

CERN-INTC-2014-054 ; INTC-P-420

# The $^{59}\text{Cu}(p,\alpha)$ cross section and its implications for nucleosynthesis in core collapse supernovae

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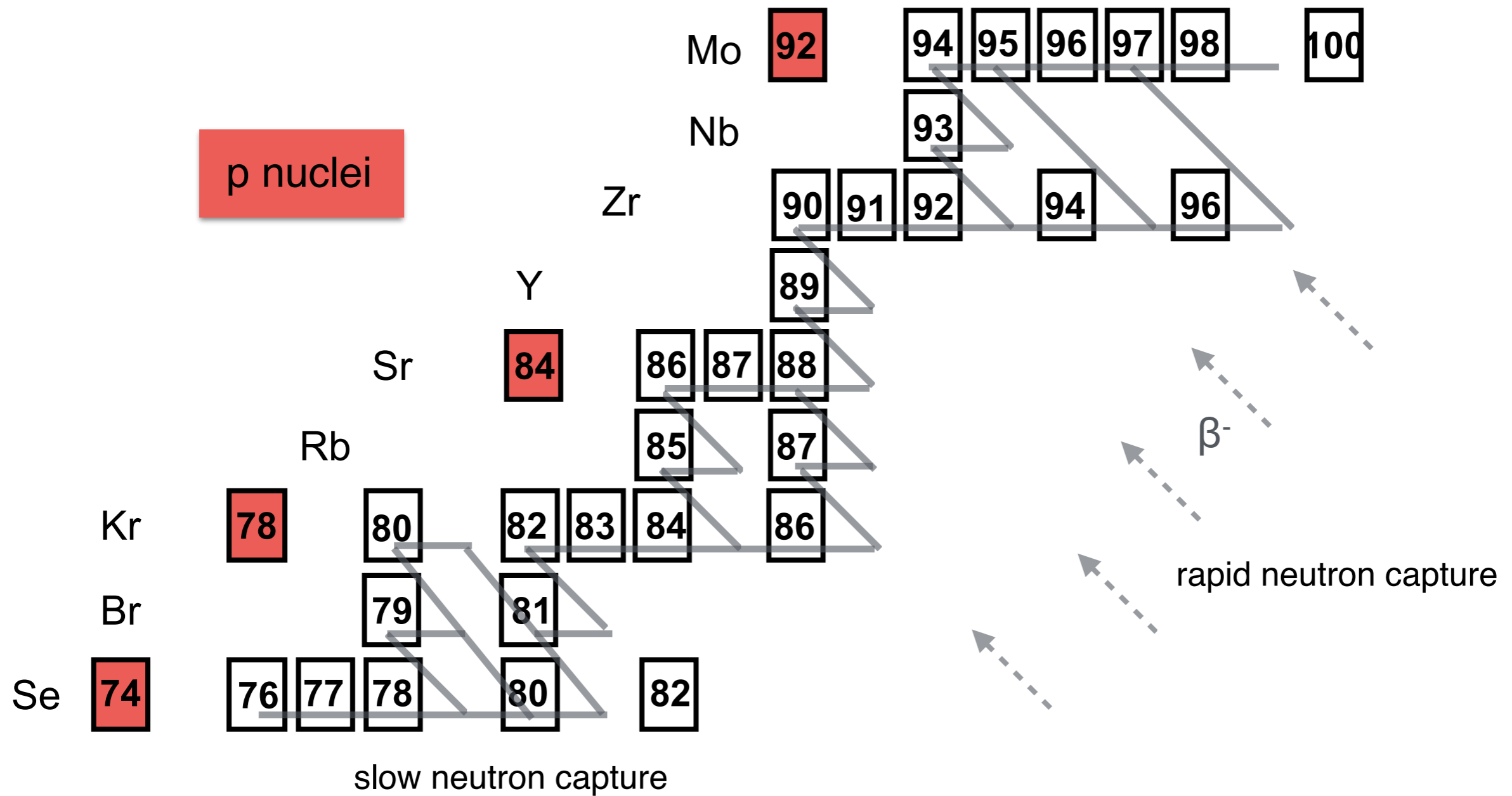
1 University of Edinburgh, 2 CEA-Saclay, 3 CERN

FWF

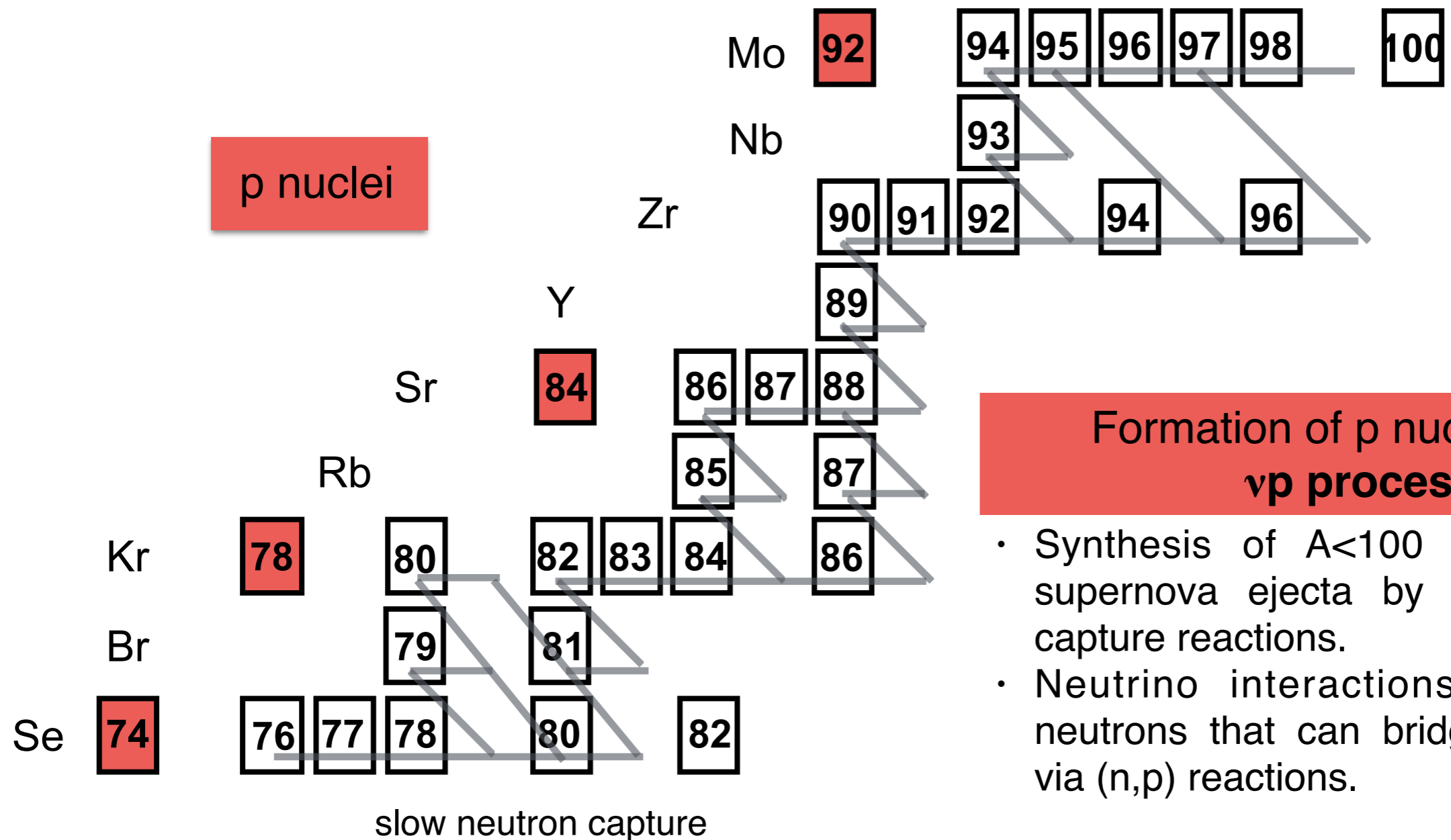
Der Wissenschaftsfonds.



# Heavy Element Formation in Stars



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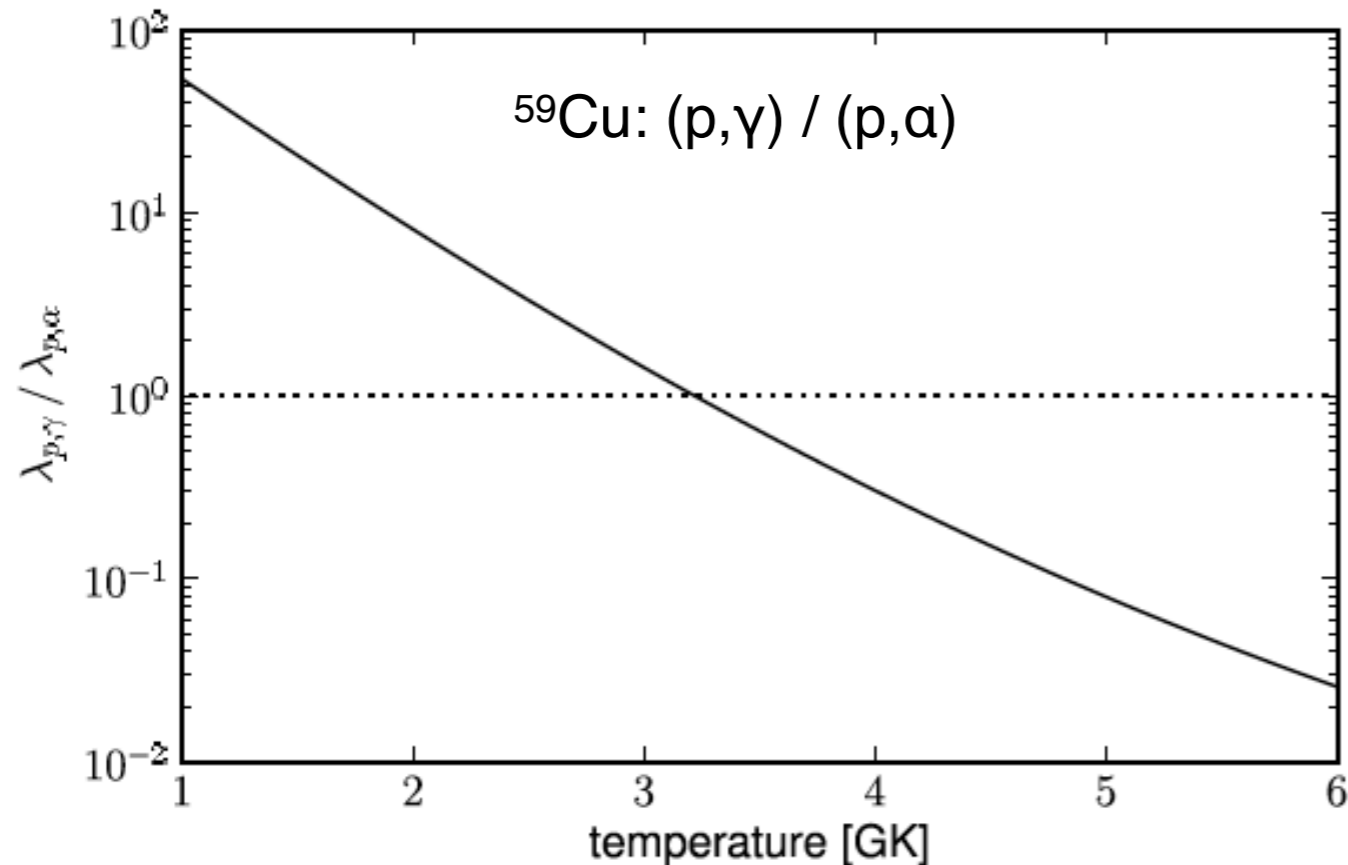
## Formation of p nuclei in the $\nu p$ process

- Synthesis of  $A < 100$  in proton-rich supernova ejecta by proton and  $\alpha$  capture reactions.
- Neutrino interactions create free neutrons that can bridge bottlenecks via (n,p) reactions.

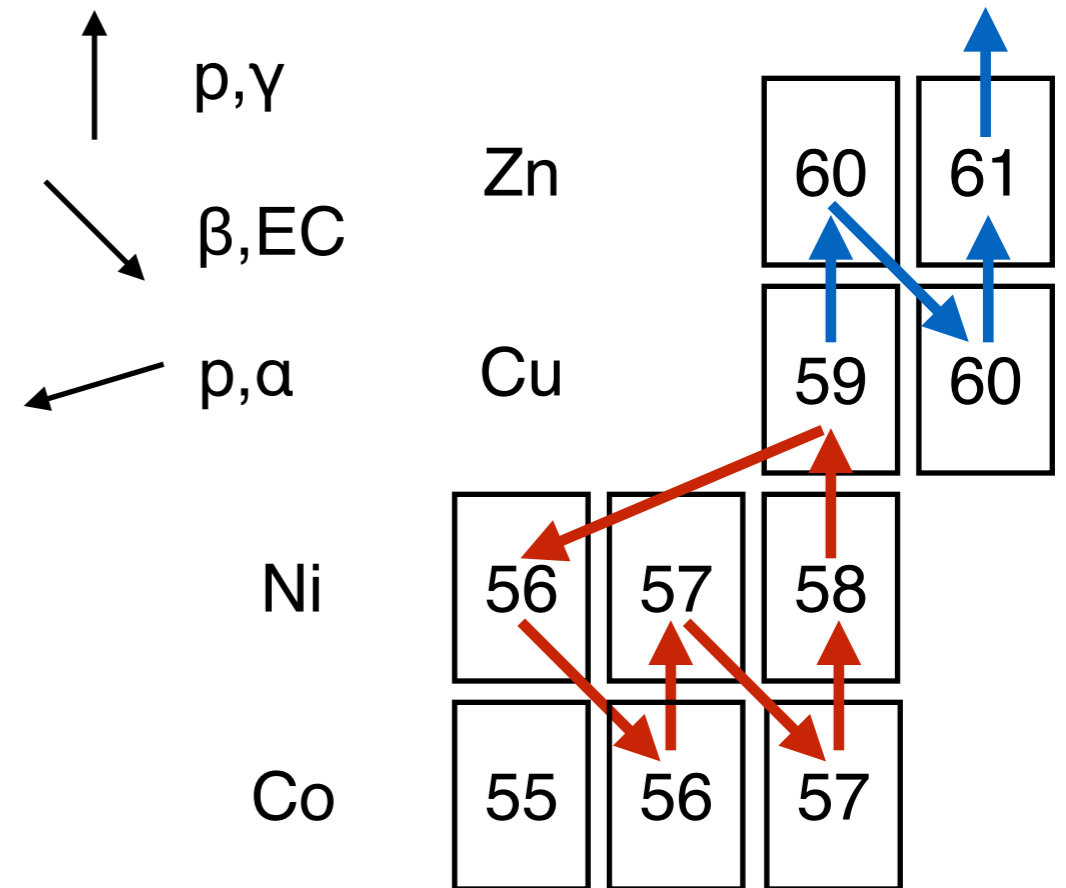
C. Fröhlich et al. Phys Rev Lett 96, 142502 (2006)

# vp process in supernovae

## Ni/Cu region: Gateway to production of the heavy elements



A. Arcones, et al., ApJ 750, 18 (2012)



**Competition between  $^{59}\text{Cu}(p,\alpha)$  and  $^{59}\text{Cu}(p,\gamma)$  sets starting temperature for heavy element formation in the  $\nu p$  process.**

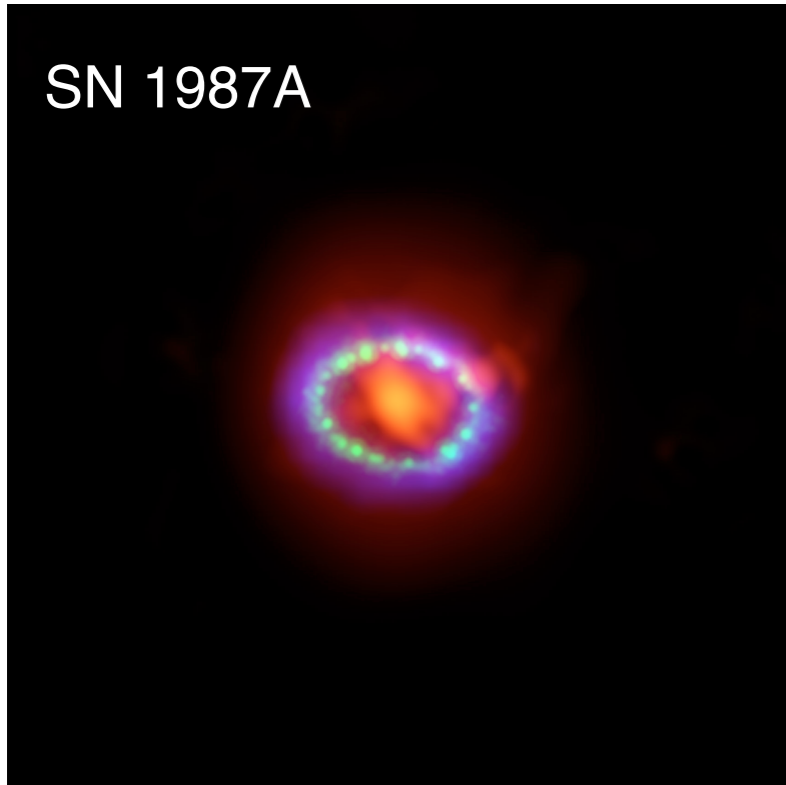
# Abundances of Cosmic X-ray Emitters

## Cosmic X-ray emitters

- Search for  $^{55}\text{Fe}$  in SN 1987A by CHANDRA mission - no detection, inconsistent with models

Leising, ApJ 651, 1019 (2006)

SN 1987A



- $^{59}\text{Cu}(p,\alpha)$  reaction rate has high impact on abundances of the X ray emitters  $^{55}\text{Fe}$  and  $^{59}\text{Ni}$  produced in supernovae

Jordan, Gupta and Meyer, Phys Rev C 68, 065801 (2003)

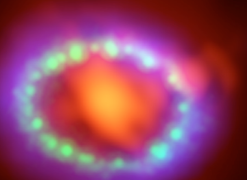
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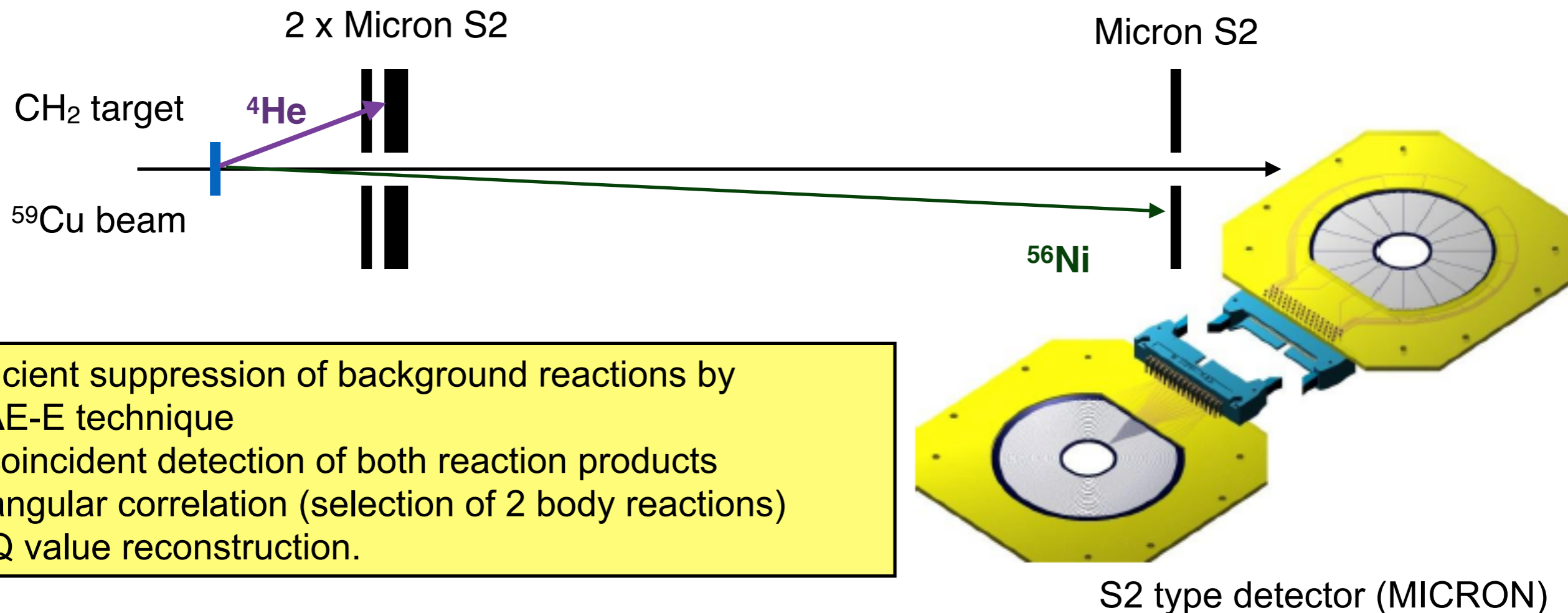
Jordan, Gupta and Meyer, Phys Rev C 68, 065801 (2003)

No experimental data exist for the  $^{59}\text{Cu}(p,\alpha)$  reaction.  
The intense  $^{59}\text{Cu}$  beam and available beam energies at HIE-ISOLDE will enable measurement at astrophysical energies (temperatures 2.5-4 GK) for the first time.

# Experimental Setup $^{59}\text{Cu}(p,\alpha)$

Detection of  $^4\text{He}$  and heavy recoil in coincidence (PRL 108, 242701 (2012)):

- $^4\text{He}$  detection: Micron S2 type Silicon detectors arranged as  $\Delta E$ -E telescope, 70  $\mu\text{m}$  and 1000  $\mu\text{m}$  thickness (angular coverage in lab 5-41 degrees)
- $^{56}\text{Ni}$  detection: S2 type detector, 70  $\mu\text{m}$  thick (angular coverage in lab 1.5-5 degrees)

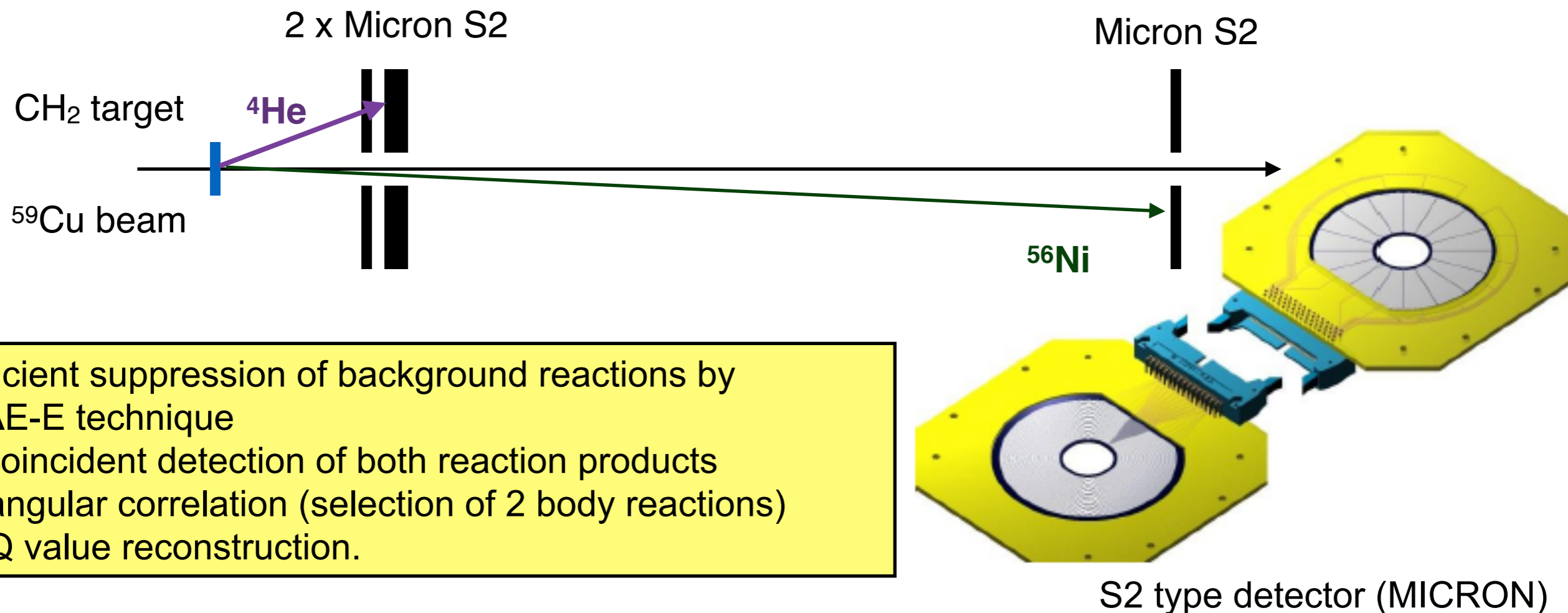


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**Detectors, targets and reaction chamber provided by Edinburgh**





# Beam time request

- Beam energies from 3.6 - 5 MeV/u cover stellar temperatures from 2.5 - 4 GK
- Background measurements with target of the same thickness containing Carbon (CD<sub>2</sub>)

## Count rate estimates:

- 2.1E5 <sup>59</sup>Cu ions per second on target
- Reaction cross section as calculated by the NON-SMOKER code
- 2h of background runs for each beam energy

<b>E<sub>B</sub></b> <b>(MeV/u)</b>	<b>E<sub>B</sub></b> <b>(MeV)</b>	<b>E<sub>CM</sub></b> <b>(MeV)</b>	<b>XS</b> <b>(mb)</b>	<b>C/h</b>	<b>Shifts</b>	<b>C</b>	<b>Unc.</b> <b>(%)</b>
5.0	295	4.6-5.0	2.0	28	2	290	6
4.7	277	4.3-4.7	1.3	14	3	300	6
4.4	259	4.0-4.4	0.7	9	4	220	7
4.0	236	3.6-4.0	0.3	3	5	105	10
3.6	212	3.2-3.6	0.1	1.4	5	45	15

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**Total request: 24 shifts**  
**(19 measurement, 1 setting up in beam, 4 beam energy changes)**

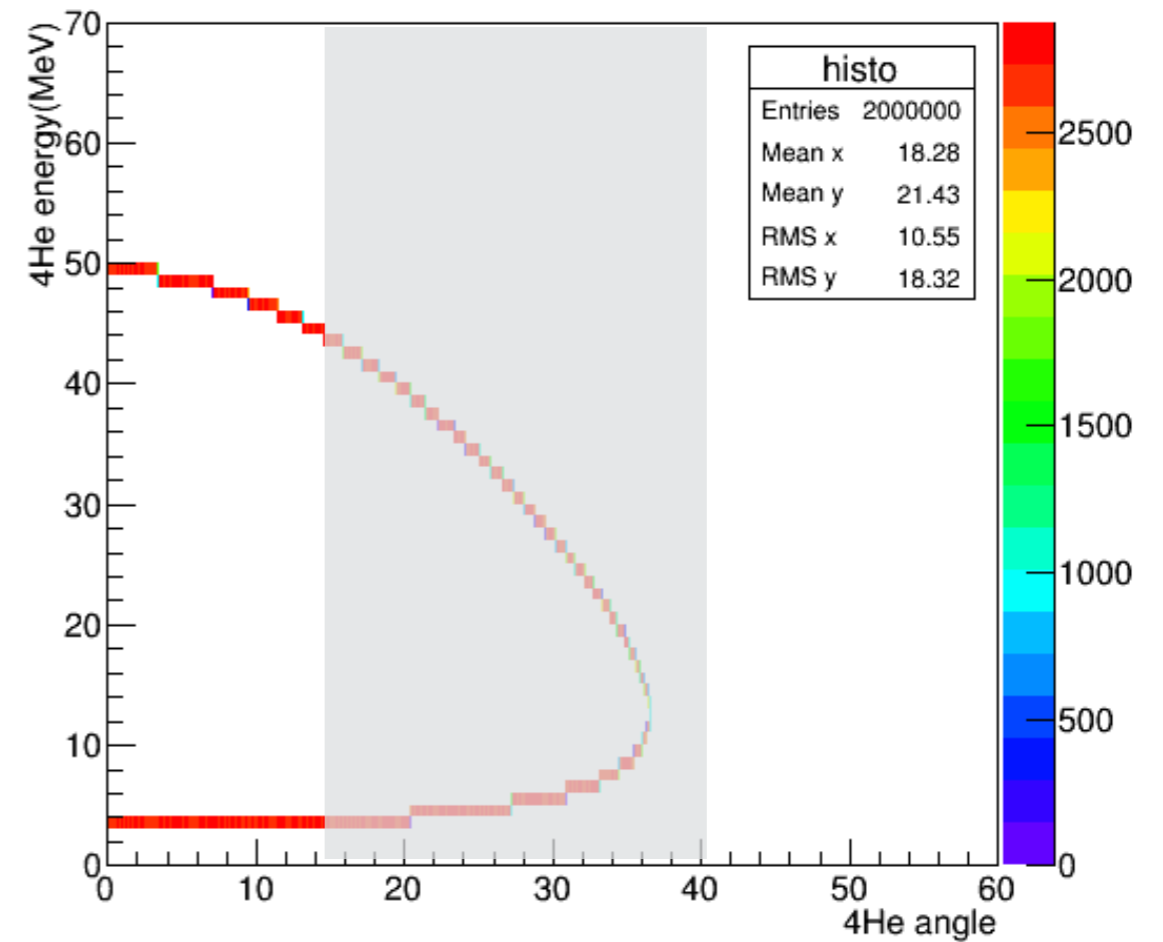
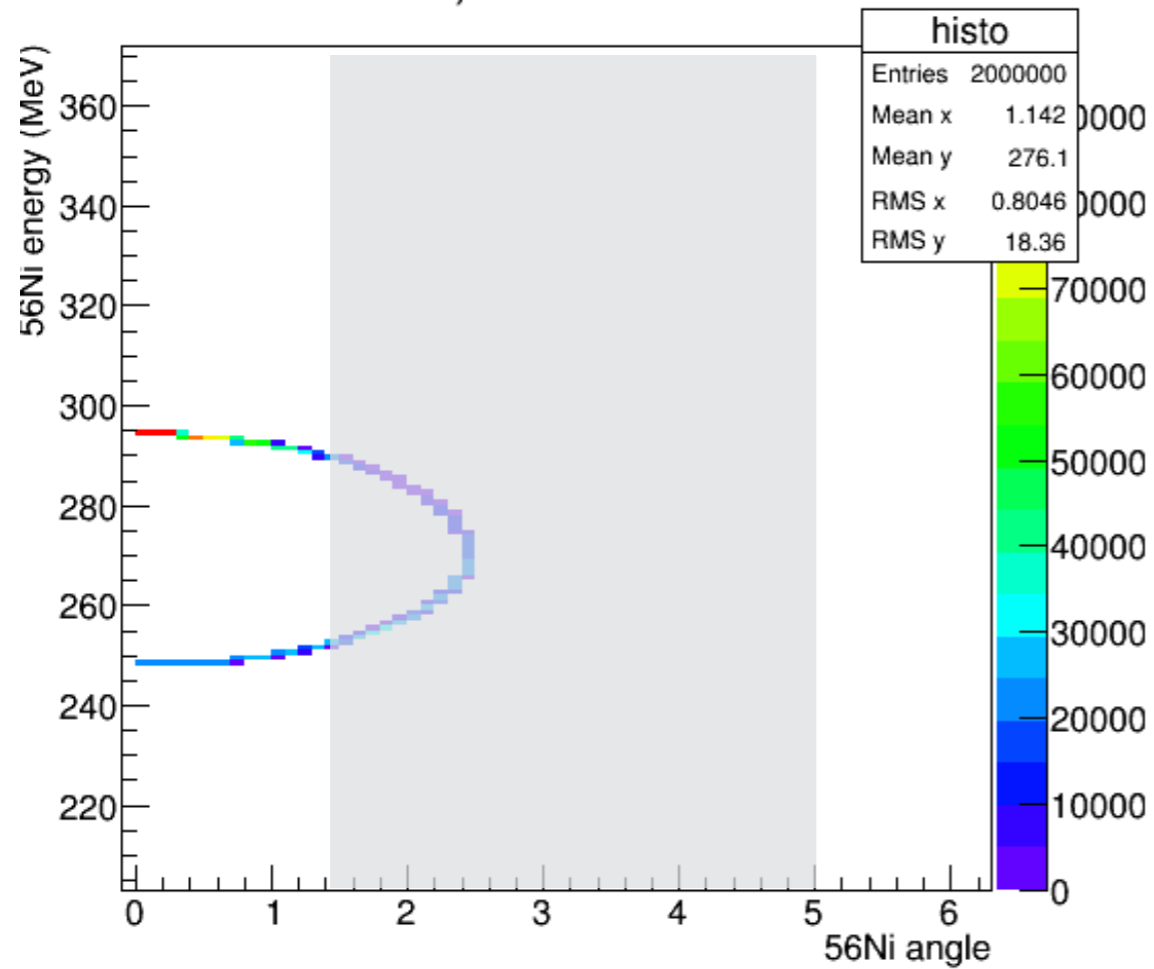
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# Extra Slides

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$^{59}\text{Cu}$  beam: 295 MeV



# Extra Slides

