Muography of a building

LIP 2020 summer internships

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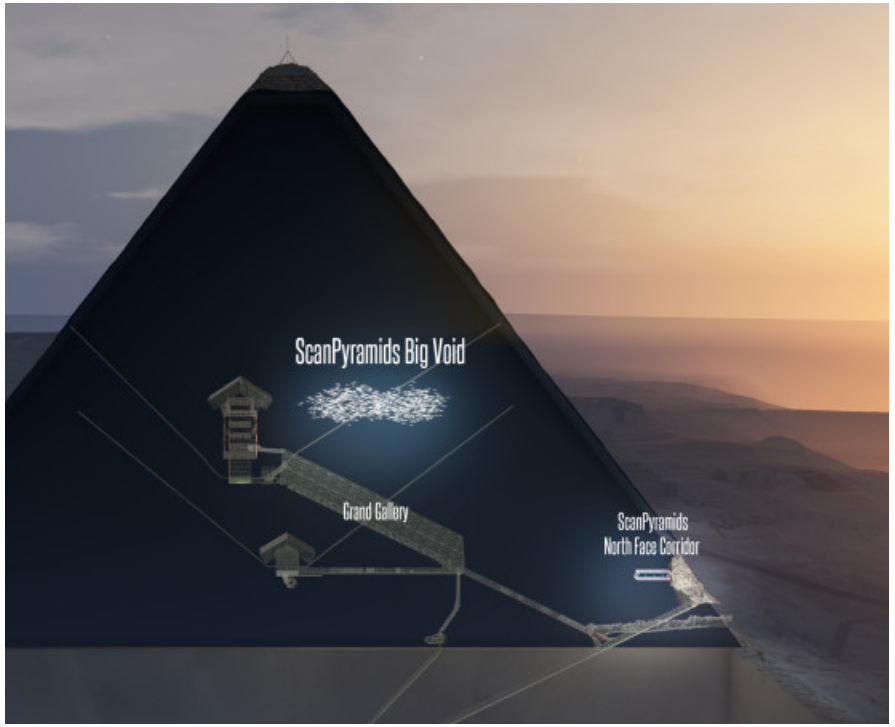
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

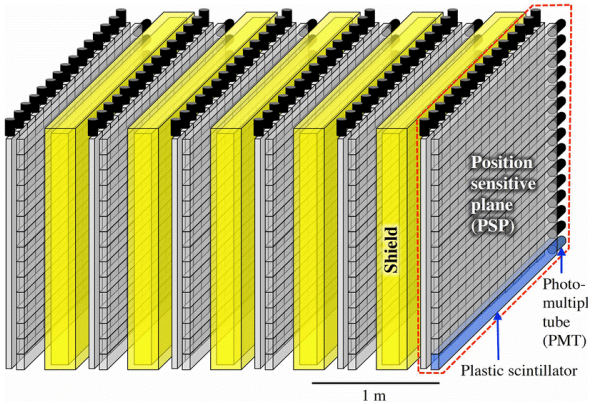
Universidade do Minho

Muons

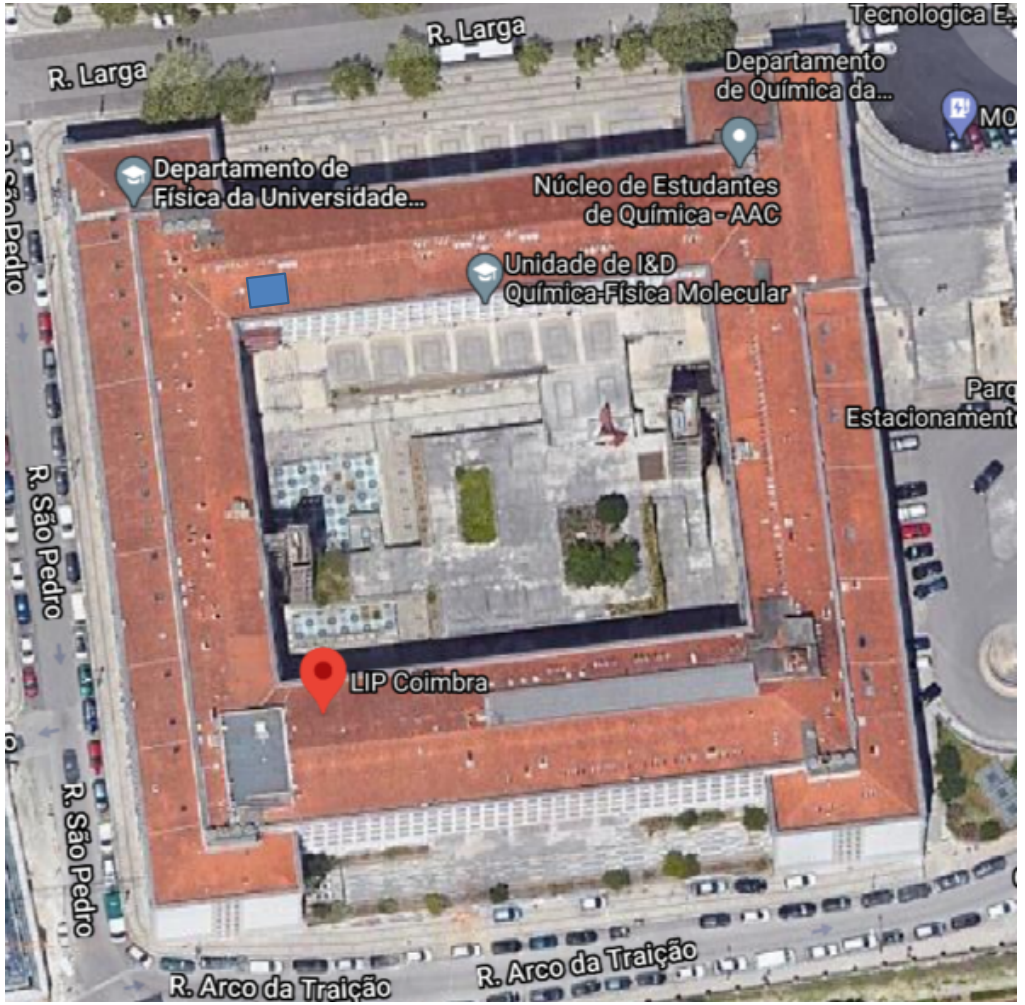
- Source: collision of cosmic rays with Earth's atmosphere
- Energy: GeV to TeV
- Mass: **207** m_e
- Interaction with matter: poor

Muography


ScanPyramids Big Void
Grand Gallery
ScanPyramids
North Face Corridor

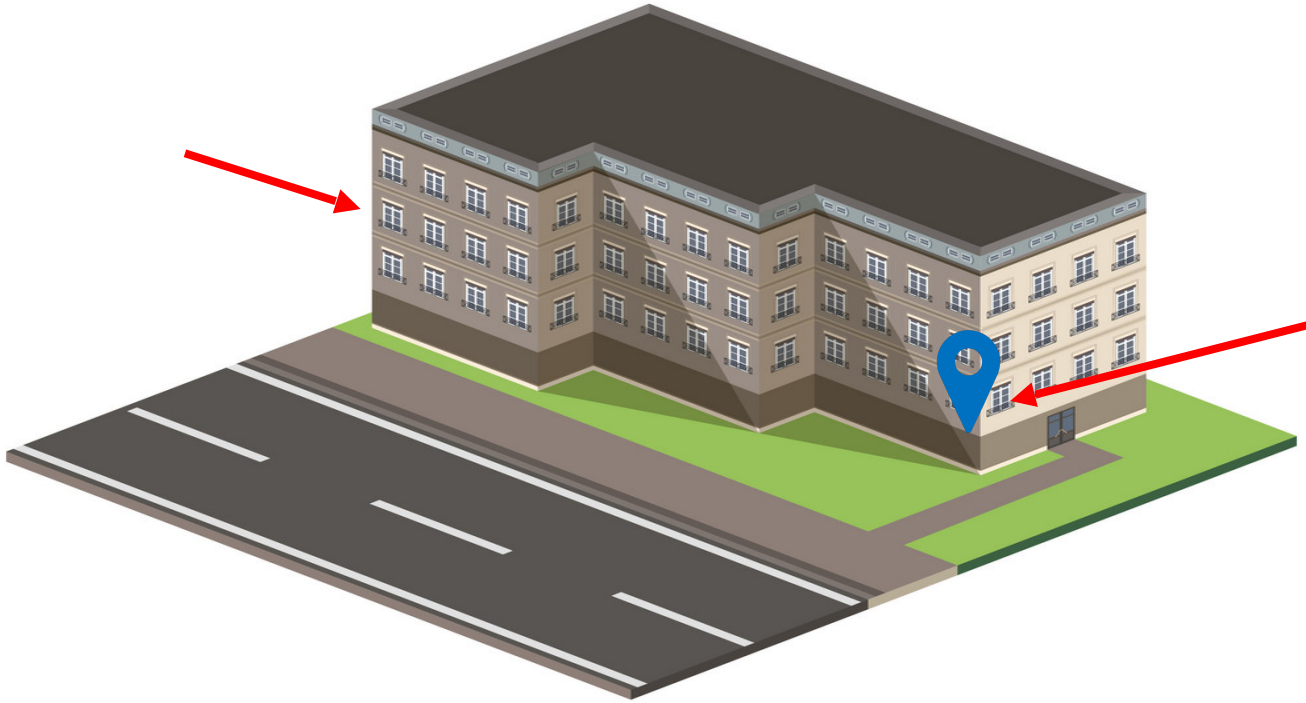

Position
sensitive
plane
(PSP)
Shield
Photo-
multipl
tube
(PMT)
Plastic scintillator
1 m

Our project


R. Larga
R. Larga
Departamento de Química da...
Departamento de Física da Universidade...
Núcleo de Estudantes de Química - AAC
Unidade de I&D Química-Física Molecular
R. São Pedro
R. São Pedro
LIP Coimbra
R. Arco da Traição
R. Arco da Traição

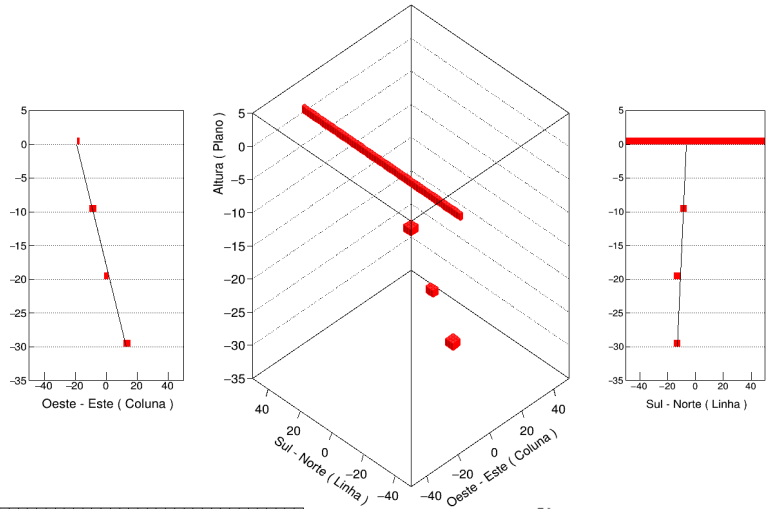
Our project

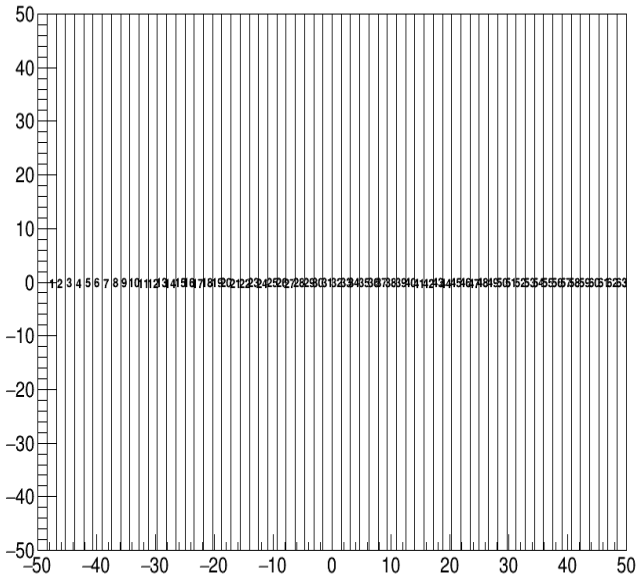
As a simple example, if the muon detector is near one of the walls there will be….

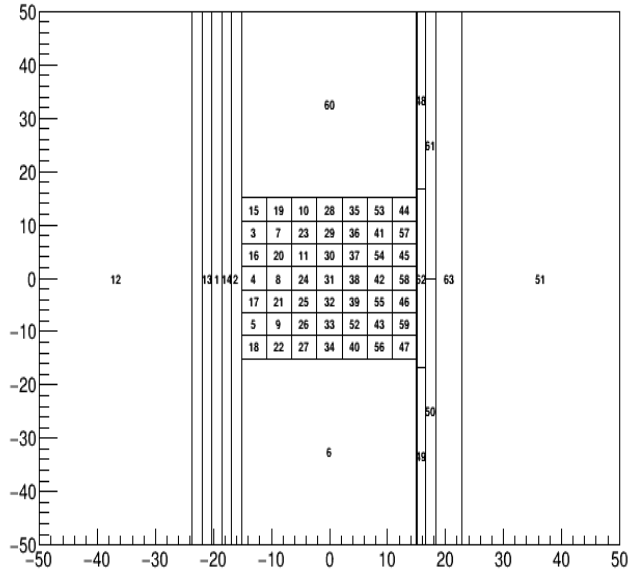


…a bigger flux of muons reaching the detector from this direction then from the other one, through which the muon has to trespass a lot more matter.

The detector







Data acquired

Row	Instance	Data	Hora	ChMax	Linha	Coluna
0	0	191210	17.429687	999	0	31
0	1	191210	17.429687	51	0	19
0	2	191210	17.429687	60	10	0
0	3	191210	17.429687	60	10	0
1	0	191210	17.429687	55	0	46
1	1	191210	17.429687	60	10	0
1	2	191210	17.429687	999	10	0
1	3	191210	17.429687	24	0	-1

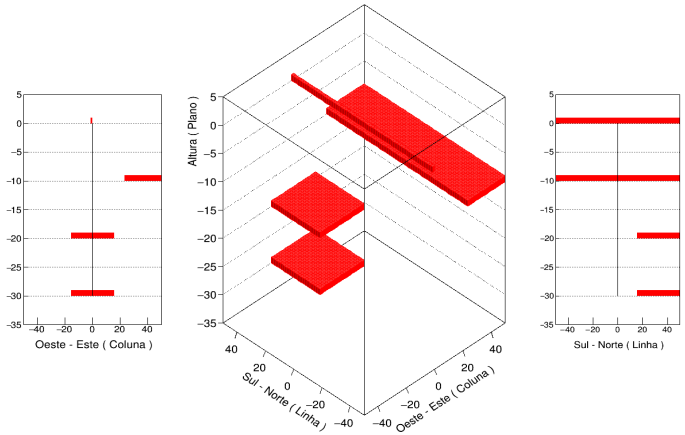
Filtering of data

- Criteria:

- 2 trigger planes
- events that cross the central region built of small square channels

15	19	10	28	35	53	44
3	7	23	29	36	41	57
16	20	11	30	37	54	45
4	8	24	31	38	42	58
17	21	25	32	39	55	46
5	9	26	33	52	43	59
18	22	27	34	40	56	47

- events that define a straight path for the muon



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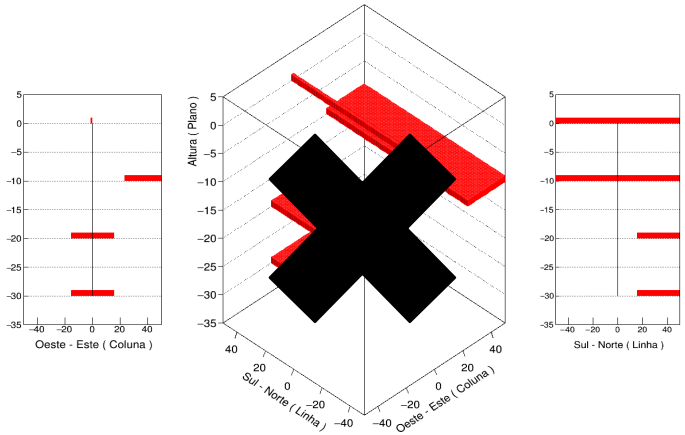


Important numbers

(for planes displacement of **14,5** cm and **33,5** cm)

Vertical trajectory muon rate
(focusing on the central region of the detector)

Vertical trajectory muon flux that reaches Earth's surface per sterradian

70 muons / m^2/ s / sr

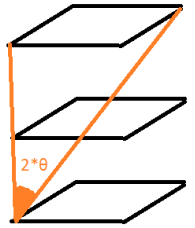
Area of one channel

A ≈ **14,44** $\times 10^{-4}$ m^2

Solid angle comprehended by one channel

($\Omega \approx 2\pi(1-\cos\theta)$)

$\Omega \approx$ **0,02 sr** $\Omega \approx$ **0,005 sr**



with 70 % reaching the detector

Vertical trajectory muon rate expected in one channel

0,0014 muons / s **0,00035 muons / s**

Planes displacement:
- **14,5 cm**
- **33,5 cm**

Detector's efficiency

March data

Detector's efficiency

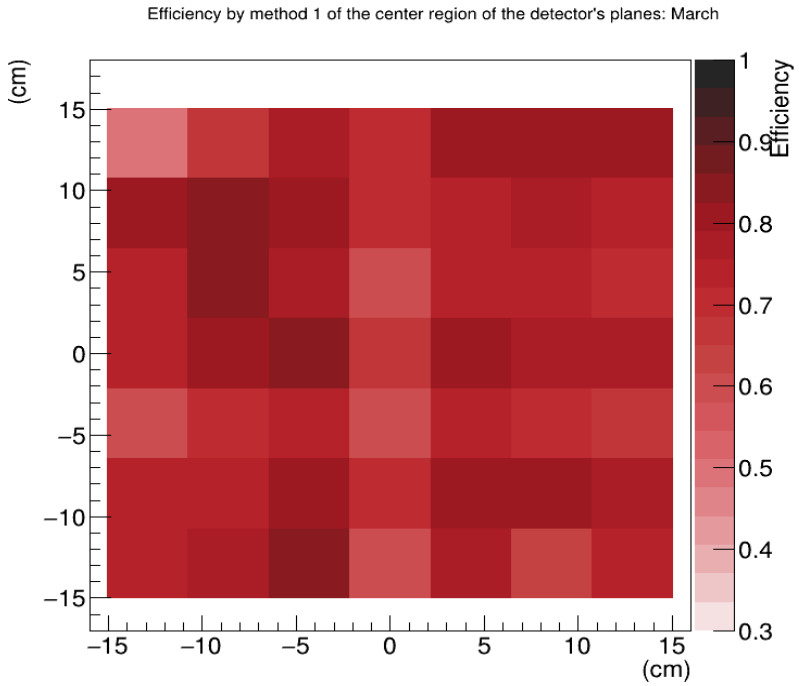
March data

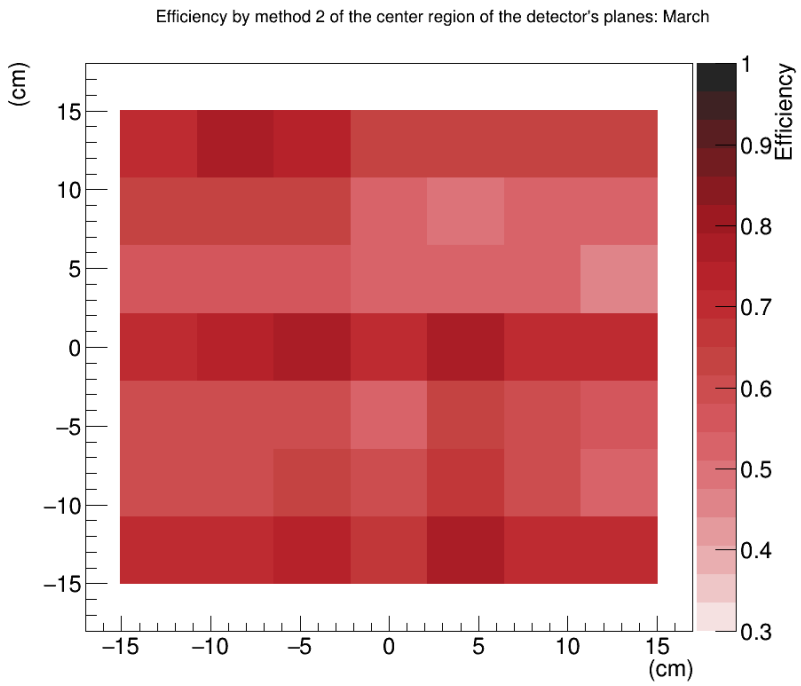
Efficiency of the not trigger plane of the detector
Method 1

$$Eff1 = \frac{number\ of\ muons\ passing\ the\ same\ channel\ on\ plane\ 1{,}2\ and\ 3}{number\ of\ muons\ passing\ the\ same\ channel\ on\ plane\ 1\ and\ 3}$$

Efficiency of one detector's plane
Method 2

$$Eff2 = \sqrt[3]{\frac{experimental\ rate\ of\ vertical\ muons}{theoretical\ rate\ of\ vertical\ muons}}$$

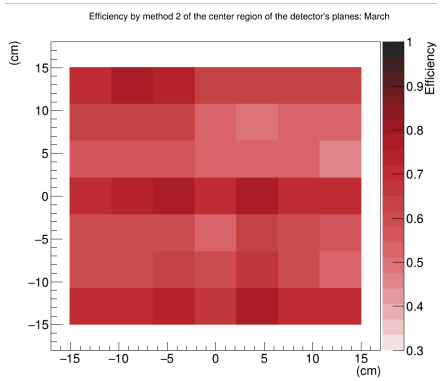


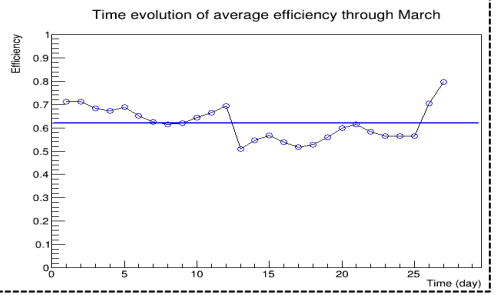


Detector's efficiency

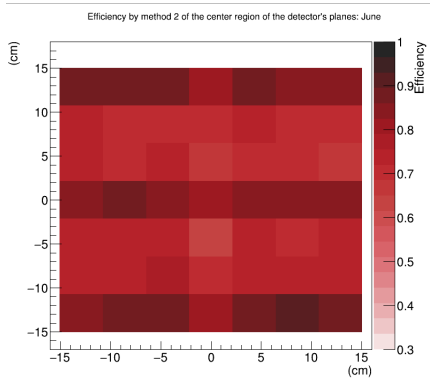
- Study of its stability and uniformity

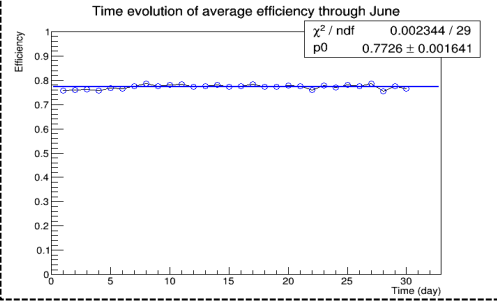
March



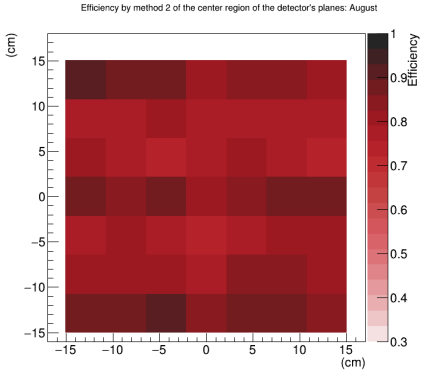


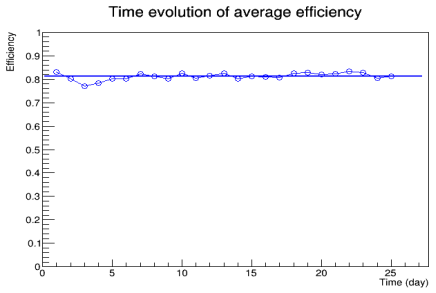
June

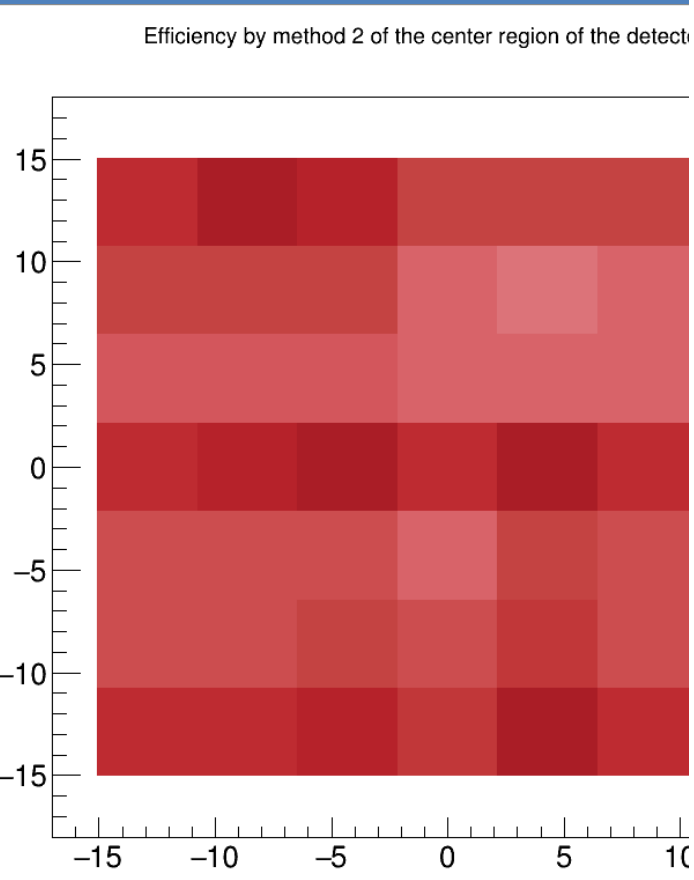


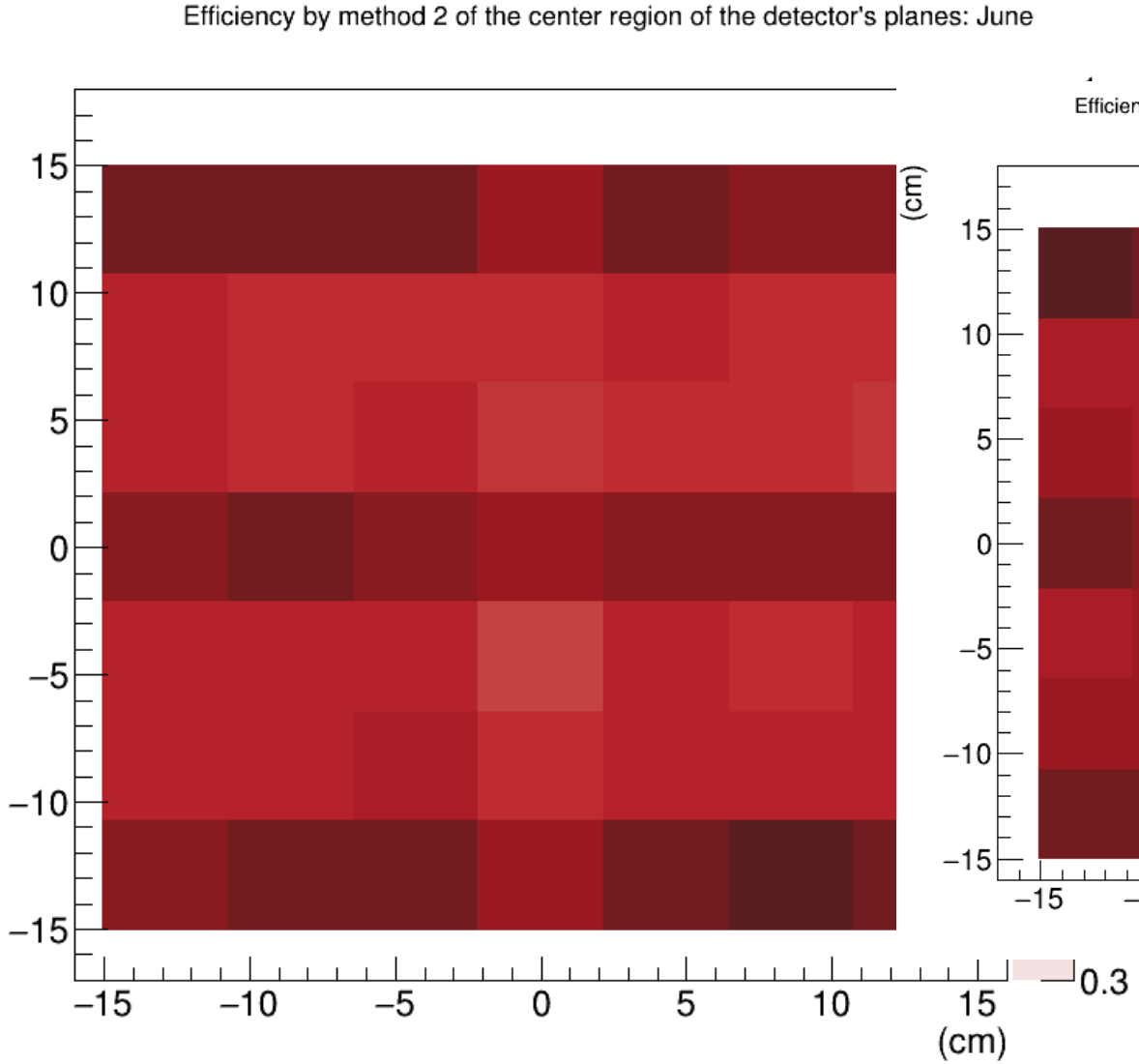


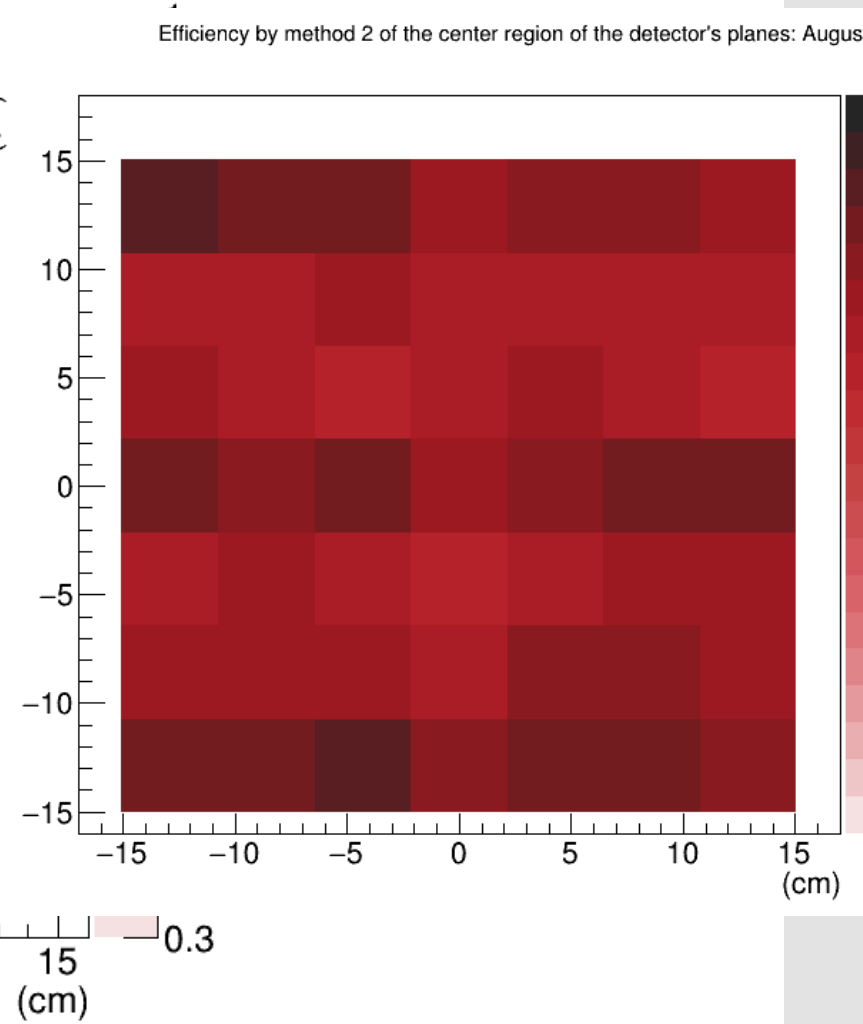
August

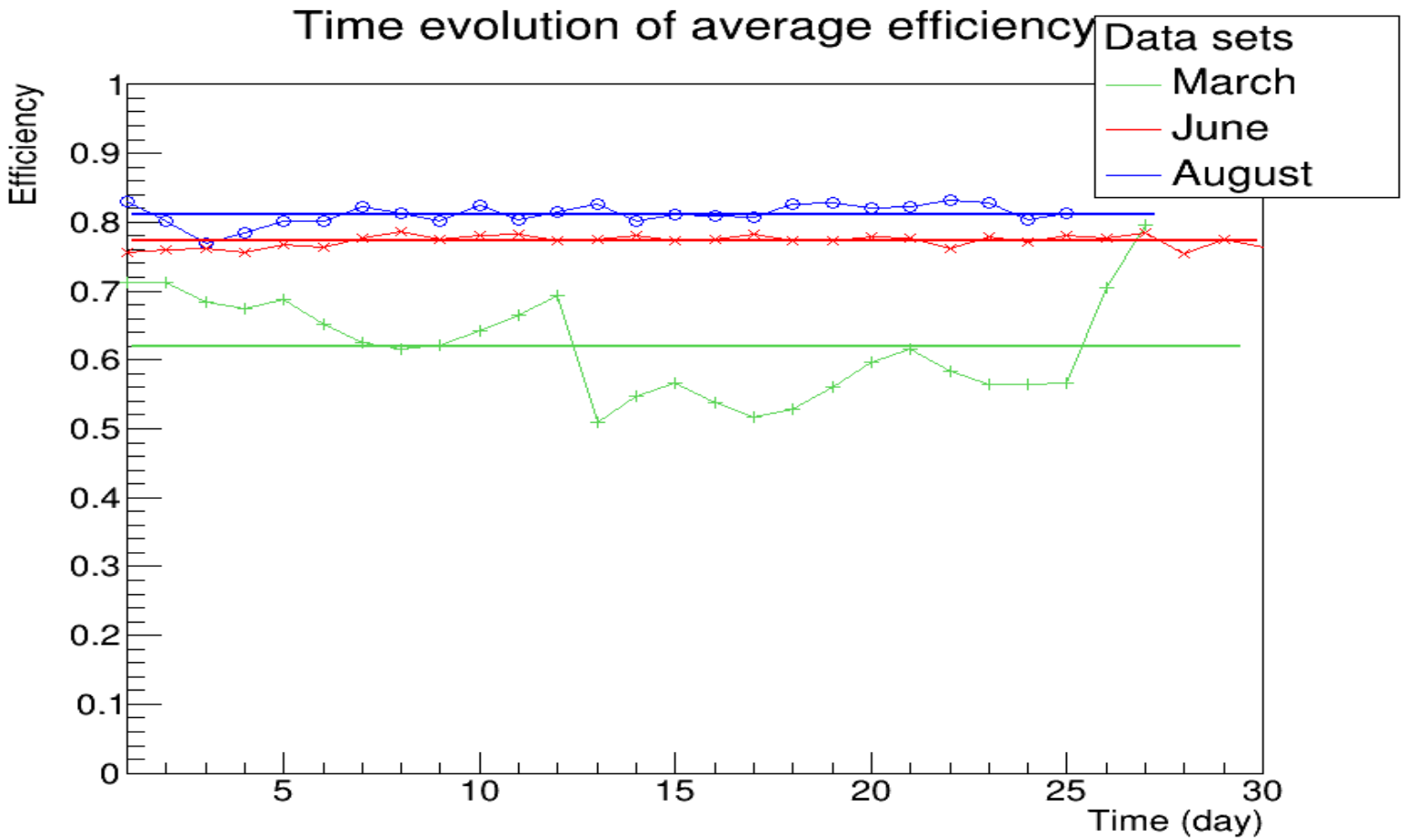




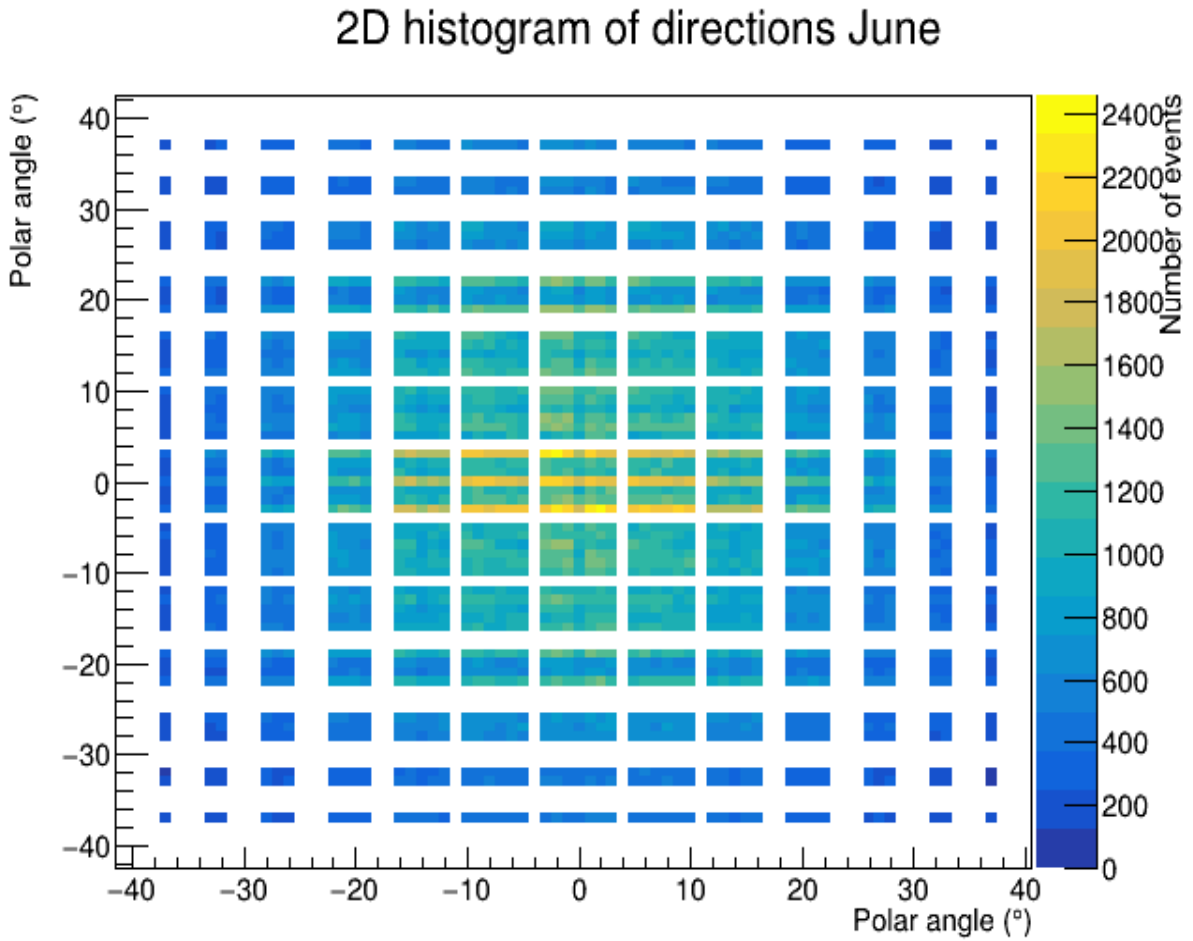

Efficiency by method 2 of the center region of the detect
15
10
5
0
−5
−10
−15
−15
−10
−5
0
5
10


Efficiency by method 2 of the center region of the detector's planes: June
(cm)
15
10
5
0
−5
−10
−15
−15
−10
−5
0
5
10
15
(cm)

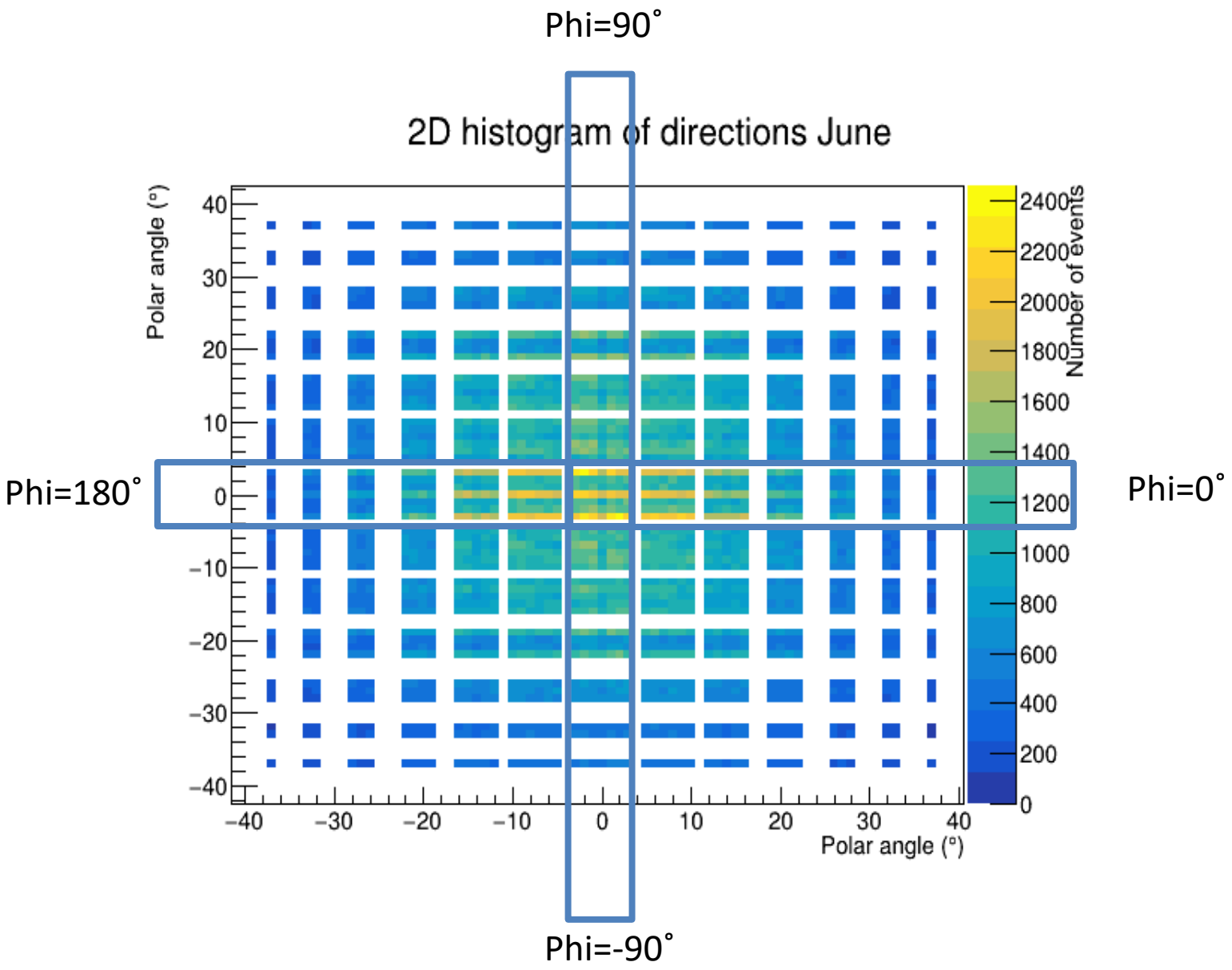

Efficiency by method 2 of the center region of the detector's planes: Augus
(cm)
15
10
5
0
−5
−10
−15
−15
−10
−5
0
5
10
15
(cm)
0.3


Time evolution of average efficiency
Data sets
March
June
August
Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
30
Time (day)

Results

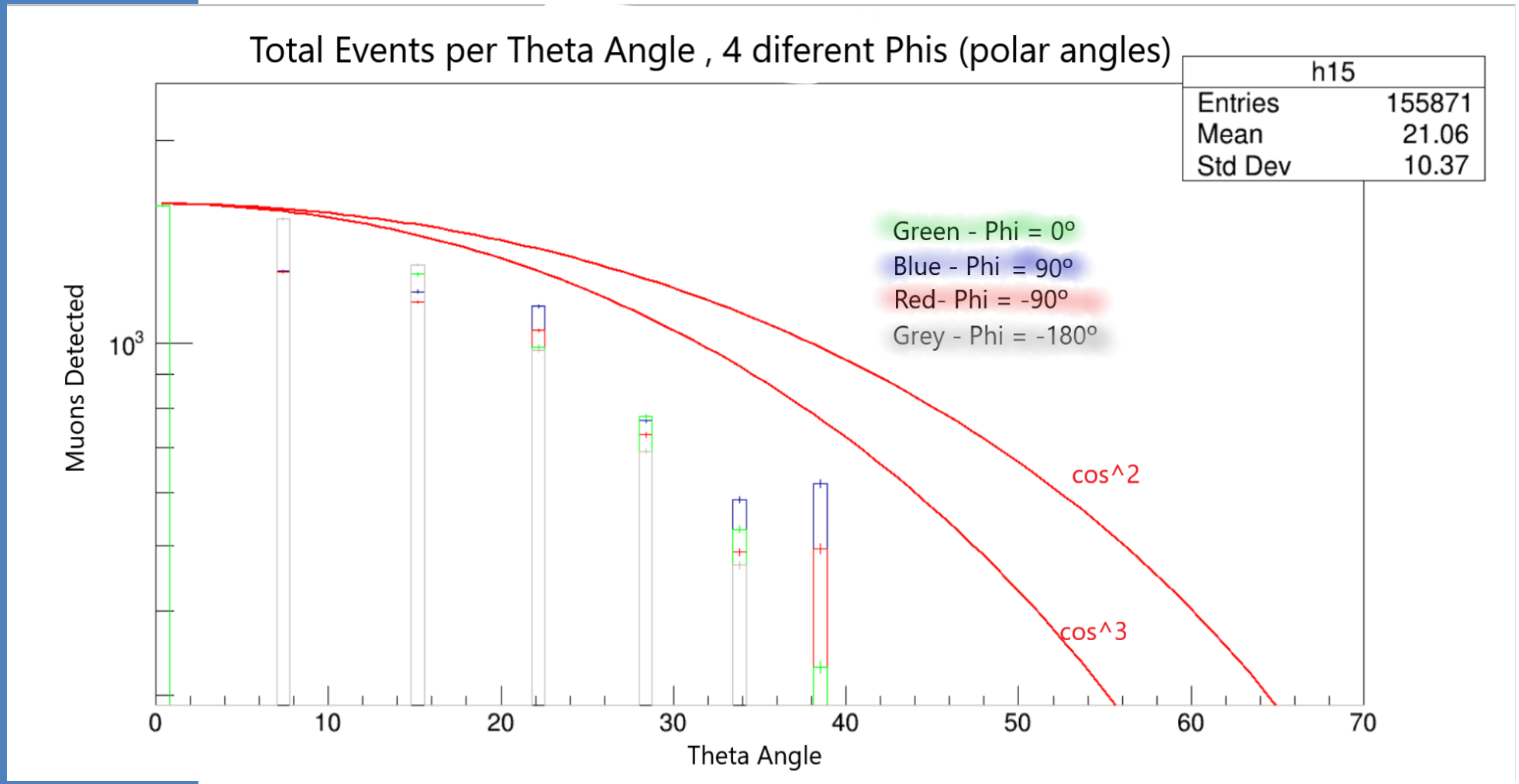

2D histogram of directions June
Polar angle (°)
40
30
20
10
0
−10
−20
−30
−40
−40
−30
−20
−10
0
10
20
30
40
Polar angle (°)
Number of events
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

Results

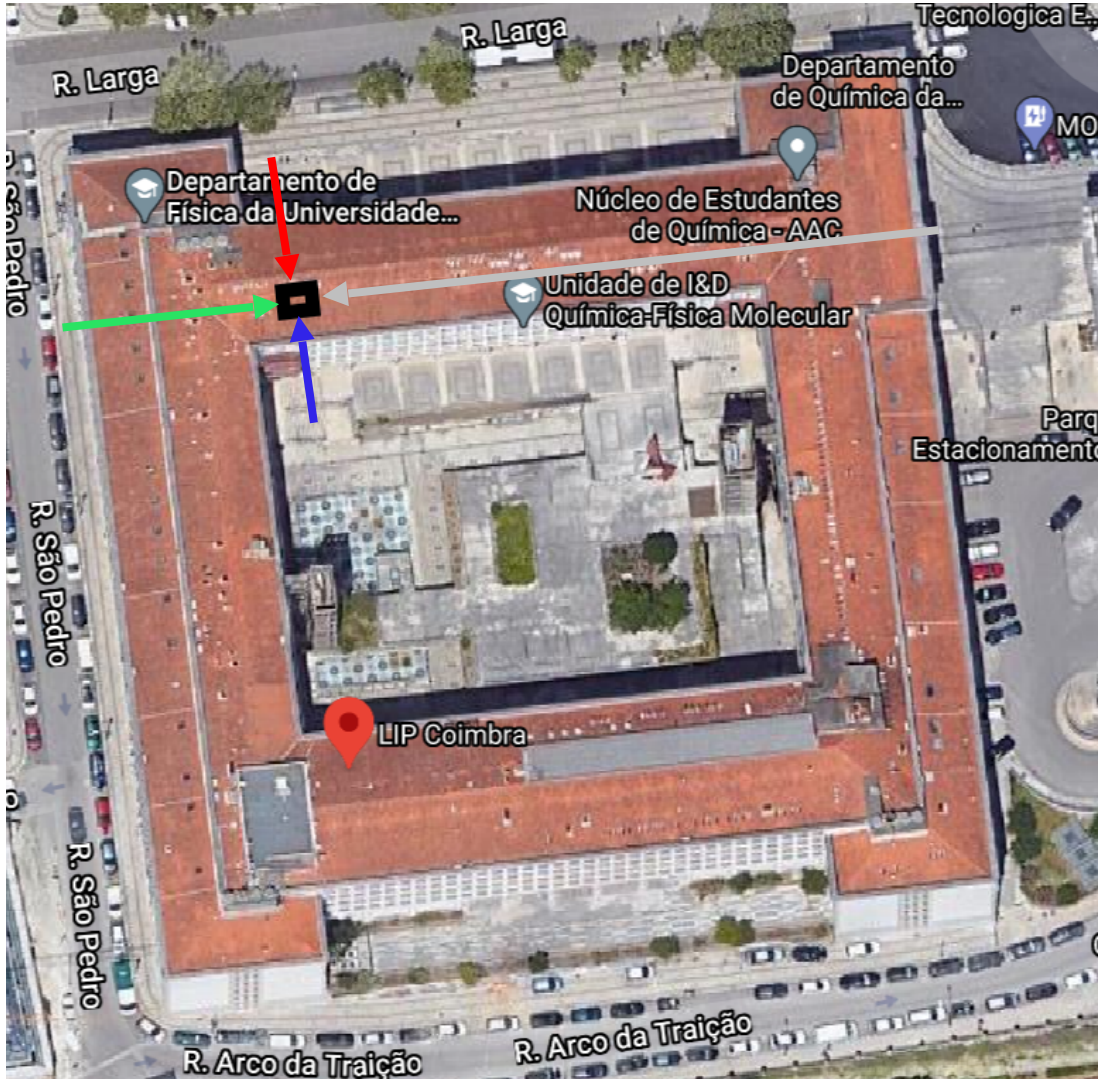

Phi=90˚
2D histogram of directions June
Polar angle (°)
Number of events
Polar angle (°)
Phi=180˚
Phi=0˚
Phi=-90˚

Results

- Reconstruction of the trajectory: zenith and azimuth angles



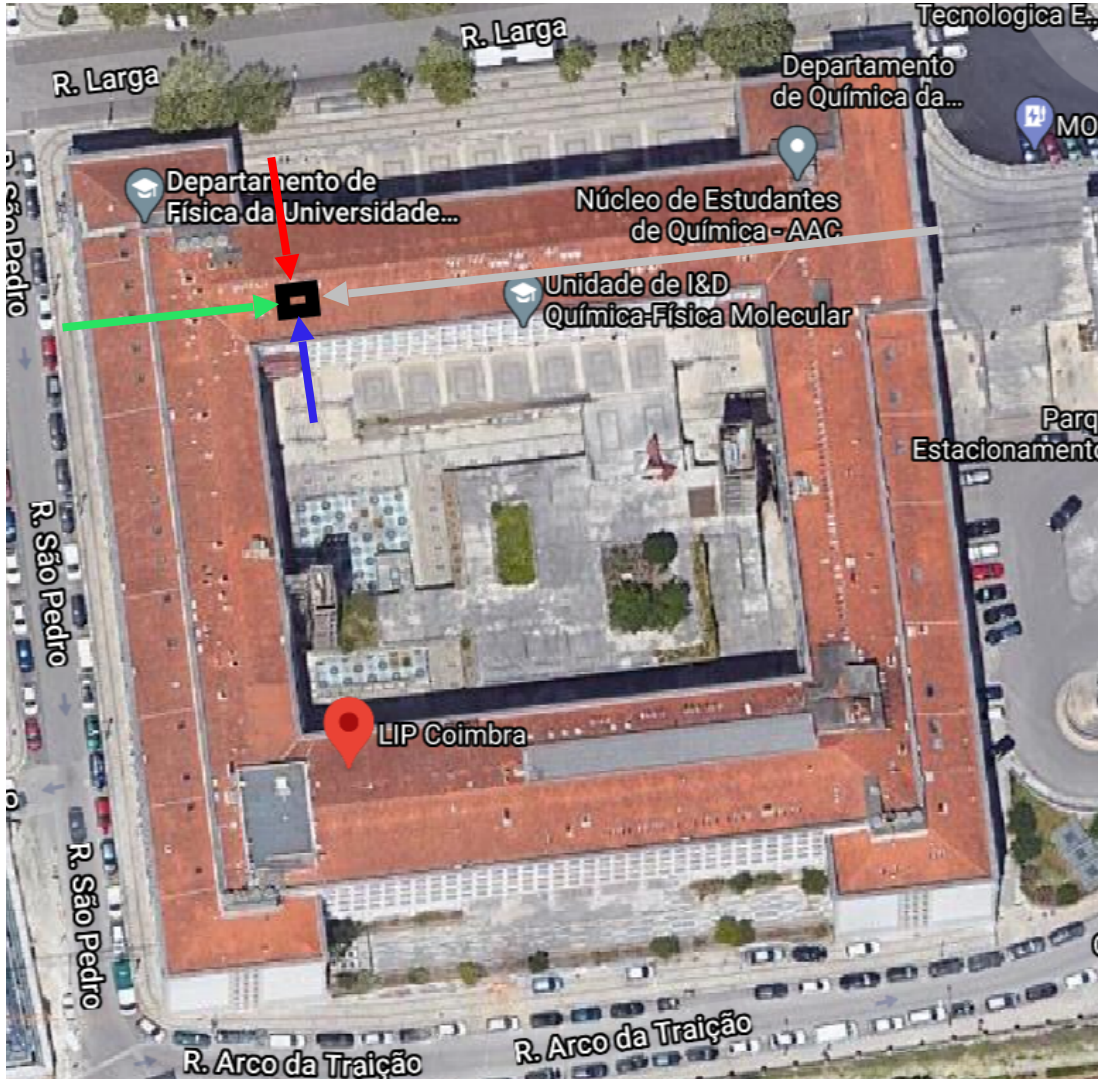
Study of the changes in the muon flux



Characteristics of the building
(from the "detector's perspective"):

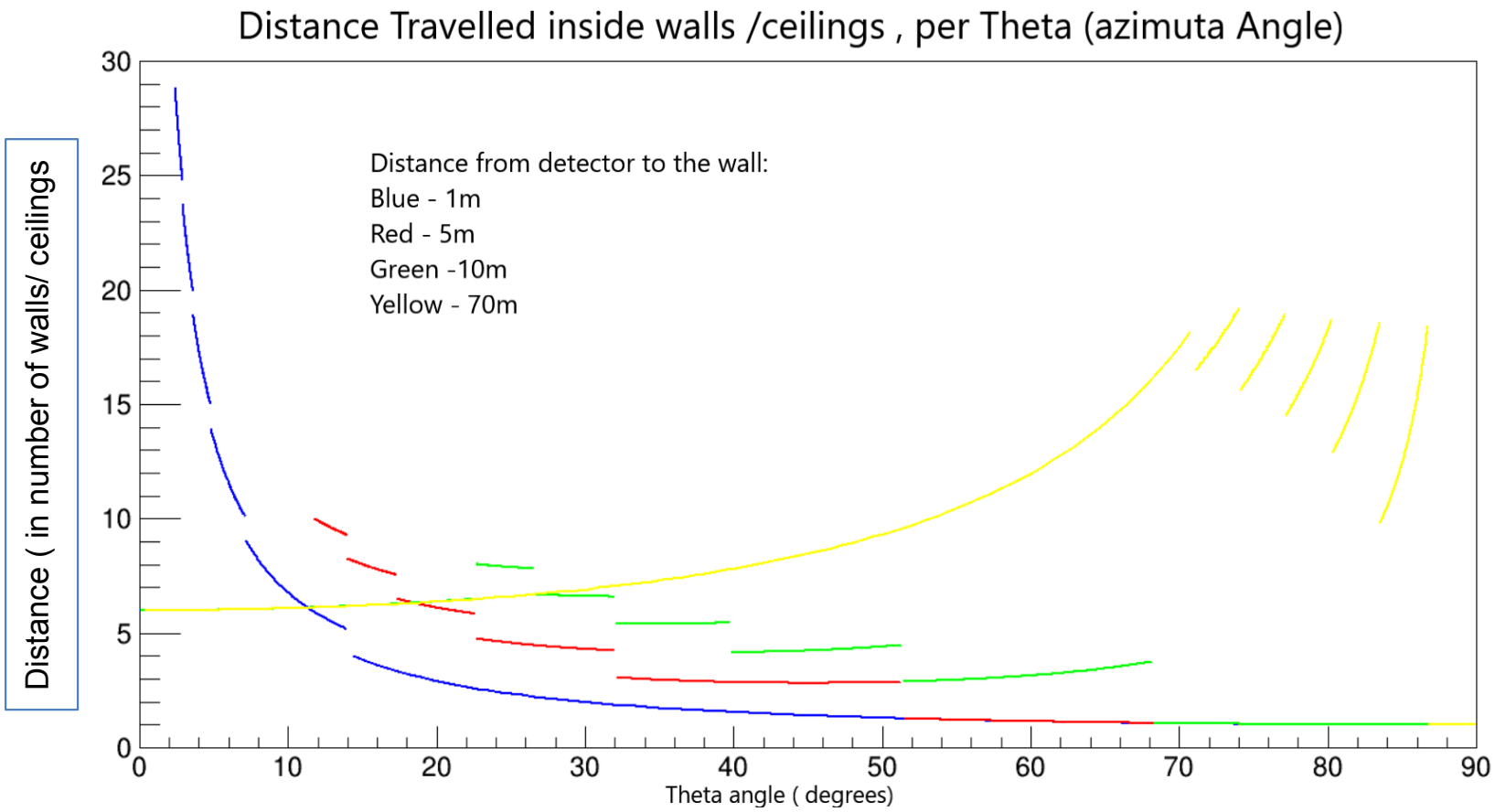
- 6 ceilings

Color	Phi
Blue	90˚
Green	180˚
Grey	0˚
Red	-90˚



Distance travelled through matter

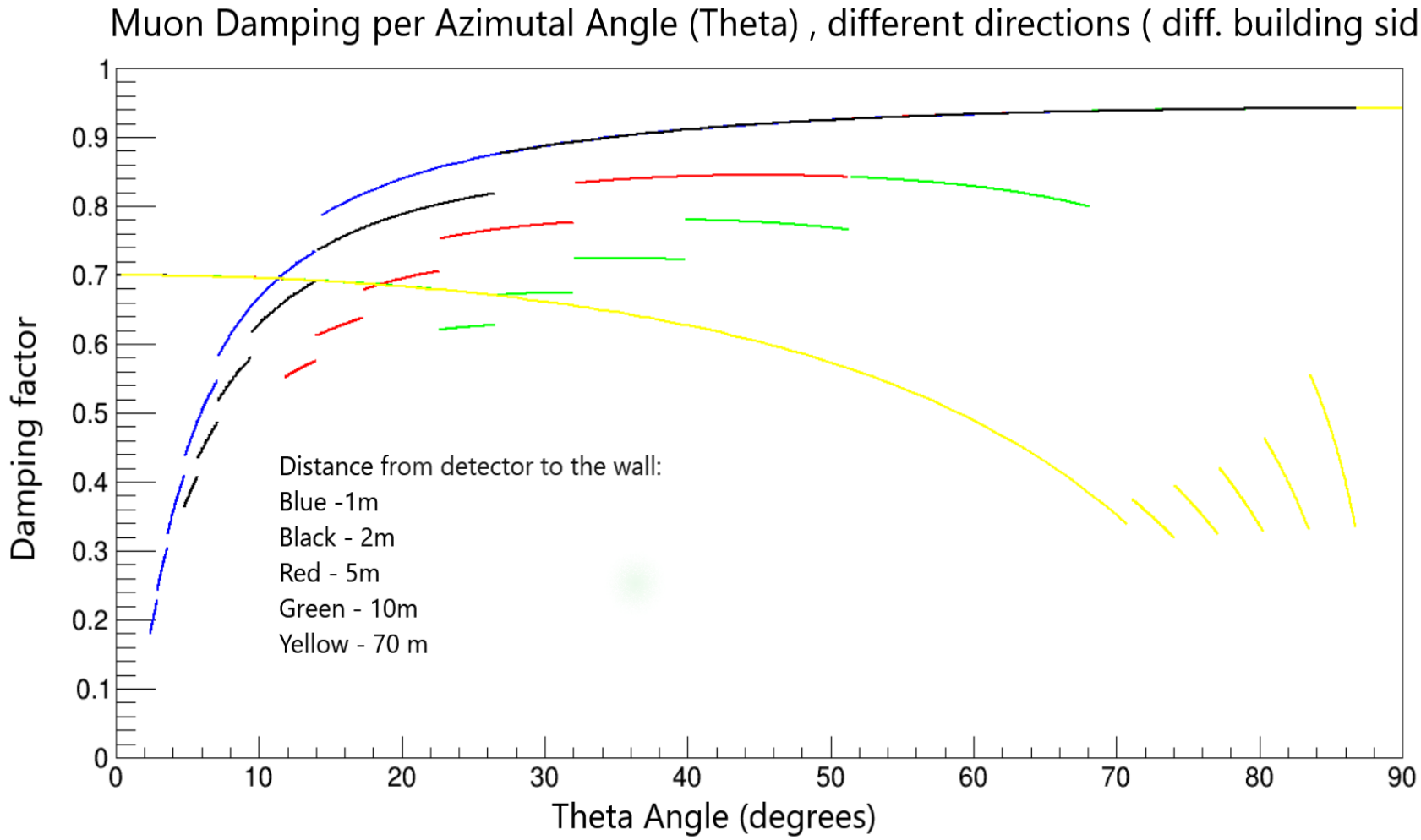
For each side of the building, how does the azimuthal angle influences the distance travelled inside matter (walls/ceilings) of the muon?



Notes:
Wall width = Ceiling width, Total ceilings – 6 , Theta = 0º -> 6 ceilings , Theta = 90º -> 1 wall

Data Collected -> 6 celling = 0,7 Damping Factor
D(6) = exp(-6/ λ) = 0.70 => λ = -6/log(0.70) = 16.8 ceilings (D(1) = $\sqrt[6]{0,7}$ = 0,94)
D(d) = exp(-d/16.8). -> Damping (d) in function of ceilings the muon went through

Relation between matter travelled and reductions in muon flux



Conclusions and next steps

- **Conclusion 1:** The efficiency of the detector has increased and is very stable but is not uniform along the detector.

Next step
Calculate the uniformity of the efficiency for each plane independently.

- **Conclusion 2**: Data seems consistent with the expected asymmetry between close and far walls, and analysis can be extended to full 2D.

Next step
Confirm the results in new data with detector at different positions.

Thank you for your attention!