(n,z) measurements on Fe and Ni (including ^{56}Ni) at LANSCE

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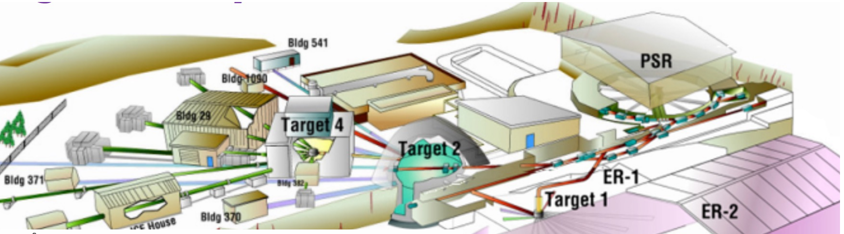
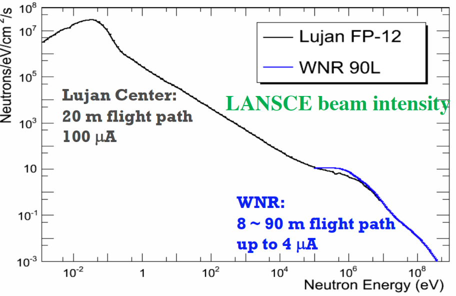
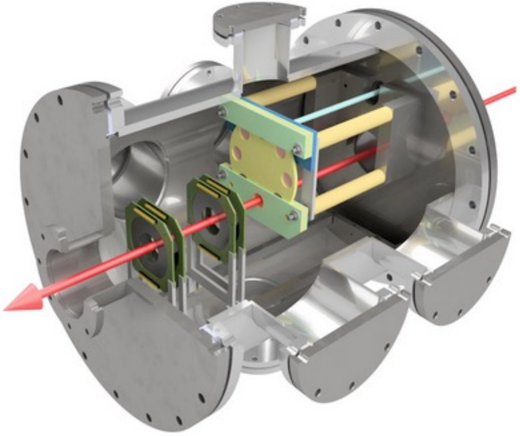
LENZ: The Low Energy (n,z) experimental station

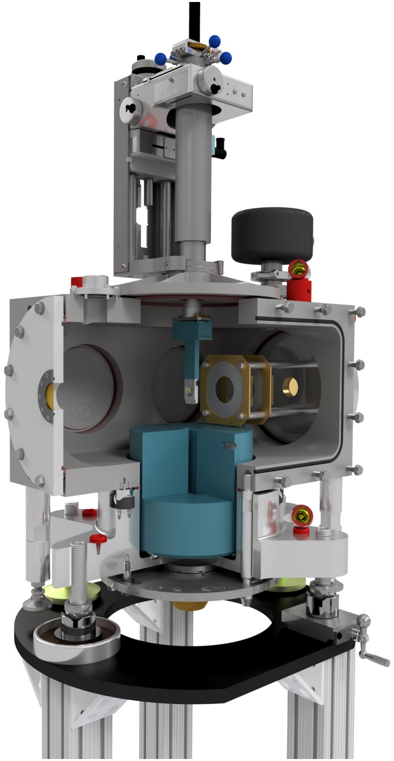
- Detect outgoing charged particles using double-sided silicon strip detectors in a compact setup close to the target sample.







Schematic diagram of the LENZ instrument, composed of two sets of dE DSSD detector telescopes at forward angles, and a target wheel in the middle of the instrument. Red arrow shows the neutron beam direction.



hotLENZ rendering by B. DiGiovine

- WNR Facility at LANSCE: fast neutrons with a broad energy spectrum ~100s of keV to ~100s of MeV

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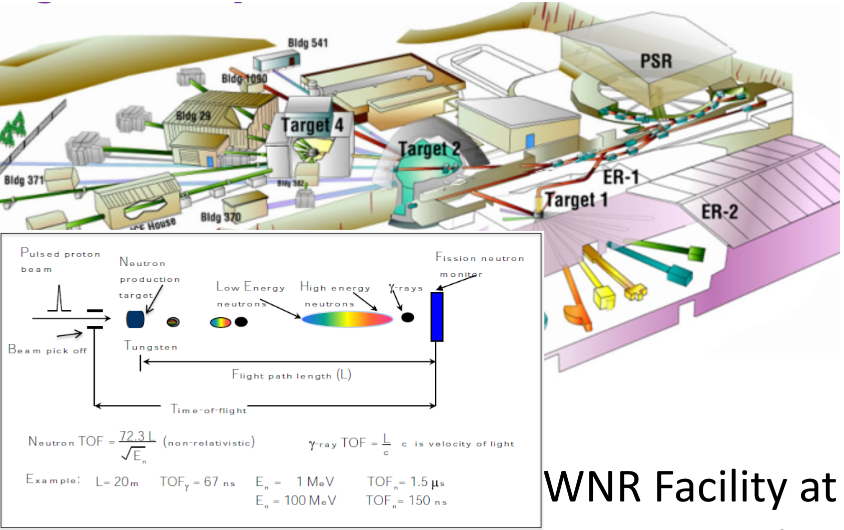
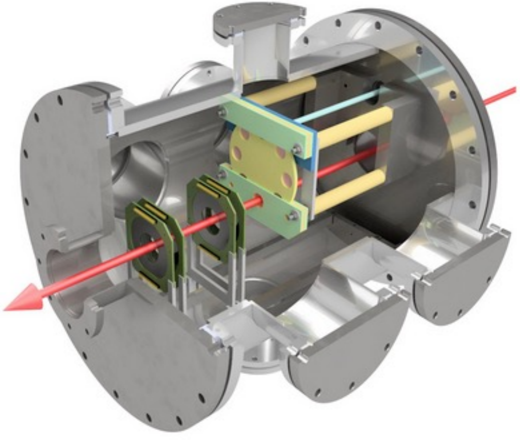


WNR Facility at LANSCE: fast neutrons with a broad energy spectrum ~100s of keV to ~100s of MeV



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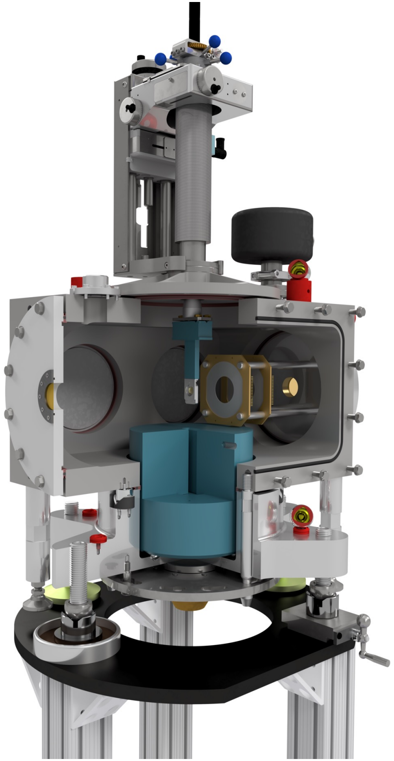
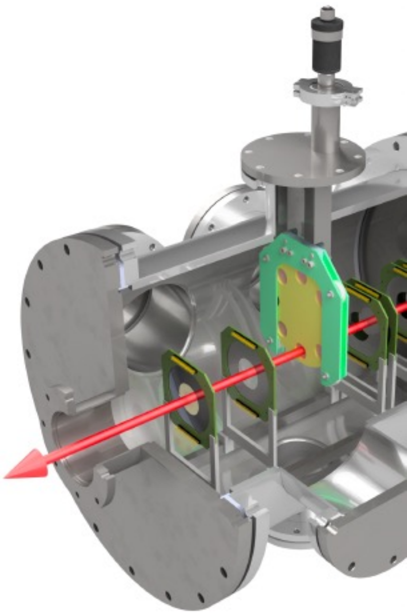


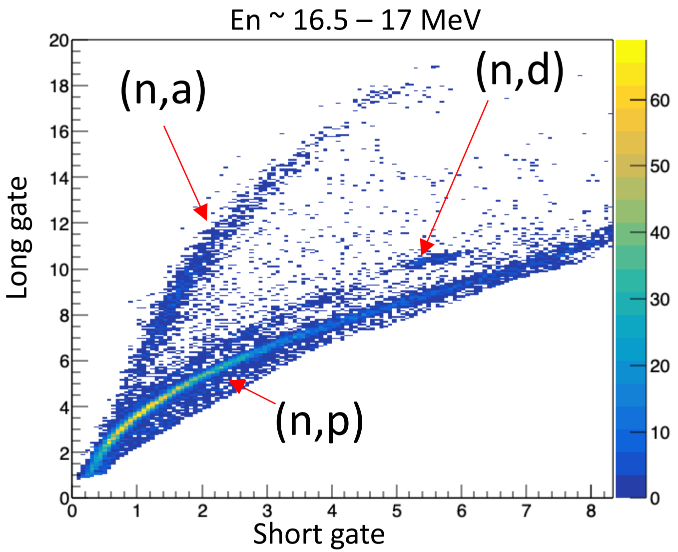
hotLENZ rendering by B. DiGiovine

Measurements of (n,z) reactions on ^{54}Fe, ^{56}Fe, ^{58}Ni, ^{60}Ni

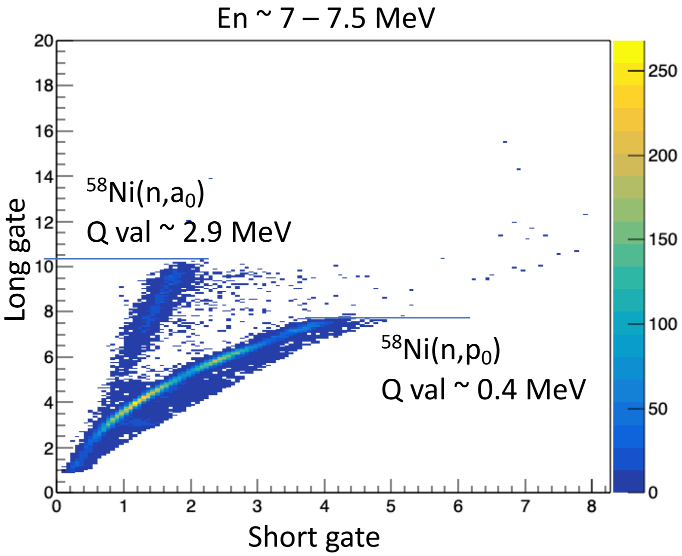
- WNR Facility at LANSCE: fast neutrons with a broad energy spectrur ~100s of keV to ~100s of MeV
- Annular silicon detectors for detecting charged particles
- Self-supported, enriched targets of ^{54}Fe, ^{56}Fe, ^{58}Ni, and ^{60}Ni with thicknesses between 1mg/cm^2 and 2.4 mg/cm^2.
- Measurements performed at the 15R flight path at WNR at a distance of 15.2m from the spallation neutron source.
- Detectors covering both forward and backward angles with a solid angle coverage of ~2 sr.
- Employ both risetime pulse shape analysis and DE-E detector setups for PID
- Consistent detector setup for all 4 targets



Risetime pulse shape analysis for PID



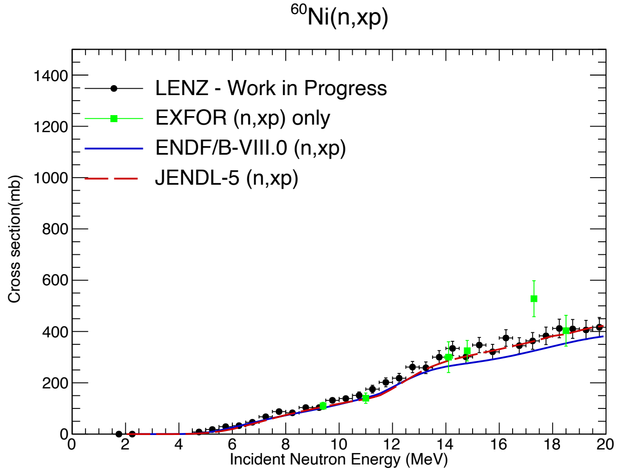
PSD spectrum for ^{58}Ni target in downstream most detector gated on En ~ 16.5 - 17 MeV

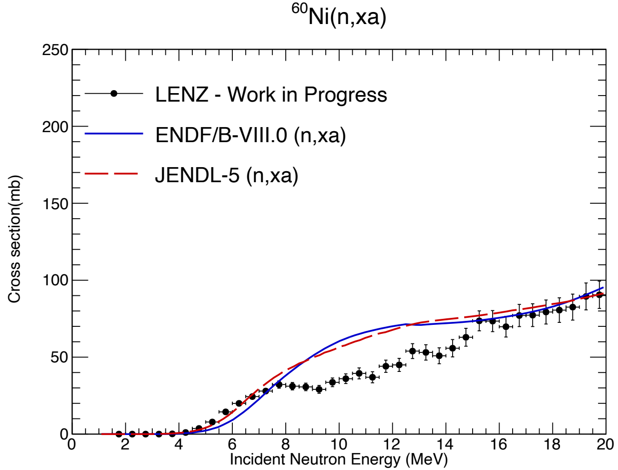


PSD spectrum for ^{58}Ni target in downstream detector gated on En ~ 7 – 7.5 MeV

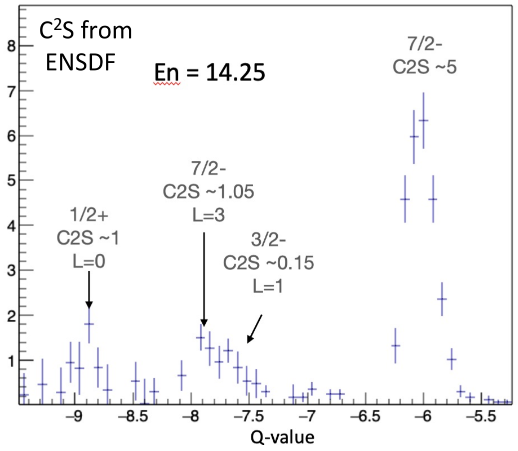
Before background subtraction

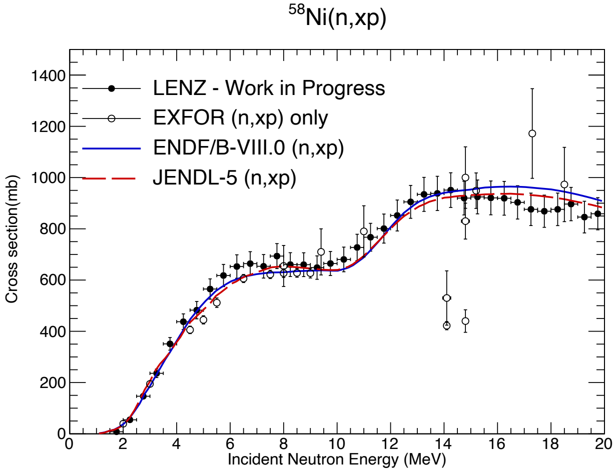
^{58,60}Ni(n,xp) and ^{58,60}Ni(n,xa) production cross sections

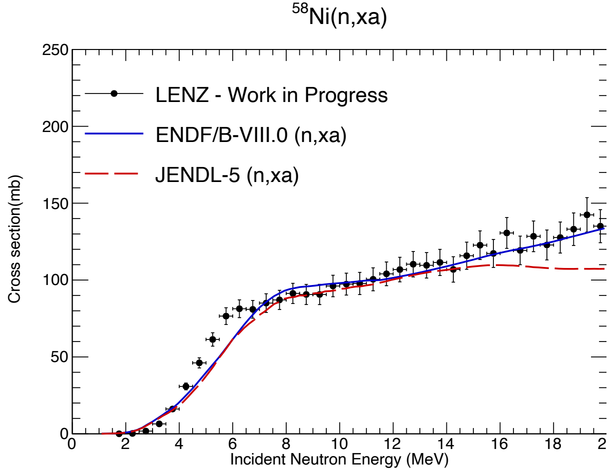




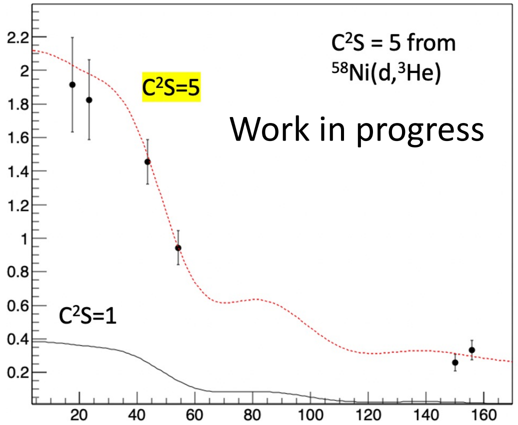
Deuteron gated



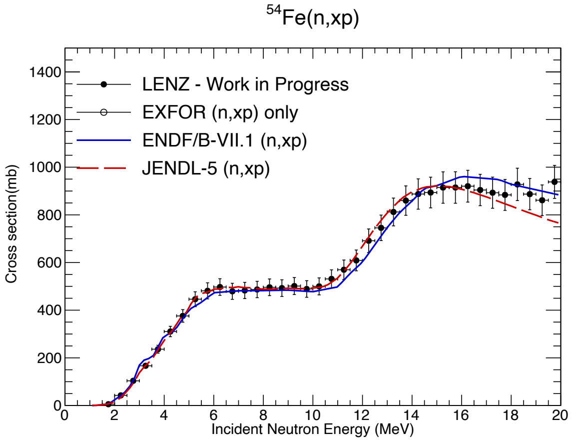


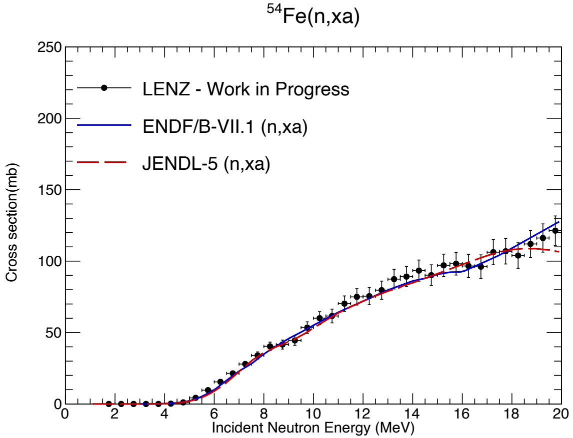


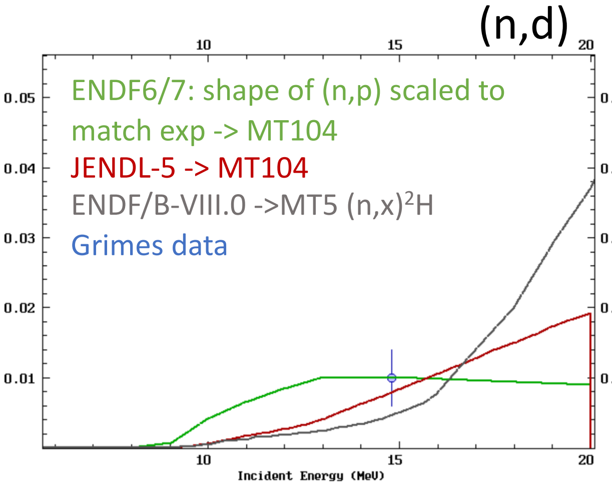
L=3 TWOFNR DWBA calculation

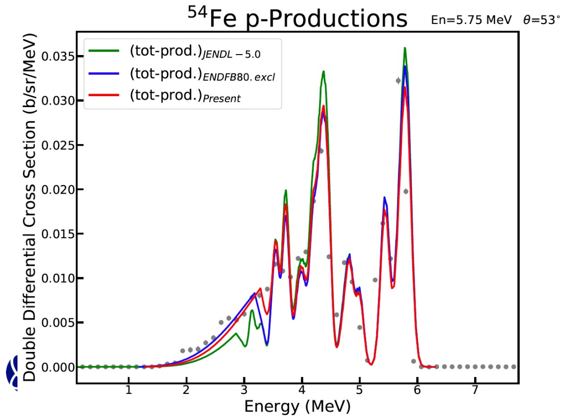


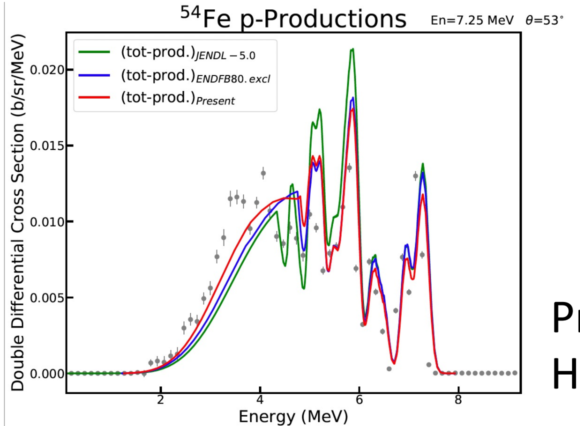
Proton and alpha production cross sections on ^{54}Fe









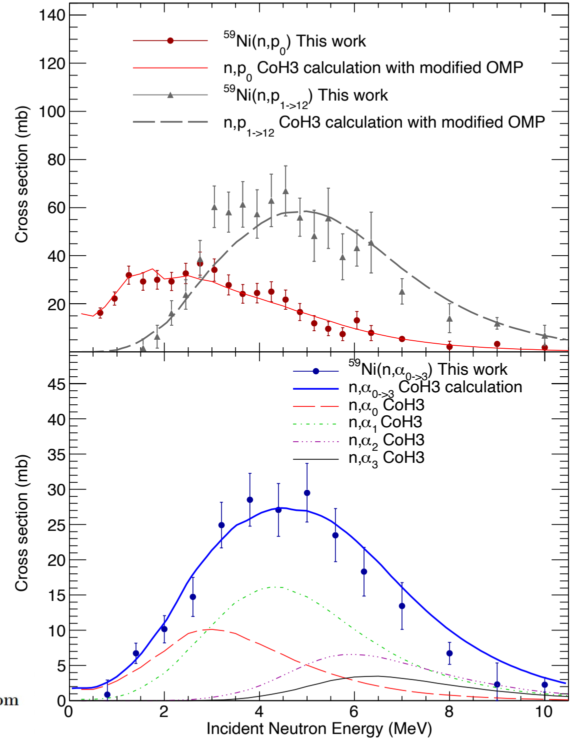


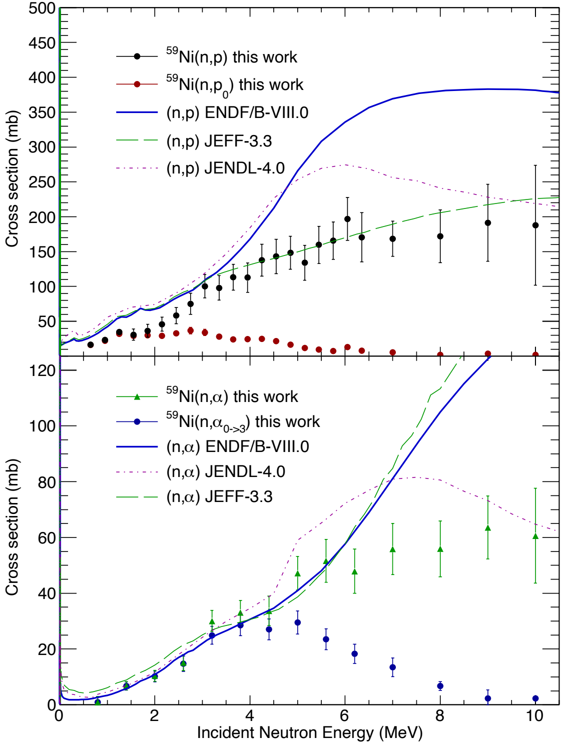
^{54}Fe ENDF/B-VIII.0 has MT=600-649 but no MT=103 (n,2p) is in MT=111 but no (n,n+p) in MT=28. Instead (n,n+p) is in (n,x)^{1}H in MT=5

Present calculations by Hyeong Il Kim (KAERI)

New data on ^{59}Ni(n,p) and ^{59}Ni(n,α) at fast neutron energies

- Statistical Hauser-Feschbach calculations performed using the code CoH3.
- For (n,p) below 3 MeV, the experimental cross section is approximately 30% lower than the available evaluations and from the calculations when using default parameters. Details on the adjustments to the OMP/level density are described in: https://doi.org/10.1103/PhysRevC.105.044608





Direct measurement of ^{59}Ni(n,p)^{59}Co and ^{59}Ni(n,α)^{56}Fe at fast neutron energies from 500 keV to 10 MeV

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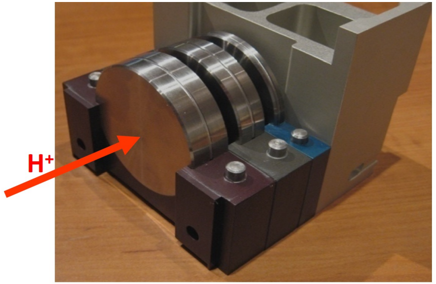
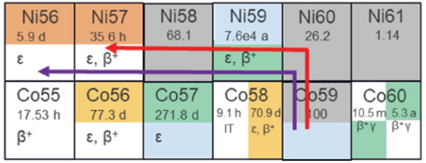
(Dated: February 10, 2022)

World unique capability that currently exists at LANSCE to study neutron induced reactions on short-lived radioactive nuclei

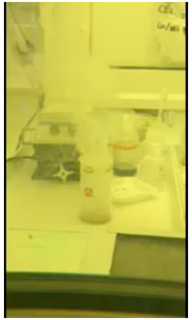
^{56}Ni production at the Isotope Production Facility at LANSCE



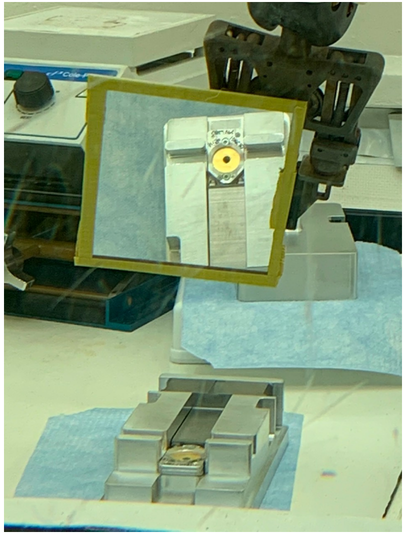


^{59}Co (p, 4n) ^{56}Ni

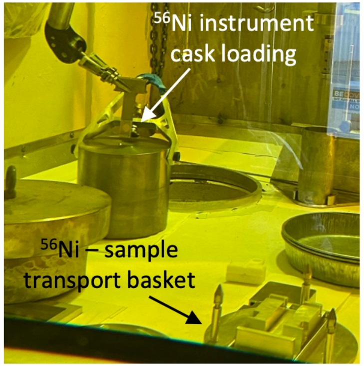
^{59}Co (p, 3n) ^{57}Ni



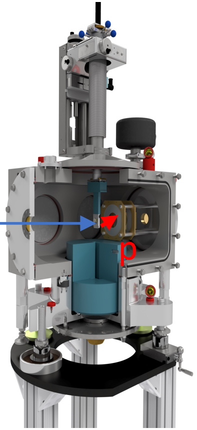
Purification and target fabrication at the Isotope Program Hot Cell Facility



Timely transportation to the high quality neutron beam facilities (WNR/Lujan) at LANSCE is critical for studying isotopes that live on the order of days.

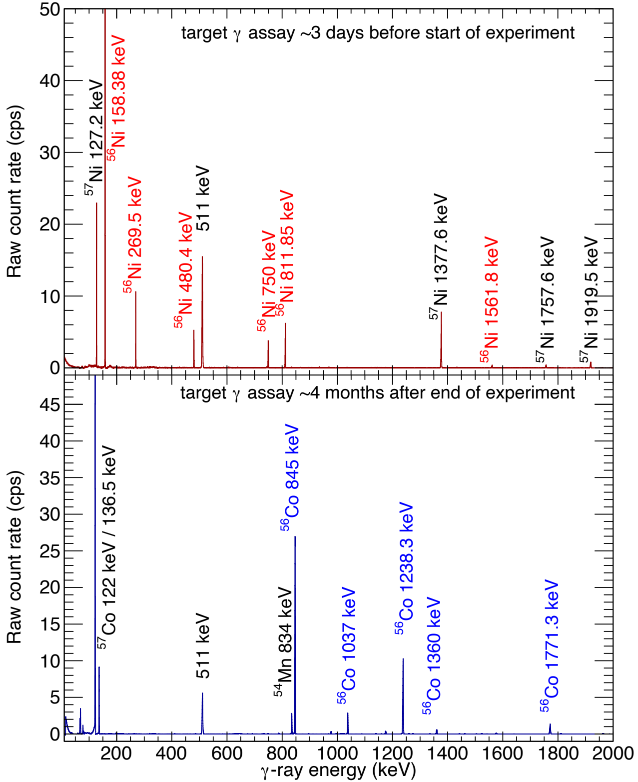


Incident neutron beam

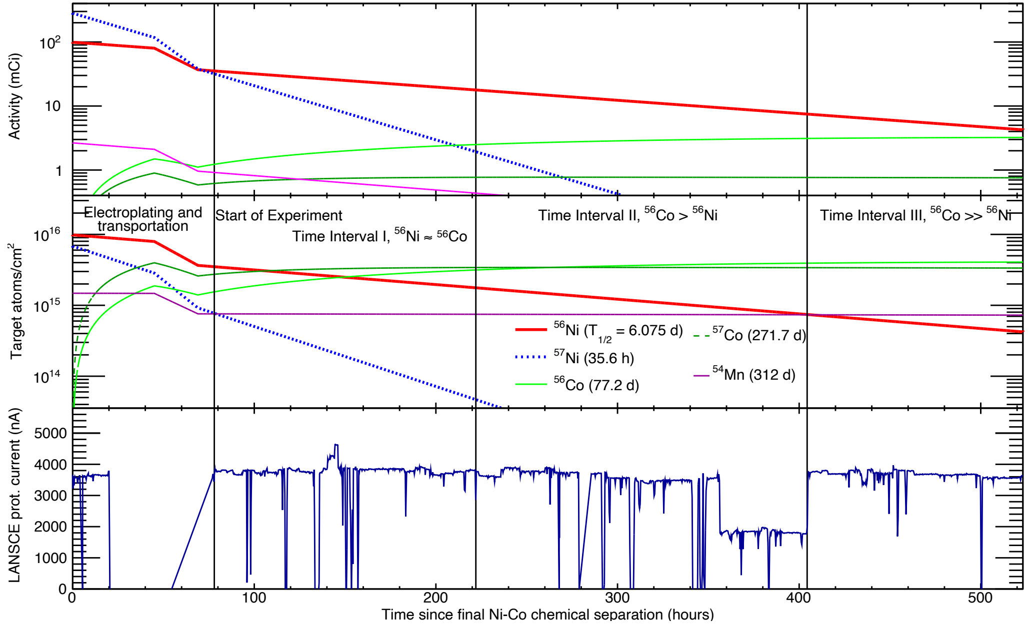


Most importantly, the infrastructure to do it SAFELY!

First direct measurement of neutron induced reactions on ^{56}Ni (and ^{56}Co)



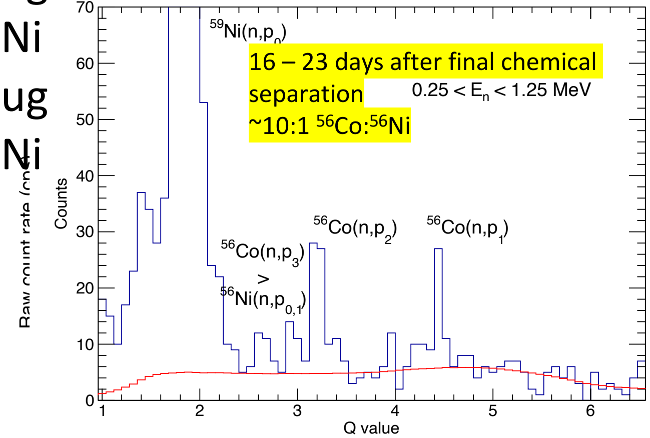
- Approach: Work backwards by analyzing the ^{56}Co(n,p) at the end of the experiment (~10:1 ^{56}Co:^{56}Ni) to determine the ^{56}Co contributions at the beginning of the experiment when ^{56}Co:^{56}Ni was ~1:1.

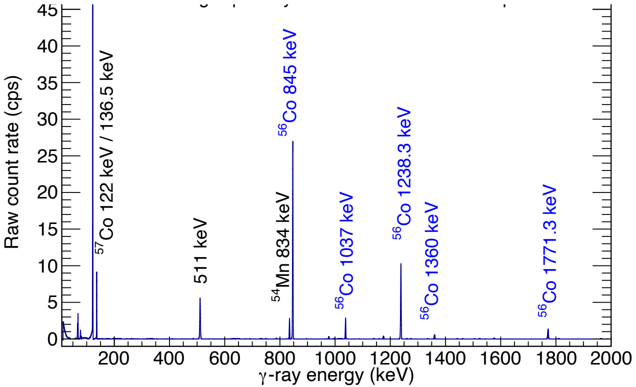


First direct measurement of neutron induced reactions on ^{56}Ni (and ^{56}Co)

~25 ug of ^{59}Ni

~75 ug of ^{58}Ni





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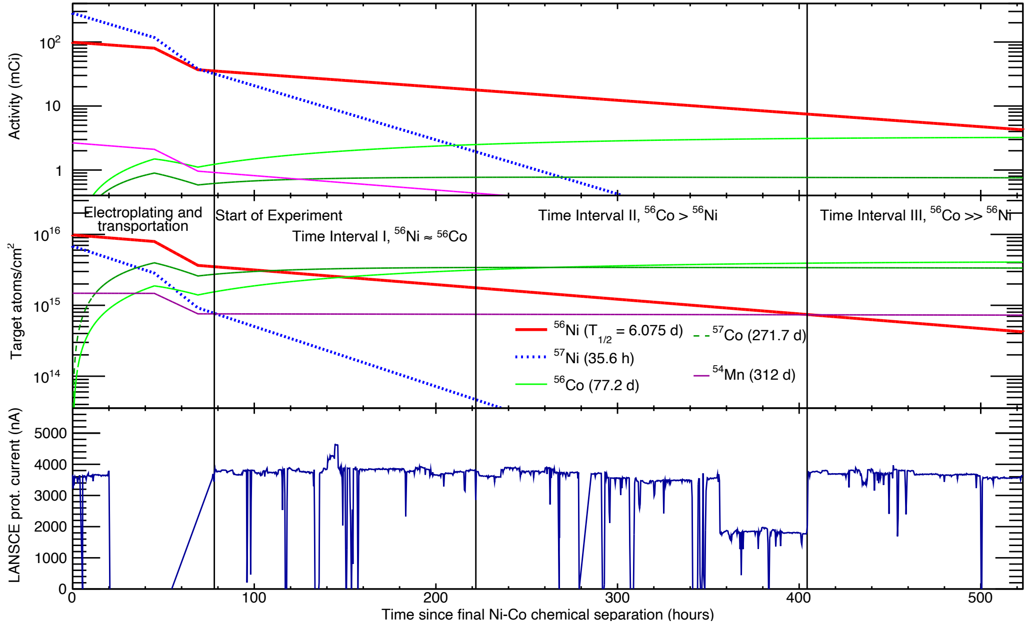
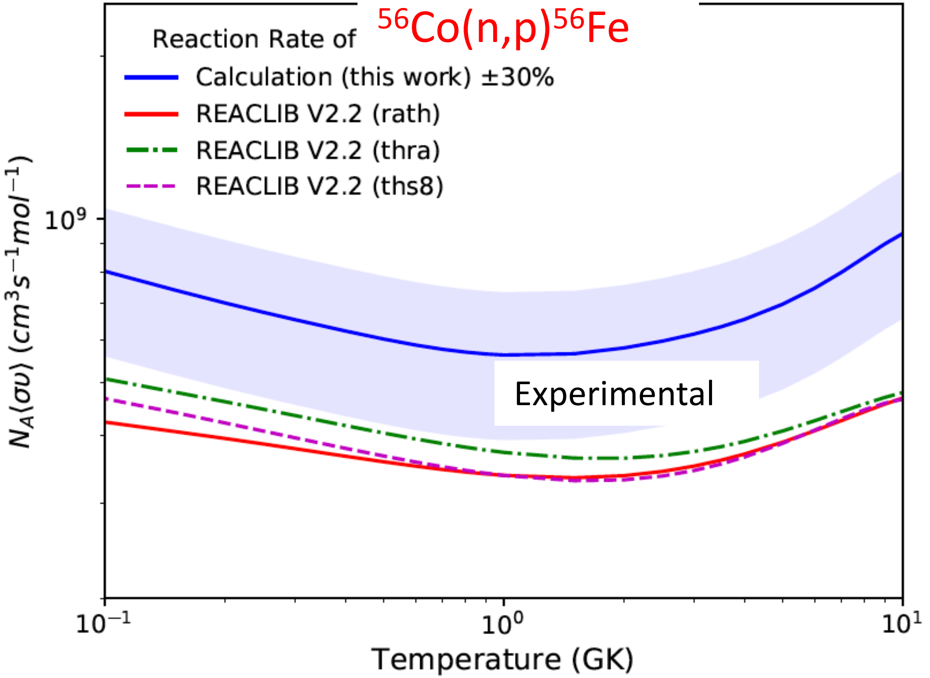
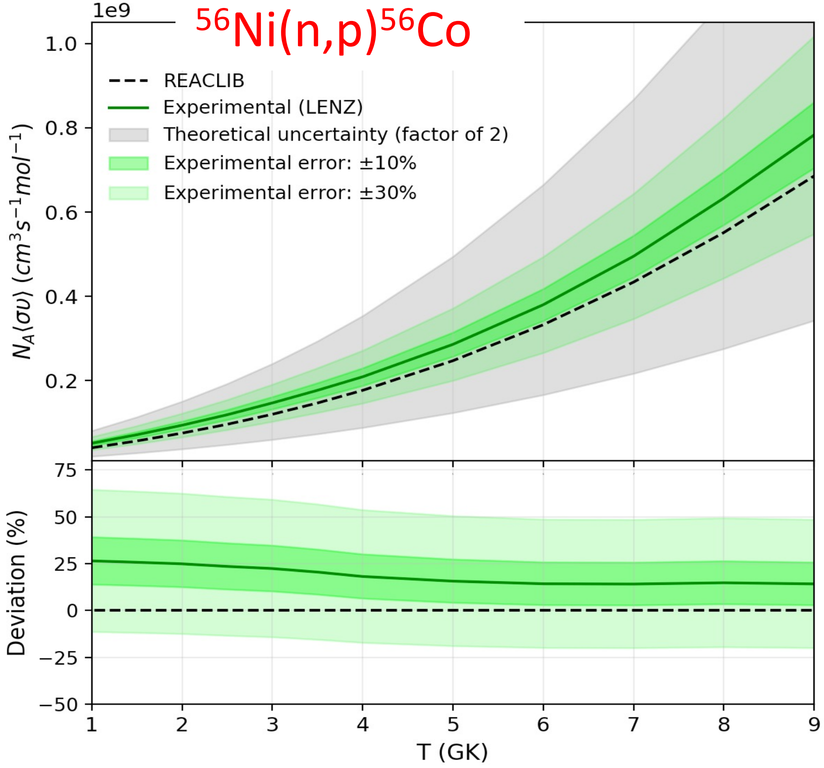


First directly measured (n,p) cross section on ^{56}Co and ^{56}Ni

- Experimental reaction rates data are compared with statistical calculation & REACLIB
- Total uncertainties from the current measurement are ~30 %

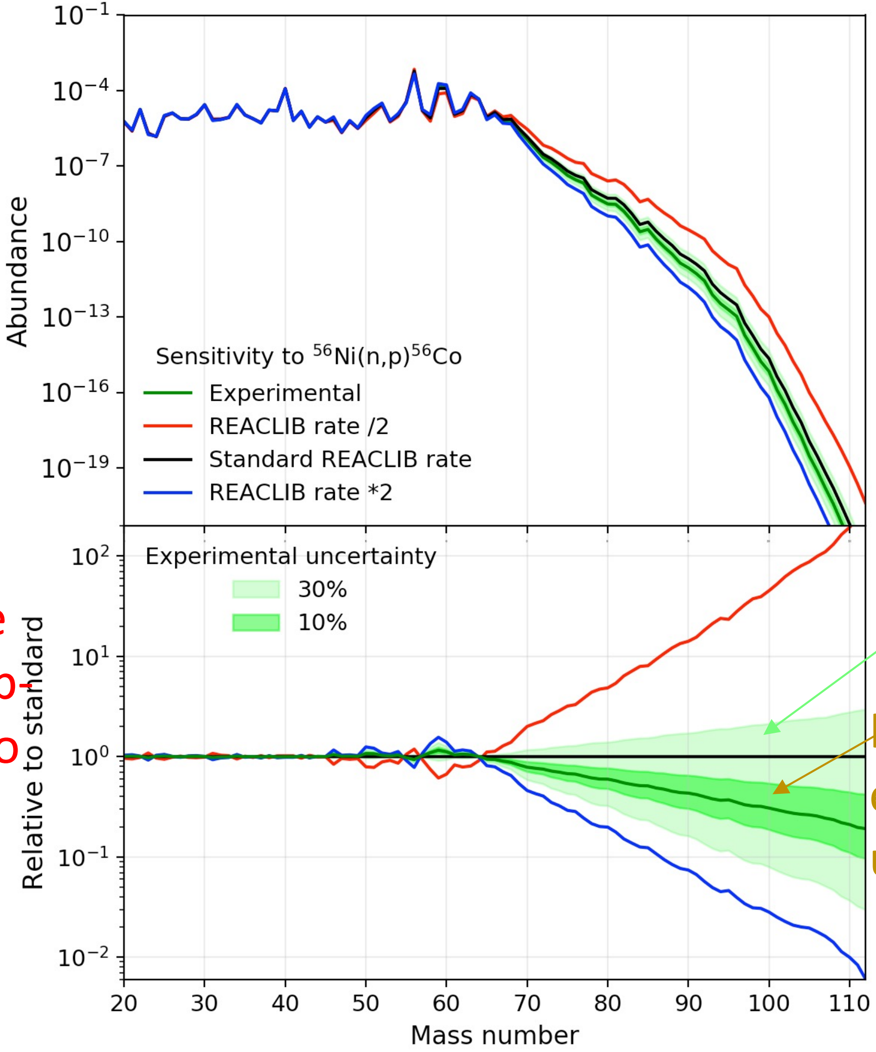
Experimental data can better constrain theoretical uncertainties in calculations





Experimental reaction rate of ^{56}Ni(n,p) was used to calculate networks for ν-driven winds CCSN, in order to provide the first experimental constraints on the role of ^{56}Ni(n,p) in νp-process

Using the experimental rate, the elemental abundances during νp-process are better understood to explain the impact of heavy element production



Current 30 % experimental uncertainty

Improved 10% experimental uncertainty

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Summary and Outlook

- First direct measurement of $^{59}Ni(n,z)$ at fast neutron energies above 100 keV was published in PRC and demonstrate the need to make direct measurements on radioactive nuclei, when feasible.

- Manuscripts detailing the first direct measurement of $^{56}Ni(n,p)$ are in development

- Together with the studies on stable ^{58}Ni and ^{60}Ni, will help to provide a more complete evaluation of the nickel isotopes at fast energies when combined with the radioisotope data.

- Measurements on $^{63}Cu(n,p)$ and $^{63}Cu(n,a)$ are currently underway (beam on target as we speak).

- Look ahead: new measurements on ^{39}K, ^{40}K, ^{35}Cl at WNR (unmoderated neutron source) with planned measurements at Lujan (moderated source) to span an even broader range of energies. In addition, measurements on zinc isotopes in collaboration with CMU.

Acknowledgements

- Nuclear reaction measurements at LANSCE: H.Y. Lee, S.A. Kuvin, B. DiGiovine, M. Borrego, P. Gastis, A. Georgiadou, C. Kelsey, M. Mocko, T. Medina, D. Votaw
- Isotope Production, Target Fabrication, and Transport: C. Vermeulen, V. Mocko, C. Lledo, K. Stosh, D. Reass, M. Brugh, R. Capton, M. Connors, L. Cummins, E. O’Brien
- Accelerator support: D. Ballard, J. Marquis, E. Kerstiens, N. Kollarik
- Radiological Safety support: M. Duran, K. Andrews, R. Miller, L. Overbay, M. Martinez
- CMU LENZ Collaborators: G. Perdikakis, N. Dimitrakopoulos, P. Tsintari

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^{63}Cu(n,a) and (n,p) state of play