Progress on Higgs recoil mass

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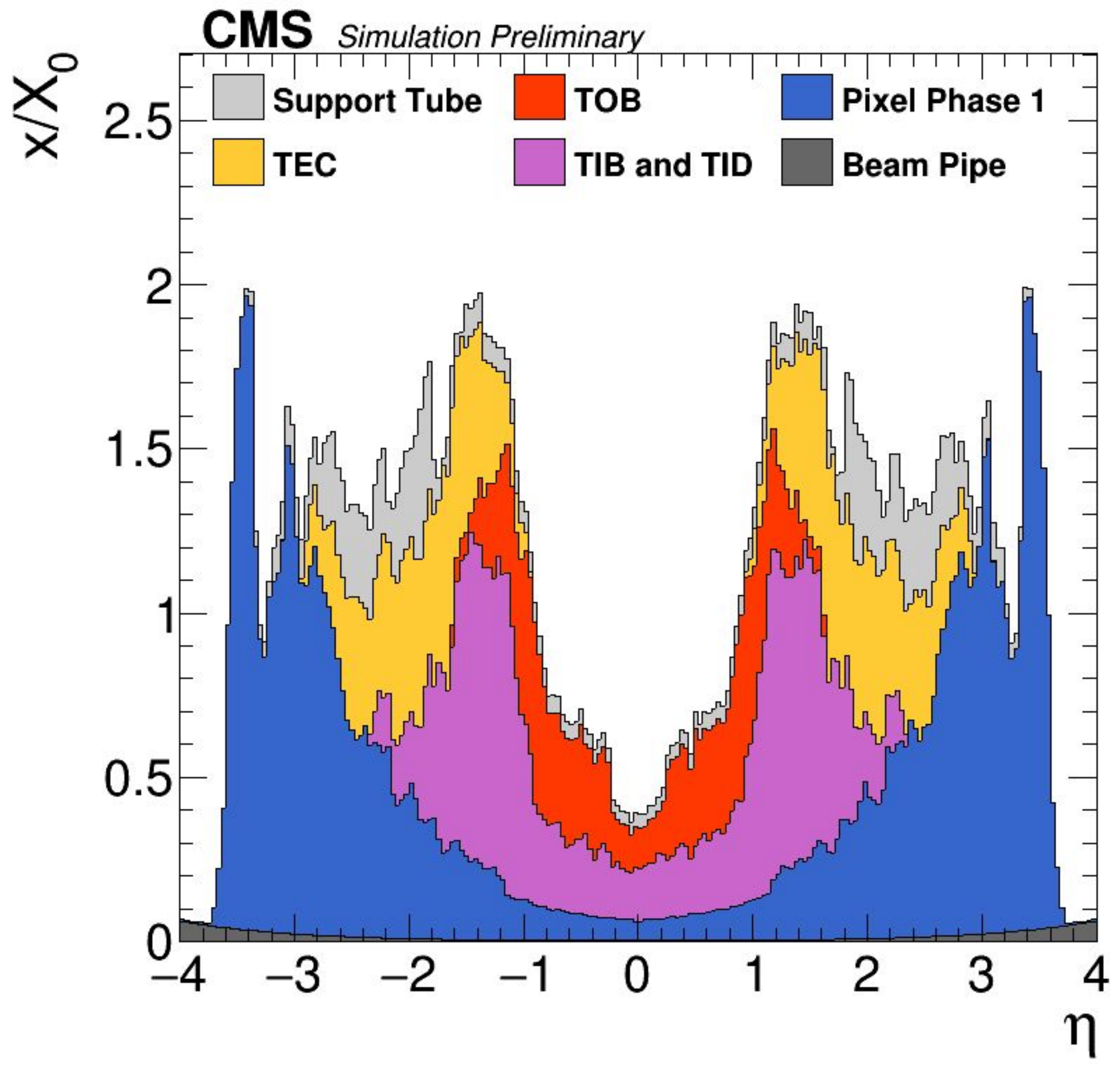
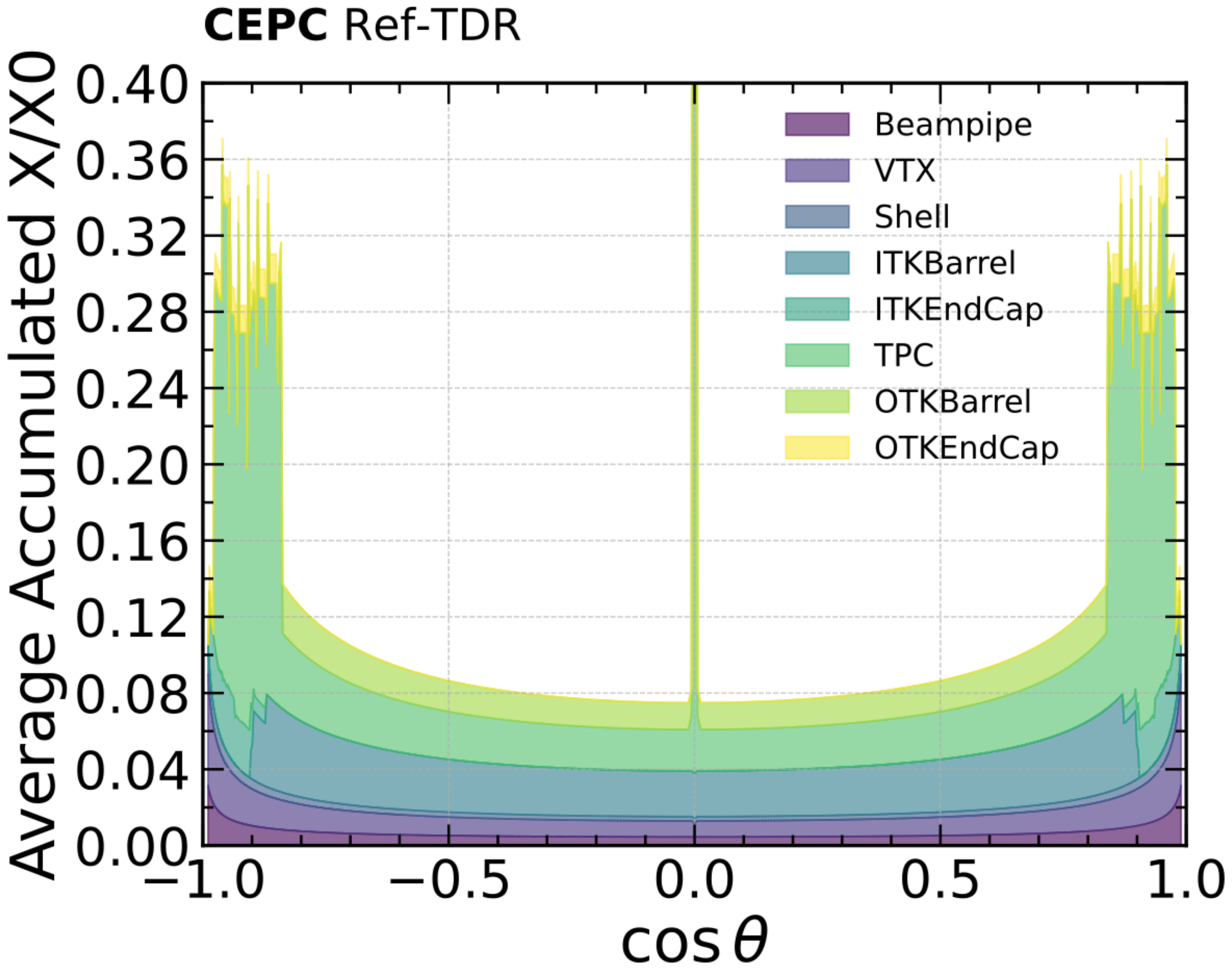
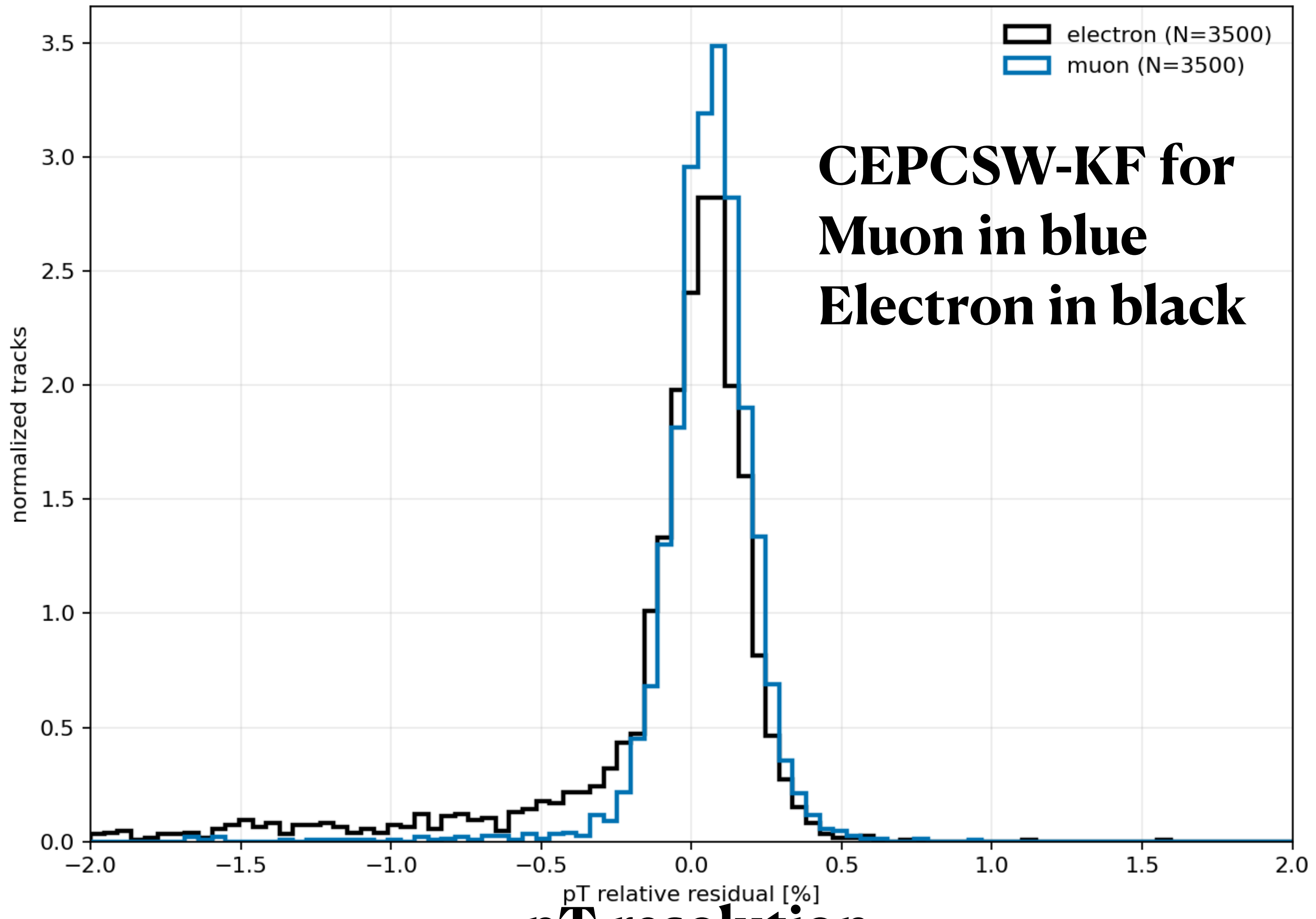
Introduction

- The Higgs mass measurement with the CEPC reference detector has been studied.
  - Using only muons, the statistical uncertainty ~ 3 MeV. A target precision ~ 4 MeV leaves little room for systematic uncertainty
  - Electron tracking has a resolution similar with muon tracking, but it suffers a large left tail due to bremsstrahlung
- A GSF (gaussian sum filter) needs to be integrated into CEPCSW for electron tracking



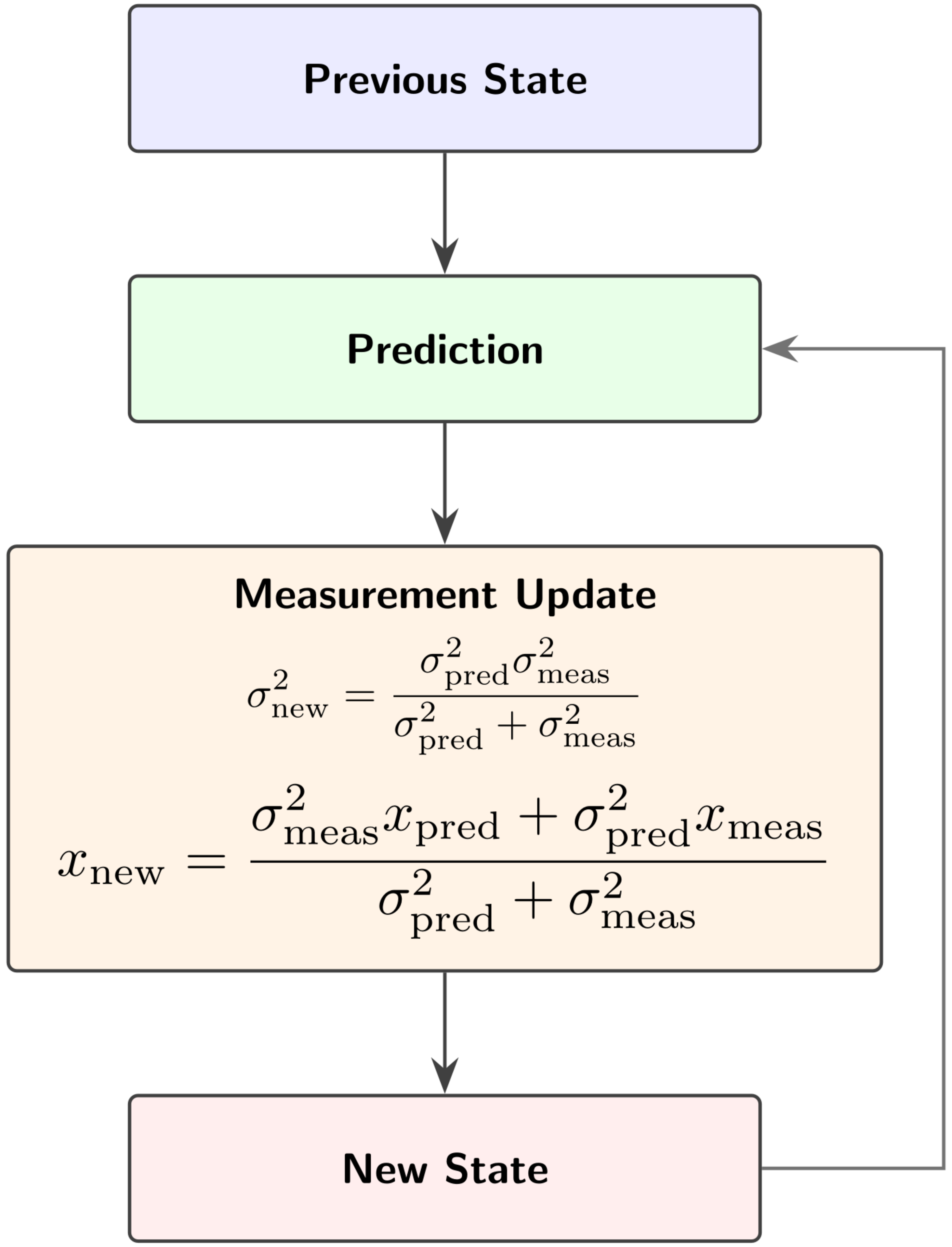




pT resolution

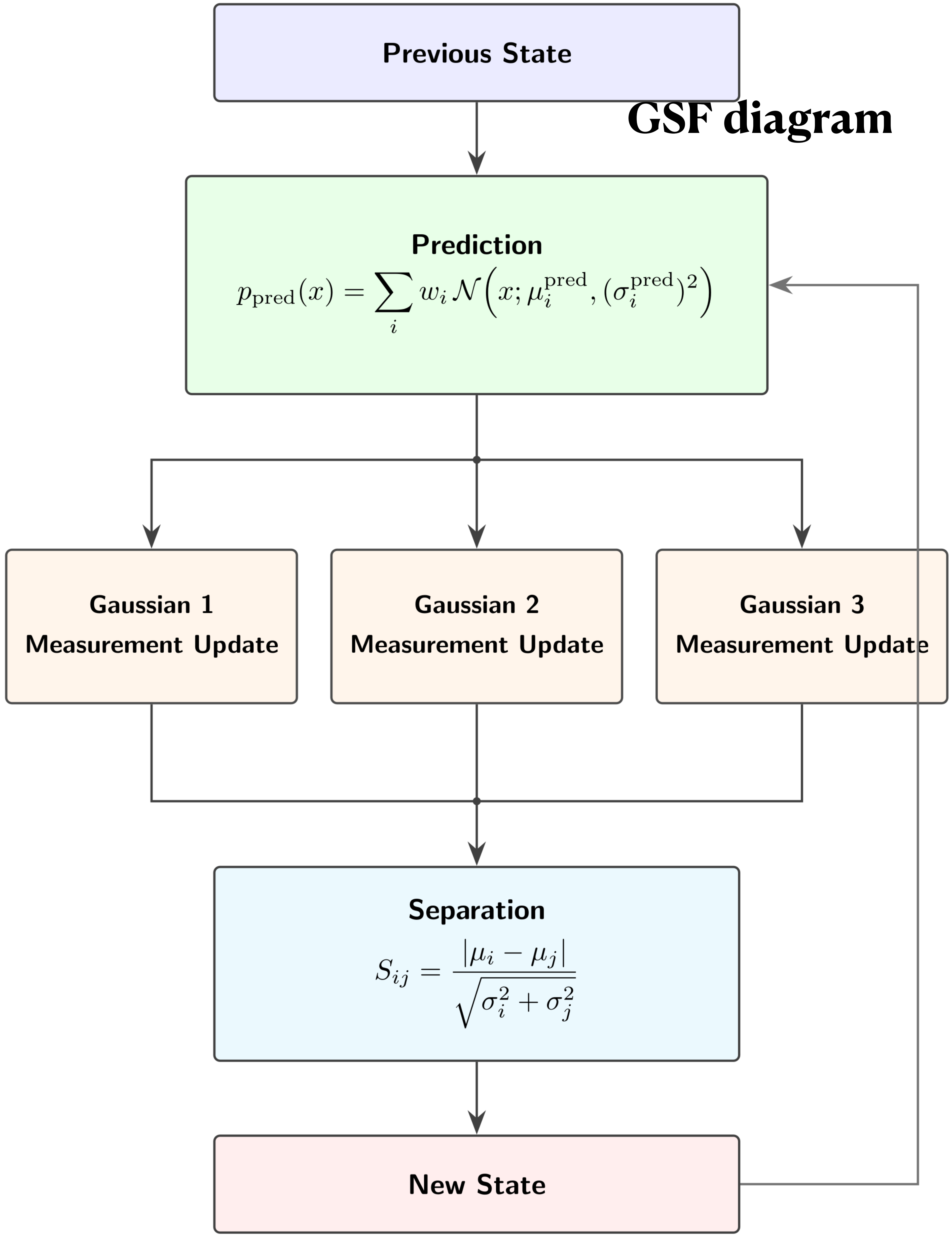
Gaussian-Sum-Filter Tracking

Kalman-filter diagram

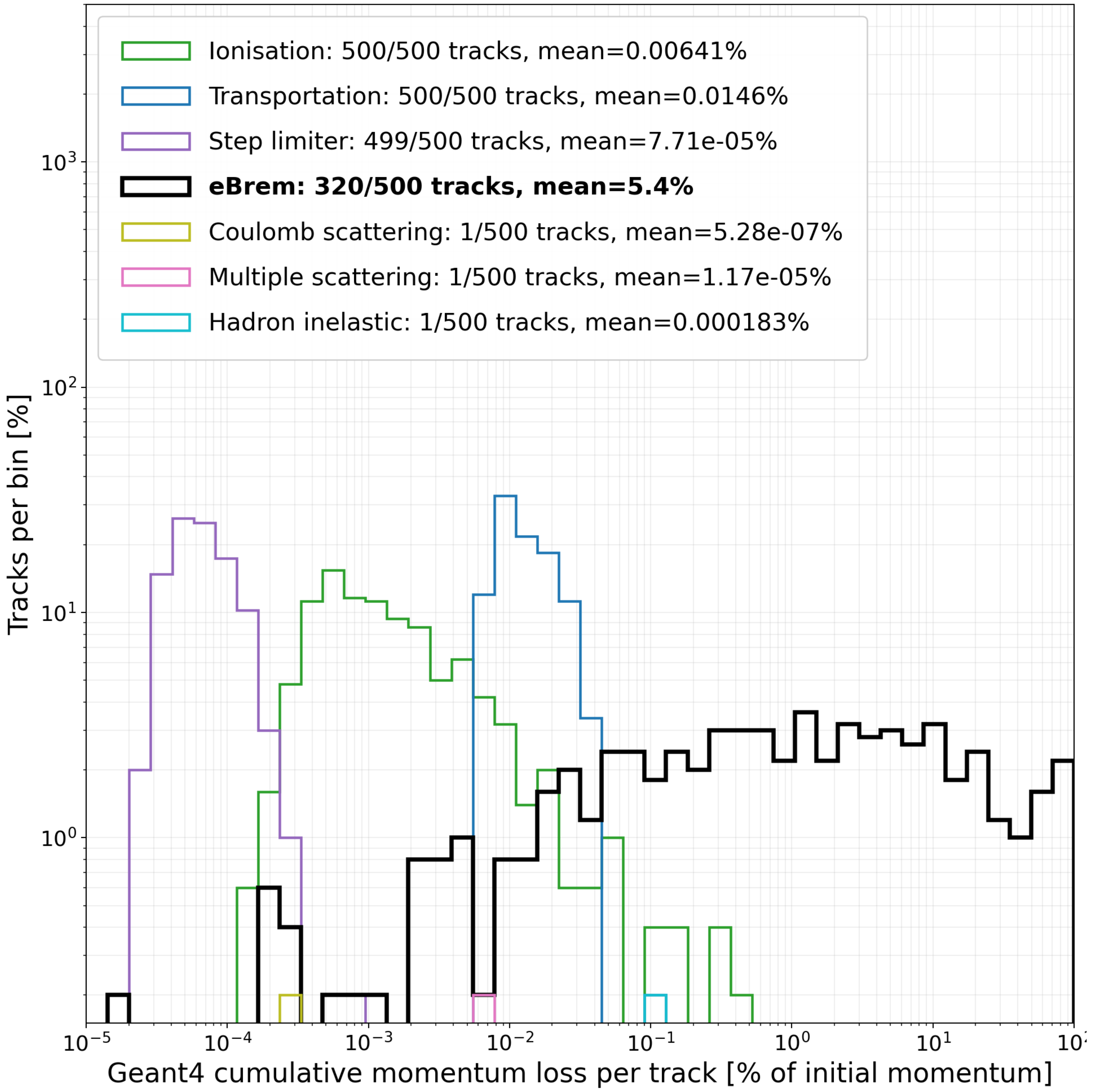


- Development
  - Gaussian-Mixture is obtained from G4 truth information
  - The existing CEPCSW KF implementation and its related classes are wrapped for use by the GSF
  - The GSF workflow developed for CEPCSW is consistent with the implementations in CMSSW and ACTS
- **The KF combines measurements under a single track-state hypothesis**
- **The GSF must identify (separate) different track-state hypothesis using the same measurements**
- Combination performance approaches that of the most precise input measurement; whereas separation performance is limited by the least precise input measurement.

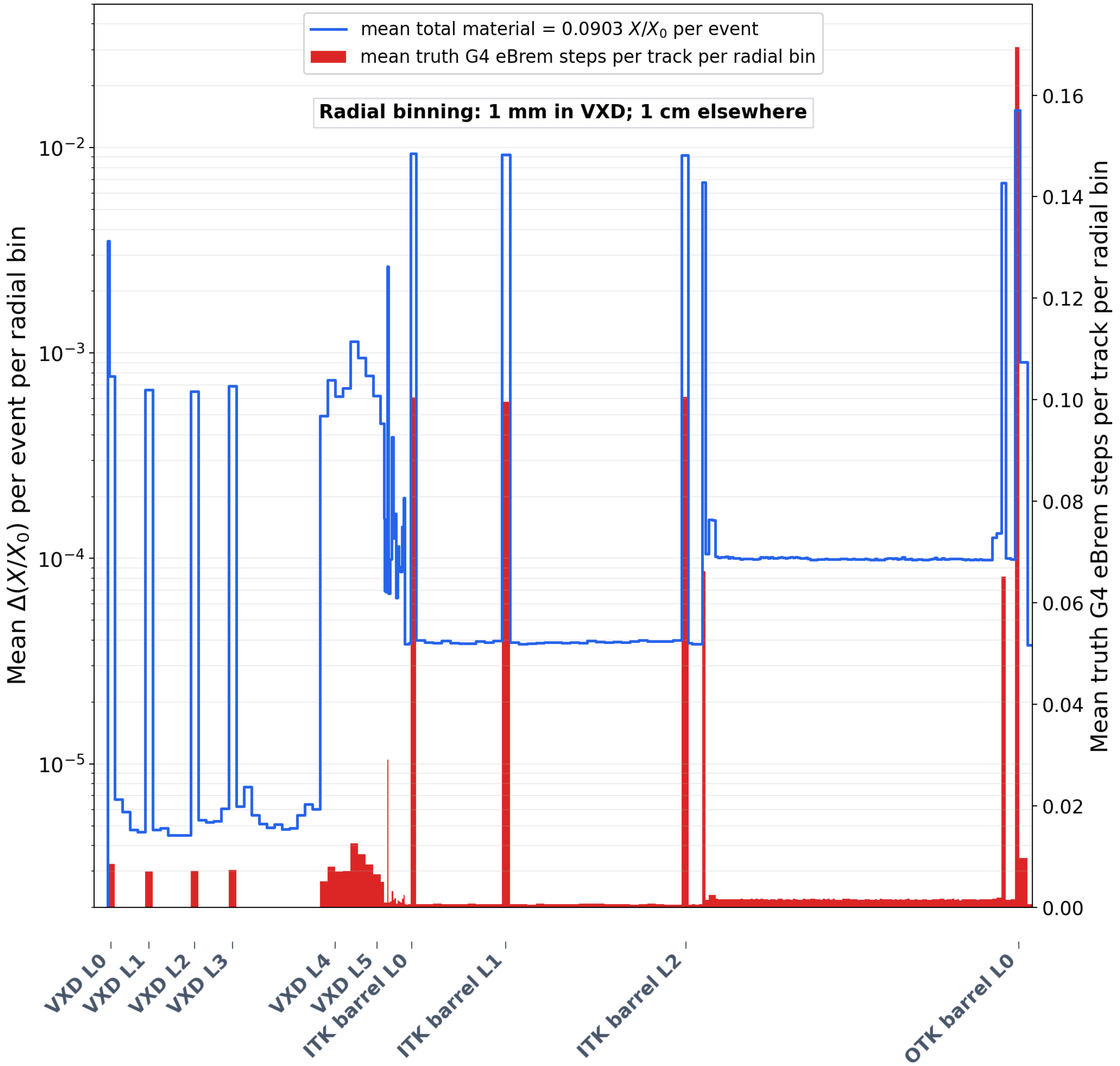
GSF diagram



eBrem Modelling



- **Inclusive ebrem energy loss per track**

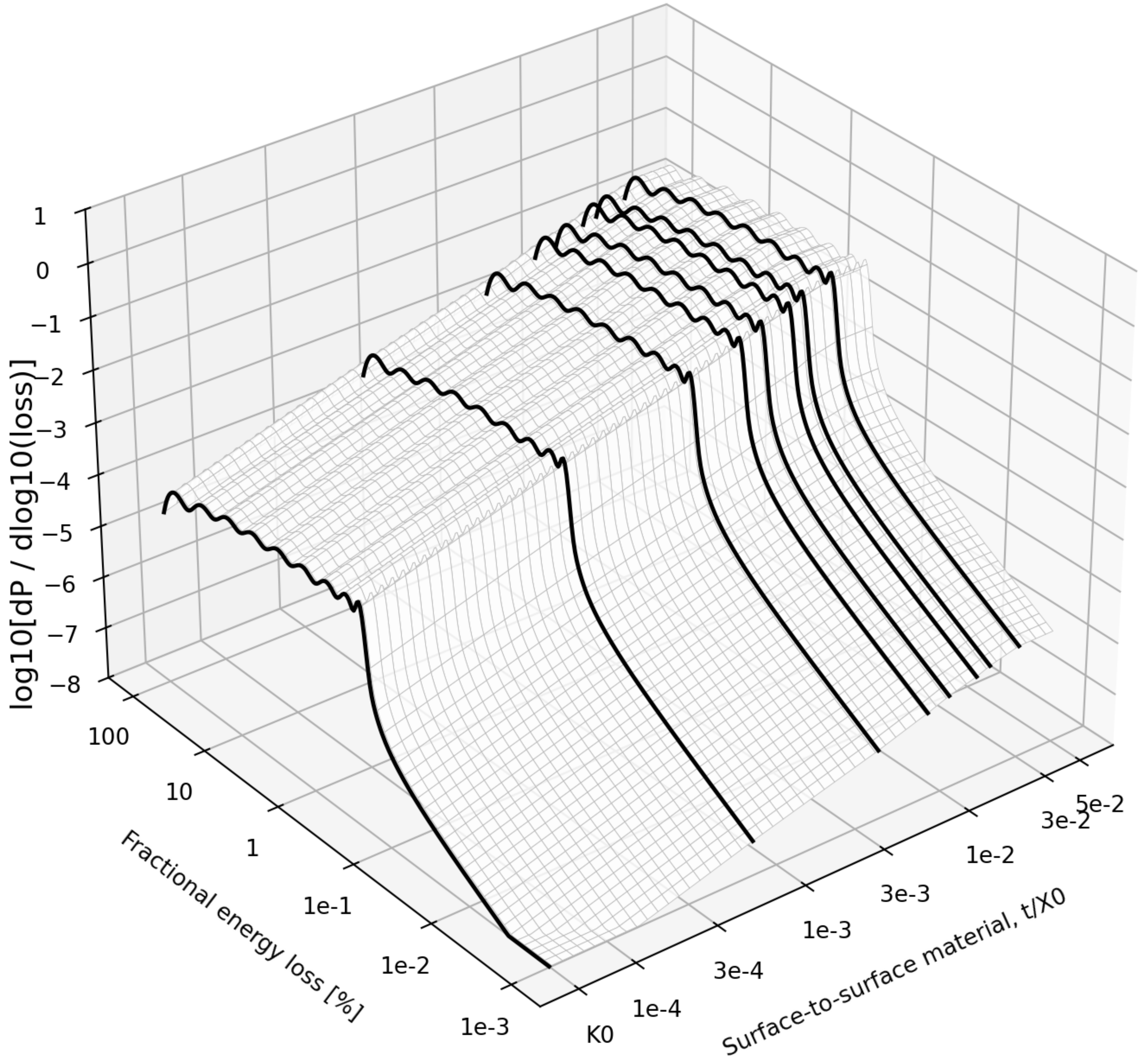


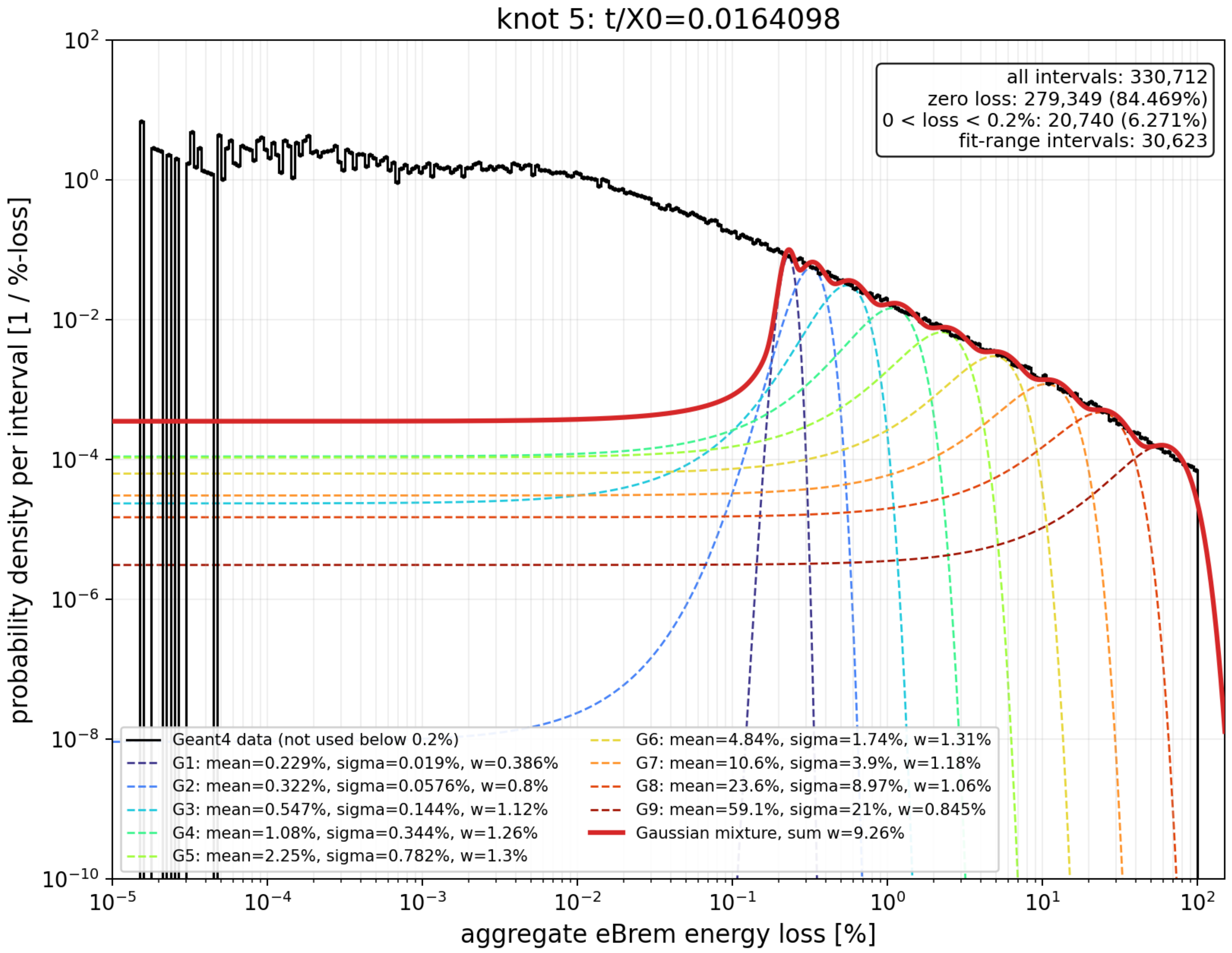
- **ebrem varies as the material thickness in radiation length ($t/X0$)**
- **G4 ebrem vs. DD4hep->MaterialBetween(p1, p2)**

Detector role	t/X0
Adjacent TPC rows	0.005%
Thin VXD layer	0.07%
Outer VXD/service	0.4%
ITK layer	0.8%
ITK-TPC brige	1.1%
TPC-OTK boundary	1.6%
Thick guard	3 %

- **7 interpolation knots for ebrem modelling**

eBrem Modelling

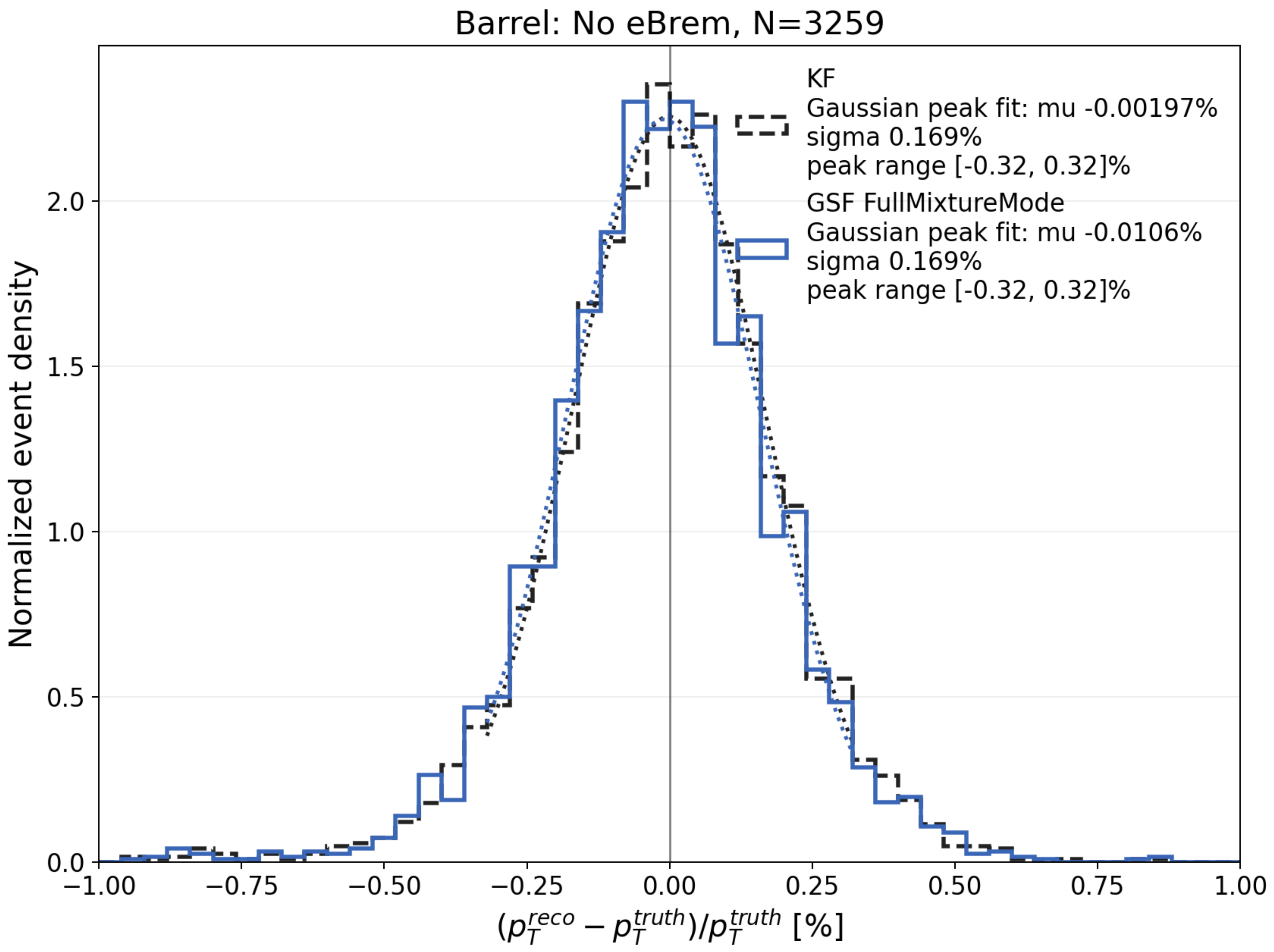


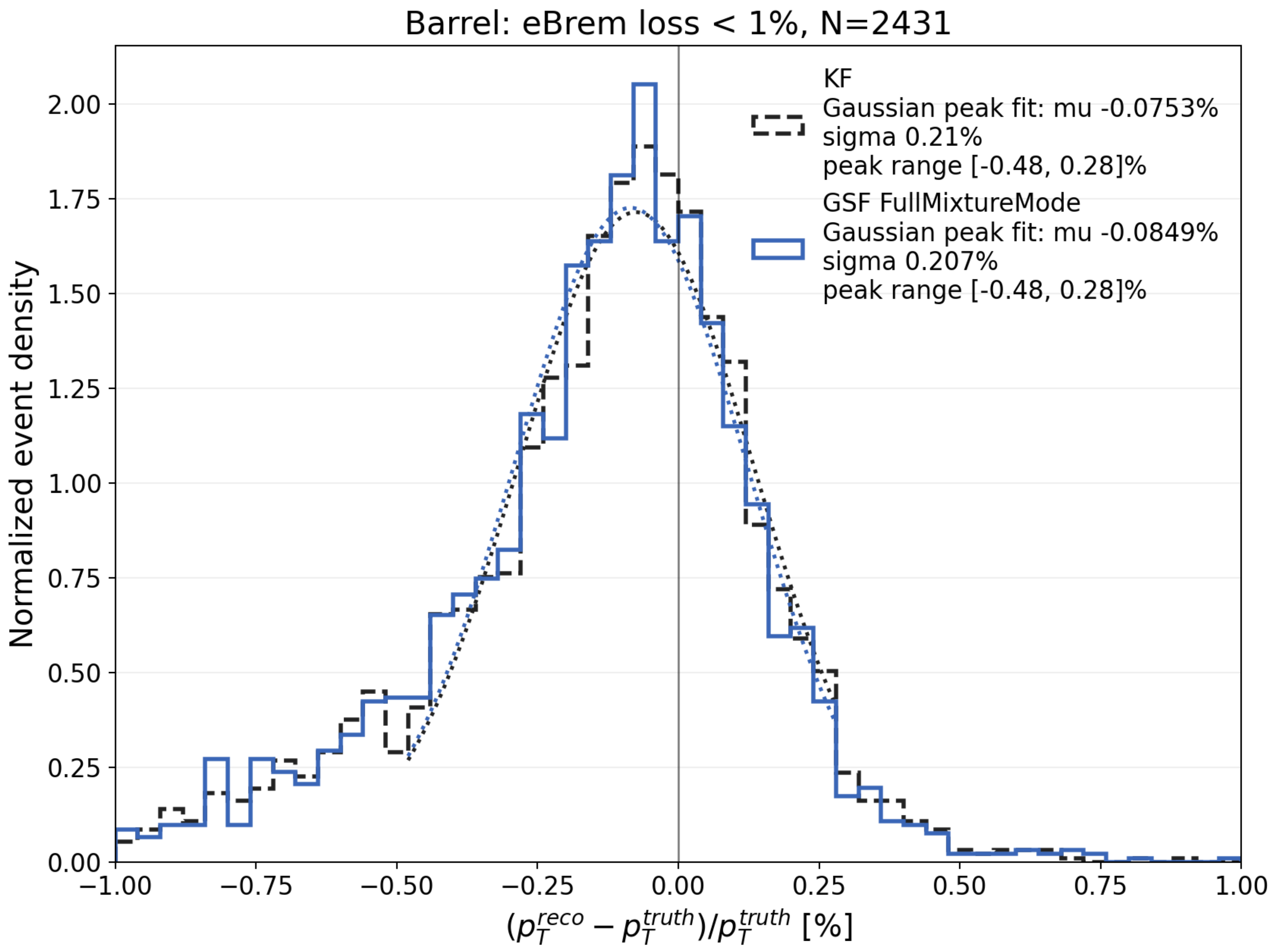


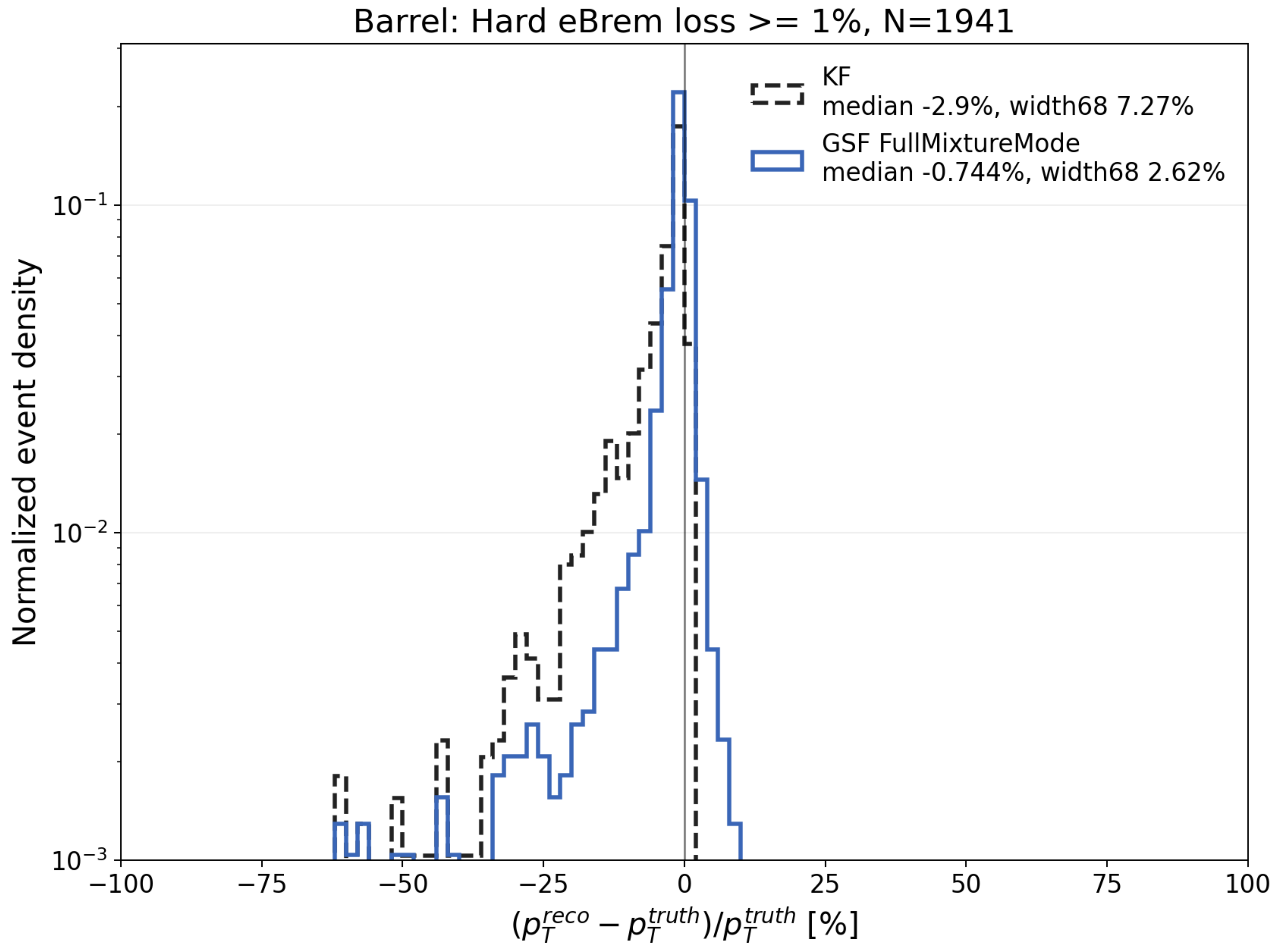
- **ebrem model is a function of radiation lengths (t/X_0)**
- **GSF algorithm reads $t/X0$ between two hits, and selected a pretrained Gaussian mixture**

- $P_{ebrem} = \Sigma w_i N(\mu_i, \sigma_i)$; **A 9-Gaussians mixture covers $0.2 - 100\,\%$ ebrem energy losses**
- **KF can handle the energy losses below $0.2\,\%$**

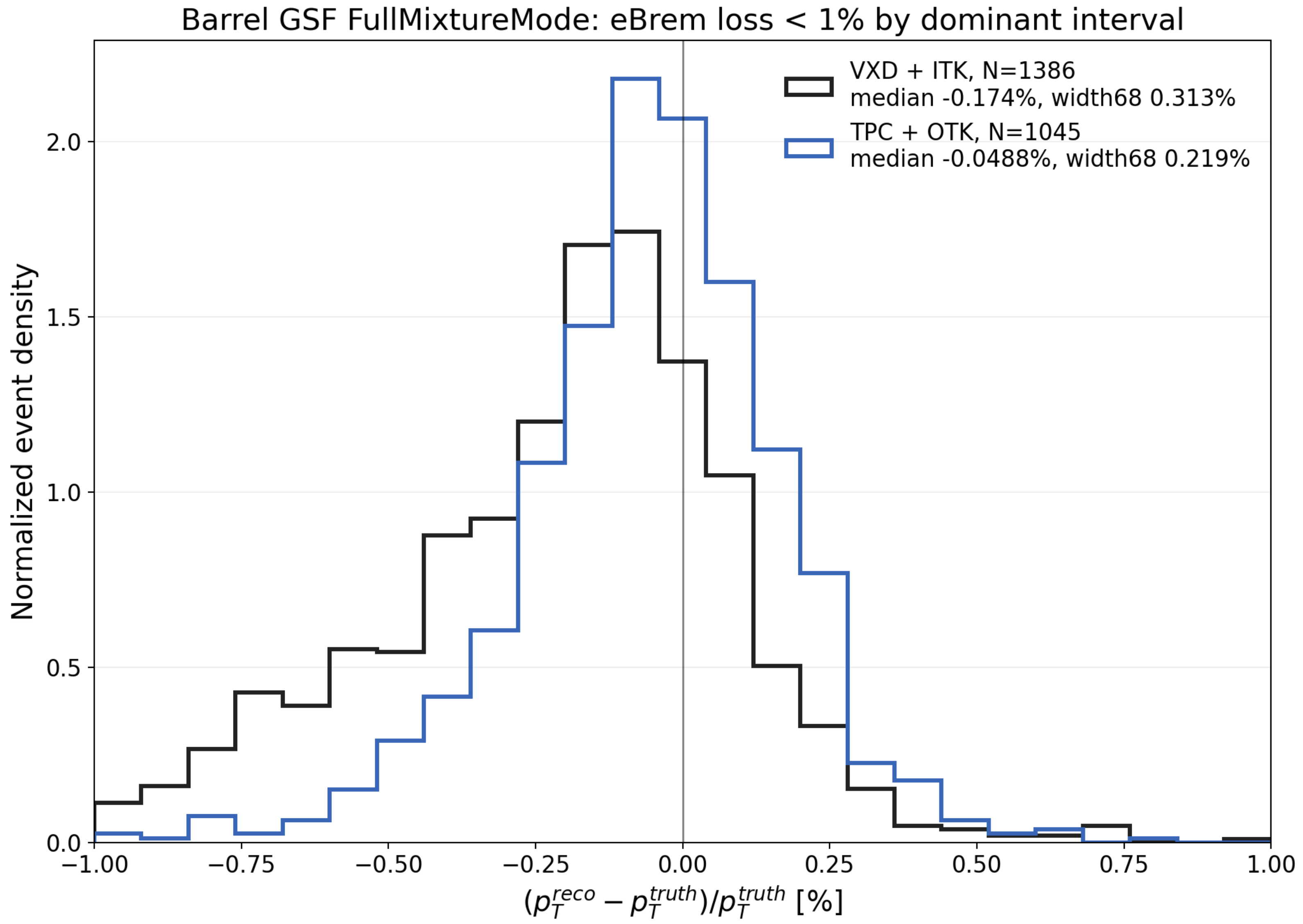
Performance



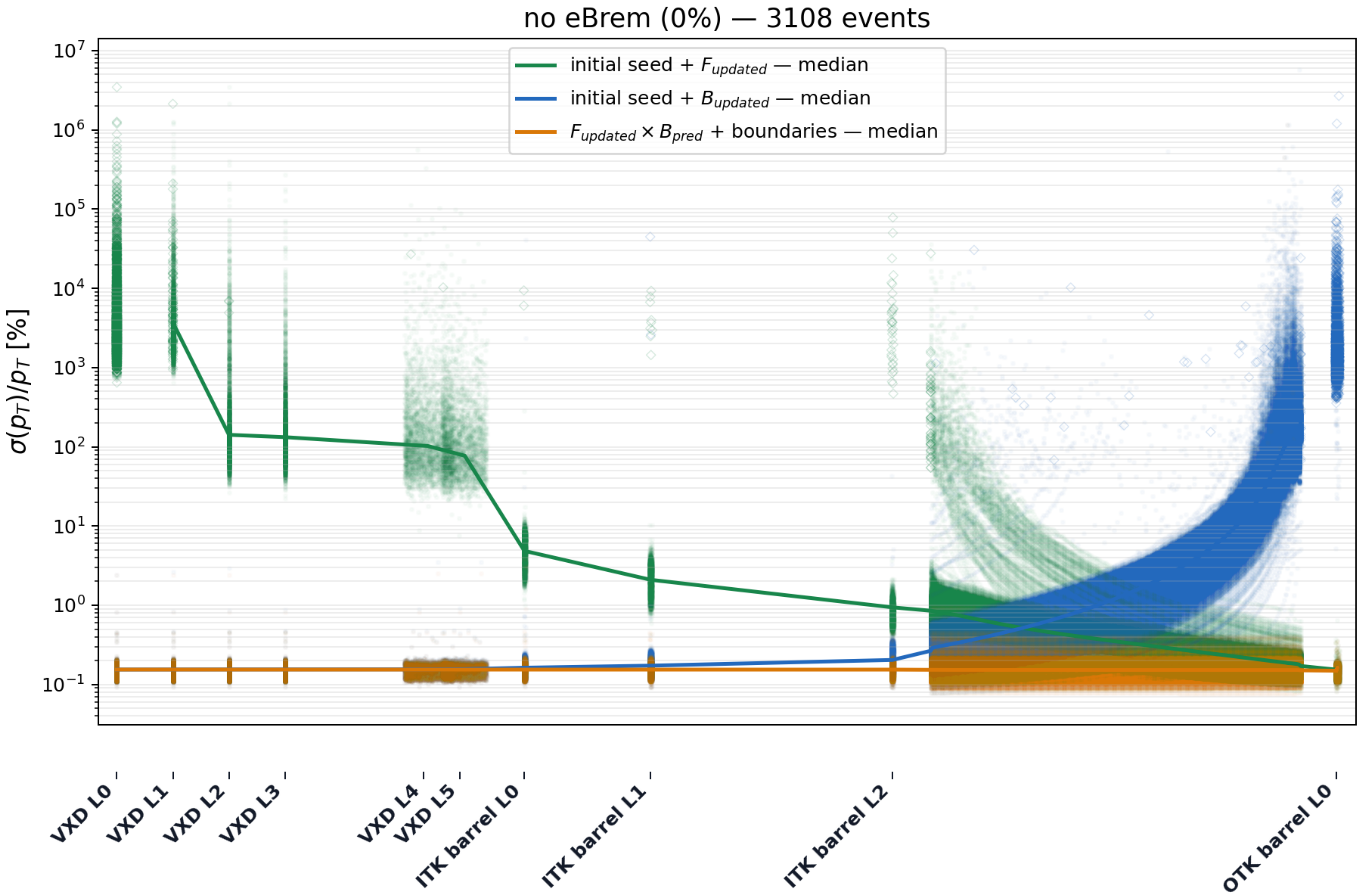




- No-ebrem events: performance comparable to that of muons, with a resolution of ~ 0.2%
- Light-ebrem events: A bias of -0.1%, which GSF cannot calibrate.
- The algo. is effective for hard-ebrem events, and mainly improves the far-left tail. It can not improve the peak resolution
- Classify light-ebrem events according to where the ebrem occurs



Diagnosis & Possible Solutions



- Standard KF:
  - Forward filter: The recursion starts from the innermost hit
  - Backward filter: The recursion starts from the outermost hit
  - Smoothing: The two filters are combined at each hit, yielding a final precision about 0.2%
- GSF:
  - No forward-filter information is available in the VXD region
  - The GSF cannot identify ebrem occurring near either end of the track
  - There are insufficient downstream hits to confirm the eBrem hypothesis
- Possible solution
  - Is the initial seed covariance too large ?
  - Use beam-spot as a visual measurement to strengthen the eBrem hypothesis for radiation occurring in the inner silicon layers

Summary & Todo

- Because of the low material budget, the GSF provides little improvement in electron tracking performance
  - Ideas to be tested
- We decide to include electron final state in the recoil mass paper because electron resolution is good.
- Explore the possibility of adding cross-section and coupling measurements, with the systematic uncertainties to be studied