

Status of the EXL Project (Preliminary results from E105 Experiment)



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February 21th, 2014



Federal Ministry
of Education
and Research



Outline

Motivation

Experiment

Examples of Data Correction

Some Preliminary Results

Summary

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Examples of Data Correction

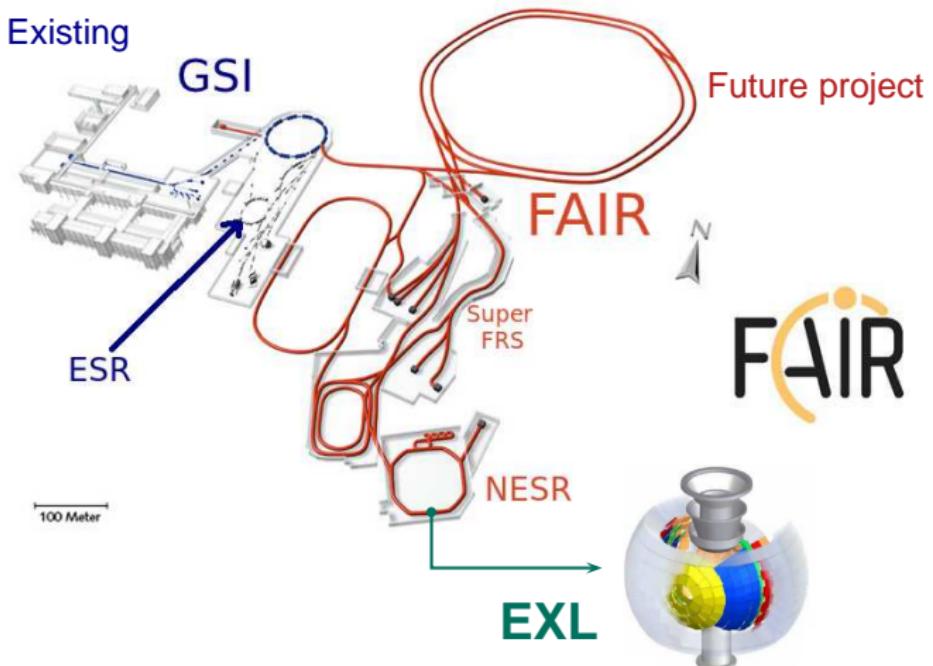
Some Preliminary Results

Summary

The Future International Facility at GSI: FAIR - Facility for Antiproton and Ion Research



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EXL: EXotic nuclei studied in Light ion induced reactions at the NESR storage ring

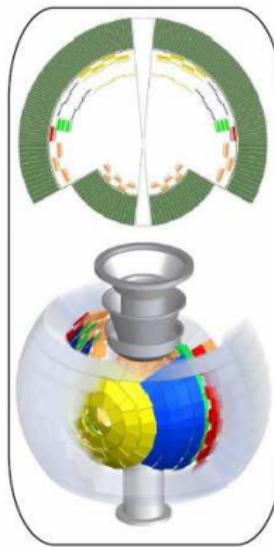


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FAIR

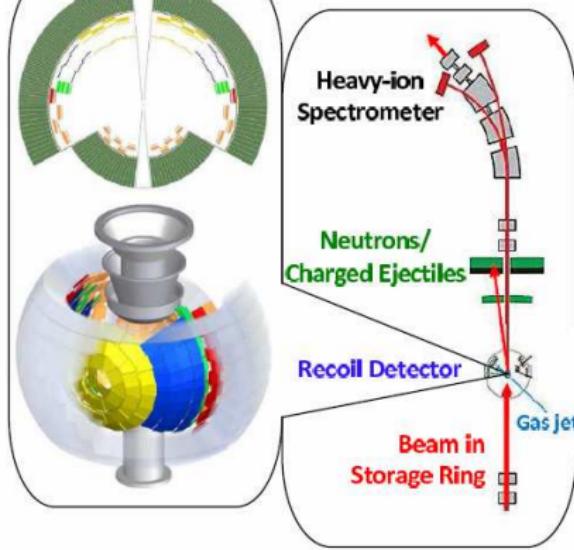
▶ ESPA

Silicon array



▶ EGPA

Scintillators array



NESR

eA-Collider

RIB from the
Super FRS

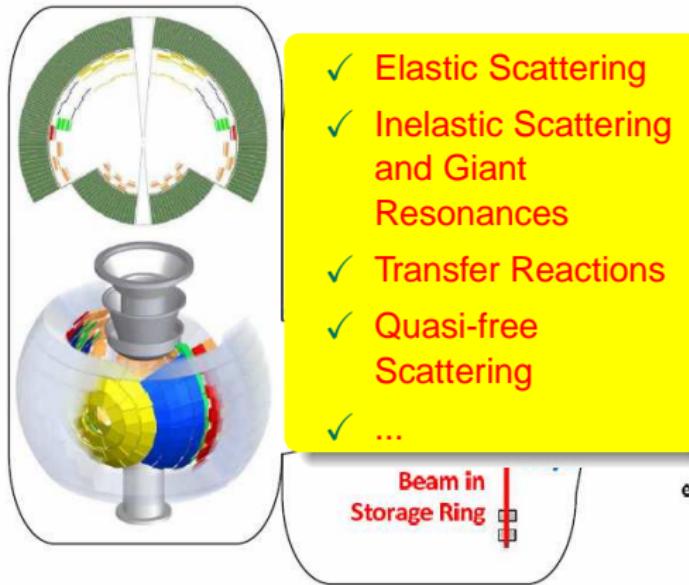
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▶ ESPA

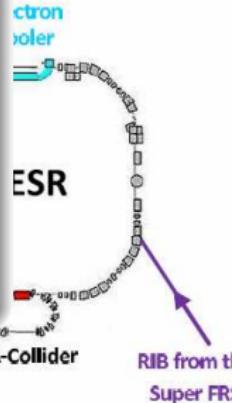
Silicon array



▶ EGPA

Scintillators array

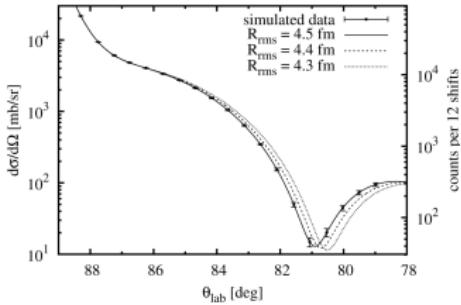
FAIR



... A year ago: Experiments with Stable and Unstable Beams @ ESR

Matter distribution

$^{56}\text{Ni} + p$



Stable beam

$^{58}\text{Ni}(p, p), (p, p')$
 $(\alpha, \alpha), (\alpha, \alpha')$

Doubly-magic nucleus

$^{56}\text{Ni}(p, p), (p, p')$

Giant Resonances

(α, α')

ISGMR ($T=0, L=0$)



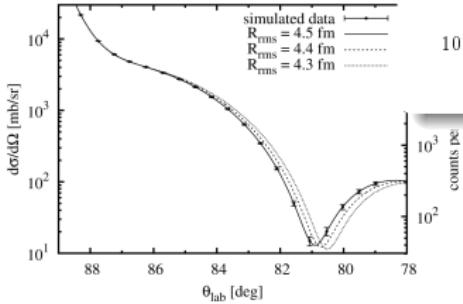
ISGDR ($T=0, L=1$)



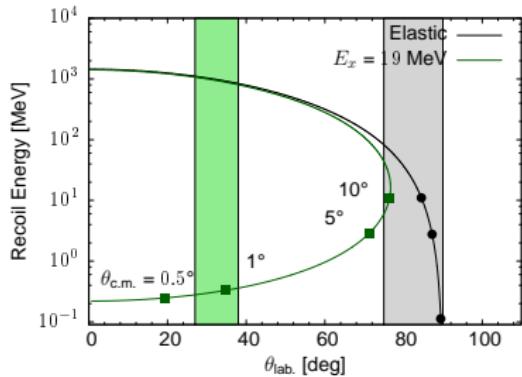
... A year ago: Experiments with Stable and Unstable Beams @ ESR

Matter distribution

$^{56}\text{Ni} + p$



Inverse Kinematics: $\alpha(^{58}\text{Ni}, \alpha')$



Giant Resonances

(α, α')
iMR ($T=0, L=0$)



1sGDR ($T=0, L=1$)



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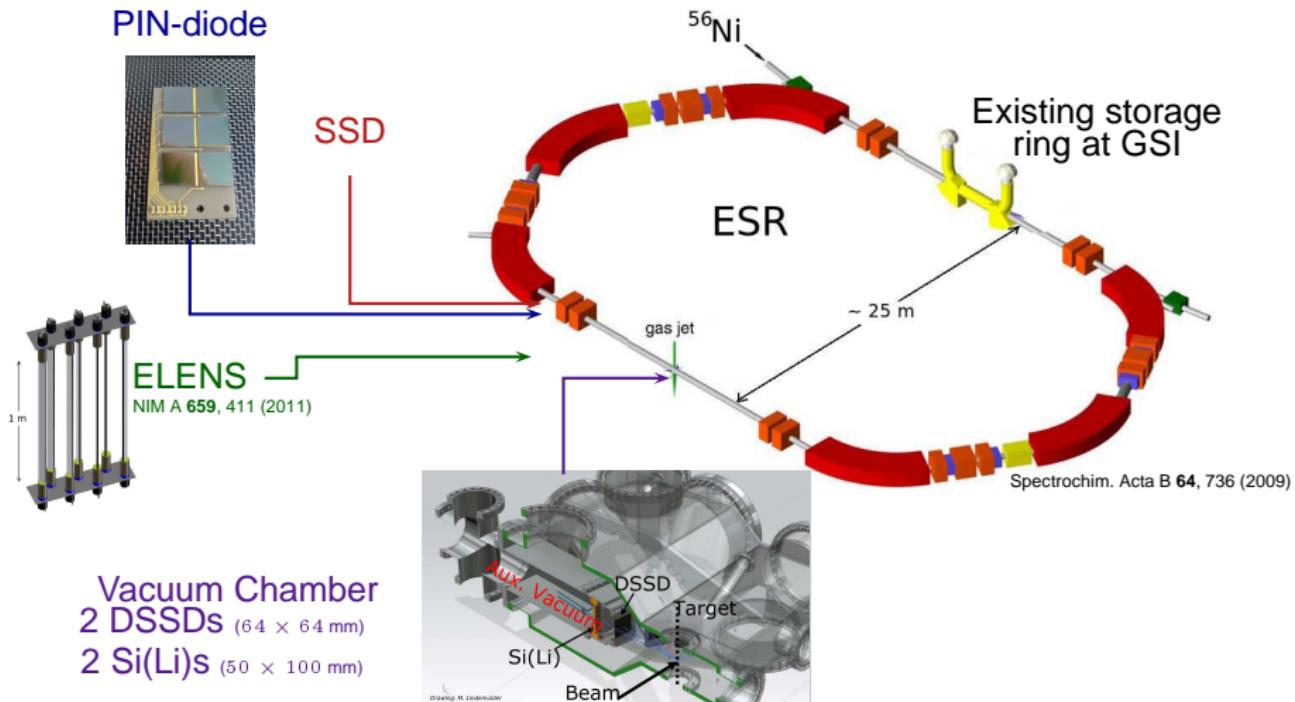
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Setup



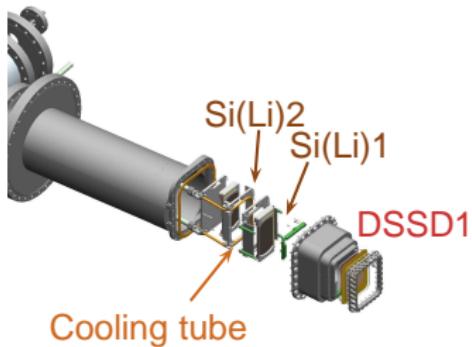
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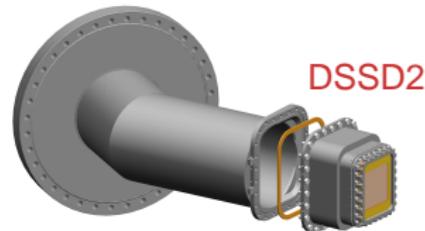
Vacuum Chamber and Bakeout



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- ✓ UHV compatible elements
- ✓ DSSDs are active windows

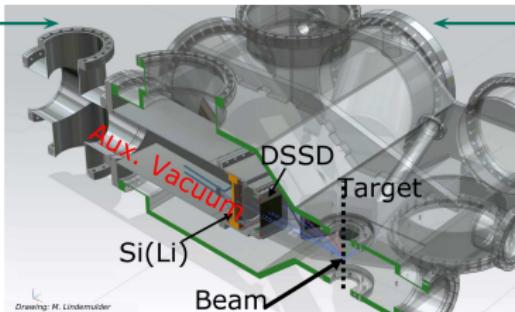


1st Pocket

$$73^\circ < \theta_{\text{lab}} < 88^\circ$$

2nd Pocket

$$27^\circ < \theta_{\text{lab}} < 38^\circ$$

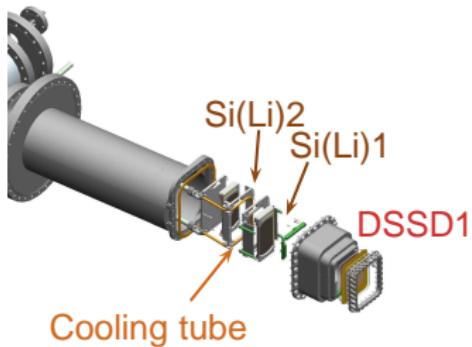


B. Streicher et al NIM A 654, 604 (2011)

(All drawings by M. Lindemulder,KVI)

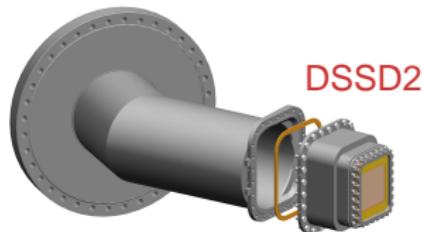
Drawing: M. Lindemulder

Vacuum Chamber and Bakeout



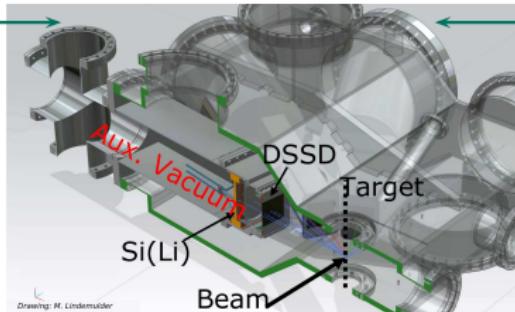
Constrains

- ✓ Si(Li) temp:
 $< 80 \text{ }^{\circ}\text{C}$
- ✓ $\Delta P_{(\text{DSSD safety})} < 10^{-2} \text{ mbar}$



1st Pocket

$$73^\circ < \theta_{\text{lab}} < 88^\circ$$



2nd Pocket

$$27^\circ < \theta_{\text{lab}} < 38^\circ$$

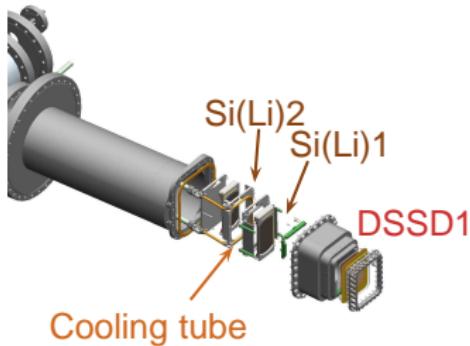
B. Streicher et al NIM A 654, 604 (2011)

Vacuum Chamber and Bakeout



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Baking at 150 °C

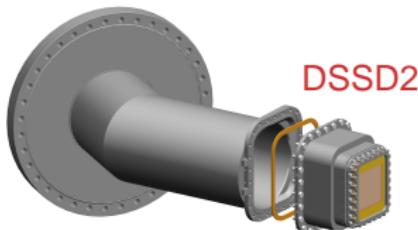


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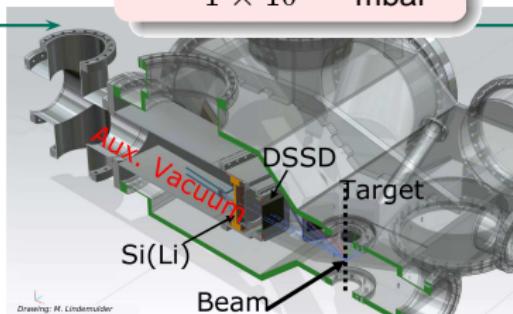
Achieved

- ✓ Si(Li) temp = -7.5°C
- ✓ $P_{\text{pocket}} = 8 \times 10^{-8} \text{ mbar}$
- ✓ $P_{\text{chamb.}} = 1 \times 10^{-10} \text{ mbar}$



2nd Pocket

$$27^\circ < \theta_{\text{lab}} < 38^\circ$$



B. Streicher et al NIM A 654, 604 (2011)

(All drawings by M. Lindemulder,KVI)

Drawing: M. Lindemulder

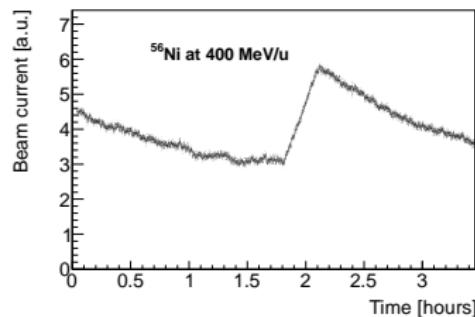
Beam and Target



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Beams:

- ▶ ^{58}Ni @ 400 (150 and 100) MeV/u
 - ~ 10^8 part. stored
- ▶ ^{56}Ni @ 400 MeV/u
 - ~ 10^6 part. stored
- ▶ Revolution frequency ~ 2 MHz

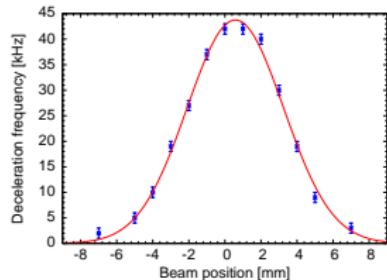


^{56}Ni (^{58}Ni) beam lifetime ~ 2 h

Targets:

- ▶ H_2
 - ~ 10^{13} part./cm²
- ▶ ^4He
 - ~ 10^{12} part./cm²

target profile



$\sigma = 3.58 \text{ mm}$ $x_0 = 0.58 \text{ mm}$

Beam and Target



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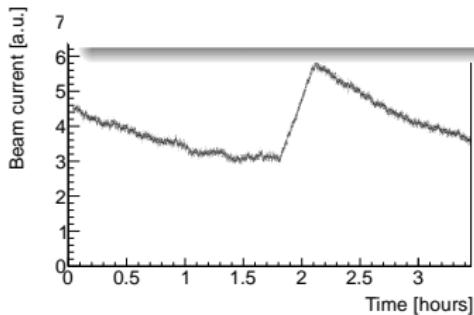
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- ▶ Rev.

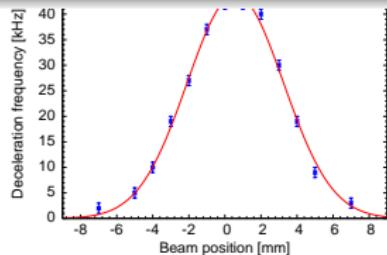
Luminosity

Targets:

- ▶ H_2
 - ~ 10^{13} part./cm²
- ▶ ^4He



^{56}Ni (^{58}Ni) beam lifetime ~ 2 h



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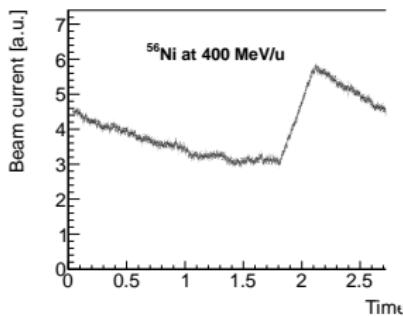
Beam and Target



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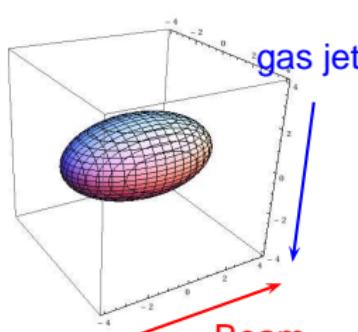
Beams:

- ▶ ^{58}Ni @ 400 (150 and 100)
 $\sim 10^8$ part. stored
- ▶ ^{56}Ni @ 400 MeV/u
 $\sim 10^6$ part. stored
- ▶ Revolution frequency ~ 2

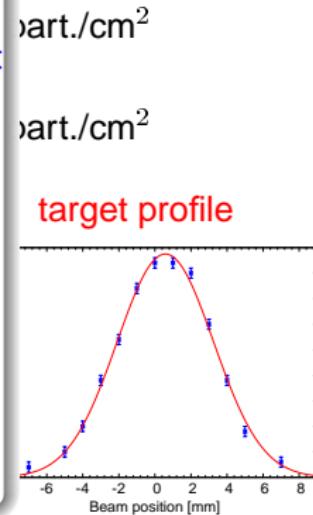


Targets:

Interaction point



- ▶ $\text{FWHM} \approx 3 \text{ mm}$
- ▶ $\text{FWHM} \approx 8 \text{ mm}$



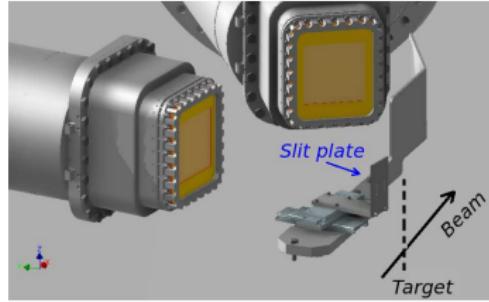
^{56}Ni (^{58}Ni) beam lifetime $\sim 2 \text{ h}$

$\sigma = 3.58 \text{ mm}$ $x_0 = 0.58 \text{ mm}$

Slit Plate

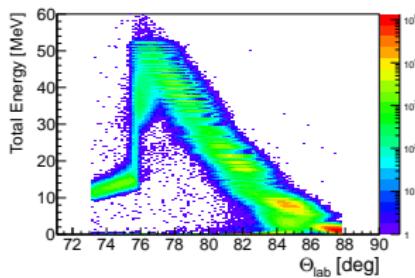
Slit plate to improve angular resolution

- ▶ Tantalum, 2 mm thick
- ▶ In front of 90 deg. pocket (1st)
- ▶ At 3 cm from target
- ▶ 1 mm and 2 mm slits
- ▶ DSSD1 rate reduced by a factor 5

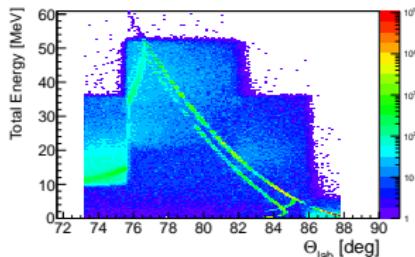


GEANT4 Simulations

Without slit



1 mm slit



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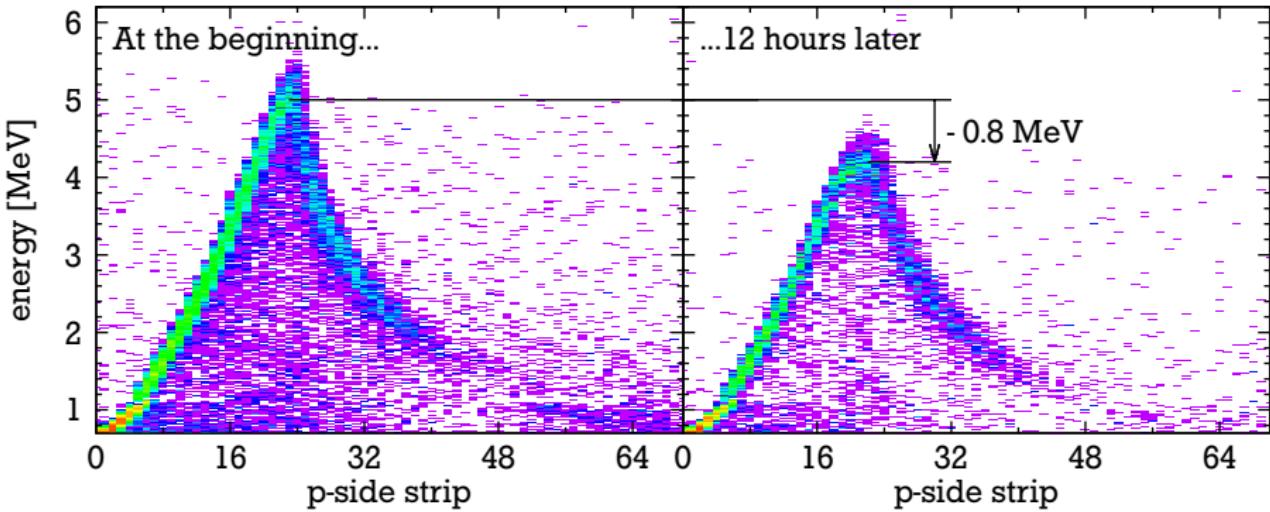
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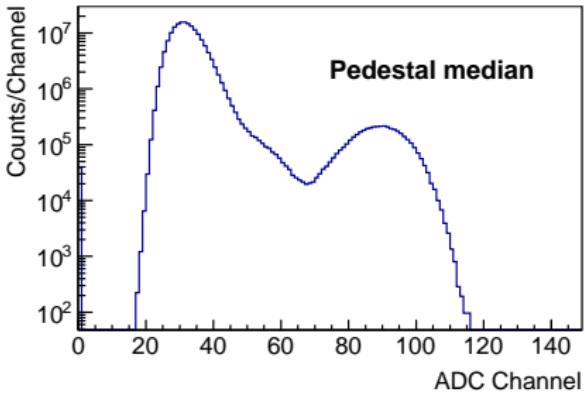
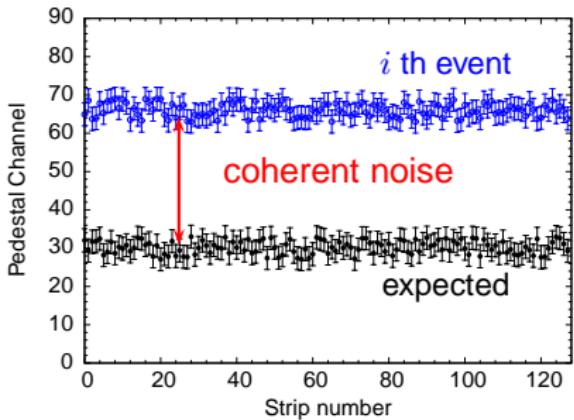
Radiation Damage in the DSSD

(courtesy of M. von Schmid)

- ▶ Beam intensity of stable ^{58}Ni beam ≈ 25 times higher than with ^{56}Ni .
- ▶ Observed deterioration of detector performance over time:
 - ▶ Leakage current increasing
 - ▶ Maximum energy decreasing \rightarrow decreased depletion depth



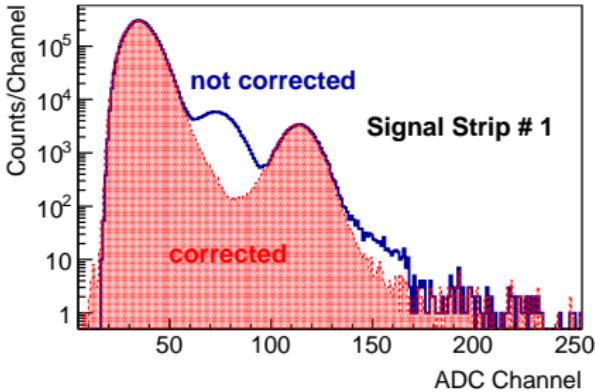
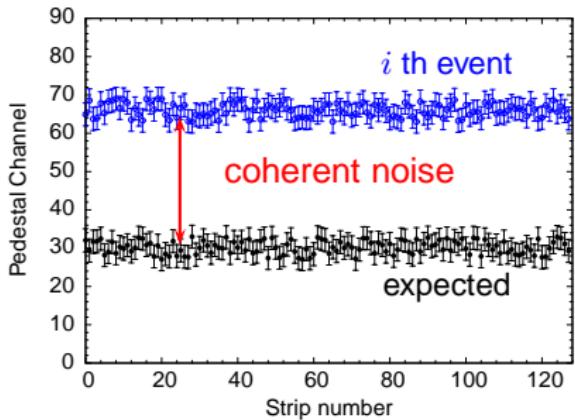
Coherent Noise Correction



- ▶ For events of low multiplicity, the pedestal average of all strips can be approximated to the median value: \tilde{a}_k
- ▶ Identify (online/offline) the "real" pedestal ($\langle a \rangle_k$) and correct for each event:

$$a_i'' = a_i' - \langle a \rangle_k, \quad \text{if} \quad \tilde{a}_k \geq nr_i$$

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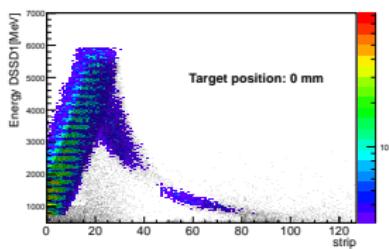
Real Positions for Target and Slit



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without slit

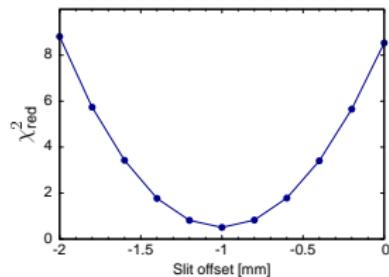
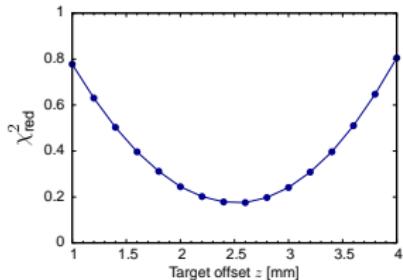
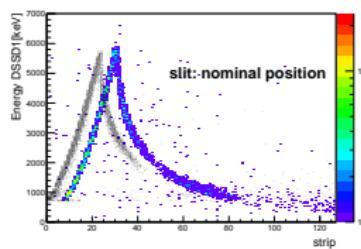
(simulation in color and experiment in dark)



$^{56}\text{Ni} + p$

with slit

(simulation in color and experiment in dark)



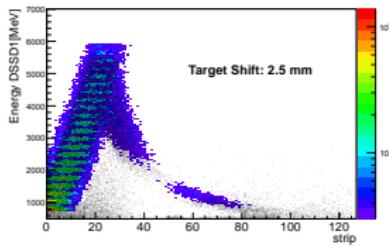
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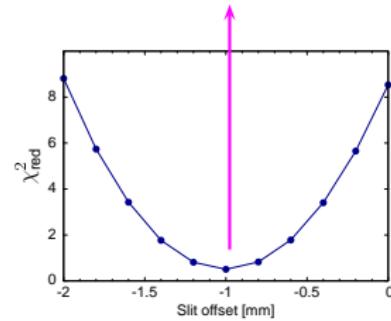
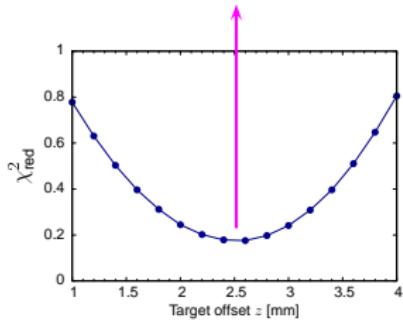
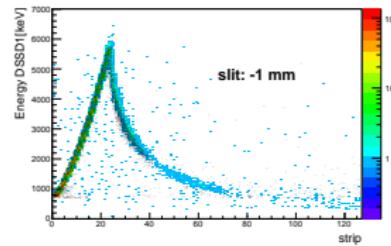
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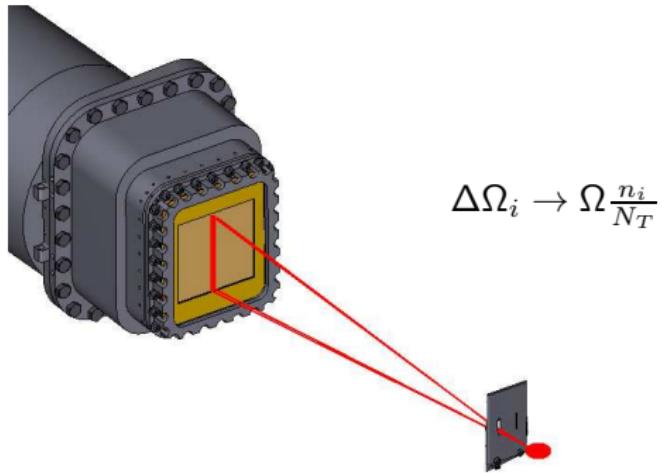
$^{56}\text{Ni} + p$

with slit

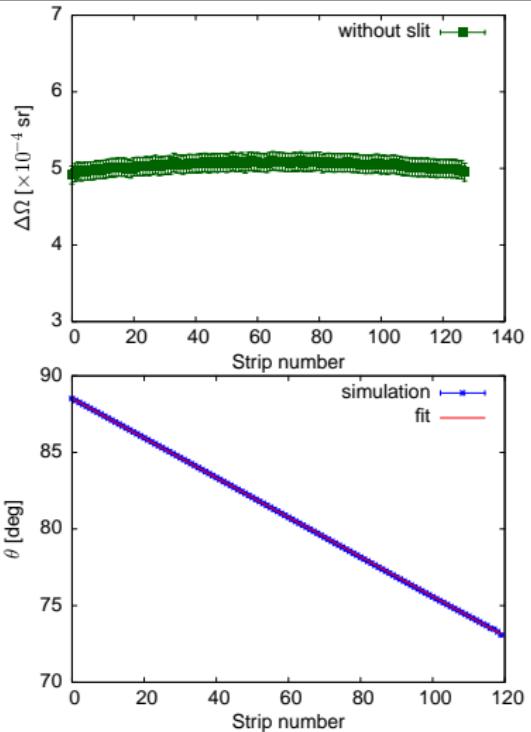
(simulation in color and experiment in dark)



Angular Calibration and Solid Angles



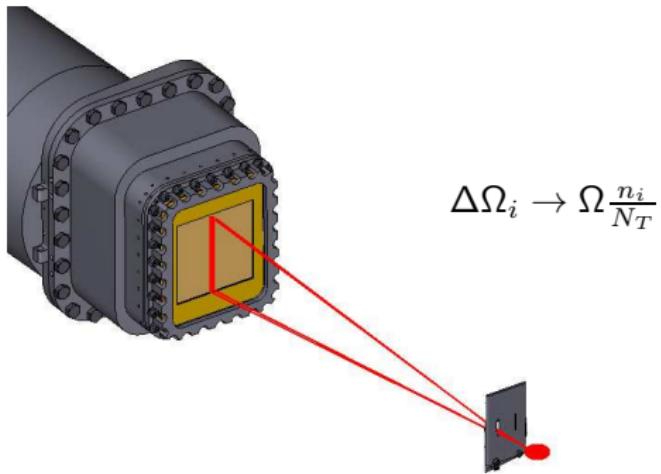
- ▶ Simulation of N_T uniformly distributed events in Ω solid angle
- ▶ At same, polar (θ) and azimuth (ϕ) angles calibration



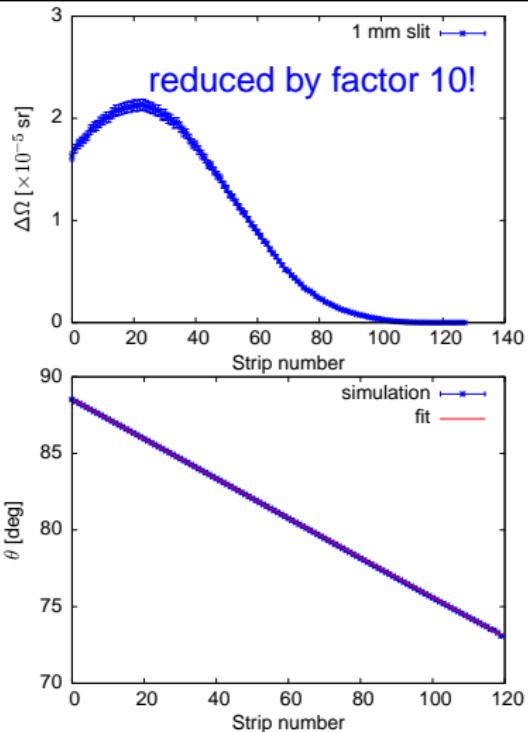
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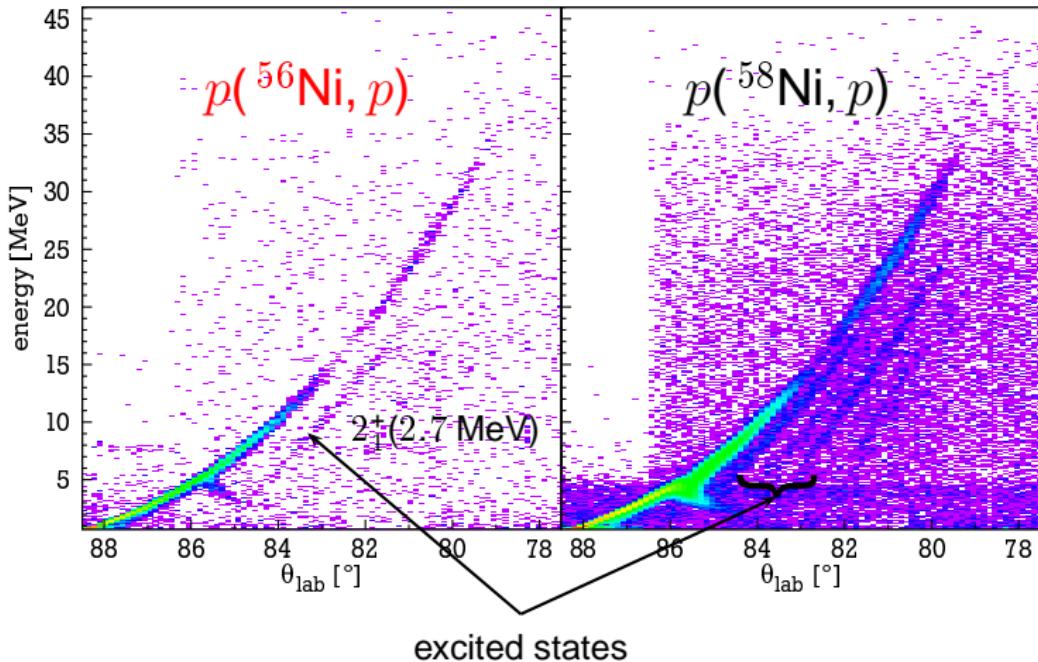
Summary

Proton elastic scattering

(courtesy of M. von Schmid, TU Darmstadt)



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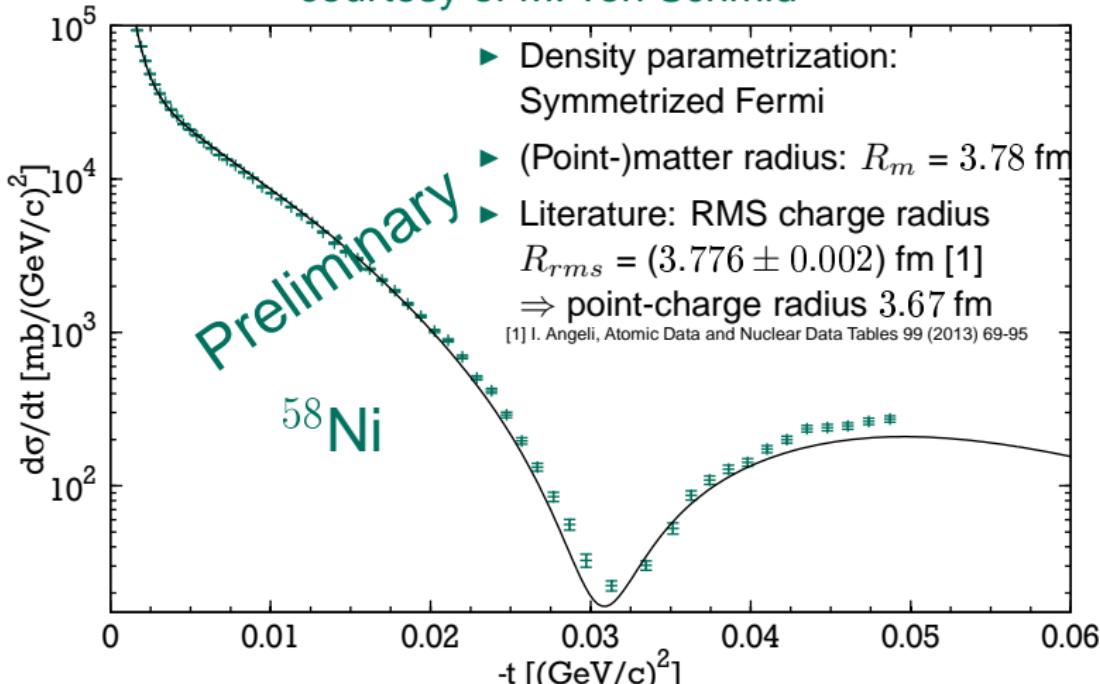
Preliminary Results: $^{58}\text{Ni}(\text{p},\text{p})^{58}\text{Ni}$ at 400 MeV/u

Cross Section Fitted with Glauber Multiple-Scattering Theory



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courtesy of M. von Schmid



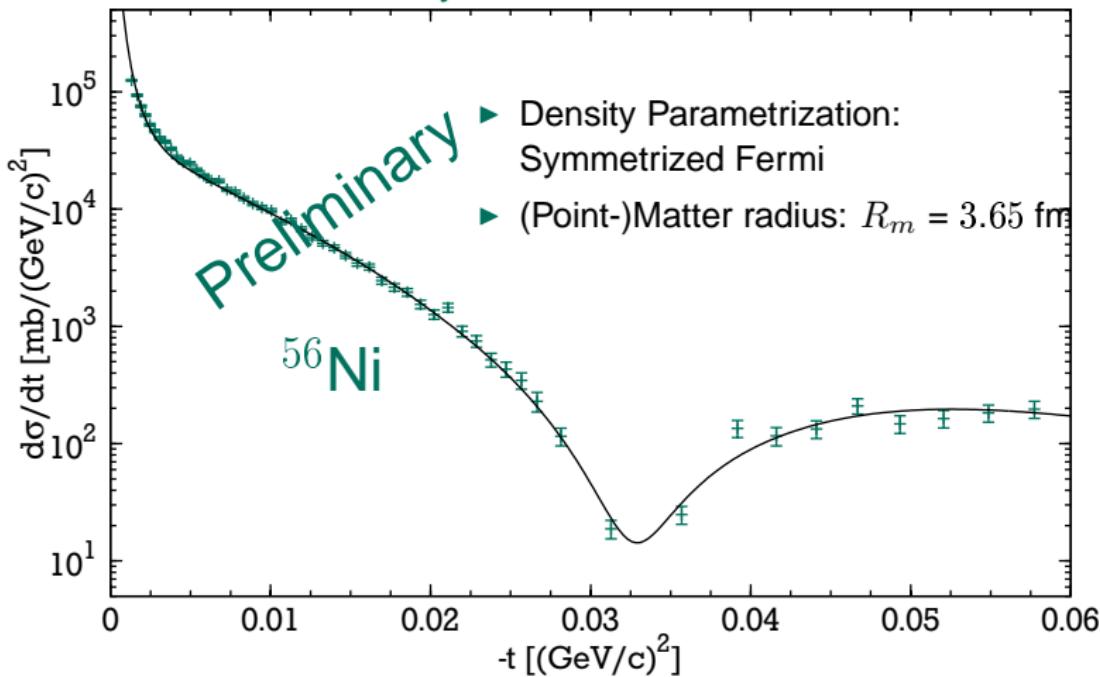
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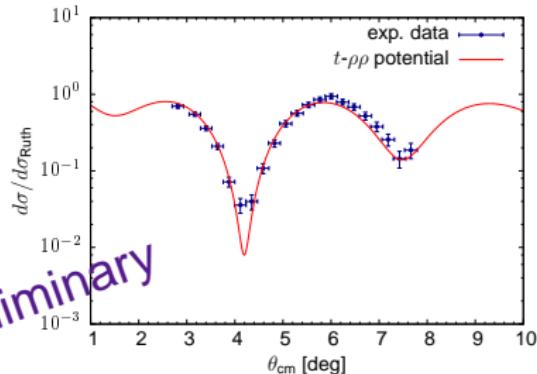
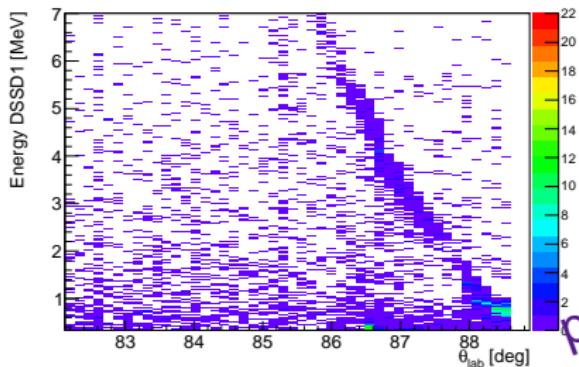


Alpha elastic scattering



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$^{58}\text{Ni}(\alpha, \alpha)$ @ 100 MeV/u



preliminary

For t - $\rho\rho$ potential:

C. A. Bertulani et al., Comput. Phys. Commun. **152**, 317 (2003)

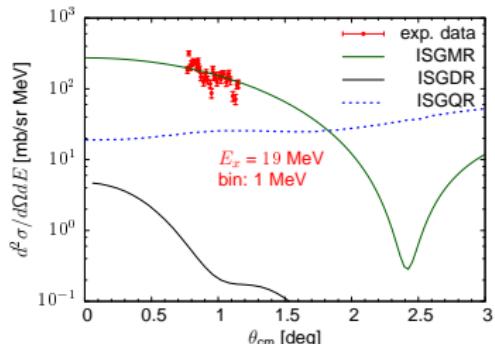
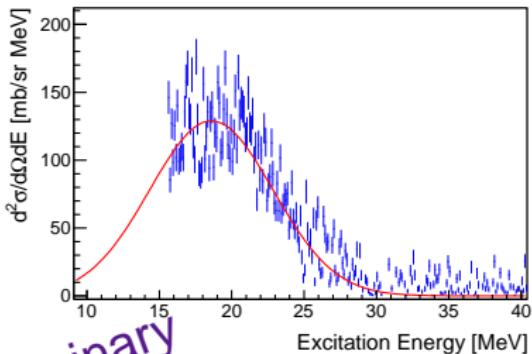
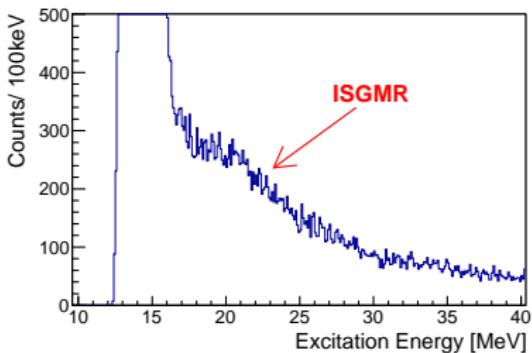
M. S. Hussein et al., Phys. Reports **201**, 279 (1991)

Alpha inelastic scattering



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$^{58}\text{Ni}(\alpha, \alpha')$ @ 100 MeV/u



preliminary

Centroid [MeV]

18.6(2)

present data

18.4(2)

PRC **73**, 014314 (2006)

$19.2^{+0.4}_{-0.2}$

"

$19.9^{+0.7}_{-0.8}$

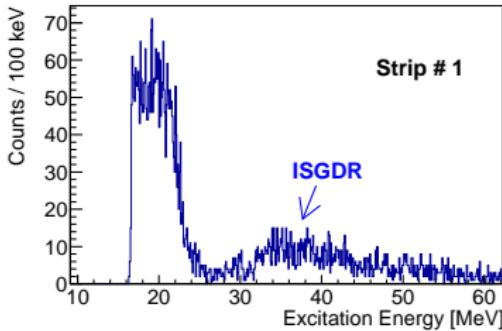
Phys. Lett. B **637**, 43 (2006)

Alpha inelastic scattering

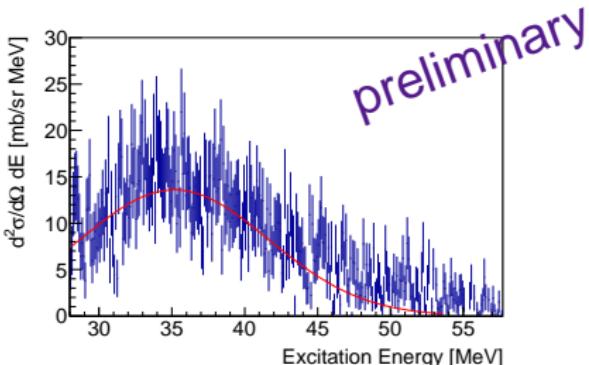


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$^{58}\text{Ni}(\alpha, \alpha')$ @ 150 MeV/u



- ▶ For this run the luminosity was a factor 10 higher than the one of 100 MeV/u.
- ▶ Recoils have lower energies (not easy to separate the ISGMR).
- ▶ But the second mode of ISGDR is extracted.

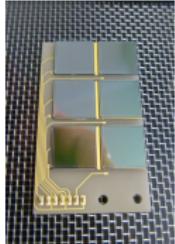
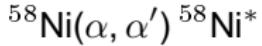


Centroid [MeV]

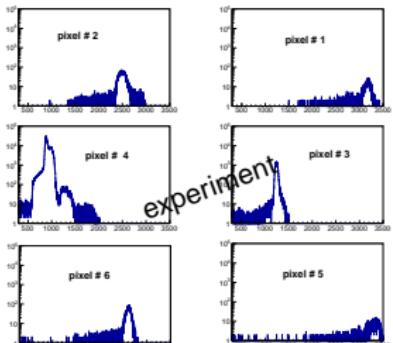
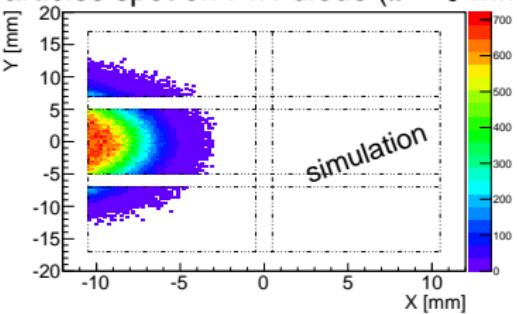
35.3(2)	present data
34.1(3)	PRC 73 , 014314 (2006)
$30.8_{-1.1}^{+1.7}$	Phys. Lett. B 637 , 43 (2006)

PIN-Diode Detector

- ▶ PIN-diode: 6 pads of $1 \times 1 \text{ cm}^2$.
- ▶ Beam like particles detection.
- ▶ Movable perpendicular to beam direction.
- ▶ Useful for coincidences with recoil detectors, e.g.

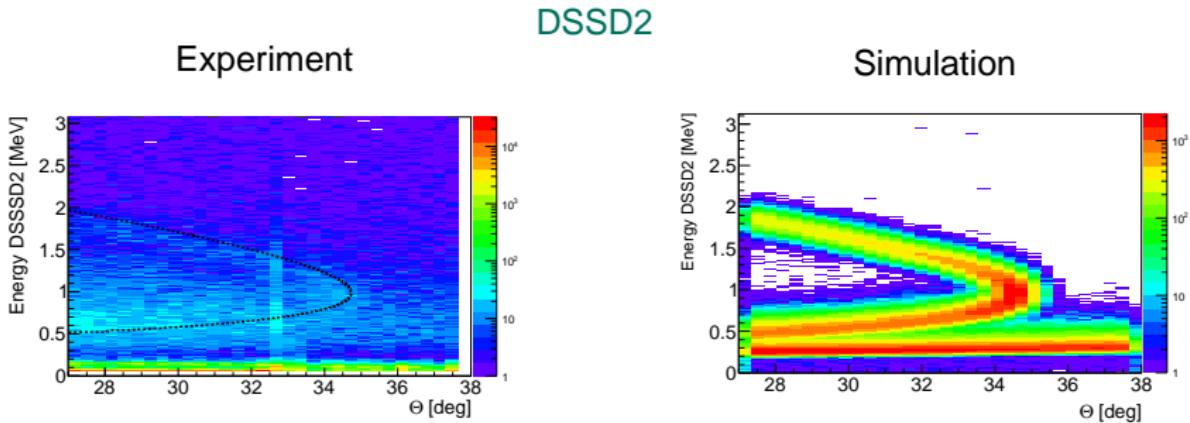


Particles spot on PIN-diode ($x = 5 \text{ mm}$)



Data taken from E087 Experiment

$^{20}\text{Ne} + p$ @ 50 MeV/u



- ▶ protons elastic scatt. and deuterons from transfer reaction
- ▶ $p(^{20}\text{Ne}, ^{19}\text{Ne})d \quad Q = -14.6 \text{ MeV}$

Outline

Motivation

Experiment

Examples of Data Correction

Some Preliminary Results

Summary

Summary

- ▶ Excellent performance of our UHV capable detection system.
- ▶ Our simulations describe a good agreement the experimental data.
Many corrections applied are based on simulations.
- ▶ First successful nuclear reaction experiment with stored RIB ever!
Preliminary results:
 - ▶ ^{56}Ni : matter radius $R_m = 3.65 \text{ fm}$
 - ▶ ^{58}Ni : matter radius $R_m = 3.78 \text{ fm}$
- ▶ For the first time GRs are being studied via an experiment with stored beam.
Evidence of ISGMR and ISGDR excitation in ^{58}Ni (proof of the EXL principle).

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