The study of the $^{22}Ne(\alpha,\gamma)^{26}Mg$ reaction at LUNA

Speaker: Denise Piatti[1,2] for LUNA collaboration

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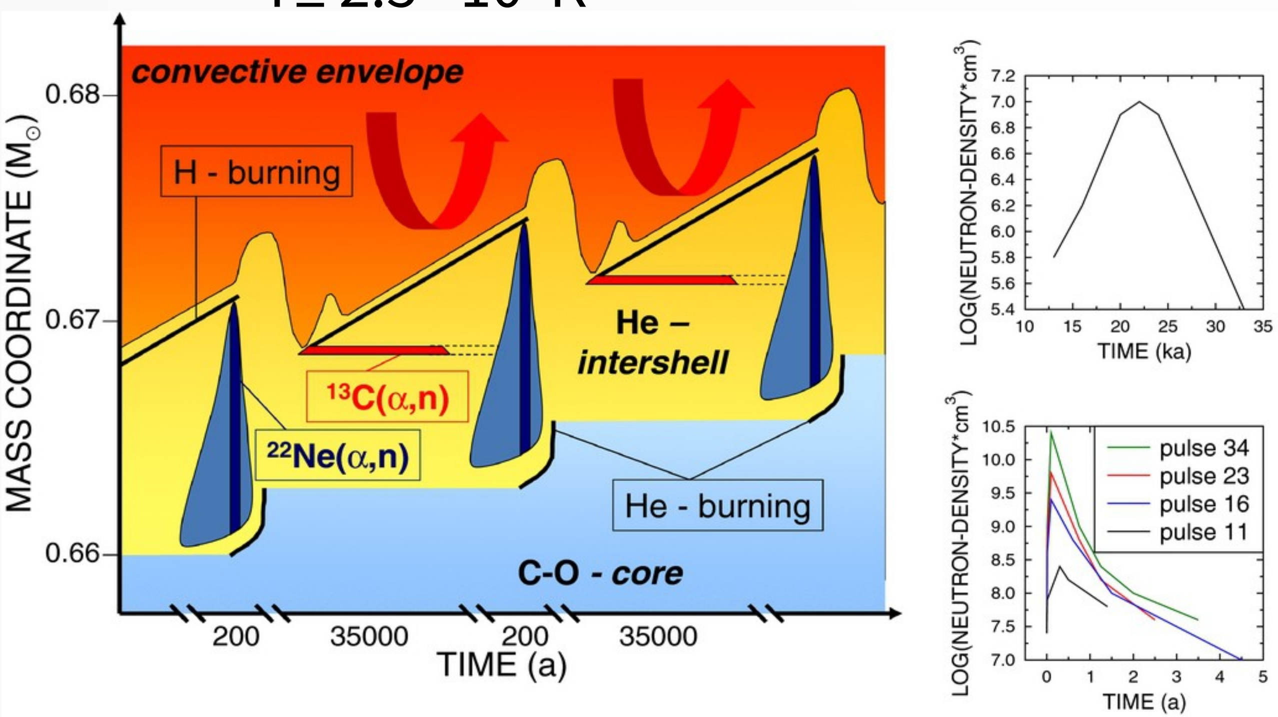
Astrophysical Motivation

- The $^{22}Ne(\alpha,\gamma)^{26}Mg$ reaction (Q_{val} = 10.6 MeV) competes with the $^{22}Ne(\alpha,n)^{25}Mg$ reaction (Q_{val} = - 478 keV) → Source of neutrons for s-process in low-mass Asymptotic Giant Branch stars (AGB)

$T \geq 2.5 \cdot 10^{8}$ K



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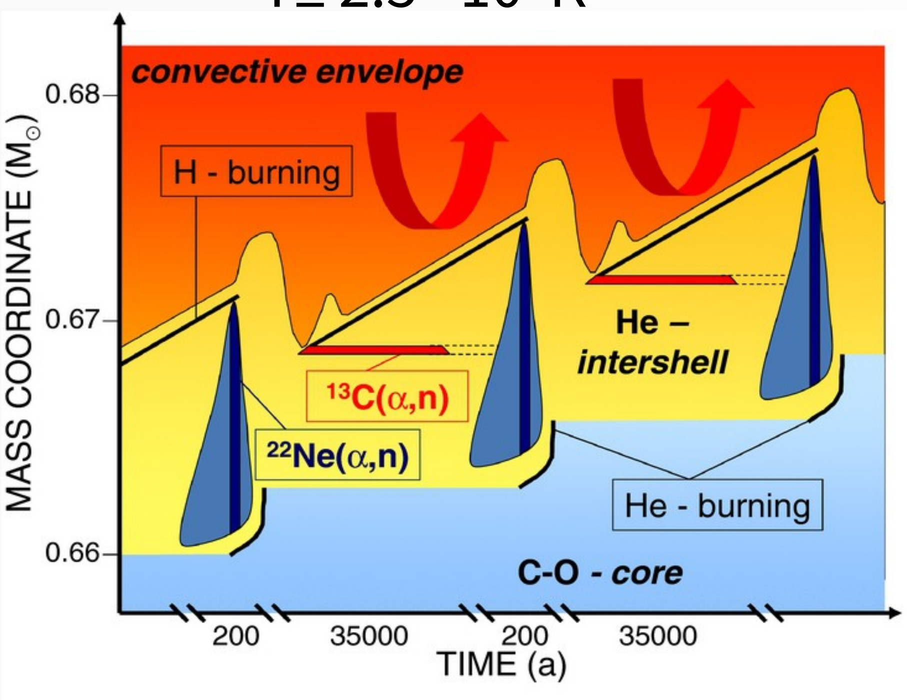
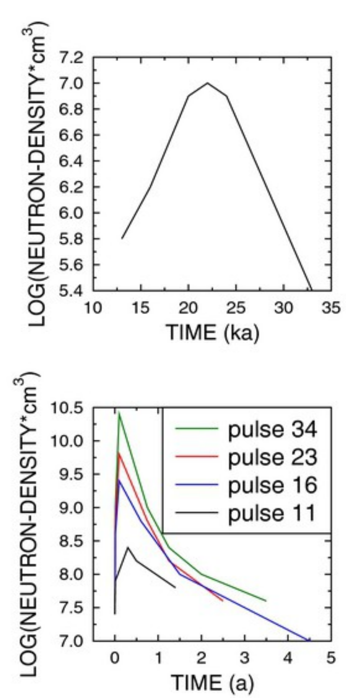


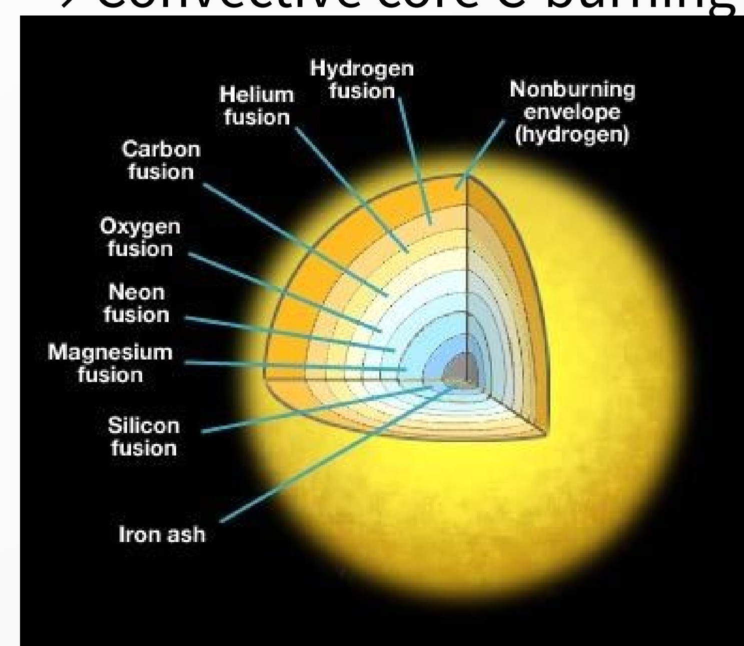


$T \geq 3 \cdot 10^8$ K

→ Convective core He-burning

$T \sim 10^9$ K

→ Convective core C-burning



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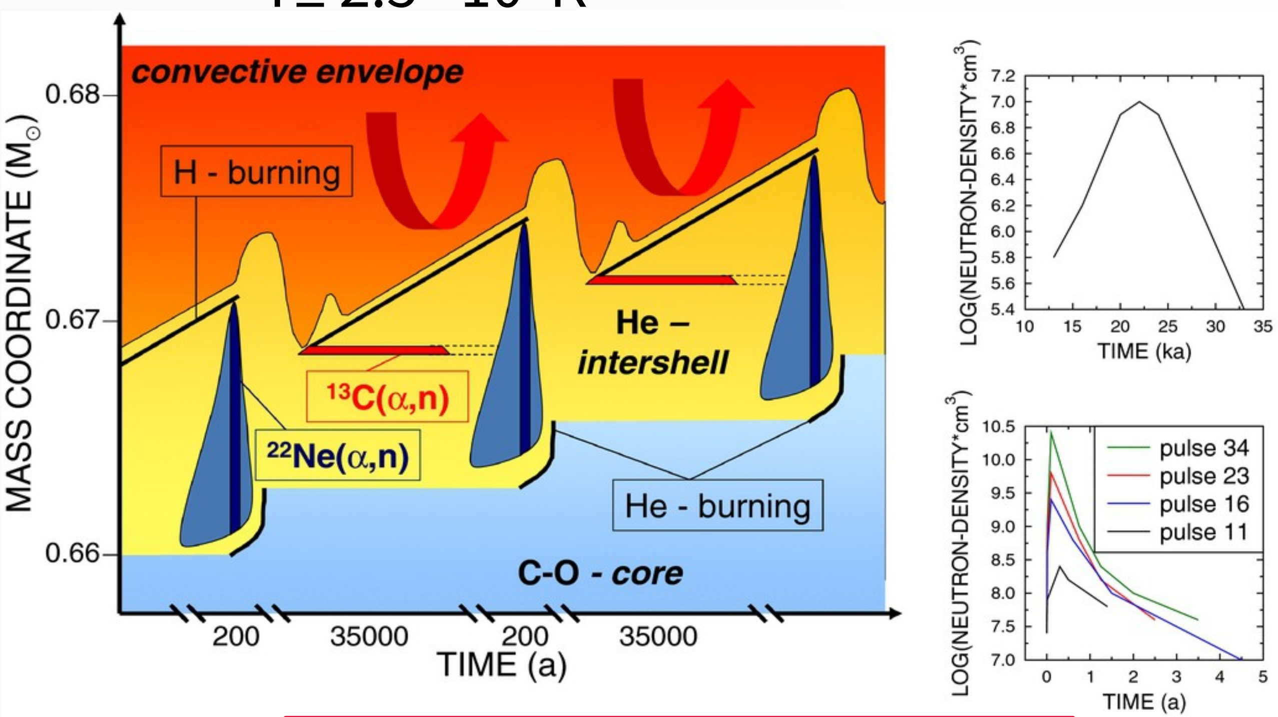


$T \geq 2.5 \cdot 10^{8}$ K

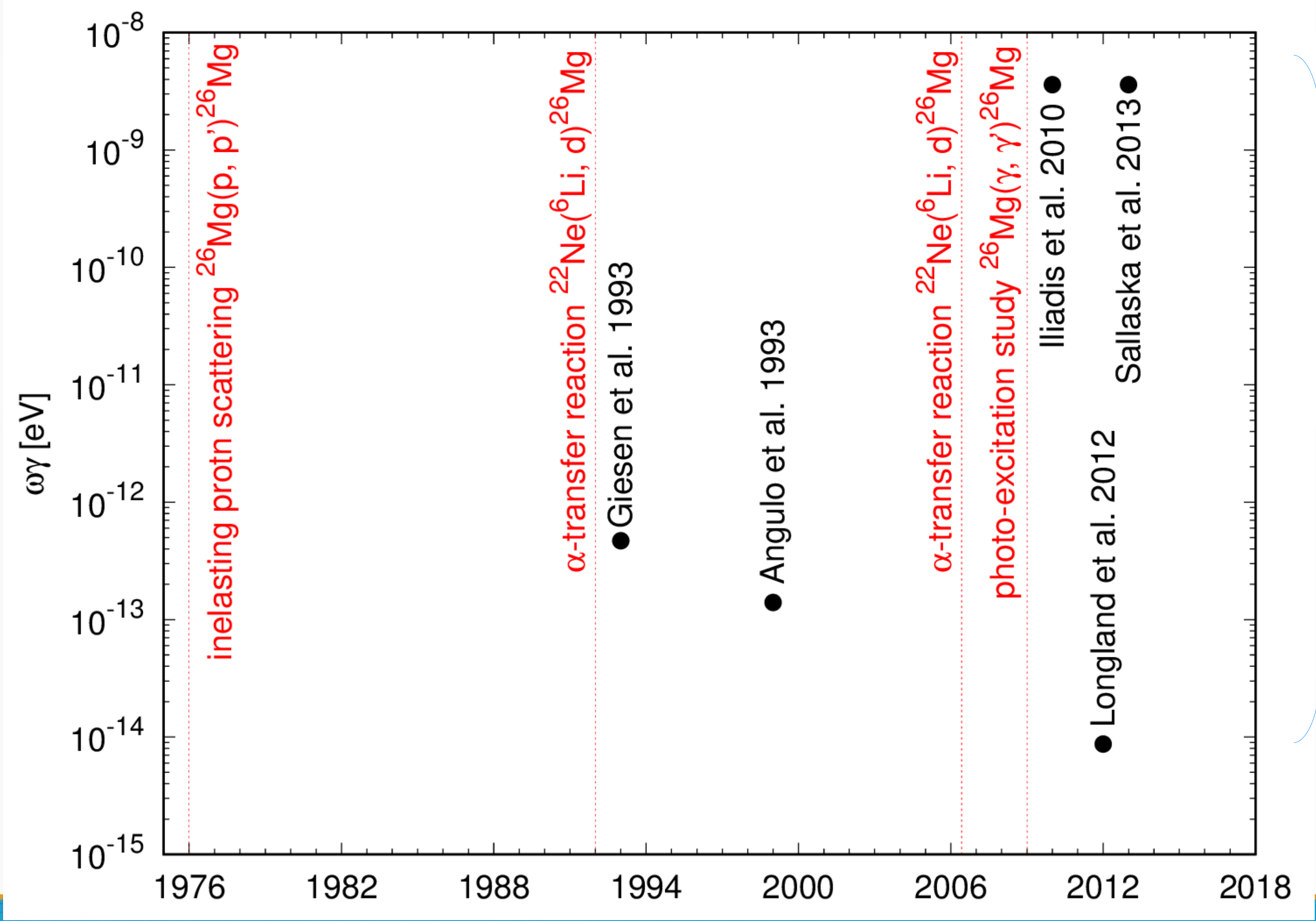
Convective core He-burning

$T \sim 10^{9}$ K

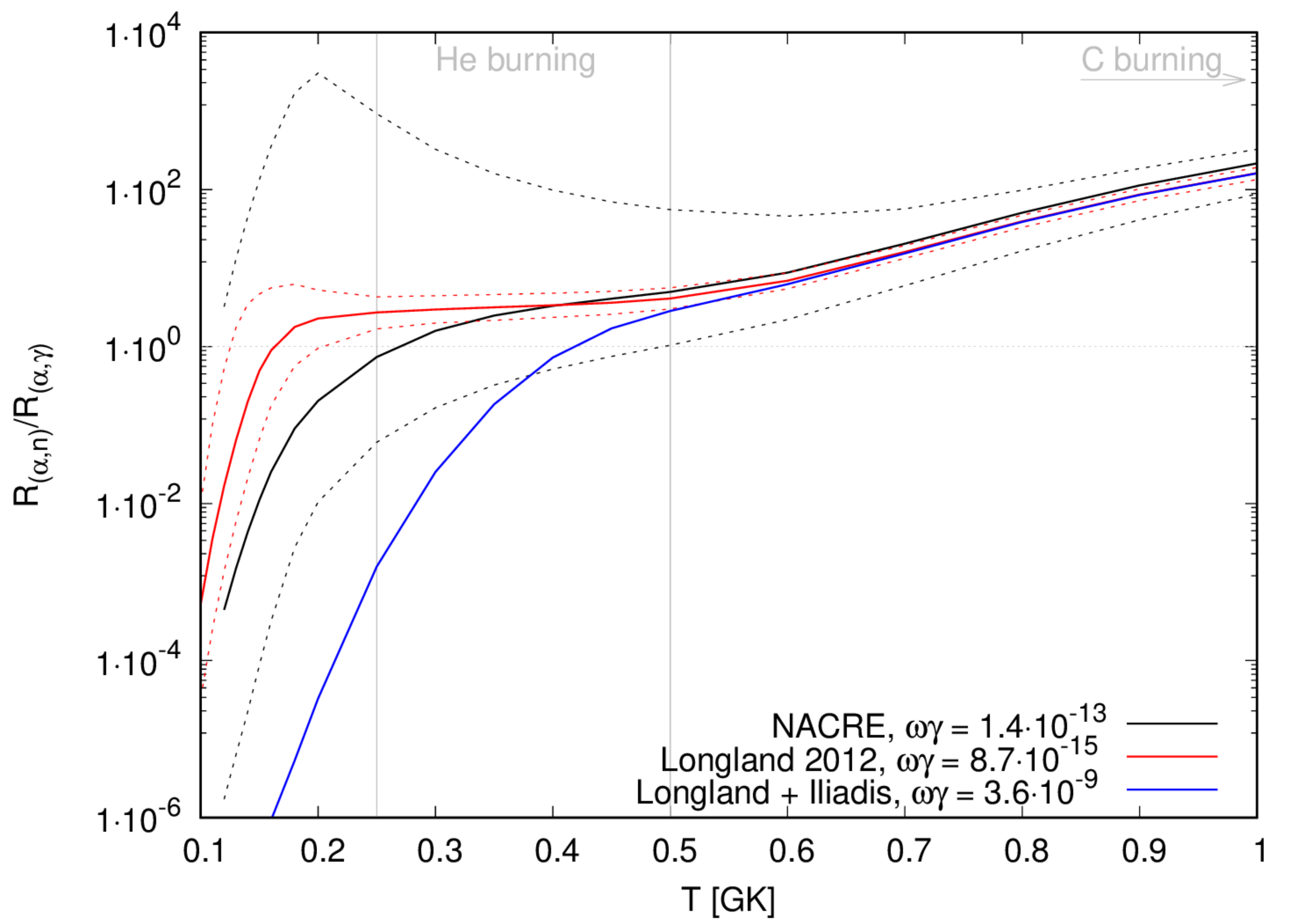
Convective core C-burning

- The $^{22}Ne(\alpha,\gamma)^{26}Mg$ reaction rate affects the nucleosynthesis of isotopes between ^{26}Mg and ^{31}P in intermediate-mass AGBs

- The non-resonant contribution is small
- Three dominating resonances:
  - $E\alpha$ = 831 keV (E_x = 11318 keV) → $\omega\gamma$ known within 6% of uncertainty ;
  - $E\alpha$ = 637 keV (E_x = 11154 keV) → negligible contribute ;
  - $E\alpha$ = 395 keV (E_x = 10950 keV) → **???** ;

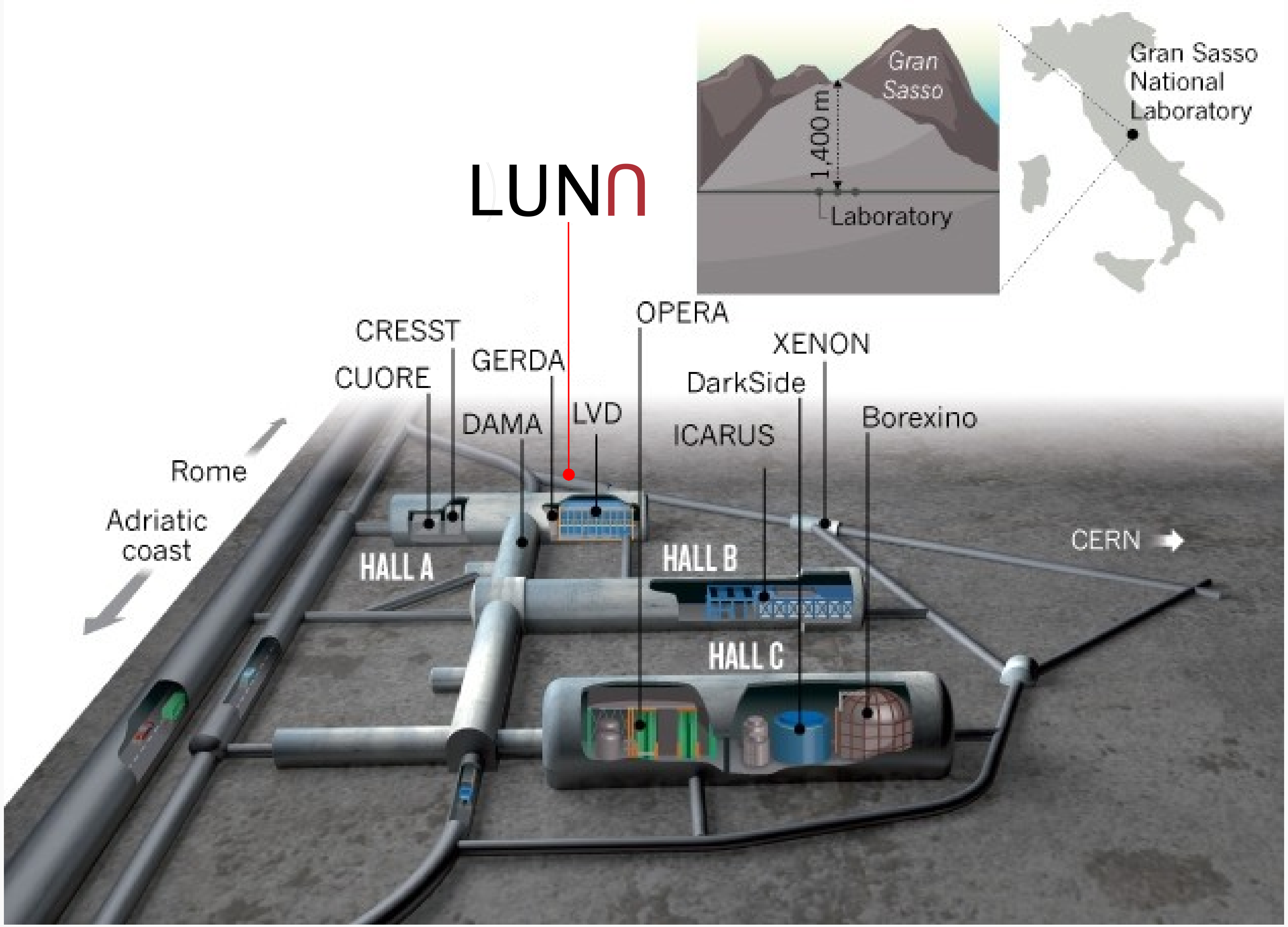


- No direct measurements
- Mainly upper limits
- ~ 6 order of magnitude

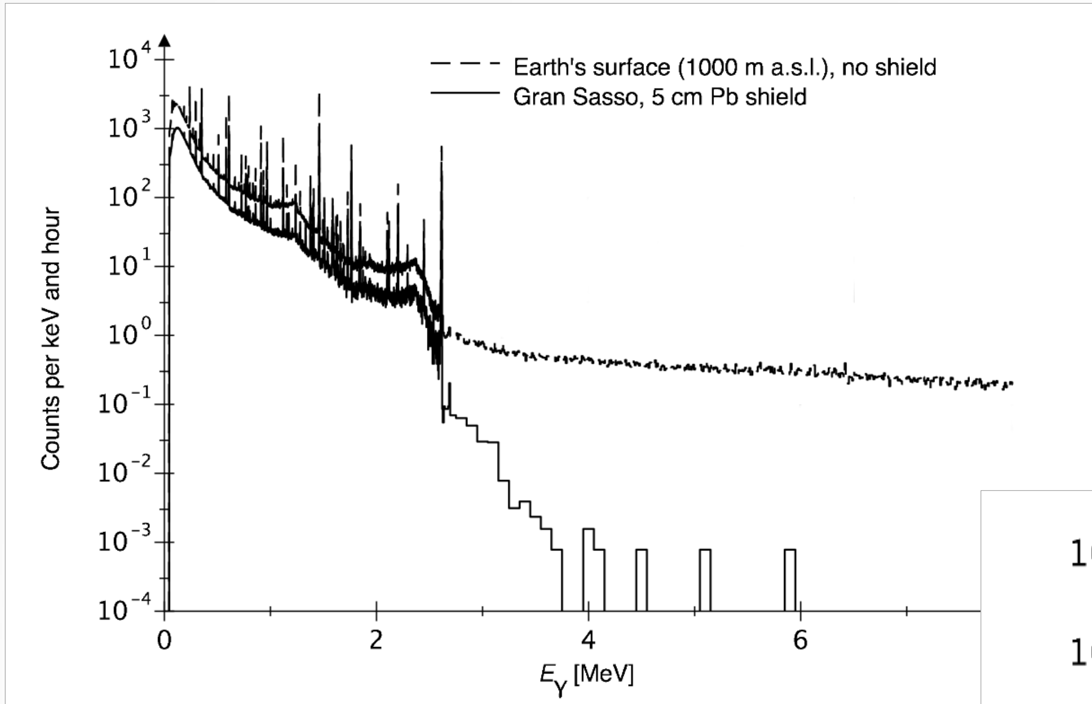


He burning
C burning
$R_{(\alpha,n)}/R_{(\alpha,\gamma)}$
T [GK]
NACRE, $\omega\gamma = 1.4\cdot10^{-13}$
Longland 2012, $\omega\gamma = 8.7\cdot10^{-15}$
Longland + Iliadis, $\omega\gamma = 3.6\cdot10^{-9}$
$1\cdot10^{4}$
$1\cdot10^{2}$
$1\cdot10^{0}$
$1\cdot10^{-2}$
$1\cdot10^{-4}$
$1\cdot10^{-6}$
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

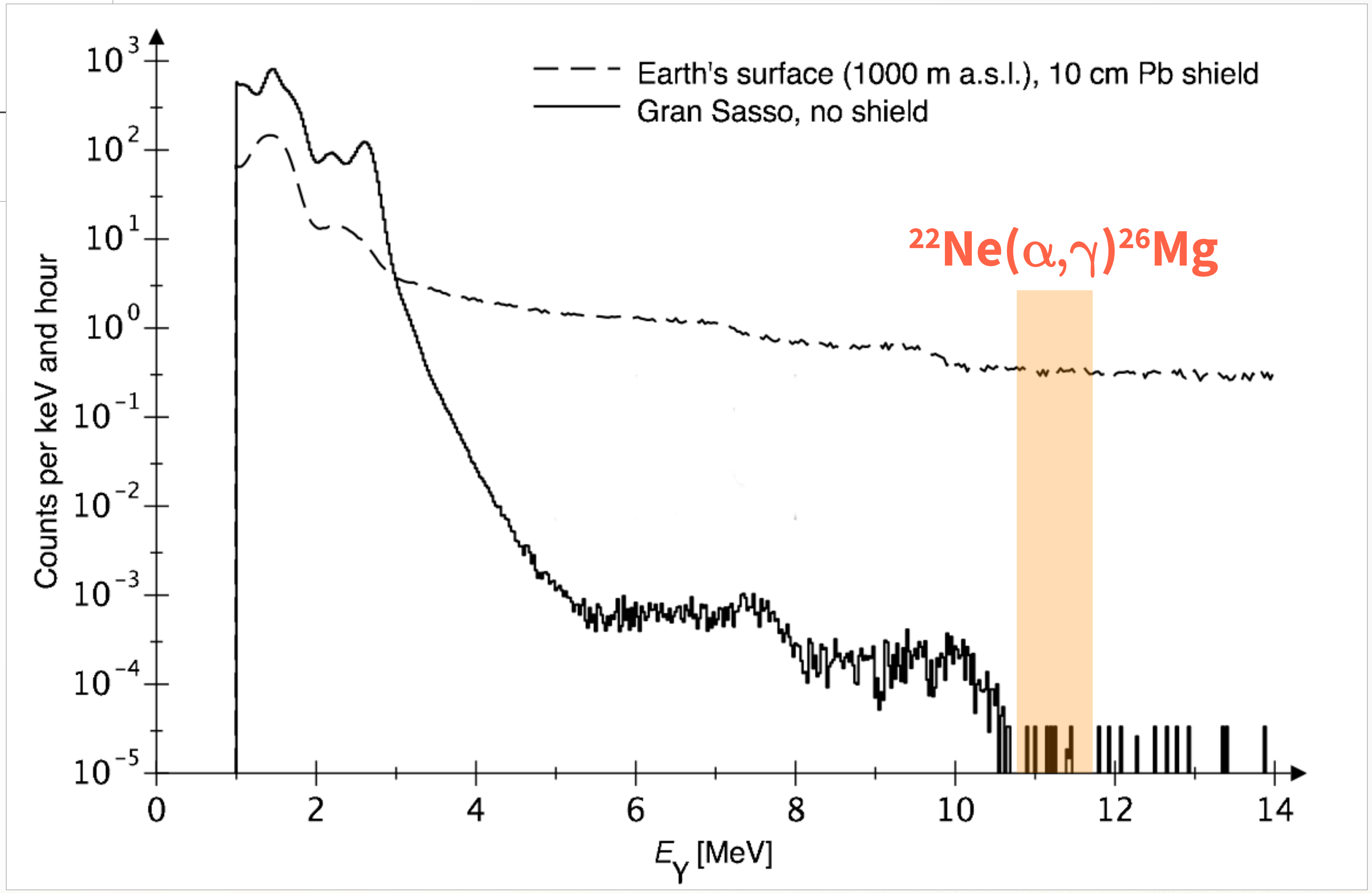
LUNA



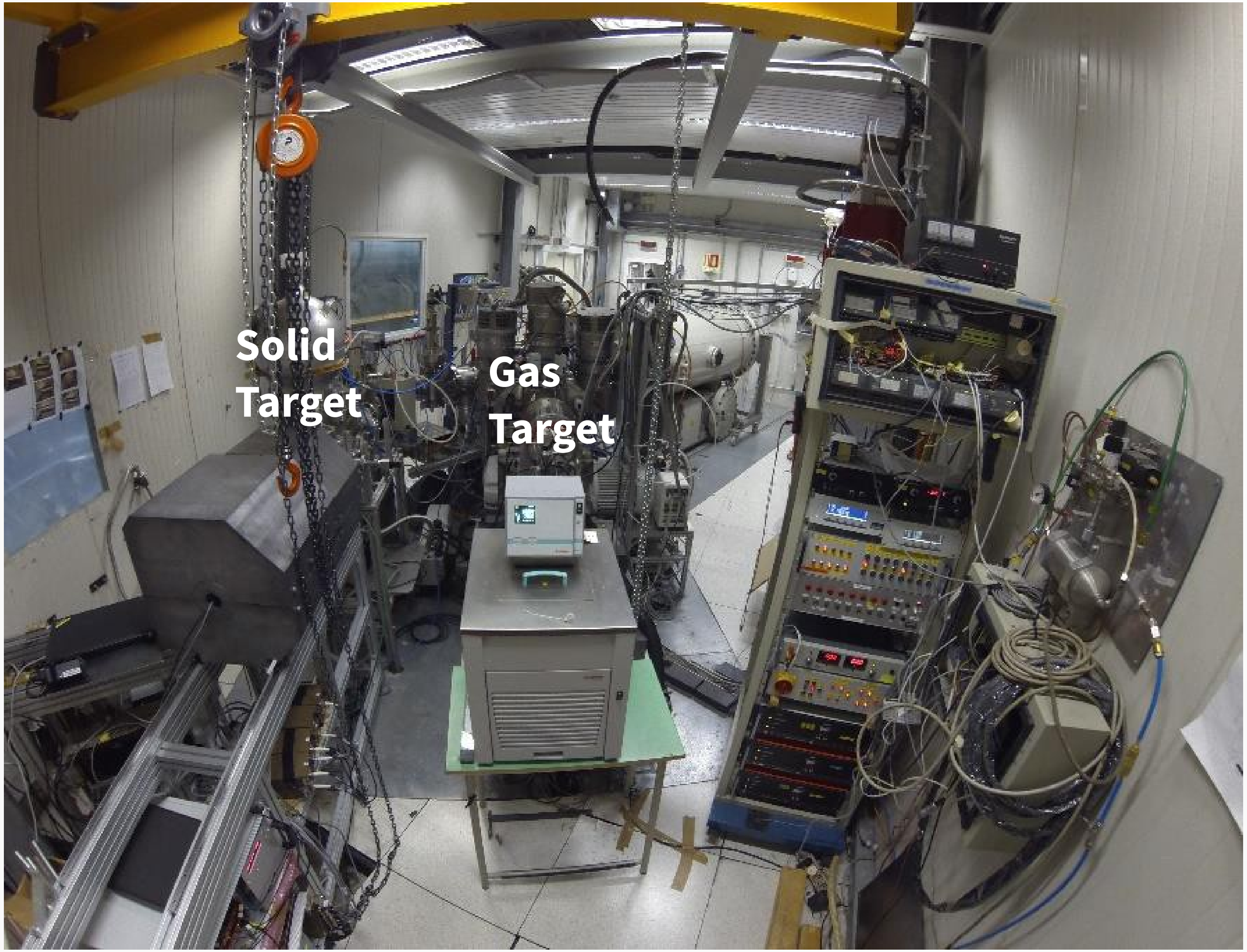
- 1400 m of Dolomite rock → natural shielding against cosmic rays
- 400kV accelerator → high intensity, higly collimated and stable H^+ and $^4He^+$ beams
- Two beam-lines: gas target and solid target



$\mu \rightarrow 10^{-6}$, n $\rightarrow 10^{-3}$



The Setup



- The measurement was performed at the gas target beam line

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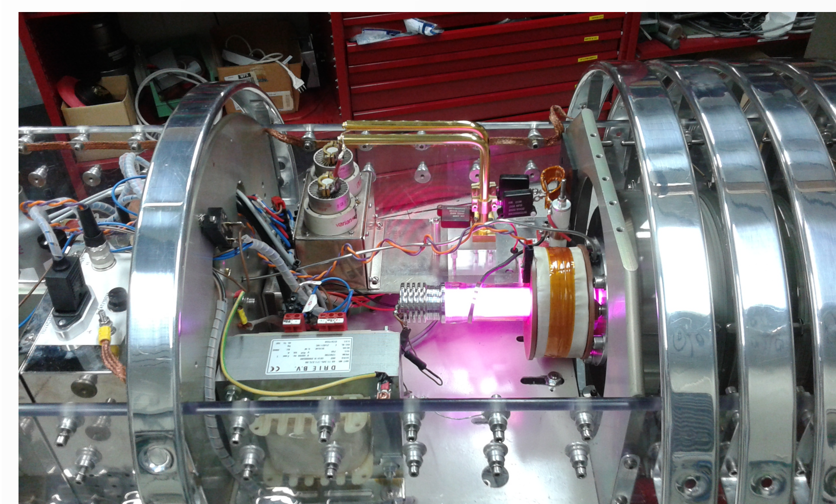
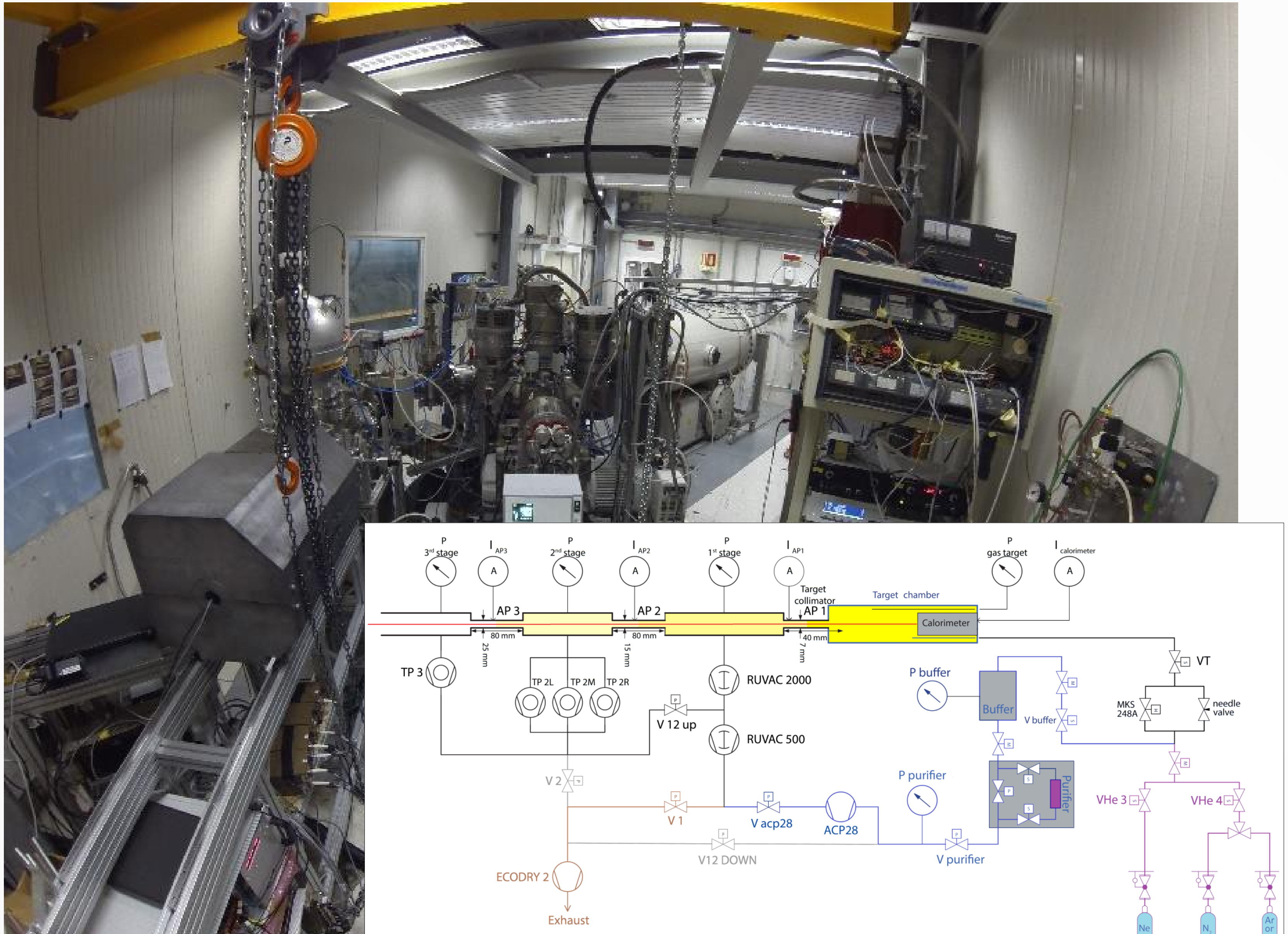
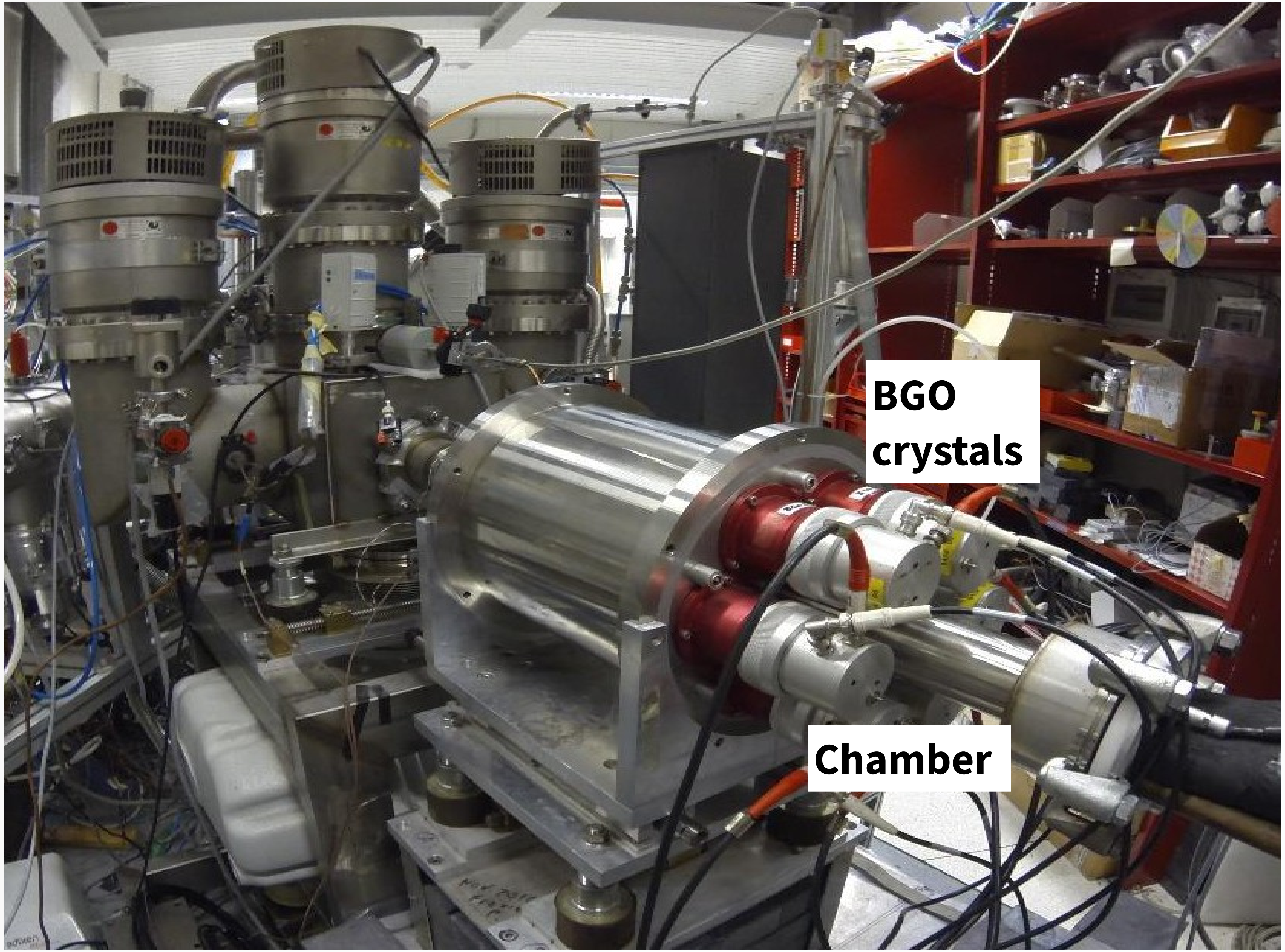
- 399.9 keV $^{+}$H beam, I ~ 250 μA

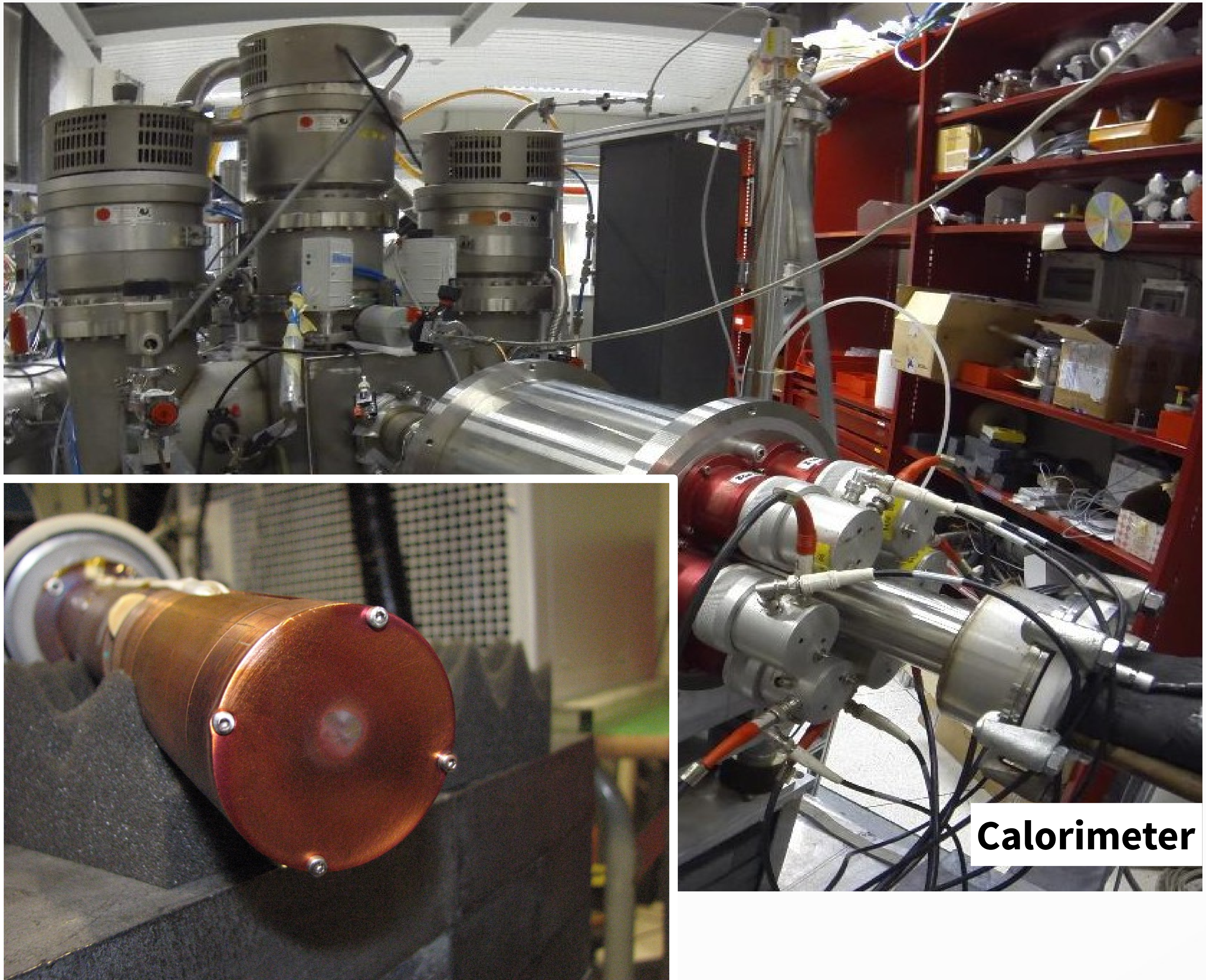




- The measurement was performed at the gas target beam line
- 399.9 keV $^{+}$H beam, I ~ 250 μA
- differential pumped windowless gas target system → three pumping stages
- $P_{line} = 10^{-7} \rightarrow 10^{-3}$ mbar
- $P_{chamber} = 1$ mbar
- Recirculation mode



- Target gas: 99.999% pure, 99.9% enriched ^{22}Ne gas
- Target chamber surrounded by the detectors: **6 optically indipendent BGO crystals**
- Solid angle ~ **4π**
- Timestamp and energy recorded for each event → **addback spectrum offline**



- 99.999% pure 22Ne gas
- The detector: 6 optically indipendent BGO crystals
- Calorimetric measurement of Ibeam
- Cold side at 7° by a cooling machine
- Hot side **kept** at 70° by the power of 8 resistors W_0
- $I_{beam} = \frac{(W_0 - W_{meas})}{(E_{beam} - \Delta E)}$

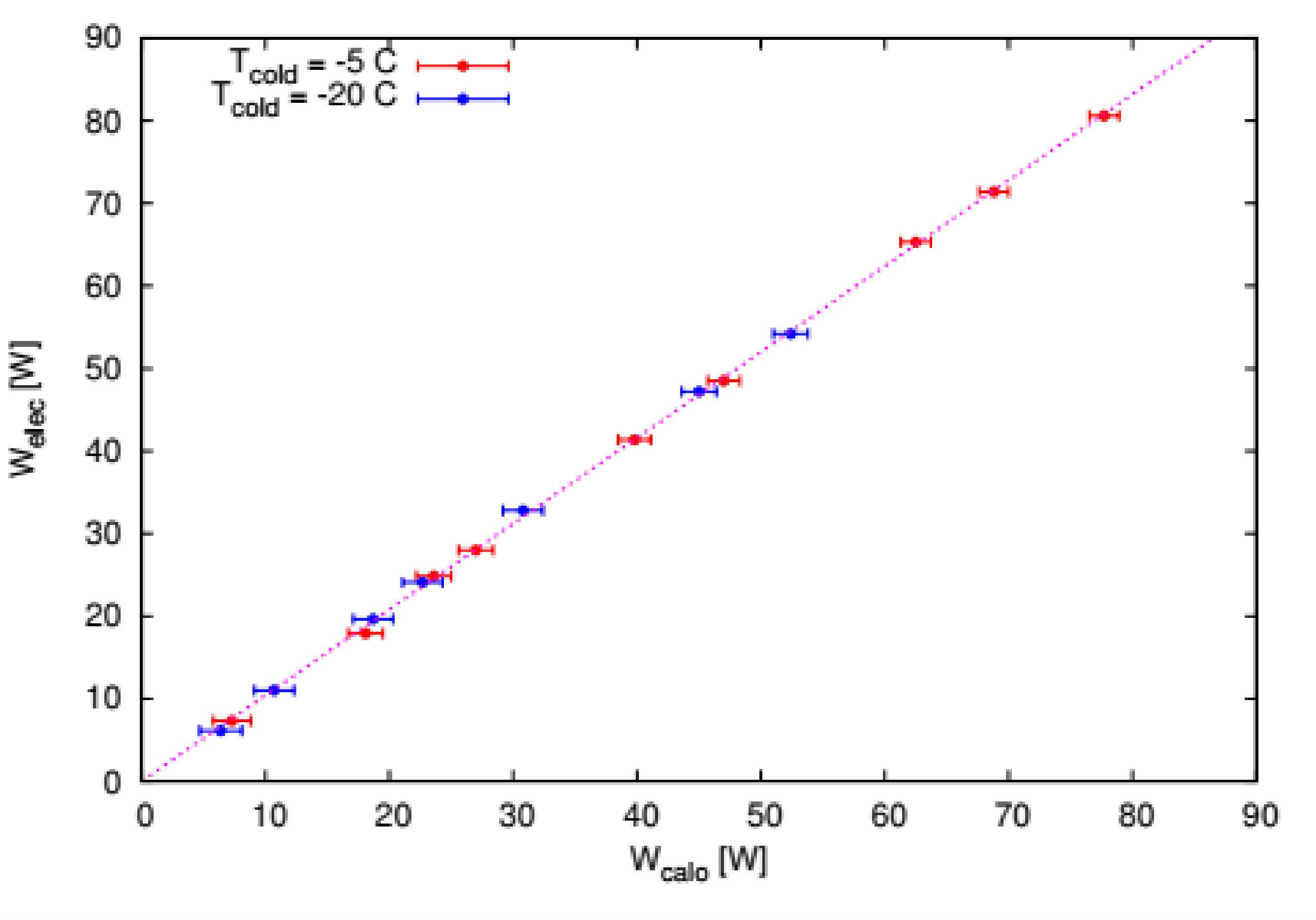
The Data Acquisition

t_m days	Q [C]	Target Gas	Target Pressure [mbar]	E_α [keV]	Aim
49	-	-	-	-	Laboratory background
0.5	13.5	Ar	0.468	399.9	Beam induced background
21.2	430	^{22}Ne	1	399.9	395 keV resonance

- Laboratory Background spectra acquired before, after and far before the measurement
- Insufficient statistics for the Beam Induced Background (B.I.B) estimation
- Contamination in the target gas was monitored using a mass spectrometer

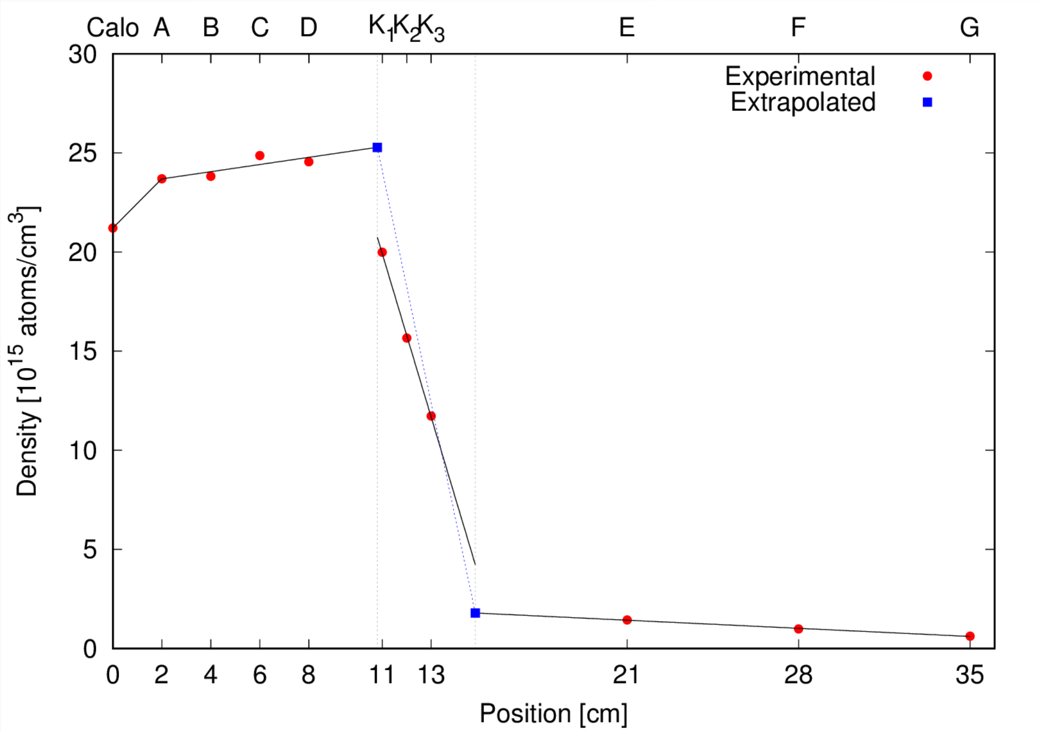
The Analysis and Results:

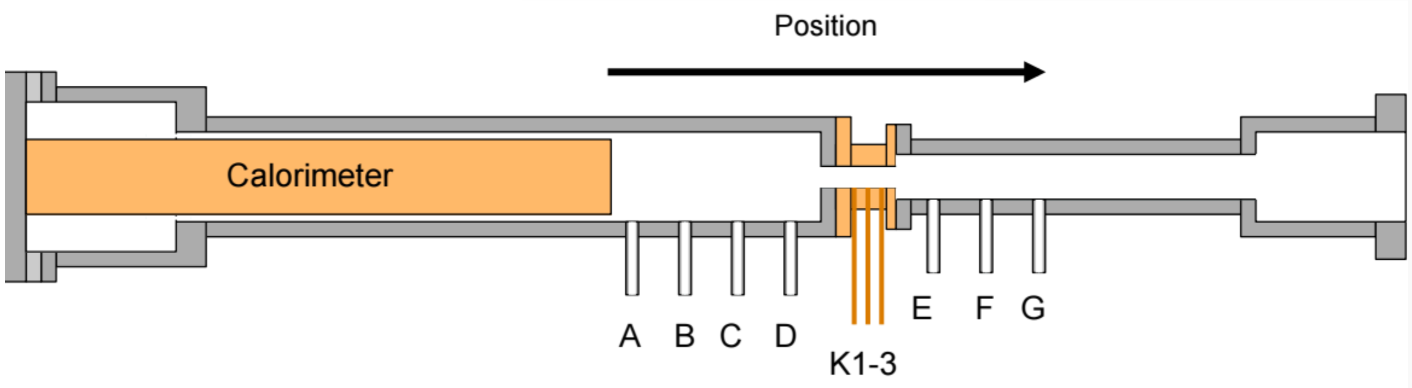
- Characterization of the setup:
  - Calorimeter calibration:



- Performed in vacuum
- For two different temperature of the cold side
- Comparing the W by the calorimeter and the W by a charge integrator

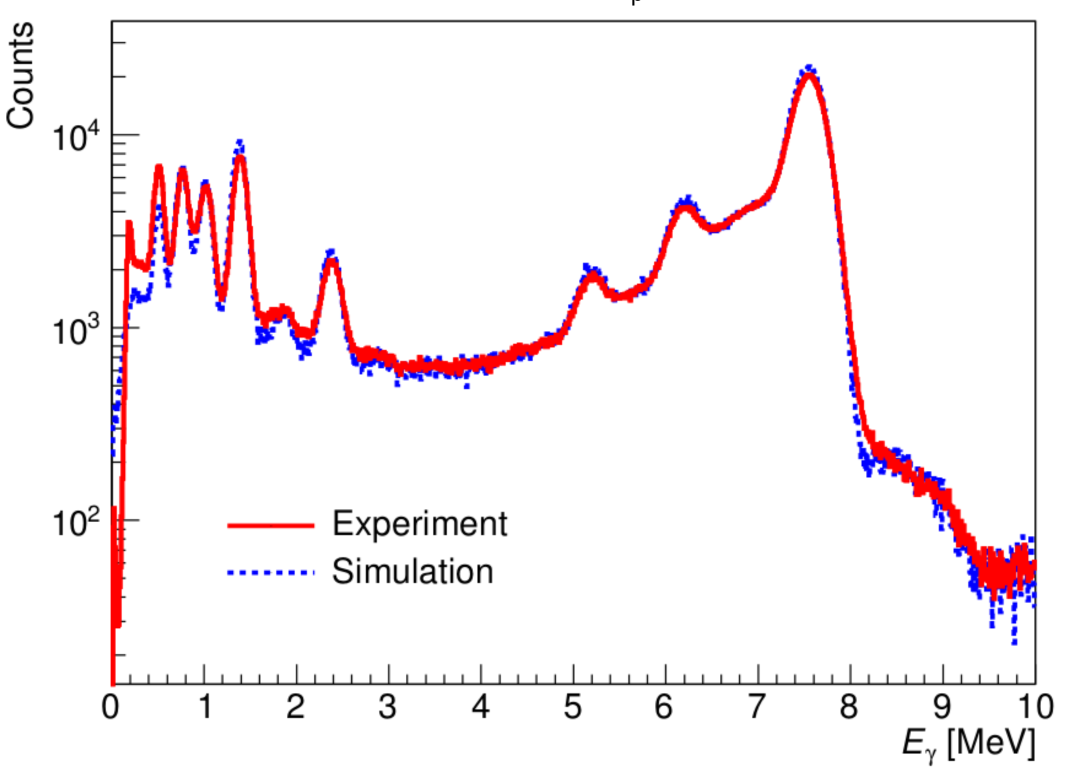
- Characterization of the setup:
  - Calorimeter calibration
  - Density profile of the target determined
    → Energy loss inside the chamber → I_{beam}



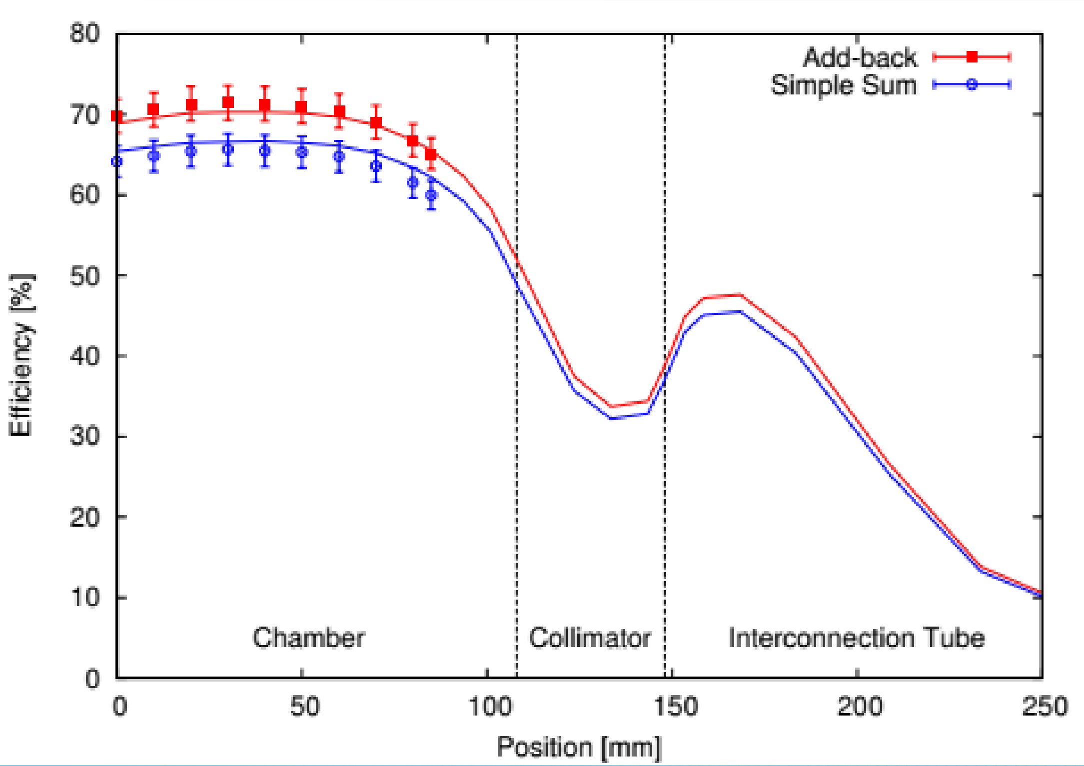


- Characterization of the setup:
  - Calorimeter calibration
  - Density profile
  - Calibration in efficiency of the detector: → tuning simulations by Geant 3 and Geant 4 codes with experimental data

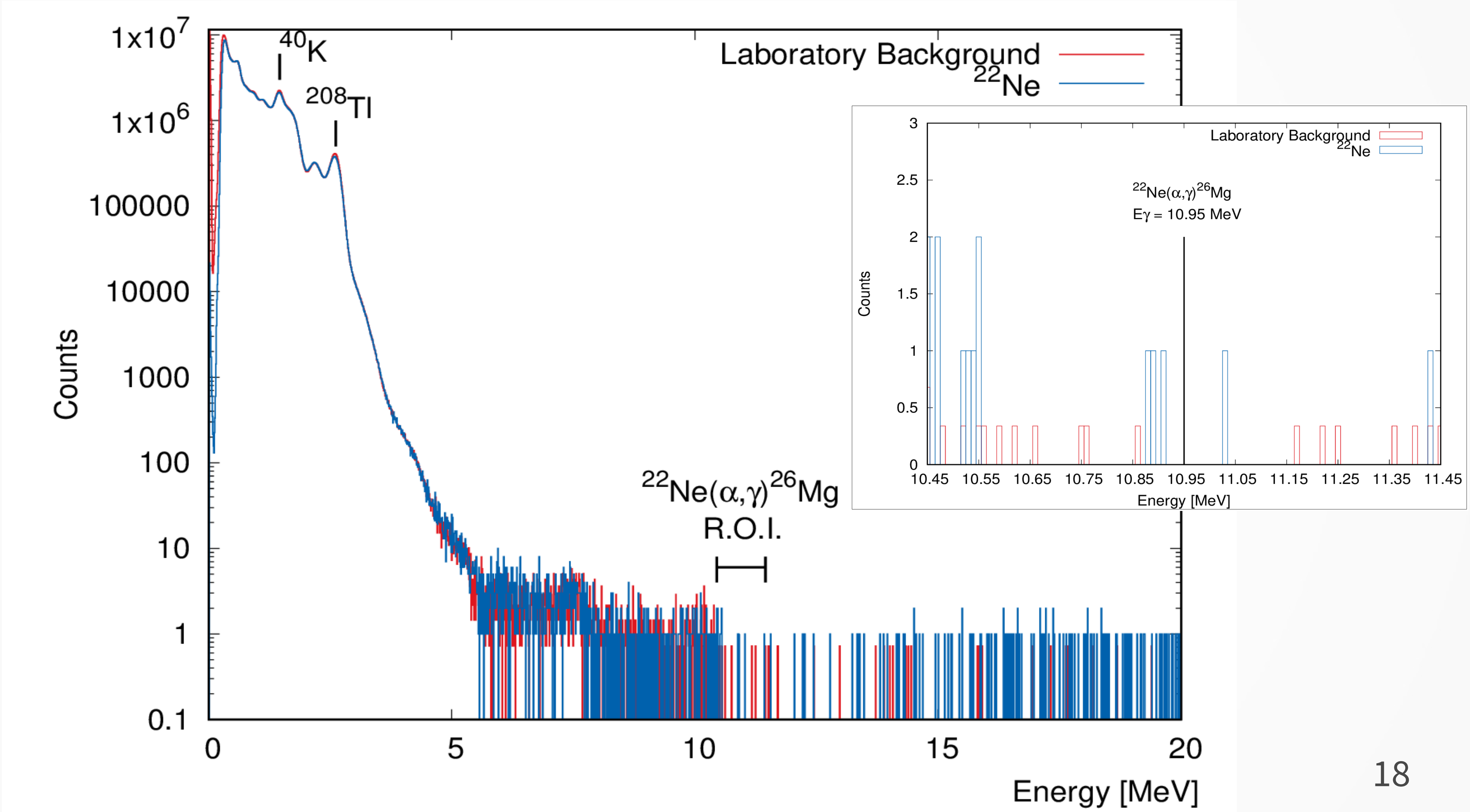
$^{14}N(p,\gamma)^{15}O$ reaction resonance at E_p = 278 keV addback spectrum



^{137}Cs point-like source



Is there a significant signal?→ Lab. Back. vs ^{22}Ne spectra



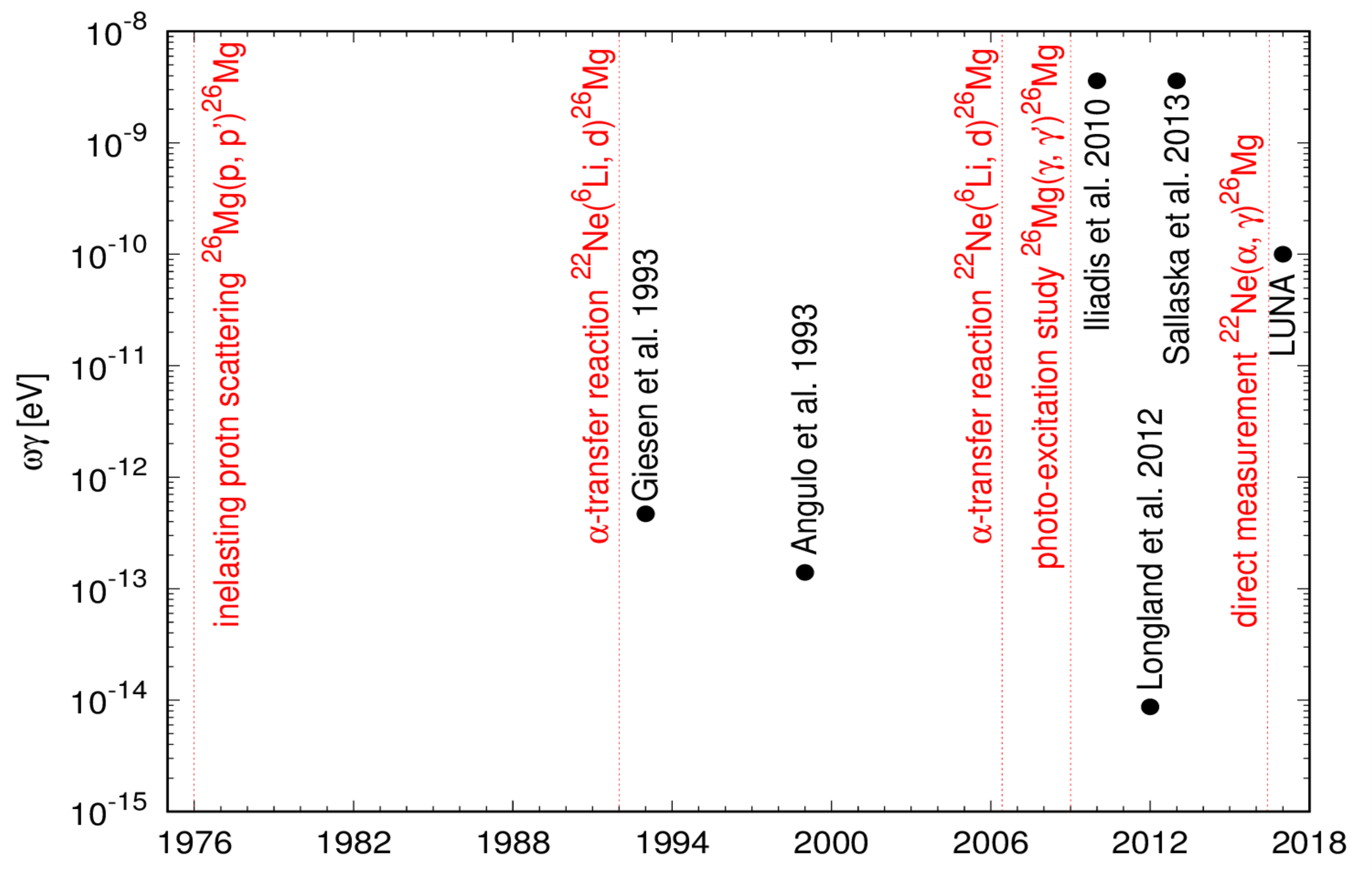
- Comparison between Laboratory Background spectra and the experimental spectra

- Calculation of the Critical Limit (L_{crit}) and of the Net Count (N) in the ROI:

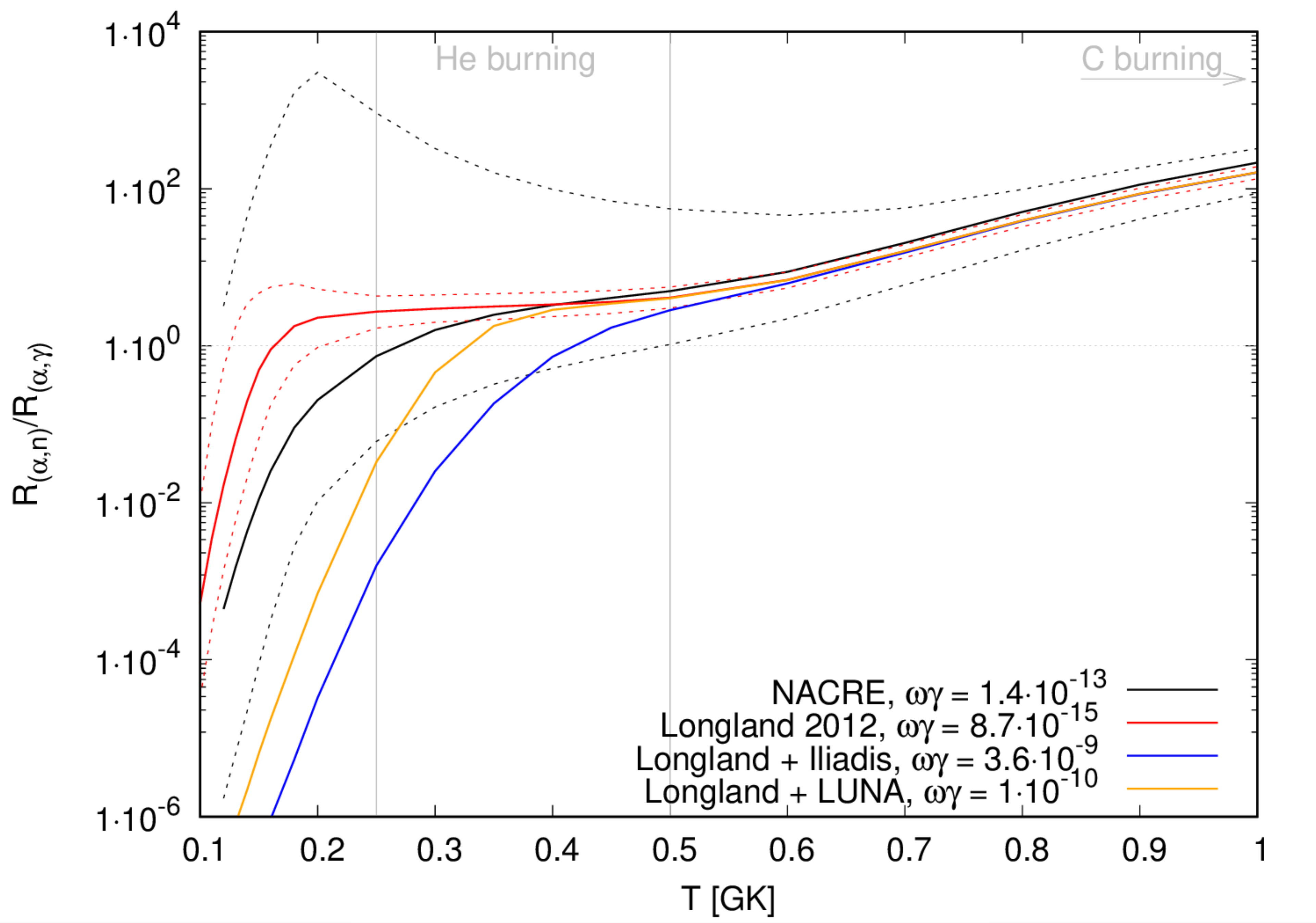
  → $\mathbf{N < L_{crit}}$

- Calculation of the Upper Limit of the resonance strength

  → $\omega\gamma_{ul} = 1 \cdot 10^{-10}$ eV



ωγ [eV]
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
10^-15
1976
1982
1988
1994
2000
2006
2012
2018
inelasting protn scattering ²⁶Mg(p, p')²⁶Mg
α-transfer reaction ²²Ne(⁶Li, d)²⁶Mg
Giesen et al. 1993
Angulo et al. 1993
α-transfer reaction ²²Ne(⁶Li, d)²⁶Mg
photo-excitation study ²⁶Mg(γ, γ')²⁶Mg
Iliadis et al. 2010
Longland et al. 2012
Sallaska et al. 2013
direct measurement ²²Ne(α, γ)²⁶Mg
LUNA



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Longland + LUNA, $\omega\gamma = 1\cdot10^{-10}$

“Preliminary” Results

- Some problems in the first campaign MUST be overcomed→ e.g. same statistics for B.I.B. and the measurement

- Some improvements still can be done→ e.g. reducing the neutrons background with a shield against neutrons around the detector

New campaign is ongoing

1 order of magnitude lower in $\omega\gamma$

Conclusion

- The fundamental role of the $^{22}Ne(\alpha,\gamma)^{26}Mg$ reaction in Astrophysics
- Why going underground?
- Experimental Results and ...
- … Issues

Thank You for the Attention

LUNA Collaboration

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