# Direct measurement of $^{13}C(\alpha,n)^{16}O$ reaction towards its *s*-process Gamow peak

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# Astrophysical motivation

- **Neutron source** of main component of the s (slow neutron capture) process

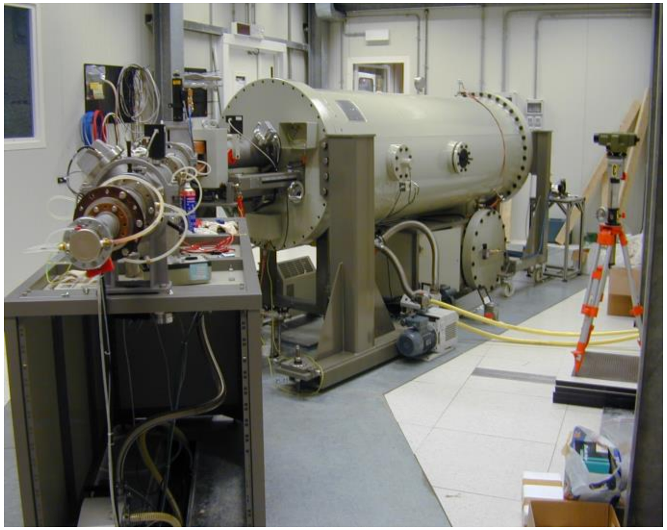
- Takes place in „$^{13}$C pockets” in thermally pulsing, low-mass **AGB stars**

- Average T ~90-100 MK → Energy range of **Gamow Window ~140-240 keV**

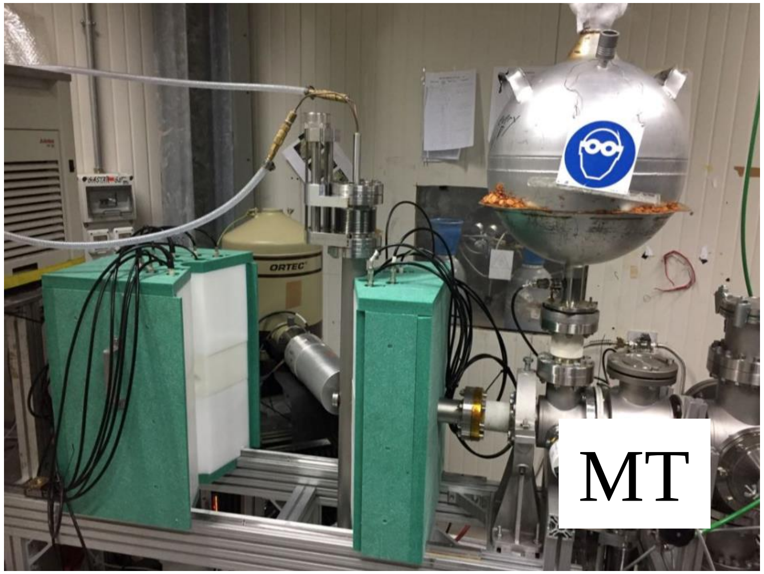
- Better understanding of s-process, r-process and the thermal pulses in TP-AGB stars

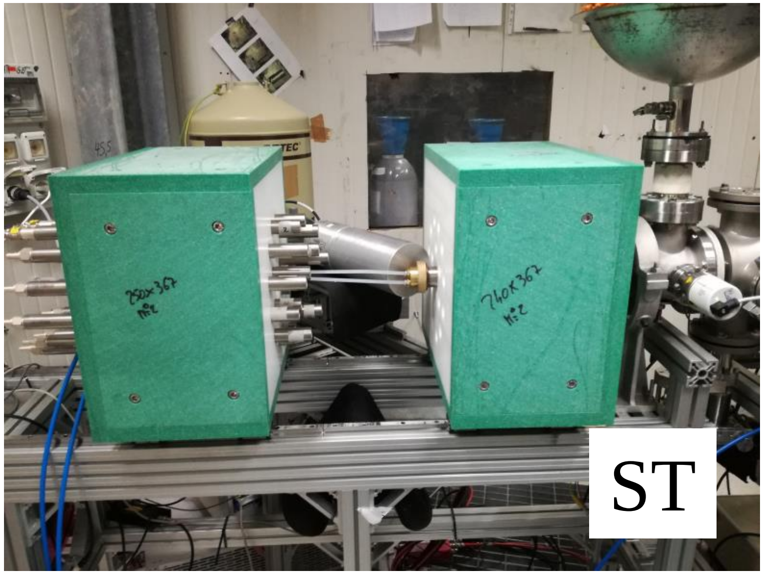
- **For more details see presentation of F. G. Ciani et al. on Friday morning**

# National Laboratory of Gran Sasso (LNGS)

- Shield of rock 1400 m
- Volume: 180000 $m^3$
- Ug Surface: 17800 $m^3$
- **Muon flux reduced: $10^6$**
- **Neutron flux red. : $10^3$**



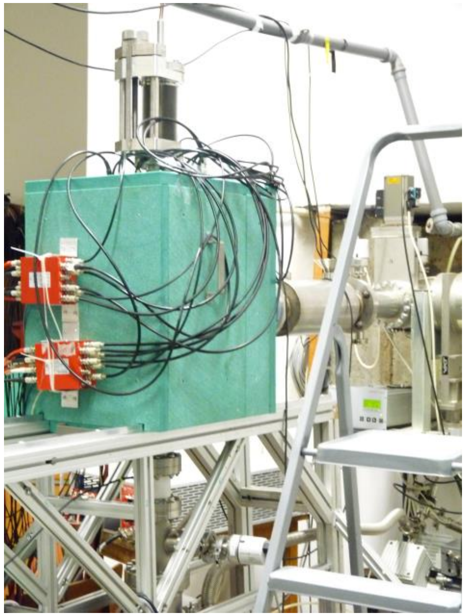
# Neutron detection efficiency

- **$^{13}C(\alpha,n)^{16}O \rightarrow E_n$=2.2-2.6 MeV emission**

- **$^{51}V(p,n)^{51}Cr$**
  - Atomki, Debrecen, Hungary
  - $^{51}Cr$ decay via electron capture $T_{1/2}$=27.7 days and emission of Eγ=320 keV

**1.** $E_{p,lab}$=1.7, 2.0, 2.3 and 2.6 MeV ($E_n$=0.13, 0.42, 0.71 and 0.99 MeV)

**2.** Activation techniques :



$$N_R = \frac{N_\gamma}{B \cdot \eta_{320}} \cdot \frac{e^{\lambda t_w}}{1 - e^{-\lambda t_c}} \cdot \frac{\lambda \cdot t_i}{1 - e^{-\lambda t_i}}, \quad \eta_n = \frac{N_n}{N_R},$$

# Neutron detection efficiency

## AmBe radioactive source

- $E_n$=0-12 MeV ; weighted $E_n$~ 4.0 MeV
- Universita di Napoli ‘Federico II’, Italy
- $R=\gamma(4.4 MeV)/n_{total}=0.575\pm4.8\%$
- γ detection with $LaBr_3$:Ce, NaI, HPGe

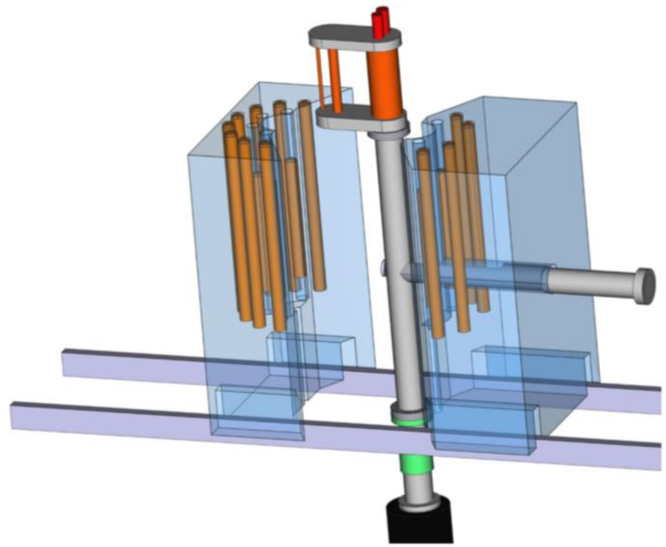
$$^{9}\mathrm{Be} + ^{4}\mathrm{He} \rightarrow ^{12}\mathrm{C} + n\ ,$$

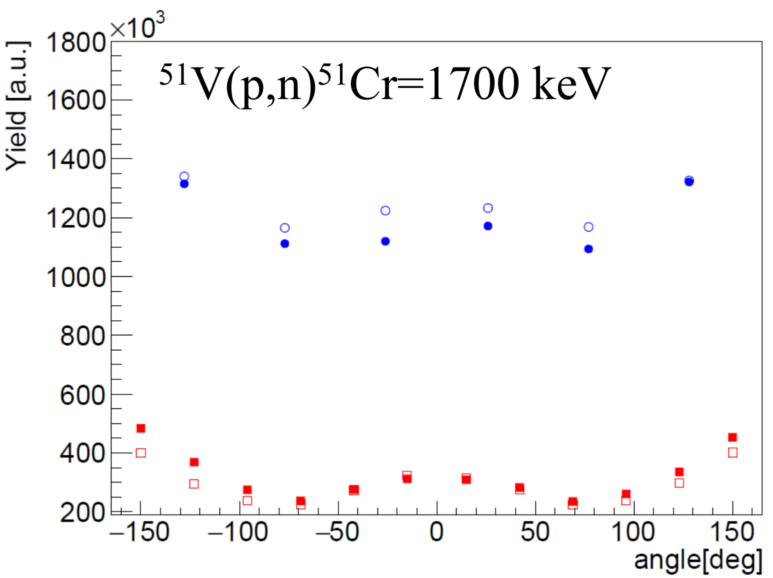
$^{12}C$ → Eγ=4.4 MeV,

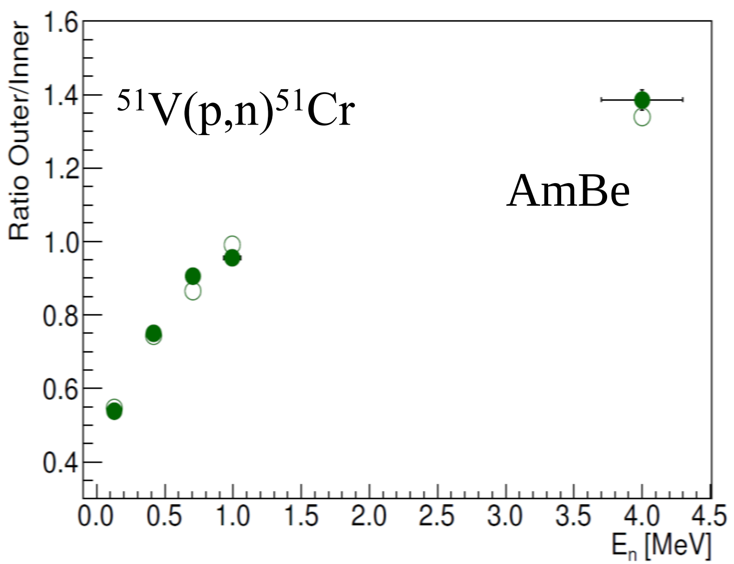
$$A_n = \frac{N_\gamma}{\eta_{4.4} R t},$$

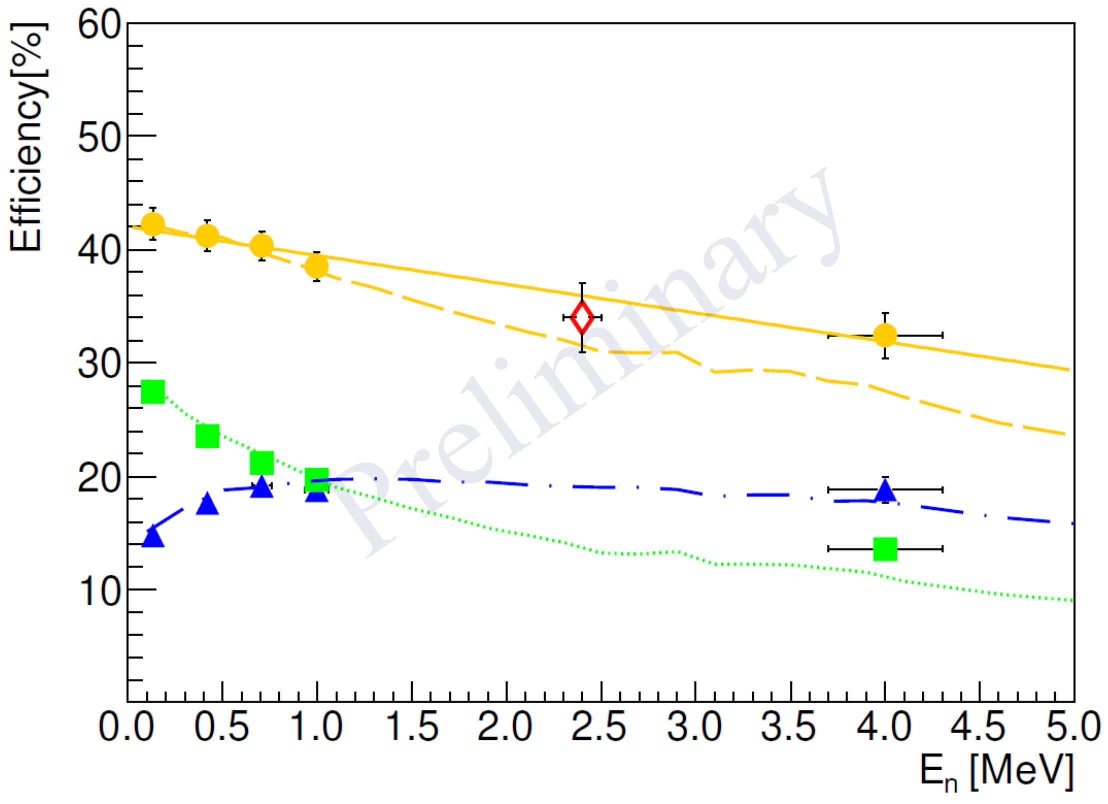
# Geant 4 simulation

- All components around detector region are included
- "Neutron high precision" physics
- Thermal scattering correction for water and polyethylene








In order to interpolate the neutron detection efficiency in $E_n$= 2.2-2.6 MeV:

A. Scaling factor $L_{scal}$=0.78 between the simulated and measured data

B. Low- and high-energy data points were fitted with a linear function

An average from methods **A** and **B** were accepted $\boldsymbol{\eta_n}$**=(34±3)%** and **(37±3)%**

# Summary and outlook

- Unprecedented ultra-low internal + external background with $^{3}$He counter combined with **PSD**: background rate ~**1** Count/hour (Talk of F. G. Ciani et al.)
- Well-characterised neutron detection efficiency of the experimental setup using $^{51}$V(p,n)$^{51}$Cr reaction, AmBe source and Geant4 simulation; **$\eta_n$=(34±3)% (MT)** and **(37±3)% (ST)**
- **New methodology** monitoring target (Ciani et al. DOI: 10.1140/epja/s10050-020-00077-0)

↓

As a first-time **direct measurement** in the *s*-process Gamow peak of $^{13}$C($\alpha$,n)$^{16}$O

## In Progress

- Extrapolation of s-factor in astrophysical Gamow window
- Evaluation of astrophysical impact

# The LUNA collaboration

https://luna.lngs.infn.it/

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