Fast way to determine *pp*-collision time at the SPD experiment

Polina Filonchik

Moscow Institute of Physics and Technology

filonchik.pg@phystech.edu

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SPD experiment

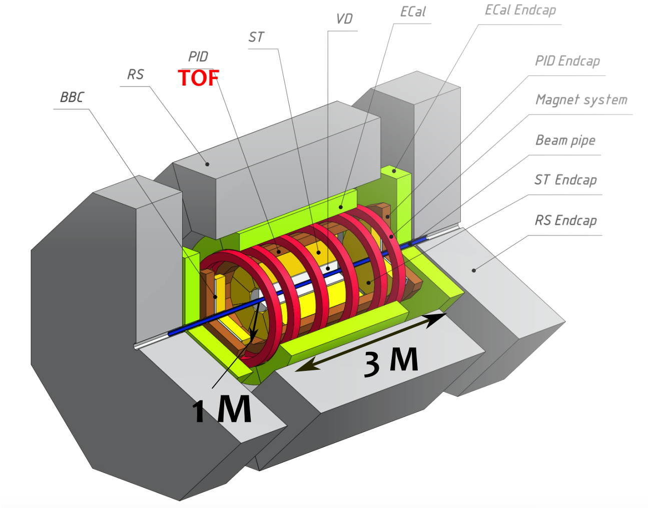


Figure 1: General layout of the SPD setup

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: $\frac{\sigma_p}{p} = 2\%$
3. TOF radius is 1 m and length of 3 m

The collision data was generated by the Pythia8-based programme written by Semyon Yurchenko.

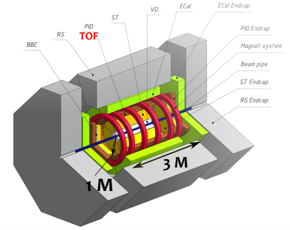


Figure 2: General layout of the SPD setup

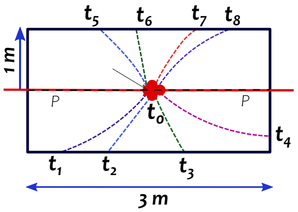


Figure 3: Scheme of TOF detector

Plan

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

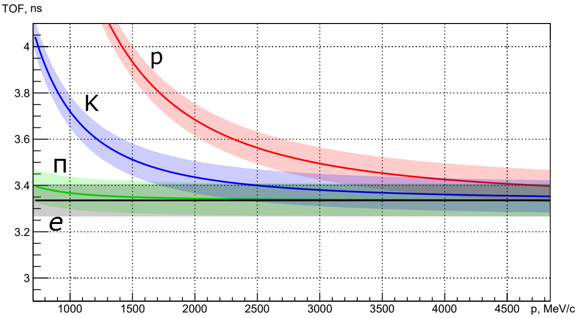


Figure 4: Dependence of *TOF* on momentum *p* for 4 types of particles: p, *K*, π, *e*.

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

where t_i - the detector signal of the i-th particle from one event, $\sigma_t = 70\ ps$, $\frac{\sigma_p}{p} = 2\%$ and

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

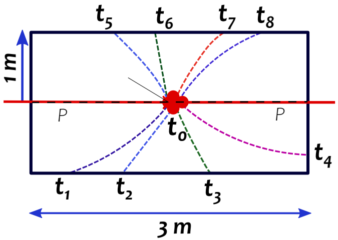


Figure 5: Scheme of TOF detector

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

$$\sigma_{tof}(p) = \sigma_p \cdot \left|\frac{dtof}{dp}\right| = \sigma_p \frac{L}{\sqrt{1 + \frac{m^2c4}{p^2c^2}}} \cdot \frac{m^2c^4}{p^3c^3} < \sigma_{tof}(0.5\ GeV/c) \approx 8ps \quad (3)$$

$$min\ \chi^2 \rightarrow t_0 = \sum_i \frac{t_i - tof_i}{n} = \sum_i \frac{t_{diff_i}}{n} \quad (4)$$

time execution by brute-force (all combinations) algorithm $\sim$ 1 s

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

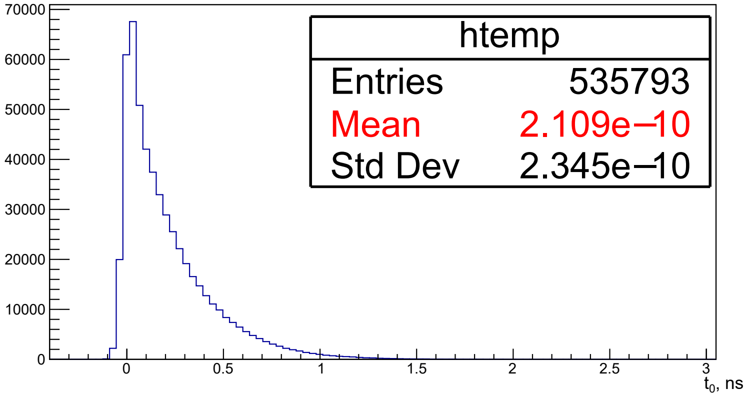


Figure 6: t_0-distribution in hypothesis that all particles are pions.

Figure 7: 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

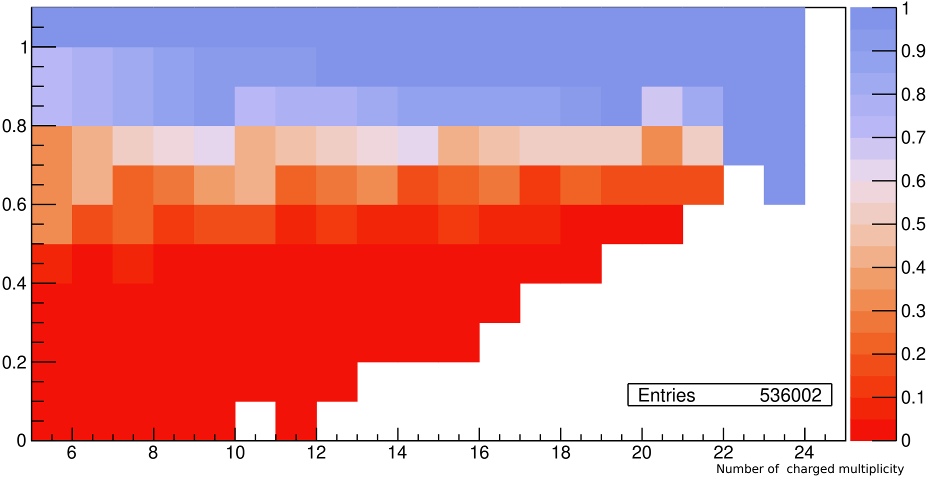


Figure 8: CDF of $\pi^{\pm}$ appearance as a function of charge multiplicity

All π and part of earliest tracks

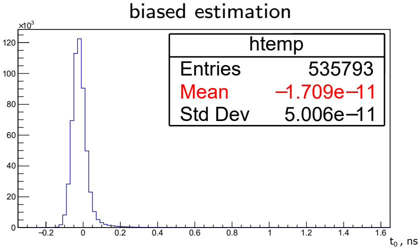


Figure 9: t_0-distribution, where only 60% of earliest tracks of event

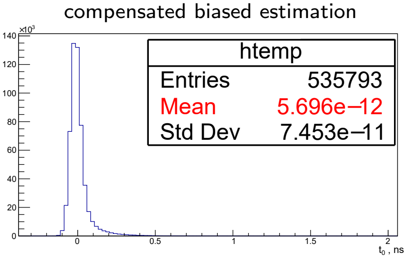


Figure 10: t_0-distribution, where 70% of earliest tracks of event

Figure 11: Difference between the detector's signal and TOF for pions

$$t_{diff} = t_i - tof$$

TOF difference due to particle's types

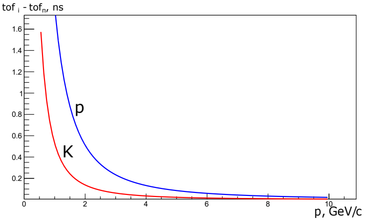


Figure 12: Difference of time of flight between kaons and pions; protons and pions

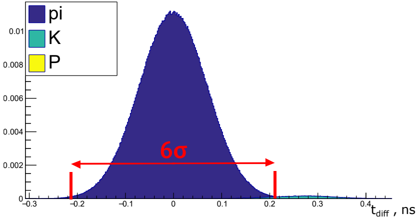


Figure 13: Distribution t_{diff} of π and misidentified K for momentum $< 1.5\ GeV/c$ and 3 and more particles

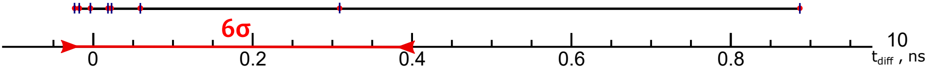
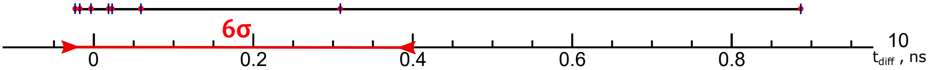


Figure 14: Difference between the detector's signal and TOF for pions

$$t_{diff} = t_i - tof$$

Sliding window method



Window's size - $\pm 3\sigma_t$ (± 210 ps); $t_{diff} = t_i - tof$

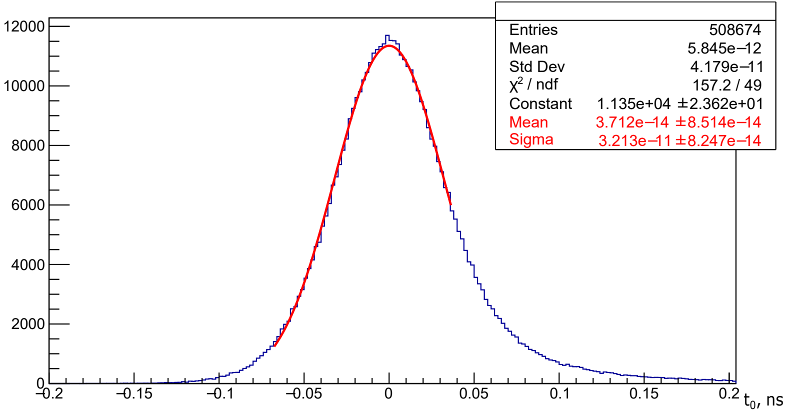


Figure 15: t_0-distribution with sliding window method

Some artifacts here

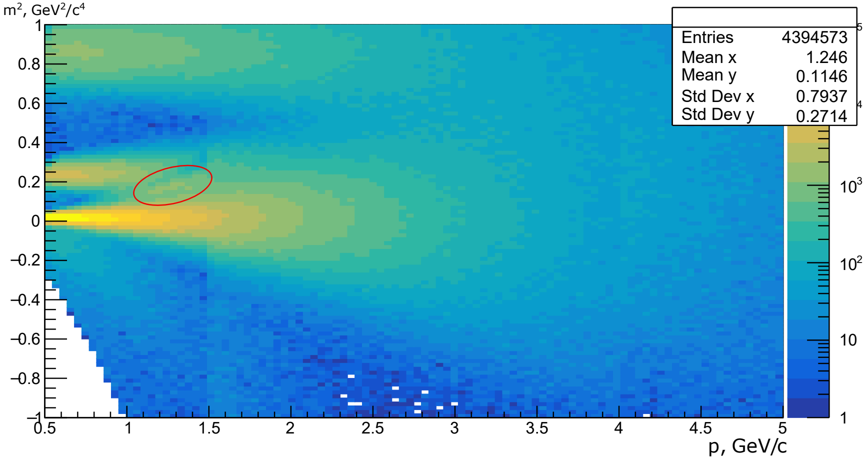


Figure 16: Dependence m^2 on p

Error of estimation t_0

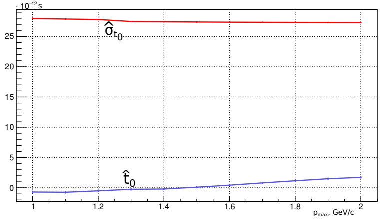


Figure 17: Dependence mean estimations of t_0 and σ_{t_0} on momentum upper limit p_{max}.

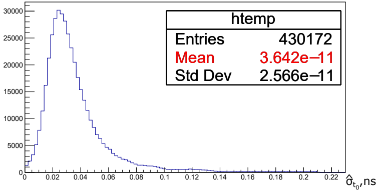


Figure 18: Distribution of sample variance $\hat{\sigma}_{t_0}$ of t_0.

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

where $t_{diff} = t_i - tof$

Acceptance rate

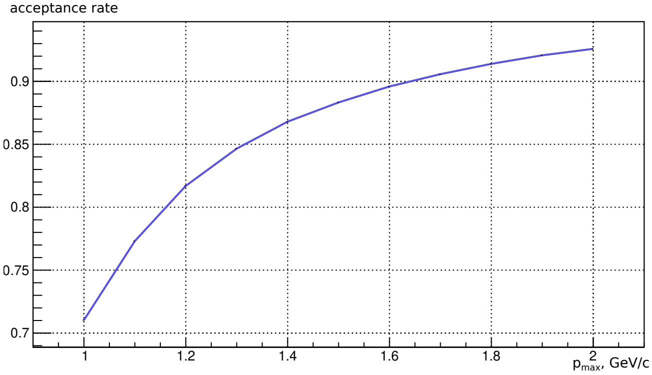


Figure 19: Dependence of acceptance rate on momentum limit p_{max}

$$\text{Acceptance rate} = \frac{N_{3\sigma}(0.5 < p < 1.5 \text{ GeV/c and } n \geq 3)}{N(p > 0.5 \text{ and } n > 5)}$$

n – count of charged particles with defined conditions in one event

Results

1. Typical time to find t_0 is around 300 ns per event.
2. 10^6 times faster than brute-force (all combinations) algorithm.
3. Unbiased estimation of t_0 with $\sigma = 32$ ps by sliding window method.
4. For 90% input events.

Thank you for your attention!