APEX G4 simulation

Julio Ureña, Justo Martín-Albo, Anselmo Cervera

APEX meeting - 8 February 2024

DEEP UNDERGROUND NEUTRINO EXPERIMENT

INSTITUT DE FÍSICA CORPUSCULAR

Introduction

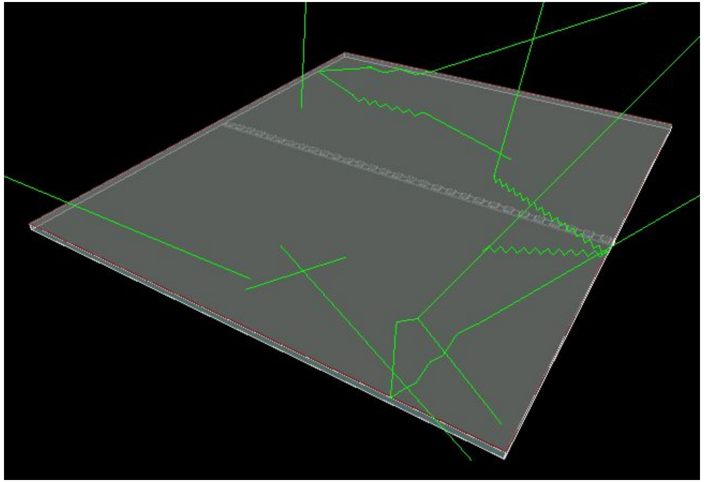
- APEX has been simulated using Geant4

- Several configurations, including the baseline one, have been considered
  - Baseline APEX
  - Side SiPMs
  - Side SiPMs x2
  - Detached DF (XA approximation)

- The goal is to obtain preliminary estimates of the PCE to motivate the changes which will hopefully increase the APEX module PCE

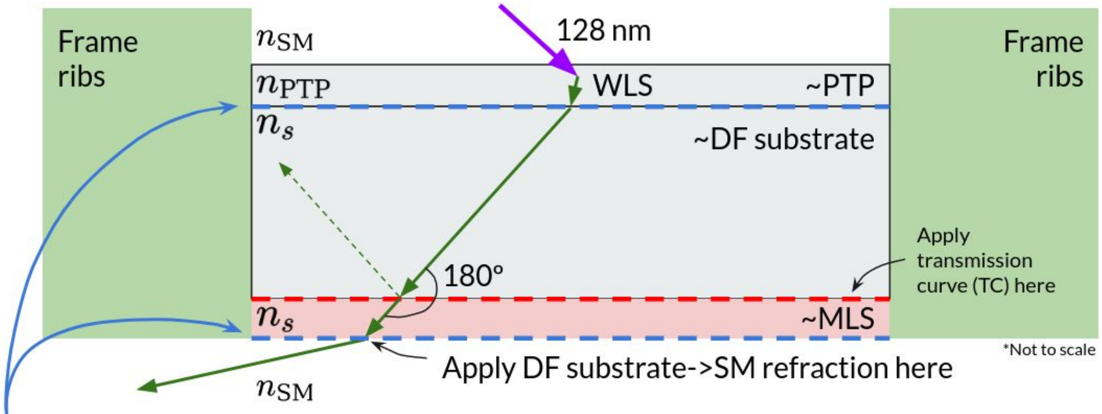
APEX baseline - implementation features

- Geometry surrounded by LAr
- pTP coating deposited on top of the DF
- **<u>DF deposited on top of the WLS plate (WLSp)</u>**
- PhotonExport filters transmission curves measured @ IFIC
- 495x450x6 mm3 WLSp
- G2p WLSp w/ 16 mg/(PMMA kg) cromophore concentration (Specs. measured @ MiB)
- All WLSp faces covered w/ vikuiti foils - only holes for SiPMs
- 30 Broadcom AFBR-S4N44P044M (2x2 SiPM array each) per board
  - implemented typical PDE vs wavelength curve (peaking at ~63%)
  - dimensions gotten from technical drawing in datasheet
  - epoxy windows
- SiPMs board placed along the 450 mm long side
- Optical contact between SiPMs and WLSp
- Photons are randomly generated 0.1 mm above the pTP
- **<u>SiPMs facing one of the biggest WLSp faces</u>**



From 2023/02/07 talk on Photon Collectors WG

First caveat



For a realistic simulation of the DF, refraction in every surface must be simulated, but as we have seen, refraction cannot be separated from reflection

From Geant4 user's guide > Tracking and physics > Physics processes > Optical photon processes > Boundary process:

*"As expressed in Maxwell's equations, **Fresnel reflection and refraction are intertwined through their relative probabilities of occurrence**. Therefore neither of these processes, nor total internal reflection, are viewed as individual processes deserving separate class implementation."*

From 2023/02/07 talk on Photon Collectors WG

First caveat

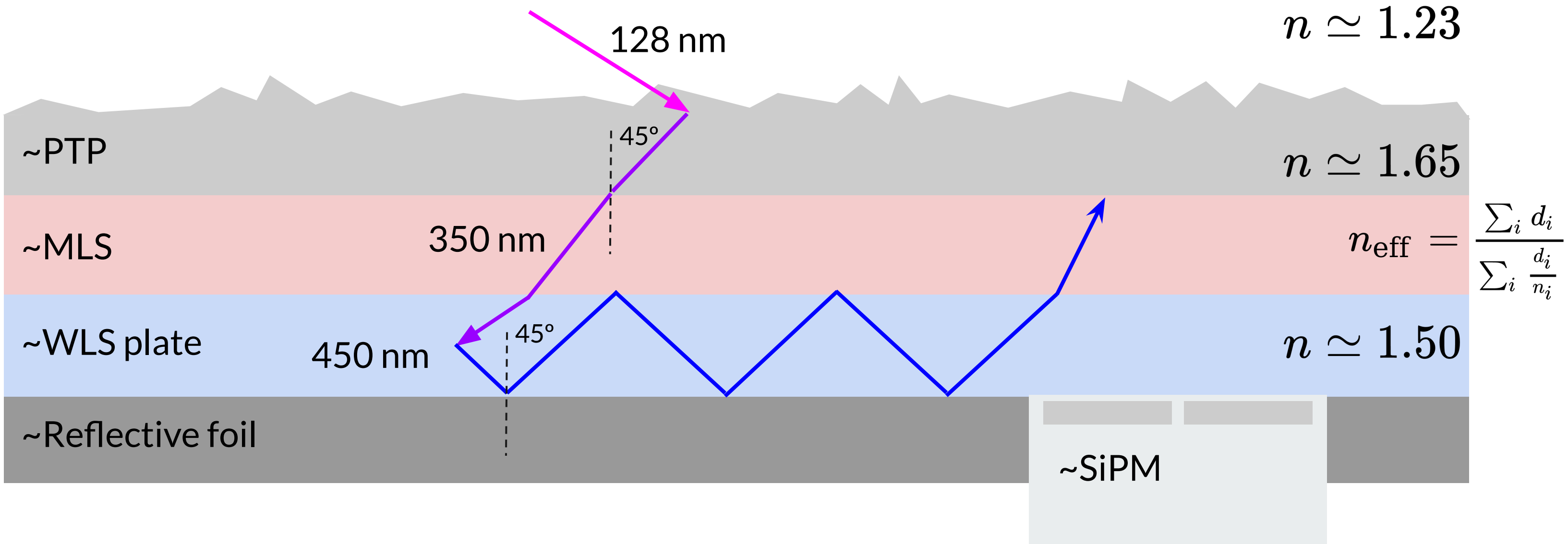
$$ITC(\lambda, \theta_{sm}) = \frac{T_m(\lambda,\theta_{sm})}{FT_{n_{su}}^{n_{sm}}(\theta_{sm}) \cdot FT_{n_{sm}}^{n_{DF}}(\alpha(\theta_{sm}))}$$

Within this approximation, we know what the refractive index of the dichroic filter is (the effective r. index of the MLS) and we can compute the angle of the light that propagates within the ~MLS using Snell's law

$$ITC(\lambda, \theta_{sm}) = \frac{T_m(\lambda,\theta_{sm})}{FT_{n_{su}}^{n_{sm}}(\theta_{sm}) \cdot FT_{n_{sm}}^{n_{\text{eff}}}(S(\theta_{sm}))}$$

32

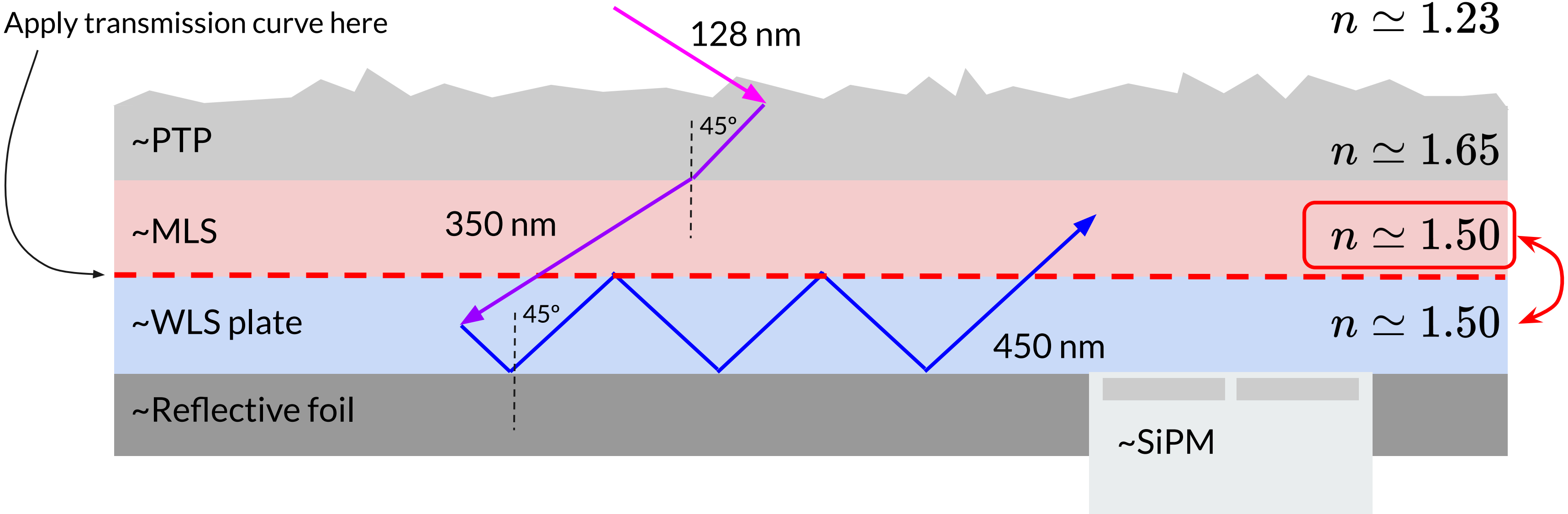
DF implementation details



*Not to scale

Assuming $n_{\mathrm{eff}} \simeq 1.68$

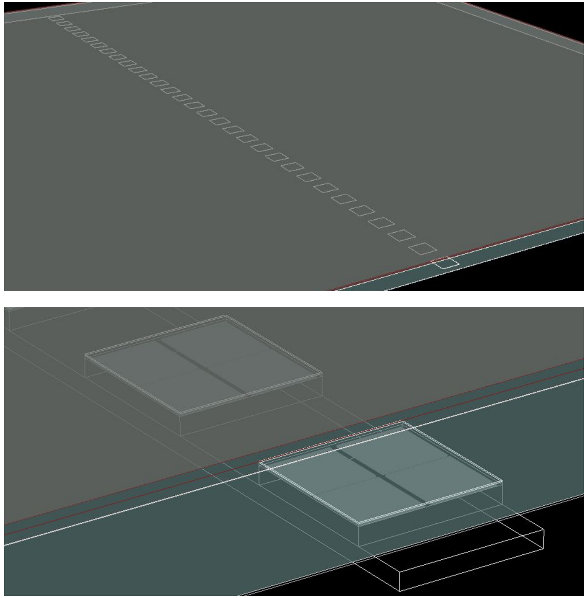
DF implementation details



*Not to scale

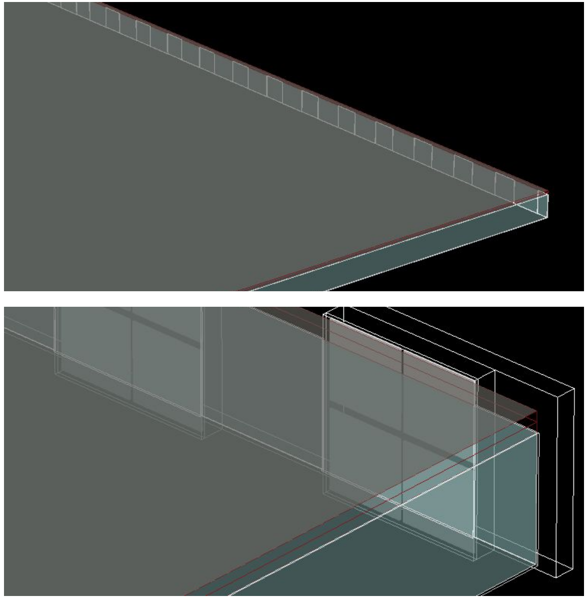
Results

Baseline



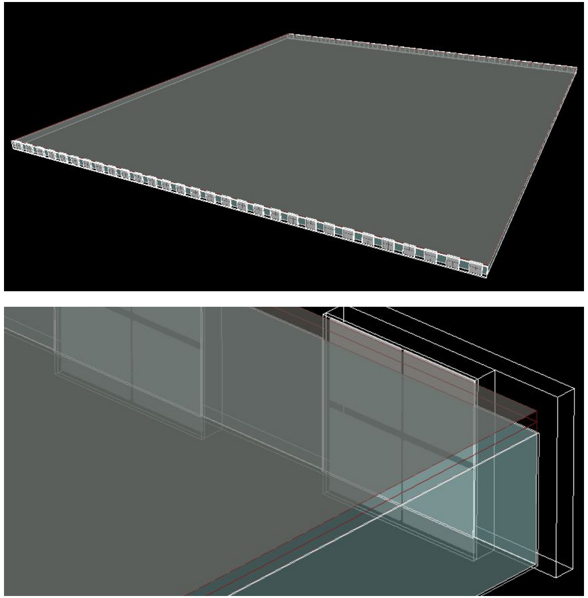
PCE ~ 0.63%

Side SiPMs



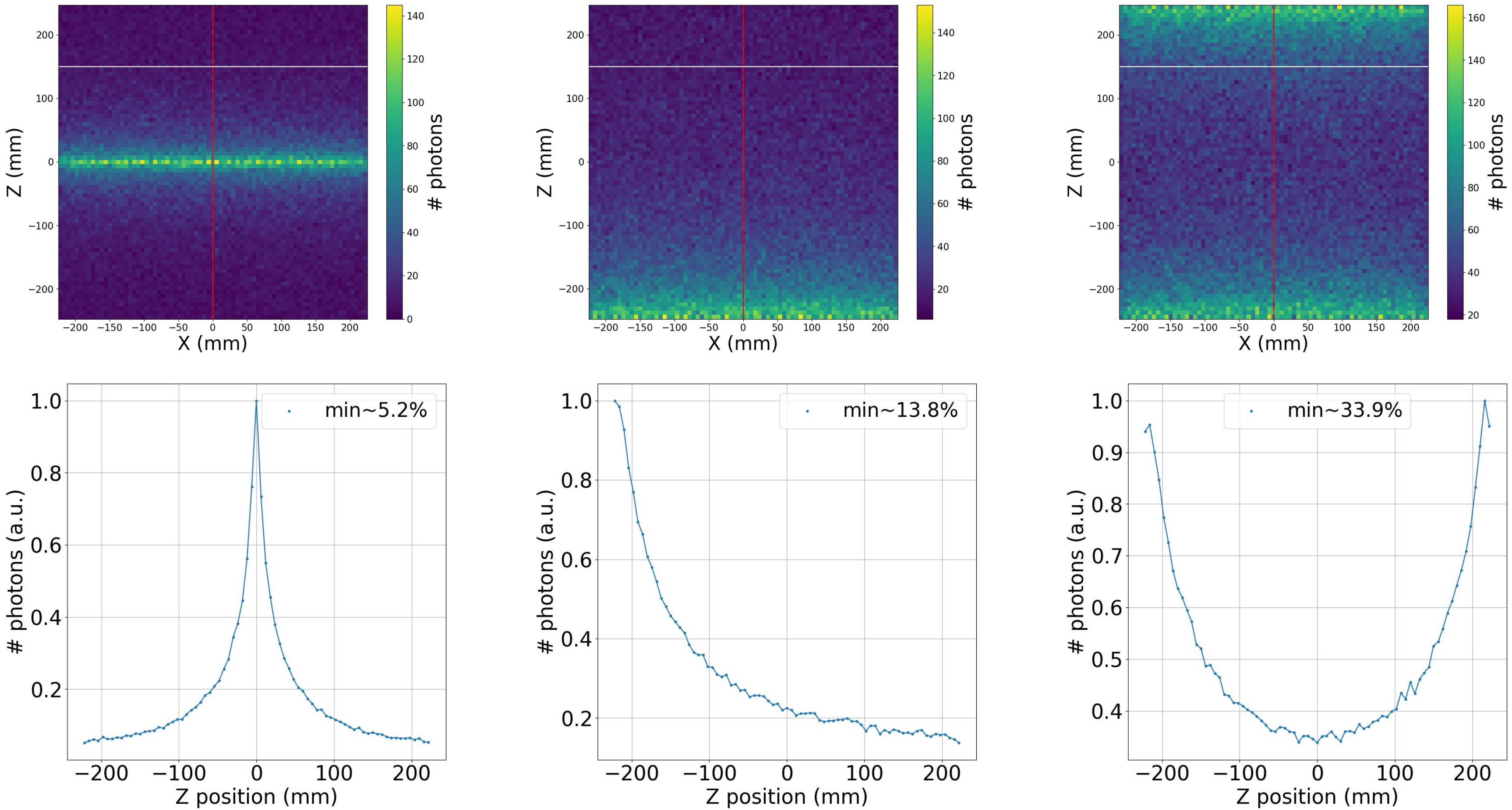
PCE ~ 1.23%

Side SiPMs (doubled)



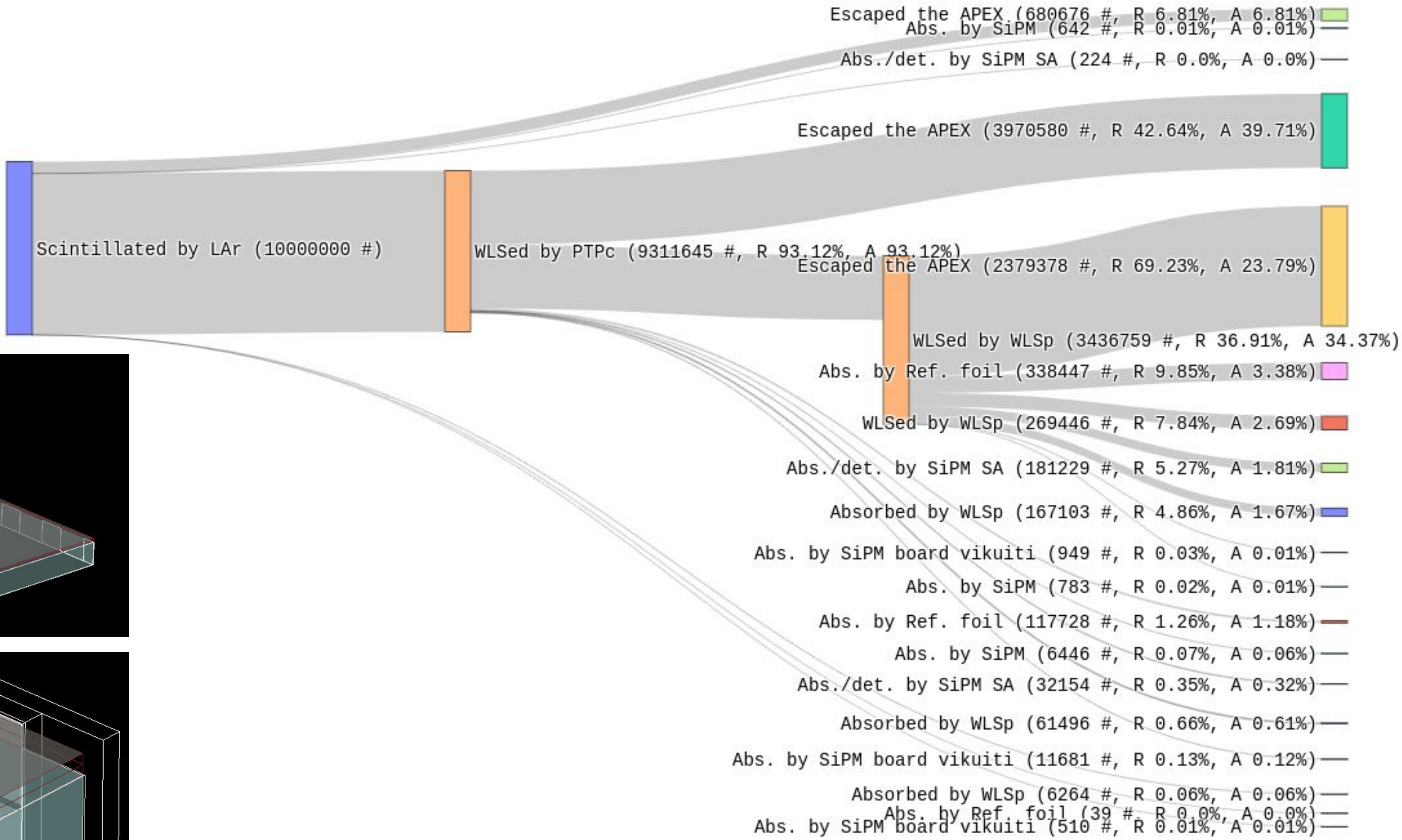
PCE ~ 2.27%

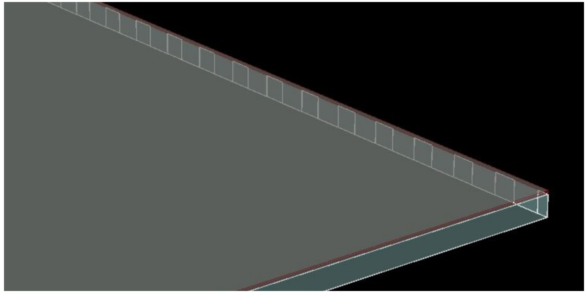
Detected photons: Where in the plate were they shifted?

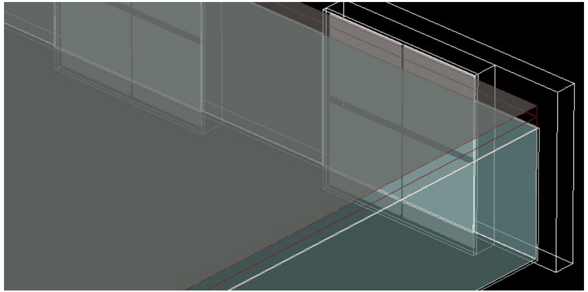


APEX side-SiPMs detailed

PCE ~ 1.23%

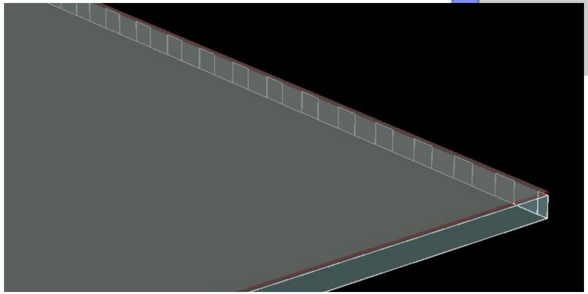


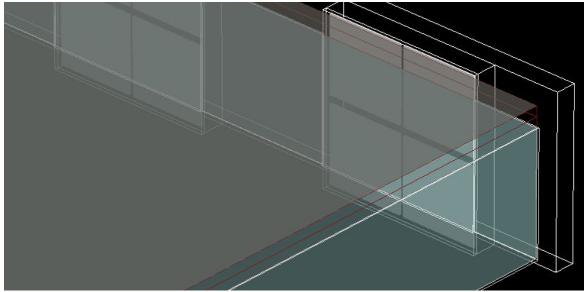


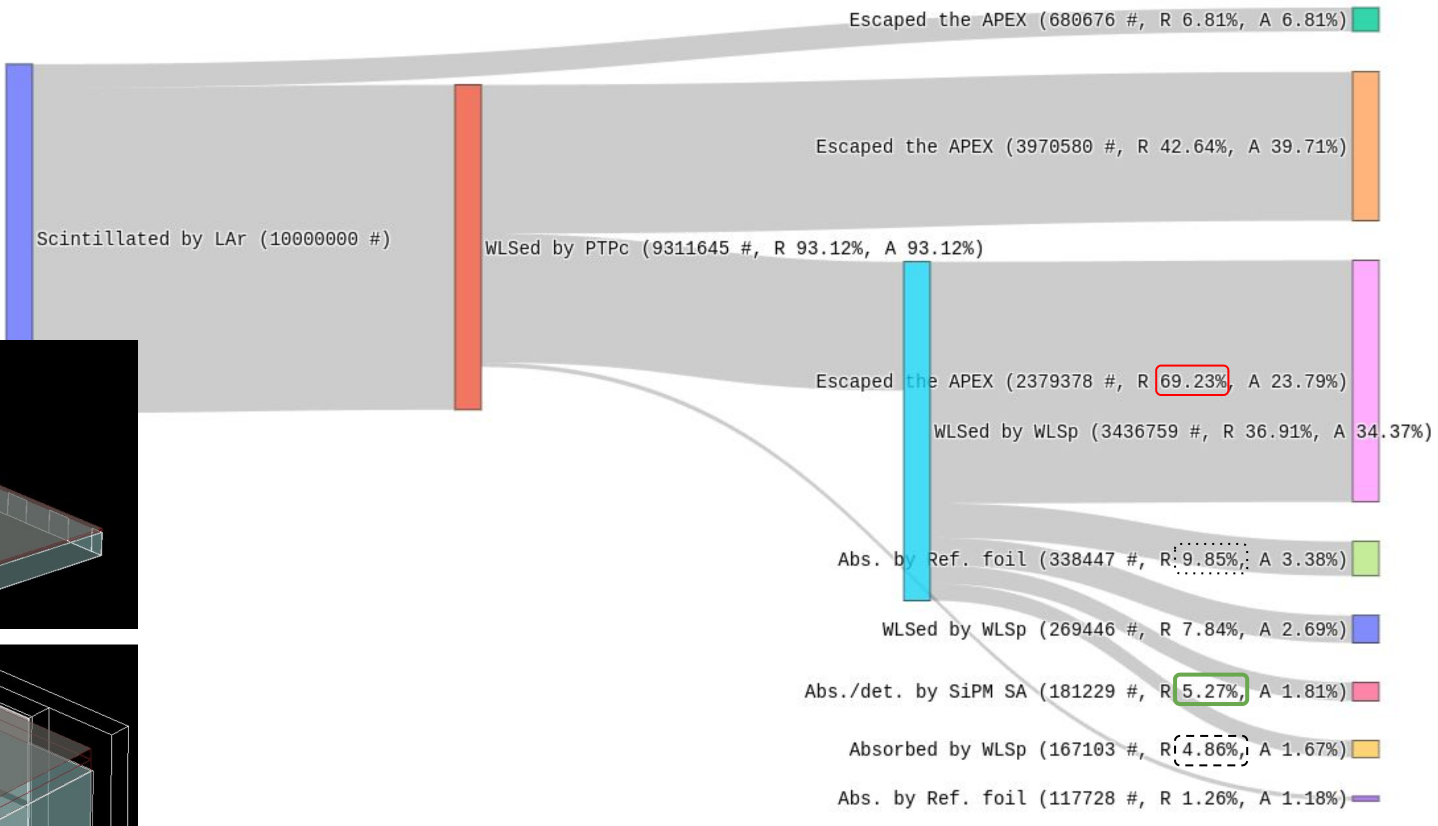


APEX side-SiPMs detailed

PCE ~ 1.23%



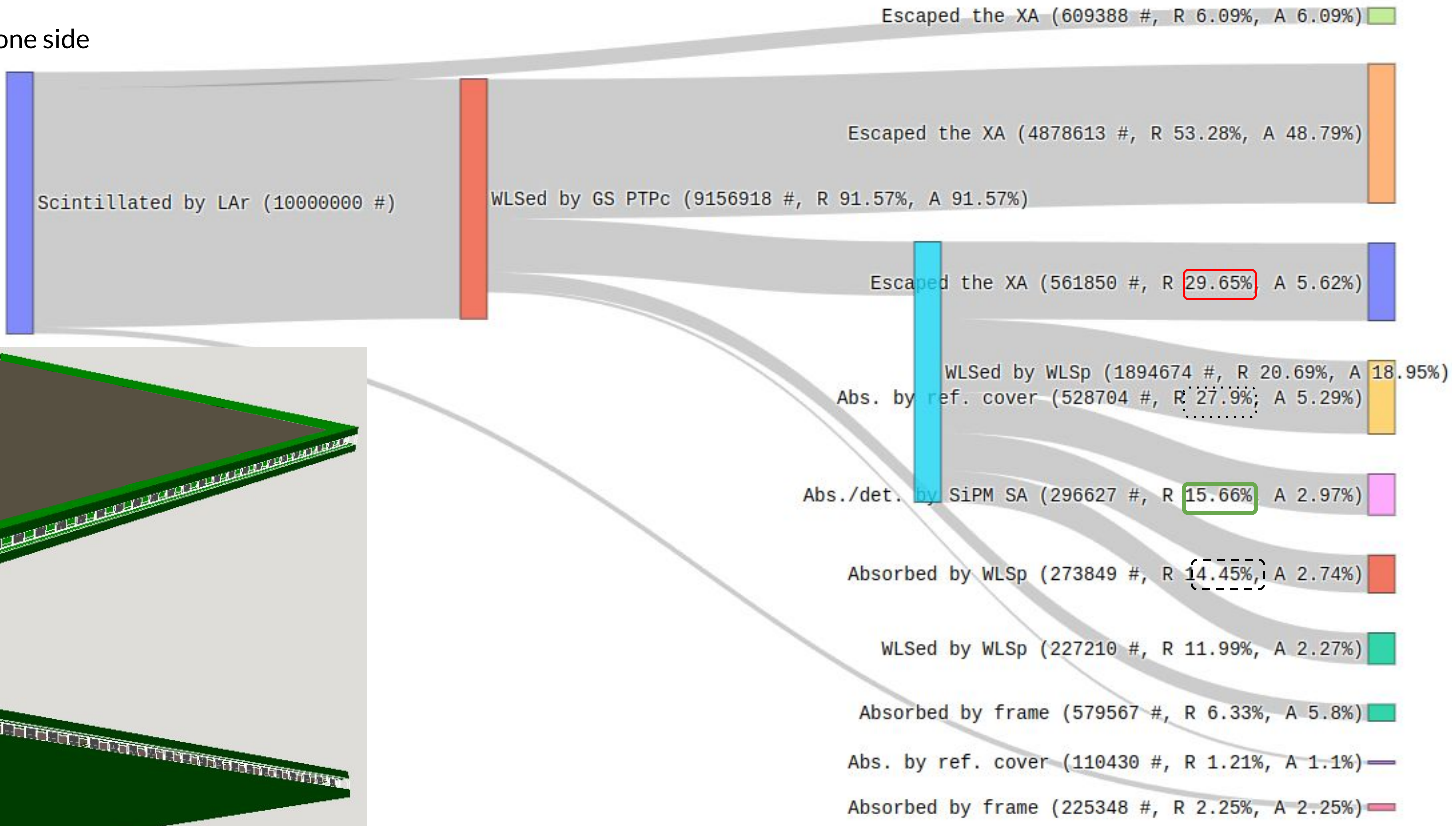


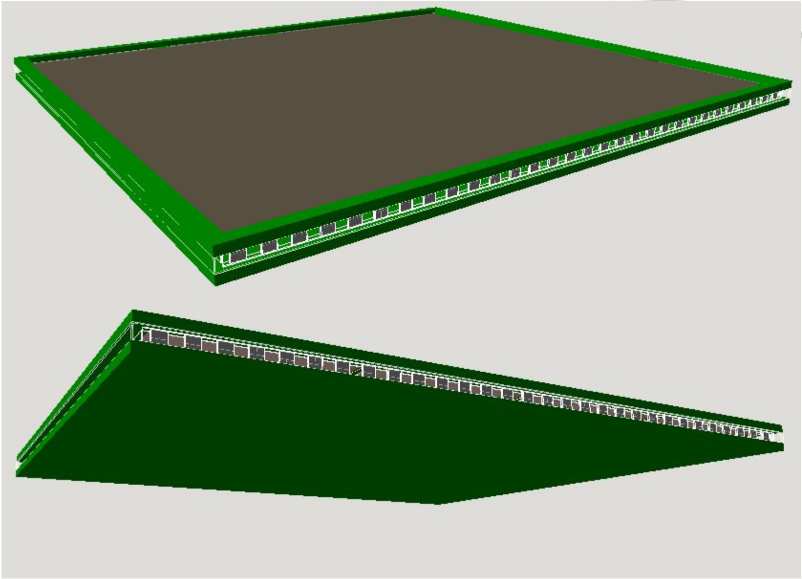


APEX with separated DF (XA approximation)

- APEX dimensions
- 30 Broadcom SiPMs on just one side
- Optical contact
- Same DFs

PCE ~ 1. 73 %





Summary table and conclusions

- Gluing the SiPMs onto an small face ~duplicates the PCE
- It also makes better use of the whole APEX surface

Configuration	APEX baseline	APEX side SiPMs	APEX 2x side SiPMs	APEX-like XA (~APEX w/ detached DF)	APEX 2x side SiPMs w/ cut WLSp (MiB, SC)	APEX side SiPM w/ no DF	APEX side SiPM w/ no DF, detached pTP
PCE (%)	0.63	1.23	2.27	1.73	pending	pending	pending

- Total internal reflection (TIR) seems more efficient than direct-DF based trapping