$^{18}O(p, \gamma)\,^{19}F$ at LUNA

Motivation

Setup

Measurements

Low energy resonance data analysis

Data quality

Conclusions & Outlook

Direct measurement of the cross section for the $^{18}O(p, \gamma)^{19}F$ reaction at LUNA

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Motivation

Astrophysical Context

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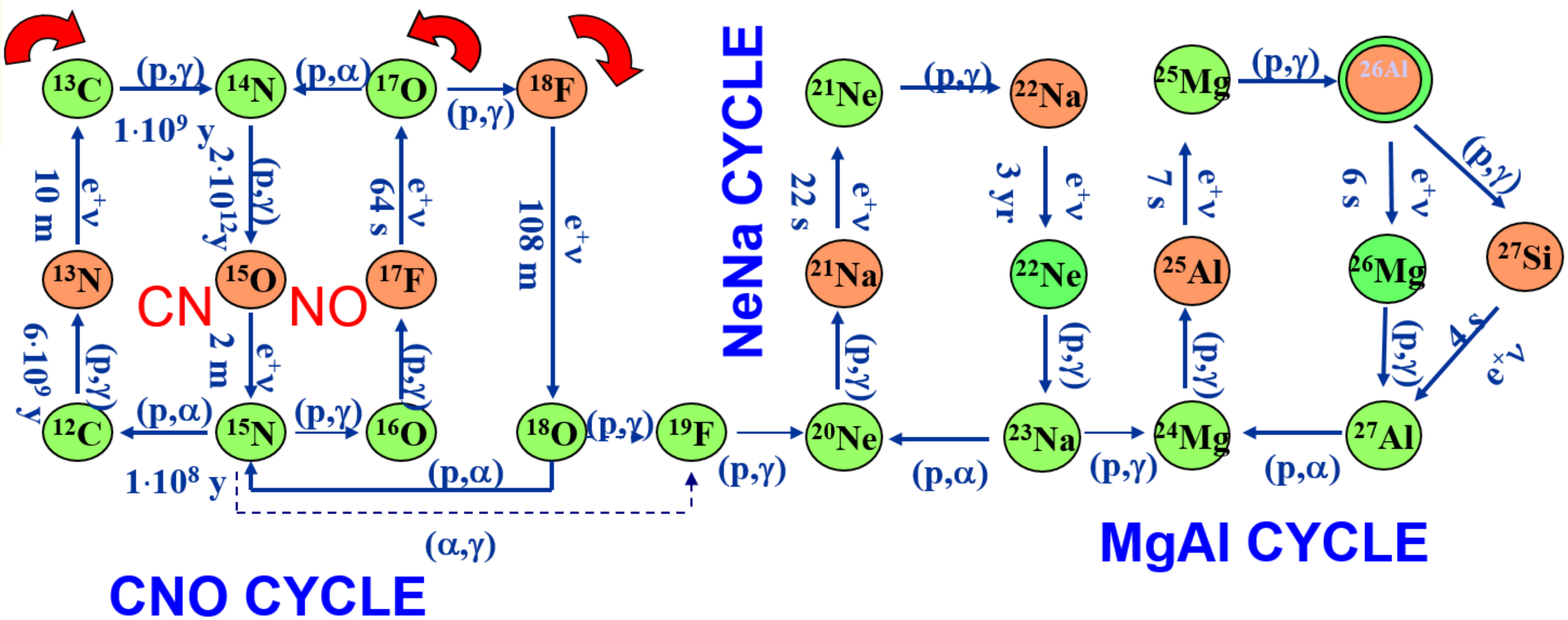
- $^{18}O(p,\gamma)$ competes with $^{18}O(p,\alpha)$ and may provide an explanation for an observed ^{18}O depletion in presolar grains. (L.R. Nittler et al., 2008; S. Palmerini et al., 2011; P. C. Scott et al., 2006) *[1, 2, 3]*.

Production of heavier nuclei

- ✓ NeNa cycle
- ✓ MgAl cycle



Motivation

Prior status

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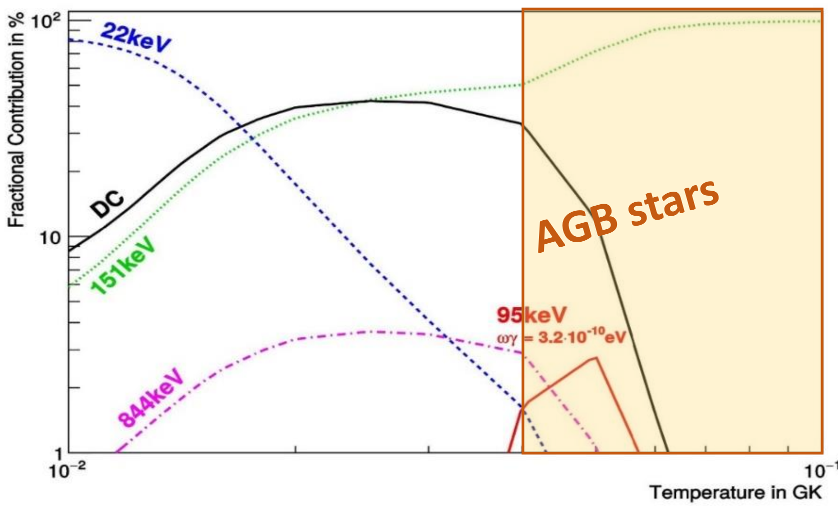
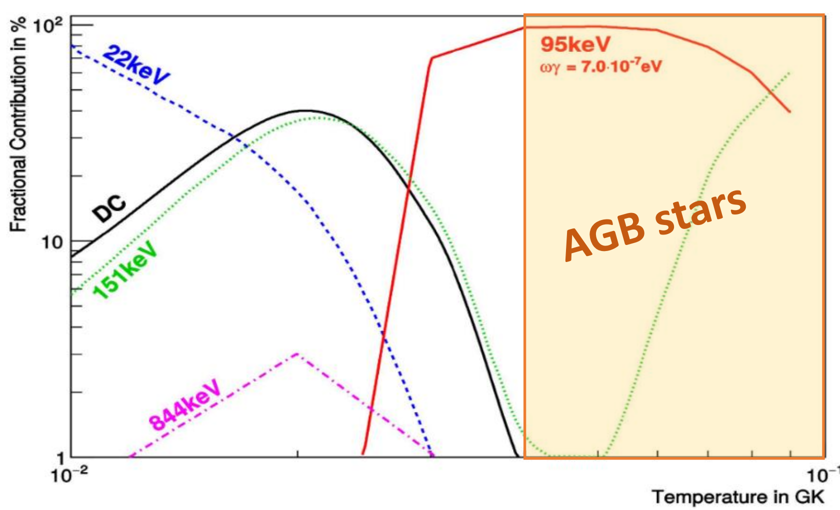


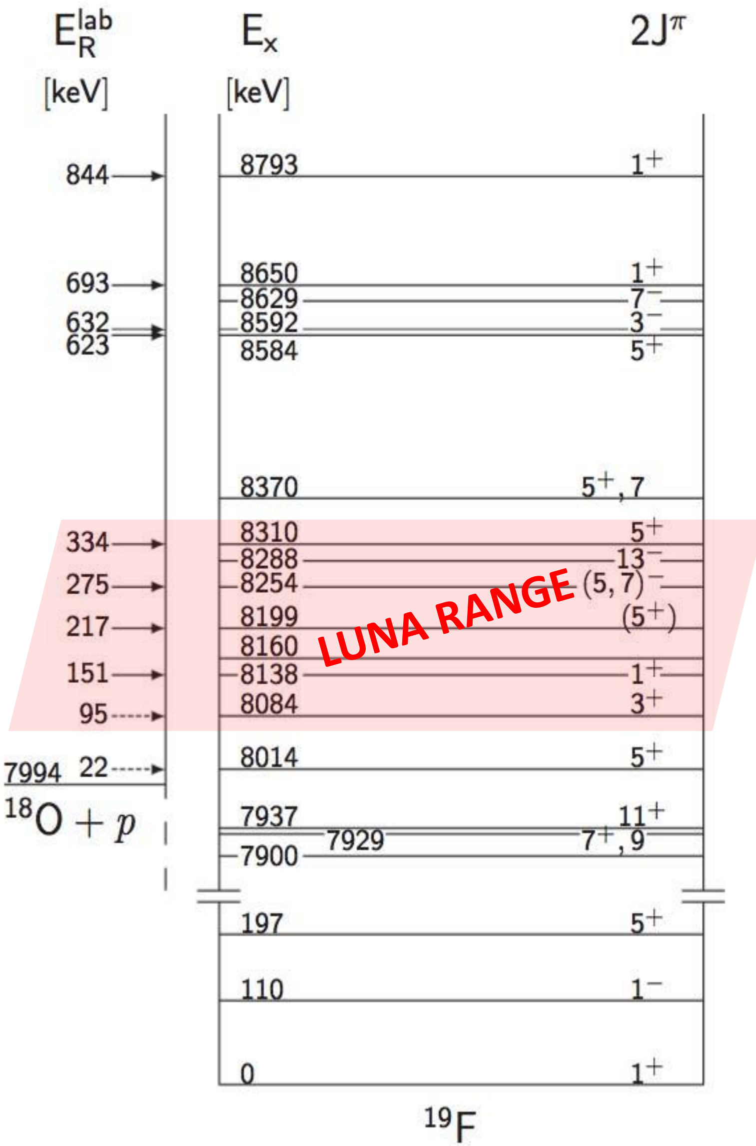


The 95 keV resonance strength is disputed. (M. Q. Buckner et al., 2012, H. T. Fortune et al., 2013) [4, 5]

The direct capture component has only been measured for E_p>150 keV. (M. Wiescher et al., 1980) [6]

Reaction rate contributions according to M. Q. Buckner et al., 2012[4] (up) and to H. T. Fortune et al., 2013[5] (down).

$^{18}O(p,\gamma)^{19}F$ at LUNA
Experimental campaign



- LUNA 2015 BGO data
  - ✓ E_P = 89-400keV
  - ✓ Environmental background
  - ✓ Beam induced background

- LUNA 2016 HPGe data
  - ✓ E_P = 140-400keV
  - ✓ Environmental background

Aims: measurement of the on-resonance, off-resonance branching ratios and the direct cross section

✓ Resonance energies:

$E_p = 151keV$
$E_p = 217keV$
$E_p = 275keV$
$E_p = 334keV$
plus $E_p = 95keV$ → only BGO data

Setup

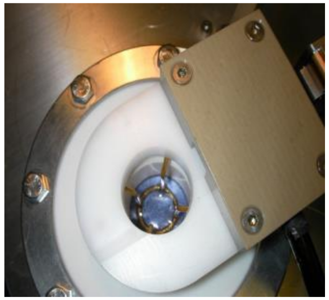
^{18}O solid targets

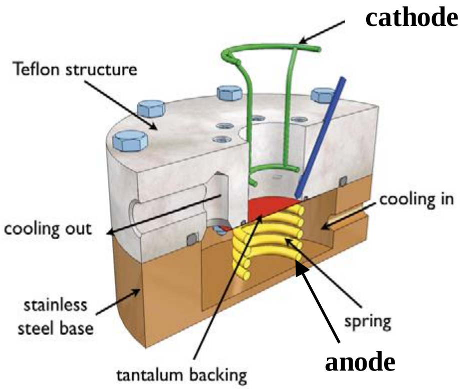
Requirements

- Target nuclide content
- Known stoichiometry
- Stability under beam
- High purity

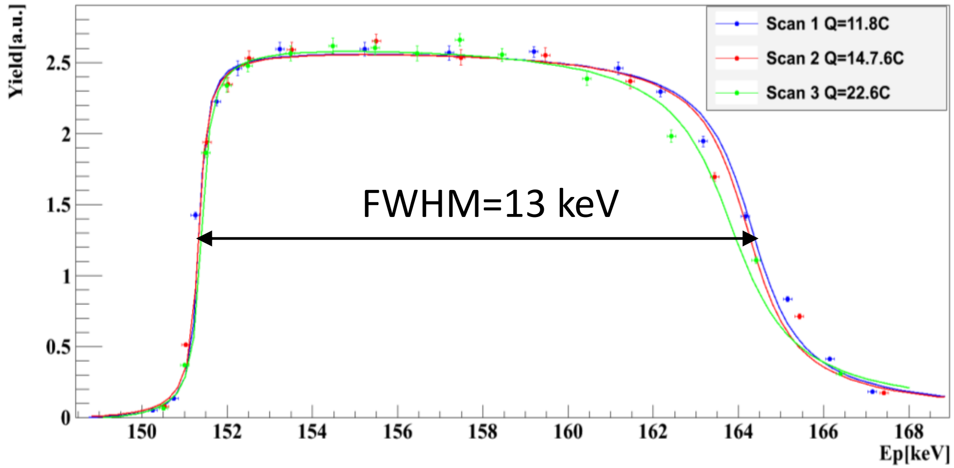
Production

Ta backing + Anodization Ta_2O_5 + enrichment O-18 (99%)





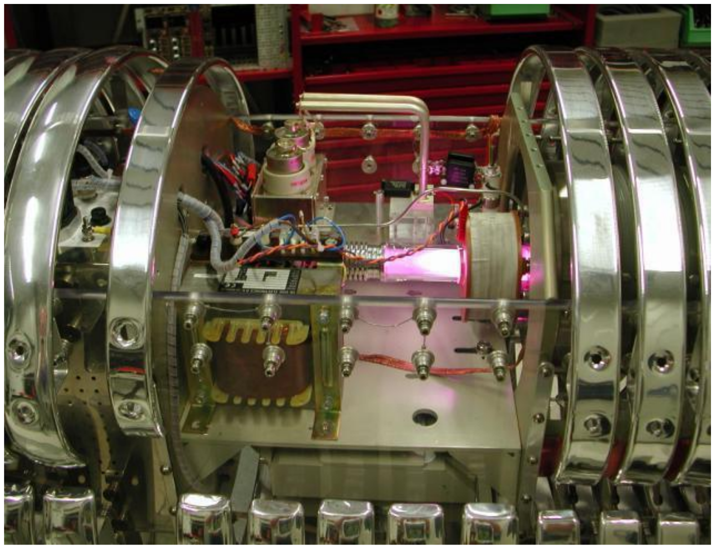
In situ resonance scan to monitor target profile and degradation:



Here: 151 keV resonance in $^{18}O(p, \gamma)^{19}F$

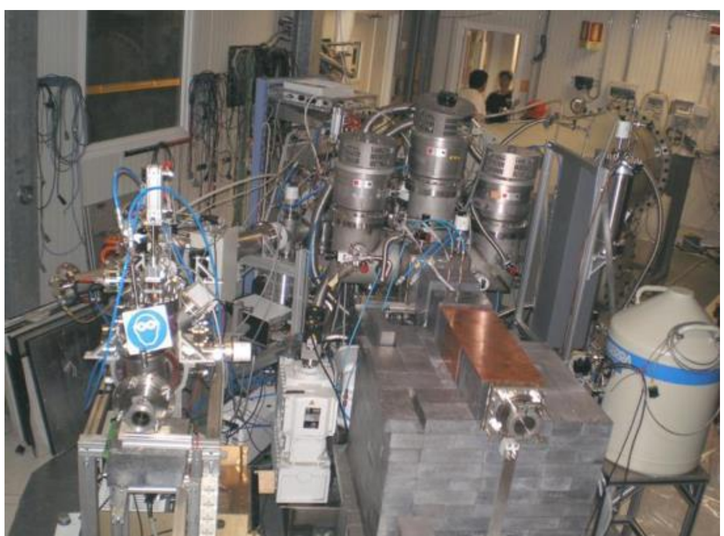
Setup

Detectors, beamlines



Accelerator

RF source for H,
$V_{terminal}$ up to 400 kV,
I_{typ}: 200 μA



Beam lines

- Solid target beamline on the left
- Gas target beamline on the right

Setup

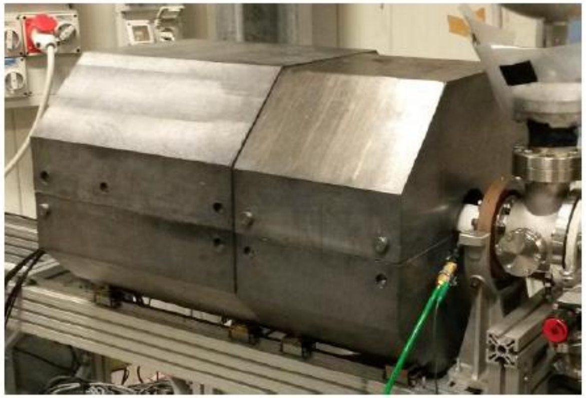
BGO & HPGe detectors (1st & 2nd phase of measurement)

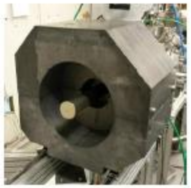
Features BGO

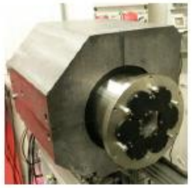
- BGO detector with 6 segments
- Close to 4π geometry
- Efficiency: ca. 40% at 8MeV
- Energy resolution: ca. 3% at 8MeV

DAQ BGO

- 6 independent channels→offline summing

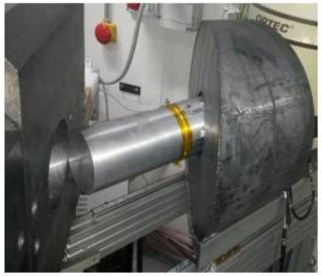






Features HPGe

- Efficiency: ca:
  (1-5)% at (0.1-0.2)MeV
  (5-0.5)% at (0.2-8)MeV
- Energy resolution:
  ca: (1-0.2)% at (0.1-9)MeV



Lead Shielding BGO & HPGe

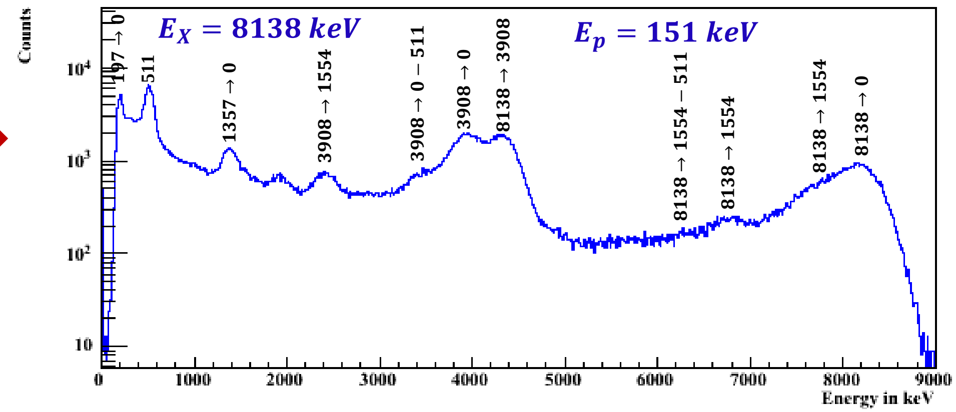
- BGO fully sorrounded (0°) with 10 cm of Pb
- HPGe fully sorrounded (55°) with 15 cm of Pb

Measurements

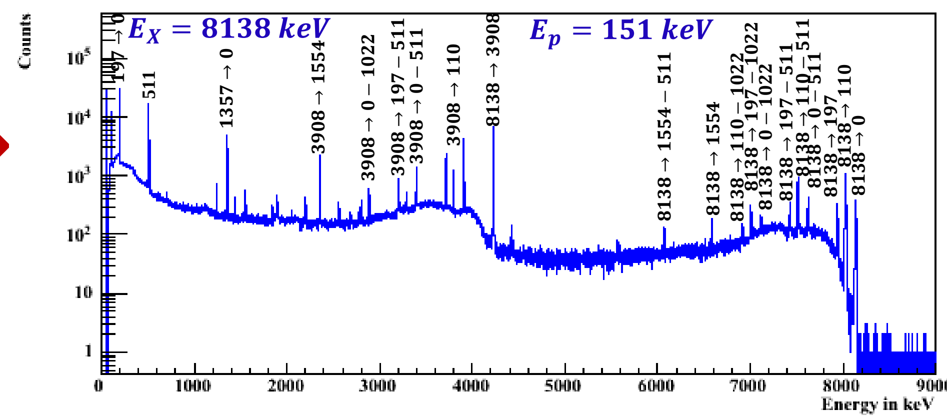
From the BGO to HPGe

Examples of spectra acquired with BGO and HPGe detectors:

- Single BGO segment, high efficiency



- HPGe detector, high energy resolution in order to resolve single transitions

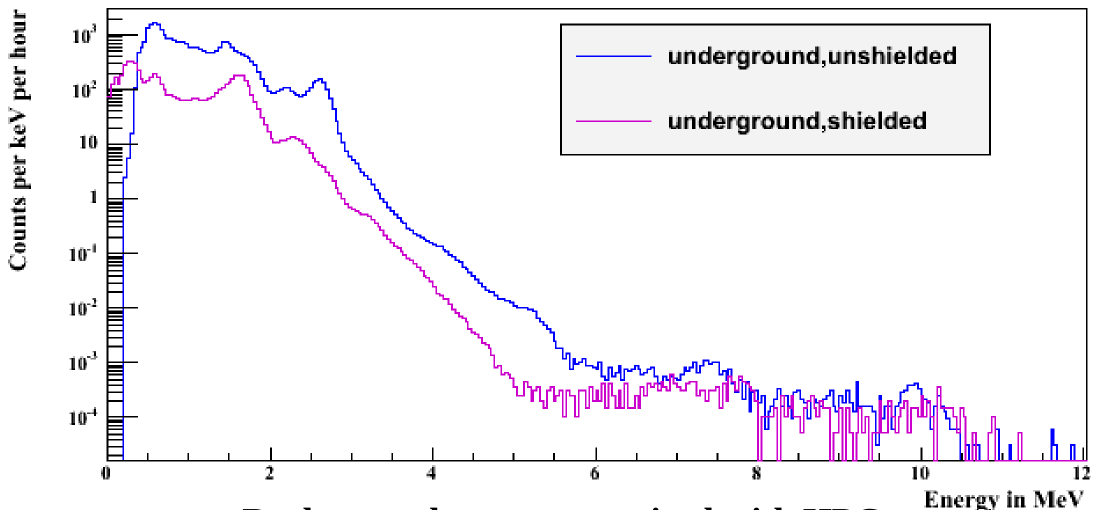


- Important for branchings!!!

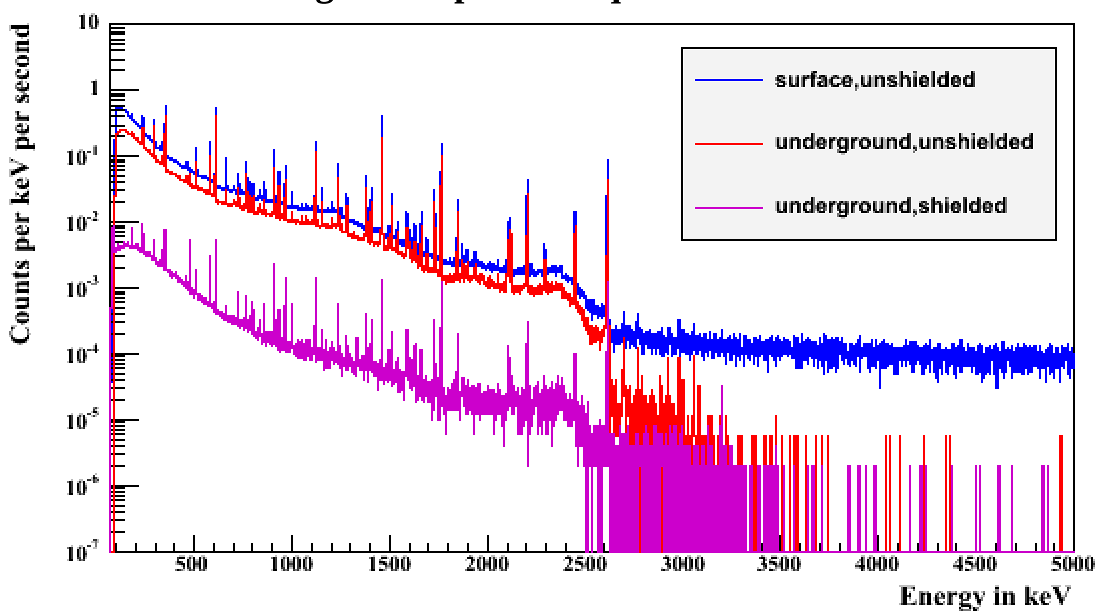
Motivation

Advantages of an underground measurement

Background spectra acquired with BGO



Background spectra acquired with HPGe



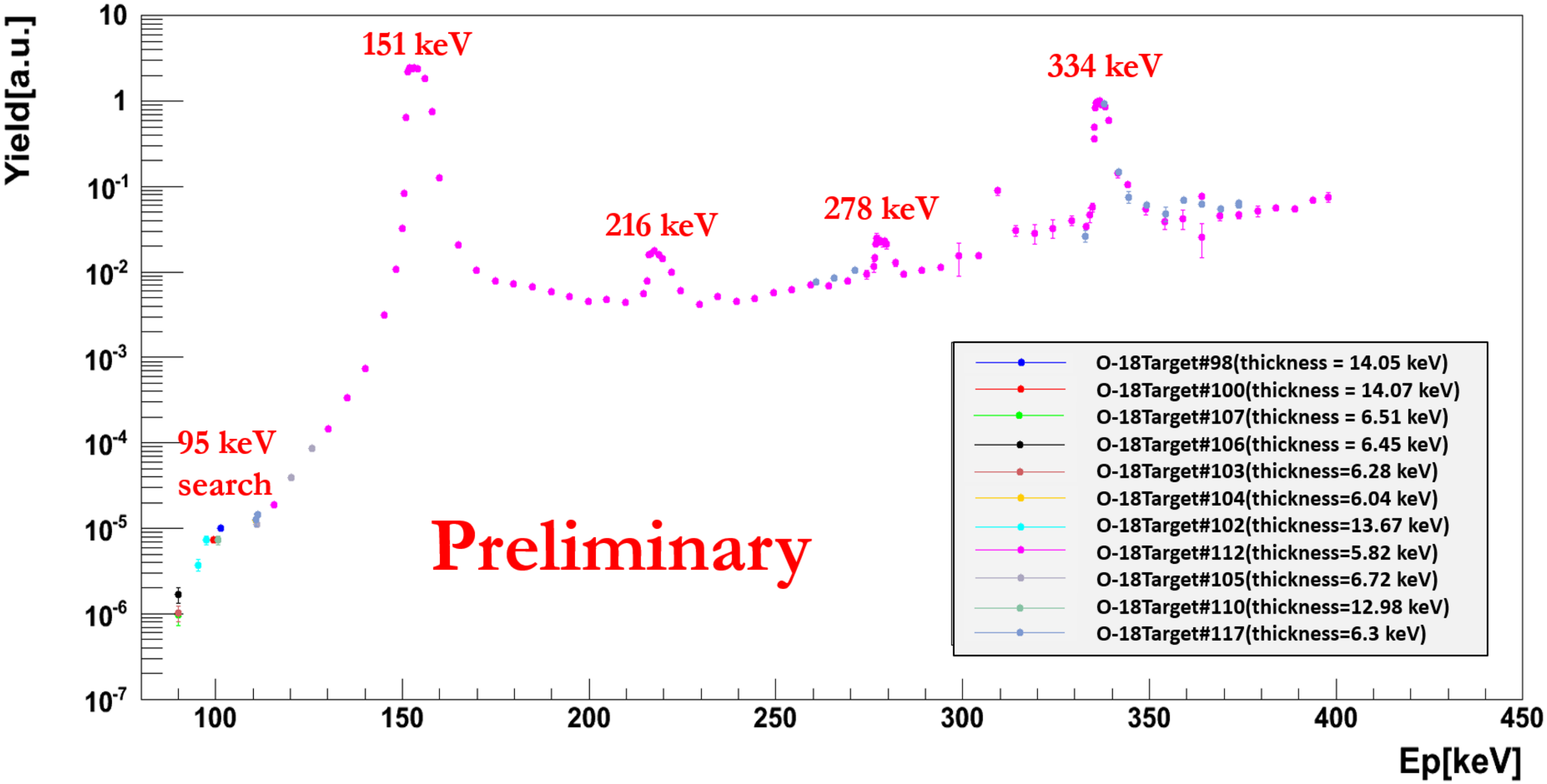
$$\frac{underground}{surface}$$

$\mu \rightarrow 10^{-6}$

$n \rightarrow 10^{-3}$

$^{18}O(p, \gamma)^{19}F$ at LUNA

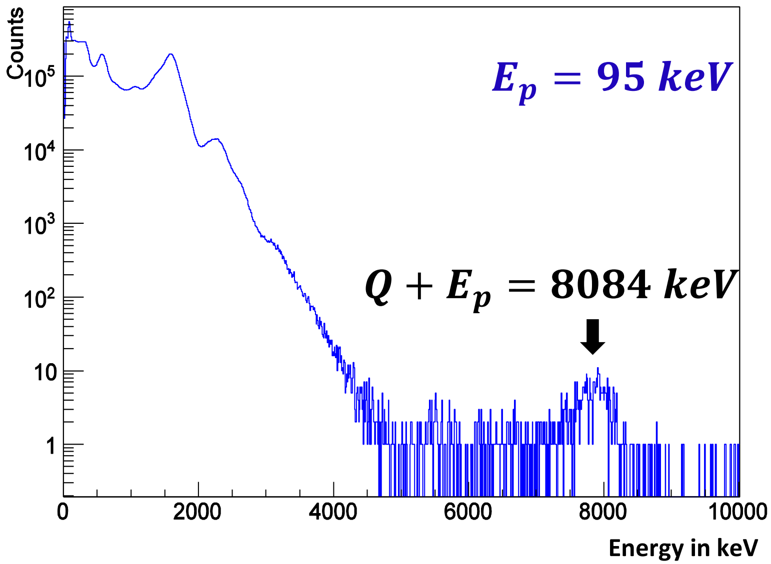
State of the art



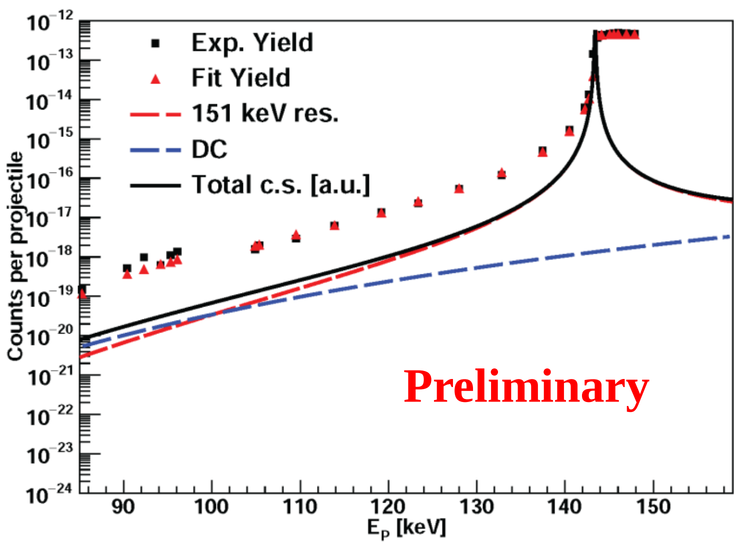
Excitation function acquired with BGO.

Low energy resonance data analysis

What do you get from the BGO?



- A clear signal at 8084 keV is visible in the full BGO spectrum, acquired at Ep = 95 keV.



- A preliminary analysis including the 151 keV resonance and the direct capture contributions is ongoing. No sign of strong resonance as predicted by H. T. Fortune et al., 2013[5].

Data quality

Excellent resolution (~2keV) & low background=high data quality

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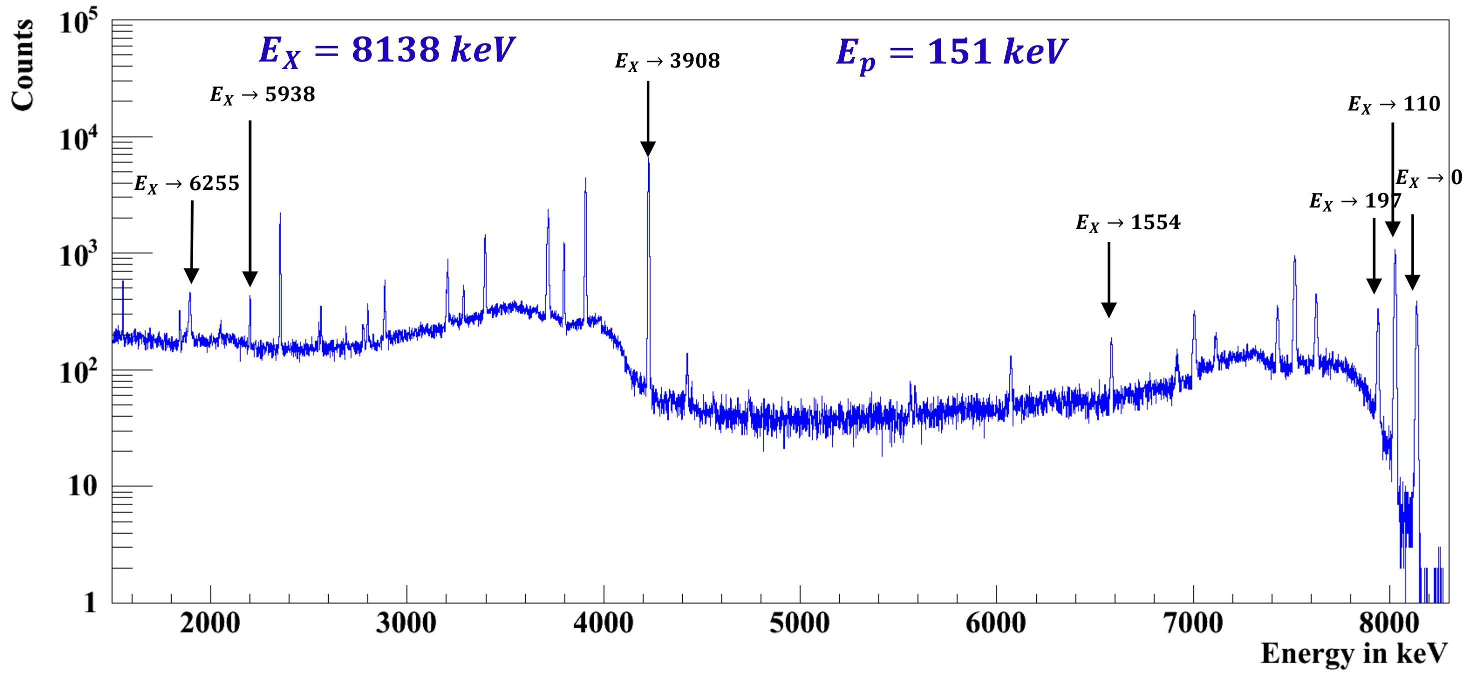
- Motivation
- Setup
- Measurements
- Low energy resonance data analysis
- **Data quality**
- Conclusions & Outlook

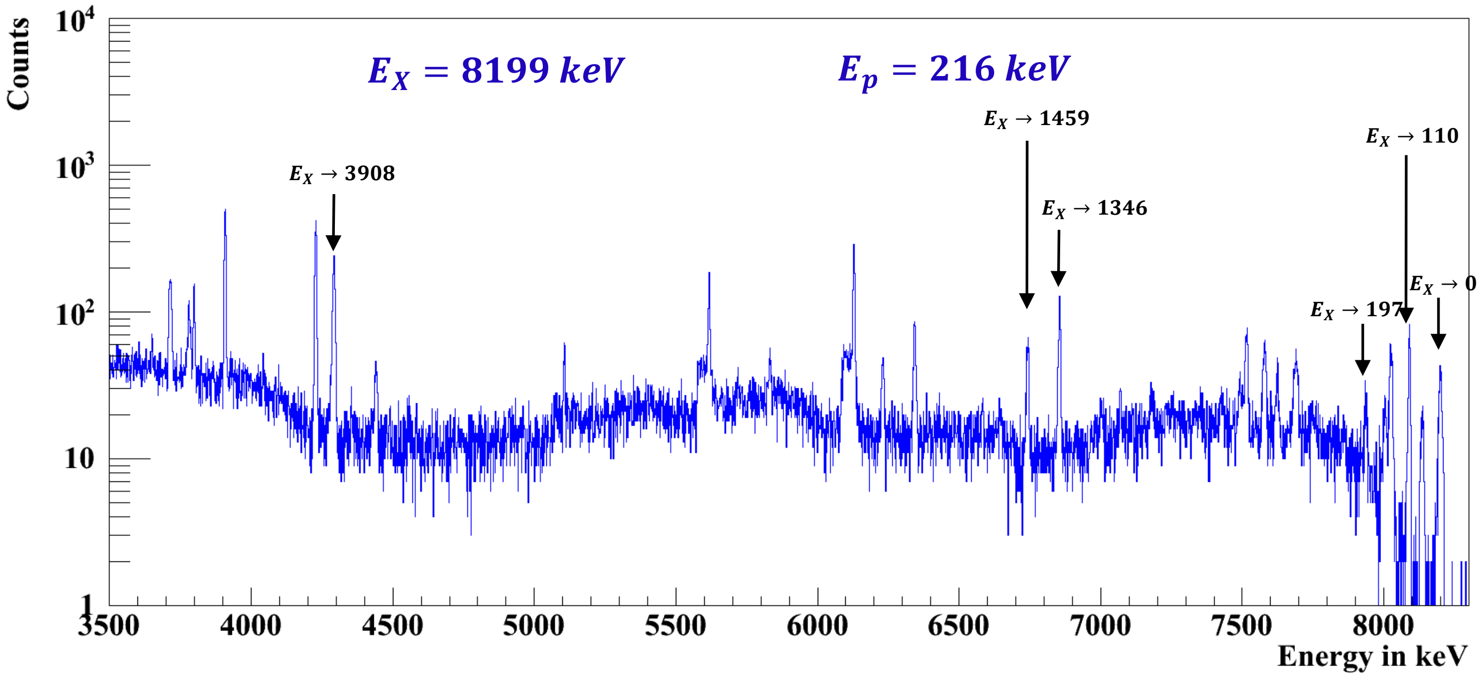


E_γ (keV)	State (keV)	Branchings ratio (%) LUNA	Branchings ratio (%) Wiescher et al., 1980[6]
1883	6255	2.1 ± 0.2	3 ±1
2200	5938	1.1 ± 0.1	1.0 ± 0.5
4230	3908	54.9 ± 3.3	54 ± 2
6584	1554	2.0 ± 0.4	2 ± 1
7941	197	7.3 ± 0.2	8 ± 1
8028	110	24.1 ± 0.8	24 ± 2
8138	0	8.5 ± 0.8	8 ± 1

Preliminary

Data quality

Excellent resolution (~2keV) & low background=high data quality



E_γ (keV)	State (keV)	Branchings ratio (%) LUNA
4291	3908	30.7 ± 2.5
6740	1459	10.7 ± 0.8
6853	1346	22.1 ± 2.6
8002	197	8.9 ± 2.4
8089	110	14.8 ± 1.0
8199	0	12.9 ± 1.5

Preliminary

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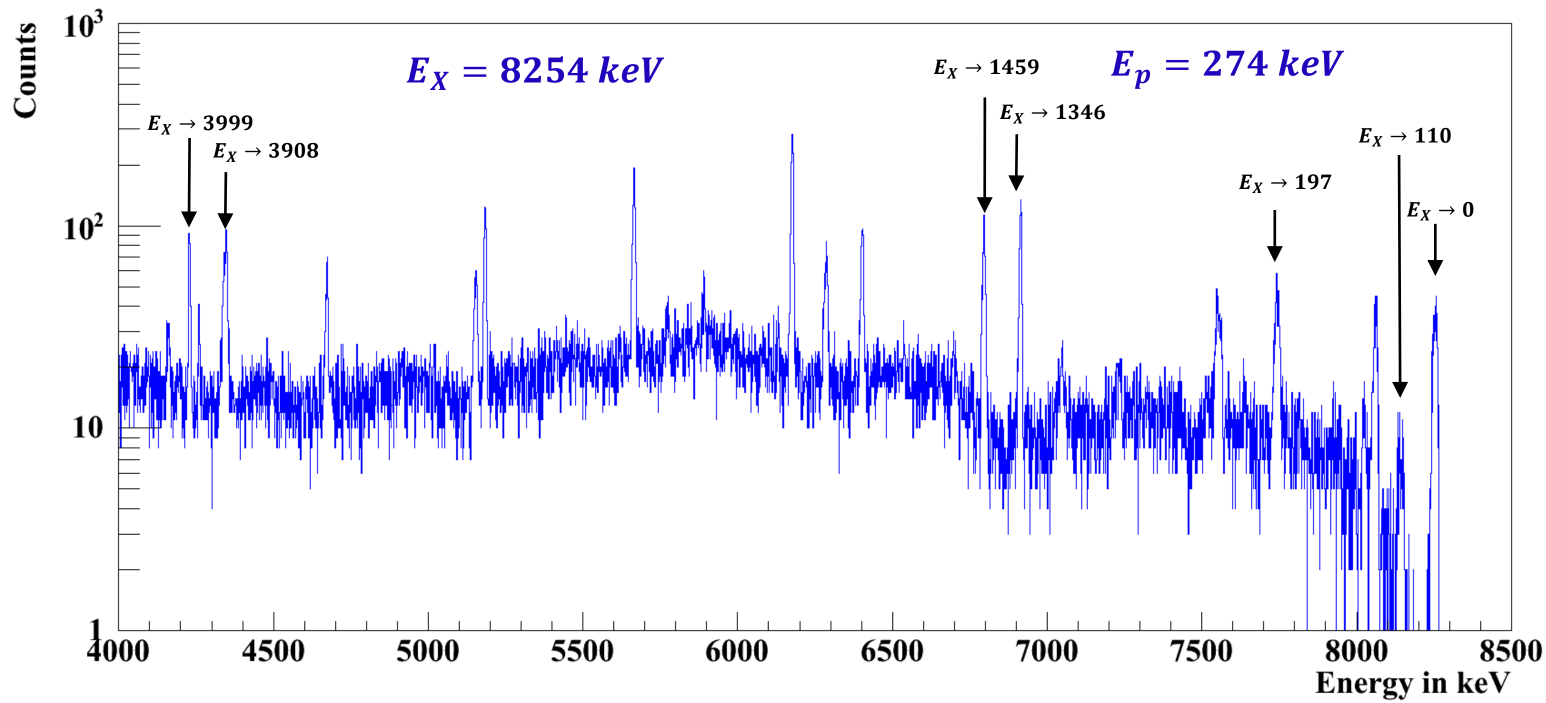

E_γ (keV)	State (keV)	Branchings ratio (%) LUNA	Branchings ratio (%) Wiescher et al., 1980[6]
4257	3999	3.0 ± 1.0	
4346	3908	13.4 ± 3.6	25 ± 8
6795	1459	5.1 ± 0.2	24 ± 8
6910	1346	37.3 ± 4.5	33 ± 10
8057	197	14.5 ± 2.4	18 ± 7
8144	110	3.6 ± 1.5	
8254	0	23.1 ± 2.8	

Preliminary

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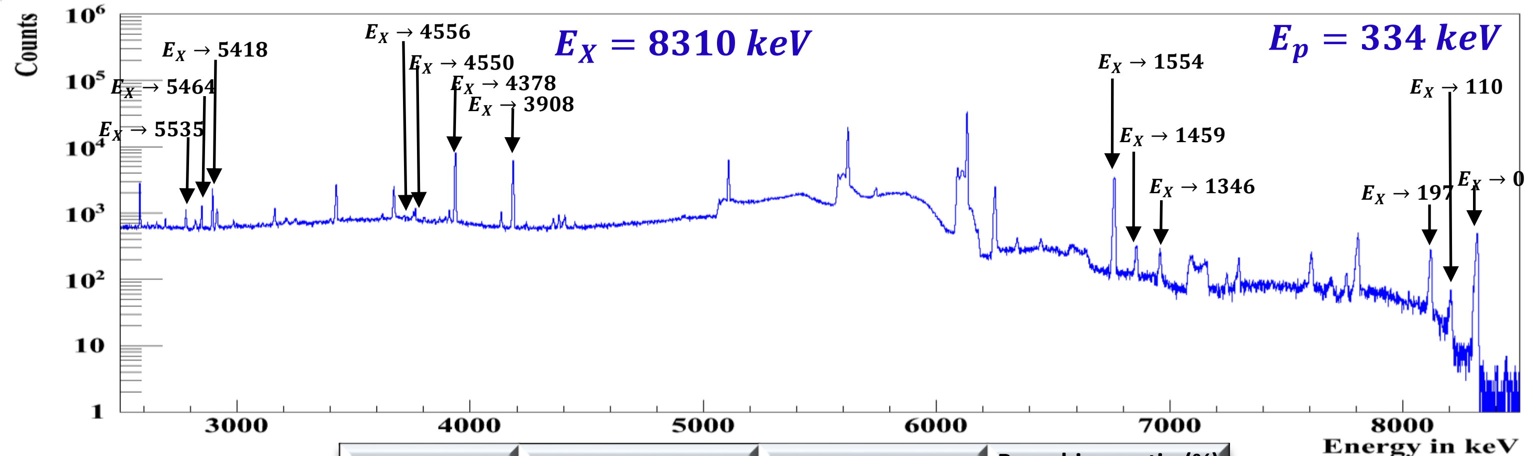
Excellent resolution (~2keV) & low background=high data quality



E_γ (keV)	State (keV)	Branchings ratio (%) LUNA	Branchings ratio (%) Wiescher et al., 1980[6]
2775	5535	1.3 ± 0.1	
2846	5464	2.3 ± 0.3	
2892	5418	5.3 ± 0.6	
3754	4556	0.9 ± 0.4	
3760	4550	1.1 ± 0.2	
3932	4378	33.4 ± 1.0	40 ± 2
4402	3908	1.0 ± 0.8	
6756	1554	40.7 ± 3.3	48 ± 2
6851	1459	2.3 ± 0.3	
6964	1346	2.1 ± 0.2	
8113	197	3.0 ± 0.7	
8200	110	0.7 ± 0.3	
8310	0	6.1 ± 1.6	12 ± 1

Conclusions & Outlook

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- Conclusions of the study of the 95 keV resonance energy
- Determination of gamma-ray branchings regarding non resonance component is ongoing
- Finalization of gamma-ray branchings and strengths regarding on-resonance low energy component

References

[1] L. R. Nittler et al., Astrophys. J. 682, 1450 (2008).
[2] S. Palmerini et al., Astrophys. J. 729, 3 (2011).
[3] P. C. Scott et al., Astron. Astrophys. 456, 675 (2006).
[4] M. Q. Buckner et al., Phys. Rev. C 86, 065804 (2012).
[5] H.T. Fortune et al., Phys. Rev. C 015801 (2013).
[6] M. Wiescher et al., Nuclear Physics A 349 (1980) 165-216.
[7] R. B. Vogelaar et al., Physical Review C 42, 753 (1990).
[8] C. Iliadis et al., Nuclear Physics A 841 (2010) 251.

Thank you for your attention!

The LUNA collaboration

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