Status of online filter at the SPD straw tracker

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The goals of study

- Development of methods and creation of software for modelling the response of SPD tracker in the trigger-free regime.
- Development of algorithms for reconstruction of events in the trigger-free regime.
- Investigation of reconstruction efficiency and purity on MC simulation data.
- Development of prototype software for event reconstruction at the stage of online data filtering.

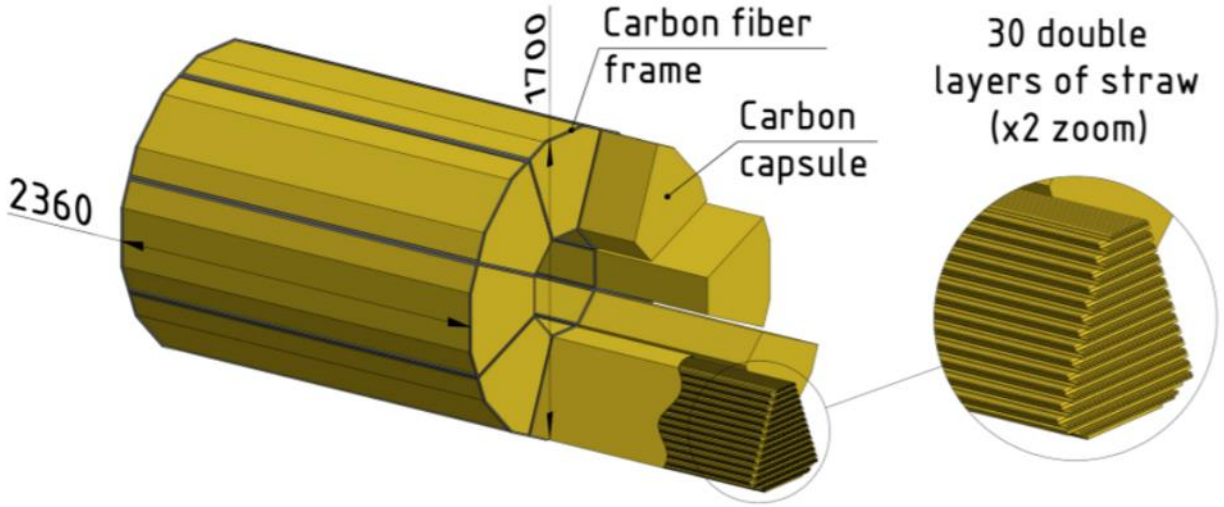


Fig.1. Schematic representation of the straw tracker

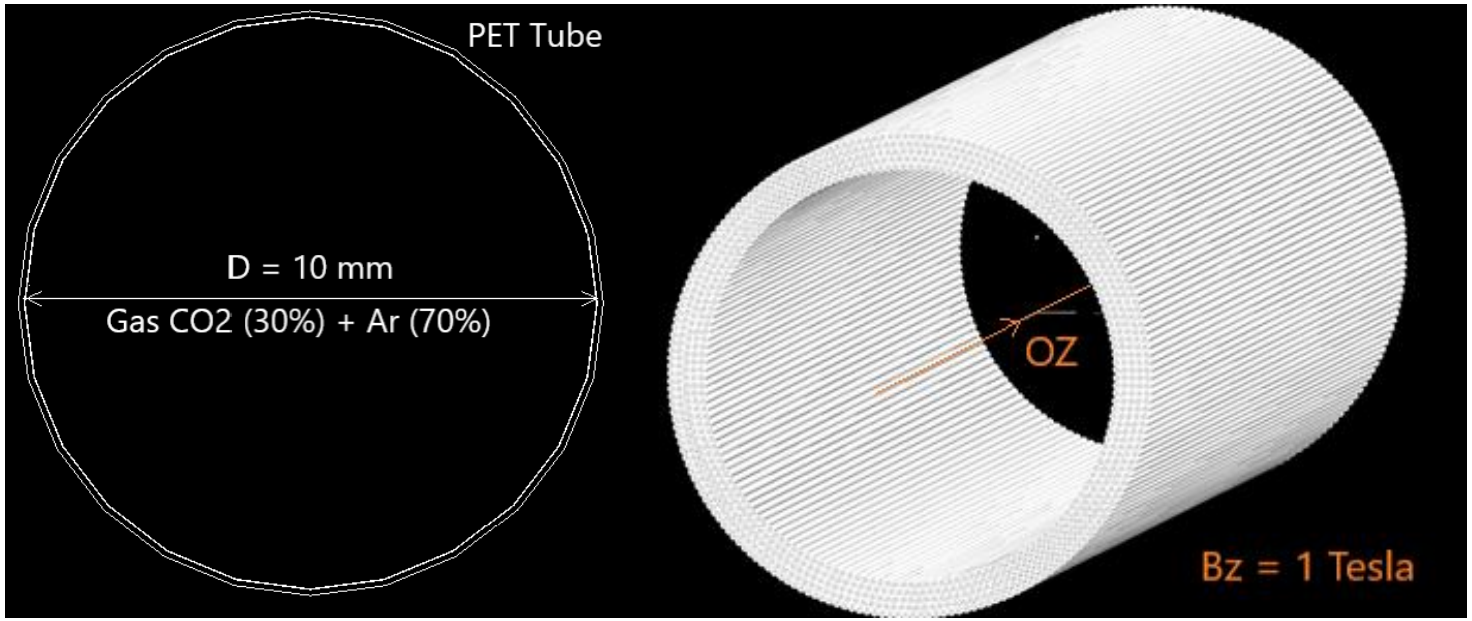


Fig.2. Straw-tube segment model(left), full detector model (5 layers) (right) built by Geant4 from the GeoModel file.

Event Generation

Time slice: 10 μs, proton bunch crossings occur every 76 ns

Primary vertex $(0, 0, Z_{pr})$ where Z_{pr} : $f(Z) = \frac{1}{\sigma\sqrt{\pi}} e^{-\frac{1}{2}\left(\frac{Z-Z_0}{\sigma}\right)}$, σ = 30 cm, Z_0 = 0

Probability of pp beam crossings: $f(k) = \frac{\lambda^k}{k!} e^{-\lambda}$, λ = 0.3

Muons:

- $E = 1\ GeV$,
- uniformly distributed in 4π space,
- number of particles: $f(k) = \frac{\lambda^k}{k!} e^{-\lambda}$, λ = 7

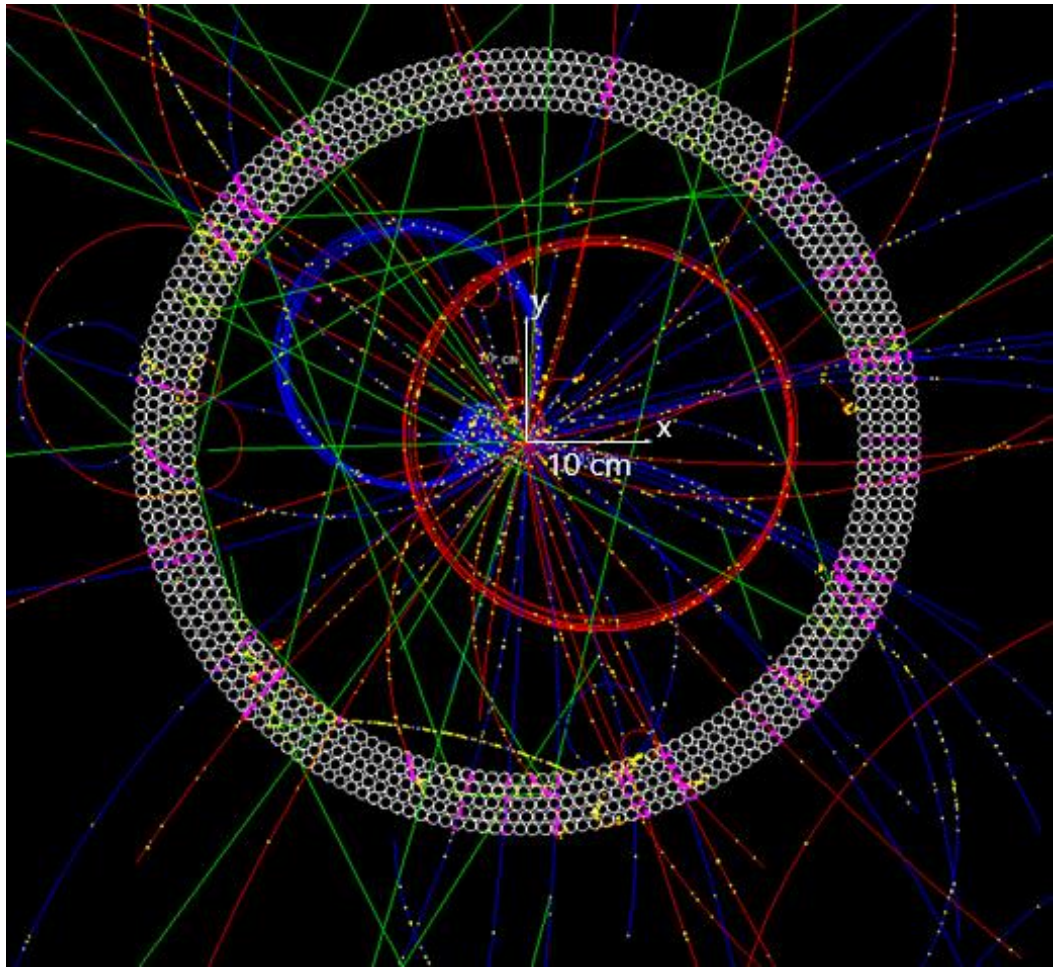
Pythia8:

- $\sqrt{s} = 27\ GeV$,
- softQCD = on

Launch 1 event: Oxy plane.

Pythia8

1 GeV muons



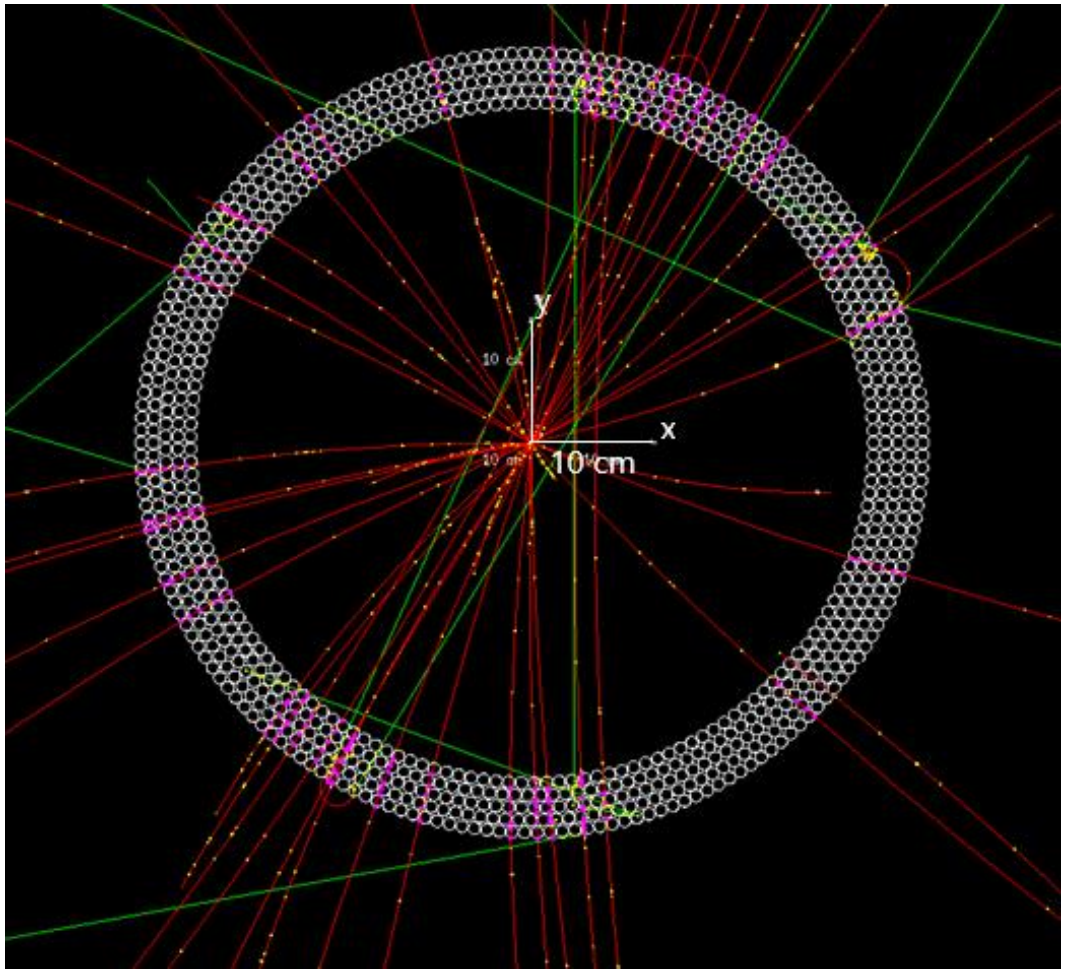
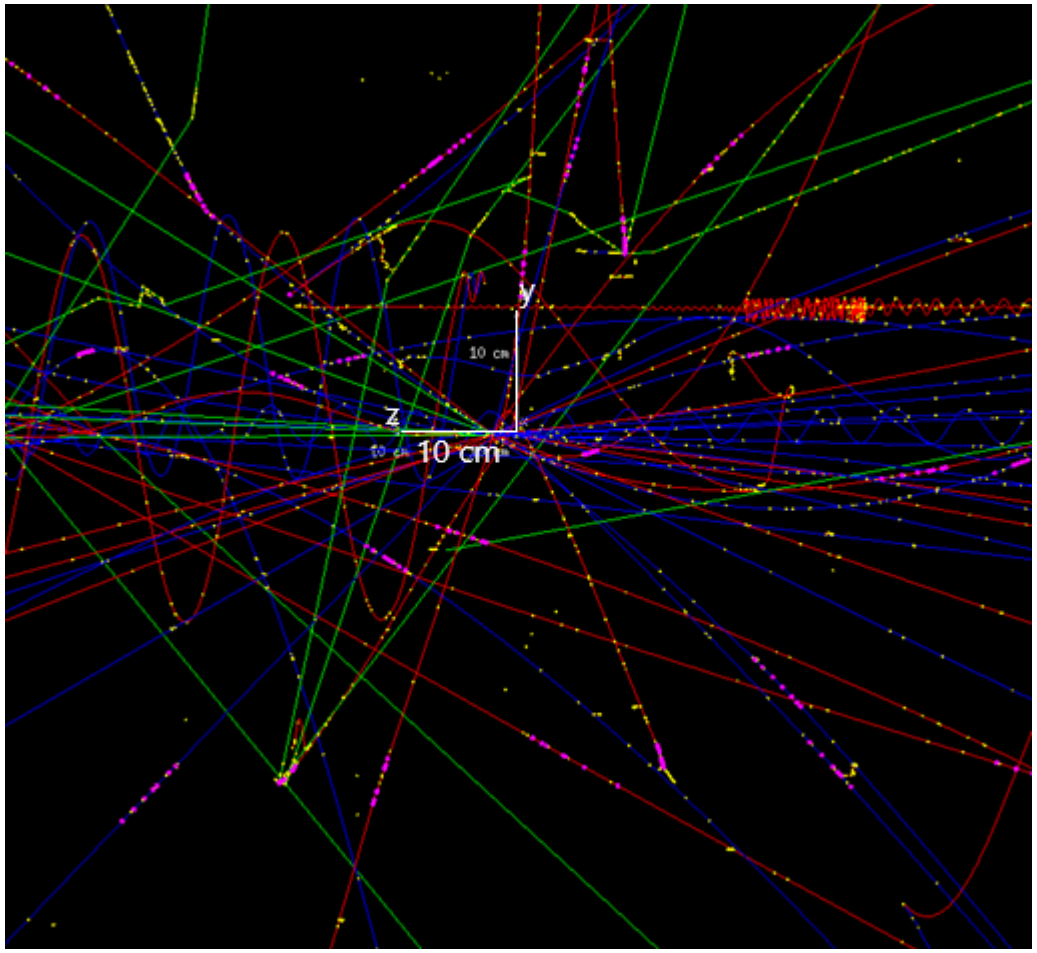


Fig.3. pp-interaction: Pythia8 event (generation) without photons (left), only muons E = 1 GeV (right). Pink dots – Hits (points of energy loss in the sensitive volume).

Launch 1 event: Ozy plane.

Pythia8

1 GeV muons



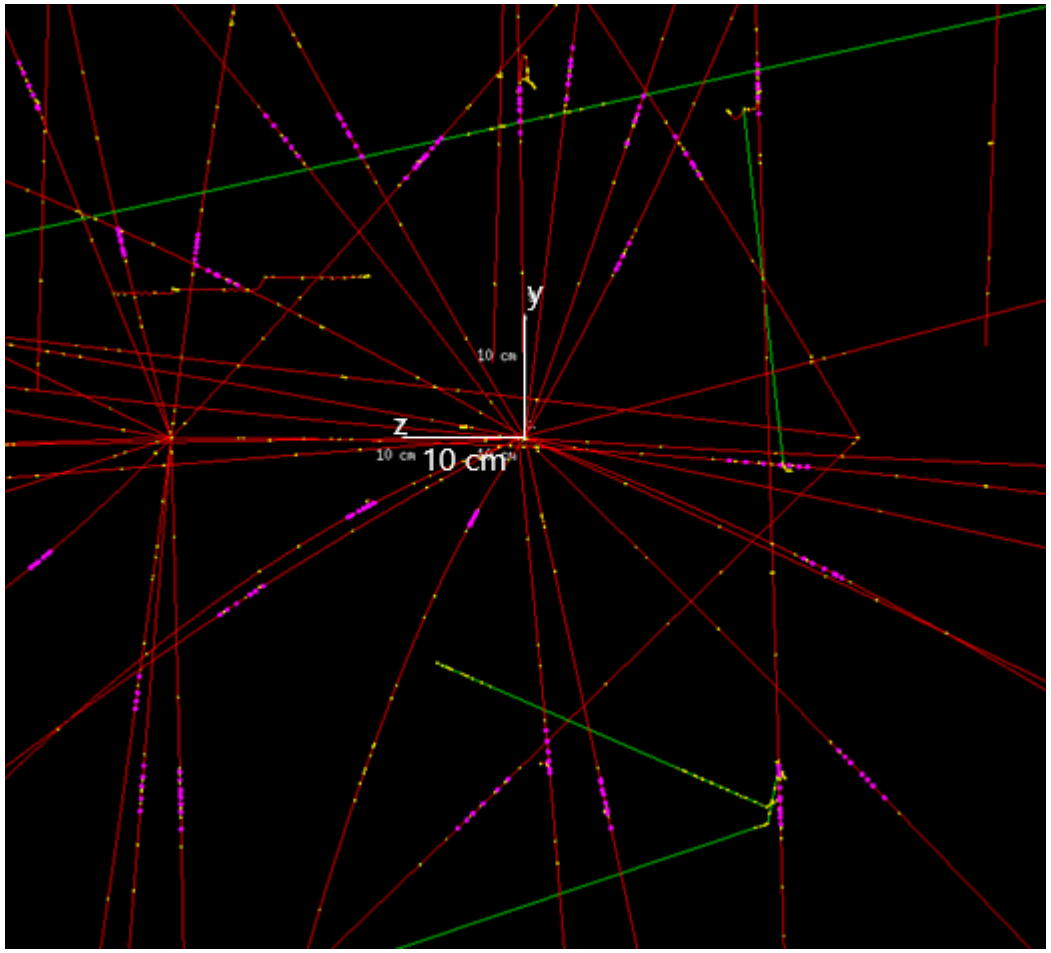


Fig.4. pp-interaction: Pythia8 event (generation) without photons (left), only muons E = 1 GeV (right). Pink dots – Hits (points of energy loss in the sensitive volume).

Selection criteria

Pythia8 establish hit:

- All primary particles except e^-, e^+
- E_k > 100 MeV

Vertex reconstruction

Step 1. Parabola approximation in Oxy

$$y(x) = a_2x^2 + a_1x + a_0$$

Step 2. Calculating the length of the parabolic segment

$$l = \int_0^X \sqrt{1 + (2a_2x + a_1)^2}\, dx =$$

$$= \frac{1}{4a_2}\left(\begin{array}{c}\log\left[\left|\sqrt{((2a_2x + a_1)^2 + 1)} + 2a_2x + a_1\right|\right] + \\ + (2a_2x + a_1)\sqrt{(2a_2x + a_1)^2 + 1}\end{array}\right)$$

Step 3. Linear function approximation

$$z(l) = b_1l - b_0$$

Step 4. Extrapolation to the Z-axis

$$Z_0 = z(0) = b_0$$

Features of approximation

In case of non-monotonic behavior of either x or y it is chosen as a function of another one

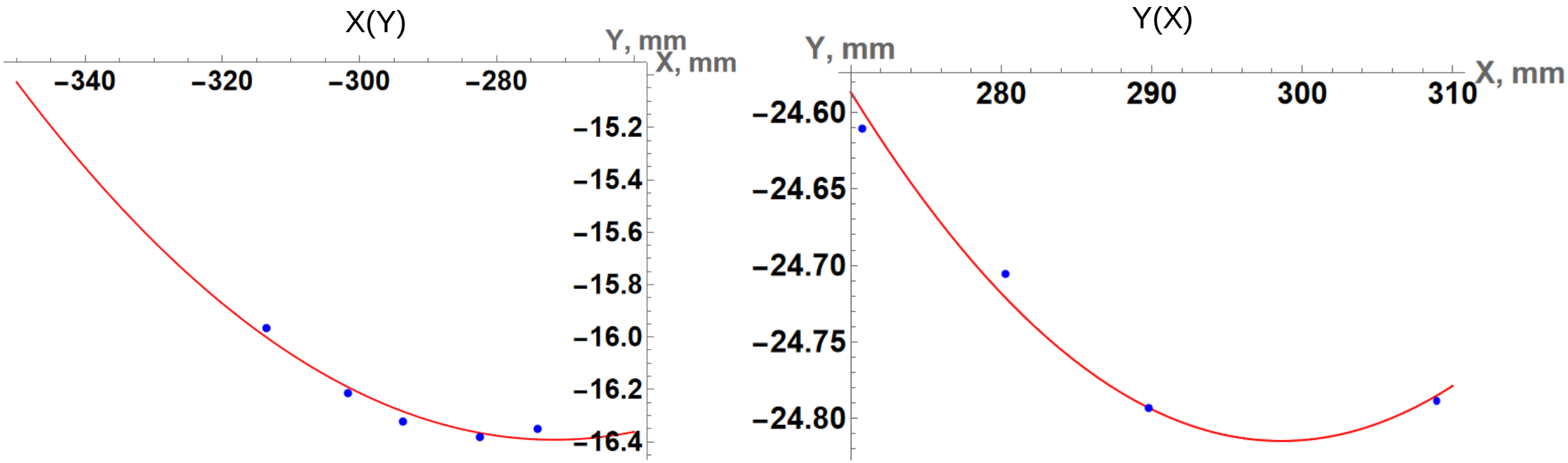


Fig.5. Parabolic approximation choices of track in XOY plane

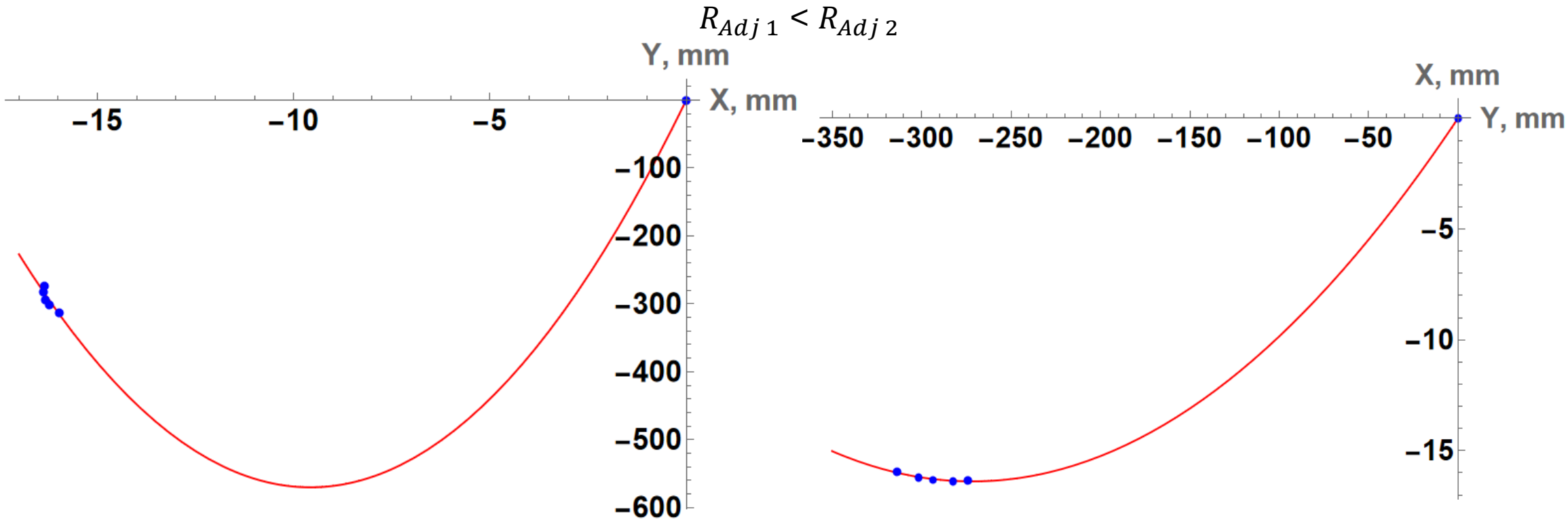


Fig.6. Approximation of the same track Y(X) (left), X(Y) (right).

$$R^2 = 1 - \frac{\sum_i \left(y_i - f(x_i)\right)^2}{\sum_i (y_i - \bar{y})^2} \qquad R^2_{Adj} = 1 - \frac{(1 - R^2)(n-1)}{n - k - 1}$$

k – number of hit points, n – polynomial degree

Track selection after approximation

$$RSS \text{ ("regression residuals squares")} = \sum_{i=1}^{n} \left(z_i - (b_0 + b_1 l_i)\right)^2$$

$RSS = 0.5$ $RSS = 1.0$ $RSS = 1.5$

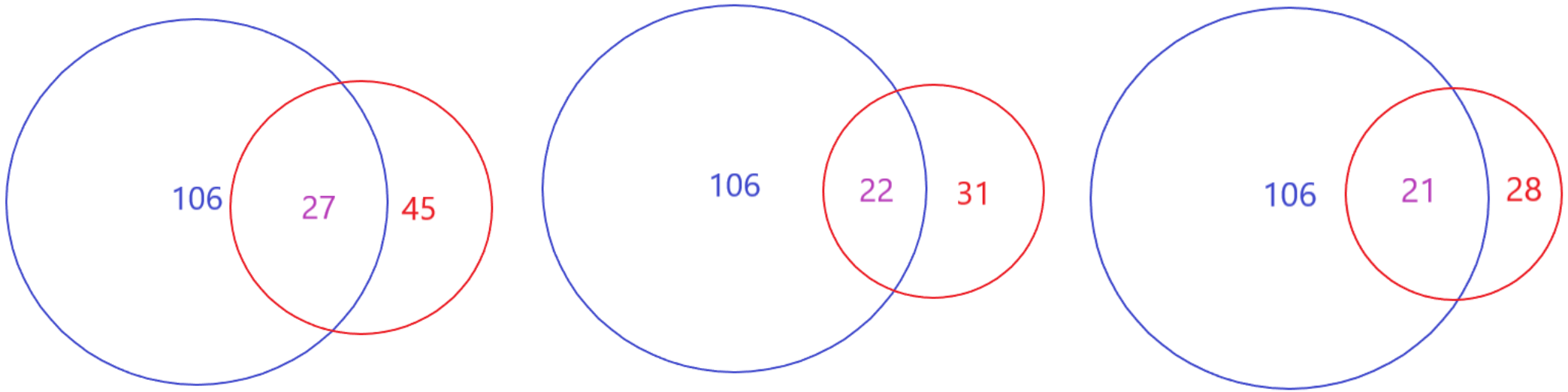
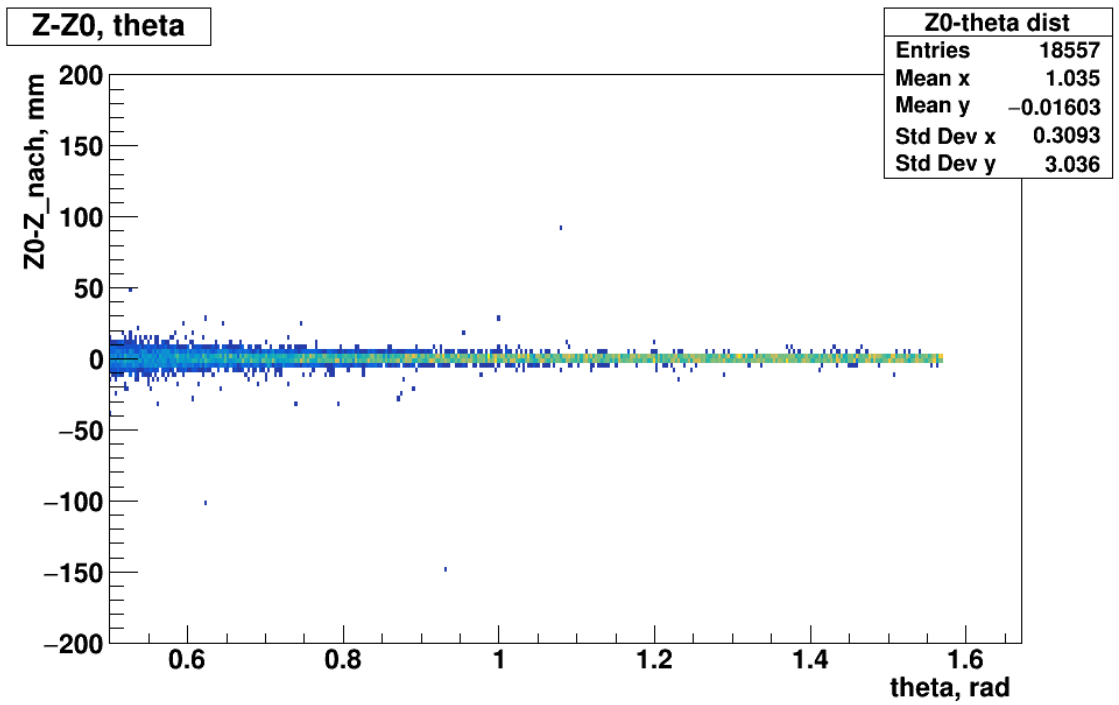


Fig. 7. Blue circle - total number of "bad" tracks ($|Z_{pr} - Z_0| > 1$ cm), red circle - number of dropped tracks by RSS $z(l)$

Muons



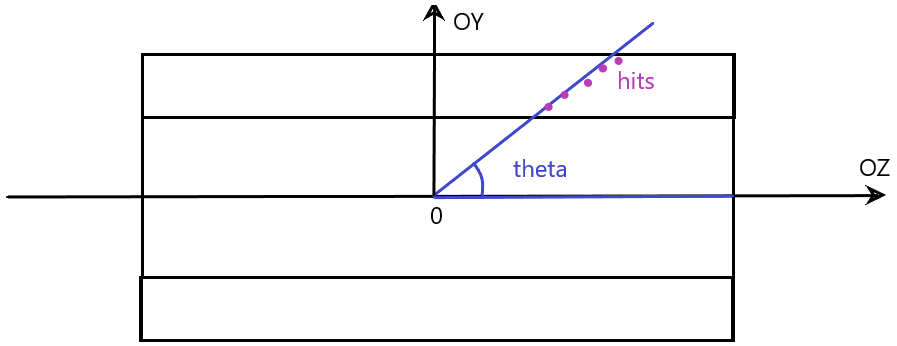


Fig.9. Visualisation of the theta angle

Pythia8

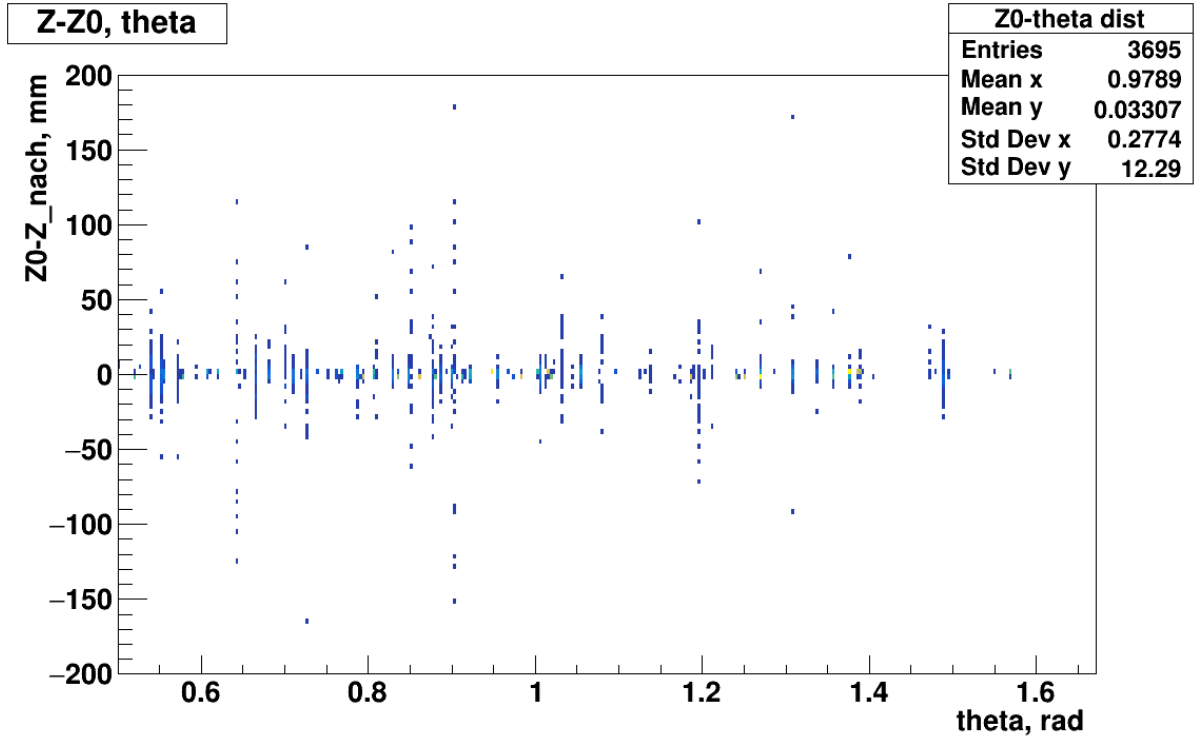
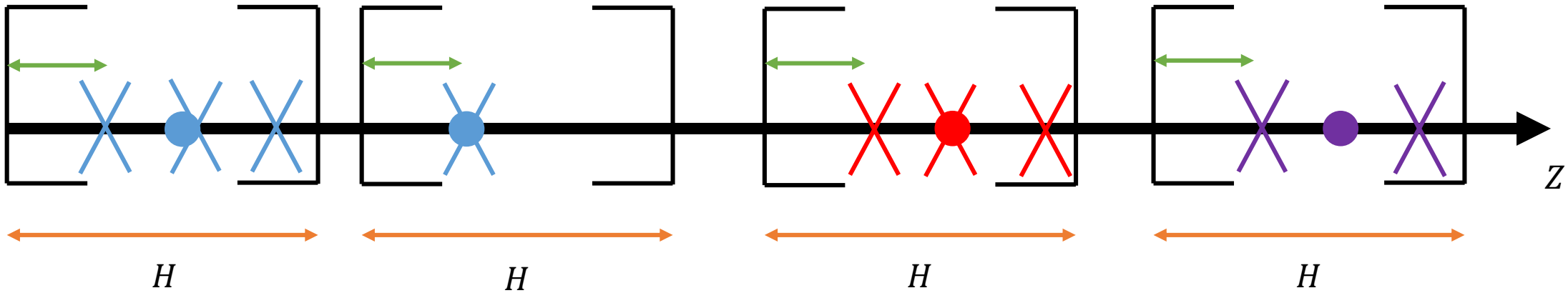


Fig.8. Distribution of the deviation of the reconstructed vertex from the true vertex along the polar angle θ muons (left), Pythia8 (right).

Reconstruction algorithm

- The Z_0 array is sorted in ascending order and divided into intervals
- The average Z_0 within the interval is the reconstructed vertex
- Search for a vertex, Z_{nach} coordinate of which belongs to the interval
- Matching unique TrackID lists

Result: $N_{true} = 3, N_{rec} = 4, N_{right} = 2$



Results

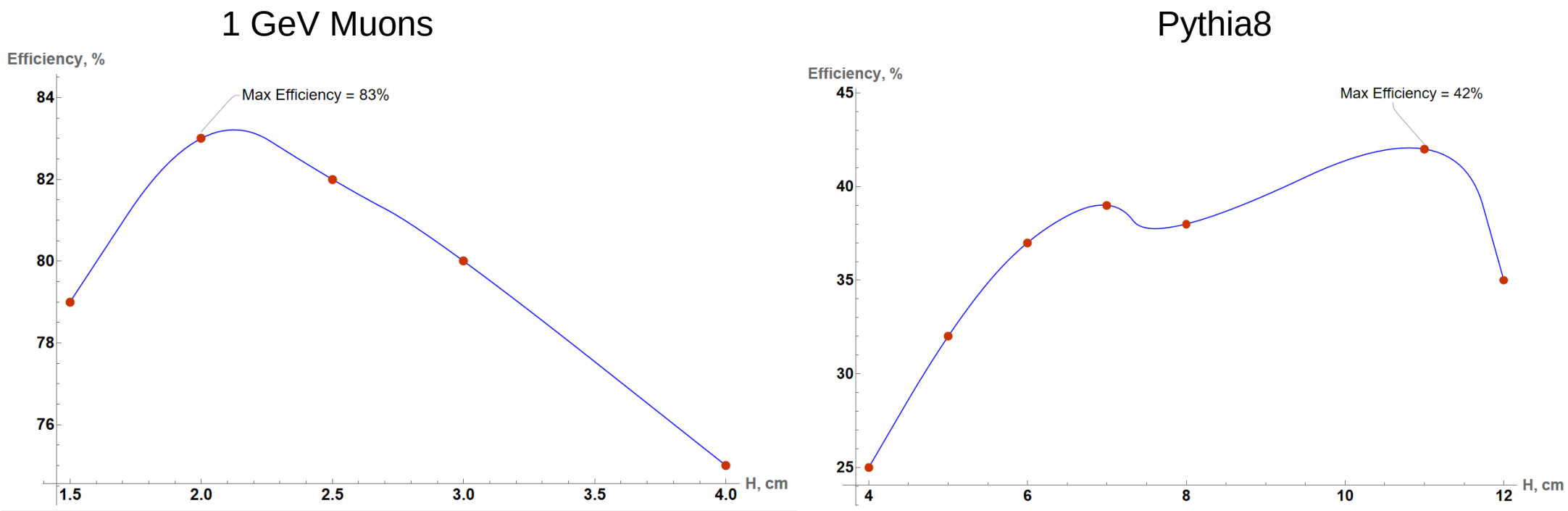


Fig.10. Track reconstruction efficiency as a function of the partitioning step H

- Maximum of reconstruction eff (muons): 83% (H = 2 cm)
- Maximum of reconstruction eff (Pythia8): 42% (H = 11 cm)

Conclusion and TODO

- The simplest and fastest possible algorithm for vertex recovery and clustering is tested
- The recovery efficiency was evaluated for muons and generation with Pythia8
- Kmeans algorithm was tried, but the clustering efficiency under the given conditions is not high enough for further application
- The next step is to improve the algorithm: complicating the rules of track selection, evaluating ‘bad’ tracks, improving the efficiency of clustering