Realistic simulation and hit reconstruction for the Straw Tracker

Ekaterina Mosolova

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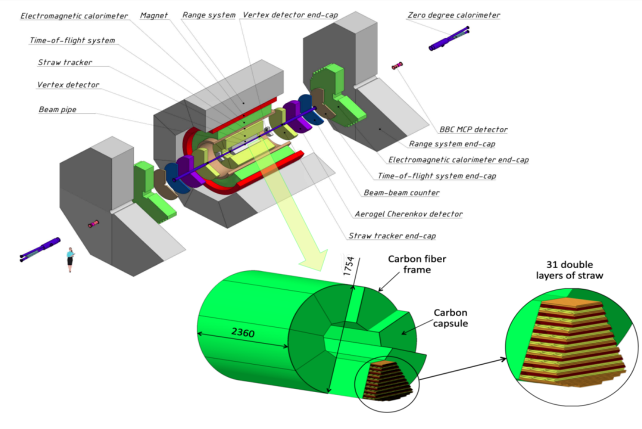
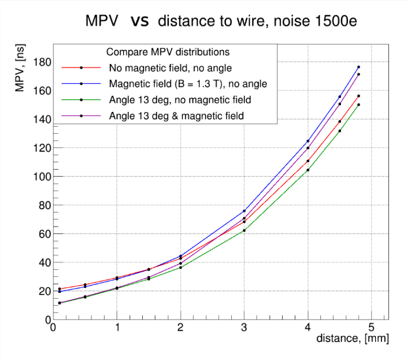
Straw Tracker – the main tracking system of SPD

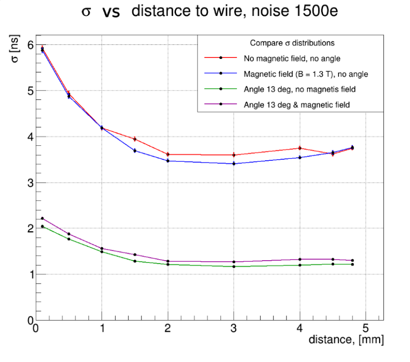


Straw diameter: 10mm thickness 36μm PET

Barrel is made of 8 modules with up to 31 double-layers, with the ZUV orientation $(0^\circ, +3^\circ, -3^\circ)$

2023| Sonya B. parameterized mode and variance of the straw signal registration time distribution by Garfiled++/LTSpice





Straw diameter: 10 mm
Anode diameter: 30 mkm
Gas mixture: Ar+CO2 / 70:30 [%]
Gas gain = 4.5E4
Peaking time 25 ns

Signal amplification 3 mV/fC
Noise is implemented
Threshold 10 mV
VMM3-based readout model
Source: Diploma by Sonya B.

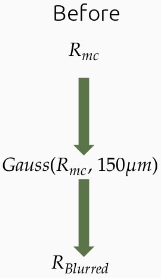
Two versions of SPDROOT are used.

1. Geometry-update-spring 2023: $\sigma(R_{MC})$ is const $= 150\mu$m
2. Development 2024: $\sigma(R_{MC})$ is $0.06506 * exp(-3.26 * R_{MC})$

Before the SPDROOT blurred the MC point

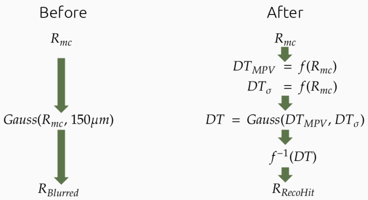
File: `spddata/hits/vnt/SpdMCStrawHit1D.cxx`

- Initially, there was no simulation of the real signal.
- Monte Carlo Point was blurred in an almost infinite while loop with a fixed variance of 150 μm



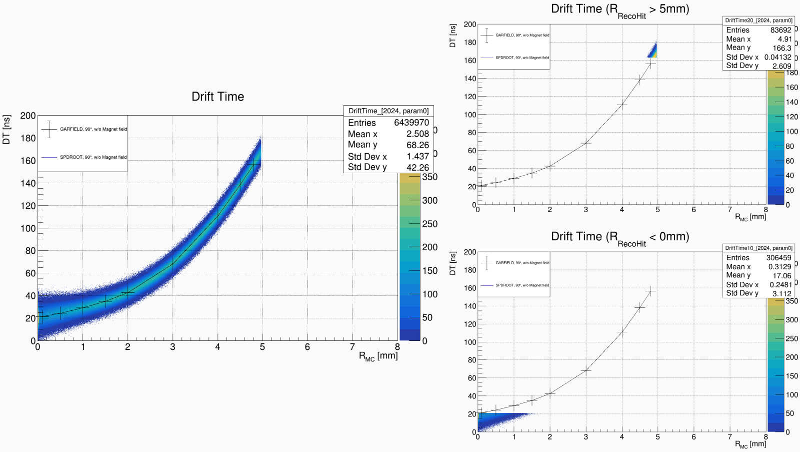
We introduced the realistic signal parameterization (Hit Reconstruction) to SPDROOT

File: `spddata/hits/vnt/SpdMCStrawHit1D.cxx`



- The distribution of the drift time (DT) is provided by Sonya B.
- The DT is calculated for each Monte Carlo point
- Afterward, DT is smeared by $\sigma(DT) = f(R_{MC})$
- Roots of the inverse function (parabola) provide $R_{RecoHit}$

4% of hits are lost near the anode
Less than 1% is reconstructed outside the tube

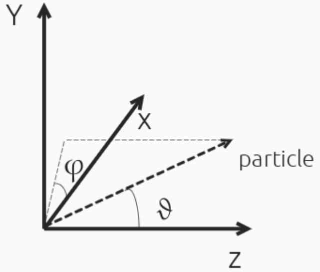


Therefore, the accuracy of hits position estimation is an object of utter importance.

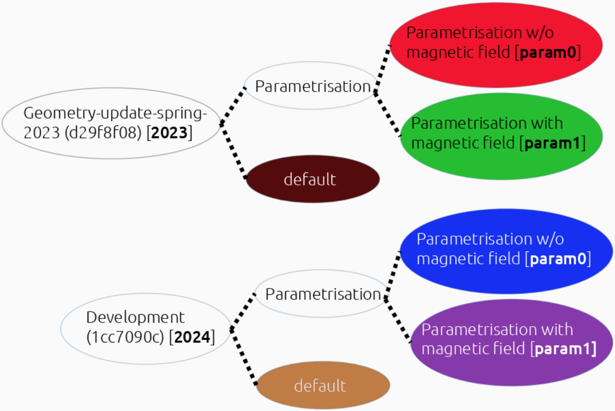
Simulation settings

- **Patricle:** muon (μ, pdg $= 13$)
- **Energy:** 1GeV
- **Generator:** SpdIsotropicGenerator
  - θ**:** is angle between Z-axis and beam (**now we used** $\theta = 90°$)
  - ϕ**:** From 0° to 360°

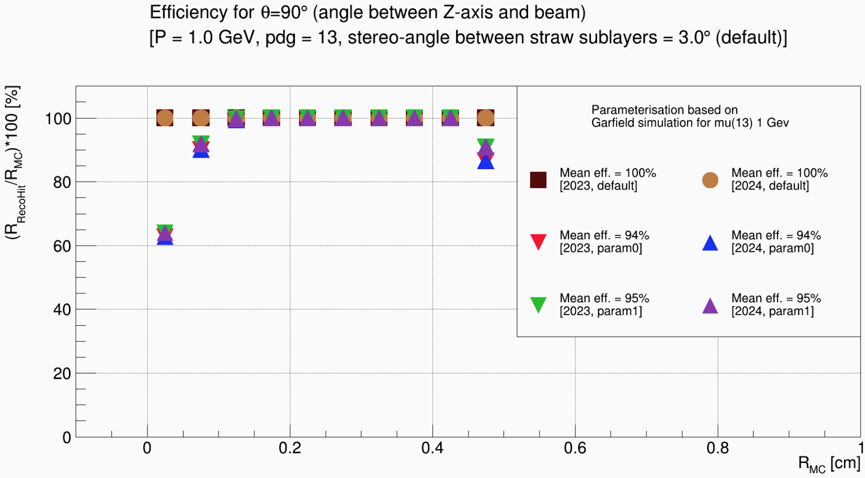
- **Detectors:** Only Straw Barrel
- **Vertex:** Off
- **Magnet:** field_full1_8.bin
- **Events:** 100k (for $\theta = 90°$)



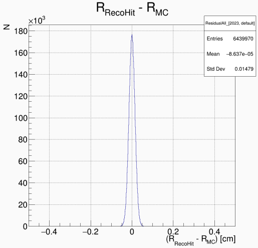
The comparision includes simuls by two versions of SPDROOT w/o magnetic field (param0) and w/ magnetic field 1.3T (param1)

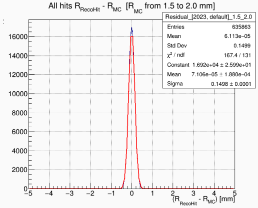


Reconstruction efficiencies for param0/1 difference are the same

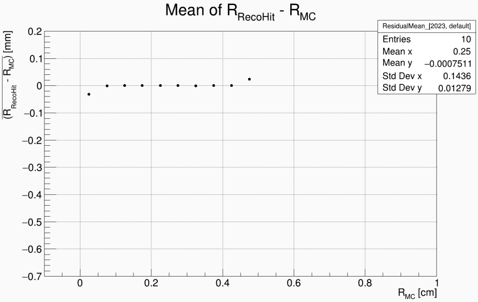


Distributions of residuals over areas R_{mc} We are considering 10 ranges [mm]: [0.0–0.5), [0.5–1.0), [1.5–2.0), etc.





This is default version 2023

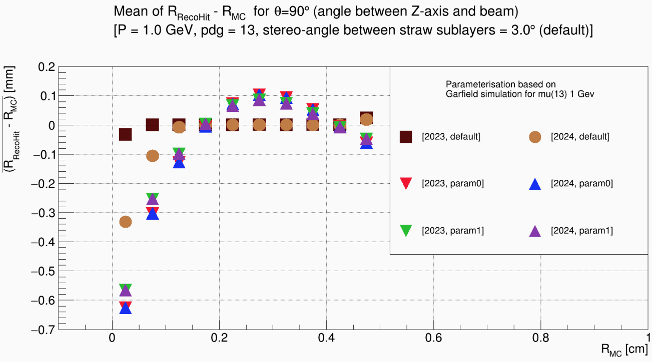


Mean of $R_{RecoHit} - R_{MC}$

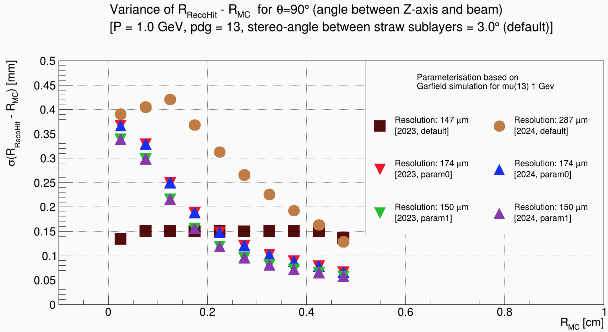
$R_{RecoHit}$ for defaul version is $gRandom \to Gaus(R_{MC}, \sigma(R_{MC}))$

$R_{RecoHit}$ for param version is calculated from smearing function

In Development2024 version (defaut) toy parameterization was added

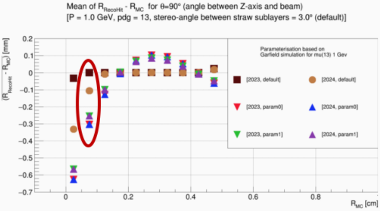


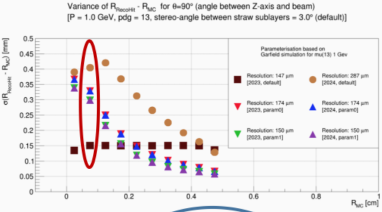
Variance of $R_{MC} - R_{RecoHit}$

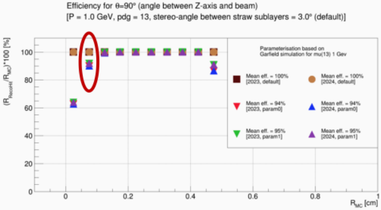


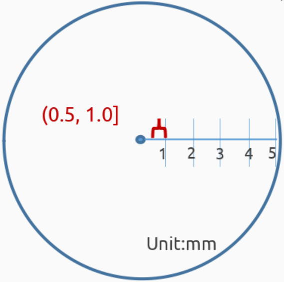
1. $\sigma(R_{MC})$ for 2023 defaul version is const $= 150\mu m$
2. $\sigma(R_{MC})$ for 2024 defaul version is $0.06506 * exp(-3.26 * R_{MC})$
3. $\sigma(R_{MC})$ for 2023/4 param0/1 calculated with SmearHit func.

Let's look at interesting areas: from 0.5 to 1.0;

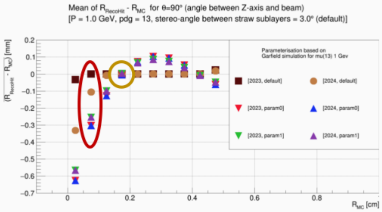


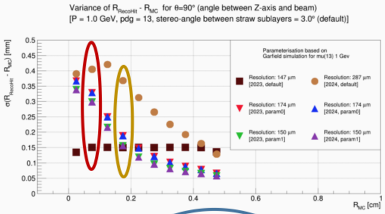


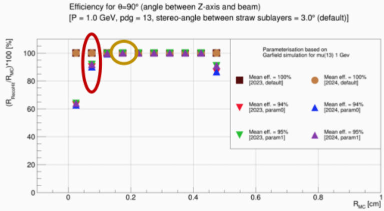


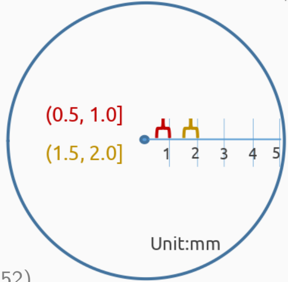


Let’s look at interesting areas: from 0.5 to 1.0; from 1.5 to 2.0

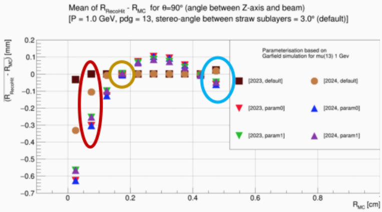


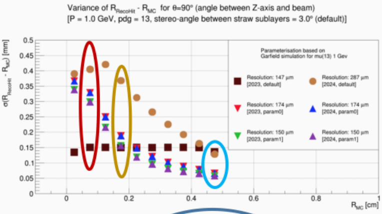


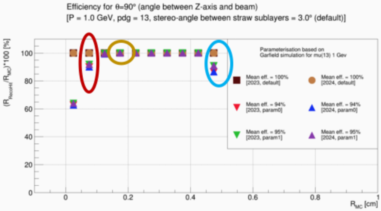


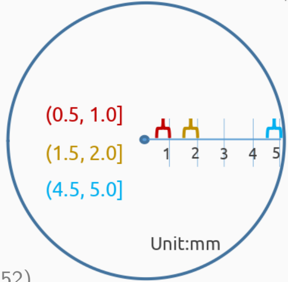


Let's look at interesting areas: from 0.5 to 1.0; from 1.5 to 2.0 and from 4.5 to 5.0 mm

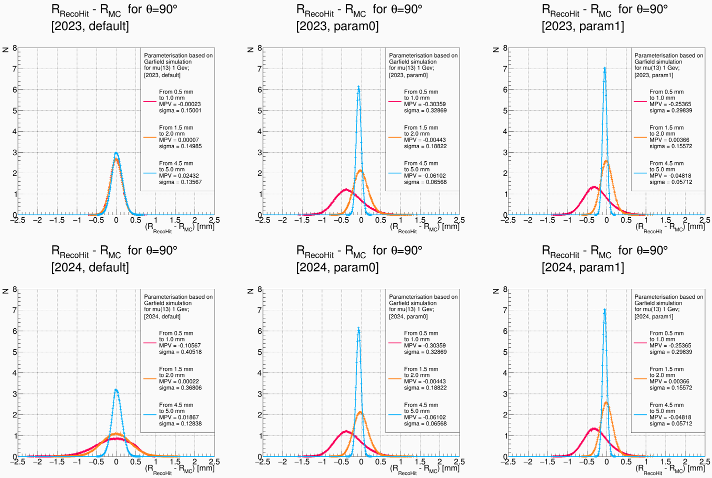








Residual for three selected point



Summary

- Parameterization for signals was conducted by Sonya B. both cases accounting for the magnetic field or neglect.
- Differences in reconstruction accuracy were observed with and without a magnetic field, prompting an investigation into their significance. For both parametrization we used magnetic field in SPDROOT's simulation.
- A realistic parameterization is introduced, incorporating hit reconstruction as the first step toward enhanced accuracy.
- We created first version hit's reconstruction. This stage is the first on the way to implementing realistic parameterization.
- A certain level of inaccuracy – residual error – exists in the reconstruction. This is a systematic error that can be calibrated. In reality, we will have bayes.
- Resolution is dependent on the radius.
- A resolution of 150 μm can be achieved.
- Results for additional beam angles (26 and 40 degrees) will be presented next week (18 sep/ SPD Physics & MC Meeting).

Thank you for your attention!

bckp

Efficiency: details

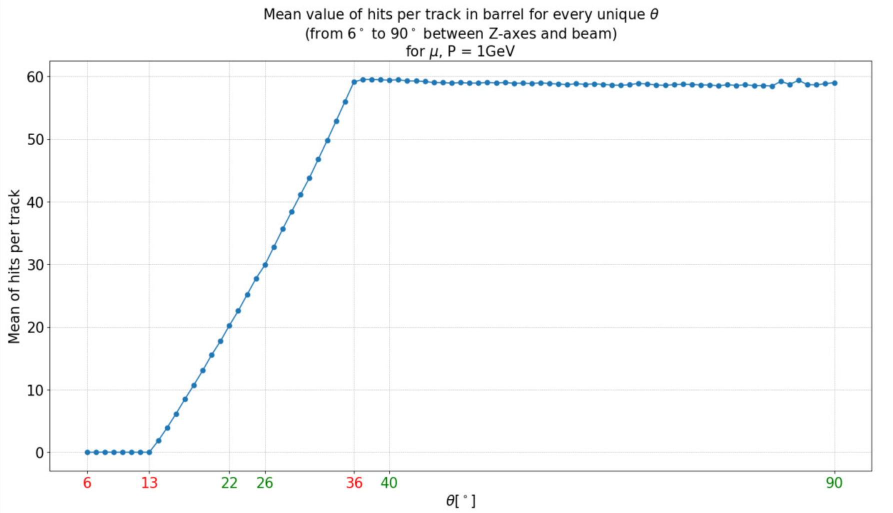
To calculate the efficiency in the range of R_{mc} from 0.0 to 0.5 cm, the total number of R_{mc} was counted, then it was calculated how many of these R_{mc} were reconstructed:

$Eff = \frac{N_{RecoHit}}{N_{totalOfHits}}$

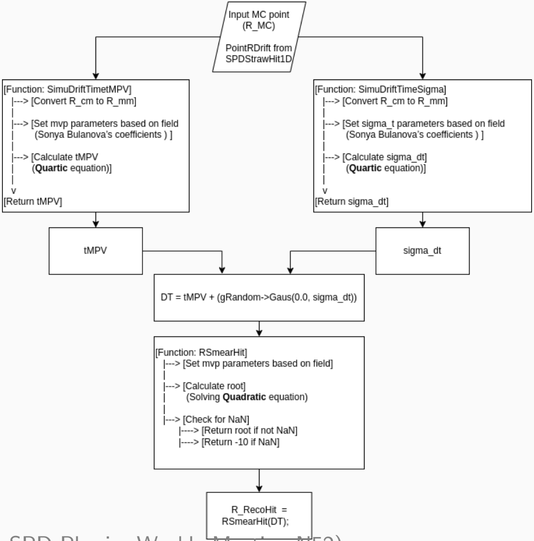
The efficiency of the parameterized version is lower than in the default version.

No reco in default.

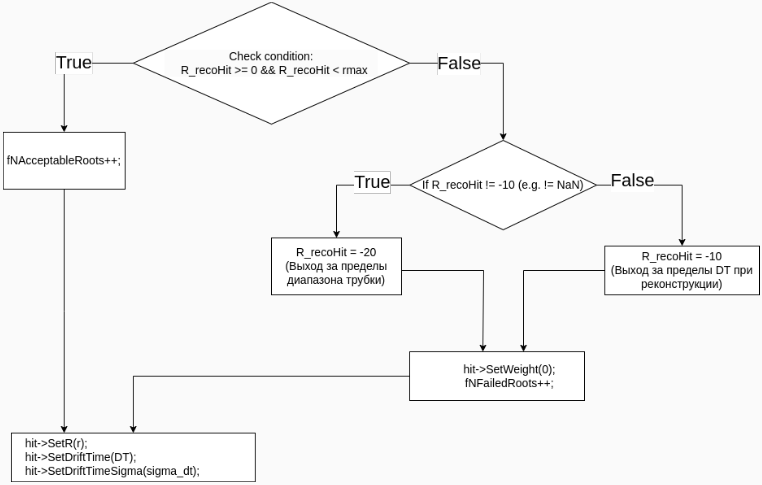
Mean value of hits per track in barrel



1. Drift time (DT) from R_{mc} and Garfield's simulations
2. $R_{RecoHit}$ from DT

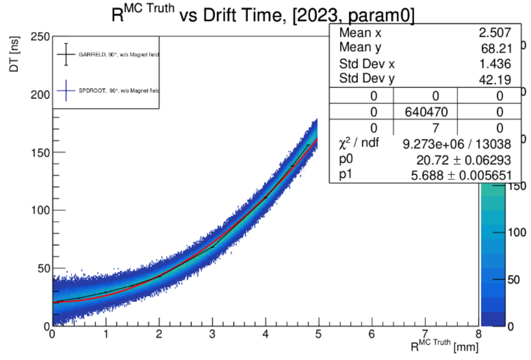


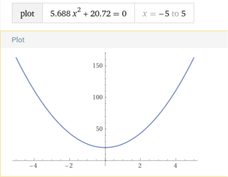
Create hit position in param0/1

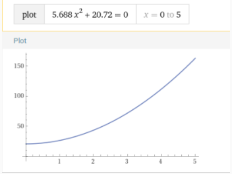


Create hit position in default

Coeff for quadratic equation (param0)



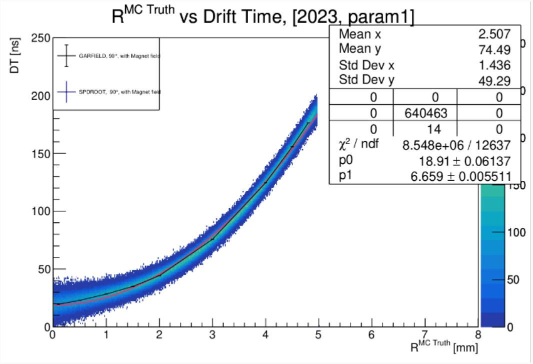




Derivative

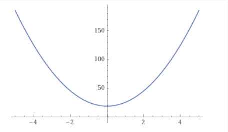
$$\frac{d}{dx}\left(5.688\,x^2 + 20.72\right) = 11.376\,x$$

Coeff for quadratic equation (param1)



plot | $6.659\,x^2 + 18.91 = 0\,x$ | $x = -5$ to 5

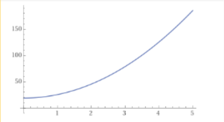
Plot



Input interpretation

plot | $6.659\,x^2 + 18.91 = 0$ | $x = 0$ to 5

Plot



Derivative

$$\frac{d}{dx}(6.659\,x^2 + 18.91) = 13.318\,x$$