Overview and perspectives on programs at the S-DALINAC

S-DALINAC

Superconducting-**DA**rmstadt-**LIN**ear-**AC**celerator

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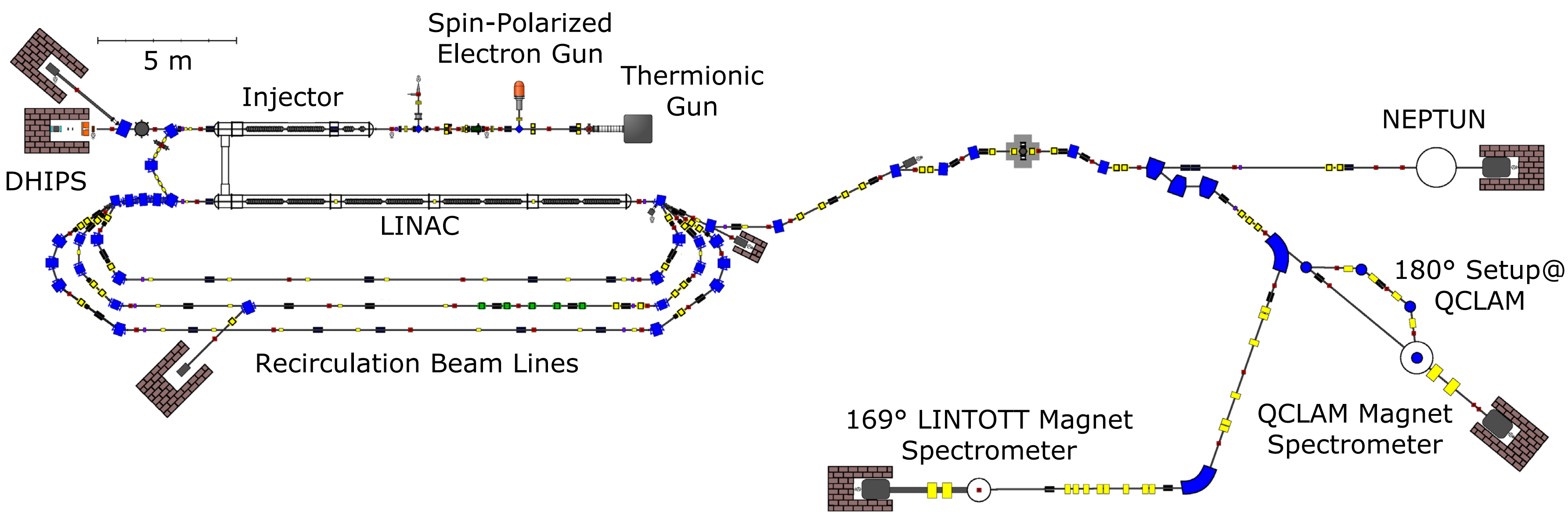

<u>Thrice recirculating operation</u>

Energy gain injector:	10 MeV
Energy gain LINAC:	30.4 MeV
Beam current:	20 µA

ERL mode possible since upgrade in 2015/2016

Operating Principle and Parameters

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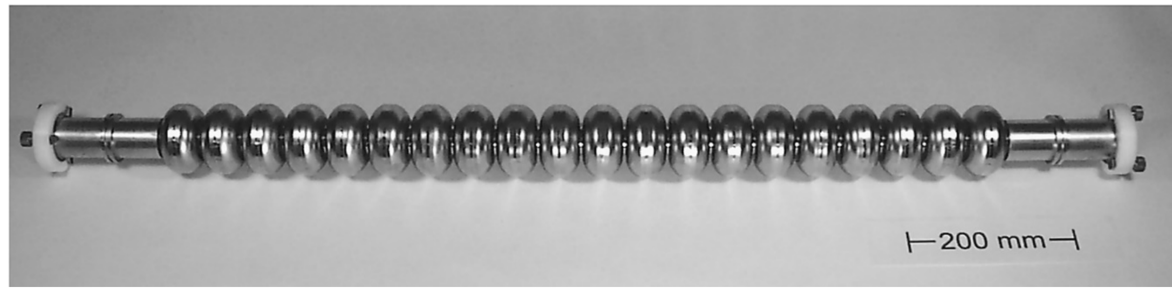
SRF injector

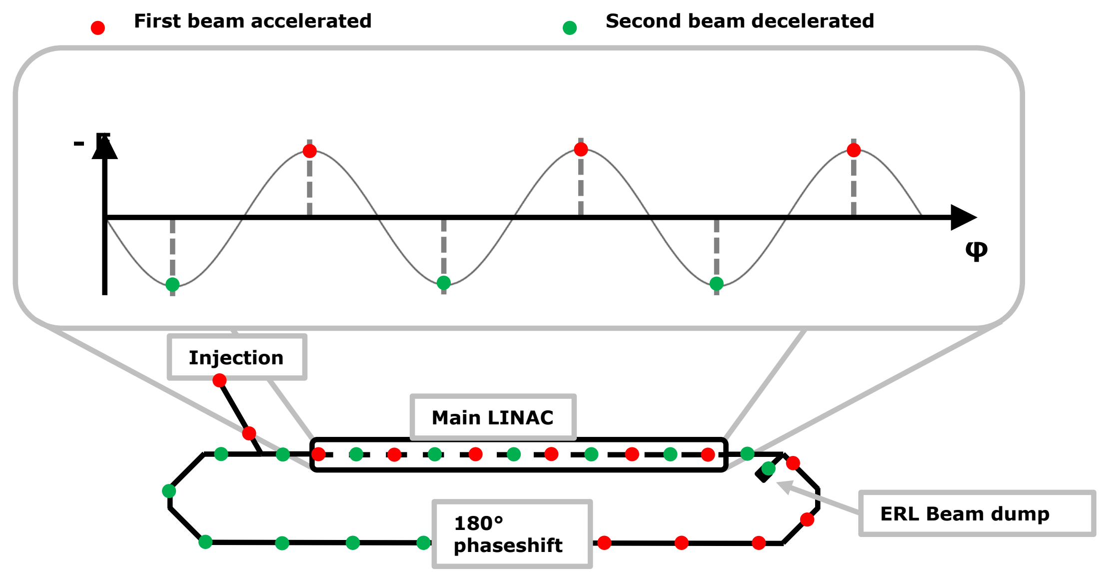
- 1x 6-cell (β=0.86) as capture
- 2x 20-cell (β=1)

SRF main linac

- 8x 20-cell (β=1)



- Particles: electrons
- Design:
  - Injector: 10 MeV, 60 μA
  - Extracted beam: 130 MeV, 20 μA
- Rep. rate: 2.997 GHz
- cw (continuous wave) operation
- ERL modes possible



Overview Operation Modes and Commissioning

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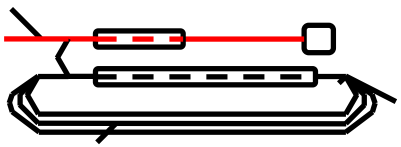
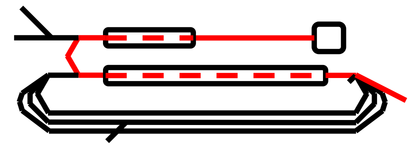
- Modification lattice 2015/2016
- Commissioning of modes followed beam time schedule

Injector



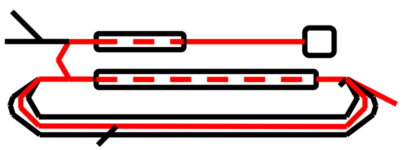
December 2016

Single pass



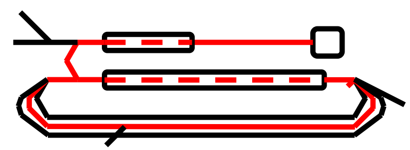
December 2016

1x rec.



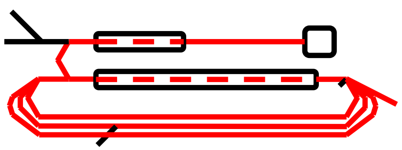
May 2017

1x ERL



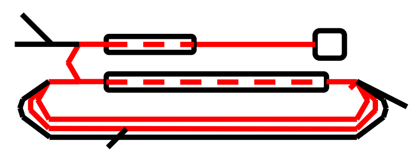
August 2017

3x rec.



November 2018

2x ERL



August 2021

Once-Recirculating ERL Operation

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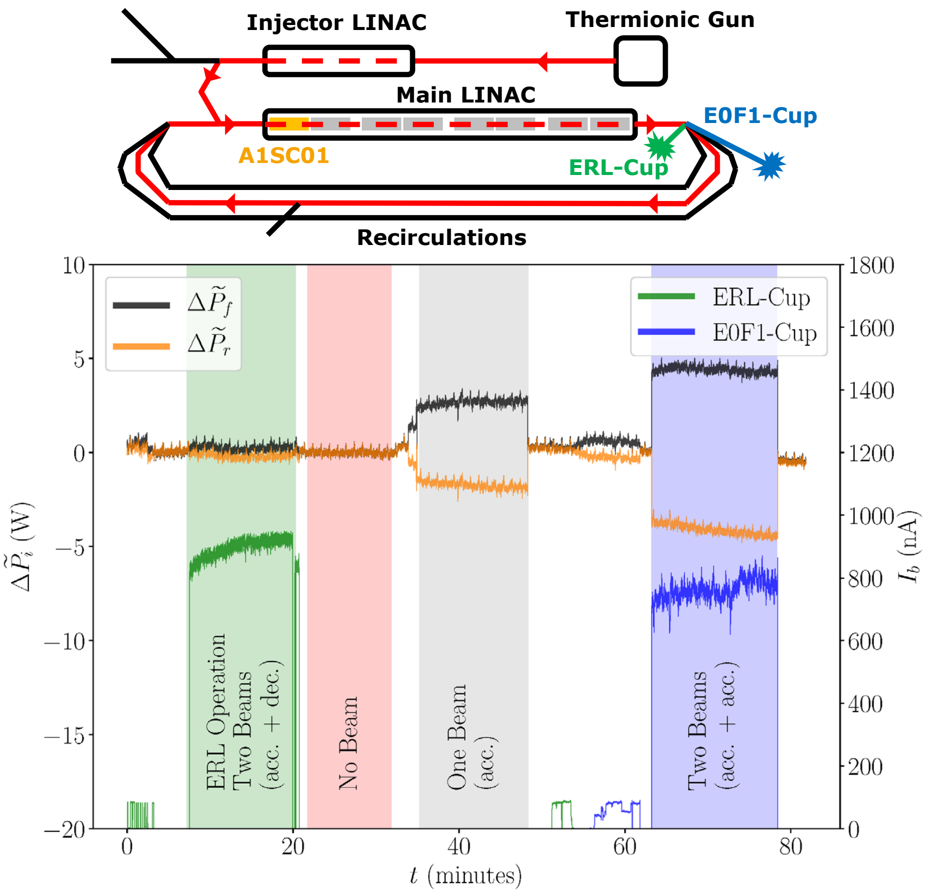

August 2017: First ERL in Germany

- Energy gain injector: 2.5 MeV
- Energy gain LINAC: 20.0 MeV
- Current (I_{in}): 1.2 μA

$$\varepsilon_{RF} = \frac{P_{RF,acc.} - P_{RF,ERL}}{P_{RF,acc.}}$$

RF-recovery effect:

$$\varepsilon_{RF} = (90.1 \pm 0.3)\%$$

M. Arnold et al., First operation of the superconducting Darmstadt linear electron accelerator as an energy recovery linac, Phys. Rev. Accel. Beams ***23****, 020101 (2020).*

Challenges of twofold ERL (sharing model)

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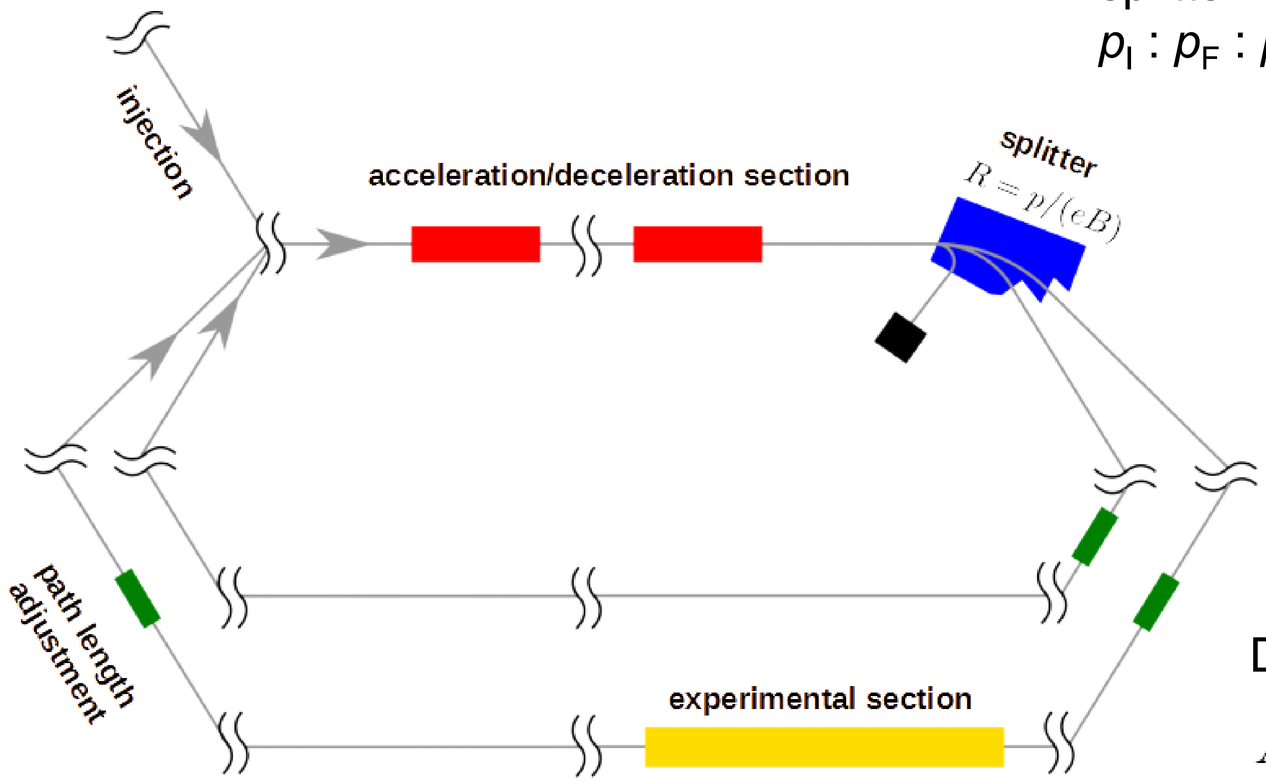
Objective functions result from splitter magnet ratio:
$p_I : p_F : p_S = 1 : 4.73 : 8.32$



Degrees of freedom:

$\vec{A}, \vec{\phi}, \vec{L}, \vec{R}_{56}$

Twofold ERL @ S-DALINAC

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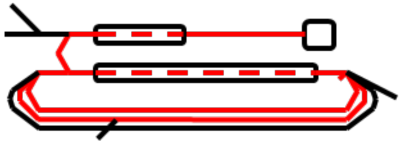
Stable operation (2.3 μA)

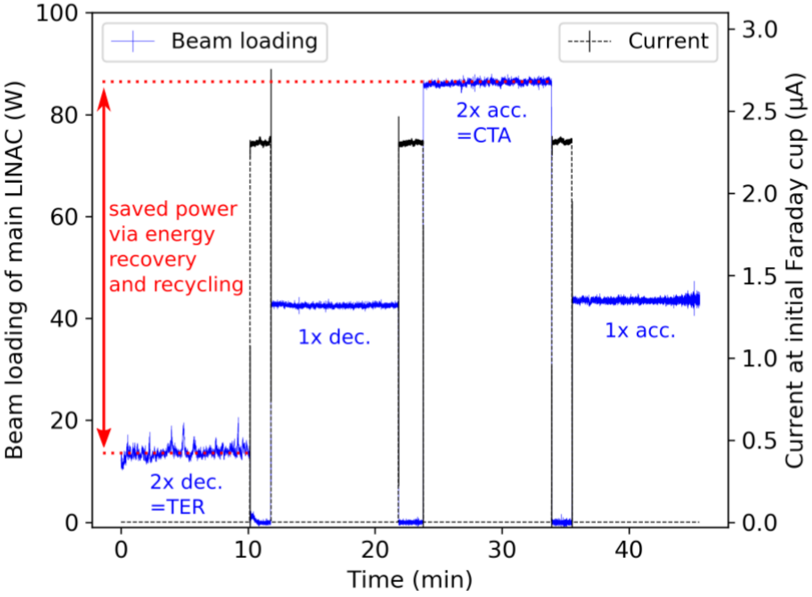


Efficiency:

$$\eta = \frac{P_{\mathrm{b,Con}} - P_{\mathrm{b,ERL}}}{P_{\mathrm{b,Con}}} = (84.0 \pm 1.2)\ \%$$

Scaling factor:

$$S_I = \frac{1}{1-\eta} \approx 6$$



F. Schliessmann et al., *NATURE Physics, in final review*

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Twofold ERL @ S-DALINAC

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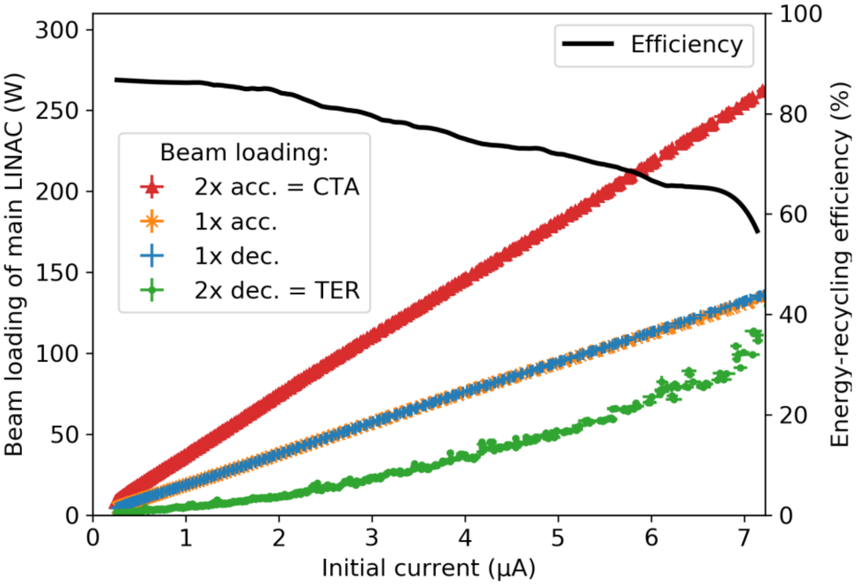
Ramping measurement (0.2-7 μA)

Efficiency:

$\max(\eta) \approx 87\ \%$

Scaling factor:

$\max(S_I) \approx 8$



F. Schliessmann et al., *NATURE Physics, in final review*

Experimental Sites

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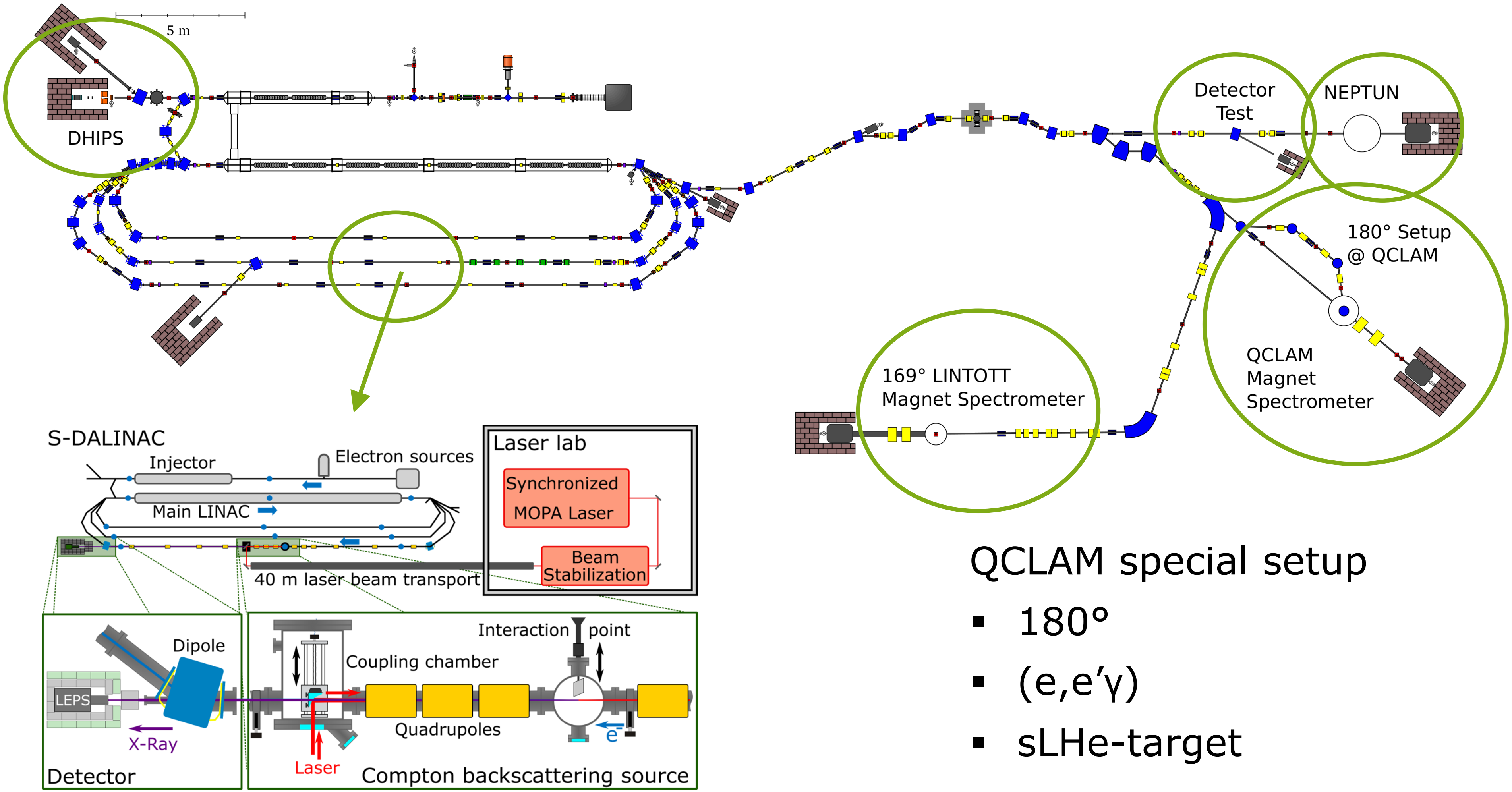

QCLAM special setup

- 180°
- (e,e′γ)
- sLHe-target

Darmstadt High-Intensity Photon Setup

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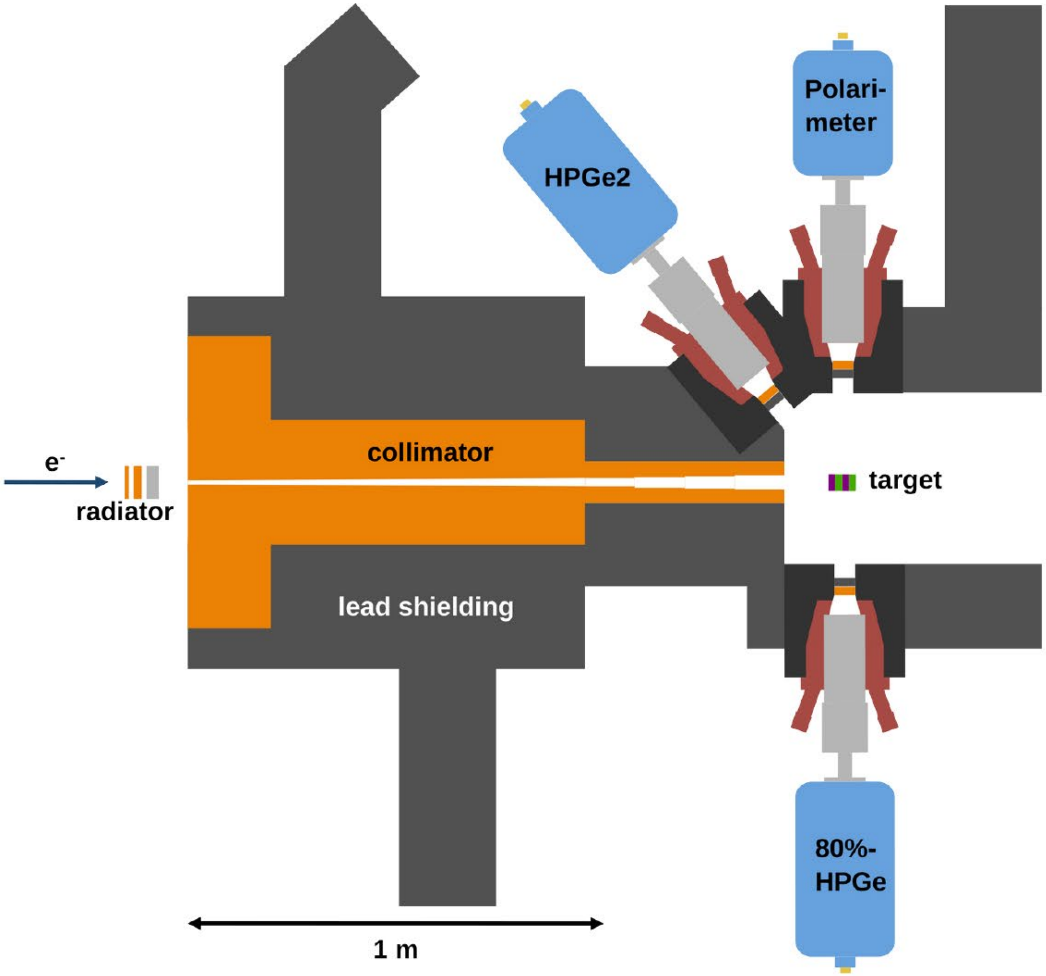
- $E(e^-) < 10$ MeV
- $I(e^-) < 60$ µA



Recent NRF Highlights from DHIPS
(M.Beuschlein, tomorrow B02)

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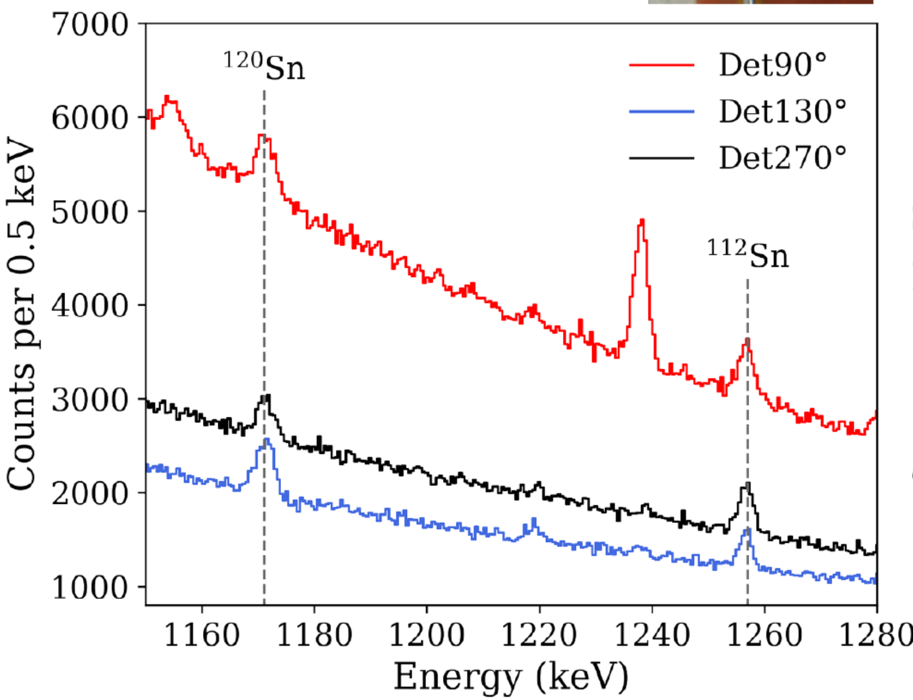
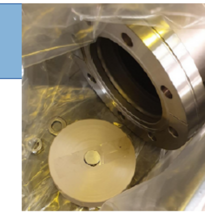
^{120}Sn vs. ^{112}Sn

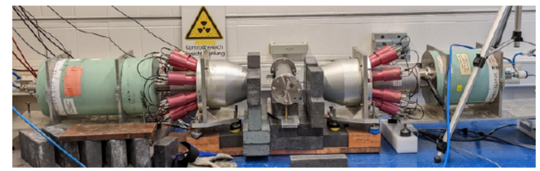
- $E(e^-)$ = 2.4 MeV
- ➔ $B(E2; 0^+_1 \rightarrow 2^+_1)$ of ^{120}Sn

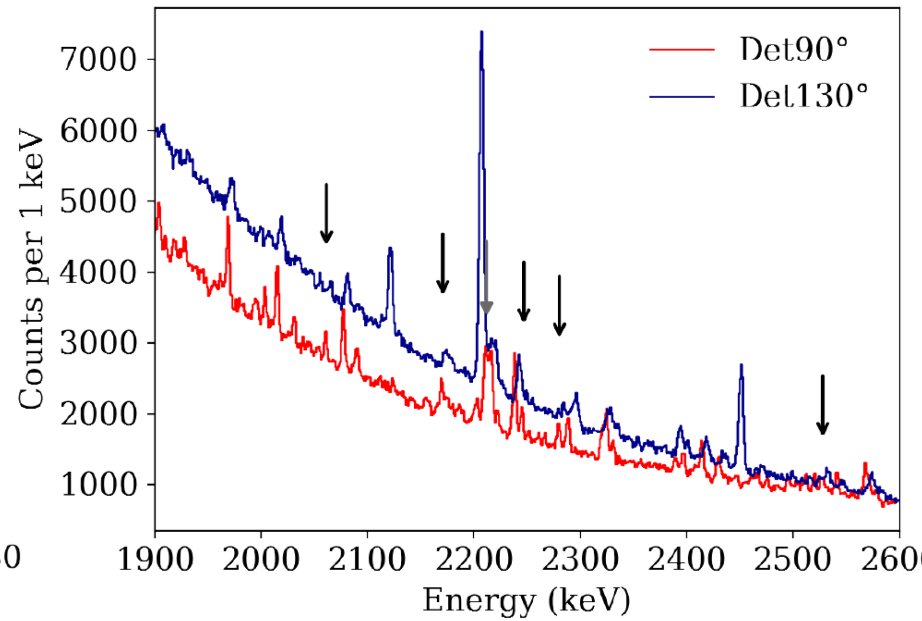


^{242}Pu



- $E(e^-)$ = 3.7 MeV
- ➔ M1 strength, scissors mode





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Last Year‘s NRF Highlight from DHIPS

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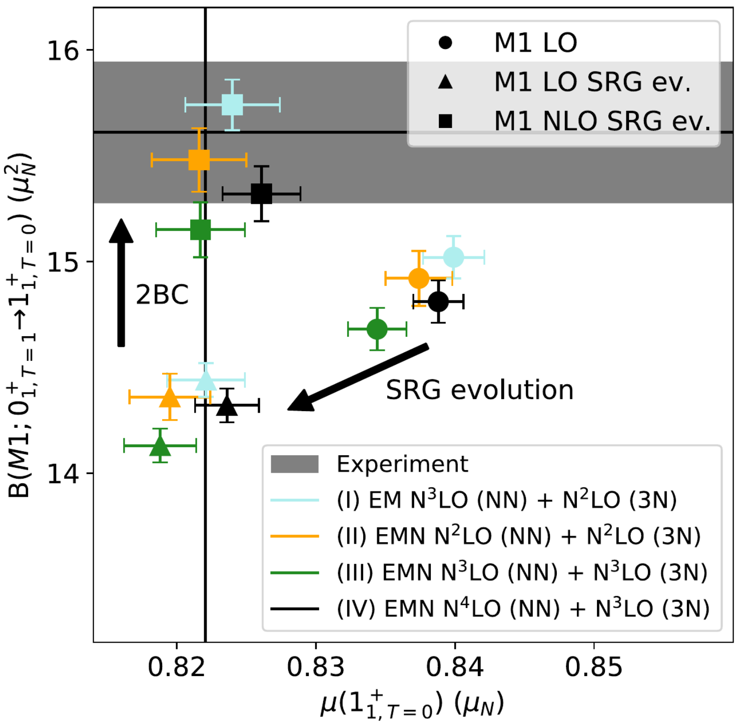
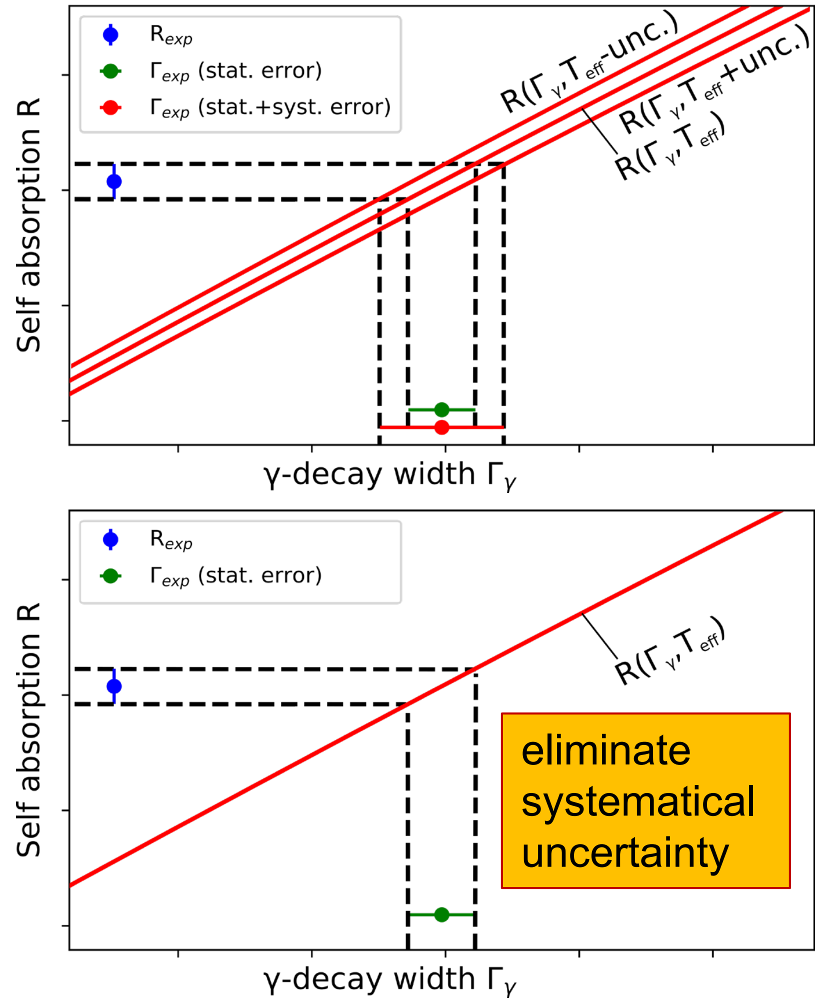




U. Friman-Gayer et al. Phys. Rev. Lett. **126**, 102501 (2021)

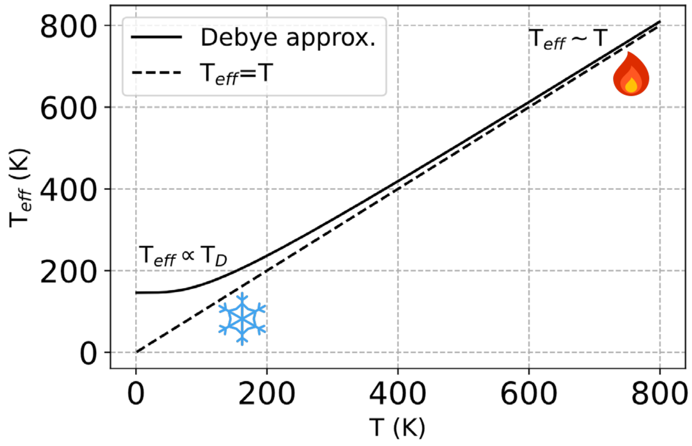
T-dependent Relative Self-Absorption

(P. Koseoglou, today A01)

- High-precision level widths and decay strengths
- Sensitive test of the modeling of nuclear forces and EM transitions

- Temperature-controlled target system
- Reduce systematic errors from uncertainty in T_{eff} by cooling/heating the targets

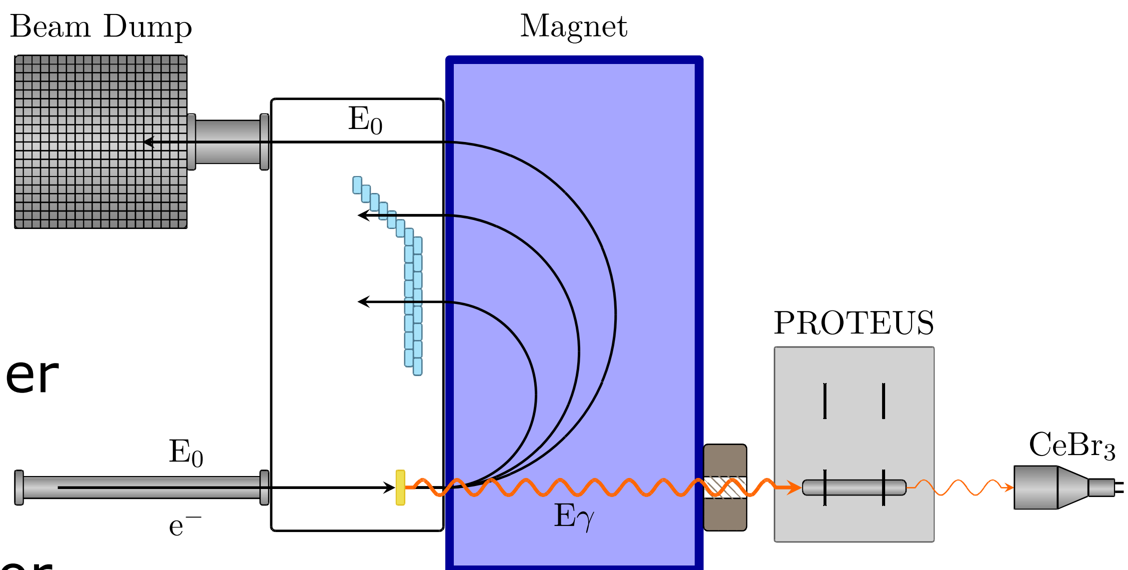
$$R = 1 - g\frac{A_{sc}^{abs}}{A_{sc}^{nrf}} = R\left(\Gamma_\gamma, T_{eff}\right)$$



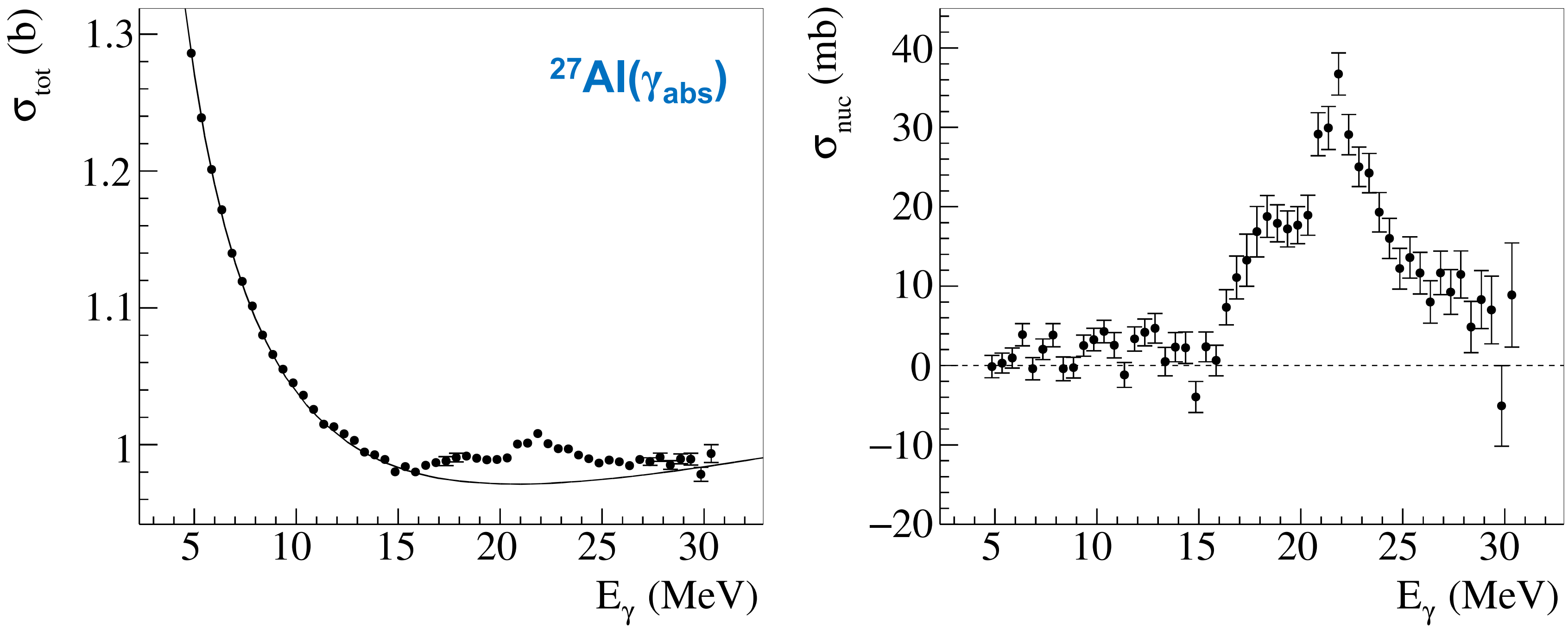
NEPTUN Photon Tagger
(AG Aumann)

- Tagged Bremsstrahlung from 5 to 35 MeV
- 224 scintillator strips
- Upgraded for photoabsorption experiments:
  - Rapid target changer
  - Large CeBr as zero degree detector
  - High precision collimator

NEPTUN setup for photoabsorption experiments



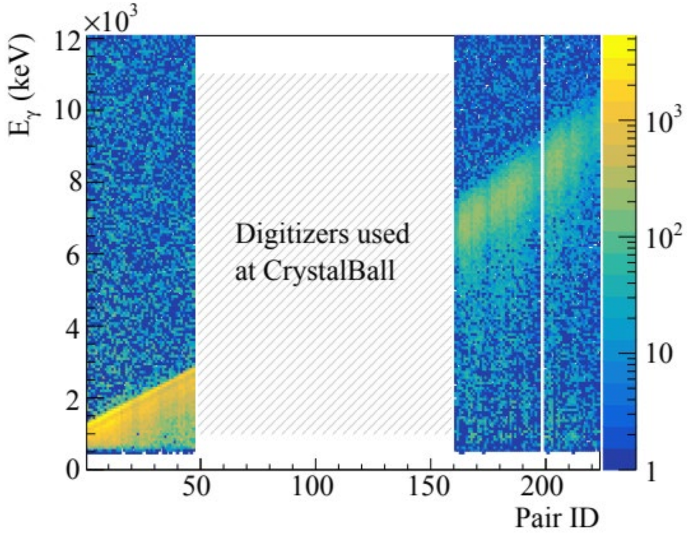
NEPTUN Photon Tagger
(M. Baumann, tomorrow B04)



First test: photo absorption cross section of aluminium

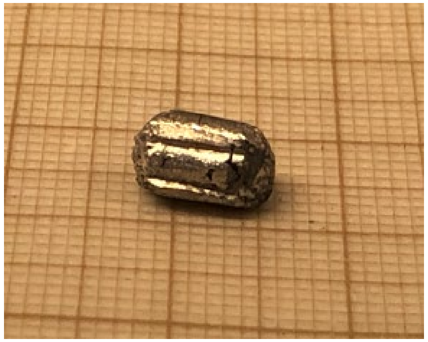
NEPTUN: Developments in 2020

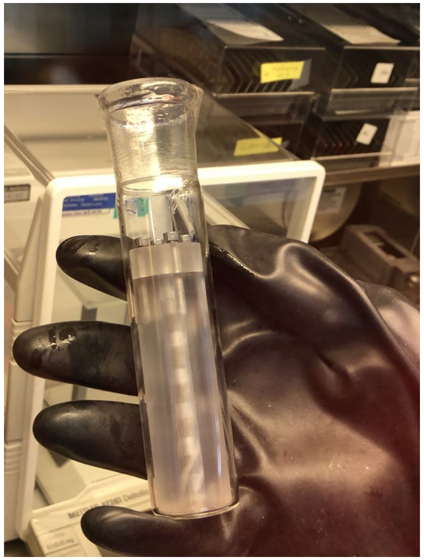
Experiment 2020:
- low energy beam (20 MeV)
- Commissioning of
  - PROTEUS target changer
  - MiniPIX gamma beam monitor



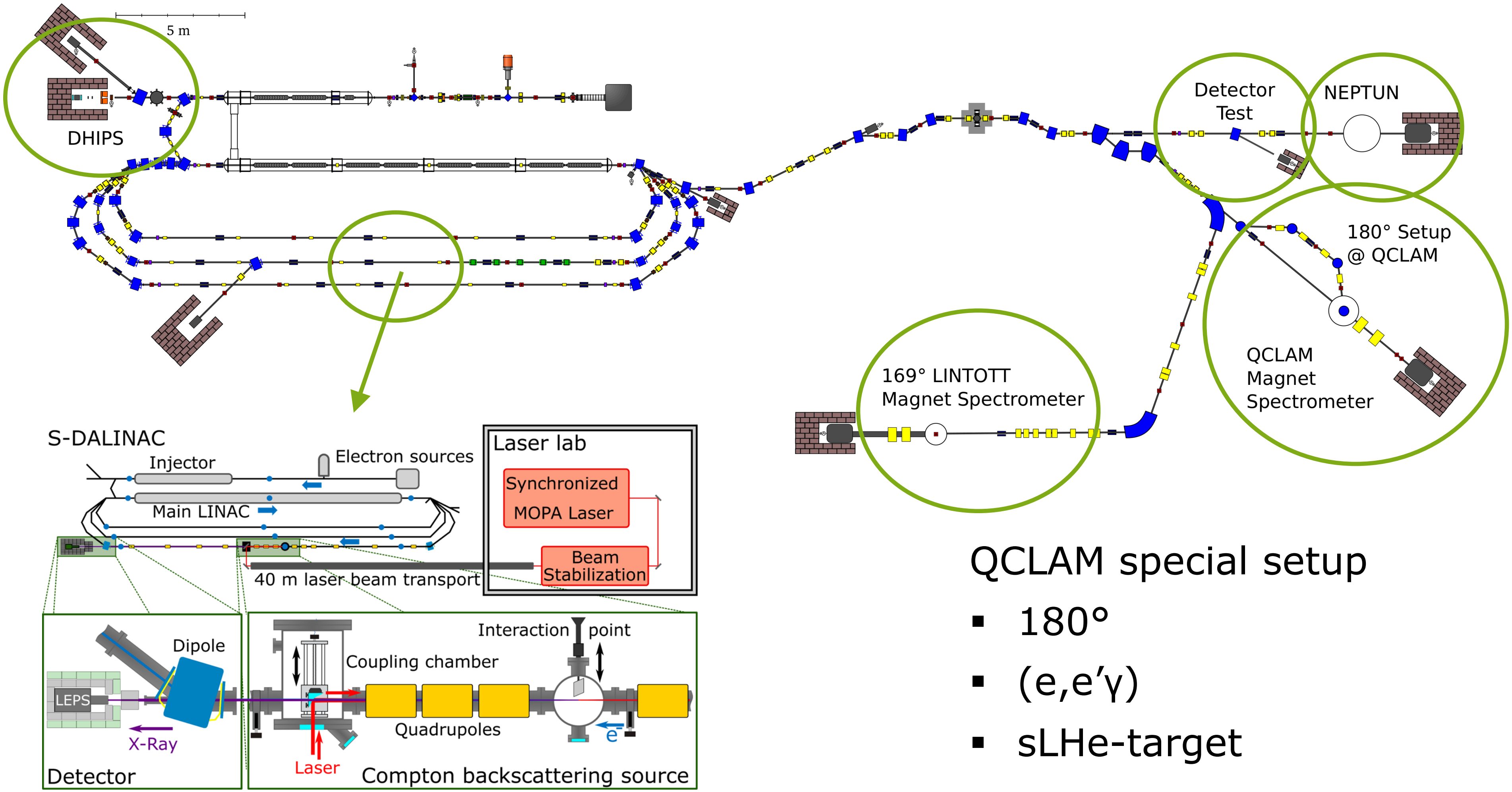
Production-beamtime postponed to ‘22 due to CoViD case

Preparations for 2022:
- ^{48}Ca photo-absorption measurements
- 7 targets (total mass: 1.3 g) prepared at GSI
- Design of mounting and transport system





Experimental Sites



QCLAM special setup

- 180°
- (e,e′γ)
- sLHe-target

Detector Test Set-up at the S-DALINAC

(AG Galatyuk + linac group)

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Goals:

- R&D on diamond- and silicon-based radiation-hard detectors

  → highest possible timing performance

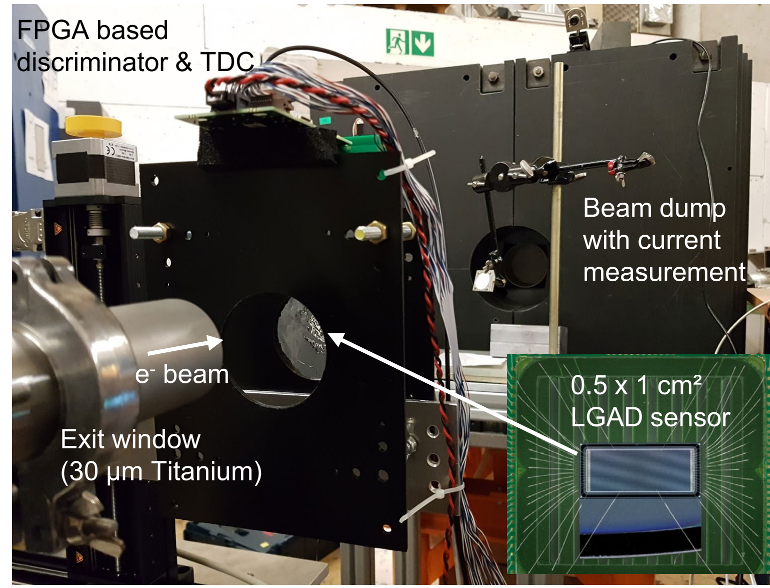
  → Investigation of radiation damage

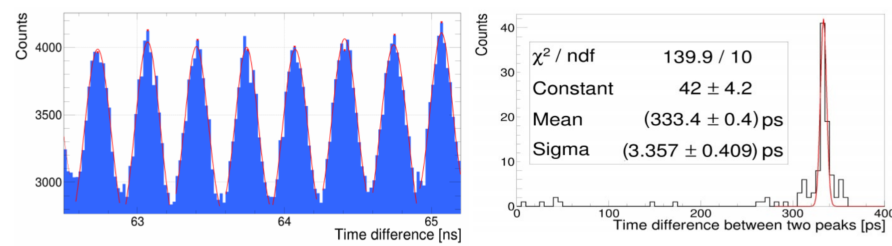
  → Test of new read-out electronics

  → Develop new beam diagnostics concepts

- Successful proof-of-principle test with resolving the 3 GHz time structure of the S-DALINAC

- Next test beam planned





Analysis of time difference of subsequent events
→ 3 GHz time-structure of the S-DALINAC resolved

[*W. Krüger et al. (2022). "LGAD technology for HADES, accelerator and medical applications", NIM A 1039, p. 167046.*]

Quadrupole–Clamshell Spectrometer (QCLAM)

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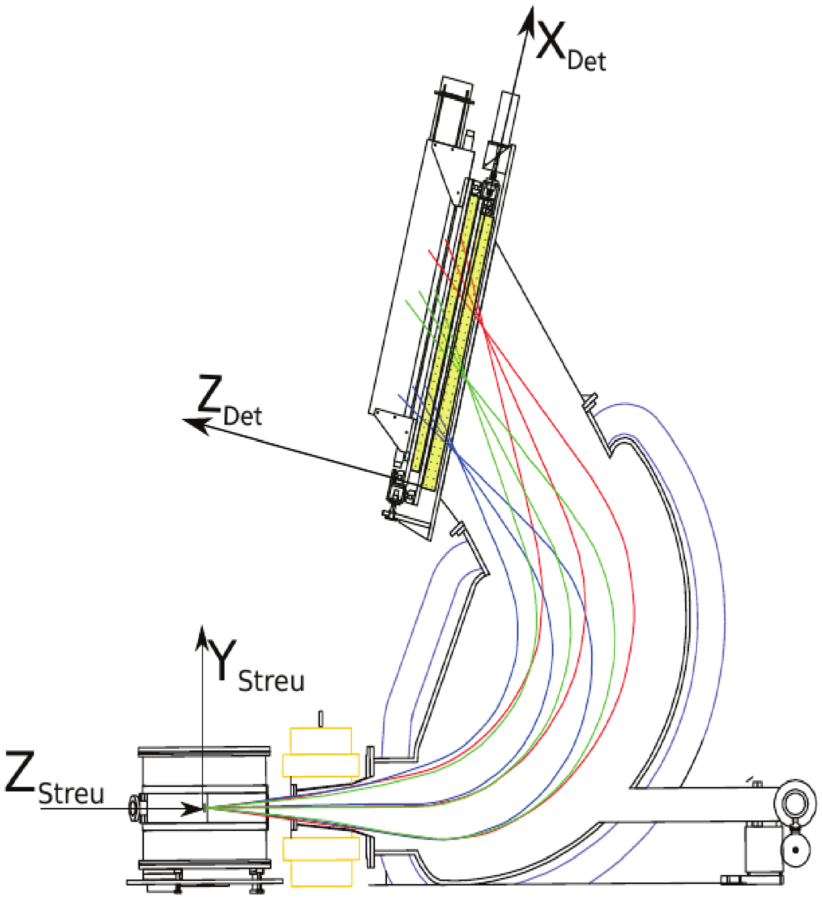
- Spectrometer for electron scattering
  - Sophisticated magneto-optical system for large acceptance, ~35 msrd
  - Detection block of multiwire drift chambers, scintillators, and Cherenkov detectors.

- Perfect for coincidence mesurements
  - large acceptance
  - fast timing



Programs @ QCLAM

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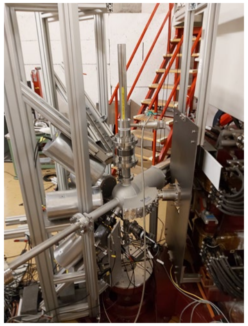
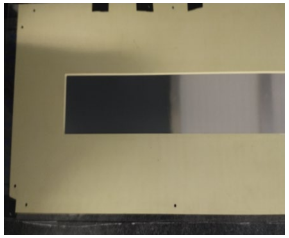
- sLHe target
  (I. Jurosevic, today A01)
- 180° scattering
  (M. Spall, today B02)
- Coincidence experiment (e,e'γ)
  → 3rd funding period
- DAQ re-development.
- Improved gas feed system.
- New multiwire drift chambers under construction.




(e,e'γ) @ QCLAM: Principle and Setup

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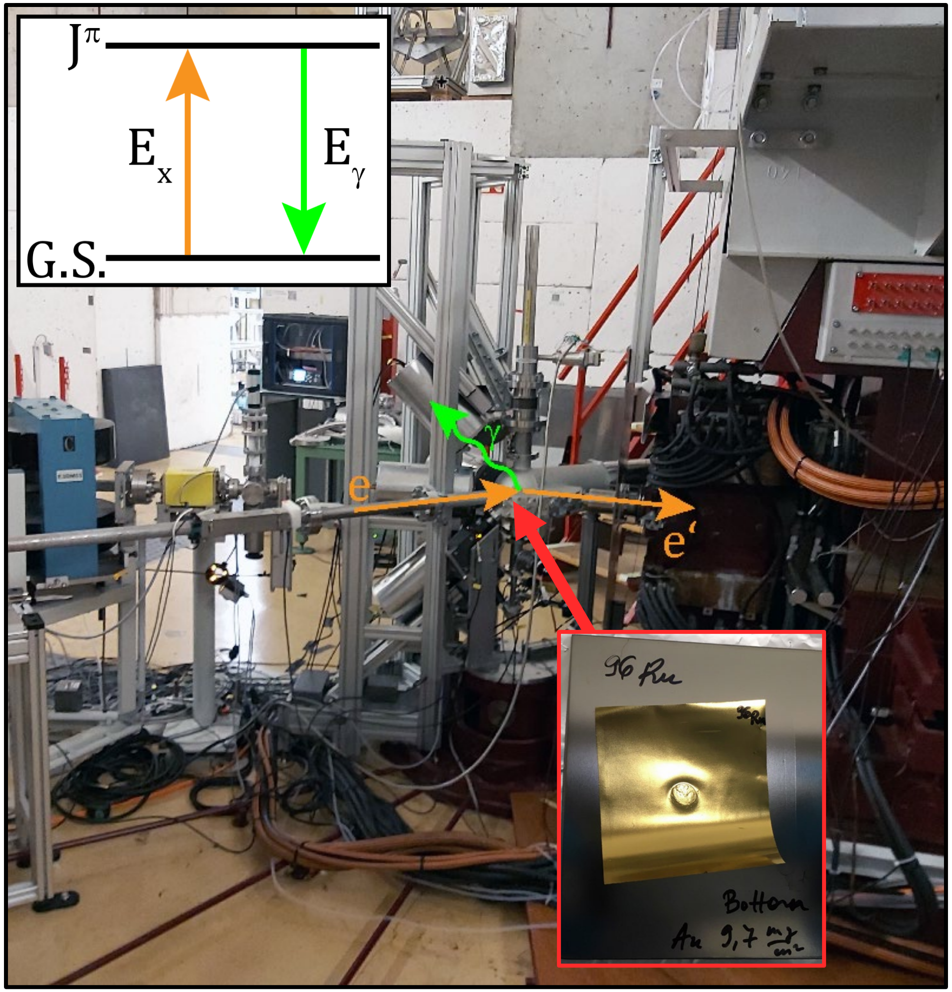
- Unique setup world-wide
  - e^- spectrometer: QCLAM
  - γ detectors: 6x $LaBr_3$:Ce
- Inelastic nuclear excitation and prompt γ-decay
- Pure EM interaction
- Exclusive reaction
- Sensitive to interference of F_L / F_T as function of θ_γ



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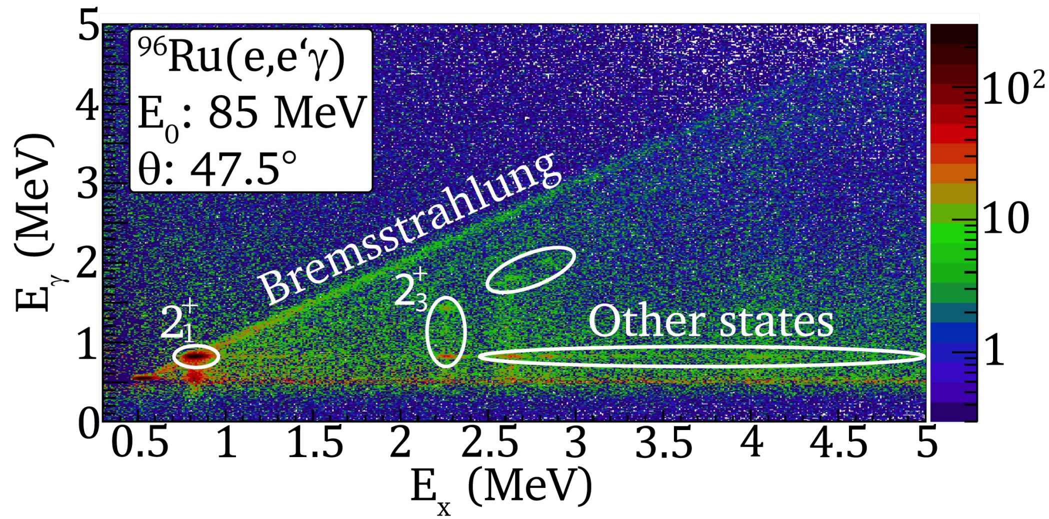
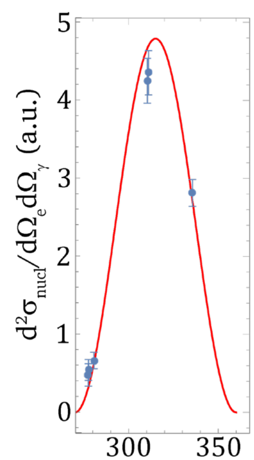
(e,e‘γ) @ S-DALINAC: First Data

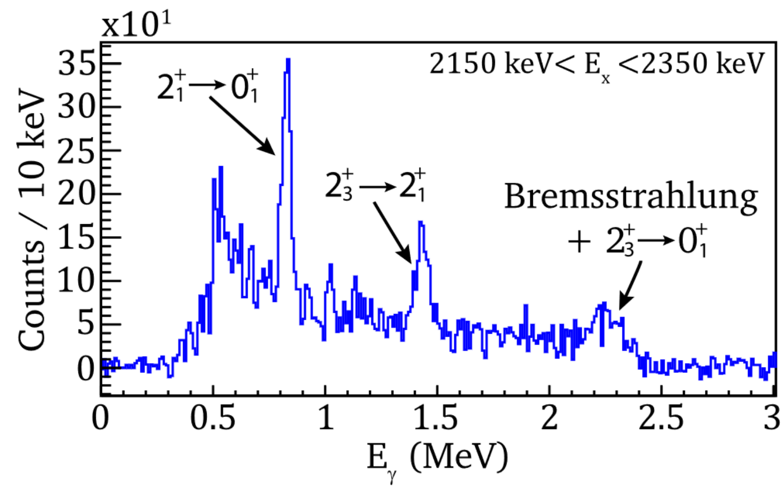
(G. Steinhilber, PhD thesis, 2022)

TECHNISCHE UNIVERSITÄT DARMSTADT

- First ^{96}Ru(e,e‘γ) production run in 2021
- First open-shell nucleus investigated in (e,e’γ)
- Measured:
    - New spectroscopic features (4 MeV entry)
    - Branching ratios $I(2_3^+ \rightarrow 0_1^+) = 7.3(45)\%$
    - Pronounced angular distribution of 2_1^+state







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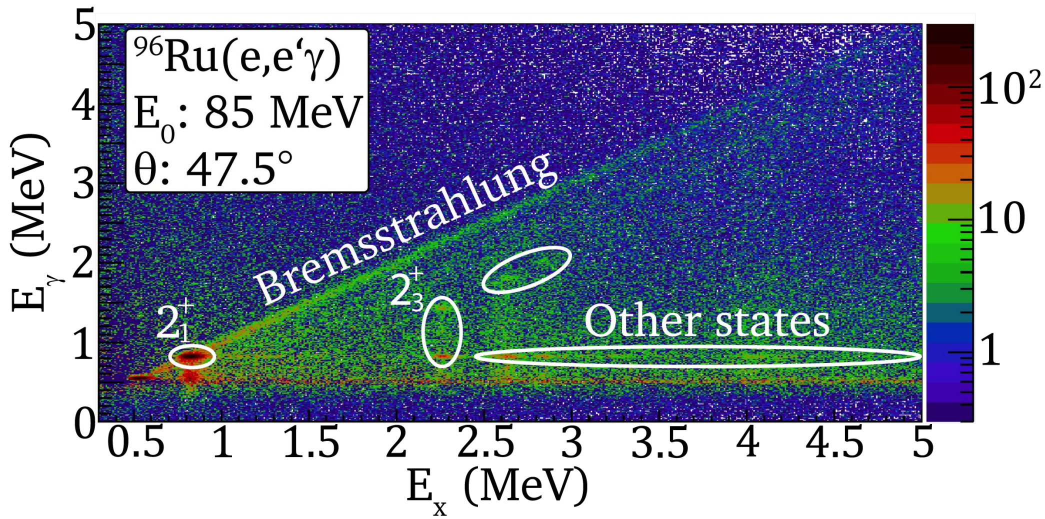
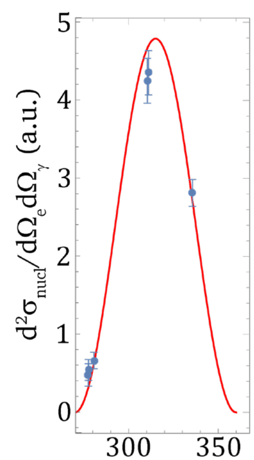
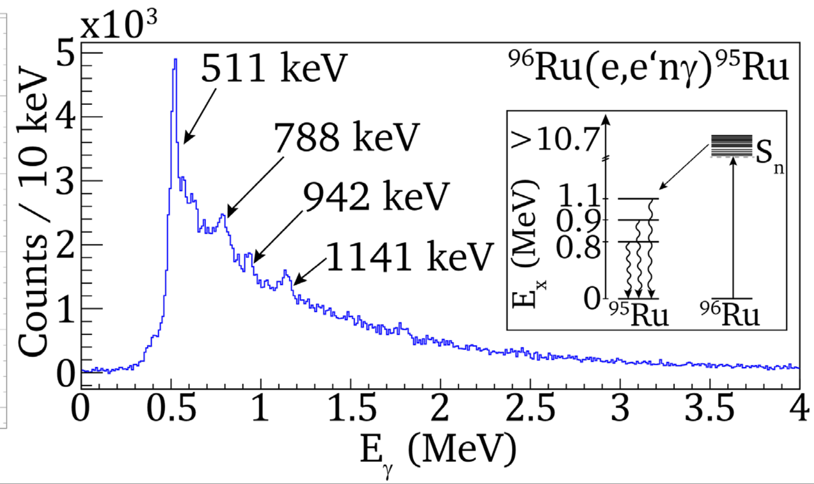
- First open-shell nucleus investigated in (e,e’γ)
- Measured:
  - New spectroscopic features
  - ^{96}Ru(e,e‘nγ)^{95}Ru
  - prompt γ‘s from entry levels from GDR decay
  - new opportunities!







S-DALINAC Upgrades within ELEMENTS

Beam spot of about 100 µm (3σ), stabilized: **500 k€**

- Stabilization of RF-system (e.g. temperature), 3 GHz master oscillator
- Optimization of 6D emittance, streak camera station
- FUGG „SERAPHIC" approved by Res.Dept. → DFG

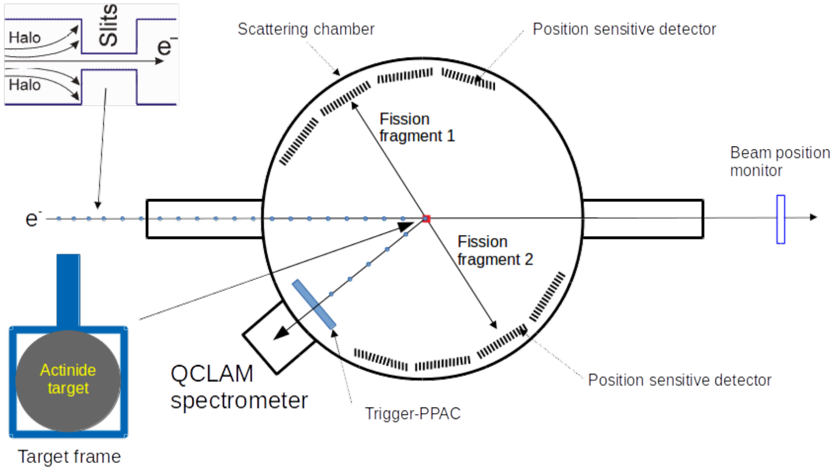
(A. Brauch et al.)

E.g.: Universal streak camera, Hamamatsu, 1 ps resolution

(e,e'f) setup @ QCLAM: **1300 k€**

- Complemented by 650 k€ FUGG, DFG → 1,300 k€ in total
- Fission chamber incl. goniometer (80 k€)
- Detectors (bunch and fragment identification) (1,220 k€)

(G. Steinhilber et al.)



Thank you for your attention!

Picture: Jan-Christoph Hartung