JINR Association of Young Scientists and Specialists

Conference "Alushta-2022"

Software method of determination of the event collision time with the ToF detector of the MPD at the NICA

Baryshnikov Victor(*)

on behalf of the MPD TOF Group

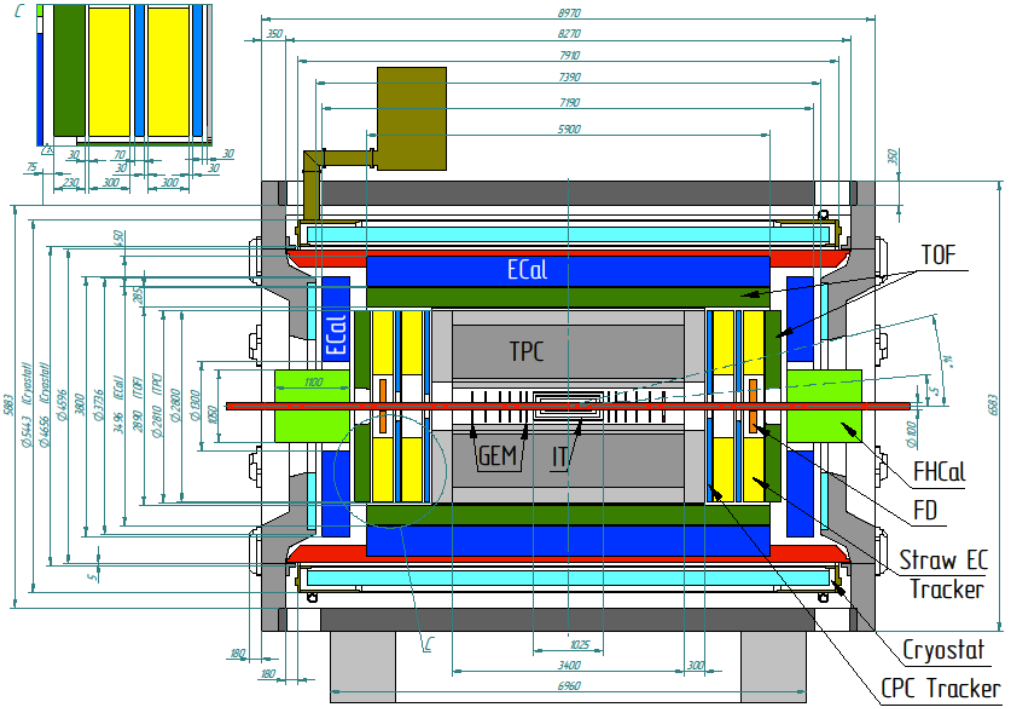
(*) NICA JINR (RUSSIA)

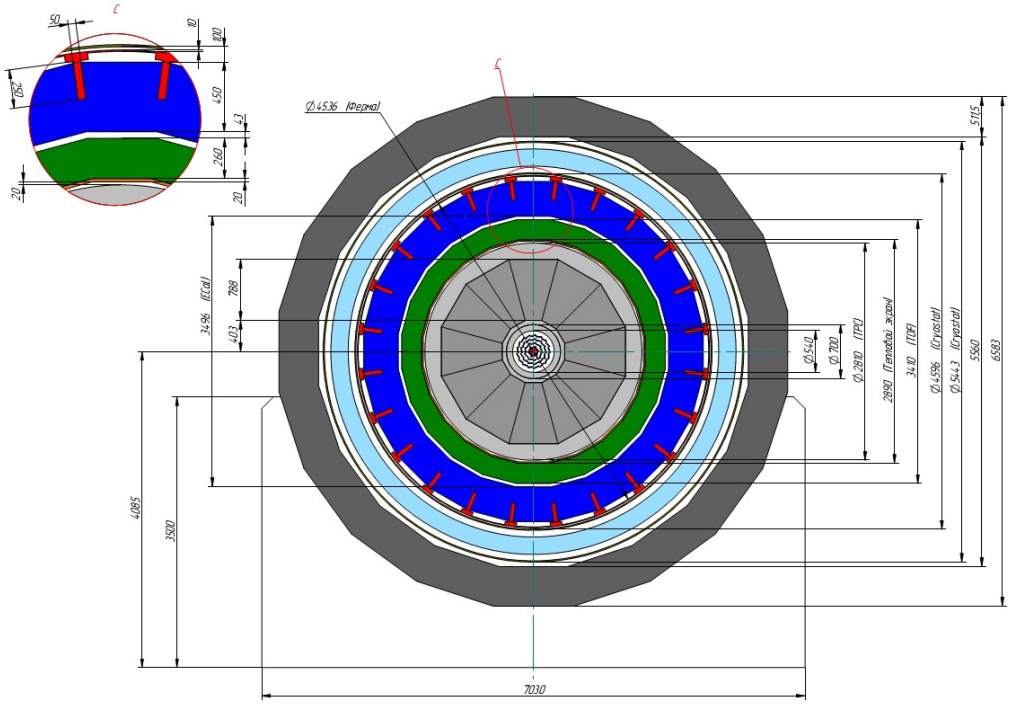
Outline: presented results

This talk presents an overview of the software method of determination of the event collision time by ToF detector of the MPD at the NICA.

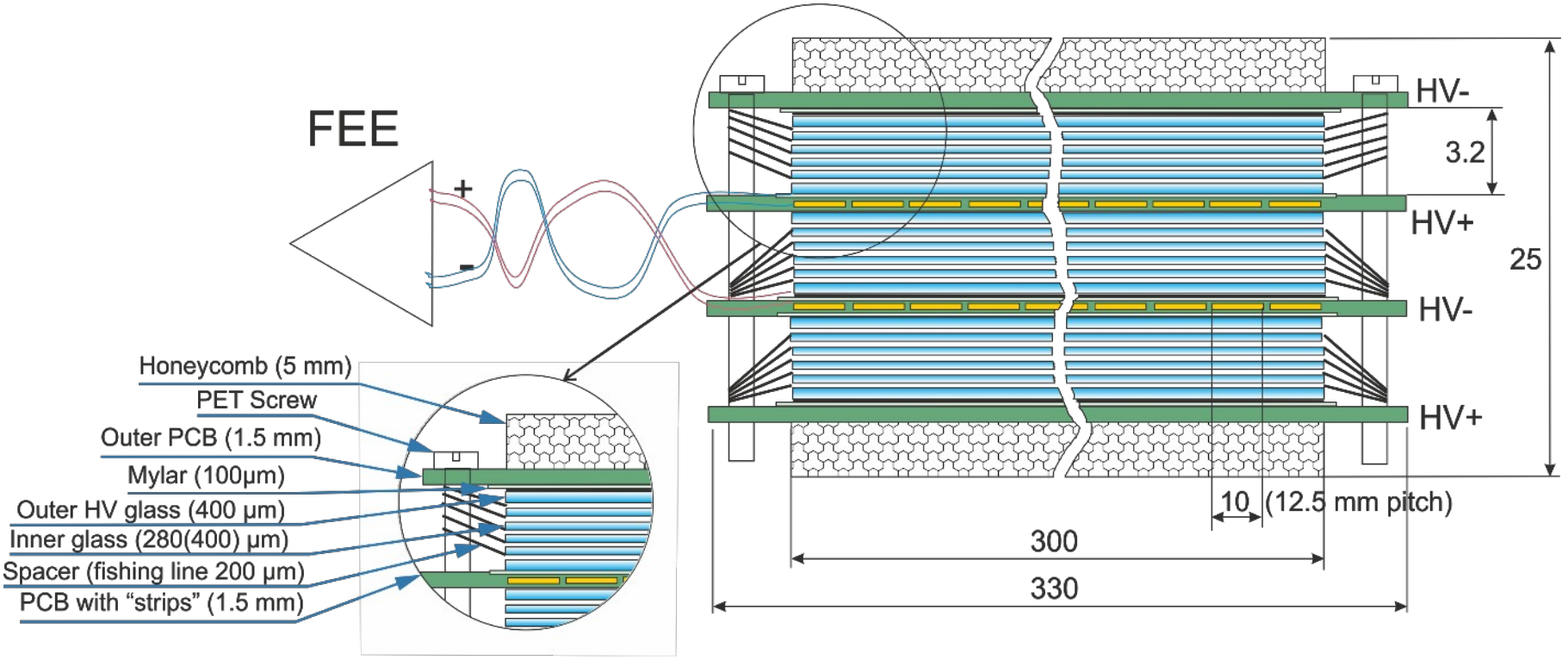
1) MPD and TOF detectors.
2) MC simulation of gold nuclei collisions and data reconstruction.
3) Event and track selection.
4) Event collision time measurement performed by the TOF detector.
5) Results:
   a) Efficiency of the determination of the event collision time;
   b) Resolution of the event collision time;
   c) Effect of the event collision time resolution on the PID performance.

MPD and TOF detectors



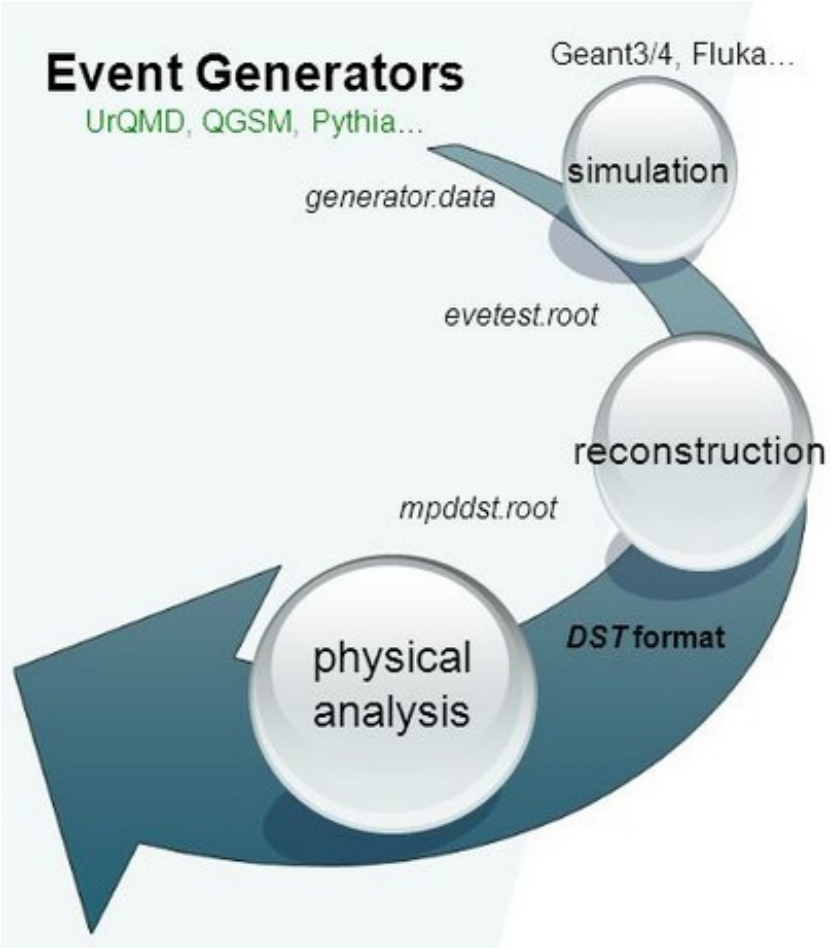


MPD and TOF detectors



MC simulation of gold nuclei collisions and data reconstruction

- GEANT-3, LAQGSM generator, collision data and new MpdTofHitProducer with event time for runMC.C
- reco.C
- Software method of determination of the event collision time by the ToF



Event and track selection

1) The particle must hit the TOF detector.
2) Tracks must have a primary vertex. Also, events with multiple reconstructed vertices are rejected.
3)Since the event collision time is a measurement that is needed to identify particles by means of the time-of-flight technique performed by the TOF detector, only events with a minimum number of tracks associated with hitting the TOF detector are selected.
4) Ions and photons are rejected.

- Since the bunches have a small but finite size and it is not known which of the particles in the bunches have collided, the event collision time has a natural spread with respect to the nominal beam crossing. Therefore, an event collision time has to be measured on an event-by-event basis.

Event collision time measurement performed by the TOF detector

For each track from the each interval $t^j_{\exp,i}$, $\sigma t^j_{\exp,i}$ and then the weight W^j_i are estimated:

$$m^2_{proposed} = p^2 \cdot \left| \left(\frac{t \cdot c}{L} \right)^2 - 1 \right|; \qquad j = 1, \ldots, N_{interval} \qquad \vec{m}_{j,i} = m_1, m_2, \ldots, m_{n^j_{tracks}}$$

$$t^j_{\exp,i} = \frac{\sqrt{(m^j_i)^2 \cdot c^2 + (p^j_i)^2}}{p^j_i \cdot c} \cdot L^j_i$$

$$\sigma t^j_{\exp,i} = \sqrt{\left(\frac{\partial t^j_{\exp,i}}{\partial p^j_i} \right)^2 \cdot (\sigma p_i{}^j)^2 + \left(\frac{\partial t^j_{\exp,i}}{\partial L^j_i} \right)^2 \cdot (\sigma L^j_j)^2}$$

$$\left(\frac{\partial t^j_{\exp,i}}{\partial p^j_i} \right) = \frac{L^j_i}{c} \cdot \left[\frac{1}{\sqrt{(p^j_i)^2 + (m^j_i)^2 \cdot c^2}} - \frac{\sqrt{(p^j_i)^2 + (m^j_i)^2 \cdot c^2}}{(p^j_i)^2} \right] = \left[\frac{L^j_i}{c} \cdot \frac{1}{\sqrt{(p^j_i)^2 + (m^j_i)^2 \cdot c^2}} - \frac{1}{p^j_i} \cdot t^j_{\exp,i} \right]$$

$$\frac{\partial t^j_{\exp,i}}{\partial L^j_i} = \frac{\sqrt{(m^j_i)^2 \cdot c^2 + (p^j_i)^2}}{p^j_i \cdot c} = \frac{t^j_{\exp,i}}{L^j_i}$$

$$W^j_i = \frac{1}{\sqrt{(\sigma_{TOF})^2 + (\sigma t^j_{\exp,i})^2}}$$

$$\sigma L^j_i = 1 cm \ll 150 - 170 cm$$

The event collision time, resolution of event collision time and X^2 are then calculated from the following equations:

$$t^{TOF\ j}_{ev,\ i}(\vec{m}^j_i) = \frac{\sum_{n^j_{tracks}} W^j_i \cdot (t_{TOF} - t^j_{\exp,i})}{\sum_{n^j_{tracks}} W^j_i}$$

$$\sigma t^{TOF\ j}_{ev,\ i}(\vec{m}^j_i) = \sqrt{\frac{1}{\sum_{n^j_{tracks}} W^j_i}}$$

$$\chi_j{}^2(\vec{m}^j_i) = \sum_{n^j_{tracks}} \frac{\left(t_{TOF} - t^{TOF\ j}_{ev,\ i} - t^j_{\exp,i} \right)^2}{(\sigma_{TOF})^2 + (\sigma t^j_{\exp,i})^2}$$

Event collision time measurement performed by the TOF detector

Now $\tilde{t}_{ev}^{TOF,\tilde{j}}$ and $\tilde{\sigma}t_{ev}^{TOF,\tilde{j}}$ are recalculated for each interval using only tracks belonging to other intervals.

$$\tilde{t}_{ev}^{TOF,\tilde{j}} = \frac{\sum_{j=1 \wedge j \neq \tilde{j}}^{N_{interval}} t_{ev}^{TOF,j} \cdot \left(\frac{1}{\chi_j^2}\right)}{\sum_{j=1 \wedge j \neq \tilde{j}}^{N_{interval}} \left(\frac{1}{\chi_j^2}\right)} \qquad \tilde{\sigma}t_{ev}^{TOF,\tilde{j}} = \frac{\sum_{j=1 \wedge j \neq \tilde{j}}^{N_{interval}} \sigma t_{ev}^{TOF\ j} \cdot \left(\frac{1}{\chi_j^2}\right)}{\sum_{j=1 \wedge j \neq \tilde{j}}^{N_{interval}} \left(\frac{1}{\chi_j^2}\right)}$$

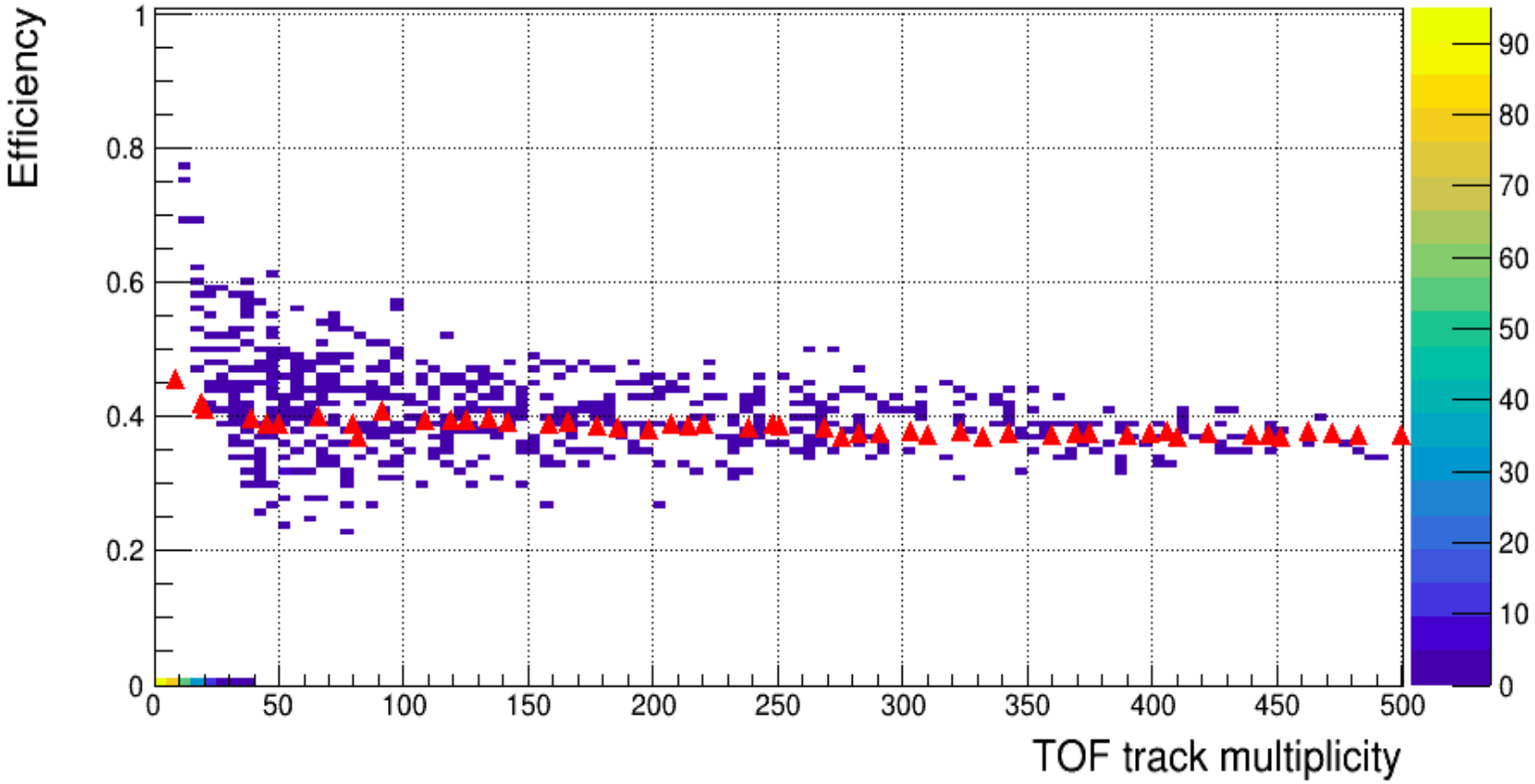
$$\tilde{W}_{\tilde{j}} = \sqrt{\frac{1}{\sum_{j=1 \wedge j \neq \tilde{j}}^{N_{interval}} \left(\frac{1}{\chi_j^2}\right)}} \qquad \tilde{j} = 1, \ldots, N_{interval}$$

Finally, we find the weighted averages of t_{ev}^{TOF} and σt_{ev}^{TOF} .

$$t_{ev}^{TOF} = \frac{\sum_{j=1}^{N_{interval}} \tilde{t}_{ev}^{TOF,\tilde{j}} \cdot \left(\frac{1}{\tilde{W}_{\tilde{j}}}\right)}{\sum_{j=1}^{N_{interval}} \left(\frac{1}{\tilde{W}_{\tilde{j}}}\right)} \qquad \sigma t_{ev}^{TOF} = \frac{\sum_{j=1}^{N_{interval}} \tilde{\sigma}t_{ev}^{TOF,\tilde{j}} \cdot \left(\frac{1}{\tilde{W}_{\tilde{j}}}\right)}{\sum_{j=1}^{N_{interval}} \left(\frac{1}{\tilde{W}_{\tilde{j}}}\right)}$$

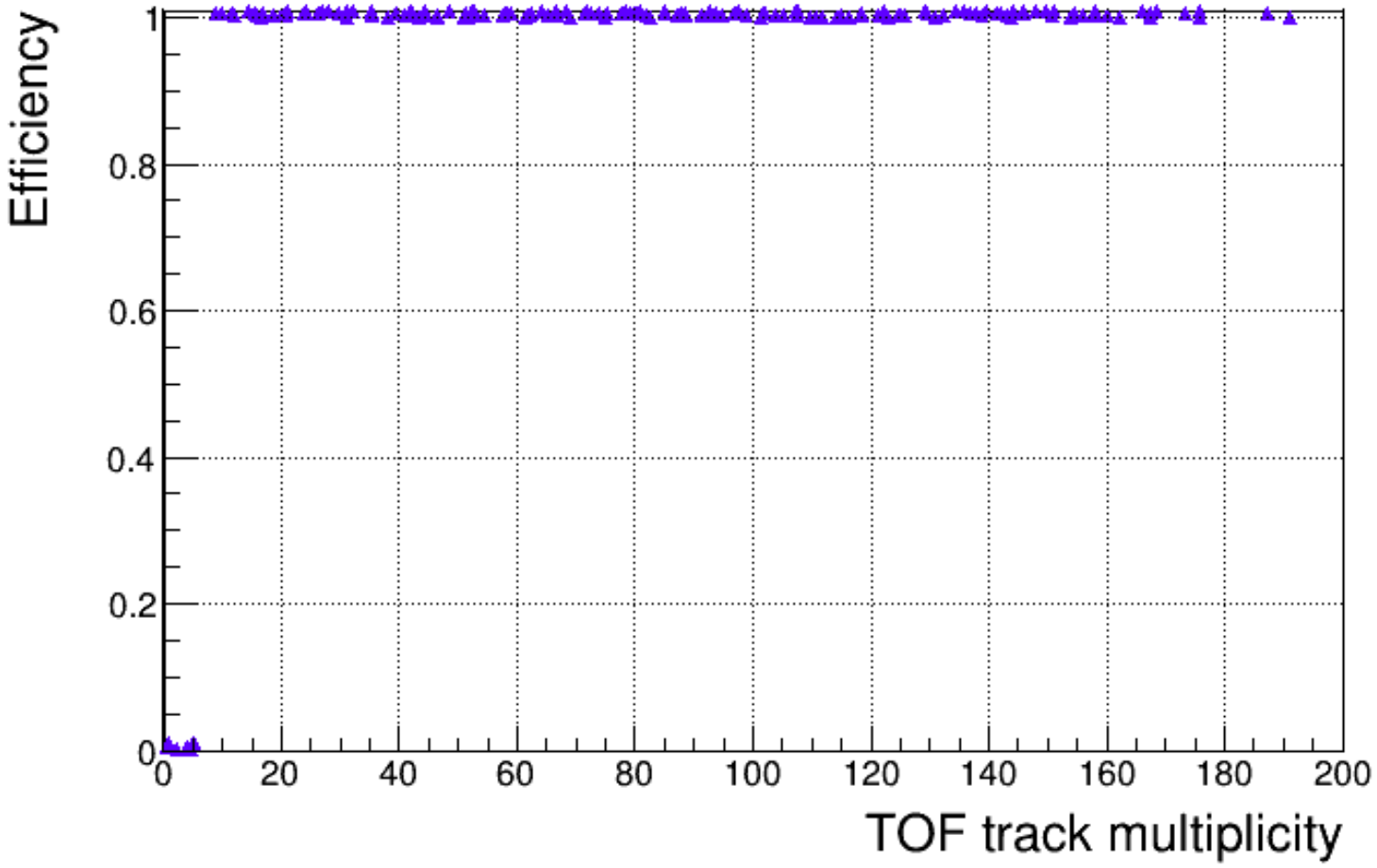
$$\sigma t_{ev}^{TOF} \sim \sqrt{\frac{1}{n_{tracks}^{j}}}$$

Results: Efficiency of the determination of the event collision time



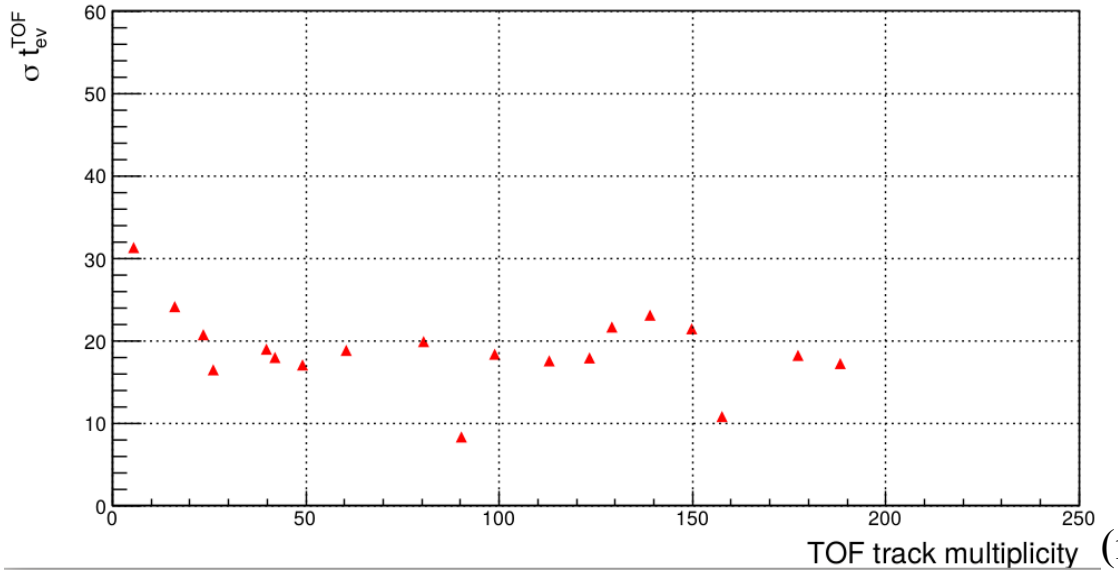
(TOF track without applying the basic requirements)

Results: Efficiency of the determination of the event collision time

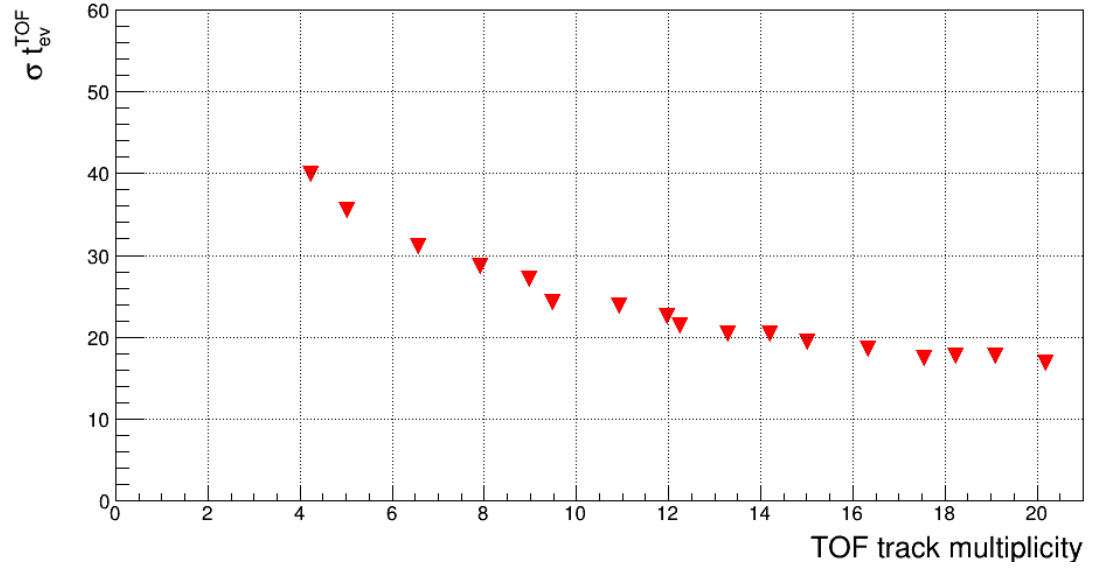


(TOF track with applying the basic requirements)

Results: Resolution of the event collision time



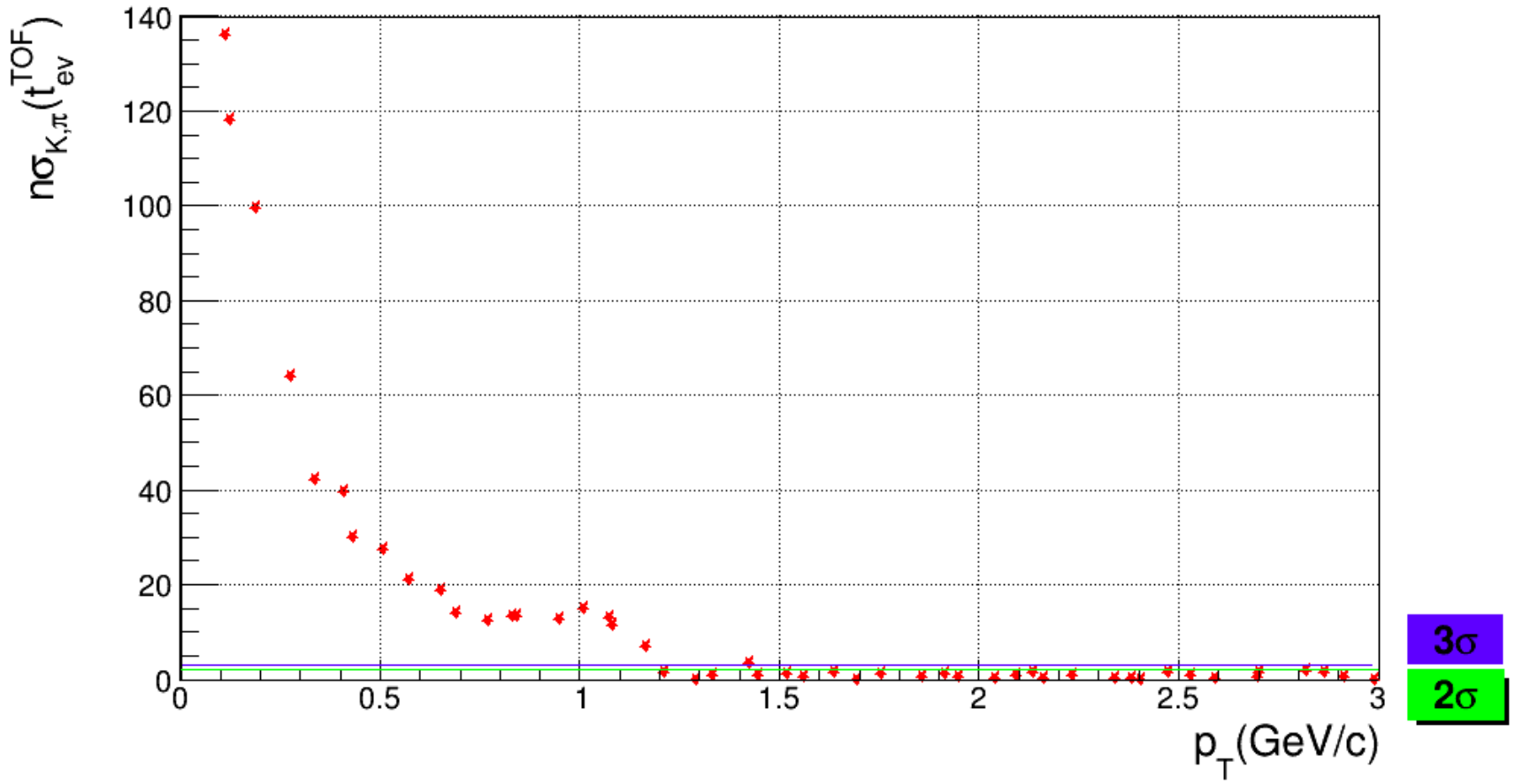
(in the events)



(in the intervals)

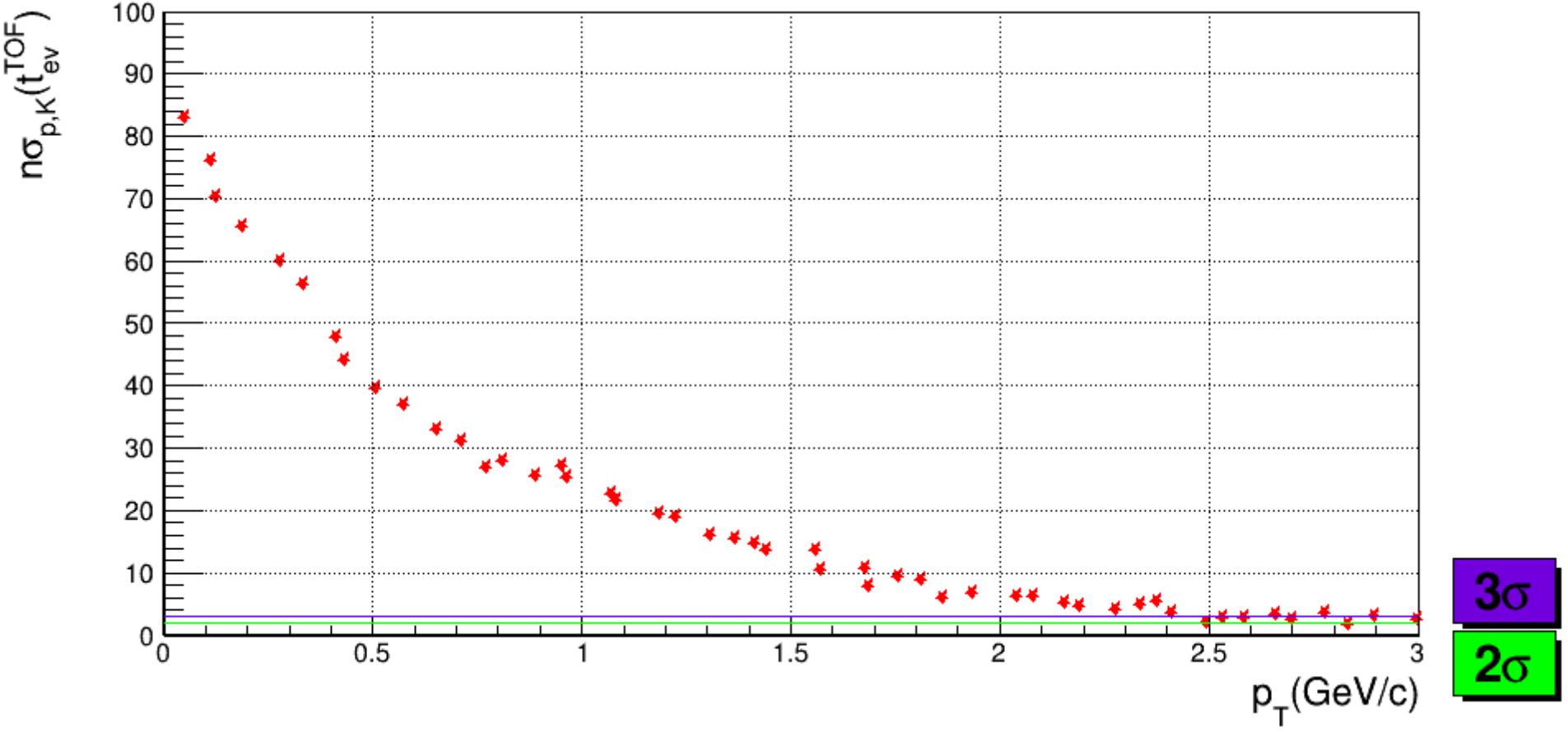
Results: Effect of the event collision time resolution on the PID performance

$$\sigma^2_{PID} = \sigma^2_{TOF} + \sigma^2_{t_{ev}^{TOF}} + \sigma^2_{t_{\exp}} \qquad n\sigma_{TOF} = \frac{t_{TOF} - t_{ev} - t_{\exp}}{\sigma_{PID}} \qquad n\sigma_{i,j}(t_{ev}^{TOF}) = \frac{t_{\exp,i} - t_{\exp,j}}{\sigma_{PID,j}}(t_{ev}^{TOF}) \quad i,j = \pi, K, p$$



Results: Effect of the event collision time resolution on the PID performance

$$\sigma_{PID}^2 = \sigma_{TOF}^2 + \sigma_{t_{ev}^{TOF}}^2 + \sigma_{t_{exp}}^2 \qquad n\sigma_{TOF} = \frac{t_{TOF} - t_{ev} - t_{exp}}{\sigma_{PID}} \qquad n\sigma_{i,j}(t_{ev}^{TOF}) = \frac{t_{exp,i} - t_{exp,j}}{\sigma_{PID,j}}(t_{ev}^{TOF}) \quad i,j = \pi, K, p$$



Thank you for your attention.