Experimental techniques for in-ring reaction studies with EXL

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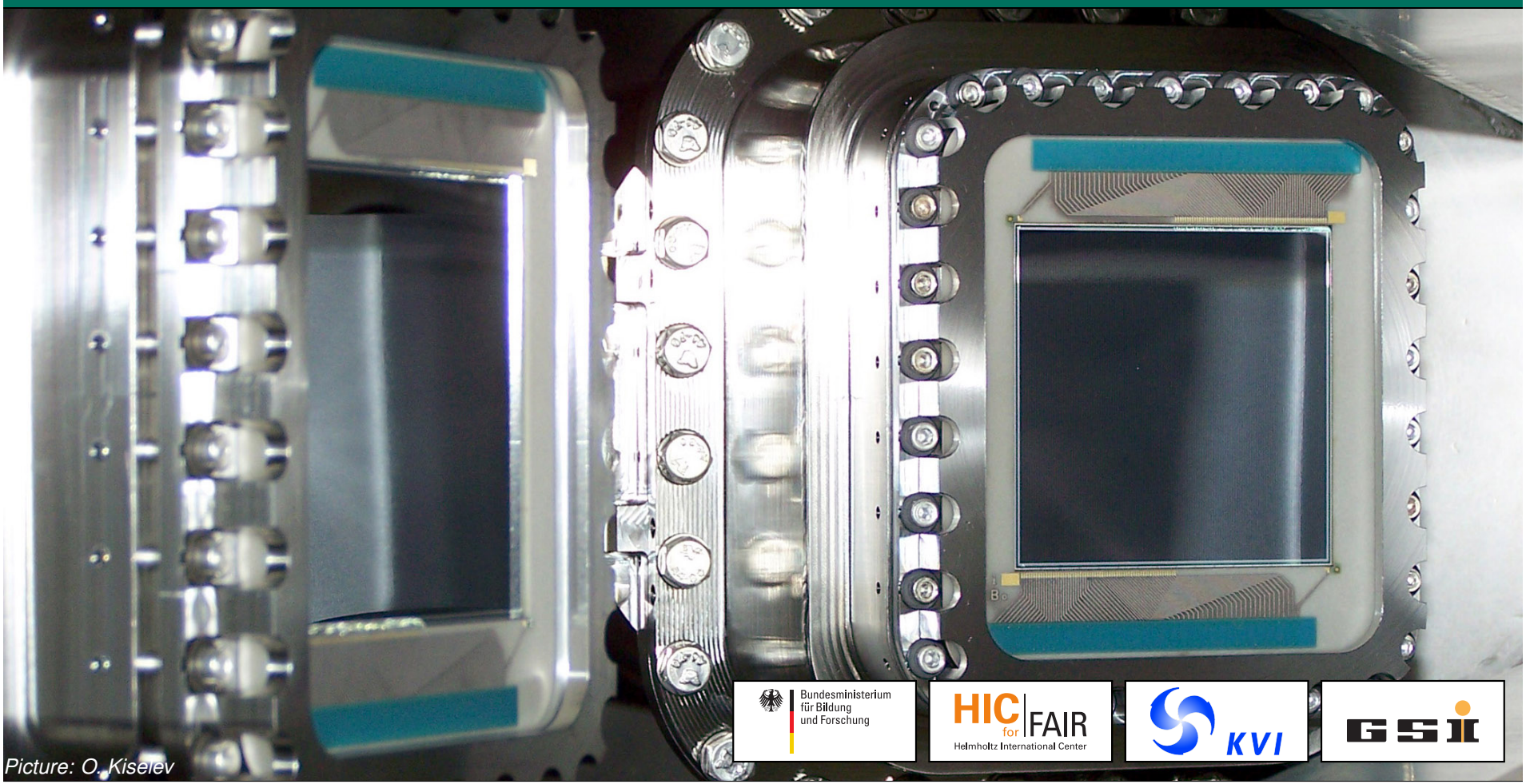
Mirko von Schmid for the EXL collaboration



Picture: O. Kiselev

The EXL project

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- "**EX**otic nuclei studied in **L**ight-ion induced reactions at storage rings"
- **Direct reactions** of exotic beams in **inverse kinematics** on an internal gas-jet target
  - Measurements at very **low momentum transfer**
  - Kinematically complete measurement

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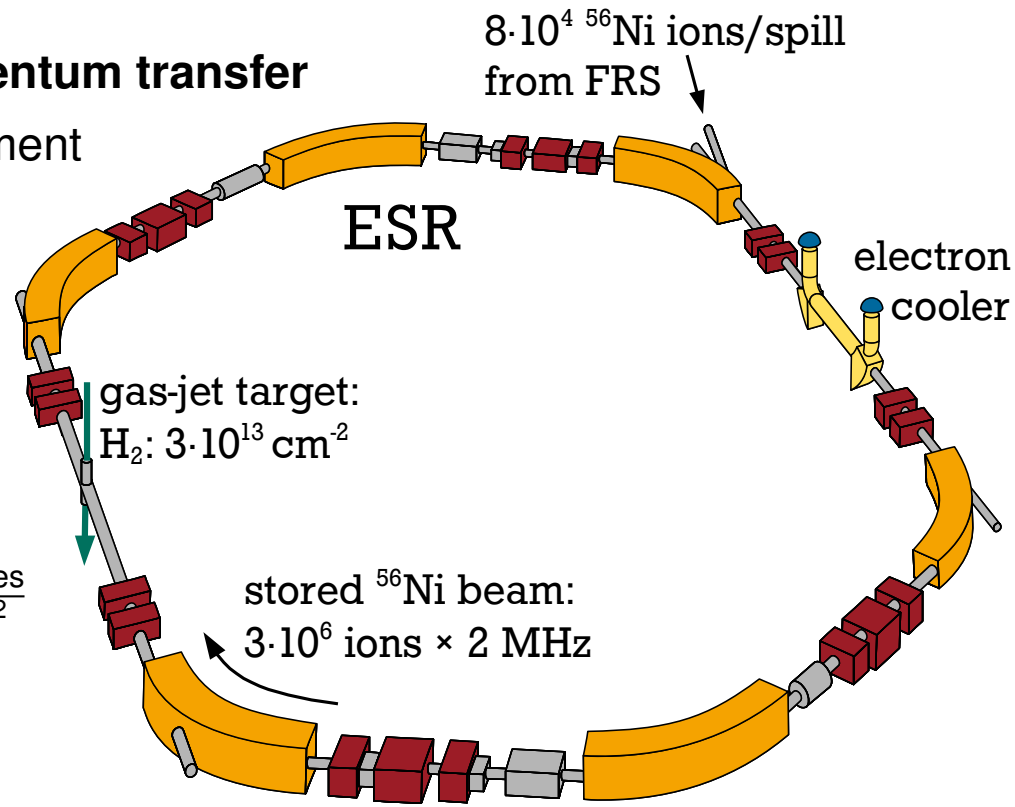
- **Direct reactions** of exotic beams in **inverse kinematics** on an internal gas-jet target
  - Measurements at very **low momentum transfer**
  - Kinematically complete measurement
- First EXL experiment with radio-active beam at the ESR, GSI:
  - ^{20}Ne, ^{58}Ni and **^{56}Ni** beams
  - ^{4}He and **H_2** gas-jet targets
  - ^{56}Ni(p,p) **luminosity**: $2 \cdot 10^{26}$ $\frac{\text{particles}}{\text{s cm}^2}$



Picture: Phys. Scr. T156 (2013) 014016

Experimental setup at the ESR

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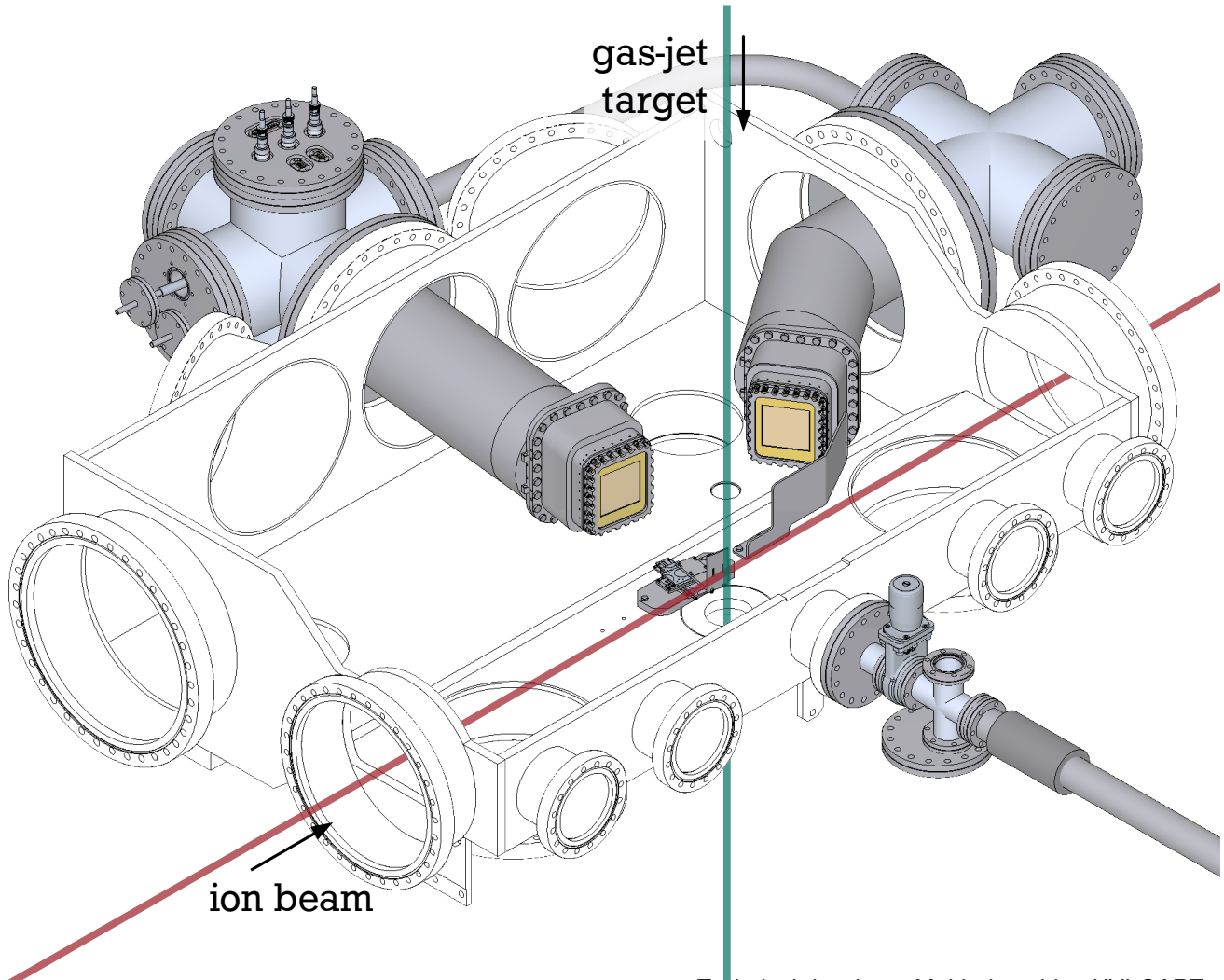

Technical drawings: M. Lindemulder, KVI-CART

Experimental setup at the ESR

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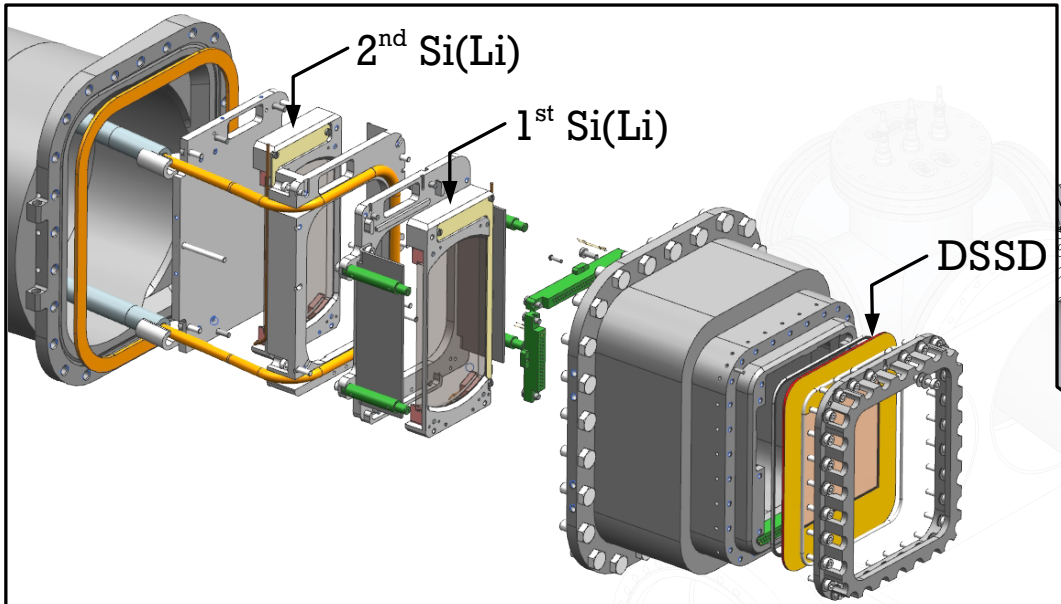
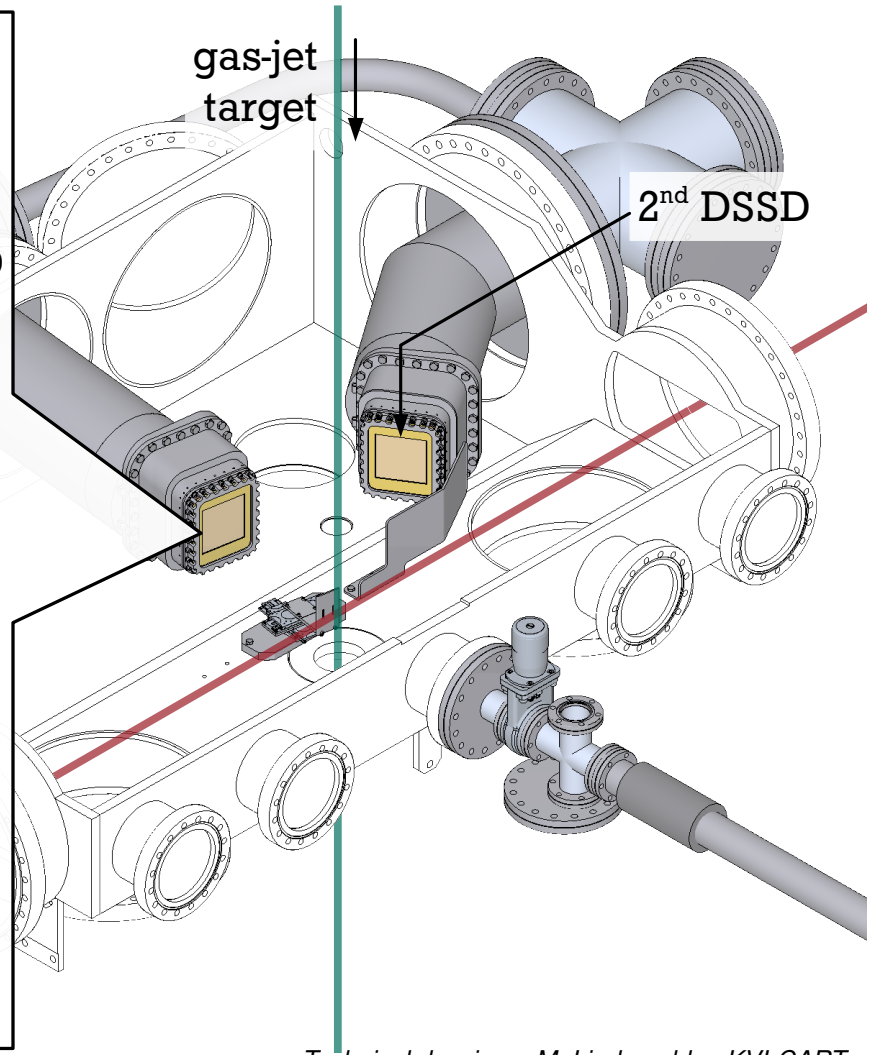


- **DSSD**: 128 × 64 strips, (6 × 6) cm^2, 285 μm thick
- **Si(Li)**: 8 pads, (8 × 4) cm^2, 6.5 mm thick
- **Active vacuum barrier**
  B. Streicher et al., Nucl. Instr. and Meth. A 654, 604 (2011).



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Experimental setup at the ESR

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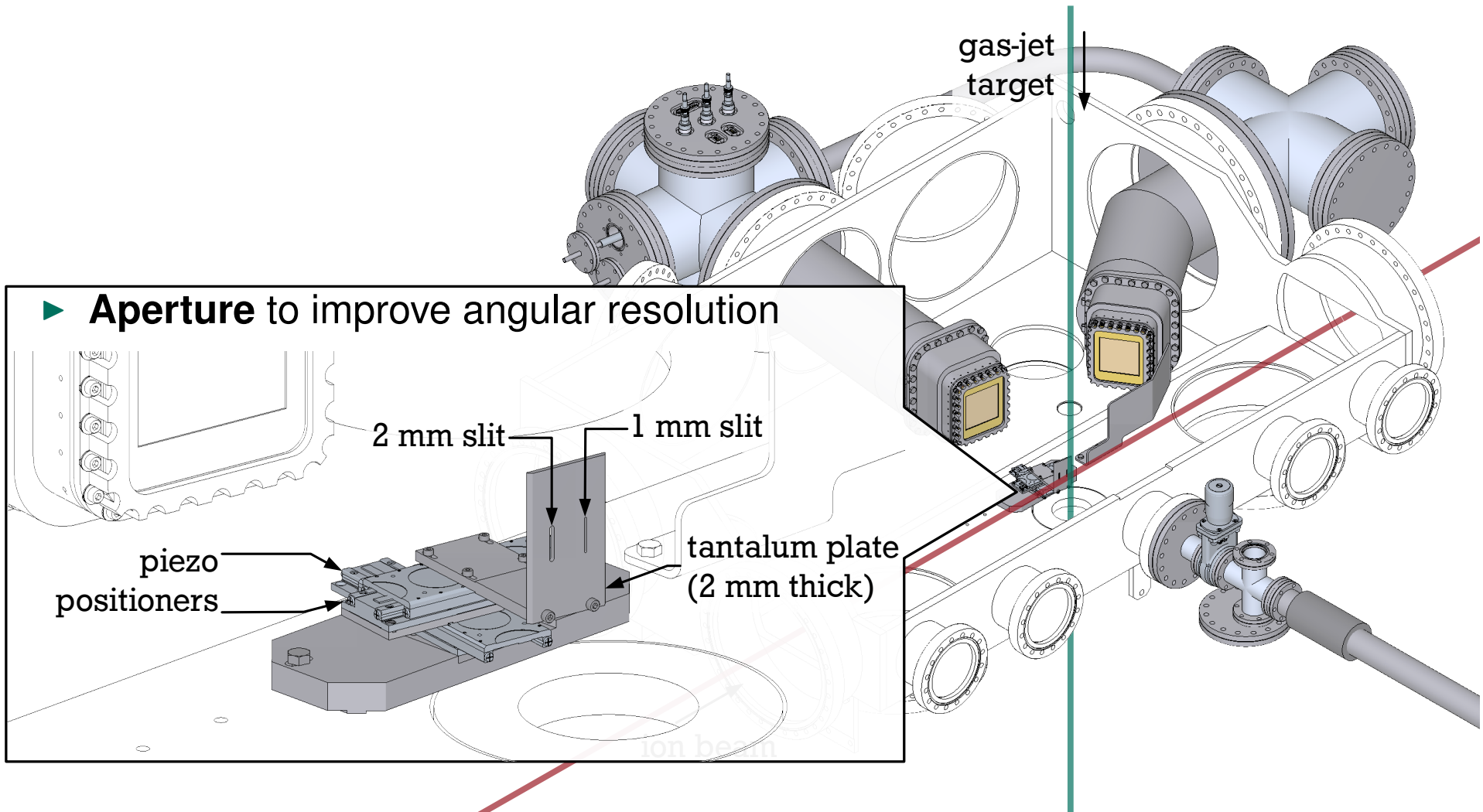

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DSSDs for EXL
“Compensated” Window Design

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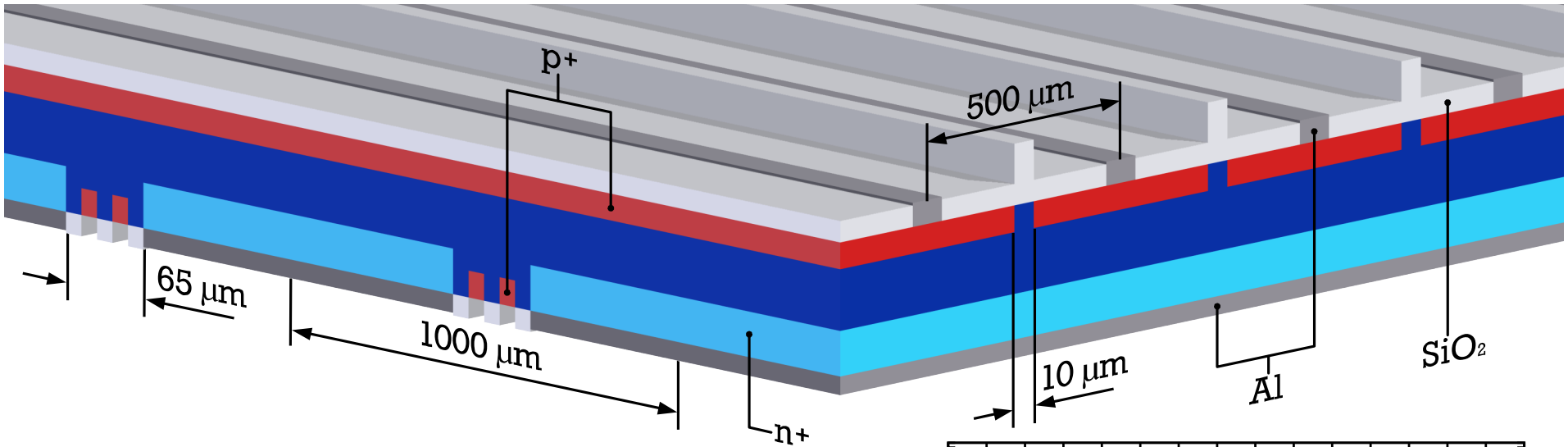
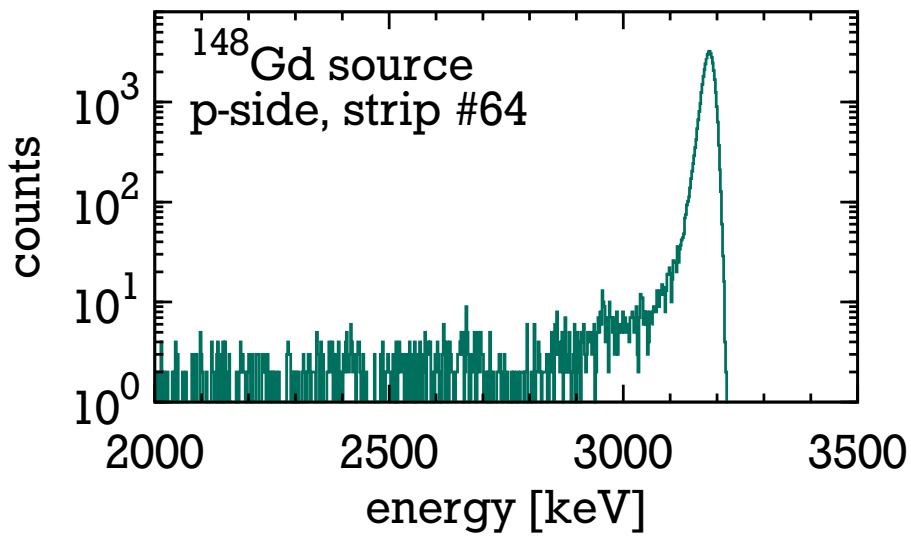


- Thin-window design:
  - p^+-implant on p-side: 500 Å thick
  - Al metallization: 600 Å thick
  - thin SiO_2 layer: 500 Å thick
- Compensation of different energy losses for low-energy particles



DSSDs for EXL
UHV Compatible PCB and Readout

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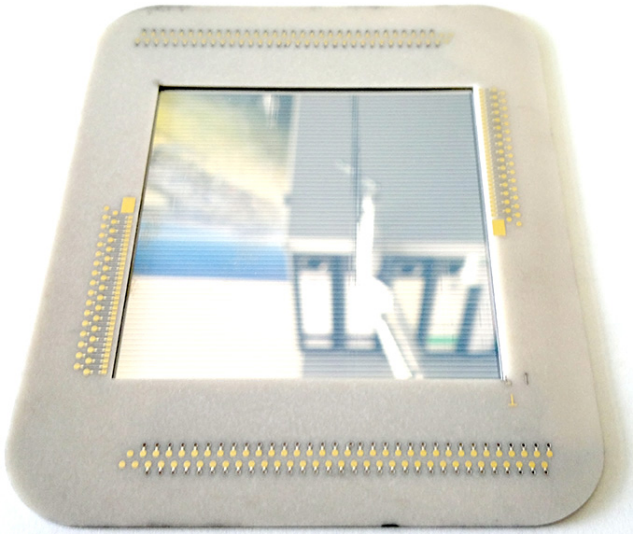
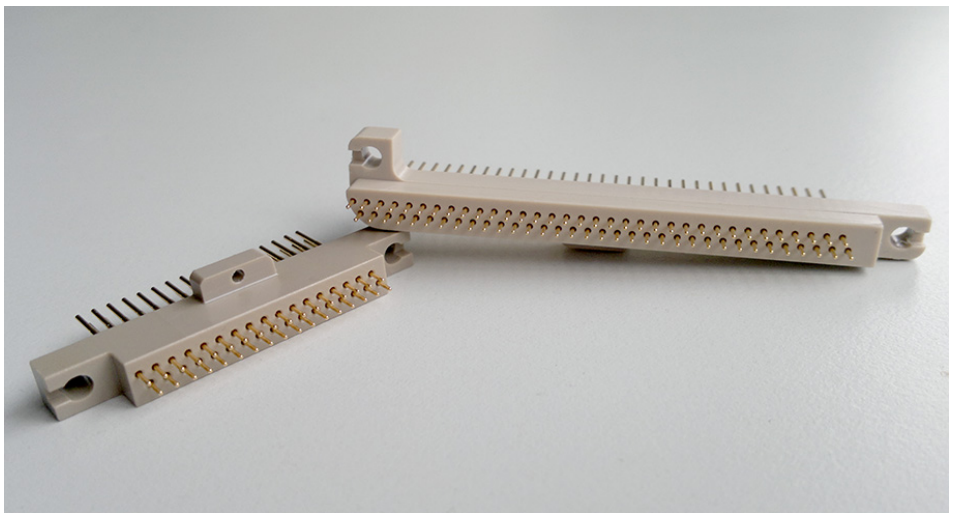
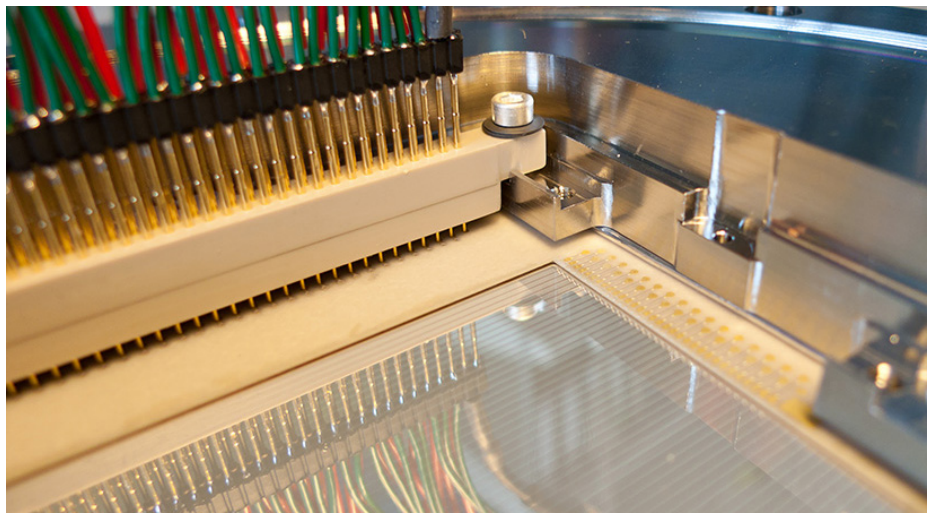
- DSSD on AlN PCB
  - “clean“ UHV side with sealed feedthroughs; no soldering, no connectors etc.
  - Readout of all 192 strips from the back side
- Reversible contacting via spring pins in custom made connector made of PEEK
  - heat resistant till 160°C at least







Vacuum concept

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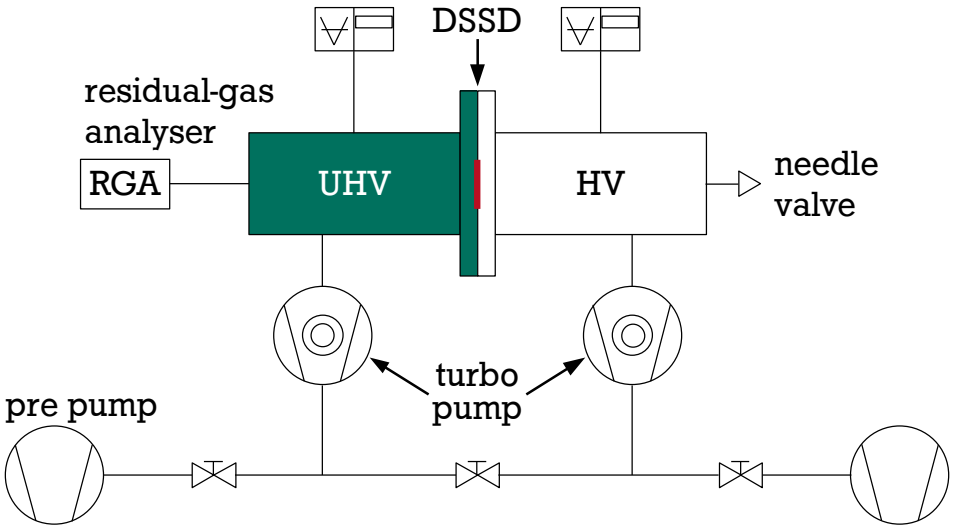

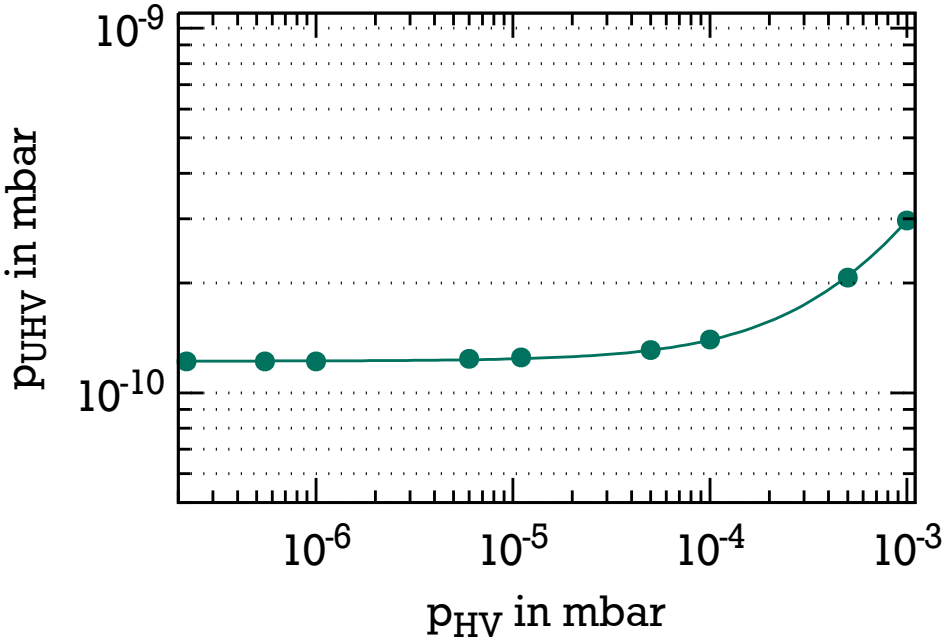

- First successful tests using $(2 \times 2)\,\mathrm{cm}^2$ DSSD prototype
- Artificial leak on HV side (needle valve)
- Vacuum separation by 6 orders of magnitude difference achieved

B. Streicher et al., Nucl. Instr. and Meth. A 654, 604 (2011)

Elastic proton scattering
^{56}Ni(p,p) at 390 MeV/u

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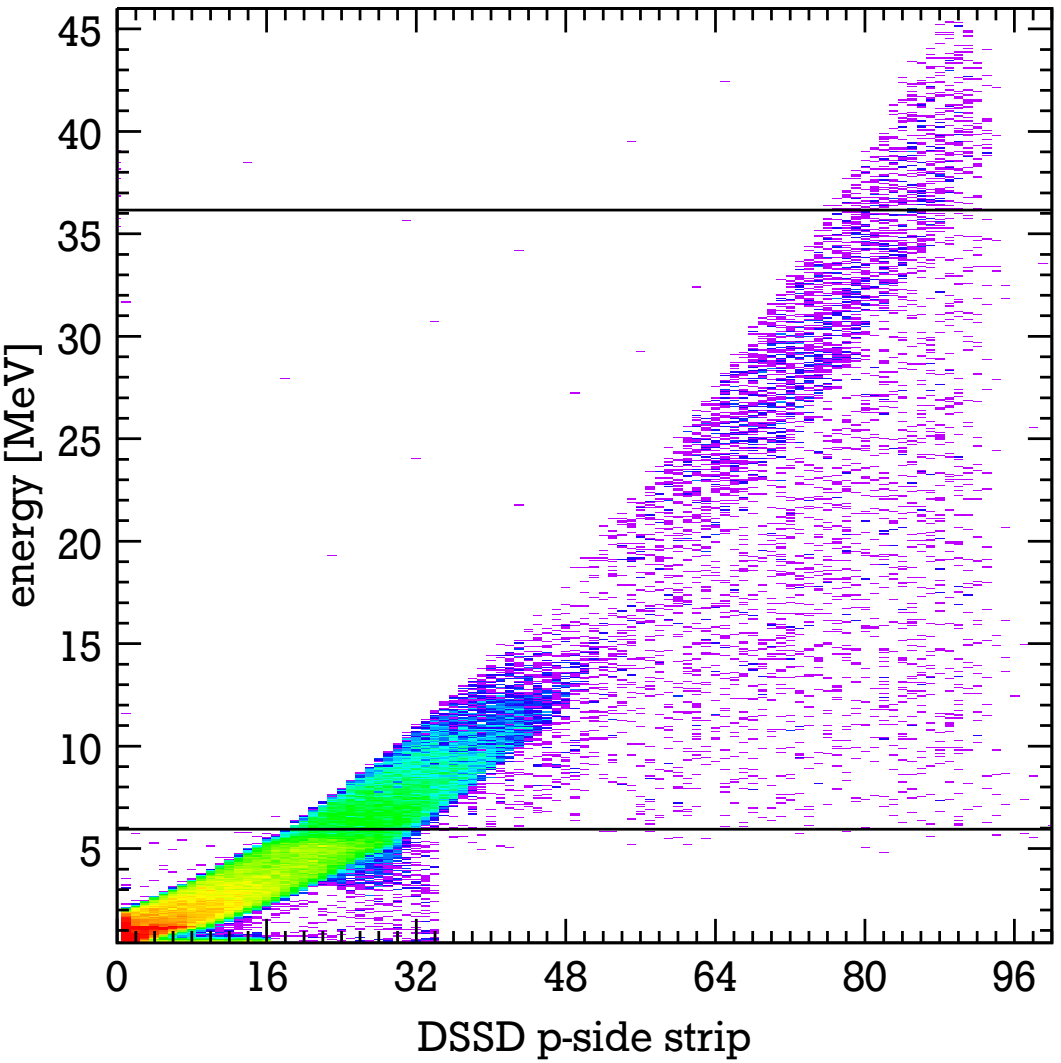

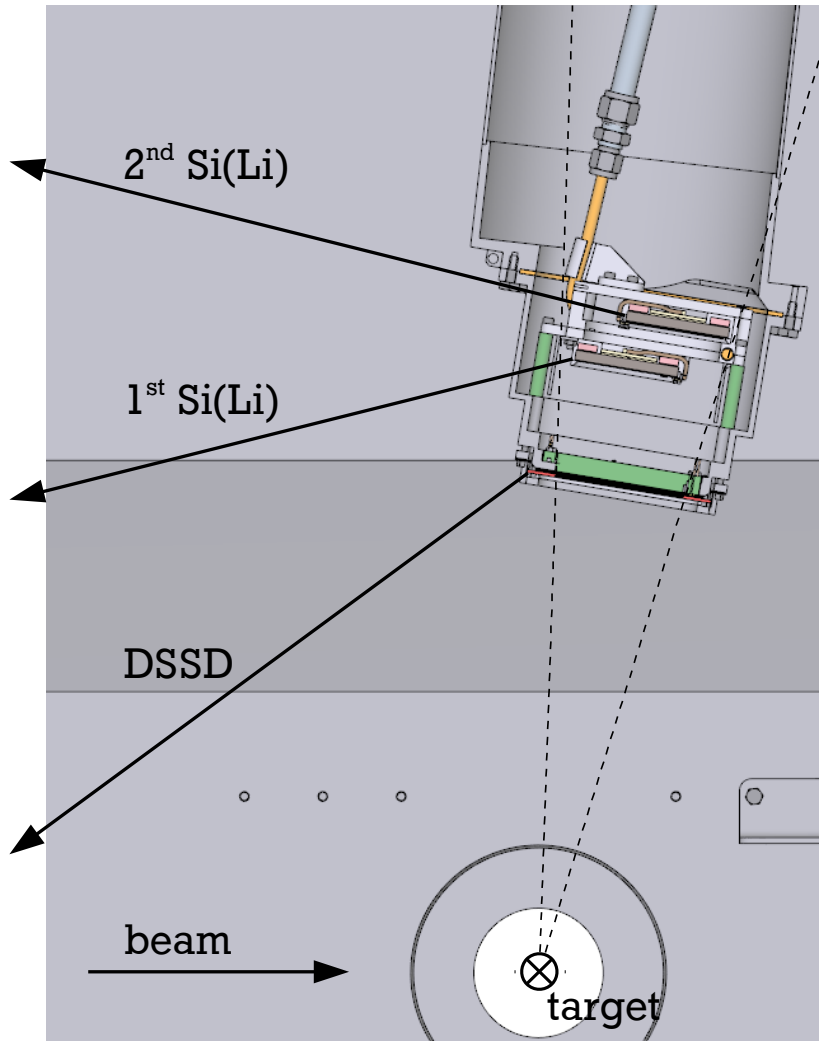

Technical drawings: M. Lindemulder, KVI-CART

Elastic proton scattering
^{56}Ni(p,p) at 390 MeV/u with 1 mm aperture

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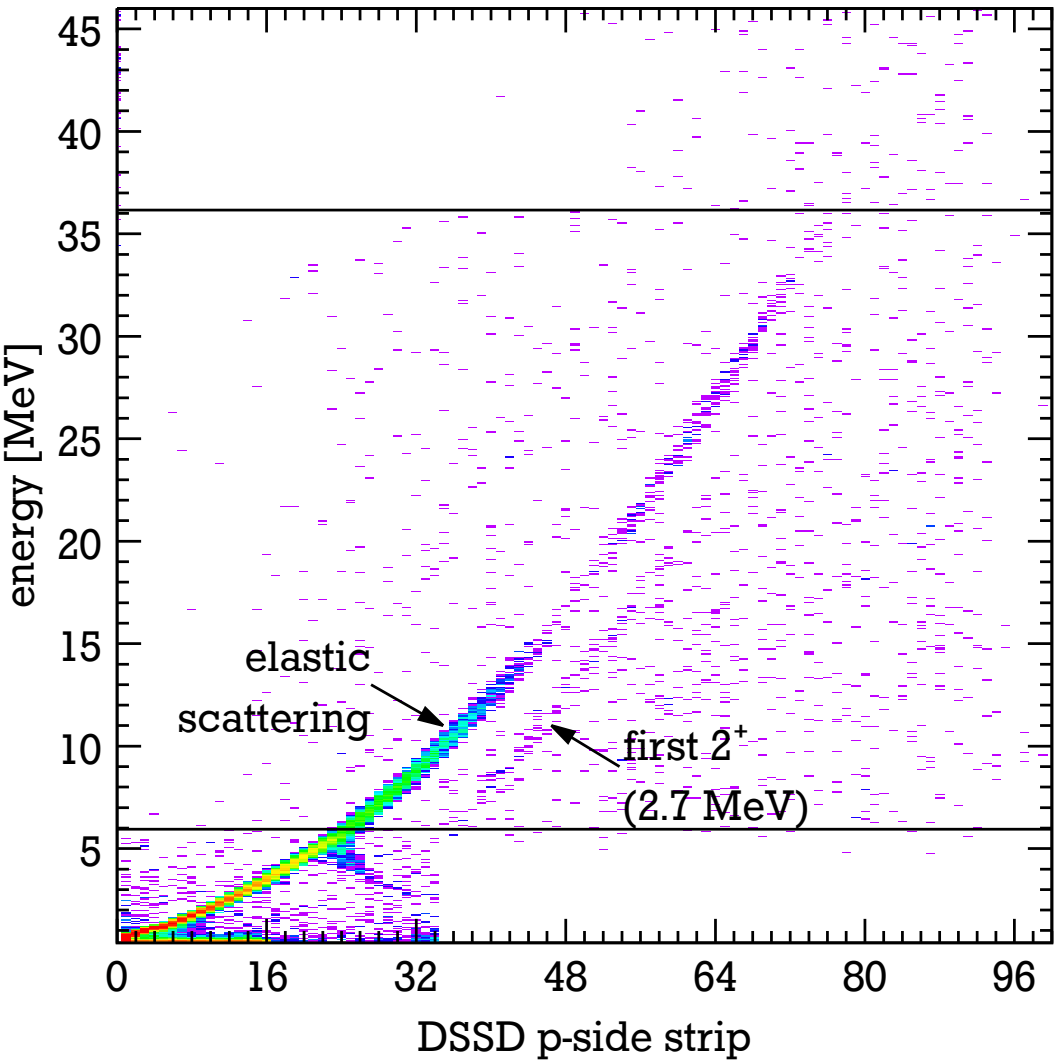

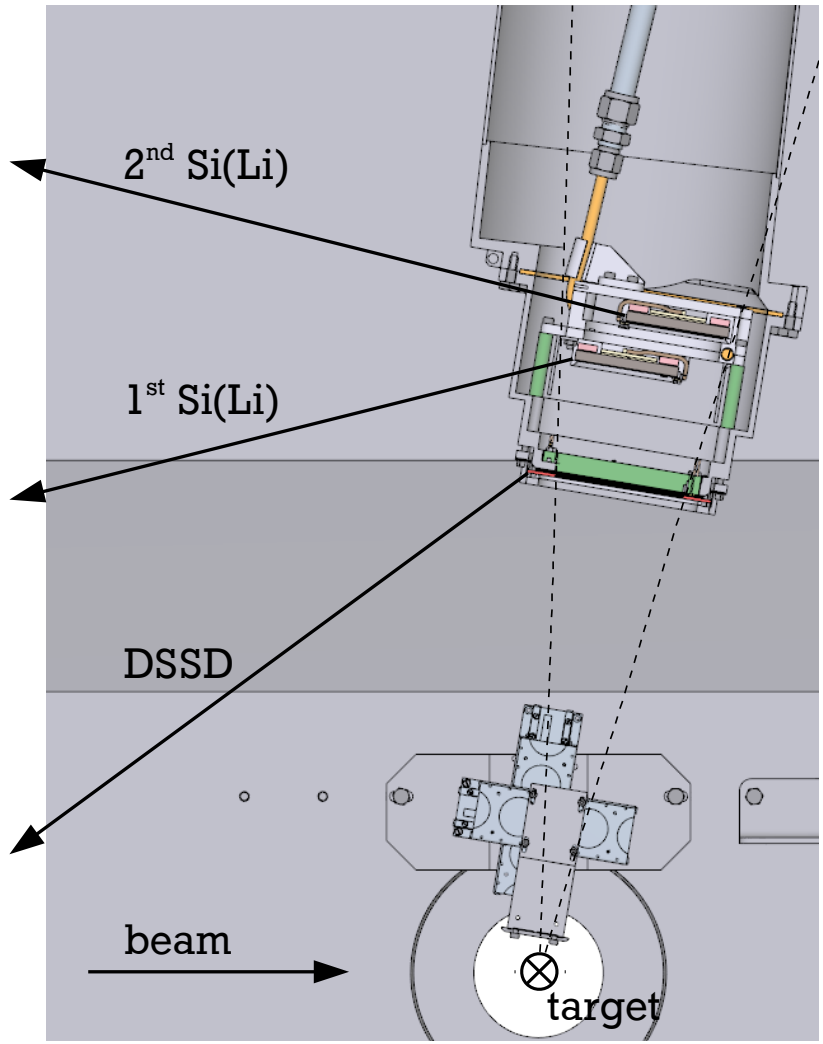

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Data taken with the 2nd DSSD

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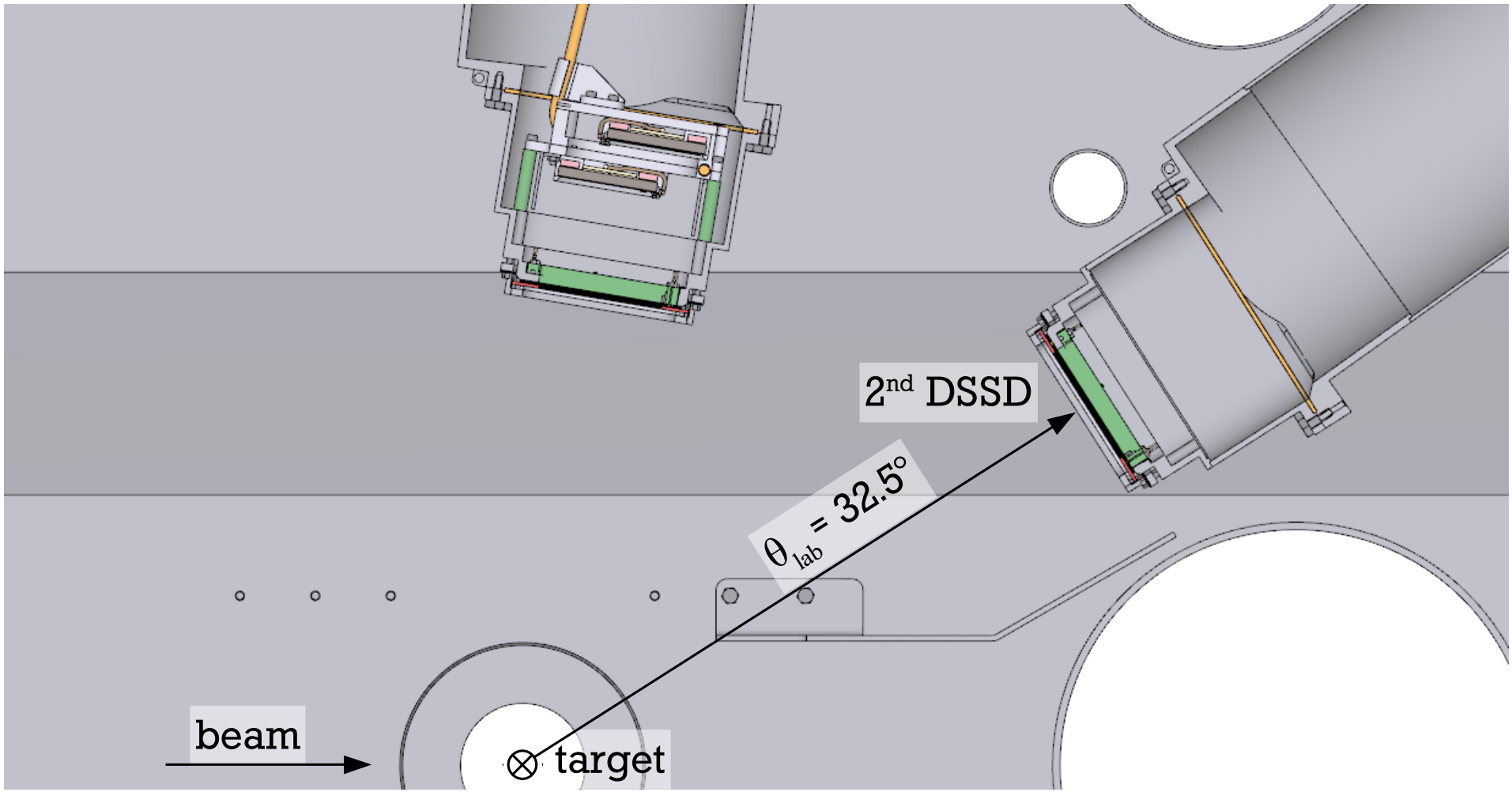

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Inelastic alpha scattering
^{58}Ni(α, α') at 100 MeV/u

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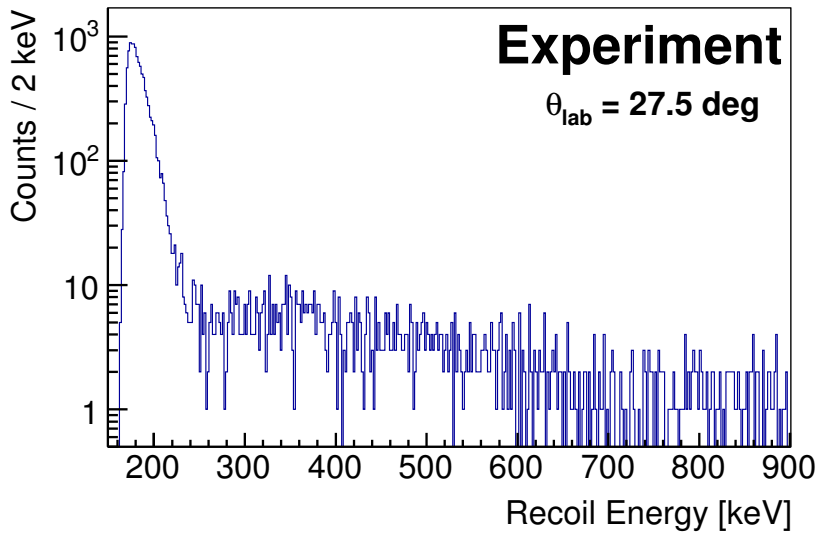

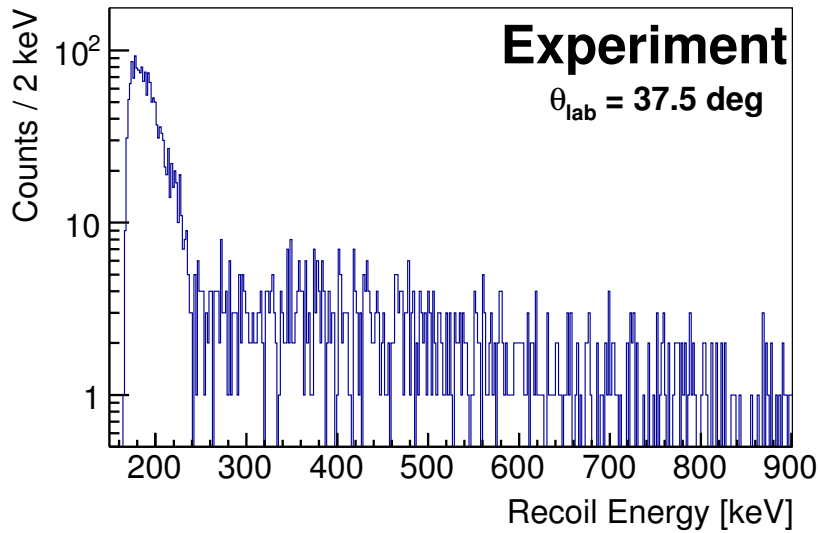

Analysis by J.C. Zamora, TU Darmstadt

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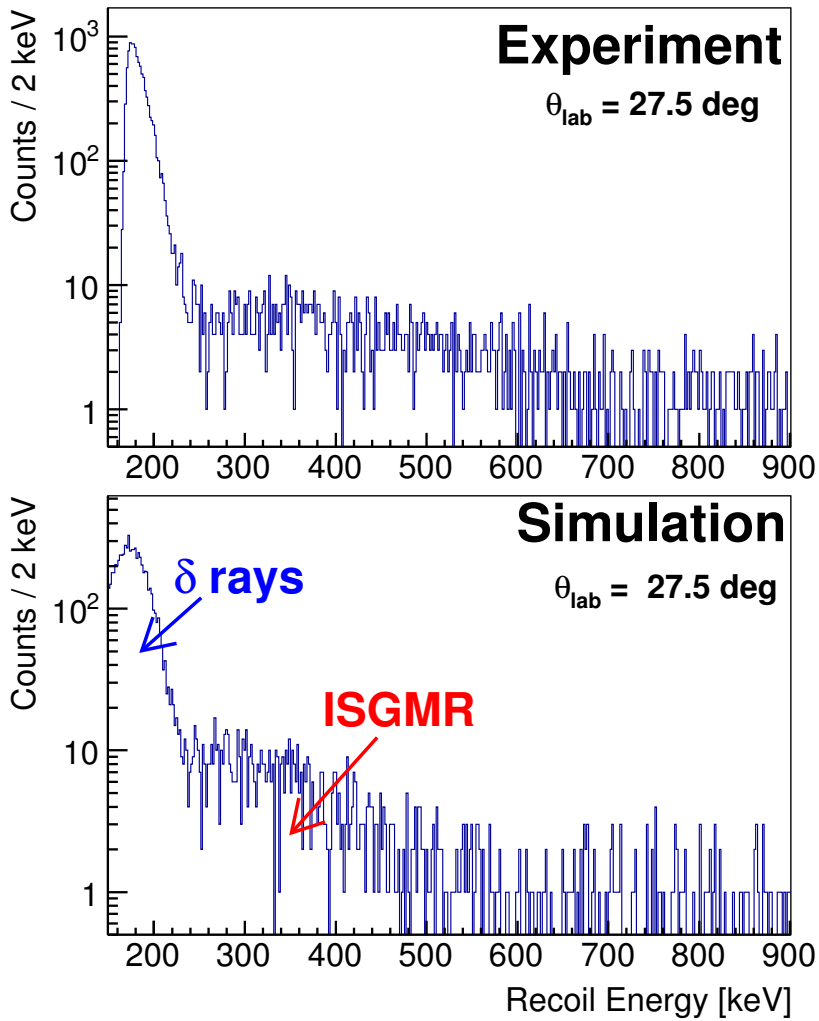

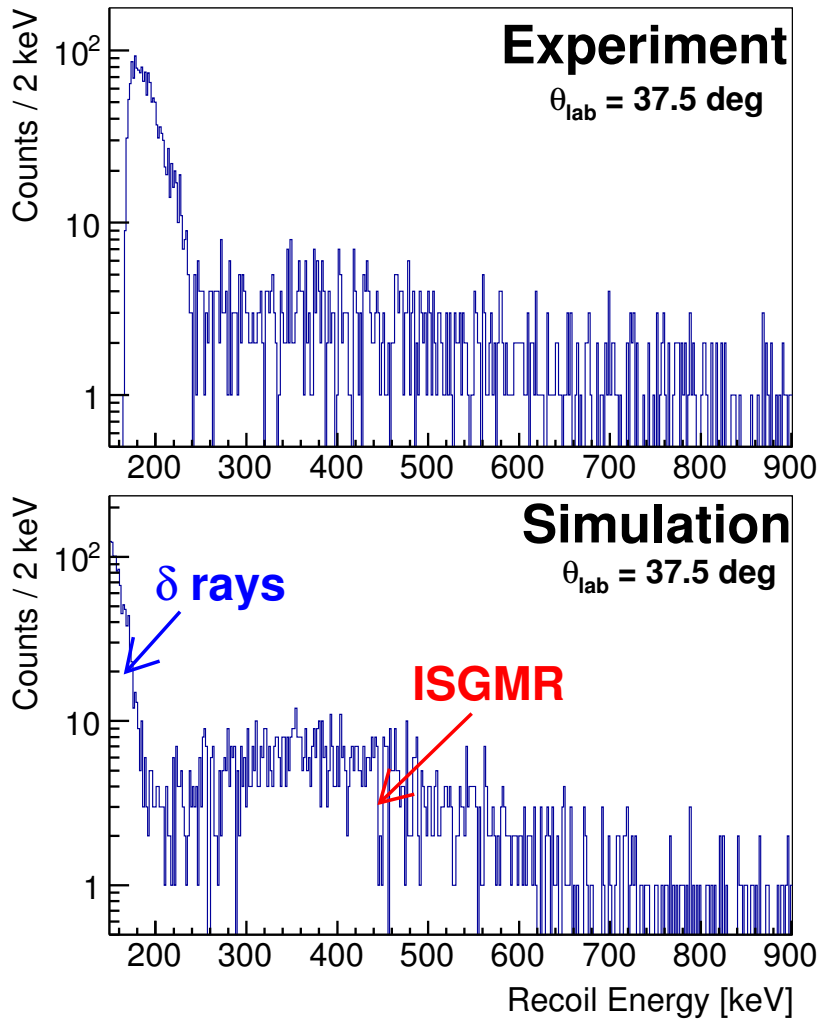

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Transfer reaction ^{20}Ne(p, d)^{19}Ne at 50 MeV/u

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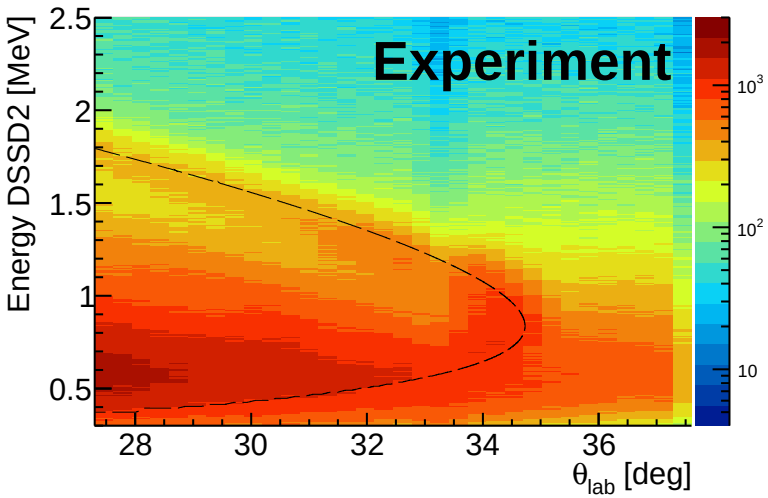

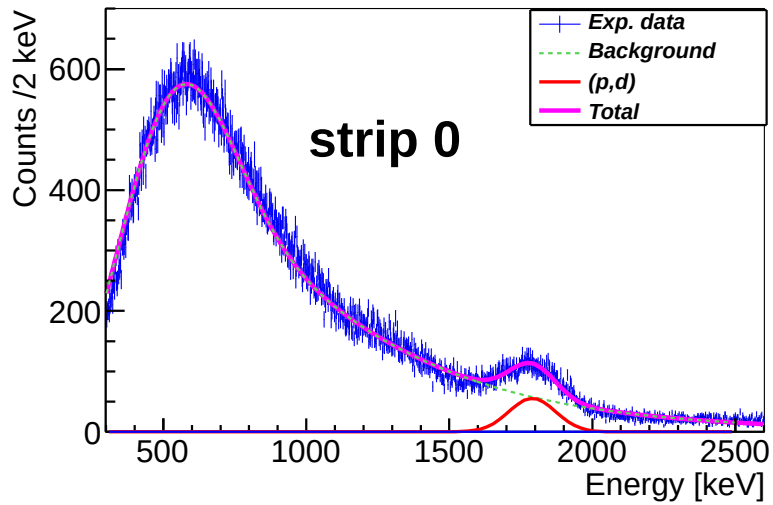

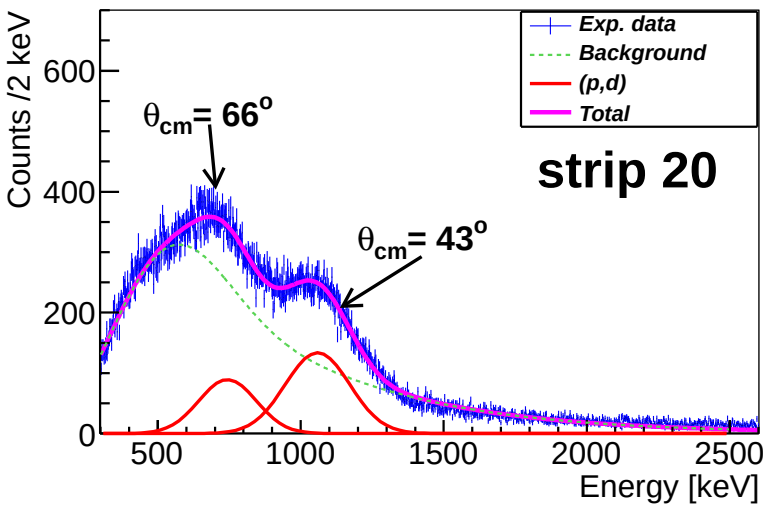

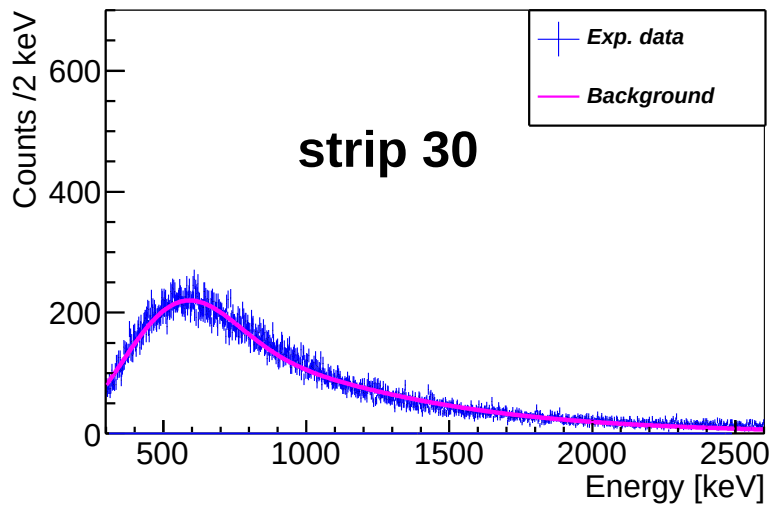

Analysis by J.C. Zamora, TU Darmstadt

Conclusion

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- First successful nuclear reaction experiment with stored exotic beams ever.
- Feasibility of EXL concept proven.
  - Principle of vacuum separation works.
  - Allows to study nuclear reactions with stored beams at low momentum transfer.

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  - Nuclear matter distribution and RMS radius of ^{56}Ni: $\left\langle r_m^2 \right\rangle^{1/2} = (3.76 \pm 0.08)\,\mathrm{fm}$

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- Successfully demonstrated the possibility to study giant resonances and transfer reactions with EXL.

Outlook

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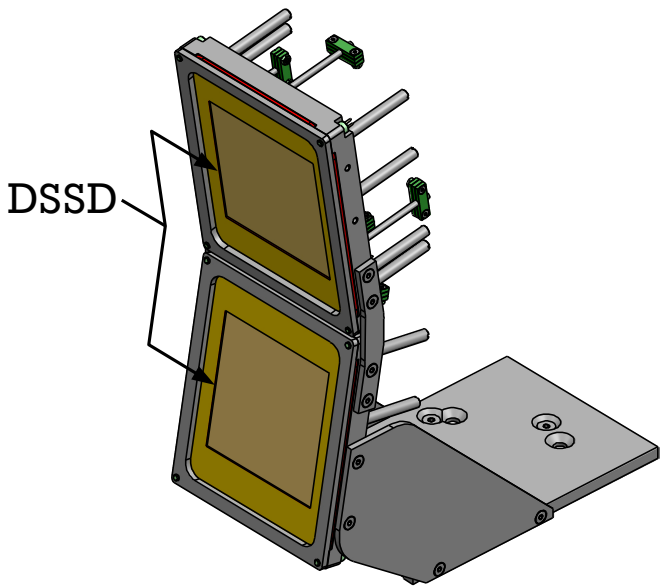
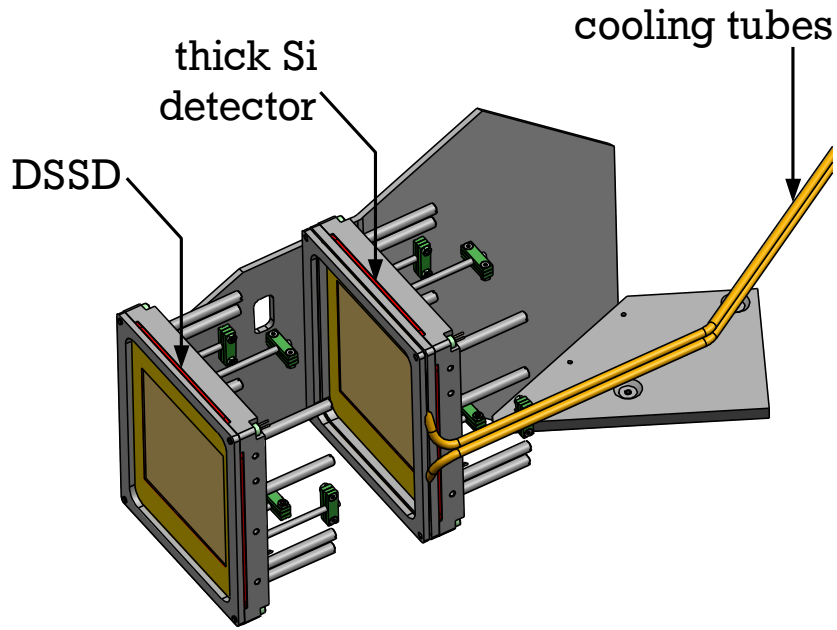
- Upgraded detector setup covering a substantially larger solid angle is planed.
  - Detectors placed directly in the UHV.





- Future experiments envisaged at GSI and at FAIR using CRYRING, ESR and HESR.

Technical drawings: M. Lindemulder, KVI-CART

Thank you for your attention

S. Bagchi[1], S. Bönig[2], M. Csatlós[3], I. Dillmann[4], C. Dimopoulou[4], P. Egelhof[4], V. Eremin[5], T. Furuno[6], H. Geissel[4], R. Gernhäuser[7], M. N. Harakeh[1], A.-L. Hartig[2], S. Ilieva[2], N. Kalantar-Nayestanaki[1], O. Kiselev[4], H. Kollmus[4], C. Kozhuharov[4], A. Krasznahorkay[3], T. Kröll[2], M. Kuilman[1], S. Litvinov[4], Yu. A. Litvinov[4], M. Mahjour-Shafiei[1,8], M. Mutterer[4], D. Nagae[9], M.A. Najafi[1], C. Nociforo[4], F. Nolden[4], U. Popp[4], C. Rigollet[1], S. Roy[1], C. Scheidenberger[4], M. von Schmid[2], M. Steck[4], B. Streicher[2,4], L. Stuhl[3], M. Takechi[4], M. Thürauf[2], T. Uesaka[10], H. Weick[4], J. S. Winfield[4], D. Winters[4], P. J. Woods[11], T. Yamaguchi[12], K. Yue[2,4,13], J.C. Zamora[2], J. Zenihiro[10]

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