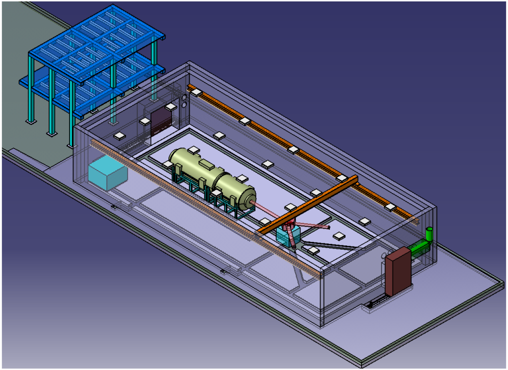
The Program of LUNA MV



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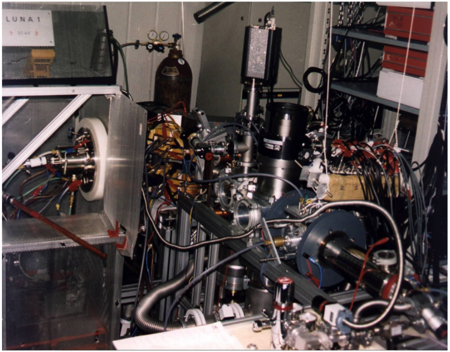
LUNA

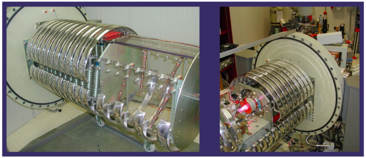
INFN
Istituto Nazionale di Fisica Nucleare

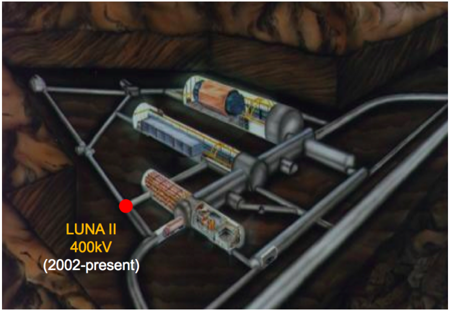
LUNA 1

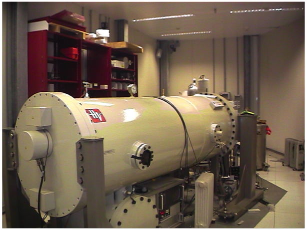


- Setup to measure p-p chain reactions
- 50 kV platform built by students
- ^{3}He(^{3}He, 2p)^{4}He - solar neutrino problem

LUNA 2

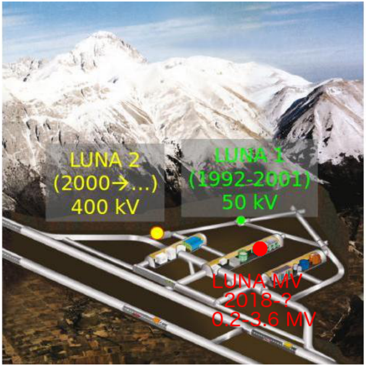






- Moved down the corridor a few meters
- In operation since 2002
- 50 - 400 kV accelerator
- 500 μA protons, alphas on target
- $^{14}N(p,\gamma)^{15}O$ - CNO neutrinos / age of the Universe

LUNA MV



H
$^{1}H^{+}$ (TV: 0.3 – 0.5 MV): 500 µA
$^{1}H^{+}$ (TV: 0.5 – 3.5 MV): 1000 µA

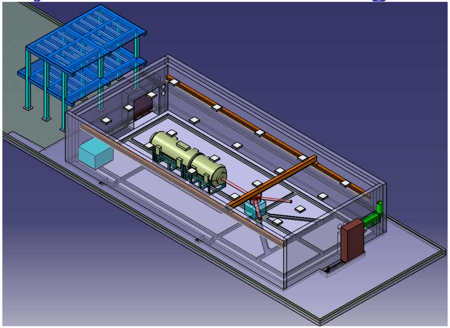
He
$^{4}He^{+}$ (TV: 0.3 – 0.5 MV): 300 µA
$^{4}He^{+}$ (TV: 0.5 – 3.5 MV): 500 µA

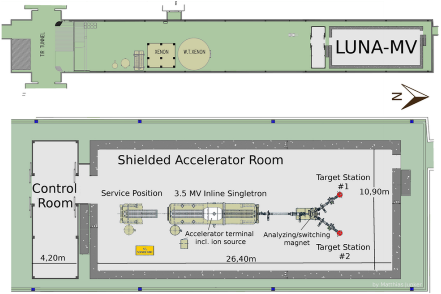
C
$^{12}C^{+}$ (TV: 0.3 – 0.5 MV): 100 µA
$^{12}C^{+}$ (TV: 0.5 – 3.5 MV): 150 µA
$^{12}C^{++}$ (TV: 0.5 – 3.5 MV): 100 µA

- Progetto Premiale MIUR - 2 grants total 5.3 MEuro
- 0.2 - 3.5 MV single-ended Cockcroft-Walton [1]
- High-intensity H, He, C beams
- Program: carbon burning, neutron sources

[1] Sen, A. et al. NIM B 450 (2019), 390

Layout, neutron shielding



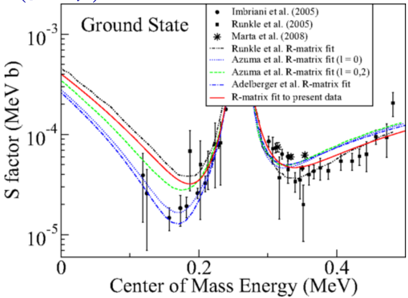


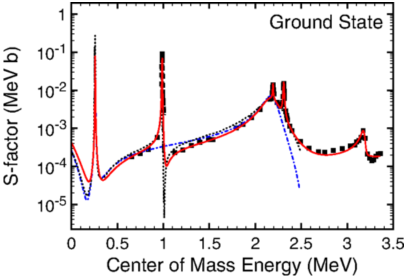
- 80 cm conrete walls to reduce any produced neutron flux below bg level outside
- Beam intensity limited as function of species, energy
- Neutron monitors can provide interlock

MCNP: $\Phi_n = 1.38\ 10^{-7}$ n/(cm^2 s)
GEANT4: $\Phi_n = 3.40\ 10^{-7}$ n/(cm^2 s)

Φ_n(LNGS) = $3\ 10^{-6}$ n/(cm^2 s)

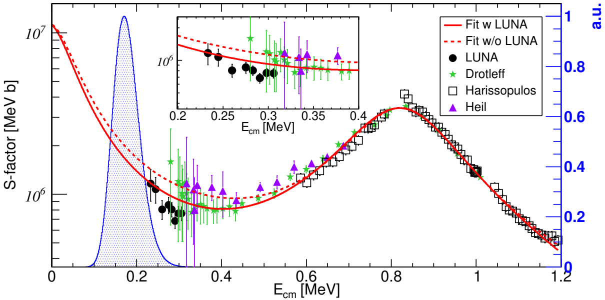
$^{14}N(p,\gamma)^{15}O$





- Commissioning & science measurement
- Connect high-energy to low-E region covered by LUNA 400
- Li et al. 2016: "The inconsistencies between the low-energy data and the extrapolation from higher-energy data result in a large systematic uncertainty in S(0). Additional measurements of the low-energy ground-state transition and the γ_0 width of the $E_x = 6.79$ MeV state are critically needed to further reduce the uncertainty of the total cross section at stellar energies."

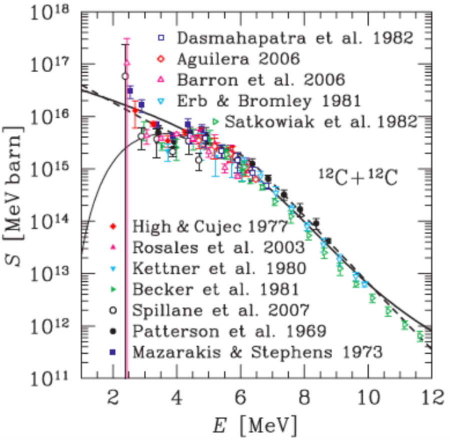
$^{13}C(\alpha, n)^{16}O$



[2] Ciani et al. PRL (in press)

- Main s process neutron source
- Reached Gamow peak with LUNA 400 [2]
- Large offsets between higher E datasets
- Connect low with high E using LUNA MV

$^{12}C+^{12}C$



Gasquez et al. 2007

- $^{12}C(^{12}C,\ p,\alpha)^{23,20}\{Na,Ne\}$
- proton, alpha (and neutron) channels
- Spillane et al. 2007: "The C+C fusion reactions are an excellent case for experimental studies with a future underground facility, such as a 3 MV high-current, single-stage accelerator with an electron-cyclotron-resonance ion source."

$^{12}C+^{12}C$ - γ measurements

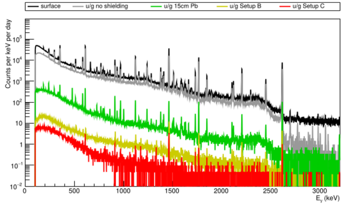


Figure 9a: Environmental background in HPGe detectors in different shielding configurations.

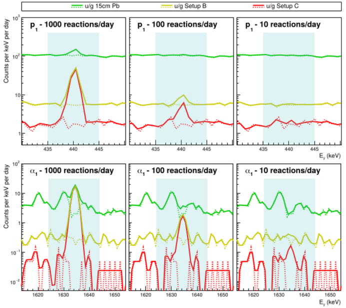
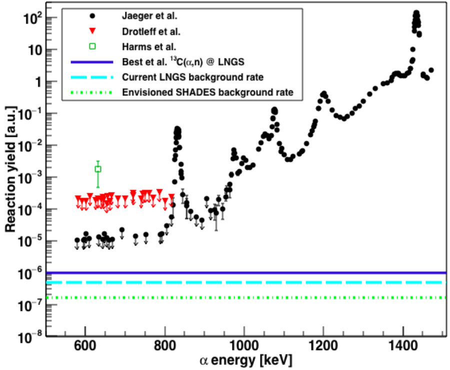
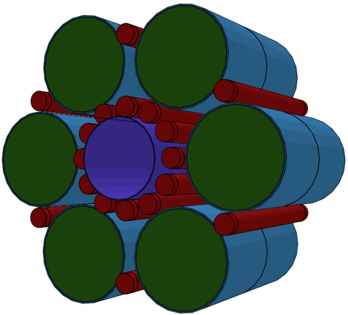


Figure 9b: Visualization of a hypothetical reaction yield (solid) on top of the background levels of shielded setups from Fig. 9a (dotted).

- $^{12}C(^{12}C, p)^{23}Na$: Q = 2.241 MeV, 440 keV 1st excited state in Na
- $^{12}C(^{12}C, \alpha)^{20}Ne$: Q = 4.617 MeV MeV, 1634 keV 1st excited state in Ne
- Massive lead shield and radon flushing → push sensitivity to below 100 reactions/day

$^{22}Ne(\alpha, n)^{25}Mg$

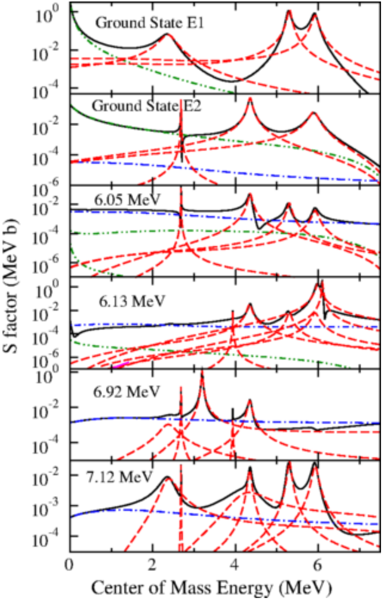


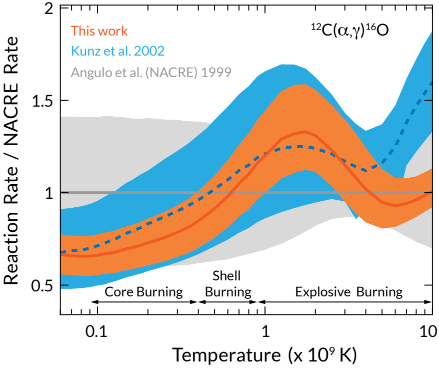


- Weak s process neutrons
- Threshold 565 keV: perfect for LUNA MV
- Jaeger et al. only stopped by neutron bg flux
- LNGS automatic reduction by 3-4 o.o.m.
- “SHADES” ERC project

erc
European Research Council
Established by the European Commission

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





deBoer et al. Rev Mod Phys 89 (2017) 035007

- The holy grail

Summary

- LUNA MV will investigate the most important reactions for astrophysics
- Factory acceptance test passed in late 2019
- Installation foreseen fall 2021
- On-site acceptance tests 2022
- LUNA 400 to be installed near MV
- Both accelerators will be LNGS facilities

The LUNA collaboration

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