The Temperature-dependent Relative Self-Absorption (TRSA) method - A01

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P. Koseoglou, M. L. Cortés, J. Isaak, V. Werner, M. Beuschlein, J. Kleemann, O. Papst, N. Pietralla, U. Ahmed, K. E. Ide, I. Jurosevic, C. M. Nickel, M. Spall, T. Stetz and R. Zidarova

Institut für Kernphysik, Technische Universität Darmstadt

Part of

- Nuclear Resonance Fluorescence (NRF) method
- Relative Self-Absorption (RSA) method

A. Zilges, D. Balabanski, J. Isaak, N. Pietralla, Prog. Part. and Nucl. Phys. **122** 103903 (2022)

Importance of high precision level widths and decay strengths measurements:

- Structure classification of atomic nuclei
- Crucial test of the modeling of nuclear forces and of nuclear quantum transitions

U. Friman-Gayer et al. Phys. Rev. Lett. **126**, 102501 (2021)

Nuclear Photonics

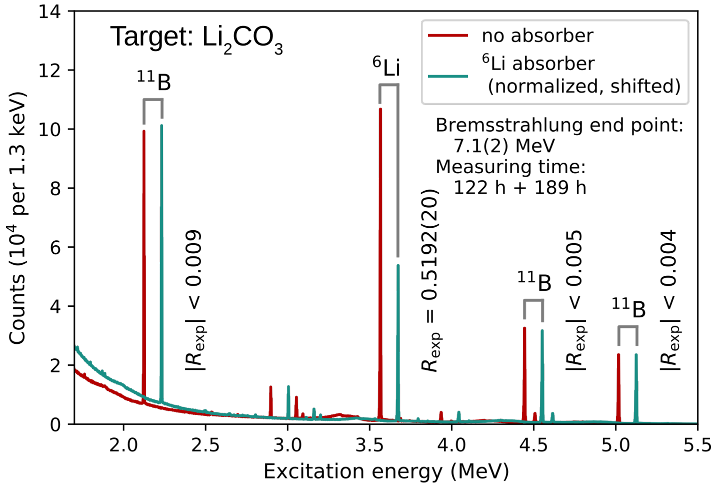
LOEWE
Exzellente Forschung für Hessens Zukunft

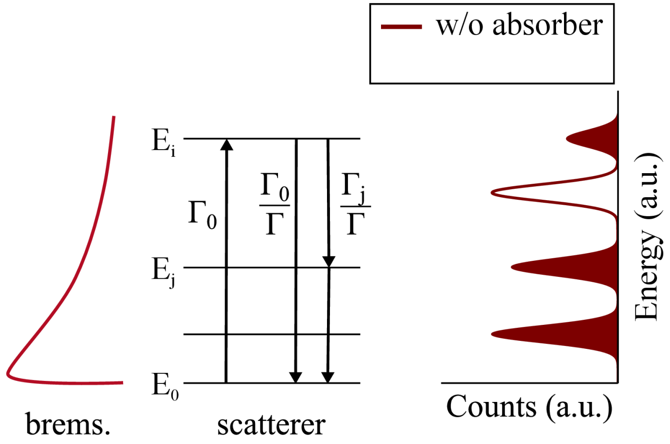
SFB 1245

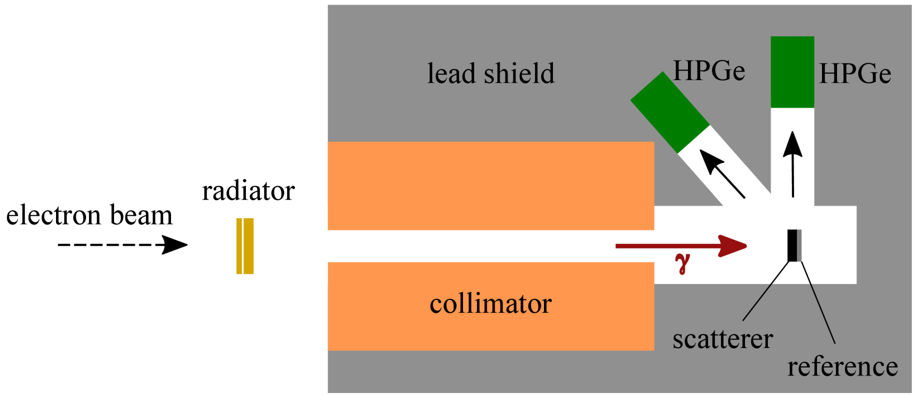
DFG Deutsche Forschungsgemeinschaft

Measurement of the 0_1^+ excited state level width in ^{6}Li with RSA

Darmstadt High-Intensity Photon Setup@S-DALINAC







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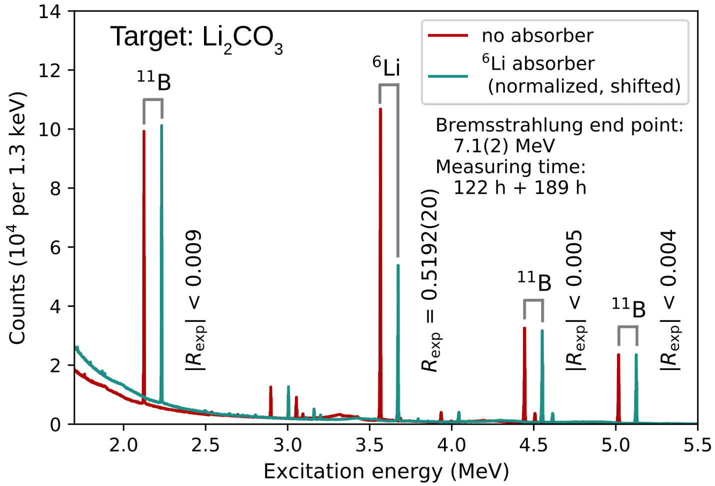

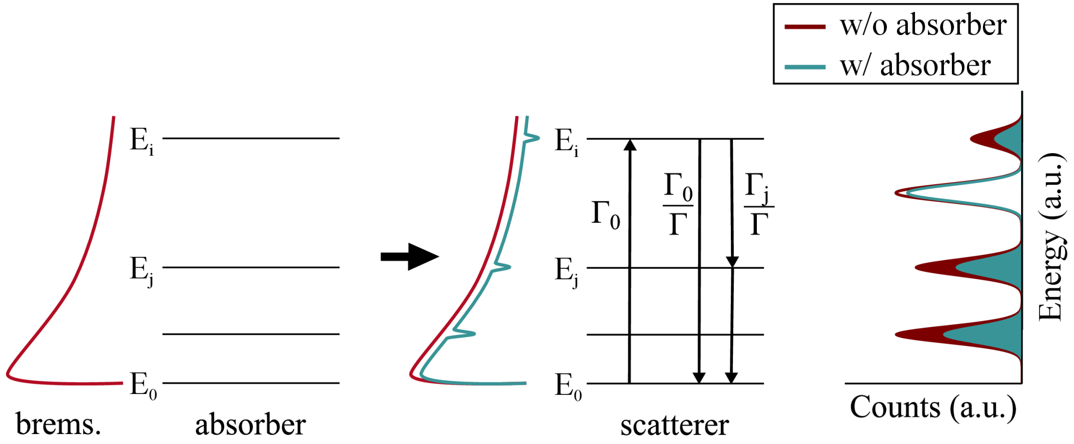

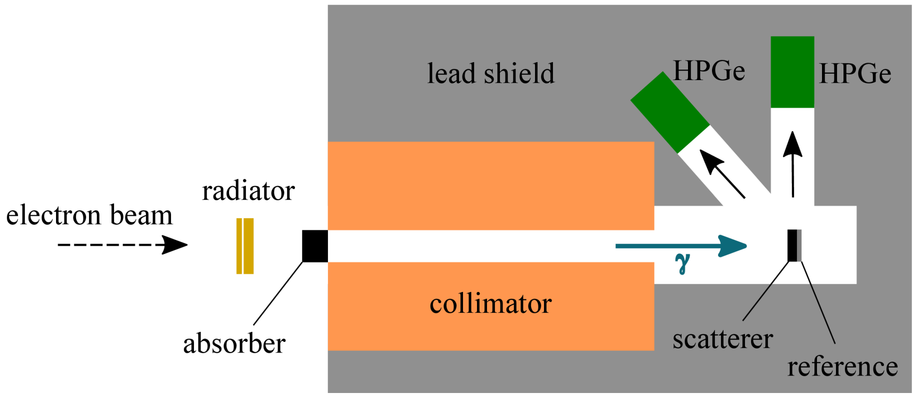

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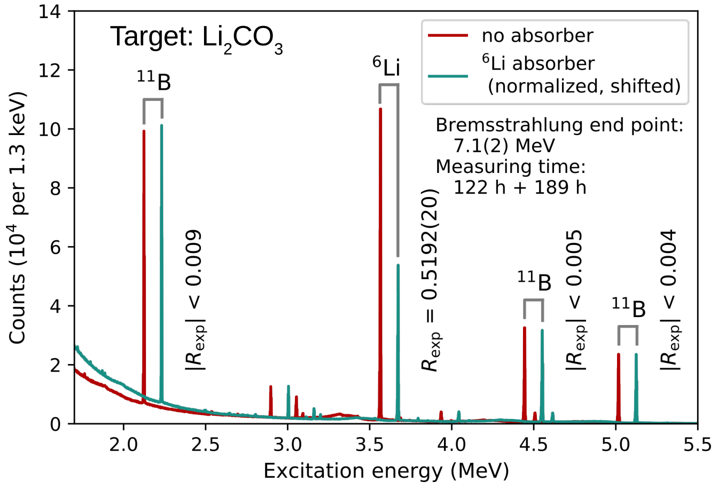
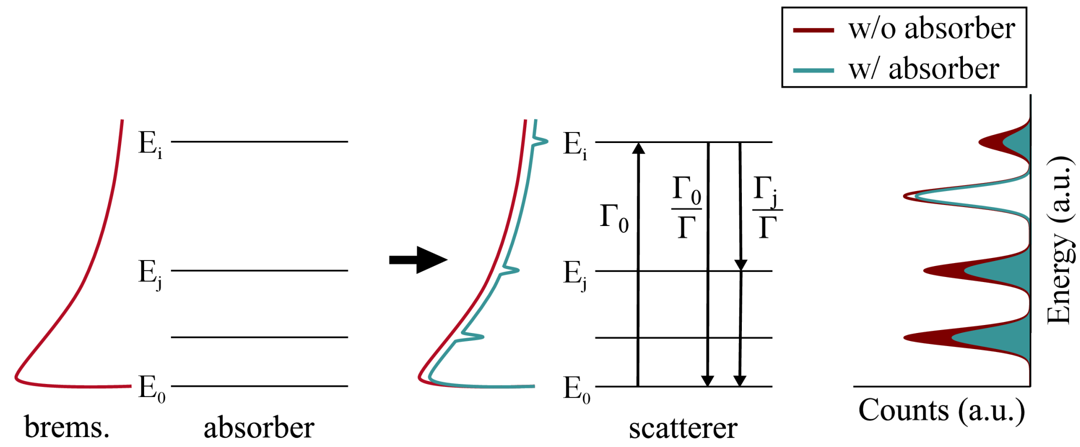
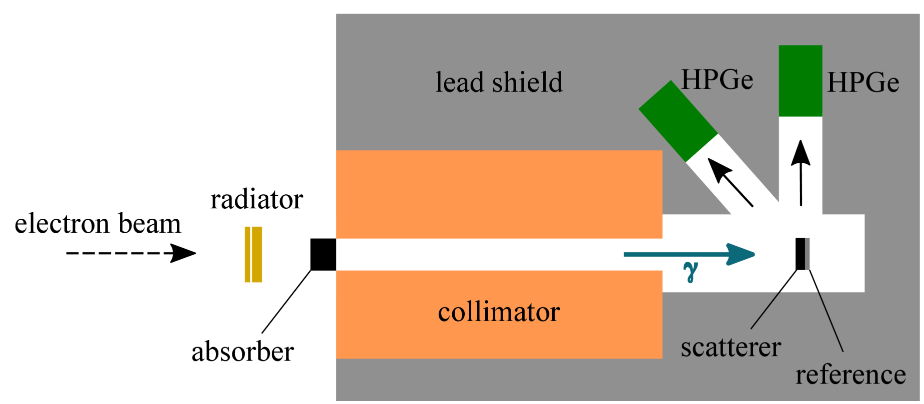




$$R = 1 - g\frac{A_{sc}^{abs}}{A_{sc}^{nrf}} = R\left(\Gamma_\gamma, T_{eff}\right)$$



R_{exp} = 0.5192(20) stat.

$\Gamma_{\gamma,\, 0+\rightarrow 1+}$ = 8.17(14) stat. (11) syst. eV

B(M1;$0^+ \rightarrow 1^+$)= 15.61(33) μ^2_N

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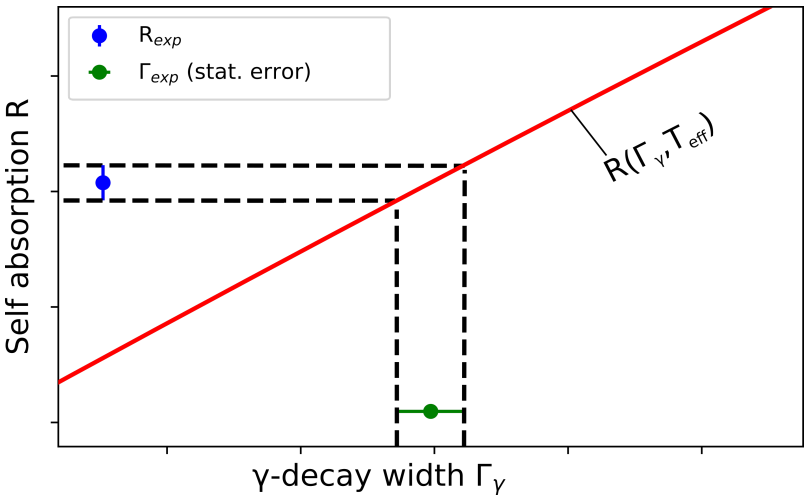

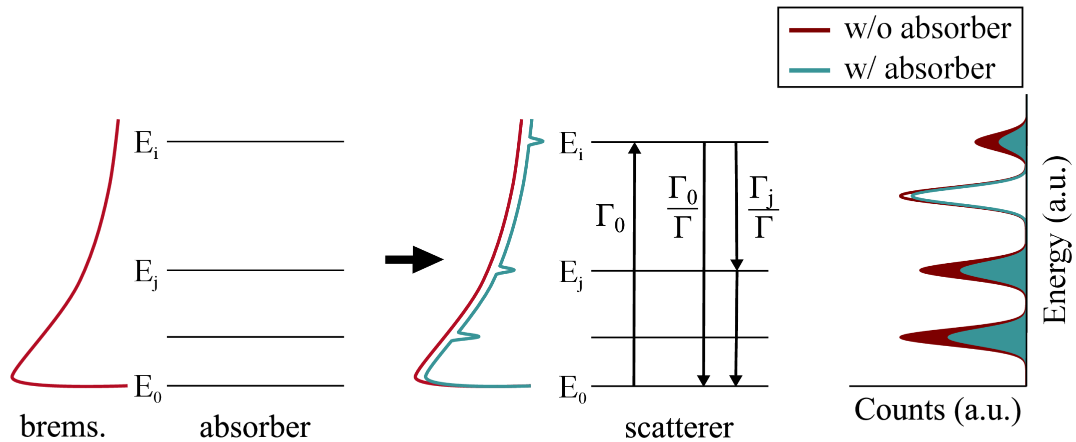

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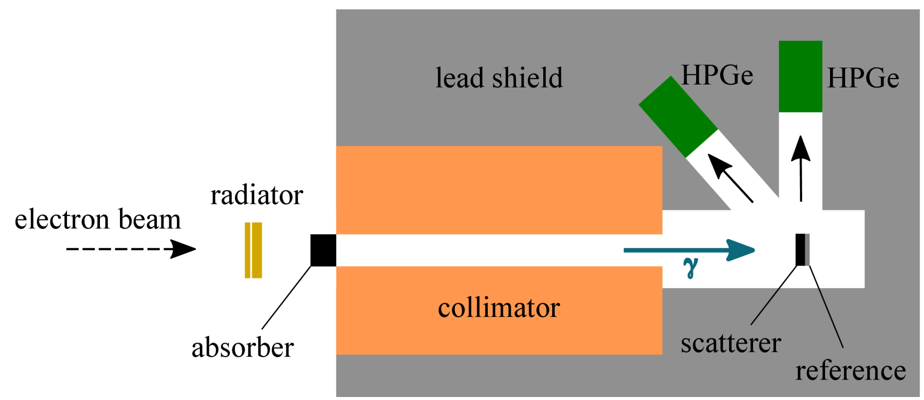

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Measurement of the 0^+_1 excited state level width in ^{6}Li with RSA

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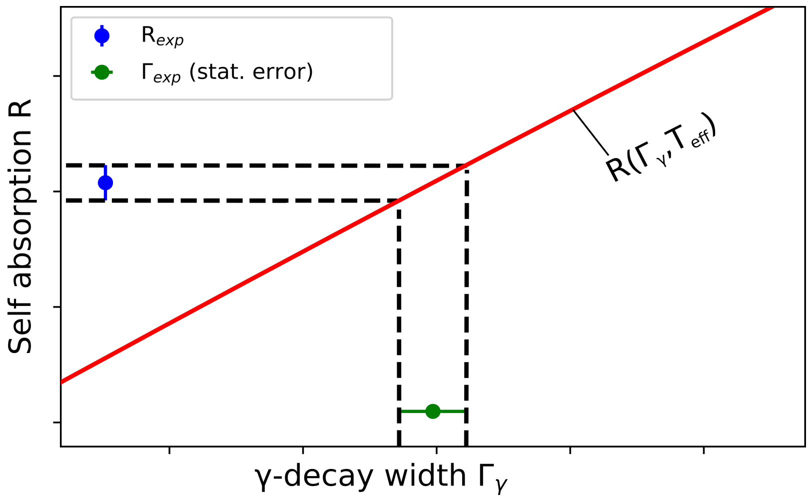

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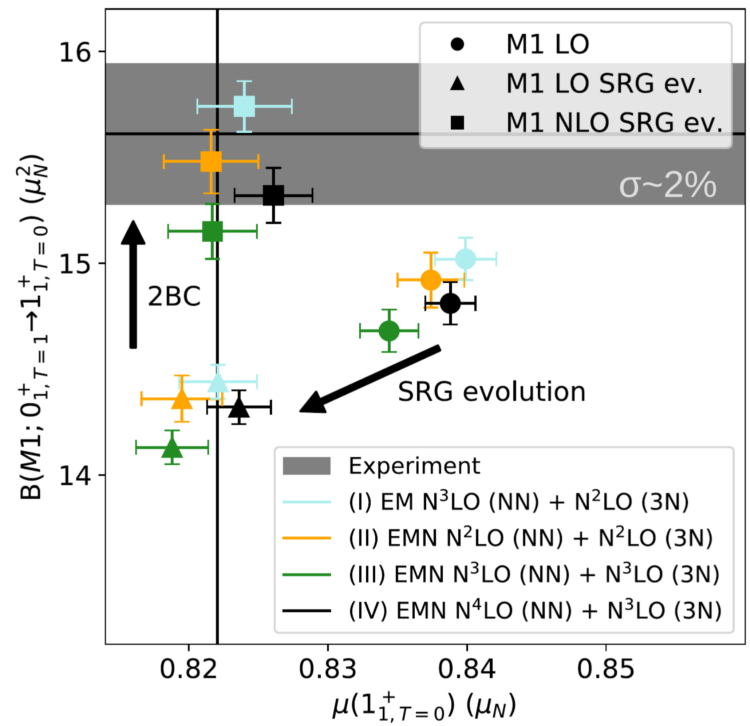

- Similarity Renormalization Group corrections of the M1 operator
- Contributions of the 2 Body Currents to the M1 operator

U. Friman-Gayer et al. Phys. Rev. Lett. **126**, 102501 (2021)

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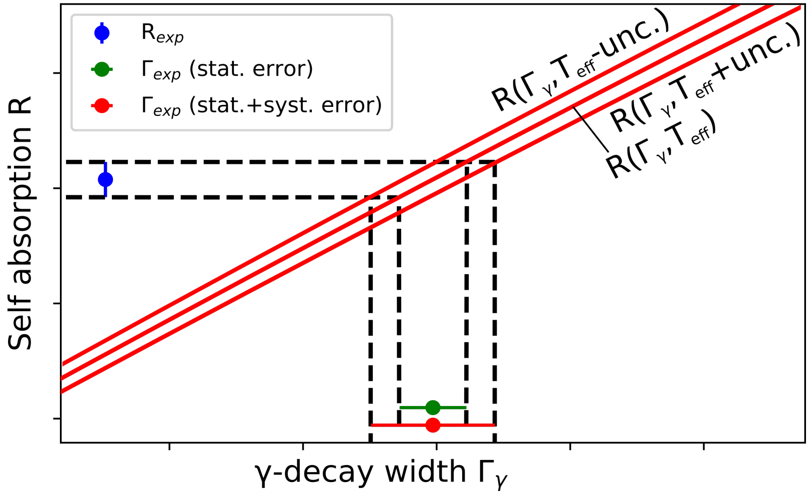

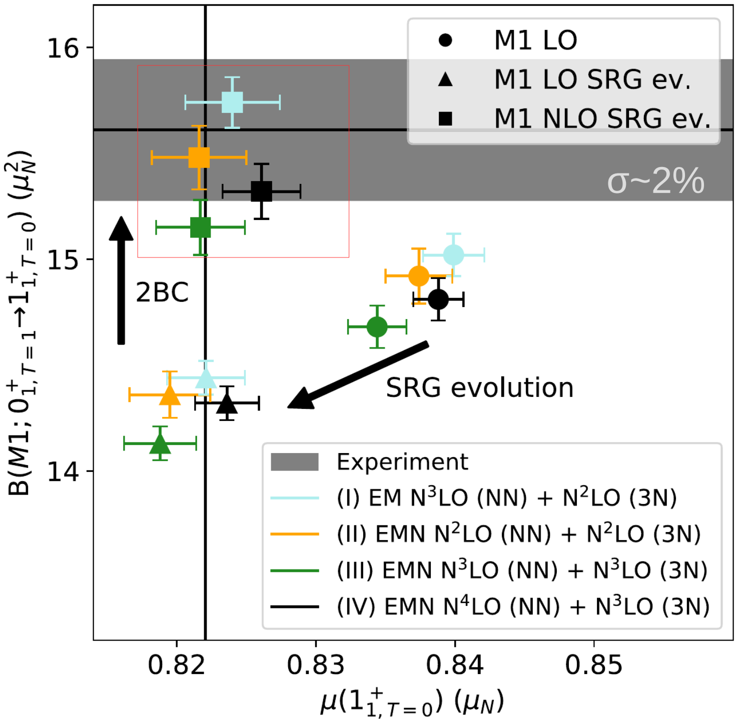

Measurement with the TRSA method for higher precision

$$R = 1 - g\frac{A_{sc}^{abs}}{A_{sc}^{nrf}} = R\left(\Gamma_\gamma, T_{eff}\right)$$

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Dependence on the T_{eff}

- For Γ<<Δ:

$$\sigma \propto \Gamma_0 \cdot e^{-\left(\frac{E-E_r}{\Delta}\right)^2}$$

- The thermal motion and the lattice vibrations broaden the cross-section.

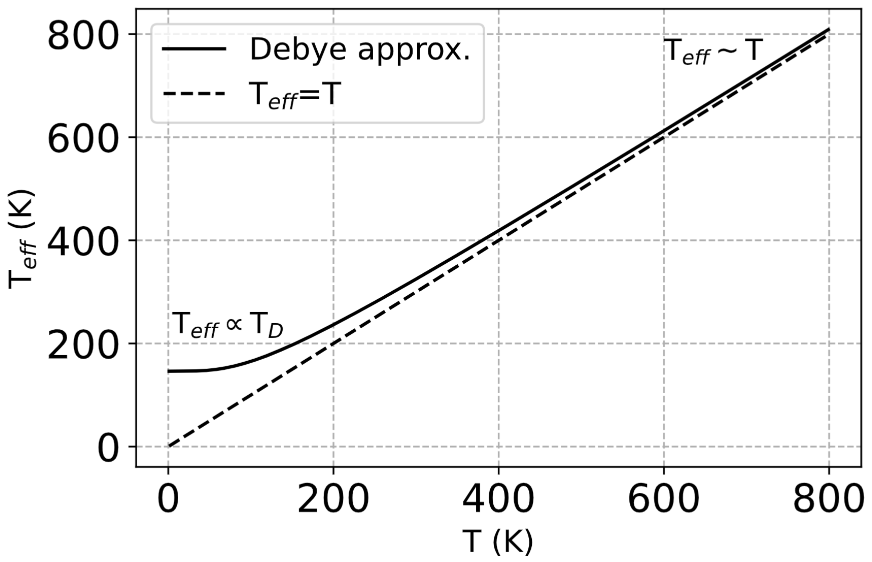
- Doppler width: $\Delta = \sqrt{\frac{2k_B T_{eff}}{Mc^2}} \cdot E_r$

- For a solid target: **Effective temperature**

  from Debye approximation*:*

$$T_{\text{eff}} \approx 3T \cdot \left(\frac{T}{T_D}\right)^3 \int_0^{T_D/T} t^3 \cdot \left(\frac{1}{e^t - 1} + \frac{1}{2}\right) dt$$

- The Debye temperature is not measured for many chemical compounds.



Dependence on the T_{eff}

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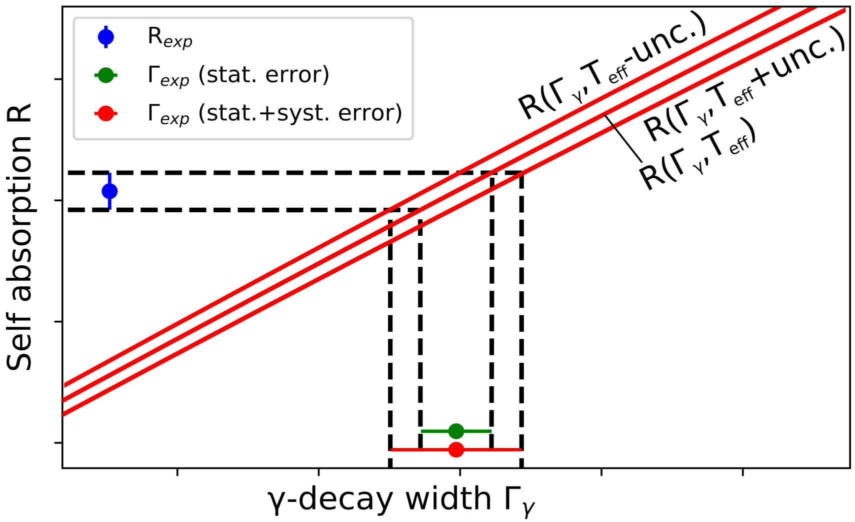

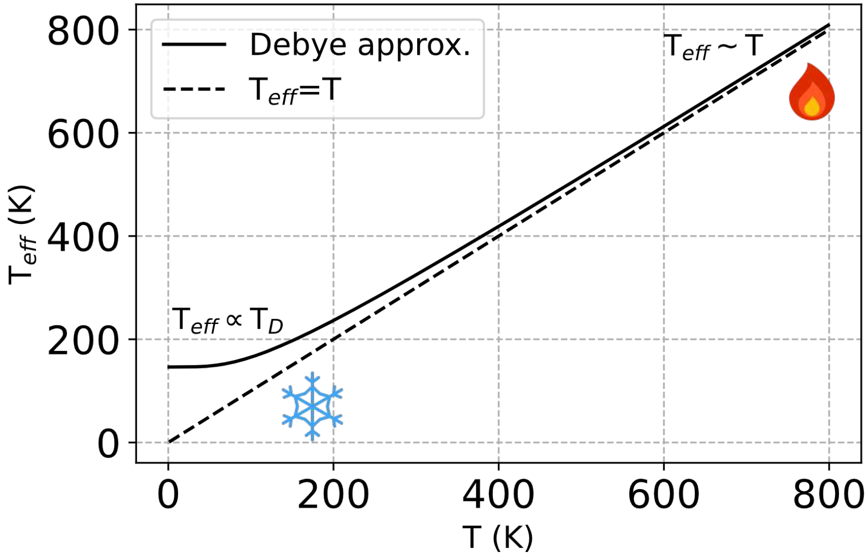

Temperature-dependent RSA measurements:

- Get independent of the theoretical calculations of the effective temperature and the uncertainty in the T_D
- **High-precision level width measurements**
- Reduce the systematic uncertainties of the measured transition matrix elements
- Heat-up/cool-down the absorber/scatterer

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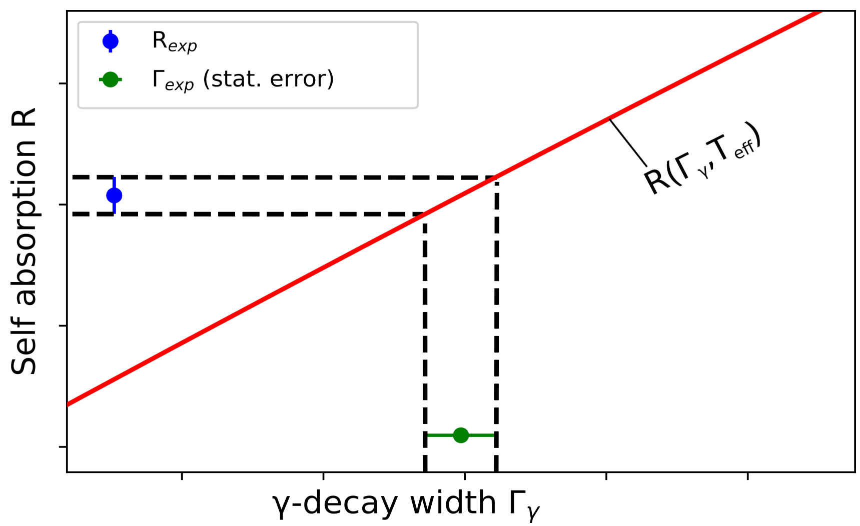

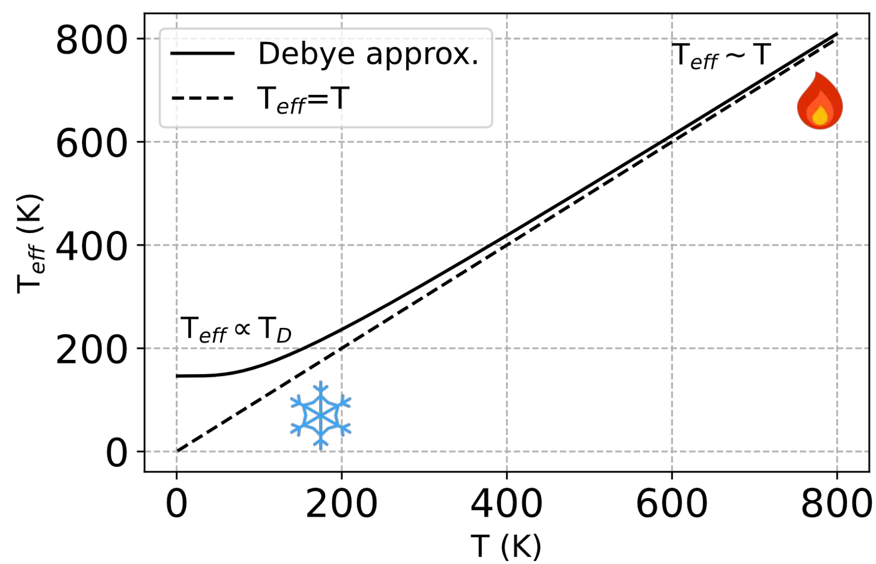

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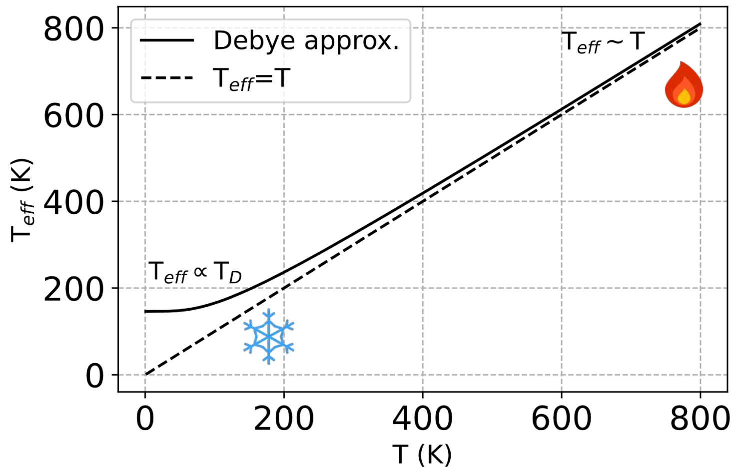
Temperature-controlled target system

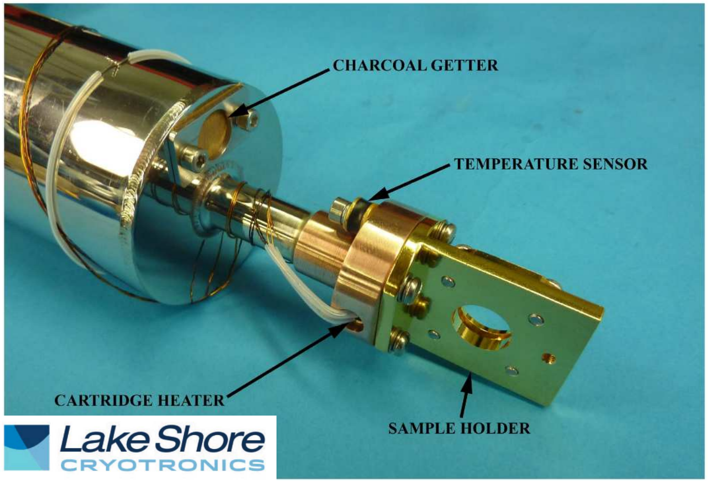
LAKE SHORE model VPF-100 system

- LN_2 temperature – 500 ºC
- Under vacuum
- Temperature controller

Measurements for the next funding period:

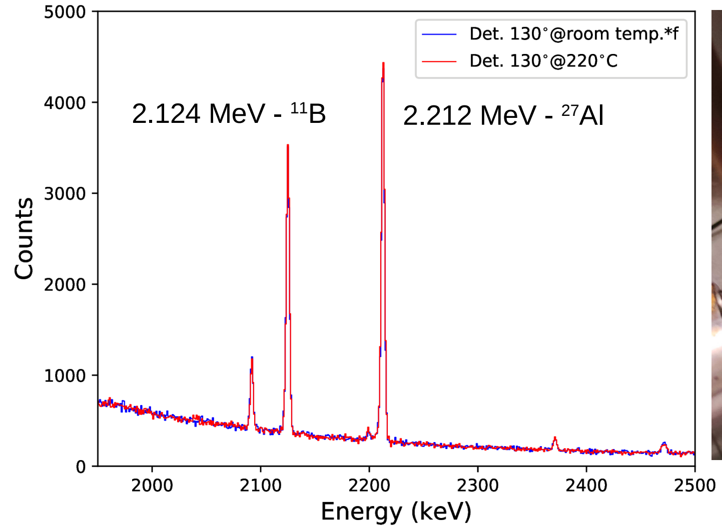
- ^{6}Li, ^{11}B, ^{27}Al
- on isotopes which can not be used as non-compound materials, like gases and toxic materials
- level density investigations
- effective temperature measurements
- high precision Debey temperature measurements





TRSA measurements in ^{27}Al

- DHIPS@S-DALINAC
- Beam energy: 5.4 MeV
- Beam current: 40 μA
- 2 HPGe detectors
  - @90°
  - @130°
- Absorber: 28mm thick ^{27}Al (6g)
- Scatterer: 5g ^{27}Al + 0.4g ^{11}B (for normalization)

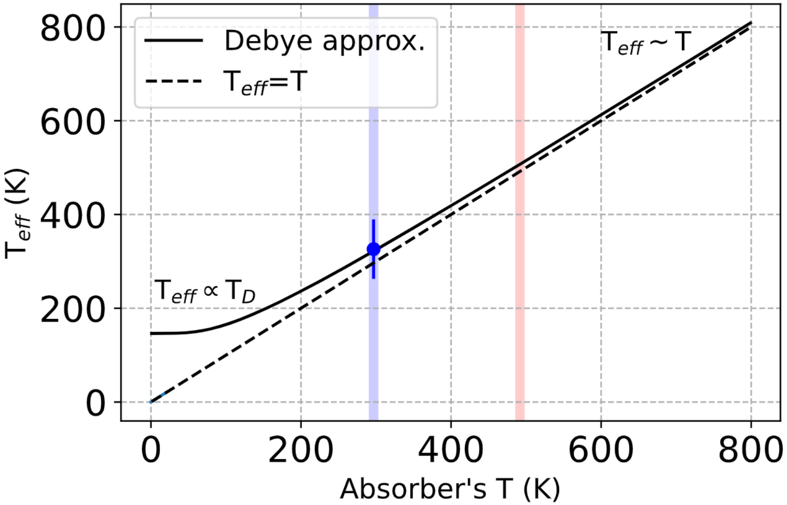


In total:

- 11h w/o absorber
- 47h w/ absorber@room temp.
- 58h w/ absorber@220°C

Temperature effect: $$effect = 1 - f\frac{Al_{sc}^{room}}{Al_{sc}^{220}}$$

Normalization factor: $$f = \frac{B^{220}}{B^{room}}$$



TRSA measurements in ^{27}Al

Preliminarily results

E_γ (keV)	Transition	Temp. effect	Theor. calc. with ries code	Γ (meV)	$\Gamma_{lit.}$ (meV)
2212.01	$(7/2^+) \rightarrow 5/2^+(g.s.)$	0.024 (13)	0.038	18 (4)	17.19 (31)
2982.00	$3/2^+ \rightarrow 5/2^+(g.s.)$	0.033 (12)	0.047	128 (26)	116.7 (25)
3956.40	$3/2^+ \rightarrow 5/2^+(g.s.)$	0.060 (19)	0.033	209 (69)	177 (11)

N. Pietralla et al., Phys. Rev. C **51**, 1021 (1995)
U. Friman-Gayer, ries code, https://github.com/uga-uga/ries

In total:

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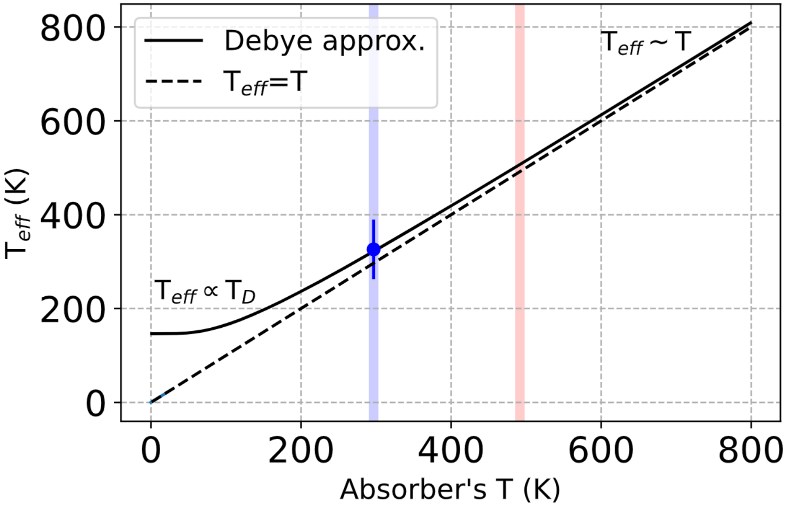

Thank you for your attention!

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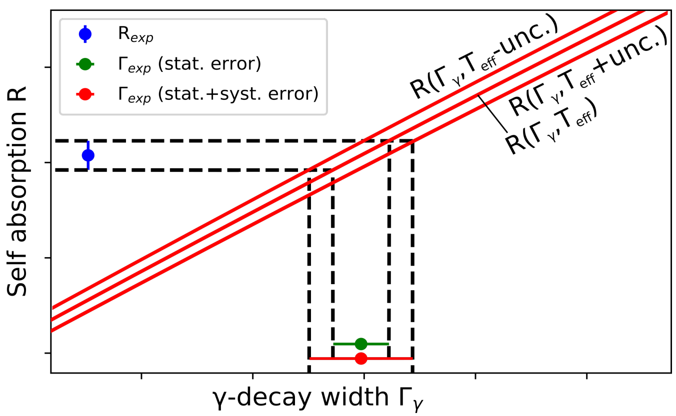

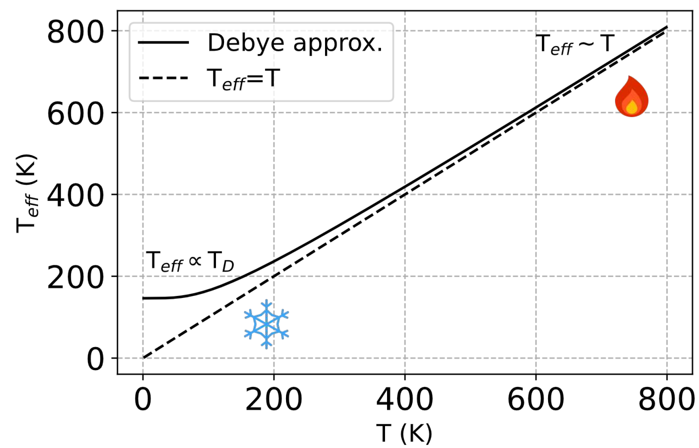

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