INVERSE-ALPHA-X: α-scattering on unstable proton-rich tin isotopes in inverse kinematics for the astrophysical *p*-process

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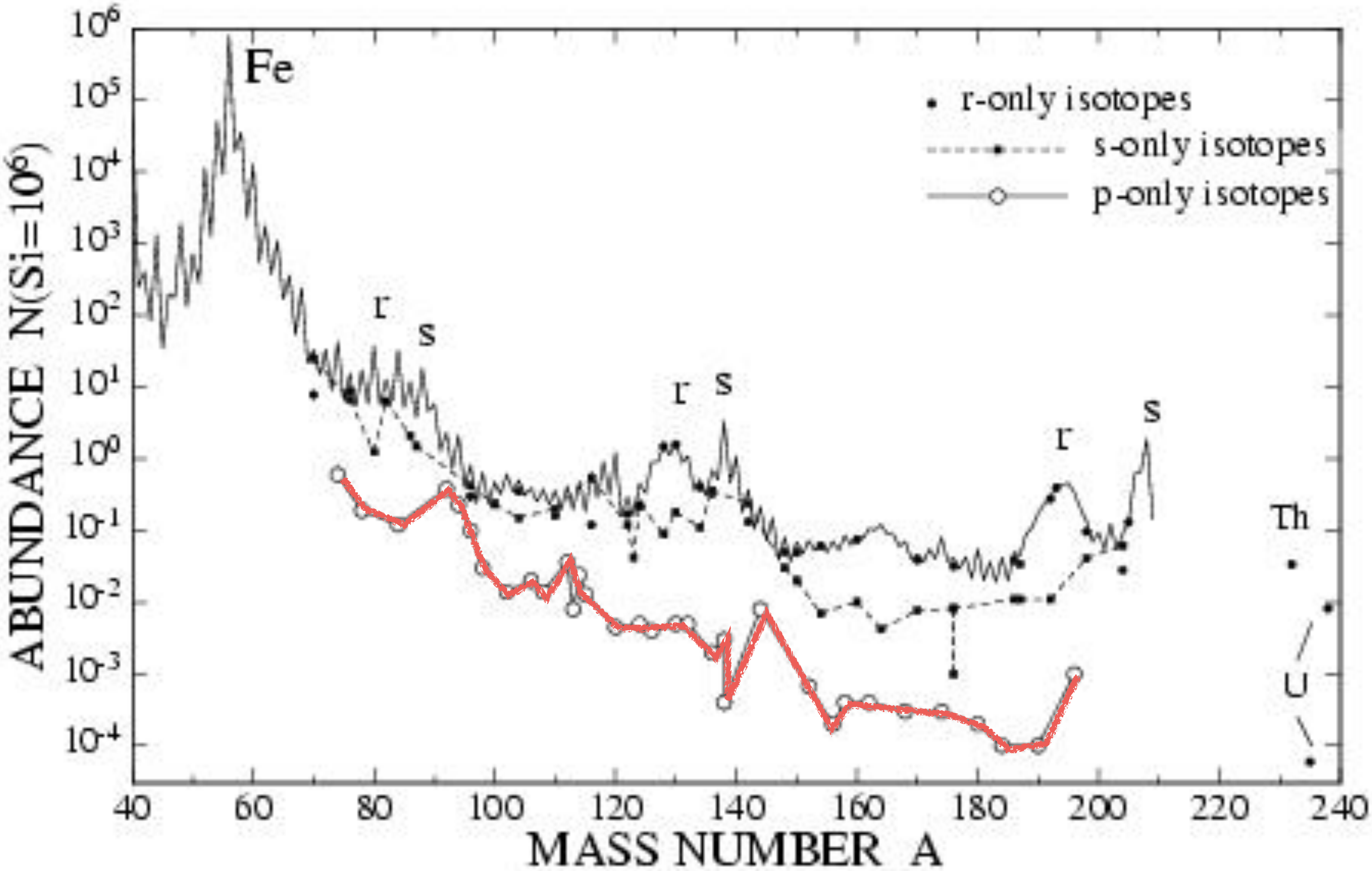
Outline

- Motivation:
  - Astrophysical ***p*-process**
  - Uncertainties related to **α nuclear potentials**
  - Innovative use of **thin helium targets**
  - Results of the **Test Experiment** at **INFN/LNS**

- Proposed experiment:
  - Elastic **α scattering** in **inverse kinematics** on **exotic ^{108,110}Sn,** and stable **^{112}Sn**

Astrophysical *p*-process

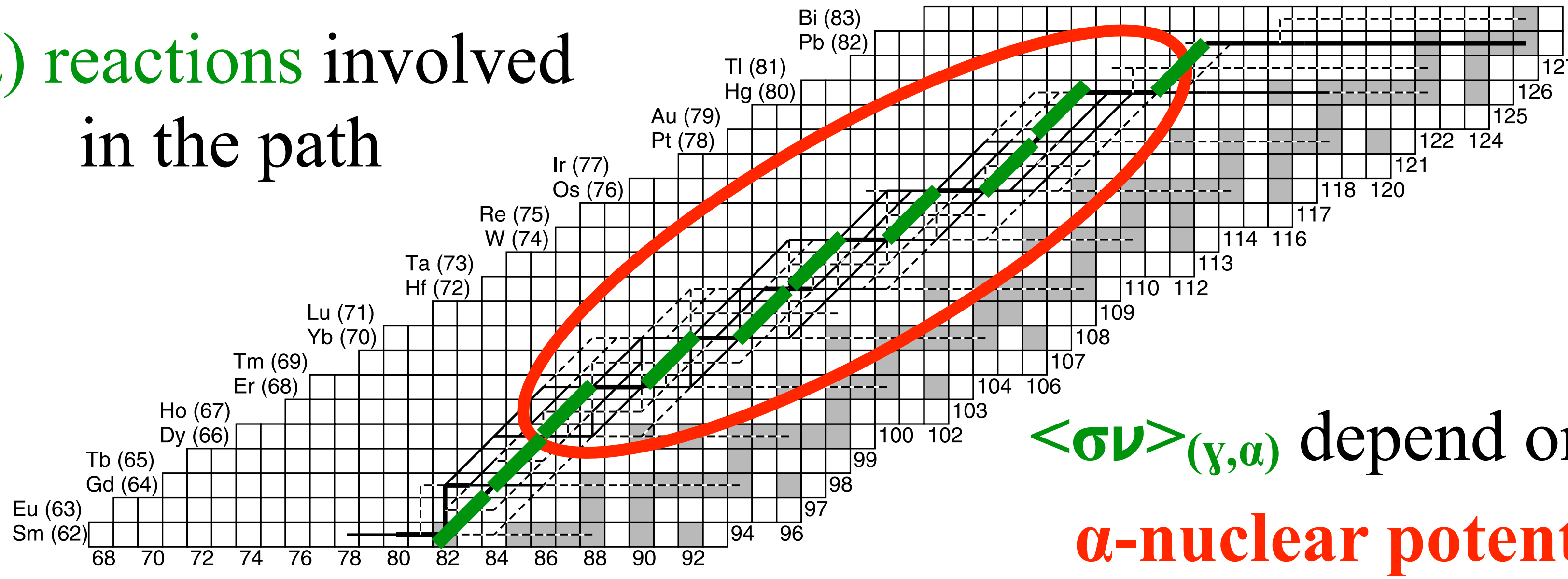


p-process Sensitivity Studies

- Sensitivity studies of *p*-process nucleosynthesis point out the strong dependence of the α-nuclear potential in the production of heavy *p*-nuclei

(ɣ,α) reactions involved in the path

Z



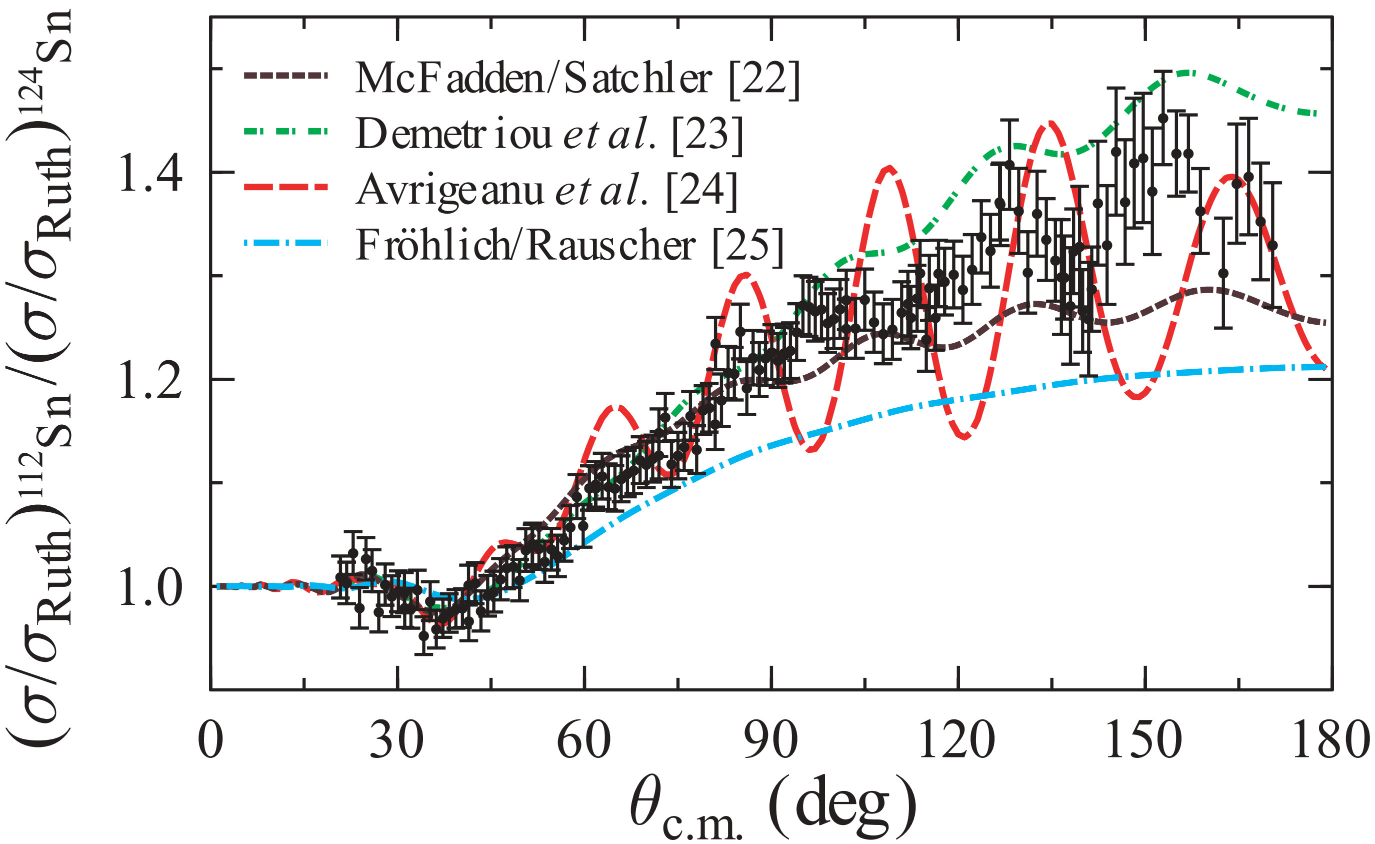
N

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

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

α-nuclear potentials

Mass dependence in stable Sn isotopes

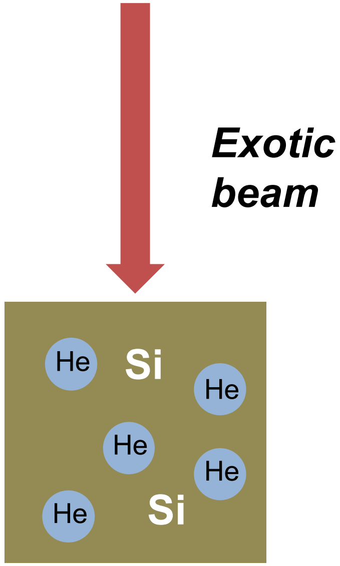


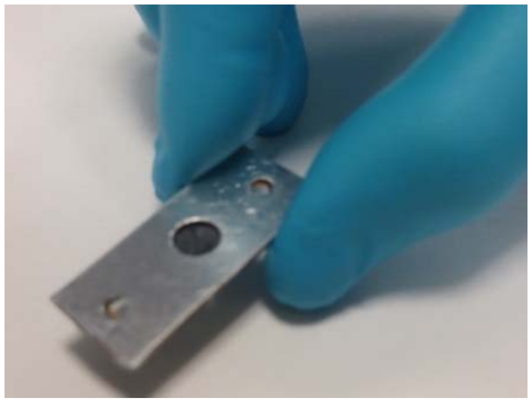
D. Galaviz *et al.*, Phys. Rev. C 71, 065802 (2005)

New Helium targets

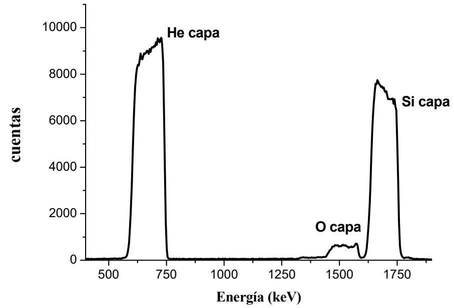
Development of He solid targets for nuclear reaction experiments

	GODINHO et al. (MS)	Vanderbist et al. (Ionic Implant.)	Raabe et al. (Ionic Implant.)	Ujic et al. (Ionic Implant.)
Metal (10^{15} at/cm^2)	**9250 (Si)**	1200 (Al)	4200 (Al)	1200 (Al)
He (10^{15} at/cm^2)	**4060**	275	270	130
O (10^{15} at/cm^2)	**700**	60	100	??

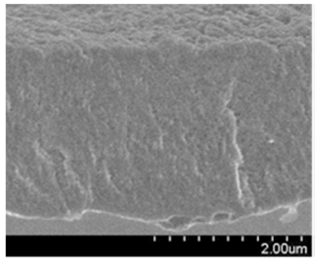




Self-supported Si:He target



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)

Motivation summary

- *Motivation:* Sensitivity of **heavy *p*-nuclei** production to **α nuclear potentials**

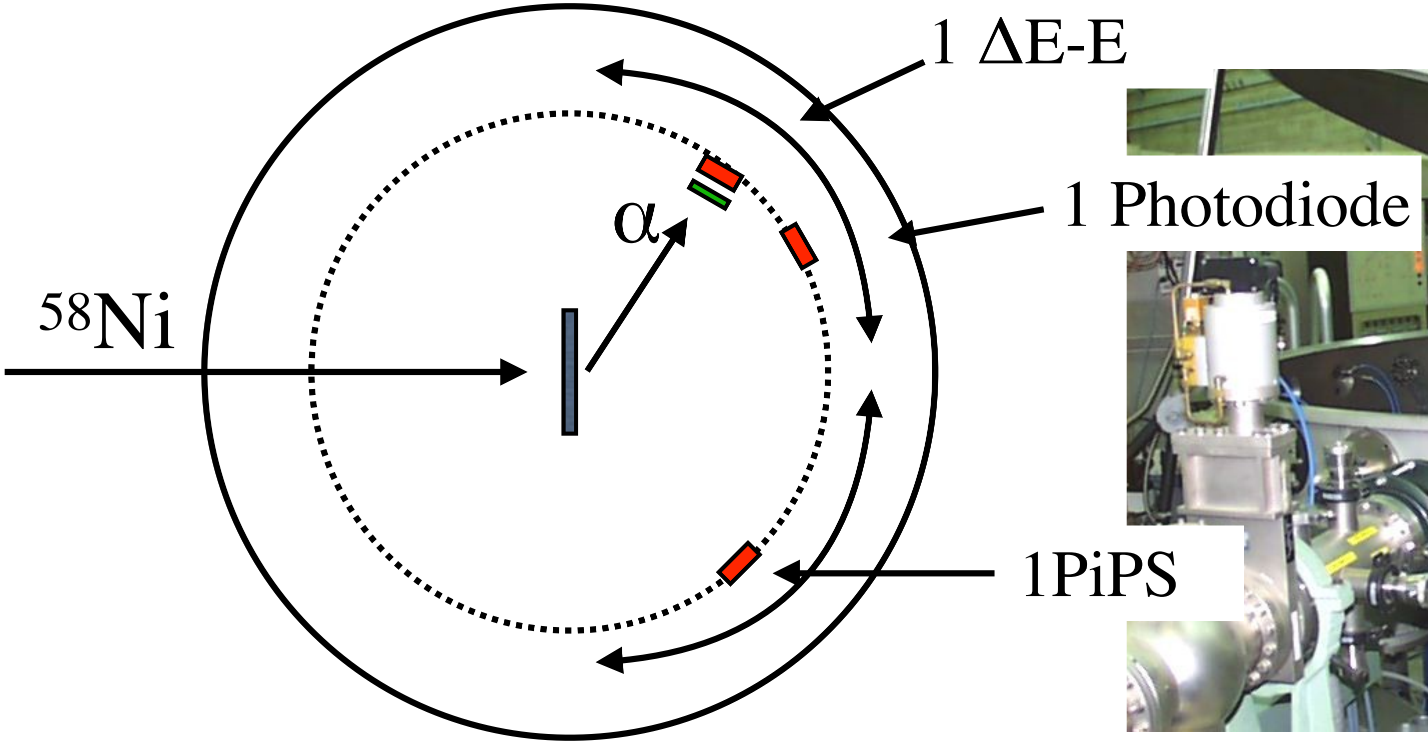
- *Goal*: Determine **α nuclear potentials** on **heavy unstable isotopes**

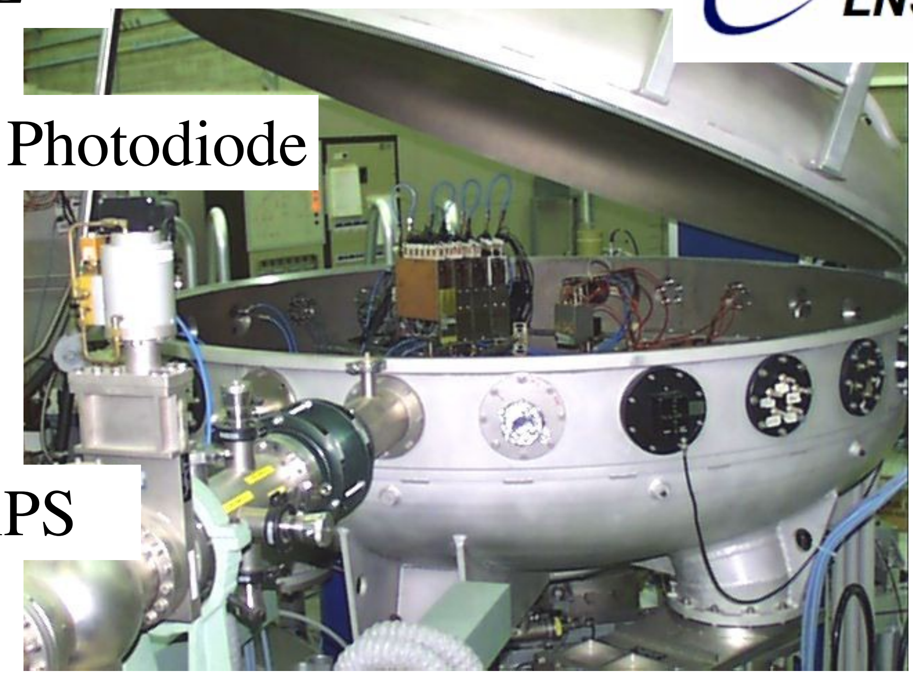
- *Opportunity:* Innovative use of **new thin helium targets** in **scattering experiments** in **inverse kinematics**

- *Proposal at ISOLDE*: Measurement of **α nuclear potentials** for the **first time** on **exotic nuclei** at energies around the **Coulomb barrier**

Test Experiment

- Performed at INFN/LNS
- Developed in the framework of an stable beam experiment proposed at the CT2000 scattering chamber

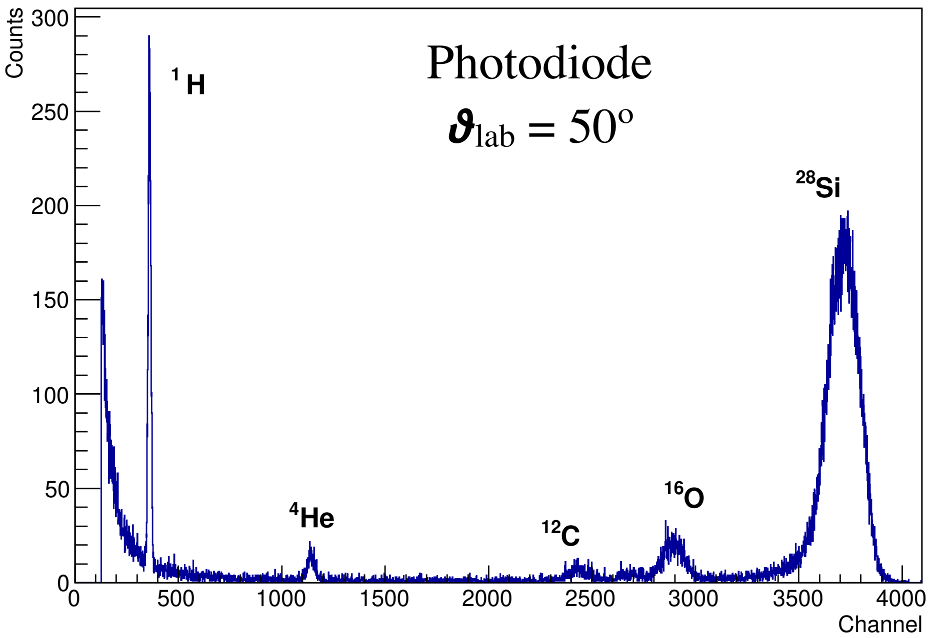


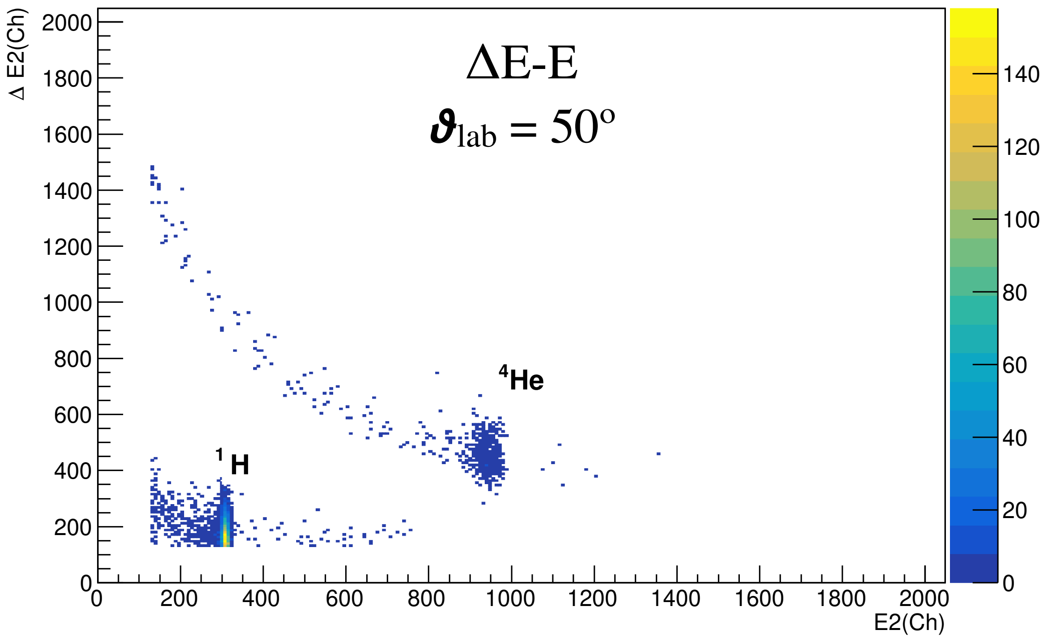


Test Experiment

- Performed at INFN/LNS
- Developed in the framework of an stable beam experiment proposed at the CT2000 scattering chamber

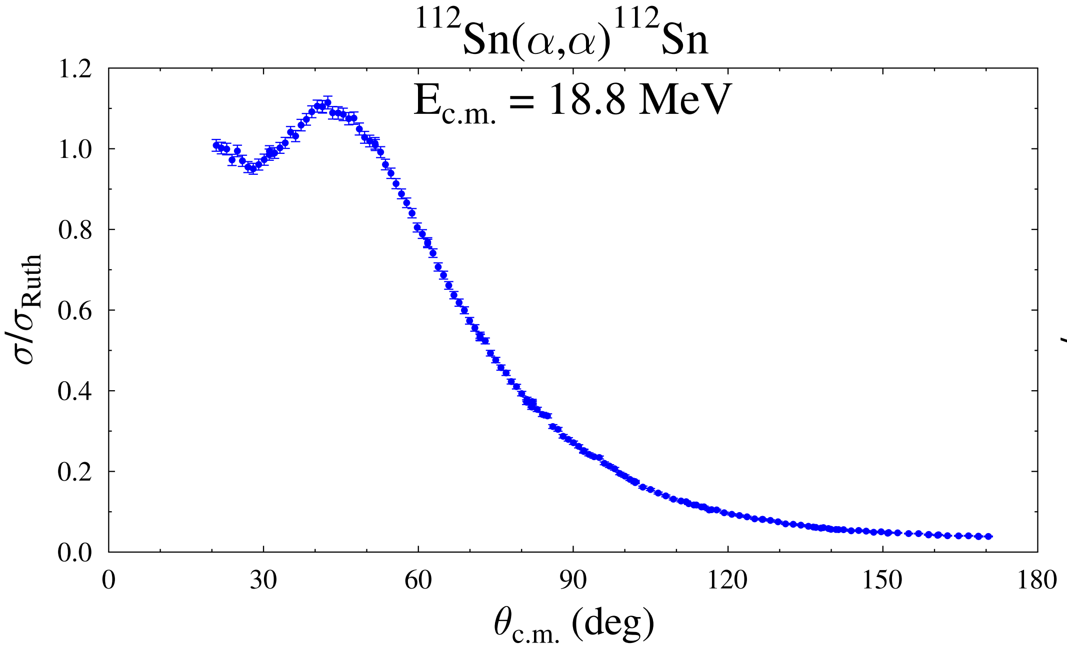
$^{4}He(^{58}Ni,\alpha)^{58}Ni$ @ 150 MeV



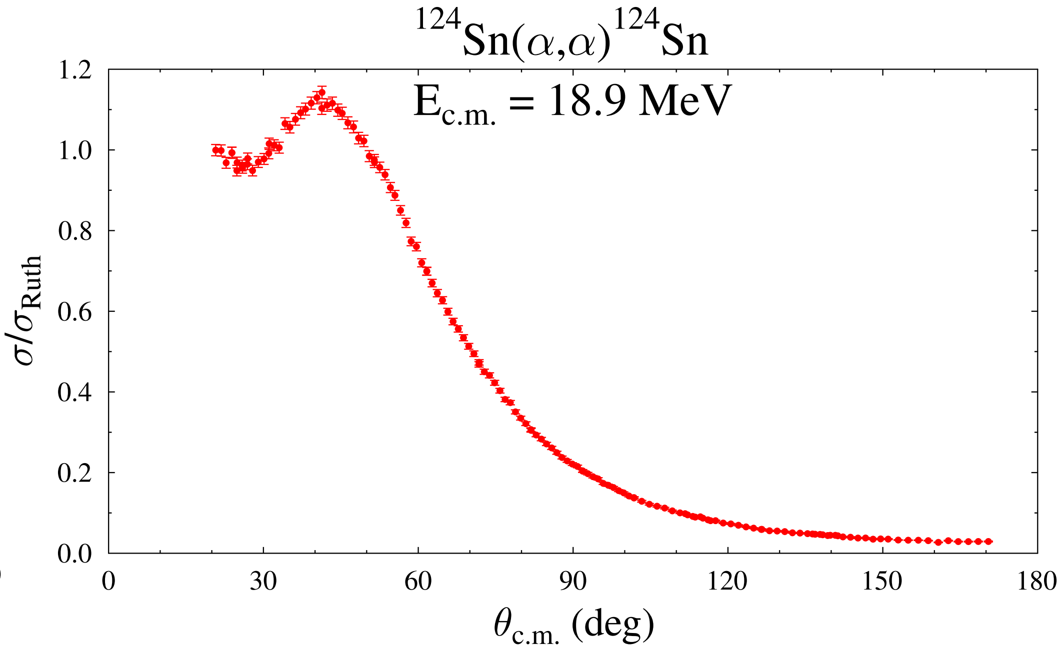


Previous Works

- Measurement of the $^{4}He(^{A}Sn,\alpha)^{A}Sn$ elastic scattering cross section in **inverse kinematics** at energies close to the Coulomb barrier



Benchmark data with new approach

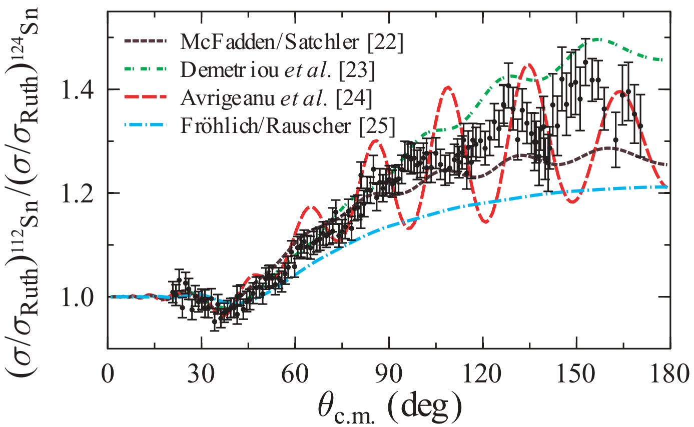


Analyse mass dependence

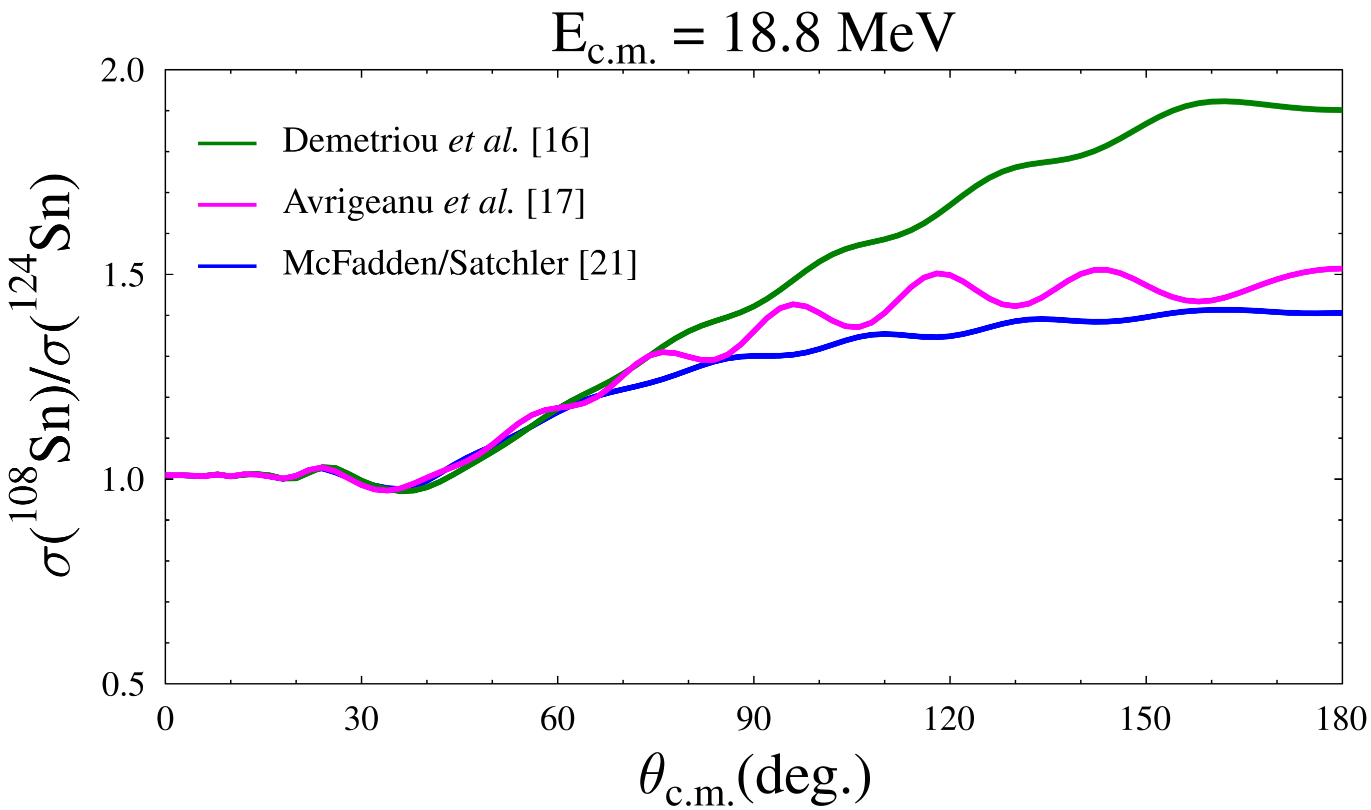
D. Galaviz *et al.*, Phys. Rev. C 71, 065802 (2005)

Proposed experiment

- Measurement of the **$^{4}He(^{A}Sn,\alpha)^{A}Sn$** reaction same E_{cm}: mass dependance of **α nuclear potentials**



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



Proposed experiment

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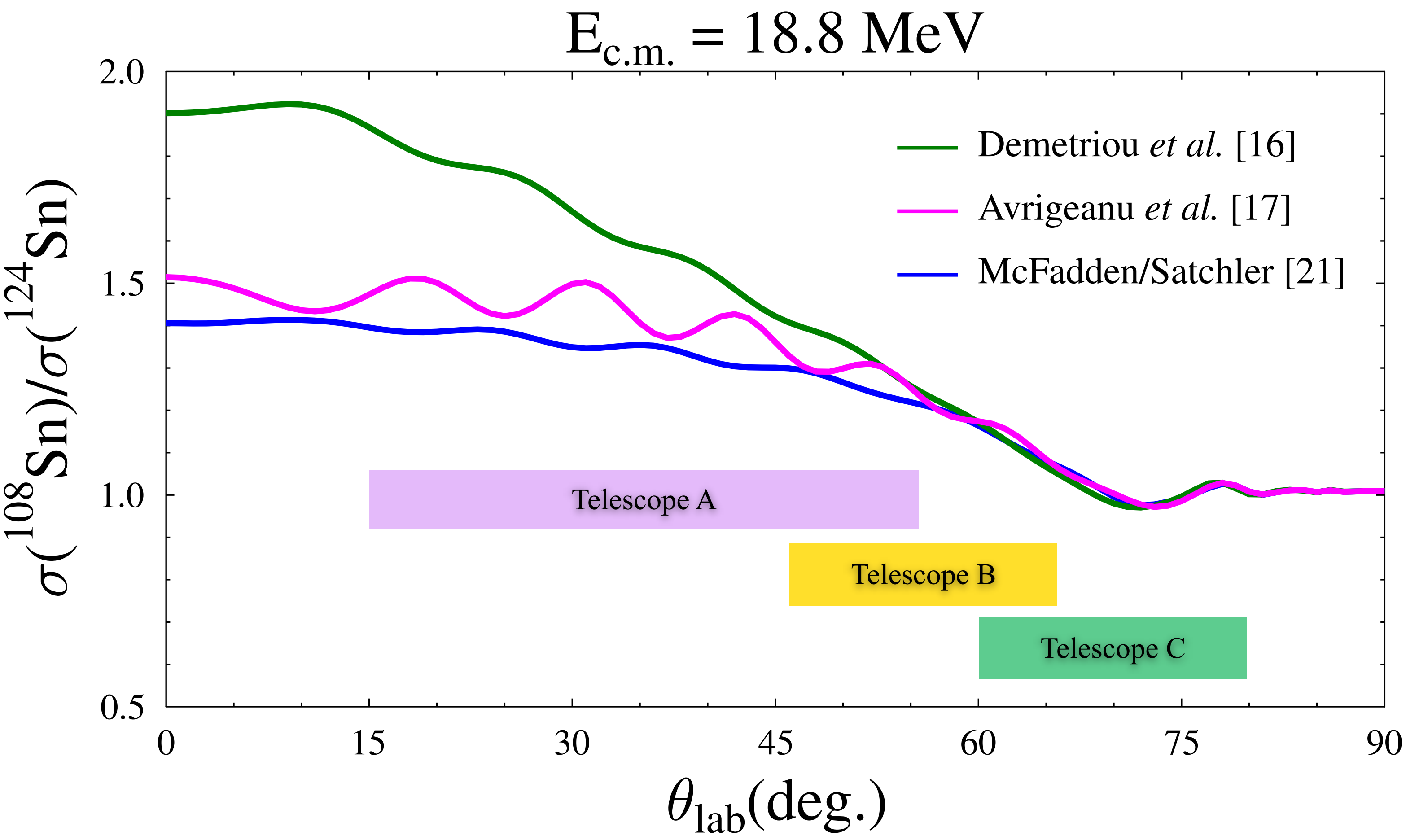
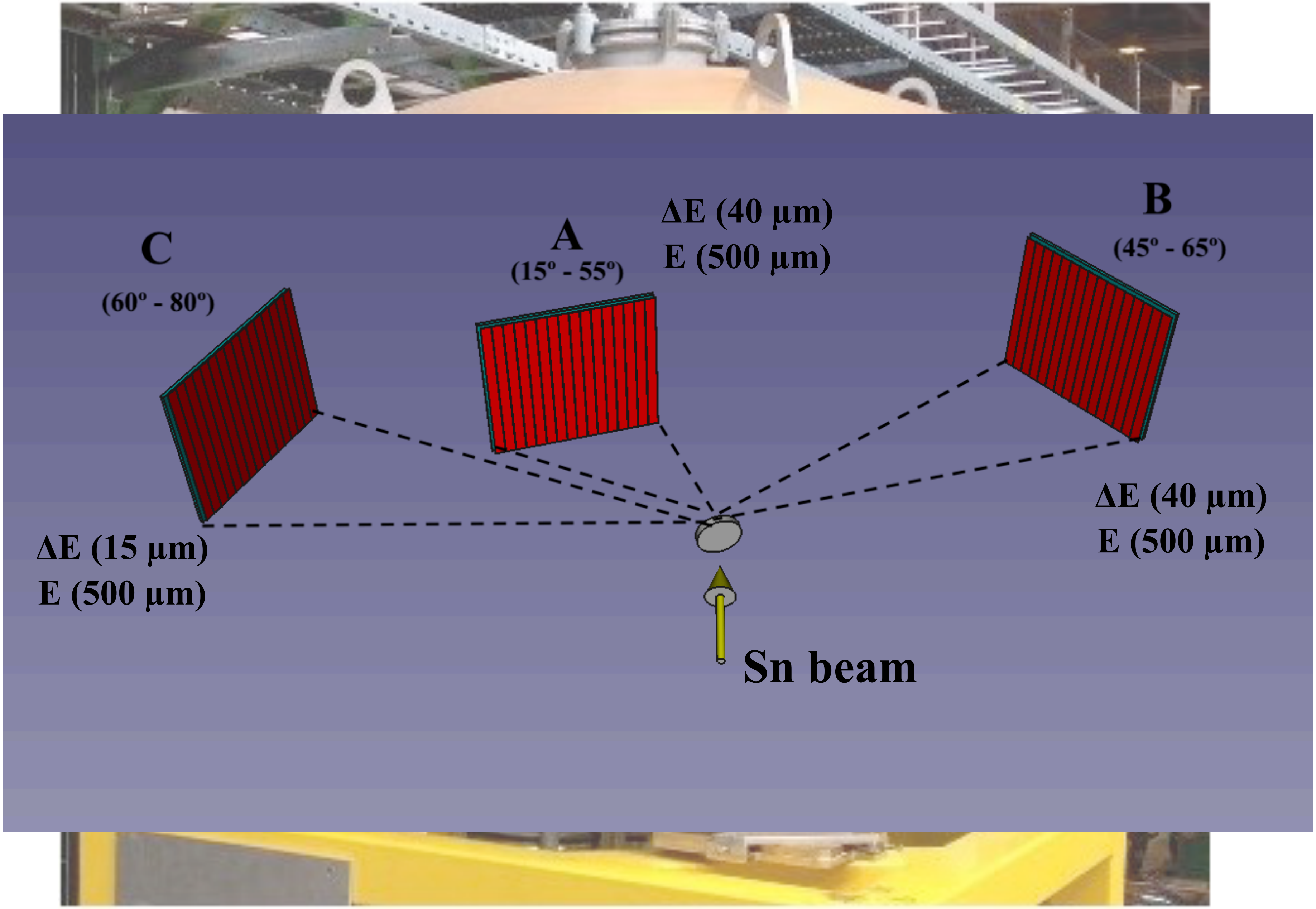
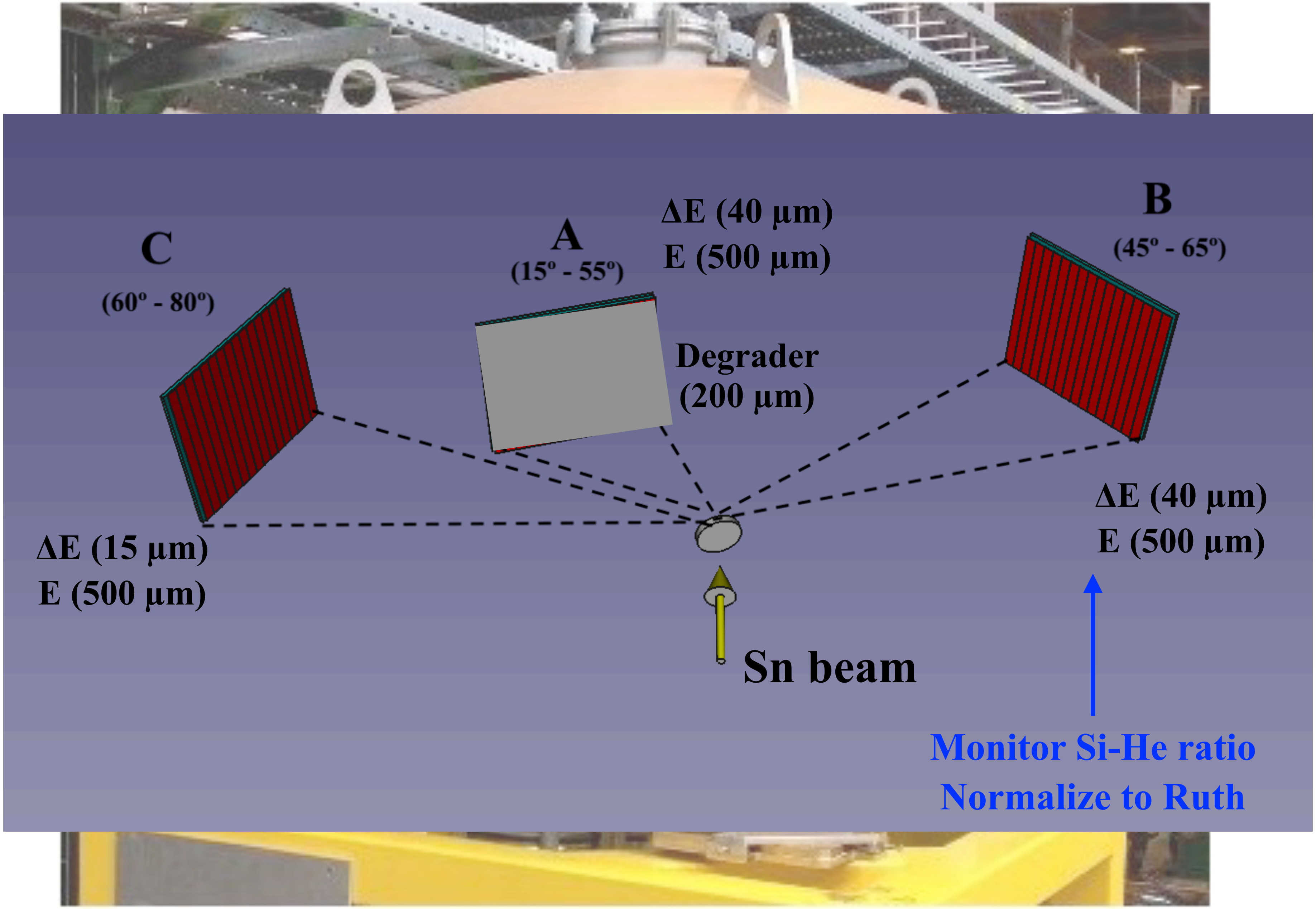


Proposed experiment

Proposed experiment



Proposed experiment



Proposed experiment

Beam	E(MeV/u)	Intensity (pps)	Shifts
^{112}Sn	4.9	5×10^7	3
^{110}Sn	4.9	5×10^7	**5**
^{108}Sn	4.9	5×10^6	**15**
	Calibration and electronics, beam changes		3

Total RIB: **20 Shifts**

Proposal Outlook

- This proposal is part of a development series:
  - Targets developed and characterized in SSF: **CNA- Seville**
  - Benchmark measurement at a LSF: **LNS-Catania**
  - Experiment using unstable isotopes in RIB: **HIE-ISOLDE**
- Follow up:
  - Analyse the impact on **p-process network** calculations
  - Measurements on **heavier unstable isotopes**

Participants

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Thank you!

Start Backup Slides

TAC Comments

α-scattering on unstable proton-rich tin isotopes in inverse kinematics for the astrophysical p-process					
CDS#	**Proposal #**	**IS #**	**Setup**	**Shifts**	**Isotopes**
CERN-INTC-2021-031	INTC-P-602		SEC (XT03)	23	110Sn; 108sn
Beam intensity/purity, targets-ion sources	The discussed yields have been recently measured have been delivered on more than one occasion.				
HIE-ISOLDE	The requested isotopes have all been delivered before. The energy of 4.9MeV/u is not problematic. The beams are quite high in intensity and may produce prompt radiation problems.				
General implantation and setup					
General Comments					
Safety	ISIEC to be provided and Electrical inspection to be performed before start of the experiment.				
TAC recommendation	**The TAC does not see any serious issues with this proposal.**				

Expected Maximum Rates

I_{max} (^{112}Sn) = 5 x 10^7 pps
Rate= 12 Hz rate
Δt_{pulse} =1 ms

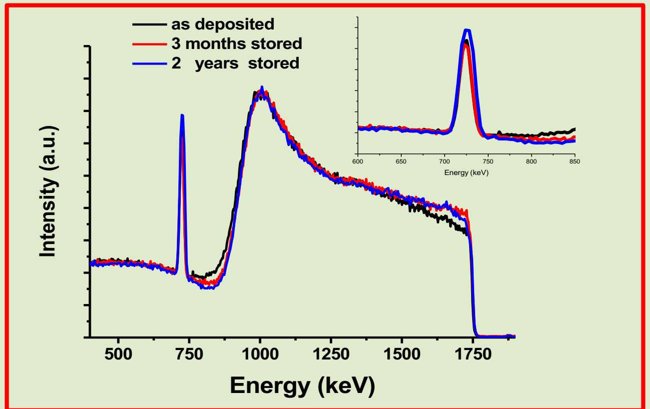
Detector	Distance (mm)	$\Delta\vartheta_{lab}$ (º)	Strip Rate (counts/s)	Strip Rate (counts/pulse)	Prompt Strip Rate (counts/s)
A	70	15º - 55º	6.5	0.55	550
B	140	45º - 65º	5.6	0.46	465
C	140	60º - 80º	24.9	2.1	2.1 x 10^3

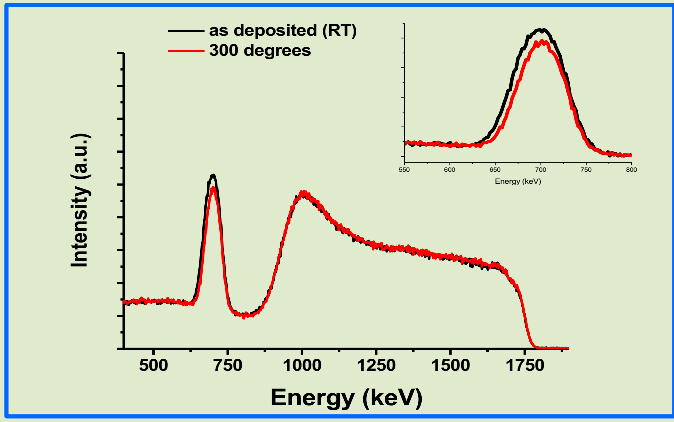
Target Stability

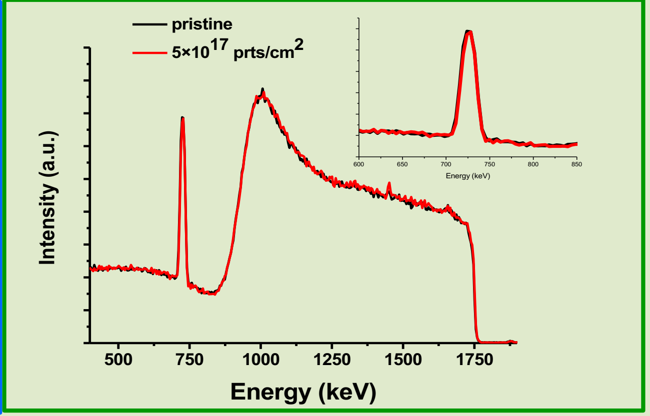
CNA-ICMS: Si:He

Stability if the targets

- ➢ Temperature
- ➢ Radiation
- ➢ Aging







V Godinho, F. J. Ferrer, et al ACS Omega, 1 (2016) 1229–1238

X CPAN DAYS Salamanca, 29 - 31 October 2018

p-process Sensitivity Studies

- Sensitivity studies of *p*-process nucleosynthesis point out the strong dependence of the α-nuclear potential in the production of heavy *p*-nuclei

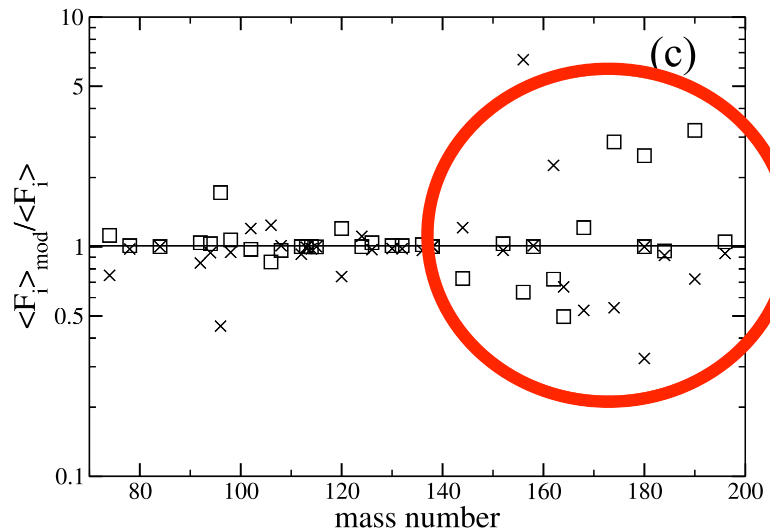


FIG. 10.—Ratio of *p*-abundances calculated with modified rates and the currently accepted HF rates for all (*a*) *n*-induced, (*b*) *p*-induced, and (*c*) α-induced reactions and their inverse processes. Squares and crosses denote results obtained with rates 3 times smaller and larger, respectively.

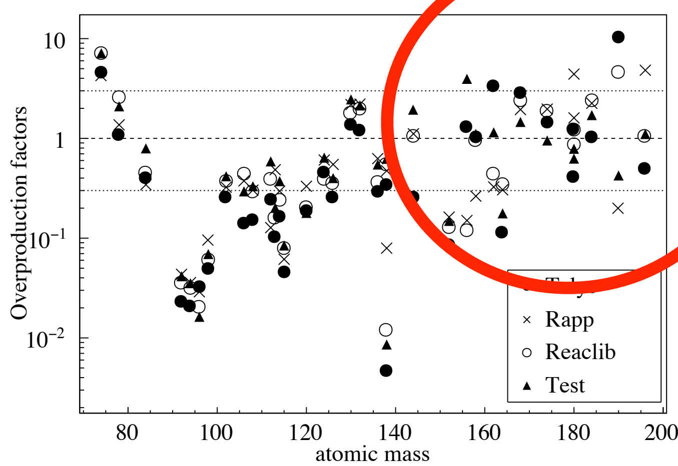
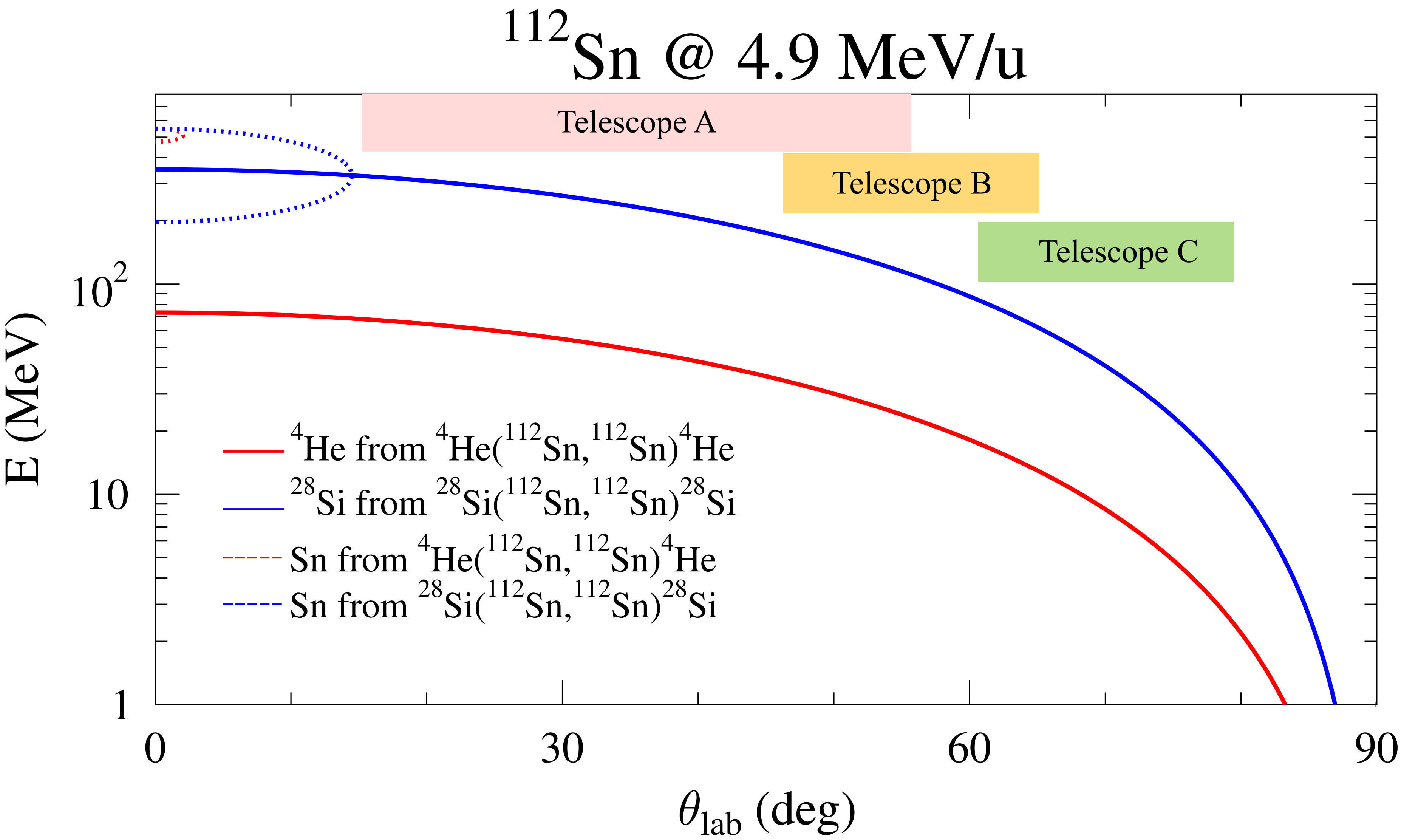


Figure 4. Overproduction factors for 35 p-nuclei obtained from post-processing calculations of 25M$_\odot$ SNII. Crosses indicate data extracted from Rapp et al, open circles and full circles indicate results from NucNet tools code using the same temperature and density trajectories and seed nuclei as Rapp et al, but with Reaclib 2.0 and Talys reaction rates, respectively (see text for details). Solid triangles are the results of the test calculations.

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

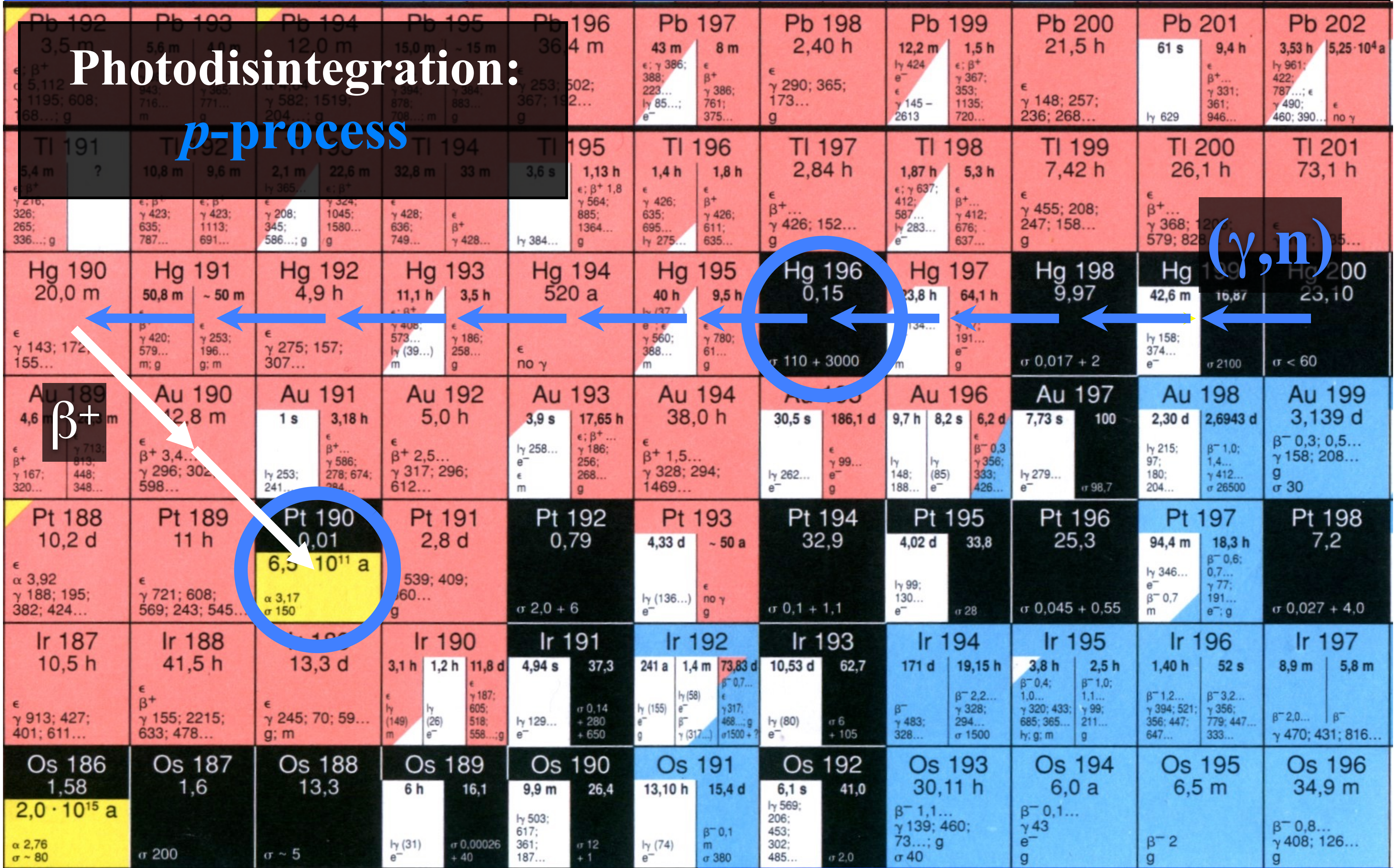
A. Simon *et al.*, J Phys. G: Nucl. Part. Phys. **44**, 064006 (2017)

Kinematics



^{112}Sn @ 4.9 MeV/u
Telescope A
Telescope B
Telescope C
^{4}He from ^{4}He(^{112}Sn,^{112}Sn)^{4}He
^{28}Si from ^{28}Si(^{112}Sn,^{112}Sn)^{28}Si
Sn from ^{4}He(^{112}Sn,^{112}Sn)^{4}He
Sn from ^{28}Si(^{112}Sn,^{112}Sn)^{28}Si
E (MeV)
10^2
10
1
0
30
60
90
θ_{lab} (deg)

Astrophysical *p*-process



Astrophysical *p*-process

Astrophysical *p*-process