Realistic simulation and hit reconstruction for the Straw Tracker

Ekaterina Mosolova

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Straw Tracker – the main tracking system of SPD



 $\begin{array}{l} \mbox{Straw diameter: 10mm thickness 36} \mu m \mbox{PET} \\ \mbox{Barrel is made of 8 modules with up to 31 double-layers,} \\ \mbox{with the ZUV orientation } (0^\circ, +3^\circ, -3^\circ) \end{array}$

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

з



 σ vs distance to wire, noise 1500e

Compare a distributions

No magnetic field, no angle

(agnetic field (B = 1.3 T), no angle

distance. [mm]

ingle 13 deg, no magnetis field

Angle 13 deg & magnetic field

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

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

- 1. Geometry-update-spring 2023: $\sigma(R_{MC})$ is const = 150 μ 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. Mosolova E. (PNPI | SPD Physics Weekly Meeting N52)

Simulation settings

- Patricle: muon (μ , pdg = 13)
- Energy: 1GeV
- Generator: SpdIsotropicGenerator
 - θ : is angle between Z-axis and beam (now we used $\theta = 90^{\circ}$)
 - *φ*: From 0° to 360°
- Detectors: Only Straw Barrel • Vertex: Off • Magnet: field_full1_8.bin • Events: 100k (for $\theta = 90^{\circ}$)

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

Efficiency for θ =90° (angle between Z-axis and beam) IP = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)]



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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.



Mean of $R_{RecoHit} - R_{MC}$ $R_{RecoHit}$ for defaul version is $gRandom \rightarrow Gaus(R_{MC}, \sigma(R_{MC}))$ $R_{RecoHit}$ for param version is calculated from smearing function In Development2024 version (defaut) toy parameterization was added

> Mean of $R_{\text{RecoHit}} - R_{\text{MC}}$ for θ =90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)]



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



Variance of $R_{\text{RecoHit}} \cdot R_{\text{MC}}$ for θ =90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)]

1. $\sigma(R_{MC})$ for 2023 defaul version is const = 150μ 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;



Mean of R_{Receille} - R_{MC} for 0=90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)] Variance of $R_{\text{PecoH1}} - R_{\text{MC}}$ for θ =90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)]

> Parameterisation based on Gartield simulation for mu(13) 1 Gev

> > .

0.8

Resolution: 287 um

Resolution: 174 um

A Resolution: 150 μm [2024, param1]

3 4 5

R_{an} [cm]

(2024, default)

[2024, param0]

Let's look at interesting areas: from 0.5 to 1.0; from 1.5 to 2.0 $\ensuremath{$

[mm] (June - Rucc) [mm] 0.2 0.5 Parameterisation based on Gartield simulation for mul13) 1 Gev Parameterisation based on Garfield simulation for mul13) 1 Gev 0.45 0.4 Resolution: 287 µm solution: 147 µm [2023, default] (2024, default) (2023, detault) 12024, default 0.35 -0.1 0.3 Resolution: 174 µm -0.2 12023. param04 🔺 (2024, param0) (2023, param0) [2024, param0] 0.25 -0.3 0.2 Resolution: 150 um Resolution: 150 um • [2023, param1] A [2024, param1] [2023, param1] [2024, param1] -0.4 0.15 -0.5 0.1 -0.6 0.05 -0.7 0.6 0.8 0.2 0.6 0.8 R_{MC} [cm] R_{MC} [cm] Efficiency for 0=90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)] Rue)"100 [%] emeterisation based on feld simulation for mu(13) 1 Gev 100 ¥ Mean eff. = 10 (2023, default) Mean eff. = 1009 (2024, default) 80 . (0.5, 1.0]Mean eff. - 941 (2023, paramol Mean eff. - 94% (2024, param0) 60 (1.5, 2.0]5 4 Mean eff. = 957 [2023, peram1] Maan eff. = 95% [2024, param1] 40 20 0.8 R_{MC} [cm] Unit:mm Mosolova E. (PNPI | SPD Physics Weekly Meeting N52)

Mean of $R_{\text{Recottle}} \cdot R_{\text{MC}}$ for θ =90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)]



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

Variance of R_{Bacoldi} - R_{MC} for 0=90° (angle between Z-axis and beam)

[P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)] 0.2 0.5 [mm] (June - Hand) Parameterisation based on Garfield simulation for mul13) 1 Gev Parameterisation based on Garfield simulation for mu(13) 1 Gev 0.45 0.4 solution: 147 µm Resolution: 287 µm [2023, default] (2024, default) (2023, detault 12024, default 0.35 -0.1 0.3 -0.2 12023. param04 I2024. param08 (2023, param0) [2024, param0] 0.25 -0.3 0.2 Resolution: 150 µm Resolution: 150 um [2023, param1] A [2024, param1] [2023, param1] -0.4 0.15 -0.5 0.1 -0.6 0.05 -0.7 0.6 0.8 0.6 0.8 R_{MC} [cm] R_{MC} [cm] Efficiency for 0=90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)] R.w.)*100 [%] Parameterisation based on Garfield simulation for mu(13) 1 Gen 100 Aean elf. = 100% 2023. detaulti 80 . Mean eff. = 100* (2024. default) (0.5, 1.0] Mean eff. - 94% (2023, paramol Mean eff. - 94% (2024, param0) 60 (1.5, 2.0]5 2 4 Mean eff. = 951 (2023, param1) Maan eff. = 95% [2024, param1] 40 (4.5, 5.0]20 0.8 R_{MC} [cm] Unit:mm Mosolova E. (PNPI | SPD Physics Weekly Meeting N52)

Mean of R_{Bernite} - R_{MC} for e=90° (angle between Z-axis and beam) [P = 1.0 GeV, pdg = 13, stereo-angle between straw sublayers = 3.0° (default)]

16

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.
- $\bullet\,$ 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

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



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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)



Coeff for quadratic equation (param1)

