A01: Precision structure of excited states of light nuclei: Status and Outlook

TECHNISCHE UNIVERSITÄT DARMSTADT

Marcel Schilling

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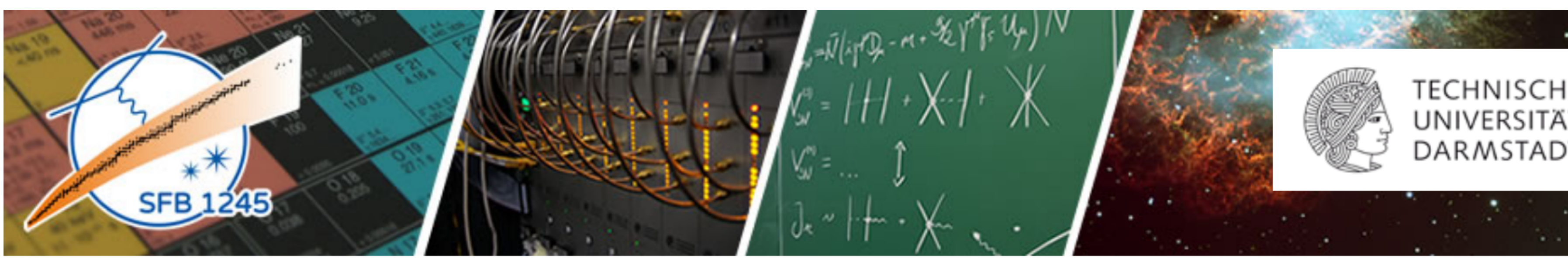
PhD Students: Michaela Hilcker, Bernhard Maaß, Marcel Schilling

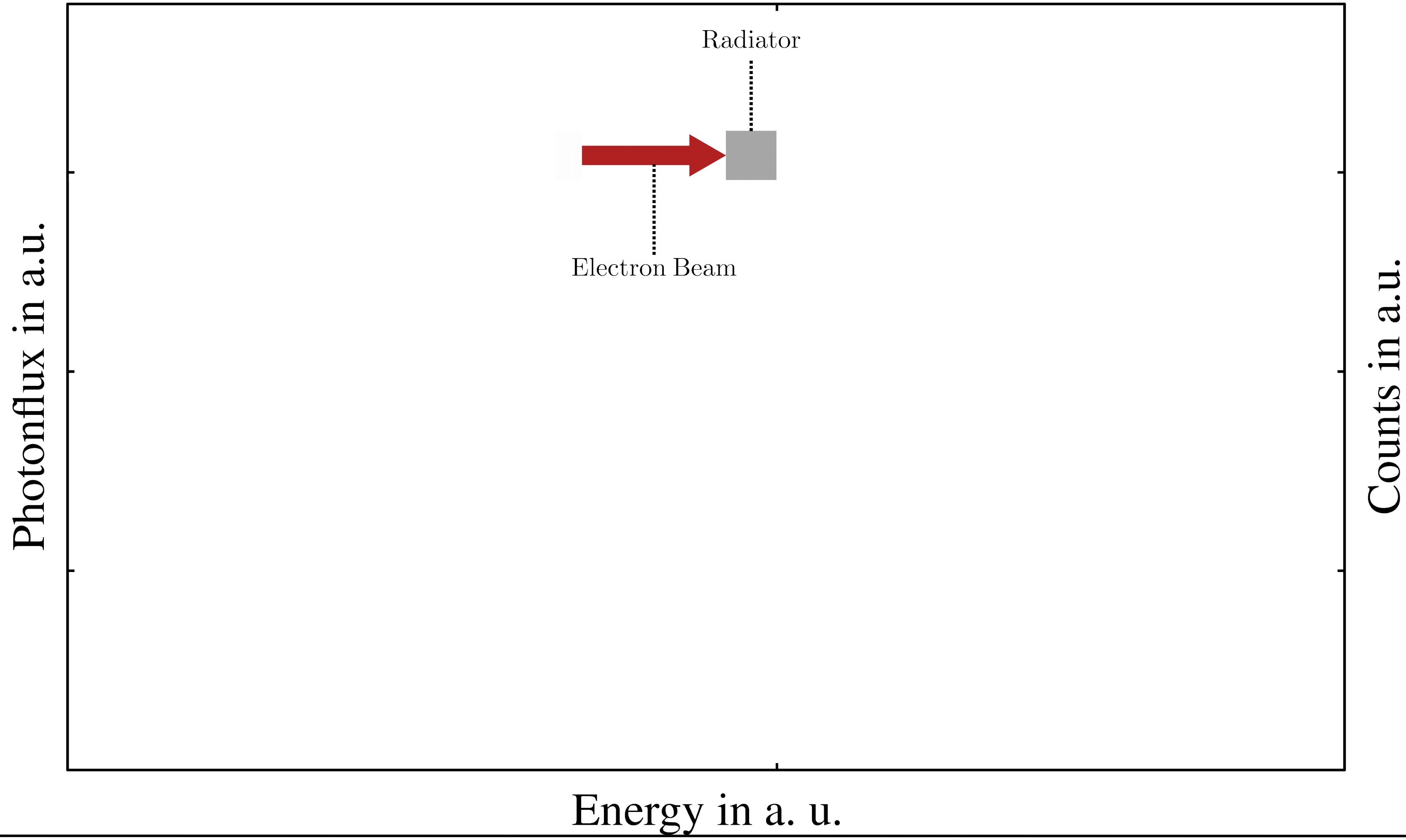


Goals of Project A01:
Precision data on electromagnetic observables of light nuclei

- Precision data → Test of ab initio chiral EFT calculations(A02, A05)
- Photon scattering: ^{6}Li
  - ➔ transition matrix element: $1^+ \rightarrow 0^+$

Photon scattering: ^{11}B
  - ➔ mandatory for extracting $Q(2^+_1)$ of ^{12}C in A03
- Electron scattering: ^{4}He
  - ➔ transition form factor: $0^+ \rightarrow 0^+$
- Laser spectroscopy: ^{8}B
  - ➔ charge radius (B. Maas)

Relative Self Absorption



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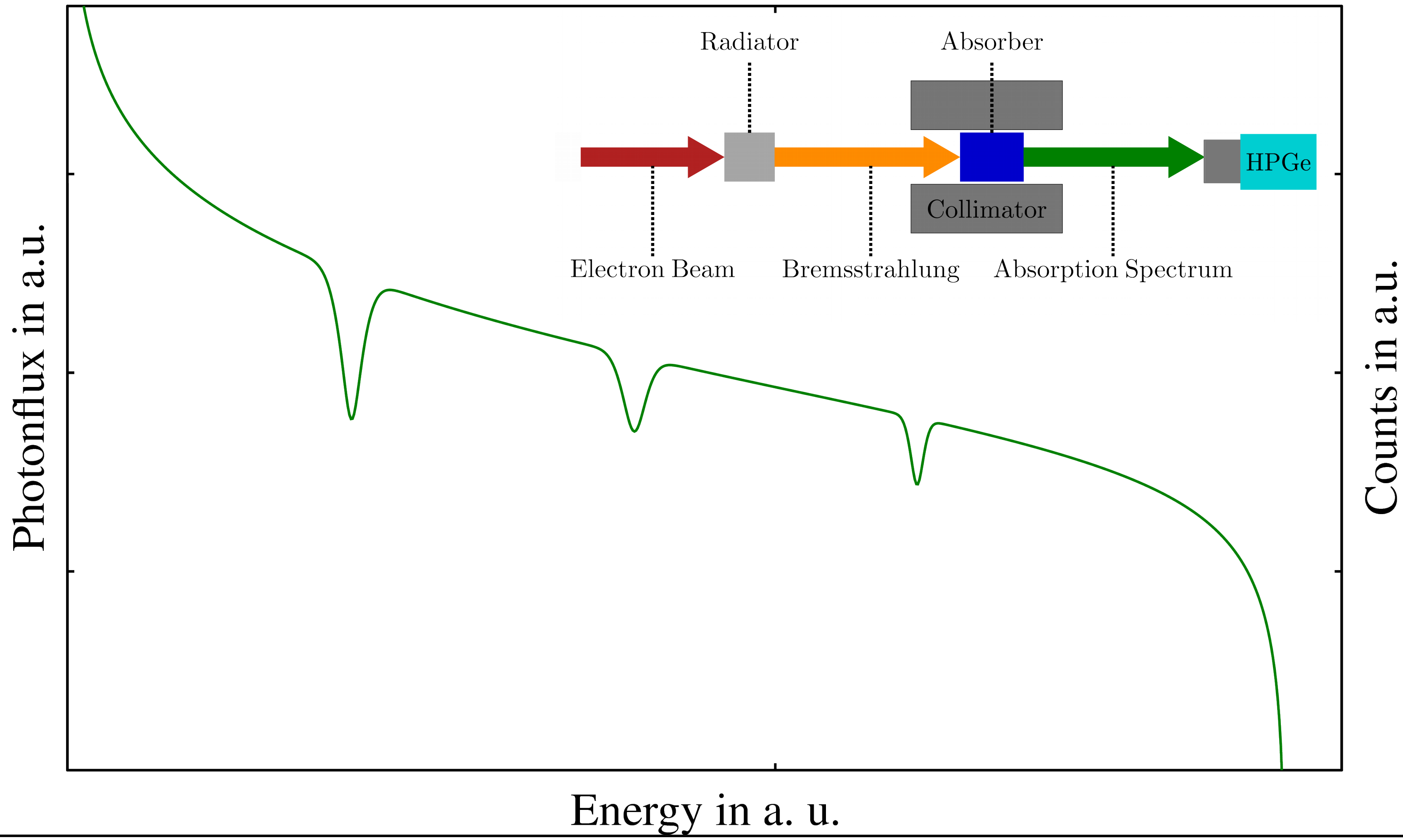

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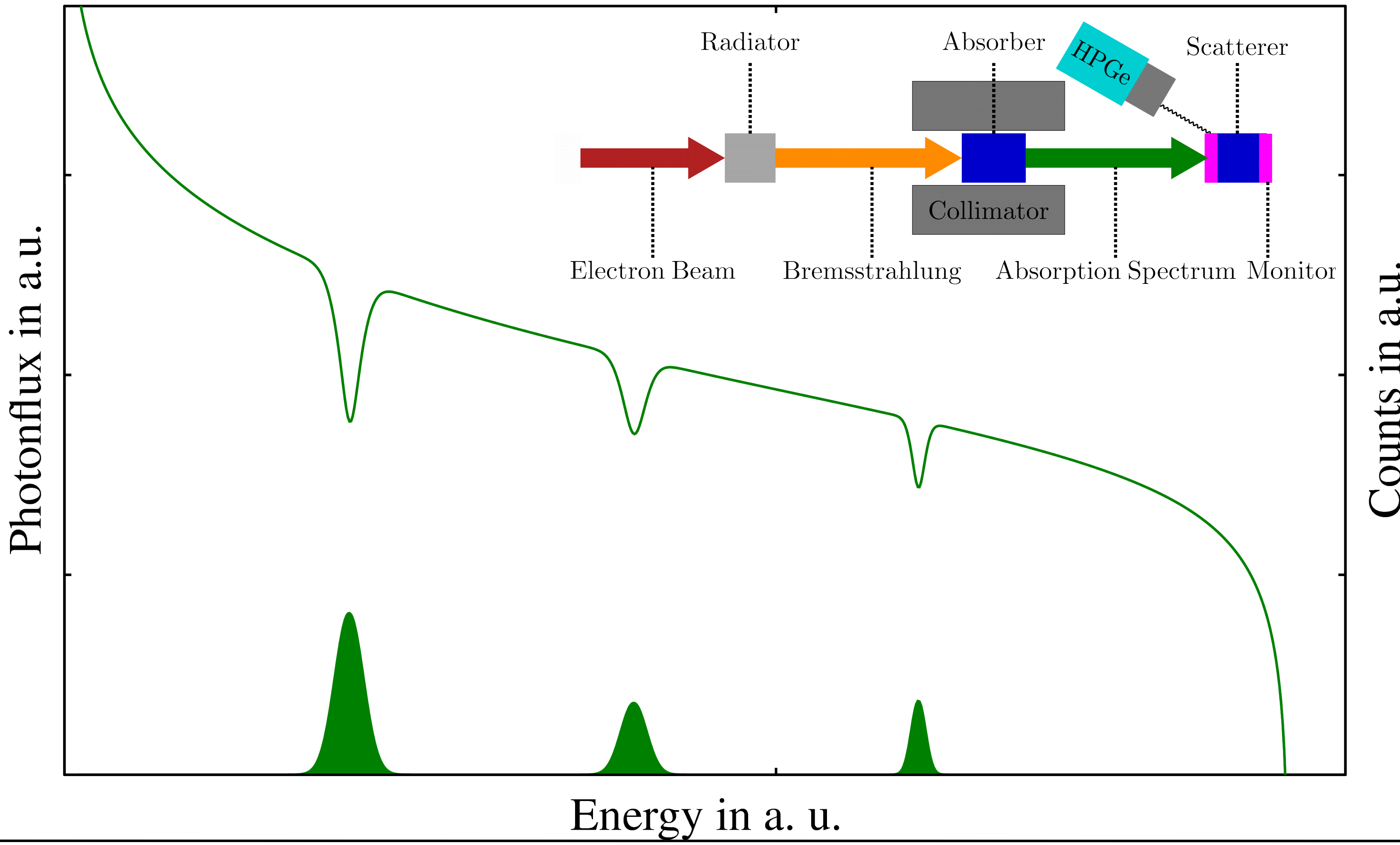

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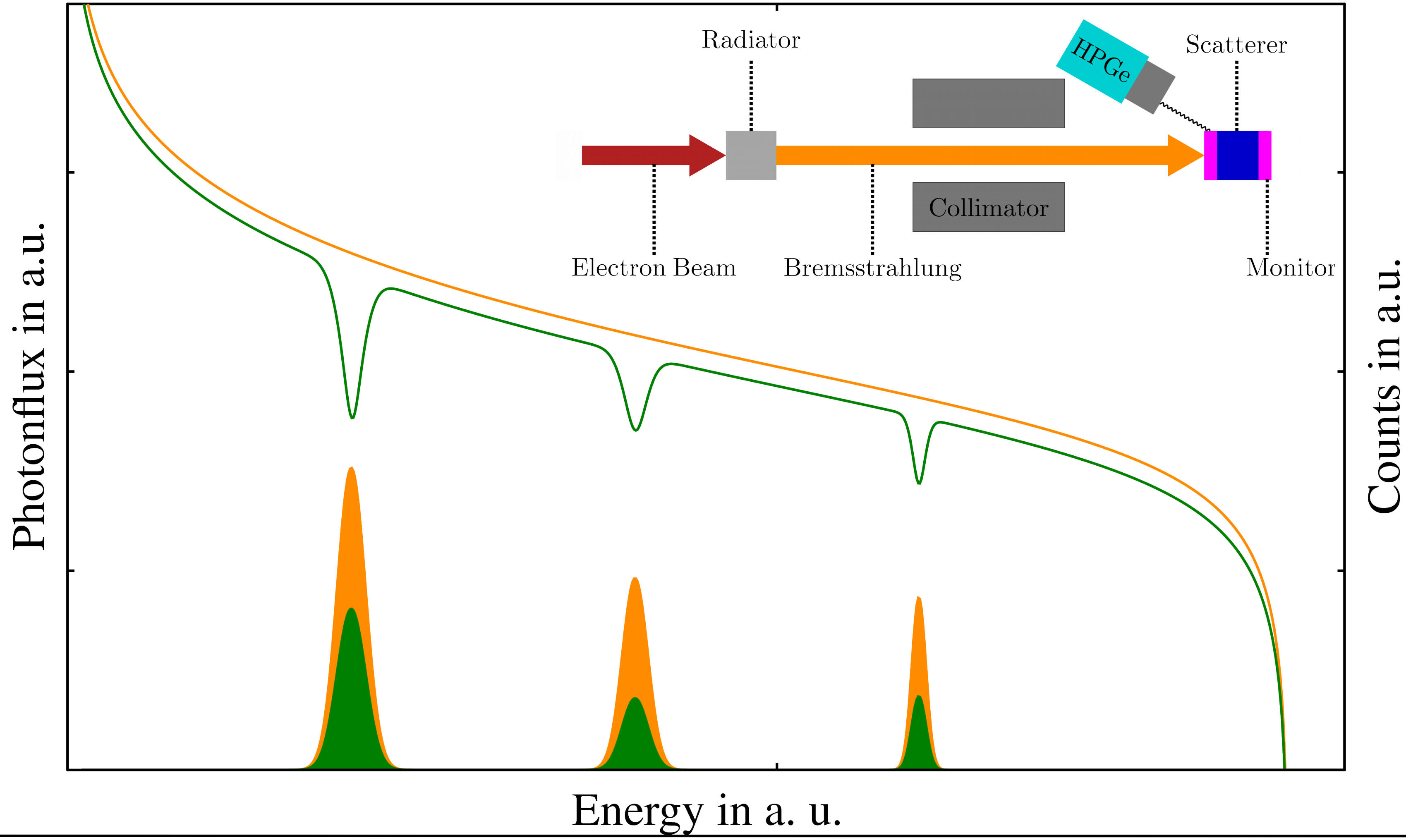

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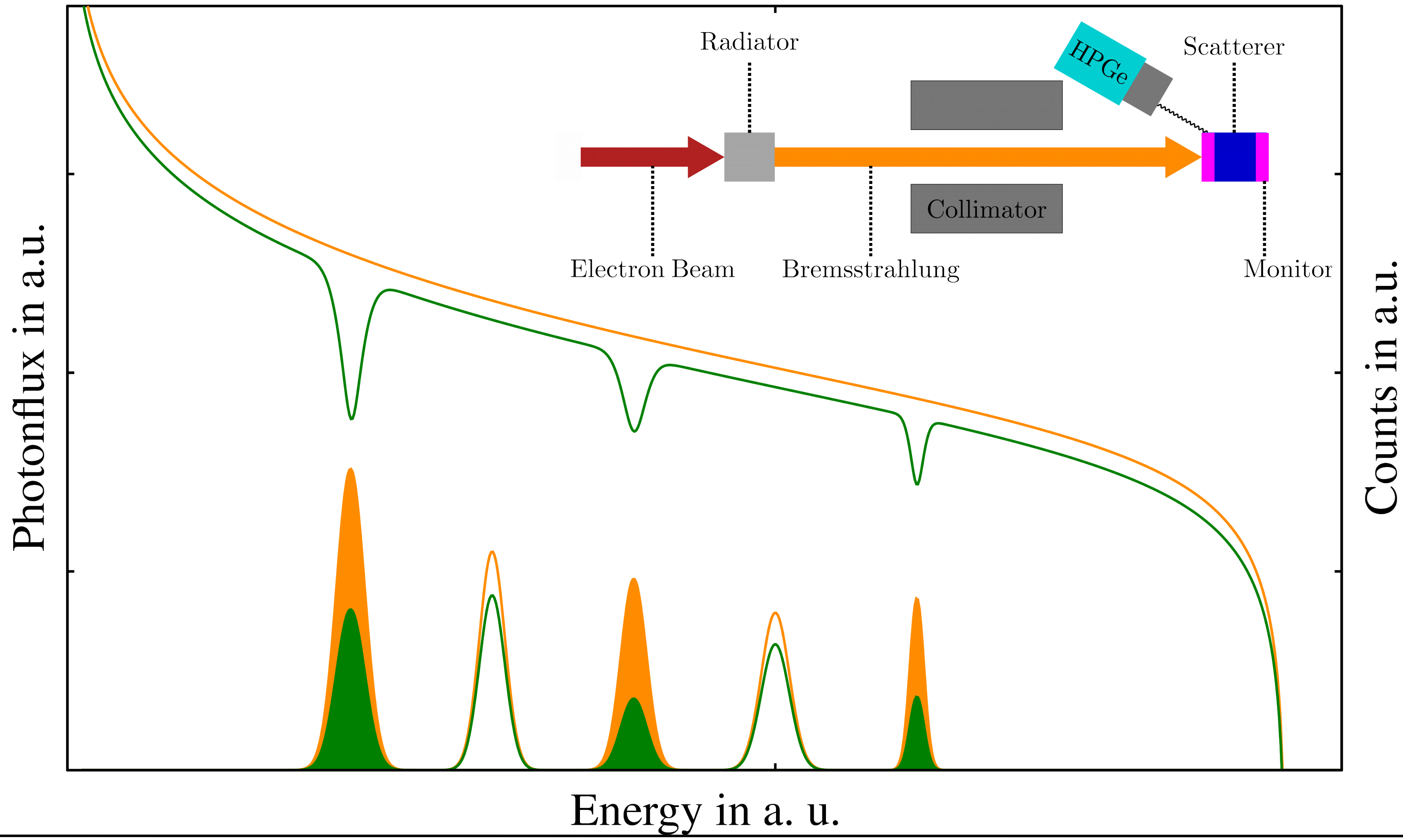

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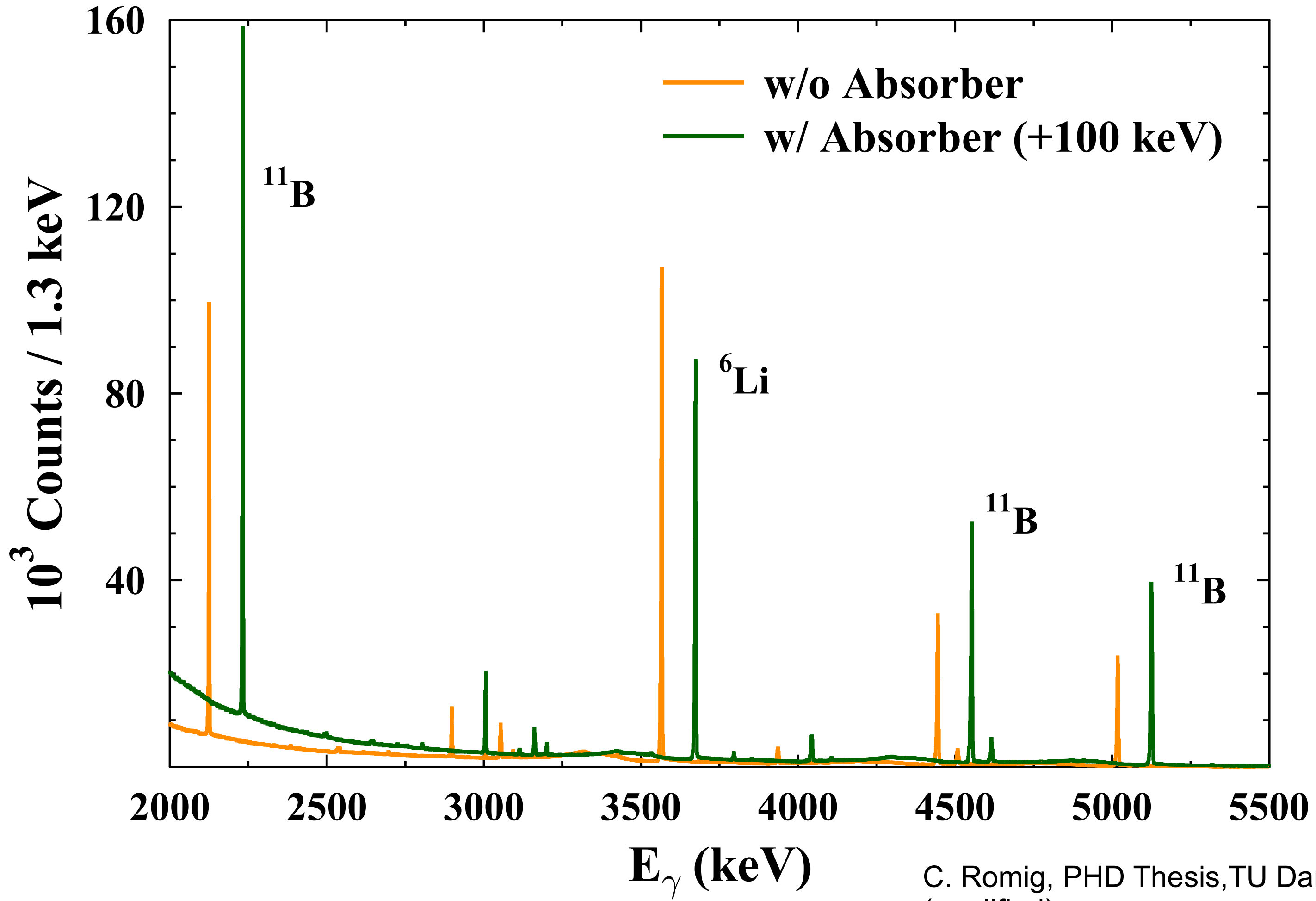

C. Romig, PHD Thesis,TU Darmstadt, 2015 (modified)

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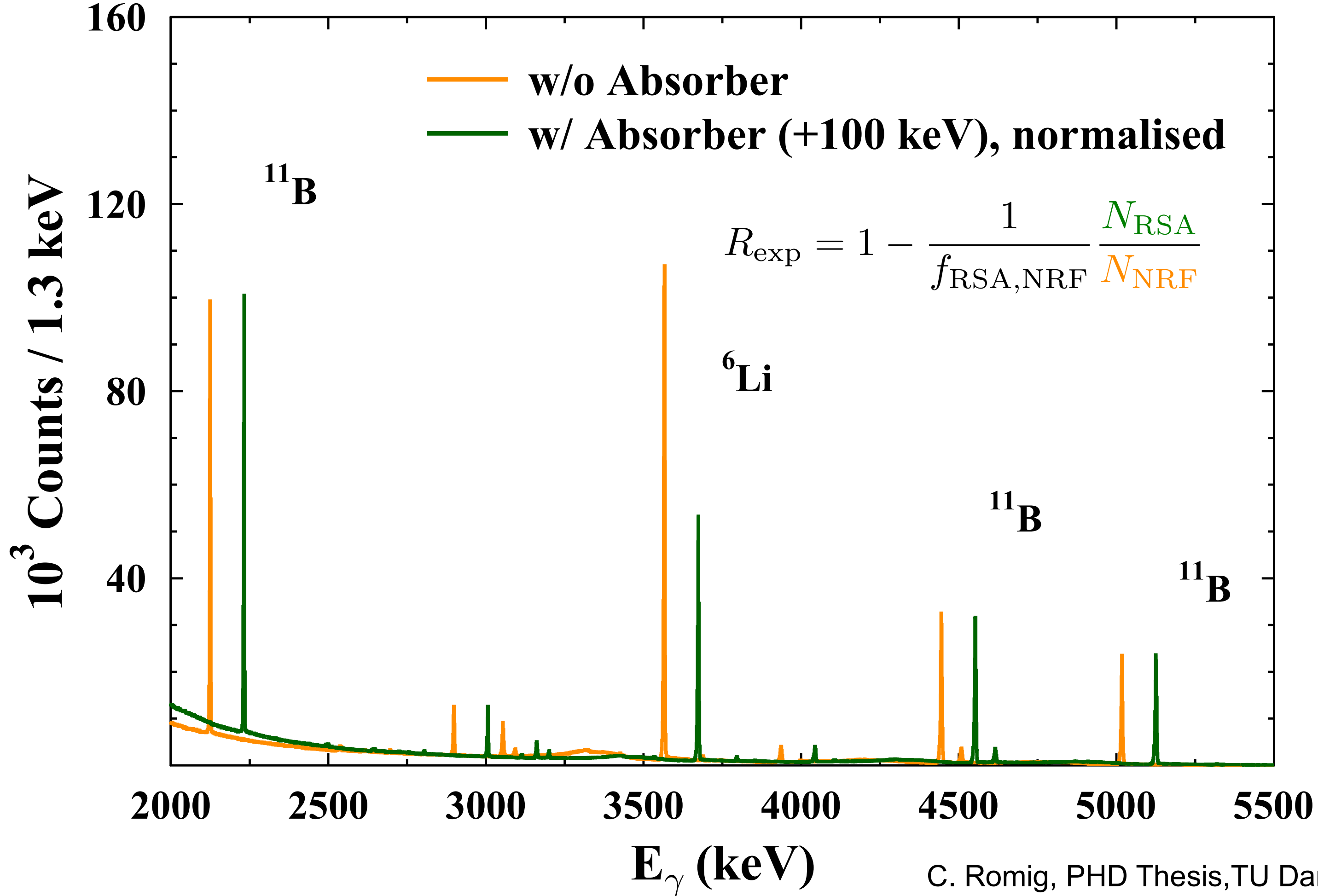

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Relative Self Absorption

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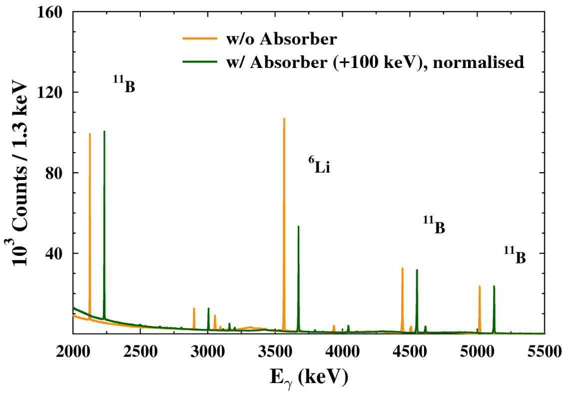

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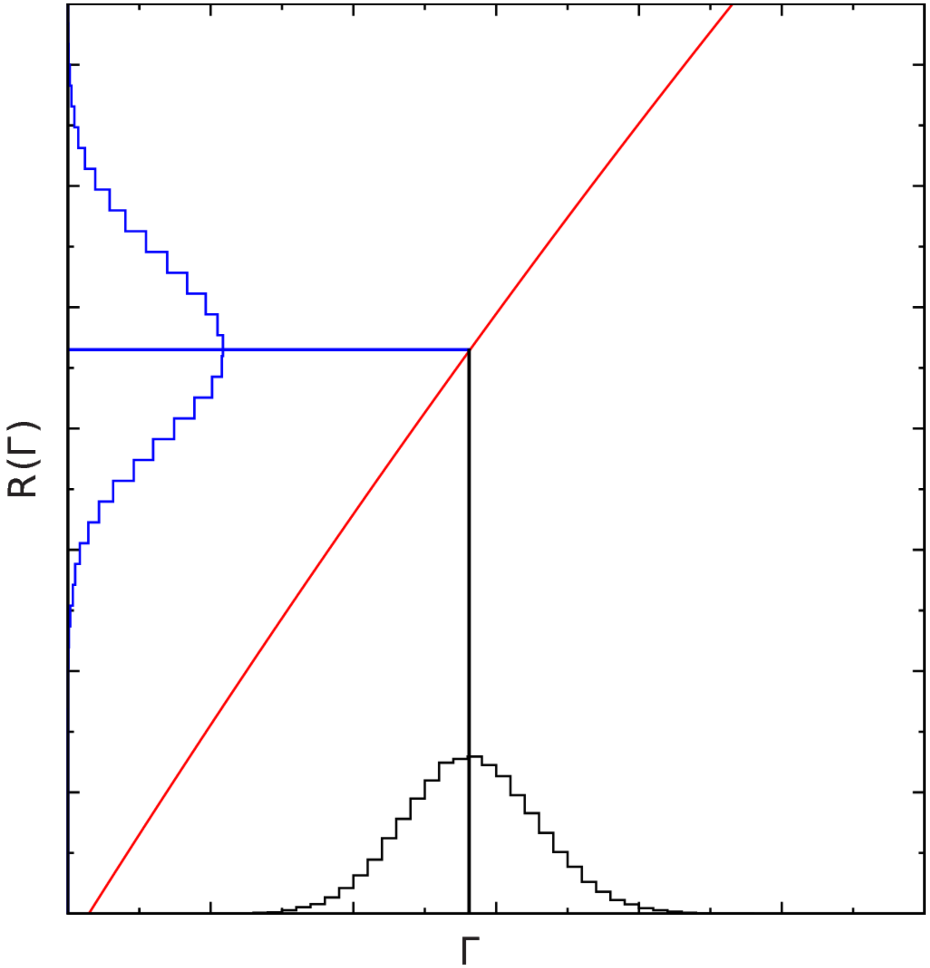
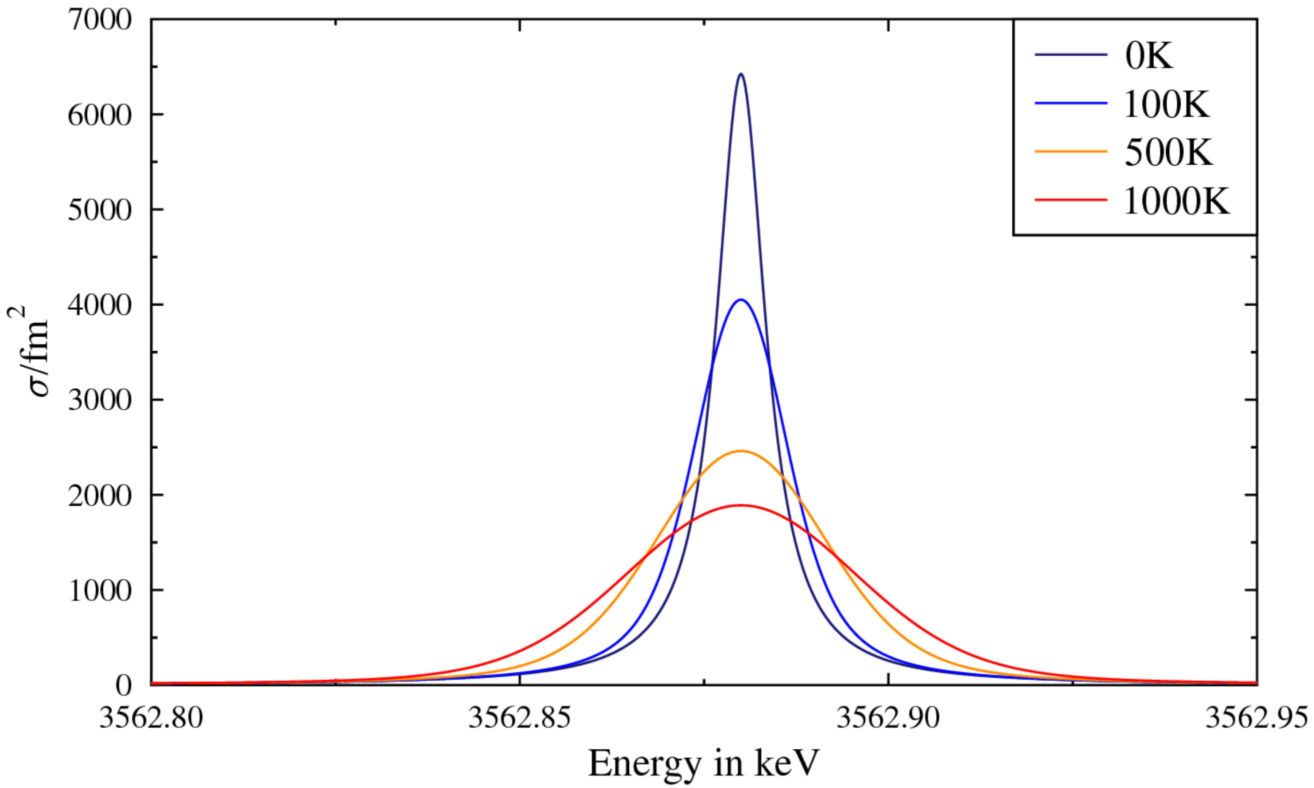


Relative Self Absorption - ^{6}Li
Influence of Temperature

$$\sigma \rightarrow \Delta \rightarrow T_{(eff)}$$

σ: cross section   Δ: Doppler width   T: temperature



Relative Self Absorption - ^{6}Li

Calculation of effective Temperature

$$\sigma \rightarrow \Delta \rightarrow T_{(eff)}$$

σ: cross section   Δ: Doppler width   T: temperature

- Vibration of Atom ⇒ T_{eff}

  → phonon density of states $g_a(\nu)$ using Density Functional Theory

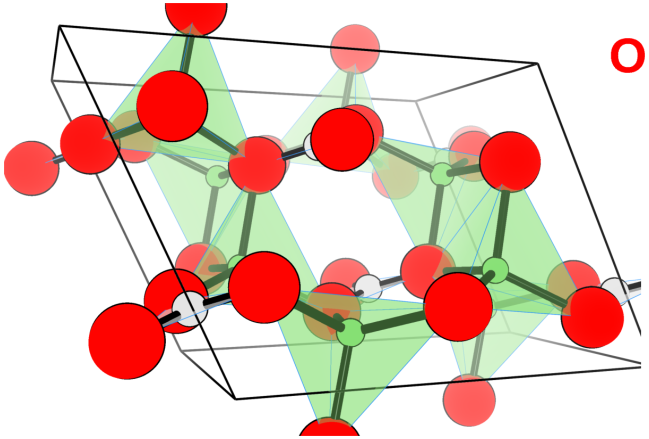
  → Local Density Approximation (LDA)

  → Generalized Gradient Approximation (GGA)

$$k_{\mathrm{B}}T_{\mathrm{eff}} = \int \mathrm{h}\nu g_{\mathrm{a}}(\nu)\left(\frac{1}{\mathrm{e}^{\frac{\mathrm{h}\nu}{k_{\mathrm{B}}T}} - 1} + \frac{1}{2}\right)$$

Relative Self Absorption - ^{6}Li

Calculation of effective Temperature



LDA

- Strong binding
- Short bonds

GGA

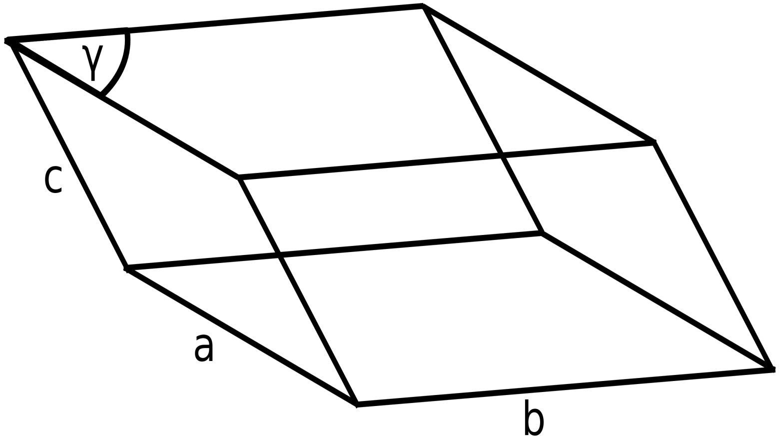
- Weak binding
- Long bonds

	a	b	c	γ
LDA	8.368 Å	4.966 Å	6.001 Å	115.502°
GGA	8.475 Å	5.038 Å	6.412 Å	114.958°
Experiment[1]	8.359 Å	4.973 Å	6.197 Å	114.830°

[1] H. Effenberger and J. Zemann, Z. Kristallographie 150, 133-138 (1979)

Relative Self Absorption - ^{6}Li

Calculation of effective Temperature



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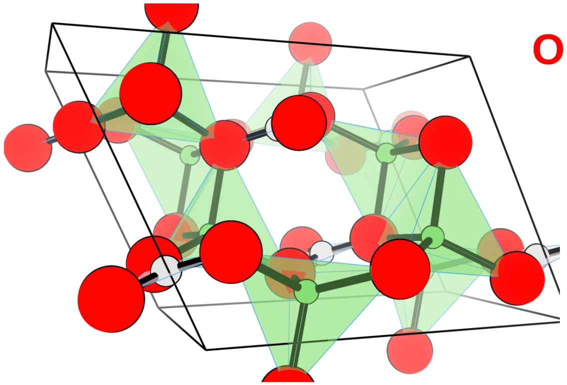
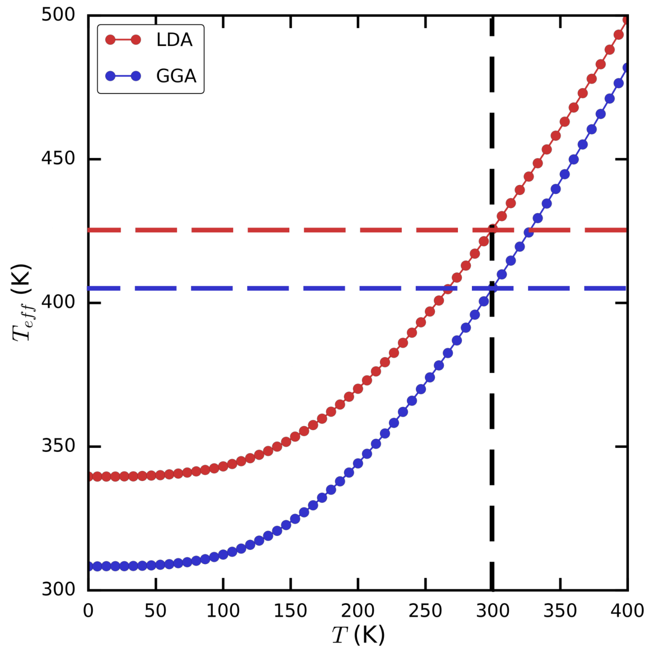


O, C, Li

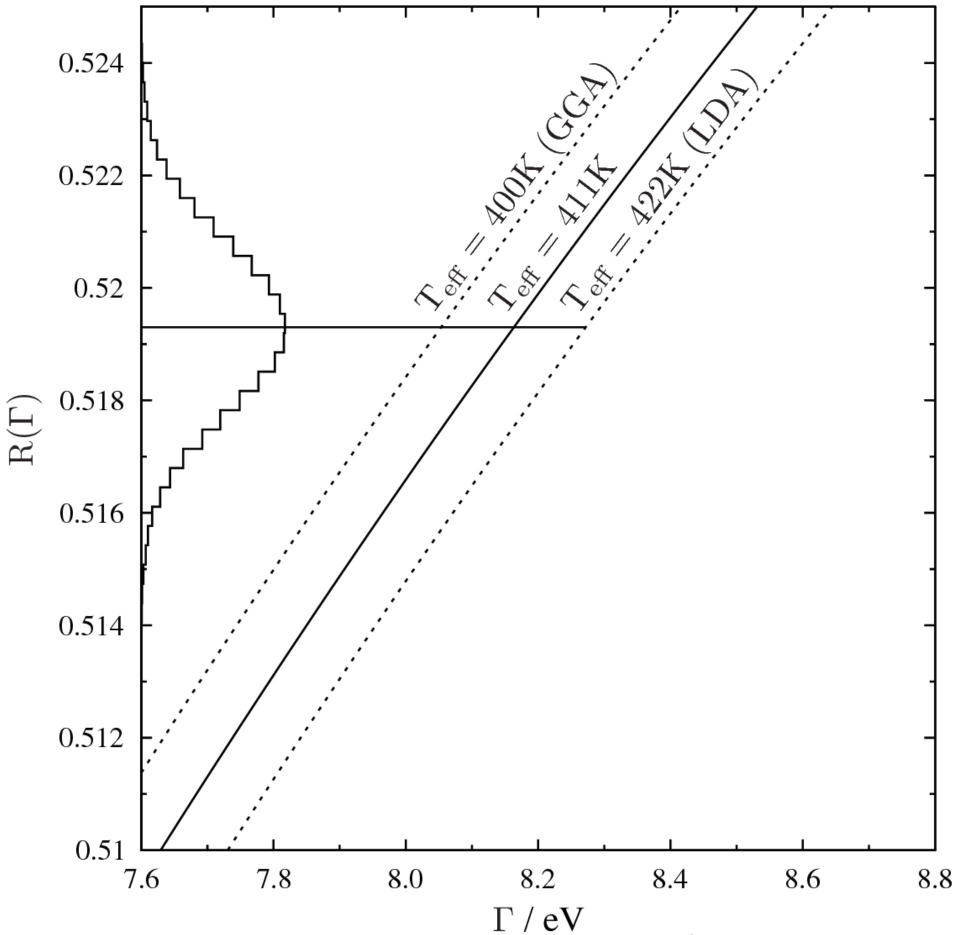
LDA	GGA
• Strong binding	• Weak binding
• Short bonds	• Long bonds



J. Rohrer, TU Darmstadt 2016

Relative Self Absorption - ^{6}Li

Calculation of nuclear transition width



U.Gayer, to be published, 2017

Relative Self Absorption - ^{6}Li

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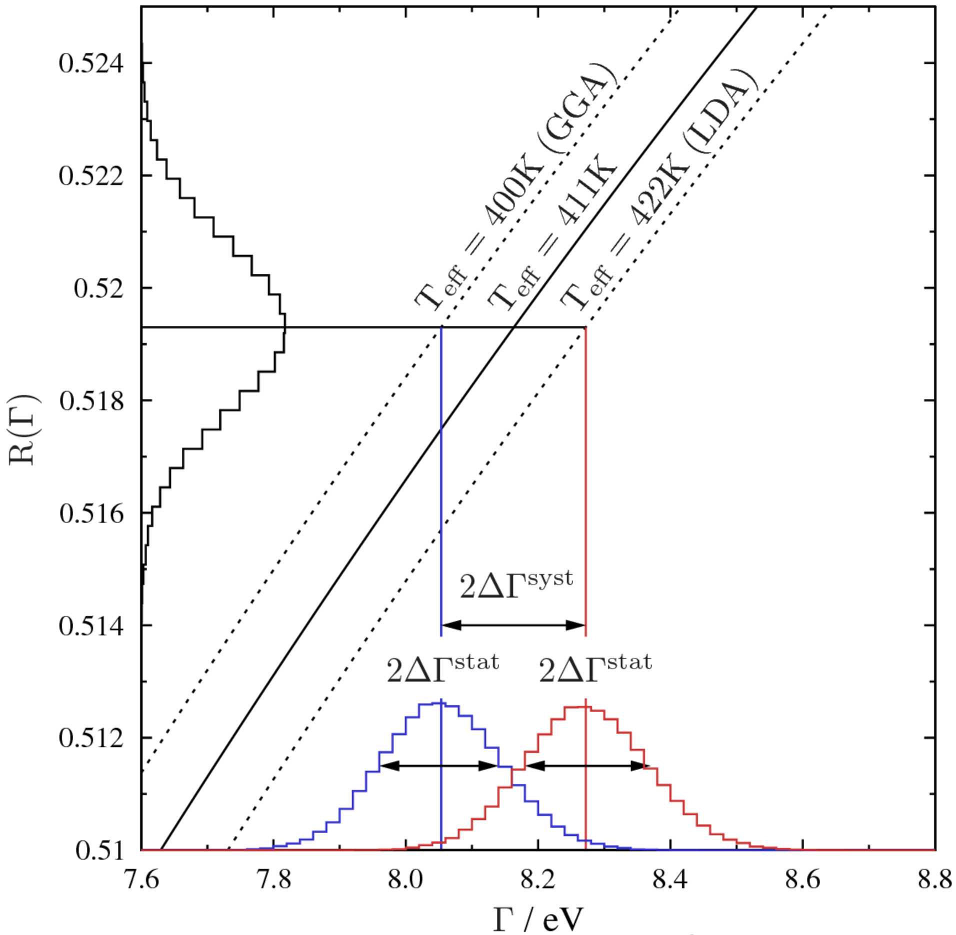


U.Gayer, to be published, 2017

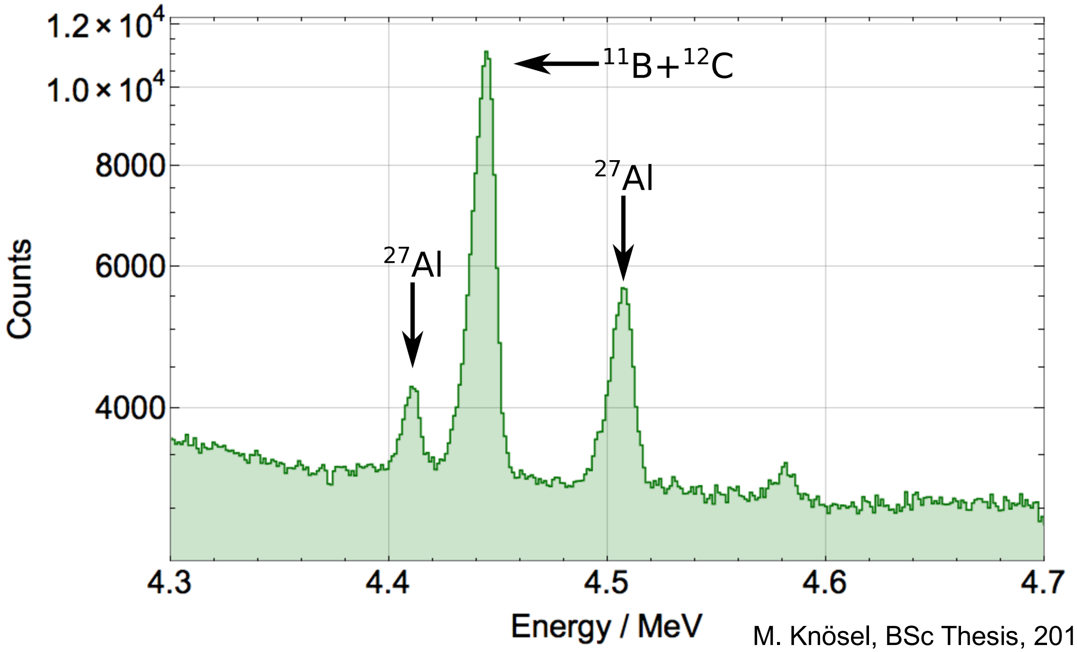
$R=0.5193(15)$

$\Gamma=8.16(9_{stat})(11_{sys})\text{eV}$

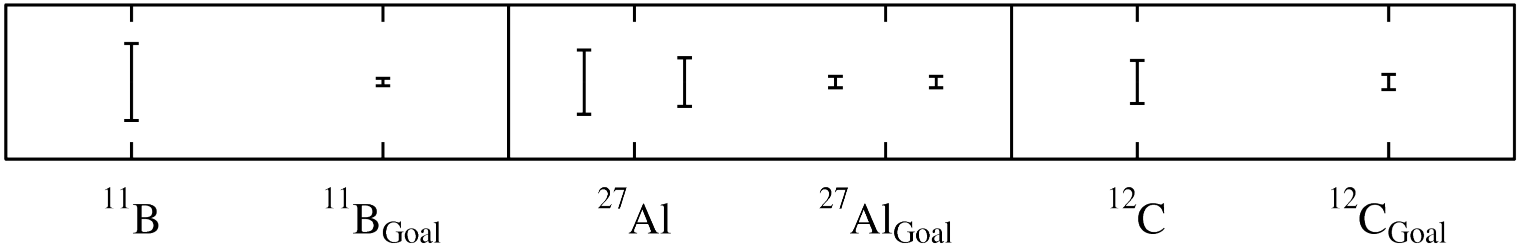
$\Gamma_{Lit}=8.2(2)\text{eV}$

Upcoming RSA Experiment – ^{11}B

- Goal: Extract $\Gamma(2^+_1)$ of ^{12}C for A03
  → Precision ~2%
- Overlap: ^{11}B and ^{12}C
  E(^{11}B) = 4445keV
  E(^{12}C) = 4439keV
- Experimental Campaign
  I. RSA on ^{11}B
  II. NRF on ^{27}Al
  III. NRF on ^{12}C



M. Knösel, BSc Thesis, 2016



Upcoming RSA Experiment - ^{11}B

- Experiment Informations
  - → Time: ~15 days
  - → Location: DHIPS @ S-DALINAC
  - → Energy: ~5 MeV
  - → Target: Ready for Experiment
    - → Scatterer: ^{11}B (99.79atomic%)
    - → Monitor: ^{27}Al (chem. 99.995%)
    - → Targetcontainer: E-CU (DIN EN 13600)
    - → Sealing: Pressure
  - → When? Spring 2018

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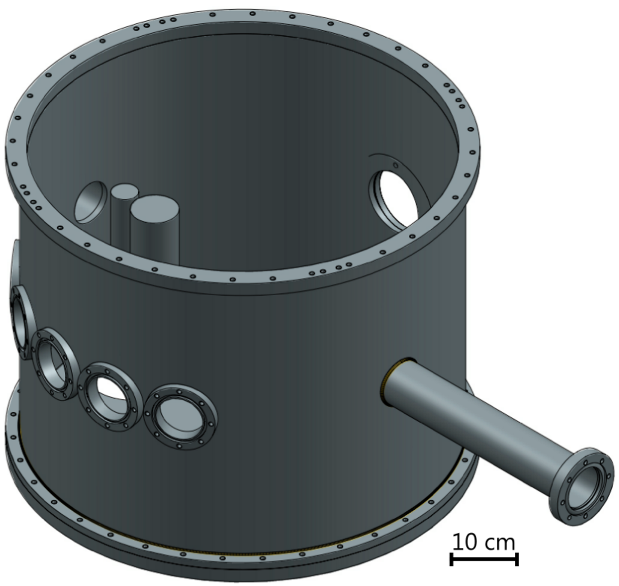
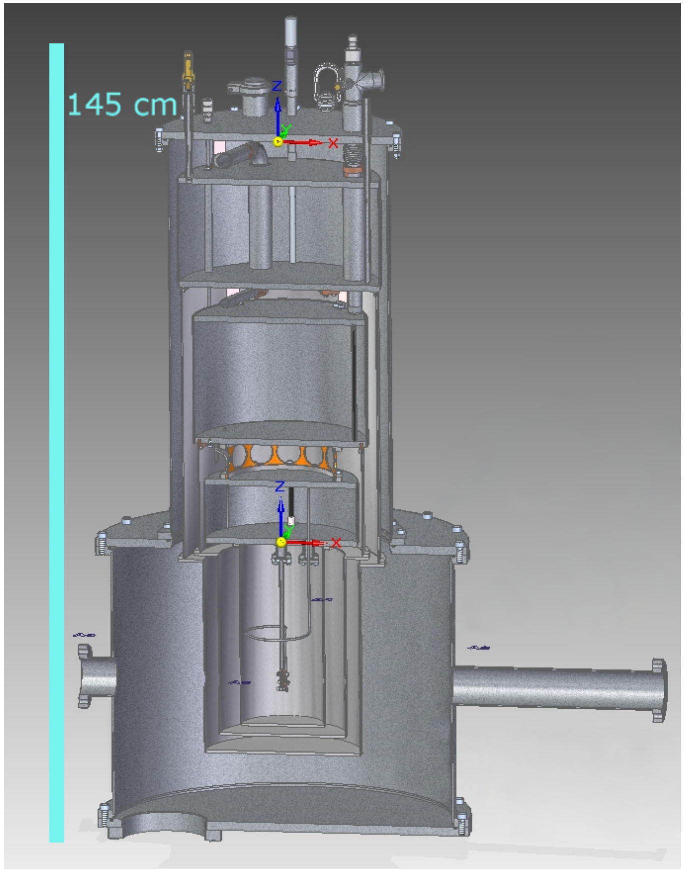
- Electron scattering: ^{4}He
  - → transition form factor:$0^{+} \rightarrow 0^{+}$
- Laser spectroscopy: ^{8}B
  - → charge radius (B. Maas)

Electron scattering - ^{4}He
Conception of a superfluid liquid helium target

- QCLAM overview → M. Singer
- Must fit into experimental environment
- Special requirements for cryosystem

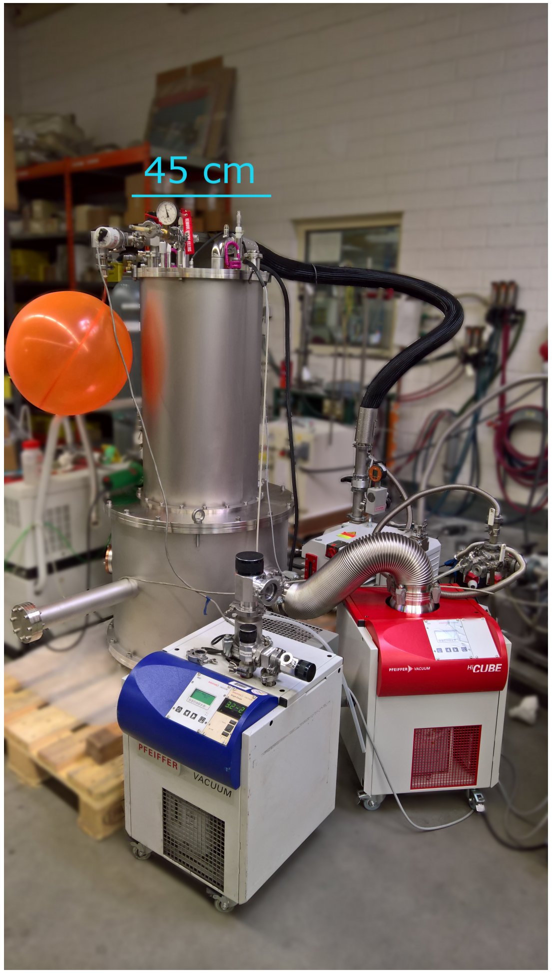


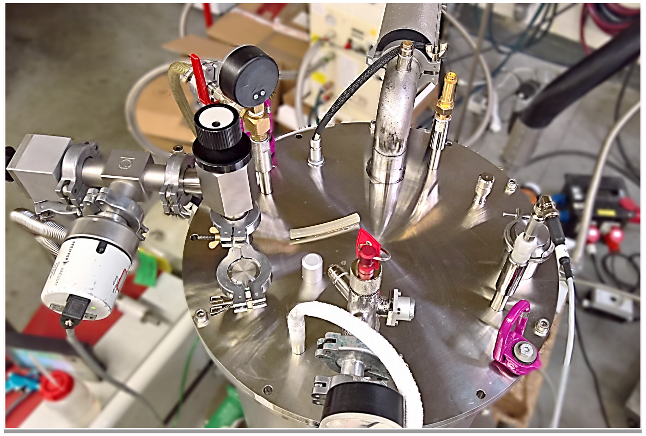
M. Hilcker, private communication



CryoVac, Troisdorf, 2017

Electron scattering - ^{4}He
Cryostat tests @ CryoVac

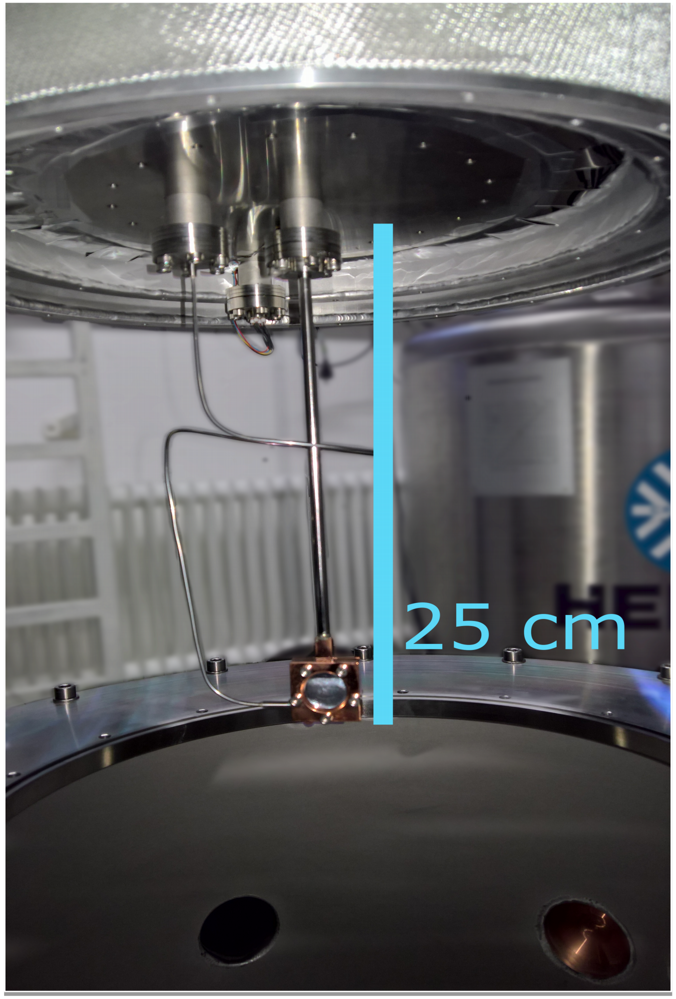




M. Hilcker,
private communication

Electron scattering - ^{4}He
Reassembling and Testing @ IKP

- Delivered end of July 2017
- Reassembly complete
- Cryogenic test in progress



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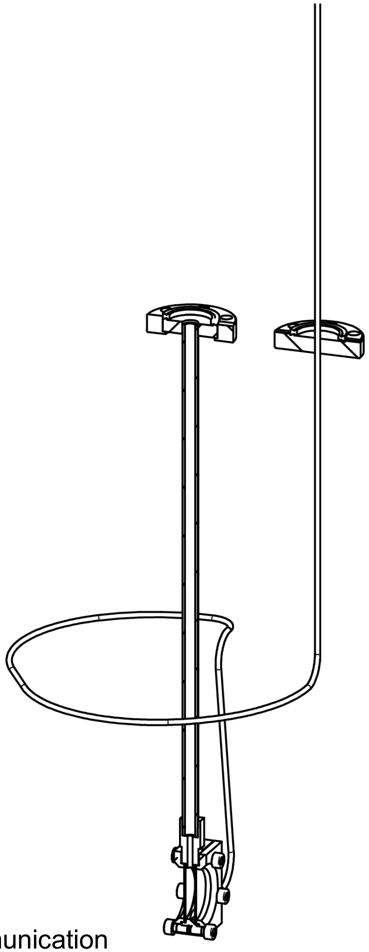

M. Hilcker, private communication

Electron scattering - ^{4}He
Timetable of Experiment

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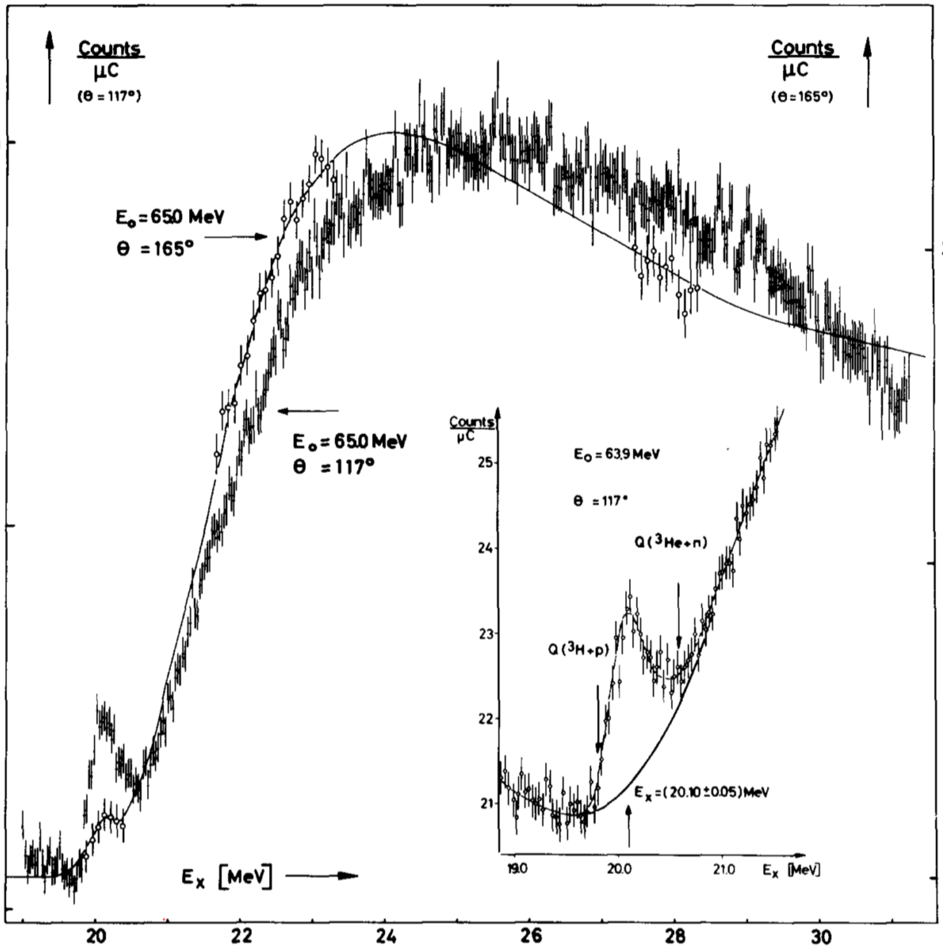
- First measurement May 2018 possible
- Count rate:
  7.5 Counts/s
  at 117° with 1 µA
- Up to 2 weeks needed to change scattering angle



T. Walcher, Phys. Lett. 31B, number 7, (1970)

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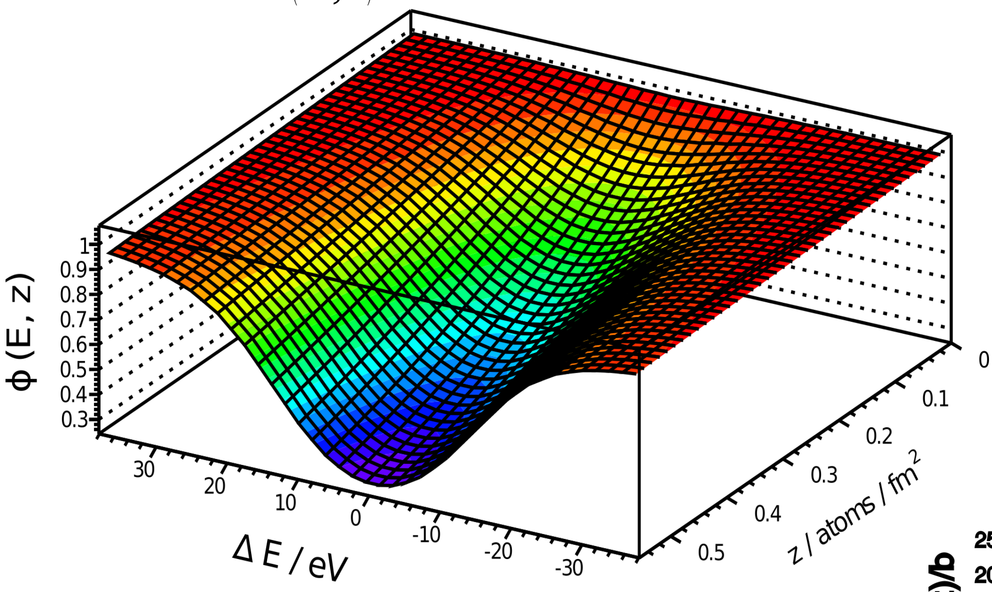
Relative Self Absorption

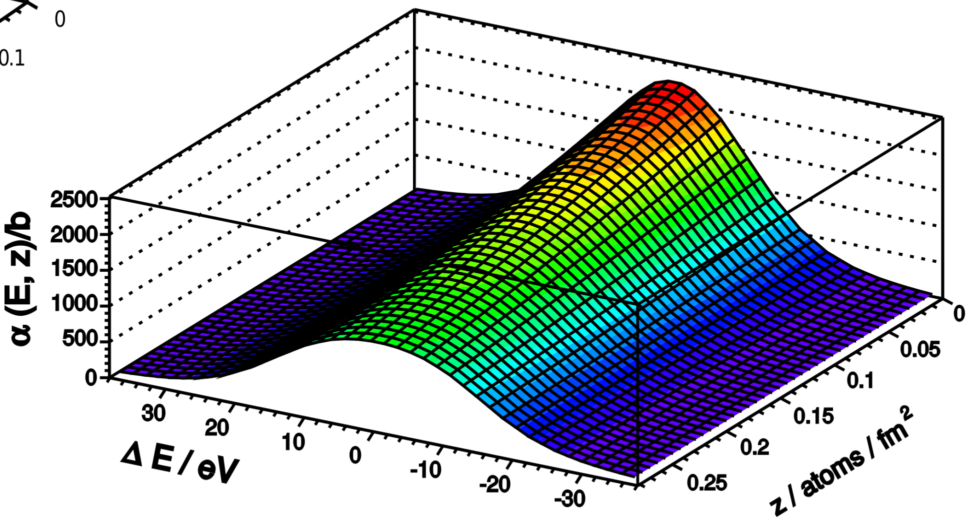
photon-flux density

$$\Phi\left(E,z\right)=e^{-\left(\kappa_{at}\left(E\right)+\sigma^{D}_{0\rightarrow i}\left(E\right)\right)z}$$



resonance-absorption density

$$\alpha\left(E,z\right)=\sigma^{D}_{0\rightarrow i}\left(E\right)\cdot\Phi\left(E,z\right)$$



Relative Self Absorption – ^{6}Li

Calculation of R

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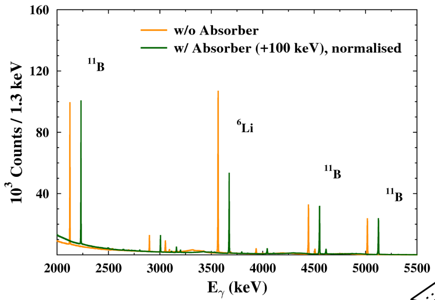

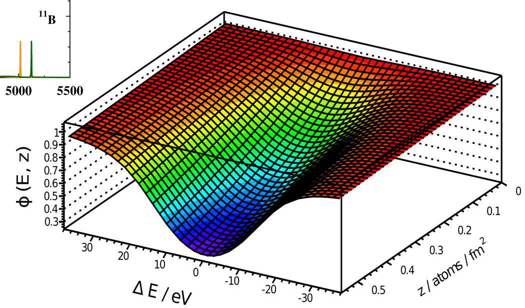

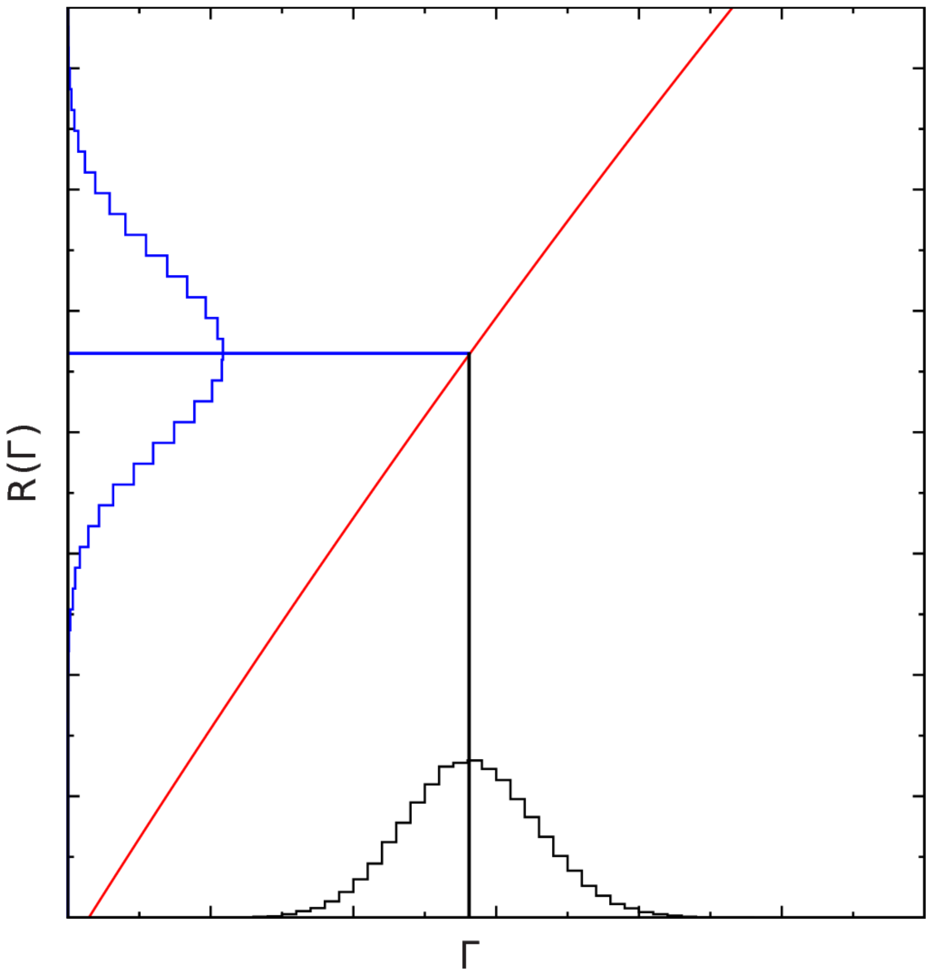

$$R = 1 - \frac{\int_{da}^{ds+da} \int_{-\infty}^{\infty} \alpha(E,z)\, dE dz}{\int_{0}^{ds} \int_{-\infty}^{\infty} \alpha(E,z)\, dE dz}$$

$$\alpha(E,z) = \sigma^D_{0\rightarrow i}(E) \cdot e^{-\left(\kappa_{at}(E) + \sigma^D_{0\rightarrow i}(E)\right) z}$$