Direct measurement of the 64.5 keV resonance strength in the $^{17}O(p,\alpha)^{14}N$ reaction at LUNA

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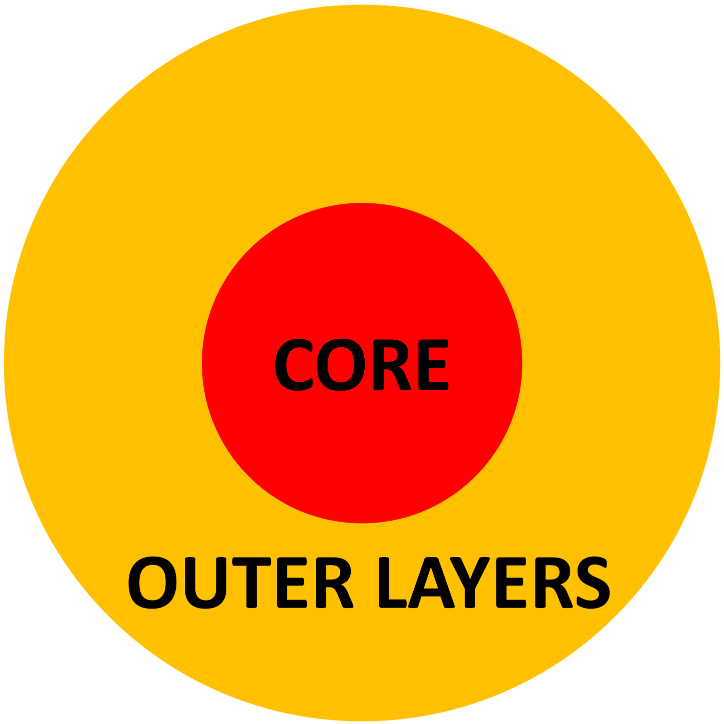
5 Ottobre 2017

GIANTS - Bologna

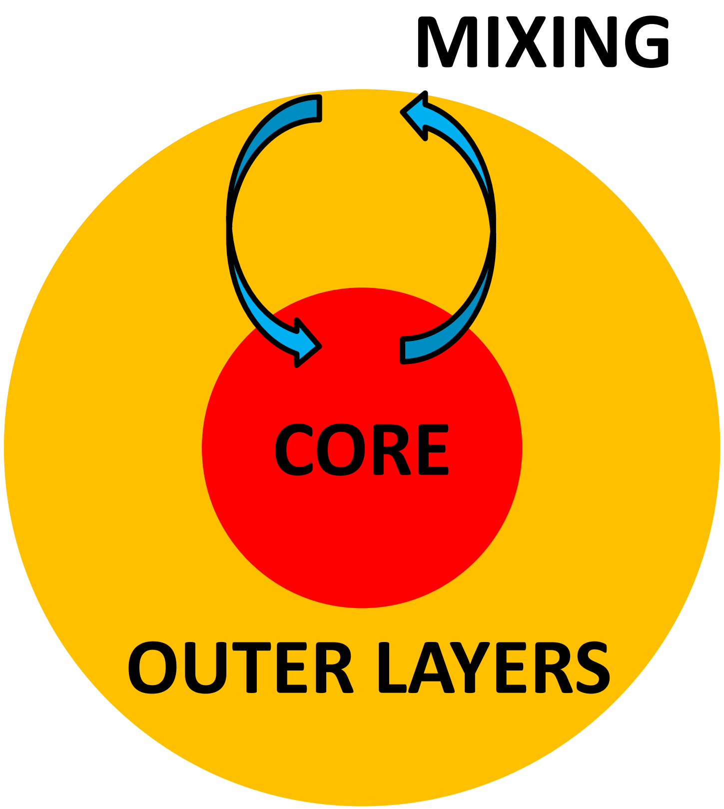
ASTROPHYSICAL MOTIVATION



- **Giant Branch stars**
- Burn hydrogen via CNO cycle in the core (T=0.03-0.1 GK)
- CNO signature = isotopic abundance pattern at equilibrium

- CNO signature observed in outer layers!

ASTROPHYSICAL MOTIVATION

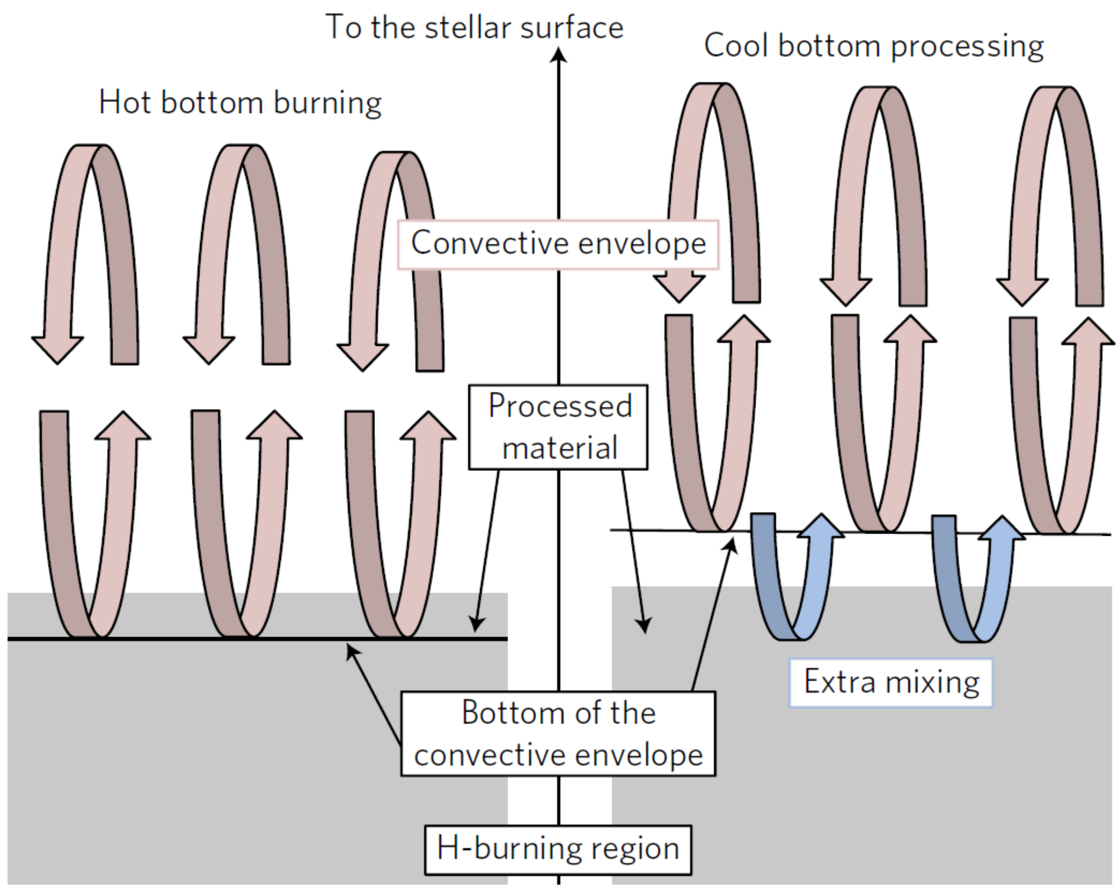


- **Giant Branch stars**
- Burn hydrogen via CNO cycle in the core (T=0.03-0.1 GK)
- CNO signature = isotopic abundance pattern at equilibrium

- CNO signature observed in outer layers!
- Convective / recirculating processes carry CNO products to outer layers
- Physical nature often unknown
- Affect reliability of stellar evolution models

MIXING PROCESSES

- How can we study these unknown mixing processes?
- Trace them with CNO isotopes
- **^{17}O is an ideal tracer for HBB / CBP**



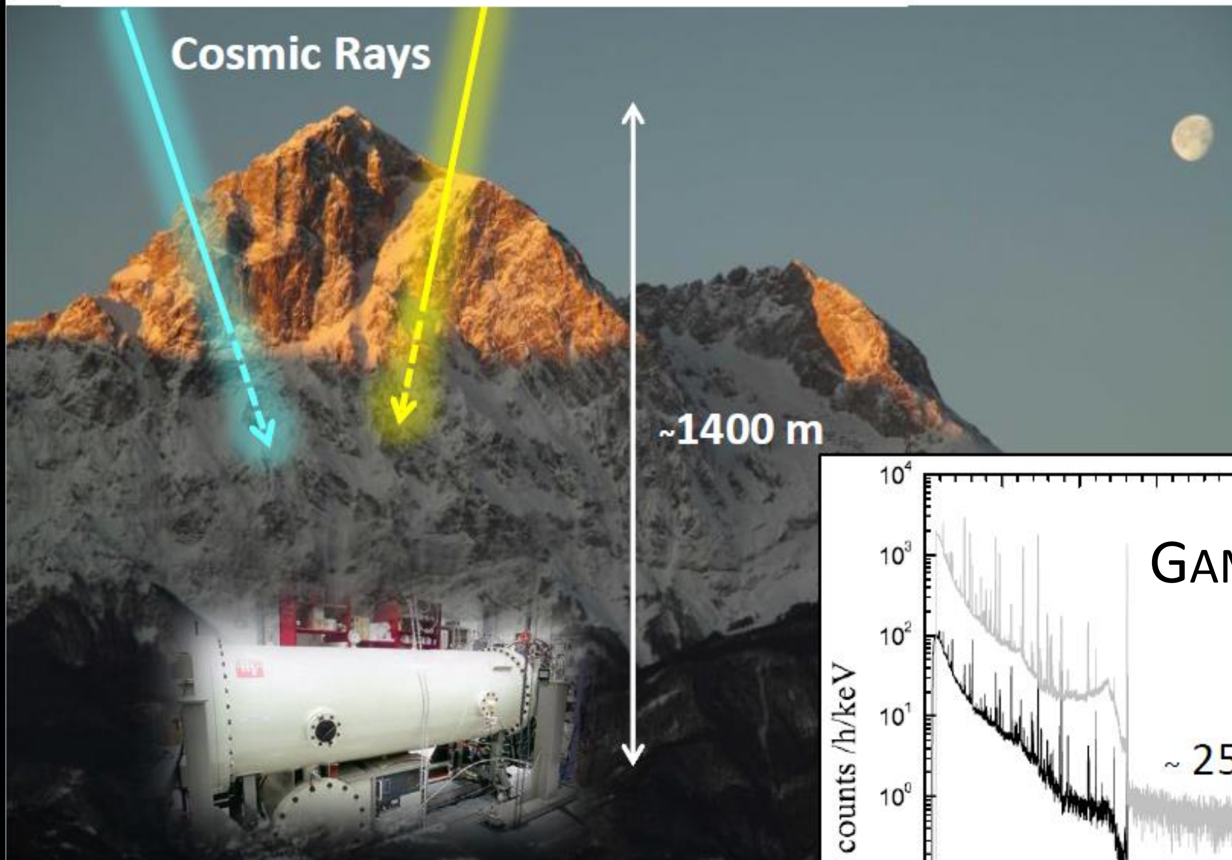
AIMS

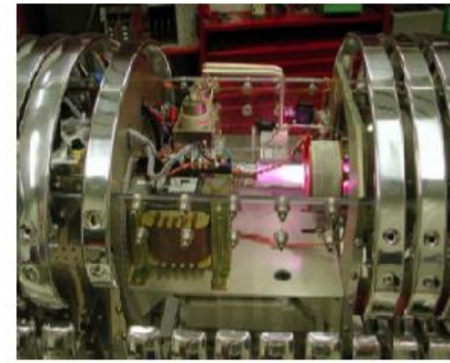
- Stellar models are affected by uncertainties in $^{17}O/^{16}O$ and uncertainties come primarily from **destruction** rate of ^{17}O

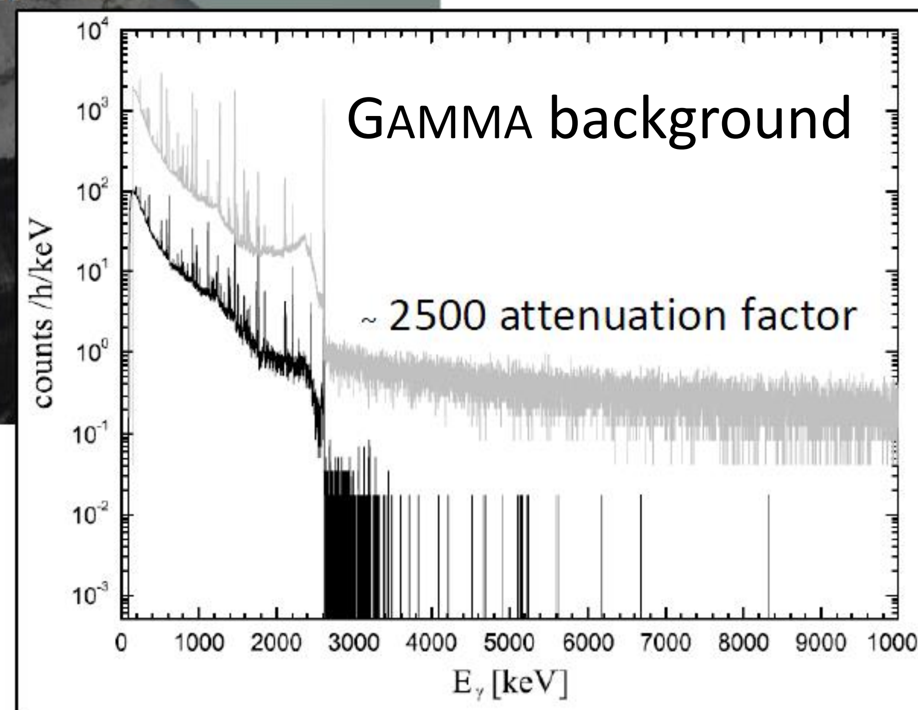
- **$^{17}O(p,\alpha)^{14}N$**
- **Our aim**: study this reaction at relevant energies to reduce the uncertainties in the ^{17}O isotopic abundances
- Very low counting rates expected: ~1 count/h

- Natural background will be a problem. How do we solve this?

THE LUNA EXPERIMENT

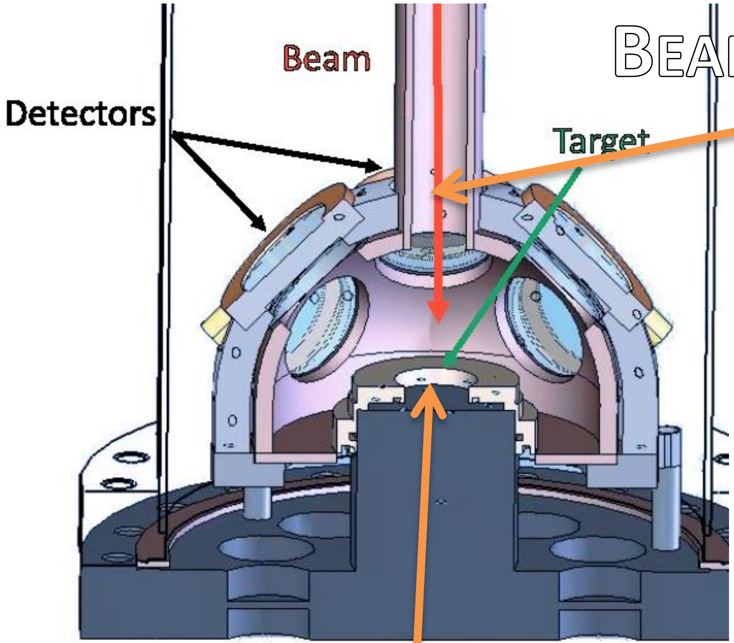


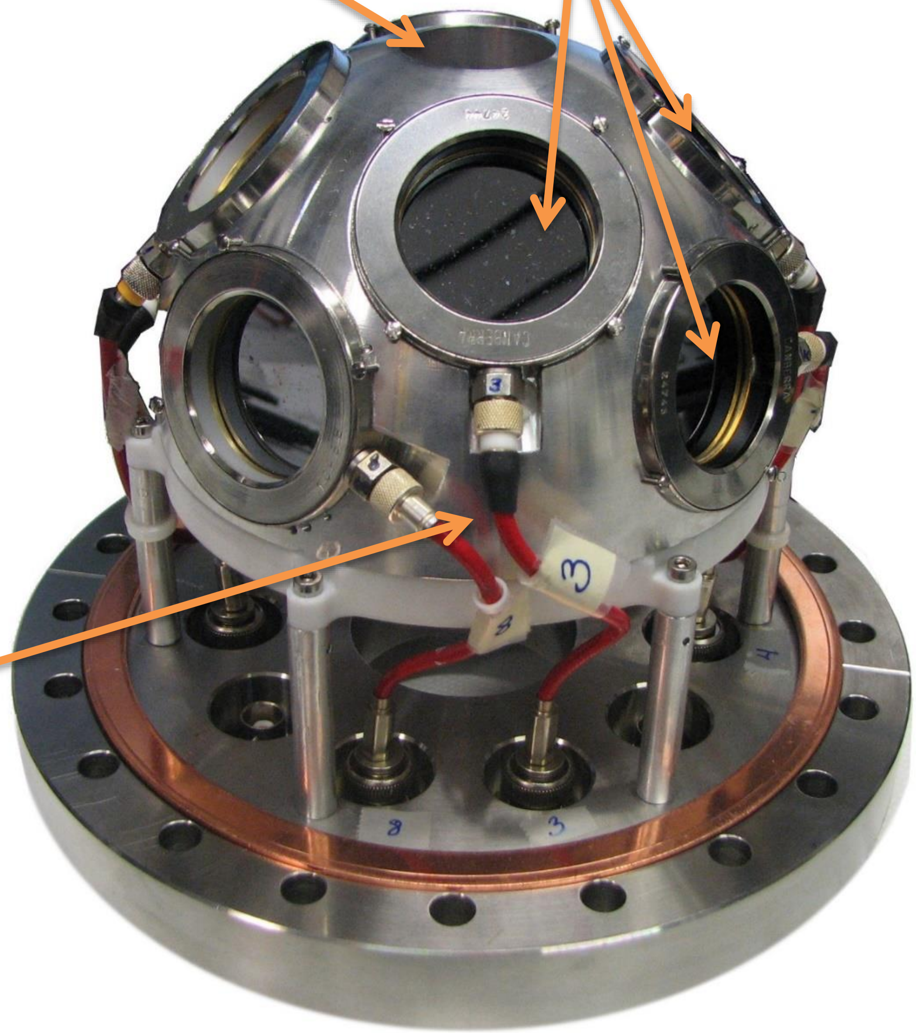




Thanks to the natural shielding of Gran Sasso Laboratory, background will be significantly reduced, allowing a direct measurement.

REACTION CHAMBER





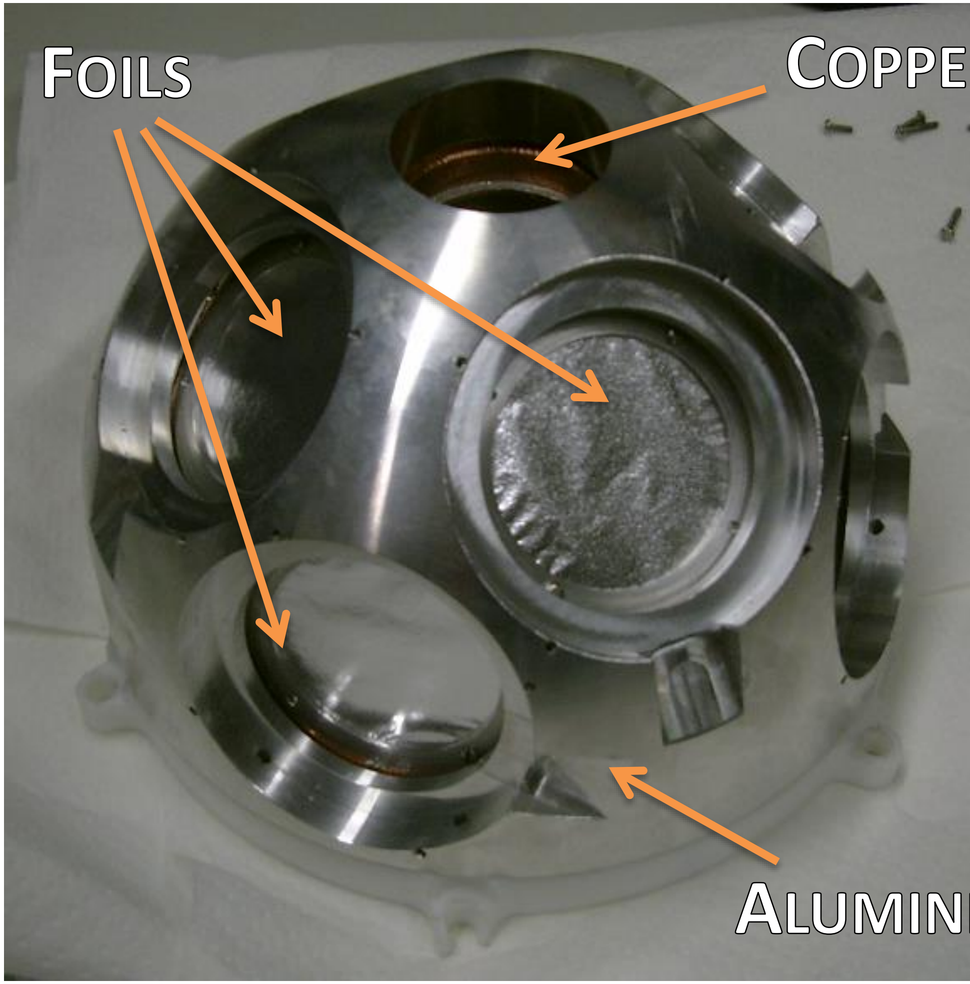
THE FOILS

- **Back-scattering protons will hit the silicon detectors**
  1. Will damage detectors
  2. Will increase background
- Foils mounted to shield detectors

- **Foils must be:**
  1. Thick to stop protons
  2. Thin to let alphas through
  3. Homogeneously thick, rugged, free of pinholes ...

- **Finding a compromise was difficult**
- Aluminised Mylar, roughly 2.4μm thick, was chosen
- For $^{17}O(p,\alpha)^{14}N$: 200 keV protons stopped and 1 MeV alpha particles detected at 200-250 keV

The foils



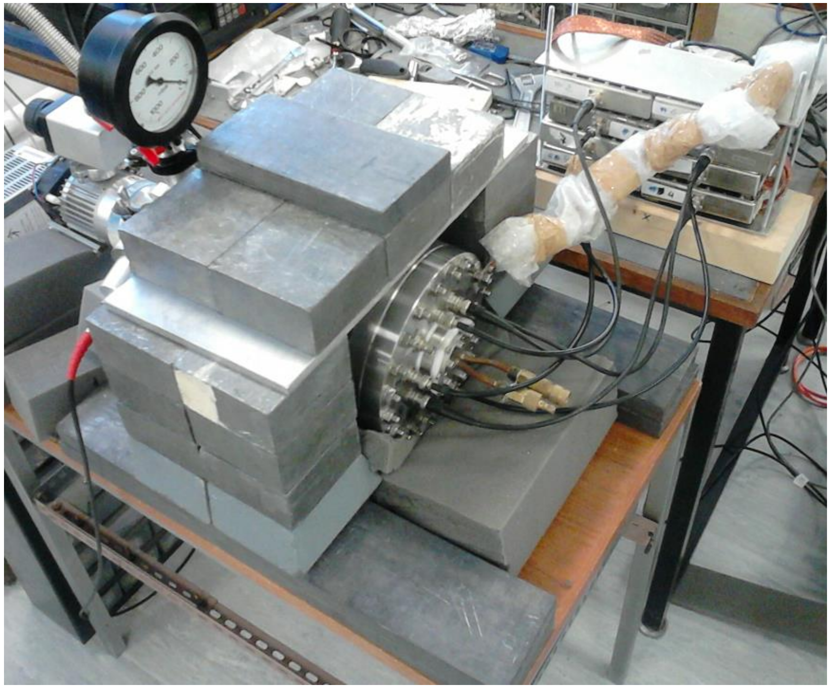
The foils

BACKGROUND REDUCTION IN SI DETECTORS

- Advantage of moving underground for gamma spectroscopy is well-established
- What about alpha spectroscopy?
- Does a **lead castle** help?
- We compared the background in Edinburgh and Gran Sasso

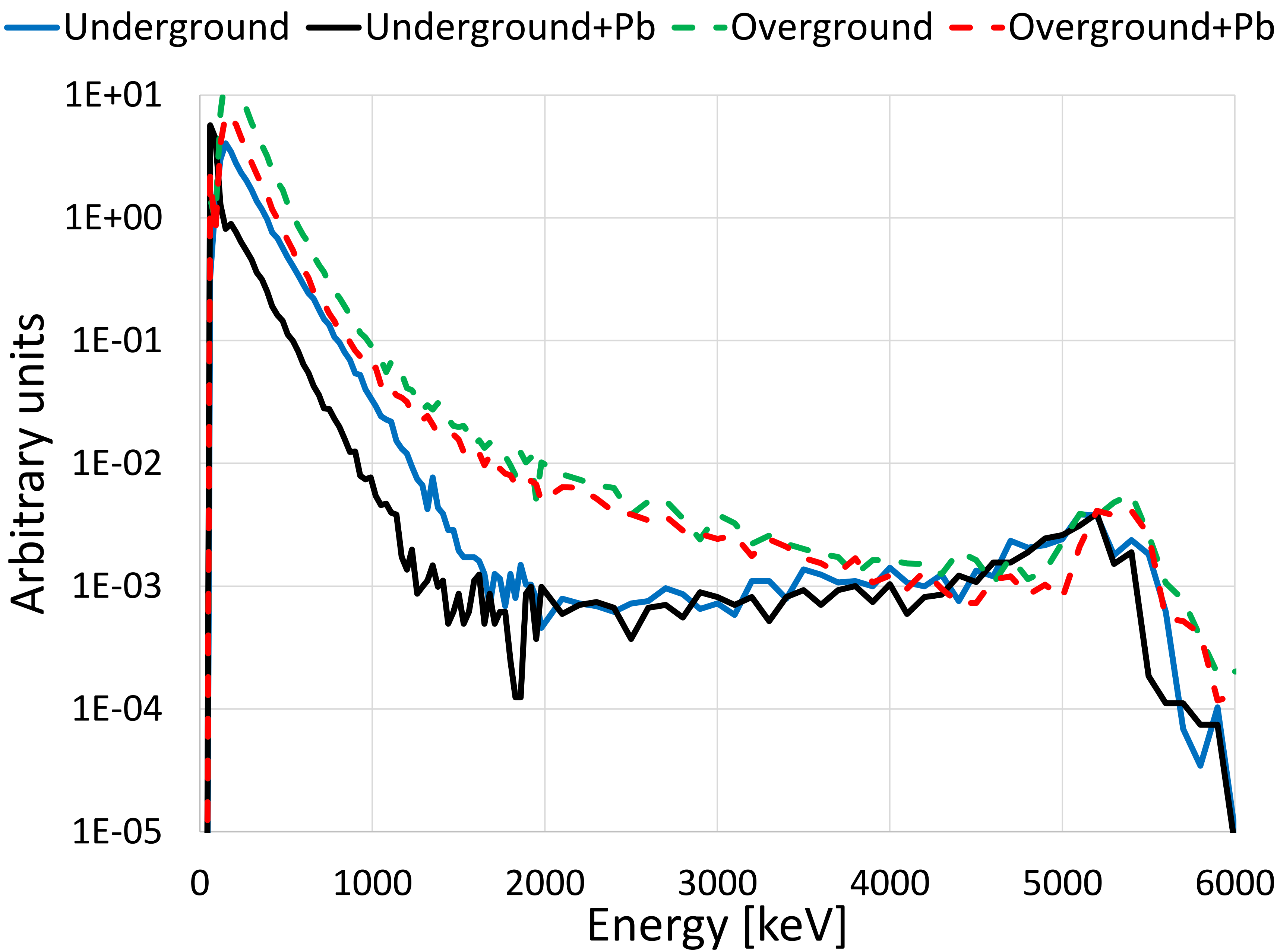
GRAN SASSO

EDINBURGH



BACKGROUND REDUCTION

BACKGROUND REDUCTION IN SI DETECTORS



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DOI 10.1140/epja/i2015-15094-y

THE EUROPEAN
PHYSICAL JOURNAL A

Regular Article – Experimental Physics

Resonance strengths in the $^{17,18}O(p,\alpha)^{14,15}N$ reactions and background suppression underground

Commissioning of a new setup for charged-particle detection at LUNA

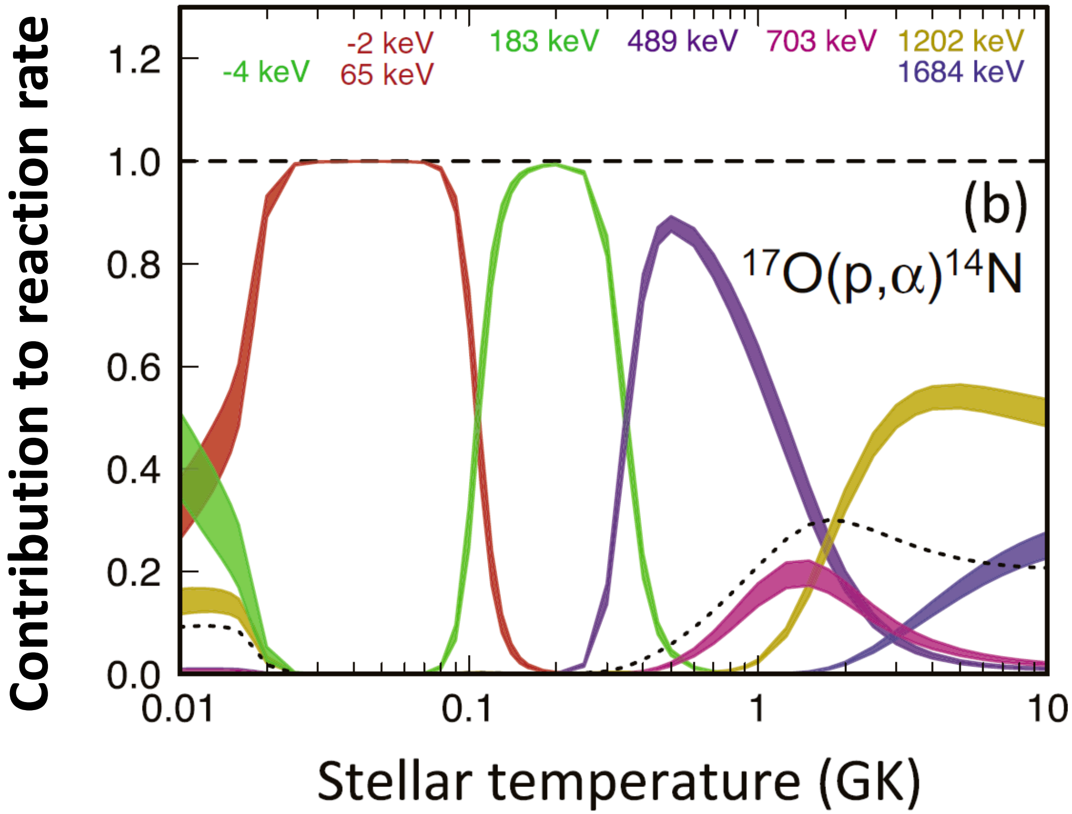
LUNA Collaboration

C.G. Bruno[1], D.A. Scott[1], A. Formicola[2], M. Aliotta[1,a], T. Davinson[1], M. Anders[3], A. Best[2], D. Bemmerer[3], C. Broggini[4], A. Caciolli[4,5], F. Cavanna[6], P. Corvisiero[6], R. Depalo[4,5], A. Di Leva[7], Z. Elekes[8], Zs. Fülöp[8], G. Gervino[9], C.J. Griffin[1], A. Guglielmetti[10], C. Gustavino[11], Gy. Gyürky[8], G. Imbriani[7], M. Junker[2], R. Menegazzo[4], E. Napolitani[5], P. Prati[6], E. Somorjai[8], O. Straniero[2,12], F. Strieder[13], T. Szücs[3], and D. Trezzi[10]

$^{17}O(p,\alpha)^{14}N$

NUCLEAR PHYSICS ASPECTS

- Q-value = 1.2 MeV. Alpha energy at emission = 1 MeV
- After foils: alpha energy = 200 - 250 keV
- Two narrow resonances at 70 and 193 keV (Lab. frame)
- Resonances dominant at astrophysical temperatures
- **AIMS: measure E_p=70 and 193 keV resonances**



Buckner et al., PRC **91** (2015)

FINDING THE REGION OF INTEREST

- Counting rate at E_p=193 keV -> 8000 counts/C (OK!)
- Counting rate at E_p=70 keV -> few counts/C (very low!)
- How do we find the signal at E_p=70 keV?

FINDING THE REGION OF INTEREST

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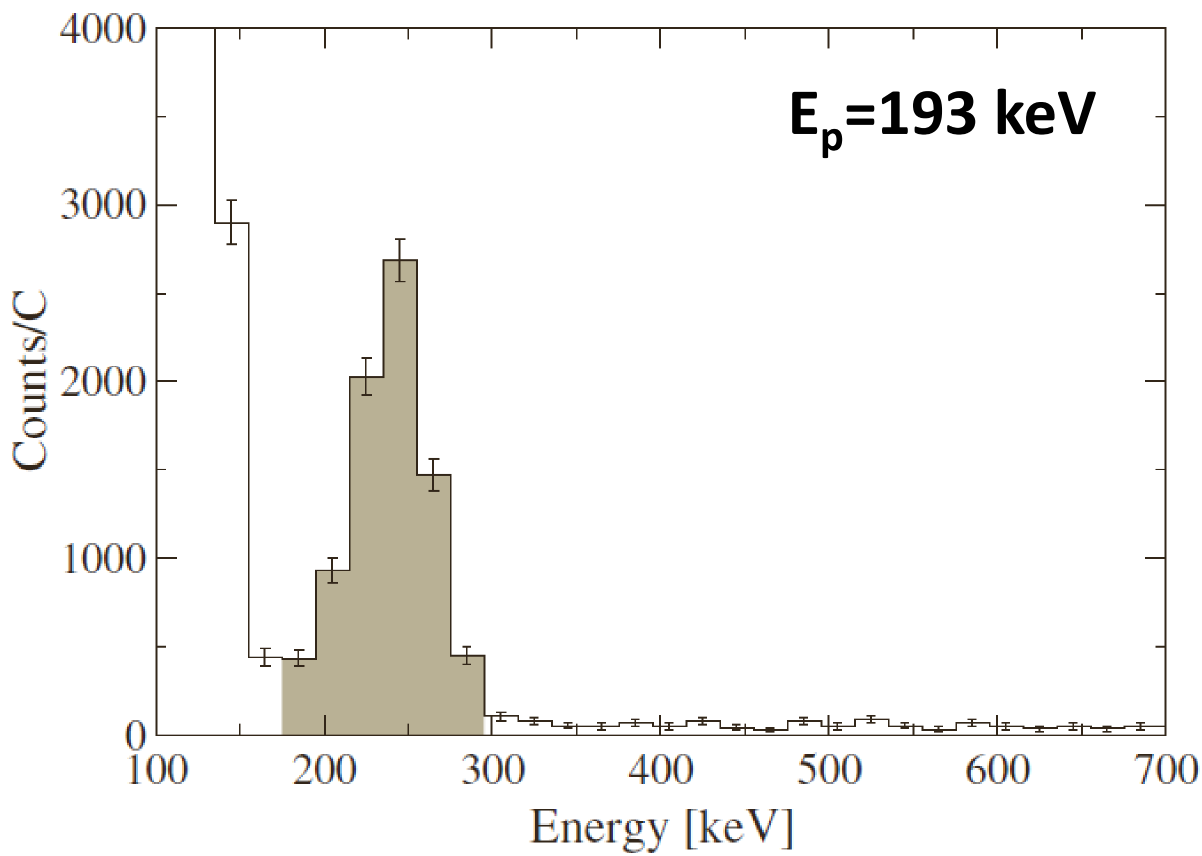
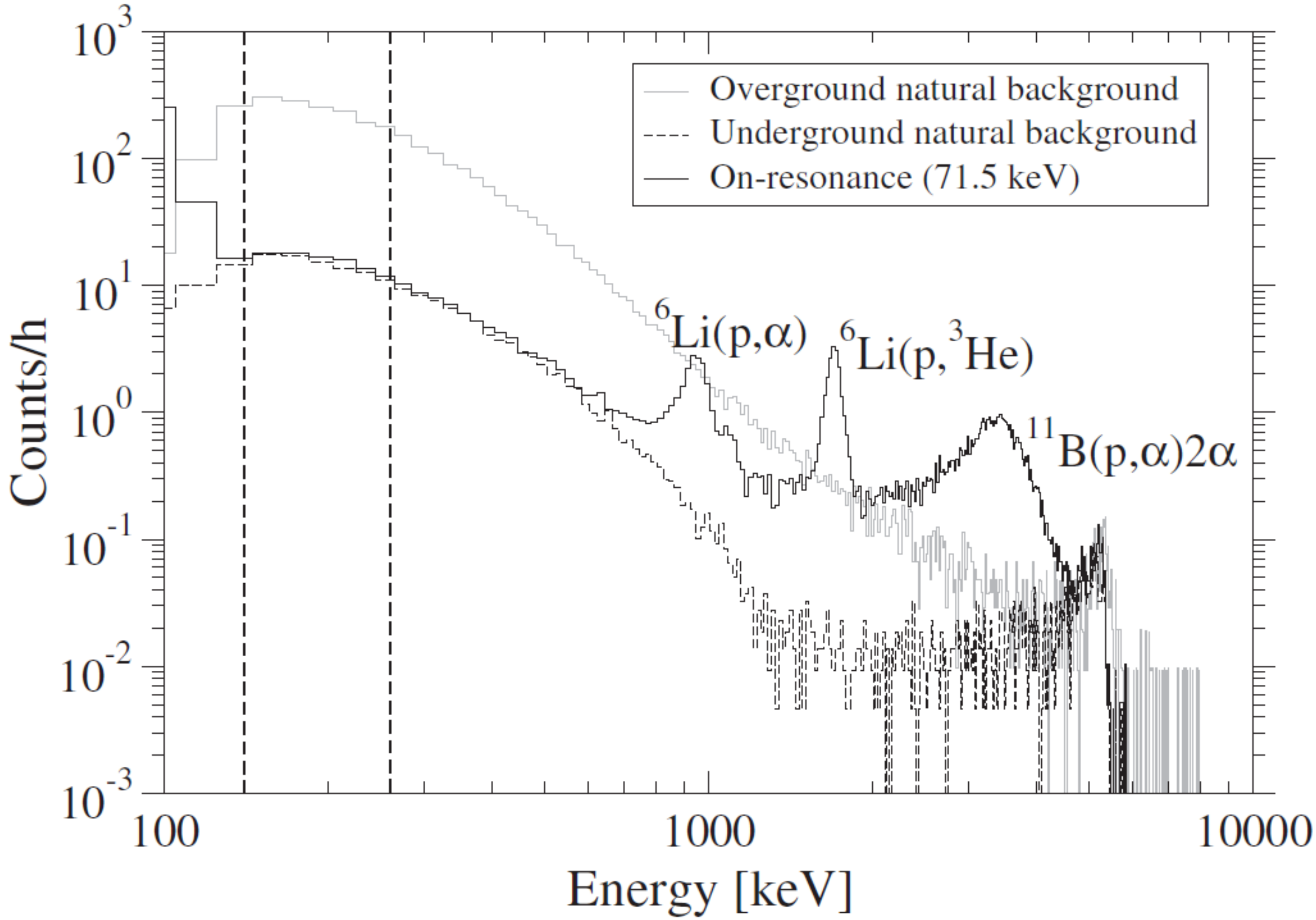
- Counting rate at E_p=70 keV -> few counts/C (very low!)
- How do we find the signal at E_p=70 keV?
- Define a ROI at E_p=193 keV
- Use ROI defined at E_p=70 keV (small correction needed)



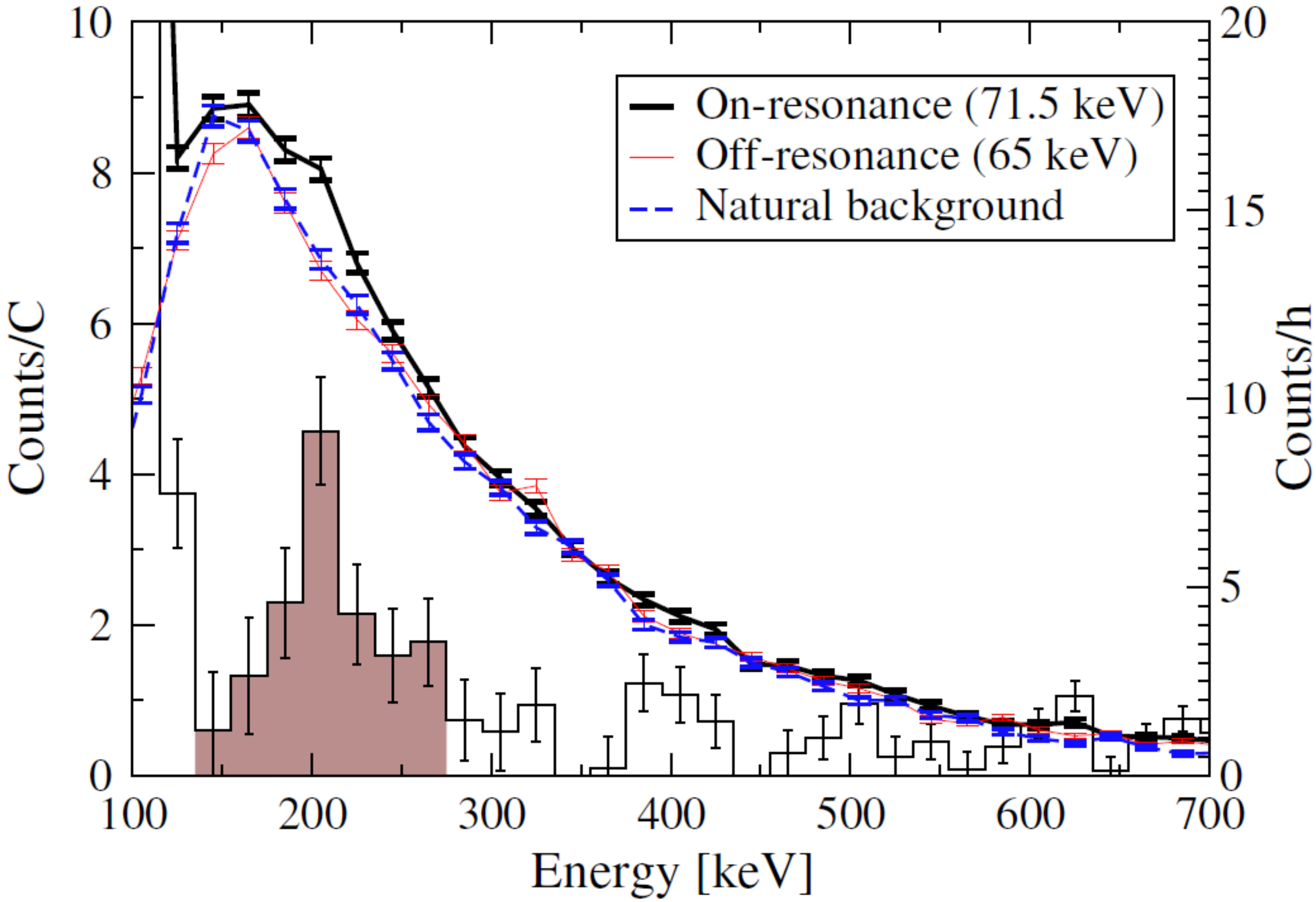
RAW SPECTRA

- On-resonance and natural background in agreement
- Natural background is the main source of background
- Large reduction compared with overground



SUBTRACTED SPECTRA

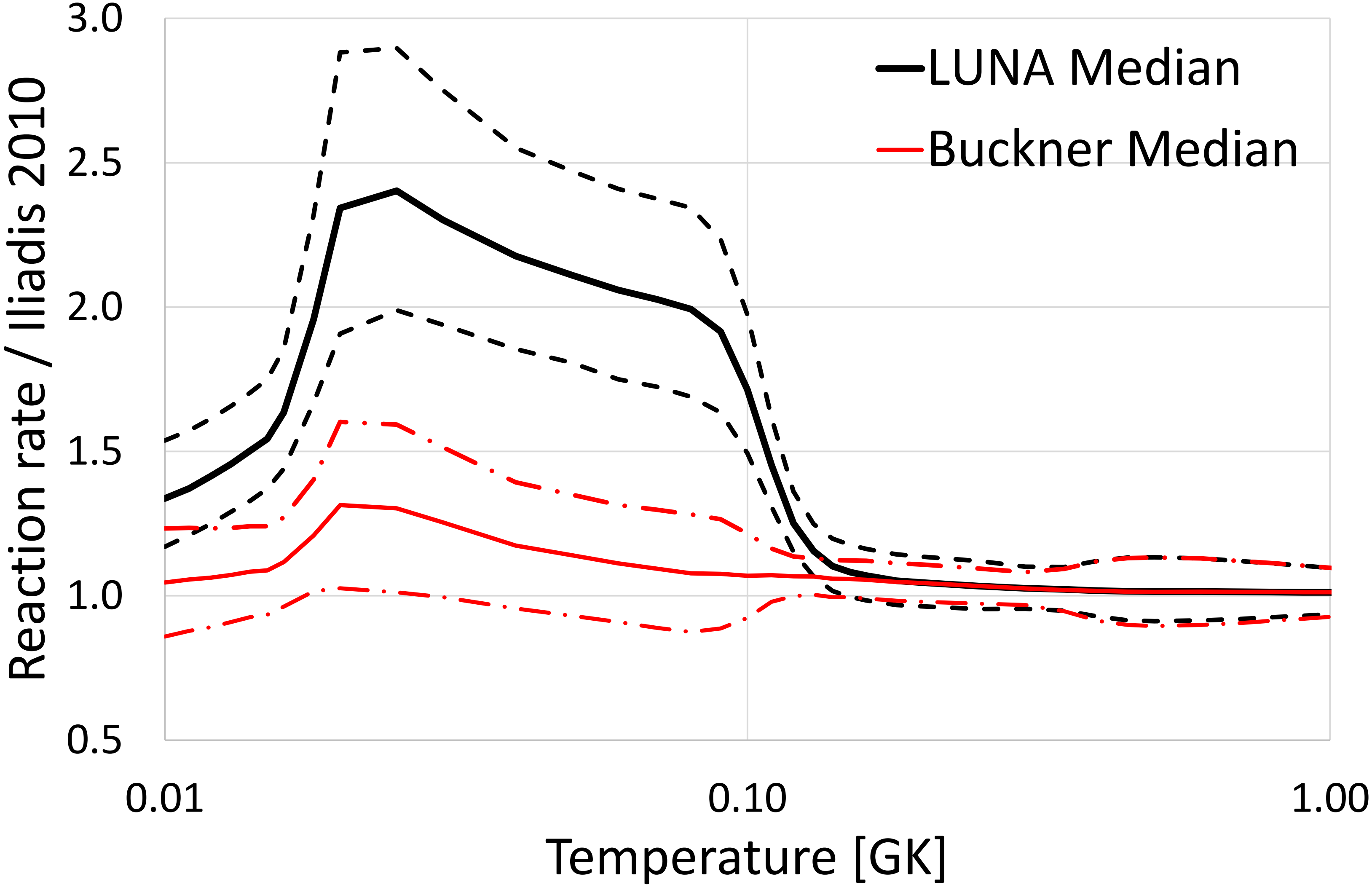
- Clear peak in the green region of interest
- Shape looks reasonable
- No obvious structures in the off-resonance
- Maximum Likelihood employed to extract counts



REACTION RATE

REACTION RATE

- Compared with Iliadis 2010 compilation and Buckner 2015
- Same input file, changed only 70 keV resonance



PRL 117, 142502 (2016) PHYSICAL REVIEW LETTERS week ending 30 SEPTEMBER 2016

Improved Direct Measurement of the 64.5 keV Resonance Strength in the $^{17}O(p,\alpha)^{14}N$ Reaction at LUNA

C. G. Bruno,[1,*] D. A. Scott,[1] M. Aliotta,[1,†] A. Formicola,[2] A. Best,[3] A. Boeltzig,[4] D. Bemmerer,[5] C. Broggini,[6] A. Caciolli,[7] F. Cavanna,[8] G. F. Ciani,[4] P. Corvisiero,[8] T. Davinson,[1] R. Depalo,[7] A. Di Leva,[3] Z. Elekes,[9] F. Ferraro,[8] Zs. Fülöp,[9] G. Gervino,[10] A. Guglielmetti,[11] C. Gustavino,[12] Gy. Gyürky,[9] G. Imbriani,[3] M. Junker,[2] R. Menegazzo,[6] V. Mossa,[13] F. R. Pantaleo,[13] D. Piatti,[7] P. Prati,[8] E. Somorjai,[9] O. Straniero,[14] F. Strieder,[15] T. Szücs,[5] M. P. Takács,[5] and D. Trezzi[11]

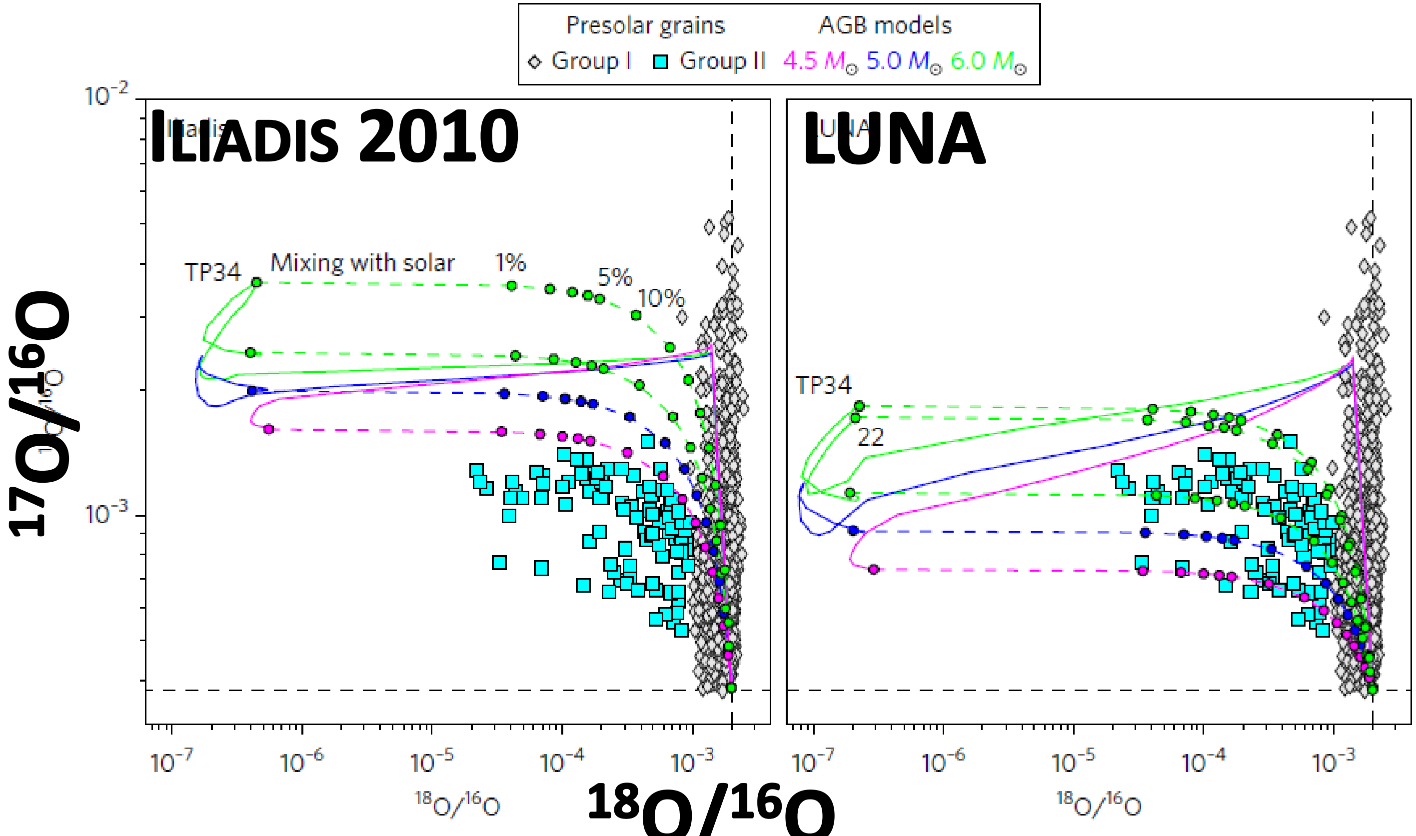
(LUNA Collaboration)

ASTROPHYSICAL IMPLICATIONS

- Oxygen-rich Group II pre-solar grains
- Tentative origin: low-mass AGB stars and CBP mixing
- CBP is introduced ad-hoc.

ASTROPHYSICAL IMPLICATIONS

- Oxygen-rich Group II pre-solar grains
- New production site: massive AGBs
- Excellent agreement with Hot Bottom Burning models
- No need for ad-hoc Cool Bottom Process
- First evidence of pre-solar grains from massive AGBs!



nature astronomy

LETTERS

PUBLISHED: 30 JANUARY 2017 | VOLUME: 1 | ARTICLE NUMBER: 0027

Origin of meteoritic stardust unveiled by a revised proton-capture rate of ^{17}O

M. Lugaro[1,2*], A. I. Karakas[2-4], C. G. Bruno[5], M. Aliotta[5], L. R. Nittler[6], D. Bemmerer[7], A. Best[8], A. Boeltzig[9], C. Broggini[10], A. Caciolli[11], F. Cavanna[12], G. F. Ciani[9], P. Corvisiero[12], T. Davinson[5], R. Depalo[11], A. Di Leva[8], Z. Elekes[13], F. Ferraro[12], A. Formicola[14], Zs. Fülöp[13], G. Gervino[15], A. Guglielmetti[16], C. Gustavino[17], Gy. Gyürky[13], G. Imbriani[8], M. Junker[14], R. Menegazzo[10], V. Mossa[18], F. R. Pantaleo[18], D. Piatti[11], P. Prati[12], D. A. Scott[5,†], O. Straniero[14,19], F. Strieder[20], T. Szücs[13], M. P. Takács[7] and D. Trezzi[16]

A&A 598, A128 (2017)
DOI: 10.1051/0004-6361/201629624

Astronomy & Astrophysics

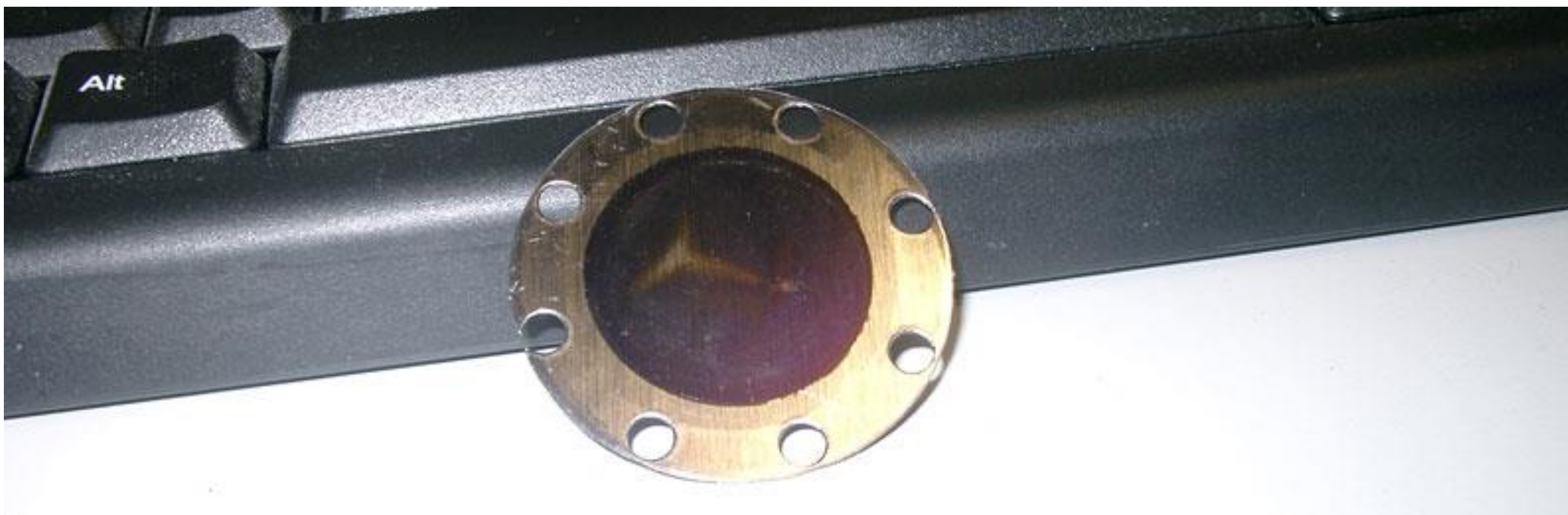
The impact of the revised ^{17}O(p, α)^{14}N reaction rate on ^{17}O stellar abundances and yields

O. Straniero[1,2], C. G. Bruno[5], M. Aliotta[5], A. Best[6], A. Boeltzig[3], D. Bemmerer[4], C. Broggini[7], A. Caciolli[7,8], F. Cavanna[9], G. F. Ciani[3], P. Corvisiero[9], S. Cristallo[1,16], T. Davinson[5], R. Depalo[7,8], A. Di Leva[6], Z. Elekes[10], F. Ferraro[9], A. Formicola[2], Zs. Fülöp[10], G. Gervino[11], A. Guglielmetti[12], C. Gustavino[13], G. Gyürky[10], G. Imbriani[6], M. Junker[2], R. Menegazzo[7], V. Mossa[14], F. R. Pantaleo[14], D. Piatti[7,8], L. Piersanti[1,16], P. Prati[9], E. Samorjai[10], F. Strieder[15], T. Szücs[4], M. P. Takács[4], and D. Trezzi[11]

Thank you for your attention!

DETECTORS AND TA_2O_5 TARGET

- 8 silicon detectors (Canberra PIPS)
- Surface: 9 cm^2
- Thickness: 5x300 μm, 3x700 μm
- Dead layer: ~20-50nm
- Resolution: 40 keV for the Am peak (5486 keV)



- 5 (or 15) keV thick for 200 keV protons
- Stable under beam bombardment (up to 20C)
- $H_2{}^{17}O$ water at ~95% enrichment
- $H_2{}^{18}O$ water at ~95% enrichment

E_P=193 KEV RESONANCE

- Clear peak in the green region of interest determined from 193 keV resonance