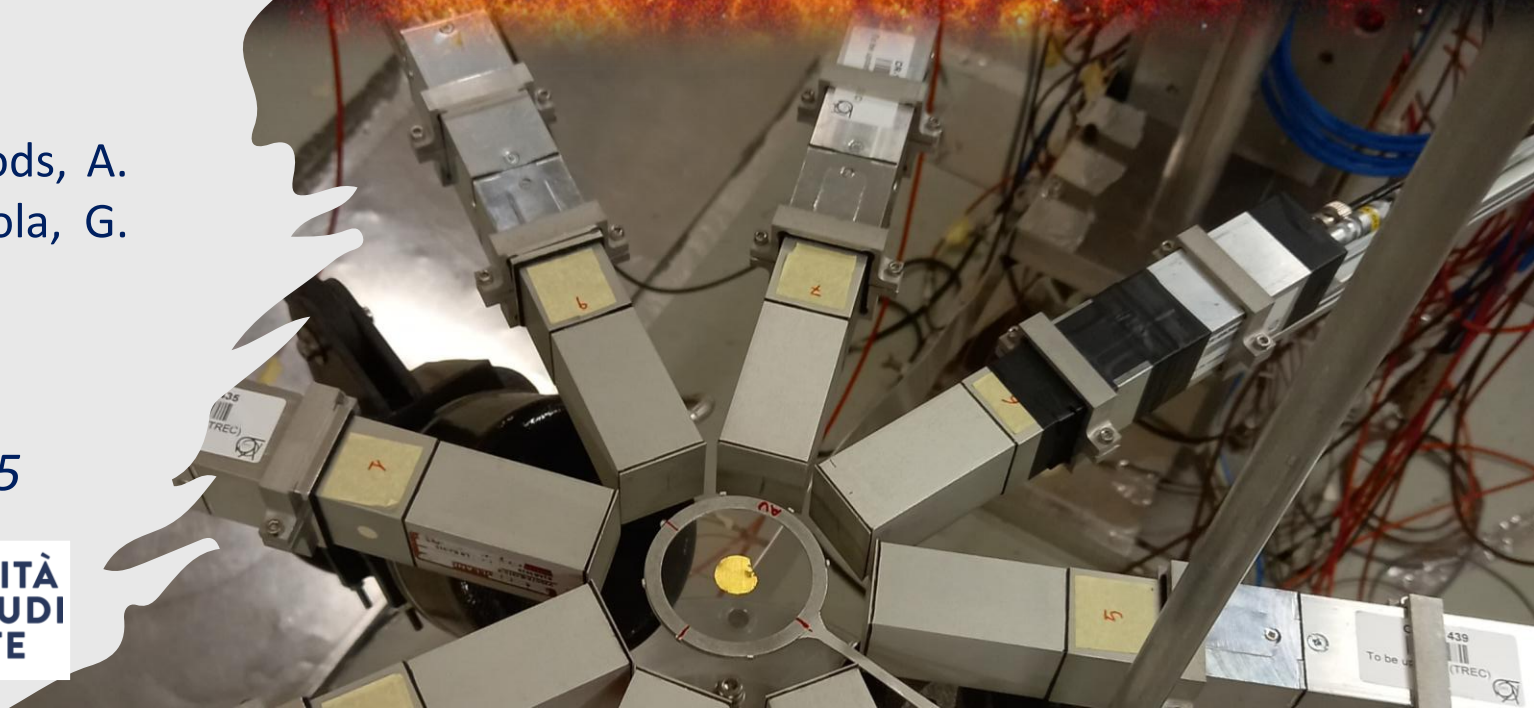
Measurement of (n,γ) cross sections for nucleosynthesis at n_TOF: the cases of ^{30}Si(n,γ) & ^{64}Ni(n,γ)



Michele Spelta,

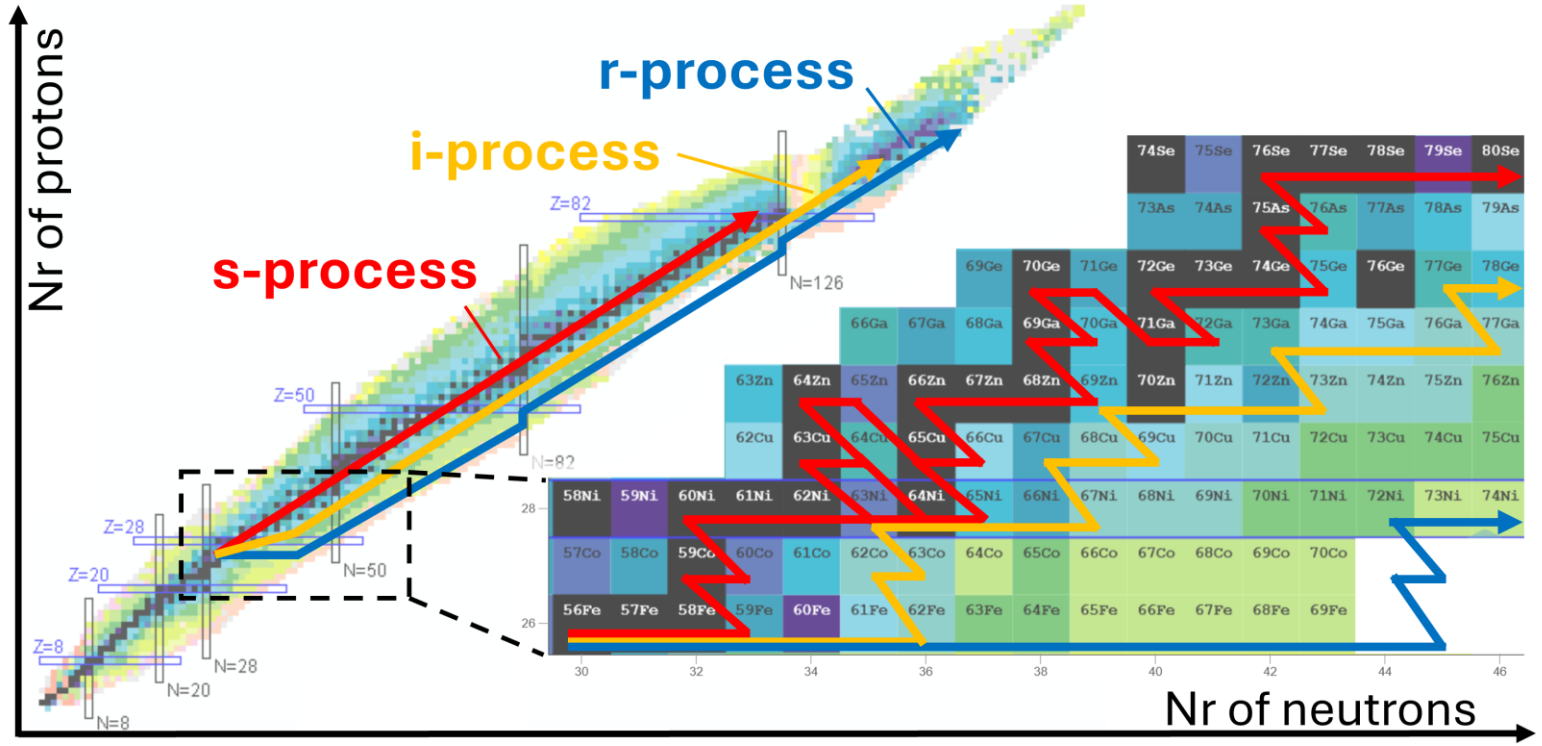
F. García-Infantes, T. Heftrich, C. Lederer-Woods, A. Manna, A. Mengoni, P.M. Milazzo, R. Mucciola, G. Tagliente and the n_TOF Collaboration

EuNPC 2025, Caen *21-26 September 2025*

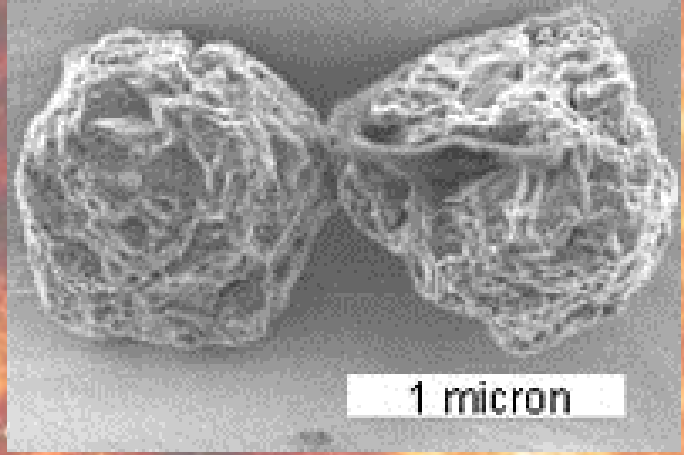
CERN n_TOF INFN TRIESTE UNIVERSITÀ DEGLI STUDI DI TRIESTE

Nucleosynthesis

Neutron capture reactions are at the base of the synthesis of all the elements heavier than iron, therefore (n,γ) cross sections represent important inputs for stellar nucleosynthesis models.



SiC grains in meteorites



Relevance of ^{30}Si(n,γ)

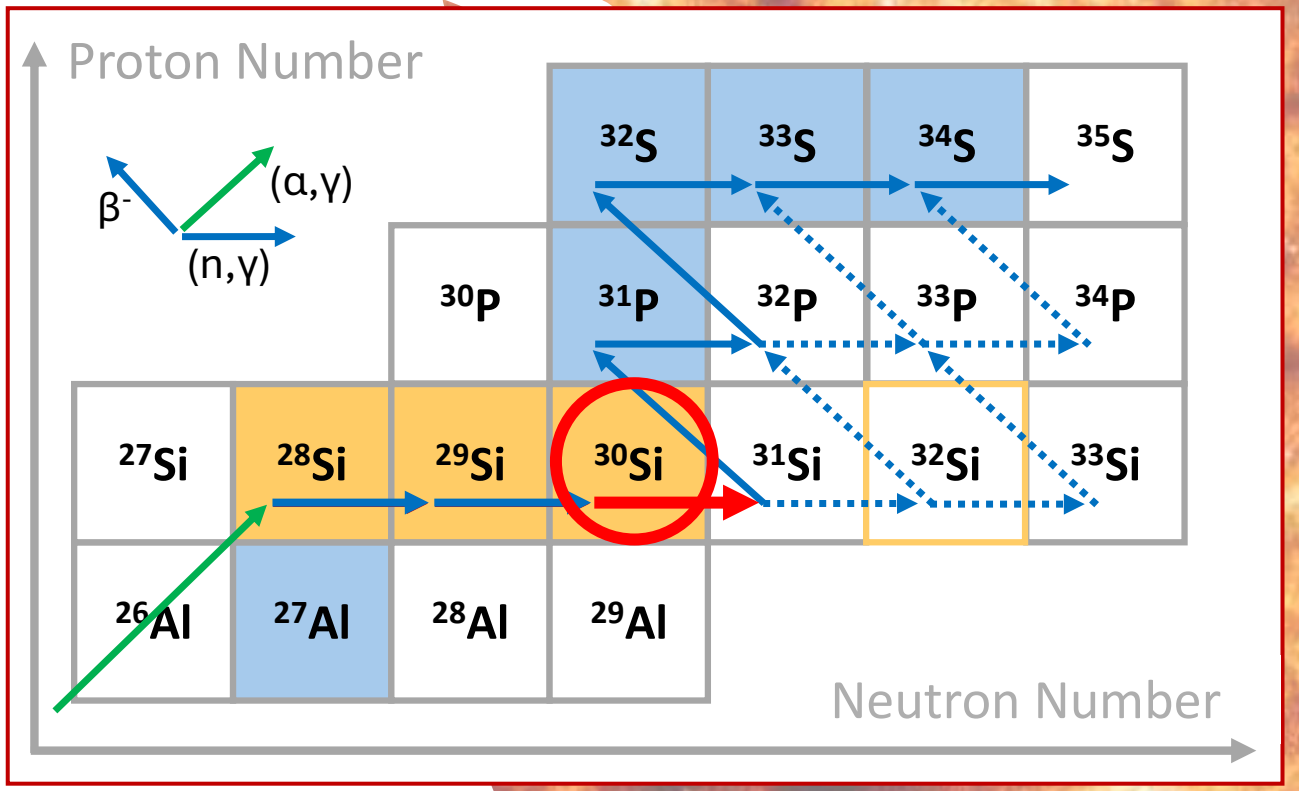
^{30}Si(n,γ) is important to **model the nucleosynthesis of ^{30}Si**:

- ^{29}Si and ^{30}Si are mostly made via (n,γ) reactions in the **convective carbon-shell of massive stars** at ≈ 1 GK (90 keV)

  *Pignatari et al, ApJ Suppl. **225** 24 (2016)*

  *Rauscher et al, ApJ **576** 323 (2002)*

- In these conditions, ^{30}Si(n,γ) determines the destruction rate of ^{30}Si, thus its final abundance

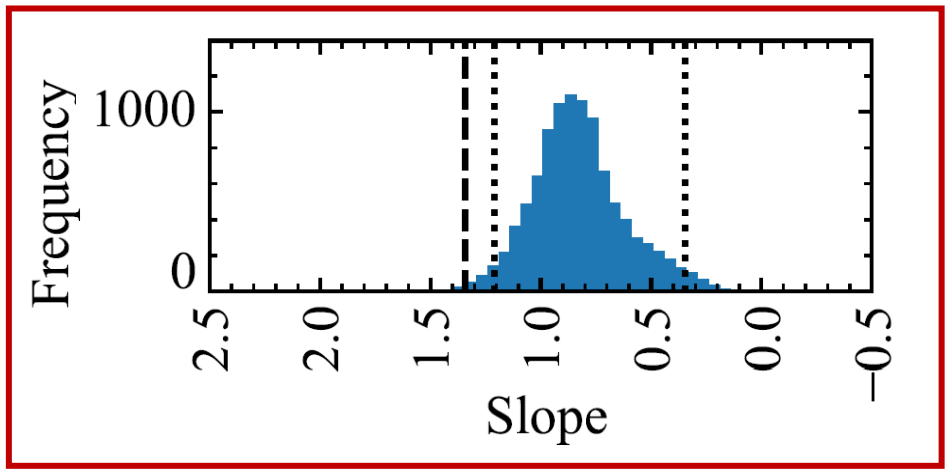


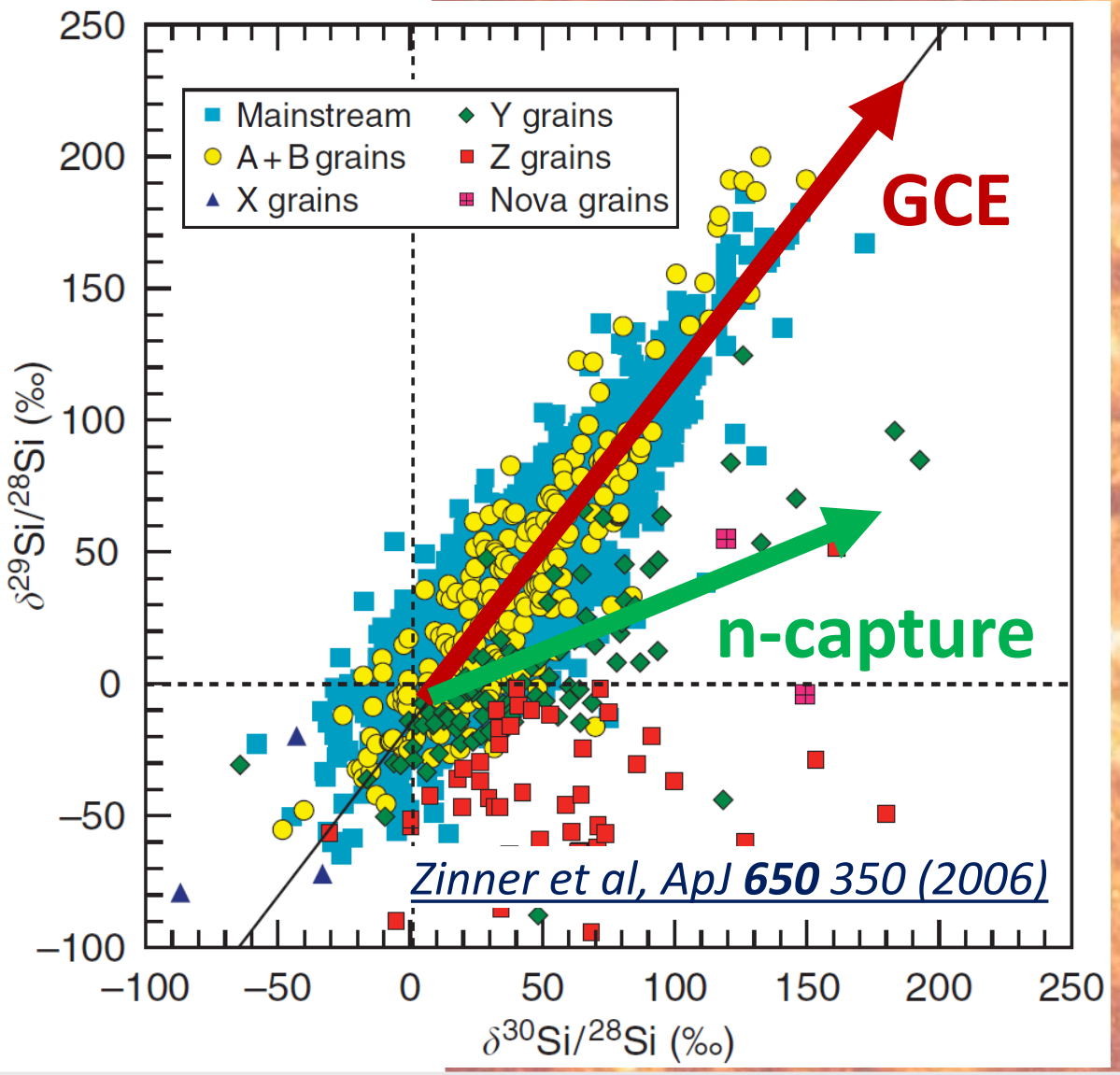
Relevance of ^{30}Si(n,γ)

^{30}Si(n,γ) is important to better understand the long-standing **problem of the Si isotopic ratios measured in SiC grains**:

- Absolute values
- **Slope of correlation line**
  (*sensitive to neutron capture rates*)

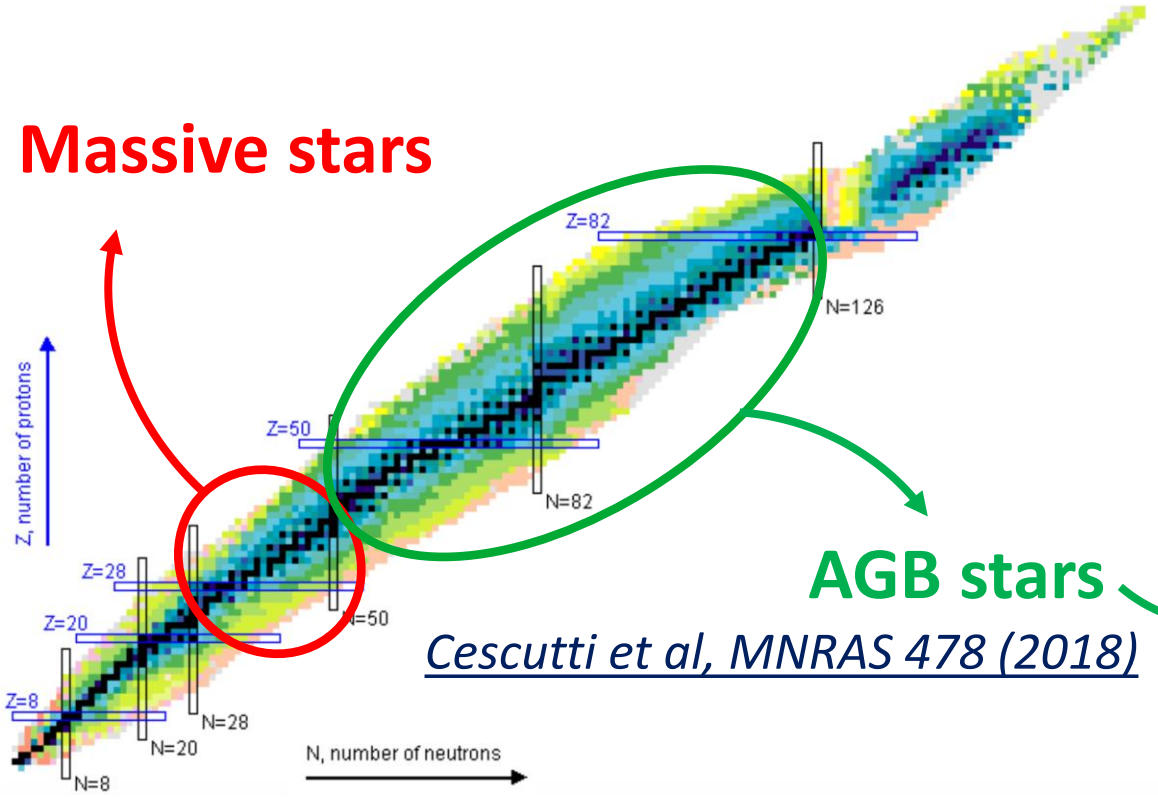
*Fok et al, ApJ Lett. **977** 1 (2024)*

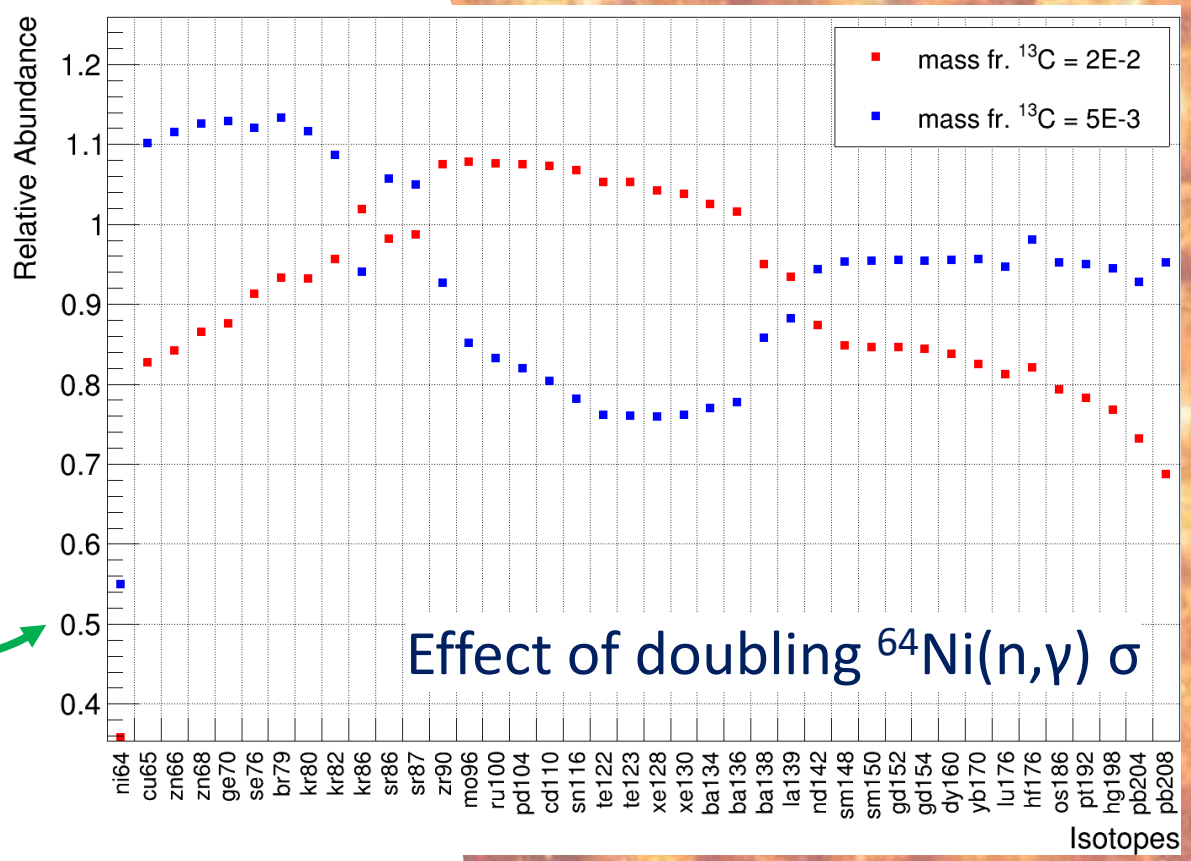




Relevance of ^{64}Ni(n,γ)

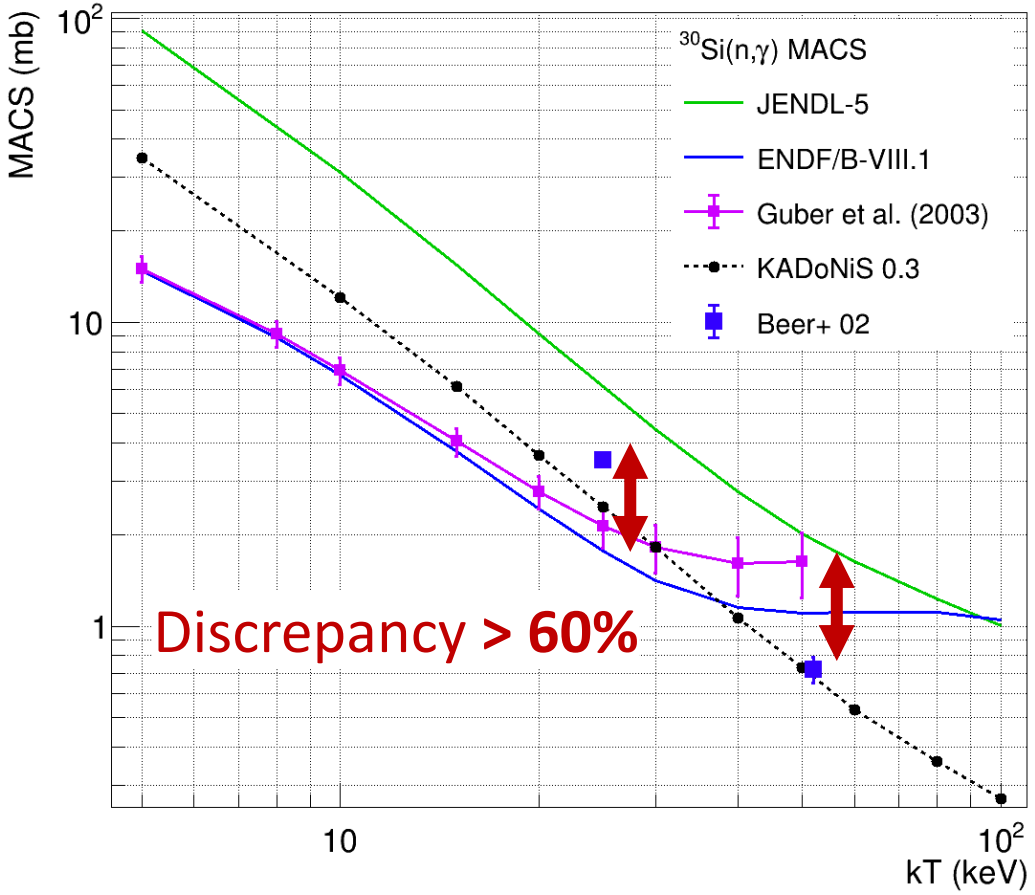
^{64}Ni is among the **seeds of the s-process**, therefore its (n,γ) cross section turned out to **affect the predicted abundance of many heavier isotopes**, up to Pb.

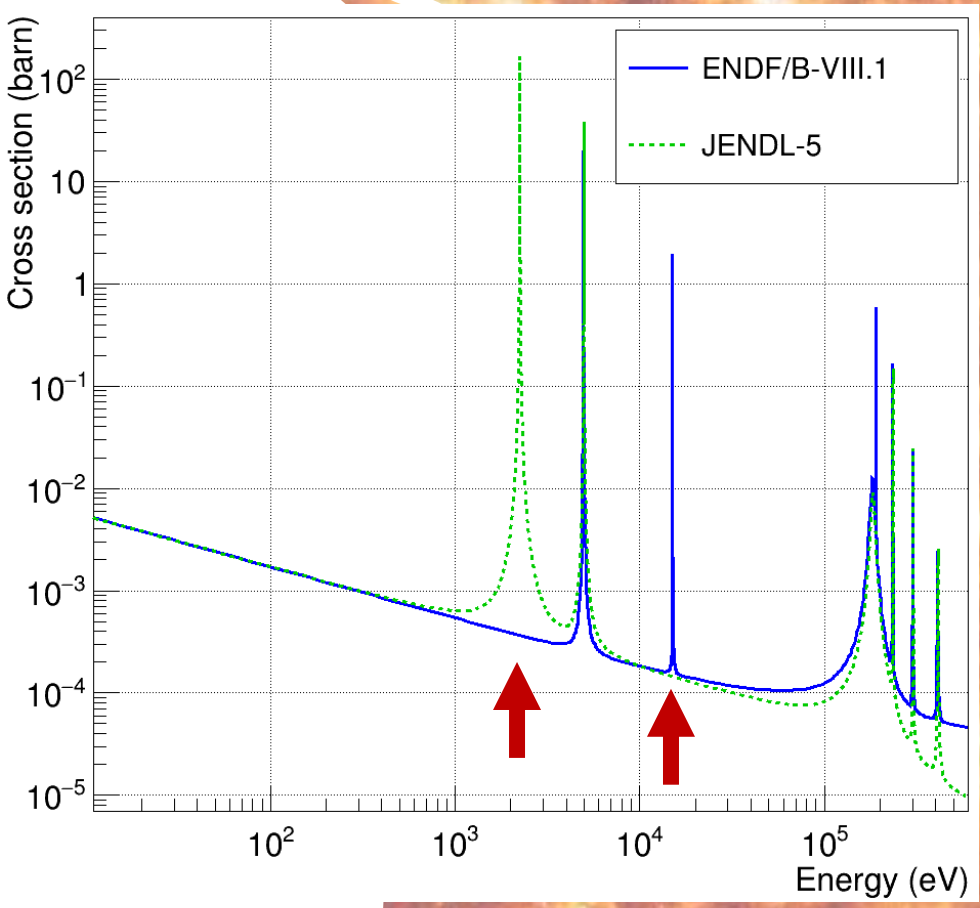




Data in literature

^{30}Si(n,γ) data in the literature are **scarce and discrepant**, leading to important discrepancies in the cross sections recommended by different evaluations





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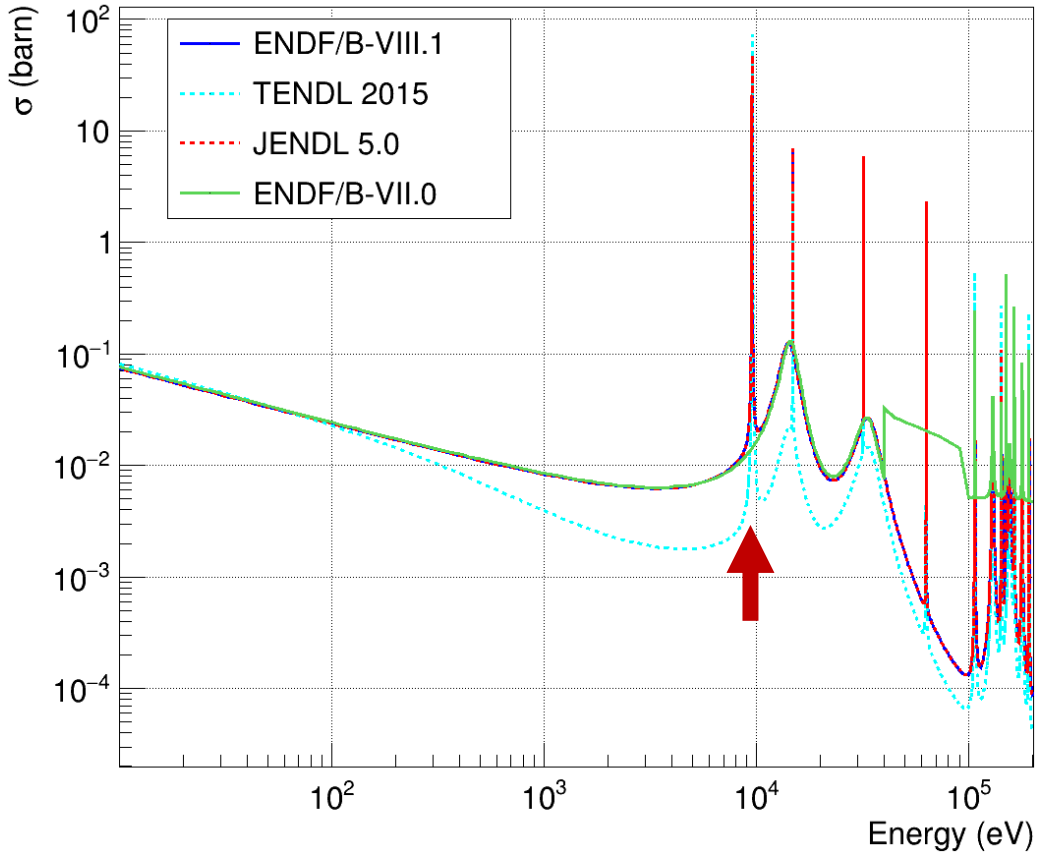
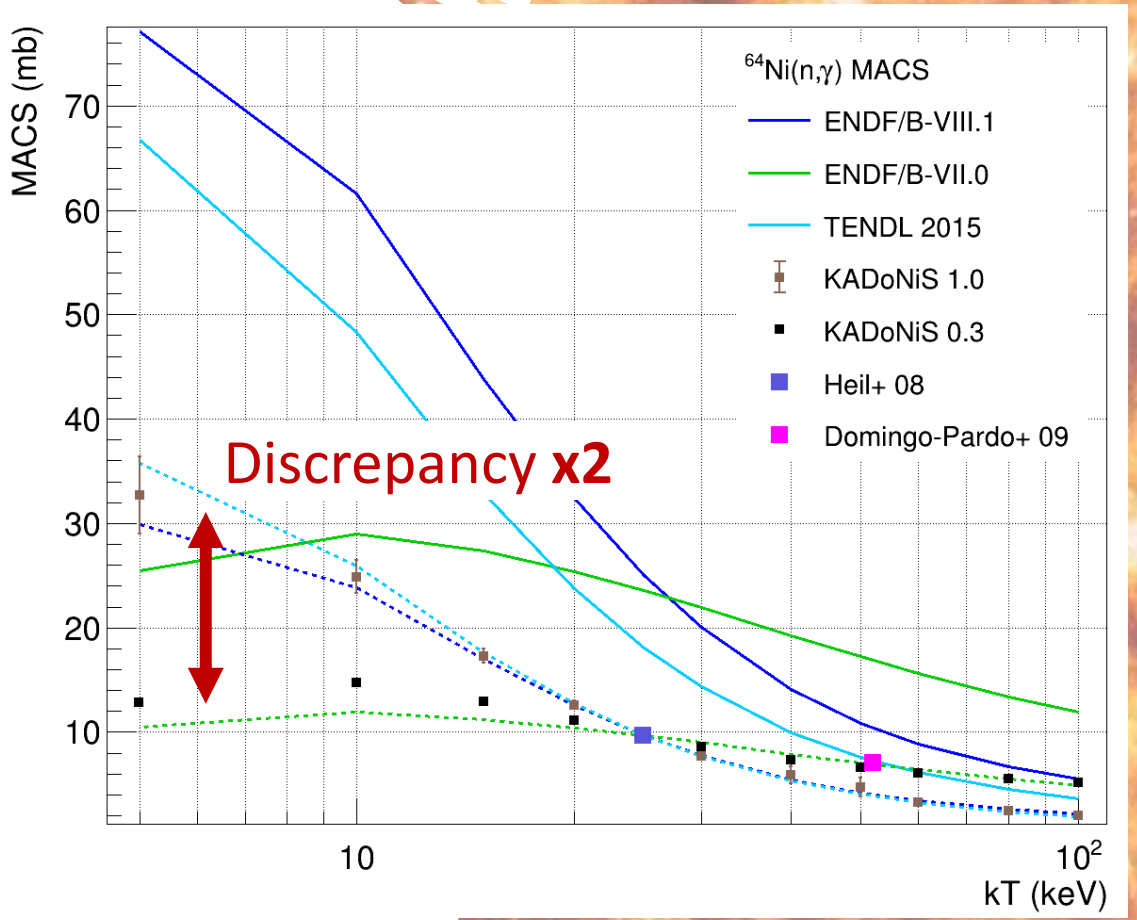
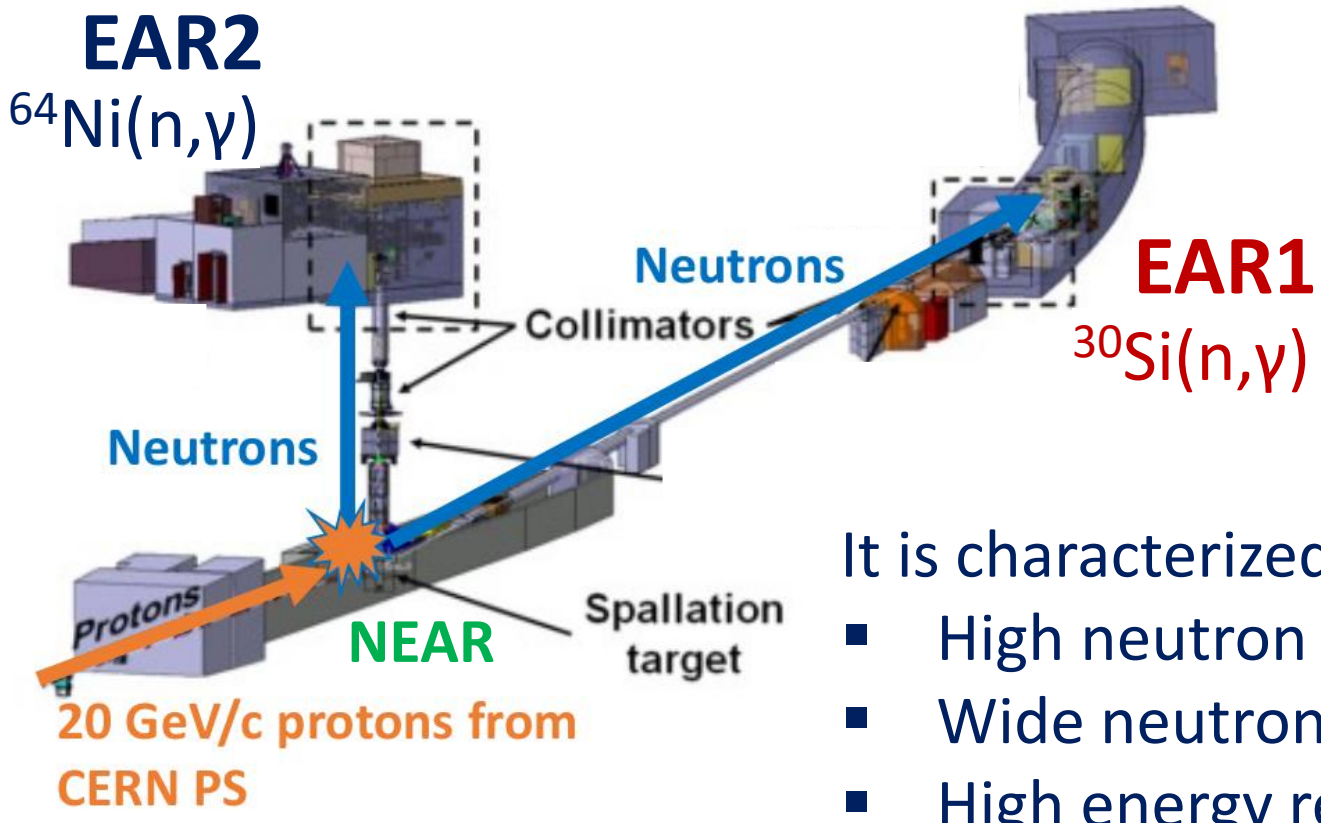




n_TOF facility

The **n_TOF facility** is a **pulsed white neutron source at CERN**



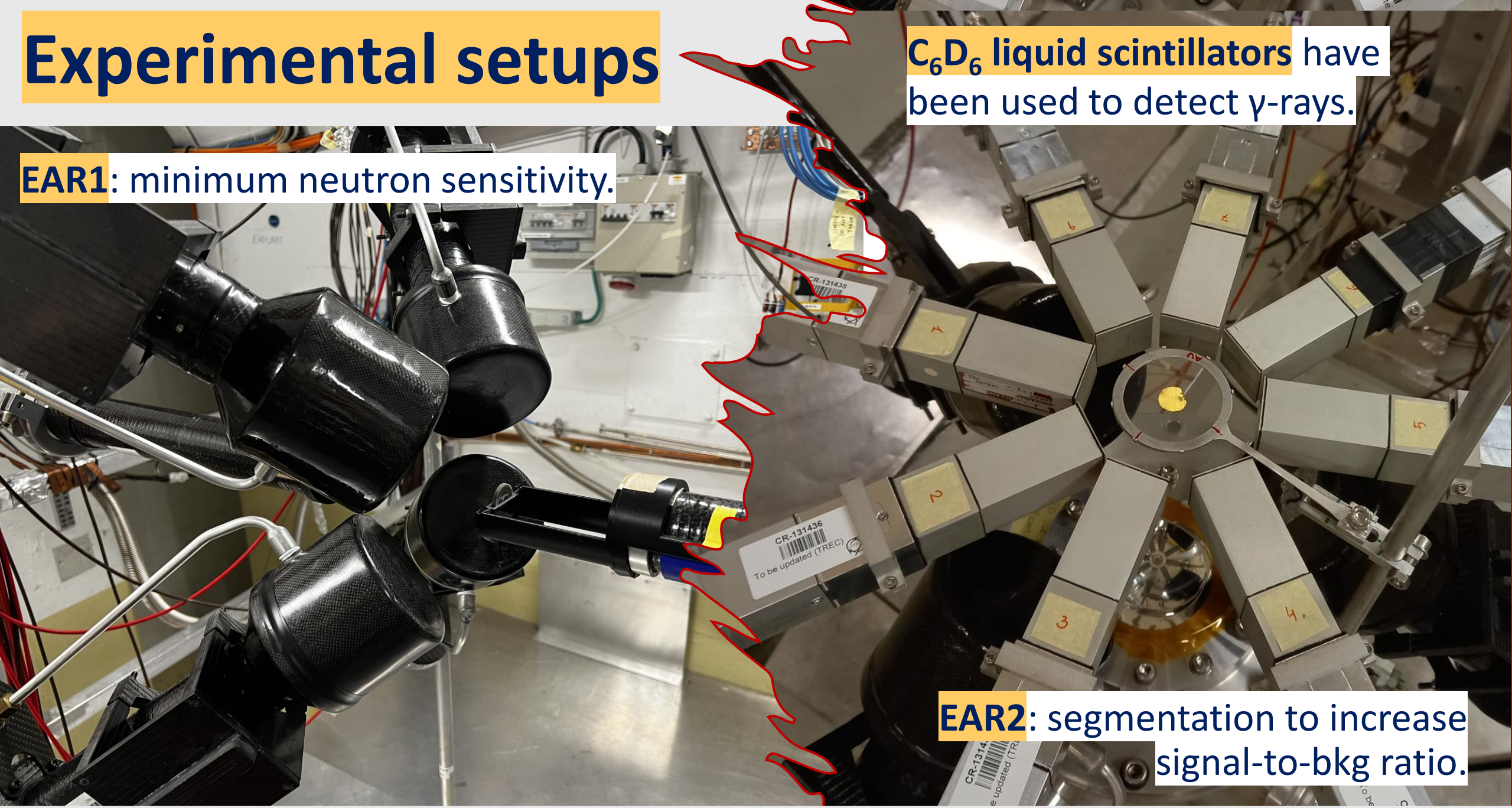
It is characterized by:

- High neutron flux
- Wide neutron energy range
- High energy resolution

Experimental setups

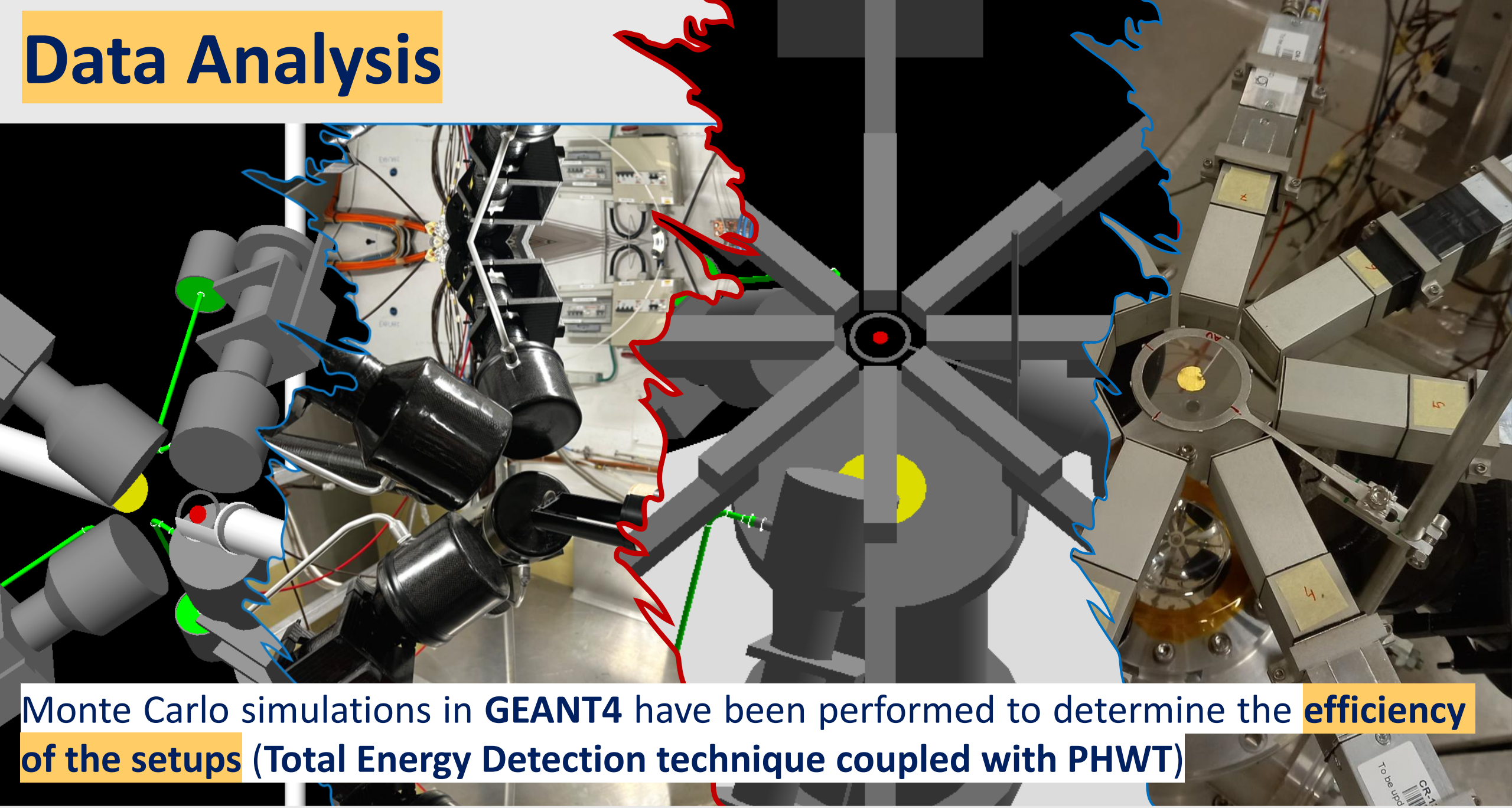
C_6D_6 liquid scintillators have been used to detect γ-rays.

EAR1: minimum neutron sensitivity.



EAR2: segmentation to increase signal-to-bkg ratio.

Data Analysis

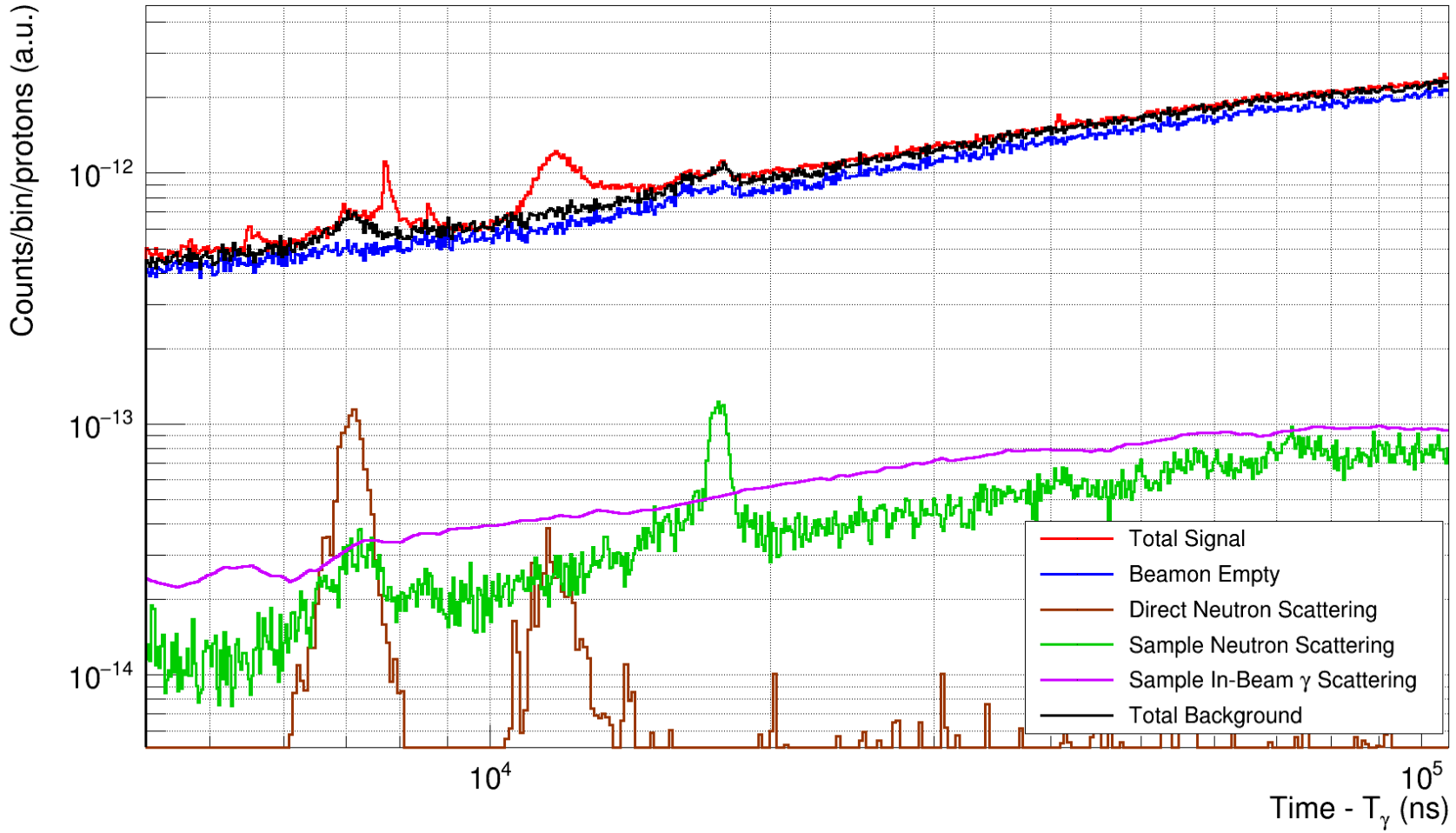


Monte Carlo simulations in **GEANT4** have been performed to determine the **efficiency of the setups** (**Total Energy Detection technique coupled with PHWT**)

Data Analysis

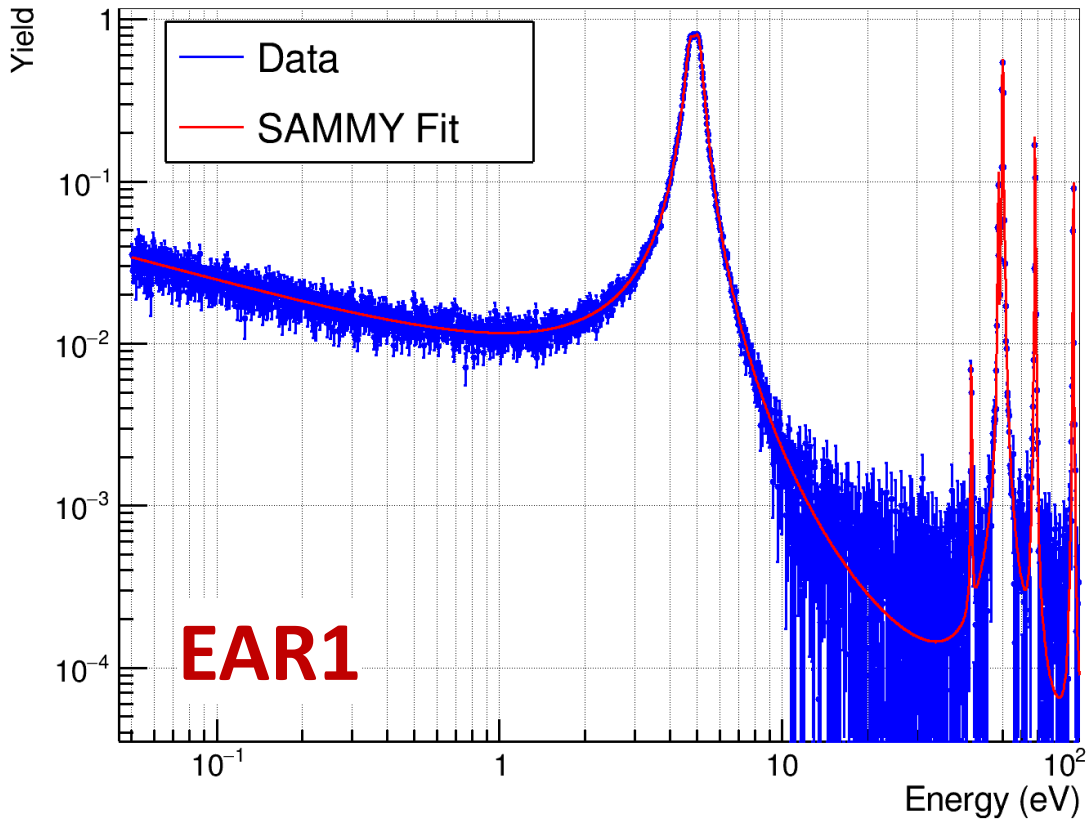
The **background** has been estimated with ancillary measurements and subtracted

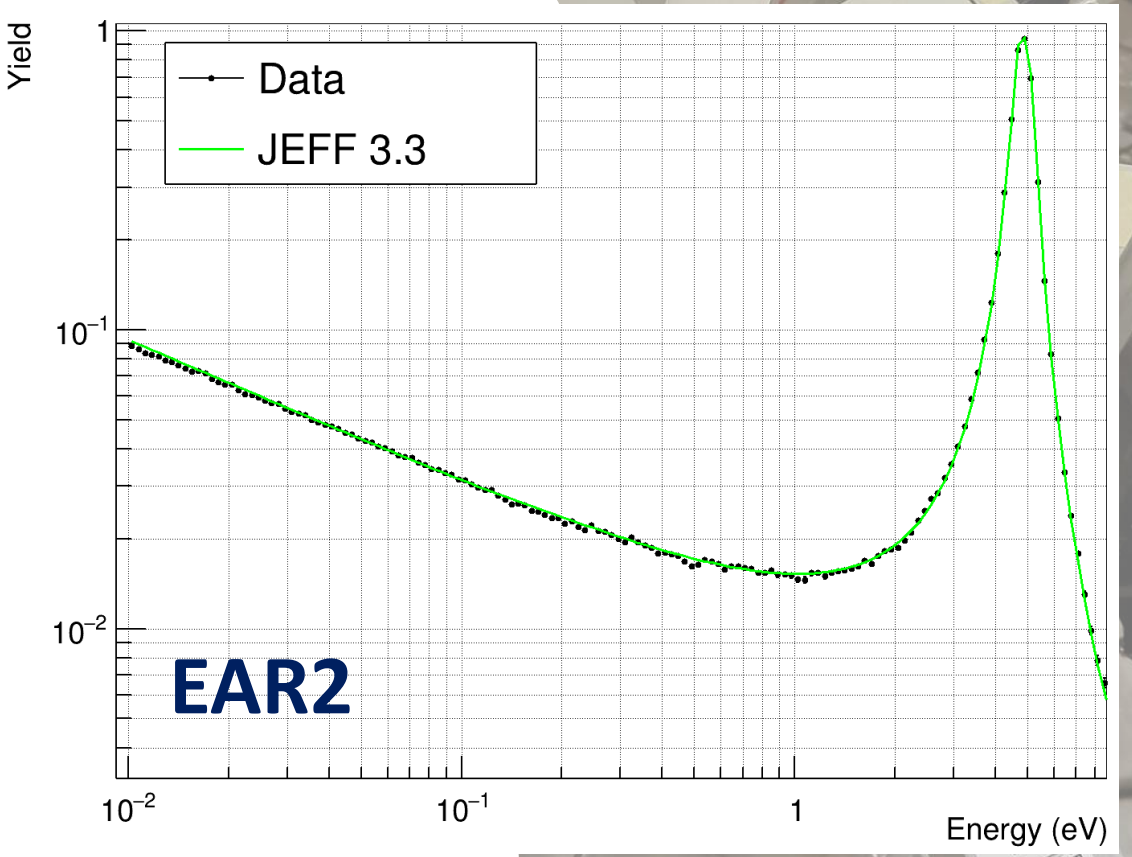
- **Empty** = sample-independent background
- **Lead** = sample-dependent in-beam γ rays scattering
- **Carbon** = sample-dep. neutron scattering
- **GEANT4** = neutron sensitivity



Data Analysis

The **normalization** has been performed with the **technique of the saturated resonance** using the **4.9 eV resonance of ^{197}Au**



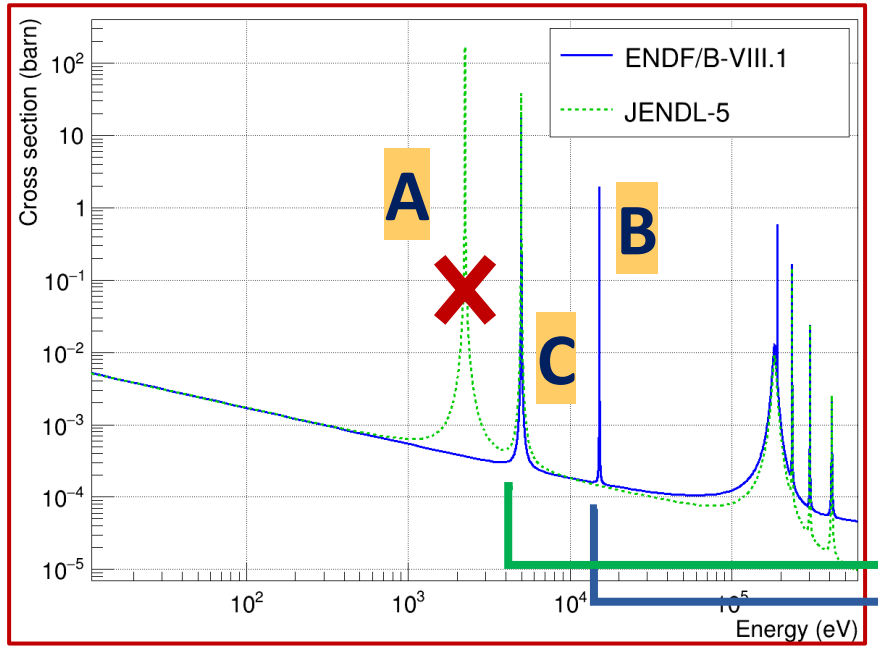


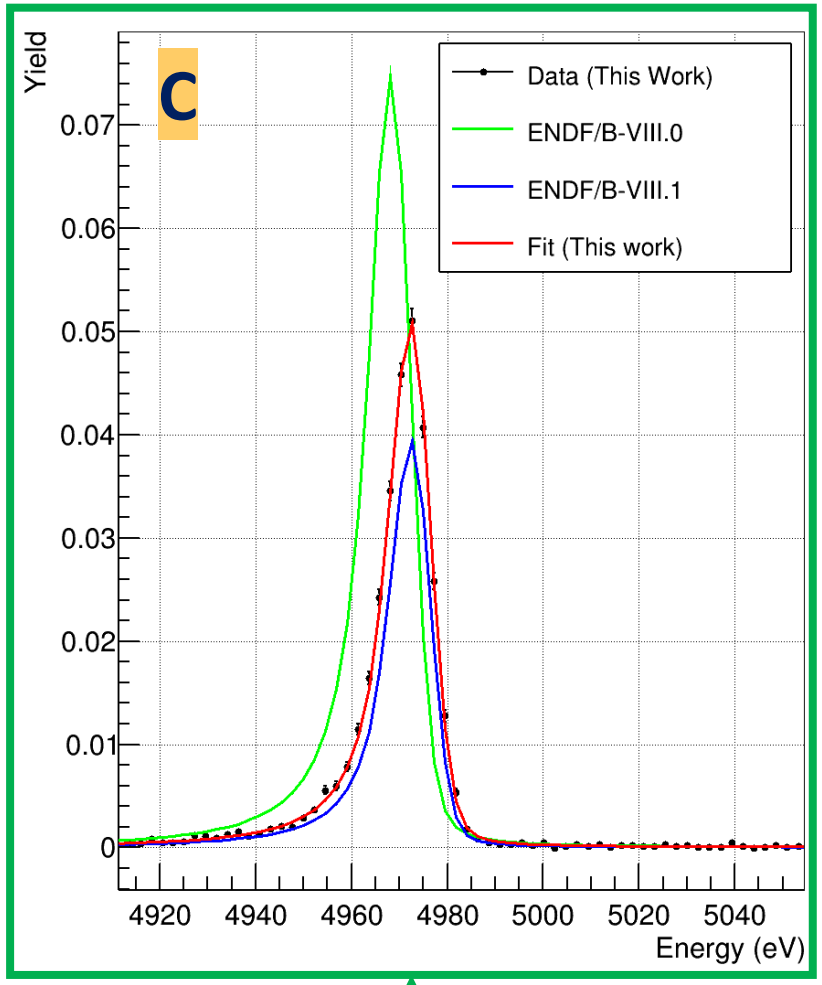
^{30}Si(n,γ): Preliminary Results

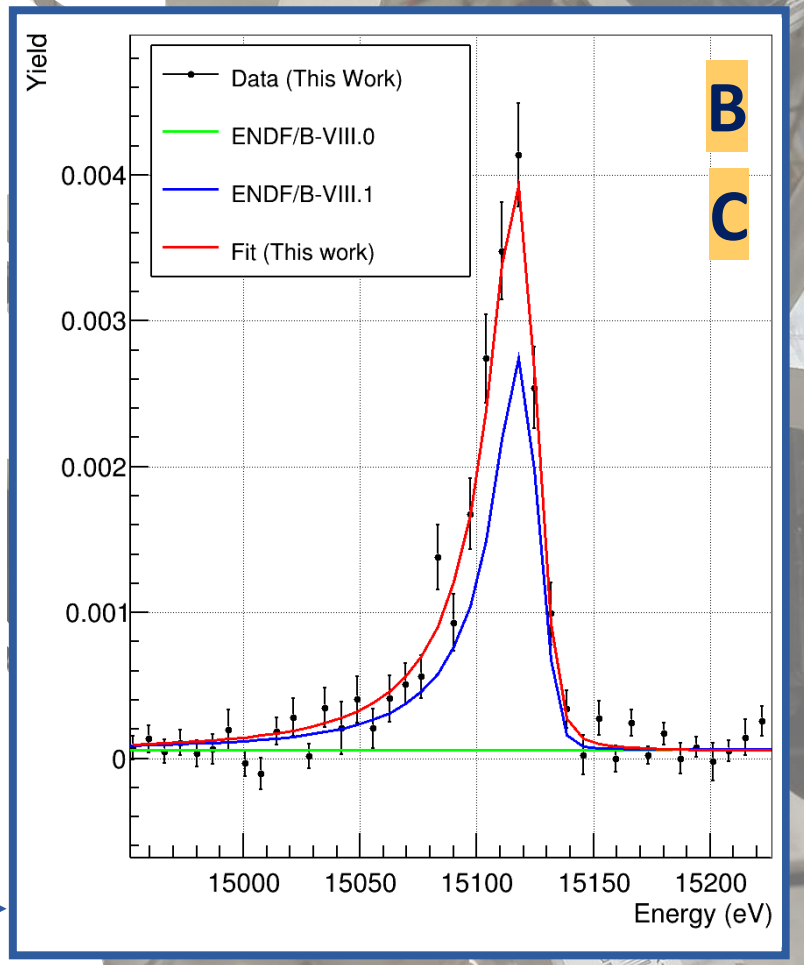
A. **No** resonance at **2.35 keV**

B. Resonance at **14.1 keV**

C. Kernels are **≈30% larger than Guber**, but smaller than JENDL-5







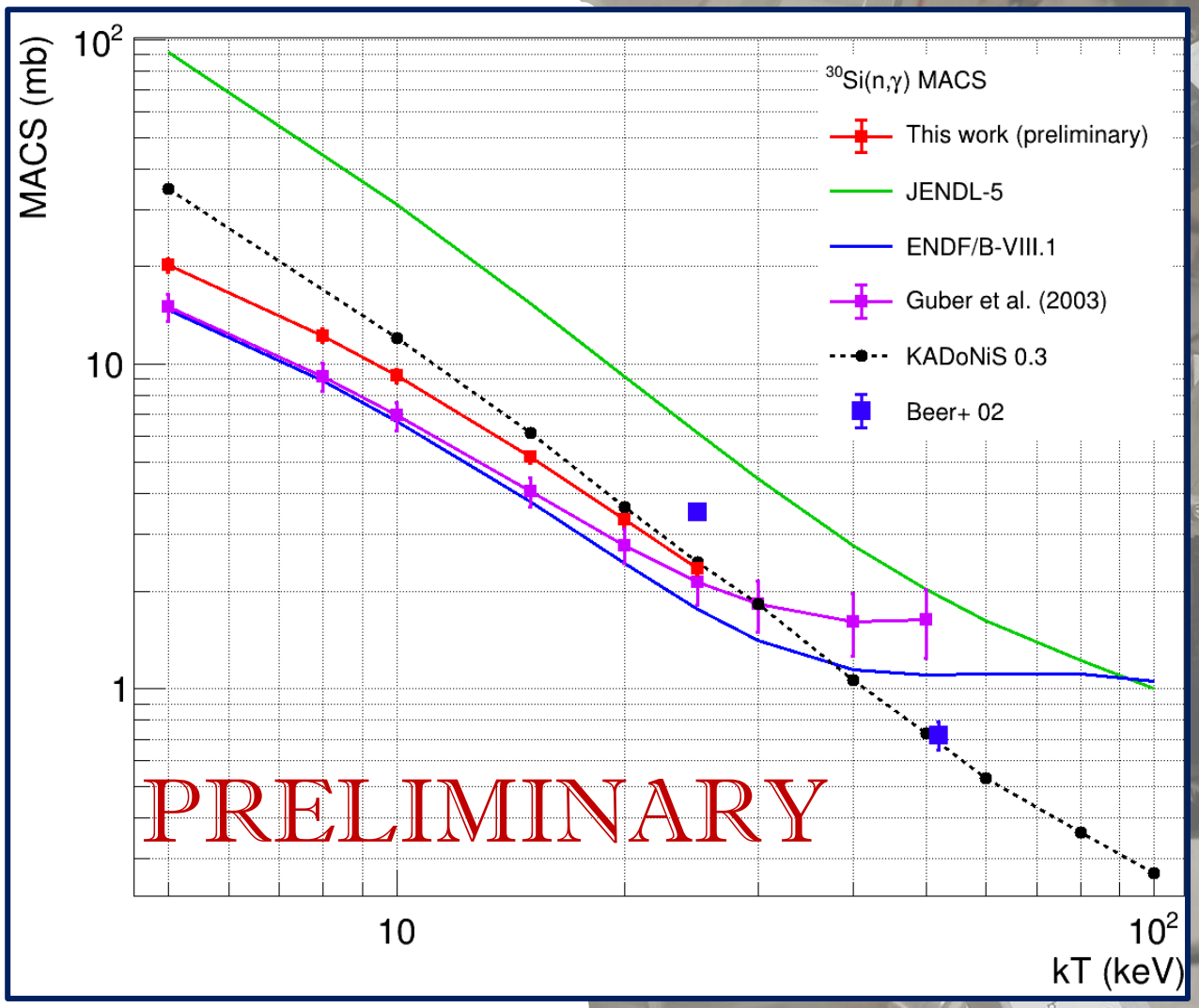
^{30}Si(n,γ): Preliminary Results

Preliminary MACS

(Only up to 25 keV where measured resonances dominate)

- Intermediate between latest previous measurements

- **Direct capture** still missing (0.3-0.5 mb expected)
- **Extension up to 90 keV** ongoing



^{64}Ni(n,γ): Preliminary Results

A. **No** resonance at **9.52 keV**

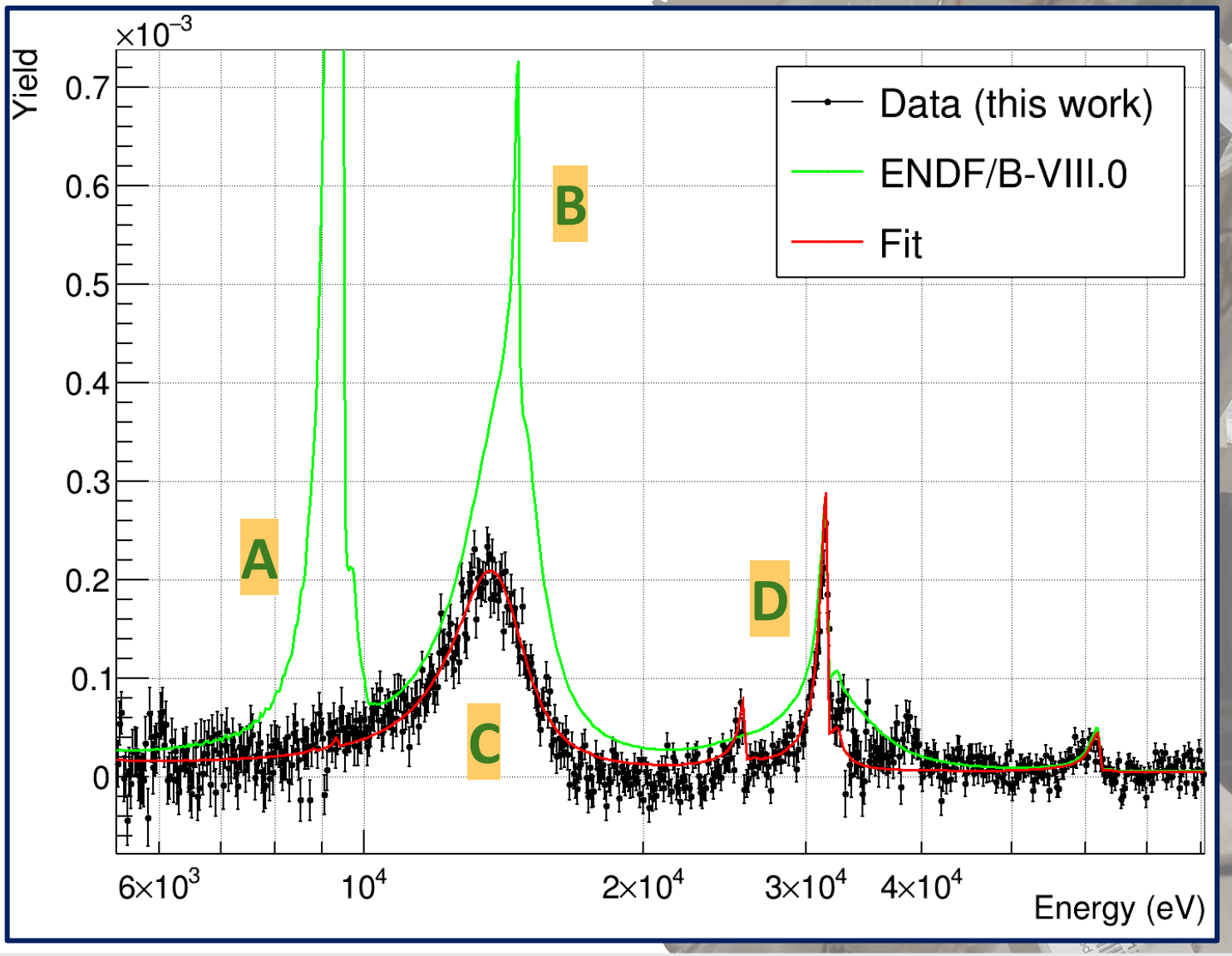
B. **No** resonance at **14.8 keV**

Only in Beer+ (1975)

C. **Reduced** capture kernel for resonance at **13.7 keV**

≈ Wisshak+ (1984)

D. Scattered neutrons captured in **Al resonances pollute region around 30 keV**

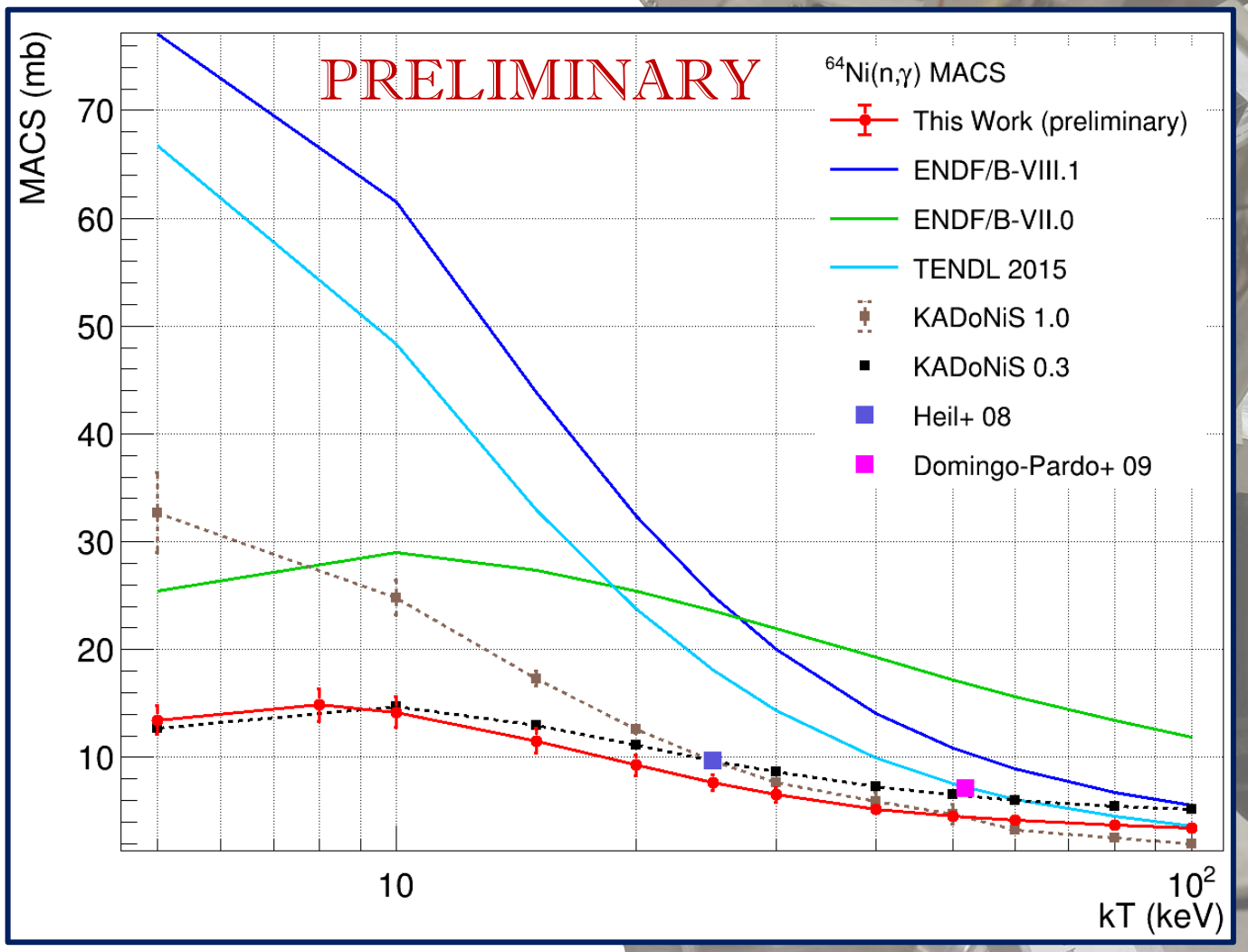


^{64}Ni(n,γ): Preliminary Results

Preliminary MACS

- Close to **activation measurements**
- Similar to extrapolation of **KADoNiS0.3**

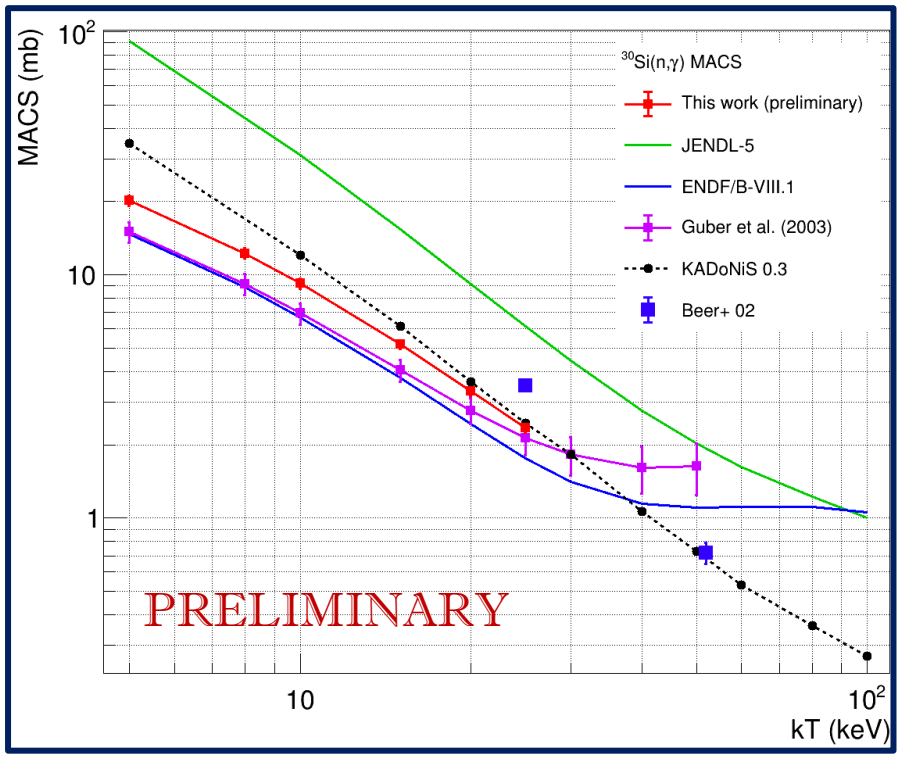
- **Direct capture** to be adjusted (*small contribution expected*)
- Not yet fully reliable @ **30 keV**

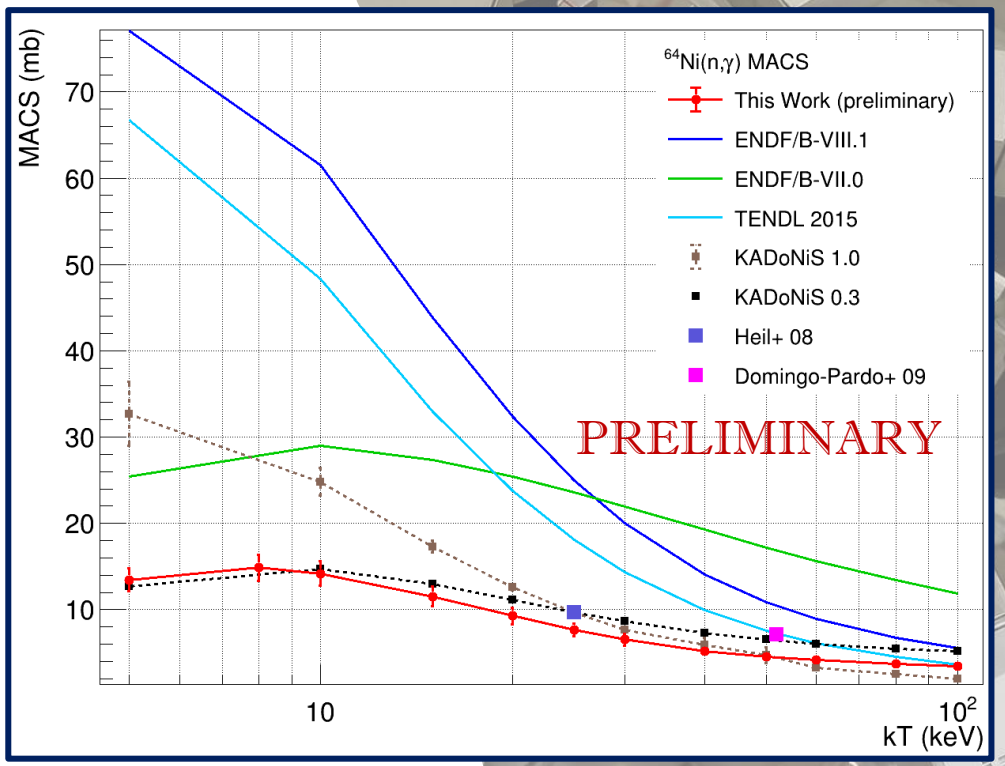


Conclusion

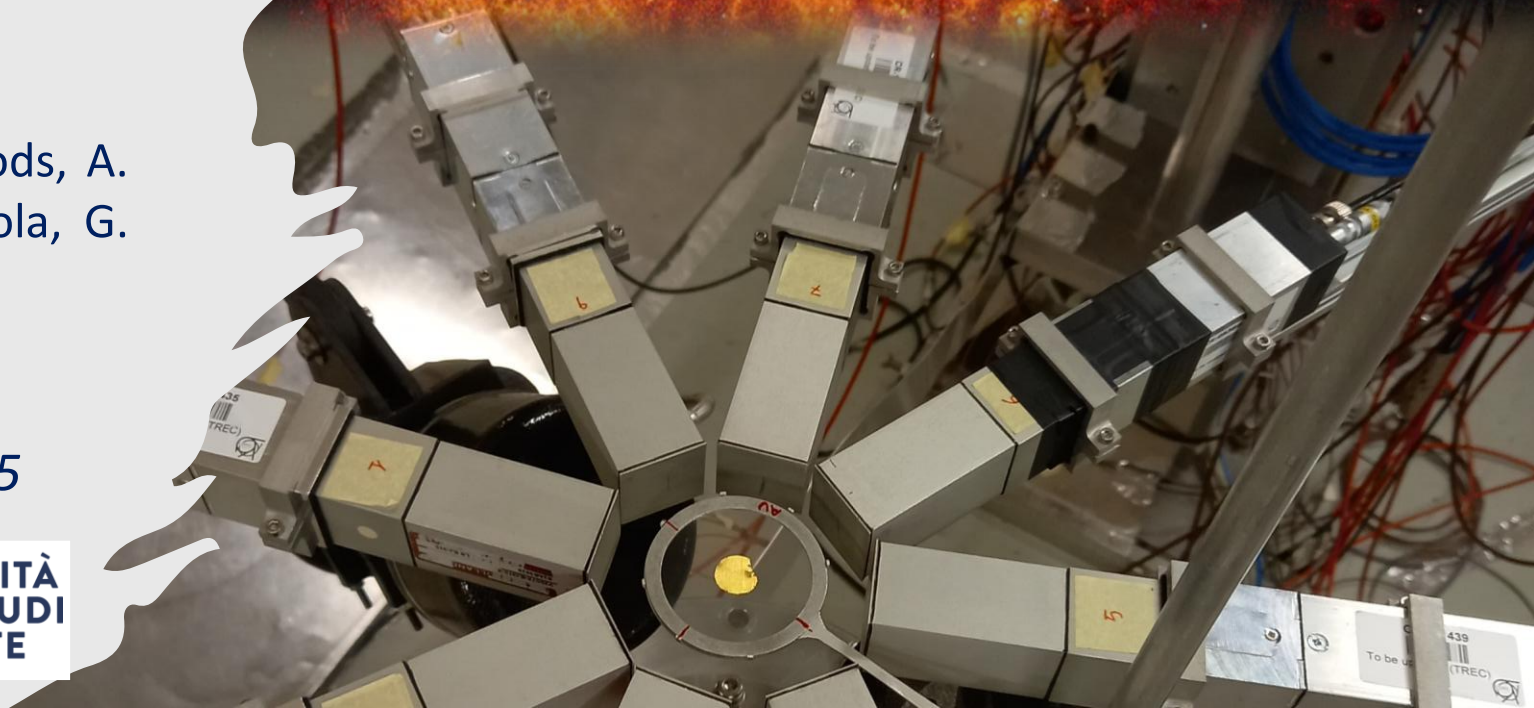
This project has received funding from the European Union's Horizon Europe Research and Innovation programme under grant agreement No 101057511

- Accurate (n,γ) cross sections are crucial for studying stellar nucleosynthesis
- **^{30}Si(n,γ)** is important to understand Si abundances in SiC grains, **^{64}Ni(n,γ)** to accurately model the s-process in massive and AGB stars
- These cross sections have been measured at the **n_TOF facility at CERN**:





Measurement of (n,γ) cross sections for nucleosynthesis at n_TOF: the cases of ^{30}Si(n,γ) & ^{64}Ni(n,γ)



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