Beyond Stability:
α-scattering with exotic nuclei for α-nuclear potential constrainment

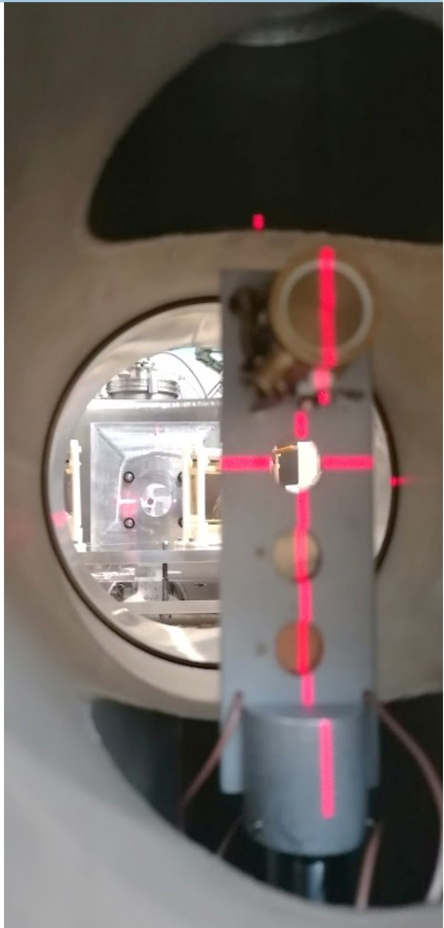
Nuclear Physics and Astrophysics XII

Thursday, 10th September 2026

Francisco G. Barba

Outline

- Why study α-nuclear potentials?
- Challenges of the measurement
- Setup and benchmark of technique
- Status of $^{4}He(^{A}Sn,^{4}He)^{A}Sn$ analysis with exotic Sn

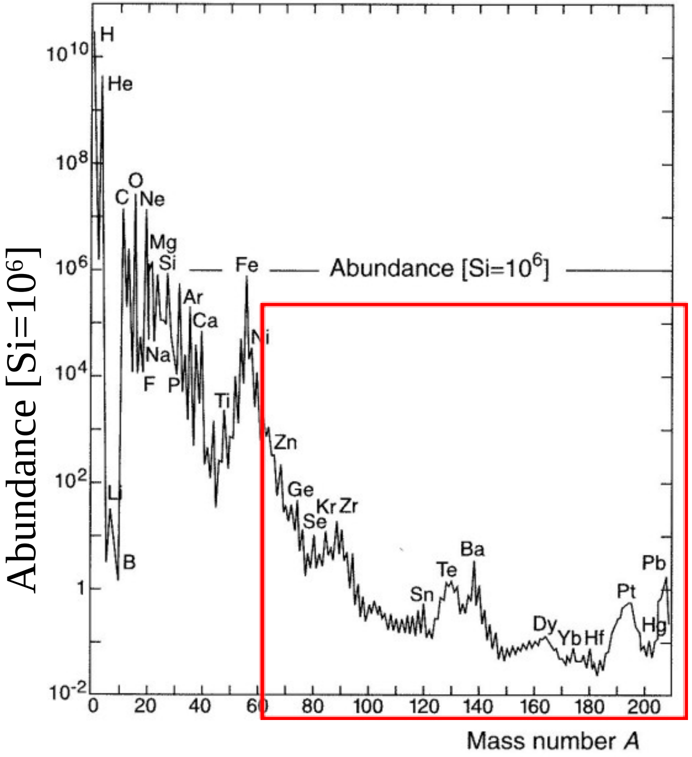


Motivation

Solar Abundance Distribution (SAD)

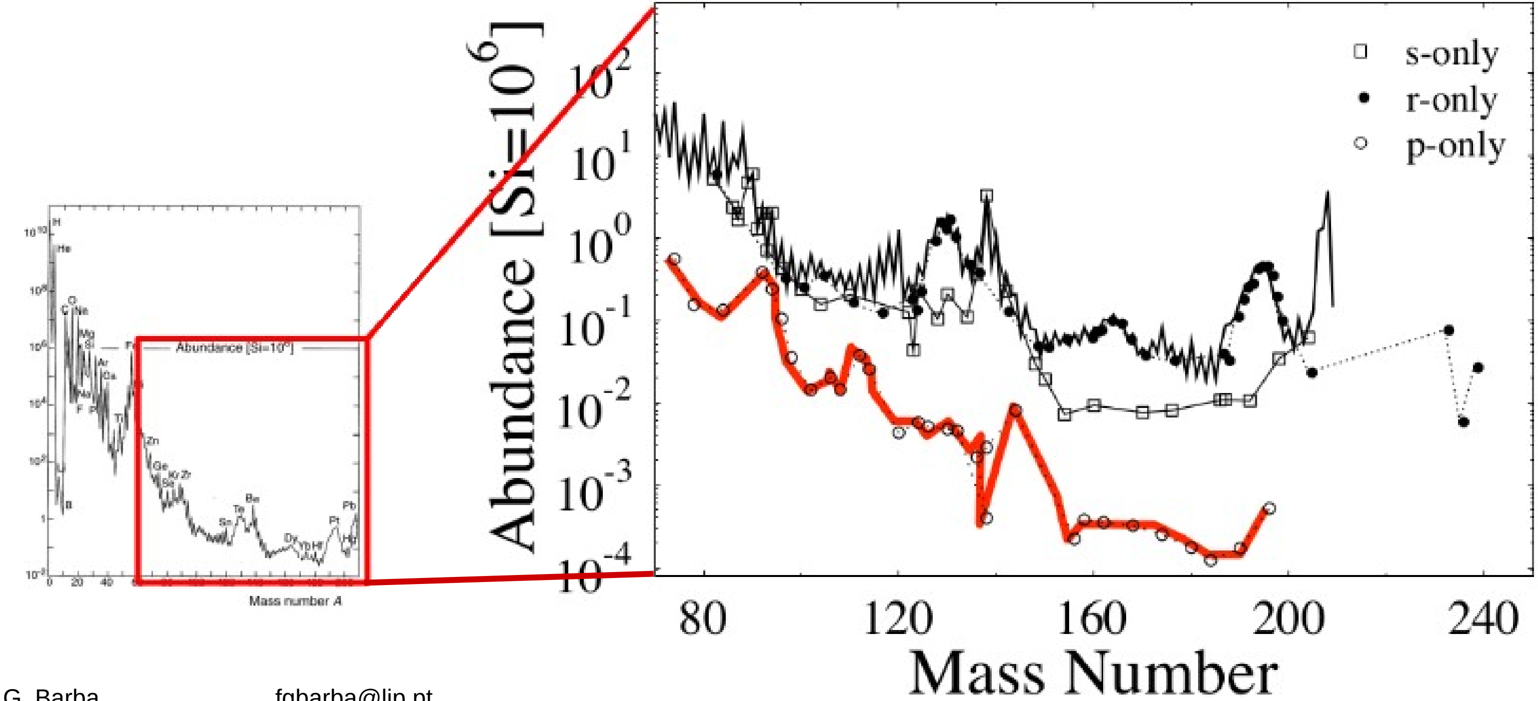
Bulk of elements:
- BBN
- Fusion phase

Heavy elements:
- **Neutron capture** processes



Motivation

p-nuclei



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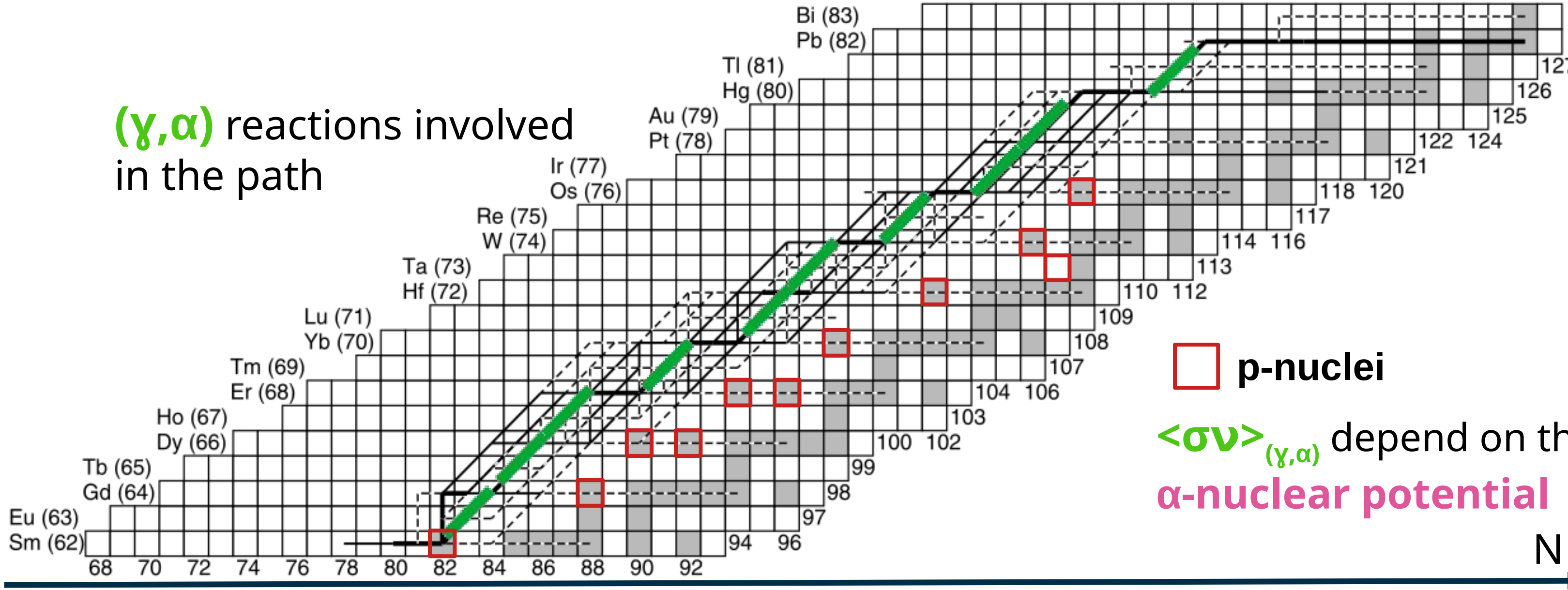
Motivation

Sensitivity studies of gamma Process

Z

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

(ɣ,α) reactions involved in the path



p-nuclei

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

N

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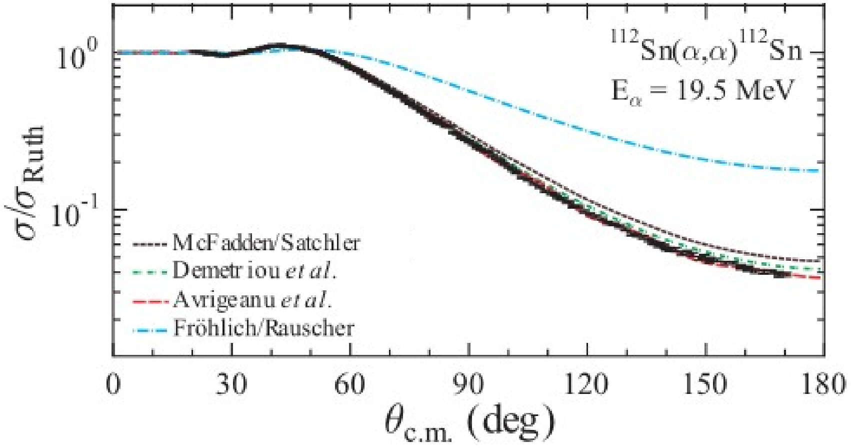
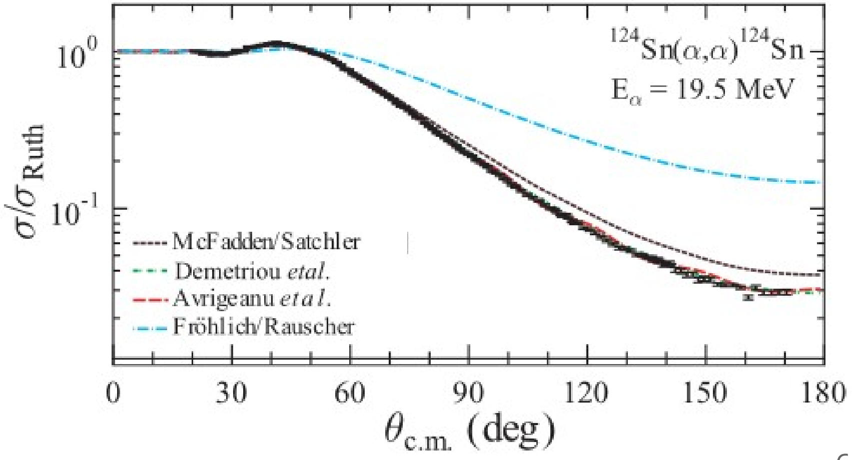
Motivation

α-nuclear potentials: elastic scattering





D. Galaviz, et al. Phys. Rev. C 71, 065802 (2005)

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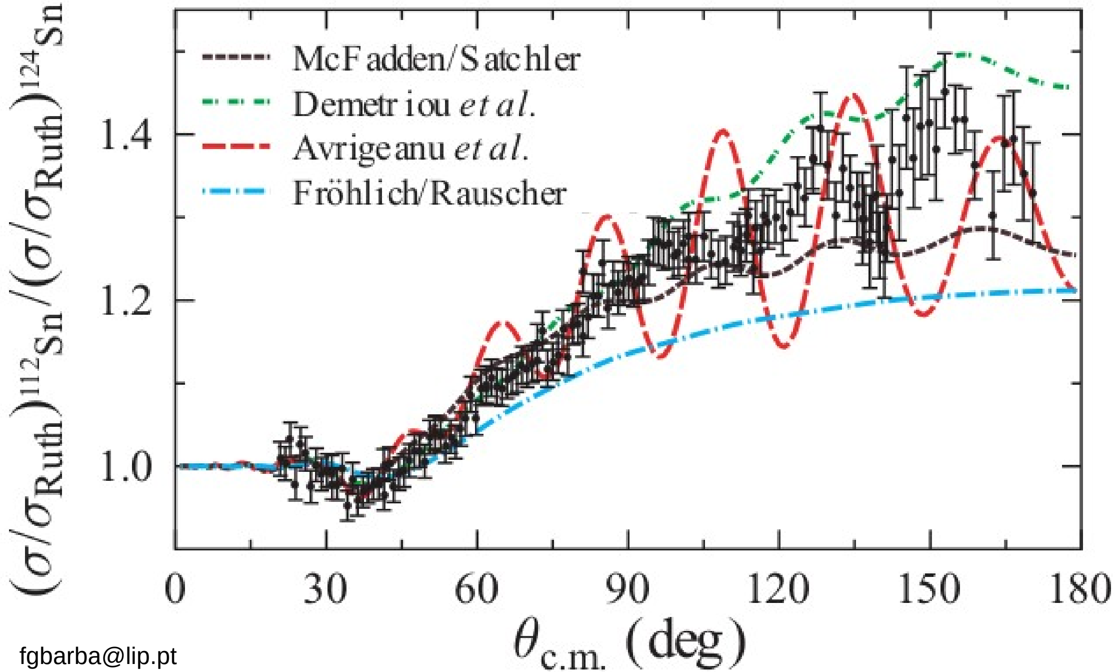
Motivation

α-nuclear potentials: elastic scattering

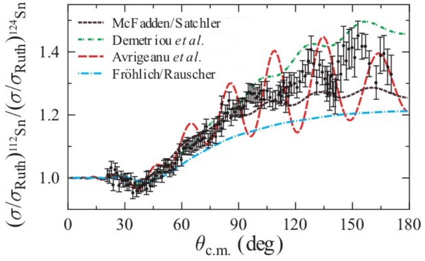
Mass dependence in stable Sn isotopes

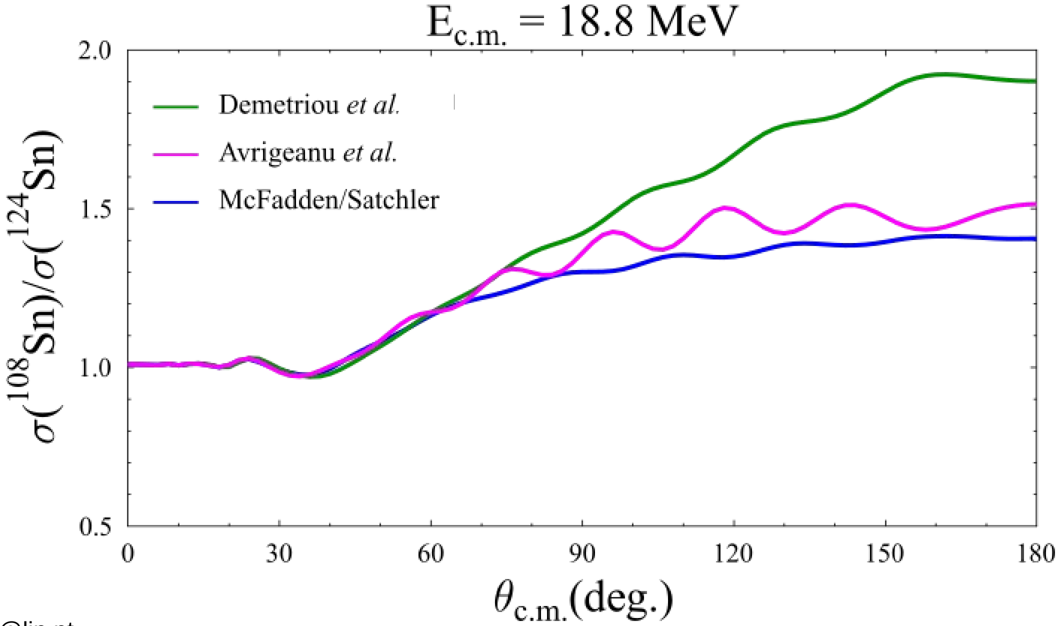


D. Galaviz et al,
PRC71, 0650802 (2005)

Motivation

α-nuclear potentials: elastic scattering





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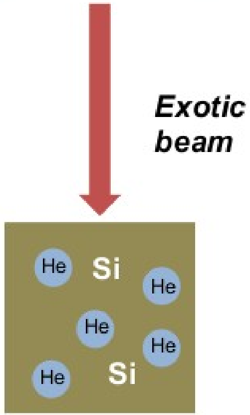
Si/He Targets

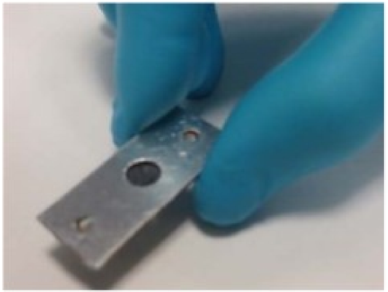
Contact person: F. J. Ferrer

Contact person: A. Fernández

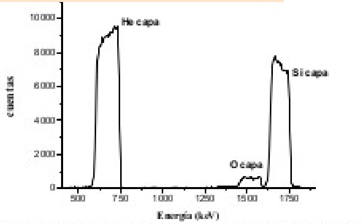
Thin films with High He content

Element	Si	He	C	N	O	H
atoms/cm² (x10¹⁵)	2820	1280	100	390	380	475

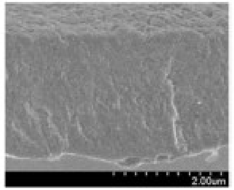




Self-supported Si:He target



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

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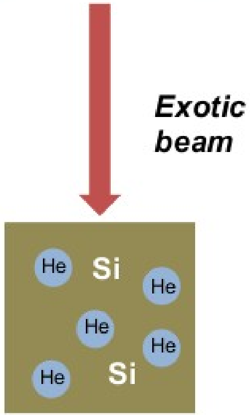

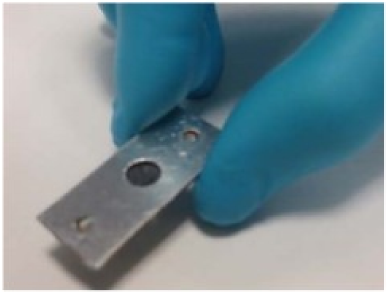

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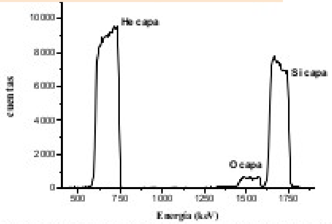

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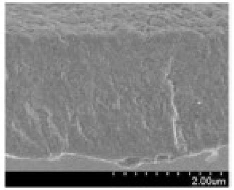

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Si/He Targets

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Thin films with High He content

Elastic Scattering in **inverse kinematics**

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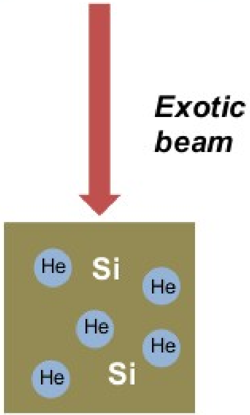
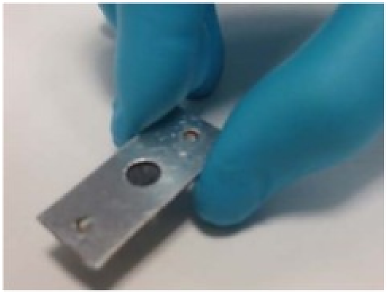
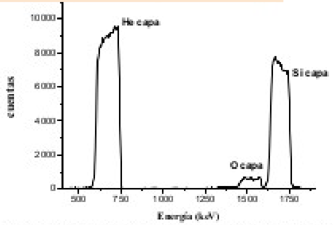
atoms/cm^2 ($\times10^{15}$)	2820	**1280**	100	390	380	475

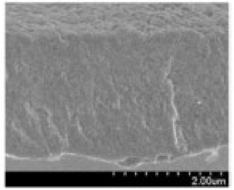




Self-supported Si:He target



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



SEM corss section of the Si:He target

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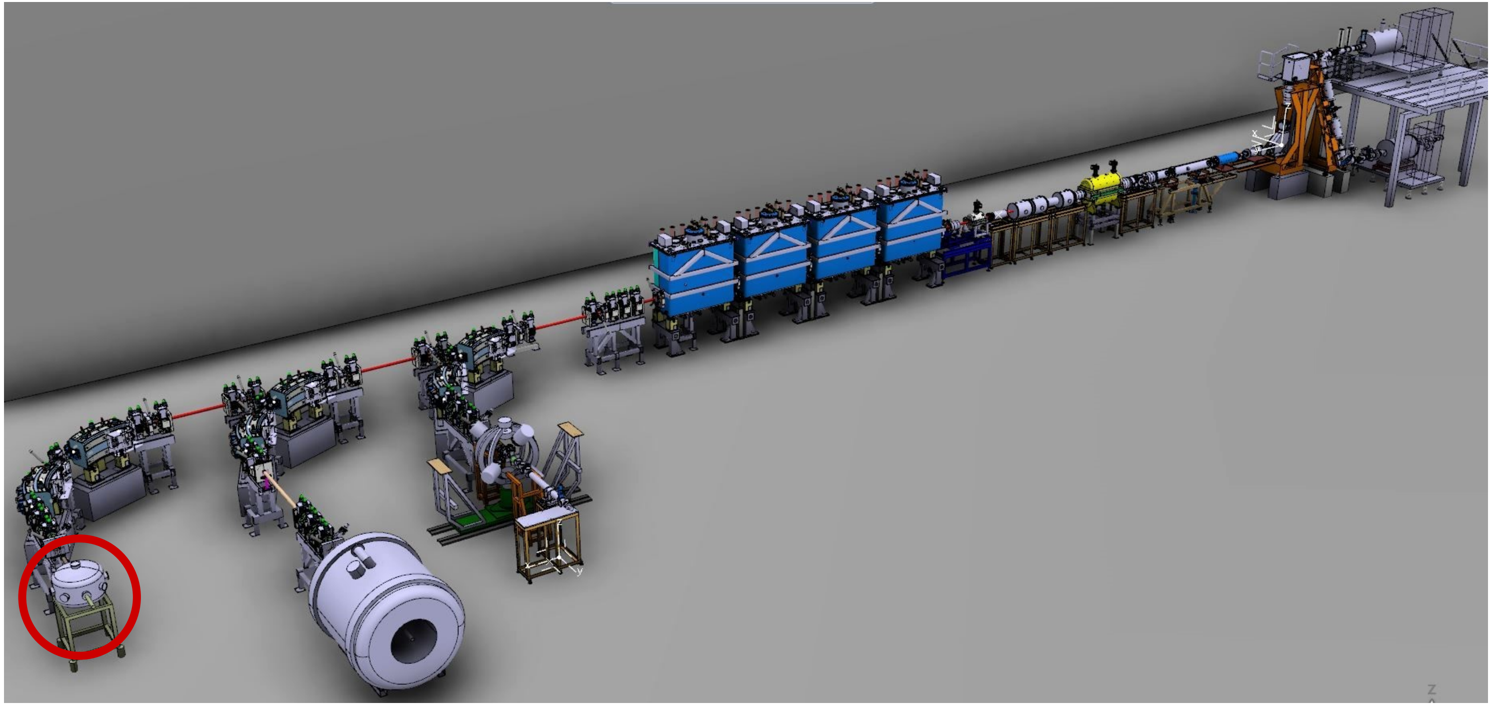
Setup



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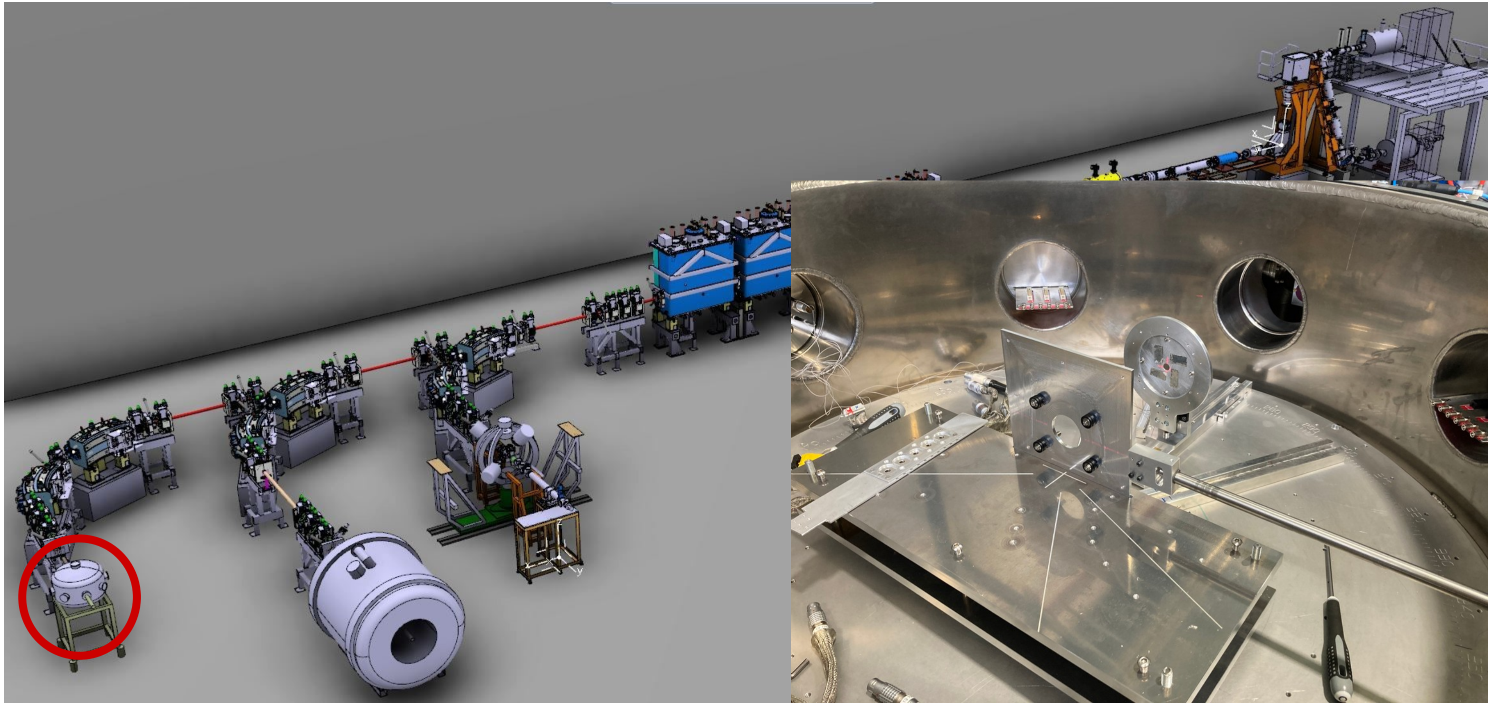
Setup



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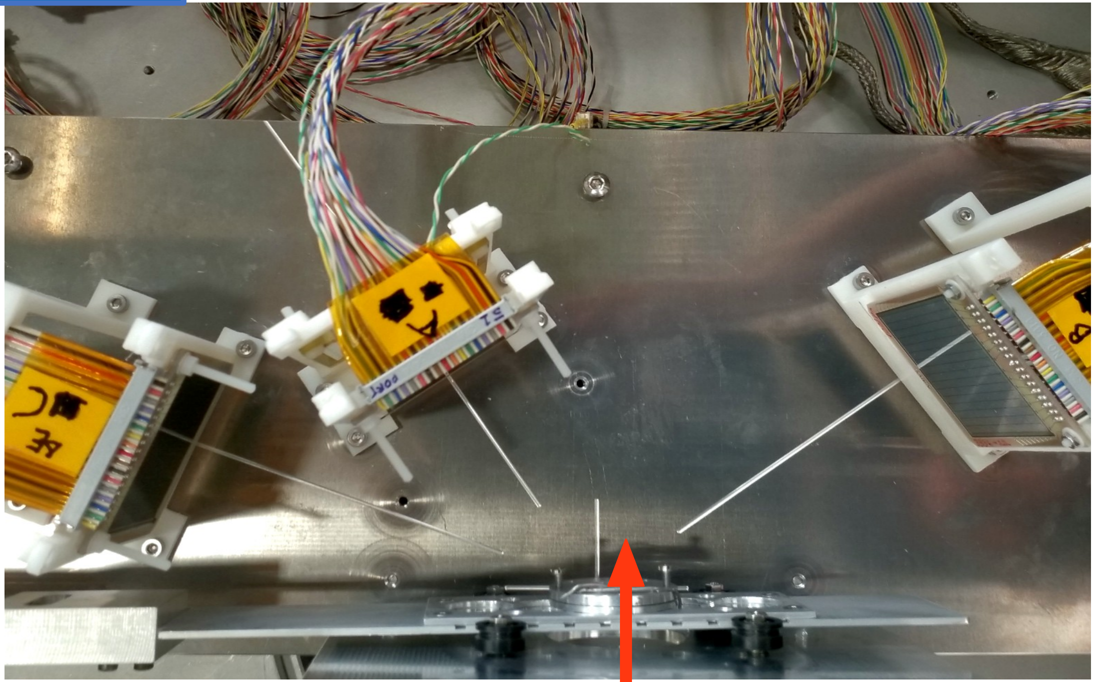
Setup



Beam

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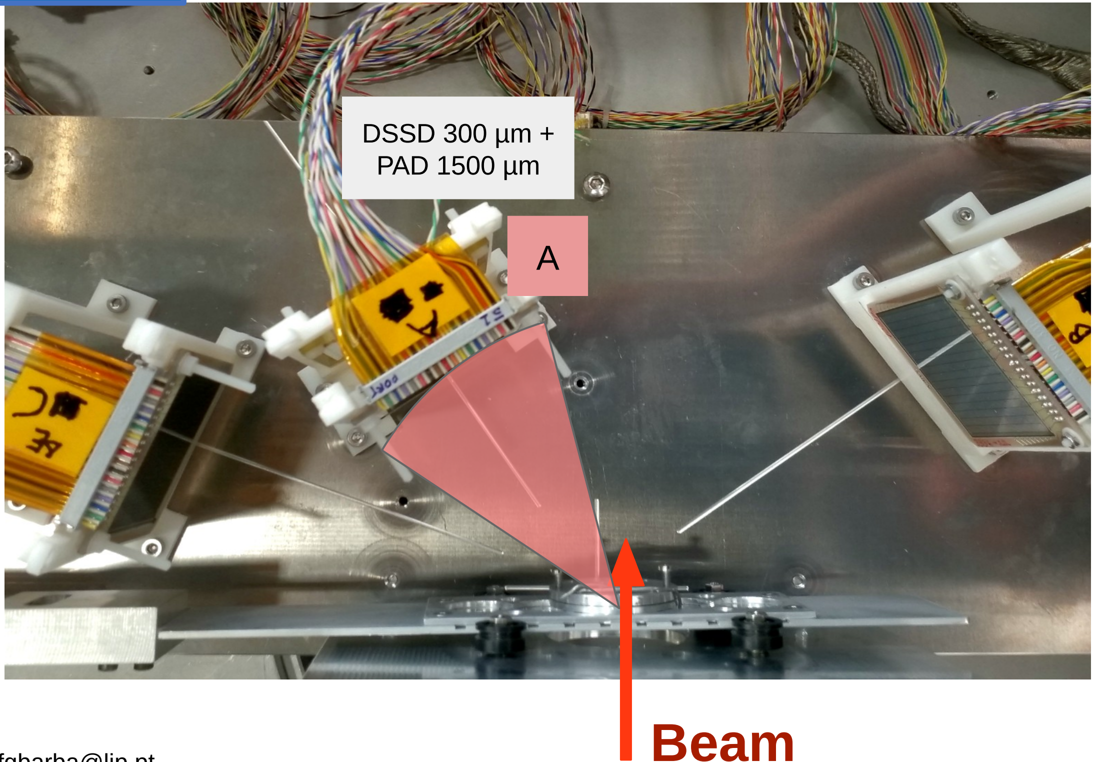
Setup

Telescope A
19º to 51º



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Setup

Telescope A
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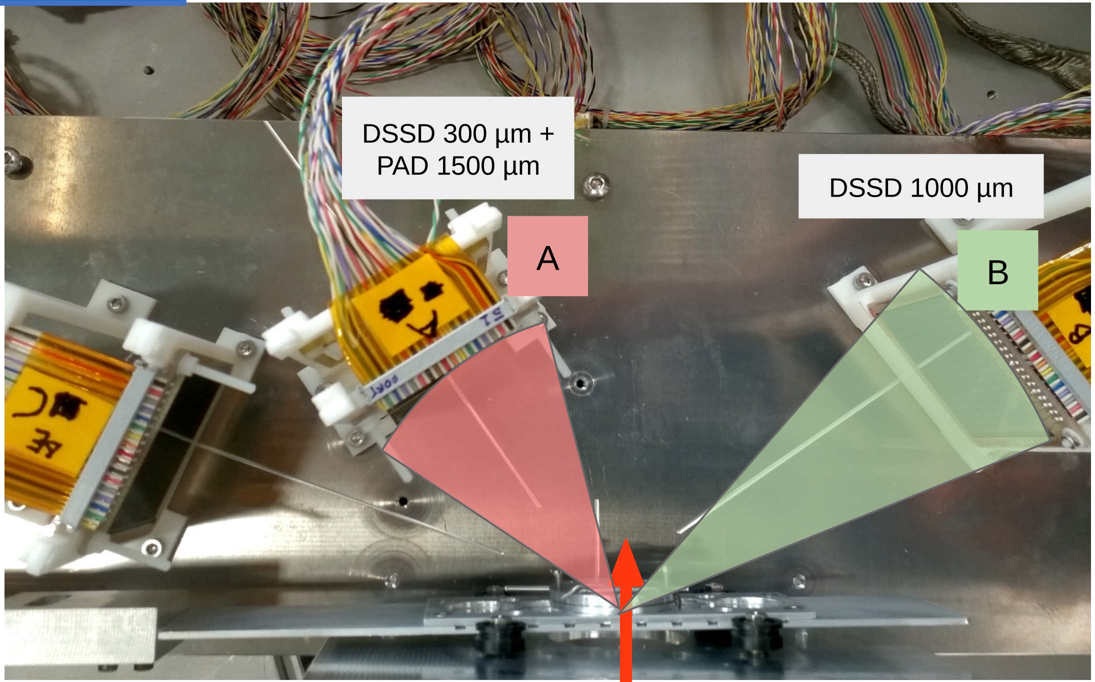


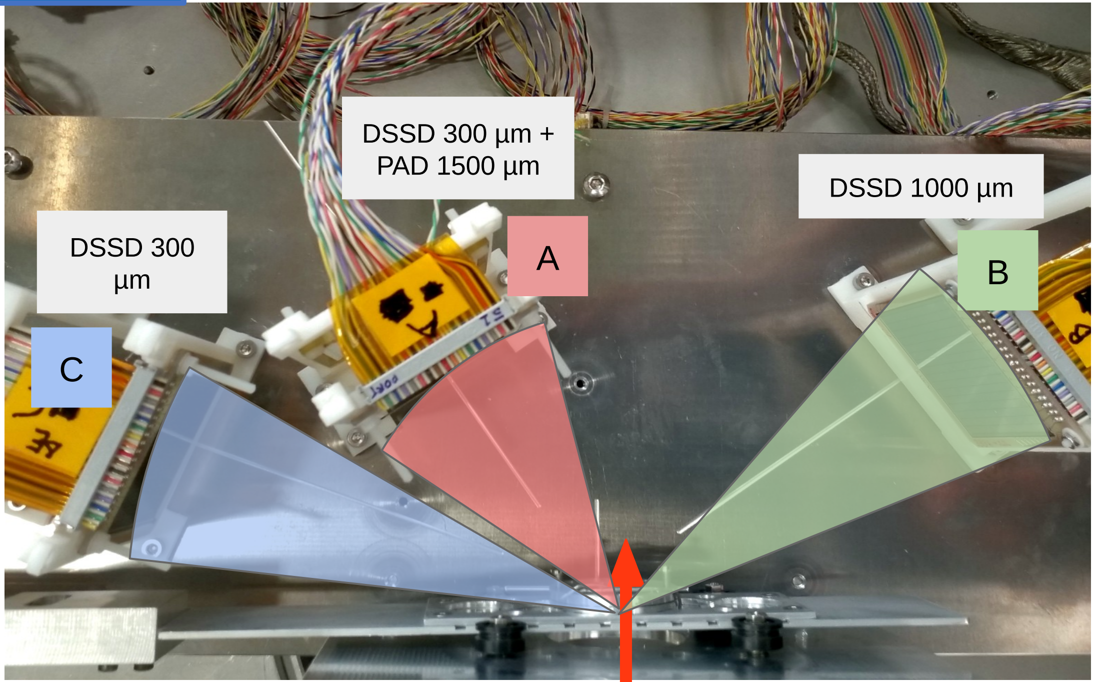
Detector B
46º to 65º

Beam

Setup

Telescope A
19º to 51º

Detector C
60º to 78º



Detector B
46º to 65º

Beam

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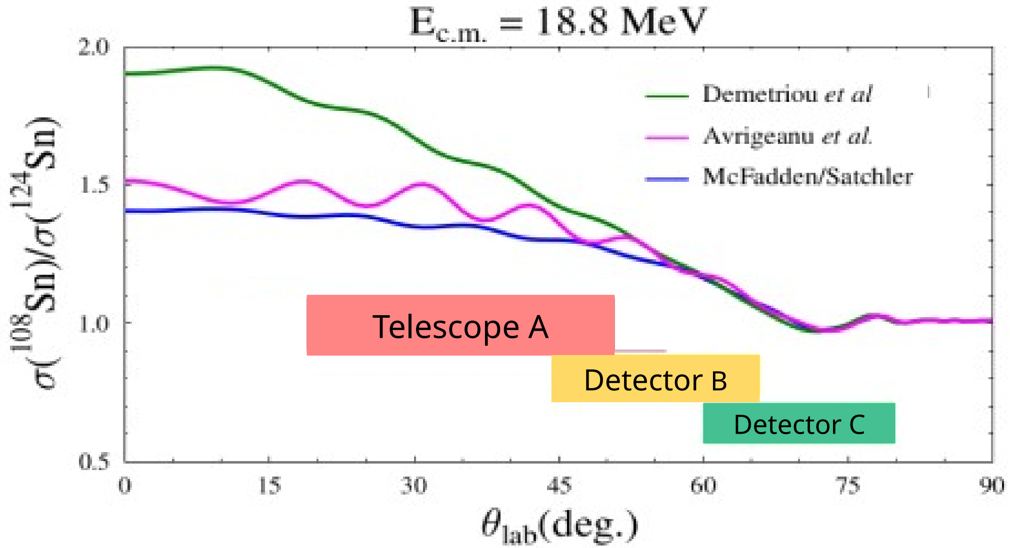
IS698 Experiment

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



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Beam and targets

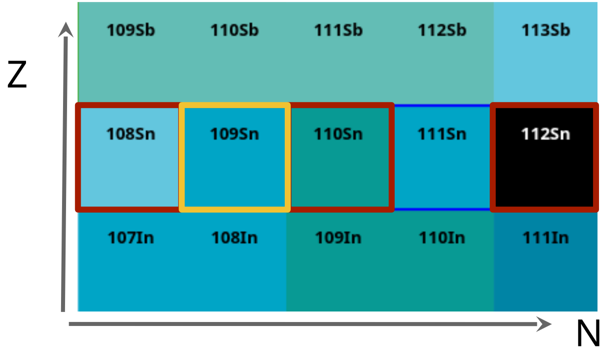
Pilot Beam E_{Beam}= 4.9 MeV/u

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

Sn Beam E_{Beam}= 4.9 MeV/u

^{112}Sn (I ≈ 30 pA) ^{108}Sn (I ≈ 50 pA)

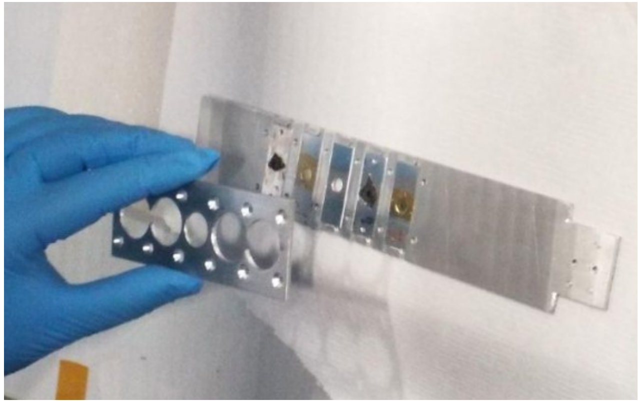
^{110}Sn (I ≈ 80 pA) ^{109}Sn (I ≈ 90 pA)



Targets

^{197}Au ≈ 300 μg/cm²

^{4}He ≈ 2 x 10^{18} atoms/cm²



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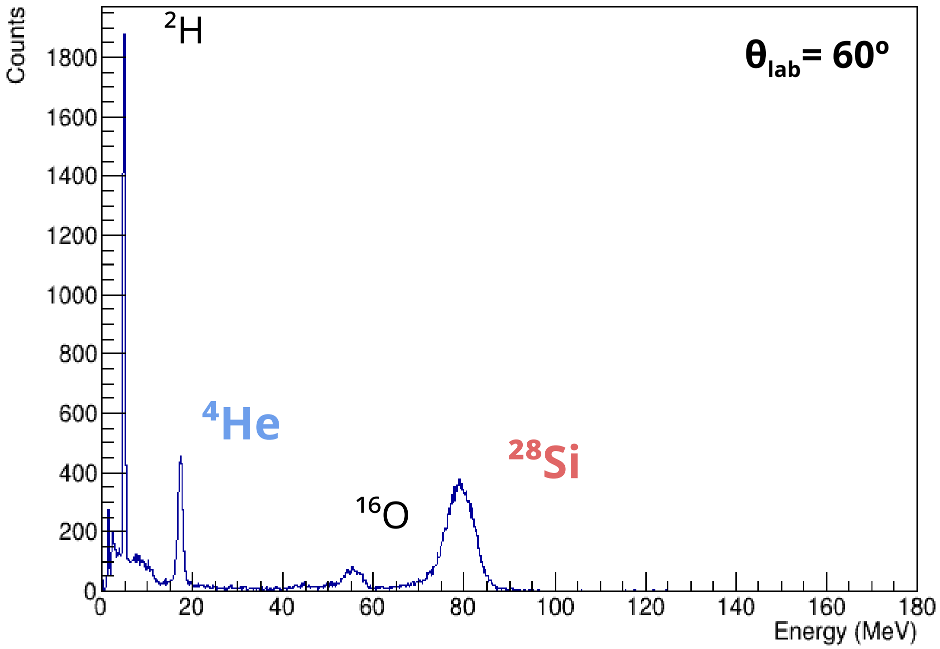
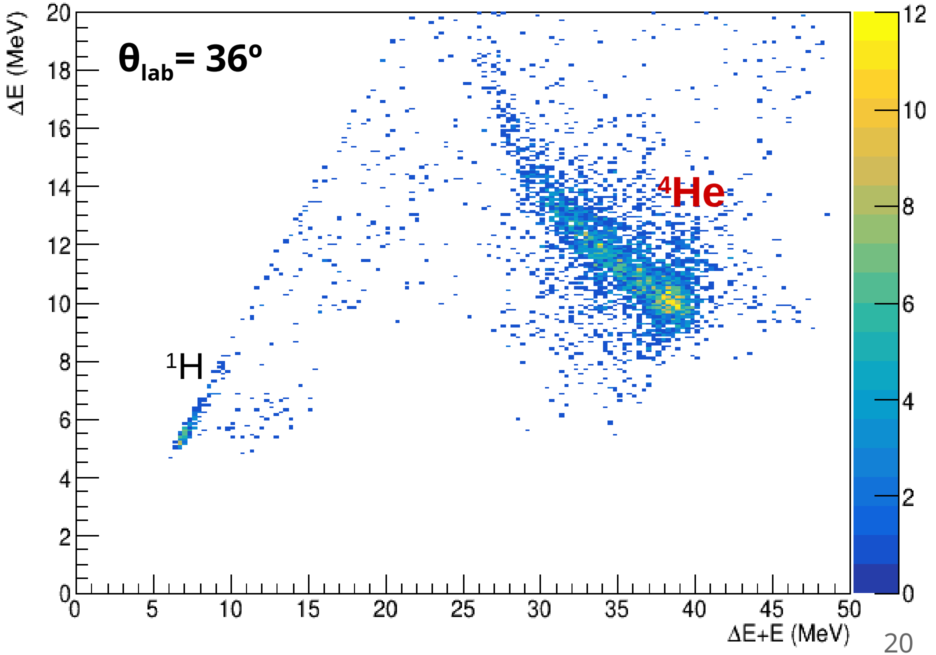
Experimental Data

$^4He(^ASn,^4He)^ASn$ @ 4.9 MeV/u

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



^{108}Sn beam scattering on **Si/He-target**



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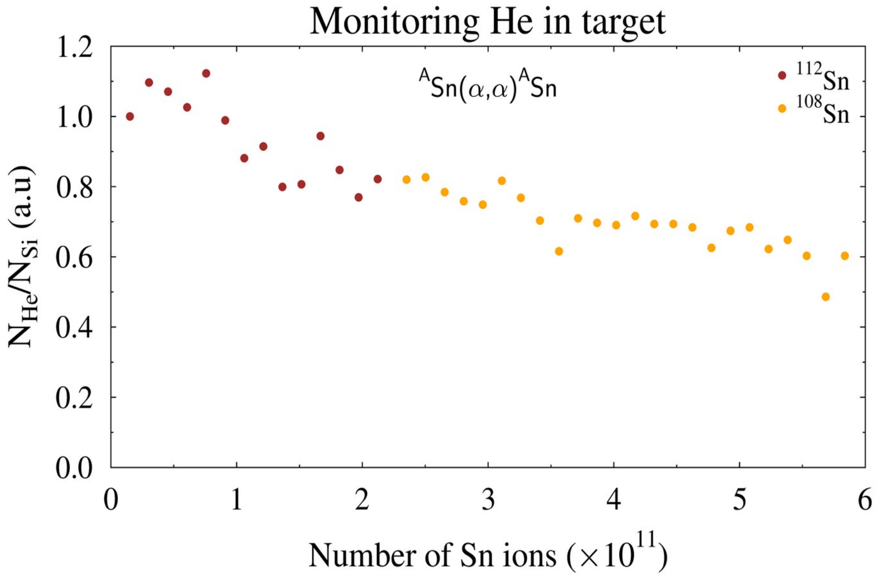
Before counting…!

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**



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

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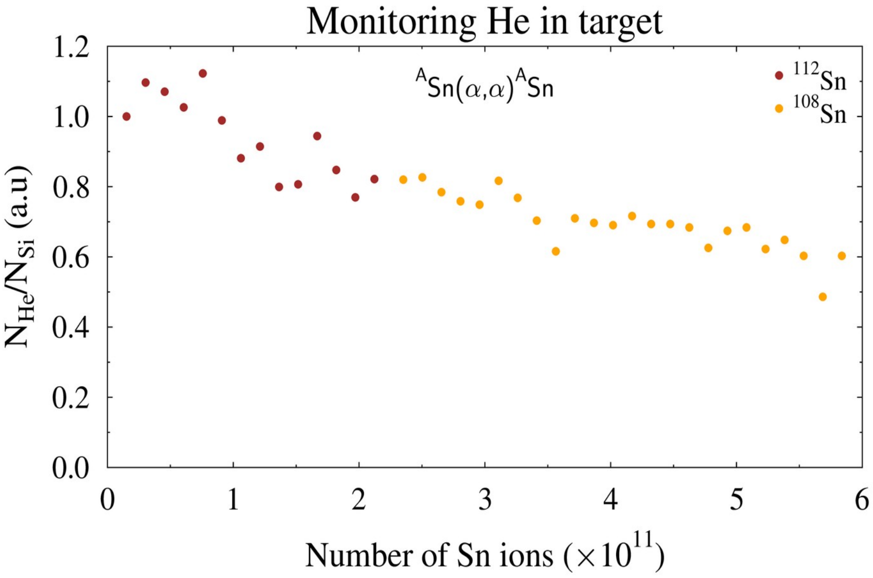
$$\alpha_i = \frac{N^i_{He}(60^\circ)}{N^i_{Si}(60^\circ)} \frac{N^0_{Si}(60^\circ)}{N^0_{He}(60^\circ)}$$



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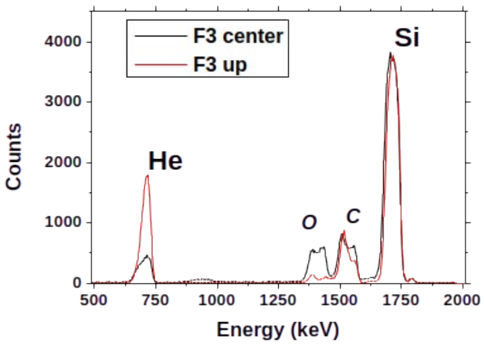
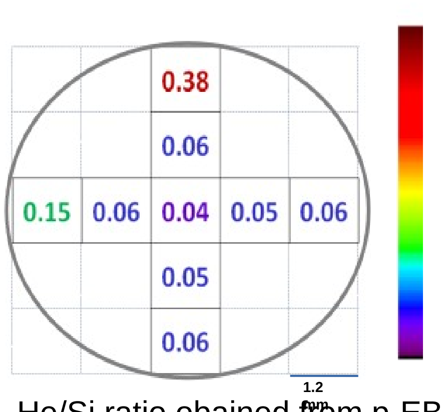
Before counting…!

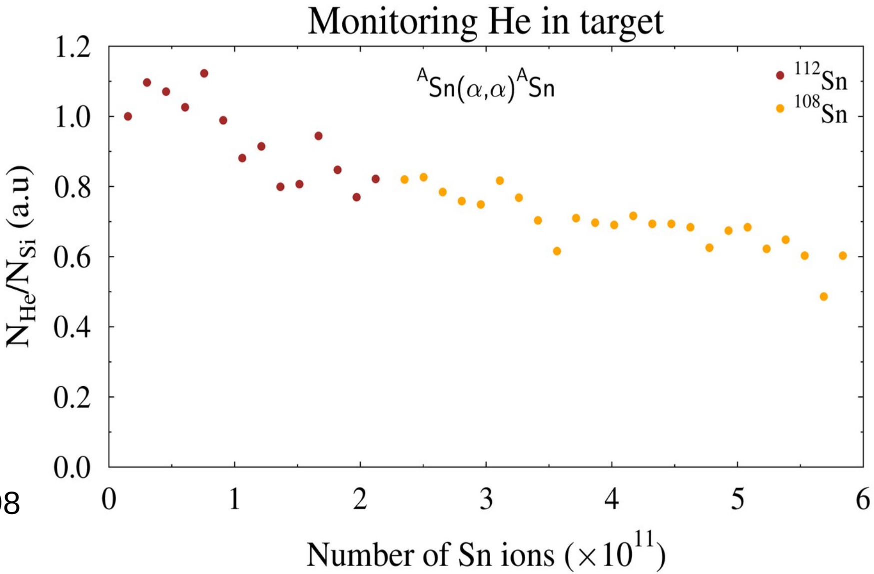
Amount of ^{4}He over time



p-EBS spectrum of the F3 Si:He in different target points after IS698



He/Si ratio obained from p-EBS analysis of the F3 Si/He after IS698



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

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Preliminary results

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

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

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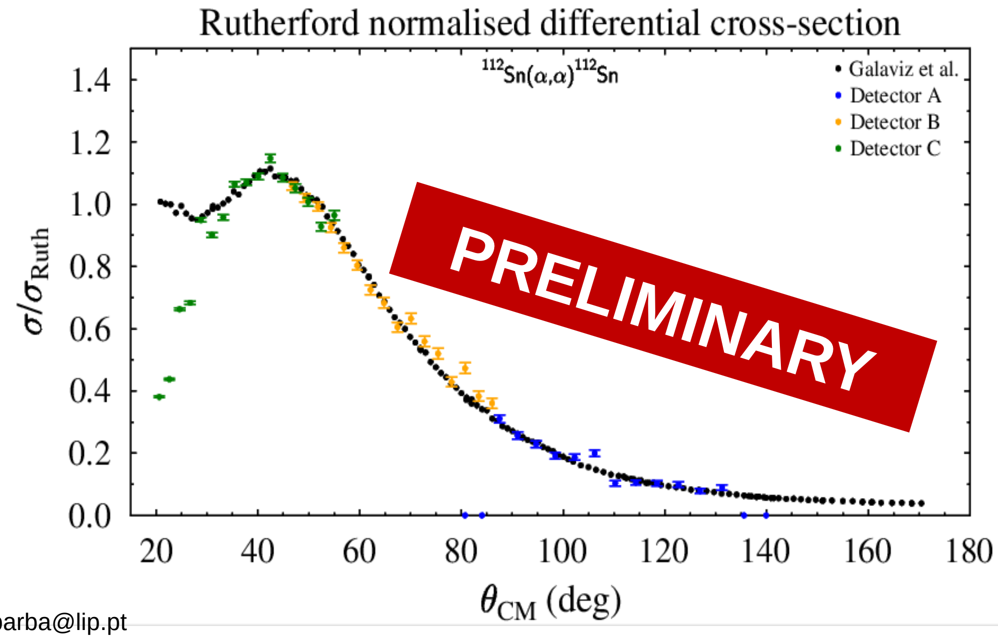

Note: Statistical error bars

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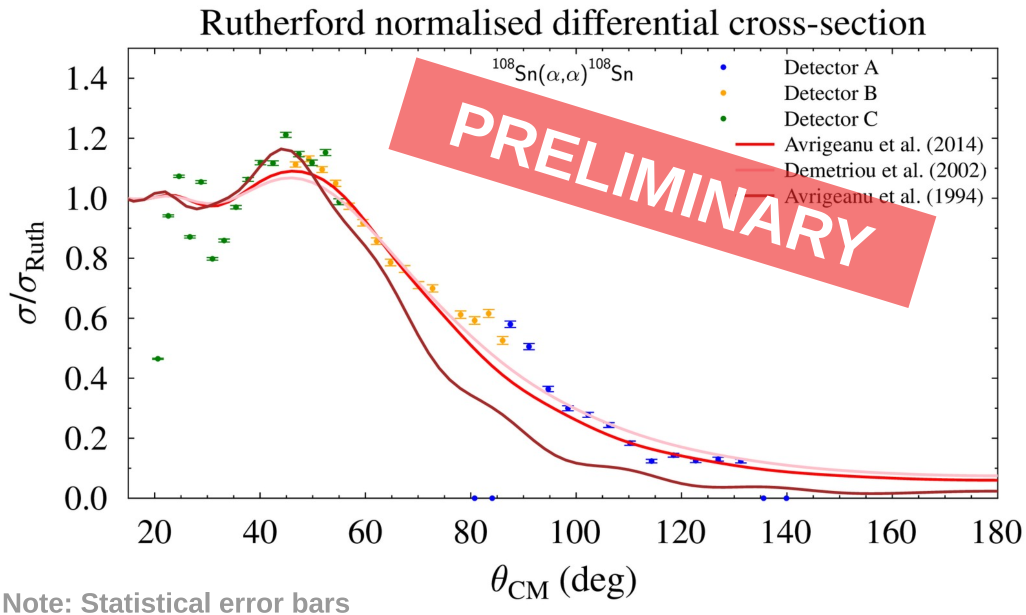
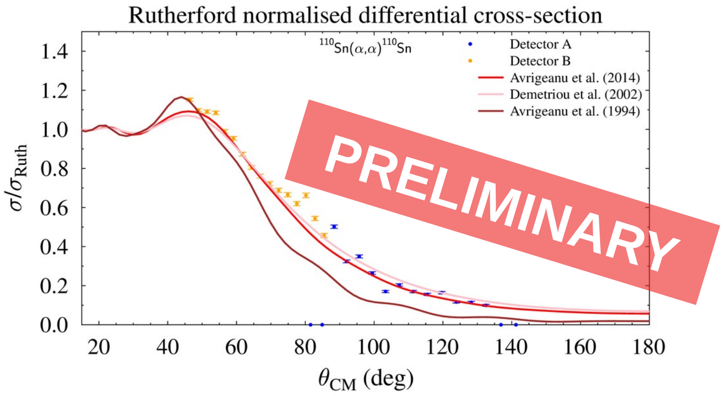
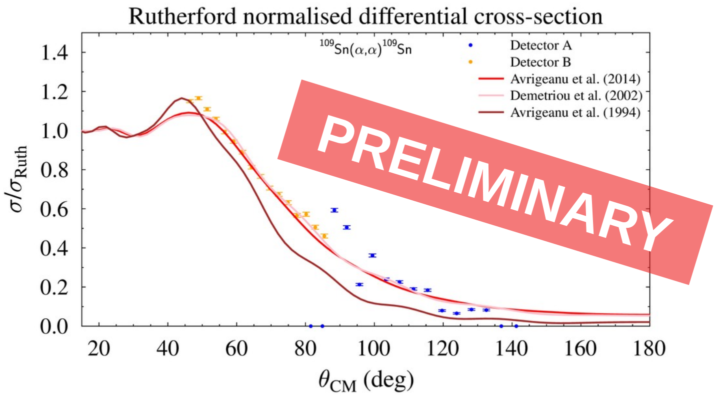
Preliminary results







Note: Statistical error bars

Conclusions

- **Four angular distributions** measured covering a large angular range.
- **Good performance** of high concentration ^{4}He targets
- **Analysis defined** for all the angular regions.
- **Technique benchamarked** with previously measured data in direct kinematics
- **Preliminary data on radioactive** nuclei showing consistency of the method

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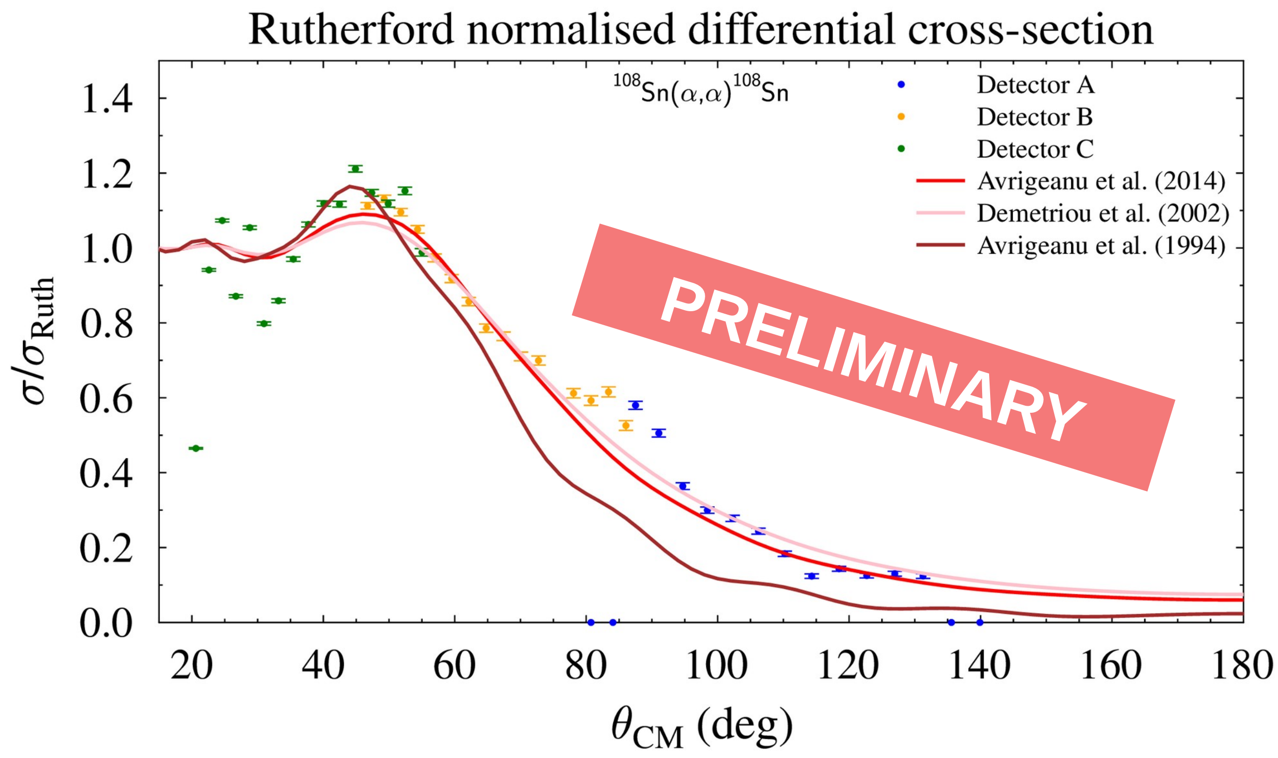
Acknowledgments

D. Galaviz, F. J. Ferrer, A. M. Sánchez-Benítez, L. Acosta, B. Amorim, F. G. Barba, M. L. Benito, M. J. Borge, J. Cederkall, M. M. R. Chisti, M. La Cognata, J. G. Correia, Y. Demane, A. Di Pietro, C. Ducoin, E. Fadakis, A. Fernández, B. Fernandez, J. P. Fernández, P. Figuera, L. M. Fonseca, L. M. Fraile, S. Freeman, V. García, V. Godinho, J. Gómez Camacho, D. Hufschmidt, K. Johnston,U. Koester, L. Lamia, B. Olaizola, A. Perea, R. Pires, A. Rodriguez, S. Rothe, E. Siesling, O. Tengblad, P. Teubig, A. Tumino, M. Xarepe

RENASCER Project: CERN/FIS-PAR/0009/2021
SCORE Project: EXPL/FIS-NUC/0364/2021
FCT PhD Fellowship: UI/BD/154300/2022 Spanish Project: PID2023-147569NB-C22

BACKUP SLIDES

Preliminary results



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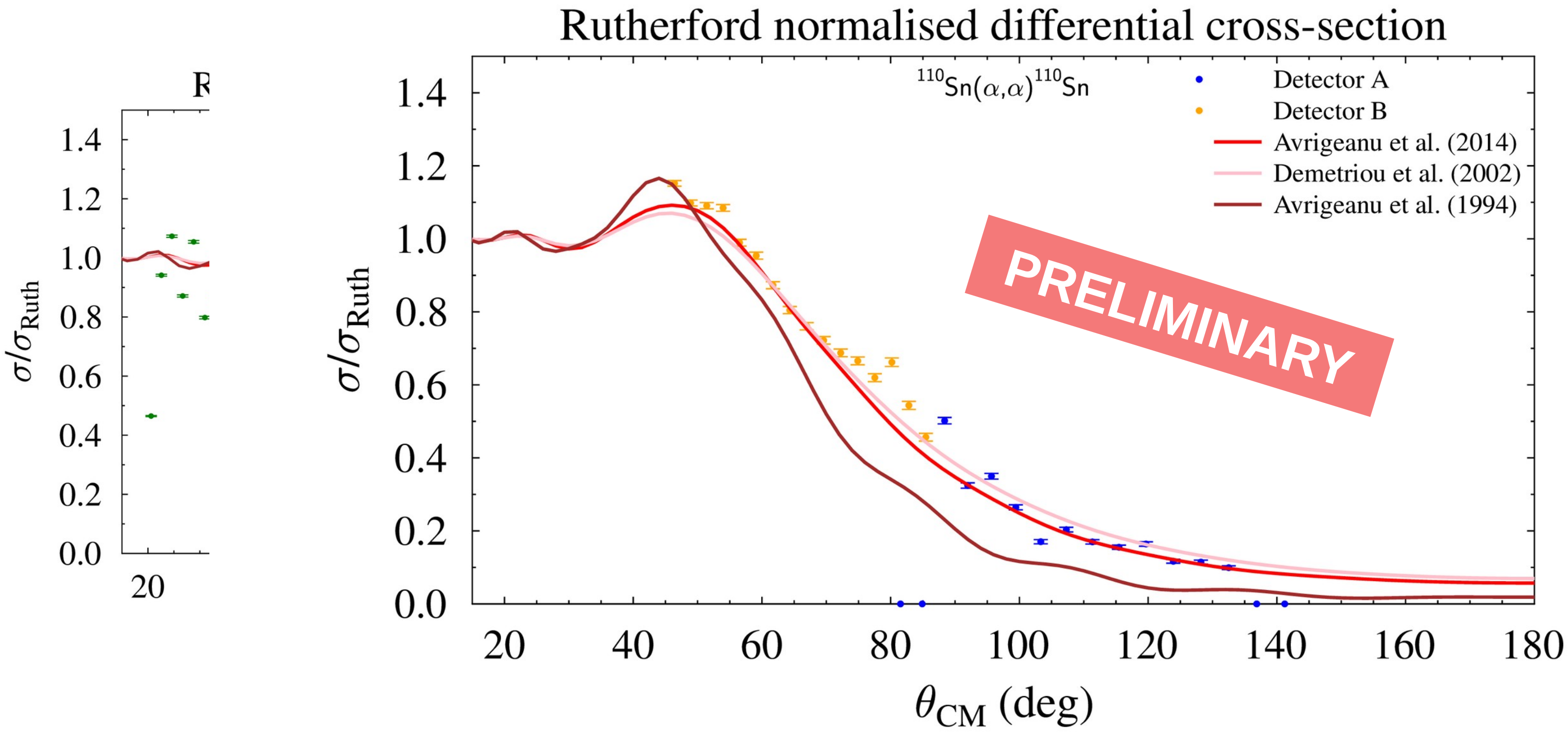
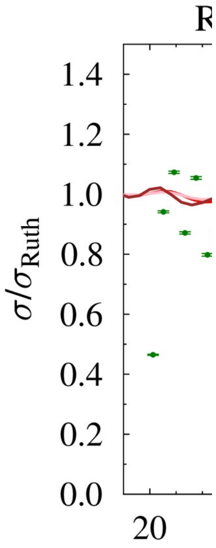
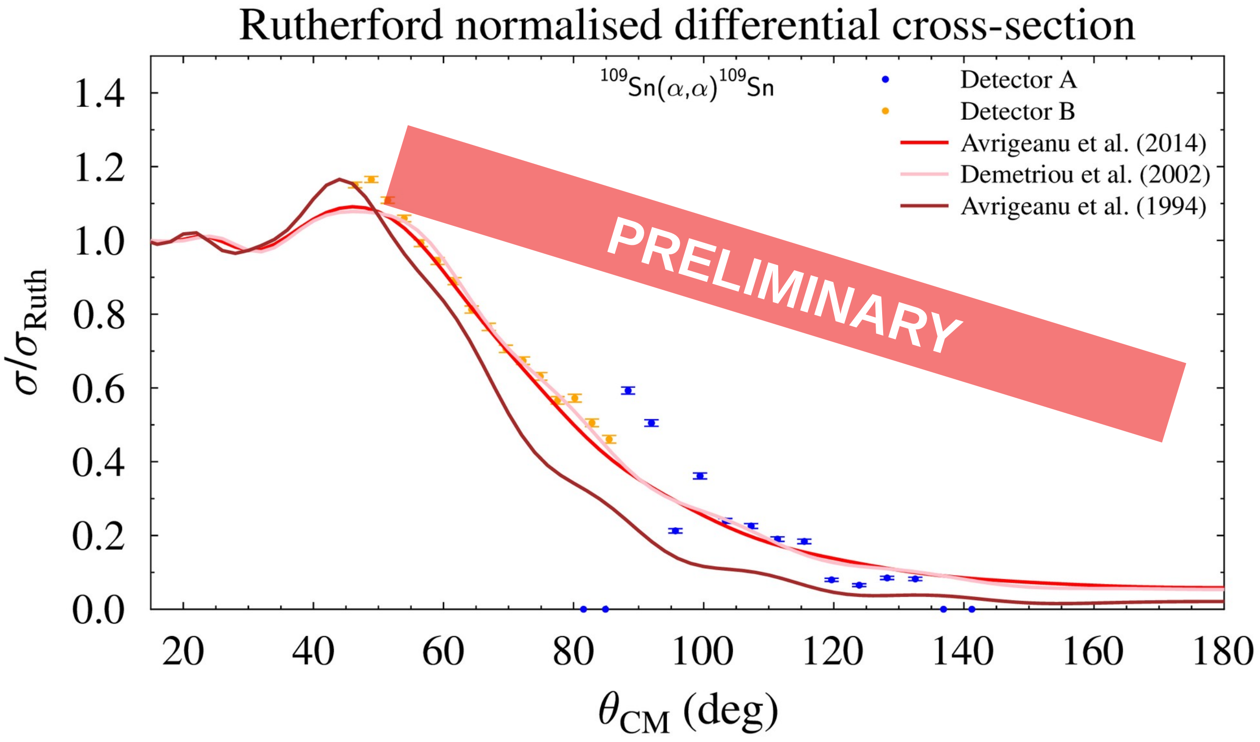
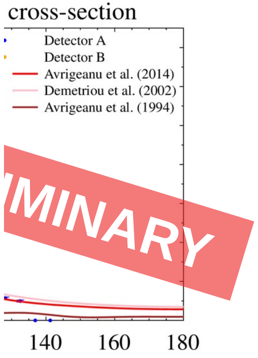


Preliminary results

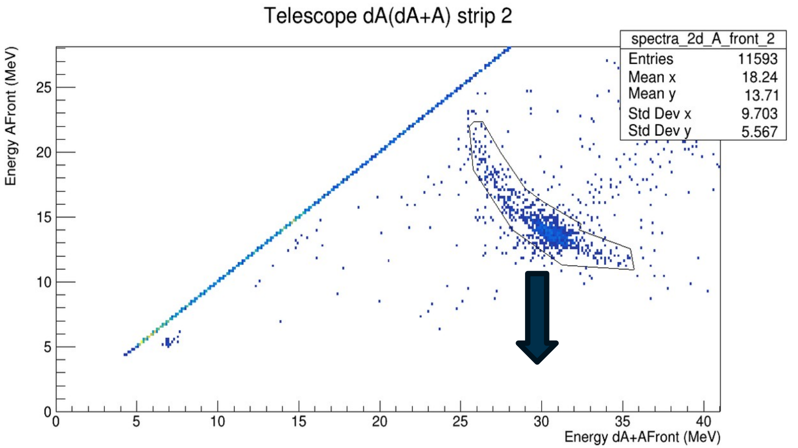


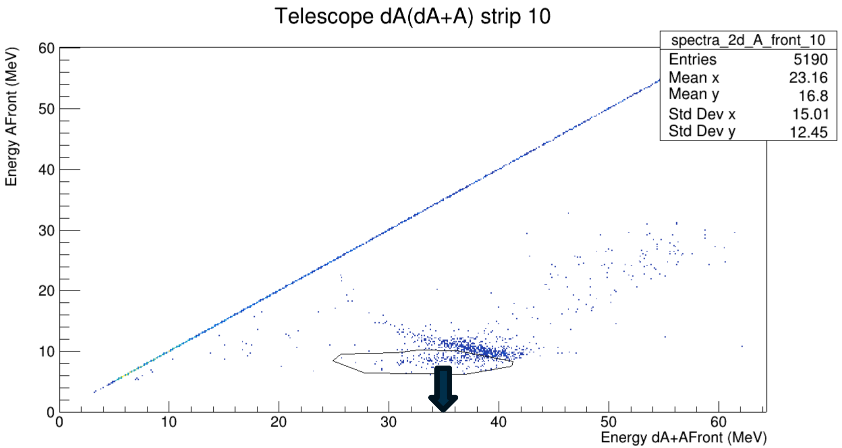




Detector A

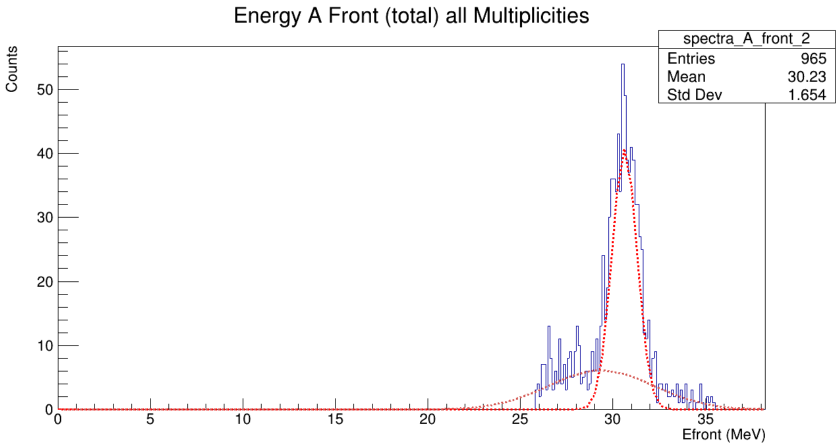
- Separate what is punch through (consider Elastic Peak higher energy)
- Projection on Total Energy Axis

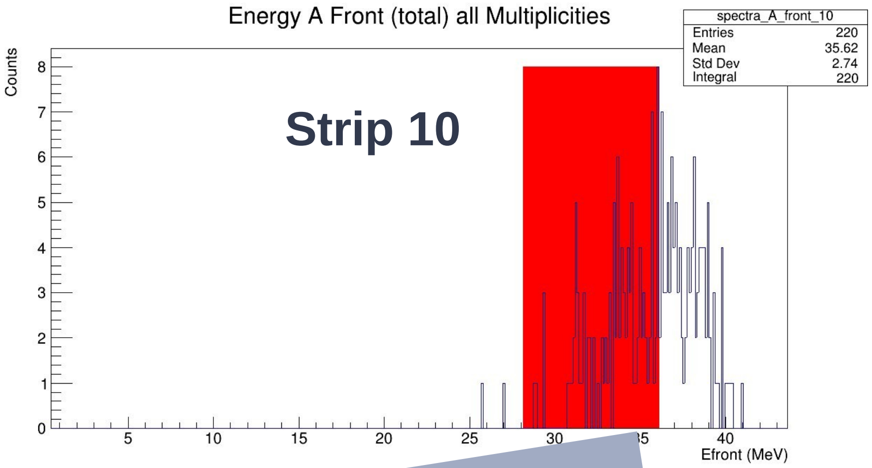




Detector A

- Select regions for elastically scattered alpha-particles

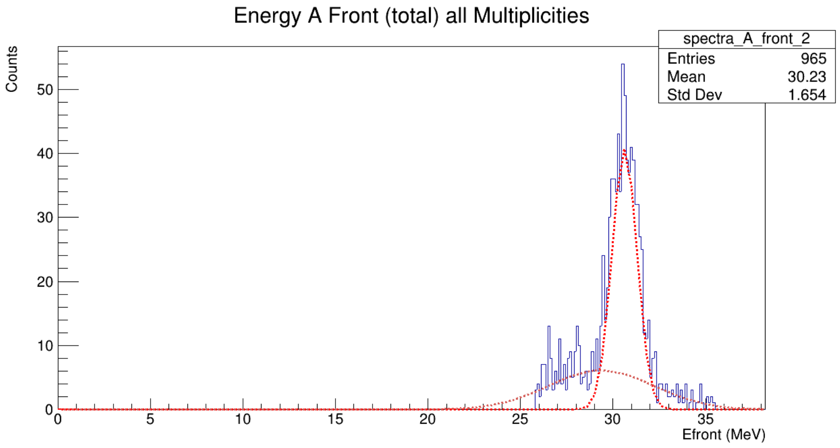


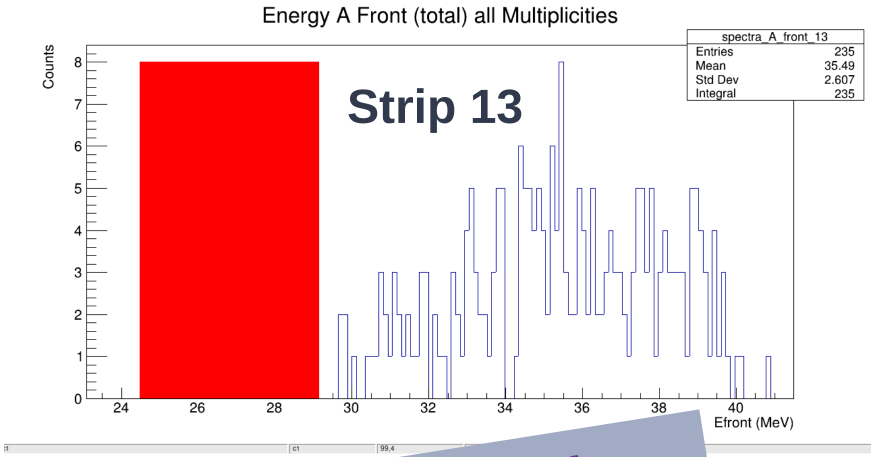


Kinematics!

Detector A

- Select regions for elastically scattered alpha-particles

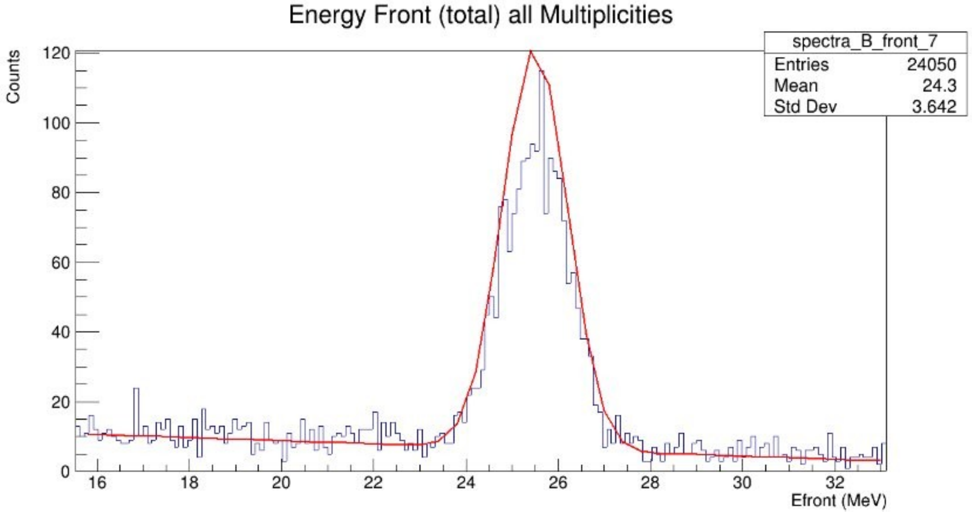




Kinematics!

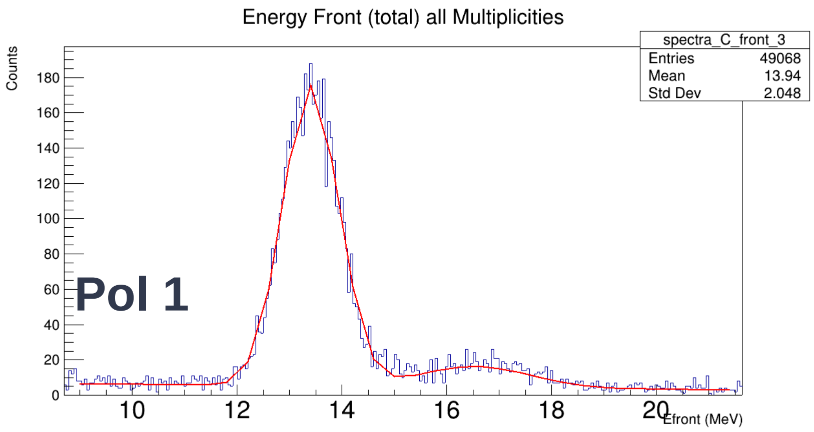
Detector B

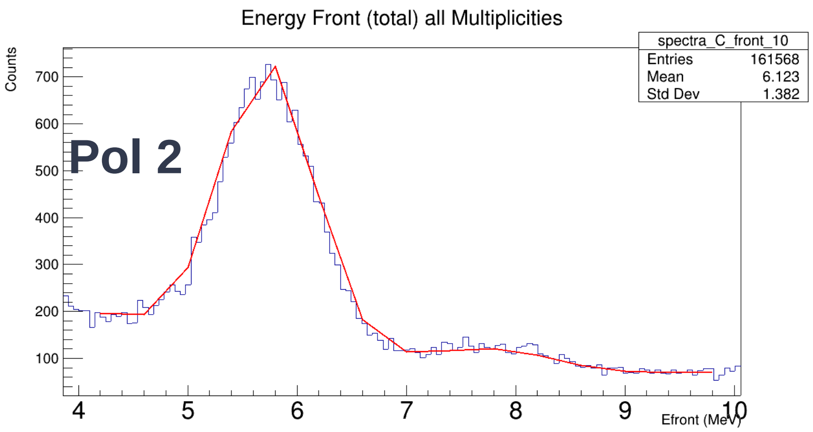
I wish they all could be detectors B….!
Fit Gaus + pol1
Integrate in centroid +/- sigma
Apply counter-bg/counter factor to integral in **each pixel**



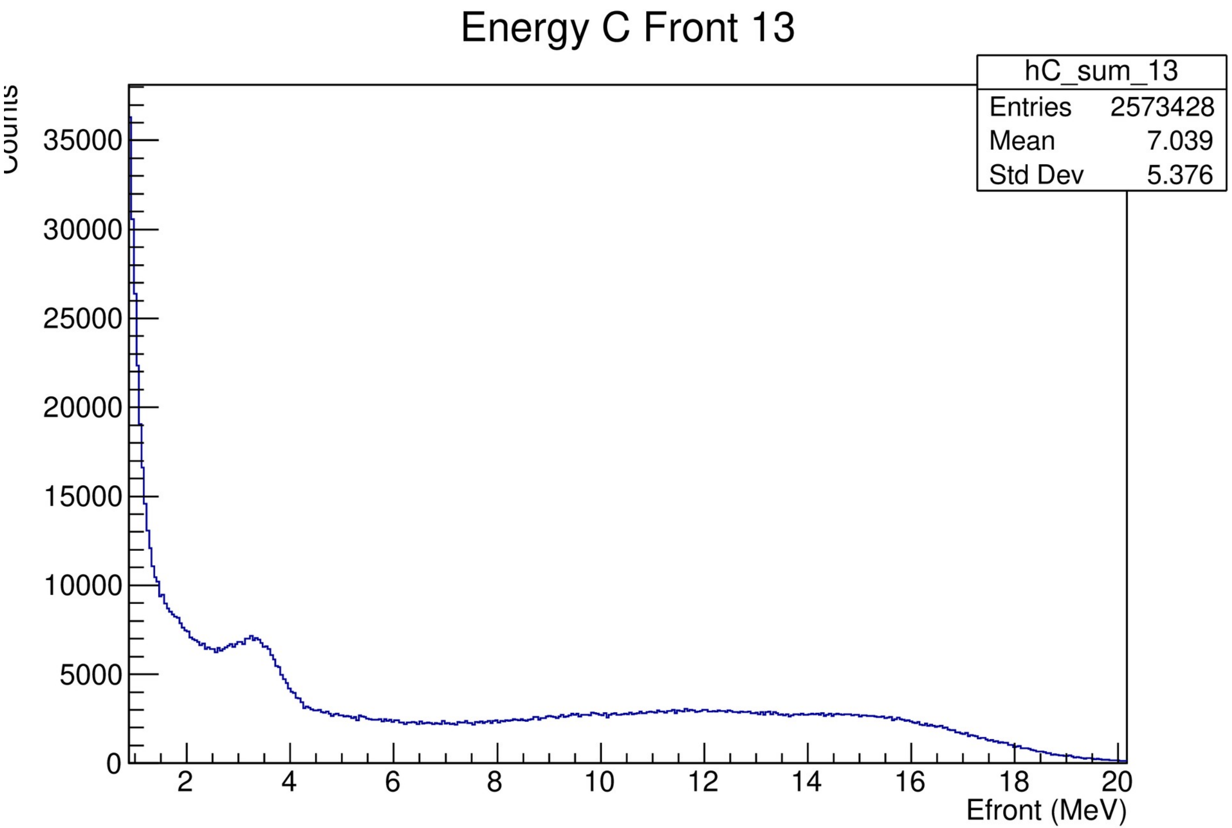
Detector C

Separete Linear bg from quadratic bg
Fit gaus+gaus+pol
Integrate in centroid1-sigma1 and centroid2+sigma2
Apply counter-bg/counter to the amounts in **each pixel**





Detector C: Problem at higher lab angles



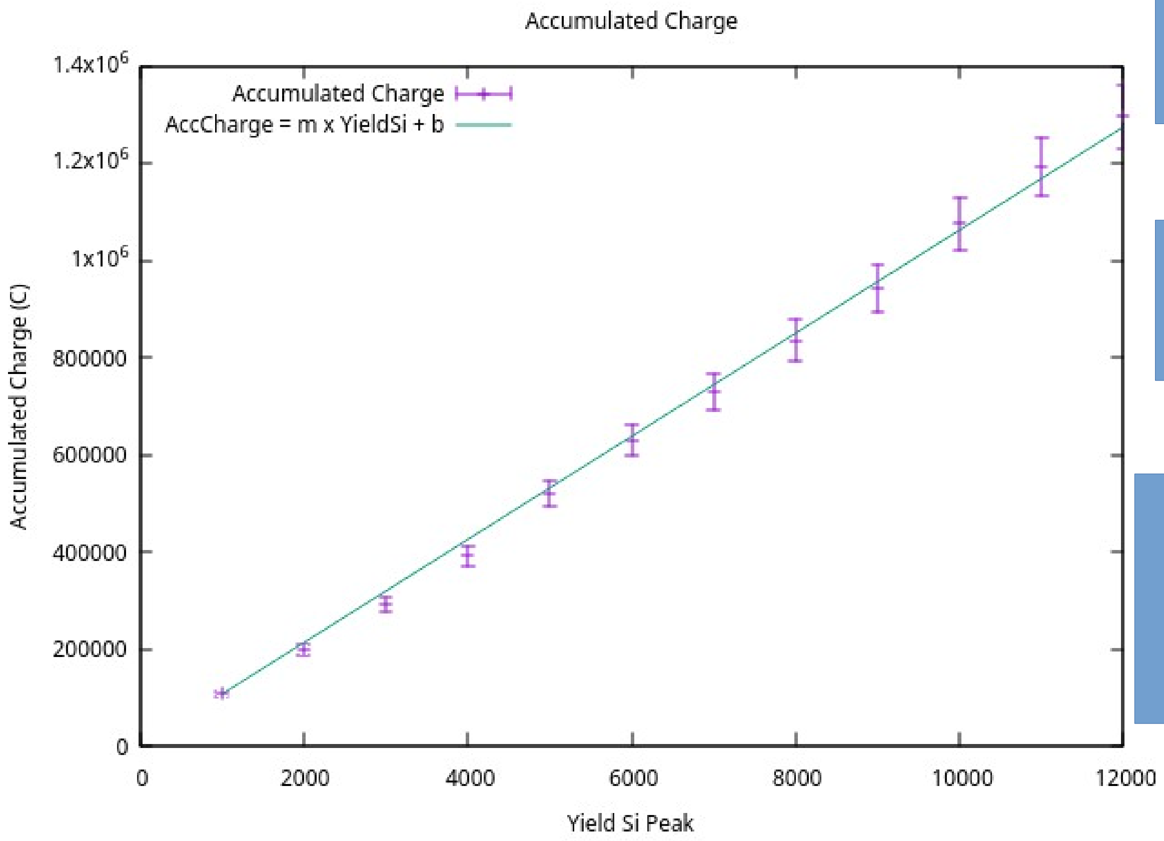
Constant Si signal

Linear scale

Purple integrated current
Green Fit

Accumulated Charge has to be proportional to Si Peak Counts

CHECK

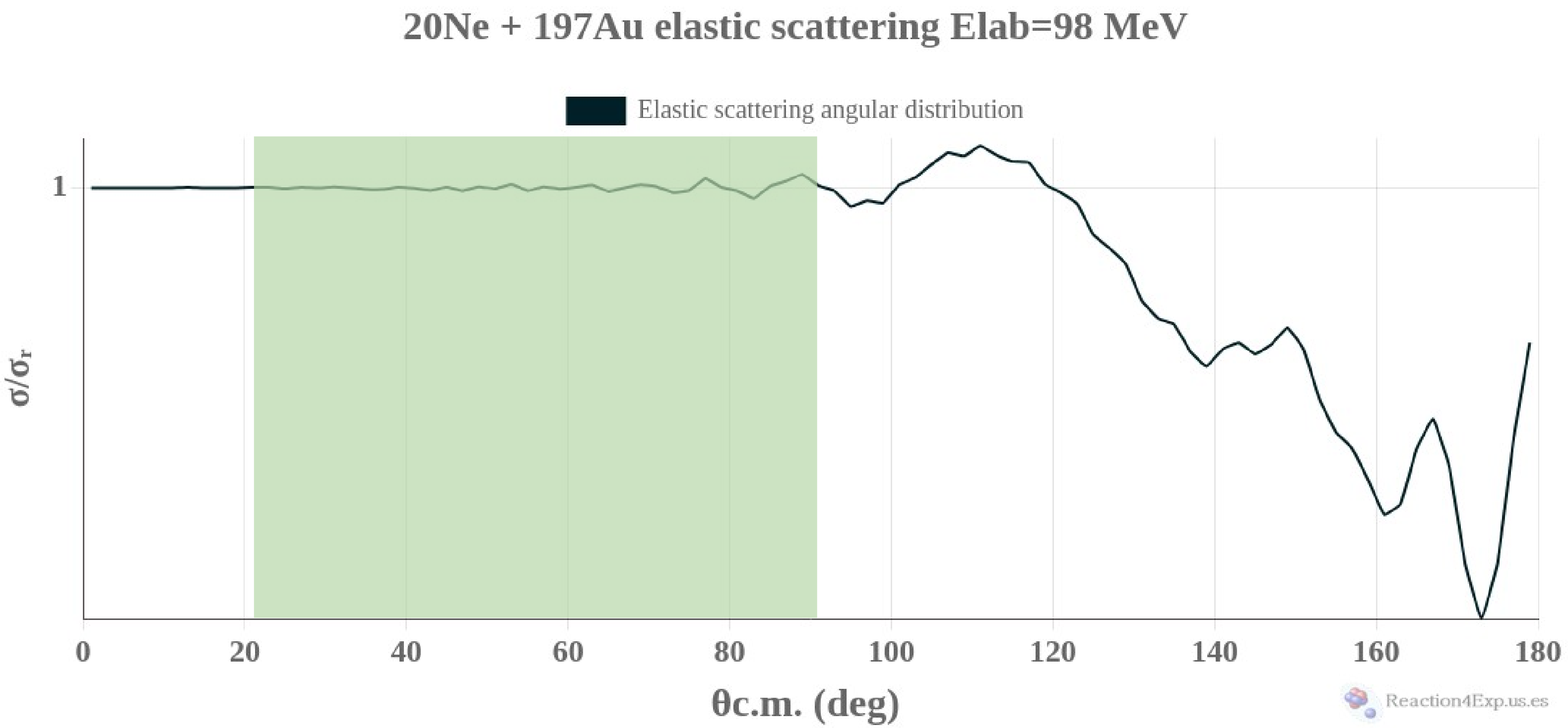


5% error bars

Shows that Si holds okayish

We can consider He/Si as criteria

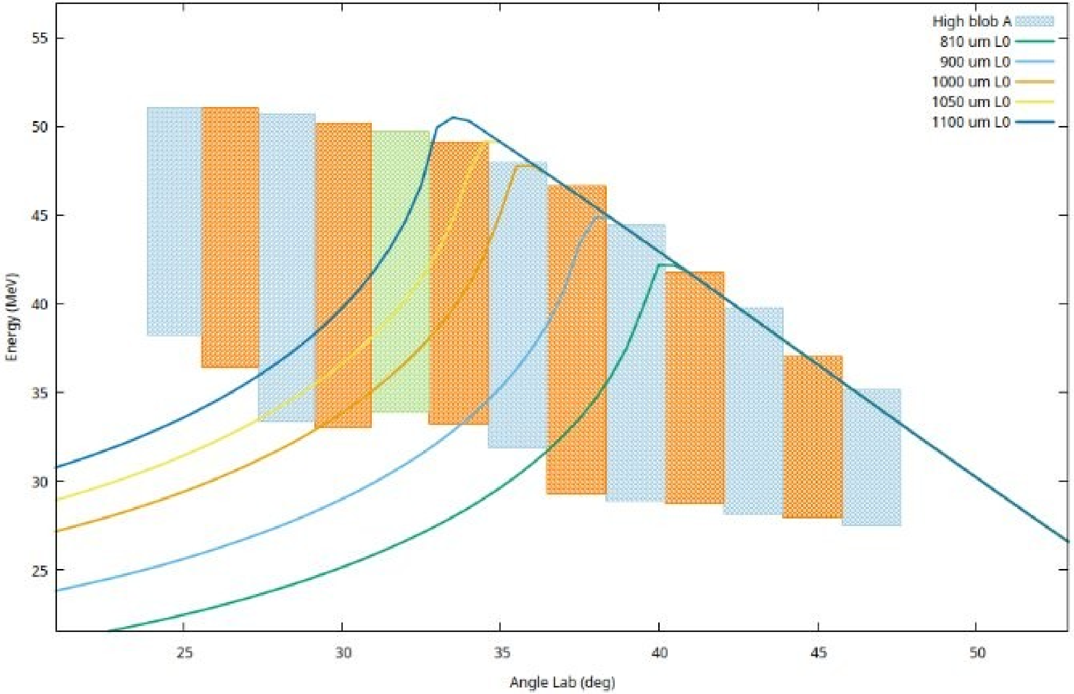
Backup: Pilot Beam calculated xs



Detector A – inelastic channels

E(level) (keV)	XREF	J^{π}(level)
0.0	ABCDEFGHIJKLMNOPQ	0+
1256.69 4	BCDEFGHIJKLMN PQ	2+
2150.87 5	BC E LMN	2+
2190.81 6	C E H LMNO Q	0+
2247.39 6	BC EF HIJKLMN P	4+
2354.21 6	BC EF H LMN PQ	3-
2476.16 11	BC E H MN Q	2+
2520.70 7	BC EFGHI MN P	4+
2549.22 14	EF HIJK MN	6+
2556.6 3	B	(2+)
2617.62 18	E MN	0+
2721.06 14	B E MN	2+
2756.02 9	B E M	3+

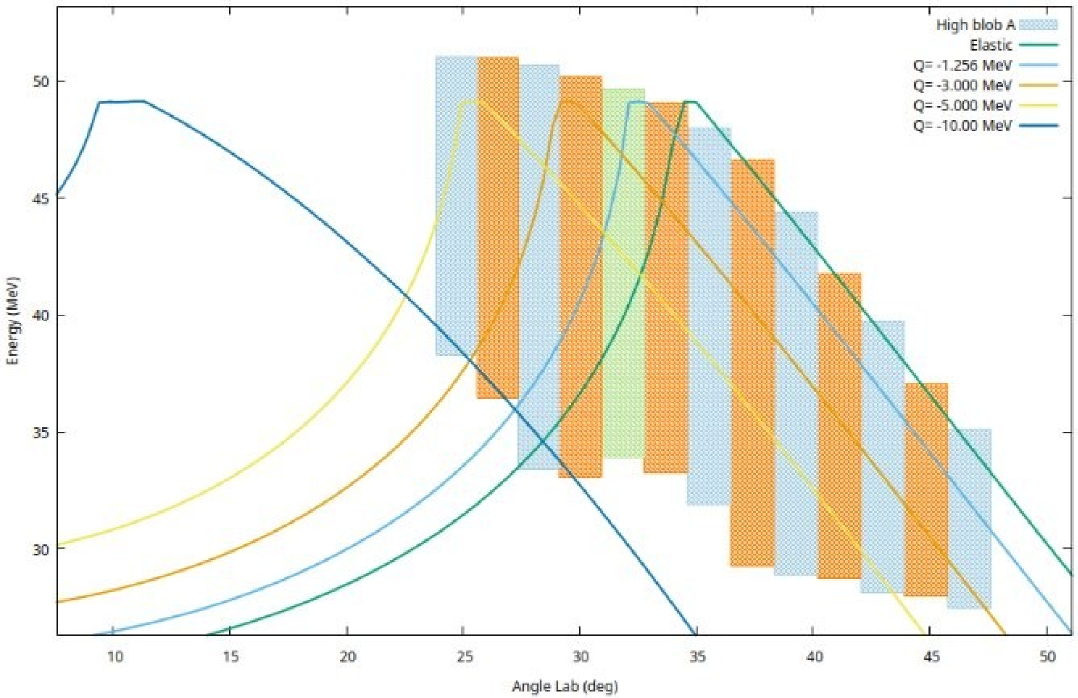
Energy deposited by elastic scattered ^{4}He in different Si thicknesses



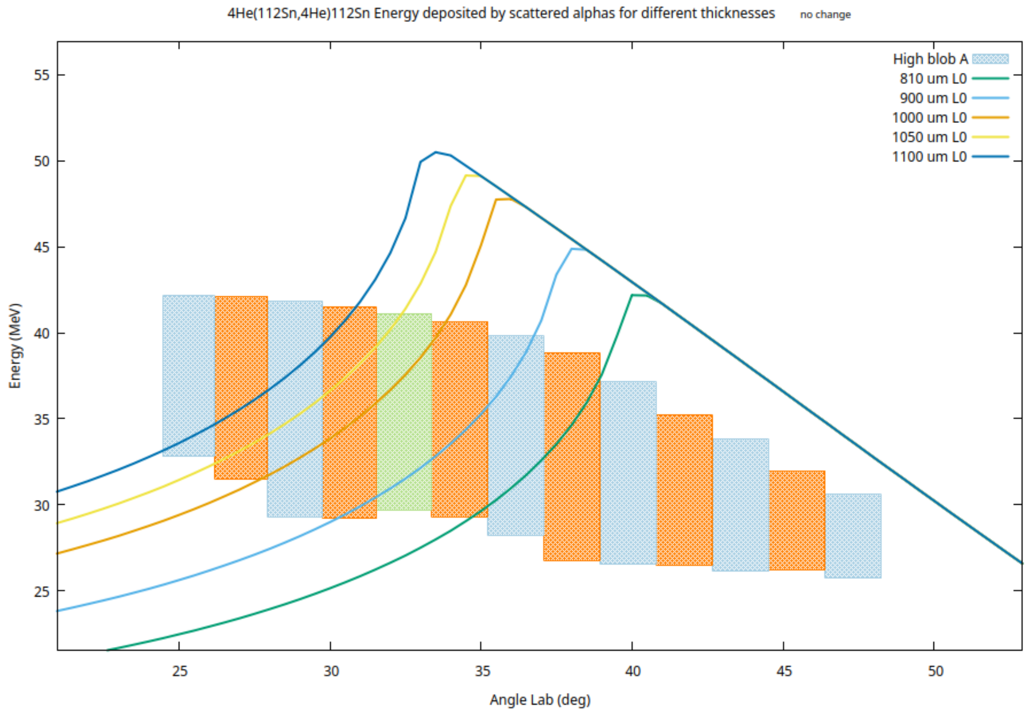
Detector A

E(level) (keV)	XREF	J^{π}(level)
0.0	ABCDEFGHIJKLMNOPQ	0+
1256.69 *4*	BCDEFGHIJKLMN PQ	2+
2150.87 *5*	BC E LMN	2+
2190.81 *6*	C E H LMNO Q	0+
2247.39 *6*	BC EF HIJKLMN P	4+
2354.21 *6*	BC EF H LMN PQ	3-
2476.16 *11*	BC E H MN Q	2+
2520.70 *7*	BC EFGHI MN P	4+
2549.22 *14*	EF HIJK MN	6+
2556.6 *3*	B	(2+)
2617.62 *18*	E MN	0+
2721.06 *14*	B E MN	2+
2756.02 *9*	B E M	3+

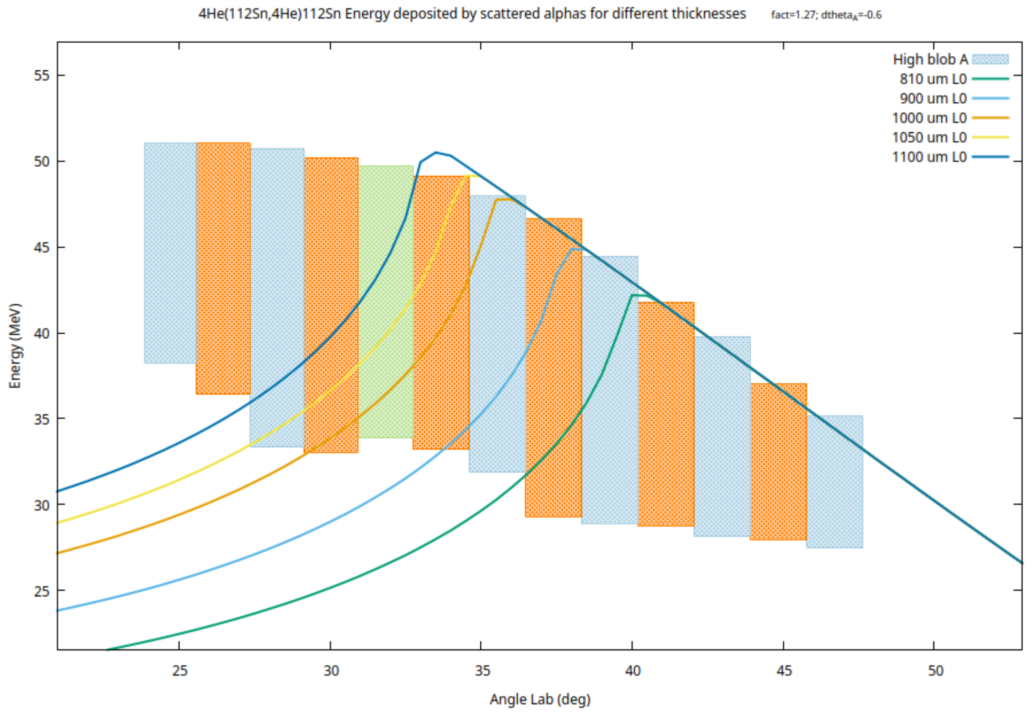
Energy deposited by scattered ^{4}He in 1050 um Si for different Sn excited states



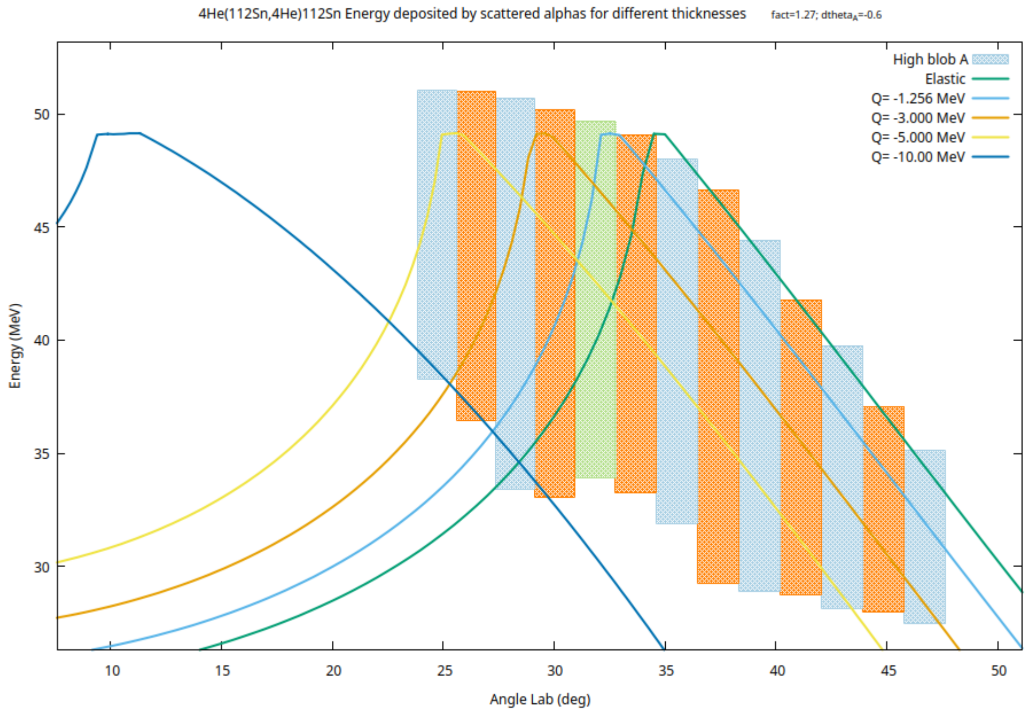
- Energy deposited by alphas from elastic scattering at different thicknesses



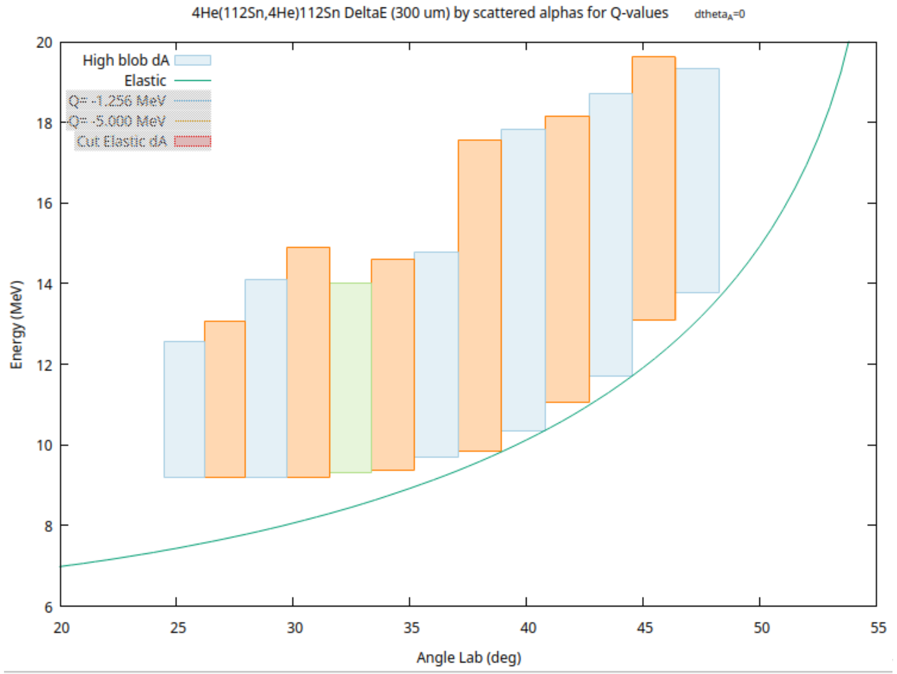
- Adjusted gain **in pad** and angular shifted to meet the kinematic curves



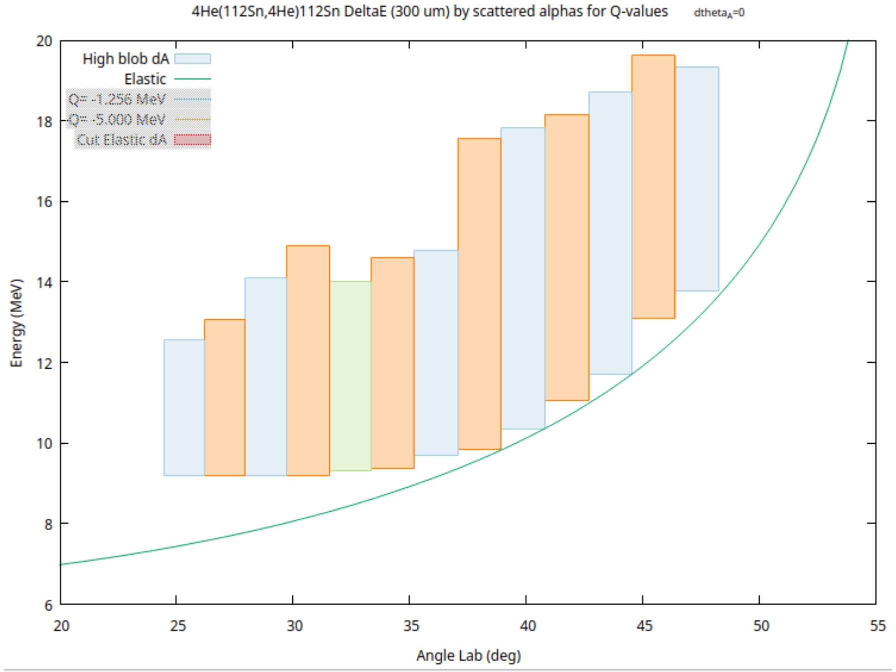
- Assuming thickness of **1050 um** in the telescope

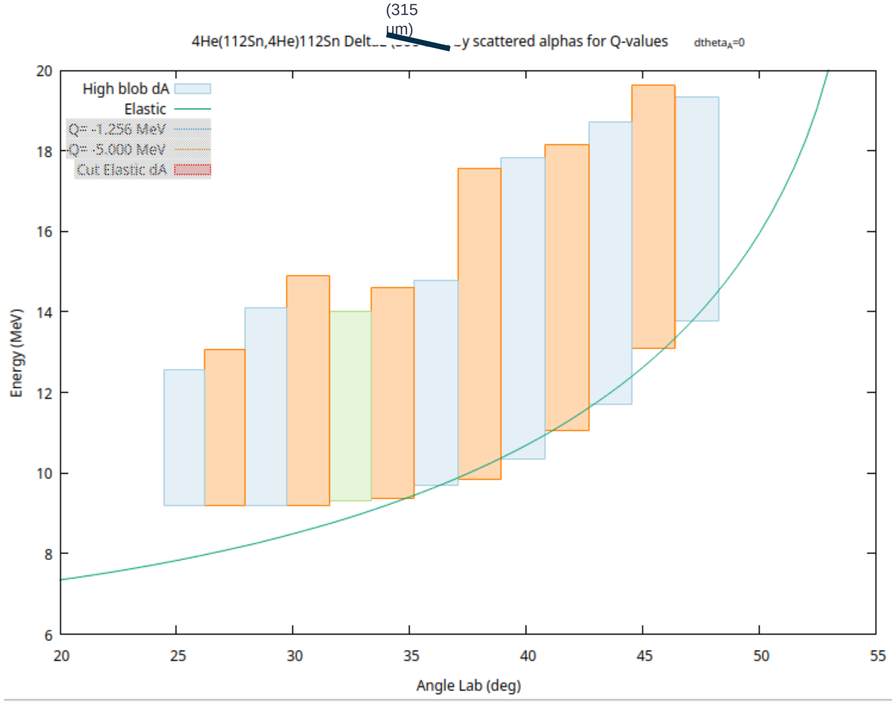


- Energy deposited by elastic alphas in deltaE detector (300 um)

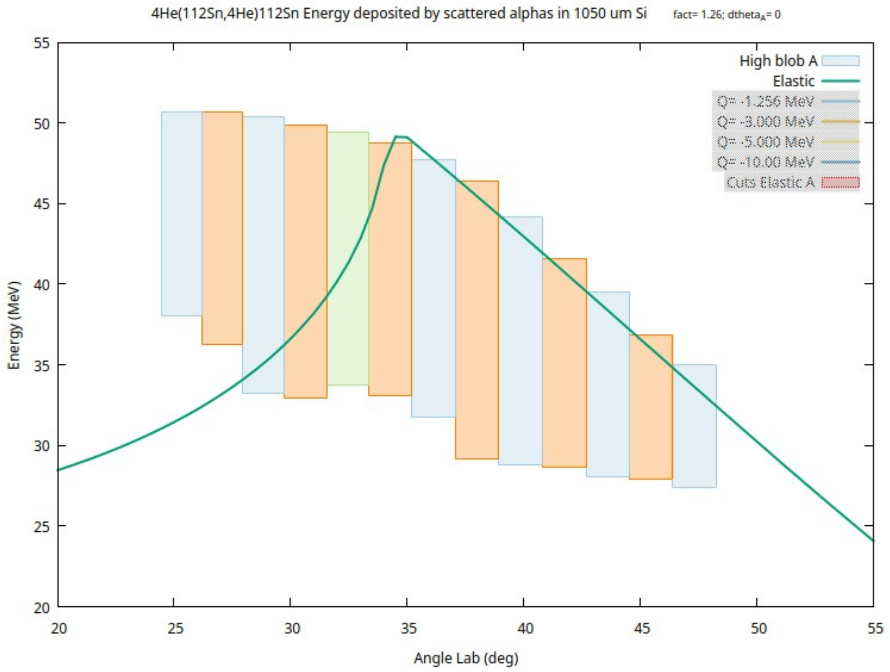


- Adjusted deltaE thickness to 315 um and removed angular shift

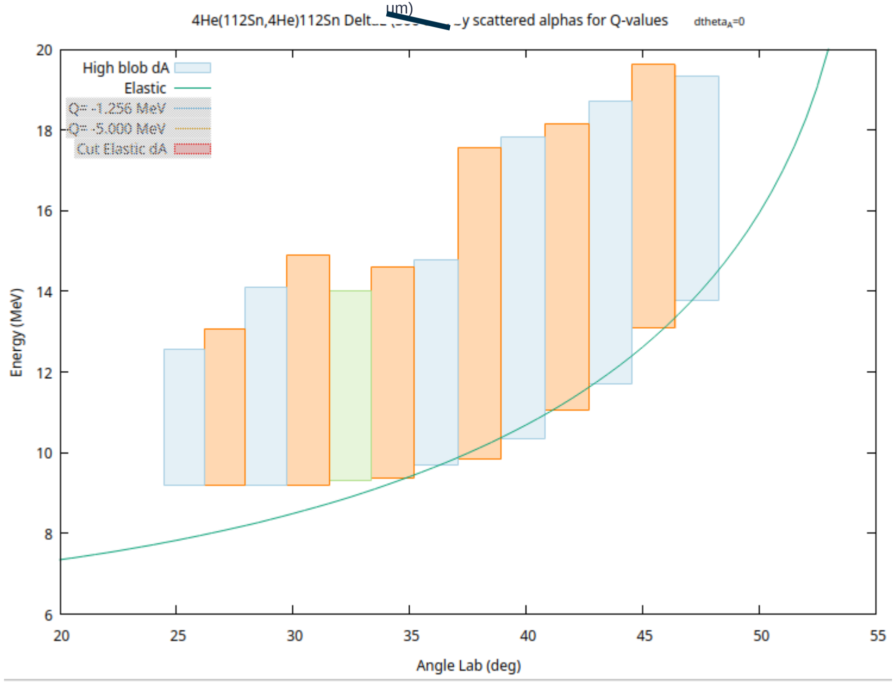





315
um
735 um


4He(112Sn,4He)112Sn Energy deposited by scattered alphas in 1050 um Si
fact= 1.26; dtheta$_A$= 0
High blob A
Elastic
Q= -1.256 MeV
Q= -3.000 MeV
Q= -5.000 MeV
Q= -10.00 MeV
Cuts Elastic A
Energy (MeV)
Angle Lab (deg)

(315
um)


4He(112Sn,4He)112Sn Delt
y scattered alphas for Q-values
dtheta$_A$=0
High blob dA
Elastic
Q= -1.256 MeV
Q= -5.000 MeV
Cut Elastic dA
Energy (MeV)
Angle Lab (deg)

Angular Calibration

$^{197}Au(^{20}Ne,^{20}Ne)^{197}Au$ @ 4.9 MeV/u

Pilot Beam Spectra