Electron scattering off ^{10}B under 180°

M. Spall, M. Singer, J. Birkhan, I. Brandherm, M. L. Cortés, F. Gaffron, K. E. Ide, J. Isaak, I. Jurosevic, P. von Neumann-Cosel, F. Niederschuh, N. Pietralla, G. Steinhilber and T. Stetz

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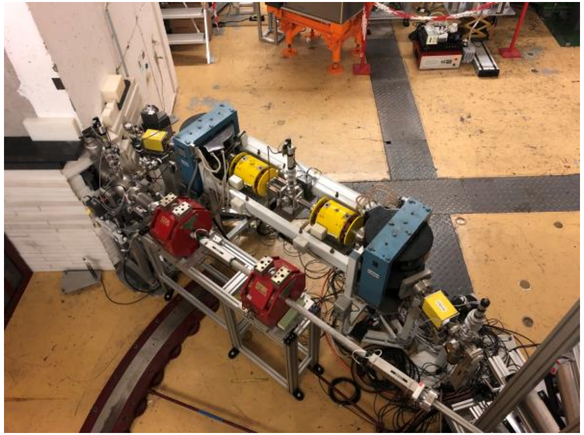
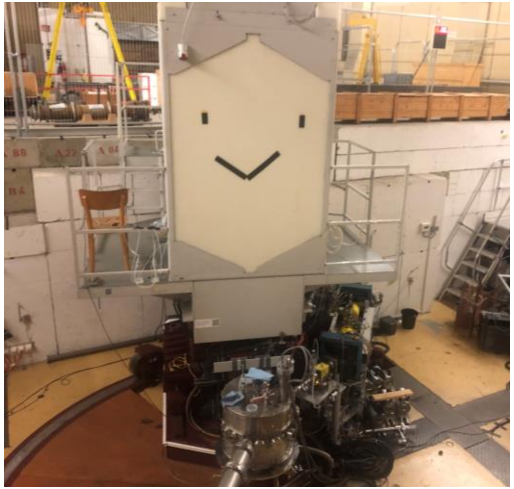




*Supported by the Deutsche Forschungsgemeinschaft
(DFG, German Research Foundation) Project-ID 279384907 - SFB 1245.

Spin-M1 and Gamow-Teller (GT) resonances

- Fundamental excitation modes of a nucleus

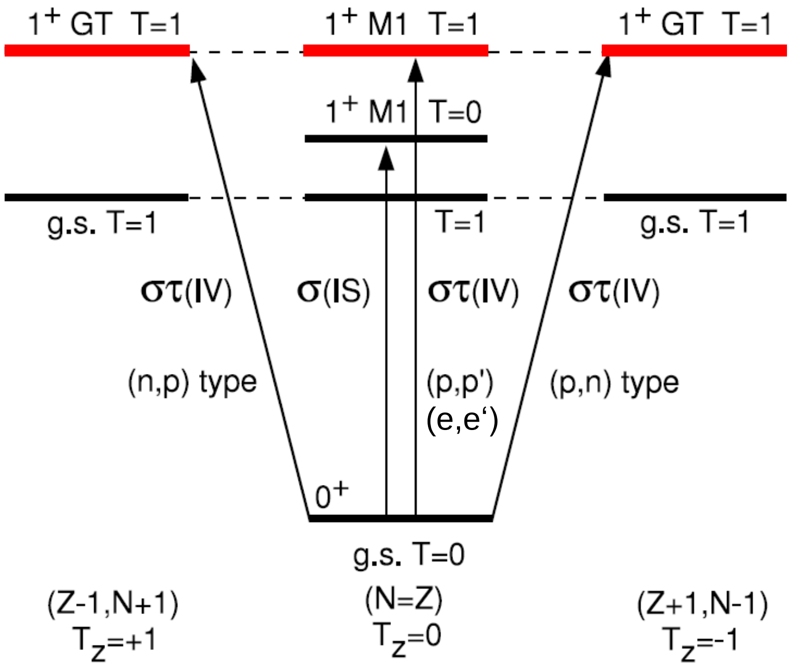
- Spin-M1 and GT resonances are closely related
  - Spin-M1: $\Delta T_Z = 0$
  - GT: $\Delta T_Z = \pm 1$

- Transition matrix elements are identical in first order
  - $B(M1_{\sigma\tau}) = \frac{1}{2J_i+1}\frac{1}{2}\frac{C^2_{M1}}{2T_f+1}\langle J_f T_f \| \| \sum_{j=1}^{A} (\boldsymbol{\sigma}_j \boldsymbol{\tau}_j) \| \| J_i T_i \rangle$
  - $B(GT) = \frac{1}{2J_i+1}\frac{1}{2}\frac{C^2_{GT}}{2T_f+1}\langle J_f T_f \| \| \sum_{j=1}^{A} (\boldsymbol{\sigma}_j \boldsymbol{\tau}_j) \| \| J_i T_i \rangle$

Y. Fujita, B. Rubio, W. Gelletly, Prog. Part. Nucl. Phys. 66, 549 (2011)

Isospin analogue states

- Isospin symmetry for an even-even nucleus
- Analogous states due to identical space and spin configurations
- Analogous states have a corresponding transition strength



Y. Fujita, B. Rubio, W. Gelletly, Prog. Part. Nucl. Phys. 66, 549 (2011)

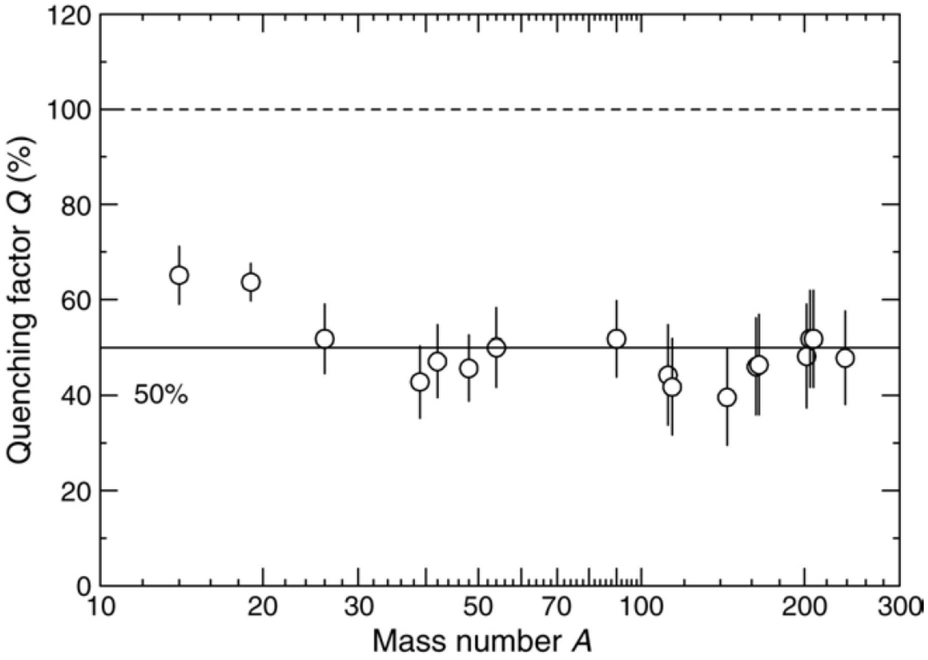
Gamow-Teller quenching factor

- Quenching $= \dfrac{\text{exp. strength}}{\text{theo. prediction}}$

- Systematic reduction by ~ 50%

- Impact on current problems in nuclear structure and astrophysics

➡ Same behavior for spin-M1?



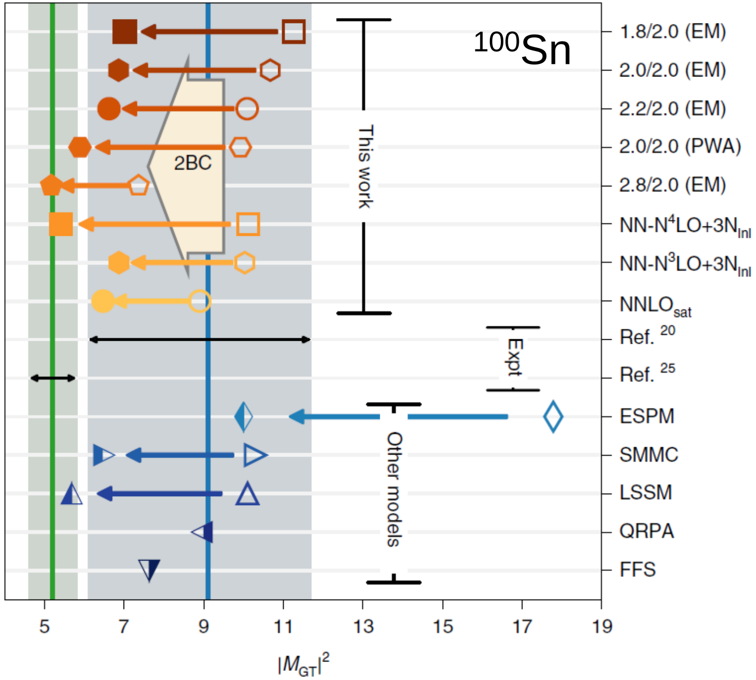
M. Ichimura, H. Saakai, T. Wakasa, Prog. Part. Nucl. Phys. 56, 446 (2006)

Systematic predictions of electroweak processes in nuclei

- Quenching must be at least a 2nd order effect

- Two-body currents (2BC) contribute to quenching

- Little is known in light nuclei and for higher multipoles

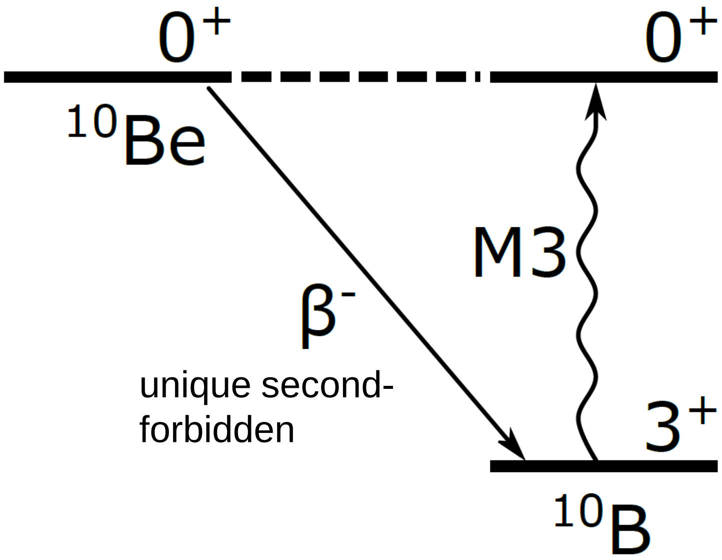


P. Gysbers et al., Nature Physics 15, 428-431 (2019)

Analogue transitions to forbidden β-decay

Research focus: Magnetic transitions with higher multipolarity (M2, M3, M4)

- Study analogue transitions to forbidden β-decay in **light nuclei**
  - Learn more about quenching for **higher multipoles**



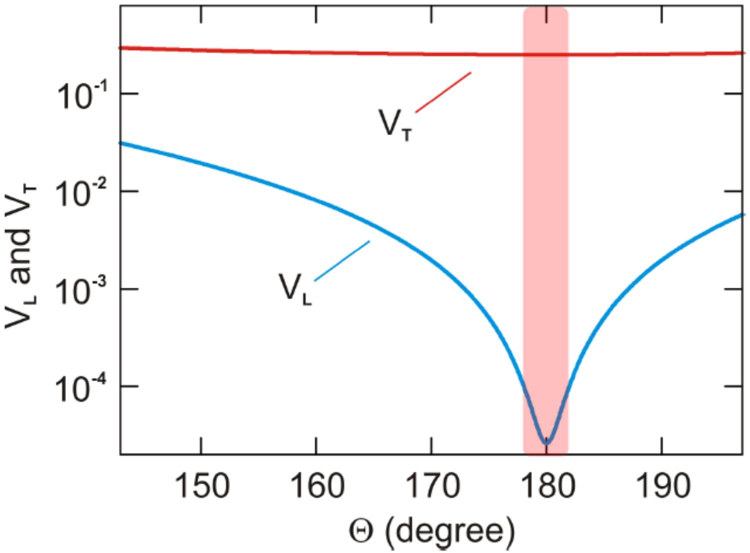
Electron scattering under 180°

$$\left(\frac{d\sigma}{d\Omega}\right) = \left(\frac{d\sigma}{d\Omega}\right)_L + \left(\frac{d\sigma}{d\Omega}\right)_T$$

$$V_L \times |F_L(\vec{q})|^2 \qquad V_T \times |F_T(\vec{q})|^2$$

Transverse response enhanced by three orders of magnitude:

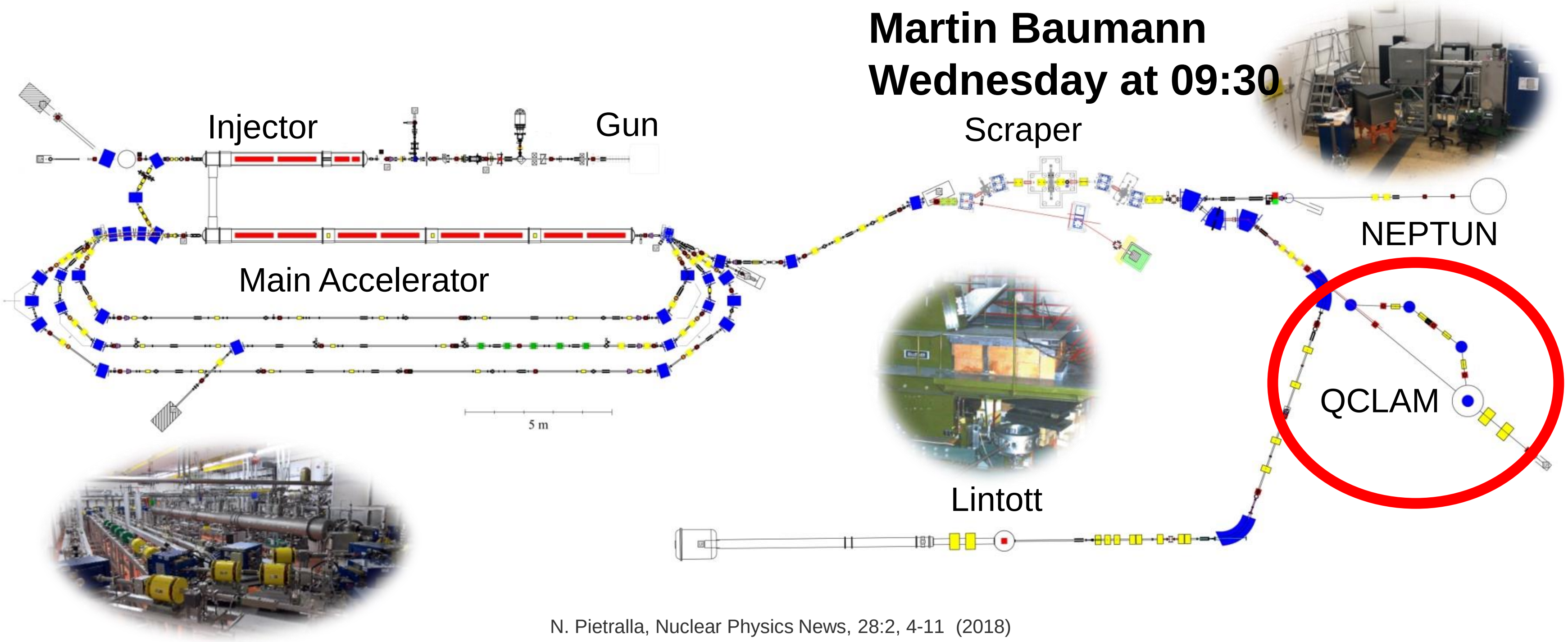
$$\frac{V_T}{V_L}(180°) \sim 10^3$$



Optimal method for measuring transverse excitations!

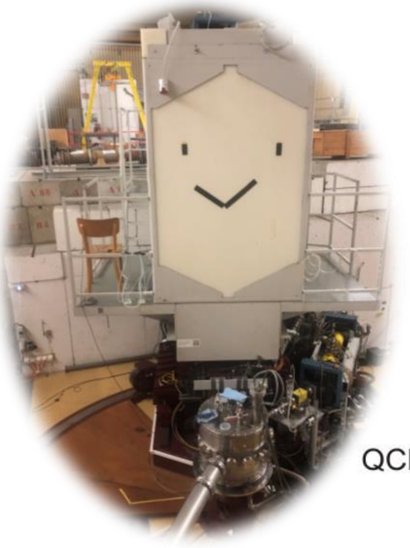
Superconducting-Darmstadt Linear Accelerator (S-DALINAC)

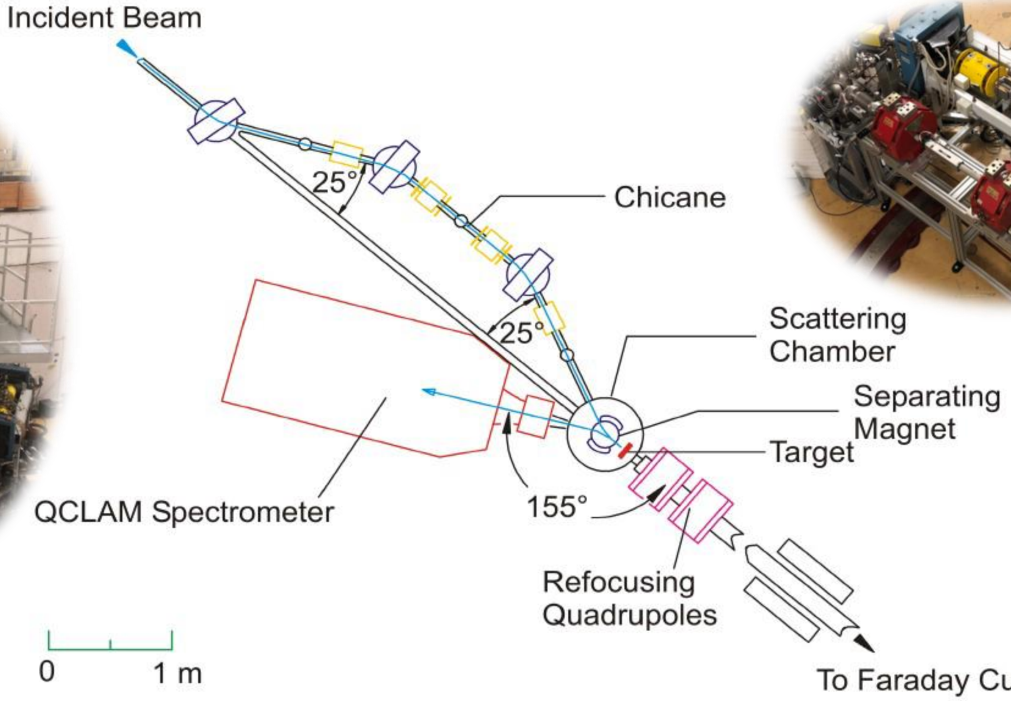
Martin Baumann
Wednesday at 09:30

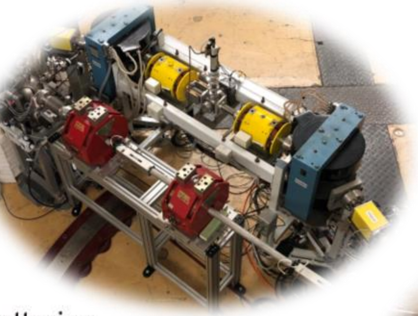


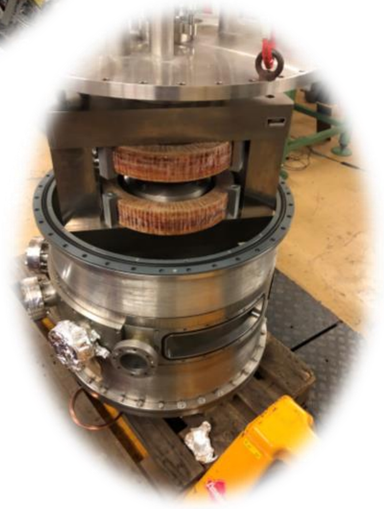
N. Pietralla, Nuclear Physics News, 28:2, 4-11 (2018)

180° system at the QCLAM spectrometer

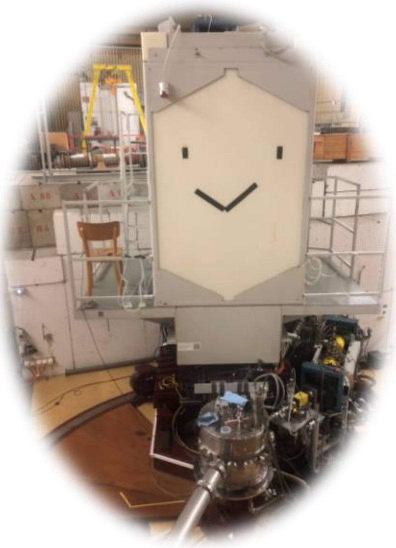


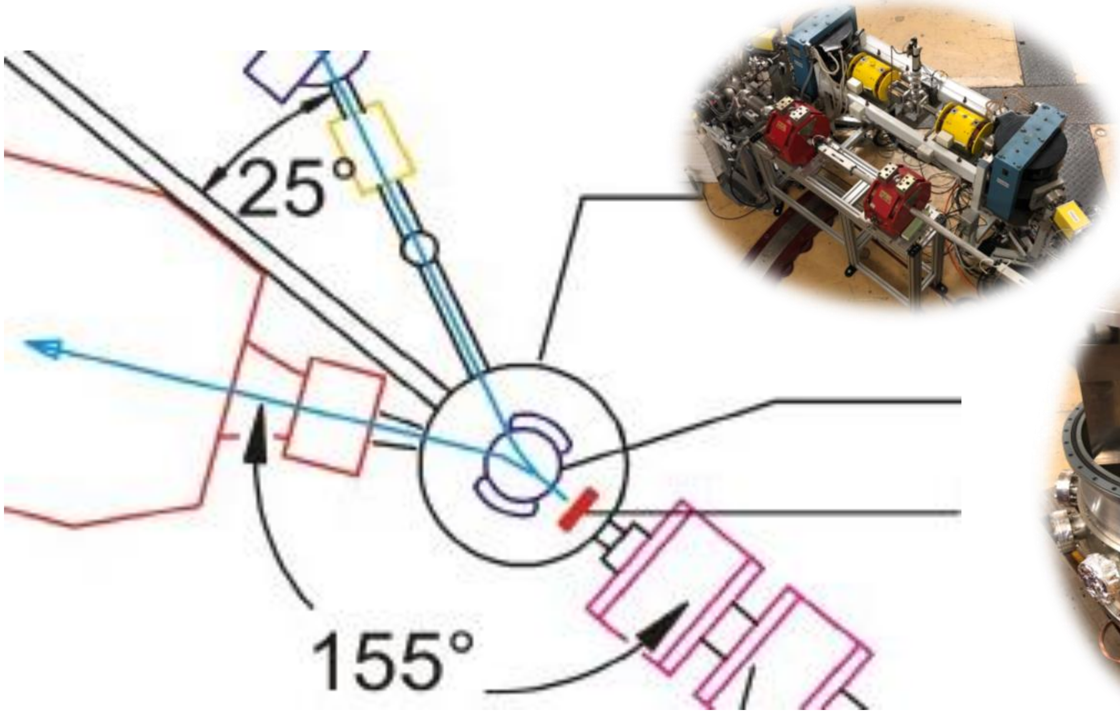






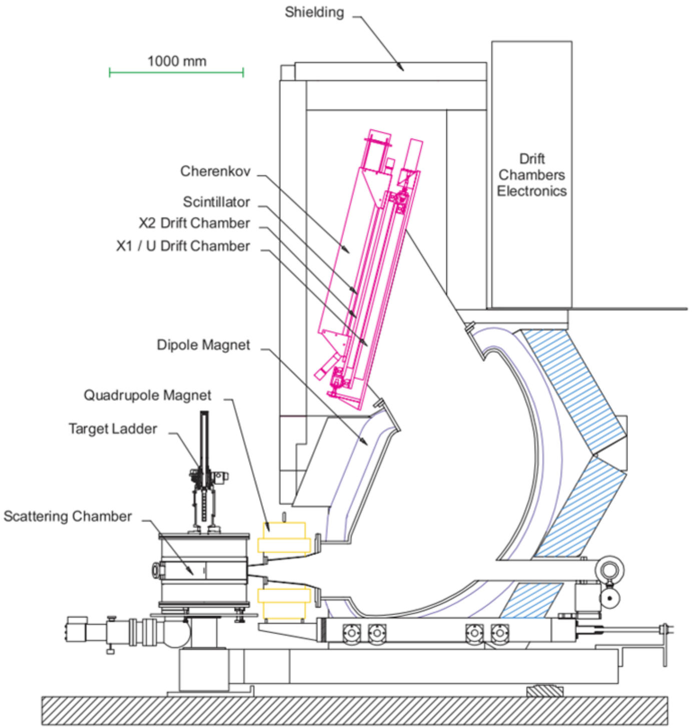
180° system at the QCLAM spectrometer





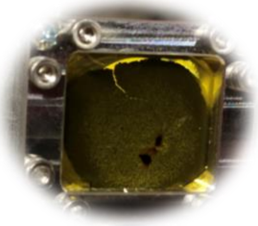
QCLAM spectrometer

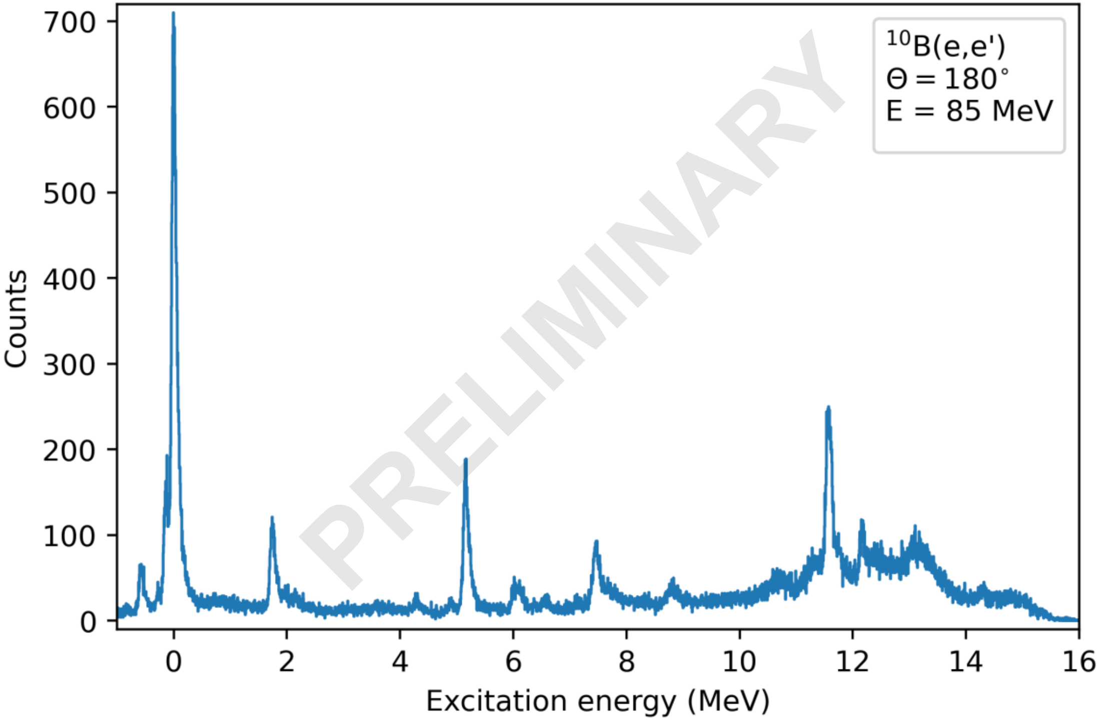
- Magnetic spectrometer for (e,e’) and (e,e’x) experiments
- Scattering angles: 35° - 155° and 180°
- Momentum acceptance: $\Delta p/p = \pm 10\ \%$
- Solid angle: 35 msr
- Energy resolution: $\Delta E/E \approx 3 \cdot 10^{-4}$



$^{10}B(e,e')$

- Effective momentum transfer
  - 0.90 fm^{-1}
- Target
  - 17 mg/cm² ^{10}B
  - 2 mg/cm² Kapton





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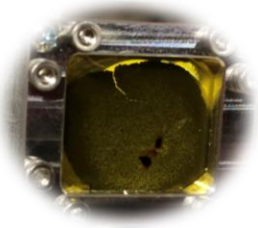
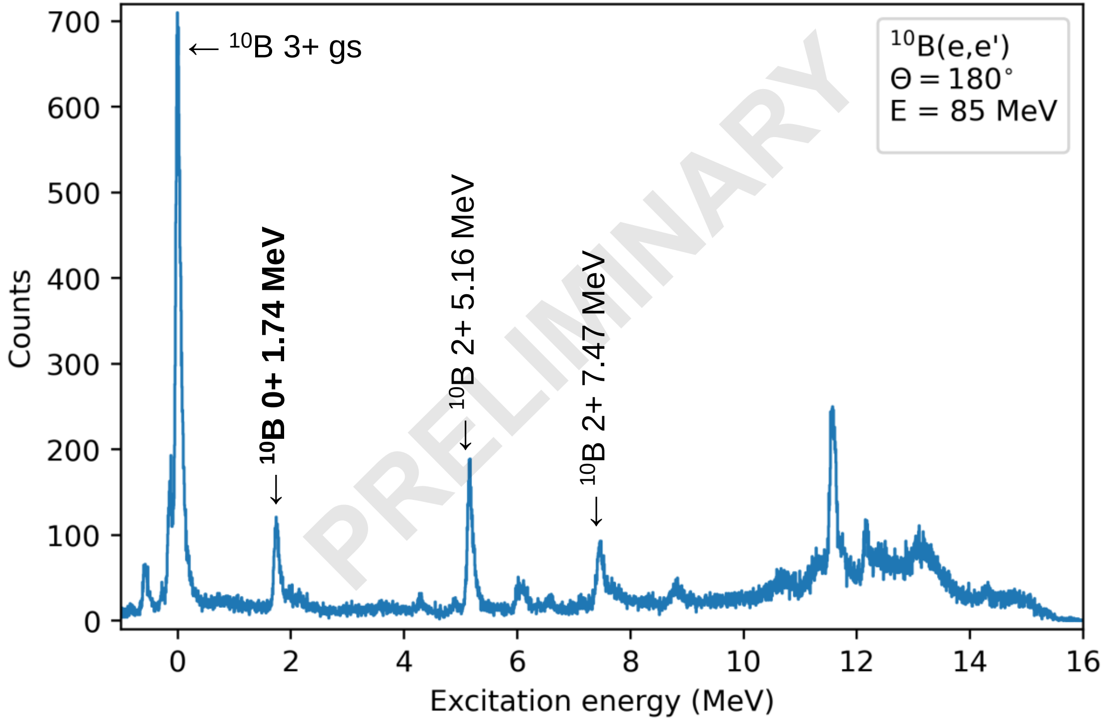
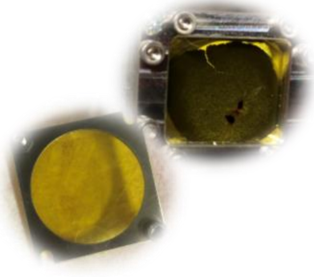
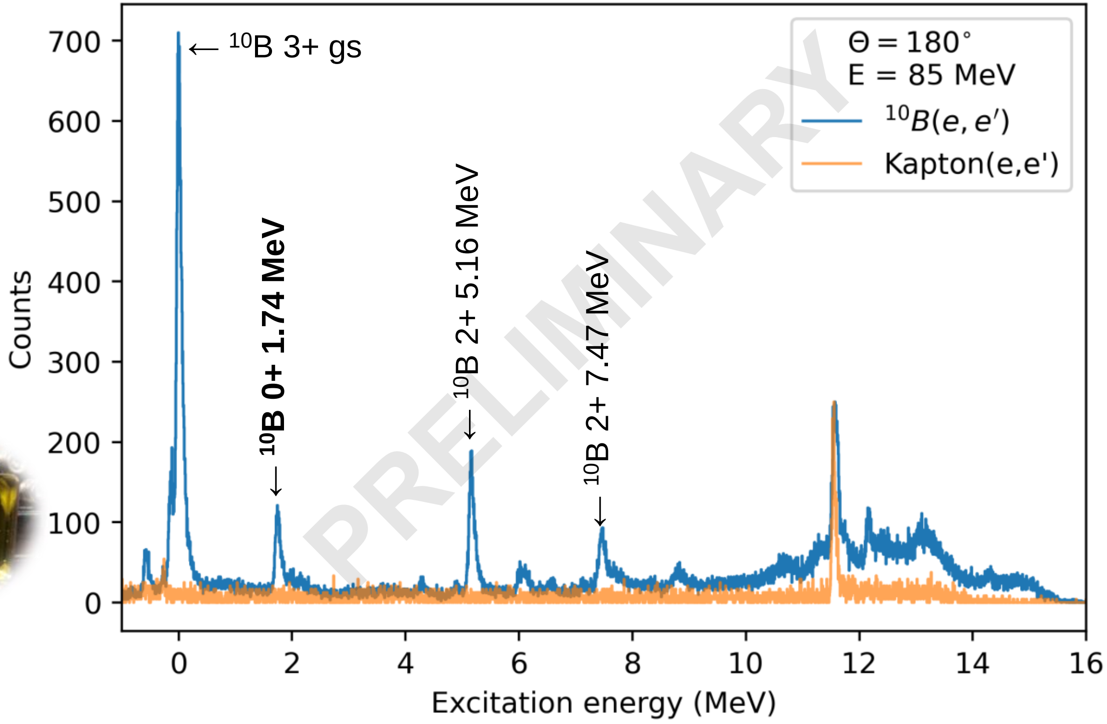




Influence of Kapton

- Comparing Kapton and Boron spectra
- Kapton contributions can be seen easily (^{1}H, ^{12}C, ^{14}N, ^{16}O)
- Recoil compared to Boron
  - ^{12}C: 220 keV
  - ^{14}N: 420 keV
  - ^{16}O: 560 keV





Calculation of the form factor for 0_1^+ of ^{10}B

Differential cross section:

$$\frac{d\sigma}{d\Omega} = \frac{dN}{d\Omega}\frac{1}{Q} \cdot \left(e \frac{M_{Mol}}{N_A} \frac{1}{\rho x} \right)$$

only depends on the target!

$$\Rightarrow \frac{|F_T(q)|^2_{inel}}{|F_T(q)|^2_{el}} = \frac{\frac{dN_{inel}}{d\Omega}\frac{1}{Q_{inel}}}{\frac{dN_{el}}{d\Omega}\frac{1}{Q_{el}}} \triangleq \frac{a^{korr}_{inel}}{a^{korr}_{el}}$$

Need events below the corresponding peaks

No need of the efficiency of the detector system

Peak approximation in (e,e‘) experiments

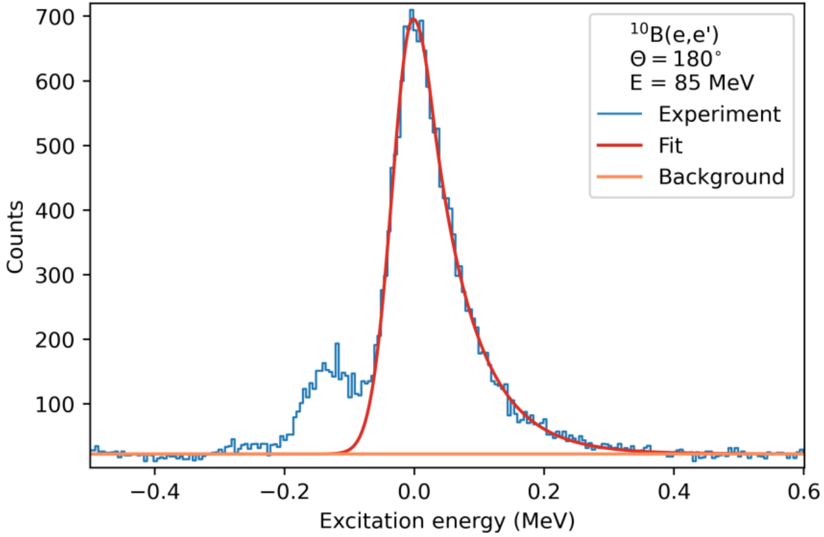
TECHNISCHE UNIVERSITÄT DARMSTADT

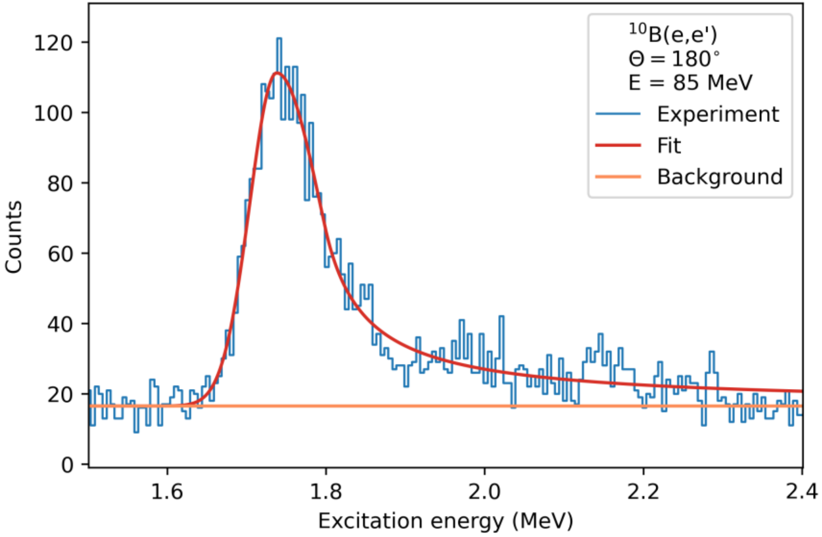
Phenomenological fit

$$y(x) = U(x) + y_0 \cdot \begin{cases} \exp\left[\frac{(x-x_0)^2}{2\sigma_1^2}\right] & \text{for } x < x_0 \\ \exp\left[\frac{(x-x_0)^2}{2\sigma_2^2}\right] & \text{for } x_0 \leq x \leq x_0 + \eta\sigma_2 \\ \exp\left[-\frac{\eta^2}{2}\right] \cdot \left(\frac{\gamma\sigma_2}{\eta}\right)^{\gamma} \cdot \left(x - x_0 + \frac{\gamma\sigma_2}{\eta} - \eta\sigma_2\right)^{-\gamma} & \text{for } x > x_0 + \eta\sigma_2 \end{cases}$$

Parameter: y_0, x_0, σ_1, σ_2, η and γ

Calculation of the counts





Counts: 16120

Counts: 3105

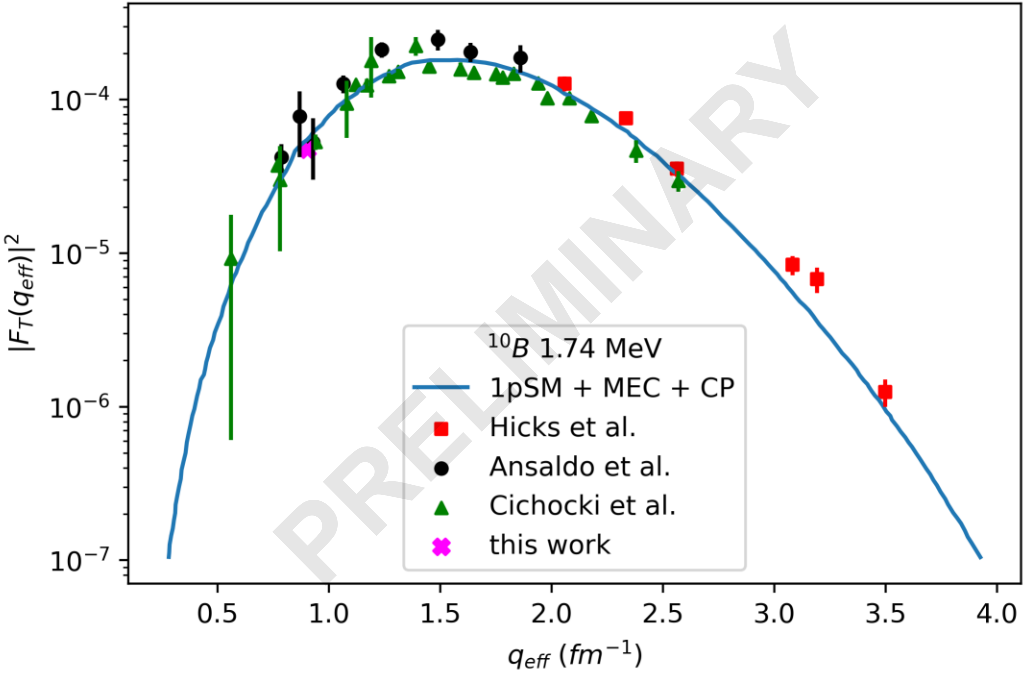
Full width at half maximum (FWHM) ≈ 208 keV

Preliminary form factor for 0_1^+ of ^{10}B

- Preliminary calculation results in $|F_T\,(q)|^2_{inel} = 4.24 \cdot 10^{-5}$

- Determination of the uncertainty is ongoing

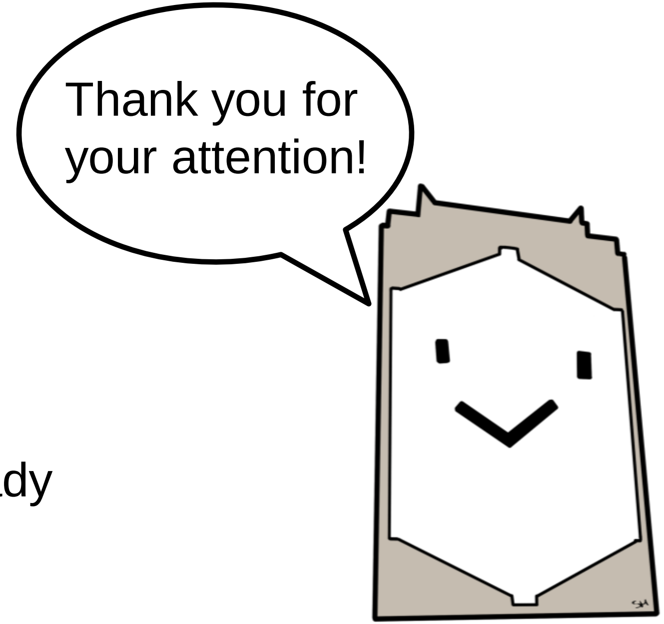
- Measurements for lower q values are needed



Theo. model taken from Cichocki et al., Phys. Rev. C 51, 2406 (1995)

Summary and outlook

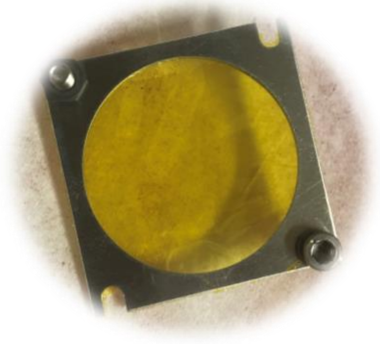
- We are able to do (e,e‘) experiments under 180°
- ^{10}B(e,e‘) data will be further investigated
- Further q values should be measured with $E_{beam} \leq 65$ MeV ($\triangleq 0.69\ fm^{-1}$) for ^{10}B
- Technical improvements of the 180° system are ready for the next beam time / about to be finished
  - Calibration system
  - Sliding seal

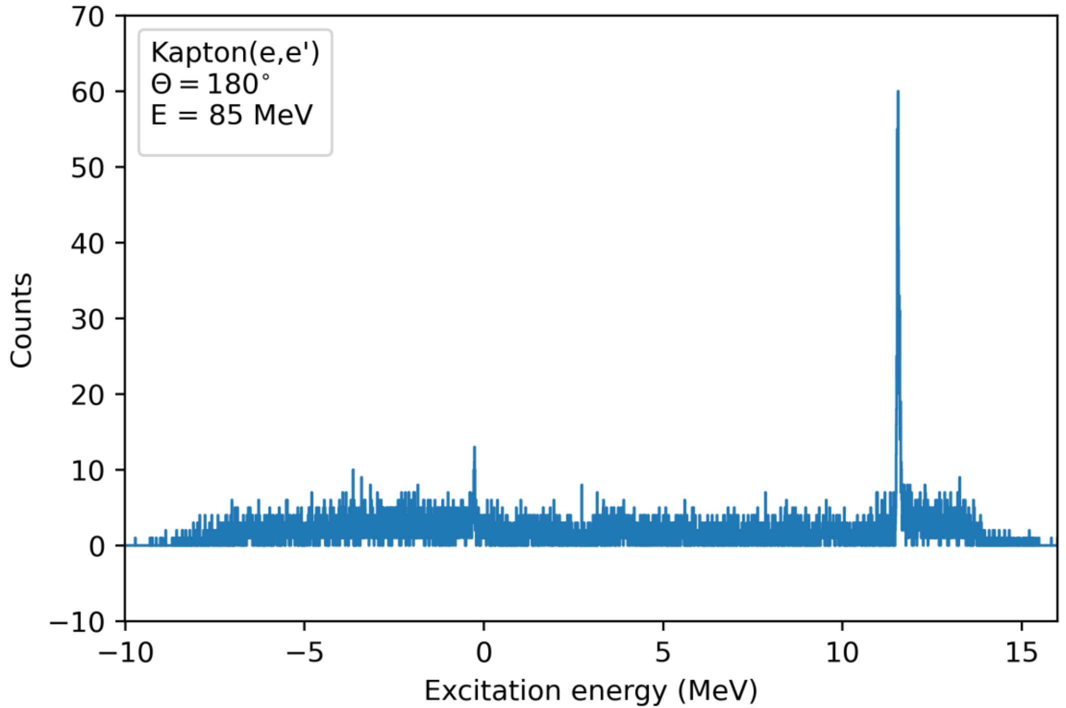


Backup

Kapton(e,e‘)

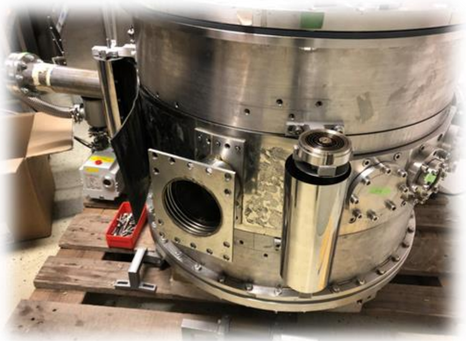
- Target properites
  - Kapton (^{1}H, ^{6}C, ^{7}N, ^{8}O)
  - 2 mg/cm² Kapton

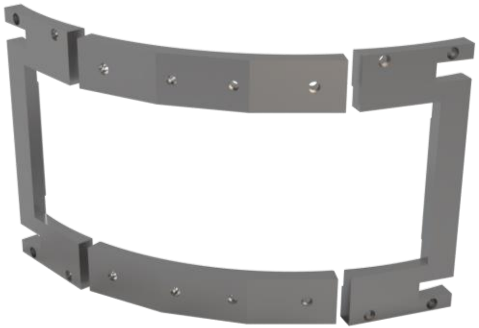




A sliding seal for the scattering chamber

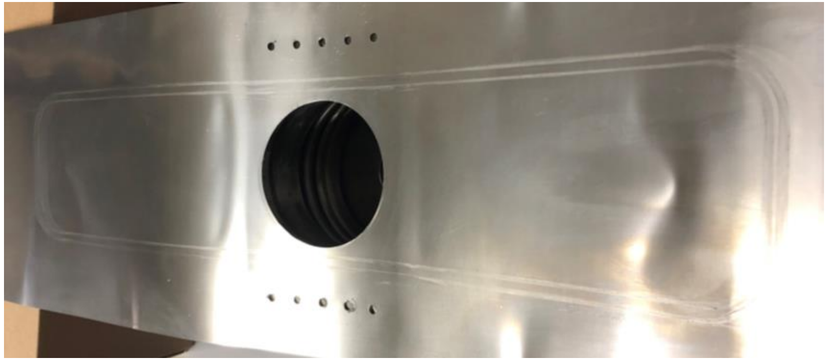
- Elaboration of an improved version
- Ordering missing or defective parts
- Creation of a 3D model
- Ordering new „Presser design“
- Assembling new sliding seal

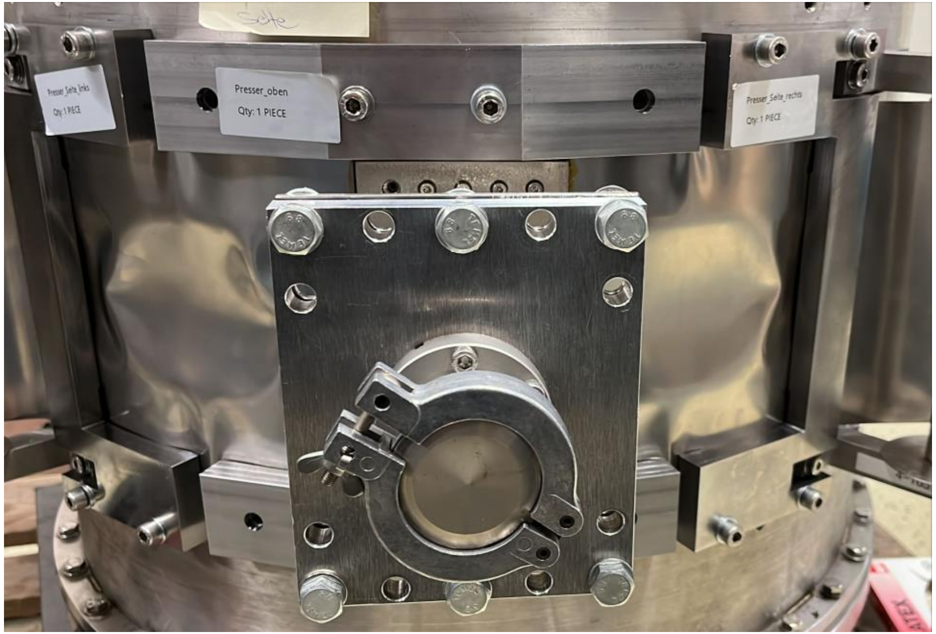




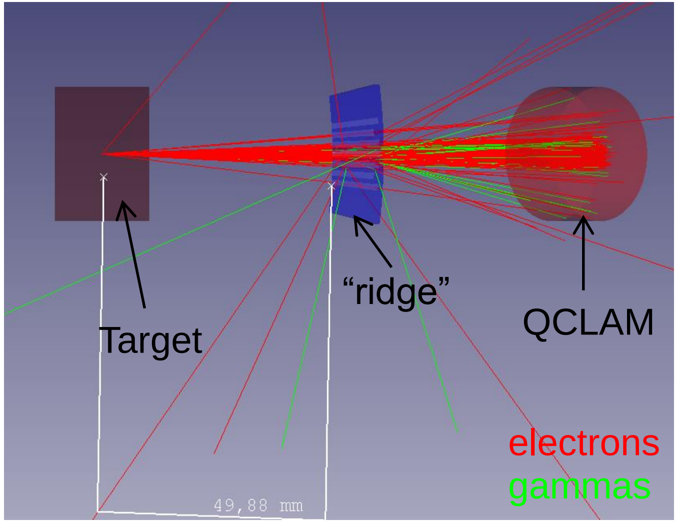
New concept

- New concept looks promising
- Thicker rubber sealing
- Small leakage due to the gaps

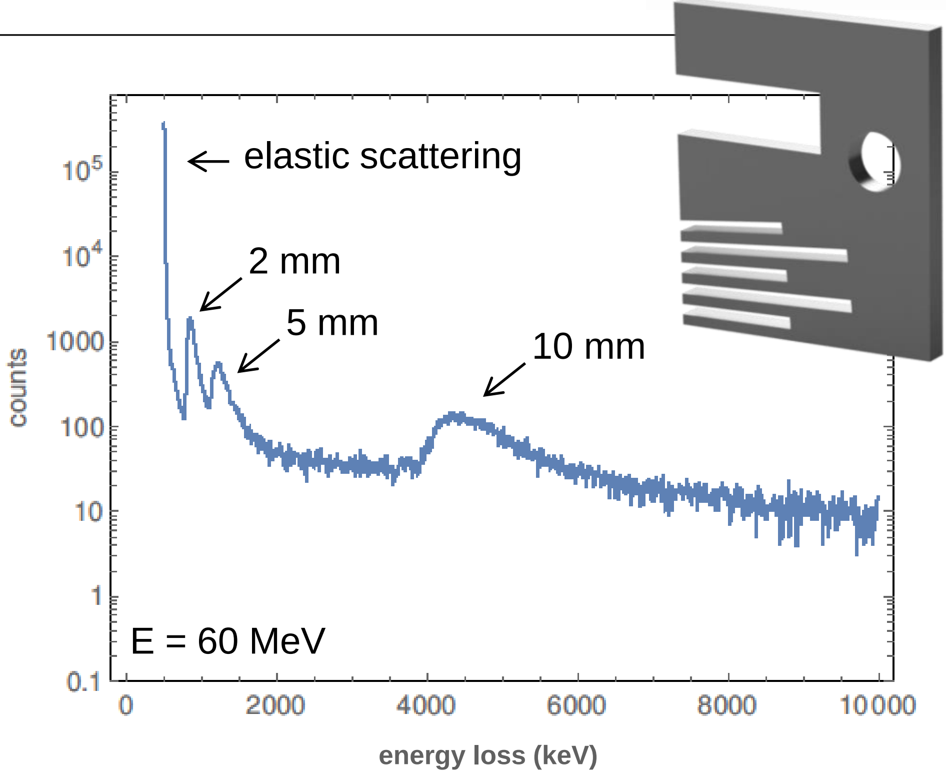




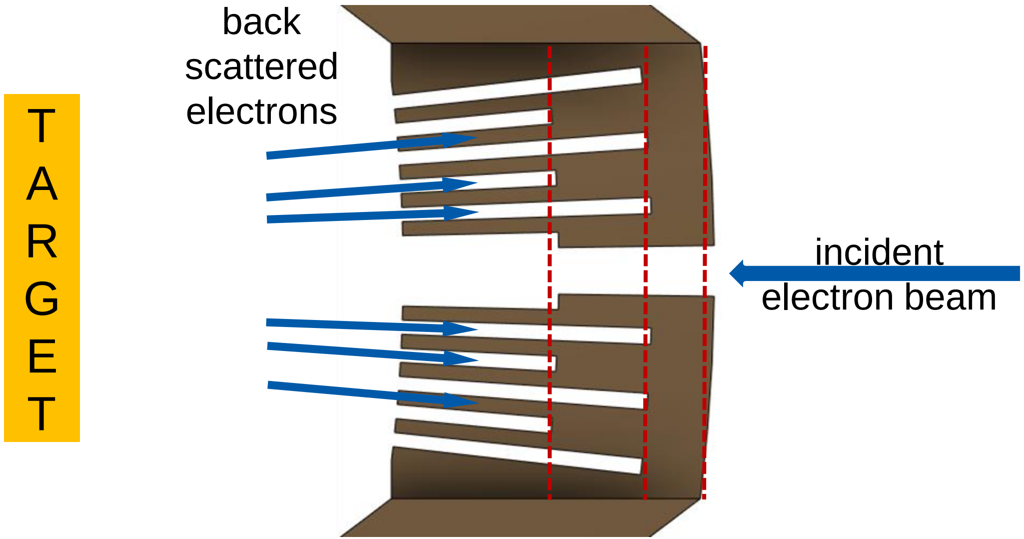
Geant4 simulation



produces

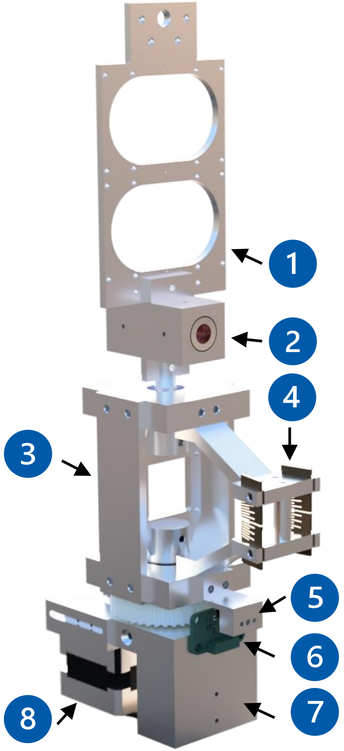


Functionality of the calibration system



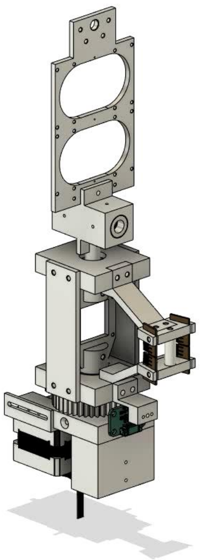
- Cuts of different depths define vertical scattering angle
- Peak in spectrum for each material thickness
- Horizontal scattering angle is calibrated by the rotation of the ridges around the target

New calibration system

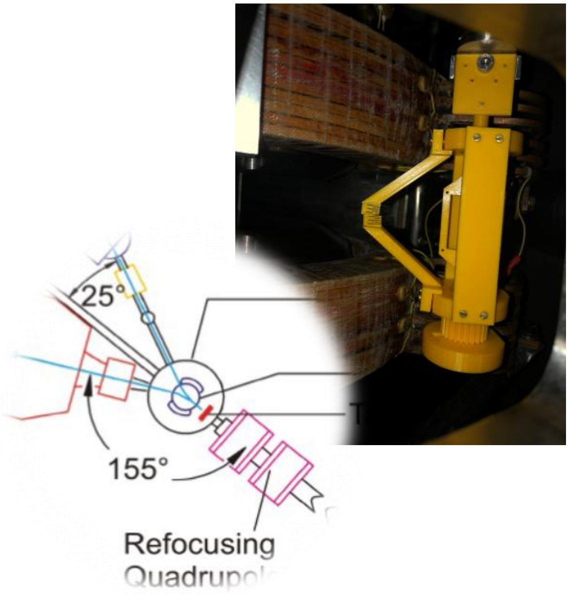


Components

1. Target ladder
2. Laser adapter
3. Rotational corpus
4. Calibration ridges
5. Magnet
6. Hall sensor
7. Counterweight
8. Stepper motor

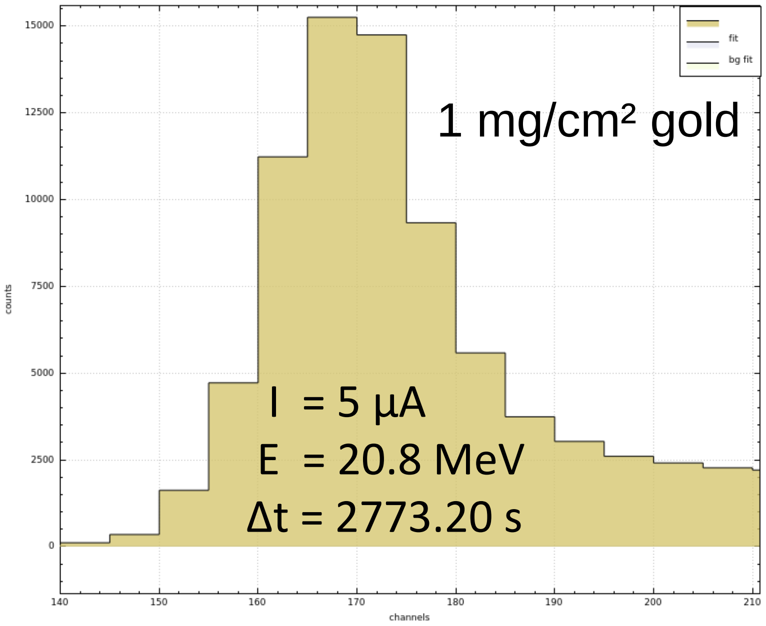


Placement in the scattering chamber



Count rate estimation for calibration ridges

Count rates of the commissioning beam time August 2020



1 ridge with 5 slits

Horizontal and vertical angle acceptance: **± 40 mrad**

Ridge thickness: **1 mm**
Slit angle: **0.5°**

Assuming a homogeneous distribution of backscattered electrons:
0.128 electrons per second per slit

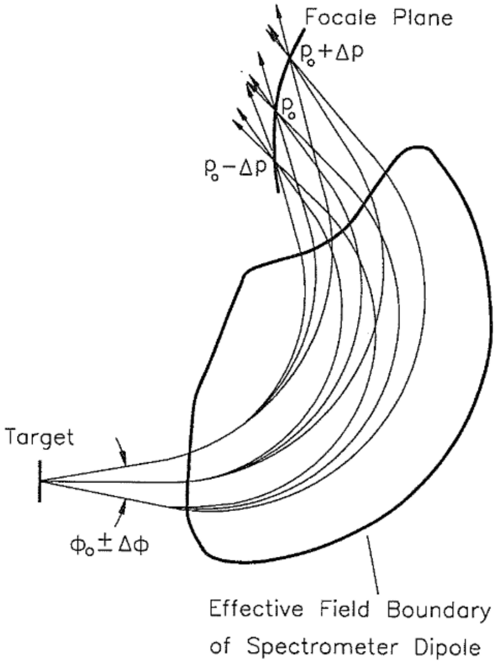
Calibration

Calibration measurement is needed to:

- Reconstruct the exp. scattering angle
- Determine the location of the focal plane

Usually done with a sieve slit measurement

- Various slits with known position
- Clear assignment in the spectrum



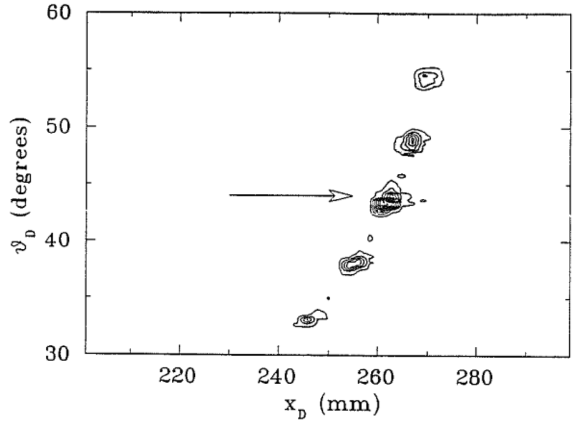
G. Lüttge, Dissertation, TH Darmstadt D17 (1994)

Sieve slit measurement

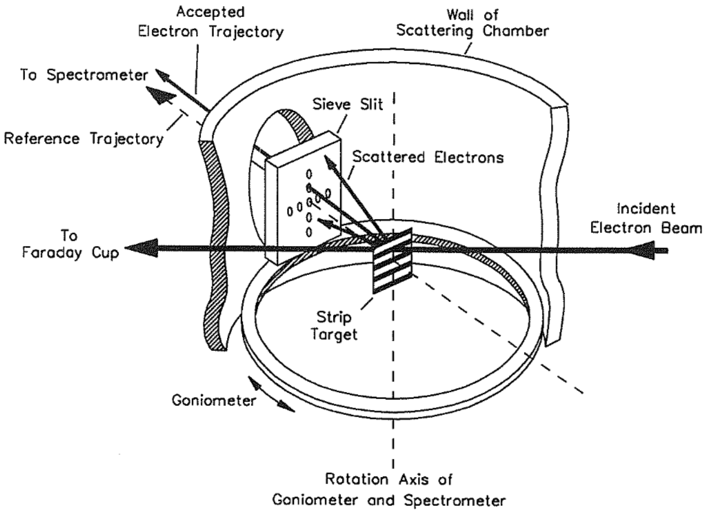
Experimental setup

- No dipole separation magnet
- Sieve slit mounted on a Goniometer
- Target at the pivot point

produces



G. Lüttge, Dissertation, TH Darmstadt D17 (1994)



Disadvantage:

Different experimental setup!

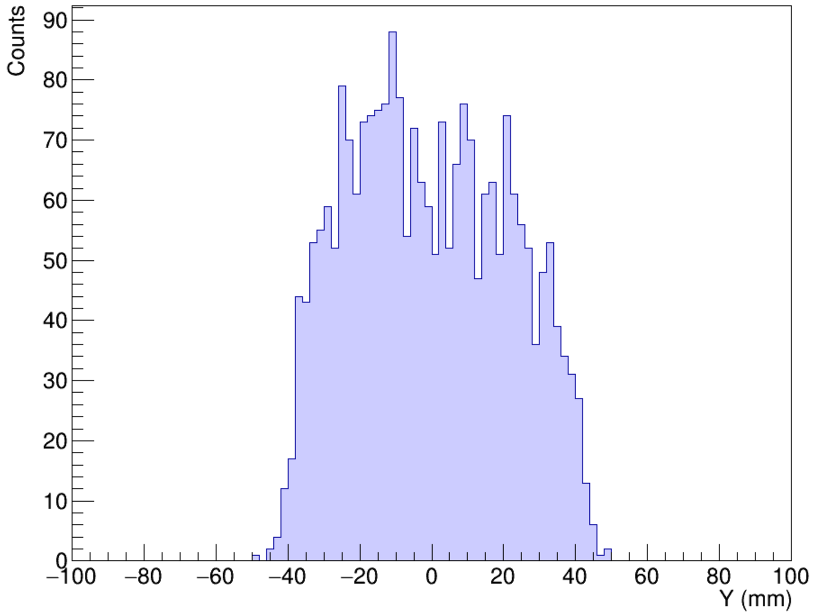
Ongoing development and improvement

- Continuous development
  - 2^{nd} gen. finished
  - Stability
  - Handling

- Sieve slit
  - Horizontal 2.5°, 4°, 5.5°
  - Vertical 2.5°, 4°
  - Thickness 2.5 mm

Response of the calibration system

^{27}Al(e,e‘) without cal. sys.



^{27}Al(e,e‘) with cal. sys.