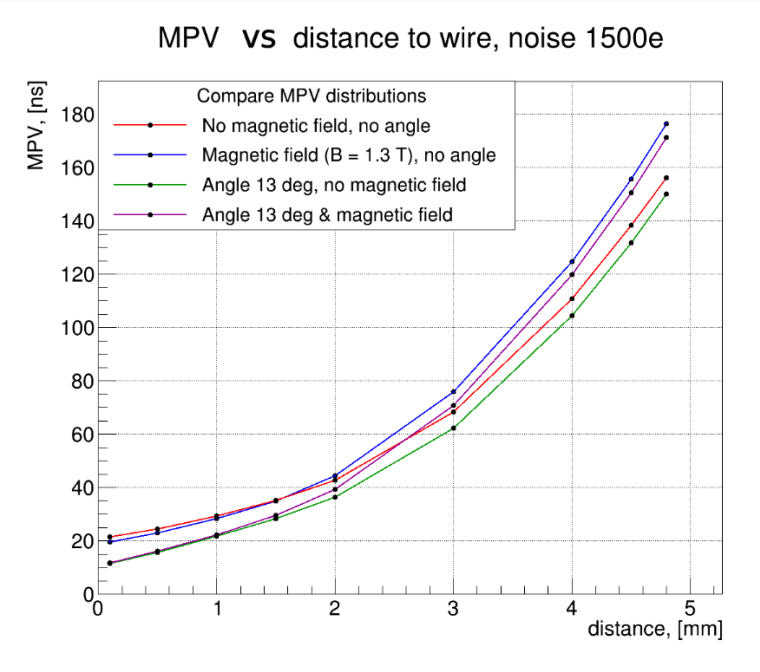
Update on Realistic Simulation and Hit Reconstruction for the Straw Tracker

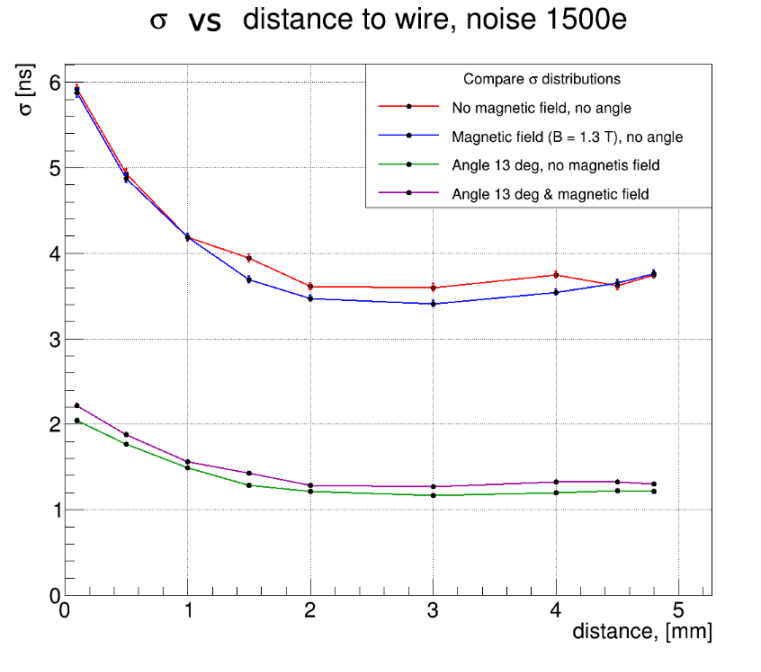
E. Mosolova, V. Bautin, S. Bulanova, A. Mukhamejanova
Supervisors: Katerina Kuznetsova, Temur Enik, Viktor Kim

April 16, 2025

PNPI | 49 SPD Physics and MC Meeting

2023| Sonya B. & Vitalii B. parameterized mean value and resolution of the straw signal time using Garfield++/LTSpice modeling





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

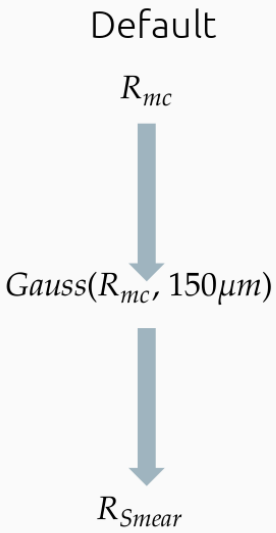
Noise is implemented, Threshold 10 mV

VMM3-based readout

model by Vitalii B.

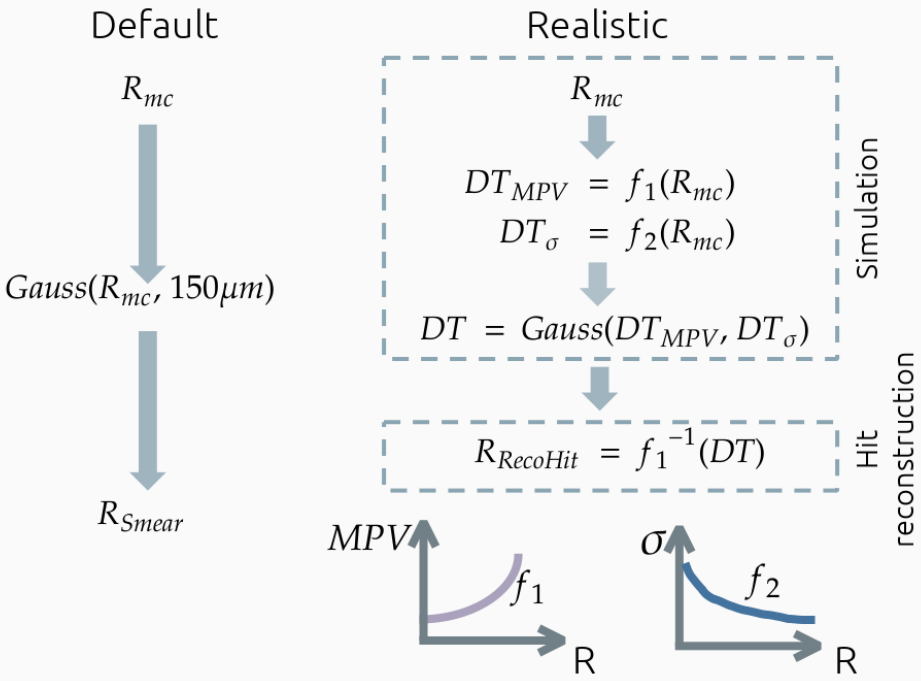
Source: Diploma by Sonya B.

By default SPDROOT accounts for the final straw resolution by smearing the MC hit coordinates



- Monte Carlo Point was smearing in an almost infinite while loop with a fixed variance of 150 μm

The realistic signal parameterization and hit reconstruction

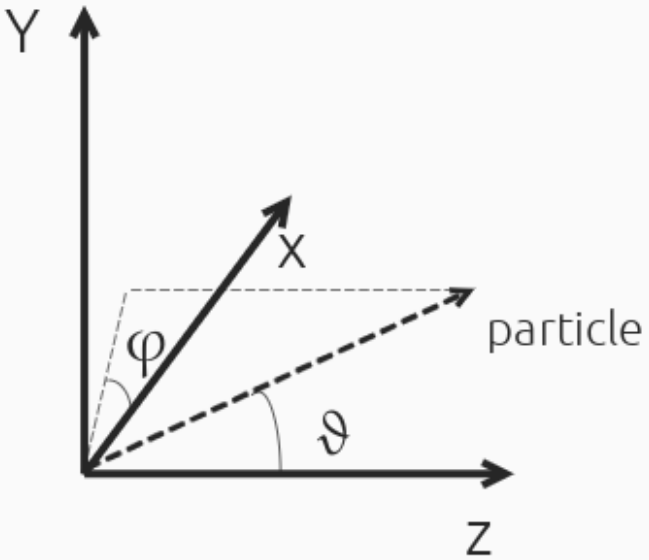


- The distribution of the drift time (DT) is provided by Sonya B. & Vitalii B.
- The DT is calculated for each Monte Carlo point
- Afterward, DT is smeared by $\sigma(DT) = f(R_{MC})$
- Roots of the inverse function provide $R_{RecoHit}$

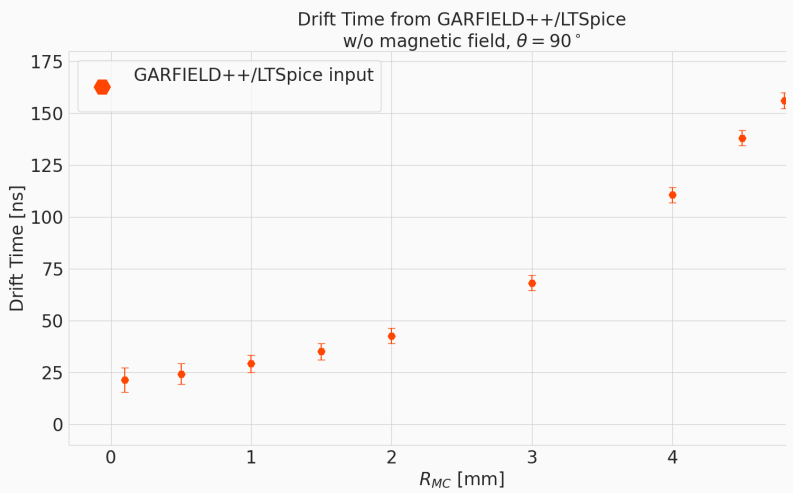
See my slides from VIII SPD Collaboration Meeting 8 Nov. 2024

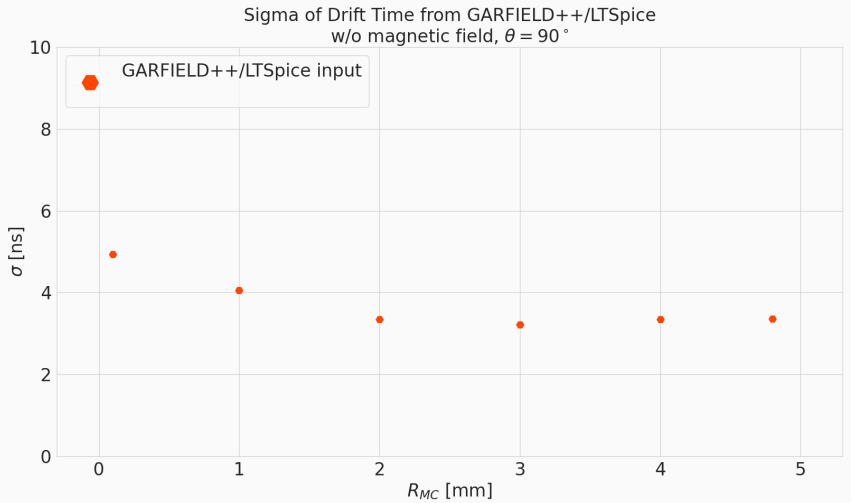
Simulation settings | git b63cf4

- **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:** w/o magnetic field
- **Events:**
  10k

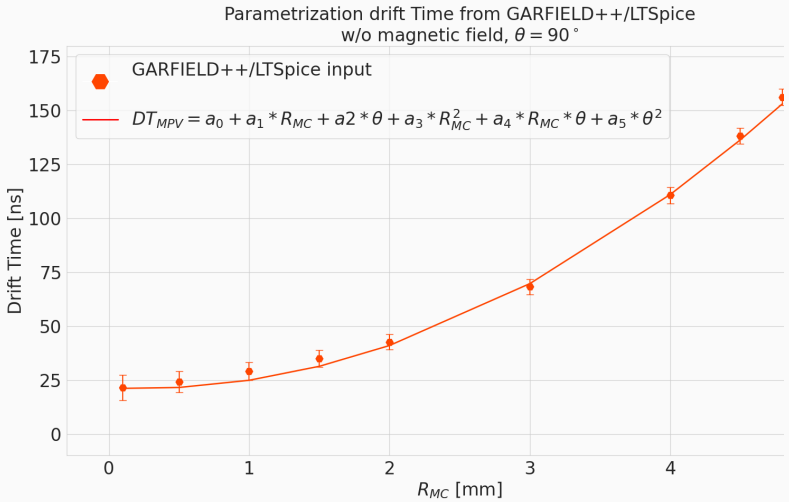


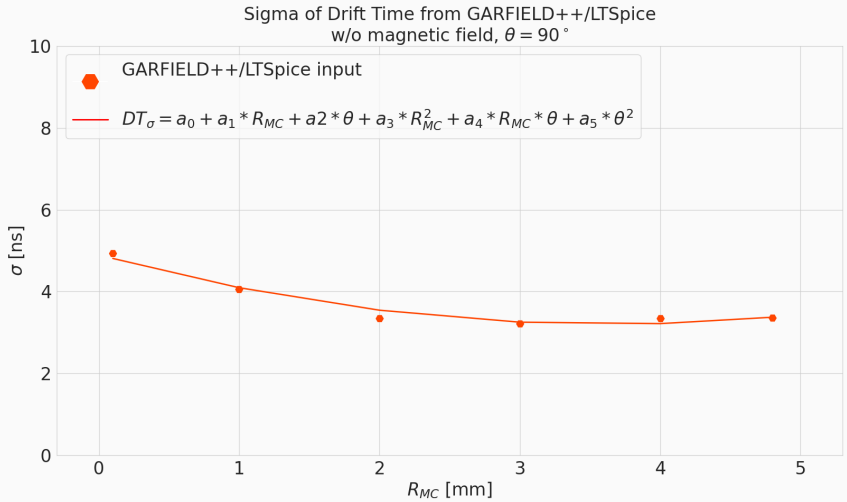
The distribution of the drift time (DT) is provided by Sonya B. Vitalii B.



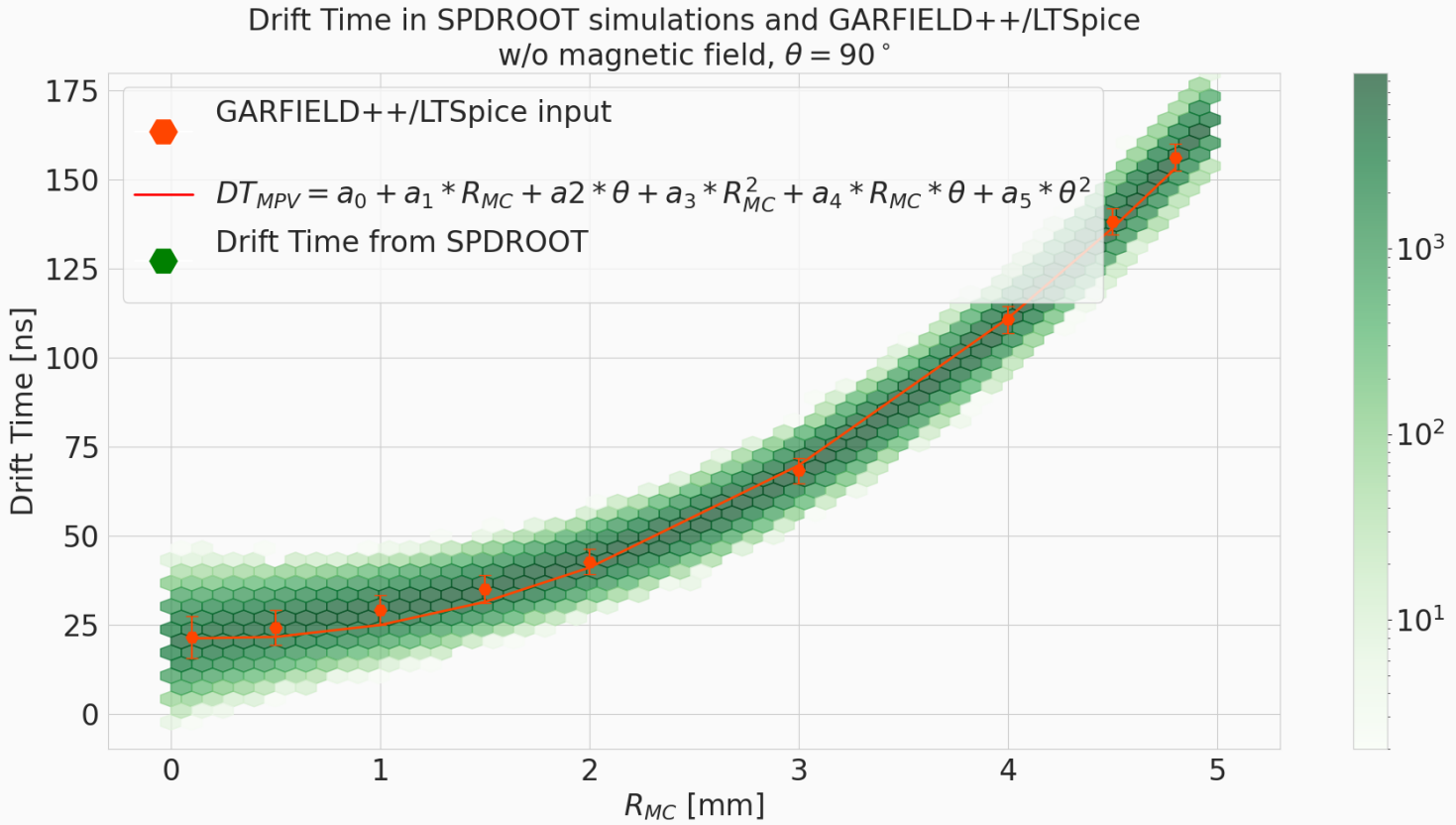


Parametrization DT using least squares

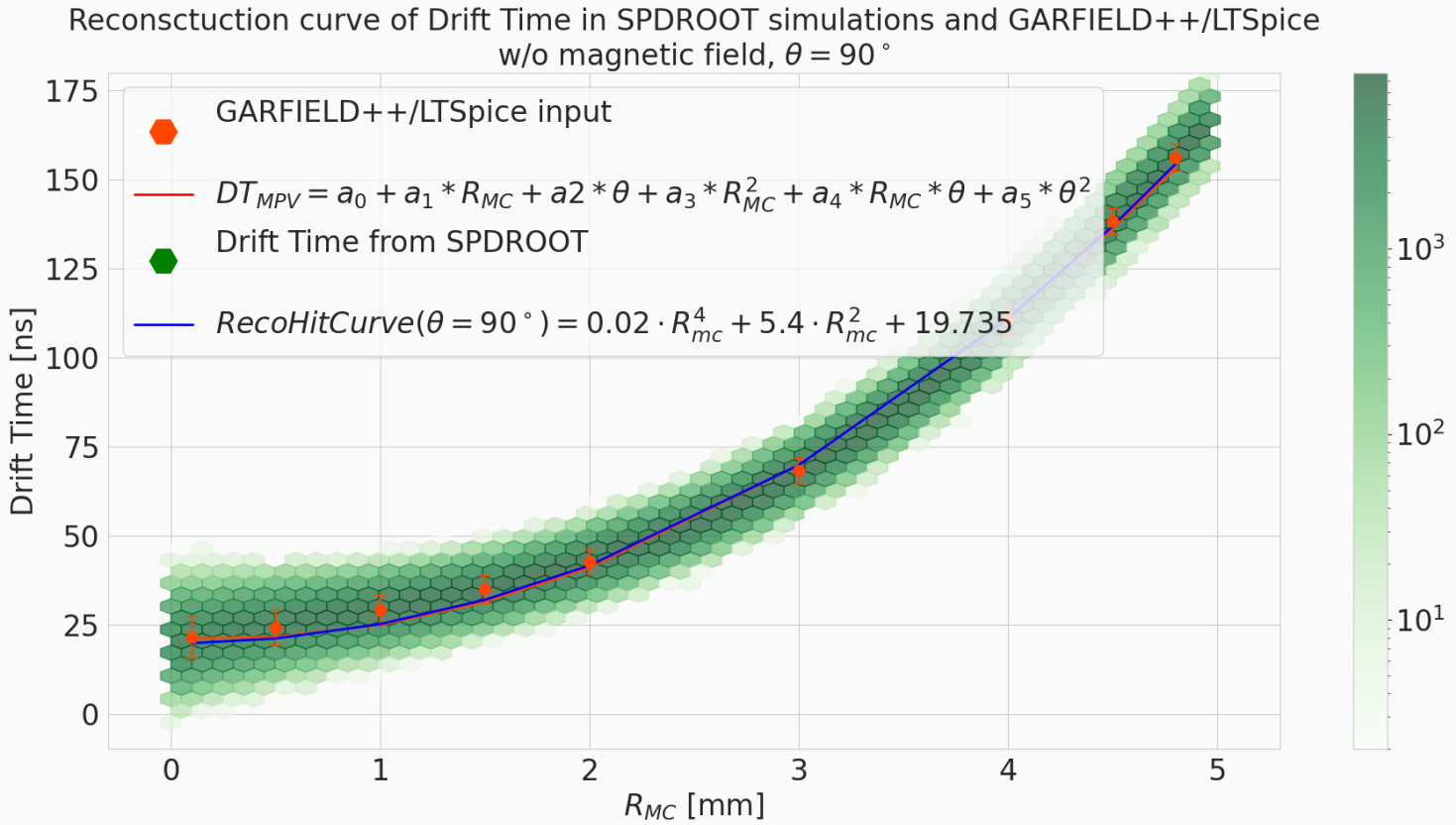




The DT is calculated for each Monte Carlo point and smeared



Calibration curve for hit reconstruction

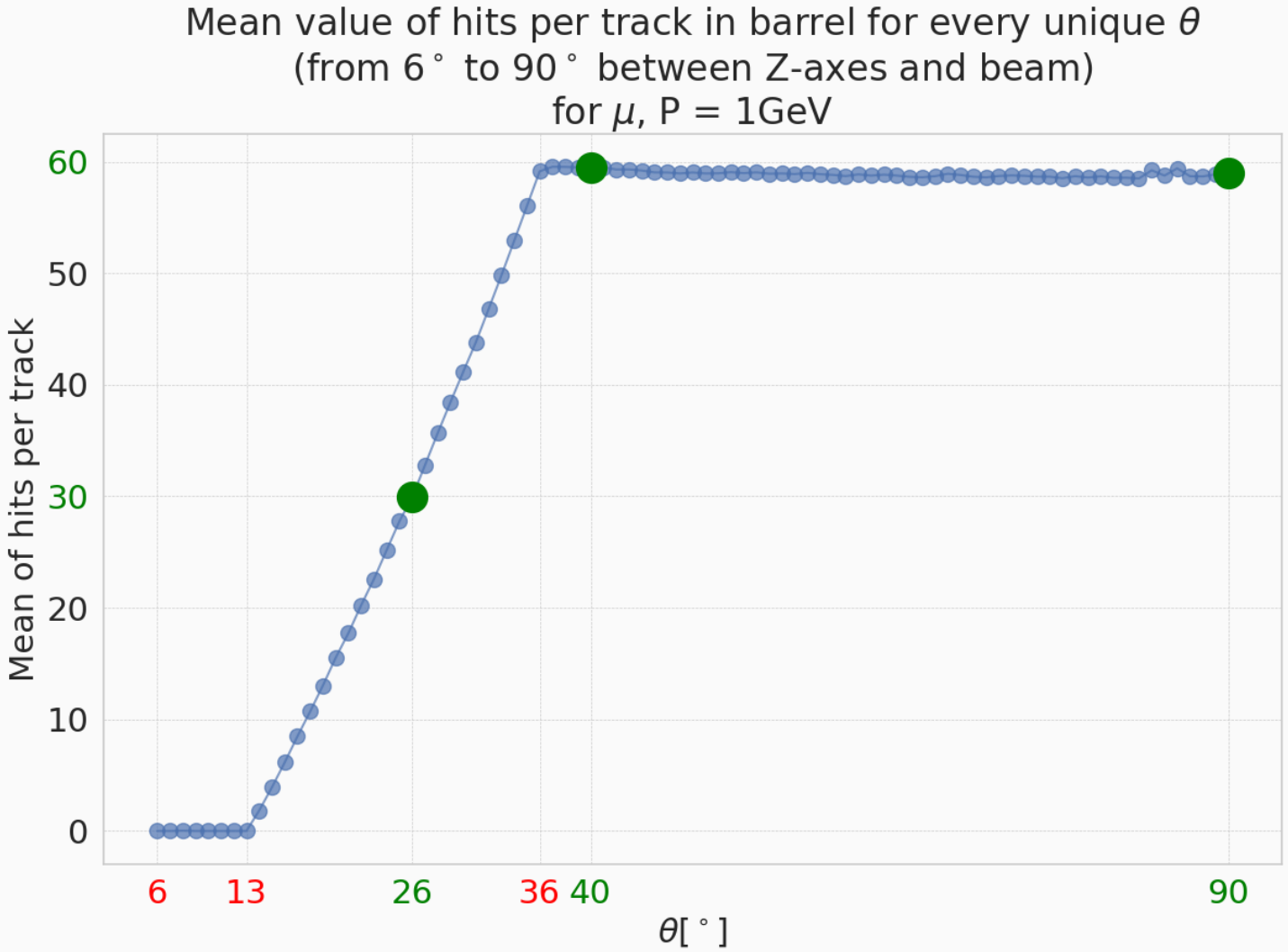


Steps for Simulation and Reconstruction

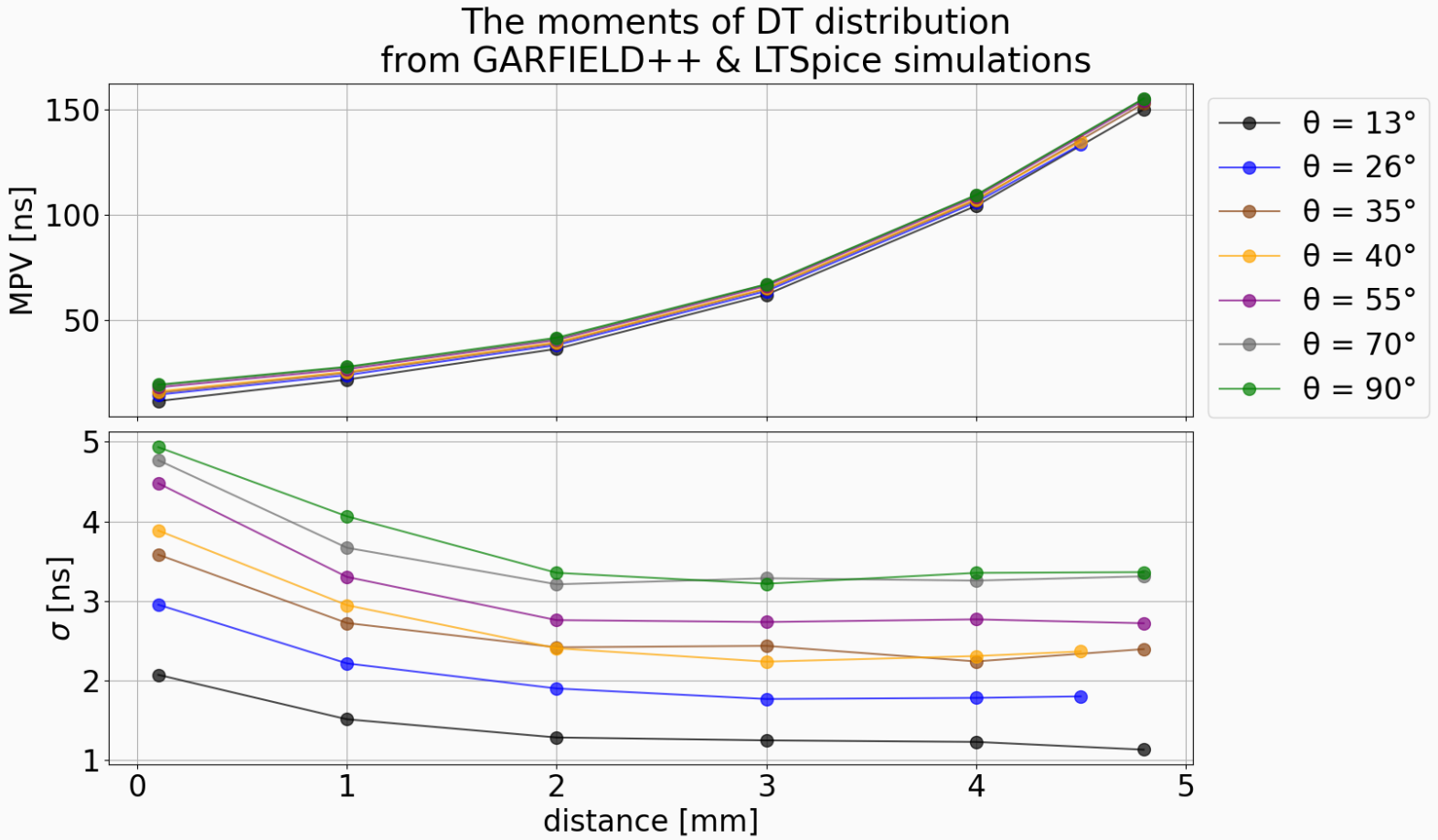
1. **Realistic Simulation based on Garfield/LTSpice parametrization**:
   - For a MC point get the distance to an anode wire and the polar angle of the corresponding track (R_{MC}, θ)
   - From the parametrized dependencies mean, sigma(DT) = $f(R_{MC}, \theta)$ get the most porbable value of the drift time
   - Apply smearing using a Gaussian function with the σ
2. **Hit Reconstuction using the calibration function** $R_{hit} = f(\theta, DT)$:
   - Use θ from MC track (assume in the future to be provided by the Patern Recognition)
   - Resolve the equation for the given DT and θ

Now, I want to be able to perform these steps for a range of angles

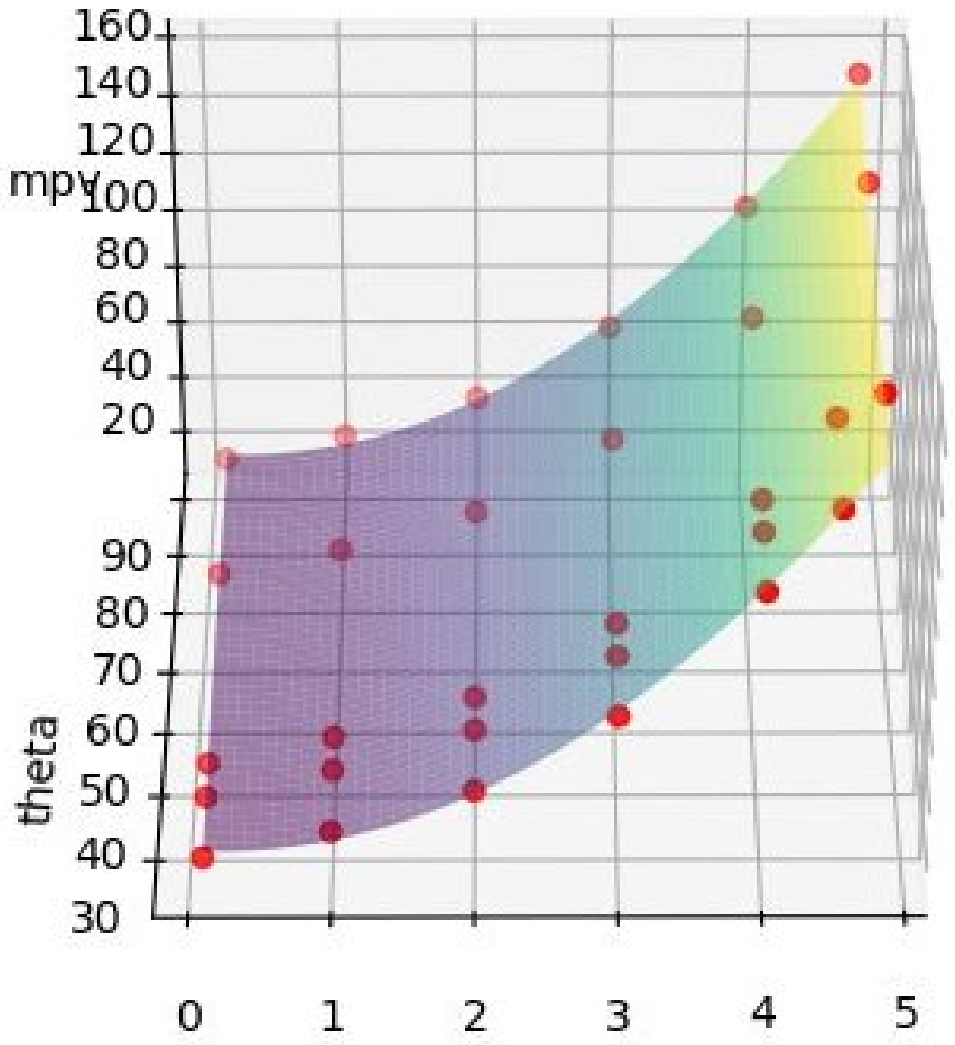
Now, I want to be able to perform these steps for a range of angles



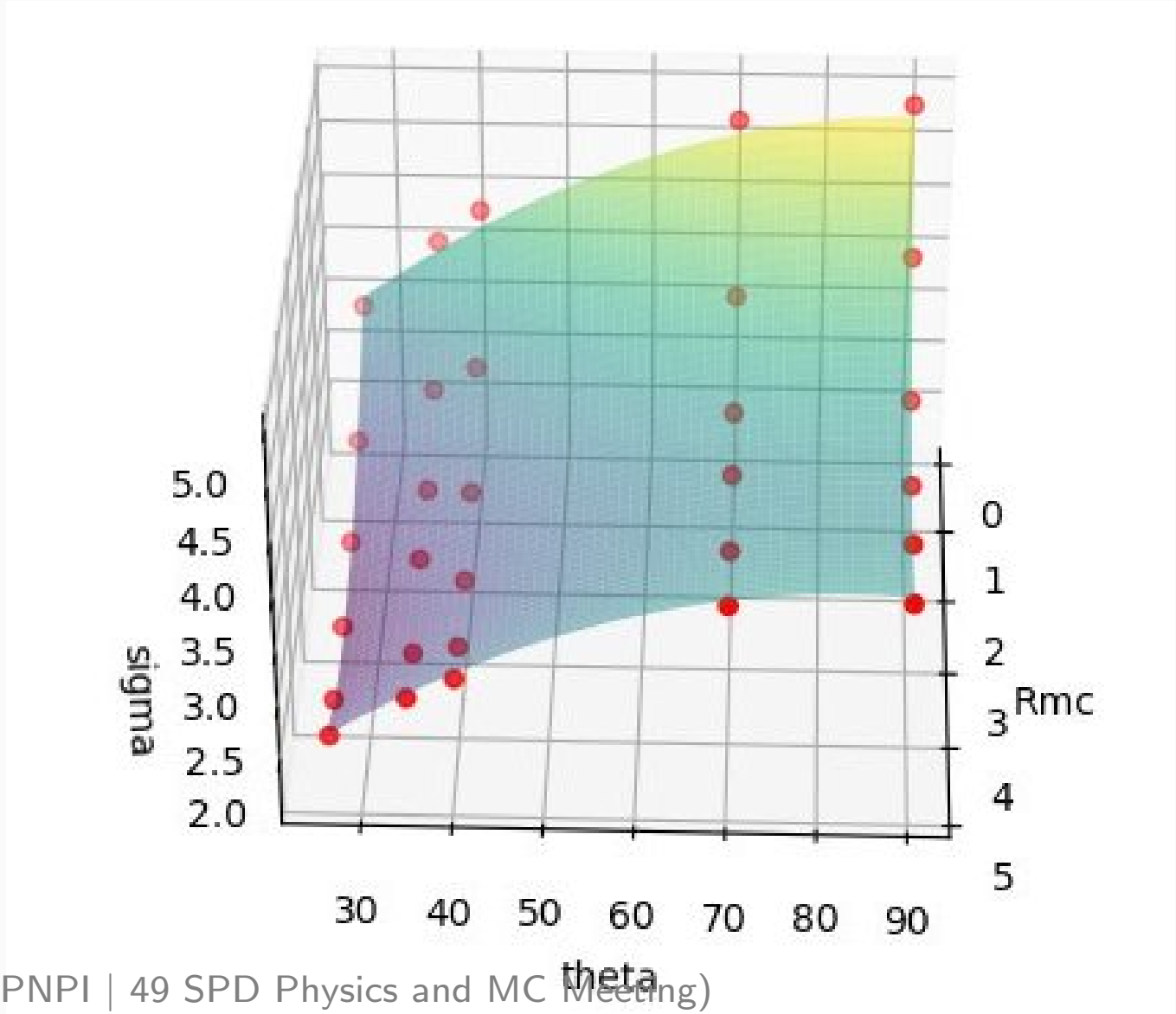
Creating the parametrization for realistic DT simulation – Garfield/LTSpice dataset



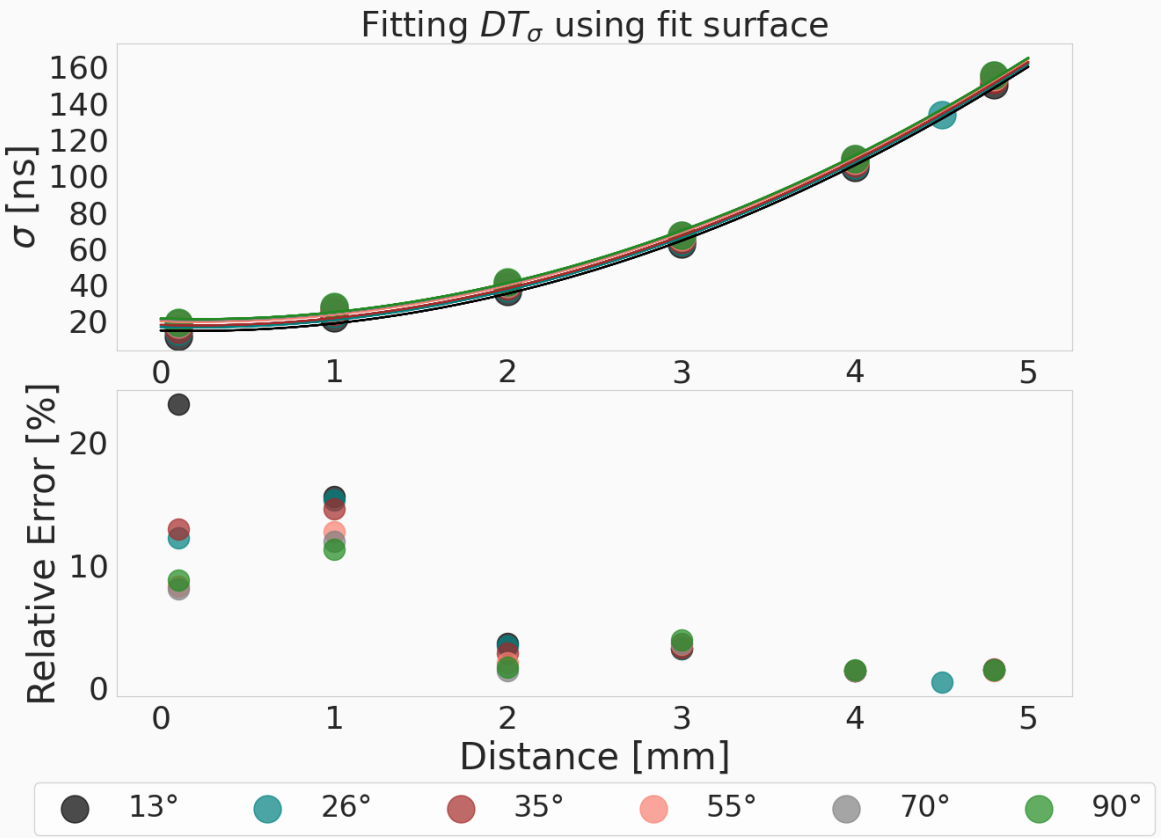
Parametrization for realistic simulation - mean value as a function of R_{MC}, θ



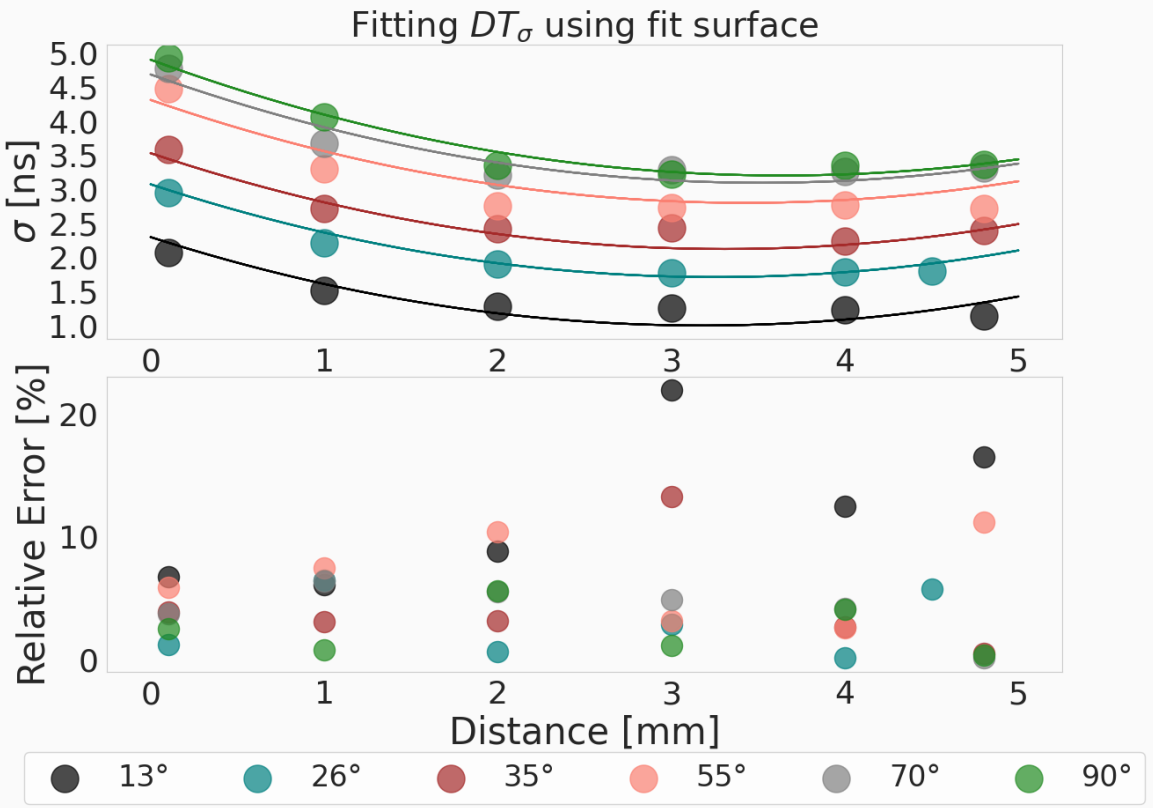
Parametrization for realistic simulation - time resolution as a function of R_{MC}, θ



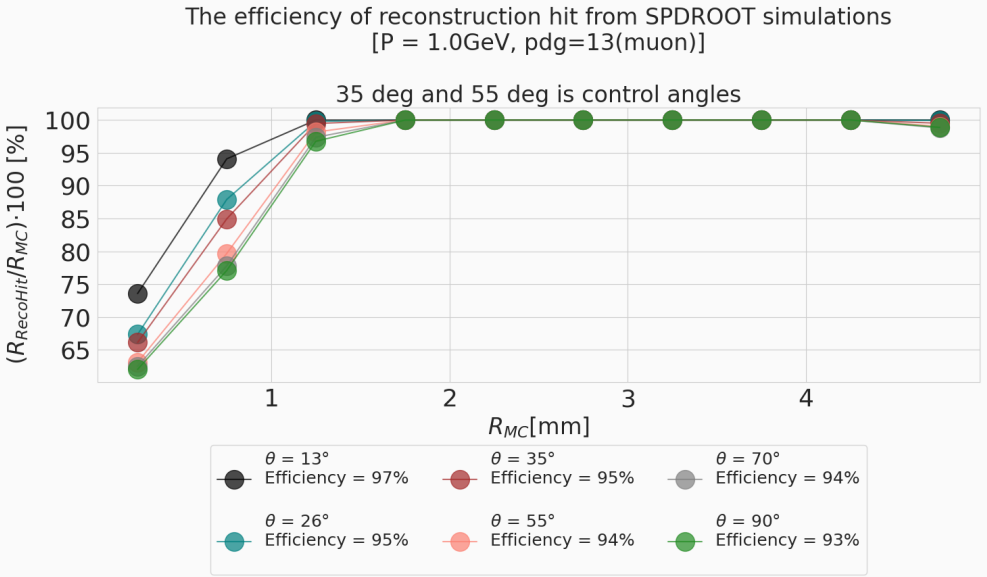
Parametrization for realistic simulation - relative errors of the parametrized mean value

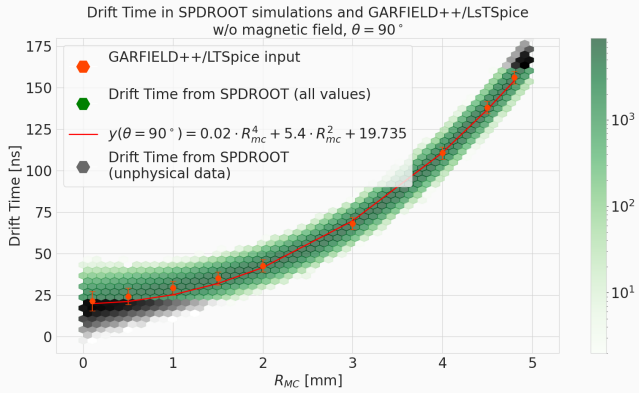


Parametrization for realistic simulation - relative errors of the parametrized time resolution



Hit reconstruction – efficiency

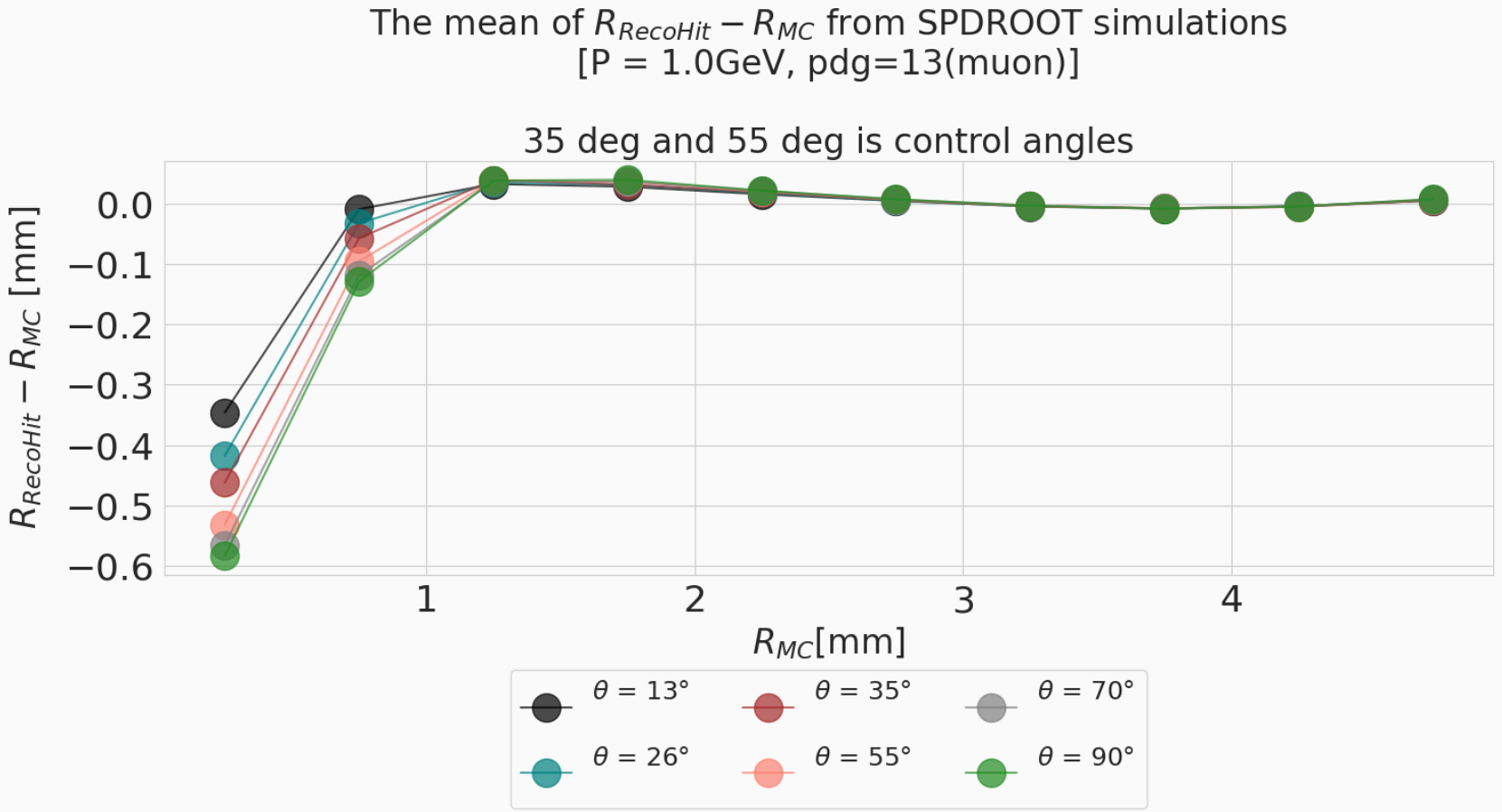




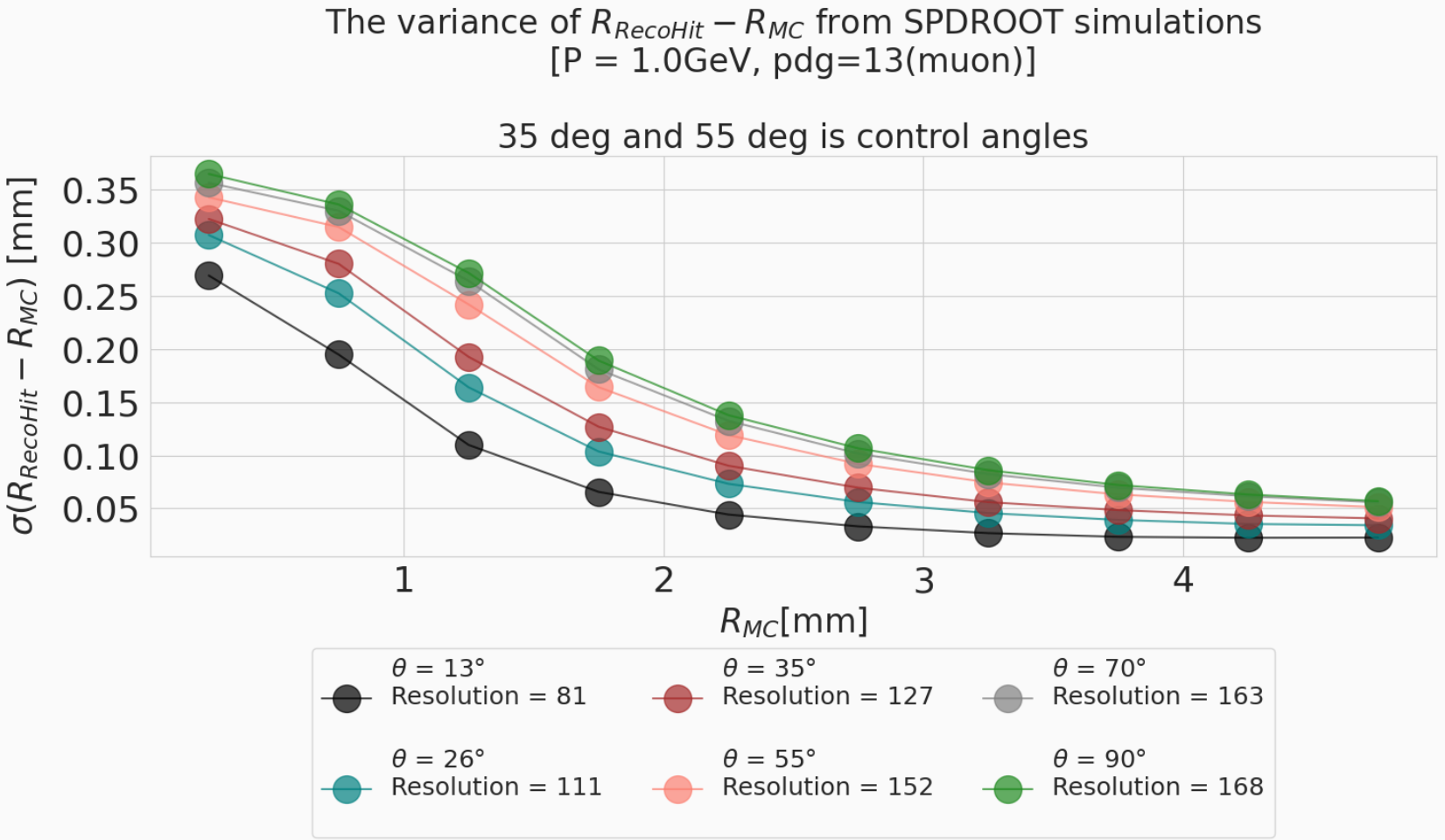
- For each hit use DT and angle to reconstruct the coordinate
- Use roots of $DT = f(R, theta) = R^4 + ...$ to reconstruct R_{hit} for given θ

- If no roots (see the gray area) – drop the hit in the current version (to be improved later)

Hit Reconstruction. 35° and 55° are control angles
Residual



Hit Reconstruction. 35° and 55° are control angles
Resolution



Conclusion

- The parametrized drift time mean value and resolution as functions of R_{mc}, θ are implemented to provide realistic straw response simulation. The parametrization includes given models of the straw tube and readout electronics
- The hit reconstruction procedure uses the simulated time and parameterized calibration function $DT = f(R, \theta)$
- Improvement on the hit reconstruction procedure is ongoing

Next steps

- Make the current version available for further tests
- Check momentum resolution for MinBias sample using the current parametrization. Note that the parametrization is done for relativistic muons, which have the worst time resolution