The Shielding of the LUNA-MV site

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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:

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

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

$$^{13}C(\alpha,n)^{16}O \quad from \quad ^{12}C(\alpha,\gamma)^{16}O$$

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

Luna-MV site (December 2009)

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NUCLEAR RECTION

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

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

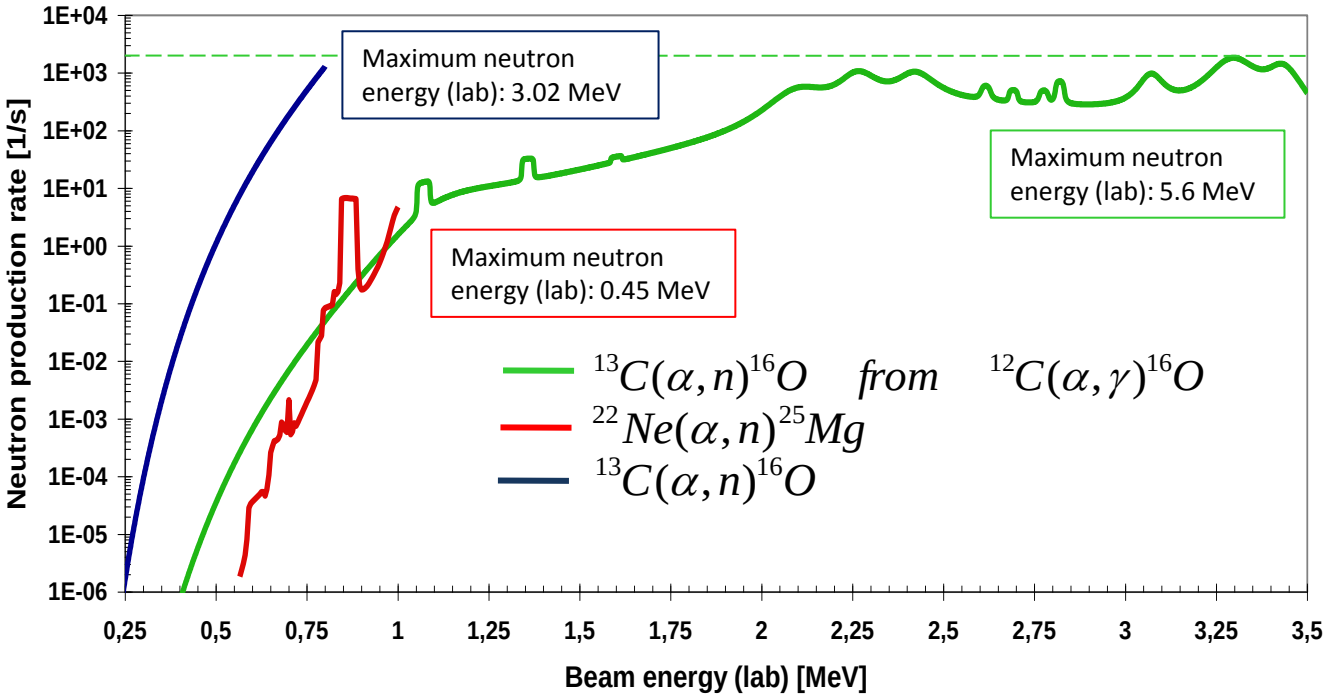
$^{22}Ne(\alpha,n)^{25}Mg$

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

$^{13}C(\alpha,n)^{16}O$ *from* $^{12}C(\alpha,\gamma)^{16}O$

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

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



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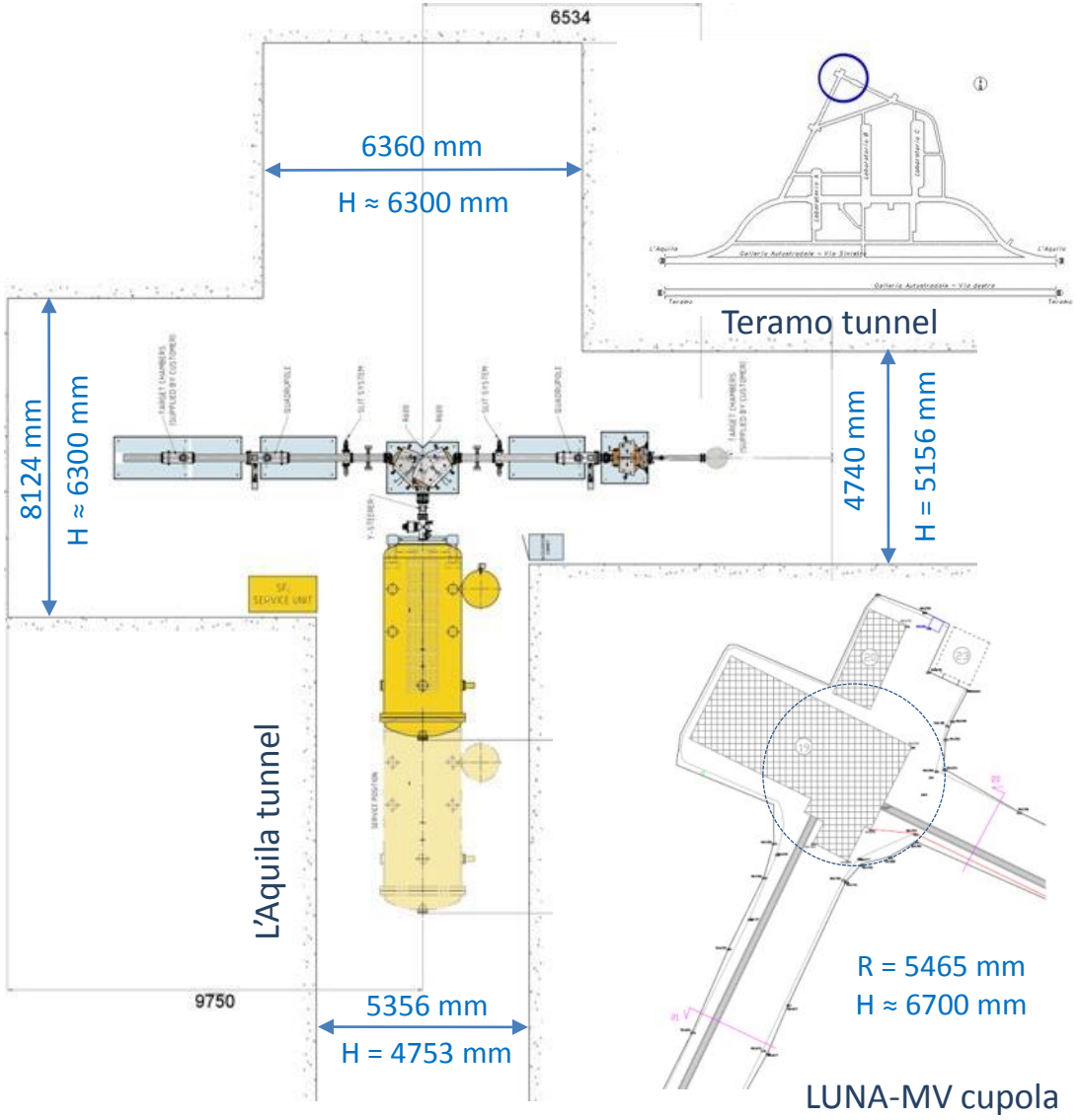
LUNA-MV site

- 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]:

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

- We start by considering two options:
  - ➡ Wall
  - ➡ Labyrinth



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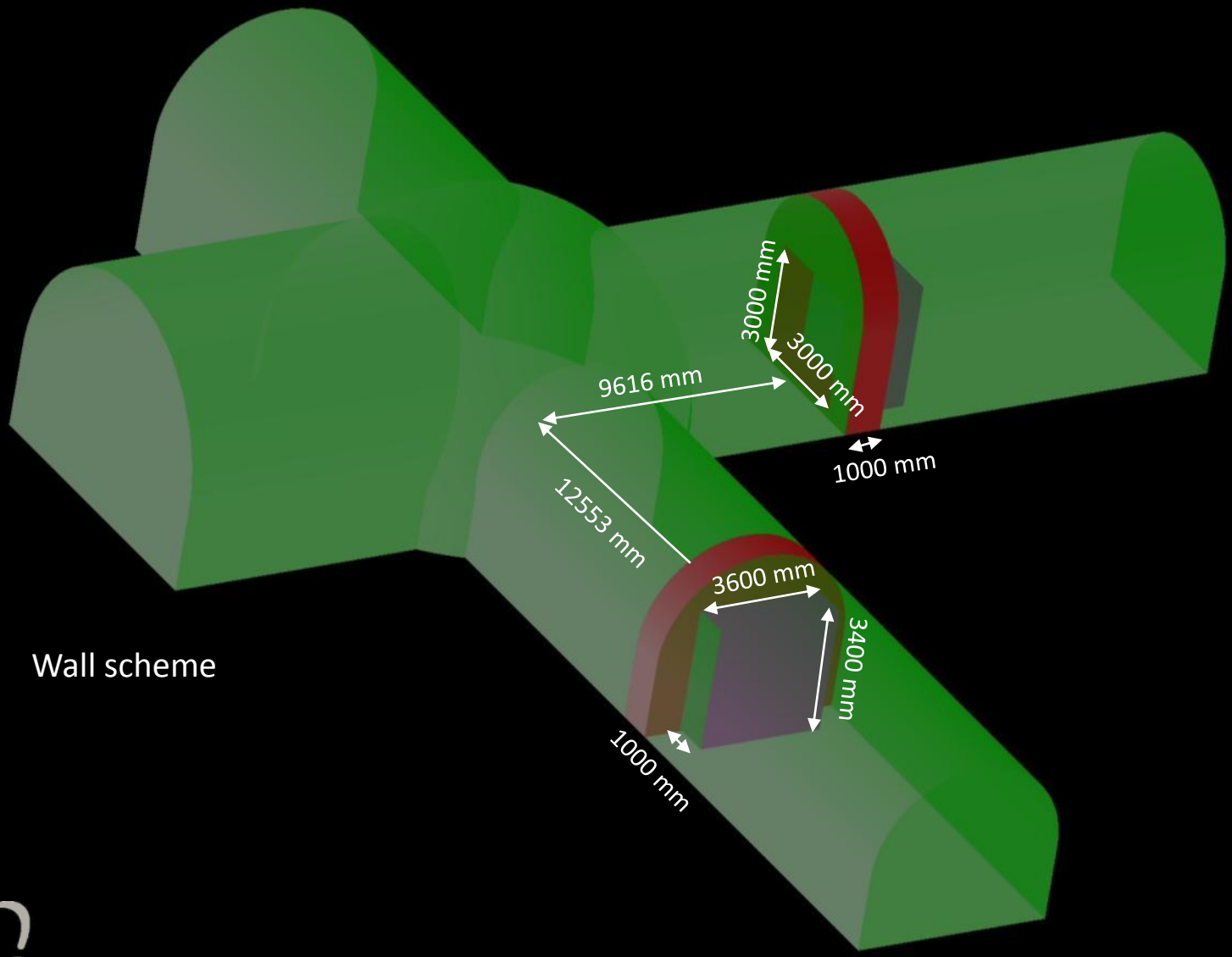

Wall scheme

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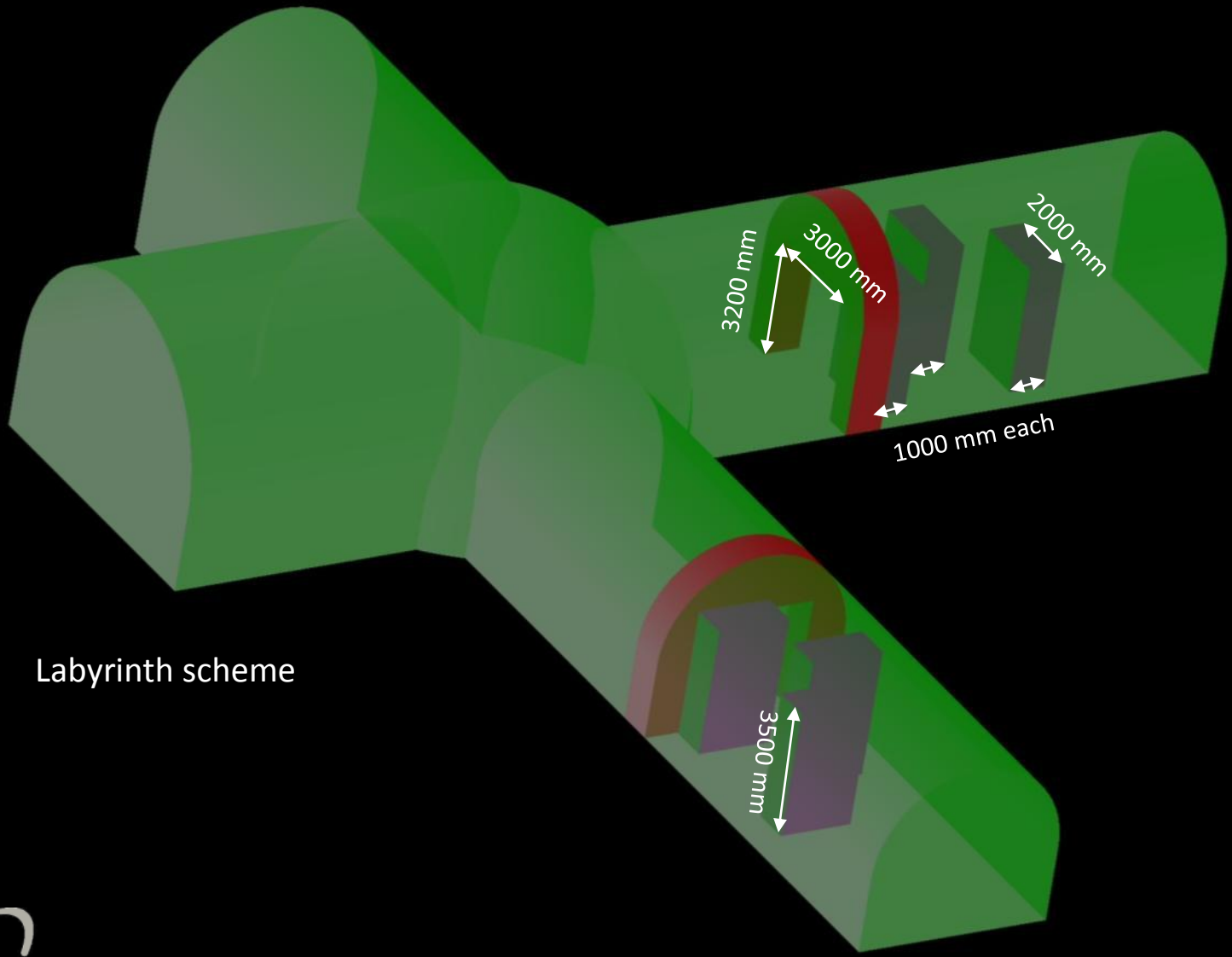

Labyrinth scheme

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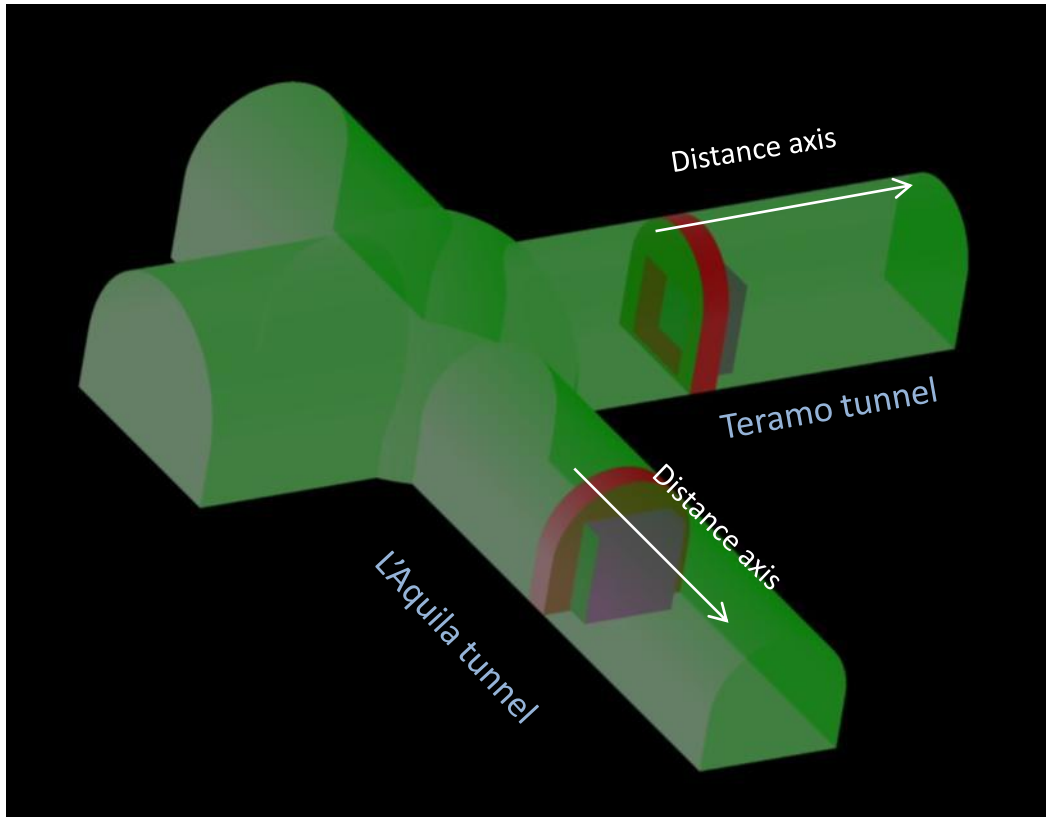
Monte Carlo Simulations

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

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 ($Ca_2 B_6 O_{11} 5H_2O$)
7% Water



* Lemmo’s nuclear astrophysics Simulation Code

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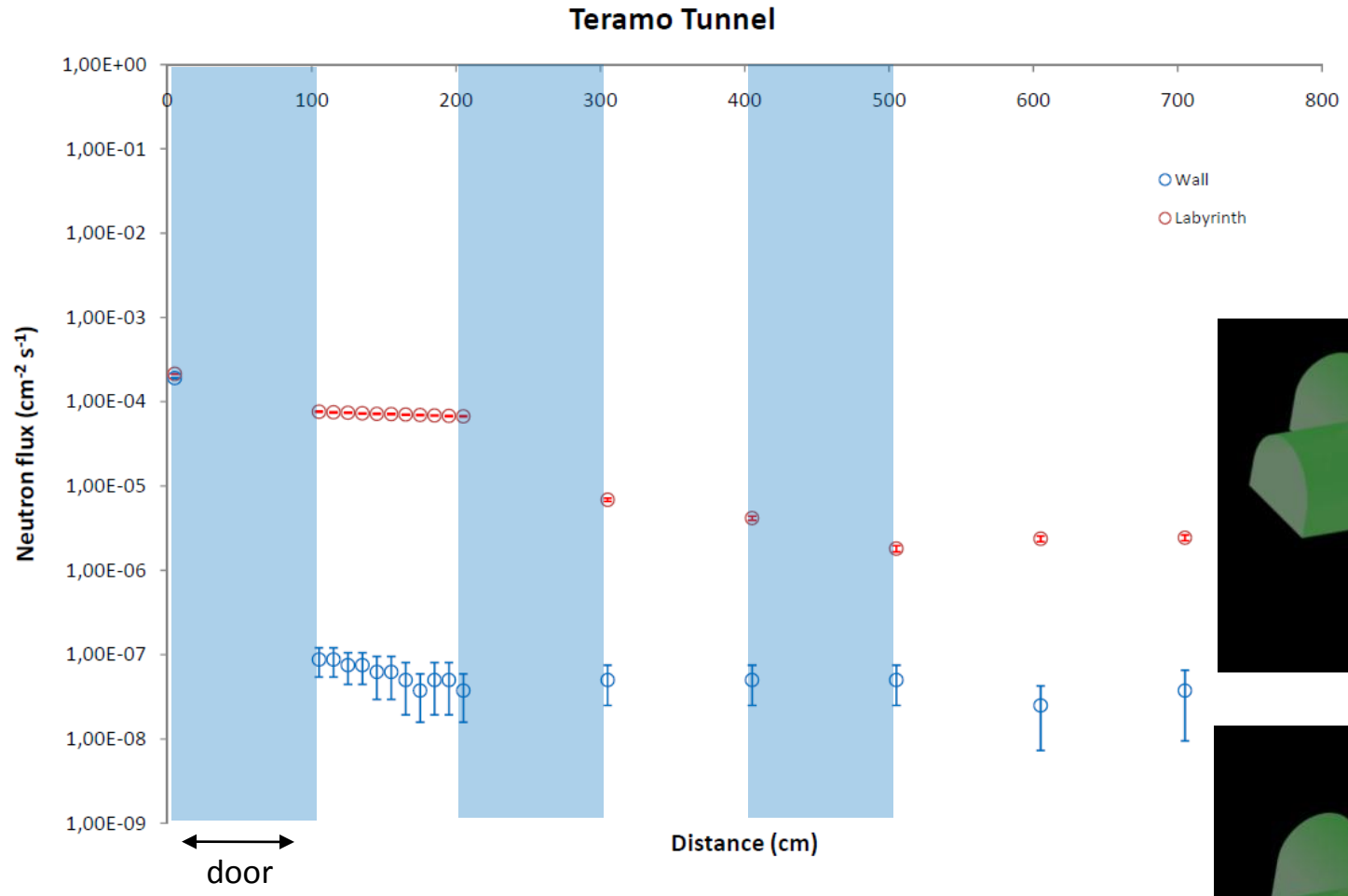
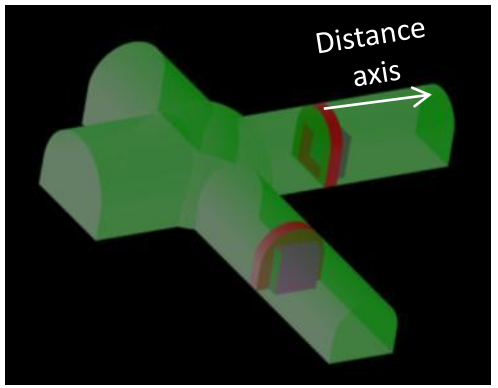
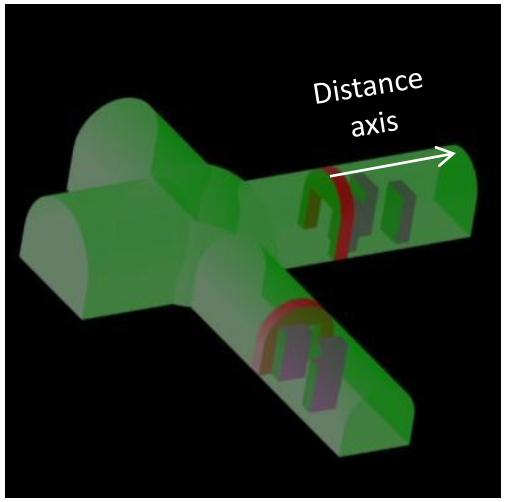




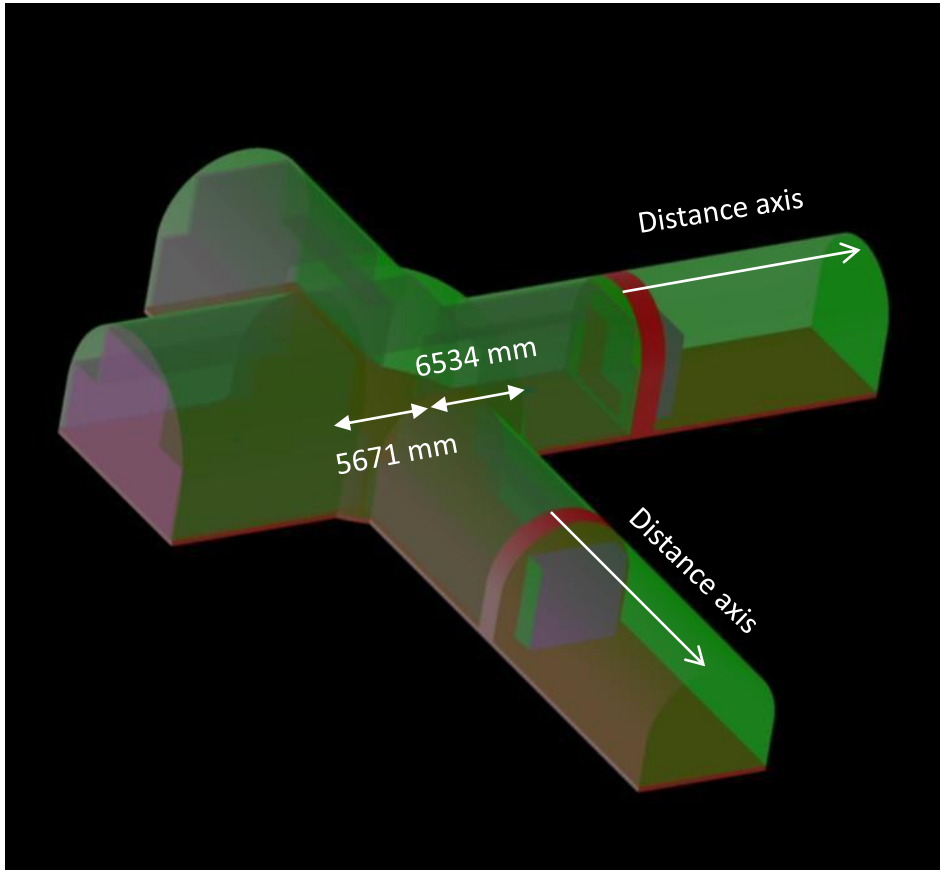


The Shielding of the LUNA-MV site

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 m^2)
- Increase the statistics from 1M to 4M events;



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The Shielding of the LUNA-MV site

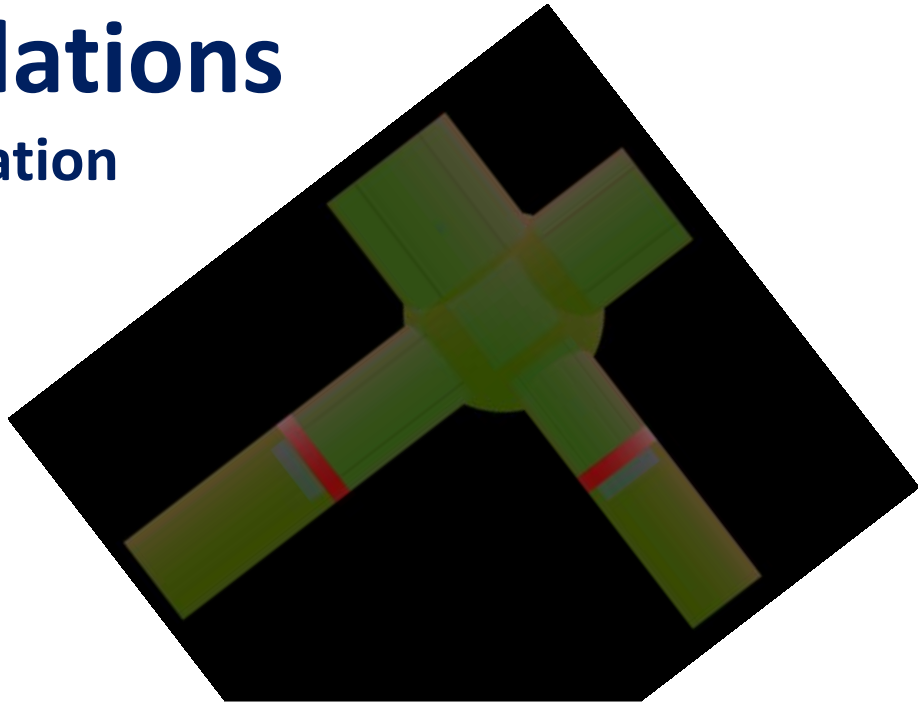
Monte Carlo Simulations

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 ($Ca_2 B_6 O_{11} 5H_2O$)
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 m^2)
  - Monte Carlo minimum flux detectable: 3.125 10^{-9} $cm^{-2}s^{-1}$

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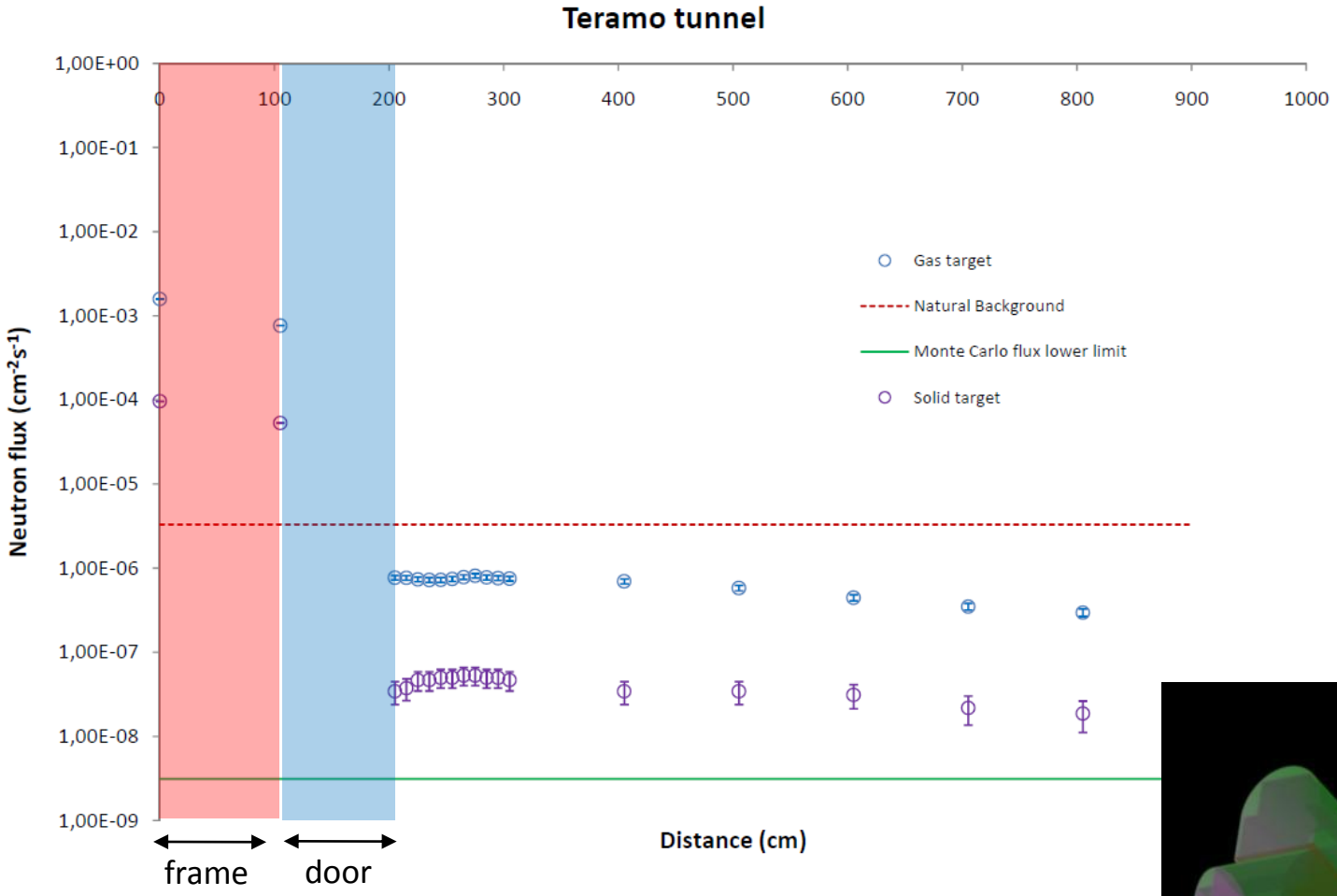

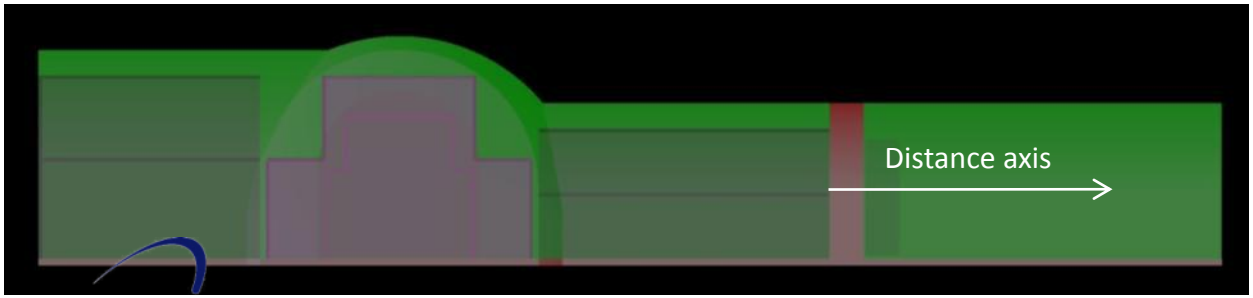

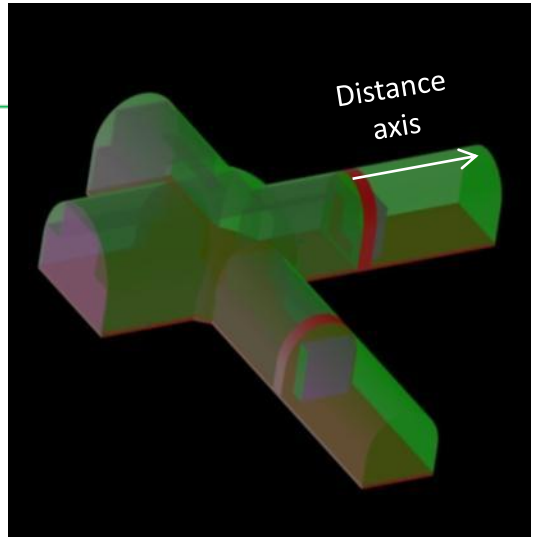

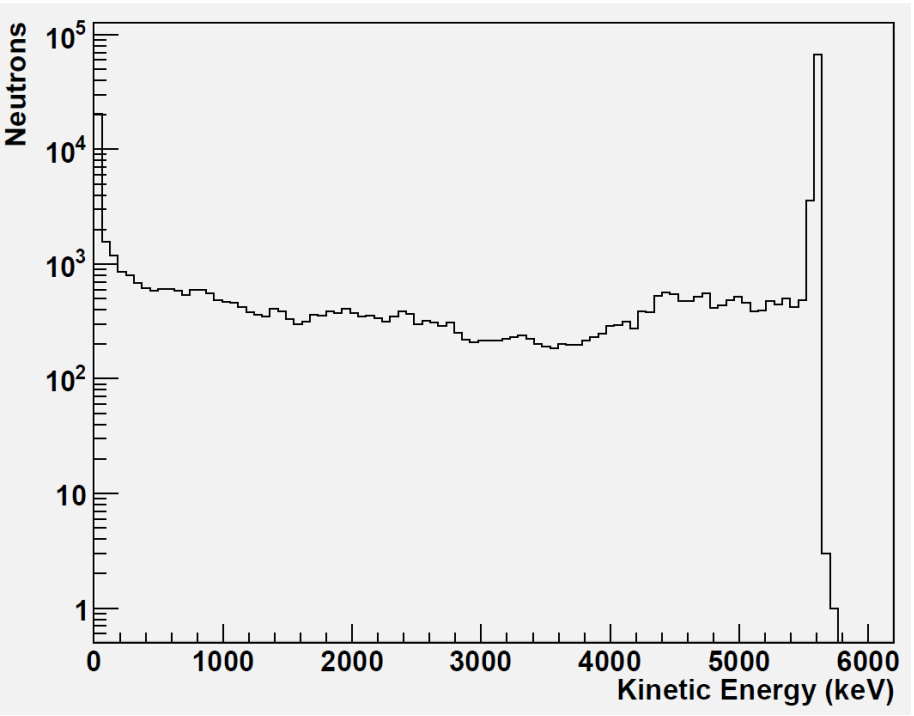

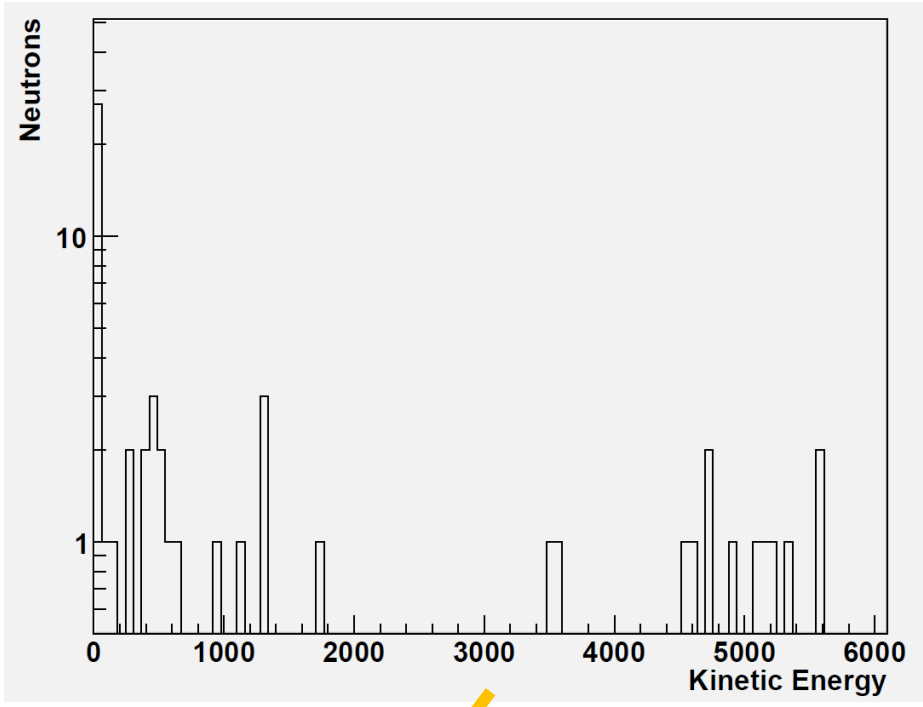

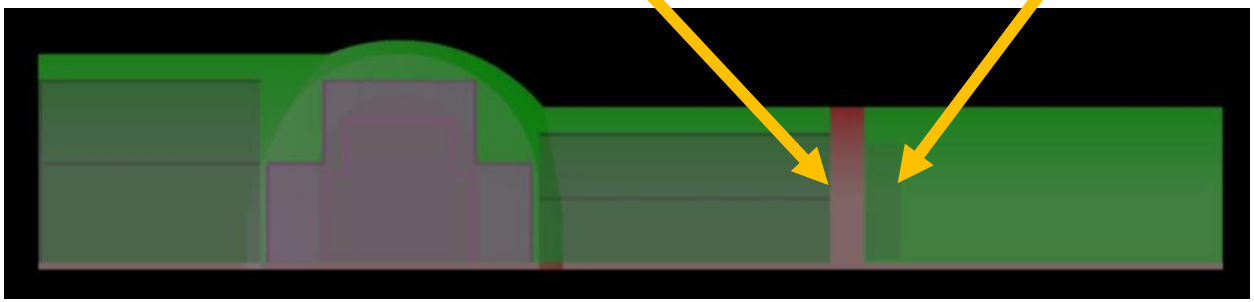

Simulation for gas target on

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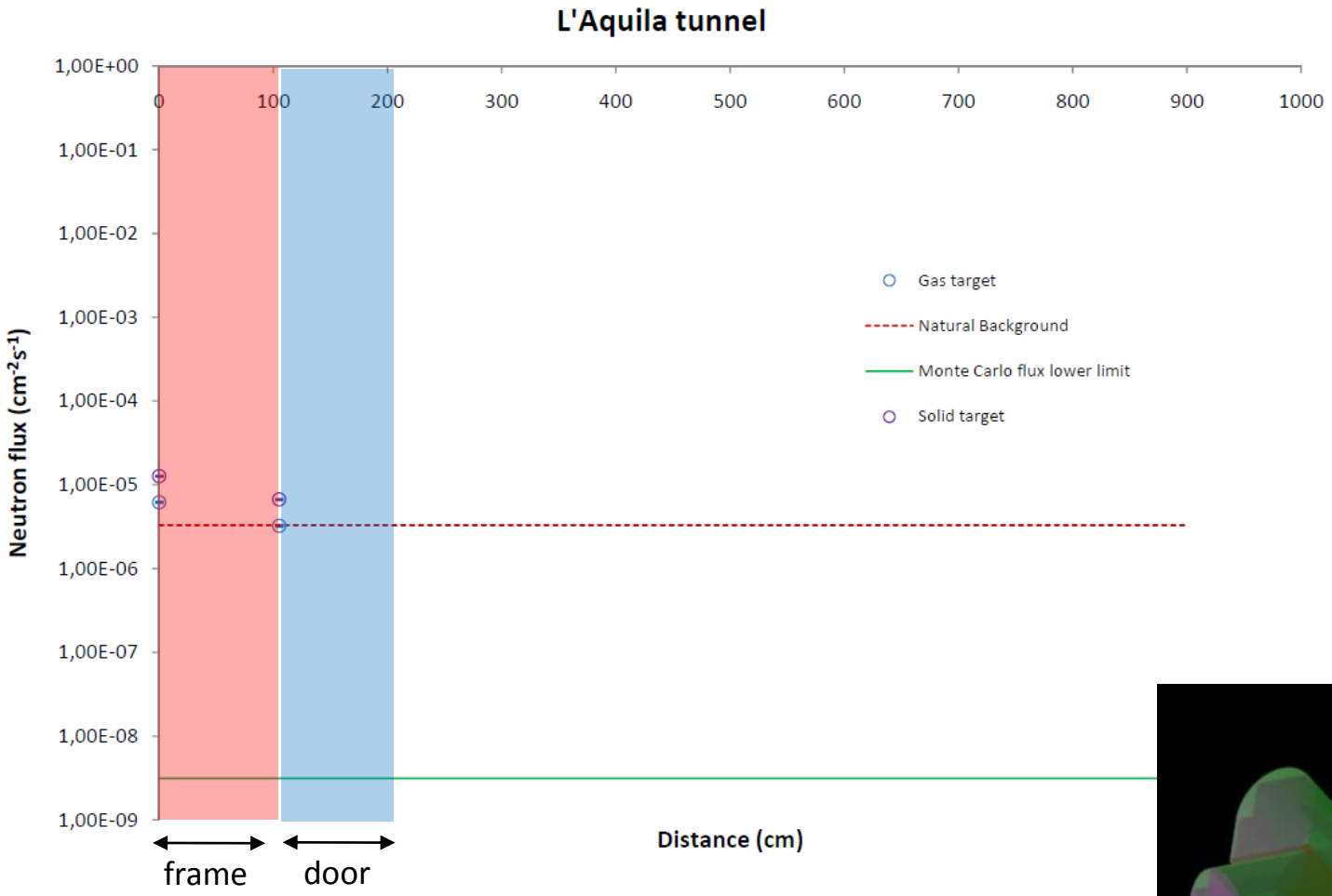

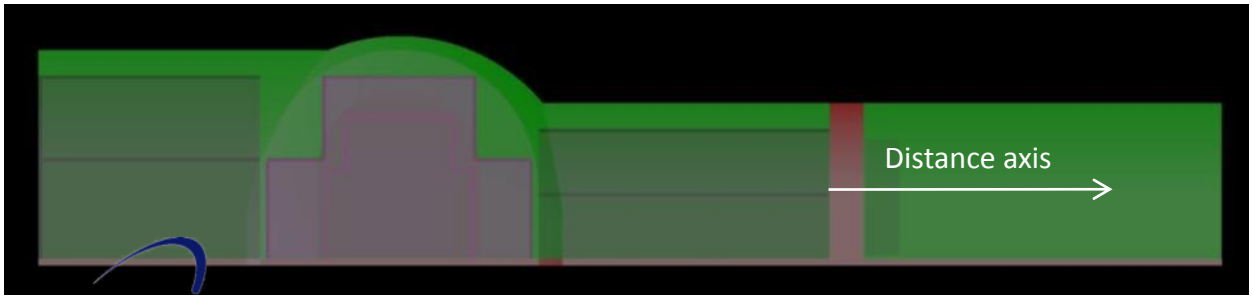

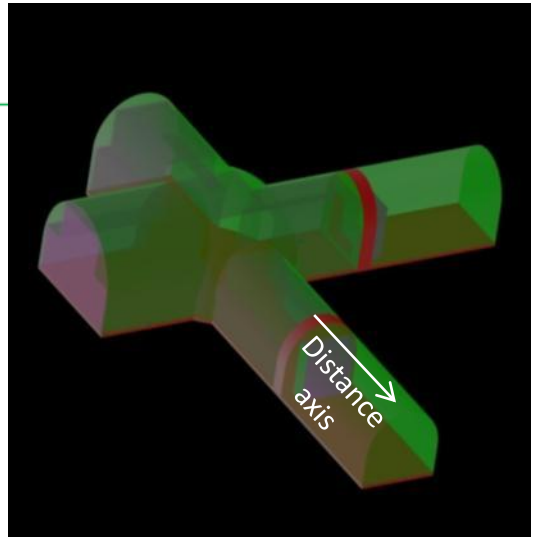

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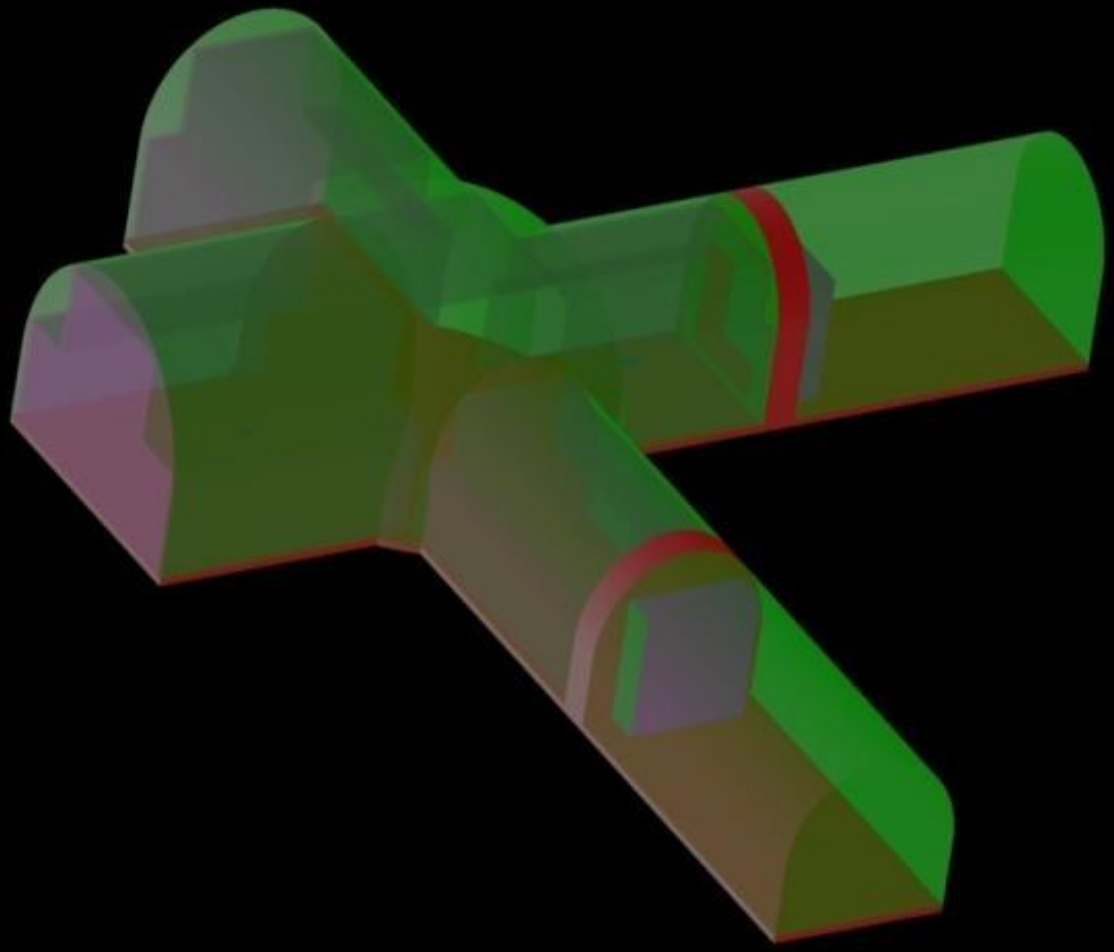

Mean ceiling flux*:
$3.75\ 10^{-9}\ cm^{-2}\ s^{-1}$

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

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

* Fluxes are calculated at 1 m inside the rock

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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)

Thank you for your attention…

Thanks to Bruno Dulach and Paolo Martella

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The Shielding of the LUNA-MV site

References

Geant4 simulation tools: http://www.geant4.org/
Lemmo’s nuclear astrophysics Simulation Code: alemut@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
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