Determination of *pp*-collision time with TOF detector(Update)

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Task and initial conditions

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

1. In this work only tracks with momentum below 500 MeV will not be considered.
2. Resolution of TOF detector $\sigma_t = 70\ ps$.
3. Momentum resolution: $\frac{\sigma_p}{p} = 2\%$
4. TOF radius is 1 m and length of 3.772 m.

Plan of simulation

1. Get tracks of charged particles with momentum over 500 MeV from Pythia8 events with $\sqrt{s} = 27\ GeV$.
2. Calculate intersection point with TOF detector(t_i).
3. Calculate arc length of trajectory(L_i).
4. Smear t_i with $N(t_i, 70\ ps)$ and p_i with $N(p_i, 0.02 \cdot p_i)$.
5. Using information about arc lengths of trajectories, TOF hits and particle momentum determine time of pp-collision(t_0).

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Brute force

How brute force works:

1. Choose particles types to make tof hypotheses$\rightarrow [\pi^{\pm}, K^{\pm}, p^{\pm}]$.

$$tof_{ik} = \frac{L_i}{c}\sqrt{1 + \frac{m_k^2}{p_i^2}} \tag{1}$$

2. For every event check all tracks hypotheses combinations - 3^N variants.
3. On every step calculate t_0 and χ^2 and find χ^2_{min}.

$$\chi^2 = \sum^{N} \frac{(t_0 + tof_{ik} - t_i)^2}{\sigma_t^2 + \sigma_{p_i}^2}, \quad t_0 = \frac{1}{\mu}\sum^{N} \frac{t_i - tof_{ik}}{\sigma_t^2 + \sigma_{p_i}^2}, \quad \mu = \sum^{N} \frac{1}{\sigma_t^2 + \sigma_{p_i}^2} \tag{2}$$

4. Time complexity $O(N \cdot 3^N)$.

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4. Time complexity $O(N \cdot 3^N)$ - **very slow!!!**

Genetic algorithm

How genetic algorithm works:

1. Create population of random candidate solutions - $v([m_i]_k)$.
2. Create mutant vector from random candidates in population(DE-inspired):

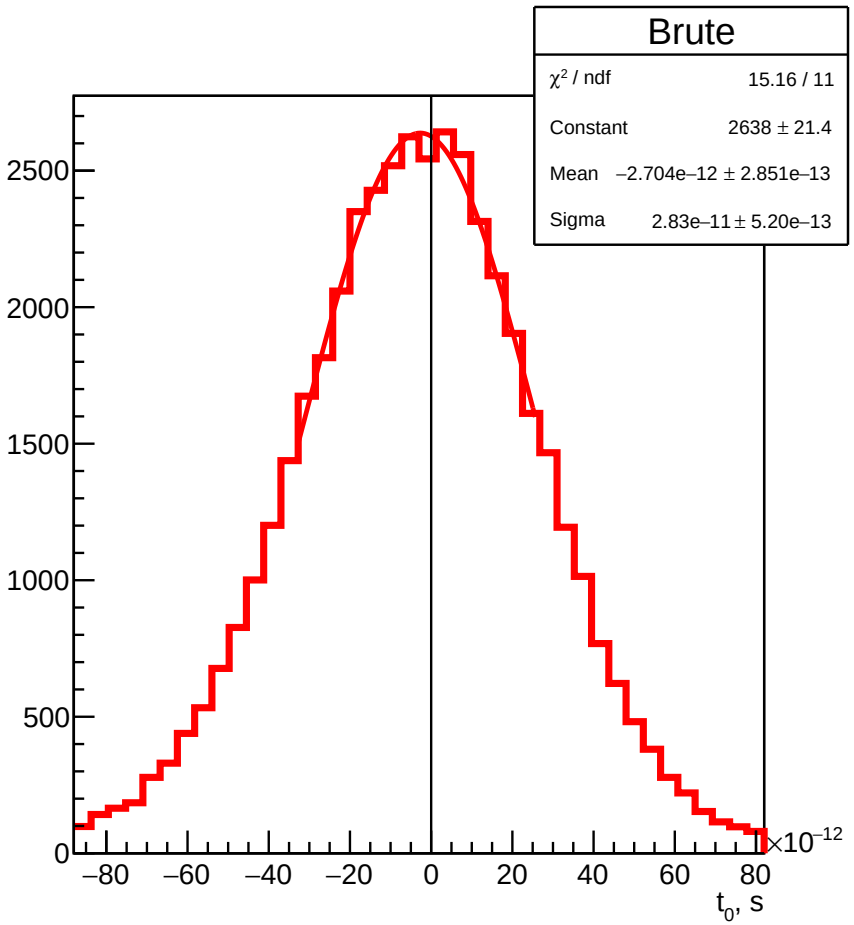
$$v_{mut} = v_r + F \cdot (v_p - v_q) \tag{3}$$

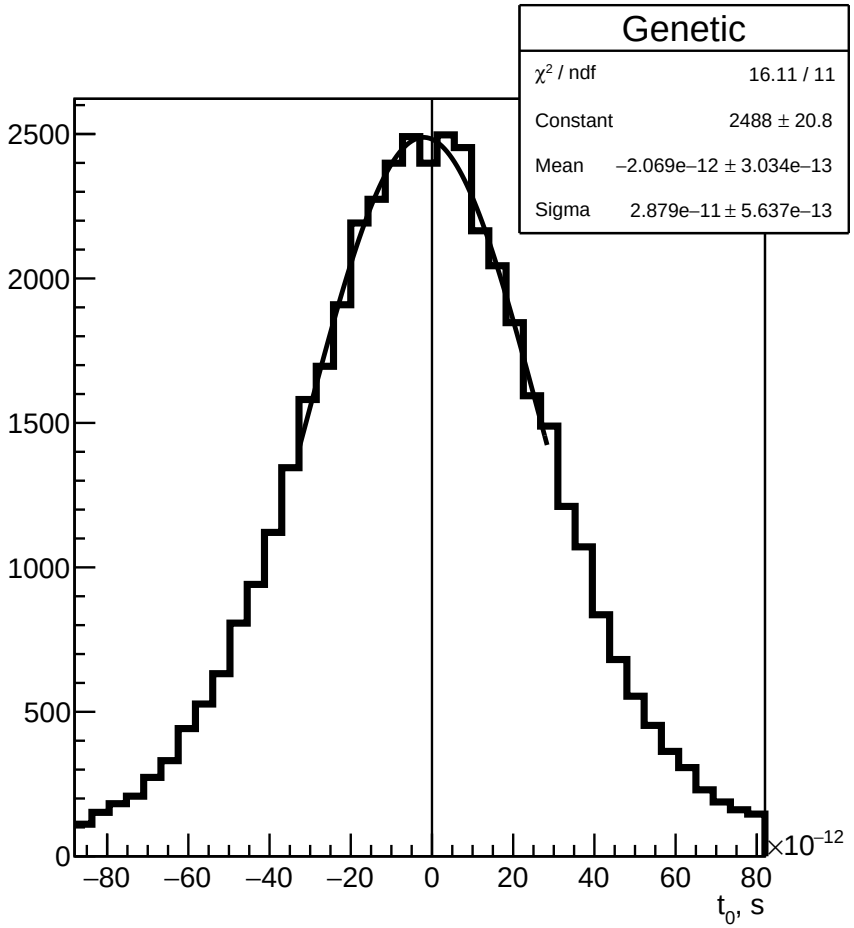
3. Check if $\chi^2_{mut} < \chi^2_r$ then replace v_r with v_{mut}. If not, population remains unchanged - **Darwinian selection**.
4. Repeat
5. After some number of steps stop and choose χ^2_{min} as an answer.
6. Time complexity - $O(N \cdot N_{population} \cdot N_{steps})$, $800 < N_{steps} < 1000$.

Genetic algorithm vs Brute force

- Brute force gives solution with minimal χ^2, but very slowly.
- Genetic algorithm has less accuracy, but much faster.

Comparison of 2 algorithms was done on events with number of tracks $4 < N < 15$.



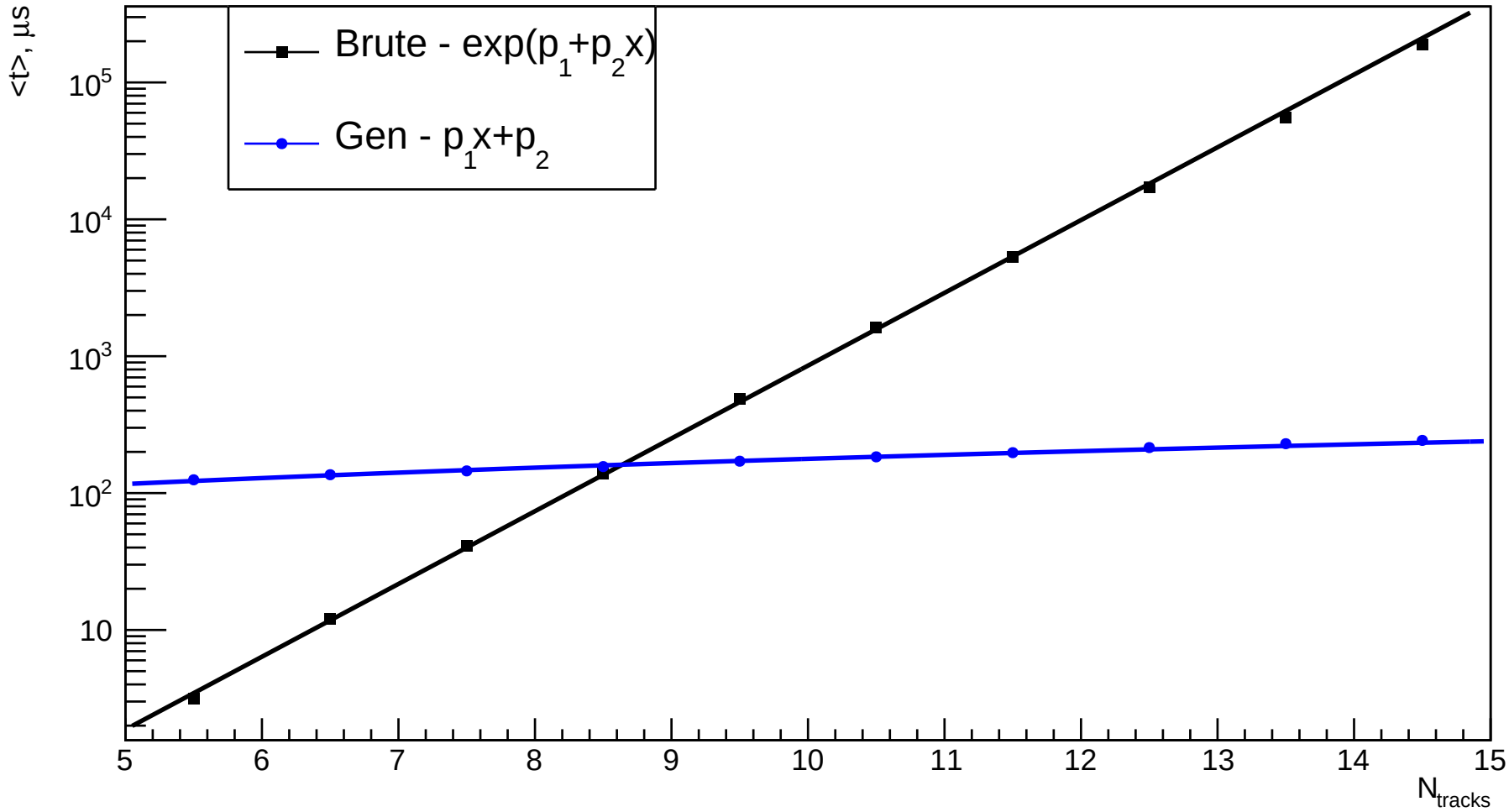


Genetic algorithm vs Brute force

1. Brute Force resolution of t_0 is 28 ps and Genetic Algorithm is 29 ps.
2. PID event efficiency for Brute Force is 66.7% and for Genetic algorithm it is 63.3%.
3. PID track efficiency for Brute Force is 97.2% and for Genetic algorithm is 96.8%.

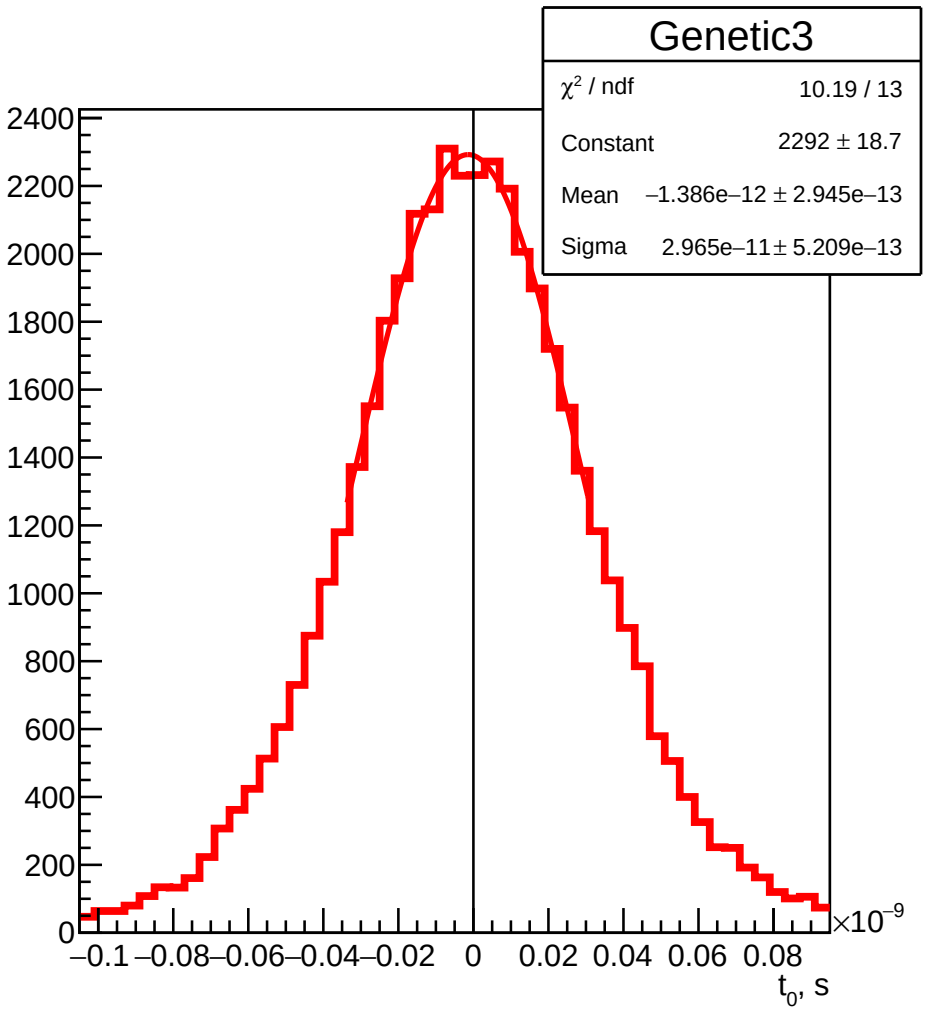
PID event efficiency - percentage of events where all tracks were guessed correctly.
PID track efficiency - percentage of tracks that were guessed correctly.

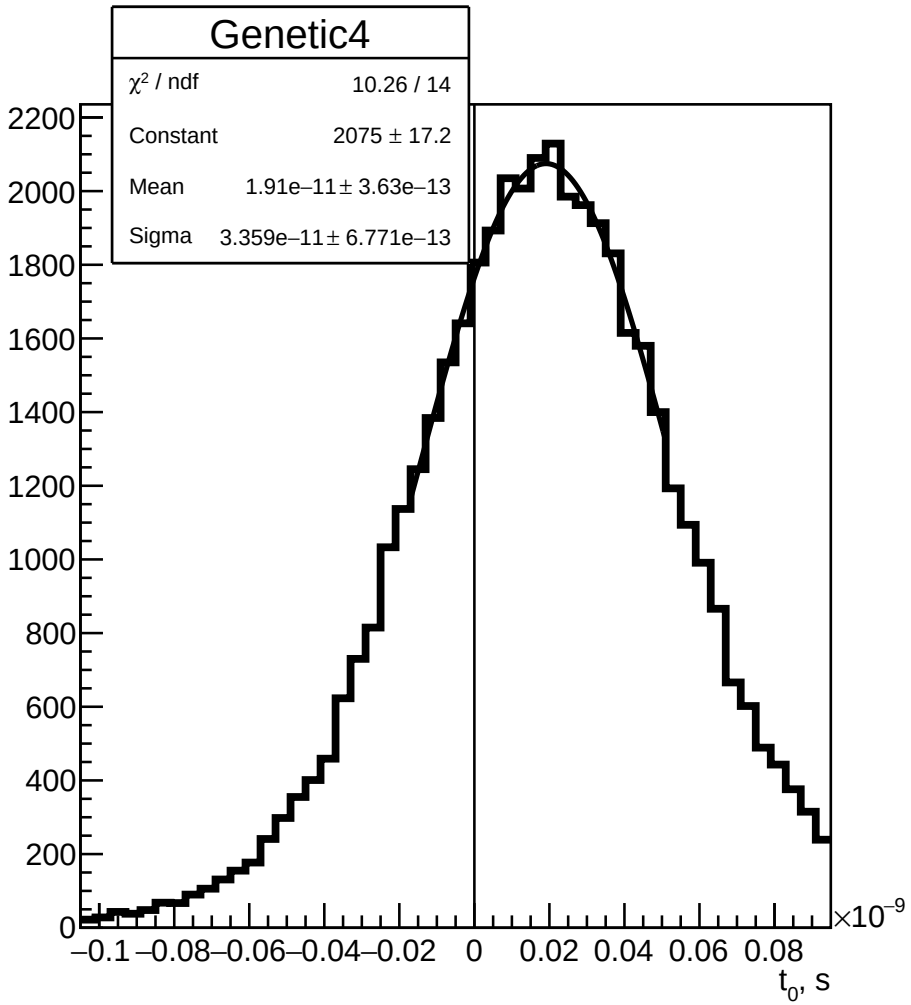
Time complexity



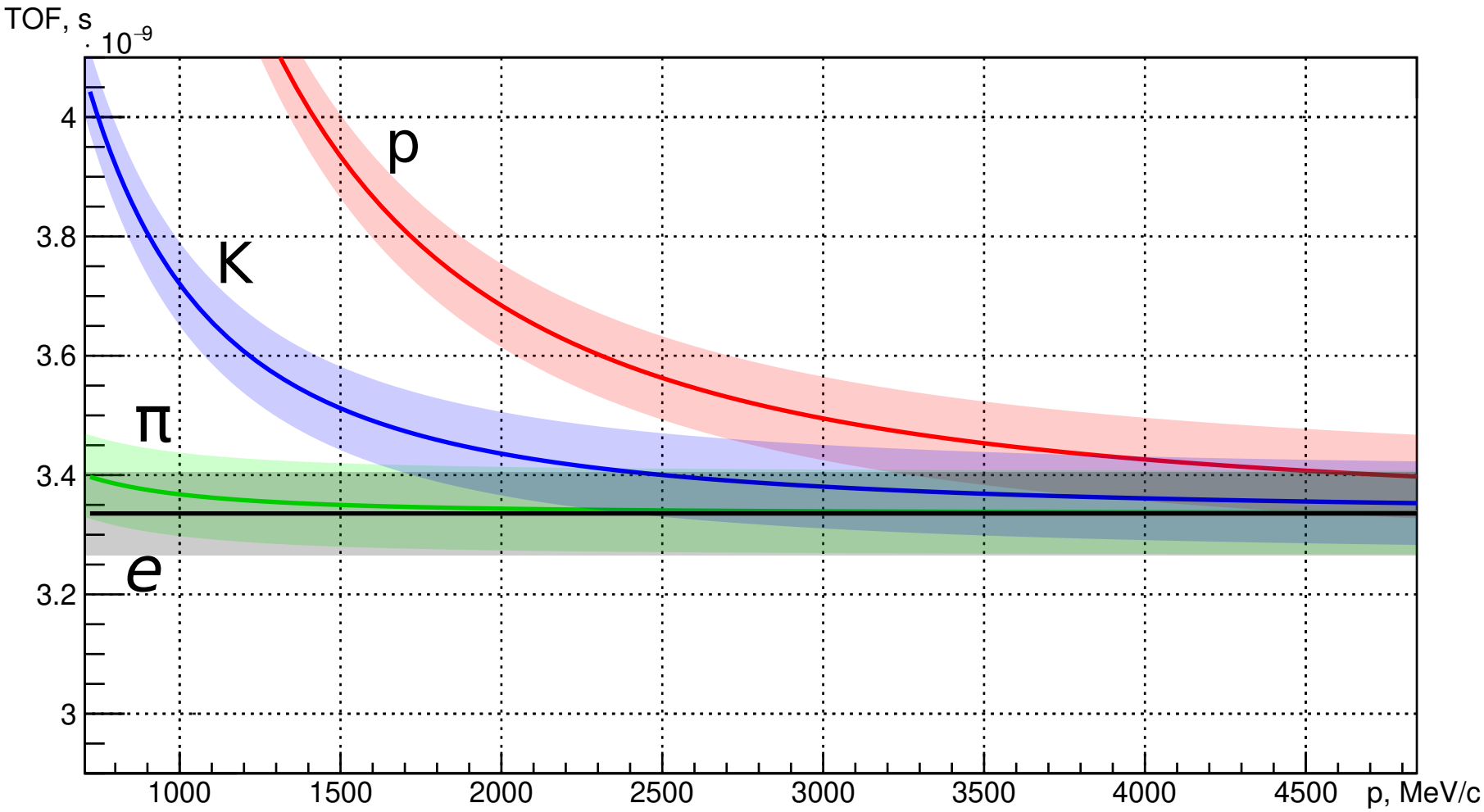
Different hypotheses

Genetic3 hypotheses is $[\pi^{\pm}, K^{\pm}, p^{\pm}]$
Genetic4 hypotheses is $[e^{\pm}, \pi^{\pm}, K^{\pm}, p^{\pm}]$





TOFs

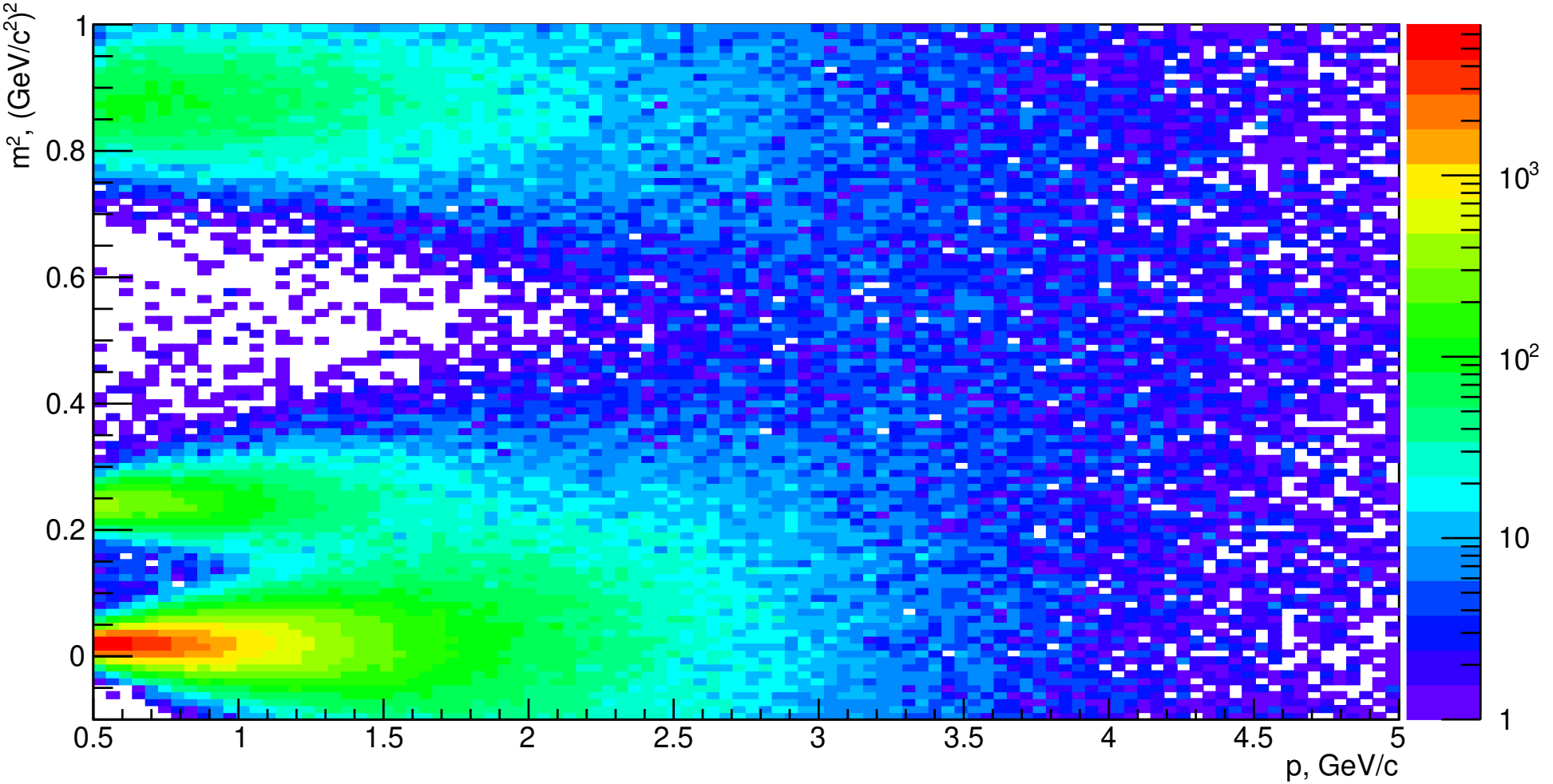

TOF, s
$\cdot 10^{-9}$
4
3.8
3.6
3.4
3.2
3
p
K
π
e
1000
1500
2000
2500
3000
3500
4000
4500
p, MeV/c

PID

Mass reconstruction procedure:

- Exclude particle from event
- Calculate t_0 with N-1 particles
- Calculate TOF of particle that was excluded
- Calculate mass of this particle
- Repeat

PID masses



Summary

1. In events with low multiplicity($4 < N < 15$) Brute Force on average spend 5 ms per event, and Genetic algorithm 0.160 ms.
2. Run time grows slowly as function of multiplicity for Genetic algorithm.
3. Brute Force resolution of t_0 is 28 ps and Genetic Algorithm is 29 ps.
4. PID event efficiency for Brute Force is 66.7% and for Genetic algorithm it is 63.3%.
5. PID track efficiency for Brute Force is 97.2% and for Genetic algorithm is 96.8%.

Outlook

1. Compare DE-inspired algorithm with other types of Genetic algorithms.
2. Optimise Genetic algorithm to decrease run time so it can be used online.
3. Create PID procedure with high efficiency(Will be reported on 7th of September)

Thank you for your attention!