

TOPIC 1 Light Nuclei

LIGHT NUCLEI CHALLENGES AND EXPERIMENTAL TOOLS

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IEM-CSIC

Light Nuclei in Nature

Proton Rich
Neutron Rich
Resonances

Z
↑

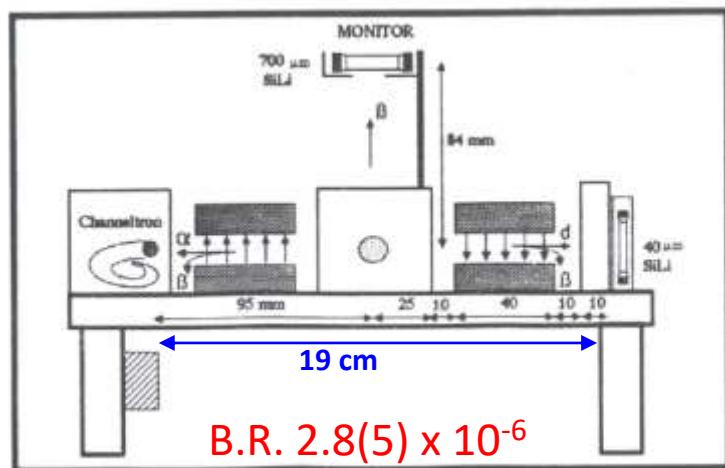
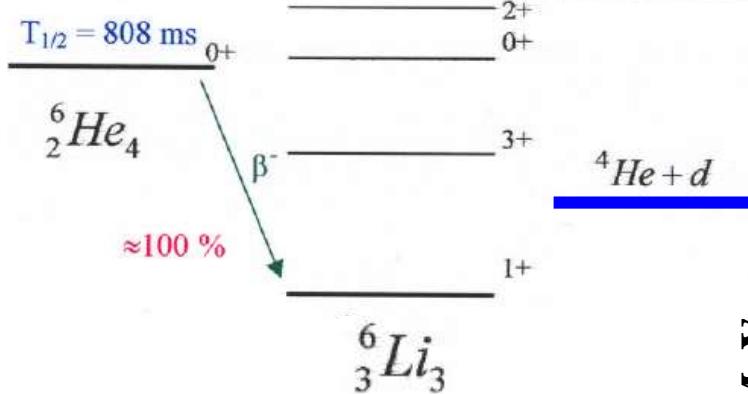
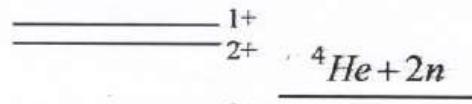
		15F unbound	16F unbound	17F 64.8 s	18F 109.7 m	19F	20F 11 s	21F 4.16 s
		12O unbound	13O 8.58 ms	14O 70.6 s	15O 2.03 m	16O	17O	18O
		11N unbound	12N 20.4 m	13N 20.4 m	14N	15N	16N 7.13 s	17N 4.17 s
		9C 125 ms	10B 19.3 s	11C 20.4 m	12C	13C	14C 5730 y	15C 2.45 s
		8B 770 ms	9B unbound	10B	11B	12B 20.20 ms	13B 17.33 ms	14B 13.8 ms
		7Be	8Be unbound	9Be	10Be 1.6 10 ⁶ y	11Be 13.8 s	12Be 23.6 ms	13Be unbound
		6Li	7Li	8Li 840 ms	9Li 179 ms	10Li unbound	11Li 8.5 ms	12Li unbound
		3He	4He	5He unbound	6He	7He unbound	8He 119 ms	9He unbound
		1H	2H	3H 12.323 y	5H unbound	7H unbound	10He unbound	-
		n						

- Halo Structure
- Cluster Structure
- Exotic decay modes
- Coupling to Continuum
- Broad excited states

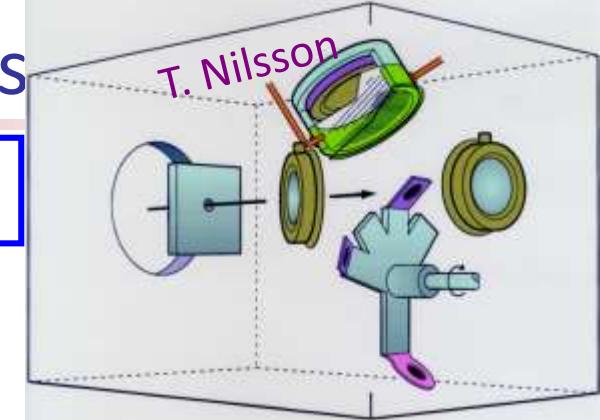


Beta-delayed deuterons

$$Q_{\beta d} = 3.007 - S_{2n} \text{ MeV} = 2.033 \text{ MeV}$$

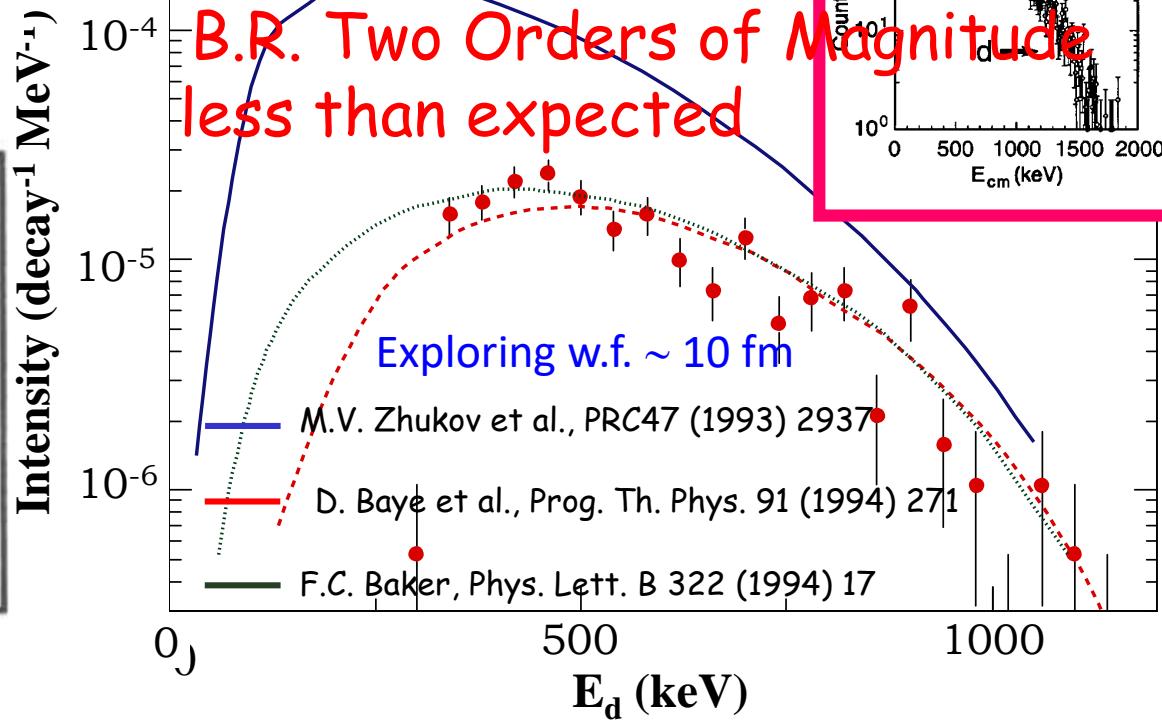


Riisager et al., PLB235(90)30

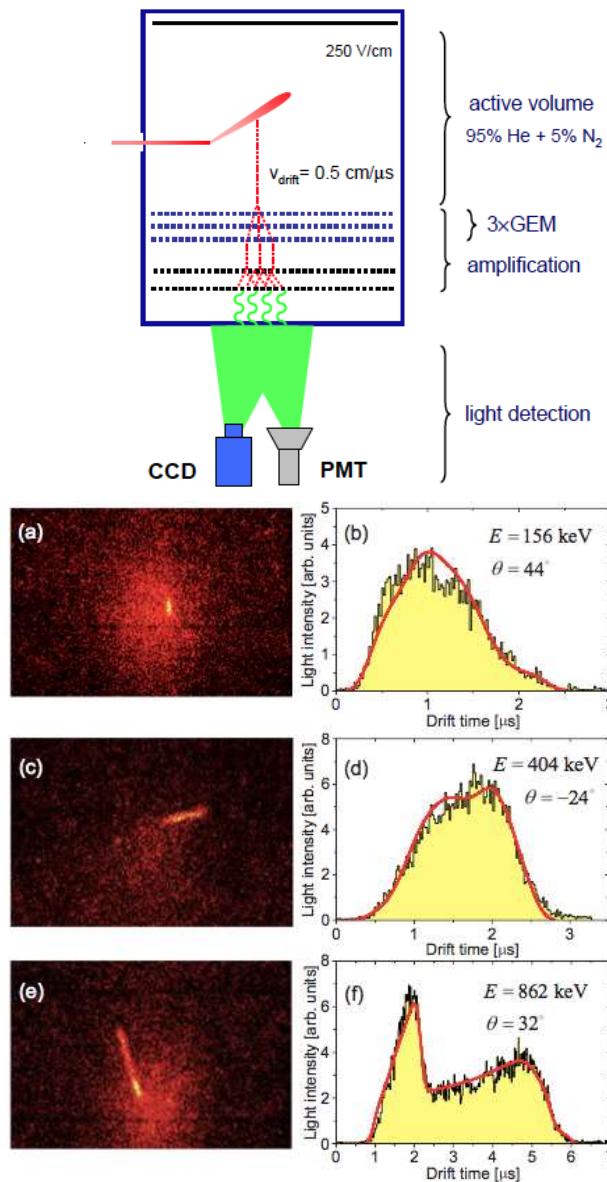


M.J.G. Borge et al., Nucl. Phys. A560 (1993) 664

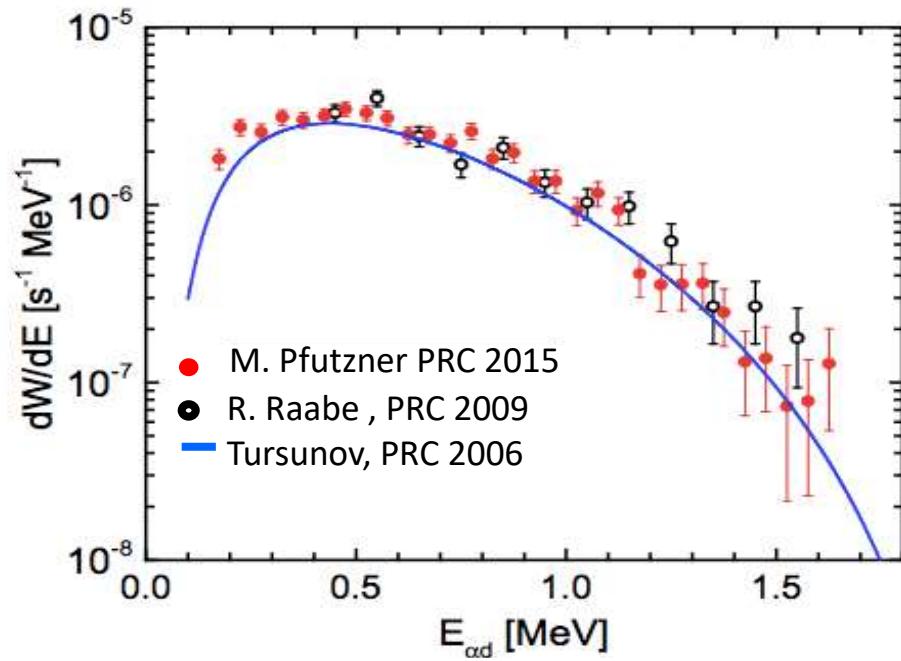
Anthony et al., PRC 65 (2002) 034310



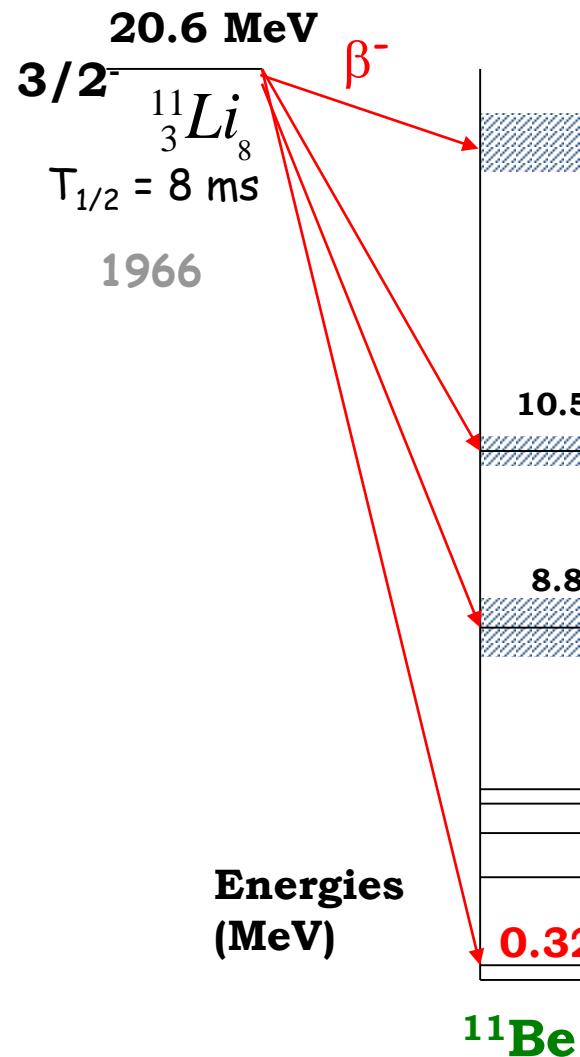
Optical Time projection Chamber



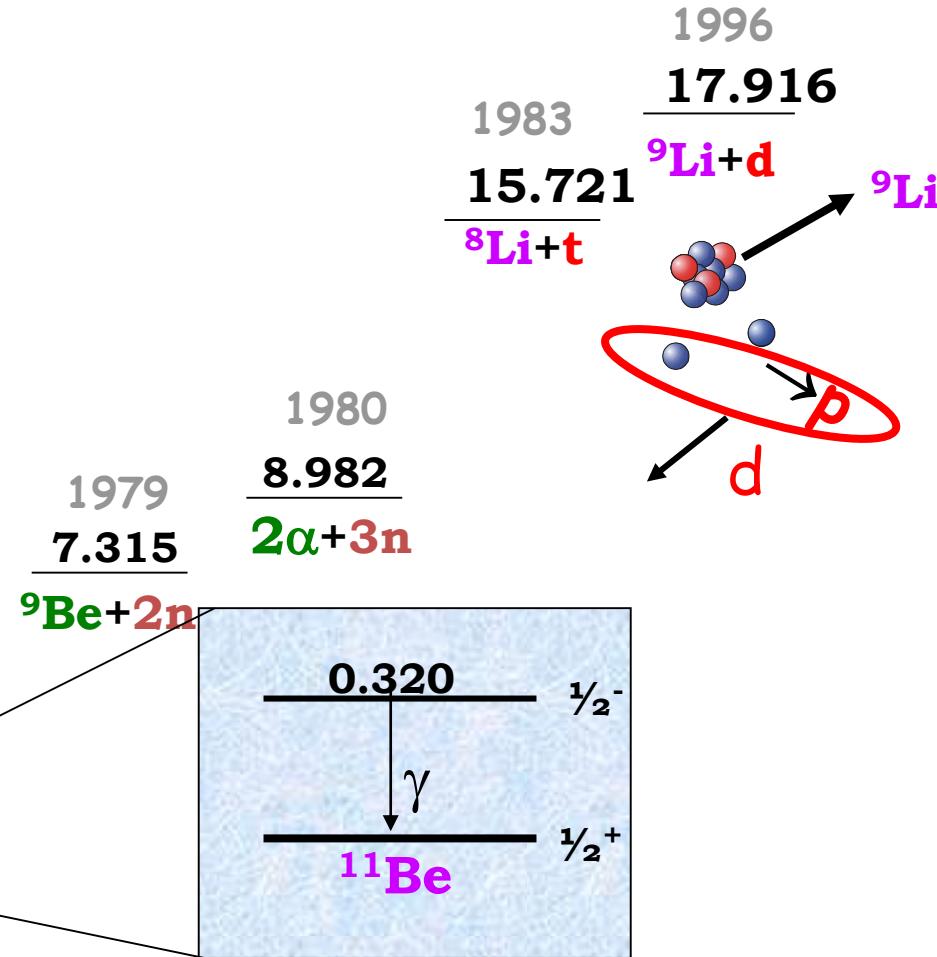
- Aim to determine the βd spectrum at low energy to distinguish between the different theories.
- Experiment done at REX-ISOLDE: ${}^6\text{He}$ beam @ 3MeV/u



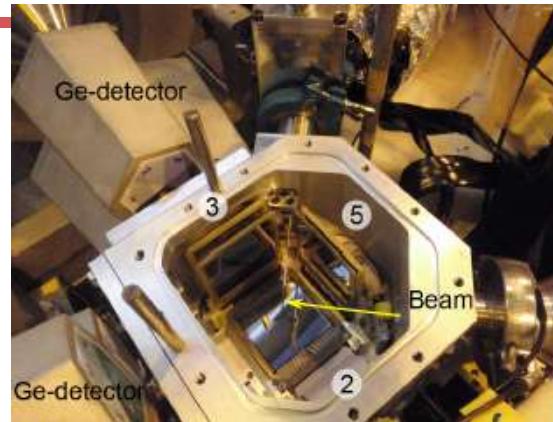
- ✓ $d+\alpha$ center of mass energy down to 150 keV
- ✓ $B.R. = 2.78(34) \times 10^{-6} (E_d > 100 \text{ keV})$
- ✓ Spectrum follows the 3-body model of Tursunov while intensity is 20% larger.



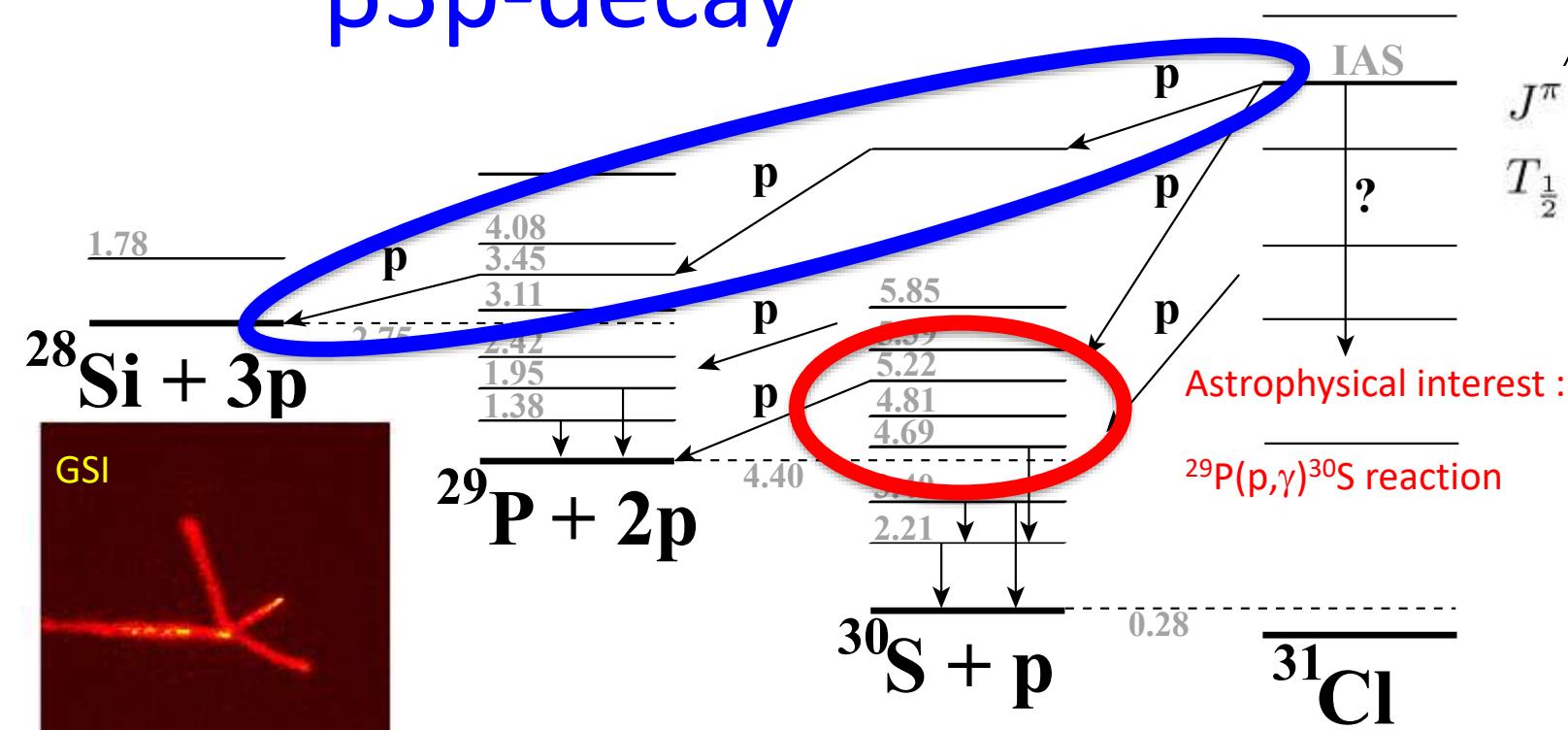
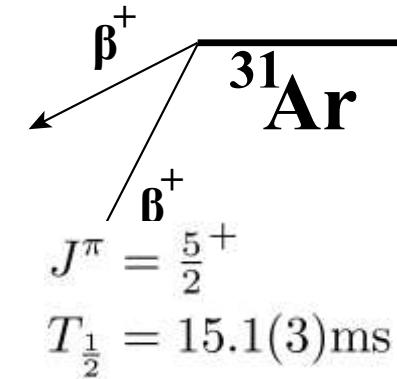
Even a neutron rich- nuclei emit charged particles



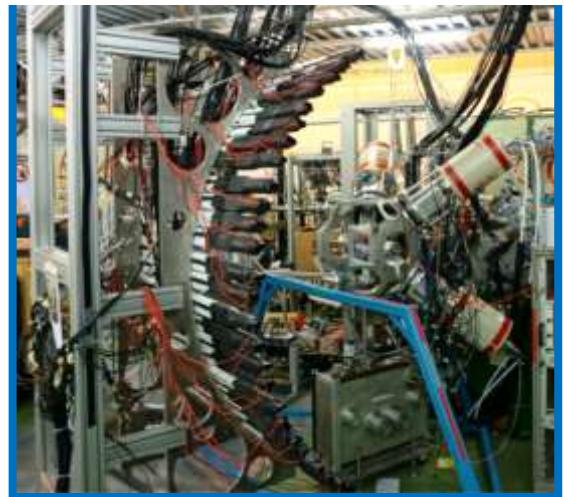
Bazin, PRC44 (1992) 69
 Fynbo PRC59 (1999) 2275
 $\text{BR}(\beta^+ 3\text{p}) \leq 0.11\%$



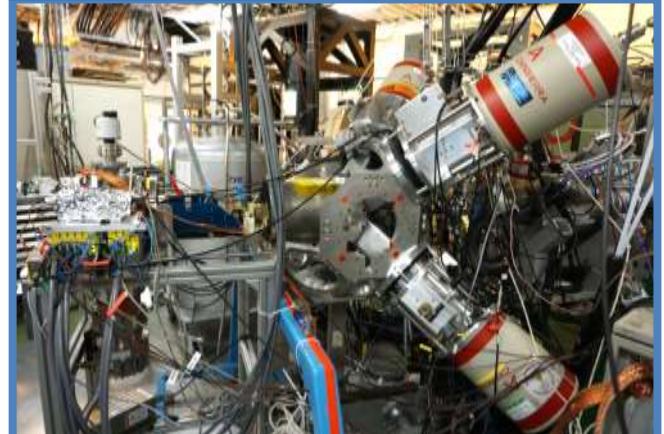
$\beta^+ 3\text{p}$ -decay



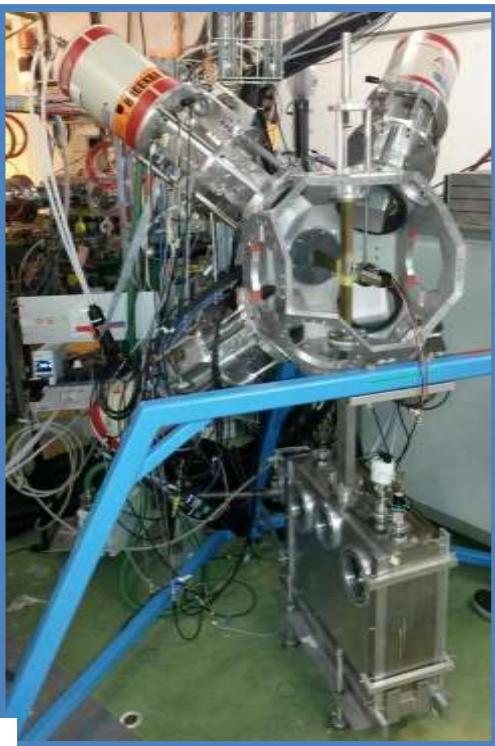
Neutron Spectroscopy



Particle Spectroscopy



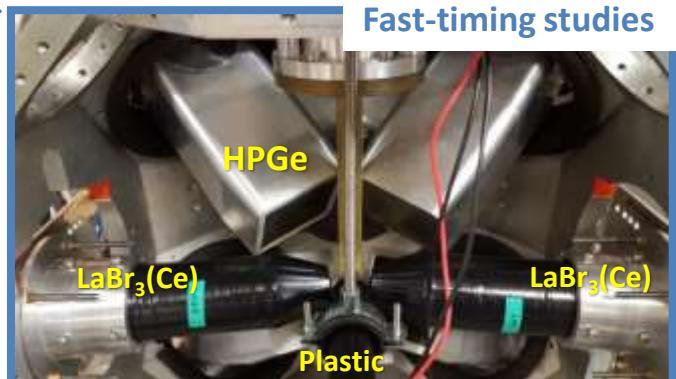
Absolute
Determination of
the $\beta\alpha$ decay of
 ${}^{16}\text{N}$, \rightarrow CNO cycle



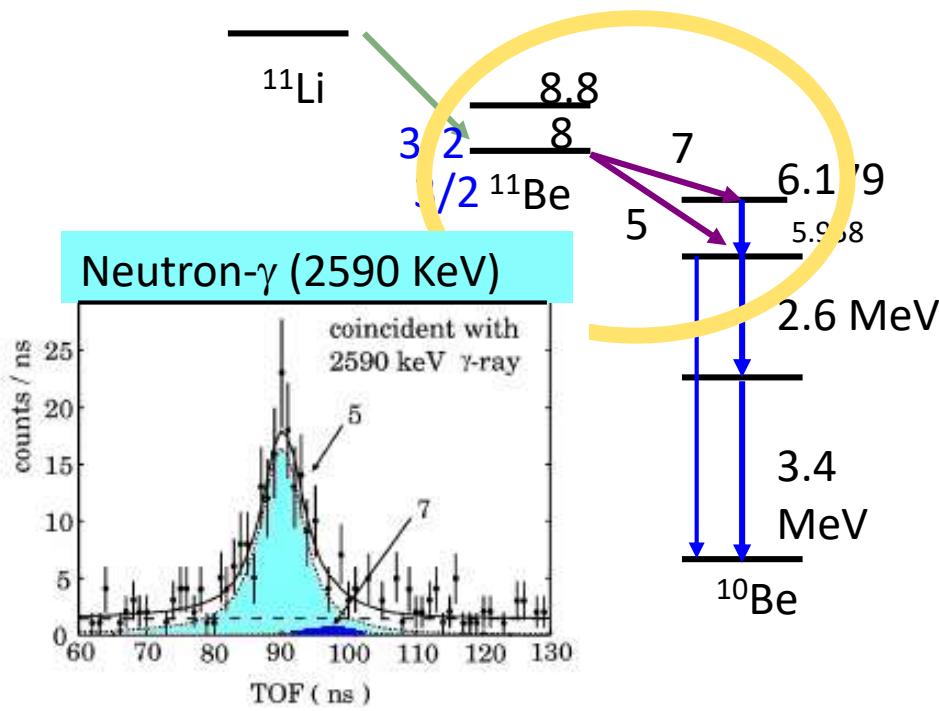
High beta-gamma efficiency



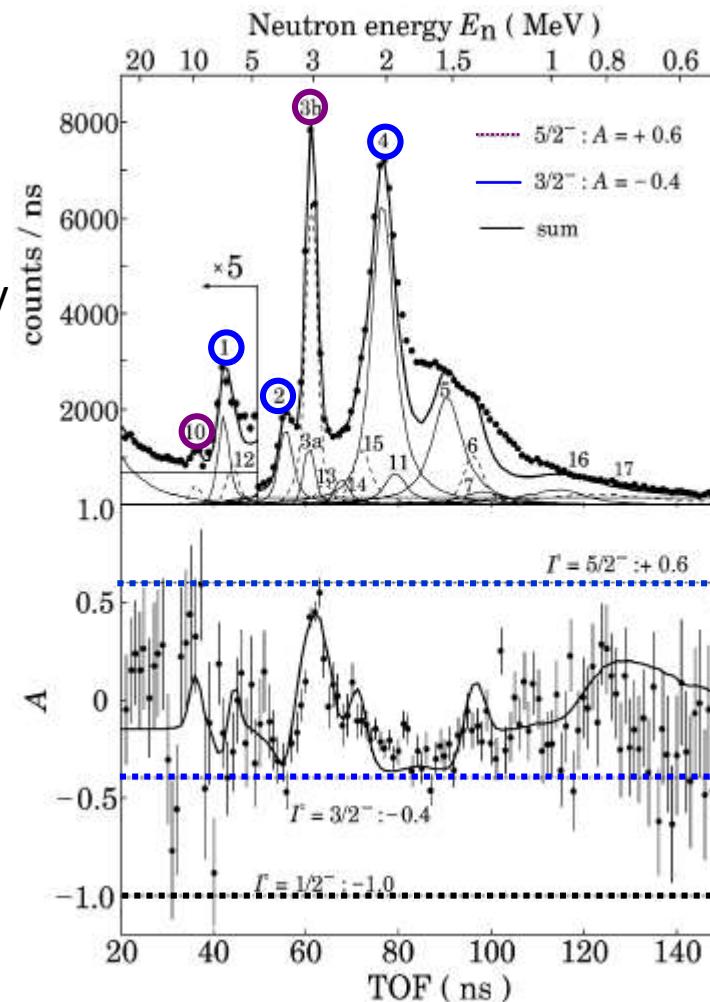
${}^{34}\text{Mg}$, ${}^{34}\text{Al}$ decays \rightarrow crossing
of the spherical and deformed
configurations at N=20



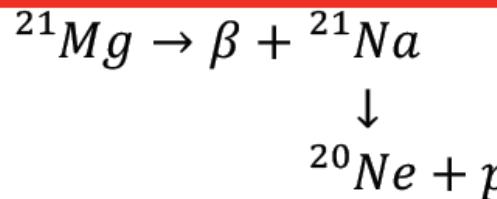
Fast-timing studies



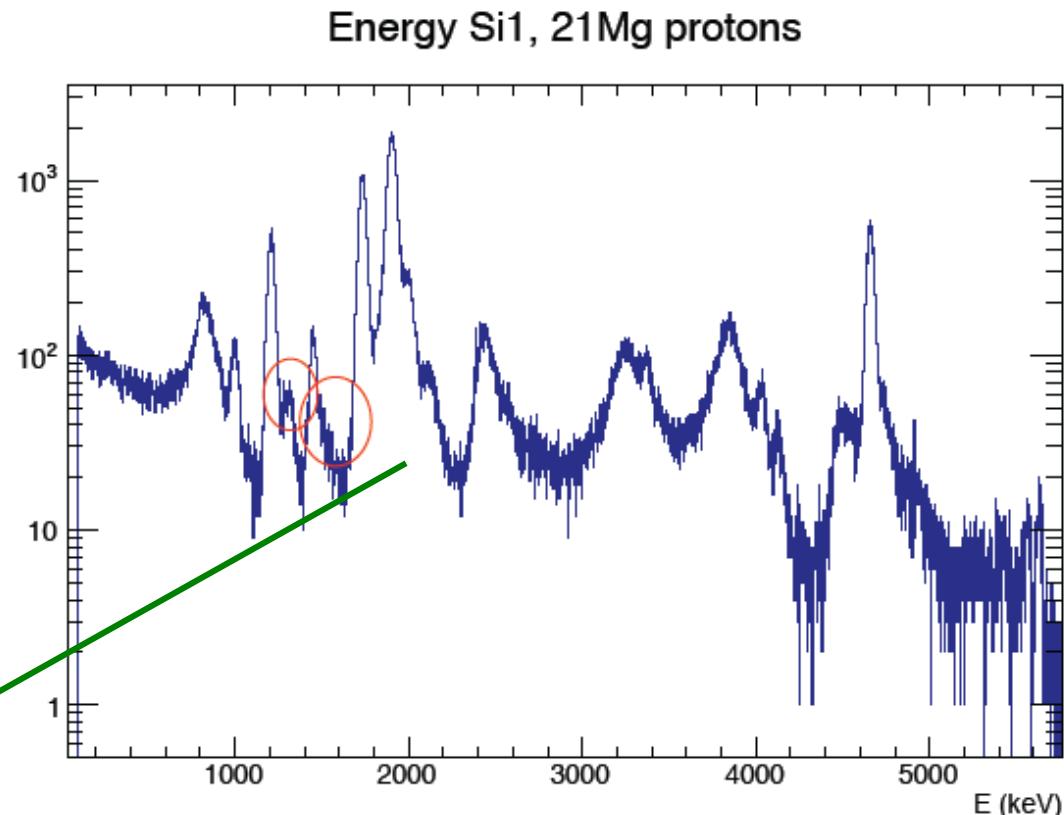
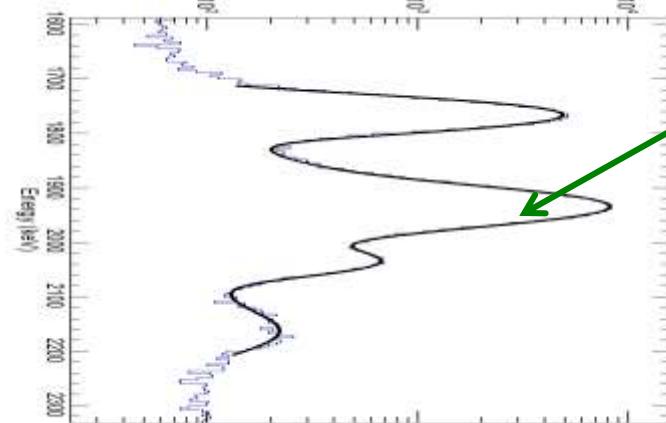
- Spin polarized ^{11}Li beam
- $\beta\gamma$, βn , $\beta\text{-}\gamma\text{-n}$ coincidences
- Spin and parities of 7 levels in ^{11}Be assigned.



Hirayama, Phys. Lett. B 611
(2005)239



Analysis of the particle spectrum in terms of Breit-Wigner + Gaussian to improve fit
has helped to clean the spectrum



$$Q_p = 1416 (6) \text{ keV} : ^{21}\text{Na}(8827) \rightarrow ^{20}\text{Ne}(4968) + p$$

$$Q_p = 1626 (17) \text{ keV} : ^{21}\text{Na}(8303) \rightarrow ^{20}\text{Ne}(4247) + p$$

M.V. Lund et al., Eur. Phys. J A 51 (2015) 113

In this presentation the different tools used to study the exotic decay modes in light nuclei have been illustrated with emphasis in examples where the same physics case has been solved step by step in different Facilities.

For future EURISOL-DF I list the pending subjects.

- **Study of gamma width/particle widths near particle emission threshold. Mainly relevant for astrophysics studies.**
- **Explore in detail the beta-delayed 2p emitters, only two cases are known in detailed: ^{22}Al and ^{31}Ar . The decay mechanism so far identified as sequential but direct is not excluded and should be explored in other cases.**
 - Need to develop other beams and higher intensity. The most attractive ^{27}S and ^{35}Ca decay.
- In light nuclei many states are broad: Beta decay charged particle spectrum obtained with his resolution allowed for the identification of interference between the states and from to extract the state spin.
- Walk along many different techniques used in different facilities to answer question on exotic decays. Certainly the used of TPC is crucial to unreveal properties of very low produced nuclei.
- Achieve 5 keV resolution in Si detectors will allow for performing searches for scalar components in weak interaction at the level of 0.1 % being able to be competitive with LHC results.

**LIGHT NUCLEI
DECAY STUDIES
MAINLY AT ISOLDE (JYVASKYLA AND TRIUNF),
GOING ON SINCE MANY YEARS
NOT AT SPIRAL I (BUT AT SPIRAL II)
COMPLEXITY (INSTRUMENTATION)
MOST OF IT DONE?
ONLY PRECISION MEAUREMENTS?**