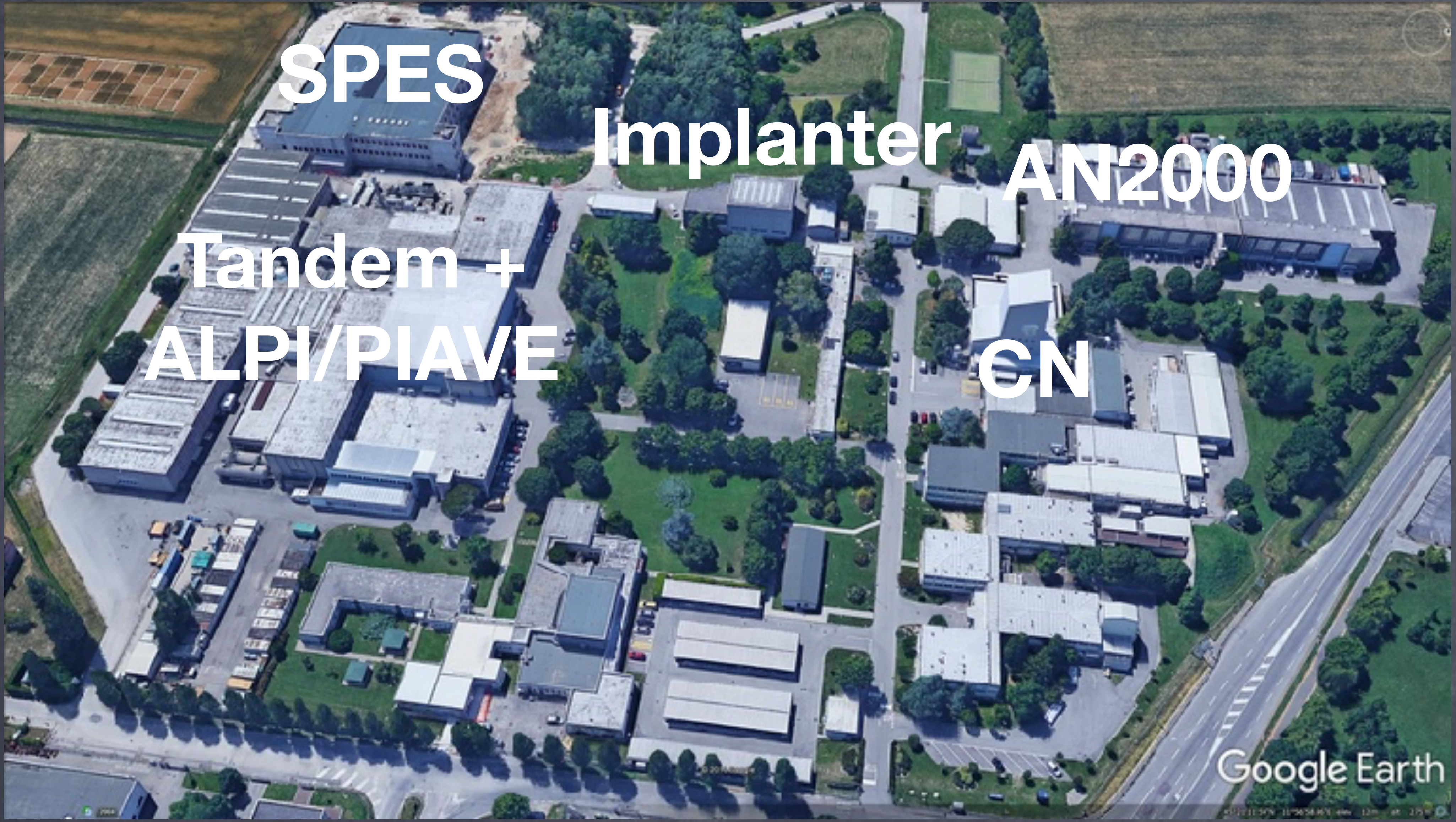
5th of July 2017 - LNGS



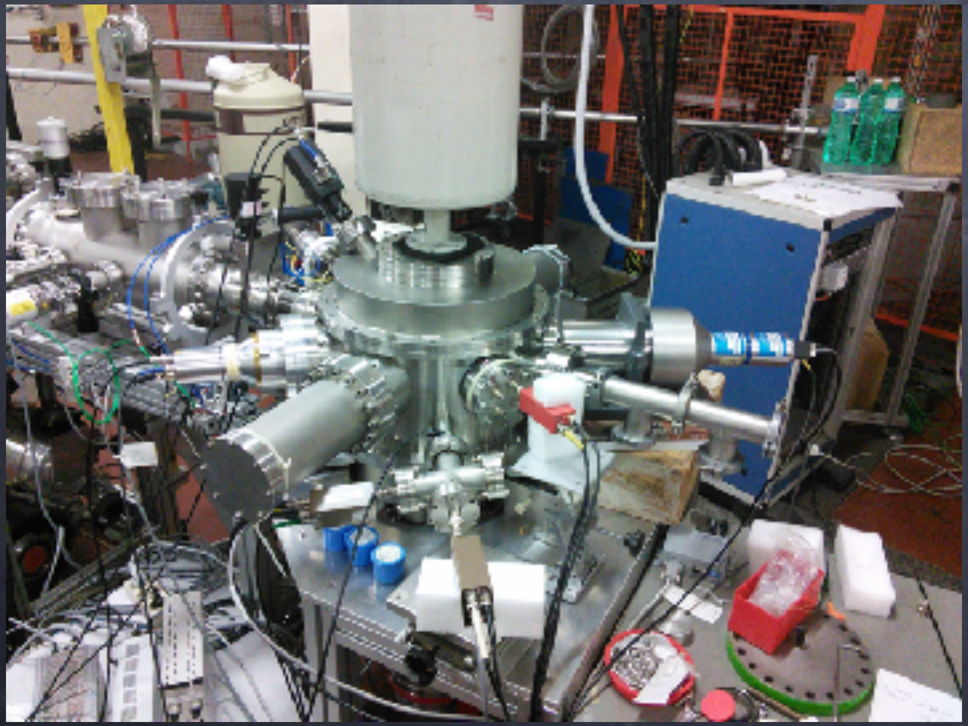
Nuclear astrophysics at LNL: $^{10}B(p,\alpha)^{7}Be$

A. Caciolli
University of Padua

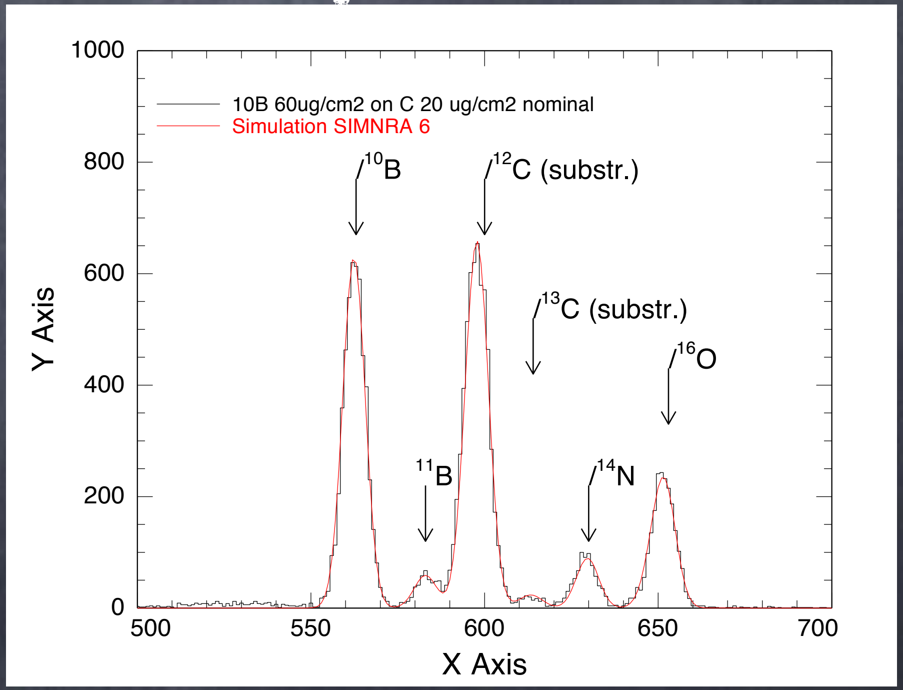
Targets preparation and analysis

- Target lab produces targets with the evaporation technique
- Implanter that was used for ^{22}Ne targets with good stability
- Reactive Sputtering setup (TiN and CrN)
- RBS, NRA, ERDA, Micro-beam facilities at AN2000, and CN
- SIMS facility at the Padua University

dedicated to study ^{12}C target with a isotopic ratio ^{12}C/^{13}C above 10^5 to be used at LUNA-MV to study the ^{12}C(α,γ)^{16}O reaction

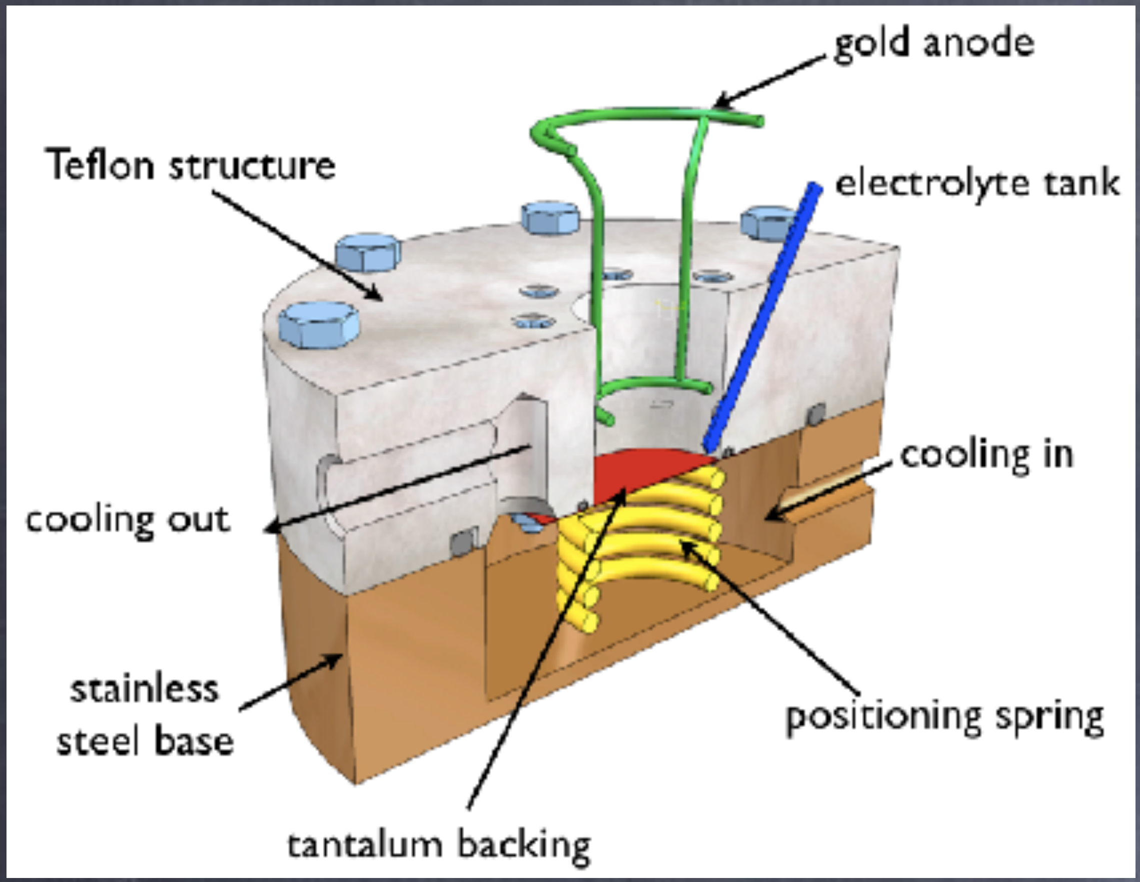


^{10}B(p,α)^{7}Be study: ^{10}B/C target analysis with RBS



target characterisation and study of contaminant

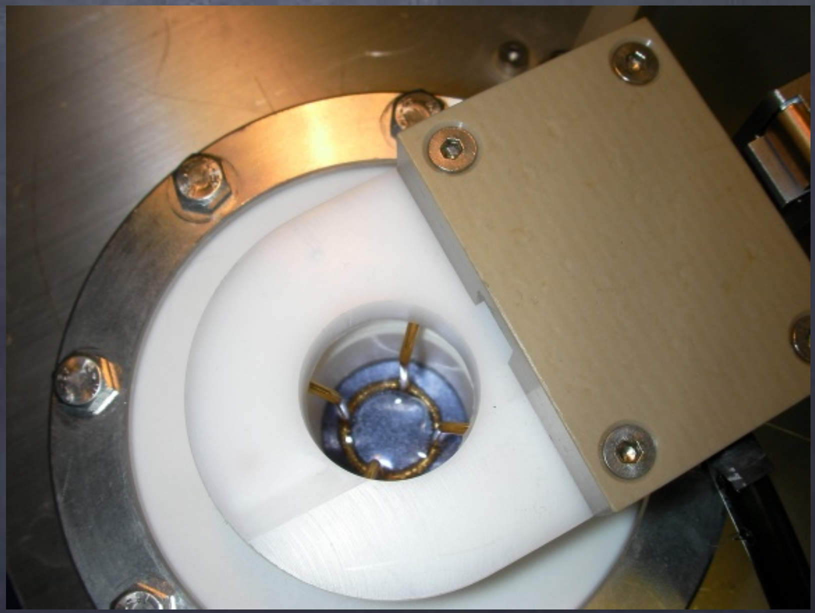
Ta_2O_5 LUNA targets



Ta_2O_5 enriched targets
^{17}O up to 69% (with 5% ^{18}O)
^{18}O up to 96%

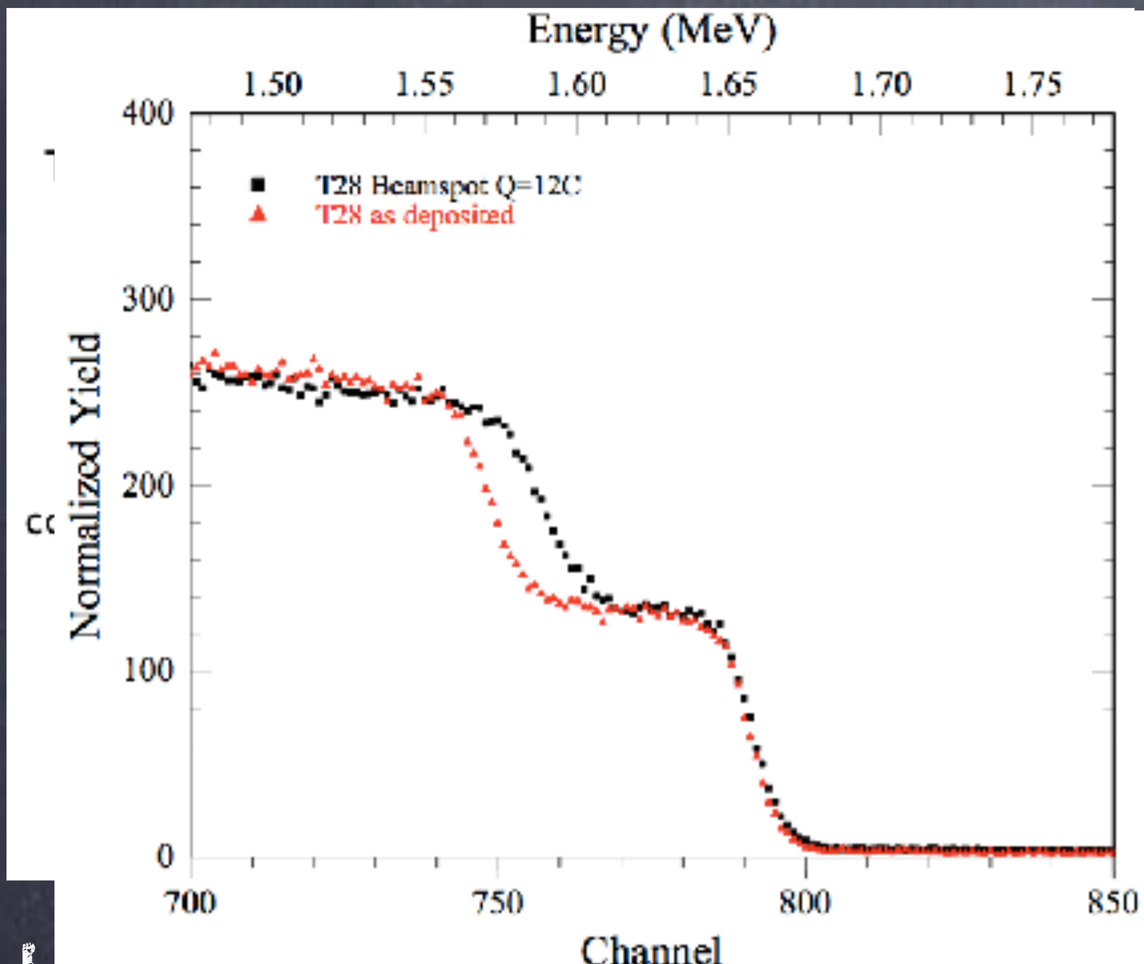
backing treated with acid citric and cooled to 25 °C during the anodisation process

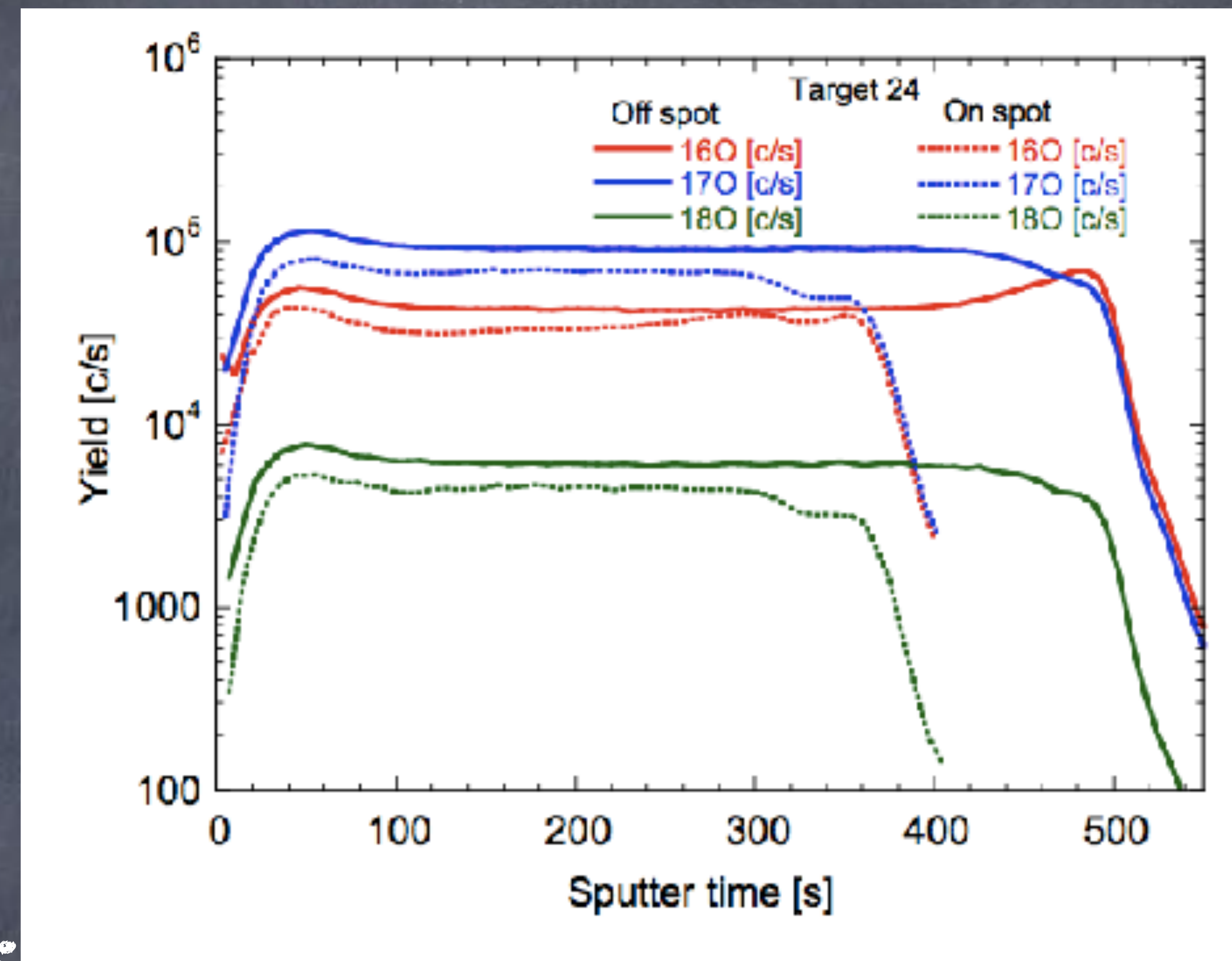
targets from 110 nm up to 550 nm

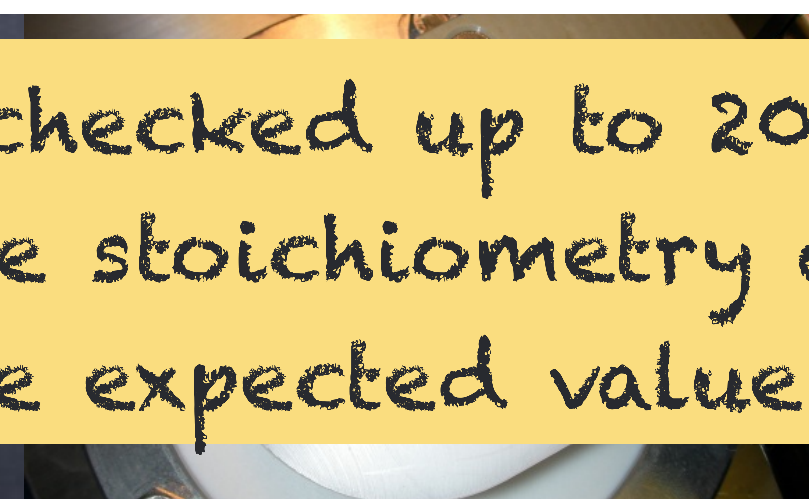


stoichiometry and isotopic oxygen abundances checked by RBS and SIMS techniques

Ta_2O_5 LUNA targets





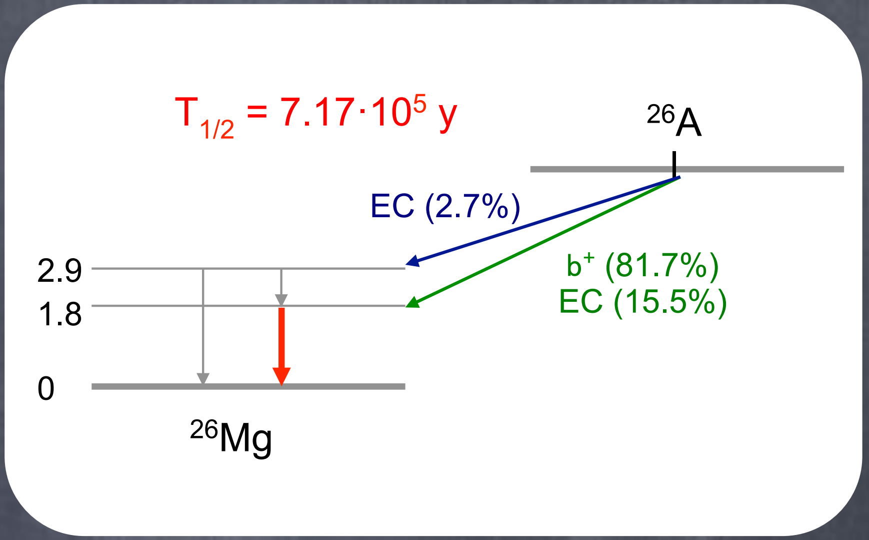


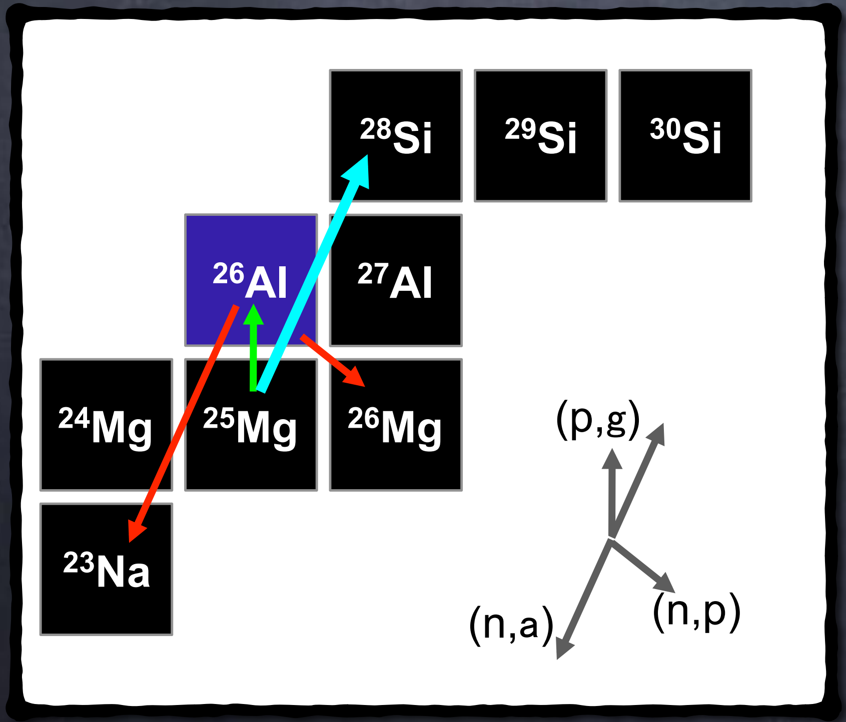
target stability monitored and checked up to 20 C irradiated charge. After that value stoichiometry and isotopic ratio differs from the expected value

Study of $^{25}Mg(\alpha,n)^{28}Si$

The detection of ^{26}Al in our Galaxy and in pre-solar meteorites is a direct proof of "recent" nucleosynthesis

^{26}Al is mainly produced by explosive C/Ne burning in stars with $M > 8\ M_\odot$ (Limongi and Chieffi 2006)

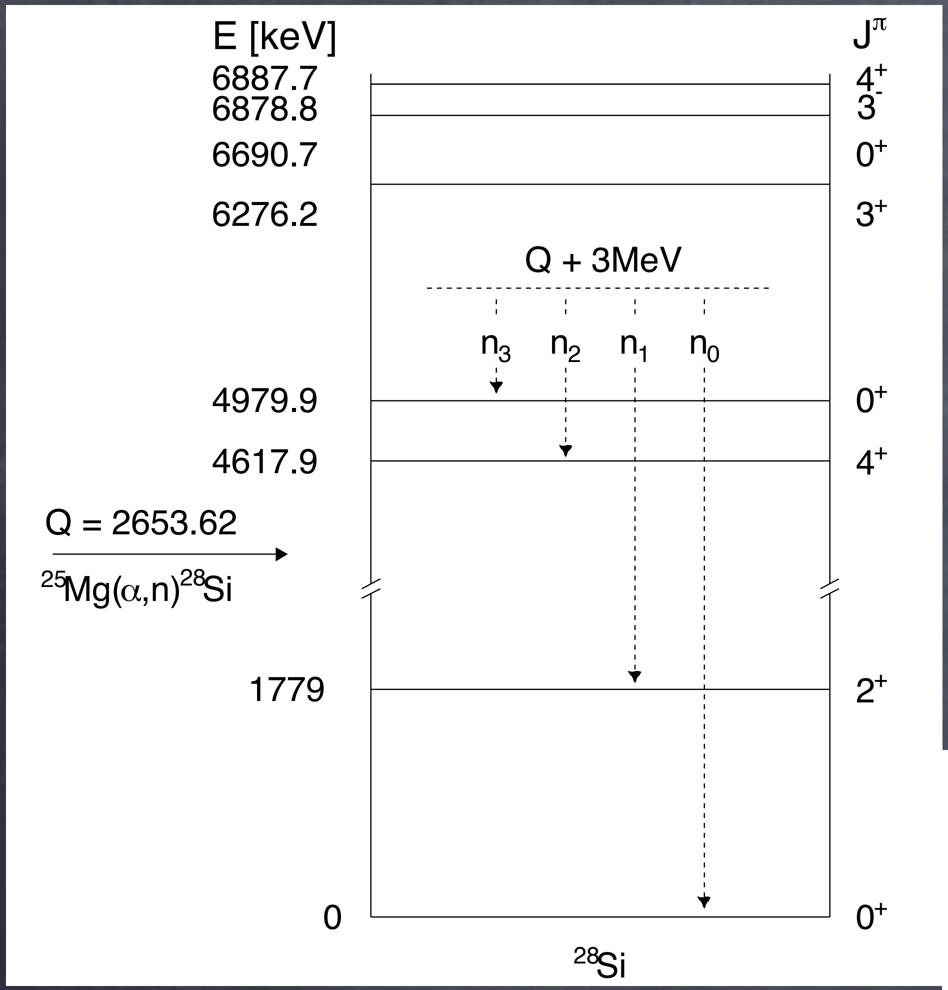


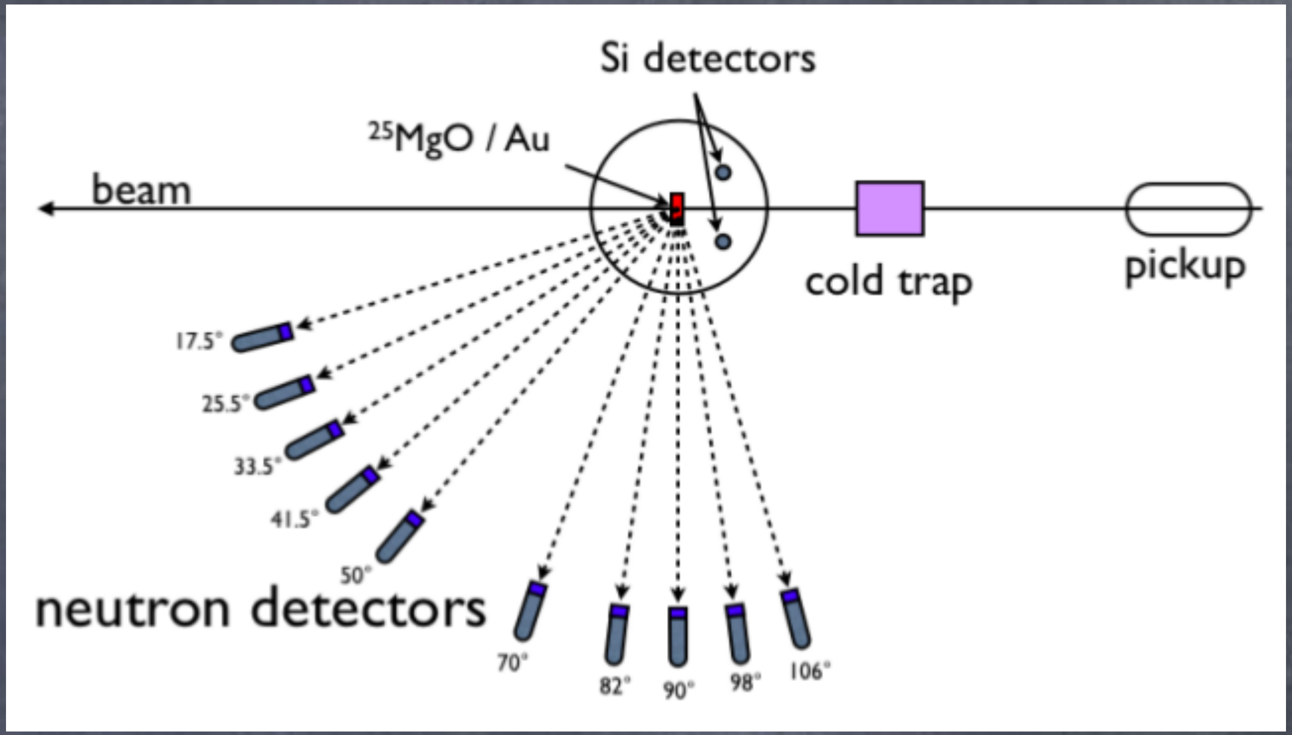


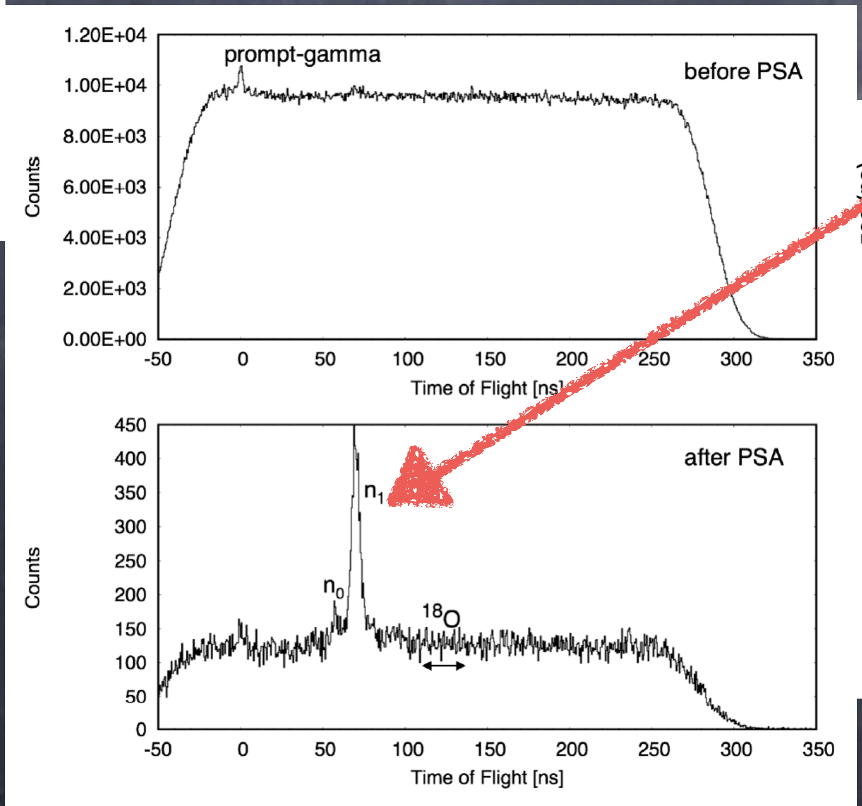
Reaction[b]	Rate Multiplied By 10	2	0.5	0.1	Source[c]	Uncertainty[d]
$^{25}Mg(\alpha,n)^{28}Si$	0.10	0.49	1.8	4.0	nacr	18%
$^{24}Mg(n,\gamma)^{25}Mg$	5.2	1.6	0.61	0.24	ka02	
$^{26}Al^t(n,p)^{26}Mg$	0.14	0.58	1.6	3.2	present	
$^{25}Mg(p,\gamma)^{26}Al^t$	1.7	1.4	0.58	0.14	il10	4%
$^{30}Si(p,\gamma)^{31}P$	0.51	0.77	1.3	2.0	il10	14%
$^{20}Ne(\alpha,\gamma)^{24}Mg$	1.8	1.4	0.64	0.28	il10	11%

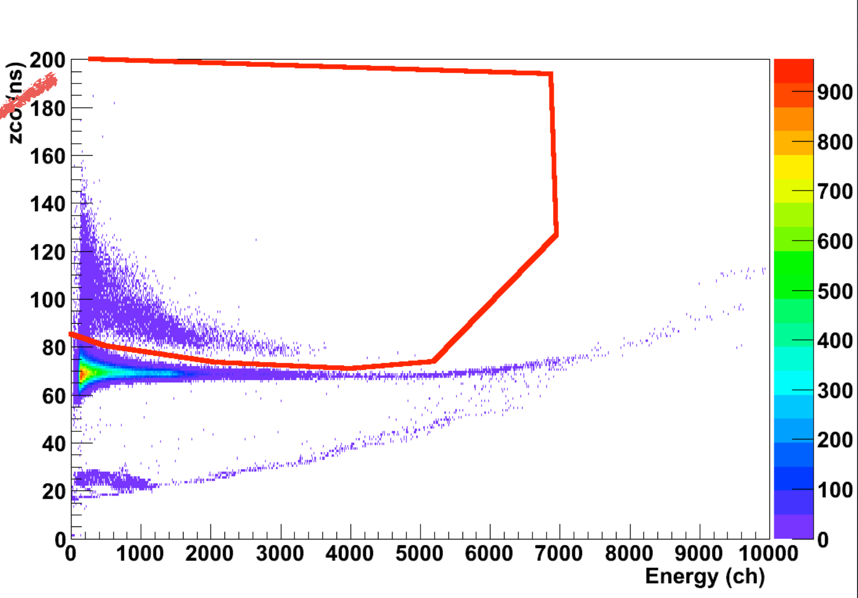
Iliadis et al, APJSS 2011

$^{25}Mg(\alpha,n)^{28}Si$ experiment



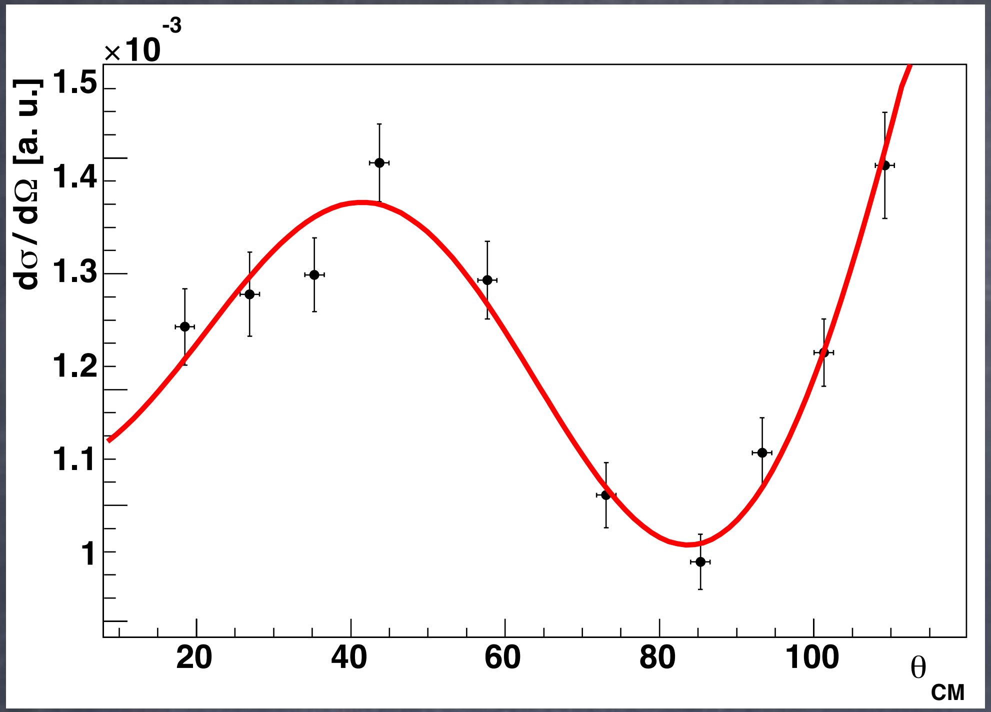


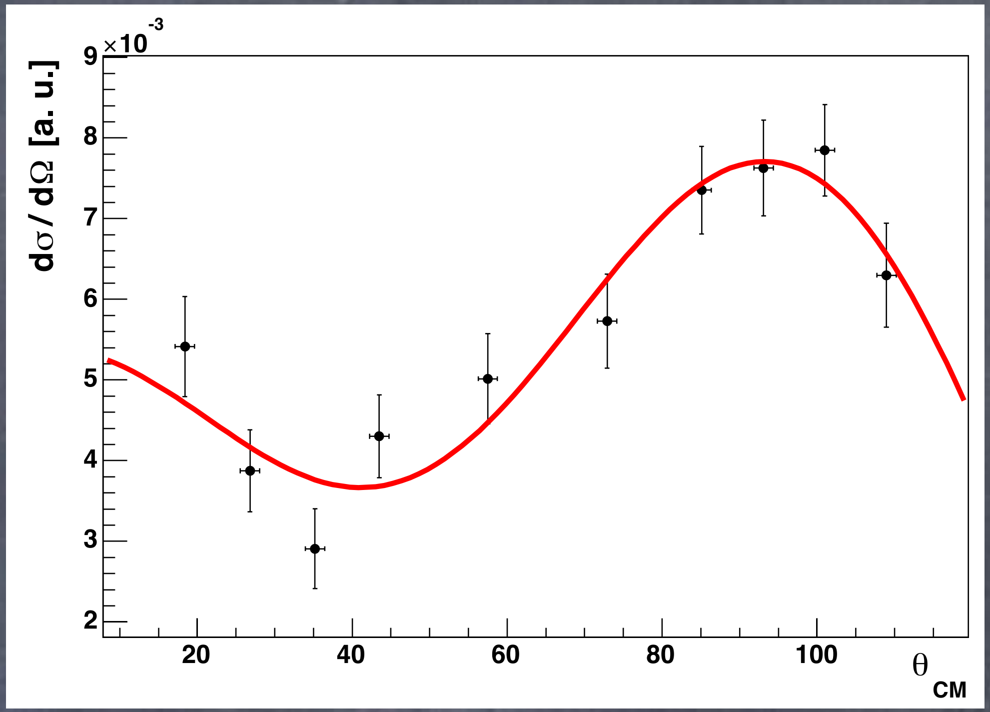




- Beam Energy: 3, 3.5, 4, 4.5, 5 MeV
- Beam Current: 200 pnA pulsed beam
- Target MgO/Au (70μg/cm^2, ^{25}Mg 95.75%)
- 2 Si detectors @ 150°
- 2 $LaBr_3$(Cr) for γ-detection
- RIPEN placed from 17.5° to 106°

$^{25}Mg(\alpha,n)^{28}Si$ results





We measured the angular distribution at five energies from 3 up to 5 MeV and we observed discrepancies with respect to the fitting assumptions made in a previous paper

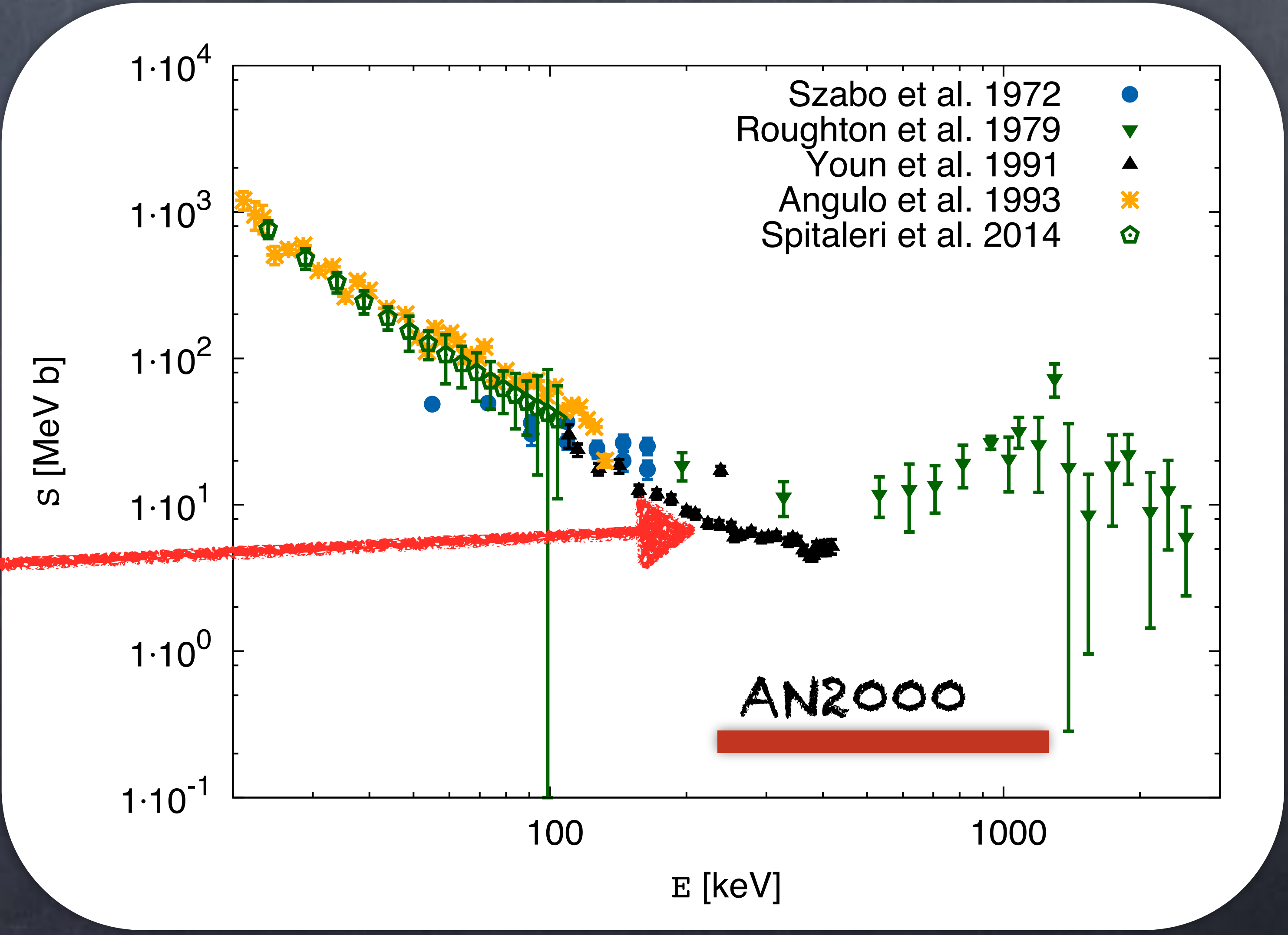
Caciolli et al. EPJA2014

A. Caciolli, T. Marchi, R. Depalo, S. Appannababu, N. Blasi, C. Broggini, M. Cinausero, G. Collazuol, M. Degerlier, D. Fabris, F. Gramegna, M. Leone, A. Lombardi, P. Mastinu, R. Menegazzo, G. Montagnoli, C. Rossi Alvarez, V. Rigato, and O. Wieland

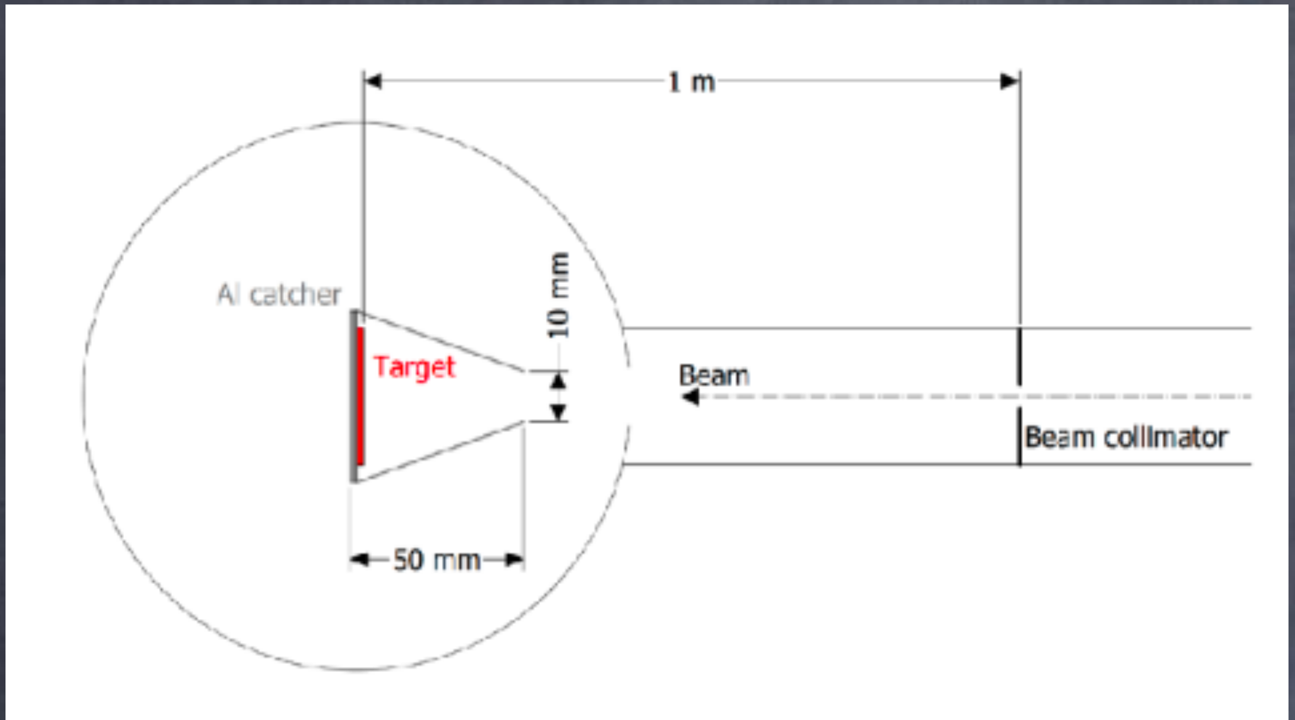
$^{10}B(p,\alpha)^{7}Be$ study

- It is important for BBN and as contaminant in new generation fusion reactors
- data in literature shows discrepancies in the energy region of the AN2000 and high uncertainties
- Indirect methods needs new data with high precision for normalisation

Angulo et al. normalised previous data from Youn et al by a factor 1.83



$^{10}B(p,\alpha)^{7}Be$ experiment



Setup for activation method

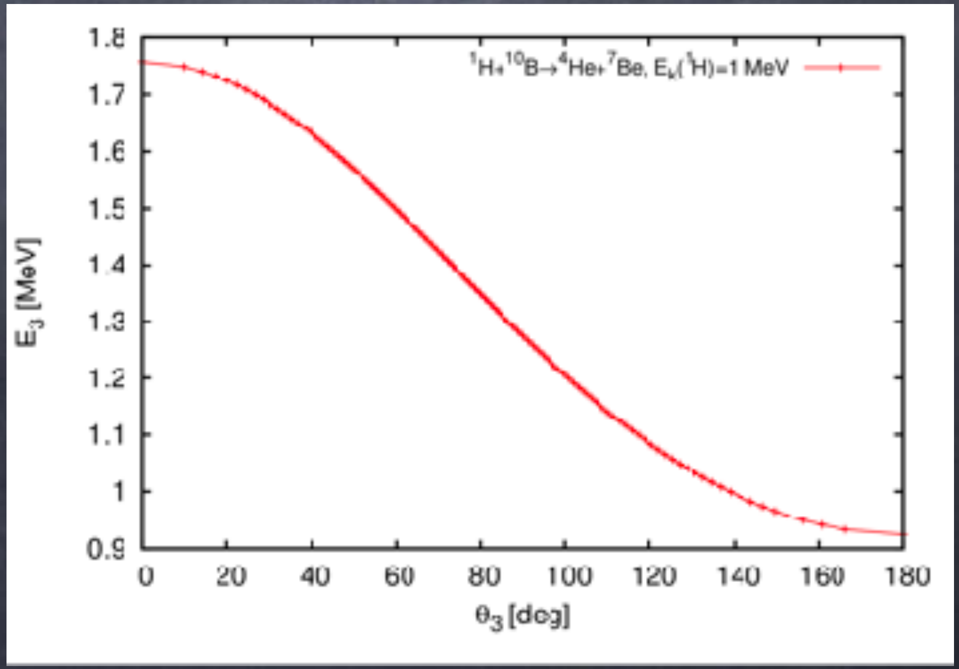
The target were irradiated with proton beam for several hours.

Cross section determined by counting the decays of the ^{7}Be ($T_{1/2}$ ~ 57 d) produced during the irradiation. The low level counting facility of the LNL laboratories were used for this purposes.
The measurements at the AN2000 were done in December 2014 and the irradiated samples were counted until March 2015

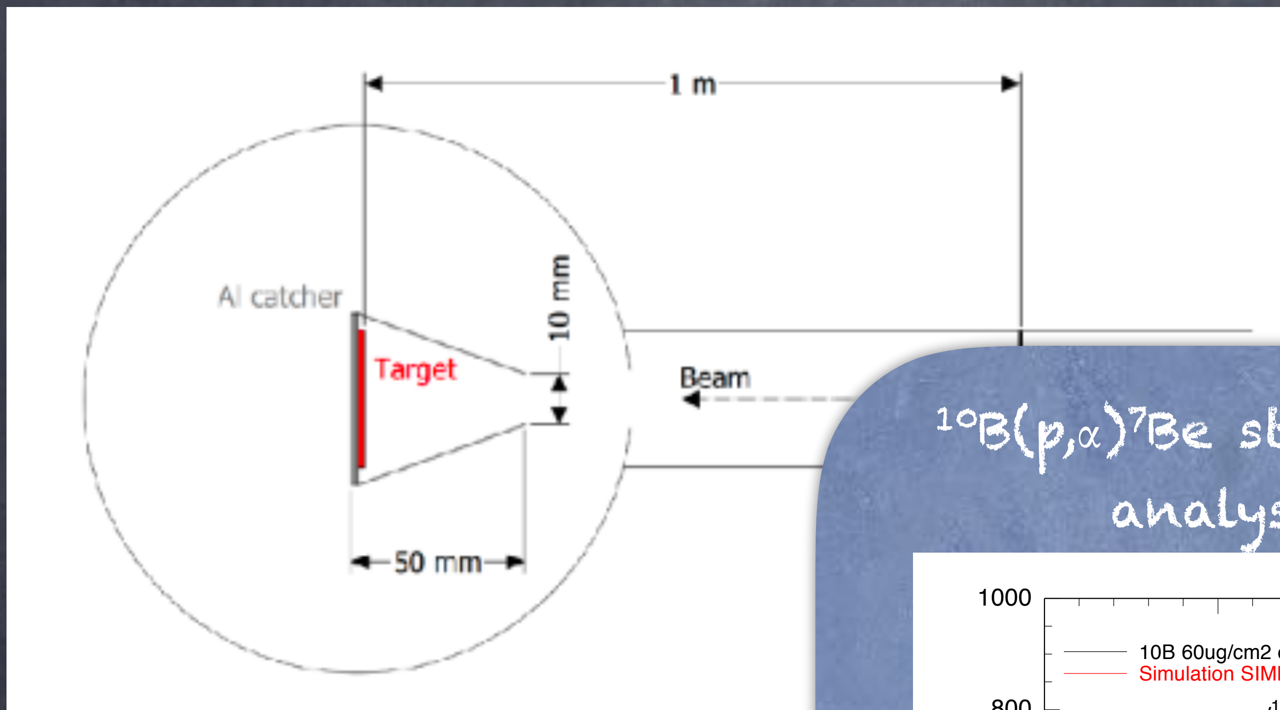
E = 250-1190 keV

I = 200 - 300 nA

Target surrounded by a 0.2 mm thick Al catcher to collect backscattered ^{7}Be nuclei



$^{10}B(p,\alpha)^{7}Be$ experiment

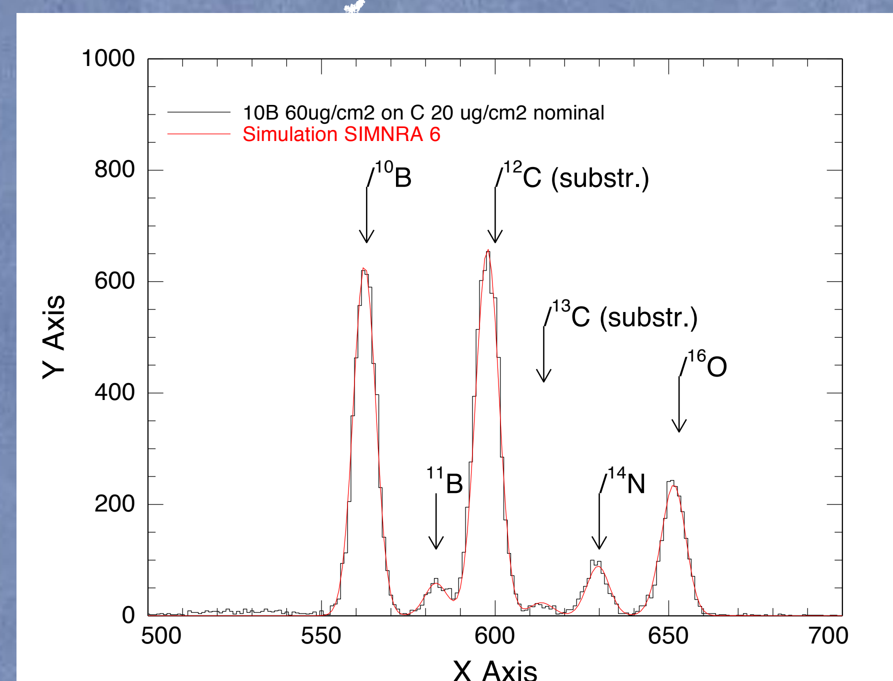


Setup for activation method

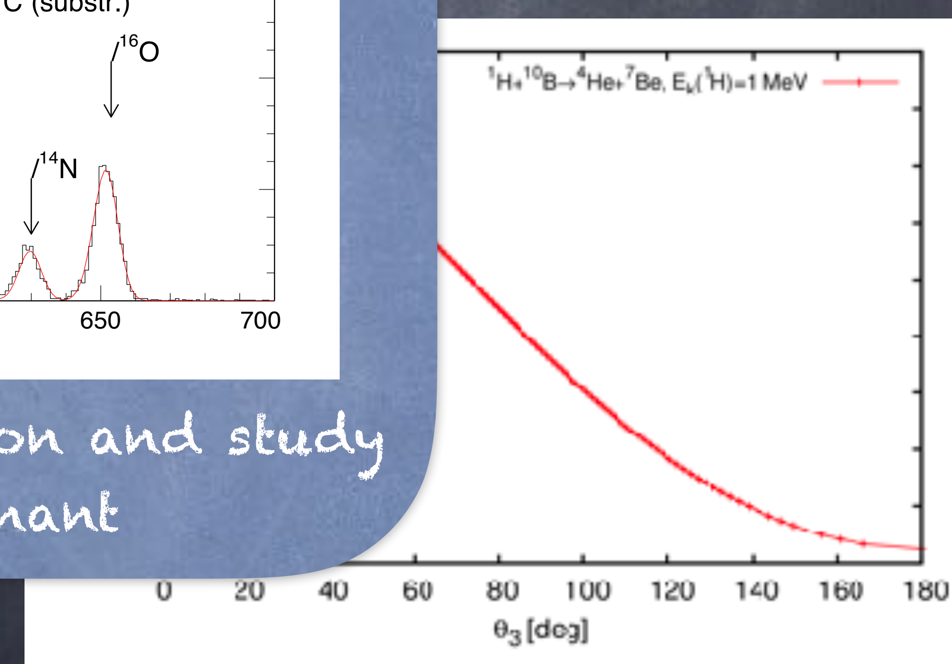
The target were irradiated with proton beam for several hours.

Cross section determined by counting the decays of the ^{7}Be ($T_{1/2}$ ~ 57 d) produced ... diation. The low level ... of the LNL laboratories ... or this purposes. ... ts at the AN2000 were ... 2014 and the irradiated ... nted until March 2015

$^{10}B(p,\alpha)^{7}Be$ study: $^{10}B/C$ target analysis with RBS



target characterisation and study of contaminant



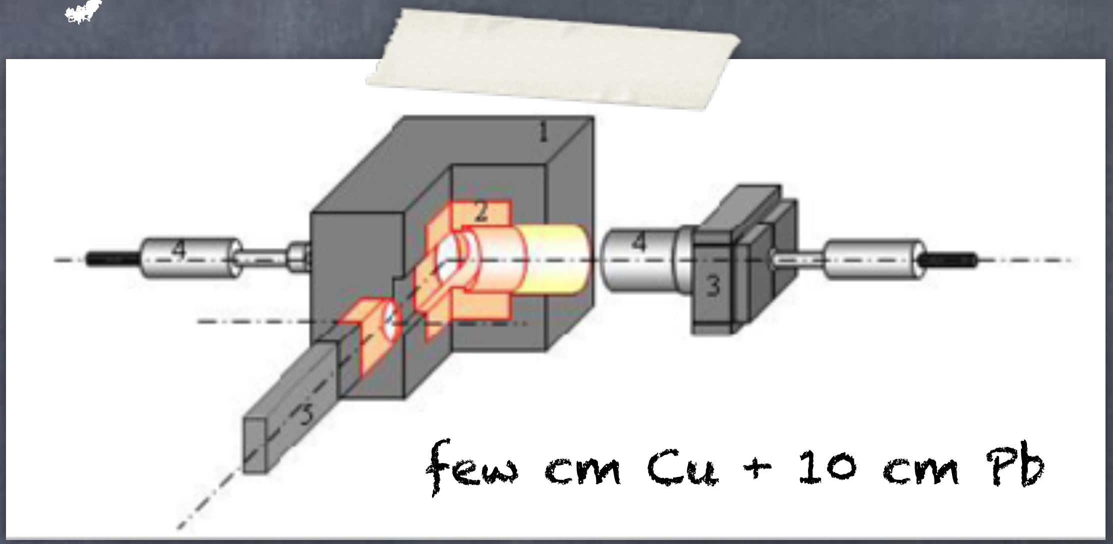
E = 250-1190 ke...

I = 200 - 300 ...

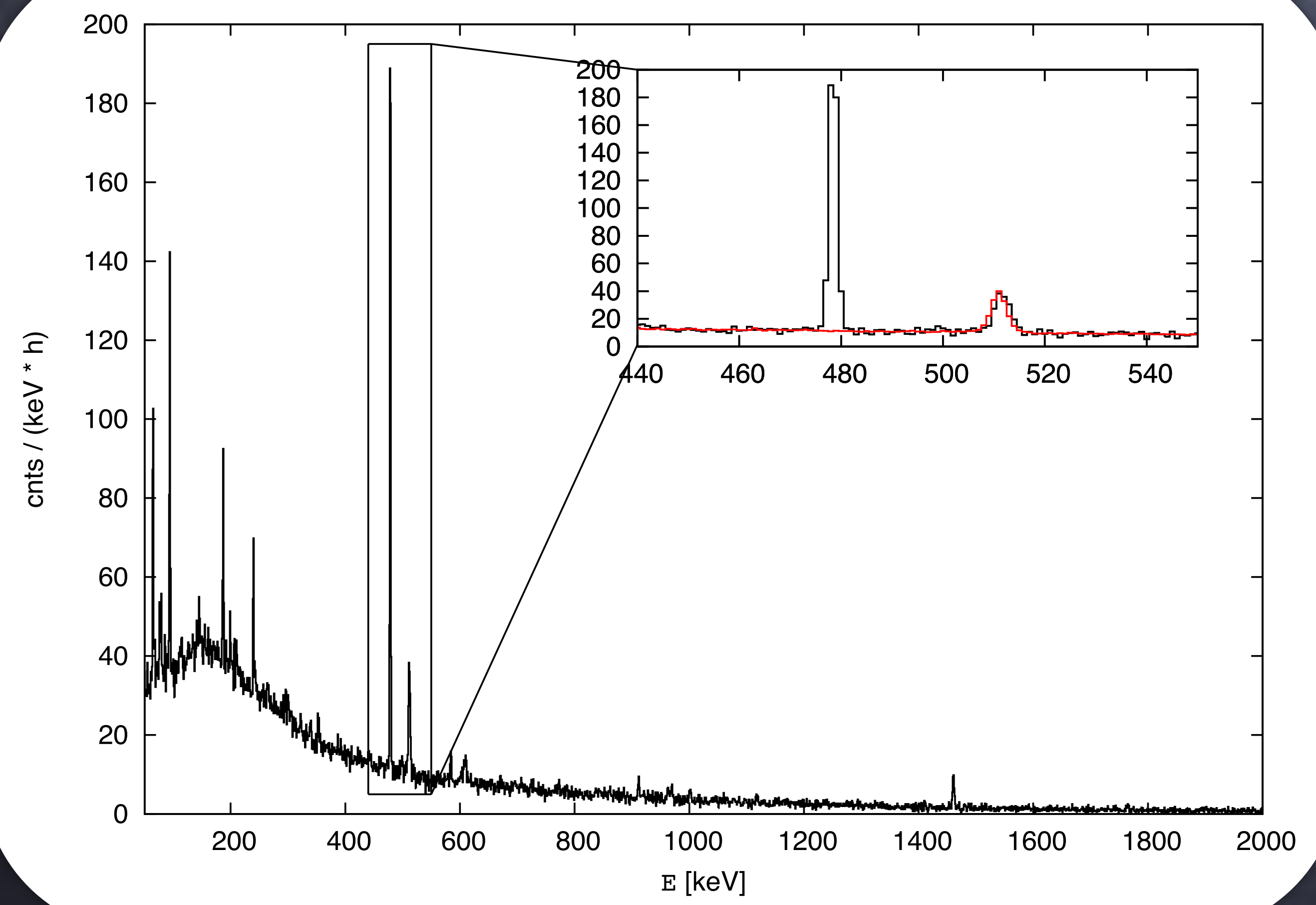
Target surrounded by a ... Al catcher to collect back... nuclei

$^{10}B(p,\alpha)^7Be$ experiment

Activation method: ^7Be decay counted in the low counting facility of LNL

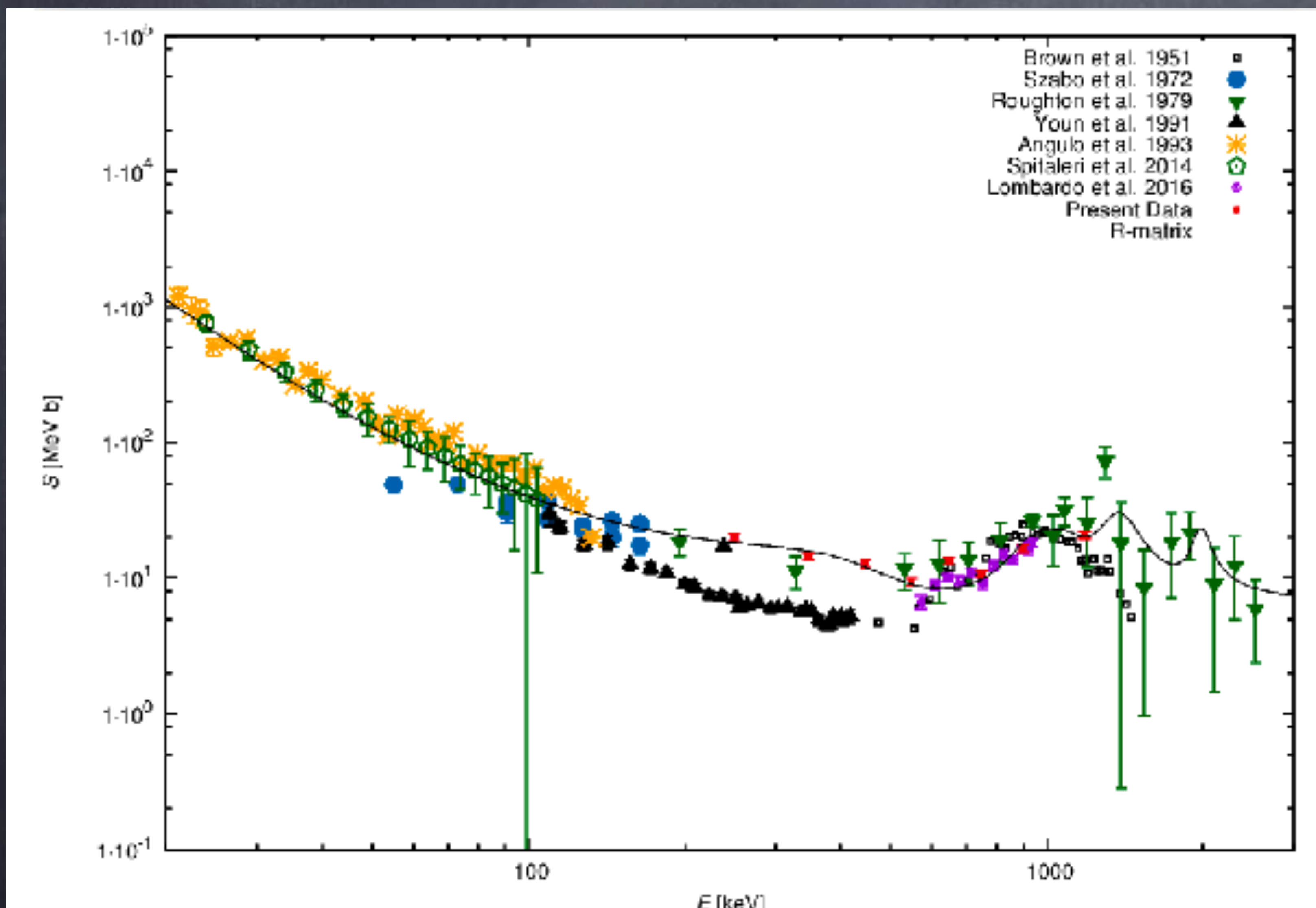


bck reduction of a factor 100 in the ROI (478 keV) ≃ 0.01 cps



$^{10}B(p,\alpha)^7Be$ results

A. Caciolli, R. Depalo, C. Broggini, M. La Cognata, L. Lamia, R. Menegazzo, L. Mou, S. M. R. Puglia, V. Rigato, S. Romano, C. Rossi Alvarez, M. L. Sergi, C. Spitaleri, A. Tumino - EPJ A 52 (2016) 136

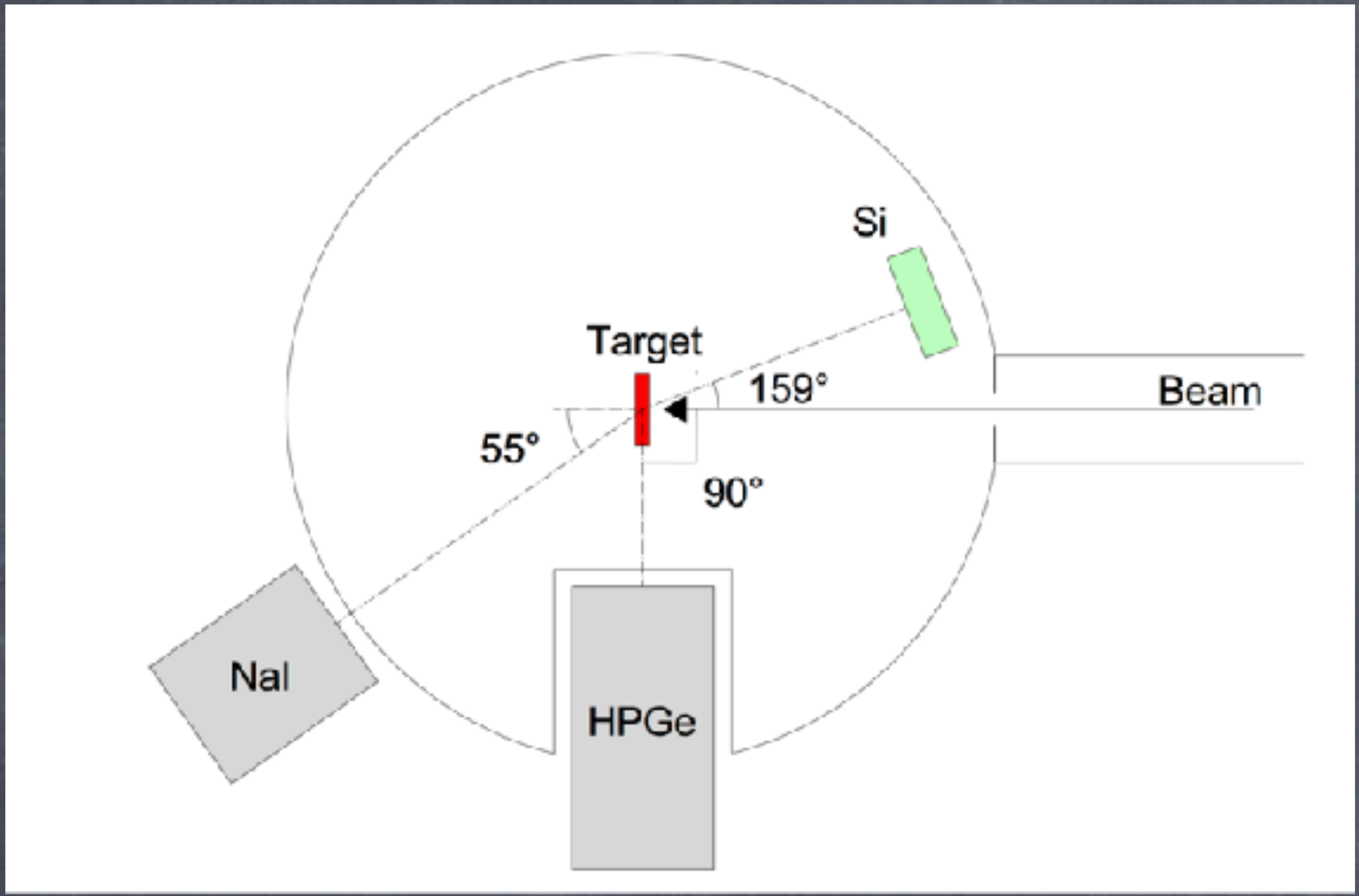


E_X [MeV]	E_R [MeV]	J^π	Γ_p [MeV]	Γ_α [MeV]	Γ_{tot} [MeV]
8.699	0.01	$5/2^+$		0.015	
9.2	0.50	$5/2^+$	0.0018	0.501	0.503
9.645	0.96	$3/2^-$	0.031	0.222	0.252
9.78^a	1.09	$5/2^-$	0.018	0.221	0.239
$9.97^{a,b}$	1.28	$7/2^-$			
10.083	1.39	$7/2^+$	0.187	0.047	0.234
10.679	1.99	$9/2^+$	0.106	0.098	0.204

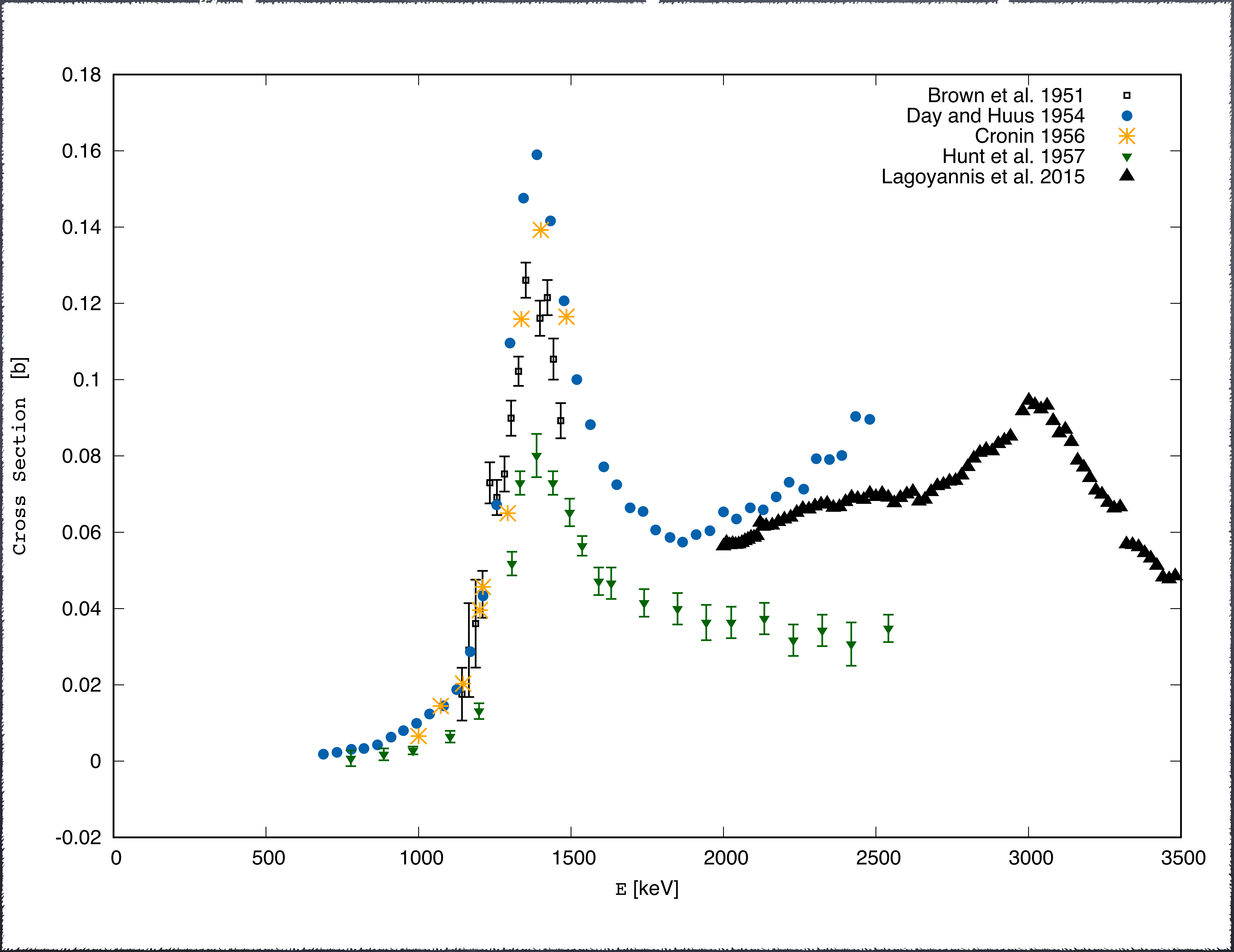
[a] The α decay of this level is not reported in the literature.
[b] This level is not used in the R-matrix fit.

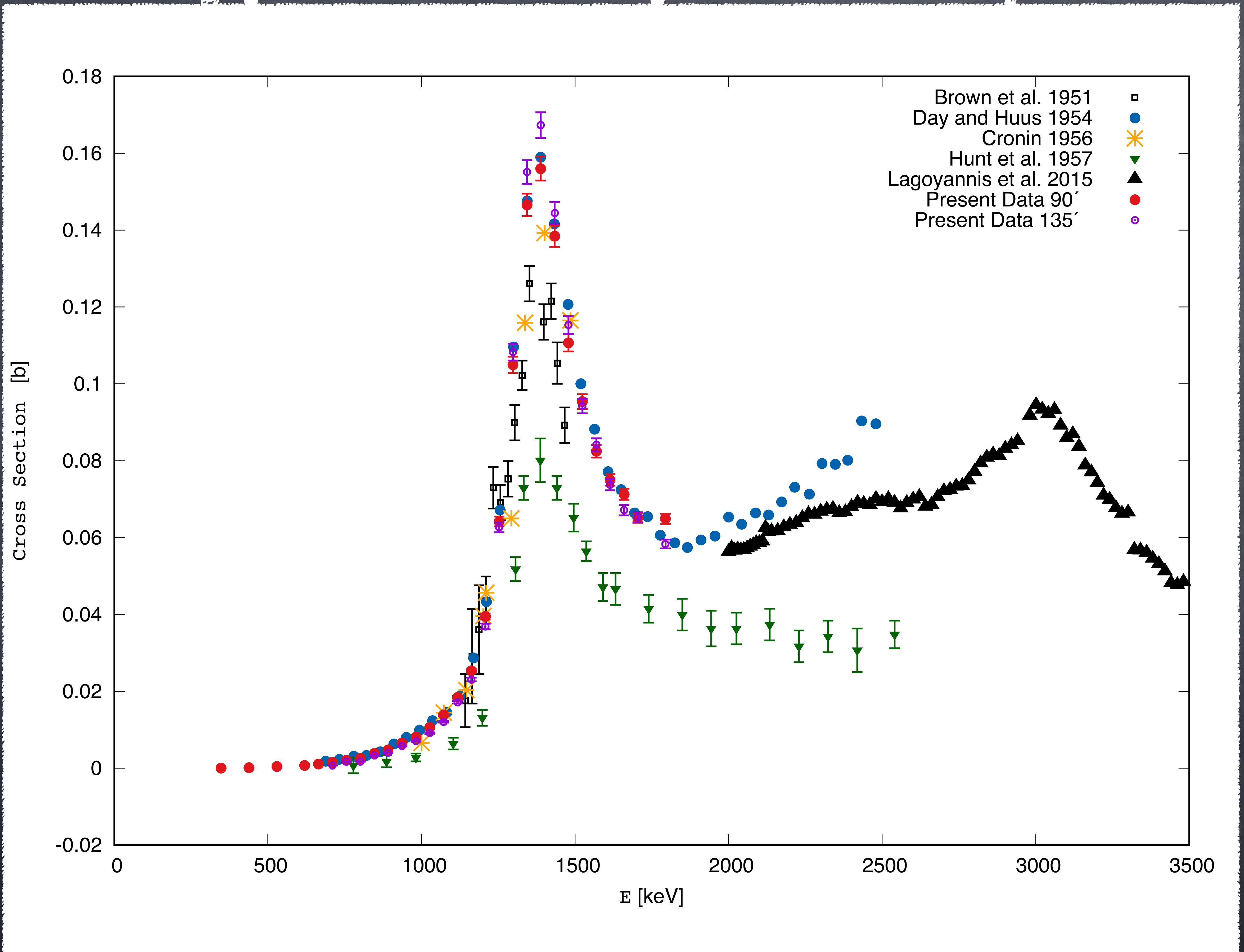
non resonant contribution of 6 MeV b

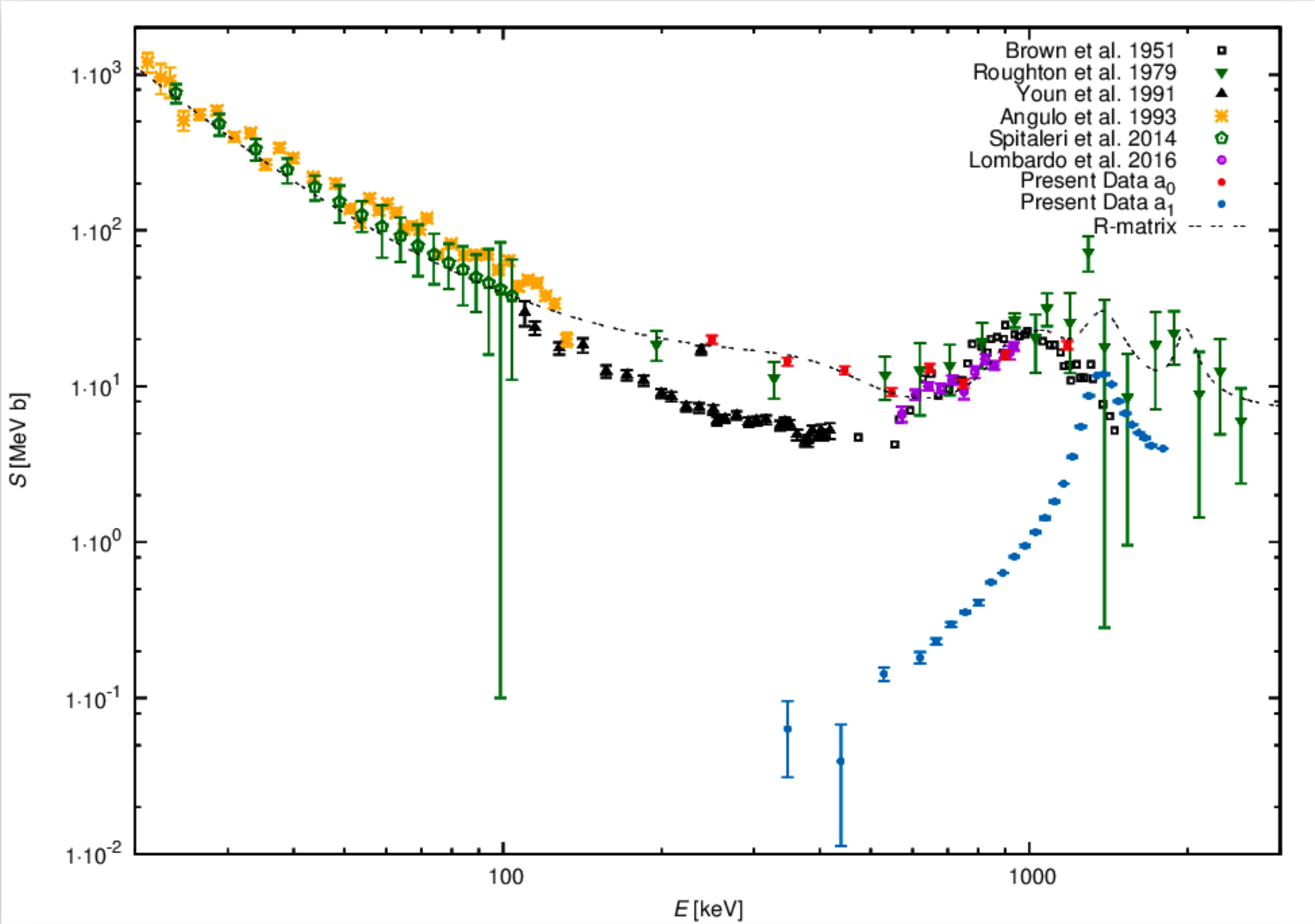
the α_1 channel



2 detectors for gamma detection
Si for target analysis
E = 300 - 2000 keV

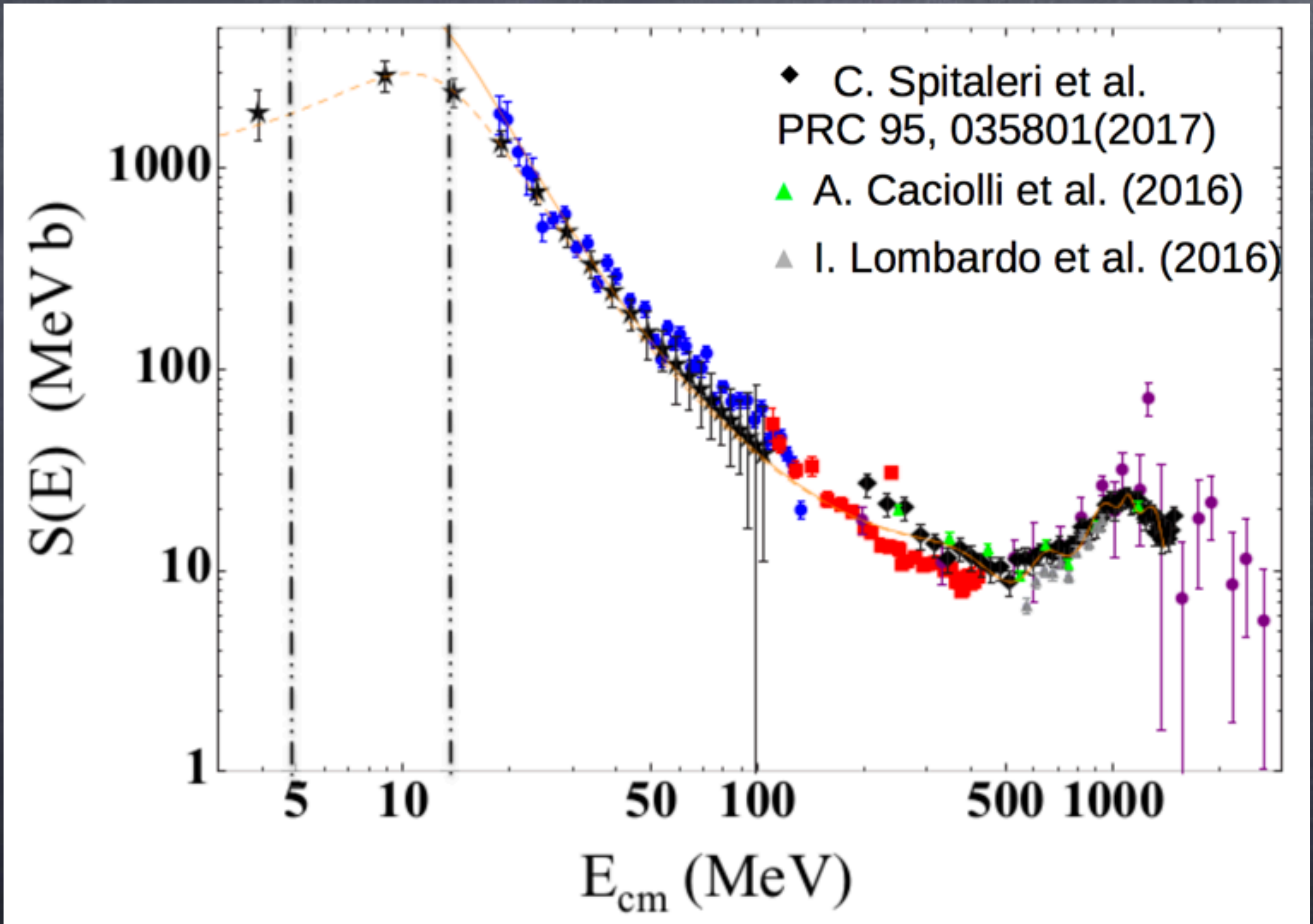

Brown et al. 1951
Day and Huus 1954
Cronin 1956
Hunt et al. 1957
Lagoyannis et al. 2015
Cross Section [b]
E [keV]
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
500
1000
1500
2000
2500
3000
3500


Brown et al. 1951
Day and Huus 1954
Cronin 1956
Hunt et al. 1957
Lagoyannis et al. 2015
Present Data 90´
Present Data 135´
Cross Section [b]
E [keV]
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
500
1000
1500
2000
2500
3000
3500

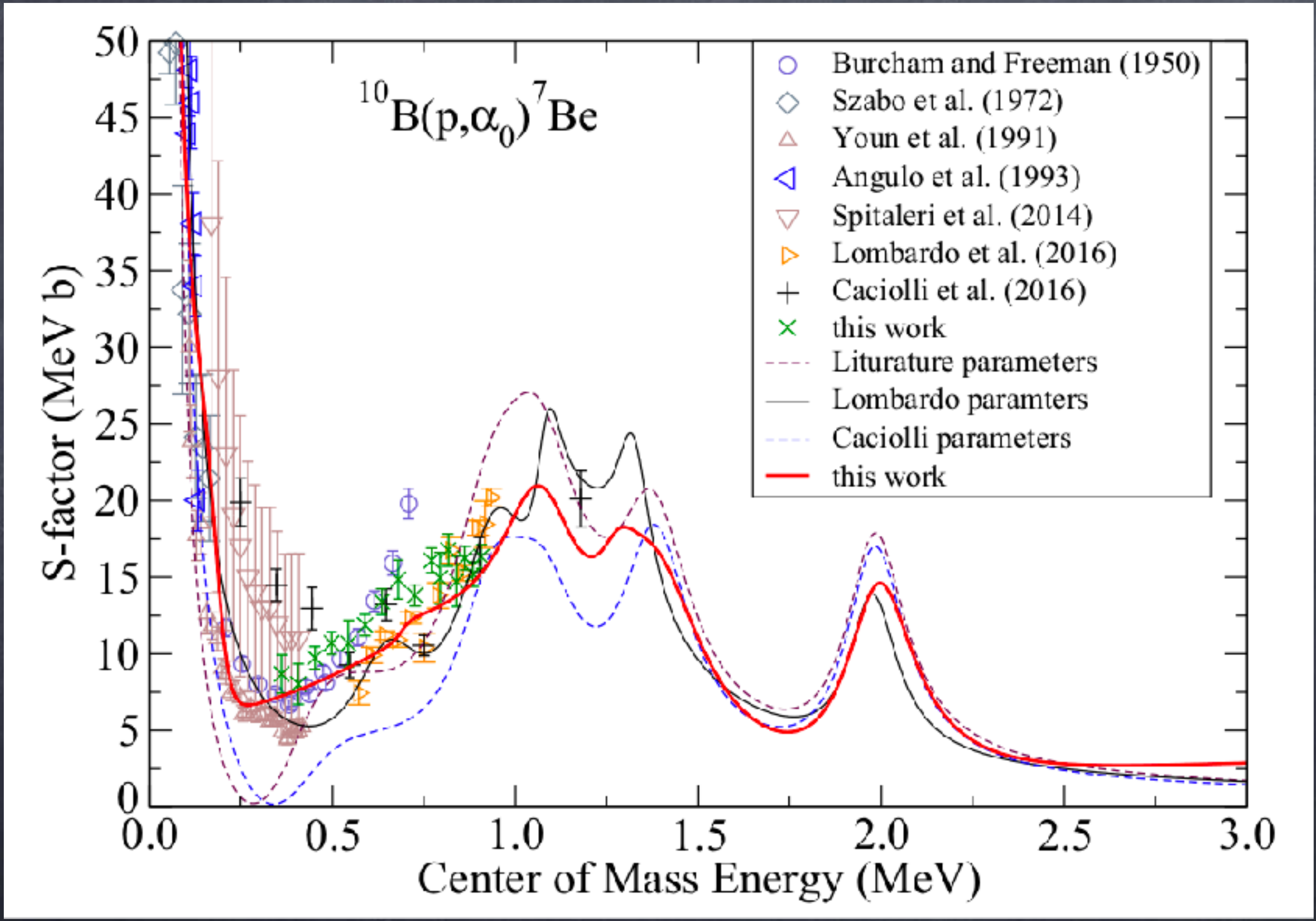


Brown et al. 1951
Roughton et al. 1979
Youn et al. 1991
Angulo et al. 1993
Spitaleri et al. 2014
Lombardo et al. 2016
Present Data a_0
Present Data a_1
R-matrix
$1 \cdot 10^3$
$1 \cdot 10^2$
$1 \cdot 10^1$
$1 \cdot 10^0$
$1 \cdot 10^{-1}$
$1 \cdot 10^{-2}$
S [MeV b]
100
1000
E [keV]

Comparison with recent THM new data



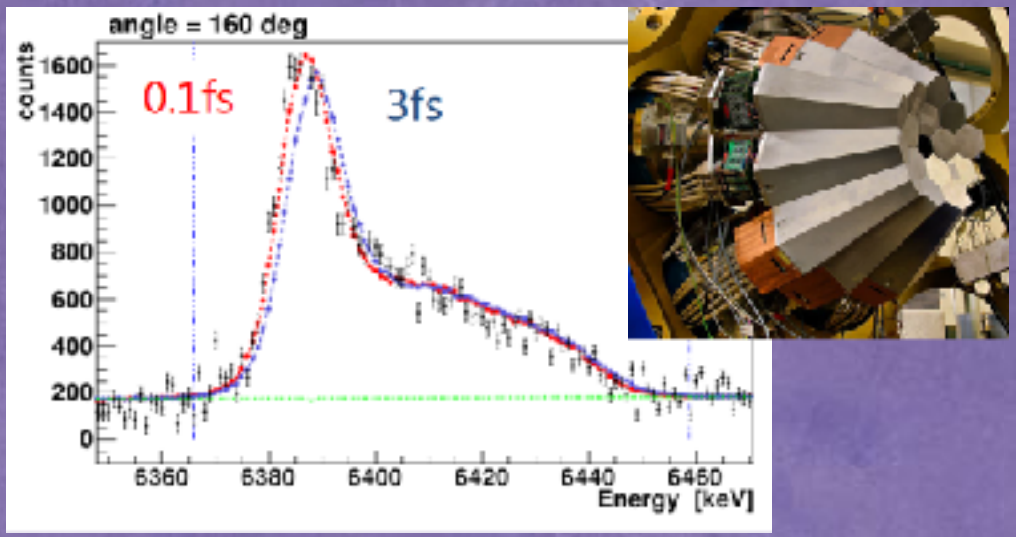
and with data from Notre Dame



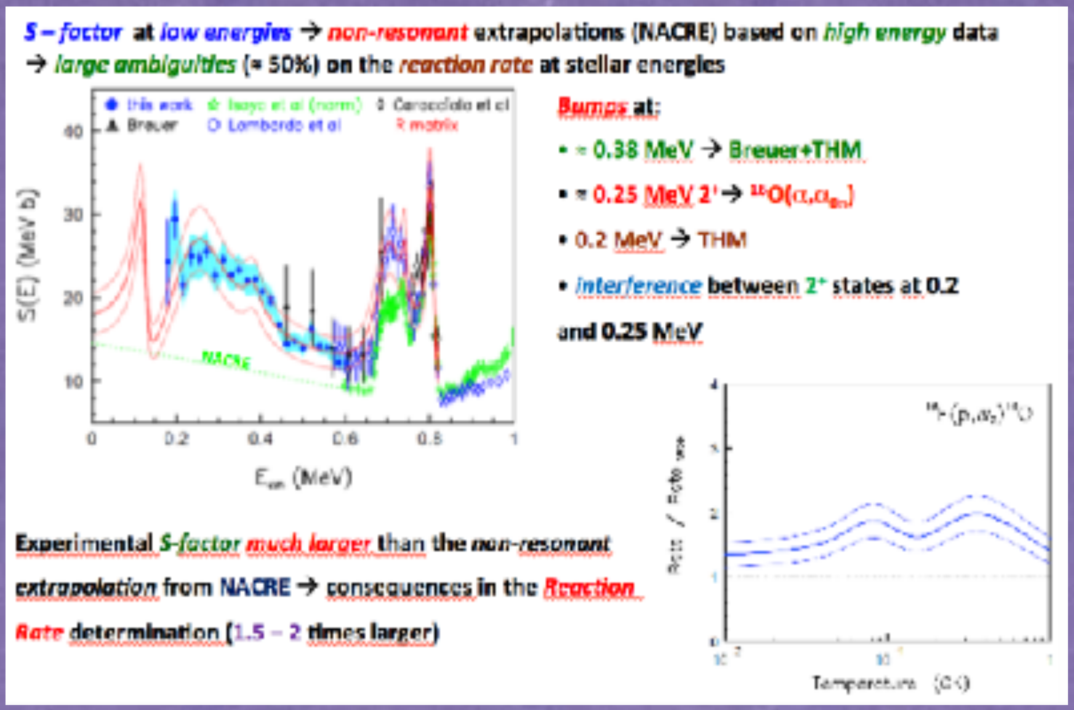
M. Wiescher et al. PRC 95, 044617 (2017)

Nuclear Astrophysics at LNL

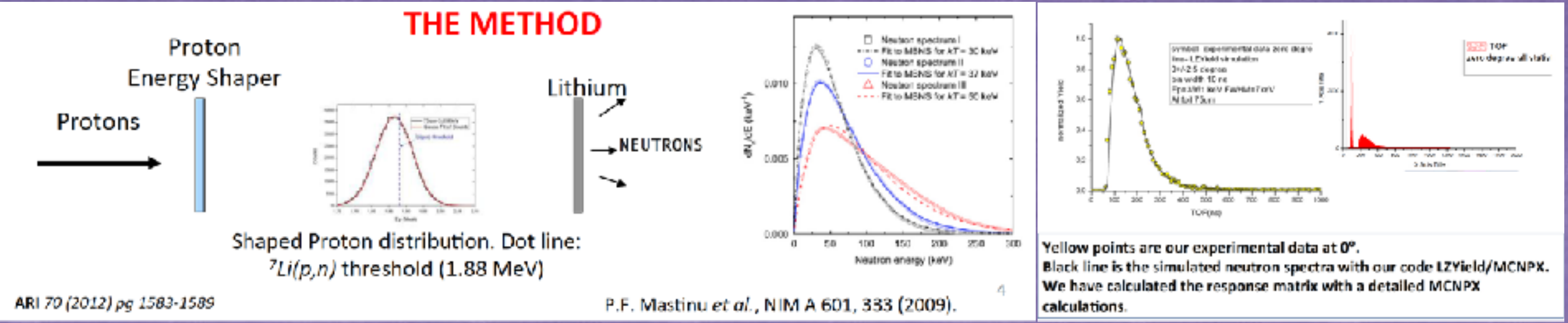
^{16}O 6.79 MeV excited level lifetime at AGATA



DSAM sensitivity below 1 fs



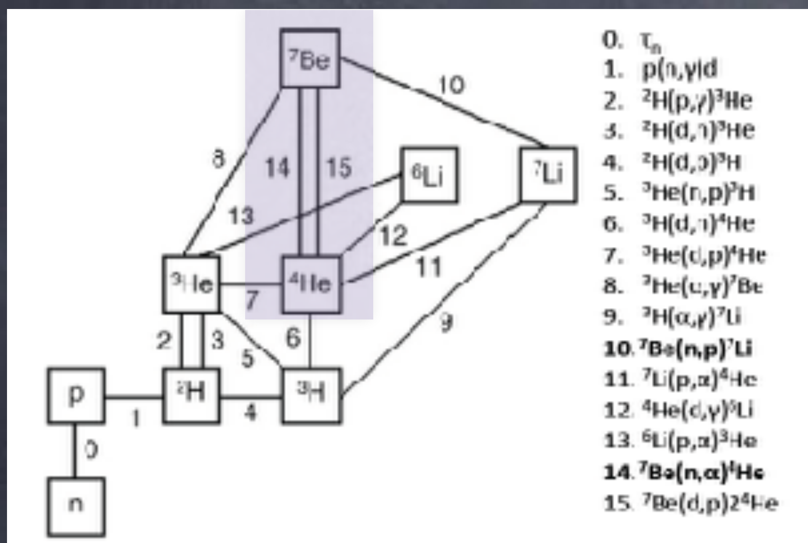
$^{19}F(p,\alpha_0)^{16}O$ @ NASPERA

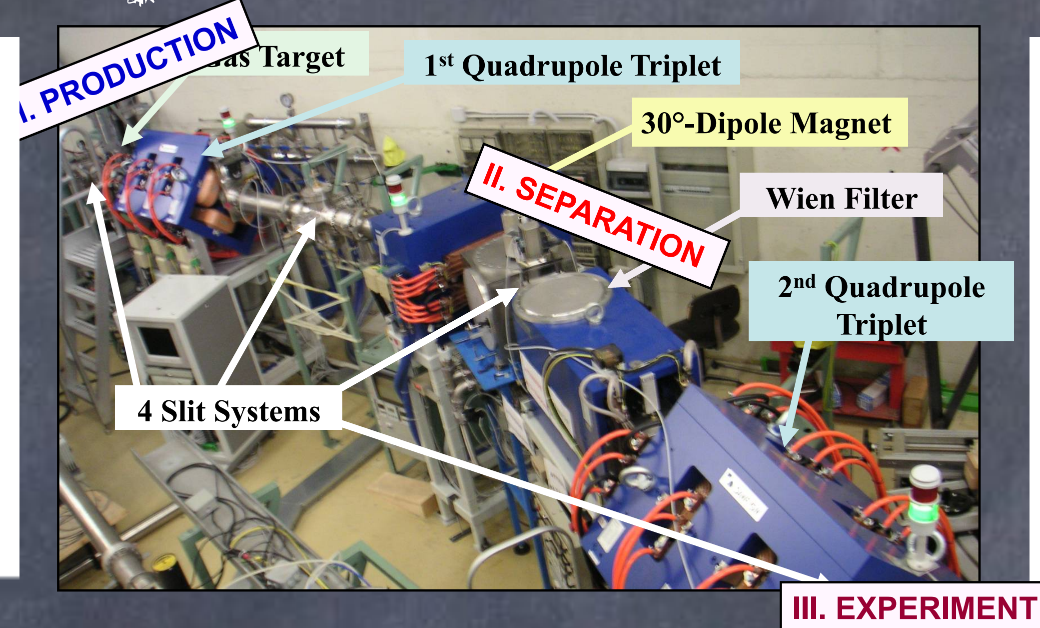


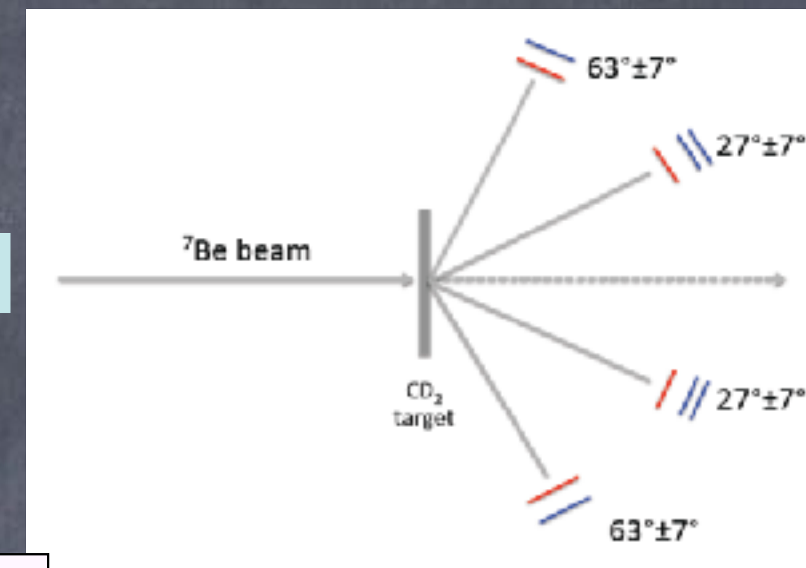
Maxwellian distributed neutron beams at BELINA and LENOS

New experiments

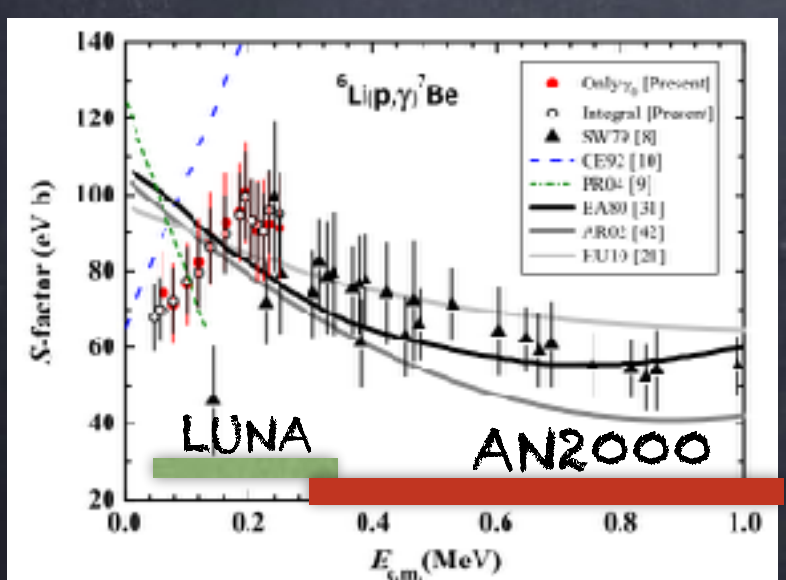
BELICOS: study of the $^{7}Be(n,\alpha)\alpha$ with THM







Study of the $^{6}Li(p,\gamma)^{7}Be$ at LUNA and LNL



two complementary techniques:
prompt-gamma detection and activation method

Cover a wide energy range to better constraint the R-matrix and to study the resonance parameters

Summary

- The S-factor of the $^{10}B(p,\alpha)^{7}Be$ has been measured from 250 keV up to 1.2 MeV and the results is a factor of 2 higher than the previous measurements of Youn et al.
- Still remains some tension with new published data and the need to complete the region above 1.5 MeV
- New nuclear astrophysics studies are planned for the end of this year and the 2018 to continue our nuclear astrophysics program at LNL