



EIC TOF study

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EIC Asian group meeting
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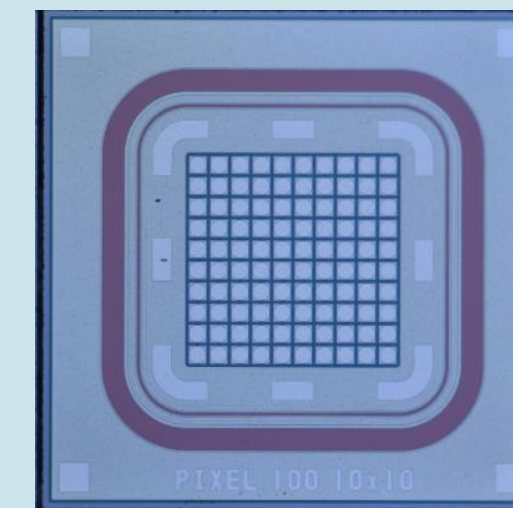
Timing detector in the EPIC collaboration

- The EPIC detector is designed compactly with ~ 1.7 T magnetic field
 - Time-of-Flight (ToF) measurement is the main technique for particle identification (PID)
 - Excellent timing resolution is necessary for PID over a wide p_T and rapidity region
- It is rumored that barrel (hadron end-cap) ToF requires a spatial resolution of 30 μm (30 μm) and a timing resolution of 30 ps (25 ps), which covers 10.9 m^2 (2.22 m^2)
 - Very high spatial resolution is not necessary for EIC due to not high multiplicity environment
- Expected radiation is 10^{10} $n_{\text{eq}}/\text{cm}^2$ at top luminosity $\sim 10^{34}$ $\text{cm}^{-2}\text{s}^{-1}$
 - This is very small compared to HL-LHC environment with $10^{15\sim 16}$ $n_{\text{eq}}/\text{cm}^2$ @ luminosity $\sim 10^{35}$ $\text{cm}^{-2}\text{s}^{-1}$

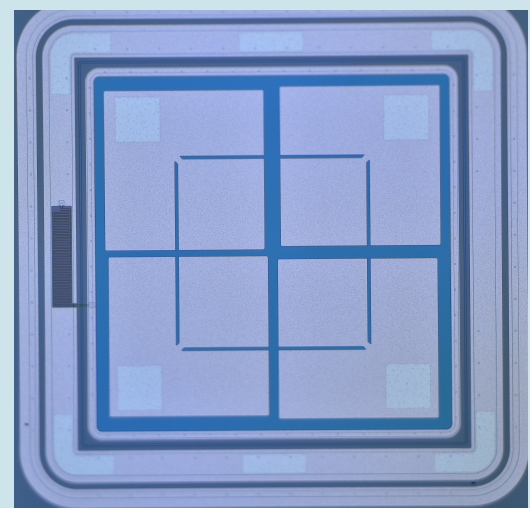
TOF design suitable for EIC

- Proposed TOF at EPIC
 - Barrel type: $R \sim 636$ mm, $-1.4 < \eta < 1.4$
 - Endcap type: $z \sim 1915$ mm, 1925 mm, $1.8 < |\eta| < 3.4$
 - AC-LGAD: ~ 30 ps timing resolution, $30\mu\text{m}$ spacial resolution?
- AC-LGAD development status
 - Developed by BNL and KEK (with HPK) to use at HL-LHC ATLAS
 - Pixel: $40 \times 40 \mu\text{m}^2$ on $1 \times 1 \text{ mm}^2$ chip
 - Pad: $500 \times 500 \mu\text{m}^2$ on $3 \times 3 \text{ mm}^2$ chip
 - Strip: $40 \times 1000 \mu\text{m}^2$ on $3 \times 10 \text{ mm}^2$ chip

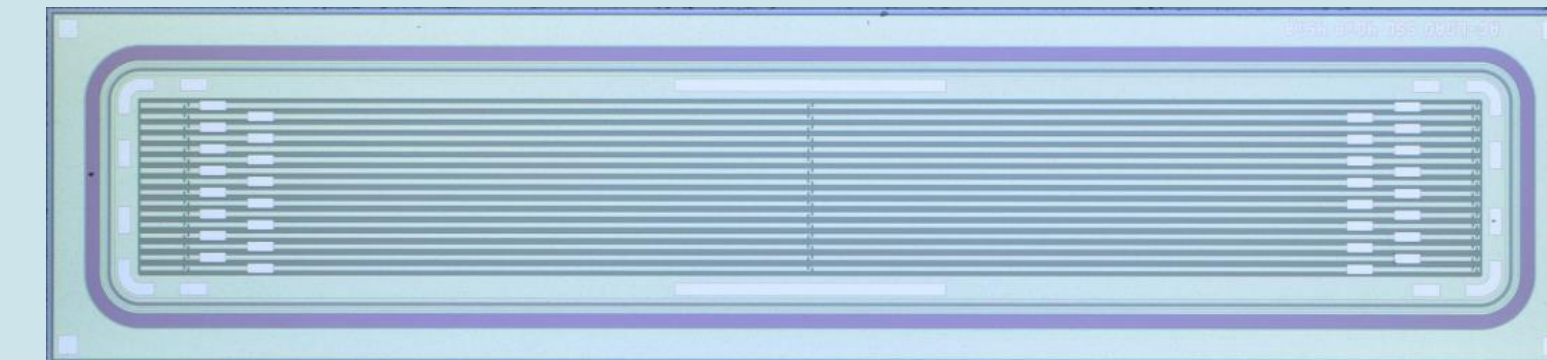
Pixel type



Pad type

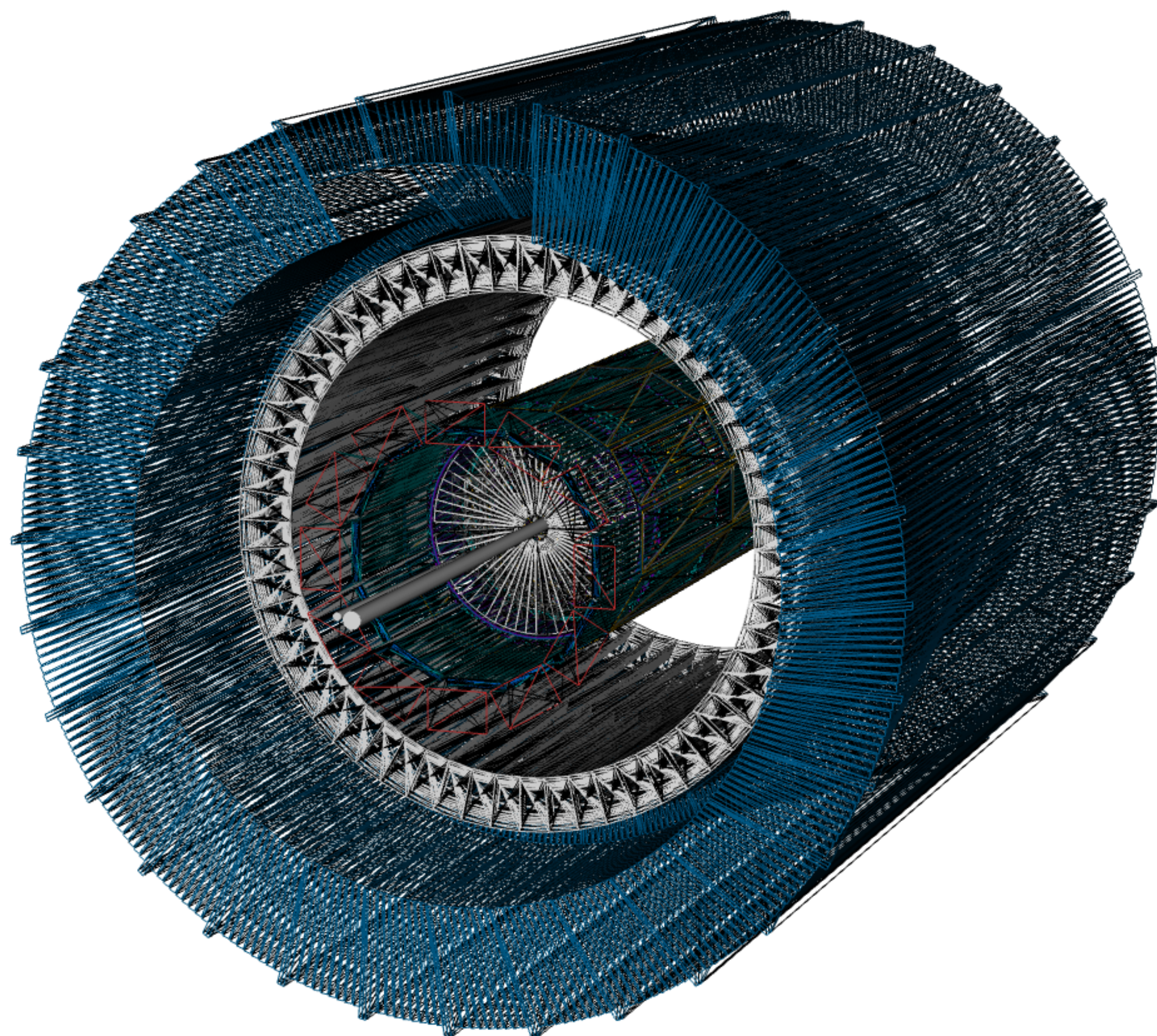


Strip type

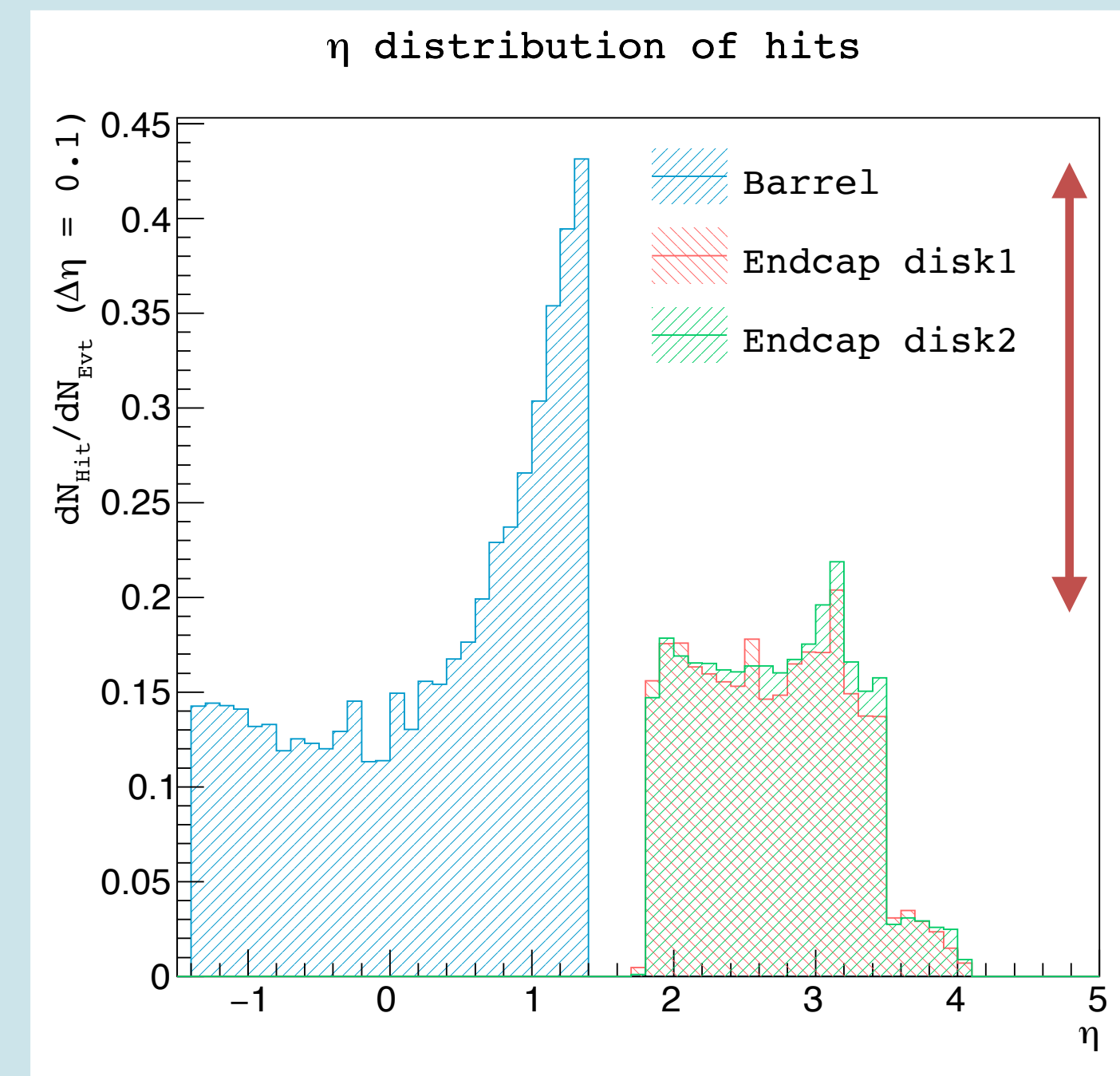
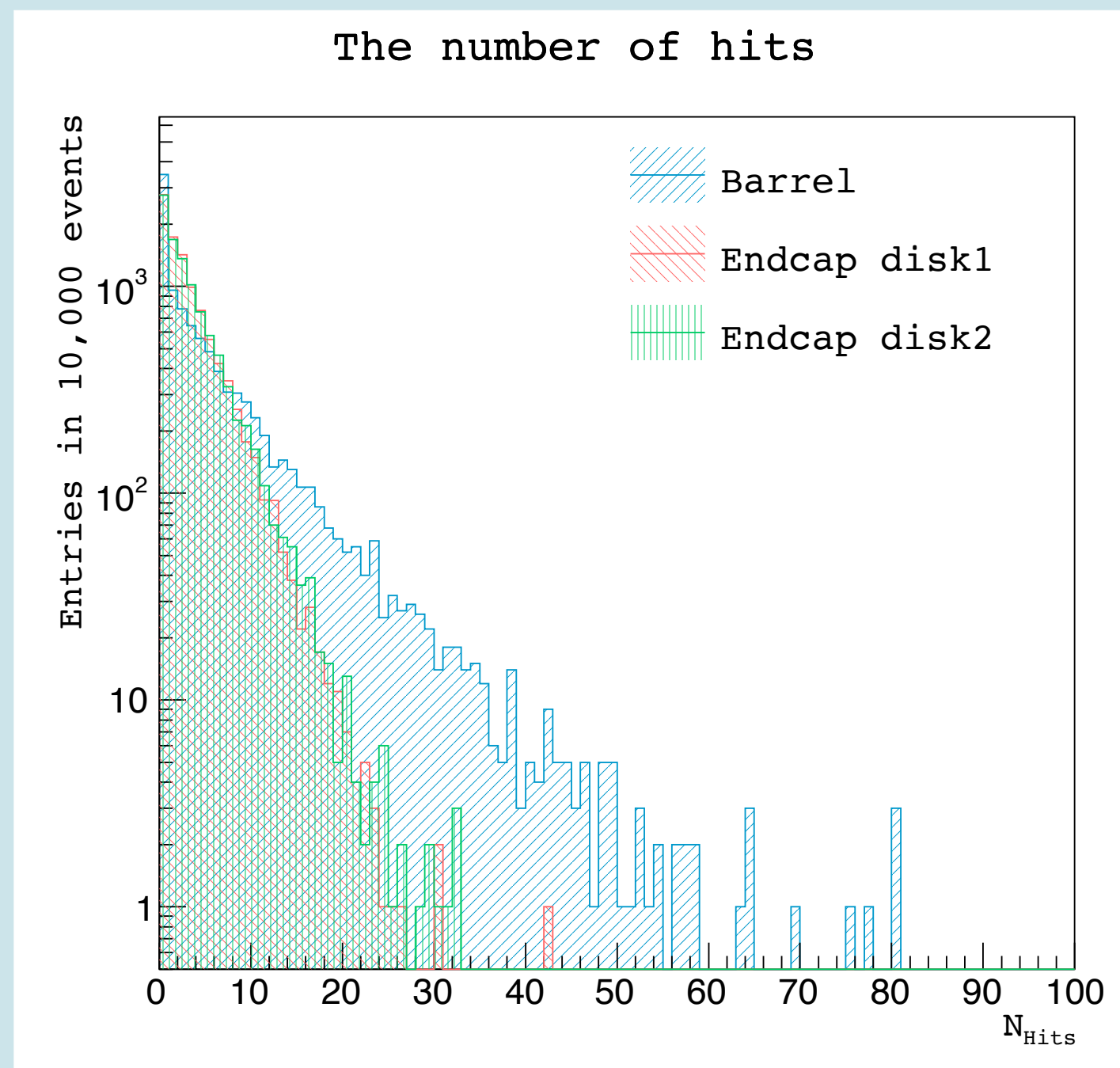


Simulation condition

- Detector response and data reconstruction
 - EPIC detector (based on DD4Hep): <https://github.com/eic/epic>
 - EICRecon: <https://github.com/eic/ElCrecon>
 - Pythia8 NC DIS $Q^2 > 1 \text{ GeV}^2$ in ep (18GeV electron + 275GeV proton beam) collisions (HepMC data archived in S3)
 - 10,000 events
- TOF detector in simulation
 - Sensor segment size of barrel-TOF: 100um x 1cm
 - Sensor segment size of endcap-TOF: 100um x 100um
 - Sensor thickness: 300um



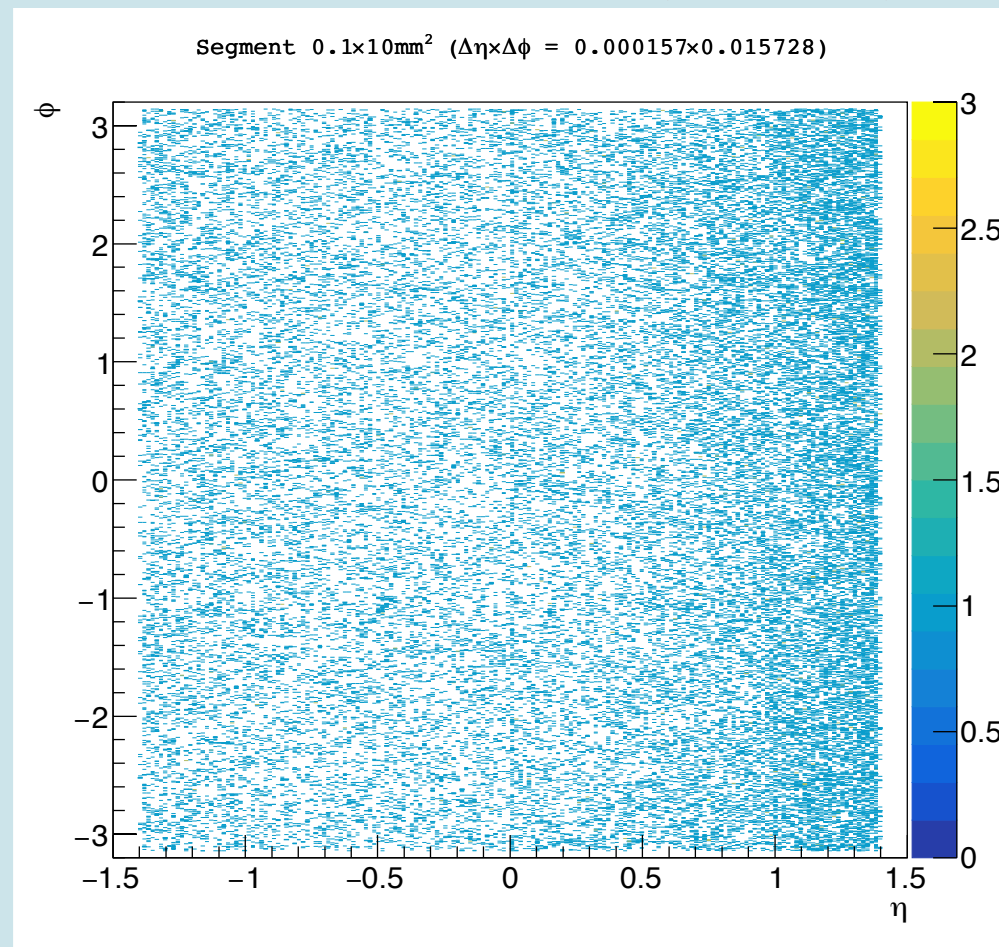
The number of hits of TOF



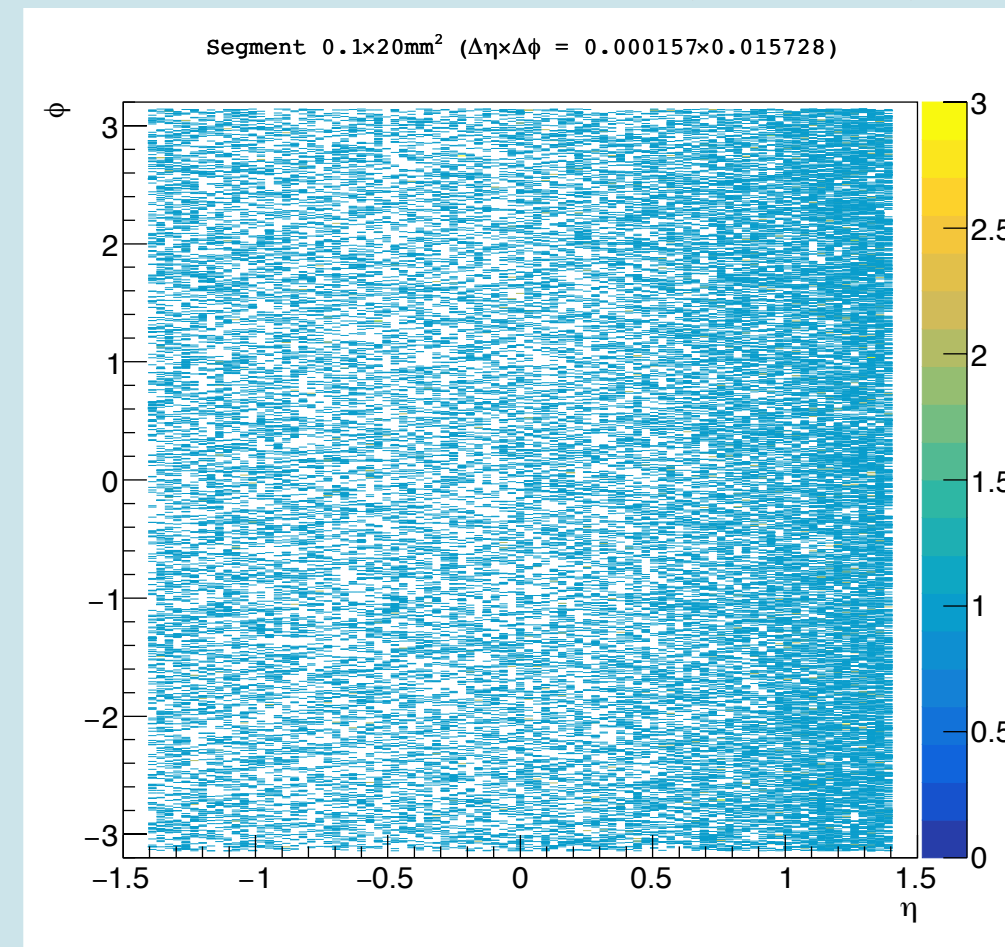
- The number of mean hits per event of barrel-TOF is about 5.2 hits/event, and of endcap-TOF is about 2.8 (3.0) hits/event on disk1 (disk2)
- 35% and 28% of events have no hits on barrel-TOF and endcap-TOF, respectively
- The maximum hit per event achieves ~ 80 on barrel-TOF and ~ 30 on endcap-TOF

Barrel-TOF occupancy

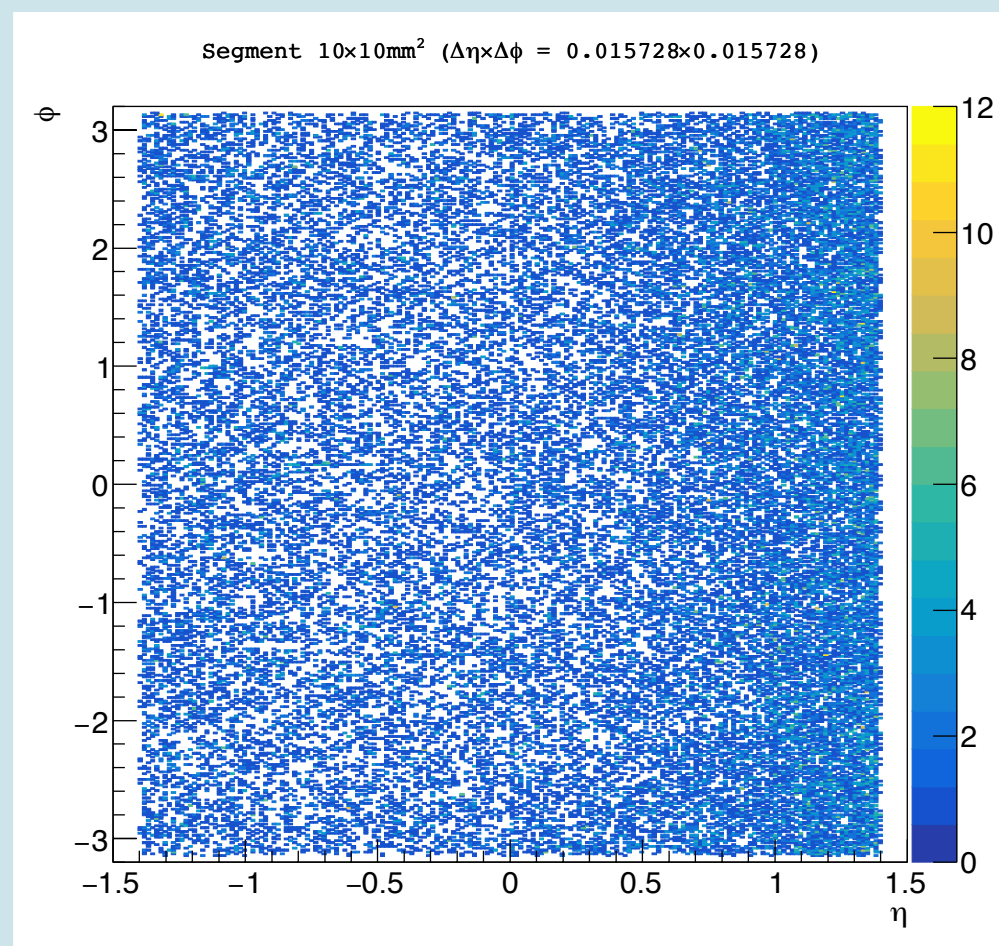
100um x 1cm ($\phi \times \eta$)



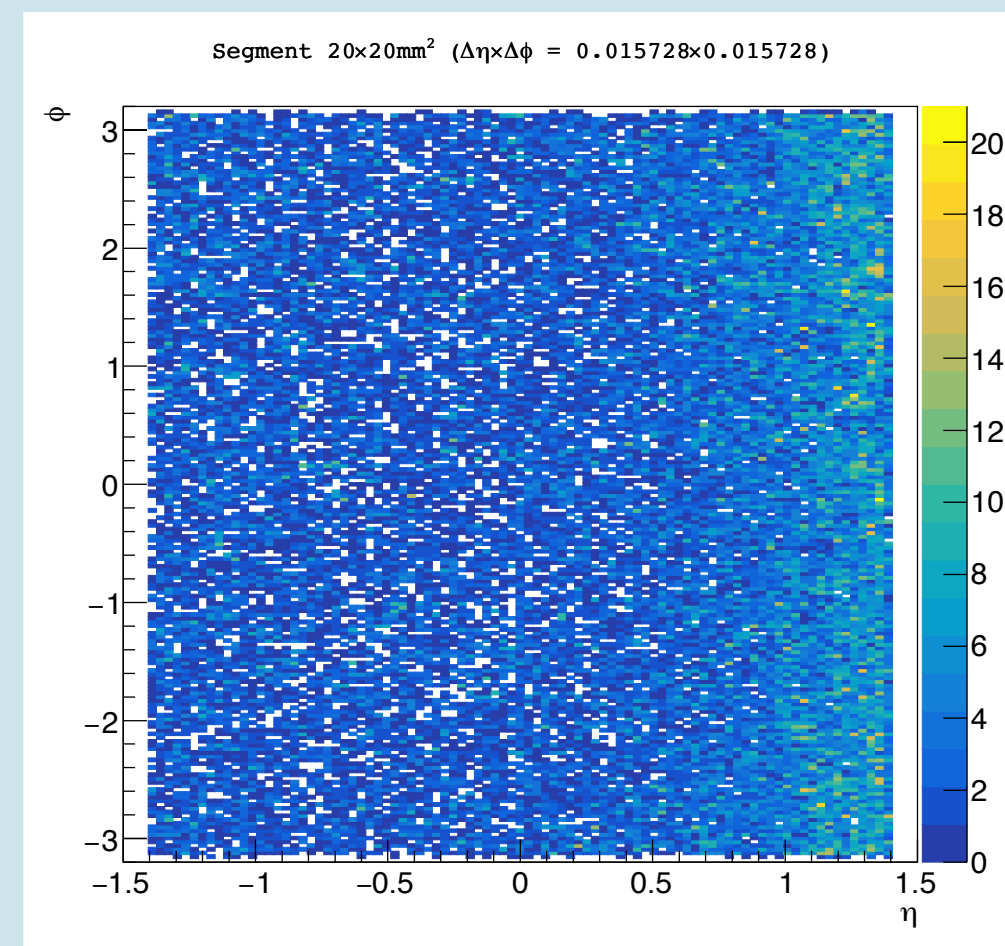
100um x 2cm ($\phi \times \eta$)



1cm x 1cm ($\phi \times \eta$)



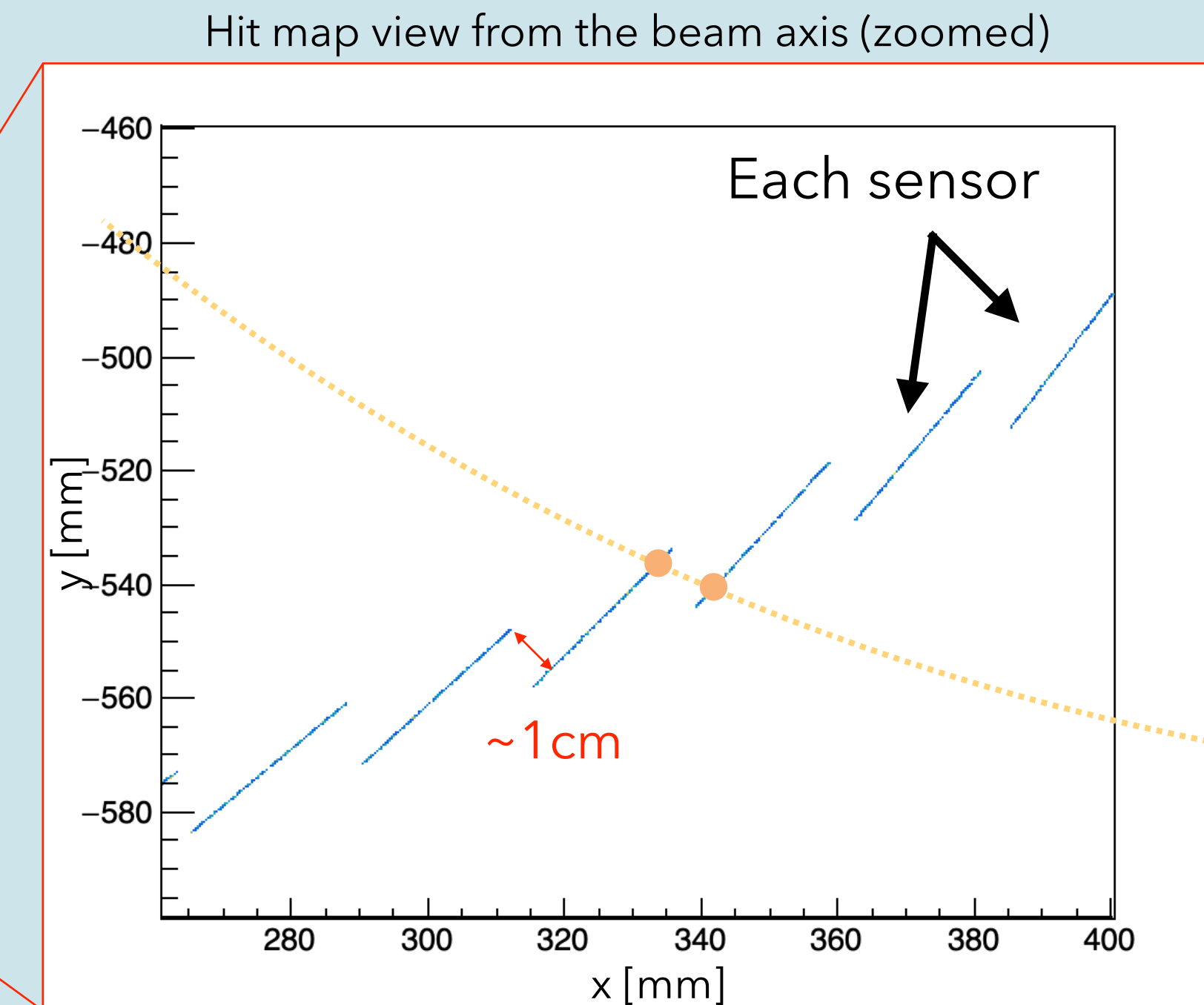
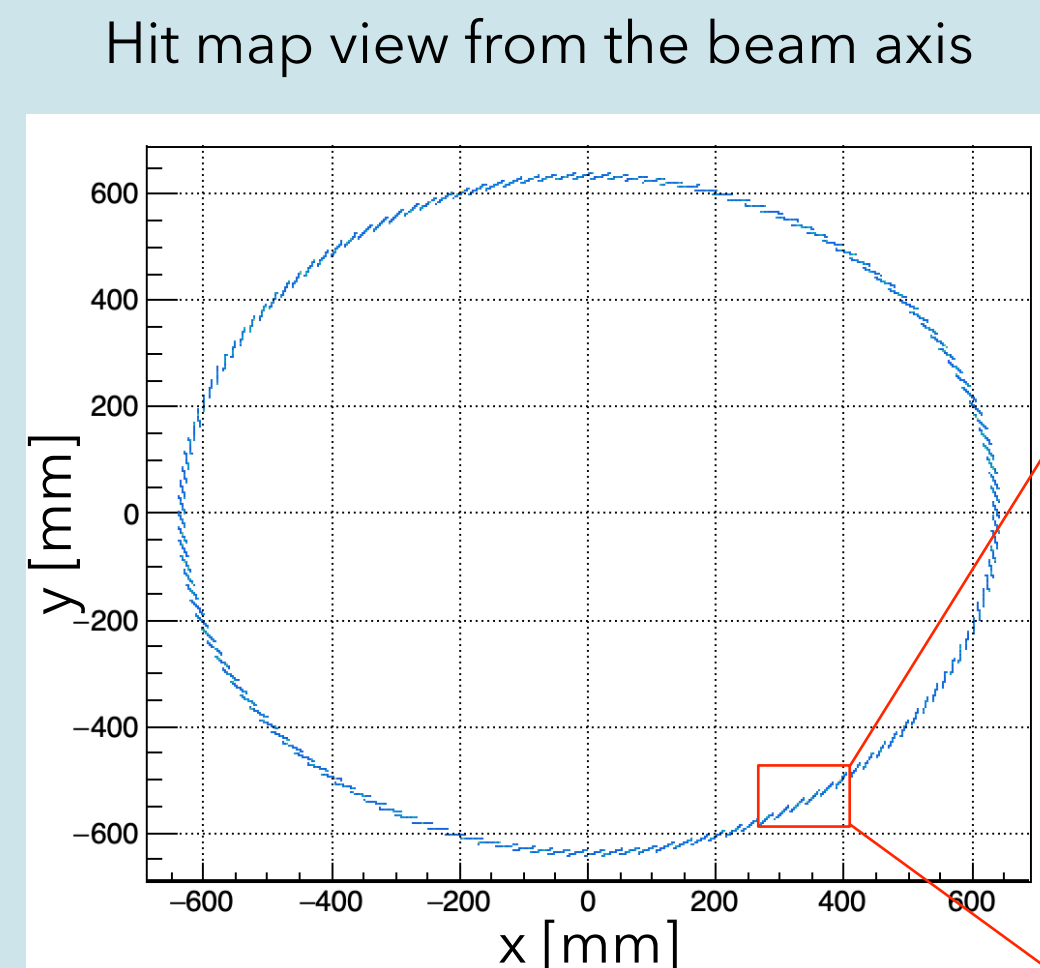
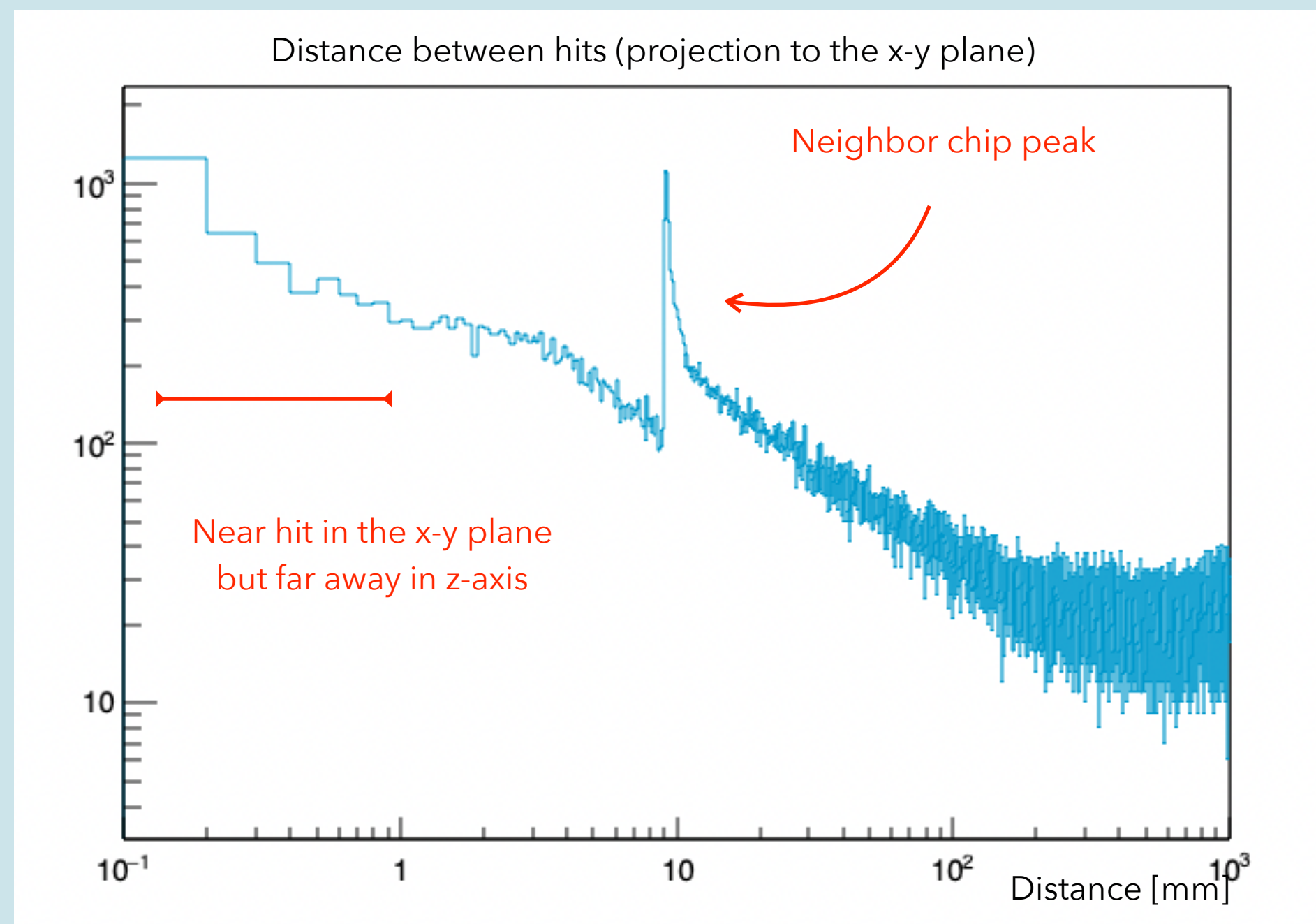
2cm x 2cm ($\phi \times \eta$)



- The maximum multiple-hit segment
 - 100um x 1cm (strip-type) : 3×10^{-4}
 - 100um x 2cm (strip-type) : 3×10^{-4}
 - 1cm x 1cm (pad-type) : 12×10^{-4}
 - 2cm x 2cm (pad-type) : 20×10^{-4}
- The plots are rough approximations
 - Chips are distributed in an arrangement with a certain structure (see next slide)

Barrel-TOF

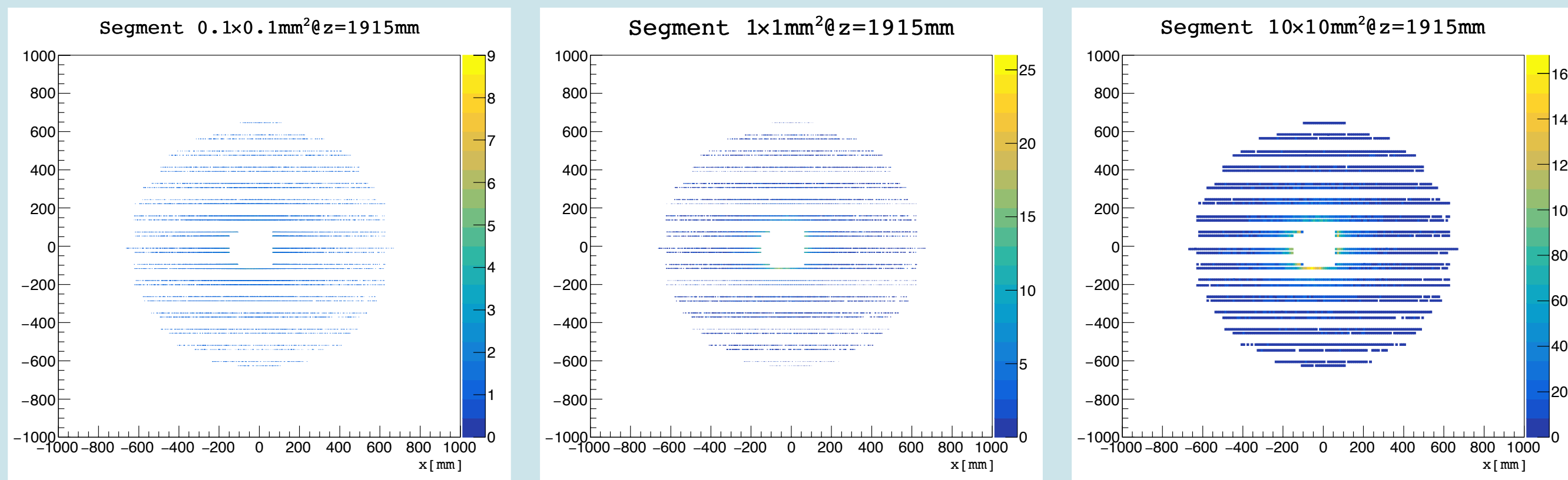
Distance between hits



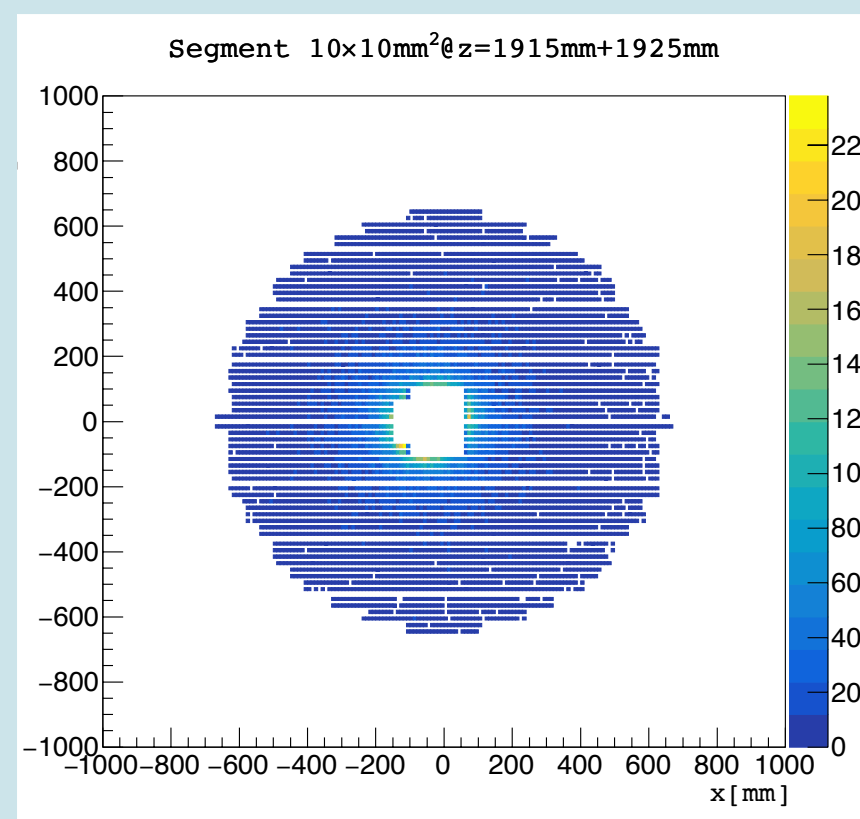
- Some hits are generated by the same particle on a different chip
- The occupancy is possibly lower than one shown on the previous page

Endcap TOF occupancy

Occupancy of Disk1



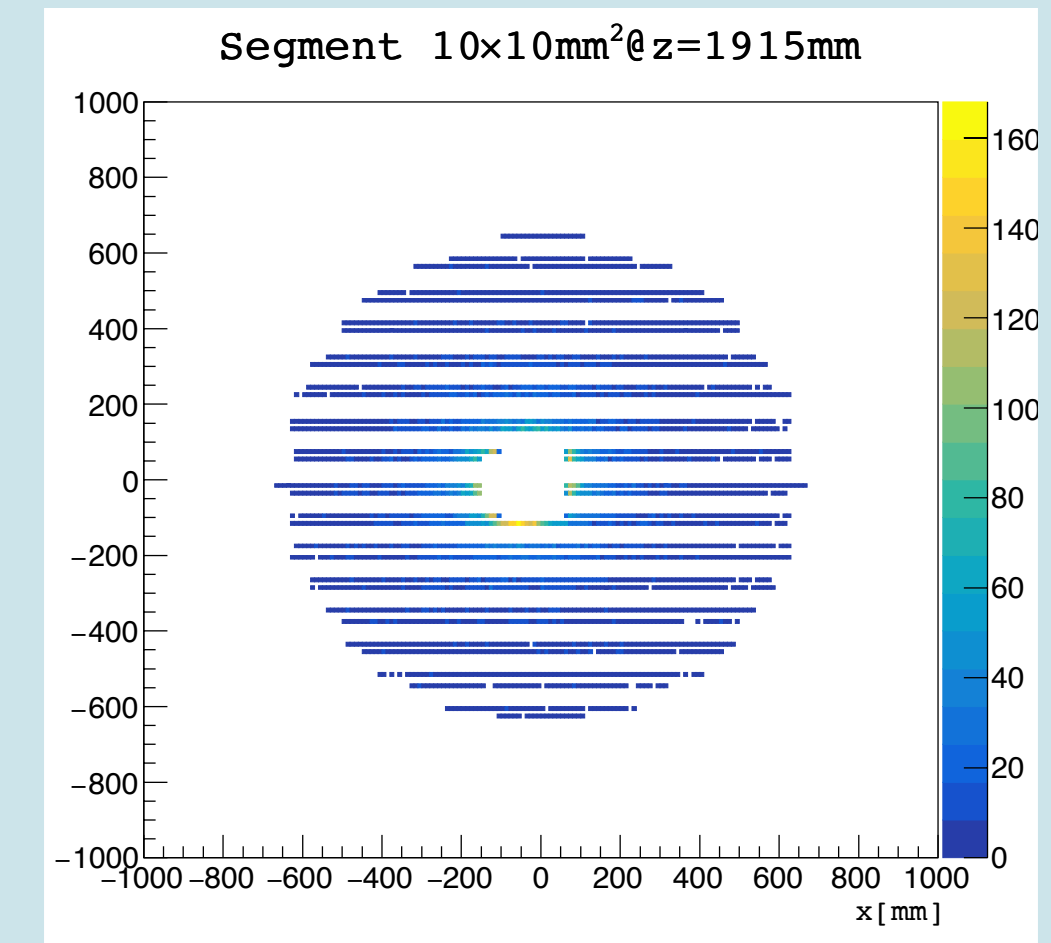
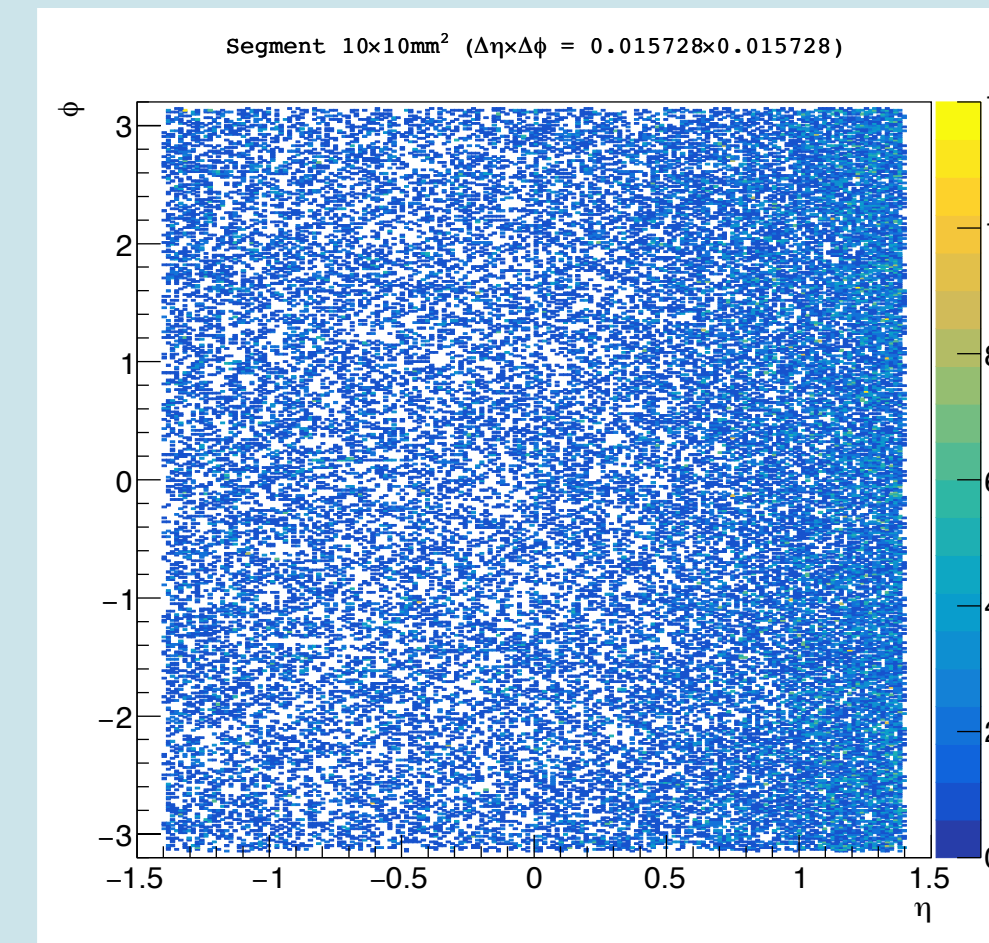
Occupancy of Disk1+ Disk2



- The maximum multiple-hit segment
 - 100um x 100um (pad-type) : 9×10^{-4}
 - 1mm x 1mm (pad-type) : 2.5×10^{-3}
 - 1cm x 1cm (pad-type) : 1.7×10^{-2}
- The plots are reasonable approximations
 - Chips are distributed in a flat plane
- An unexpected gap has been observed
 - This is the cause of the smaller endcap TOF entries (see p.6)

Summary

- Barrel and endcap TOF performance study has started
- In NC DIS $Q^2 > 1 \text{ GeV}^2$ in ep collisions
 - The number of hits on Barrel (Endcap) TOF per event is ~ 5 (~ 3)
 - 35% (28%) of events have no hit on Barrel TOF (End-ap TOF)
 - The number of maximum hits is ~ 80 (~ 30) on Barrel TOF (Endcap TOF each disk)
- Occupancy of Barrel TOF (the first approximation)
 - 100um x 1cm (strip-type) : 3×10^{-4}
 - 100um x 2cm (strip-type) : 3×10^{-4}
 - 1cm x 1cm (pad-type) : 12×10^{-4}
 - 2cm x 2cm (pad-type) : 20×10^{-4}
- Occupancy of Endcap TOF (the first approximation)
 - $0.1 \times 0.1 \text{ mm}^2$: $\sim 9 \times 10^{-4}$
 - $1 \times 1 \text{ mm}^2$: $\sim 2.5 \times 10^{-3}$
 - $10 \times 10 \text{ mm}^2$: $\sim 1.6 \times 10^{-2}$



The segment size of a few cm^2 is good enough for the barrel-TOF ($30 \times 30 \text{ um}^2$ is overqualified)

The endcap TOF is necessary to check the rapidity dependence