

The challenging direct measurement of the 65 keV resonance strength of the $^{17}\text{O}(p,\gamma)^{18}\text{F}$ reaction at LUNA

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ASTROPHYSICAL MOTIVATION

A precise determination of proton capture reaction rates on oxygen is mandatory to predict the **abundance ratios** of the oxygen isotopes in stellar environments where hydrogen burning is active. Among these reactions of astrophysical interest the $^{17}\text{O}(p,\gamma)^{18}\text{F}$ reaction ($Q = 5607$ keV) plays a crucial role in **AGB** nucleosynthesis as well as in explosive hydrogen burning occurring in **type Ia novae**. At temperature of interest for the AGB scenario ($20 \text{ MK} < T < 80 \text{ MK}$) the main contribution to the astrophysical reaction rate comes from the $E_{\text{cm}} = 65$ keV resonance, while at the novae temperatures ($100 \text{ MK} < T < 400 \text{ MK}$) the $E_{\text{cm}} = 183$ keV resonance dominates together with the direct capture (DC) component (Fig. 1).

An accurate direct measurement of the resonance strength is crucial to improve the reaction rate determination and to help constraining the stellar models

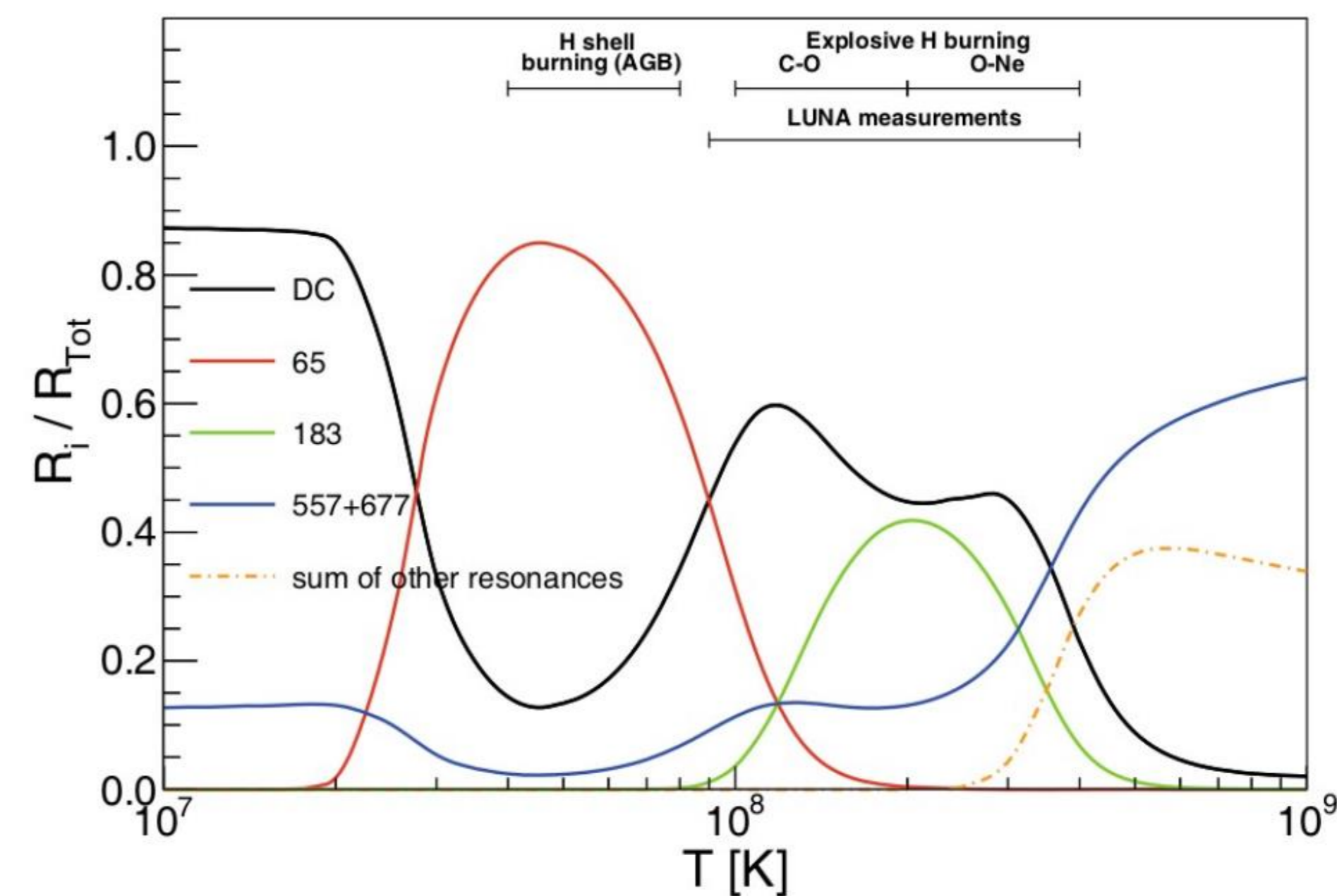


Figure 1: Fractional contribution of the reaction rate of the $^{17}\text{O}(p,\gamma)^{18}\text{F}$

STATE OF THE ART

Recent measurements of the $^{17}\text{O}(p,\gamma)^{18}\text{F}$ reaction have been performed at LUNA using both the prompt γ -ray detection and the activation method. These led to a **precise determination** of the $E_{\text{cm}} = 183$ keV resonance strength [5].

The strength of the $E_{\text{cm}} = 65$ keV resonance is presently determined only through **indirect measurements** [1-4], with the adopted value of $\omega\gamma = (1.6 \pm 0.3) \times 10^{-11}$ eV: its last evaluation was made in 2005 by Fox et al. [4], from the resonance strenghts of $^{17}\text{O}(p,\alpha)^{14}\text{N}$, $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ and the a partial width of $^{14}\text{N}(\alpha,\alpha)$ scattering.

This $\omega\gamma$ value leads to a number of expected events so low that a direct determination of the strength of the $E_{\text{cm}} = 65$ keV resonance strength is only possible by **reducing to the minimum the environmental and beam-induced background sources**, so LUNA at LNGS is particularly suitable because it is covered by a 1400 m thick overburden rock, which reduces the cosmic muon flux by six orders of magnitude.

CRITICAL POINTS OF THE MEASUREMENT

- Low expected counting rate: **$N = 0.31$ reactions/C**
- The environmental and beam induced background must be reduced
- The knowledge of the beam induced background is crucial for a solid evaluation of the signal
- The target must be well characterized **in thickness and stoichiometry**
- The detection efficiency **must be maximized**
- Data analysis focused on a regime with **$S/N \approx 1$**

TARGET CHARACTERIZATION

- Targets made by **anodisation** of **Ta backings** with **oxygen-enriched water**
- Well-known stoichiometry [6] of the anodised backing **Ta_2O_5**
- Ta backing treated with **acid bath** for impurities reduction
- Anodisation of tantalum backings in water enriched in ^{17}O and ^{18}O (Fig. 2)
- Targets of **different thickness** produced to monitor beam induced background



Figure 2: Oxygen Targets, left: different thickness, right: before and after 20 Coulomb.

γ -RAY ACQUISITION SYSTEM

- BGO detector** 4π segmented high efficiency detector
- Shielding lead + borated polyethylene** for further background reduction of about 2 orders of magnitude (Fig. 4)
- Alluminum target chamber and target holder** to reduce absorption



Figure 3: Detail of the setup shielding

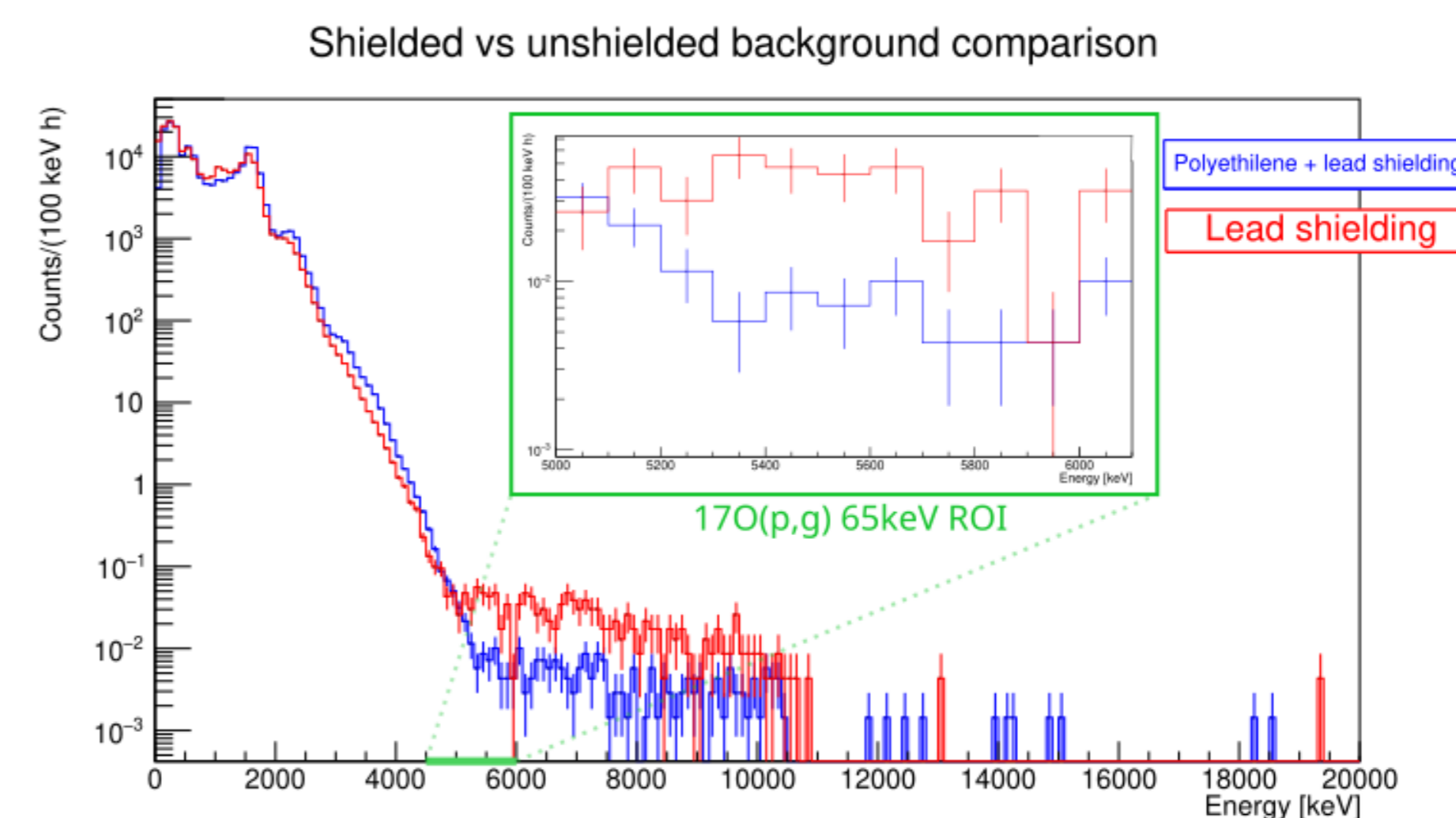


Figure 4: Environmental background reduction

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PRELIMINARY CHARACTERIZATION OF THE SETUP

Monte Carlo simulations using the **Geant4** toolkit.

Simulations used to:

- Efficiency determination: 74% at 661 keV
- Target characterization (Fig. 5)
- Data analysis

Comparison with experiment (Fig.6):

- Difference **< 3%**
- Many aspects** of the real setup taken into account:
 - Single crystal energy resolution,
 - Low energy threshold,
 - Pile-up,
 - Unstable products decay

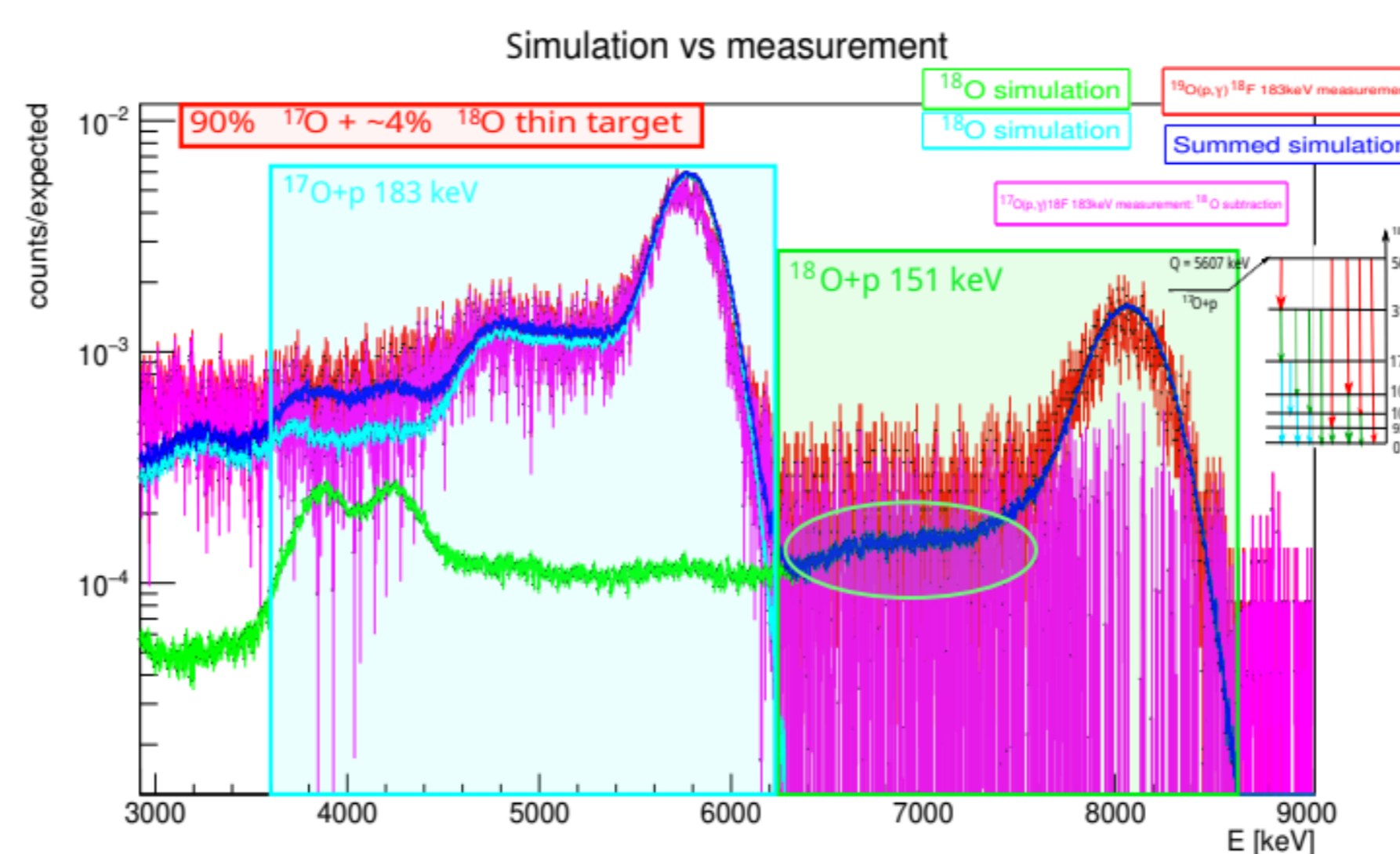


Figure 5: $^{17}\text{O}(p,\gamma)^{18}\text{F}$ 183 keV resonance simulation

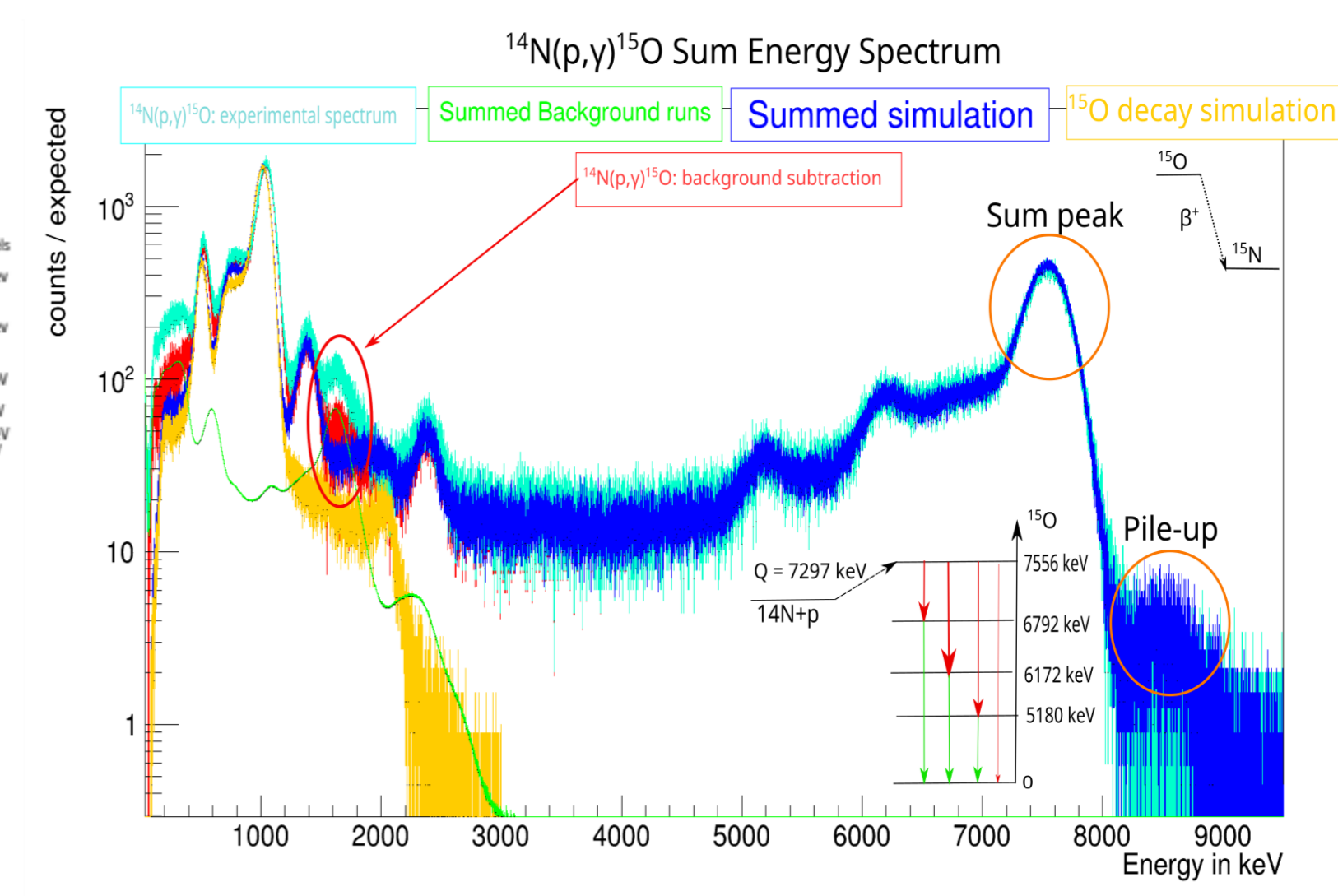


Figure 6: $^{14}\text{N}(p,\gamma)^{15}\text{O}$ simulation