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

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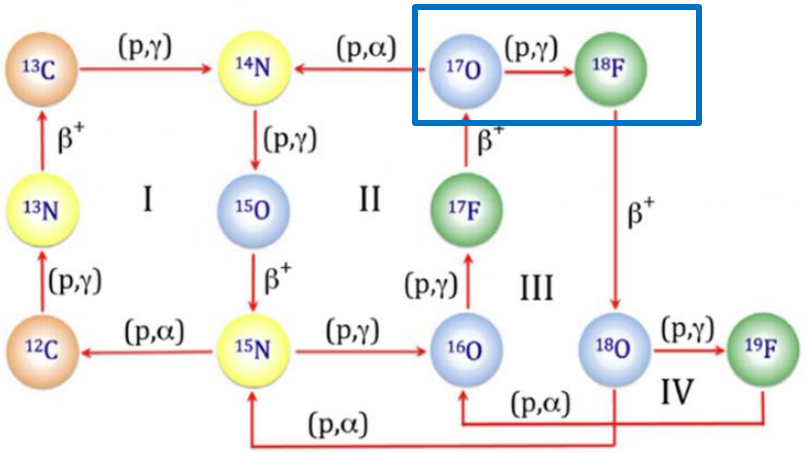
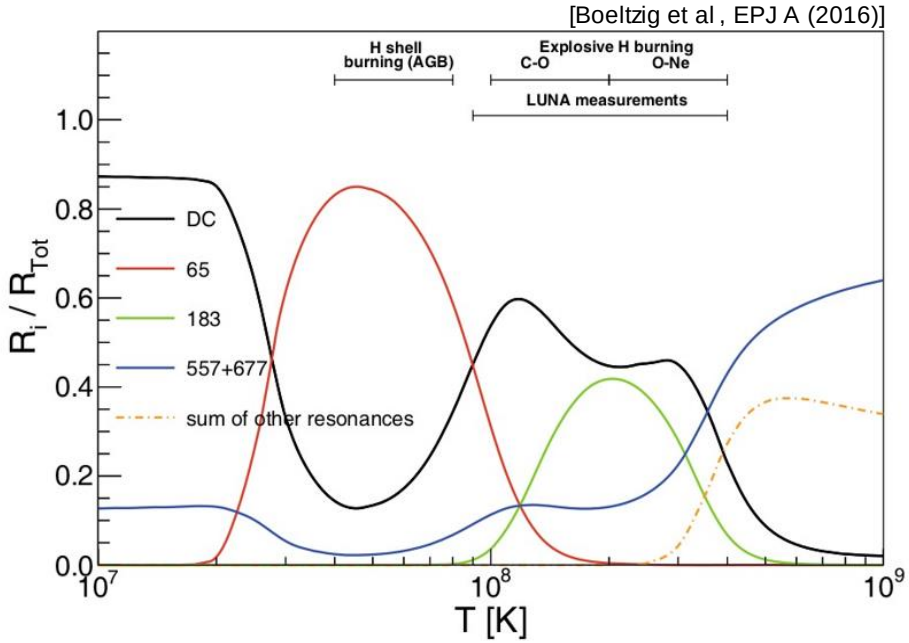
Astrophysical Motivation

- $^{17}O(p,\gamma)^{18}F$ reaction (Q = 5607 keV) takes part to CNO cycle, active during H-shell burning in AGB stars.
- Footprint of AGB nucleosynthesis and mixing processes is the oxygen isotopic ratio observed in presolar grains
- Model predictions still struggle to match observations
- For 30 < T < 100 MK (35 < E_G < 140 keV) the resonance E_{cm}=65 keV (E_x = 5672 keV) dominates the reaction rate



[Boeltzig et al , EPJ A (2016)]



Fractional contributions to the reaction rate of the $^{17}O(p,\gamma)^{18}F$ as a function of the temperature

State of the Art

Only indirect measurements reported for the E_{cm}= 65 keV resonance :

- Γ_α = (130±5) eV from $^{14}N(\alpha,\alpha)^{14}N$ measurement [H-B. Mak et al. NPA (1980)]
- Γ_γ = (0.44±0.02) eV from the measured $\omega\gamma(\alpha,\gamma)$ [I. Berka et al. NPA (1977)]
- Γ_p = ? = indirect measurements and the direct measurement performed at LUNA [(p,α) channel – C.Bruno et al. PRL 117 (2016)] disagree by a factor of ~ 2

Updated estimate: **$\omega\gamma = (1.6 \pm 0.3) \times 10^{-11}$ eV** [M.Q. Buckner et al PRC 91, 015812 (2015)]

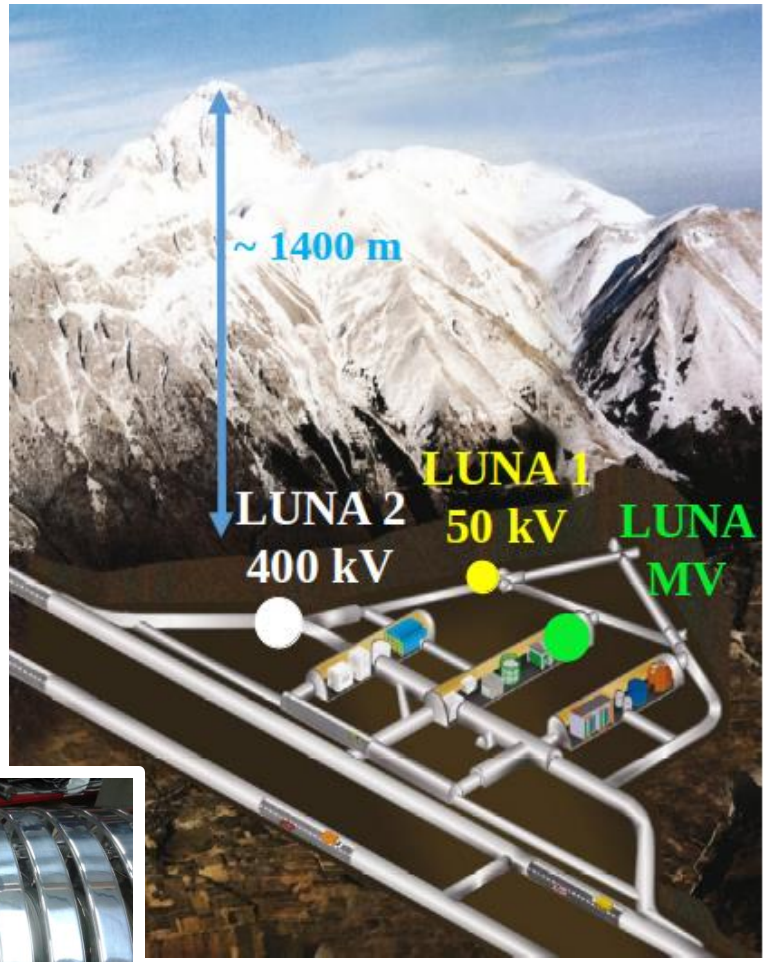
Typical Direct Measurement ingredients:
- 100% ^{17}O target
- Beam current ~100 μA

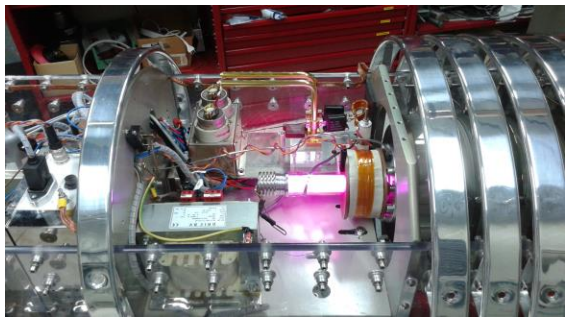
0.08 reactions/h

HIGH SENSITIVITY SETUP IS REQUIRED

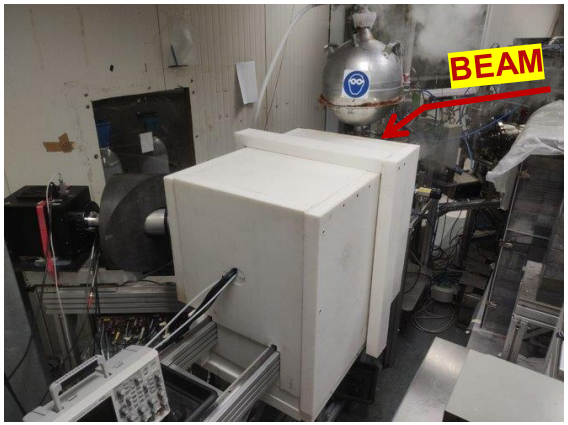
Laboratory for Underground Nuclear Astrophysics

- Under 1400 m of rock = natural shielding
- Cosmic-ray background reduction
  - Muon = x 10^{-6}
  - Neutron = x 10^{-3}
  - In particle spectra = x 10^{-1}
- High intensity and stability accelerator (up to mA and 0.5 mA for H^+ and He^+)

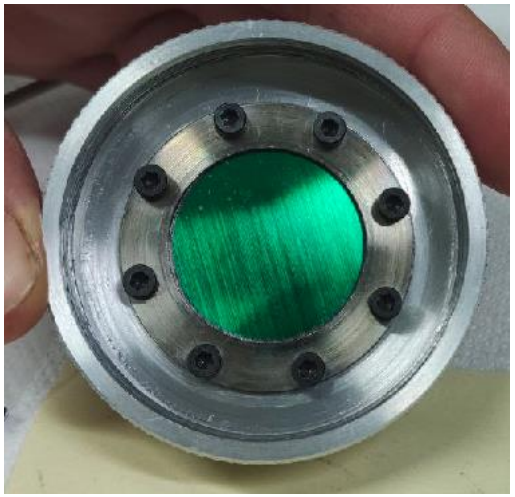




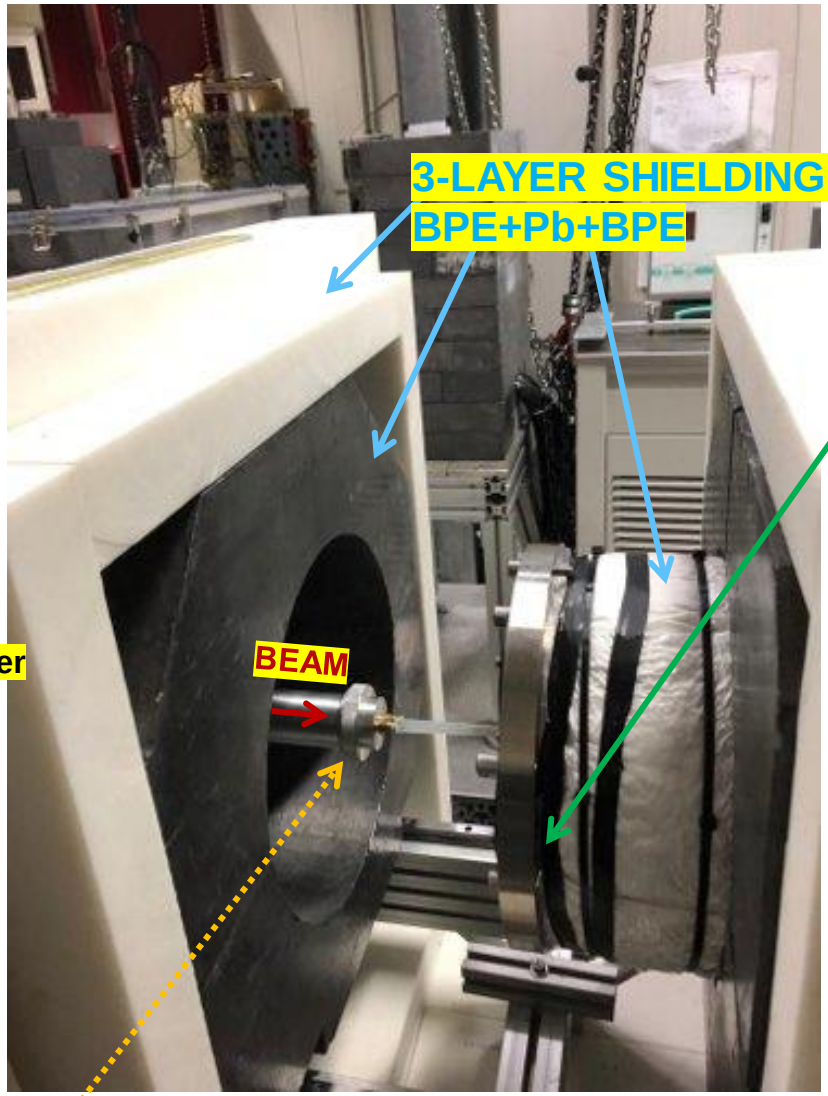
Setup



Ta_2O_5 target made by anodic oxidation with ^{17}O (90%) enriched water

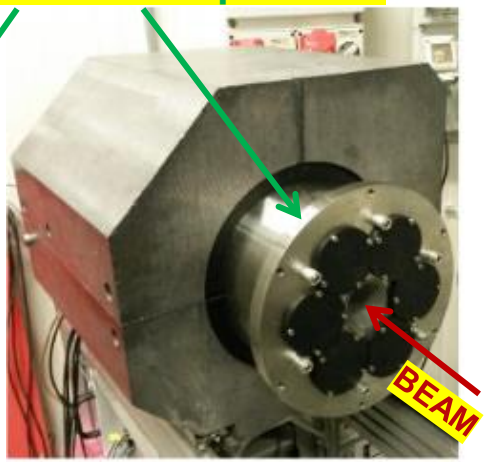


Al CHAMBER AND TARGET HOLDER



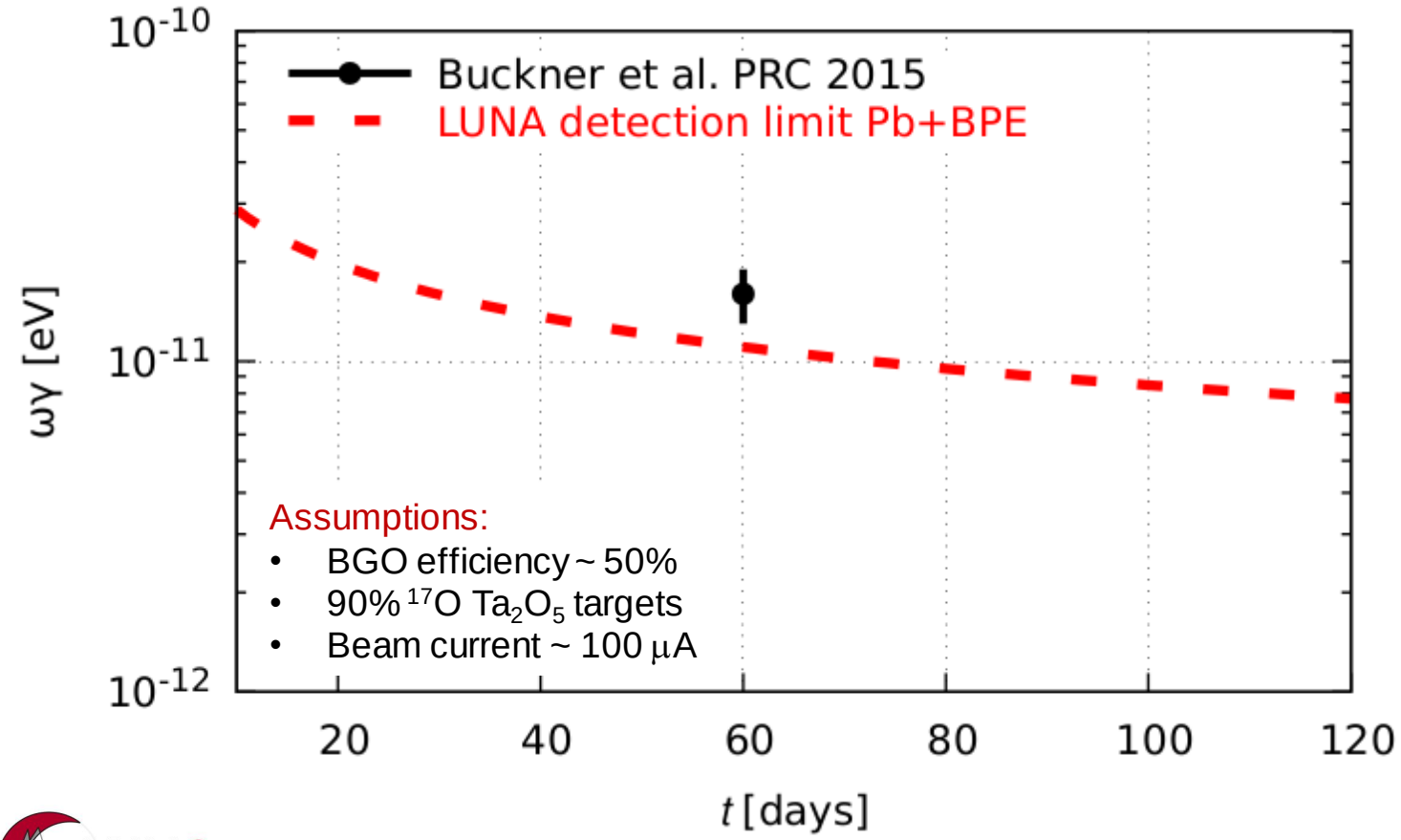
This part can move back and forth

4Π BGO DETECTOR
6 independent crystals
TAS mode possible



Achieved Sensitivity

- 3 layer shielding: BPE + Pb + BPE -> reduction of the background by a factor ~5
- Al chamber and target holder -> ~20% increase in efficiency w.r.t. previous brass and stainless steel setup



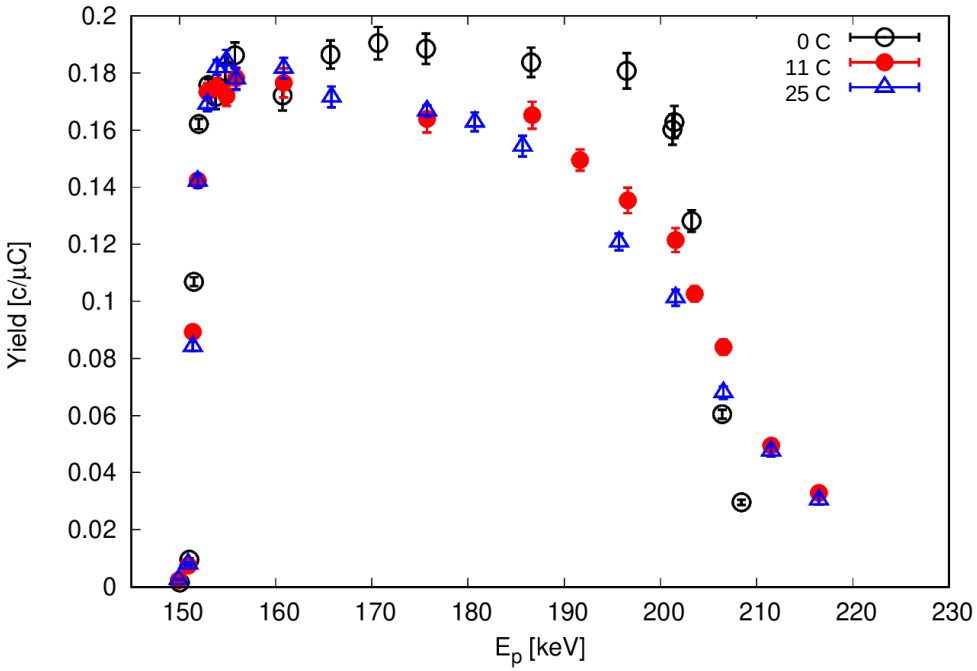
The Beam Induced Background nightmare

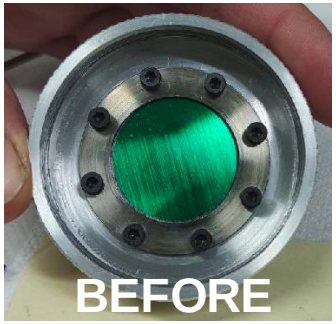
- BIB is due to contaminants in the oxide layer or in the backing that react with the beam
- The scariest contaminants are those that populates the ROI and with much higher cross section than the reaction of interest
- Ta is known for its H and D storage properties
- p+D reaction has a Q = 5493.5 keV (only ~ 100 keV lower than the $^{17}O(p,\gamma)^{18}F$ reaction) and a cross section higher by many orders of magnitudes
- With BGO poor resolution the ROI for $^{17}O(p,\gamma)^{18}F$ reaction is 5200-6200 keV

No way to distinguish/resolve the p+D and the $^{17}O(p,\gamma)^{18}F$ *sum* peak

Data Acquisition

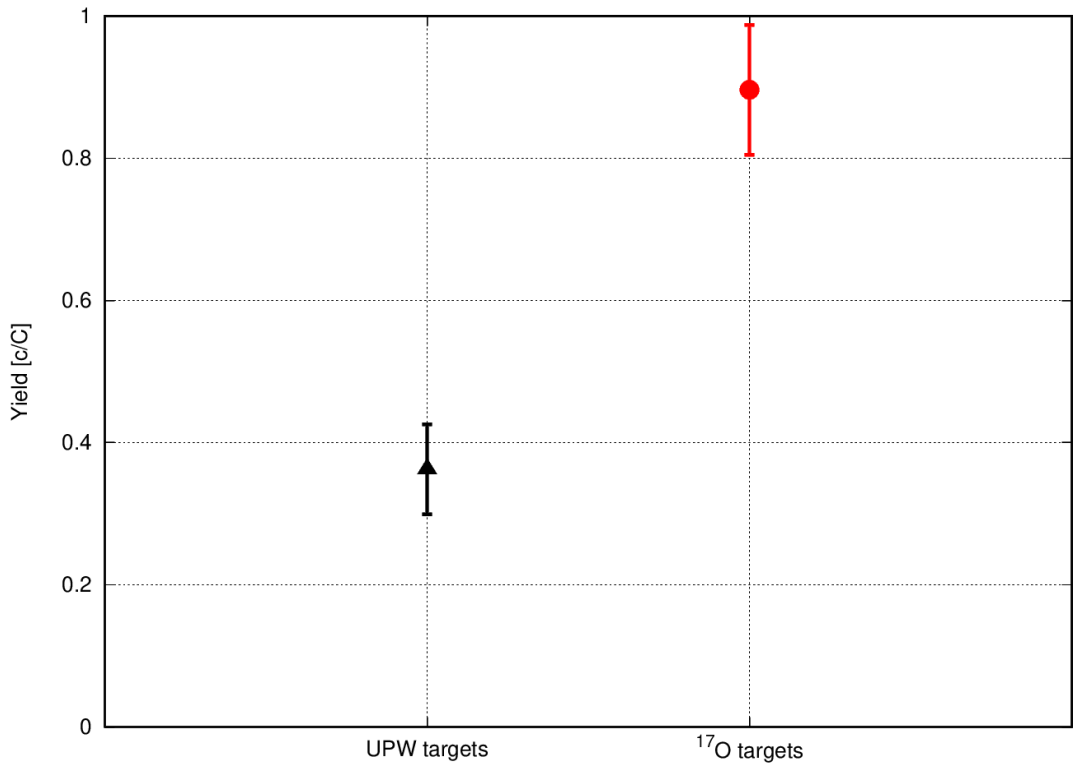
- BGO efficiency via simulations tuned on devoted measurements
- Target monitoring and online characterization via periodic scan of 151 keV resonance in $^{18}O(p,\gamma)^{19}F$ reaction + run on top of 193 keV resonance in $^{17}O(p,\gamma)^{18}F$
- Additional offline analysis for target characterization: SIMS and RBS
- 420 C on top of resonance with ^{17}O targets
- 300 C with UPW targets (NO ^{17}O) to monitor Beam Induced Background
- DC at E_p=141, 184, 187, 190 keV



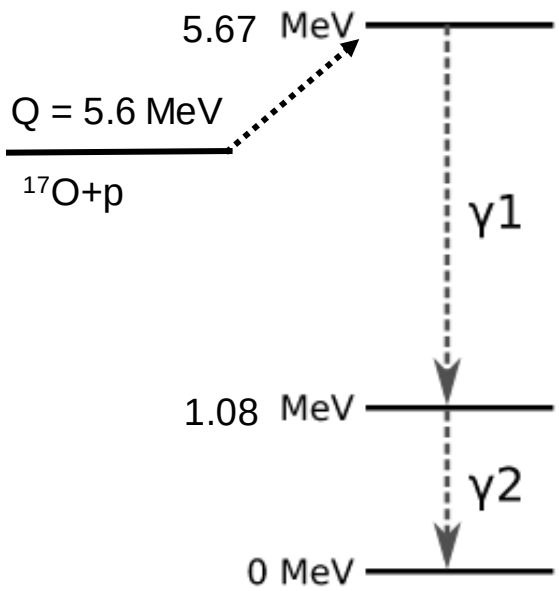


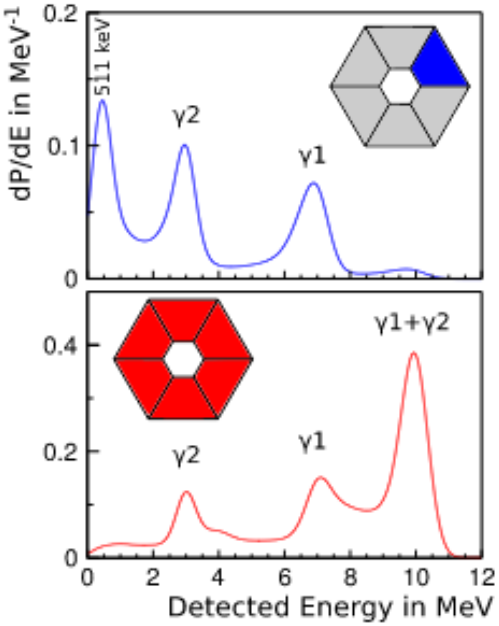
Analysis I

- Comparison between runs on the 65 keV resonance in UPW and ^{17}O targets
- Looking for a significant excess in count rate
- Apply more refined statistical tools to get the $\omega\gamma$ -> Rolke Method

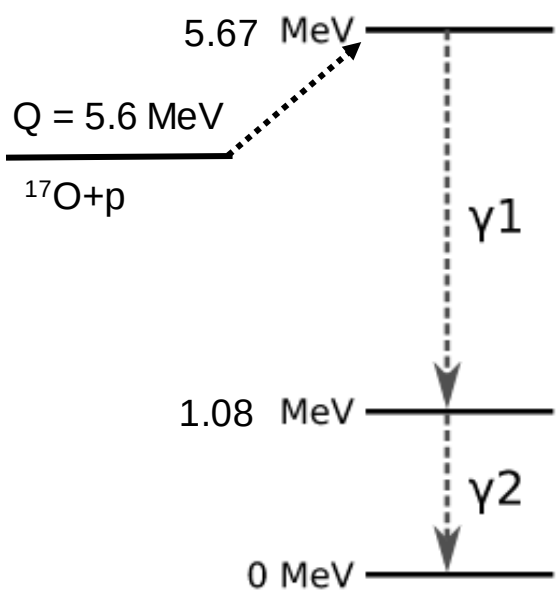


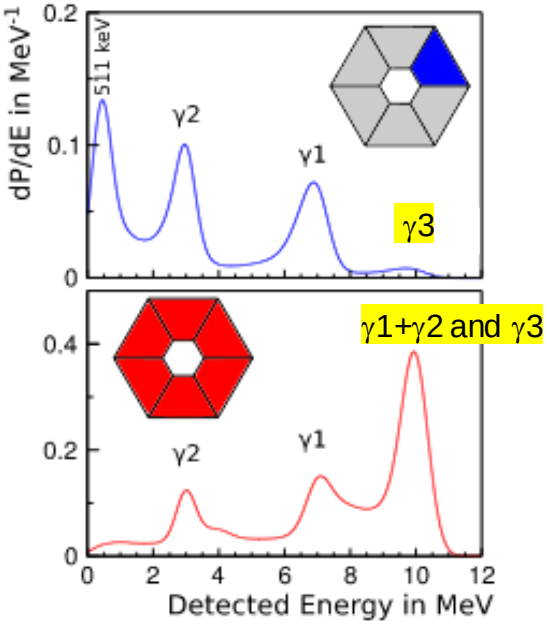
The Gate Analysis

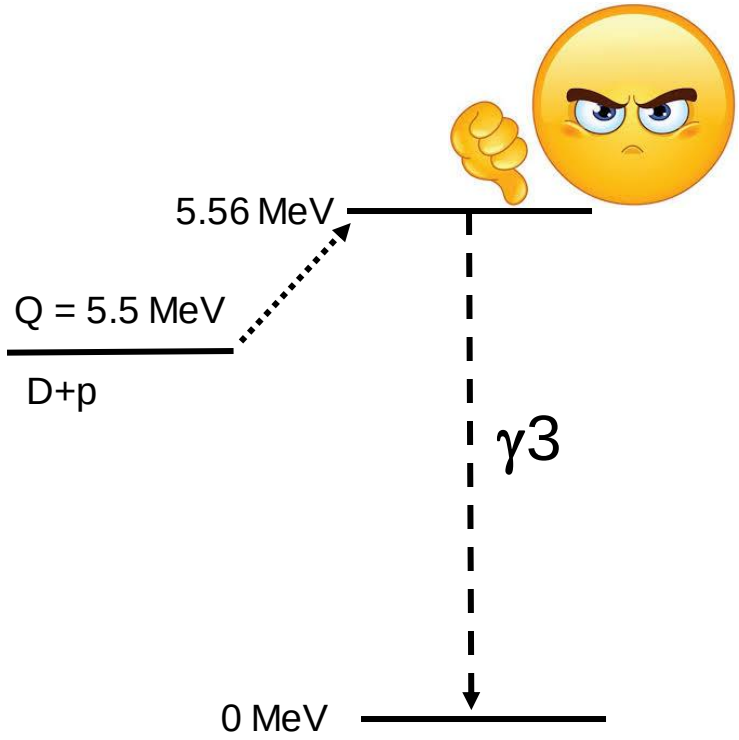




- Assume a cascade with 2 γ-rays emitted in coincidence
- The single BGO crystal will detect only one of the 2 γ-rays
- Since we are saving for each event the energy deposited and the timestamp we can produce the addback spectrum summing all the γ-rays in coincidence
- In the addback you observe the sum peak

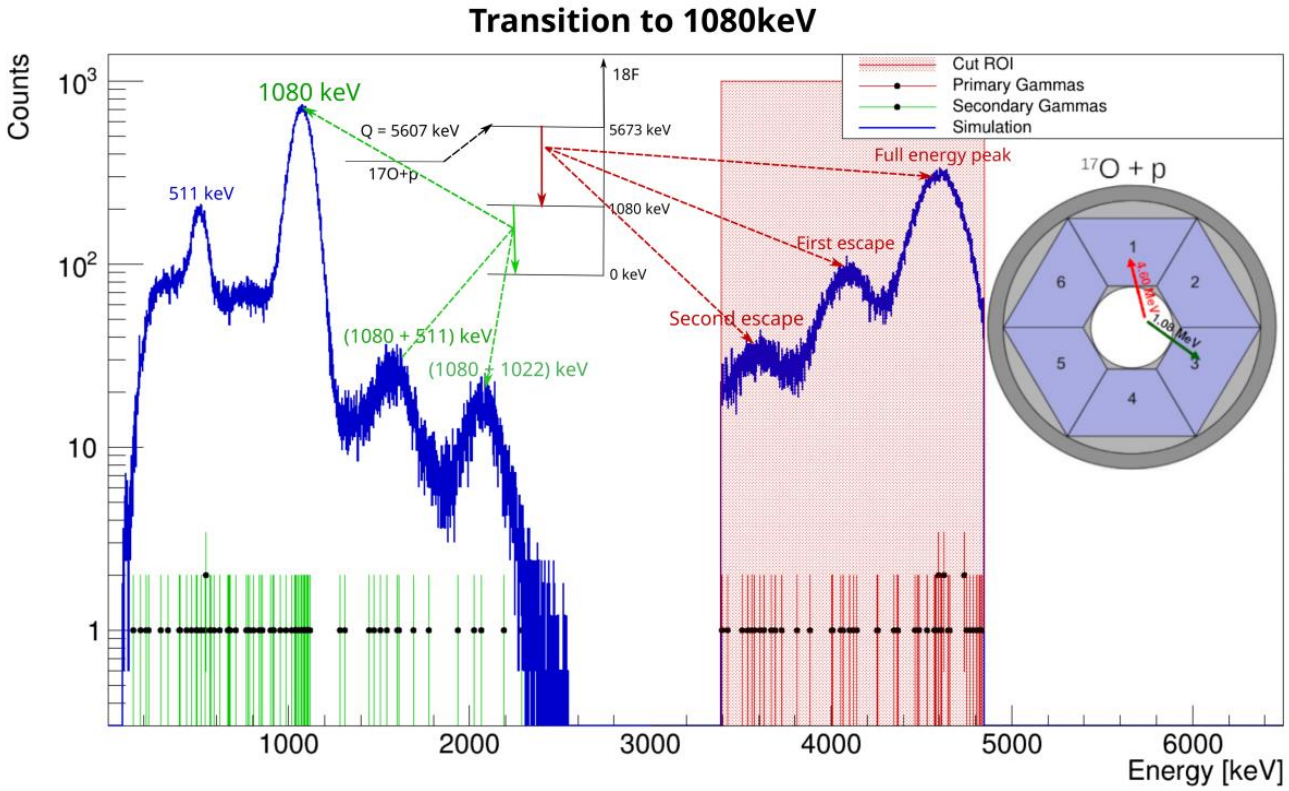






BUT the sum peak might be also populated by a single γ-ray with Eγ ~ γ1+γ2 produced by a contaminant reacting with the beam

- As well as you can construct the sum peak you can also de-construct it
- Gating in the ROI and looking at which γ-rays contributed to the sum peak
- You consider only coincident γ-rays corresponding to the $^{17}O(p,\gamma)^{18}F$ cascade



Preliminary Results

- Target offline analysis is still ongoing
- As well as both 65 keV resonance data analysis
- They however reported preliminary results in good agreement suggesting a higher $\omega\gamma$ than reported in literature

Preliminary Results Removed

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Thank You For Your Attention!