χ^2 track fitting in Acts

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Ralf Farkas
ralf@uni-bonn.de

Bundesministerium für Bildung und Forschung
ErUM-Data IDT
UNIVERSITÄT BONN

Part 1

Acts

Acts — a common tracking software

- experiment independent toolkit for track reconstruction
- open source: github.com/acts-project
- track parametrization: $\vec{x} = (d_0, z_0, \phi, \theta, q/p, t)$

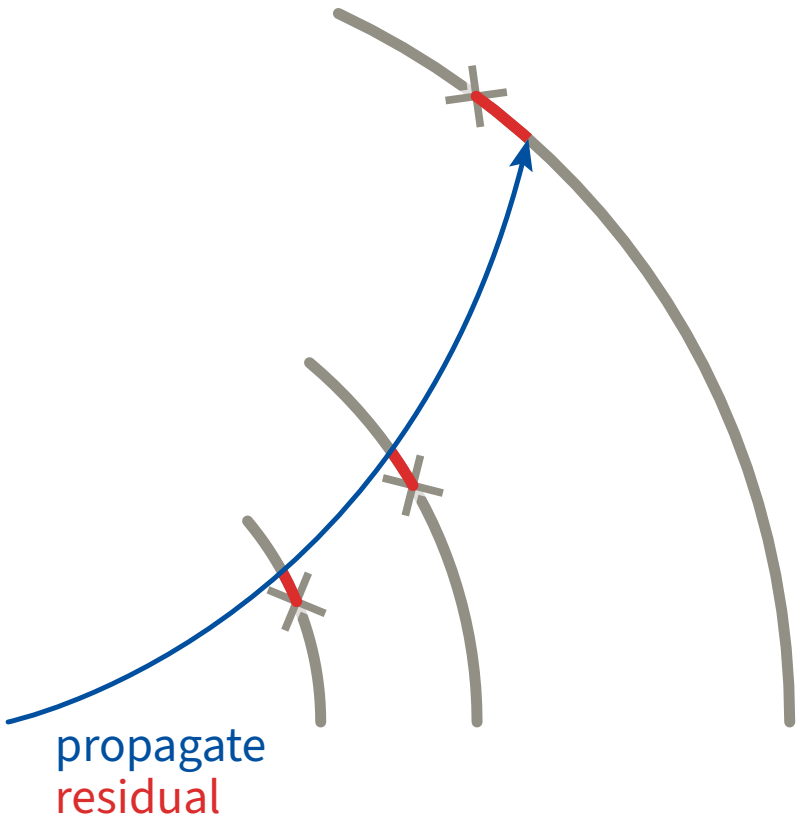
Part 2

Gχ^2F: general approach

global χ^2 fitter — Actor

- starting track parameters $\vec{x}_0$ (6-dim)
- propagation with transport matrix H
- residuals (per layer) $r = m - H\vec{x}_0$

$$\chi^2 = r^T \,\mathrm{cov}^{-1}\, r$$



global χ^2 fitter — Actor

- starting track parameters $\vec{x}_0$ (6-dim)
- propagation with transport matrix H
- residuals (per layer) $r = m - H\vec{x}_0$

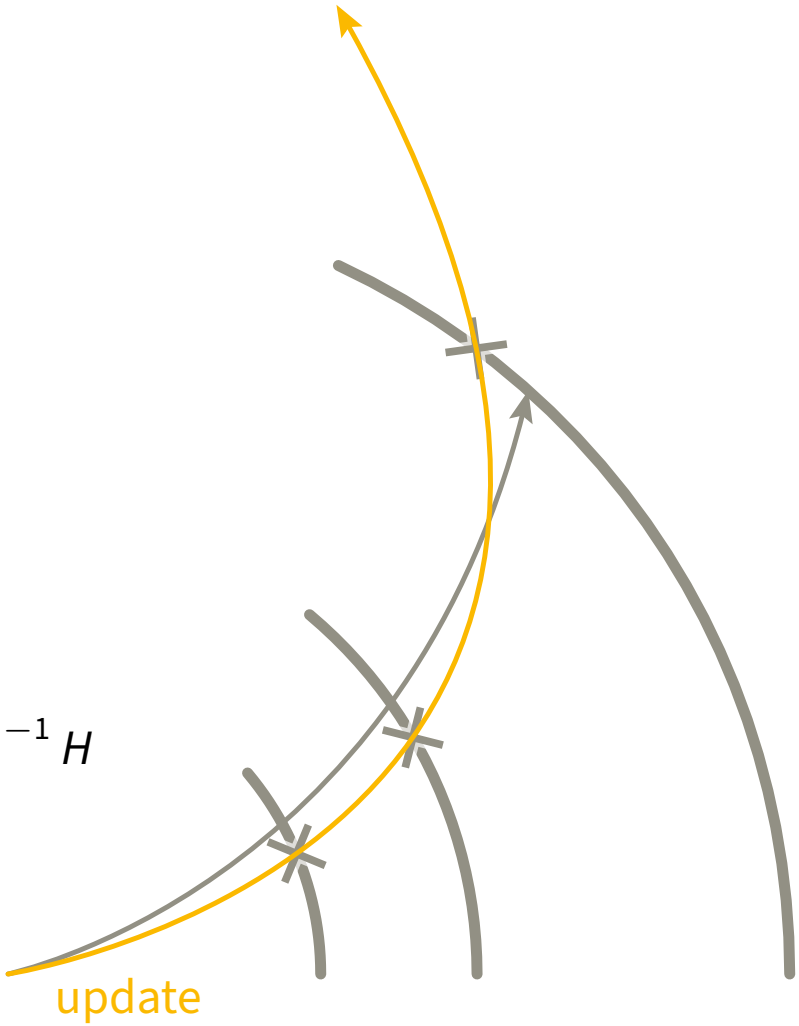
$$\chi^2 = r^T \operatorname{cov}^{-1} r$$

- update

$$\frac{\mathrm{d}\chi^2}{\mathrm{d}x} = -2H^T \operatorname{cov}^{-1} r \qquad \frac{\mathrm{d}^2\chi^2}{\mathrm{d}x^2} = 2H^T \operatorname{cov}^{-1} H$$

$$\vec{x}_1 = \vec{x}_0 - \left(\frac{\mathrm{d}^2\chi^2}{\mathrm{d}x^2}\right)^{-1} \frac{\mathrm{d}\chi^2}{\mathrm{d}x}$$

- iteration



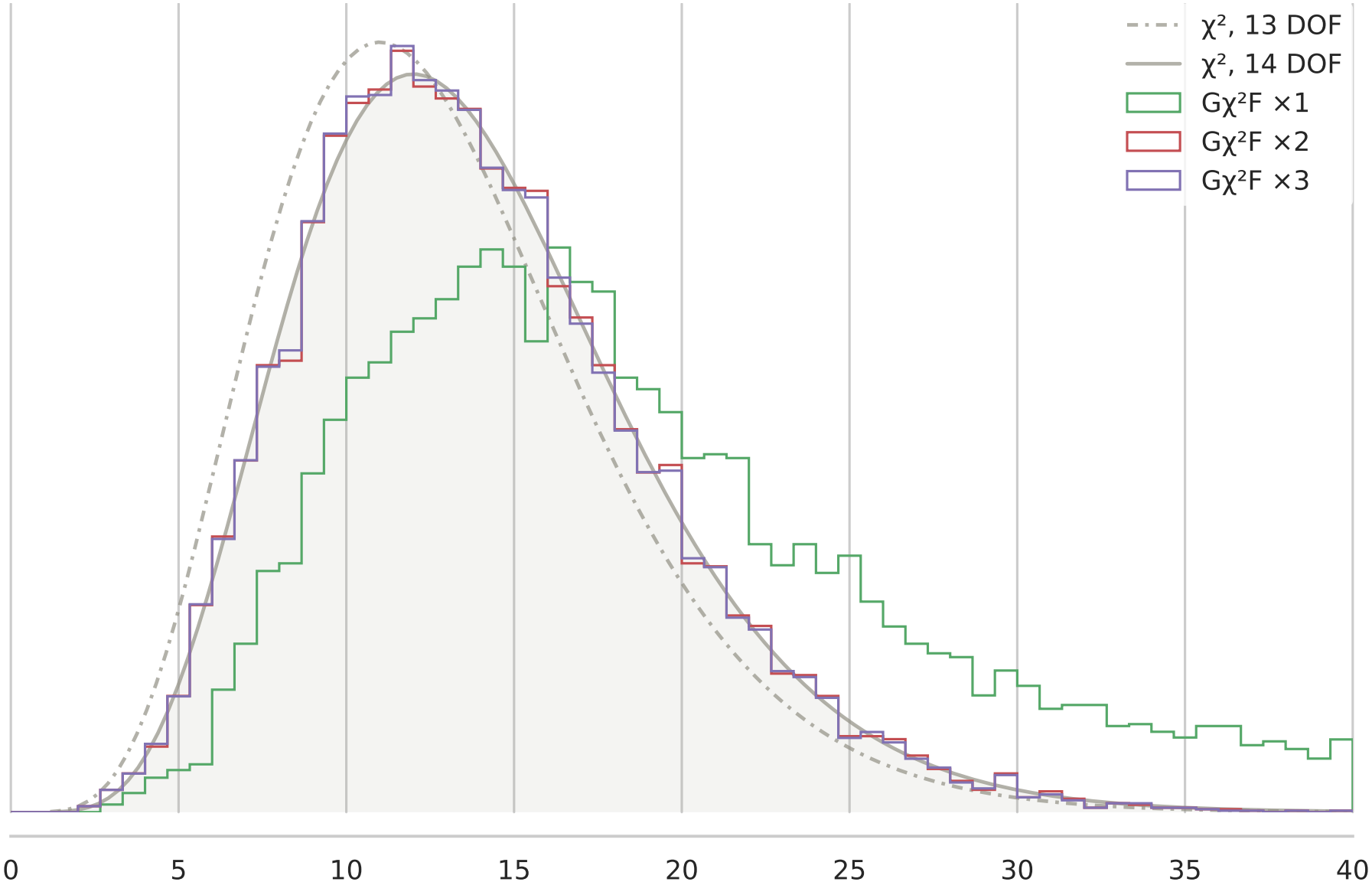
Part 3

results

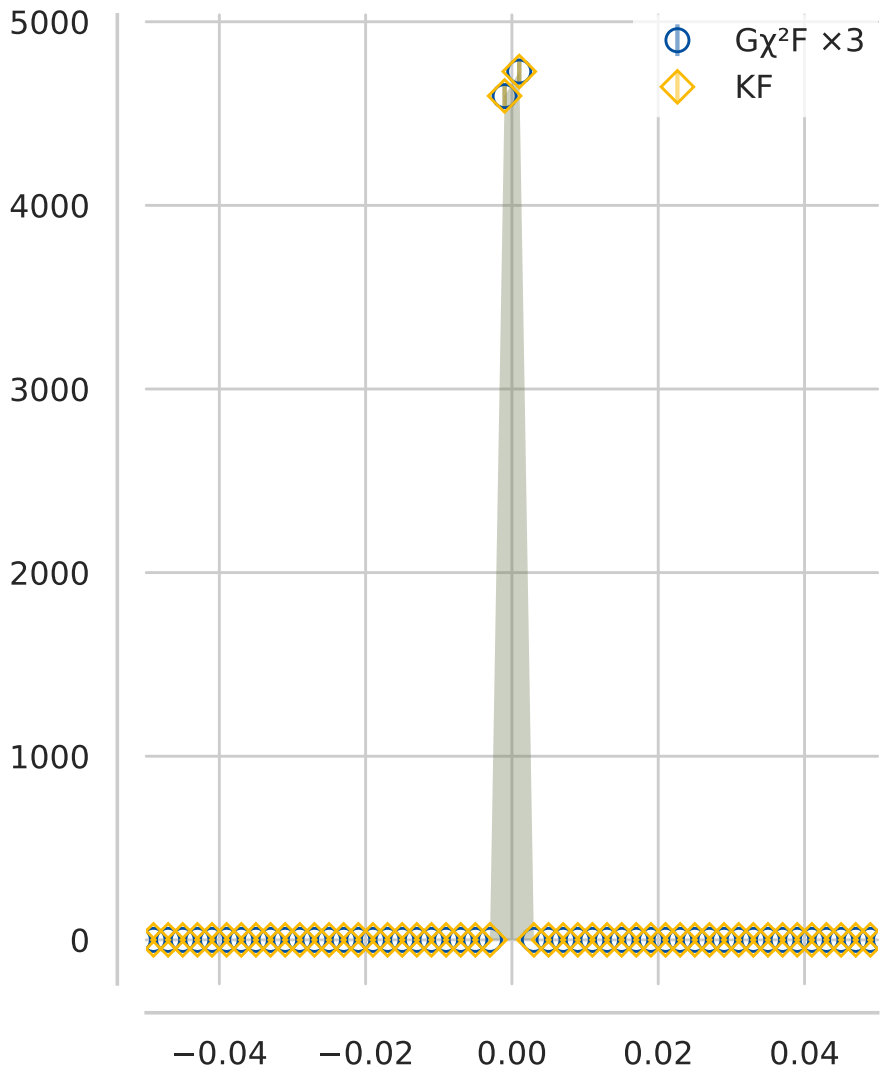
setup

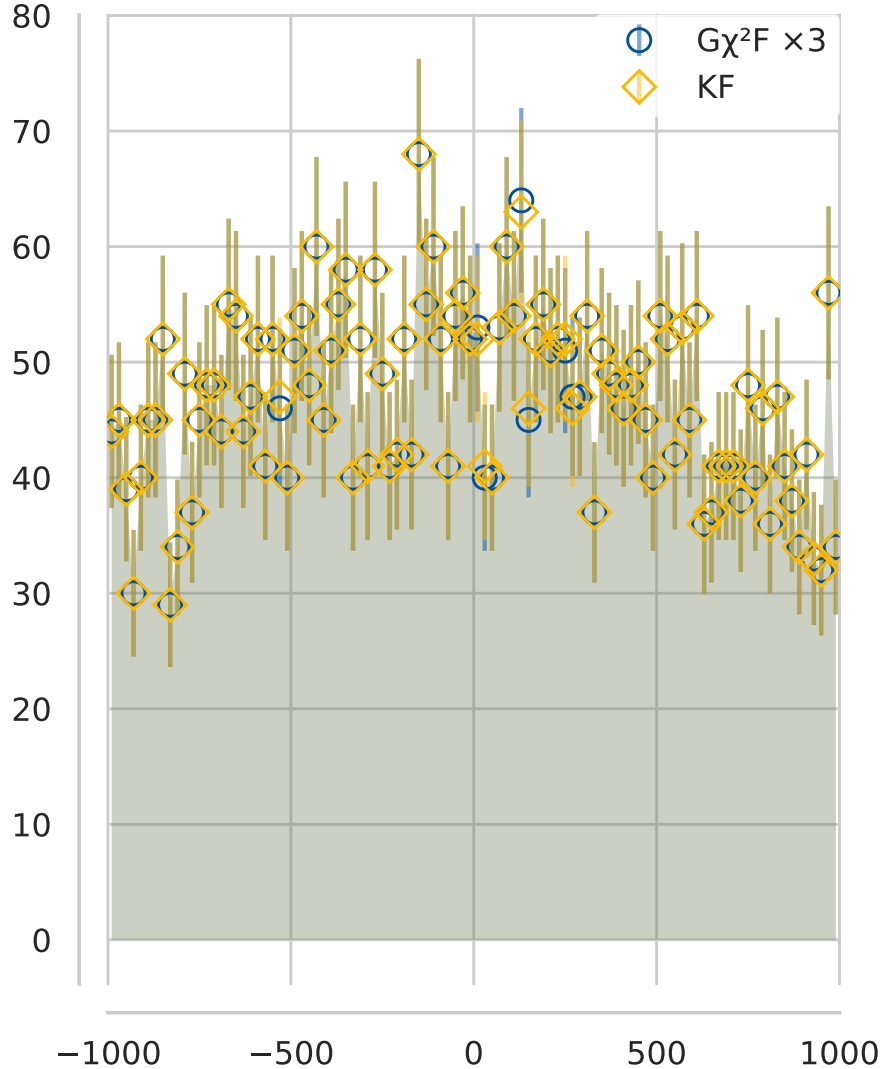
- simulated events
  - 9-layer telescope detector, pixel layers → x
  - $\vec{B} = (0, 0, 0)$
  - 1 muon per event, 10k events
  - *no* scattering, radiation, ...
- gaussian smearing of measurements
- reconstruction
  - TruthTrackFinder → smeared (true) starting parameters
  - Gχ²F with multiple iterations

χ^2 distribution — 10k events $n_{\text{DOF}} = 2 \times 9 - 4 = 14$

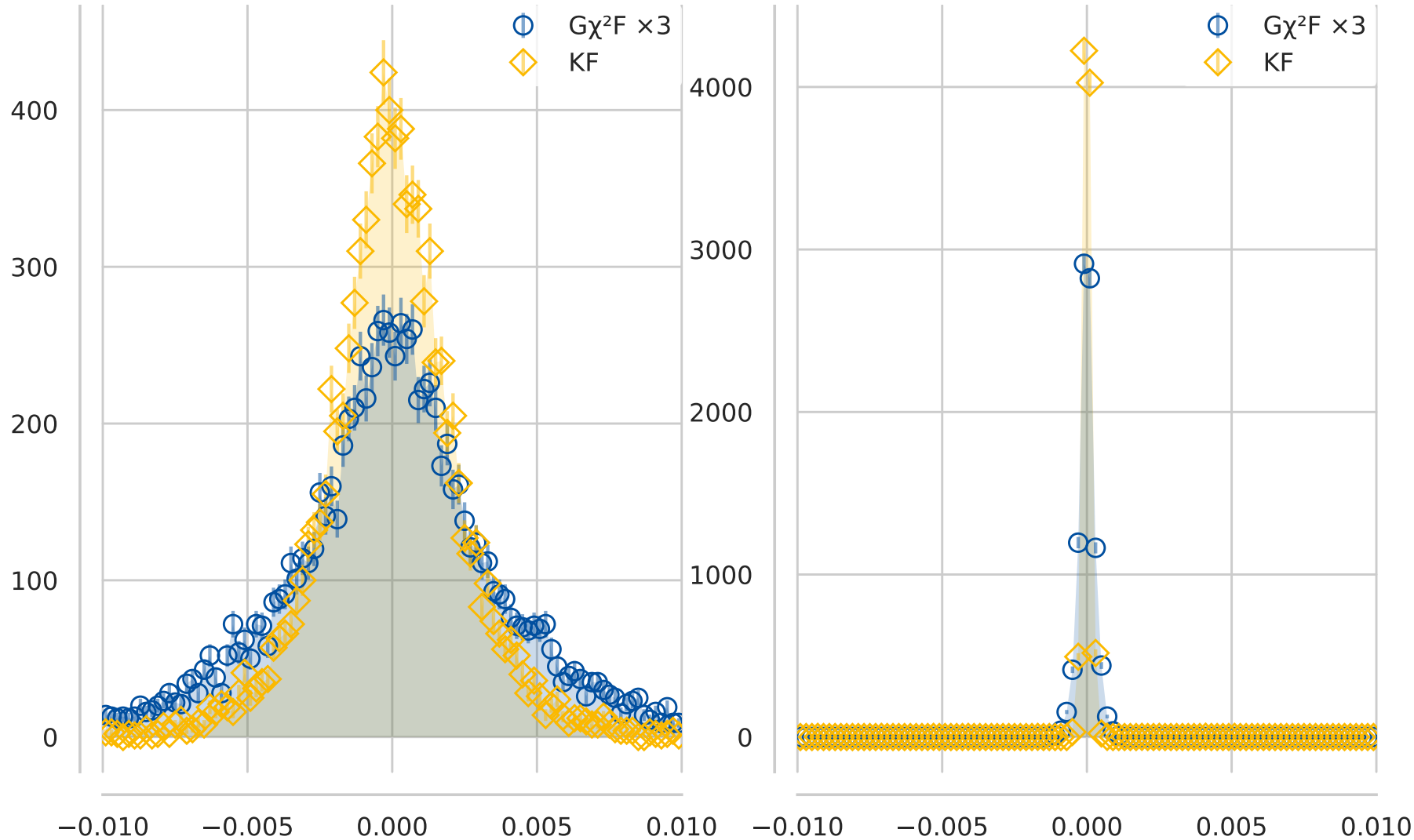


residuals on track parameters — q/p, t (true-reco)

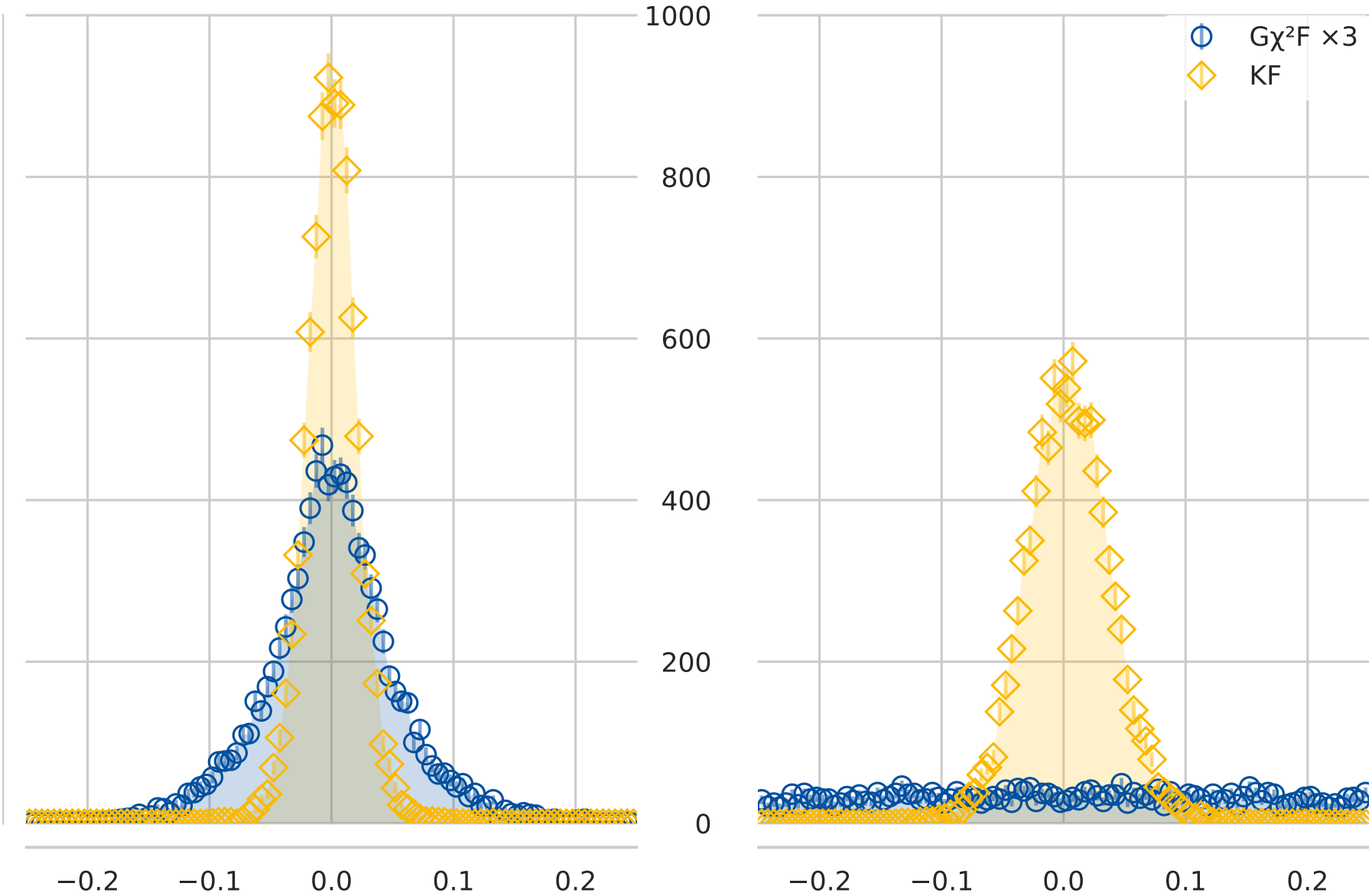




residuals on track parameters — ϕ, θ (rad)



residuals on track parameters — d_0, z_0 (mm)



Part 4

summary

summary

- ✓ Unit Test + Algorithm + Example + python bindings
- ✓ gives reasonable results
- ✓ almost ready to be merged with Acts main (PR #1099 🔗)
- ☐ what's happening with z_0?
- ☐ multiple scattering + energy loss
  - minimization?

$$\chi^2 = \sum_{\text{meas}} \frac{r^2_{\text{meas}}}{\sigma^2_{\text{meas}}} + \sum_{\text{scat}} \left(\frac{\theta^2_{\text{scat}}}{\sigma^2_{\text{scat}}} + \frac{(\sin\theta_{\text{loc}})^2 \phi^2_{\text{scat}}}{\sigma^2_{\text{scat}}} \right) + \sum_{\text{Eloss}} \frac{(\Delta E - \overline{\Delta E})^2}{\sigma^2_{\text{Eloss}}}$$