KU LEUVEN

Single-neutron transfer on ^{68}Ni

Andreas Ceulemans

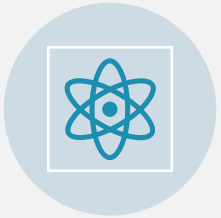
ISOLDE WORKSHOP AND USERS MEETING

29th Nov – 1st Dec 2023

EURO-LABS
EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

Contents

ISOLDE Solenoidal Spectrometer



Why study ^{68}Ni(d,p) ?

The ISS detector

Preliminary results

Outlook

KU LEUVEN

Contents

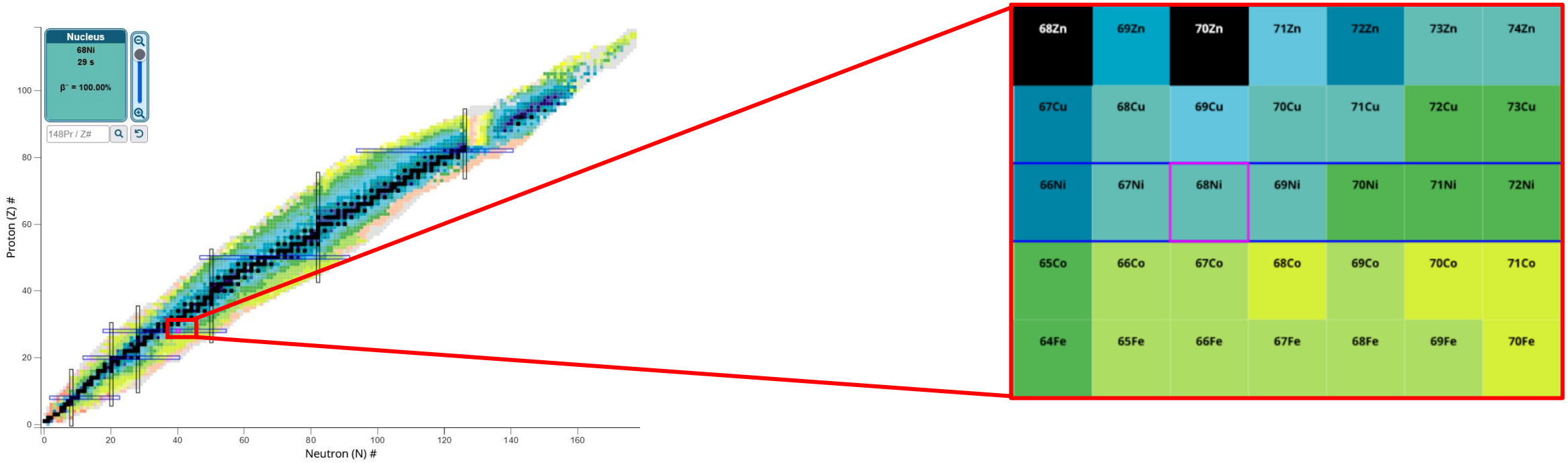
ISOLDE Solenoidal Spectrometer

- Why study ^{68}Ni(d,p) ?
- The ISS detector
- Preliminary results
- Outlook

KU LEUVEN

Why research nickel isotopes?

- Proton magic number Z = 28
- Collectivity around N = 40
- Extension of region towards N=50



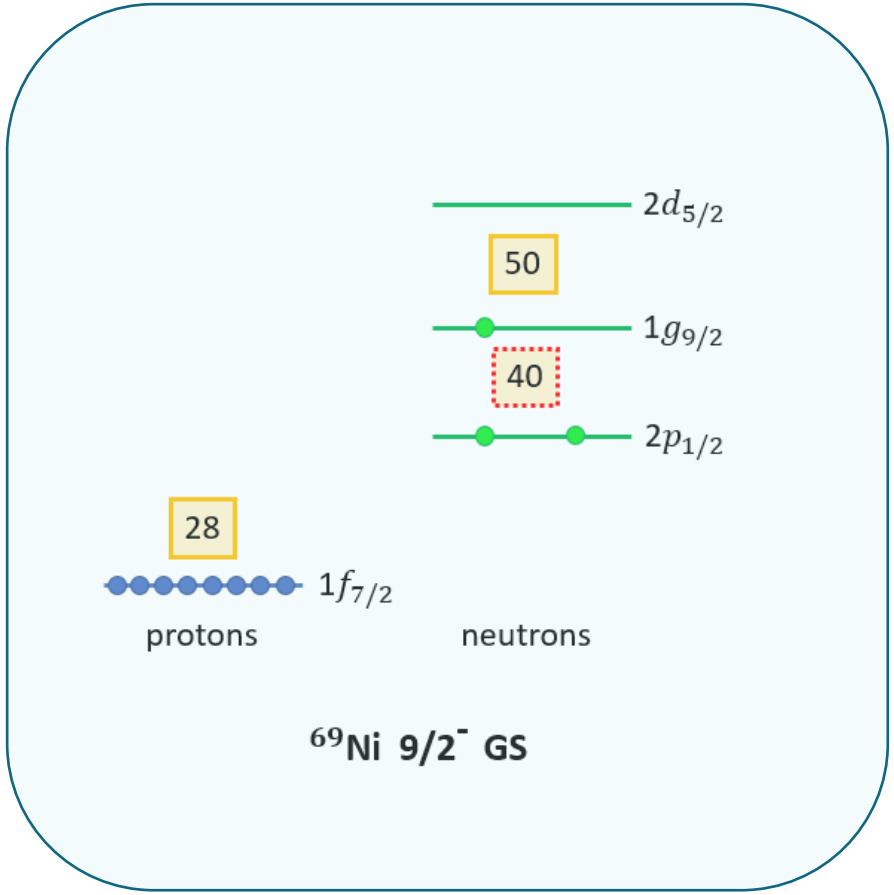
C. Santamaria et al. PRL 115, 192501(2015)
A. Gade and S. N. Liddick J. Phys. G: Nucl. Part. Phys. 43, 024001(2016)

Figures from: National nuclear data center, NuDat 3 ,https://www.nndc.bnl.gov/nudat3/,

Magicity and collectivity near ^{68}Ni

- Magic numbers: 2, 8, 20, 28, 50, 82 & 126
- N = 40 subshell closure + $1g_{9/2}$ and $2d_{5/2}$
  → Quadrupole collectivity

- ^{68}Ni displays:
  - High 2^+ energy
  - Low B(E2; $0_1^+ \rightarrow 2_1^+$)
  - Weak discontinuity of 2n separation energy
- "Island of inversion" below ^{68}Ni
  - Ground states Fe and Cr deformed



O. Sorlin et al., Physical Review Letters 88, 092501 (2002).; N. Bree et al., Physical Review C 78, 047301 (2008).
S. Rahaman et al., The European Physical Journal A 34, 5 (2007).; F. Flavigny et al, Physical Review C 99, 054322 (2019).
Lenzi, S. M. and Nowacki, F. and Poves, A. and Sieja, K., Physical Review C 82, 054301, (2010).

Our investigation

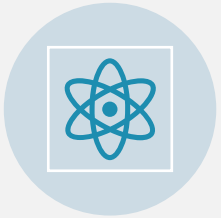
- Shell model calculations use neutron $pfg_{9/2}d_{5/2}$ basis space
- $\nu d_{5/2}$ is needed to explain collectivity
- Location $\nu d_{5/2}$ not known in neutron-rich nickel

- Transfer reaction ^{68}Ni(d,p) ^{69}Ni
- Performed at ISOLDE, CERN in november 2022

Lenzi, S. M. and Nowacki, F. and Poves, A. and Sieja, K., Phys. Rev. C, 82, 5 054301(2010)
N. Shimizu et al., Prog. Theor. Exp. Phys. 01A205(2012)

Contents

ISOLDE Solenoidal Spectrometer



Why study ^{68}Ni(d,p) ?

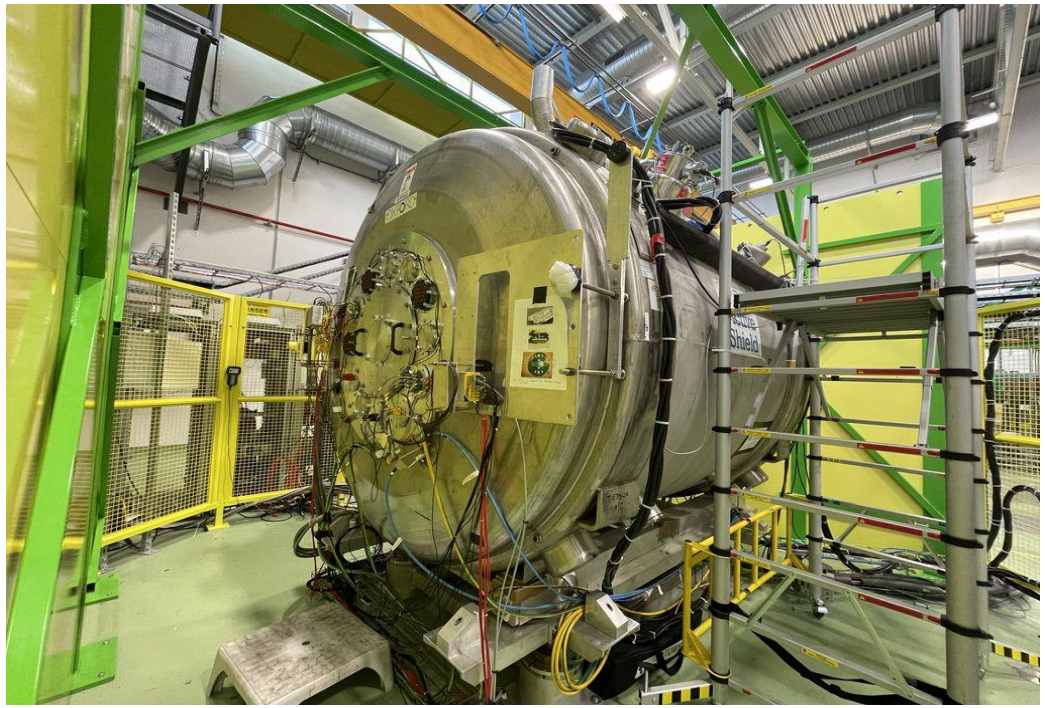
The ISS detector

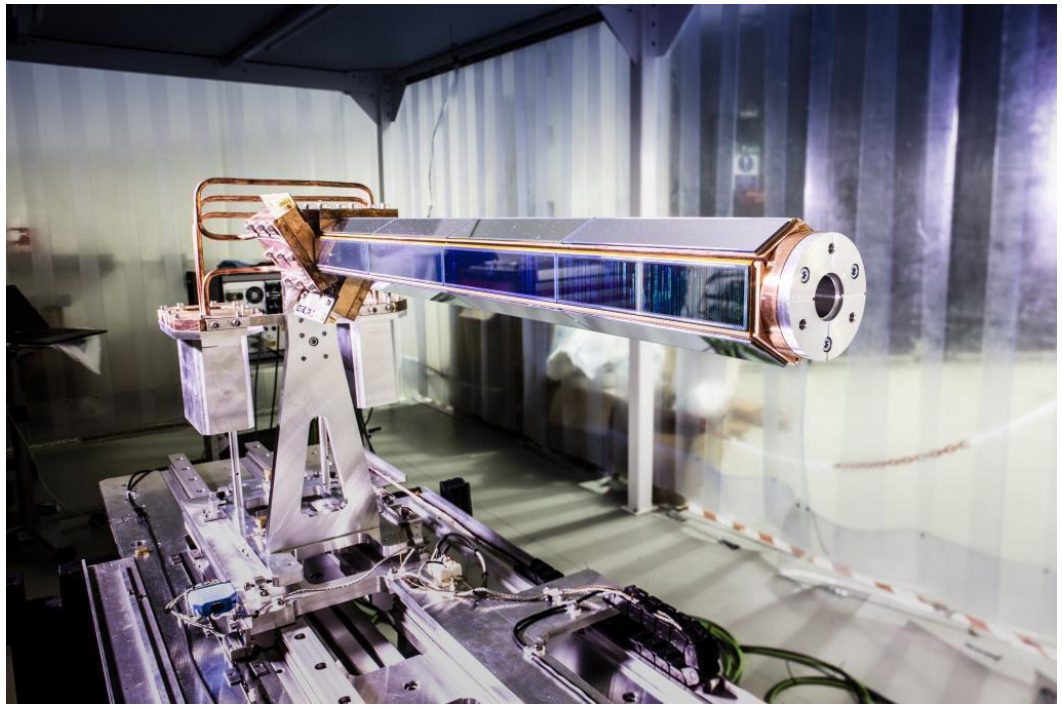
Preliminary results

Outlook

The ISS detector

Solenoid can produce magnetic field up to 2.5T





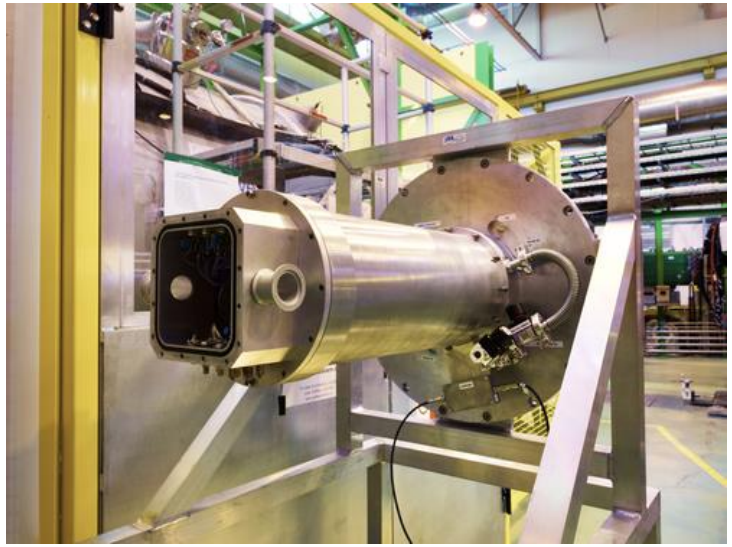
Si-array consists of DSSD’s for detecting protons

Pictures provided by the ISS collaboration

Auxilary detectors

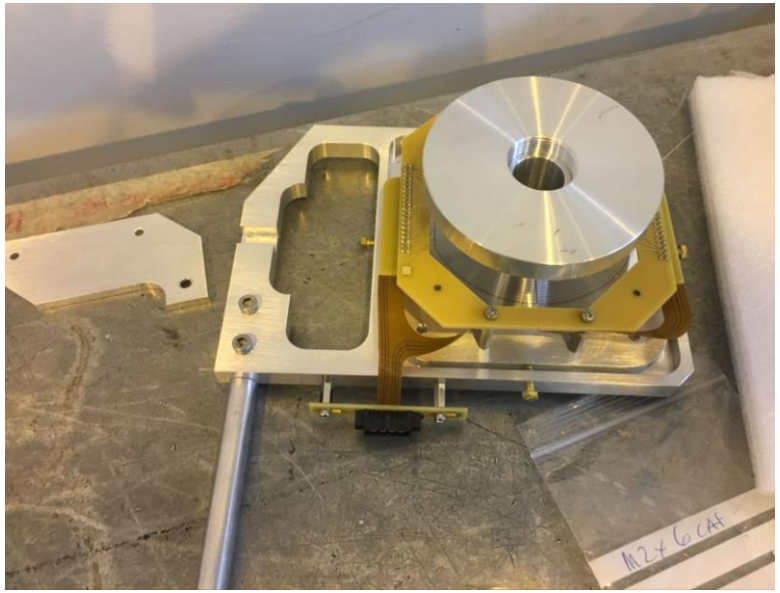
Gas filled recoil detector

- MWPC chamber
- Bragg chamber



Elastic scattering detector

- Micron S1 double-side silicon detector
- Shielded by aluminum plate



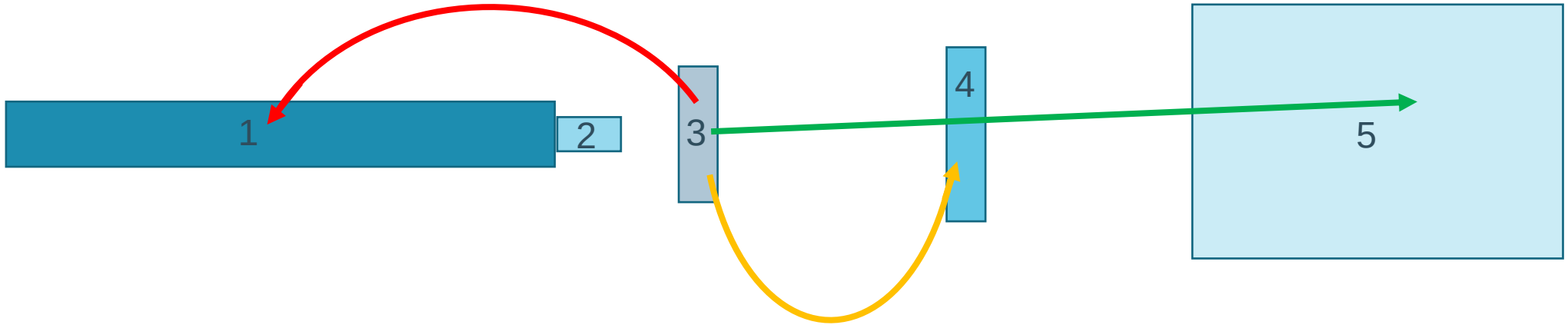
Pictures provided by the ISS collaboration

Schematic setup

Legend

1) Si array
2) Array blocker
3) Target
4) Scattering detector
5) Gaseous recoil detector

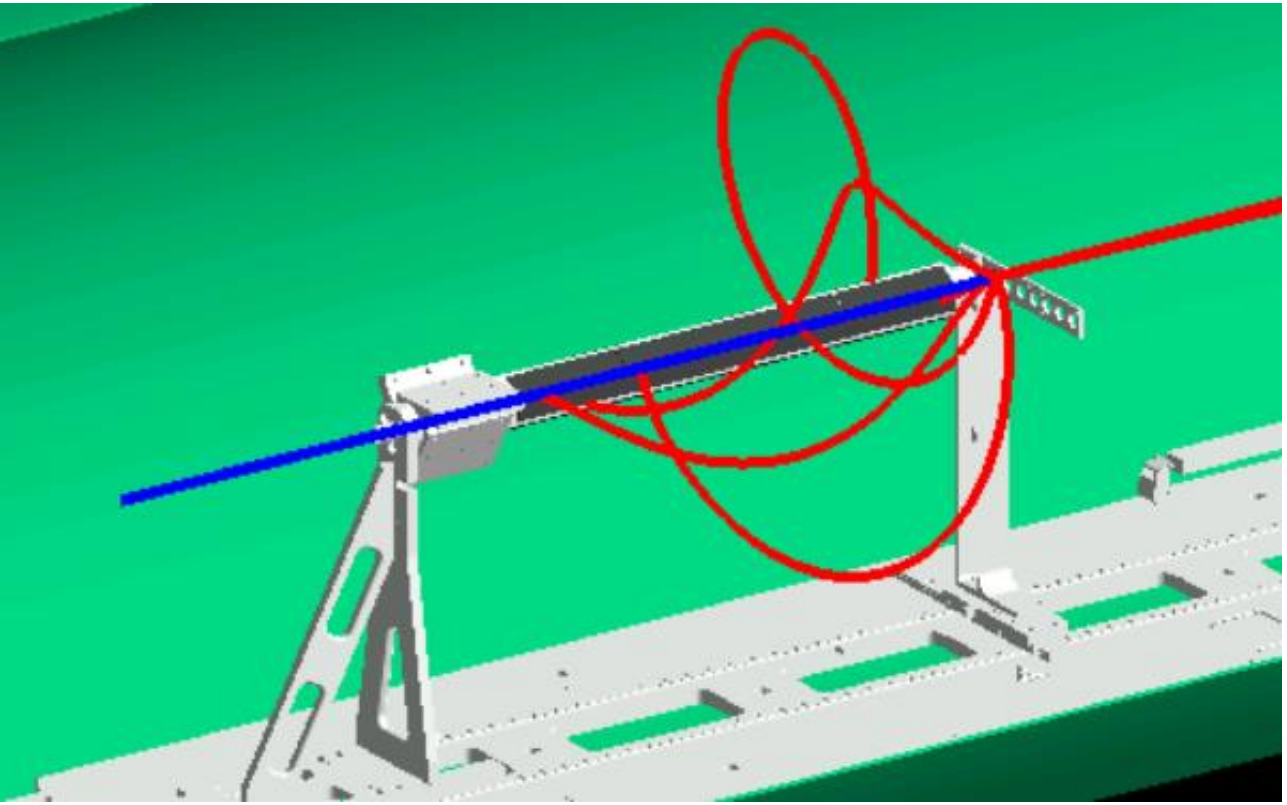
Proton
Deuteron
^{69}Ni Recoil



Beam direction

Reaction: ^{68}Ni(d,p) ^{69}Ni

Nuclear reactions using ISS



One-nucleon transfer reactions:

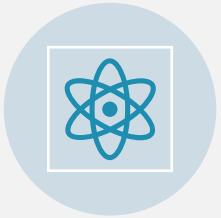
^{68}Ni(d,p) ^{69}Ni

- Selective population of states
- Angular distribution determined by L-transfer
- Solenoidal technique improves energy resolution

Figure from simulation made using nptool software;A Matta, P Morfouace, N de Séréville, F Flavigny, M Labiche, and R Shearman. Journal of Physics. G, 43(4):45113–, 2016

Contents

ISOLDE Solenoidal Spectrometer



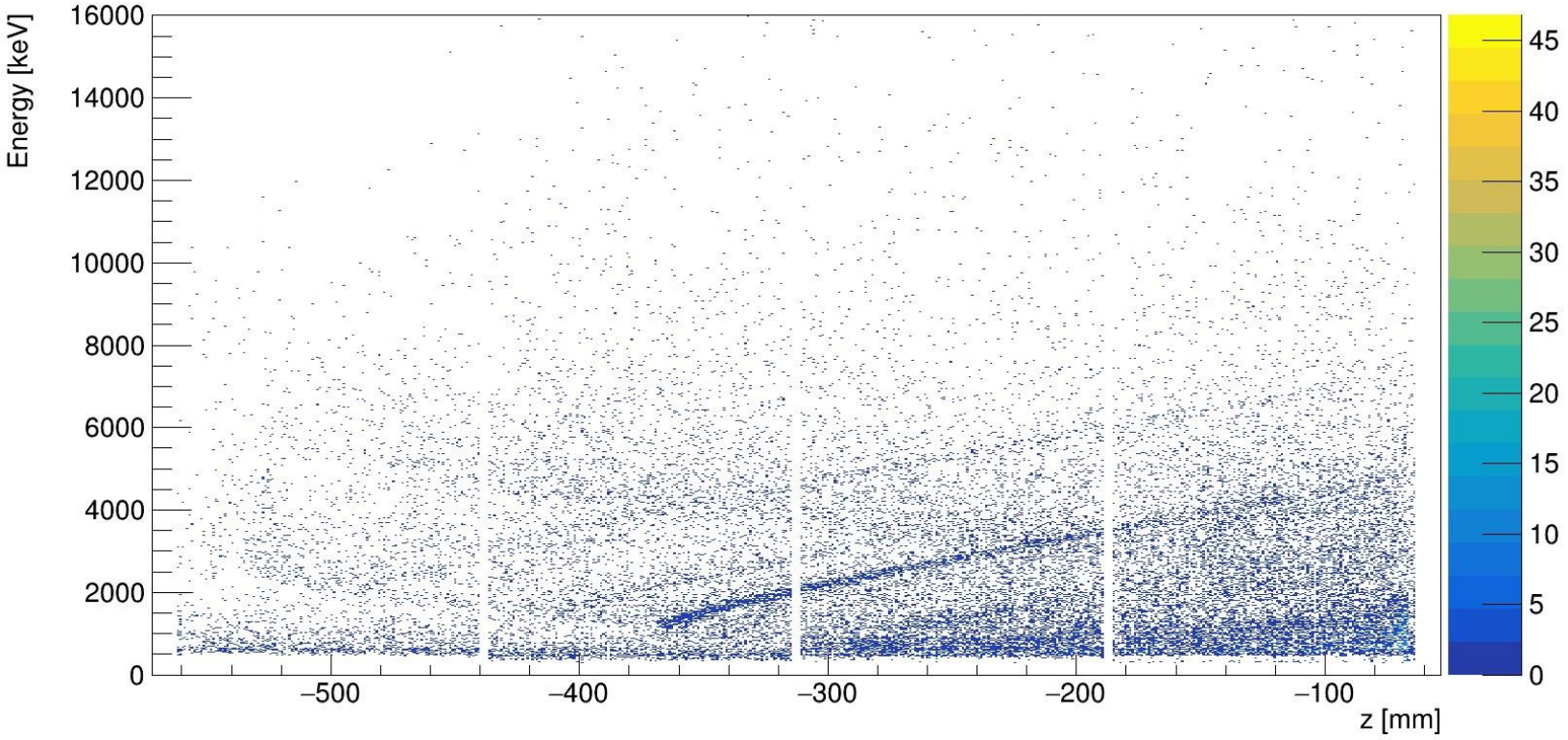
Why study ^{68}Ni(d,p) ?

The ISS detector

Preliminary results

Outlook

ISS array proton energy vs z spectrum

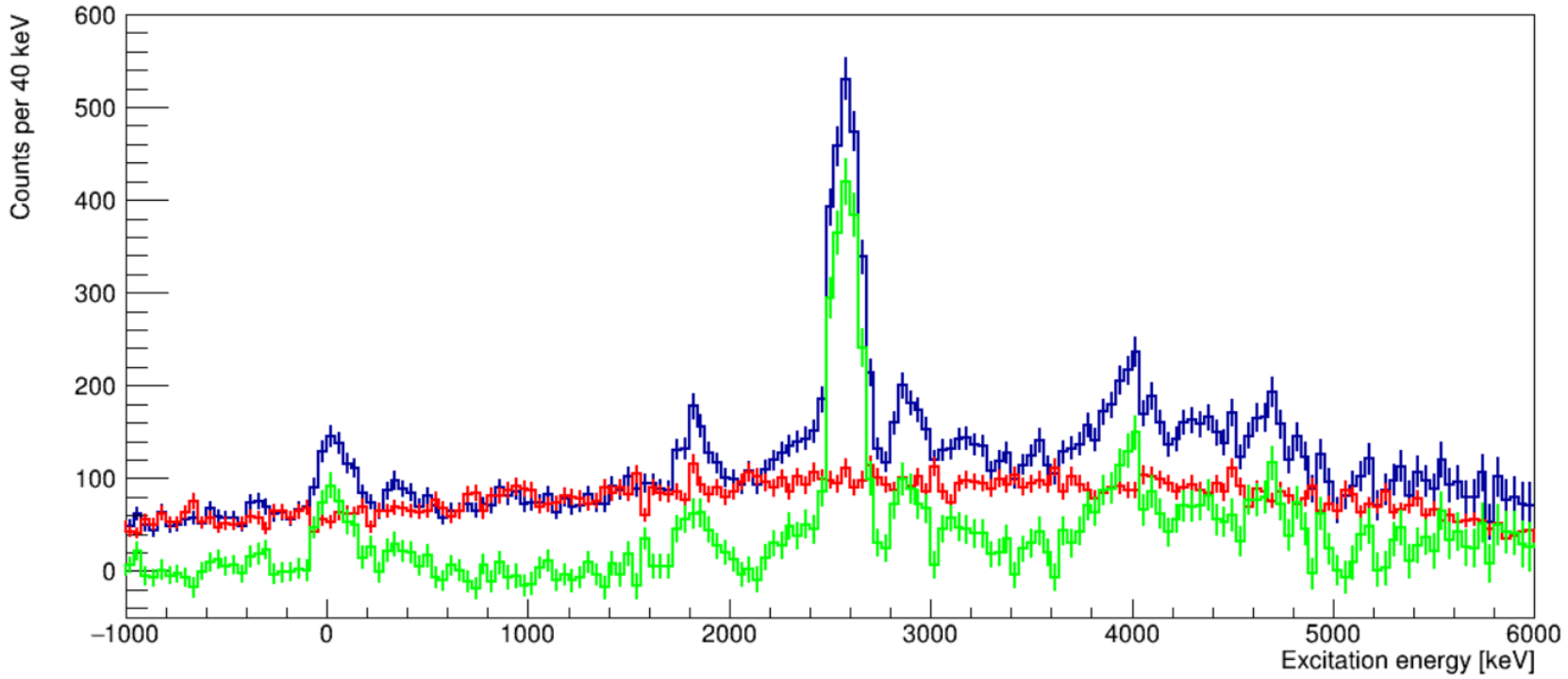


- Spectrum from protons on array
- Energy levels are diagonal lines

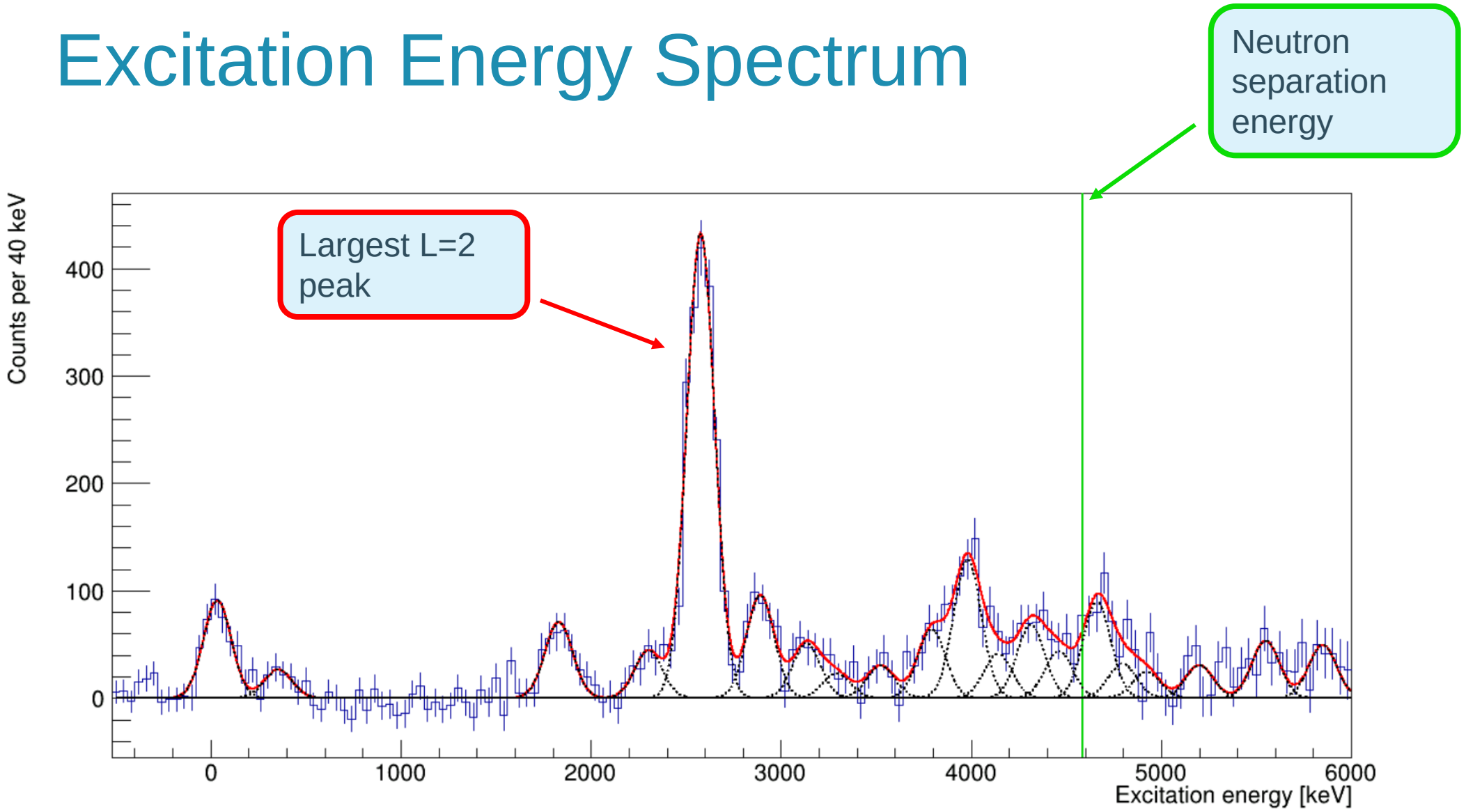
Excitation energy spectrum

- Reaction kinematics used to obtain excitation energy
- Laser off for Gallium background

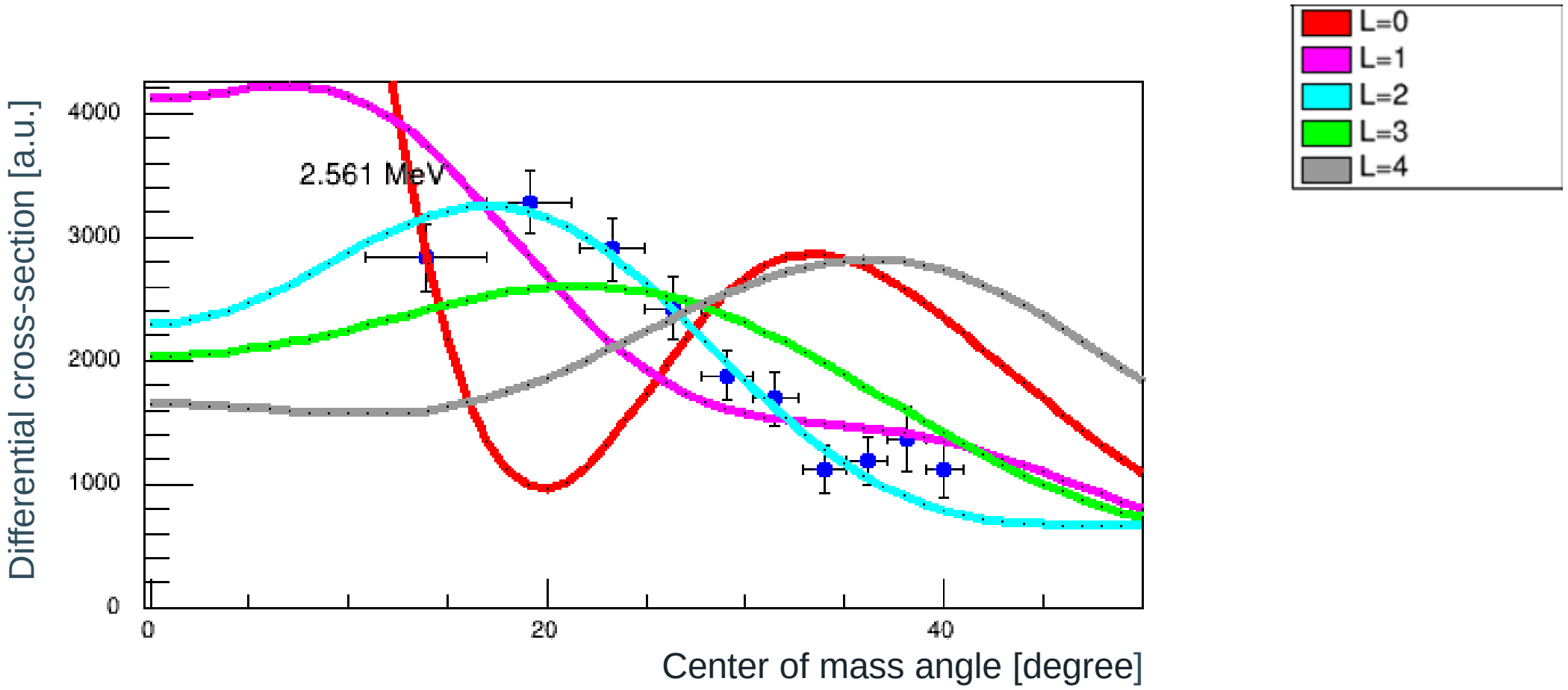
- **Ni + Ga**
- **Ga bg (scaled)**
- **Ni bg subtracted**



Excitation Energy Spectrum



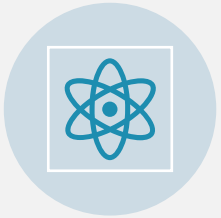
Angular Distribution (2.5 MeV state)



Angular distributions generated using FRESCO:
. J. Thompson. Coupled reaction channels calculations in nuclear physics. Computer physics reports, 7(4):167–212, 1988.

Contents

ISOLDE Solenoidal Spectrometer



Why study ^{68}Ni(d,p) ?

The ISS detector

Preliminary results

Outlook

Conclusion

- Data analysis for ^{68}Ni(d,p) is nearly finished and article in preparation
- (At least one) state has been found corresponding to $\nu d_{5/2}$ orbital

- Want to know more about ISS?

Poster presentation and more talks in the Friday afternoon session ;)

Acknowledgements

- This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No 101057511

A. Ceulemans[1], L. P. Gaffney[2], F. Flavigny[3], A. Alharbi[2], H. Ayatollahzadeh[4], Y.Ayyad[5], F. Browne[6], A. Camaiani[1], D. Clarke[7], A. Dolan[2], Z. Eleme[8], S. Fracassetti[1] ,S. J. Freeman[6], G. Georgiev[6,9], S. Goula[8], A. Heinz[10], B.R. Jones[2], A. Kawęcka[10], J. Keatings[4], T. Kröll[11], P. MacGregor[6] , M.V. Managlia[10], A. Mitchell[12], J. Ojala[2], B. Olaizola[6], N. Patronis[8], O. Poleshchuk[1], R. Raabe[1], A.M. Sánchez-Benítez[13], D. K. Sharp[7], M.E. Stamati[8], H. Törnqvist[10], A. Youssef[1] and the ISS collaboration

[1]KU Leuven, Belgium; [2]University of Liverpool, U.K.; [3]LPC Caen, France; [4]University of the West of Scotland, U.K.; [5]Universidade de Santiago de Compostela, [6]CERN-ISOLDE, Switzerland; [7]University of Manchester, U.K.; [8]University Of Ioannina, Greece.; [9]IJCLab, France; [10]Chalmers university of Technology, Sweden; [11]Technische Universität Darmstadt, Germany, [12]Australian National University, [13]University of Huelva, Spain

Thanks for listening

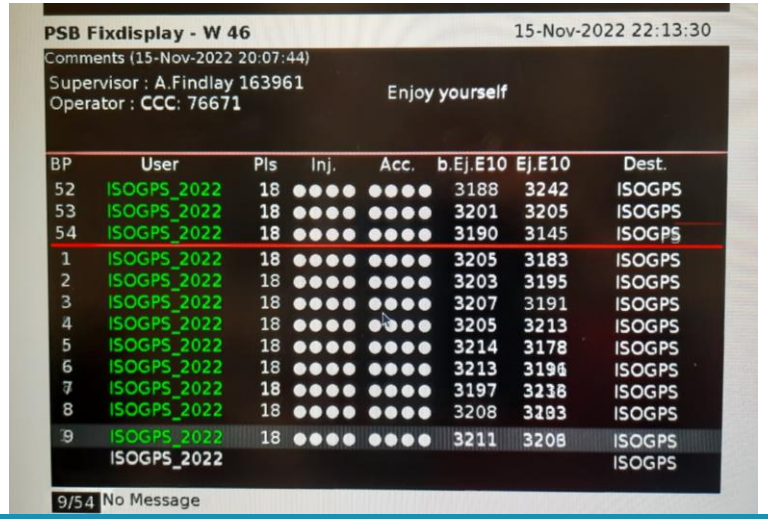
Backup slides

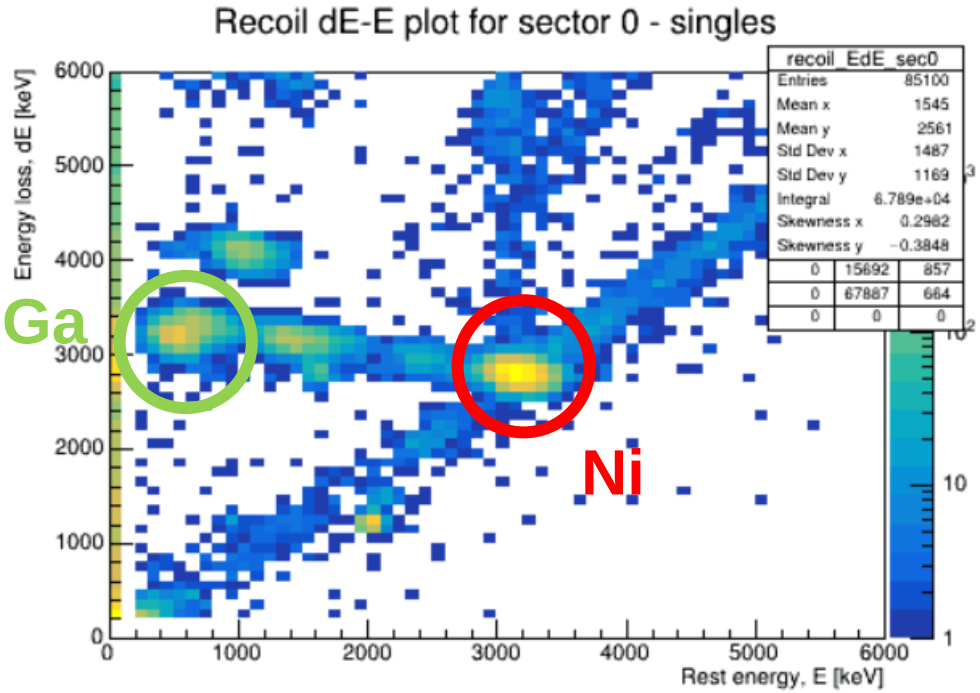
Reaction Info

- Transfer reaction: ^{68}Ni(d,p) ^{69}Ni
- Beam energy: 6 MeV/u
- Target: 137 µg/cm^2 CD_2
- Estimated beam intensity: 5×10^4 ions/µC

Ga background

- Isobaric Ga contamination
- Use of 3s beam gate and consecutive proton pulses
- Laser off for Ga background

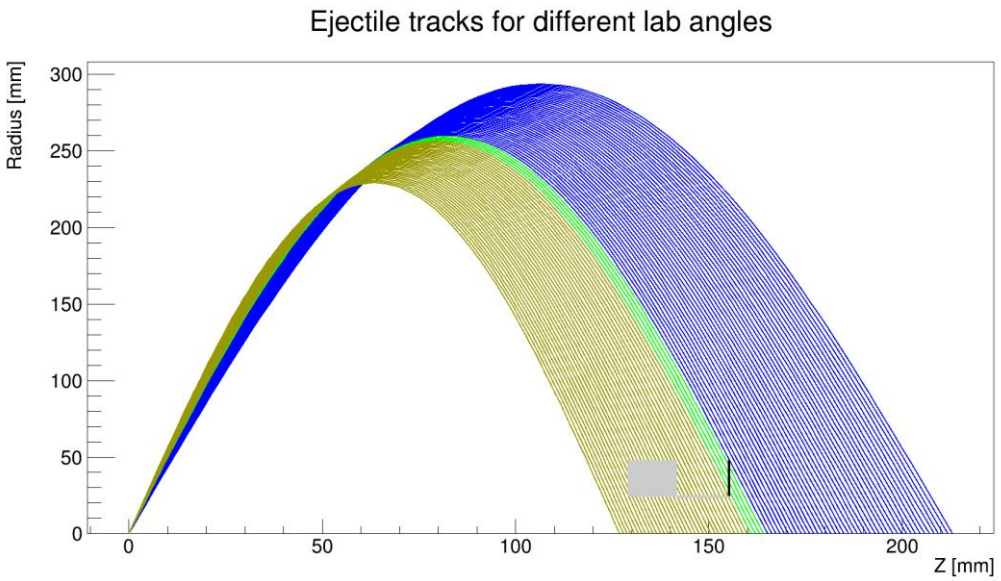




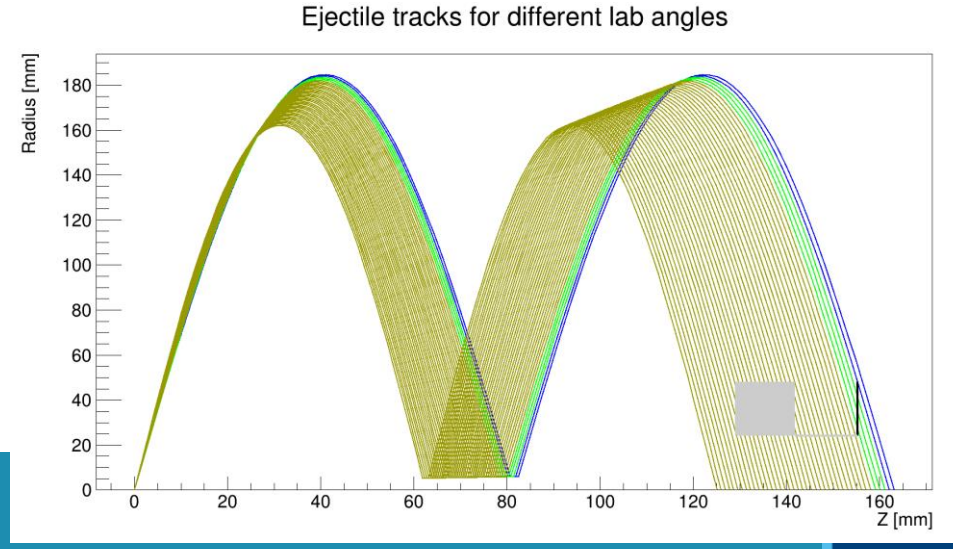
Configuration	Ratio Ni:Ga
No beam gate	**1:7**
With beam gate	**4:1**

68Ni scattering on d

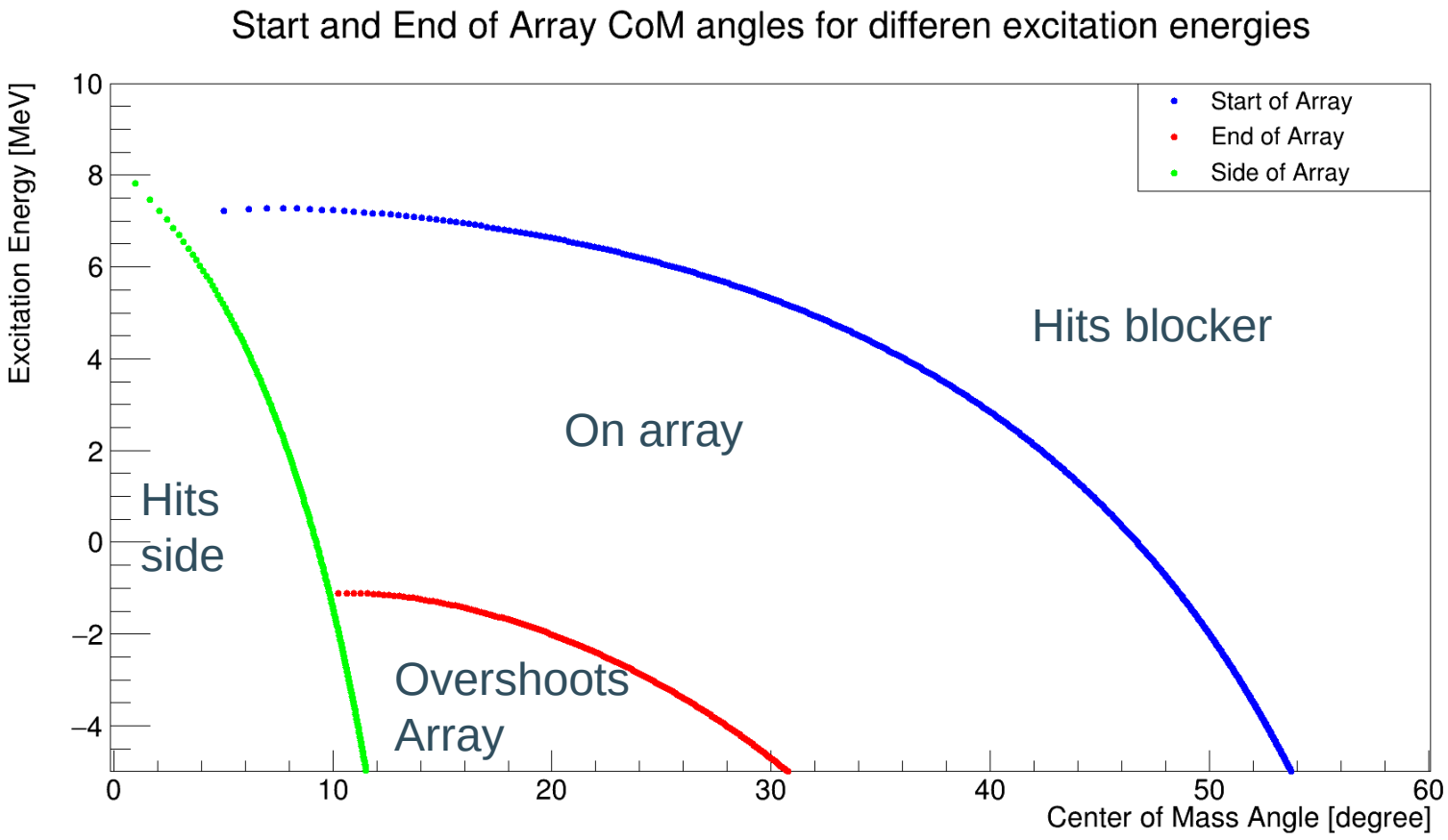
- Single turns
- $\theta_{lab} \in [78.59°, 78.74°]$
- $E_{kin} \in [1.769, 1.724]$ MeV



- Double turns
- $\theta_{lab} \in [82.04°, 82.11°]$
- $E_{kin} \in [0.868, 0.852]$ MeV



Detection Limits



Excitation Energy [MeV]	Angular Range [°]
0	9,2 – 46,7
0,3	9,1 – 46,1
1,77	8,1 – 42,9
2,5	7,6 – 41,0
2,8	7,3 – 40,1
3,1	7,1 – 39,2
4	6,2 – 36,1
4,35	5,9 – 34,7
4,7	5,6 – 33,1

Overlay angular ranges