Storage Rings and the Task Force

Nasser Kalantar-Nayestanaki,
KVI, University of Groningen

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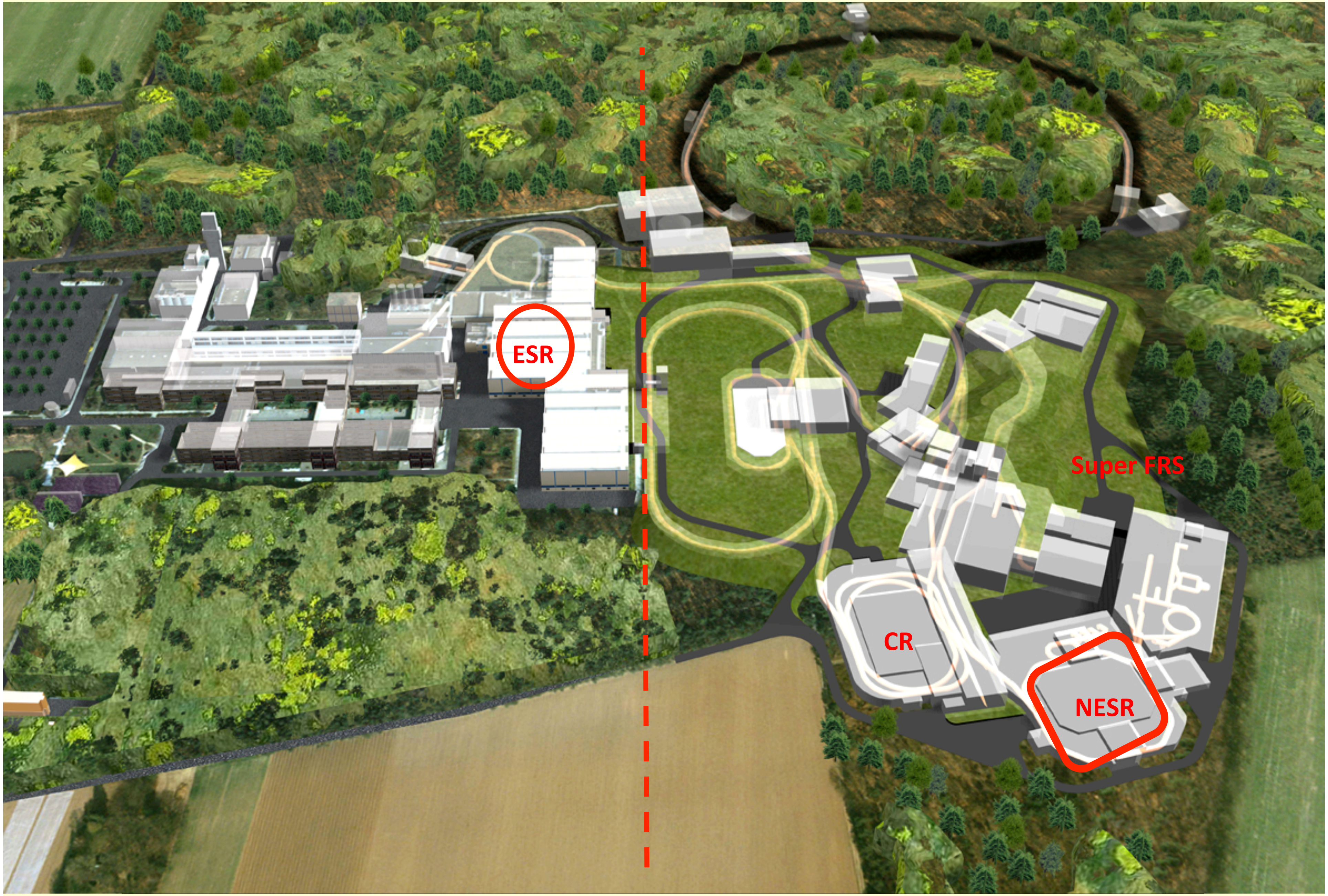

ESR
Super FRS
CR
NESR

Why low momentum transfers hadronic scattering?

✓ Investigation of Nuclear Matter Distributions along Isotopic Chains:

⇒ halo, skin structure

⇒ probe in-medium interactions at extreme isospin (almost pure neutron matter)

⇒ in combination with electron scattering (ELISe project @ FAIR):
separate neutron/proton content of nuclear matter (deduce neutron skins)

method: elastic proton scattering at low q: high sensitivity to nuclear periphery

✓ Investigation of Giant Monopole Resonance in Doubly Magic Nuclei:

⇒ gives access to nuclear compressibility ⇒ key parameters of the EOS

⇒ new collective modes (breathing mode of neutron skin)

method: inelastic α scattering at low q

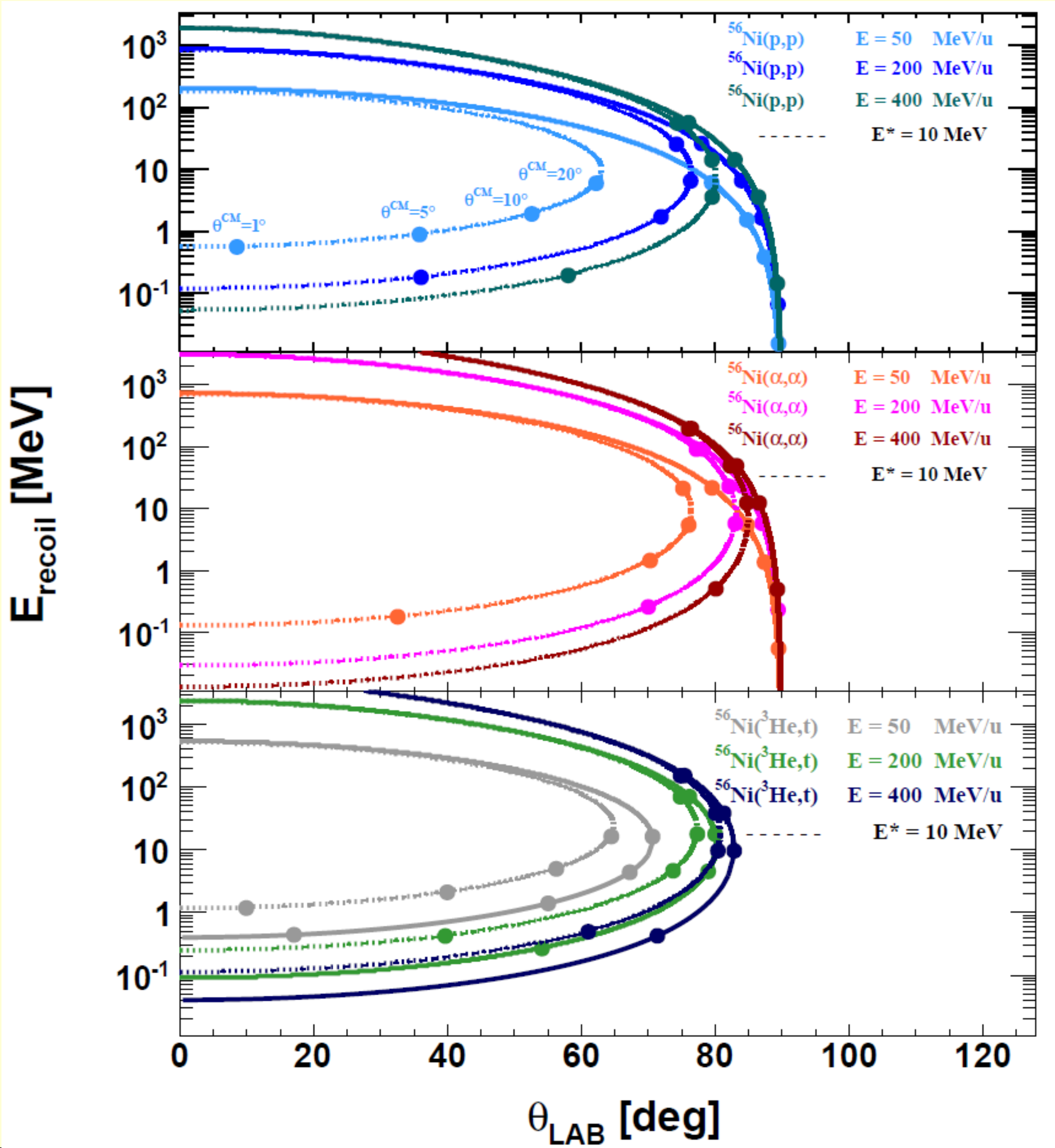
✓ Investigation of Gamow-Teller Transitions:

⇒ weak interaction rates for N = Z waiting point nuclei in the rp-process

⇒ electron capture rates in the pre-supernova evolution (core collapse)

method: (^{3}He,t), (d,^{2}He) charge exchange reactions at low q

Kinematics for inverse reaction for ^{56}Ni



Advantages and disadvantages of storage-ring experiments

Advantages:

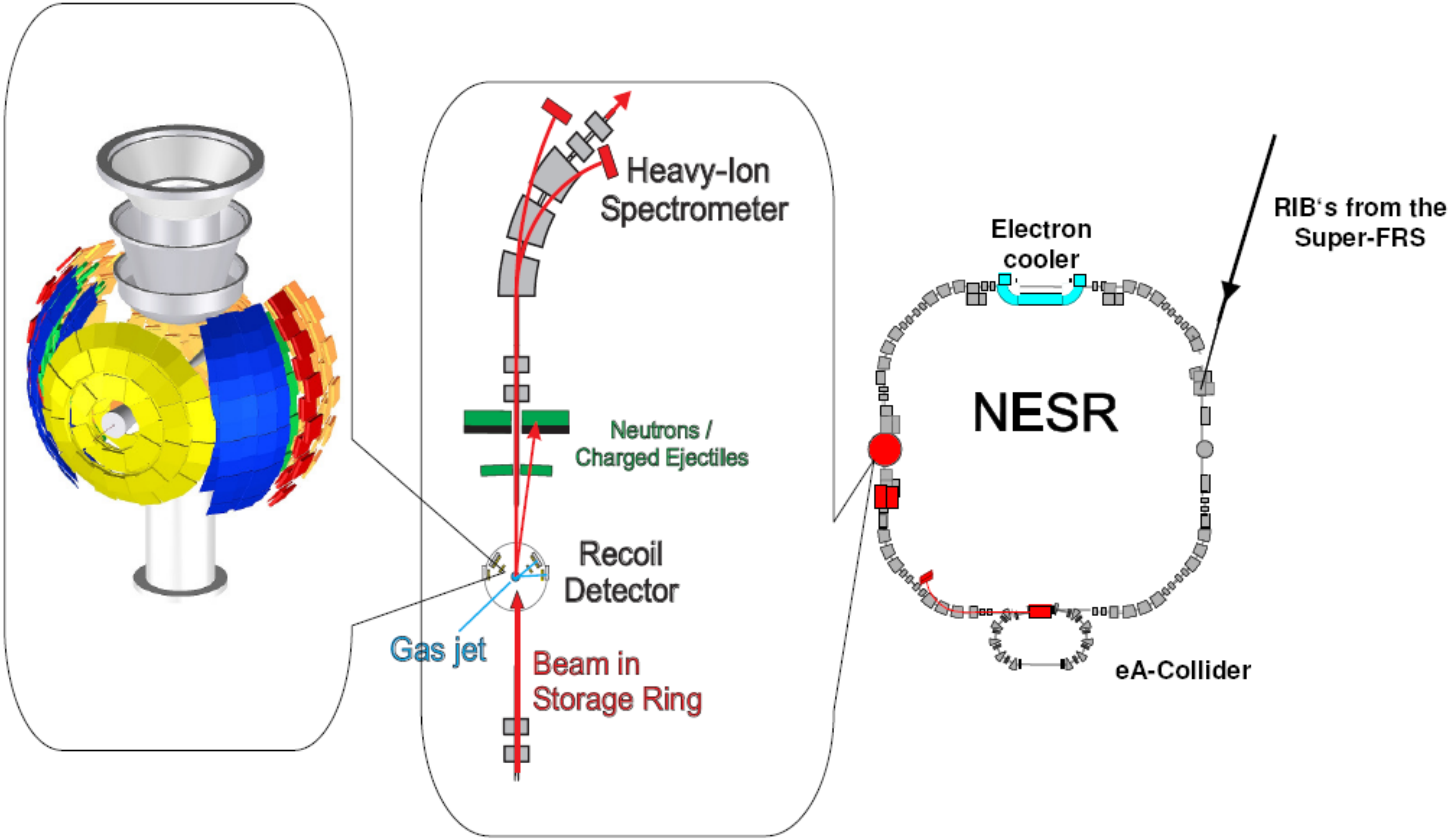
- Large intensities in the ring
- Little energy loss in the target
- No target window (no background)
- High resolution of the beam (cooling)
- Forward focusing for high-energy particles

Disadvantages:

- Ultra high vacuum
- Very small recoil energies for low q
- Thin targets

R^3B (external tar.)	vs.	EXL (ring exp.)
External target (thick)		*Internal target (thin)*
Low beam current		*High beam current*
High-energy particles		*Low-energy particles*
Large momentum transfer		*Small momentum transfer*
Target contamination		*No target window*
Quasi-elastic scattering		*Giant resonances*

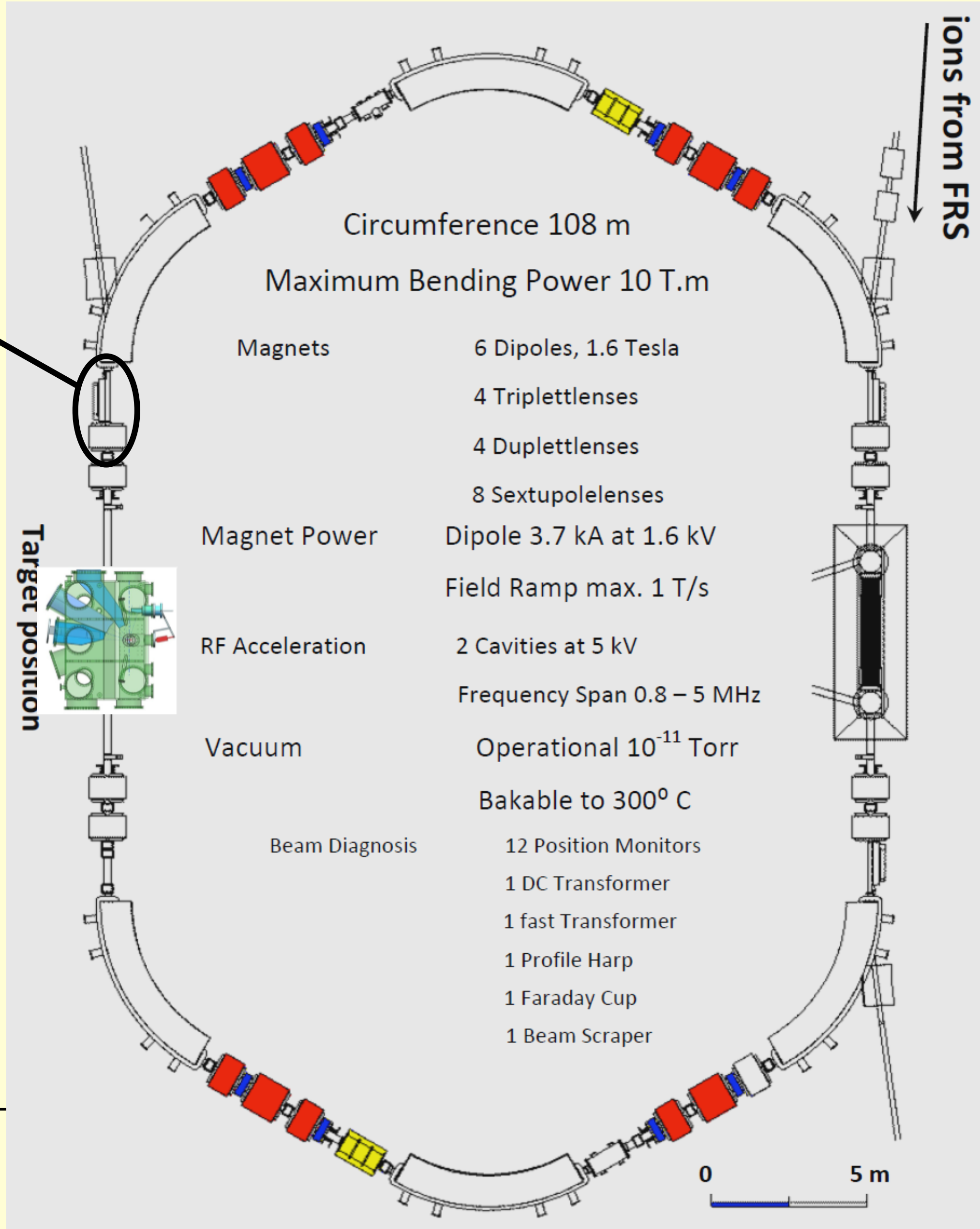
Nuclear Reaction experiments at NESR



First reaction experiments with the existing ring at GSI (ESR)

Setup @ ESR ring

Pin diode



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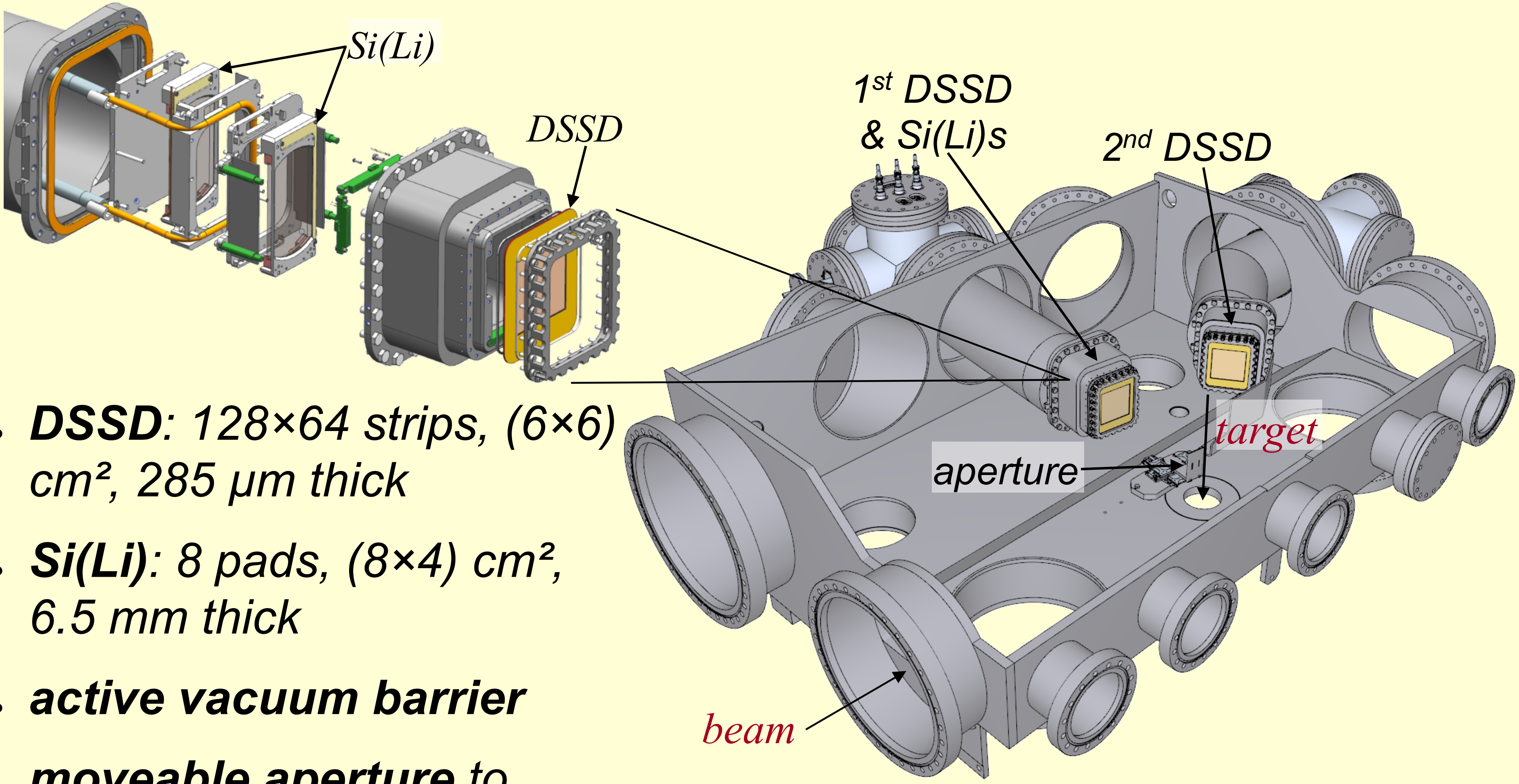
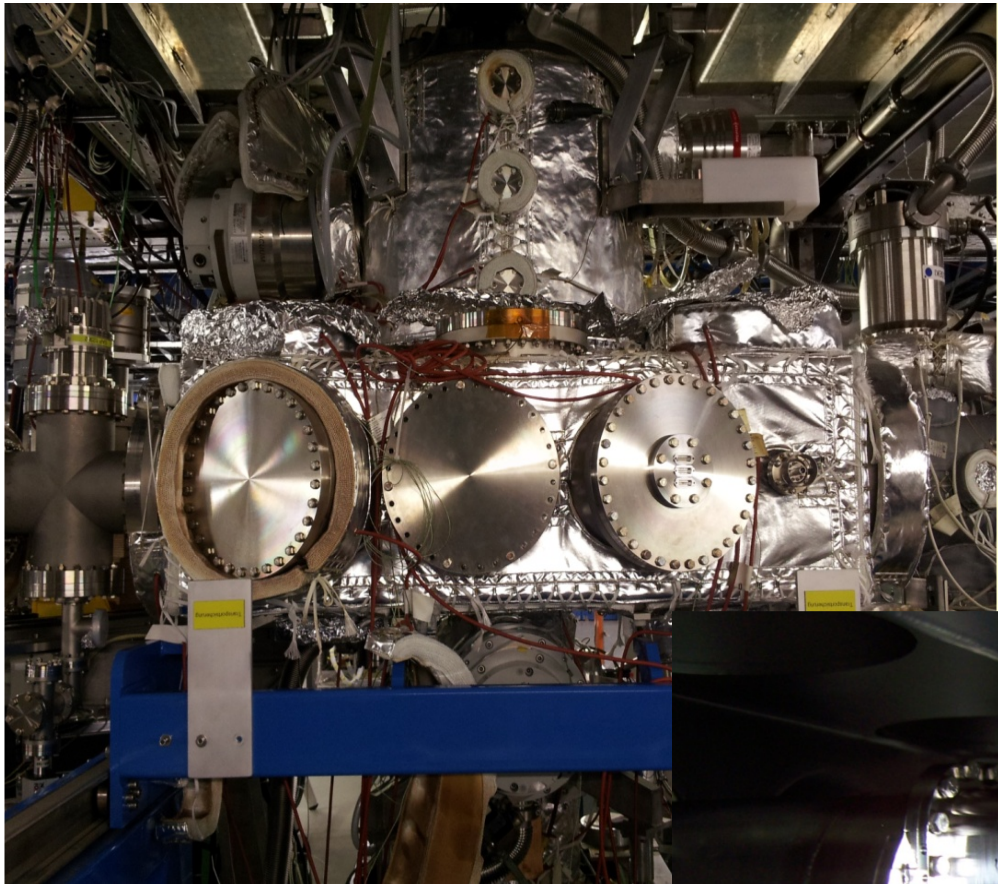
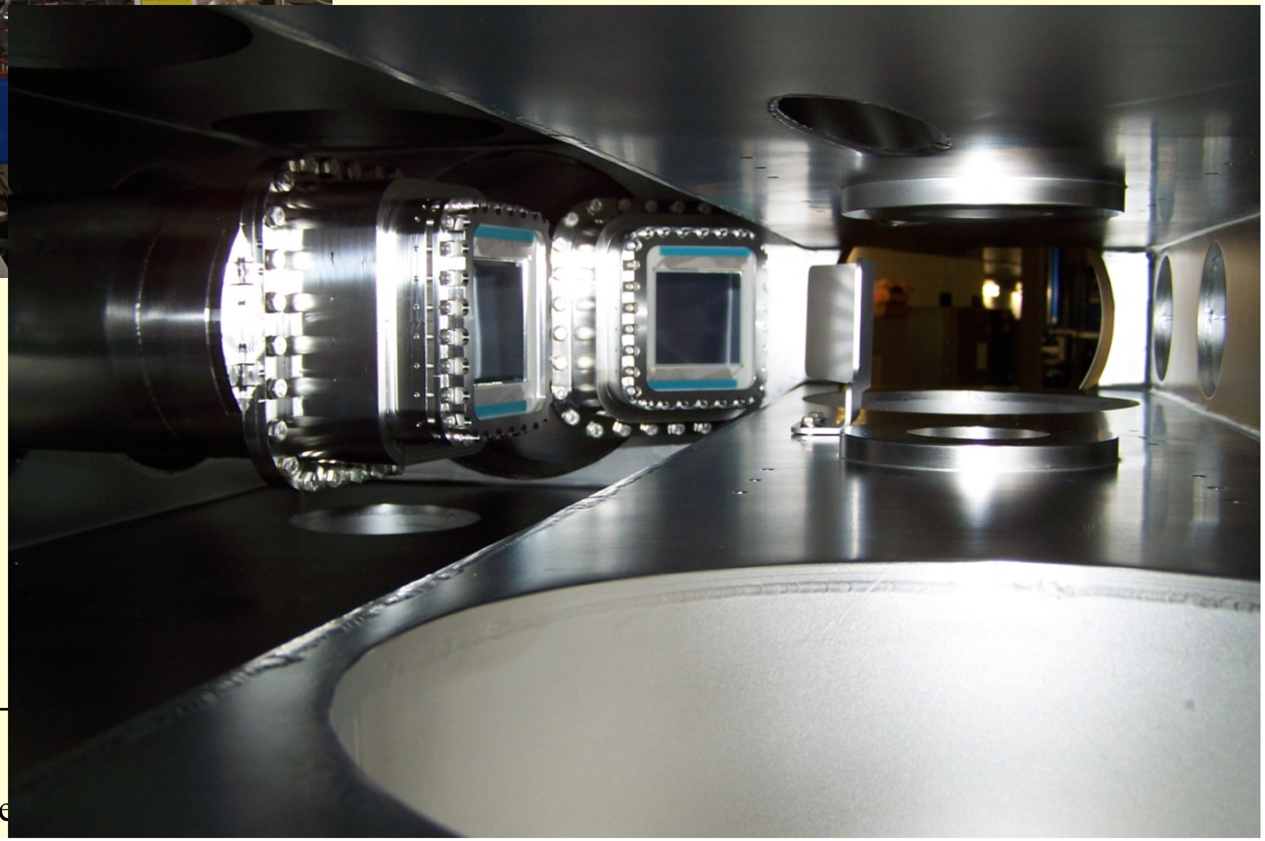
The new ESR Scattering chamber

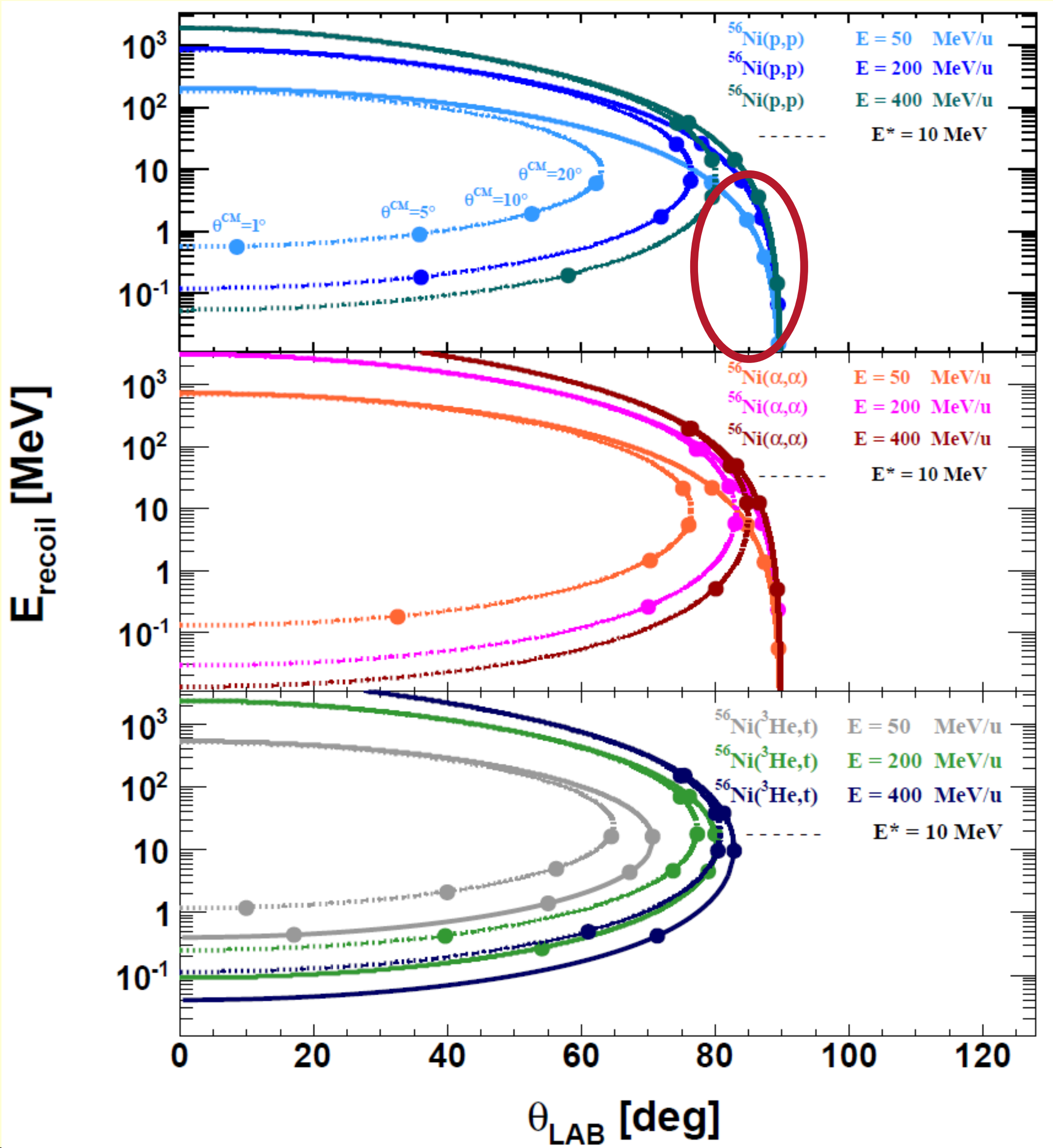


- ***DSSD****: 128×64 strips, (6×6) cm², 285 µm thick*
- ***Si(Li)****: 8 pads, (8×4) cm², 6.5 mm thick*
- ***active vacuum barrier***
- ***moveable aperture*** *to improve angular resolution*

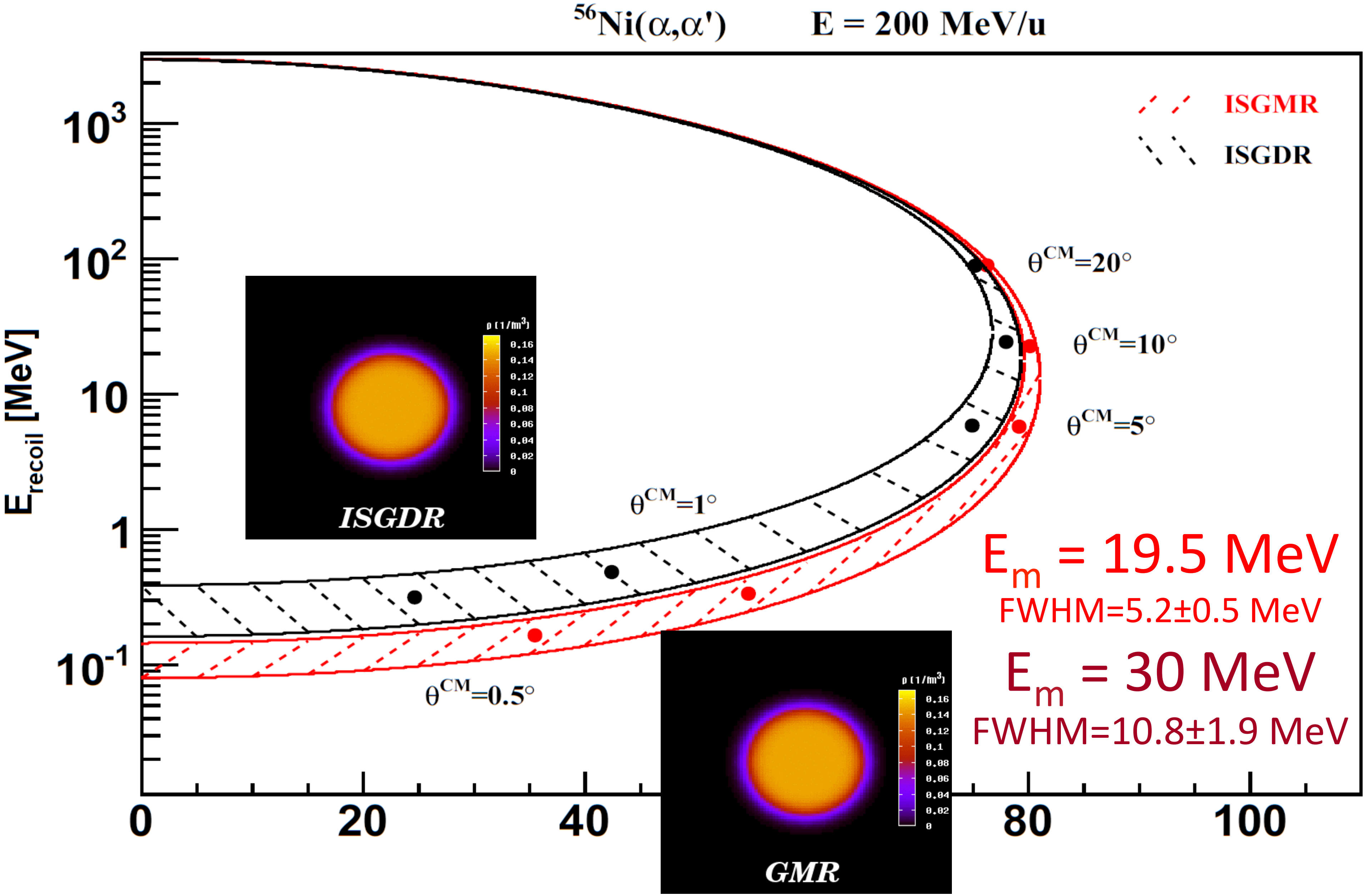




Kinematics for inverse reaction for ^{56}Ni



ISGMR/ISGDR channels in ^{56}Ni with (α,α')



E_m = 19.5 MeV
FWHM=5.2±0.5 MeV

E_m = 30 MeV
FWHM=10.8±1.9 MeV

^{56}Ni Beam

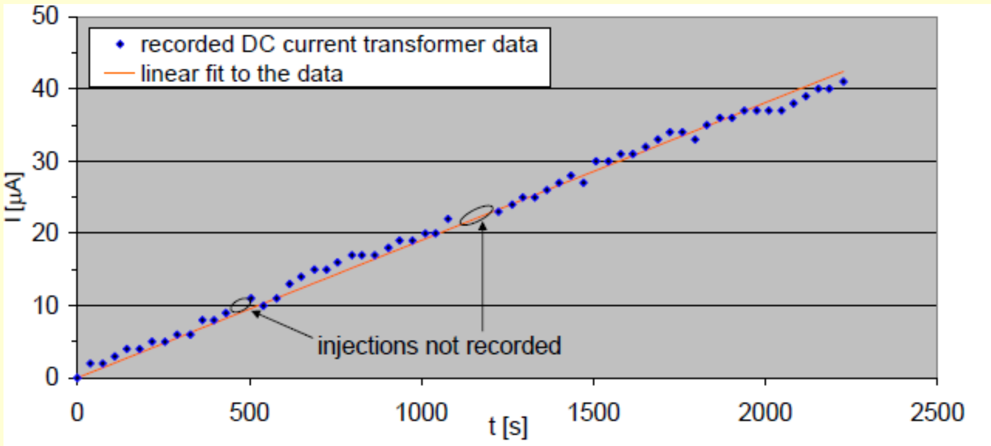
FRS: fragmentation of 600 MeV/u ^{58}Ni beam

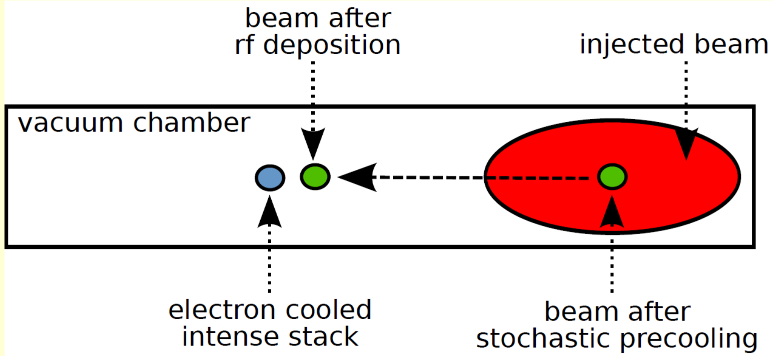
injection to ESR: **7 x 10^4** ^{56}Ni per injection

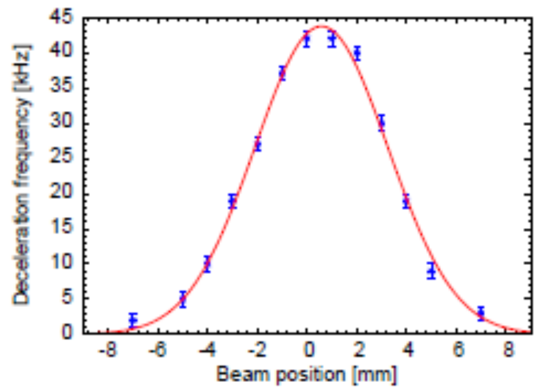
stochastic cooling, bunching and stacking (60 injections):

4.8 x 10^6 ^{56}Ni in the ring

F. Nolden, M. Steck







σ = 3.78 mm x_0 = 0.58 mm

luminosity: H_2 target: 2 x 10^{13} cm^{-2}

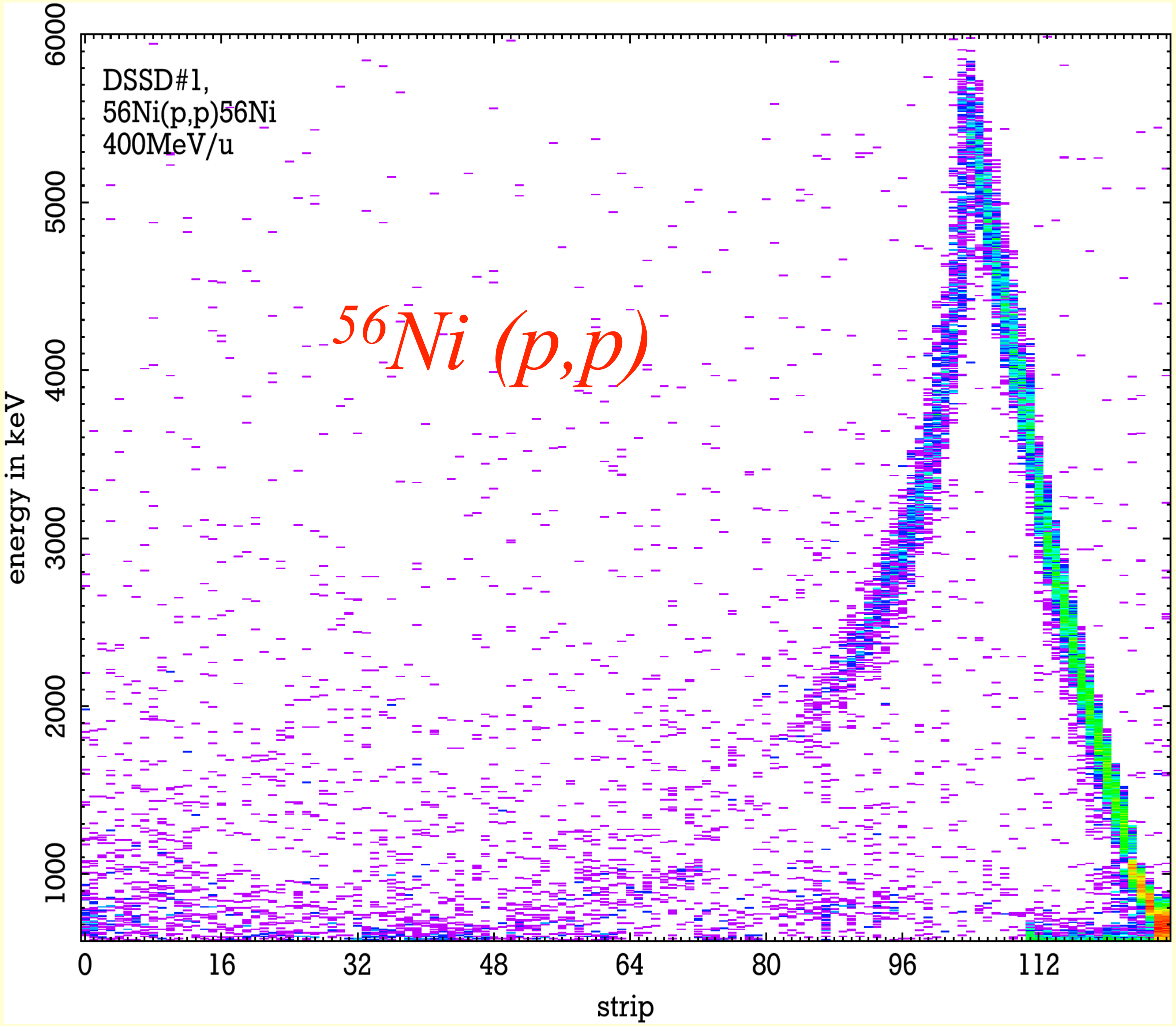
$\Rightarrow$ **L = 2 x 10^{26} cm^{-2} sec^{-1}**
(reduced by aperture)

First results with radioactive beam

October 25, 2012:

First Nuclear Reaction Experiment with Stored Radioactive Beam!!!!

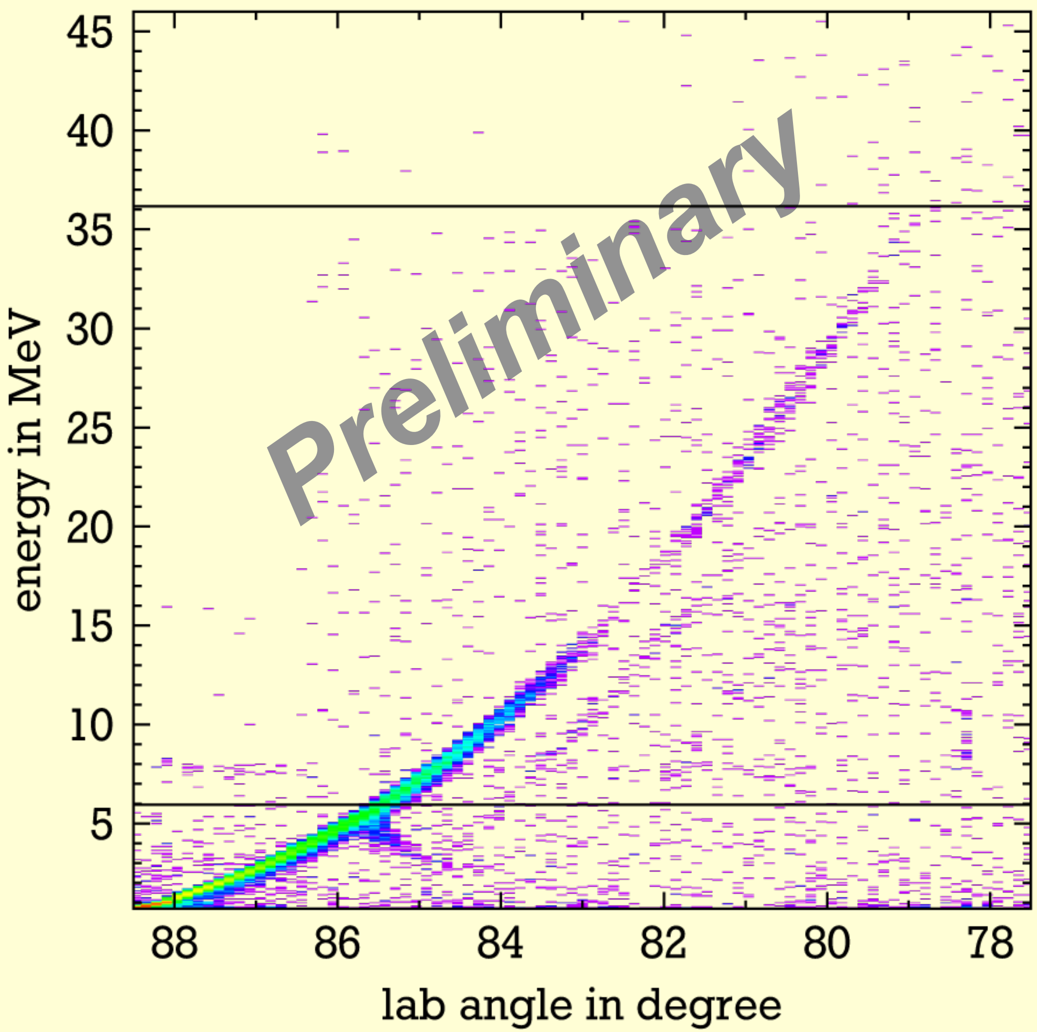
Beam energy 400 MeV/u

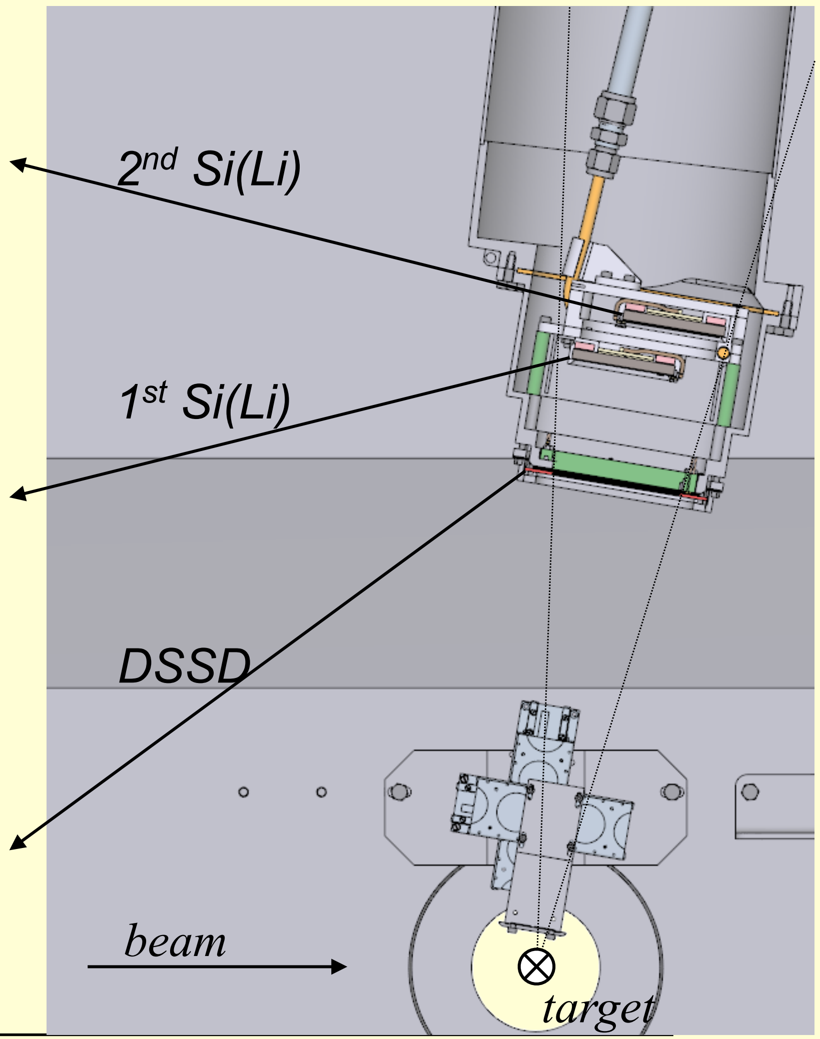


First results with radioactive beam

M. v. Schmid

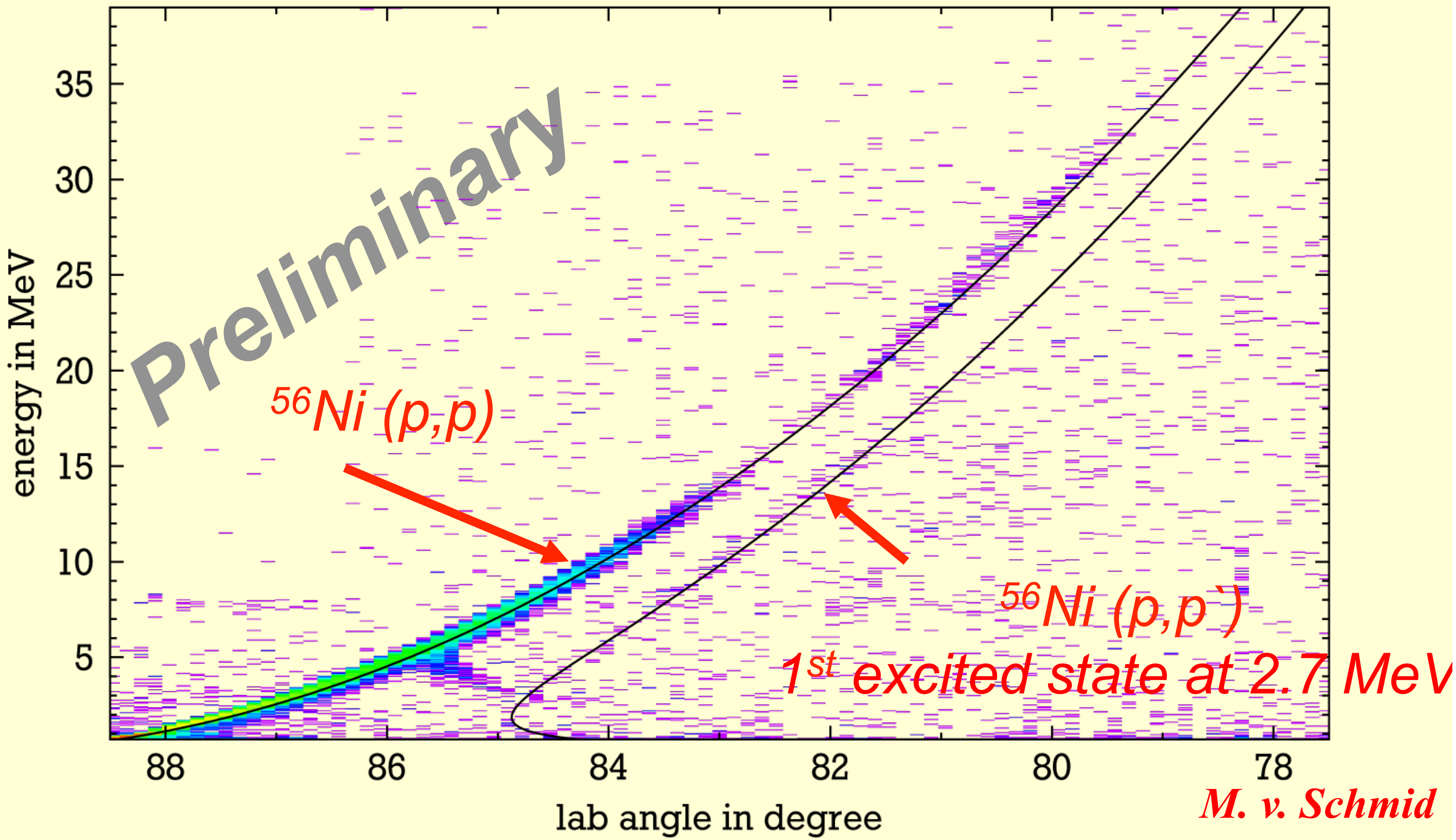
$^{56}Ni(p,p)$, $E = 400$ MeV/u





First results with radioactive beam

$^{56}Ni(p,p')$, $E = 400$ MeV/u *Identification of Inelastic Scattering*

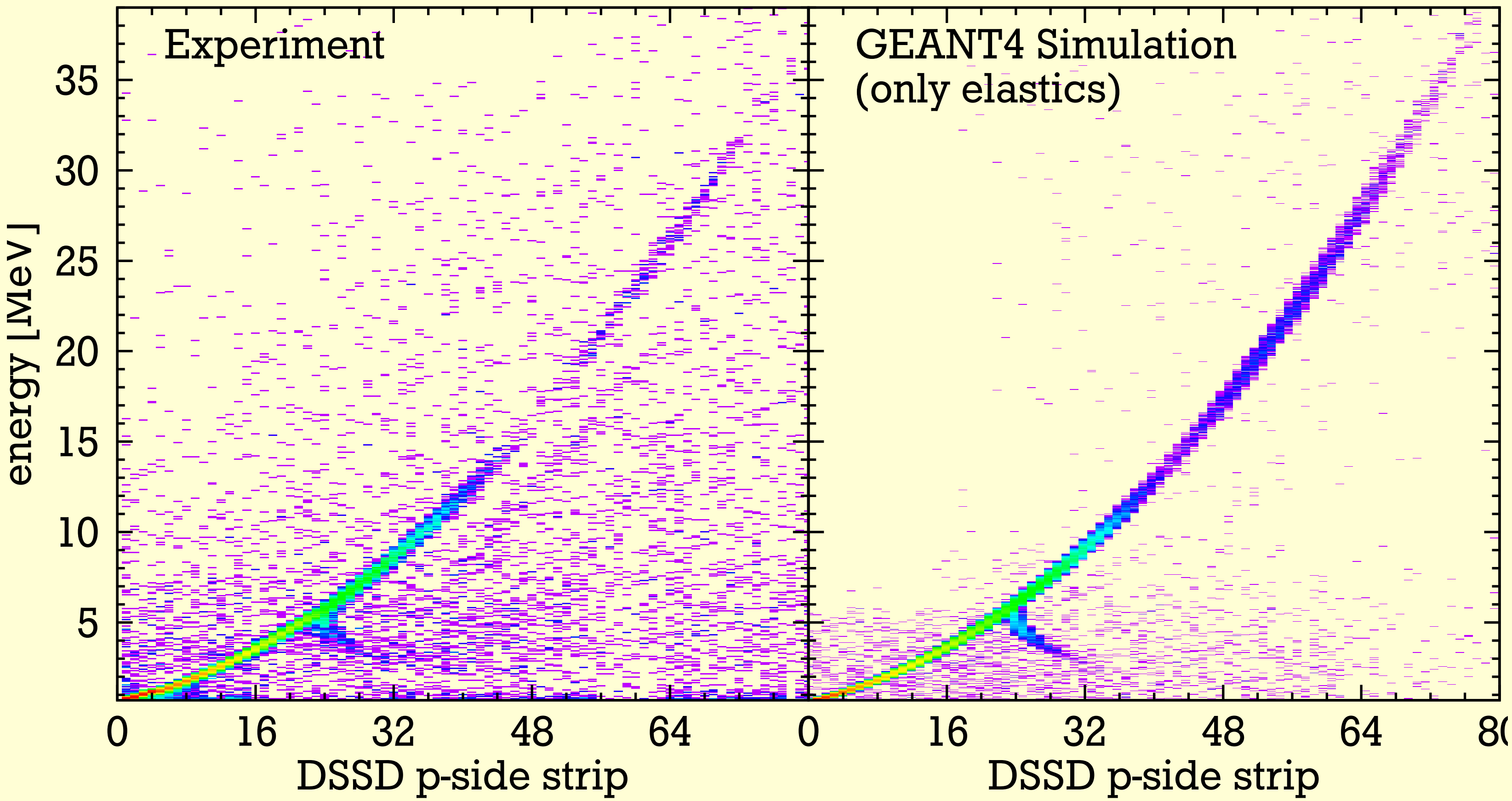


M. v. Schmid

Experiment versus simulations

M. v. Schmid
and
J.C. Zamora

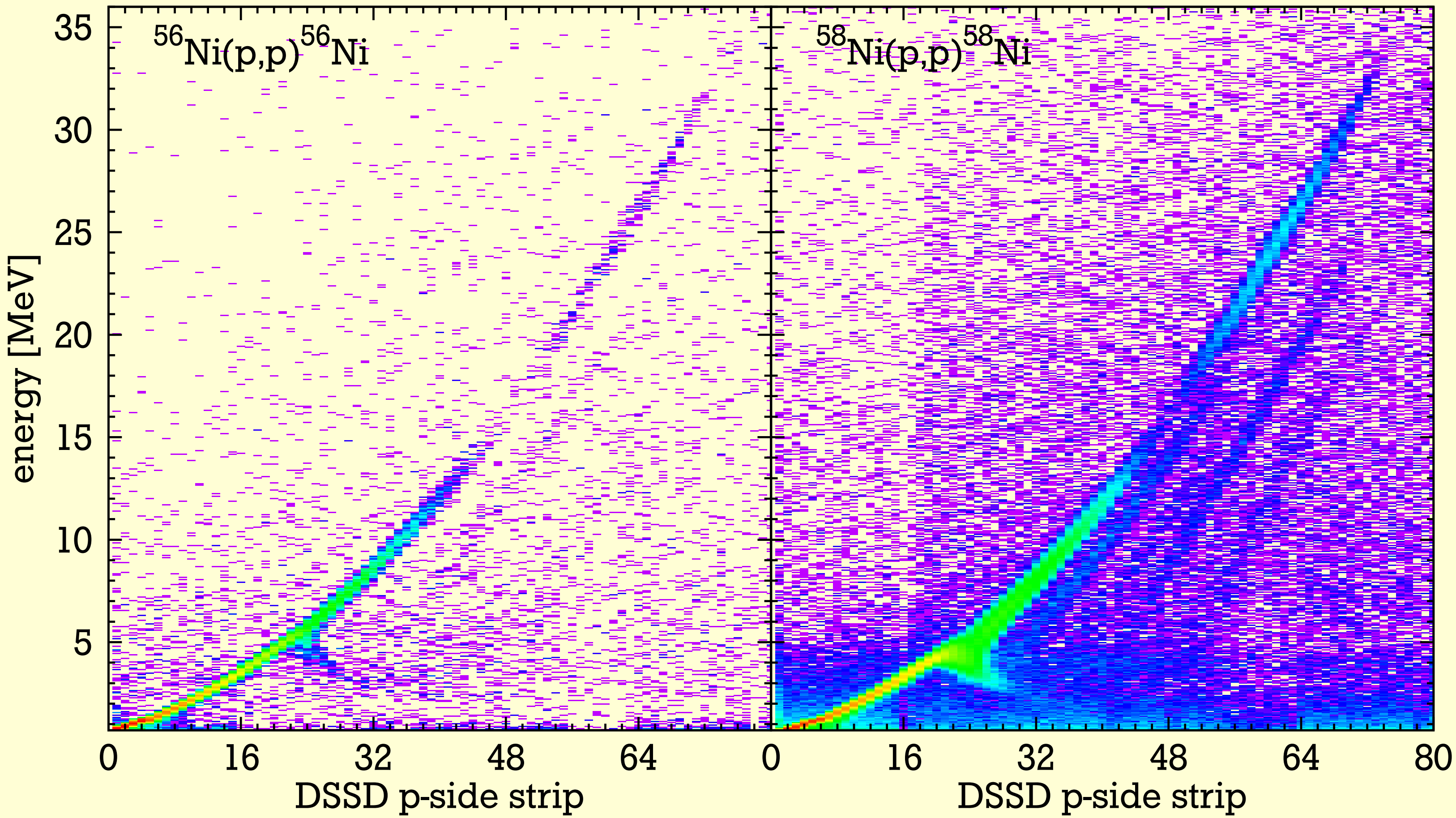
^{56}Ni(p,p), E = 400 MeV/u



Proton scattering from Ni isotopes

^{56,58}Ni(p,p), E = 400 MeV/u

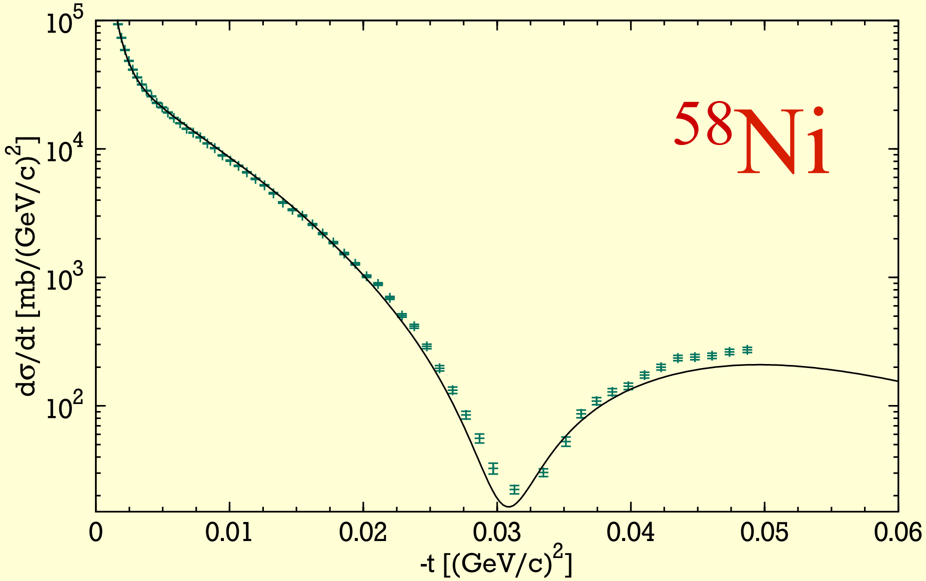
M. v. Schmid

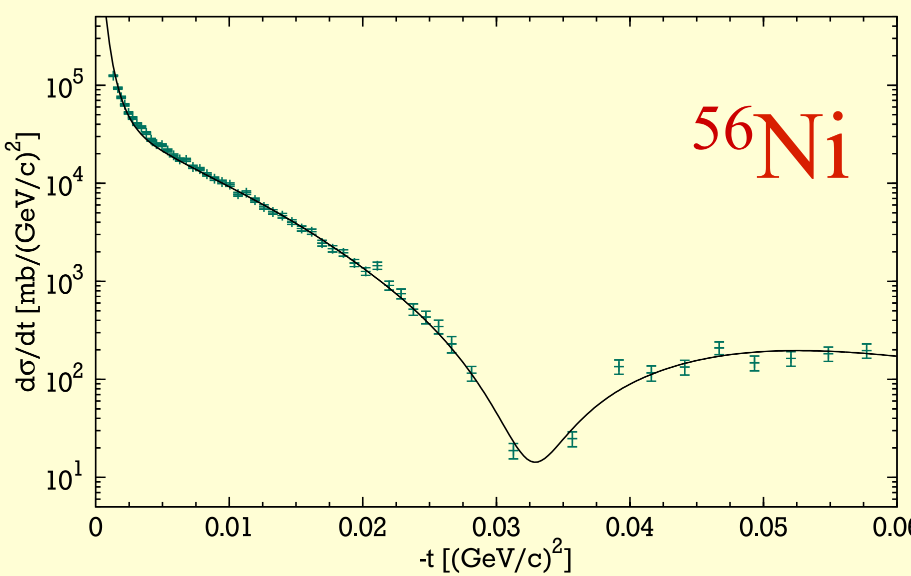


Elastic scattering of protons from ^{58}Ni and ^{56}Ni

^{56,58}*Ni(p,p), E = 400 MeV/u Angular Distribution*

M. v. Schmid

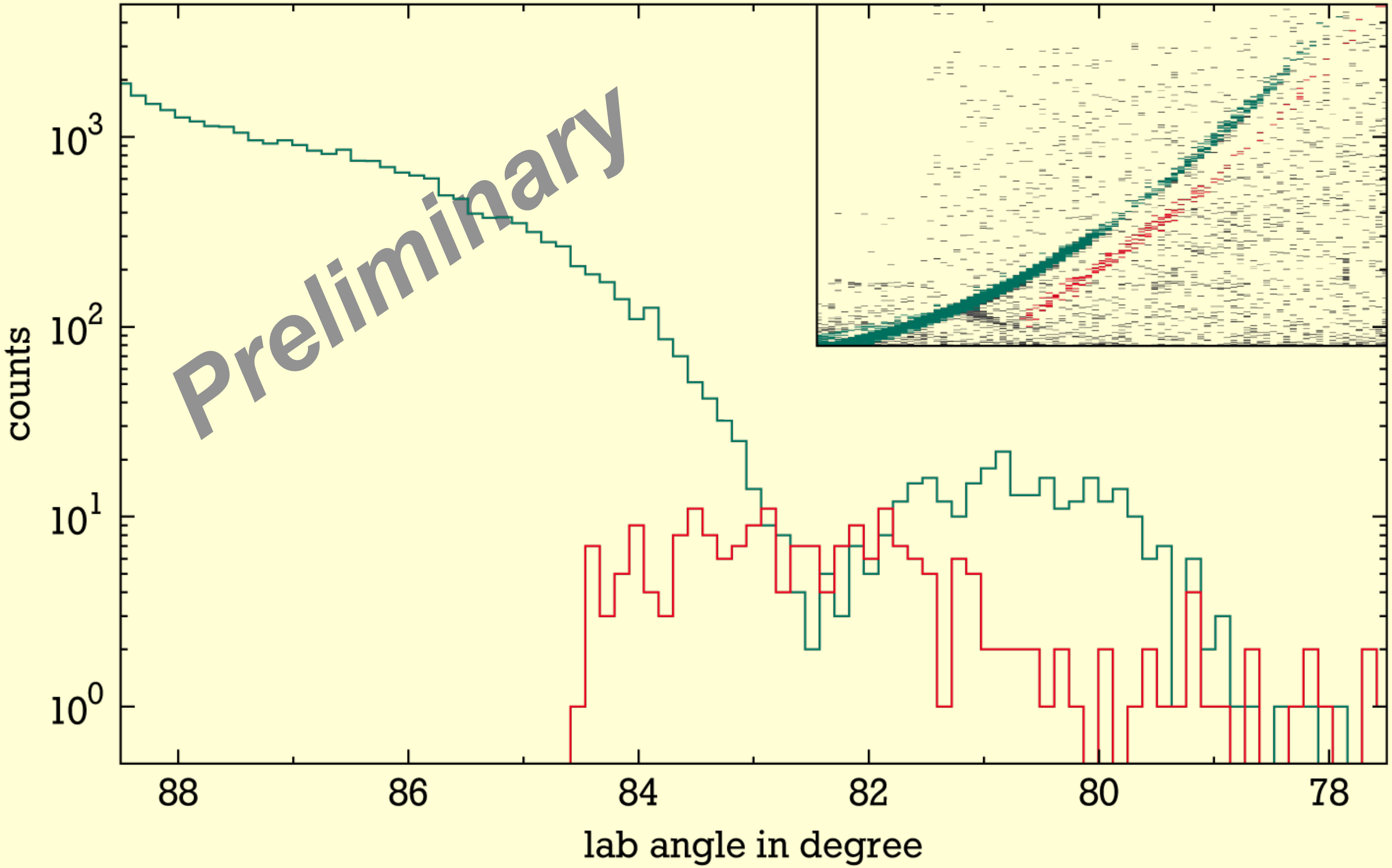




First results with radioactive beam

^{56}Ni(p,p'), E = 400 MeV/u Angular Distribution

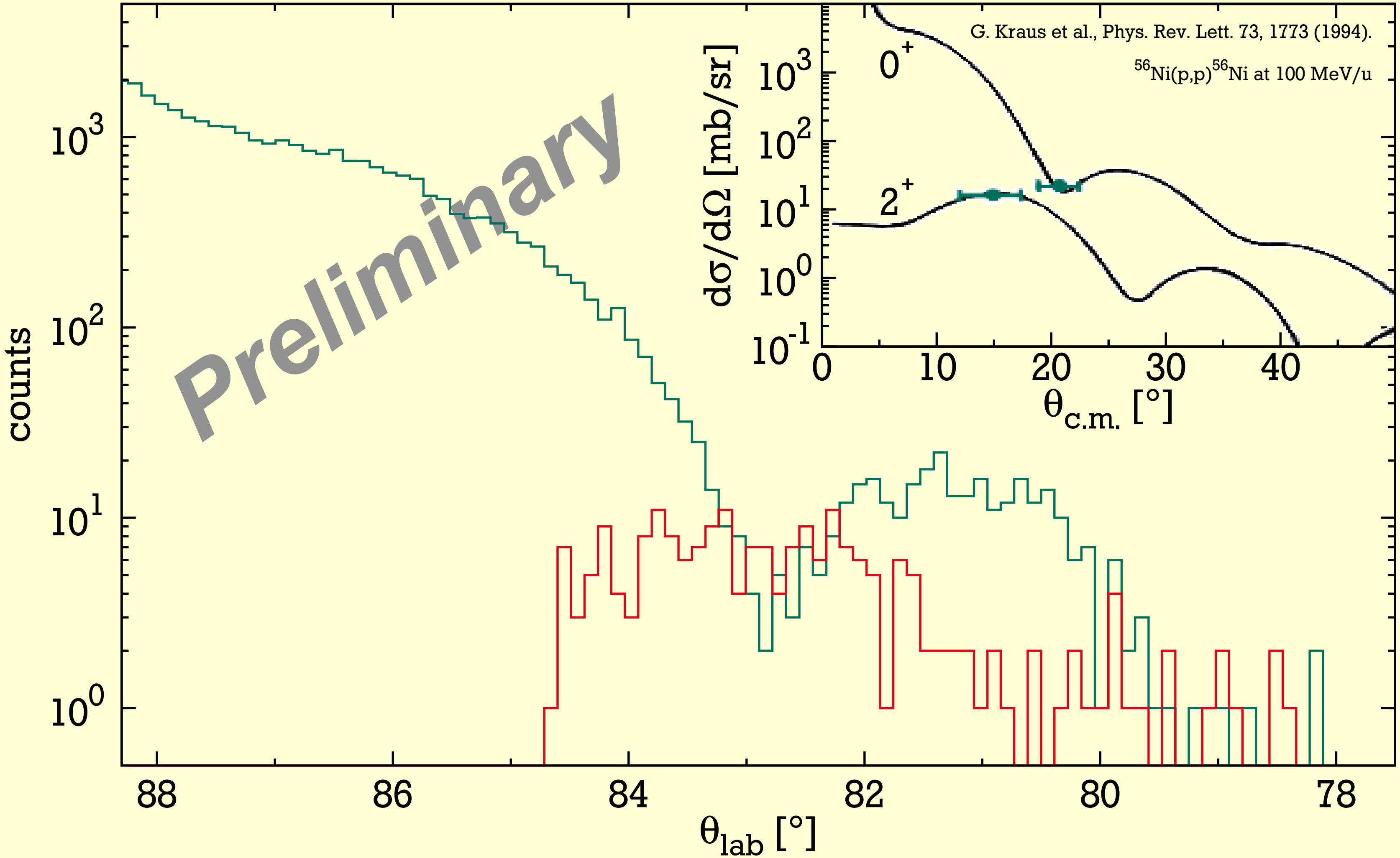
M. v. Schmid



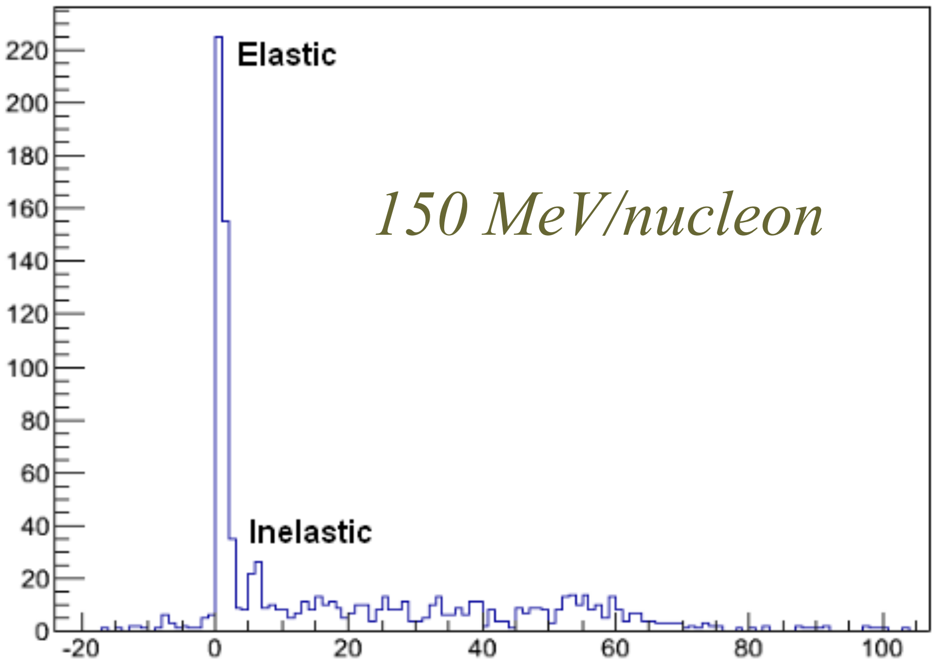
First results with radioactive beam

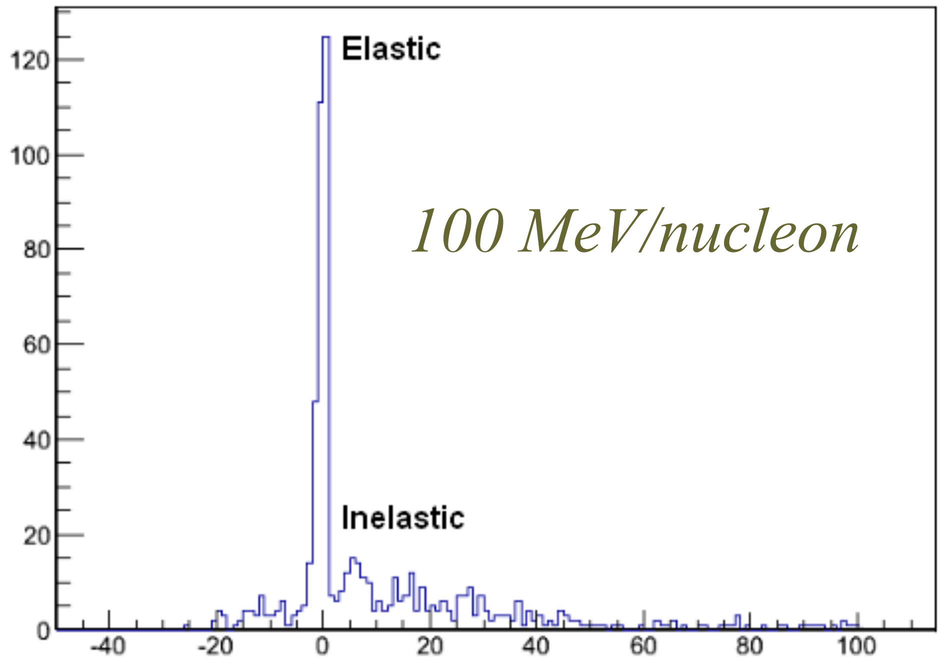
^{56}Ni(p,p'), E = 400 MeV/u Angular Distribution

M. v. Schmid

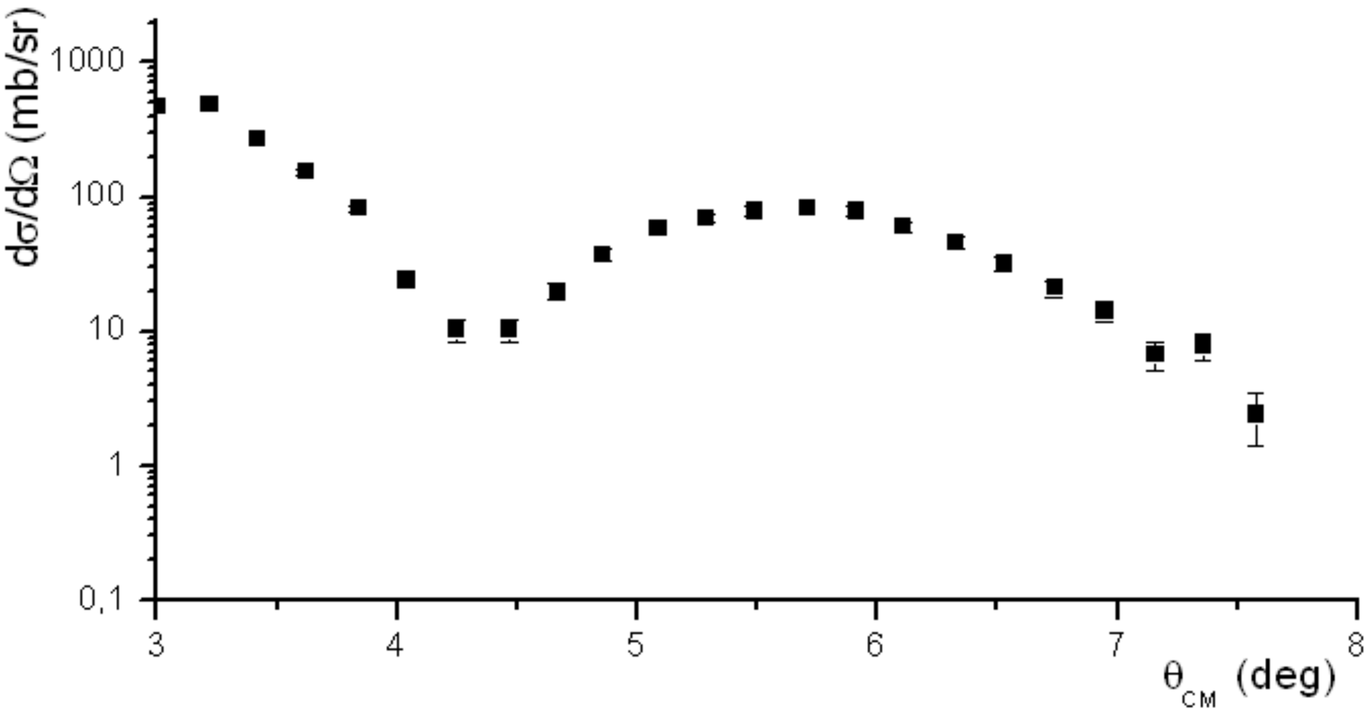


^{58}Ni with ^{4}He target



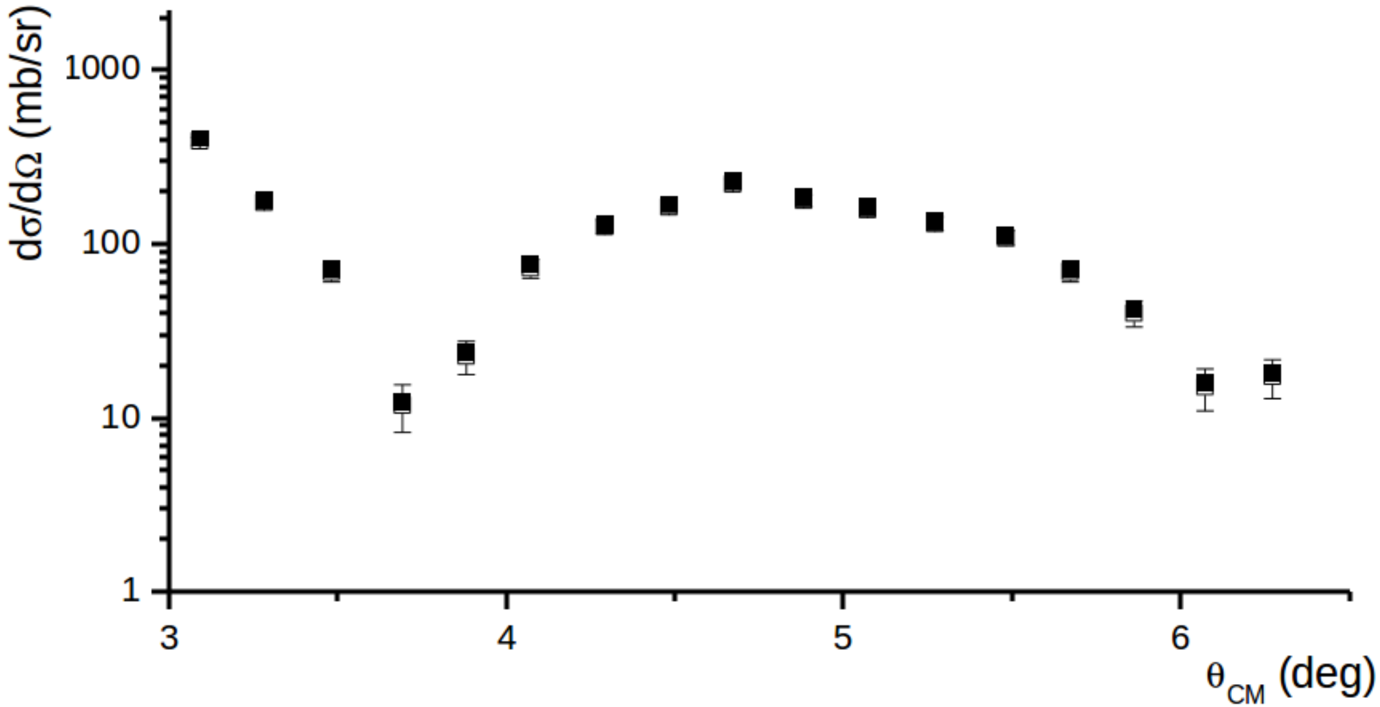


Maartje Kuilman



100 MeV/nucleon

^{58}Ni elastic (α,α)



150 MeV/nucleon

Maartje Kuilman

university of groningen

Isoscalar Giant Monopole Resonance

reaction: ^{58}Ni on He target

energy: 100 MeV/u

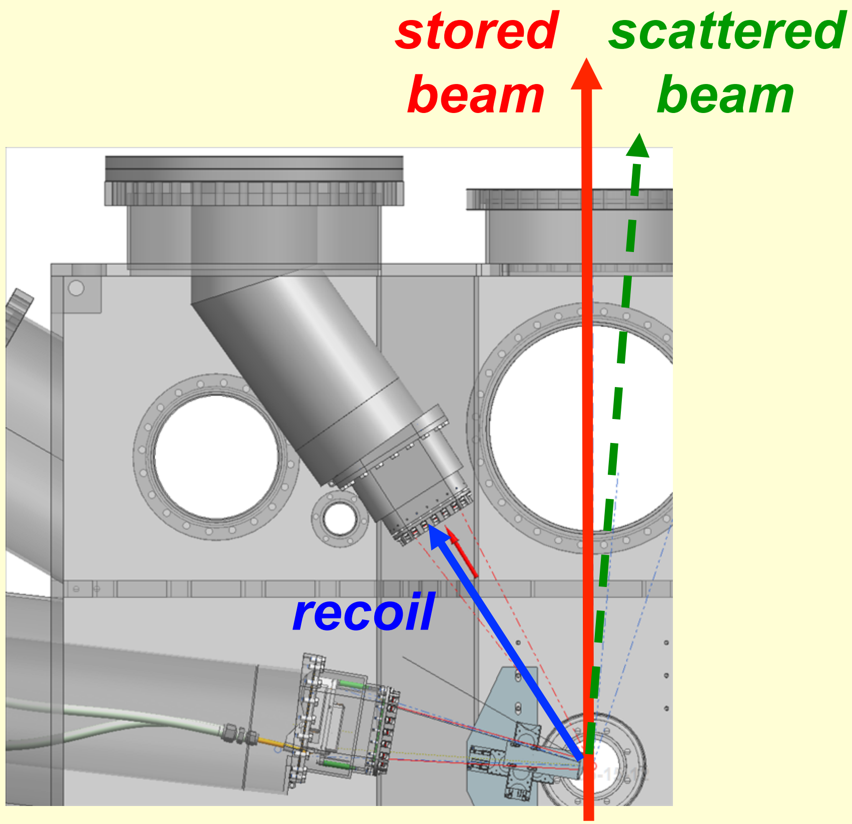
target: 8 X 10^{12} /cm^3

detectors: DSSD

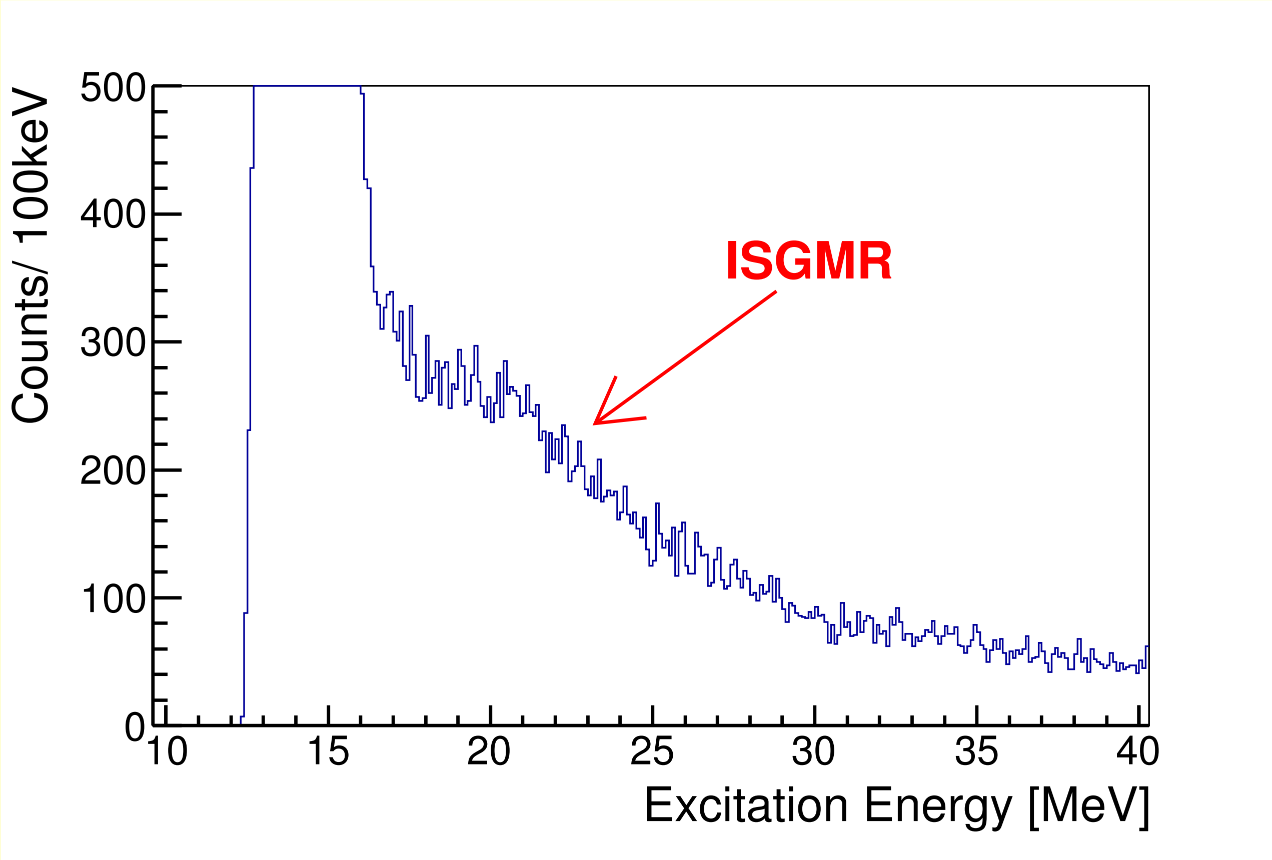
$\Theta_{Lab} = 27° - 38°$

PIN diodes

$\Theta_{Lab} = 0.2° - 1°$

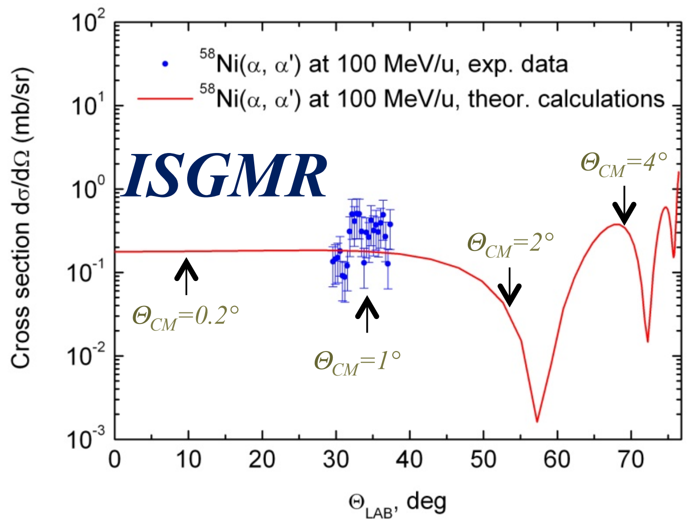


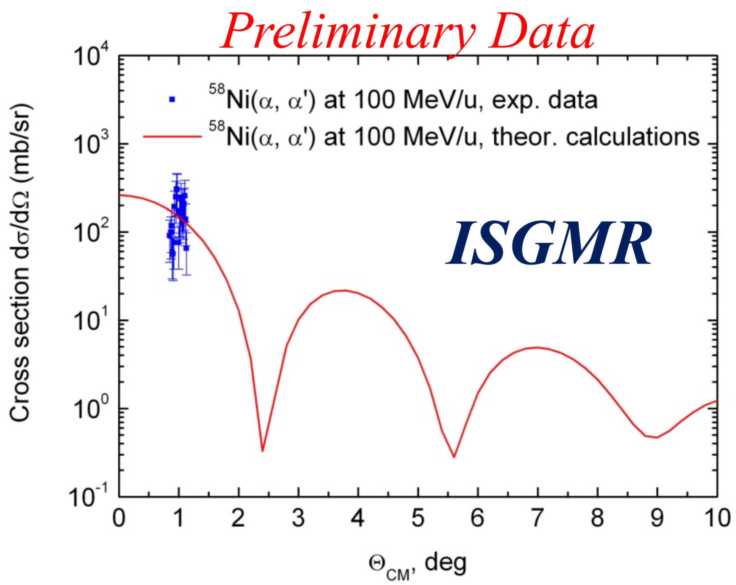
Giant resonances?



J.C. Zamora

Isoscalar Giant Monopole Resonance





Unnormalized
Cross sections!!

O. Kiselev, C. Rigollet,
S. Roy, J.C. Zamora

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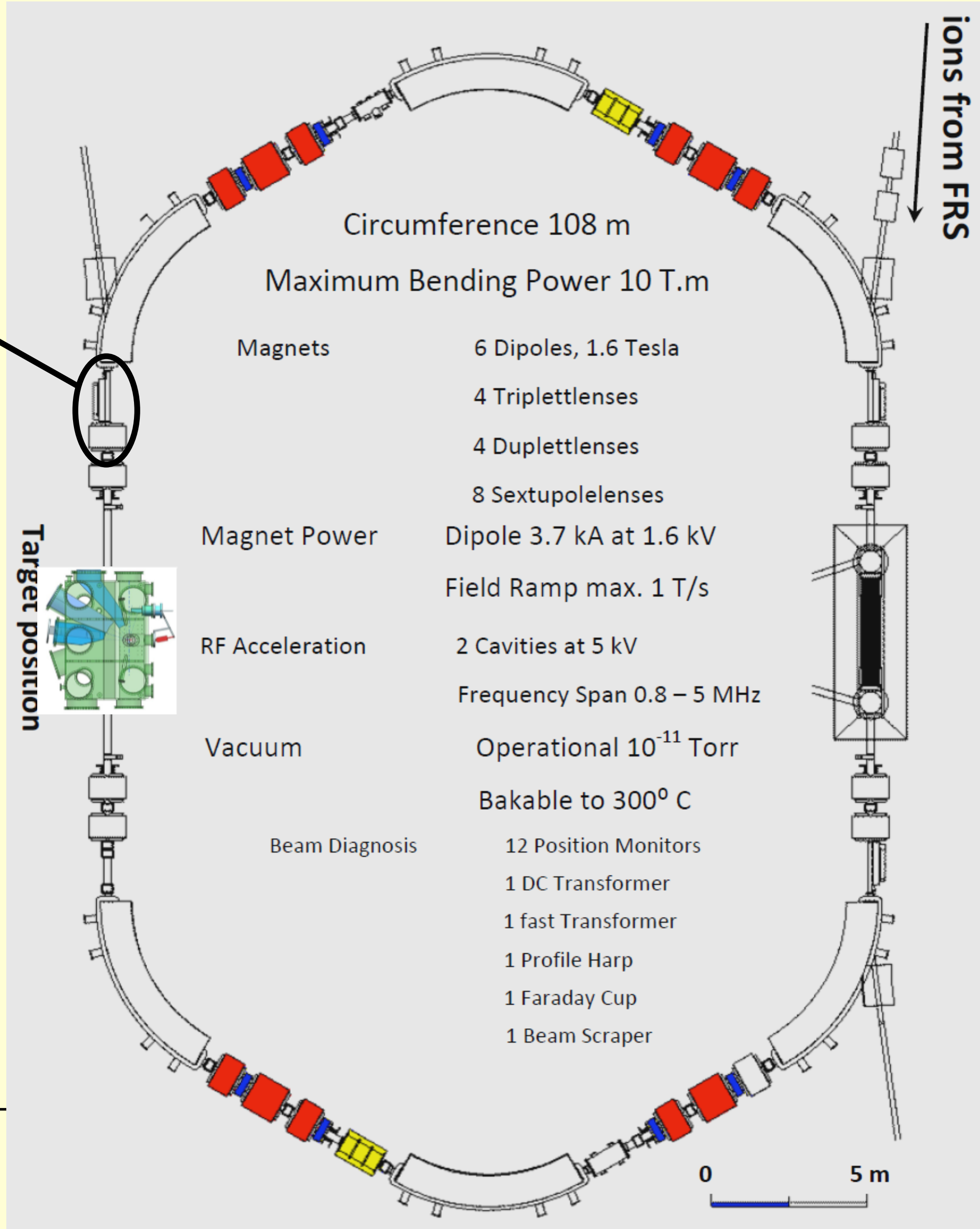
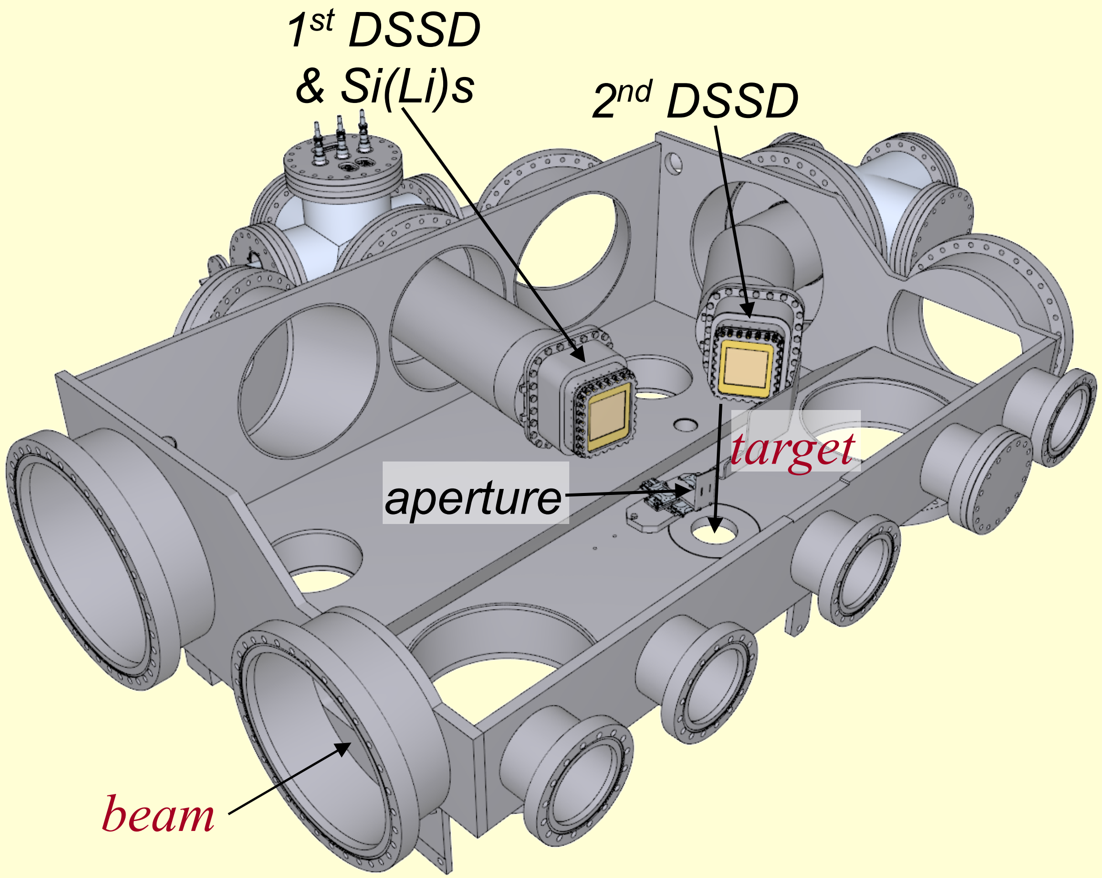
Setup @ ESR ring

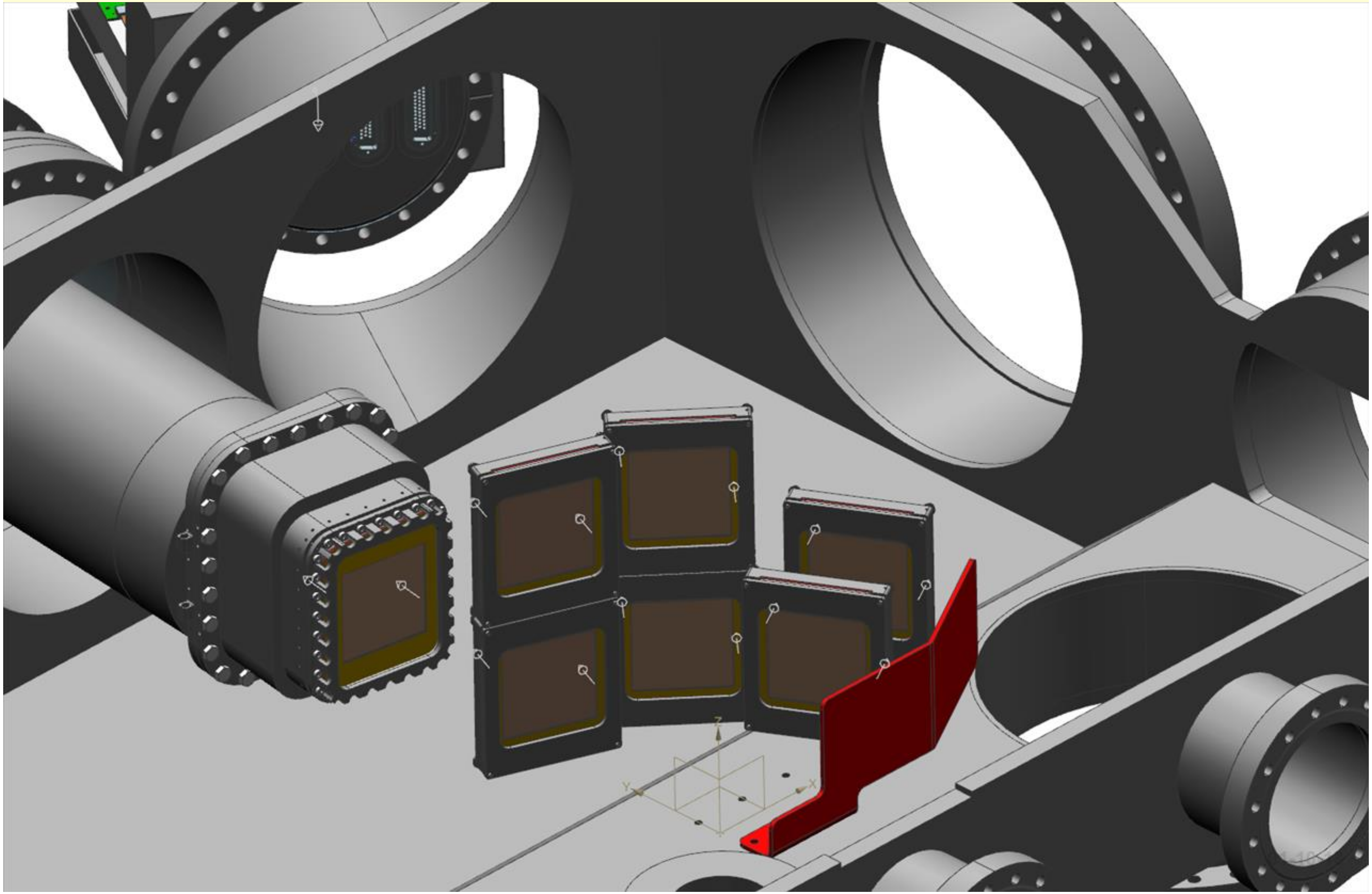
Pin diode



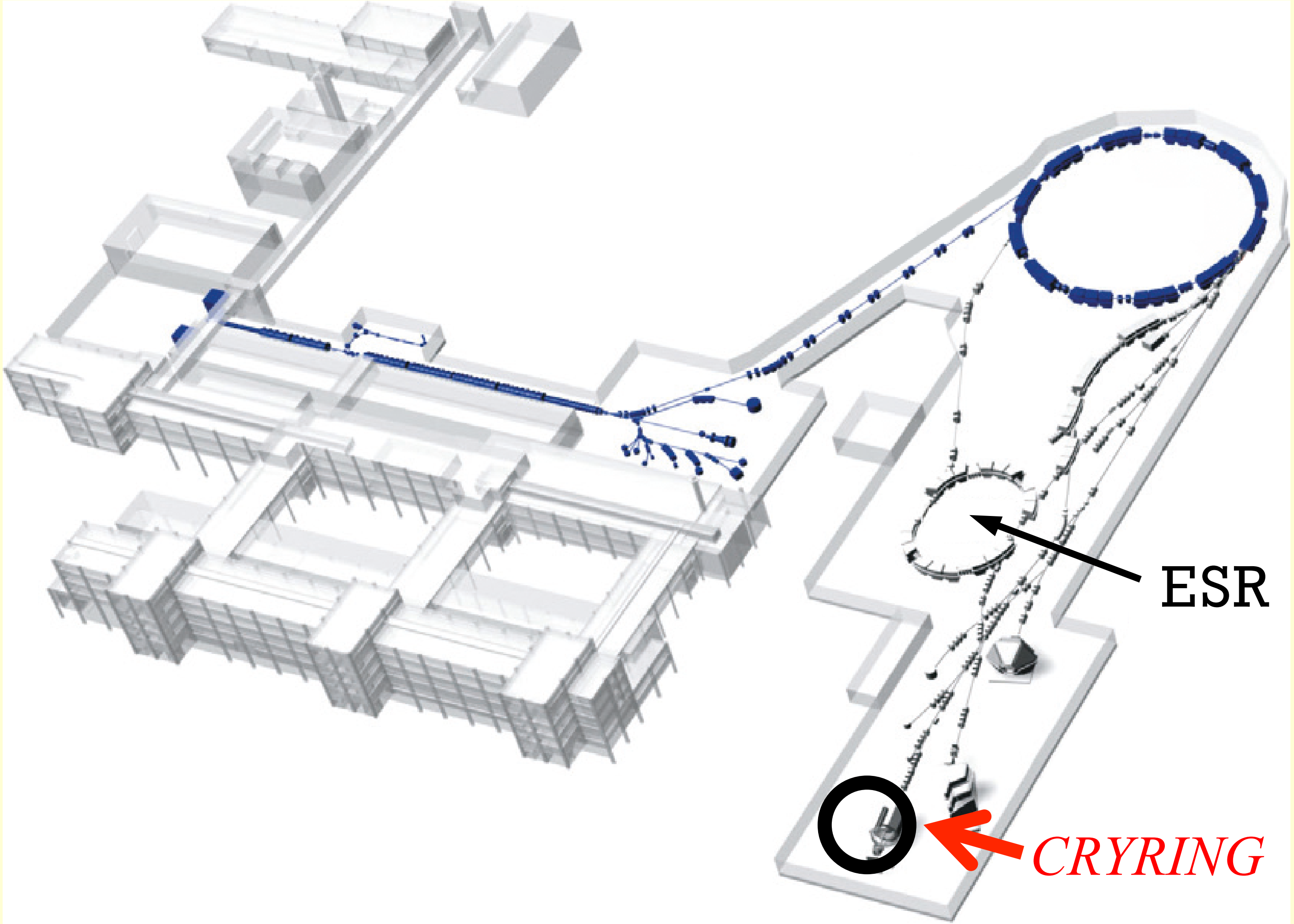
The first EXL experiment



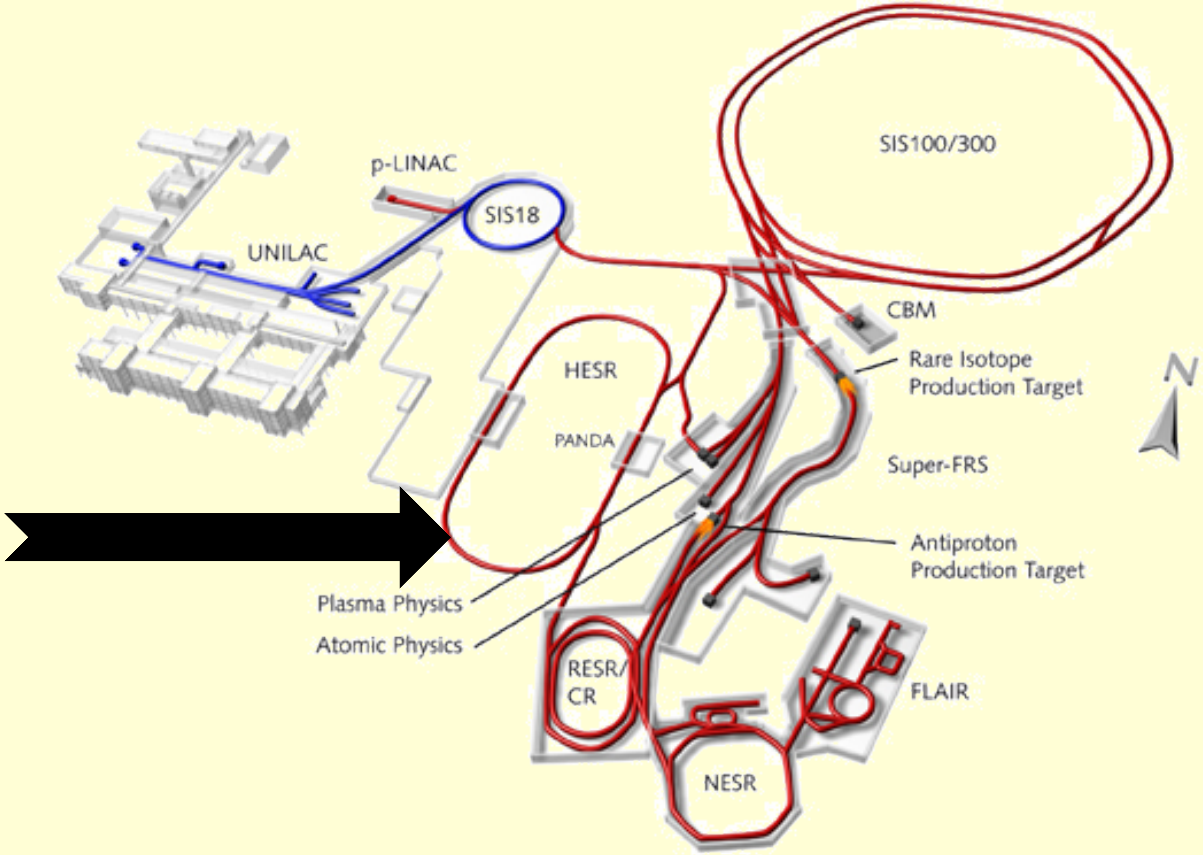
Upgrade of the first EXL experiment



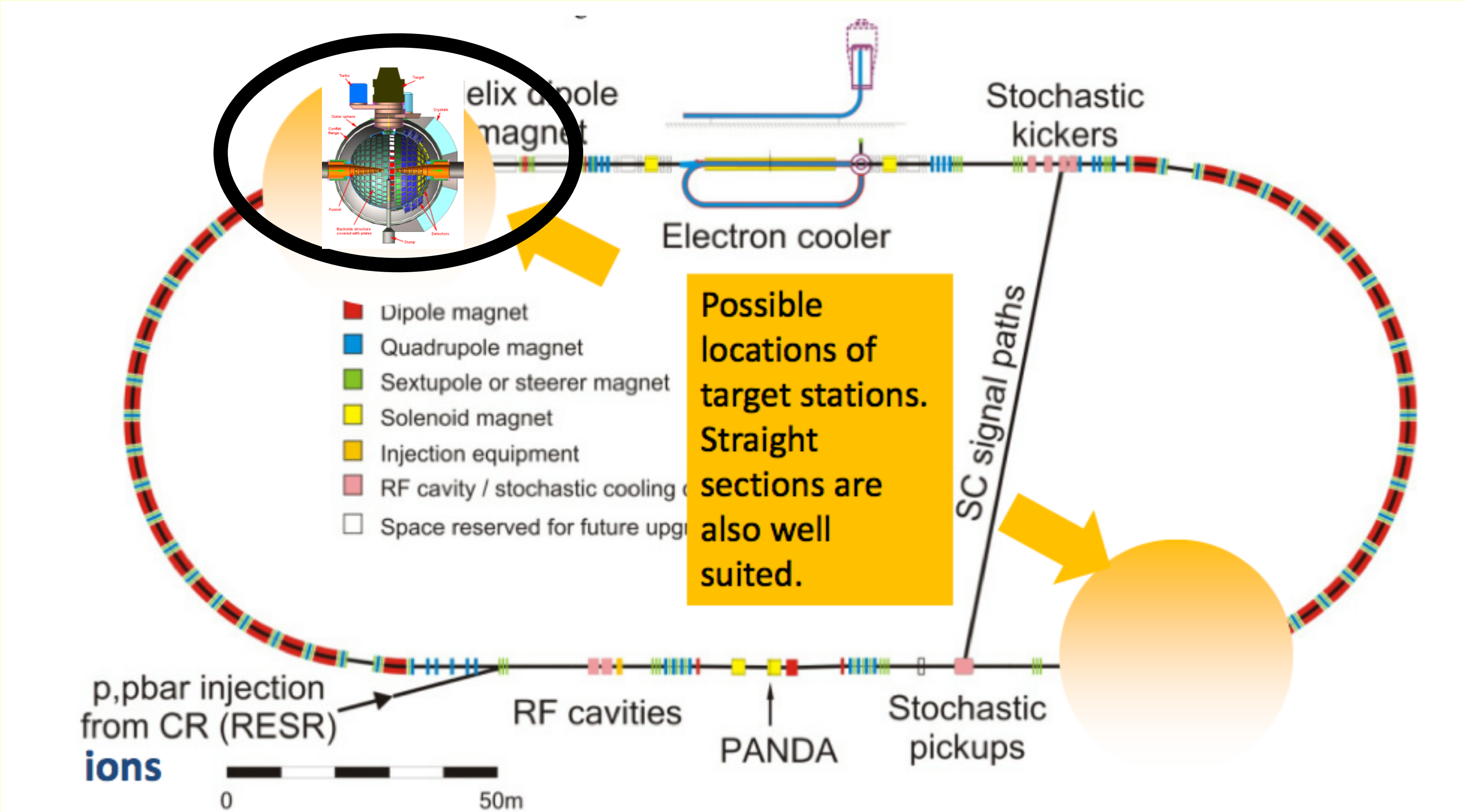
Intermediate-range Plans for rings



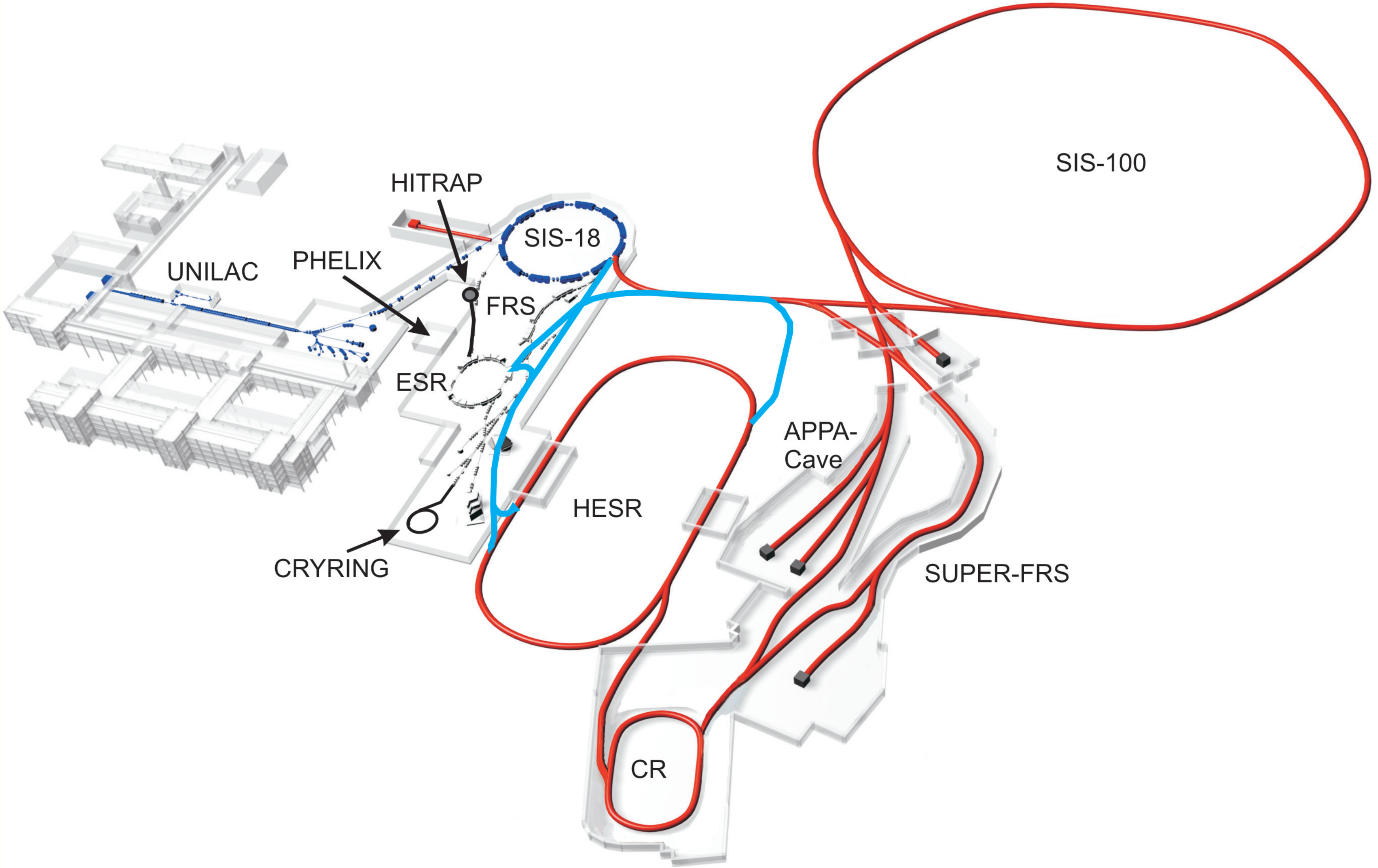
Intermediate-range Plans for rings



Intermediate-range Plans for rings



Intermediate-range Plans for rings



Storage Ring Task Force

Members are:

- Yuri Litvinov (GSI, FLAIR, chair)
- Thomas Stöhlker (GSI, APPA)
- Reinhold Schuch (Stockholm, APPA)
- Thomas Nilsson (Chalmers, NUSTAR)
- Jürgen Gerl (GSI, NUSTAR)
- Helmut Weick (GSI, ILIMA)
- Simon Haik (GSI, ELISe)
- Michael Lestinsky (GSI, APPA)
- Angela Demian-Bräuning (GSI, APPA)
- Frank Herfurth (GSI, APPA)
- Peter Egelhof (GSI, EXL)
- Nasser Kalantar (KVI-CART, EXL)
- Klaus Peters and Lars Schmitt [GSI, PANDA]
- Dieter Prasuhn [Jülich, PANDA]

Conclusions and outlook

- The low-q physics program covers a large part of nuclear structure and reactions.
- Bulk properties (radius, compressibility etc.), shell structure and correlations can be studied in asymmetric matter.
- First reaction measurements have already been performed and beautiful results are emerging.
- R&D for detection systems for nuclear reactions is well underway. TDR can be produced soon.
- In collaboration with APPA, ILIMA and ELISe, ideas for storage rings @ FAIR are being pursued. Task force is formed and is studying the options.

The EXL-E105 Collaboration

S. Bagchi[1], S. Bönig[2], M. Castlós[3], I. Dillmann[4], C. Dimopoulou[4], P. Egelhof[4], V. Eremin[5], H. Geissel[4], R. Gernhäuser[6], 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], M. Mutterer[4], D. Nagae[8], 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[9], H. Weick[4], J.S. Winfield[4], D. Winters[4], P.J. Woods[10], T. Yamaguchi[11], K. Yue[4,7], J.C. Zamora[2], J. Zenihiro[9]

[1] KVI, Groningen
[2] Technische Universität Darmstadt
[3] ATOMKI, Debrecen
[4] GSI, Darmstadt
[5] Ioffe Physico-Technical Institute, St.Petersburg
[6] Technische Universität München
[7] Institute of Modern Physics, Lanzhou
[8] University of Tsukuba
[9] RIKEN Nishina Center
[10] The University of Edinburgh
[11] Saitama University

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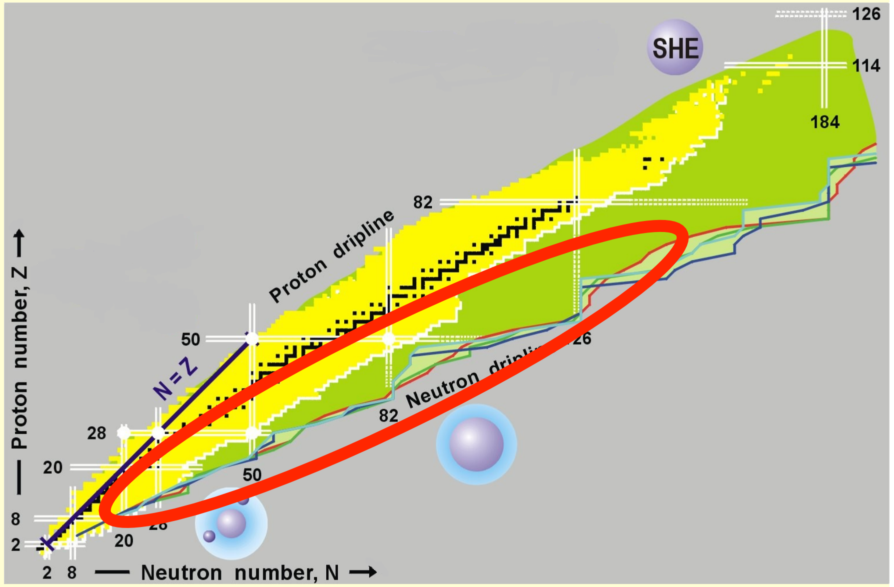
Thank you!

Main Physics Goals in Nuclear Structure

regions of interest:

⇒ towards the driplines for
light, medium, medium heavy
and heavy nuclei



physics interest:

- matter distributions (halo, skin…)
- single-particle structure evolution (new magic numbers, new shell gaps, spetroscopic factors)
- NN correlations, pairing and clusterization phenomena
- new collective modes (different deformations for p and n, giant resonance strength)
- parameters of the nuclear equation of state
- in-medium interactions in asymmetric and low-density matter
- astrophysical r and rp processes, understanding of supernovae

Light-ion induced direct reactions

- Elastic scattering (p,p), (α,α), …

  Nuclear matter distribution $\rho_{matter}(r)$, skins, halo structures
- Inelastic scattering (p,p'), (α,α'), …

  Deformation parameters, B(E2) values, transition densities, giant resonances
- Charge exchange reactions (p,n), (^{3}He,t), (d,^{2}He), …

  Gamow-Teller strength
- Transfer reactions (p,d), (p,t), (p, ^{3}He), (d,p), …

  Single particle structure, spectroscopic factors

  Spectroscopy beyond the driplines

  Neutron pair correlations

  Neutron (proton) capture cross sections
- Knock-out reactions (p,2p), (p,pn), (p,p^{4}He), …

  Ground state configurations, nucleon momentum dist., cluster correlations