The use of storage rings and active targets in the study of giant resonances

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KVI-CART, University of Groningen

The 5th international conference on
"COLLECTIVE MOTION IN NUCLEI UNDER EXTREME CONDITIONS"

COMEX5

Krakow, Poland

September 15, 2015

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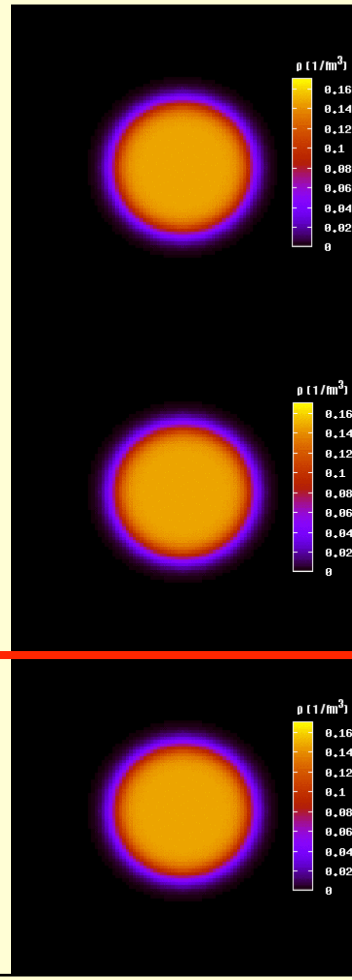
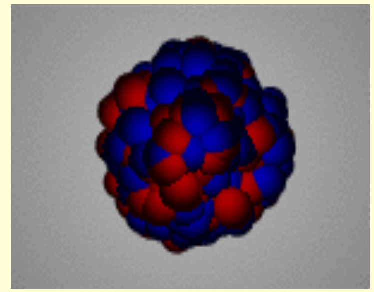
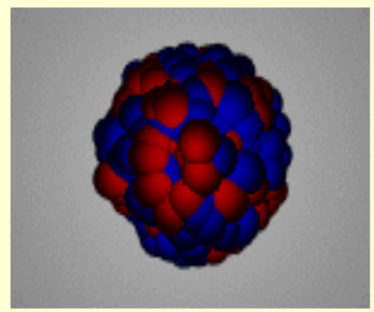
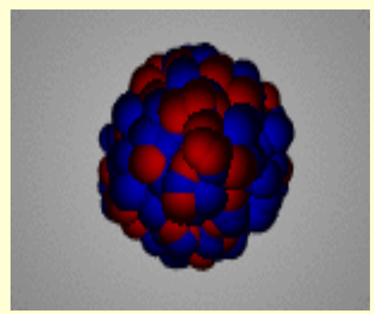
Bulk Properties

Example:
The Collective Response of the Nucleus: Giant Resonances

Compression modes

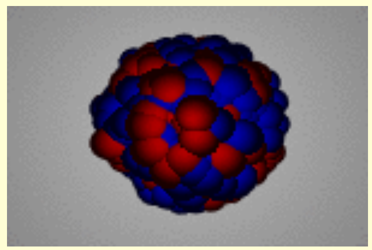
	Isoscalar (In phase) $\Delta T = 0$	*Isovector (Out of phase)* $\Delta T = 1$
Monopole $\Delta L = 0$ (GMR)		
Dipole $\Delta L = 1$ (GDR)		
Quadrupole $\Delta L = 2$ (GQR)		

Example:
The Collective Response of the Nucleus: Giant Resonances

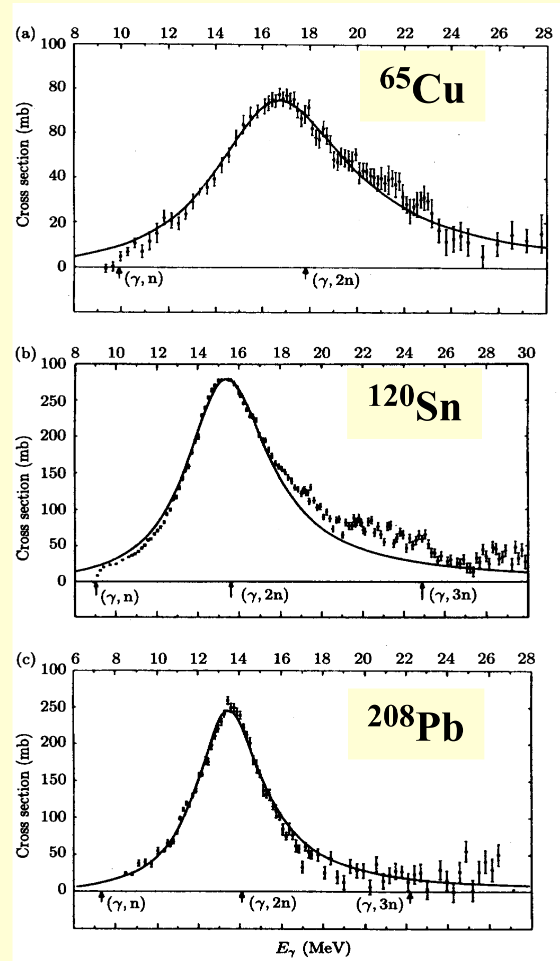
Photo-neutron cross sections

Electric giant resonances

Dipole (GDR)



Berman and Fulz, Rev. Mod. Phys. 47 (1975) 47



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Example:
The Collective Response of the Nucleus: Giant Resonances

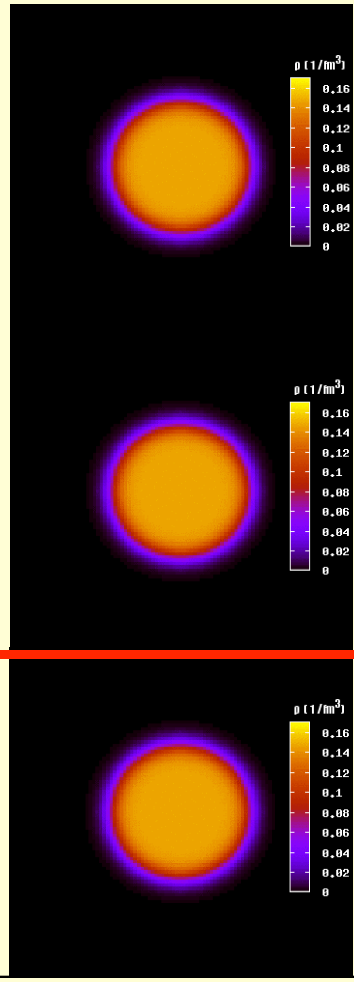
Compression modes

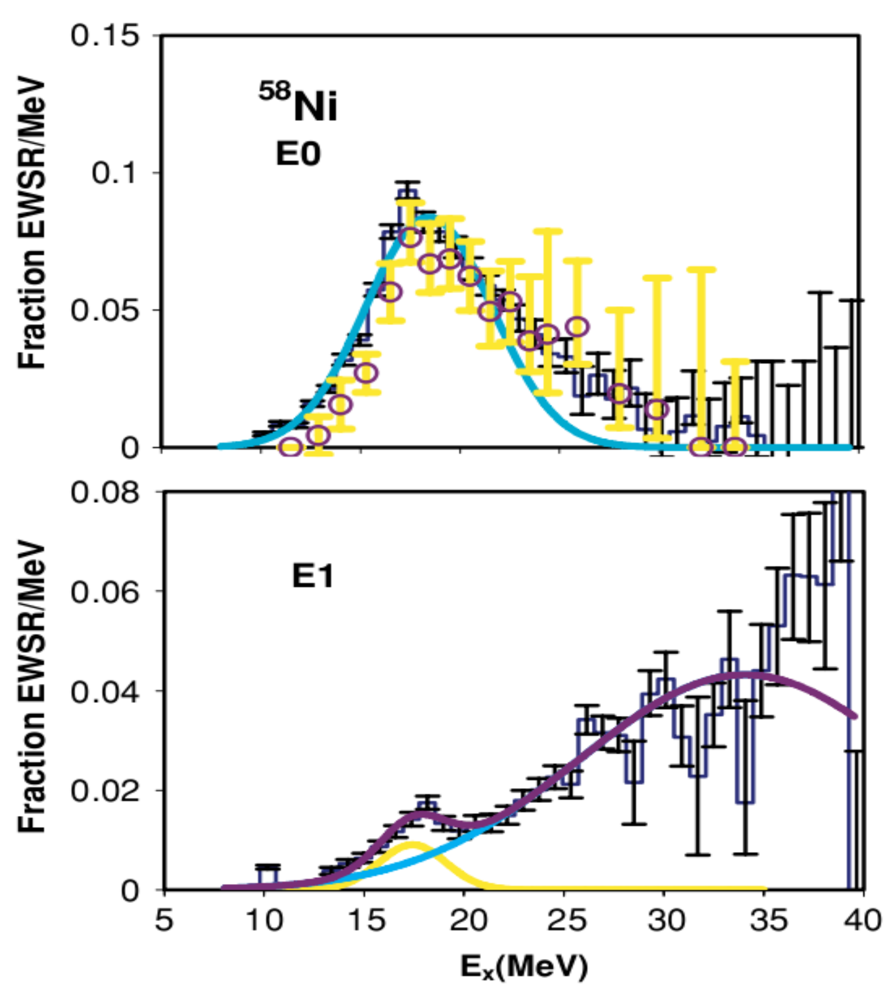
Isoscalar (In phase)
ΔT = 0

Monopole
ΔL = 0
(GMR)

Dipole
ΔL = 1
(GDR)

Quadrupole
ΔL = 2
(GQR)





Y.-W. Lui et al., Phys. Rev. C 73 (2006) 014314

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

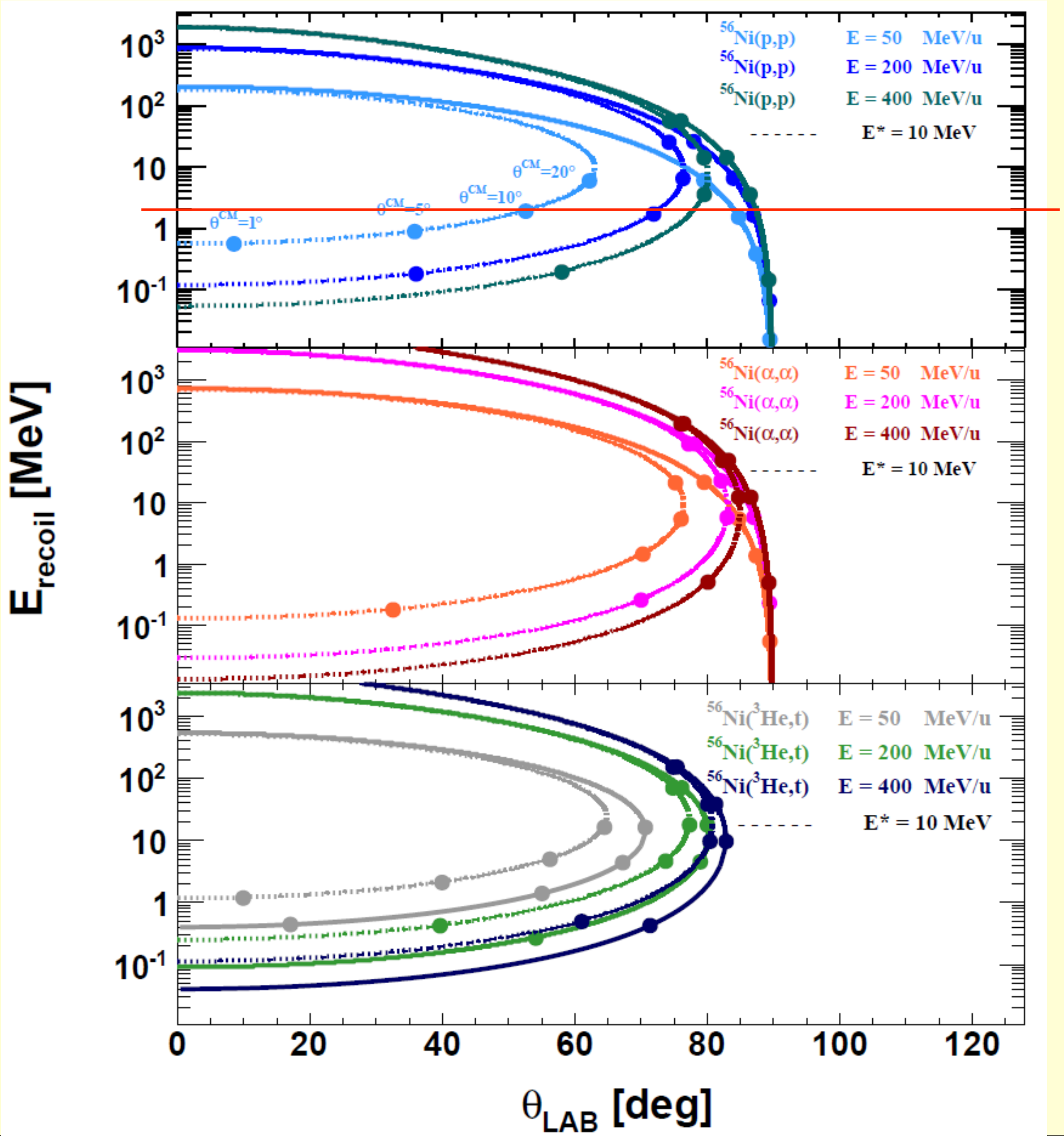
✓ Investigation of Gamow-Teller Transitions:

⇒ 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



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The EXL Collaboration

Univ. São Paulo

TRIUMF Vancouver

IMP Lanzhou

VTT Helsinki

IPN Orsay, CEA Saclay

GSI Darmstadt, TU Darmstadt, Univ. Frankfurt, FZ Jülich, Univ. Giessen, Univ. Mainz, Univ. Munich

INR Debrecen

SINP Kolkata, BARC Mumbai

KVI Groningen

INFN/Univ. Milano

Univ. Teheran

Univ. Osaka

JINR Dubna, PNPI Gatchina, KRI St. Petersburg, Ioffe Inst. St. Petersburg, Kurchatov Inst. Moscow

CSIC Madrid, Univ. Madrid

Univ. Lund, Mid Sweden Univ., Univ. Uppsala, Chalmers Inst. Göteborg

Univ. Basel

Univ. Birmingham, CLRC Daresbury, Univ. Surrey, Univ. York, Univ. Liverpool, Univ. Edinburgh

Tbilisi State University, Ilia Chavchavadze State University, Tbilisi, Georgia

Spokesperson: N. Kalantar (KVI-CART)
18 countries, 34 institutes, ~150 participants

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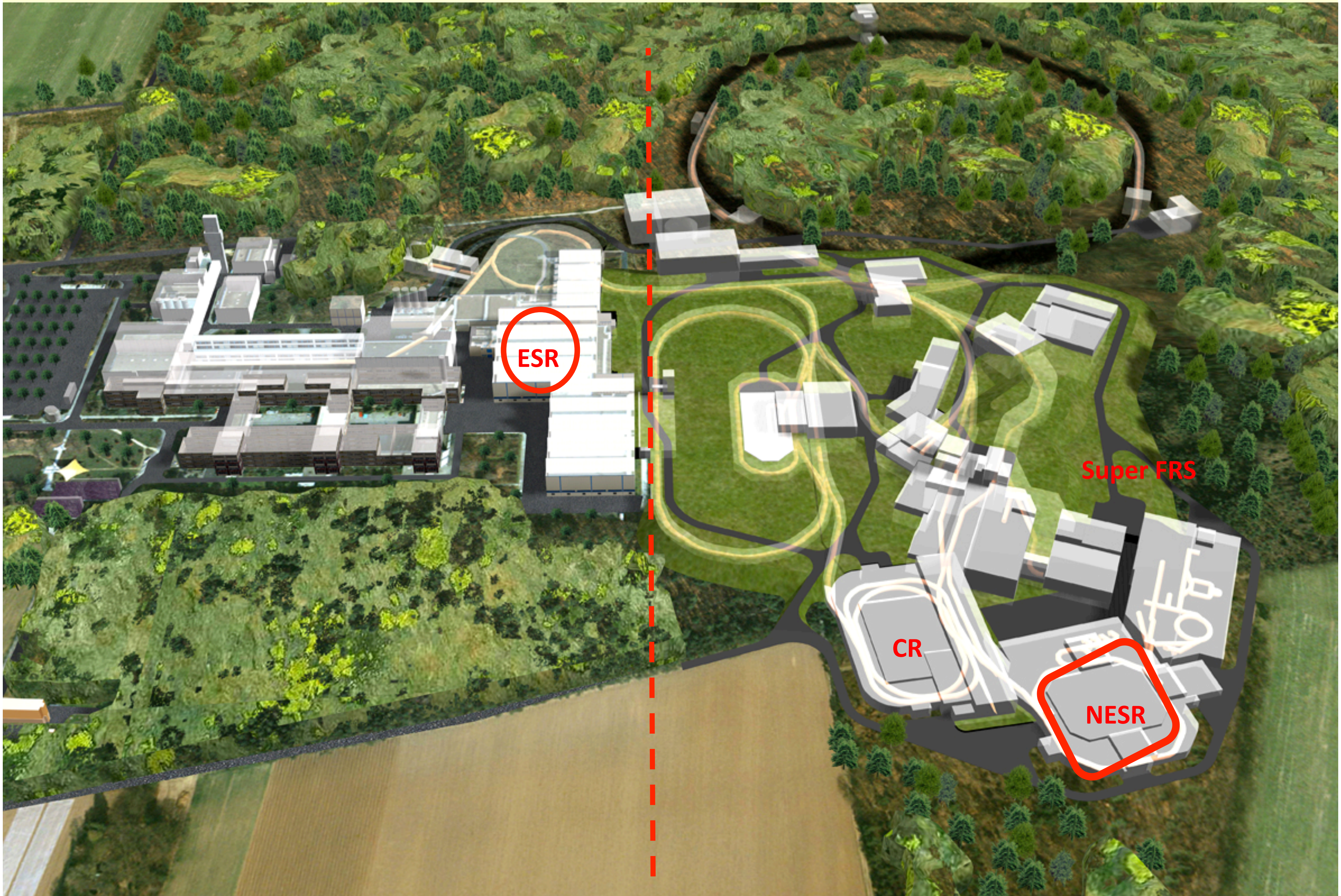

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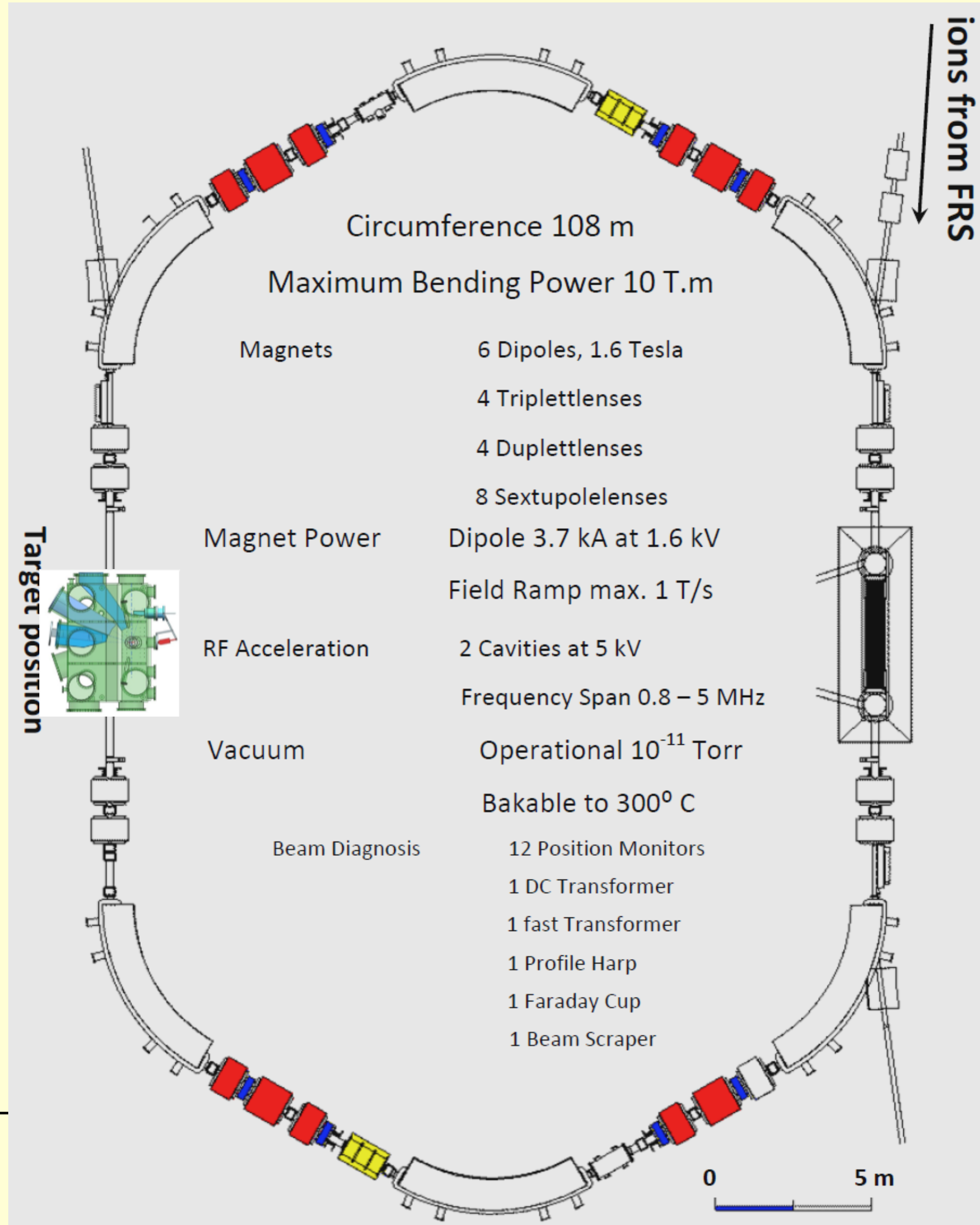
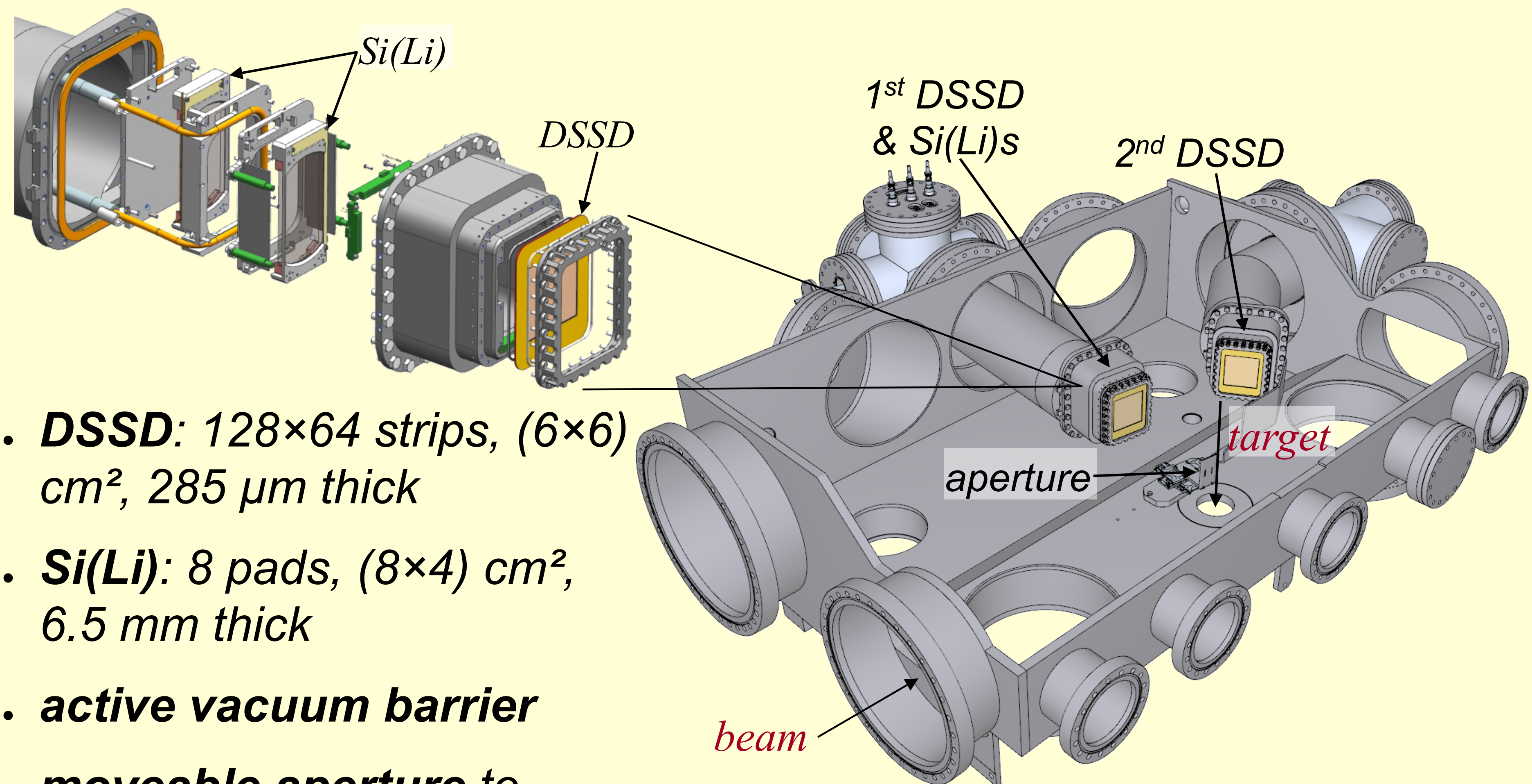
First EXL experiment with the existing storage ring at GSI (ESR)

Setup @ ESR

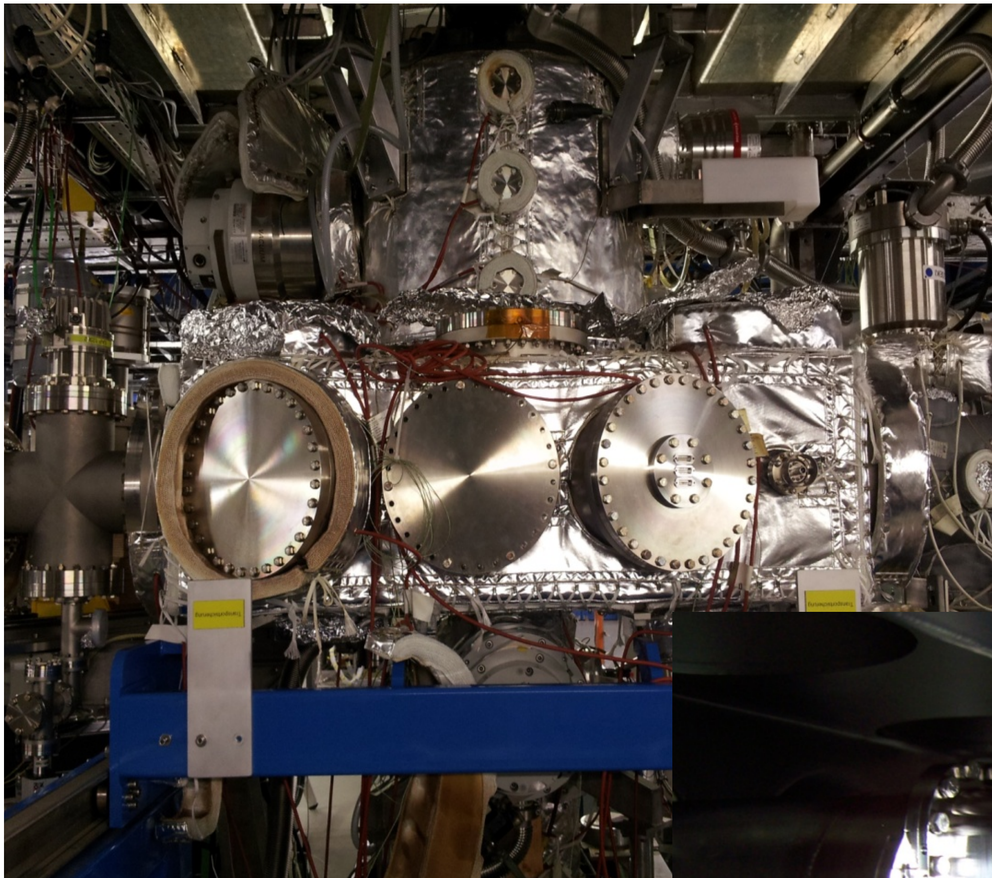


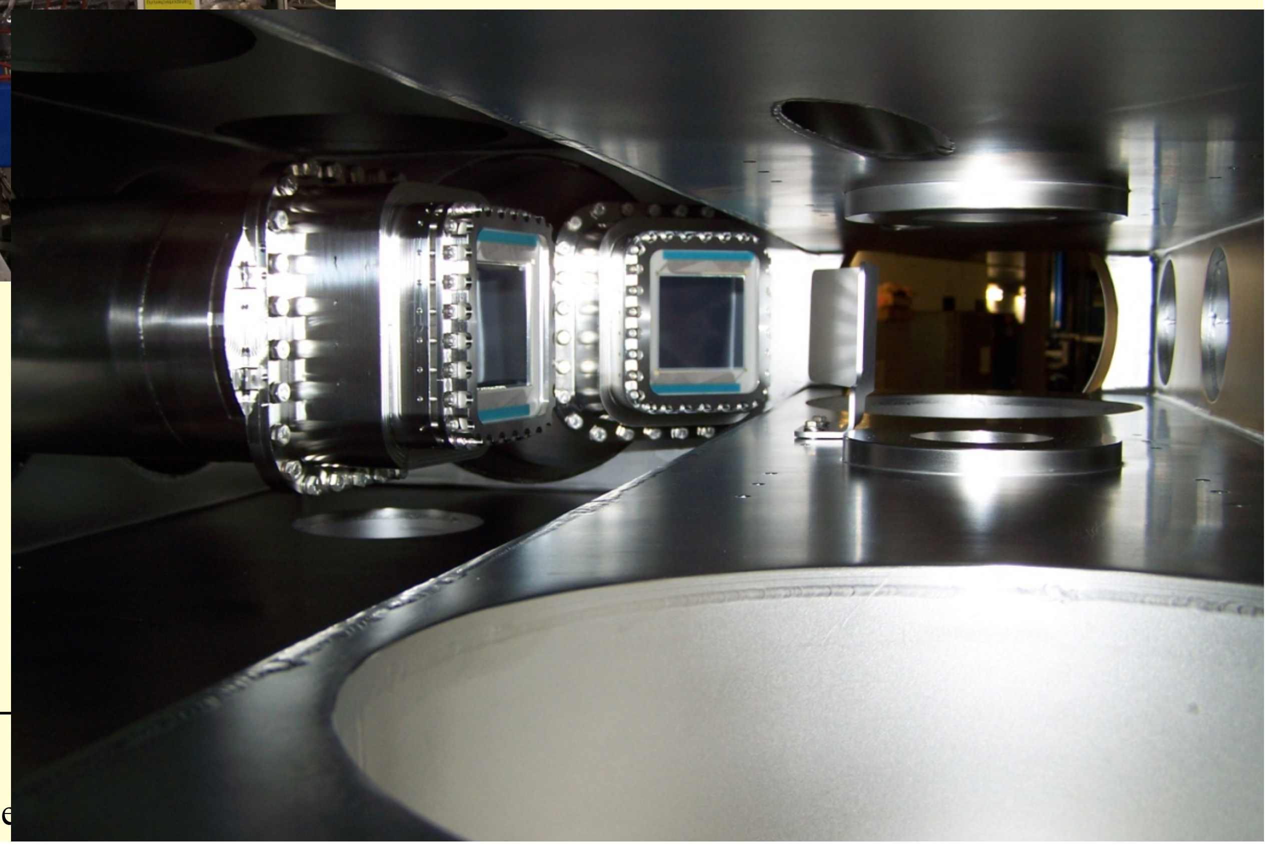
ions from FRS
Circumference 108 m
Maximum Bending Power 10 T.m
Magnets
6 Dipoles, 1.6 Tesla
4 Triplettlenses
4 Duplettlenses
8 Sextupolelenses
Magnet Power
Dipole 3.7 kA at 1.6 kV
Field Ramp max. 1 T/s
RF Acceleration
2 Cavities at 5 kV
Frequency Span 0.8 – 5 MHz
Vacuum
Operational 10^{-11} Torr
Bakable to 300° C
Beam Diagnosis
12 Position Monitors
1 DC Transformer
1 fast Transformer
1 Profile Harp
1 Faraday Cup
1 Beam Scraper
Target position
0
5 m

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*



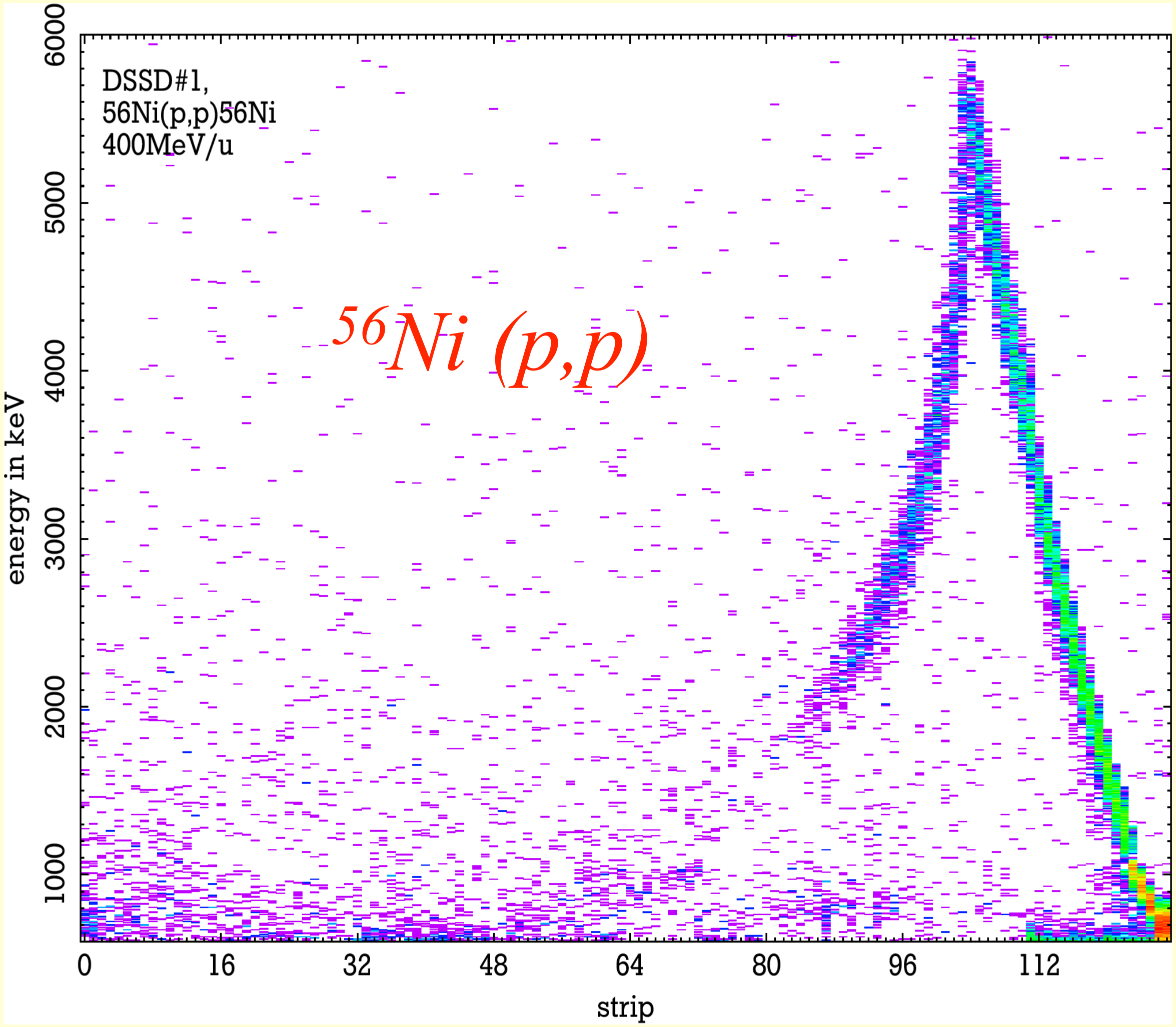


First results with radioactive beam

October 25, 2012:

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

Beam energy 400 MeV/u



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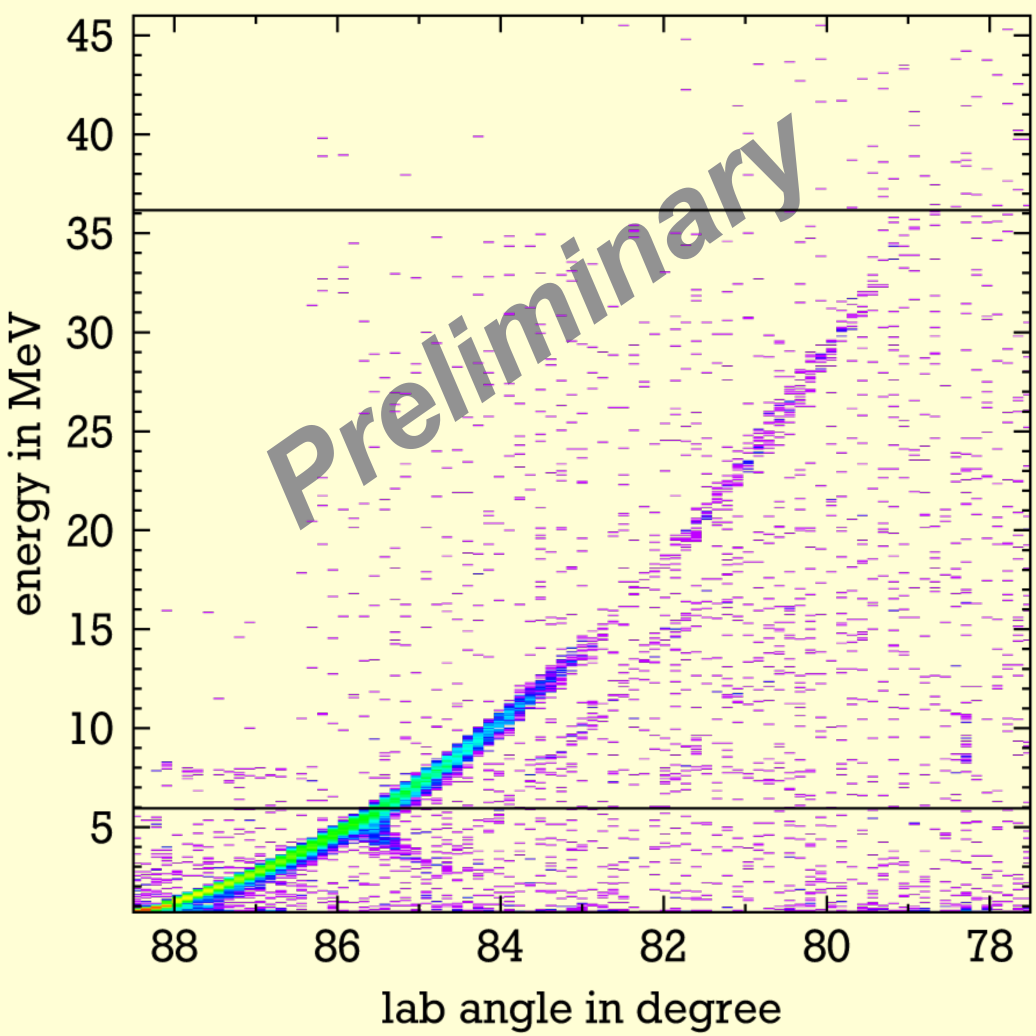
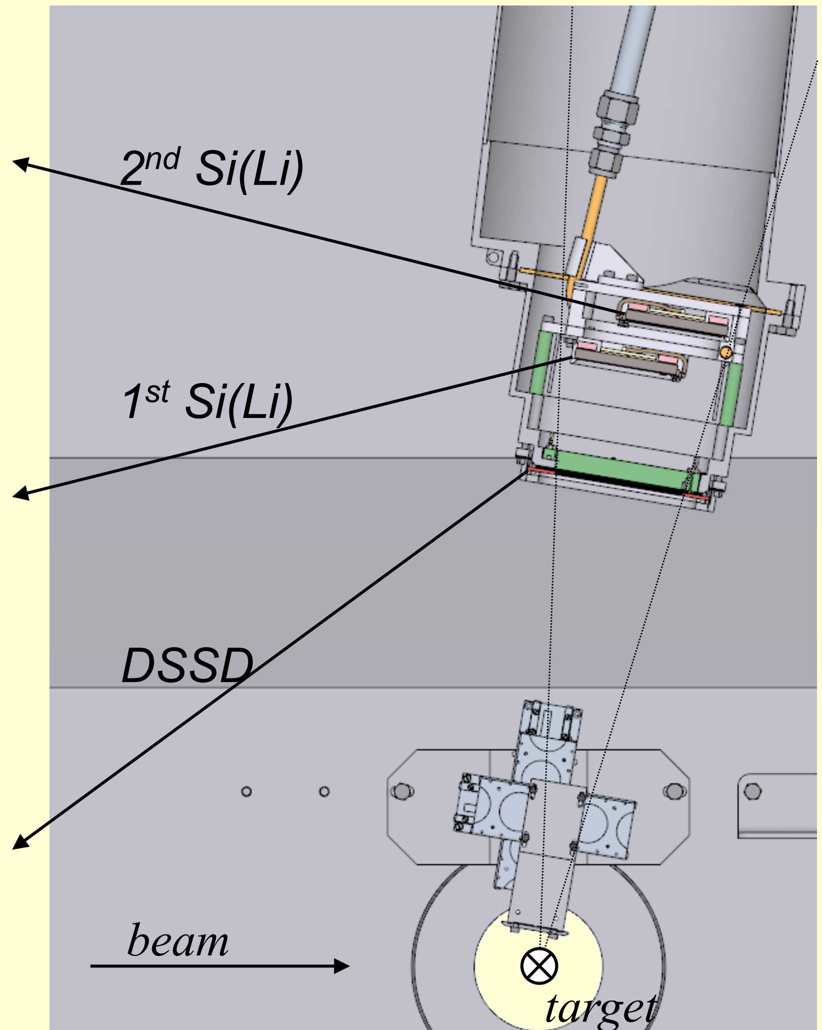
First results with radioactive beam

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





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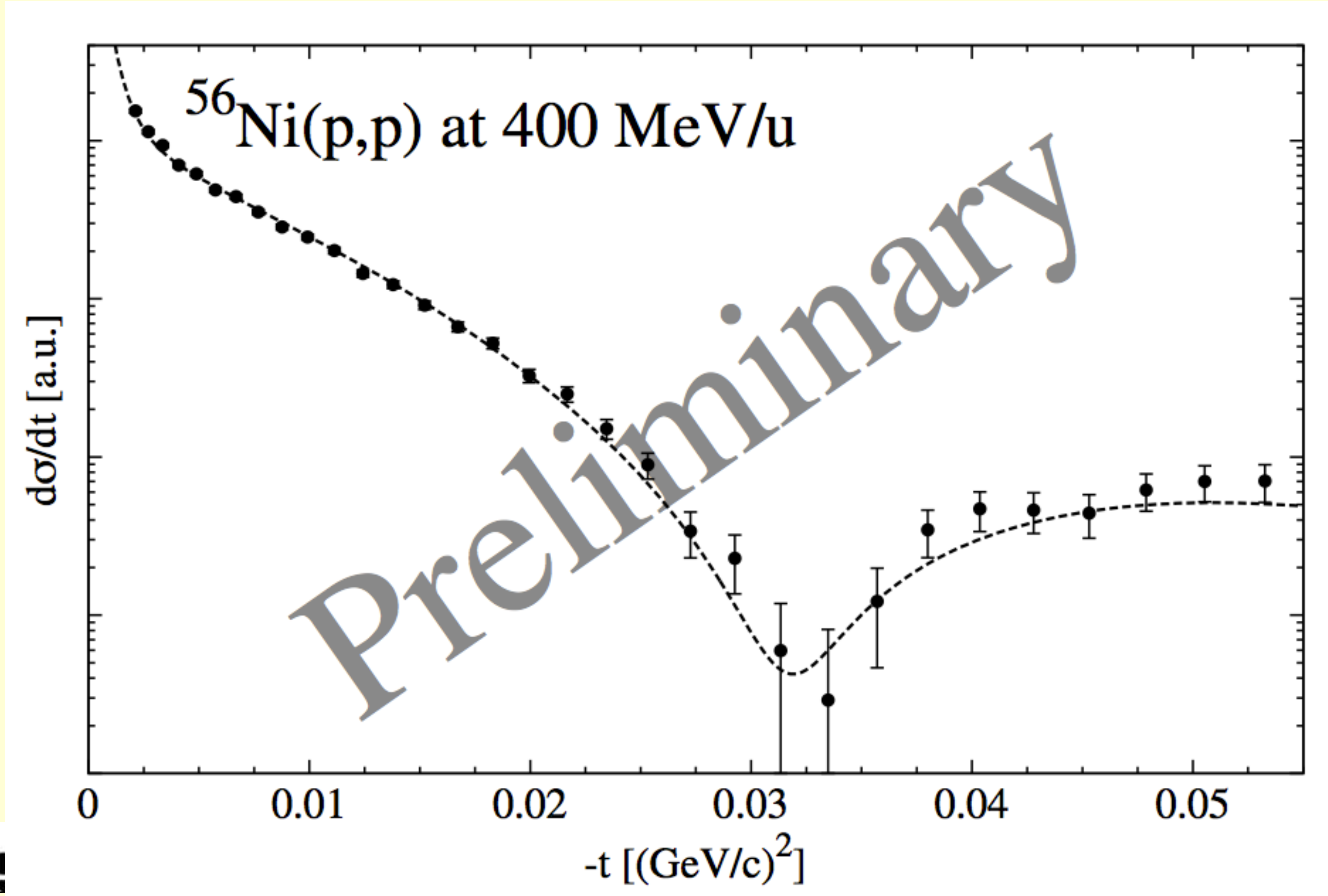
First results with radioactive beam

- Elastic p-scattering off ^{56}Ni (E105), M. von Schmid



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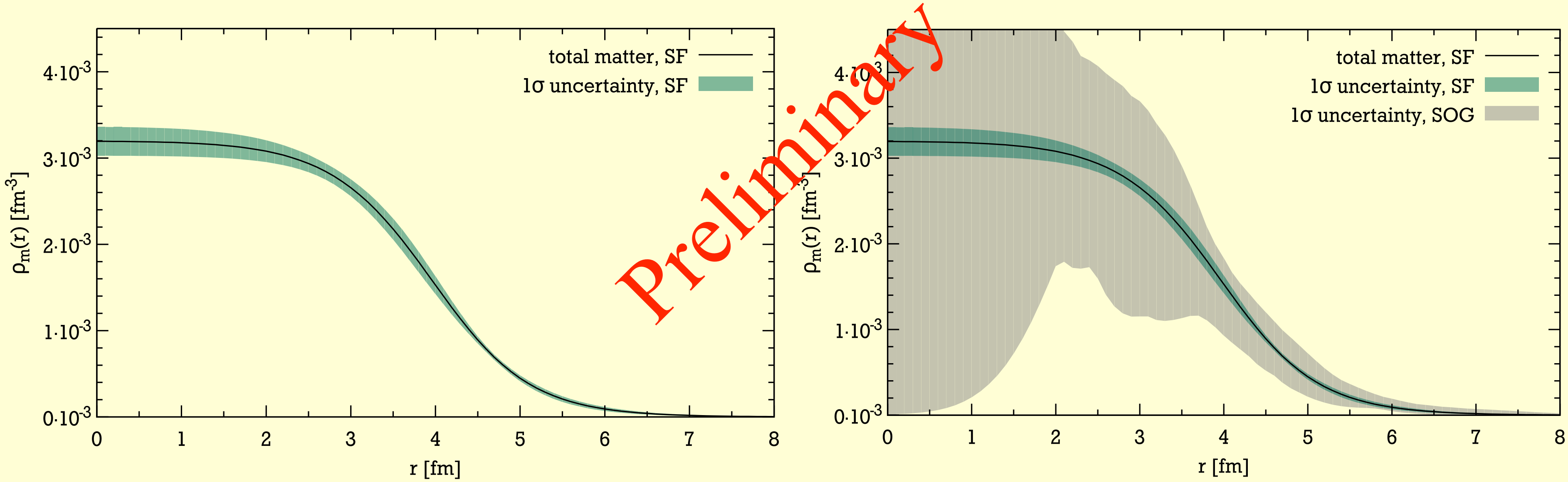
First results with radioactive beam

- Elastic p-scattering off ^{56}Ni (E105)



Density par.: Sym. Fermi
RMS matter rad. ≈3.75 fm

Thesis work Mirko von Schmid

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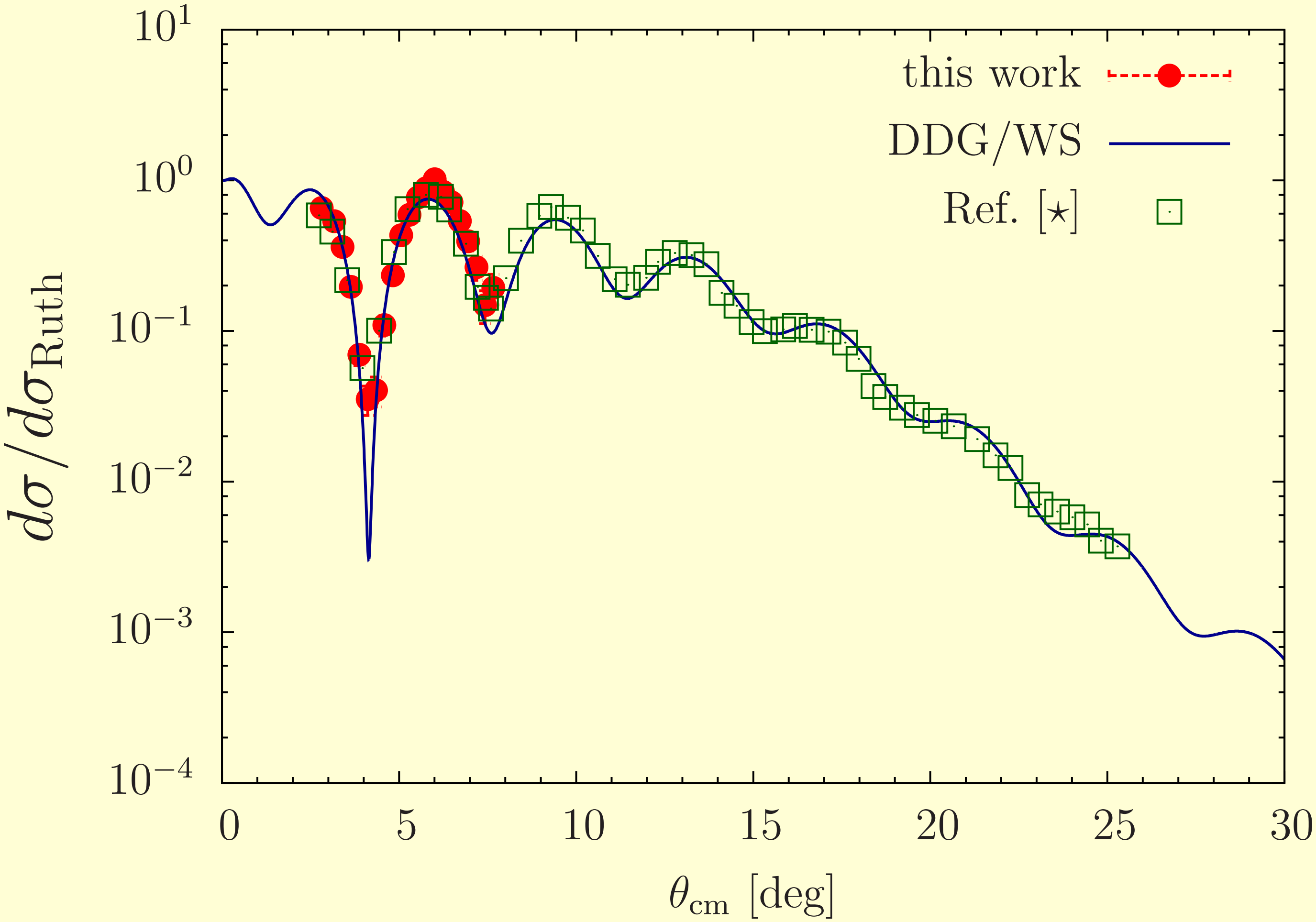
First results with radioactive beam

- Elastic alpha-scattering off ^{58}Ni (E105) at 100 MeV/u



Thesis work of J.C. Zamora

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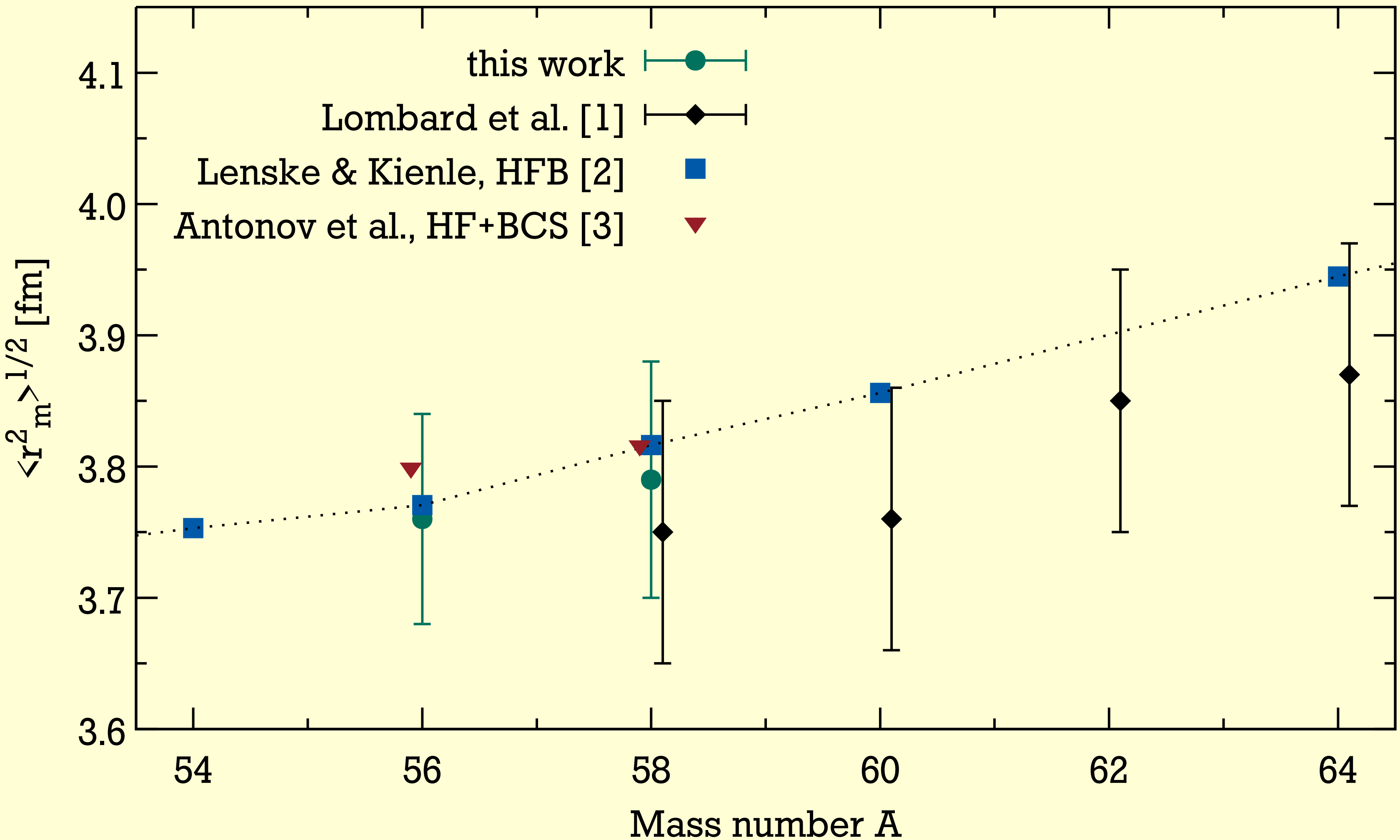
First results with radioactive beam

- Elastic p-scattering off ^{56}Ni and alpha-scattering off ^{58}Ni (E105)



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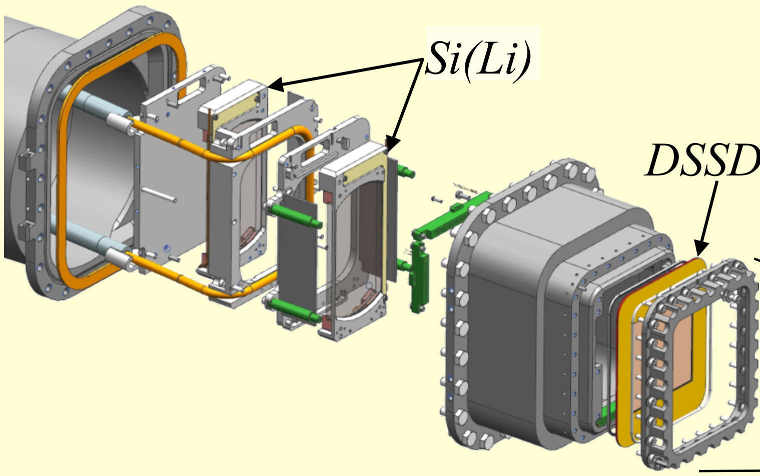
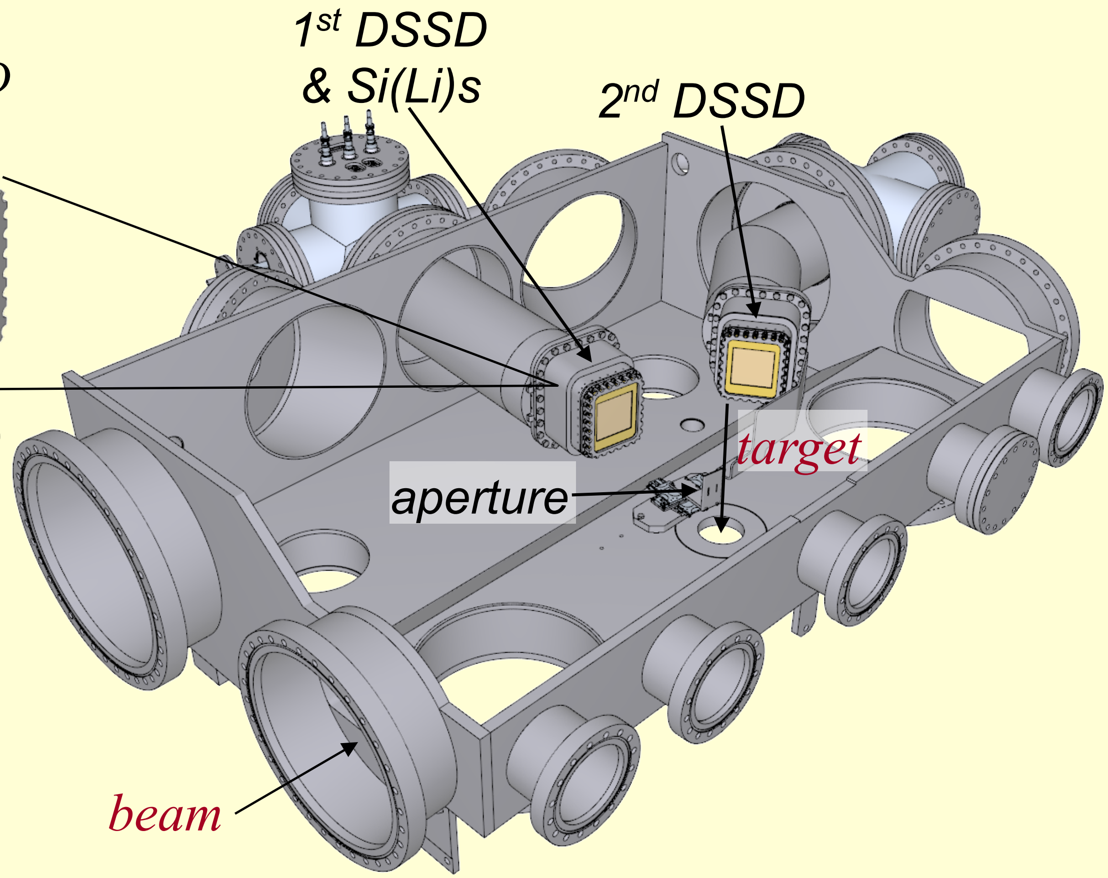
The new ESR Scattering chamber





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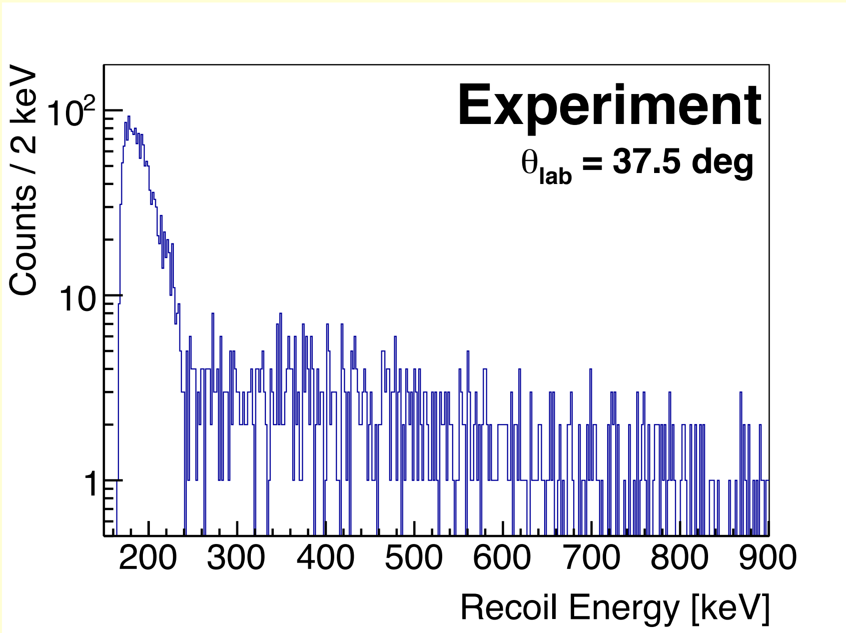
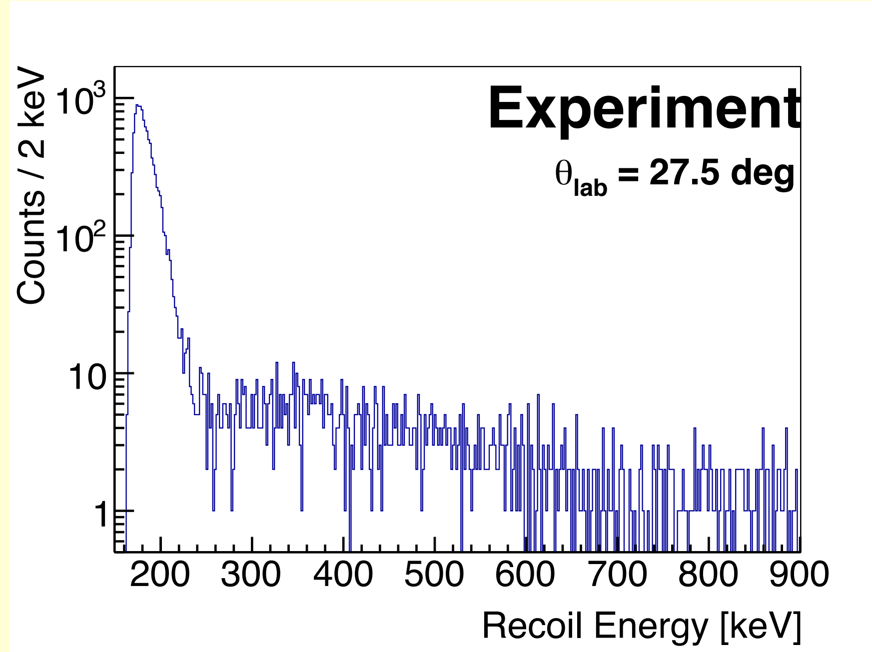
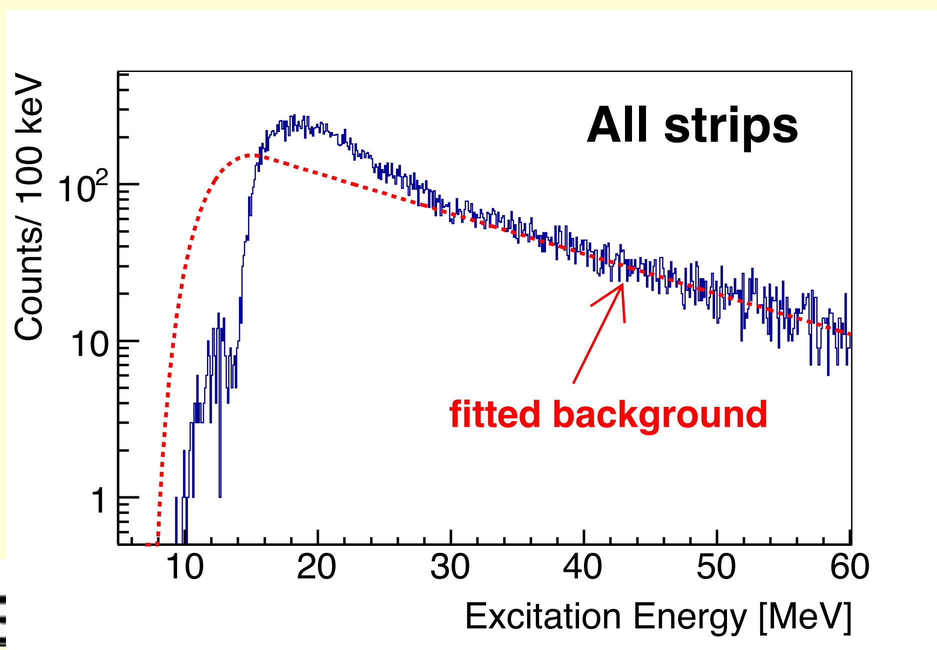
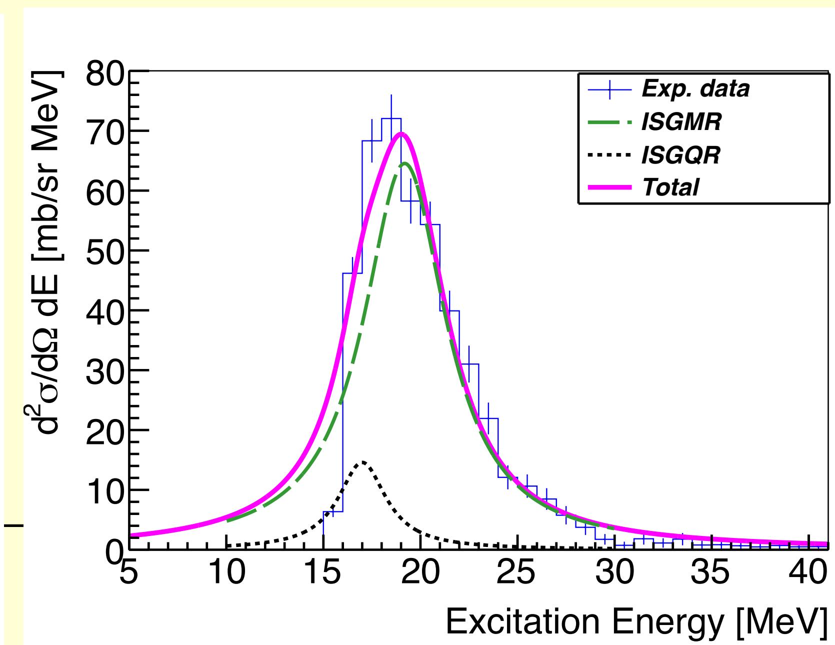
- ***moveable aperture** to improve angular resolution*

Inelastic scattering, work of J.C. Zamora



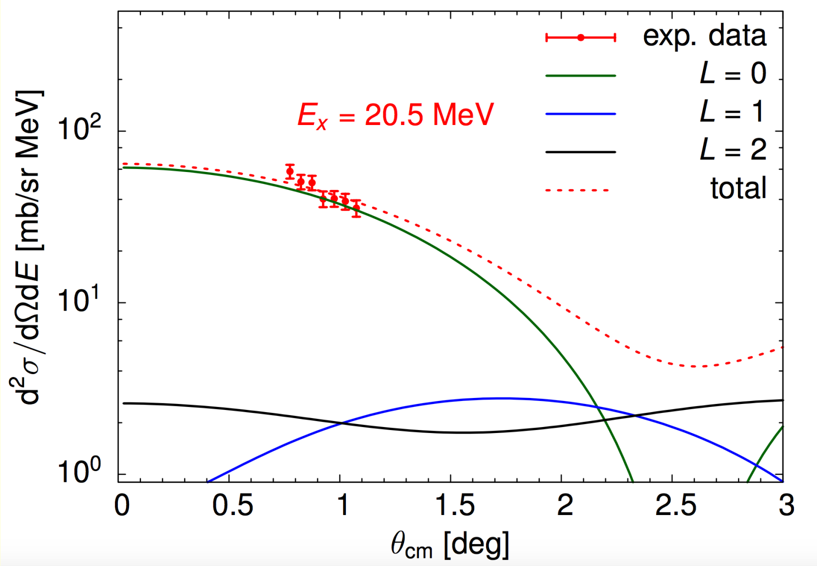


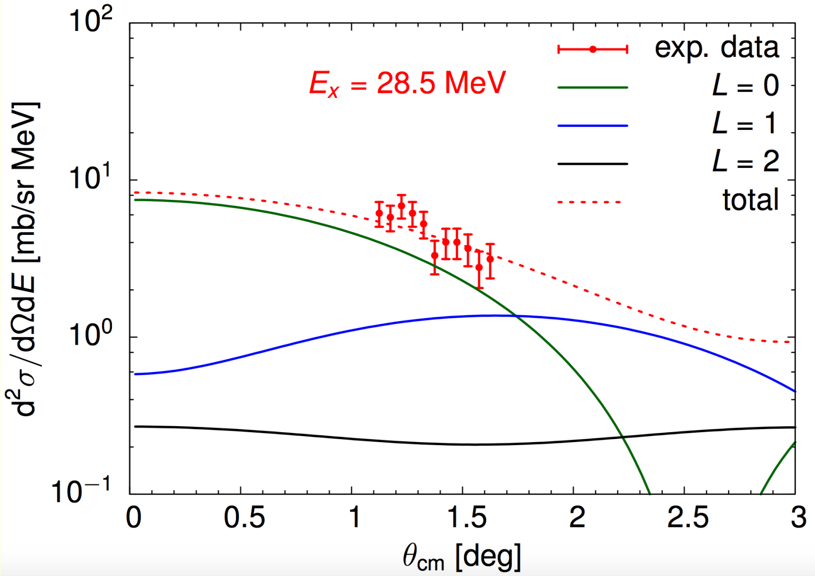


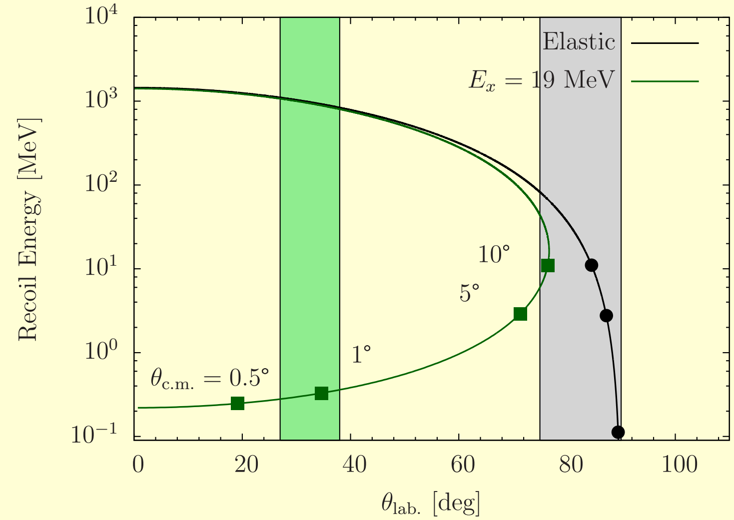


First results with radioactive beam

Inelastic scattering of alphas from 100 MeV/u ^{58}Ni (E105), J.C. Zamora







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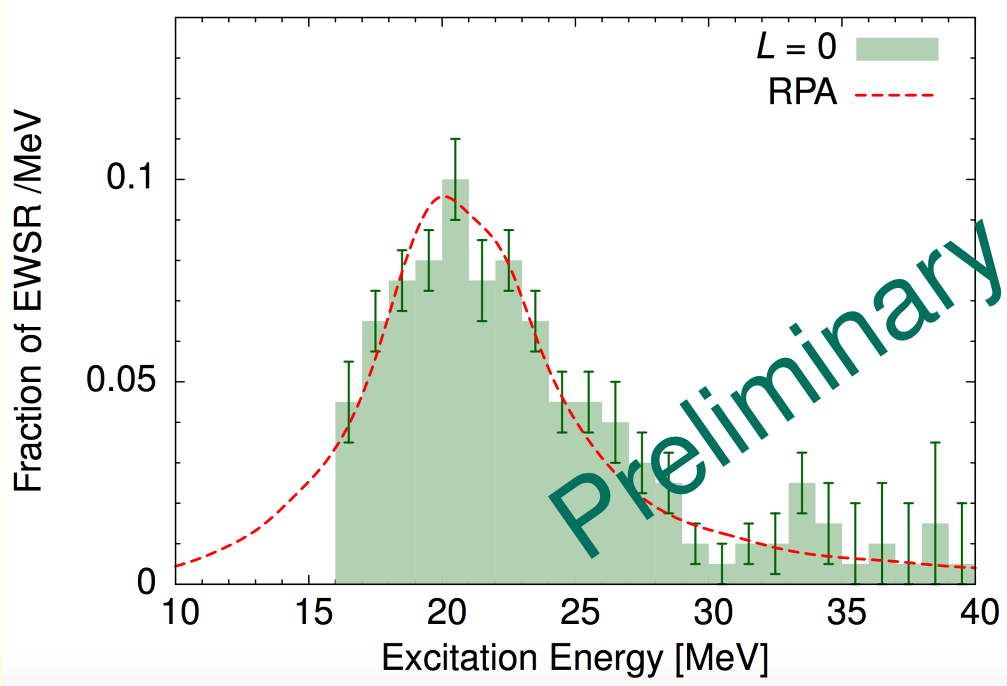
First results with radioactive beam

Inelastic scattering of alphas from 100 MeV/u ^{58}Ni (E105), J.C. Zamora



centroid [MeV]	EWSR [%]	
$21.9^{+0.8}_{-1.1}$	79^{+12}_{-11}	present data
$21.5^{+3.0}_{-0.3}$	74^{+22}_{-12}	PRC **61**, 067307 (2000)
$20.8^{+0.9}_{-0.3}$	85^{+13}_{-10}	PRC **73**, 014314 (2006)
21.1	94	RPA calculation [4]

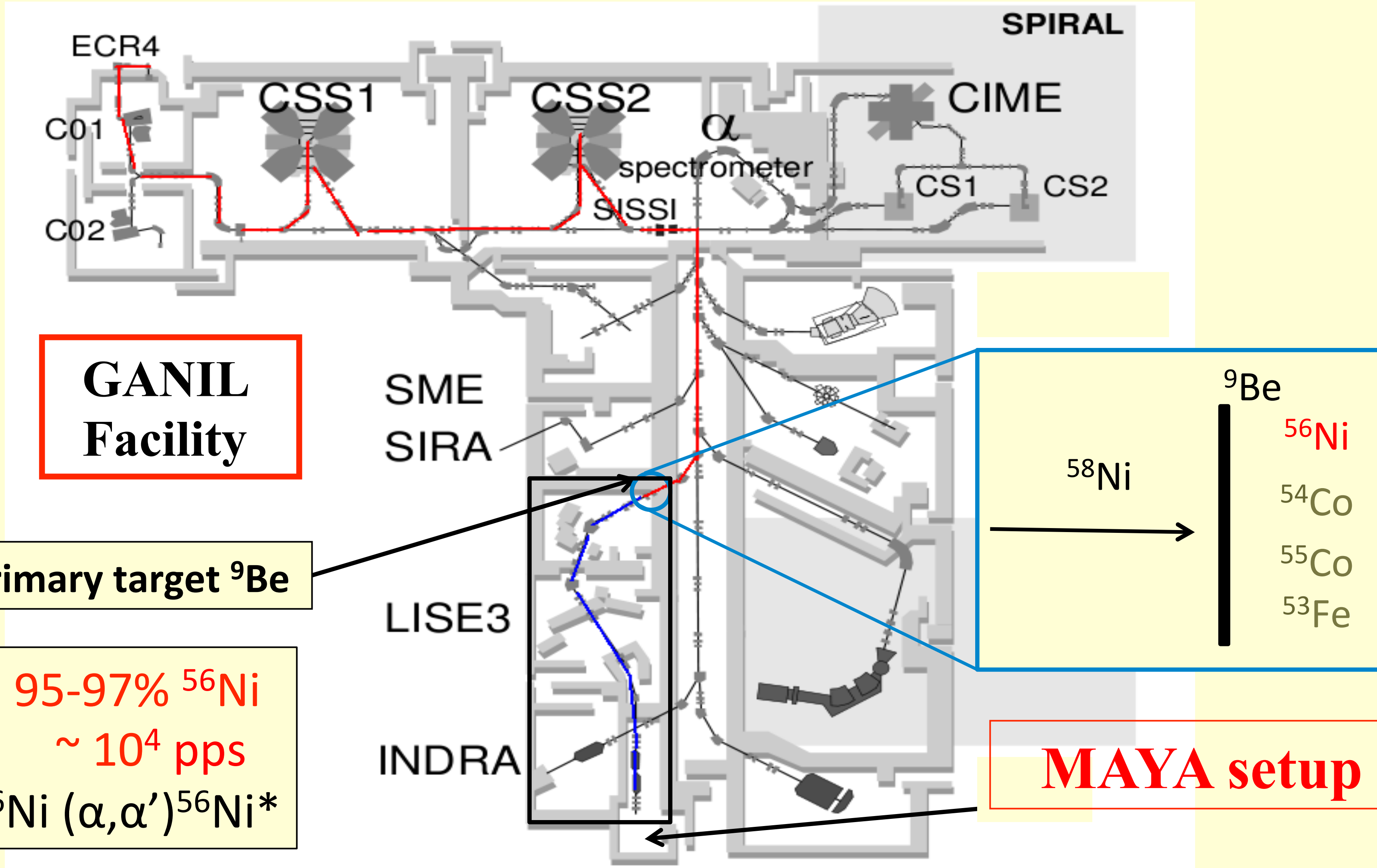
[4] G. Colò et al, Comput. Phys. Commun. 184 (2013)

Measurements with the active target MAYA at GANIL

Primary Beam:
^{58}Ni at 75 MeV/u

Primary Target: ^{9}Be
(thickness 525.6 μm)

Secondary Beam:
^{56}Ni at 50 MeV/u



GANIL Facility

Primary target ^{9}Be

95-97% ^{56}Ni
~ 10^{4} pps
^{56}Ni (α,α')^{56}Ni*

MAYA setup

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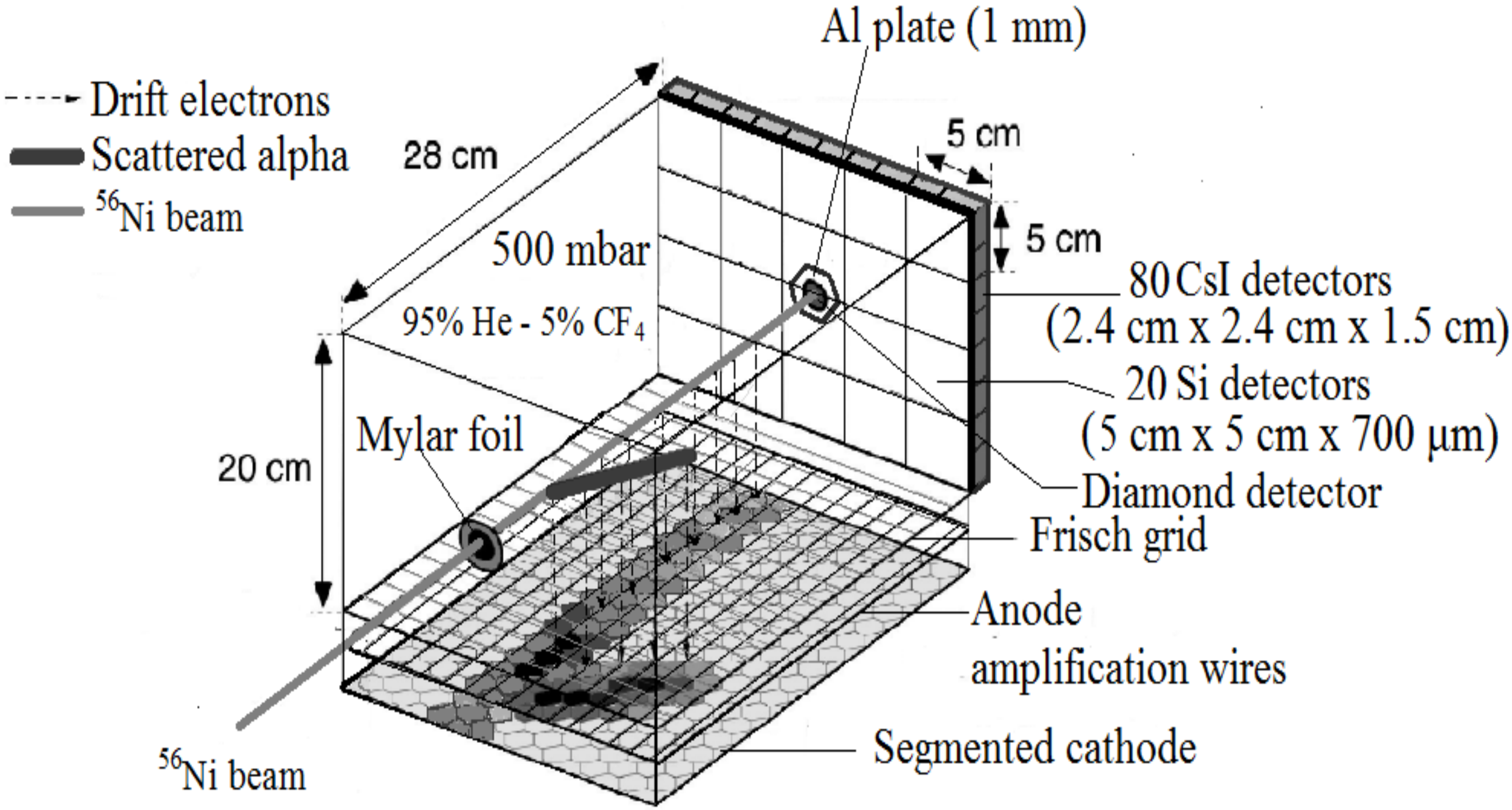
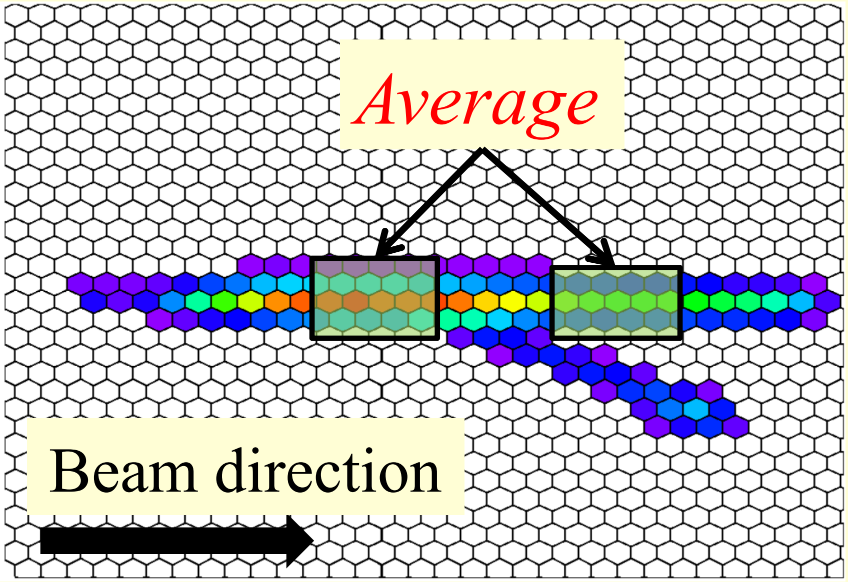
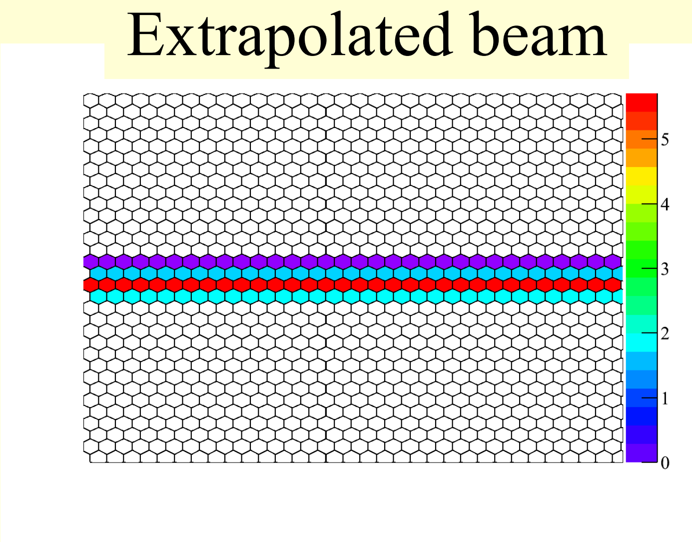
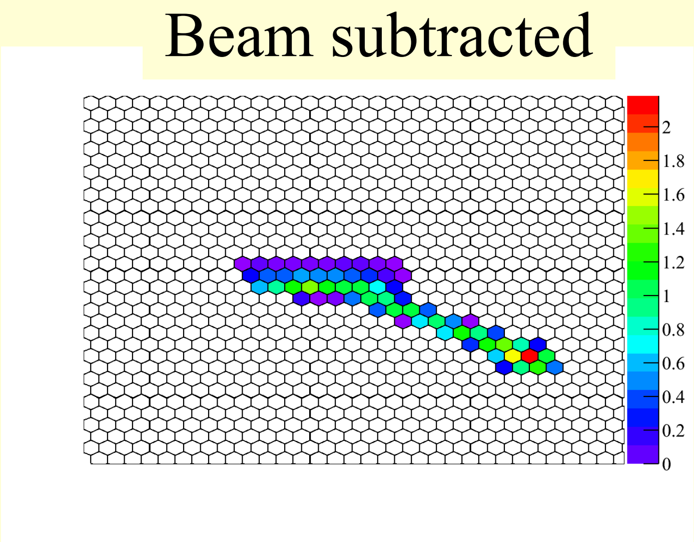
Schematic view of MAYA active target detector



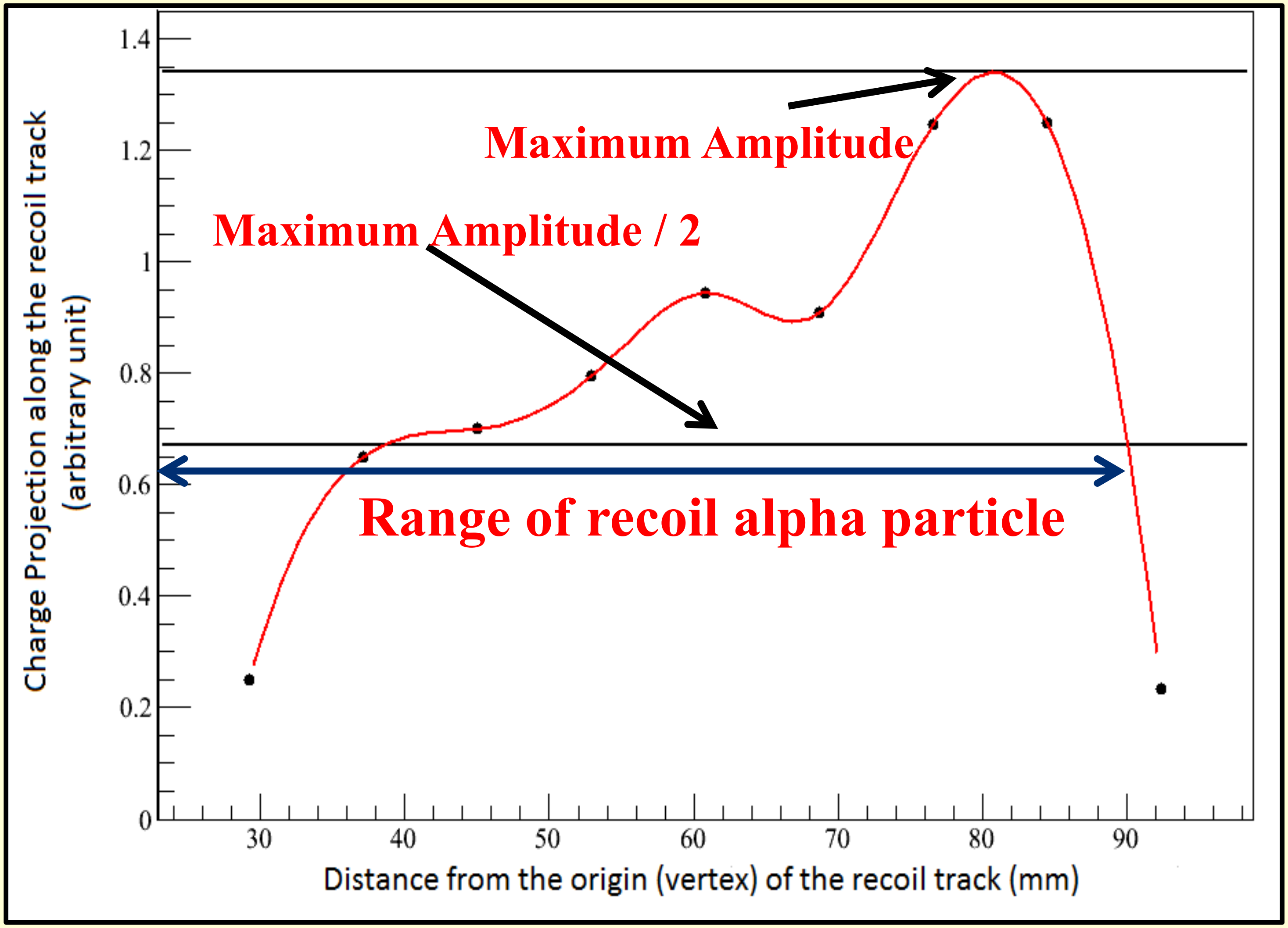
Beam Subtraction







Range extraction of recoil track



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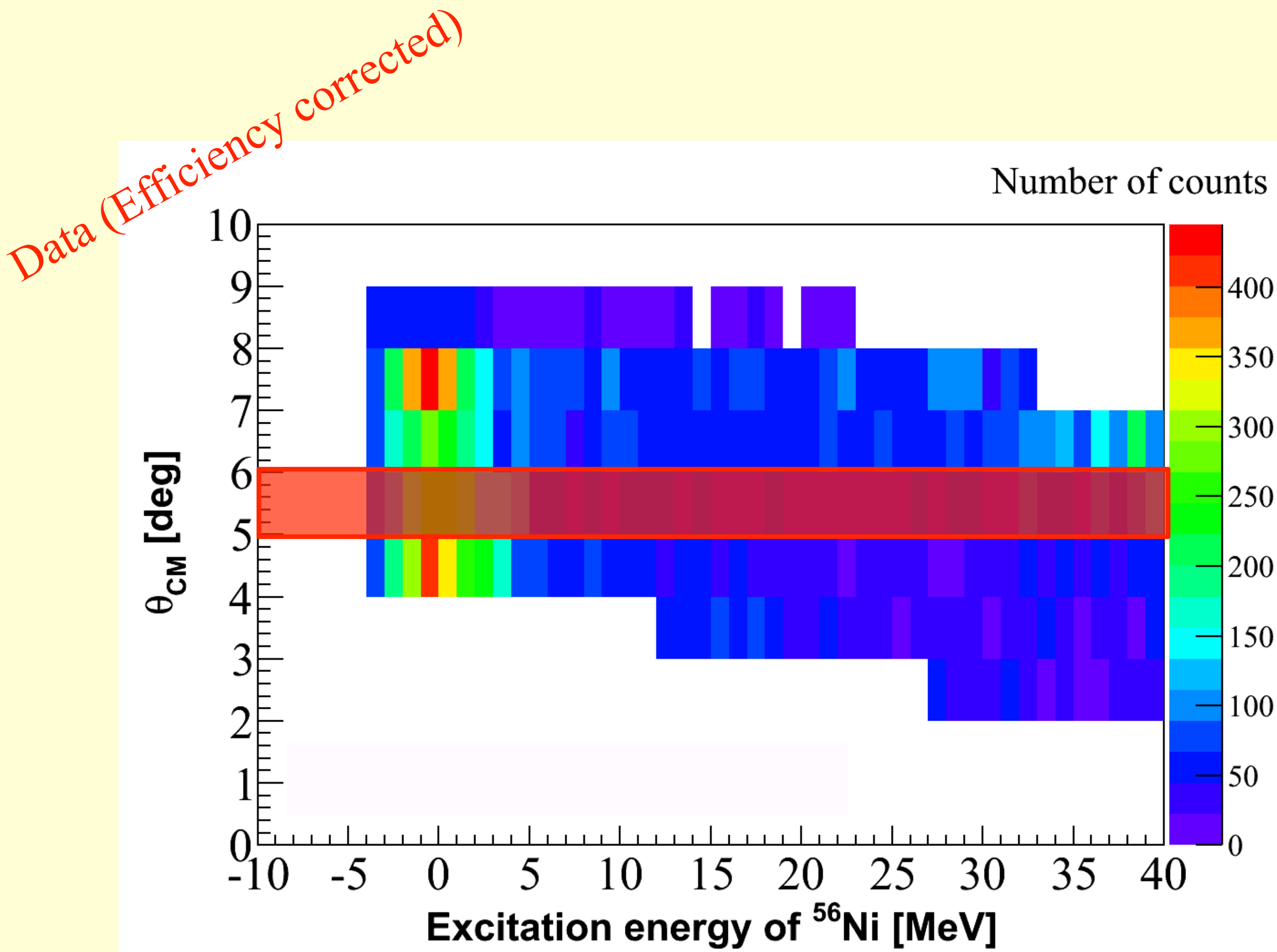
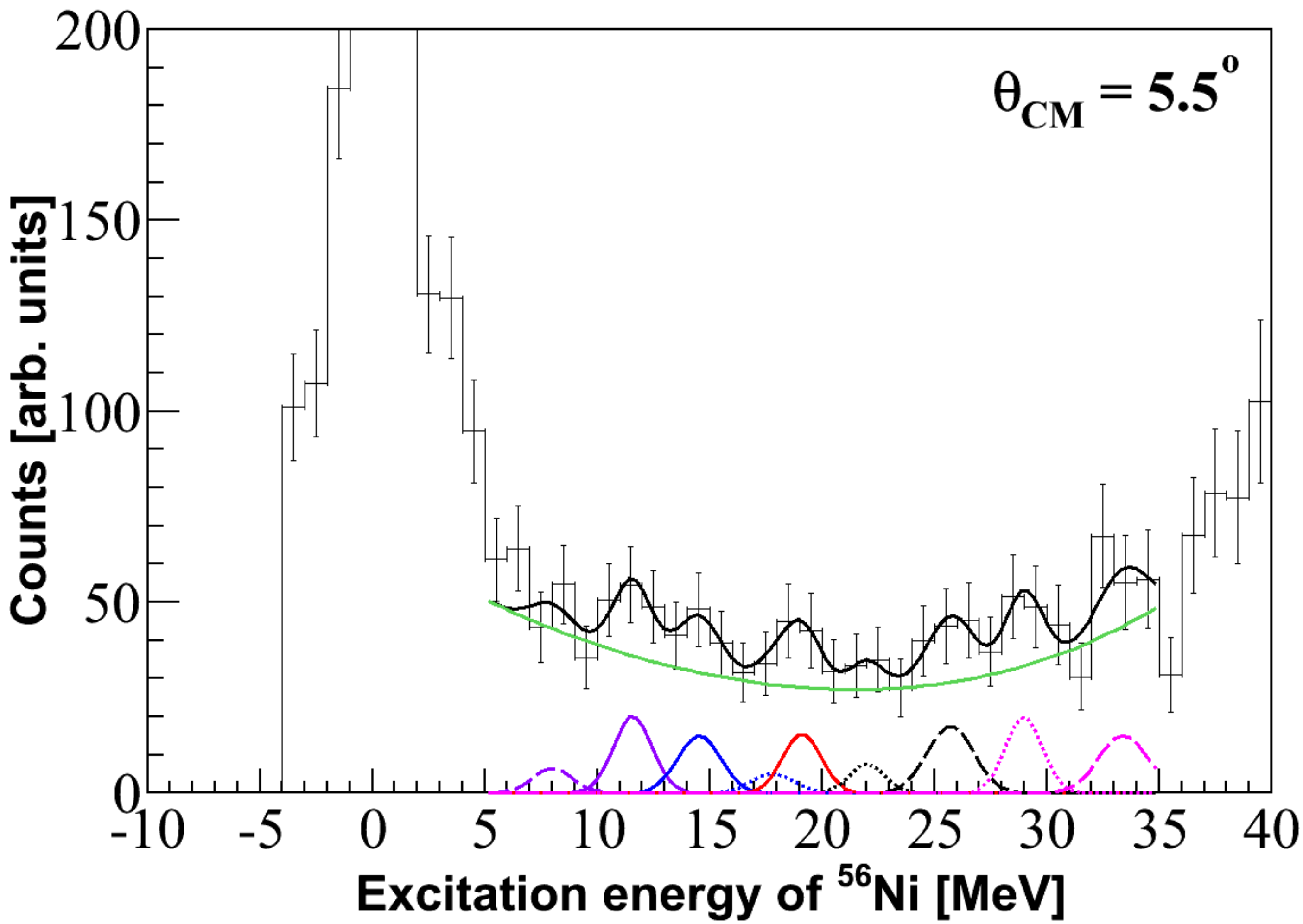
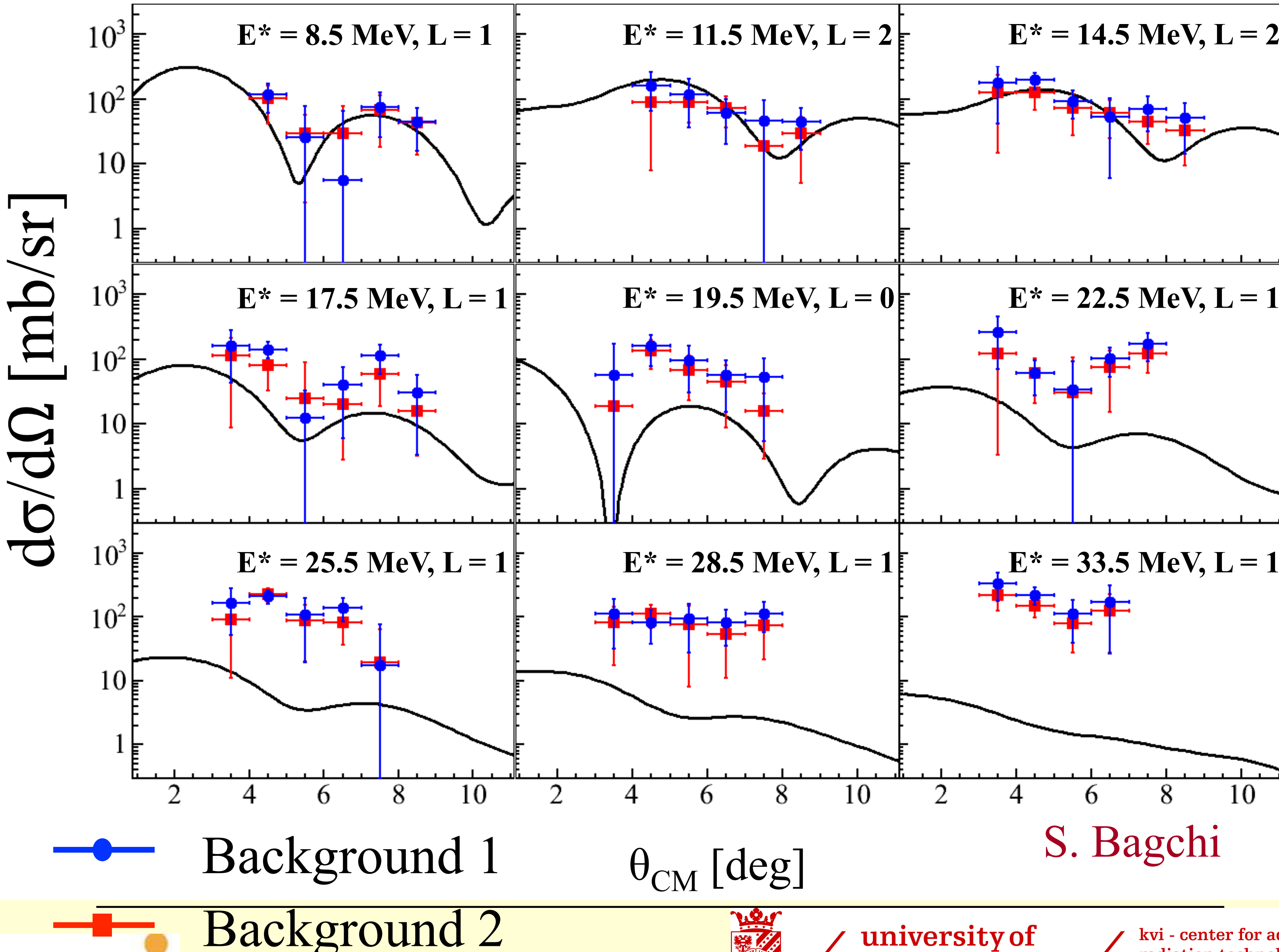
Peak fitting method



Excitation energy of ^{56}Ni at θ_{CM}=5.5°, S. Bagchi





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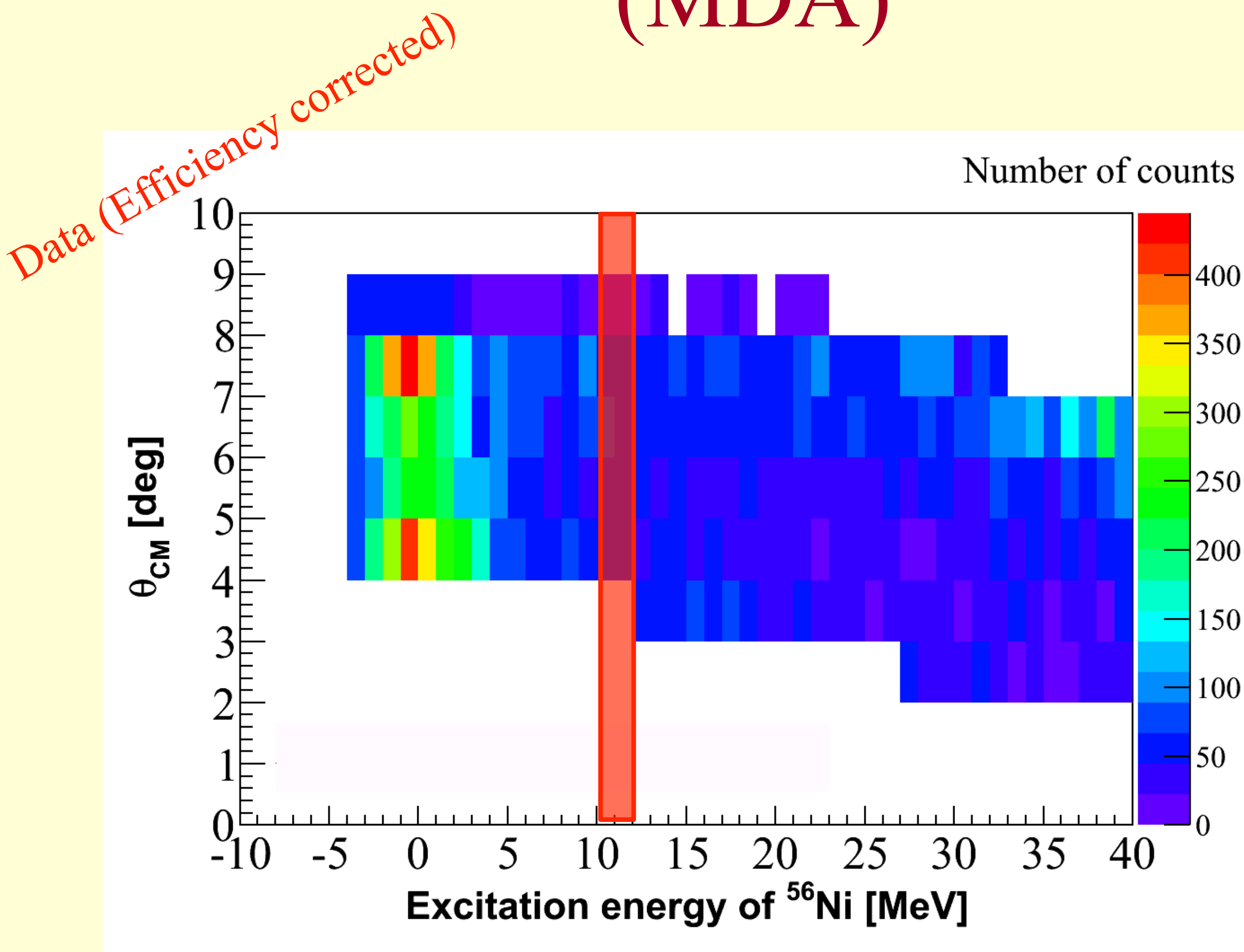
Multipole Decomposition Analysis (MDA)



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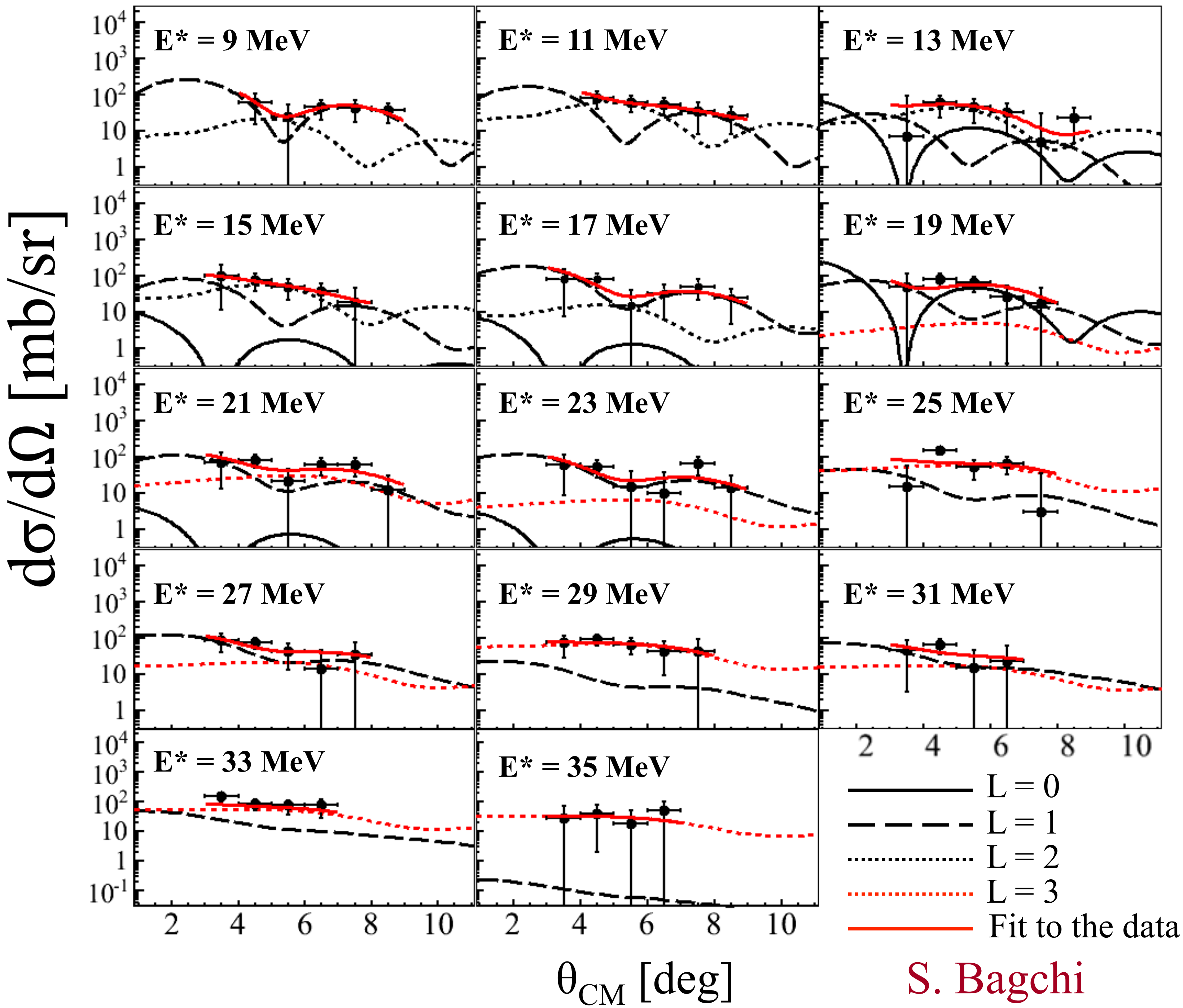

dσ/dΩ [mb/sr]
E* = 9 MeV
E* = 11 MeV
E* = 13 MeV
E* = 15 MeV
E* = 17 MeV
E* = 19 MeV
E* = 21 MeV
E* = 23 MeV
E* = 25 MeV
E* = 27 MeV
E* = 29 MeV
E* = 31 MeV
E* = 33 MeV
E* = 35 MeV
L = 0
L = 1
L = 2
L = 3
Fit to the data
θCM [deg]

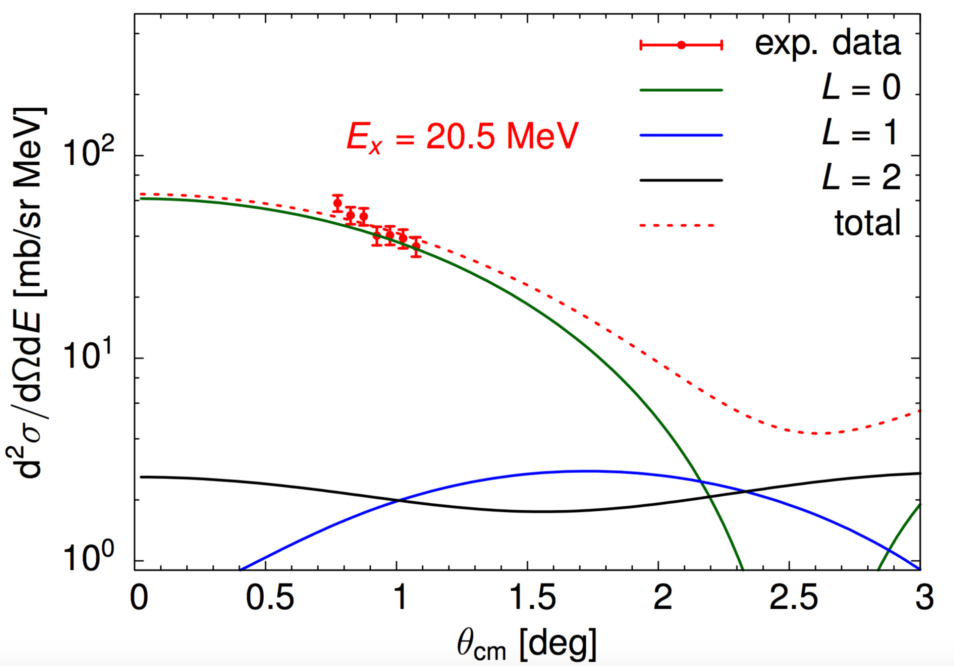
S. Bagchi

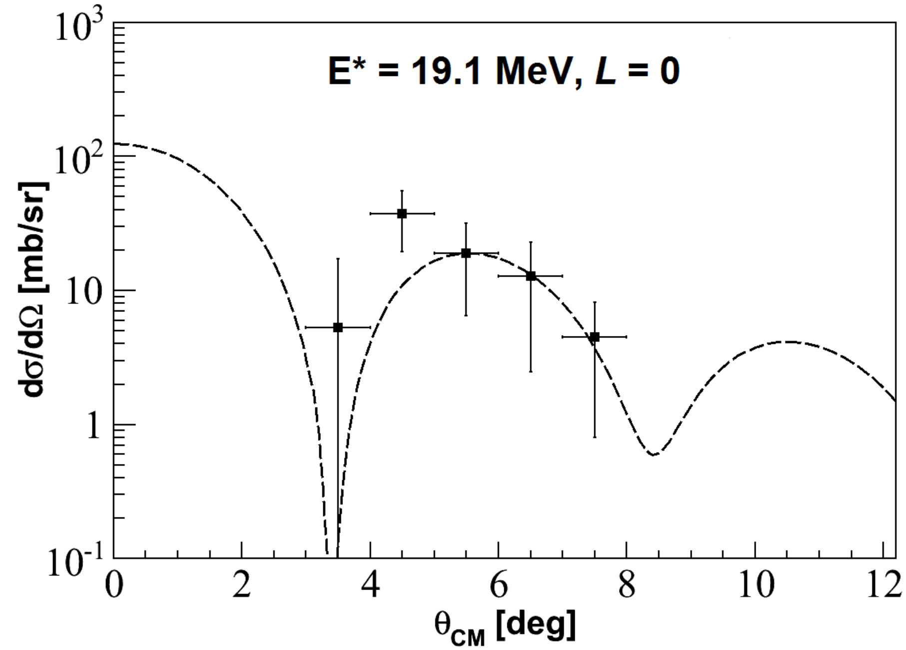
Summary of all Ni isotopes for ISGMR

L = 0, T = 0 (ISGMR)

Reaction	Gaussian fitting E* [MeV]	Gaussian fitting FWHM [MeV]	MDA E* [MeV]	MDA Width (rms) [MeV]
^{56}Ni(α,α')^{56}Ni* (this work)	19.1±0.5	2.0±0.3	18.4±1.8	2.0±1.2
^{56}Ni(d,d')^{56}Ni*	19.5±0.3	5.2	19.3±0.5	2.3
^{58}Ni(α,α')^{58}Ni*	18.43±0.15	7.41±0.13	$19.2^{+0.44}_{-0.19}$	$4.89^{+1.05}_{-0.31}$
^{58}Ni(α,α')^{58}Ni*	-	-	$19.9^{+0.7}_{-0.8}$	-
^{60}Ni(α,α')^{60}Ni*	17.62±0.15	7.55±0.13	$18.04^{+0.35}_{-0.23}$	$4.5^{+0.97}_{-0.22}$
^{68}Ni(α,α')^{68}Ni*	21.1±1.9	1.3±1.0	23.4	6.5

Monopole mode in ^{58}Ni and ^{56}Ni: ring vs. active target





^{58}Ni

^{56}Ni

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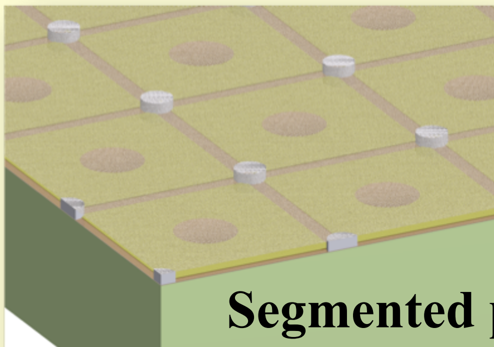
Conclusions and outlook

- Large efforts are taking place for both the ring environments as well as for active targets.
- Bulk properties (radius, compressibility etc.) are the main subject of the present low-q measurements.
- The goal is to go towards the medium heavy and heavy nuclei (astrophysical processes).
- First measurements are done with Ni isotopes and results are emerging.
- More measurements are planned with both methods.

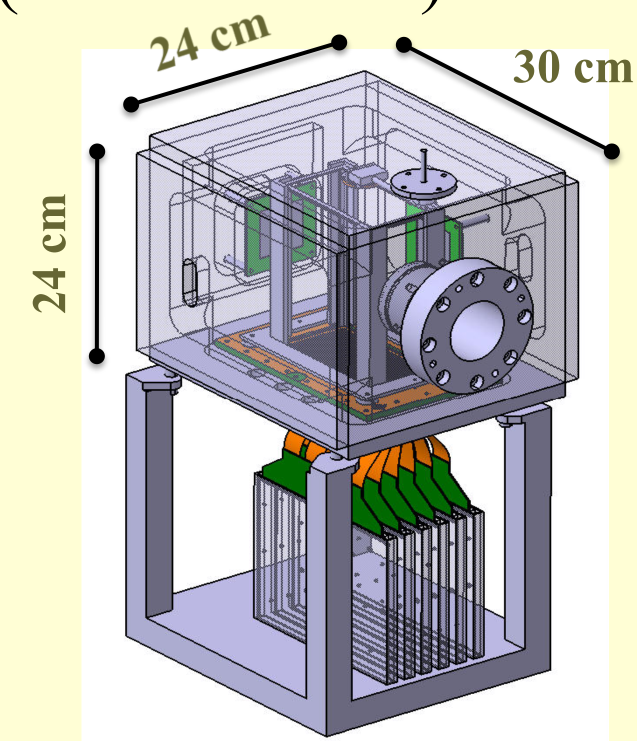
Next generation active targets

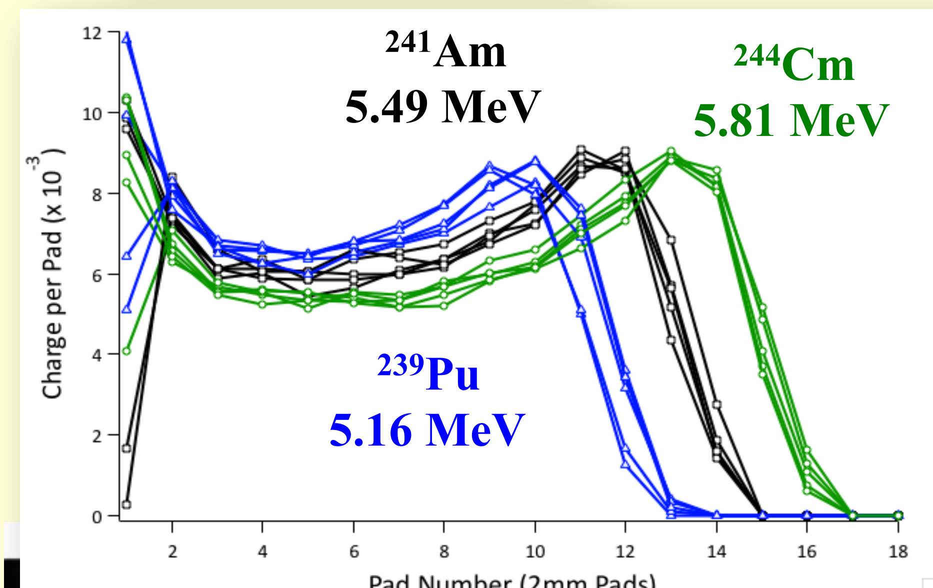
New generation of active target (ACTAR TPC)



Talk by T. Roger

Segmented pad plane: 2x2 mm^2





Range of α's in Ar+CF_4(2%) @ 1100 mbar

- Range resolution > 0.8 mm (FWHM)
- Energy resolution > 80 keV (FWHM)

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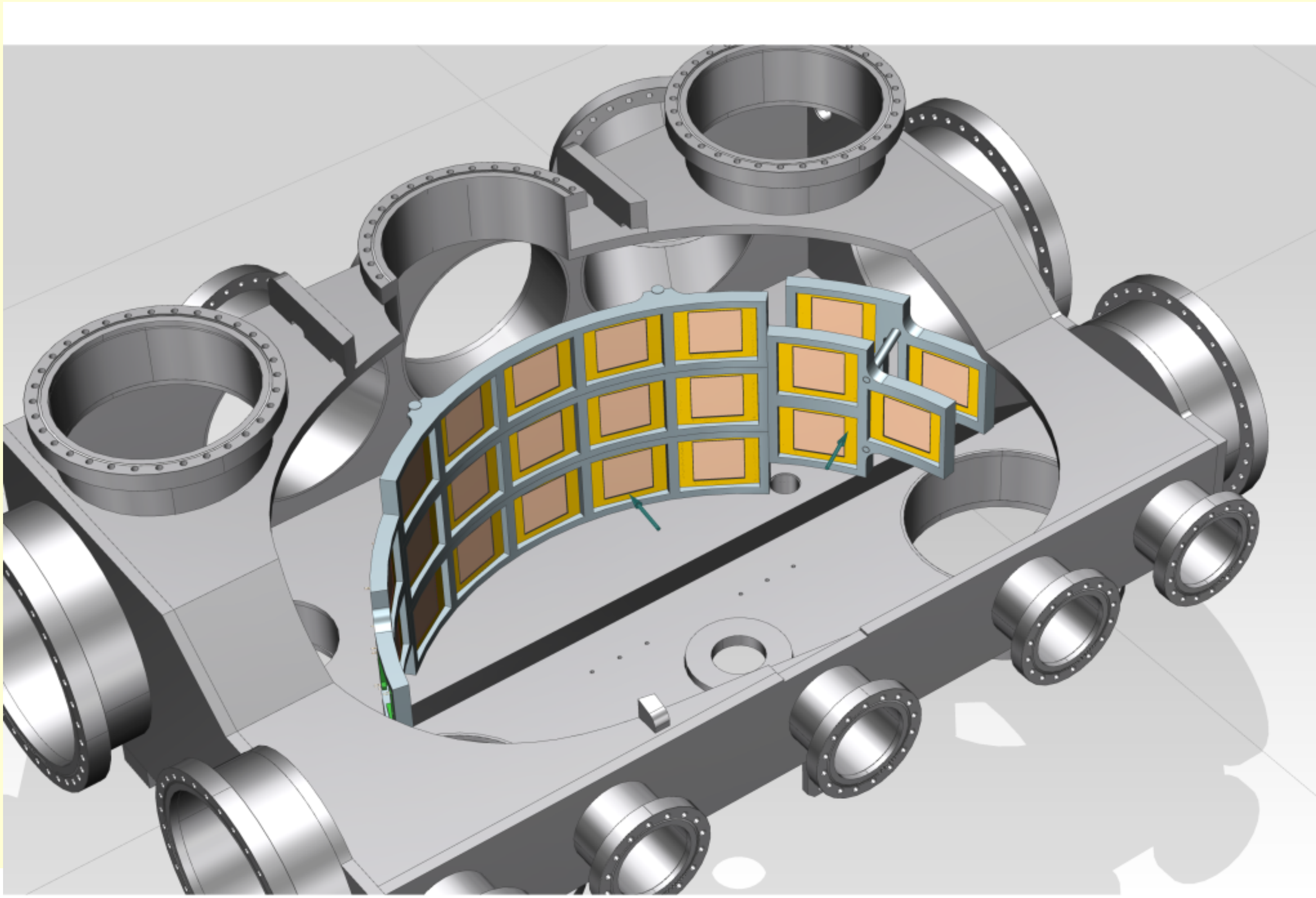
Upgrade of the first EXL experiment



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GANIL
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS
LABORATOIRE COMMUN DSM/CEA-IN2P3/CNRS

KVI

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lpc caen

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JINR
JOINT INSTITUTE FOR NUCLEAR RESEARCH

USC
UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

IFJ

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The EXL-E105 Collaboration

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Thank you!