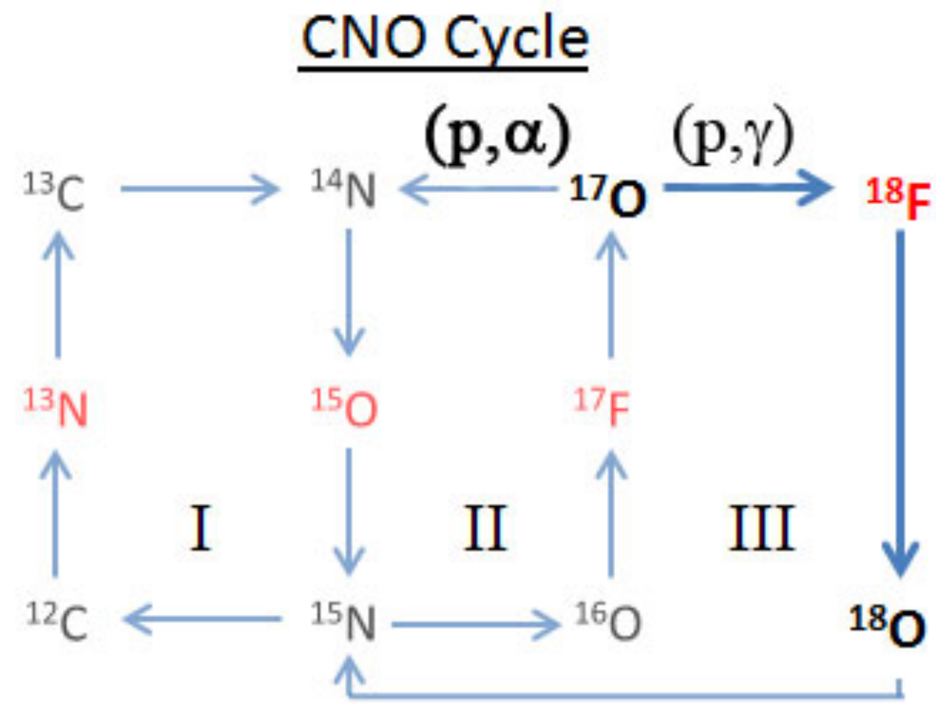
A direct underground study of the ^{17}**O(p,α)**^{14}**N reaction** at energies of astrophysical interest

Carlo Bruno

On behalf of the **LUNA** collaboration

Russbach Winter School 2014

ASTROPHYSICAL ASPECTS



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

- At branching point between CNO-II and CNO-III
- In competition with gamma channel
- Critical for ^{17}**O** and ^{18}**F** abundances
- Important in a variety of scenarios (AGB, Classical Novae...)

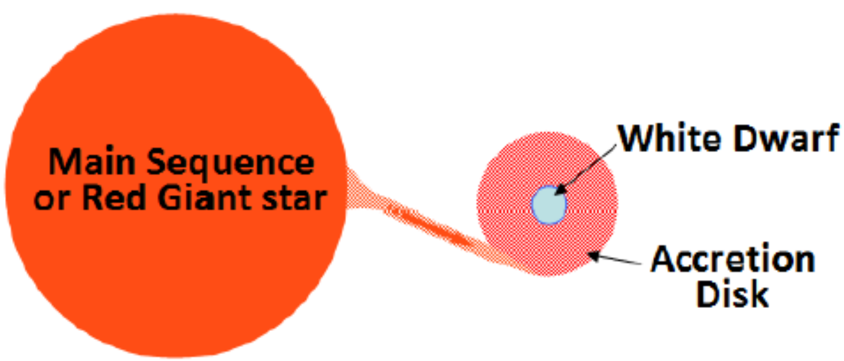
ASTROPHYSICAL ASPECTS

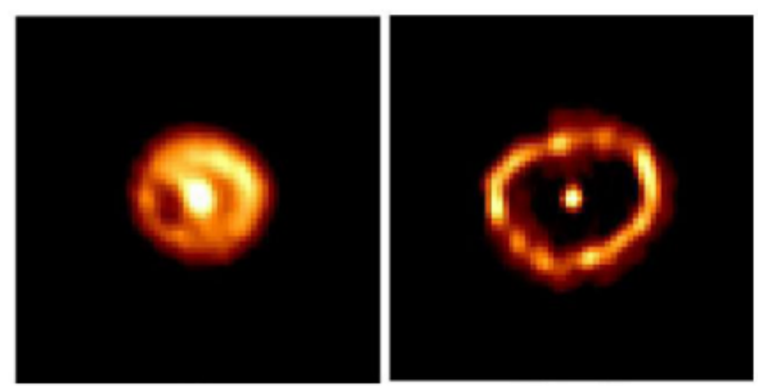
AGB stars (T=0.03-0.1 GK)

- The CNO cycle takes place in the heart of the star
- Poorly-understood extra mixing process carries CNO products to outer layers
- To understand this process ^{17}**O**/^{16}O is crucial

Classical Novae (T=0.1-0.4 GK)

- Binary systems
- An explosion occurs periodically (10^3 – 10^4 years)
- ^{17}**O** among ejecta (primary source in our galaxy?)
- ^{18}**F** abundance helps constrain astrophysical models

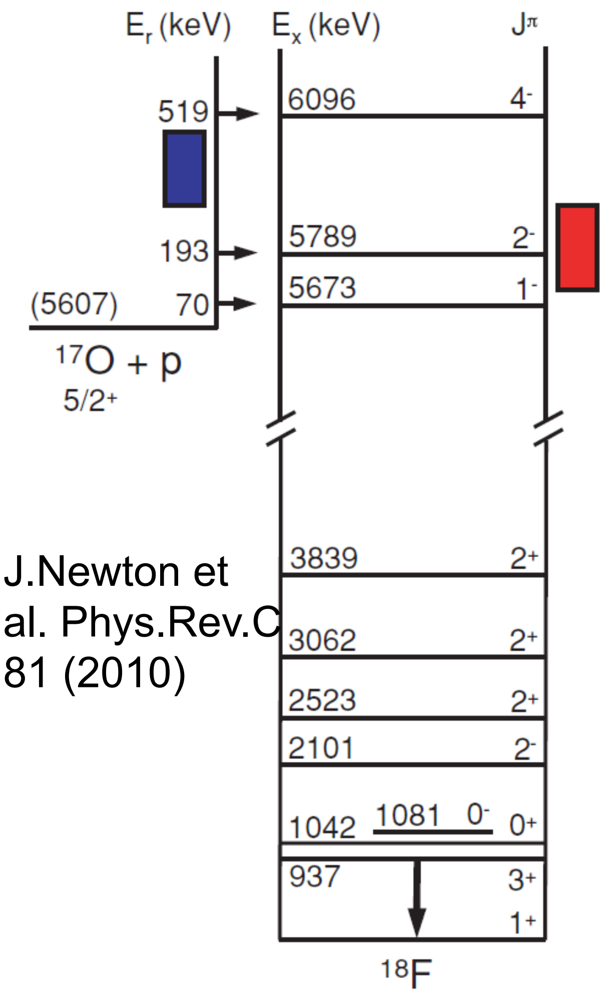




NUCLEAR PHYSICS ASPECTS

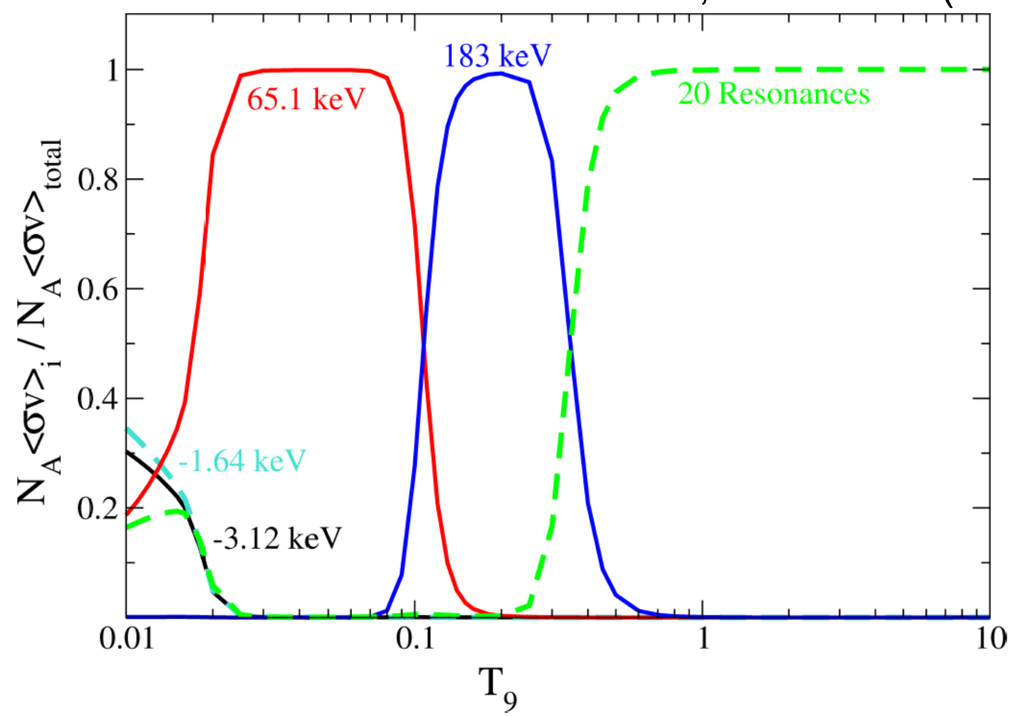
- Q-value = 1.2 MeV. Expected alpha energy = 1 MeV
- Two narrow resonances at 70 and 193 keV (Lab. frame)

ant at astrophysical temperatures



J.Newton et al. Phys.Rev.C 81 (2010)

J.Newton, PhD thesis (2010)



STATE OF THE ART

- **193 keV RESONANCE**

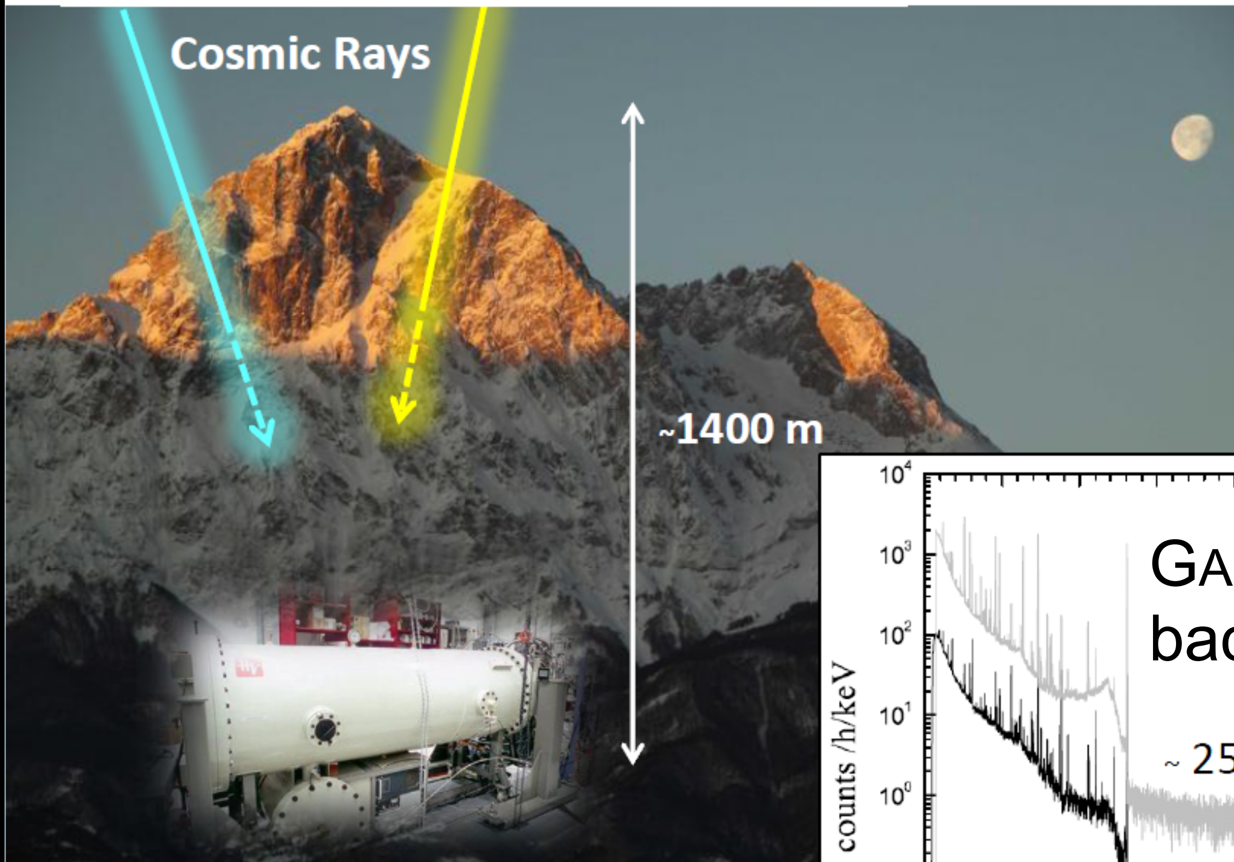
Authors	**Resonance strength**	**Approach**
Chafa (2005-07)	$(1.6 \pm 0.2) \times 10^{-3}$ eV	Indirect (activation)
Moazen (2007)	$(1.70 \pm 0.15) \times 10^{-3}$ eV	Indirect (inverse kinematics)
Newton (2010)	$(1.66 \pm 0.17) \times 10^{-3}$ eV	Direct

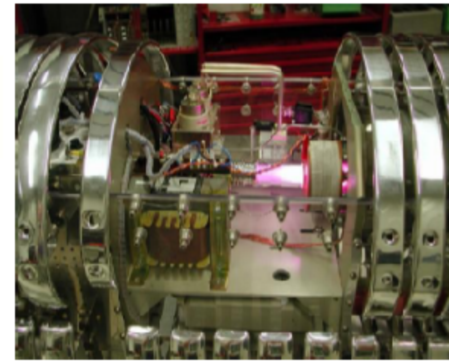
- **70 keV RESONANCE**

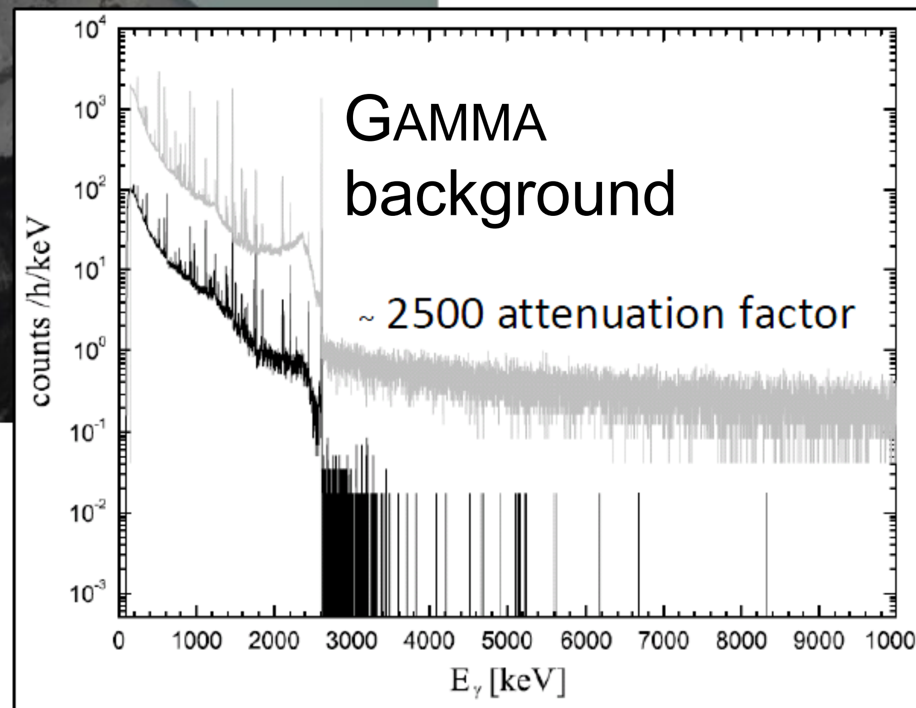
Berheide (1992)	$< 8 \times 10^{-10}$ eV	Direct (upper limit)
Blackmon (1995)	$5.5^{+1.8}_{-1.5} \times 10^{-9}$ eV	Direct
Sergi (2010)	$3.66^{+0.76}_{-0.64} \times 10^{-9}$ eV	Indirect (Trojan horse)

MEASURING THE 70 KEV RESONANCE IS OUR FINAL GOAL

THE LUNA EXPERIMENT

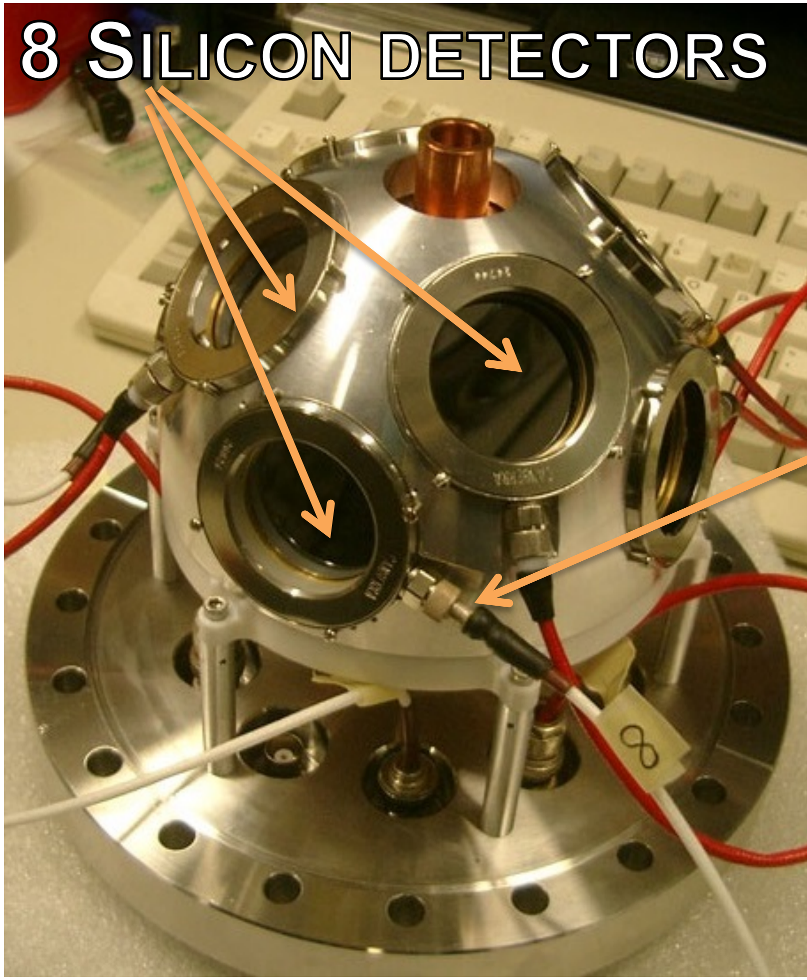






Thanks to the natural shielding of Gran Sasso Laboratory, background will be significantly reduced, allowing a direct measurement

EXPERIMENTAL SETUP



Targets are 95% enriched in ^{17}O or ^{18}O, 5 keV thick and withstand up to 20C

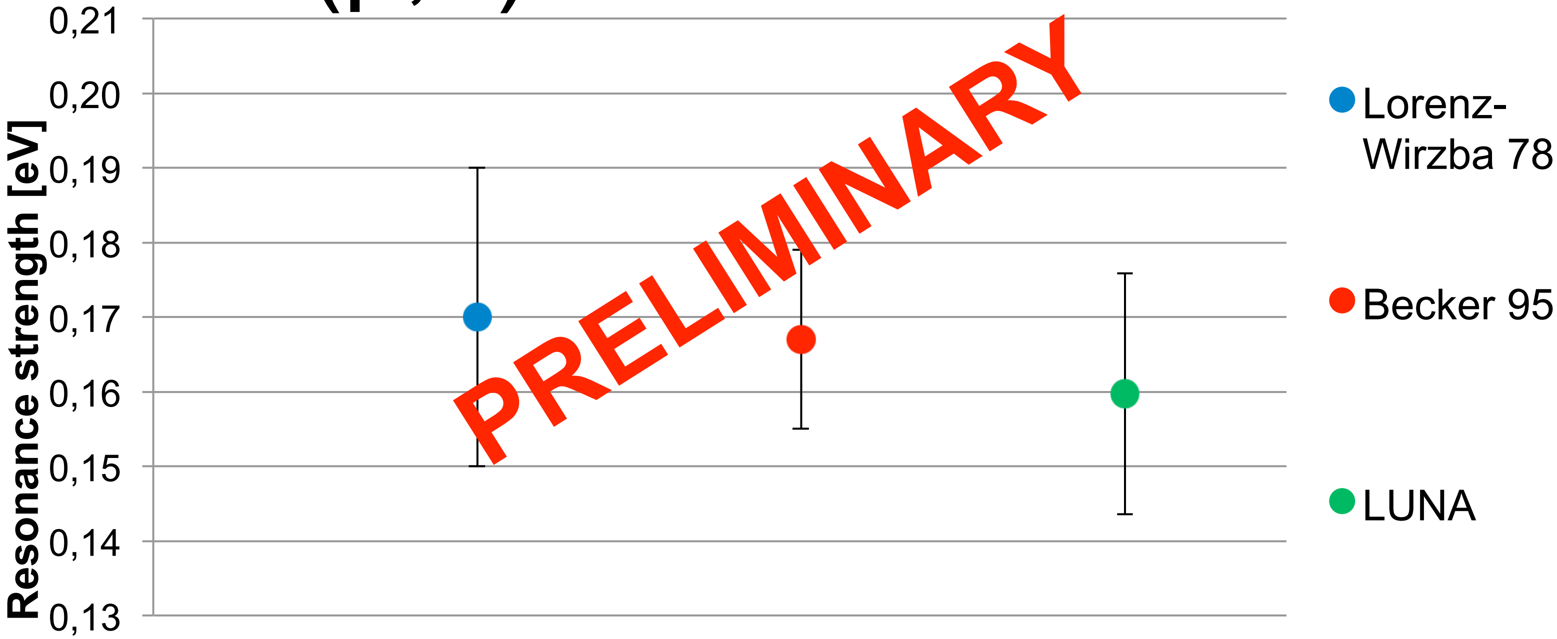
THE FOILS

- **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 2μm thick, was chosen
- For 193 keV resonance: 200 keV protons stopped and 1 MeV alpha particles detected with 250 keV

$^{18}O(p,\alpha)^{15}N$ RESONANCE TEST

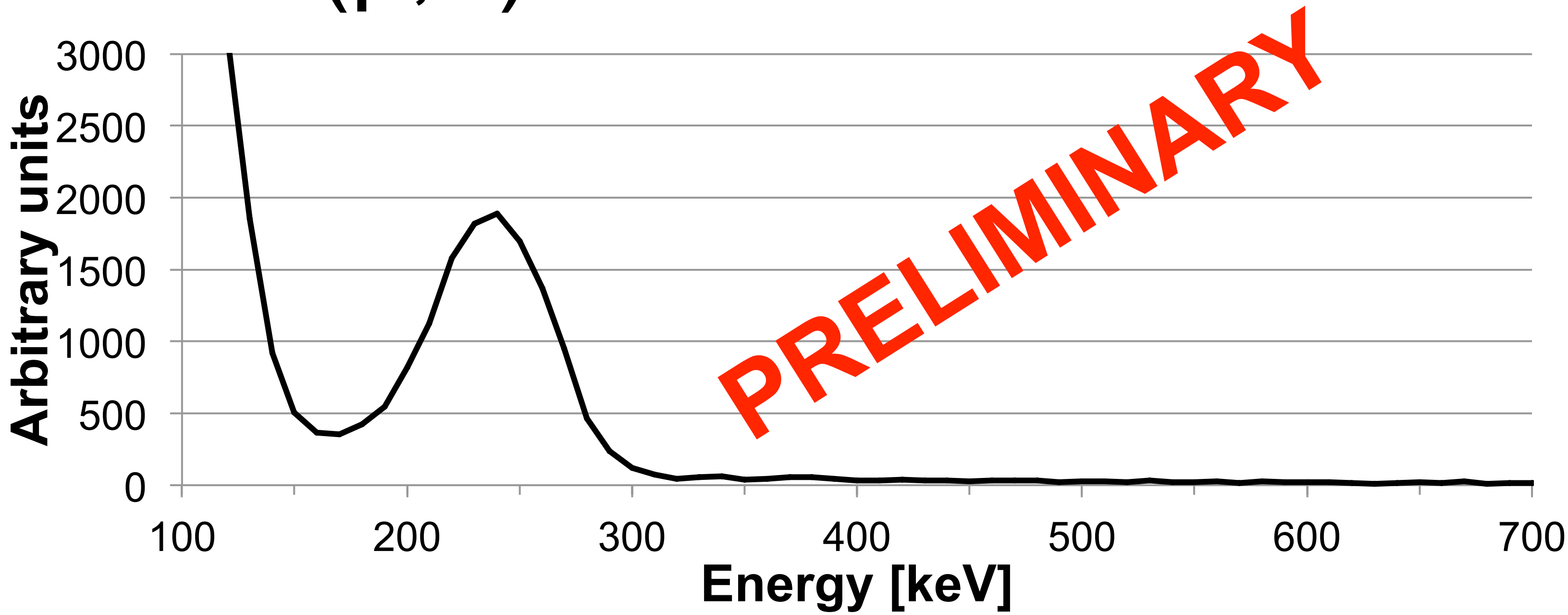


- **Resonant energy: 151 keV (lab. frame)**
- Very well-known, high Q-value (3979 keV), high rates (kHz)
- Used to **commission the setup**

- LUNA preliminary results in excellent agreement with literature
- Becker 95*, very precise, considered as reference

***Becker et al., Z Phys A 351 453-465 1995**

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



- Resonance strength relatively well-known
- 1~2 alphas/s/detector at ~250 keV
- Very similar conditions to final objective (70keV resonance)

- Clear peak visible in spite of low energy and rate
- Preliminary results are in agreement with literature
- **Commissioning complete**

70 keV RESONANCE - EXPECTATIONS

Assuming:

1. 10% total efficiency (simulated)
2. Targets with 95% ^{17}O enrichment
3. 100μA beam intensity
4. 1 neV resonance strength (conservative)
5. 2 μm aluminised Mylar foils

We get:

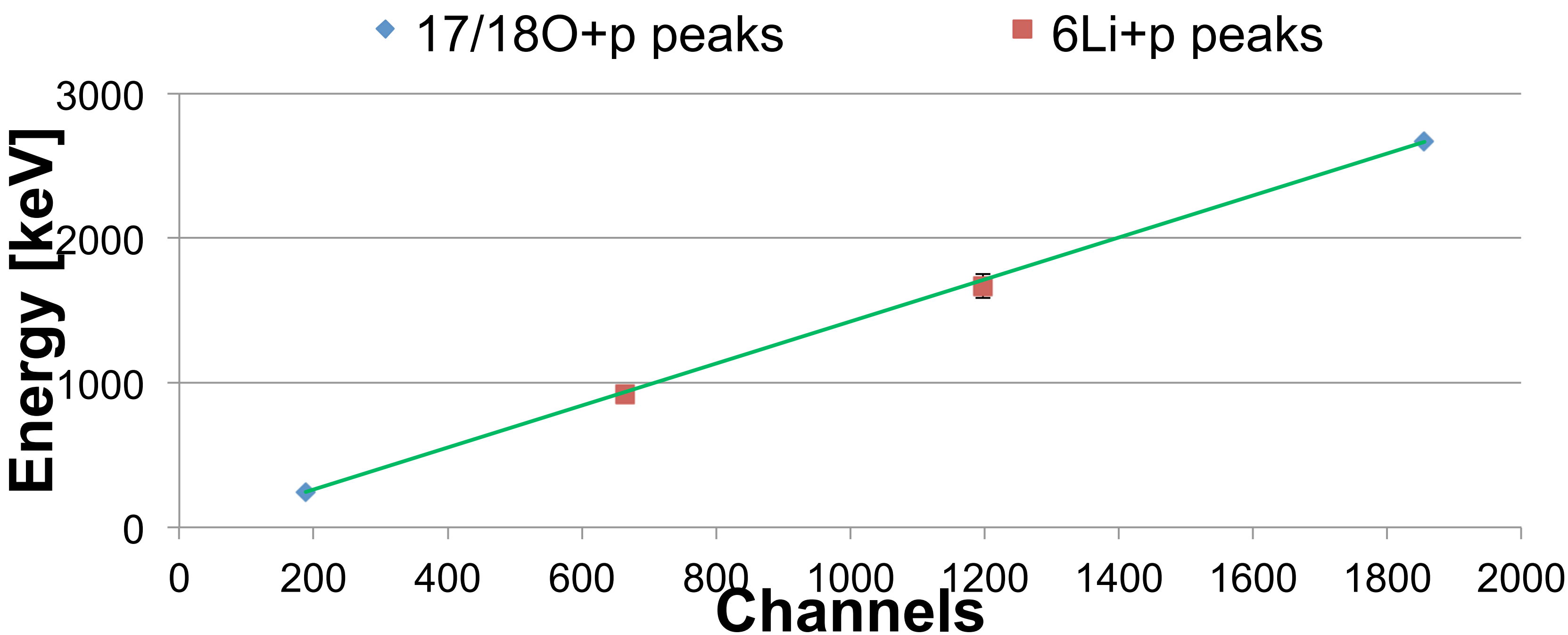
- 0.1 counts/hour/detector or 2 counts/hour in total
- Detected alpha energy around 200 keV

Considerations:

- Very low energy and rate: the background must be under control
- A long time (months) is necessary to see the signal

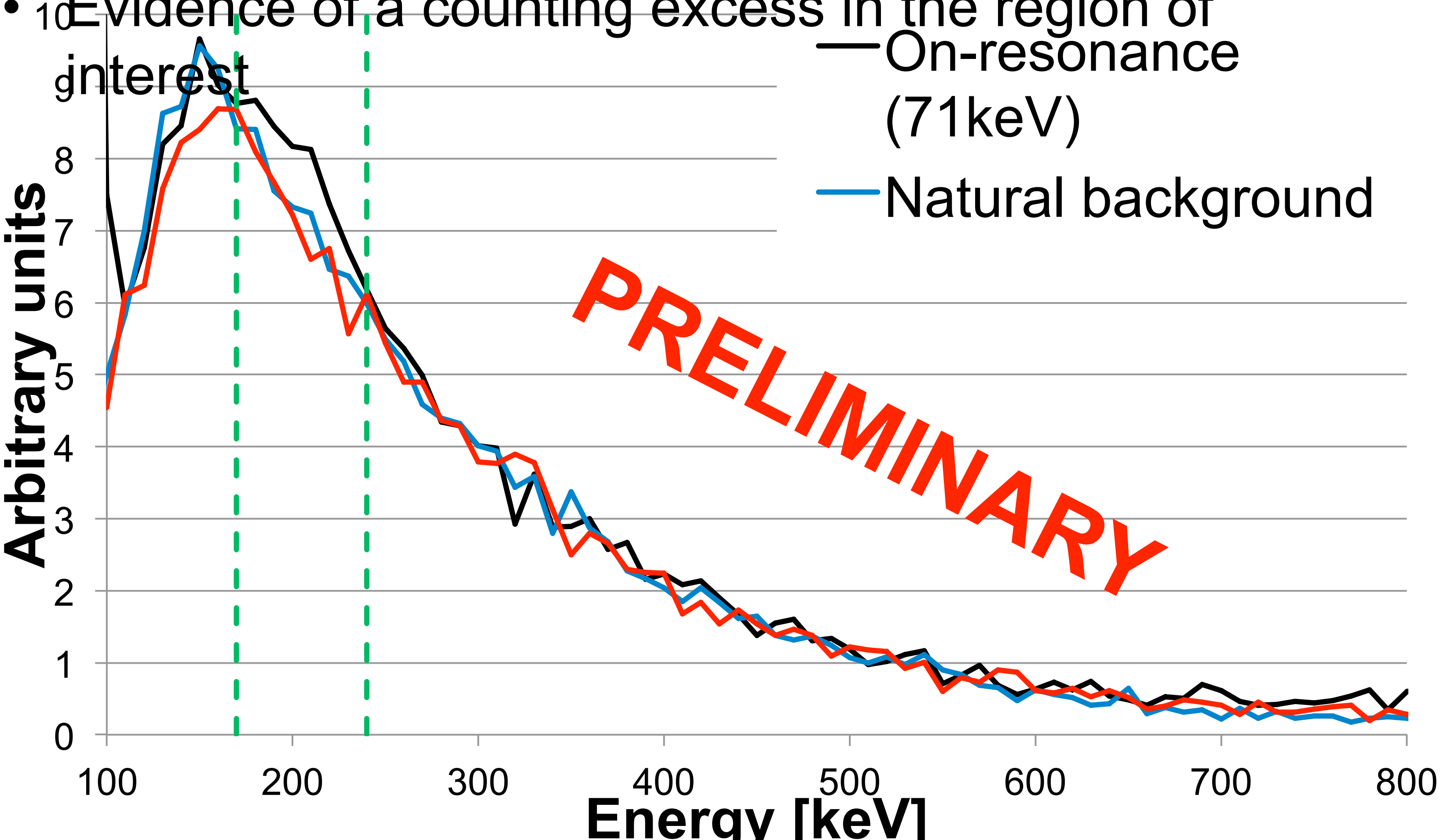
70 keV RESONANCE - PREPARATIONS

- Detectors calibrated with alphas from 151 and 193keV resonances
  - ➢ **energy** depends on foil **thickness**
- Thickness estimated by energy loss in foils
  - ➢ **thickness** depends on **calibration**
- Minimisation procedure used to find both
- Result checked with $^{6}Li(p,\alpha)^{3}He$
- **A region of interest for the 70keV signal can be defined**



70 keV RESONANCE – PRELIMINARY RESULTS

- 50C on-resonance, 60h off-resonance, 130h without beam
- No evidence of beam-induced background
- Evidence of a counting excess in the region of interest



CONCLUSIONS

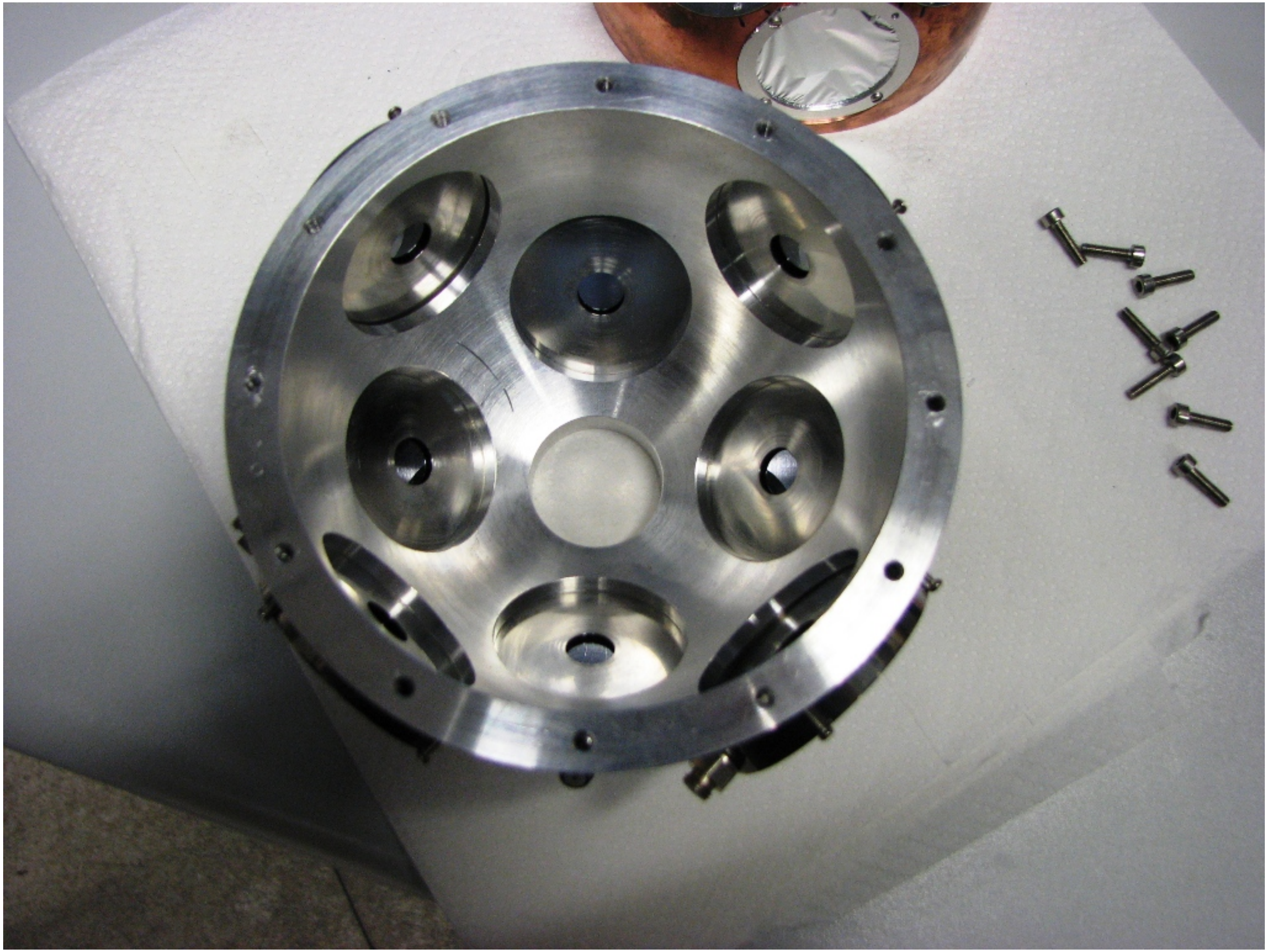
- Measurement of the elusive $^{17}O(p,\alpha)^{14}N$ reaction started
- Setup commissioning complete
- Evidence of a counting excess in the energy region where the signal is expected
- More statistics is required to draw conclusions

THE LUNA COLLABORATION

A.Best, A.Formicola, M.Junker, INFN, LNGS, Italy
D.Bemmerer, T.Szucs, Forschungszentrum Dresden-Rossendorf, Germany
C.Broggini, A.Caciolli, R.De Palo, R.Menegazzo, INFN, Padova, Italy
C.Gustavino, INFN, Roma La Sapienza, Italy
Zs.Fülöp, Gy.Gyurky, Z.Elekes, E.Somorjai, Institute of Nuclear Research (ATOMKI), Debrecen, Hungary
O.Straniero, Osservatorio Astronomico di Collurania, Teramo, and INFN, Napoli, Italy
C.Rolfs, F.Strieder, H.P.Trautvetter, Ruhr-Universität Bochum, Bochum, Germany
M.Aliotta, C.G.Bruno, T.Davinson, D.A.Scott, The University of Edinburgh, UK
F.Cavanna, P.Corvisiero, P.Prati, Università di Genova and INFN, Genova, Italy
A.Guglielmetti, D.Trezzi, Università di Milano and INFN, Milano, Italy
G.Imbriani, Università di Napoli "Federico II" and INFN, Napoli, Italy
A.Di Leva, INFN, Napoli, Italy
G.Gervino, Università di Torino and INFN, Torino, Italy

THANK YOU FOR YOUR ATTENTION!

The collimators



Experimental setup