Offline Software for the PANDA Luminosity Detector

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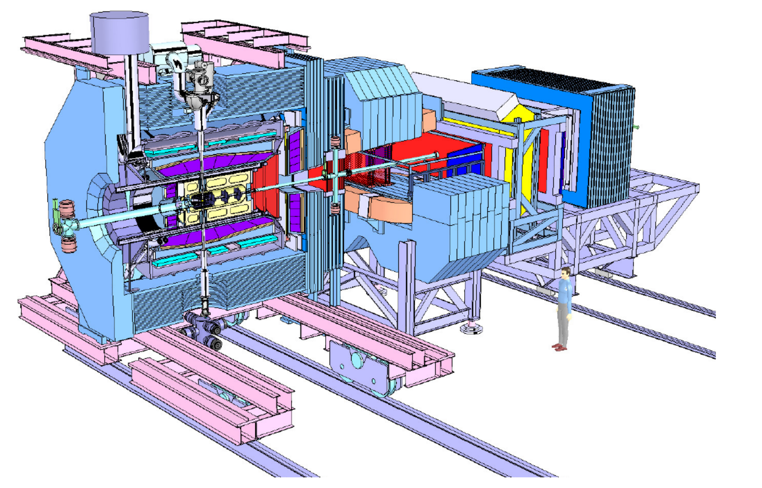
$\bar{\text{P}}$ANDA@FAIR Experiment

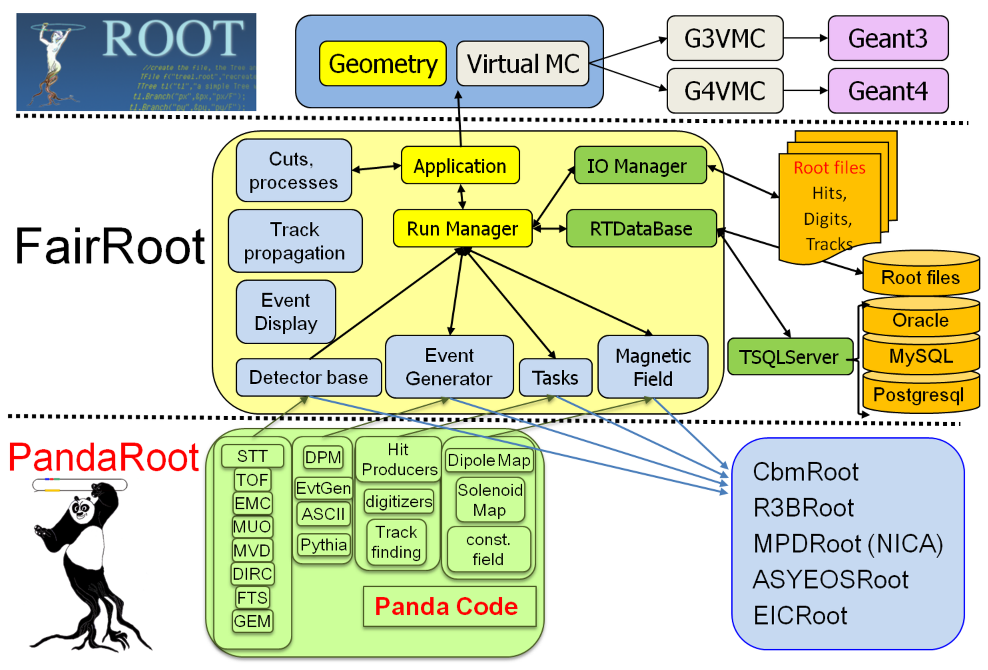
A fixed target experiment with antiproton beam (momentum range: 1.5 to 15 GeV/c)



Physics program

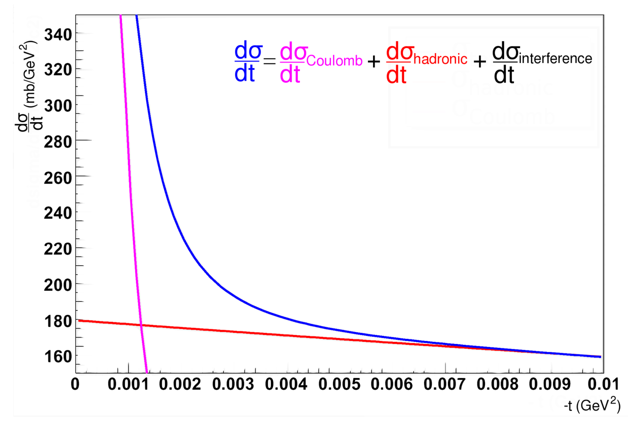
- Hadron Spectroscopy
- Hadrons in Matter
- Nucleon Structure
- Hypernuclei

PandaRoot



Luminosity Determination

$p\bar{p}$ elastic scattering

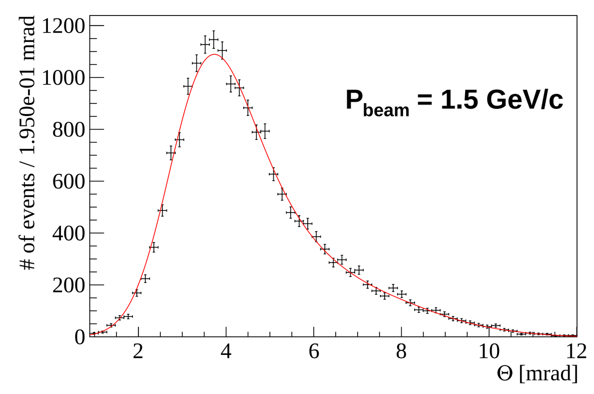


- coulomb part: can be calculated from QED
- hadronic part: measurement+models

measurement at small momentum transfer → small scattering angle θ (3-8 mrad)

Luminosity Extraction

Reconstructed data with model fit



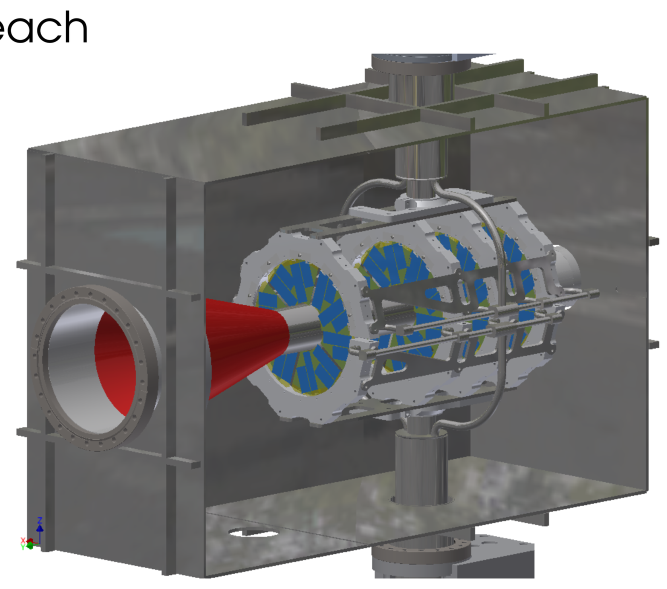
Model:

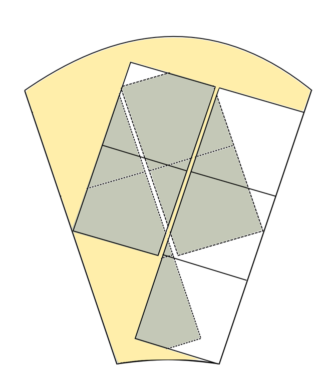
$$N = L \cdot (\sigma \cdot \epsilon) \otimes \theta_{RES}$$

N – number of events, σ – cross section
ϵ – efficiency, θ_{RES} – resolution, L – luminosity

The Luminosity Detector (LMD)

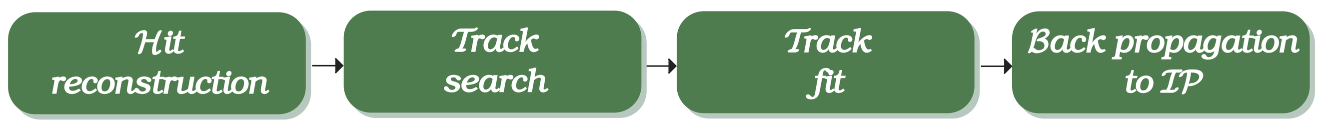
- measurement at small θ
- position ~ 11 m downstream from IP
- 4 detector planes with 10 modules each





- 10 silicon pixel sensors per module
- HV-MAPS 2×2 cm^2, 50 μm thick with 80×80 μ m^2 pixels
- CVD-diamond (200 μm) as supporting structure
- placed inside vacuum to minimize multiple scattering of $\bar{p}$

LMD Track Reconstruction Chain



Track Search

- robustness against hit losses
- flexibility to hits scattering

⇒ two competitive algorithms

Track Fit

straight line fit not suitable
⇒ "broken-lines" approach

Back Propagation

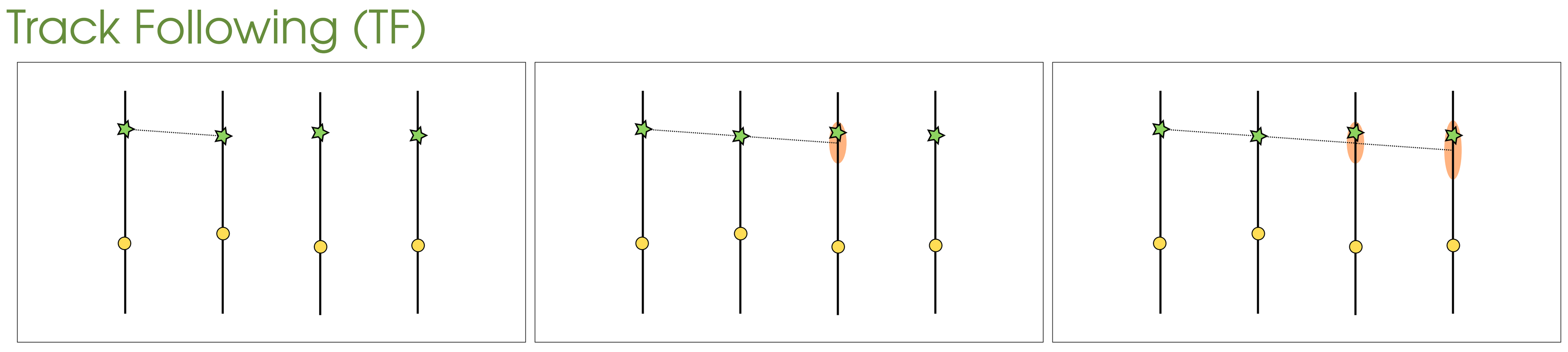
- distance between IP and LMD contains complicated magnetic field structure
- small θ angles

⇒ two competitive algorithms

Track Reconstruction

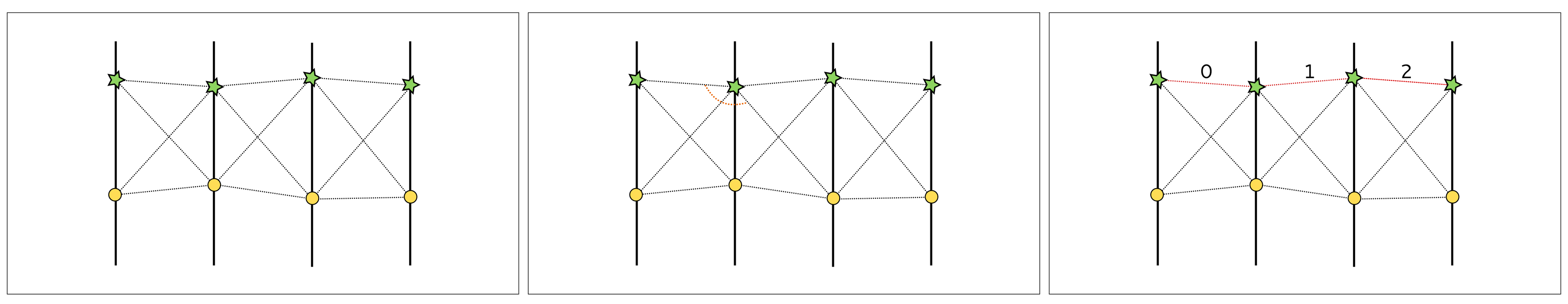
Track Search Algorithms

Track Following (TF)



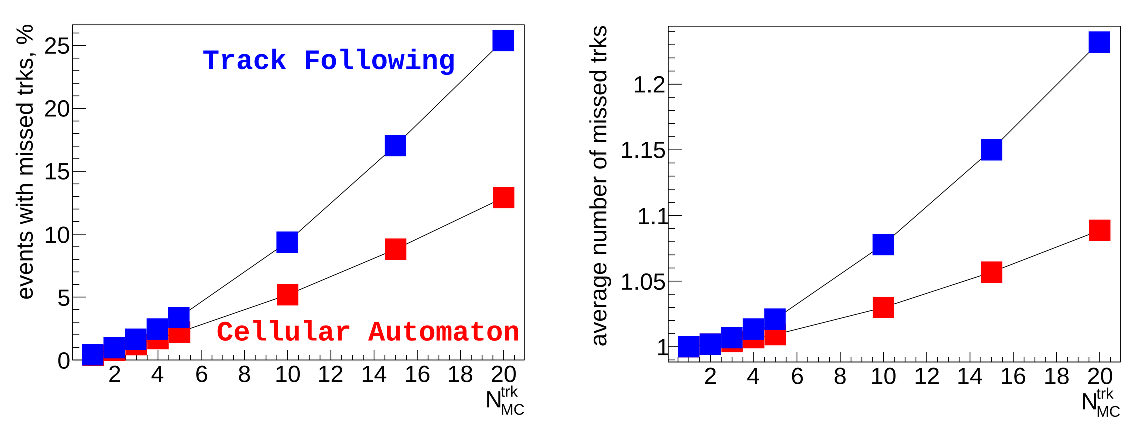
- combinations between 1st and 2nd planes
- additional hit on 3rd plane inside corridor
- additional hit on the last plane inside enlarged corridor
- *missing plane* algorithm extension: only 3 hits are necessarily

Cellular Automaton (CA)



- build all combinations between hits on pairs of planes (cells)
- search for neighboring cells by check of breaking angles
- arrange cells during evolution by number of neighbors
- *missing plane* algorithm extension: cells are also built by skipping layers in between

Results from simulation tests ($P_{beam} = 1.5\ GeV/c$)



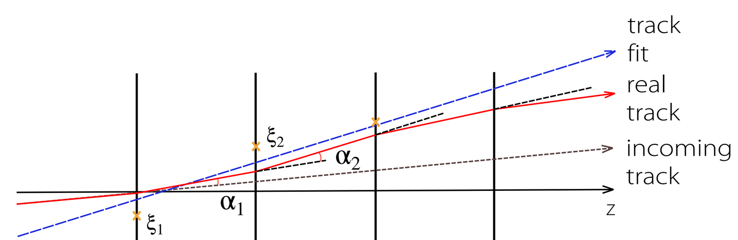
- similar amount of missed & ghost tracks for low track multiplicity
- CA gives smaller number of missed tracks at high multiplicities
- TF is faster, especially for events with high track multiplicity

Track Fit

The least squares method with "broken lines" track model (Minuit)

$$\chi^2 = \sum_{l=1}^{4}\left(\frac{(\xi^x_l - x_l)^2}{\sigma_x^2} + \frac{(\xi^y_l - y_l)^2}{\sigma_y^2}\right) + \sum_{J=1}^{4}\frac{(\alpha^x_J)^2 + (\alpha^y_J)^2}{\sigma_s^2}$$

ξ^x, ξ^y - hit coordinates with uncertainties σ_x, σ_y
x_l, y_l - coordinates of track on plane l
α^x_J, α^y_J - scattering angles on plane J



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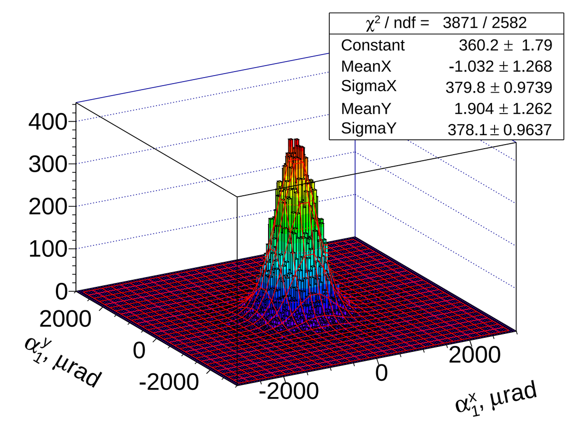


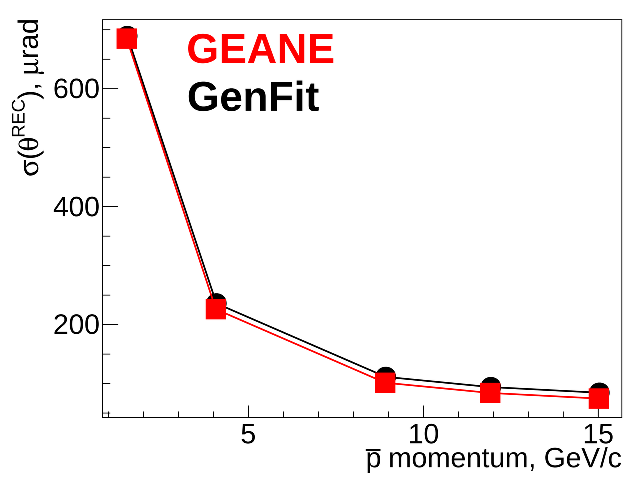
Breaking angles α^x and α^y

Resolutions and pulls of starting track point (X_{start}, Y_{start}) and momentum vector at this point (P_x, P_y, P_z) after Track Fit

Parameter	Resolution	Pull Mean	Pull Sigma
X_{start}	$14.03 \pm 0.02,\ \mu m$	$-1.3 \cdot 10^{-3}$	0.96
Y_{start}	$14.04 \pm 0.02,\ \mu m$	$2.3 \cdot 10^{-3}$	0.97
P_x	$444 \pm 2,\ keV$	$6.5 \cdot 10^{-3}$	1.1
P_y	$443 \pm 2,\ keV$	$3.9 \cdot 10^{-3}$	1.1
P_z	$18 \pm 0.1,\ keV$	$-3.4 \cdot 10^{-3}$	1.1

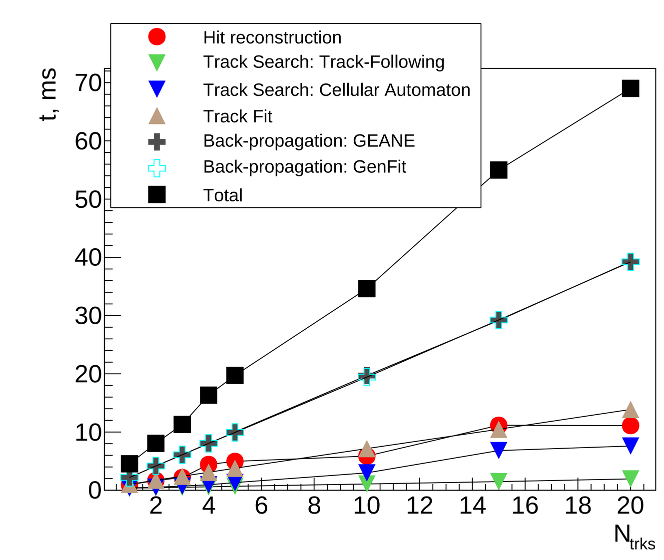
Back Propagation to Interaction Point

Recalculation of track parameters through the dipole and solenoid magnetic field
θ resolution after back propagation



decreases with decreasing momentum due to multiple scattering

Time consumption

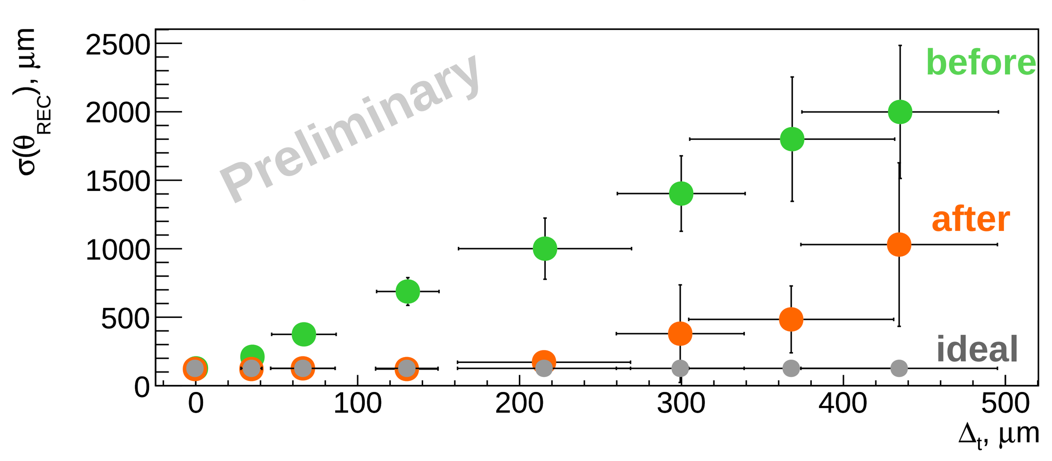


slowest process → Back Propagation
fastest process → Track Following

Relative Alignment of Modules

- Fast track-based software alignment procedure
- Based on a non-iterative least squares fitting method
- Utilizes a C++ implementation of the "matrix-crushing" algorithm Millepede

Translation misalignment influence on θ resolution

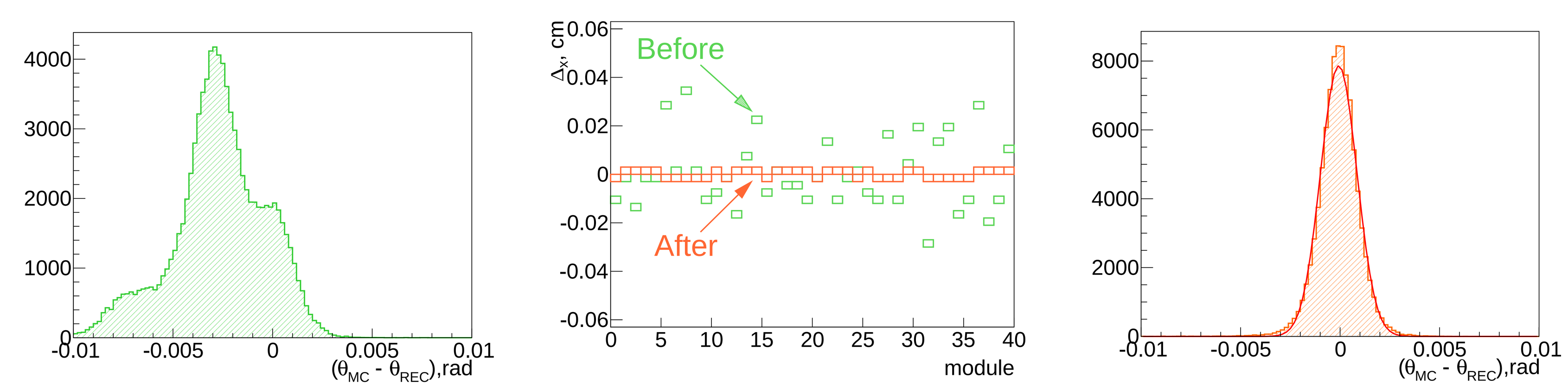


Misalignment of:

- 50 μm already disturbs reconstruction
- up to 250 μm can be corrected

Expected mechanical accuracy ($\Delta_{trans} \sim 200\ \mu$m, $\Delta_{rot} \sim$ 3mrad)

θ resolution before alignment | Δ_x before and after | θ resolution after alignment



θ resolution after alignment is the same as for modules with ideal alignment