Implementation of the Straw Tracker realistic simulation and straw hit reconstruction in SPDROOT package

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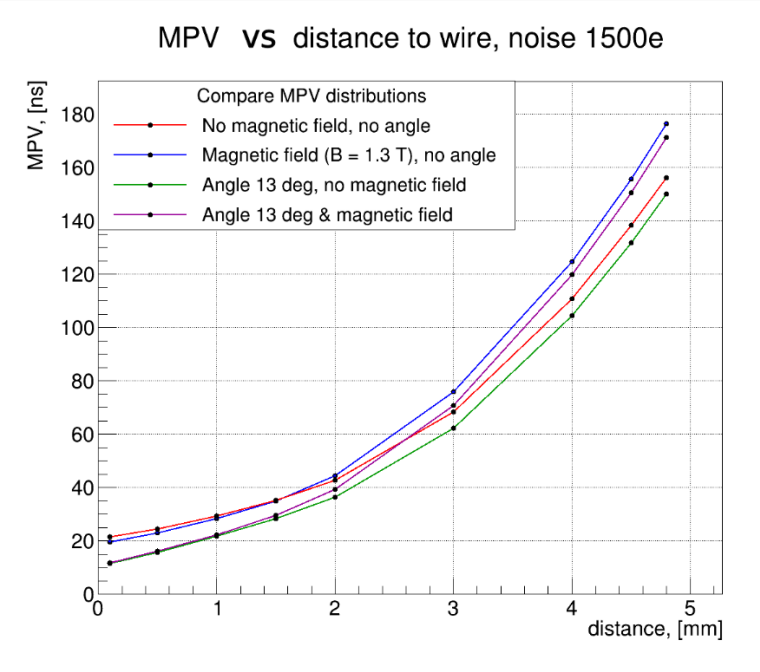
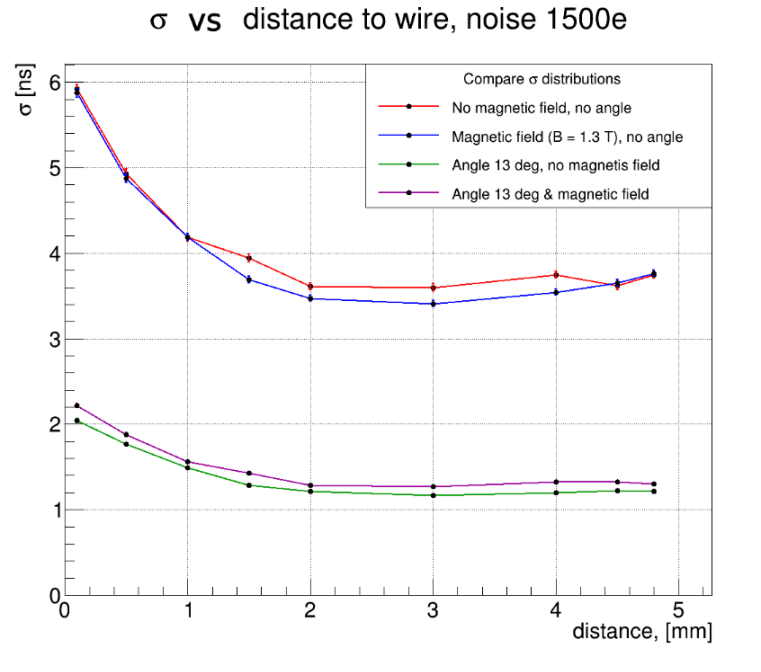
2023| Sonya B. & Vitalii B. parameterized mean value and resolution of the straw signal time using Garfield++/LTSpice modeling





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

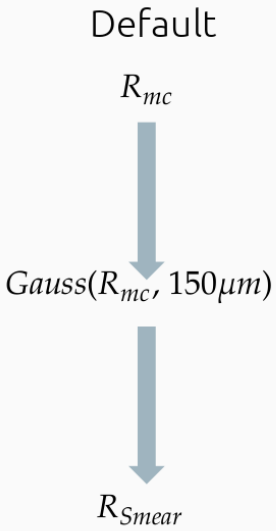
Noise is implemented, Threshold 10 mV

VMM3-based readout

model by Vitalii B.

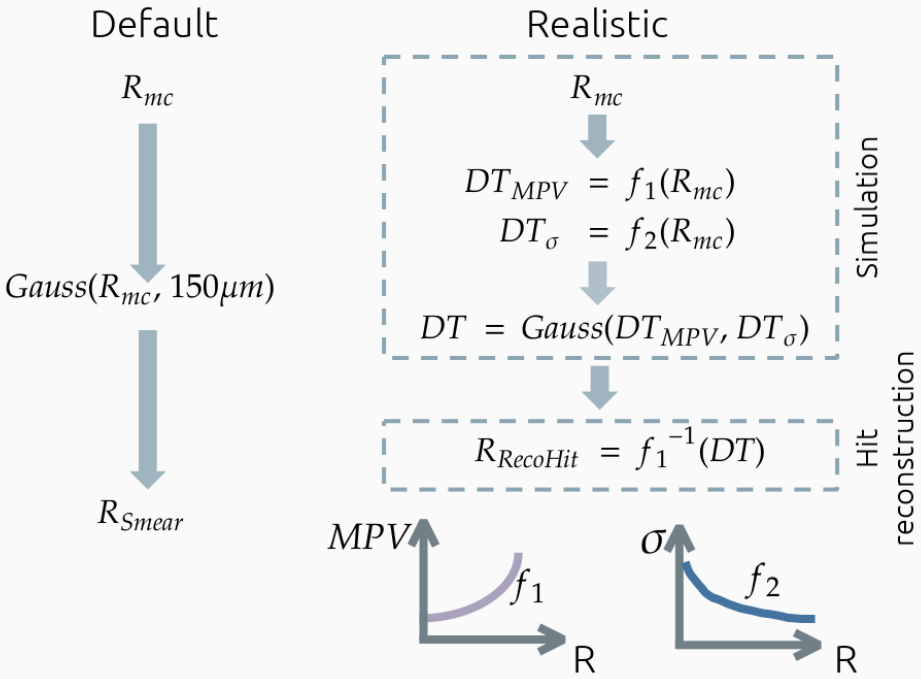
Source: Diploma by Sonya B.

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

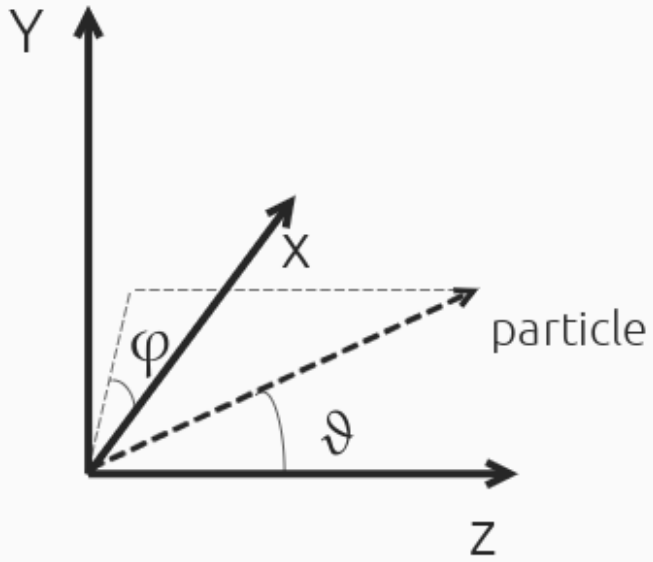


- The distribution of the drift time (DT) is provided by Sonya B. & Vitalii B.
- The DT is calculated for each Monte Carlo point
- Afterward, DT is smeared by $\sigma(DT) = f(R_{MC})$
- Roots of the inverse function provide $R_{RecoHit}$

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



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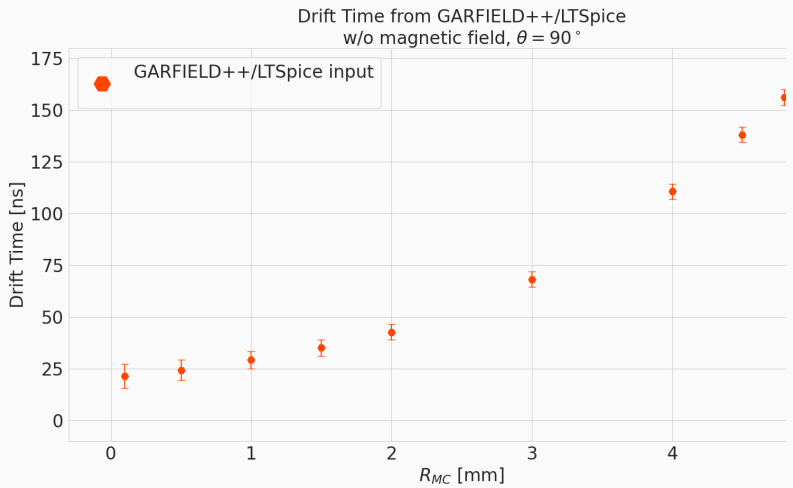
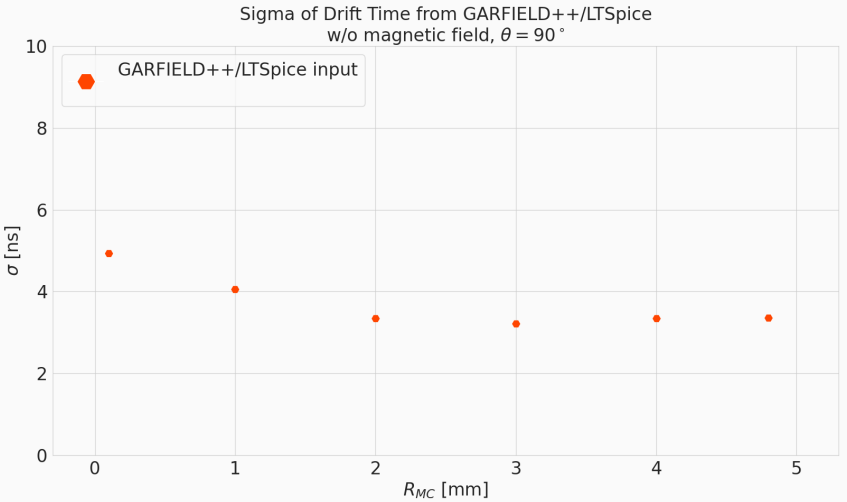
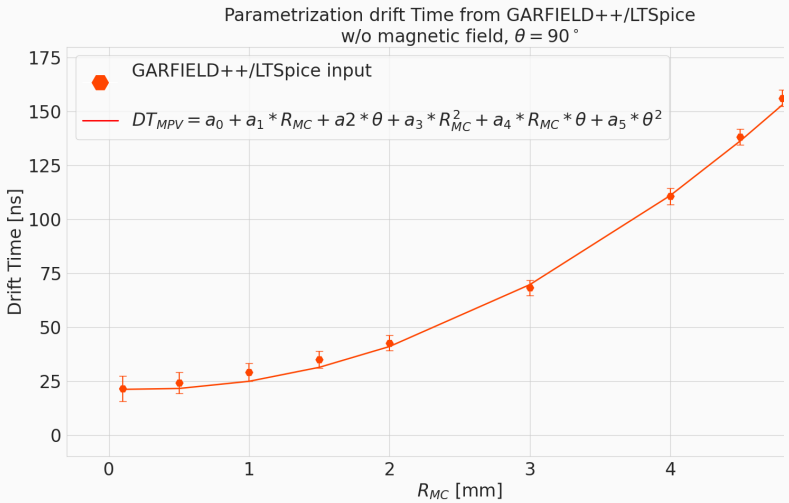
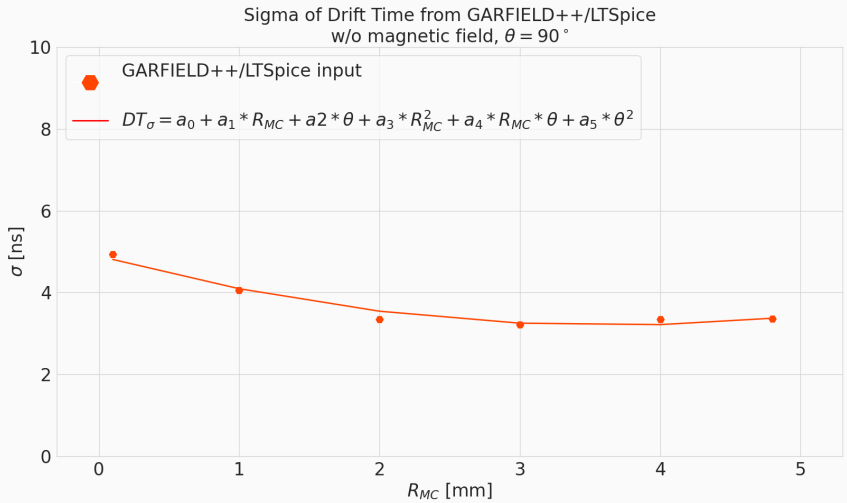


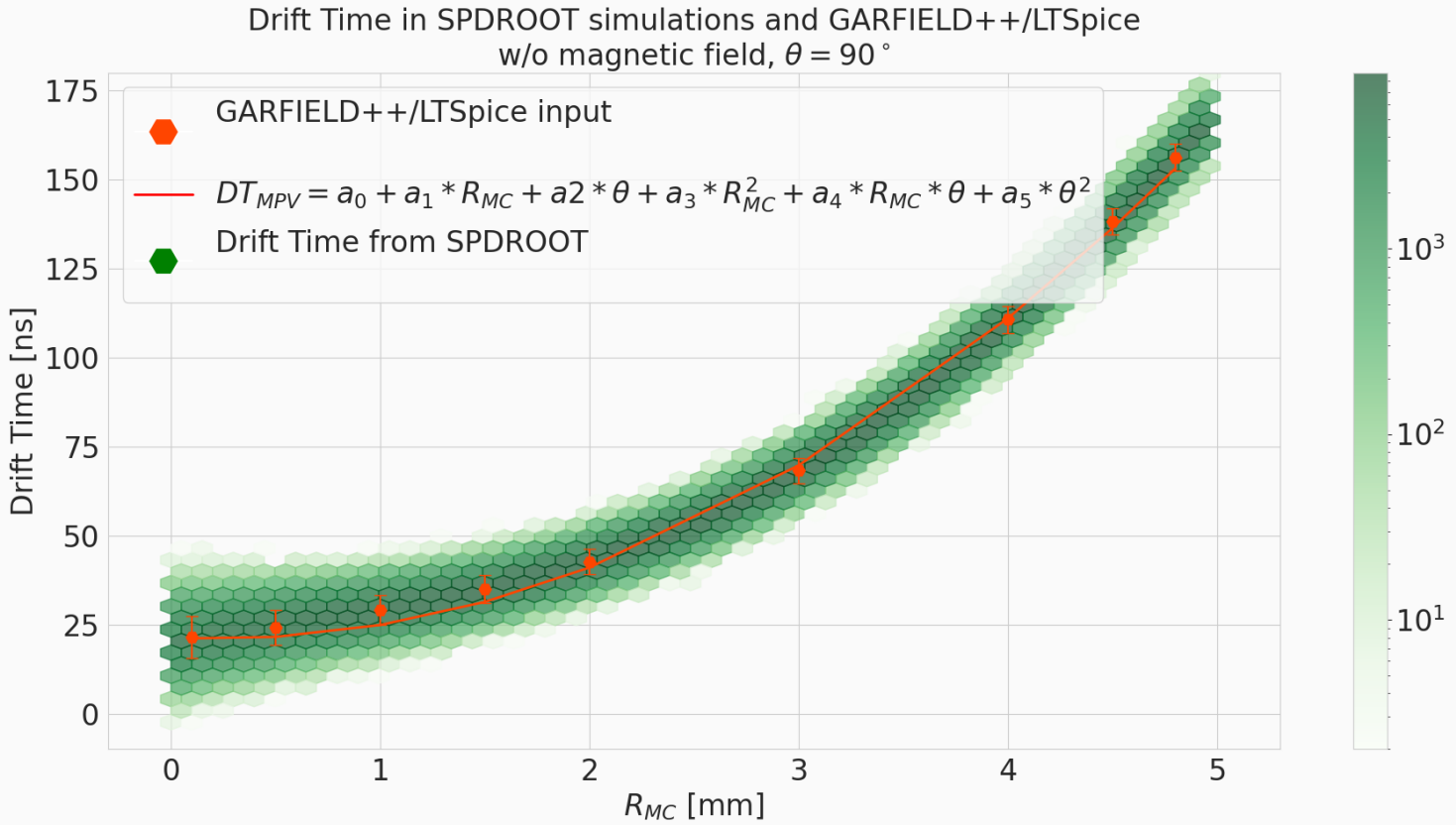


Parametrization DT using least squares

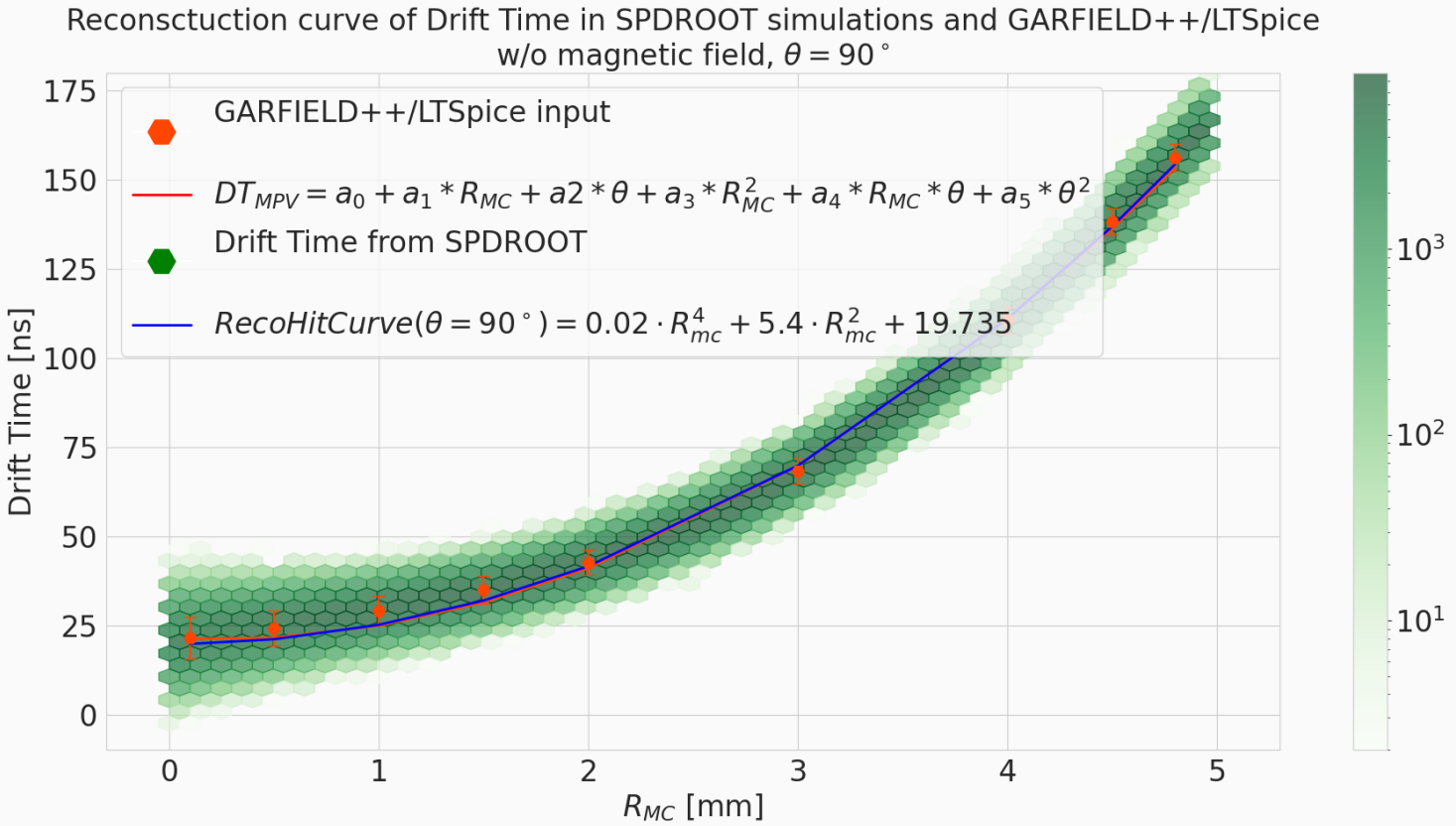




The DT is calculated for each Monte Carlo point and smeared



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

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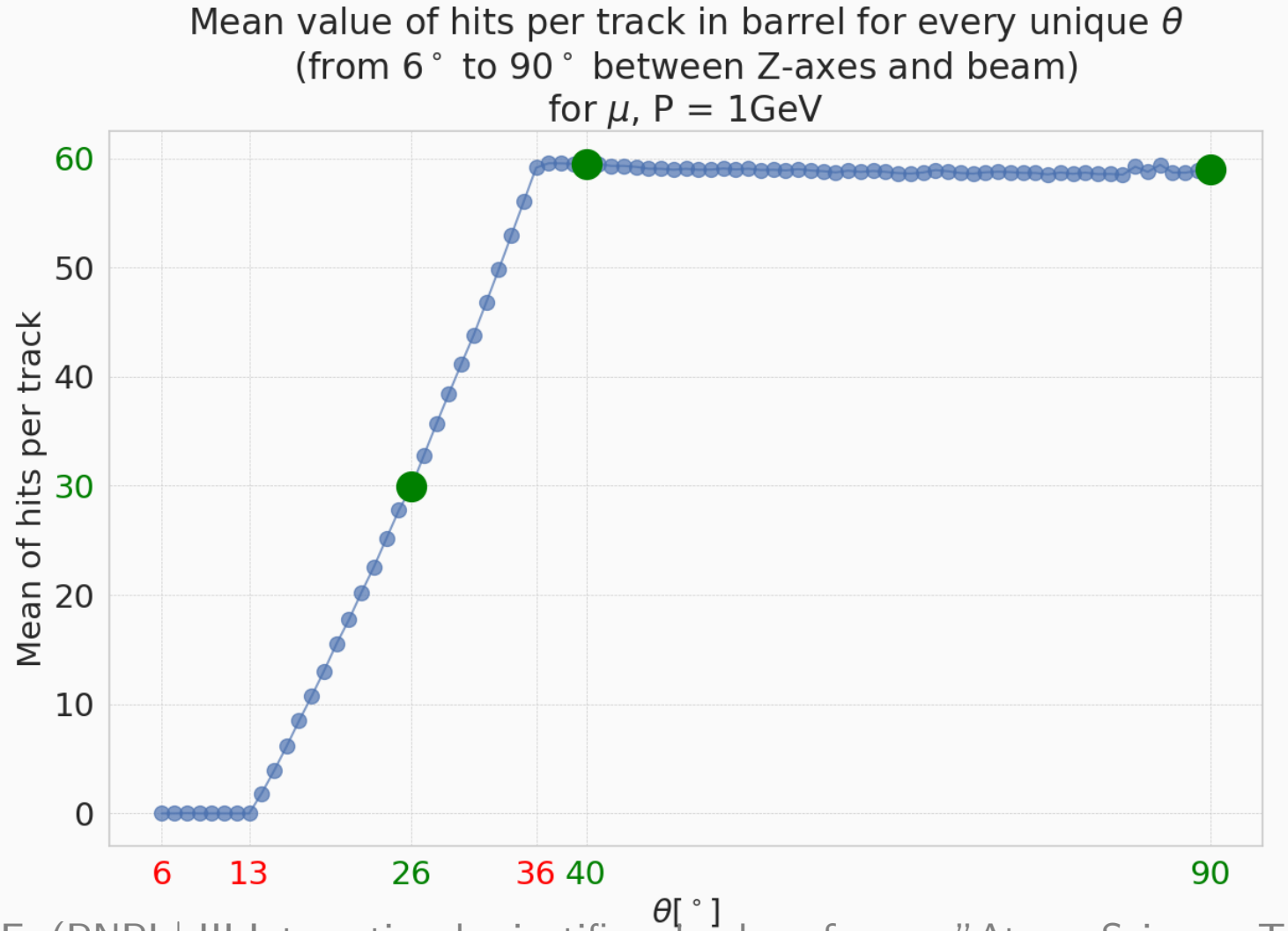
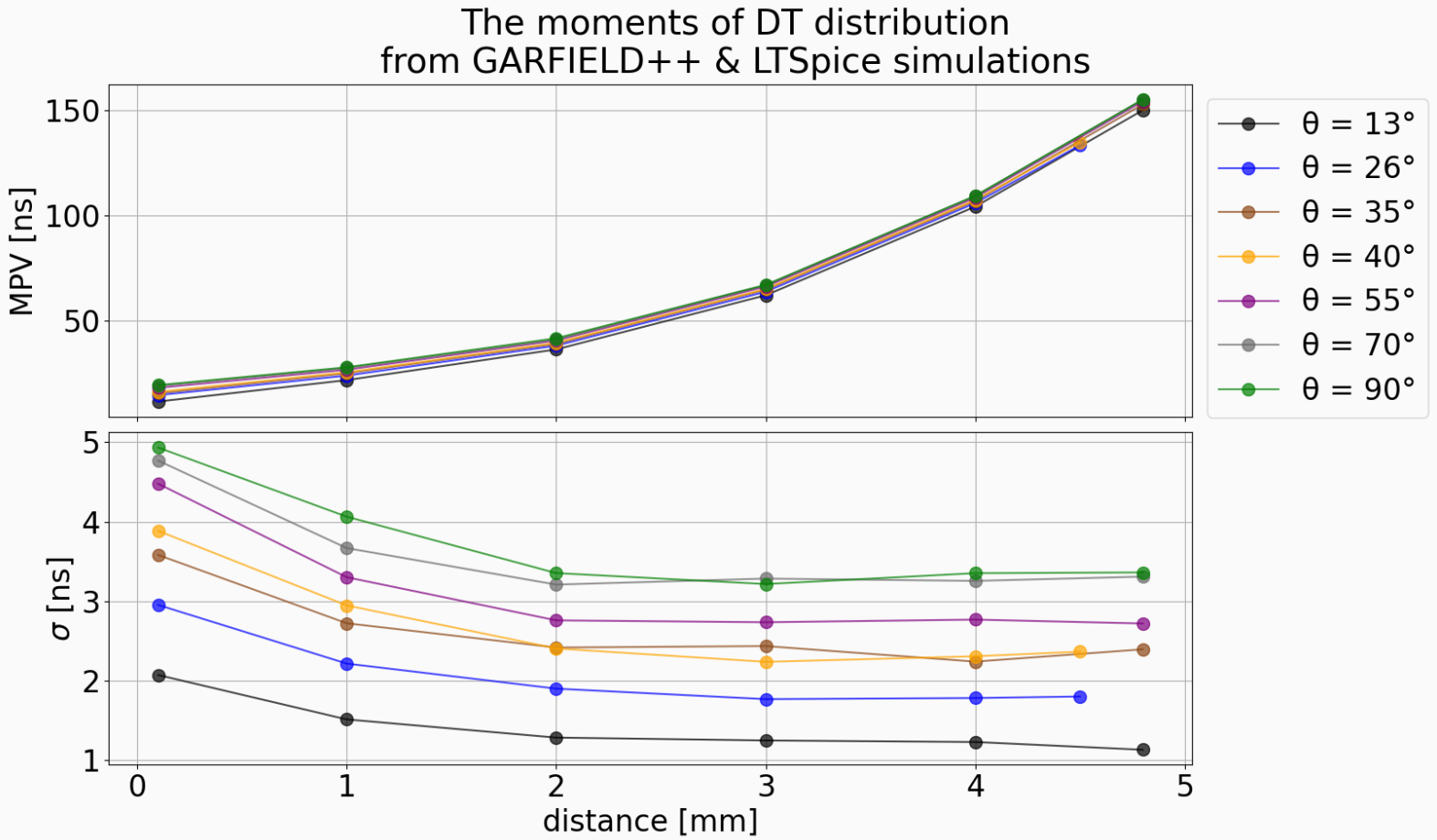
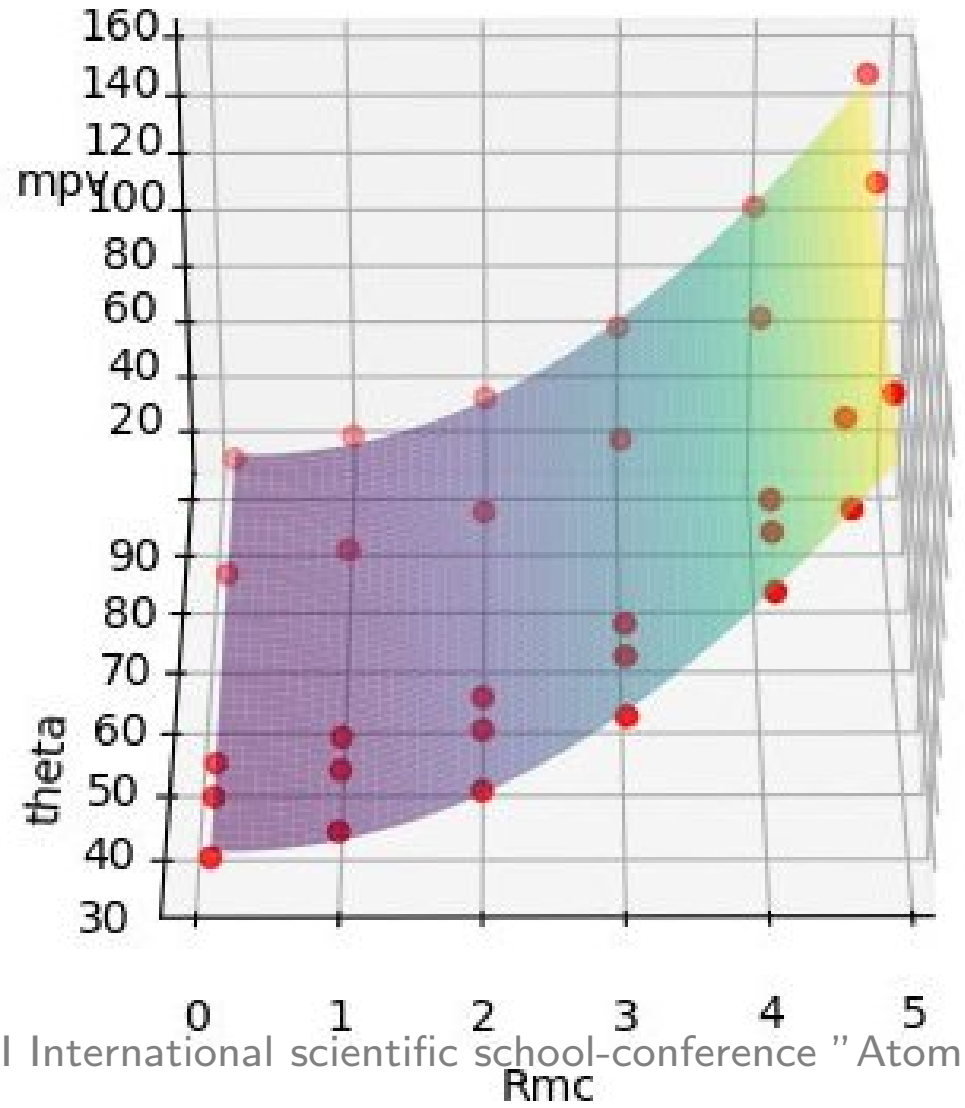


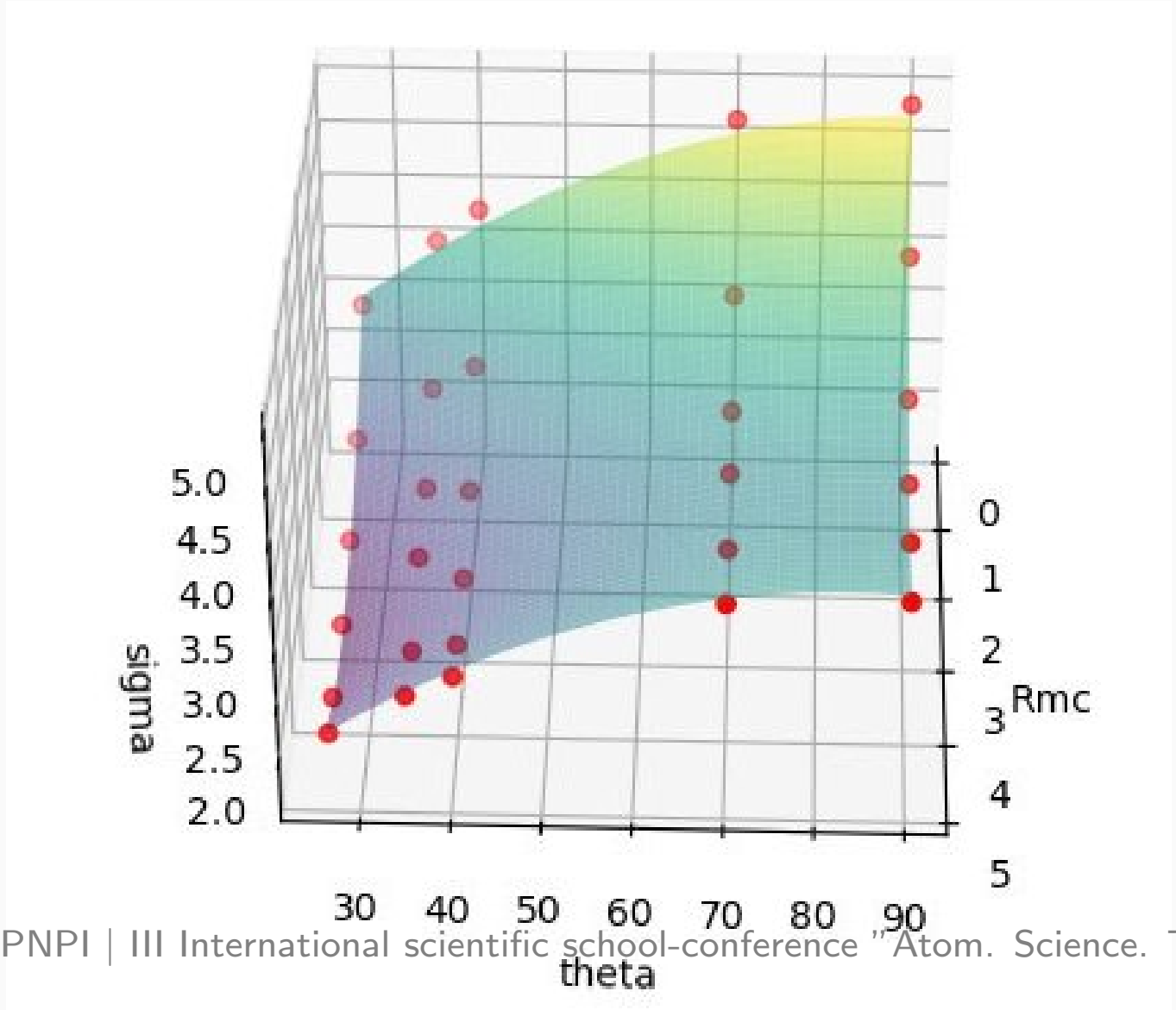
Creating the parametrization for realistic DT simulation – Garfield/LTSpice dataset



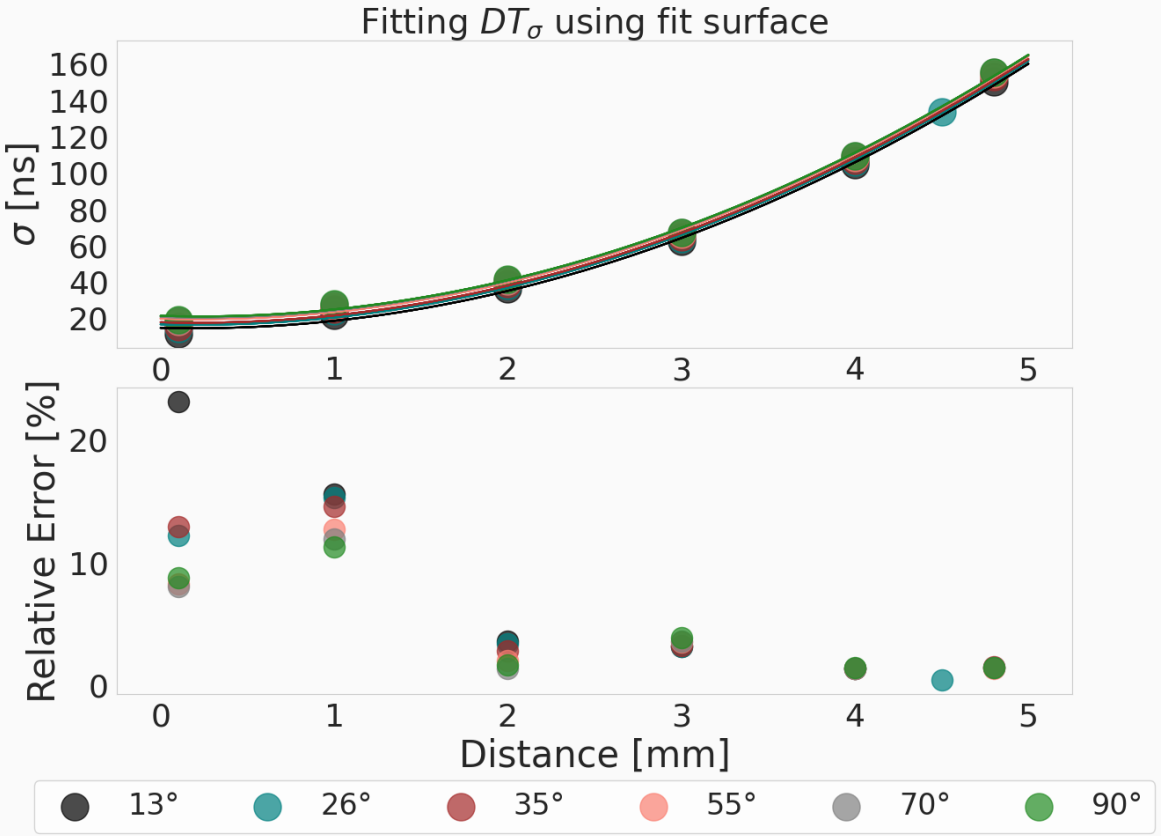
Parametrization for realistic simulation - mean value as a function of R_{MC}, θ



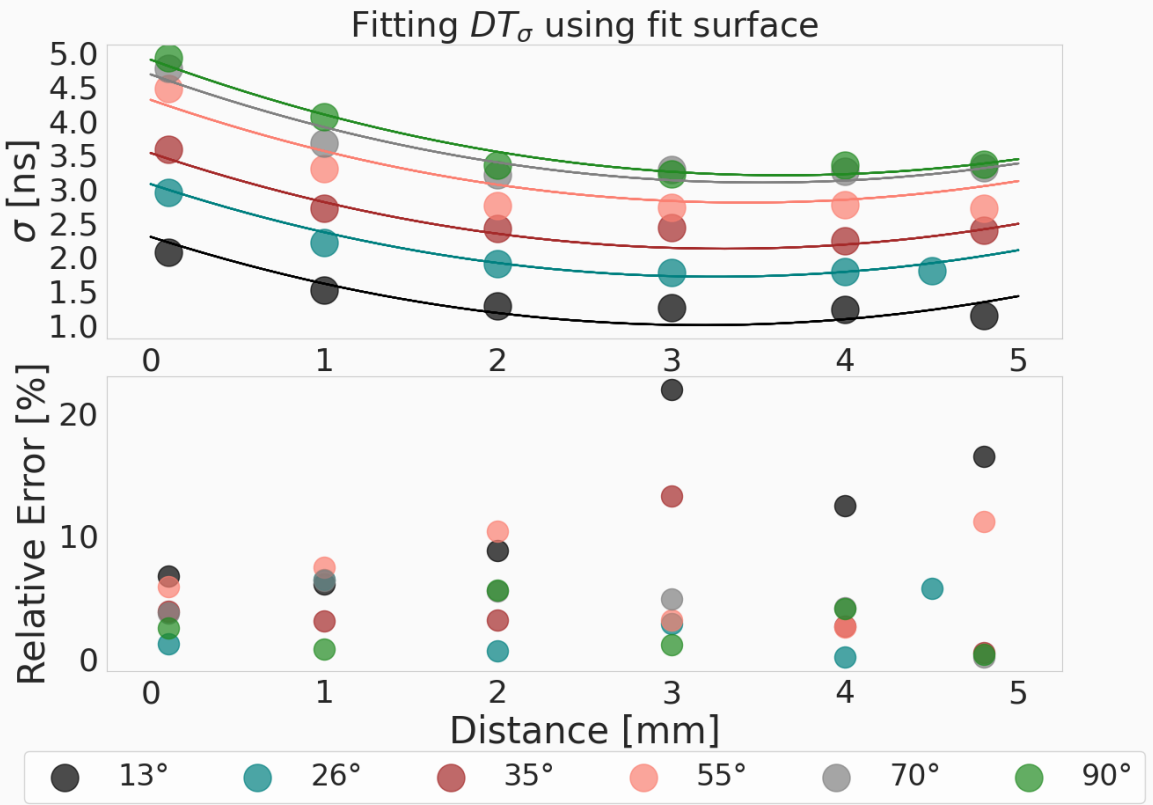
Parametrization for realistic simulation - time resolution as a function of R_{MC}, θ



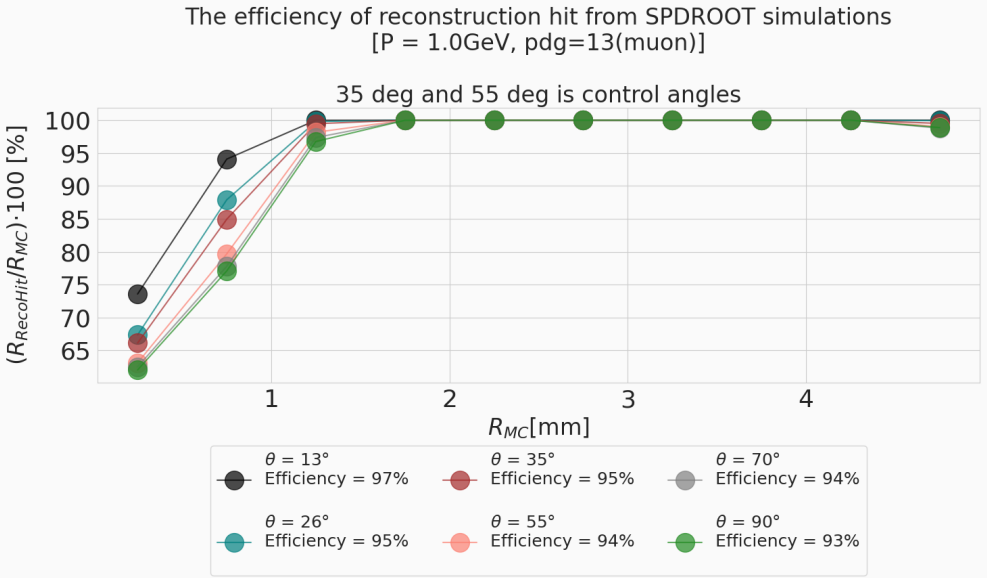
Parametrization for realistic simulation - relative errors of the parametrized mean value

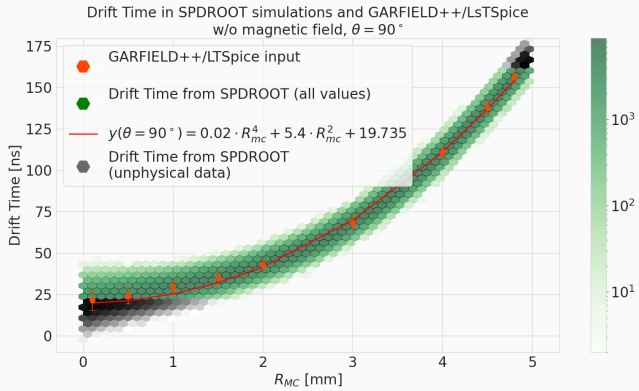


Parametrization for realistic simulation - relative errors of the parametrized time resolution



Hit reconstruction – efficiency

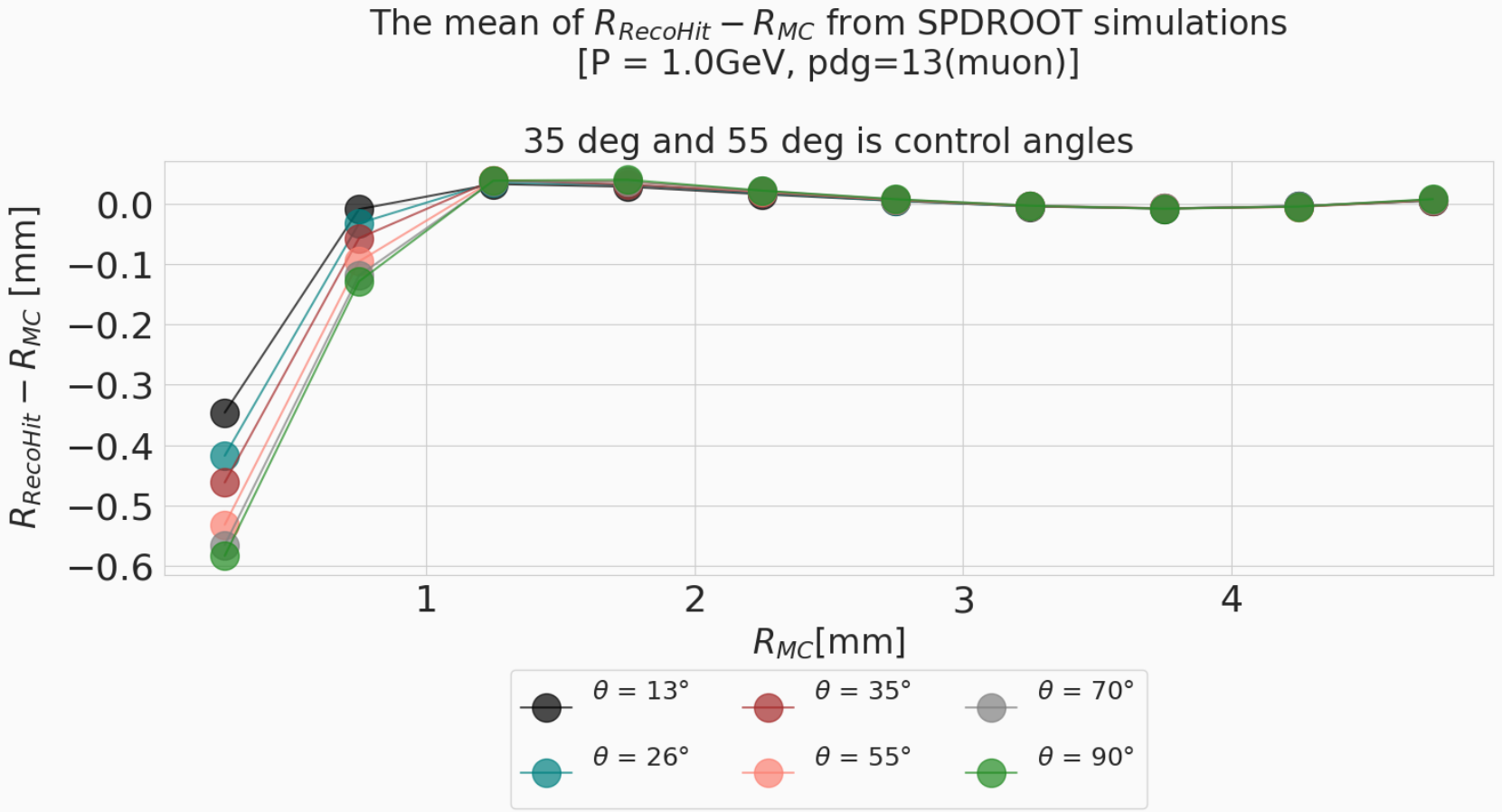




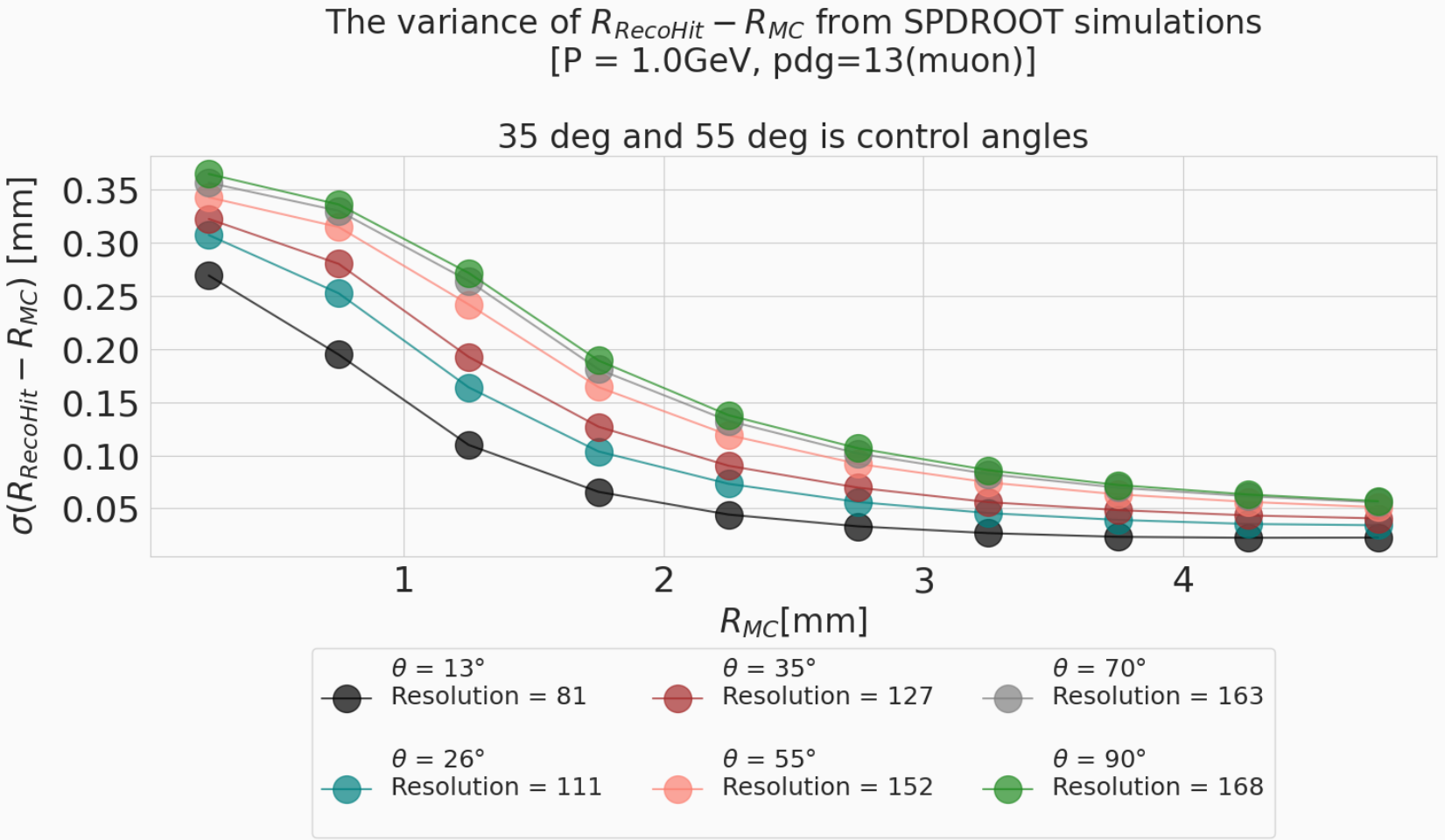
- For each hit use DT and angle to reconstruct the coordinate
- Use roots of $DT = f(R, theta) = R^4 + ...$ to reconstruct R_{hit} for given θ

- 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