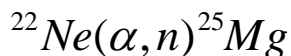
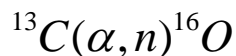


The Shielding of the LUNA-MV site

INTRODUCTION

- LUNA-MV program involves reactions which produce neutrons.
- In a very low background environment such as LNGS, it is mandatory not to increase the neutron flux above its average value.
- Source of neutrons:



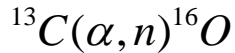
Preliminary study of the LUNA-MV neutron shielding by Monte Carlo simulations.



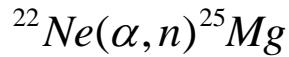
Luna-MV site (December 2009)

The Shielding of the LUNA-MV site

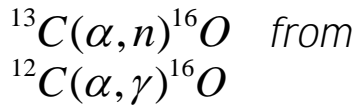
NUCLEAR REACTION



α beam intensity: 200 μA
 Target: ^{13}C , $2 \cdot 10^{17}\text{at/cm}^2$
 (99% ^{13}C enriched)
 Beam energy(lab) ≤ 0.8 MeV

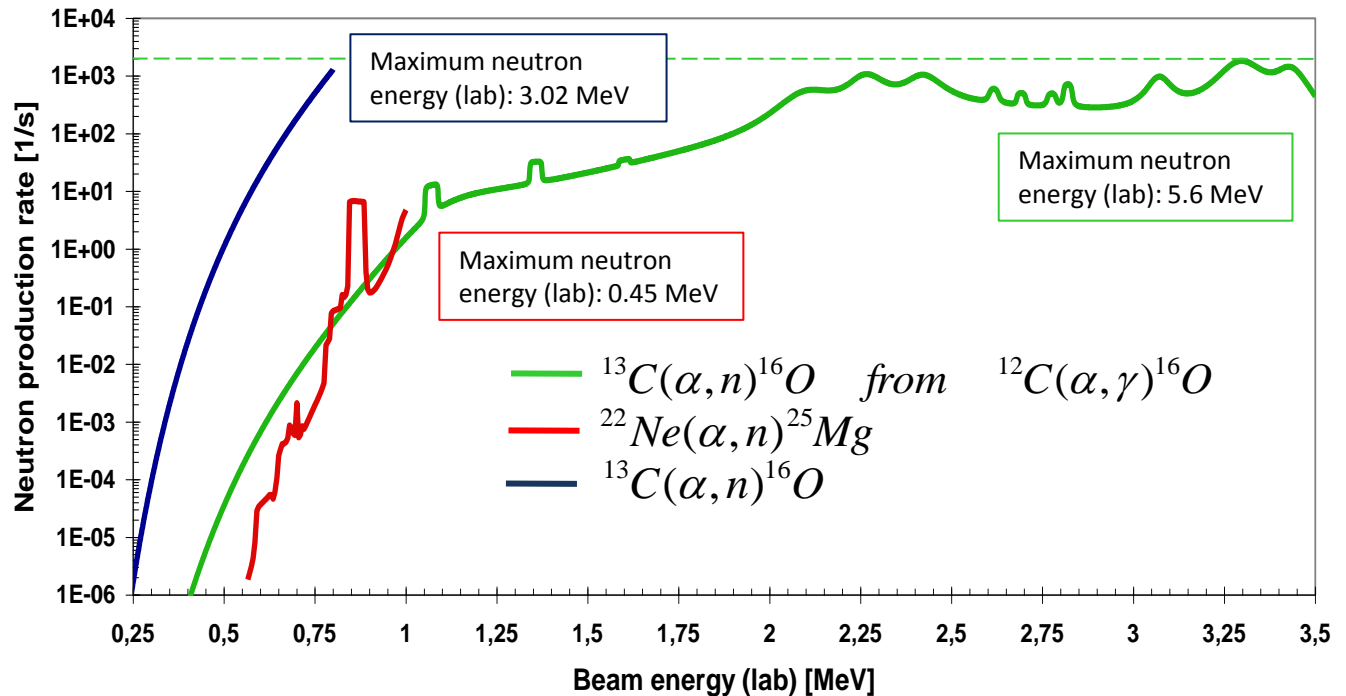


α beam intensity: 200 μA
 Target: ^{22}Ne , $1 \cdot 10^{18}\text{at/cm}^2$
 Beam energy(lab) ≤ 1.0 MeV



α beam intensity: 200 μA
 Target: ^{13}C , $1 \cdot 10^{18}\text{at/cm}^2$
 ($^{13}\text{C}/^{12}\text{C} = 10^{-5}$)
 Beam energy(lab) ≤ 3.5 MeV

- Maximum neutron production rate is about 2000 n/s
- Maximum neutron energy (lab) is 5.6 MeV



The Shielding of the LUNA-MV site

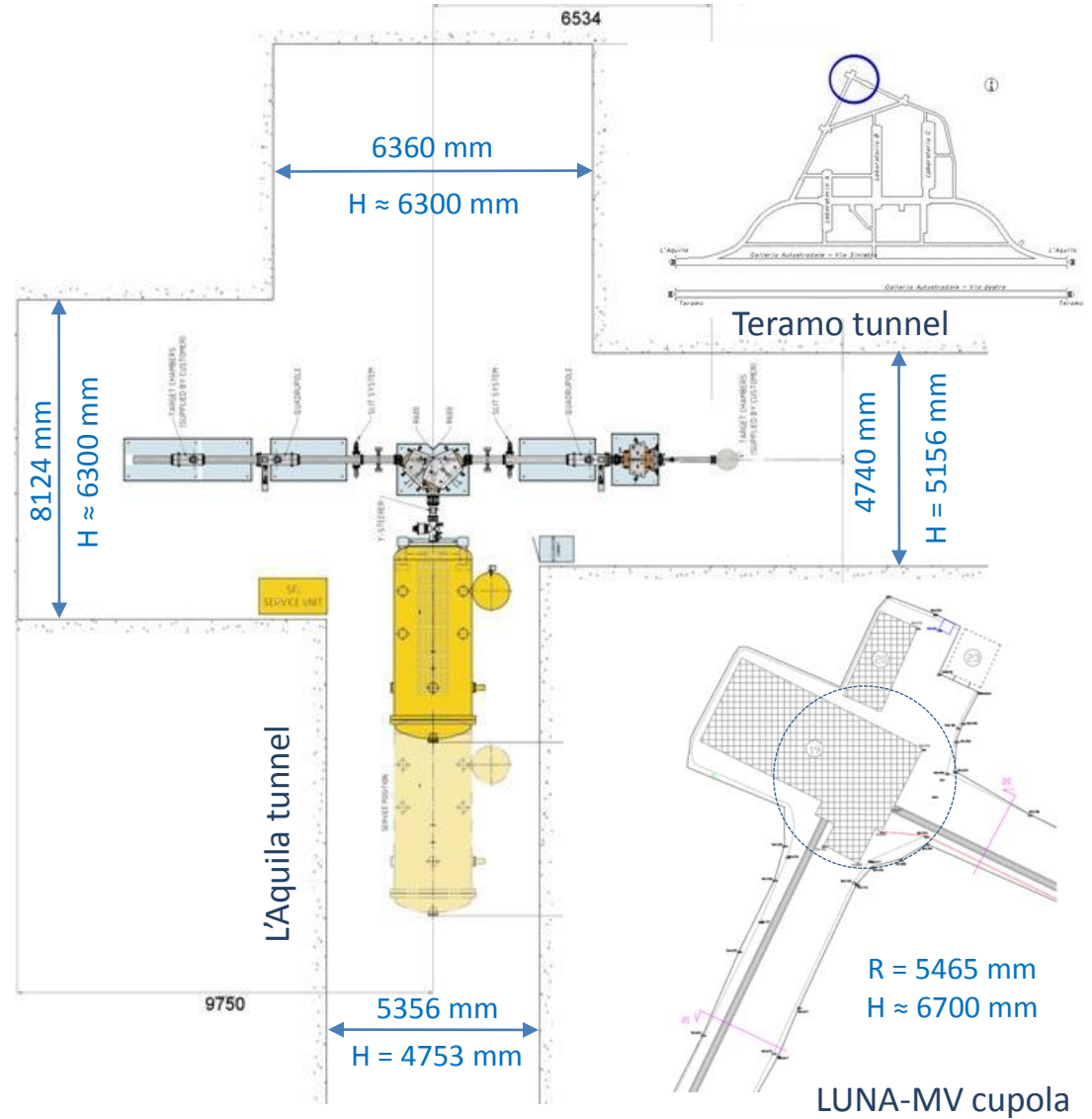
LUNA-MV site

- LUNA-MV site will be the "B-node" at the LNGS
- Total neutron flux at LNGS [Belli et al., *Il Nuovo Cimento* **101A** (1989) 959-966]:

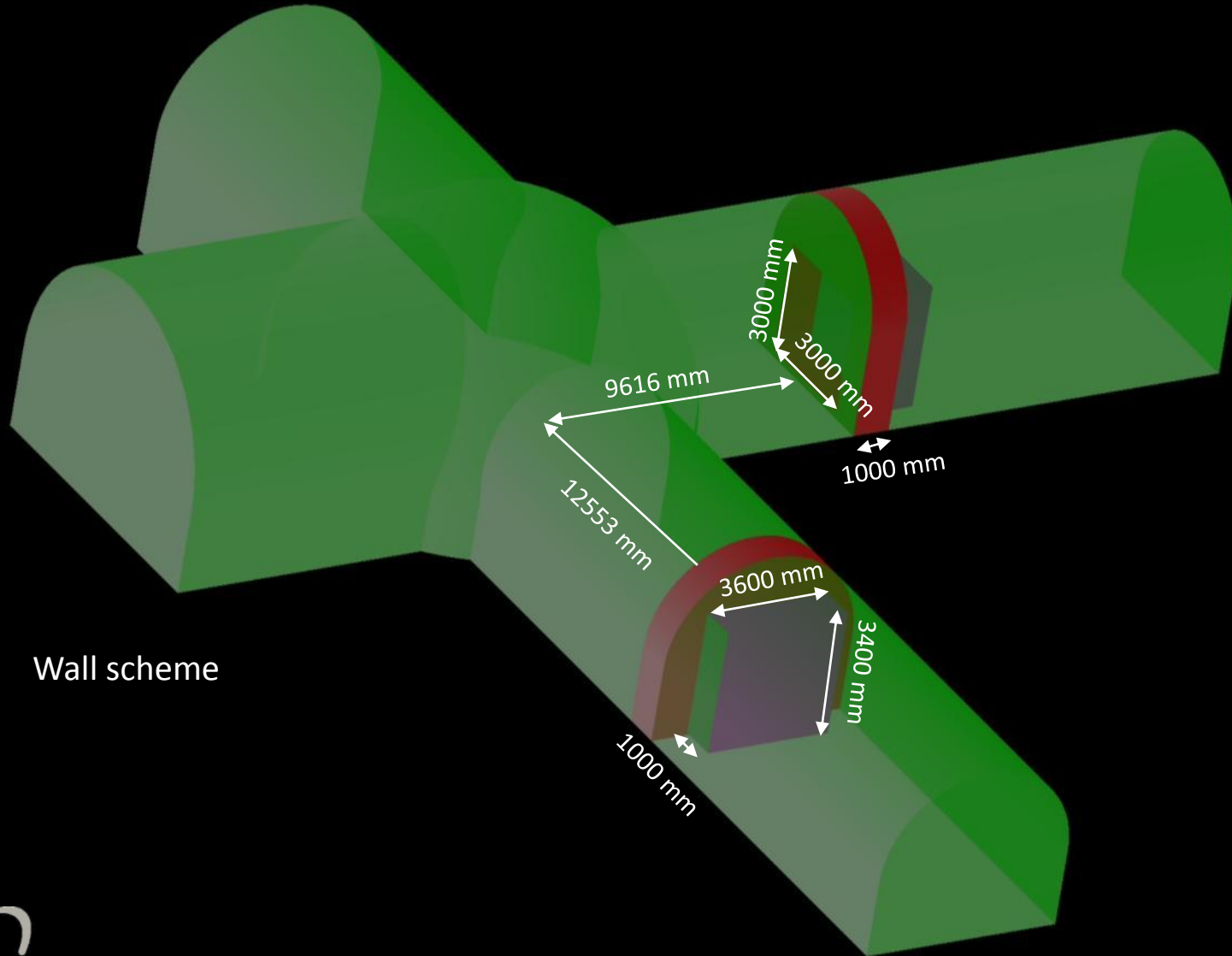
$$\Phi_{NB} = 3.3 \cdot 10^{-6} \text{ cm}^{-2} \text{ s}^{-1}$$

- We start by considering two options:

- ➔ Wall
- ➔ Labyrinth

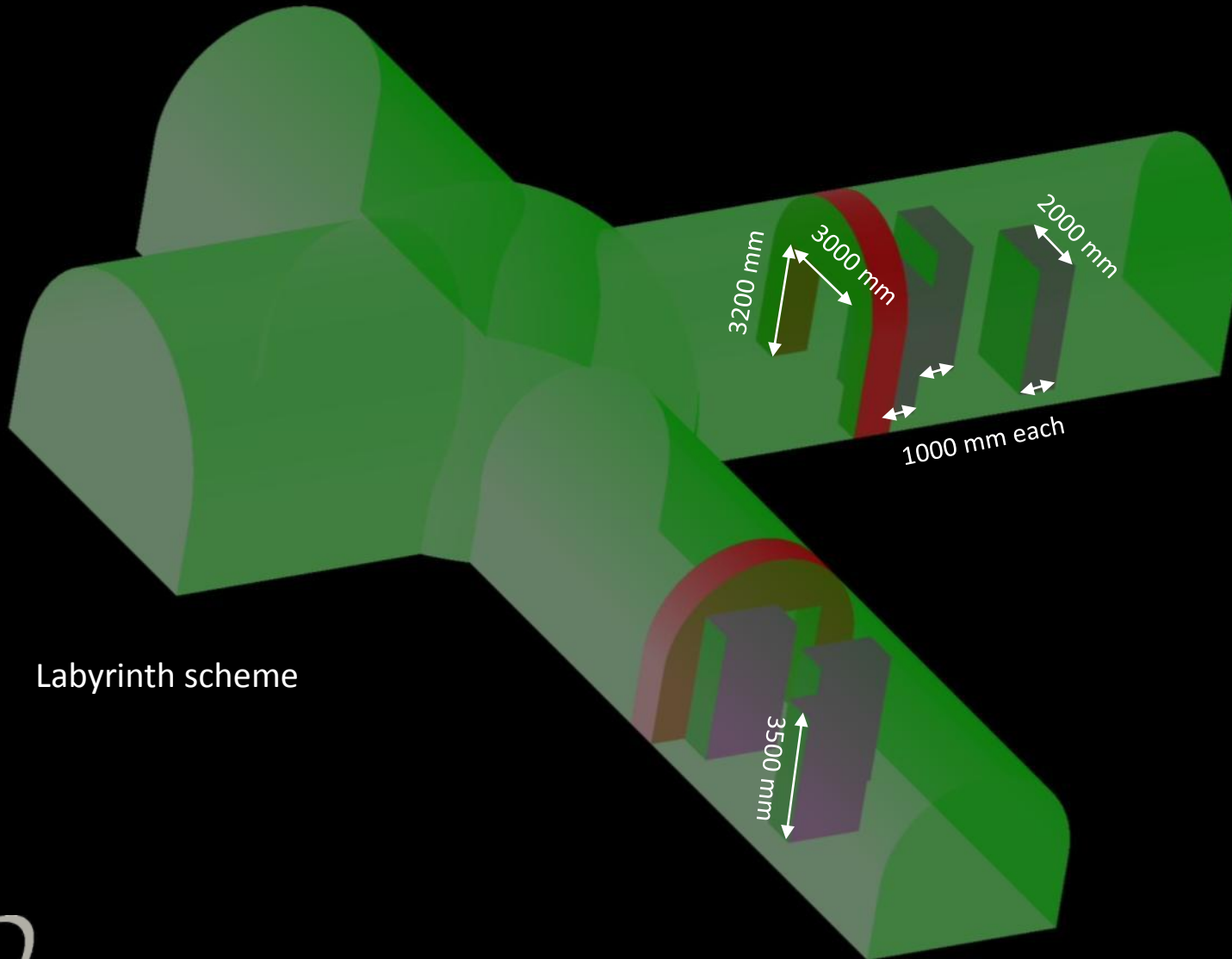


The Shielding of the LUNA-MV



Wall scheme

The Shielding of the LUNA-MV



Labyrinth scheme

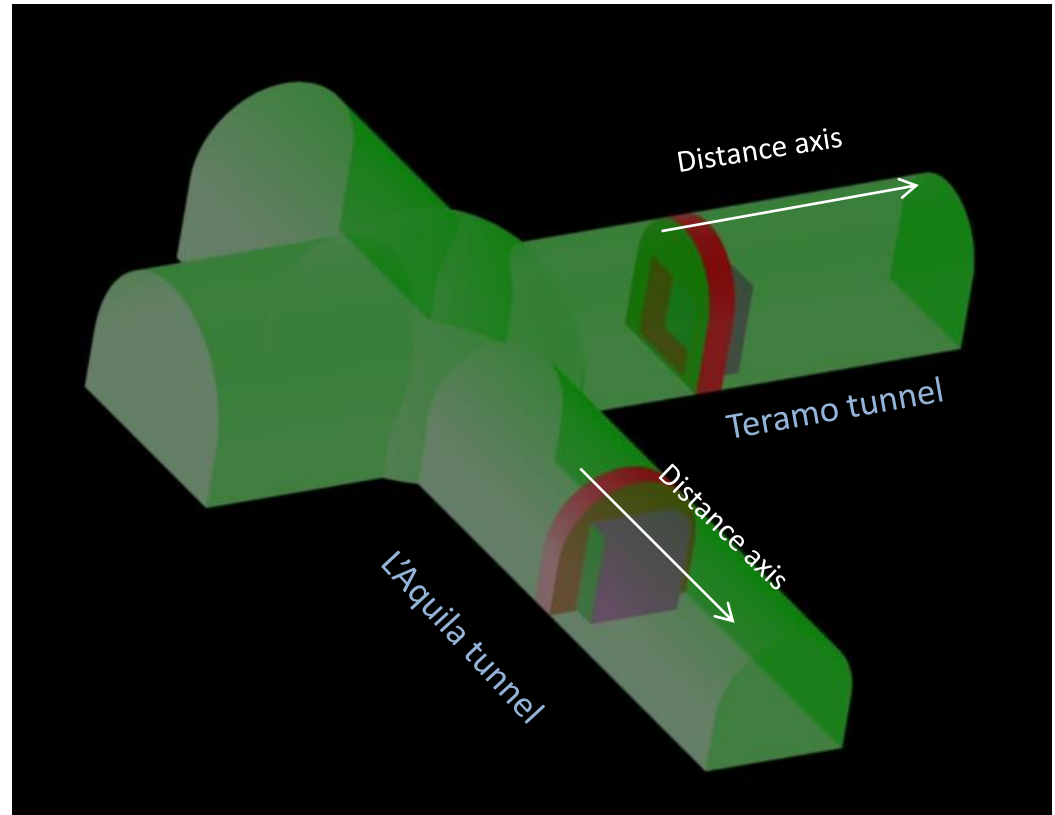
The Shielding of the LUNA-MV site

Monte Carlo Simulations

- Geant4 + LSC* simulation code:
 - 1 Million events
 - 68 fluxmeters (16 m²)
 - Monte Carlo Minimum detectable flux: $1.25 \cdot 10^{-8} \text{ cm}^{-2}\text{s}^{-1}$

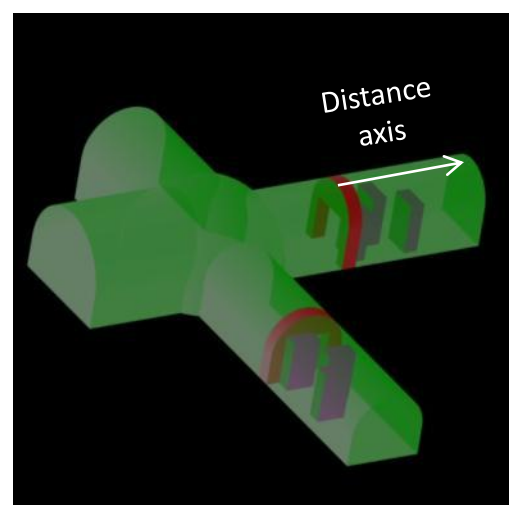
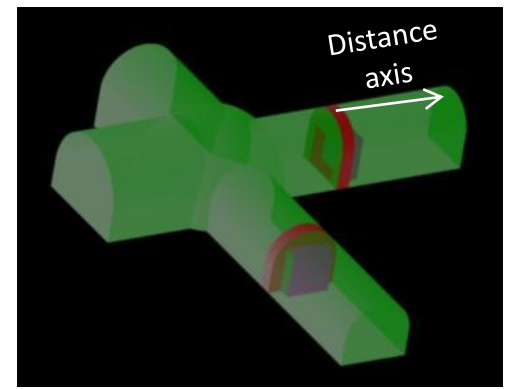
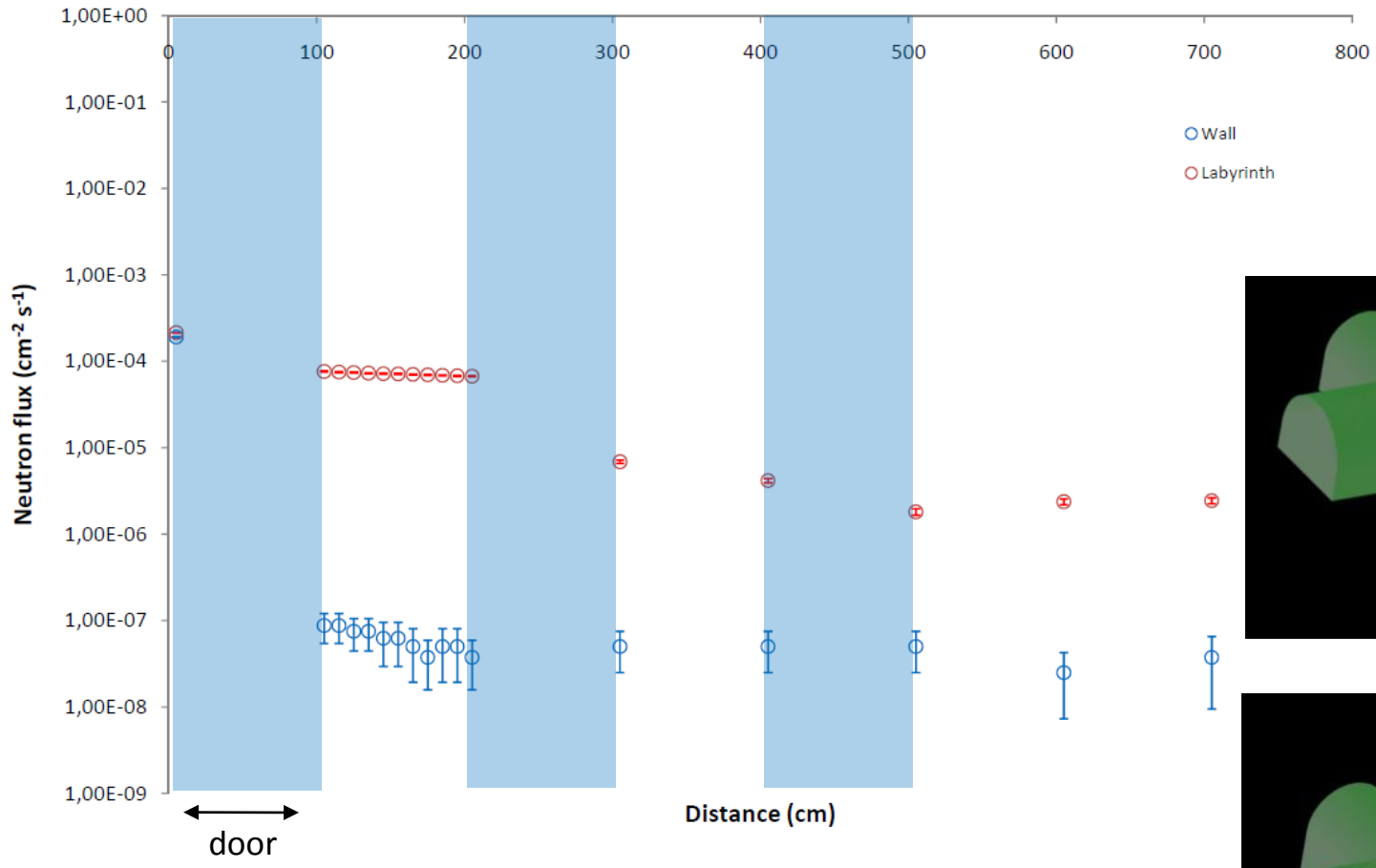
Neutron source
Rate: 2000 neutrons / s
Neutron energy (lab): 5.6 MeV
Isotropic source, point like
Monoenergetic source
Distance from ground: 1000 mm
Source position: cupola's center

Cement composition (% in weight):
8% Portland cement
29% Sand
56% Colemanite ($\text{Ca}_2 \text{B}_6 \text{O}_{11} \cdot 5\text{H}_2\text{O}$)
7% Water



* Lemmo's nuclear astrophysics Simulation Code

Teramo Tunnel

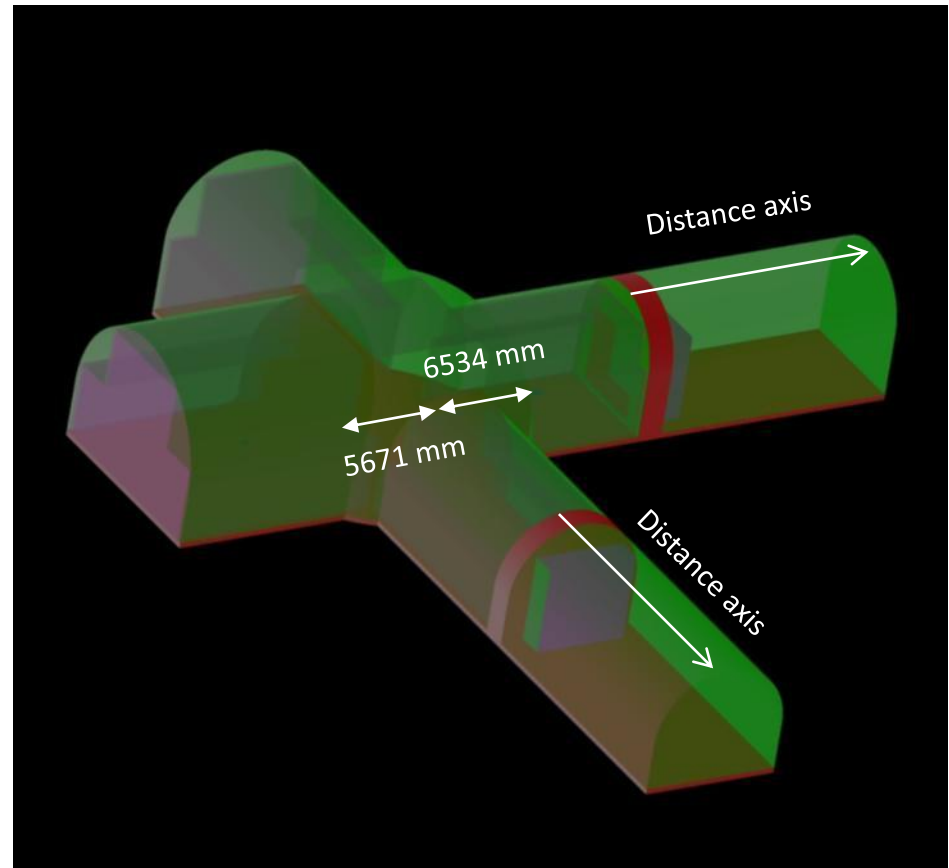


The Shielding of the LUNA-MV site

Monte Carlo Simulations

Preliminary shielding configuration

- Implementation of the 100 mm neutron HDPE(Li) shielding ;
- Implementation of the cement baseline (200 mm);
- Implementation of the solid (cylinder d=80mm, h=300 mm) and gas (box 120 x 120 x 500 mm) target chambers (40 mm thick);
- Increase the number of fluxmeters from 68 to 160 (16 m²)
- Increase the statistics from 1M to 4M events;



The Shielding of the LUNA-MV site

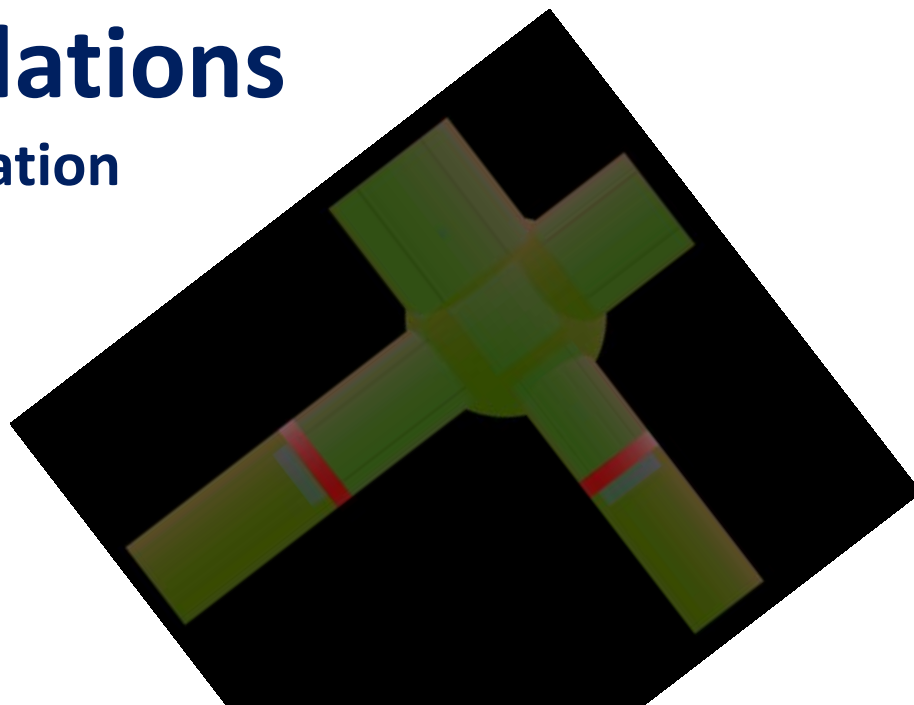
Monte Carlo Simulations

Preliminary shielding configuration

Neutron source
Rate: 2000 neutrons / s
Neutron energy (lab): 5.6 MeV
Isotropic source
Monoenergetic source
Distance from baseline: 1000 mm
Source position: solid and gas target positions

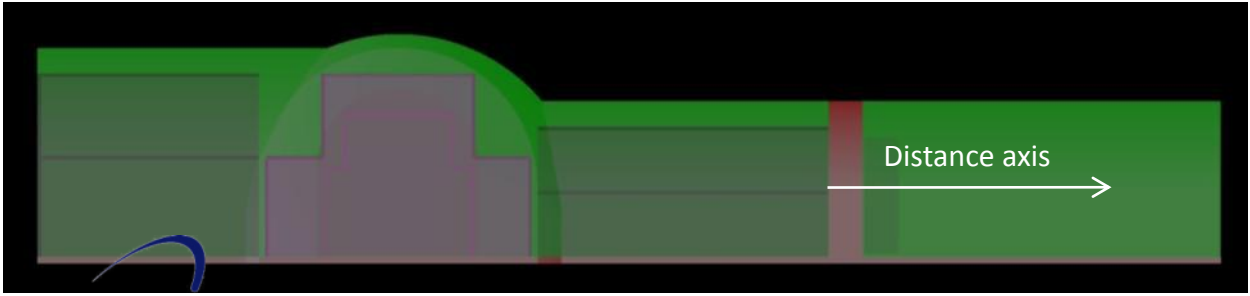
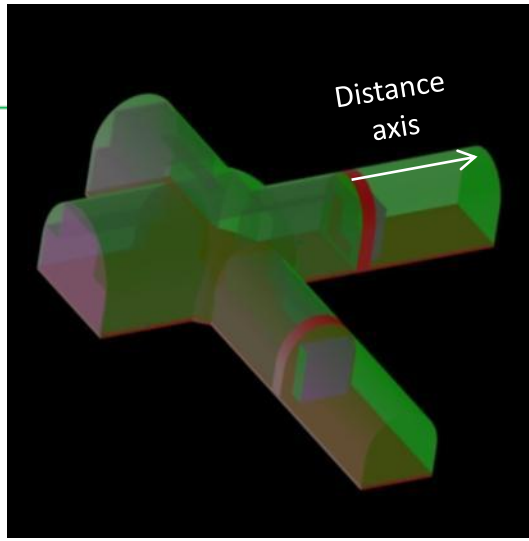
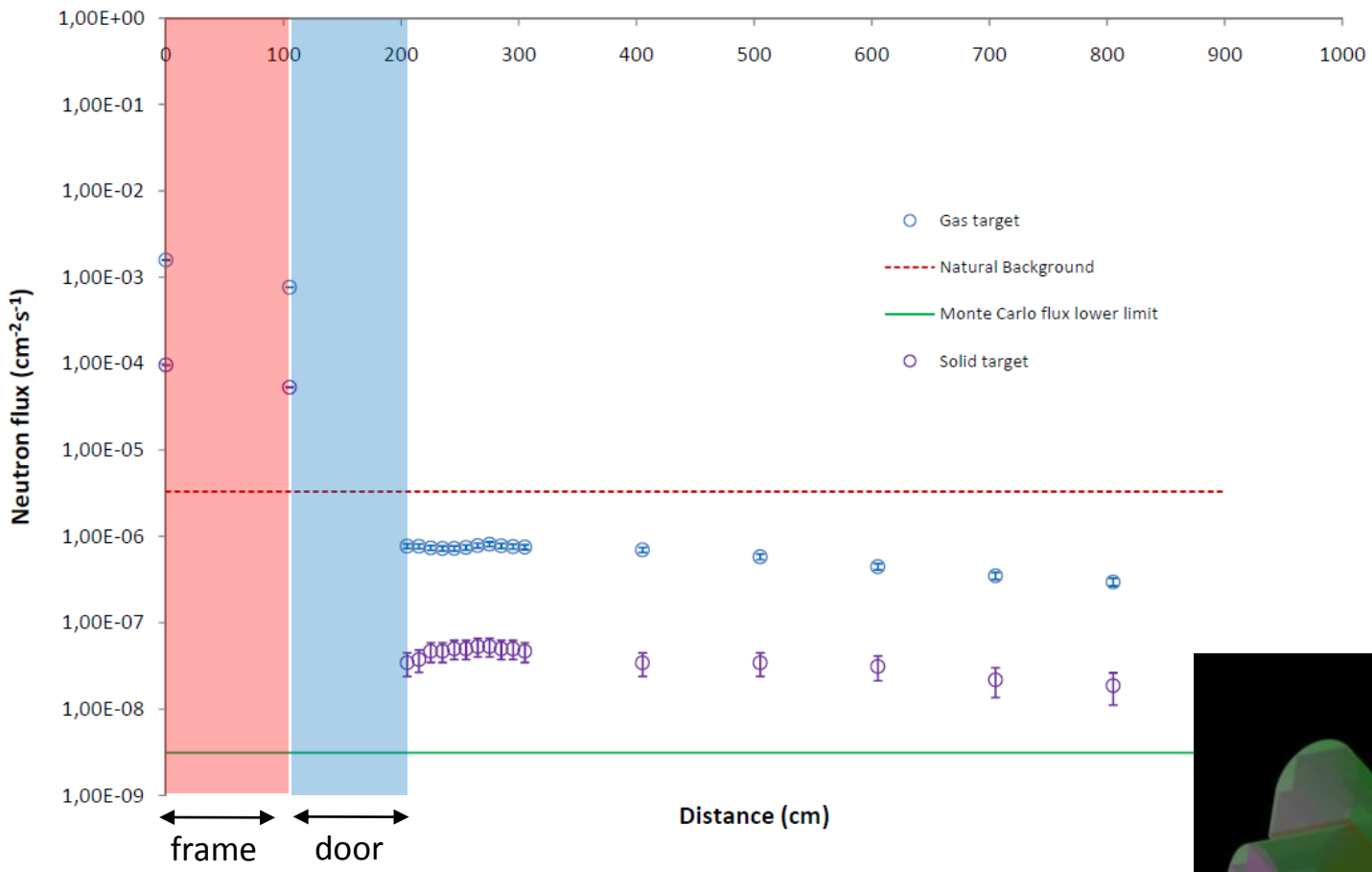
Cement composition (% in weight):
8% Portland cement
29% Sand
56% Colemanite ($\text{Ca}_2 \text{B}_6 \text{O}_{11} \cdot 5\text{H}_2\text{O}$)
7% Water

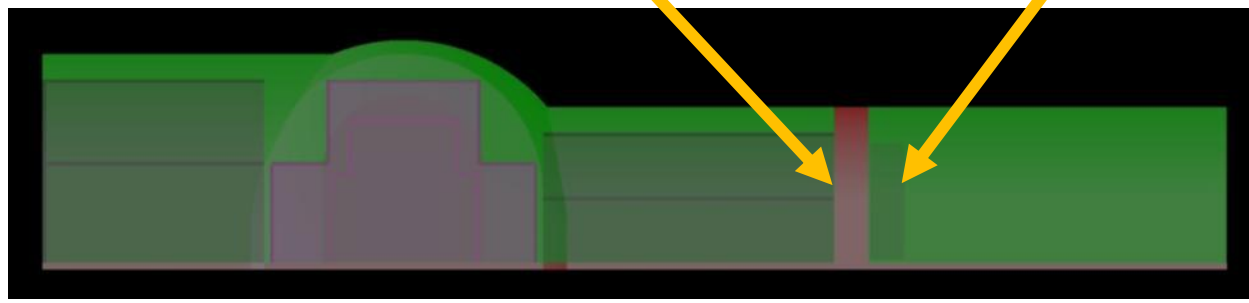
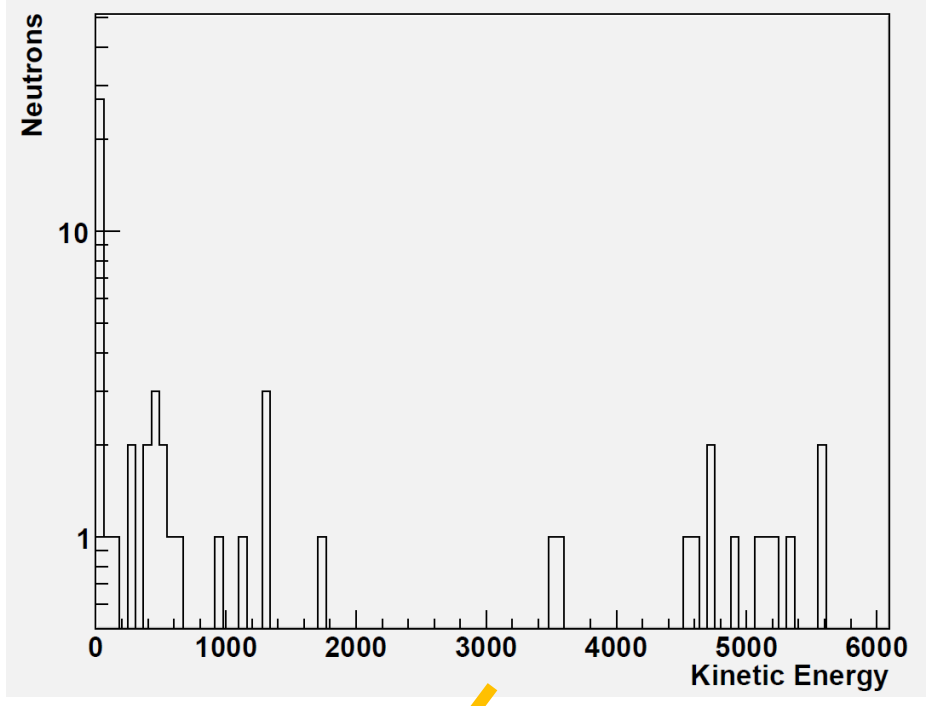
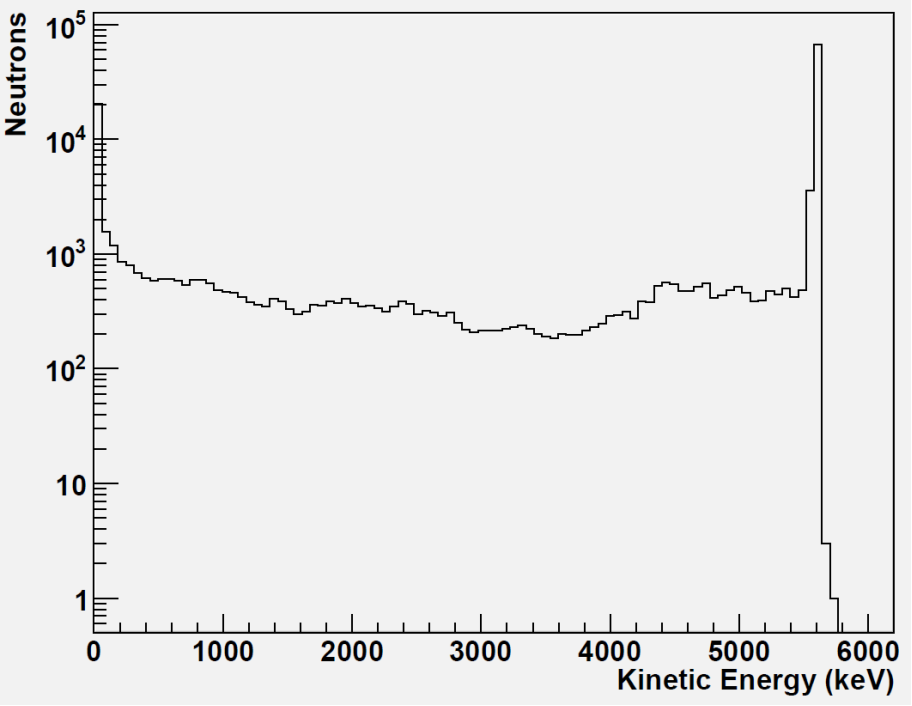
HDPE(Li) composition (% in weight)
13.566% Hydrogen
5.000 % Lithium
81.434% Carbon



- Geant4 + LSC simulation code:
 - OPENGL, VRML, Geant Ray Tracker
 - 4 Million events
 - 160 fluxmeters (16 m²)
 - Monte Carlo minimum flux detectable: $3.125 \cdot 10^{-9} \text{ cm}^{-2}\text{s}^{-1}$

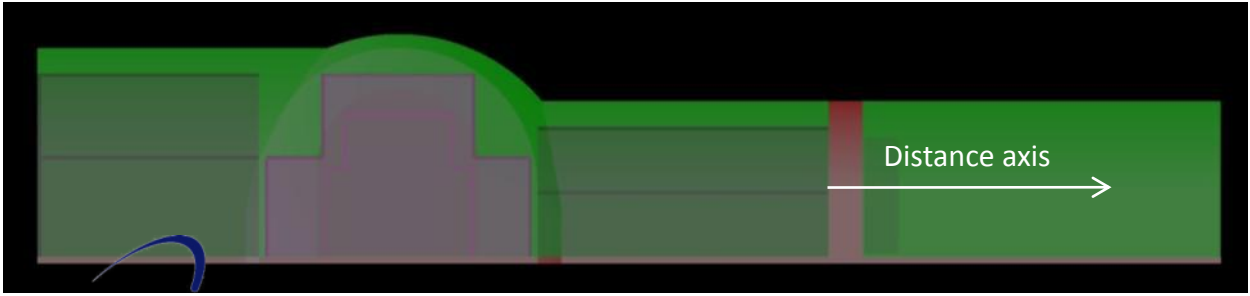
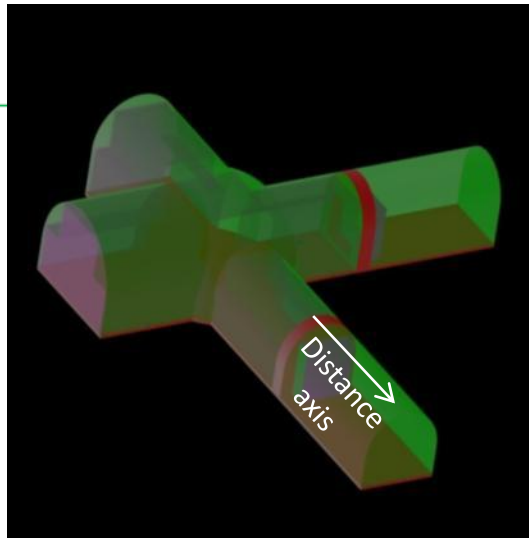
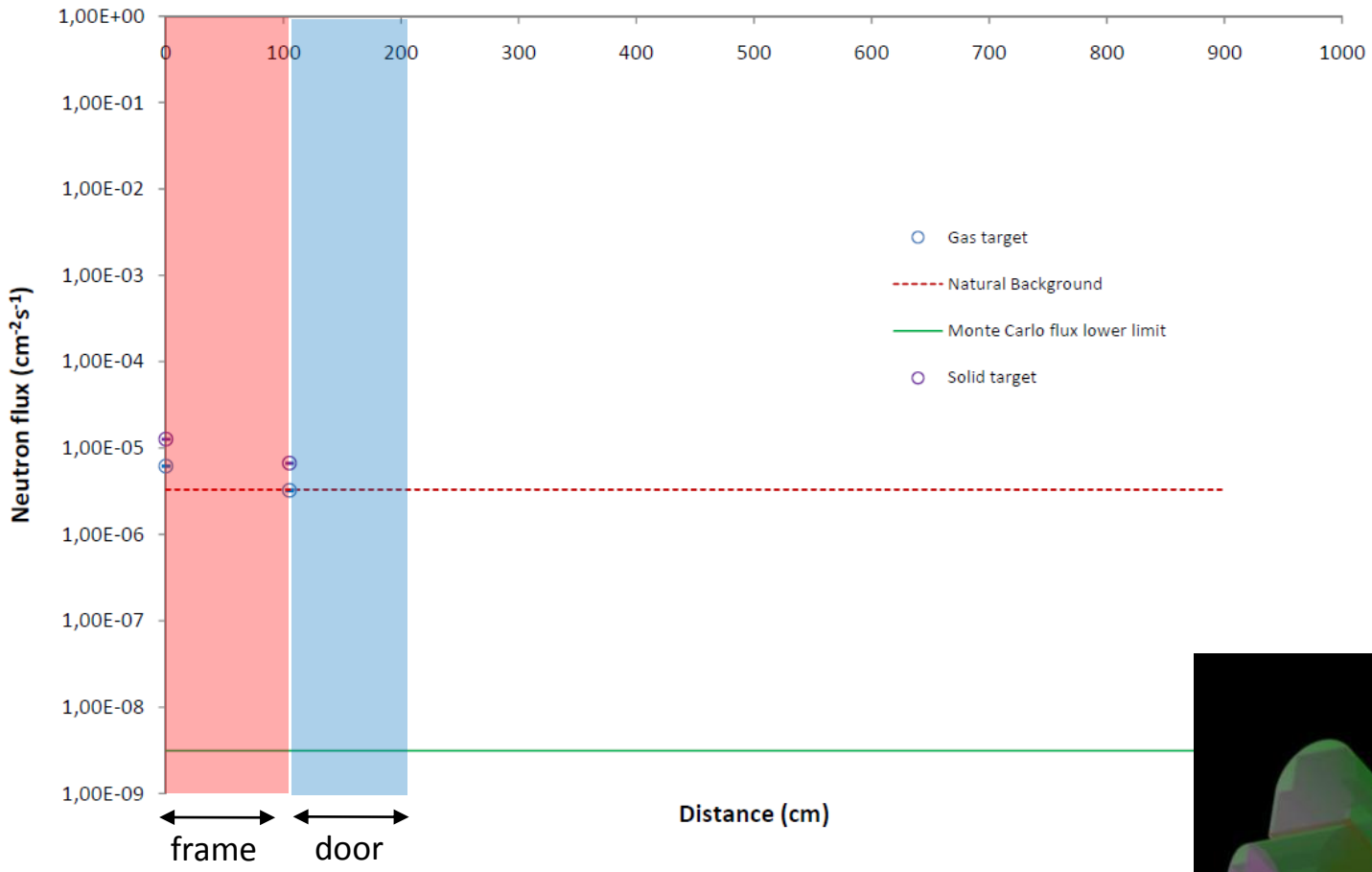
Teramo tunnel



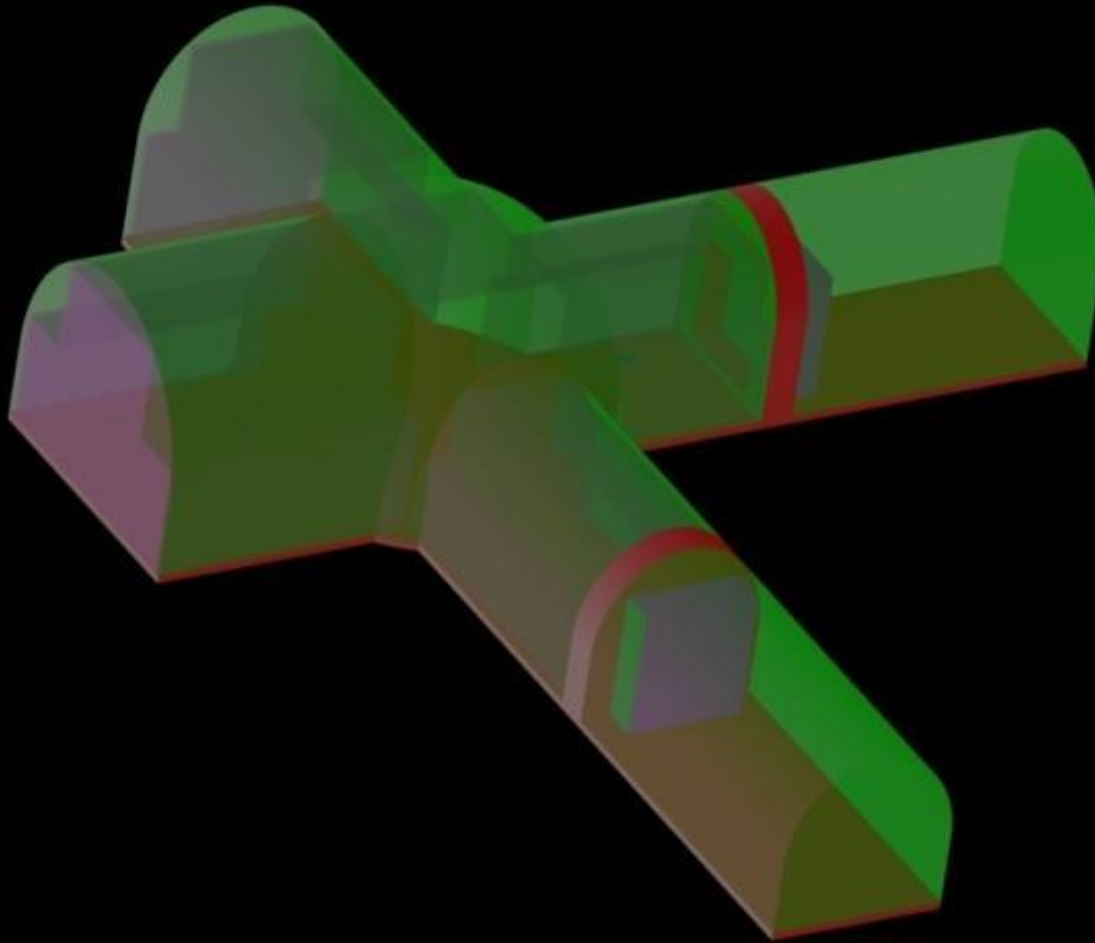


Simulation for gas target on

L'Aquila tunnel



The Shielding of the LUNA-MV



Mean ceiling flux*:
 $3.75 \cdot 10^{-9} \text{ cm}^{-2} \text{ s}^{-1}$

Mean ground flux*:
 $5.94 \cdot 10^{-9} \text{ cm}^{-2} \text{ s}^{-1}$

Mean wall flux*:
 $2.75 \cdot 10^{-6} \text{ cm}^{-2} \text{ s}^{-1}$

* Fluxes are calculated at 1 m inside the rock

The Shielding of the LUNA-MV site

Monte Carlo future simulations

- Monte Carlo simulations of the LUNA-MV site is an important tool in order to choose the best neutron shielding configuration.
- It's possible to increase the statistics by parallel computing (Condor).
- It's possible to increase the number of fluxmeters in order to have a complete map of the LUNA-MV site and of the overall LNGS underground laboratory.



Luna-MV site (December 2009)

Thanks to Bruno Dulach and
Paolo Martella

Thank you for your attention...

The Shielding of the LUNA-MV site

References

Geant4 simulation tools: <http://www.geant4.org/>

Lemmo's nuclear astrophysics Simulation Code: alemur@lbl.gov

LUNA official website: <http://luna.lngs.infn.it/>

My personal e-mail: davide.trezzi@mi.infn.it

LUNA MV – Letter Of Intent (LNGS-LOI 42/07)

P. Belli et al., Nuovo Cimento vol. 101A n.6, 959-966 (1989)

Thanks to
Bruno Dulach and Paolo Martella