Instituto Galego de Física de Altas Enerxías

Determination of the α decay width of a near-threshold proton-emitting resonance in ^{11}B

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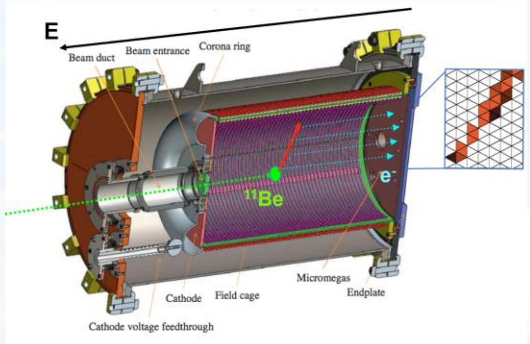
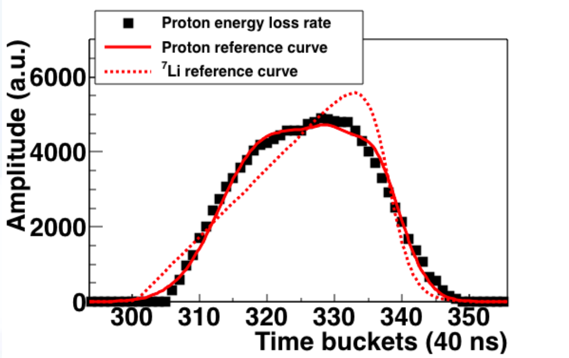
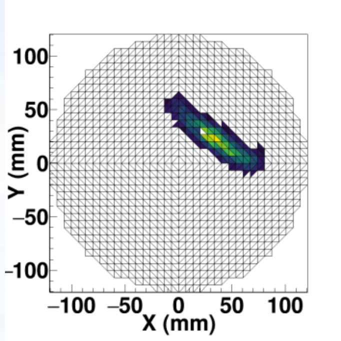
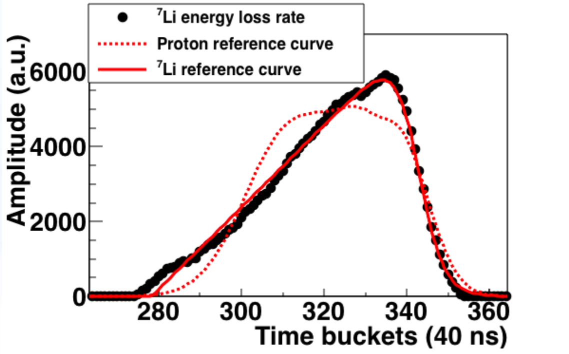
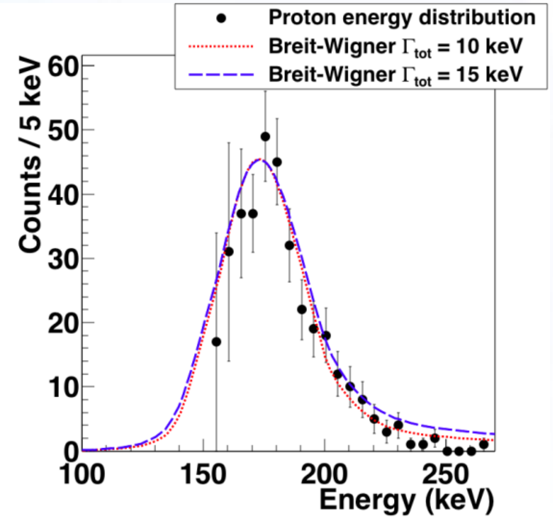
β-delayed proton emission in ^{11}Be

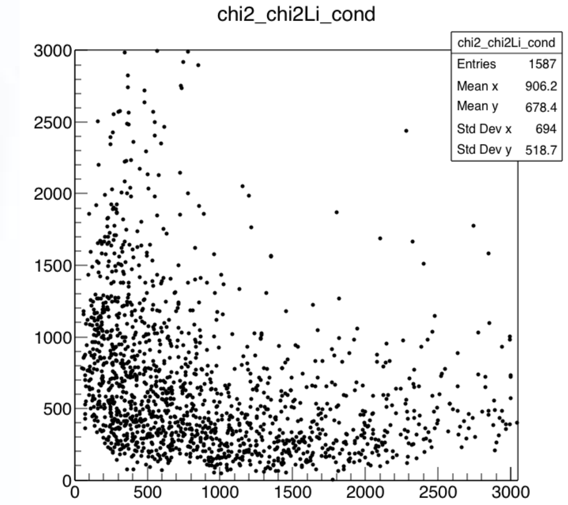












- First direct observation of β^-p in a neutron-rich nuclei.
- Branching ratio is 1.2×10^{-5}, with 30% uncertainty… Theoretical calculations yield 8.0×10^{-6}.
- A narrow resonance (12 keV) in ^{11}B was inferred. E = 11425(20) keV, Γ=12(5) keV, J^π = 1/2;3/2+
- Decay into the continuum would be characterized by a much shorter branching ratio (10^{-10}).

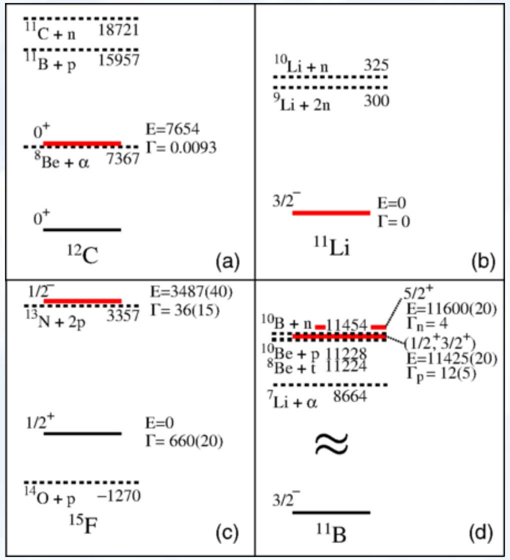
Criticisms:
arXiv:1912.06064 (2019)
EPL 130, 1 (2020)
EPJ **56**, 100 (2020)

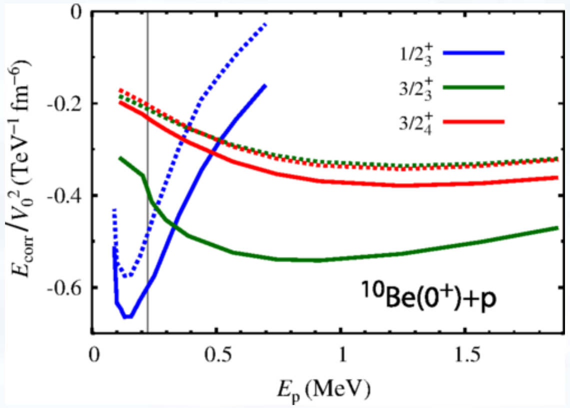
Y. Ayyad *et al.*
Phys. Rev. Lett. 123, 082501 – Published 22 August 2019; Erratum [Phys. Rev. Lett. 124, 129902 (2020)]

arXiv:2112.05622

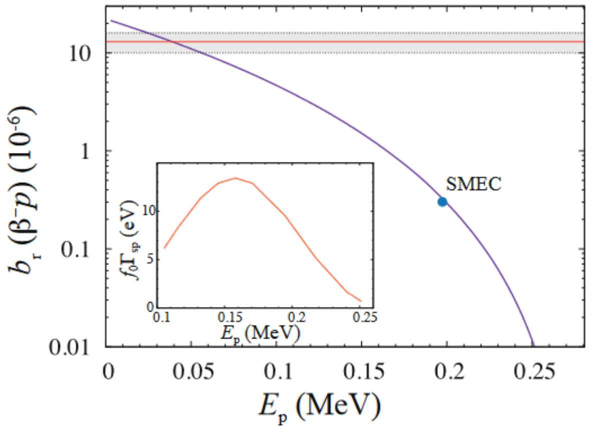
Theory tries to reproduce the result

Phys Rev Lett. 124, 042502 (2020)

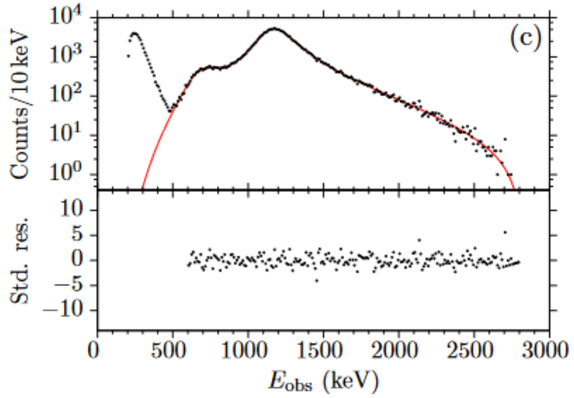




- Shell model embedded in the continuum (SMEC).
- Near-threshold collectivity driven by the interplay between nuclear interactions and decay channels.
- Single "aligned eigenstate".
- $[^{10}Be(0^+) \otimes p(s^{1/2})]^{1/2+}$, $[^{10}Be(0^+) \otimes p(s^{1/2})]^{1/2+}$ and $[^{10}B(3^+) \otimes n(d^{5/2})]^{1/2+}$
- Strongest collectivization is predicted at $E_p \simeq 142$ keV.
- Core-coupled proton state $[^{10}Be \otimes p]$ with the negligible $[^7Li \otimes \alpha]$ component.
- SMEC finds a consistent description of the beta-delayed alpha branching ratio of ^{11}Be and the $\Gamma_p(1/2_3^+)$.
- However, it does not reconcile with the branching ratio for proton emission. It should be 40 times lower.
- This is based on the assumption that a neighboring $3/2^+$ state decaying by alpha emission exists (at around 11.450 keV). Such state was inferred from R-matrix calculations.



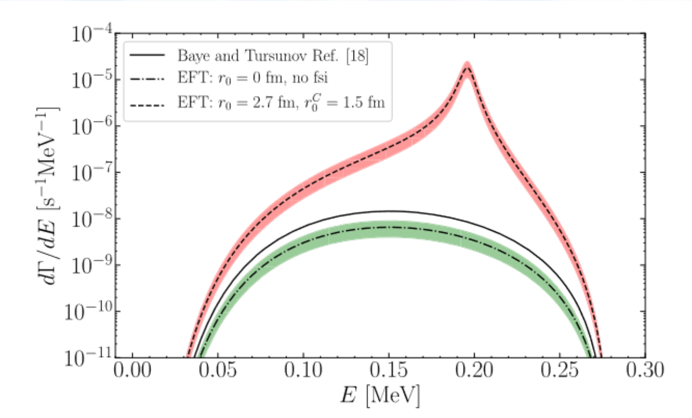
Model	I	II	III
States	$3/2^+$	$3/2^+ + 1/2^+$	$3/2^+ + 3/2^+$
χ_i^2/ndf	21.7	3.11	1.26

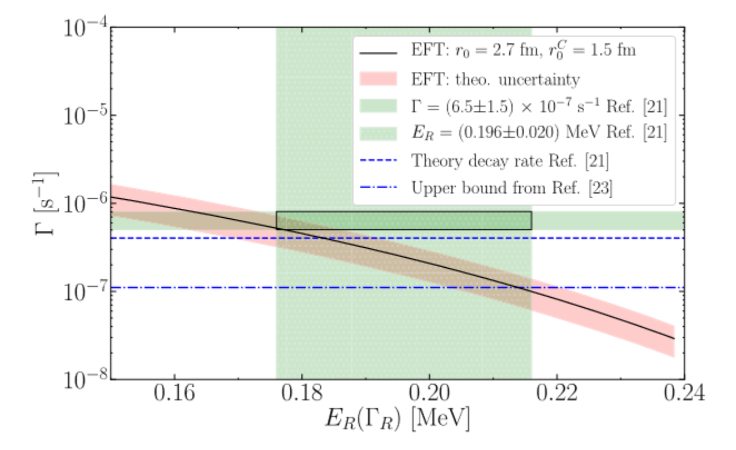


PRC 99, 044316 (2019)

Theory tries to reproduce the result

Physics Letters B 821 (2021) 136610

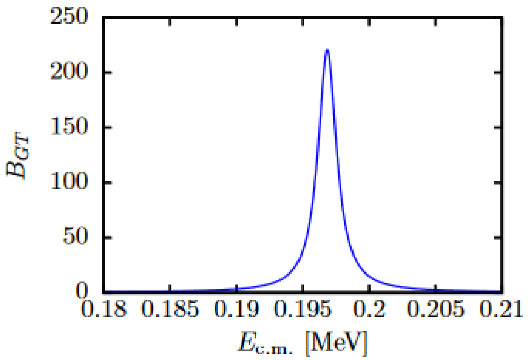




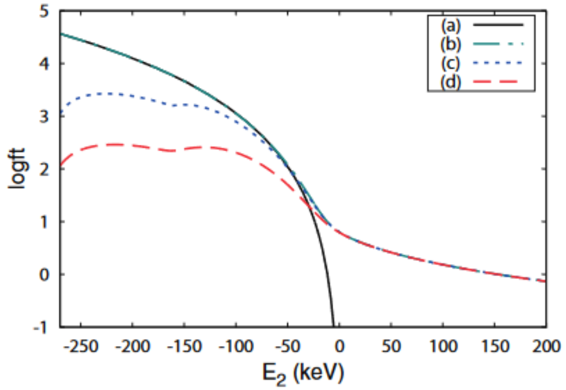
- Halo Effective Field theory (EFT) yields results consistent with the experiment. b_p =4.9 +5.6-2.9(exp) +4.0-0.8(theo.) and Γ=9.0+4.8-3.3(exp)+5.3-2.2(theo.) keV.

- No resonance: Γ=(6.6+-2.6) 10^{-10} s
- From ab-initio calculations with no-core shell model with continuum (NCSMC) b_p= (1.3+-0.5) 10^{-6} s
- Alpha decay spectroscopic factor is consistent with our estimate inferred from the decay width.
- From shell model calculations (A. Volya EPL 130, 1, 2020) the decay proceeds via the isobaric analog state with a lifetime of 2.6 10^{10} s SFp = 0.23. Small alpha width does not explain the experimental branching ratio.

Phys. Rev. C 105, 054316 (2022)

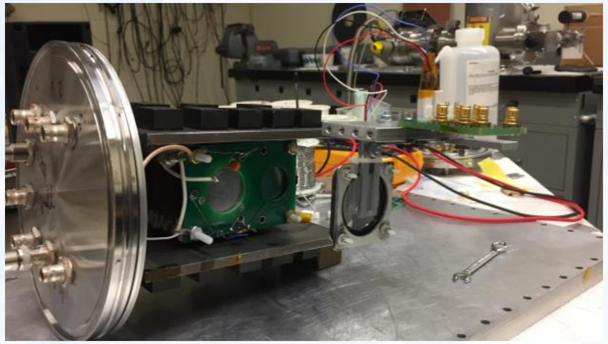


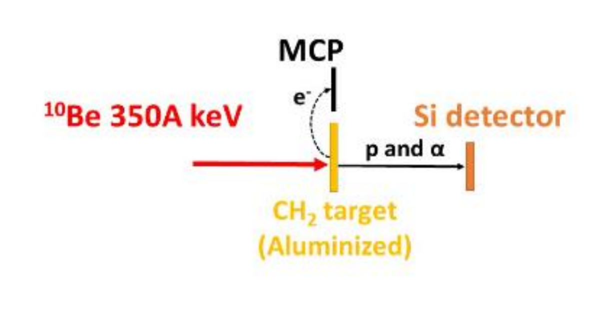
J^π	$S(^{11}B \to {}^{10}Be)$ $(0^+, 1)$	$S(^{11}B \to {}^{10}B)$ $(1_1^+, 0)$	$(1_2^+, 0)$	$S(^{11}B \to {}^{7}Li)$ $(3/2^+, 1/2)$
$1/2_1^+$	0.276	0.250	2×10^{-4}	0.218
$1/2_2^+$	0.0525	0.171	0.562	0.002
$1/2_3^+$	0.067	0.231	0.188	0.011
$3/2_1^+$	0.079	6×10^{-4}	0.215	0.009
$3/2_2^+$	4×10^{-4}	0.581	0.002	0.012
$3/2_3^+$	6×10^{-4}	0.011	0.006	0.021
$3/2_4^+$	0.067	0.034	0.35	0.006

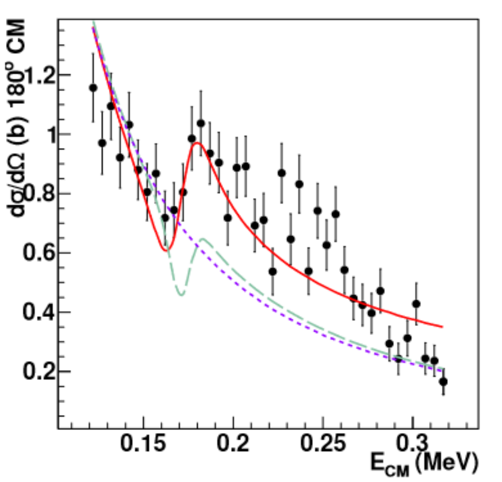


EPL 130, 1, 2020

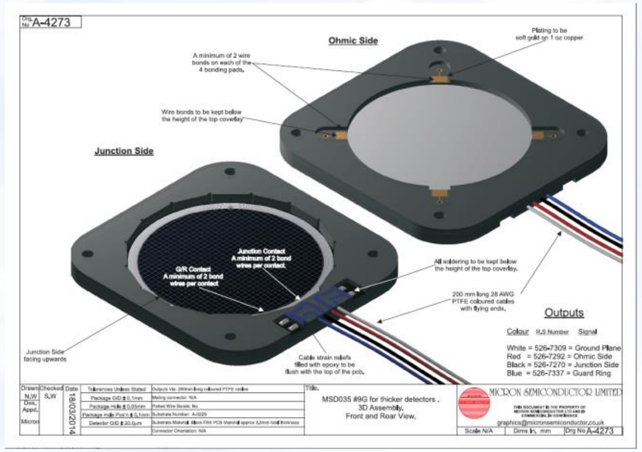
^{10}Be+p at ReA3

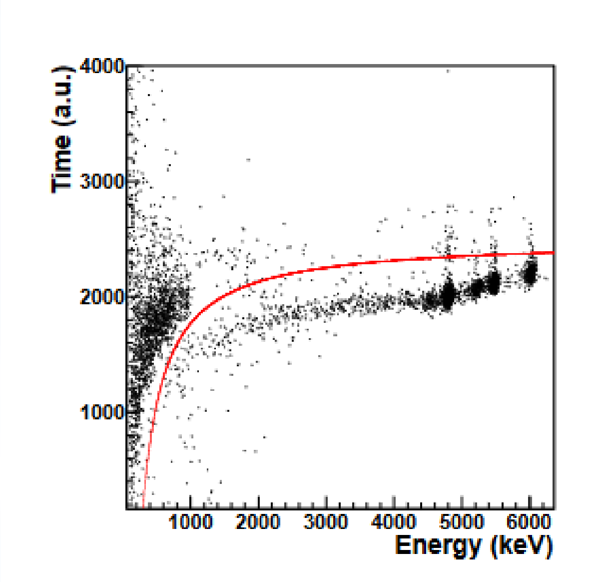


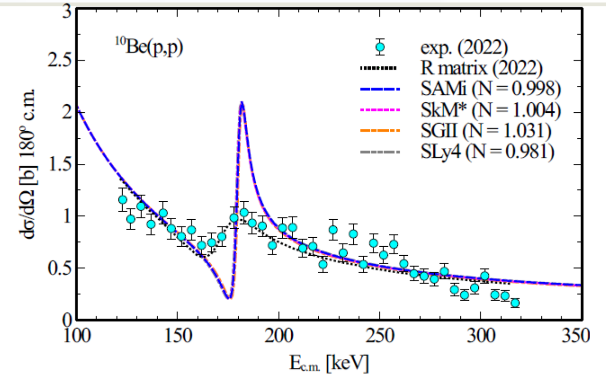




Er= (171 +-20) keV
Jp = 1/2+
Γ = 16+-3 keV
Γp = 4.5+-1.1 keV
Γa = 11+-4 keV
Sf =0.25







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N. Auerbach
V. Zelevinsky
Private comm May 2022

^{10}Be(d,n) FSU

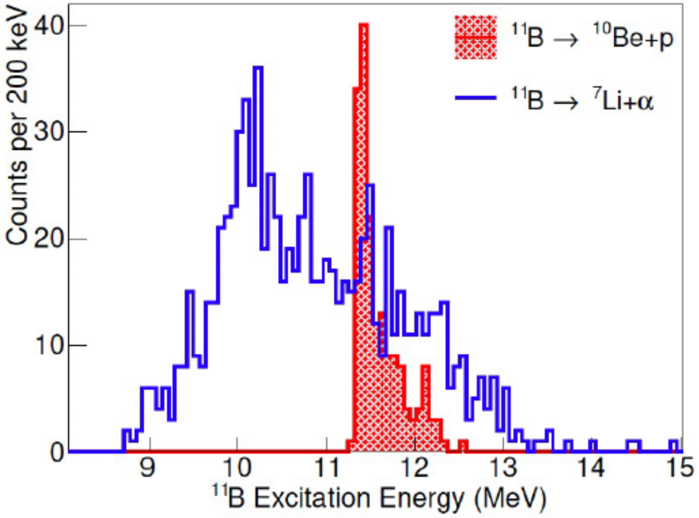

FIG. 3: Excitation energy spectrum in ^{11}B reconstructed from the $^{11}B^* \rightarrow {}^{10}Be + p$ (red) and $^{11}B^* \rightarrow {}^{7}Li + \alpha$ (blue). A prominent near-threshold peak at $E_{ex} = 11.44 \pm 0.04$ MeV is visible in the proton spectrum.

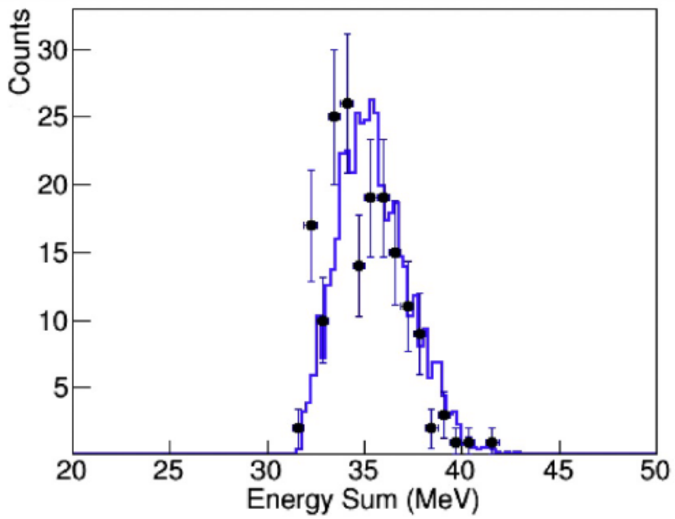

FIG. 4: Energy-sum signals of ^{10}Be + p events for the 11.44 MeV state, compared with a Monte Carlo simulation (in blue) that takes into account the DWBA-calculated angular distribution of the ^{10}Be(d,n)^{11}B* reaction. A value of $\ell = 0$ fits well the experimental data.

C2S = 0.27(6)

E_x=11.44MeV→
E_{res}=11.44-11.228=
(212+-40)keV

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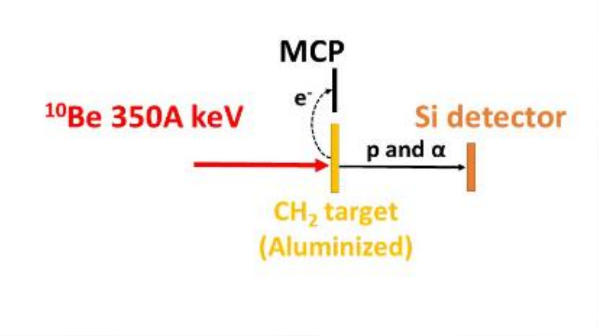
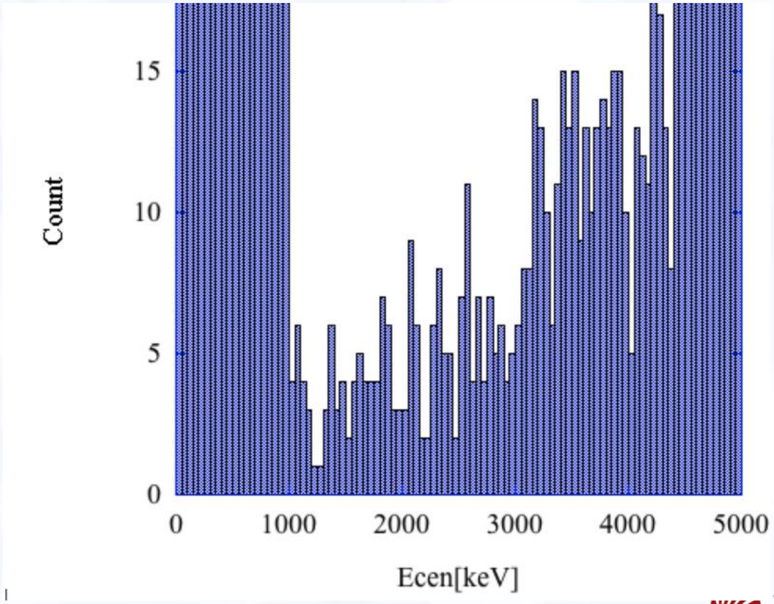
Motivation

- There are three main ingredients for solving this situation: beta decay branching ratio, energy and width.
- We can assess two of them in this experiment. Theoretical calculations are mainly feeding on energy and width to determine the branching ratio.
- It is possible to determine the alpha decay to gs and the excited state of ^{7}Li. Also, we will obtain a much better excitation function of the (p,p).
- Direct measurement of branching ratio is extremely challenging. Results of this experiment will help to understand errors in the interpretation of the previous result.
- Calculations are very sensitive to the uncertainty of these observables.
- Even if the latest results are consistent, there are some conflicts: Energy and spectroscopic factors.
- There are conflicting indications of other neighboring resonances ($3/2^{+}$) critical for the interpretation of model calculations.
- We have direct evidence of at least two open decay channels, with a relatively large uncertainty.
- Therefore, we would like to repeat the same experiment with improved statistics.

Beam time request





- 0.2 µm of CH2 thickness,corresponding to 1.78×10^{18} hydrogen atoms/cm2
- (p,p) and (p,α) reactions are of the order of 1 b/sr and 0.2 b/sr
- ^{10}Be beam at 300 keV/u
- 10^5 pps we will obtain 2/4 counts per hour and 5/10 keV energy bin.
- 6 shifts for the measurement of the reaction, focusing on the (p,α) channel. 2 extra shifts are requested for calibration purposes, if possible, using a proton beam.
- Total number of counts with 40 times larger statistics will be few hundreds per energy bin for (p,α).

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Thank you!

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