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Laboratory for Underground Nuclear Astrophysics

Matthias Junker

How to study stars underground

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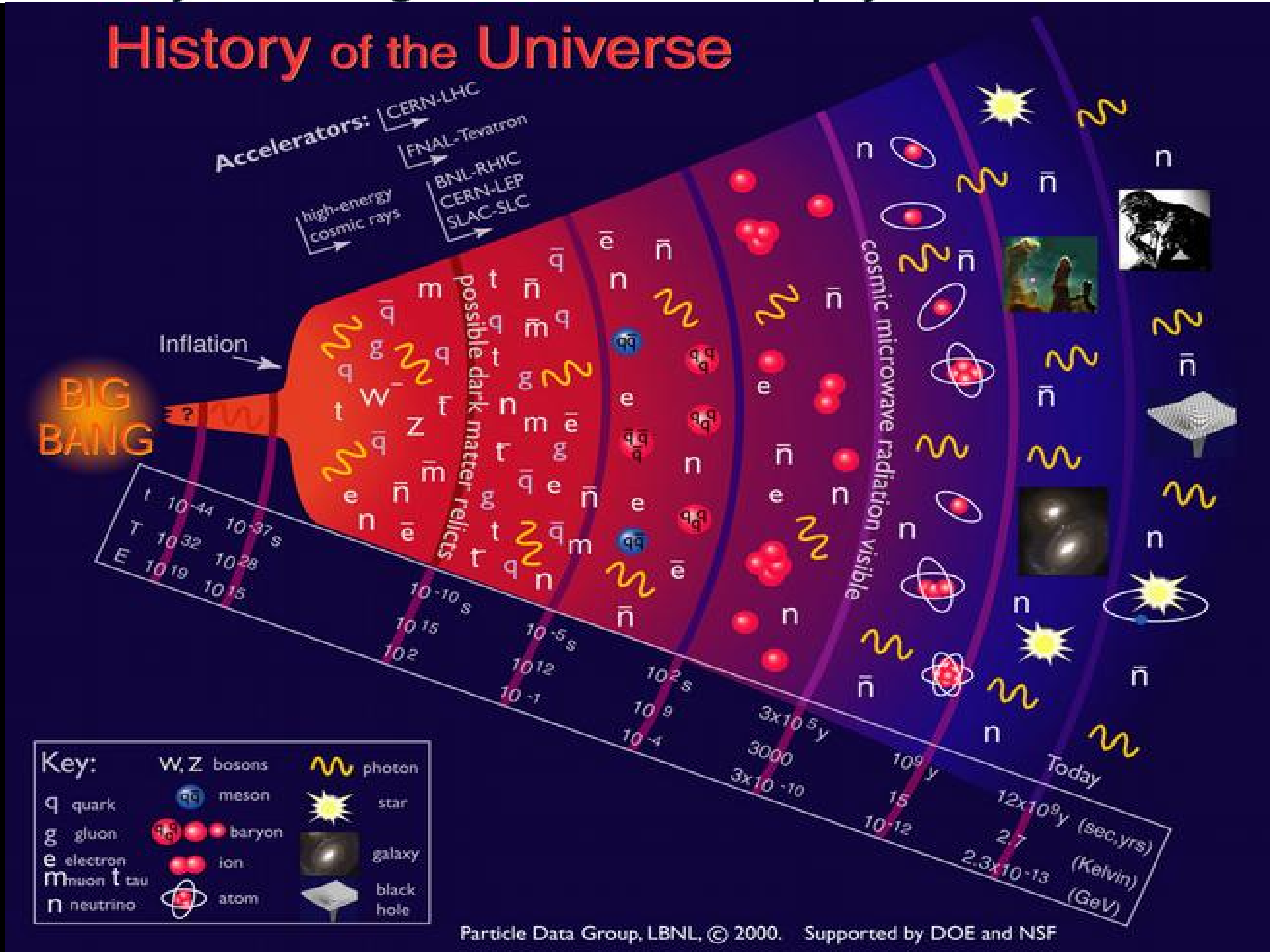
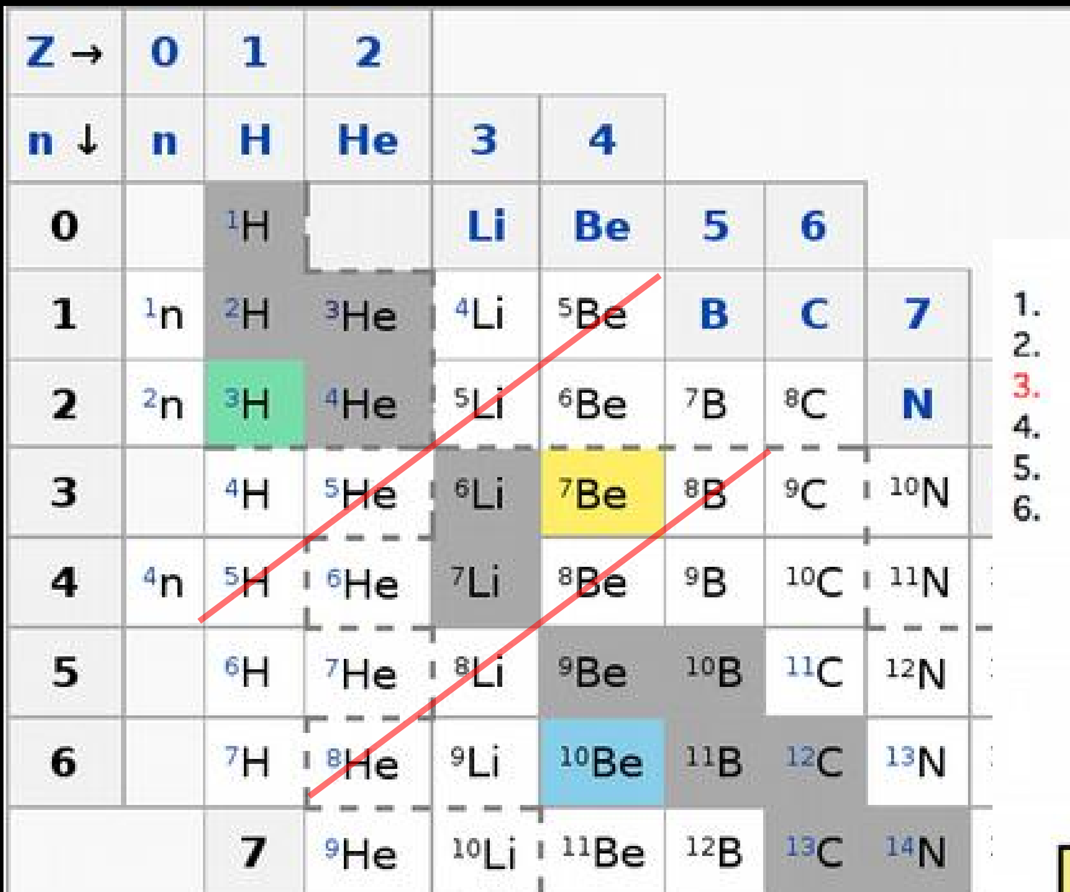
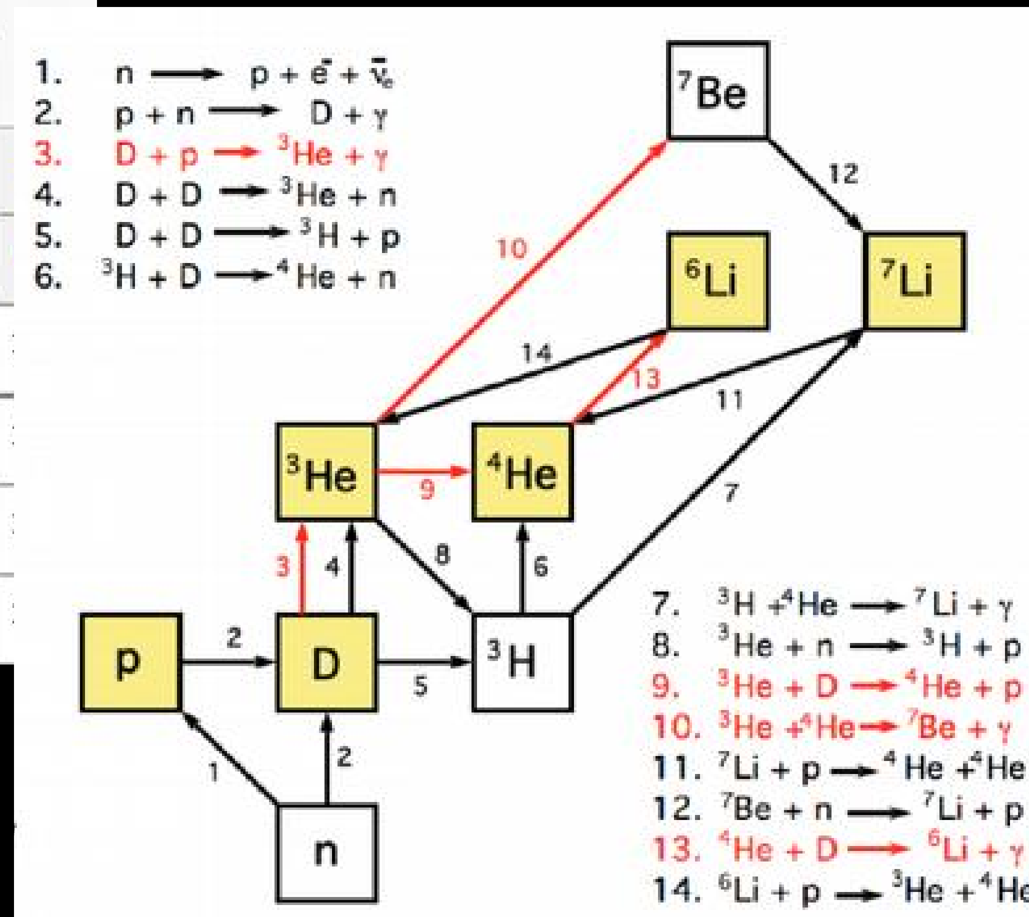


Big Bang Nucleosynthesis





The air we breath is O_2, N_2, CO_2, …

The water we drink is H_2O ….

The smart phone we use is Si, Ti, Ta, Ag, etc

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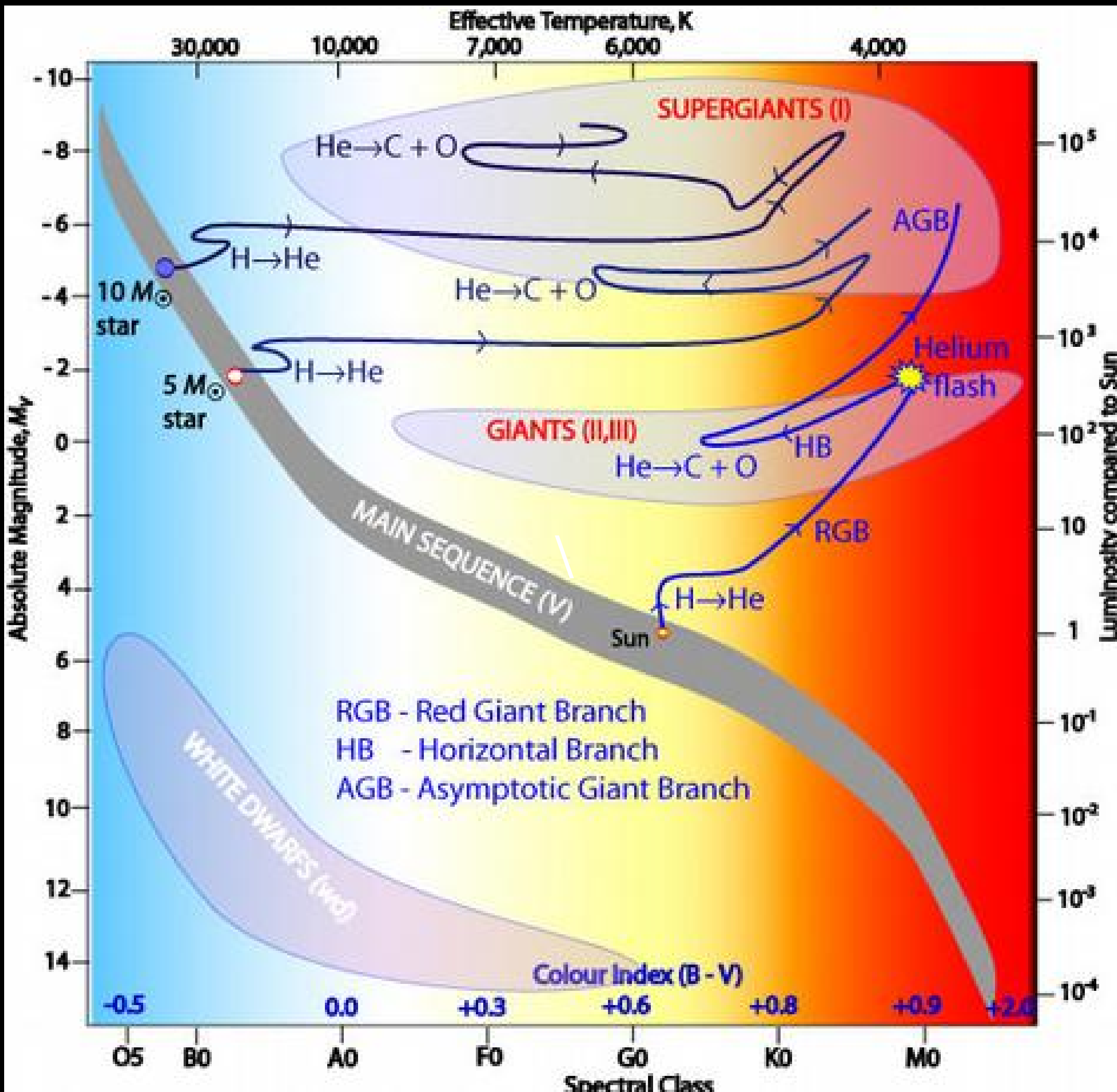
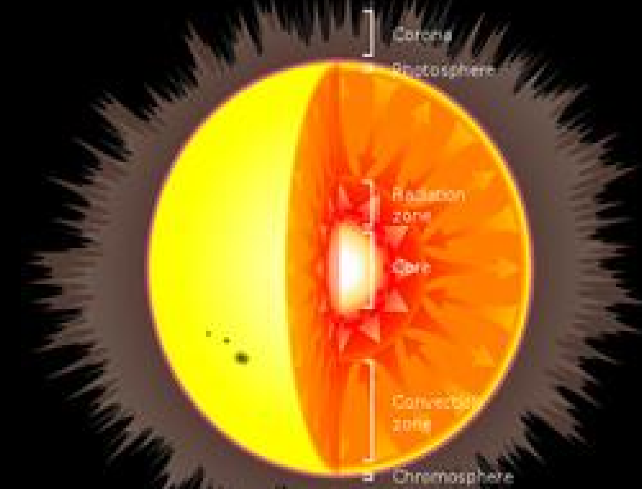
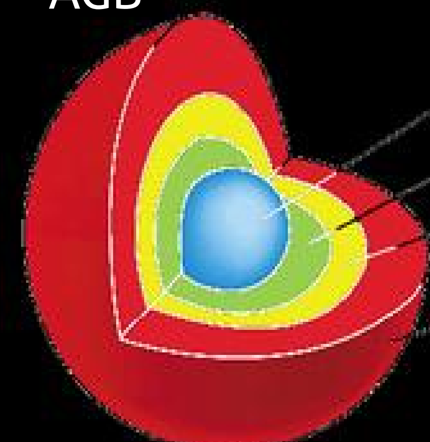




Main sequence star

AGB



Novae

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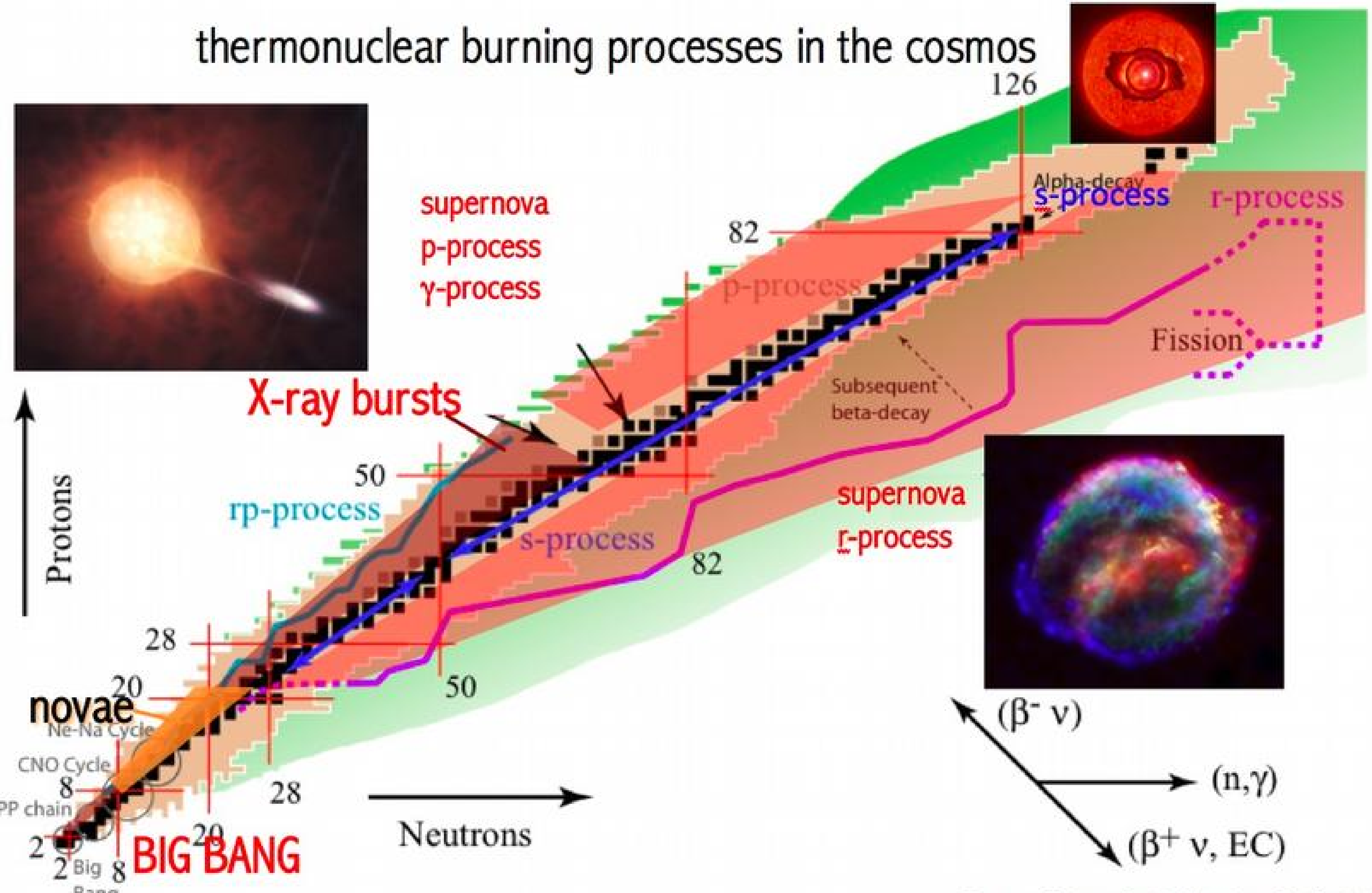
thermonuclear burning processes in the cosmos



Timmes, Schatz, Smith, Wiescher, Greife 2005

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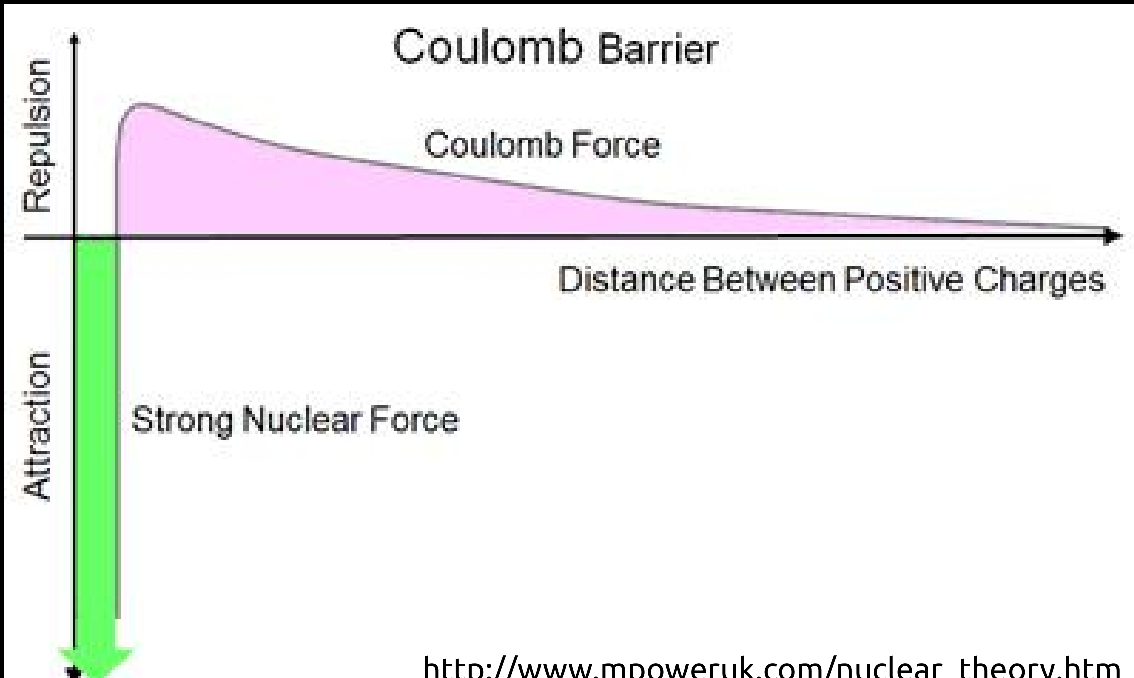
Nuclear Fusion Reactions



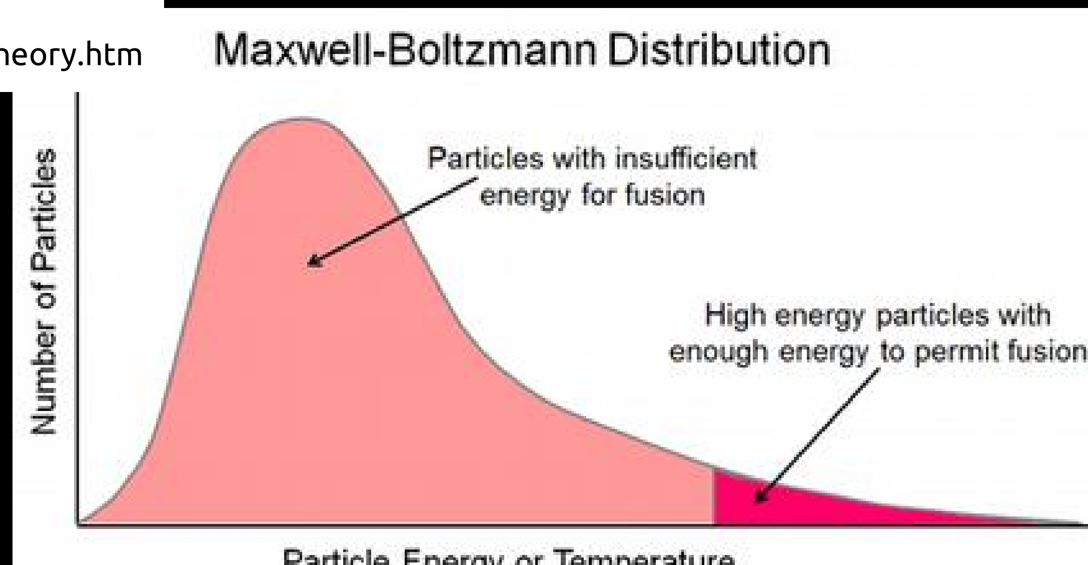
http://www.mpoweruk.com/nuclear_theory.htm

Coulomb Barrier values:

p + p	→	0,5 MeV
$^{3}He + {}^{3}He$	→	1,7 MeV
^{14}N + p	→	2,5 MeV
^{23}Na + p	→	3,4 MeV
$^{4}He + {}^{12}C$	→	4,6 MeV
$^{12}C + {}^{12}C$	→	9,4 MeV

Energy of maximum of distrib.

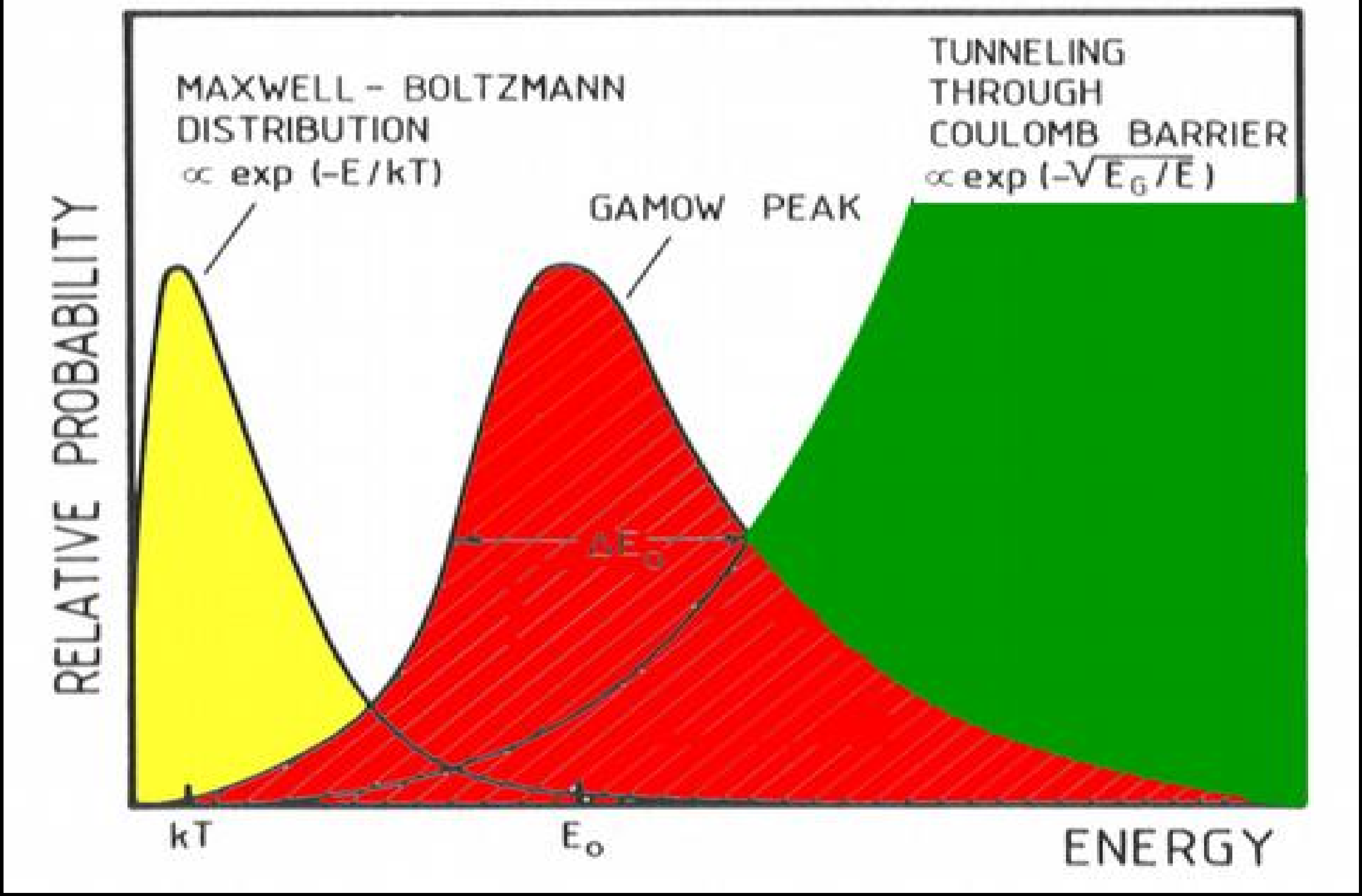
	T/GK	E/MeV
Sun	0,016	0,0014
AGB	0,300	0,026
Supernova	5	0,430



http://www.mpoweruk.com/nuclear_theory.htm

Stellar Fusion Reactions

	Gamow Energy [keV]	Astrophys Environment	Cross section [barn]	Lowest measured Energy
$^{3}He(^{3}He,2p)\,^{4}He$	21	Sun	$7\ 10^{-13}$	16,5
$^{3}He(a,g)^{7}Be$	22	Sun	$9\ 10^{-18}$	107
$^{14}N(p,g)^{15}O$	26	Sun	$4\ 10^{-21}$	200



Underground Nuclear Astrophysics at LNGS

A story 28 years lasting story of success

3.5 MV accelerator facility

Machine fully tested at producer's site
Technical infrastructure under construction
Authorizations asked

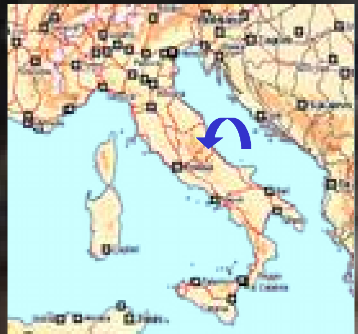
$U_{terminal}$ = 350 – 3500kV
I_{max} > 500μA (on target)
ΔE = 0.2keV
Available beams: H^+, ^4He, $^{12,13}C$

LUNA 50

(1992-2001)
50 kV

LUNA 400

(2000 – …)
$U_{terminal}$ = 50 – 400kV
I_{max} = 500μA (on target)
ΔE = 0.07keV
Allowed beams: H^+, ^4He, (^3He)



The upcoming LNGS 3.5 MV Accelerator Facility

inline Cockcroft Walton accelerator

TERMINAL VOLTAGE: 0.2 – 3.5 MV

Precision of terminal voltage reading: 350 V

Beam energy reproducibility: 0.01% TV

Beam energy stability: 0.001% TV / hrs

Beam current stability: < 5% / hrs

H

$^{1}H^{+}$ (TV: 0.3 – 0.5 MV): 500 μA

$^{1}H^{+}$ (TV: 0.5 – 3.5 MV): 1000 μA

He

$^{4}He^{+}$ (TV: 0.3 – 0.5 MV): 300 μA

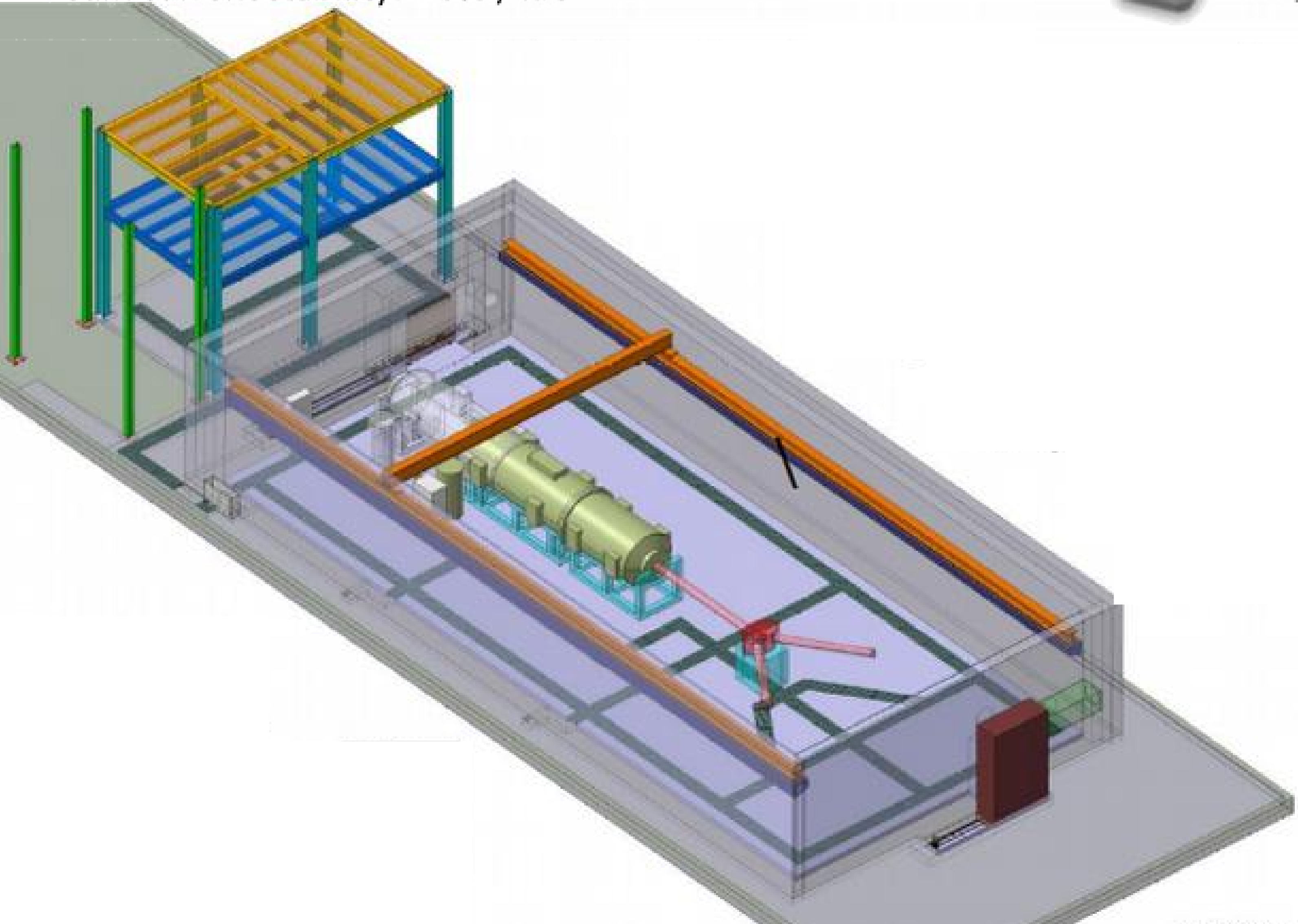
$^{4}He^{+}$ (TV: 0.5 – 3.5 MV): 500 μA

C

$^{12}C^{+}$ (TV: 0.3 – 0.5 MV): 100 μA

$^{12}C^{+}$ (TV: 0.5 – 3.5 MV): 150 μA

$^{12}C^{++}$ (TV: 0.5 – 3.5 MV): 100 μA



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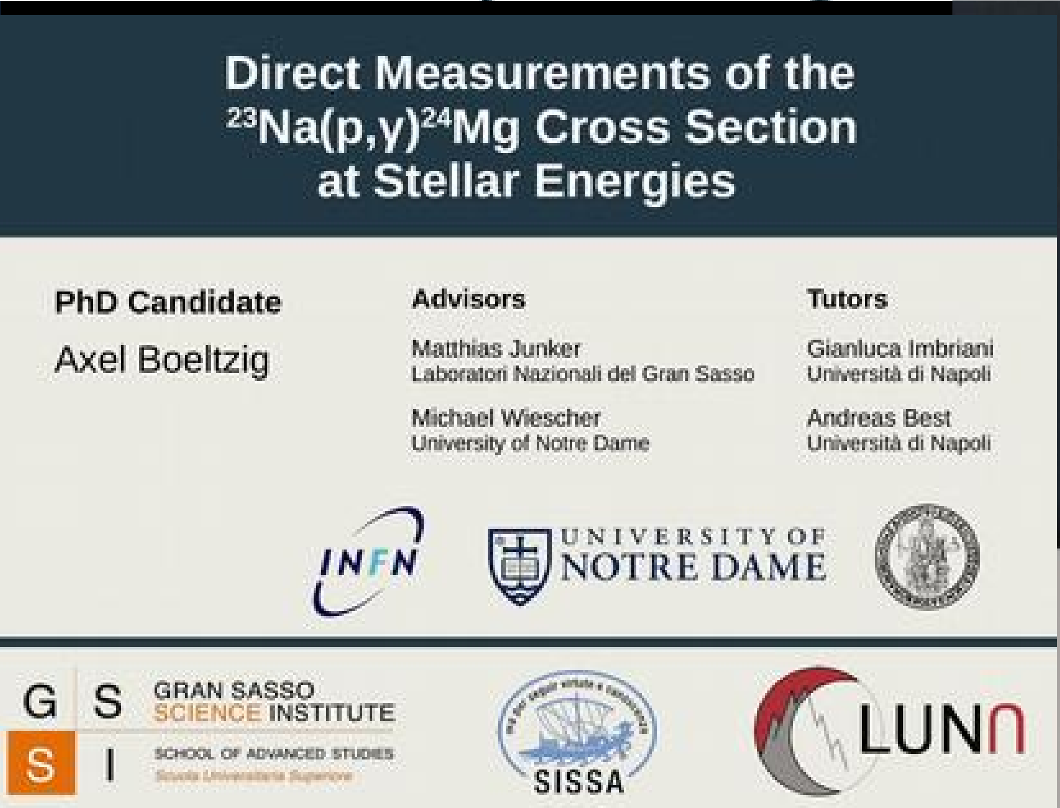

Direct Measurements of the $^{23}Na(p,\gamma)^{24}Mg$ Cross Section at Stellar Energies

PhD Candidate
Axel Boeltzig

Advisors
Matthias Junker
Laboratori Nazionali del Gran Sasso
Michael Wiescher
University of Notre Dame

Tutors
Gianluca Imbriani
Università di Napoli
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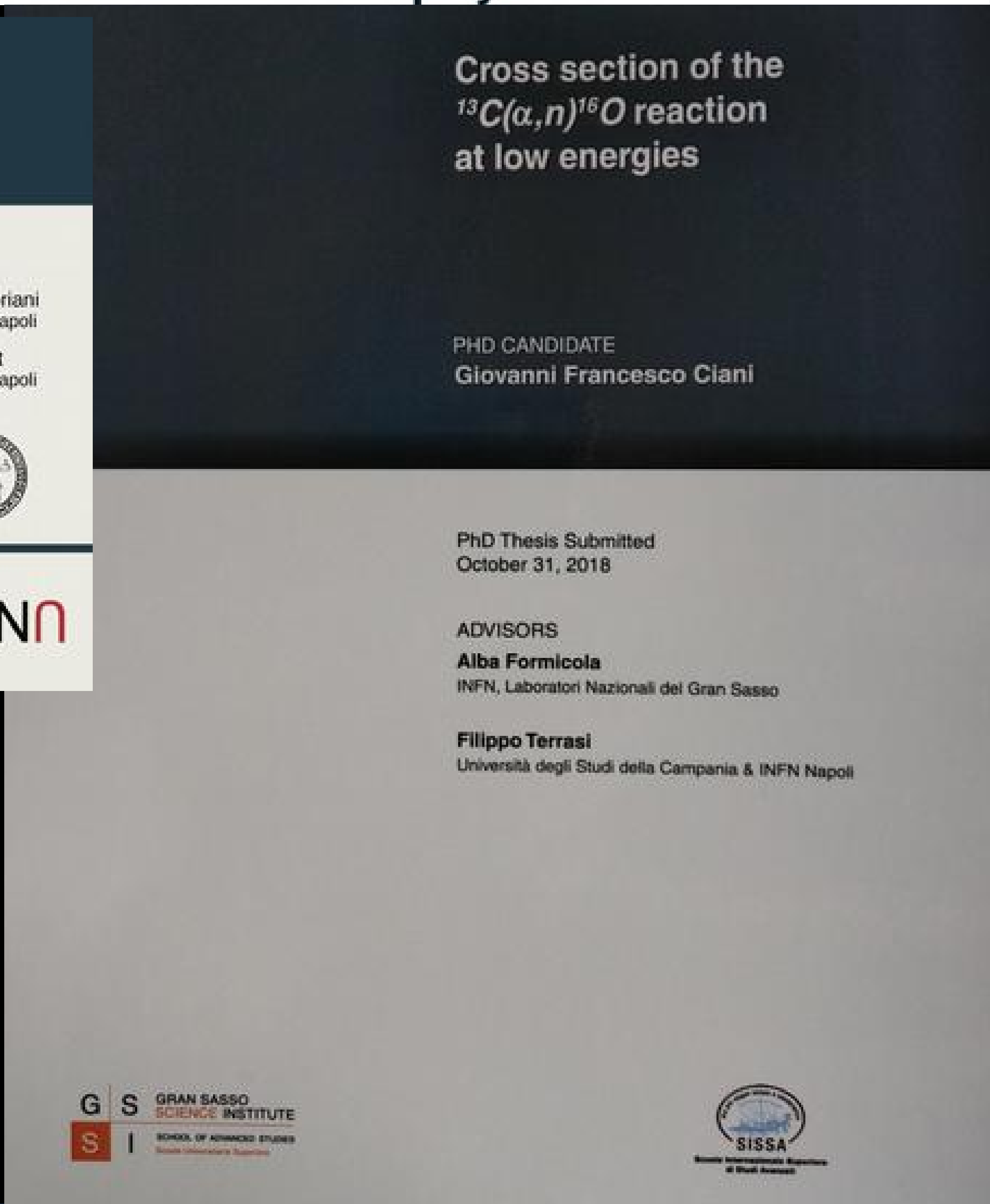
Università di Napoli

INFN
UNIVERSITY OF NOTRE DAME

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore
SISSA
LUNA



Cross section of the $^{13}C(\alpha,n)^{16}O$ reaction at low energies

PHD CANDIDATE
Giovanni Francesco Ciani

PhD Thesis Submitted
October 31, 2018

ADVISORS
Alba Formicola
INFN, Laboratori Nazionali del Gran Sasso

Filippo Terrasi
Università degli Studi della Campania & INFN Napoli

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SCHOOL OF ADVANCED STUDIES
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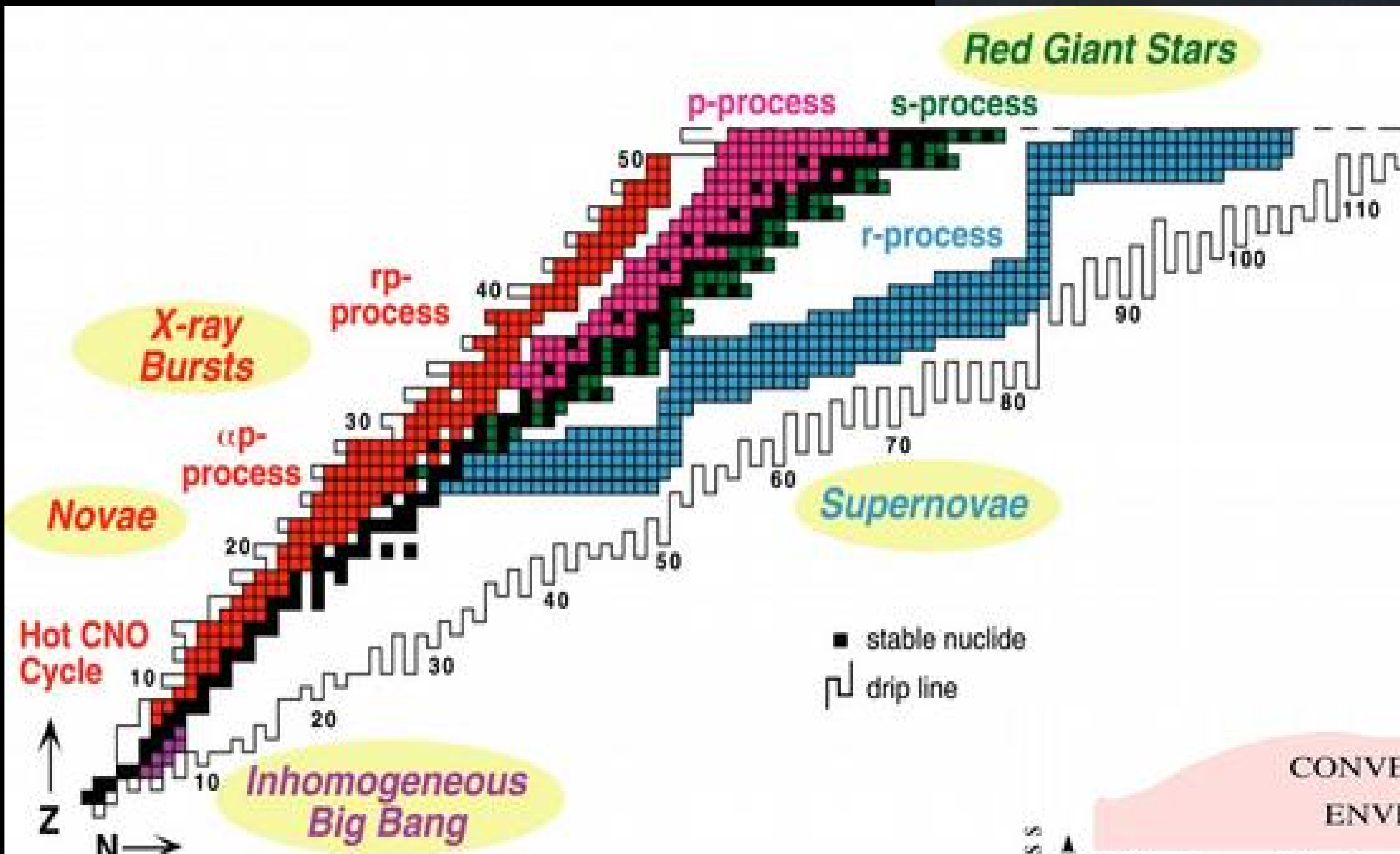
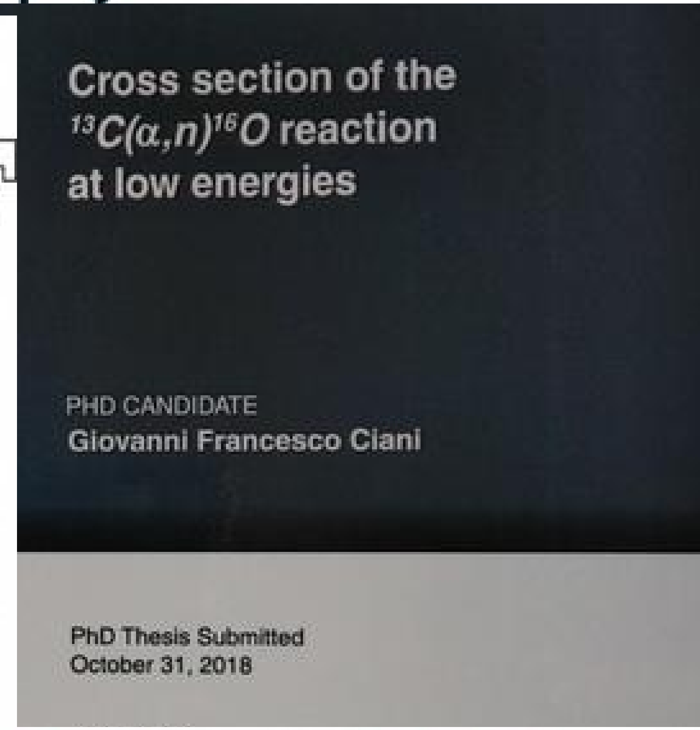
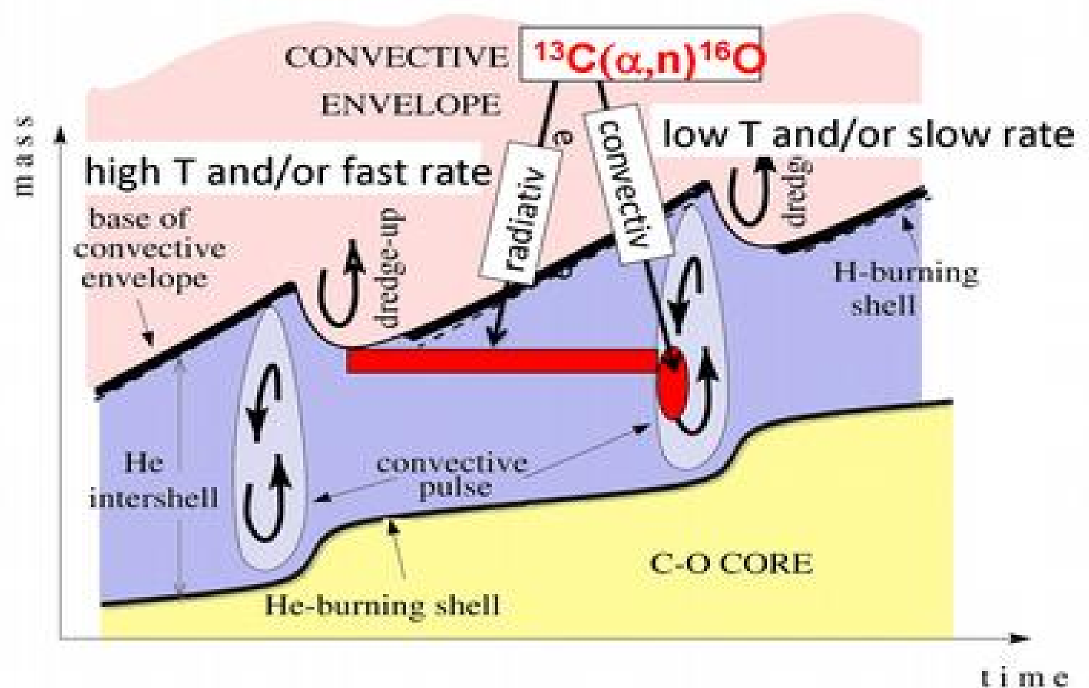




- $^{13}C(\alpha,n)$ is the dominant neutron source for the synthesis of the main s-process component of heavy elements in thermally pulsing, low-mass asymptotic giant branch stars.
- LNGS Underground Laboratory provides an ideal environment to detect rare events from astrophysical reactions thanks to the strong reduction in cosmic-ray induced background.
- The poster gives an overview of the main parts of project starting from the designing of the experimental setup, through the development of Data Acquisition system, until the data taking in Deep Underground facility of LNGS.



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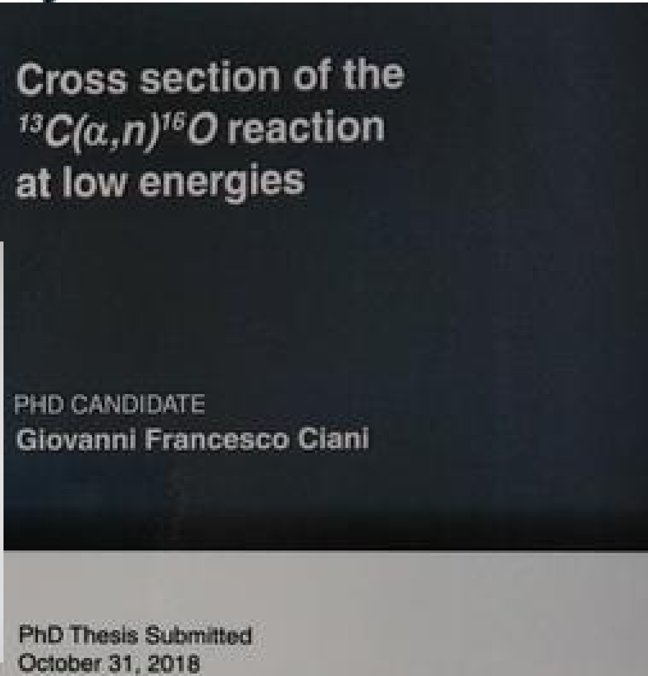
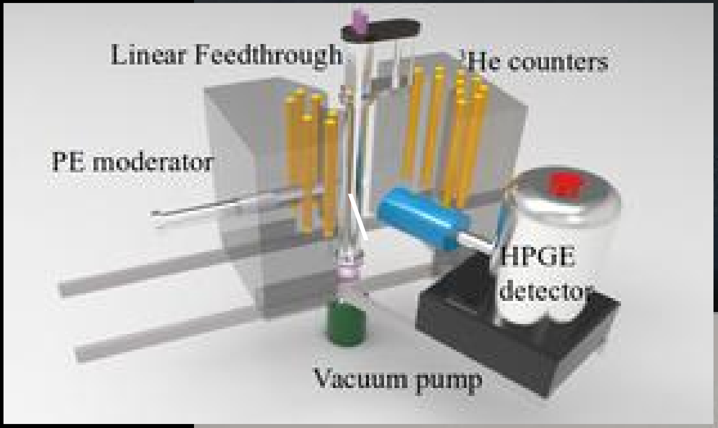
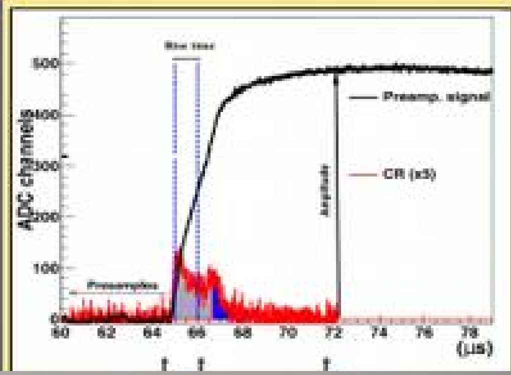
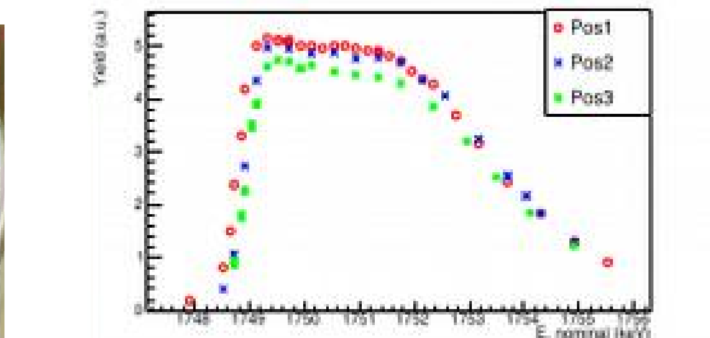
- Design of experimental setup
- Study on the setup efficiency using Geant4 simulations and measurements
- Detector characterization in a low background environment
- LabView Software Development for Data Acquisition and off line Pulse Shape Discrimination
- Material science for target preparation and characterization









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Design of experimental setup

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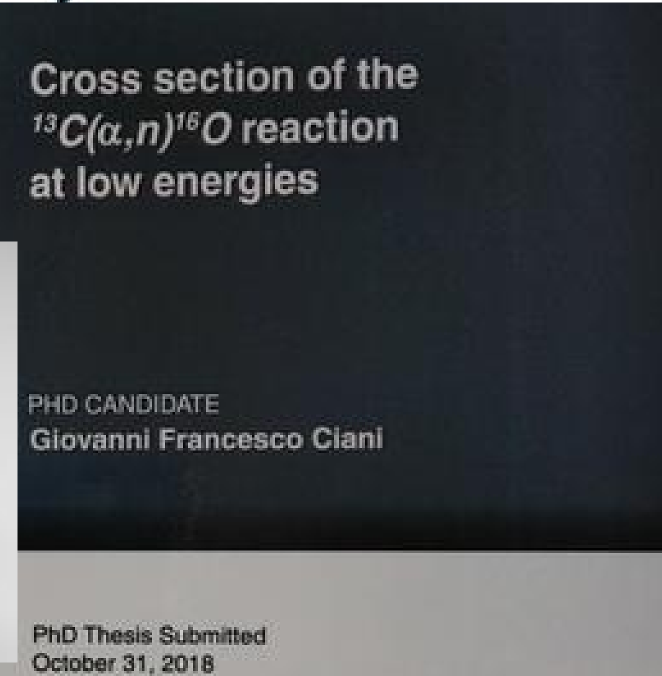

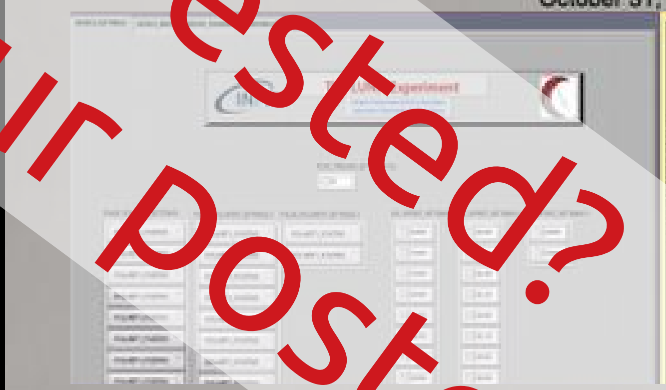

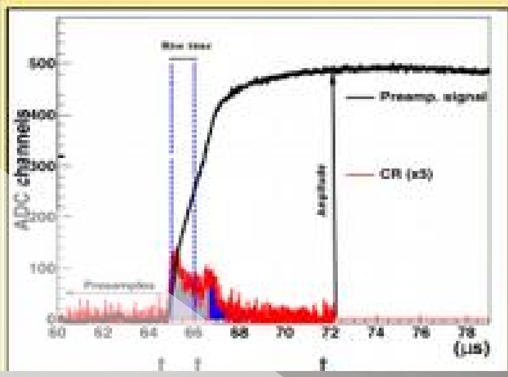

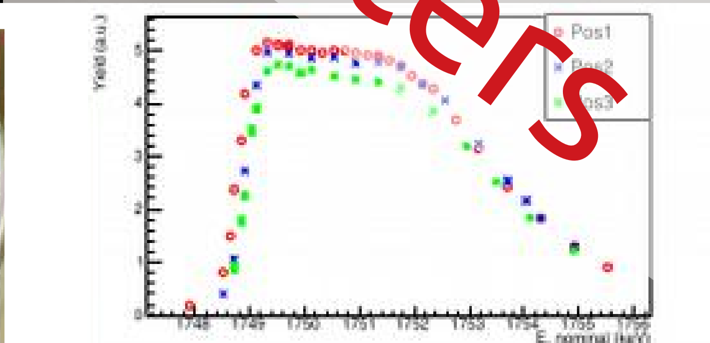

Interested? See our posters

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Giovanni Ciani, Oscar Straniero, Lucio Di Paolo

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Gran Sasso Science Institute, L'Aquila, Italy

INFN, Padova, Italy

INFN, Roma La Sapienza, Italy

Università di Genova and INFN, Genova, Italy

Università di Milano and INFN, Milano, Italy

Università di Napoli "Federico II", and INFN, Napoli, Italy

Università di Torino and INFN, Torino, Italy

Università di Bari and INFN, Bari, Italy

Osservatorio Astronomico di Collurania, Teramo, and LNGS, Italy

The University of Edinburgh, UK

Institute of Nuclear Research (ATOMKI), Debrecen, Hungary

Forschungszentrum Dresden-Rossendorf, Germany