pfRICH Occupancy

Simulation Setup

- Results presented based on 10x275 simulation (conclusions not substantially different for 10x100)
- Use geometry/code in branch irt-2.1c of irt, EICrecon, epic, and edm4eic to ensure proper pfRICH geometry and optics
  - Run in eic-shell version 25.12.0-stable
- Background sources (https://github.com/eic/simulation_campaign_datasets/blob/main/config_data/synrad_egasbrems_egascoulomb_egastouschek_hgas_10GeVx275GeV_GoldCoating_10um_10000Ahr_machineruntime_50s.json)
  - Synchrotron: root://dtn-eic.jlab.org//volatile/eic/EPIC/EVGEN/BACKGROUNDS/SYNRAD/dataprod_rel_1.0.0/10x275/GoldCoating/10um/dataprod_rel_1.0.0_synrad_10x275_run001.preproc_10000repeats.hepmc3.tree.root
  - Electron Brems: root://dtn-eic.jlab.org//volatile/eic/EPIC/EVGEN/BACKGROUNDS/BEAMGAS/electron/GETaLM1.0.0-1.0/10GeV/GETaLM1.0.0-1.0_ElectronBeamGas_10GeV_foam_emin10keV_run001.hepmc3.tree.root
  - Electron Coulomb: root://dtn-eic.jlab.org//volatile/eic/EPIC/EVGEN/BACKGROUNDS/BEAMGAS/electron/coulomb/EIC_ESR_Xsuite/dataprod_rel_1.0.1/10x275/10000Ahr/MachineRuntime50s/dataprod_rel_1.0.1_electron_coulomb_10x275_10000Ahr.hepmc3.tree.root
  - Electron Touschek: root://dtn-eic.jlab.org//volatile/eic/EPIC/EVGEN/BACKGROUNDS/BEAMGAS/electron/touschek/EIC_ESR_Xsuite/dataprod_rel_1.0.1/10x275/10000Ahr/MachineRuntime50s/dataprod_rel_1.0.1_electron_touschek_10x275_10000Ahr.hepmc3.tree.root
  - Proton Beam Gas: root://dtn-eic.jlab.org//volatile/eic/EPIC/EVGEN/BACKGROUNDS/BEAMGAS/proton/pythia8.306-1.0/275GeV/combined/pythia8.306-1.0_ProtonBeamGas_275GeV_combined.hepmc3.tree.root

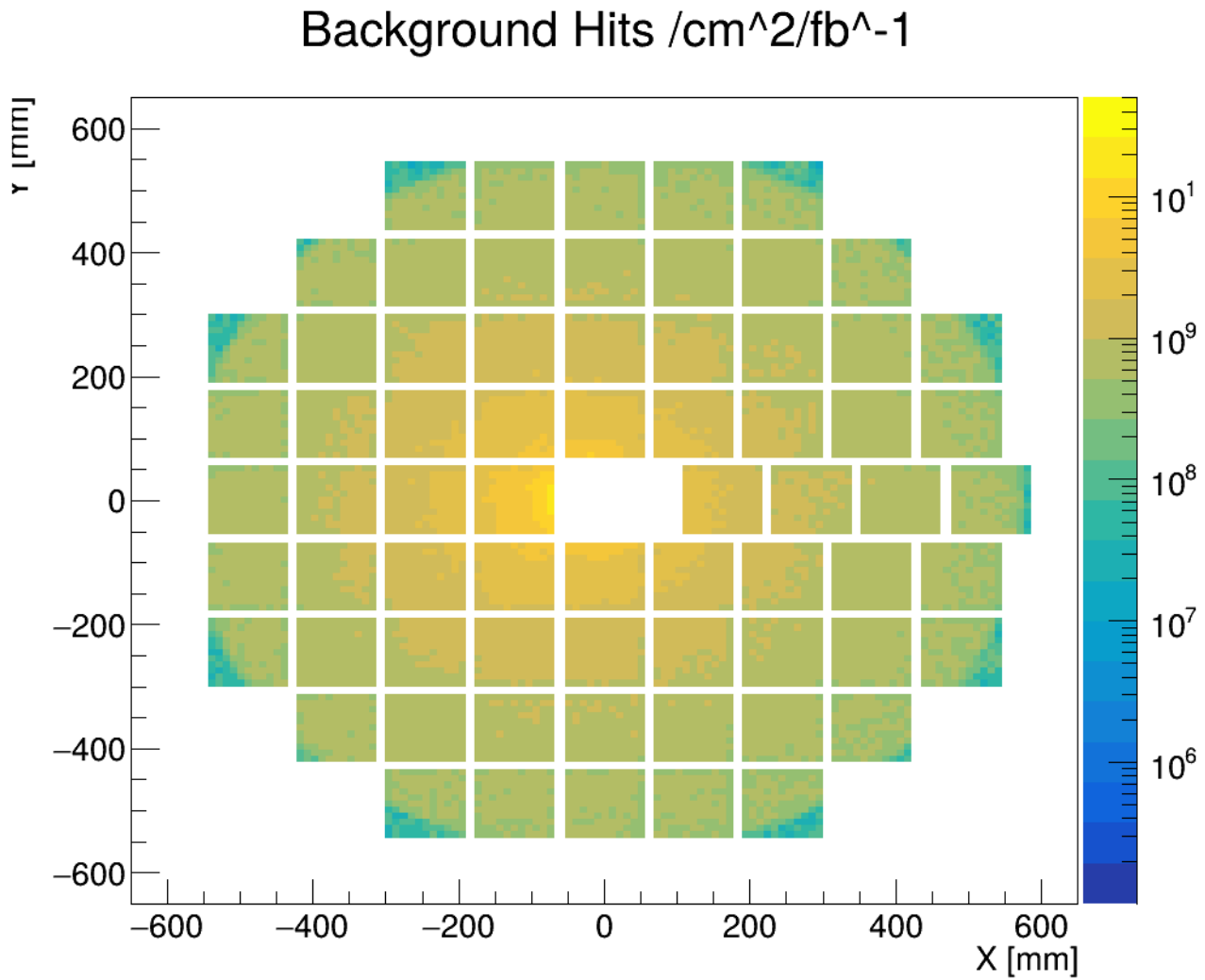
Simulation Setup

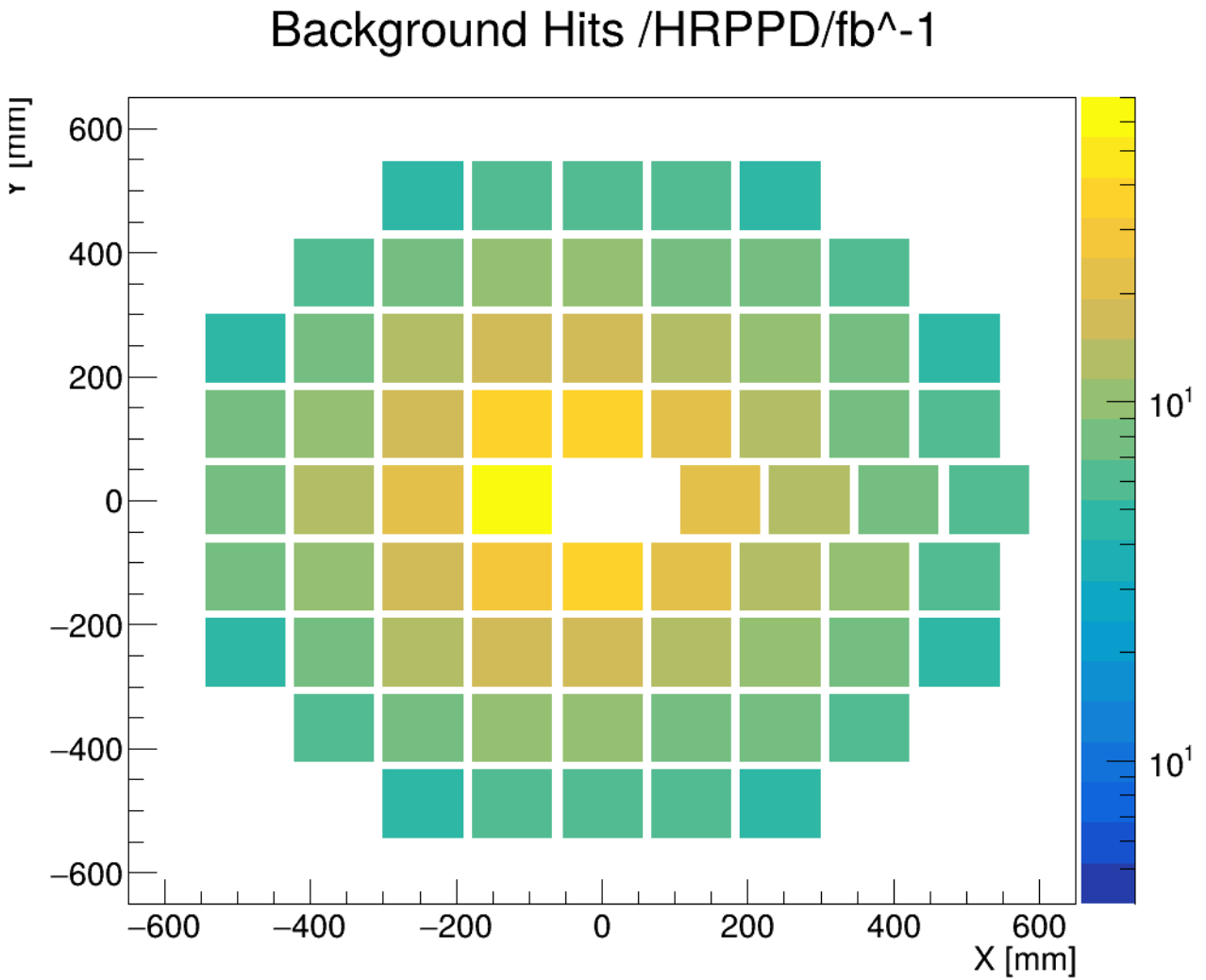
- Background Rates
  - Synchrotron: 13277000 KHz
  - Electron Brems: 3177.25 KHz
  - Electron Coulomb: 29.56 KHz
  - Electron Touschek: 233.5 KHz
  - Proton Beam Gas: 32.6 KHz

- Signal generated using Pythia6 minbias samples – 50 microbarn total cross section

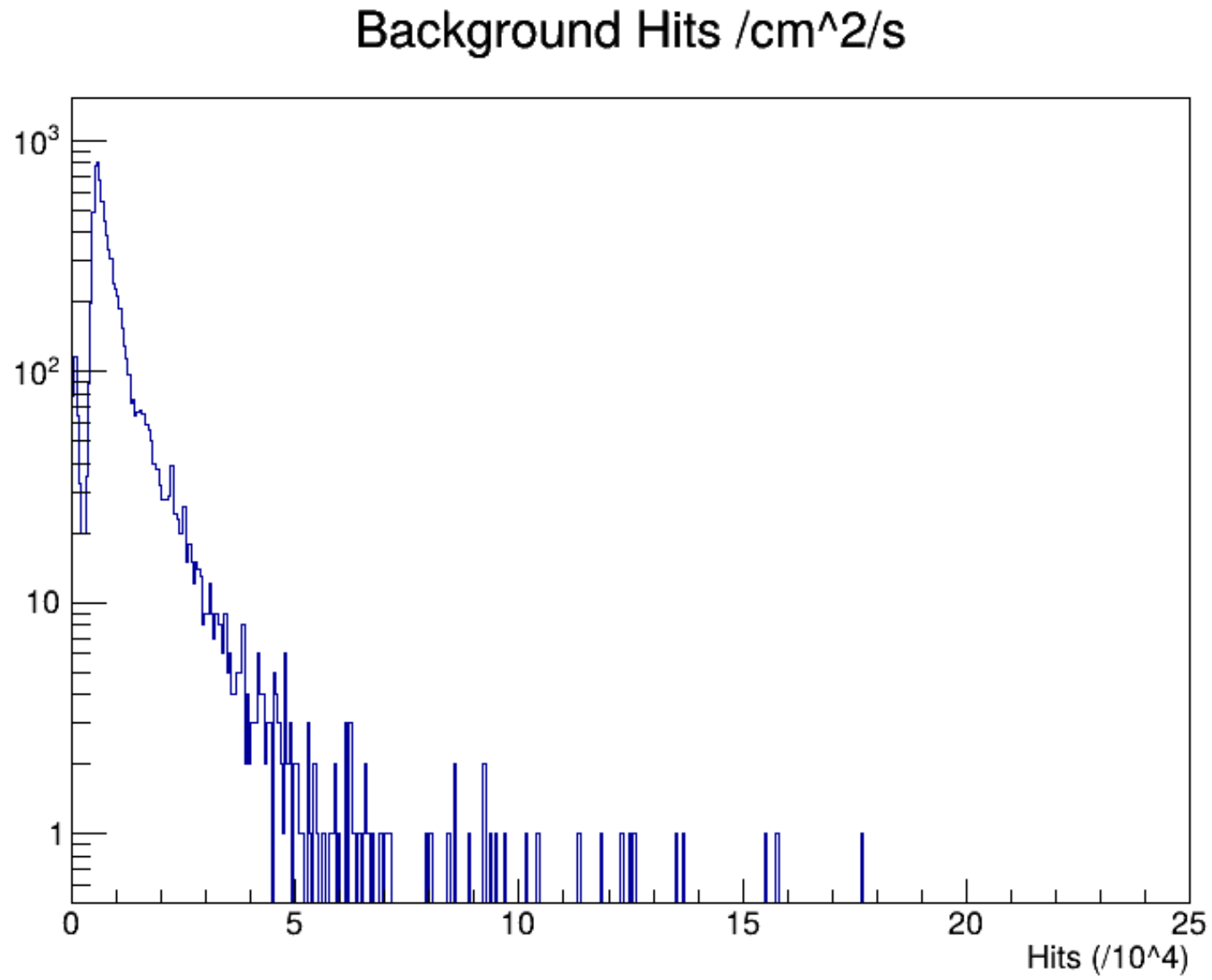
- Total signal rate at 10x250 = 500 KHz (1fb^-1 in 10^5 s)
  - Q2 < 1: 491.87 KHz
  - 1 < Q2 < 10: 0.74 KHz
  - 10 < Q2 < 100: 0.59 KHz
  - 100 < Q2 < 1000: 0.02 KHz

Background Hit Maps

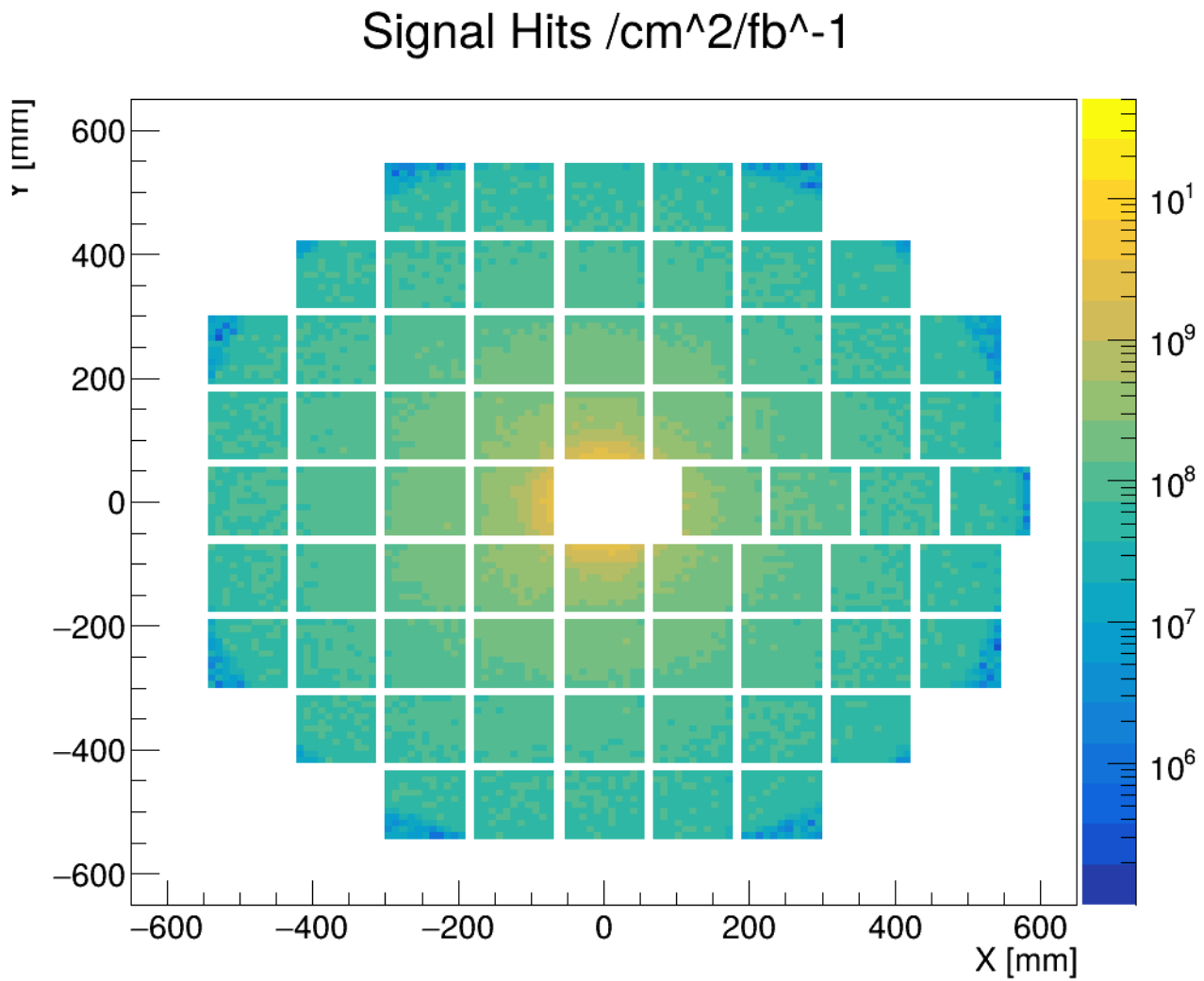


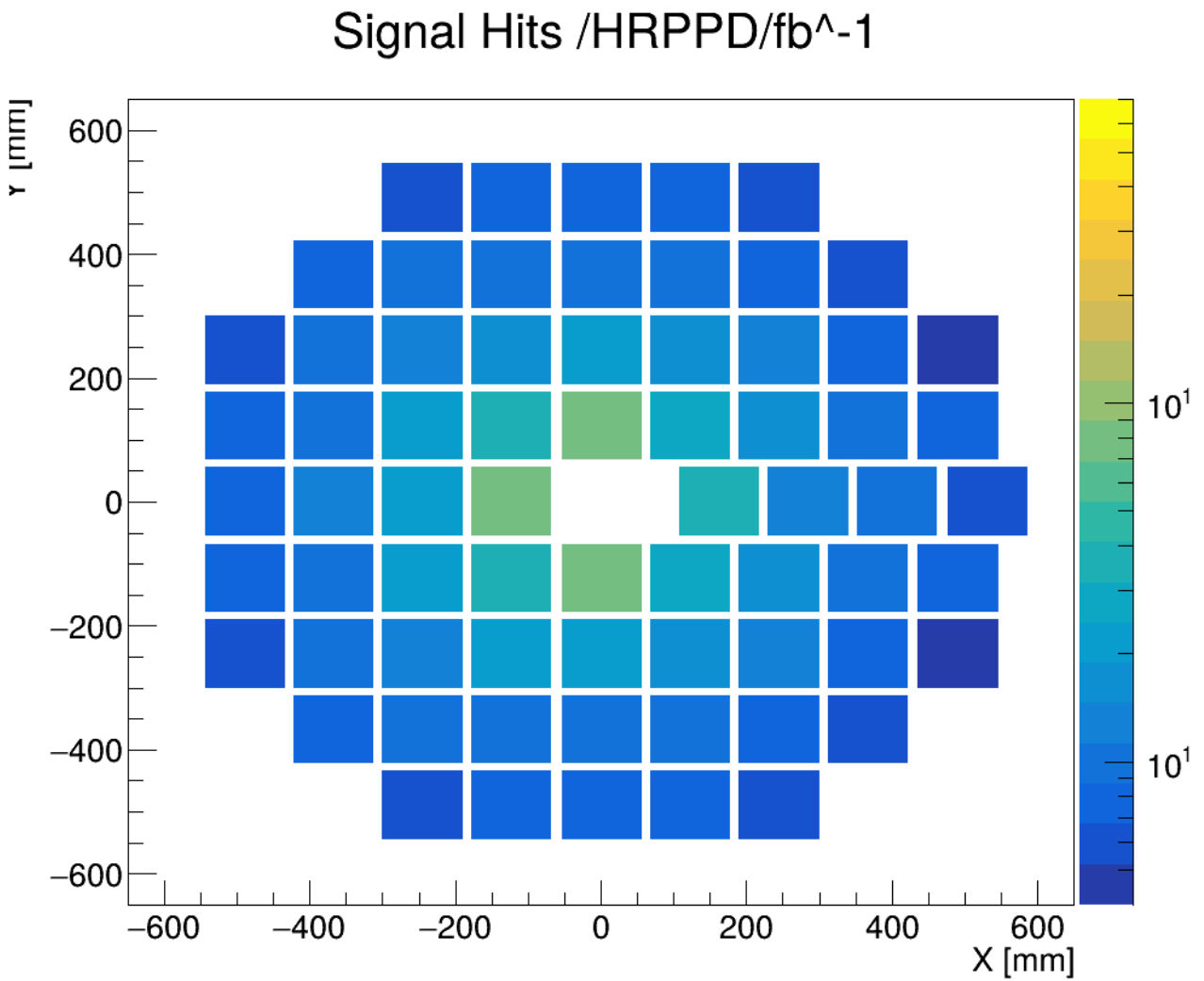


Background Hit Frequency

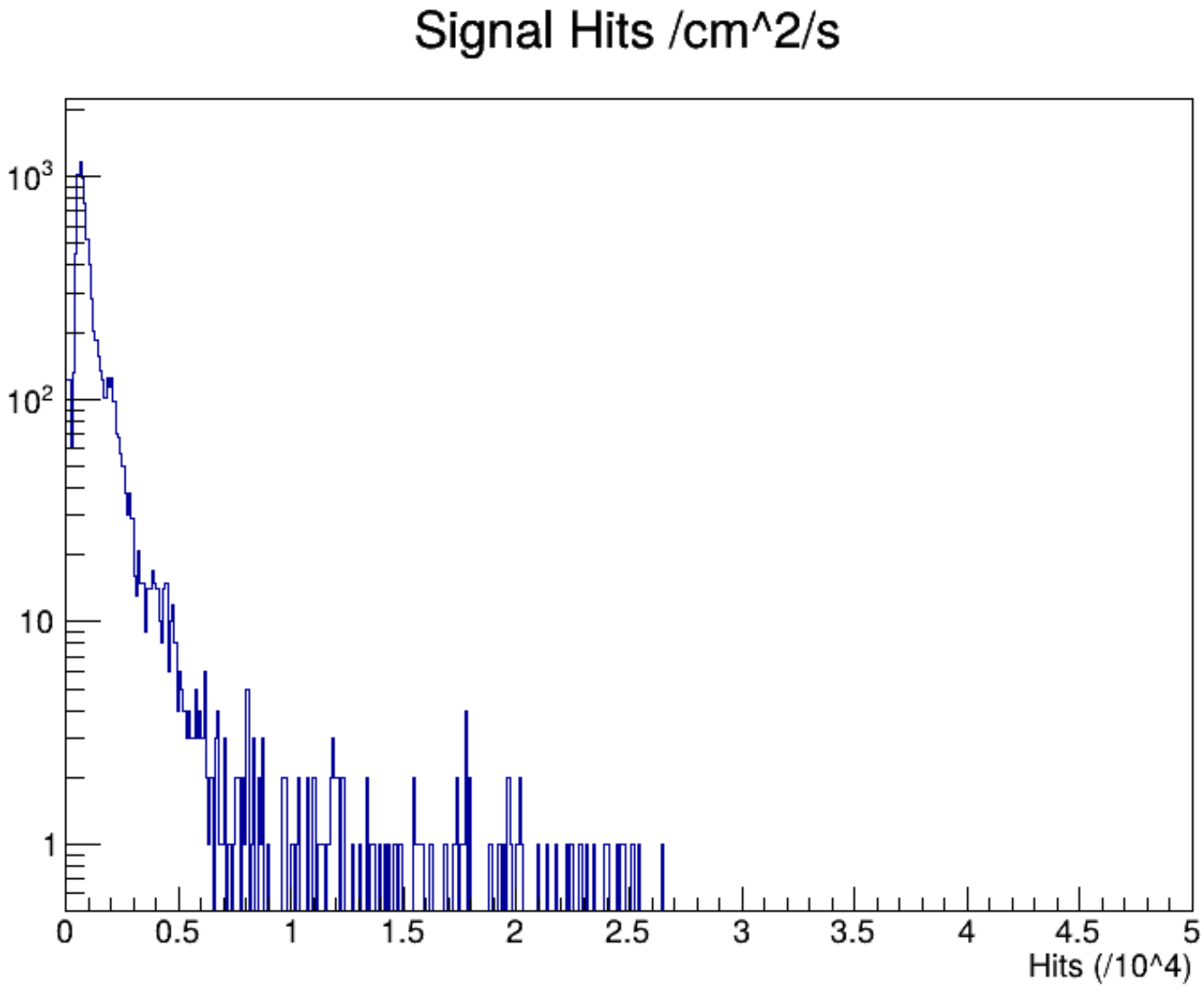


Signal Hit Maps

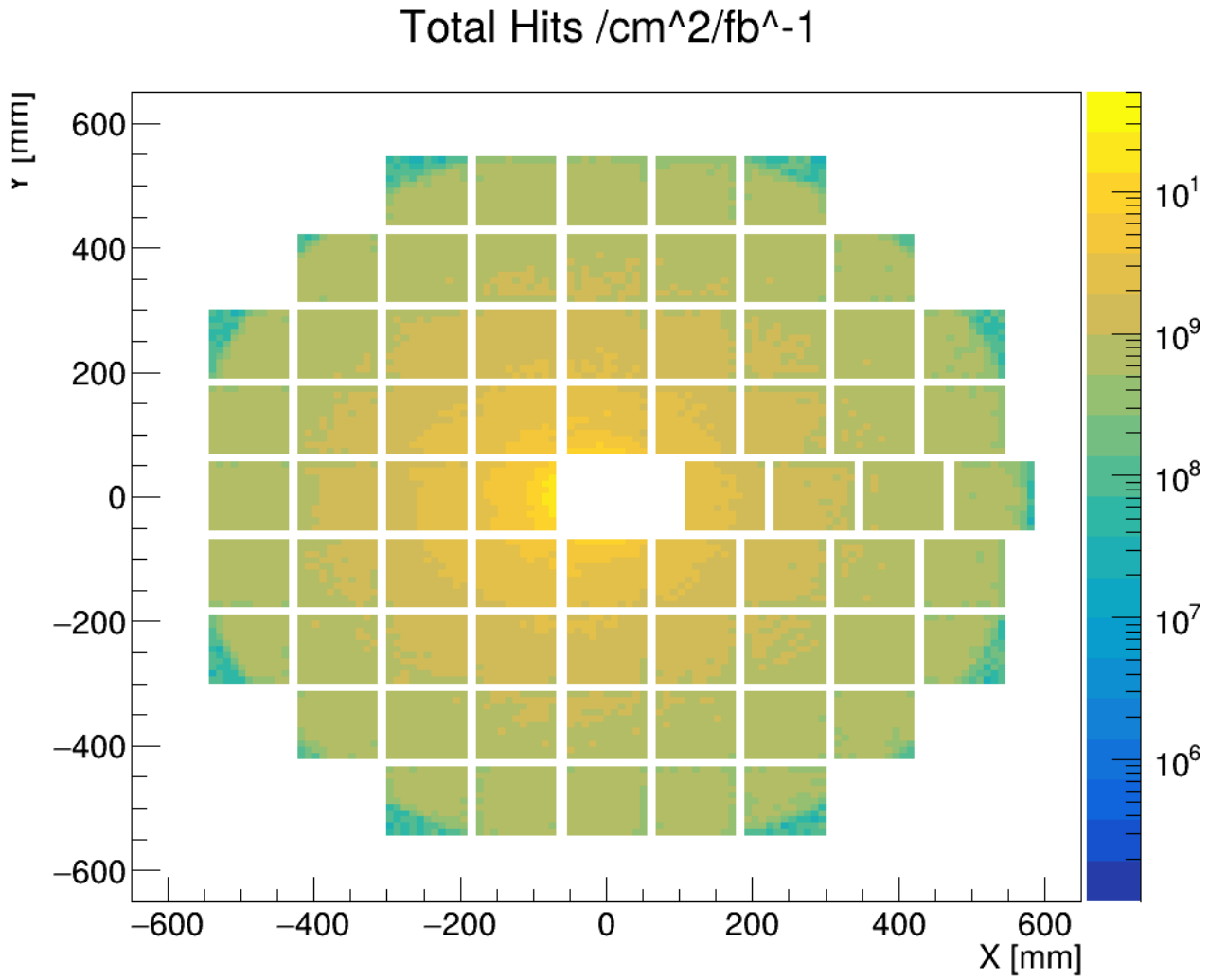


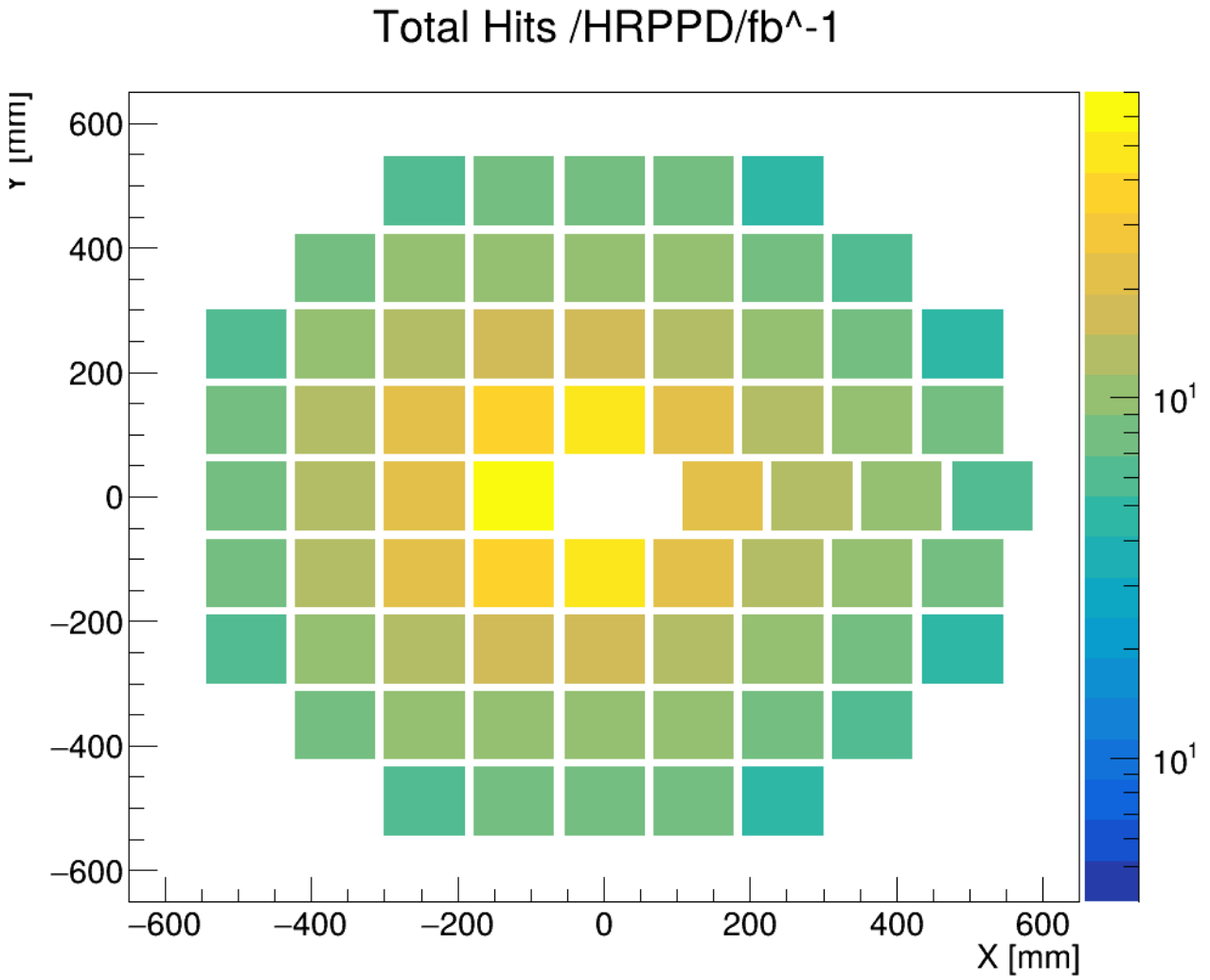


Signal Hit Frequency

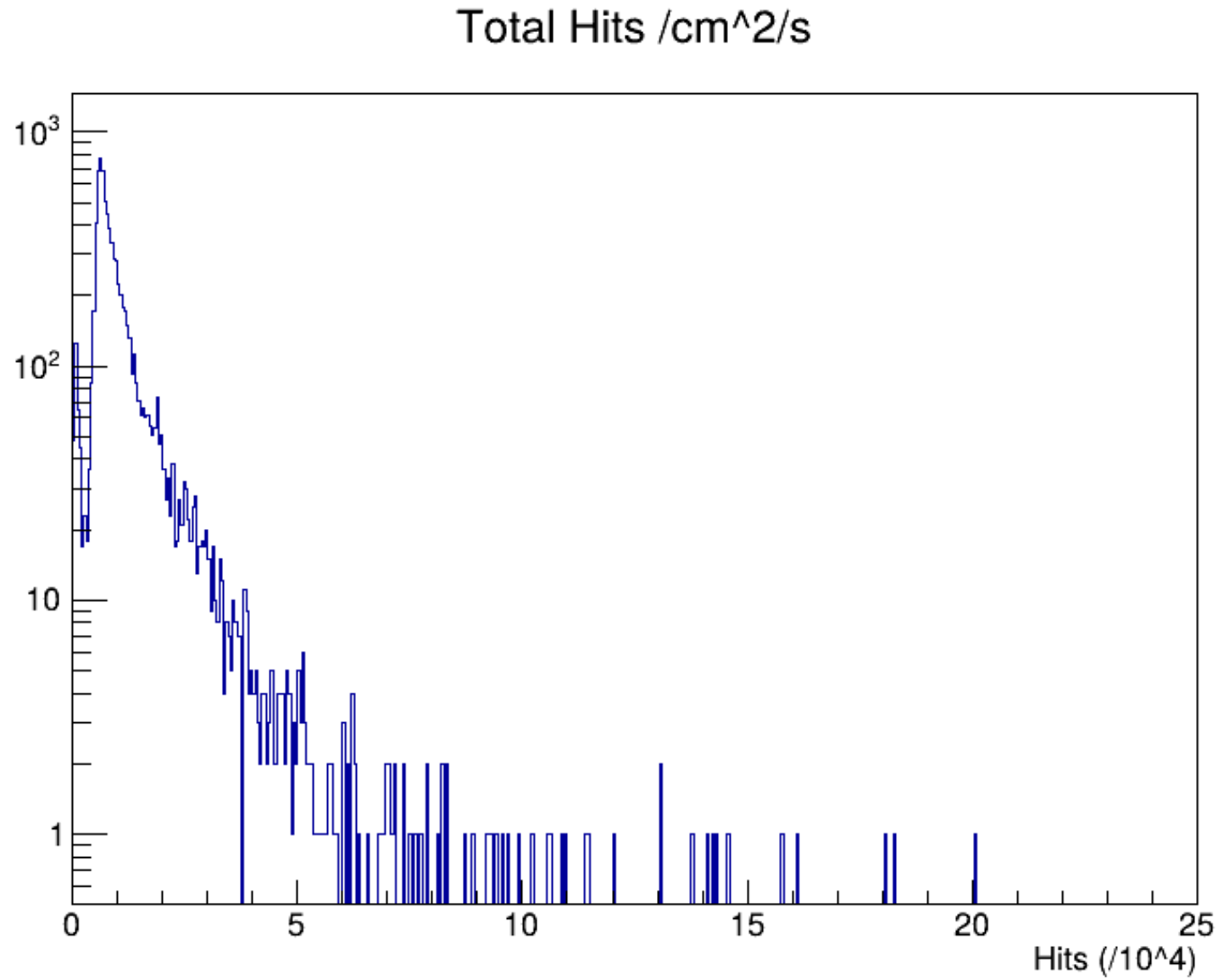


Background + Signal Hit Maps



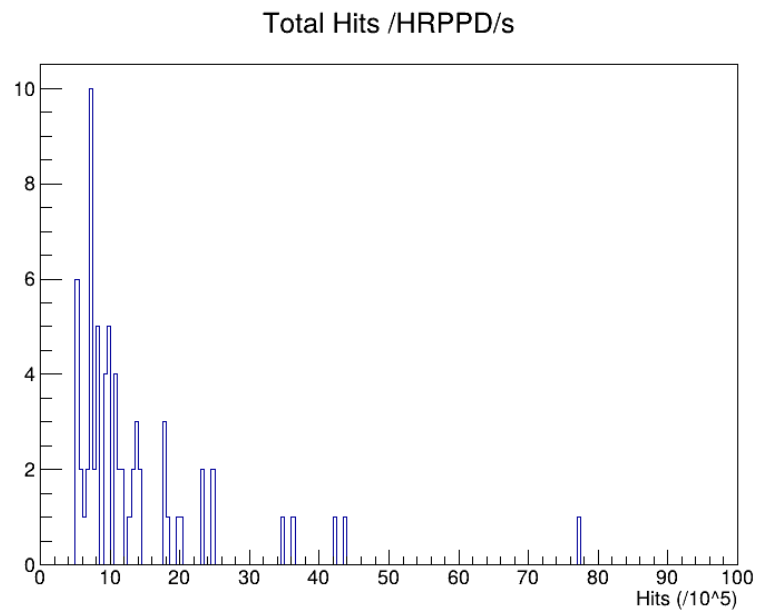


Background + Signal Hit Frequency



Data Rates

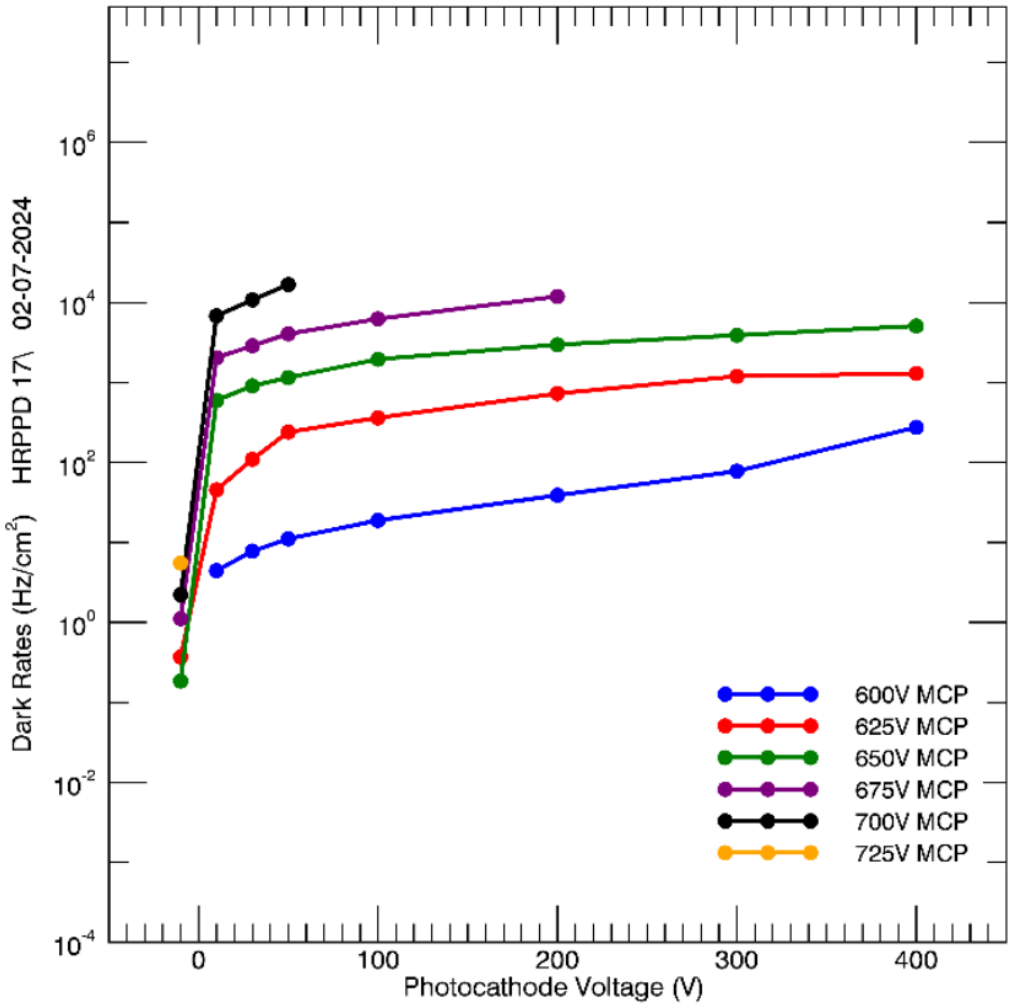
- Hit rate [/cm^2/s]
  - Hottest region: 200000
  - MPV: 6000
  - Peak region (75% of total): 5000 – 15000
- Convert Hit rate from /cm^2 to /pad: 9 pads occupy (0.325*3)^2 = 0.95 cm^2 -> Rate/pad = Rate/cm^2 * 0.95/9
- FCFD data assumption: 10 bit (5 ADC and 5 TDC) + 20% (guesstimate)
- Data rate [Mbps/pad]
  - Hottest region: 0.25
  - MPV: 0.01
  - Peak region: 0.01 – 0.02
- For the hottest HRPPD: hit rate = 7.7M/s -> data rate = 93 Mbps
- Total pfRICH sees ~90M hits/s or ~1.1 Gbps
  - 80M Backgrounds hits/s
  - 10M Signal hits/s
- lpGBT+VTRX+ bandwidth of 7.7 Gbps -> lots of room



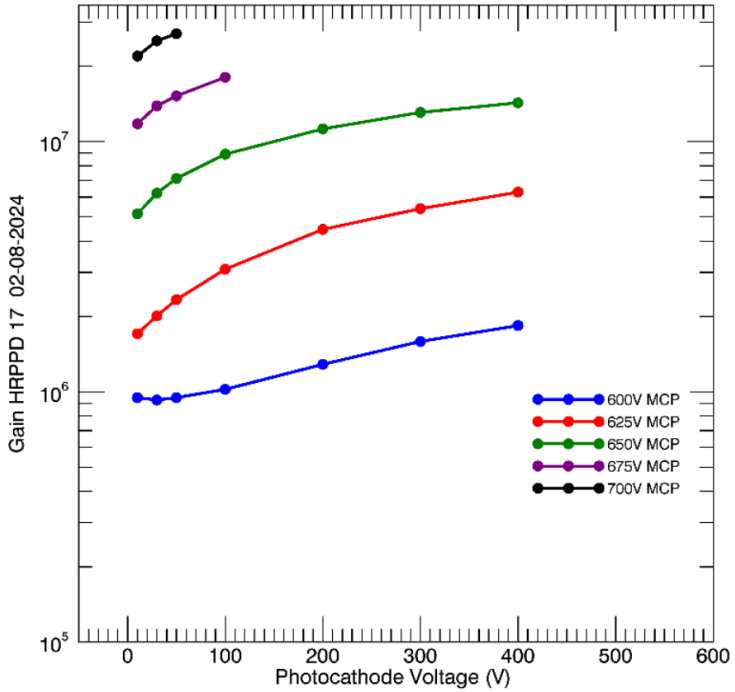
HRPPD Damage

- Prolonged operation can degrade the photocathode, affecting gain
- Generally quantify this degradation in terms of extracted charge from the anode
  - Hits * Gain / electrons/coulomb
- Assume gain of 10^5 or 10^6
- Assume 1 year = 26 weeks @ 24h per day (yes, duty cycle is too high)
- Extracted Charge @ Gain = 10^5 [C/cm^2/year]:
  - Hottest Region: 0.05
  - MPV: 0.002

Dark Count Rates



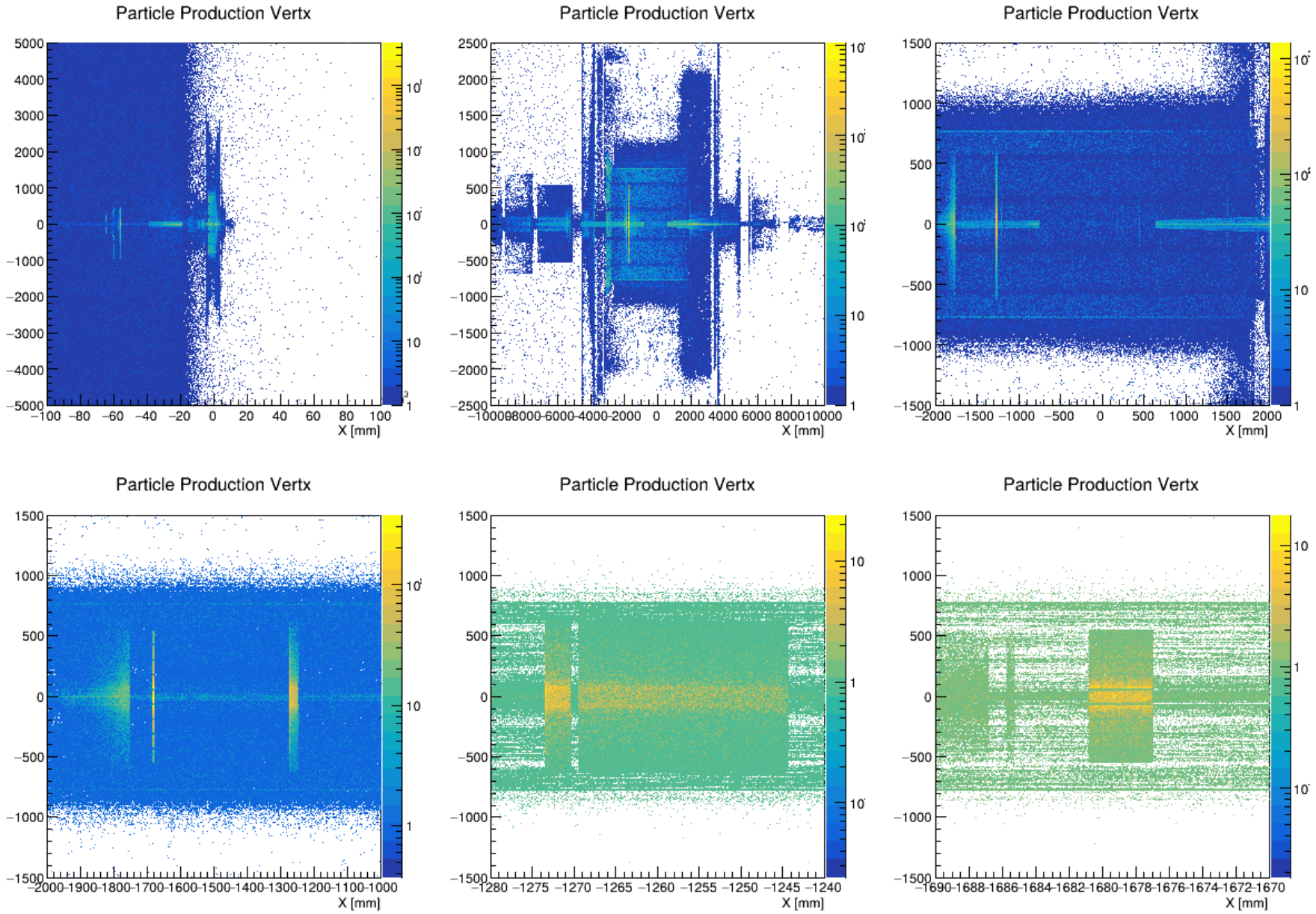
- Assuming we work at gains of a few times 10^6, we can likely expect dark rates around 100 Hz/cm^2
- Even at gains of 10^7, we would get a few KHz/cm^2
- Machine background will dominate everywhere except at the very edges of our acceptance



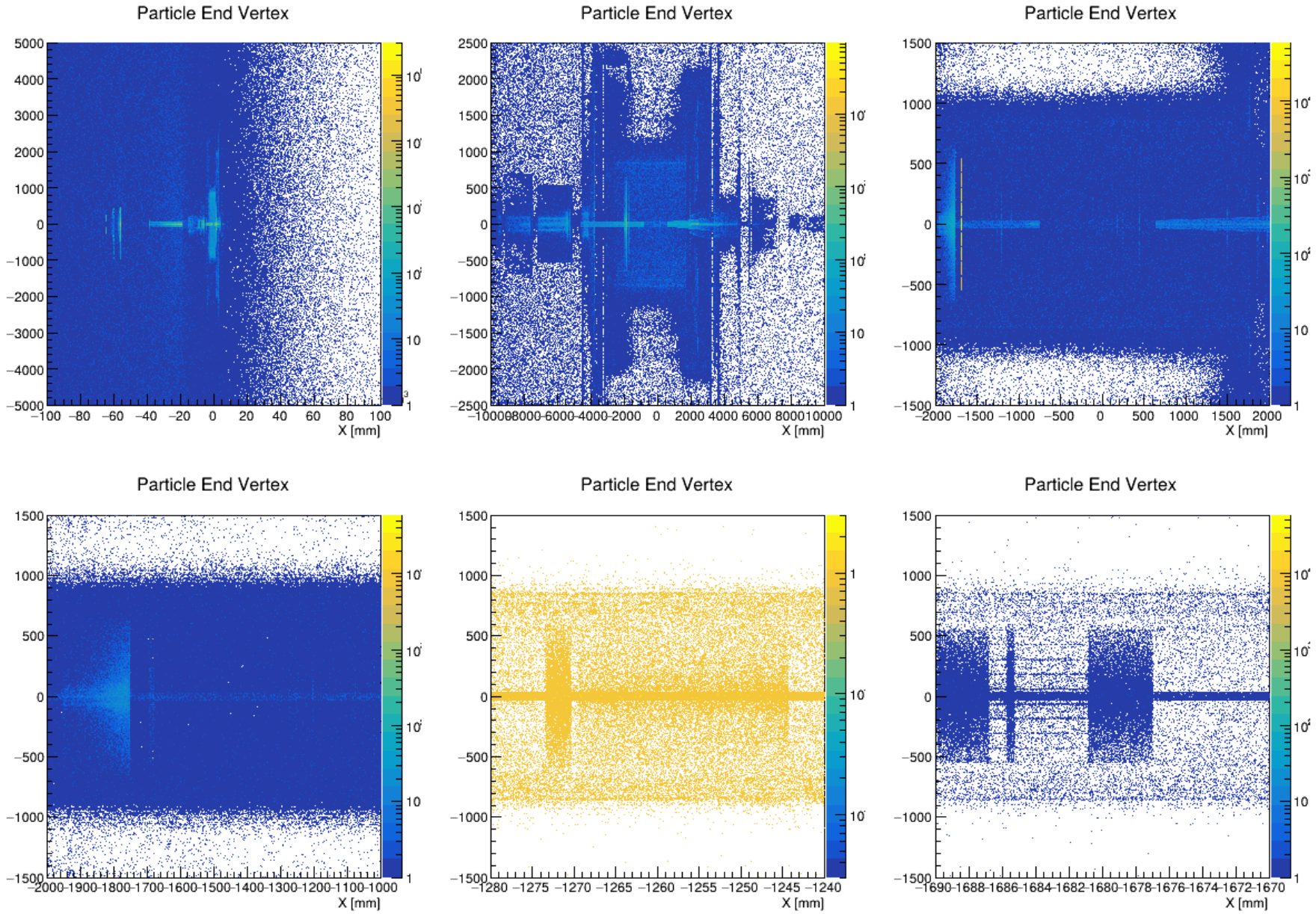
Summary

- pfRICH occupancy presented for 10x275 with all background and signal sources included
- Hottest regions of the detector (near beam pipe) see up to 200K hits/cm^2/s, but the but the bulk of the detector will see about an order of magnitude less
- pfRICH will see about 8x more background hits than signal (dark count rate should be negligible)
  - Implications for reconstruction can be discussed at another meeting, but early indications are that this is not as much of a problem as it seems
- With assumption of 12 bit output per hit, data rates are extremely manageable -> cushion to absorb higher than expected background rates and/or expand output data size
- Extracted charge calculated for aging studies
- Next steps
  - Cross check with official campaigns once irt-2 fully merged
  - Present “statistical” evaluation of signal and background overlap
  - Evaluate full reconstruction in the presence of background using irt-2

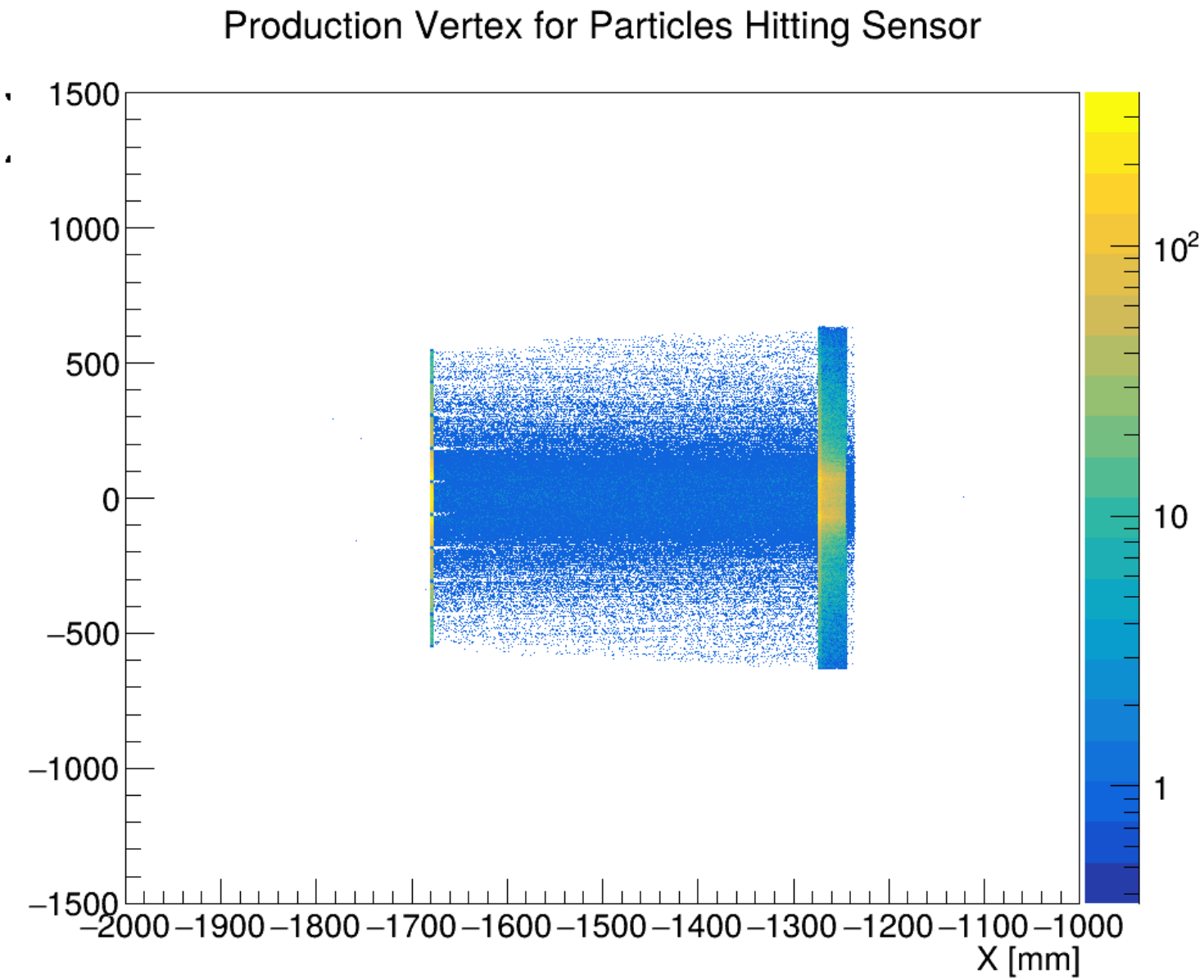
Electron Beam Gas: Production Vertex



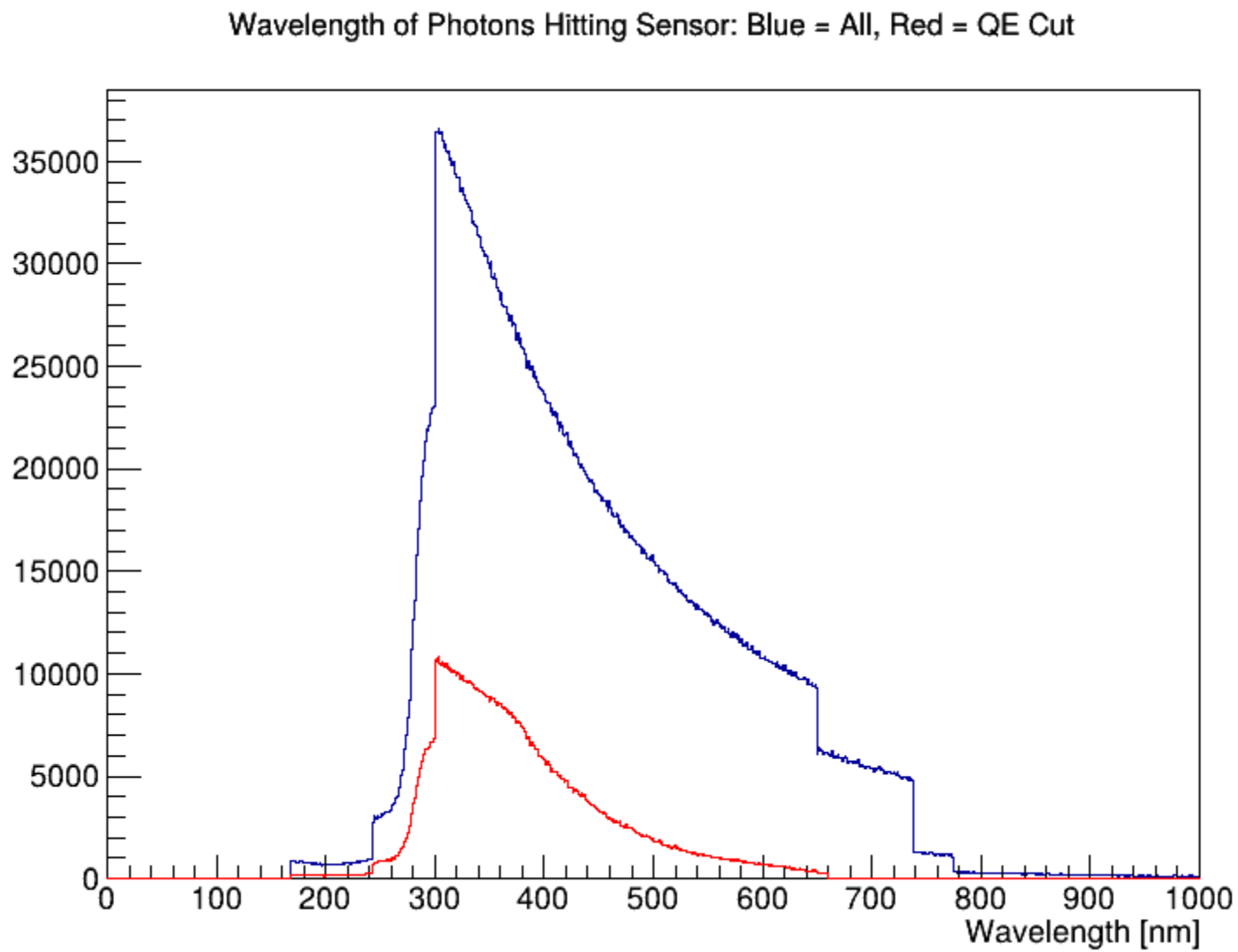
Electron Beam Gas: End Vertex



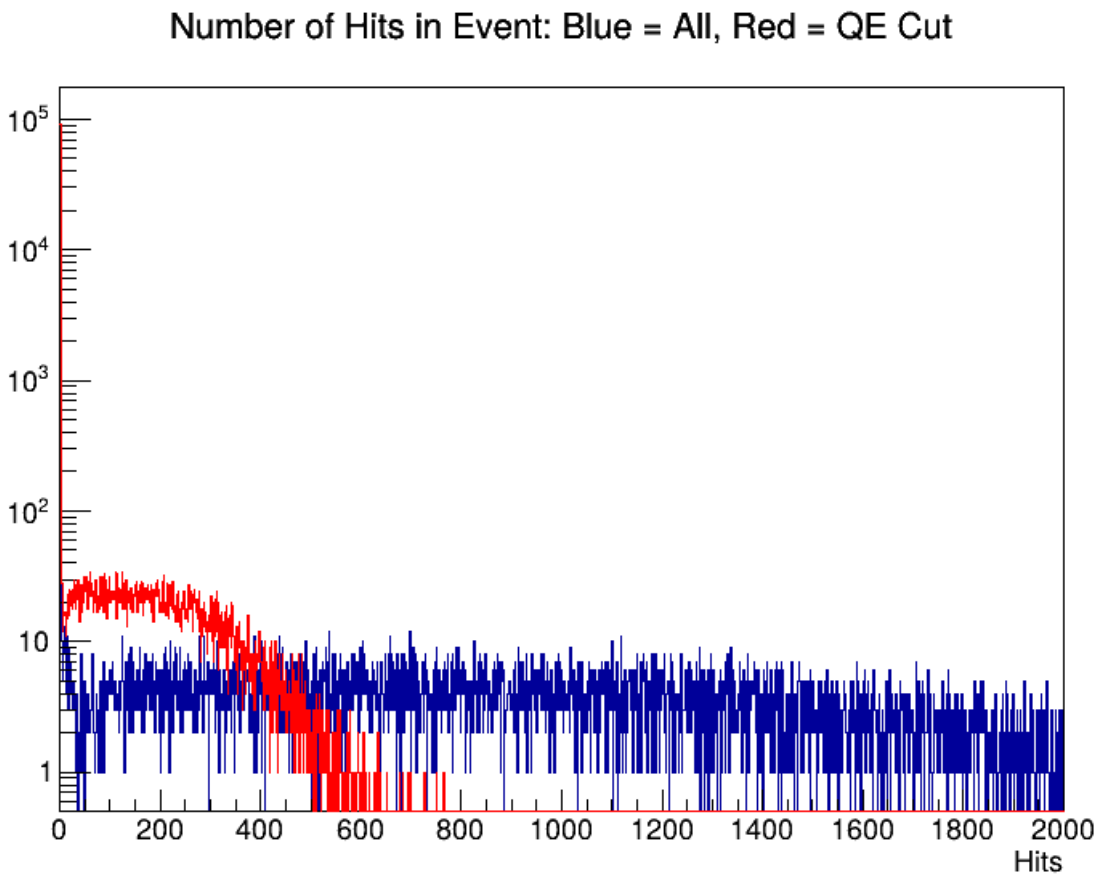
Electron Beam Gas: “Last Scatter” Before Sensor

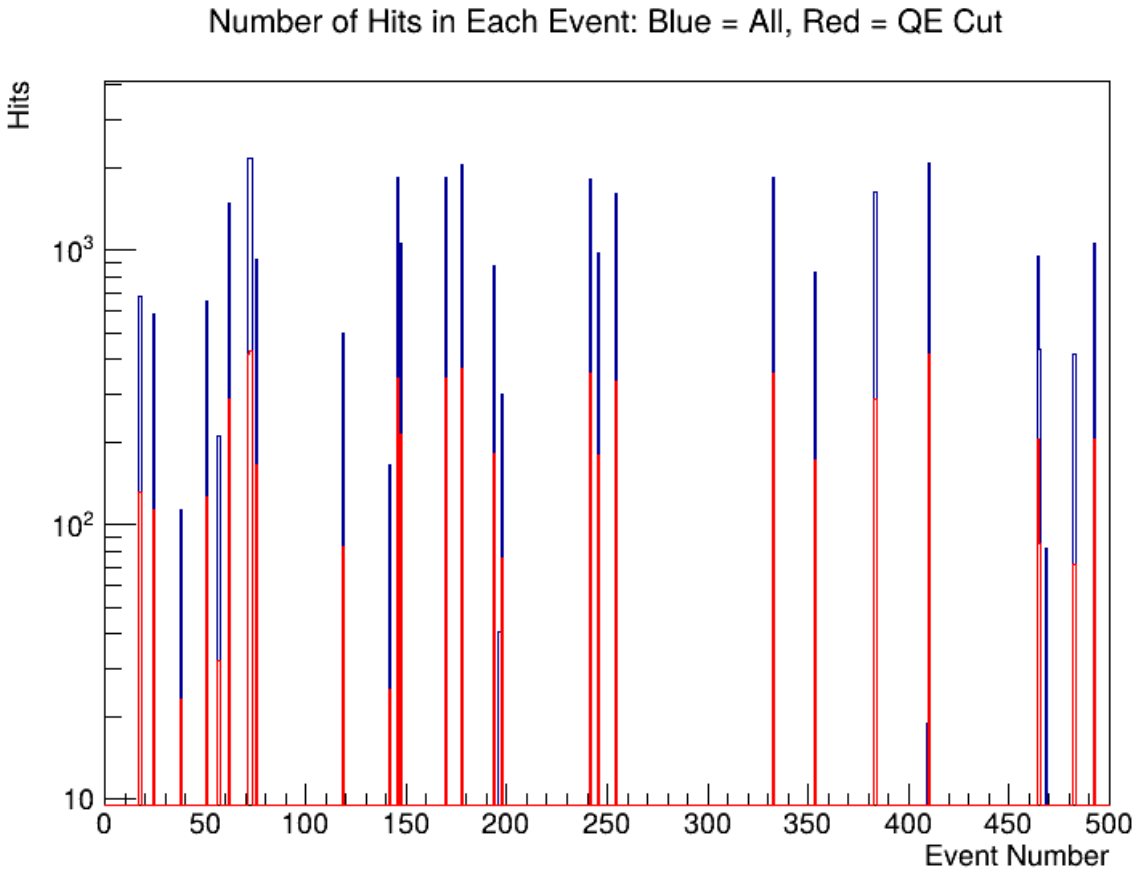


Electron Beam Gas: Photon Wavelength

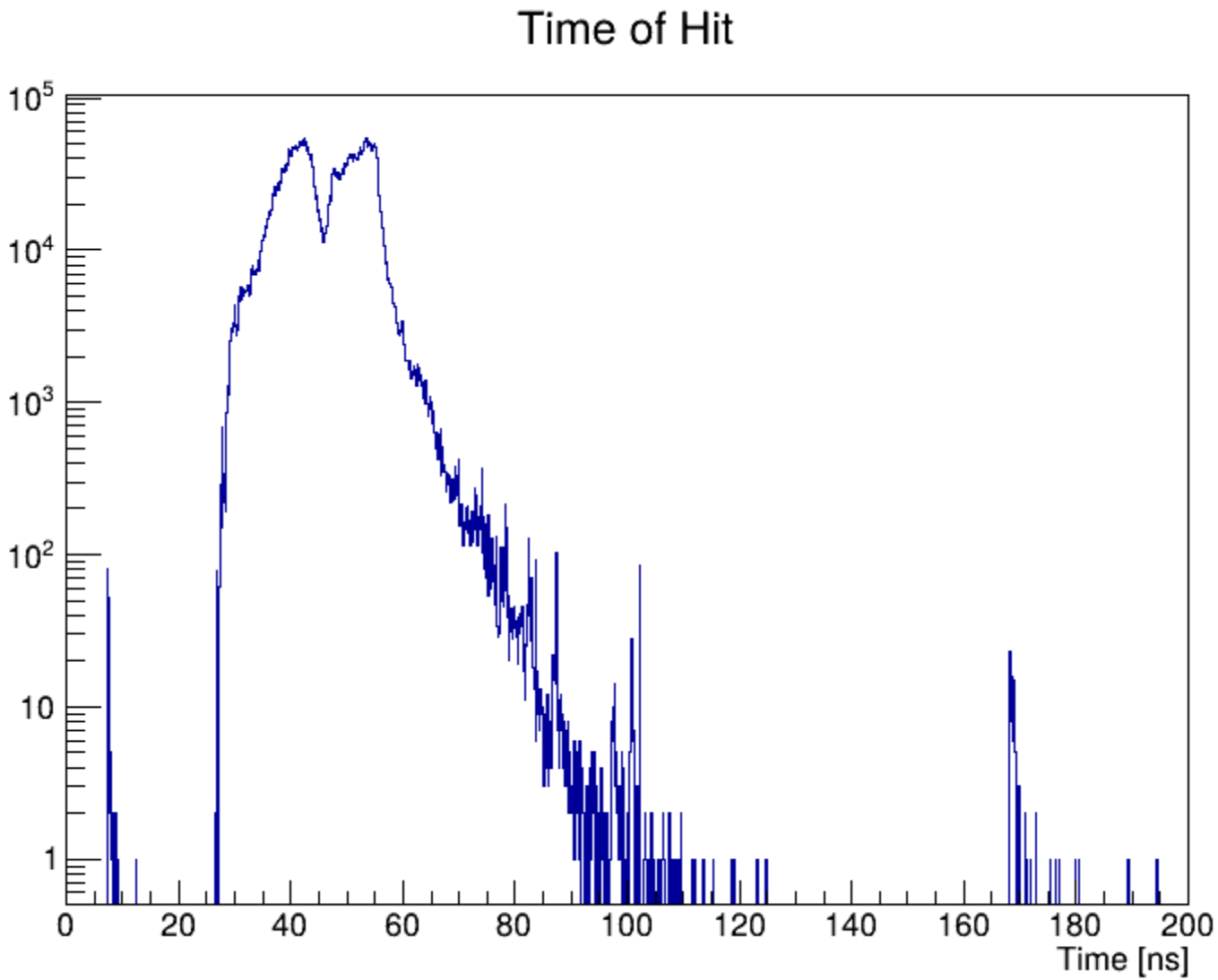


Electron Beam Gas: Event Hit Structure

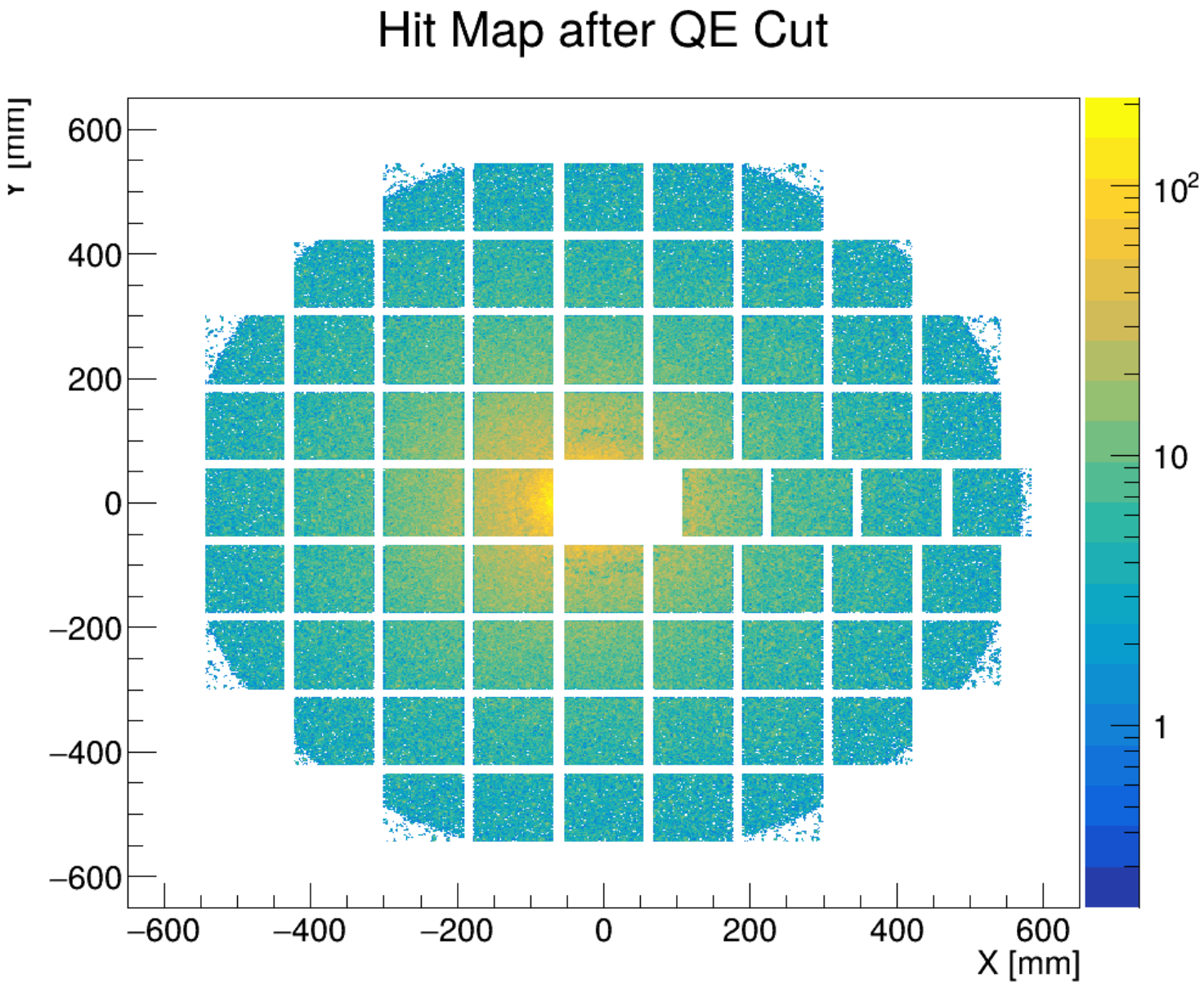




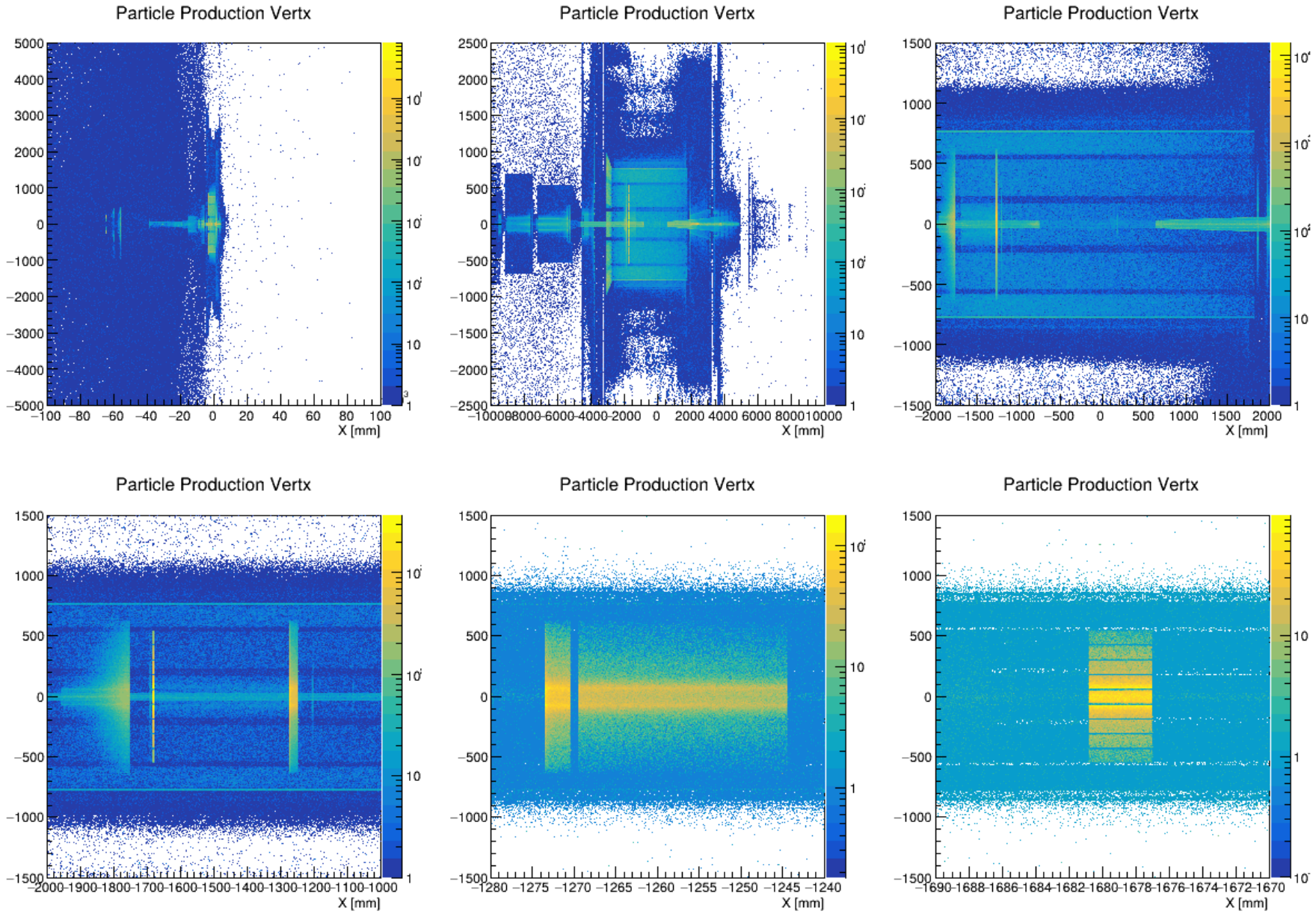
Electron Beam Gas: Hit Times



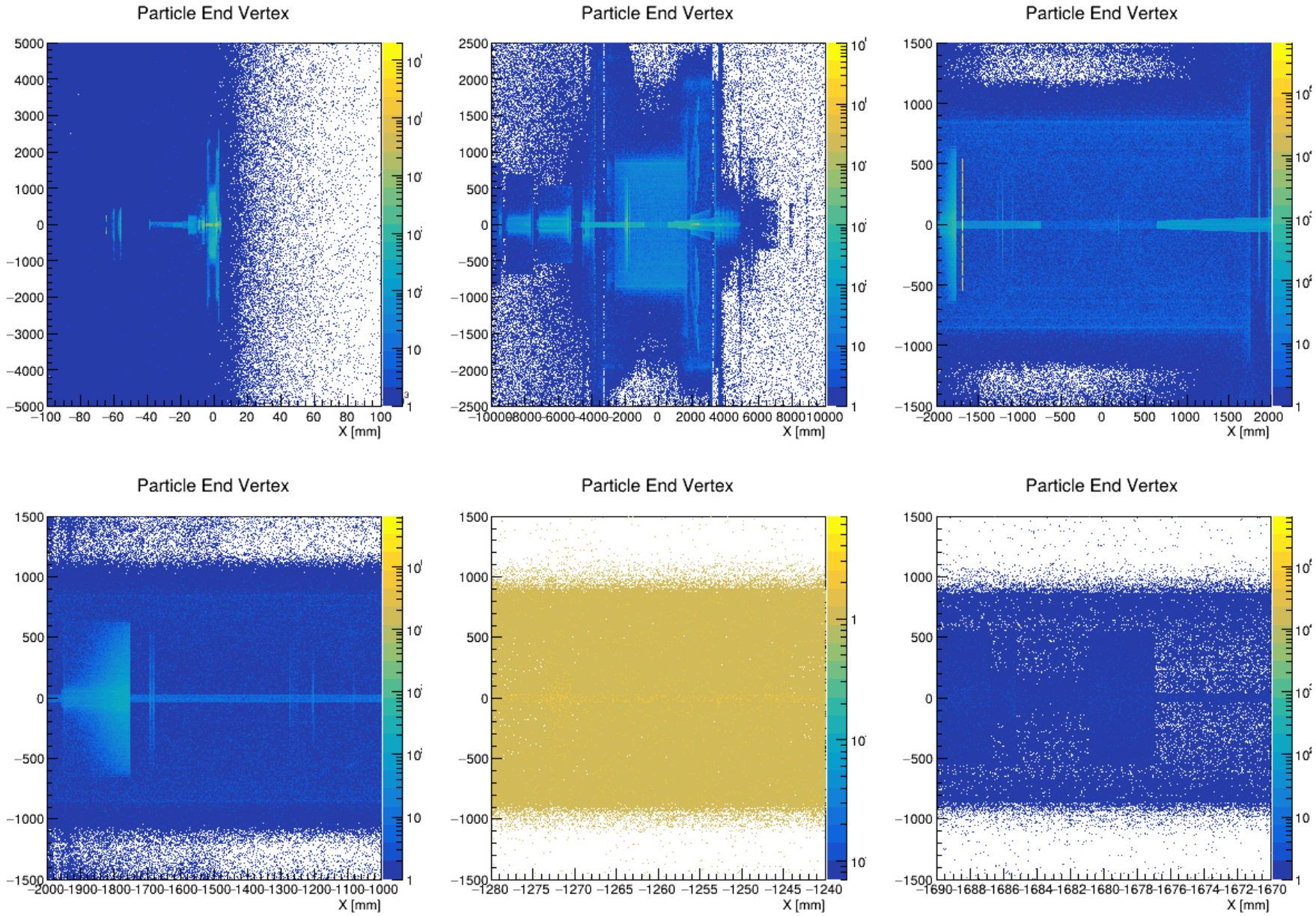
Electron Beam Gas: Hit Map After QE Cut



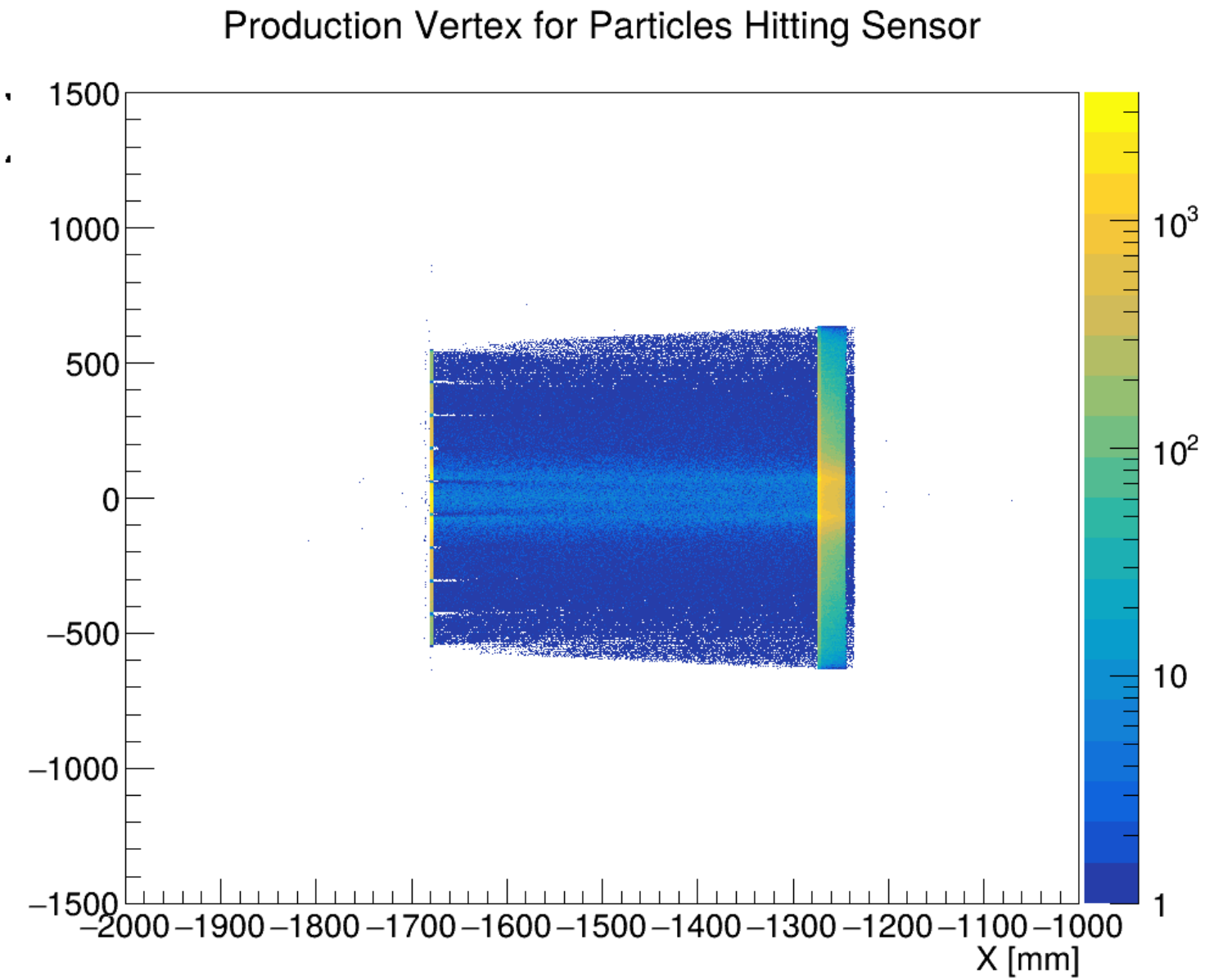
Coulomb: Production Vertex



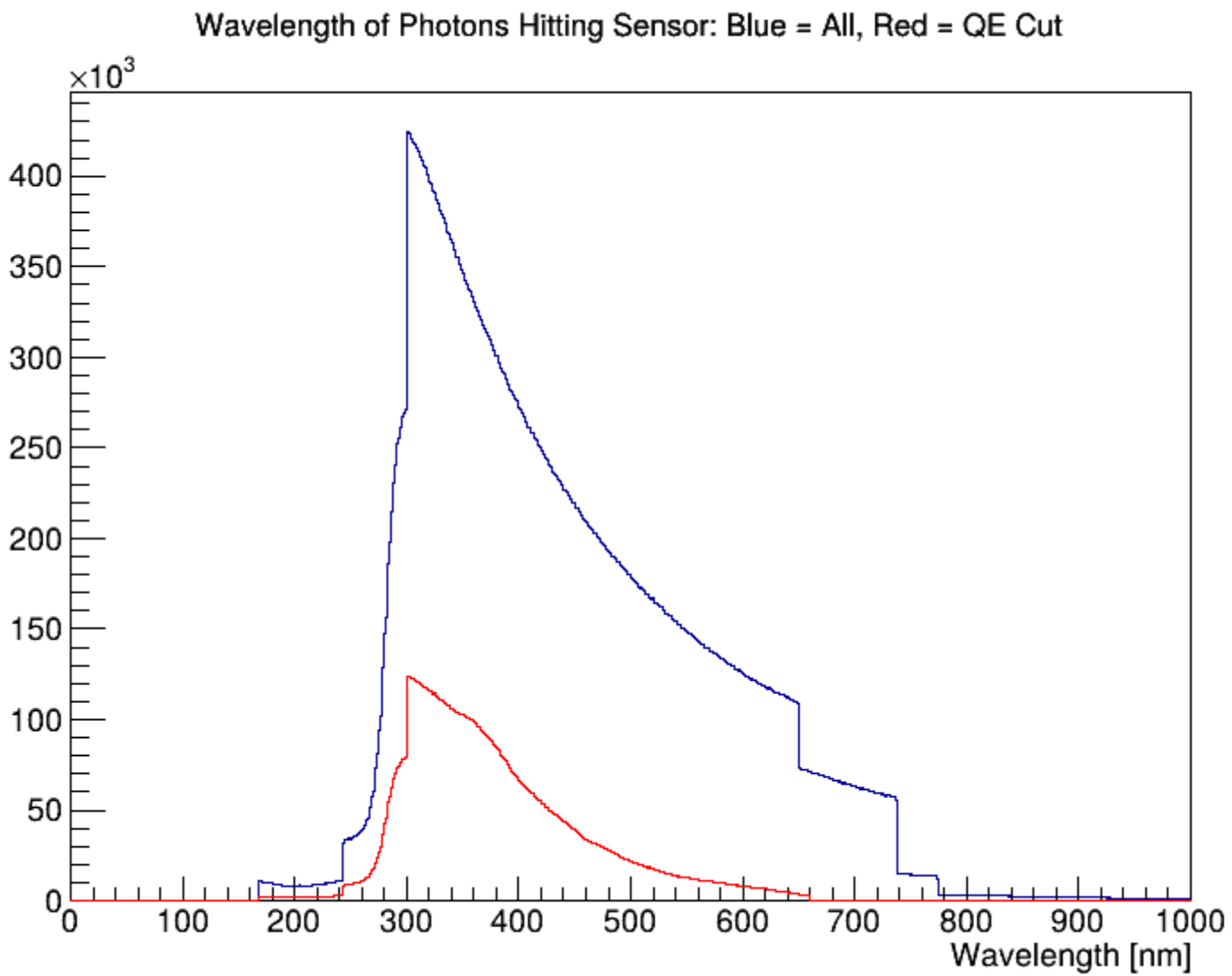
Coulomb: End Vertex



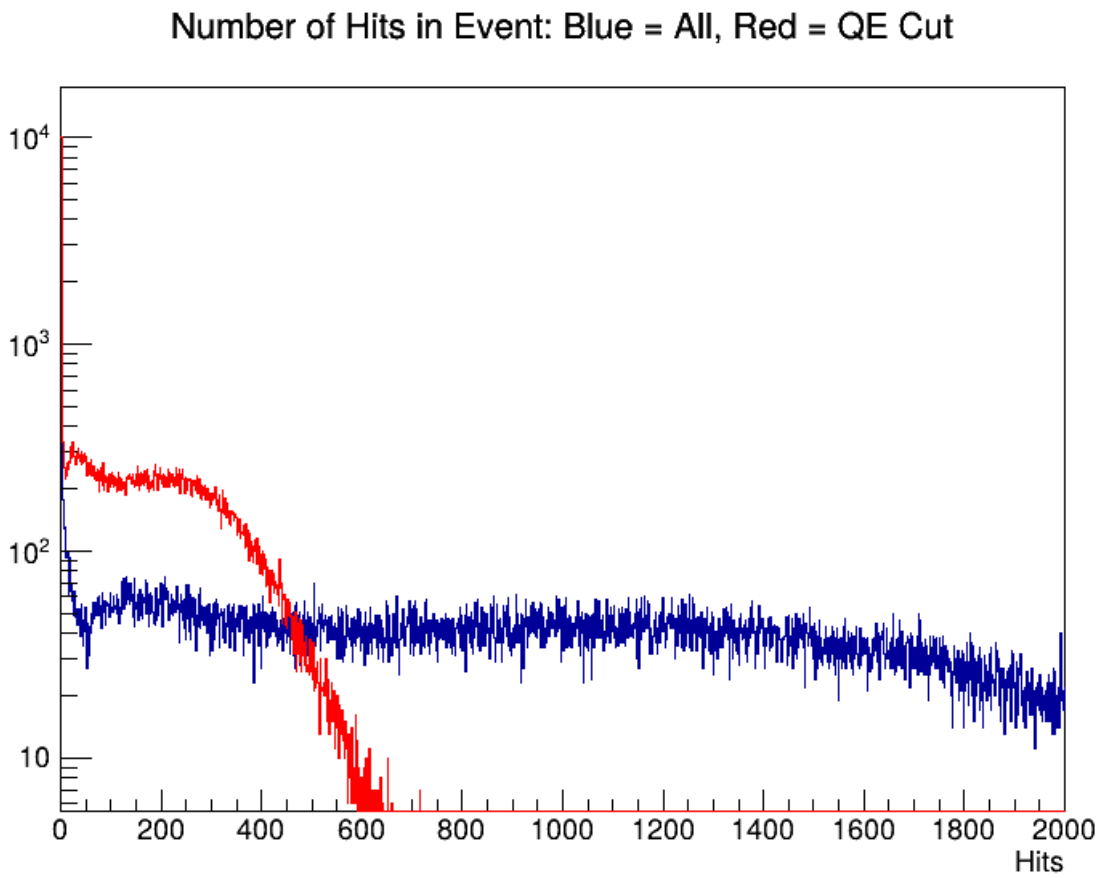
Coulomb: “Last Scatter” Before Sensor

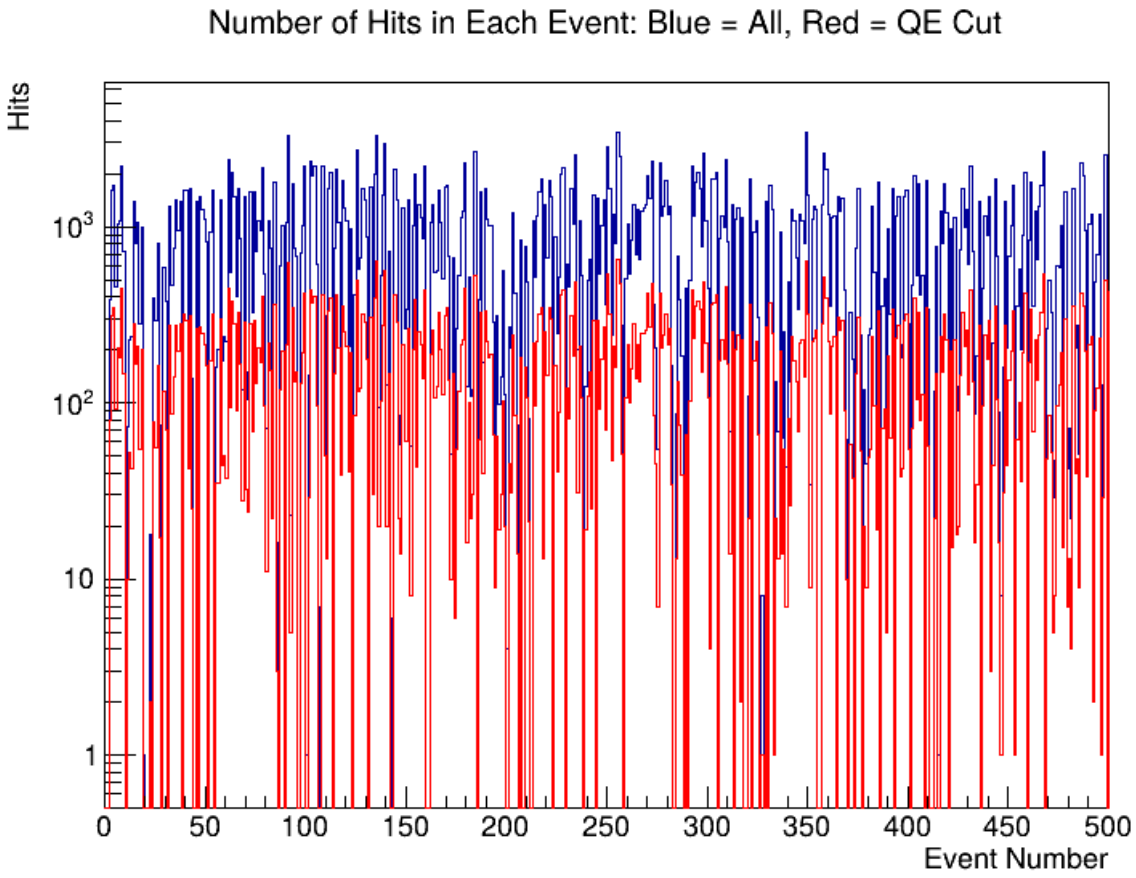


Coulomb: Photon Wavelength

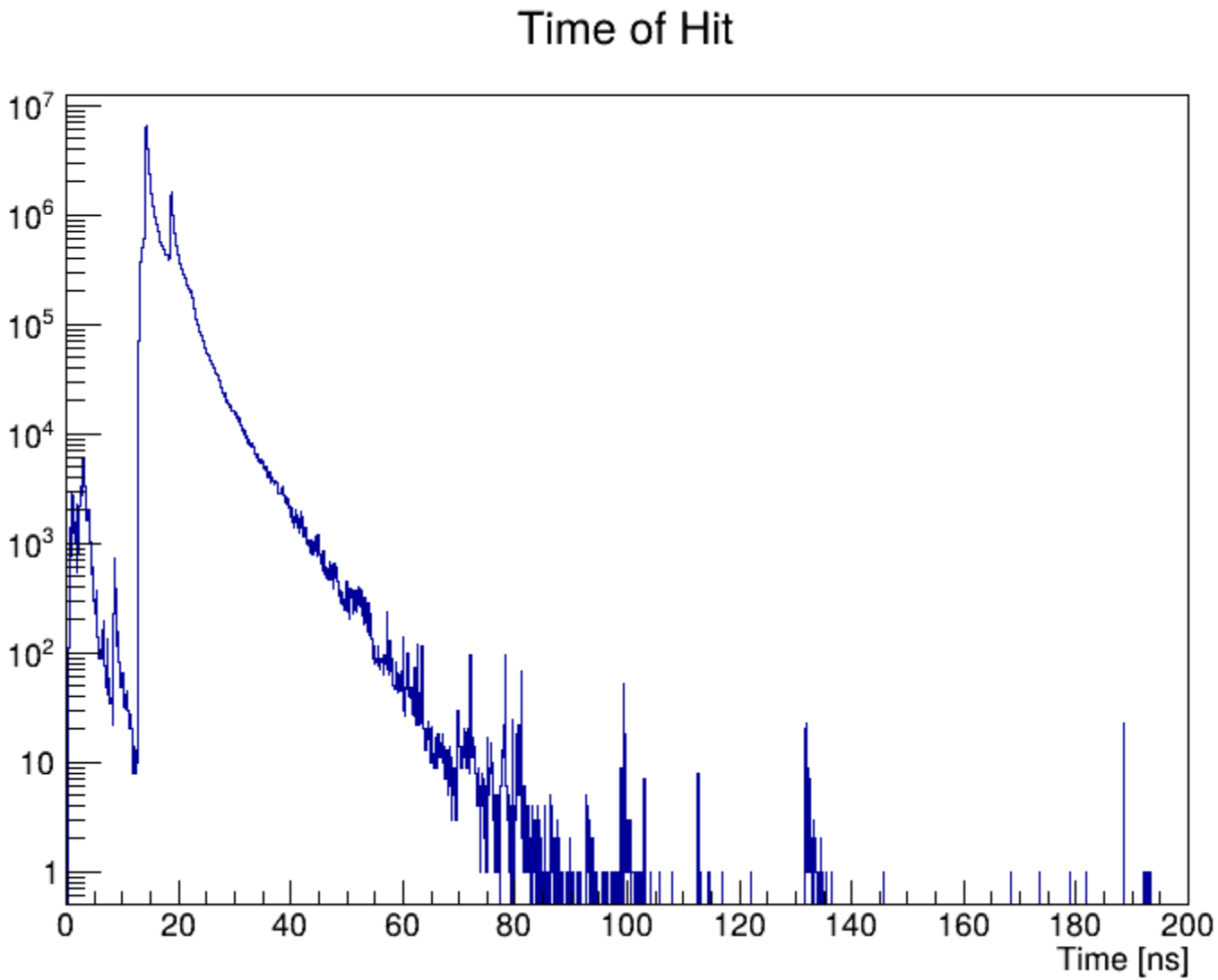


Coulomb: Event Hit Structure

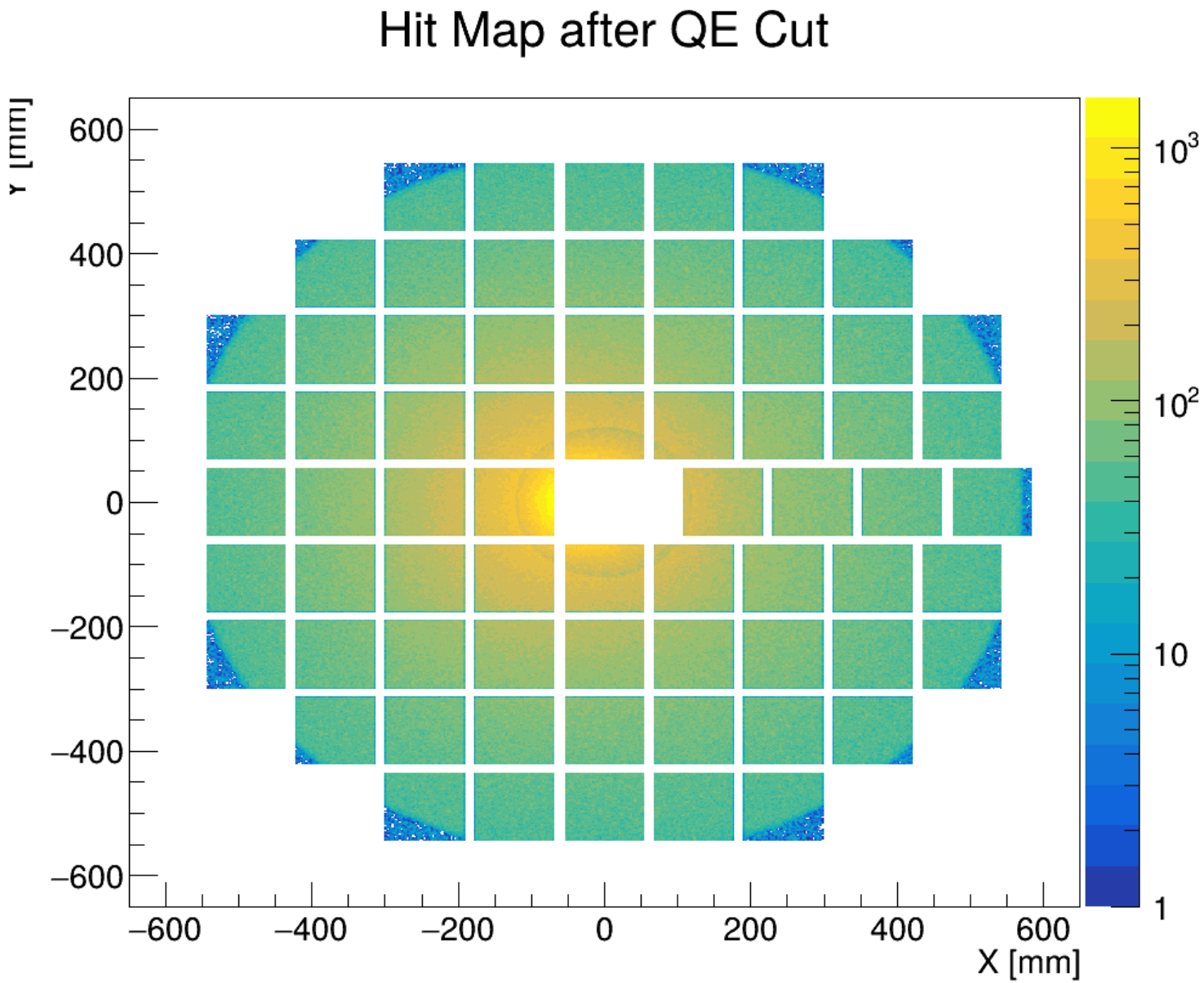




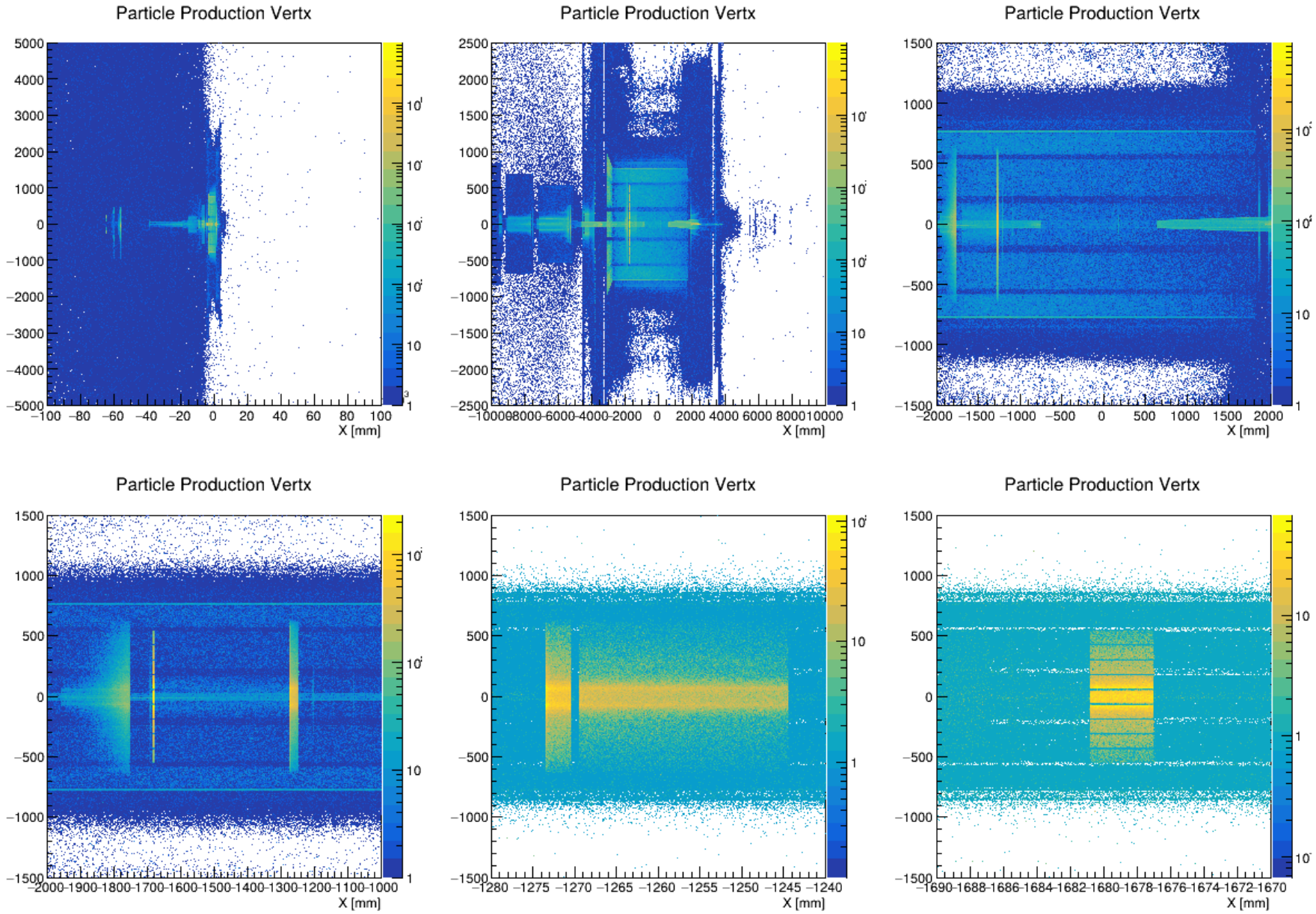
Coulomb: Hit Times



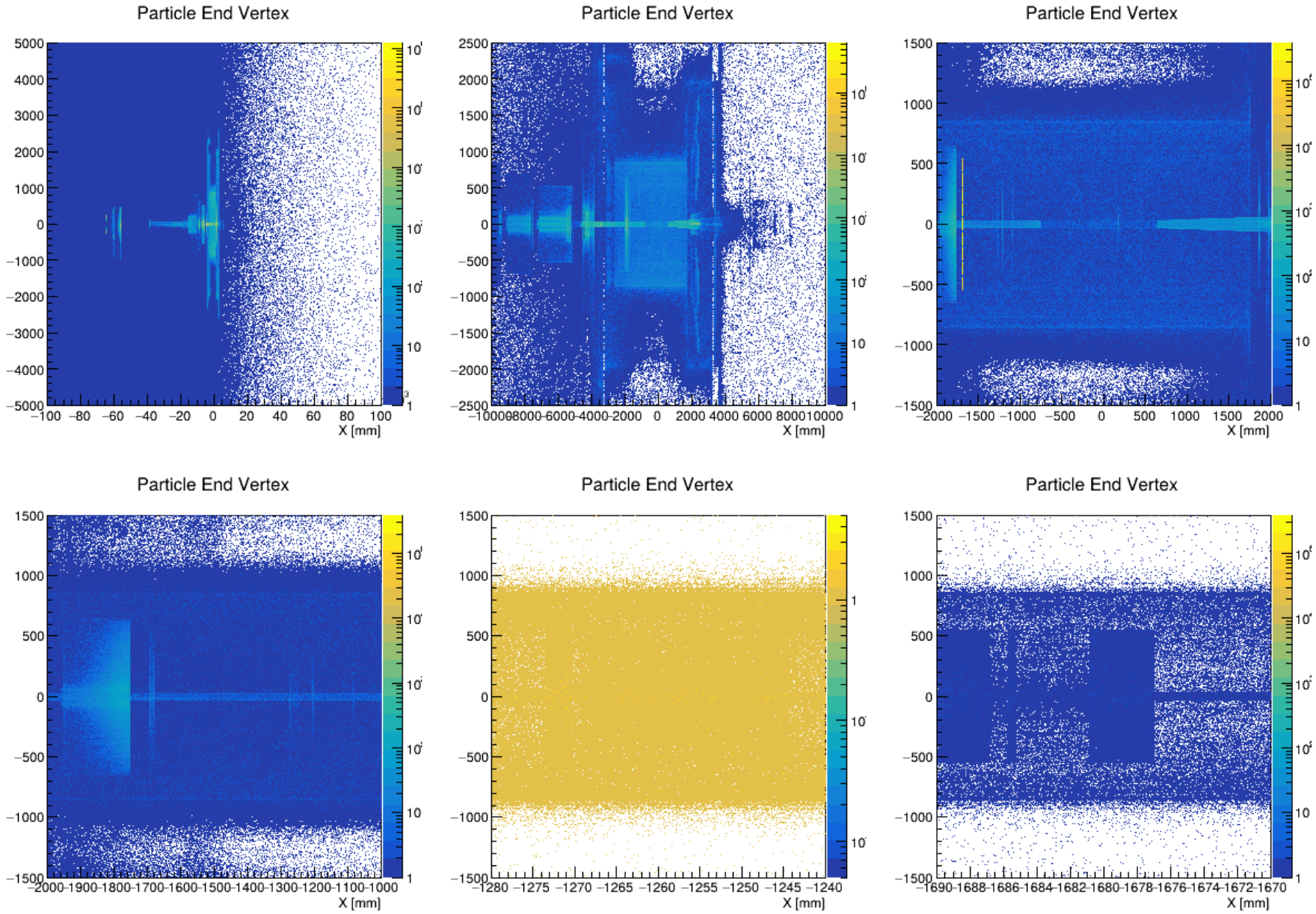
Coulomb: Hit Map After QE Cut



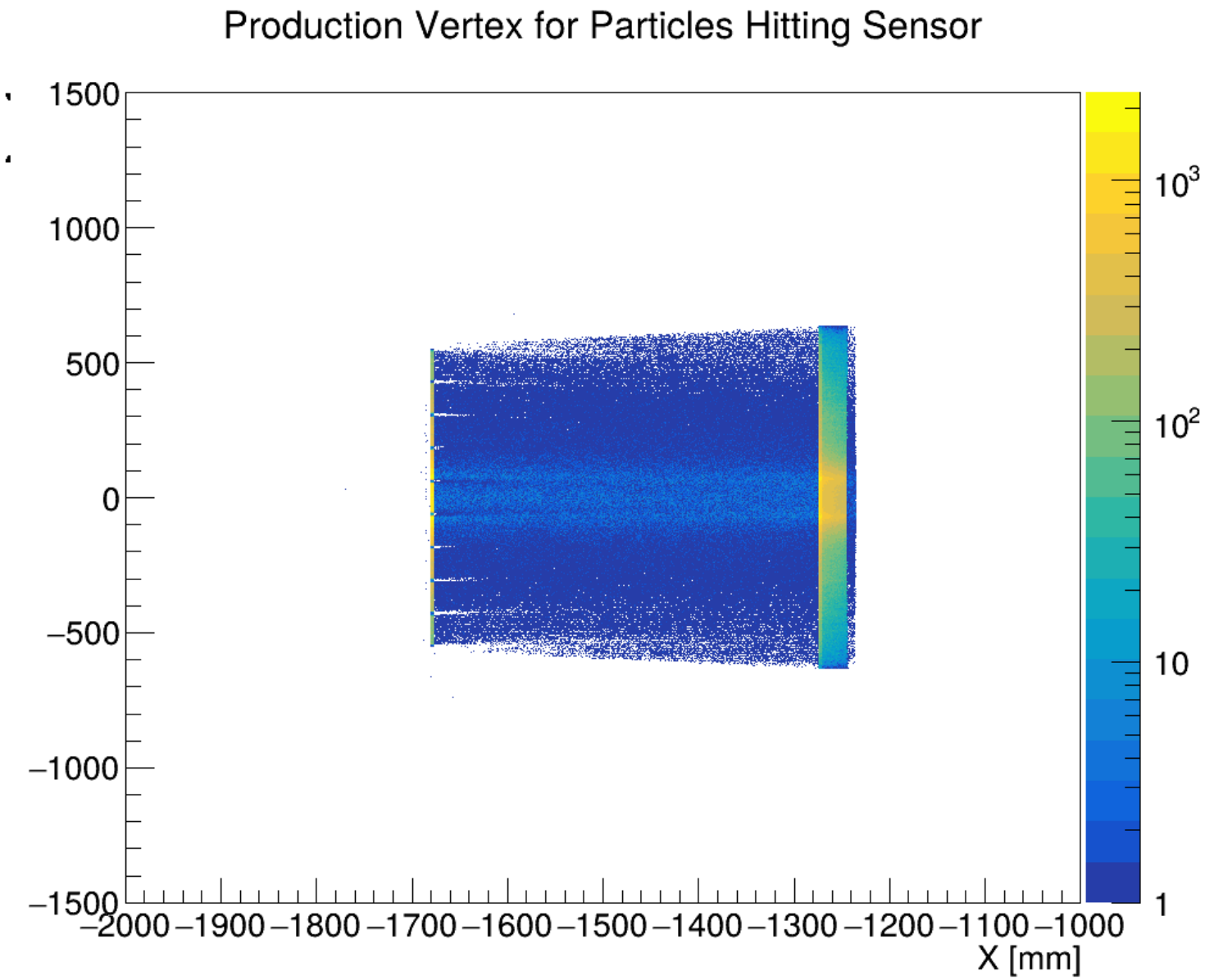
Touschek: Production Vertex



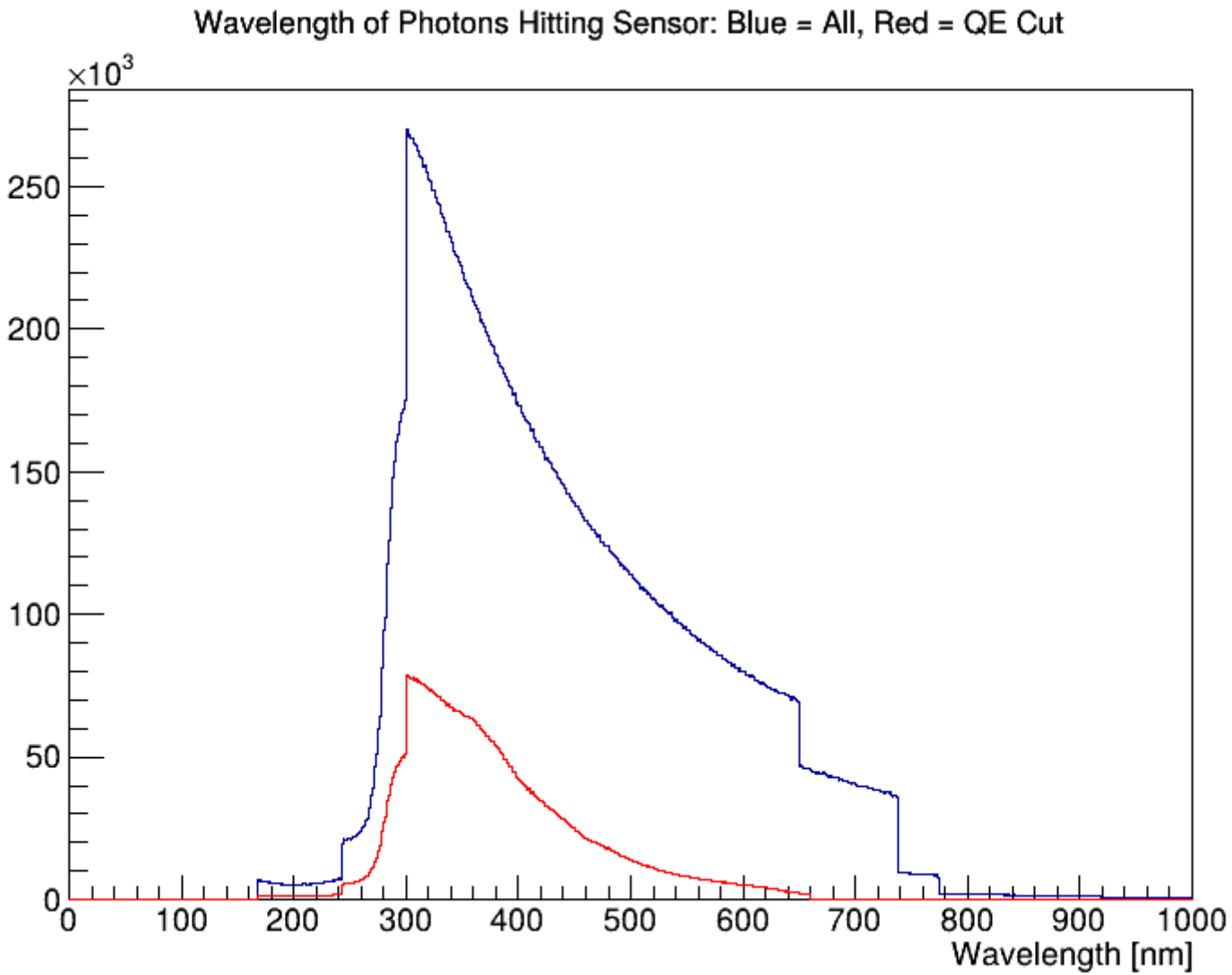
Touschek: End Vertex



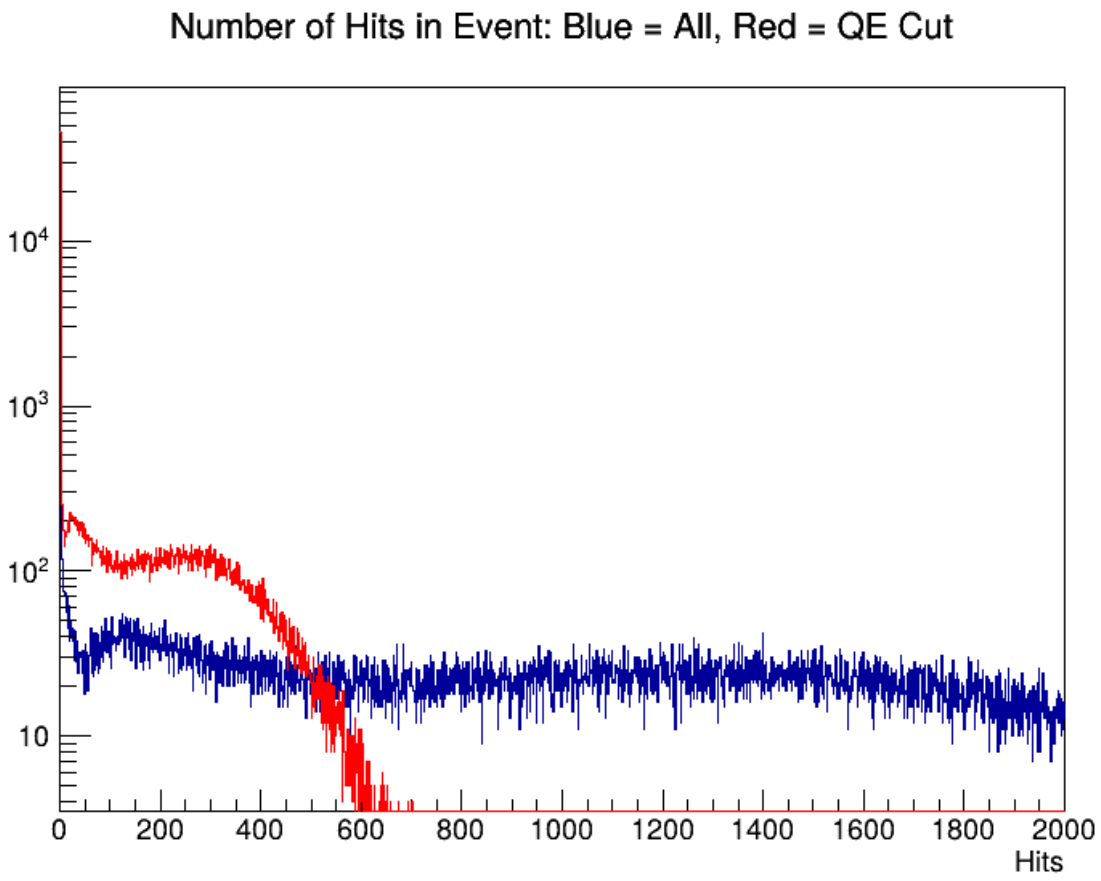
Touschek: “Last Scatter” Before Sensor

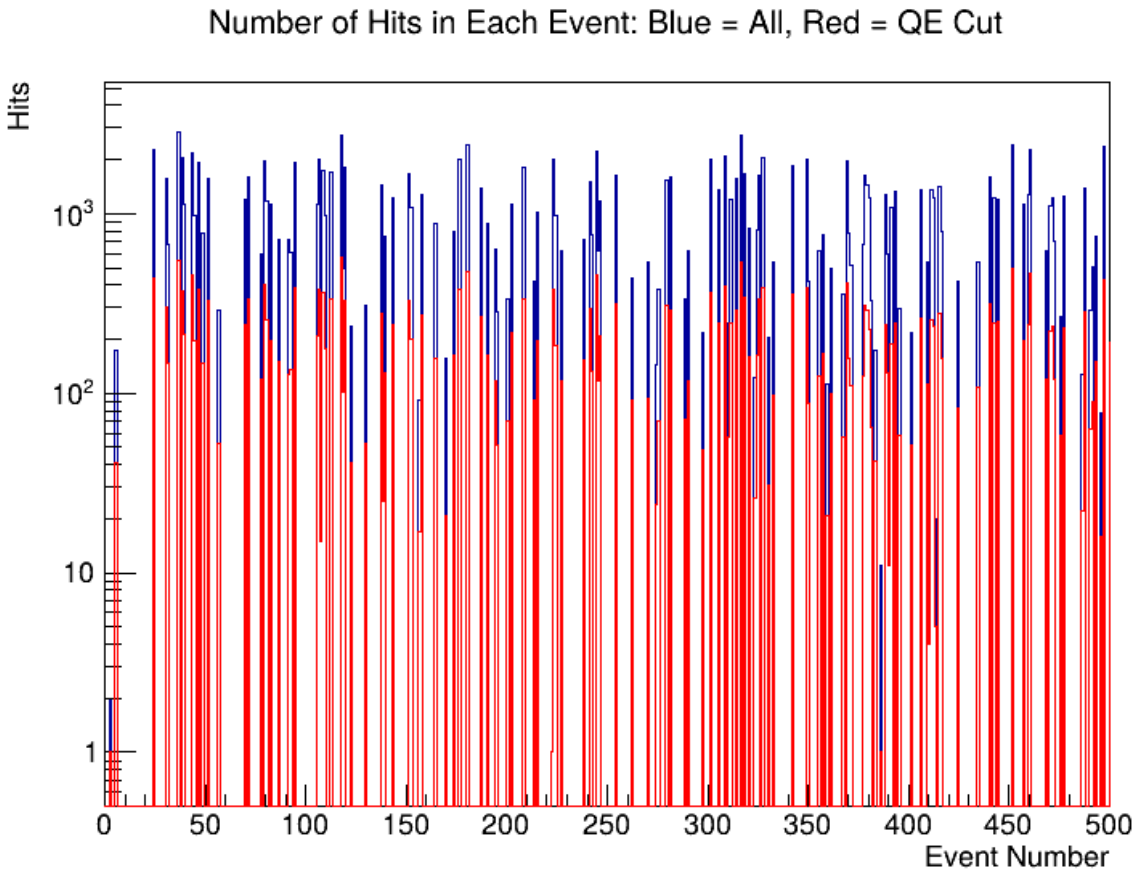


Touschek: Photon Wavelength

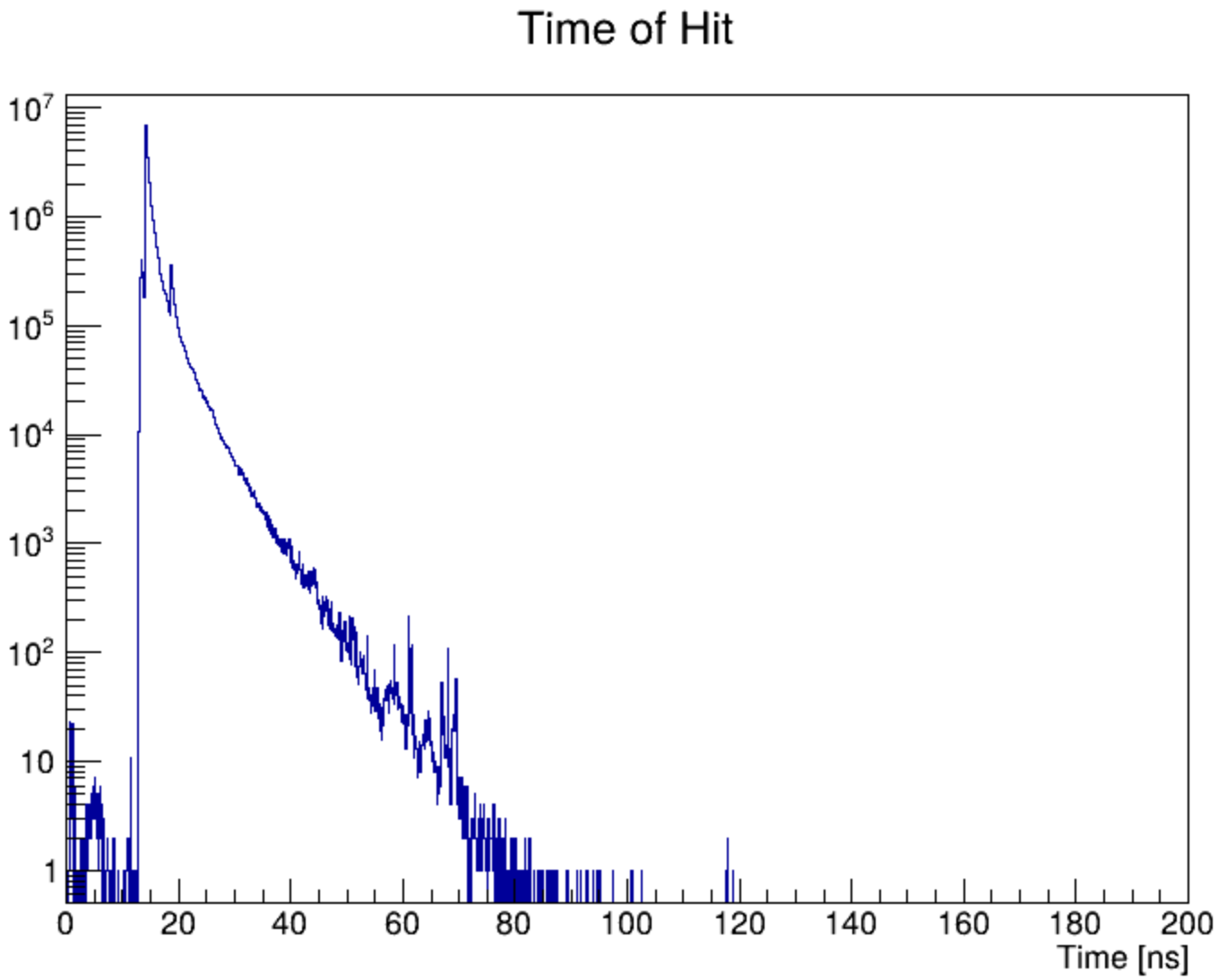


Touschek: Event Hit Structure

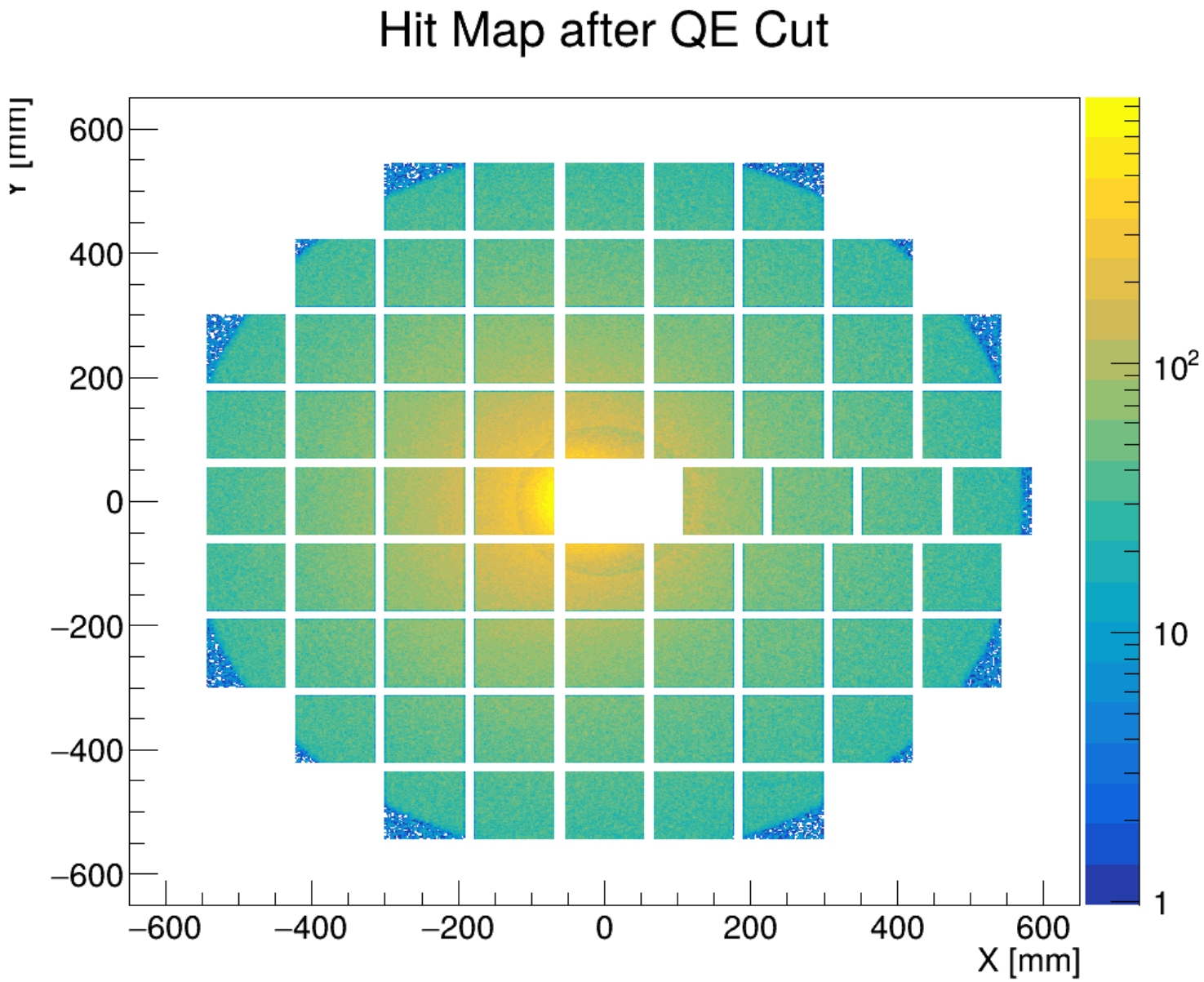




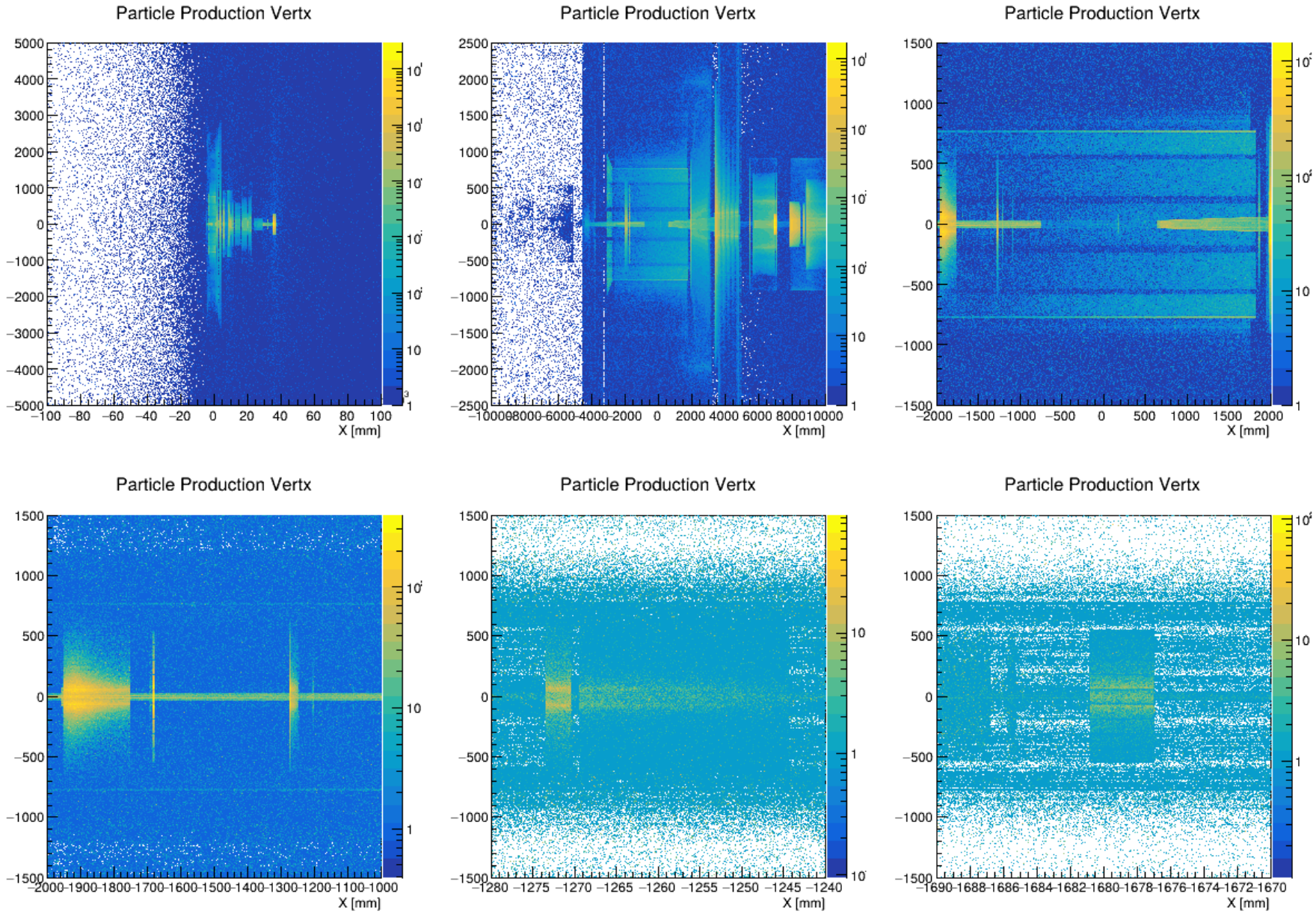
Touschek: Hit Times



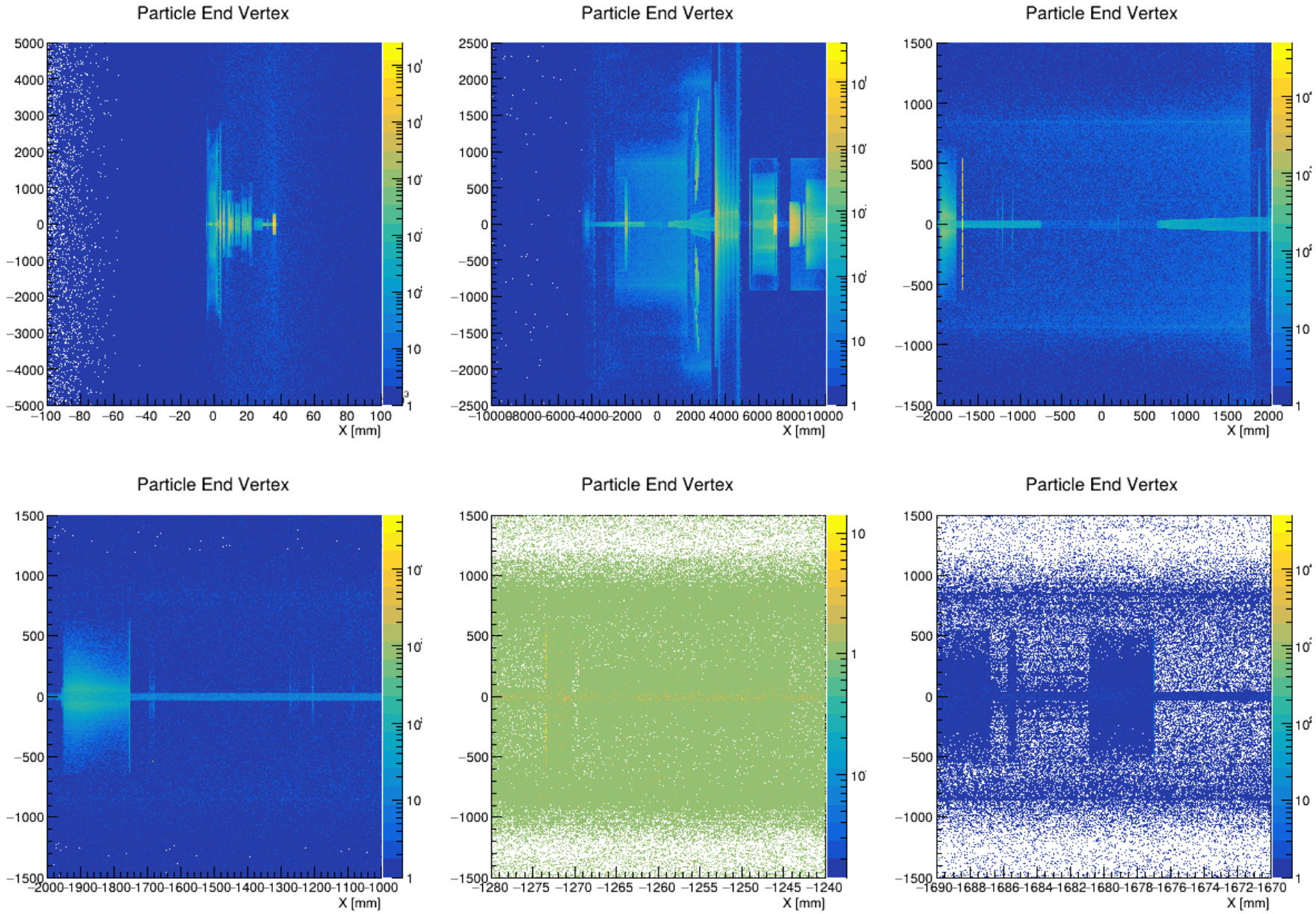
Touschek: Hit Map After QE Cut



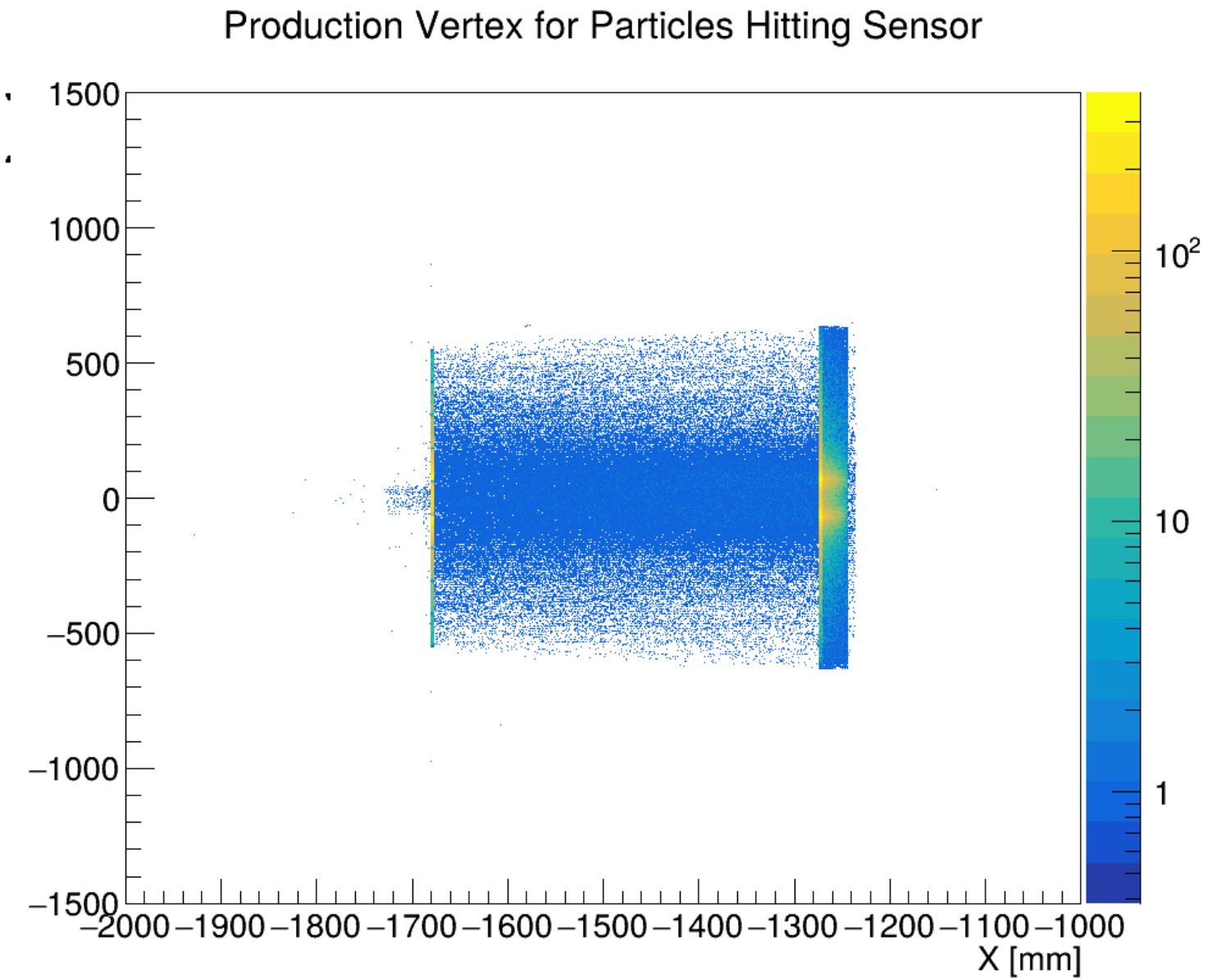
Proton Beam Gas: Production Vertex



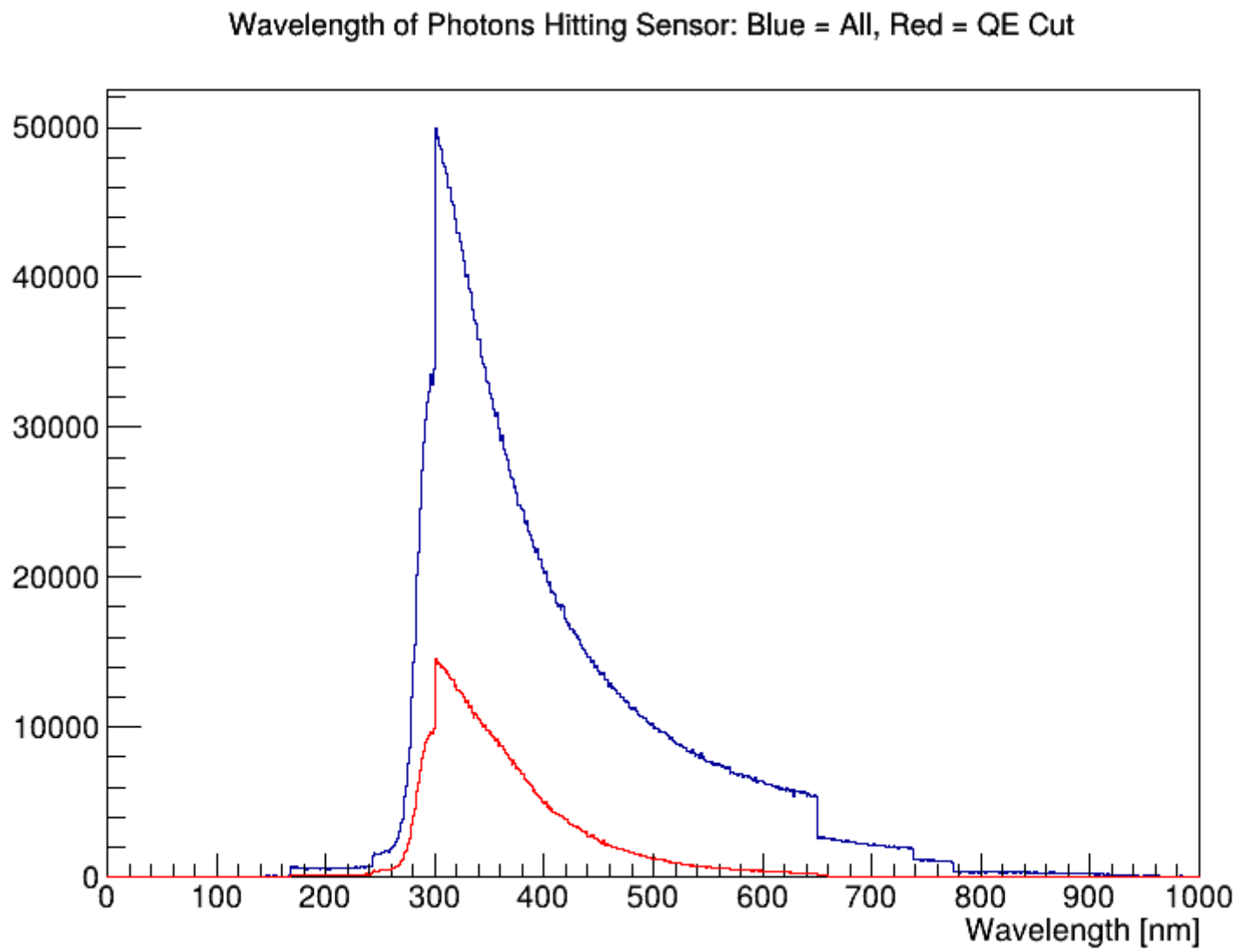
Proton Beam Gas: End Vertex



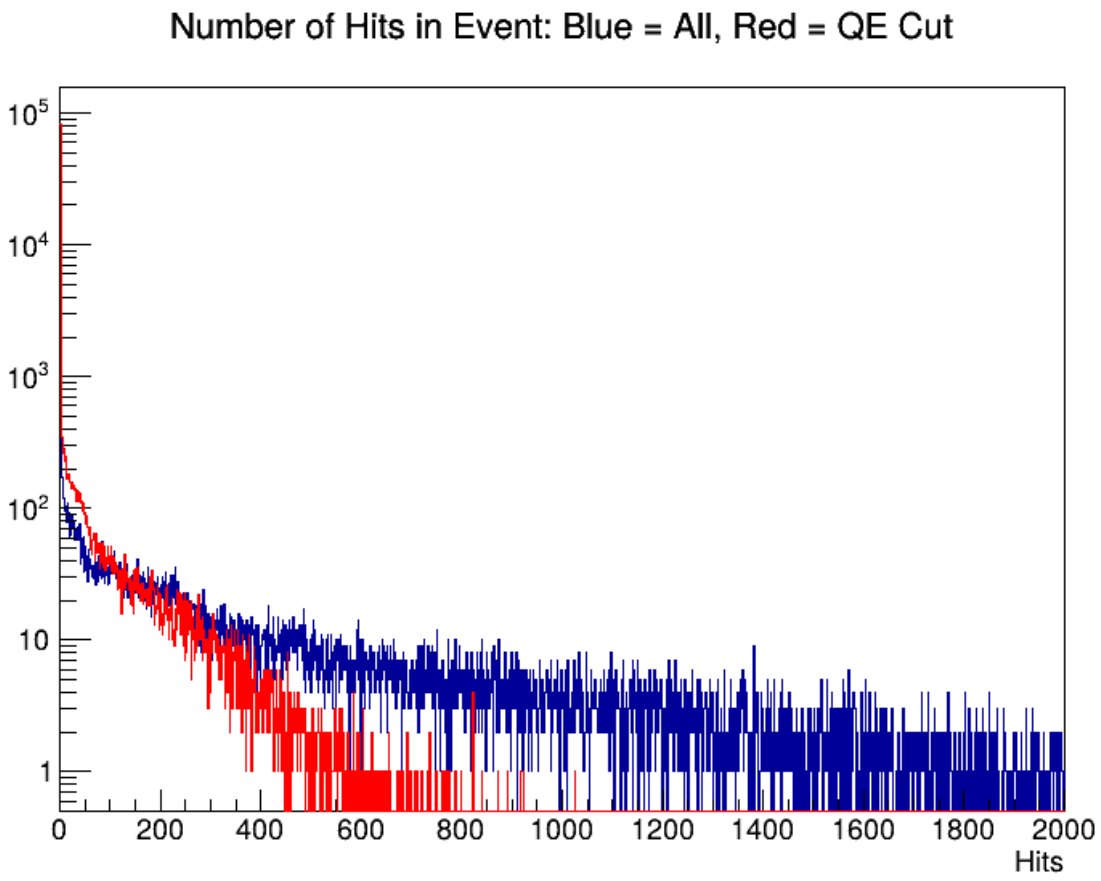
Proton Beam Gas: “Last Scatter” Before Sensor

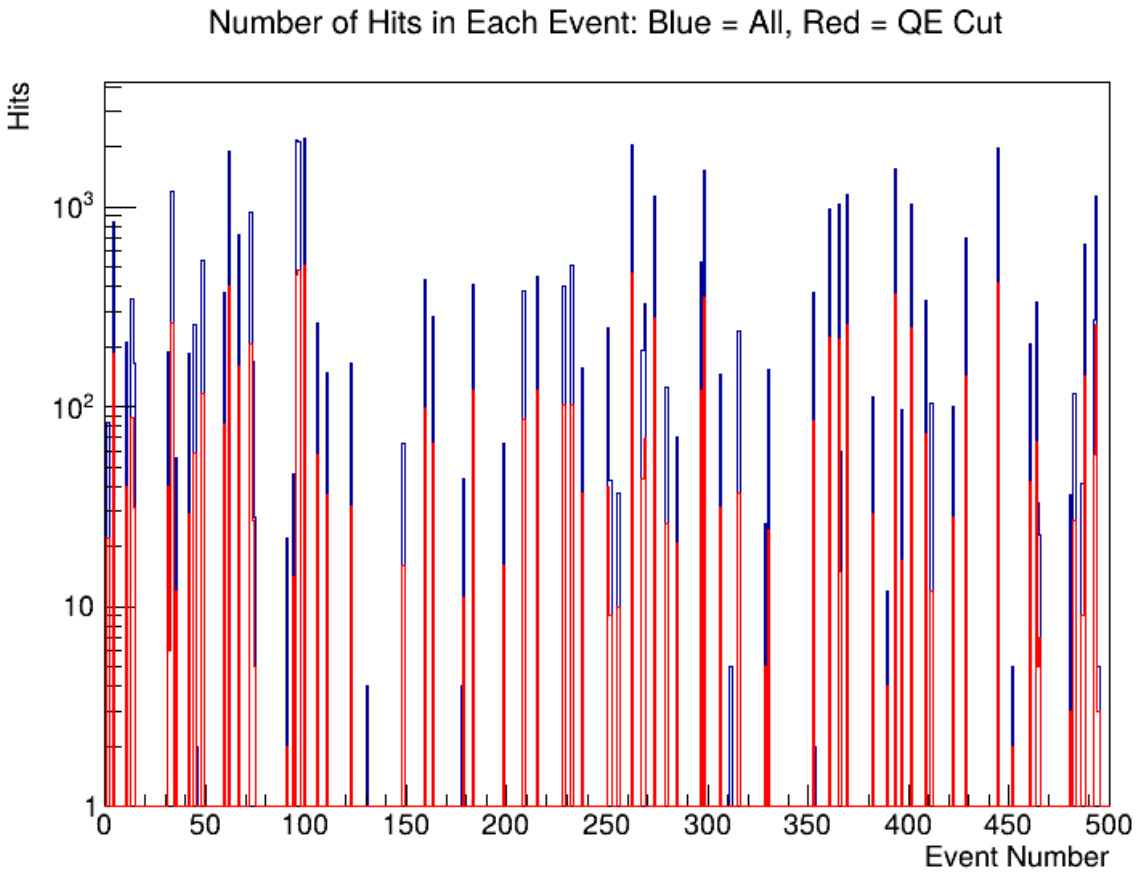


Proton Beam Gas: Photon Wavelength

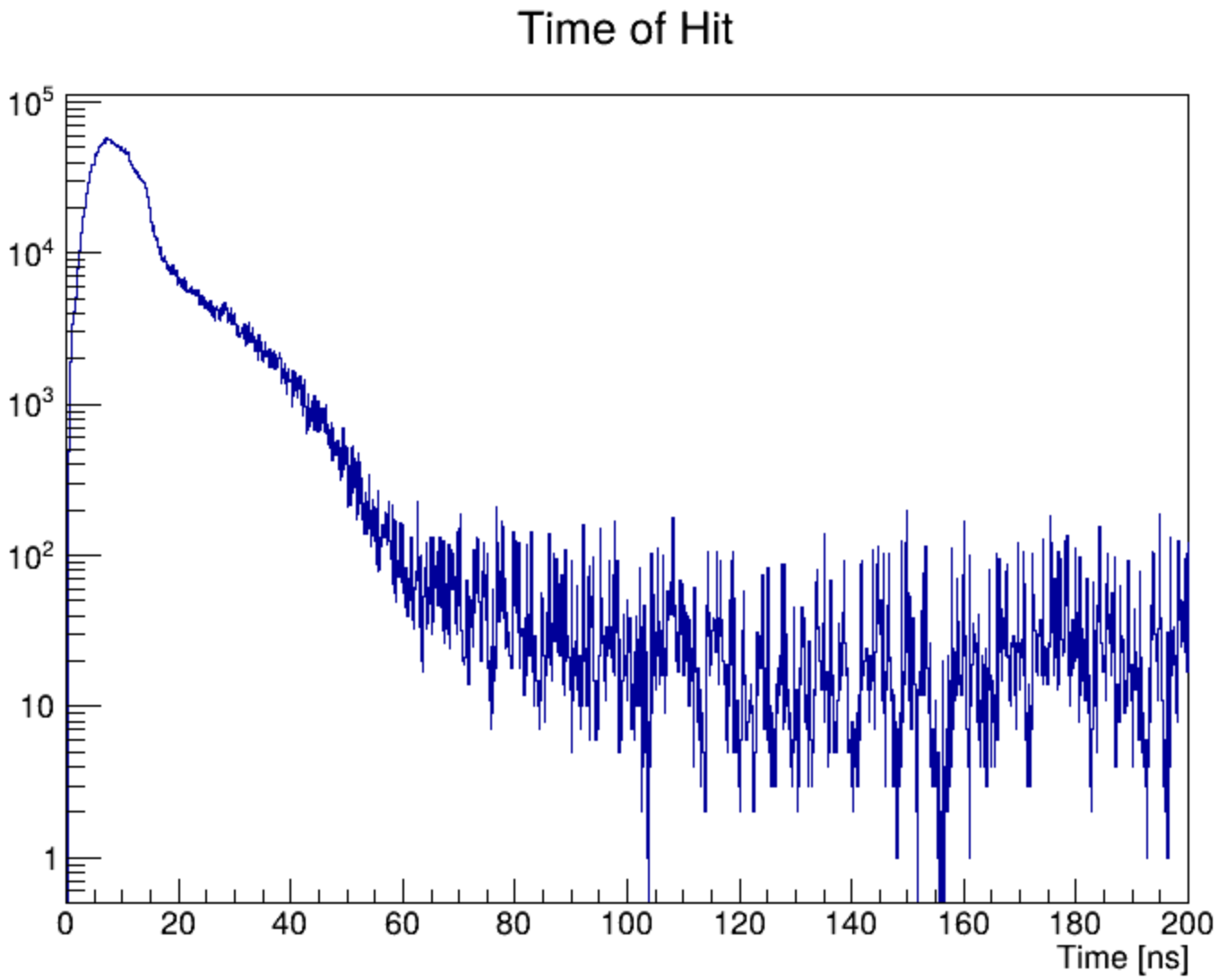


Proton Beam Gas: Event Hit Structure

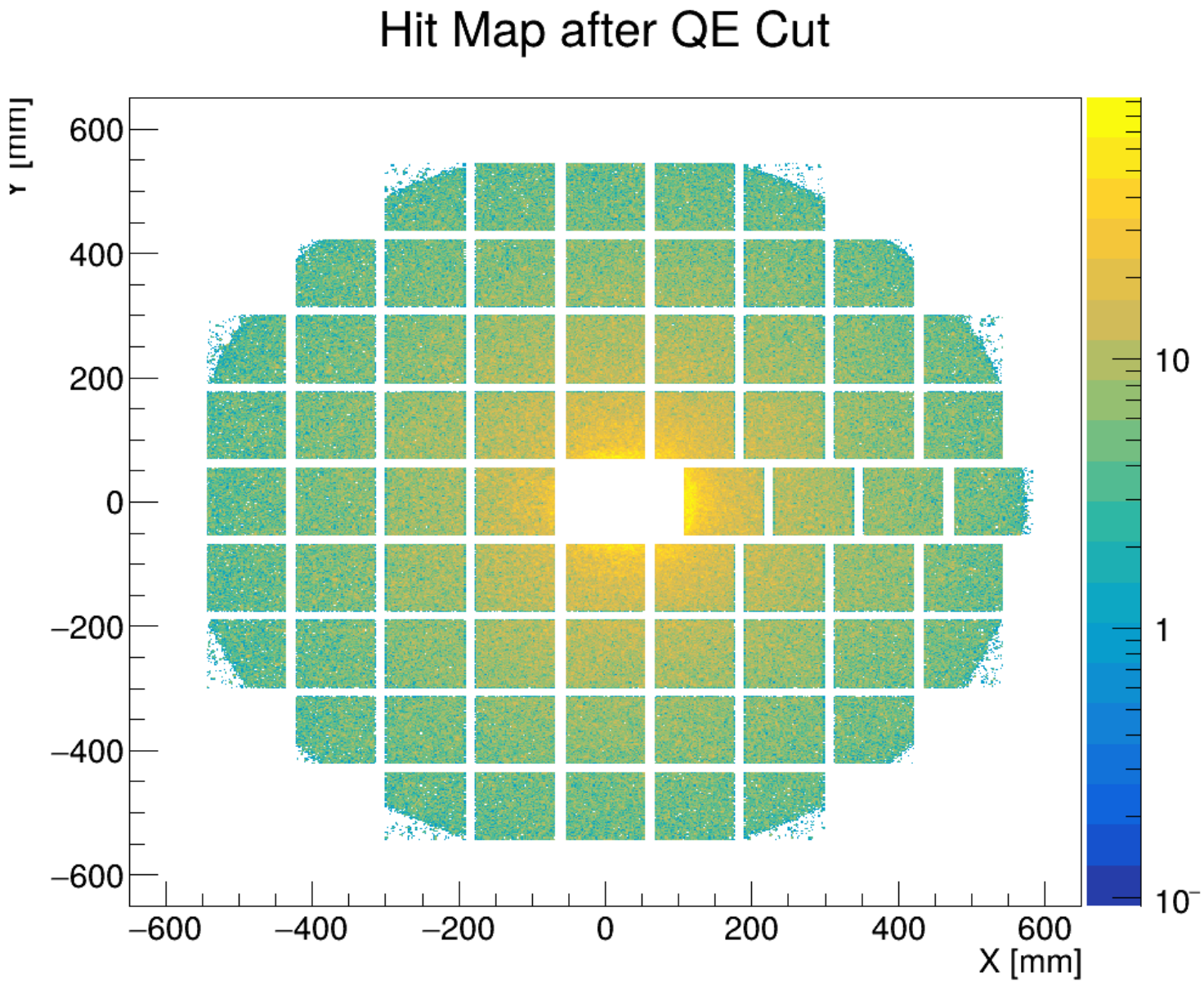




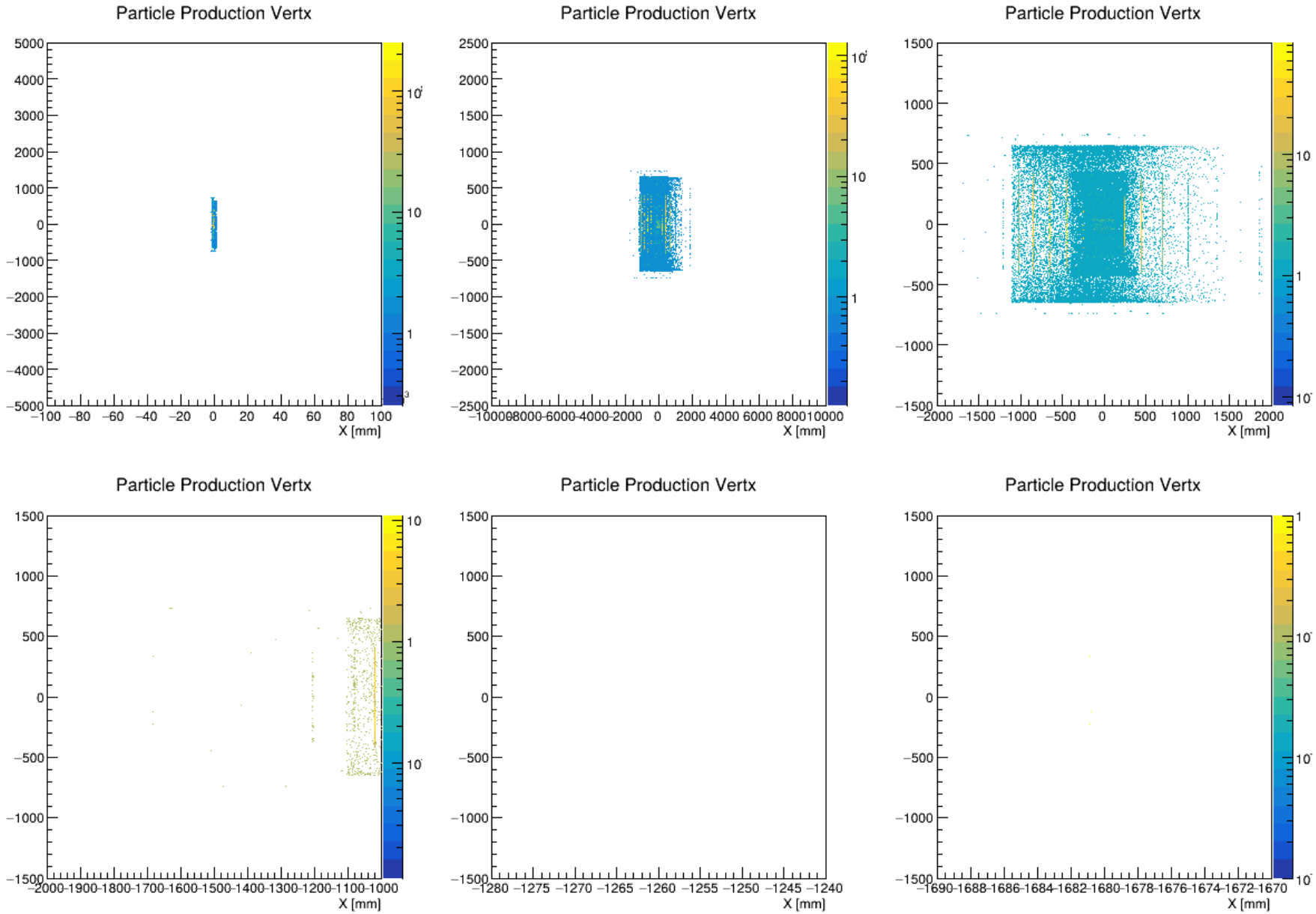
Proton Beam Gas: Hit Times



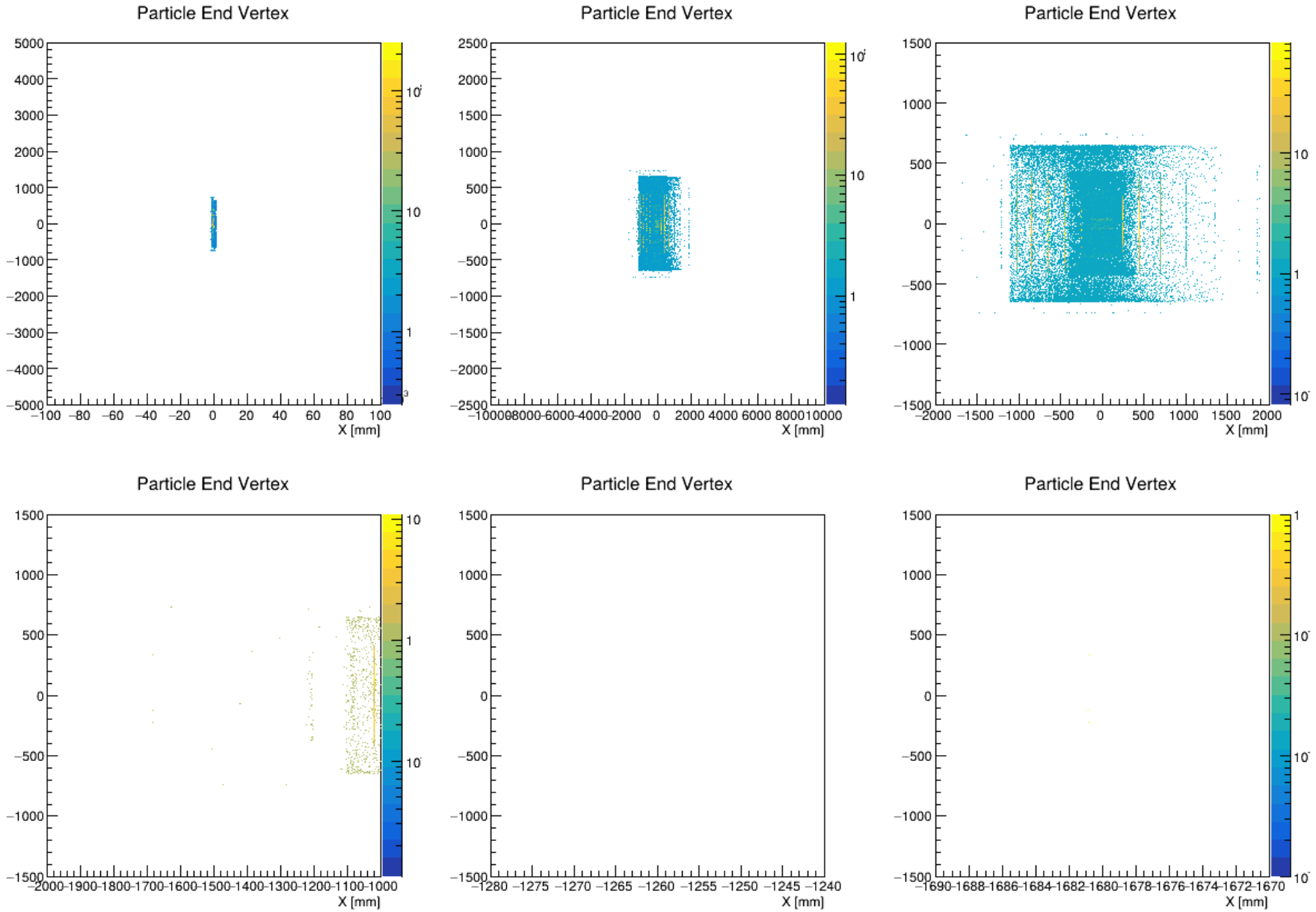
Proton Beam Gas: Hit Map After QE Cut



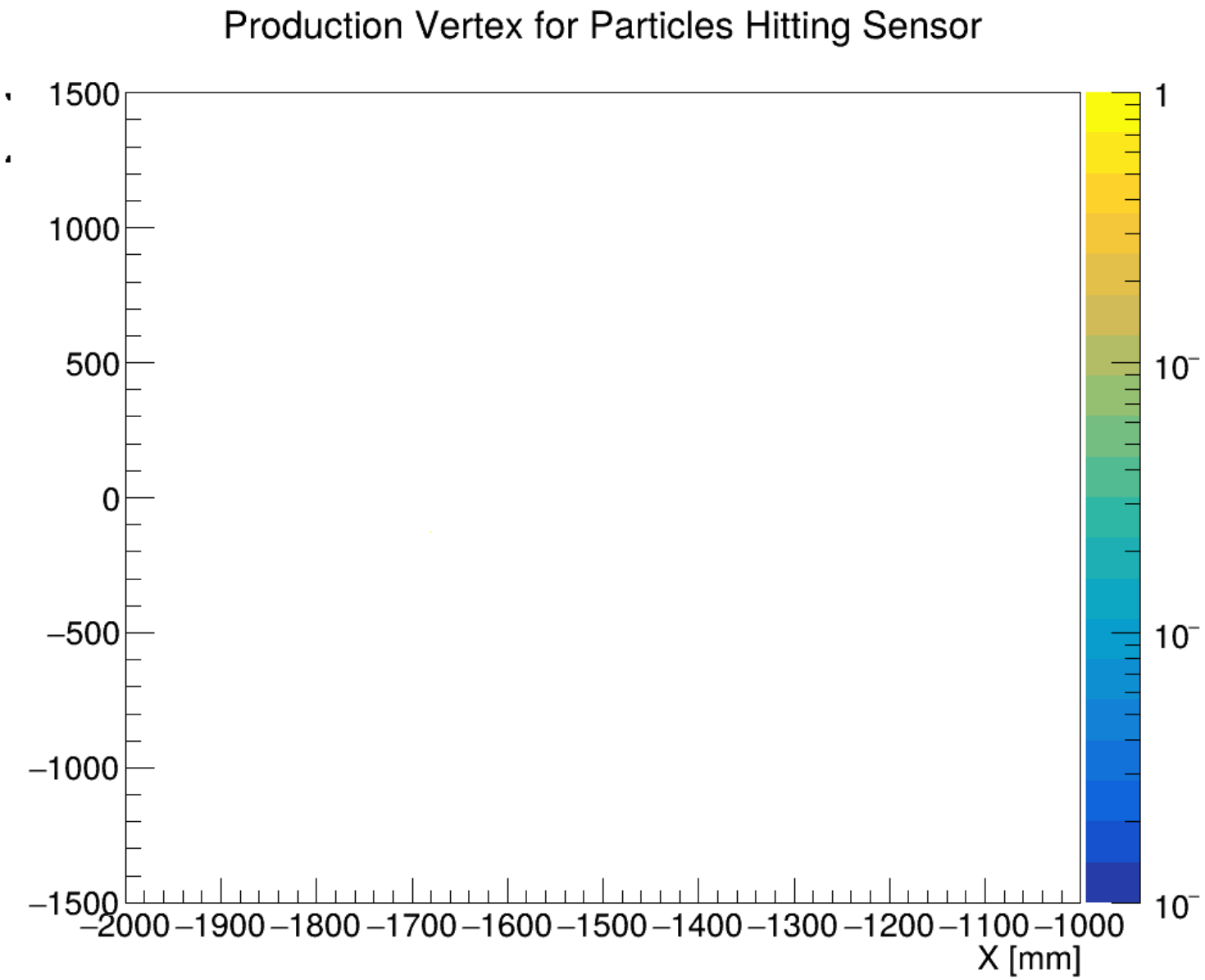
Synchrotron: Production Vertex



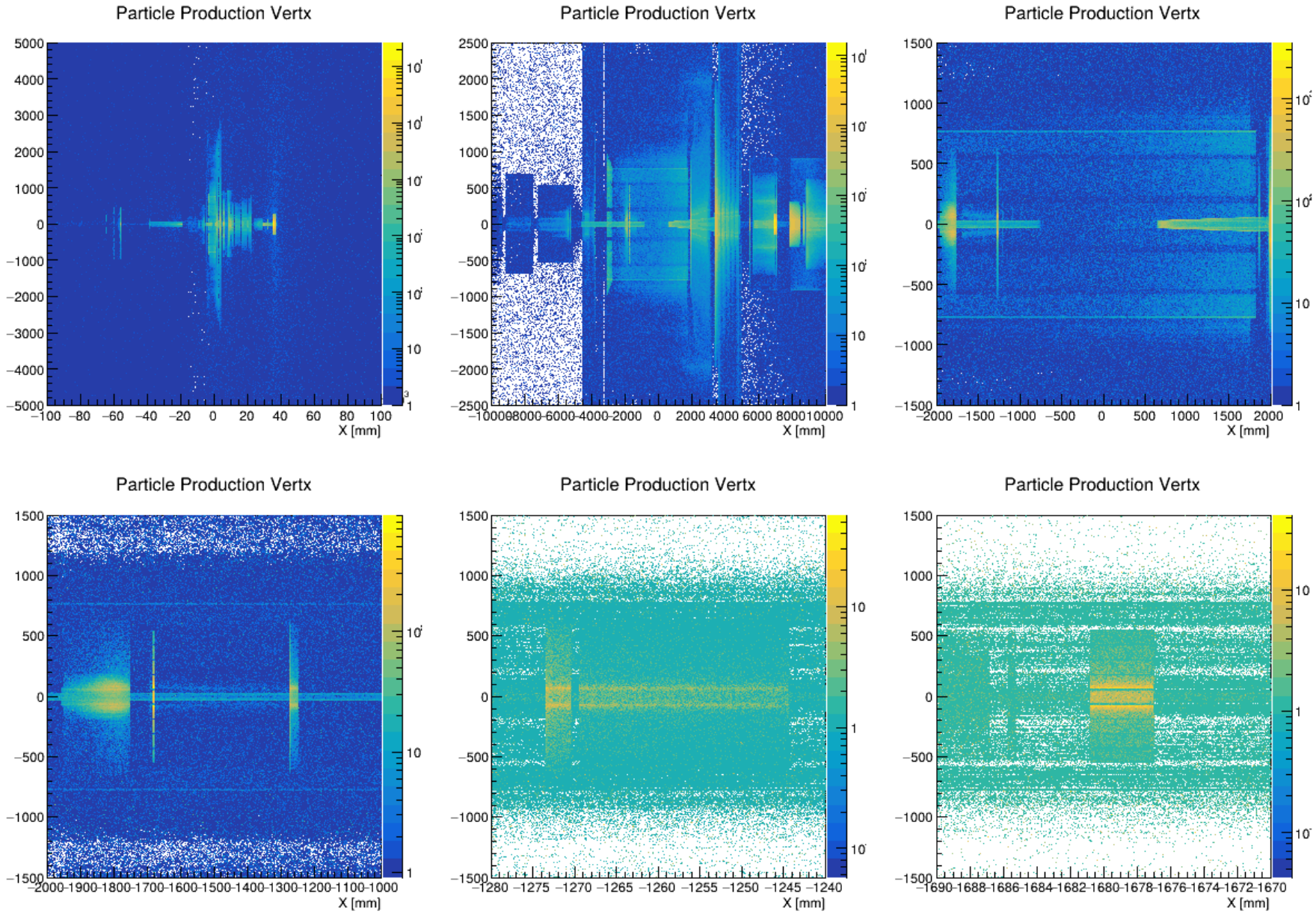
Synchrotron: End Vertex



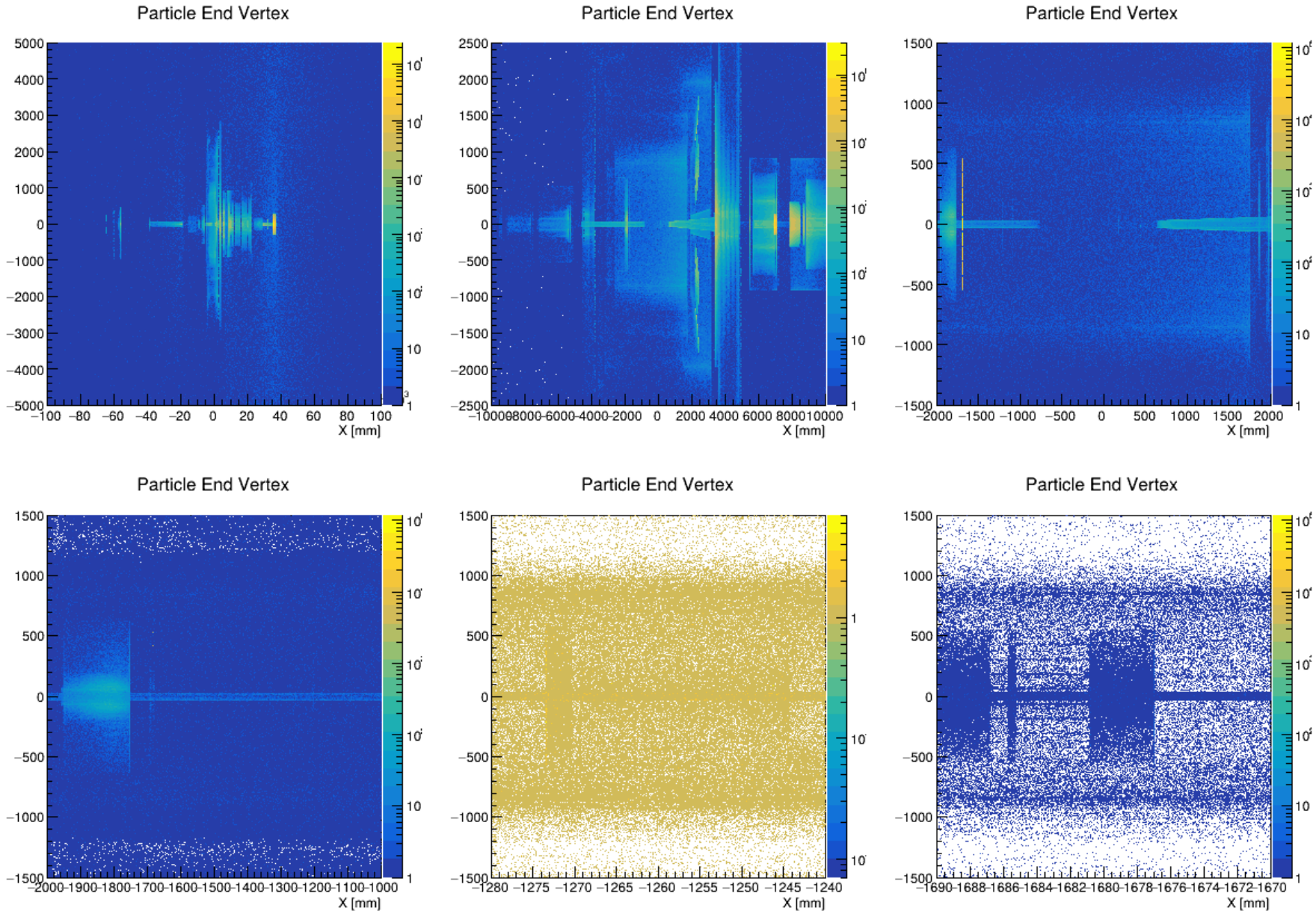
Synchrotron: “Last Scatter” Before Sensor



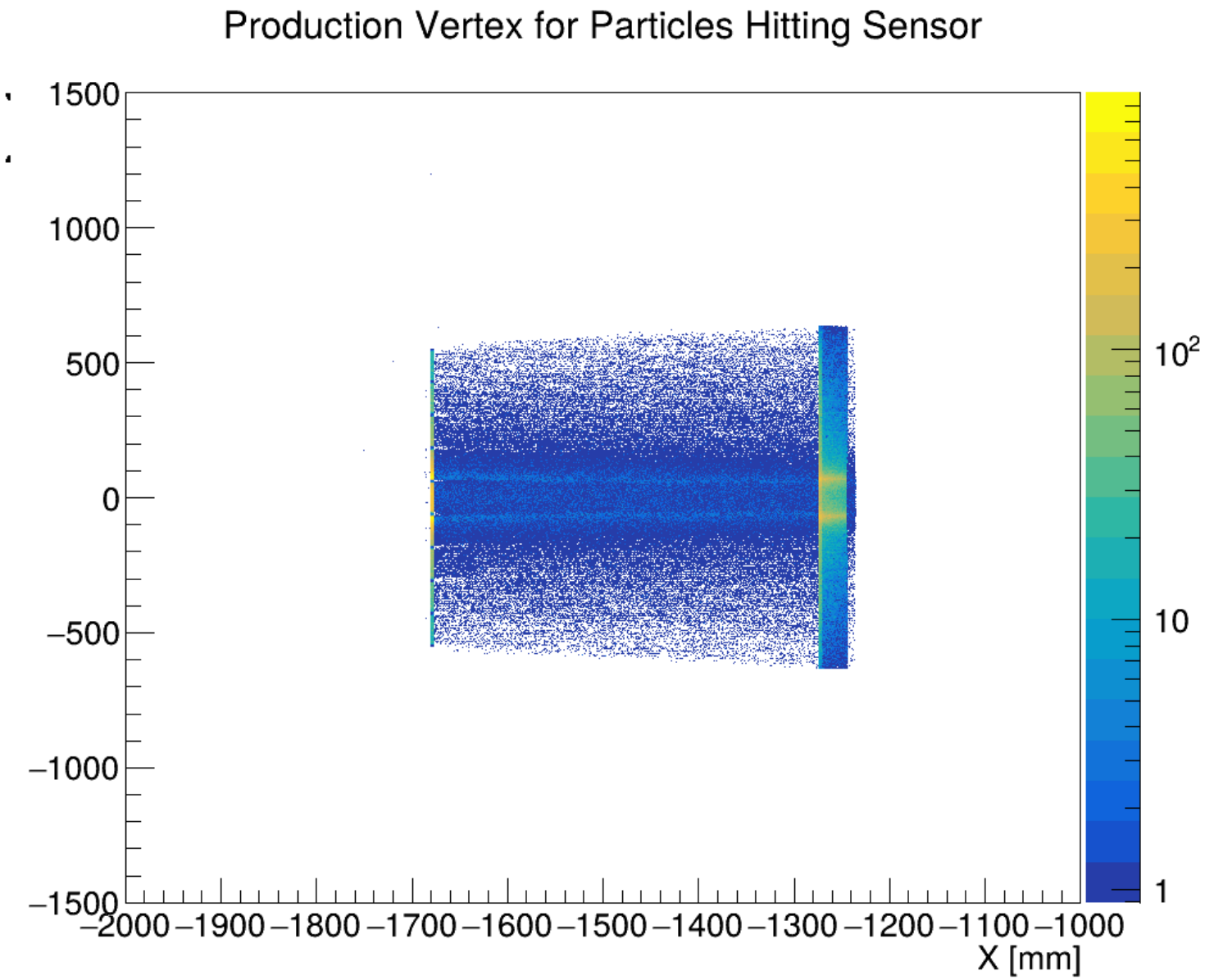
DIS Q2 < 1: Production Vertex



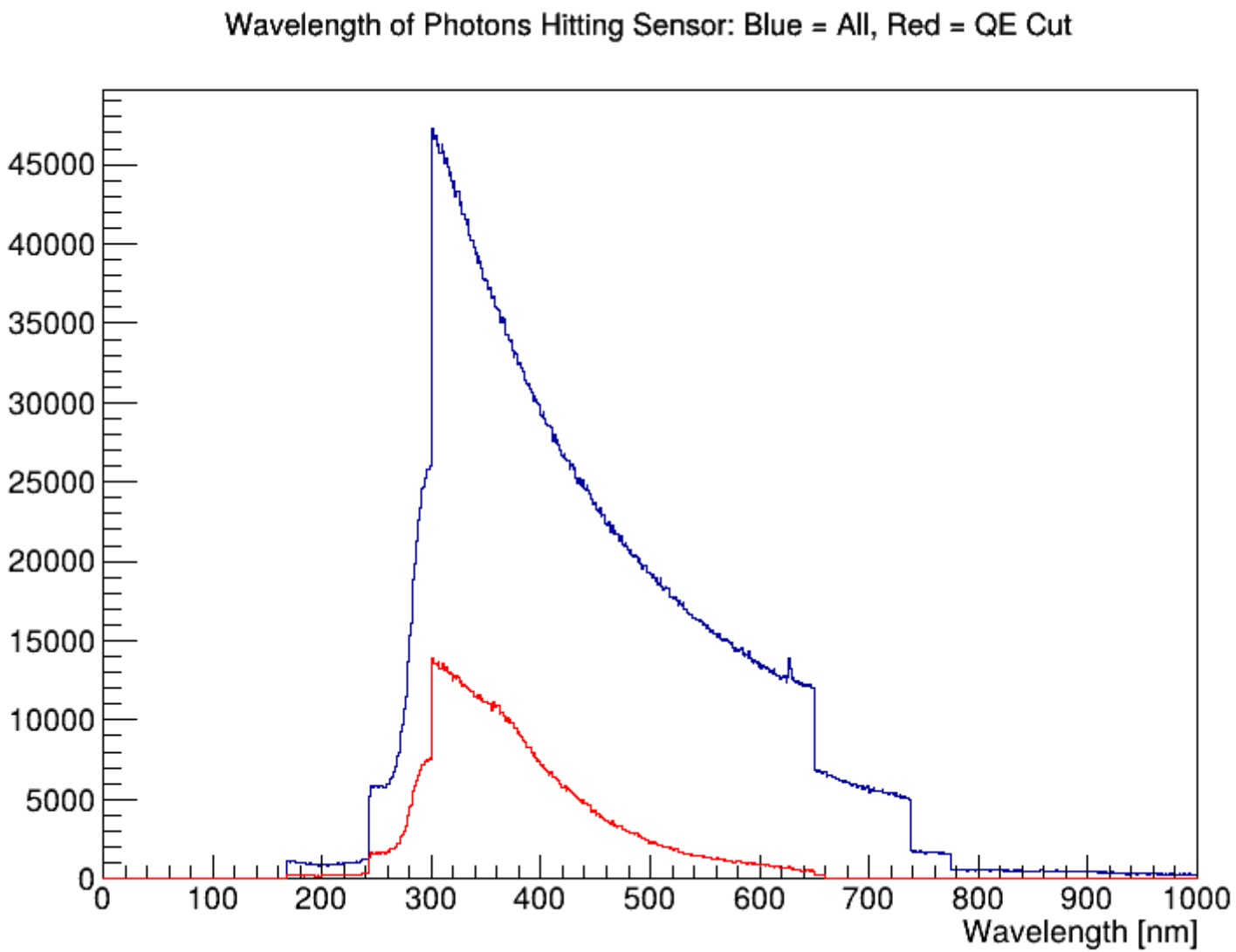
DIS Q2 < 1: End Vertex



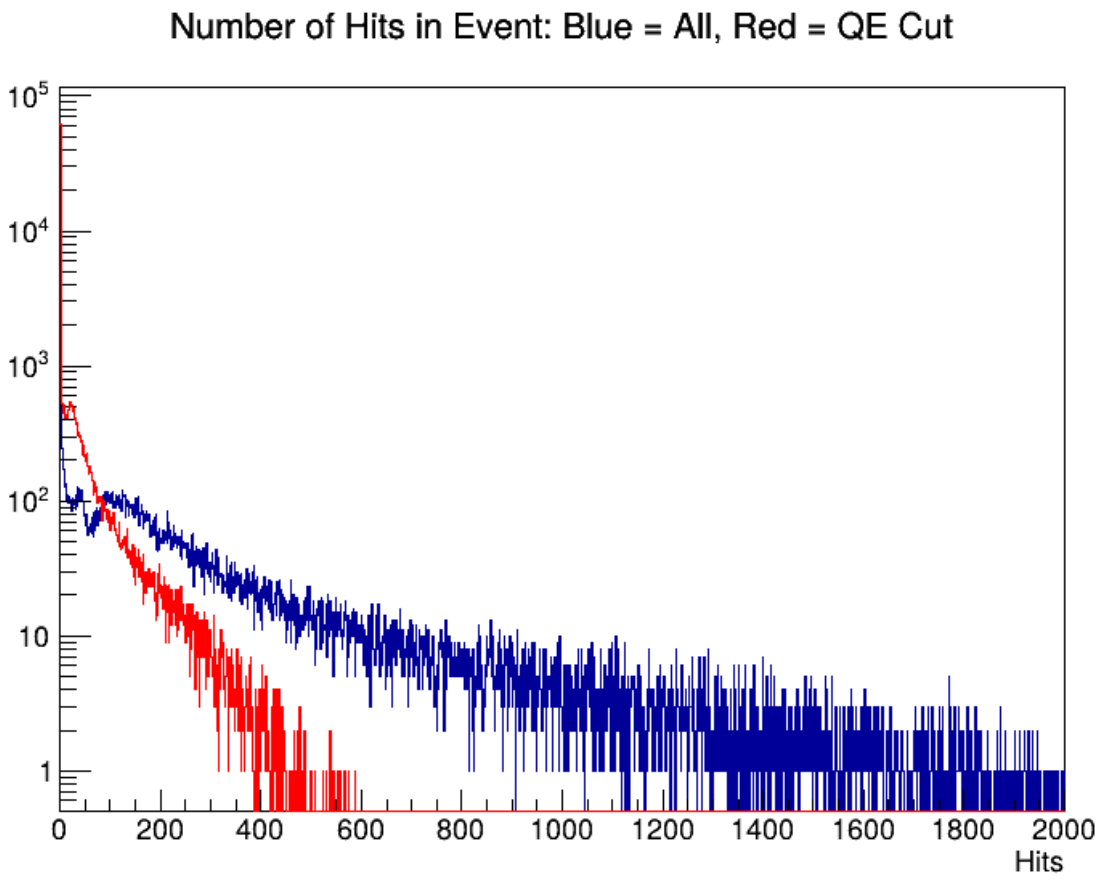
DIS Q2 < 1: “Last Scatter” Before Sensor

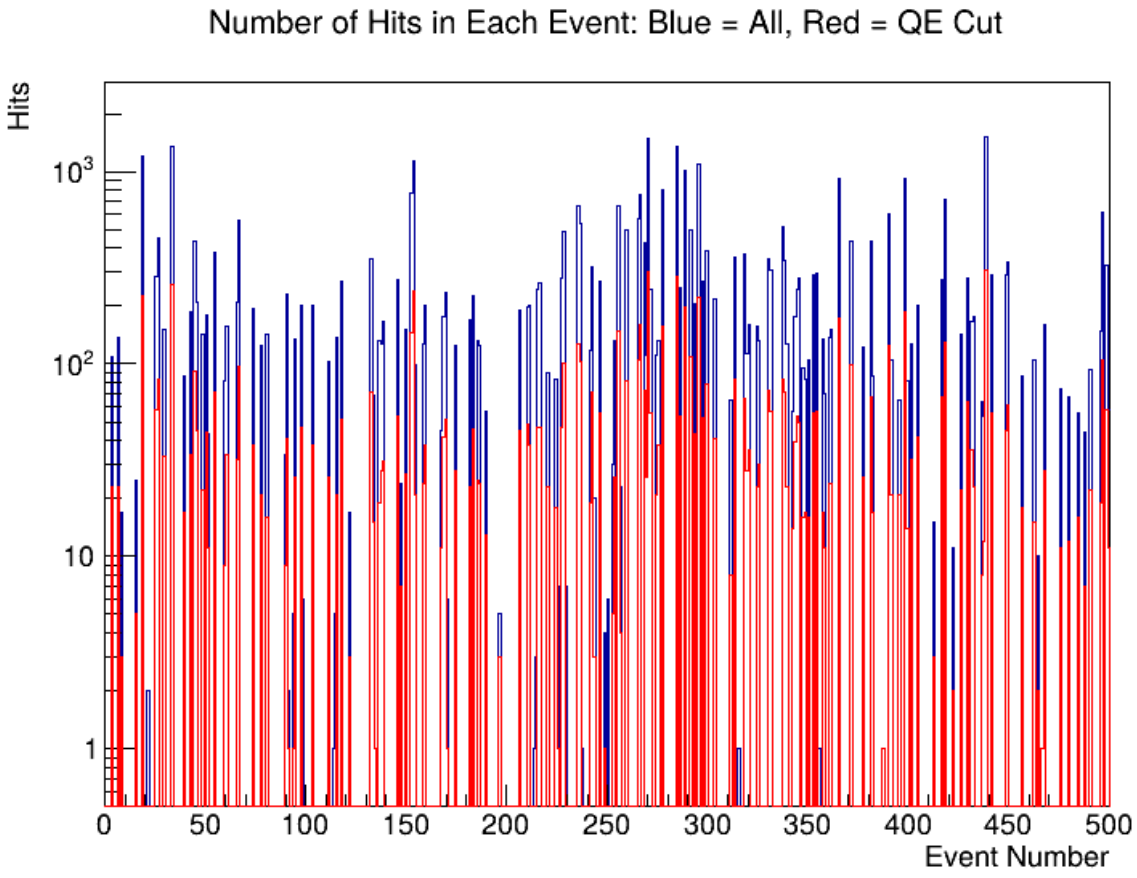


DIS Q2 < 1: Photon Wavelength

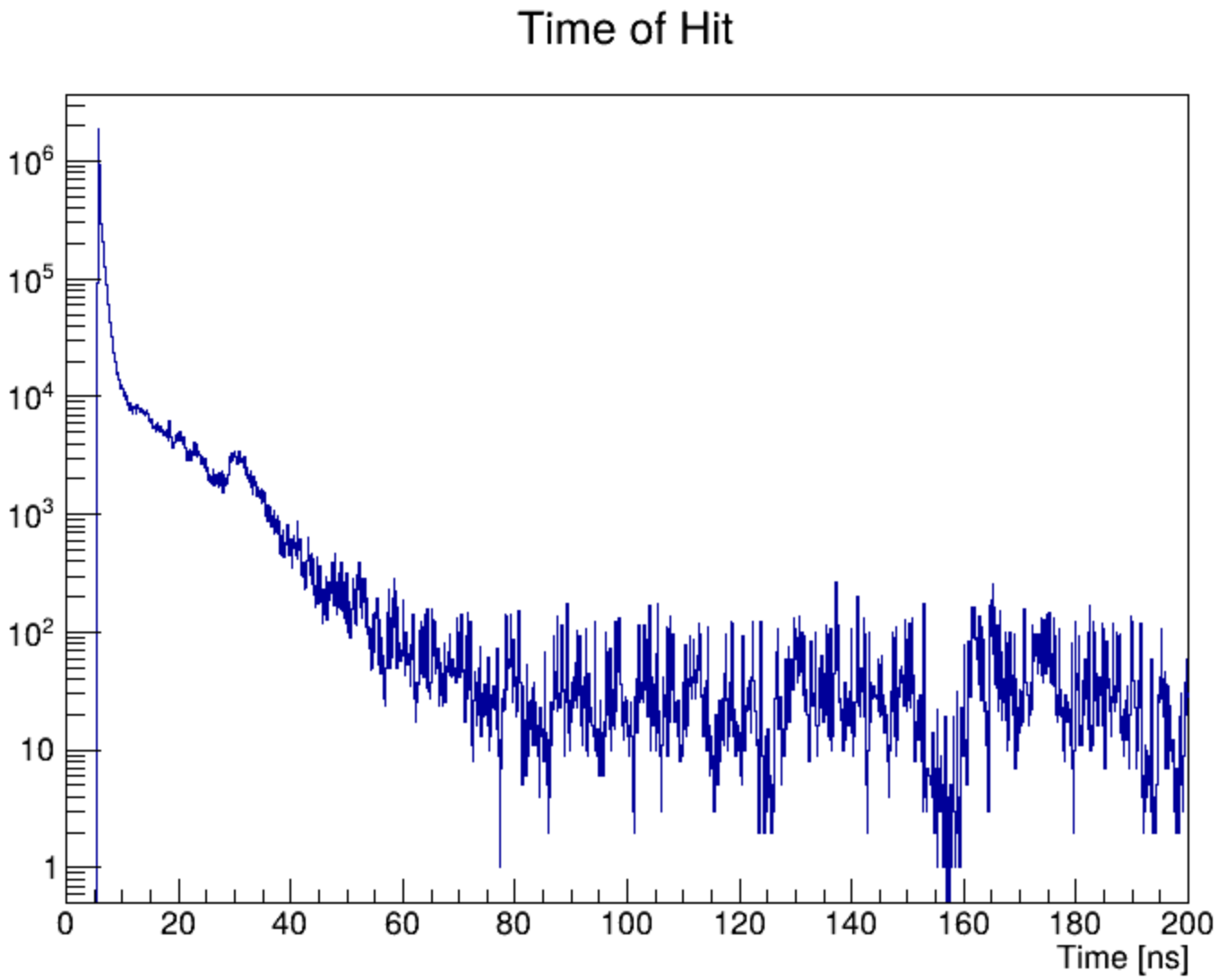


DIS Q2 < 1: Event Hit Structure

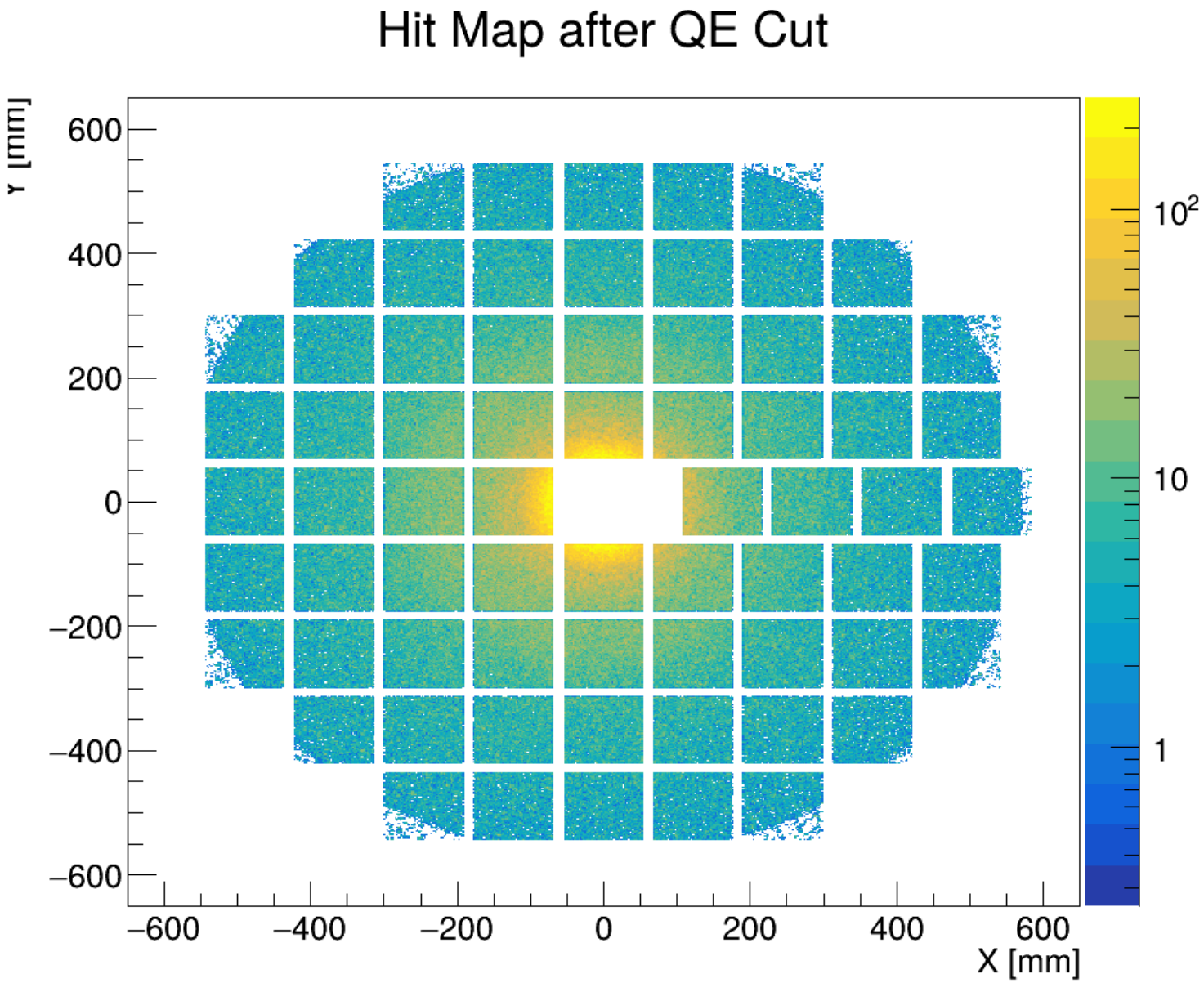




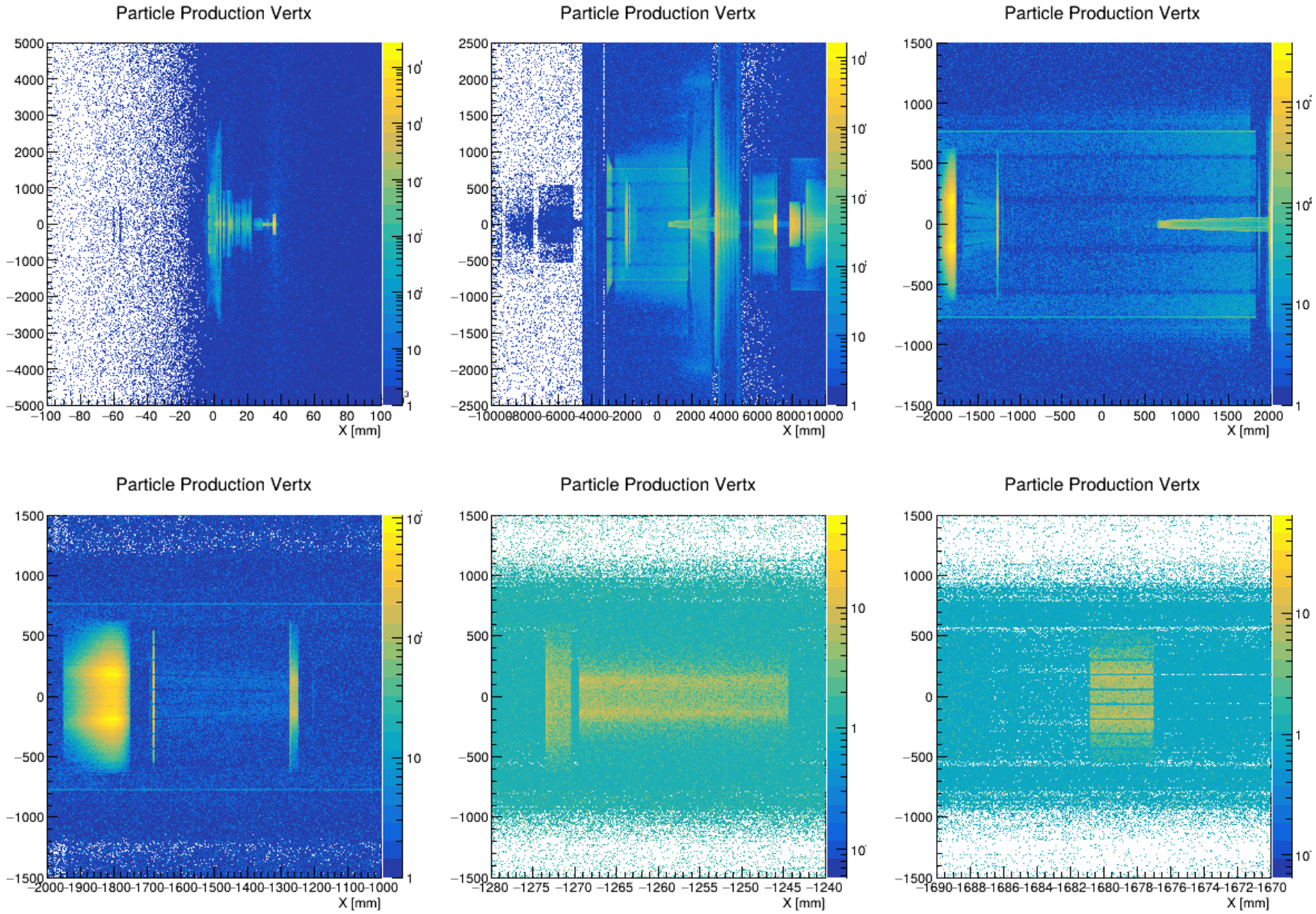
DIS Q2 < 1: Hit Times



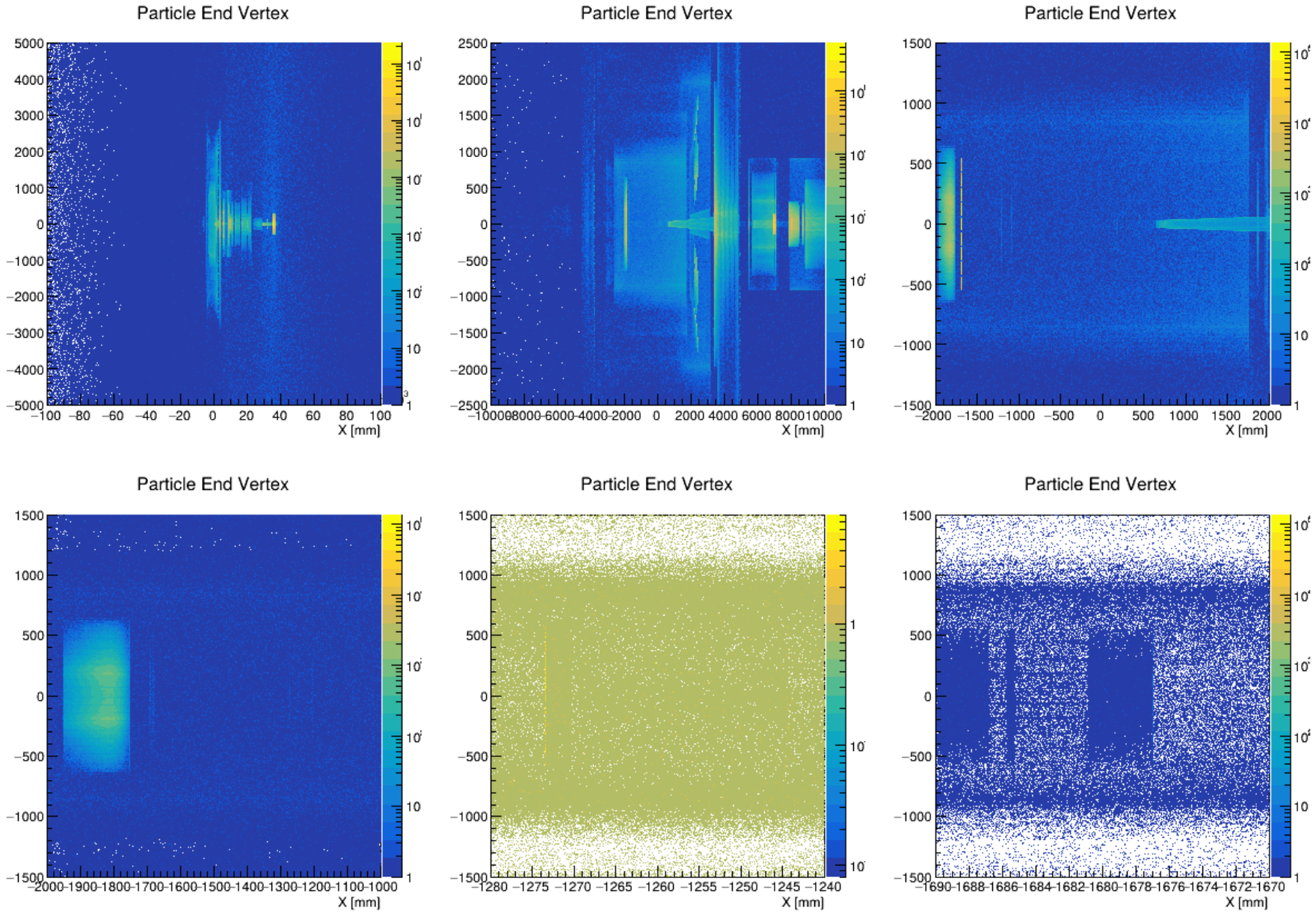
DIS Q2 < 1: Hit Map After QE Cut



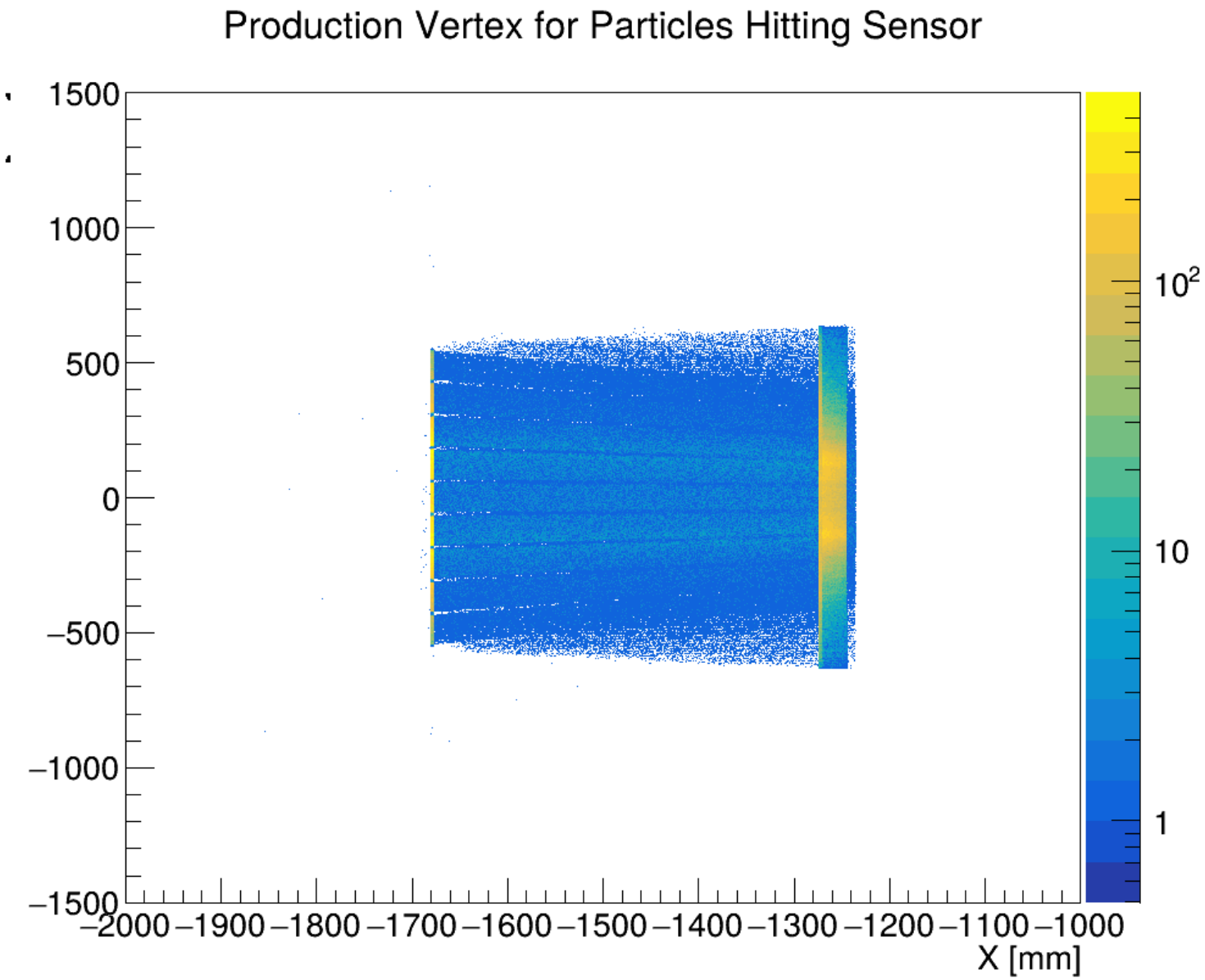
DIS Q2 1-10: Production Vertex



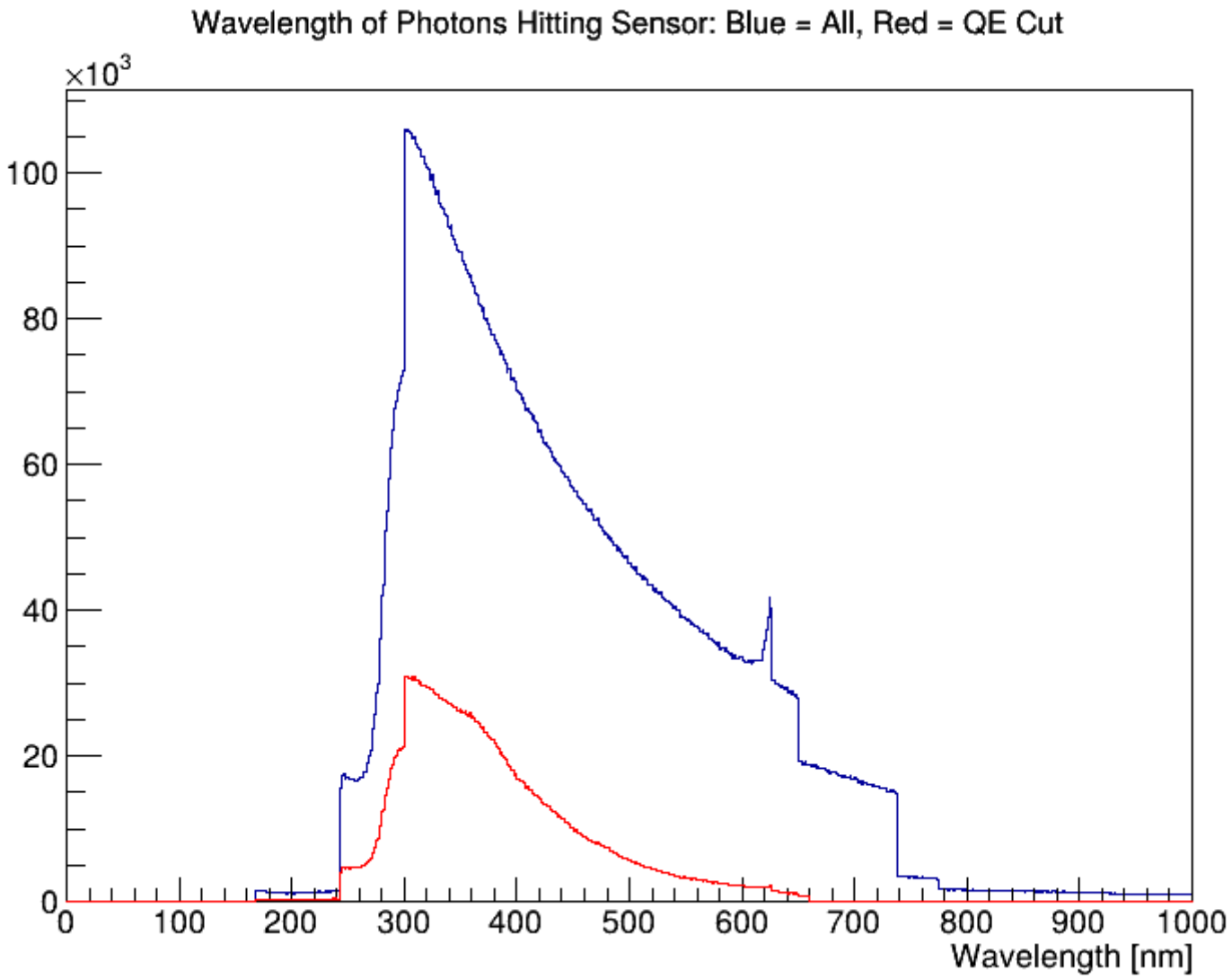
DIS Q2 1-10: End Vertex



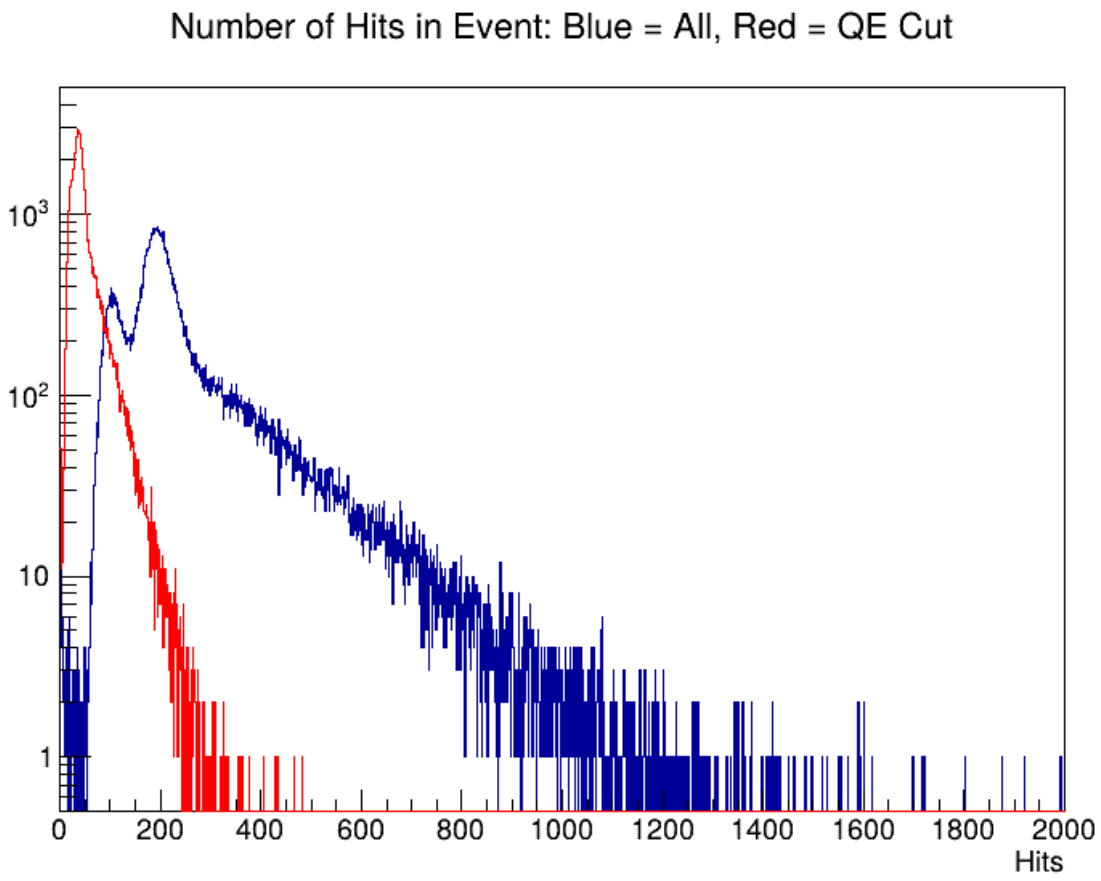
DIS Q2 1-10: “Last Scatter” Before Sensor

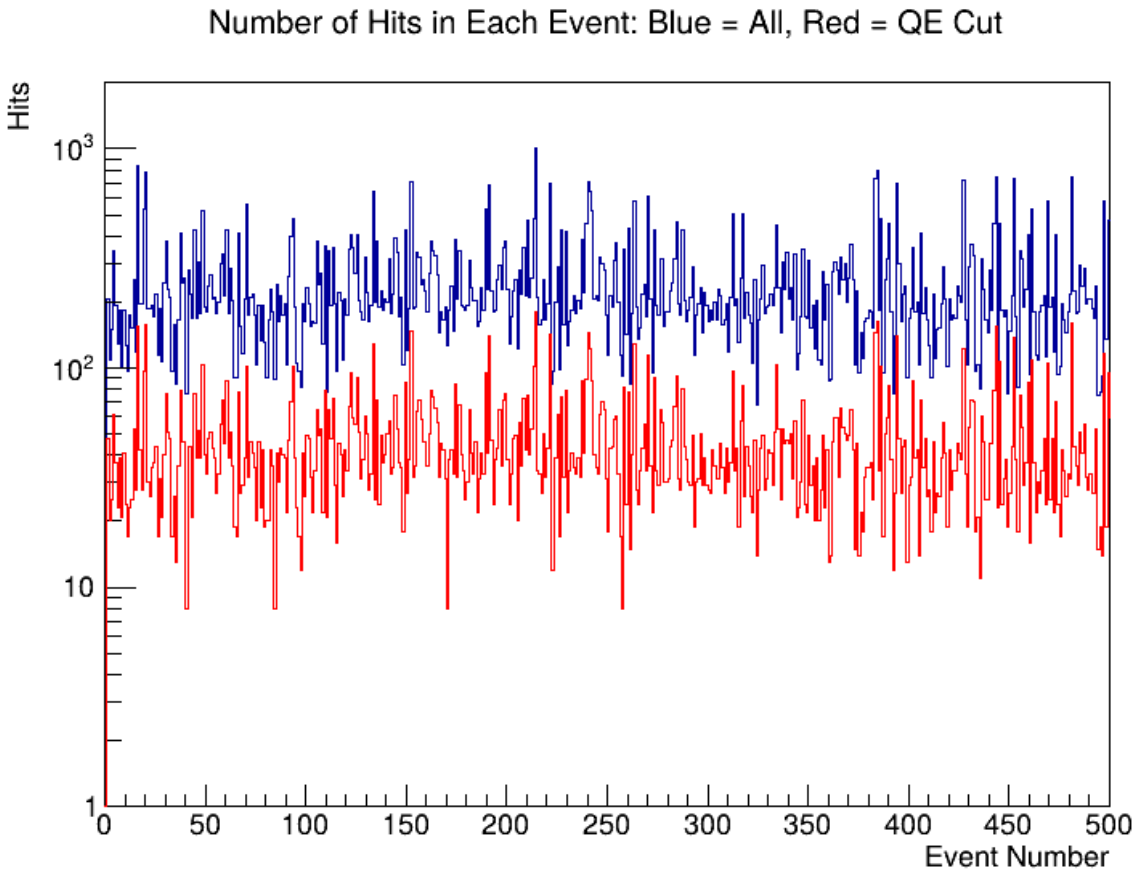


DIS Q2 1-10: Photon Wavelength

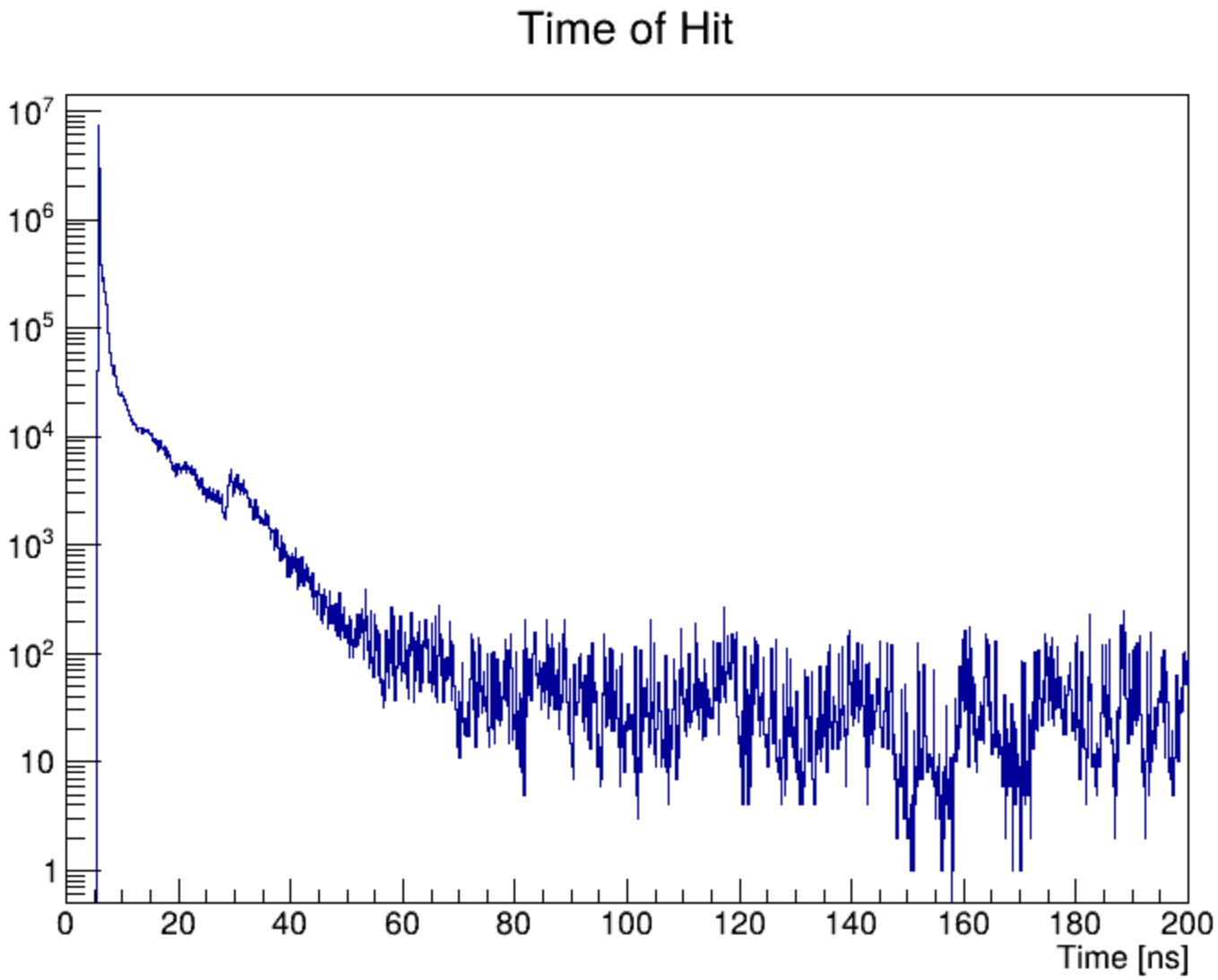


DIS Q2 1-10: Event Hit Structure

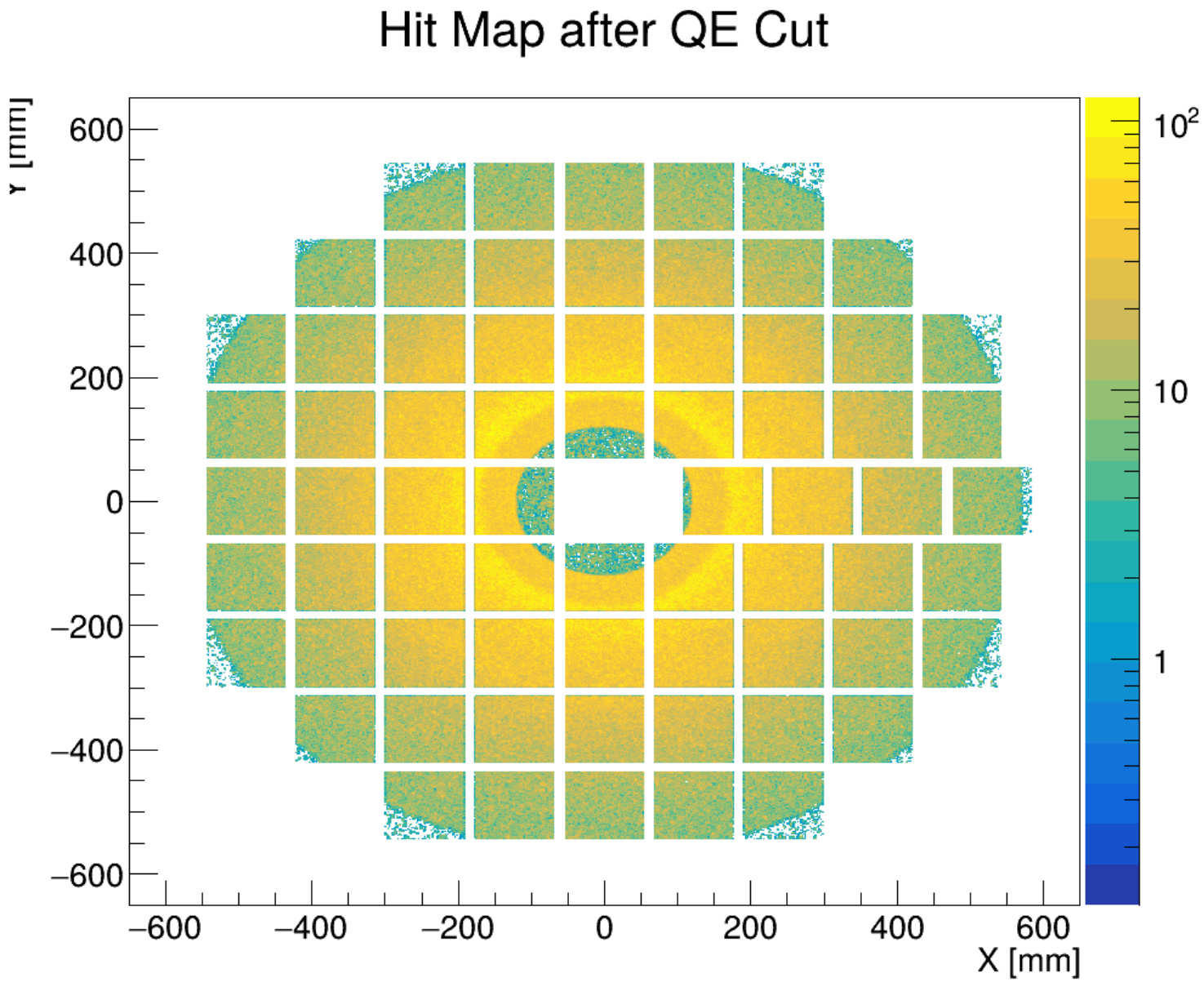




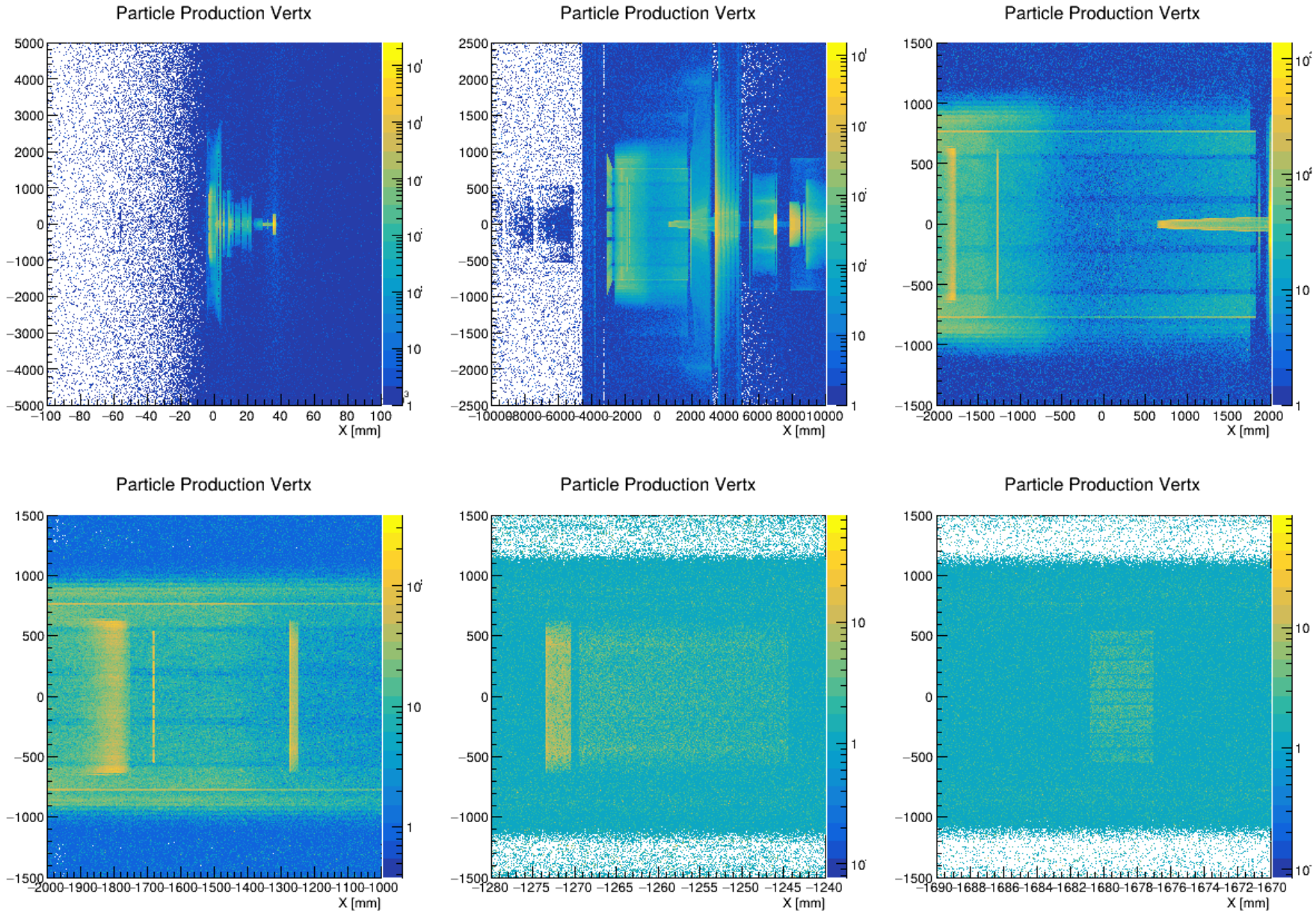
DIS Q2 1-10: Hit Times



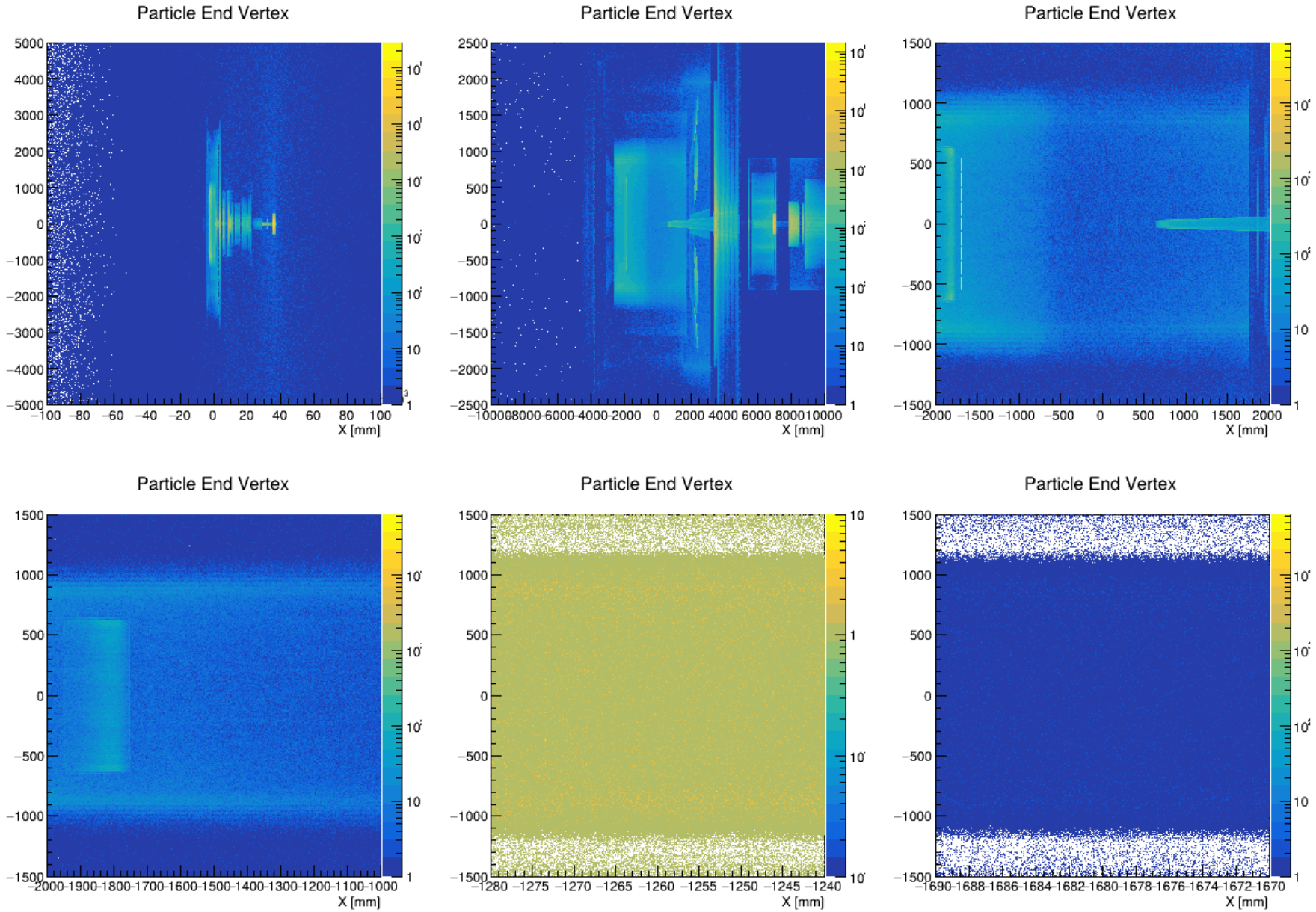
DIS Q2 1-10: Hit Map After QE Cut



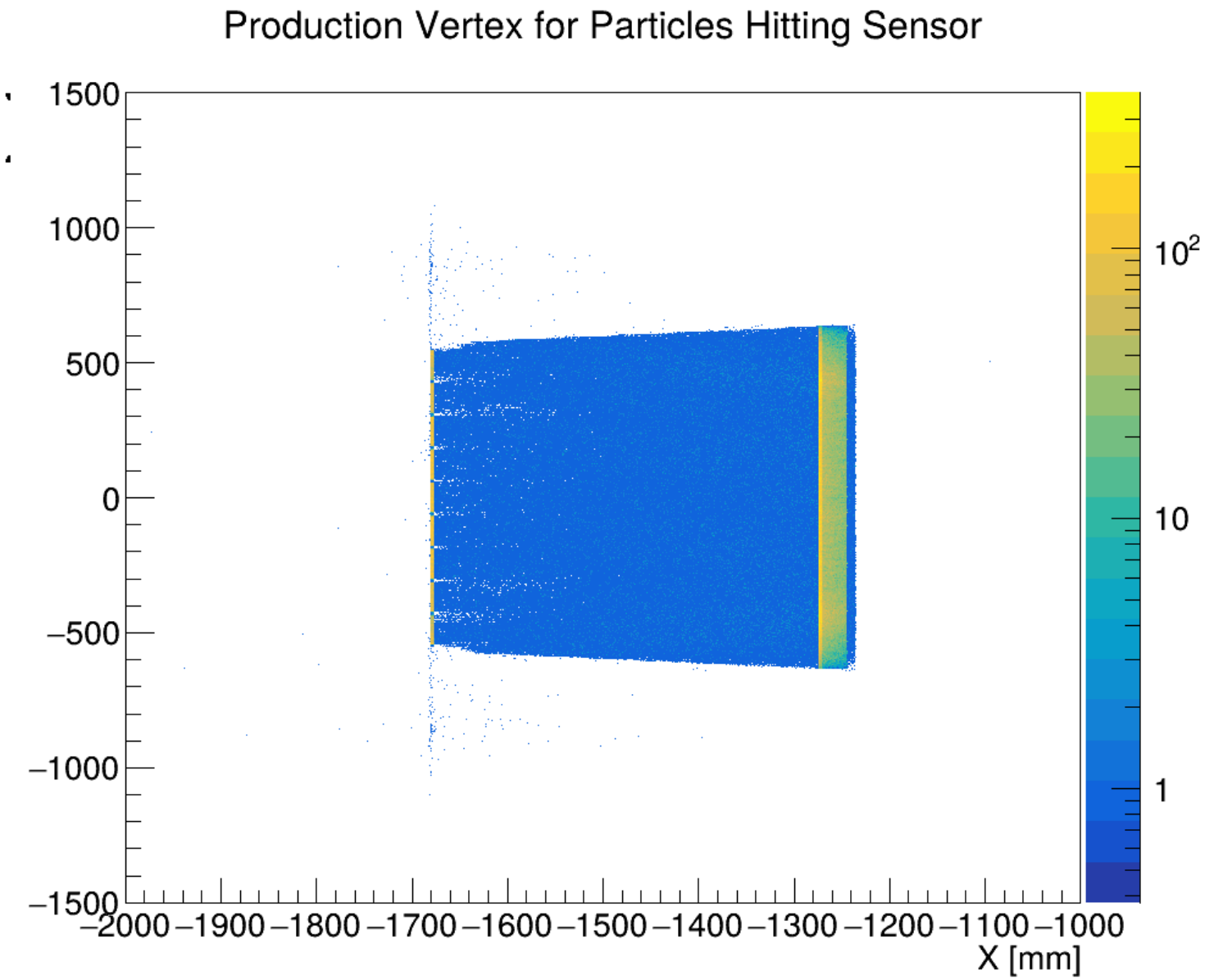
DIS Q2 10-100: Production Vertex



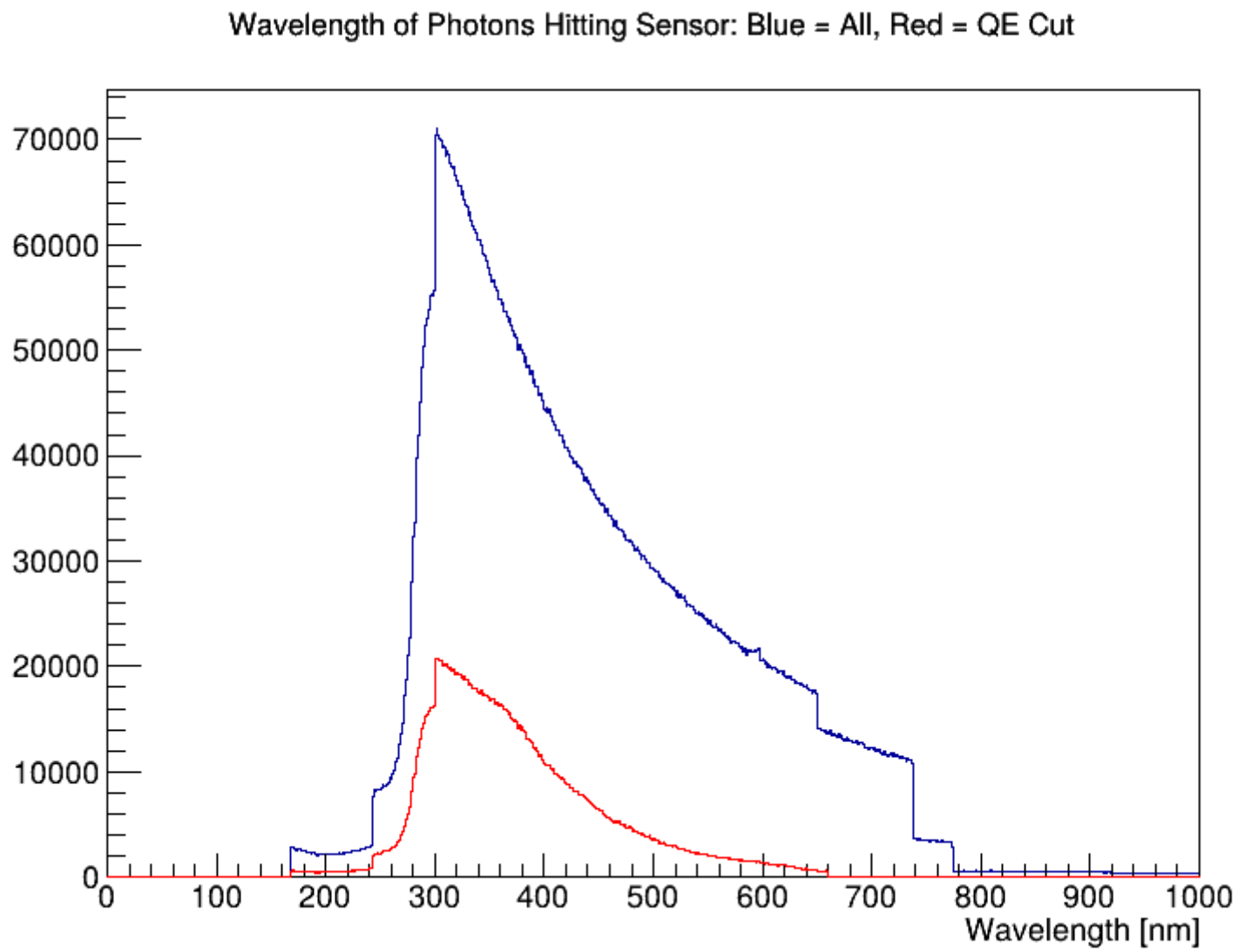
DIS Q2 10-100: End Vertex



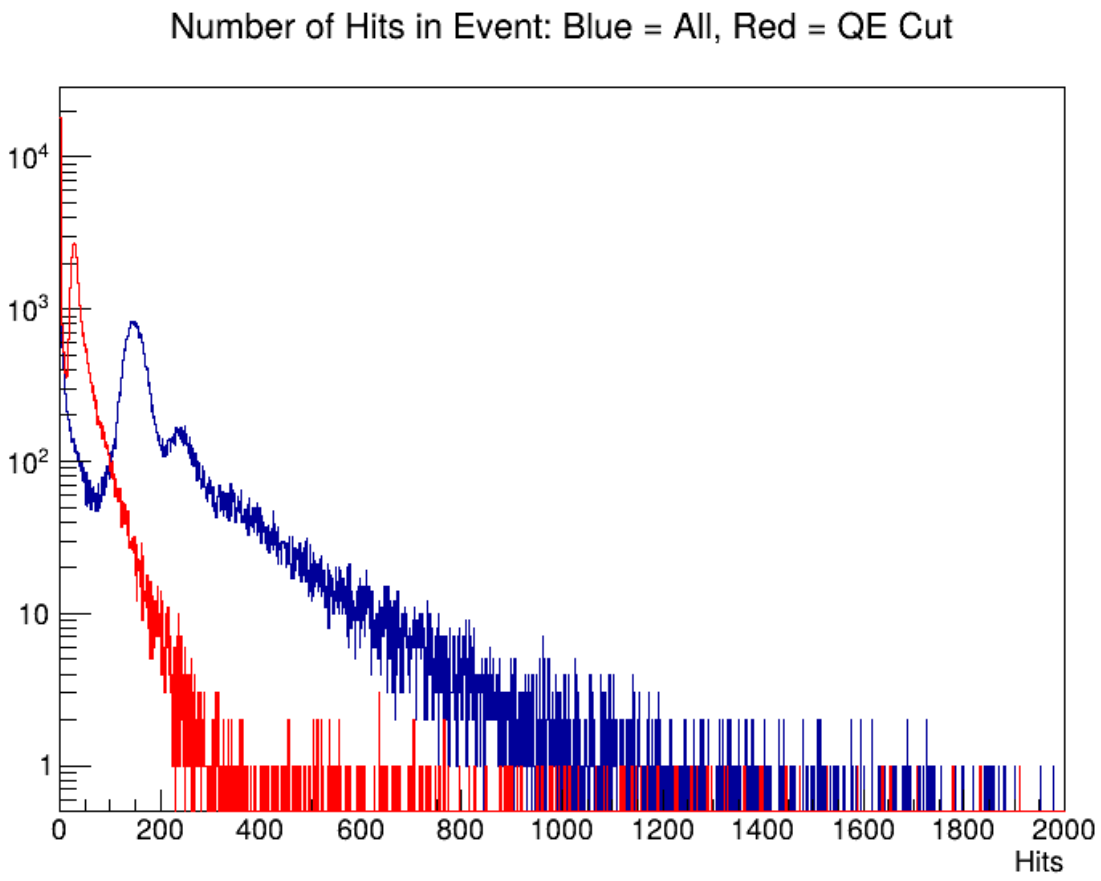
DIS Q2 10-100: “Last Scatter” Before Sensor

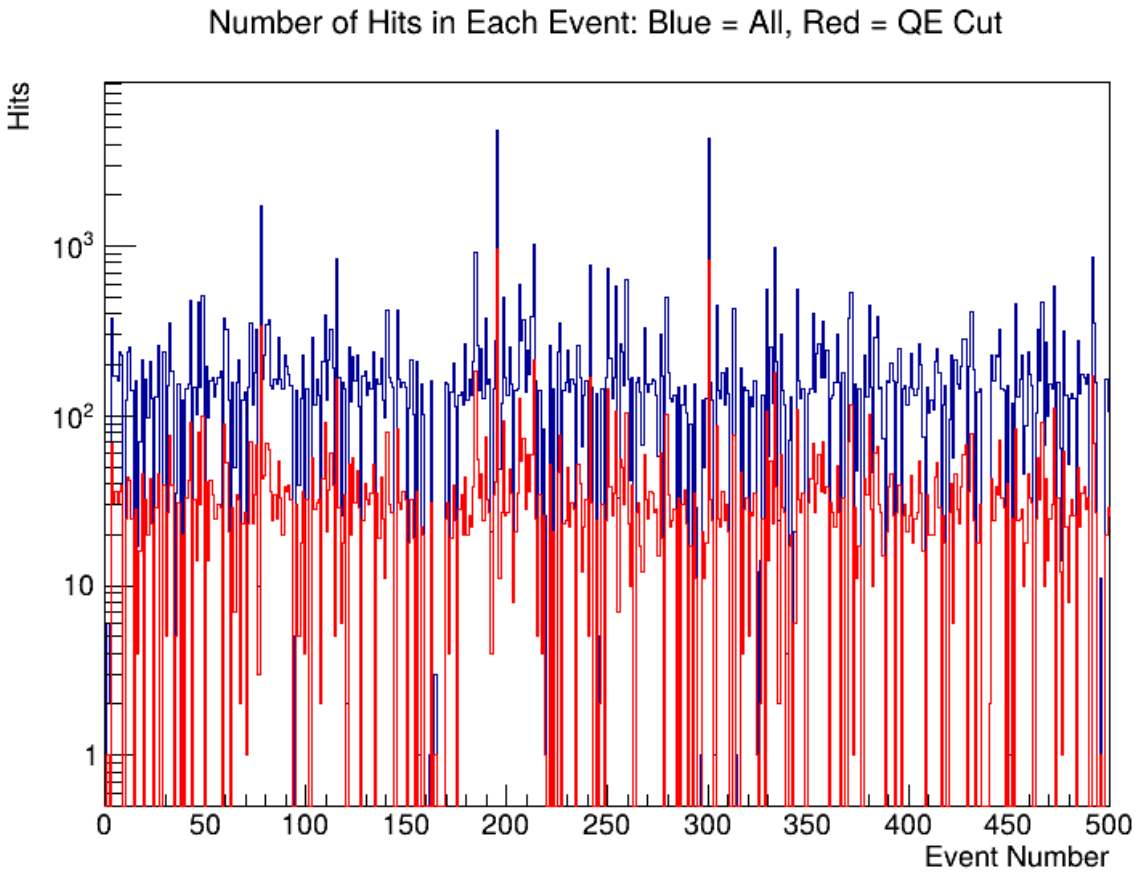


DIS Q2 10-100: Photon Wavelength

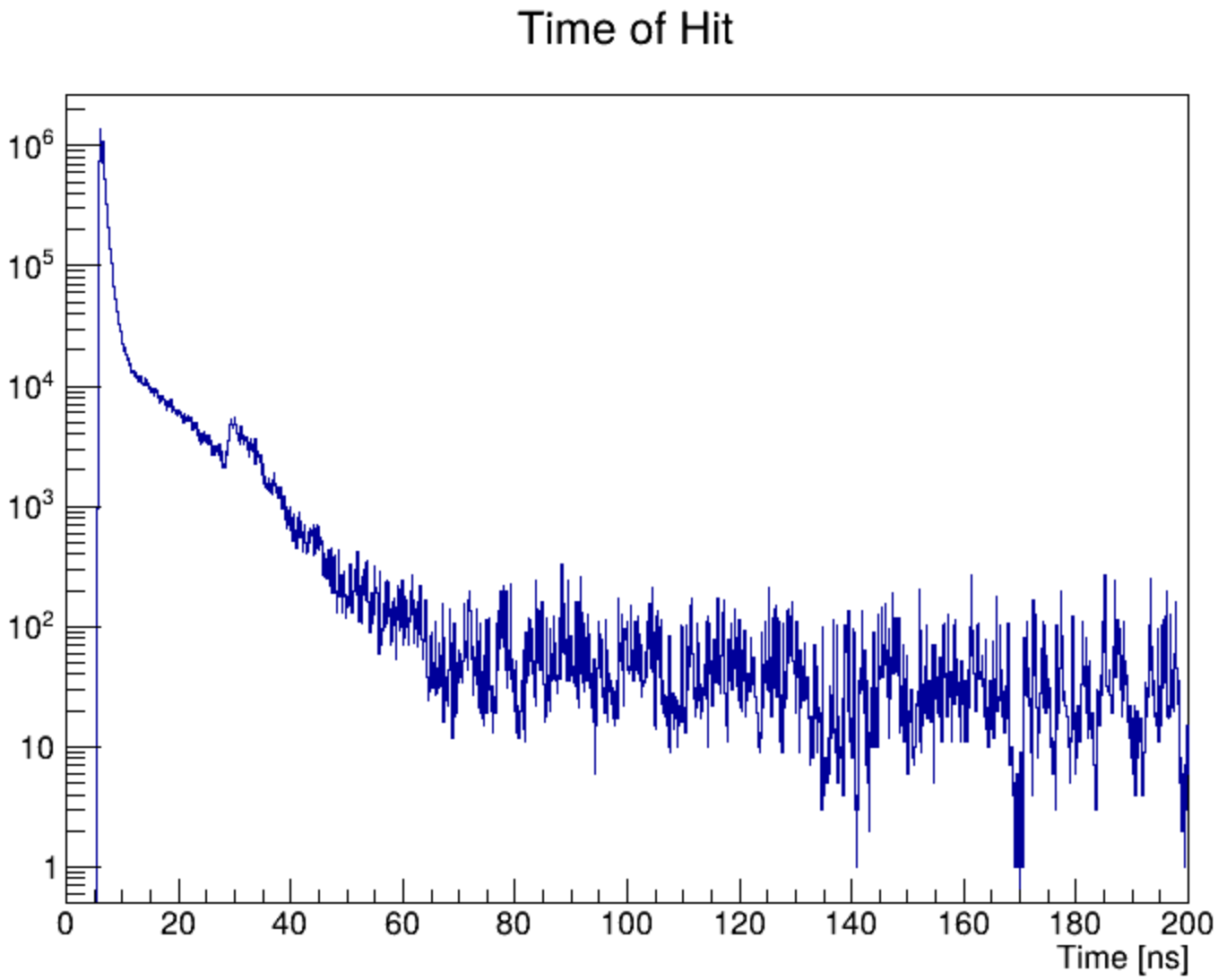


DIS Q2 10-100: Event Hit Structure

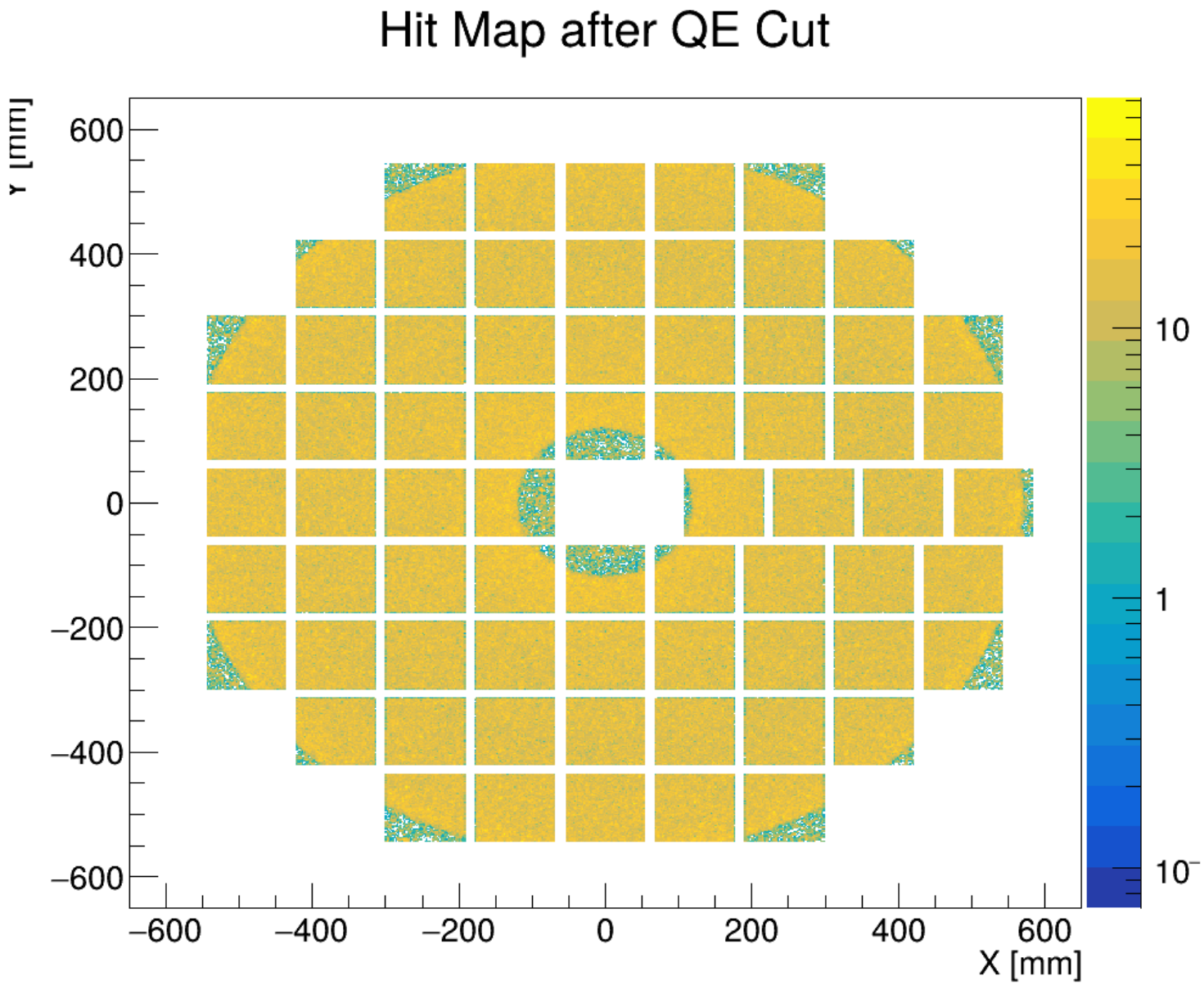




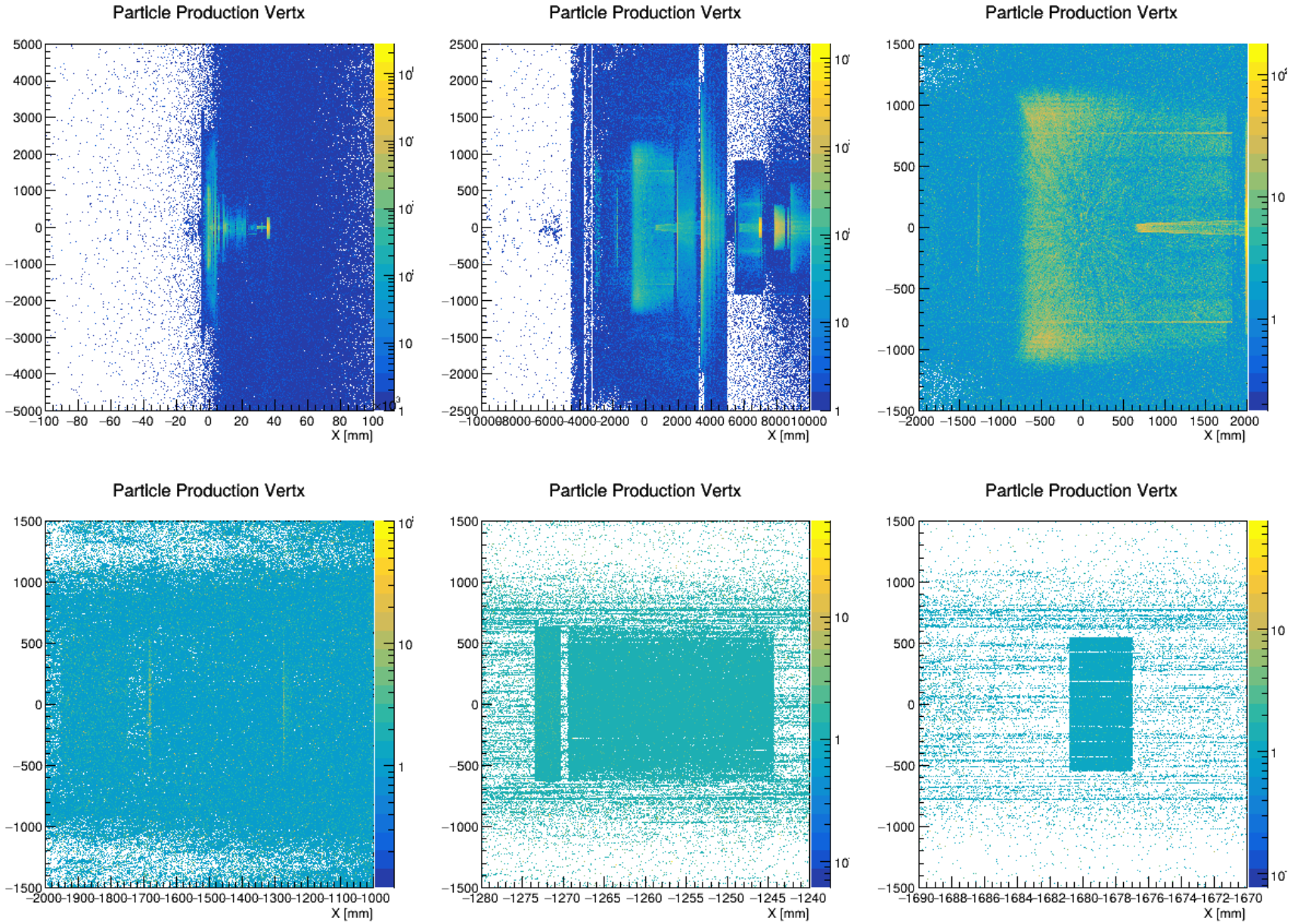
DIS Q2 10-100: Hit Times



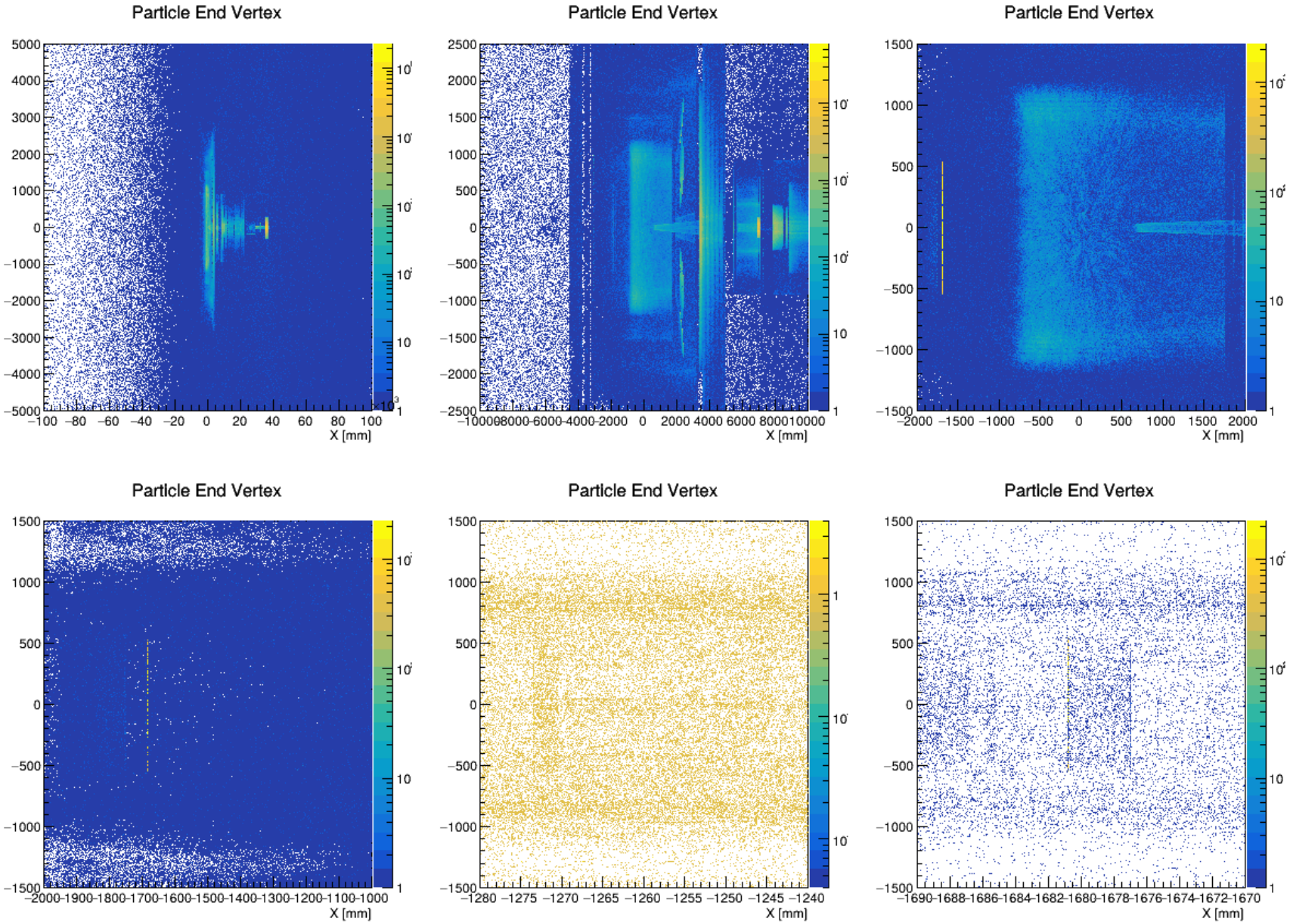
DIS Q2 10-100: Hit Map After QE Cut



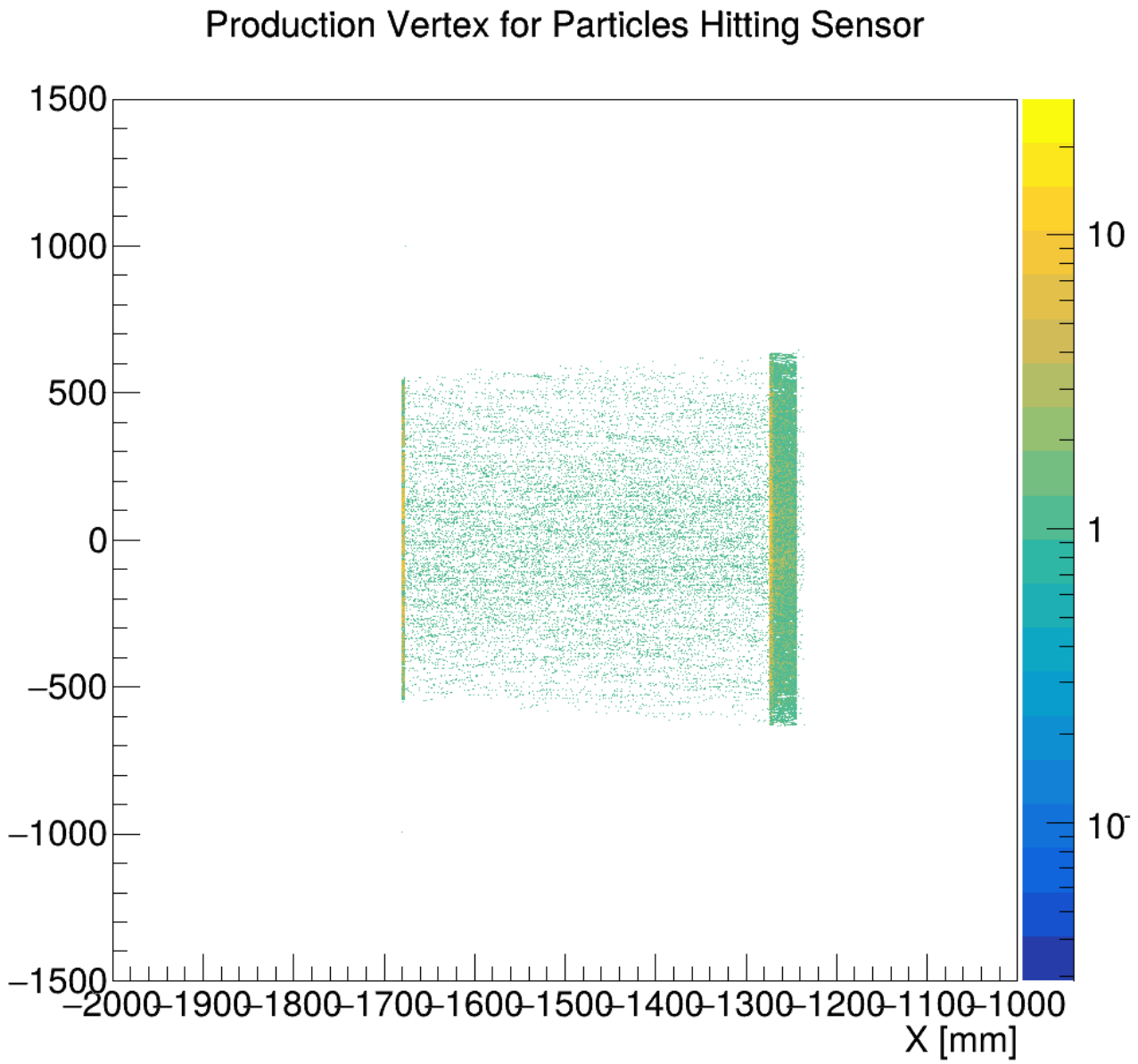
DIS Q2 100-1000: Production Vertex



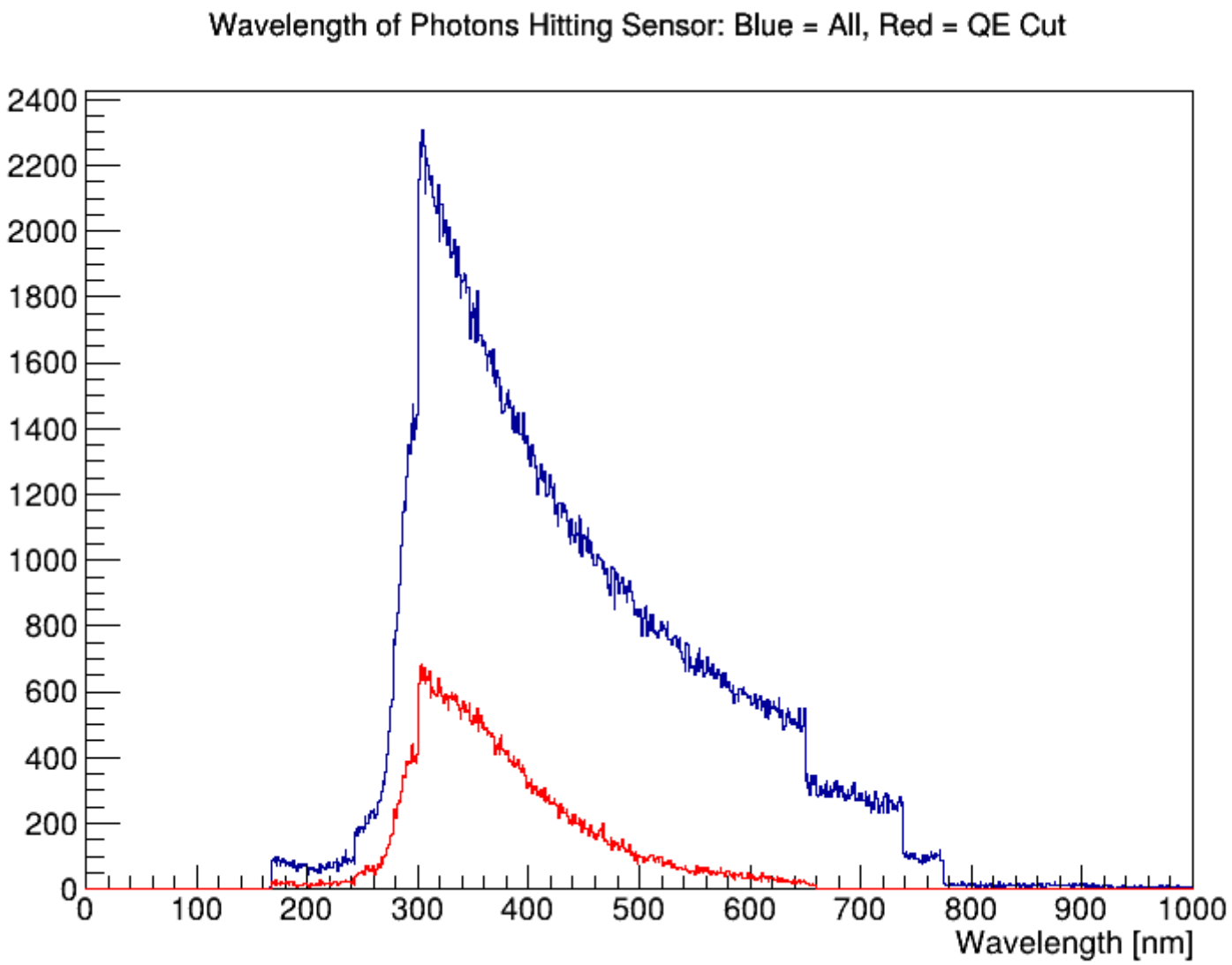
DIS Q2 100-1000: End Vertex



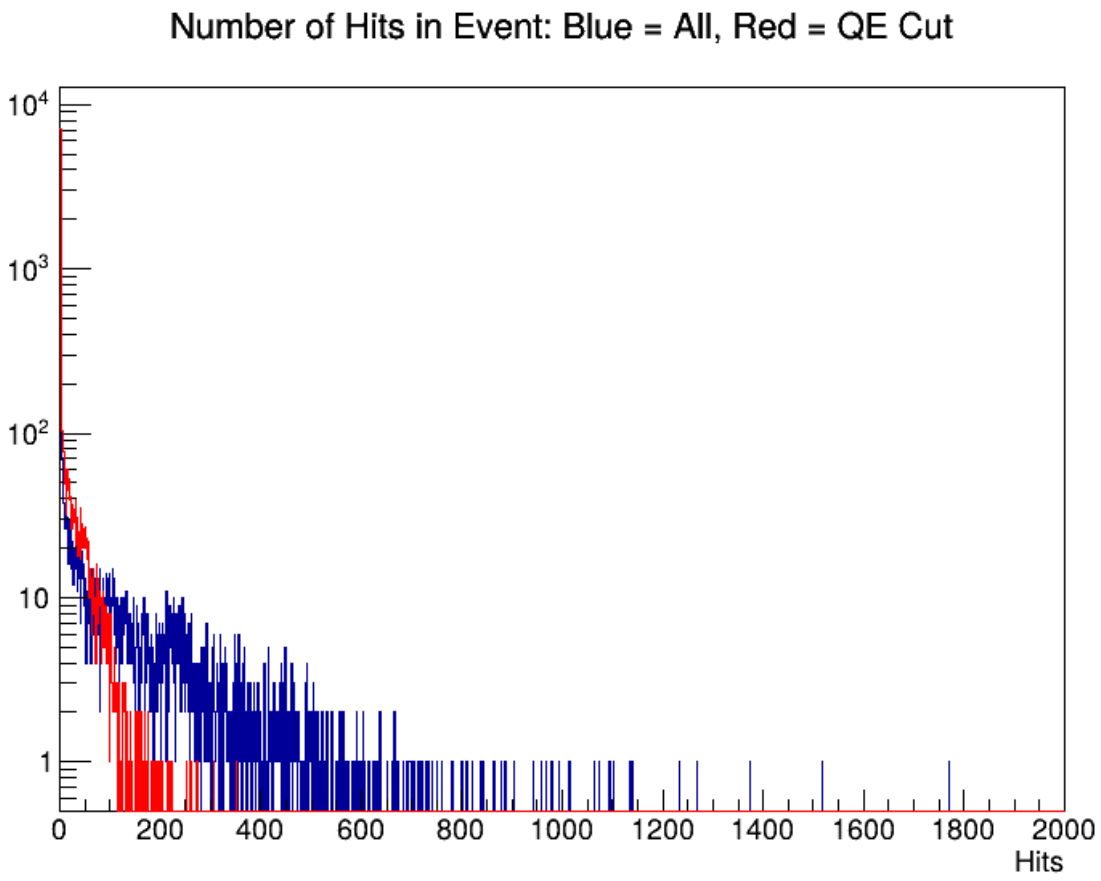
DIS Q2 100-1000: “Last Scatter” Before Sensor

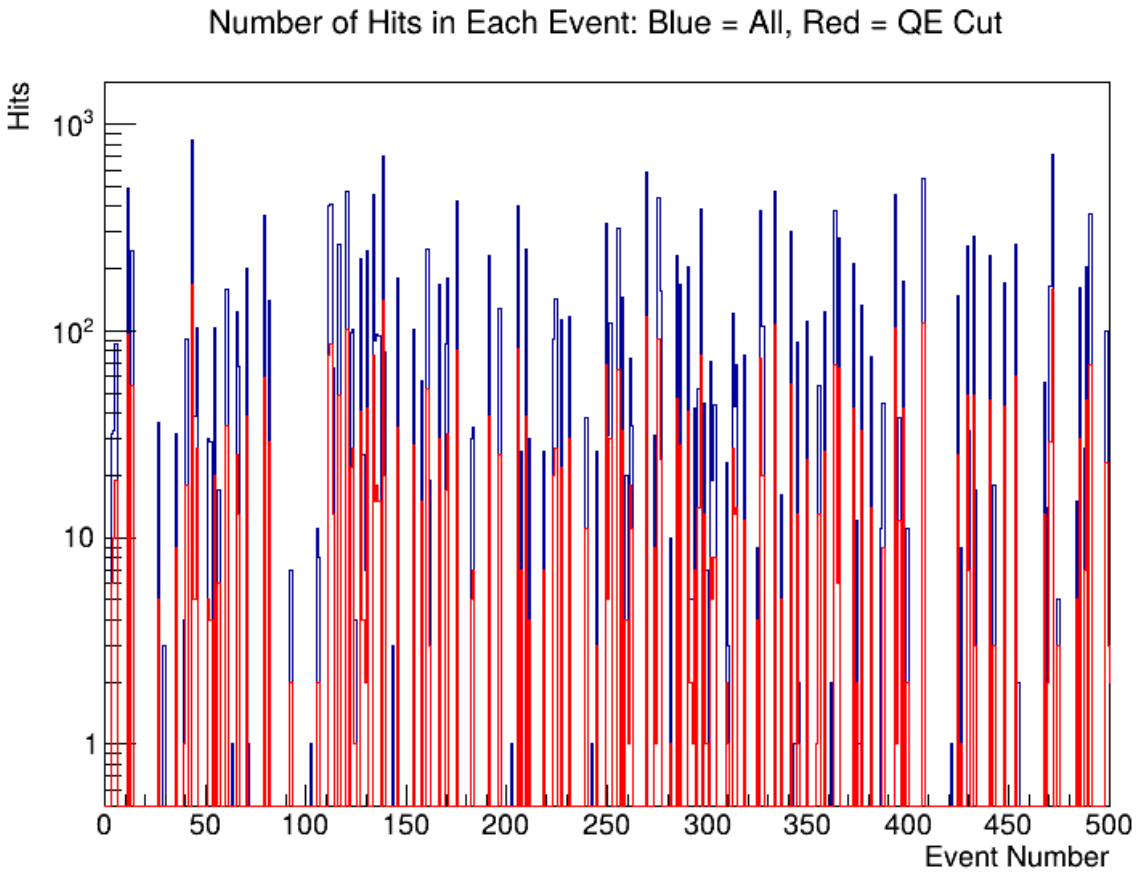


DIS Q2 100-1000: Photon Wavelength

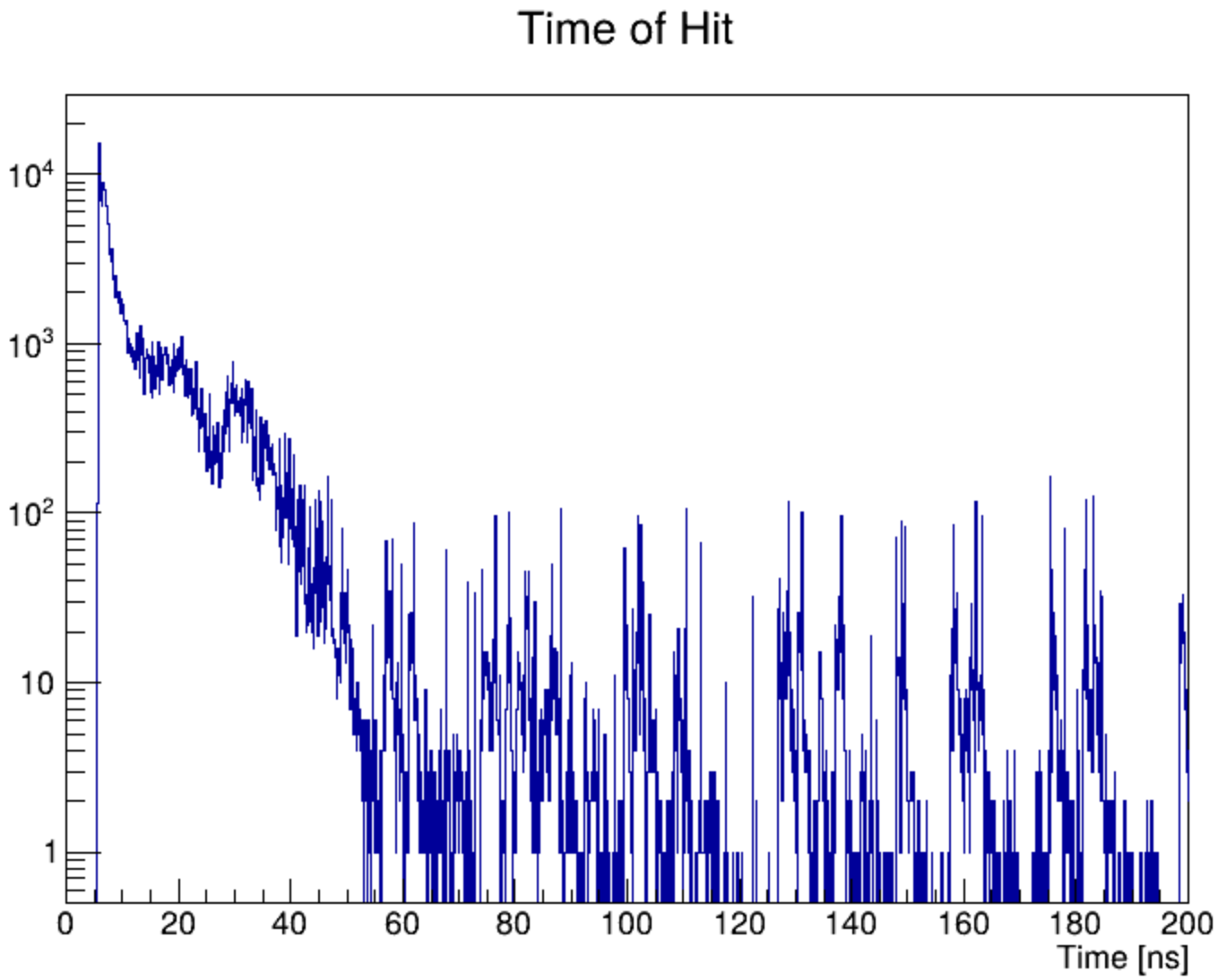


DIS Q2 100-1000: Event Hit Structure





DIS Q2 100-1000: Hit Times



DIS Q2 100-1000: Hit Map After QE Cut