Experimental exploration of electroweak interactions in nuclei

Project B02

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Current state of the 180° scattering at the QCLAM spectrometer

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Johann Isaak, Maxim Singer, Maximilian Spall

Supported by DFG under contract SFB 1245

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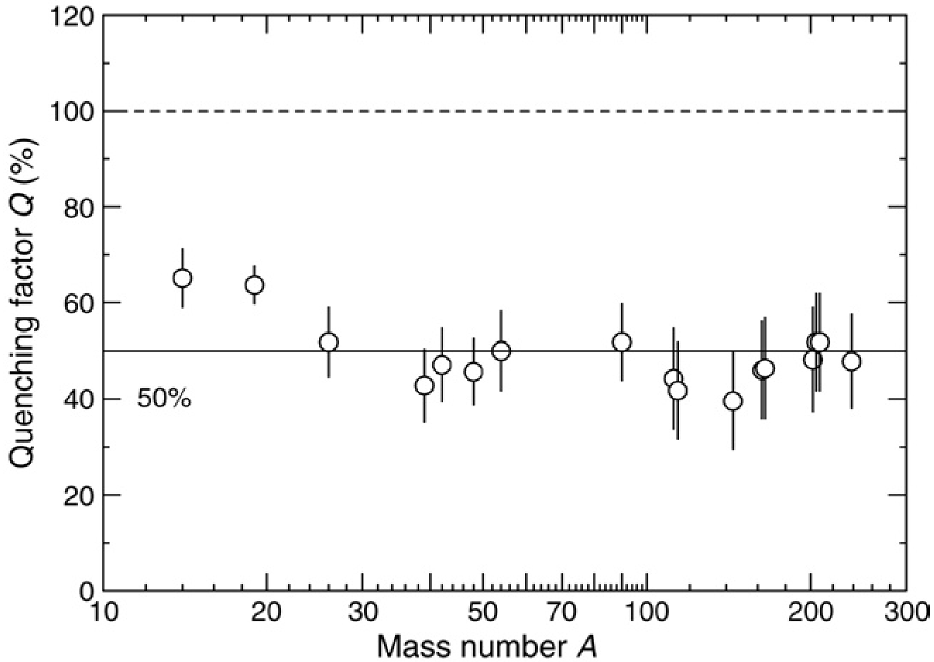
Quenching of the Gamow-Teller strength



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

- Systematic reduction by a factor of about 2
- Impact on weak interactions
- Same behavior for spin-M1?

Systematic predictions of electroweak processes in nuclei

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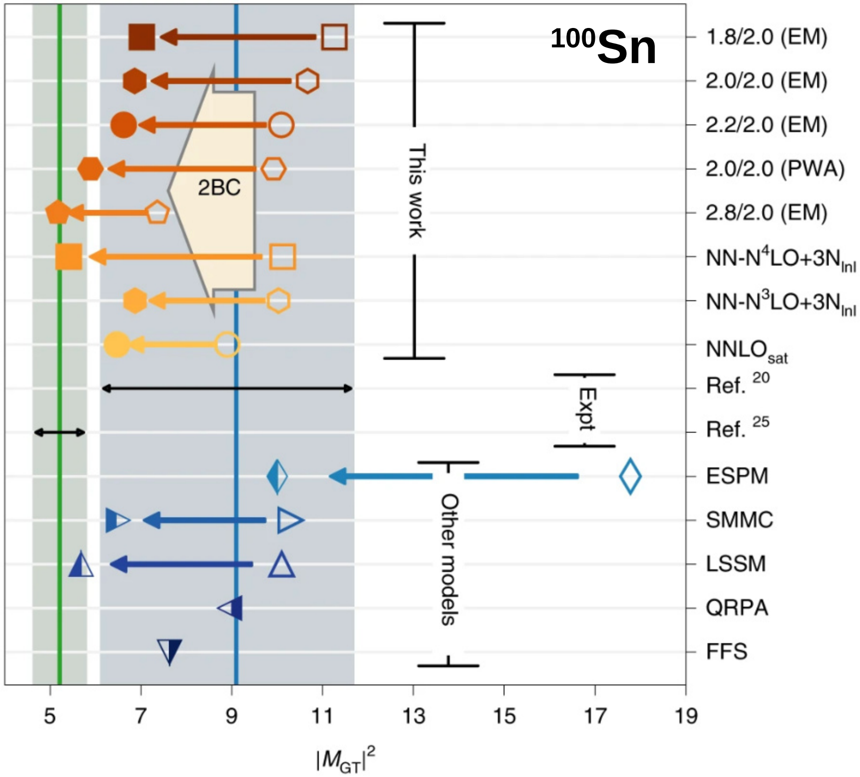
- Contributions to quenching
  - Δ resonance
  - Many-body correlations
  - Meson-exchange currents

- Ab initio calculations promise systematic treatment of electroweak processes

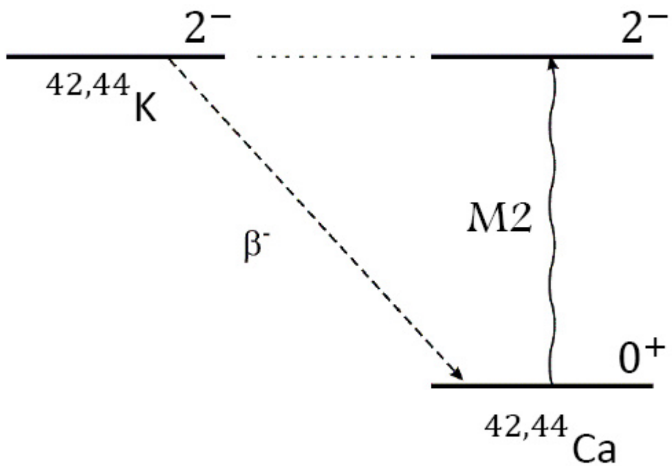
- Two-body currents differ for axial and vector coupling
  - Measure relevant observables with electromagnetic probes

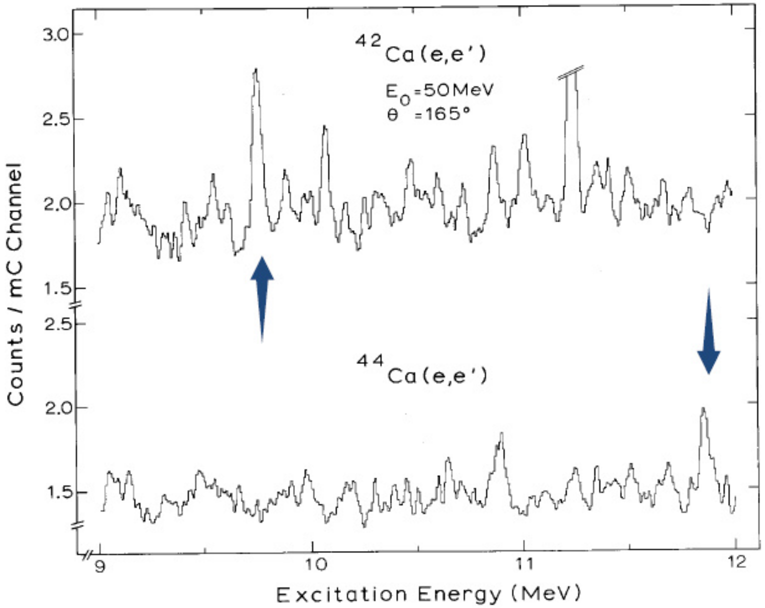


P. Gysbers et al., Nature Physics 15, 428-431 (2019)

Analogue transitions to forbidden β-decay

For example...





C. Rangacharyulu et al., Phys. Lett. **B 135,** 29 (1984).

Systematic study of analogue transitions to forbidden β decay in light nuclei with 180° electron scattering!

- Cases for M2, M3 and M4 in light nuclei, e.g. ^{10}B: $3^+_{g.s.} \rightarrow 0^+_1$

Why 180° electron scattering?

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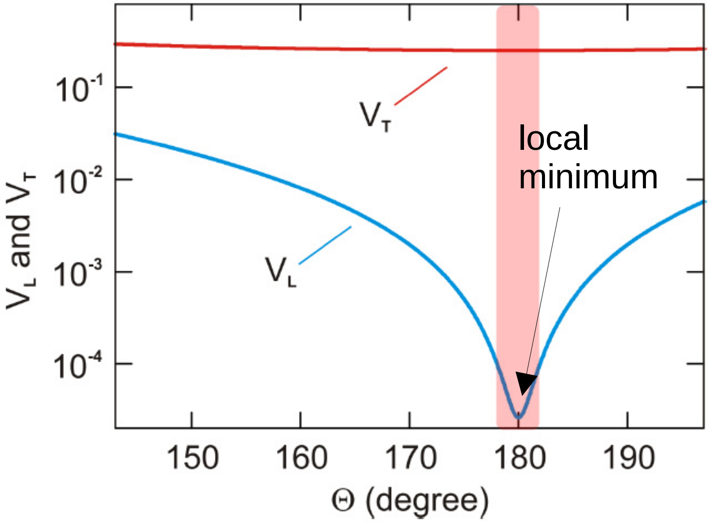
Because it is an optimal method for measuring transverse excitation!

- Compare differential cross sections longitudinal and transversal factors

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

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



Transverse response enhanced by three orders of magnitude!

$$\frac{V_T}{V_L}(180°)\sim 10^3$$

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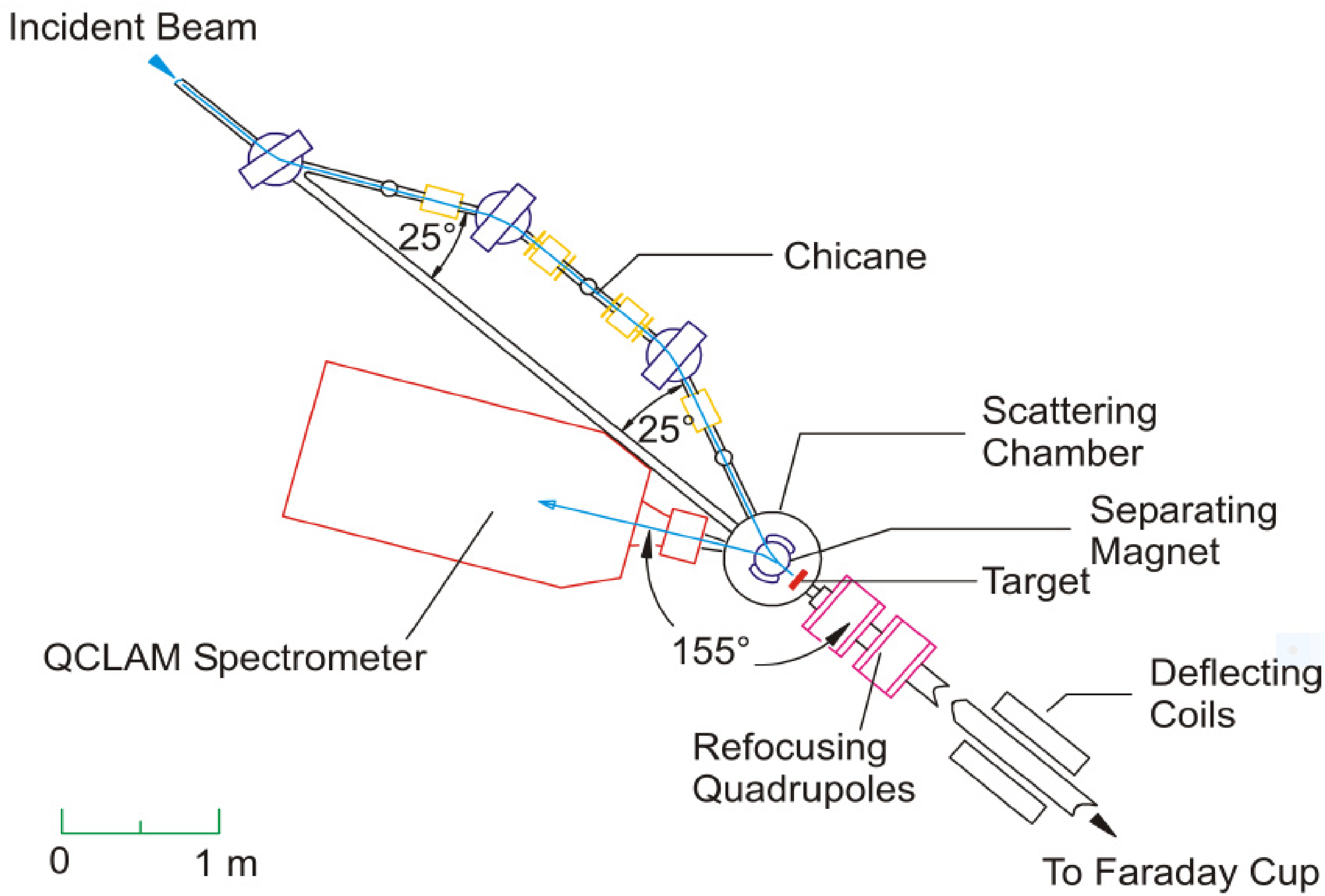
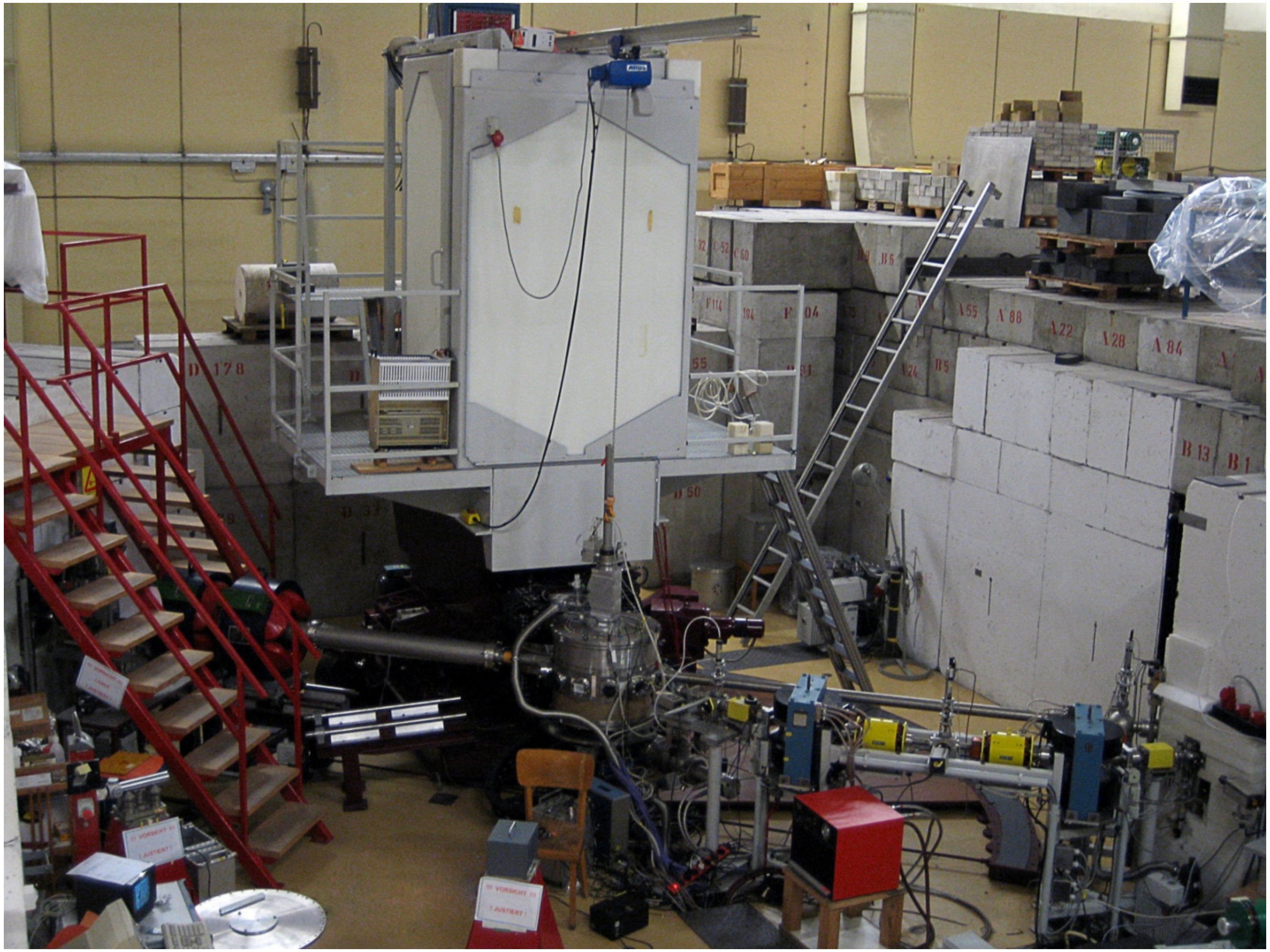
Schematic overview of the 180° system



180° System at the QCLAM spectrometer



Review and achievements of 2020

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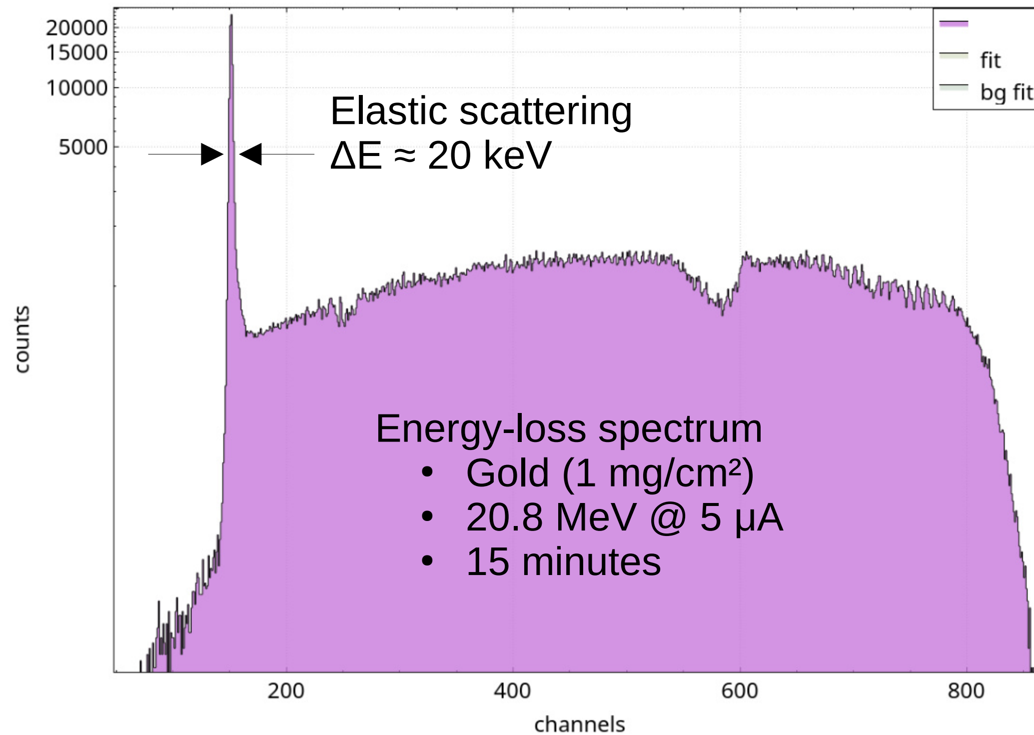
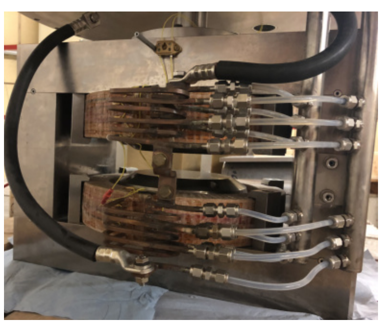
Commissioning of the 180° system:

- ✓ Mechanical setup of the 180° chicane at the QCLAM
- ✓ New dipole separation magnet
- ✓ Data acquisition





It has been shown that the basic components form a functioning unit!

→ **successful** test beam time in August 2020!

Outlook for 2021

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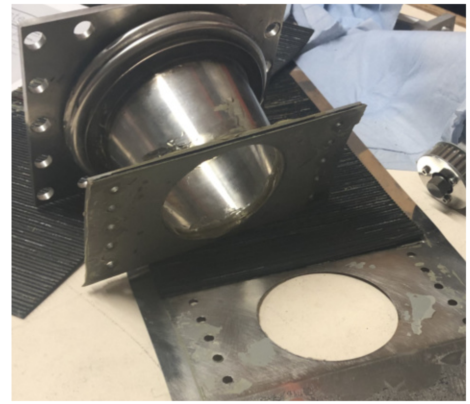
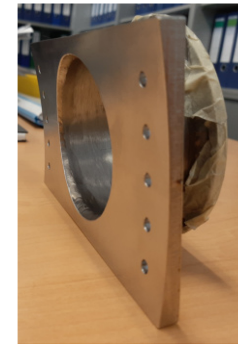
There are still some requirements for a productive 180° experiment:

Sliding seal:

- ✔ Identify broken parts
- ✗ Order new parts
  - ➢ Difficult because most things are custom made
- ✗ Assembling
- ✗ Vacuum test





M. Wehlan, FLEXOMAT GmbH

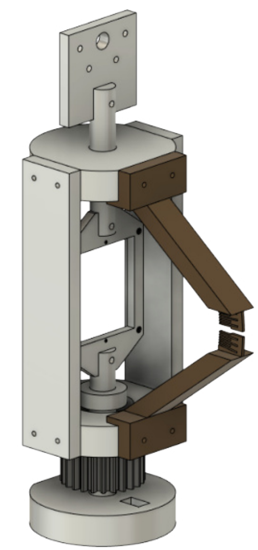
Drift chambers:

- Good efficiency is required
- Testing DC X12 3rd generation as an alternative

Sieve slit measurement:

- Common method for calibration
- Alternative calibrating system in development

M. Singer



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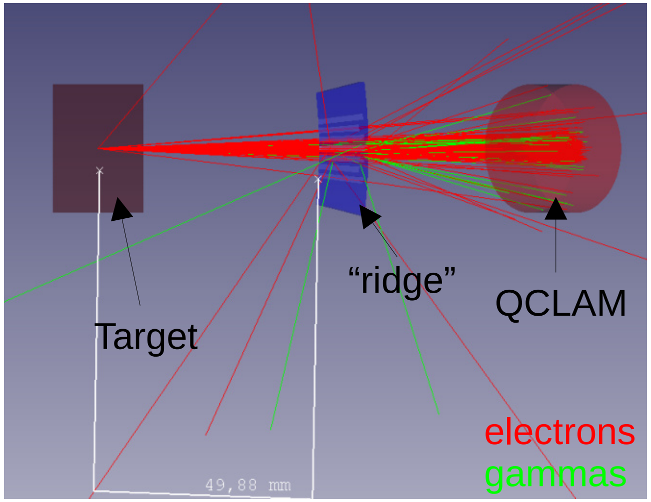
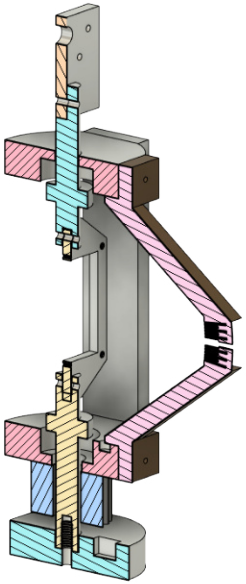
New calibrating system

Possible alternative for a sieve slit measurement!

- ✓ Geant4 simulation (M. Singer)
- ✓ Technical drawing
- ✓ 3D printing first prototype

→ In principle it's an inverse sieve-slit measurement.





Advantages	Challenges
High precision	Very filigree
Complete magneto optical system	Needs to fit in existing system

Plan for the 180° beam time

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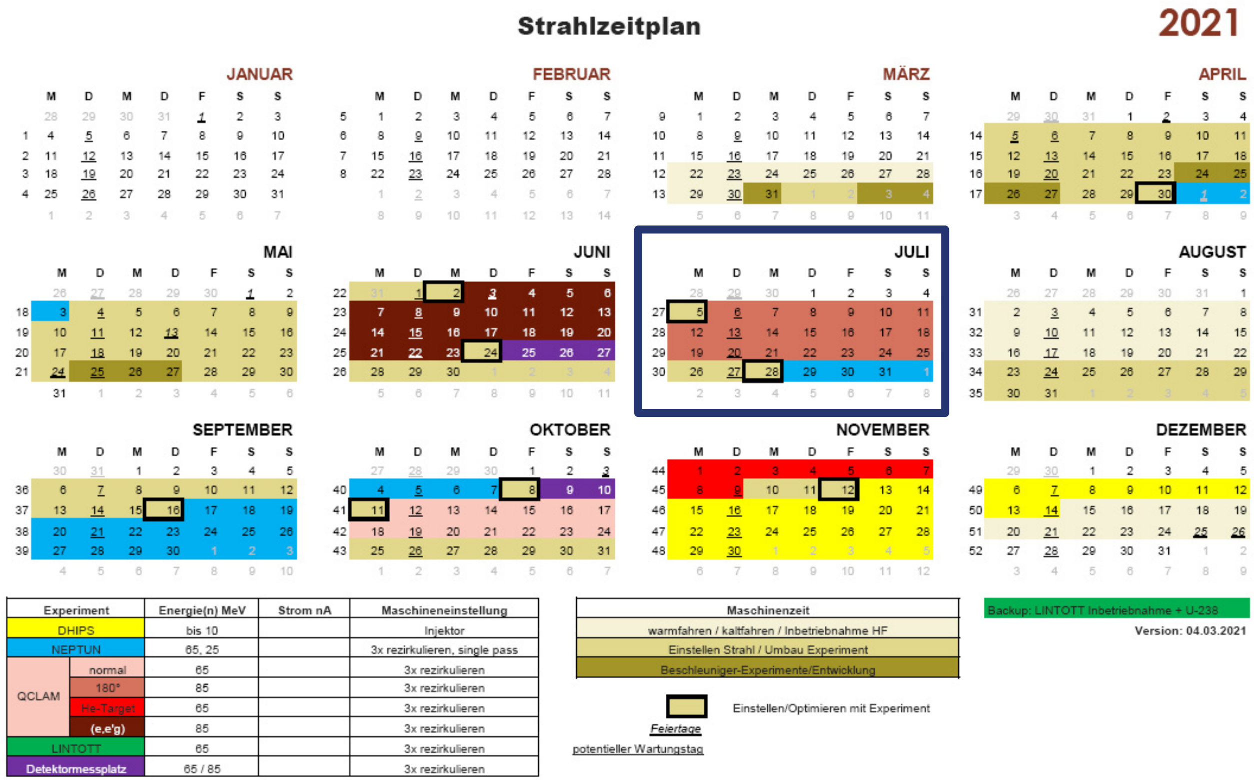

First: Sieve-slit calibration

Second: ^{10}B (M3 @ 1.74 MeV)

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Thank you for your attention!

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Backup slides

Inelastic electron scattering

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What is happening in principle?

- Electrons are scattered at the Coulomb potential of the nucleus
- Spins of the electrons and nucleus are interacting with each other

When does an interaction take place?

- Described by the differential cross section $\frac{d\sigma}{d\Omega}$
  - Related to form factors $F(\vec{q})$
    - Momentum transfer dependence
    - Reduced transition strengths $B(E/M\lambda)$
    - Spin-isospin response
    - Electroweak theory $(e,e') \Leftrightarrow (\nu,\nu')$

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Quenching

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- What is meant by quenching?

- M1 or GT resonances are valence-shell (0 ħω) excitations
  - ➢ confined in a certain excitation energy region

- Quenching = $\dfrac{\text{experimental strength in that region}}{\text{theoretical or sum rule prediction in that region}}$

- Quenching affected by many-body correlations and two-body currents

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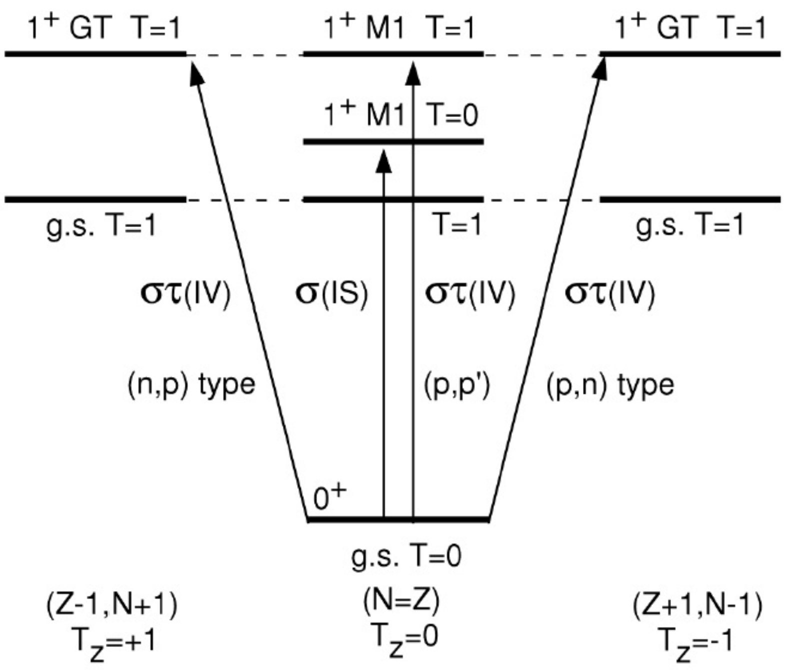
Spin-M1 and Gamow-Teller strength

Momentum-transfer dependence of quenching

- Spin flip M1: ^{40}Ar, ^{40}Ca



Y. Fujita et al., Prog. Part. Nucl. Phys. **66** (2011) 549-606.

Isobaric analogue states

- Same structure
- Transition strengths

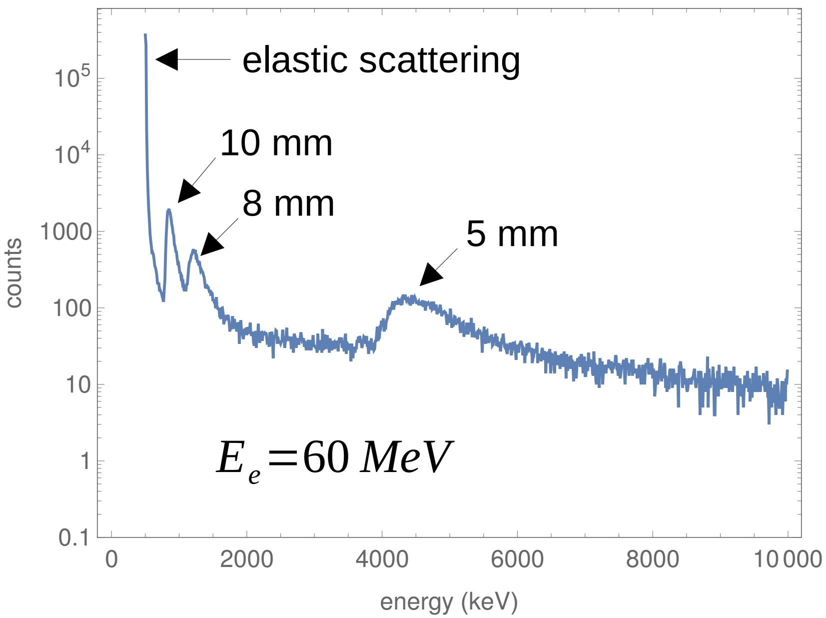
→ distinguishable via T_Z

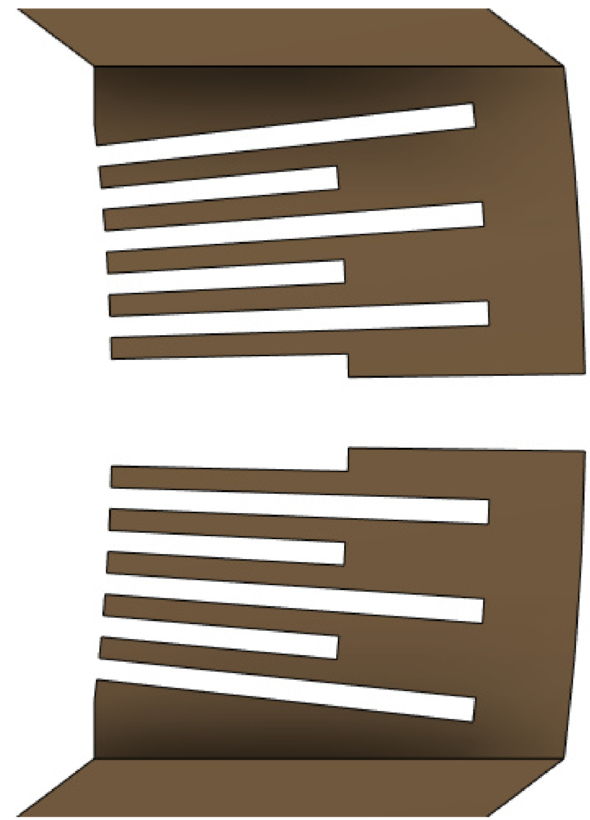
New calibrating system: Simulated spectra

Important parameters

- Material (bronze in this case)
- Slit thicknesses

→ to adjust the peaks in the energy loss spectrum!





New calibrating system: Simulated spectra 2

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High precision calibration will be possible!

- Good approximations of the dispersion angle dependencies will be available!
- Much more intermediate steps than a common sieve slit!
- More precise evaluation of the scattering data!