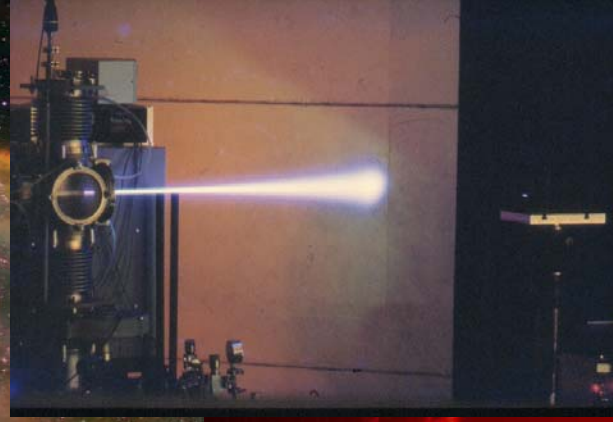
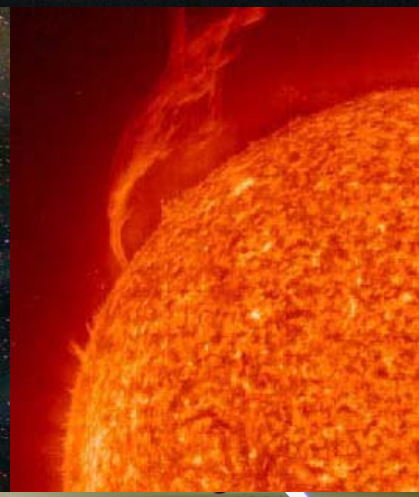
LUNA-MV – The next Underground Accelerator Facility



Frank Strieder
Ruhr-Universität Bochum, Germany
Seconda Universita di Napoli, Caserta, Italy

EuroGENESIS Workshop – Origin of the Elements
Barcelona, Catalunya
14.06.2013



Outline of this Presentation

LUNA-MV – The next Underground Accelerator Facility

- History and Status of the LUNA-MV project
- Site preparation at the Laboratori Nazionali del Gran Sasso
- Astrophysical Motivation and Advantage going Underground
- Holy Grail of Nuclear Astrophysics – $^{12}C(\alpha,\gamma)^{16}O$

History of LUNA-(MV)

Z. Phys A 350, 289–301 (1995)

ZEITSCHRIFT
FÜR PHYSIK A

Prospects for underground accelerator research

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[2] W.K. Kellogg Radiation Laboratory, Caltech, Pasadena, California, USA
[3] Institut für Physik mit Ionenstrahlen, Ruhr-Universität, Universitätsstrasse 150, D-44780 Bochum, Germany

Received: 17 August 1994

Abstract. A summer institute was convened at the Gran Sasso Laboratory (Italy), 27. June to 7. July 1994, in part to explore the advantages of an accelerator laboratory deep underground, particularly for crucial nuclear-astrophysics measurements presently limited at low energies by cosmic-ray backgrounds. Here we review specific reactions identified as needing further study in a low-background environment, and outline suitable facilities to carry out such studies.

→ in 2000: LUNA-400kV was installed
→ talk by G. Imbriani (Wednesday)

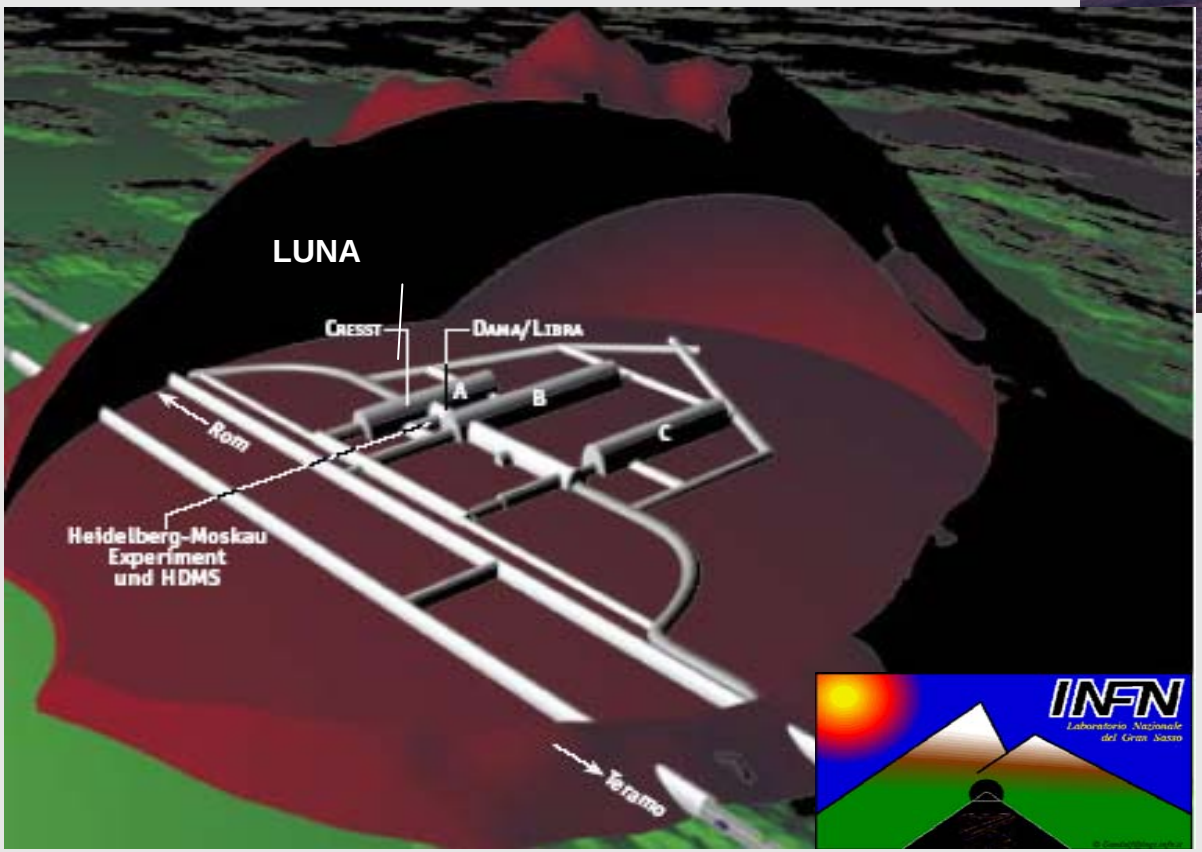
in April 2007: a Letter of Intent was presented to the LNGS Scientific Committee about key reactions in He burning and the s-process neutron sources: $^{12}C(\alpha,\gamma)^{16}O$, $^{13}C(\alpha,n)^{16}O$, and $^{22}Ne(\alpha,n)^{25}Mg$ as well as (α,γ) reactions on $^{14,15}N$ and ^{18}O

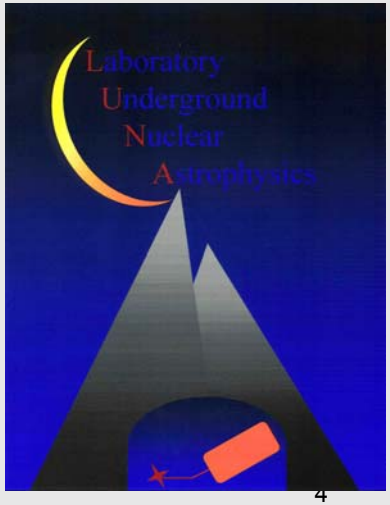
→ 3.5 MV single ended positive ion accelerator

→ … 2013 … something moved forward (finally)

LUNA-MV

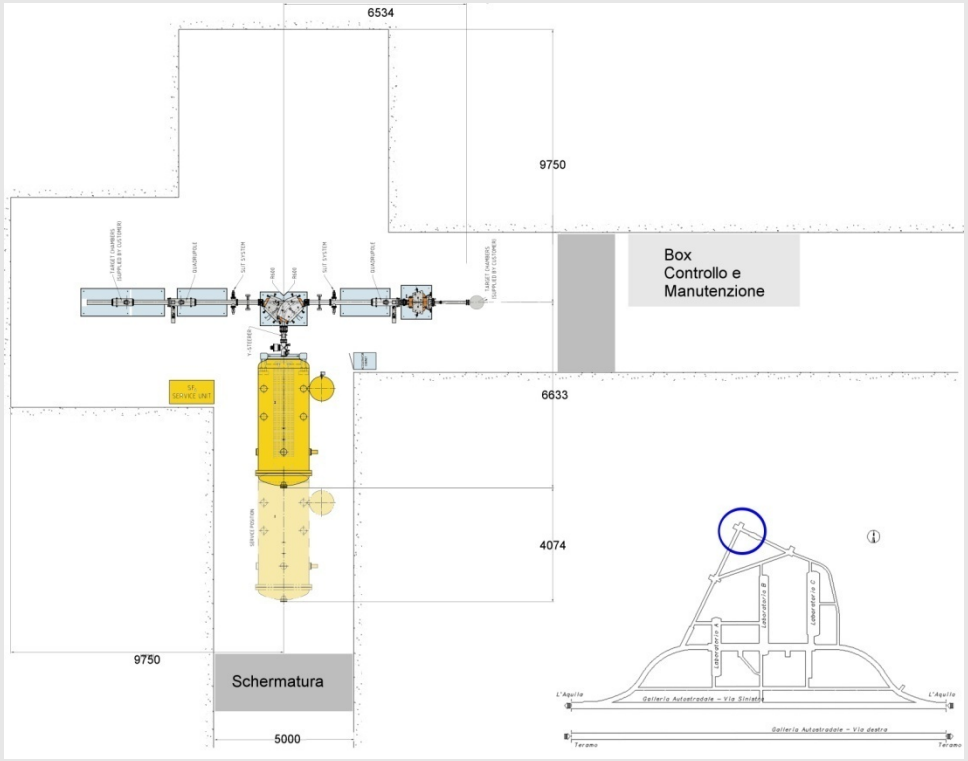
A suitable place inside LNGS has been found (Node B), far away from other experiments. A real feasibility study started!





LUNA-MV

A real feasibility study started!



LUNA-MV

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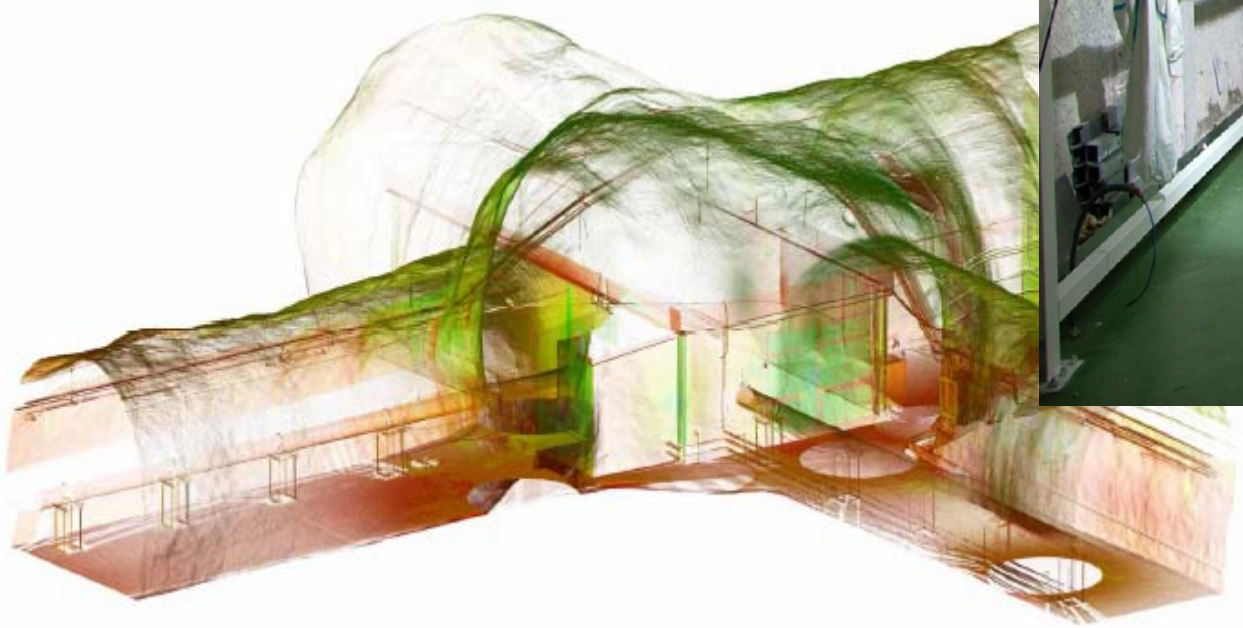
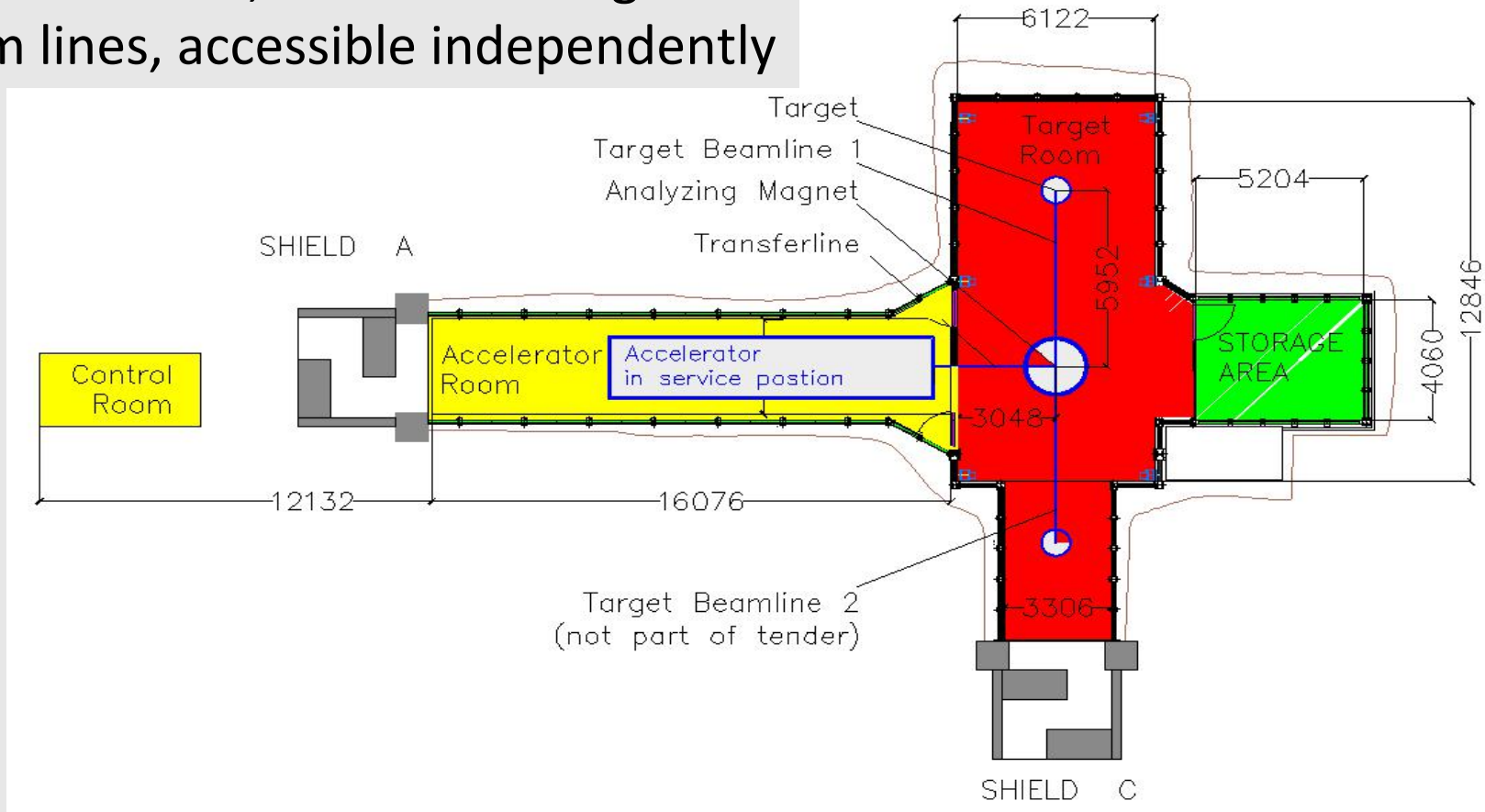


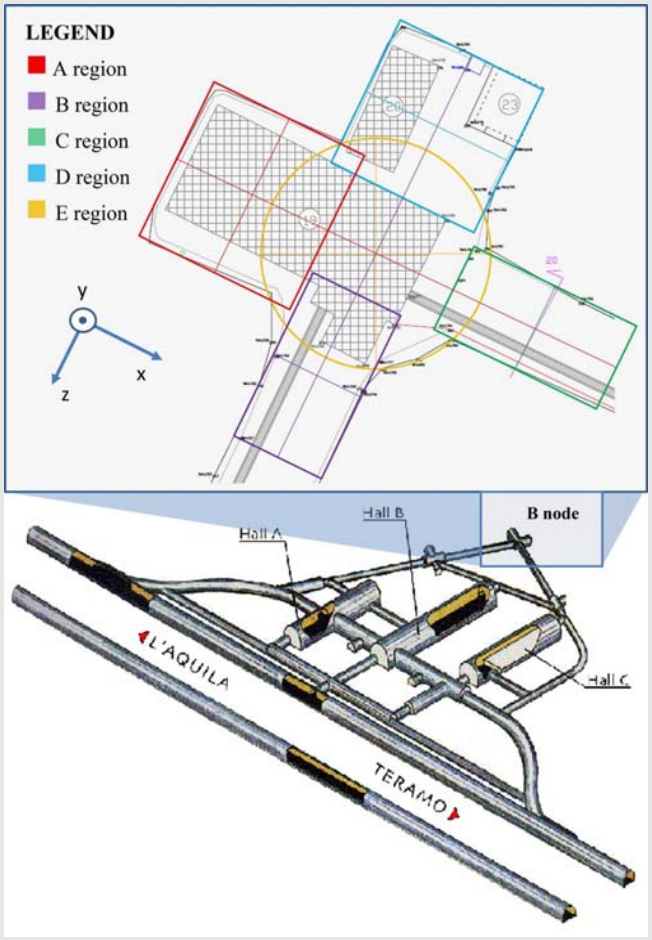
LUNA-MV

Single ended accelerator:

- with Ion source for H and He beams → high intensity α beams
- robust, commercially available
- reliable time line, reliable costing
- 2 beam lines, accessible independently

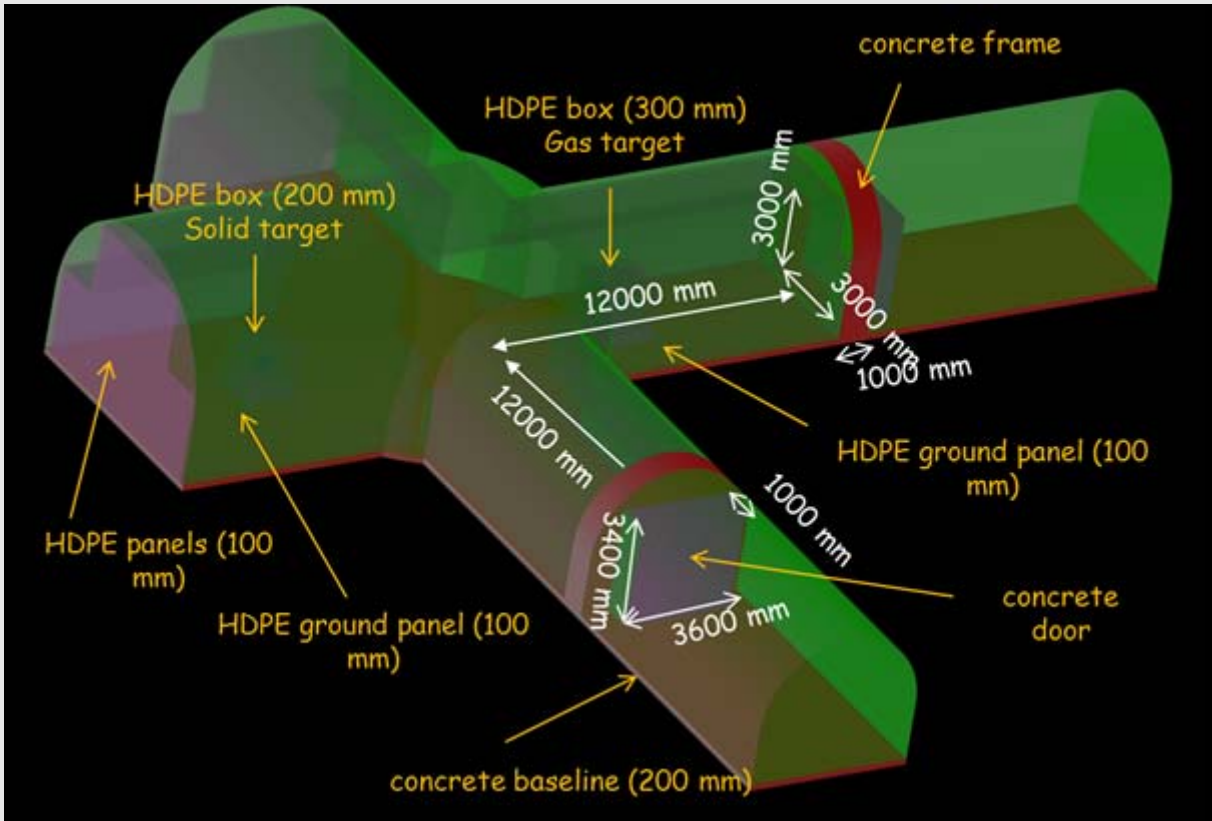


LUNA-MV



LNGS is a low background laboratory: a shielding solution has been developed and validated by Monte Carlo simulations

Just-outside the wall the n-flux is less than 1% of the LNGS natural flux!



LUNA-MV

Constrains for neutron background

Natural Neutron flux in LNGS: appr. 1 - 2×10^{-6} cm^{-2} s^{-1}

→ LUNA MV has been asked to verify compatibility with existing experiments

→ Maximum neutron rate acceptable at LUNA-MV: 2000 n/s

→ Maximum neutron energy: 5.6 MeV

LUNA has presented a shielding concept which allows to respect these constraints

The concept is approved by LNGS.

Constraints due to drinking water abstraction

LUNA MV location is close to springs used for drinkable water

→ special requirements to assure preservation of water quality

LNGS technical division has engineered a project to protect springs

LUNA-MV Workshop and status

60 participants mainly from Europe but also Asia and USA

- Status of LUNA MV
- Physics cases with round table on specific technical aspects
- Discussion on the collaboration structure

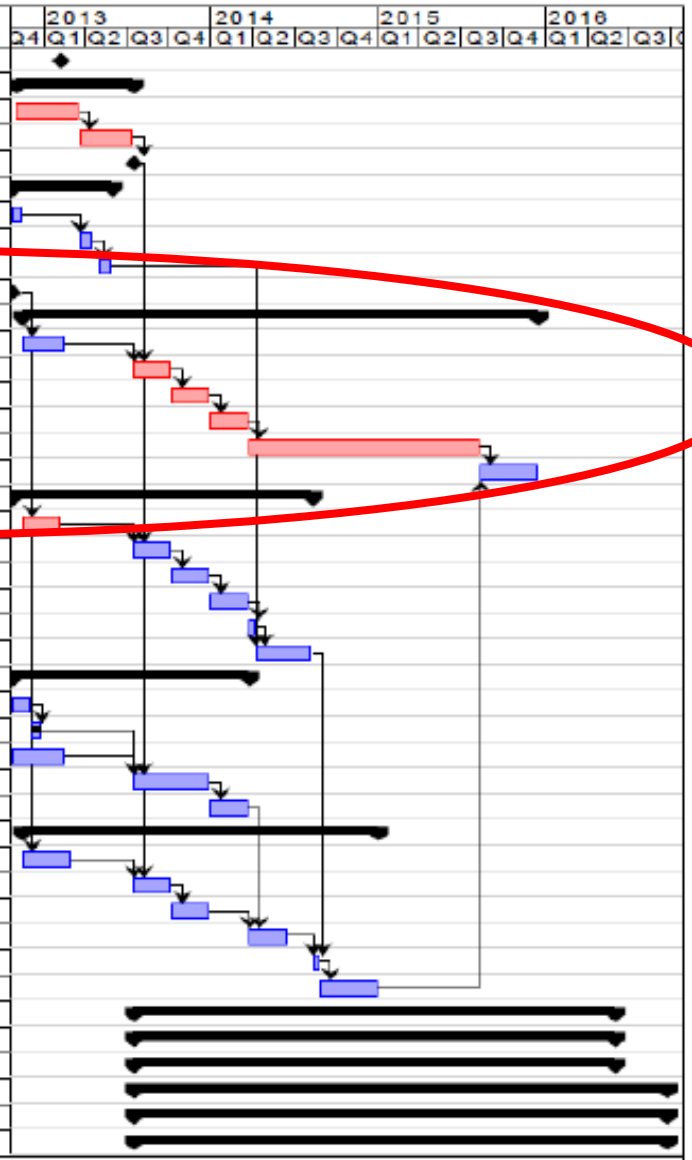
- Request for adhesions

"*adhesion should be intended as the willingness of the involved group to apply soon to the financing agency of the respective country....*"

process is still open, please contact:
alessandra.guglielmetti@mi.infn.it

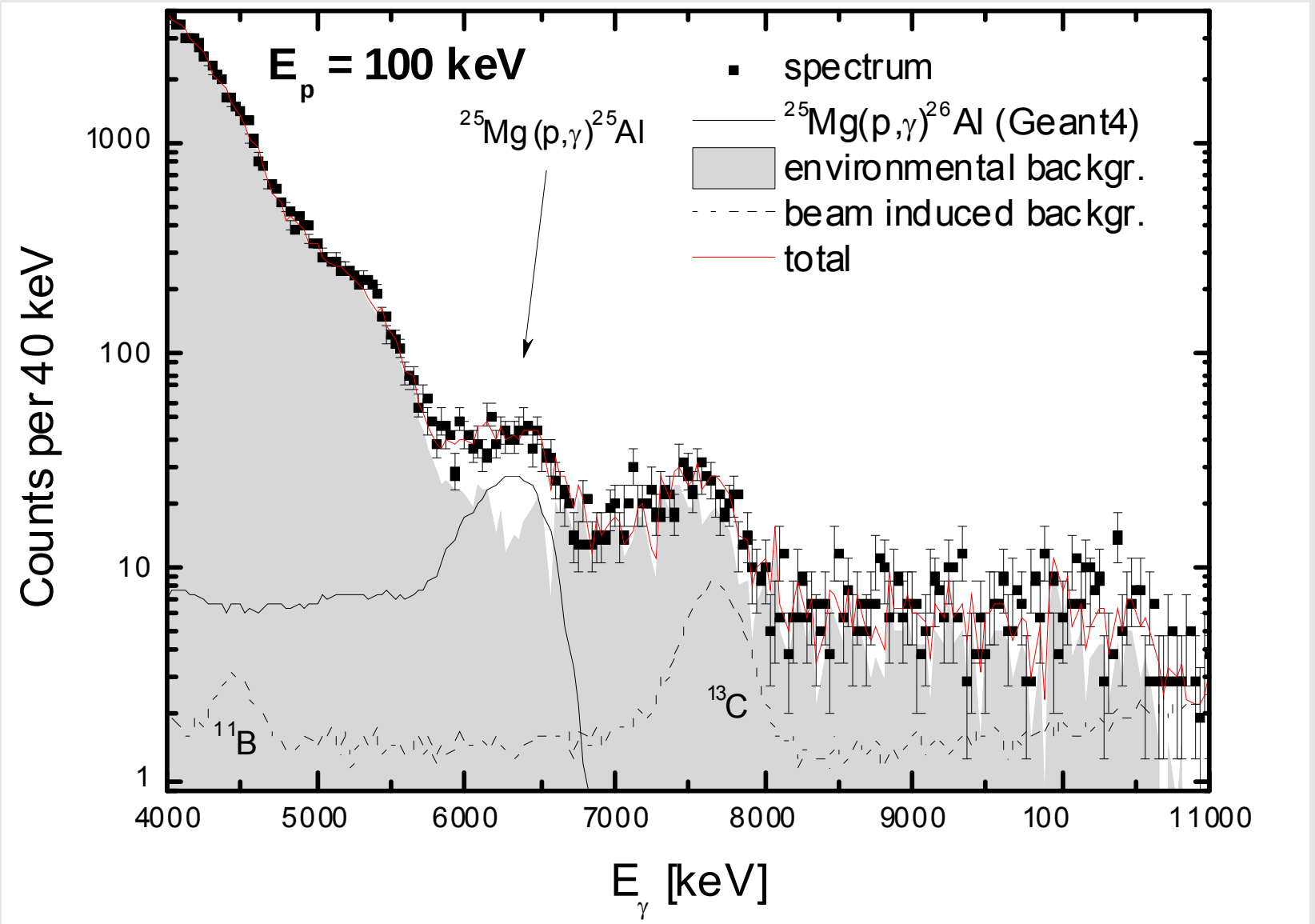
LUNA-MV Workshop and status

	Name
1	Workshop LUNA-MV
2	**Advisory opinion of Italian Health Institution (ISS)**
3	Preparation of documentation
4	Response time of ISS
5	Advisory opinion of Italian Health Institution (ISS) available
6	**Removal of Interferometer**
7	Evaluation of costs and possible returns
8	Oder to company for removal operations
9	Removal operations
10	Definition of the accelerator room dimensions
11	**Accelerator**
12	Preparation of technical requirements
13	Preparation of tender in INFN Administration
14	Call for offers
15	Assignment of tender and conclusion of contract
16	Accelerator production at supplier
17	Installation
18	**Site preparation inside LNGS undergrounds laboratories**
19	Preparation of detailed project
20	Preparation of tender in INFN Administration
21	Call for offers
22	Assignment of tender and conclusion of contract
23	Setup of construction site
24	On site construction
25	**Neutron Shielding**
26	Simulation of different solutions for accessing shielded area
27	Simulation of solution for ventilation
28	Simulation of solution for infrastructure
29	Procurement of HDPE (LI)
30	Installation of HDPE (Li)
31	**Auxiliary Plants**
32	reparation of detailed project
33	Preparation of tender in INFN Administration
34	Call for offers
35	Assignment of tender and conclusion of contract
36	Setup of construction site
37	On site construction
38	**Construction of beam lines for gas or solid target station**
45	**Gas target station**
56	**Solid state target station**
63	**Gamma ray detection system**
71	**Neutron detector**
79	**Data aquisition system**

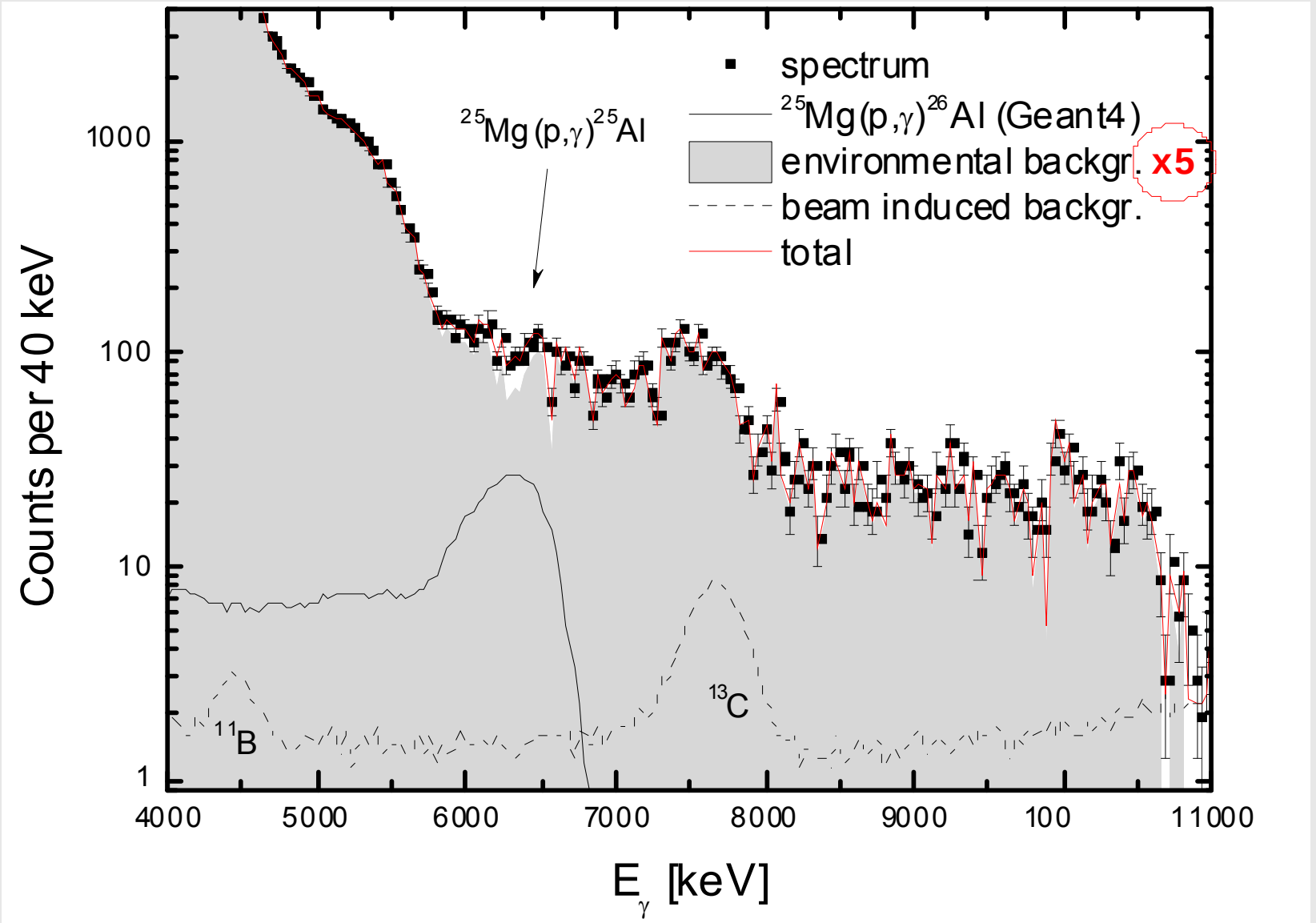


LUNA-MV

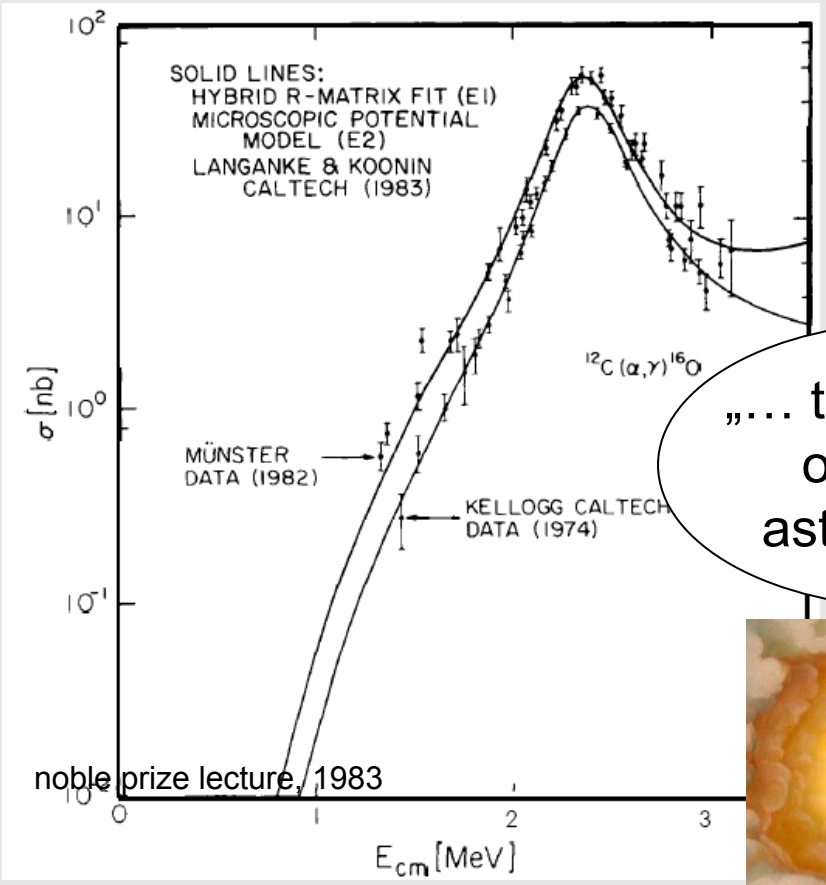
Motivation for Underground measurement



Motivation for Underground measurement



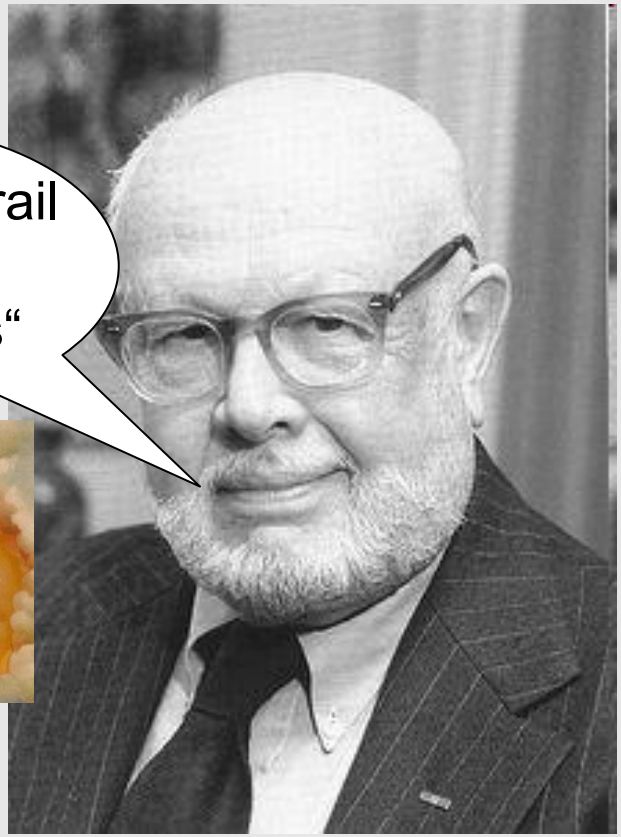
LUNA-MV Physics - $^{12}C(\alpha,\gamma)^{16}O$ almost 40 years



noble prize lecture, 1983

„… the holy grail of nuclear astrophysics“

William A. Fowler (1911 – 1995)



Nobel Prize for Physics (1983)
for „his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe“.
(shared with S. Chandrasekhar)

LUNA-MV Physics - $^{12}C(\alpha,\gamma)^{16}O$

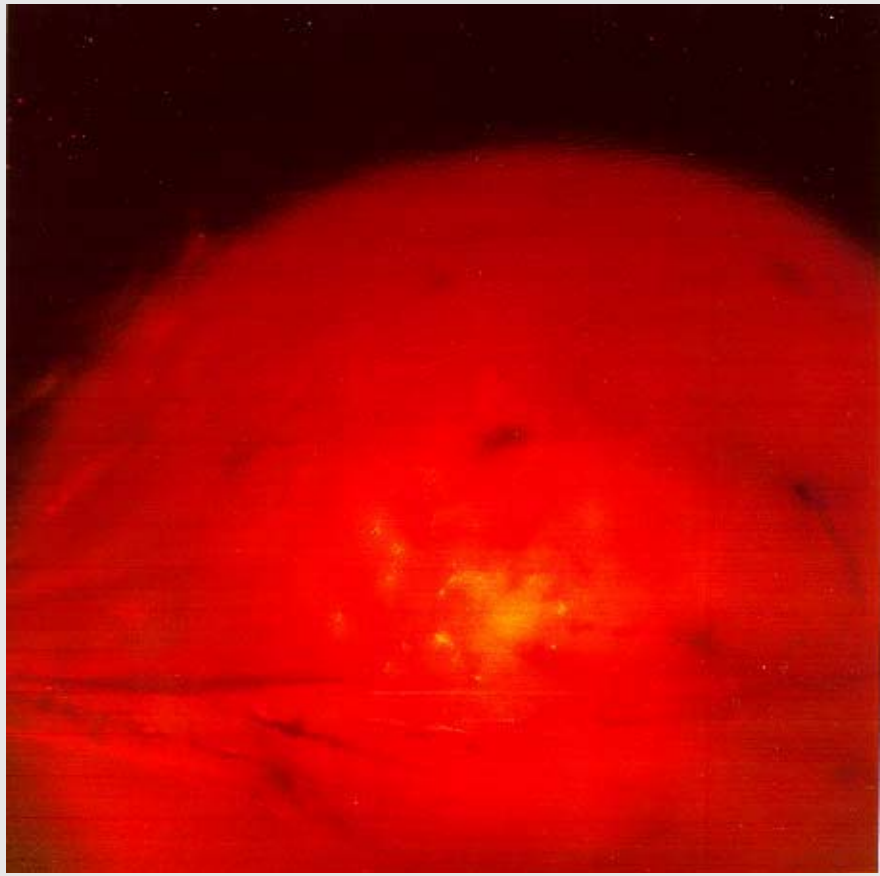
Stellar Helium burning in Red Giant Stars

the He burning is ignited on the ^{4}He und ^{14}N ashes of the preceding hydrogen burning phase (pp und CNO)

- **Carbon**
  we are made of !
- **Oxygen**
  which we breath !

Consequences

- late stellar evolution
- composition of C/O White dwarfs
- Supernova type I explosion
- Supernova type II nucleosynthesis



LUNA-MV Physics - $^{12}C(\alpha,\gamma)^{16}O$

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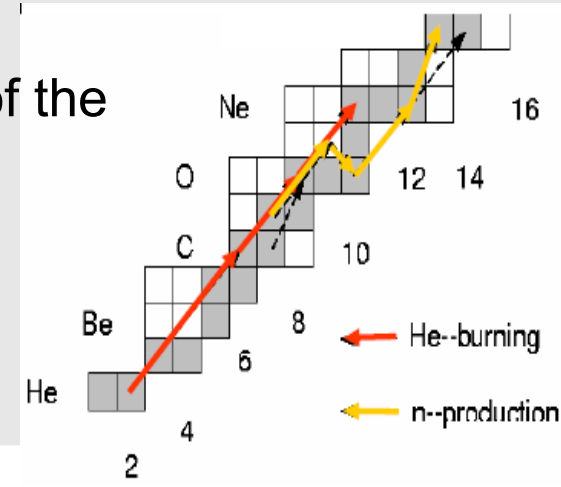


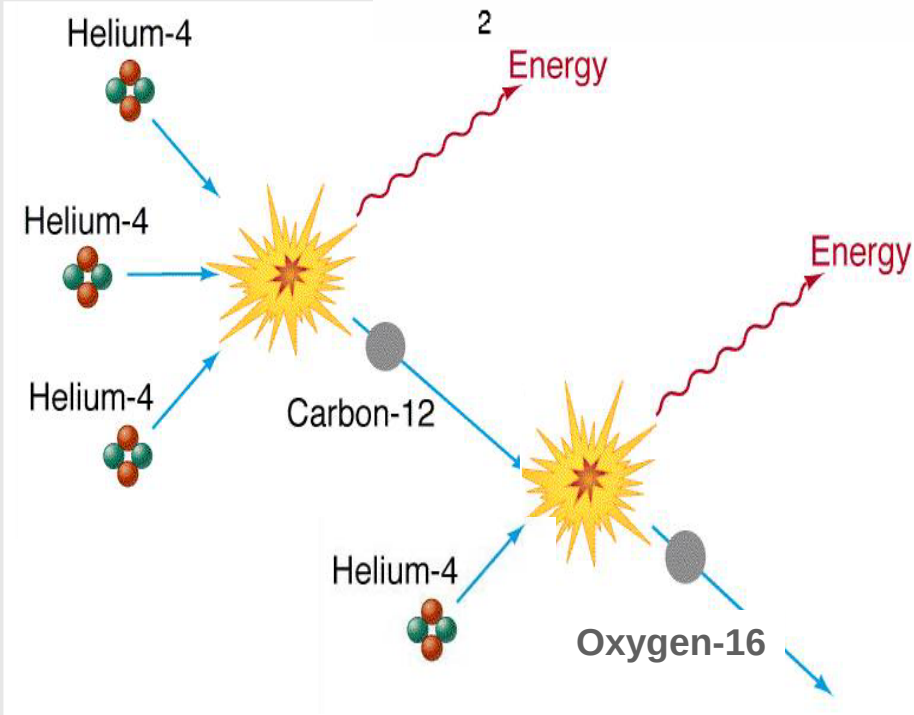
relevant questions:

Energy production and time scale of Helium burning:

$^{4}He(2\alpha,\gamma)^{12}C(\alpha,\gamma)^{16}O(\alpha,\gamma)^{20}Ne$

Neutron sources for s process:

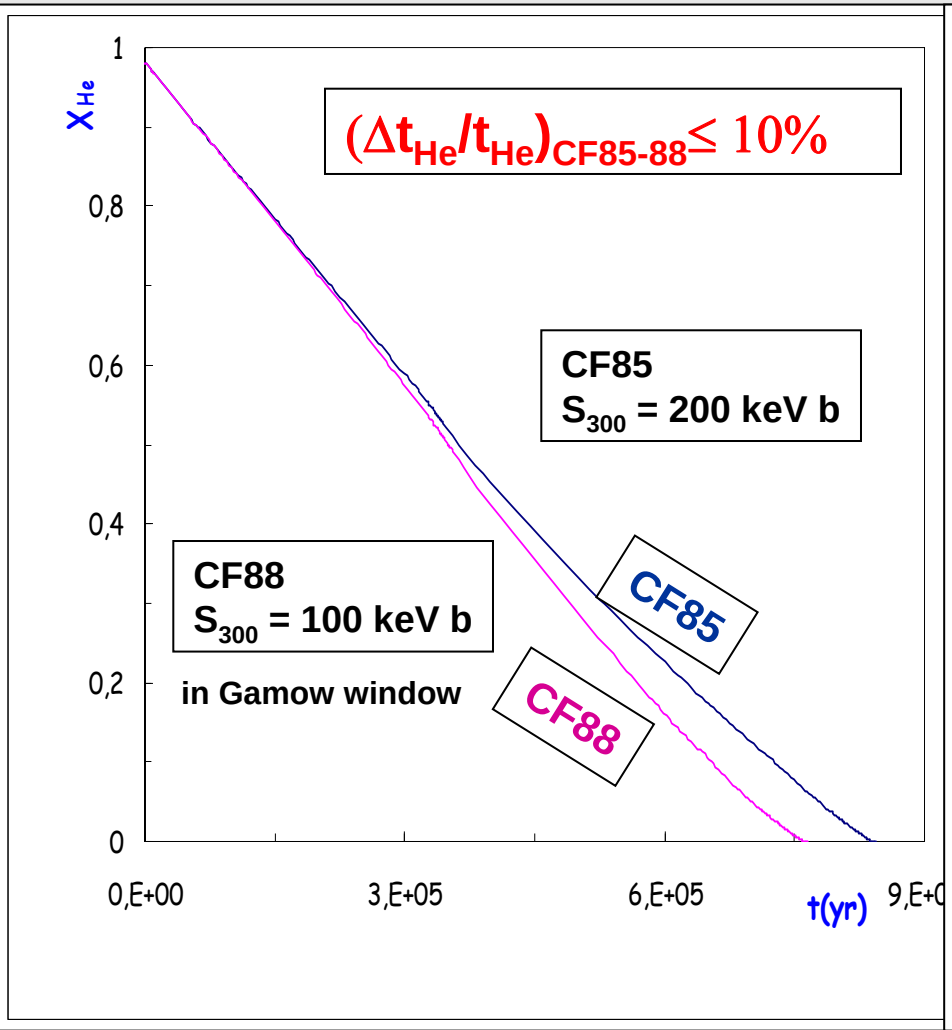
$^{14}N(\alpha,\gamma)^{18}F(\beta+\nu)^{18}O(\alpha,\gamma)^{22}Ne(\alpha,n)$
$^{22}Ne(\alpha,\gamma)$

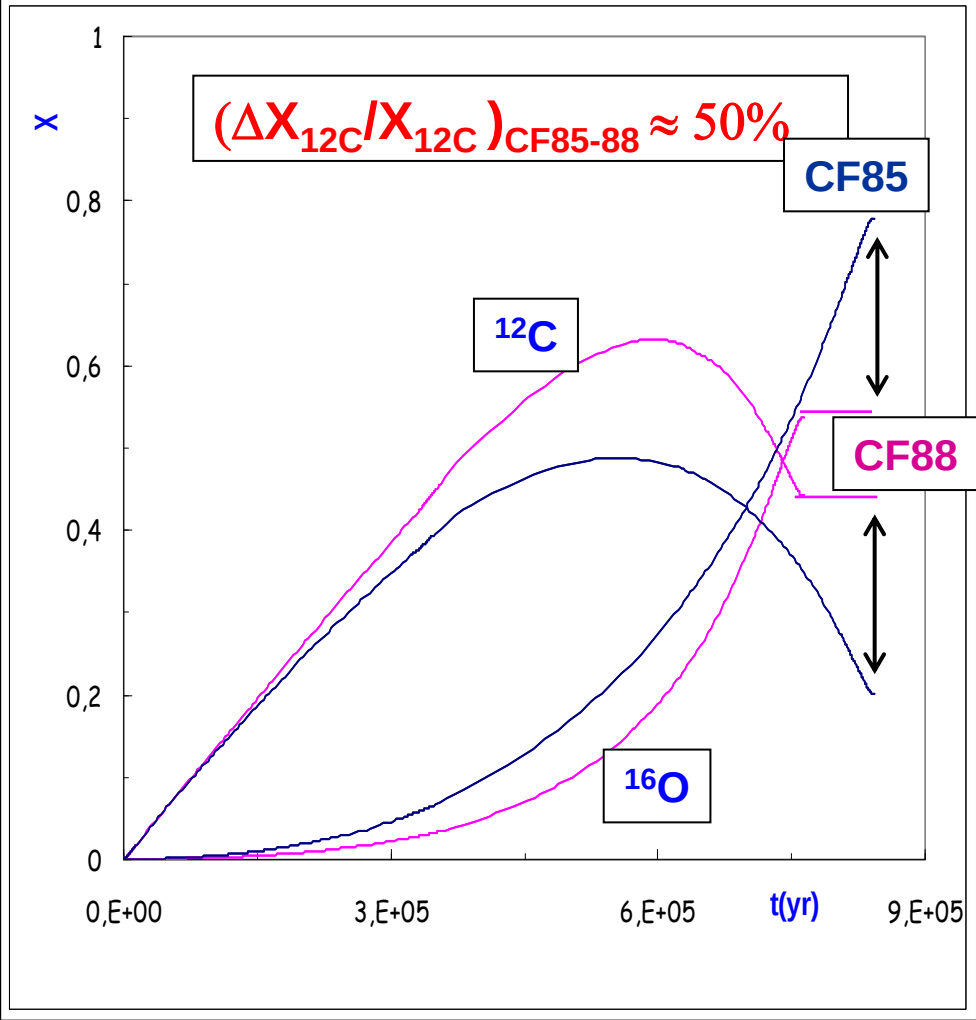


$^{12}C/^{16}O$ ratio at the end of Helium burning

example: Stellar model for a 20 M_{solar} Stern
S factor(CF85) = 2 × S factor(CF88)

G. Imbriani et al., ApJ 558 (2001) 903 & O. Straniero private communication





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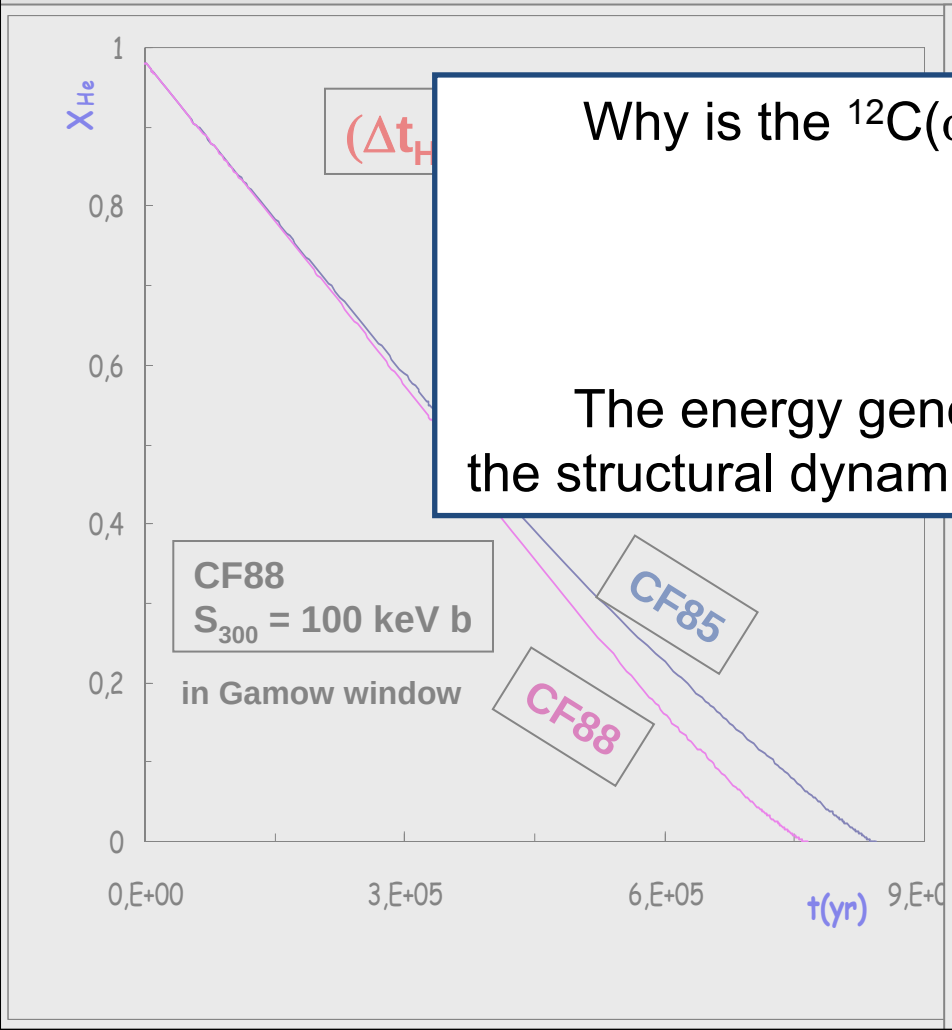
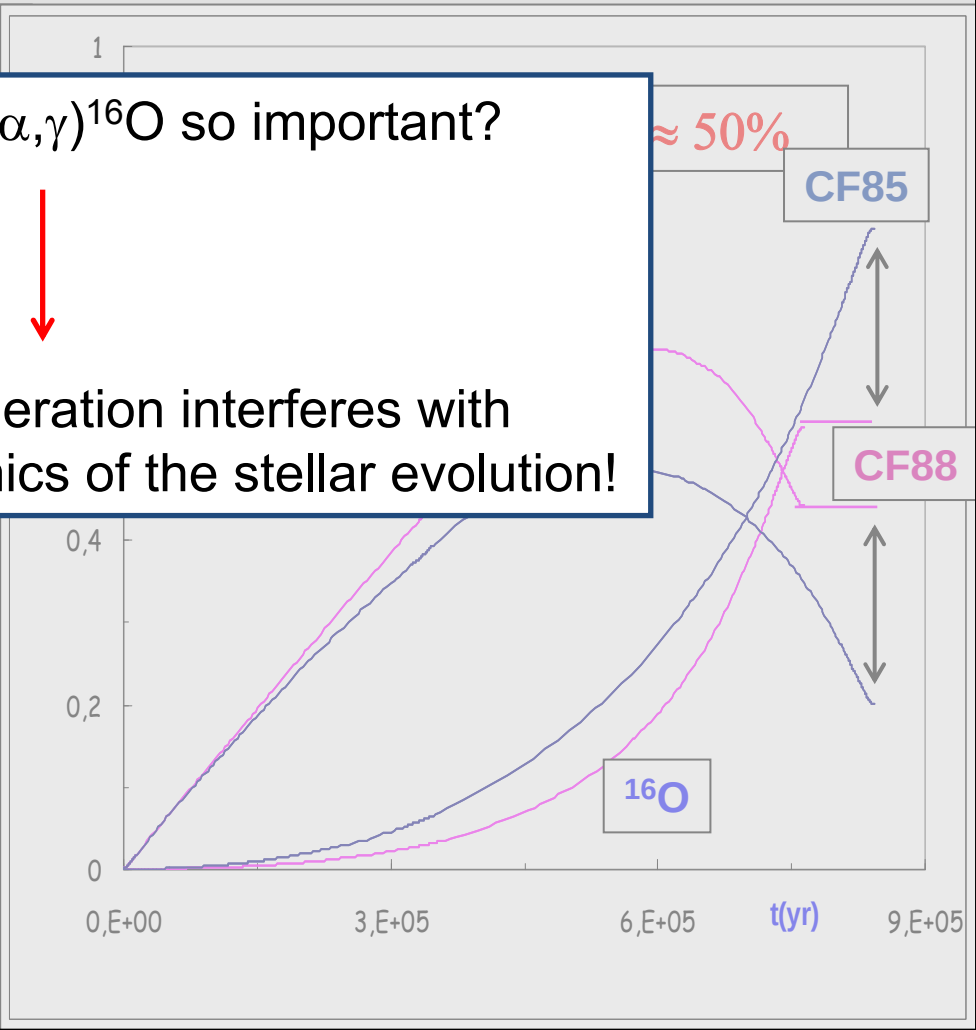


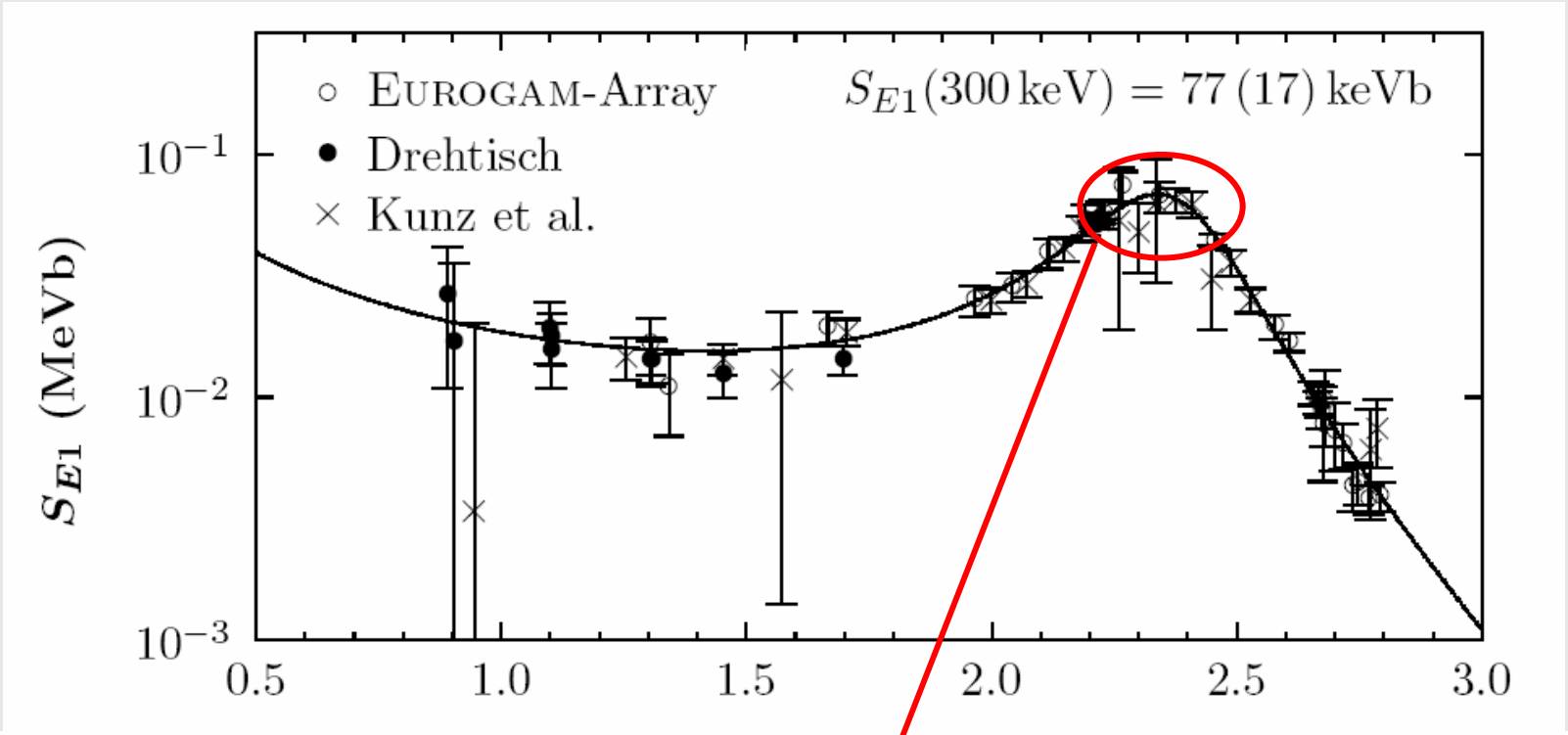
Why is the $^{12}C(\alpha,\gamma)^{16}O$ so important?

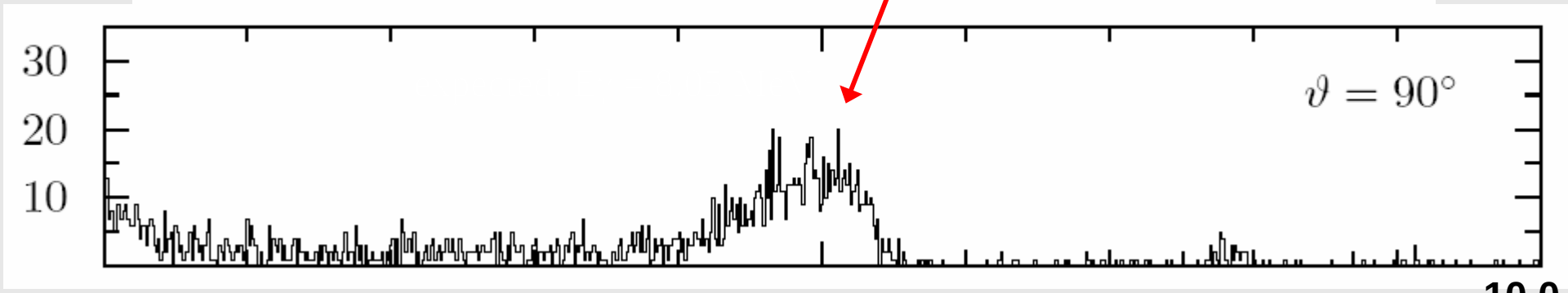
↓

The energy generation interferes with the structural dynamics of the stellar evolution!



Direct Methods – γ-ray Experiments





M. Fey, Stuttgart, Ph.D. thesis

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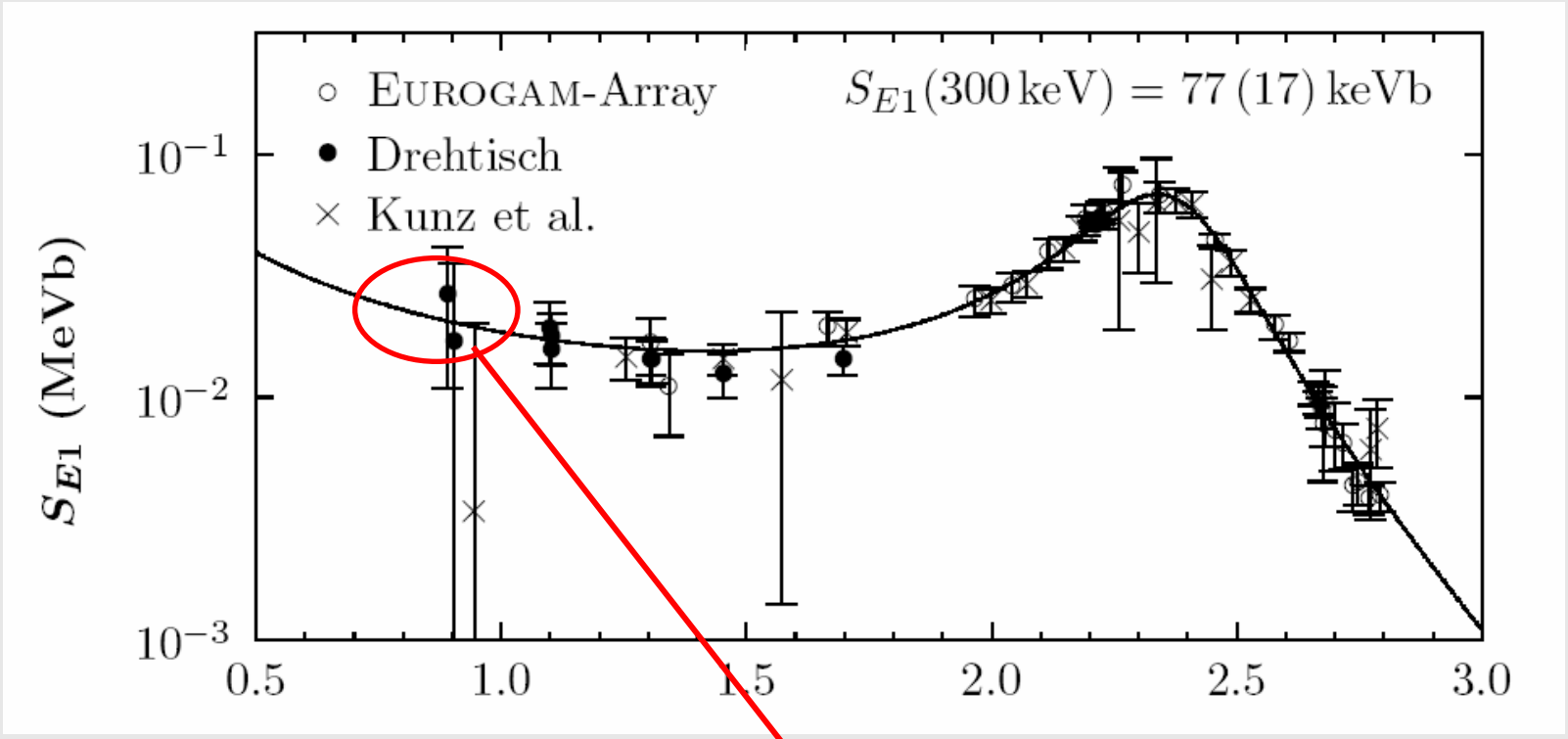
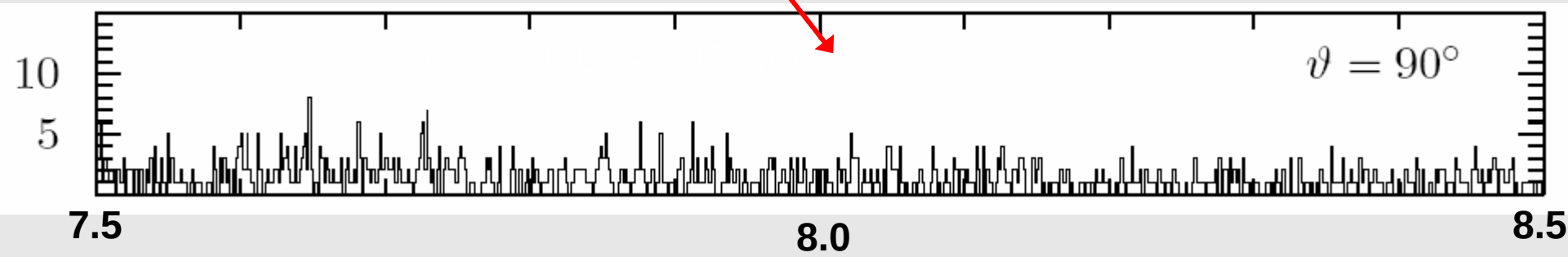


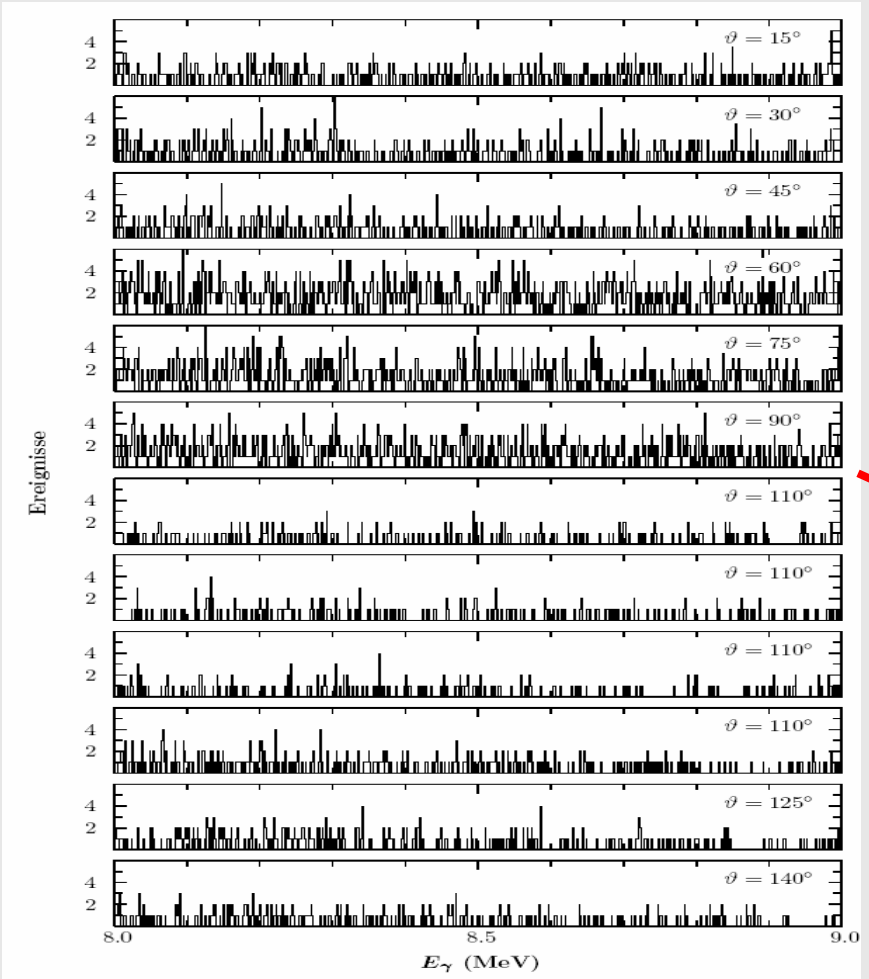


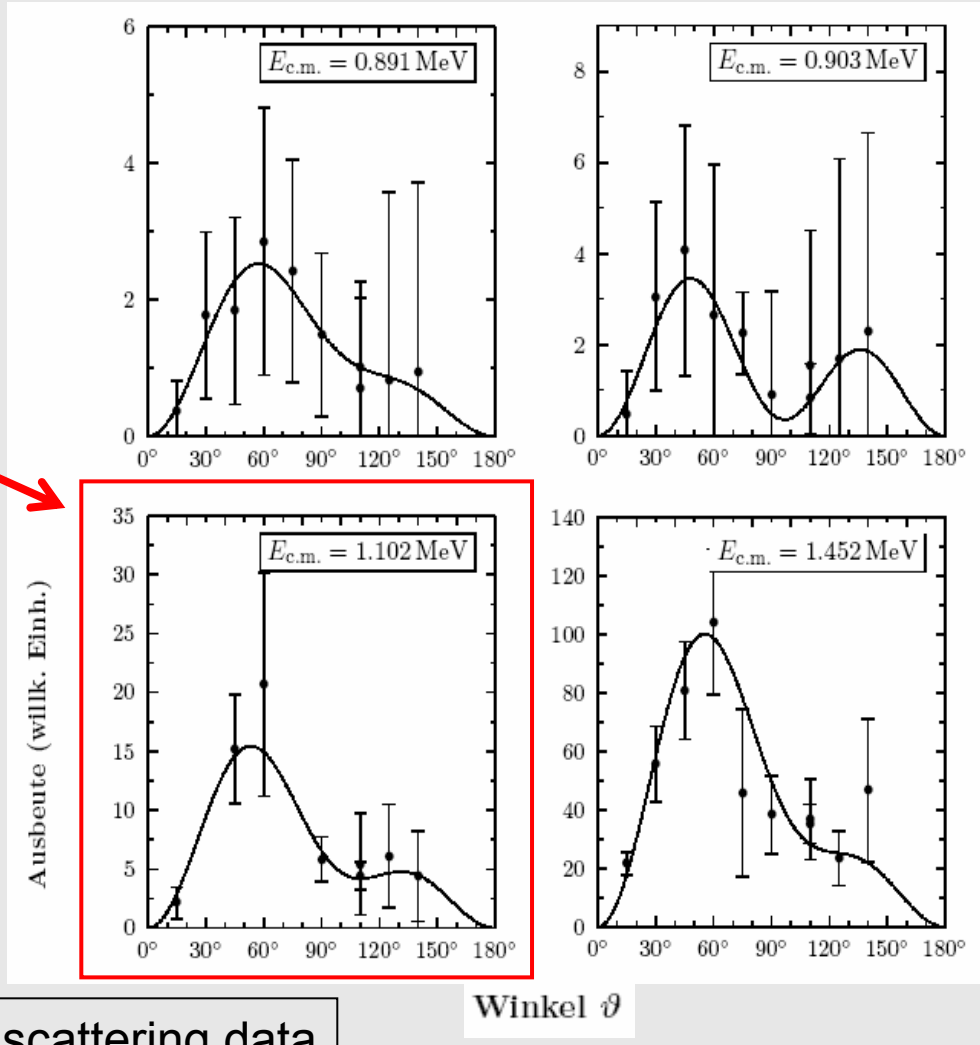
E_γ [MeV]

M. Fey, Stuttgart, Ph.D. thesis

Direct Methods – γ-ray Experiments

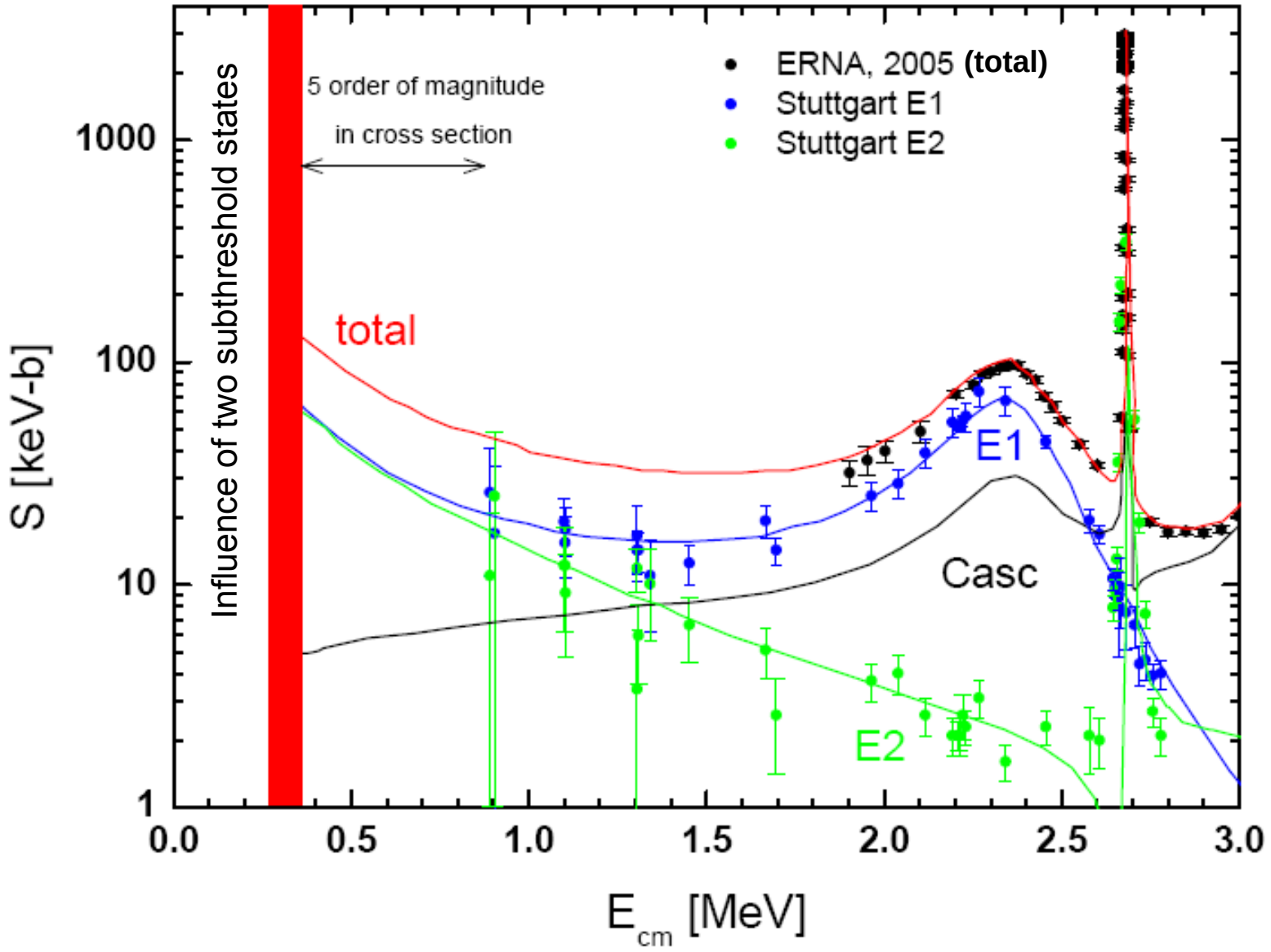
Measurements at low energies are very difficult !!



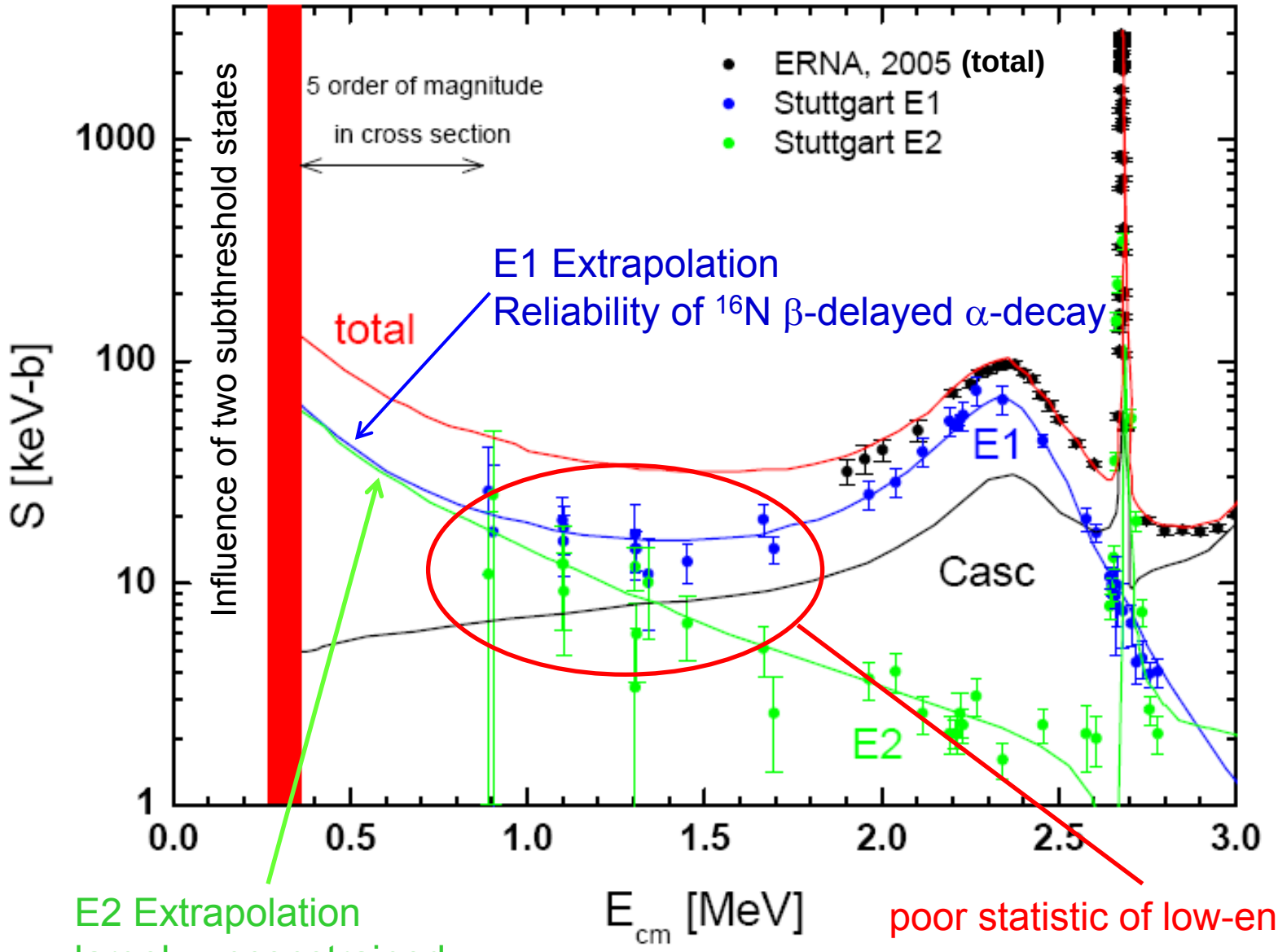


Phaseshift fixed through elastic scattering data

$^{12}C(\alpha,\gamma)^{16}O$ – State of the Art



$^{12}C(\alpha,\gamma)^{16}O$ – Open Issues



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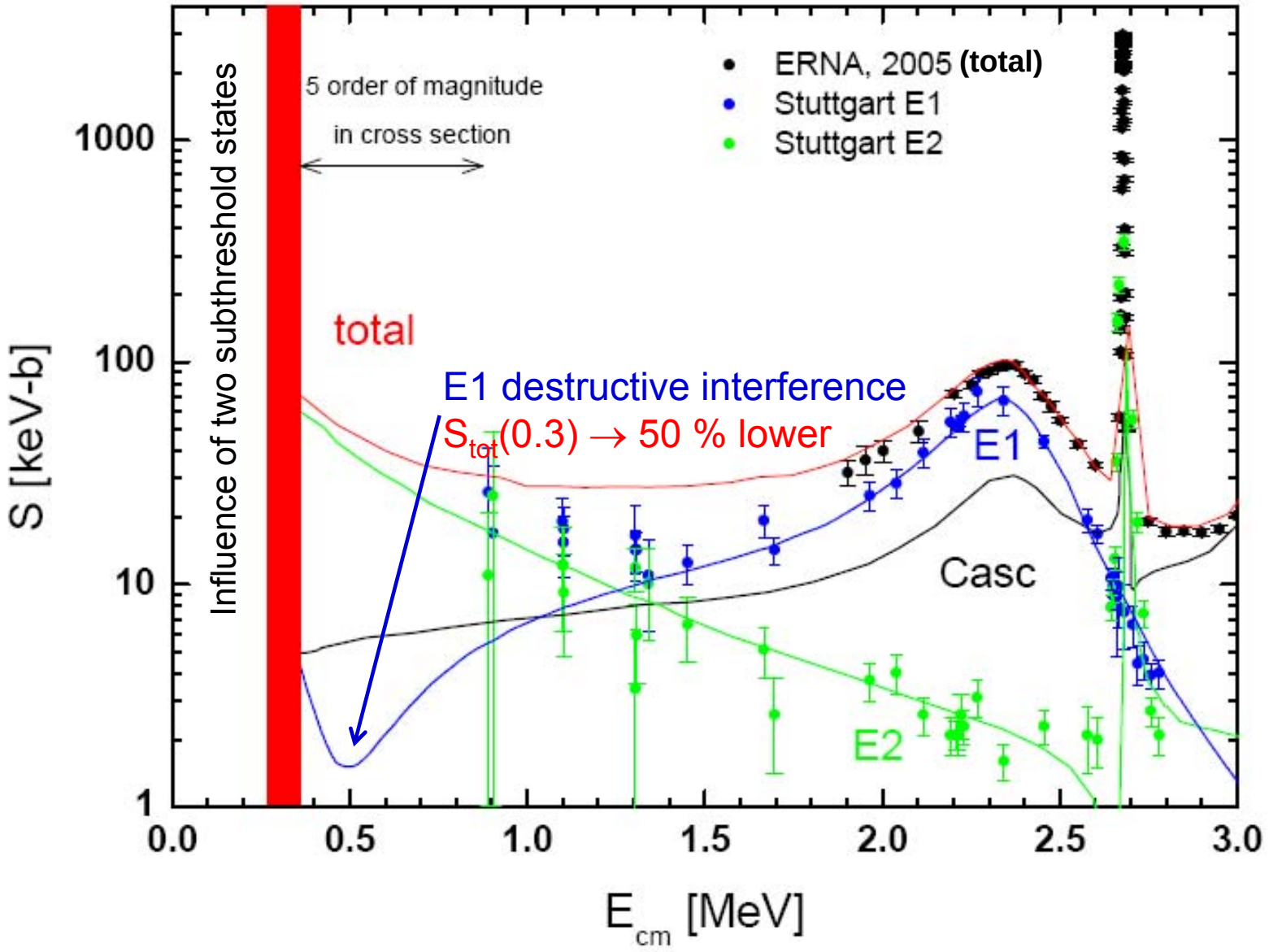


$^{12}C(\alpha,\gamma)^{16}O$ – towards LUNA-MV

Work in Progress:

a Working Group between LUNA and ERNA was established
→ ERLUNA Working Group

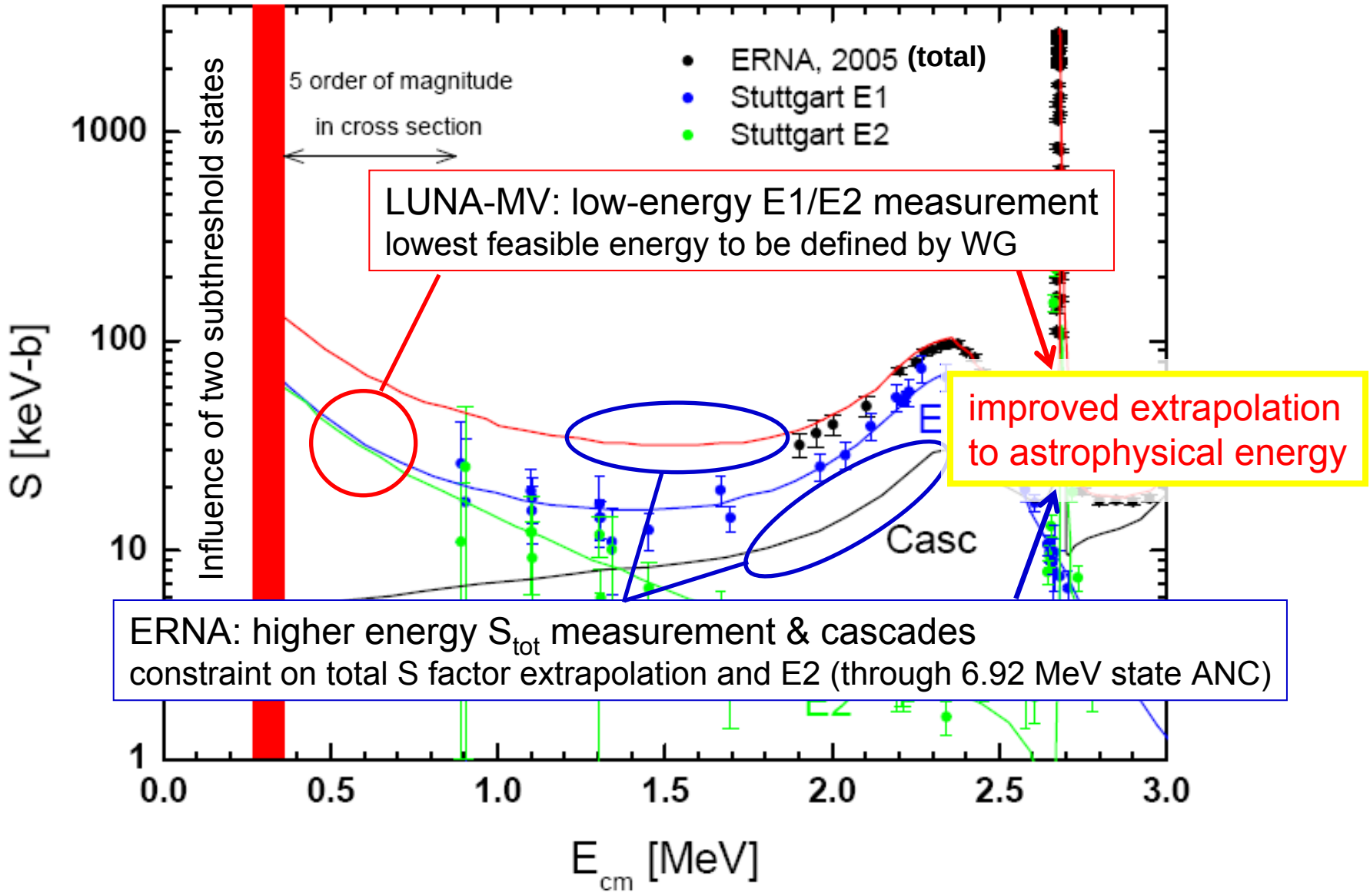
LUNA: direct kinematics - α beam, ^{12}C solid target, γ-ray detection
→ measure angular distribution with E1 and E2

ERNA: inverse kinematics - ^{12}C beam, ^{4}He gas target,
γ-ray detection & recoil mass separator
→ measure $S_{tot}(E)$ and cascade transitions

Objectives of Working Group:

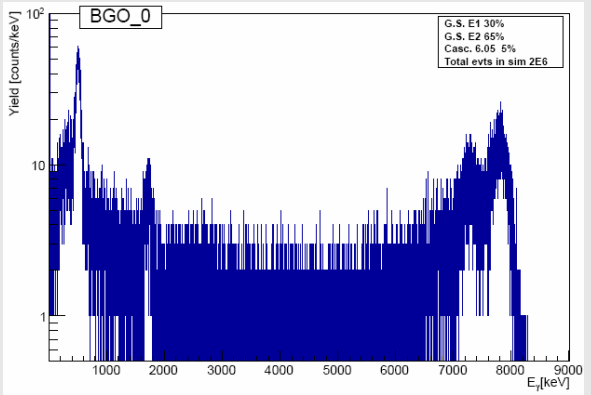
- determination of $S_{tot}(0.3)$ with sufficient precision for stellar models
- identify and exploit synergies between two different approaches
- coordinate efforts and strategy
- solve common experimental issues, e.g. γ-ray detection system
- develop improved techniques for target preparation/characterization

$^{12}C(\alpha,\gamma)^{16}O$ – Aims LUNA-MV/ERNA



$^{12}C(\alpha,\gamma)^{16}O$ – ERLUNA practical work

GEANT4 simulation of γ-ray array
example: GASP 4π BGO array

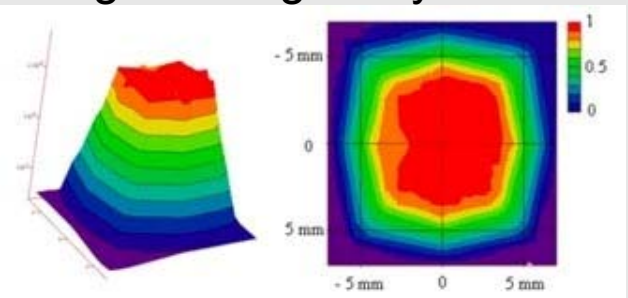


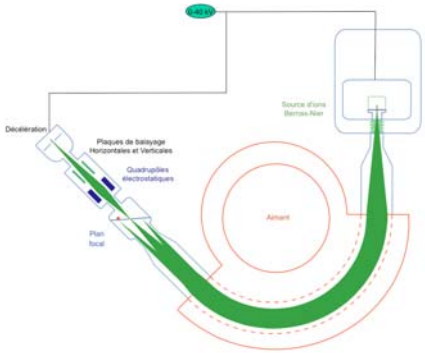
^{12}C target preparation at SIDONI (France)
contact established
preliminary studies in progress

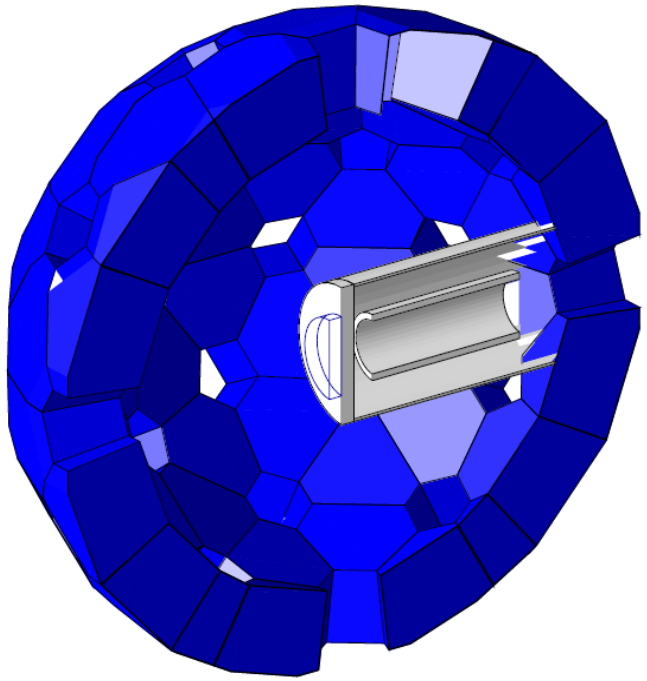
target characterization at LNL
test studies in progress

higher separation power

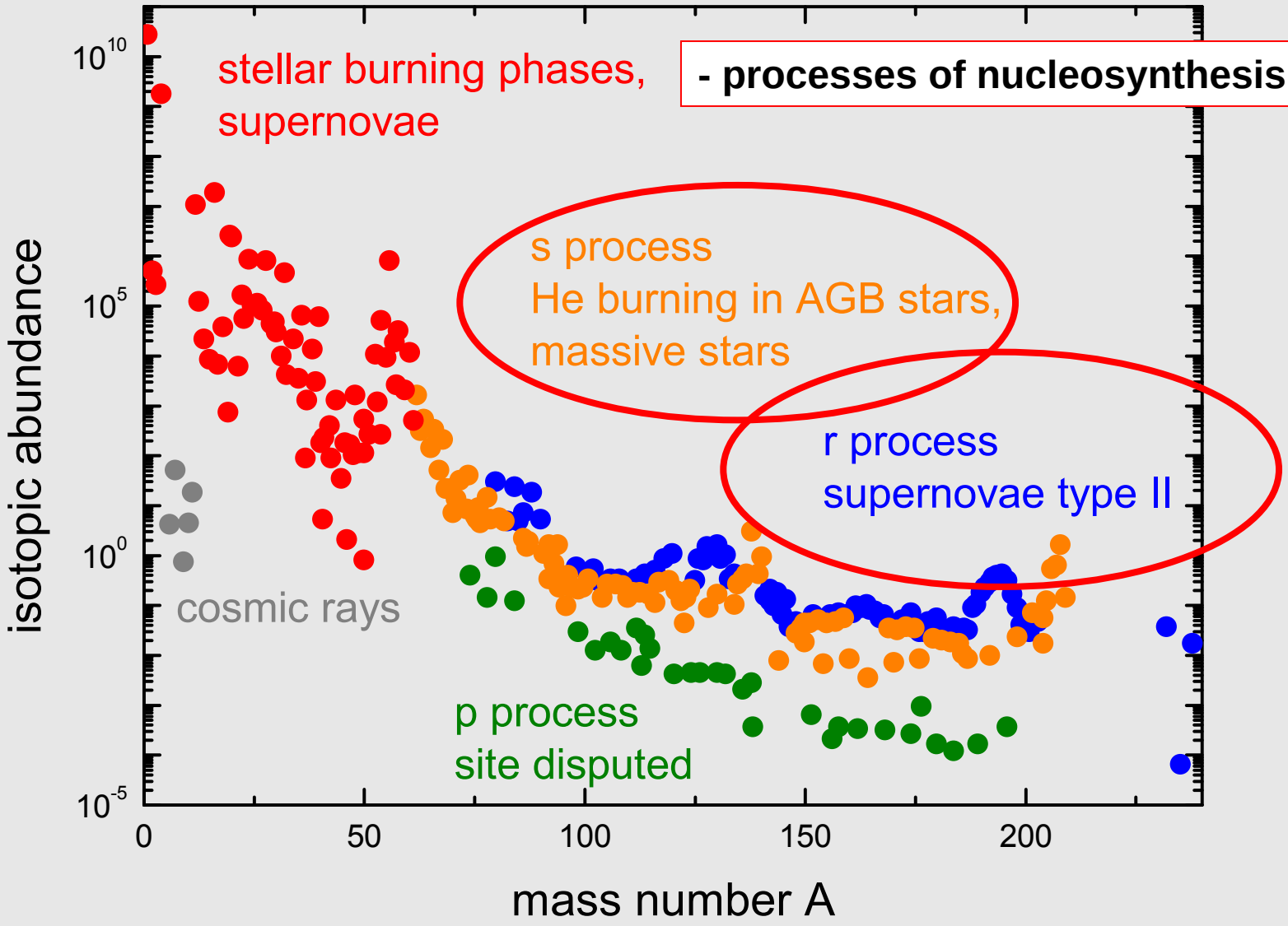
high homogeneity







LUNA-MV Physics - – Origin of the Elements



n source reactions: $^{13}C(\alpha,n)^{16}O$ and $^{22}Ne(\alpha,n)^{25}Mg$

Summary of Presentation

LUNA-MV – The next Underground Accelerator Facility

- The LUNA-MV project has been launched.
- Funding (through INFN, Italy) for accelerator and site preparation seems to be available
- Site preparation started (e.g. removal of the interferometer)
- $^{12}C(\alpha,\gamma)^{16}O$ – at low energies with sufficient statistical uncertainty will be one of the corner stones of the LUNA-MV project
- other reactions are: $^{3}He(\alpha,\gamma)^{7}Be$, $^{13}C(\alpha,n)^{16}O$, and $^{22}Ne(\alpha,n)^{25}Mg$