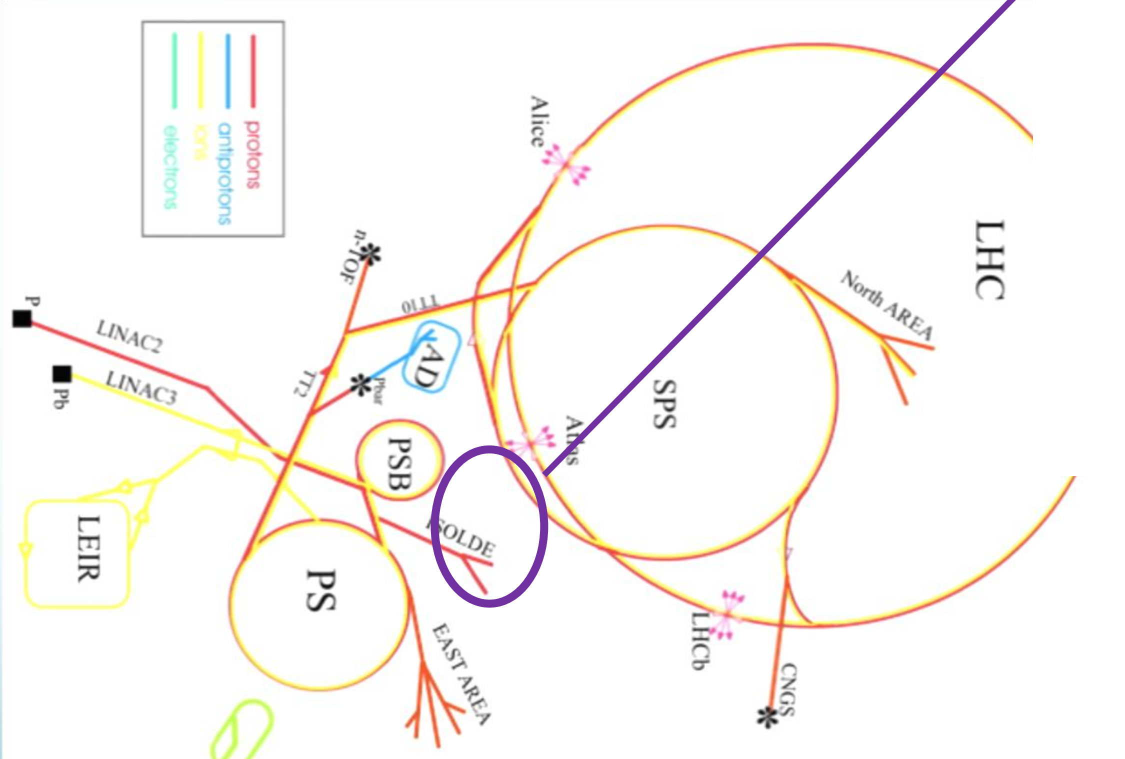


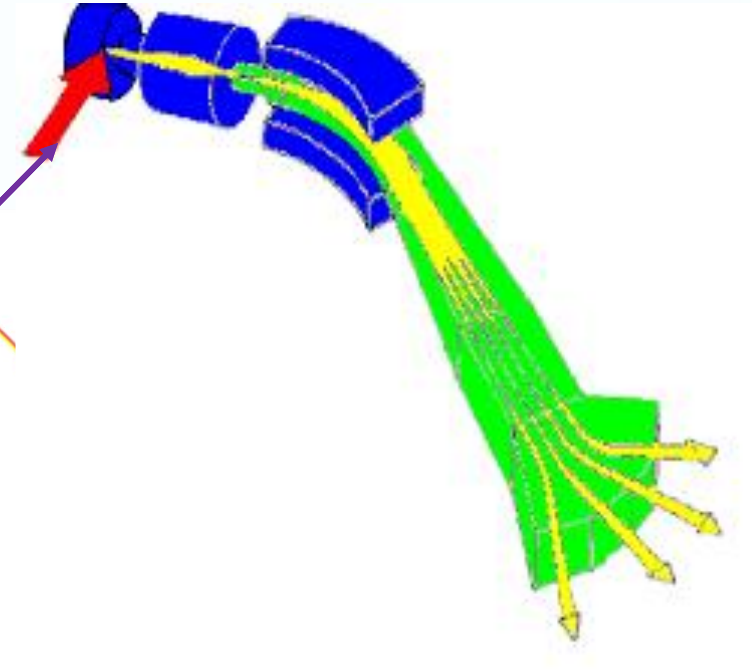
Halos

α clustering

ISOLDE: Isotope Separation On-Line @ CERN

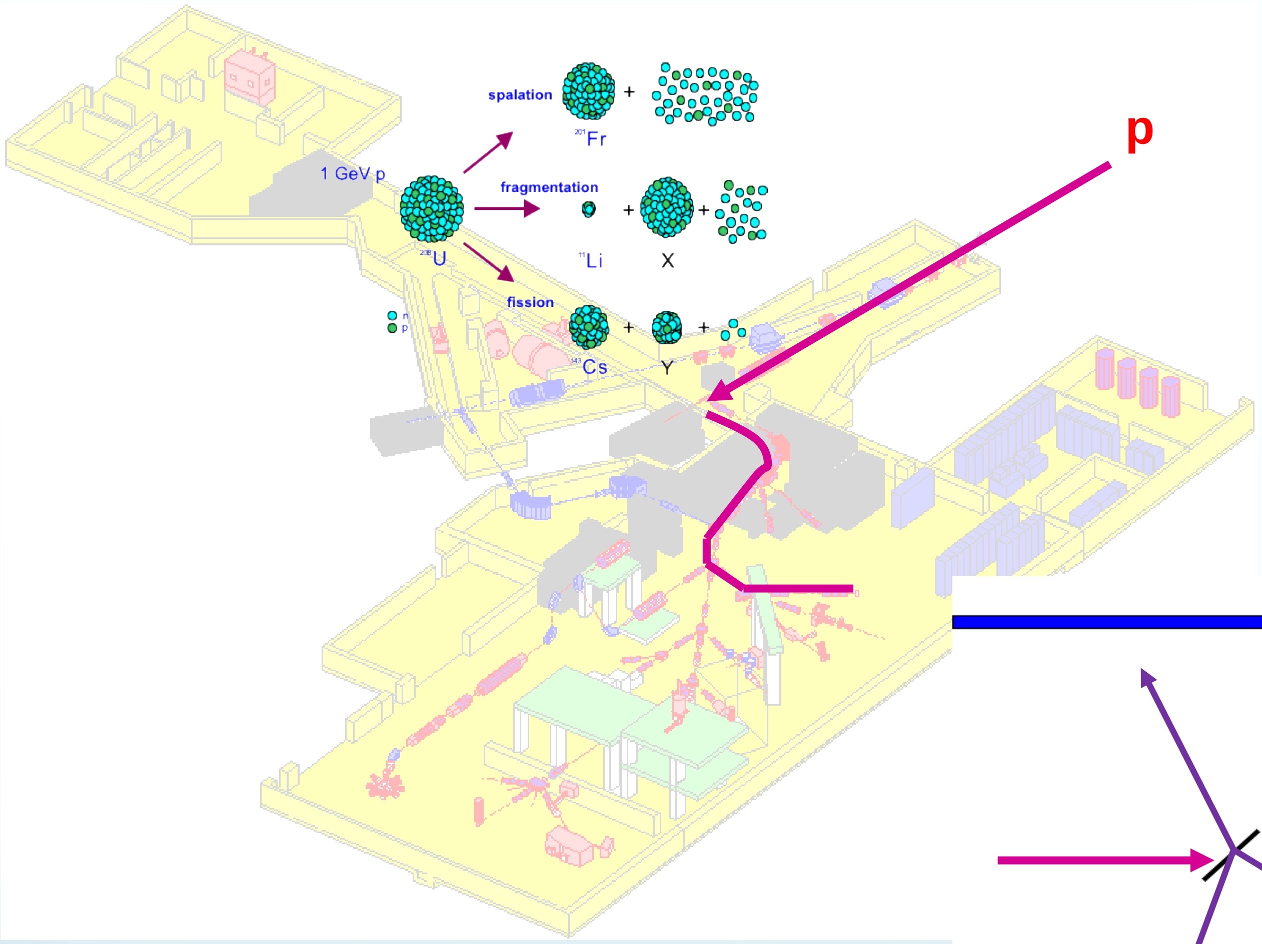
CERN accelerator complex
PS Booster → ISOLDE

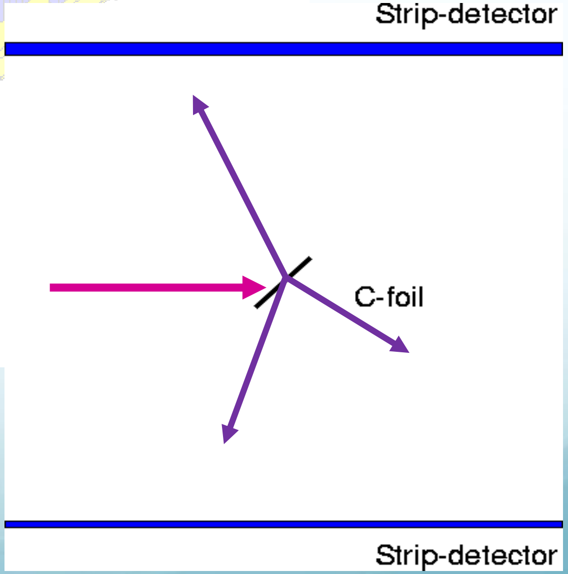




Beam: Protons 1.4 GeV
Intensity: 3 10^{13} p/p
pulse: 3μs
frecuency: 0.5-1Hz

ISOLDE Decay Experiments





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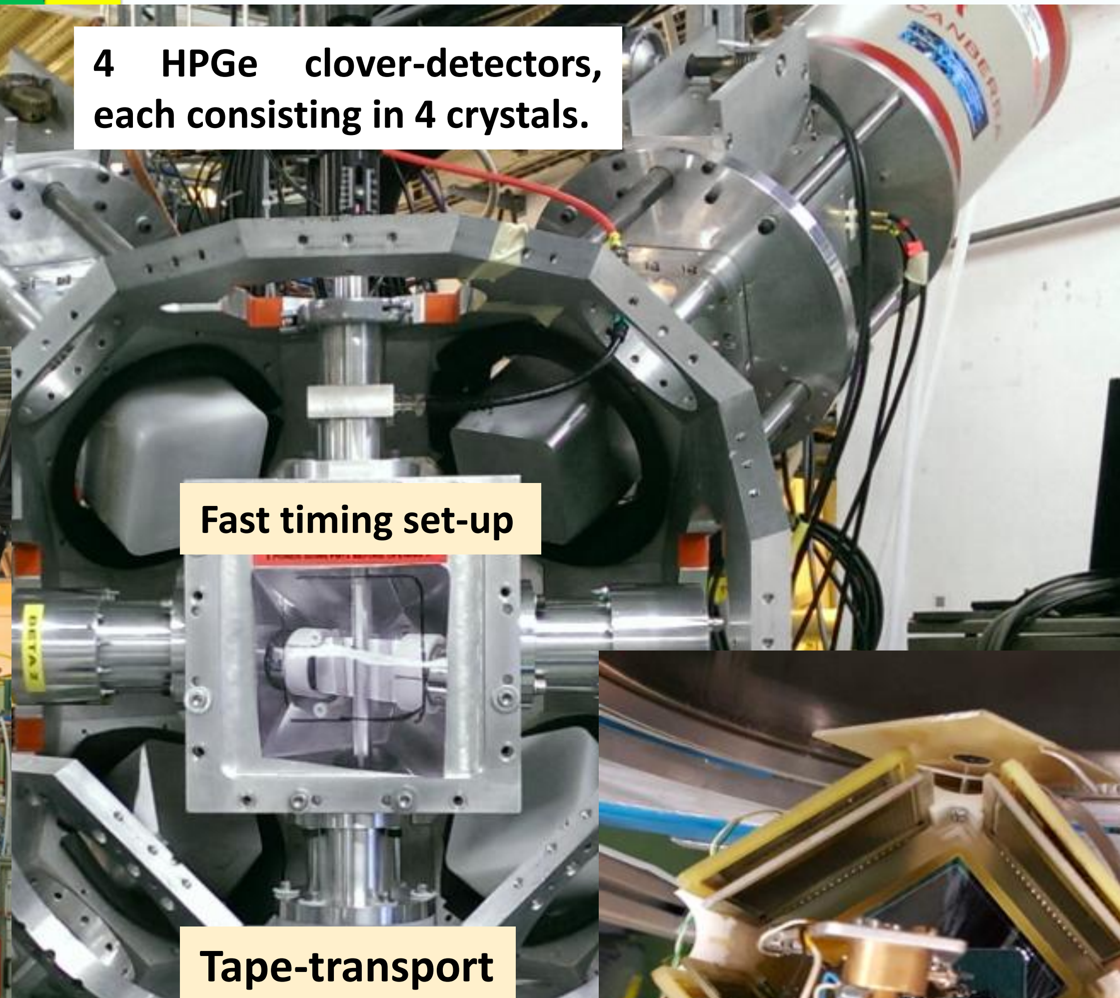
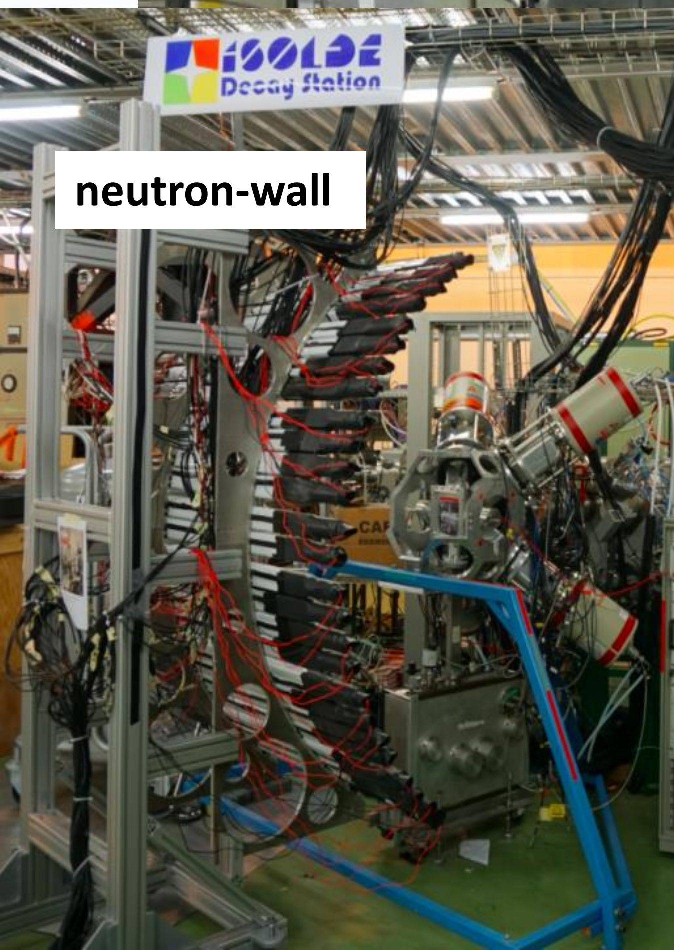
IDS – ISOLDE Decay Station

http://isolde-ids.web.cern.ch/isolde-ids/#setup

IFIN-HH

KU LEUVEN





Set-up: conversion - e under study

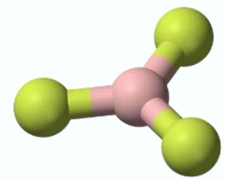
Target development: ^{8}B production @ ISOLDE

Another important TOOL for the experiment is the TARGET and ion production

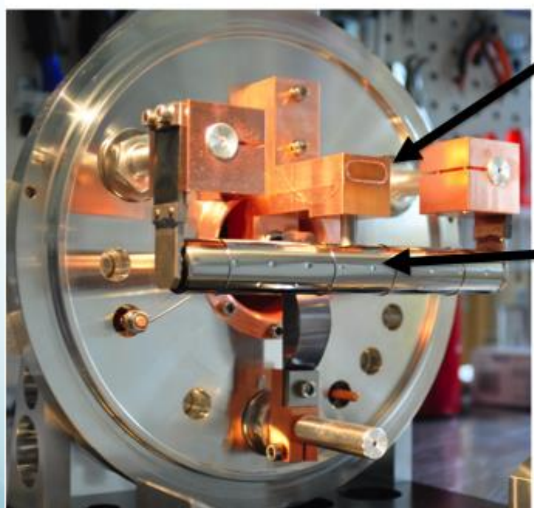
B react with most materials, get stuck → makes extraction of ^{8}B difficult

Forming volatile compounds of ^{8}B within a porous target material, makes the situation better

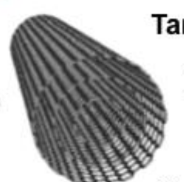
$$^{8}B \xrightarrow{SF_{6}\,(g)} {}^{8}BF_{2}^{+}$$



The Target unit #513



Cooled Cu transfer line and VADIS 7 („Plasma") Ion Source



Target container with pellets of Multi Walled Carbon Nanotubes

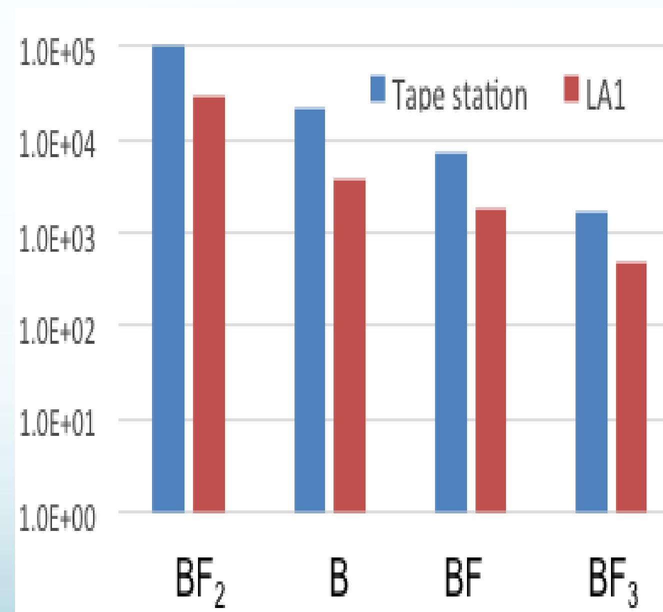
14.85 g

→ Surface area = 4455 m²

Calibrated Leak

For the injection of $\mathbf{SF_6}$ (2 bar)

1.85 • 10^{-4} mbar L / s

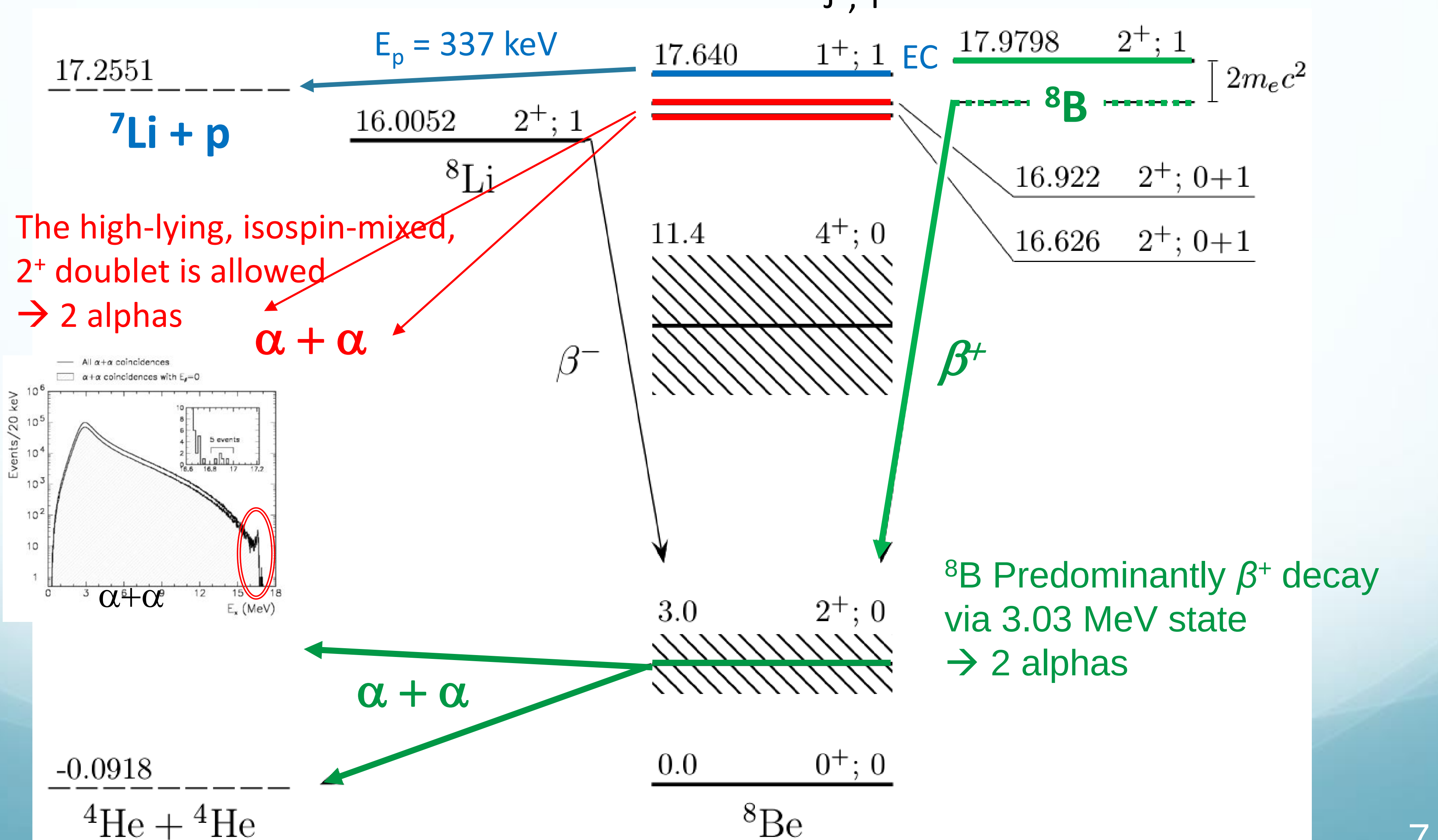


J. Ballof & C. Seiffert, contribution to the ISOLDE workshop 2015

IS633: ^{8}B Decay modes

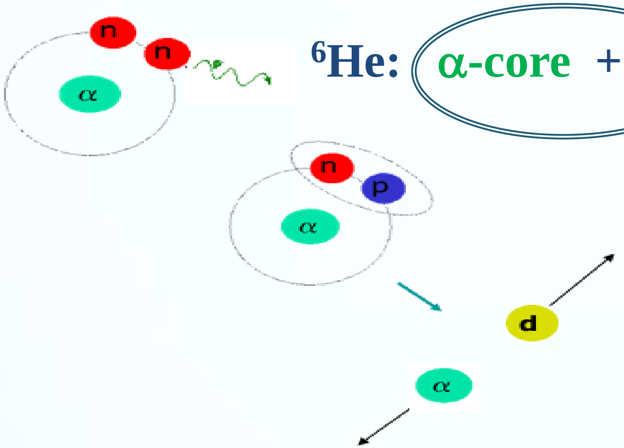
The 1^+ at 17.640 MeV accessible only via EC

O. Kirsebom et al., Phys. Rev. C 83 (2011) 065802
IGISOL 2008 – α-emission for ^{8}B neutrino spectrum



^{8}B as a proton halo nuclei

^{6}He a 2n halo → localized decay in the 2n-halo → d + alpha



^{6}He: α-core + 2n

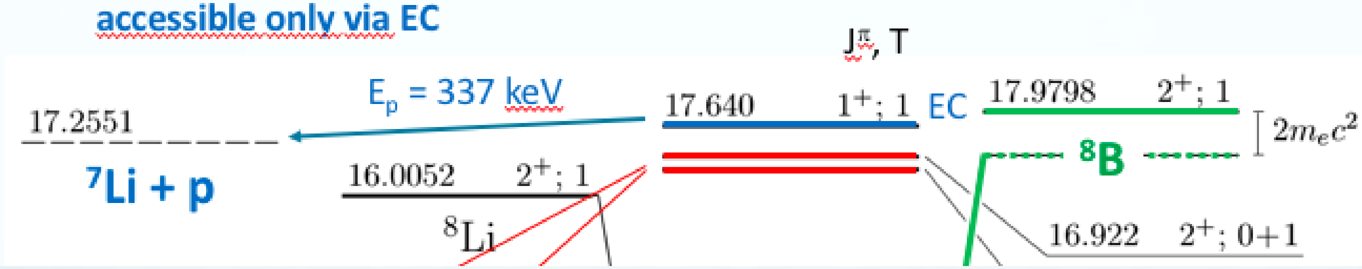
First observation of beta-delayed deuteron emission
K. Riisager et.al. Phys Let B235 (1990) 30

ISOLDE-3: IP-42

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

^{8}B as p-halo nuclei → ^{7}Be + p

The 1^{+} at 17.640 MeV accessible only via EC



For the 1^{+} at 17.640 MeV the case is the opposite: we localize the main strength of the decay to the core and the halo-p constitutes the non-decaying spectator;

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

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

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.

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

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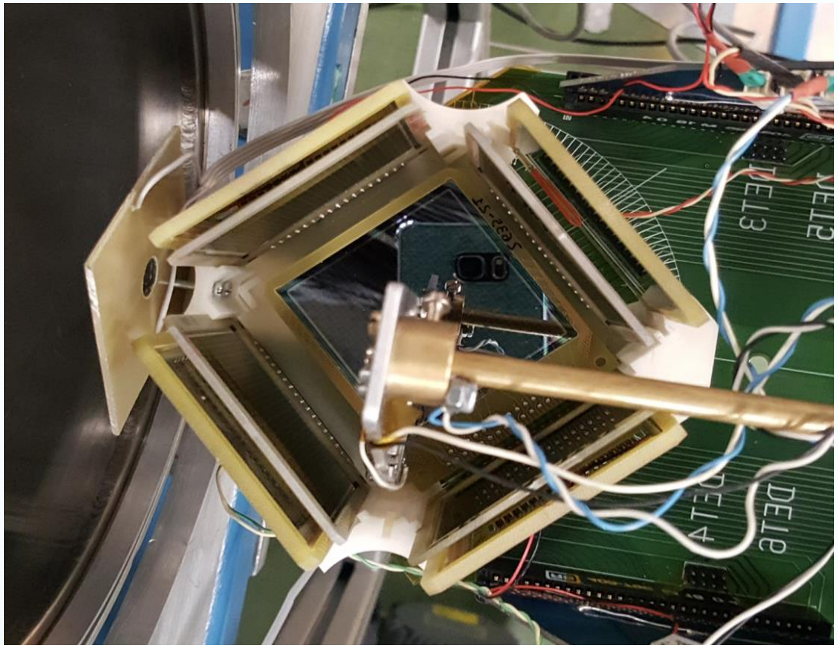
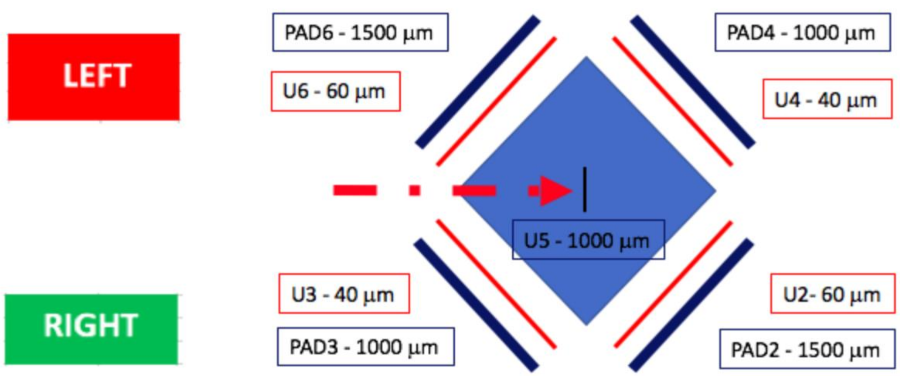
IS633: Experimental setups

16.6-16.9 MeV alpha break up states

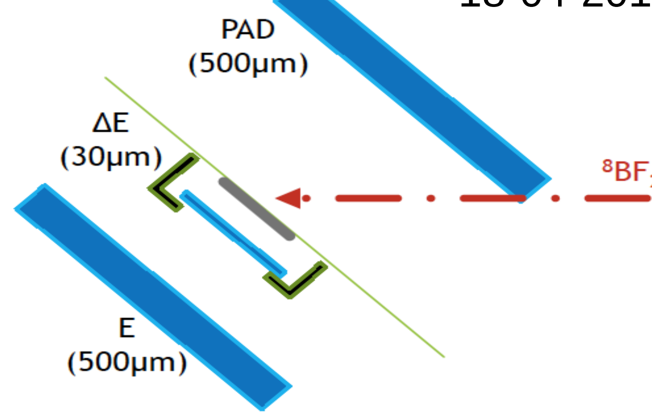


18-05-2017



17.6 MeV p emitting state

18-04-2018



Detector	Distance (mm)	Solid angle covered
PAD	12.5	27.6%
E	25	14.6%
ΔE	8	8.8%

Analysis of the 1st experiment: $\alpha-\alpha$ coincidences

3 set of Data

Low Electronic Thresholds
(40% of dead time)

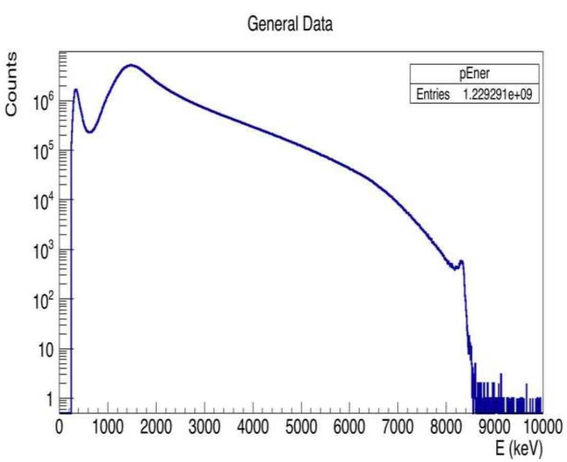
- A = 6 kHz
- Obtain general spectra
- 60 GB

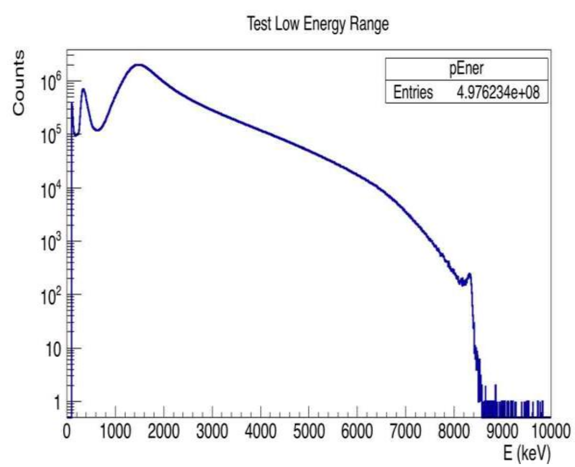
Reduced Beam intensity
Low Thresholds
(20% of dead time)

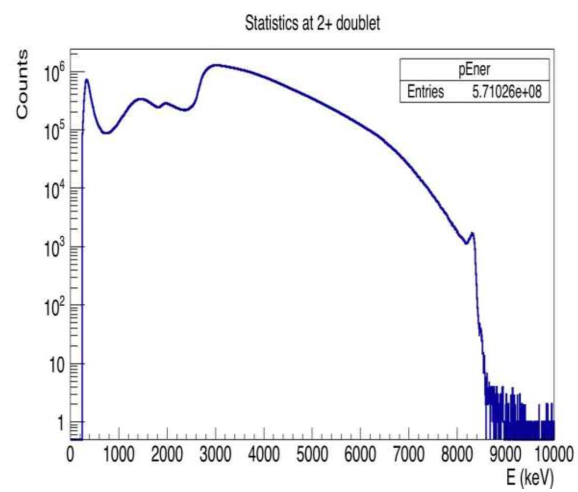
- A = 5 kHz
- Test sensitivity at low energy range
- 22 GB

Full Beam High Thresholds
(15% of dead time)

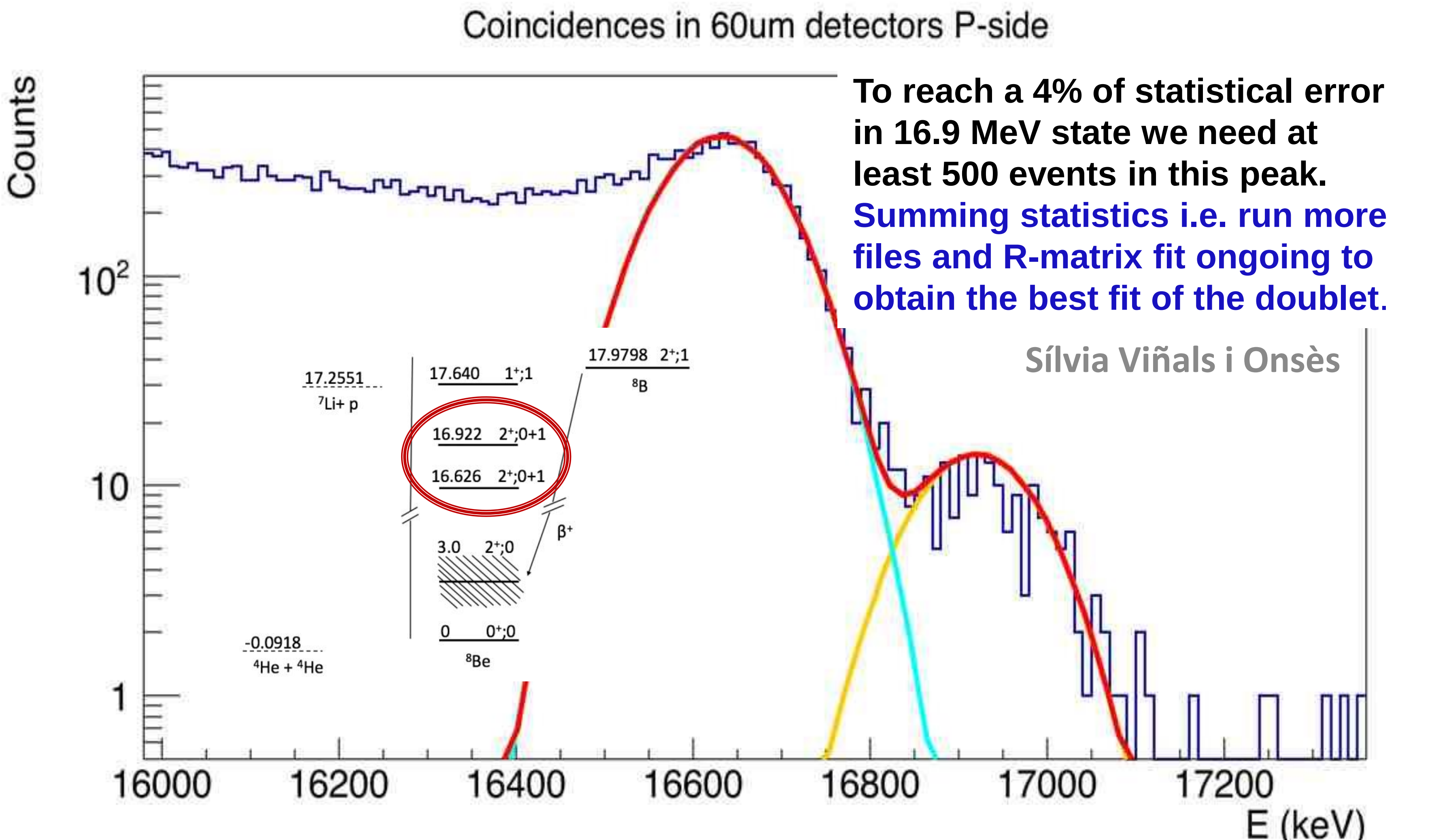
- A = 6 kHz
- Statistics in 2^+ doublet
- 40 GB
- Distorted spectra at low energies







Sum α- α energies observed in opposite detectors



To reach a 4% of statistical error in 16.9 MeV state we need at least 500 events in this peak.

Summing statistics i.e. run more files and R-matrix fit ongoing to obtain the best fit of the doublet.

Sílvia Viñals i Onsès

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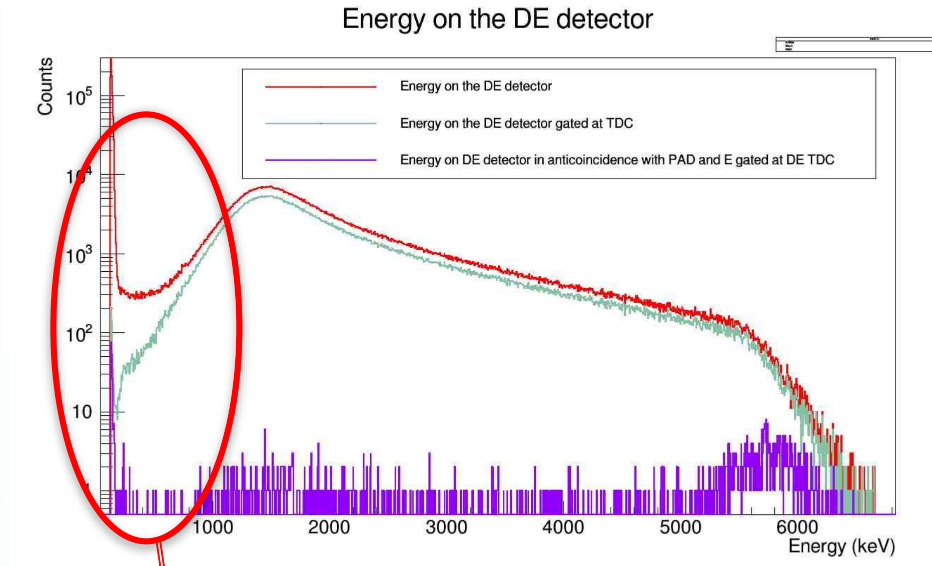
17.6 MeV state and p-branch

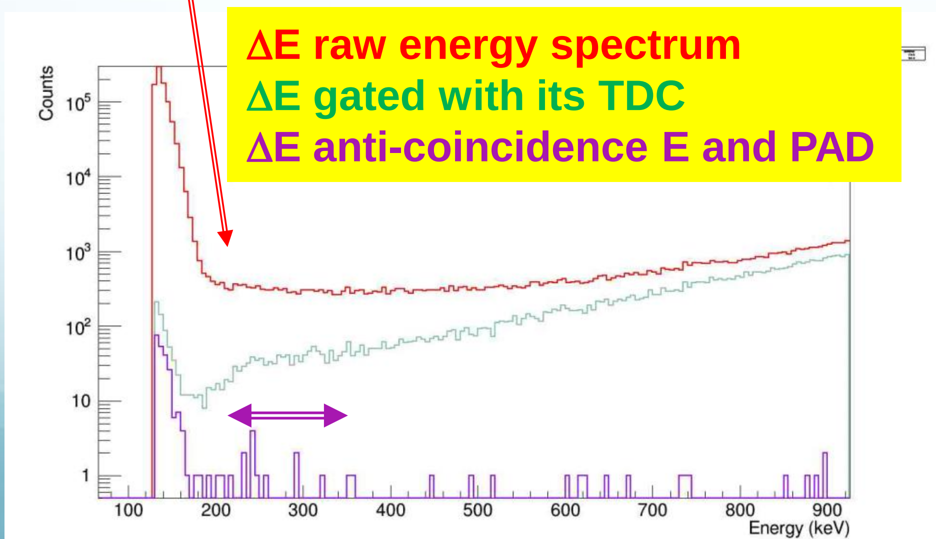
Sílvia Viñals i Onsès

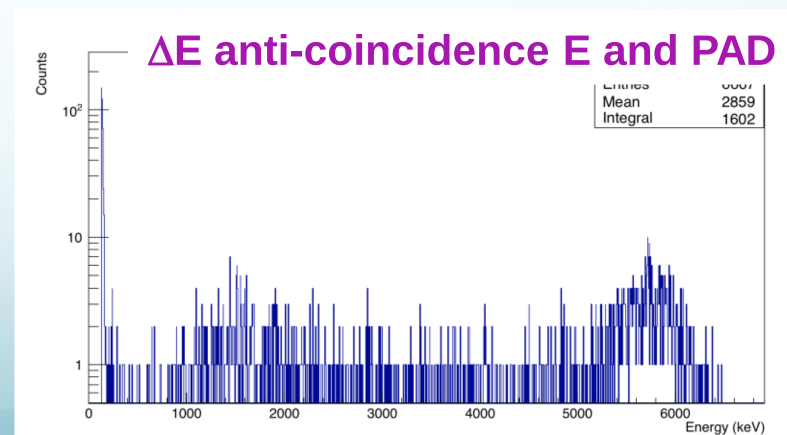


The main activity of ^{8}B – β^{+} –> 〈 〈 determines the upper limit of the branching ratio i.e. on how many events in coincidence compared to how free from background in the [250 – 400] KeV.

The theoretical upper limit is 2.310^{-8} calculated the wave function as a proton halo.

Up to now, (**10% of the data analysed**). an experimental upper limit of $4.4.10^{-6}$





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HIE-ISOLDE @ 7.5 MeV/u 2017

2017
13 experiments
10 @ Miniball
3 @ XT03
Stable beam for ISS

3 CMs : 7.5 MeV/u @ A/q=4.33

MINIBALL { **CD-Si Detectors** **Plunger**

SEC

ISS - ISOLDE Solenoidal Spectrometer

SEC @ XT03 HIE ISOLDE

http://isolde-sec.web.cern.ch

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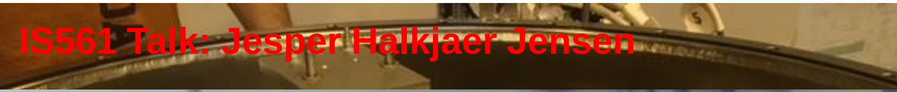
LUND UNIVERSITY

SCATTERING EXPERIMENT CHAMBER

J. Cederkall joakim.cederkall@nuclear.lu.se O. Tengblad olof.tengblad@csic.es

Expt.	Spokesperson, institution	Beam	Description
IS619	I. Martel *GEM Huelva* O. Tengblad *IEM Madrid*	^{15}C	Effects of the neutron halo in ^{15}C scattering at energies around the Coulomb barrier
IS616	A. Di Pietro *INFN Catania*	^{8}B	Reaction mechanisms in collisions induced by ^{8}B beam close to the barrier.
IS607	C. Lederer *Univ. Edinburgh*	^{59}Cu	The ^{59}Cu(p,alpha) cross section and its implications for nucleosynthesis in core collapse supernovae.
IS561	K. Riisager *IFA Univ. Aarhus*	^{9}Li	Transfer reactions at the neutron dripline with triton target
IS554	D. Gupta *Bose Inst. Kolkata*	^{7}Be	Search for higher excited states of ^{8}Be* to study the cosmological ^{7}Li problem.
IS550	S. Heinz *GSI* E. Kozulin *JINR Dubna*	^{9495}Rb	Study of the Dinuclear System ^{A}Rb + ^{209}Bi (Z1 + Z2 = 120).
IS629	**C. Mazzocchi** **Univ. Warsaw**	**^{11}Be**	**Beta decay of ^{11}Be in TPC**

SEC - Scattering Experiment Chamber



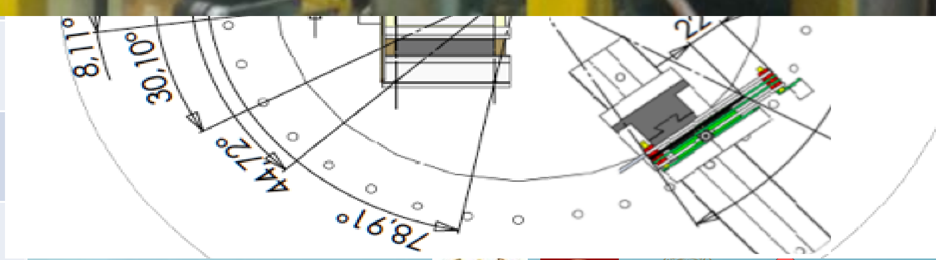
SAND n-Array

32x 10x10x10cm^3 Plastic TPS-1000

PM tubes Photonis XP4312

Power supply CAEN SY1527

DSSD S3	1	32x24	9 mm^2	$\Delta\Theta = 3^\circ$	768	768
DSSD BB7	2	32x32	4 mm^2	$\Delta\Theta = 2^\circ$	1024	2048
					Total pixels	**4096**



SI619: Effects of the neutron halo in ^{15}C scattering at energies around the Coulomb barrier

I. Martel *GEM Huelva* O. Tengblad *IEM Madrid*

Studying the low energy dynamics of the halo nucleus ^{15}C (S_n=1215 keV, S_{2n}=9395 keV) by measuring the angular distribution of the elastic scattering and ^{14}C production cross sections at Coulomb barrier energies.

The carbon isotope ^{15}C is a rather unique nucleus as its ground state exhibits the only known pure s-wave halo configuration.
The halo structure favors breakup and neutron stripping to bound states, and these effects should be observable as a sudden decrease in the angular distribution of the elastic channel around the grazing angle.

This is the first dynamical study carried out so far for the halo nucleus ^{15}C at low collision energies.
This should bring information on the coupling between elastic, neutron transfer and breakup channels, and the role of the continuum.

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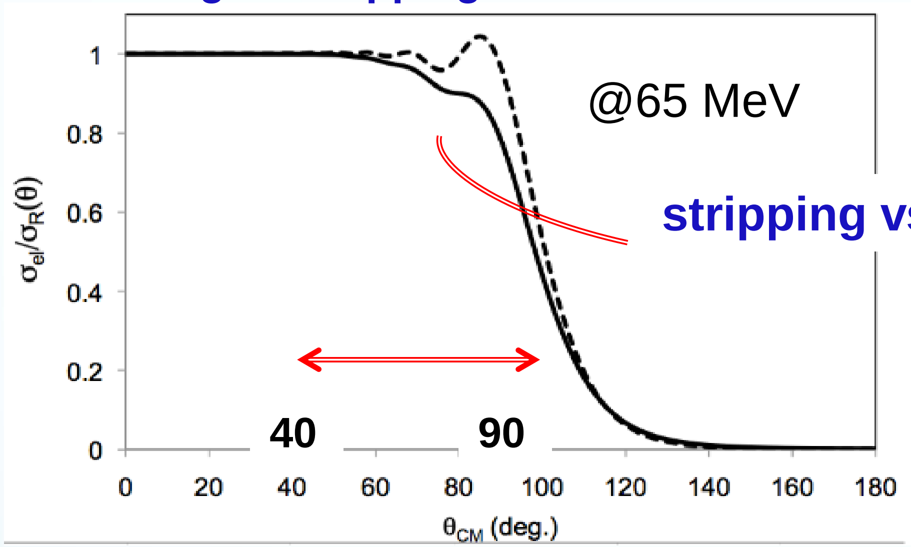
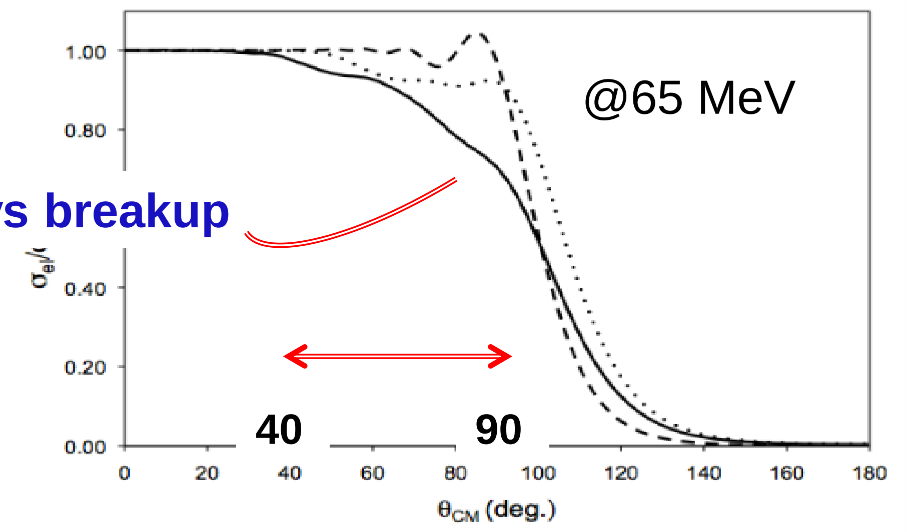
Theoretical calculations: $^{15}C + ^{208}Pb \rightarrow ^{14}C + n$

CRC
coupled reaction channel calculations
including 1n stripping

CDCC
Continuum Discretised Couple Channel
including breakup and inelastic scattering





elastic scattering, normalized to Rutherford

The ^{15}C halo modeled as neutron plus inert ^{14}C core, given that the first excited state of ^{14}C is high lying > 6 MeV.

solid line - the full calculation
dashed line - without couplings
dotted line - nuclear couplings

the effects on the elastic cross section due to breakup and 1-n stripping are quite different.
If the breakup dominates the scattering process, we should observe a strong absorption in the elastic yield even at very forward angles, ranging from 10% to 40% between 40º to 90º degrees.

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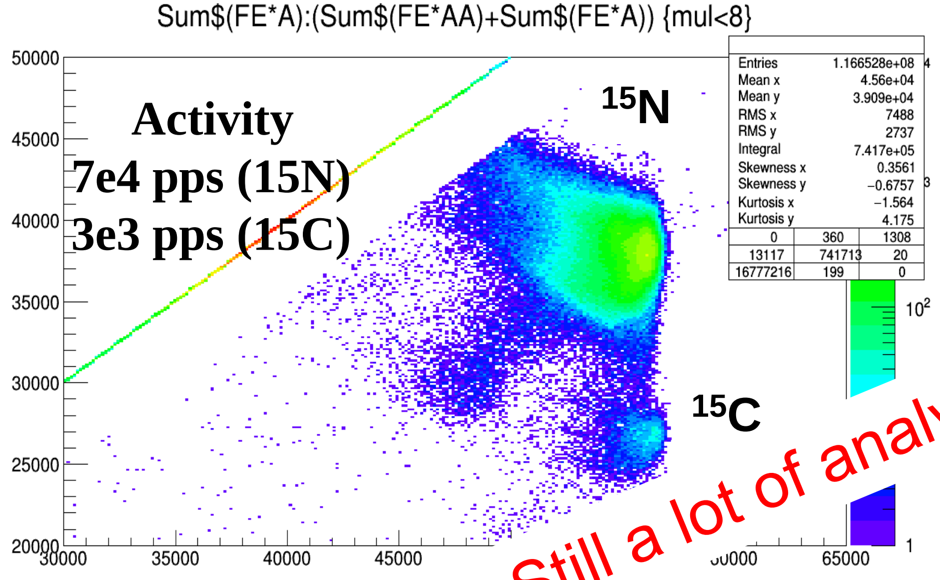
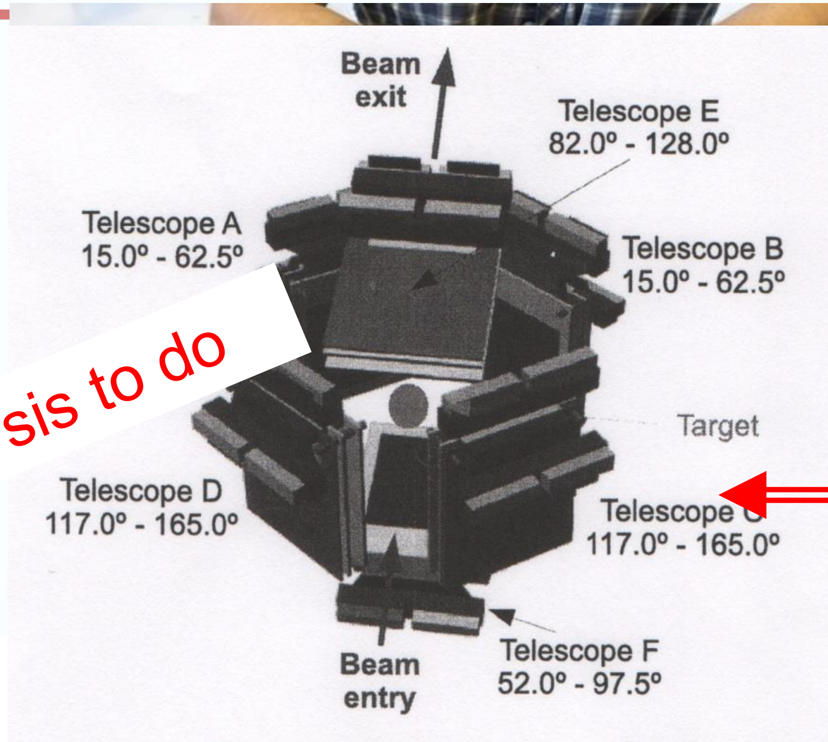
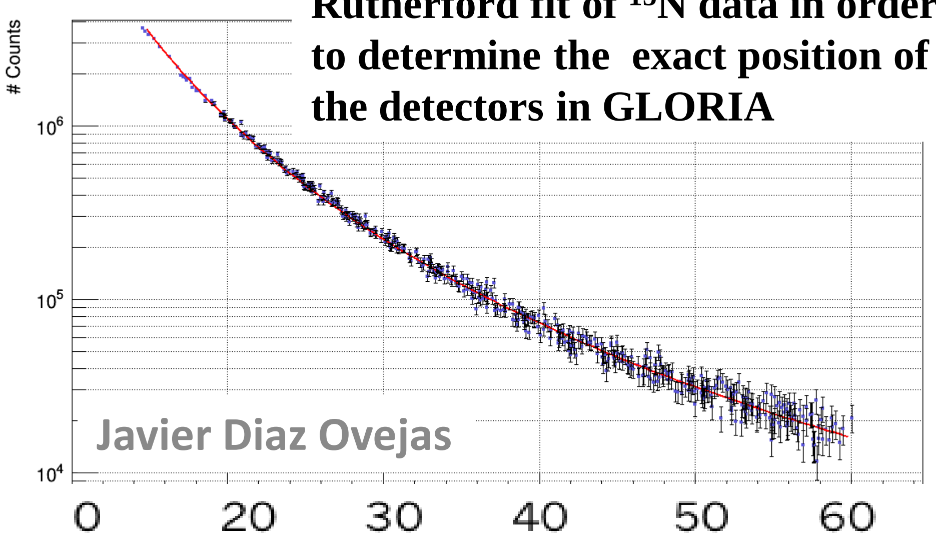
IS619: n-halo in 15C scattering at the Coulmb barrier

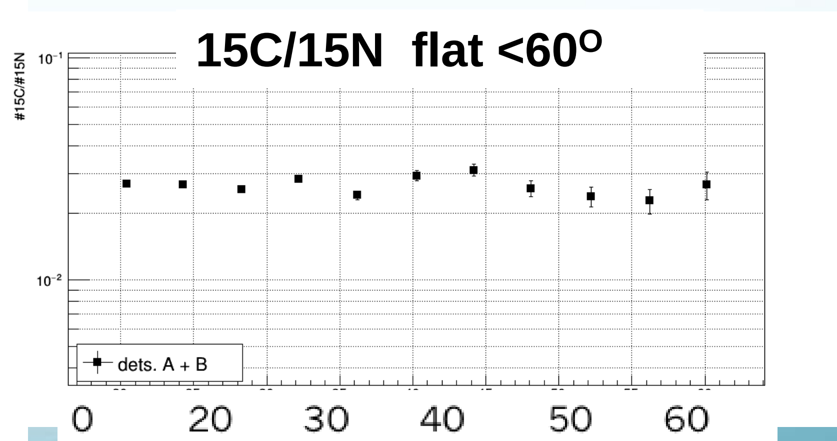




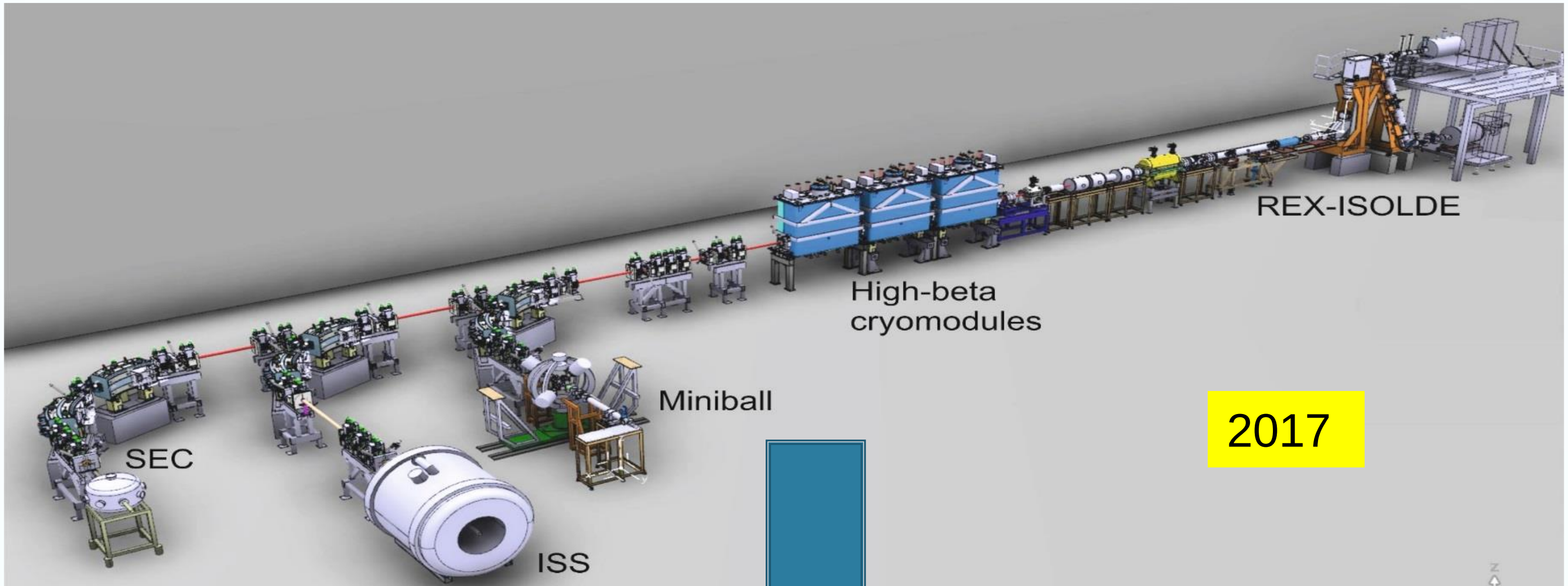
Still a lot of analysis to do

Rutherford fit of ^{15}N data in order to determine the exact position of the detectors in GLORIA



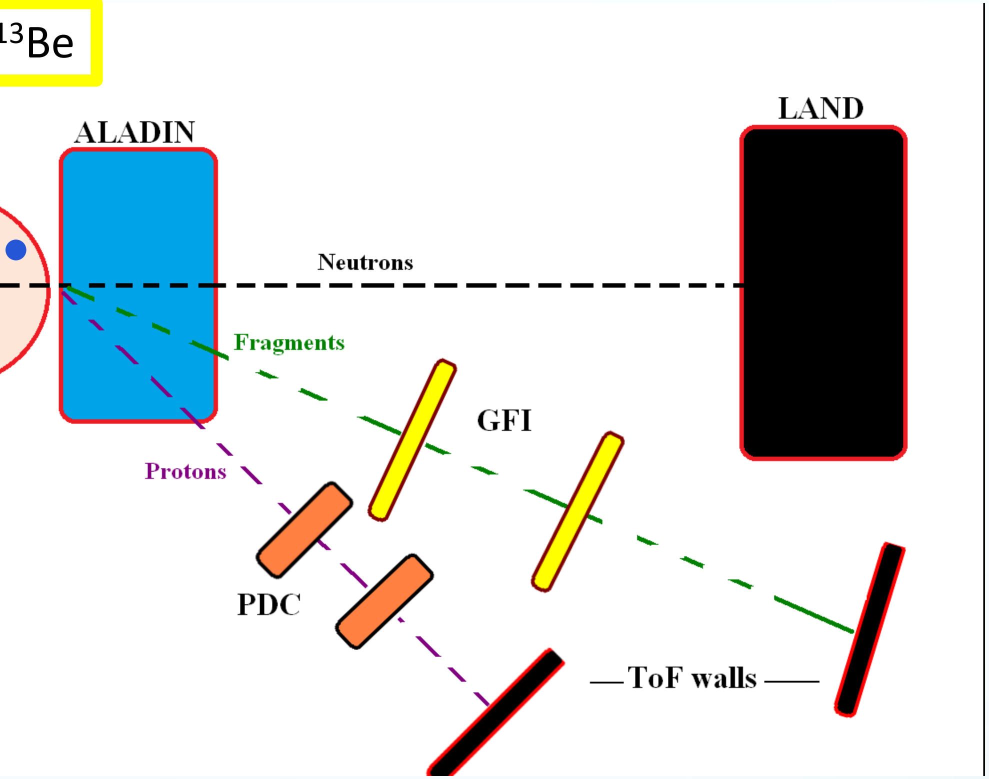


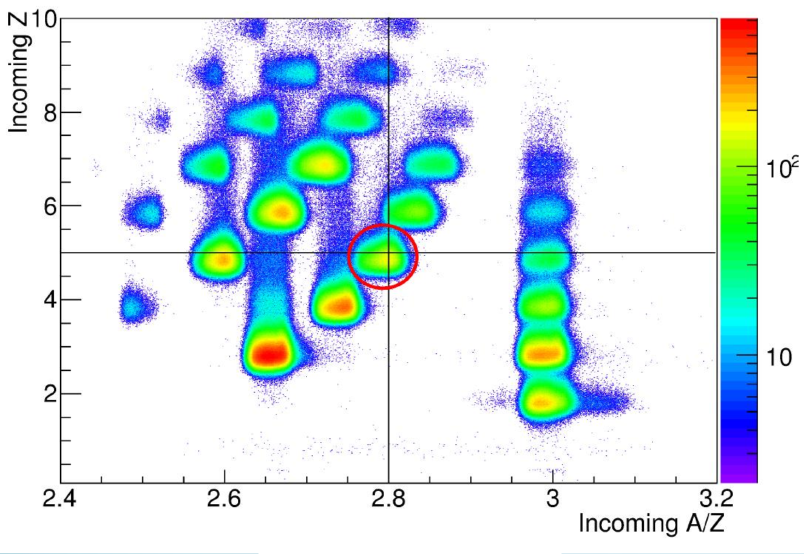
HIE ISOLDE 2017 → 2018



Previouse study

Experiment S393: $^{14}B(p,2p)^{13}Be$ @ GSI





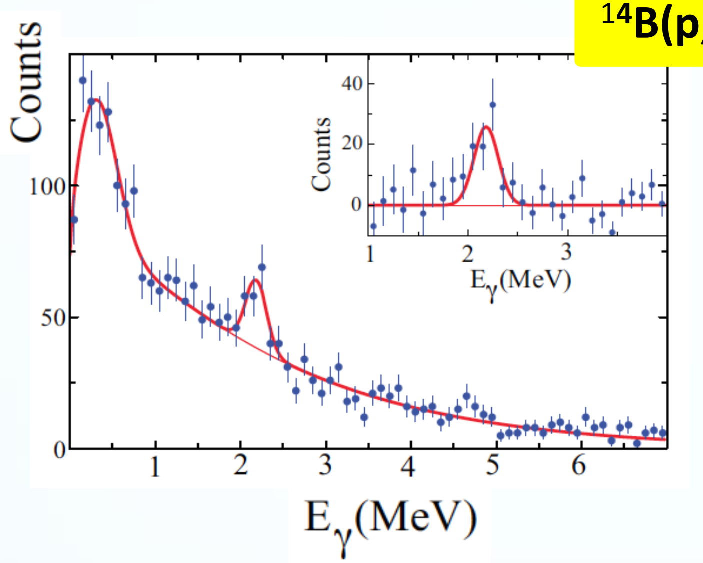
$$\frac{A}{Z} = K \cdot \frac{B\rho}{\beta\gamma}$$

Primary beam	**$^{40}Ar^{11+}$ @ 490 MeV/u**
Intensity	**$6 \cdot 10^{10}$ ions/spill.**
Production target	**Be 4 mg/cm^2**
Reaction target	**H, C, empty**

^{13}Be data from S393 @ GSI

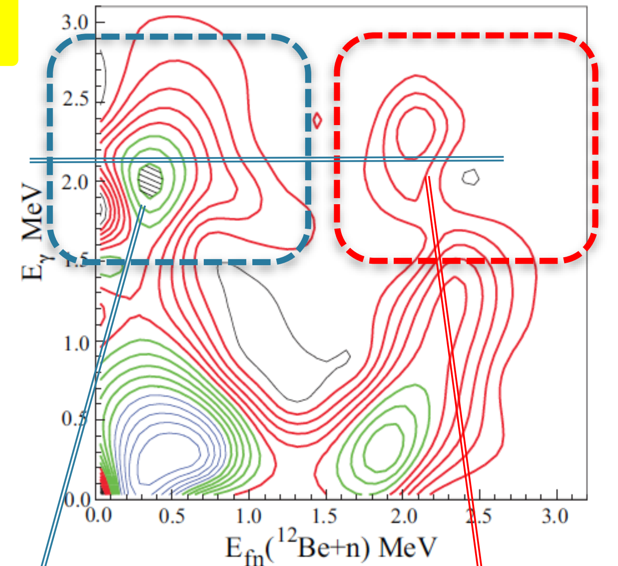
Guillermo Ribeiro

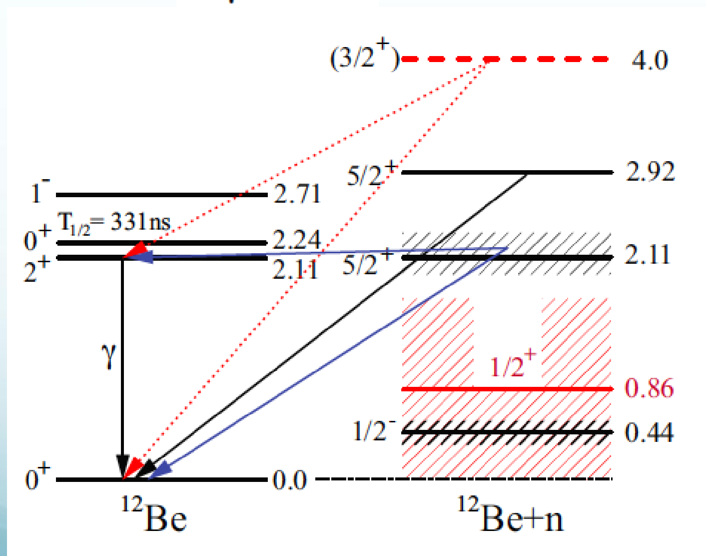
^{14}B(p,2p)^{13}Be @ 490MeV/u

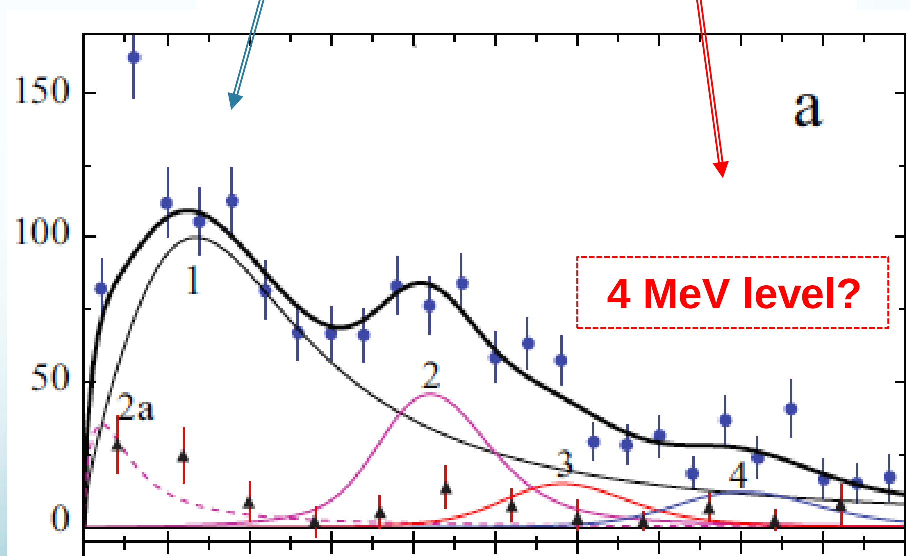


γ, ^{12}Be +n coinci

E_γ=2.1 MeV





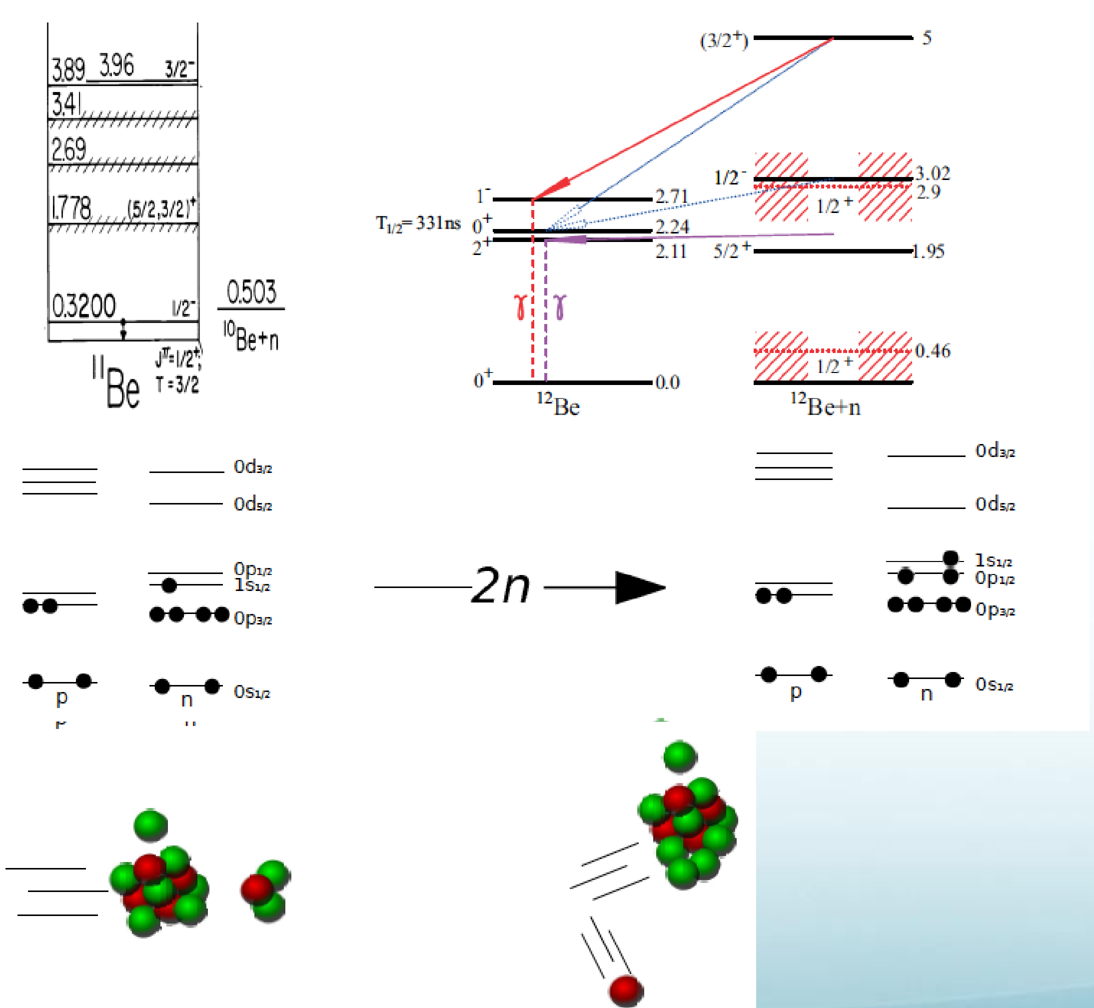


Can we settle this problem via the two-neutron transfer reaction, ^{11}Be(t , p)^{13}Be @ HIE-ISOLDE IS606 Beamtime 2018!?

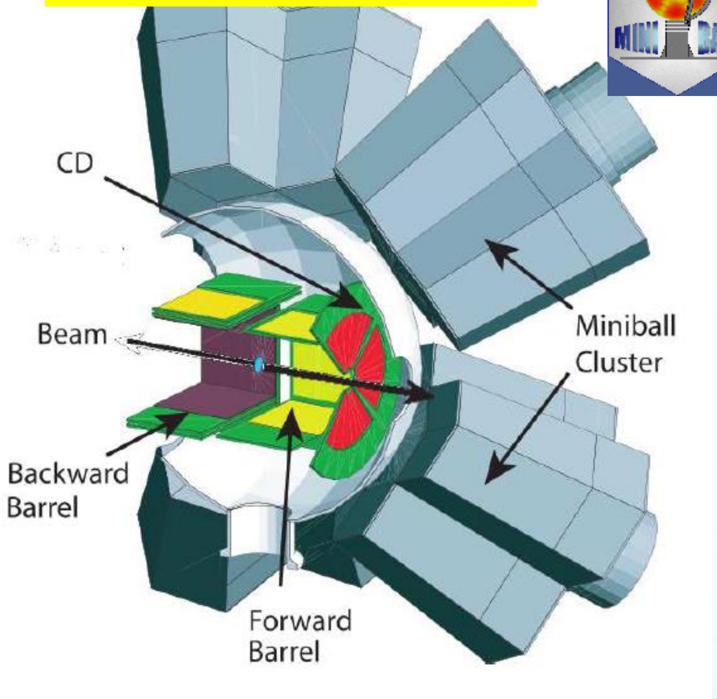
IS606 Studies of unbound states N= 8 shell closure

$^{11}Be(t,p)\,^{13}Be$

^{11}Be ^{13}Be



Miniball + T-REX



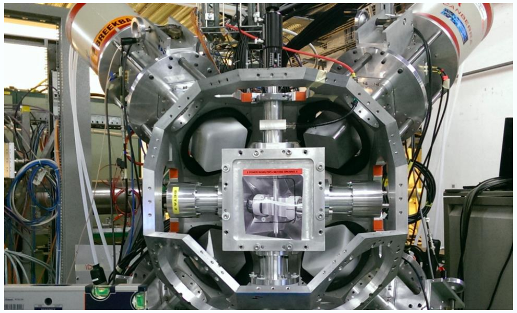
- Standard setup
  - 8 HpGe clusters
  - 12 silicon detectors (telescopes)
- Additionally
  - 1 HpGe detector at beamdump
  - Stopper foil after the CD

In summary: I have discussed

Studies of Light exotic nuclei by the MAGISOL at ISOLDE and HIE-ISOLDE

Introducing new tools

Target development leading to high yields to study ^{8}B



IDS – ISOLDE Decay Station

- **IS633: on EC in ^{8}B to excited states in ^{8}Be**

SEC – Scattering Experiment Chamber HIE ISOLDE

- **IS619: n-halo in ^{15}C scattering at the Coulomb barrier**

HIE-ISOLDE with 4 cryo modules reaching 10 MeV/u

- **IS606: Studies of unbound states in isotopes at the N= 8 shell closure**

  a complementary measurement to ^{14}B(p,2p)^{13}Be performed at GSI

Thank you for your attention!

MAGISOL