Beyond the Barrier:
exploring α-nuclear potentials with exotic heavy nuclei

Francisco G. Barba

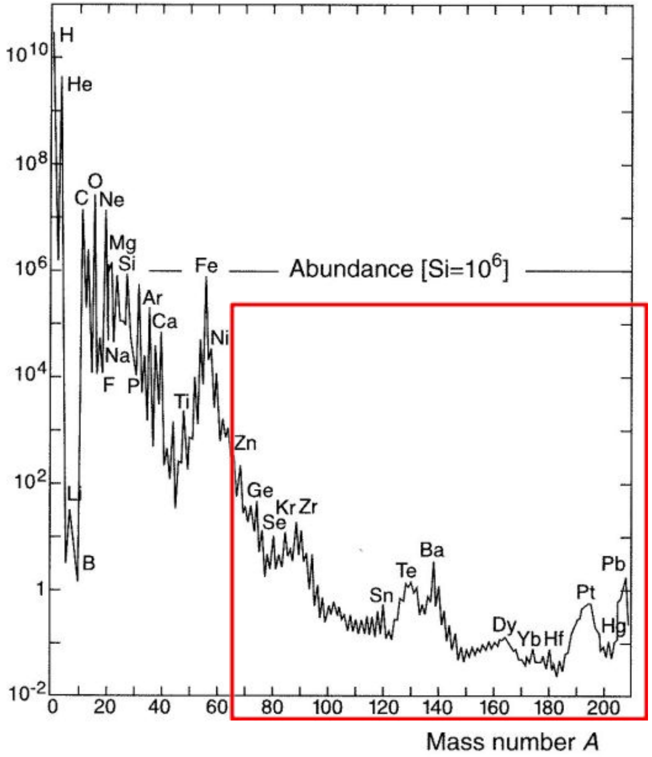
First IRENA-IANNA Workshop

Tuesday, 11th June 2023

Motivation

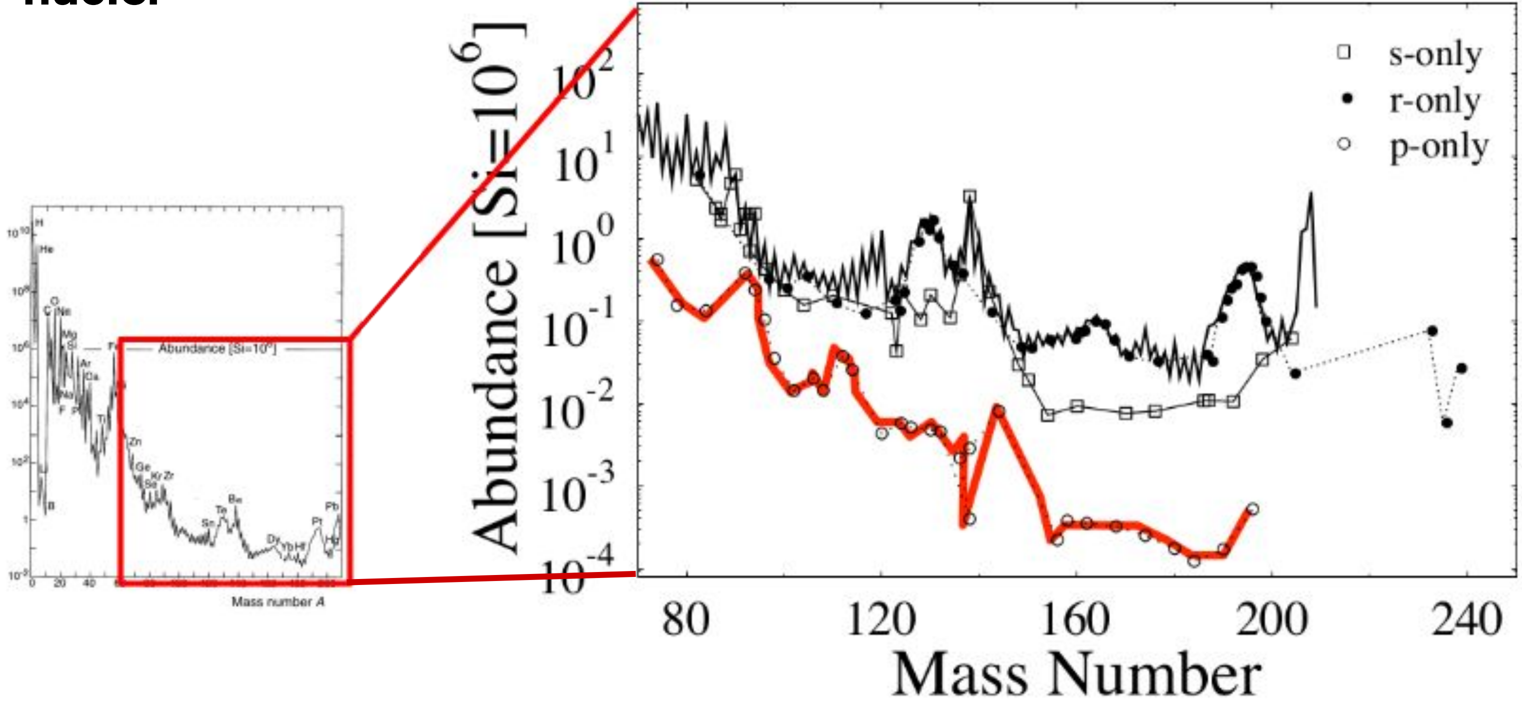
Solar Abundance Distribution (SAD)

- <u>Bulk of elements:</u>
  - ➢ BBN
  - ➢ Fusion phase
- <u>Heavy elements:</u>
  - ➢ **Neutron capture** processes



Motivation

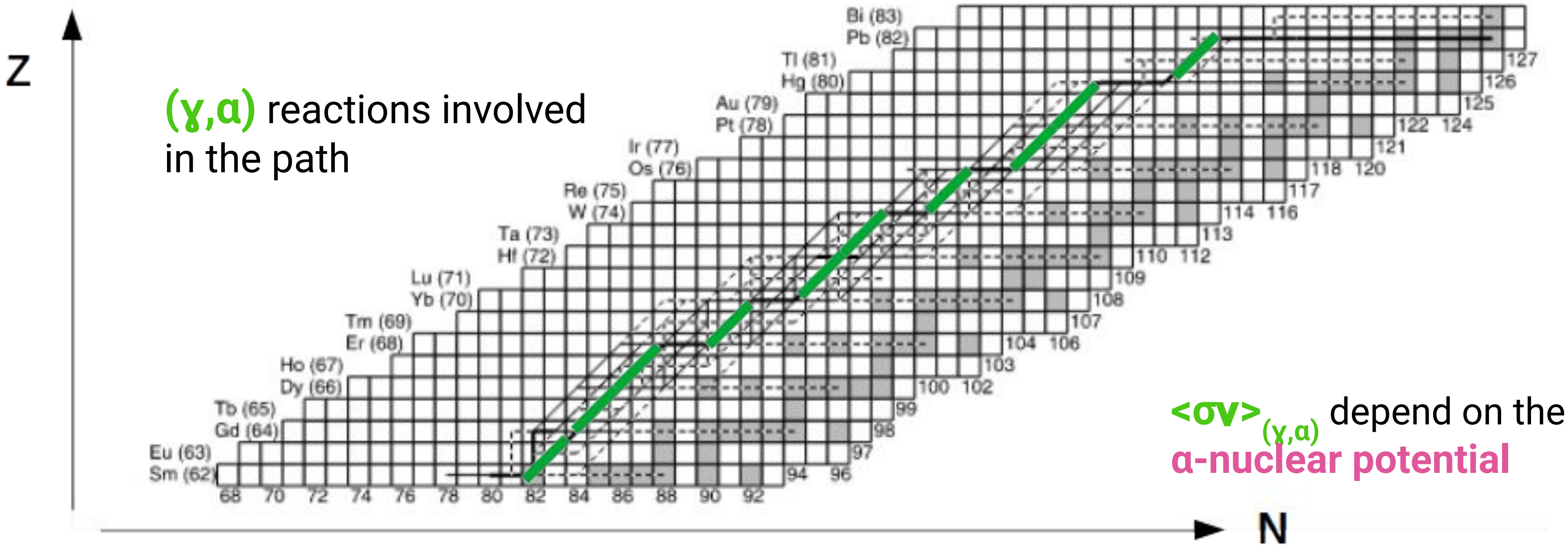
p-nuclei



Motivation

Sensitivity studies of gamma Process

W. J. Rapp et al., Astrophys. J 653, 474 (2006)

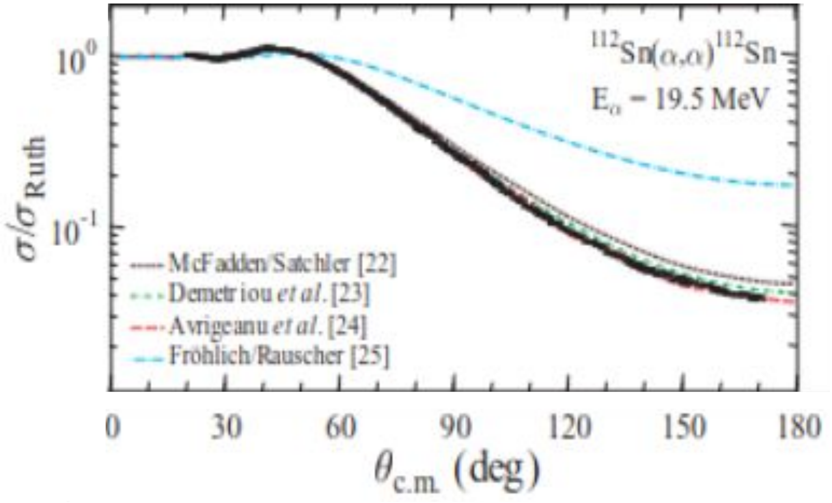


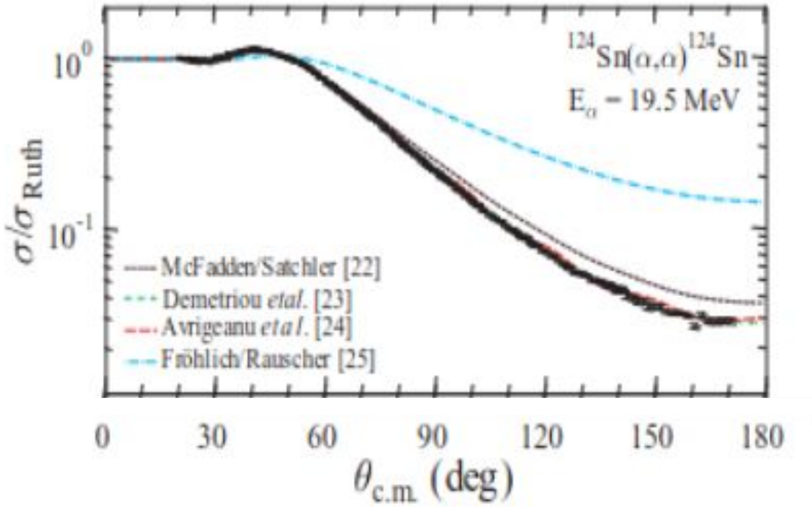
(ɣ,α) reactions involved in the path

$\langle \sigma v \rangle_{(\gamma,\alpha)}$ depend on the **α-nuclear potential**

Motivation

α-nuclear potentials: elastic scattering



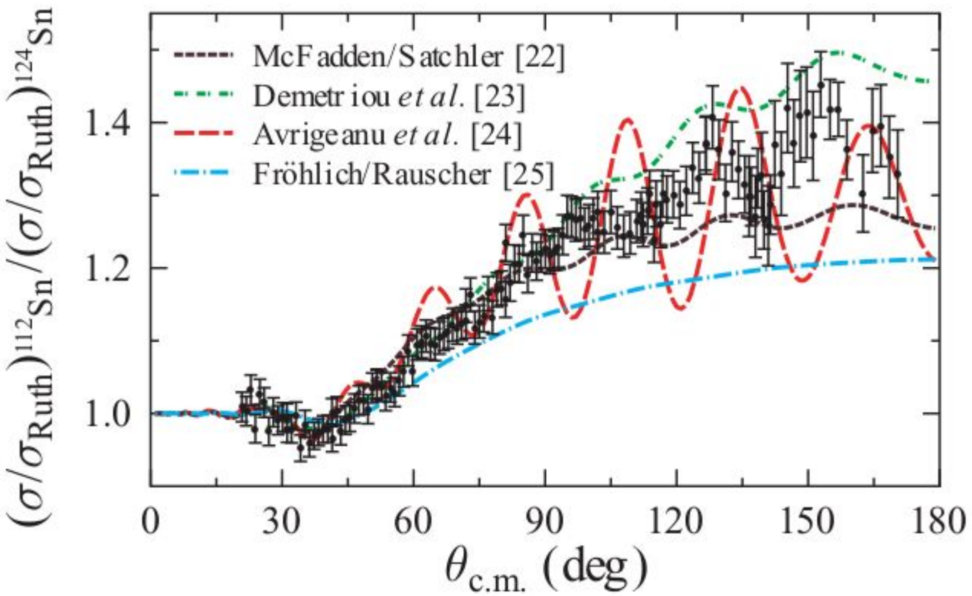


D. Galaviz et al, PRC71, 0650802 (2005)

Motivation

α-nuclear potentials: elastic scattering

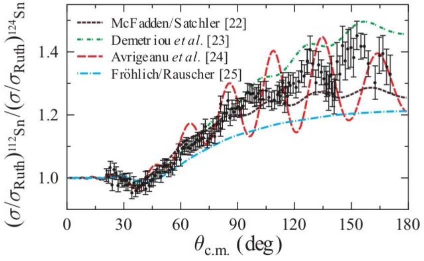
Mass dependence in stable Sn isotopes

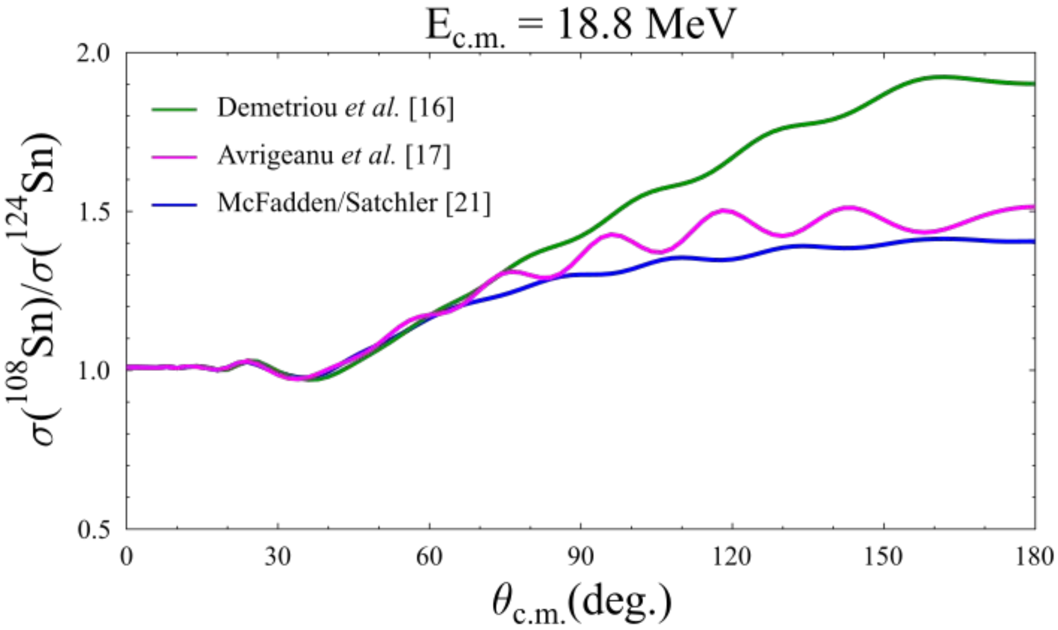


D. Galaviz et al,
PRC71, 0650802 (2005)

Motivation

α-nuclear potentials: elastic scattering

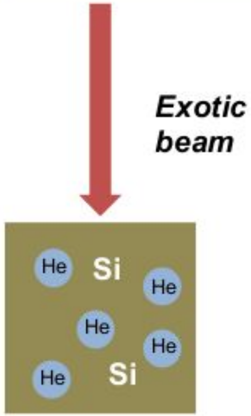


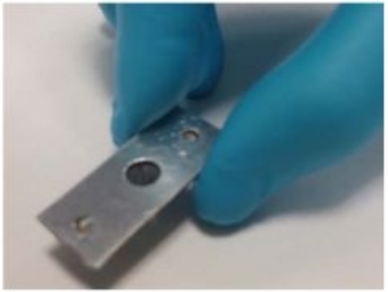


Si/He Targets

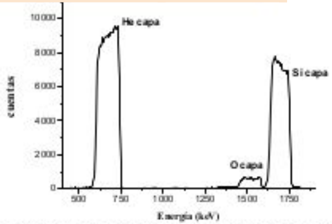
Magnetron Sputtering
Si/He thin films

Element	Si	He	C	N	O	H
atoms/cm^2 (x10^{15})	2820	1280	100	390	380	475

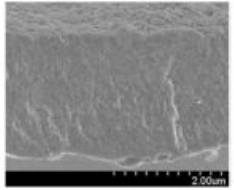




Self-supported Si:He target



RBS spectrum of Si:He target using 2,0 MeV protons and 165° scattering angle



SEM corss section of the Si:He target

V. Godinho *et al.*, ACS Omega 2016, 1 (6), 1229 (2016)

Si/He Targets

Magnetron Sputtering
Si/He thin films

Elastic Scattering in
inverse kinematics

Element	Si	He	C	N	O	H
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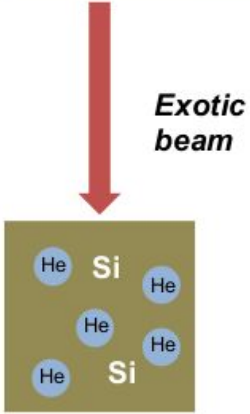

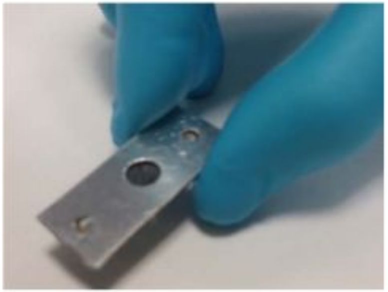

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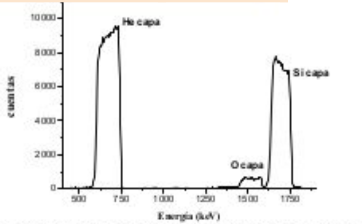

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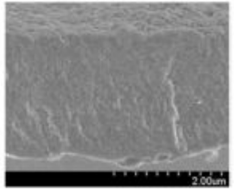

SEM corss section of the Si:He target

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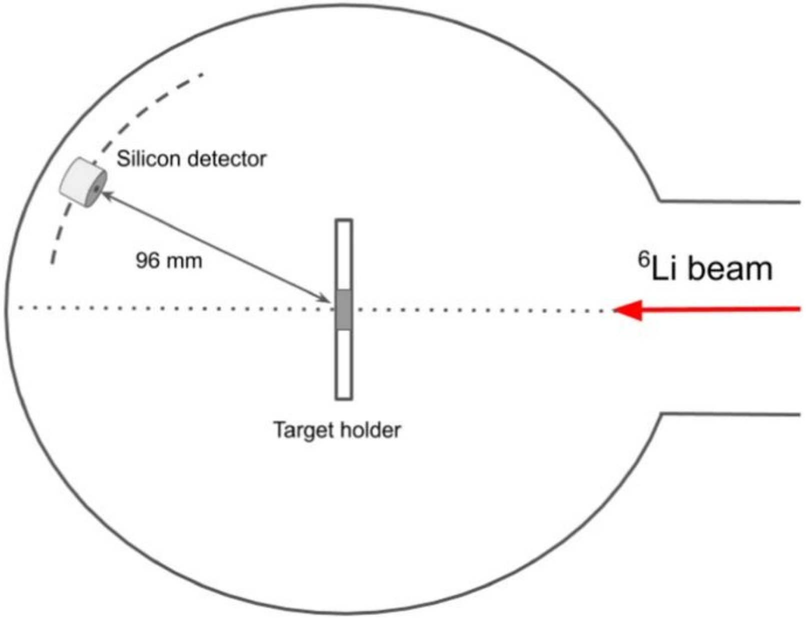
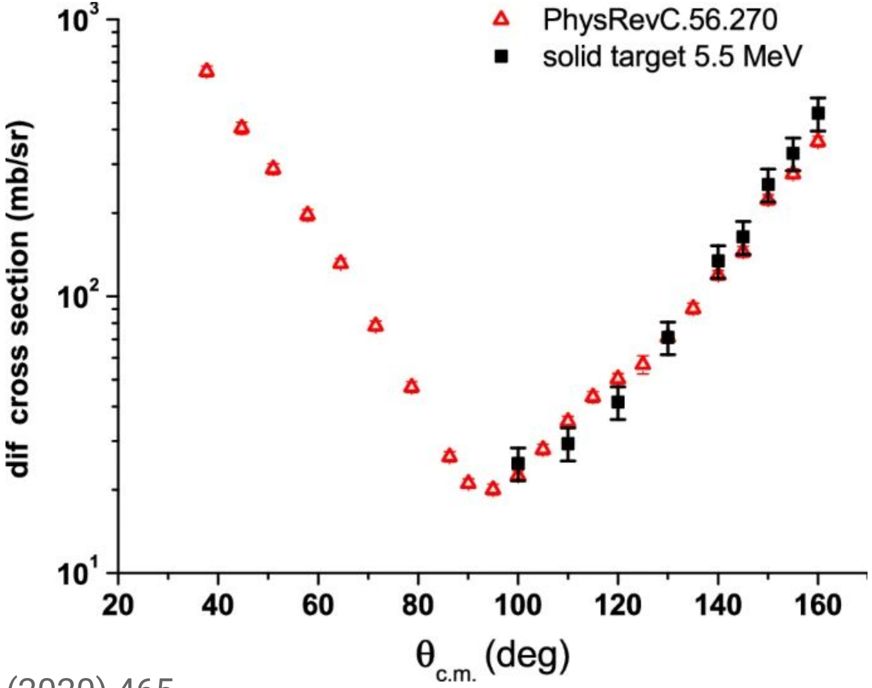
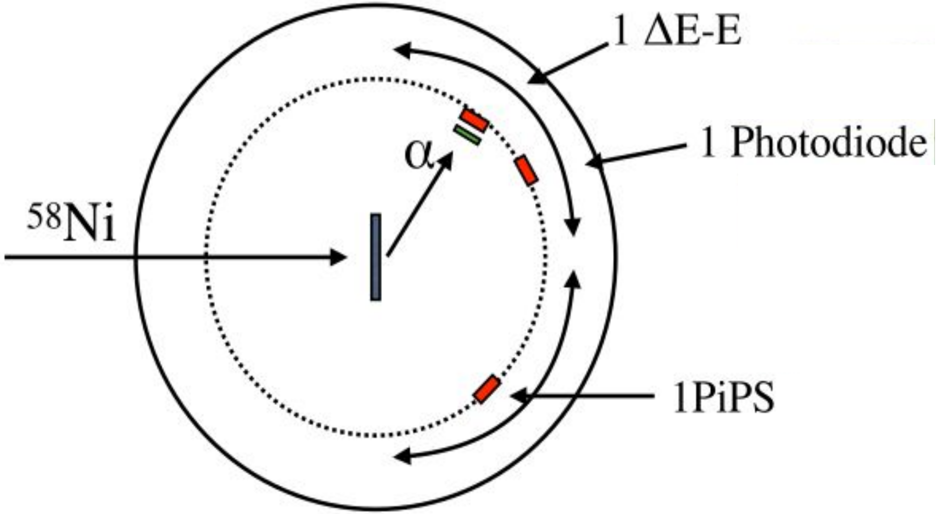
$^{4}He(^{6}Li,^{4}He)^{6}Li$ at CNA

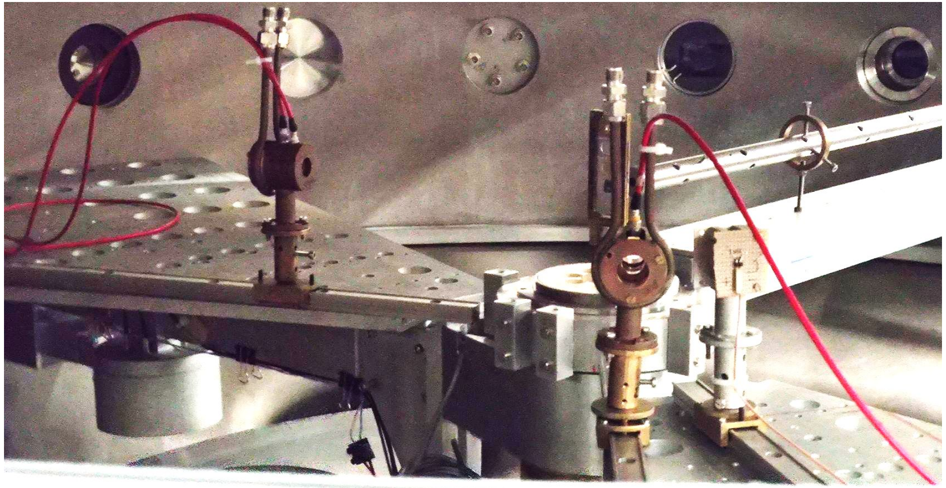




F. J. Ferrer *et. al.* EPJ+ 135, (2020) 465

$^{4}He(^{58}Ni,^{4}He)^{58}Ni$ at LNS

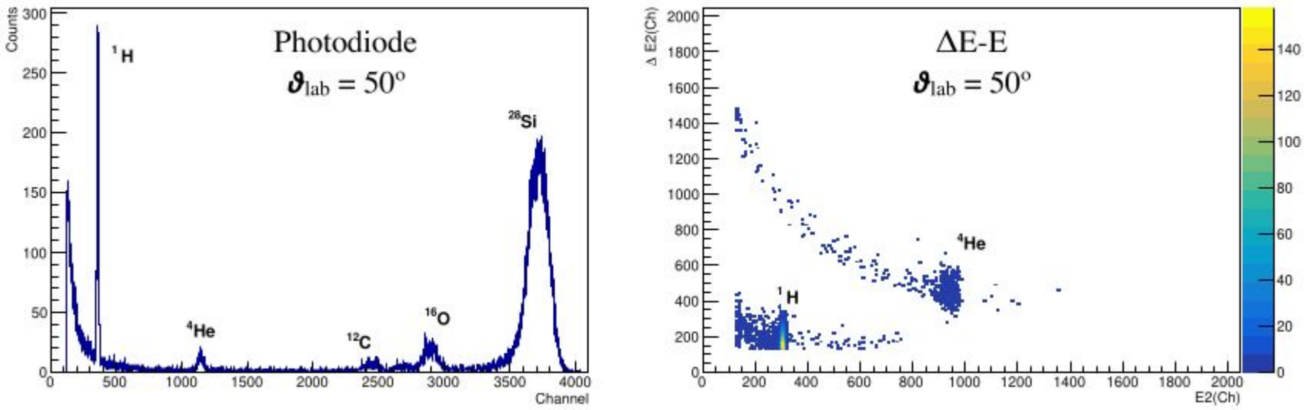




$^4He(^{58}Ni,^4He)^{58}Ni$ at LNS

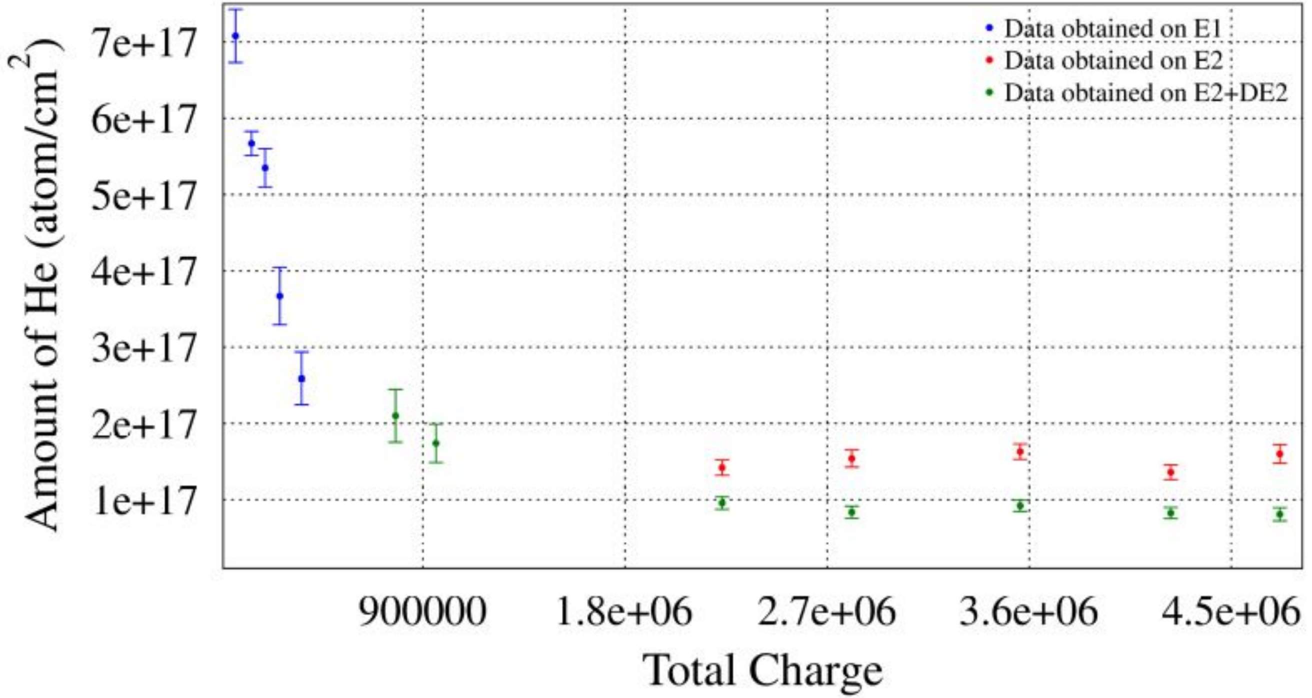
- Performed at INFN/LNS
- Developed in the framework of an stable beam experiment

$^4He(^{58}Ni,\alpha)^{58}Ni$ @ 150 MeV



$^{4}He(^{58}Ni,^{4}He)^{58}Ni$ at LNS

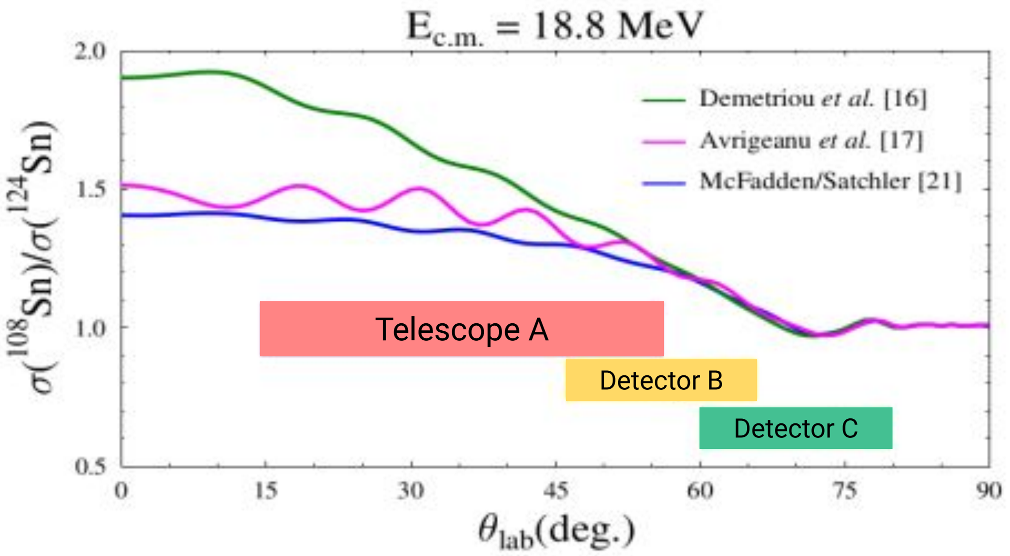
^{4}He Amount in target



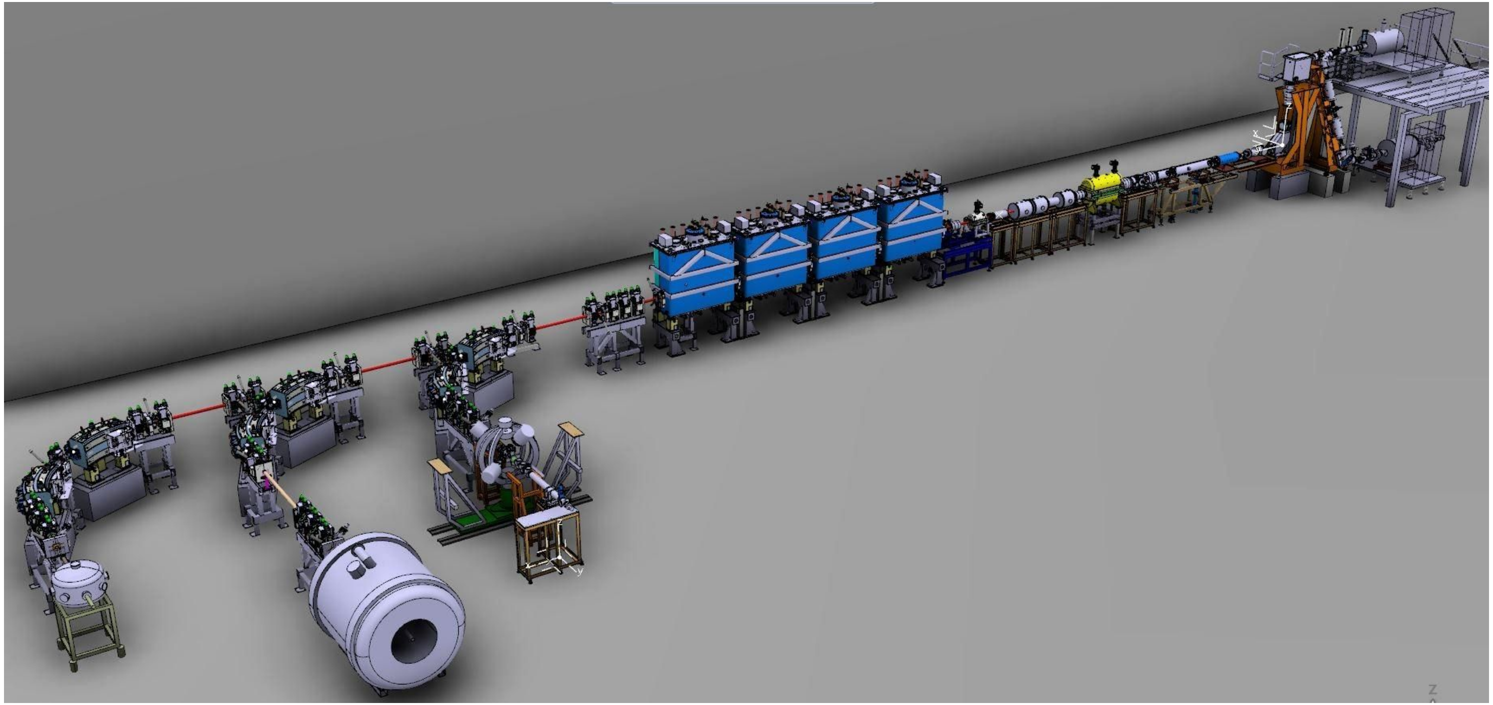
IS698 Proposal

Measurement of the $^{4}He(^{A}Sn, ^{4}He)^{A}Sn$ in inverse kinematics at the same $E_{c.m}$

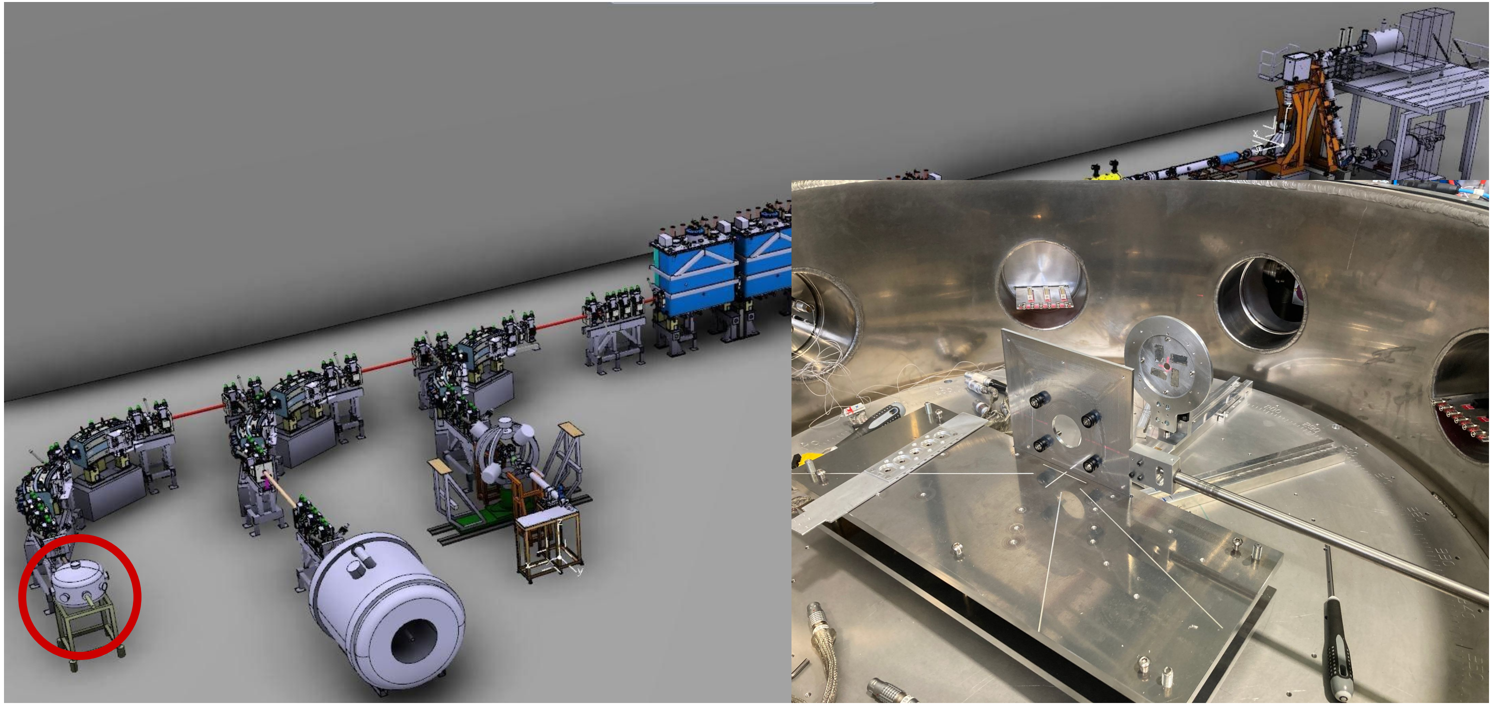
mass dependance of **α-nuclear potentials** along the Sn isotopic chain



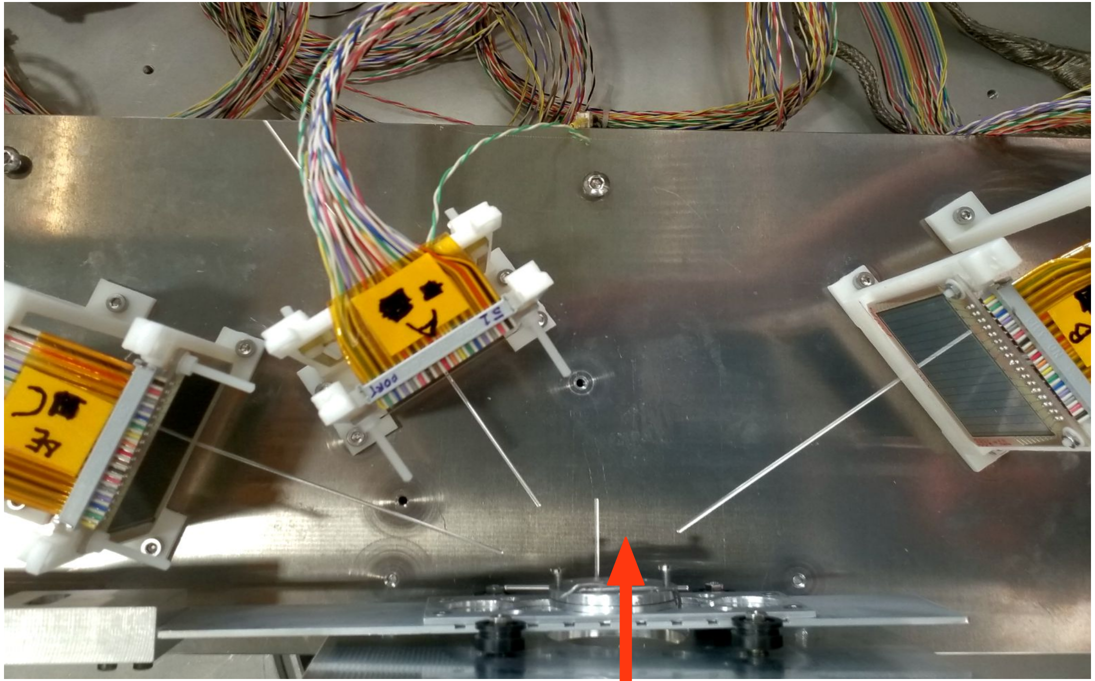
Setup



Setup



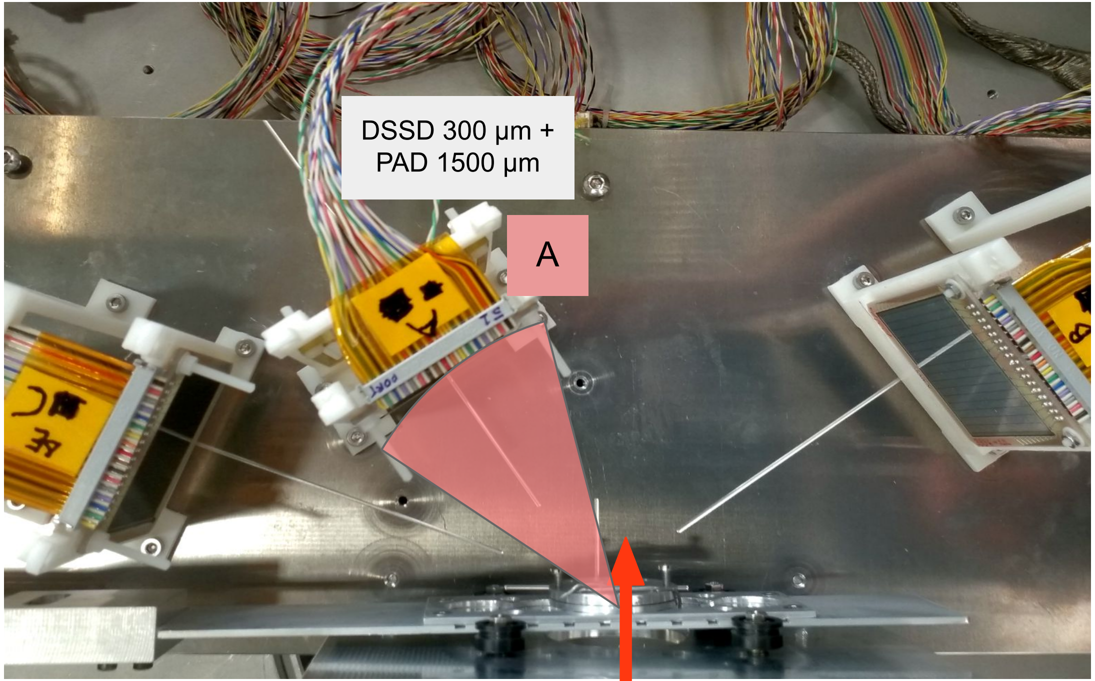
Setup



Beam

Setup

Telescope A
19º to 51º



Beam

Setup

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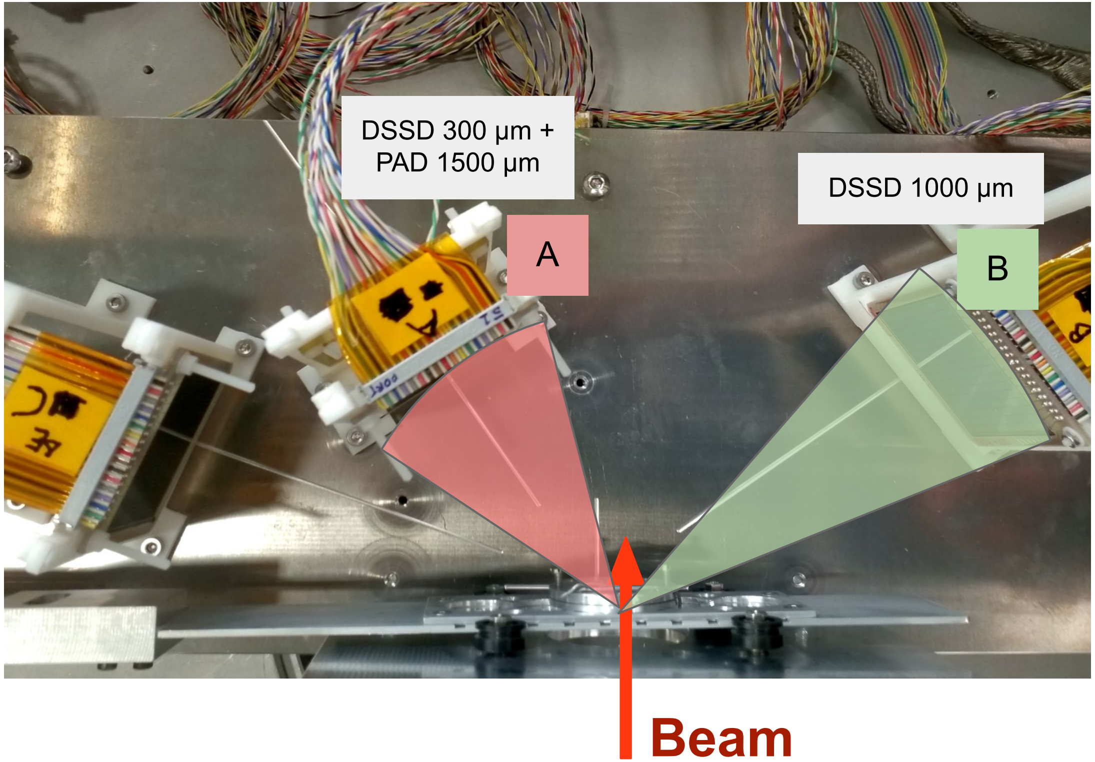
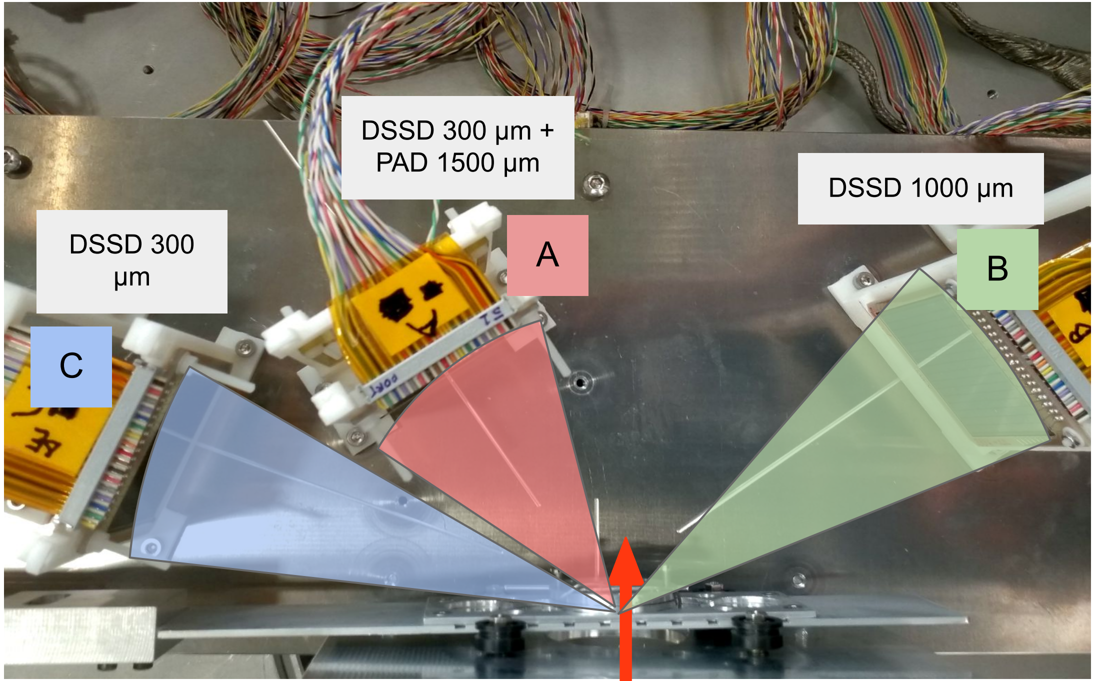


Detector B
44º to 66º

Setup

Telescope A
19º to 51º

Detector C
60º to 80º



Beam

Detector B
44º to 66º

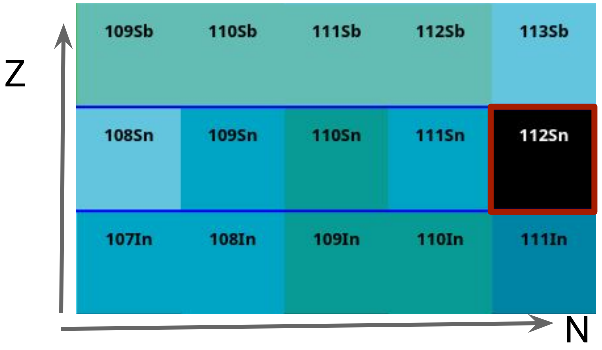
Setup

Pilot Beam E_{Beam} = 4.9 MeV/u

Cocktail of ^{12}C, ^{16}O, ^{20}Ne and ^{32}S

Sn Beam E_{Beam} = 4.9 MeV/u

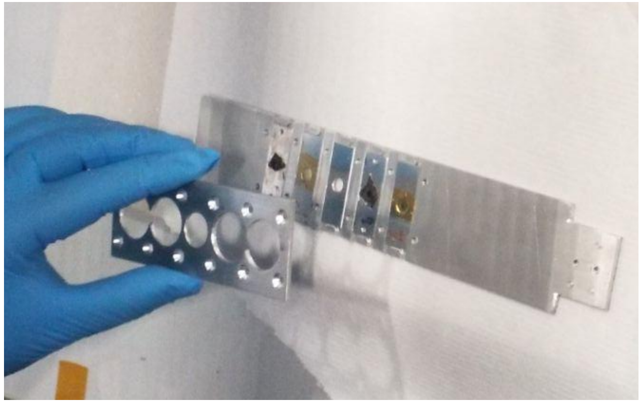
^{112}Sn with i ≈ 30 pA



Targets

^{197}Au with ≈ 300 µg/cm²

^{4}He with ≈ 2 x 10^{18} atoms/cm²



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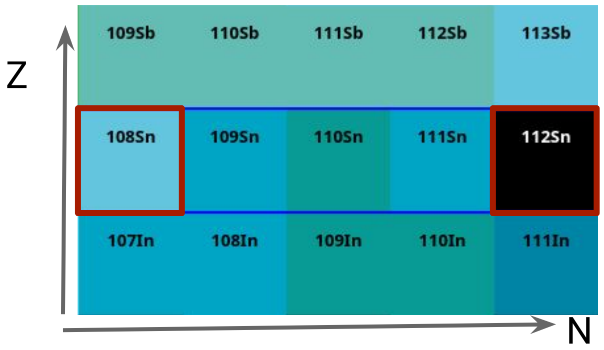
^{112}Sn with i ≈ 30 pA ^{108}Sn with i ≈ 50 pA



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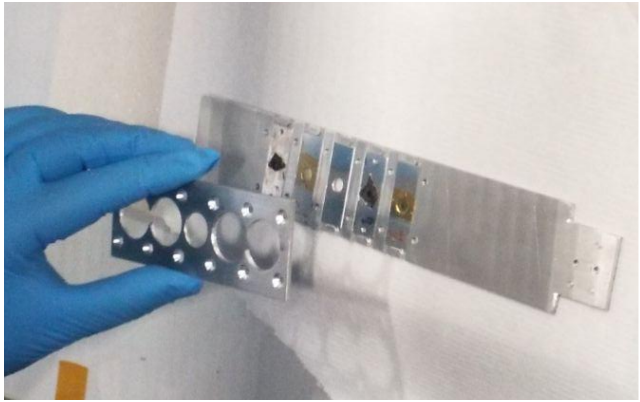

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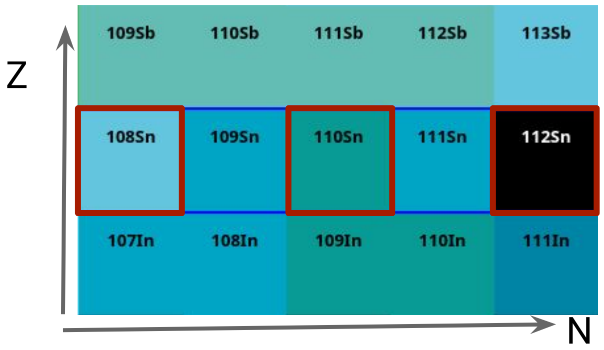
^{110}Sn with i ≈ 80 pA



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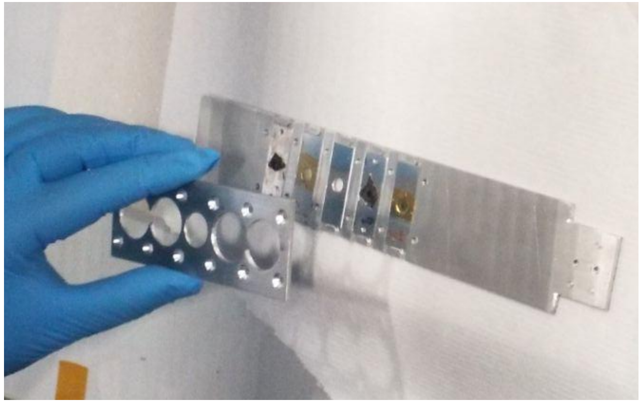

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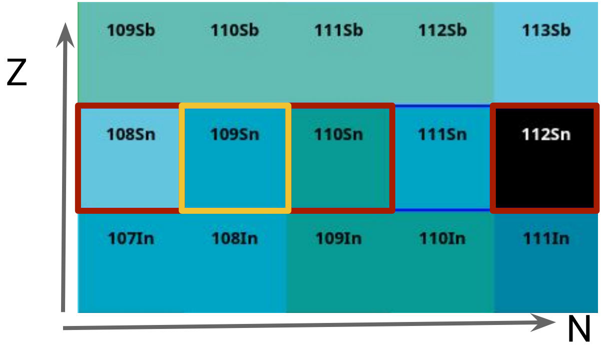
^{112}Sn with i ≈ 30 pA ^{108}Sn with i ≈ 50 pA

^{110}Sn with i ≈ 80 pA ^{109}Sn with i ≈ 90 pA



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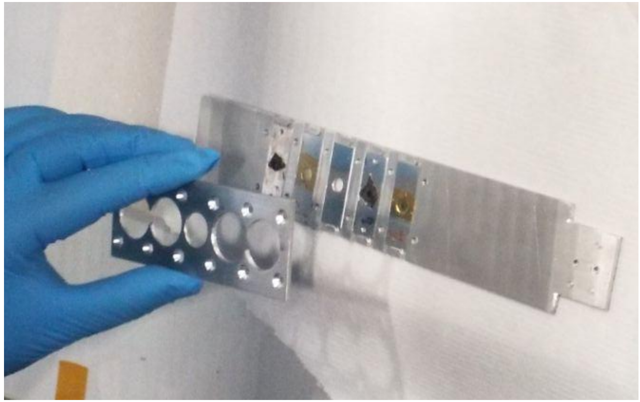


Setup

Pilot Beam E_{Beam} **= 4.9 MeV/u**

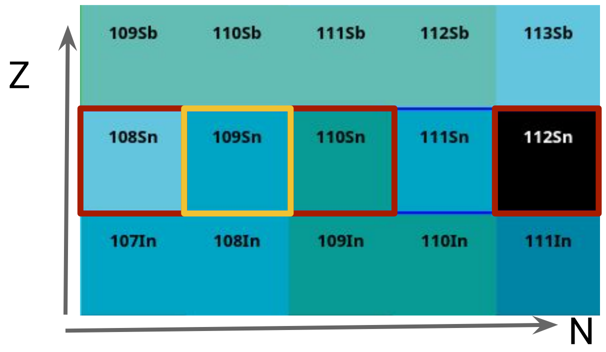
Cocktail of ^{12}C, ^{16}O, ^{20}Ne and ^{32}S

Sn Beam E_{Bea} ... eV/u

^{112}Sn with i ... n with i ≈ 50 pA

^{110}Sn with i ≈ ... pA ... ^{9}Sn with i ≈ 90 pA

23 Shifts



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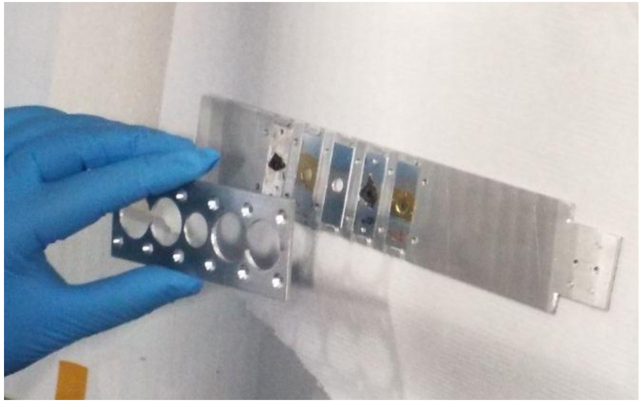
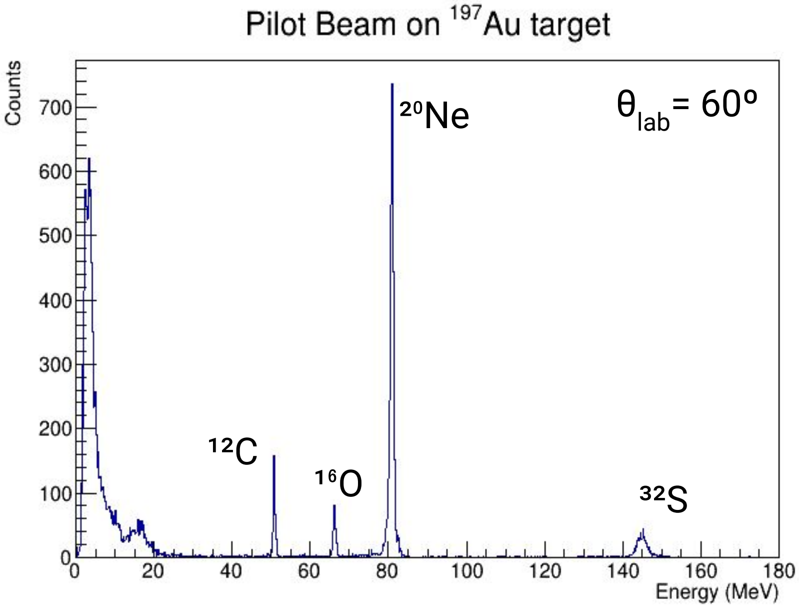
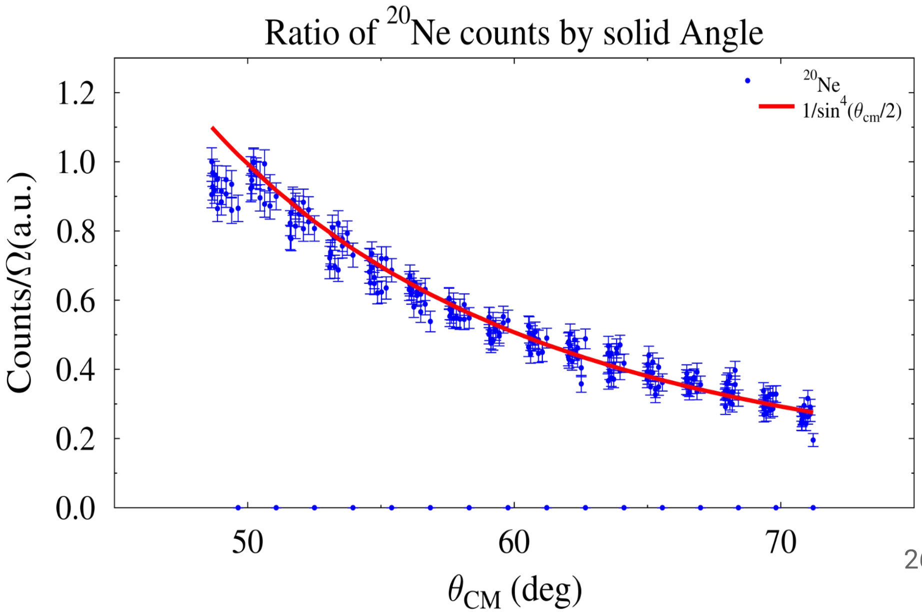


Preliminary Results

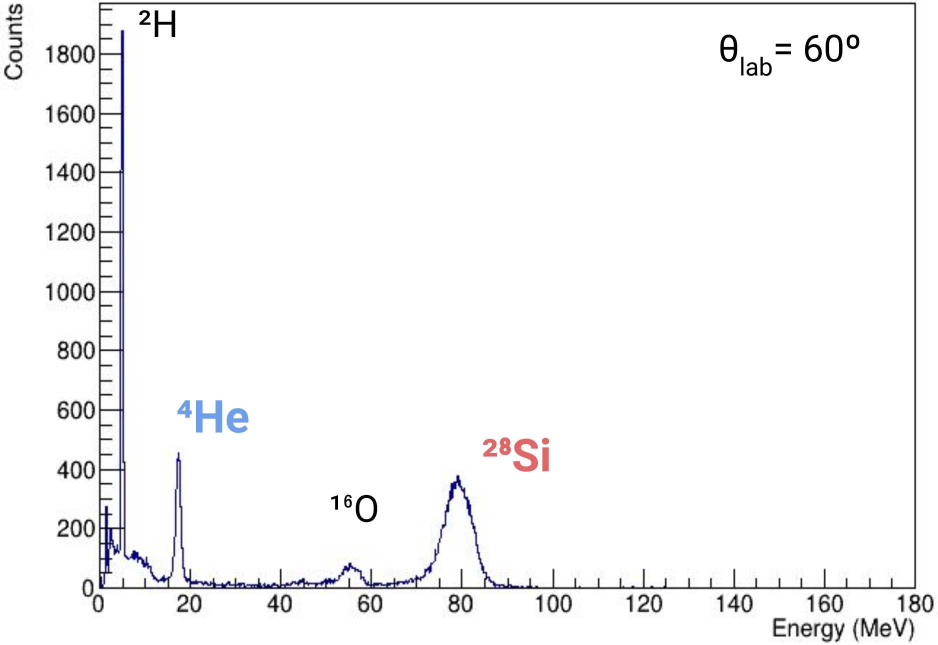
Experimental Data



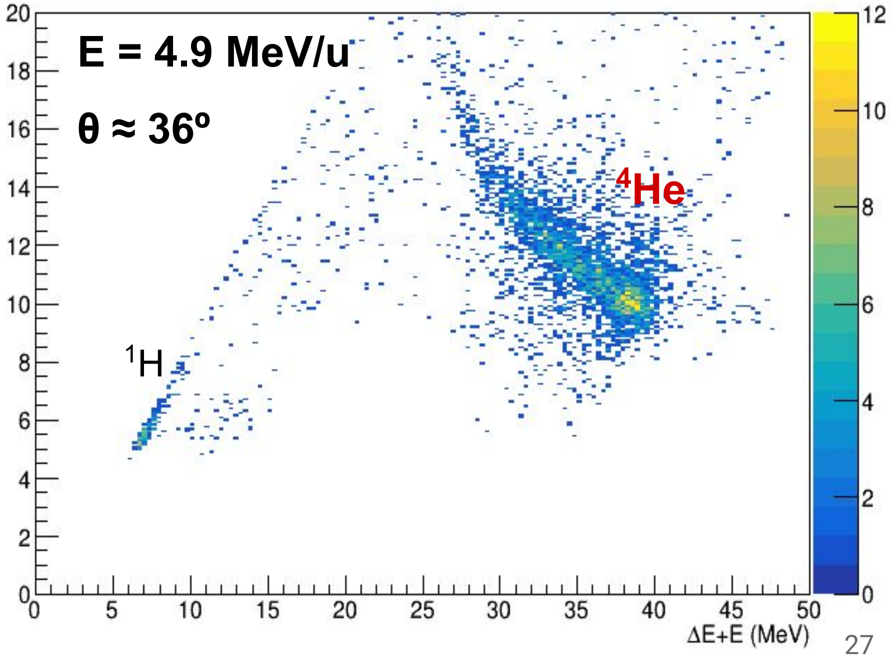


Preliminary Results

^{112}Sn beam scattering on **Si/He-target**



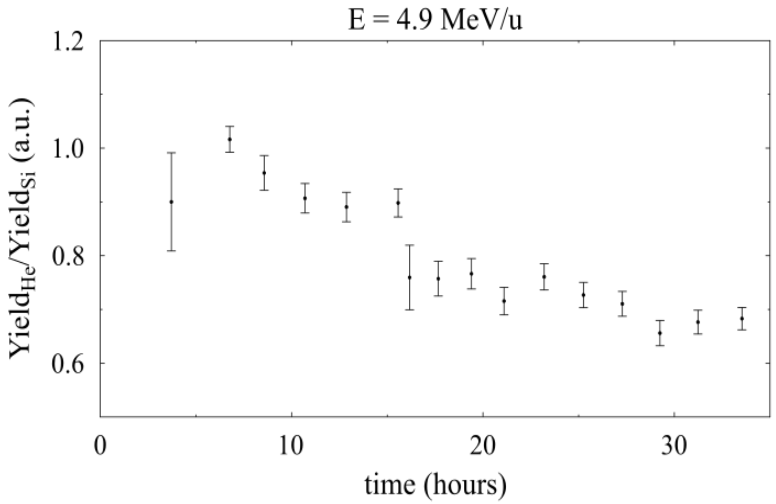
^{08}Sn beam scattering on **Si/He-target**



Preliminary Results

Amount of ^4He over time

^4He amount <u>decreases</u>



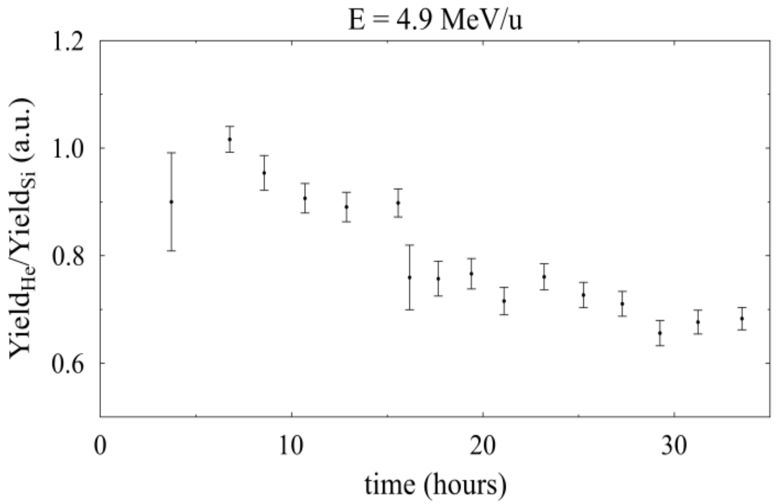
Preliminary Results

Amount of ^{4}He over time

^{4}He amount decreases

Need to account the different amount of ^{4}He on each run

★ **Normalize the integral of ^{4}He to the ratio He/Si at 60º**



Preliminary Results

Amount of ^{4}He over time

^{4}He amount decreases

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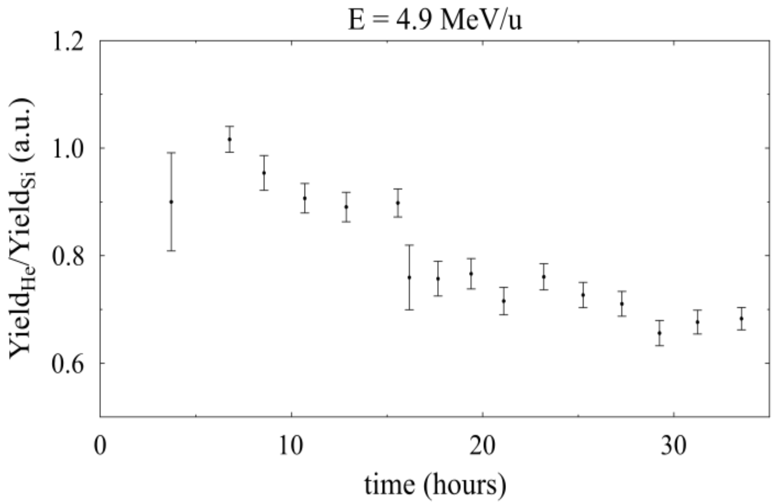
★ Normalize the integral of ^{4}He to the ratio He/Si at 60º

$$\alpha_i = \frac{N^i_{He}(60^\circ)}{N^i_{Si}(60^\circ)} \frac{N^0_{Si}(60^\circ)}{N^0_{He}(60^\circ)}$$



Preliminary Results

$^{4}He(^{112}Sn,^{112}Sn)^{4}He$ @ 18.9 MeV (CM)

$$\frac{d\sigma_{He}}{d\Omega}(\theta) = \sum_i \left(\frac{N^i_{He}(\theta)\alpha_i}{N^i_{Si}(60^\circ)} \right) \left(\frac{d\sigma_{Si}}{d\Omega}(60^\circ) \right)_{Ruth}$$

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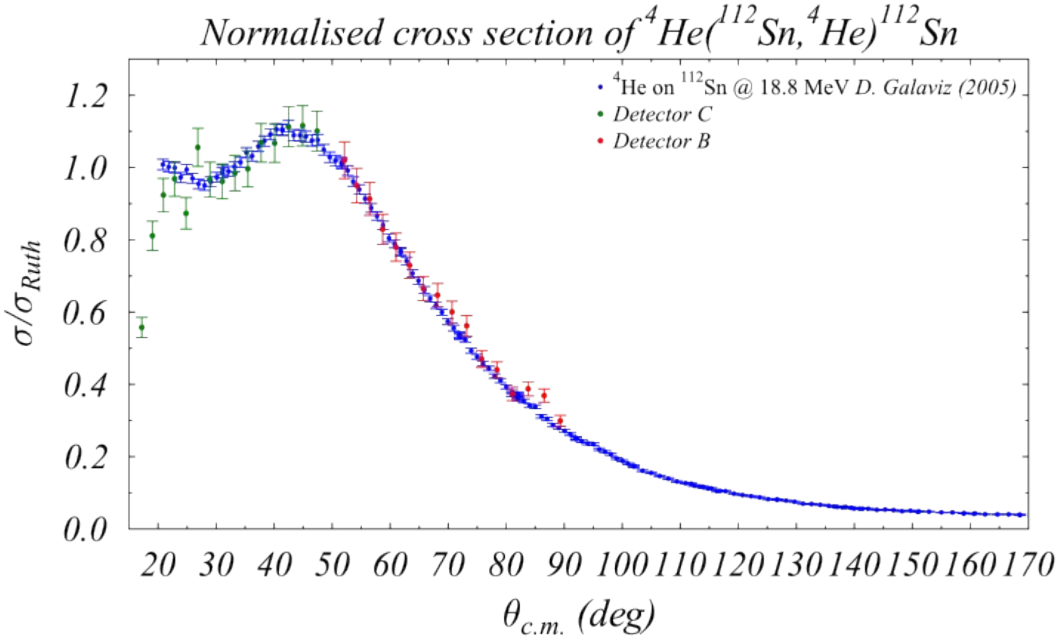
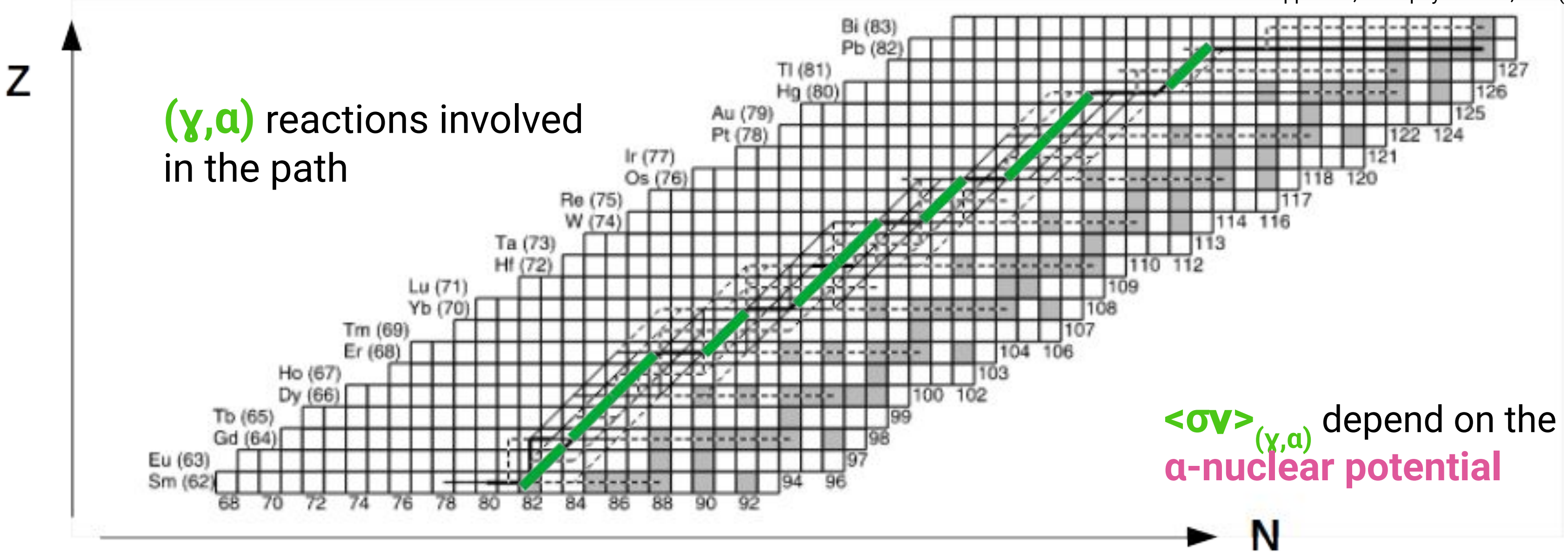


Outlook for future experiments

W. J. Rapp et al., Astrophys. J 653, 474 (2006)



(ɣ,α) reactions involved in the path

$<\sigma v>_{(\gamma,\alpha)}$ depend on the α-nuclear potential

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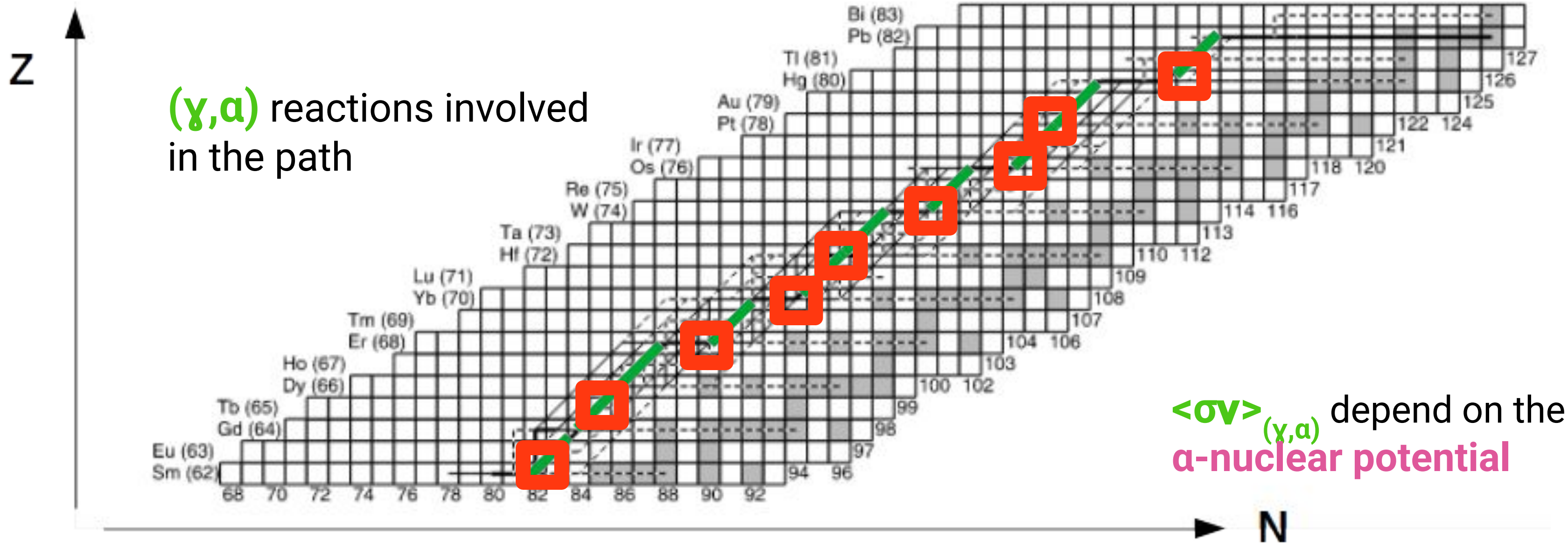

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$\langle\sigma v\rangle_{(\gamma,\alpha)}$ depend on the α-nuclear potential

Acknowledgements

RENASCER Project: CERN/FIS-PAR/0009/2021
SCORE Project: EXPL/FIS-NUC/0364/2021

Preliminary Results (backup)