LAr scintillation photon simulations and update on optical properties

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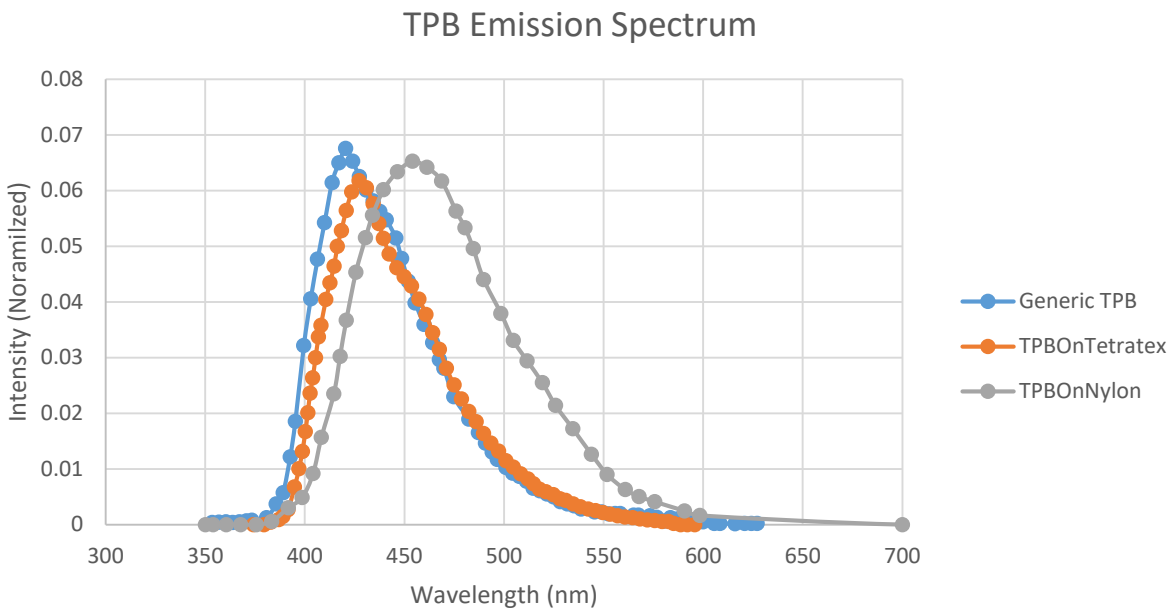
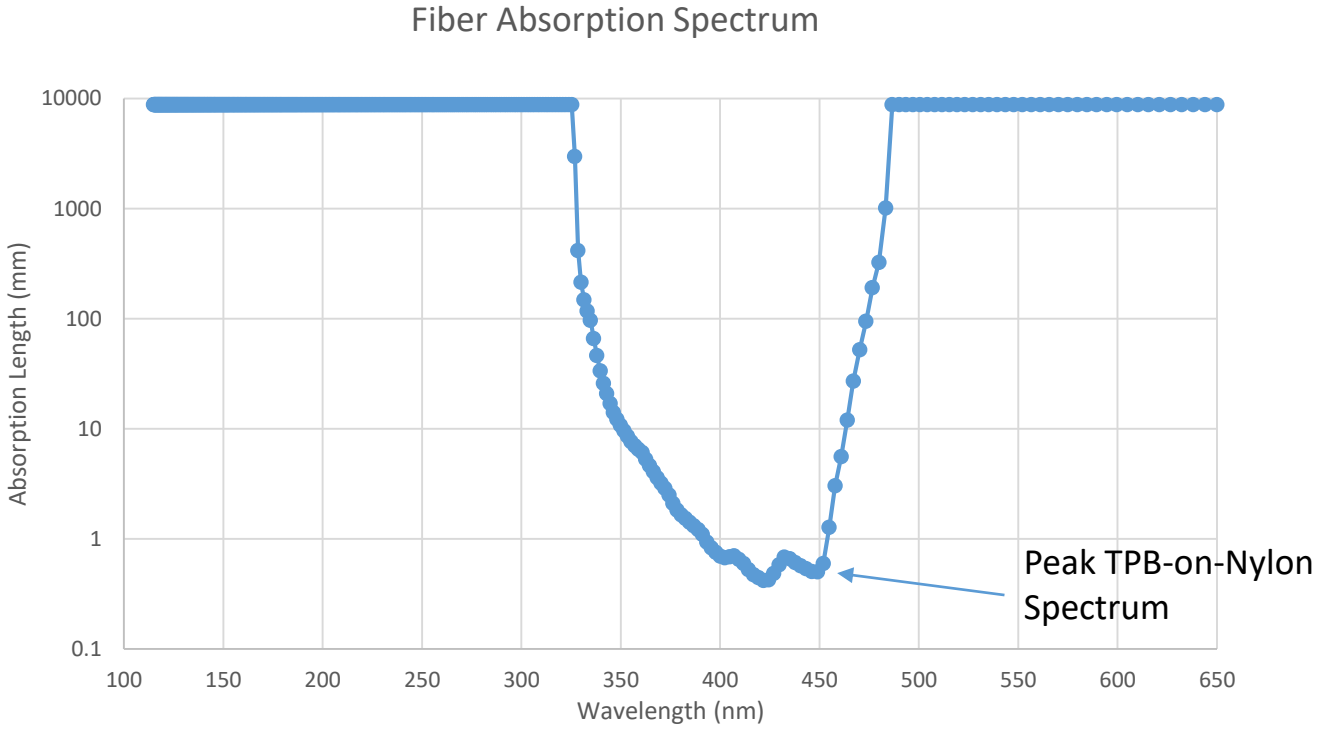
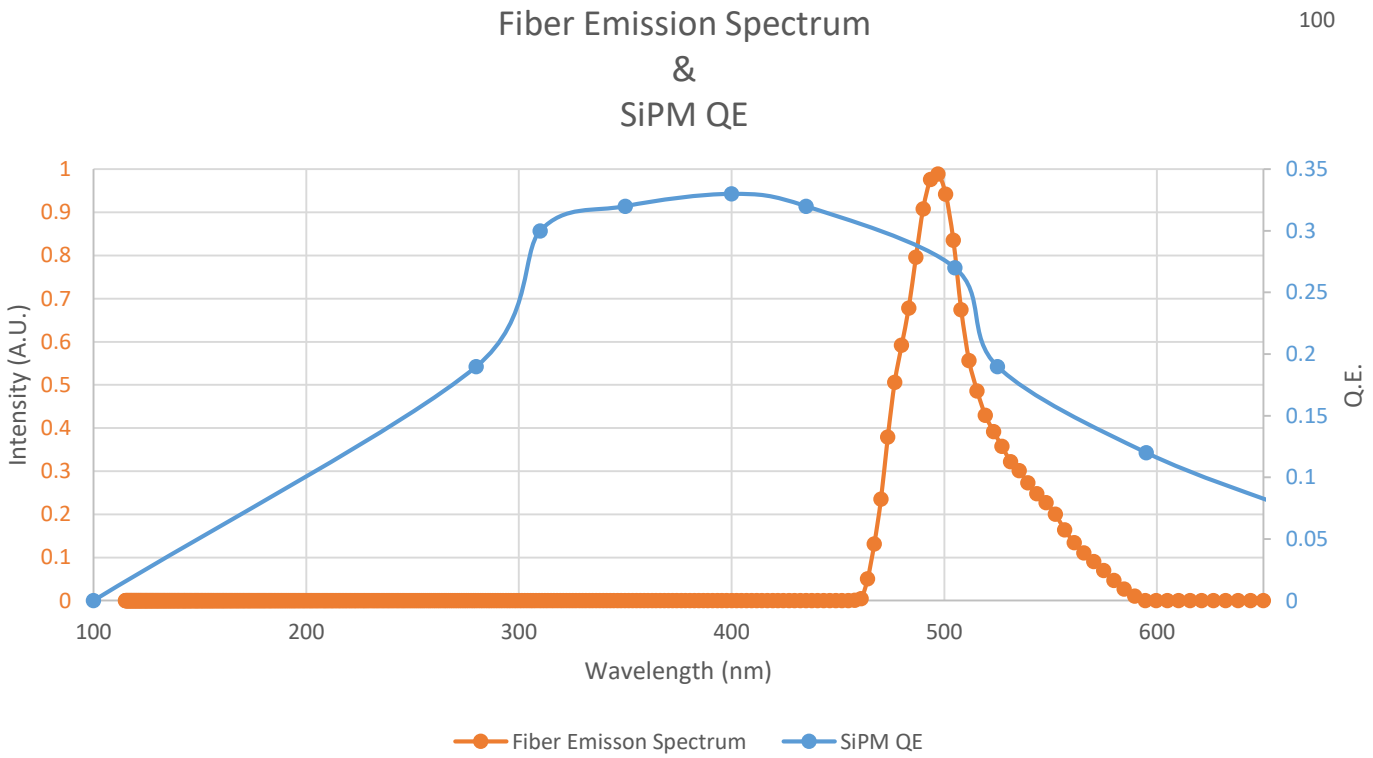
Status on Optical Properties for LGND

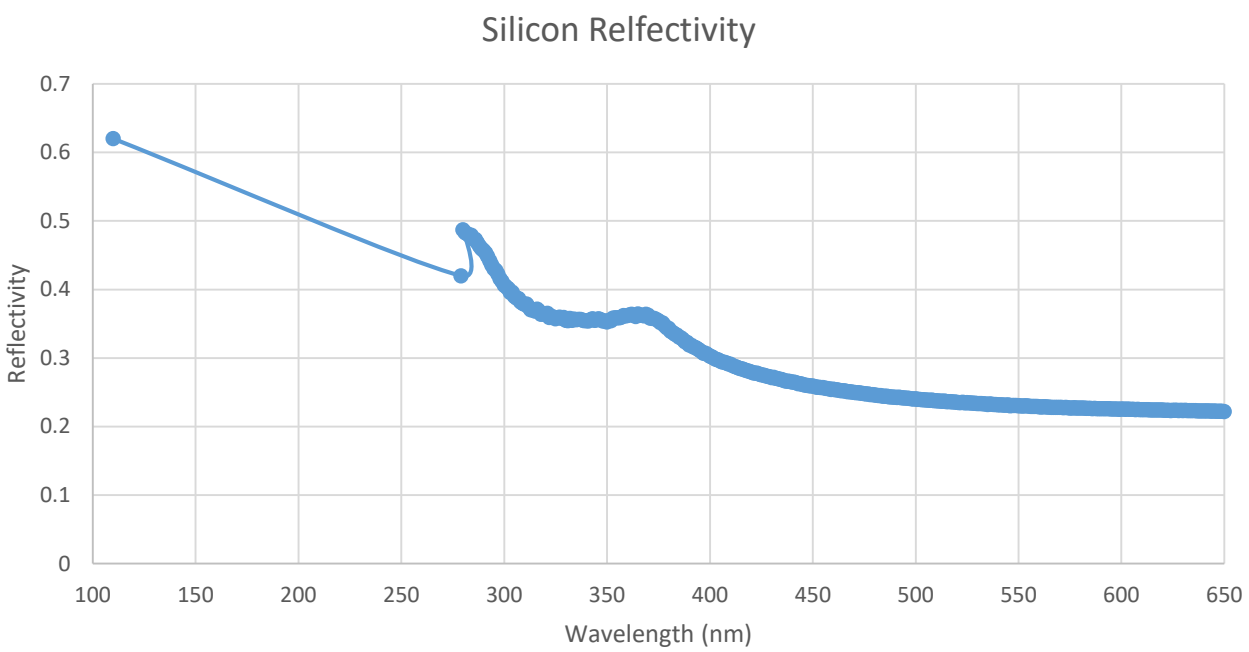
- LAr attenuation length @ 60 cm but Mario measured it to be 1.7 ± 0.7 m in “NOT super-high quality” LAr
- Square fibers 1x1mm^2 have two layers of cladding, inner and outer layers index of refraction are 1.42 and 1.49 respectively.
- Fiber core index of refraction is 1.60 and 3.8m attenuation length
- TPB refractive index set to 1.635
  - “Rough” coated on fibers -> internal reflection at TPB/fiber boundary
- TPB QE to 1.2 but might 1.0
  - Other experiments use this to tune optical sims (COHERENT QE: 1.64)
- TPB absorption spectrum is step function
  - λ_{atten}~100 nm below 420 nm
  - λ_{atten}~100 m above 420 nm
- TPB on Tetratex is diffuse reflector, with TPB optical properties.
- TPB on Nylon (fiber), has TPB optical properties

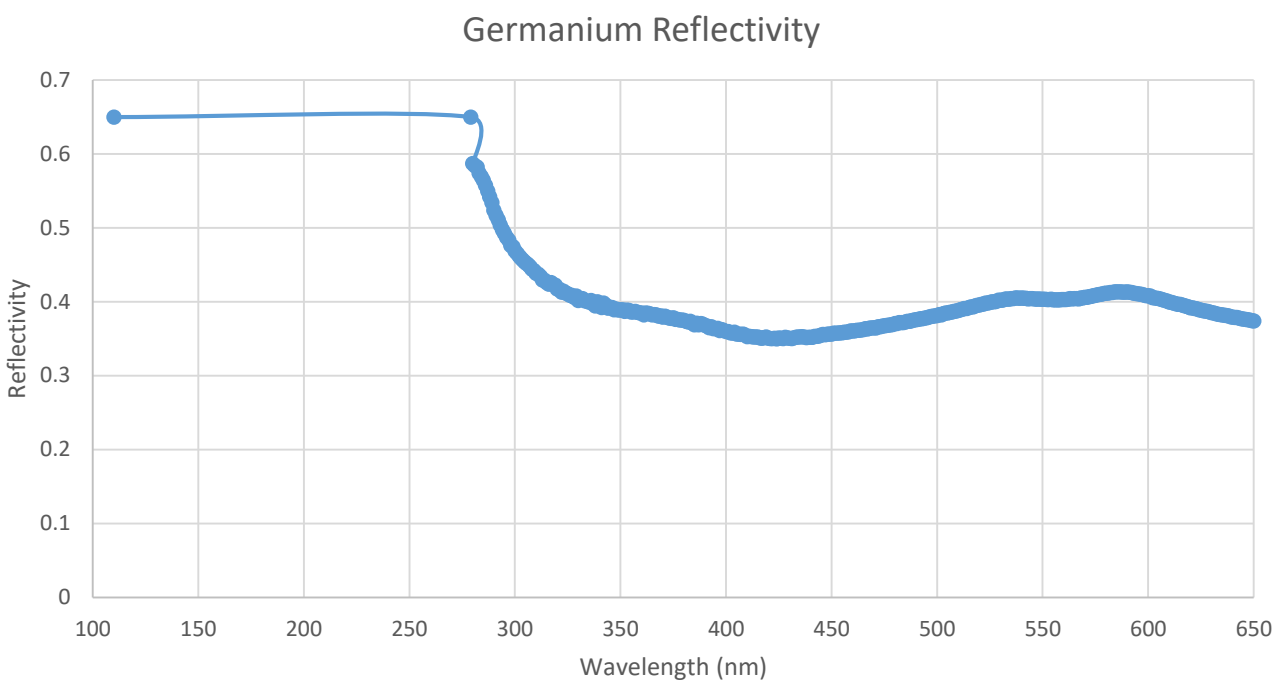


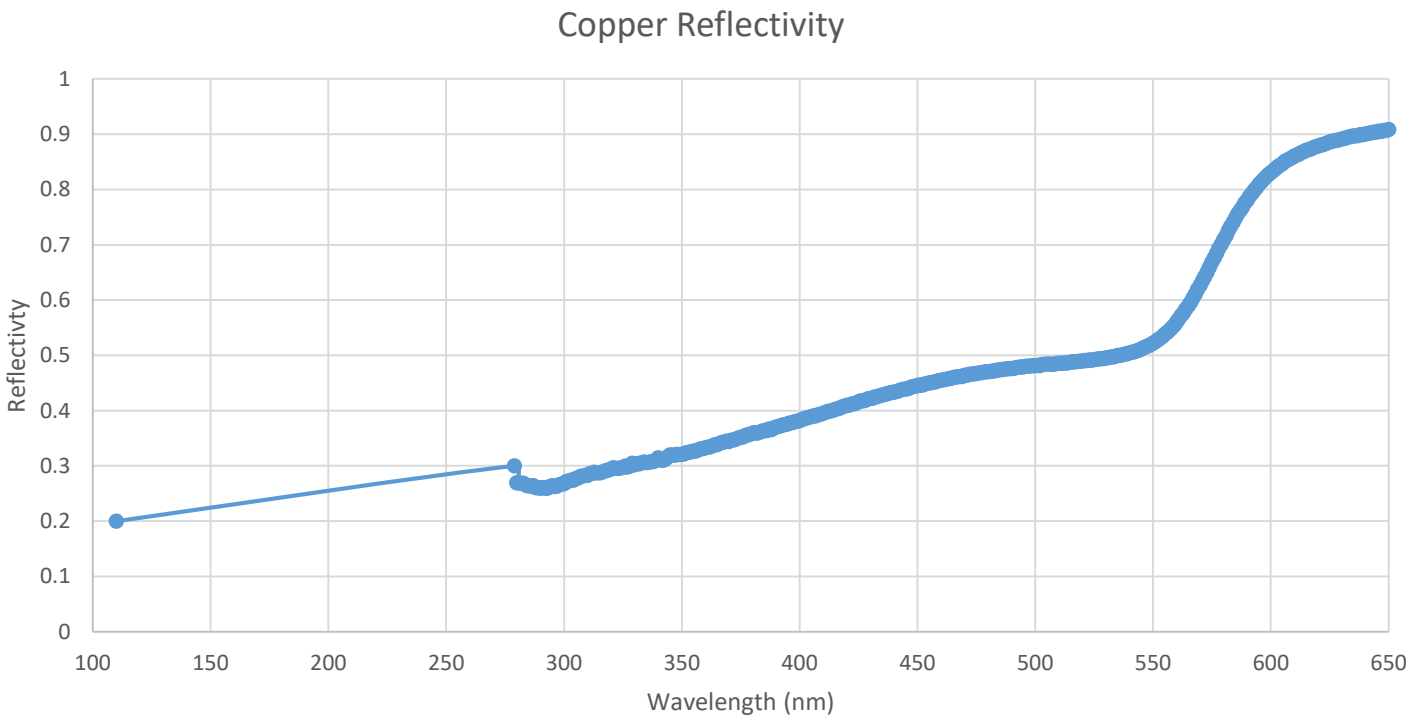




- TPB-on-Nylon is used to coat fibers and mini-shroud.
- TPB spectrums are well matched to fiber absorption.
- SiPM QE averaged over fiber emission spectrum is 0.164
- set to 1 in sims, corrected for in post processing

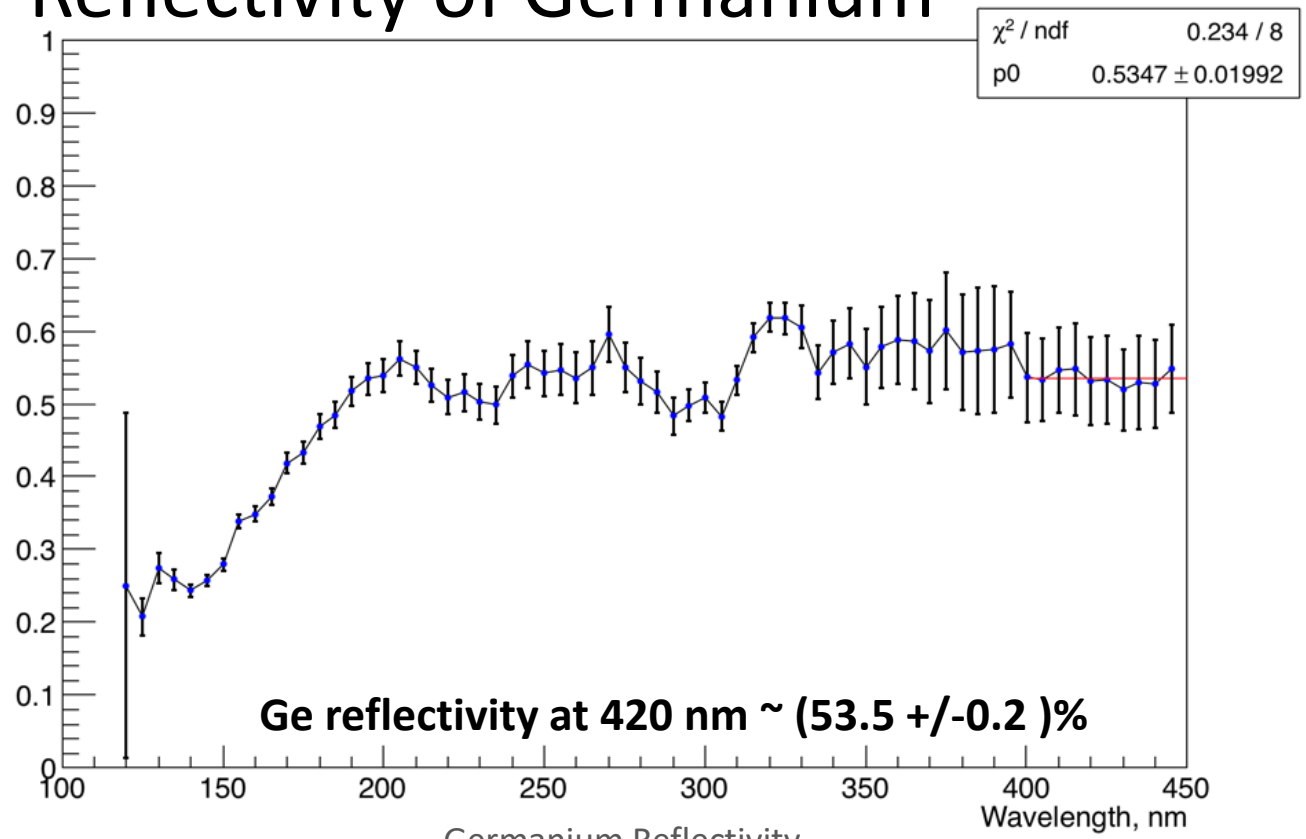


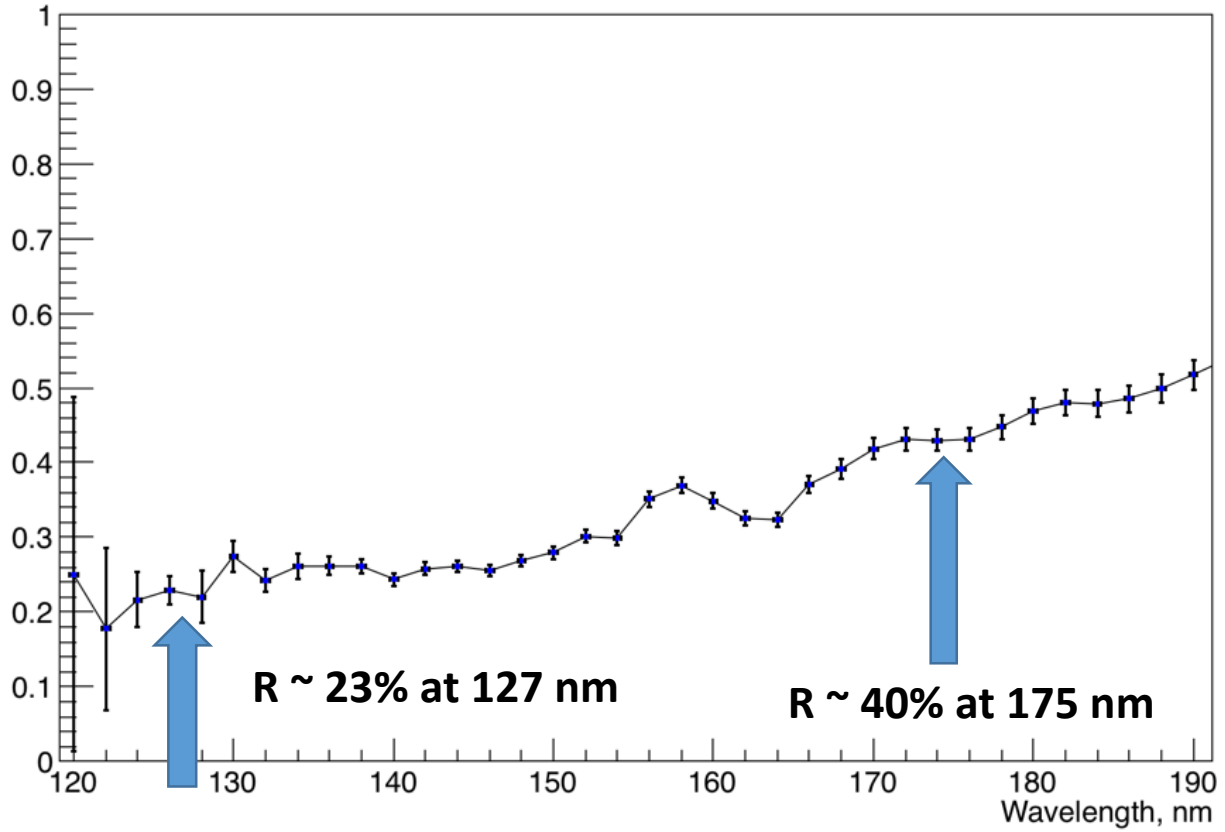




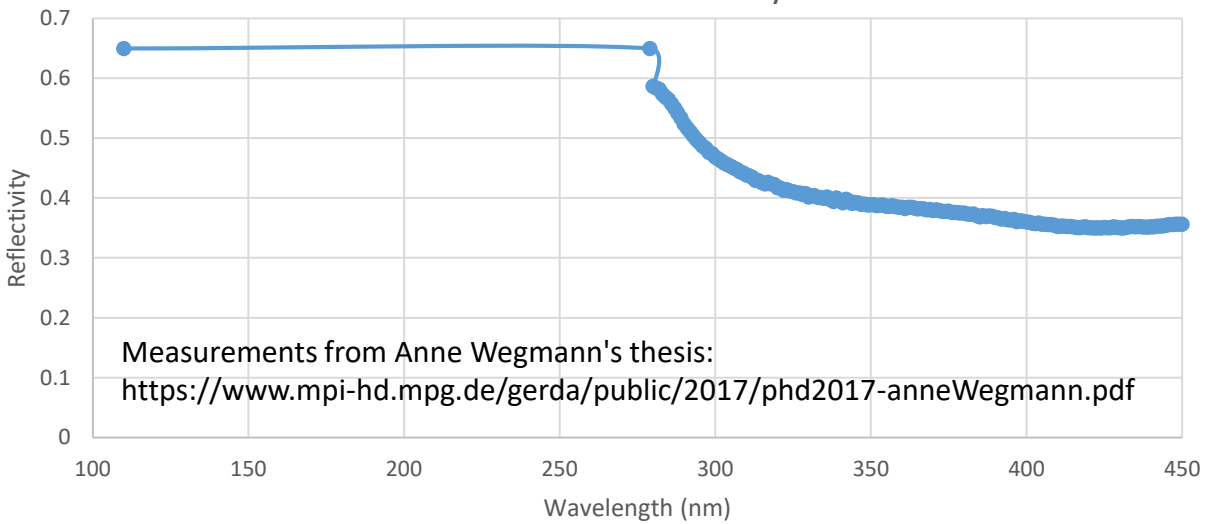
Reflectivity is not known at VUV wavelengths.

Reflectivity of Germanium





Germanium Reflectivity



Taken from:
Ivan Tolstukhin, Indiana University
Yuri Efremenko, University of Tennessee

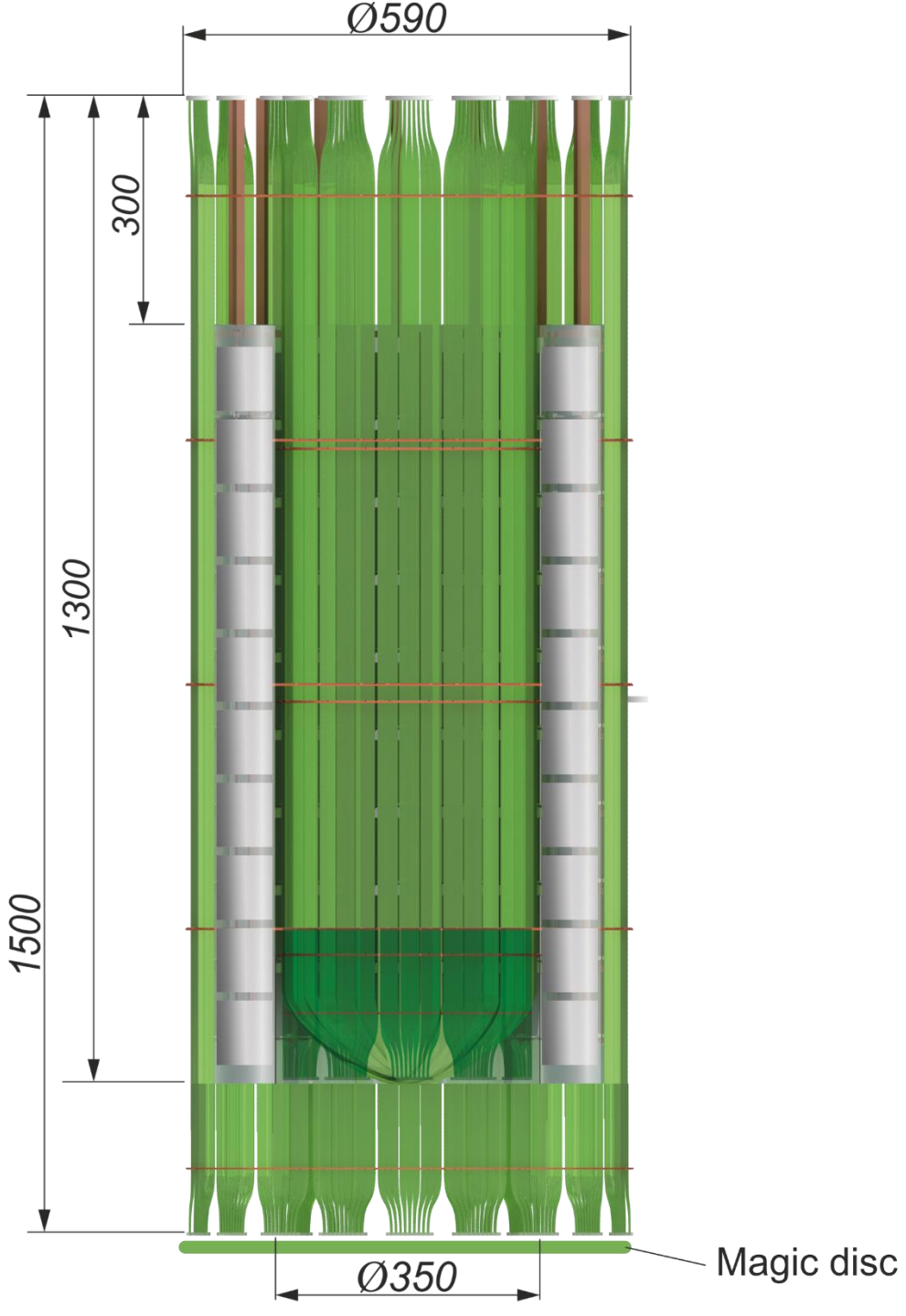
*Not yet added in MaGe

LAr Generator

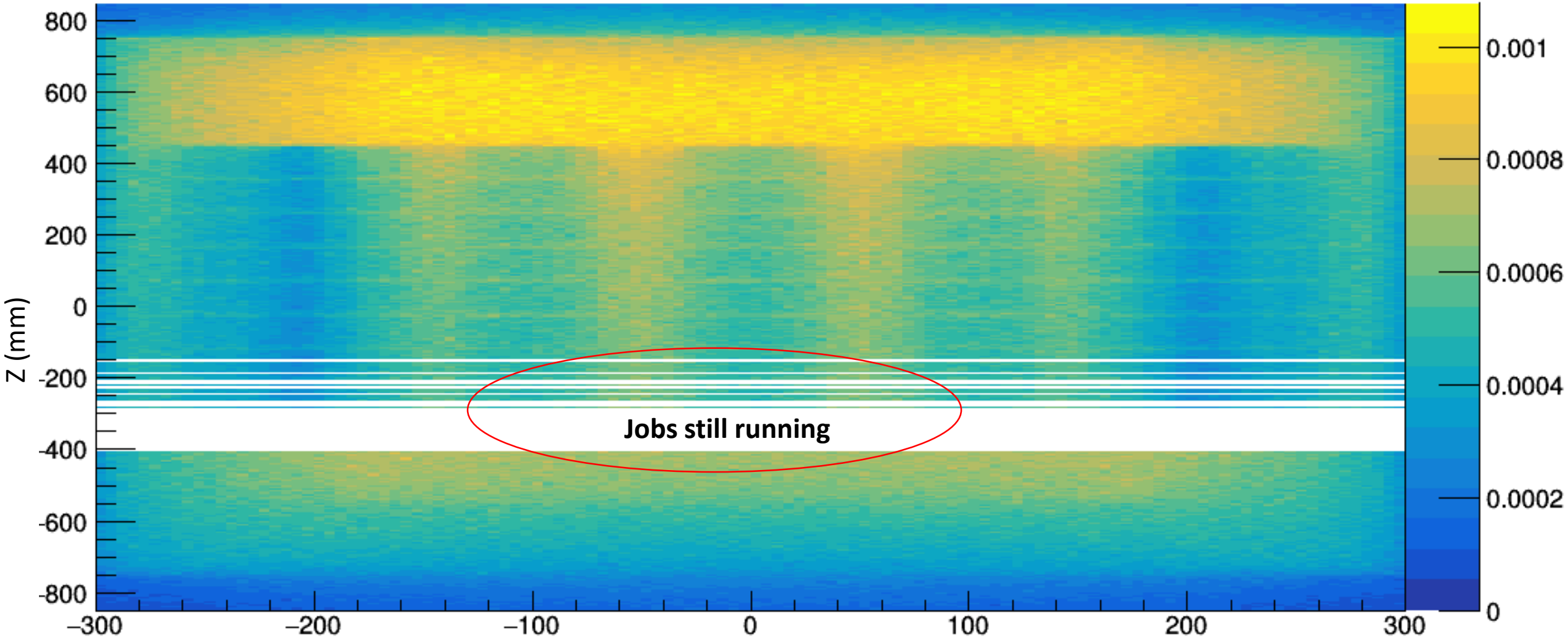
- Generate 500 VUV (μ=128 nm, σ=2.93 nm) randomly in 5x5x5 mm^3 voxels and scan entire array.
  - Each run is a 5 mm slice in Z
  - Easy to normalize each voxel when creating a Cartesian optical heat map
  - For R-Z map, have to include additional correction for $PDF(r) = {}^{2r}/_{R_{max}^2 - R_{min}^2}$
- Photon momentum:
  - $p_x = \cos(\emptyset)\sin(\theta)\,, p_y = \sin(\emptyset)\sin(\theta)\,, p_z = \cos(\theta)\,,$
  - $\emptyset \in (0,2\pi),\ \cos(\theta) \in (-1,1)$
- Need two maps:
  - Interior map is TH3D(x,y,z) extends to outer fiber array
  - Exterior map is TH2D (r,z) starts at outer fiber array and extends to radon shroud

Status of 14 String Baseline Model

- Geometry for baseline:
  - 14-strings with 8-detector ICPC -> 200 kg of ^{76}Ge placed at R = 0.235 m, total length of ~ 0.80 m
  - Fiber have reflectors at ends to imitate curved array, placed at +/- 6 cm from Ge array, 88% coverage
  - 964 (482) inner fibber array placed at R = 0.175 m, length 1.30 m
  - 1628 (814) outer fibber array placed at R = 0.295 m, length 1.50 m
  - Radon shield at 700 mm radius
  - “Magic disk” is not implemented
- 340 Z bins, ~14 hours per Z bin.
  - Sparse array -> longer sim times
  - 500 events/bin generated -> 4 events/bin detected

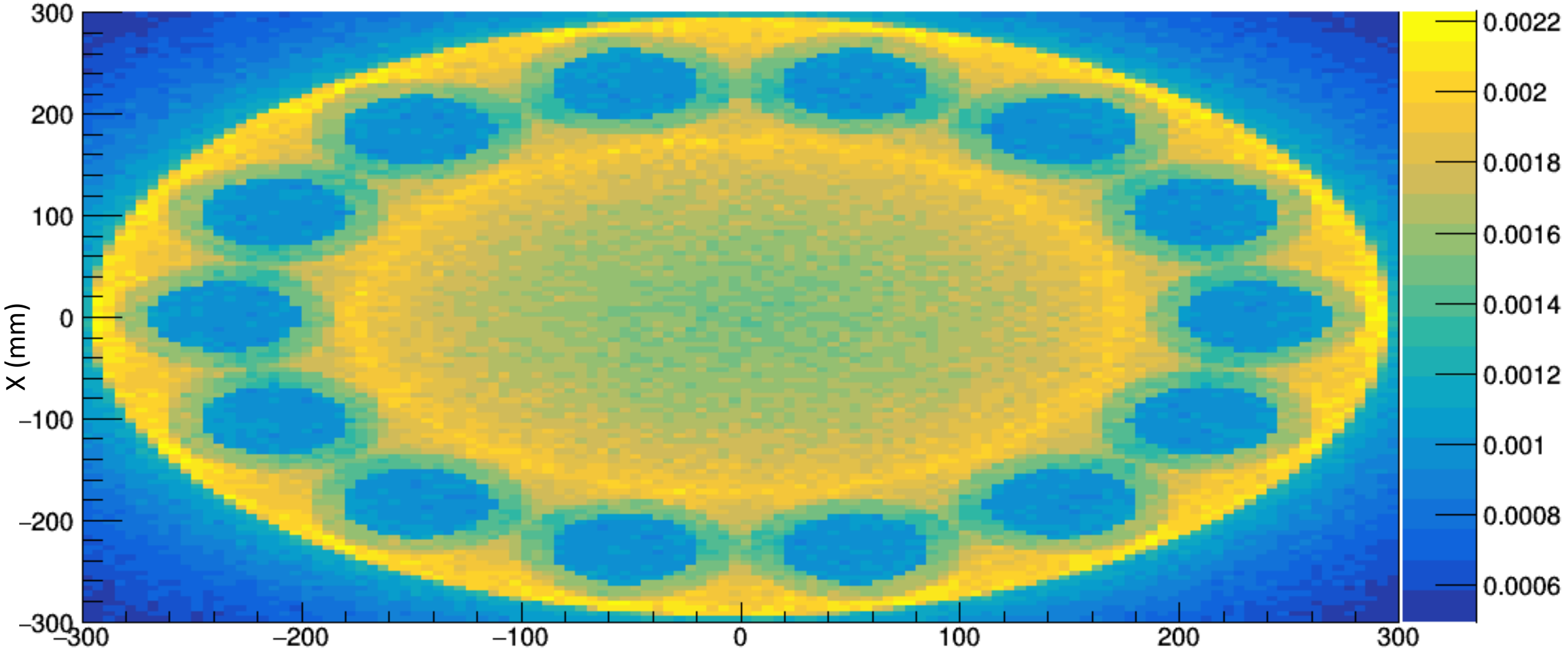


Y-Z Interior Optical Heat Map



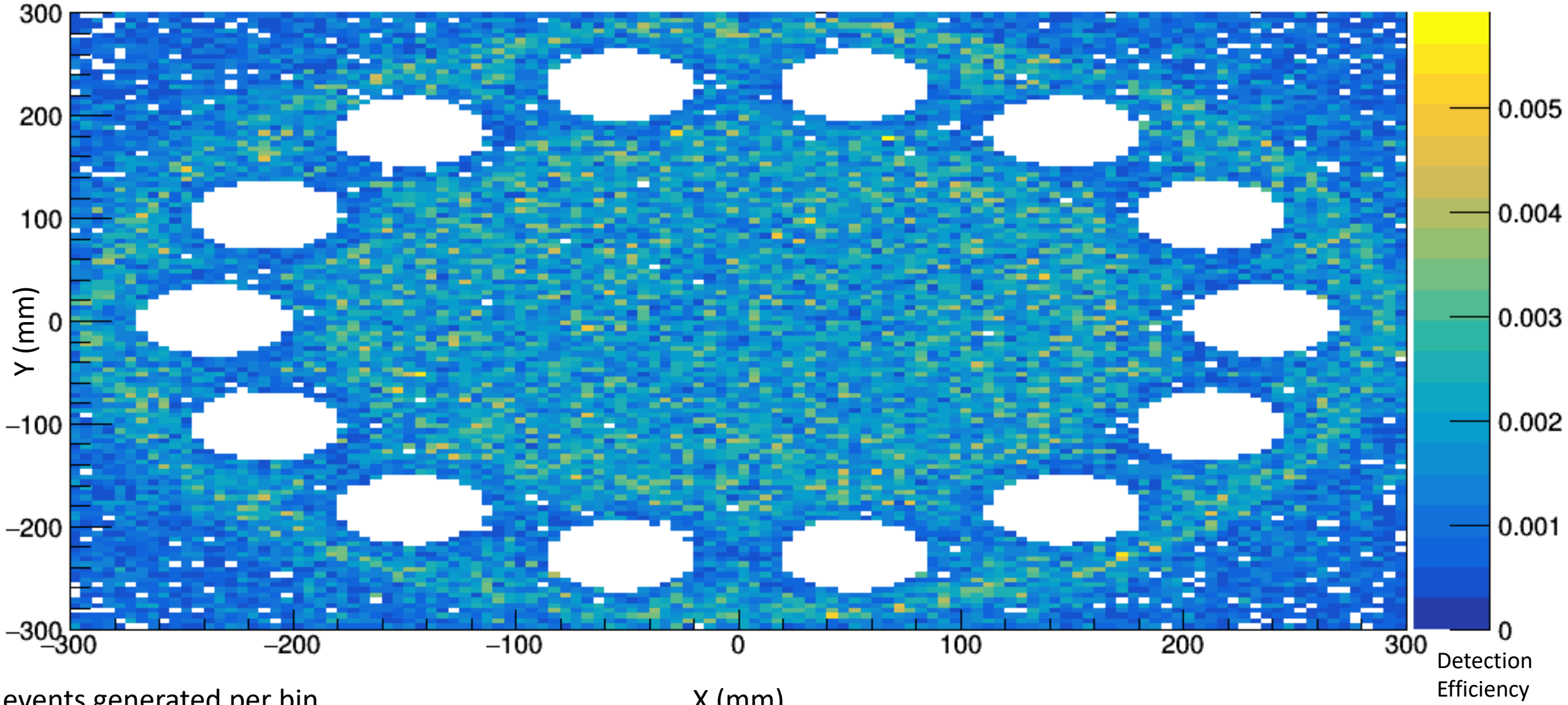
60,000 events generated per bin
Bin size of 5x5mm^2
X averaged out
Average QE of 0.164 folded in

Y-X Interior Optical Heat Map



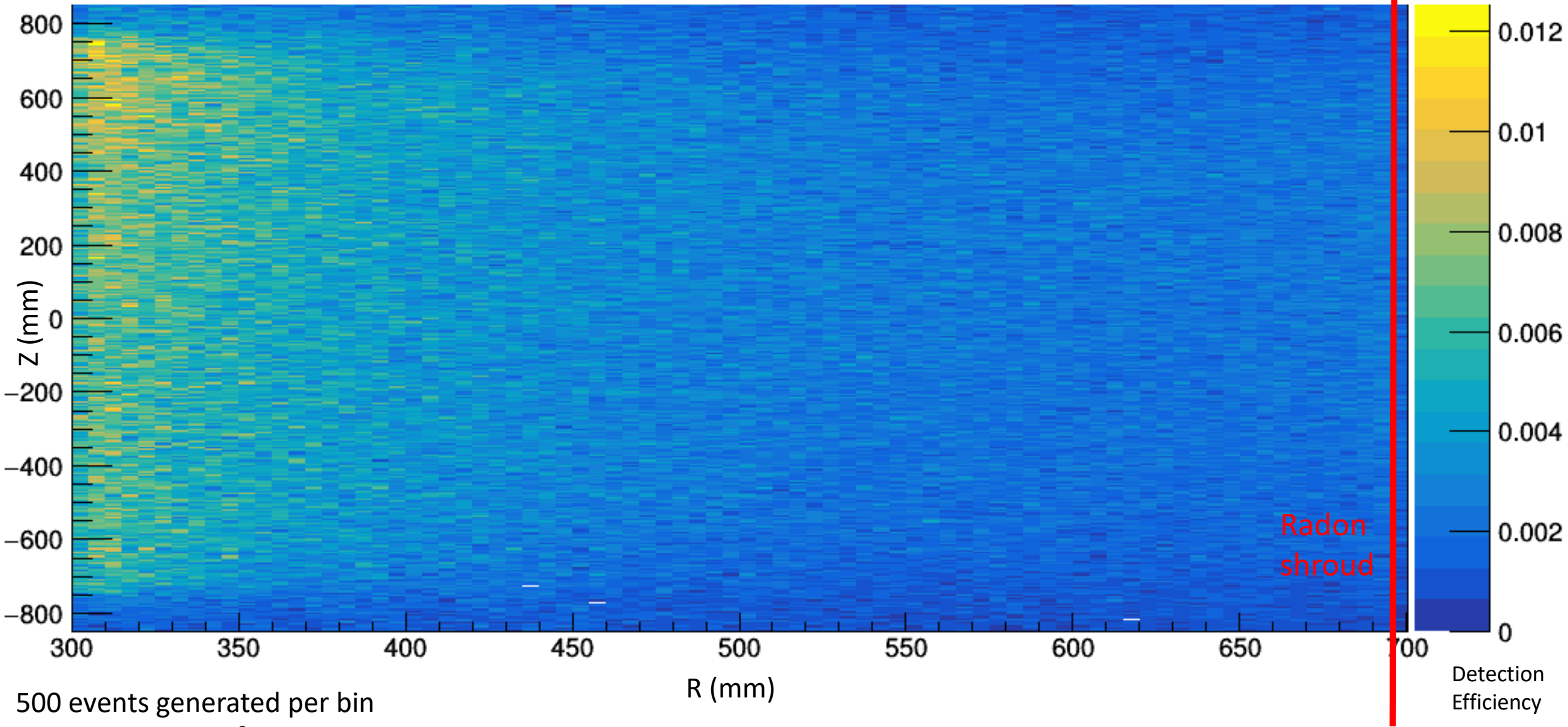
170,000 events generated per bin Bin size of 5x5mm^2
Z averaged out
Average QE of 0.164 folded in

X-Y Slice of Optical Heat Map



500 events generated per bin
Bin size of 5x5mm^2
Z = 105 mm, not an average
Average QE of 0.164 folded in
Run time ~14 hours

R-Z Exterior Optical Heat Map



500 events generated per bin
Bin size of 5x5mm^2
Φ averaged out
Average QE of 0.164 folded in

BEGe (4 diodes) + IC (6) -> 7 strings

PPC (5) + IC (5) -> 7 strings

Conclusion

- Next optical heat map iteration:
  - Realistic detector layout
  - Include proper germanium reflectivity
    - Maybe copper and silicon reflectivity too?
  - Magic disk resolved to real fiber layout
  - SiPM on both ends of fiber -> increase detection efficiency by flat amount?
  - Replace silicon with PEN
- Working on thesis -> handing off work load
  - Thesis chapter useful for future work on optical heat maps