Experimental techniques for in-ring reaction studies with EXL

Mirko von Schmid for the EXL collaboration
The EXL project

- “EXotic nuclei studied in Light-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
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- First EXL experiment with radioactive beam at the ESR, GSI:
  - $^{20}$Ne, $^{58}$Ni and $^{56}$Ni beams
  - $^4$He and $^2$H gas-jet targets
  - $^{56}$Ni(p,p) **luminosity**: $2 \cdot 10^{26}$ particles s cm$^{-2}$

- $8 \cdot 10^4$ $^{56}$Ni ions/spill from FRS

**Picture:** Phys. Scr. T156 (2013) 014016
Experimental setup at the ESR

Technical drawings: M. Lindemulder, KVI-CART
Experimental setup at the ESR

- **DSSD**: 128 × 64 strips, (6 × 6) cm², 285 µm thick
- **Si(Li)**: 8 pads, (8 × 4) cm², 6.5 mm thick
- **Active vacuum barrier**
  
  *B. Streicher et al., Nucl. Instr. and Meth. A 654, 604 (2011).*
Experimental setup at the ESR

- Ion beam
- Gas-jet
- Target
- Tantalum plate (2 mm thick)
- 1 mm slit
- 2 mm slit
- Piezo positioners

Aperture to improve angular resolution

Technical drawings: M. Lindemulder, KVI-CART
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

- 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

First successful tests using (2 × 2) cm² 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

Technical drawings: M. Lindemulder, KVI-CART
Elastic proton scattering
$^{56}\text{Ni(p,p)}$ at 390 MeV/u with 1 mm aperture
Data taken with the 2\textsuperscript{nd} DSSD

$\theta_{\text{lab}} = 32.5^\circ$

Technical drawings: M. Lindemulder, KVI-CART
Inelastic alpha scattering
$^{58}\text{Ni}(\alpha, \alpha')$ at 100 MeV/u

Analysis by J.C. Zamora, TU Darmstadt
Inelastic alpha scattering
$^{58}\text{Ni}(\alpha, \alpha')$ at 100 MeV/u

Experiment
$\theta_{\text{lab}} = 27.5 \text{ deg}$

Simulation
$\theta_{\text{lab}} = 27.5 \text{ deg}$

Experiment
$\theta_{\text{lab}} = 37.5 \text{ deg}$

Simulation
$\theta_{\text{lab}} = 37.5 \text{ deg}$

Analysis by J.C. Zamora, TU Darmstadt
Transfer reaction $^{20}\text{Ne}(p, d)^{19}\text{Ne}$ at 50 MeV/u

Analysis by J.C. Zamora, TU Darmstadt
Conclusion

- 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.

- Differential cross section of $^{56}$Ni(p,p) measured for the first time.

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

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

- Upgraded detector setup covering a substantially larger solid angle is planned.
  - 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

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