Rayleigh scattering impact on light attenuation due to Cathode and Ground Grid

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WA105 SB Meeting

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Laboratoire d'Annecy-le-Vieux
de Physique des Particules

Introduction

At last SB meeting (3 May 2017):

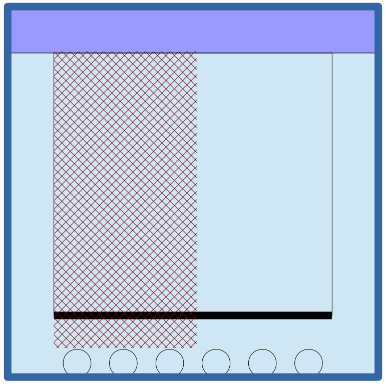
Interrogations about the difference between:

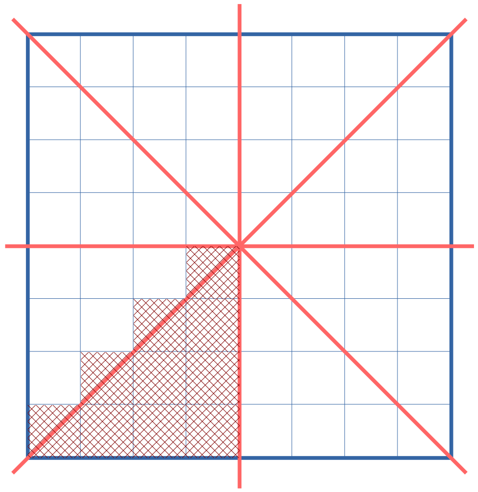
- Light **attenuation** due to the cathode obtained with **LightSim**
- Cathode + Structure **geometrical coverage**

→ Is this difference linked to the Rayleigh scattering?

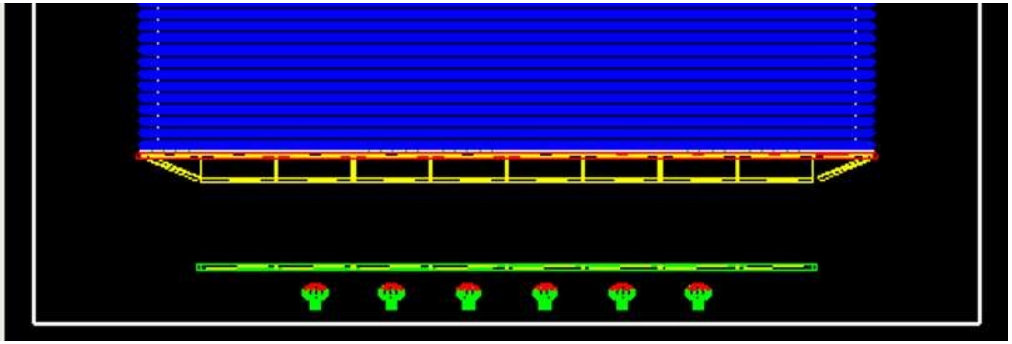
Reminder: **Method** for the different studies

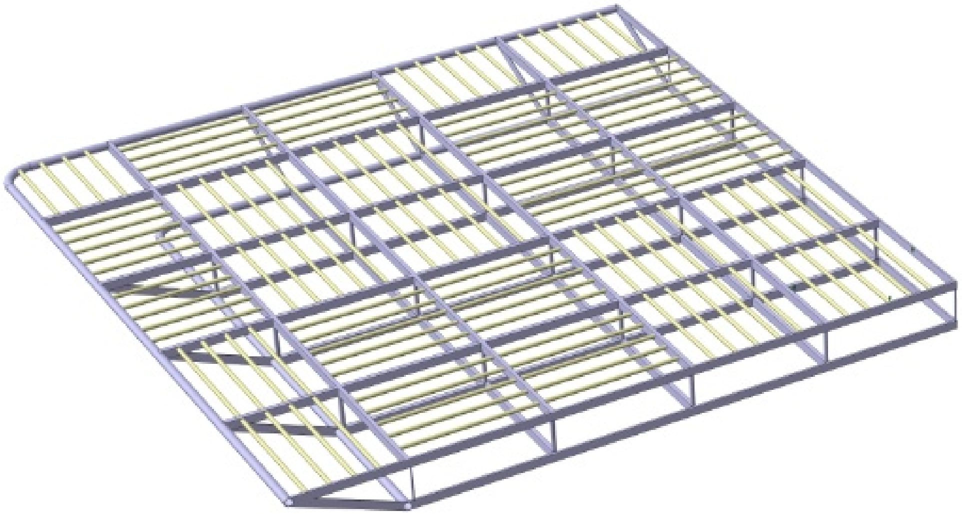
- Generation of photons at **different points** of the detector.
- For each production point, computation of the **probability to reach the PMT**

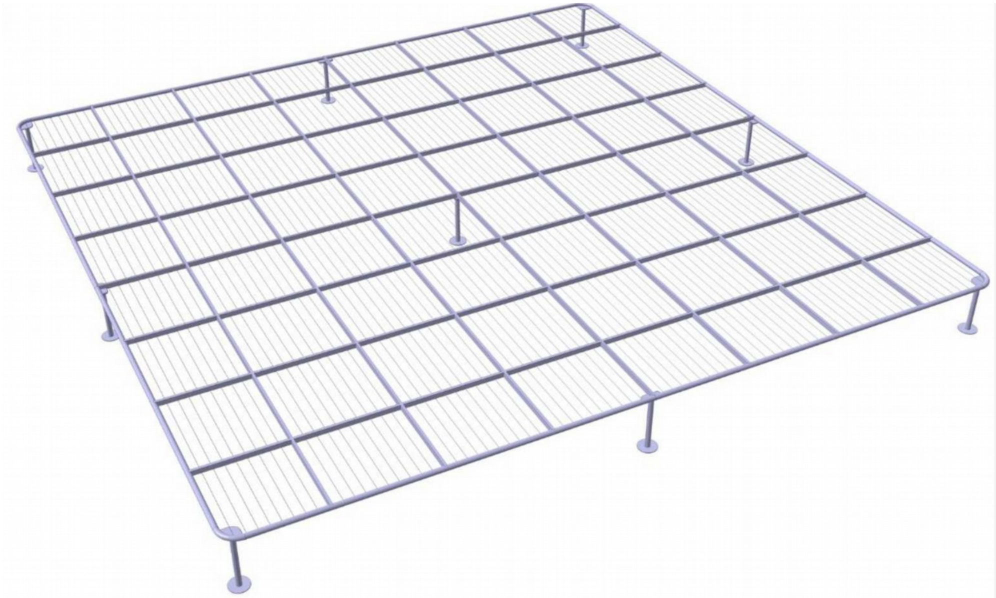




Cathode pipes, supporting structure, and ground grid







Cathode pipes: **20mm** diameter

Supporting structure:

- Rectangular Tube: **(40x20x2)mm³**
- Border tubes: **40mm** diameter

Ground grid:

- Same design as **cathode supporting structure**
- **2mm-diameter** wires

Impact on light collection (with $\lambda_{Rayleigh} = 55cm$)

Reminder: for scintillation photons, total absorption on stainless-steel.

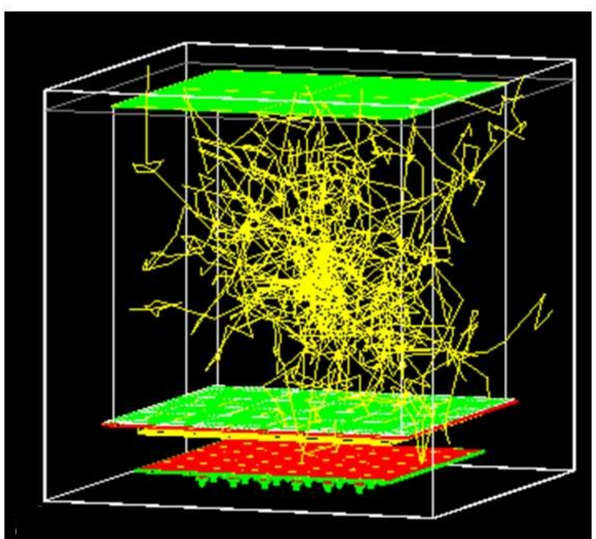
From previous talks (WA105 SB Meeting), loss of:

- 60% of collected photons on cathode pipes + supporting structure (7 December 2016)
- 25% of collected photons on ground grid (8 February 2017)

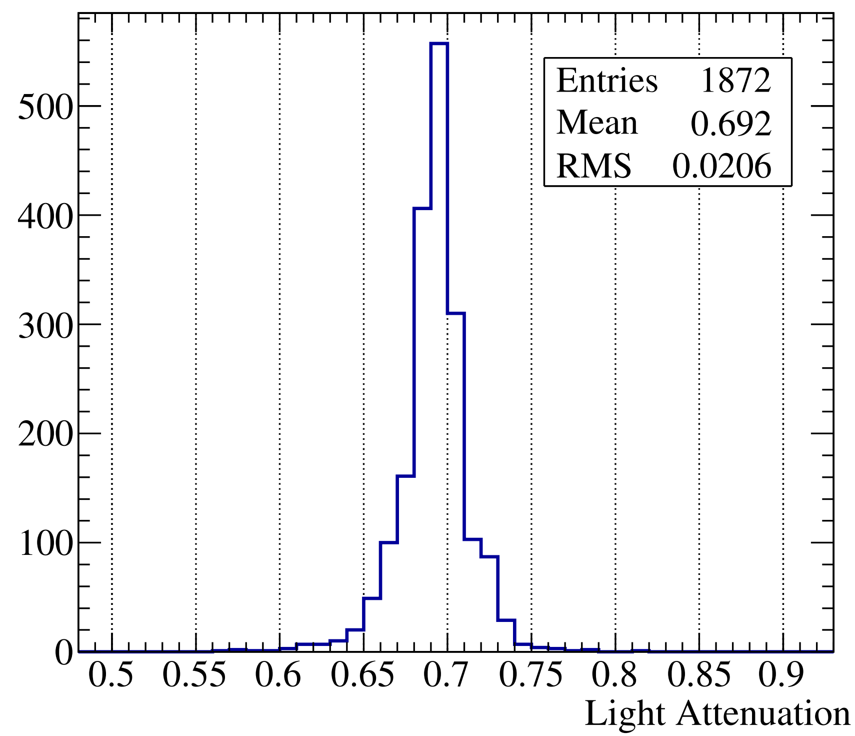
→ Attenuation of 70% due to cathode+structure+ground grid

Alessandra's talk (WA105 SB Meeting, 3 May 2017)
Geometrical coverage of cathode+structure ~20%

→ Could this difference be explained by the Rayleigh scattering ?



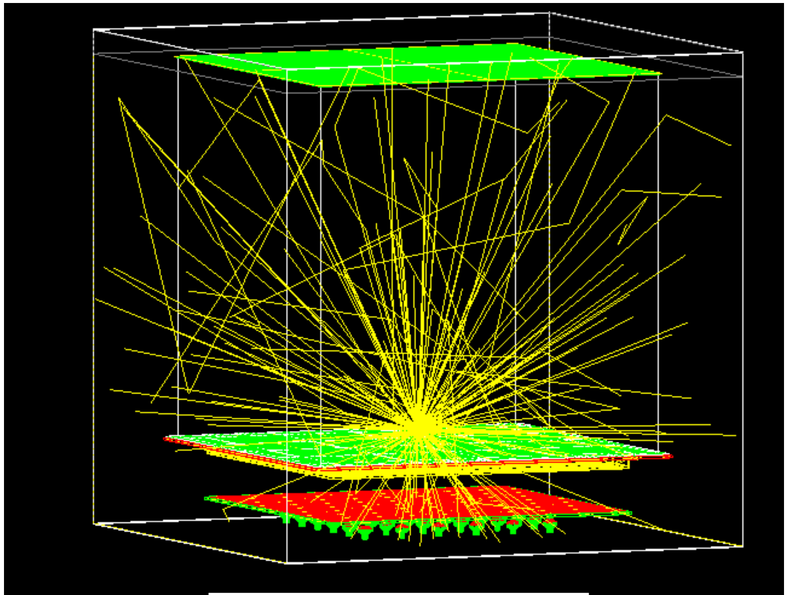
Distribution of the attenuation for different photon production points



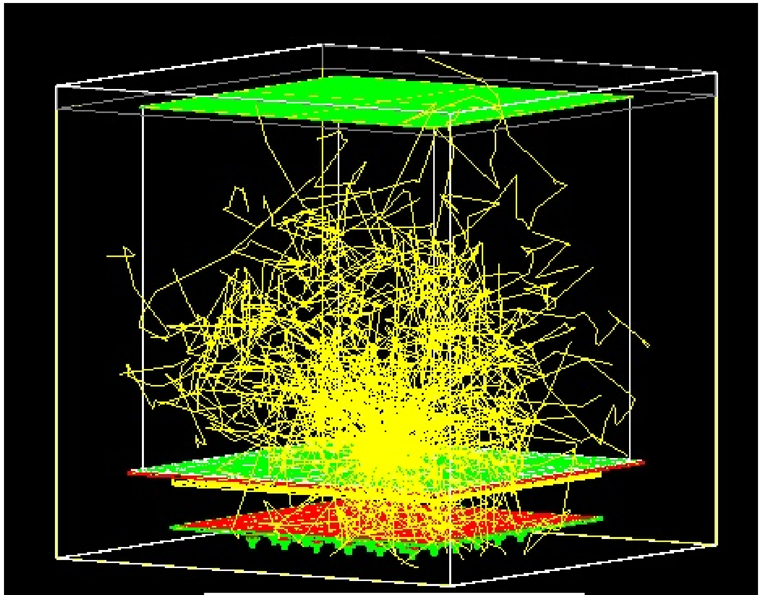
Rayleigh scattering

In LightSim, $\lambda_{Rayleigh} = 55cm$

→ Important impact on the **photon** trajectories



$\lambda_{Rayleigh} = 200m$



$\lambda_{Rayleigh} = 55cm$

To **evaluate** this effect on light attenuation:

Same study (comparison after/before cathode+structure+ground grid implementation) in the absence of Rayleigh scattering

Geometrical coverage (estimation)

- Cathode pipes:

  ~40 pipes of **20mmx6000mm** + 8 pipes of **20mmx6000mm** → 5.76m²

  → Geometrical coverage ~16%

- Cathode supporting structure:
  - Upper frame: ~22 tubes of **20mmx6000mm** → 2.64m²

    → Geometrical coverage ~7%

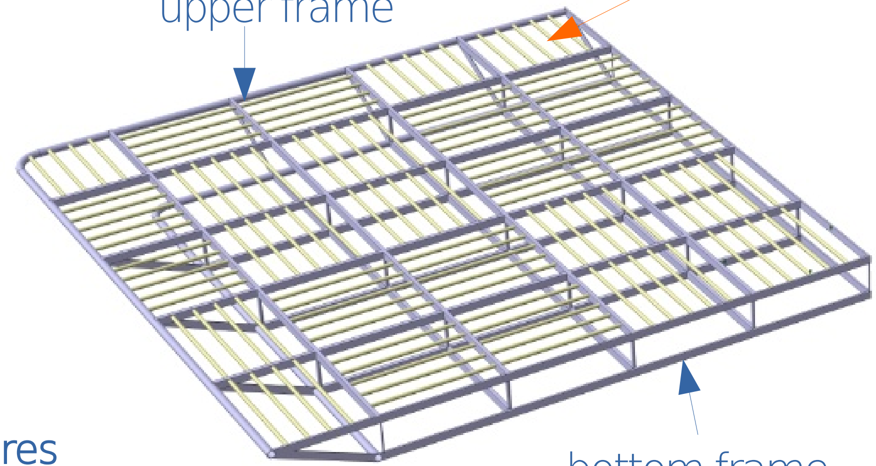
  - Bottom frame: 18 tubes of **20mmx5000mm** → 1.80m²

    → Geometrical coverage ~5%

- Ground Grid:

  Same design as supporting **structure** + 2mm-diameter wires

  → Geometrical coverage ~8%



As the frames have the same design, vertical photons "see" the cathode **pipes**, the upper **frame** and the ground grid **wires**

→ Geometrical coverage ~20%

But photons have an isotropic distribution, they will "see" more matter (bottom frame and ground grid support), especially photons produced at low Z

→ The coverage can reach ~36%

Note: the diagonal and vertical tubes **connecting** the structure frames, the border tubes **diameter** (40mm instead of 20mm) and the **thickness** of the rectangular tubes (40mm) are **not taken into account**

Rayleigh scattering impact on light attenuation

P_{CGG} = Probability to reach the PMT array **after** the cathode and ground grid **implementation**

P_0= Probability to reach the PMT array **before** the cathode and ground grid **implementation**

$$\text{Attenuation} = 1 - \frac{P_{CGG}}{P_0}$$

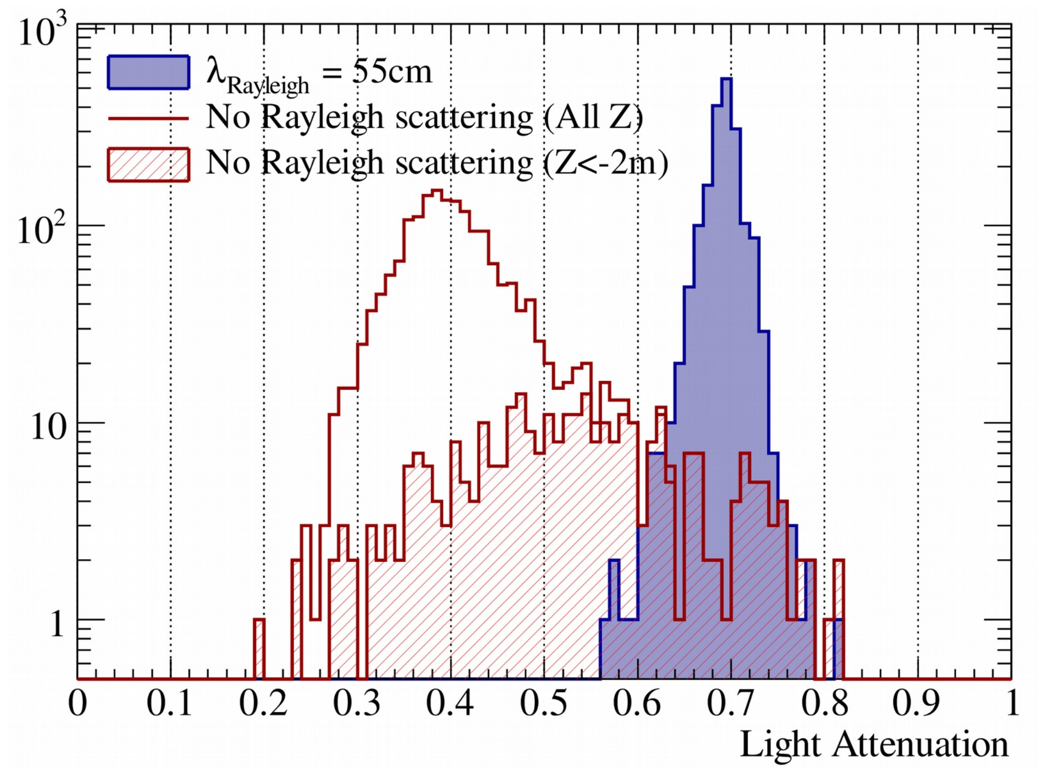
→ When there is **no** Rayleigh scattering, **mean attenuation**:

- Z > -2m: **0.40 ± 0.05**
- Z < -2m (low Z): 0.53 ± 0.12

(Z=0: center of the detector)

→ To be compared to **0.36** (geometrical coverage estimation)

Distribution of the attenuation for different photon production points



Reminder: for the **geometrical coverage** estimation, **we don't take into account:**

- **Diagonal** and **vertical** tubes connecting the 2 frames of the supporting structure
- Border tubes diameter (**40mm** instead of 20mm)
- **Thickness** of the rectangular tubes (40mm)

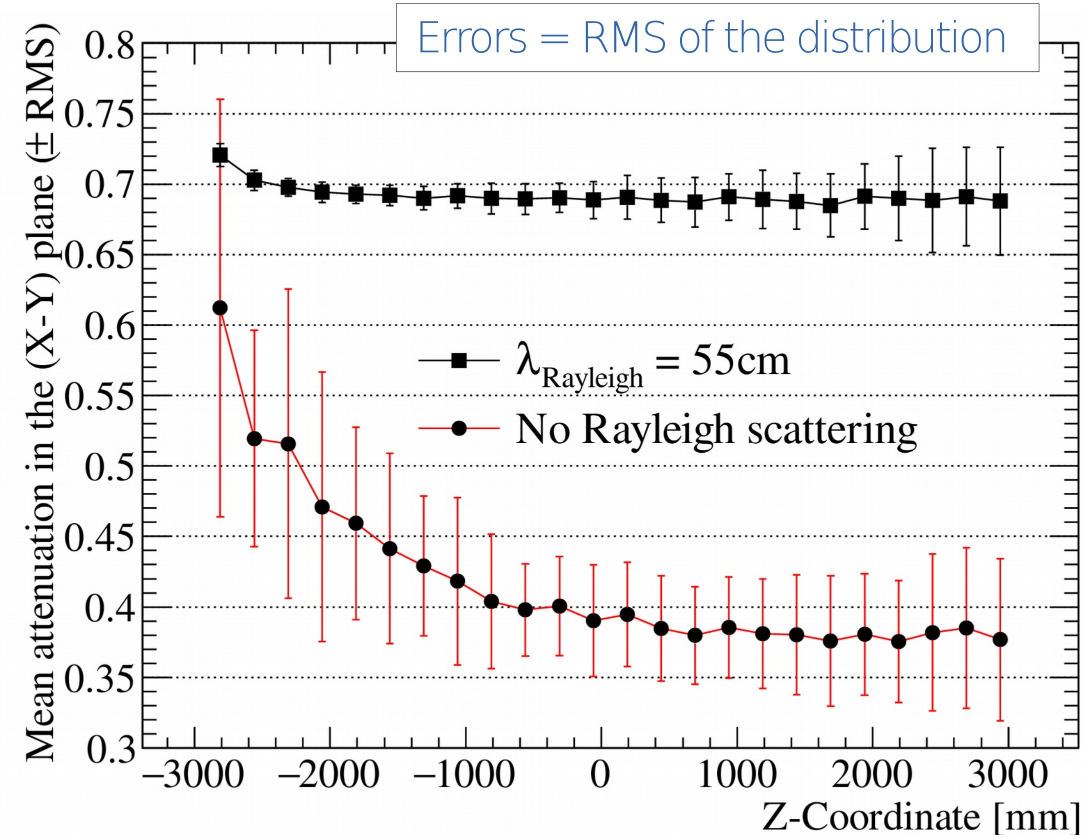
Z-Dependence of the attenuation

The attenuation depends on the **photons** production point.

To **evaluate** this effect:

- Computation of the attenuation distribution at different Z-coordinates
- Plot of the mean attenuation in each (X-Y) plane ± RMS of the distribution

- With $\lambda_{Rayleigh}$=55cm:
  - Attenuation ~0.69
- In the absence **of Rayleigh scattering**:
  - The light **attenuation** is **lower**
  - The dependence to **X and Y coordinates increases**, specially for low Z (the RMS can reach 25%)
  - For high Z, attenuation ~0.38



Conclusion

- In the absence of Rayleigh scattering, the attenuation is **consistent** with the geometrical coverage estimation.
- In the presence of Rayleigh scattering, the light attenuation **due to cathode + supporting structure + ground grid** increases from ~40% to ~70%

BACK-UP

Z Dependence of the attenuation

Errors: RMS of the distribution