Fast way to determine *pp*-collision time with TOF detector

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Task and initial conditions

Using information about particles trajectories and hits from TOF detector to determine time of *pp*-collision.

1. Resolution of TOF detector $\sigma_t = 70\ ps$
2. Momentum resolution: $\frac{\sigma_p}{p} = 5\%$ (or 2%)
3. TOF radius is 1 *m* and length of 3 *m*

Plan

1. **Selection:** Only fast particles with momentum $> 0.5\ GeV/c$ and events with more than 5 particles
2. **Analysis:** We treat all particles as pions

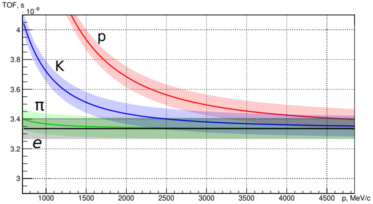


Figure 1: Dependence of TOF on momentum p for 4 types of particles: p, K, π, e.

t_0 by minimzation of χ^2

$$\chi^2 = \sum_i \frac{(t_0 + tof - t_i)^2}{\sigma_t^2 + \sigma_{tof_i}^2} \quad (1)$$

where t_i - the detector signal of the i-th particle from one event and

$$tof = \frac{L}{c}\sqrt{1 + \frac{m^2c^4}{p^2c^2}} \quad (2)$$

and for pions with $p > 0.5\ GeV/c$

$$\sigma_{tof} = \sigma_p \cdot \left|\frac{dt_{tof}}{dp}\right| = \sigma_p \frac{L}{\sqrt{1 + \frac{m^2c4}{p^2c^2}}} \cdot \frac{m^2c^4}{p^3c^3} < \sigma_{tof}(0.5\ GeV/c) \approx 20ps \quad (3)$$

$$t_0 = \sum_i \frac{t_i - tof}{n} = \sum_i \frac{t_{diff_i}}{n} \quad (4)$$

All particles are $\pi^{\pm}$

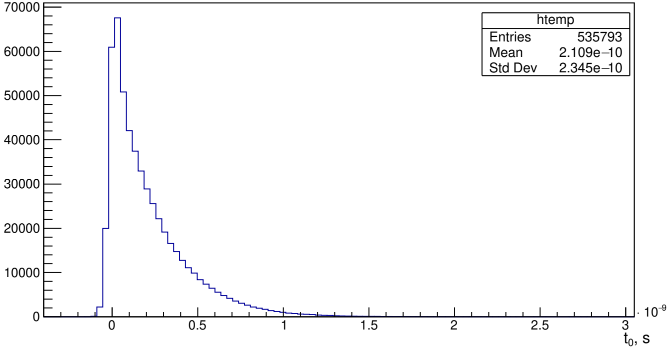


Figure 2: t_0-distribution in hypothesis that all particles are pions.

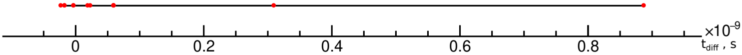


Figure 3: Difference between the detector's signal and TOF for pions

→ t_0 is biased to positive values due to heavy particles K and p.

CDF of $\pi^{\pm}$ appearance as a function of charge multiplicity

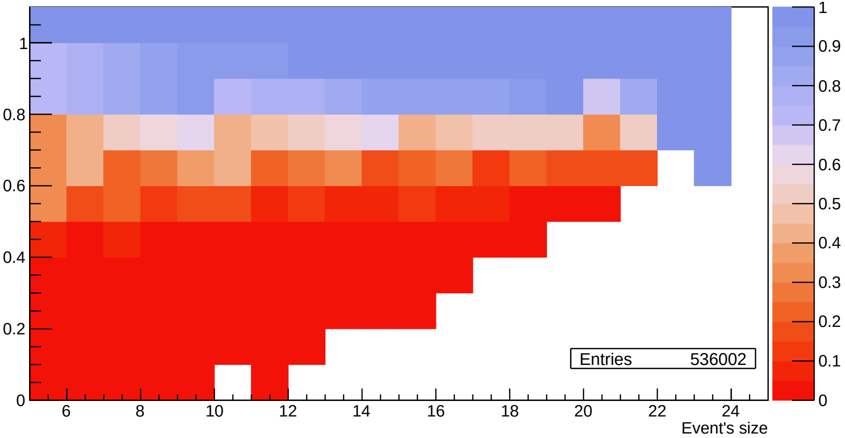


Figure 4: CDF of $\pi^{\pm}$ appearance as a function of charge multiplicity

biased estimation

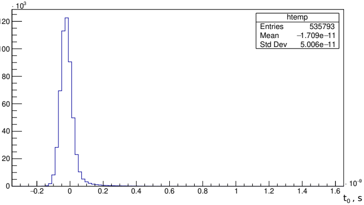


Figure 5: t_0-distribution, where only 60% of earliest tracks of event

compensated biased estimation

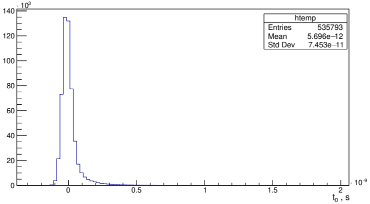


Figure 6: t_0-distribution, where 70% of earliest tracks of event

TOF difference due to PID

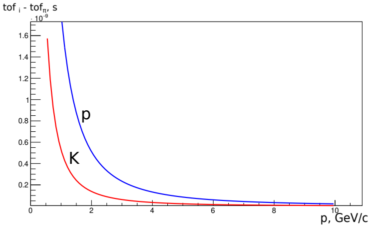


Figure 7: Difference of time of flight between kaons and pions; protons and pions

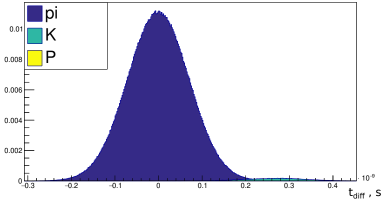


Figure 8: Distribution t_{diff} of π and misidentified K for momentum < 1.5 GeV/c and more than 3 particles

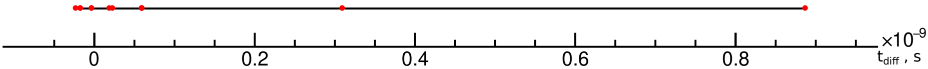
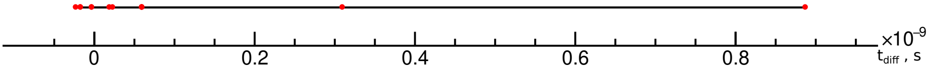


Figure 9: Difference between the detector's signal and TOF for pions



Window's size - $\pm 3\sigma$

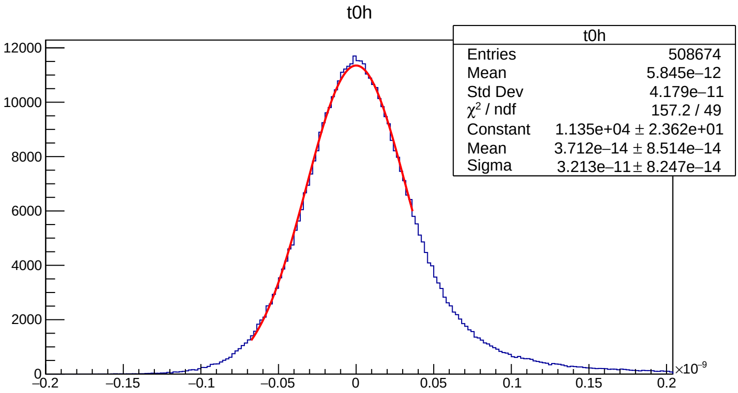


Figure 10: t_0-distribution with sliding window method

Some artifacts here

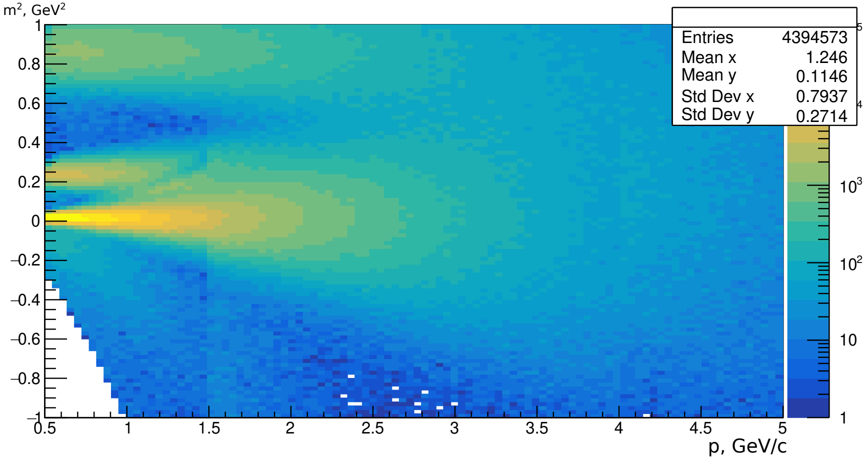


Figure 11: Dependence m^2 on p

Error of estimation t_0

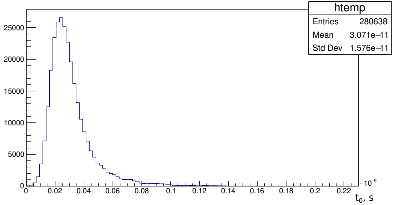


Figure 12: t_0-error with more than 6 particles

$$\sigma_{t_0} = \sqrt{\sum_i \frac{(t_{diff_i} - t_0)^2}{n(n-1)}} \tag{5}$$

where

$$t_{diff} = t_i - tof \tag{6}$$

multiplicity	ratio	$\pm 3\sigma$	$\pm 3\sigma$ / ratio
3	0.103	0.089	0.864
4	0.163	0.142	0.87
5	0.176	0.157	0.892
> 5	0.558	0.514	0.921

multiplicity $=$ n charged tracks with $0.5 < p < 1.5\ GeV/c$

$$ratio = \frac{N(tracks = n\ and\ 0.5 < p < 1.5\ GeV/c)}{N(\text{any } n)}$$

Results

1. Typical time to find t_0 is around 300ns per event
2. Unbiased estimation of t_0 with $\sigma = 32\ ps$
3. The ratio of the count of particles with $p < 1.5\ GeV/c$ and more than 3 particles to count of particles with $p > 0.5\ GeV/c$ and more than 5 particles in one event $\approx 95\%$
4. t_0 in $\pm 3\sigma\ \approx 90\%$

Thank you for your attention!