Optimization of scintillator-fibre coupling for future detectors using GEANT4

Mafalda Nunes (Faculdade de Ciências da Universidade de Lisboa);
Miguel Lameiras (Escola Secundária Luís de Freitas Branco);
Rudnei Machado (Faculdade Anhanguera Joinville - Brazil)

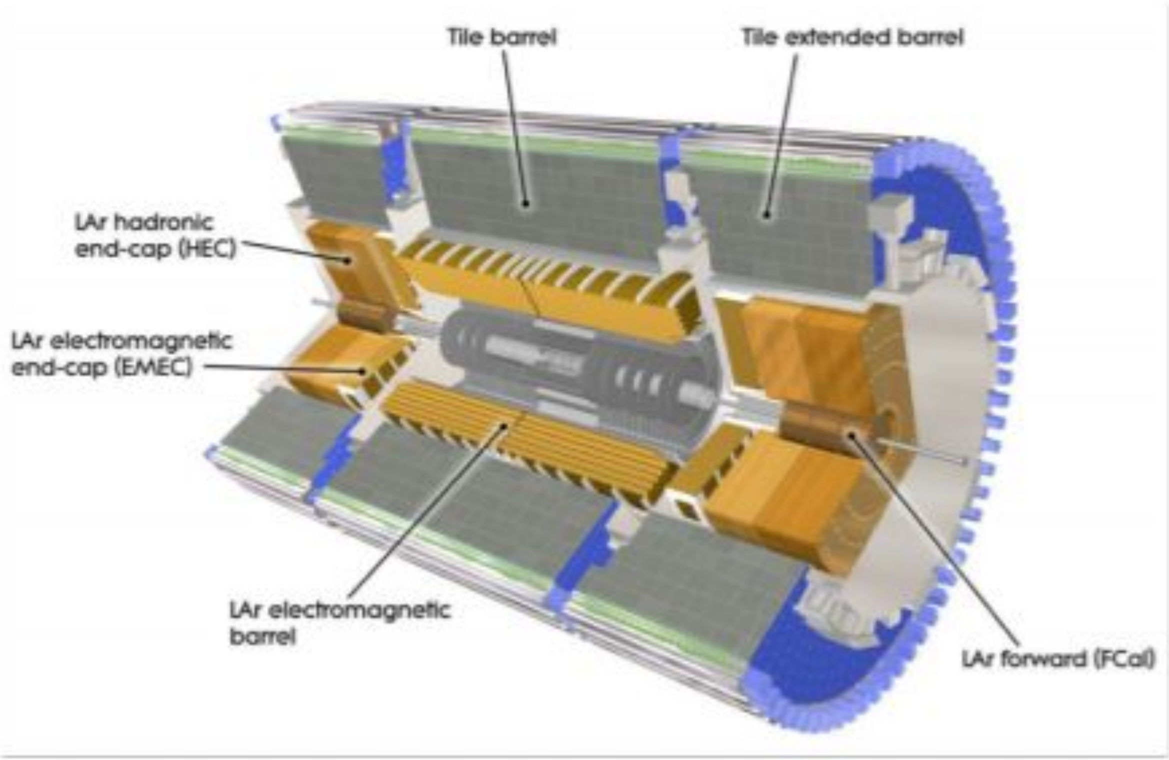
Supervisors: Ana Luisa Carvalho (LIP), Joao Gentil Saraiva (LIP)

OUTLINE

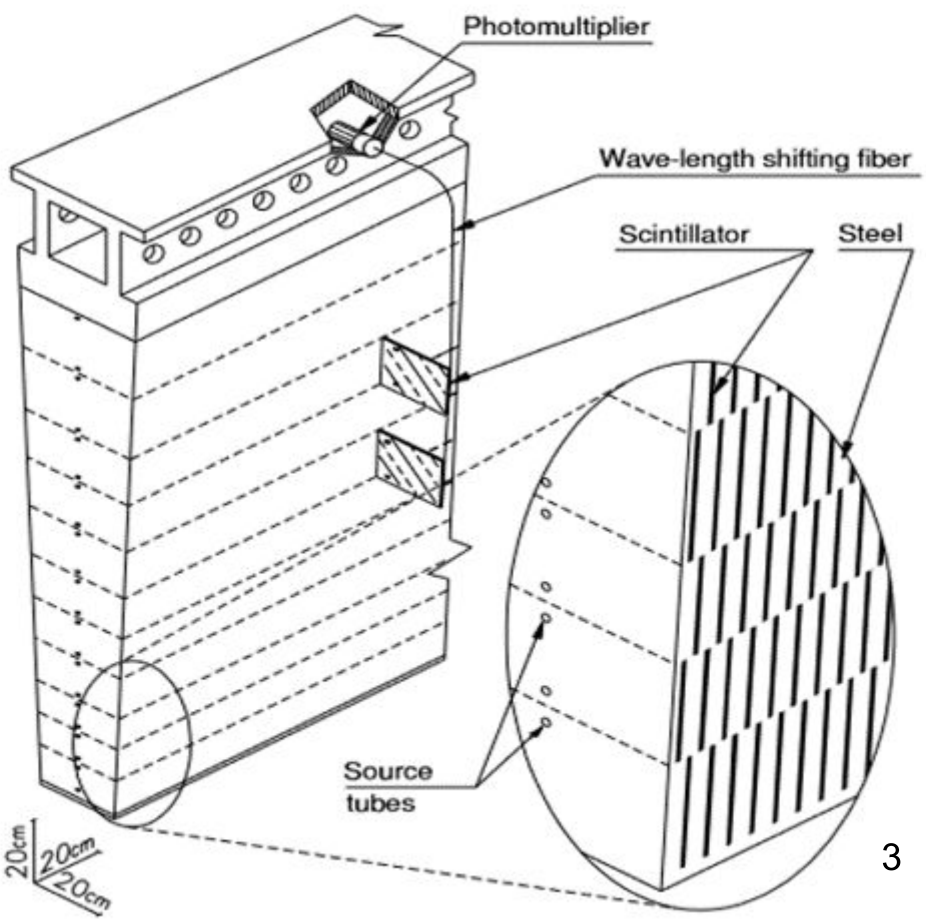
- Simulation Elements (Rudnei)
- Coupling fiber-tile (Rudnei)
- Tyvek Wrapper (Mafalda)
- Validating the Simulation (Miguel)

THE ATLAS TILE CALORIMETER (TILECAL)

[1] ATLAS Diagram



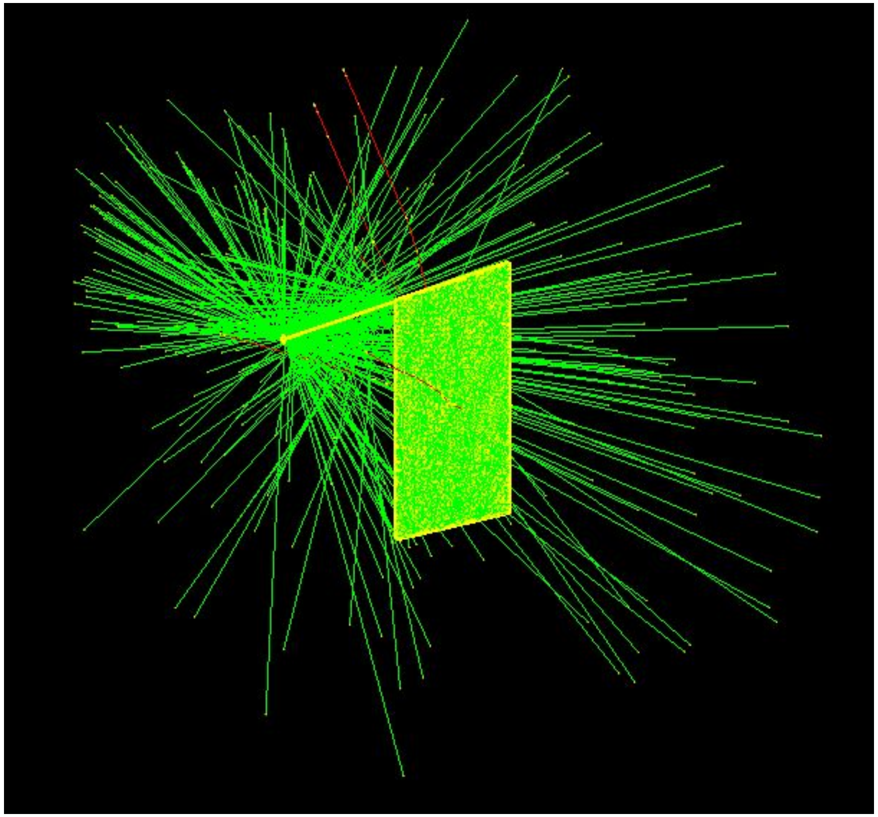
[2] ATLAS Hadronic Calorimeter



THE GOAL OF THIS PROJECT

- Validate the simulation of the experimental setup of a scintillator tile readout by a WLS optical fiber that exists at LOMaC/LIP;

- Simulation was developed by Ana Luisa Carvalho and Diogo Bastos during a course at IST;

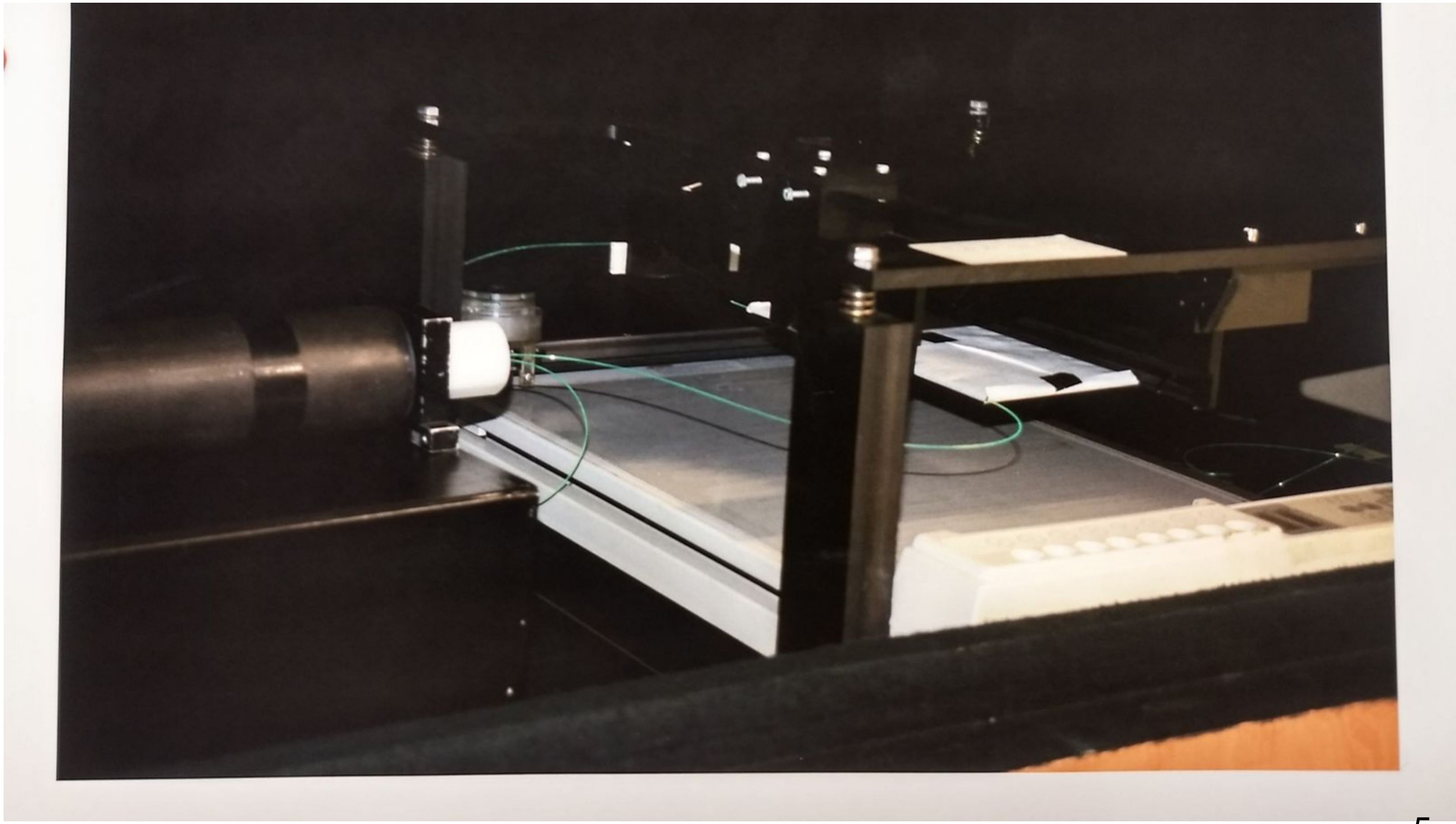


[3] GEANT4 simulation

Geant4 Simulation

- A small testing setup reproducing the same detection principle exists at LOMaC/LIP and its Geant4 simulation recently became available.

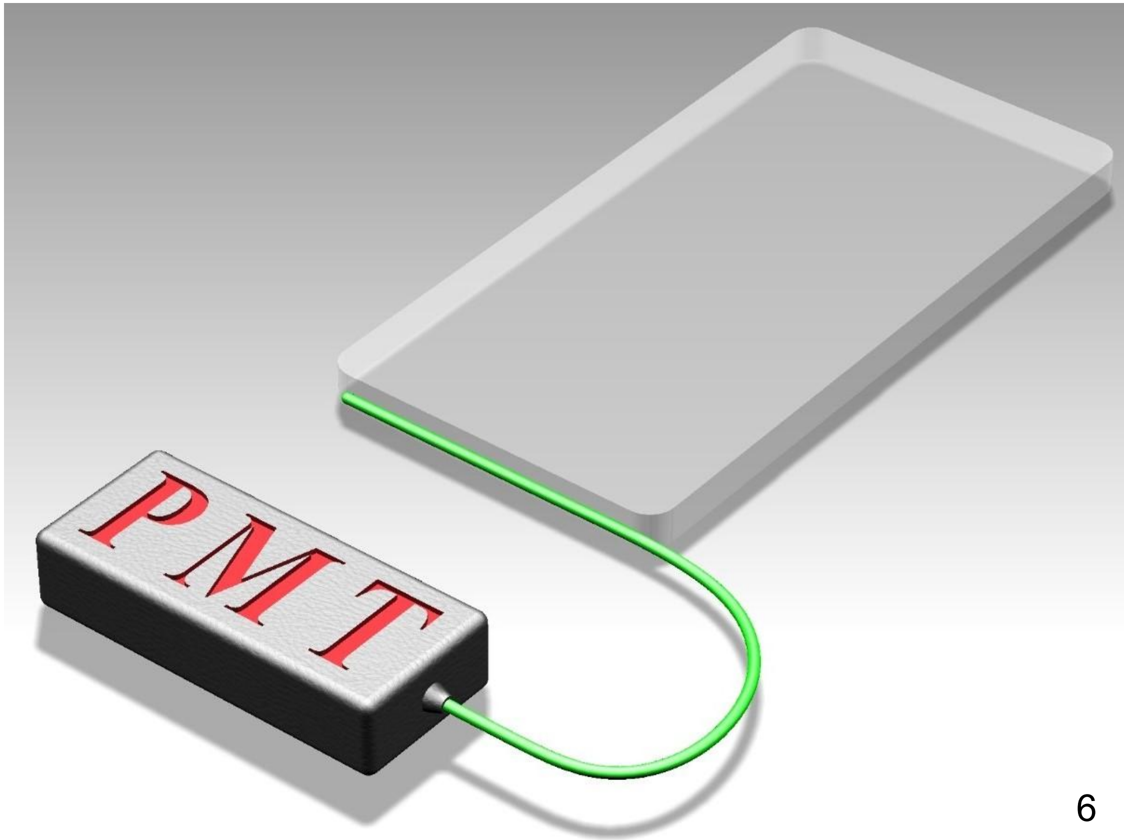
[5] LOMAC lab - Tilemeter



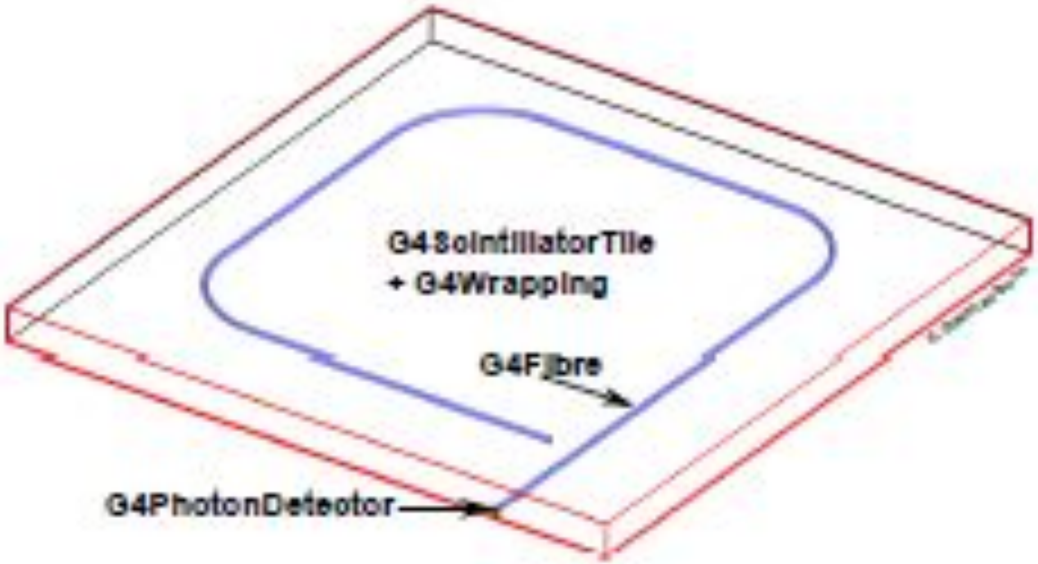
PHYSICS SIMULATIONS - GEANT4

- The geometry;
- The materials and their properties;
- Event;

[4] Initial coupling tile - fiber - PMT



Initial idea

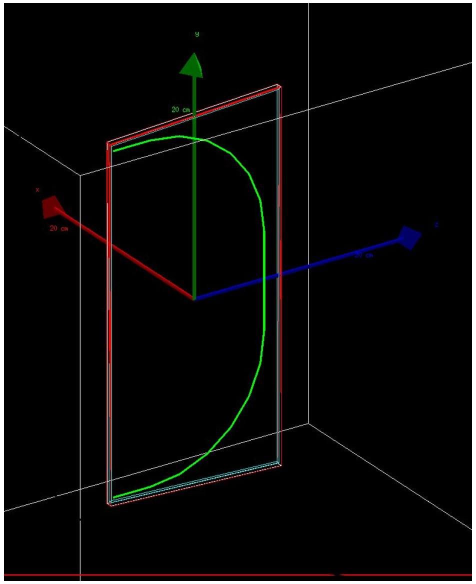


Curvature radius cannot be less than 10 cm.

Not possible for simulated tile size.

[6] Coupling in sigma

Second Coupling

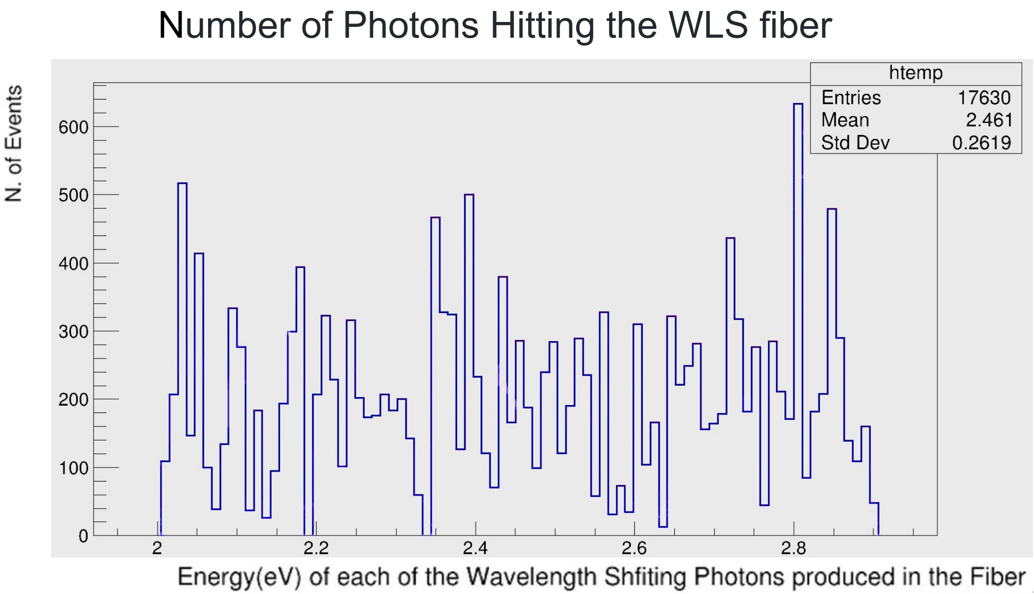


[7] Coupling in form of “U”

[8] Program lines to produce the curved parts of the fiber and the straight parts.

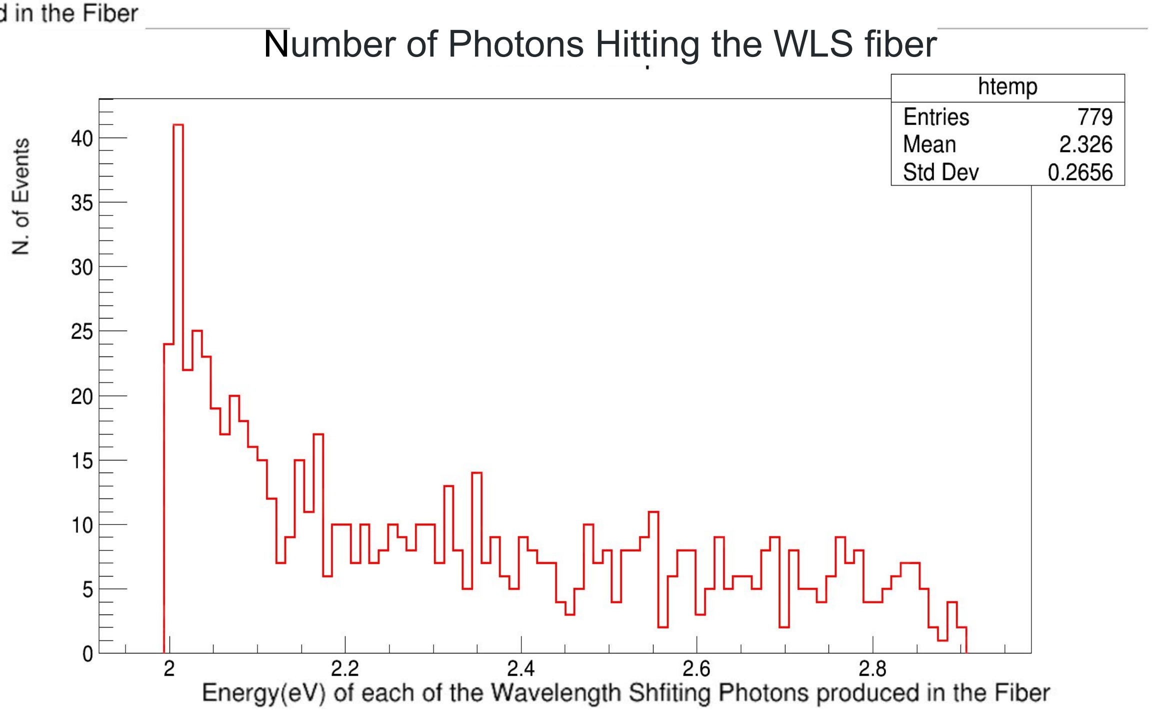
```
G4Tubs *fiber1_sigma = new G4Tubs("fiber1_sigma",0.,diam_in/2,1.6*cm,0.,2*M_PI);
G4LogicalVolume *fiber1_sigma_vol = new G4LogicalVolume(fiber1_sigma,polystyrene,"fiber1_sigma_vol");
G4VPhysicalVolume *fiber1_sigma_phy = new G4PVPlacement(0,G4ThreeVector(-2.0*mm,14.0*cm,-5.6*cm),fiber1_sigma_vol,"fiber_top", air_vol,false,0,checkOverlaps);
fiber1_sigma_vol->SetVisAttributes(new G4VisAttributes(G4Color::Green()));

G4Tubs *fiber2_sigma = new G4Tubs("fiber2_sigma",0.,diam_in/2,4.0*cm,0.,2*M_PI);
G4LogicalVolume *fiber2_sigma_vol = new G4LogicalVolume(fiber2_sigma,polystyrene,"fiber2_sigma_vol");
G4VPhysicalVolume *fiber2_sigma_phy = new G4PVPlacement(fiber_rot2,G4ThreeVector(-2.0*mm,0.,6.0*cm),fiber2_sigma_vol,"fiber_top", air_vol,false,0,checkOverlaps);
fiber2_sigma_vol->SetVisAttributes(new G4VisAttributes(G4Color::Green()));

G4VPhysicalVolume *fiber3_sigma_phy = new G4PVPlacement(0,G4ThreeVector(-2.0*mm,-14.0*cm,-5.6*cm),fiber1_sigma_vol,"fiber_top", air_vol,true,1,checkOverlaps);



// Creation of the Torus that attached to the fibers in the corners.

G4RotationMatrix *torus_rot1 = new G4RotationMatrix();
torus_rot1->rotateX(0.);
torus_rot1->rotateY(0.5*M_PI);
torus_rot1->rotateZ(0.);

G4RotationMatrix *torus_rot2 = new G4RotationMatrix();
torus_rot2->rotateX(0.);
torus_rot2->rotateY(0.5*M_PI);
torus_rot2->rotateZ(0.5*M_PI);
```

RESULTS



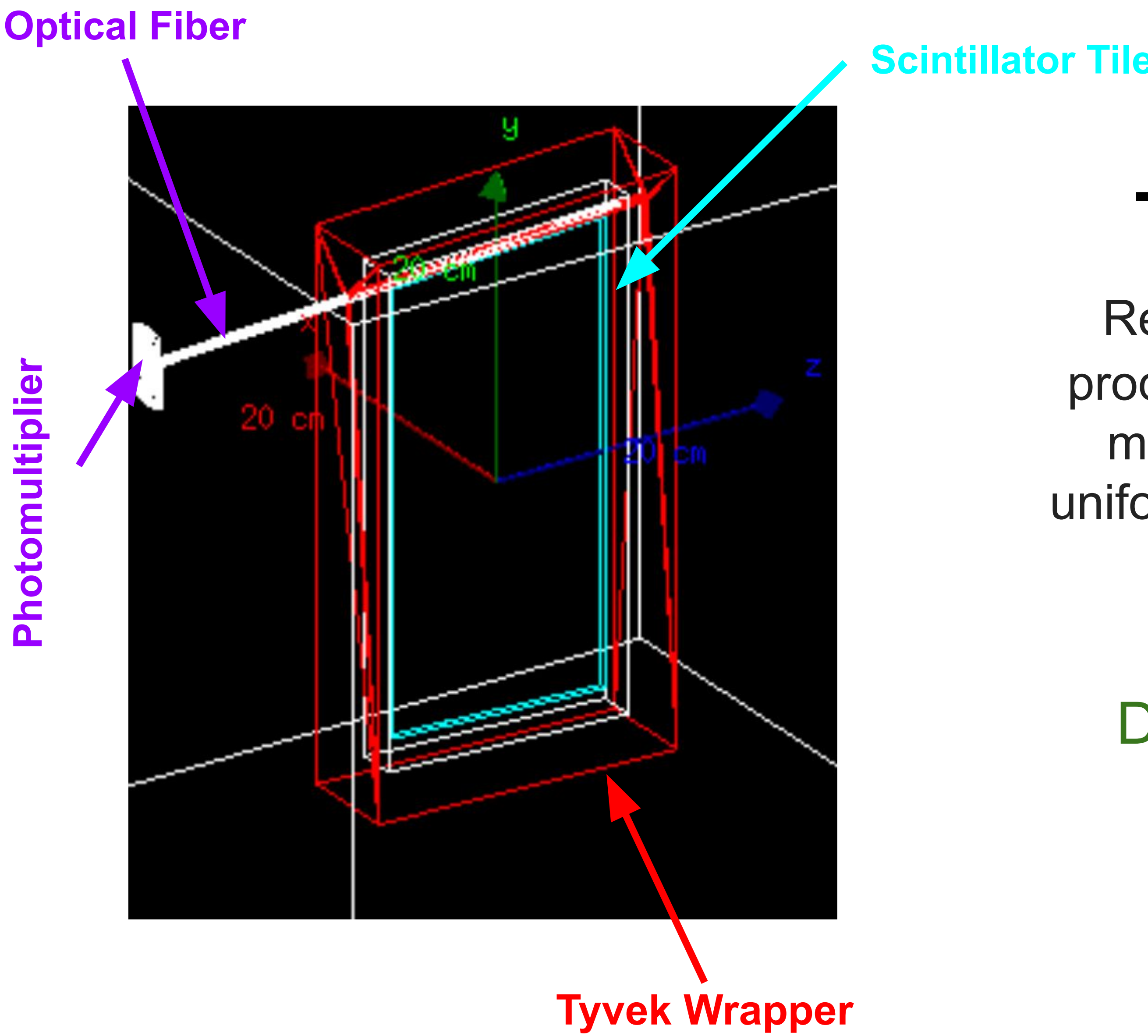
Expected result

Result obtained



N. of Events

What happens if we remove the Tyvek Wrapper

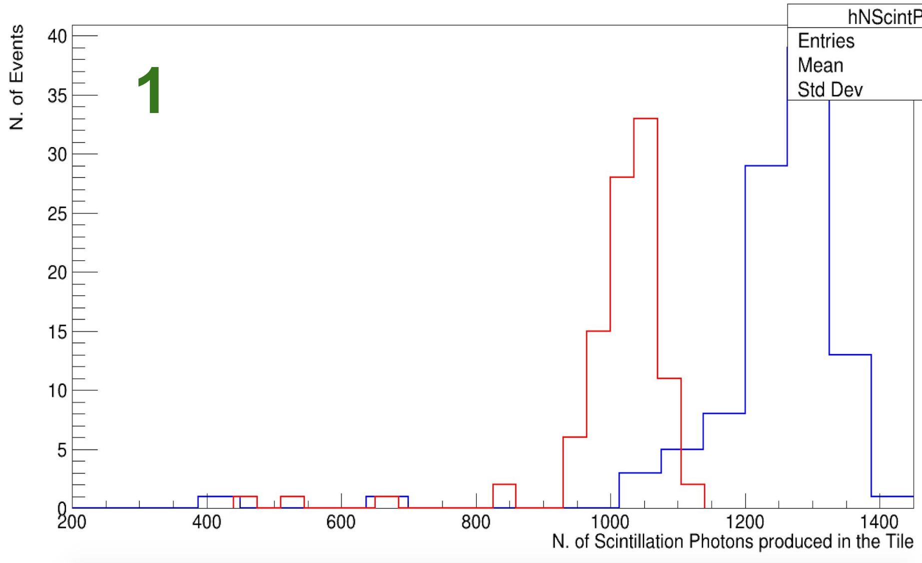


Tyvek Wrapper

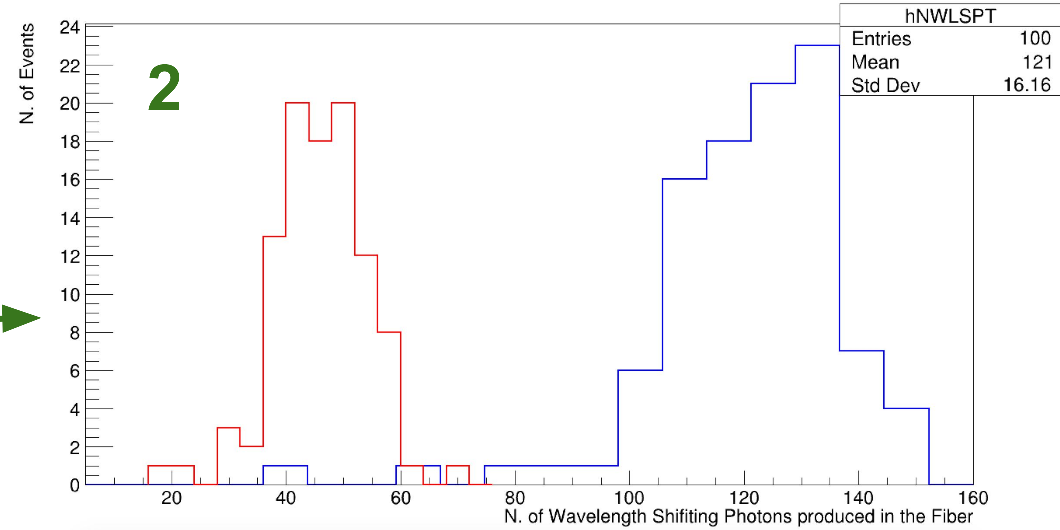
Reflect the scintillation photons produced by the tile in order to maximize and increase the uniformity of the light collection.

Note:
Dimensions are being exaggerated

Number of Scintillation Photons produced in the Tile With Tyvek and Without Tyvek for 100 events



Number of Wavelength Shifiting photons produced in the Fiber With Tyvek and Without Tyvek for 100 events



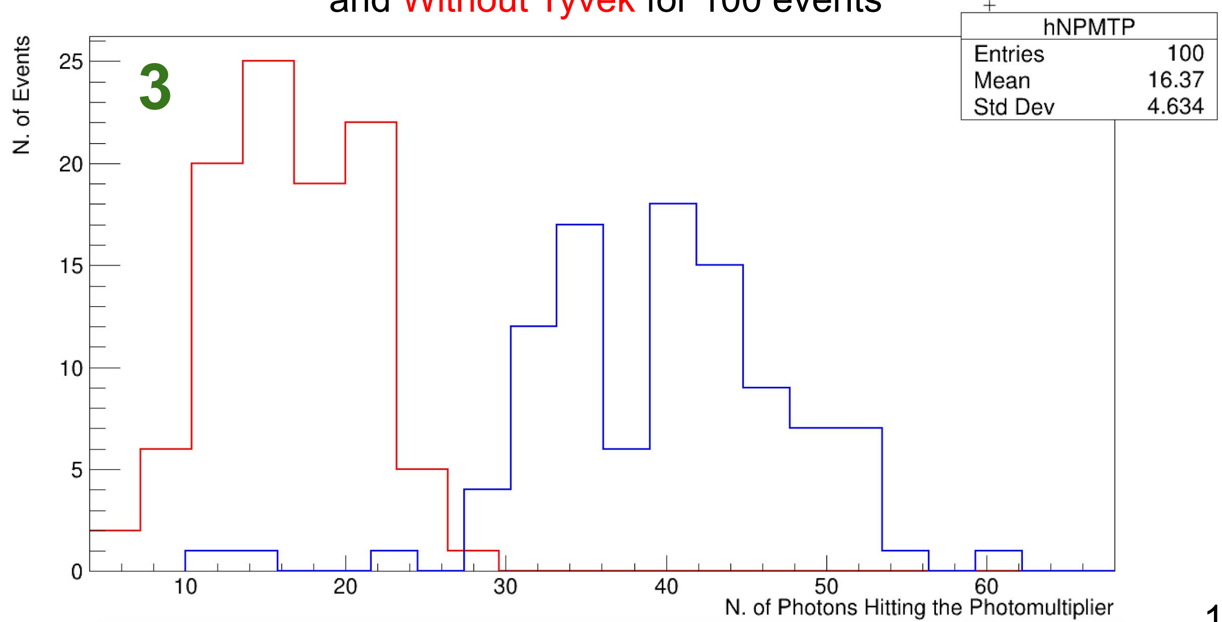
There is a greater production of Scintillation Photons With Tyvek and as a consequence the fiber absorbs more Scintillation Photons and produces more Wavelength Shifiting Photons.

Therefore more Wavelength Shifiting Photons hit the Photomultiplier.

<u>Why this happens?</u>

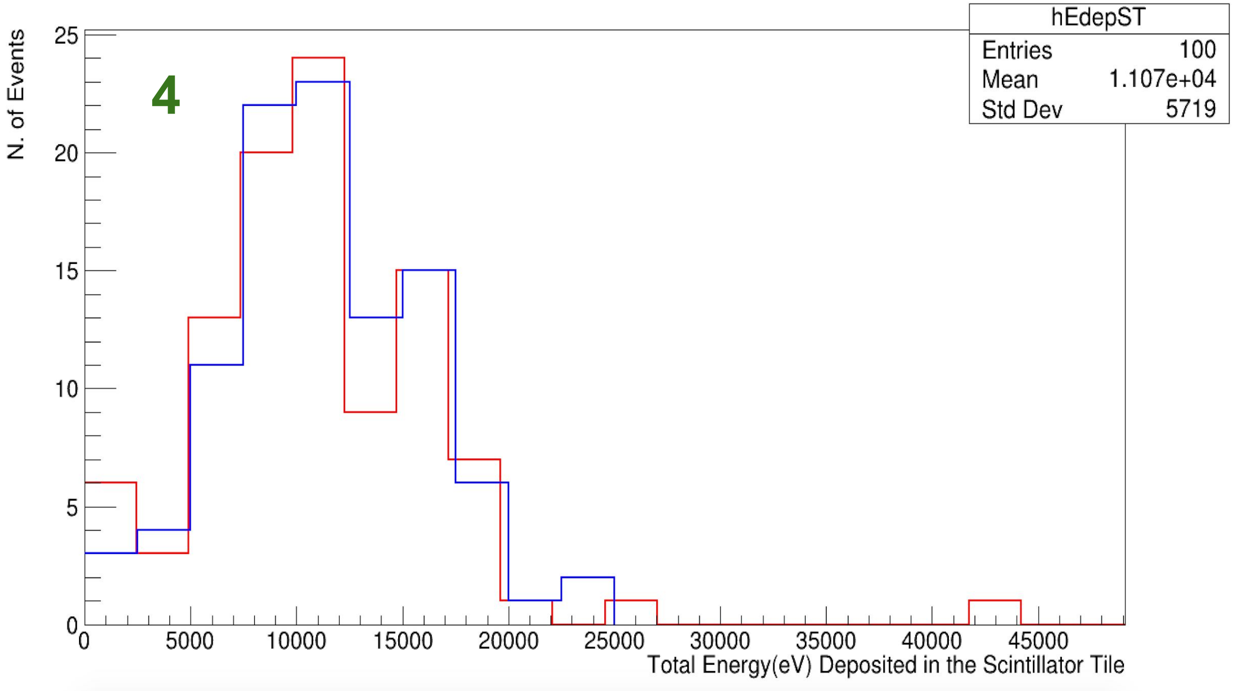
Because of Reflective properties of tyvek.

Number of Photons Hitting the Photomultiplier With Tyvek and Without Tyvek for 100 events



Note: The mean Photons value is decreasing

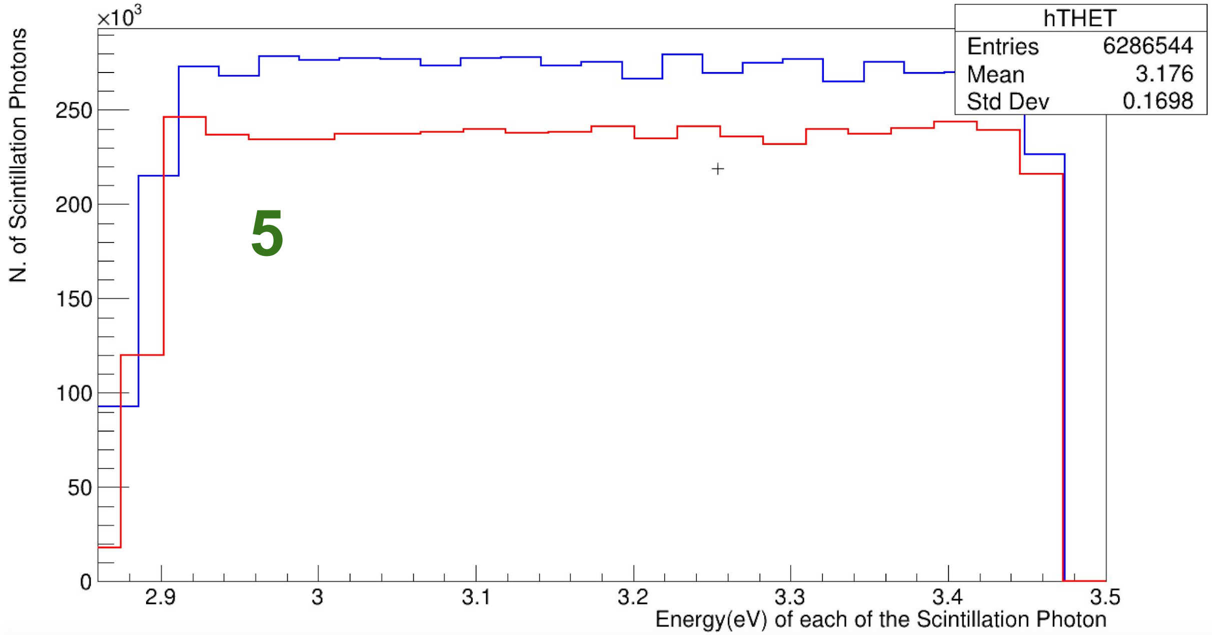
Total energy in eV deposited in the scintillator tile With Tyvek and Without Tyvek for 100 events



Only part of the electron energy is deposited in the tile.

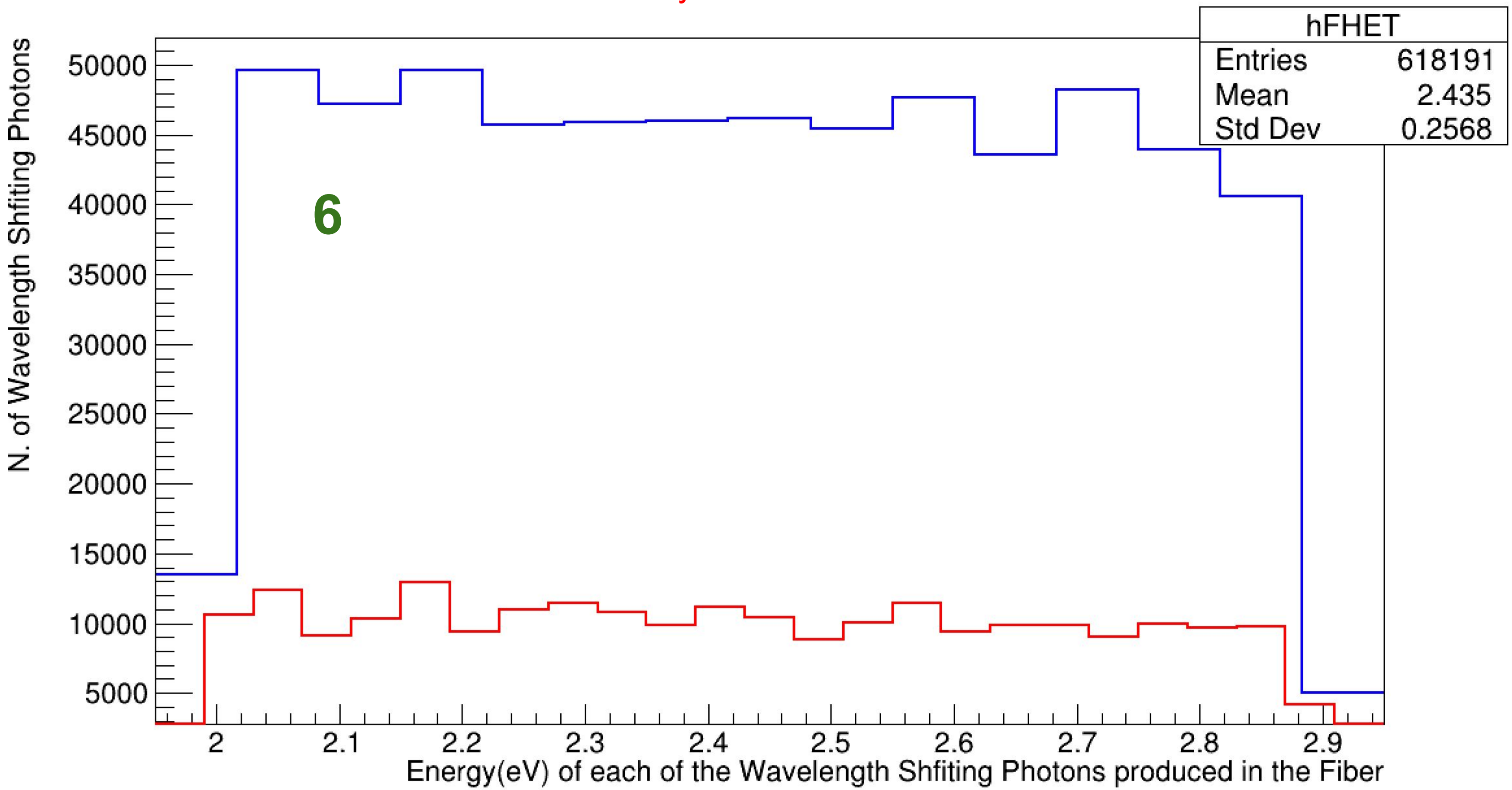
The remaining energy is distributed by each Scintillation Photon.

Energy in eV of each of the Scintillation Photons With Tyvek and Without Tyvek for 100 events



Although there are more Scintillation Photons With Tyvek, the energy of each Scintillation Photon is distributed in the same way.

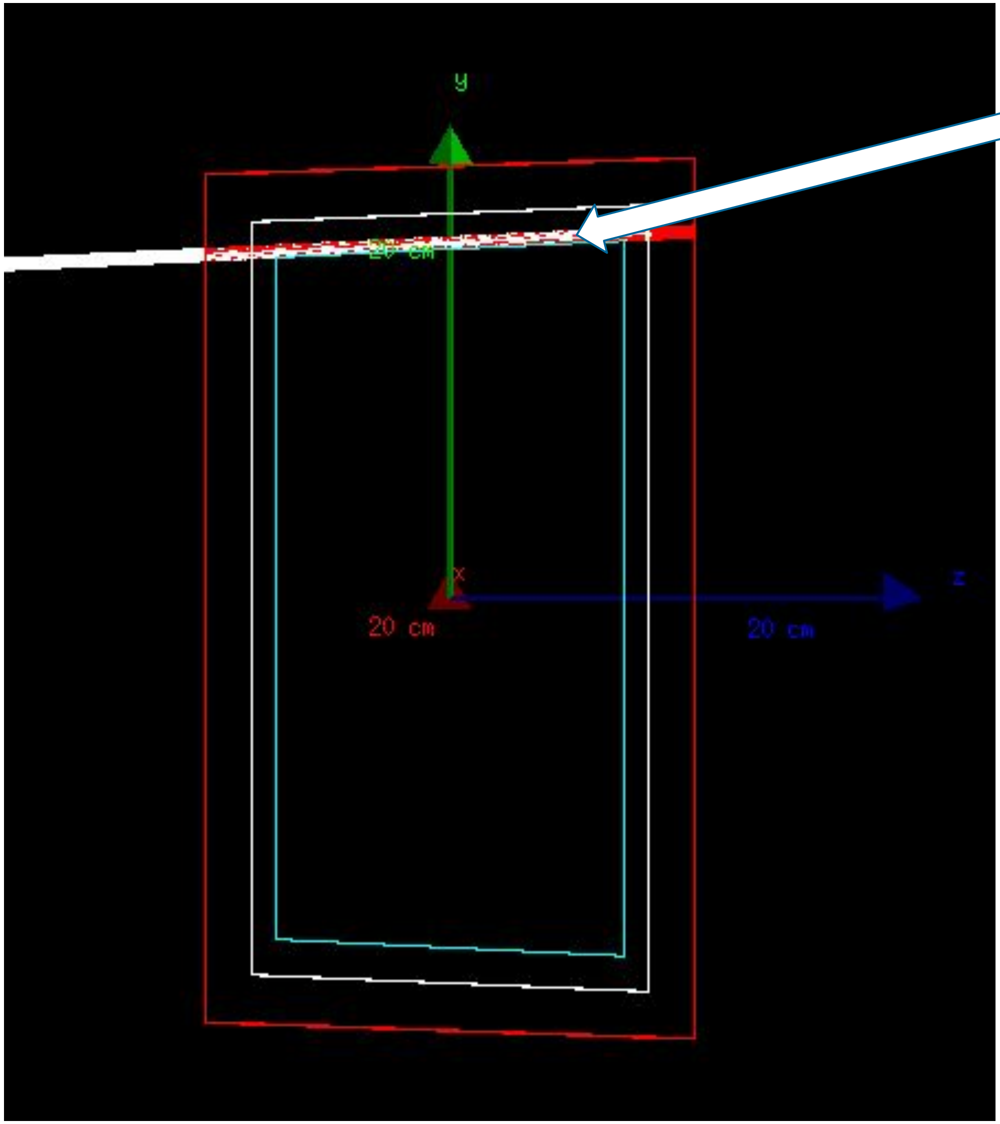
Energy (in eV) of each of the Wavelength Shfiting Photons produced in the fiber With Tyvek and Without Tyvek for 100 events.



Although we concluded that the number of Wavelength Shifting Photons produced in the fiber is greater With Tyvek, the great difference between the number of photons in this plot is due to the fact that without Tyvek we have more photons lost.

Once again the energy is being uniformly distributed by each Wavelength Shifting Photon.

Validating the Simulation

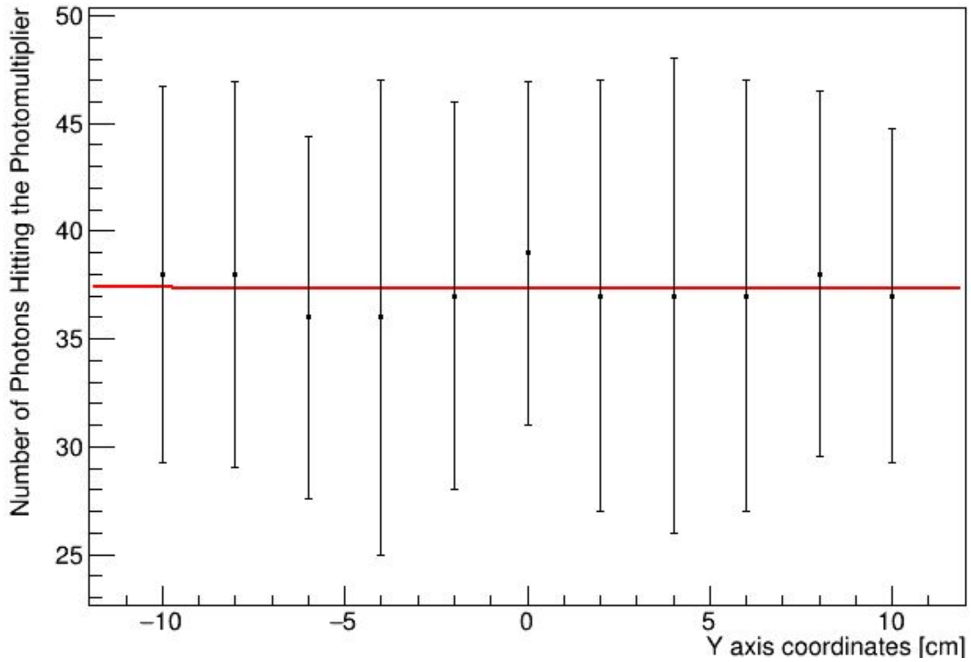


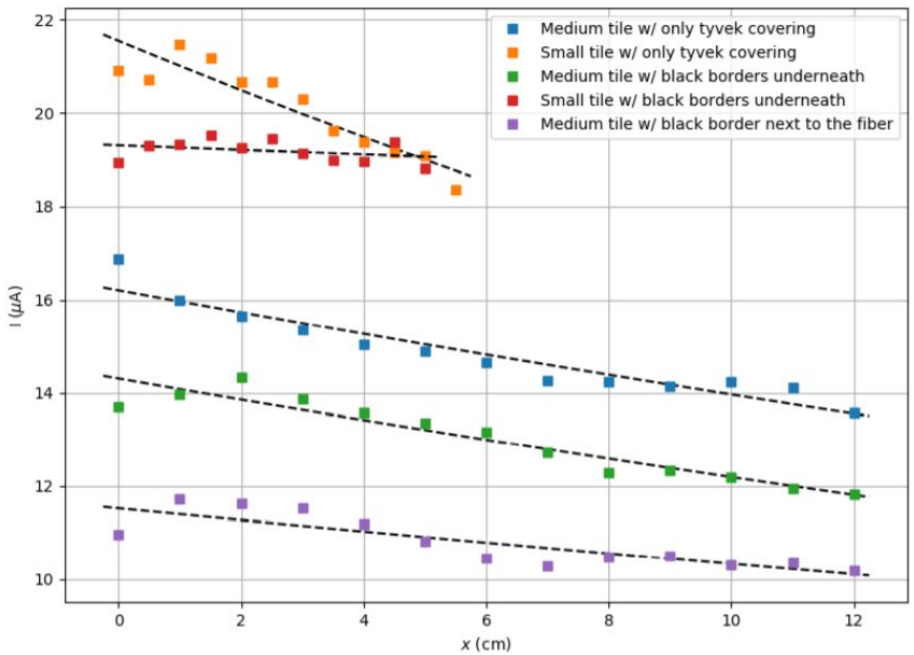
Optical Fiber

- Scan the Tile by moving the electron gun along the Y and Z axis;
- Change the attenuation length to values closer to experimental values.

Comparison with experimental results

Simulation (Left) vs Experimental results (Right)

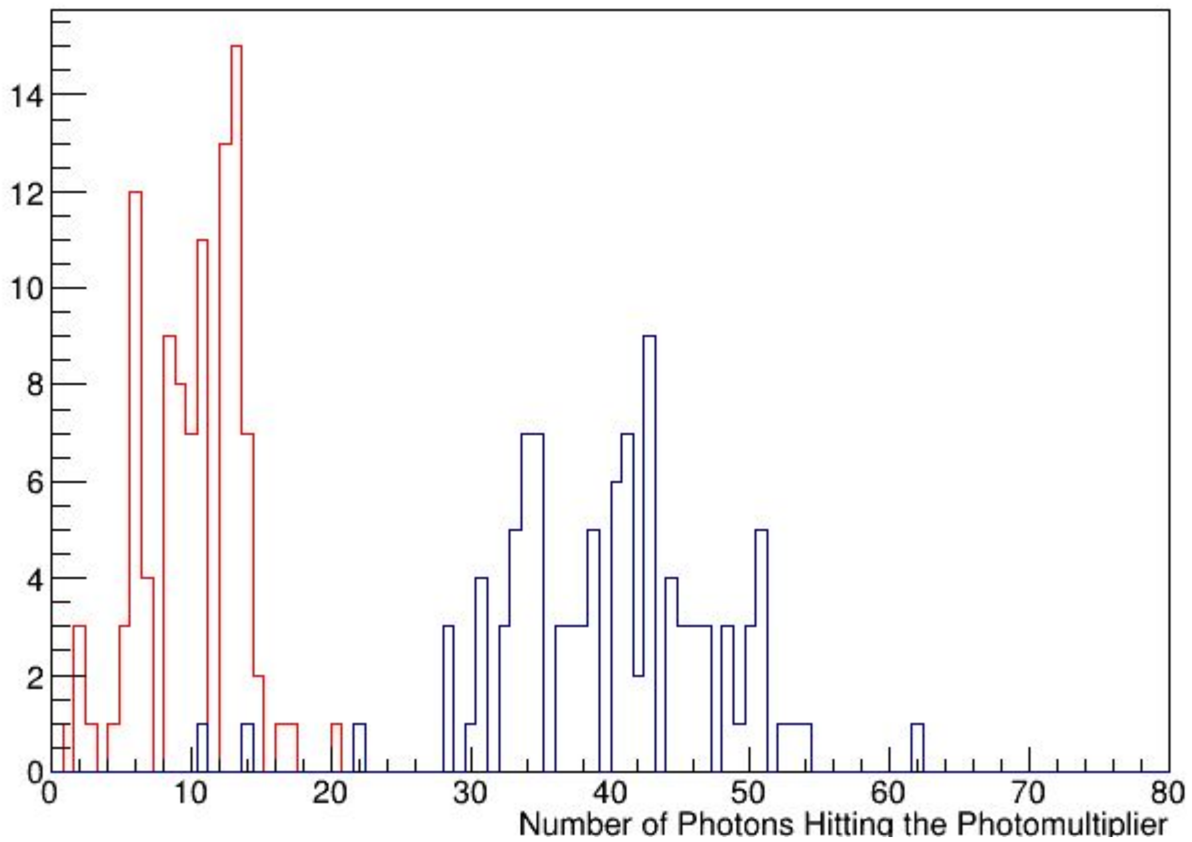




Comparison between different attenuation lengths

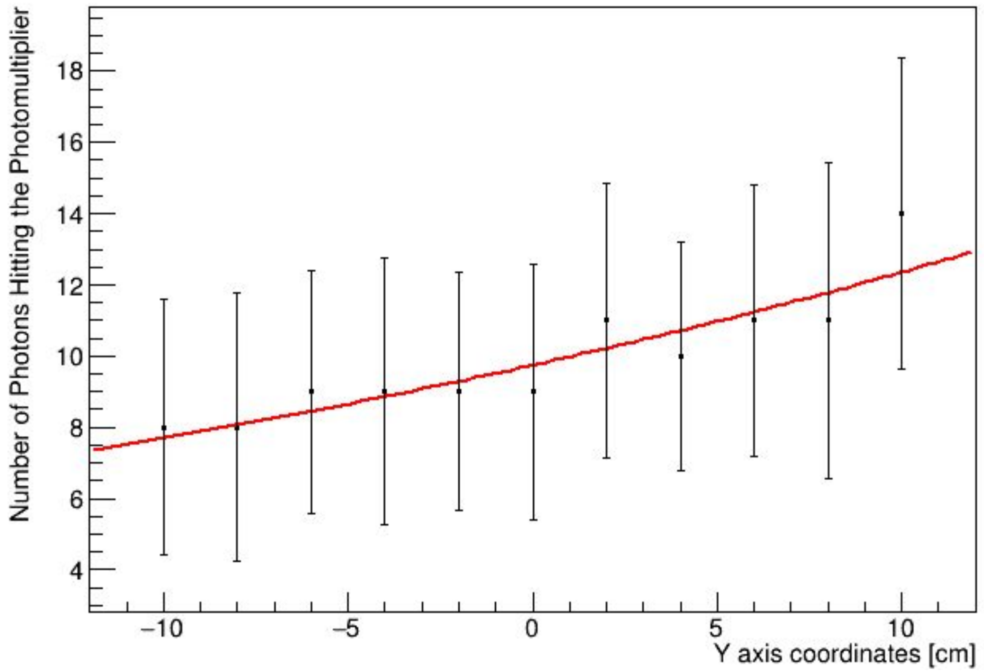
Changing the attenuation length of the Scintillator Tile will produce variations in the number of photons hitting the photomultiplier.

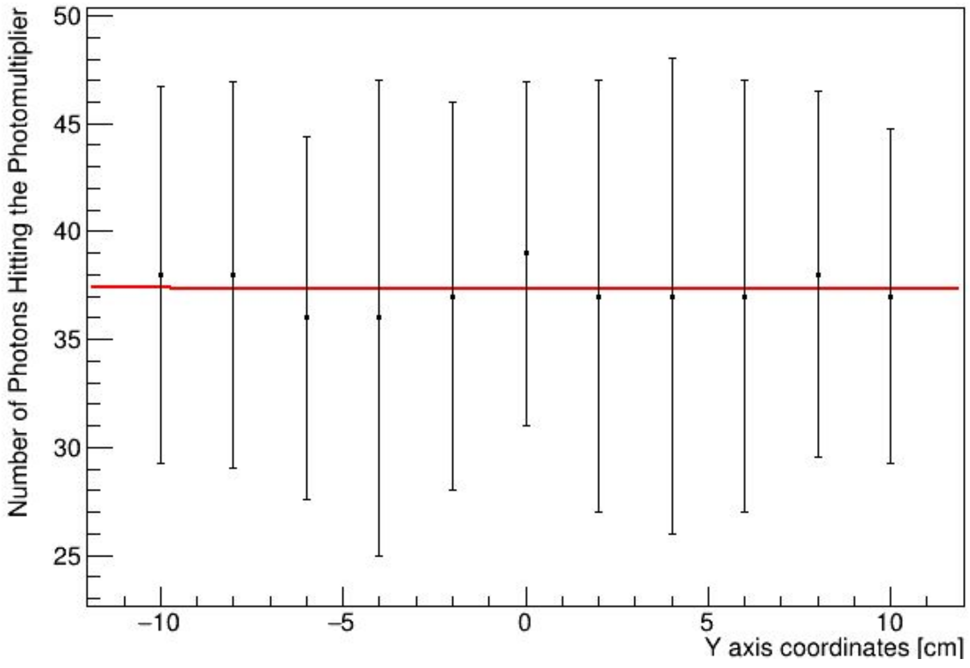
30 cm vs 380 cm



Changing gun position along the Y axis

30 cm (Left) vs 380 cm (Right)

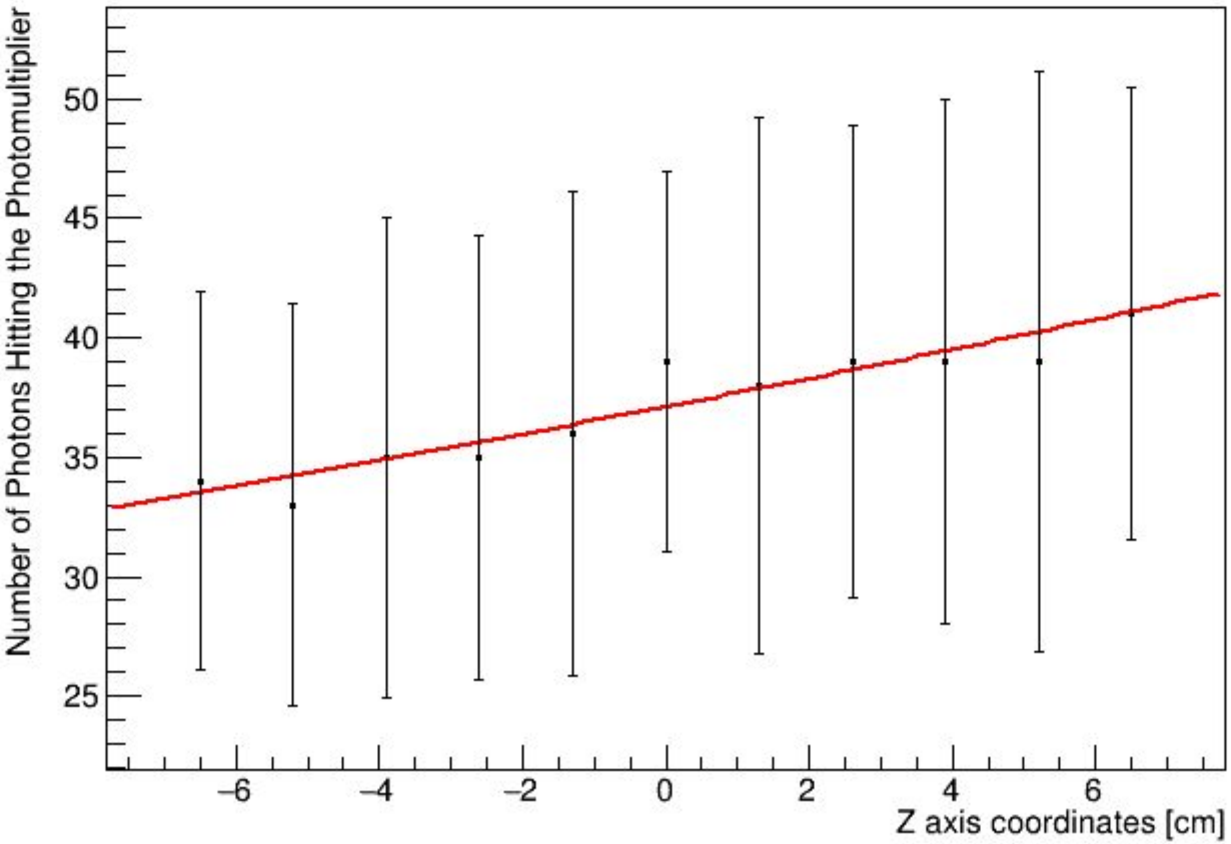




Changing gun position along the Z axis

380 cm attenuation length.

Variations along the Z axis should not produce differences in the number of photons hitting the photomultiplier. This plot shows that the opposite is happening in the simulation.



Summary

- We studied the scintillator-fiber coupling using a GEANT4 simulation based on the Atlas Tile Calorimeter scintillator-fiber coupling;
- The aim of the internship project was to validate the simulation.
- Our main results were:
  - Adapted the geometry for a different/optimized fiber coupling obtaining a non-uniform spectra of photons produced in the optical fiber;
  - Measured the impact of the Tyvek wrapping of a scintillator which increases the light collected by the scintillator as expected;
  - Scanning the Tile in both directions (Y and Z):
    - Both scans don't reproduce what was expected from experimental data;
    - Changed the absorption length from 380 cm (bulk) to 30 cm (exp) reaching a result more relatable to experimental data.

Special Thanks to LIP and our supervisors: Ana Luísa Carvalho and João Gentil Saraiva