Muons and Electrons from beam events

Arapuca Efficiency

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Arapuca PD module is composed of 16 cells arranged in two blocks, each one groups 8 cells. The cells in the two groups have different readout configuration and number of MPPC.
This is reflected in the efficiency of the two kind of “channels”.

- 8 channels read each one a single cell with 12 MPPC
- 4 channels read a parallel of two cells with 6 MPPC

As result each channel read 12 MPPC in parallel, but the MPPC - Arapuca area ratio is different

The efficiency is stable for the same particles at many energy

For electrons we have 7 energy values and then 7 very different amount of photons detected for which the MC simulation has predicted a consistent behavior

Electrons

GeV/c	6 MPPC Ph land	12 MPPC Ph land	6 MPPC Ph Detected	12 MPPC Ph Detected	6 MPPC Eff	12 MPPC Eff
0.3	756.0	750.7	7.2	15.2	0.95	2.02
0.5	1390.1	1358.5	13.3	27.8	0.96	2.05
1	3200.2	3010.2	30.7	60.6	0.96	2.01
2	6979.6	6359.0	66.5	125.6	0.95	1.98
3	11078.4	9892.9	102.5	191.4	0.93	1.93
6	24241.0	20946.4	223.2	396.0	0.92	1.89
7	28595.0	24595.8	264.1	469.4	0.92	1.91

Comparing electrons and muons the MC prediction shows not a good agreement. We think that could be due to three different factors which have to be investigated:

- Low number of photons generated in each voxel (already caused some problem)

- What dE/dx is used for electrons in the MC simulation? $\frac{dE}{dX_\mu} \neq \frac{dE}{dX_e}$

- Photons from muons and electrons have not the same average incident angle with the Arapuca surface (checked and its effect seems to be negligible)

Electrons-1

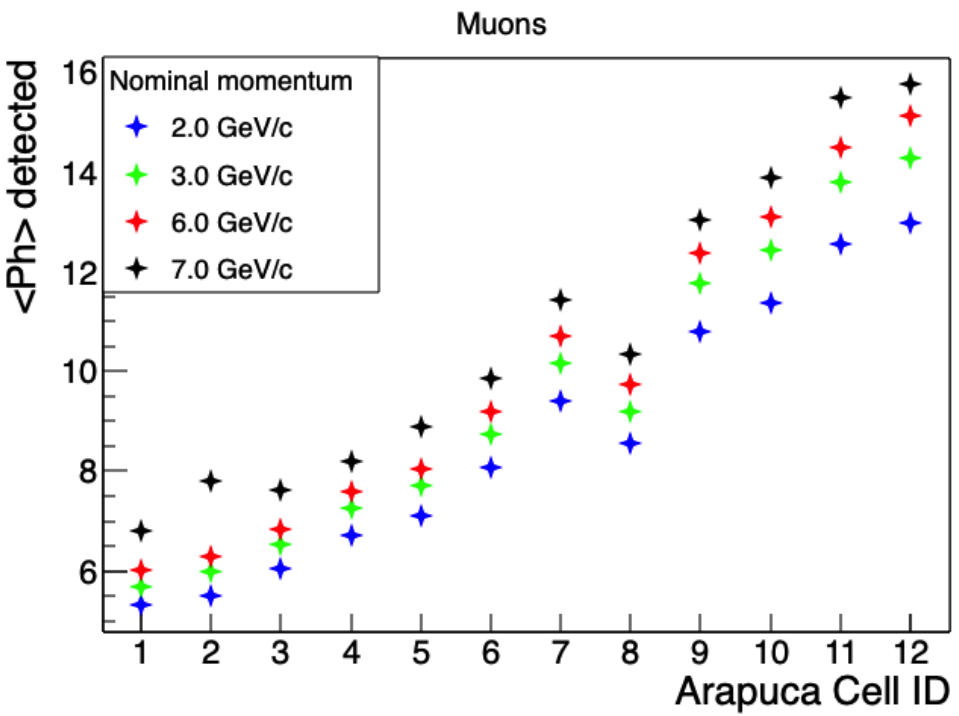
GeV/c	6 MPPC Eff	12 MPPC Eff
0.3	0.95	2.02
0.5	0.96	2.05
1	0.96	2.01
2	0.95	1.98
3	0.93	1.93
6	0.92	1.89
7	0.92	1.91

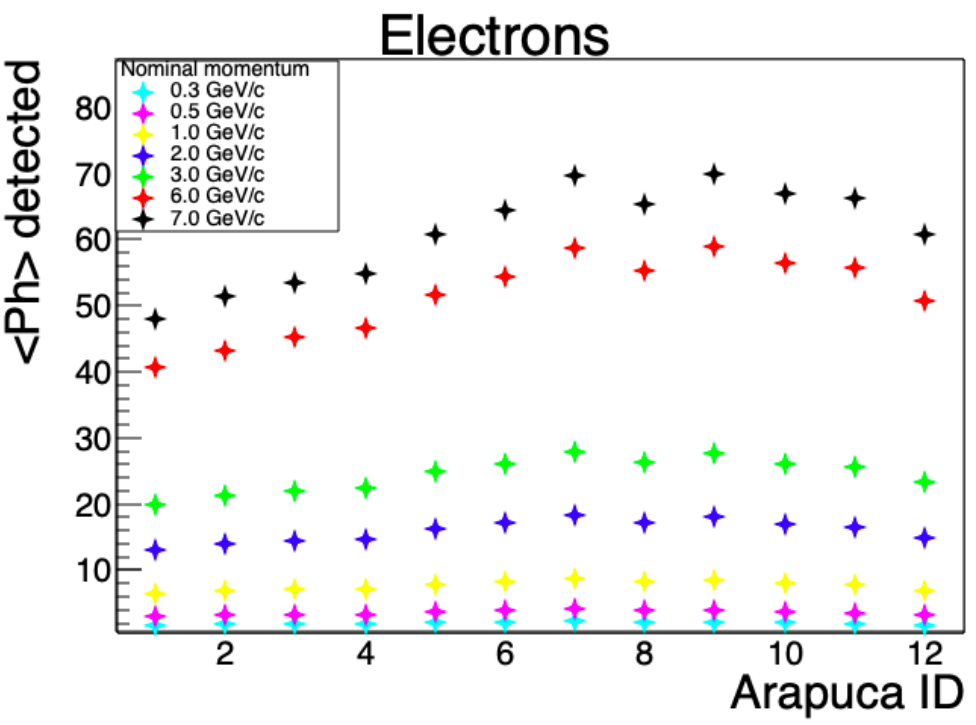
Muons

GeV/c	6 MPPC Eff	12 MPPC Eff
7	0.74	1.51
6	0.73	1.41
3	0.74	1.44
2	0.75	1.45

Photon landing on the Arapuca cells

Muons and Electrons from beam events





Angular distribution

- Aim: check overall behavior as function of source position
- Effect on wires and mesh photons transmission?
- Efficiency results are dependent?
- Procedure
  - Place source point on protodune geometry
  - Evaluate a 2D histogram (θ, φ) for whole arapuca bar
  - θ [0^o,90^o]: angle between propagation direction (***v***) and normal
  - φ [-180^o, 180^o]: angle between $\boldsymbol{v}_{yz}$ projection and ***y*** axis

    ± sign same as $\boldsymbol{v}_z$

Angular distribution

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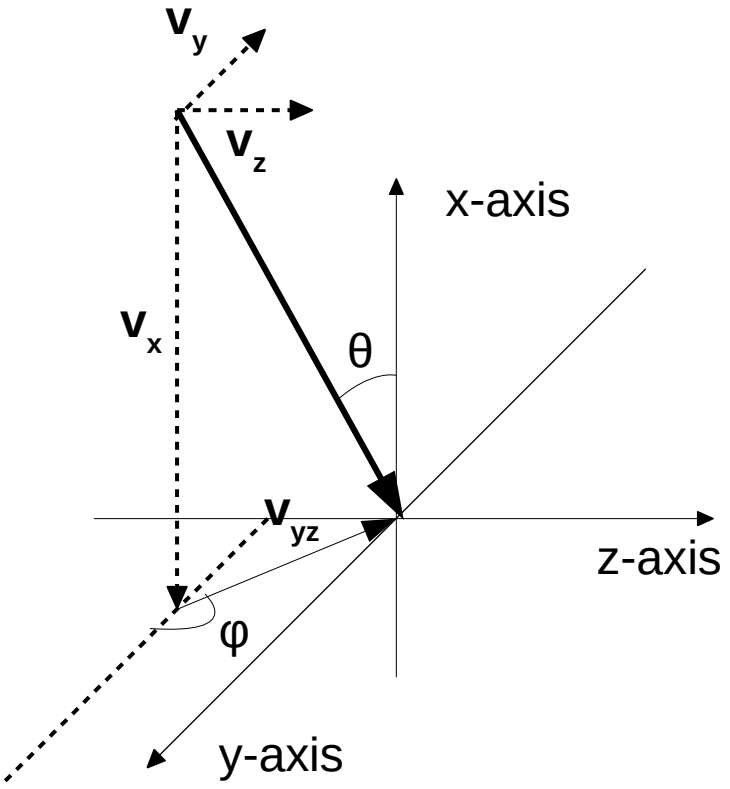
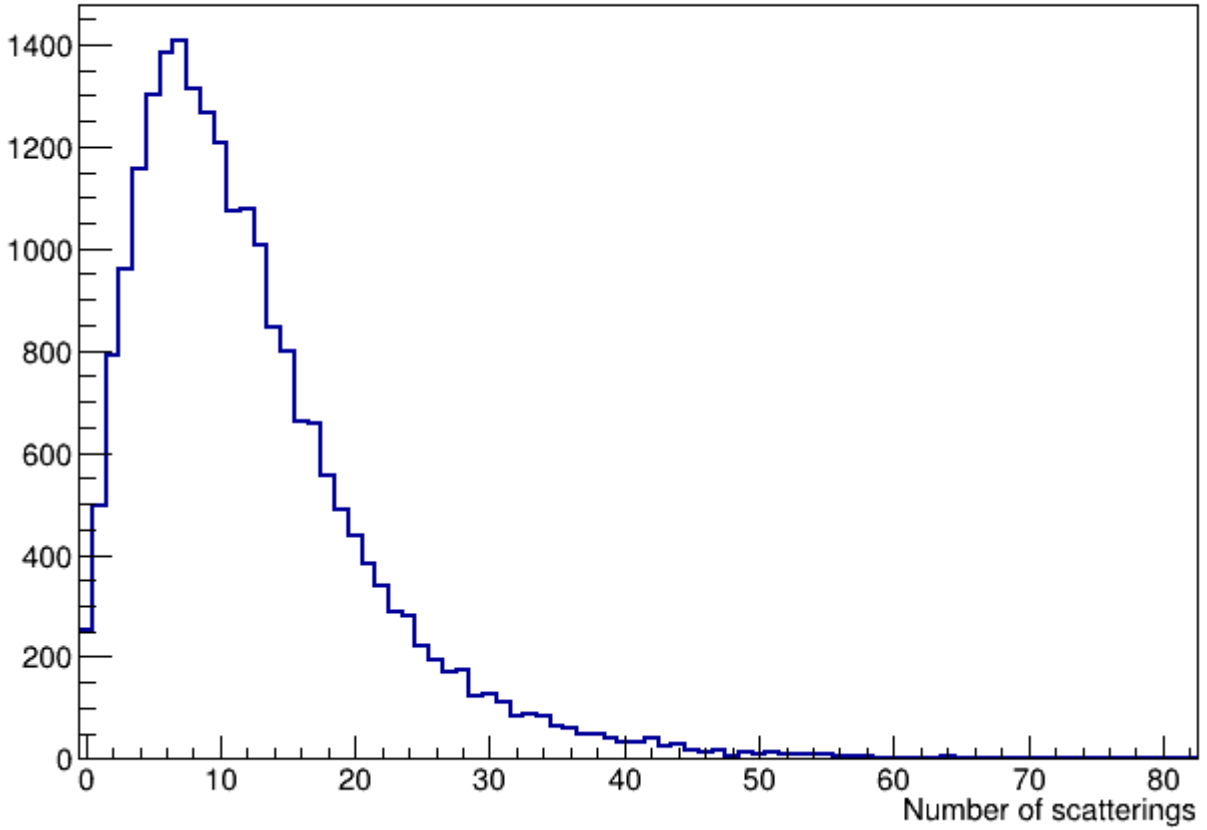
- φ [-180^o, 180^o]: angle between $\boldsymbol{v_{yz}}$ projection and ***y*** axis
  - ± sign same as $\boldsymbol{v_z}$



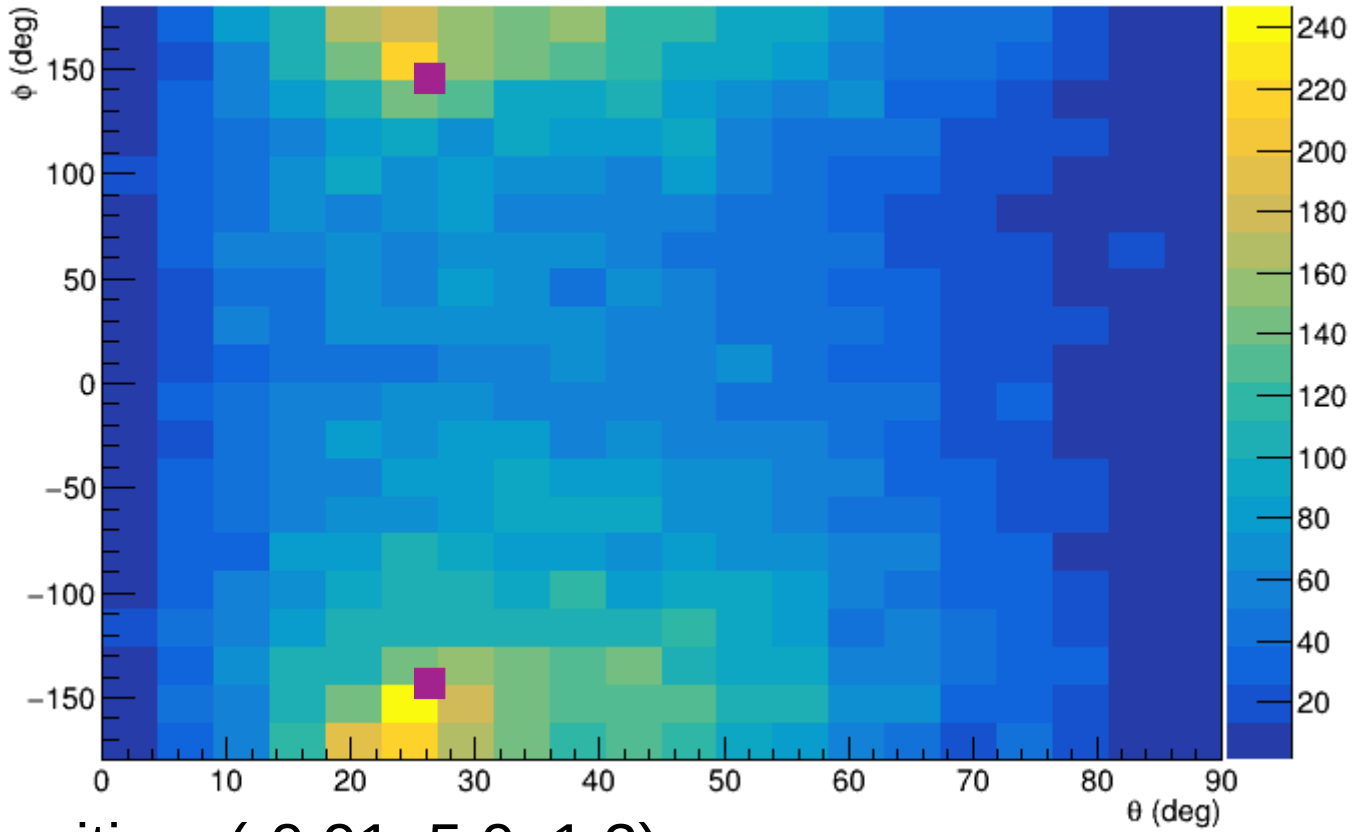
Rayleigh scatterings per photon



Source position (x,y,z): (-0.91, 5.0, 1.2)

Number of photons: 25M

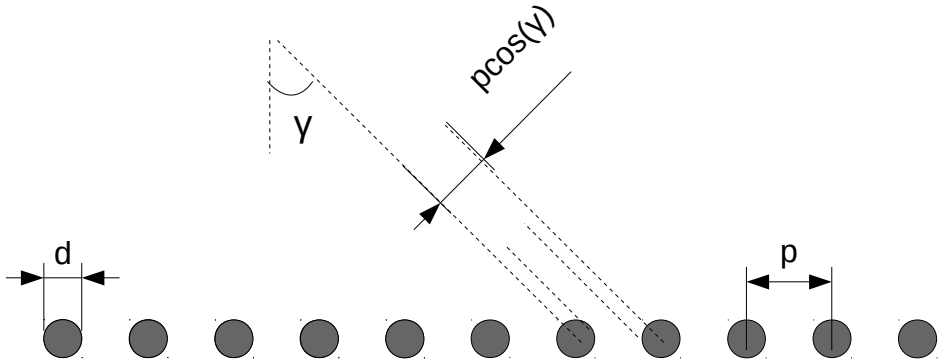
Photons angular distribution



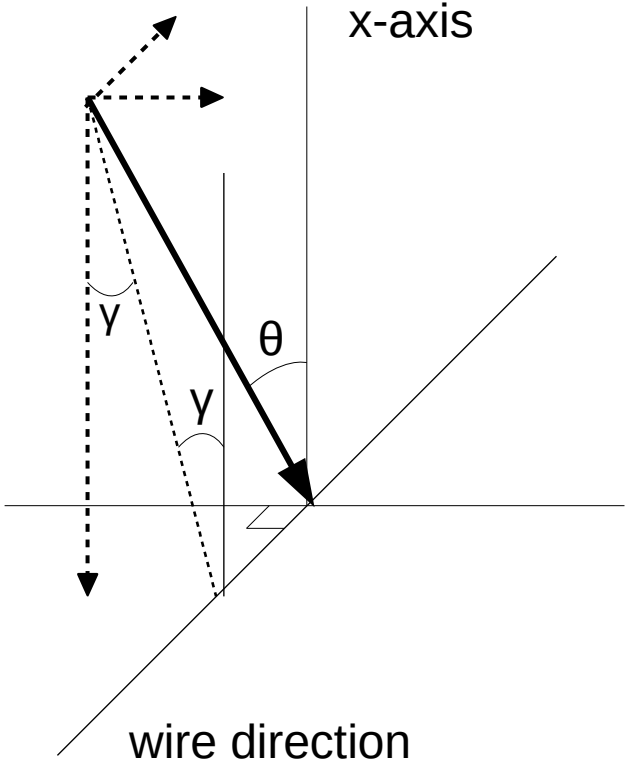
Source position: (-0.91, 5.0, 1.2)

Number of photons: 25M

Wires transmission



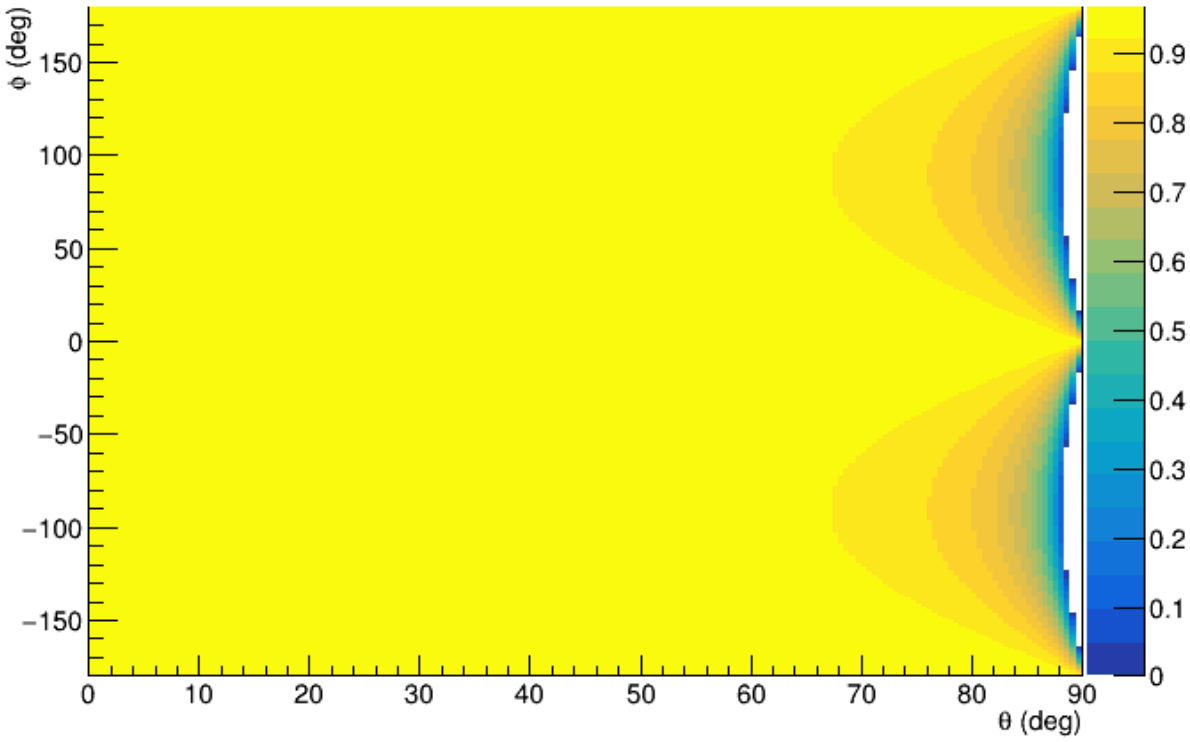
$$T_{plane} = 1 - \frac{d}{p \times \cos(\gamma)}$$



Wire plane transmission

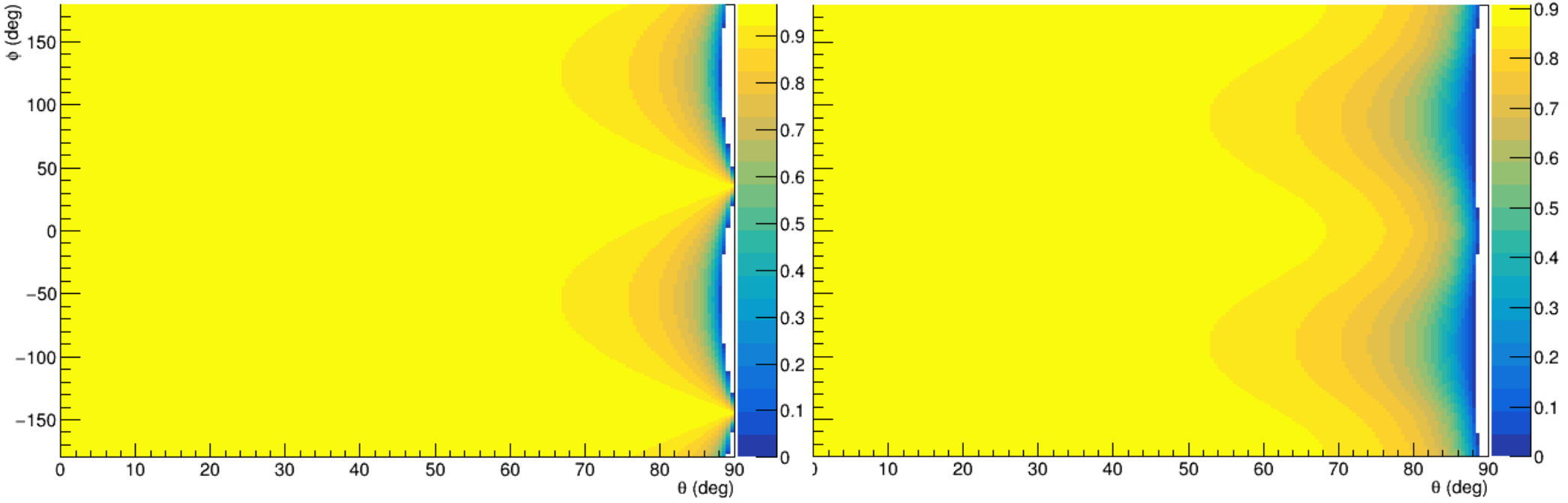
Table 2.3: APA design parameters

Parameter	Value
Active Height	5.984 m
Active Width	2.300 m
Wire Pitch (U,V)	4.669 mm
Wire Pitch (X,G)	4.790 mm
Wire Position Tolerance	0.5 mm
Wire Plane Spacing	4.75 mm
Wire Angle (w.r.t. vertical) (U,V)	35.7°
Wire Angle (w.r.t. vertical) (X,G)	0°
Number Wires / APA	960 (X), 960 (G), 800 (U), 800 (V)
Number Electronic Channels / APA	2560
Wire Tension	5.0 N
Wire Material	Beryllium Copper
Wire Diameter	150 μm



Wire angle (X,G) = 0°

Wire planes transmission



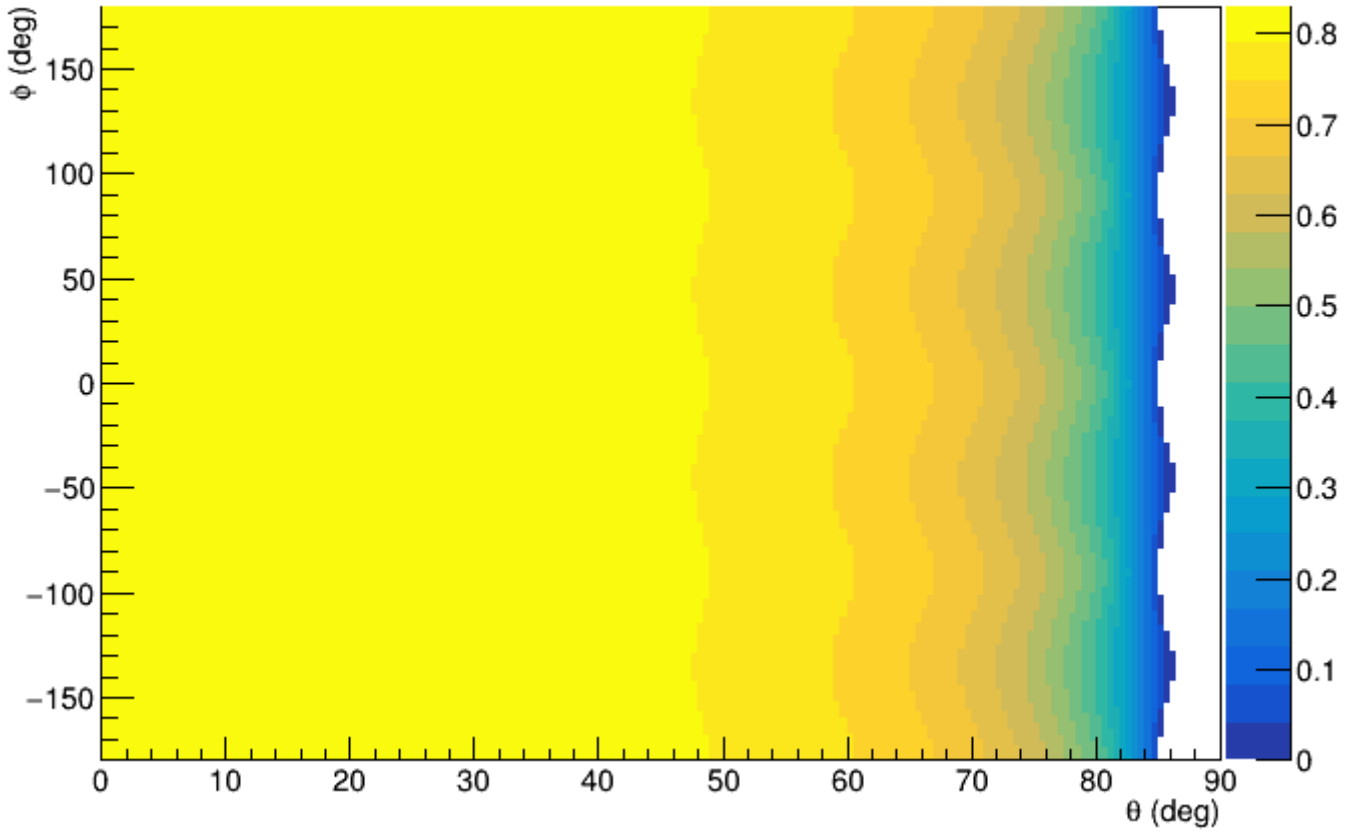
Wire angle (U,V) = 35.7°

Three wire planes

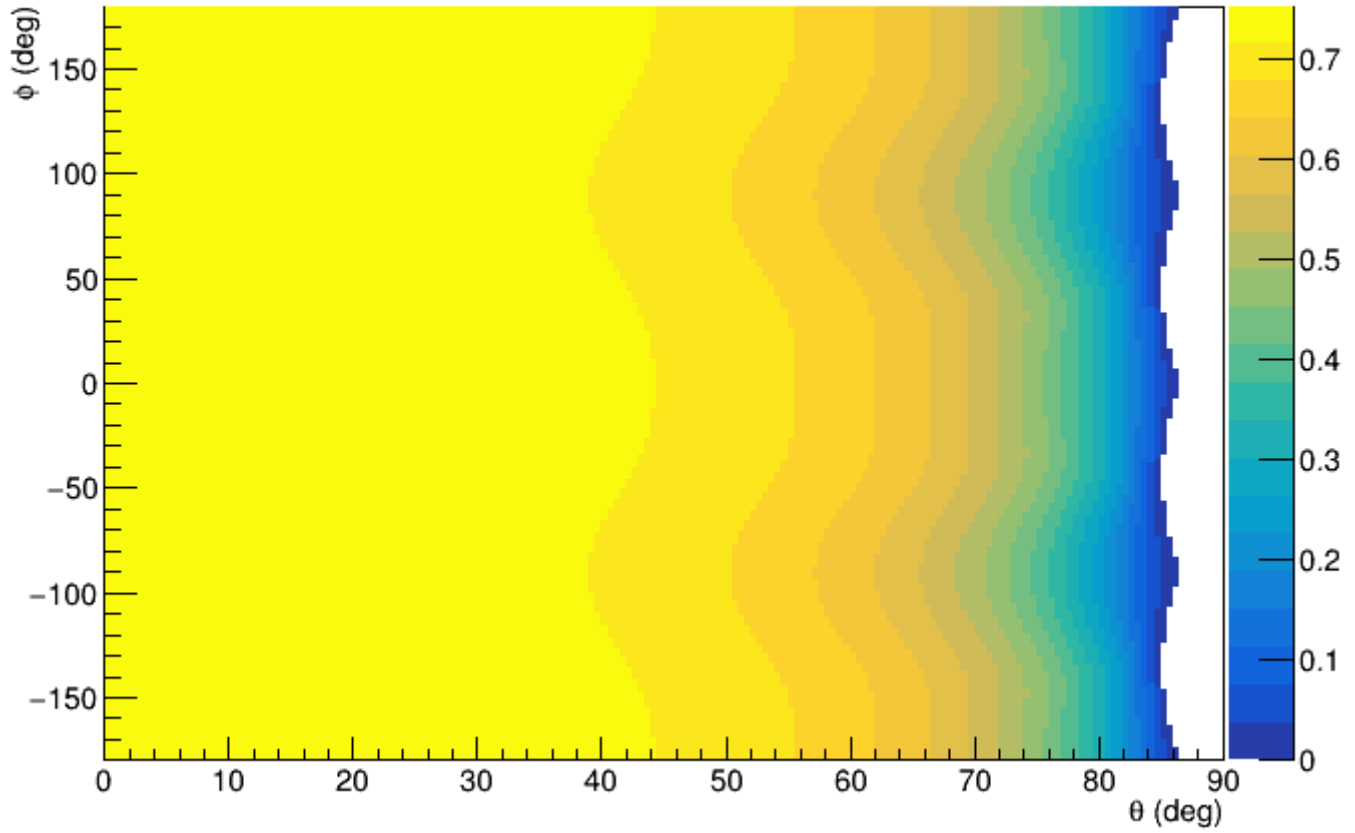
Mesh transmission estimates

- Geometry
  gauge: 80 μm
  pitch: 930 μm
  orientation: ±45°

  Almost φ independent



Total transmission estimates



Overall transmission

Source point (x, y, z)	Transmission
-0.91, 5.0, 1.2	0.696169
-1.8, 3.0, 3.5	0.676384
-2.7, 2.0, 4.7	0.668745

Straight line source

- beam orientation