FastSim Parametrization of Beam Dump

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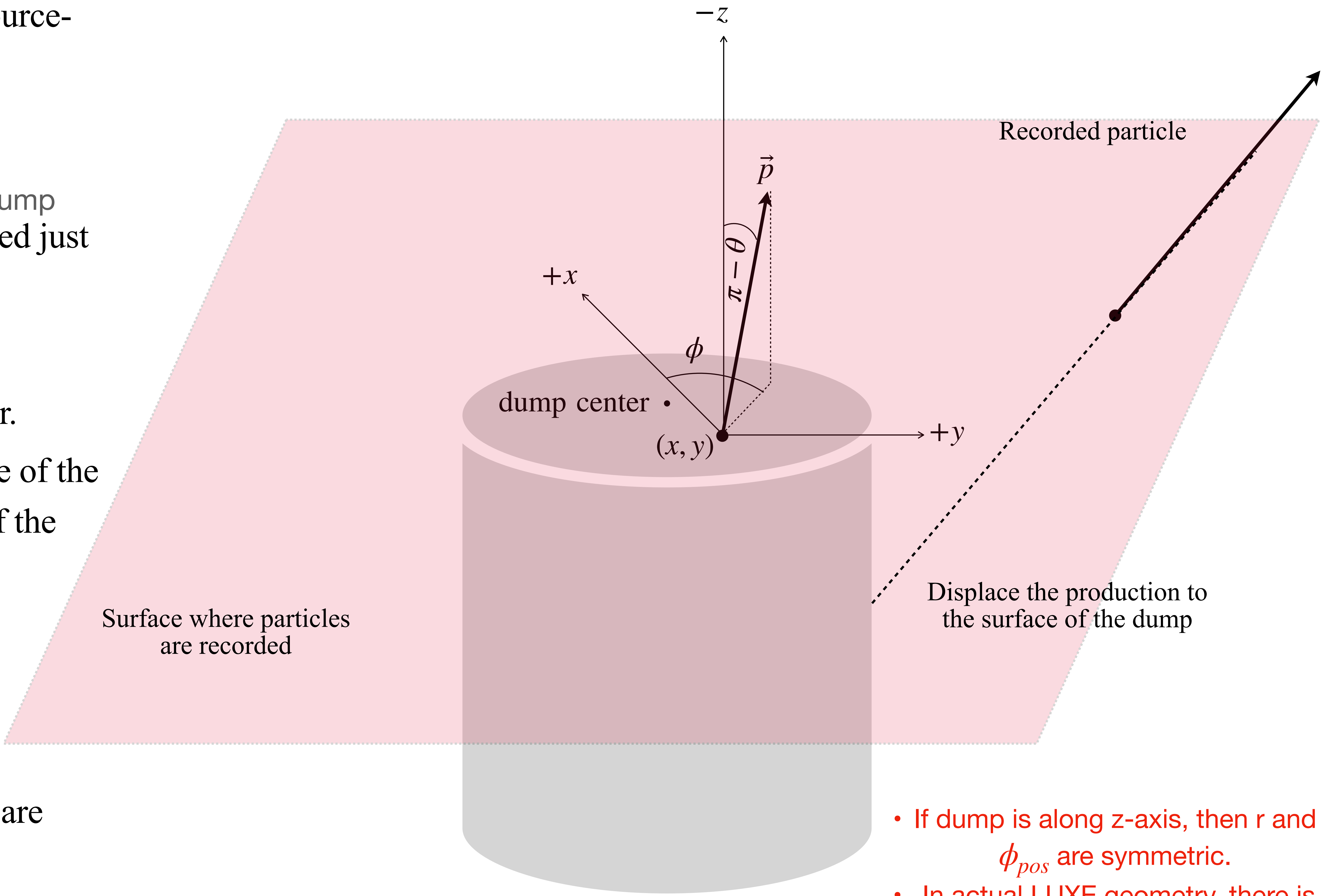
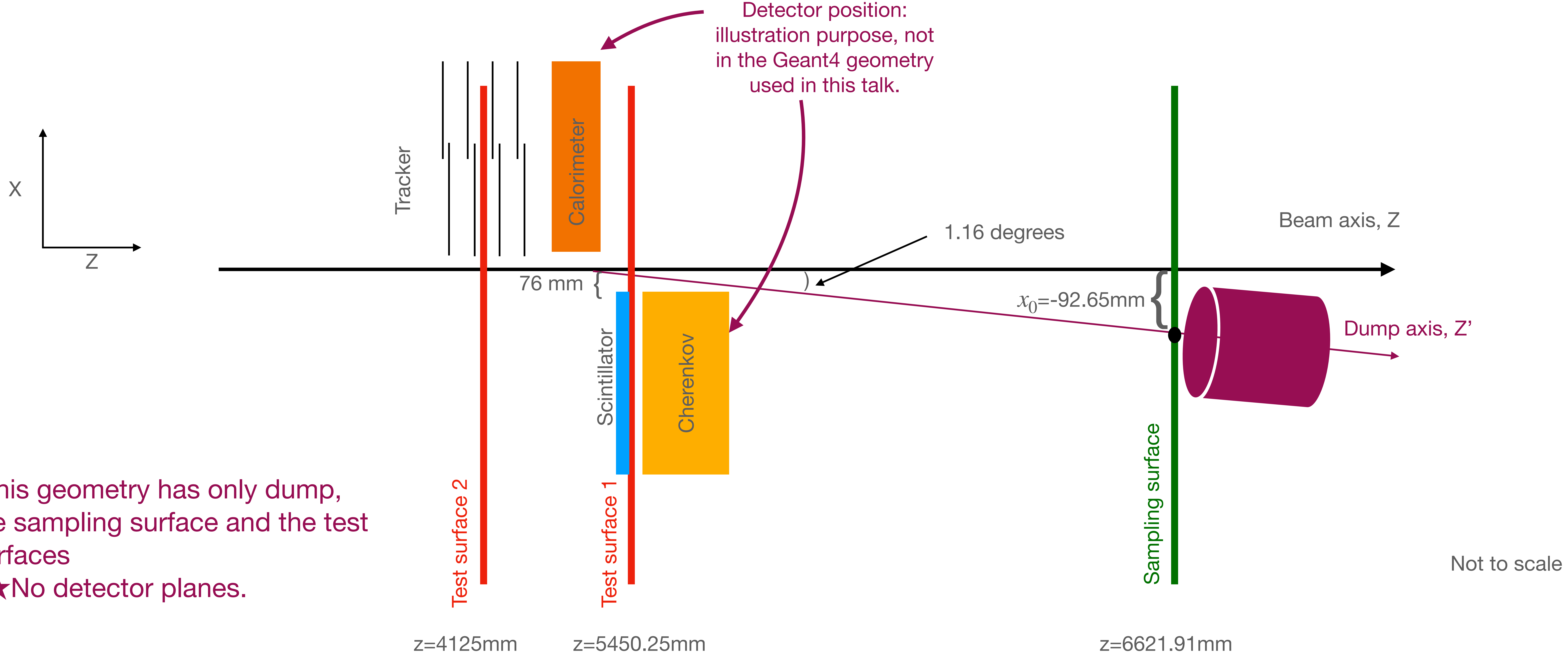
Fast simulation strategy

- Disable the dump and replace all its "output" by source-like particles
  - ★At the tracker last layer
    - ★100% of the neutron come from dump
    - ★>10% of the photons come from dump
    - ★~1% of the electrons and positrons from the dump
- Look at the dummy volume (sampling plane) located just outside of the surface of the dump
  - plot $(\frac{dN}{dE}$ and $\frac{dN}{dt})$ or $\frac{d^2N}{dEdt}, \frac{d^2N}{drd\theta_p}, \frac{d^2N}{d\phi_p d\phi_{pos}}, \ldots$
    - Here r is just $\sqrt{x^2+y^2}$, position parameter.
    - θ_p, ϕ_p is the polar angle and azimuthal angle of the momentum → representative of direction of the particle.
    - ϕ_{pos} is position azimuthal angle, and t is time.
  - Later: generate from the sampling plane according to these plots
    - ⋆ Use TH1D::GetRandom() and TH2D::GetRandom2() (for variables that are correlated) methods.



- If dump is along z-axis, then r and ϕ_{pos} are symmetric.
- In actual LUXE geometry, there is a shift - r and ϕ_{pos} are asymmetric there.

Schematic diagram of the dump in the LUXE geometry



★This geometry has only dump, the sampling surface and the test surfaces

★No detector planes.

Plot labels:

- In this talk there will be **three types of plots** compared:
    1. **FullSim** - Distributions from full Geant4 processing of the dump
    2. **Fast Sampling**: sampled randomly from the FullSim distribution at the sampling plane.
    3. **FastSim** - Geant4 processing where dump is replaced by particles following distributions in Fast Sampling above.
        (i) Plots made at test surfaces.

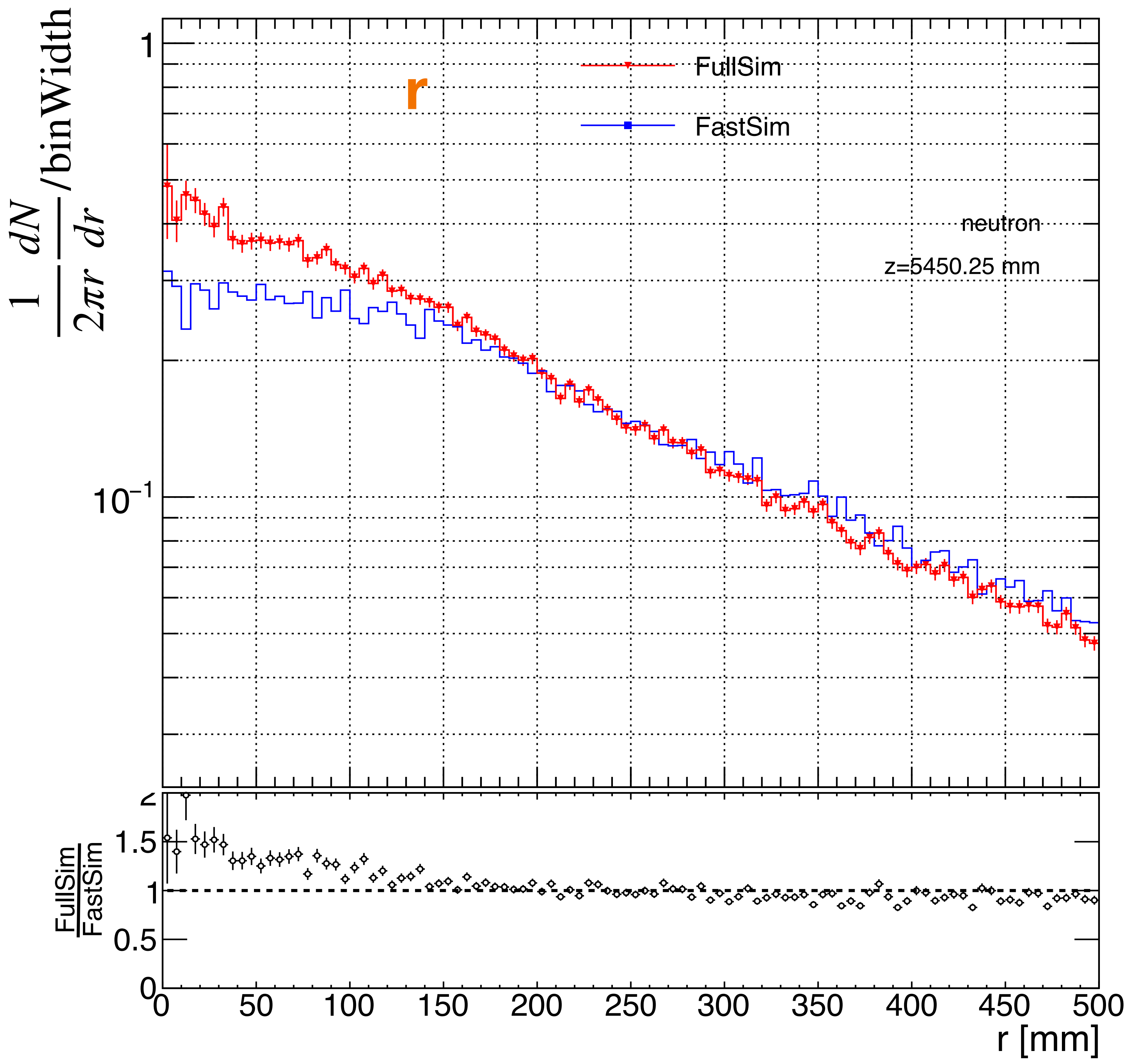
Mis-modeling of r at test surface 1:

★Last time, we showed some of the comparison plots between FullSim and FastSim.

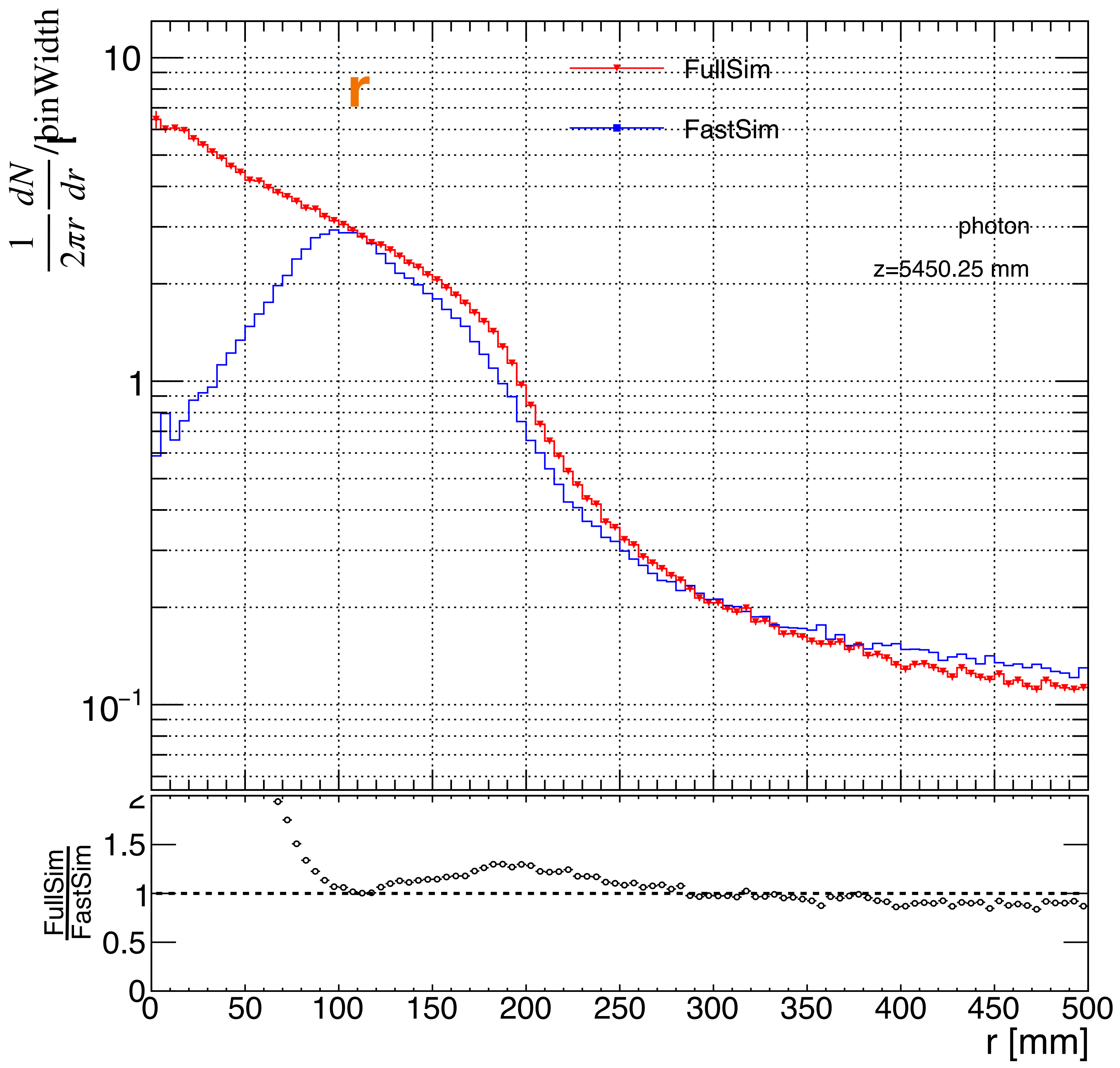
★Most of the variables match perfectly on test surface 1.

★Comparison plots shown in the previous talk.

★The r ($= \sqrt{x^2 + y^2}$) variable has a mismatch.



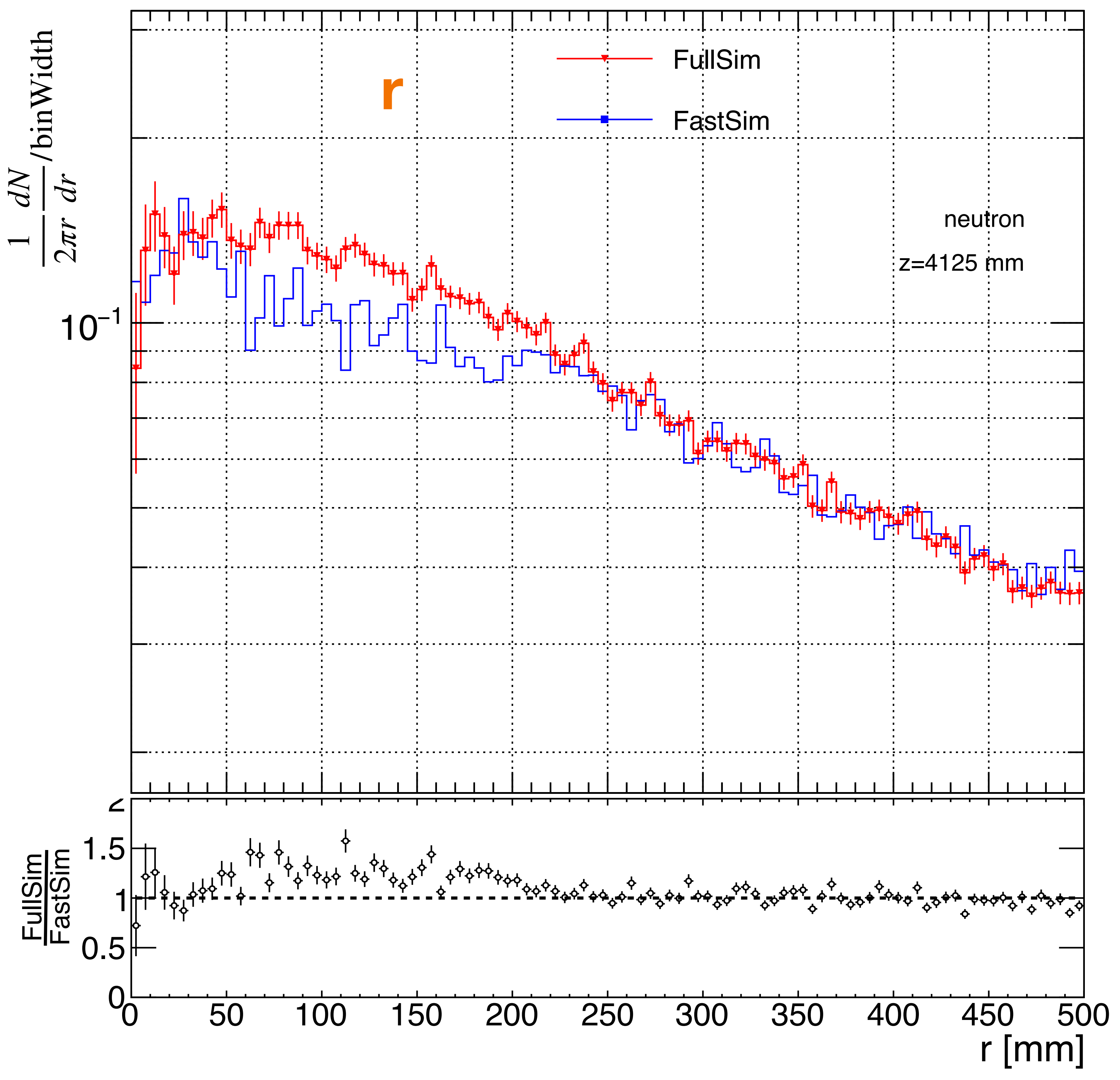
Neutron



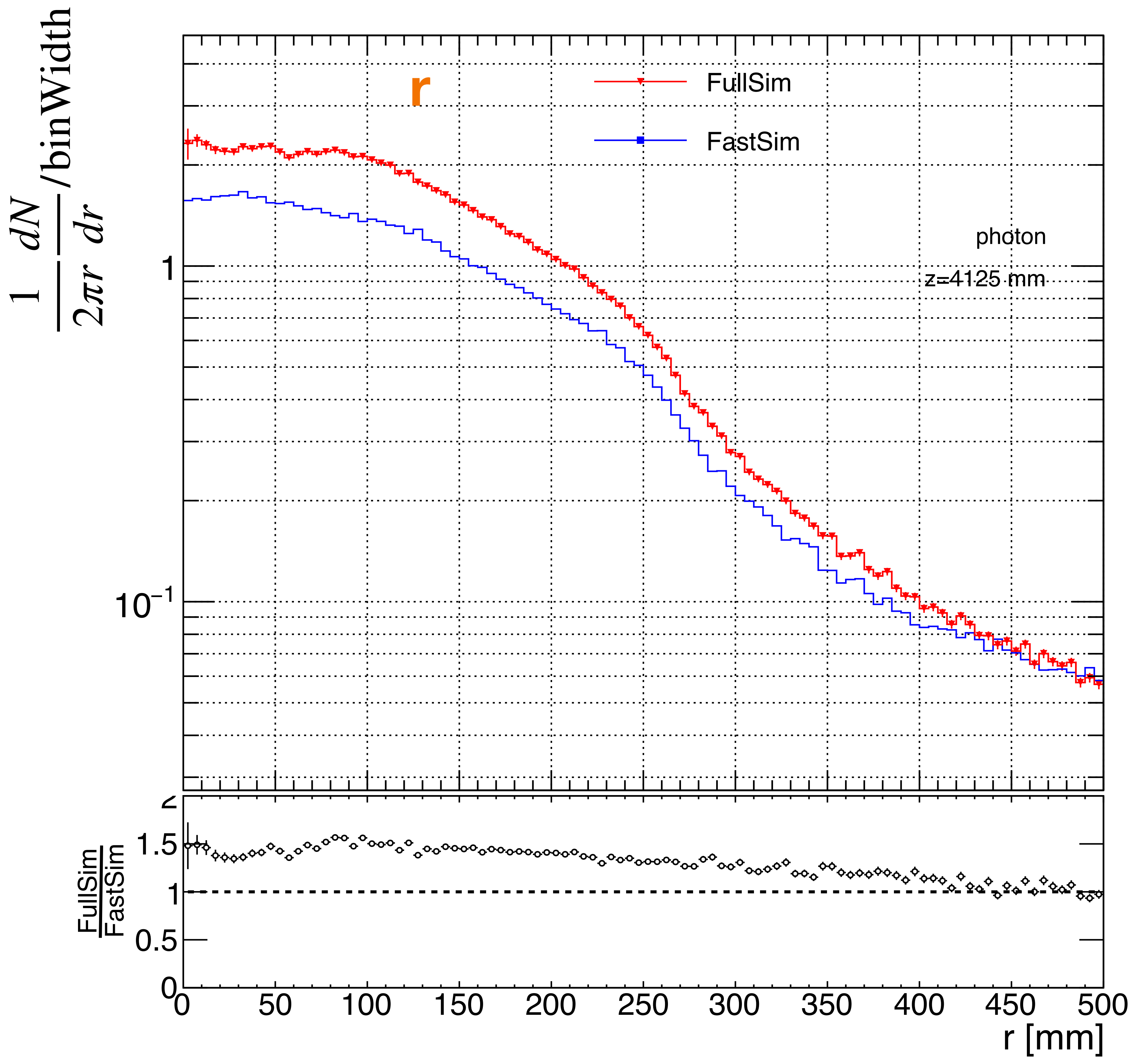
Photon

Mis-modeling of r at test surface 2:

- ★Last time, we showed some of the comparison plots between FullSim and FastSim.
  - ★Most of the variables match perfectly on test surface 1.
  - ★Comparison plots shown in the previous talk.
- ★The r ($= \sqrt{x^2 + y^2}$) variable has a mismatch.

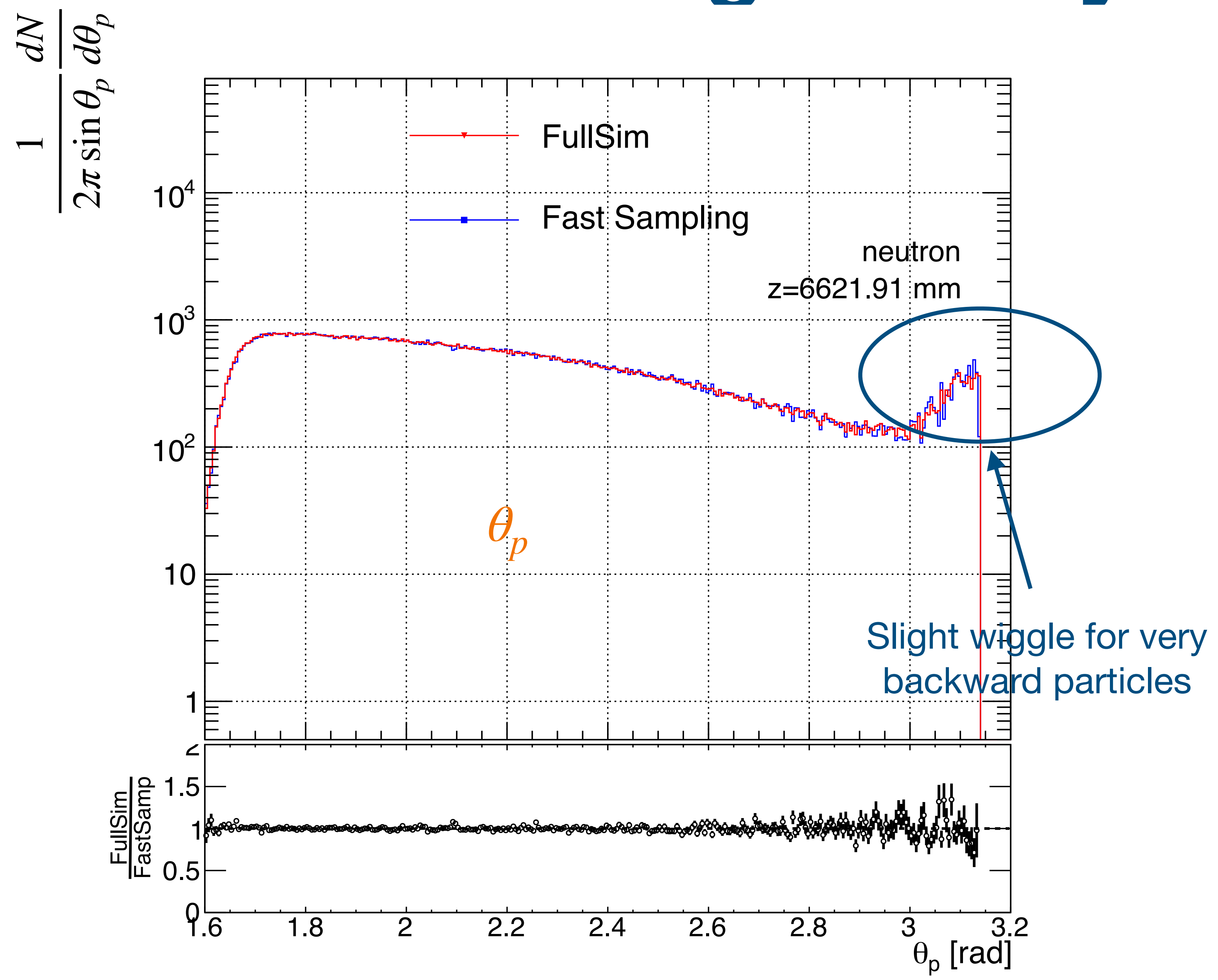


Neutron



Photon

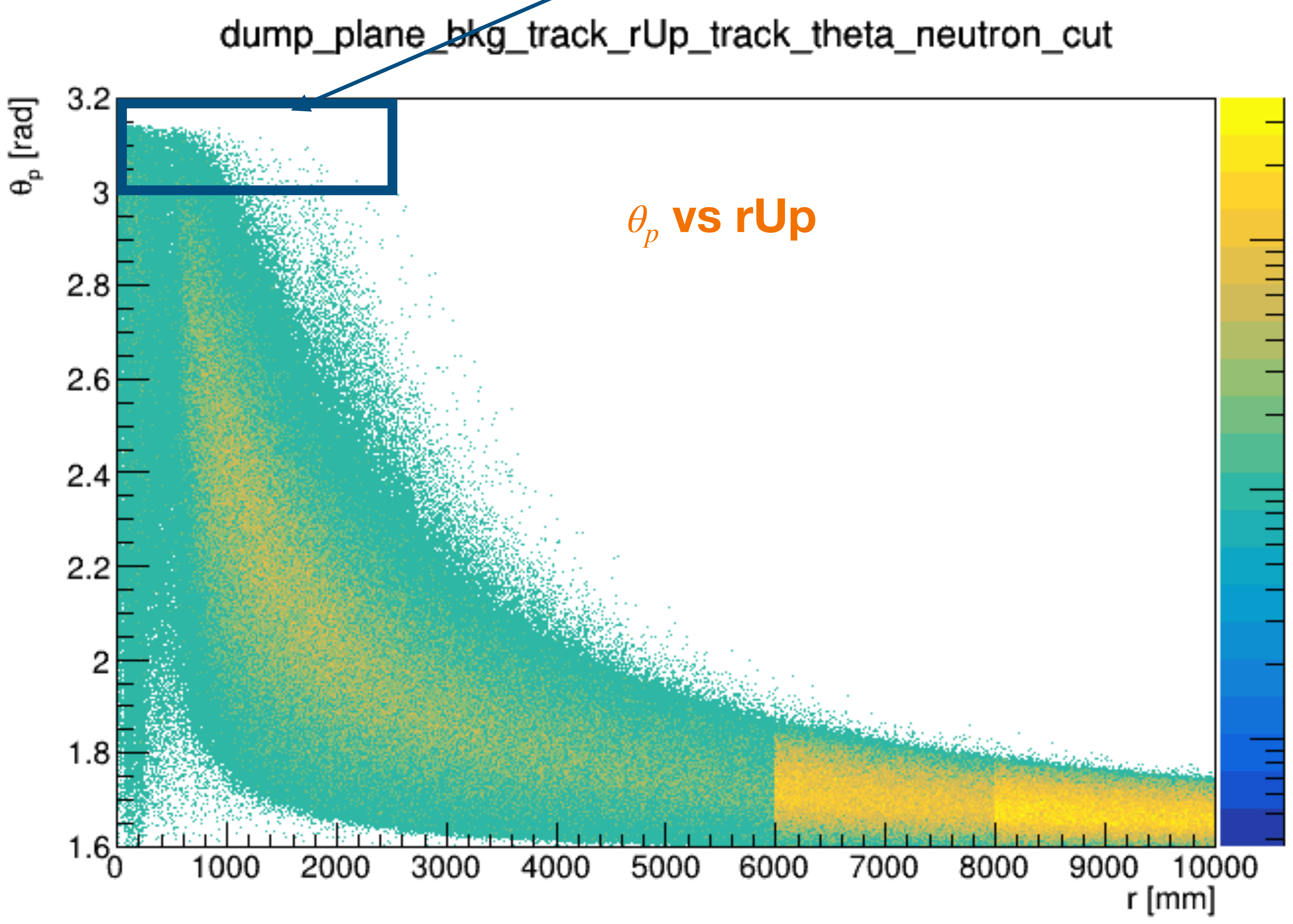
Comparison of FullSim and Fast Sampling distributions at the sampling surface for the LUXE geometry: neutron

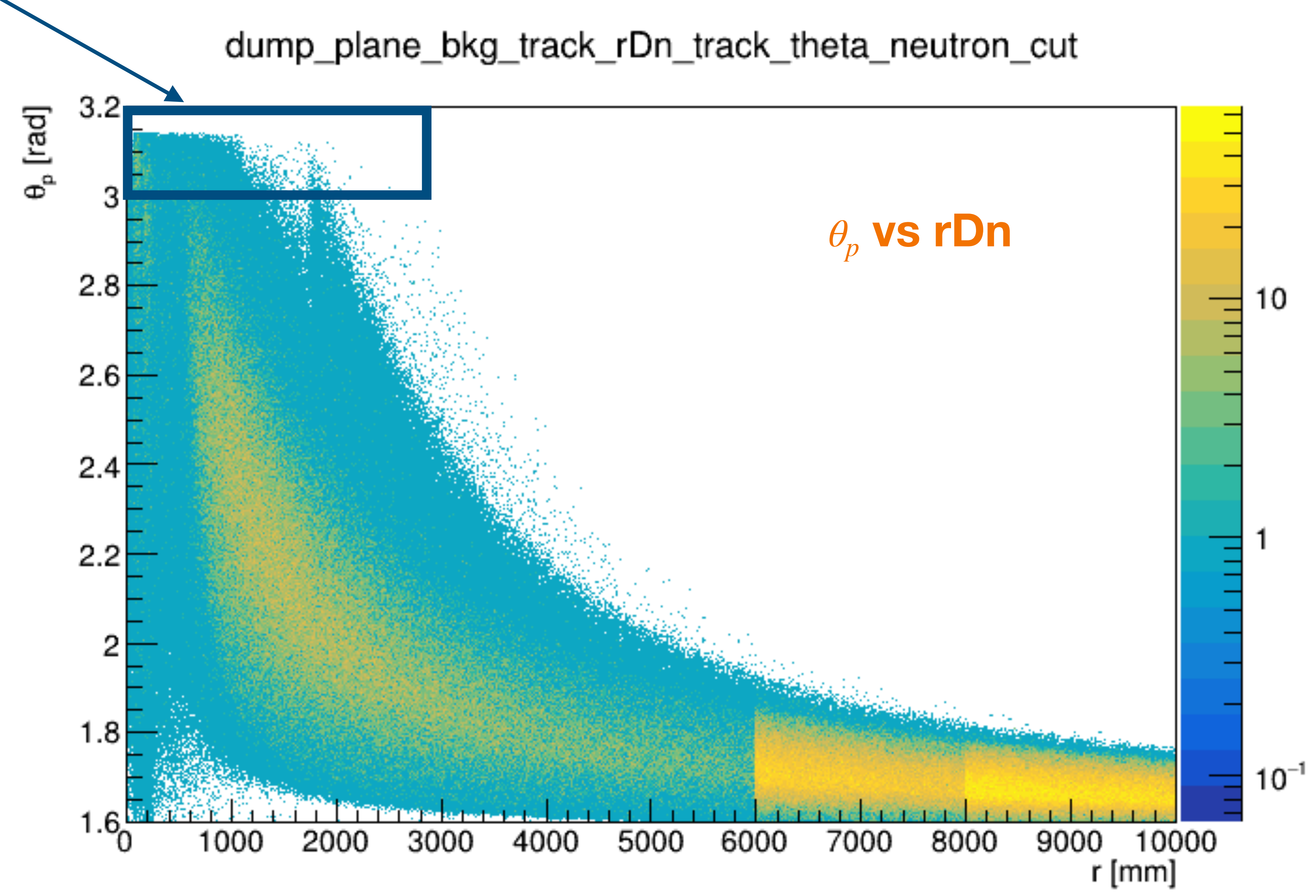


- Slight mismatch in the θ_p distribution for very backward particle ($\theta_p \gtrsim 3.0$).

- Scale the entries in the region ($\theta_p \gtrsim 3.0$) before sampling
- After sampling, check the 1D θ_p sampling plots.

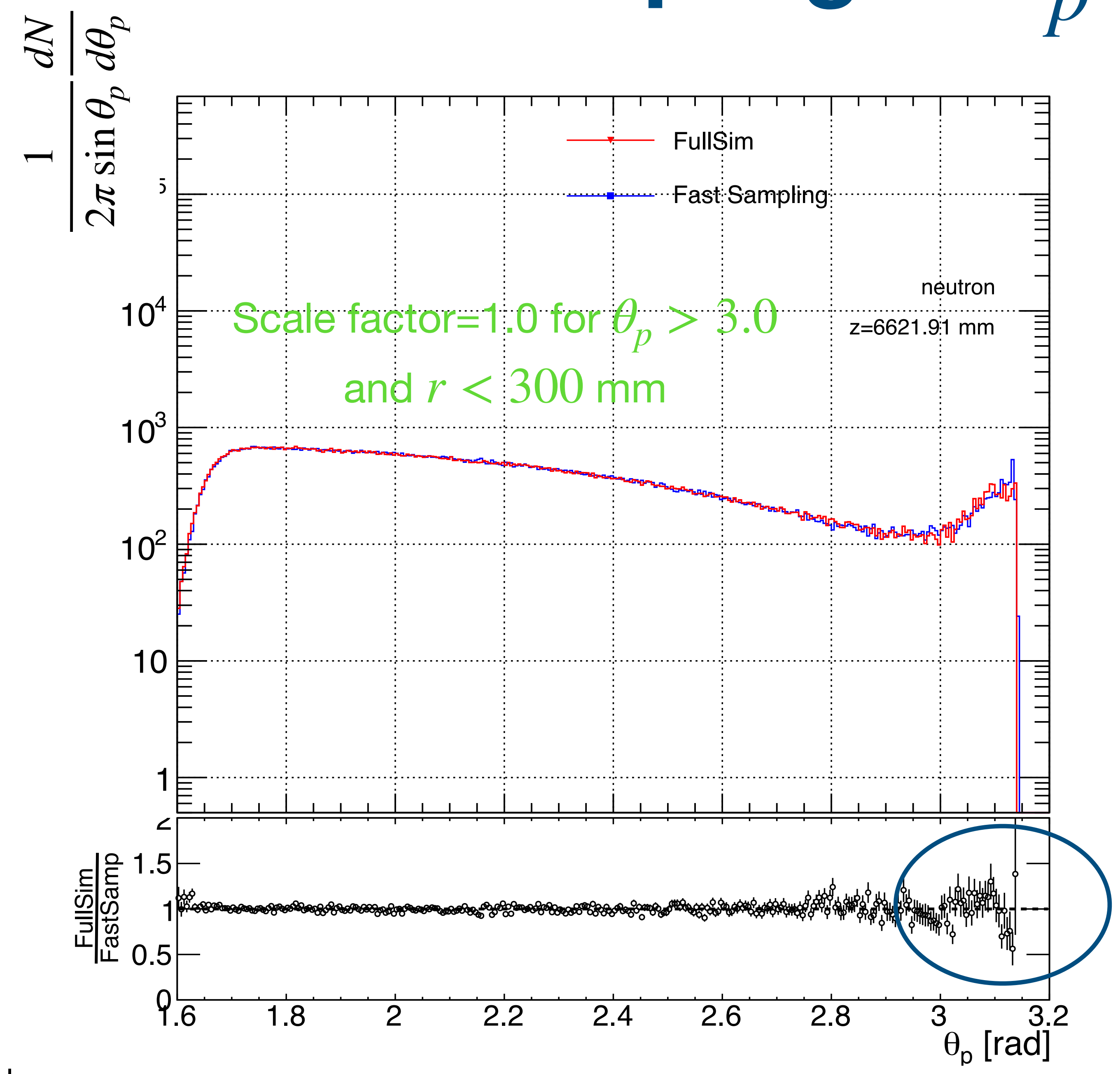
$\theta_p > 3.0$ is sampled from these regions

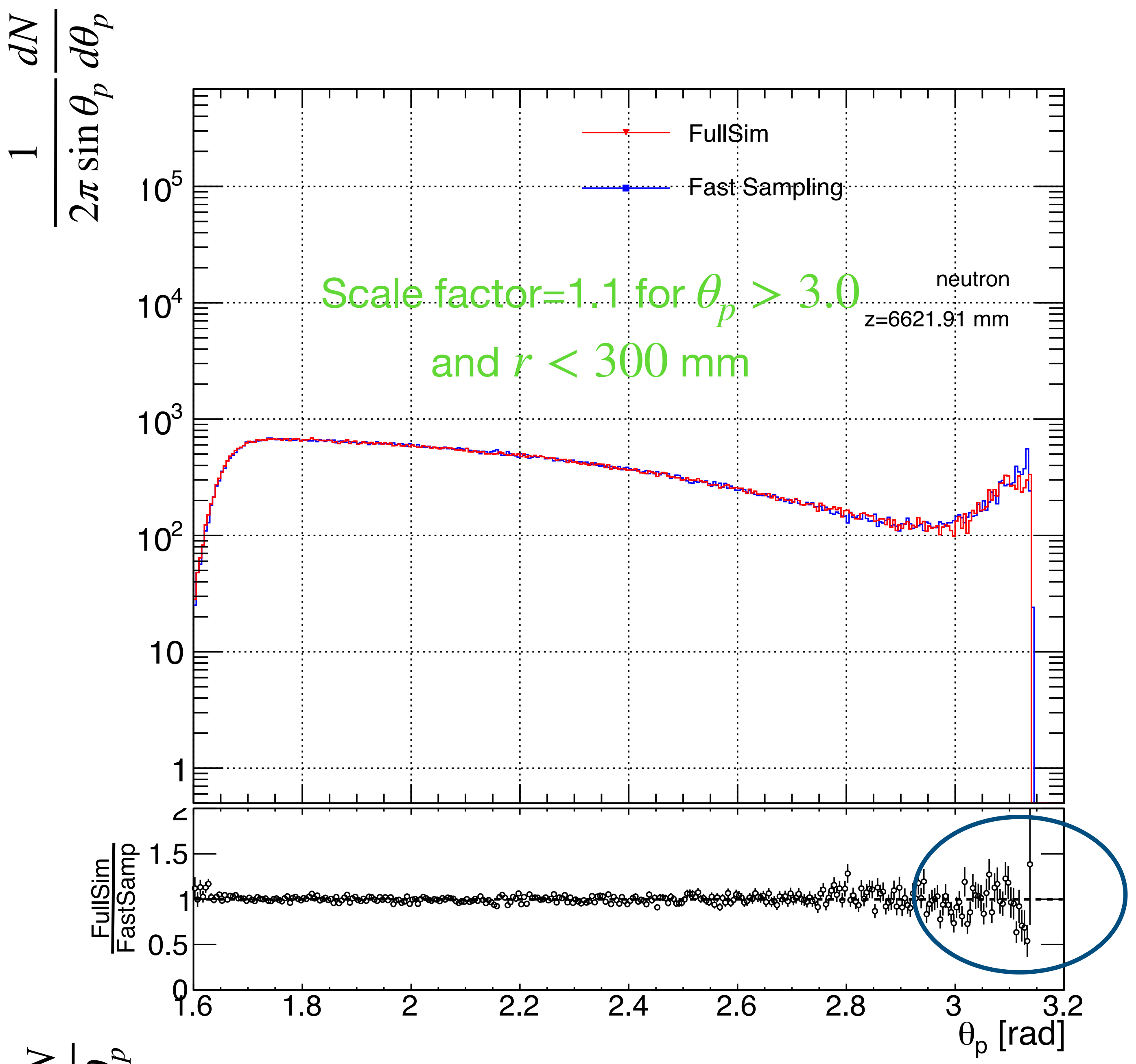


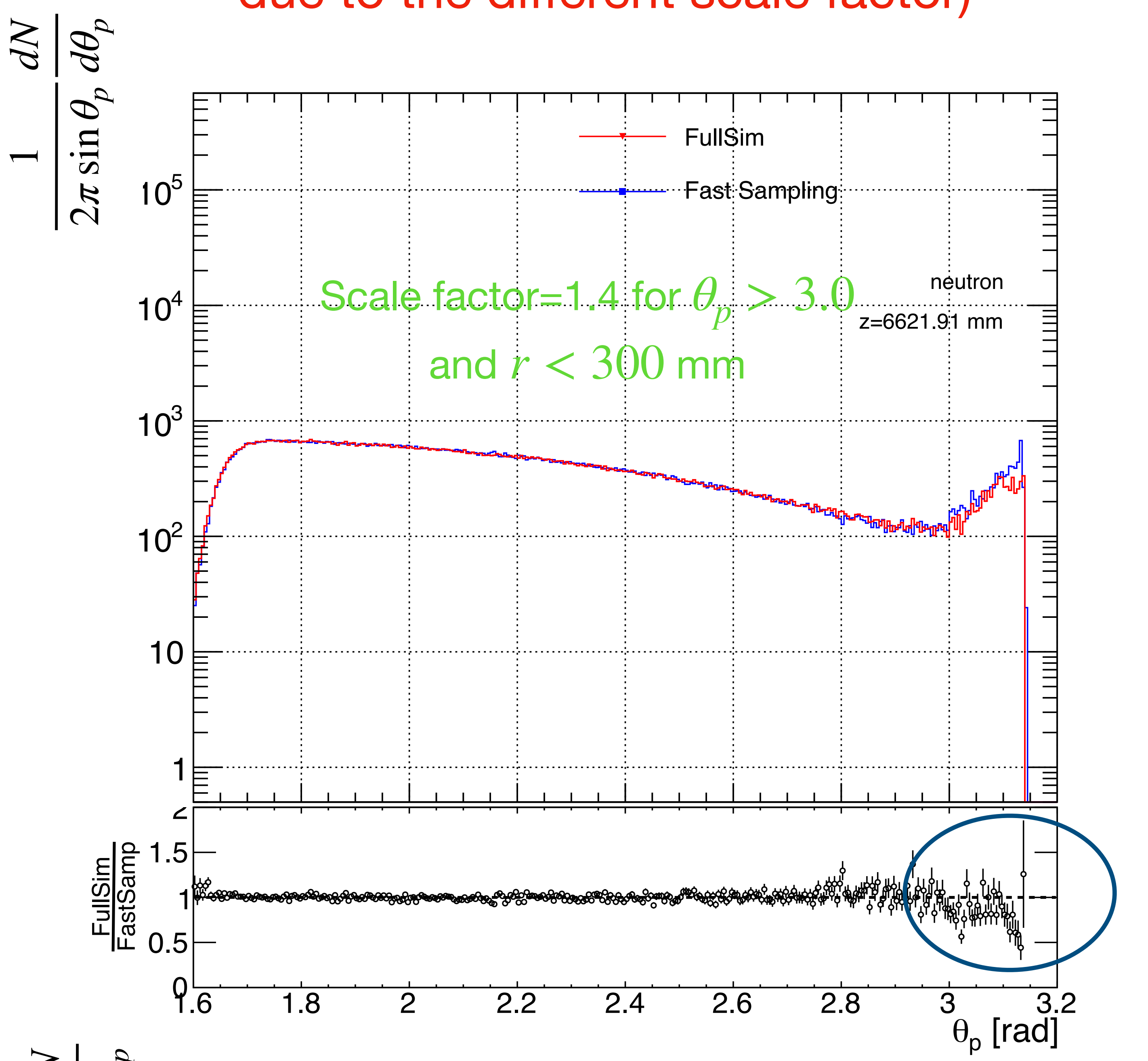


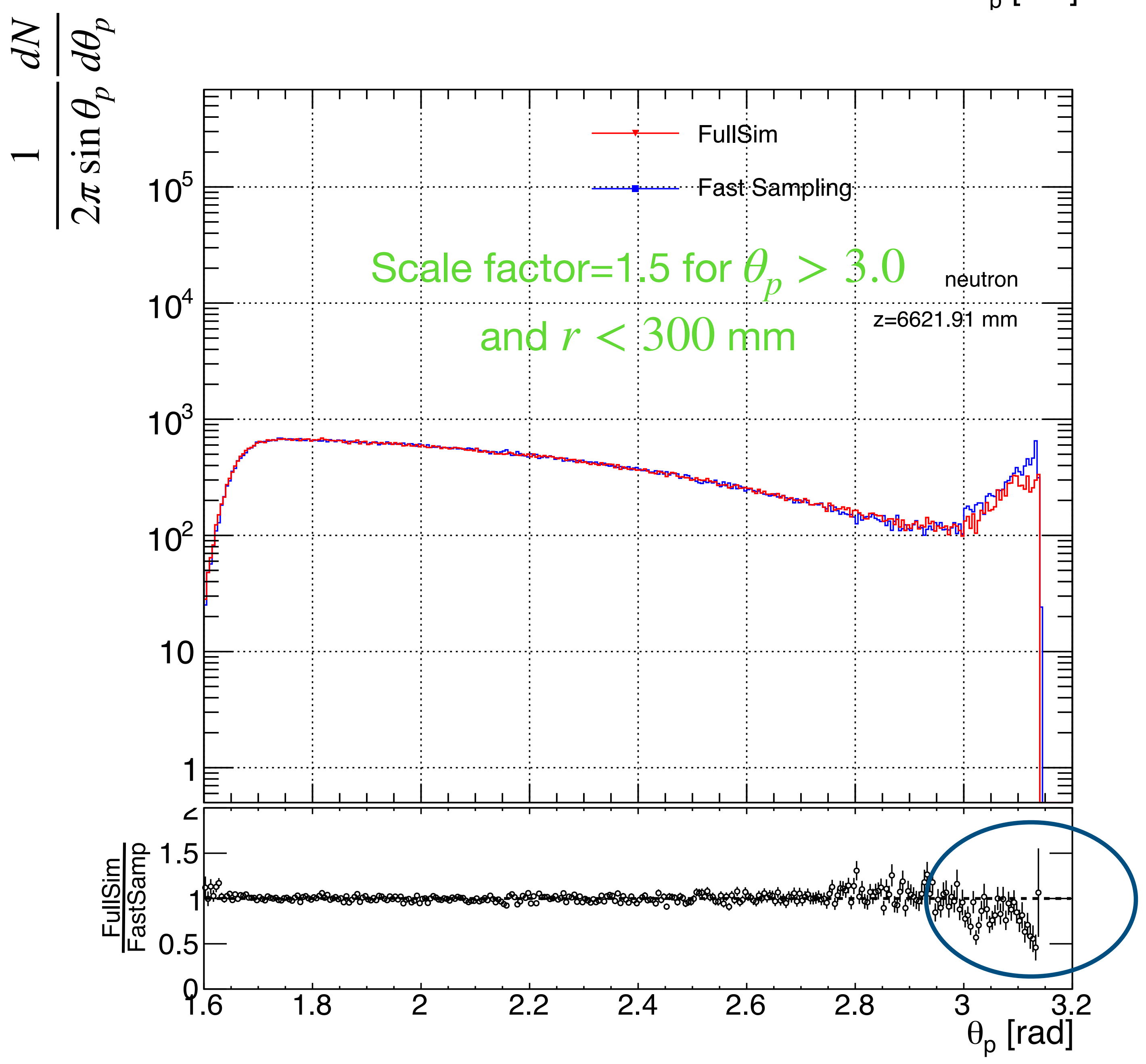
FastSampling of θ_p for different scale factors: Neutron

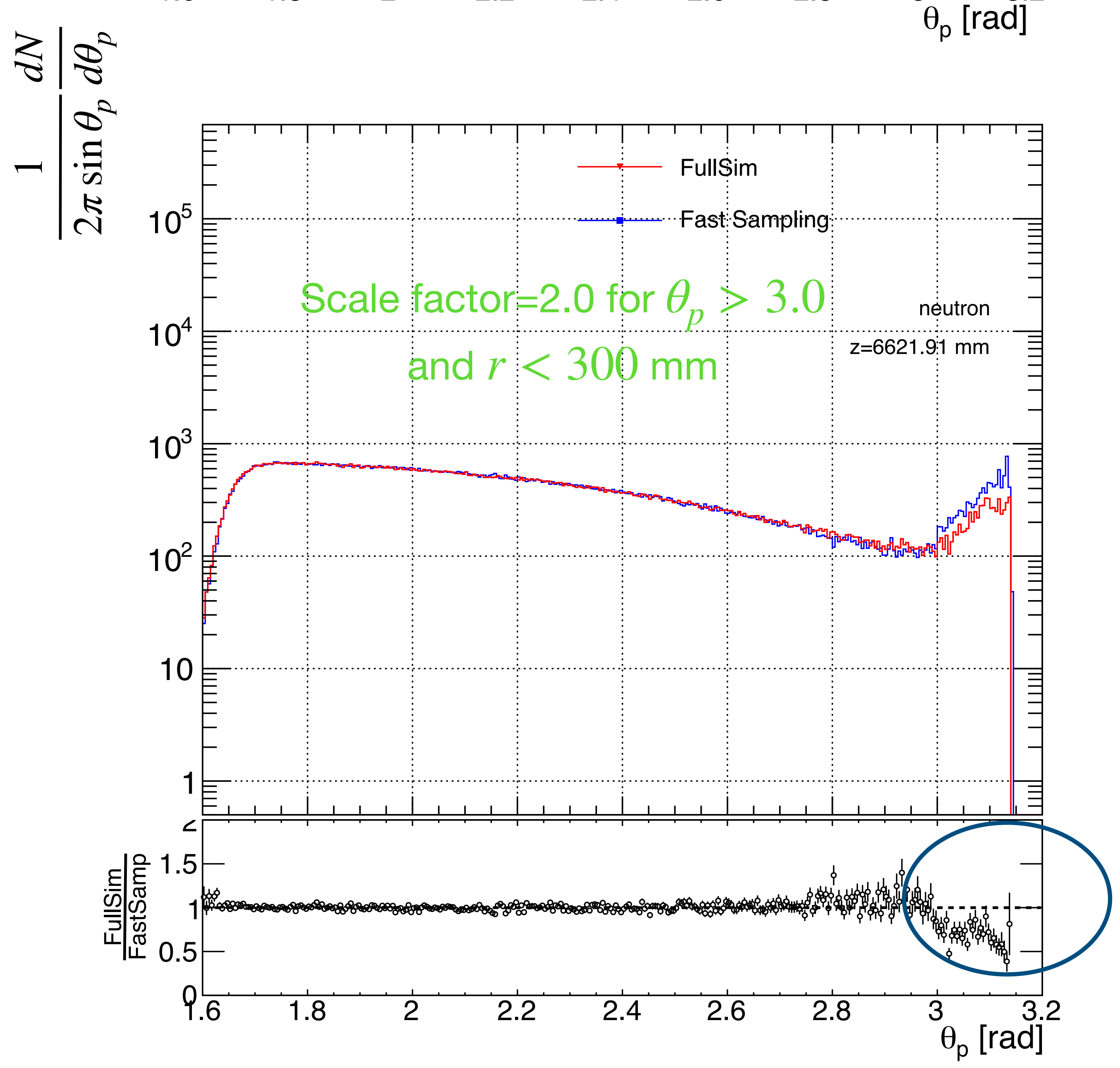
(Only FastSampling plots are changed due to the different scale factor)

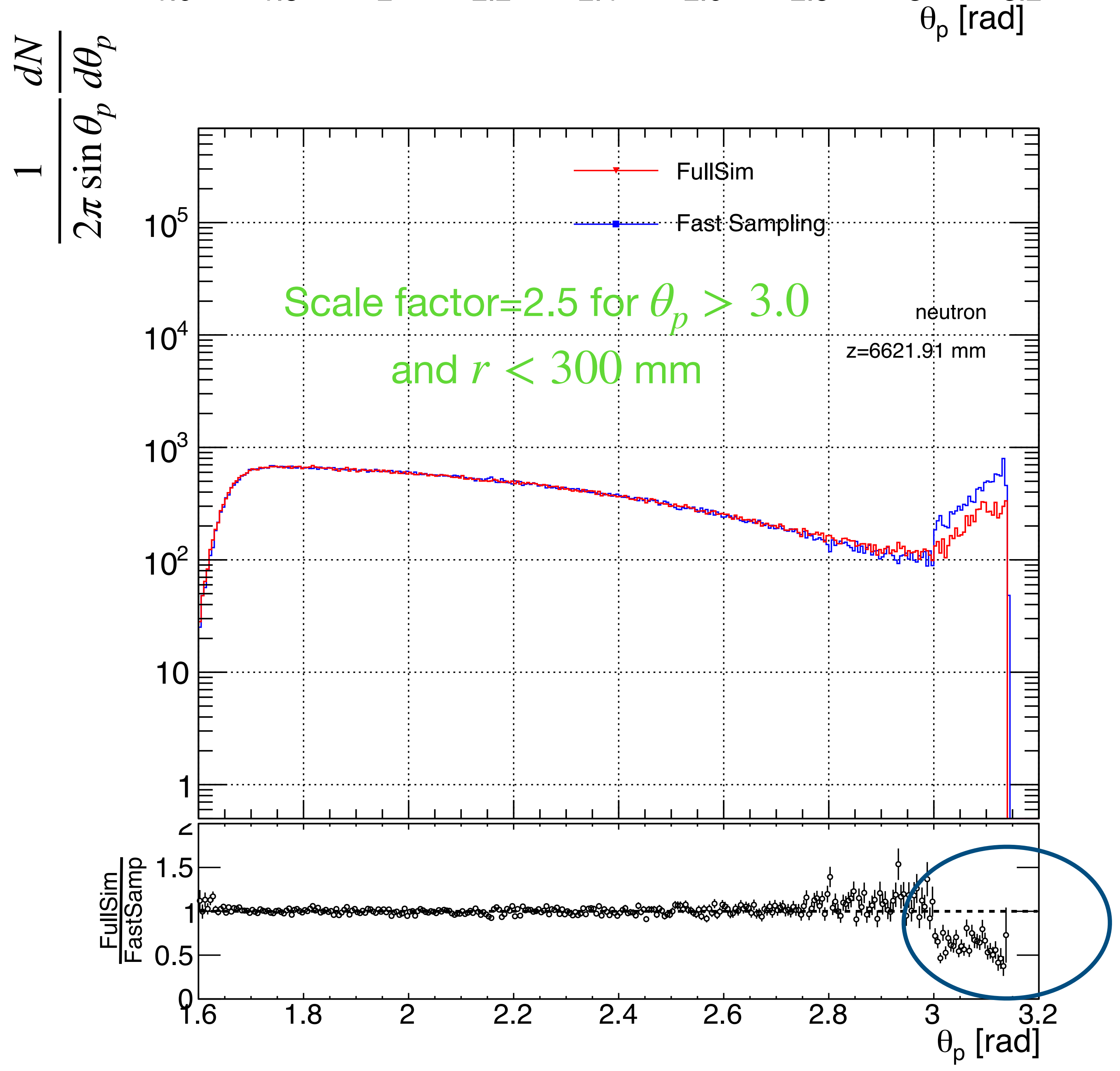




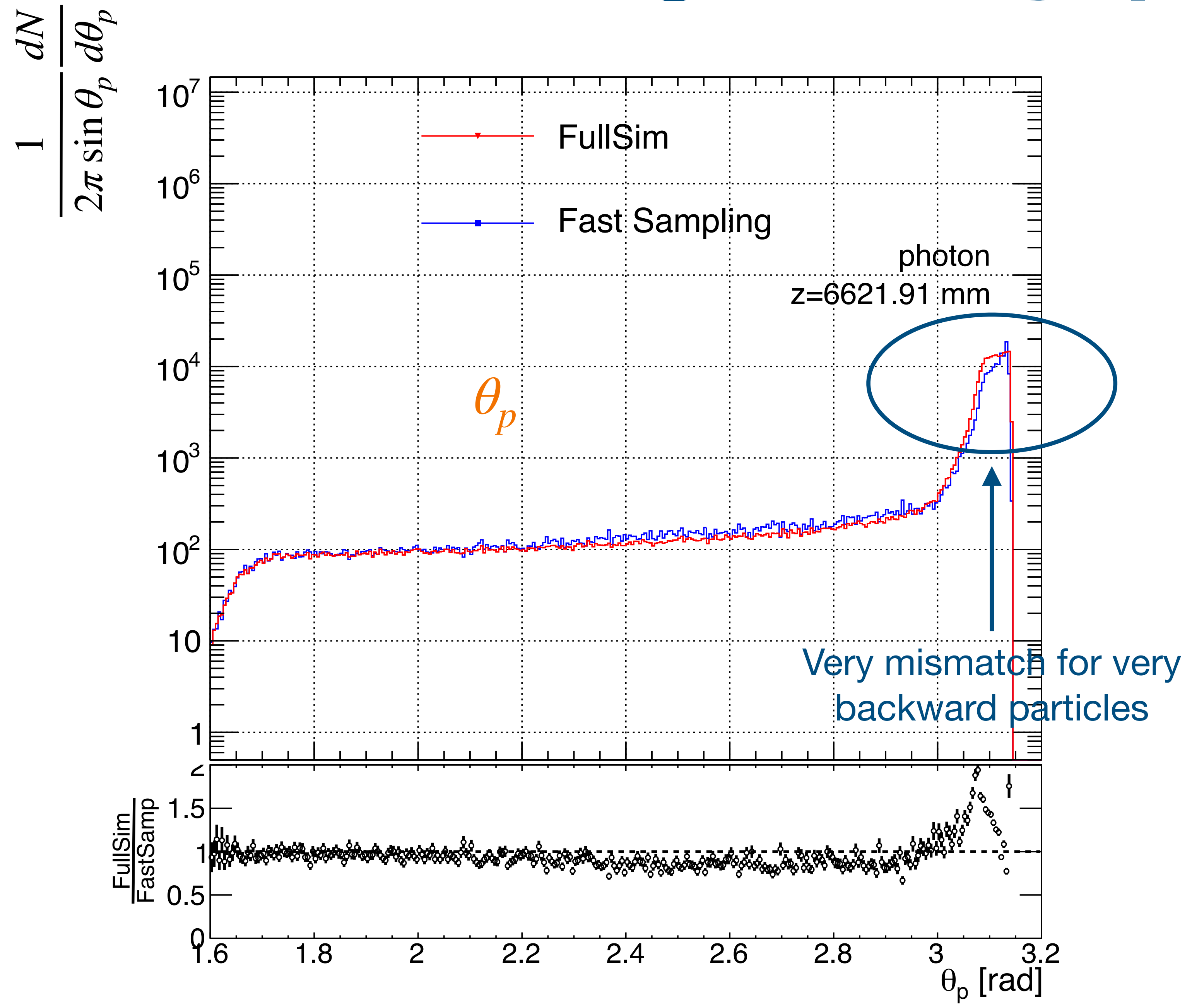








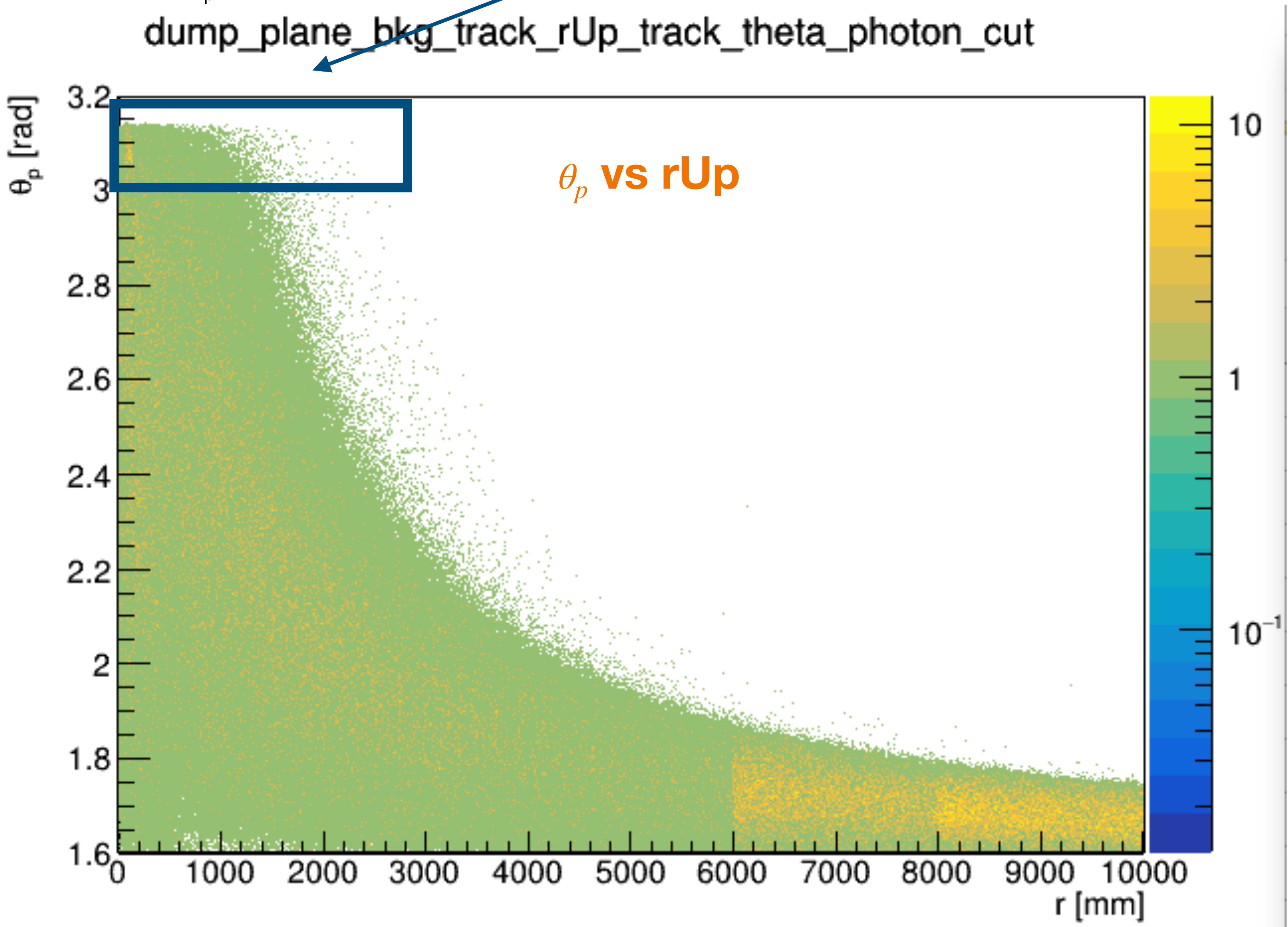
Comparison of FullSim and Fast Sampling distributions at the sampling surface for the LUXE geometry: photon

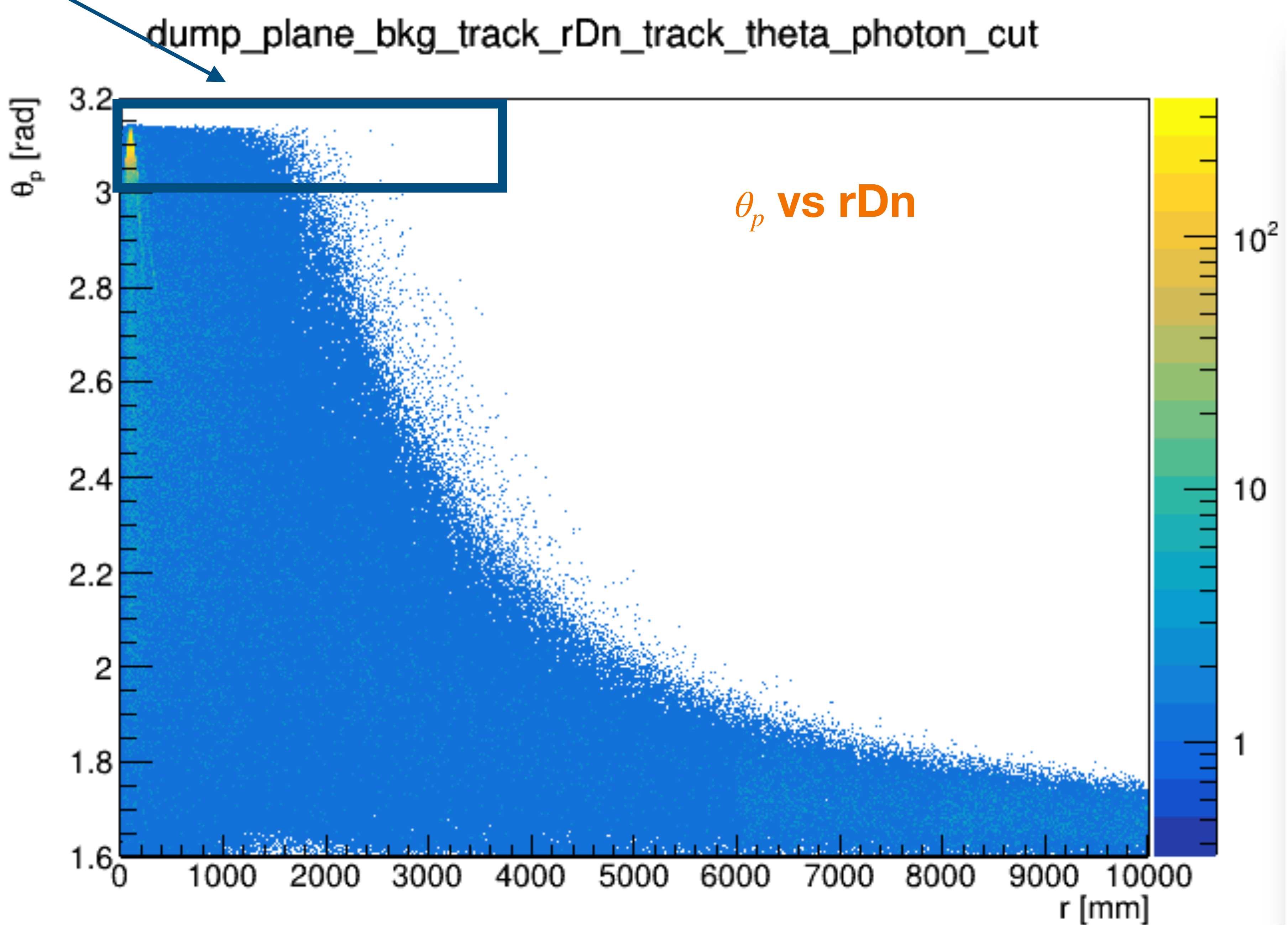


- Mismatch in the θ_p distribution for very backward particle ($\theta_p \gtrsim 3.0$).

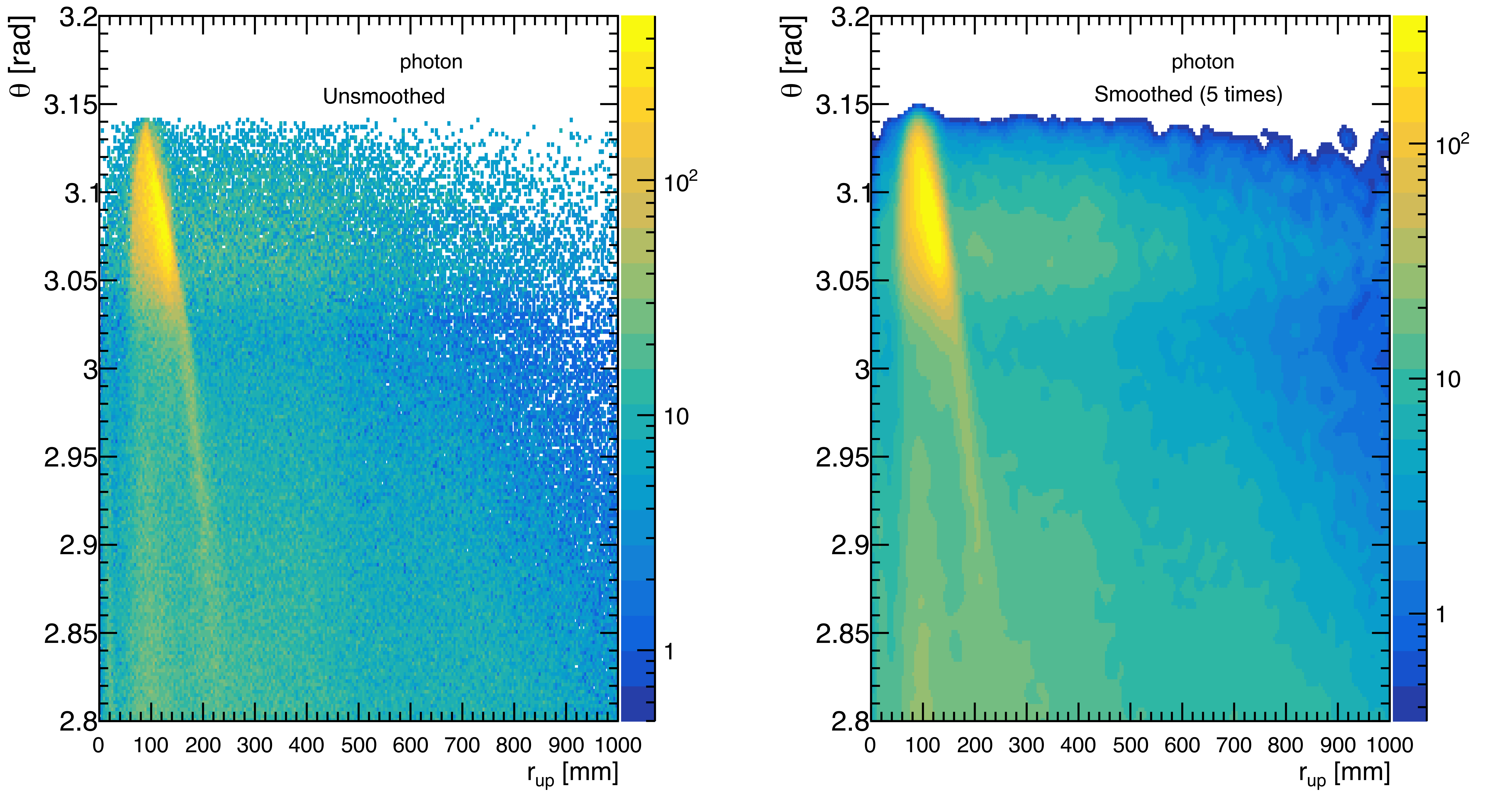
- Scale the entries in the region ($\theta_p \gtrsim 3.0$) before sampling
- The 2D plot is smoothened before sampling.
- After sampling, check the 1D θ_p sampling plots.

$\theta_p > 3.0$ is sampled from these regions





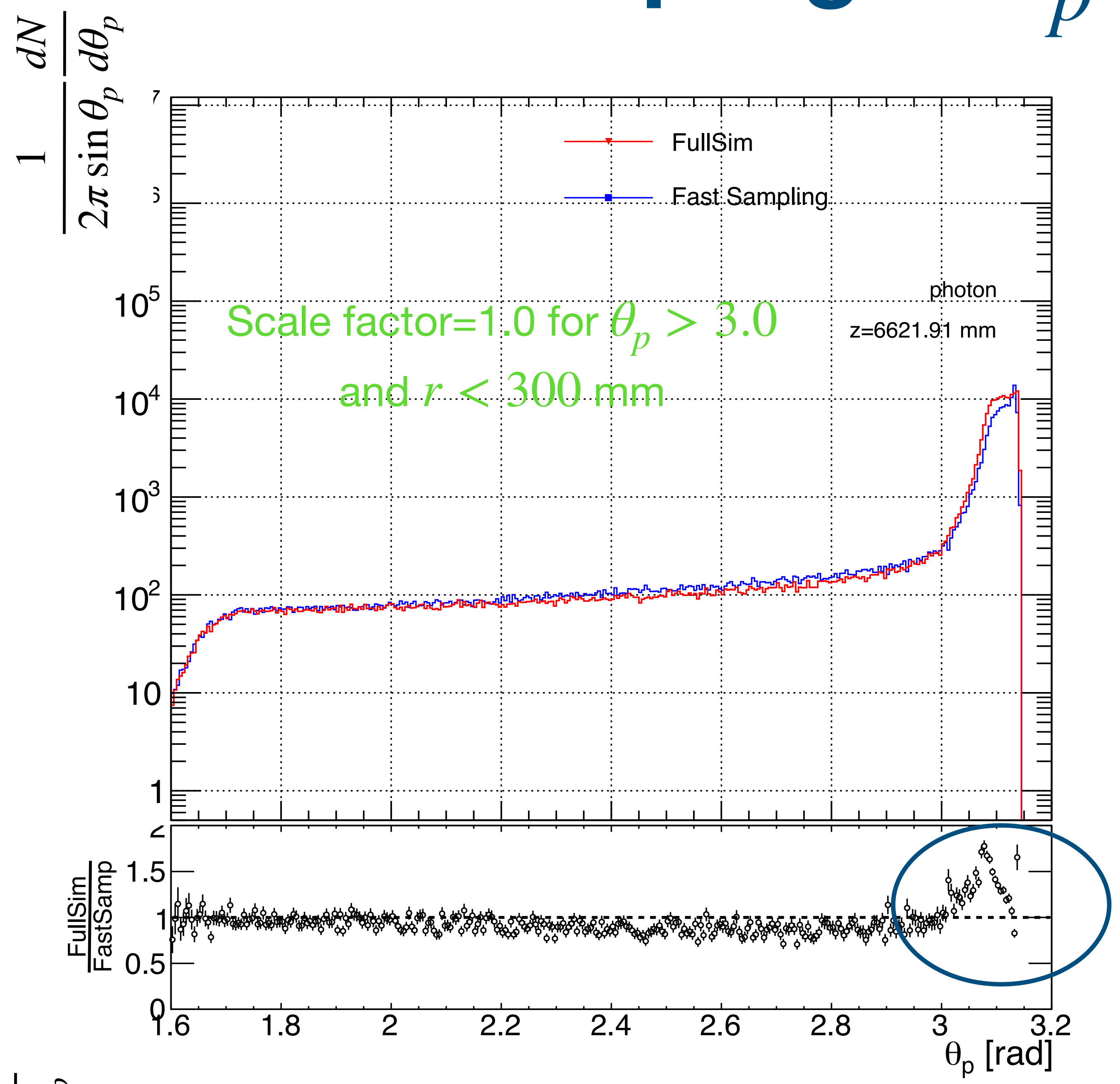
Effect of Smoothening of 2D bins: photon

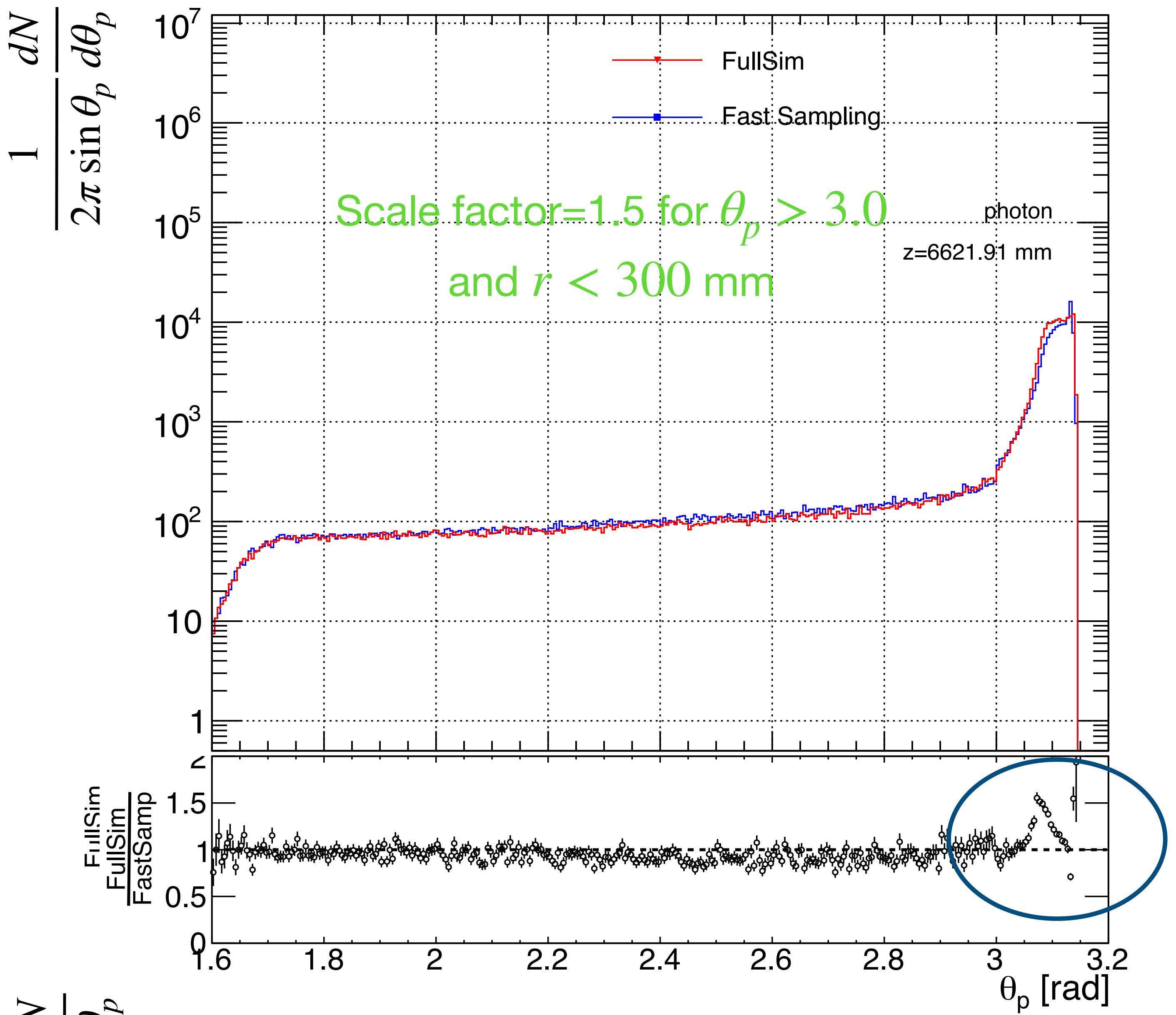


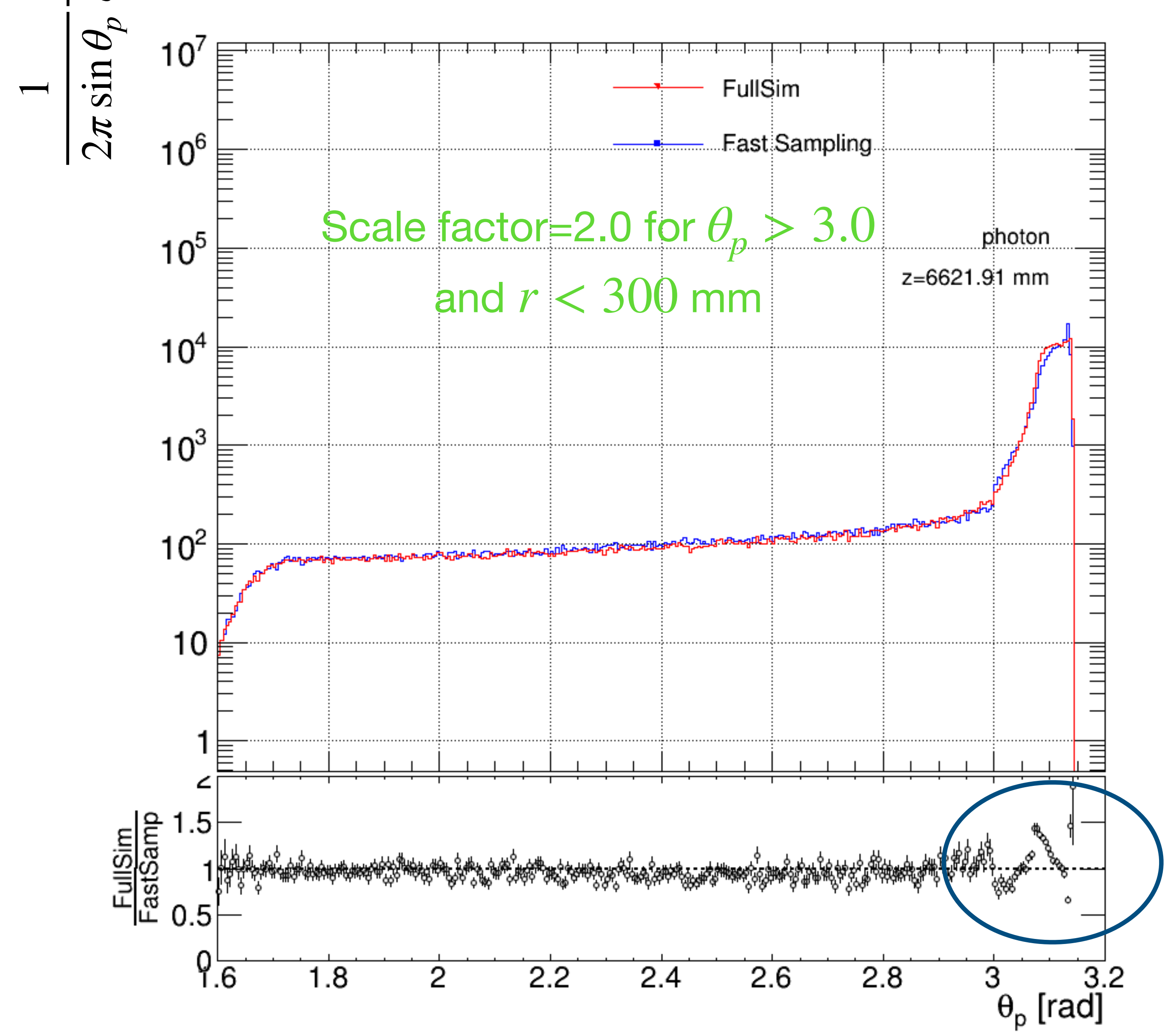
Smoothened histogram is used for sampling

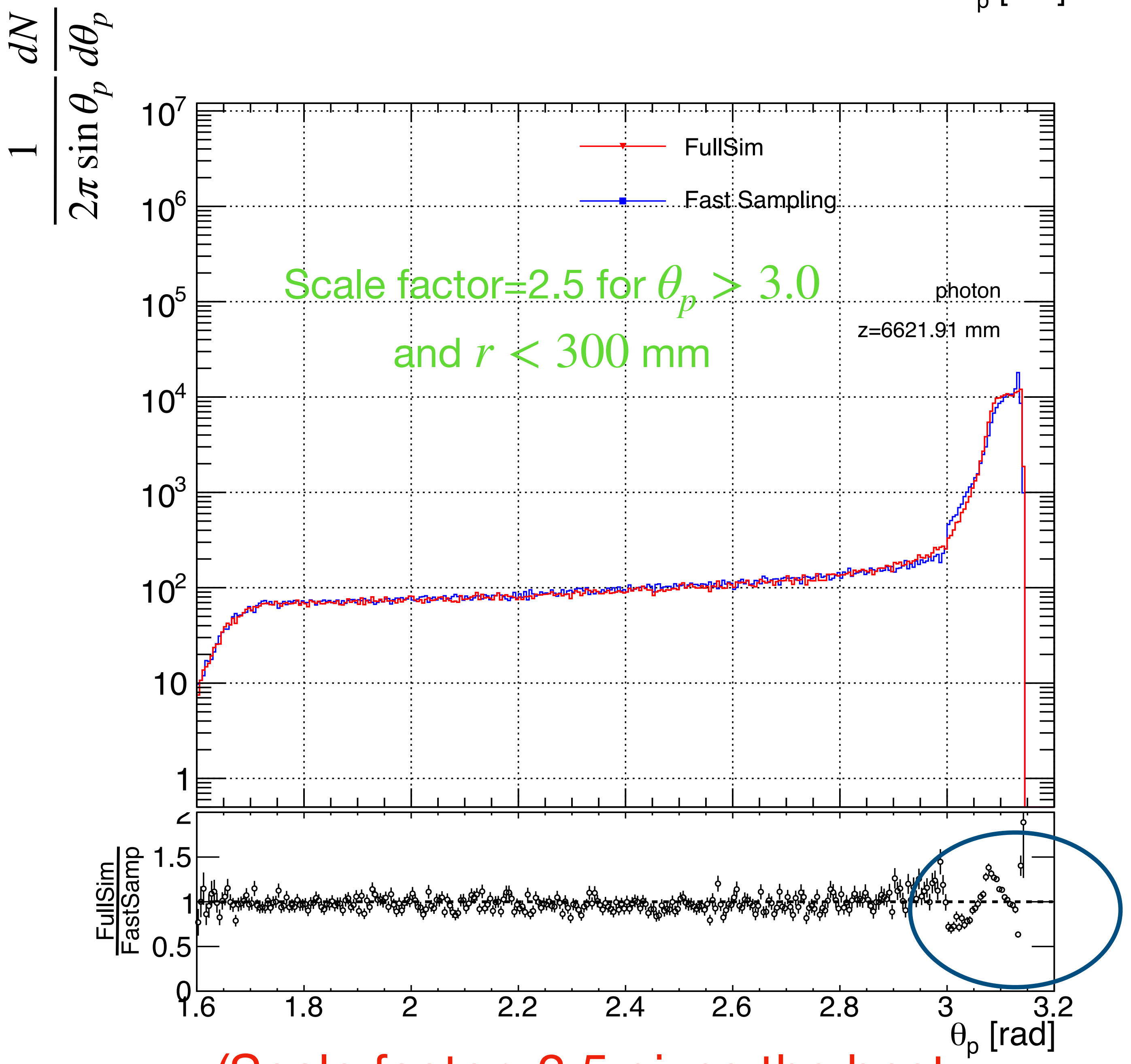
FastSampling of θ_p for scale factors: Photon

(Only FastSampling plots are changed due to the different scale factors)

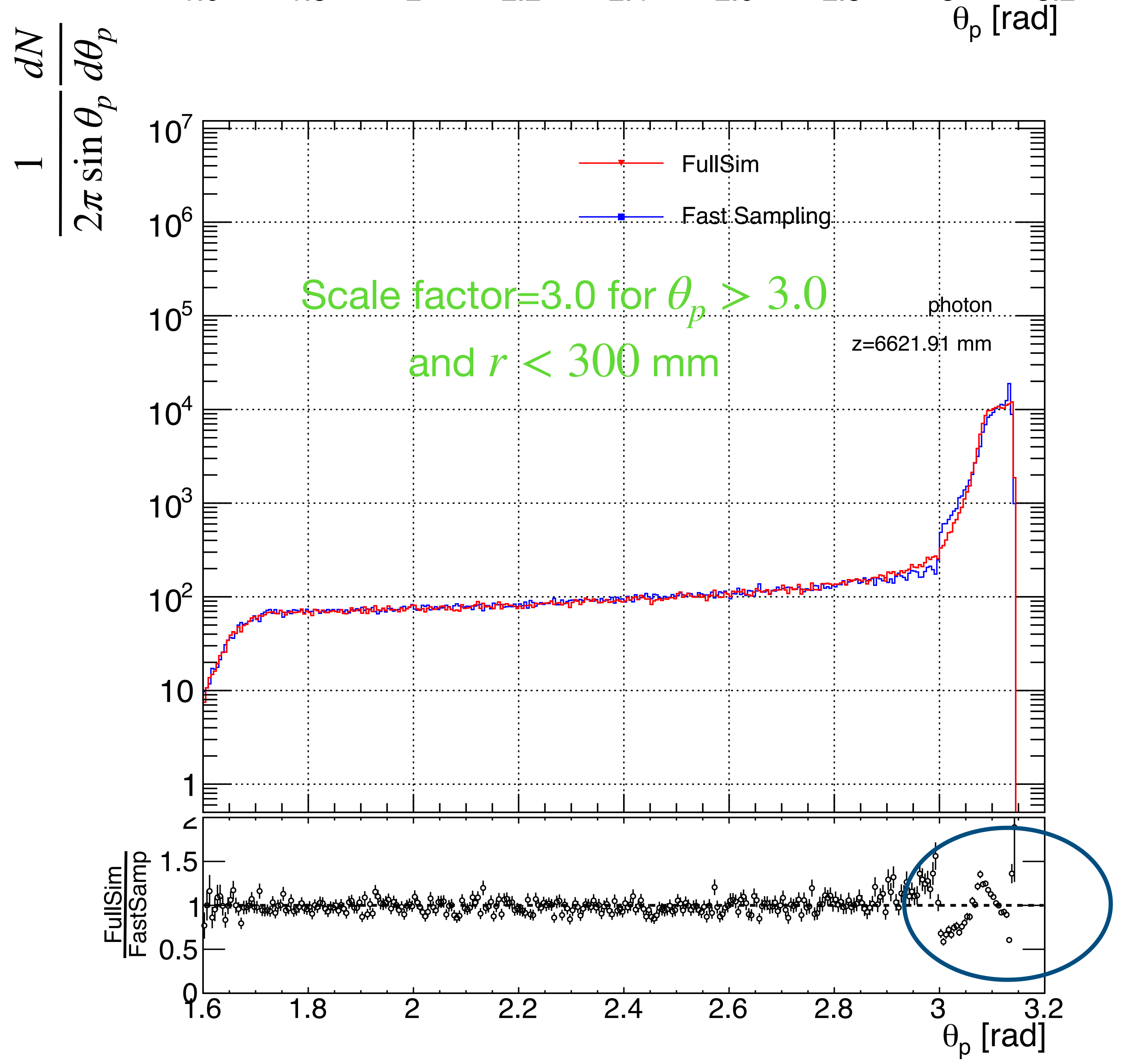


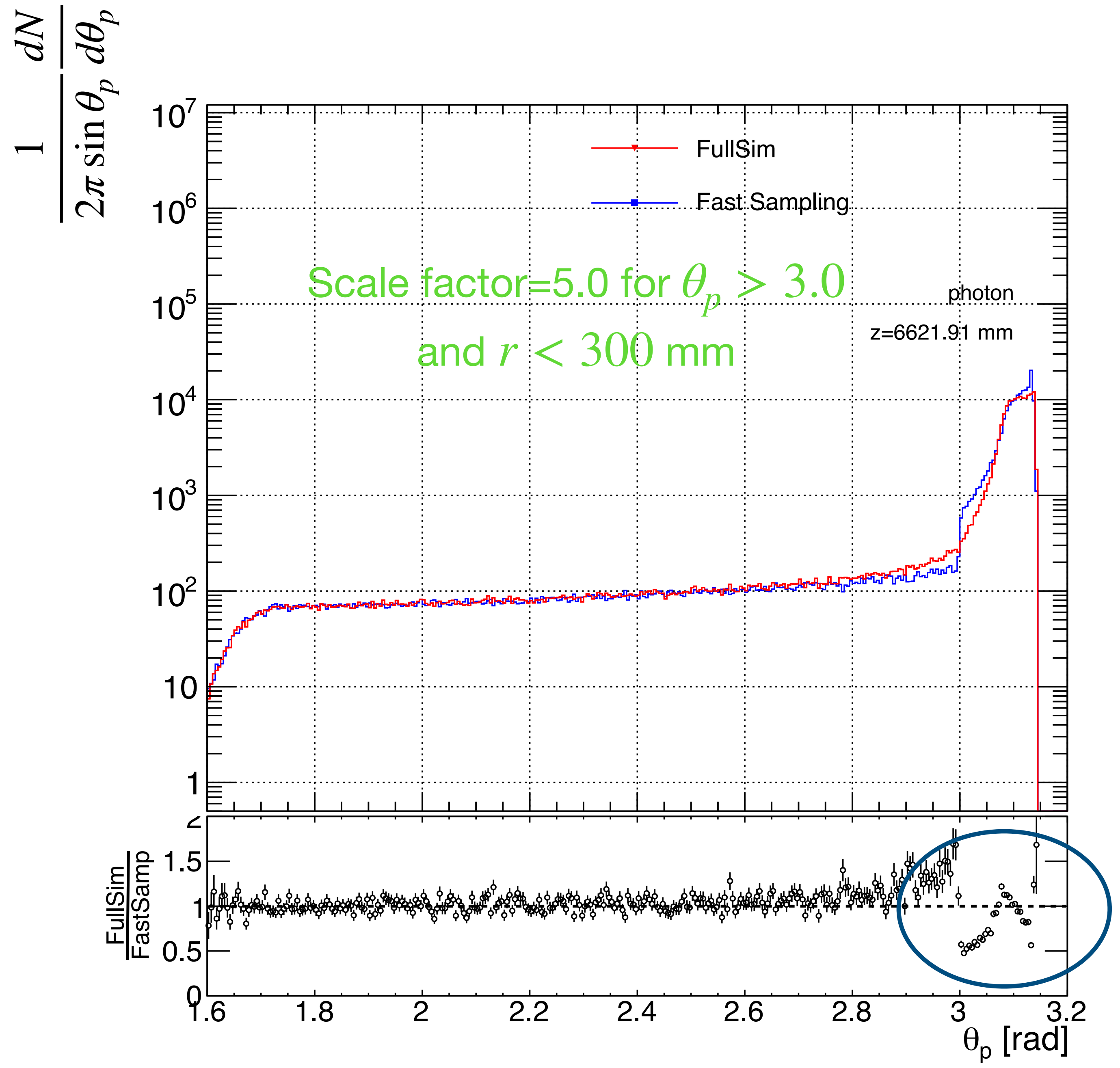






(Scale factor~2.5 gives the best match)

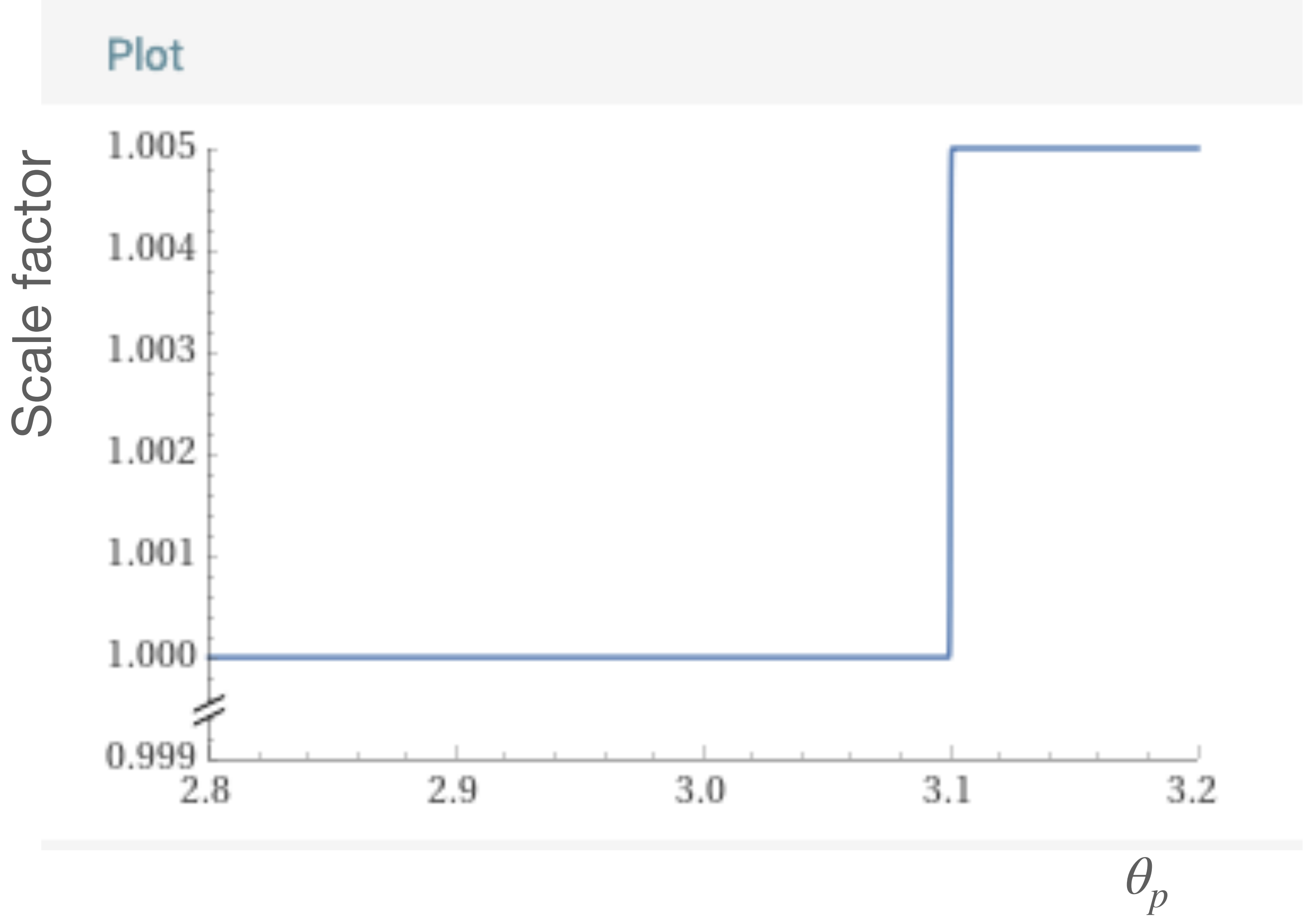




Scale factor:

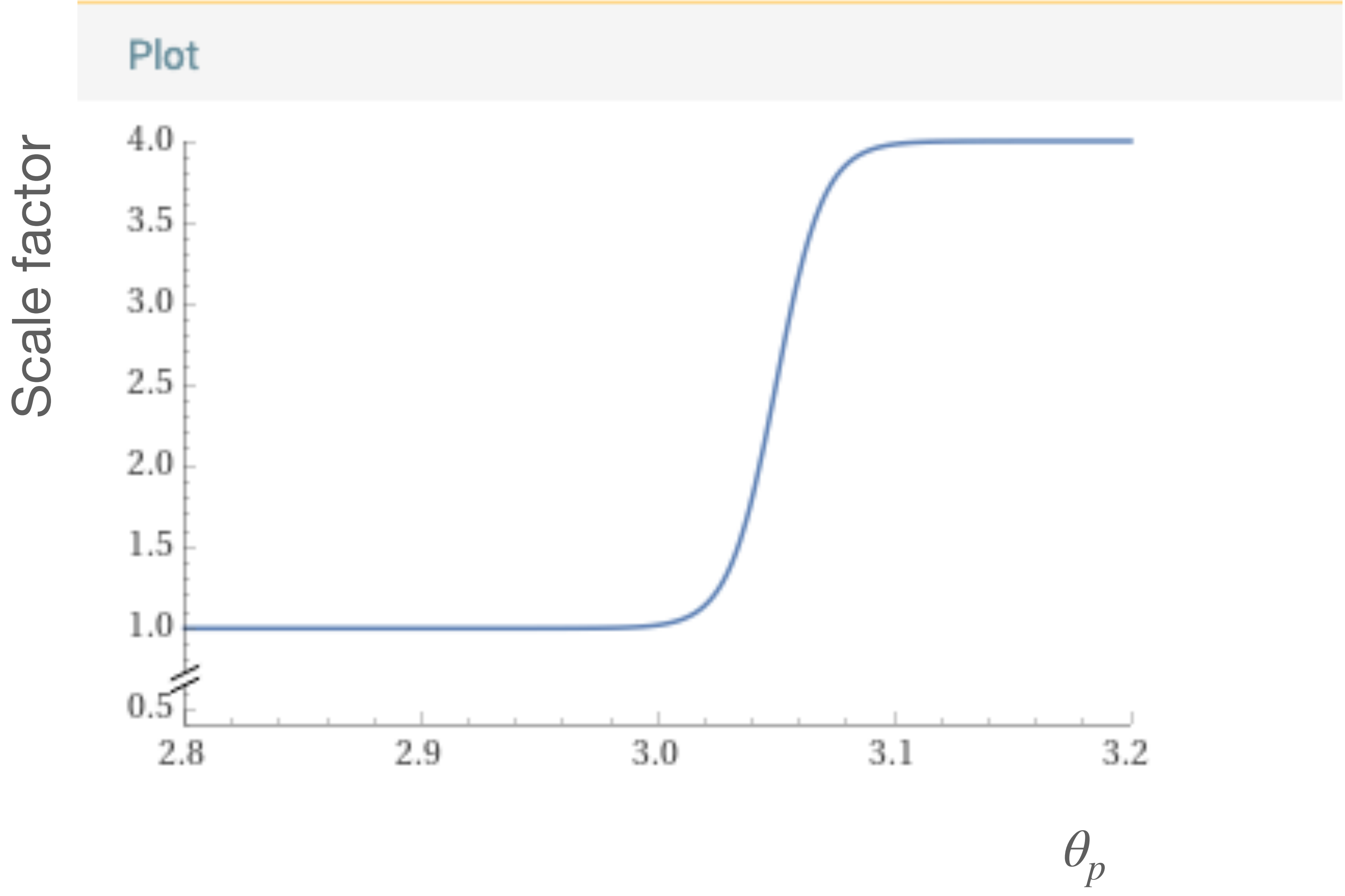
- Neutron and photon need different scale factor.
- Played with many different values and checked the FastSim distributions.
- Settled with scale factor depending only on θ_p:

plot	$1 + \frac{0.005}{1 + \exp(-\frac{\theta - 3.1}{0.0001})}$	$\theta = 2.8$ to 3.2



Neutron scale factor

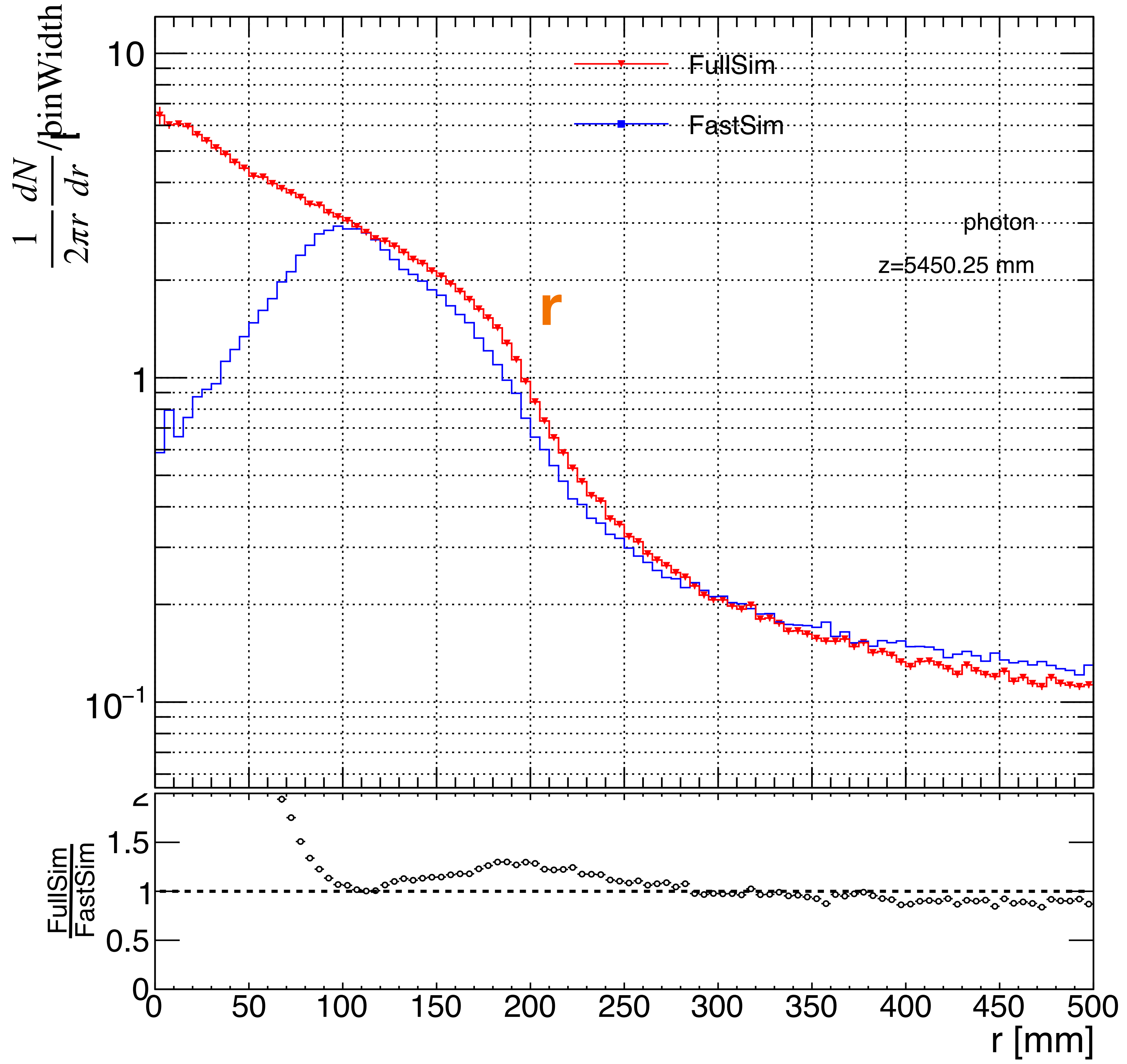
plot	$1 + \frac{3}{1 + \exp(-\frac{\theta - 3.05}{0.01})}$	$\theta = 2.8$ to 3.2



Photon scale factor

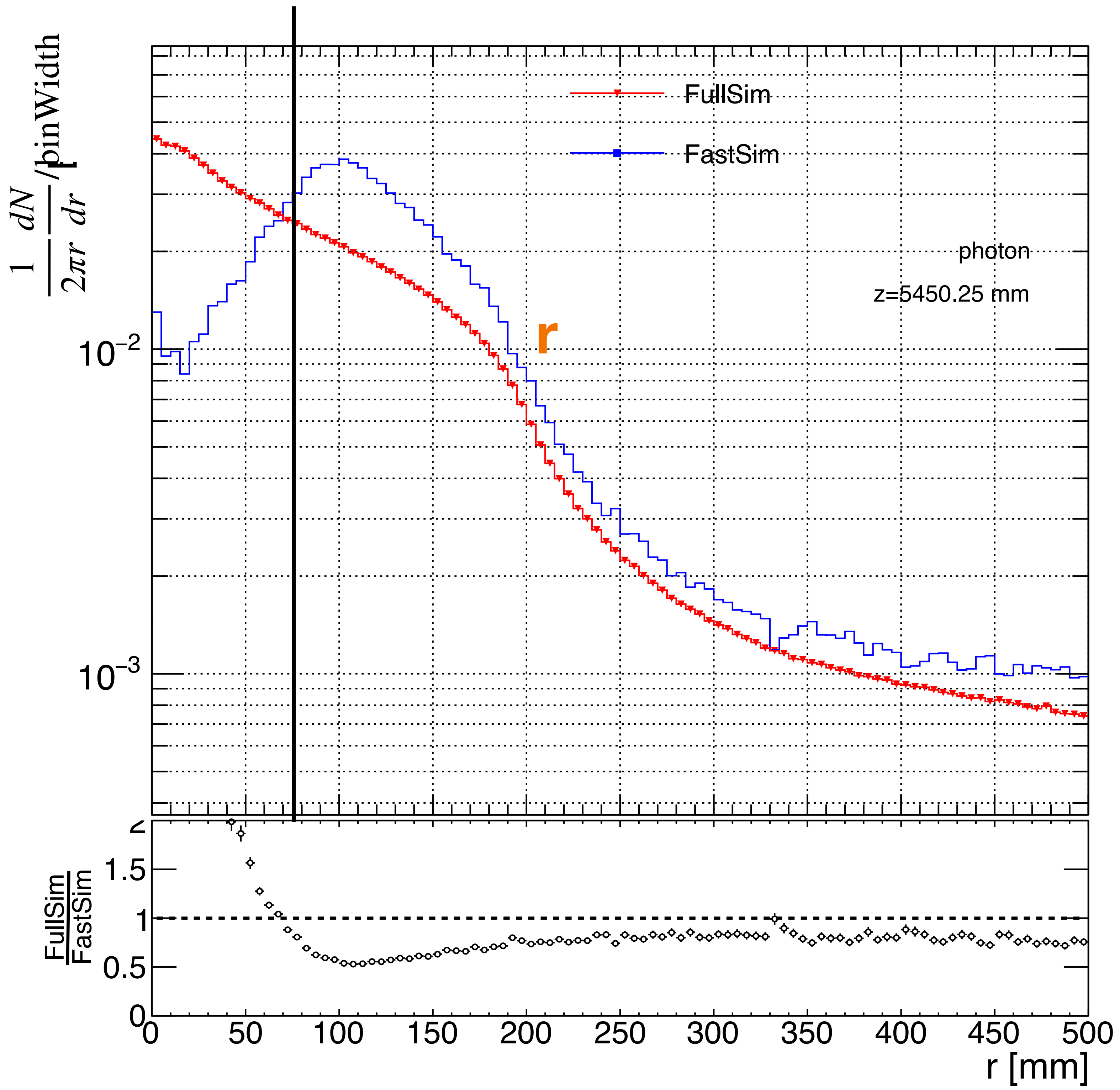
Photon at test surface 1

(Looking at the shape of the distribution)



Without scale factor on the sampling plot

The distance of scintillator screen from the beam pipe is ~76 mm.



With scale factor on the sampling plot

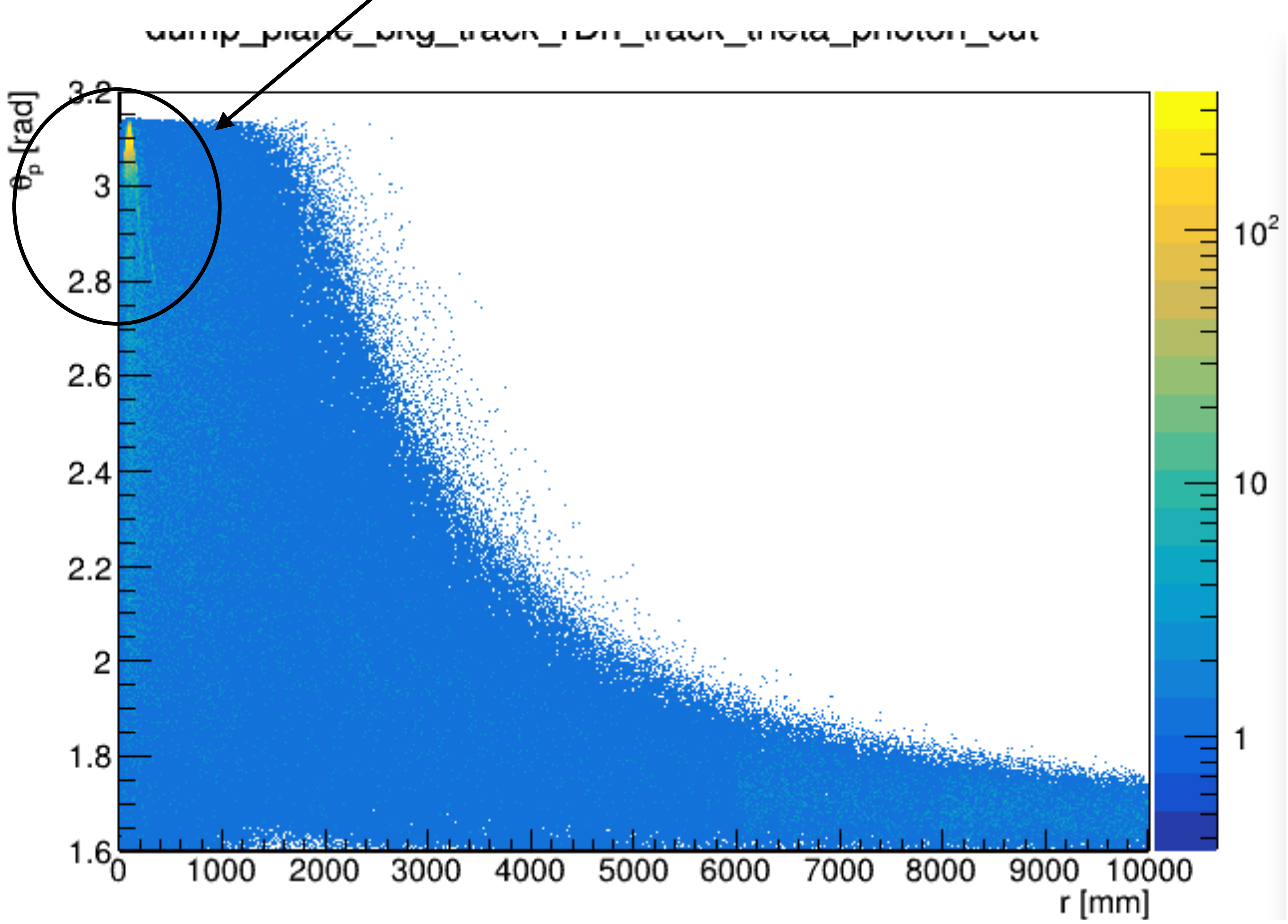
FastSim gives less photons for r < 60 mm

Simple scaling may not remove the peaking structure.

Photon at test surface 1

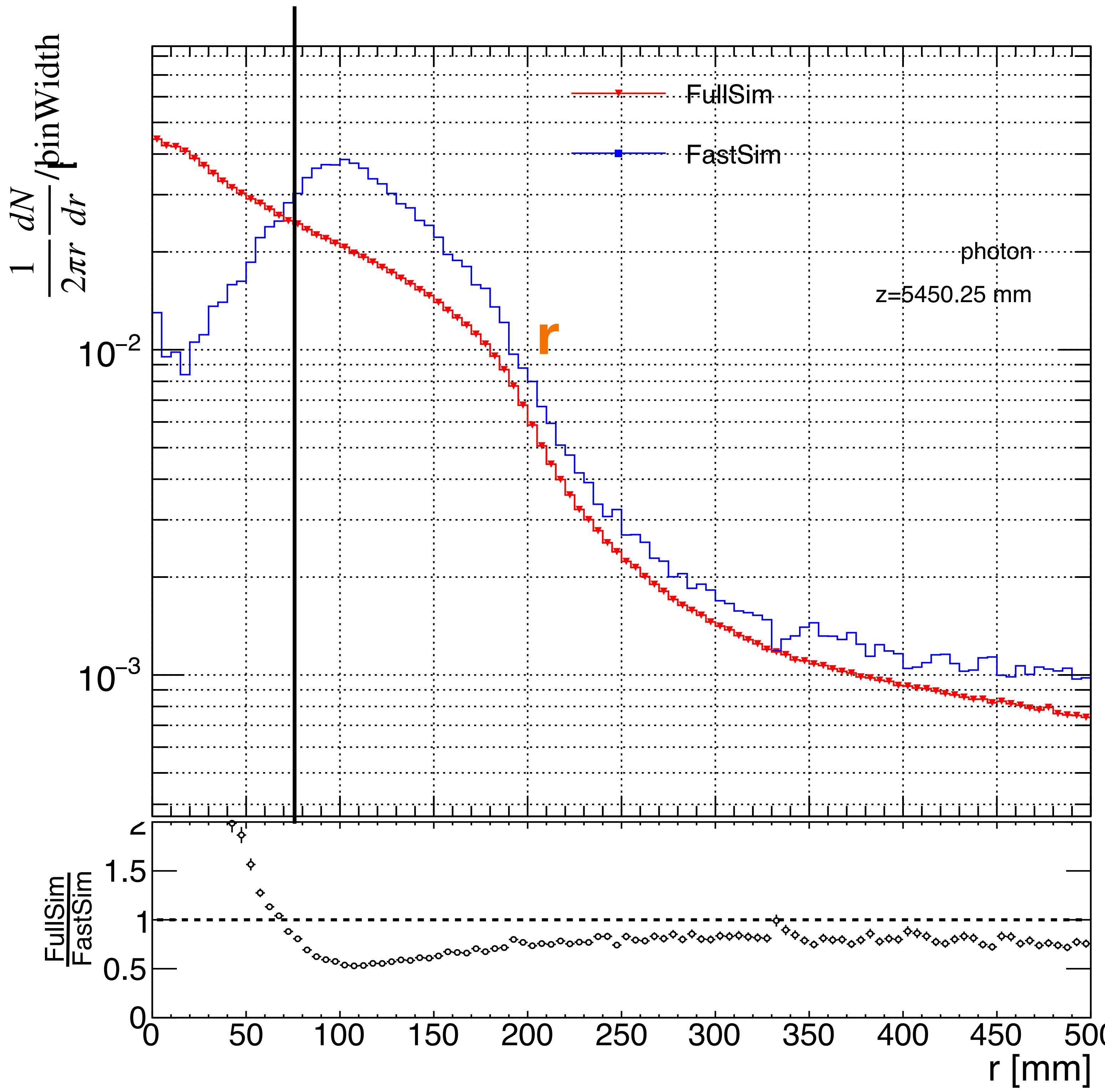
(Looking at the shape of the distribution)

The peaking structure in FastSim may be attributed to the photon source on the dump



θ_p vs r from FullSim at the sampling plane

The distance of scintillator screen from the beam pipe is ~76 mm.



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Photon at test surface 1

(Looking at the shape of the distribution)

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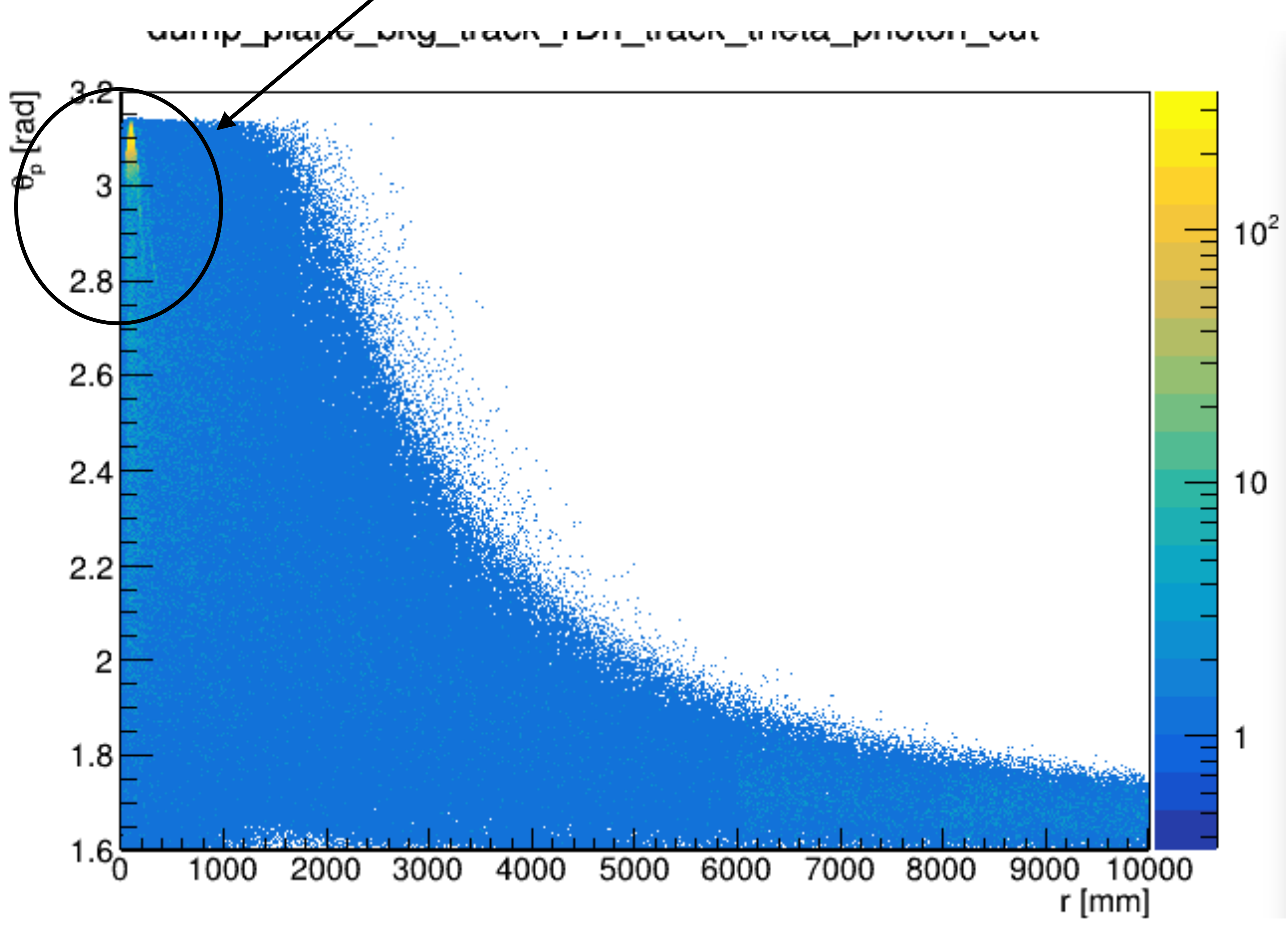
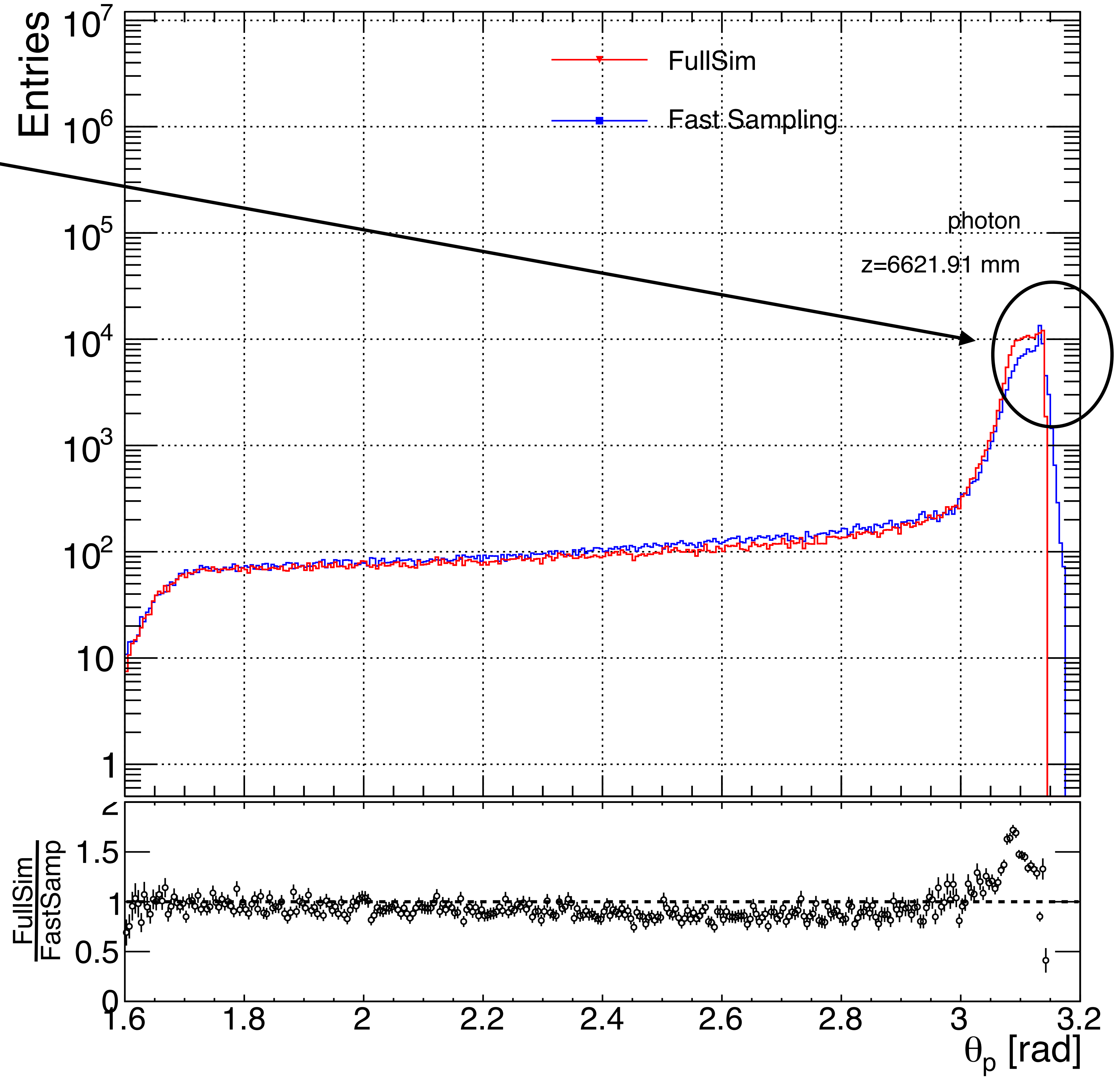


θ_p **vs r from FullSim at the sampling plane**



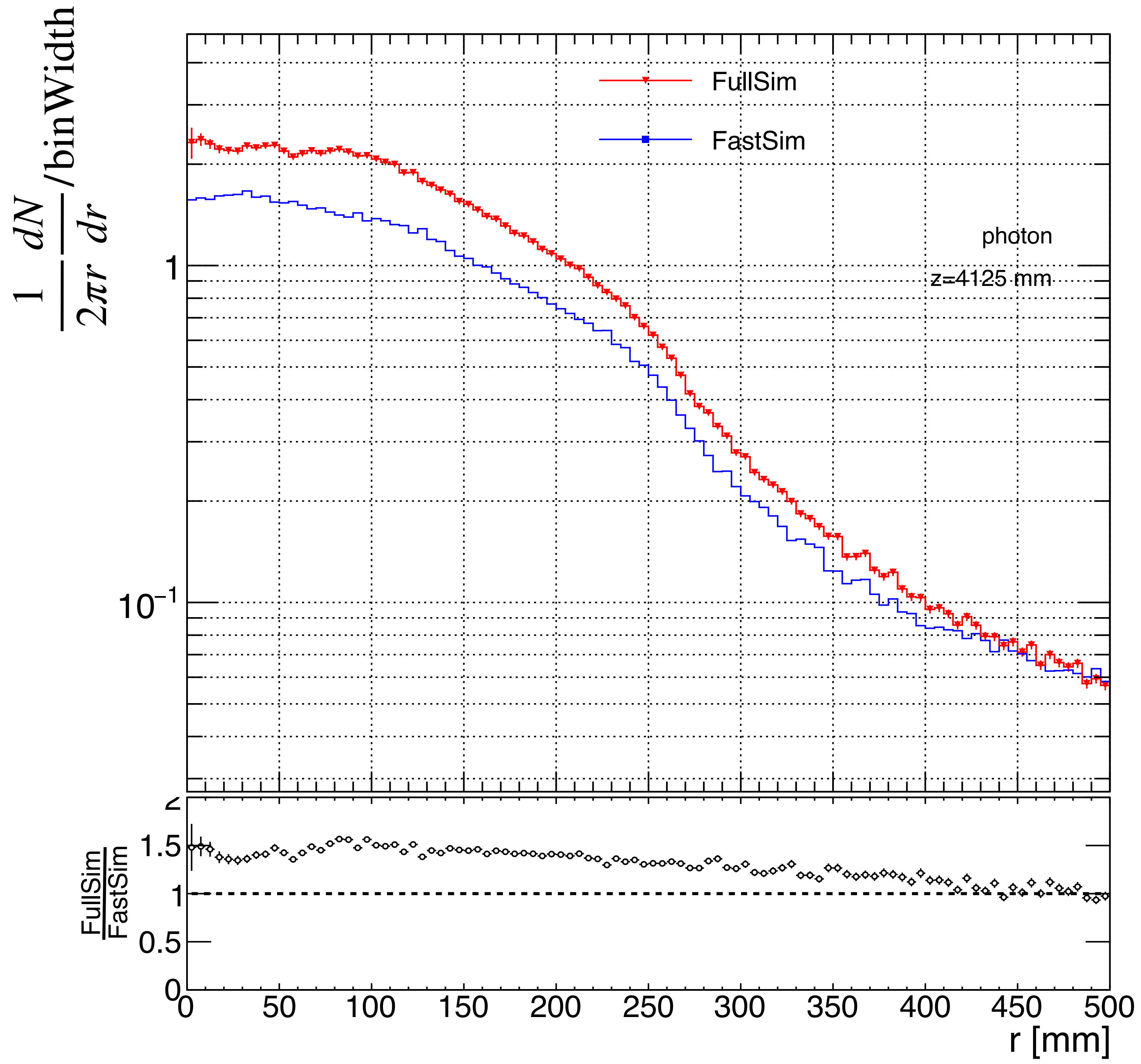
θ_p **at the sampling plane**

astSim gives less
otons for r < 60 mm

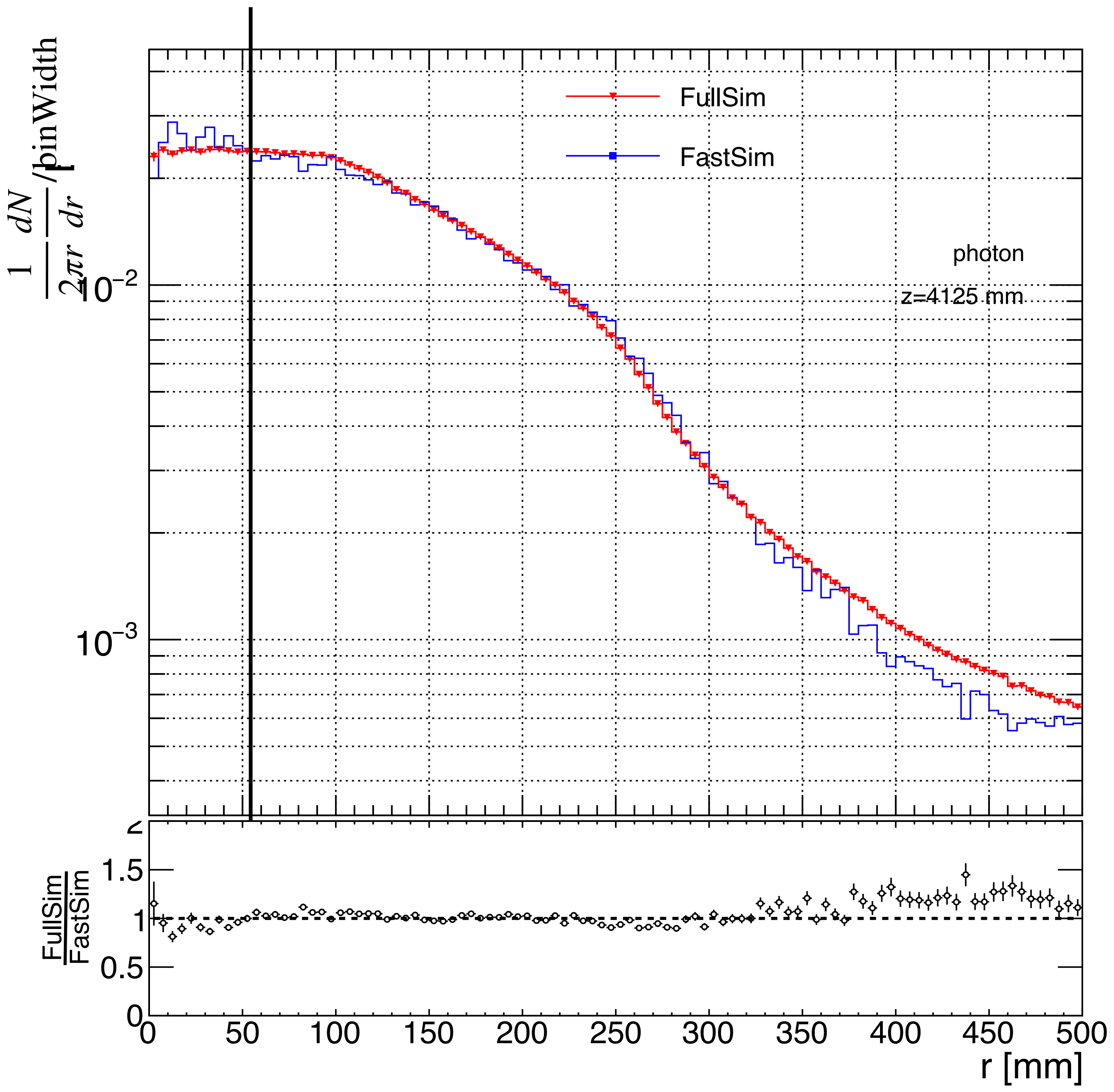
Photon at test surface 2

(Looking at the shape of the distribution)

The distance of tracker inner layer from the beam pipe is ~52 mm.



Without scale factor on the sampling plot

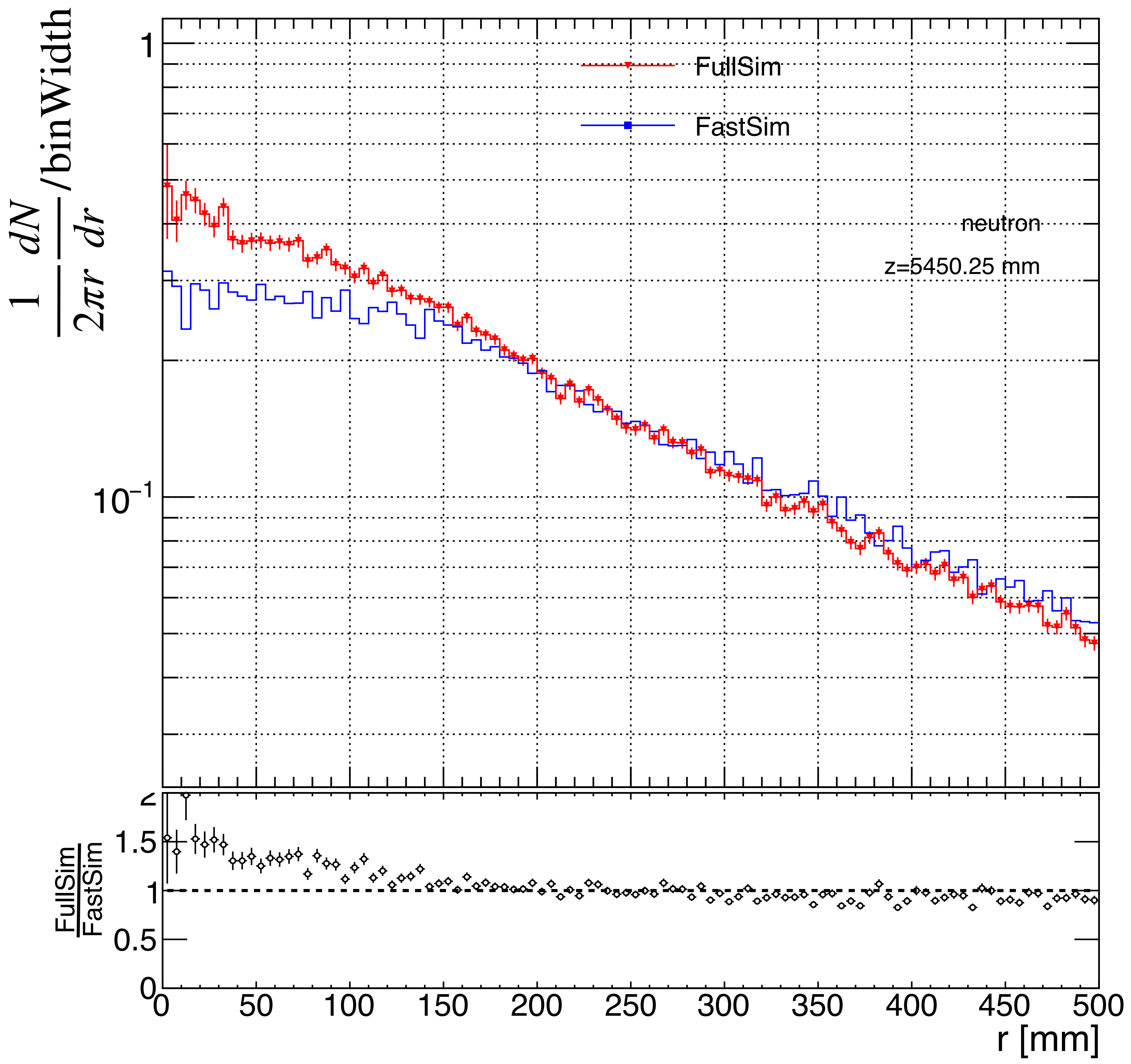


With scale factor on the sampling plot

FastSim gives similar number of photons

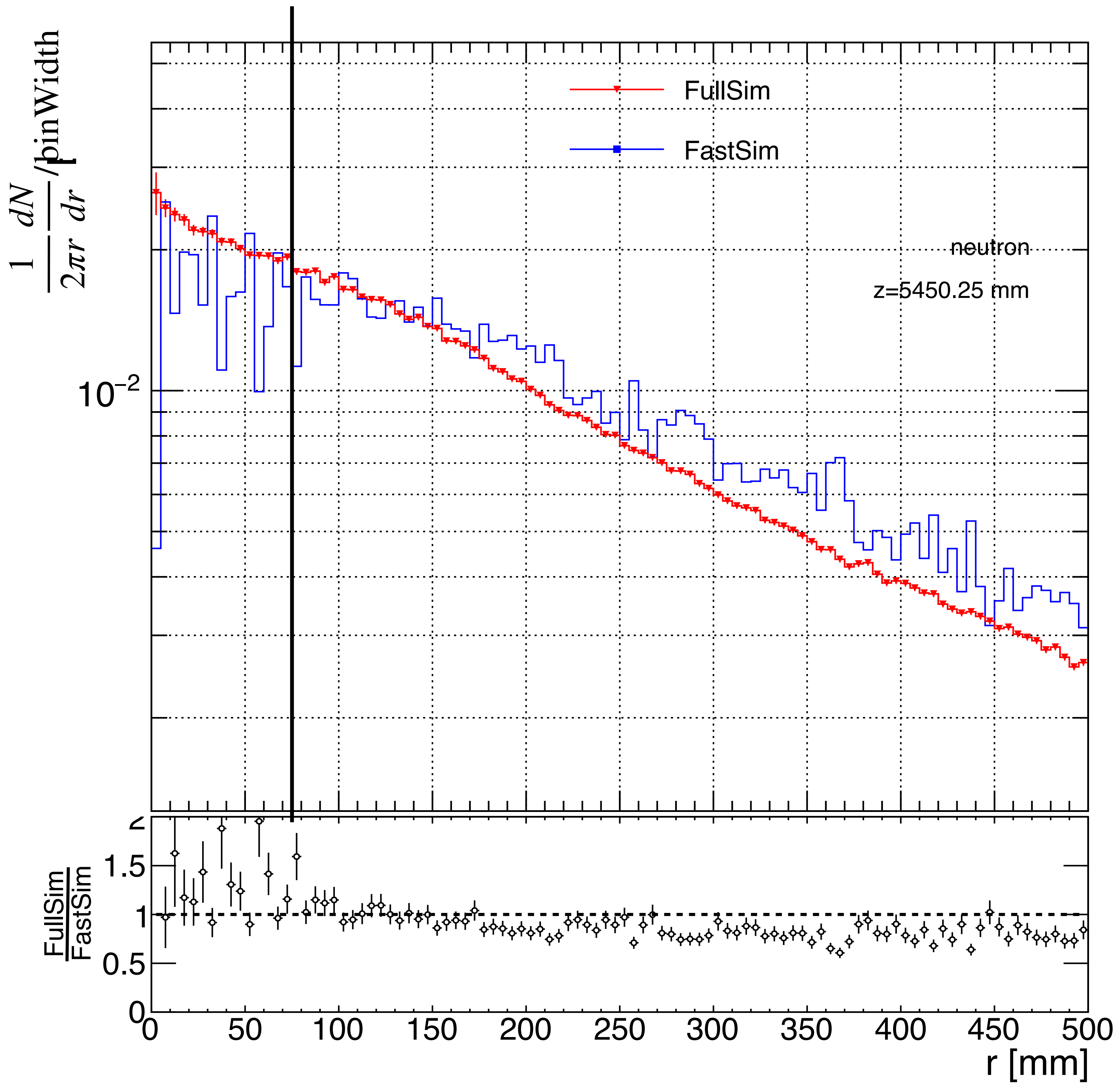
Neutron at test surface 1

(Looking at the shape of the distribution)



Without scale factor on the sampling plot

The distance of scintillator screen from the beam pipe is ~76 mm.

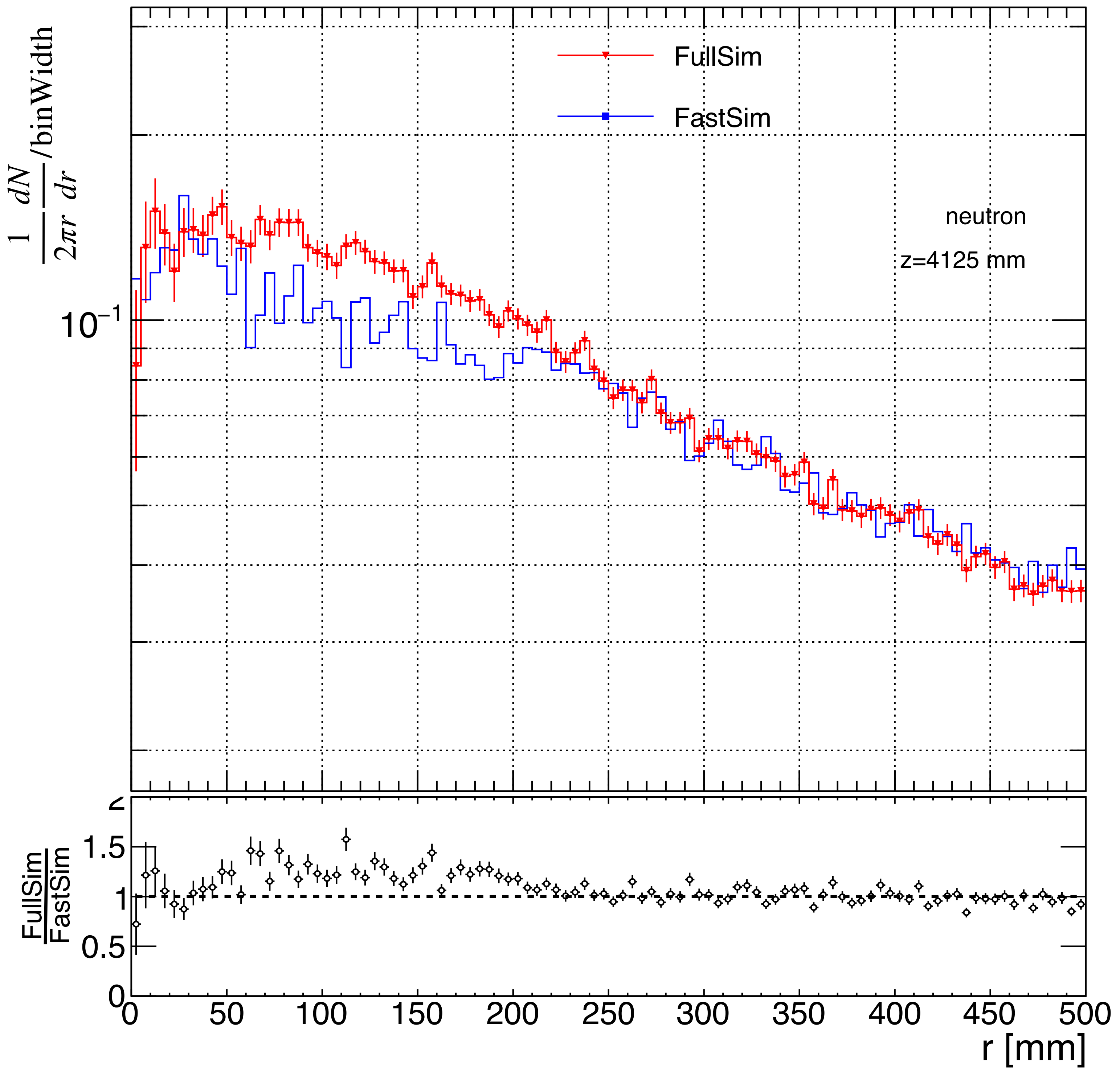


With scale factor on the sampling plot

FastSim r matches with FullSim after the application of the scale factor

Neutron at test surface 2

(Looking at the shape of the distribution)



Without scale factor on the sampling plot

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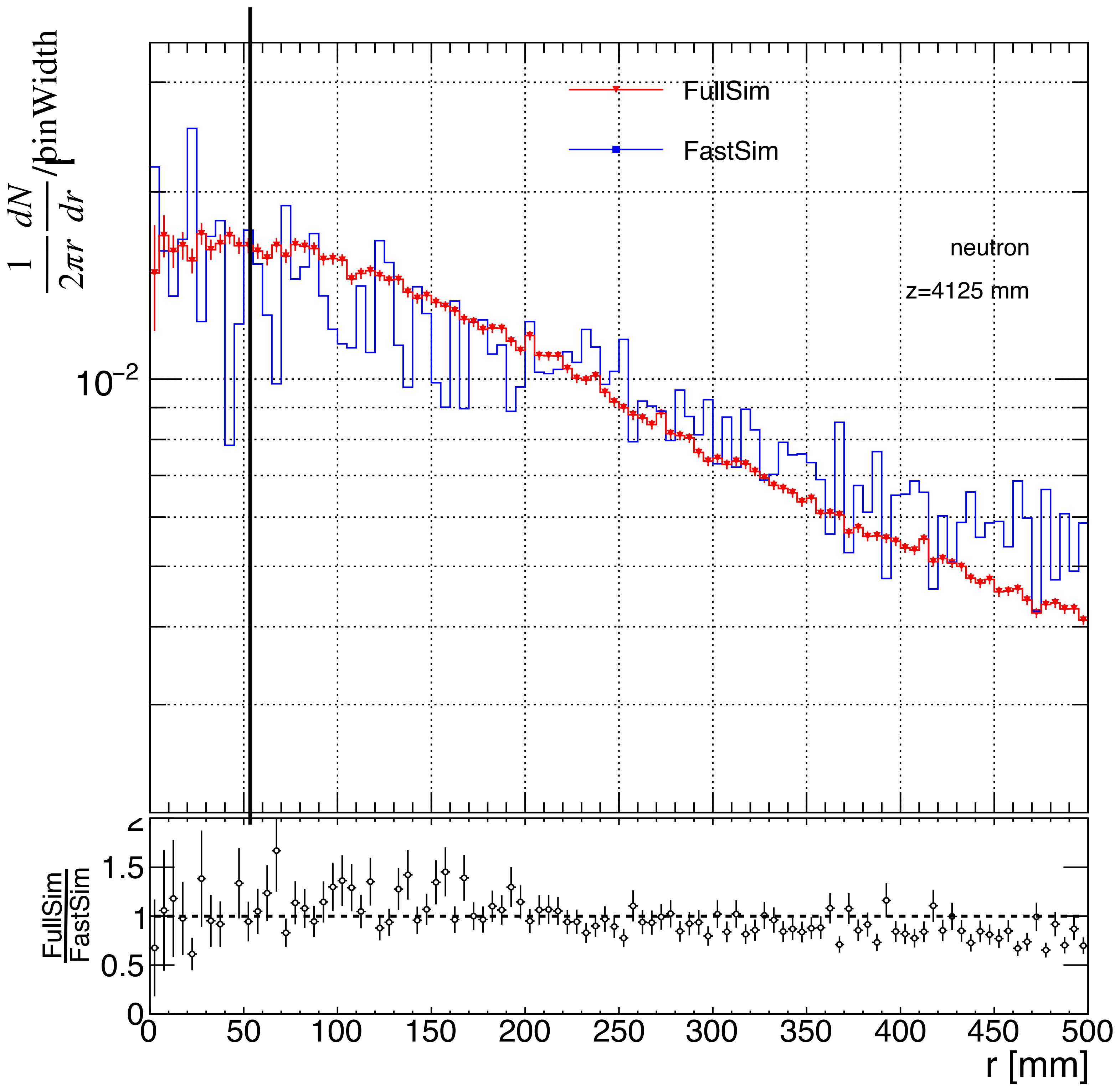


With scale factor on the sampling plot

FastSim r matches with FullSim after the application of the scale factor

Summary and Outlook

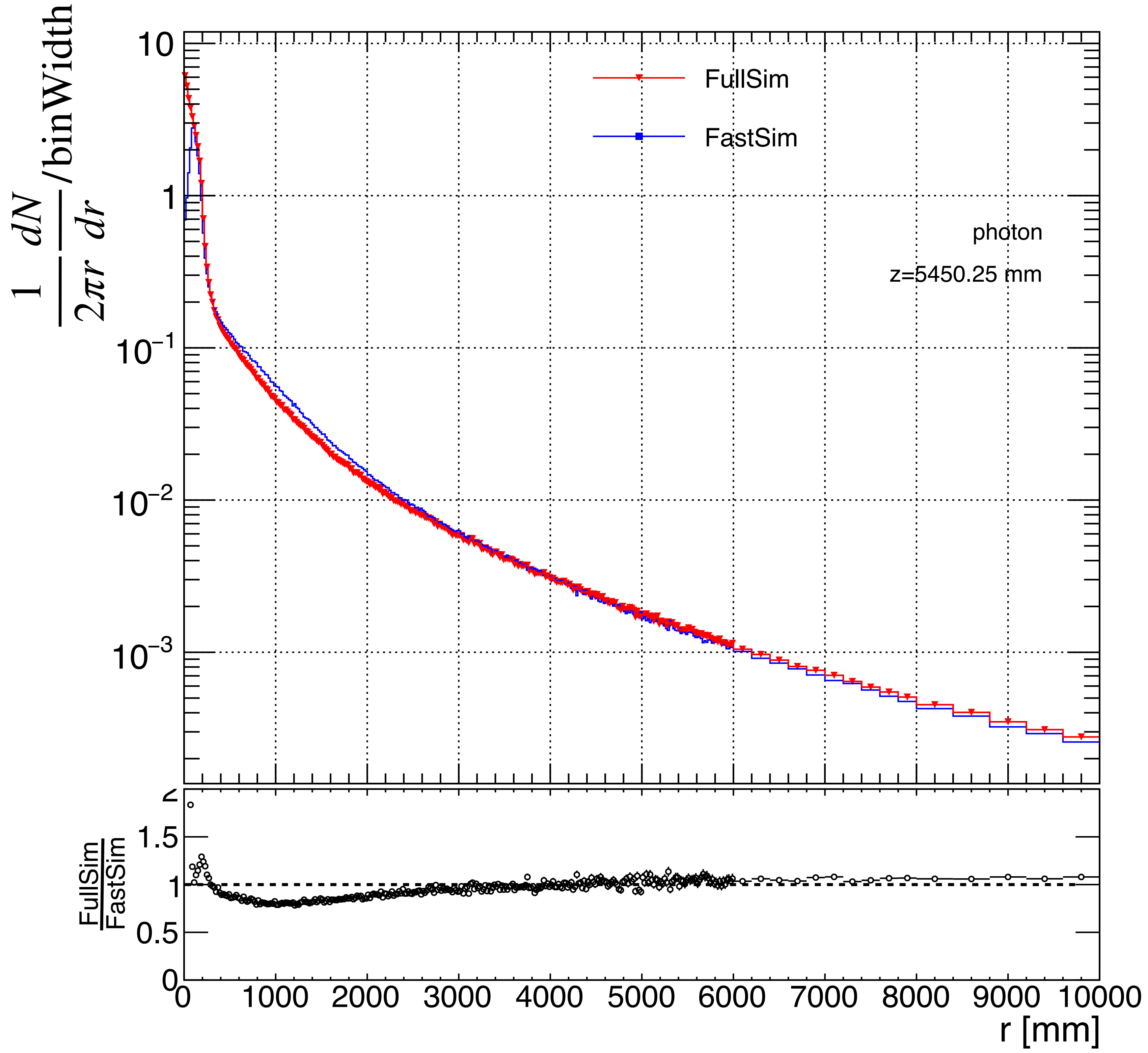
Summary and next steps:

- **Mis-modeling in very backward particles**
  - This is because the FullSim sample is statistically limited in this region.
- Scale very backward θ_p region before sampling
  - Artificial scaling.
  - Smoothening wherever necessary.
- **<u>Photons:</u>**
  - FastSim sample gives more photons in most of the regions (r>60 mm) at test surface 1.
    - $r < 60$ mm region may not be interesting for us.
  - FastSim sample gives similar photons at test surface 2.
- **<u>Neutrons:</u>**
  - FastSim sample gives similar number of neutrons as FullSim in test surface 1 and test surface 2.
    - Maybe I will play with the scale factor here a little more.
- Looking into GANs
  - More natural to parameterize the correlations.
  - However this approach will also suffer from low stats in the very-backward scenario.

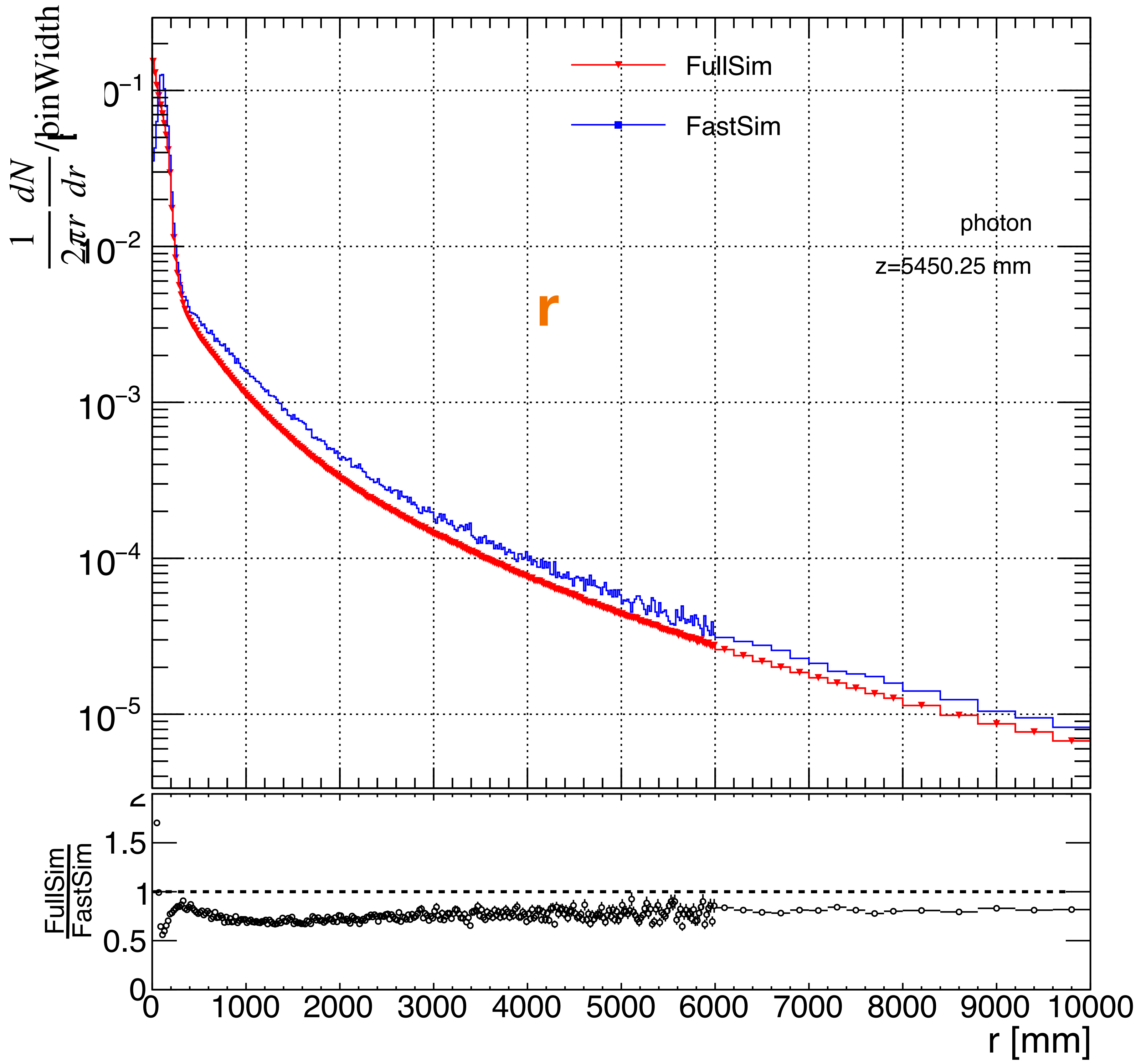
Thank you!

Backup

Photon at test surface 1



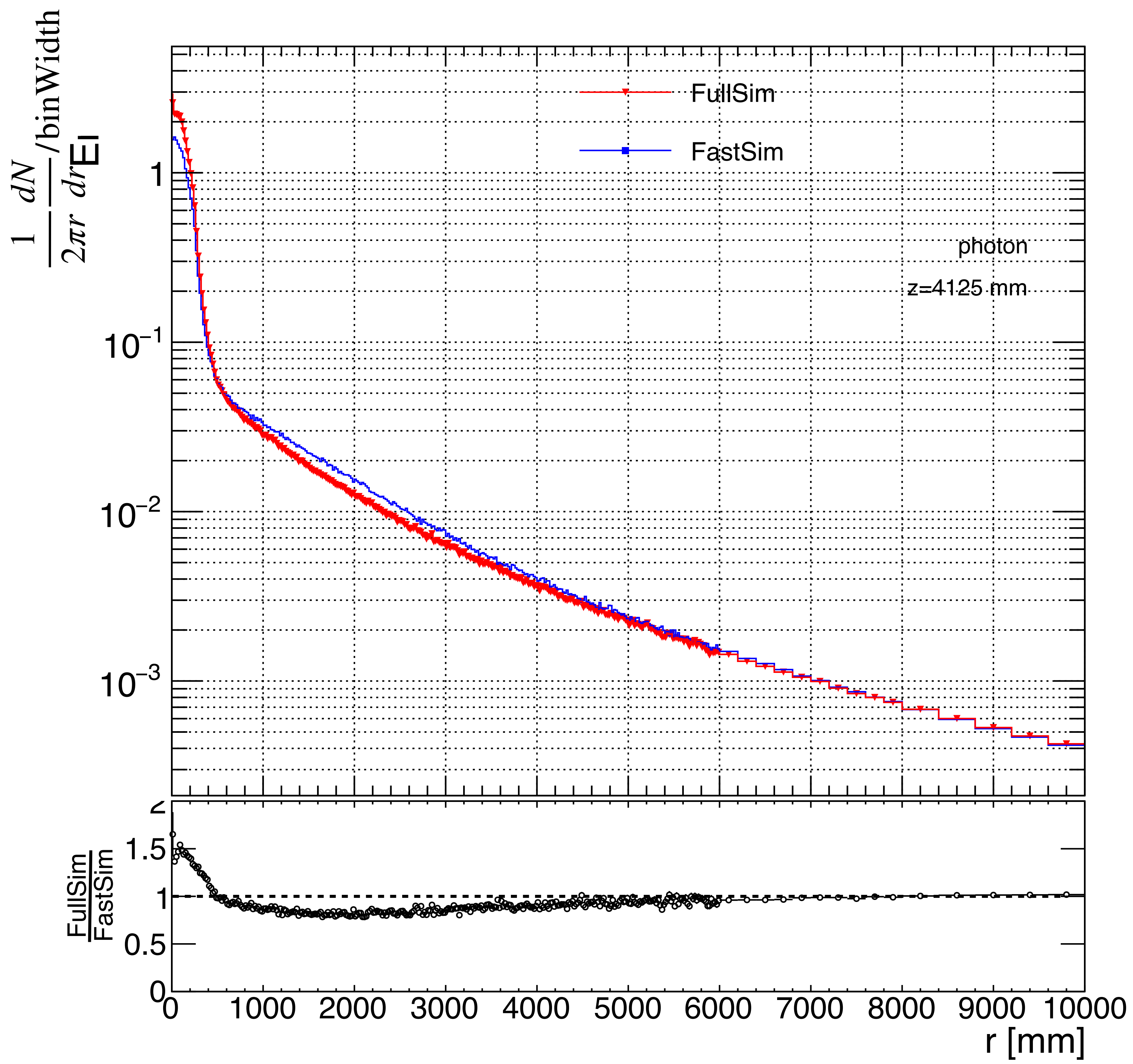
Without scale factor on the sampling plot



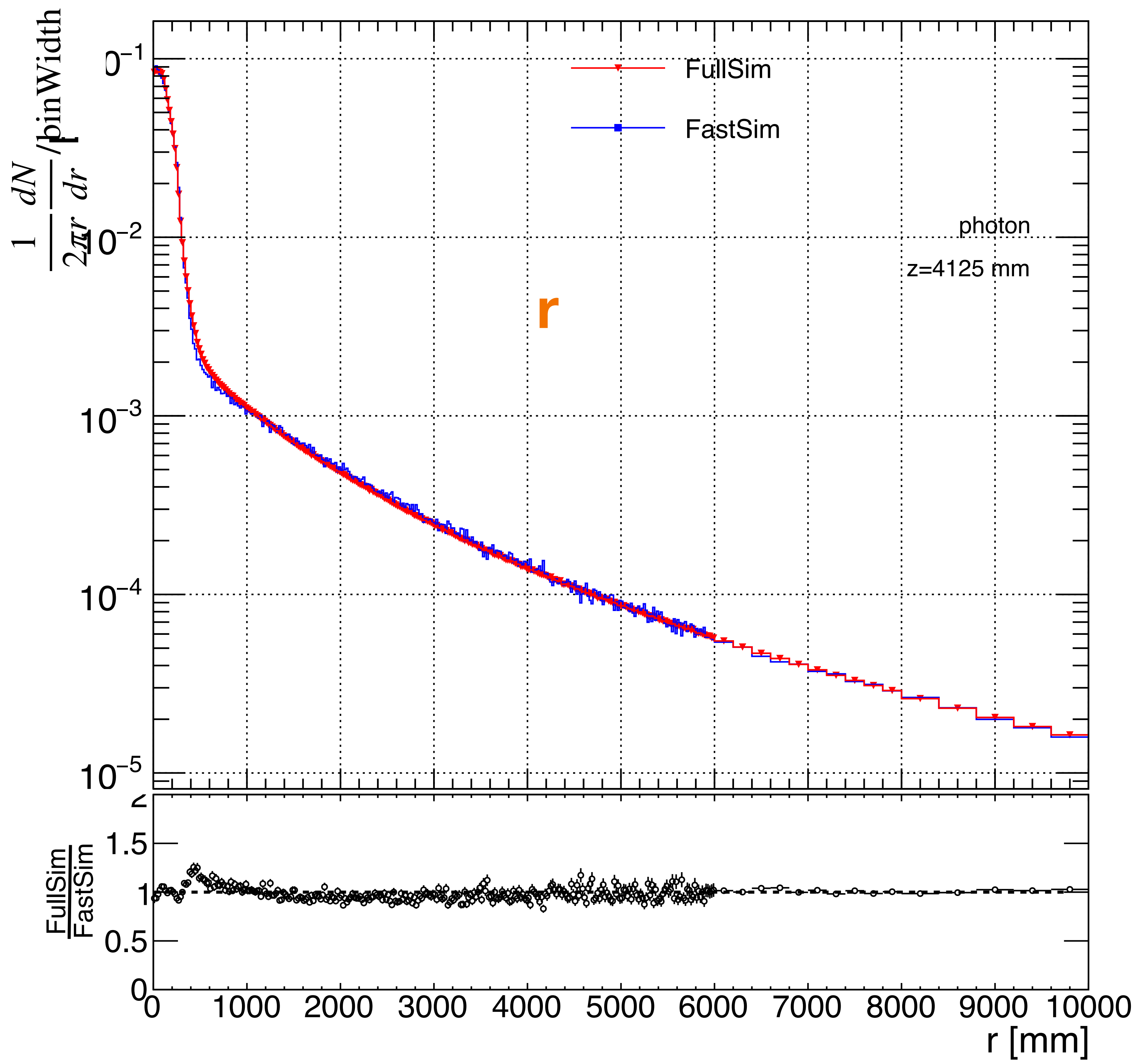
With scale factor on the sampling plot

FastSim gives more photons for r > 60 mm

Photon at test surface 2



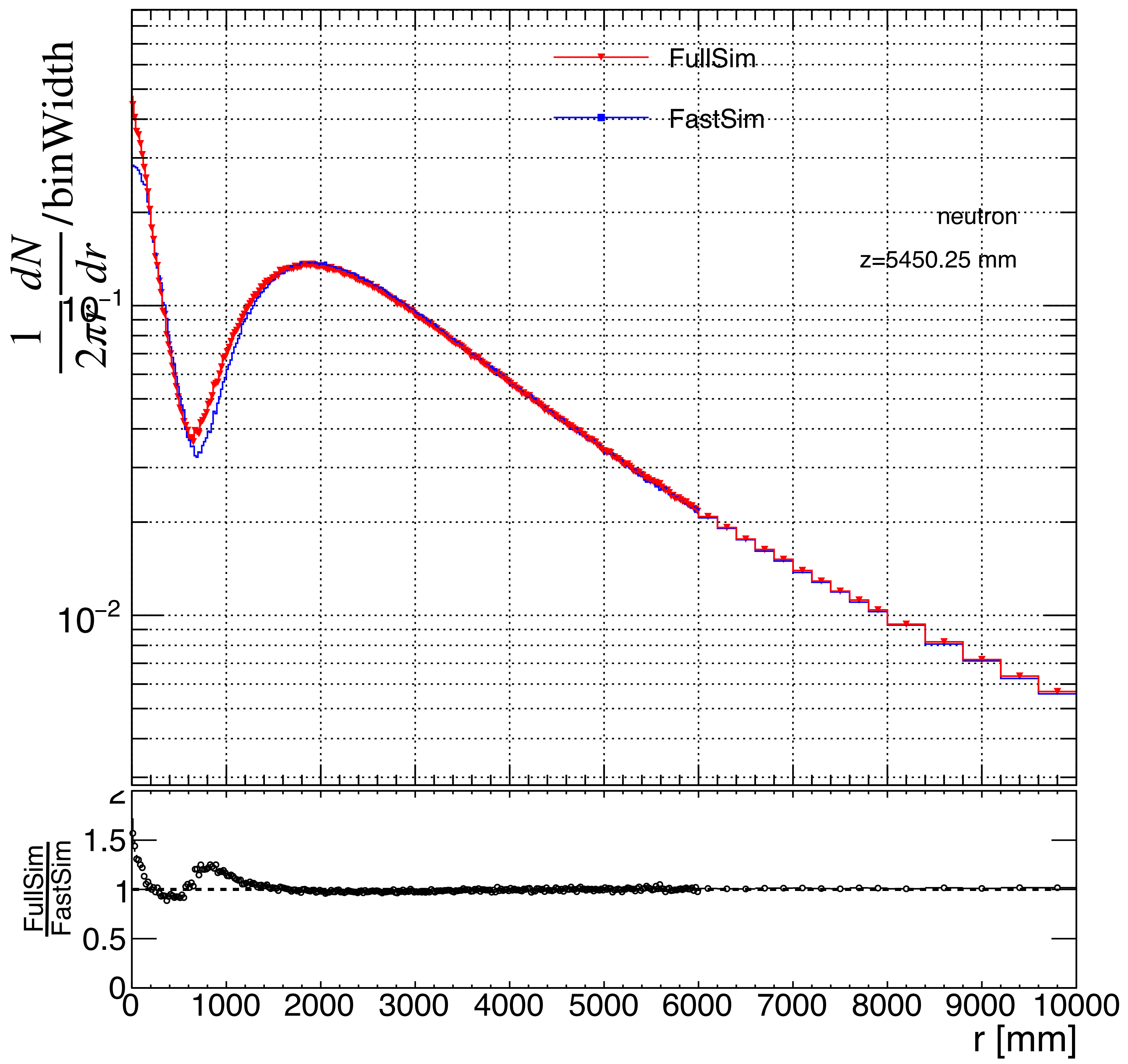
Without scale factor on the sampling plot



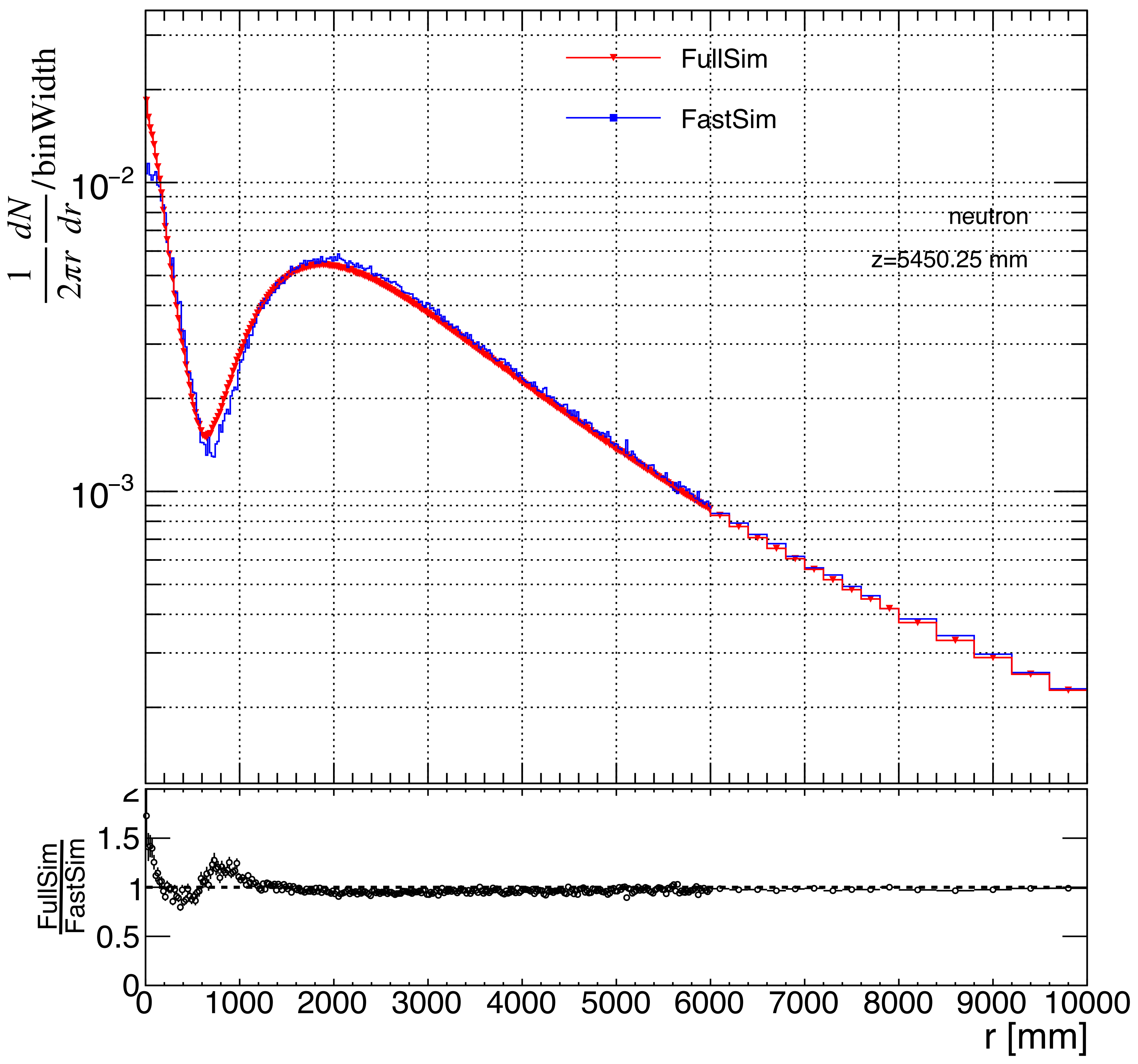
With scale factor on the sampling plot

FastSim gives similar number of photons

Neutron at test surface 1



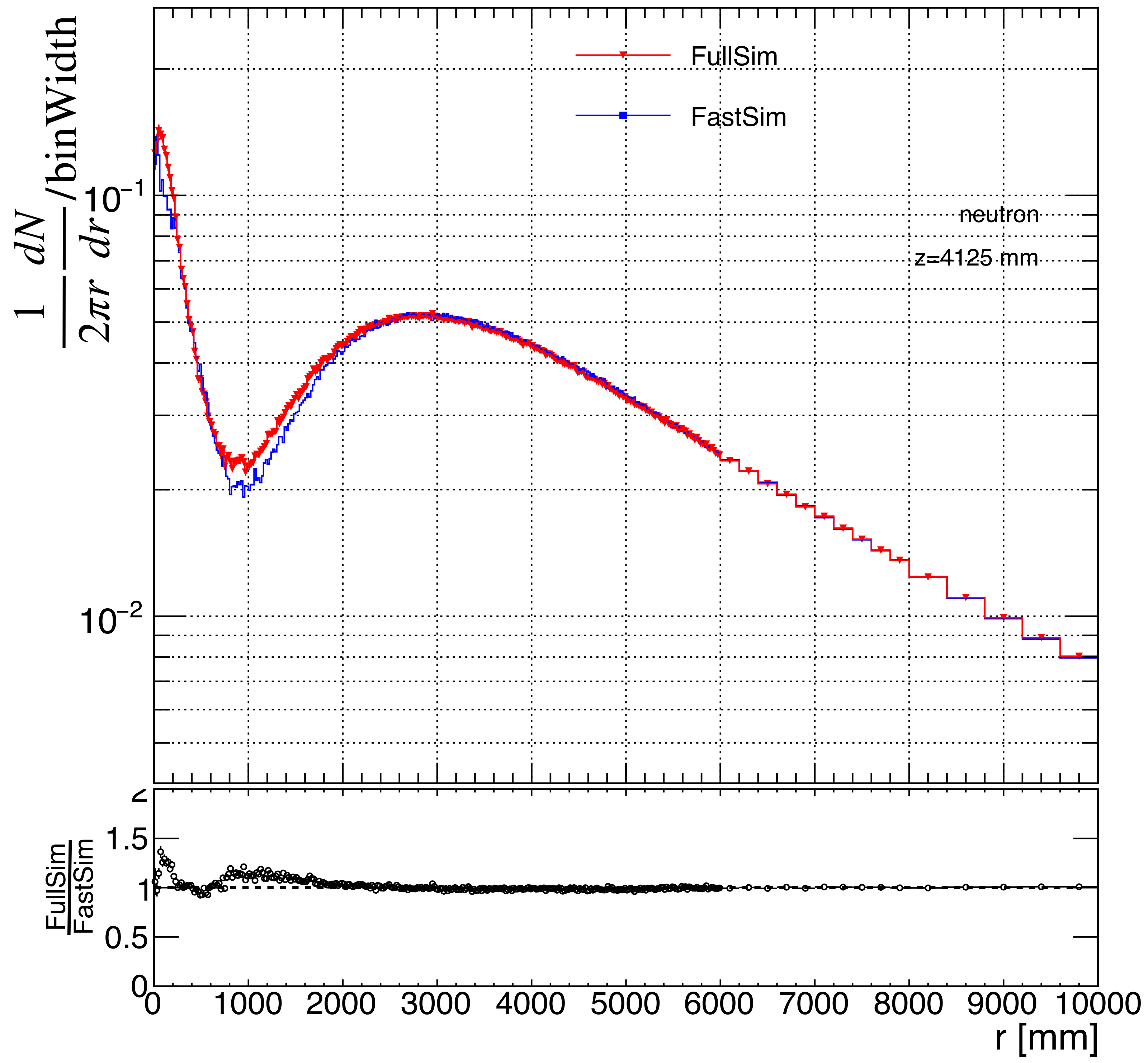
Without scale factor on the sampling plot



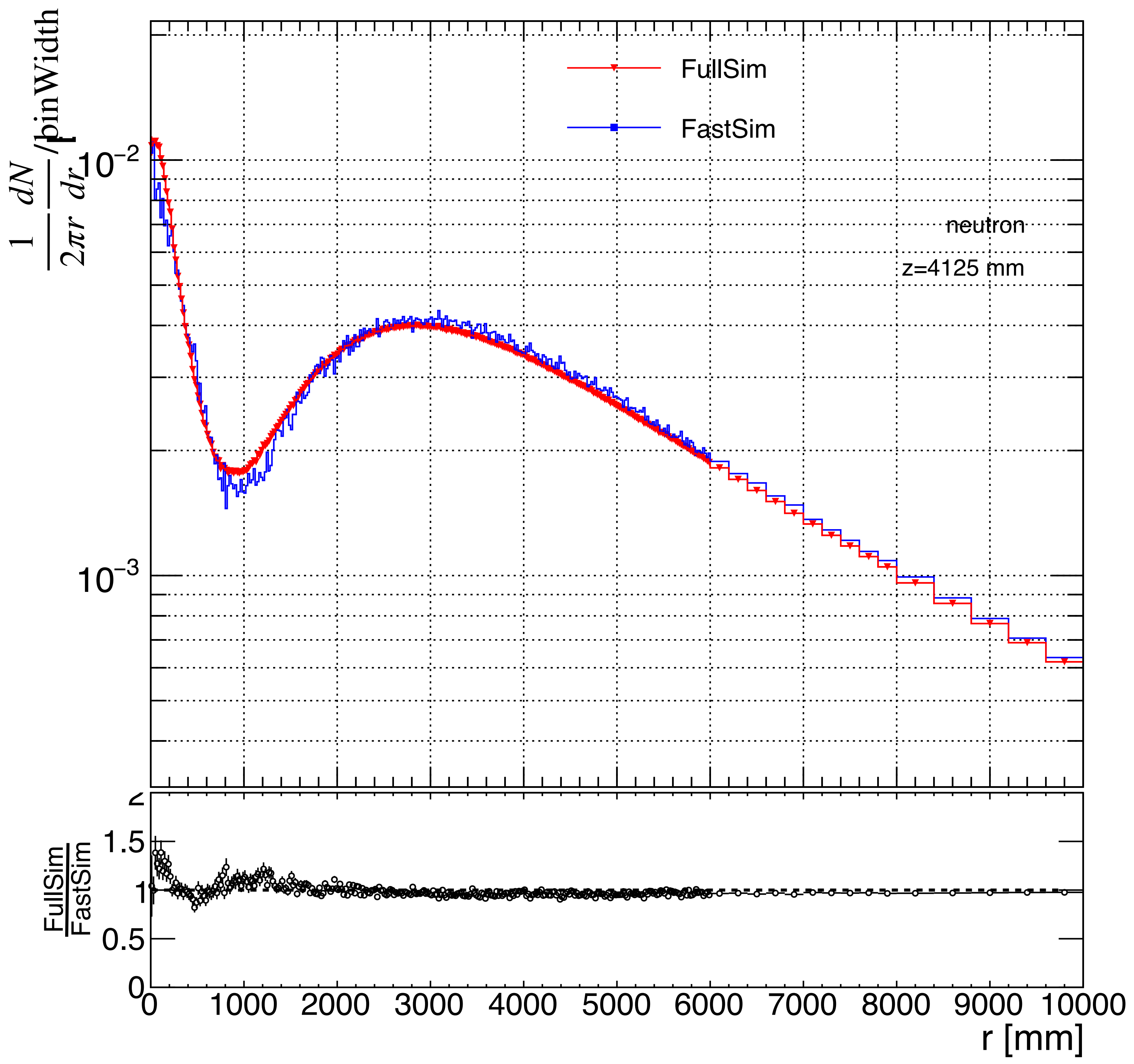
With scale factor on the sampling plot

FastSim gives similar number of neutron.

Neutron at test surface 2



Without scale factor on the sampling plot



With scale factor on the sampling plot

FastSim gives similar number of neutron.

Strategy for FastSim in LUXE Geometry

- The symmetry in r and ϕ_{pos} is unavailable for the dump particles in LUXE geometry, we need to come up with this strategy:

1. Plot $\frac{d^2N}{dxdy}$ $\rightarrow$ randomly draw x and y from this distribution.

2. This gives r and ϕ_{pos};

   (i)depending on x > x_0 or x < x_0, we select r_{Up} or r_{Dn}.

3. Plot $\frac{d^2N}{dr_{Up}d\theta_p}$ and $\frac{d^2N}{dr_{Dn}d\theta_p}$ $\rightarrow$ given the r, we project this distribution on θ_p to get $\frac{dN}{d\theta_p}$ (1D distribution)

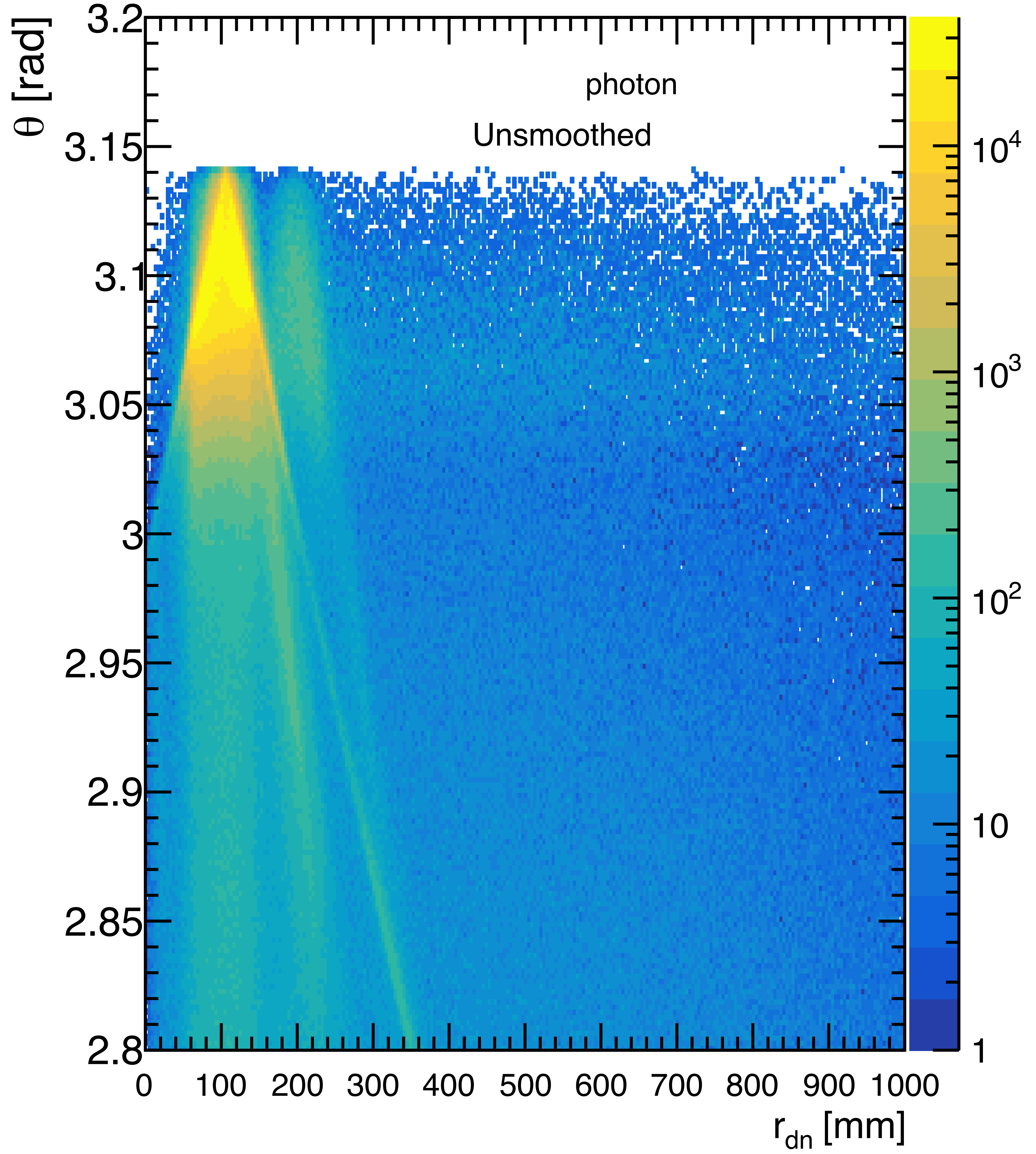
4. Plot $\frac{d^2N}{d\phi_p d\phi_{pos}}$ $\rightarrow$ given the ϕ_{pos}, we project this distribution on ϕ_p to get $\frac{dN}{d\phi_p}$ (1D distribution)

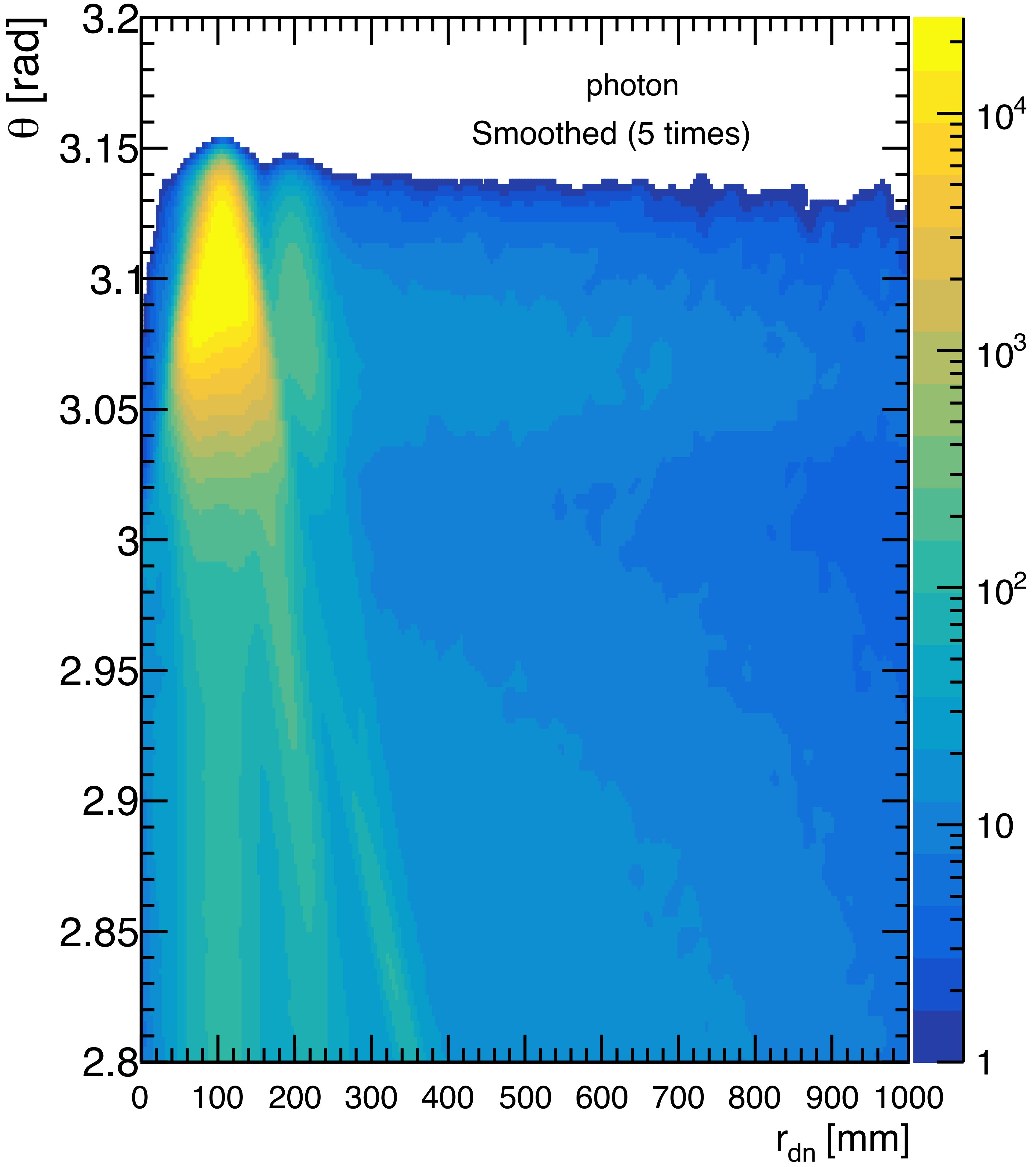
5. Randomly draw $\theta_p$from $\frac{dN}{d\theta_p}$ and ϕ_p from $\frac{dN}{d\phi_p}$

6. We have x, y, ϕ_{pos}, θ_p and ϕ_p

7. Energy and time can be randomly drawn from $\frac{d^2N}{dEdt}$ (for neutron) or $\left(\frac{dN}{dE} \text{ and } \frac{dN}{dt}\right)$(for photons).

Effect of Smoothening of 2D bins: photon



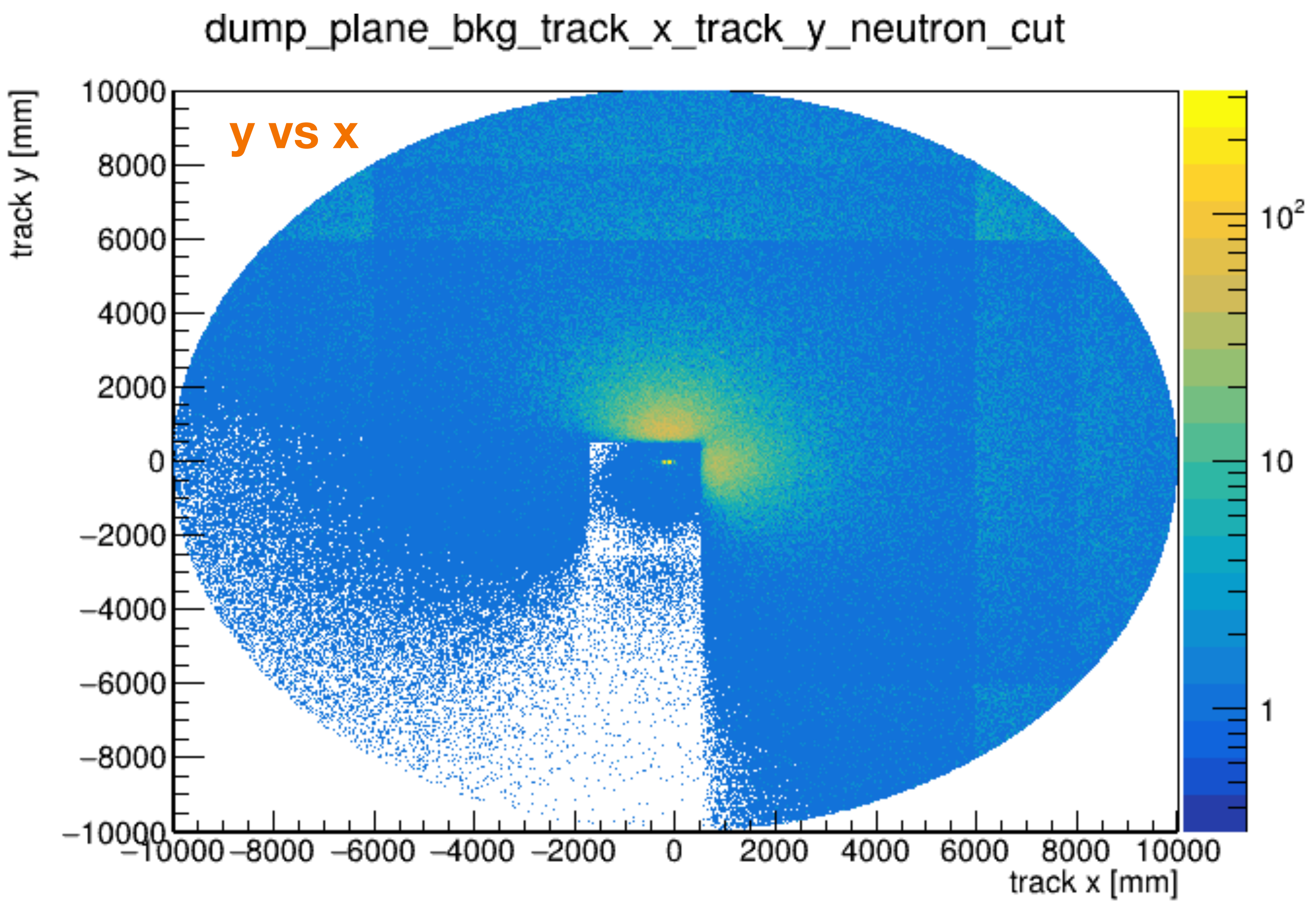


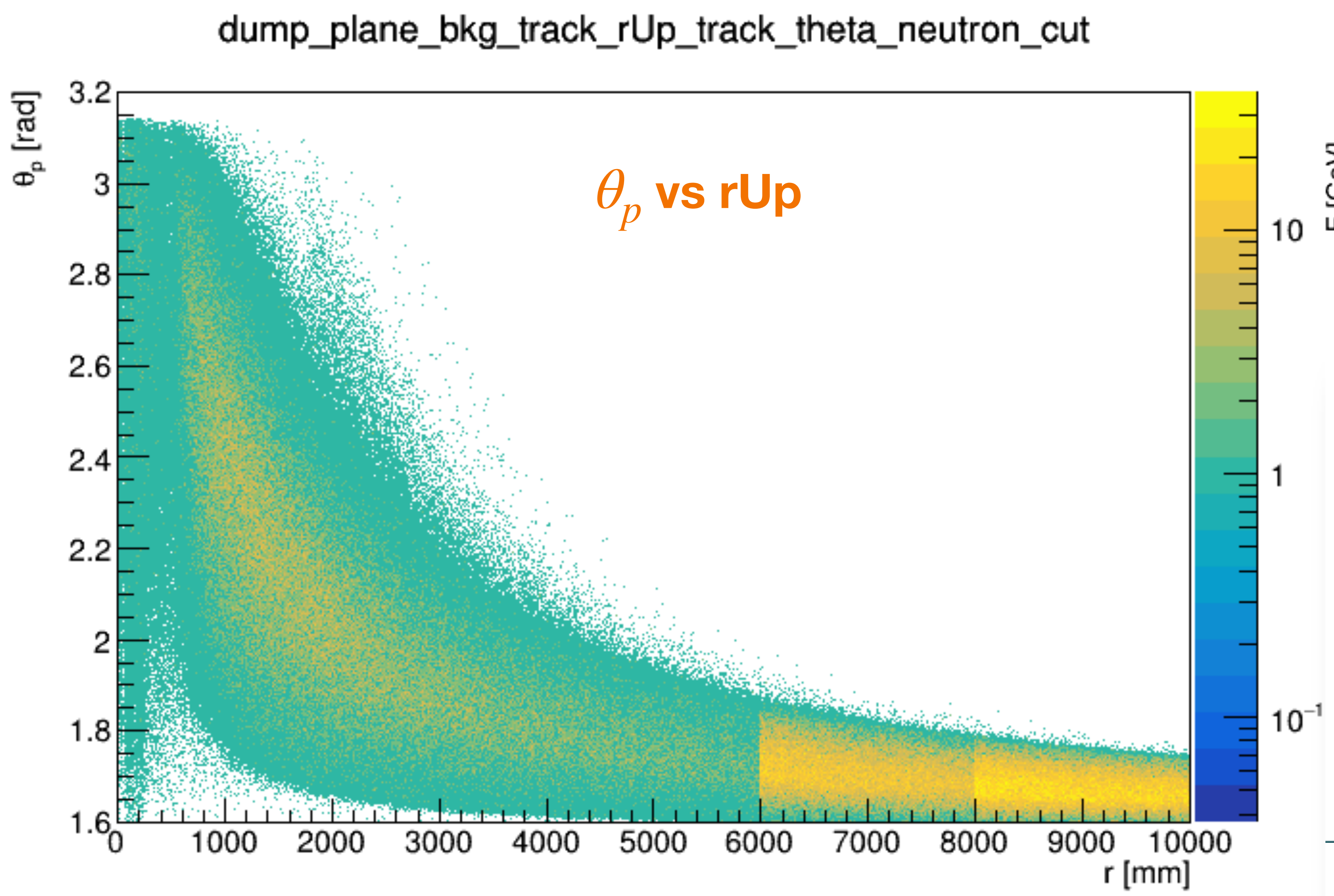
Smooth bins are used for sampling.

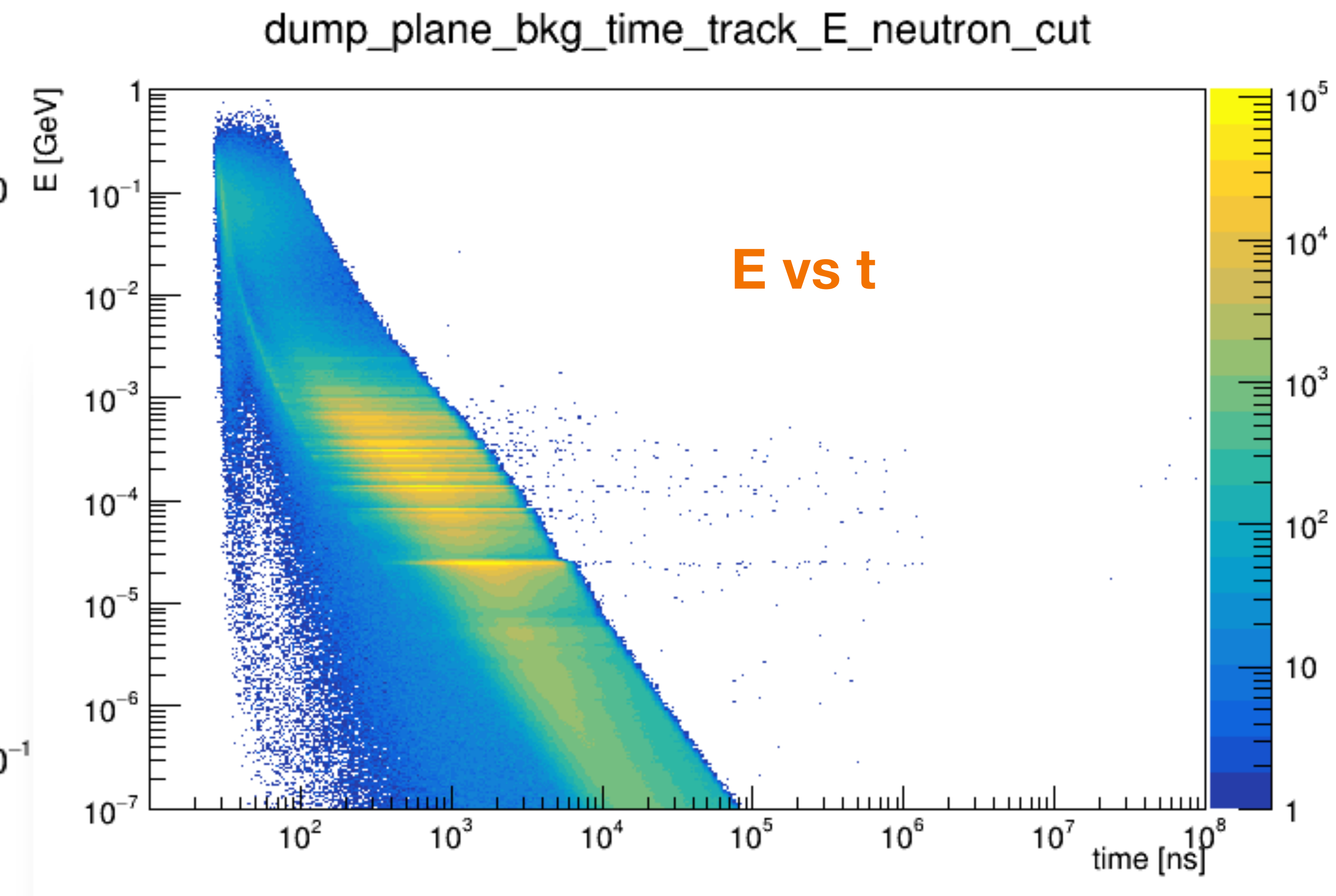
Baseline distribution plots for LUXE geometry at the sampling surface (z=6621.91mm)

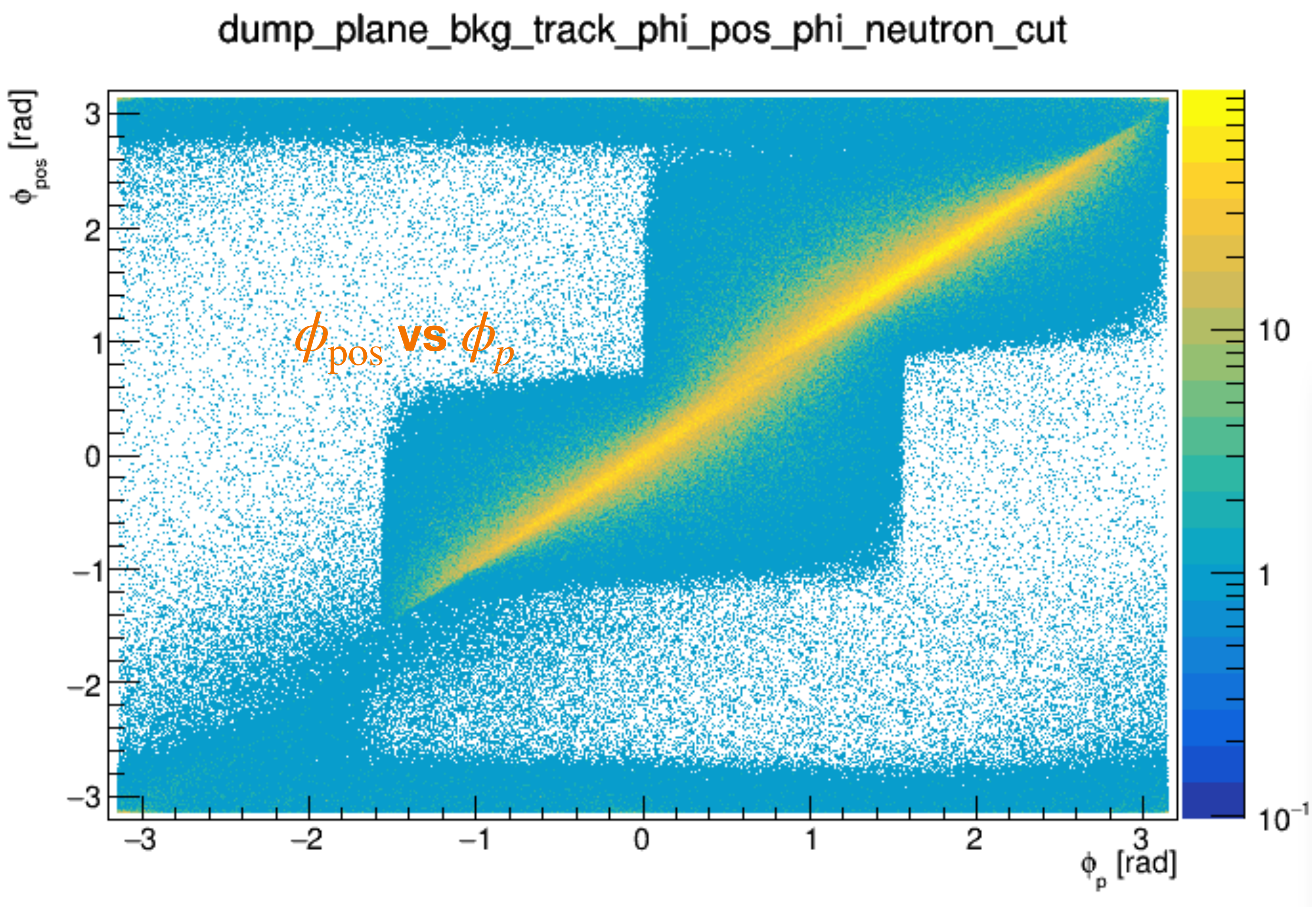
★ Plots used for sampling.

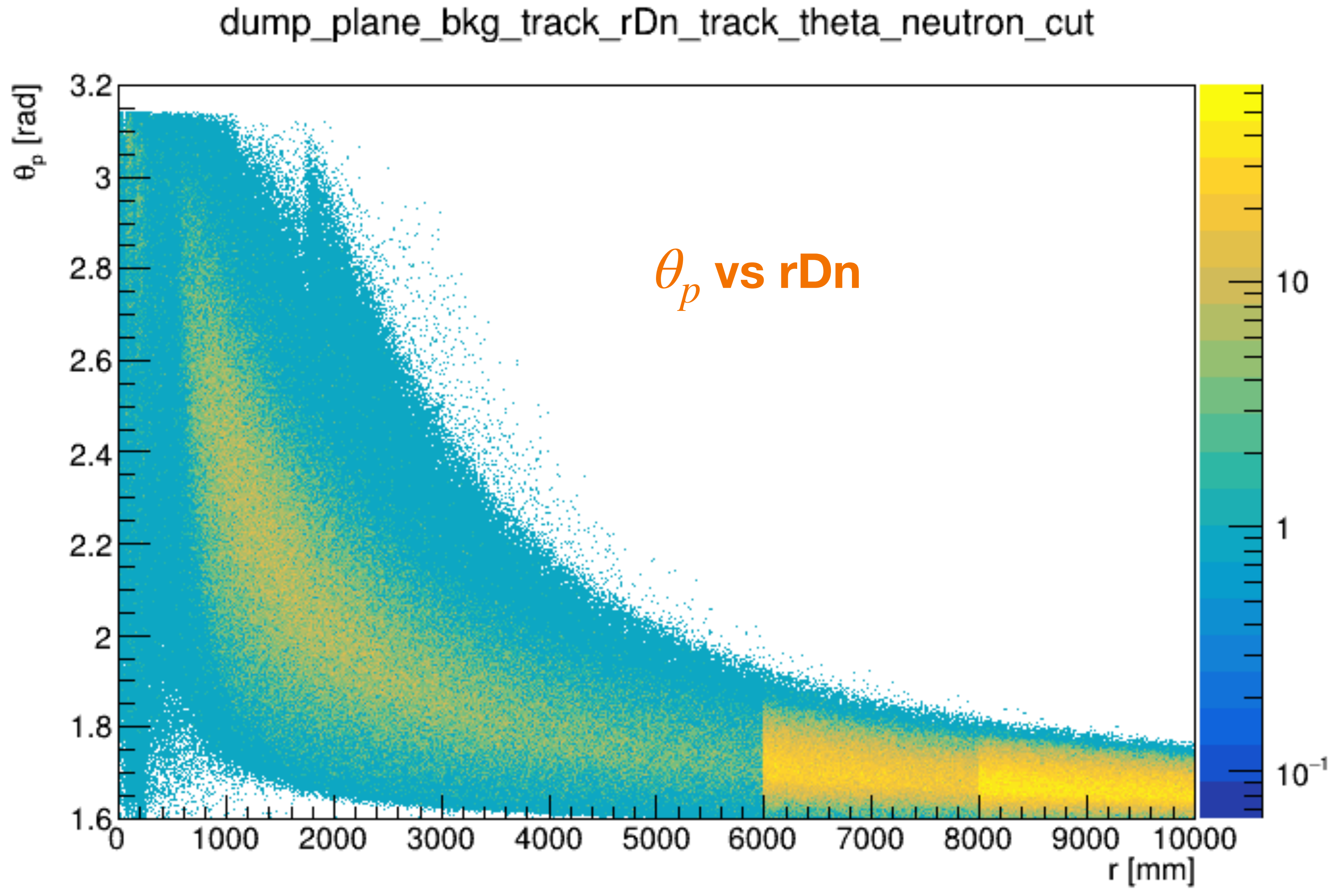
Baseline distributions from FullSim in LUXE: neutron at sampling surface







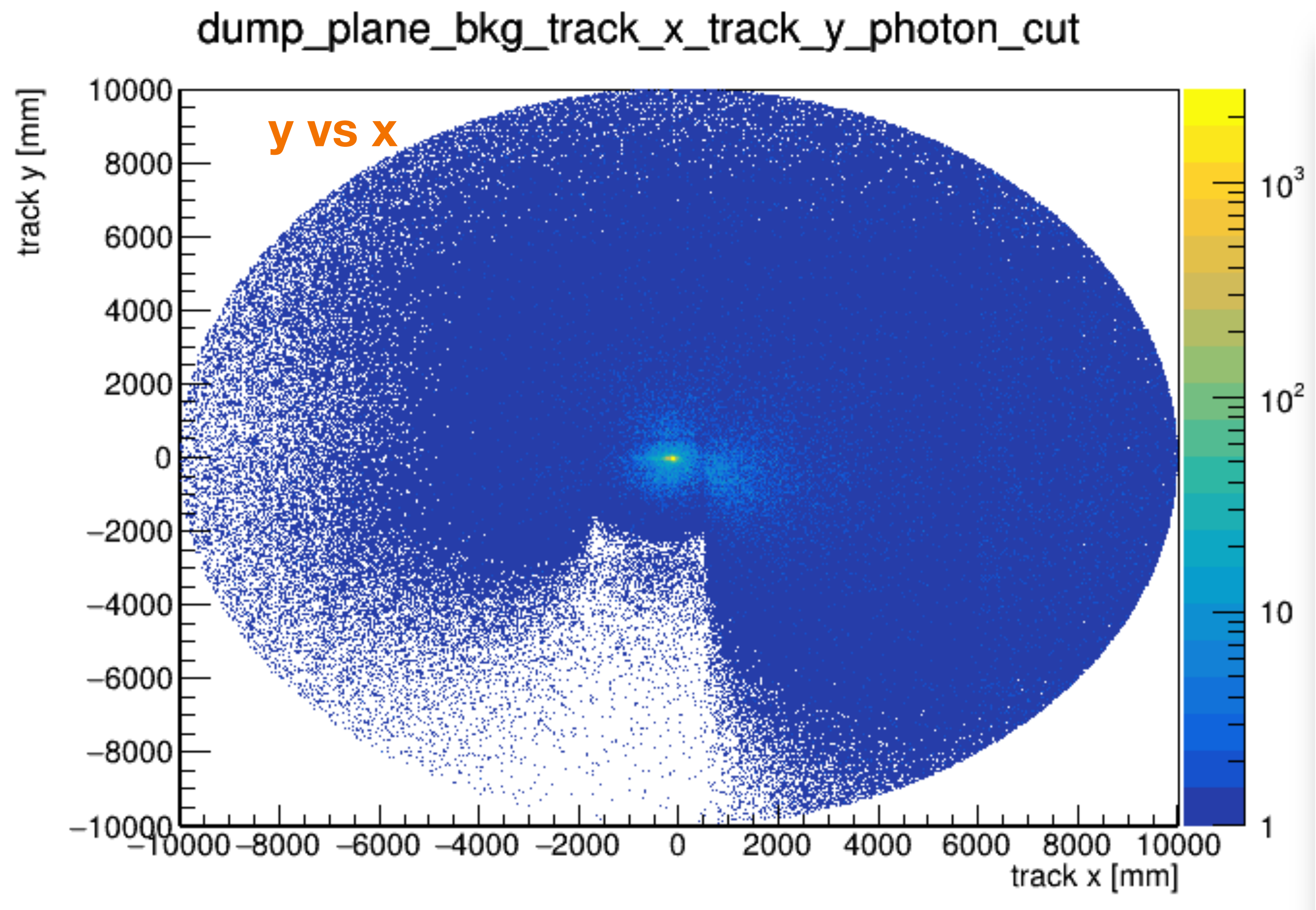


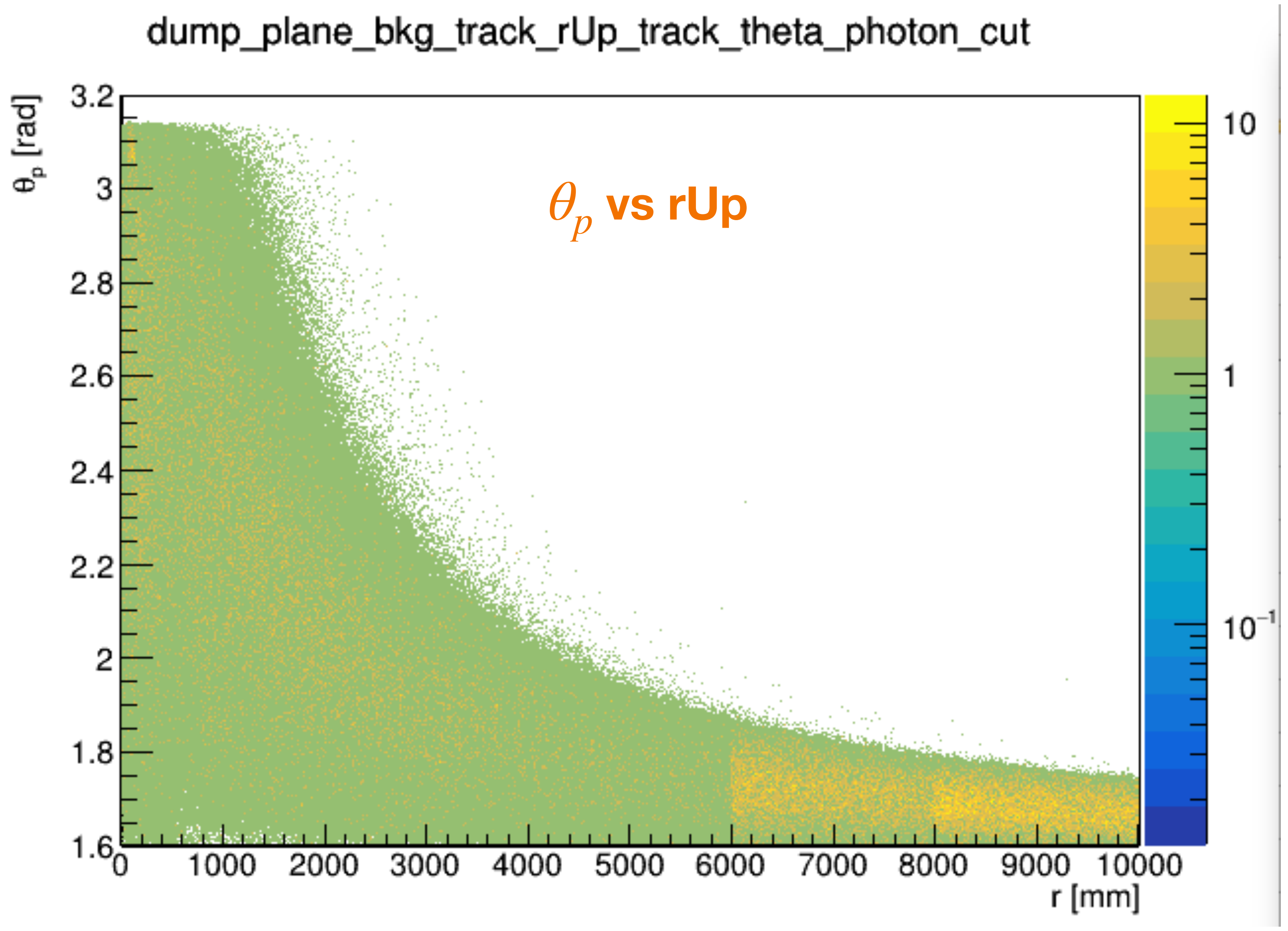


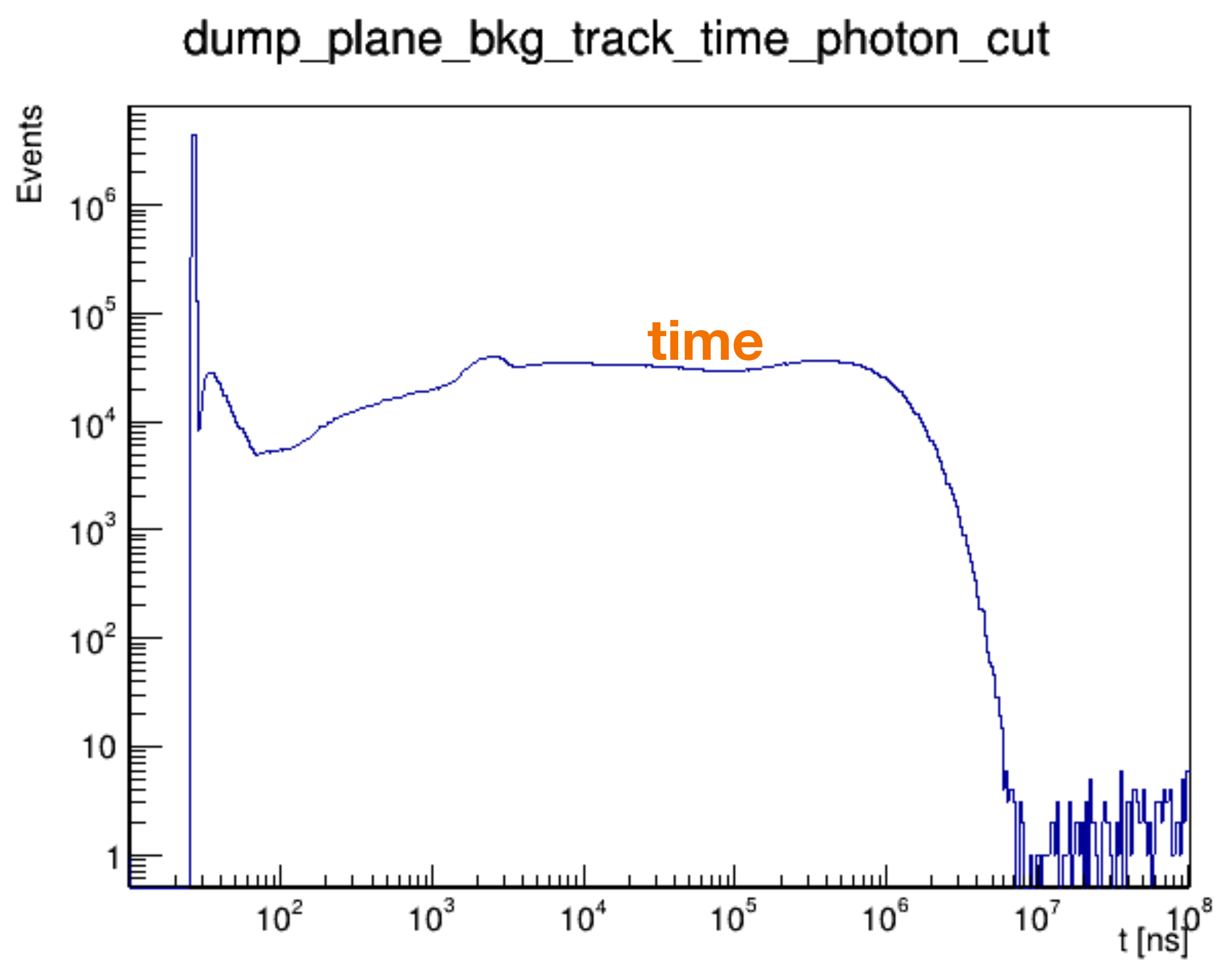
★For E vs t plot of neutron, we only go up to 100 eV of neutron.

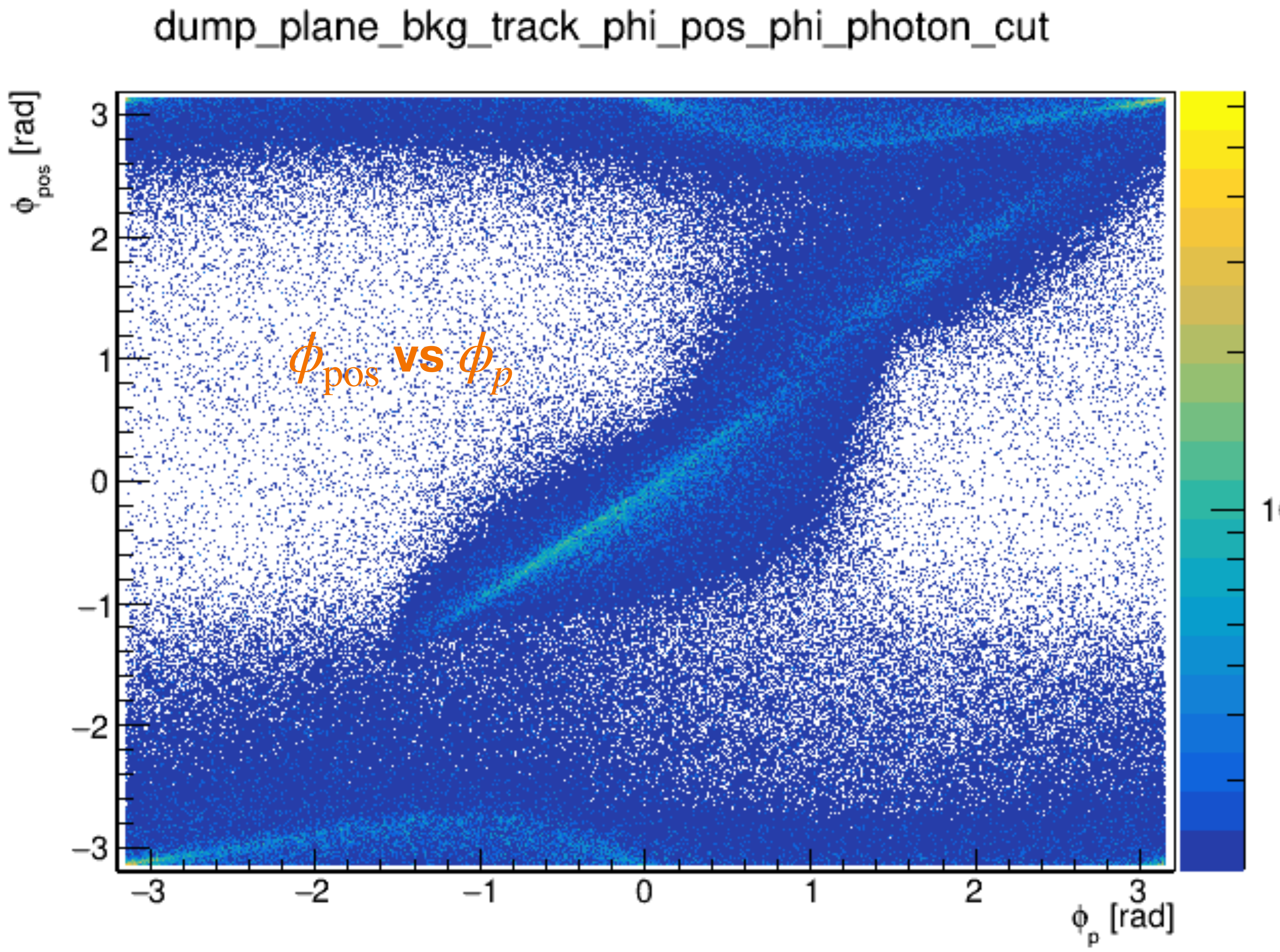
★Neutron less energetic than that are not interesting.

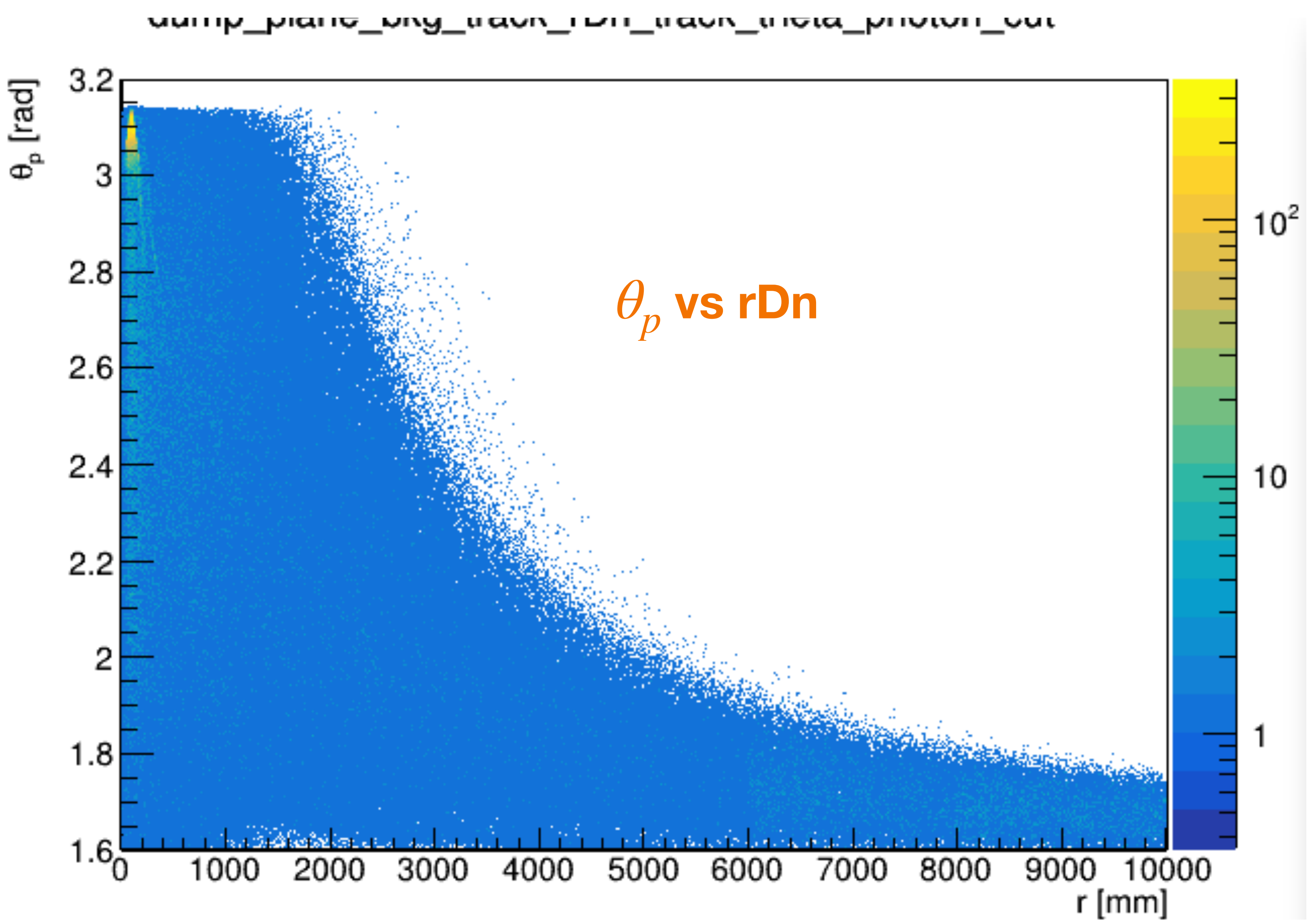
Baseline distributions from FullSim in LUXE: photon at sampling surface

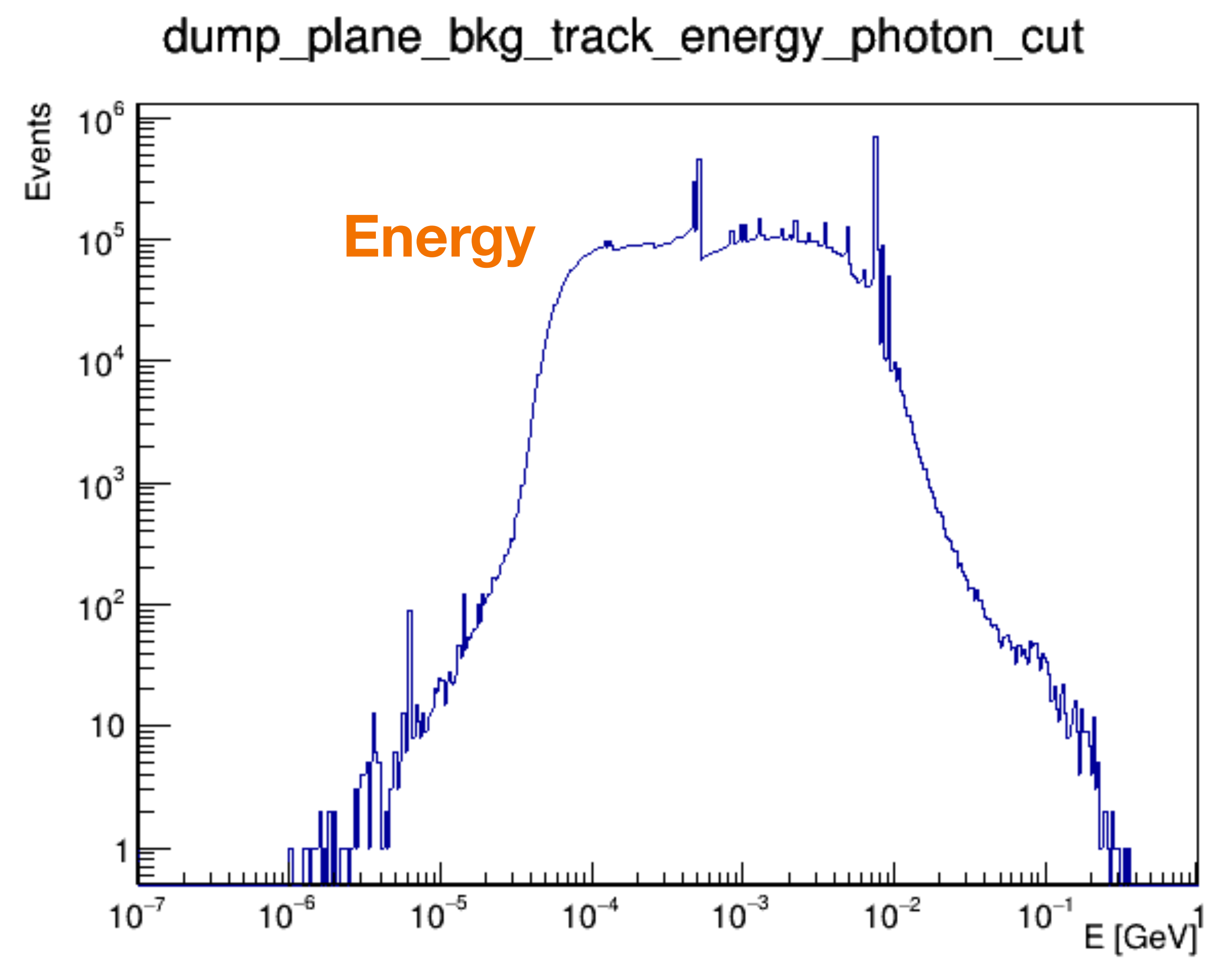




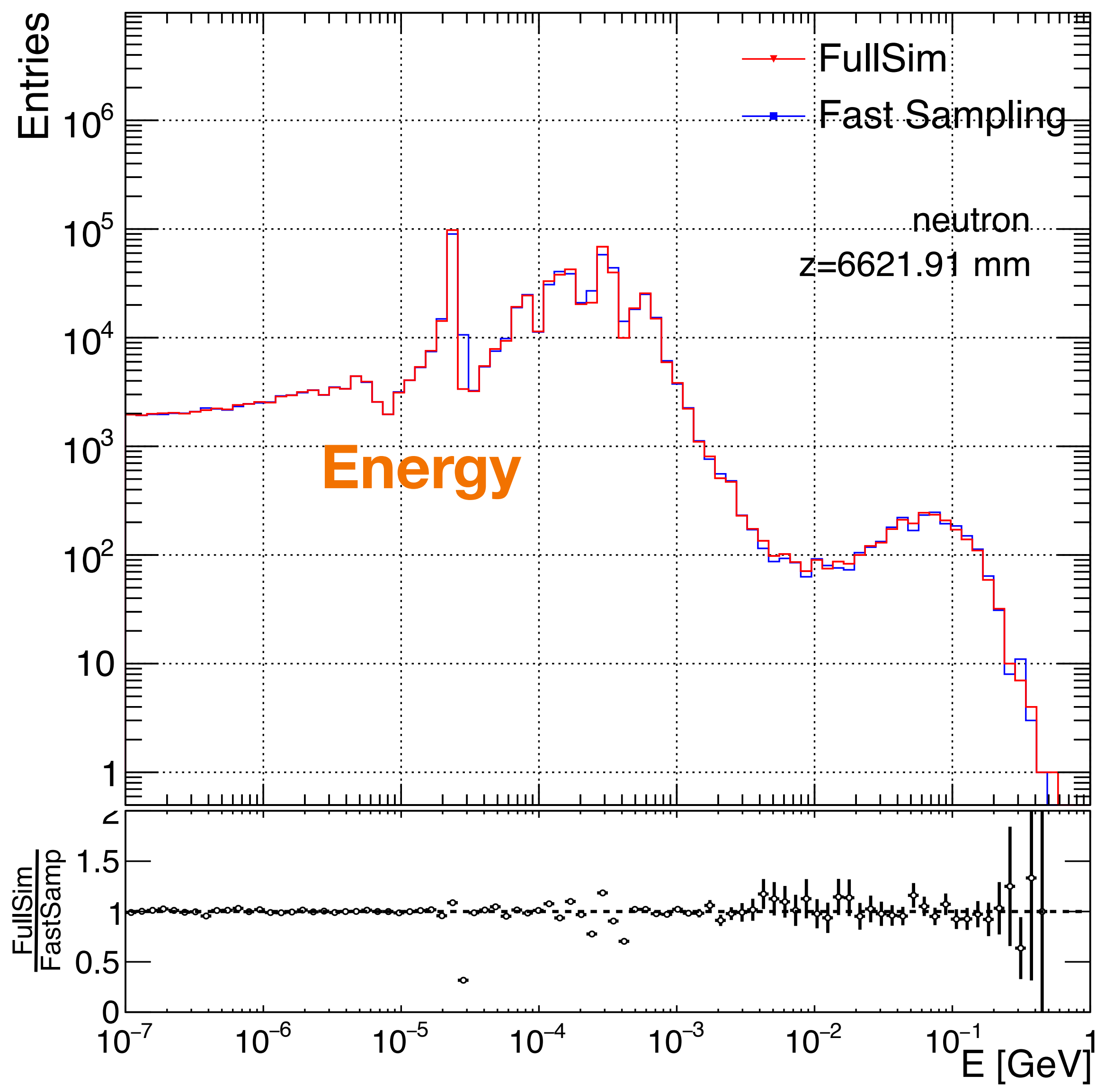


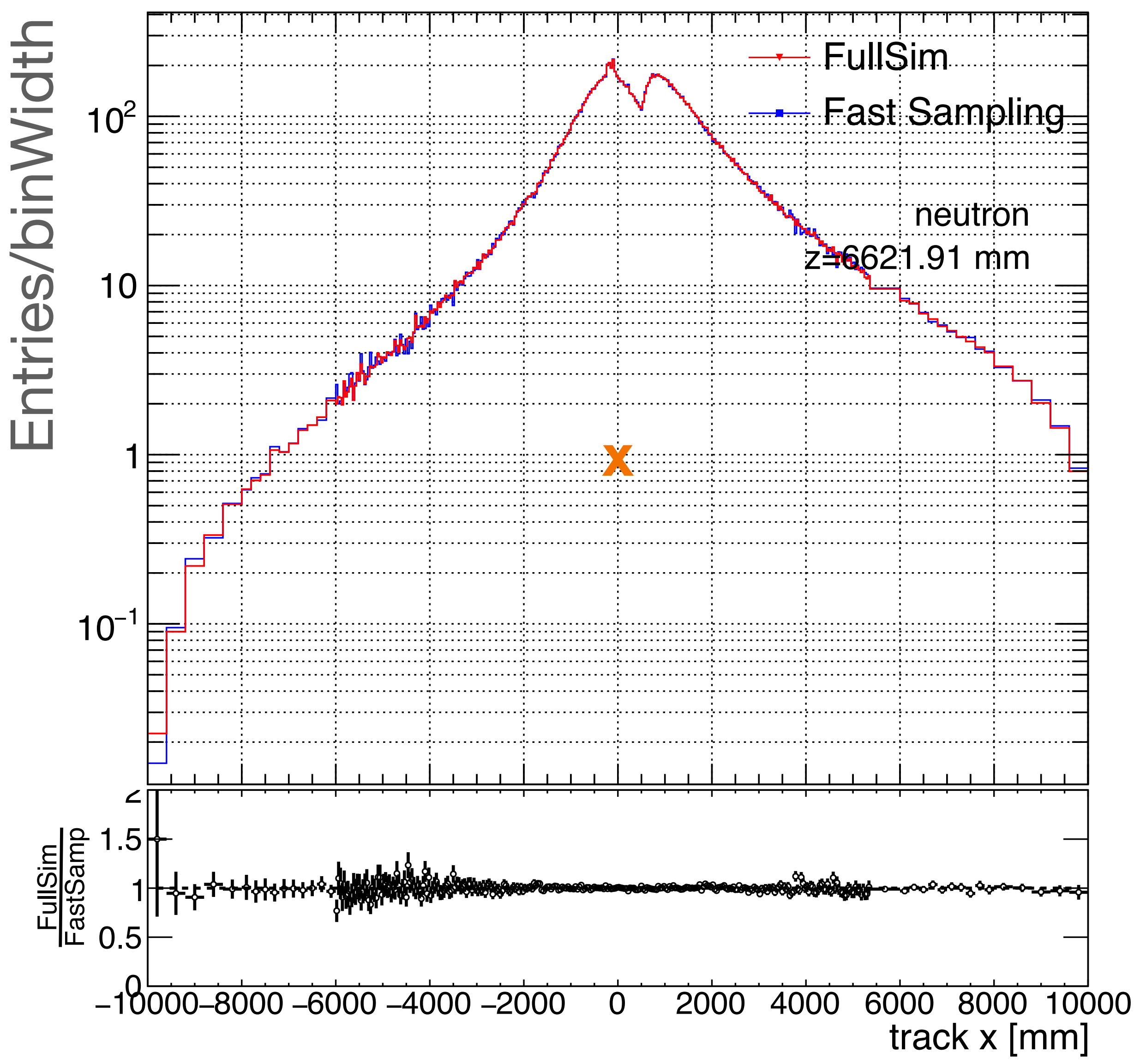


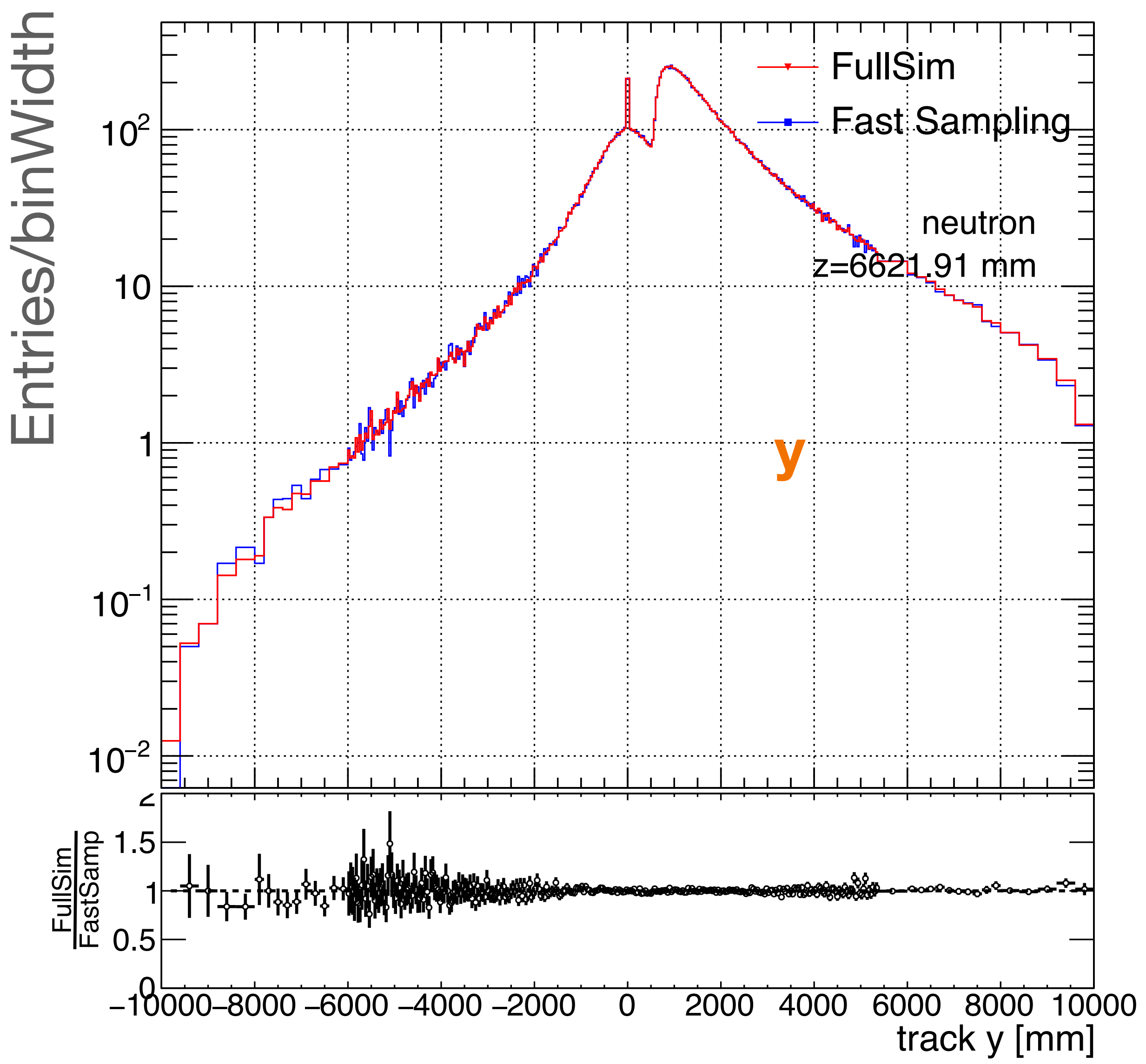


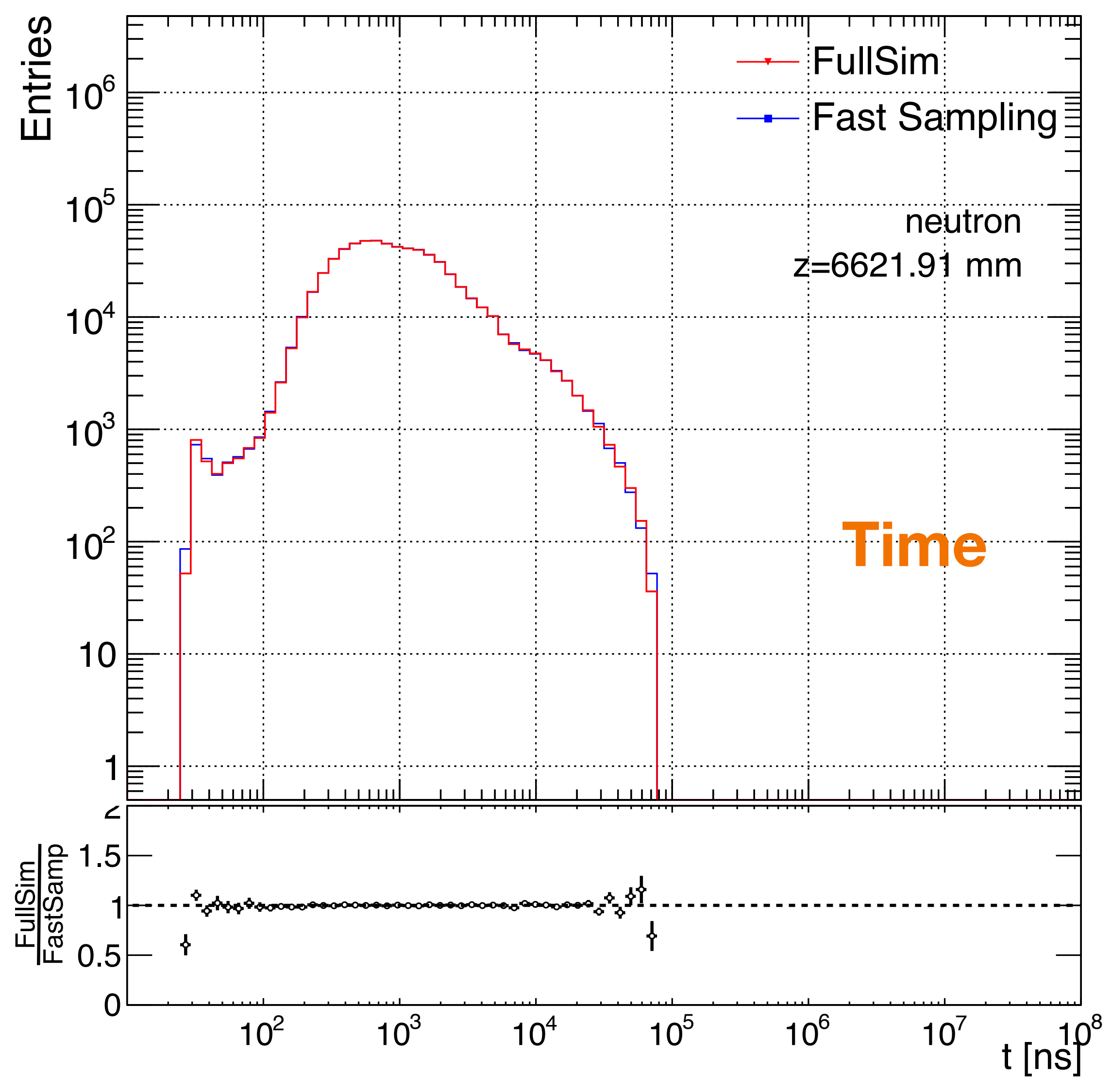


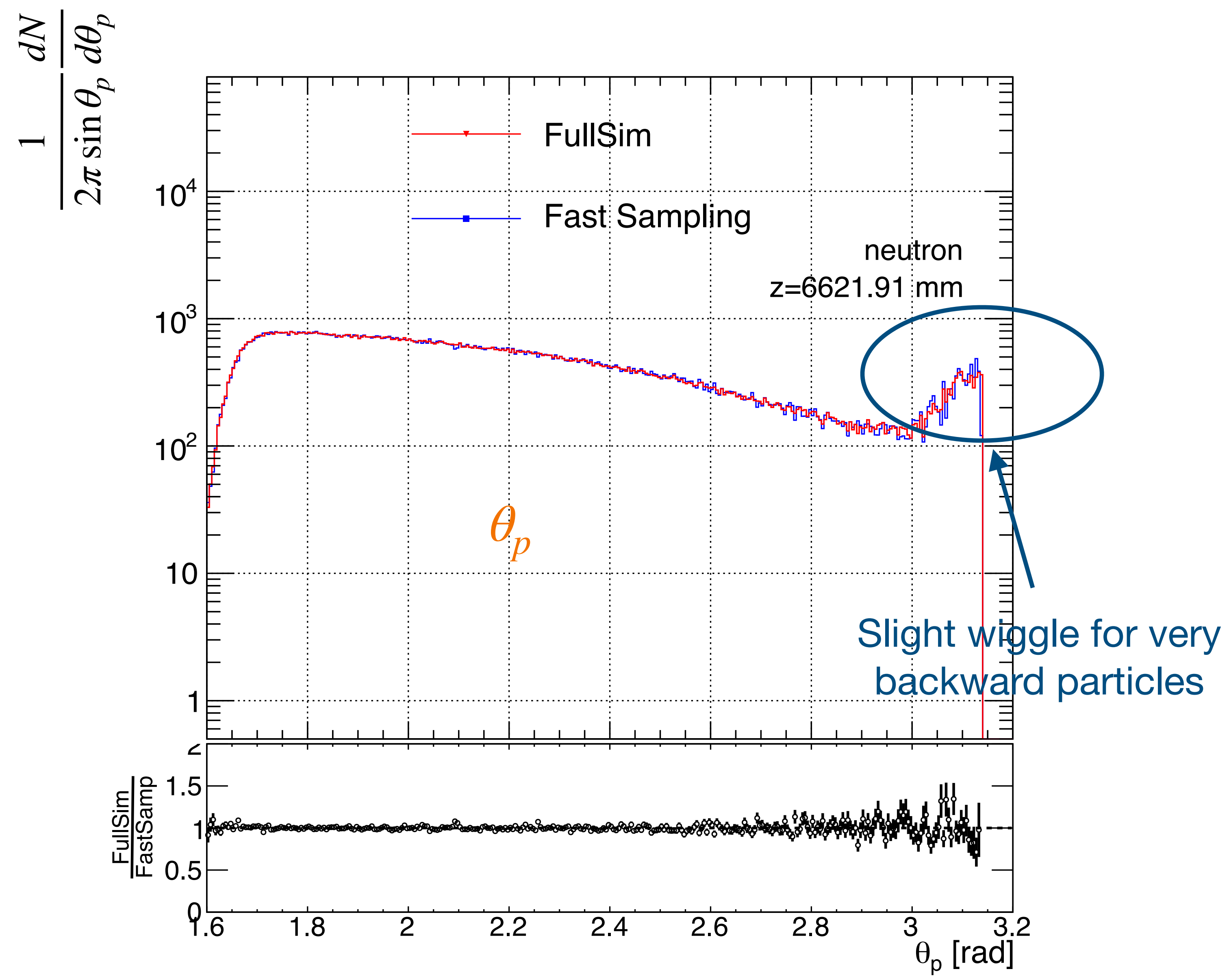
Comparison of FullSim and Fast Sampling distributions at the sampling surface for the LUXE geometry: neutron

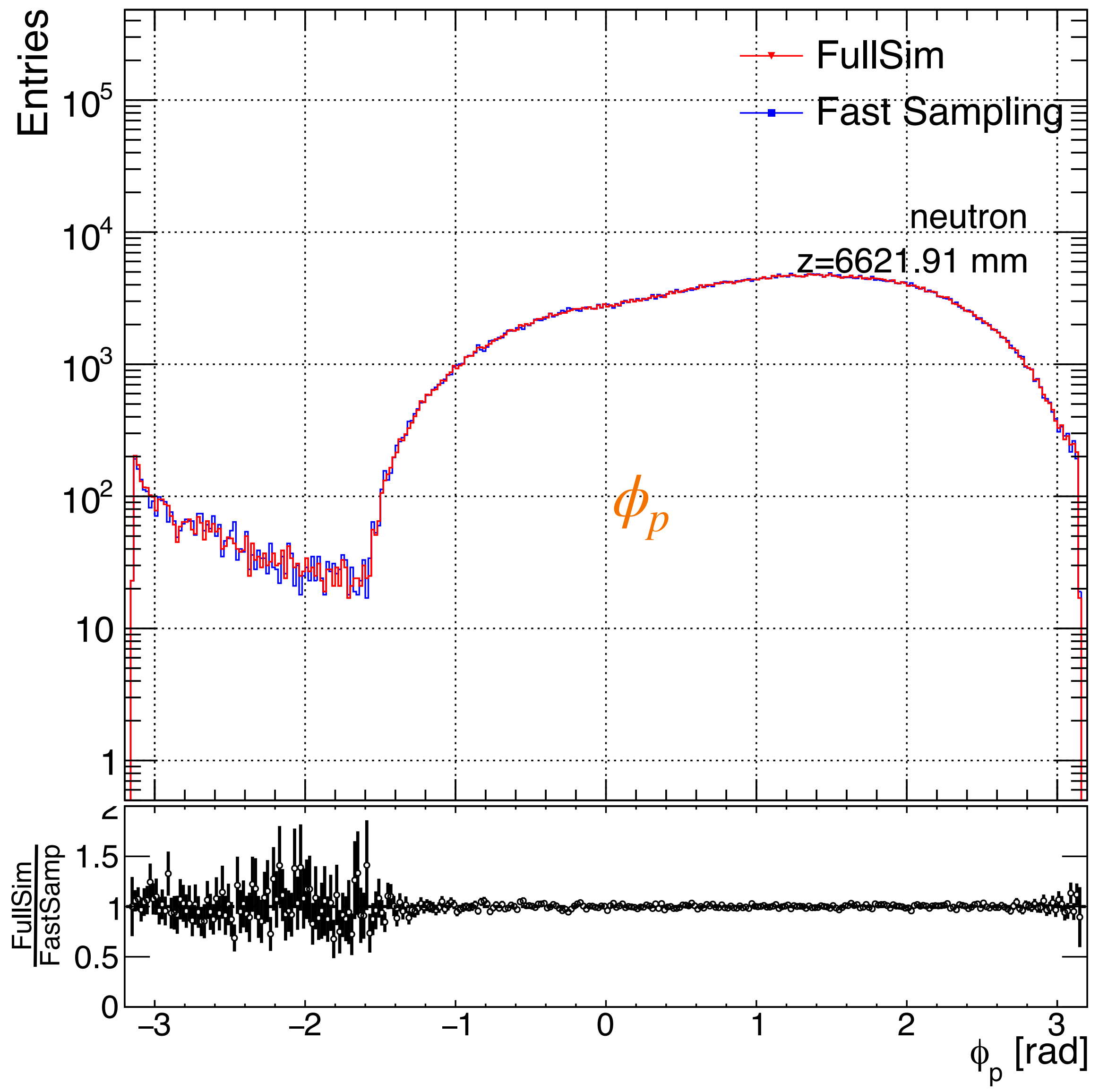






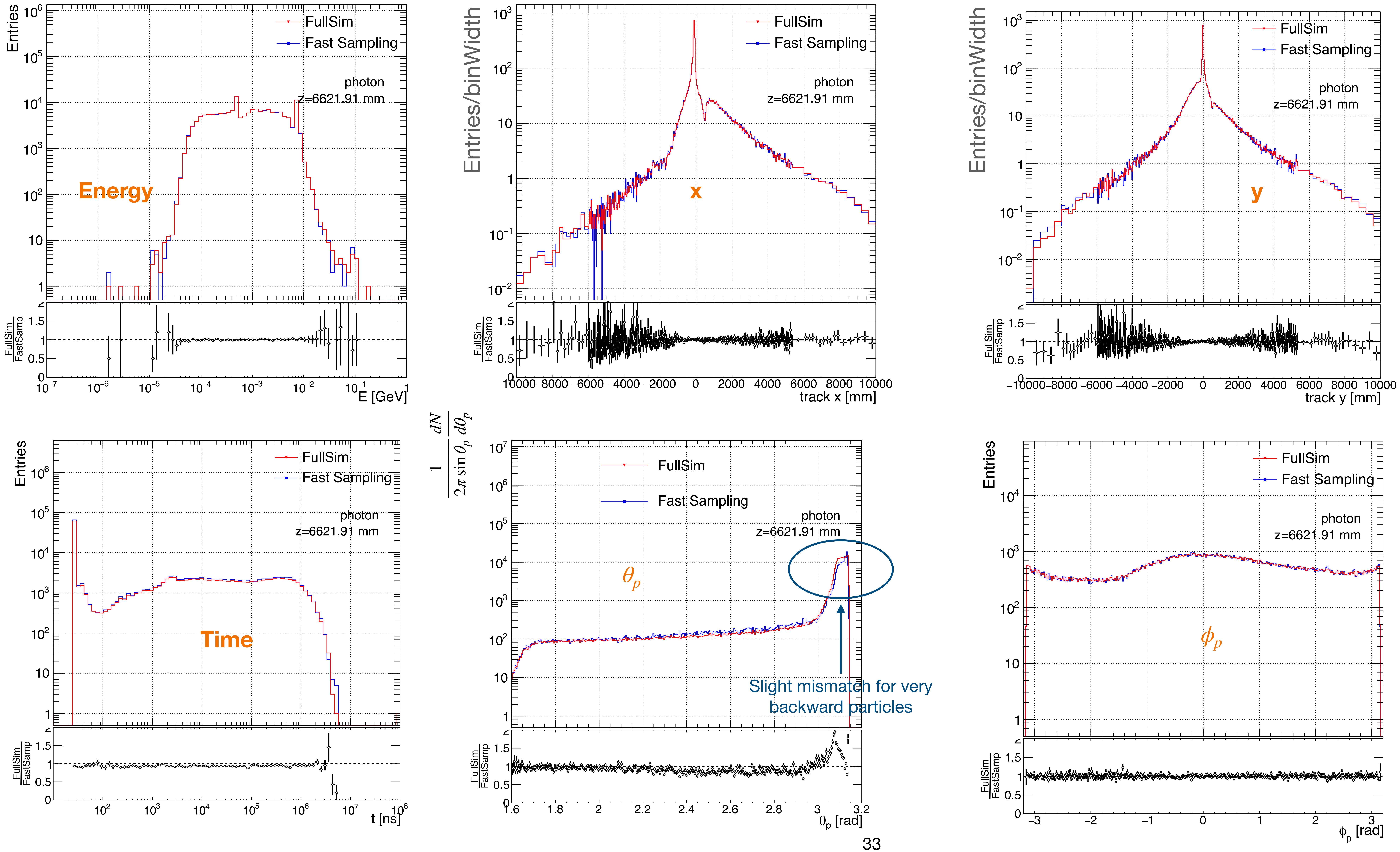






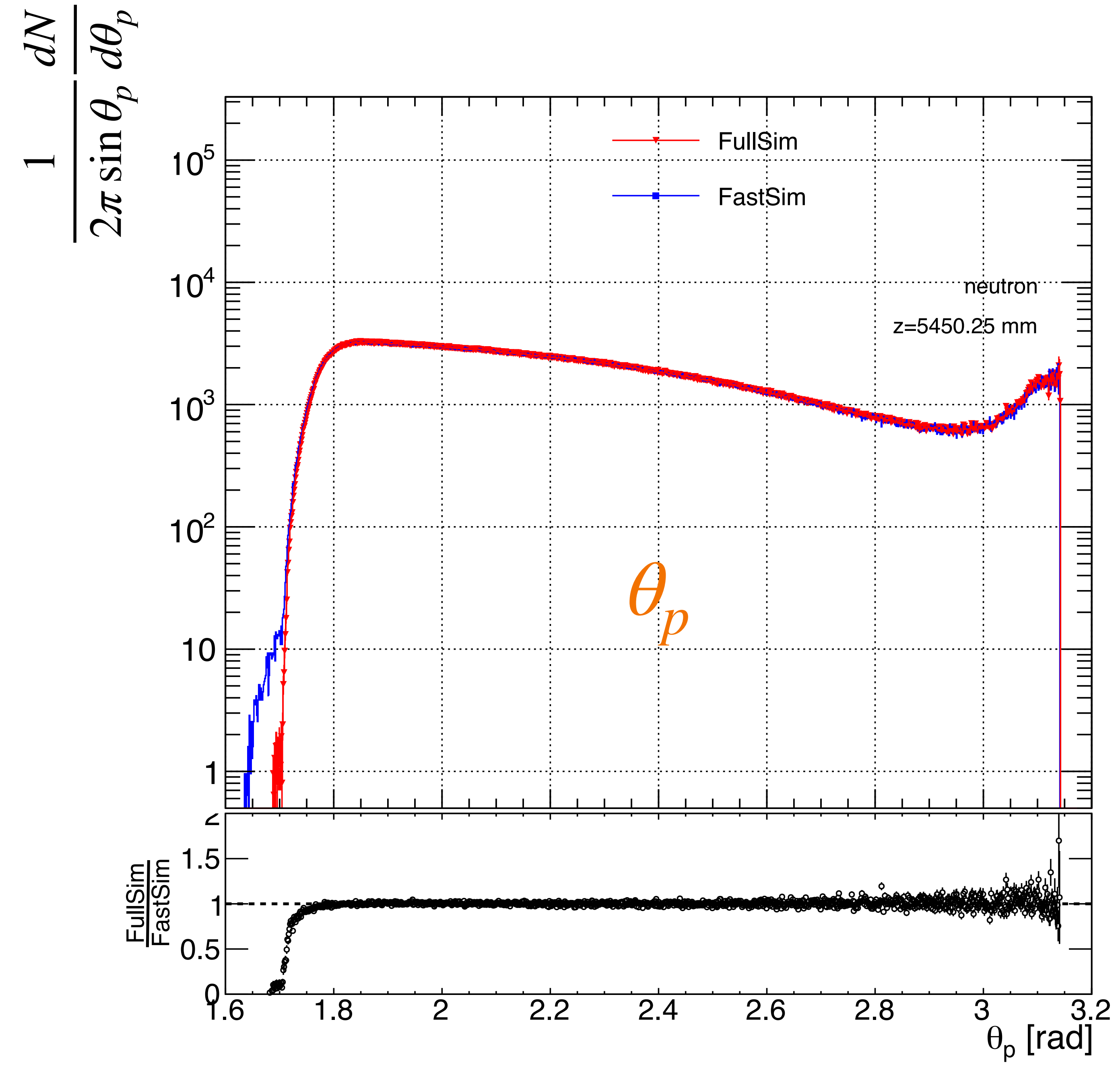
- ★Comparison of distribution at sampling surface for neutrons
  - ★Agreement is very good within the statistics except momentum direction at very backward direction.
    - ★Need to see its effect in the test surfaces.
  - ★The good modeling between FullSim and Fast Sampling is **a sanity check.**

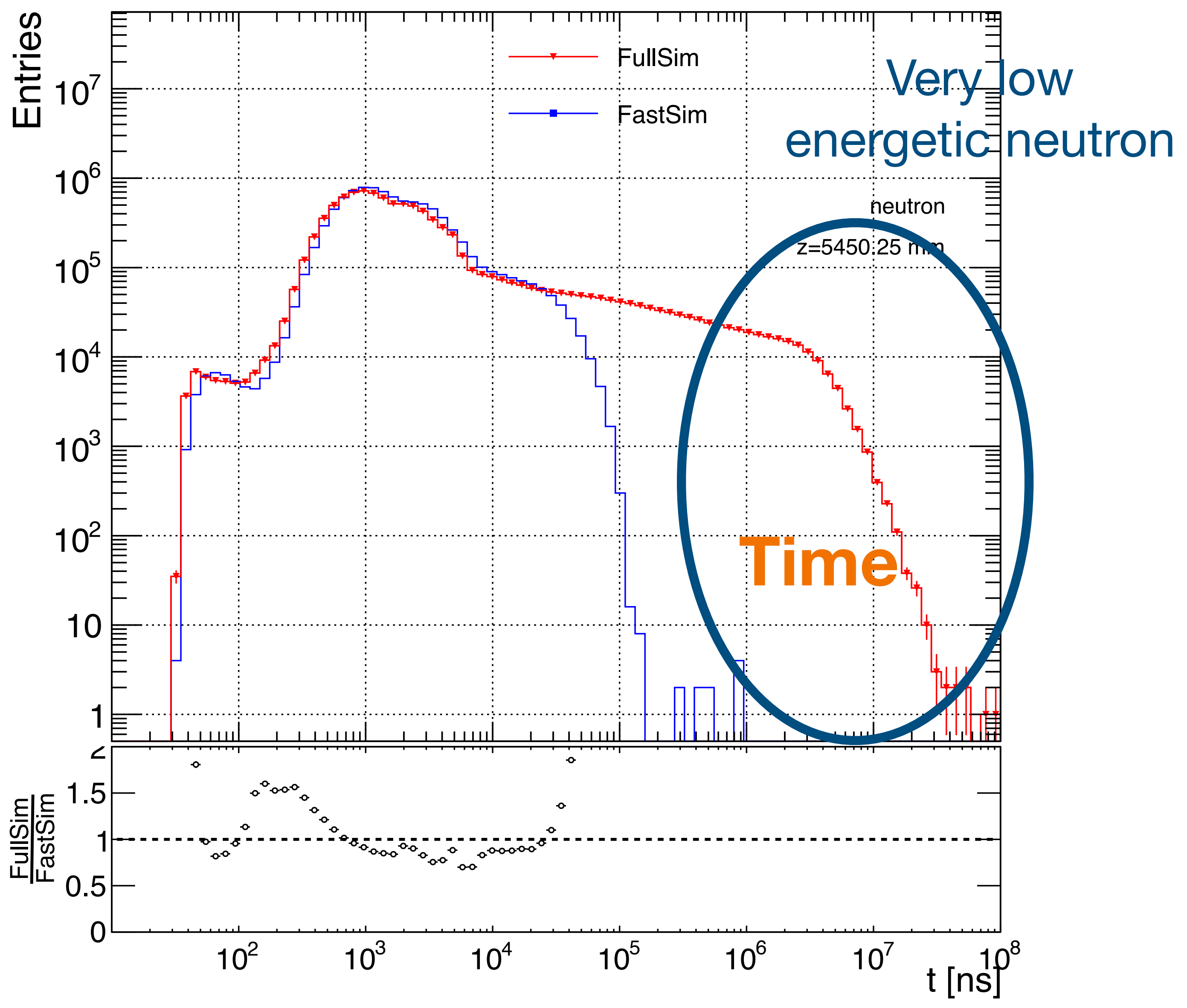
Comparison of FullSim and Fast Sampling distributions at the sampling surface for the LUXE geometry: photon

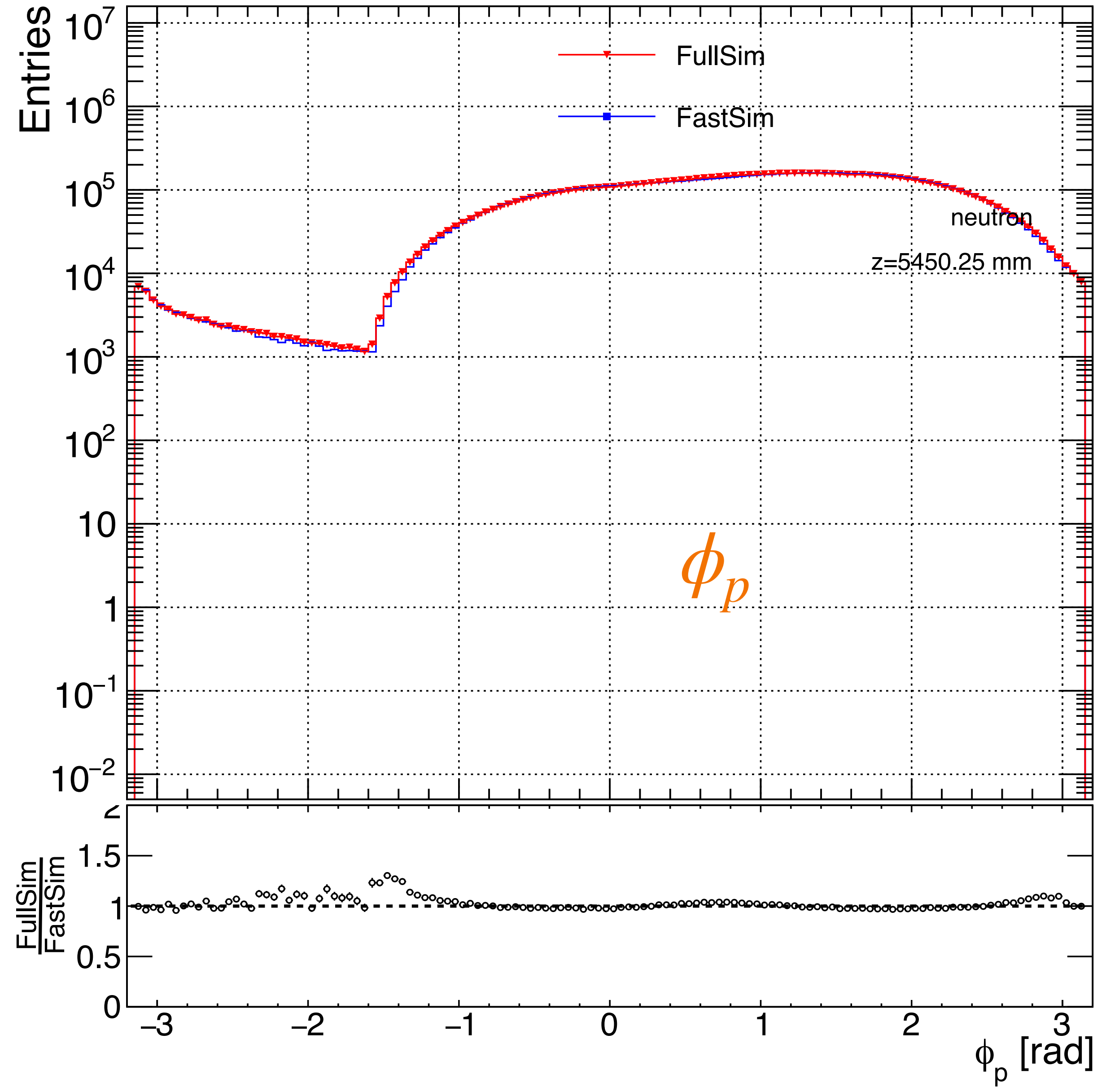


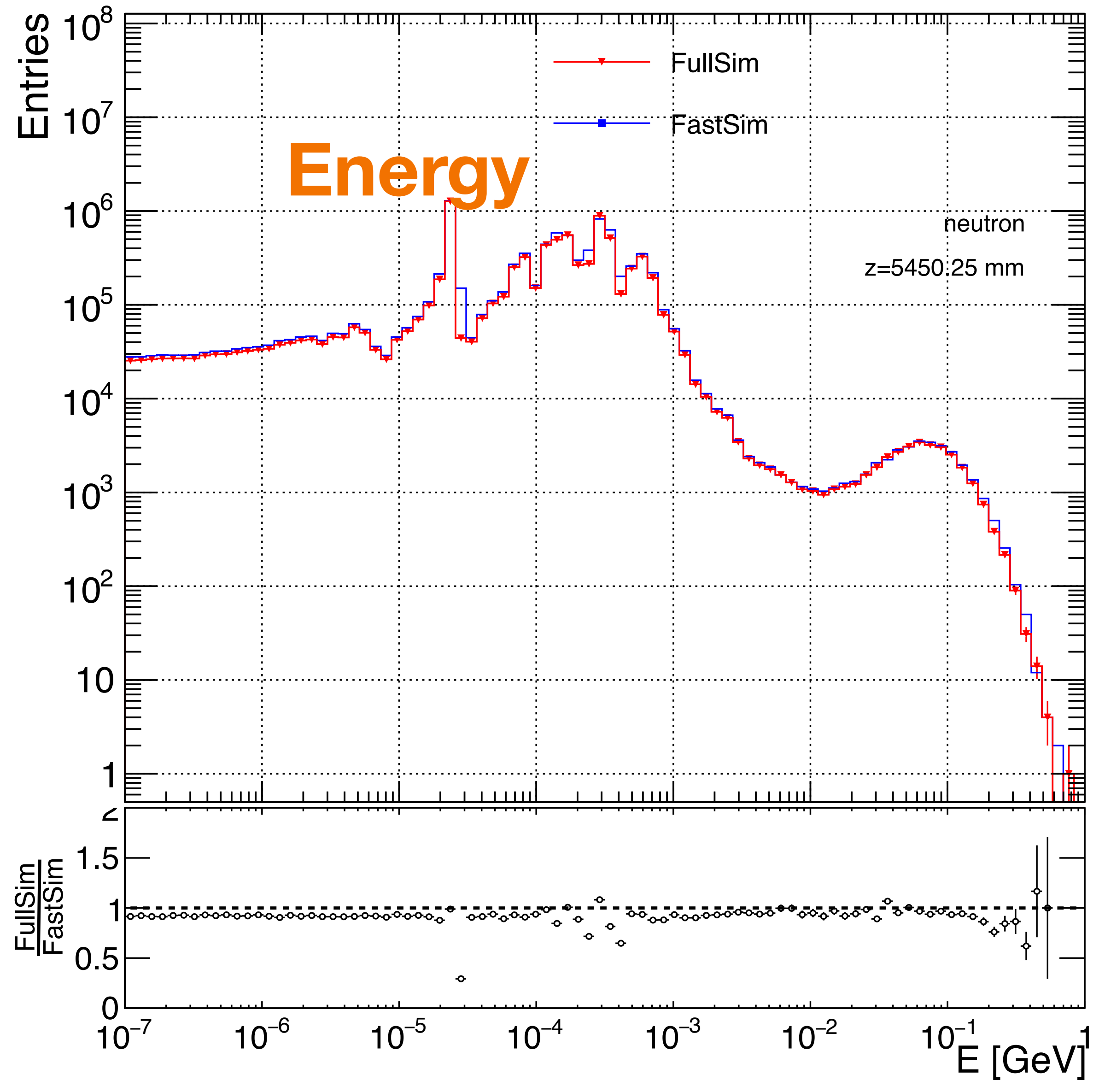
- ★Comparison of distribution at sampling surface for photons
  - ★Agreement is very good within the statistics except momentum direction at very backward direction.
    - ★Need to see its effect in the test surfaces.
  - ★The good modeling between FullSim and Fast Sampling is **a sanity check.**

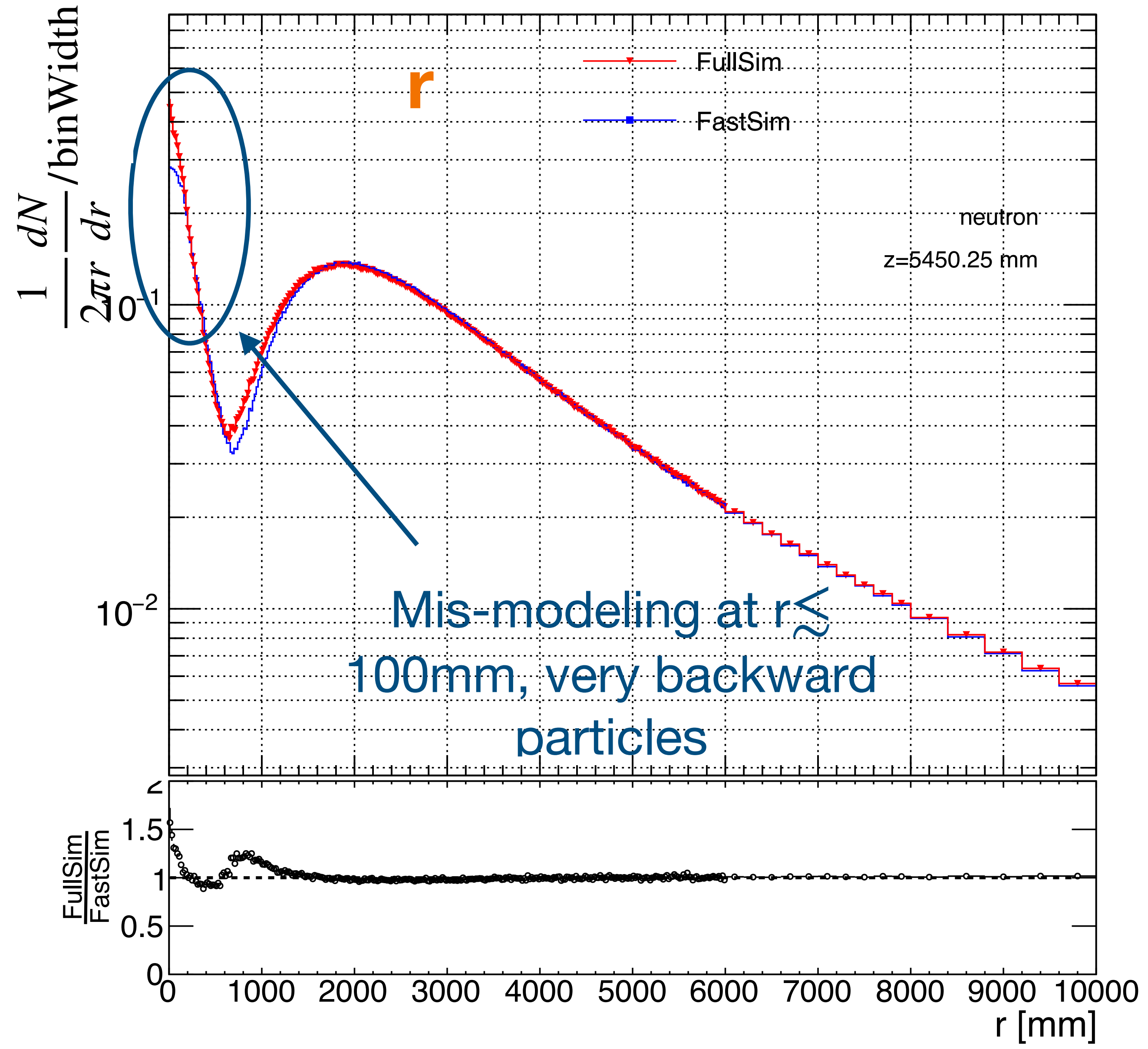
A few 1D distributions between FastSim and FullSim: neutron at the test surface 1





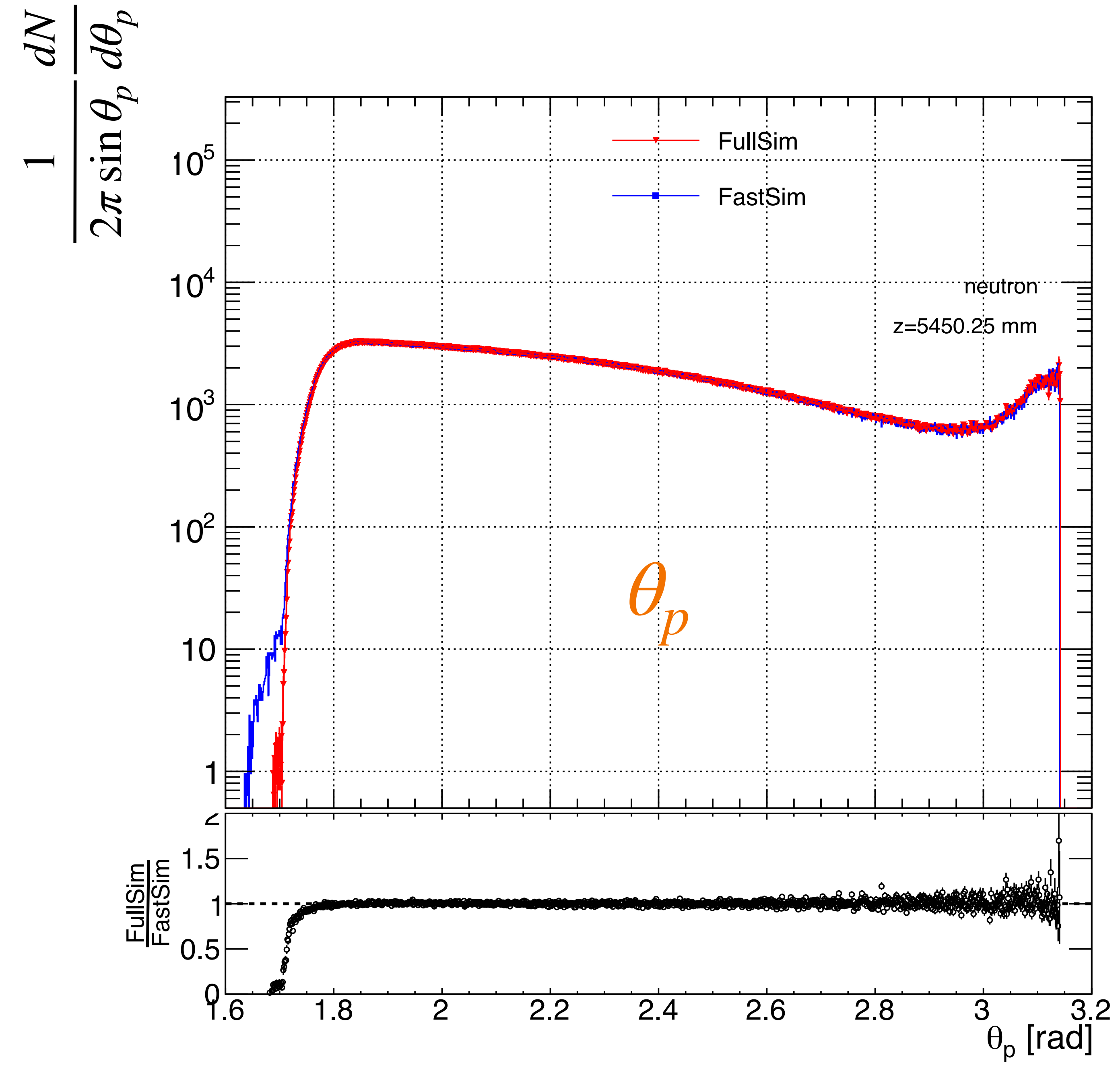


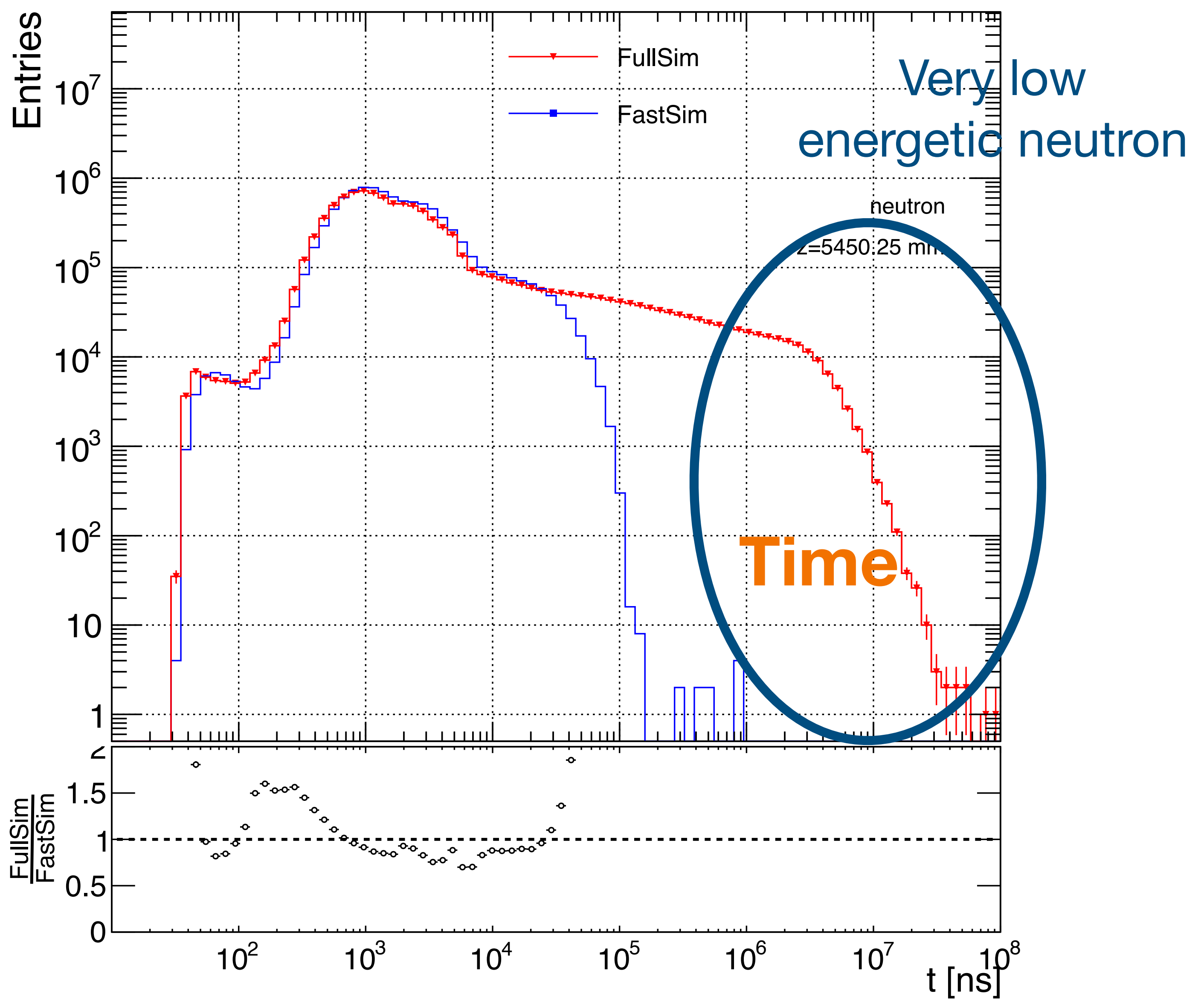


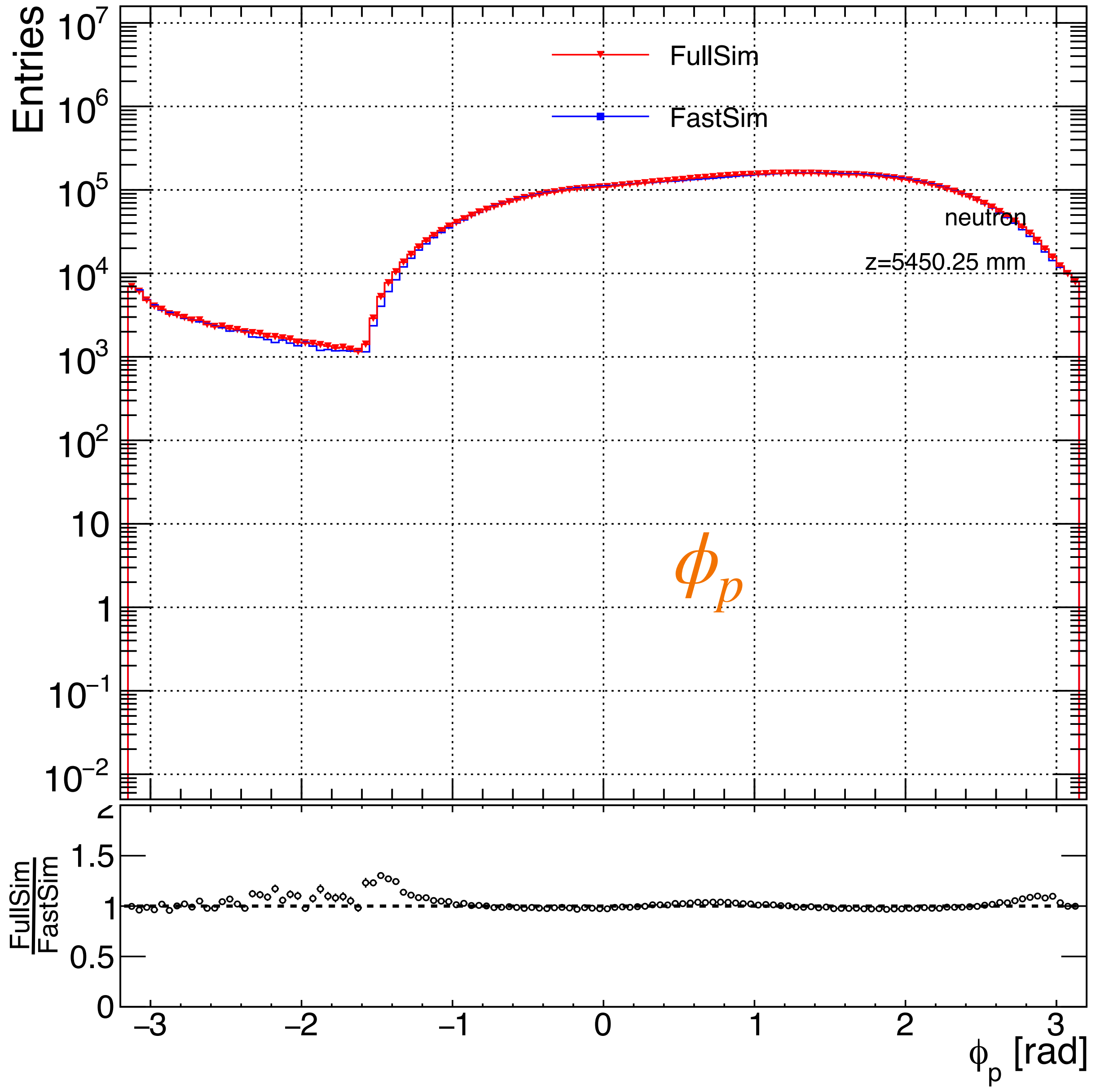


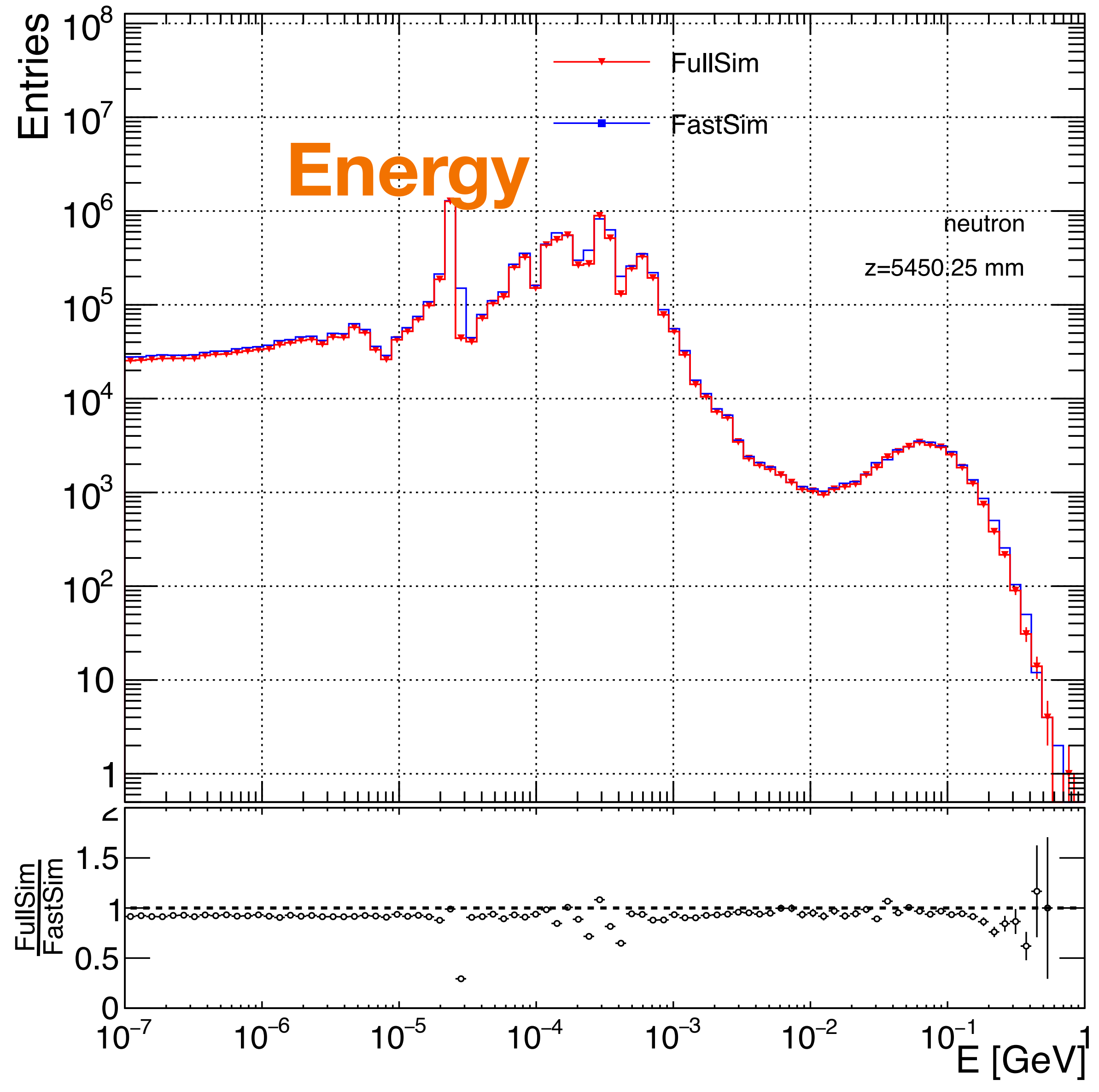
- ★Distributions are looked at **z=5450.25mm**.
- ★FullSim and FastSim has comparable statistics.
- ★FullSim and FastSim distributions are matching quite well.
    - ★Mis-modeling in very backward particles ($r \lesssim 100$ mm at z=5450.25mm).

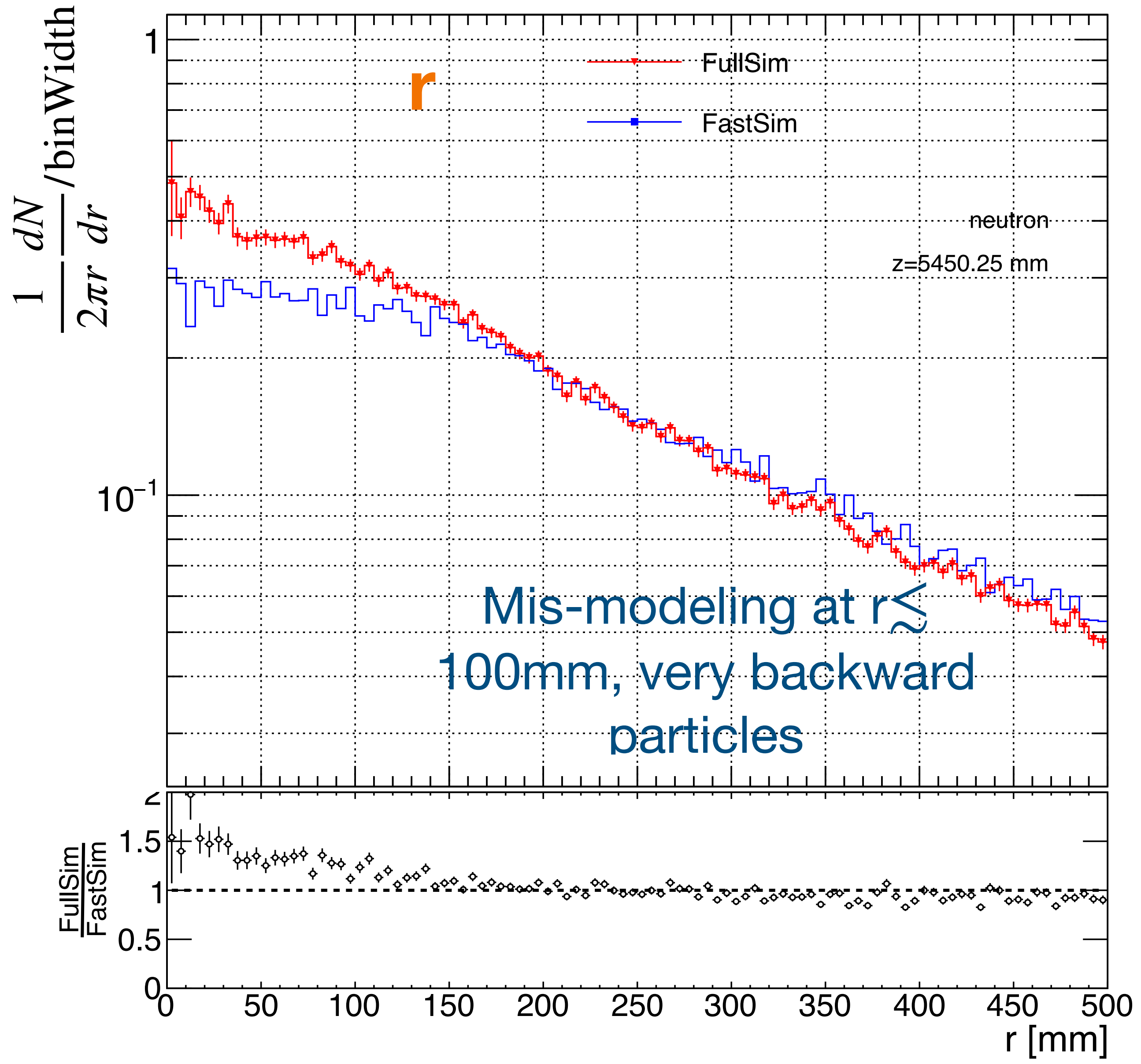
A few 1D distributions between FastSim and FullSim: neutron at the test surface 1











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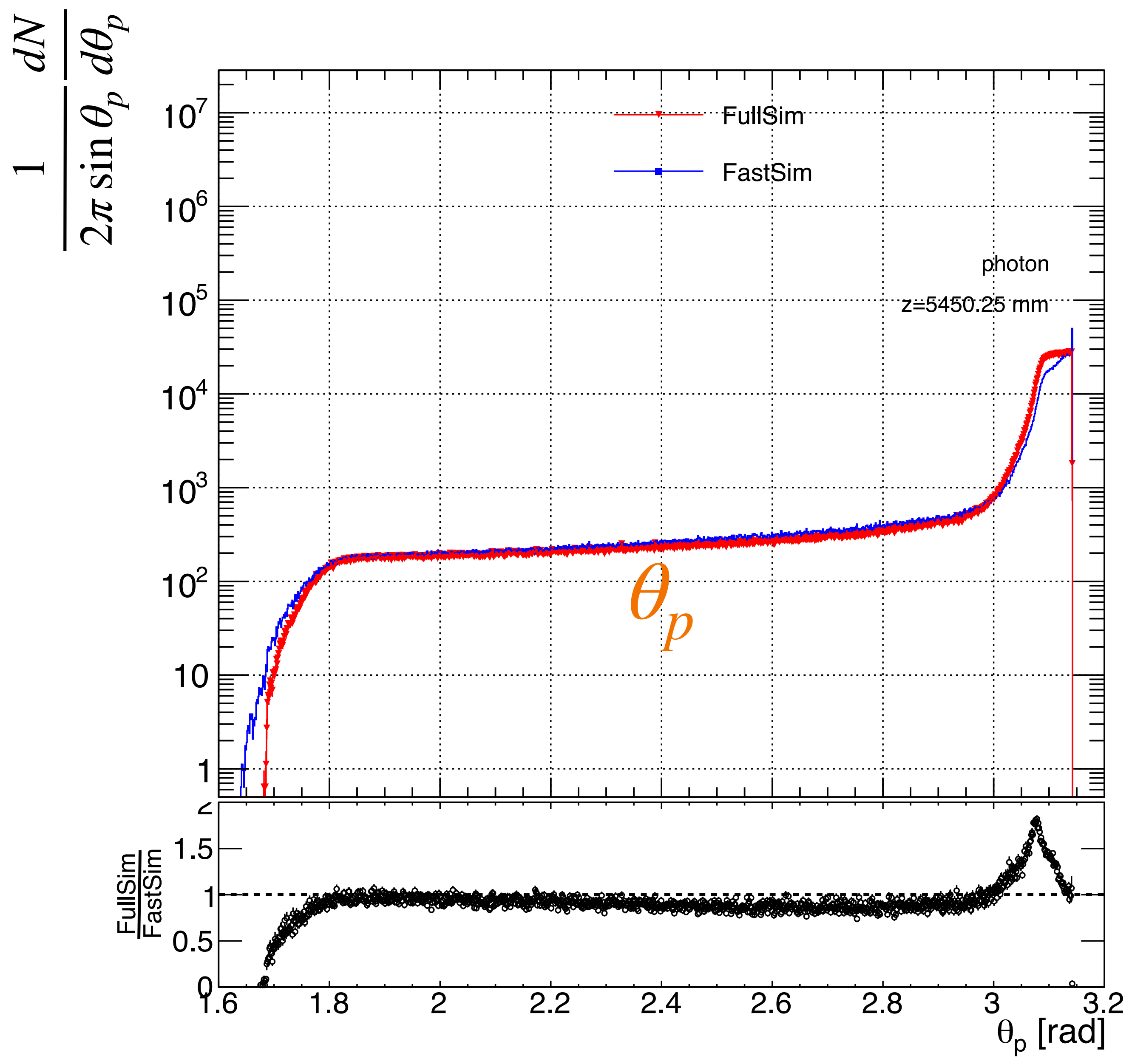
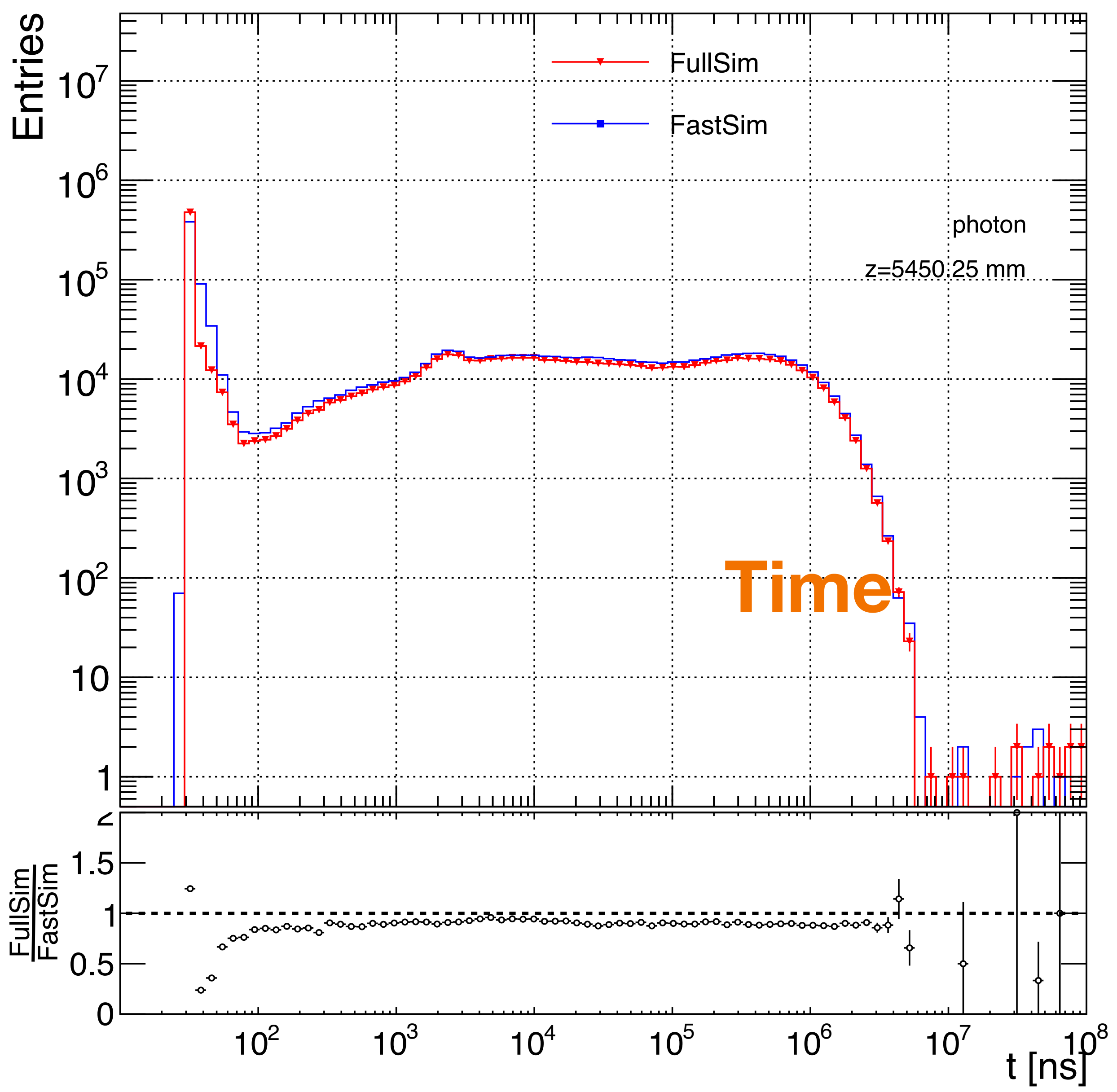
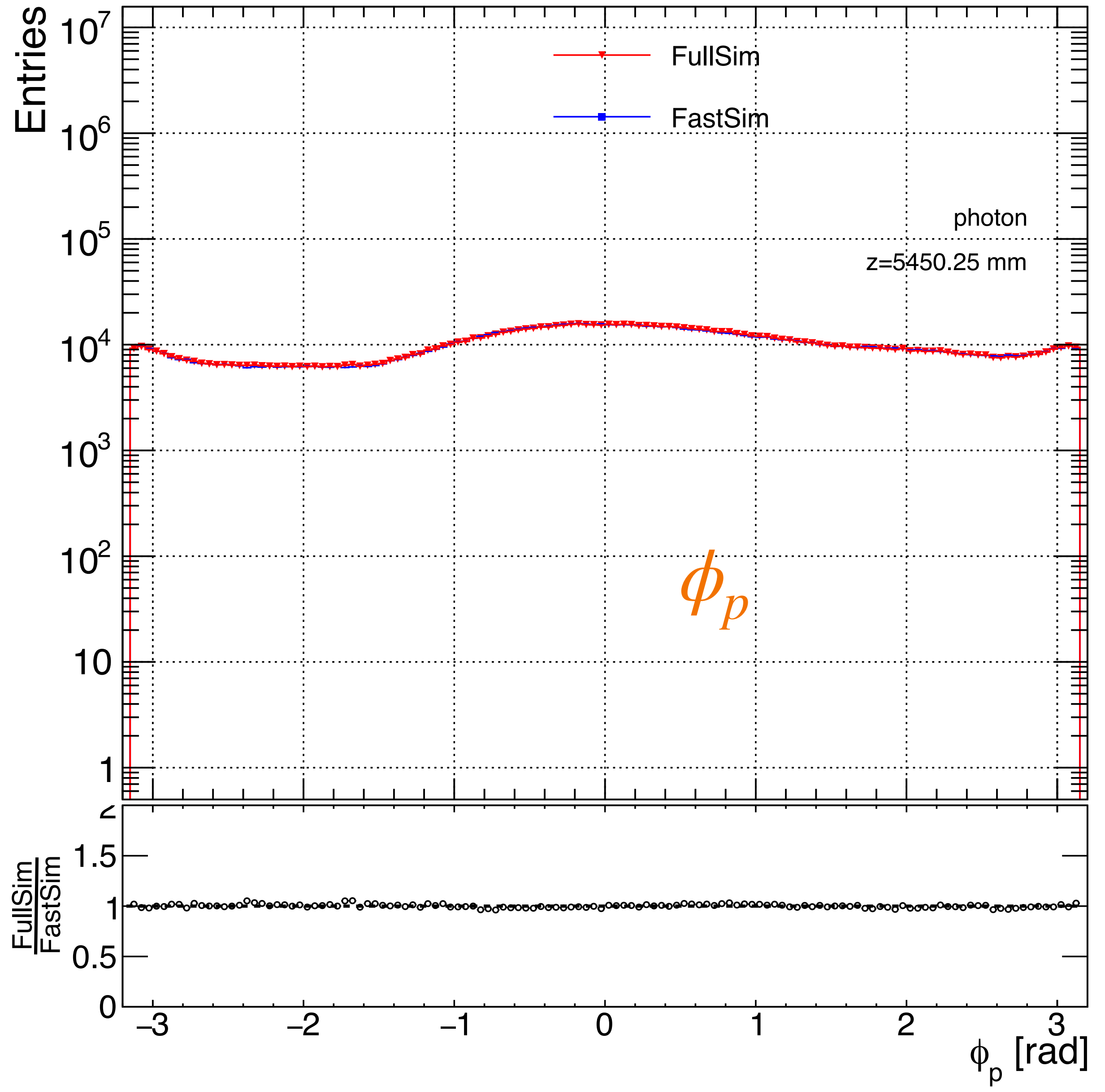
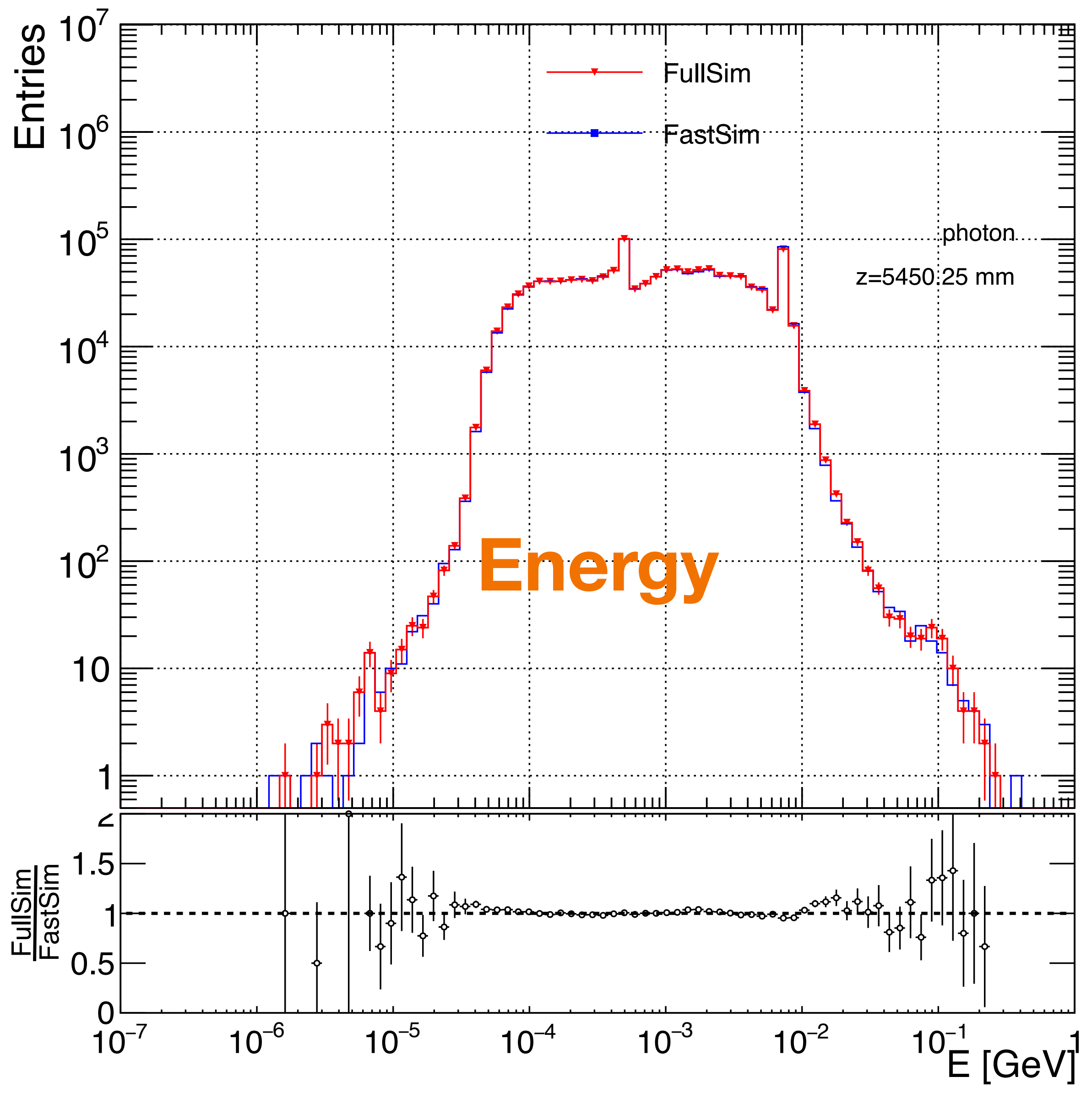
  - ★We can modify the θ_p (direction of the particles) such that this problem is resolved.

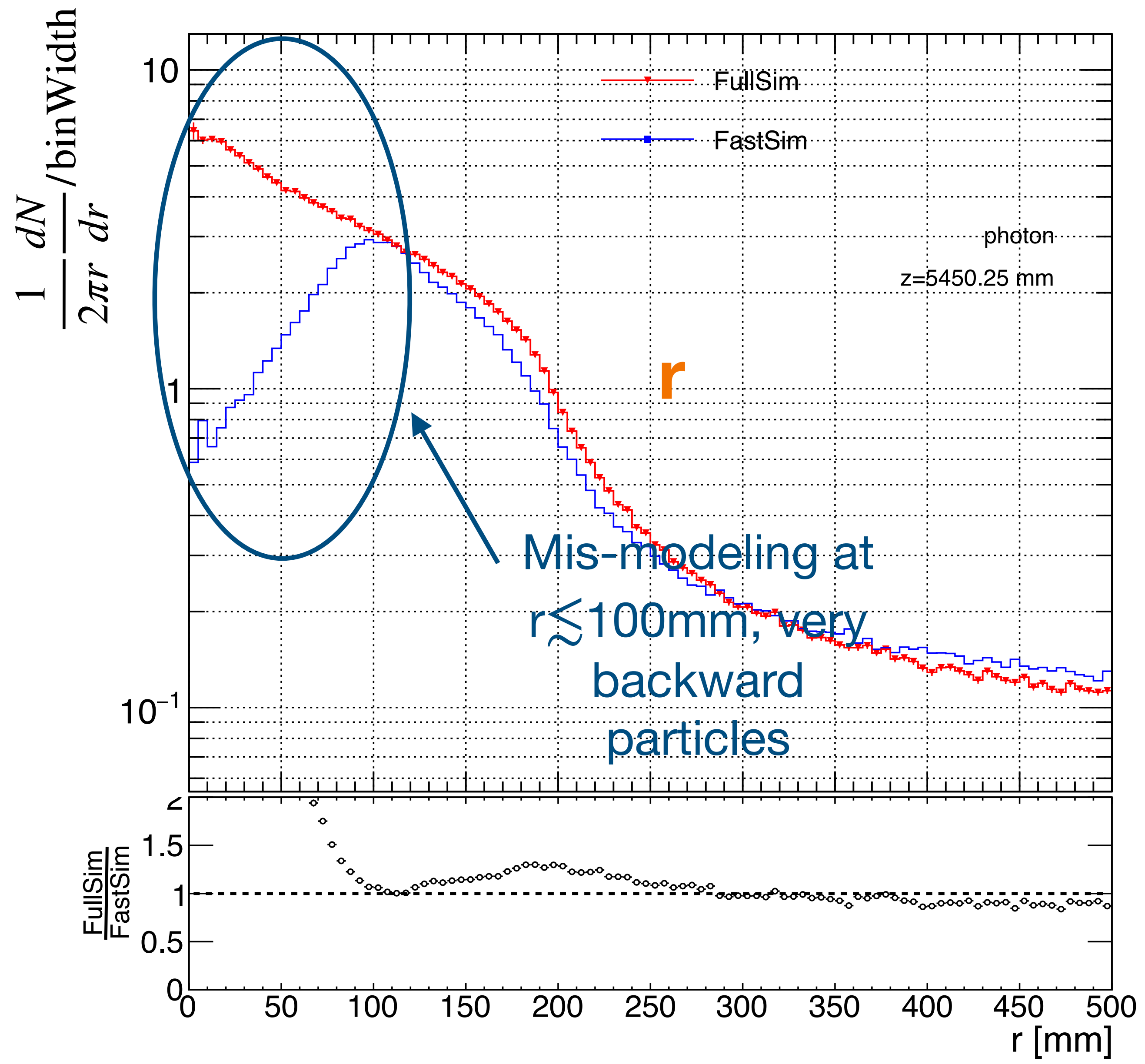
A few 1D distributions between FastSim and FullSim: photon at the test surface 1











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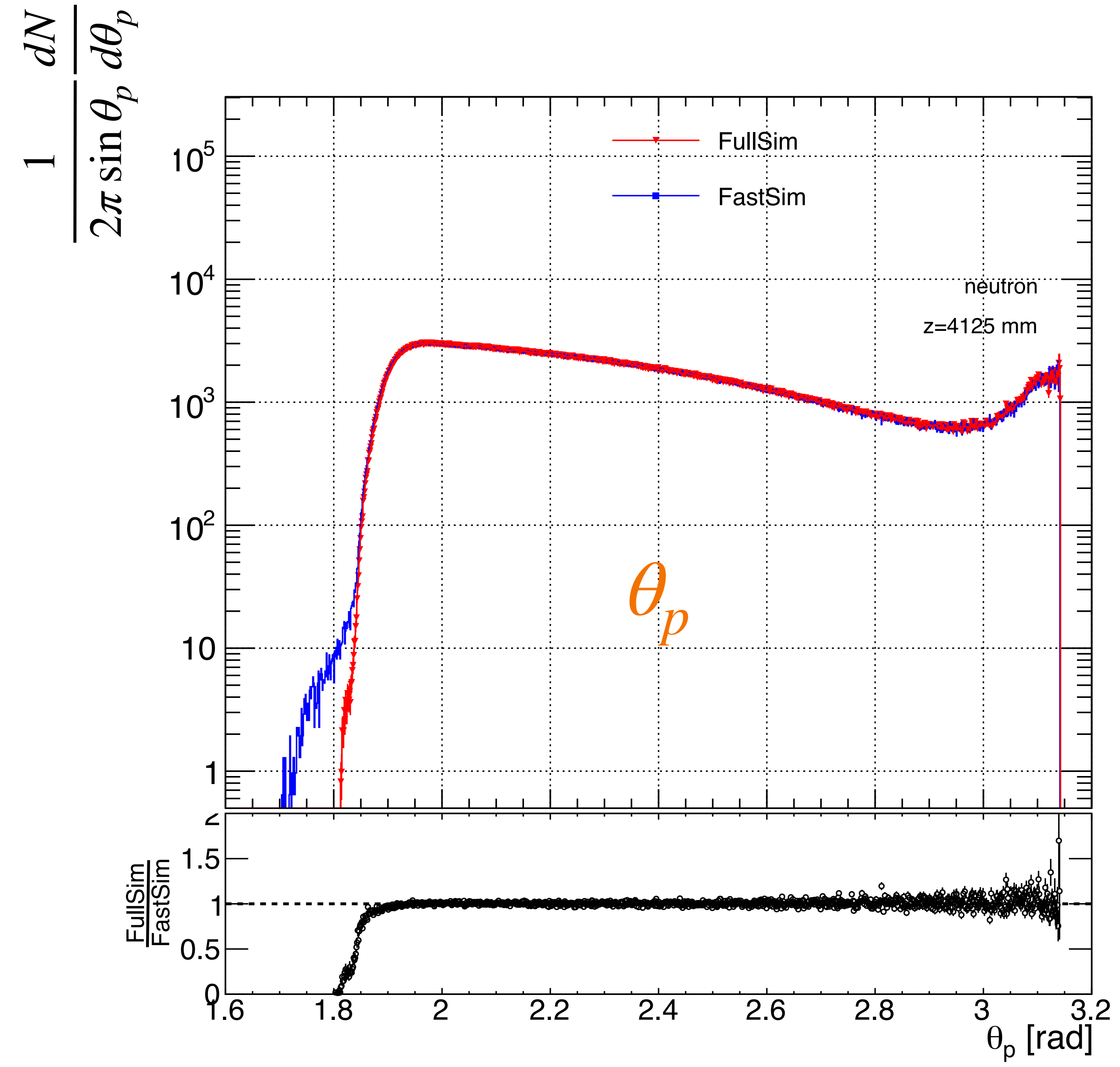
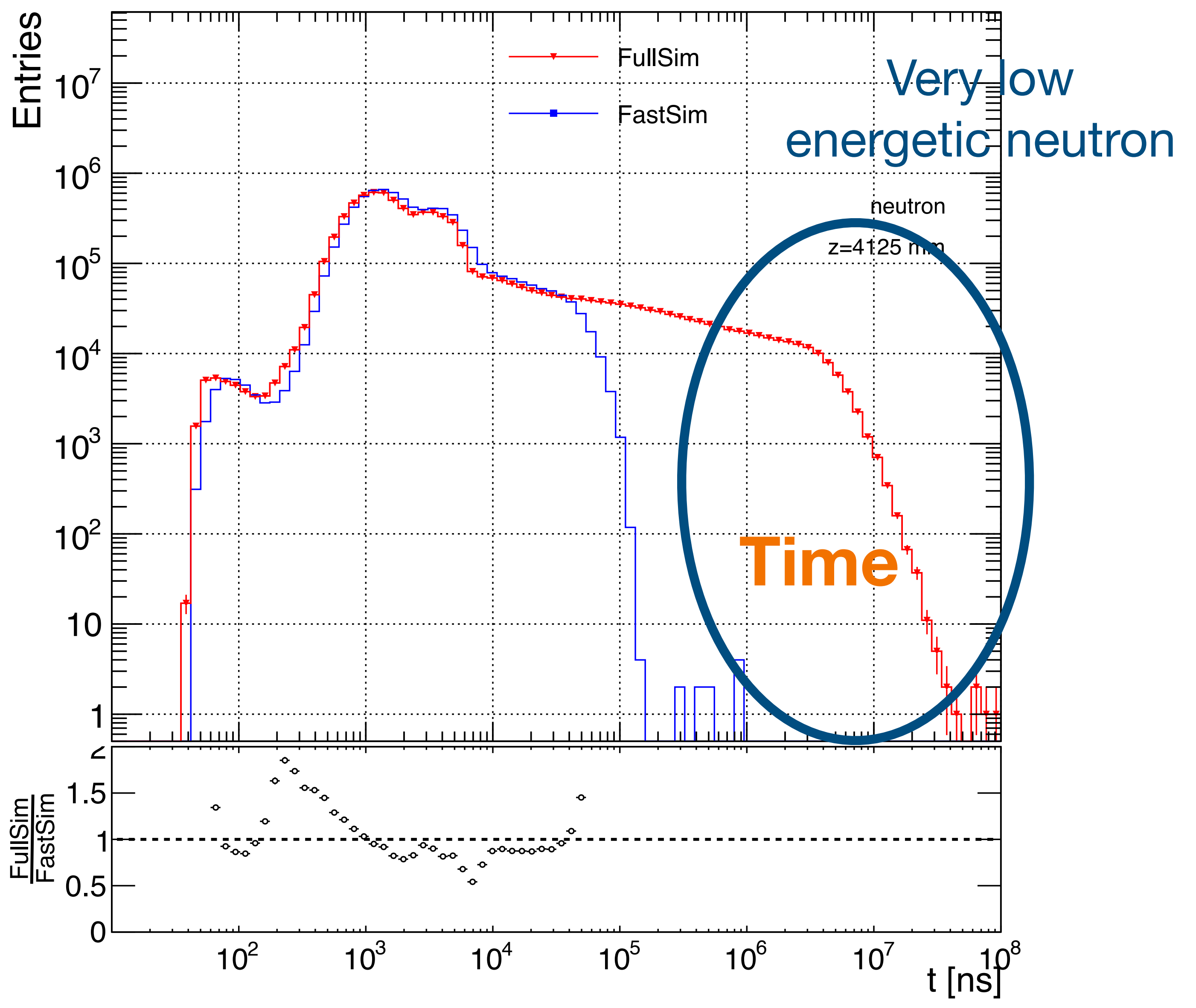
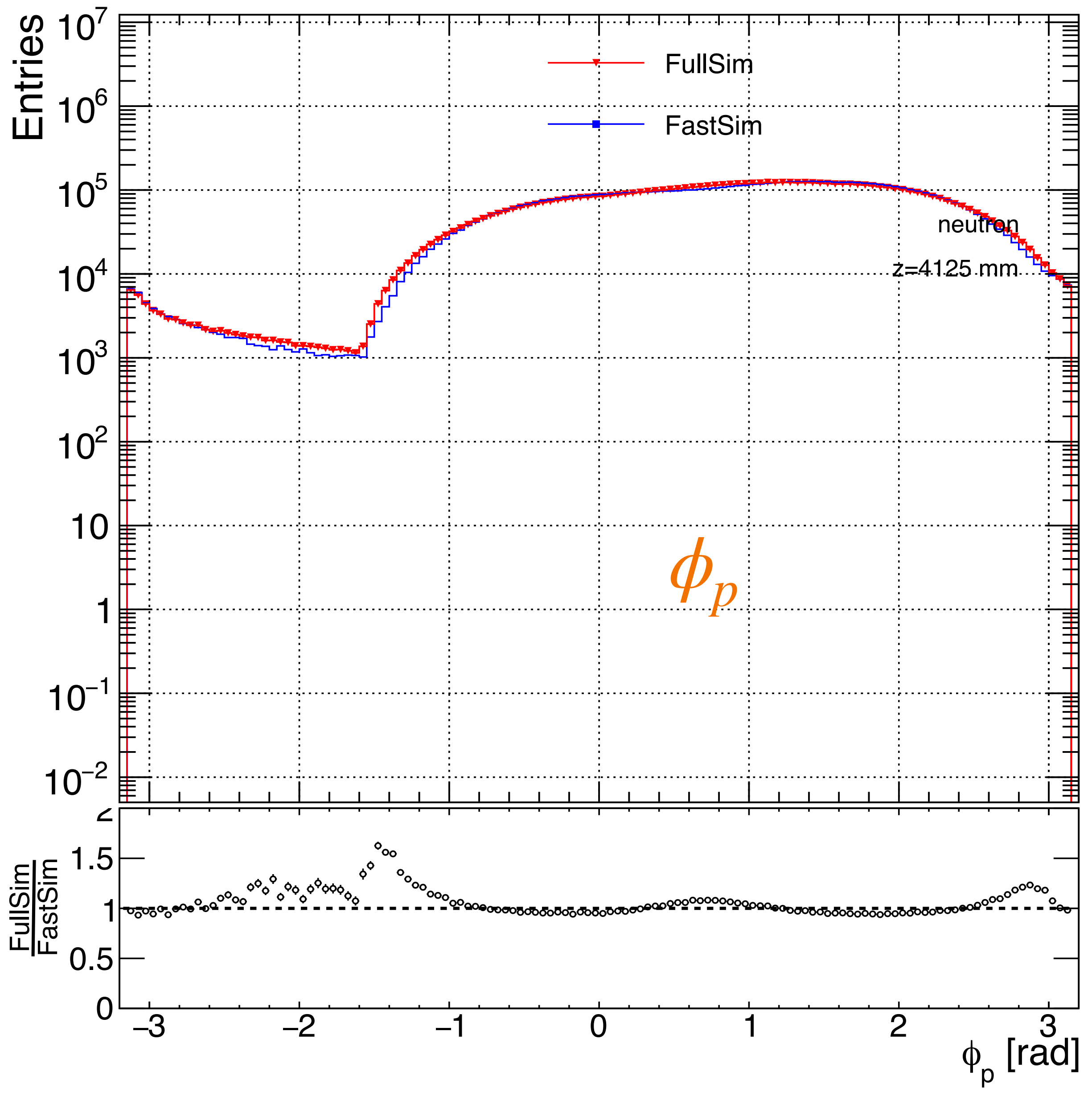
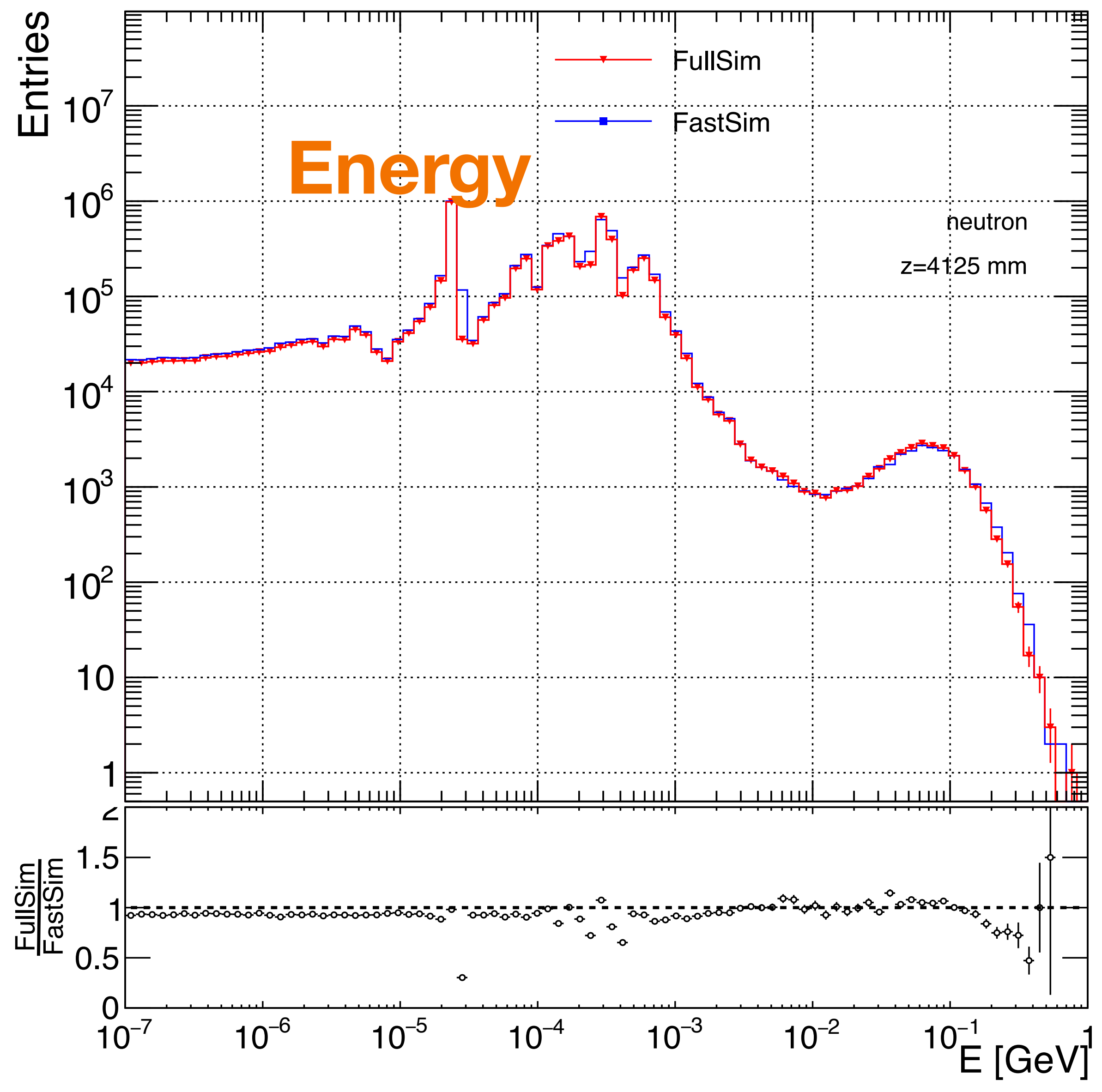
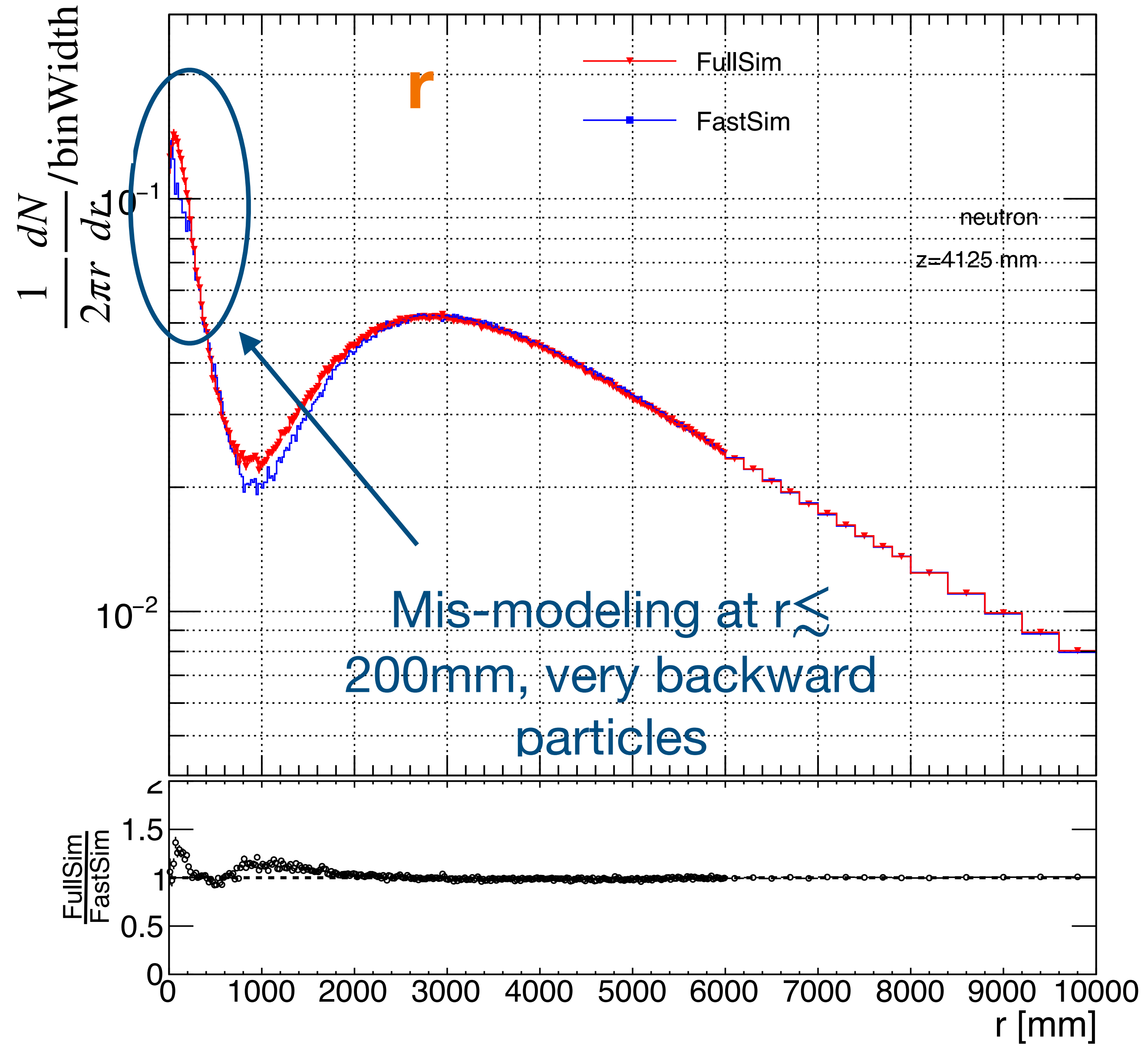
A few 1D distributions between FastSim and FullSim: neutron at the test surface 2











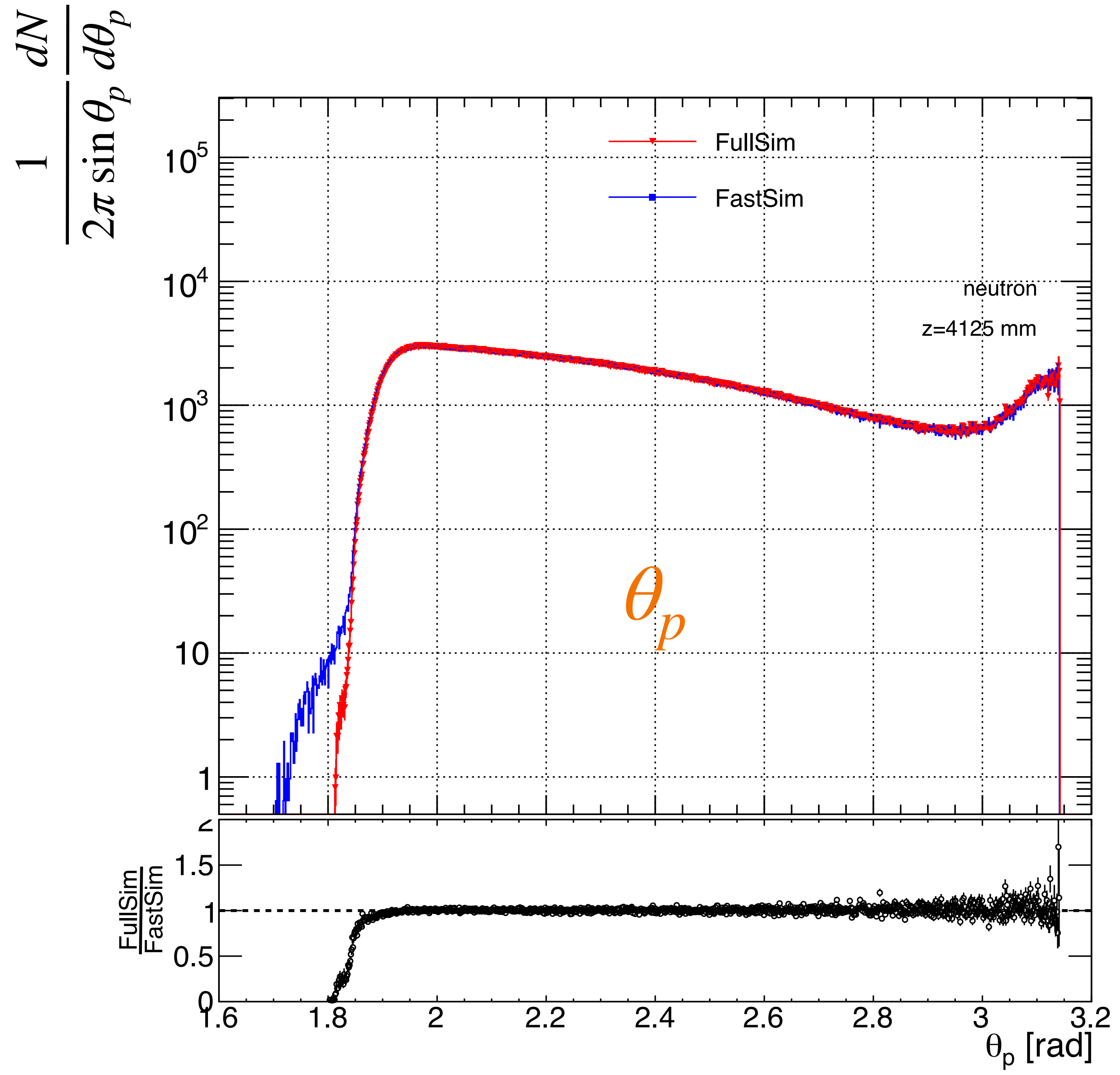
★Distributions are looked at **z=4125mm**.

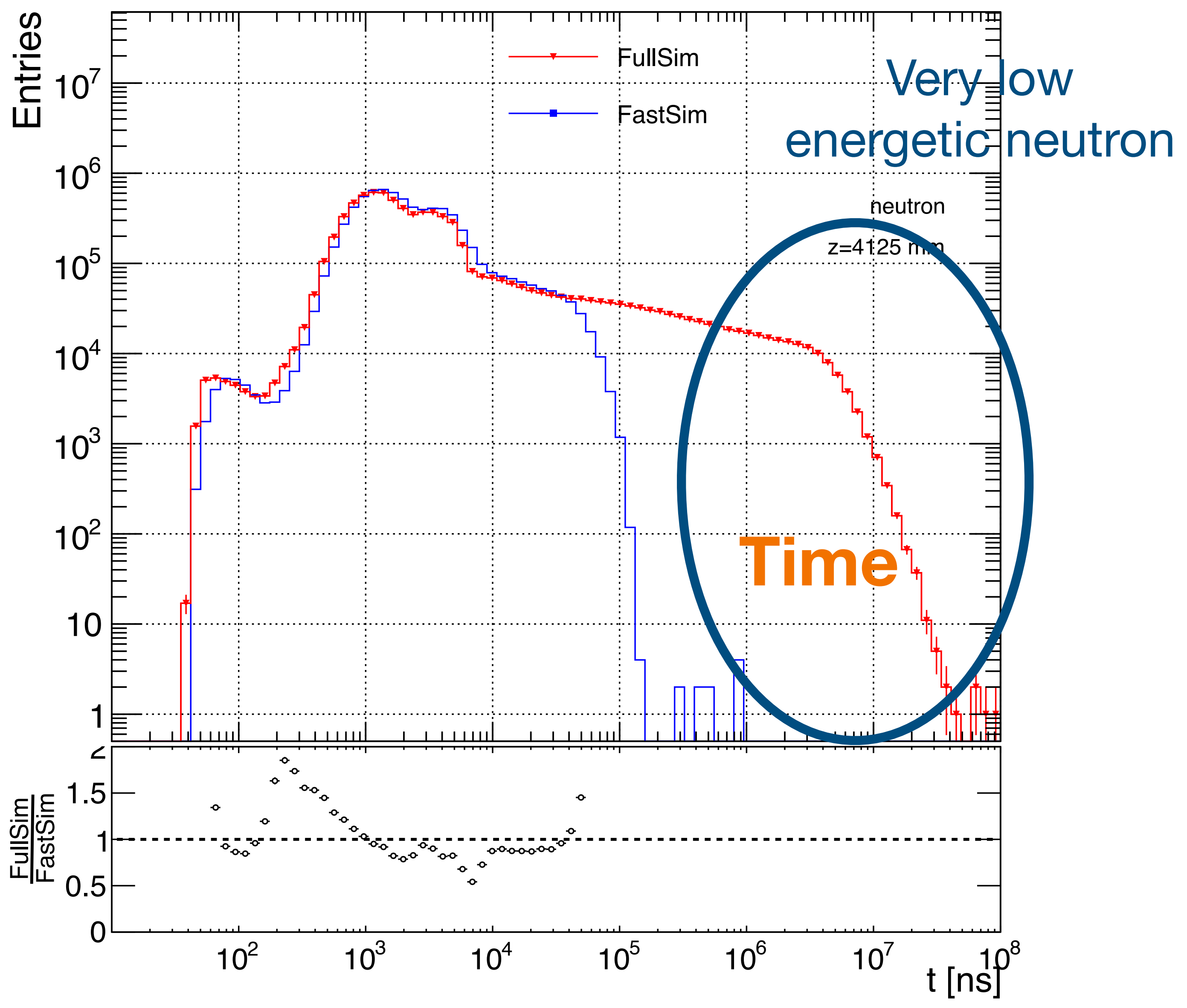
★FullSim and FastSim has comparable statistics.

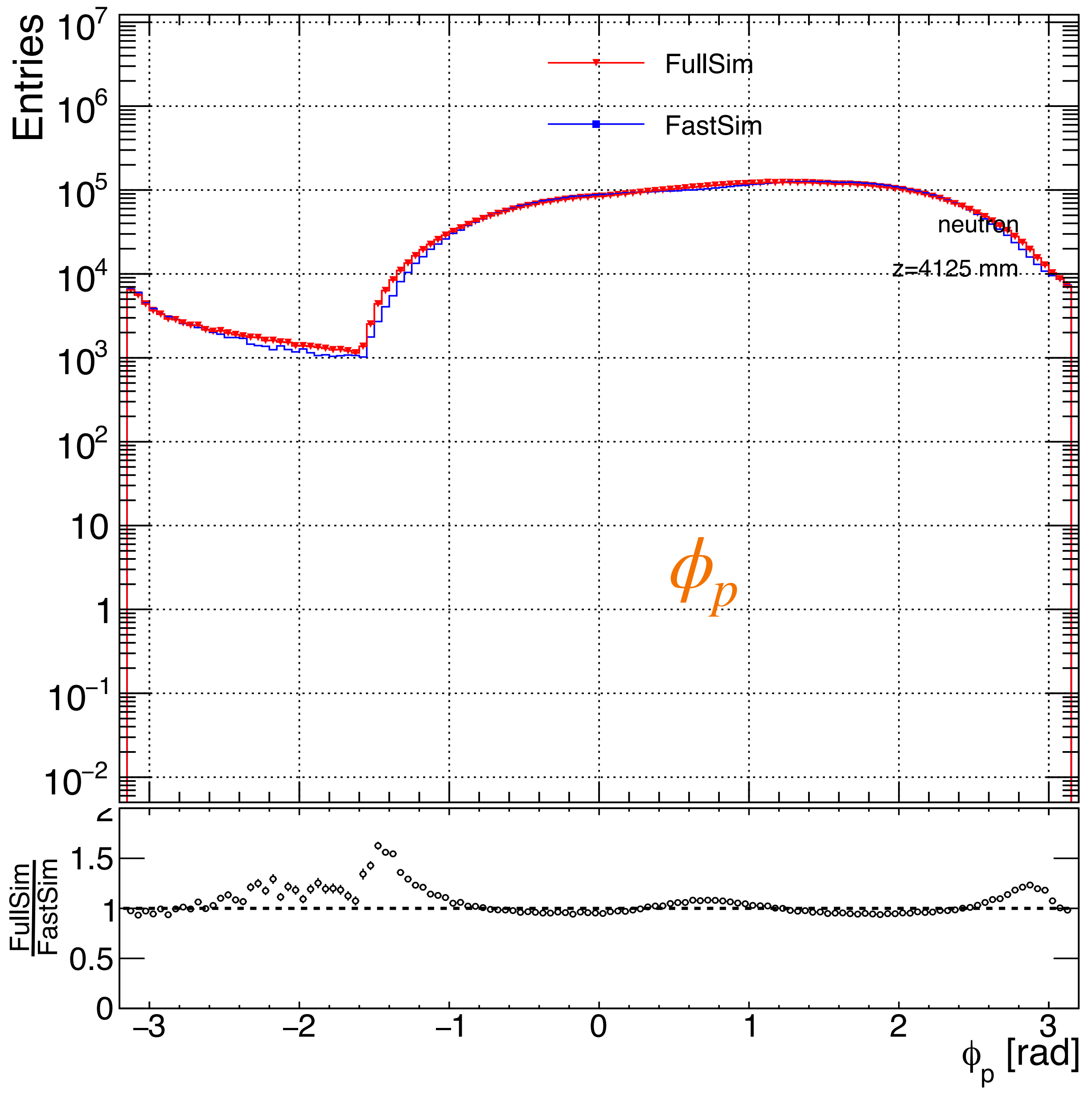
★FullSim and FastSim distributions are matching quite well.

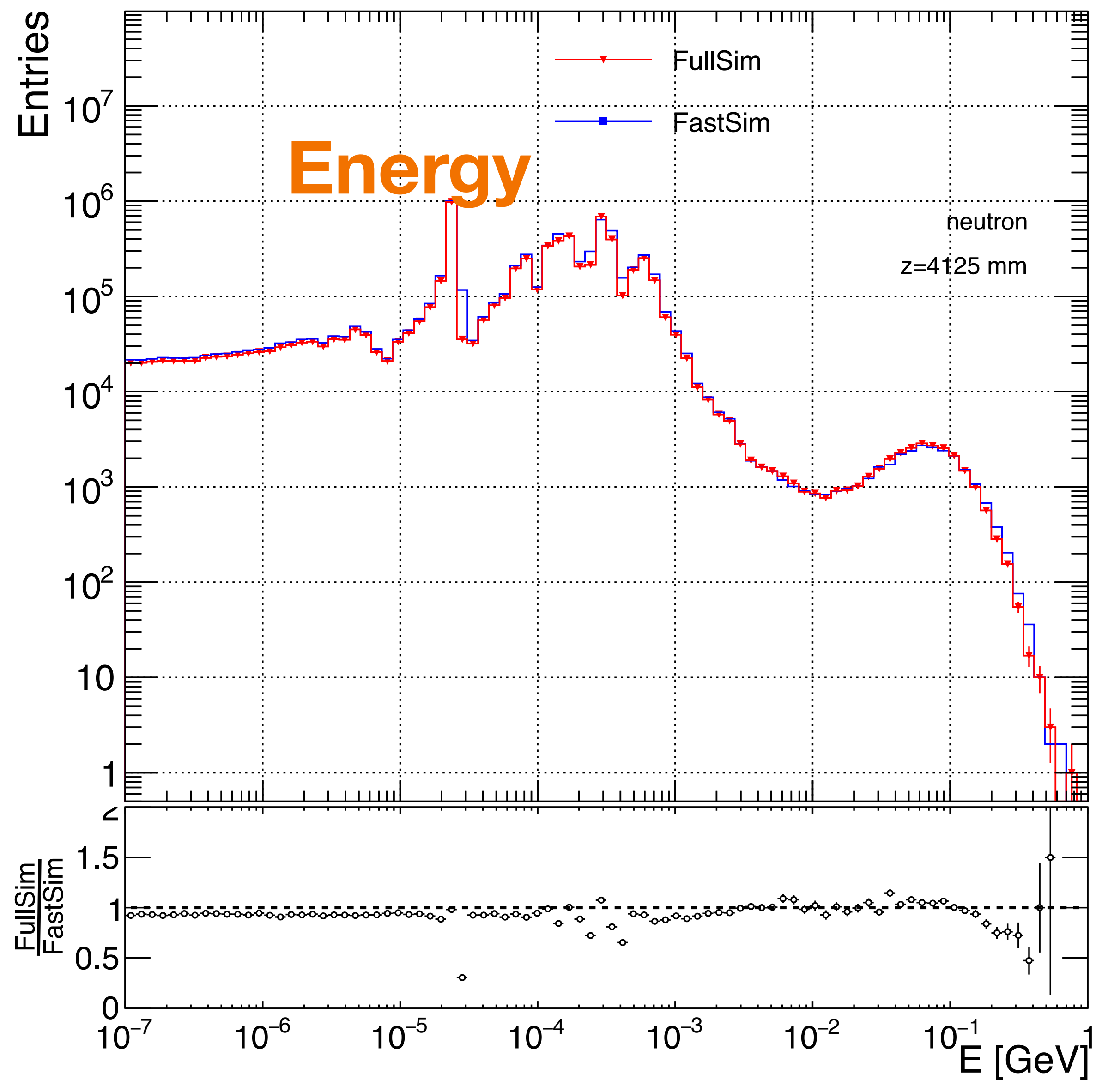
★Mis-modeling in very backward particles ($r \lesssim 200$ mm at z=4125mm).

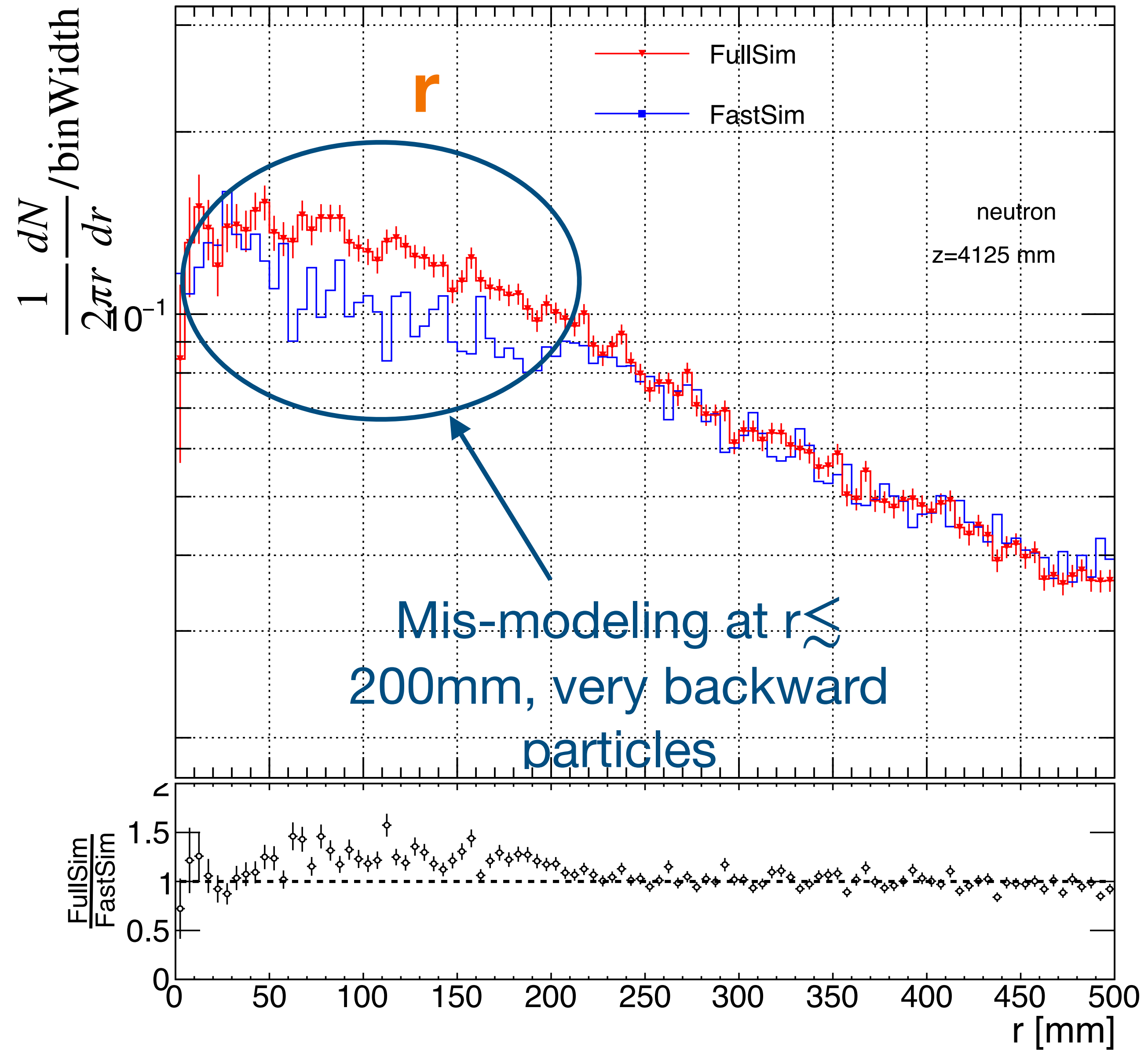
A few 1D distributions between FastSim and FullSim: neutron at the test surface 2











- ★Distributions are looked at **z=4125mm**.
- ★FullSim and FastSim has comparable statistics.
- ★FullSim and FastSim distributions are matching quite well.
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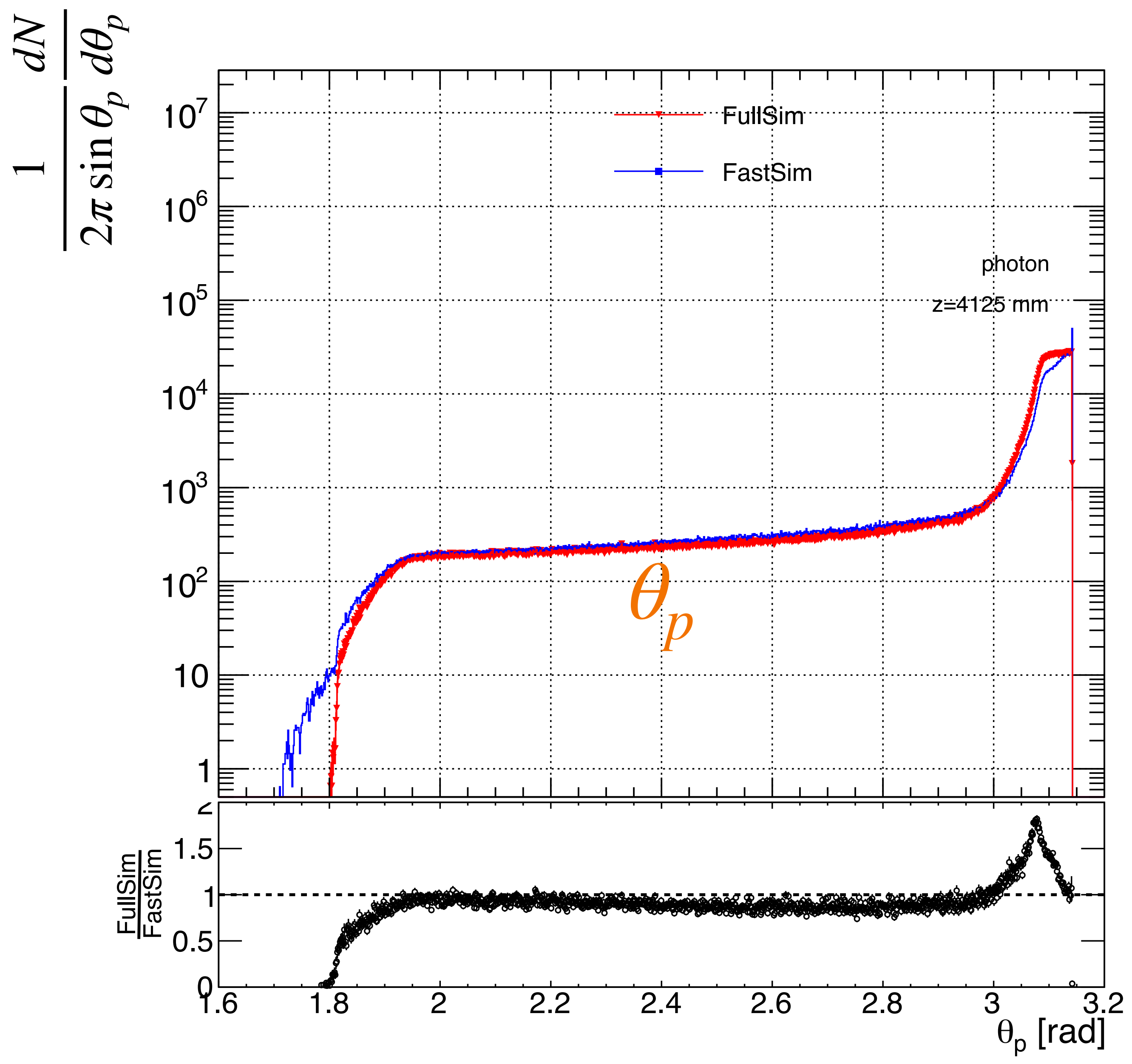
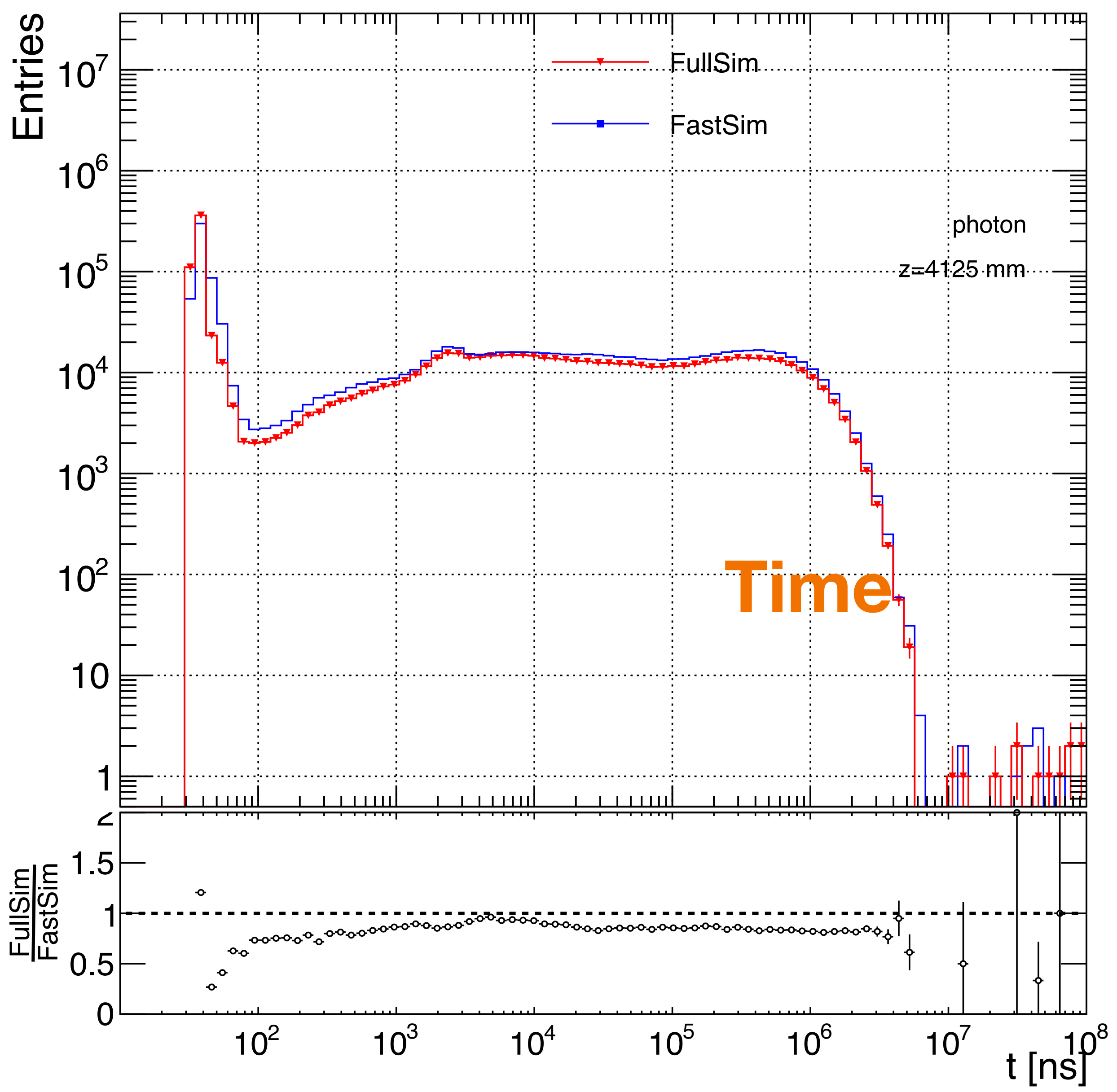
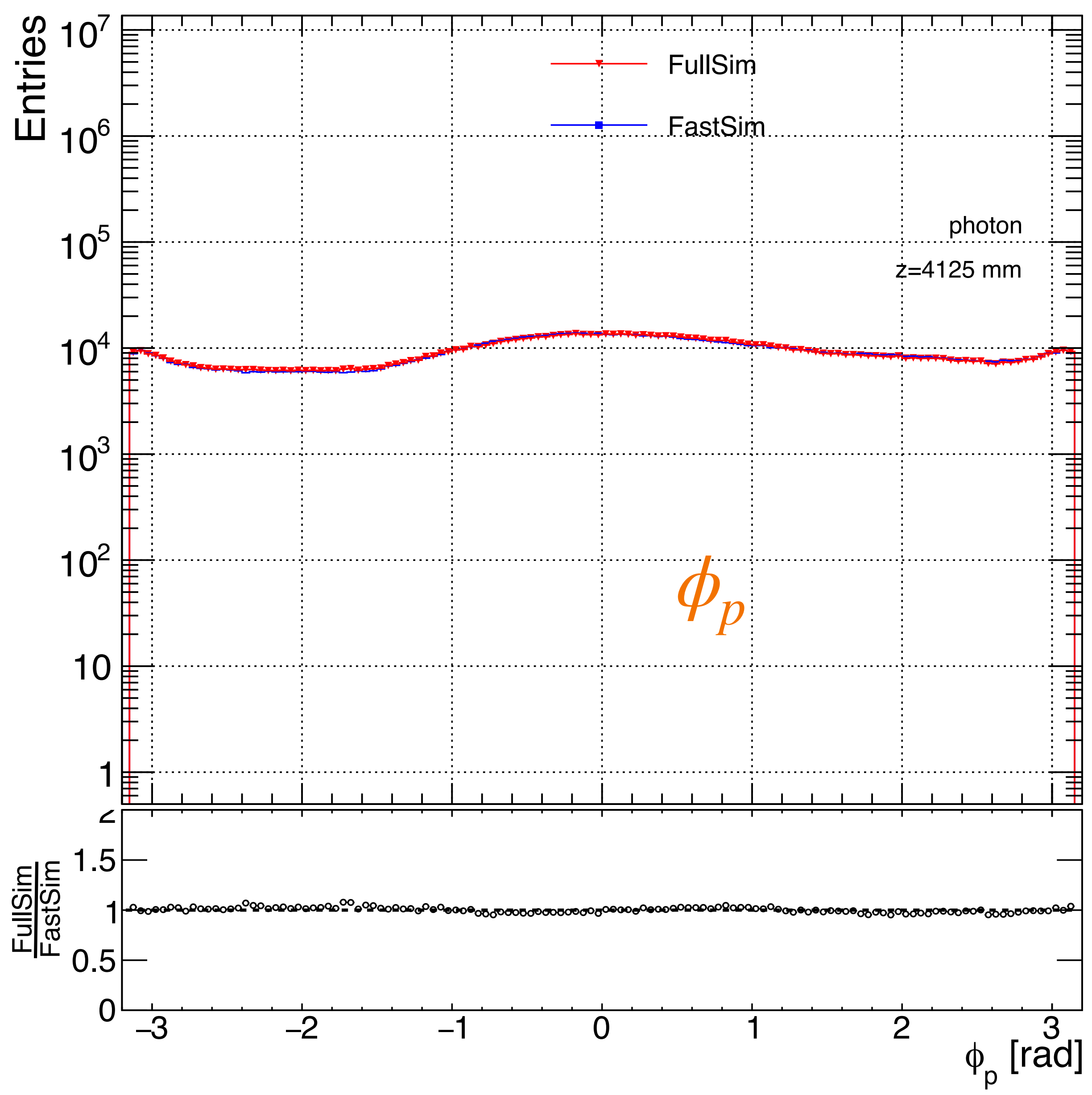
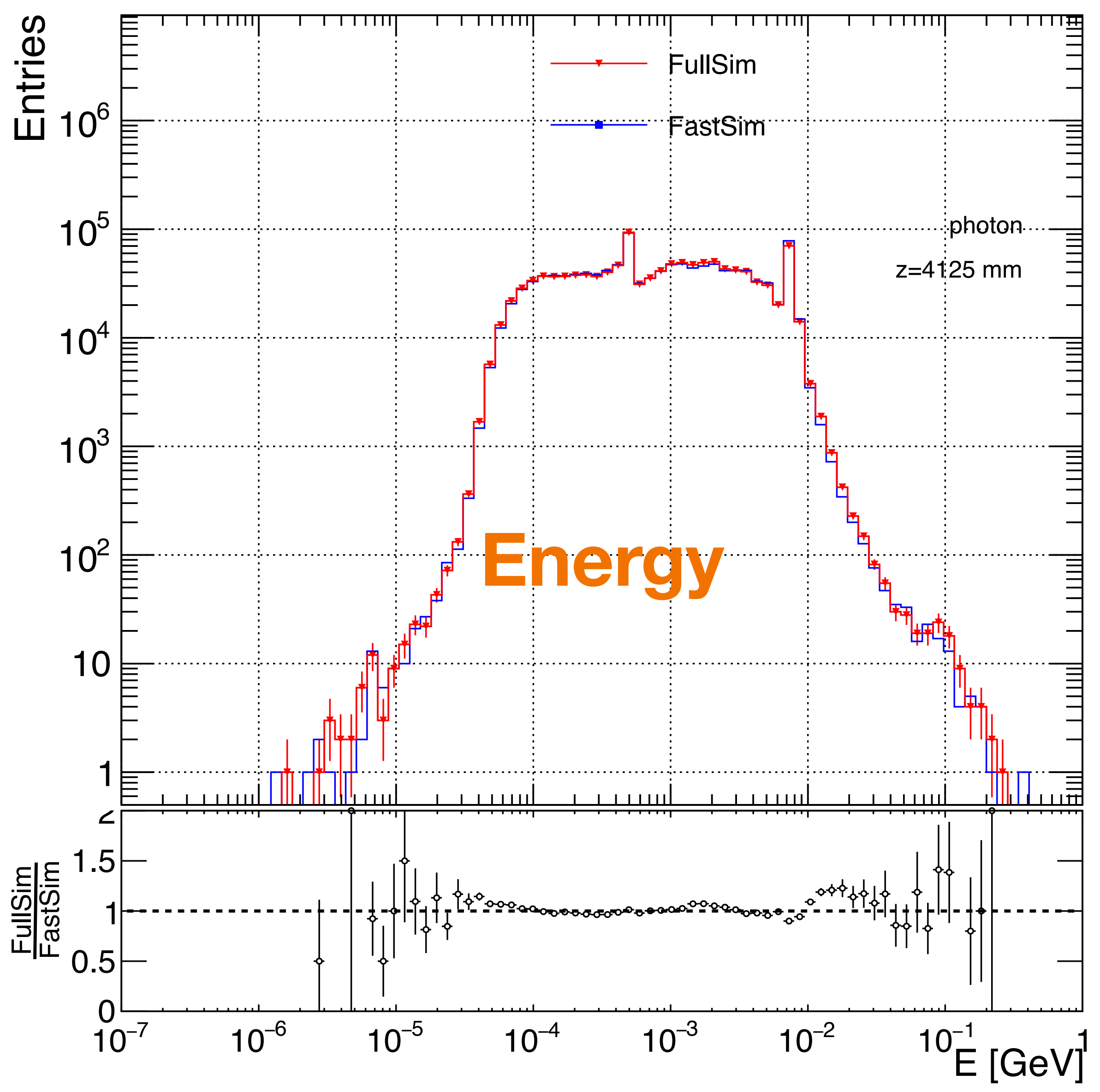
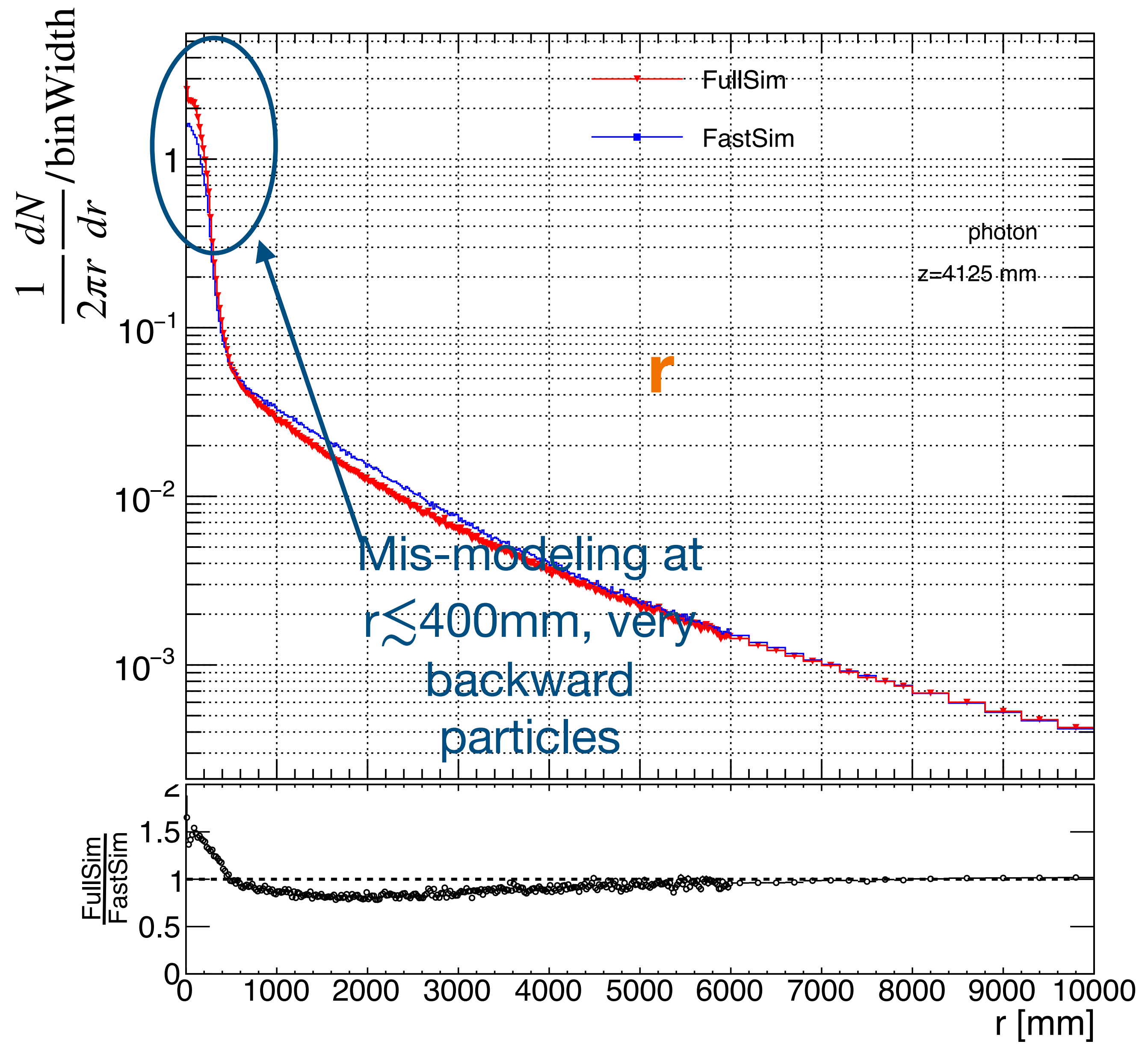
A few 1D distributions between FastSim and FullSim: photon at the test surface 2





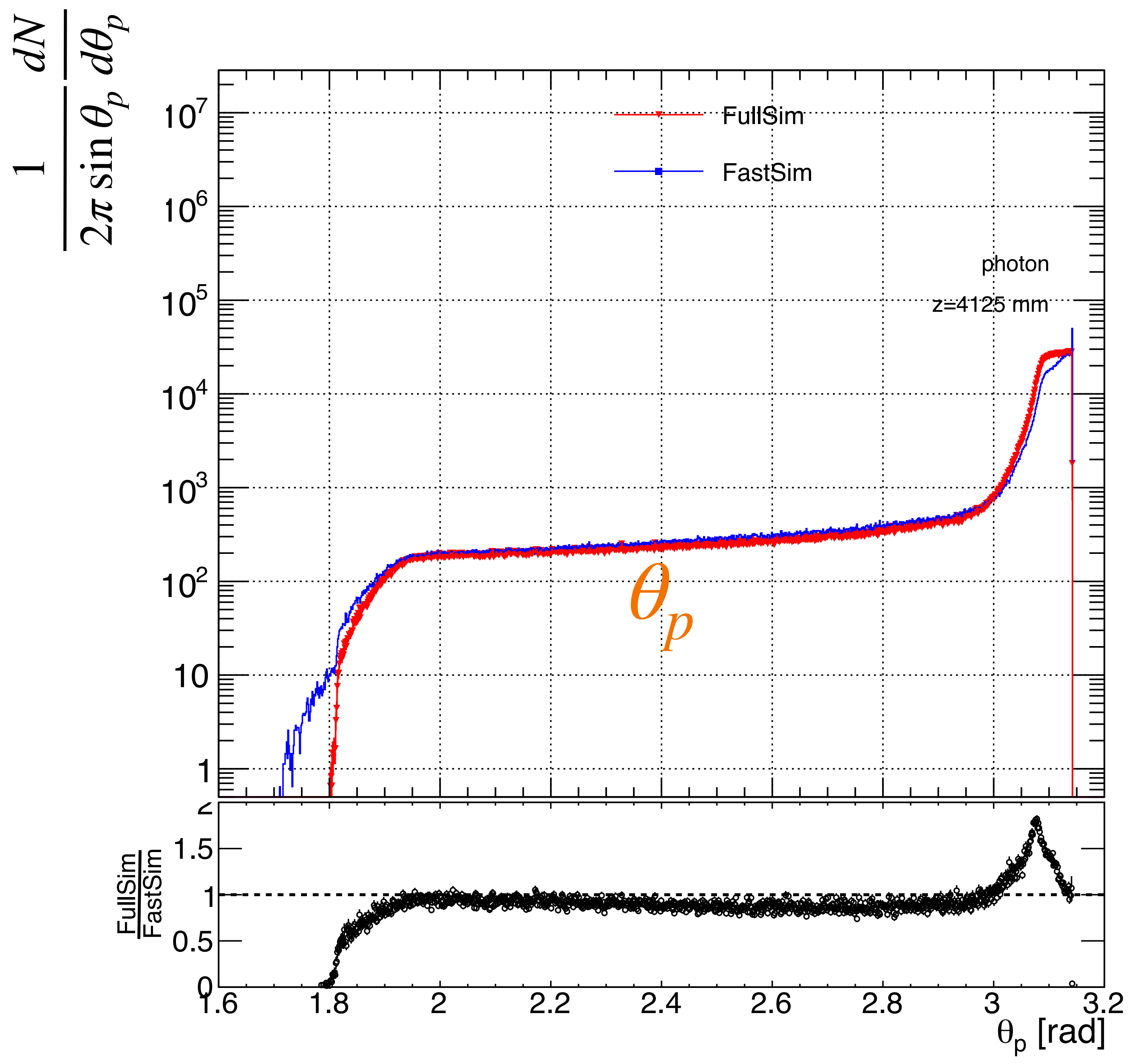


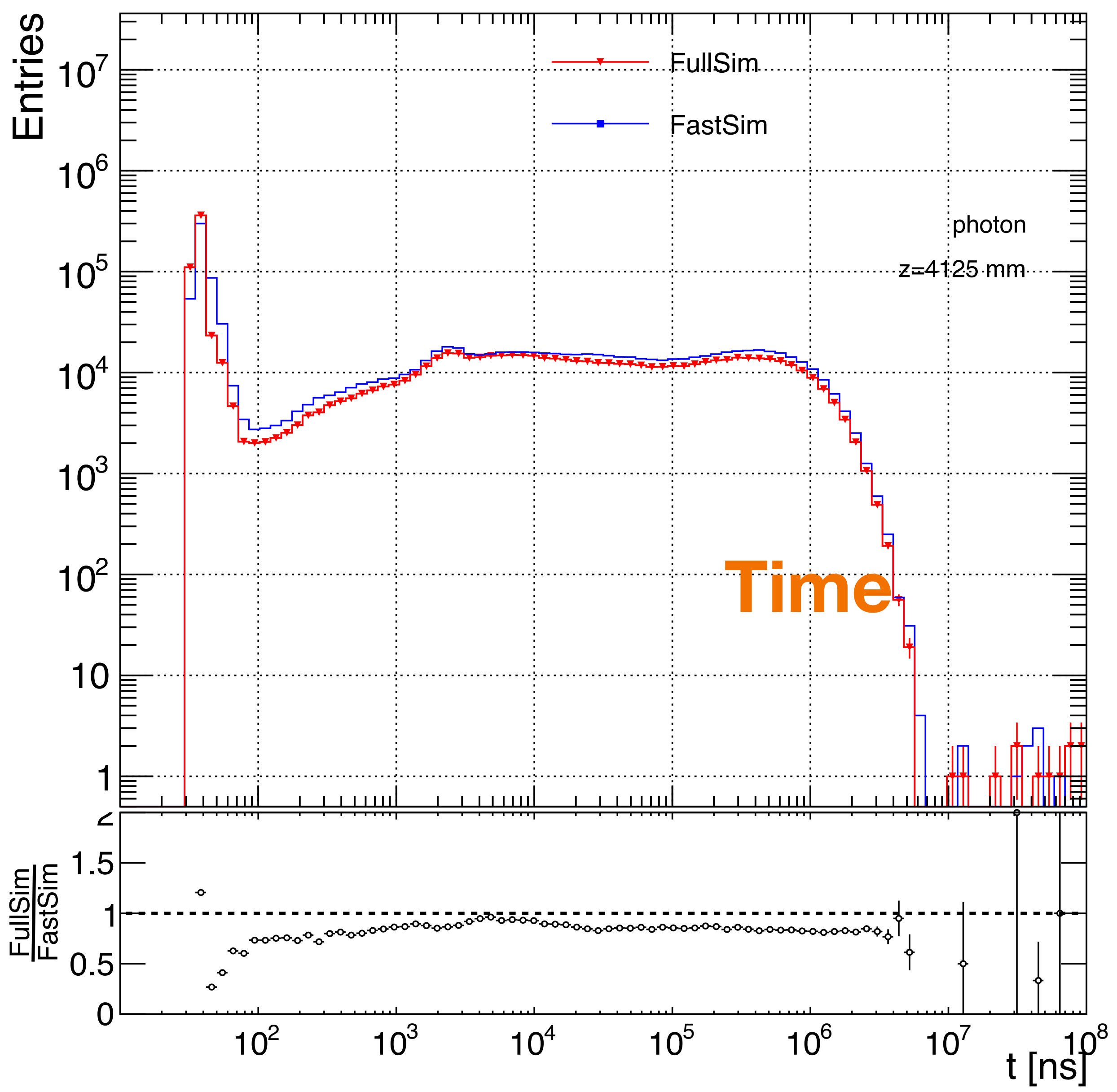


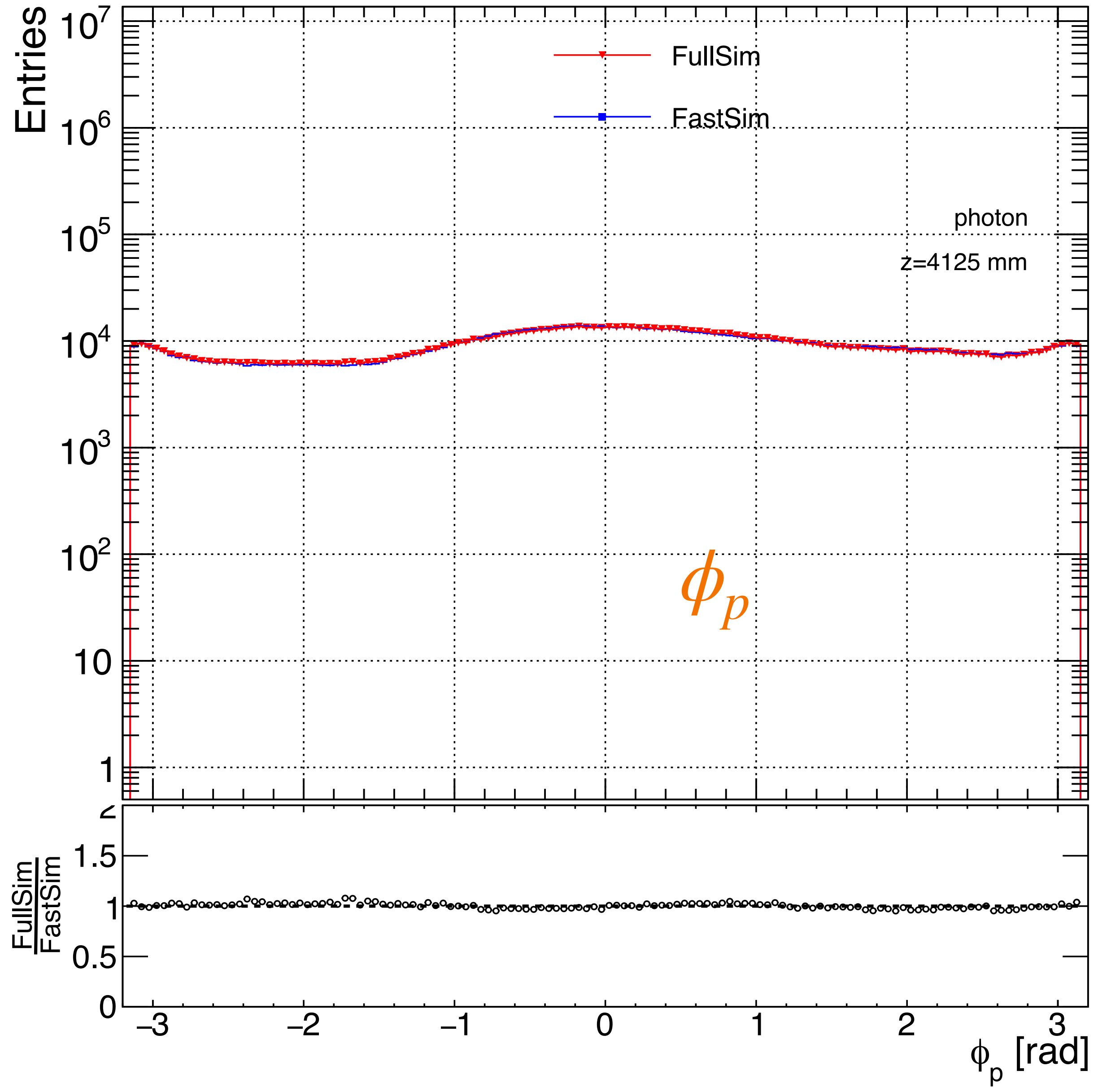


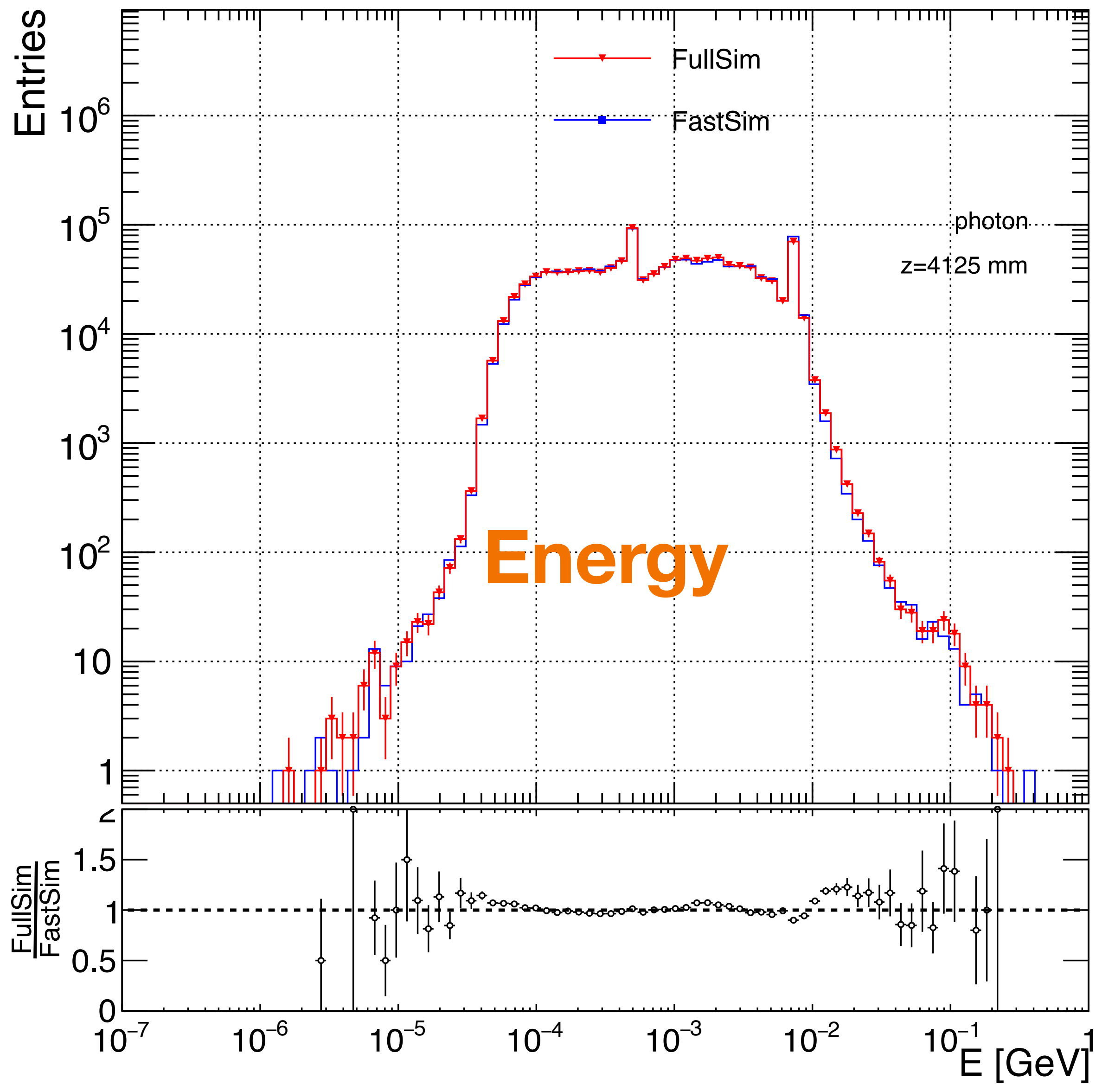
★Distributions are looked at **z=4125mm**.
★FullSim and FastSim has comparable statistics.
★FullSim and FastSim distributions are comparable.
- ★Mis-modeling in very backward particles ($r \lesssim 400$ mm at z=4125mm).

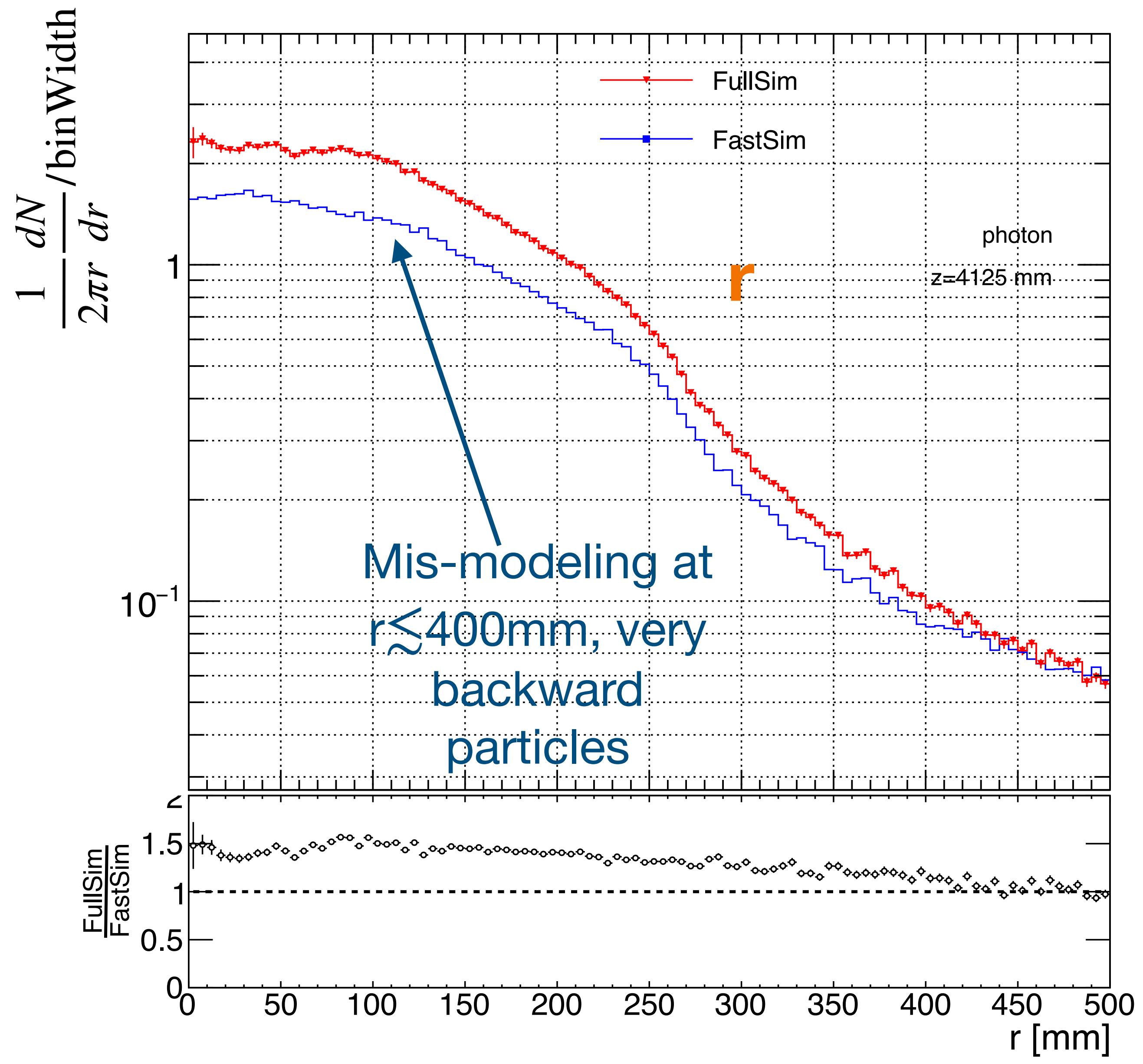
A few 1D distributions between FastSim and FullSim: photon at the test surface 2











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