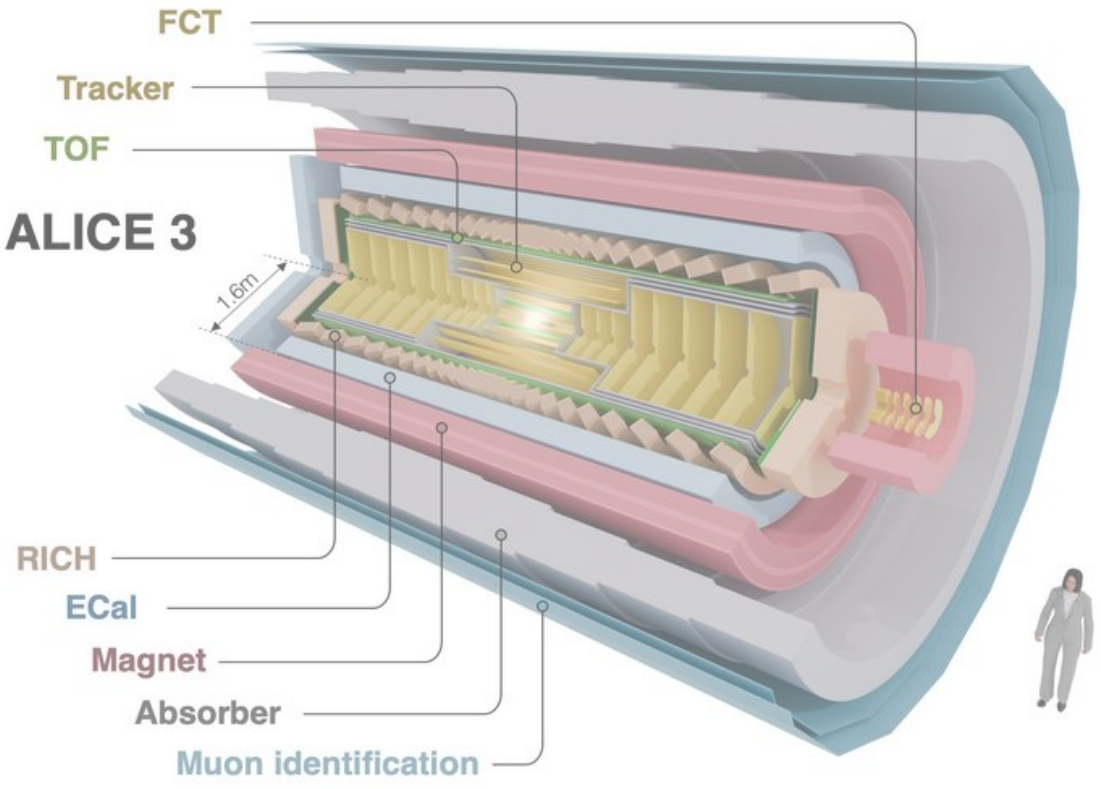
# TOF simulations

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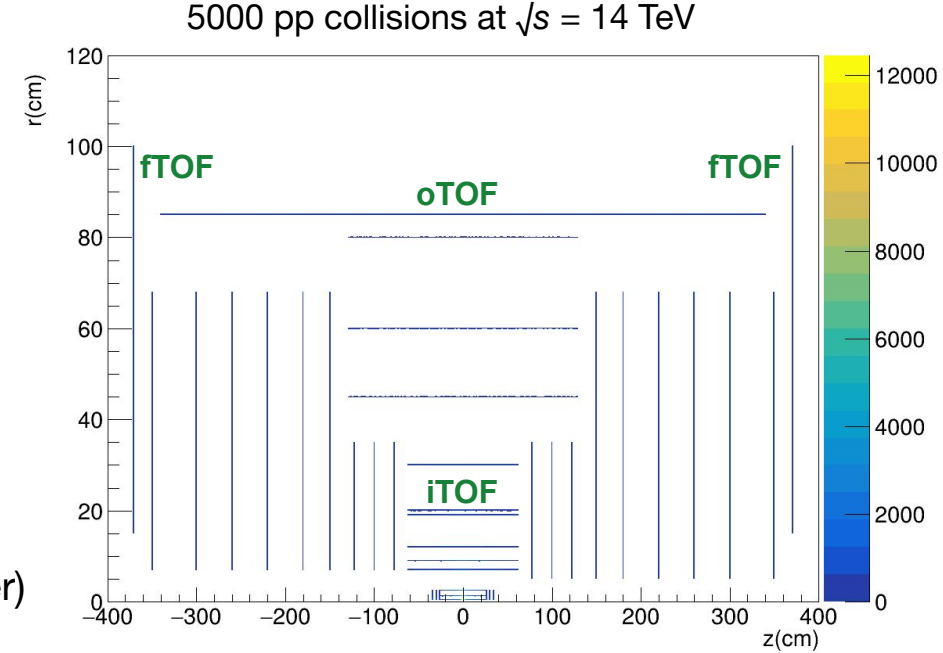
ALICE-ePIC meeting

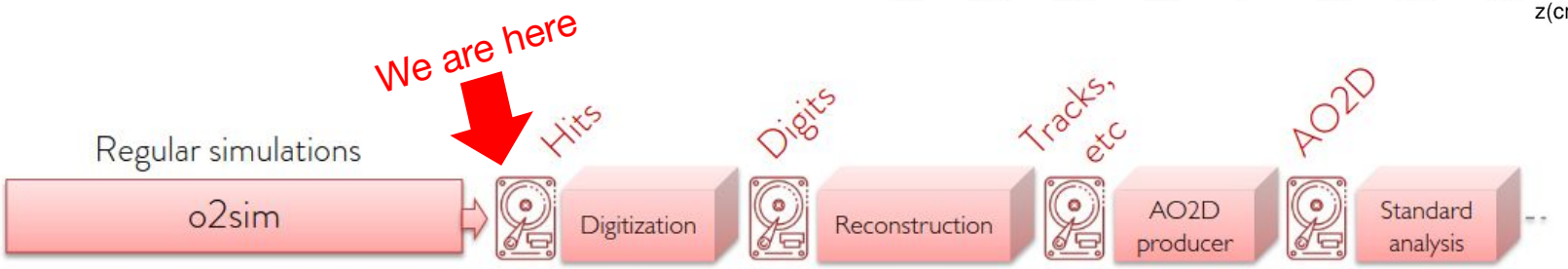
28/05/2025

# Full simulation status

- **Full O2 simulation** including TOF layers
- Physics events are generated with the **PYTHIA8** Monte Carlo event generator
- Standard particle **transport** engine Geant4
- Response from sensitive TOF layers (**hits**)
- Simulating all volumes in the ALICE 3 configuration

Current TOF geometry: simulated as a continuous cylinder of sensitive volume (thickness 2% *X*0/layer)



# Occupancy studies: hit rate

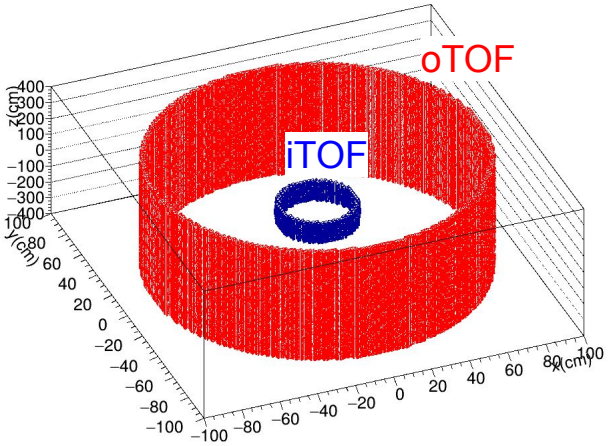
Simulated 5000 pp collisions at 14 TeV
Pythia8+Geant4 B = 2T,  IR = 24 MHz

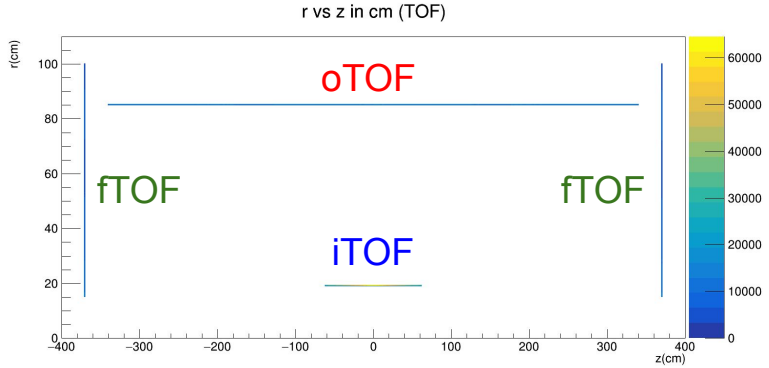
$$\text{Hit rate} = \frac{\text{Hits per event}}{\text{A}} \cdot \text{IR}$$

⟨Hit rate (iTOF)⟩ = **90** kHz/cm$^2$

⟨Hit rate (oTOF)⟩= **6.5** kHz/cm$^2$

⟨Hit rate (fTOF)⟩= **31** kHz/cm$^2$




$$\text{A}_{iTOF} = 2\pi rh = 2\pi \cdot 19 \text{ cm} \cdot 62 \text{ cm} = 14800 \text{ cm}^2 \sim 1.5 \text{ m}^2$$

$$\text{A}_{oTOF} = 2\pi rh = 2\pi \cdot 85 \text{ cm} \cdot 340 \text{ cm} = 363168 \text{ cm}^2 \sim 36 \text{ m}^2$$

$$\text{A}_{fTOF} = 2 \cdot \pi(R^2 - r^2) = 2\pi((100 \text{ cm})^2 - (15 \text{ cm})^2) = 61418 \text{ cm}^2 \sim 6 \text{ m}^2$$

# Occupancy studies: inner/outer TOF

Simulated 5000 pp collisions at 14 TeV
Pythia8+Geant4 B = 2T,  IR = 24 MHz

$$\text{Hit rate} = \frac{\text{Hits per event}}{\text{A}} \cdot \text{IR}$$

⟨Hit rate (iTOF)⟩ = **90** kHz/cm$^2$

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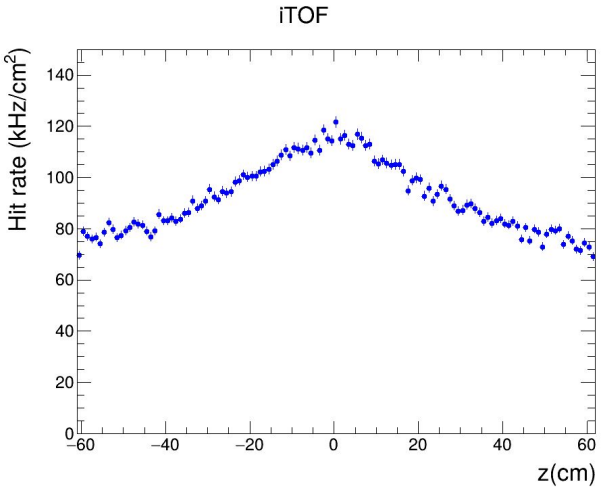
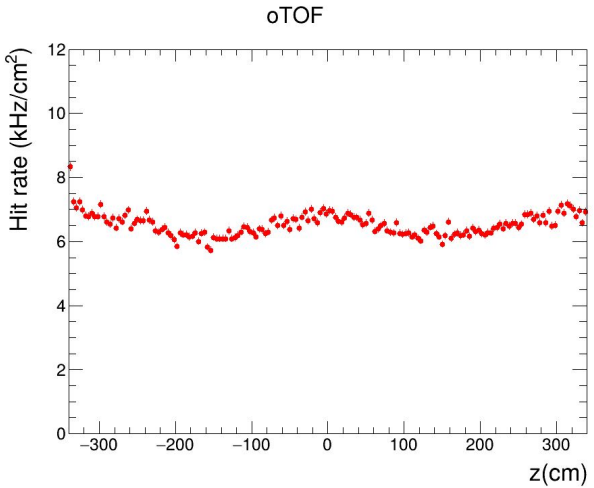


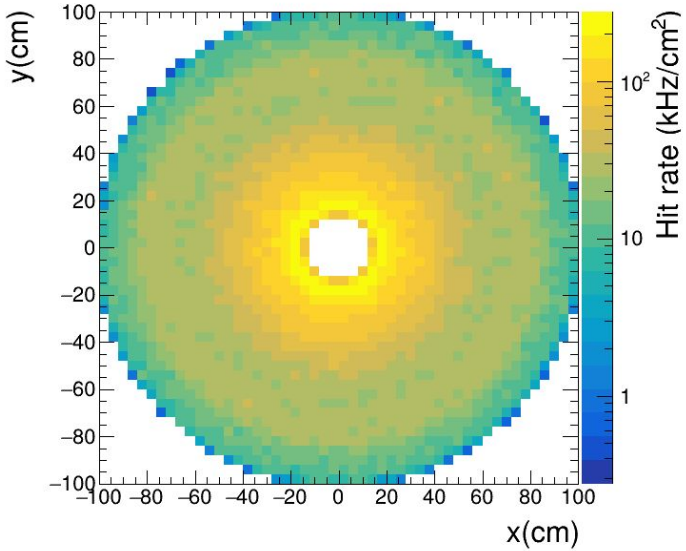



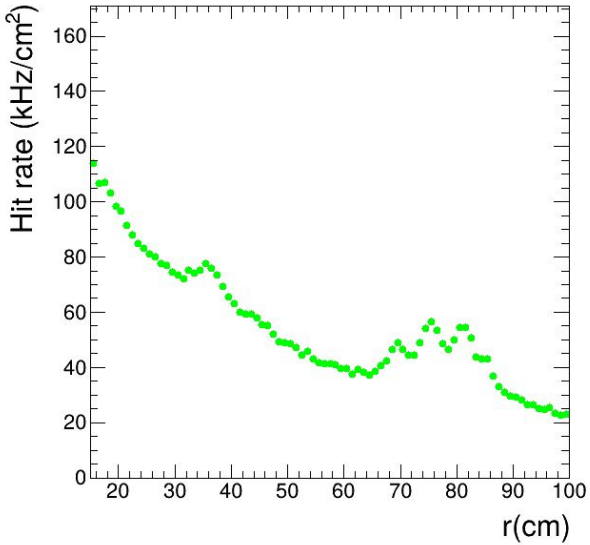
# Occupancy studies: forward TOF

Simulated 5000 pp collisions at 14 TeV
Pythia8+Geant4 B = 2T,  IR = 24 MHz

$$\text{Hit rate} = \frac{\text{Hits per event}}{\text{A}} \cdot \text{IR}$$

⟨Hit rate (fTOF)⟩= **31** kHz/cm$^2$



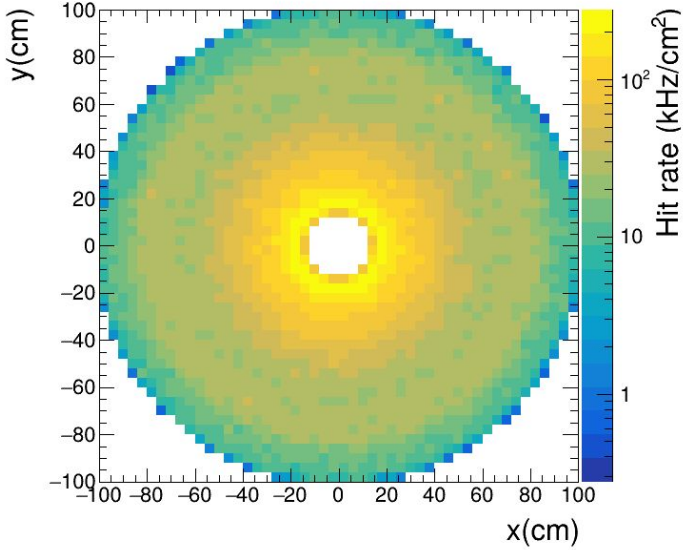



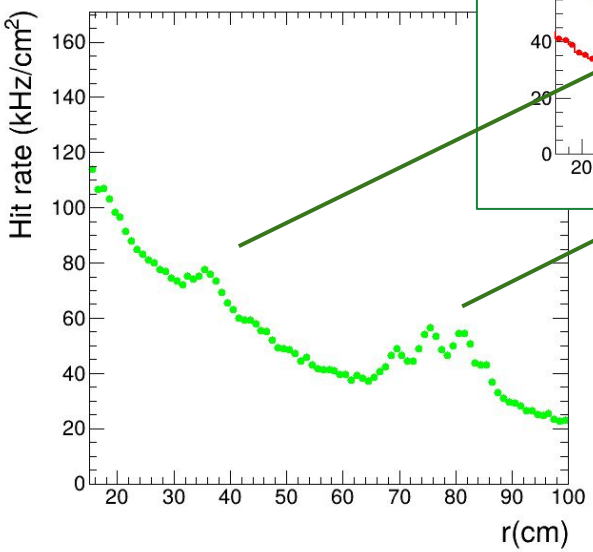
# Occupancy studies: forward TOF

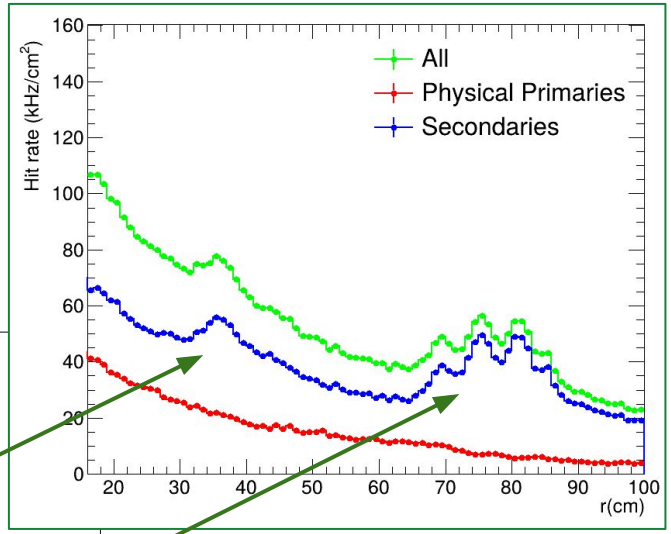
Simulated 5000 pp collisions at 14 TeV

Pythia8+Geant4 B = 2T,  IR = 24 MHz

⟨Hit rate (fTOF)⟩= **31** kHz/cm$^2$



# Matching studies

All simulated volumes

Definition of **findable** track:

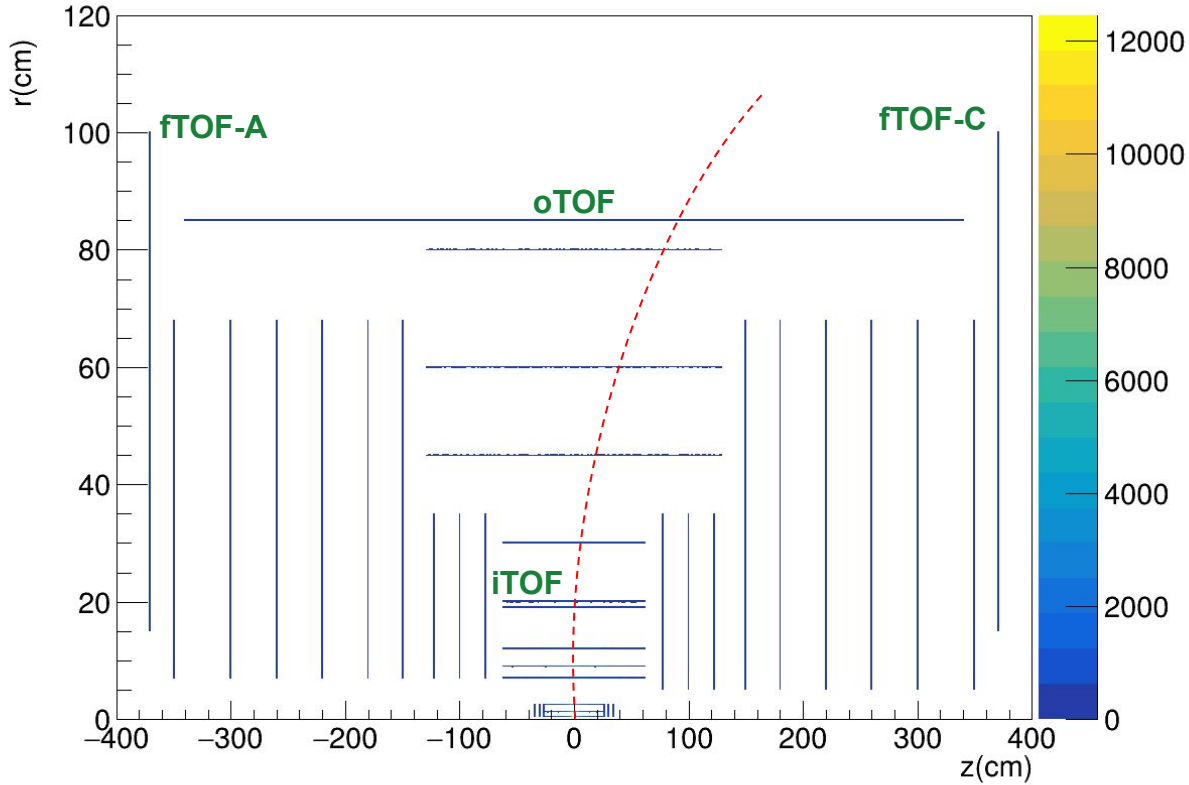
- specific trackID
- >= **7** Inner Tracker layers

$$\text{Efficiency} = \frac{N_{\text{findable}}^{\text{hitTOF}}}{N_{\text{findable}}}$$

No reconstruction/fitting

→ only “findable” MC tracks

**NB:** This is *not* a matching efficiency → missing matching algorithm between track extrapolation and TOF hits



# Matching studies: iTOF

5000 pp collisions at $\sqrt{s}$ = 14 TeV

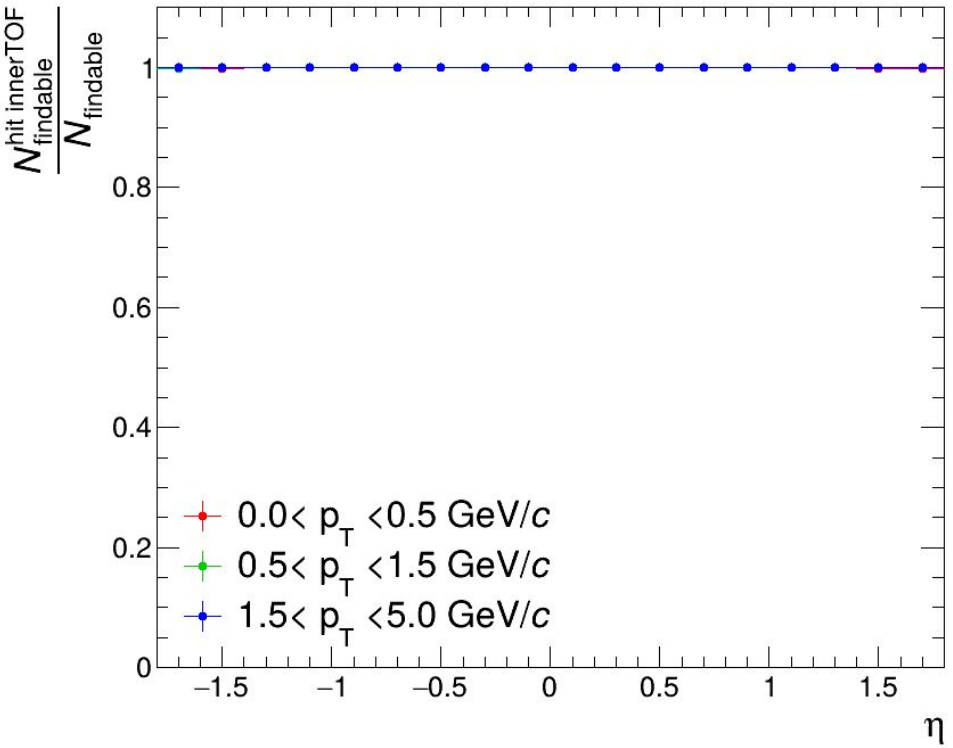
All simulated volumes

Definition of **findable** track:

- specific trackID
- >= **7** Inner Tracker layers

$$\text{Efficiency} = \frac{N_{\text{findable}}^{\text{hitTOF}}}{N_{\text{findable}}}$$

In this configuration all findable tracks have a hit in the inner TOF



# Matching studies: oTOF

5000 pp collisions at $\sqrt{s}$ = 14 TeV

All simulated volumes

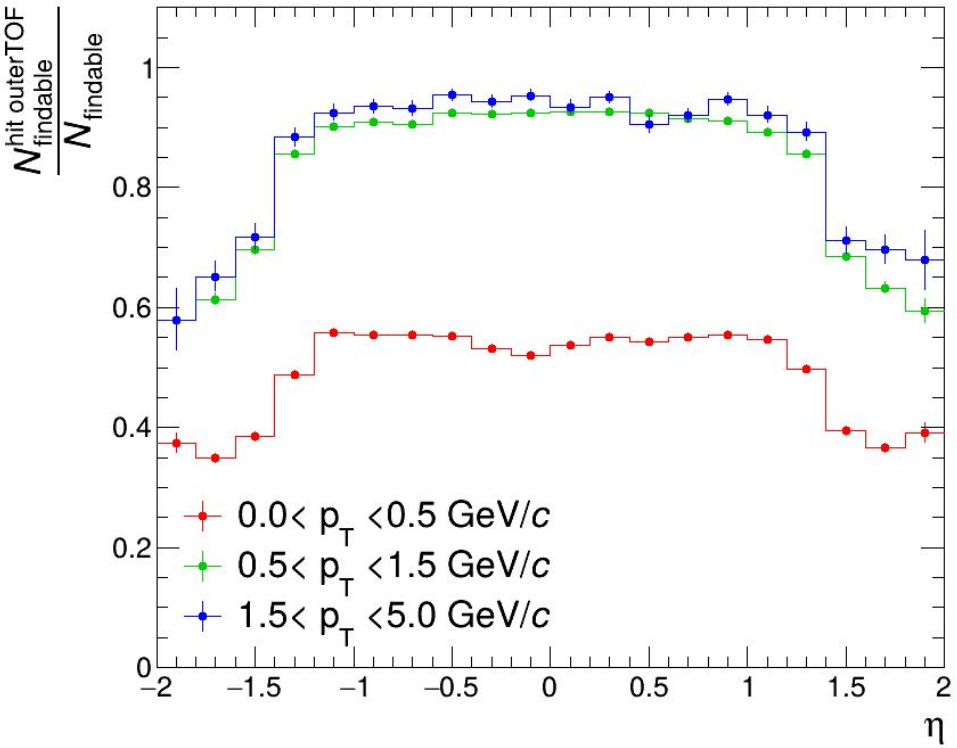
Definition of **findable** track:

- specific trackID
- >= **7** Inner Tracker layers

$$\text{Efficiency} = \frac{N_{\text{findable}}^{\text{hitTOF}}}{N_{\text{findable}}}$$

Outer TOF → flat efficiency for $|\eta| < 1$ → ~5% inefficiency at high $p_T$ (see next slide)

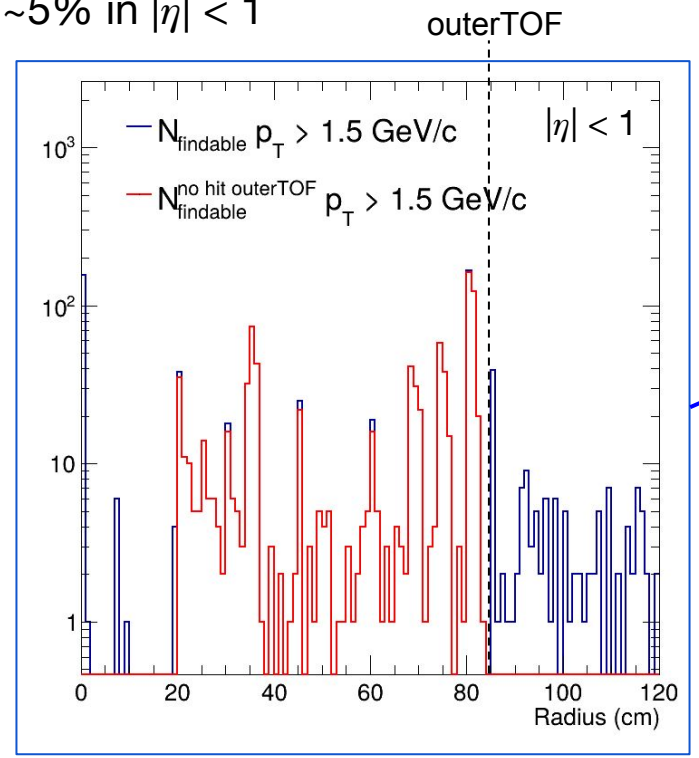
For $|\eta| > 1$ loss of efficiency after including all volumes and services in the simulation

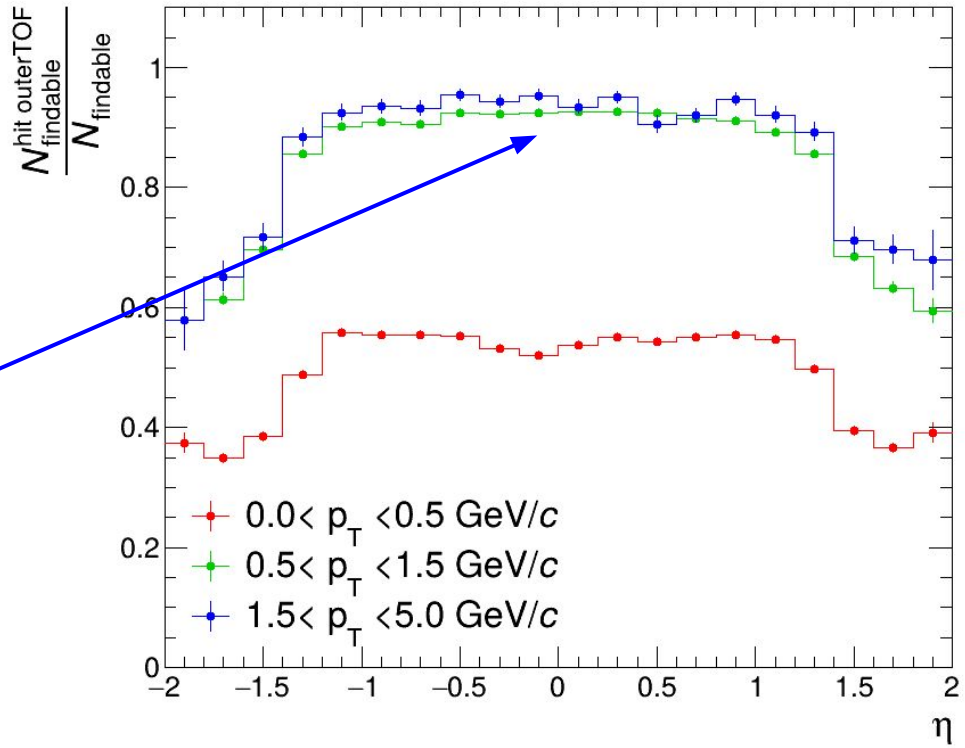


# Matching studies: oTOF

5000 pp collisions at $\sqrt{s}$ = 14 TeV

~5% in $|\eta| < 1$



# Matching studies: oTOF

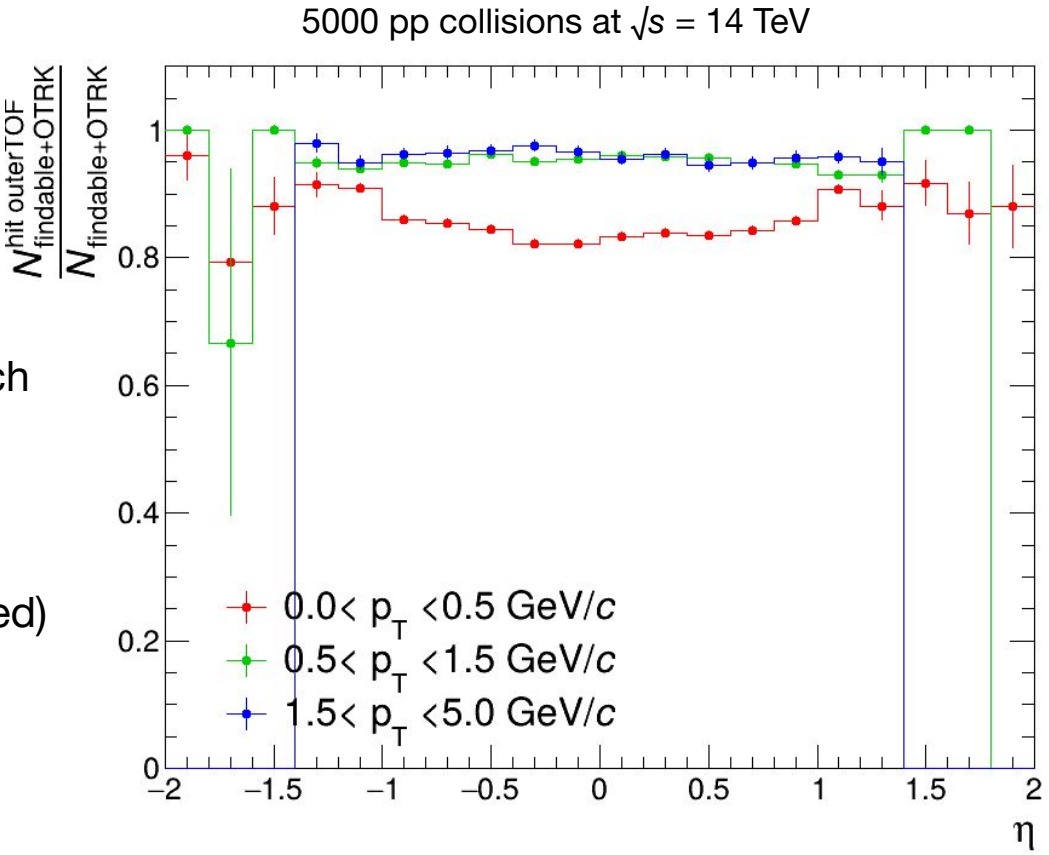
All simulated volumes

Definition of **findable** track:

- specific trackID
- >= **7** Inner Tracker layers

The track in this case is required to match the outer tracker layer R~80 cm

Asking a hit in the last layer of the outer tracker reduces the acceptance (expected) but overall increases the efficiency



# Matching studies

All simulated volumes

Definition of **findable** track:

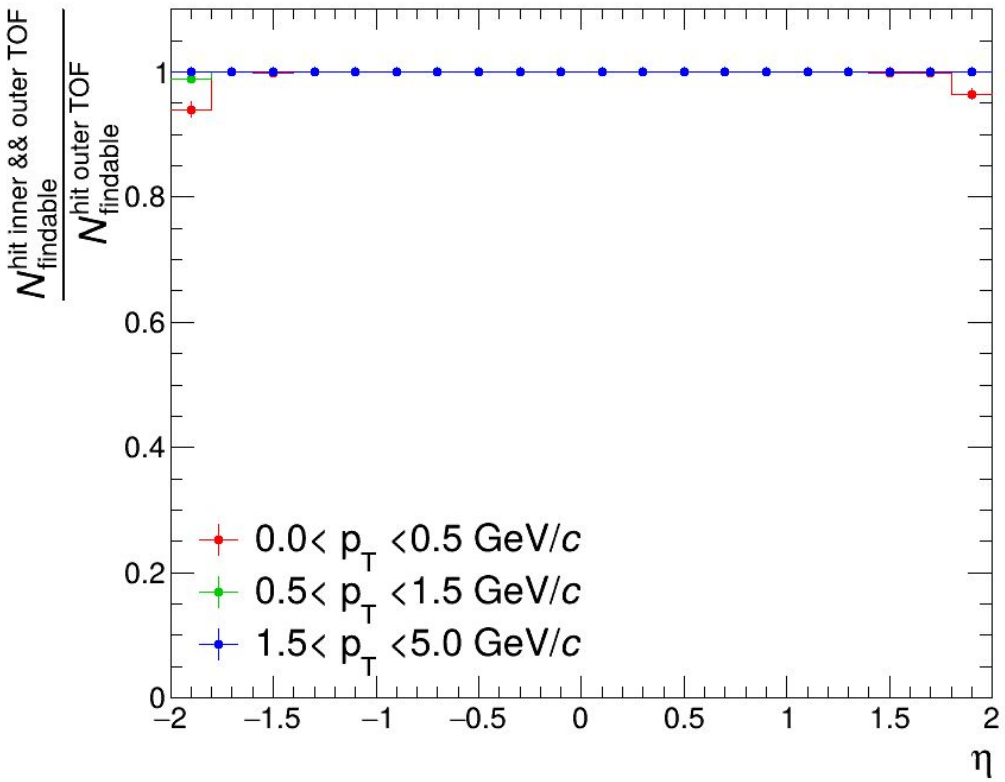
- specific trackID
- >= **7** Inner Tracker layers

Fraction of findable tracks which have hits in both inner and outer TOF

→ ~100%

$$\frac{N^{\text{hit inner \&\& outer TOF}}_{\text{findable}}}{N^{\text{hit outer TOF}}_{\text{findable}}}$$

5000 pp collisions at $\sqrt{s}$ = 14 TeV



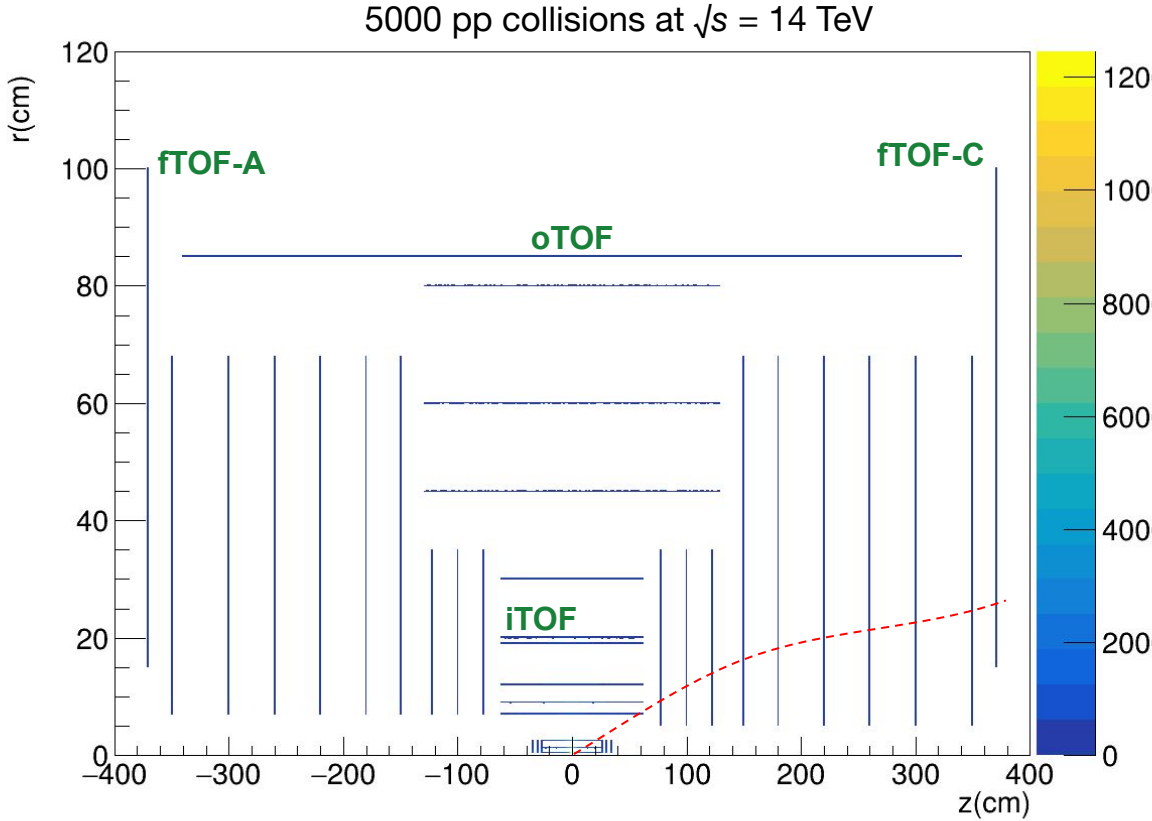
# Matching studies: fTOF

All simulated volumes

Definition of **forward findable** track:

- specific trackID
- >= **6** Forward Tracker layers only C side!

$$\frac{N^{\text{hit forward TOF}}_{\text{forward findable}}}{N_{\text{forward findable}}}$$



# Matching studies: fTOF

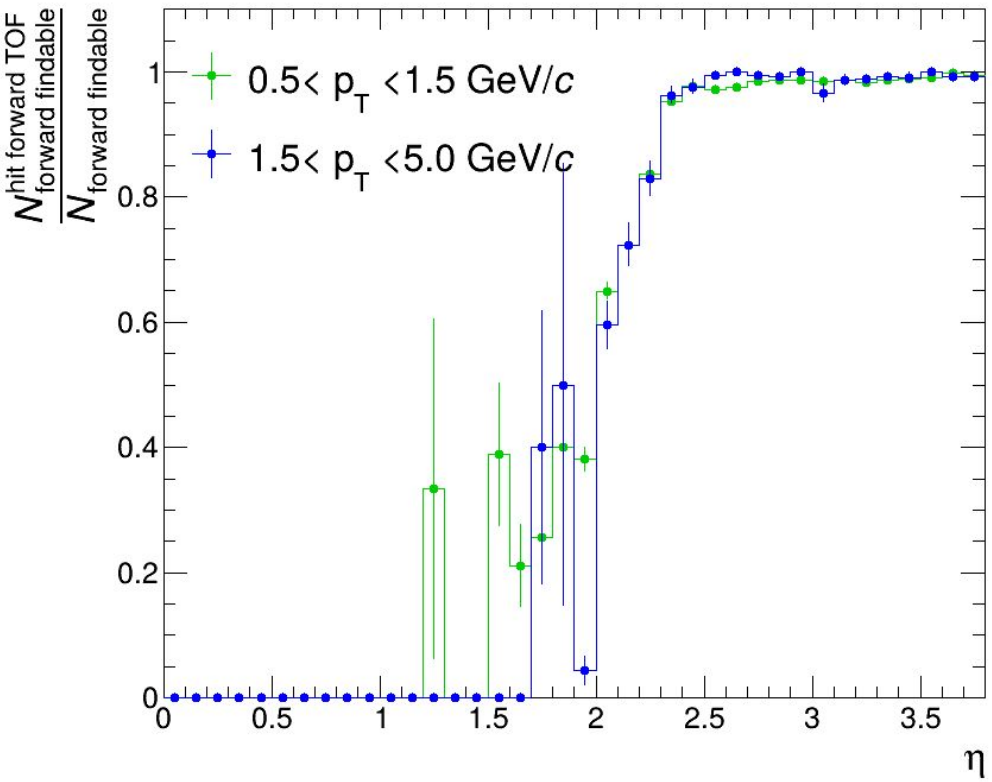
All simulated volumes

Definition of **forward findable** track:

- specific trackID
- >= **6** Forward Tracker layers only C side!

$$\frac{N^{\text{hit forward TOF}}_{\text{forward findable}}}{N_{\text{forward findable}}}$$

5000 pp collisions at $\sqrt{s}$ = 14 TeV



# Studies with fast simulation

- **Complementary** to full simulation
- **Look-up Tables** (LUTs) to produce smeared Tracks from MCParticles
- ALICE 3 parametric **TOF PID** already in place, possibility to use different resolutions (see talk from Jesper)


Credits to M. Concas and D. Chinellato presentation at ALICE3 Days

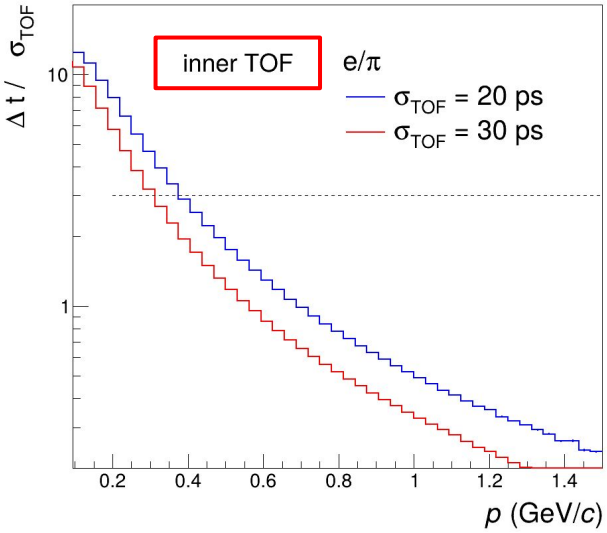
# Separation vs p

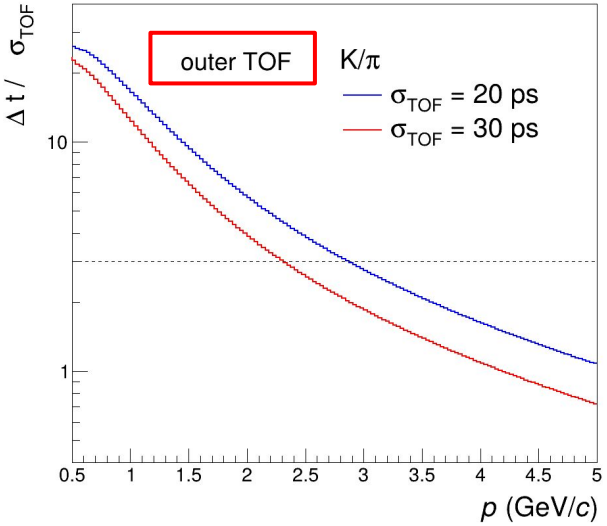
Test the **separation power** with different TOF resolutions

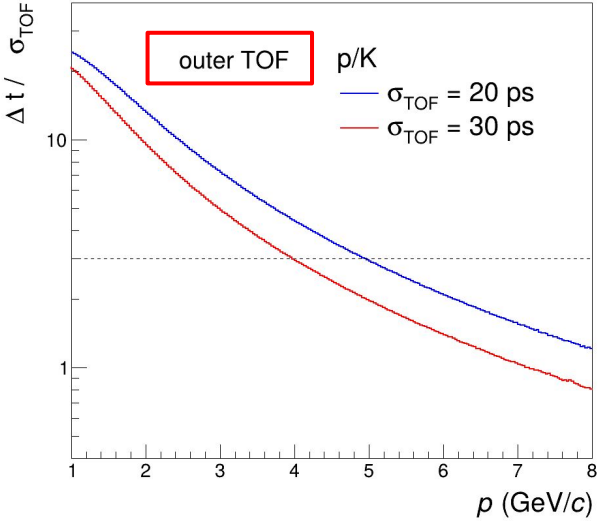
Simulates the TOF resolution with a **gaussian smearing** of (20/30 ps) and adds the contribution from tracking

Contribution from the event time currently not included yet (expected ~ 3 ps)

$$\begin{cases} TOF = t_{TOF} - t_{event} - t_{\exp_i} \\ \sigma^2_{TOF} = \sigma^2_{t_{TOF}} + \sigma^2_{trk} + \sigma^2_{event} \end{cases}$$



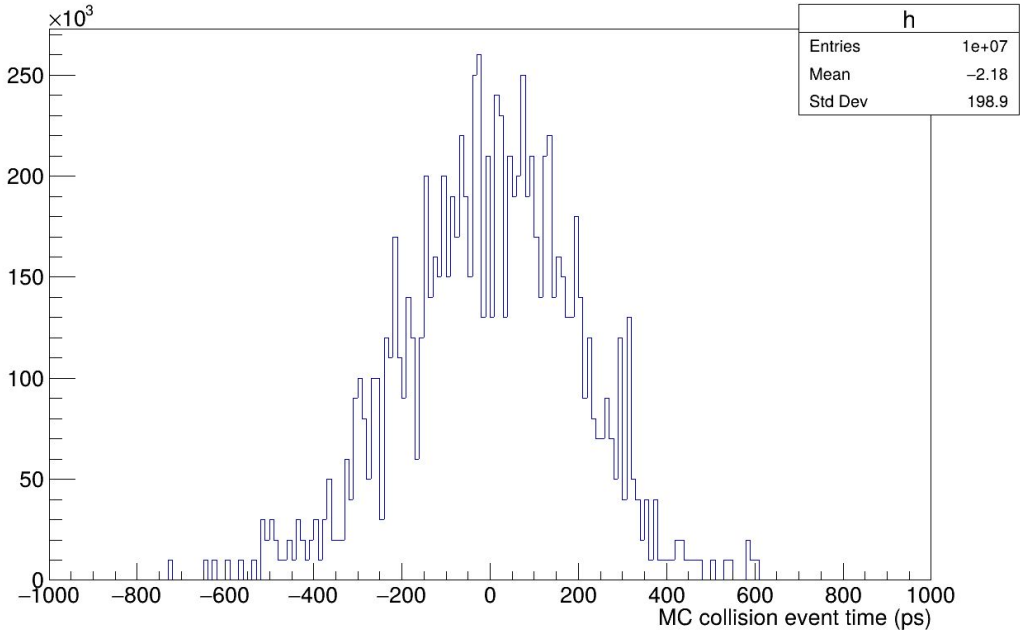



# Implementing the event time in OTF

Now included in the on the fly simulations (OTF)

$$\begin{cases} TOF = t_{TOF} - t_{event} - t_{\exp_i} \\ \sigma^2_{TOF} = \sigma^2_{t_{TOF}} + \sigma^2_{trk} + \sigma^2_{event} \end{cases}$$

- largest $\sigma_{event}$ expected for pp collisions (wrt AA)
- MC collision time simulated from the InteractionSampler of O2
- The MC collision time distribution has the correct resolution (200 ps)




NB. the generation saturates at 1000 events, after that the loop restarts (but other collisions are generated)
-> this explains the bumpiness of the distribution

# Implementing the event time in OTF

For now the event time is **extracted with the iTOF only**

The TOF resolution is simulated with a gaussian smearing + the contribution from tracking

To account also for the event time, on top of the gaussian smearing, tracks are shifted of the MC collision time

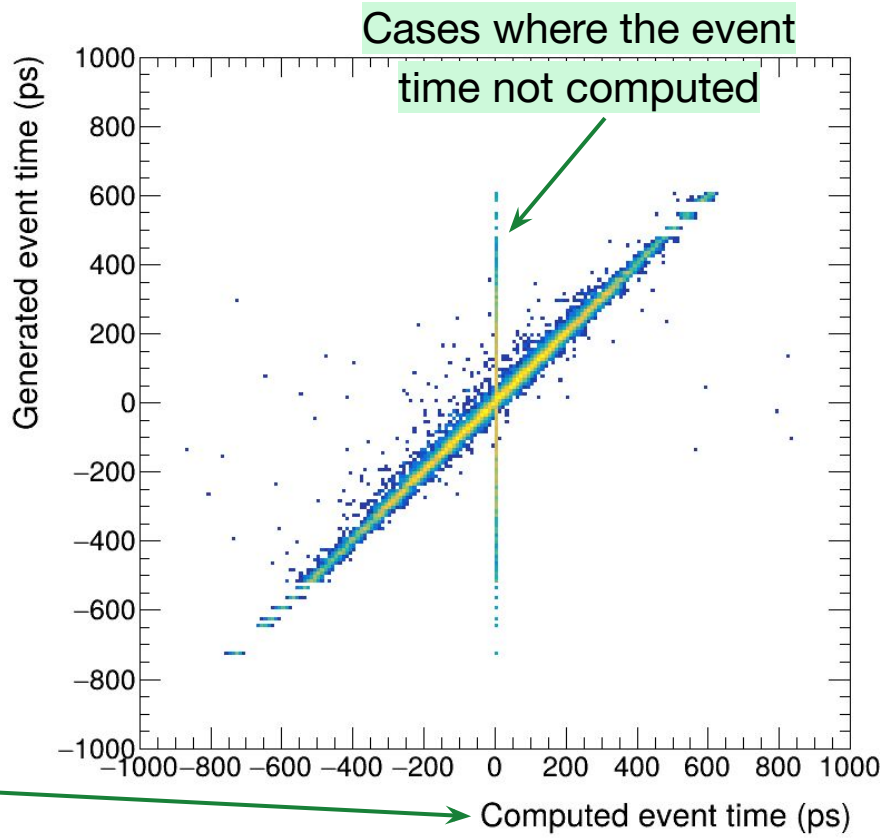
Then in a second phase, the **TOF event time** is computed **from the track information** with **smeared arrival times** and **smeared expected times**

This procedure has an **uncertainty** that depends on:

1. the precision of the expected time computation -> driven by **tracking**
2. the **number of tracks** used for the event time estimation ( $\propto 1/\sqrt{N_{tracks}}$ )

# Implementing the event time in OTF

Good correlation with the generated event time in the MC




Event time generated (MC)

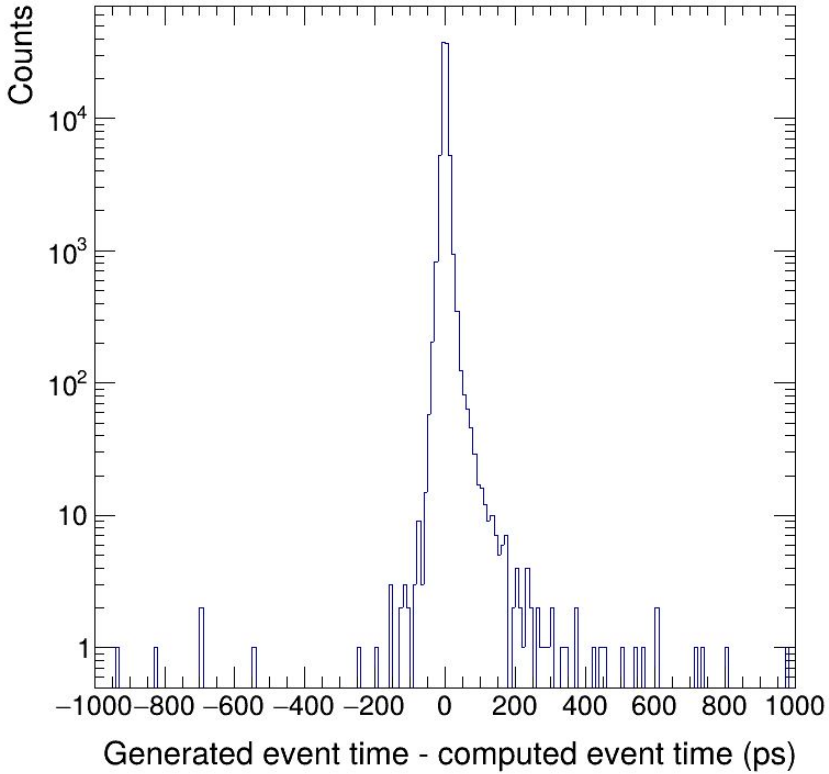
Event time reconstructed with the algorithm

# Implementing the event time in OTF

Currently the event time is **underestimated** in this algorithm (under investigation)

Few words on the algorithm

- Inherited from the LOI fast simulation
- Simple assumptions on the PID (using the MC information) for the expected times computation
- No track bias removal yet for low multiplicity events (as done in the LOI)!

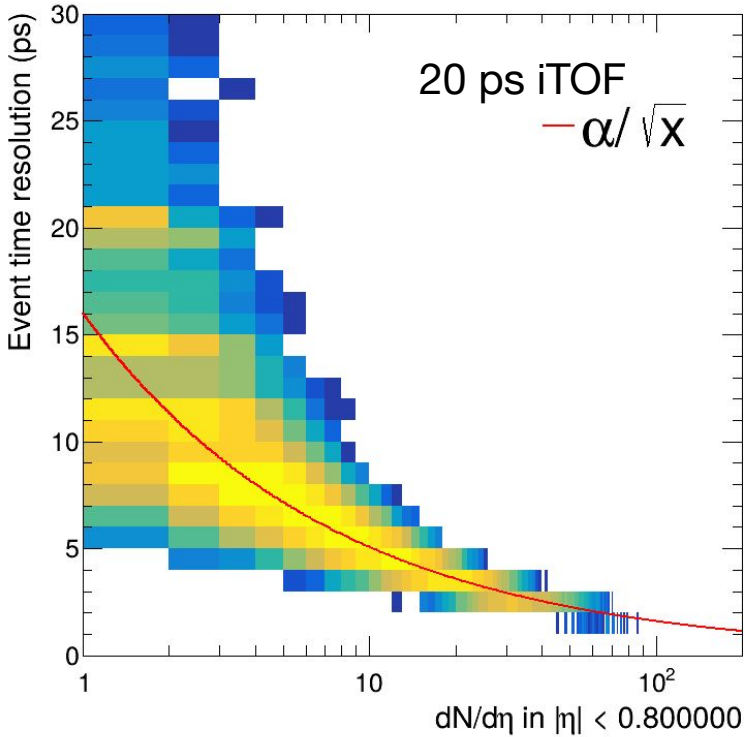


# Implementing the event time in OTF

- Every track contributes to the determination of the event time with a weight equal to

$$\sqrt{\sigma^2_{TOF} + \sigma^2_{trk}}$$

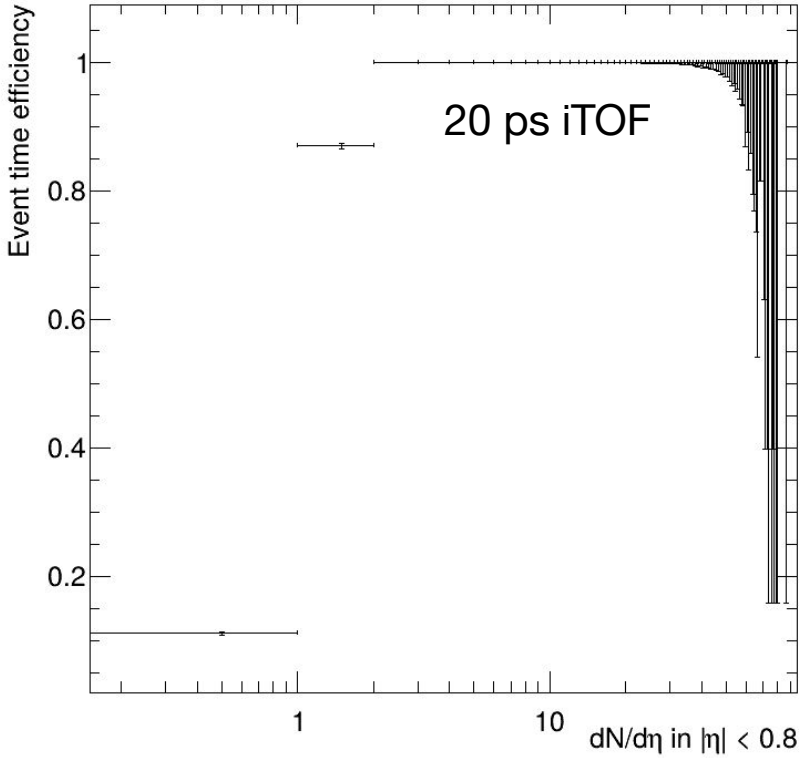
- Resolution on the event time follows the expected trend $\propto 1/\sqrt{N_{tracks}}$



# Efficiency of the event time

The event time is considered efficient when more than 2 tracks are available and the resolution is better than 200 ps

To do: use the outer/forward TOF for the computation of the event time



# Summary

- Occupancy studies extended to forward disks
- Matching studies ongoing with inner/outer/forward TOF
- Event time now included in the OTF simulation
  - first algorithm in place (LoI equivalent)
  - first efficiency calculated
  - track bias removal to be implemented