Determination of level widths in ^{15}N using nuclear resonance fluorescence

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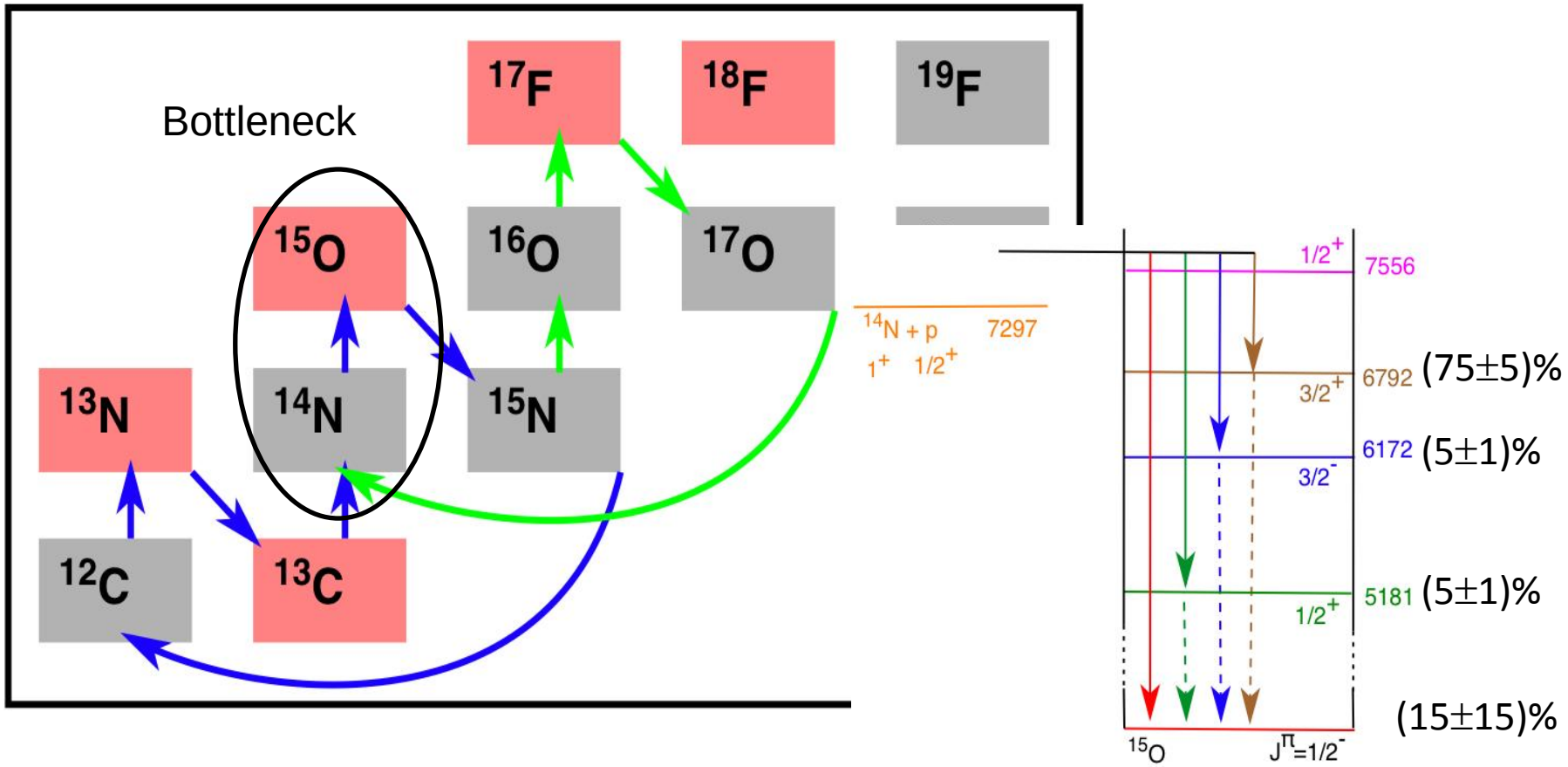
Motivation

- ^{15}N is the mirror of the astrophysically important ^{15}O
- ^{15}O is the product of the bottleneck reaction of the CNO cycle



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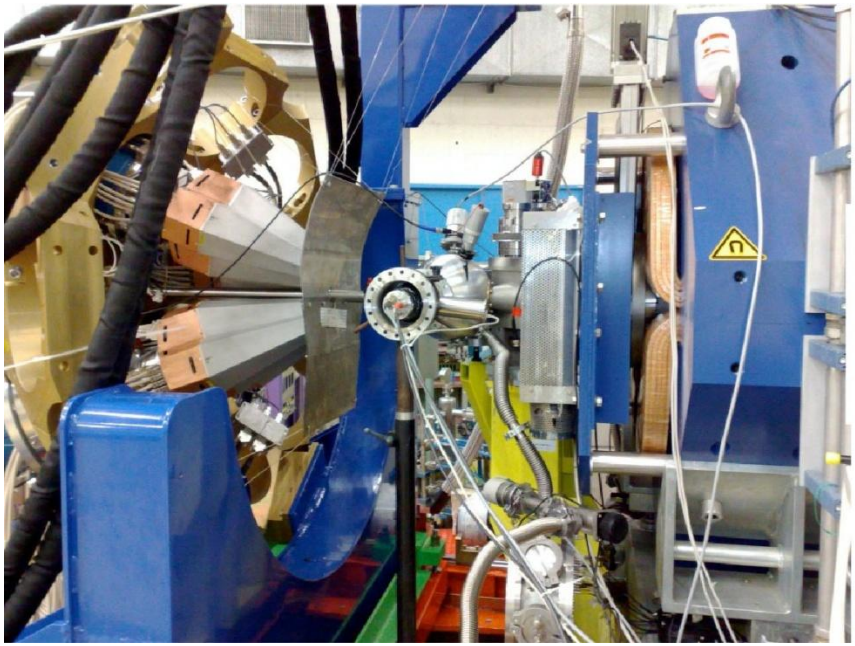
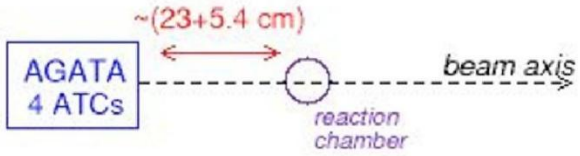
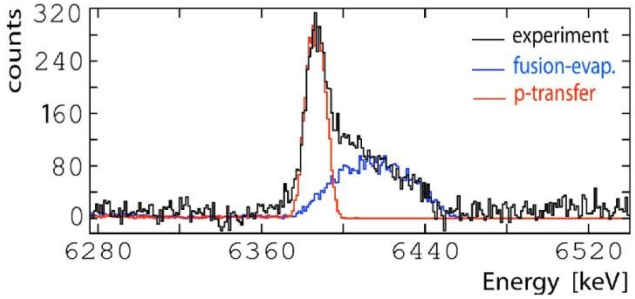
Doppler shift study of the lifetime of the 6.792 MeV level in ^{15}O

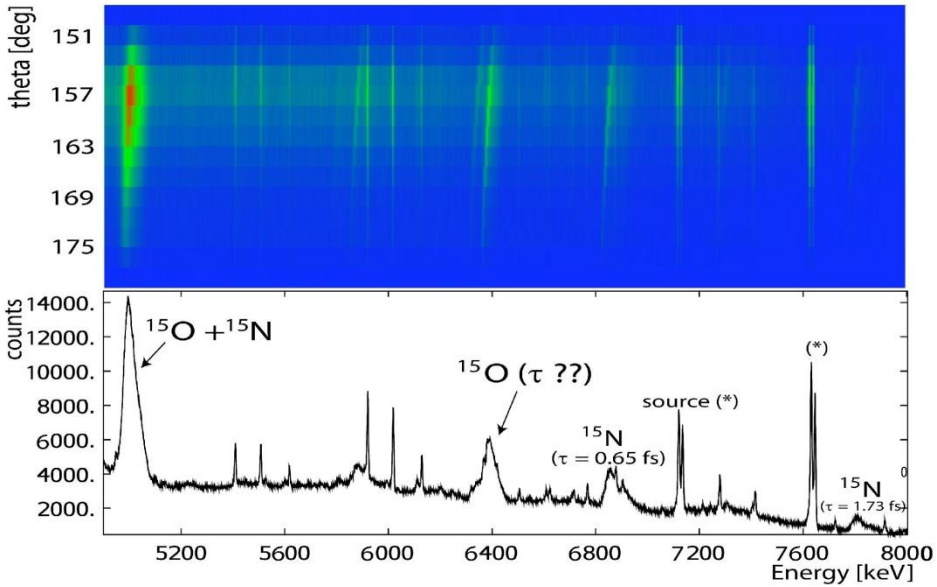


$$\Delta E_\gamma(6792) = \frac{\hbar}{\tau(6792)}$$

$$0.9\,\mathrm{eV} = \frac{\hbar}{0.7\,\mathrm{fs}}$$







- Level populated in d(^{14}N,n)^{15}O reaction
- Difficult analysis, expected lifetime ~1 fs
- ^{15}N levels were also populated in the reaction

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Motivation

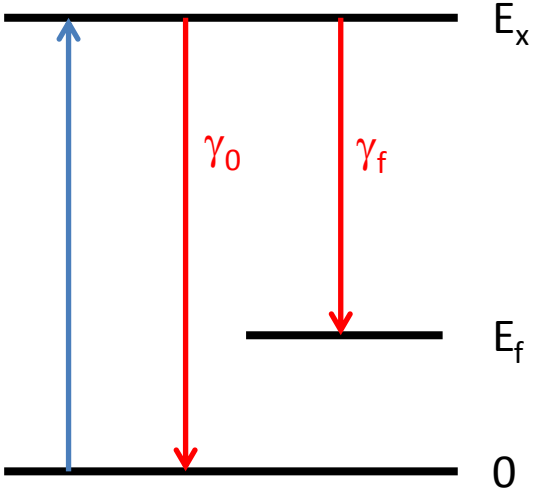
- Recent preliminary level lifetimes from a DSAM (Doppler Shift Attenuation Method) measurement are in contradiction with the literature values
- The literature values are based mostly on one NRF (Nuclear Resonance Fluorescence) measurement [1] from 1981

E_x / MeV	Level width / eV	
	NRF [1]	DSAM [2]
8.31	0.3 ± 0.2	0.108 ± 0.018
10.06	6.3 ± 0.4	0.13 ± 0.02

- Altogether 9 level with measurable width are below the p-separation energy for some cases limited precision (60% - 100% error)

[1] R. Moreh *et al.*, Physical Review C **23**, 988 (1981)
[2] C. Michelagnoli, *The lifetime of the 6.79 MeV state in ^{15}O as a challenge for nuclear astrophysics and γ-ray spectroscopy: a new DSAM measurement with the AGATA Demonstrator array,* Università degli Studi di Padova (2013)

The NRF technique



- Nuclear level excited by γ-rays
- γ-rays following the de-excitation are detected
- The photon scattering cross section, thus the count rate is proportional to the level width

$$I_\sigma(0 \to E_x \to E_f) = \frac{2J_x + 1}{2J_0 + 1}\left(\frac{\pi\hbar c}{E_x}\right)^2 \frac{\Gamma_0\Gamma_f}{\Gamma}$$

$$I_\sigma(0 \to E_x \to E_f) \sim b_0 b_f \Gamma$$

$$I_\sigma(0 \to E_x \to 0) \sim {b_0}^2 \Gamma$$

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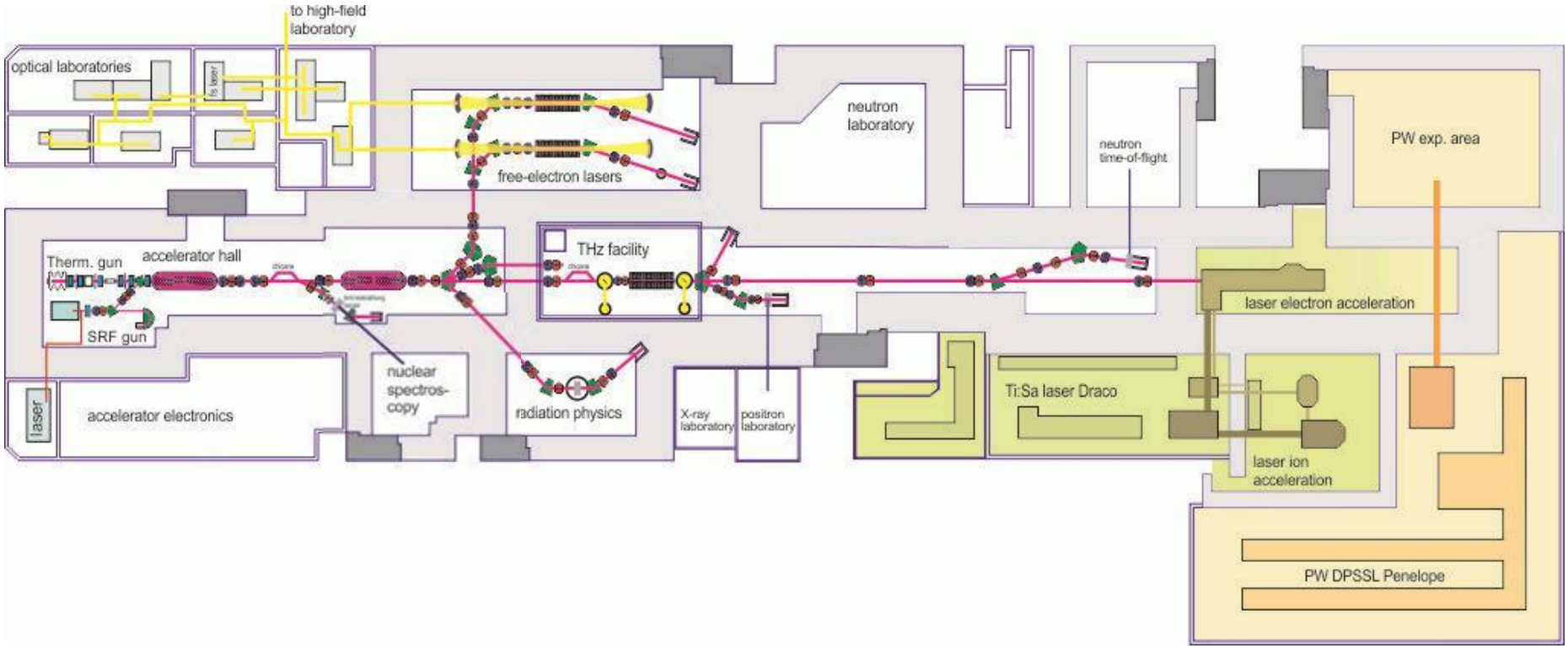
ELBE

Elektronen **L**inearbeschleuniger für Strahlen hoher **B**rillanz und niedriger **E**mittanz



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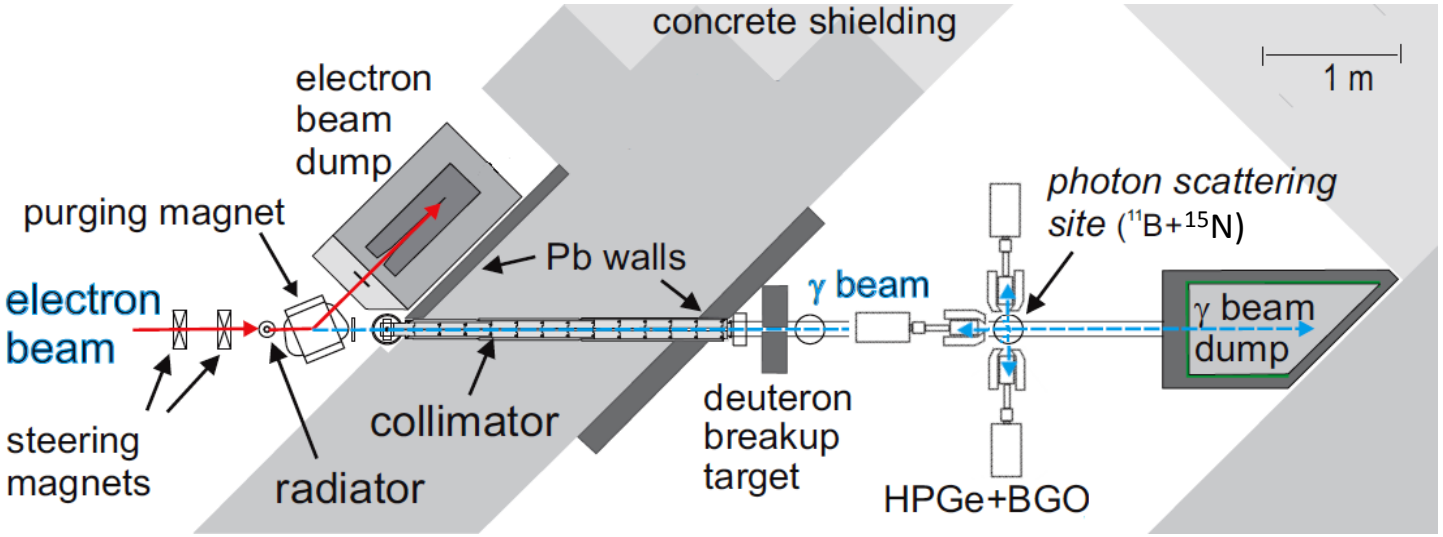
γELBE

- 4 HPGe with BGO anticompton shield
- 2 angles: 127° and 90°



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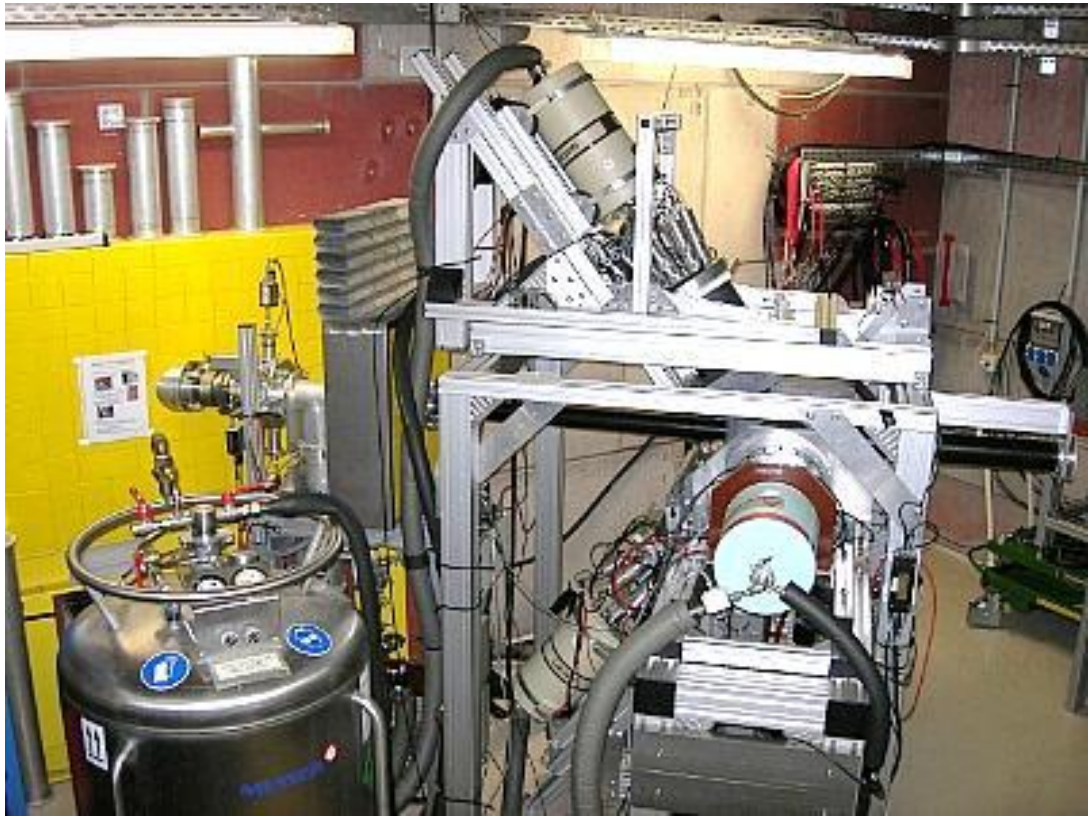

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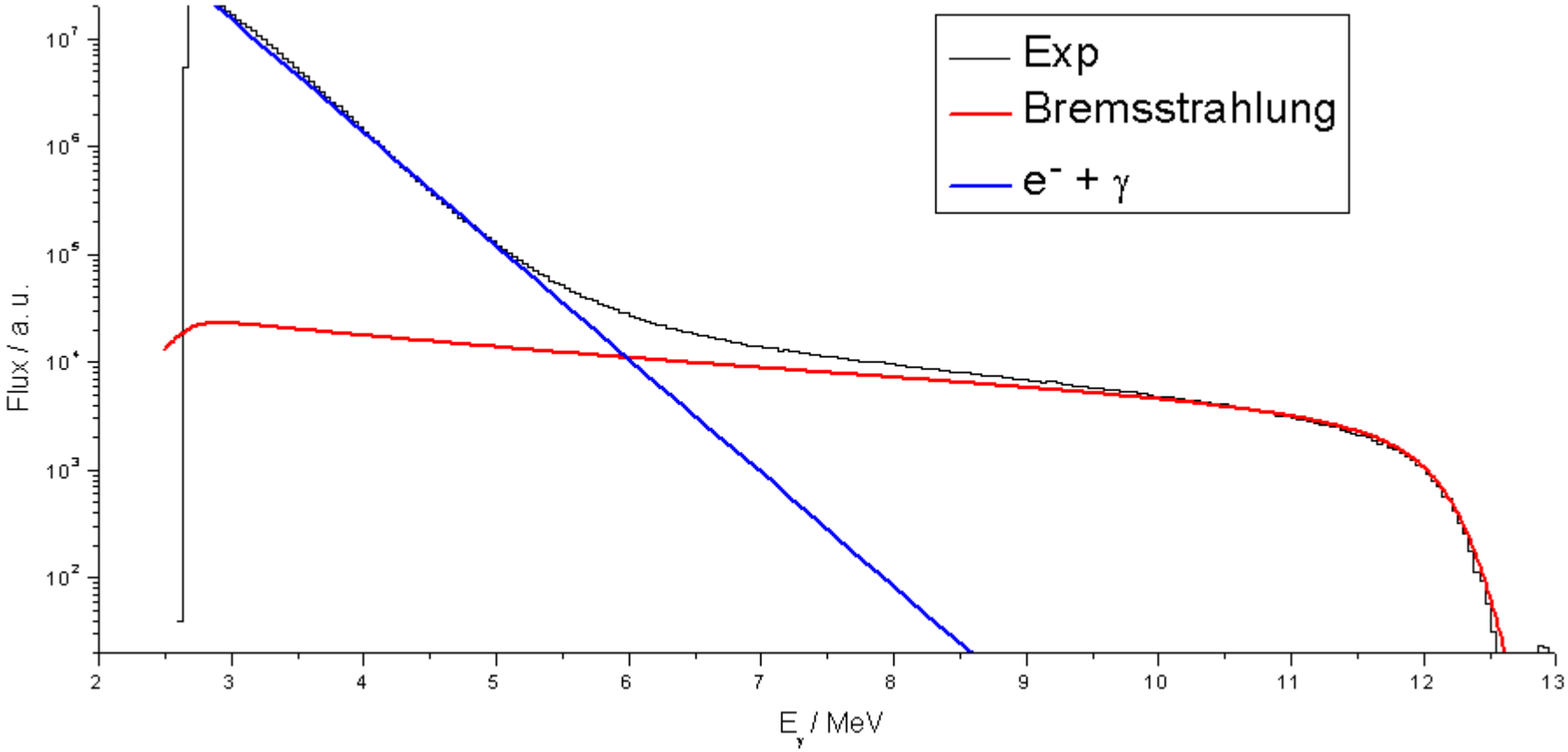
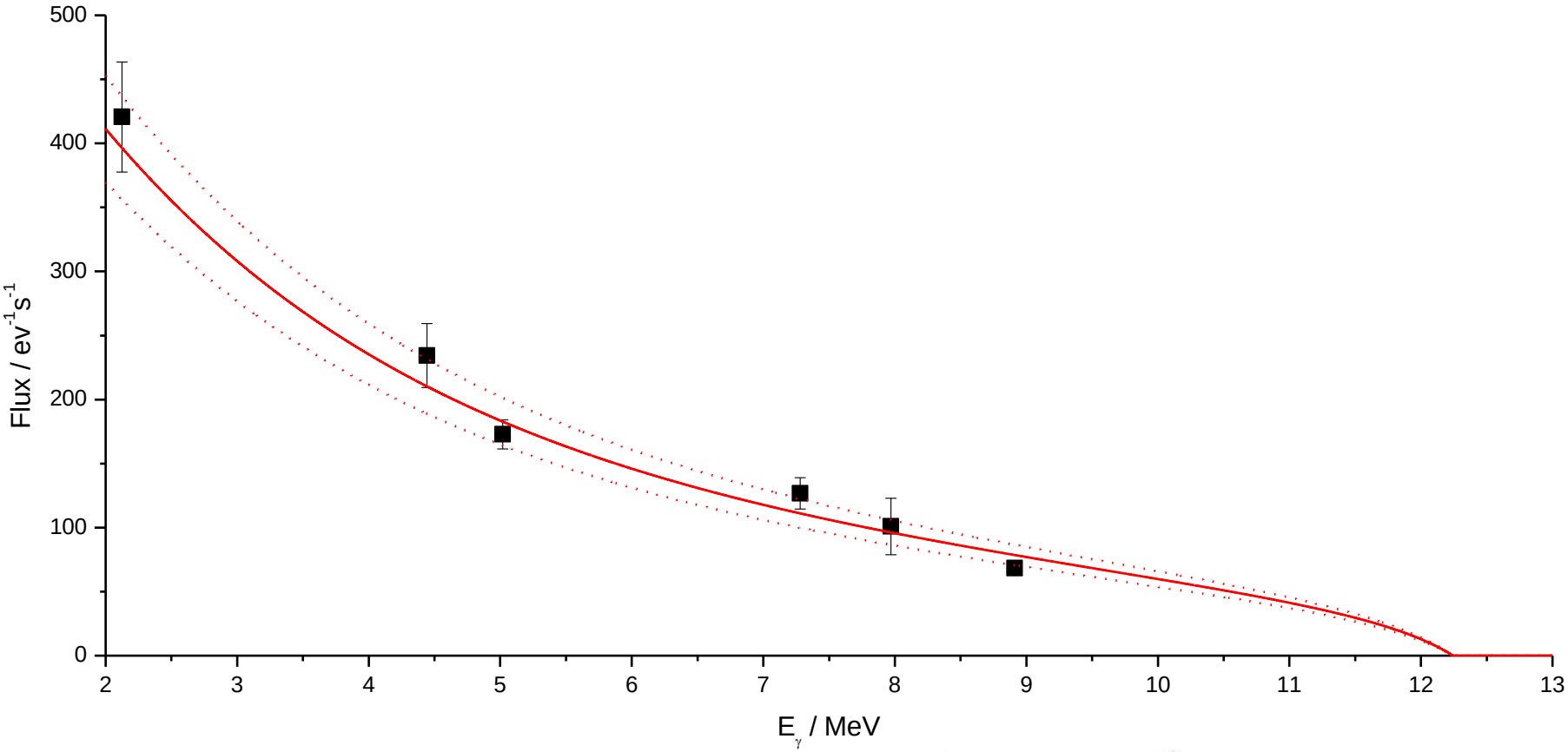
Bremsstrahlung energy distribution from Si detectors

- The endpoint was determined from deuteron breakup
- The energy distribution was calculated by the equation given in L. I. Schiff, Physical Review **83**, 252 (1951)



Bremsstrahlung flux

- The absolute flux was determined from the known level widths of ^{11}B.



Targets

- Solid nitrogen compounds enriched in ^{15}N
  - Ammonium-nitrate (NH_4NO_3): 98% enrichment
  - Ammonium-chloride (NH_4Cl): 99% enrichment
- Two pills from each material
  - ~0.5g and ~1.5g
- A ^{11}B pill was always included
  - 0.2g; 99.5% enrichment

Targets

Ammonium-chloride (NH_4Cl):

- Pro
  - Not hygroscopic
- Con
  - Less N per grams
  - Cl may cause addition peaks in the spectra

Ammonium-nitrate (NH_4NO_3):

- Pro
  - More N per grams
- Con
  - Slightly hygroscopic

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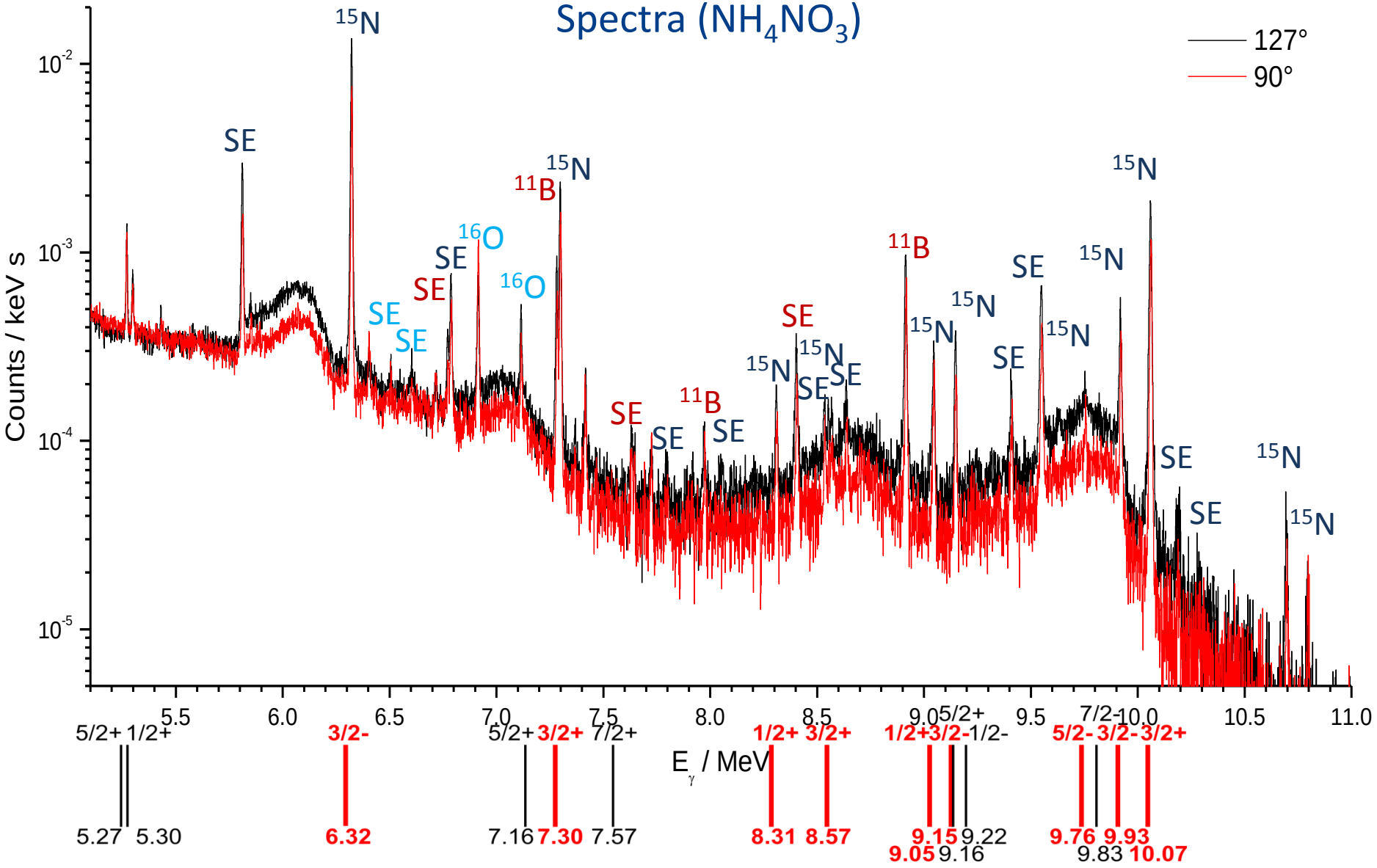
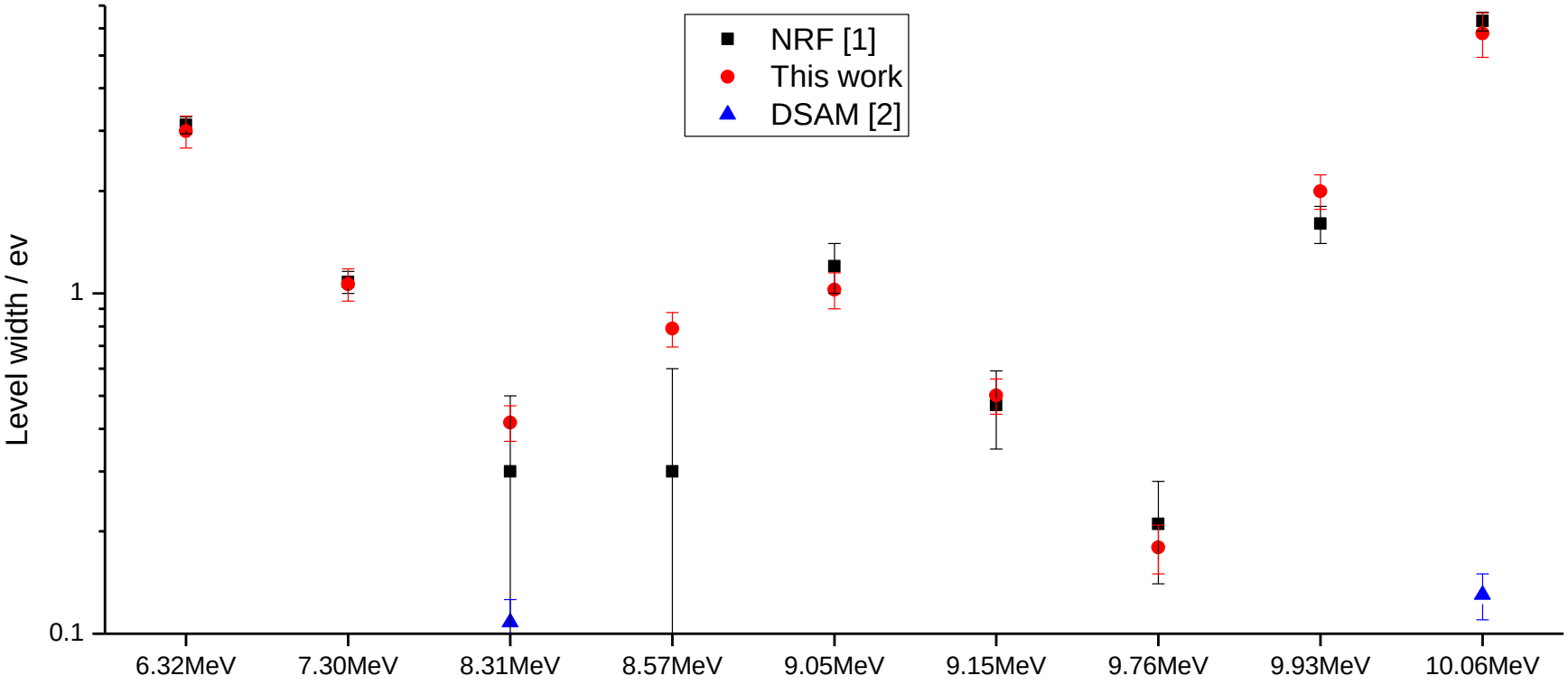
Spectra (NH_4NO_3)



Preliminary results



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Summary

- Level widths in ^{15}N have been measured
  - NRF technique
  - Bremsstrahlung
  - Solid N compounds, enriched in ^{15}N
  - 4 HPGe detectors with BGO anticompton shields

- The results supports the old NRF experiment from 1981 against the new preliminary DSAM results
- The obtained level widths have higher precision than the previous ones

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Thank you for your attention!

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