

# pfRICH Occupancy

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TIC Meeting

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# Simulation Setup

- ❑ Results presented based on 10x275 simulation (conclusions not substantially different for 10x100)
- ❑ Use geometry/code in branch irt-2.1c of irt, ElCrecon, 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](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

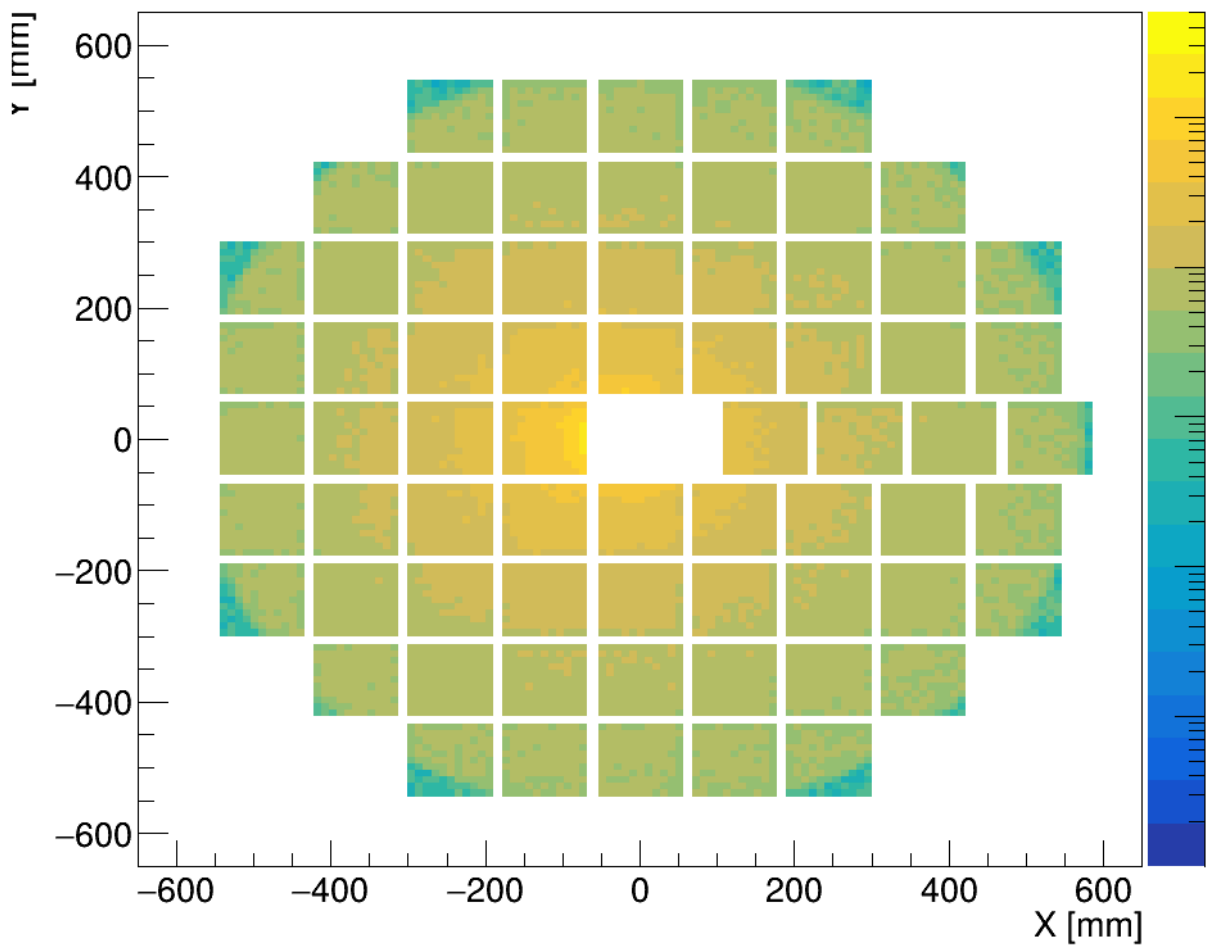
## ❑ Signal generated using Pythia6 minbias samples – 50 microbarn total cross section

## ❑ Total signal rate at $10 \times 250 = 500$ KHz ( $1 \text{ fb}^{-1}$ in $10^5$ s)

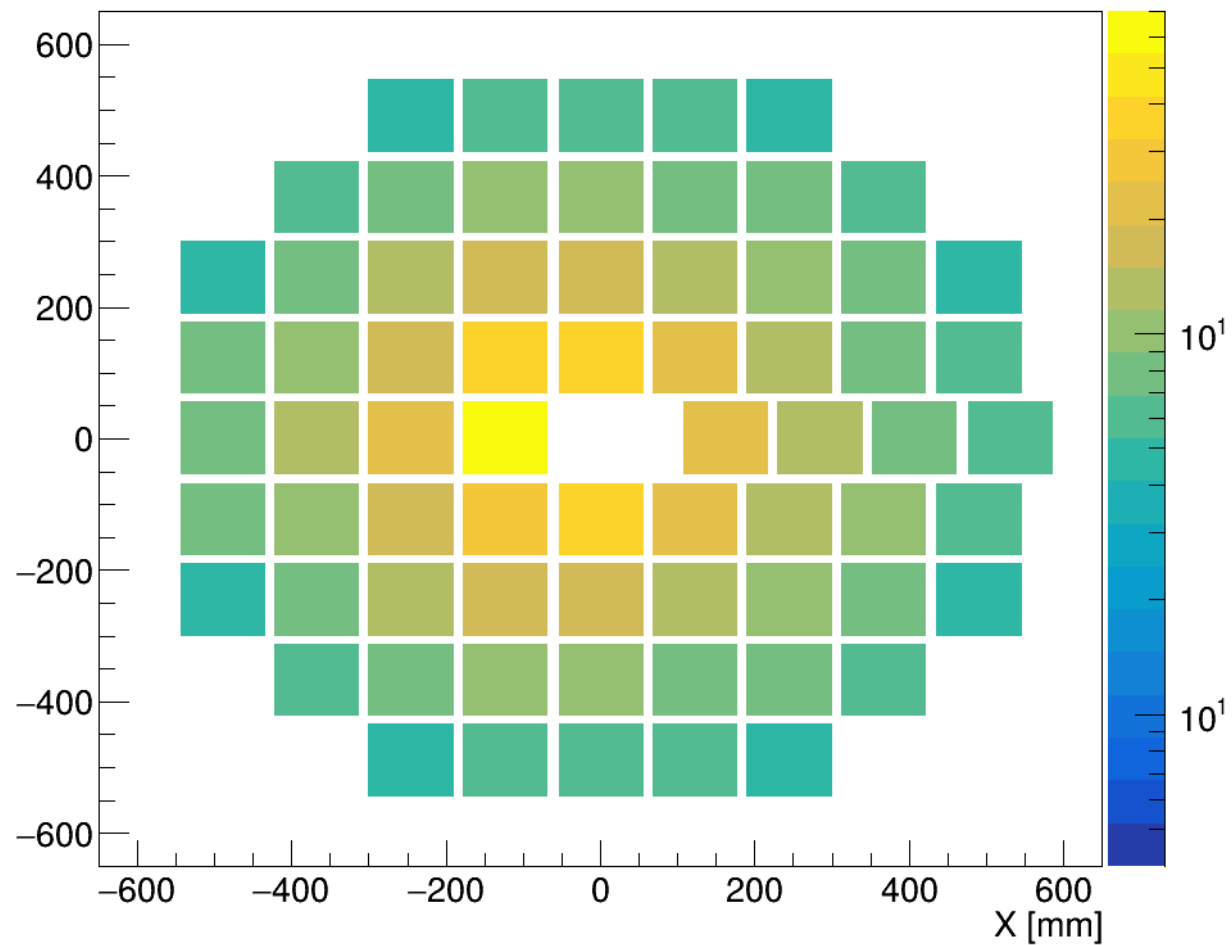
- $Q_2 < 1$ : 491.87 KHz
- $1 < Q_2 < 10$ : 0.74 KHz
- $10 < Q_2 < 100$ : 0.59 KHz
- $100 < Q_2 < 1000$ : 0.02 KHz

# Background Hit Maps

Background Hits /cm<sup>2</sup>/fb<sup>-1</sup>

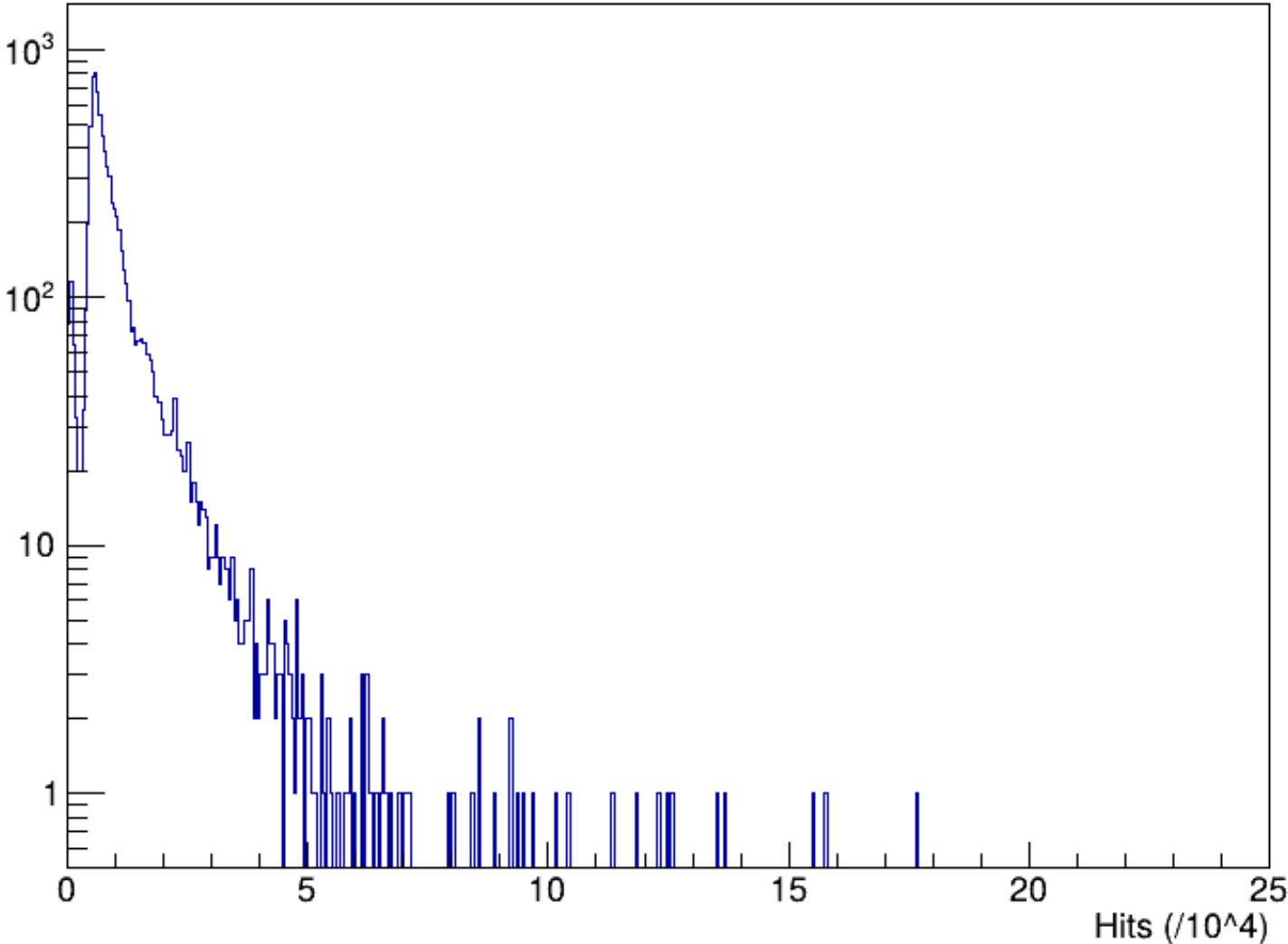


Background Hits /HRPPD/fb<sup>-1</sup>



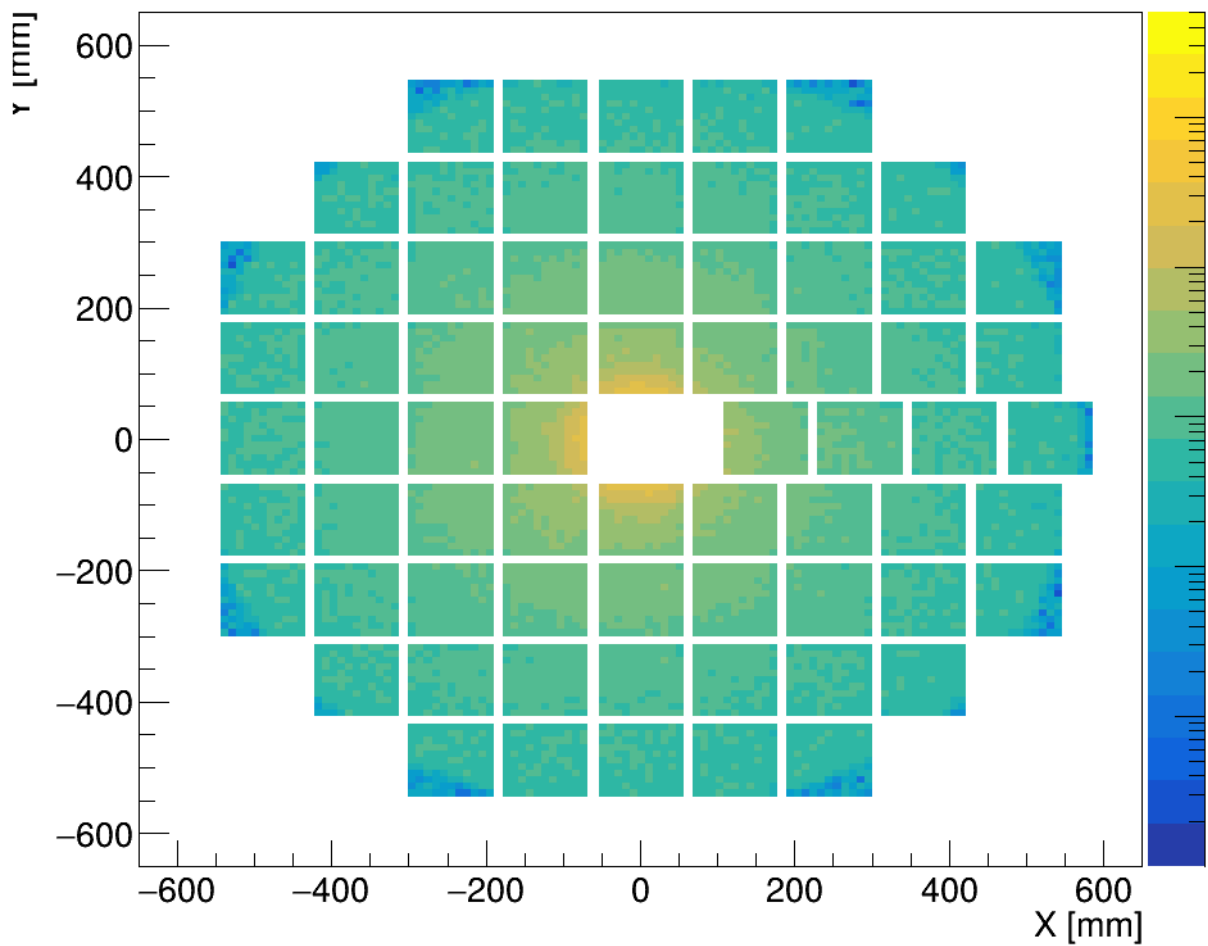
# Background Hit Frequency

Background Hits /cm<sup>2</sup>/s

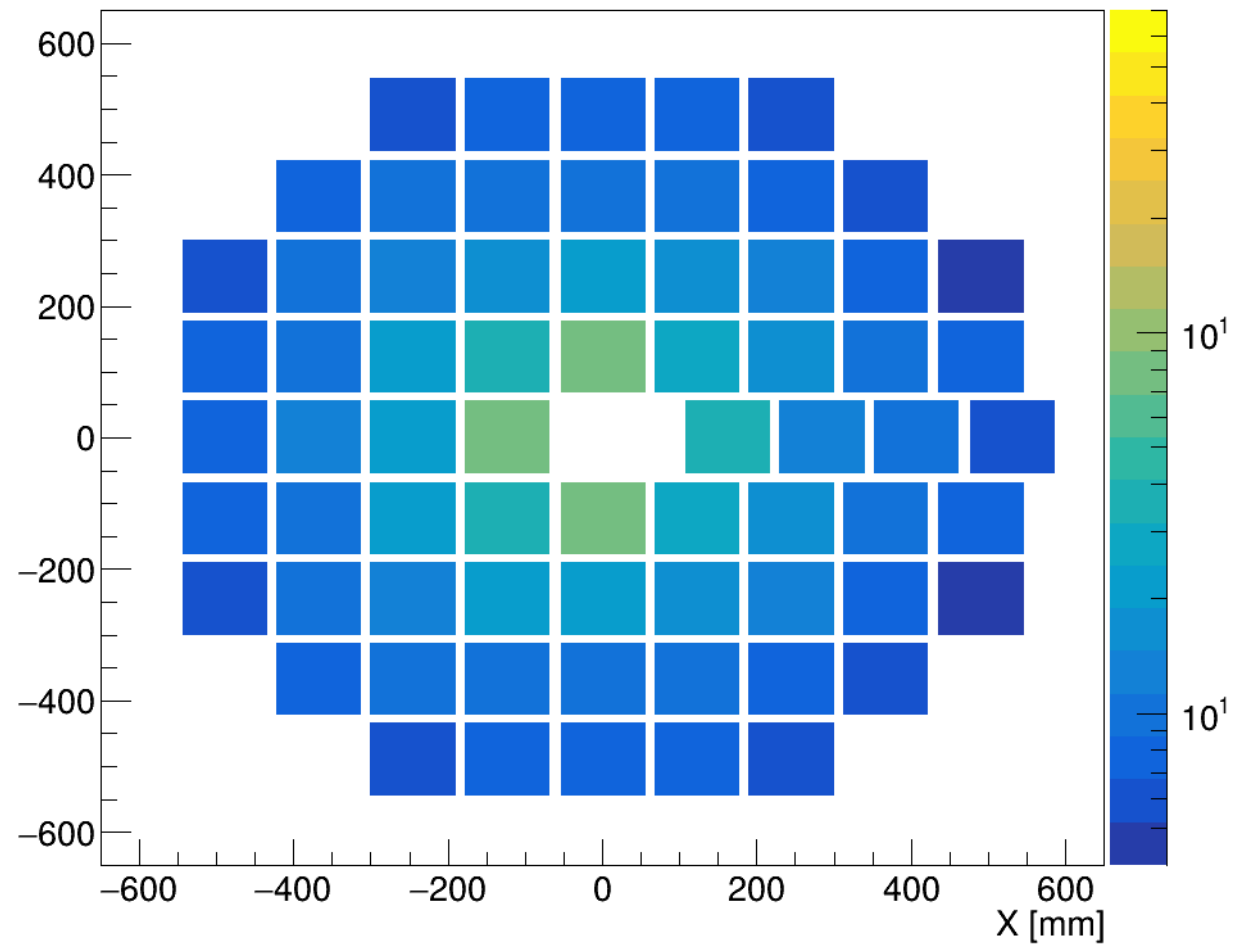


# Signal Hit Maps

Signal Hits /cm<sup>2</sup>/fb<sup>-1</sup>

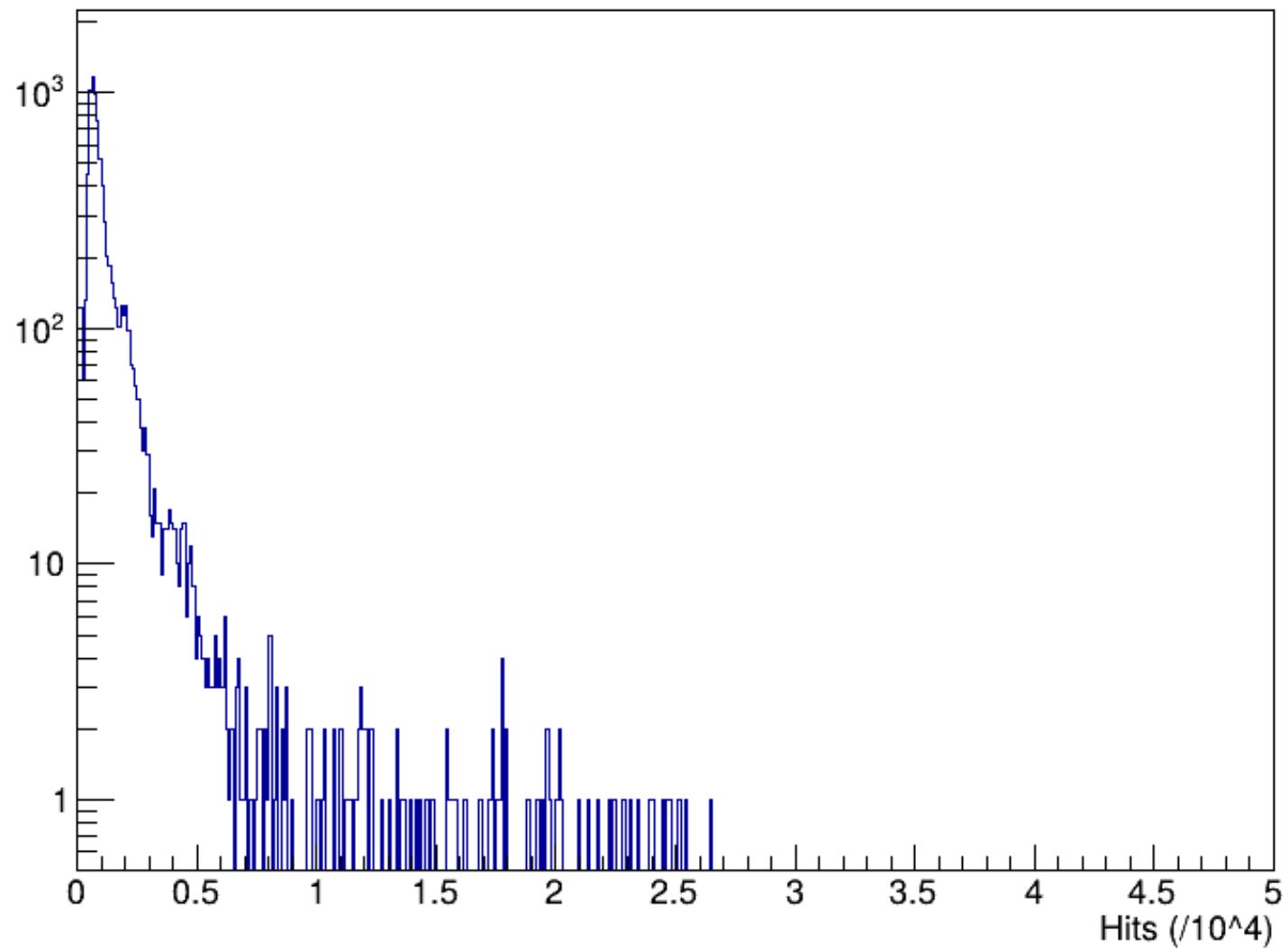


Signal Hits /HRPPD/fb<sup>-1</sup>



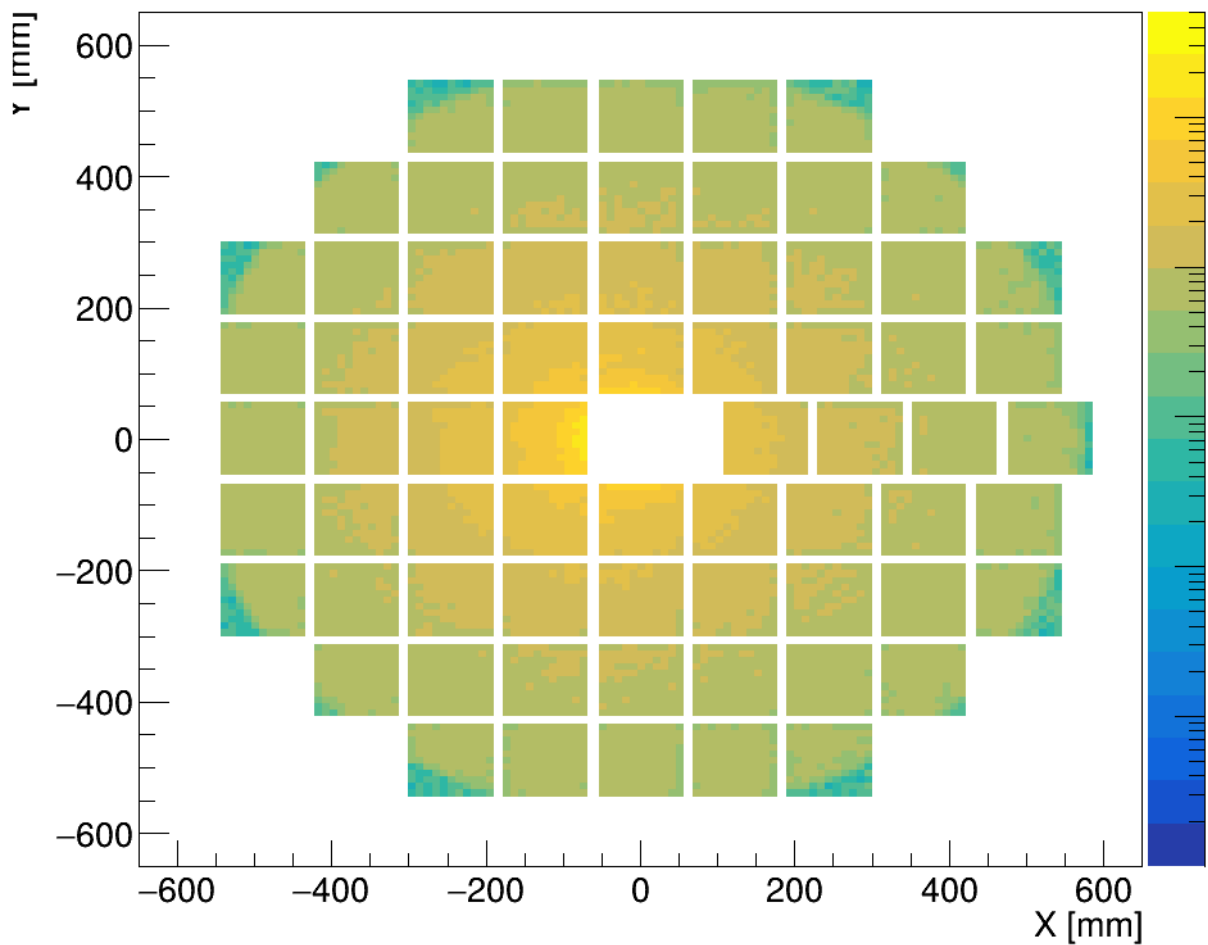
# Signal Hit Frequency

Signal Hits /cm<sup>2</sup>/s

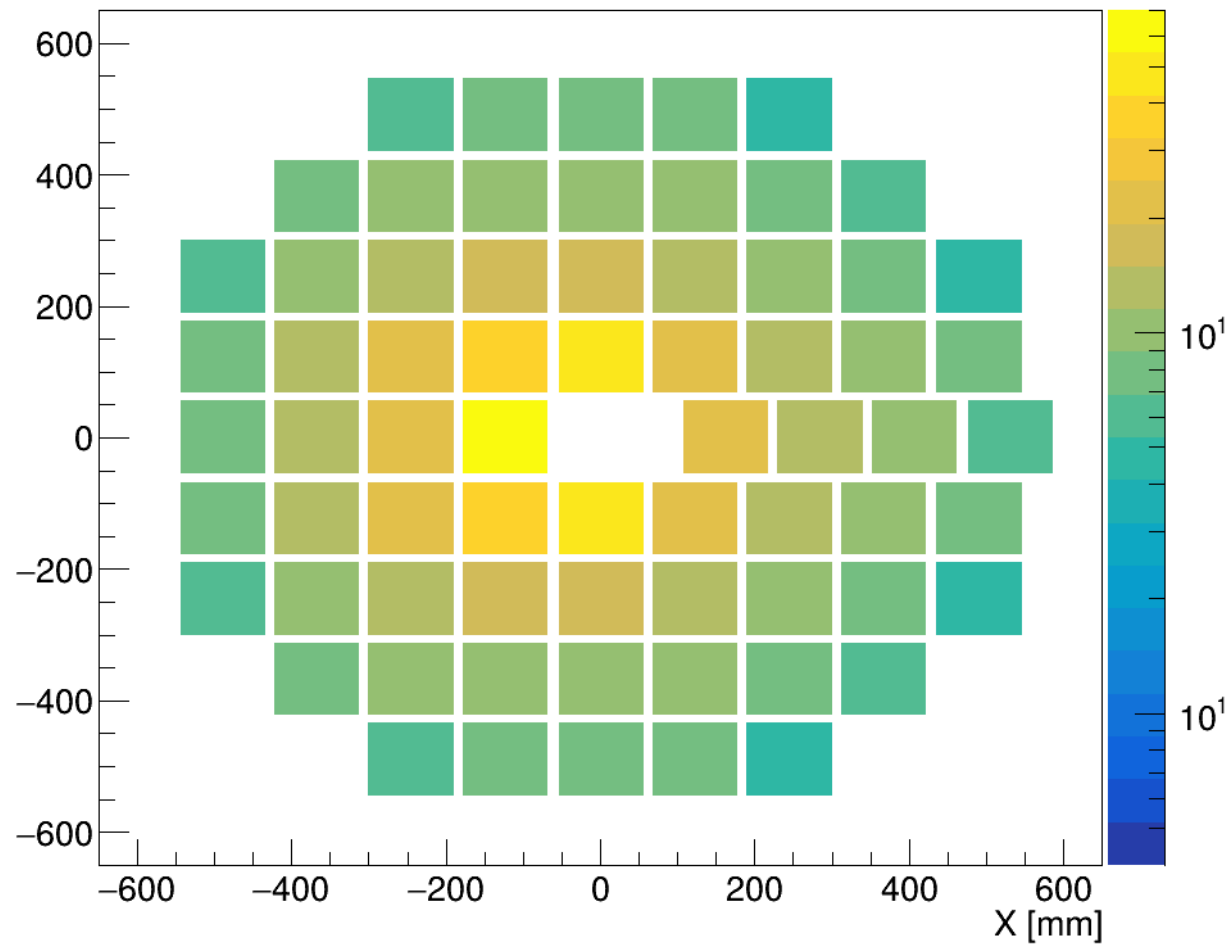


# Background + Signal Hit Maps

Total Hits /cm<sup>2</sup>/fb<sup>-1</sup>

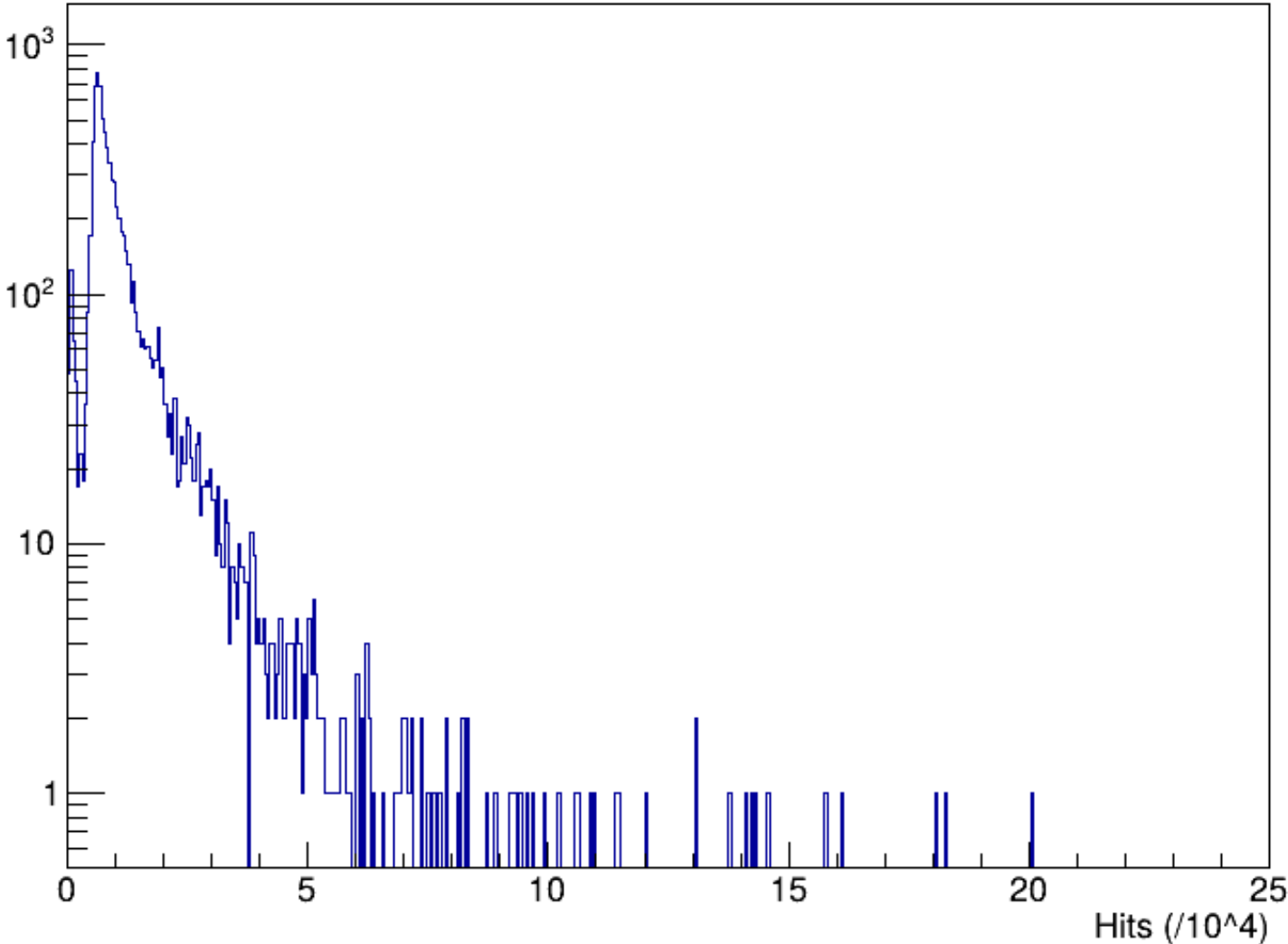


Total Hits /HRPPD/fb<sup>-1</sup>



# Background + Signal Hit Frequency

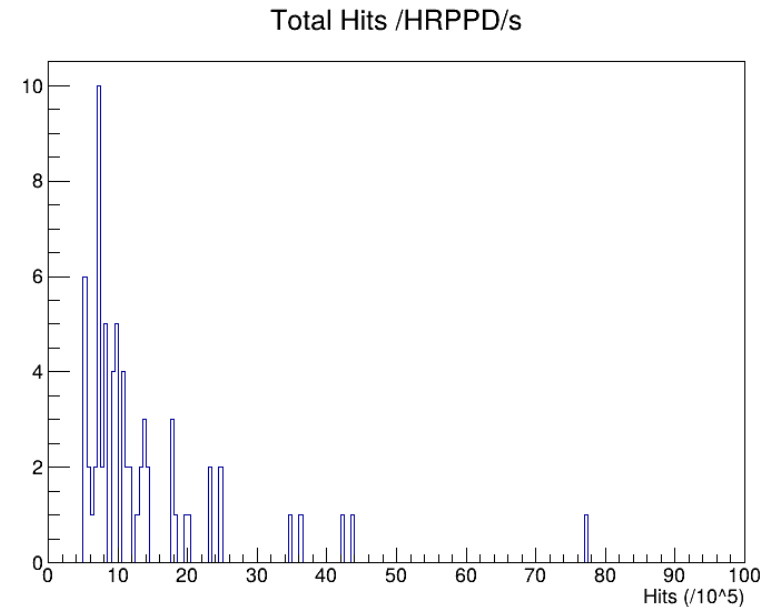
Total Hits /cm<sup>2</sup>/s



# Data Rates

\* Data rate estimates provided by Takao Sakaguchi

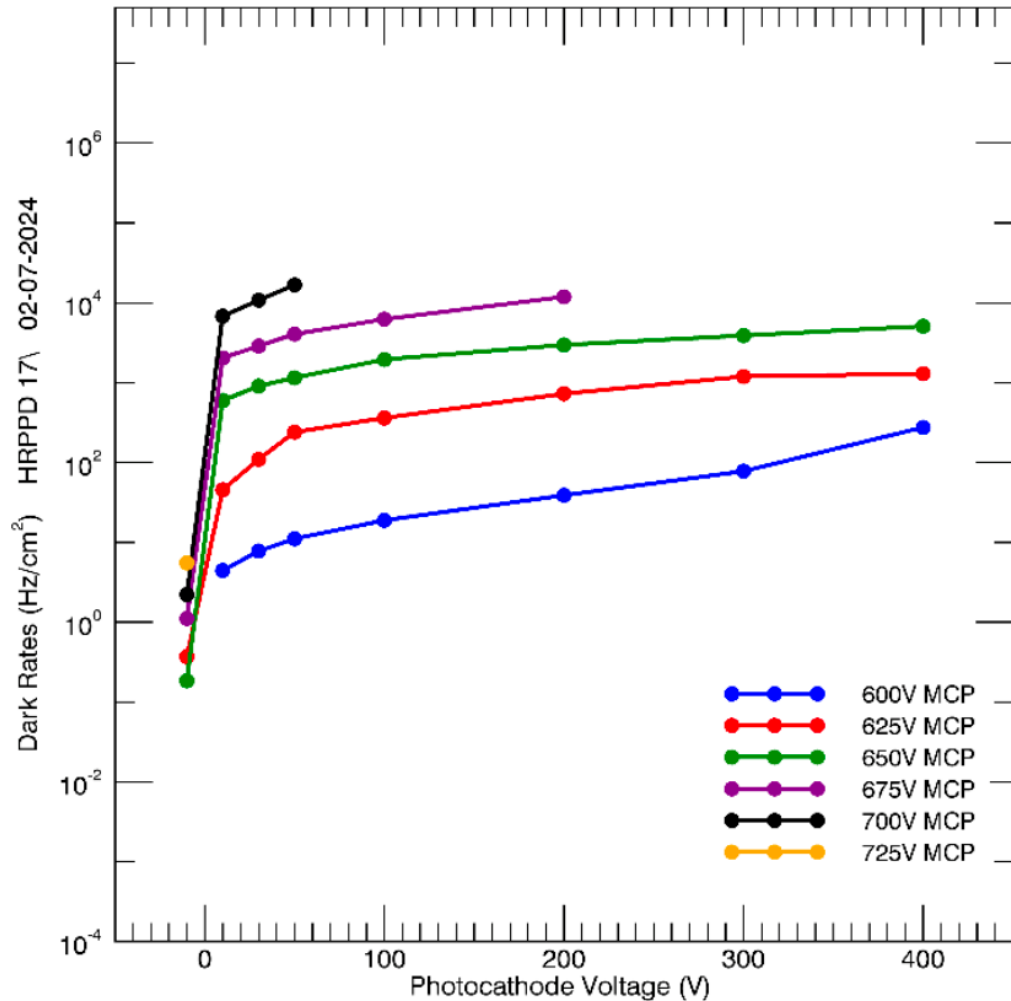
- ❑ Hit rate [/cm<sup>2</sup>/s]
  - Hottest region: 200000
  - MPV: 6000
  - Peak region (75% of total): 5000 – 15000
  
- ❑ Convert Hit rate from /cm<sup>2</sup> to /pad: 9 pads occupy  $(0.325 \times 3)^2 = 0.95 \text{ cm}^2 \rightarrow \text{Rate/pad} = \text{Rate/cm}^2 \times 0.95/9$
  
- ❑ FCFD 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 hits/s  $\rightarrow$  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  $\rightarrow$  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<sup>2</sup>/year]:
  - Hottest Region: 0.05
  - MPV: 0.002

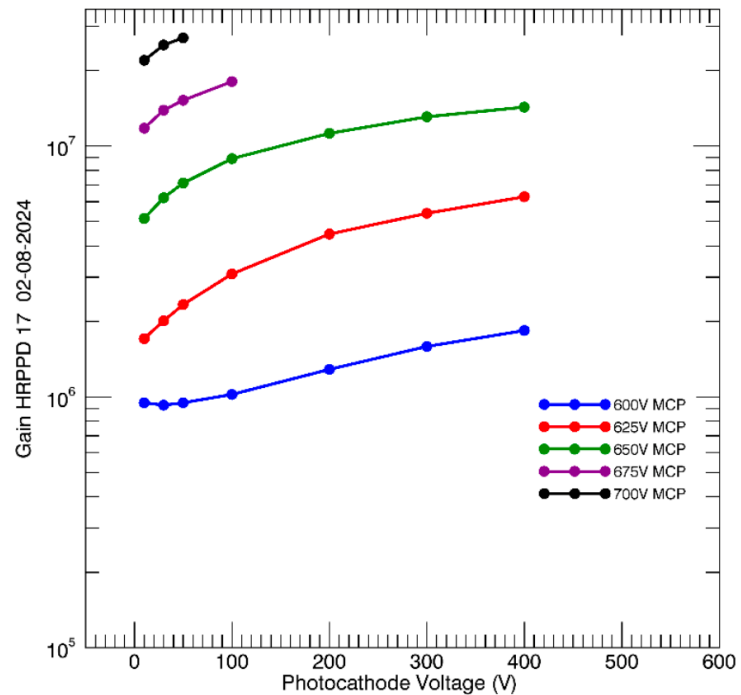
# Dark Count Rates



□ Assuming we work at gains of a few times  $10^6$ , we can likely expect dark rates around  $100 \text{ Hz/cm}^2$

□ Even at gains of  $10^7$ , we would get a few  $\text{KHz/cm}^2$

□ Machine background will dominate everywhere except at the very edges of our acceptance

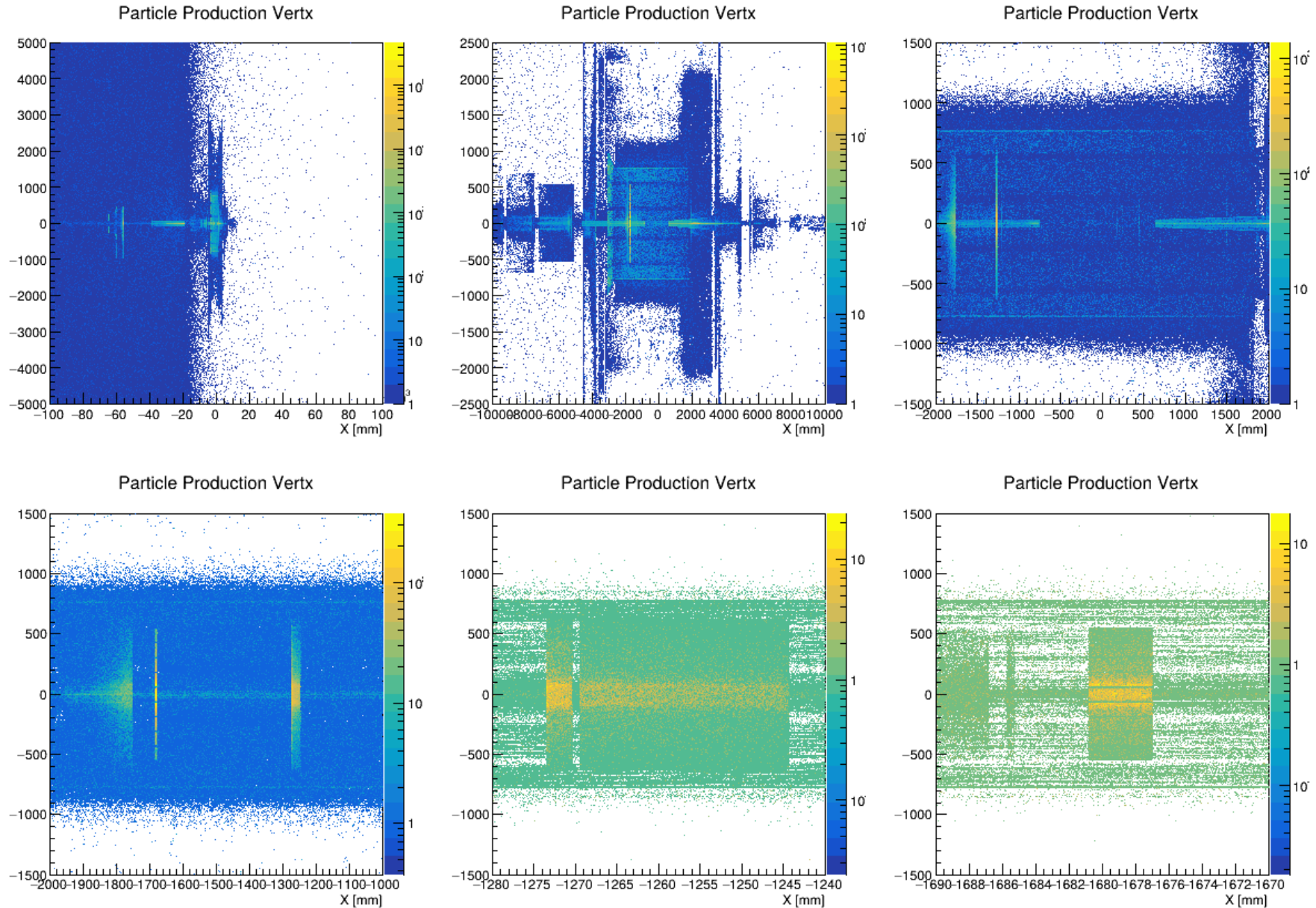


# Summary

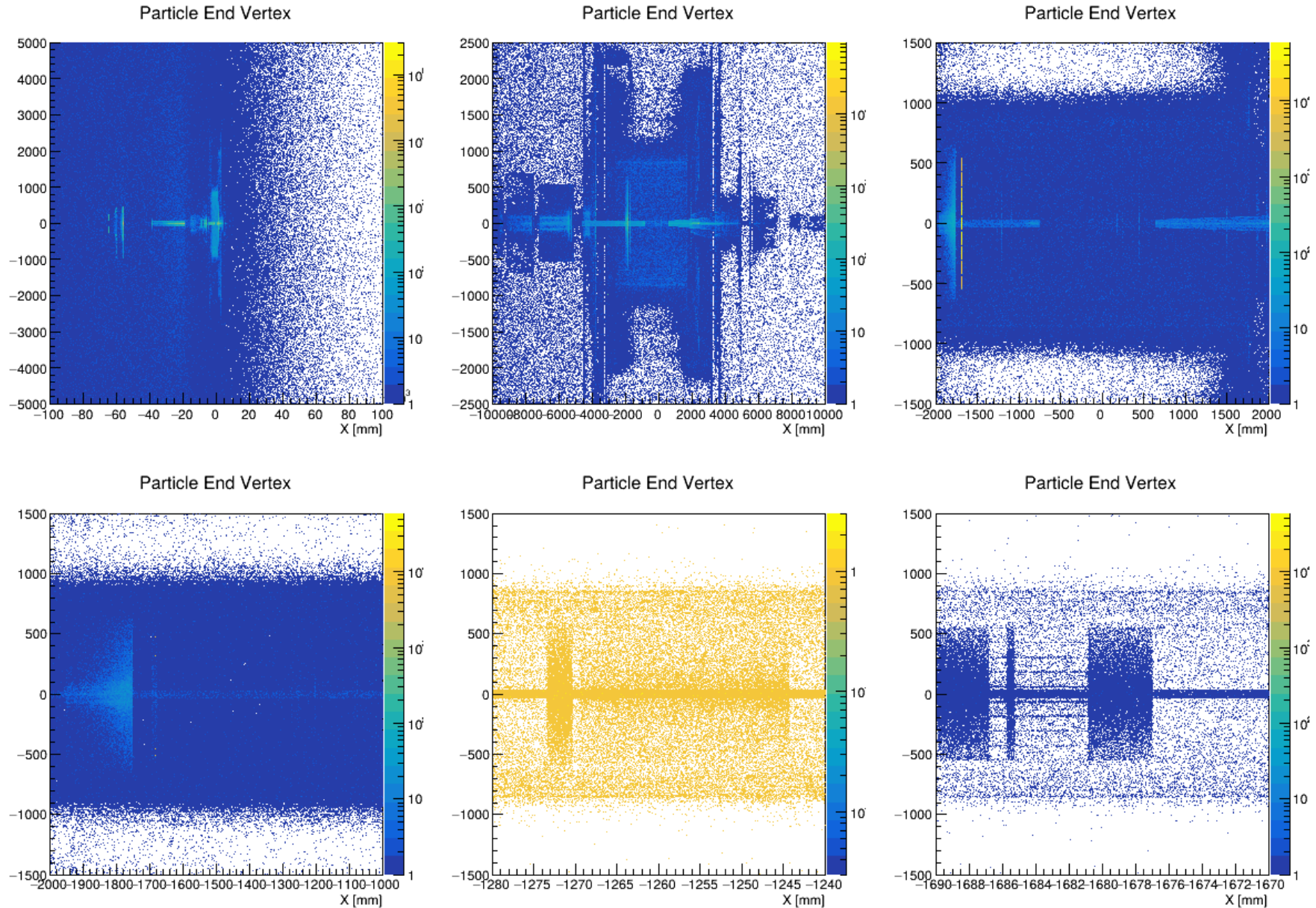
- ❑ pfRICH occupancy presented for 10x275 with all background and signal sources included
- ❑ Hottest regions of the detector (near beam pipe) see up to 200K hits/cm<sup>2</sup>/s, but the bulk of the detector will see about an order of magnitude less
- ❑ pfRICH will see about 8x more background hits 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

Backup

# Electron Beam Gas: Production Vertex

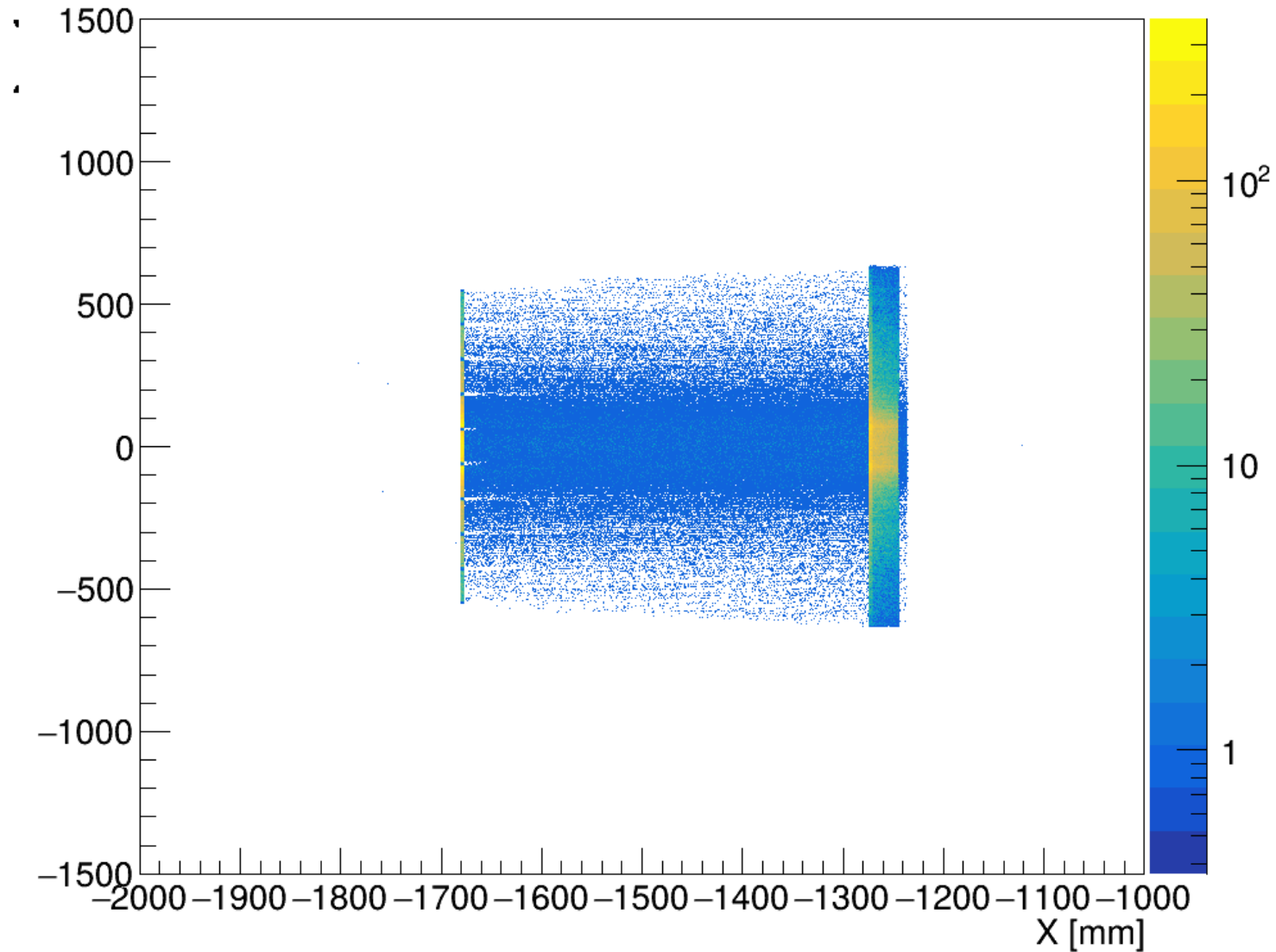


# Electron Beam Gas: End Vertex



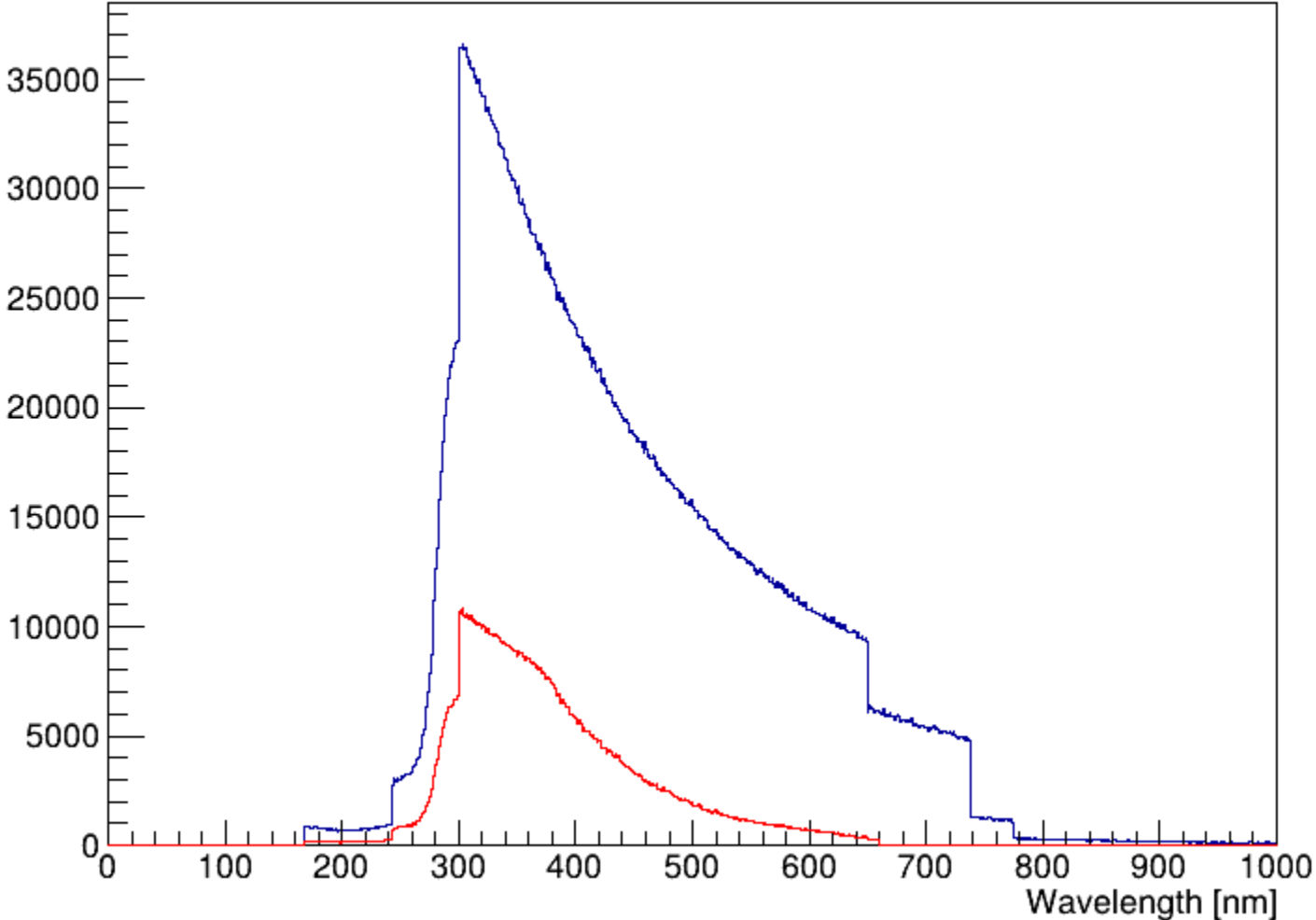
# Electron Beam Gas: “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor



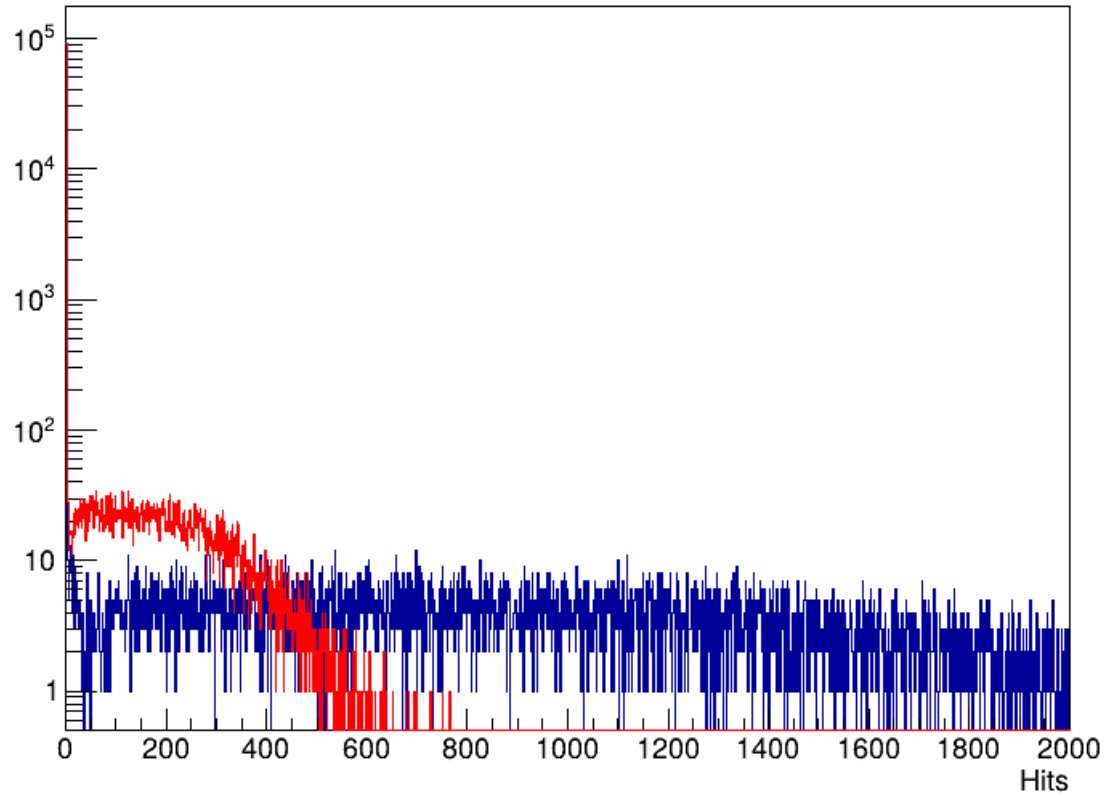
# Electron Beam Gas: Photon Wavelength

Wavelength of Photons Hitting Sensor: Blue = All, Red = QE Cut

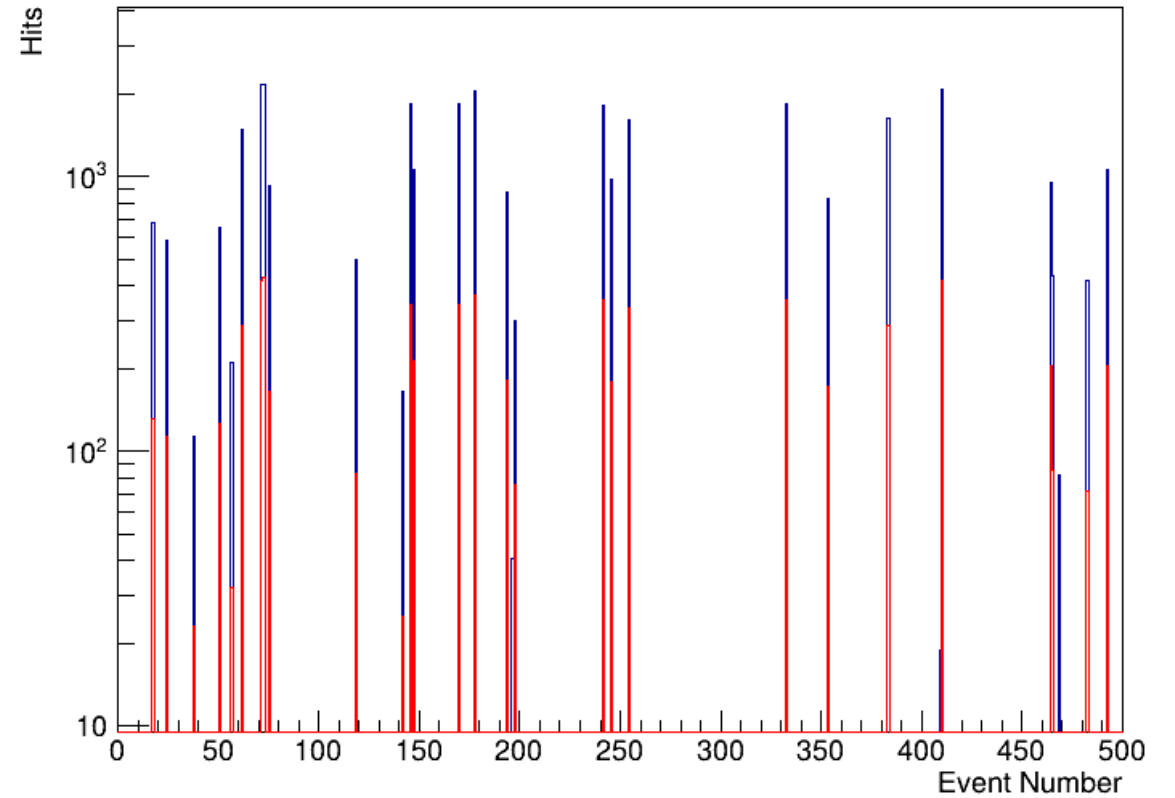


# Electron Beam Gas: Event Hit Structure

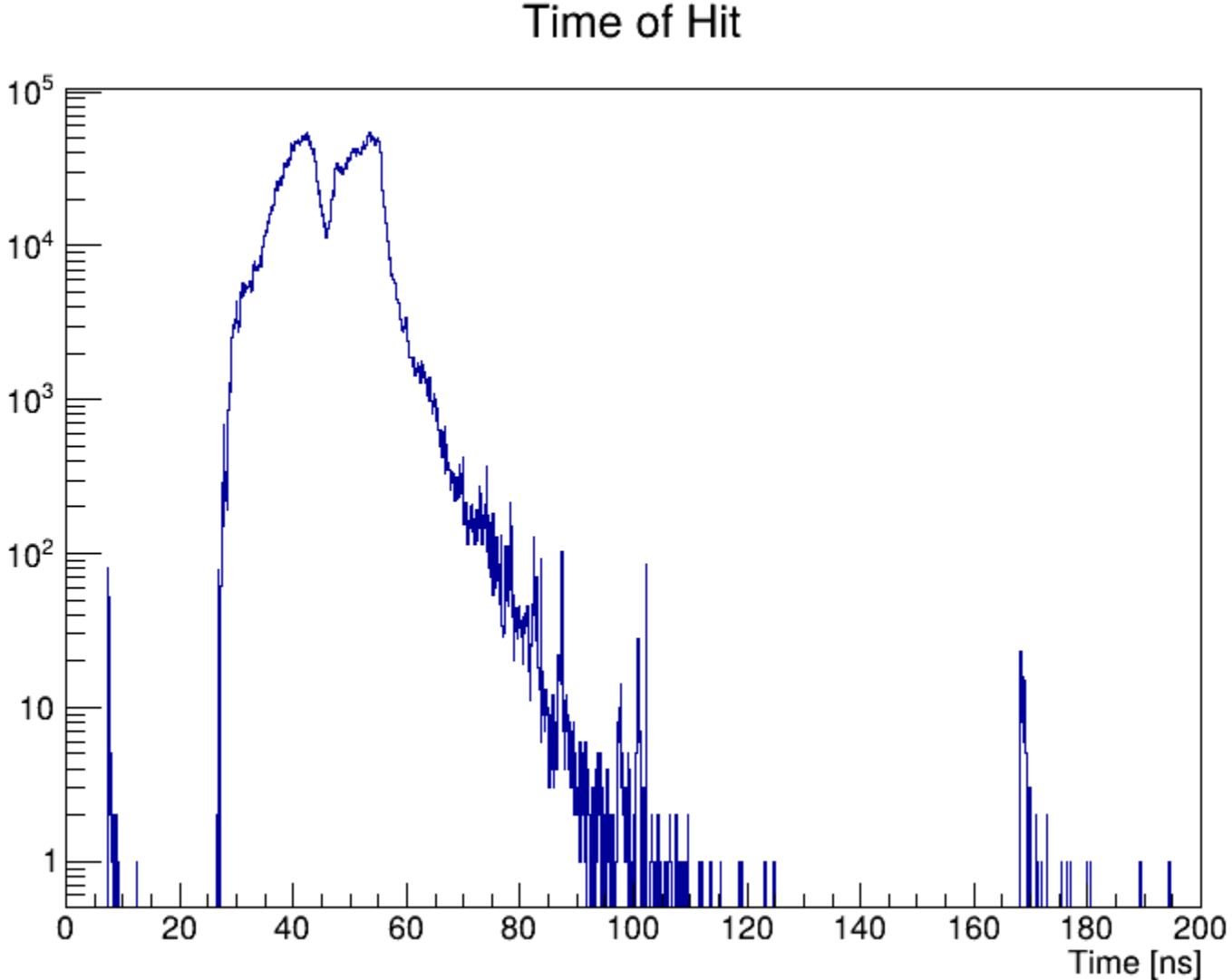
Number of Hits in Event: Blue = All, Red = QE Cut



Number of Hits in Each Event: Blue = All, Red = QE Cut

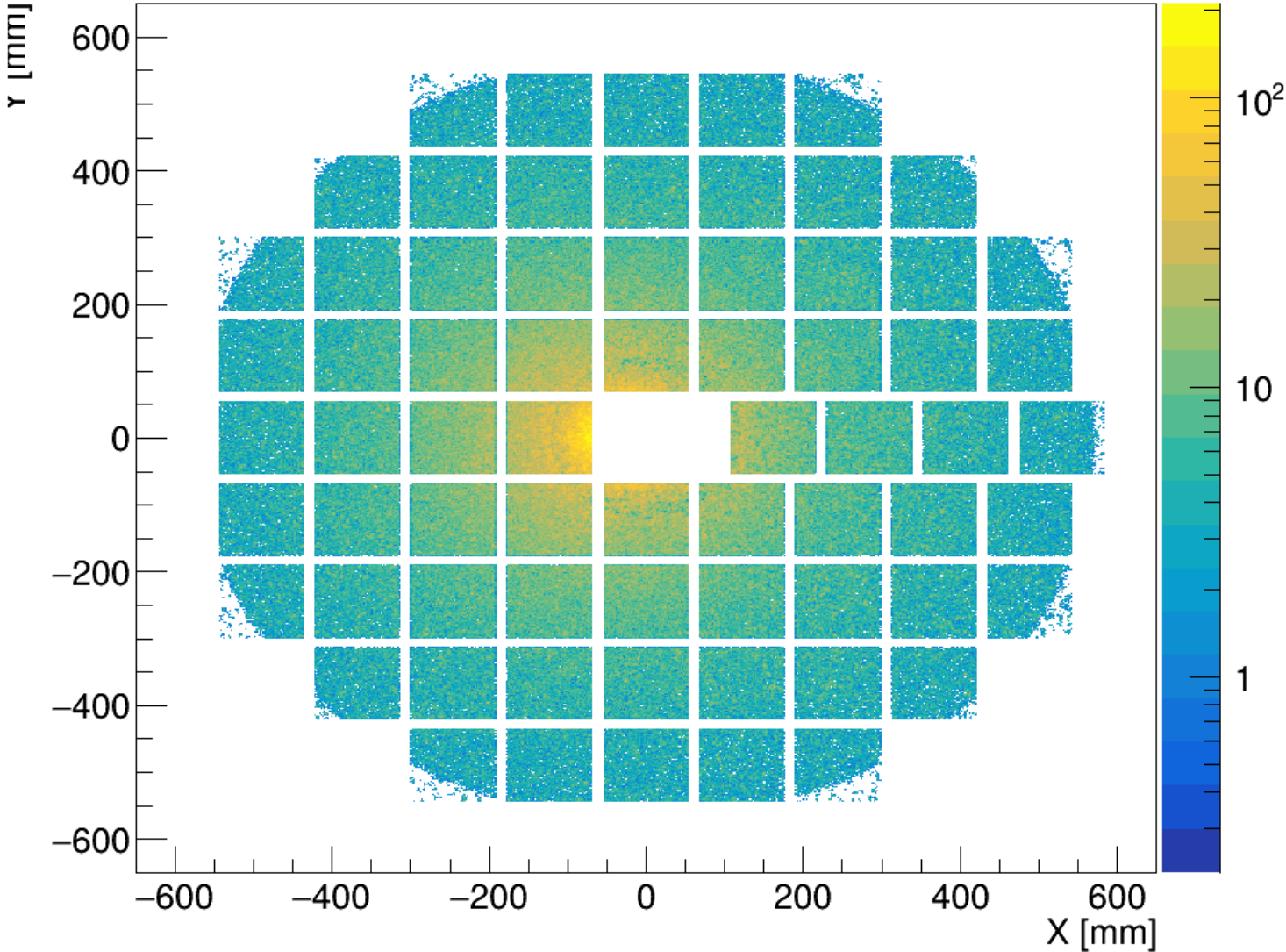


# Electron Beam Gas: Hit Times

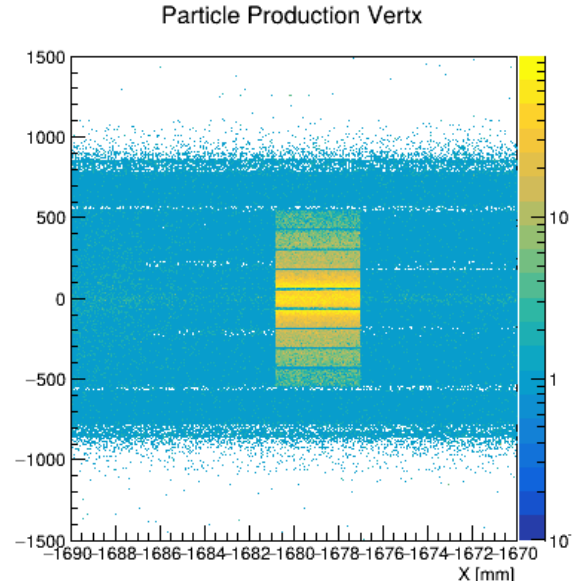
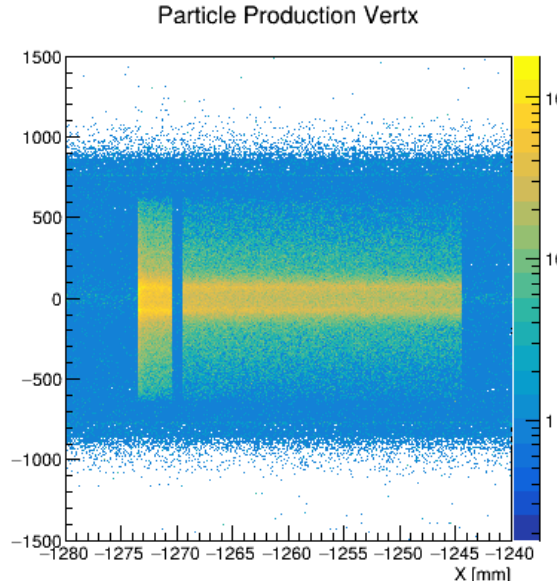
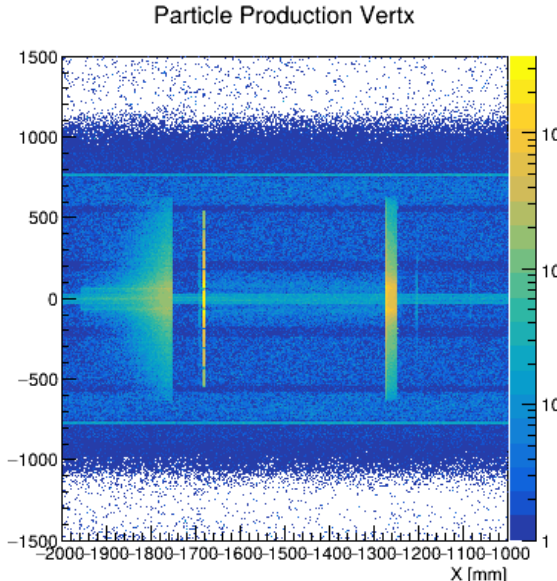
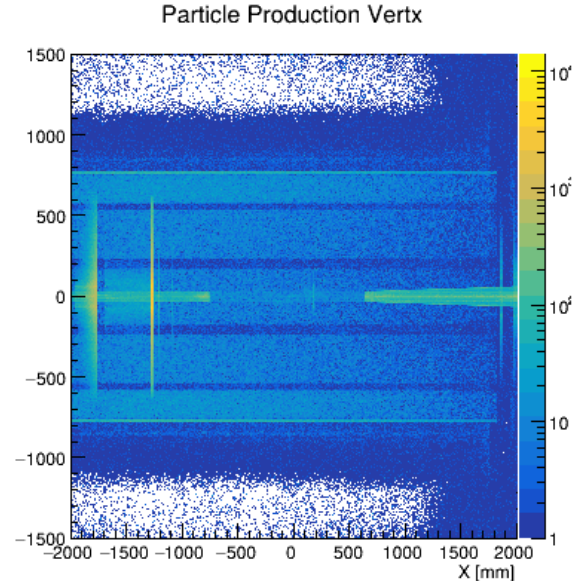
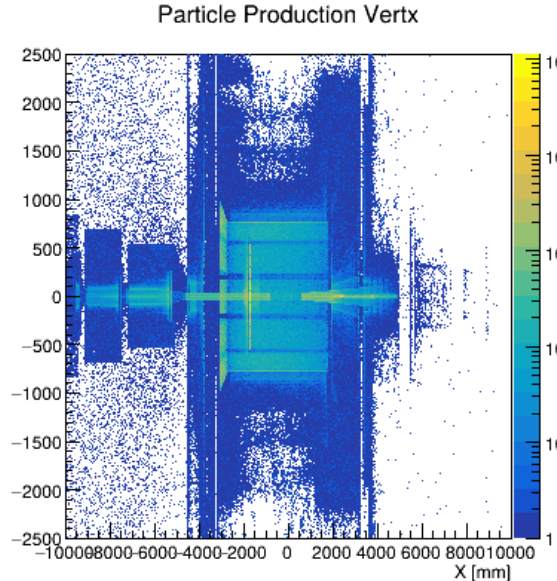
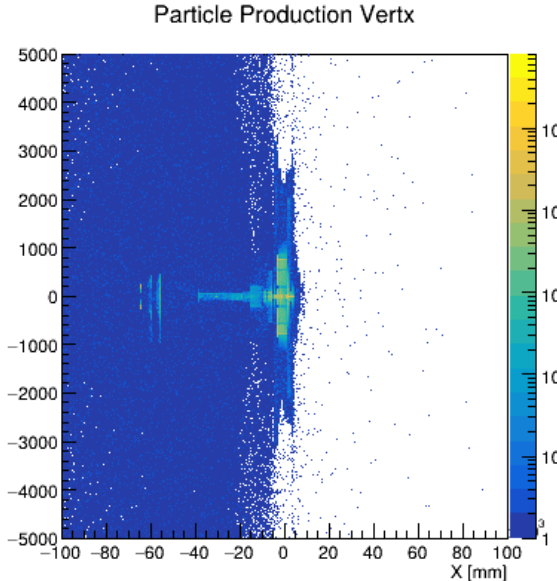


# Electron Beam Gas: Hit Map After QE Cut

Hit Map after QE Cut

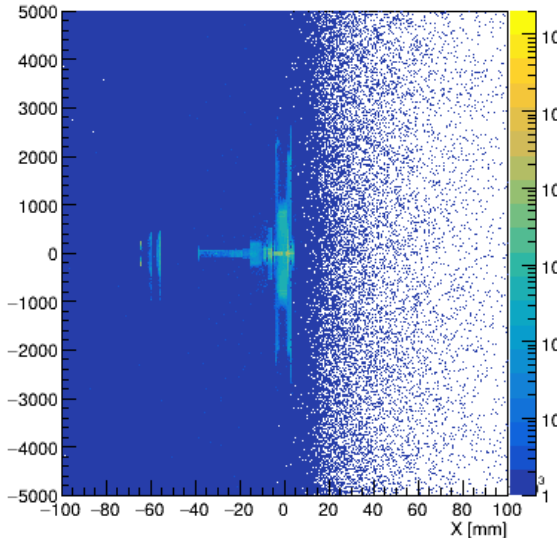


# Coulomb: Production Vertex

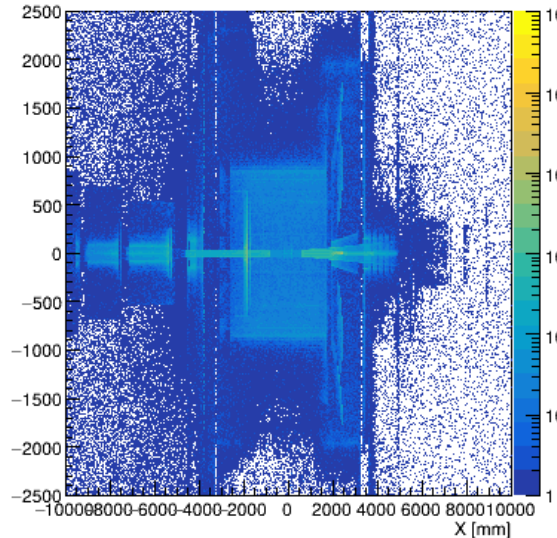


# Coulomb: End Vertex

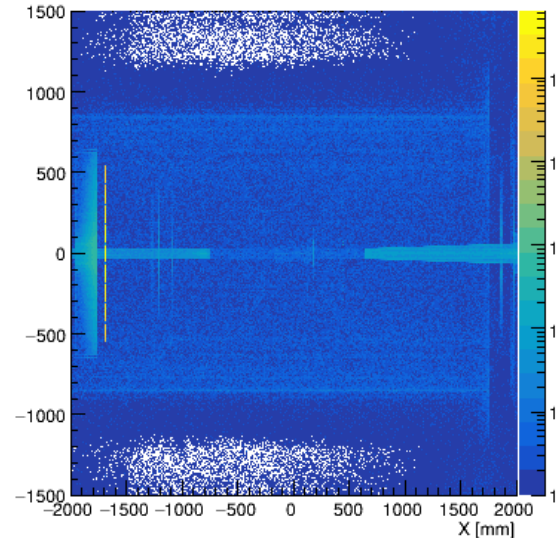
Particle End Vertex



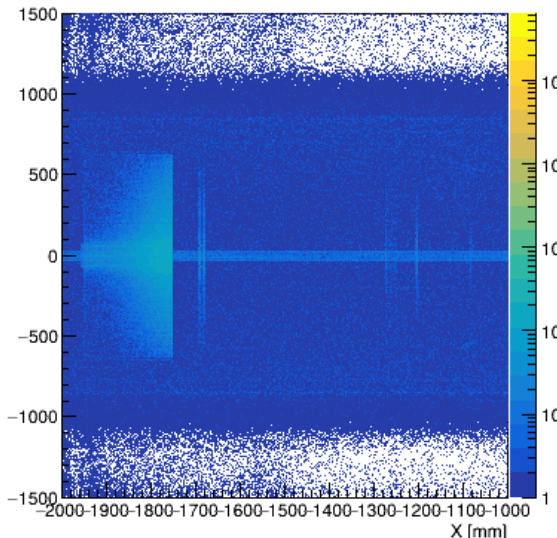
Particle End Vertex



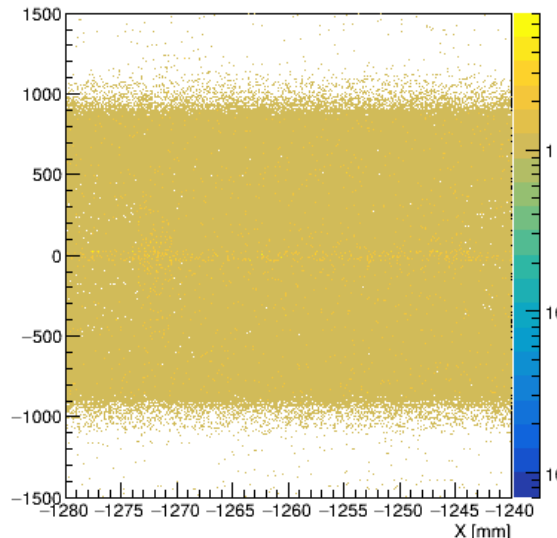
Particle End Vertex



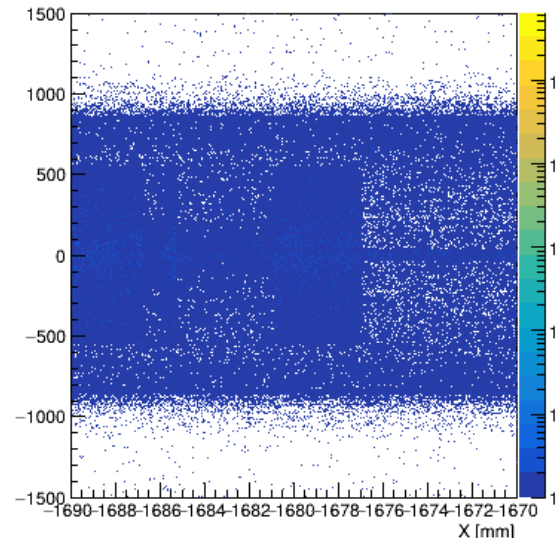
Particle End Vertex



Particle End Vertex

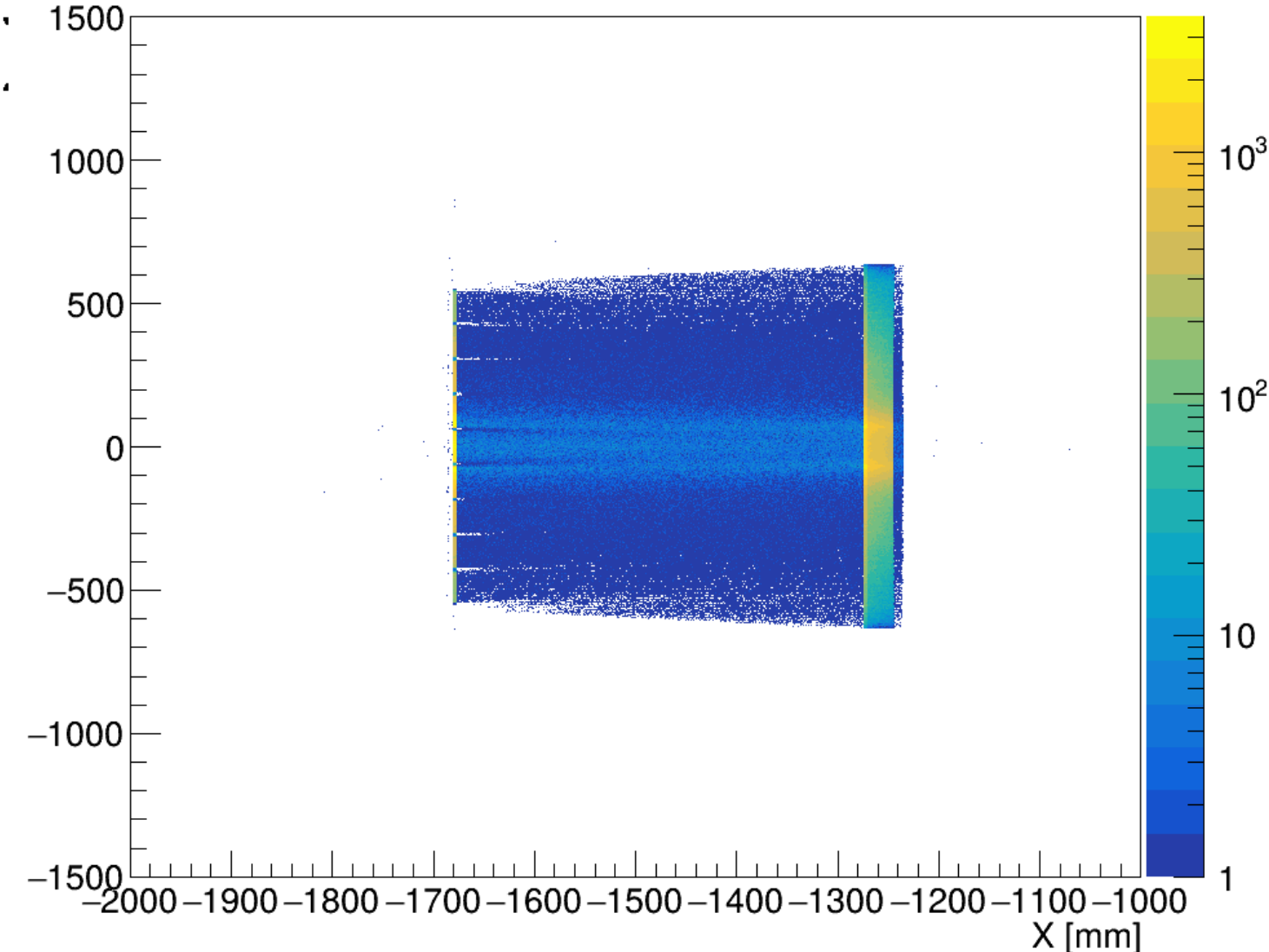


Particle End Vertex

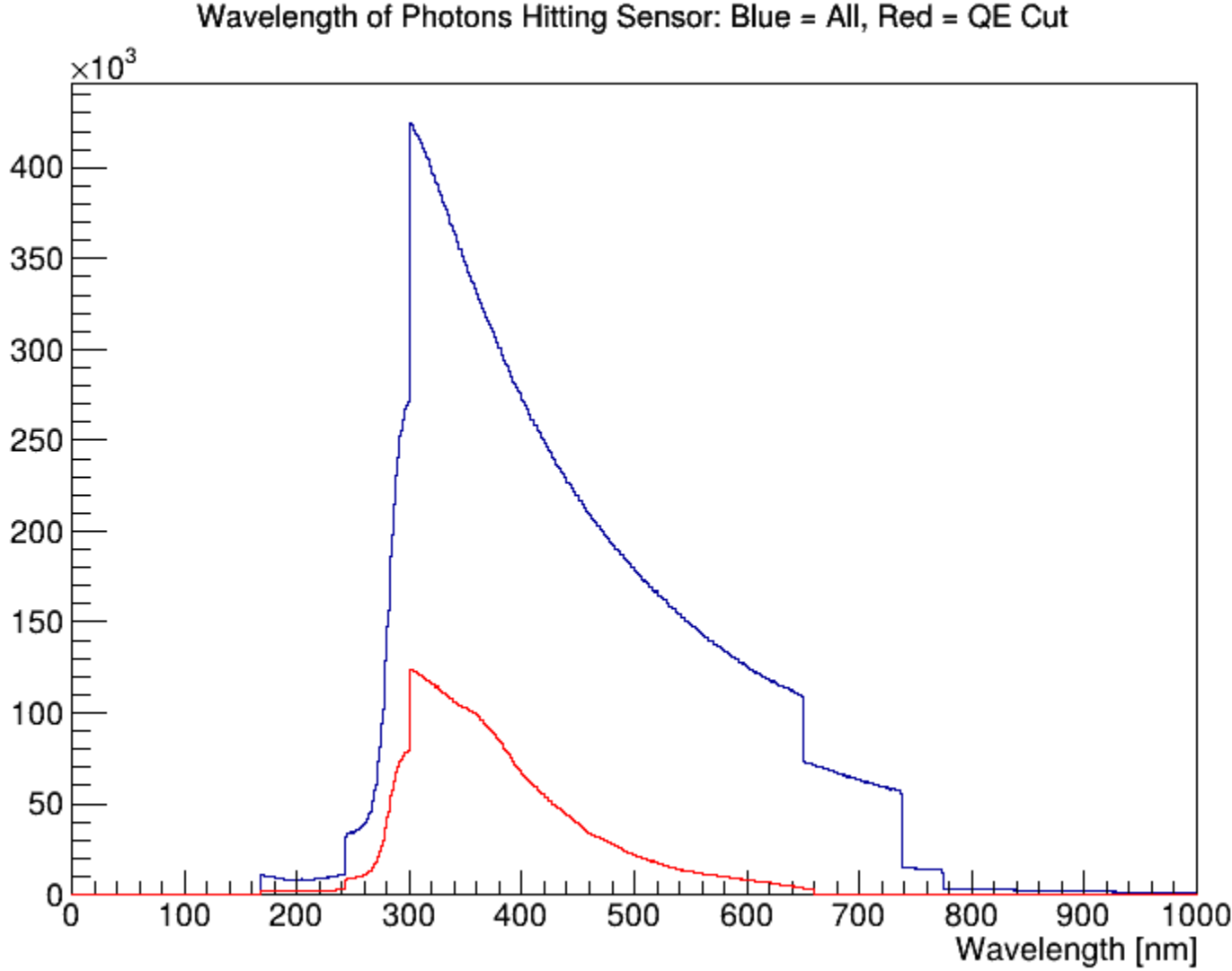


# Coulomb: “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor

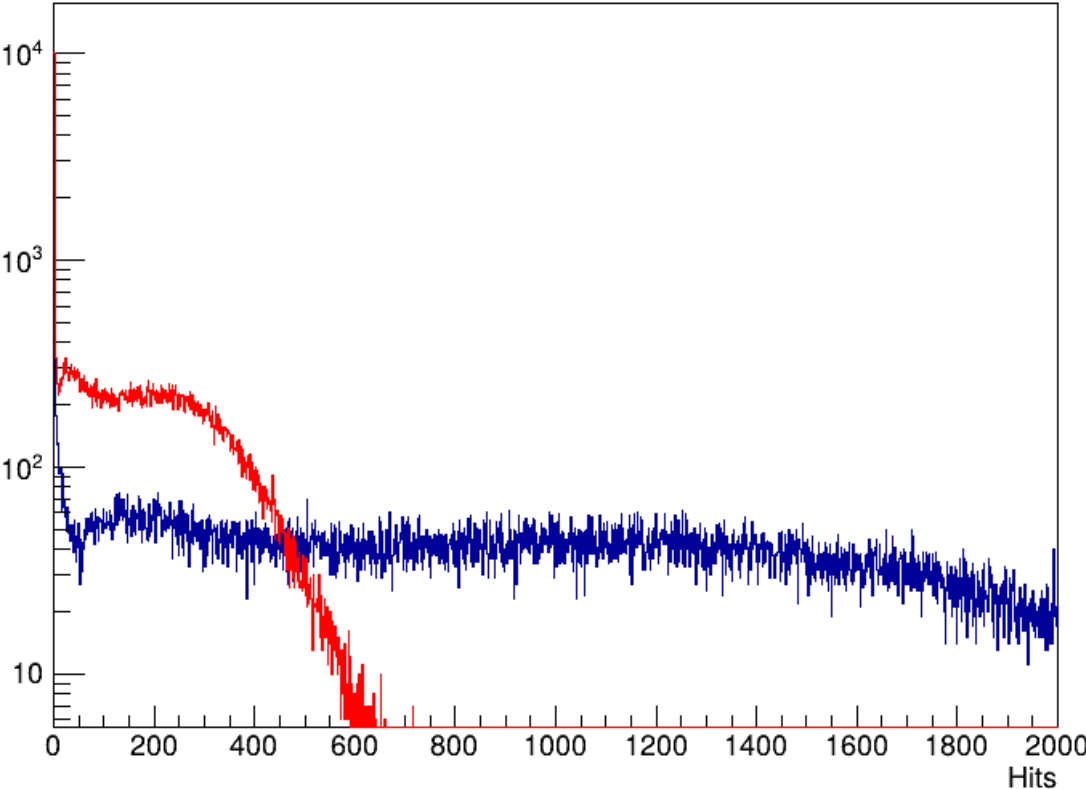


# Coulomb: Photon Wavelength

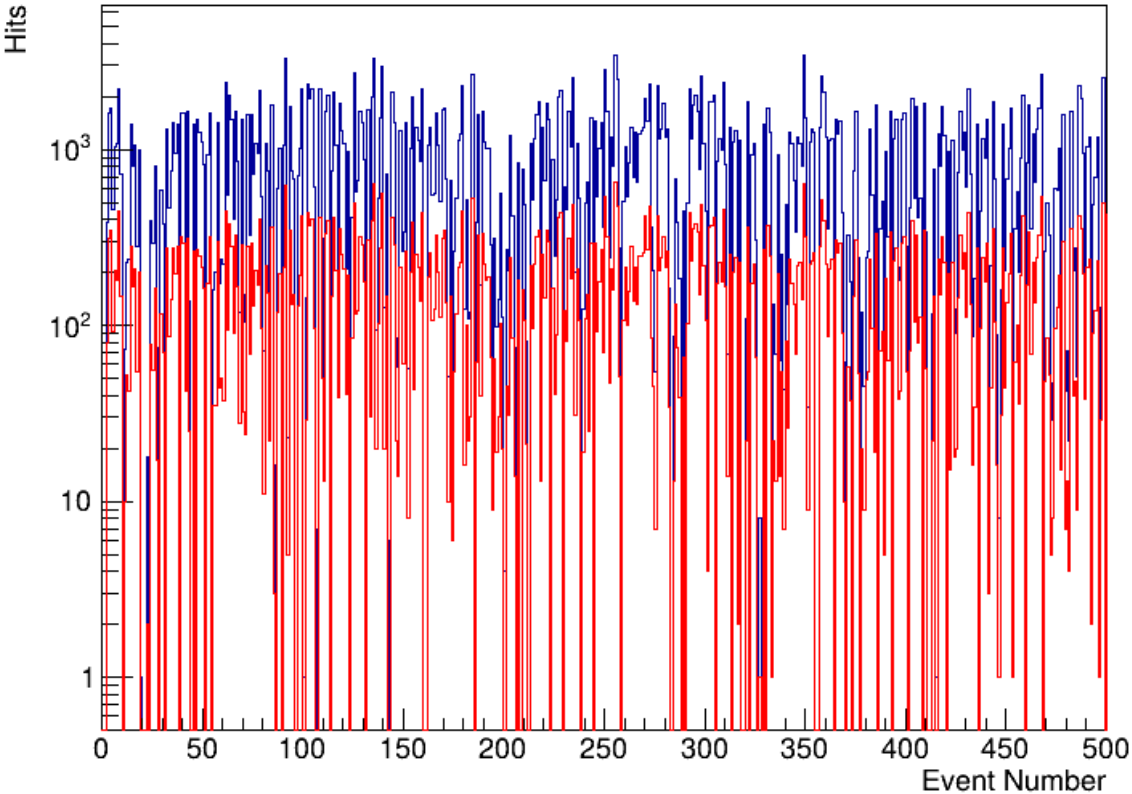


# Coulomb: Event Hit Structure

Number of Hits in Event: Blue = All, Red = QE Cut

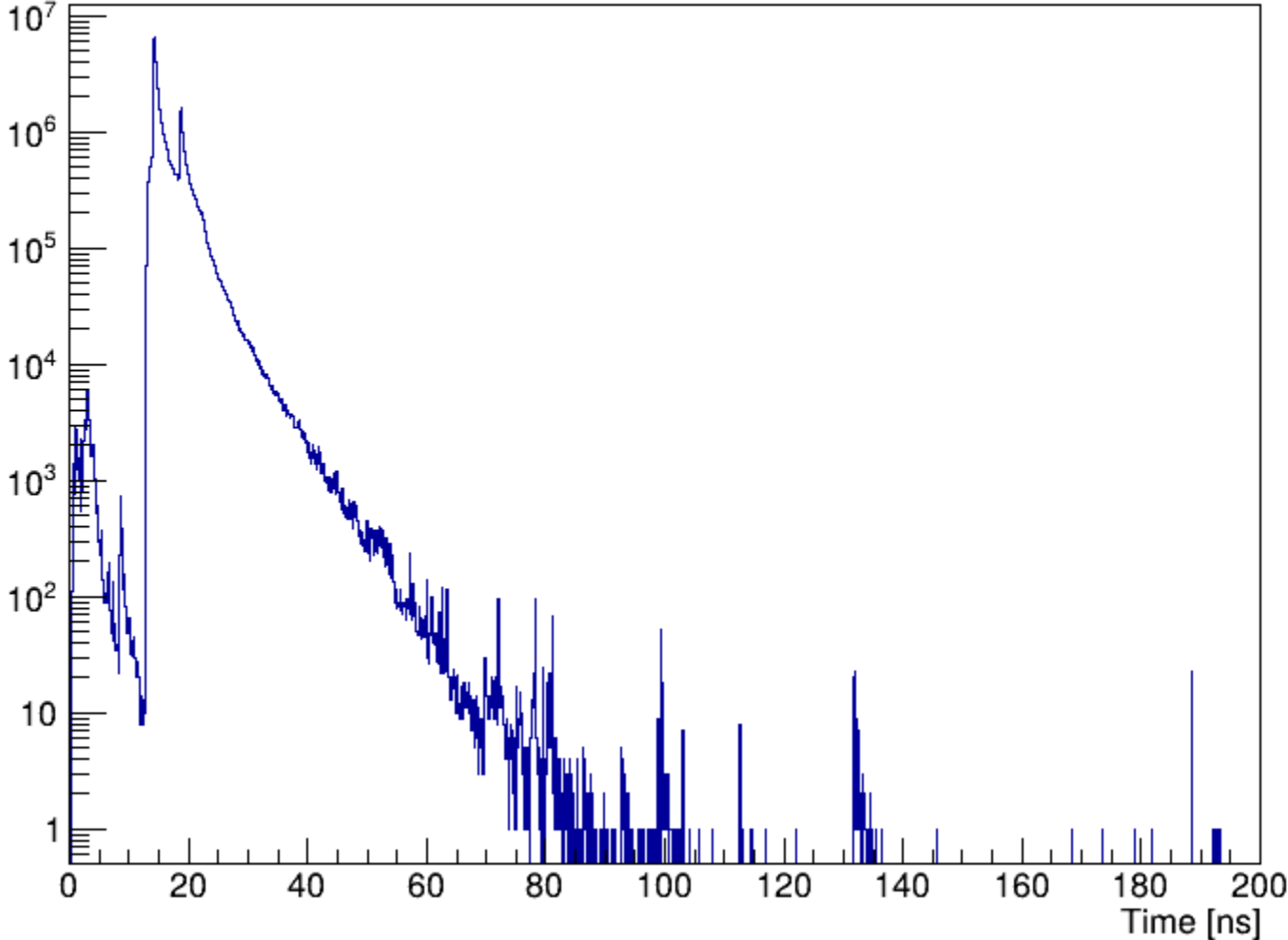


Number of Hits in Each Event: Blue = All, Red = QE Cut



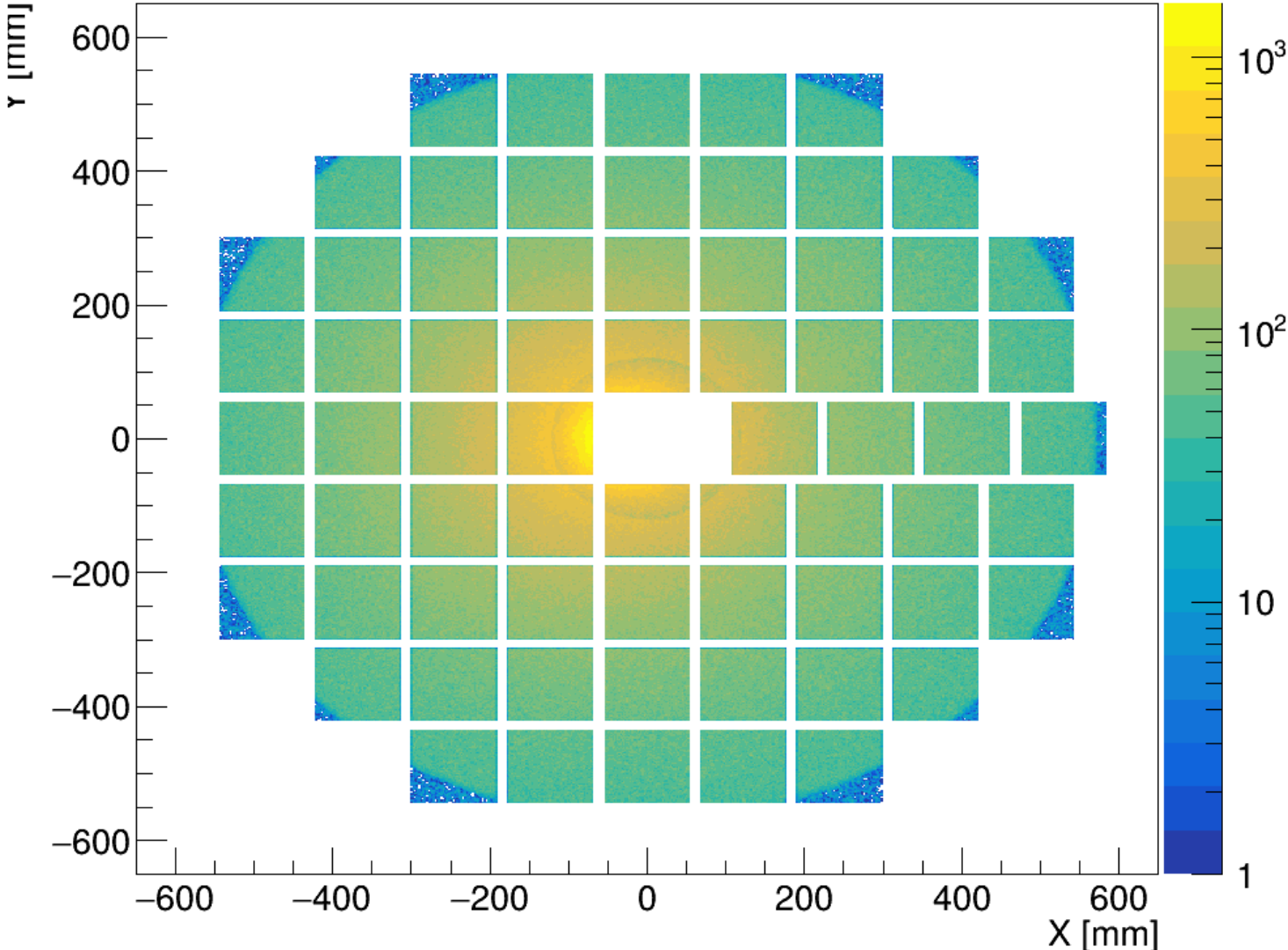
# Coulomb: Hit Times

Time of Hit



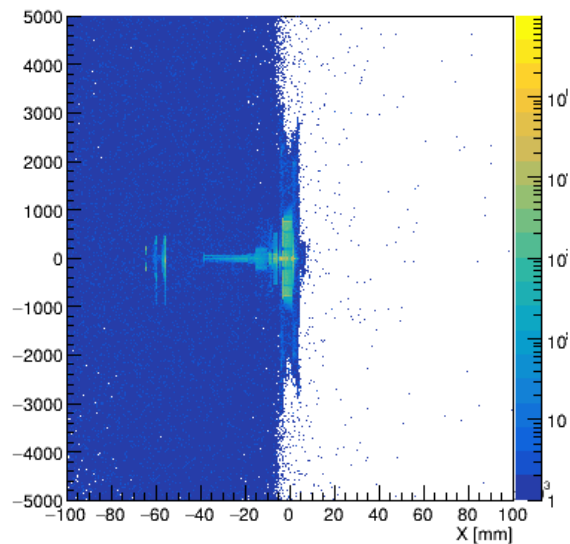
# Coulomb: Hit Map After QE Cut

Hit Map after QE Cut

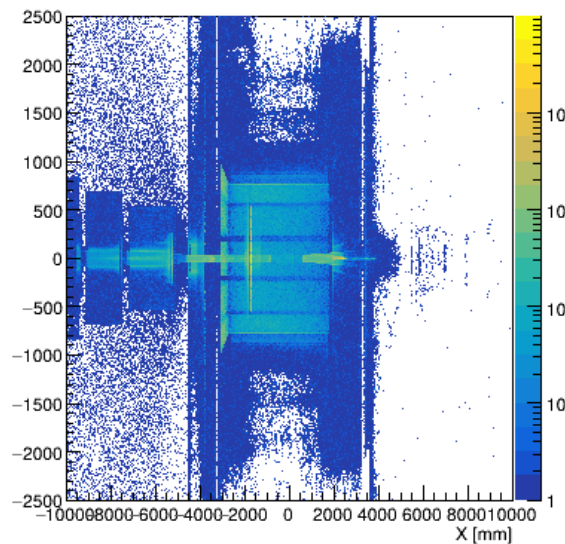


# Touschek: Production Vertex

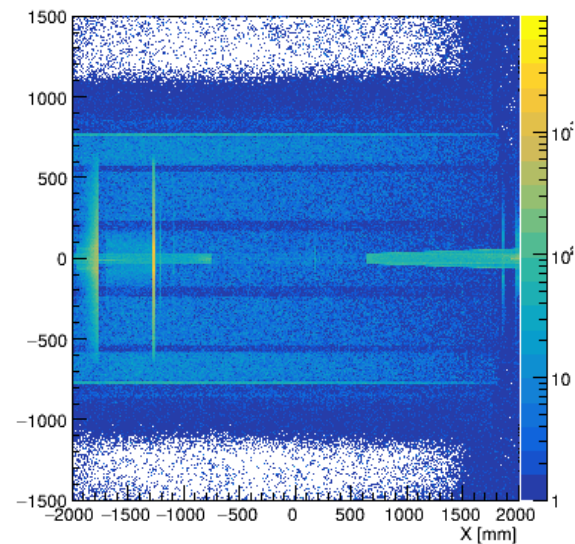
Particle Production Vertx



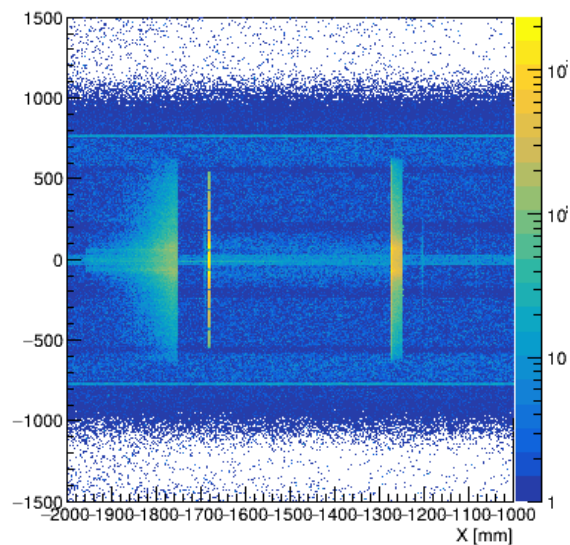
Particle Production Vertx



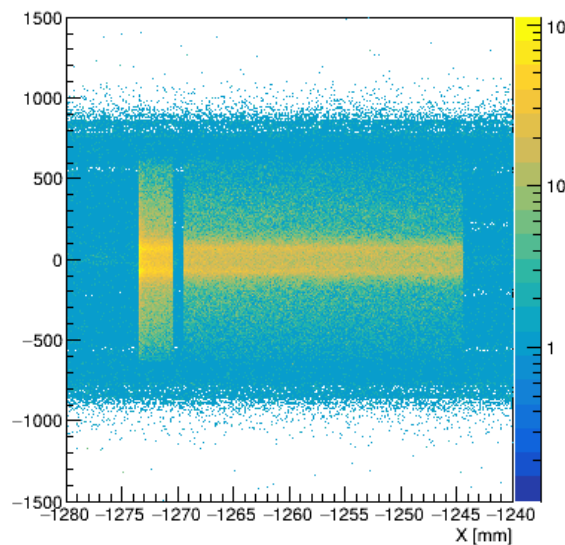
Particle Production Vertx



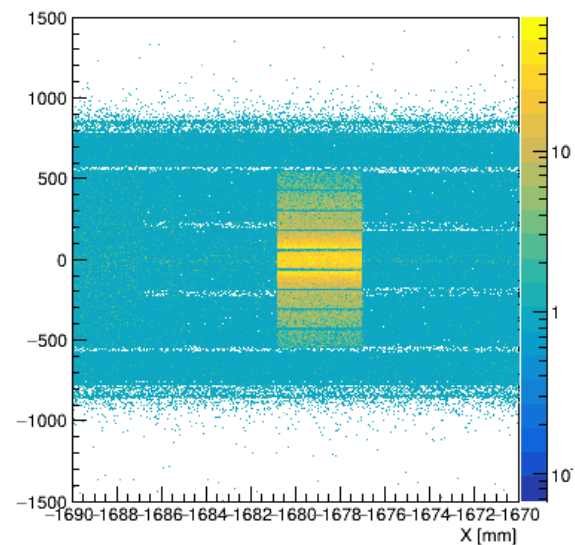
Particle Production Vertx



Particle Production Vertx

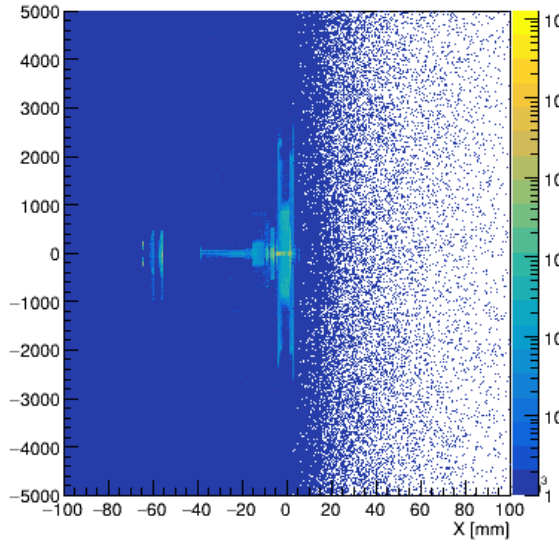


Particle Production Vertx

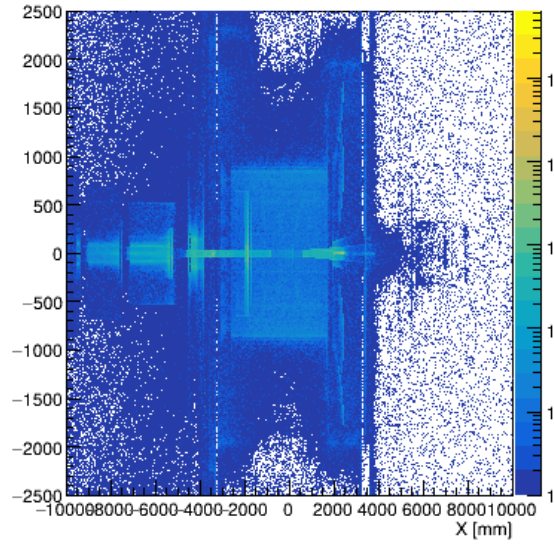


# Touschek: End Vertex

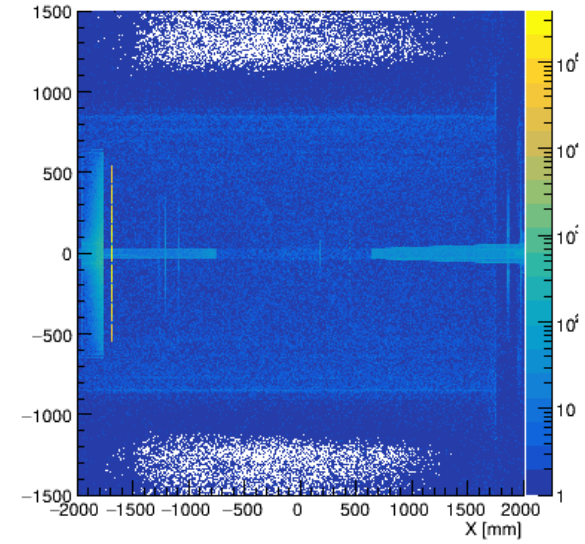
Particle End Vertex



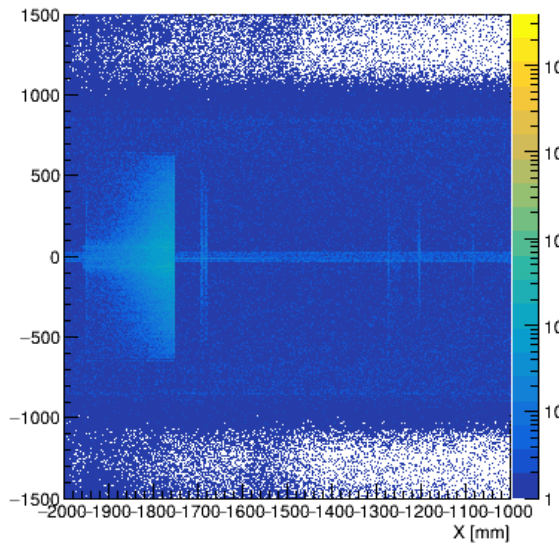
Particle End Vertex



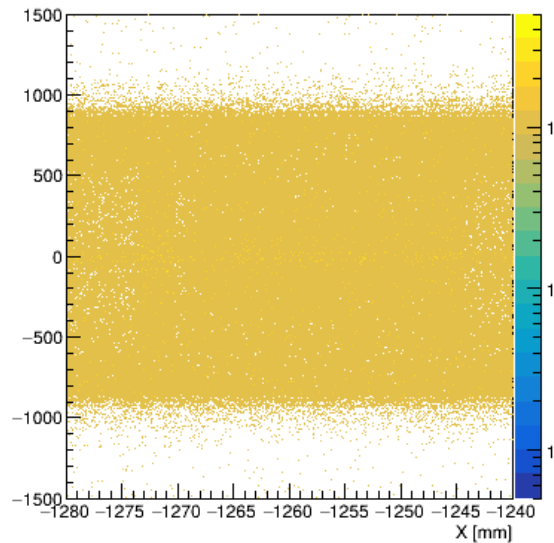
Particle End Vertex



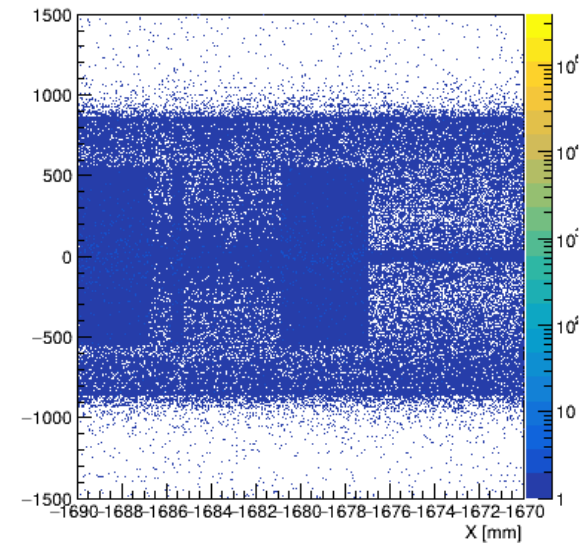
Particle End Vertex



Particle End Vertex

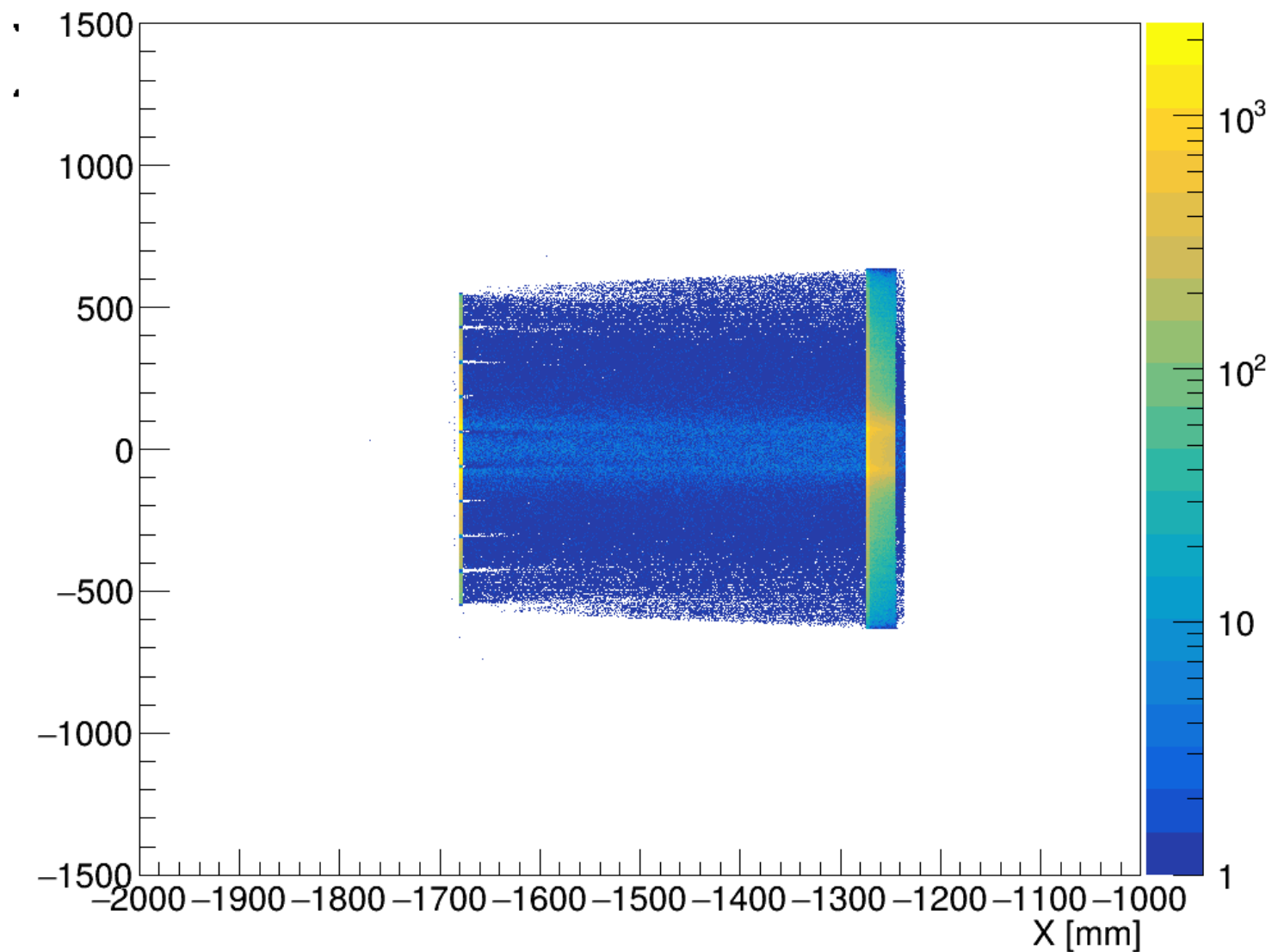


Particle End Vertex

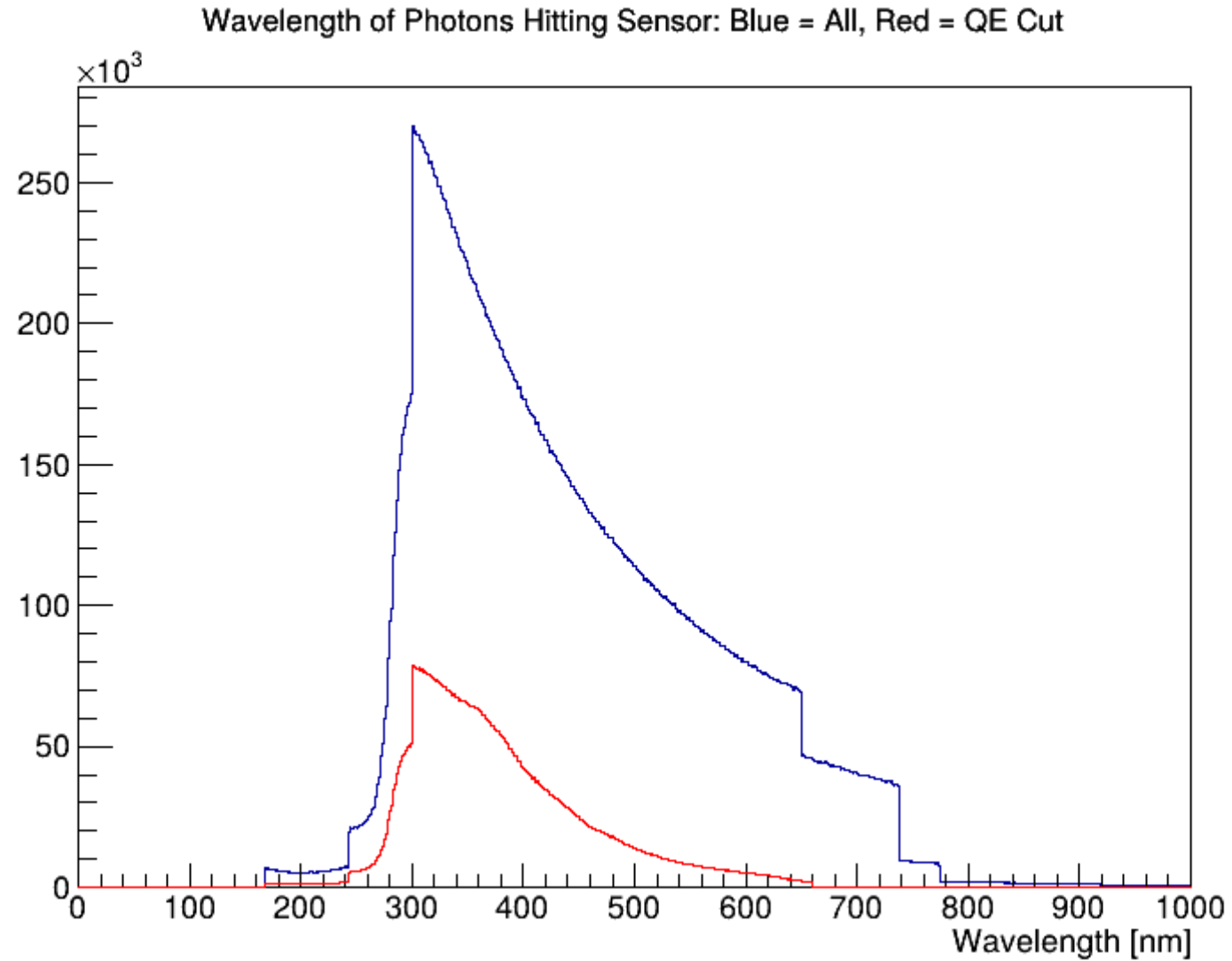


# Touschek: “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor

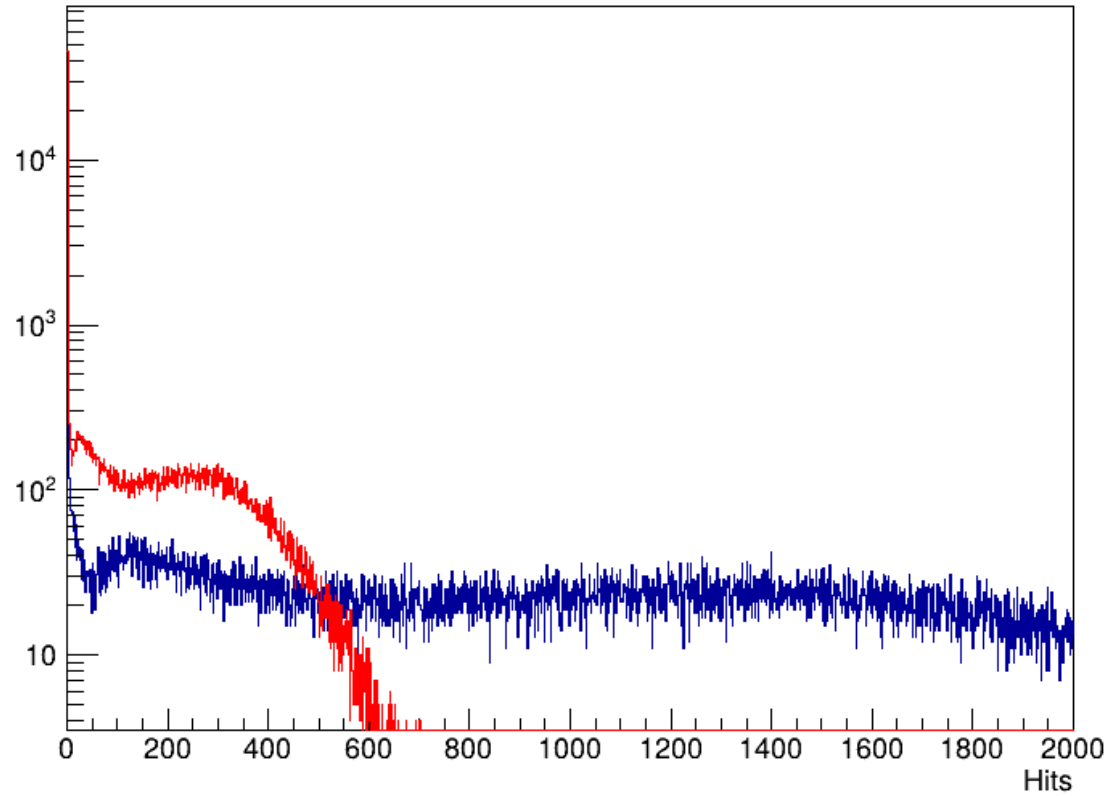


# Touschek: Photon Wavelength

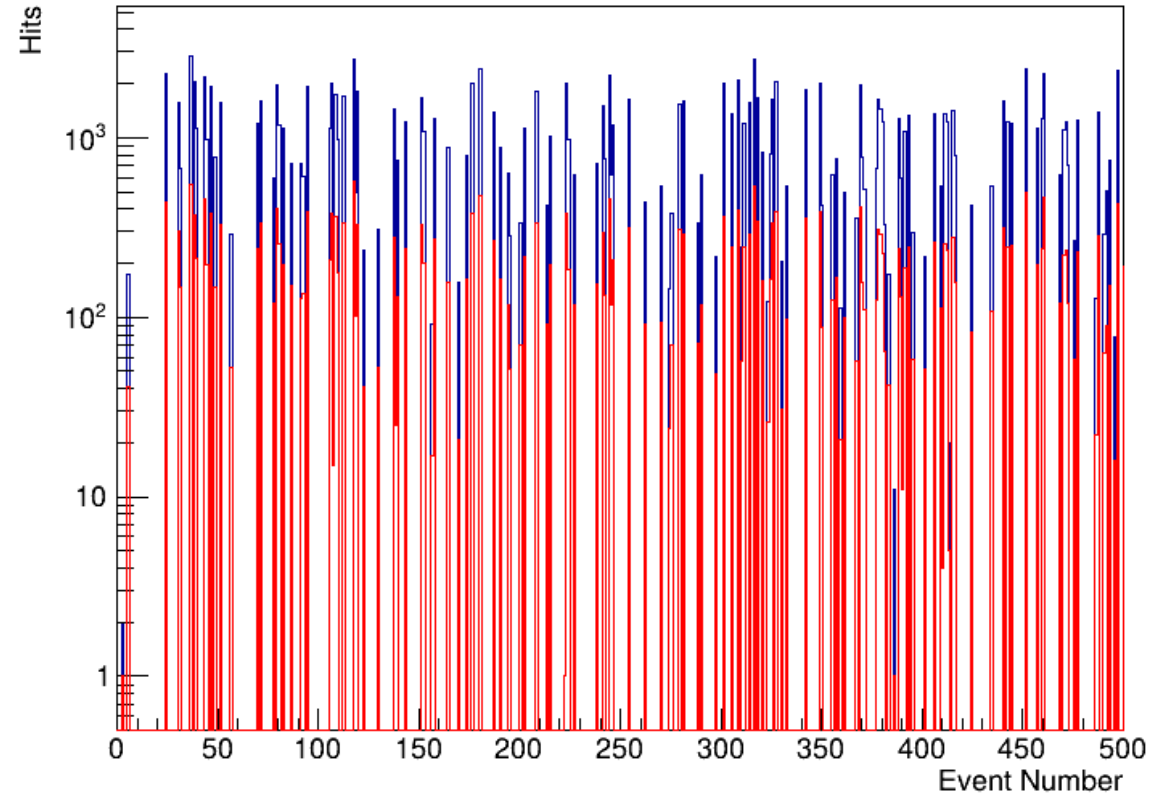


# Touschek: Event Hit Structure

Number of Hits in Event: Blue = All, Red = QE Cut

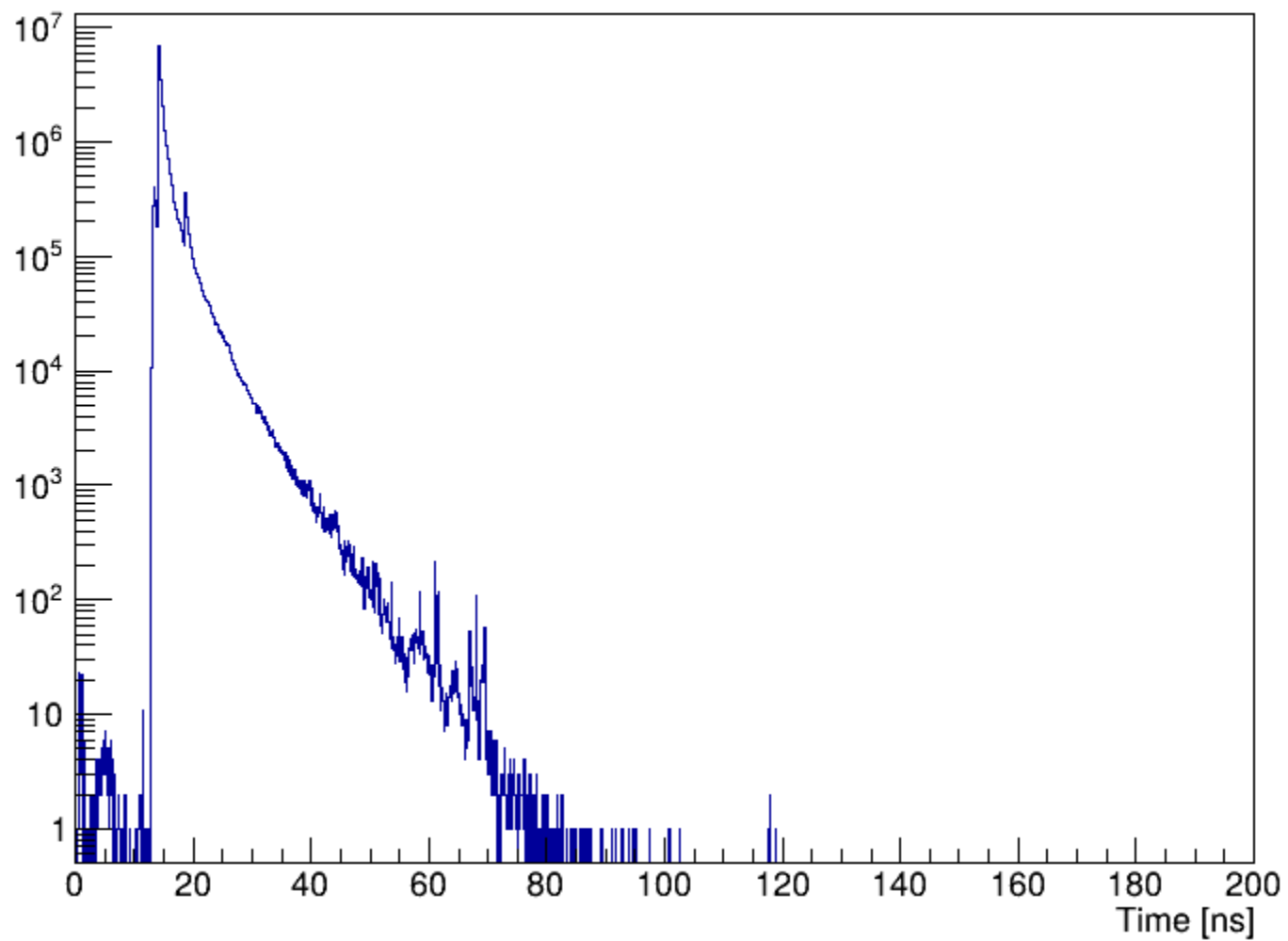


Number of Hits in Each Event: Blue = All, Red = QE Cut



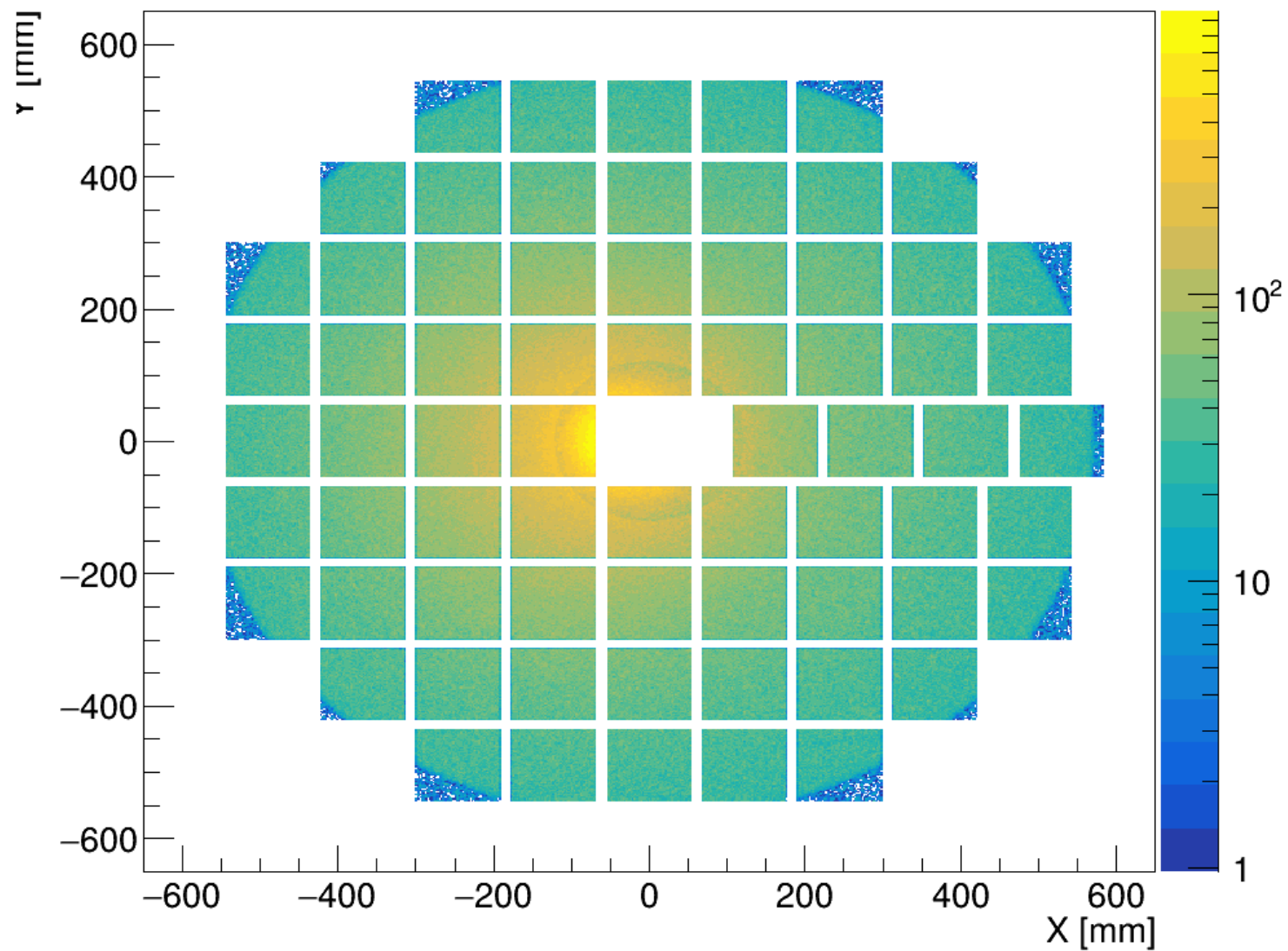
# Touschek: Hit Times

Time of Hit

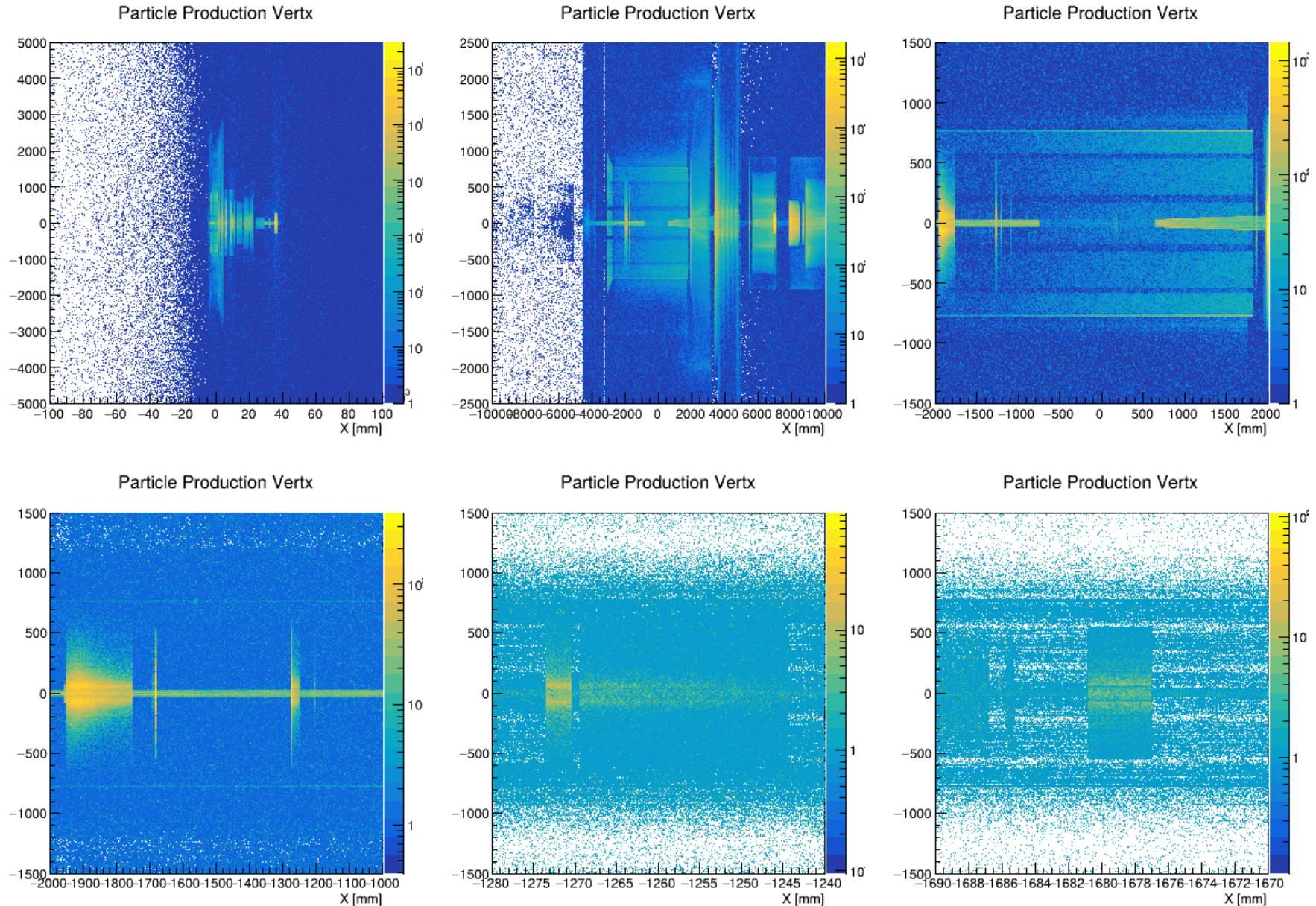


# Touschek: Hit Map After QE Cut

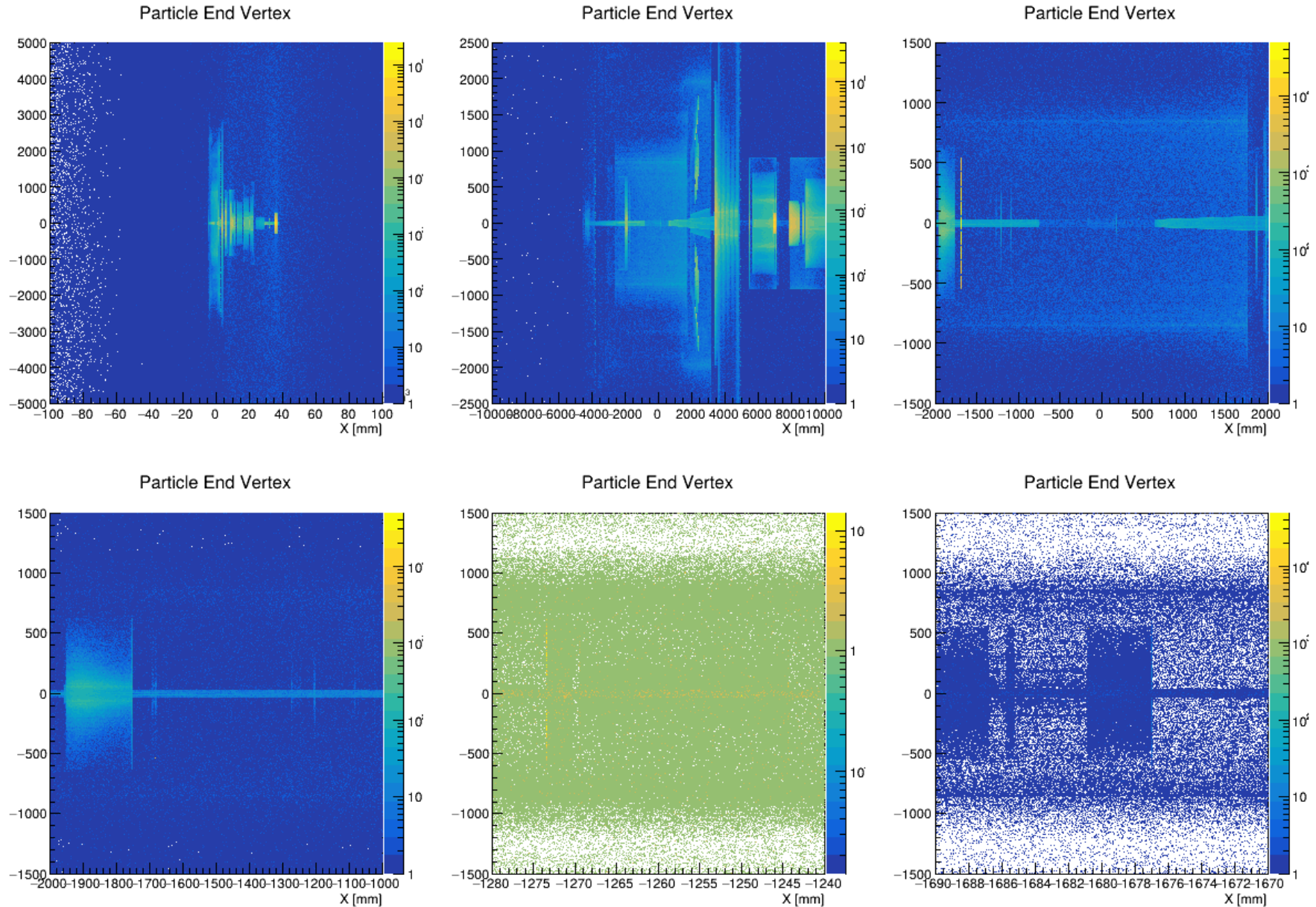
Hit Map after QE Cut



# Proton Beam Gas: Production Vertex

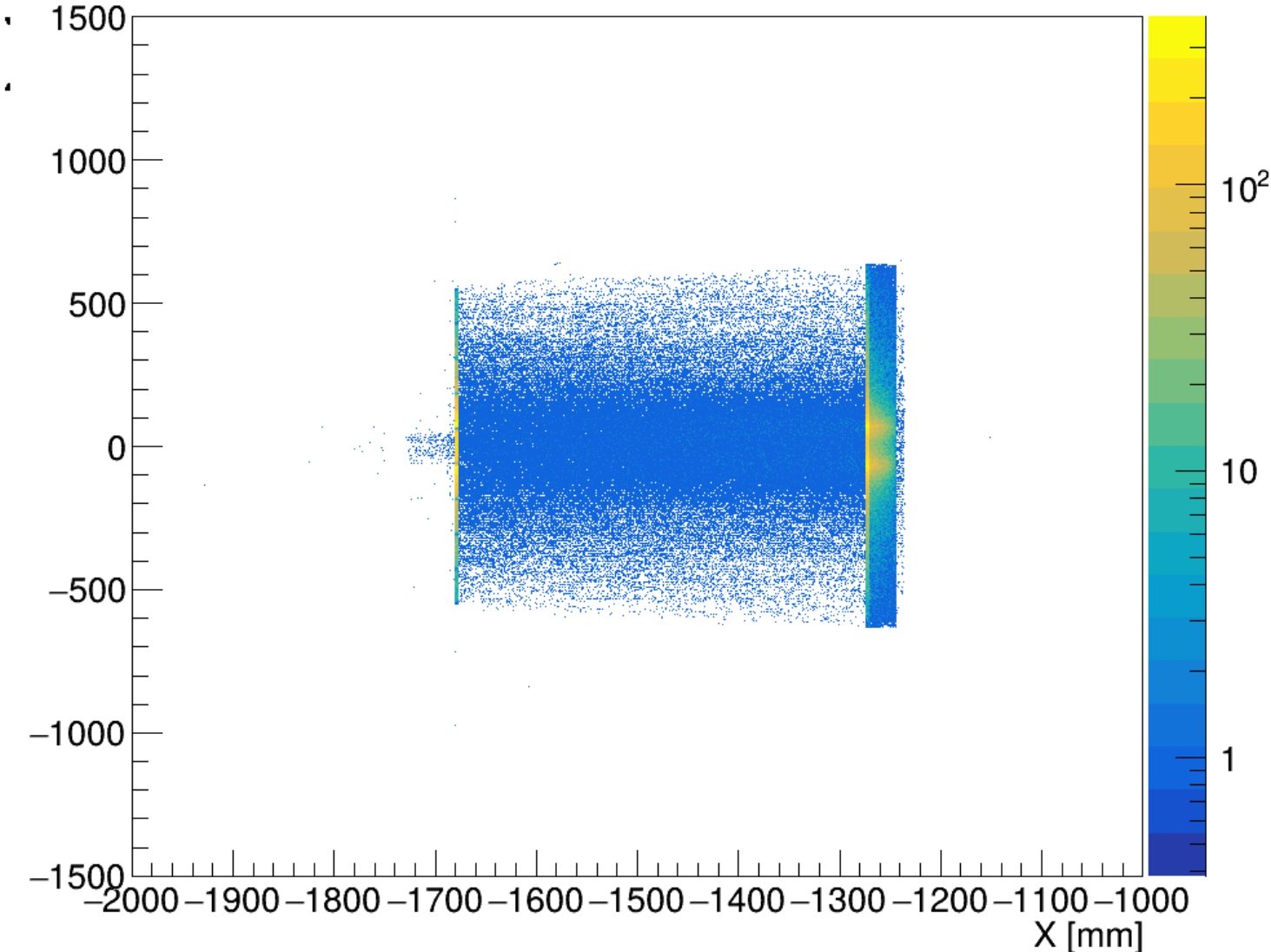


# Proton Beam Gas: End Vertex



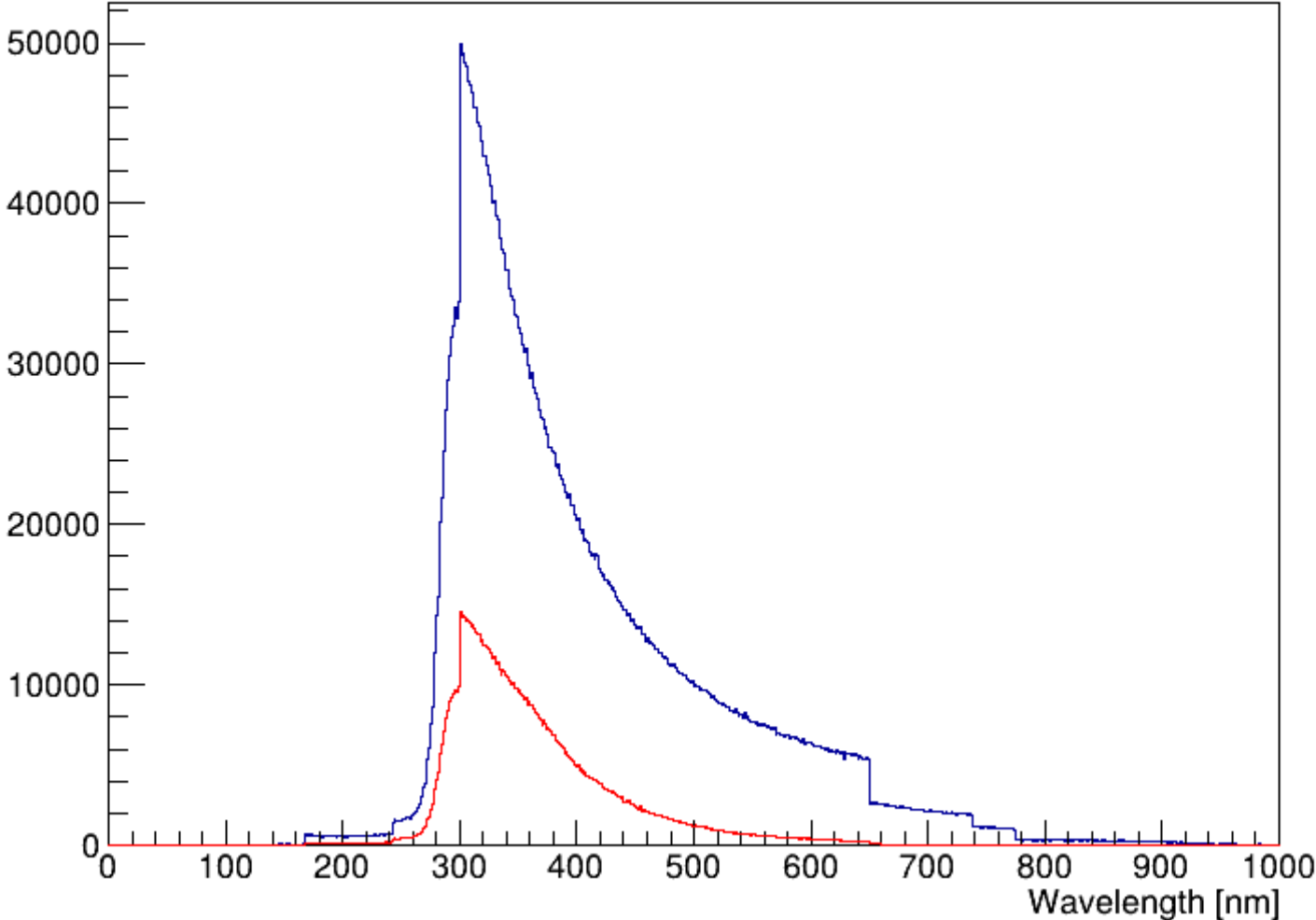
# Proton Beam Gas: “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor



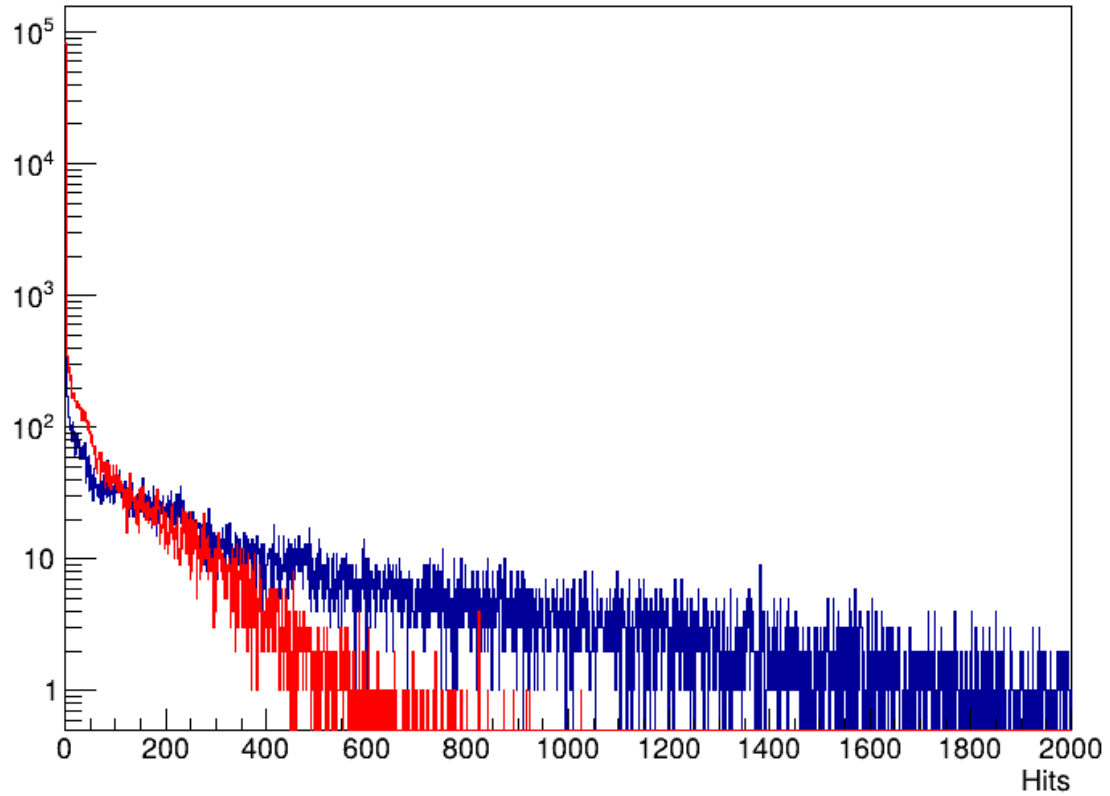
# Proton Beam Gas: Photon Wavelength

Wavelength of Photons Hitting Sensor: Blue = All, Red = QE Cut

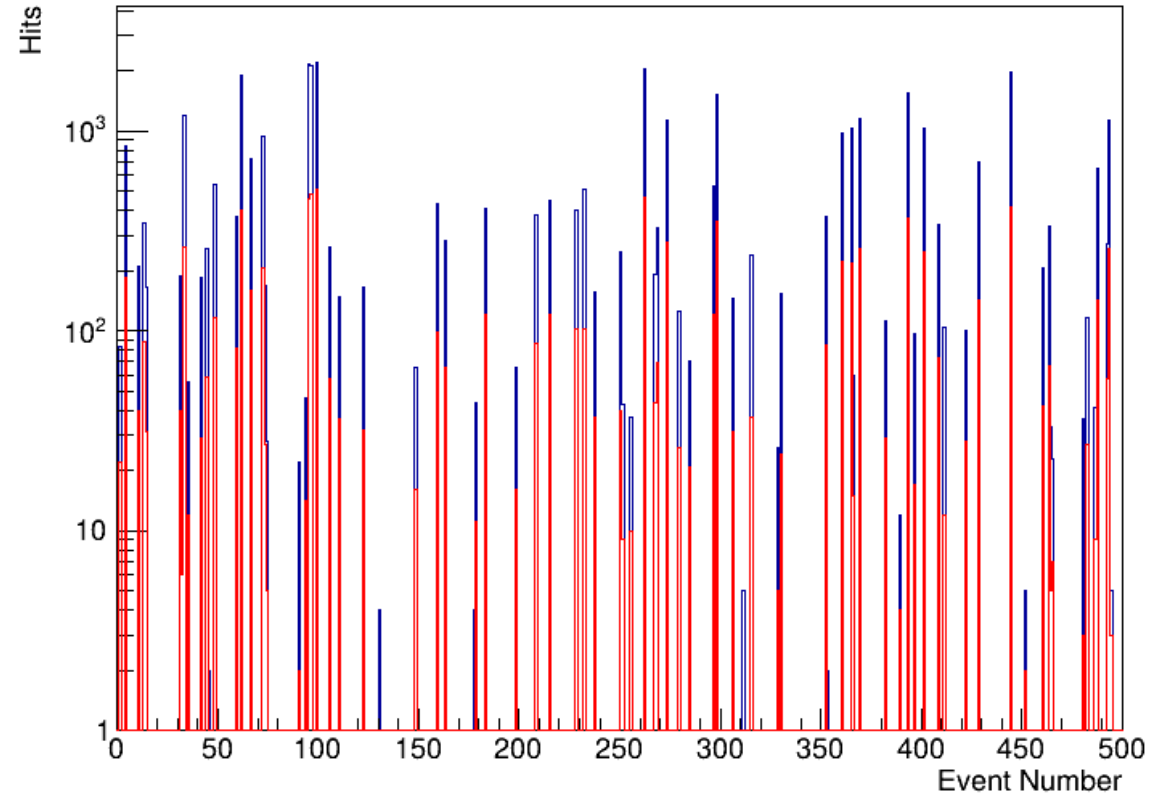


# Proton Beam Gas: Event Hit Structure

Number of Hits in Event: Blue = All, Red = QE Cut

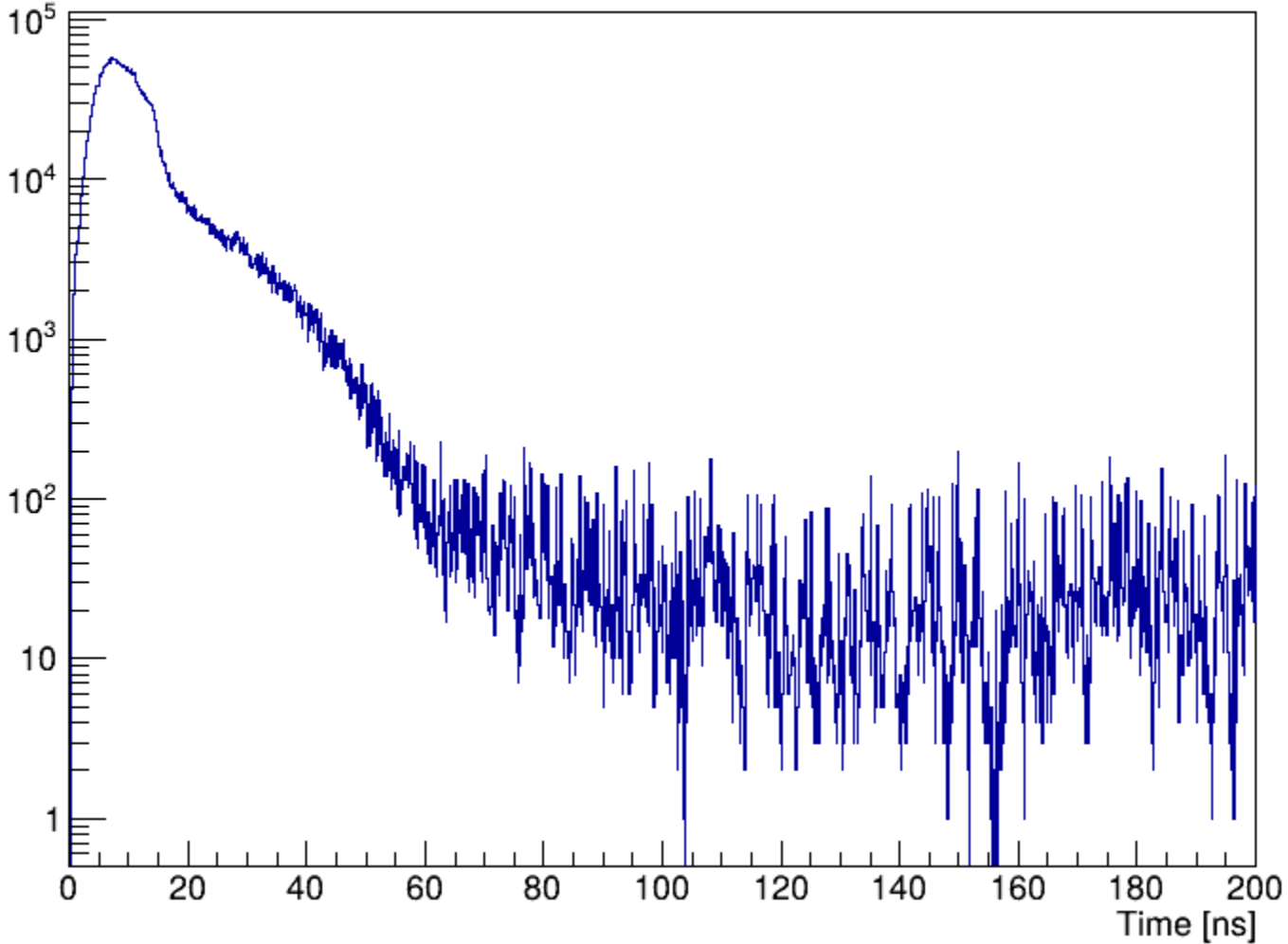


Number of Hits in Each Event: Blue = All, Red = QE Cut



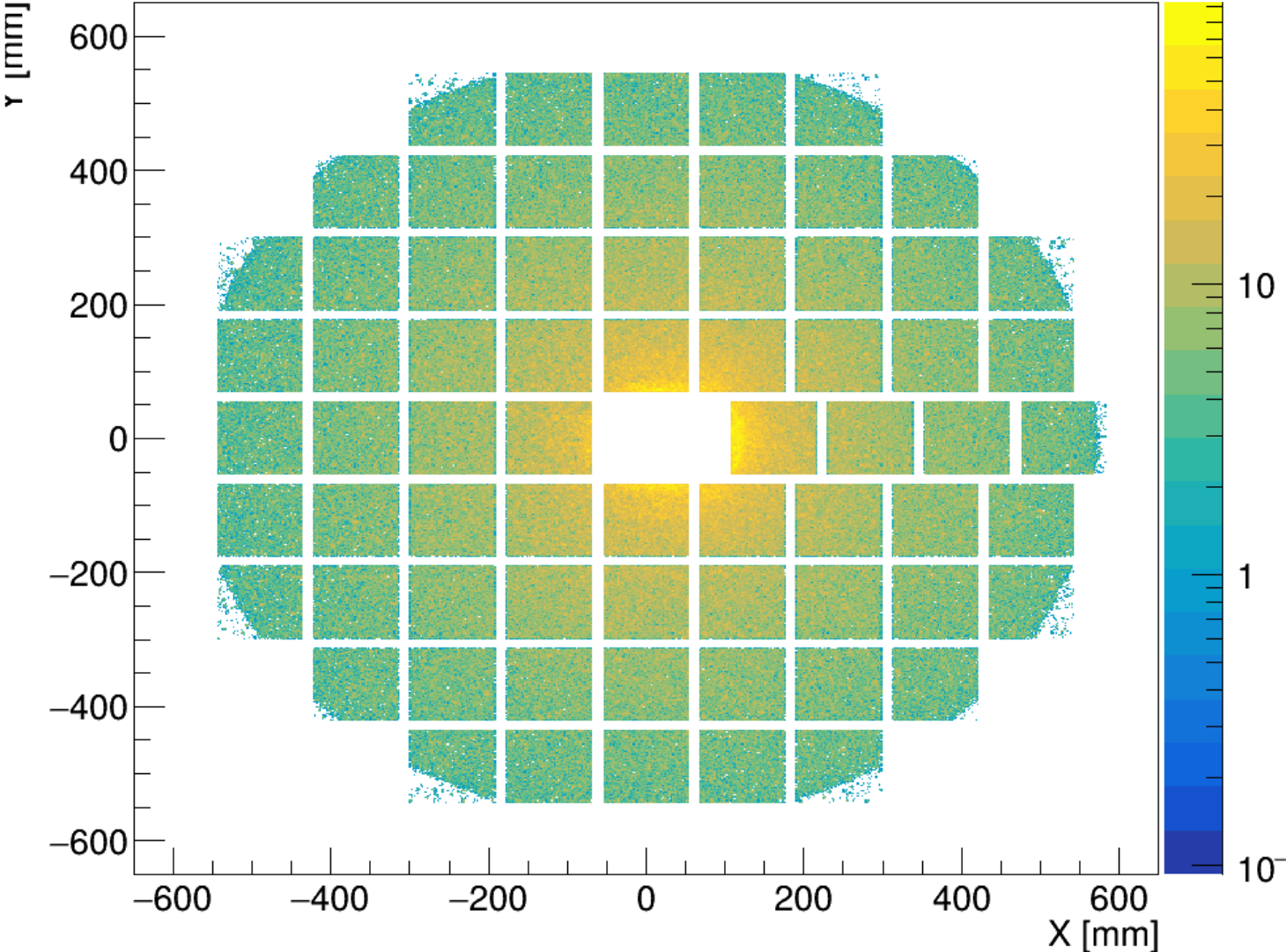
# Proton Beam Gas: Hit Times

Time of Hit



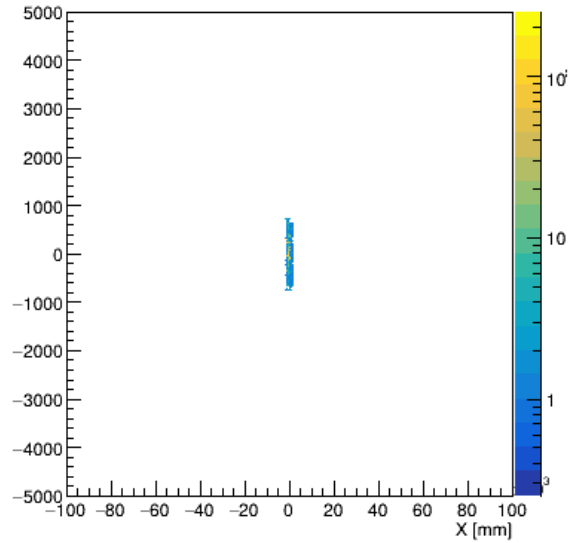
# Proton Beam Gas: Hit Map After QE Cut

Hit Map after QE Cut

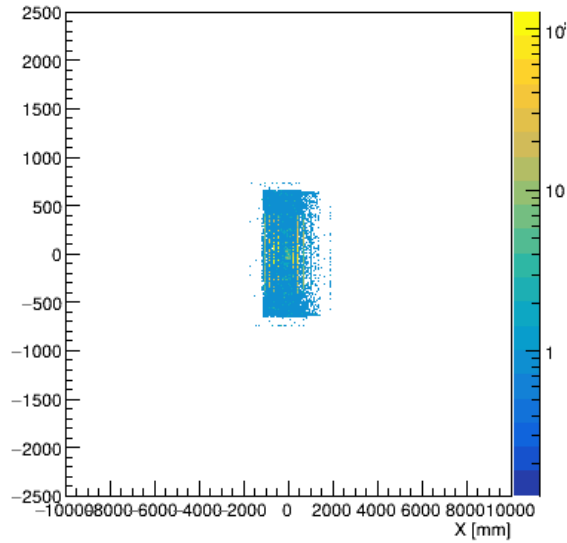


# Synchrotron: Production Vertex

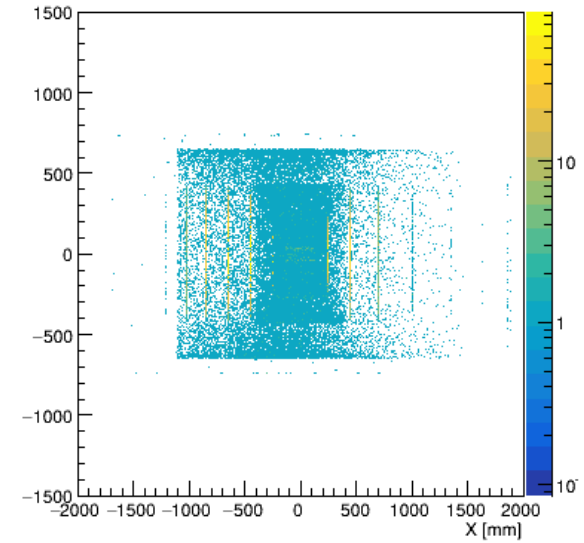
Particle Production Vertx



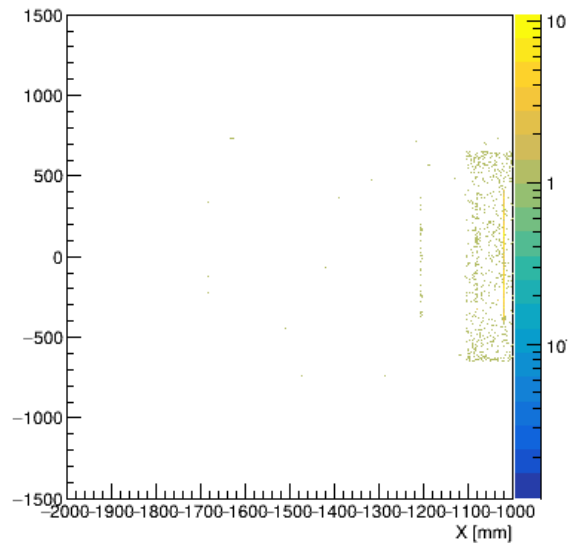
Particle Production Vertx



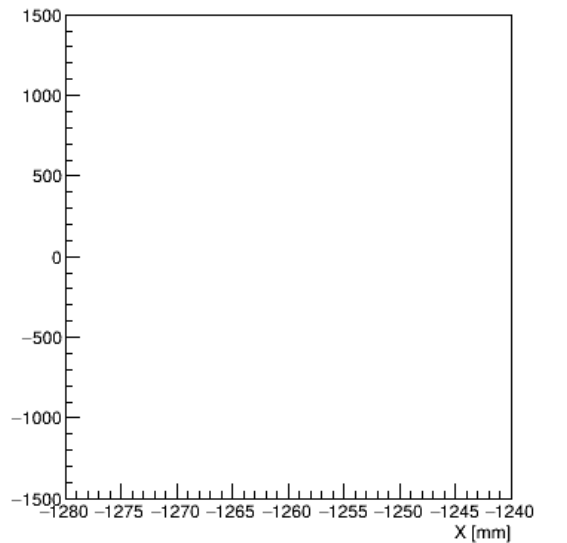
Particle Production Vertx



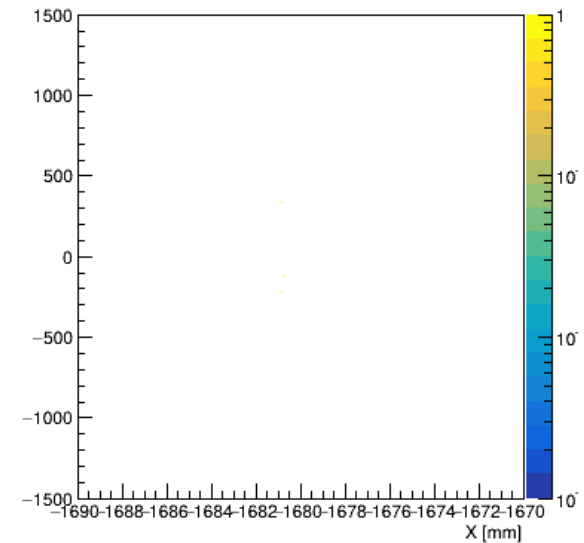
Particle Production Vertx



Particle Production Vertx

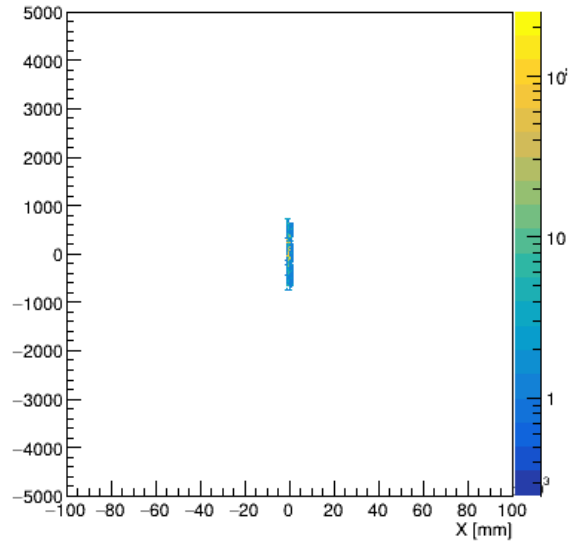


Particle Production Vertx

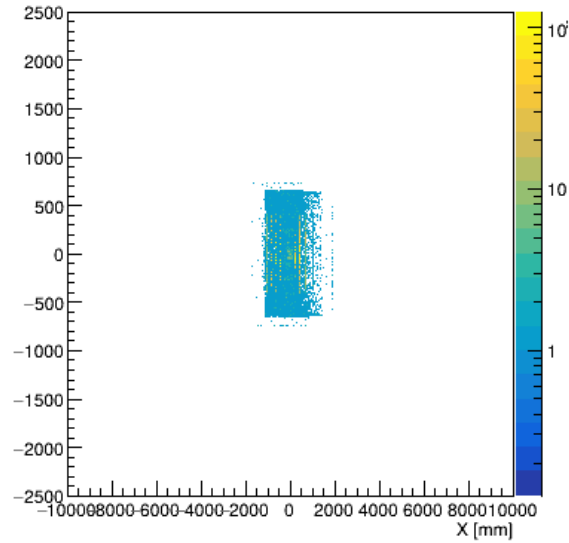


# Synchrotron: End Vertex

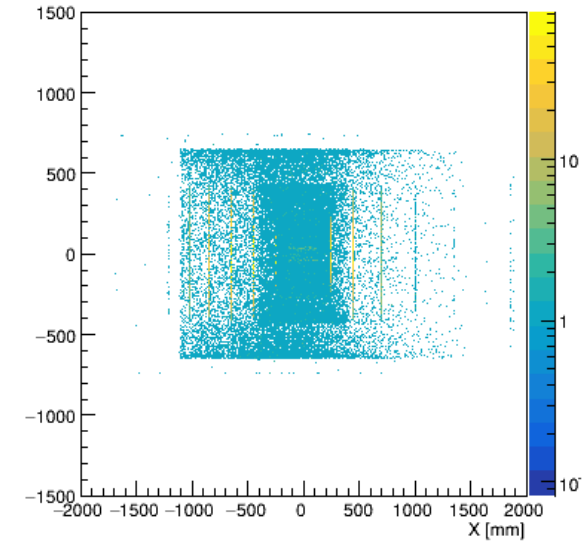
Particle End Vertex



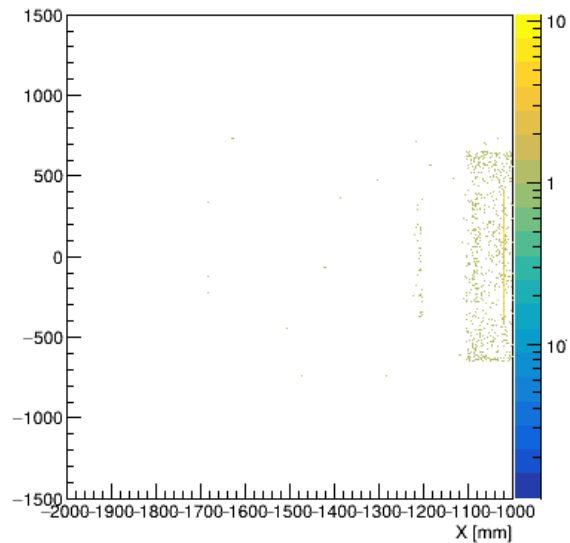
Particle End Vertex



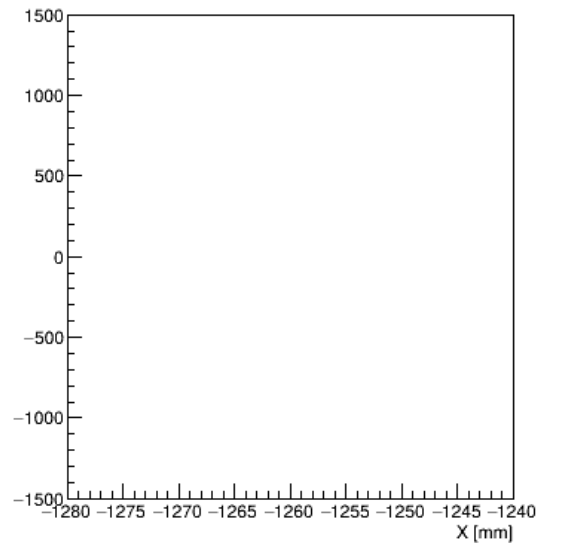
Particle End Vertex



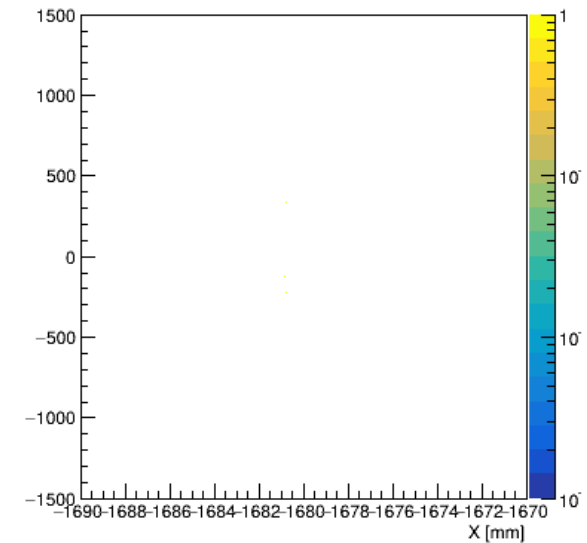
Particle End Vertex



Particle End Vertex

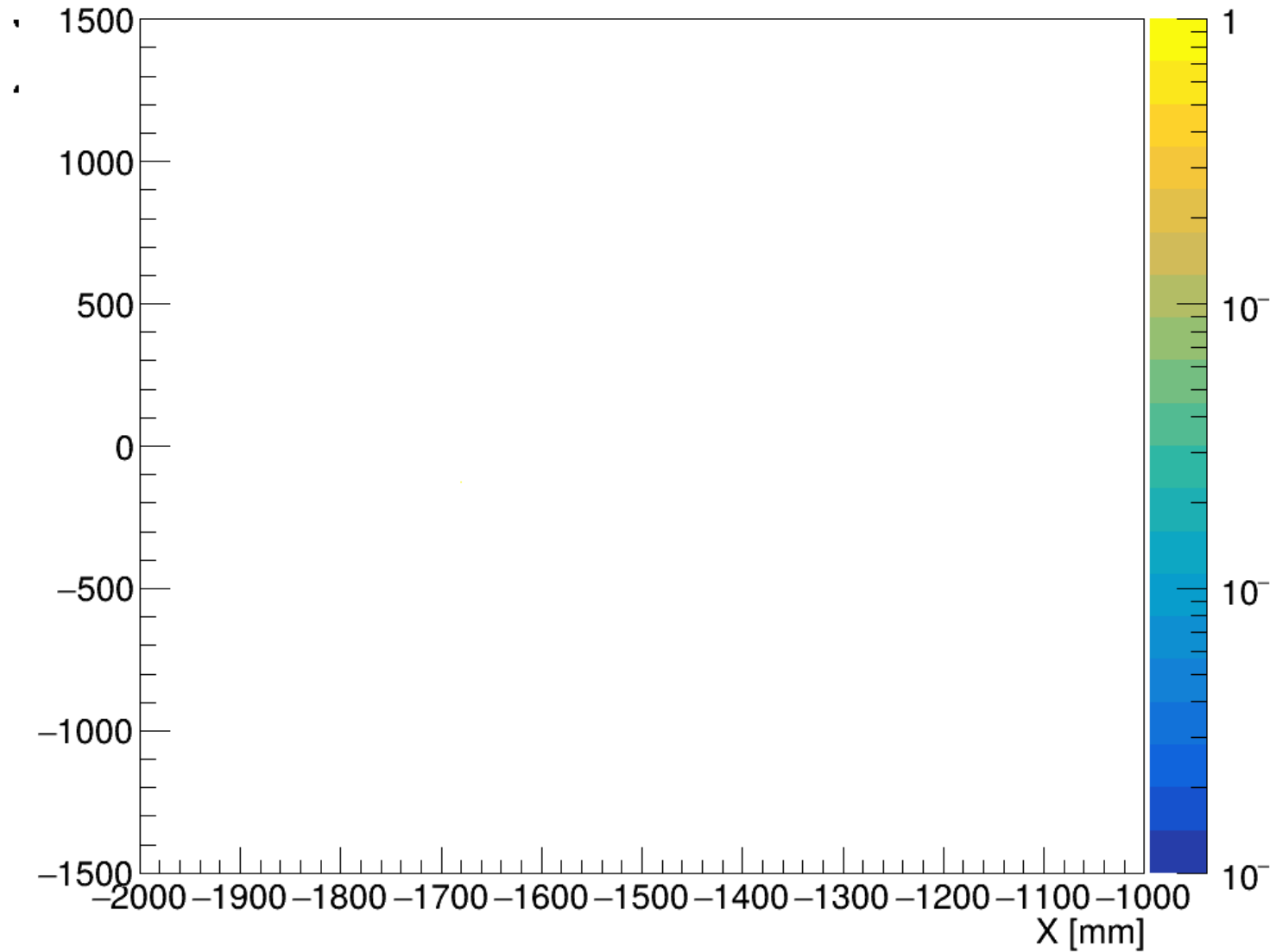


Particle End Vertex

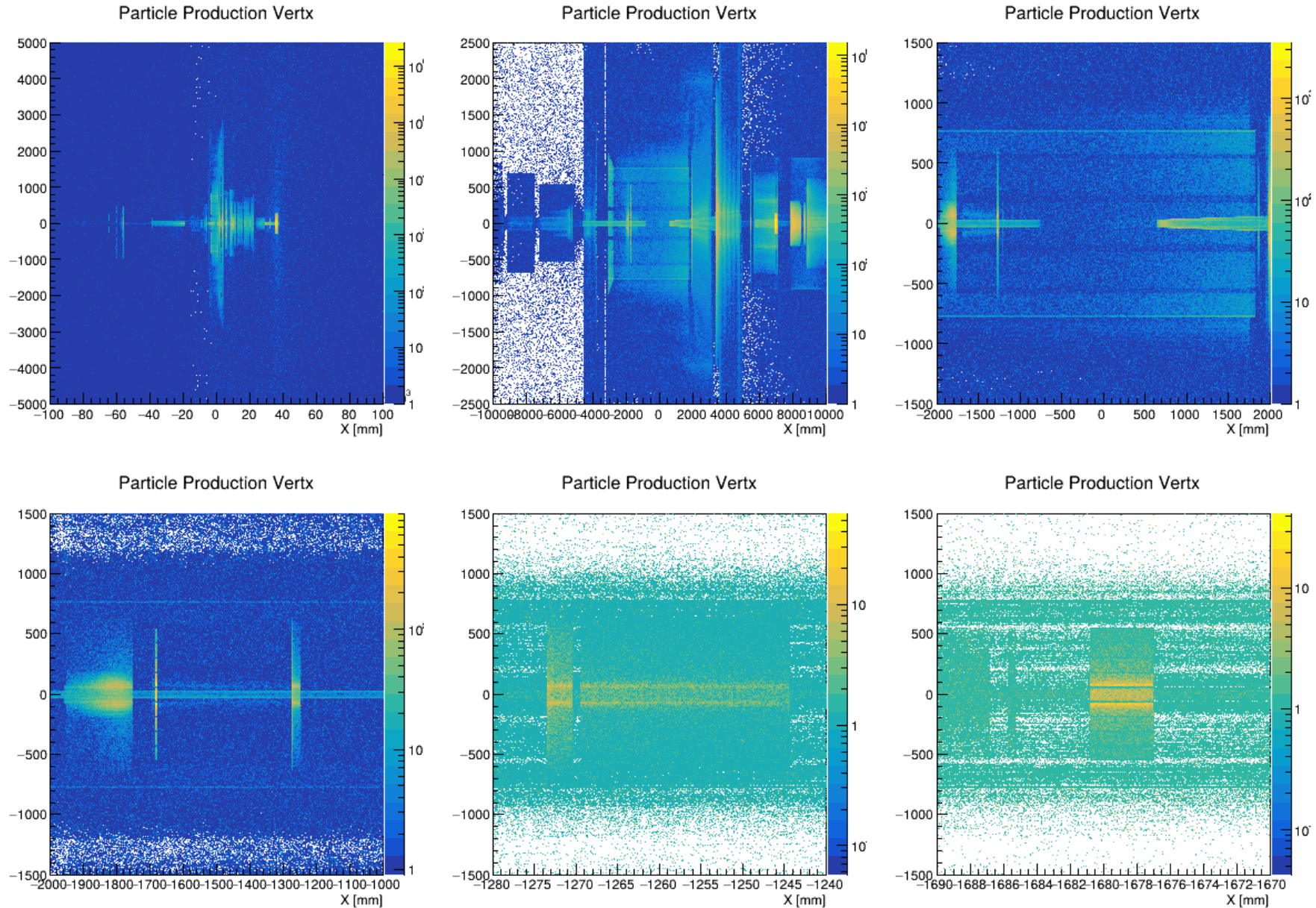


# Synchrotron: “Last Scatter” Before Sensor

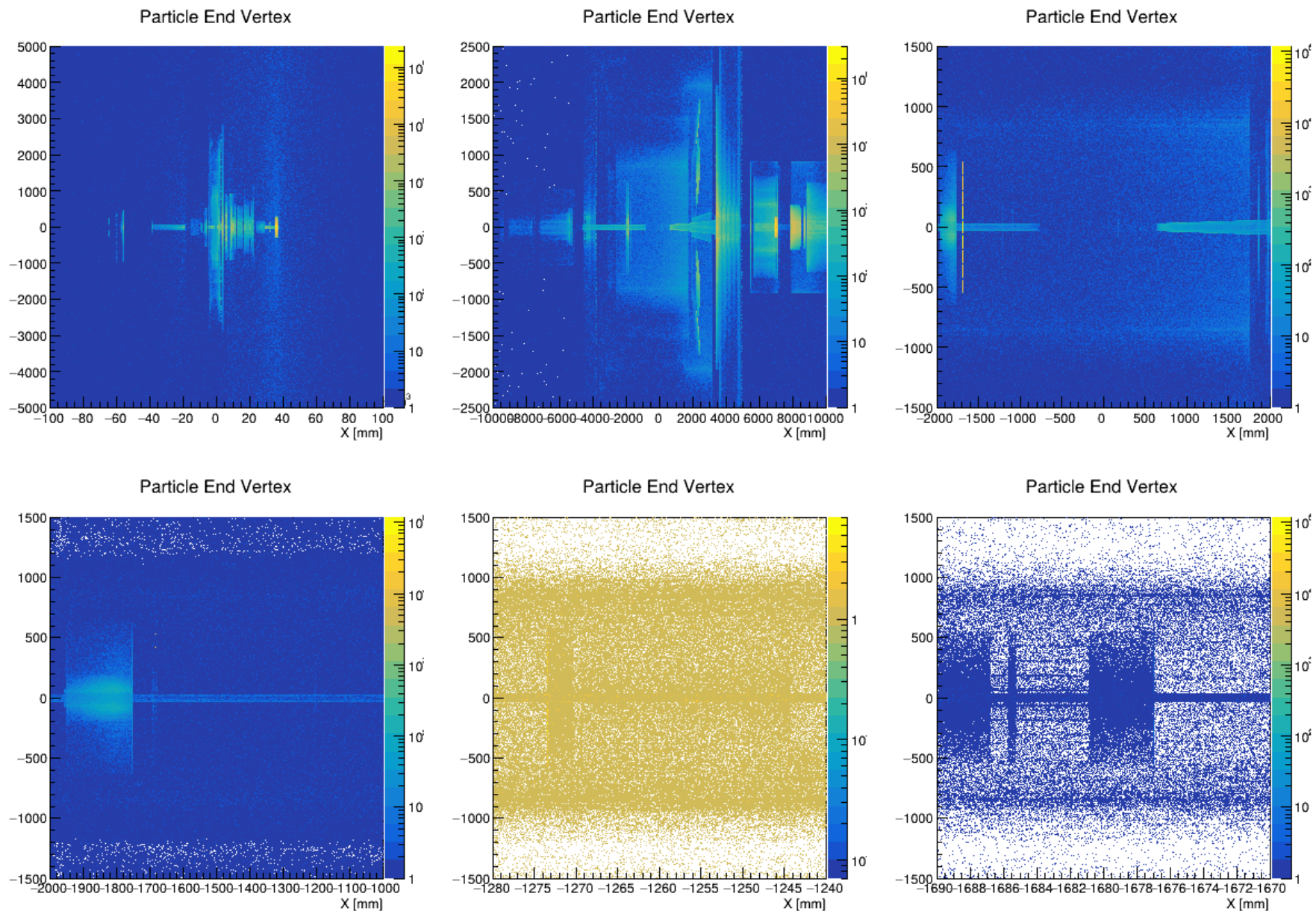
Production Vertex for Particles Hitting Sensor



# DIS $Q^2 < 1$ : Production Vertex

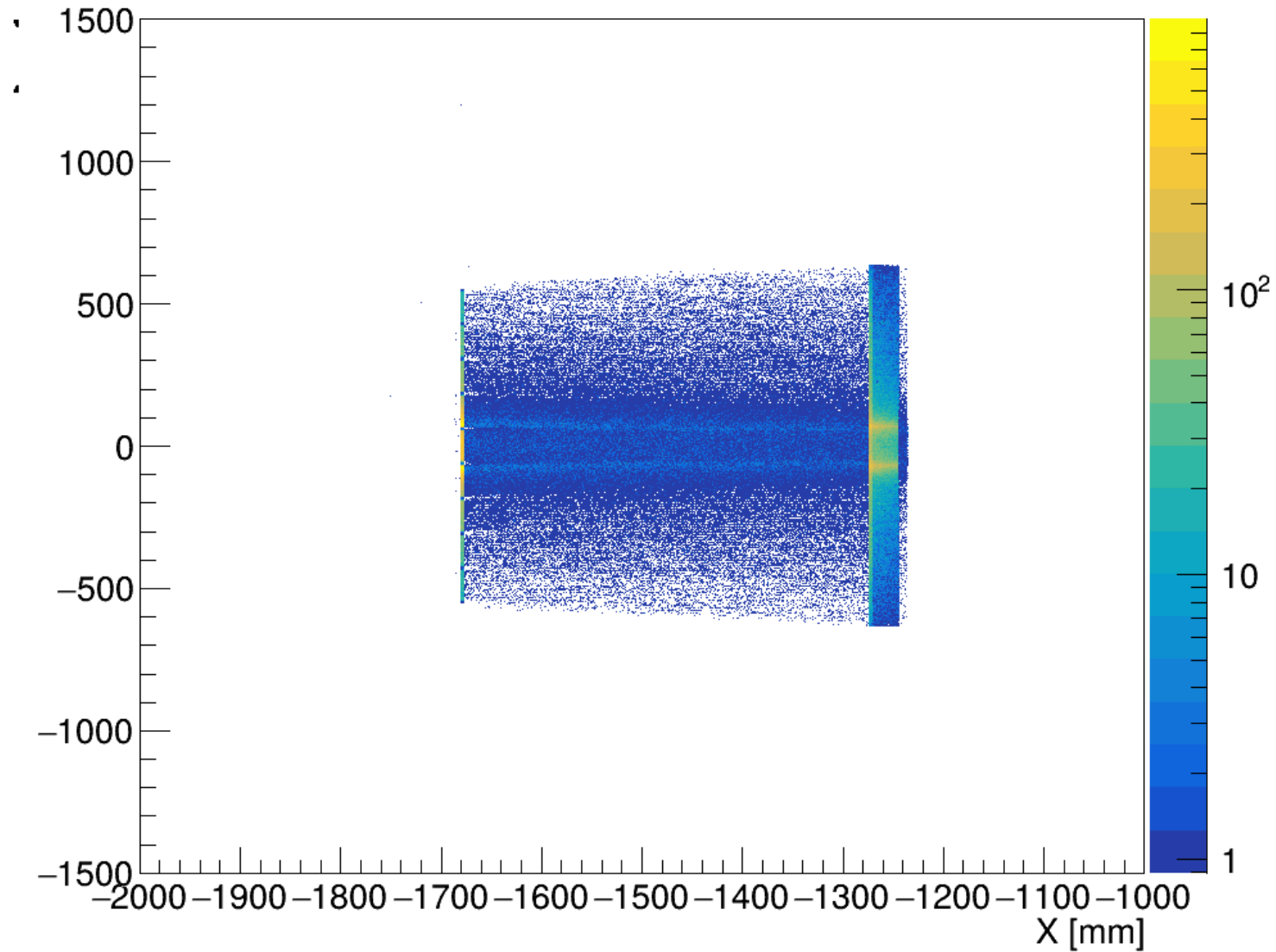


# DIS Q2 < 1: End Vertex



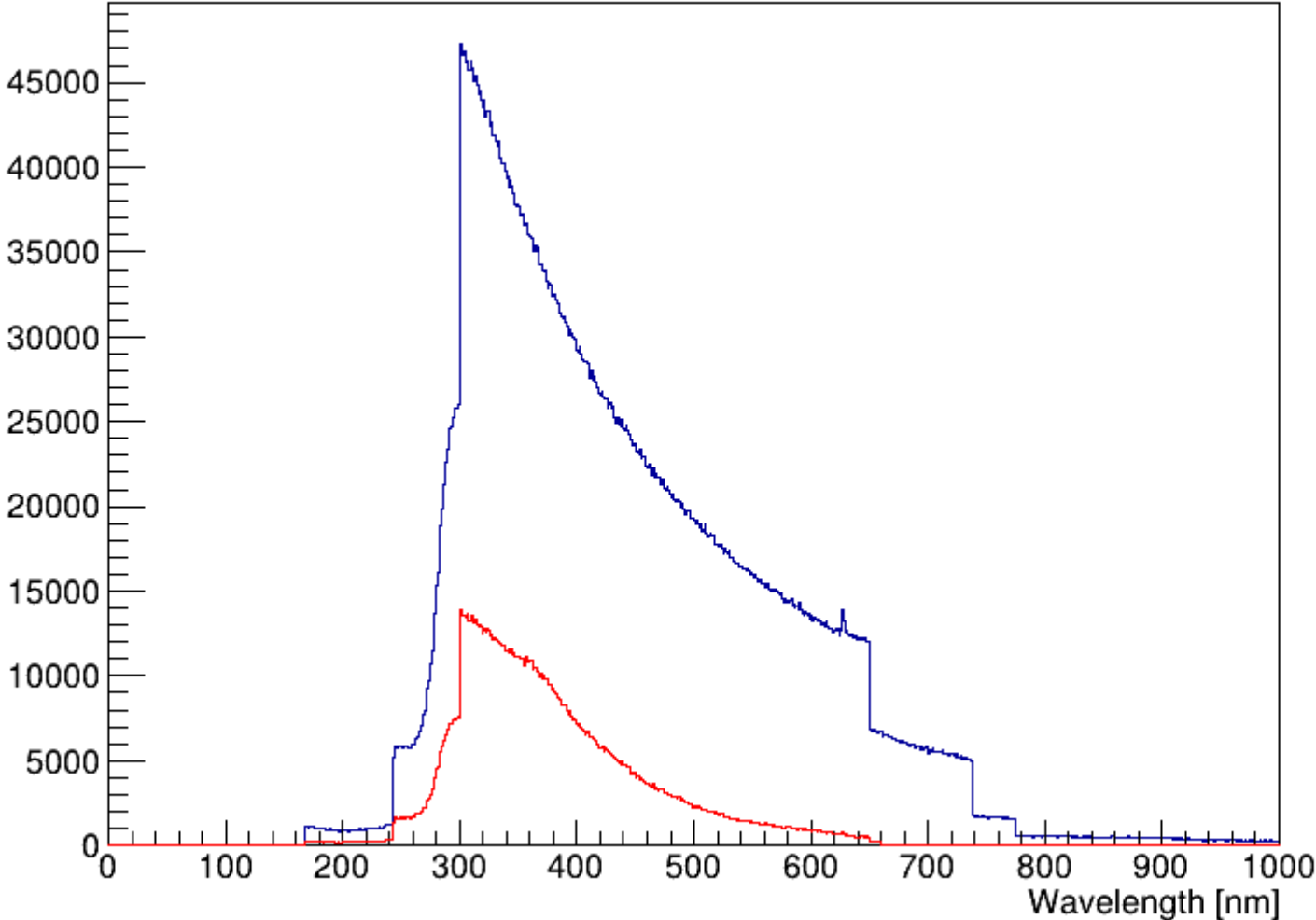
# DIS $Q^2 < 1$ : “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor



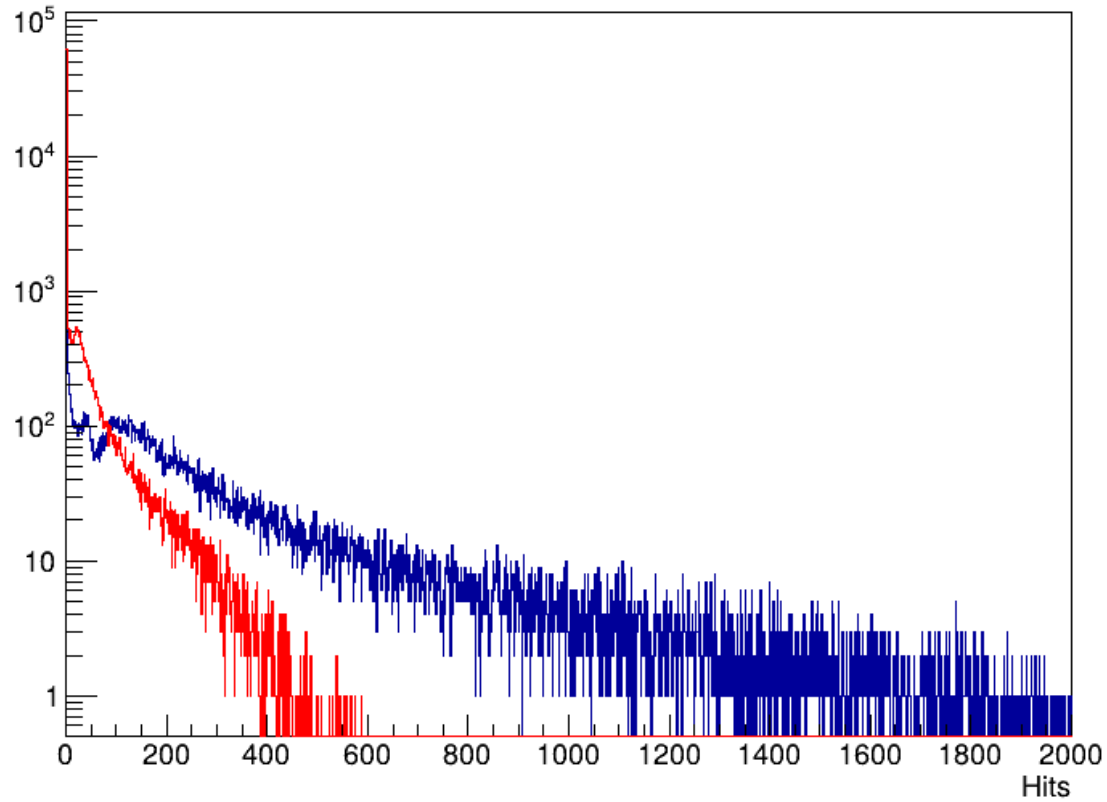
# DIS Q2 < 1: Photon Wavelength

Wavelength of Photons Hitting Sensor: Blue = All, Red = QE Cut

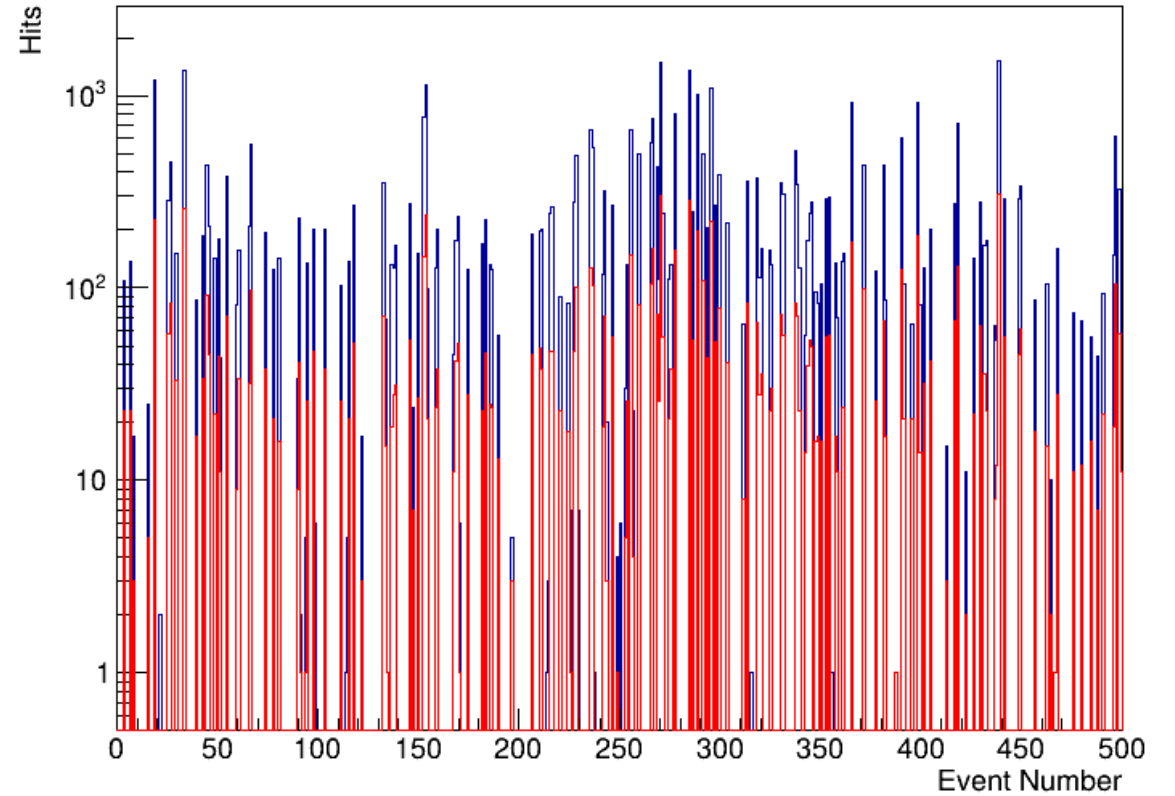


# DIS Q2 < 1: Event Hit Structure

Number of Hits in Event: Blue = All, Red = QE Cut

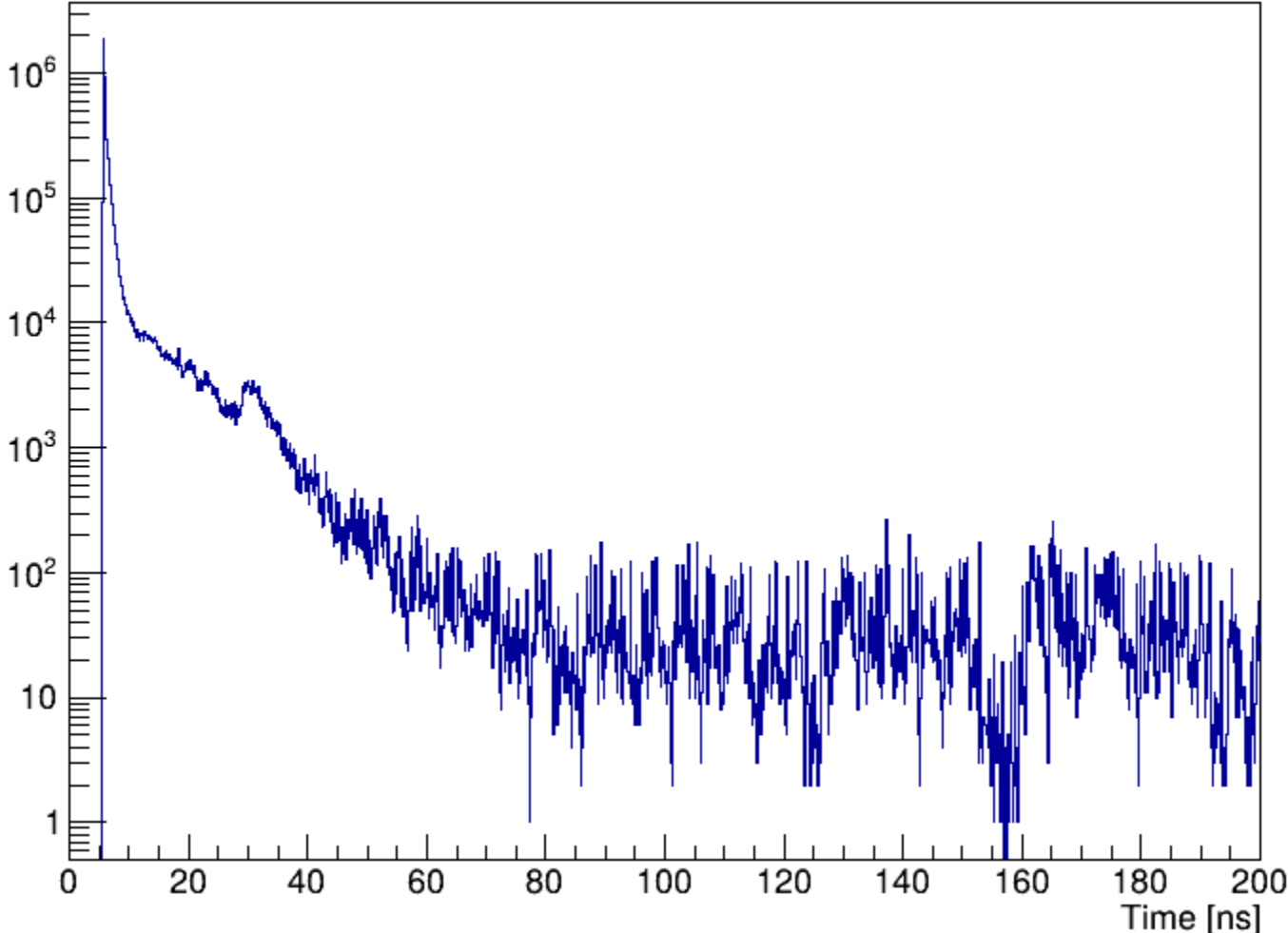


Number of Hits in Each Event: Blue = All, Red = QE Cut



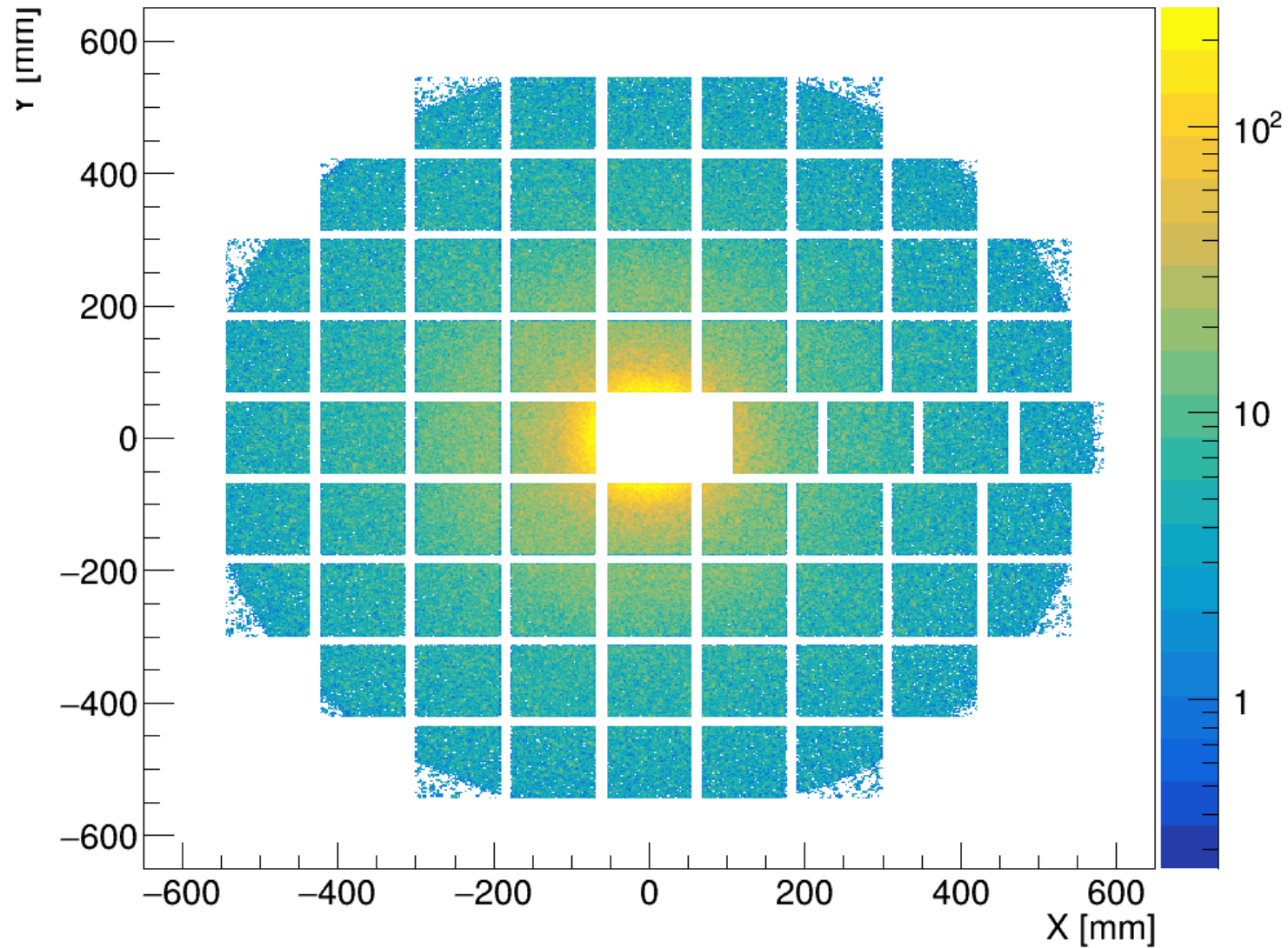
# DIS Q2 < 1: Hit Times

Time of Hit



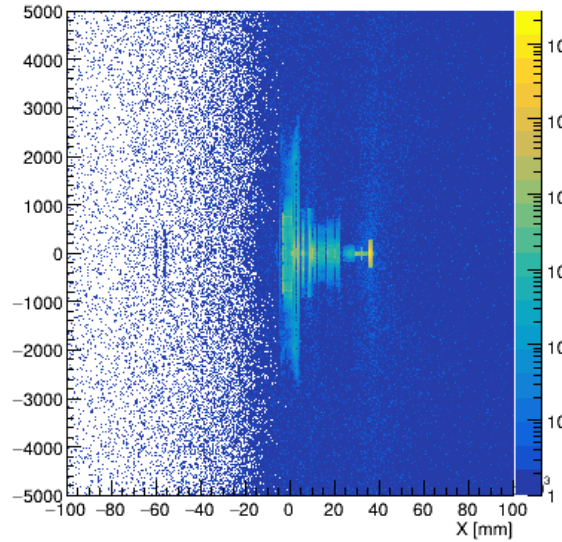
# DIS Q2 < 1: Hit Map After QE Cut

Hit Map after QE Cut

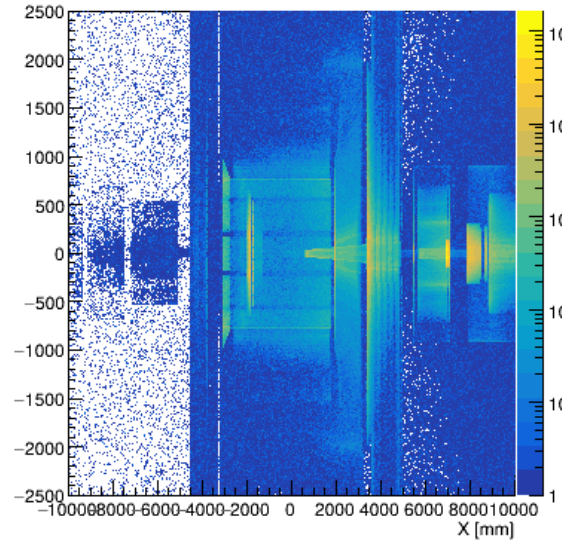


# DIS Q2 1-10: Production Vertex

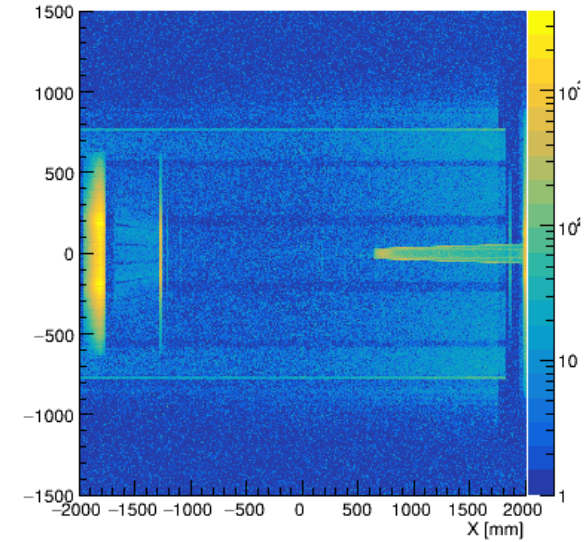
Particle Production Vertx



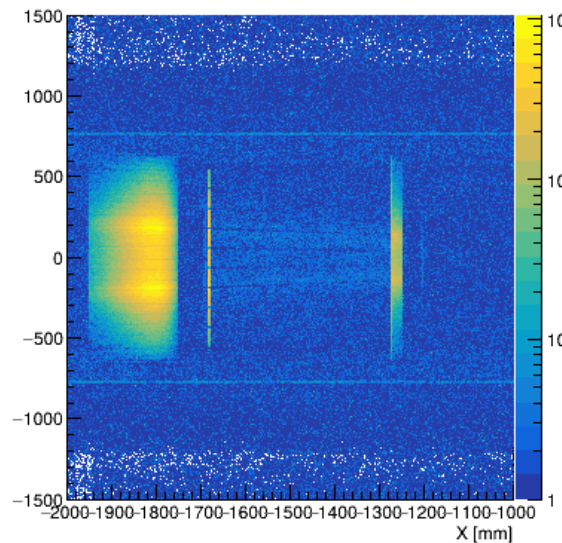
Particle Production Vertx



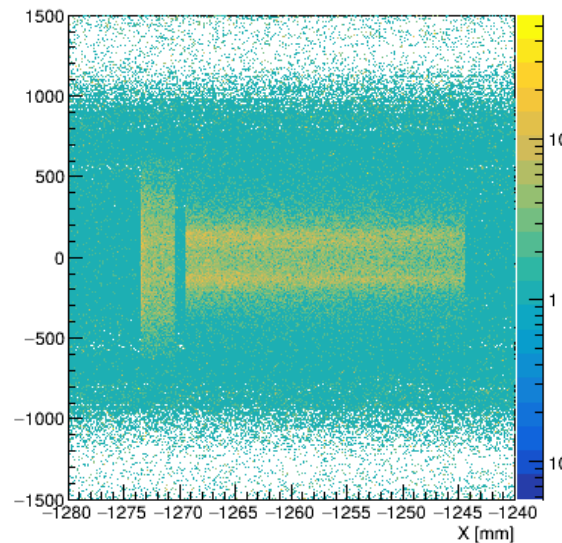
Particle Production Vertx



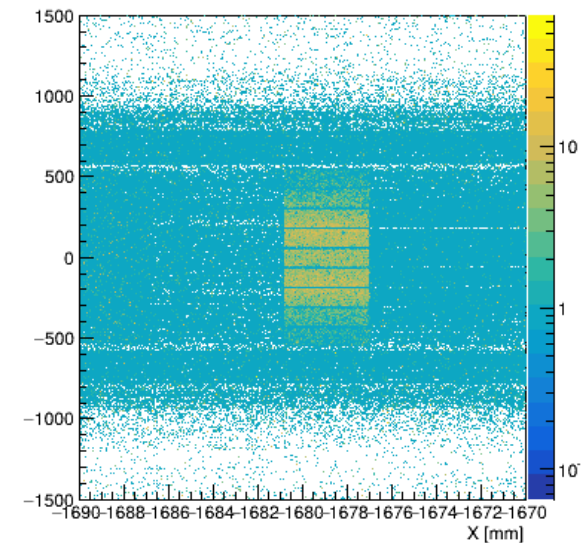
Particle Production Vertx



Particle Production Vertx

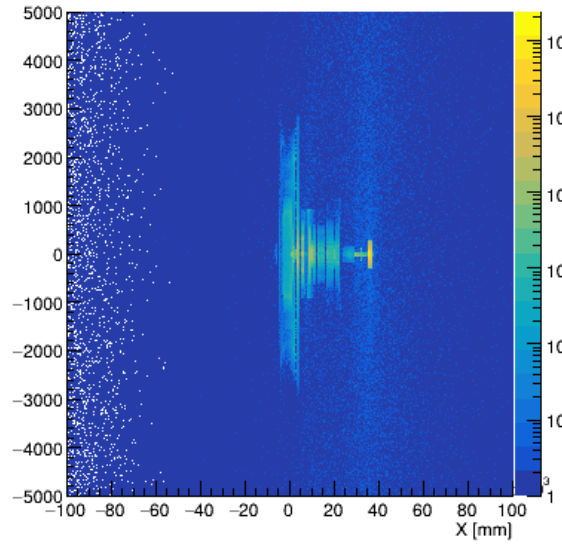


Particle Production Vertx

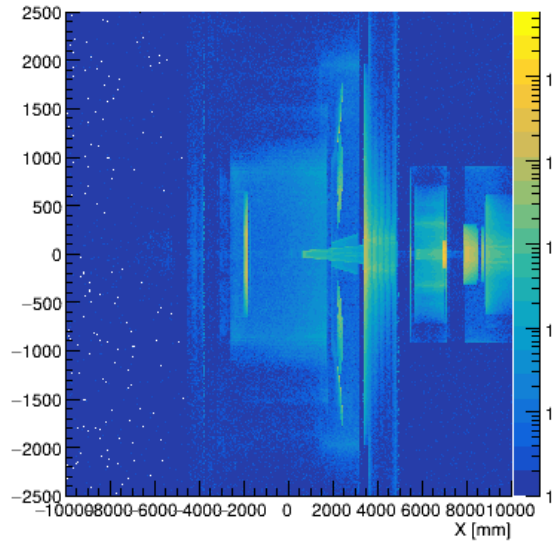


# DIS Q2 1-10: End Vertex

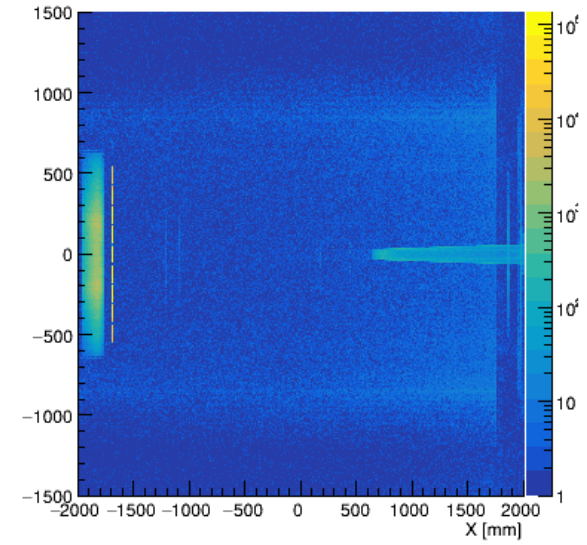
Particle End Vertex



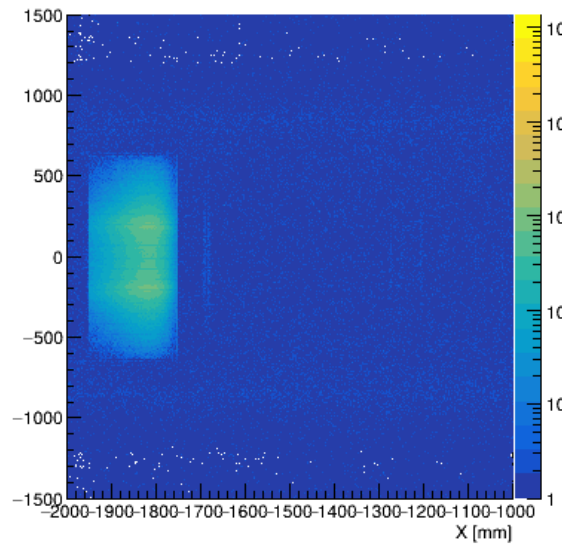
Particle End Vertex



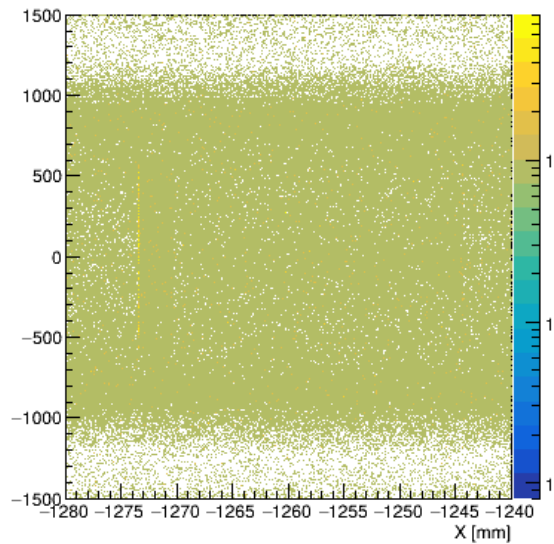
Particle End Vertex



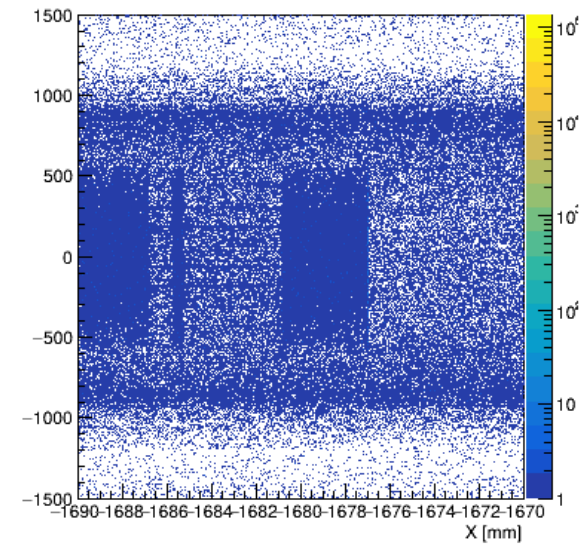
Particle End Vertex



Particle End Vertex

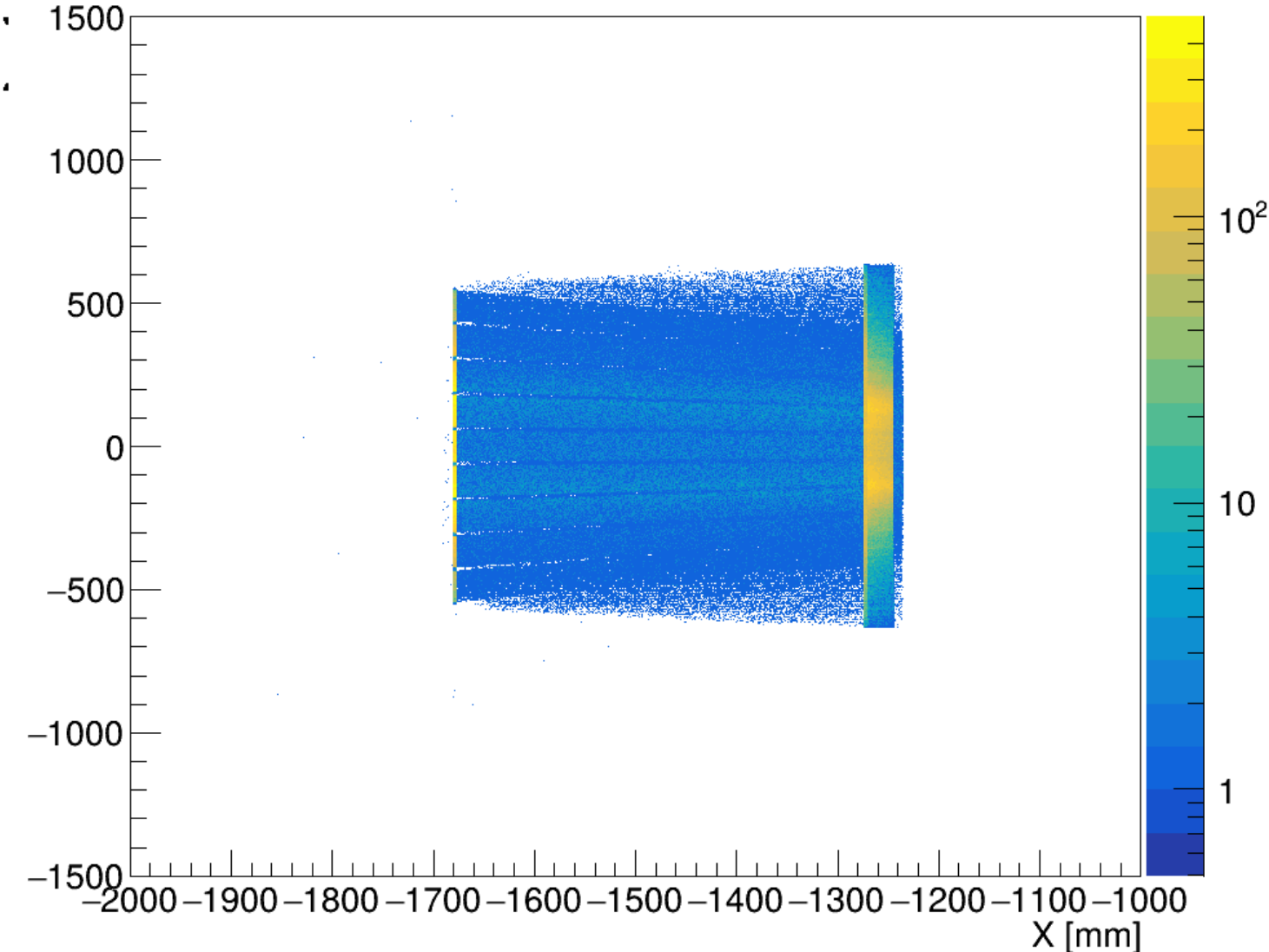


Particle End Vertex

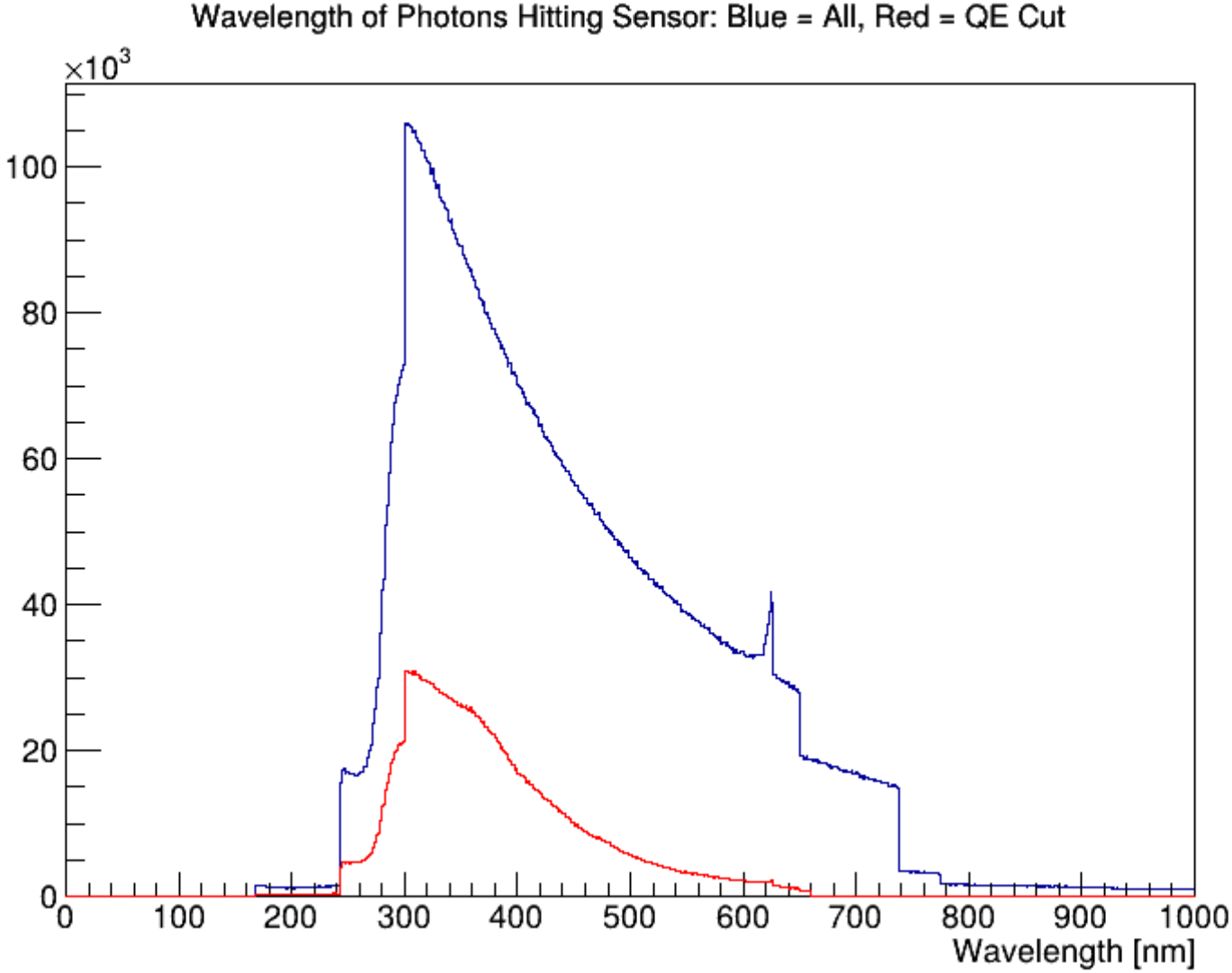


# DIS Q2 1-10: “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor

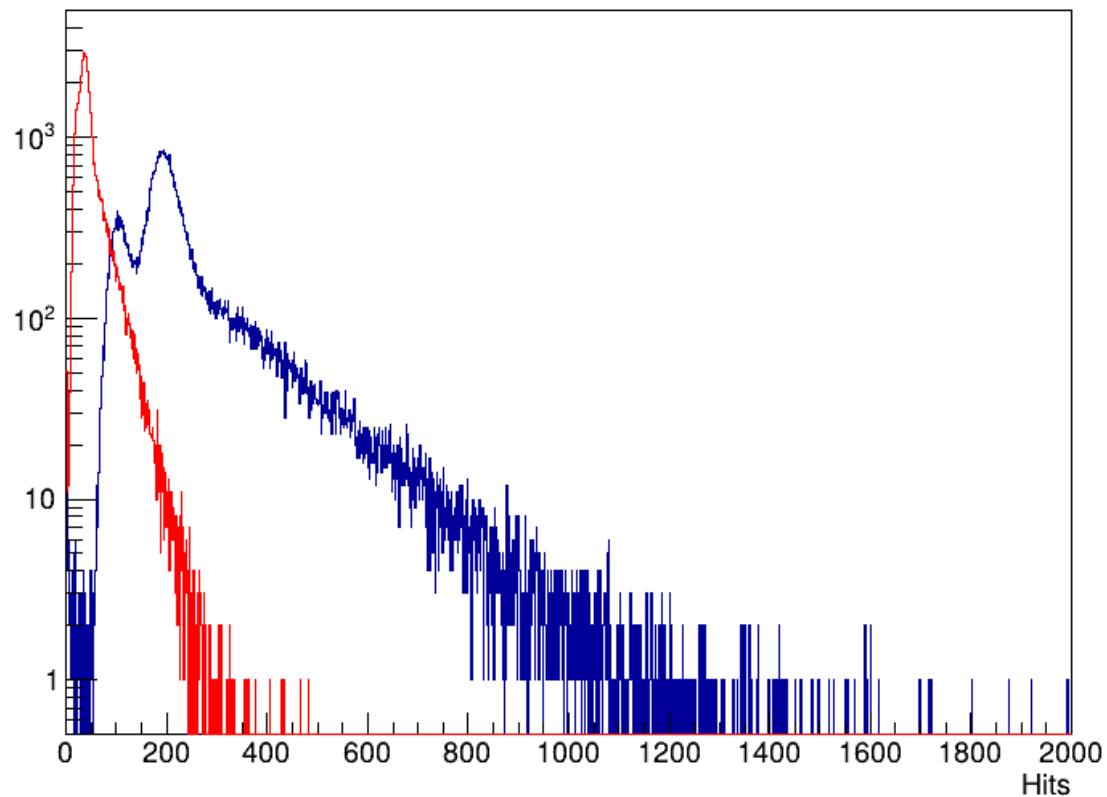


# DIS Q2 1-10: Photon Wavelength

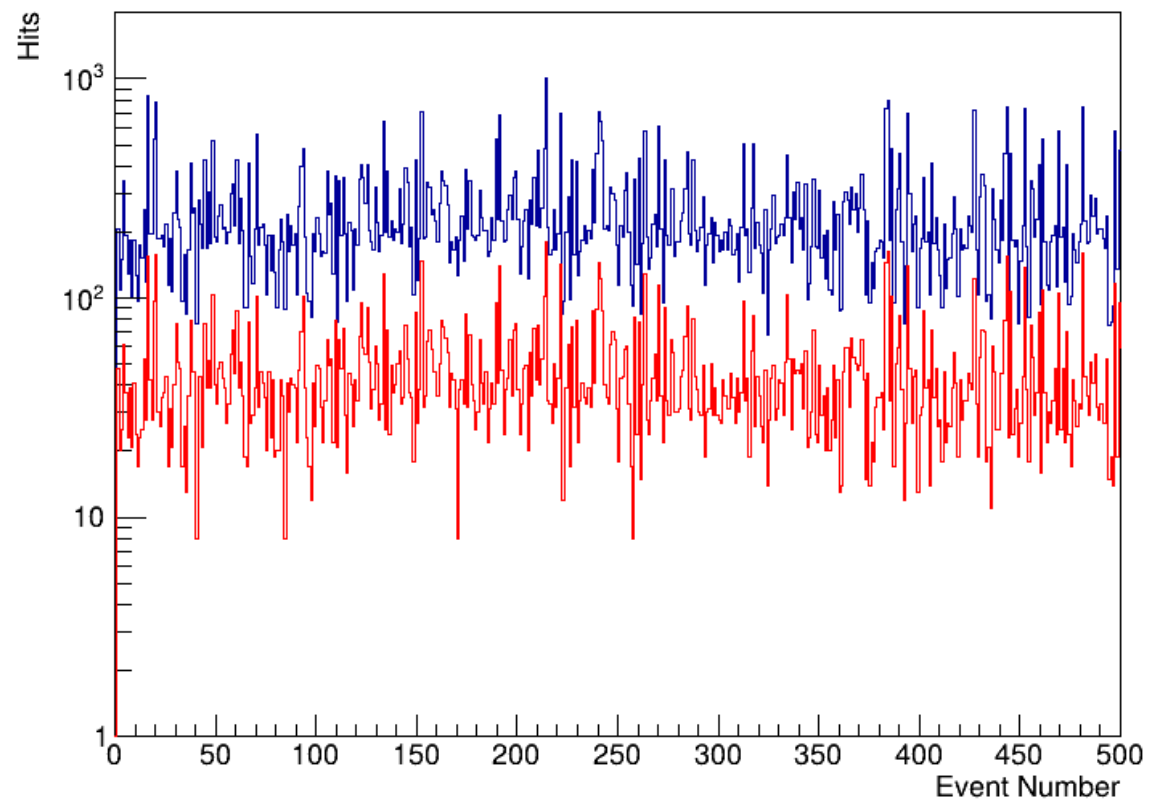


# DIS Q2 1-10: Event Hit Structure

Number of Hits in Event: Blue = All, Red = QE Cut

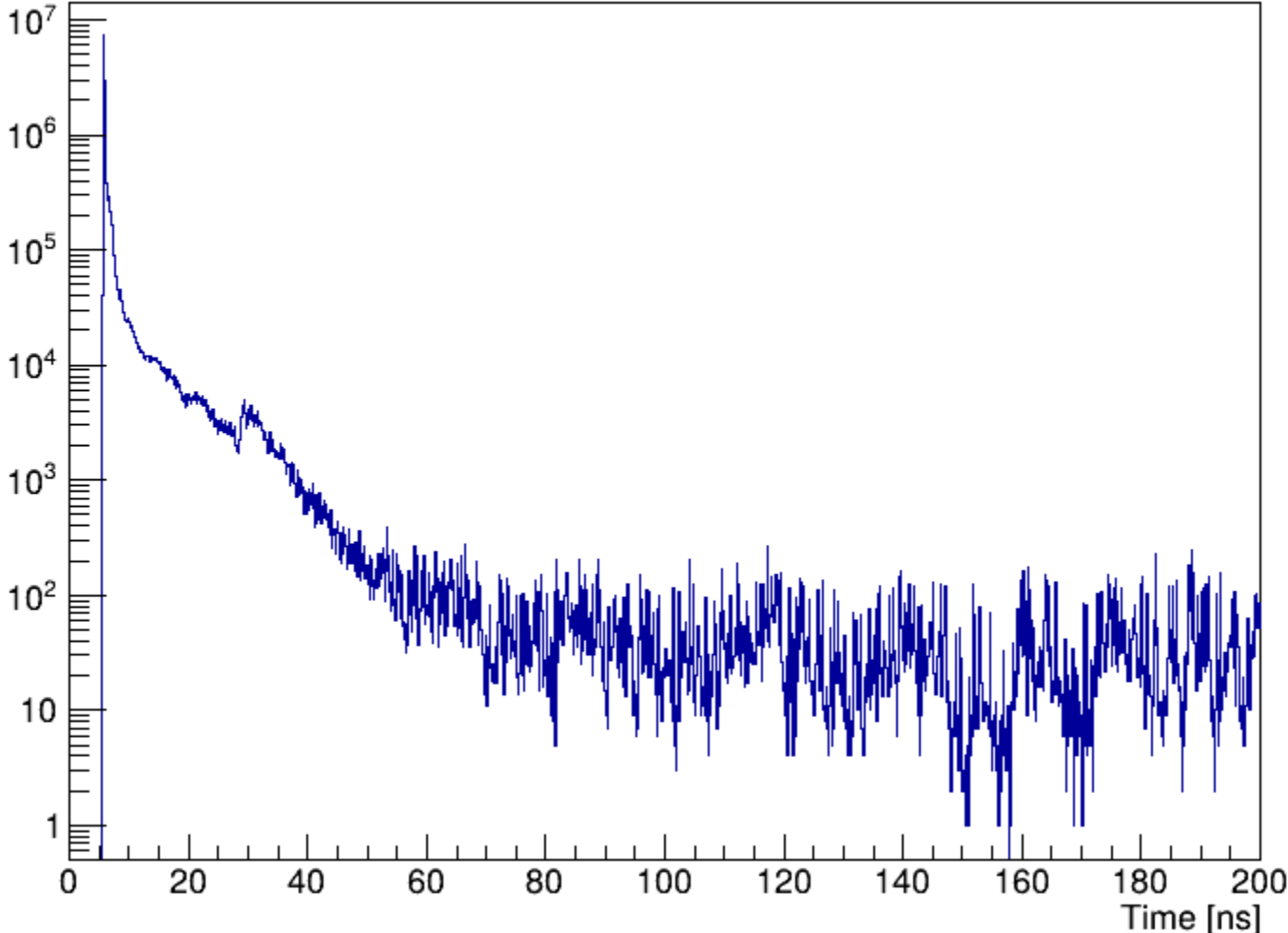


Number of Hits in Each Event: Blue = All, Red = QE Cut



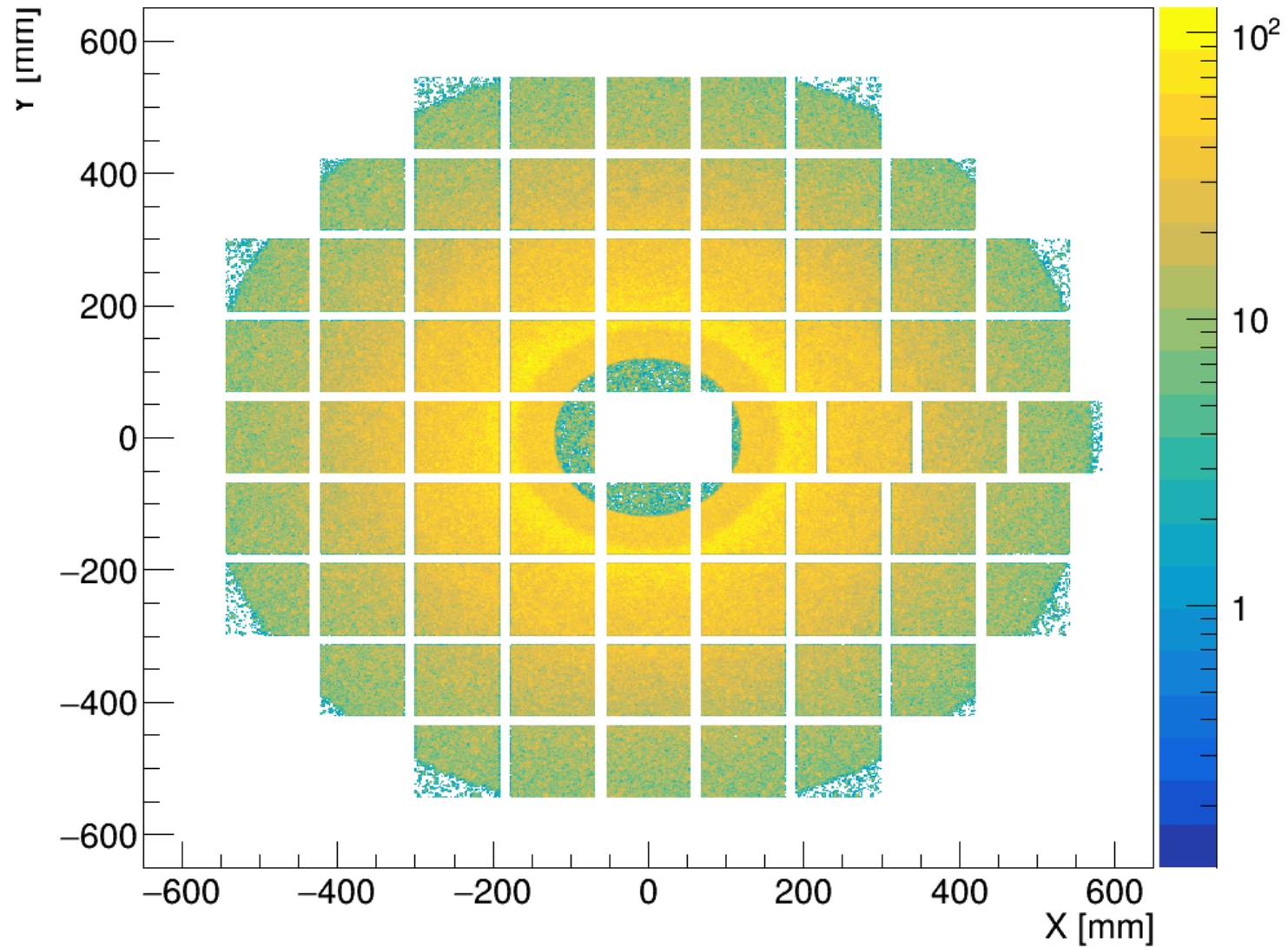
# DIS Q2 1-10: Hit Times

Time of Hit



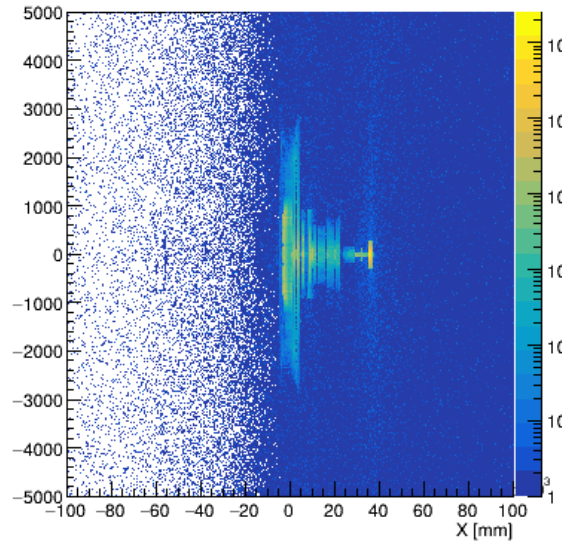
# DIS Q2 1-10: Hit Map After QE Cut

Hit Map after QE Cut

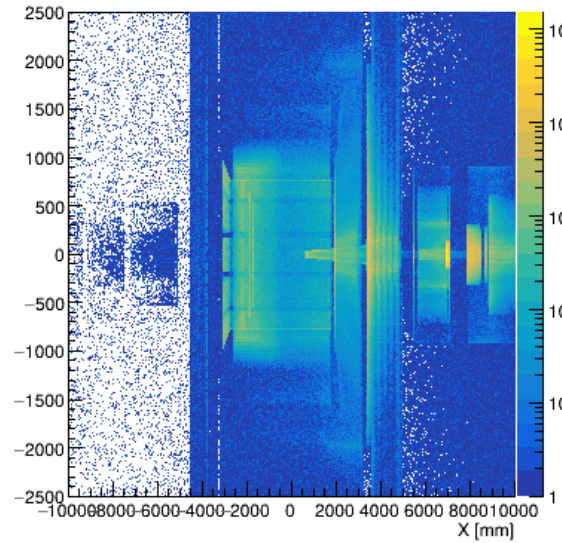


# DIS Q2 10-100: Production Vertex

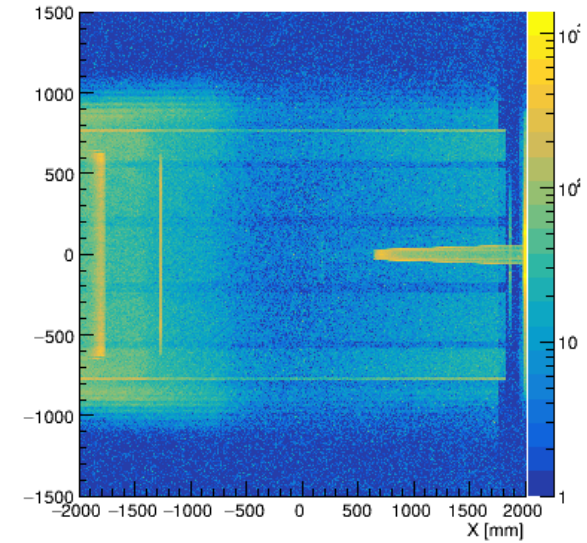
Particle Production Vertx



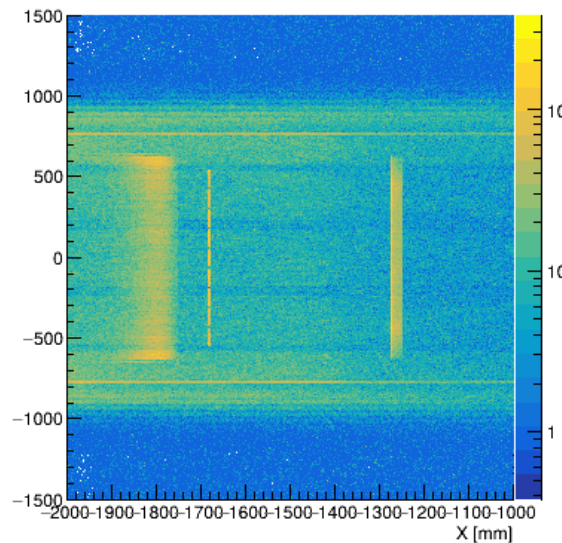
Particle Production Vertx



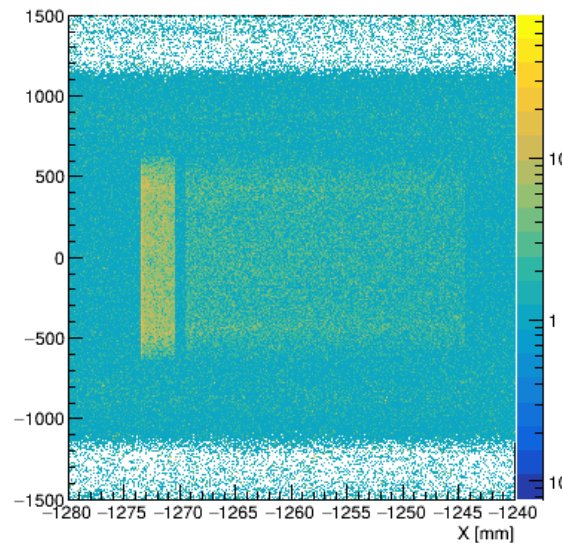
Particle Production Vertx



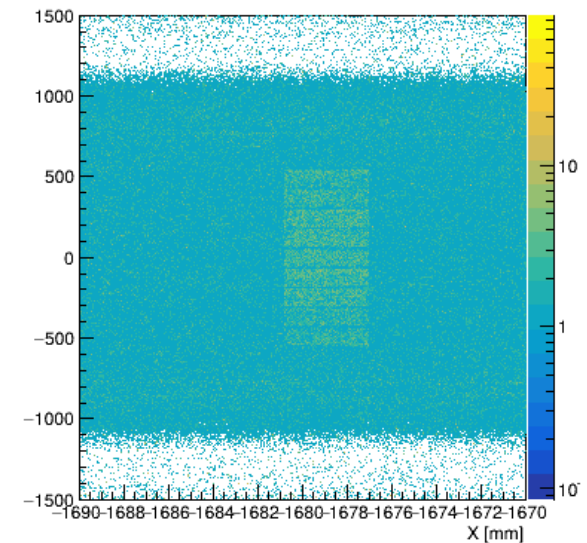
Particle Production Vertx



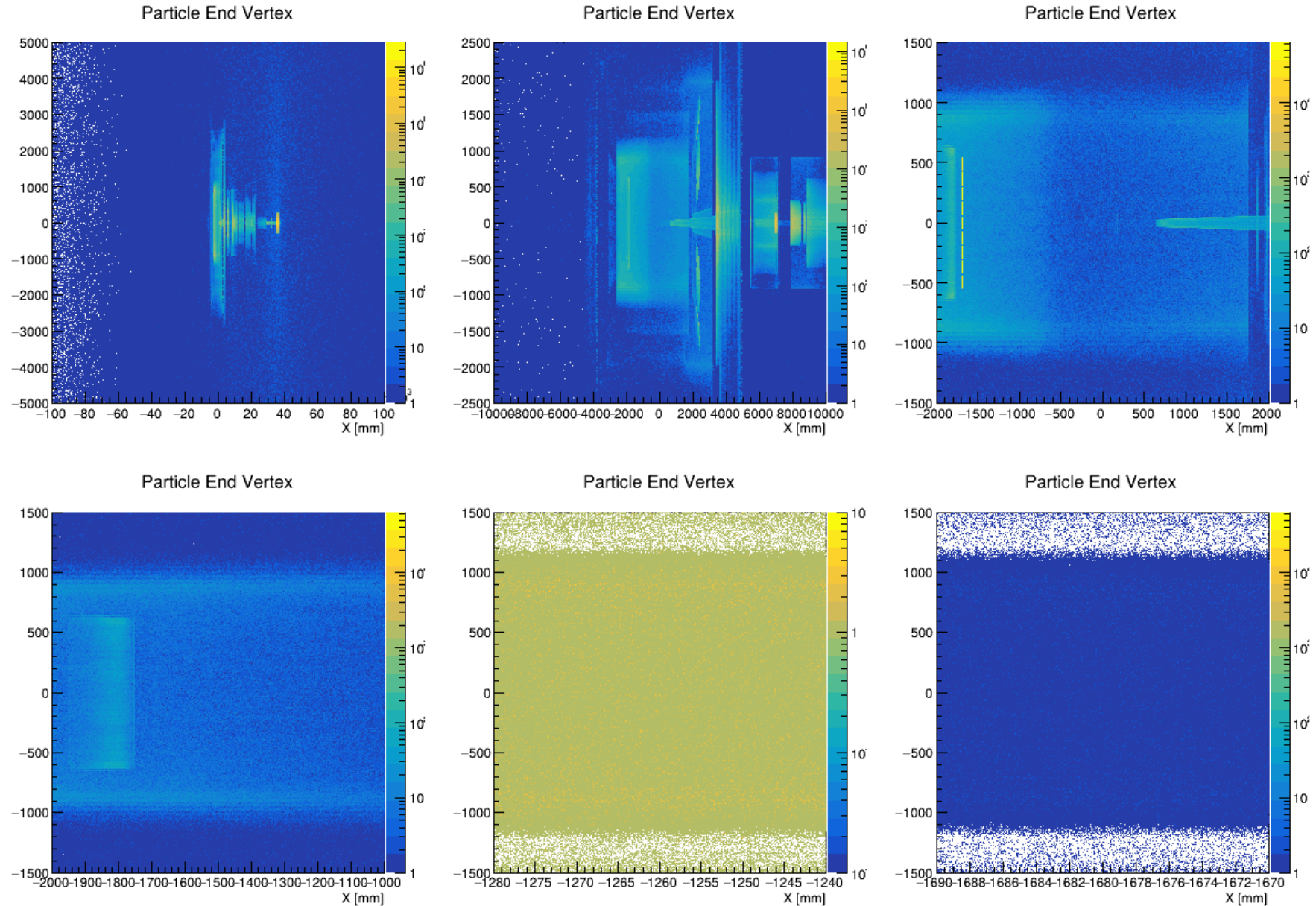
Particle Production Vertx



Particle Production Vertx

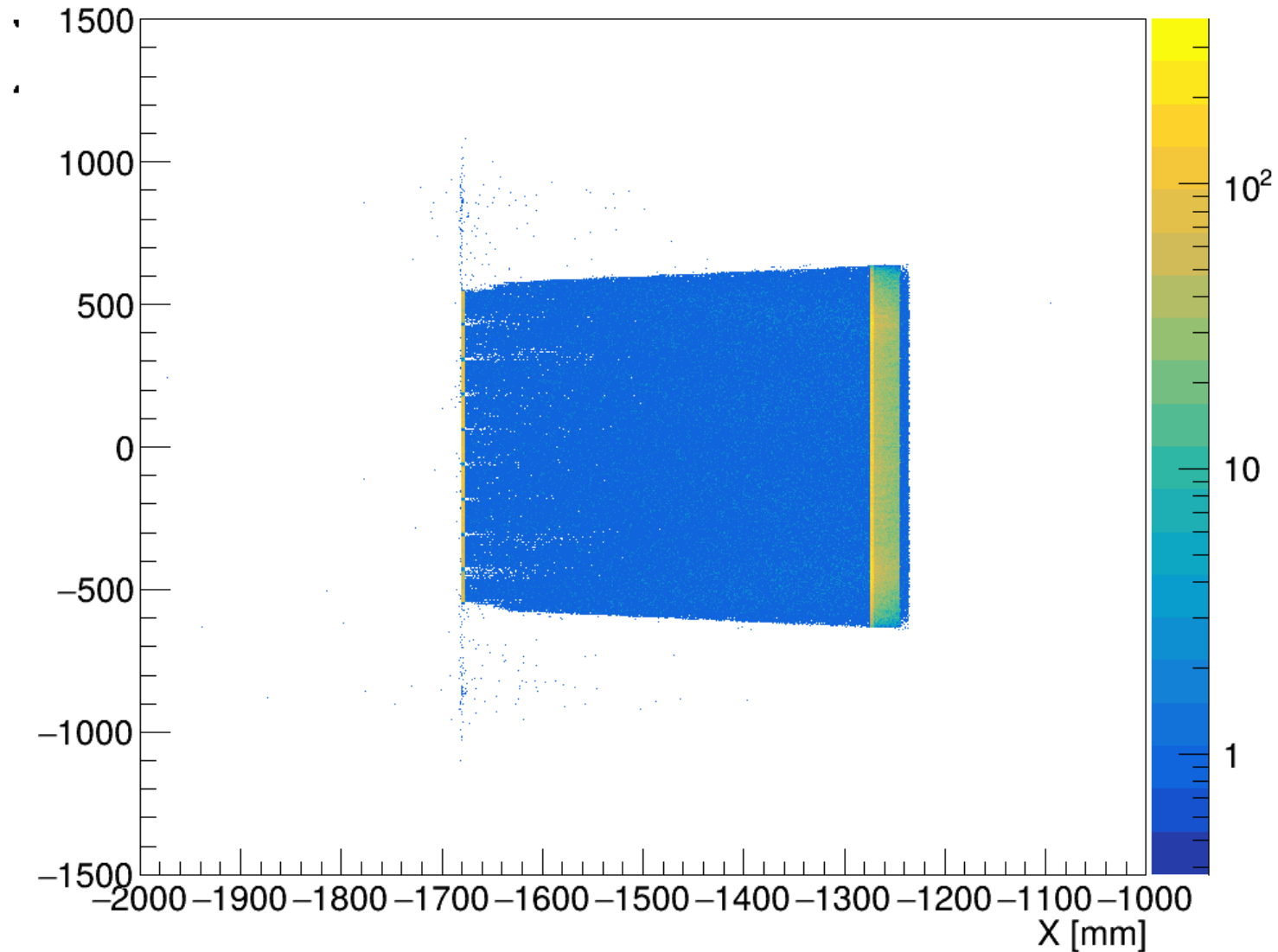


# DIS Q2 10-100: End Vertex



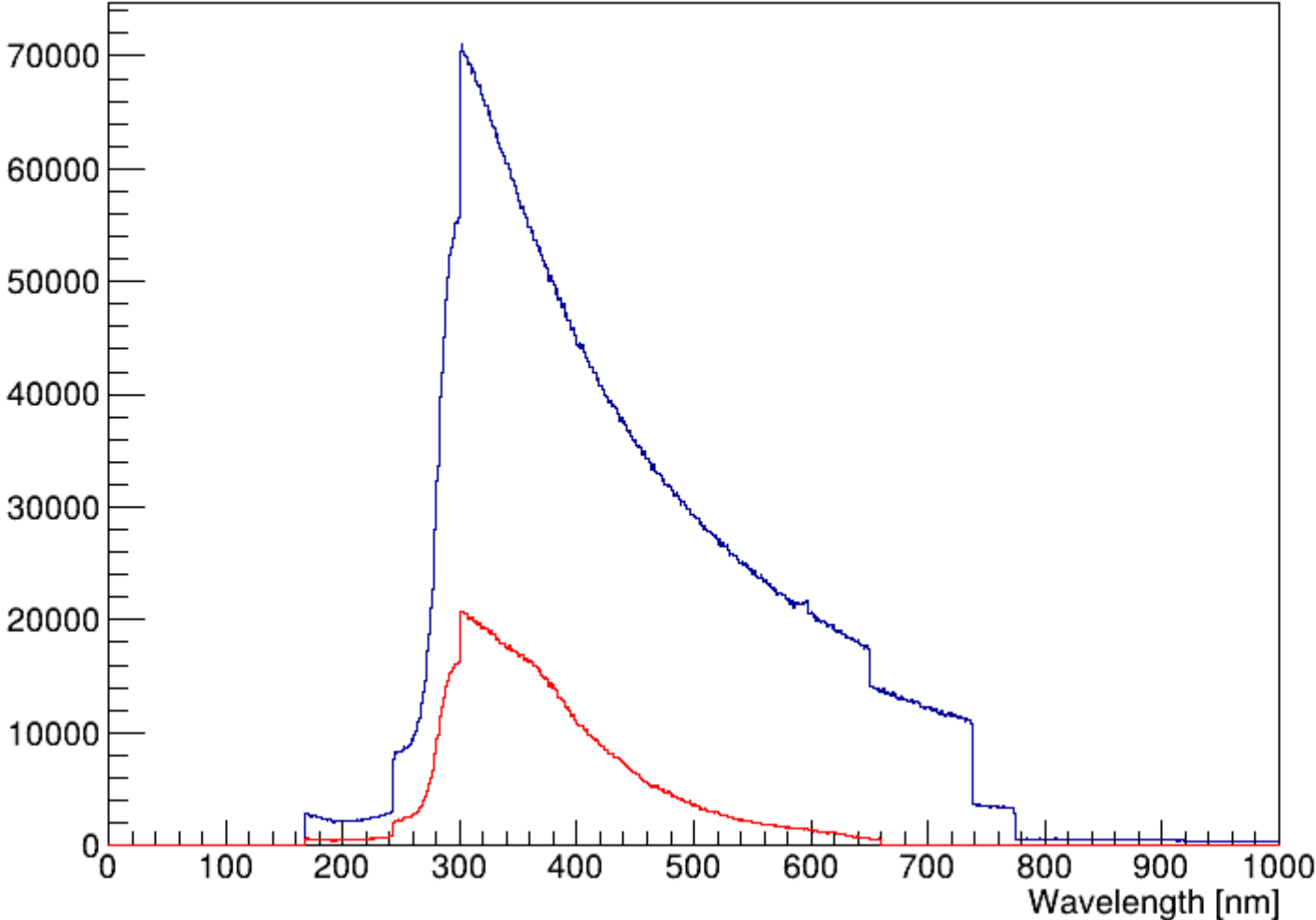
# DIS Q2 10-100: “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor



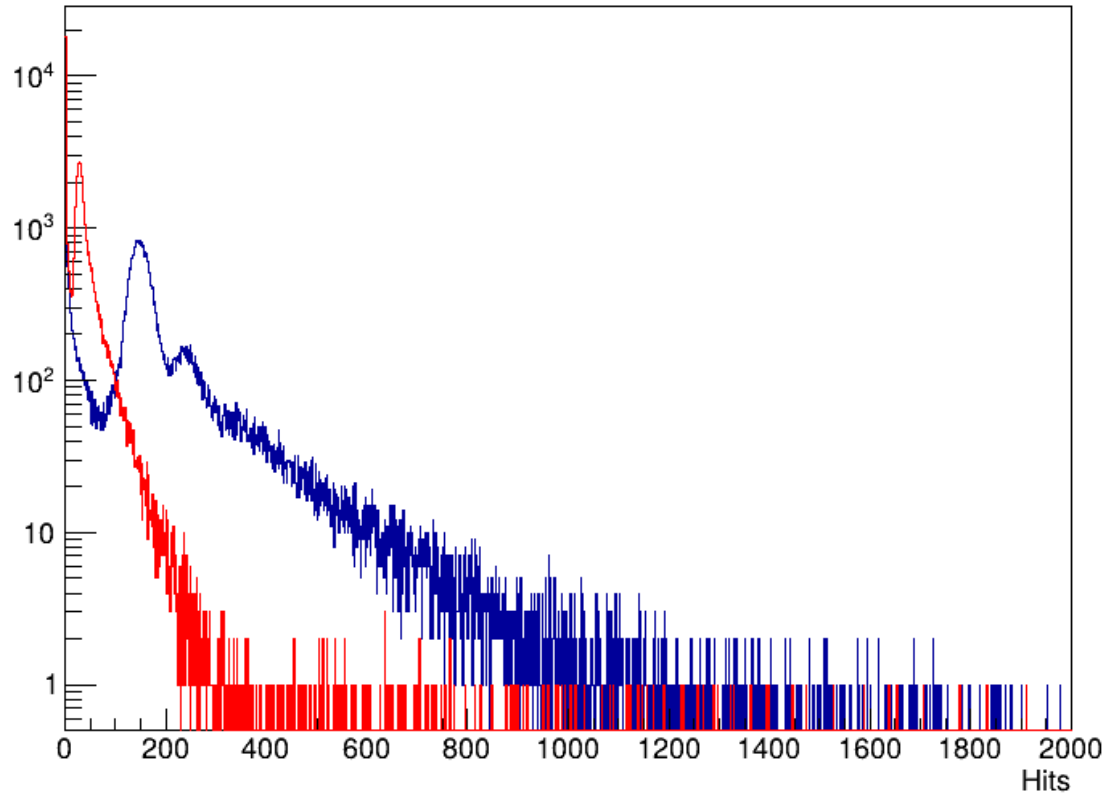
# DIS Q2 10-100: Photon Wavelength

Wavelength of Photons Hitting Sensor: Blue = All, Red = QE Cut

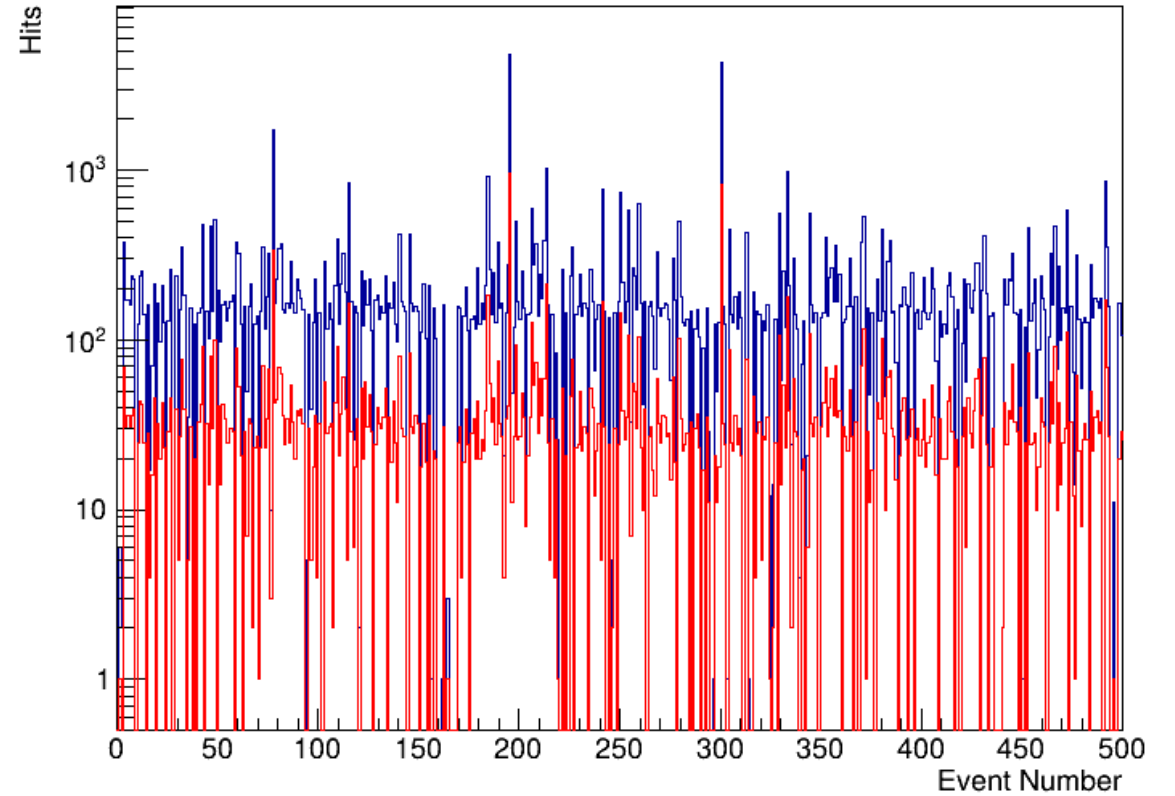


# DIS Q2 10-100: Event Hit Structure

Number of Hits in Event: Blue = All, Red = QE Cut

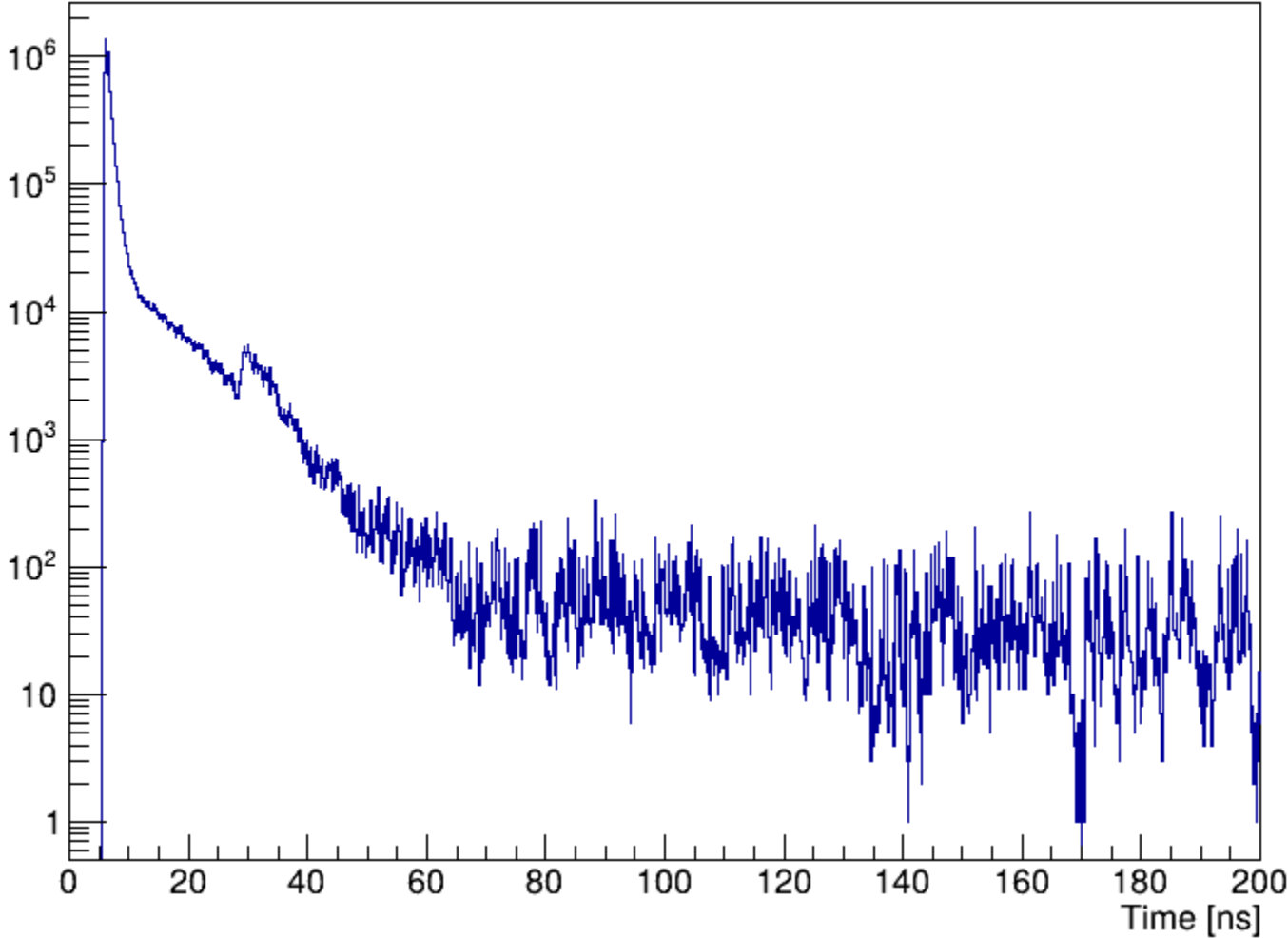


Number of Hits in Each Event: Blue = All, Red = QE Cut



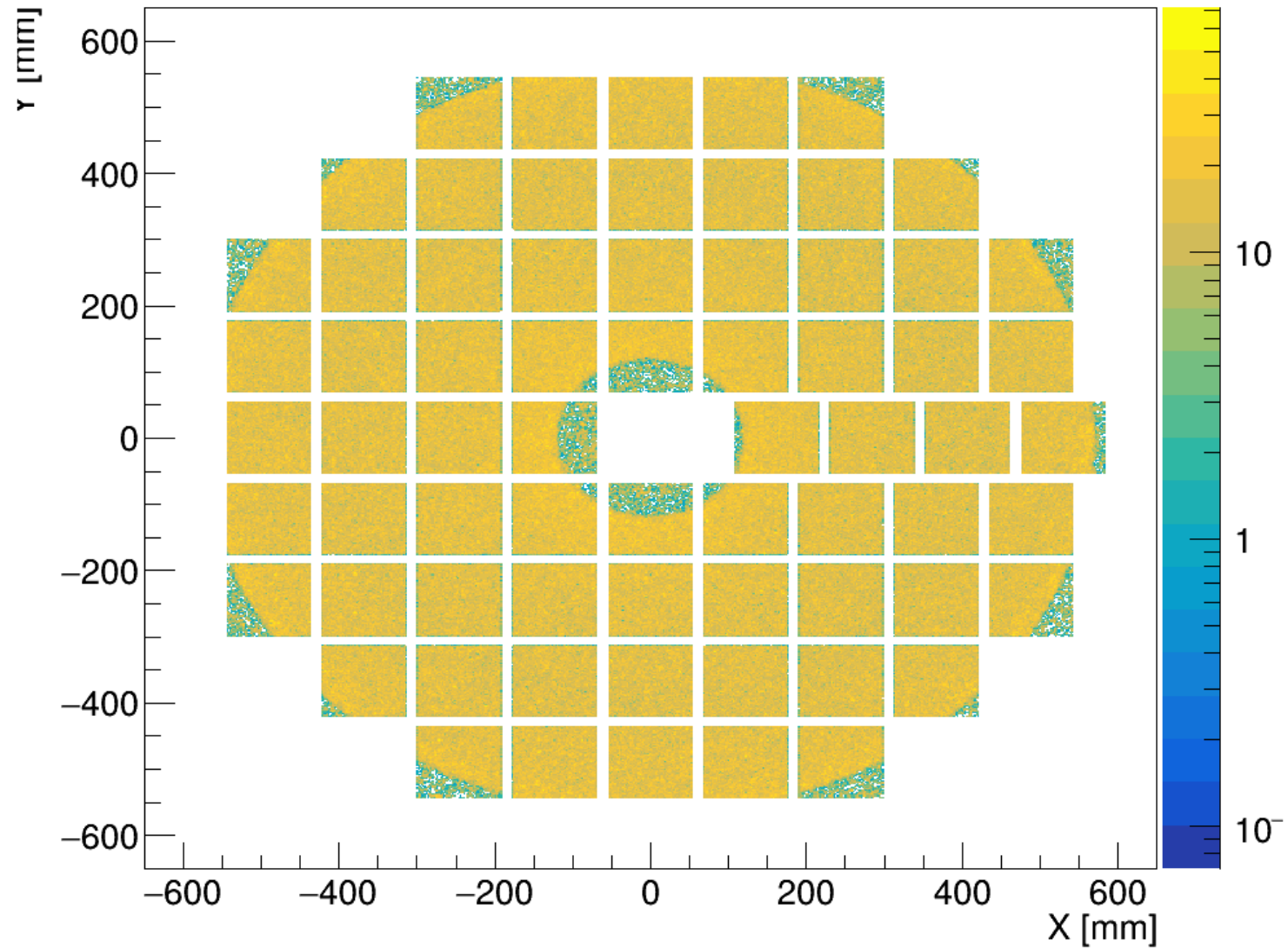
# DIS Q2 10-100: Hit Times

Time of Hit



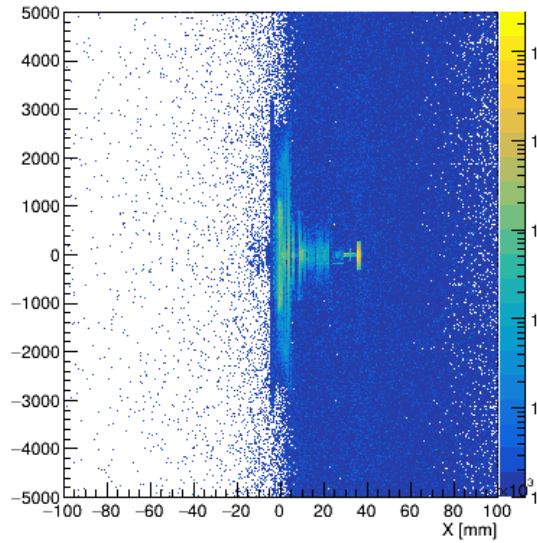
# DIS Q2 10-100: Hit Map After QE Cut

Hit Map after QE Cut

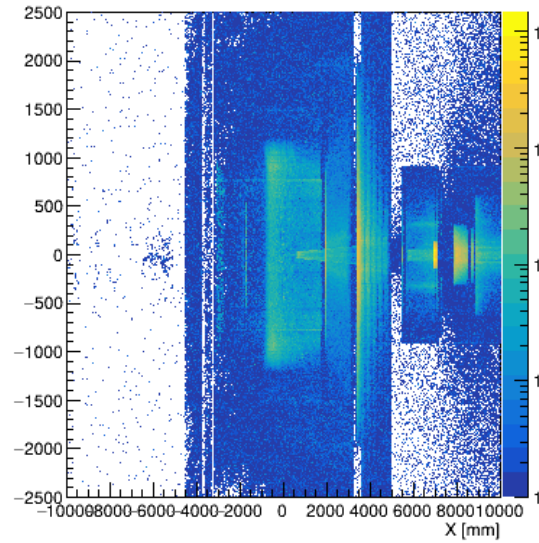


# DIS Q2 100-1000: Production Vertex

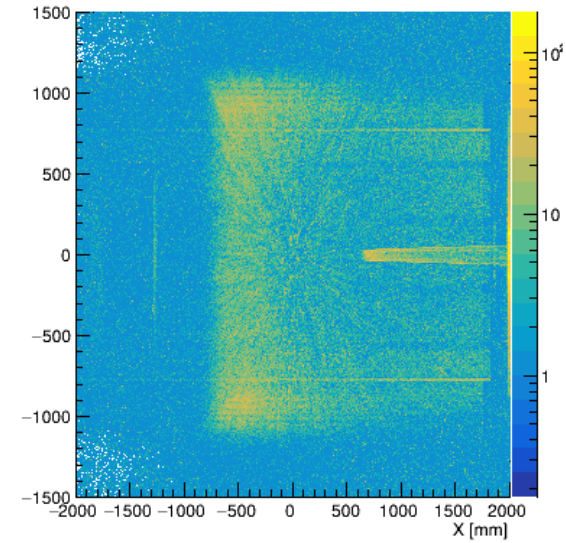
Particle Production Vertx



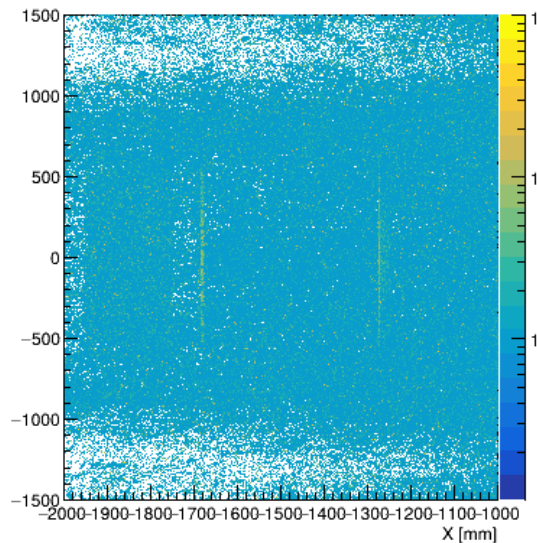
Particle Production Vertx



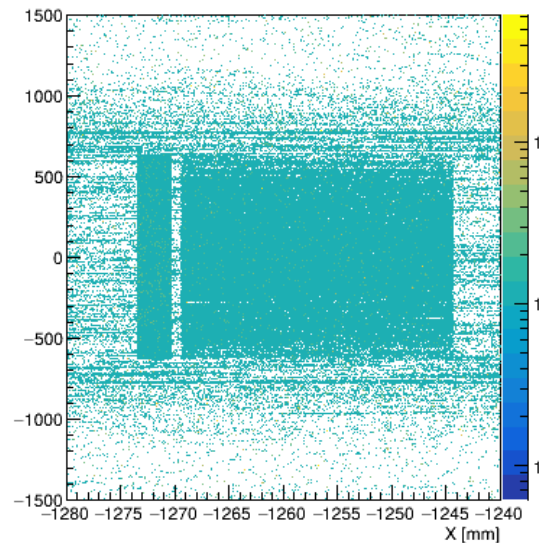
Particle Production Vertx



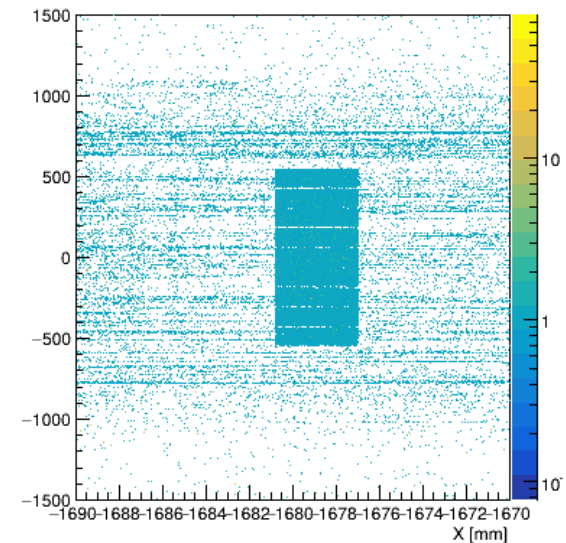
Particle Production Vertx



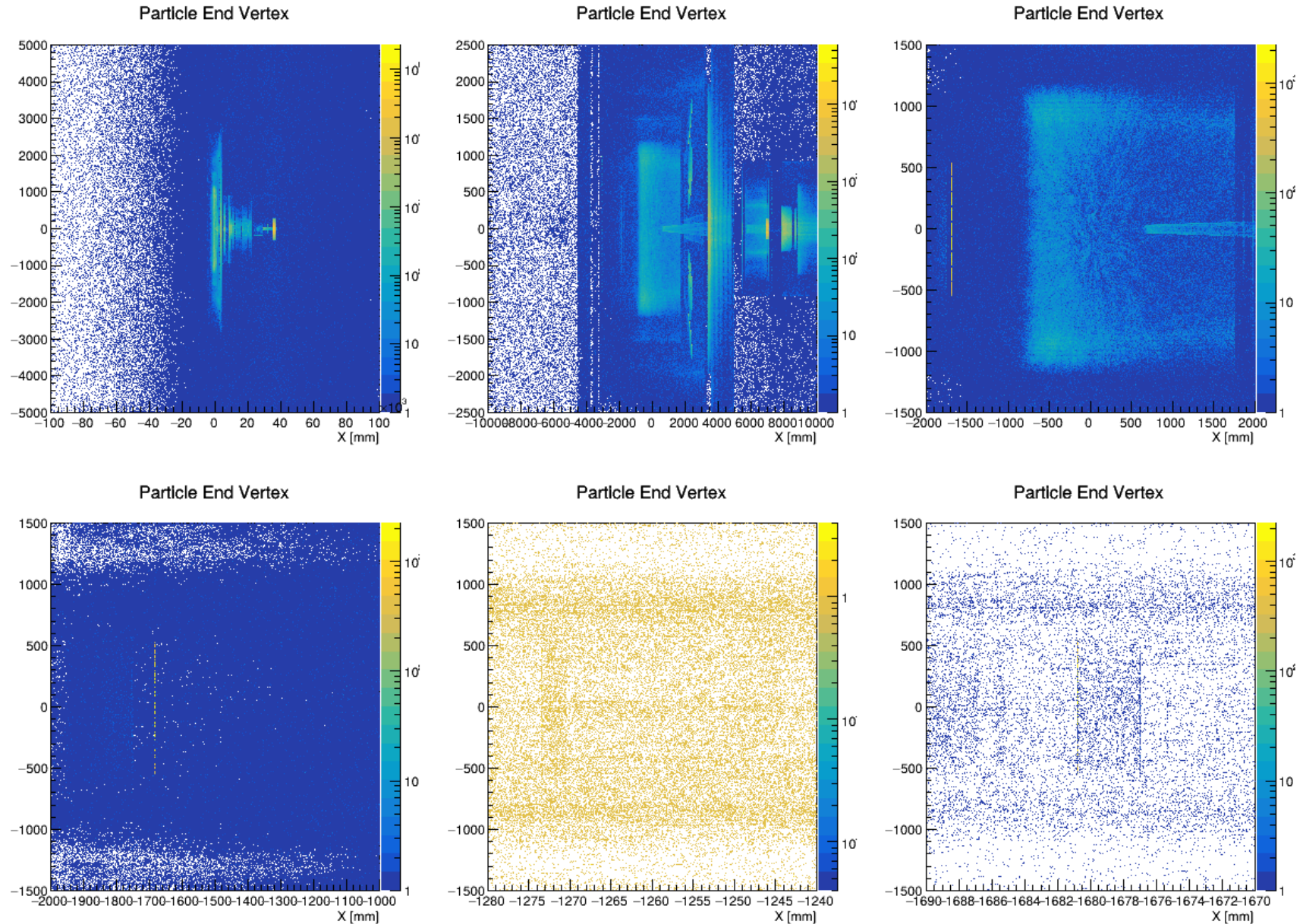
Particle Production Vertx



Particle Production Vertx

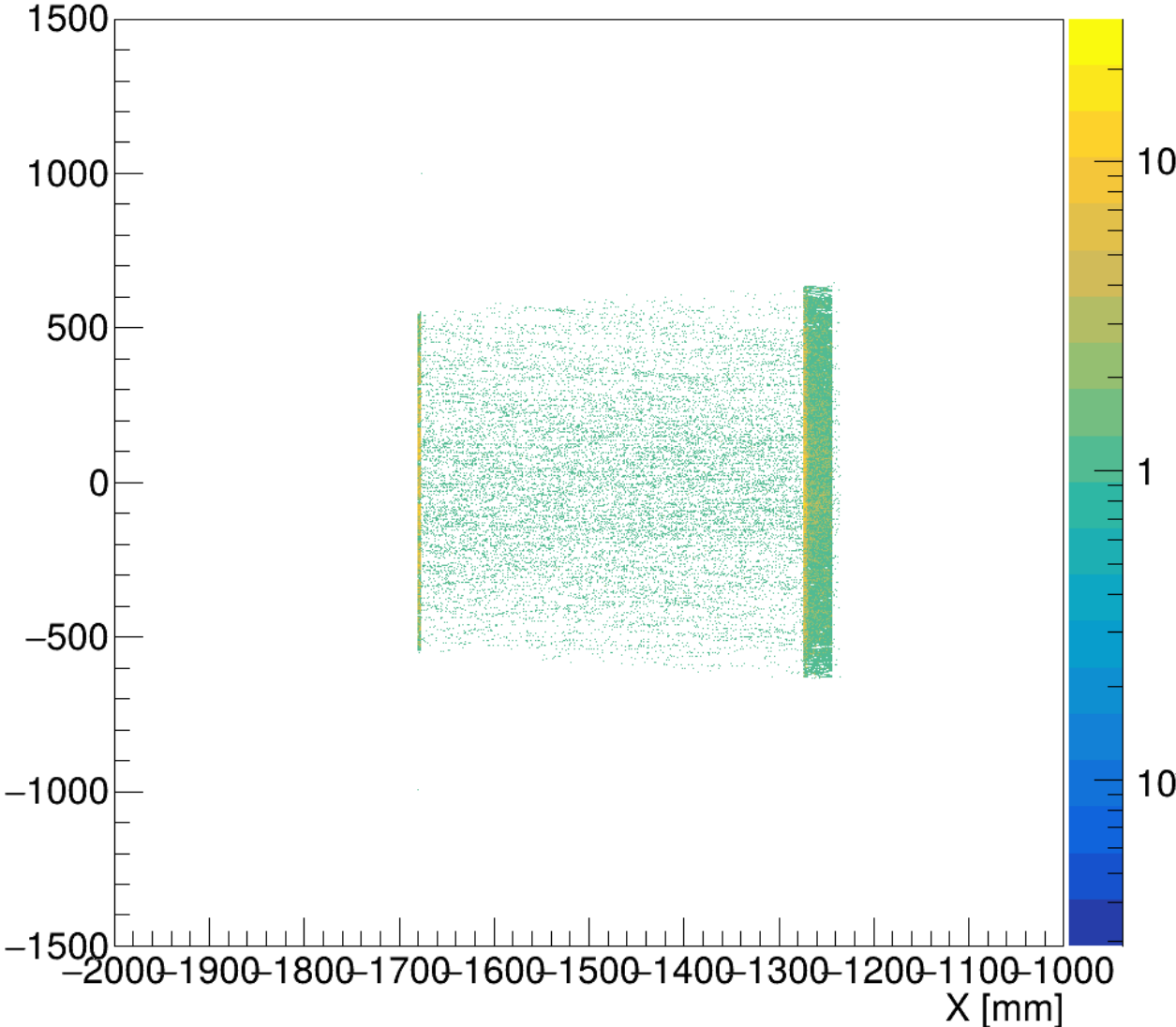


# DIS Q2 100-1000: End Vertex



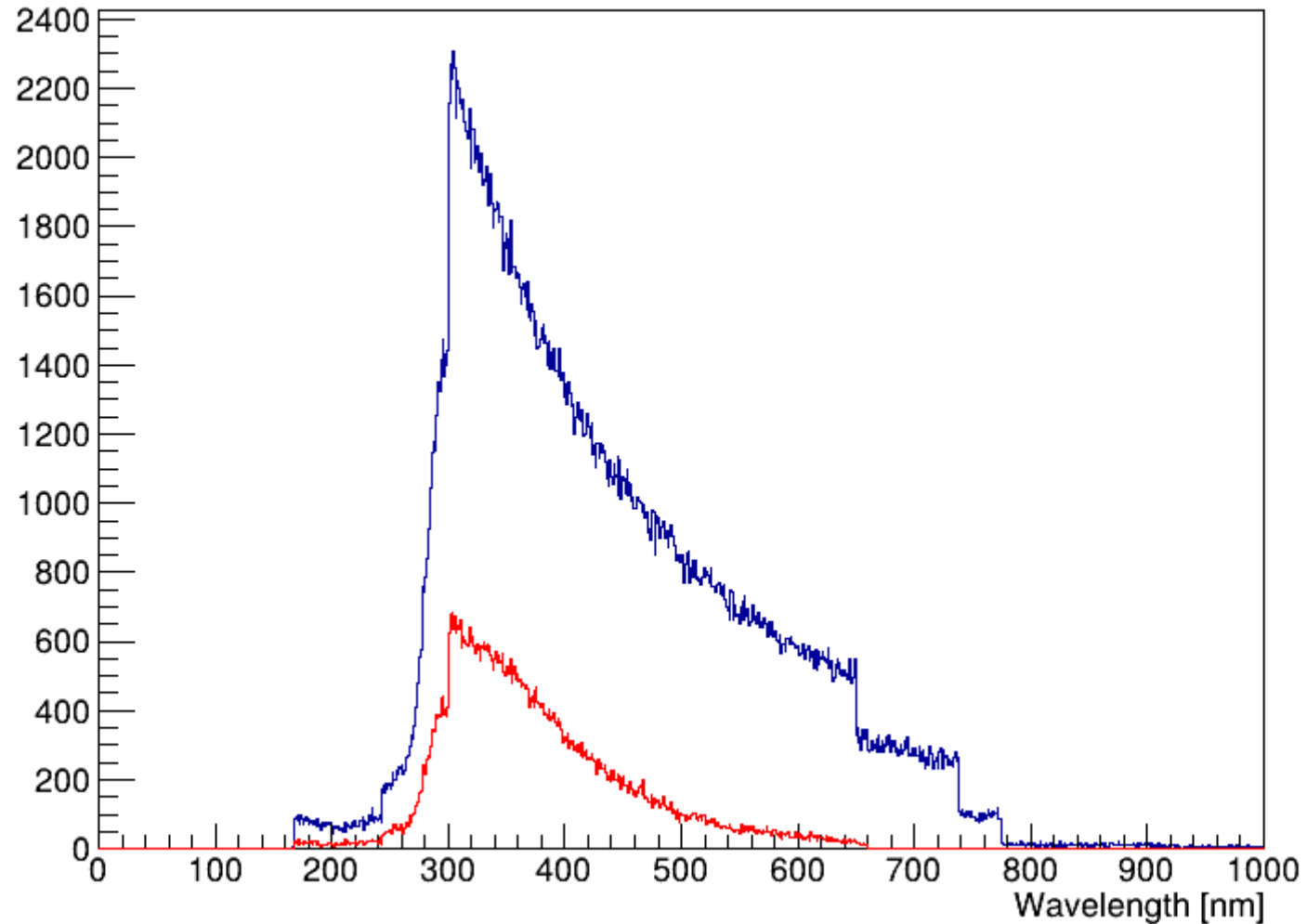
# DIS Q2 100-1000: “Last Scatter” Before Sensor

Production Vertex for Particles Hitting Sensor



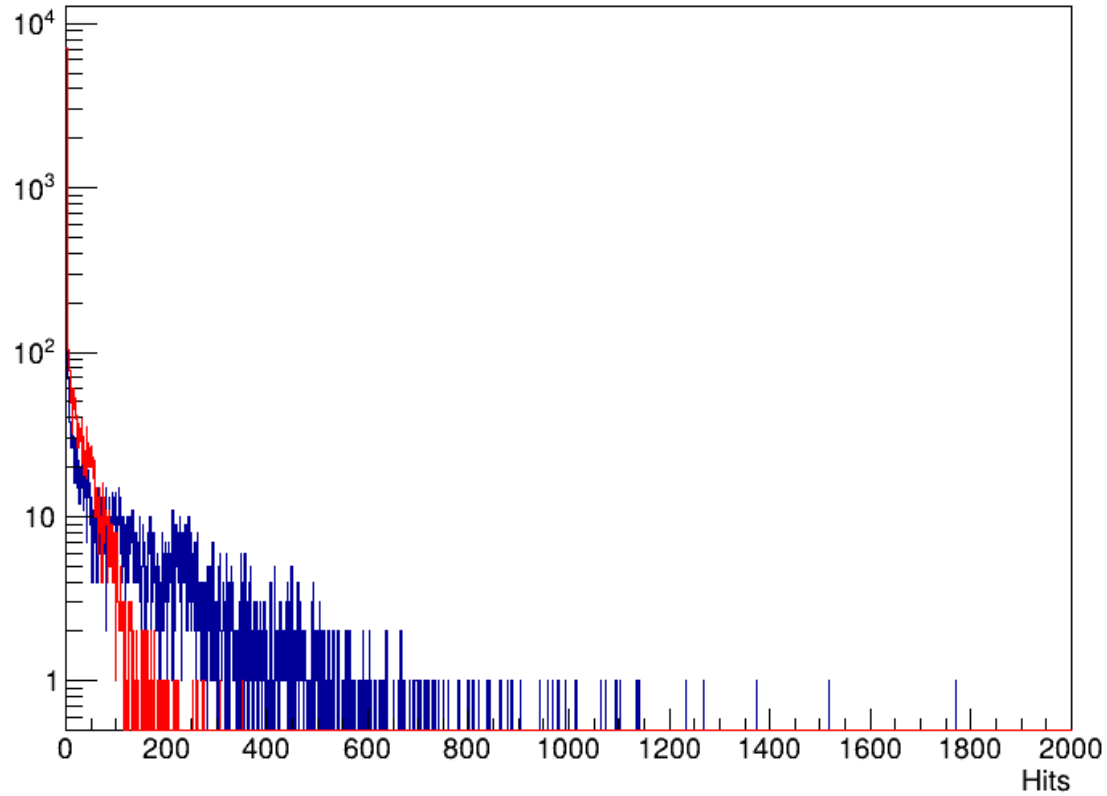
# DIS Q2 100-1000: Photon Wavelength

Wavelength of Photons Hitting Sensor: Blue = All, Red = QE Cut

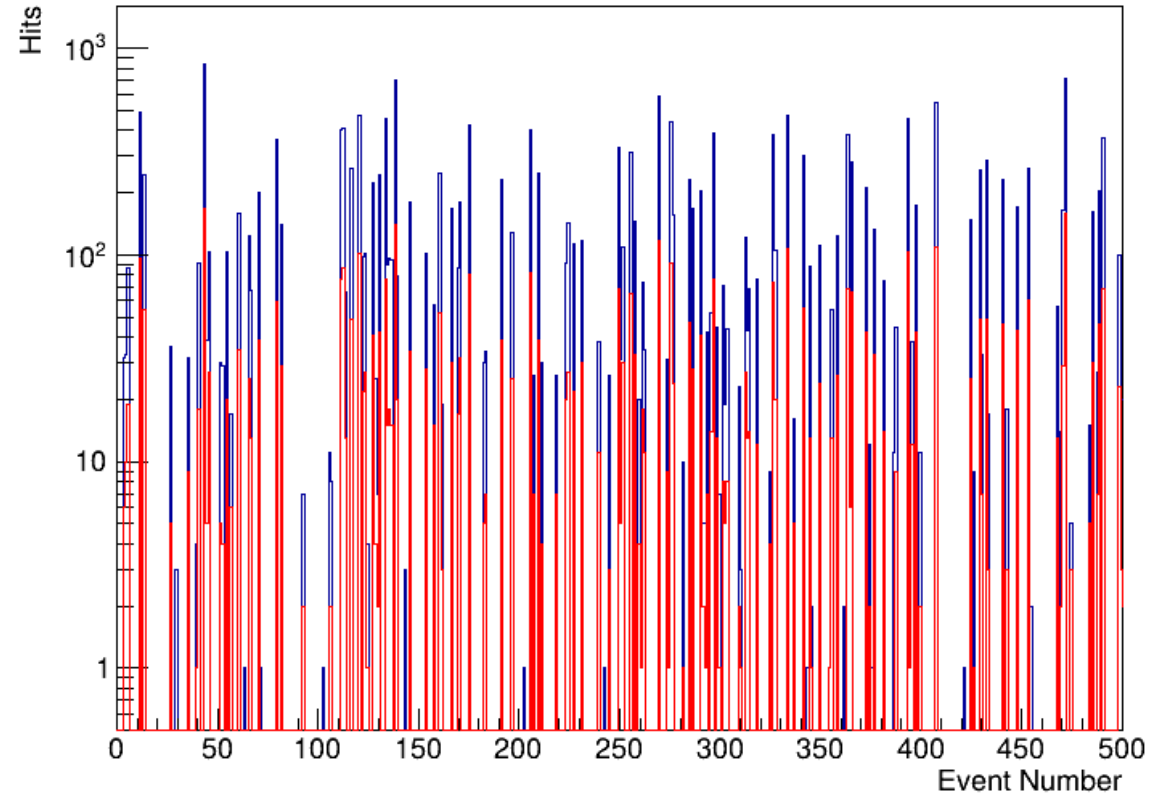


# DIS Q2 100-1000: Event Hit Structure

Number of Hits in Event: Blue = All, Red = QE Cut

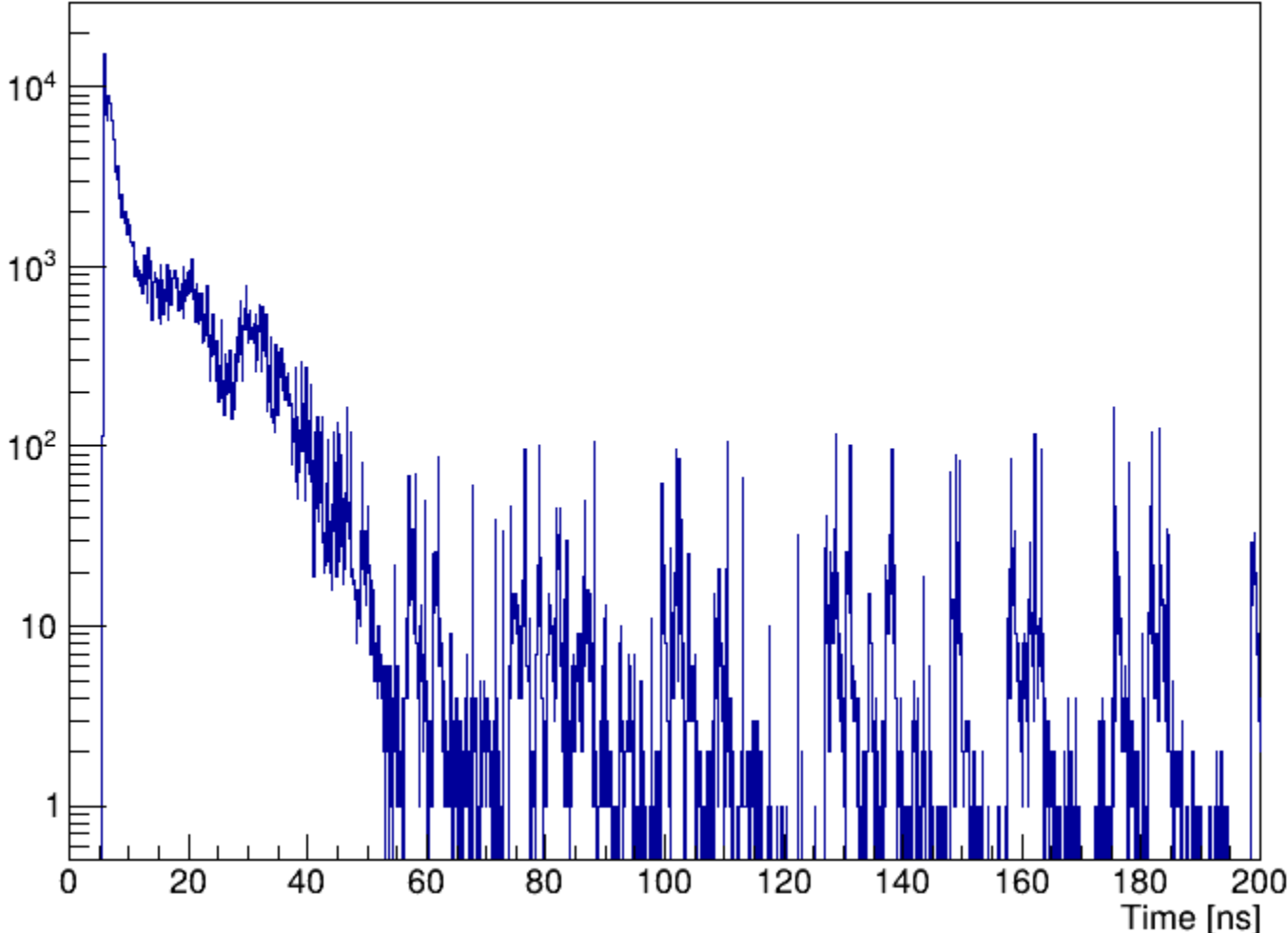


Number of Hits in Each Event: Blue = All, Red = QE Cut



# DIS Q2 100-1000: Hit Times

Time of Hit



# DIS Q2 100-1000: Hit Map After QE Cut

Hit Map after QE Cut

