



Muon tracks analysis with a Kalman Filter at NOvA

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Overview

- Introduction to NOvA and Kalman filters
- Analysis of a Kalman filter application used to reconstruct muon tracks in simulated neutrino interactions in NOvA detectors.



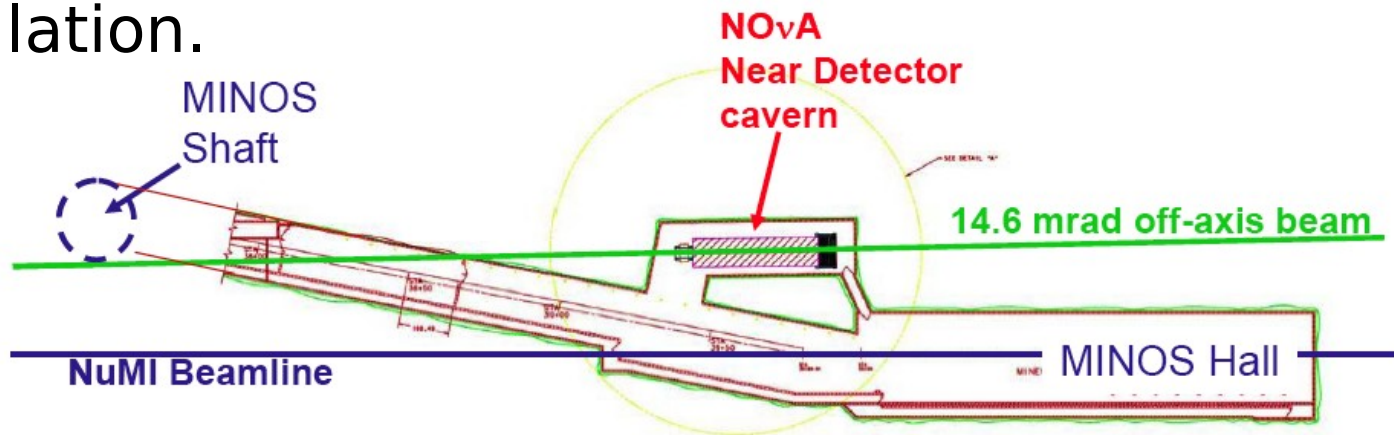
NOvA overview



NOvA

NOvA is an experiment to study $\nu_{\mu} \rightarrow \nu_e$ oscillation with the NuMI neutrino beam.

NOvA have two off-axis detectors (currently under construction) where the neutrino spectrum is narrow around 2 GeV, that is expected to maximize this oscillation.





Project's aims

- Main aim of NOvA is the measurement of $\sin^2(2\theta_{13})$, the little known angle that controls this oscillation.
- There are good chances for NOvA to detect CP violation in leptons and to measure the complex phase of neutrino mixing matrix.
- Determine neutrino mass hierarchy.



Kalman filters



Kalman filters

Kalman filters are very common and are used in a wide range of devices.

Some examples:

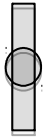
- Radars
- GPS navigation systems
- Autopilot
- Macroeconomic models



Kalman filters

Kalman Filter is an algorithm for determining **the best estimate** of the “current” state of a dynamic system.

- **Current best estimate (aka *filtered state*) with error**
- **True state**

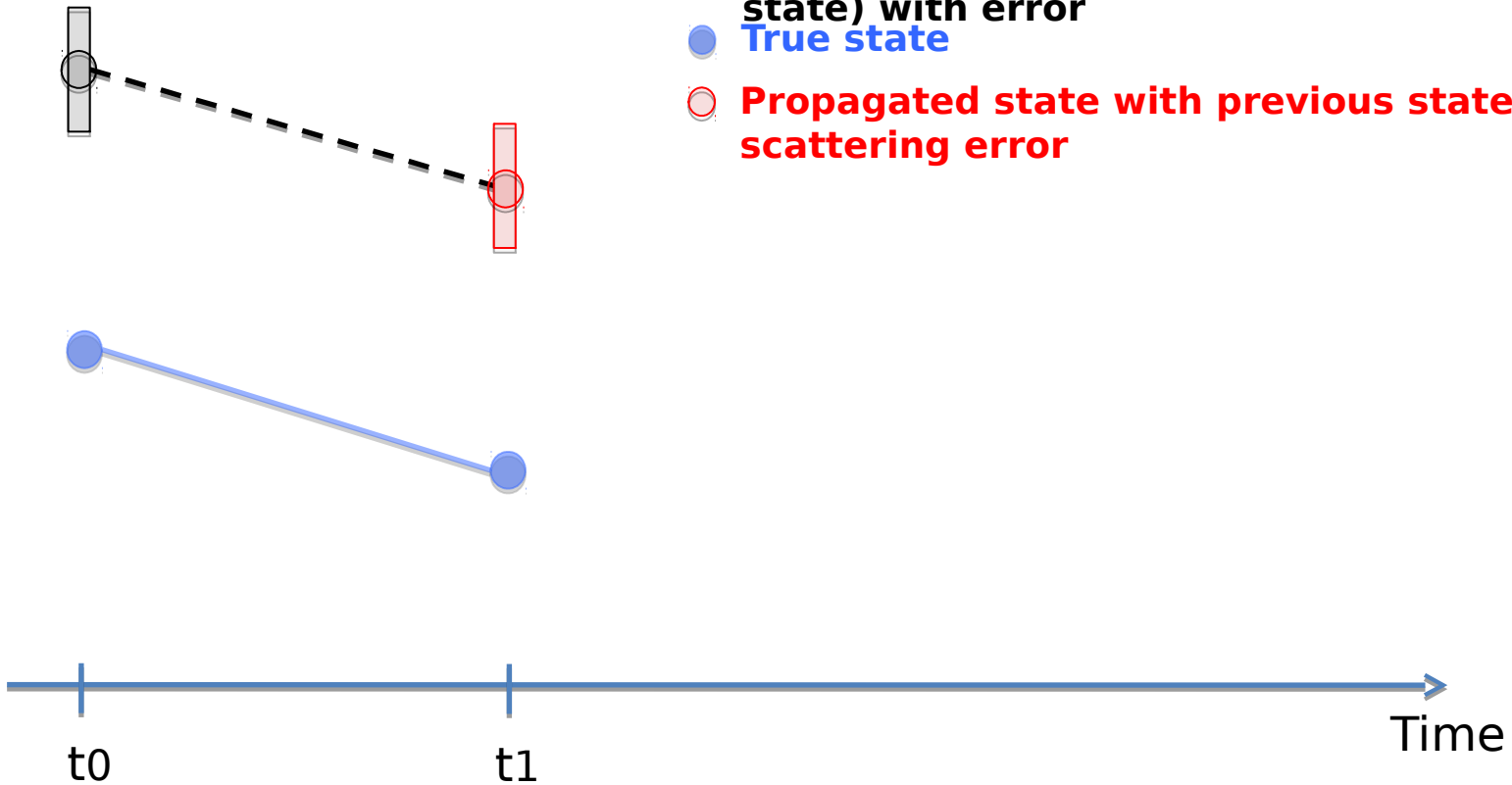




Kalman filters

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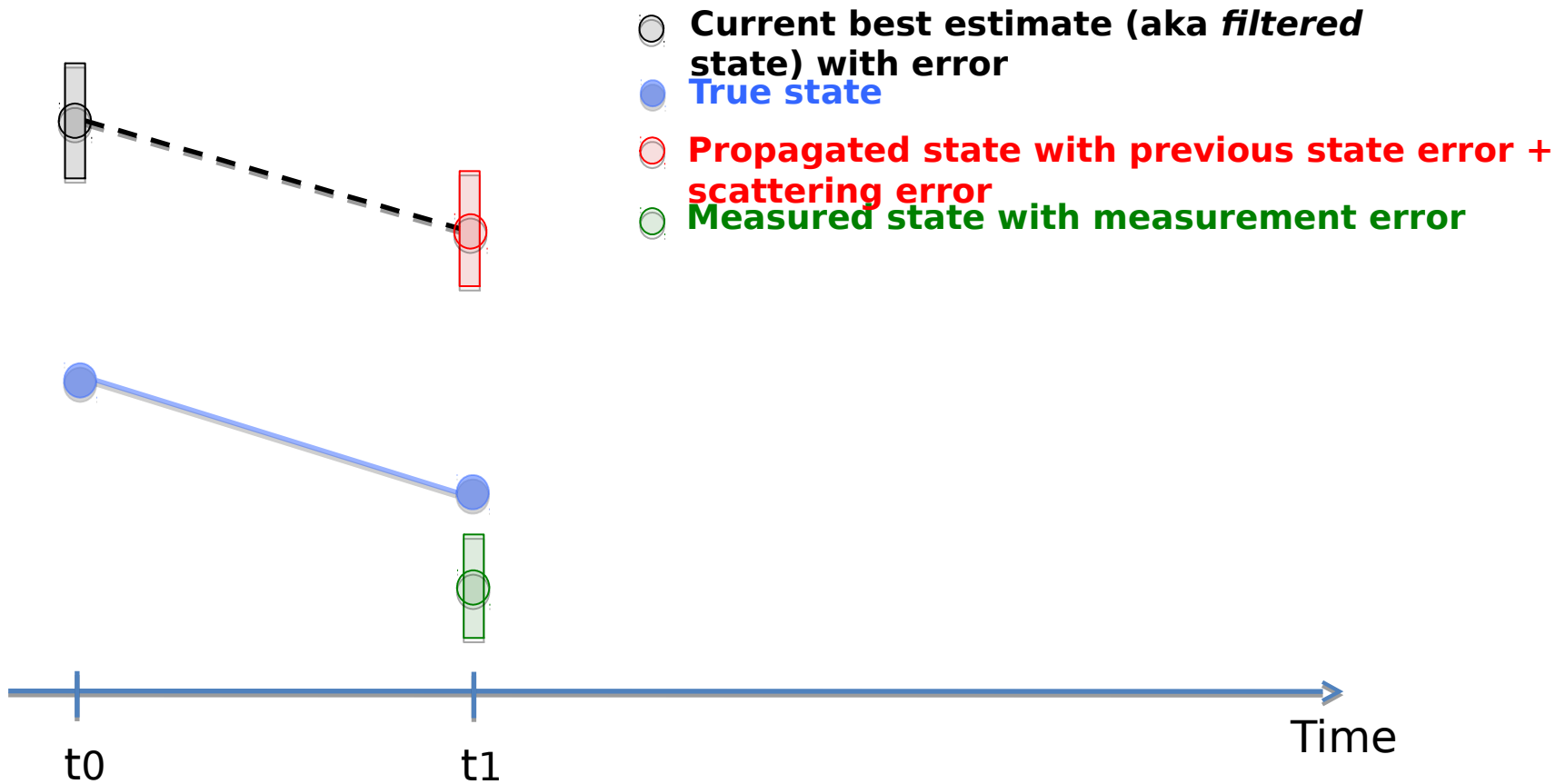
- **Current best estimate (aka *filtered state*) with error**
- **True state**
- **Propagated state with previous state error + scattering error**





Kalman filters

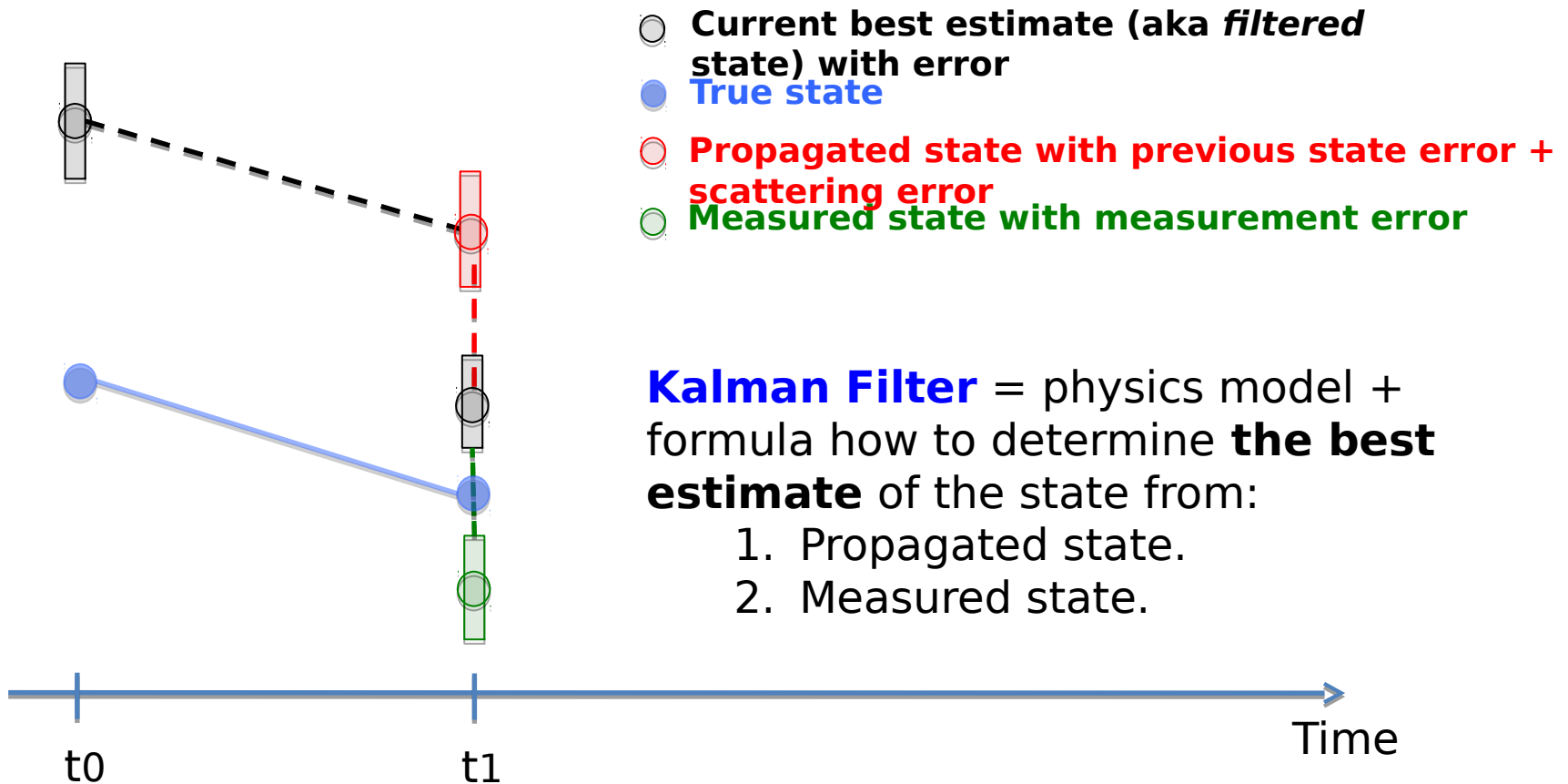
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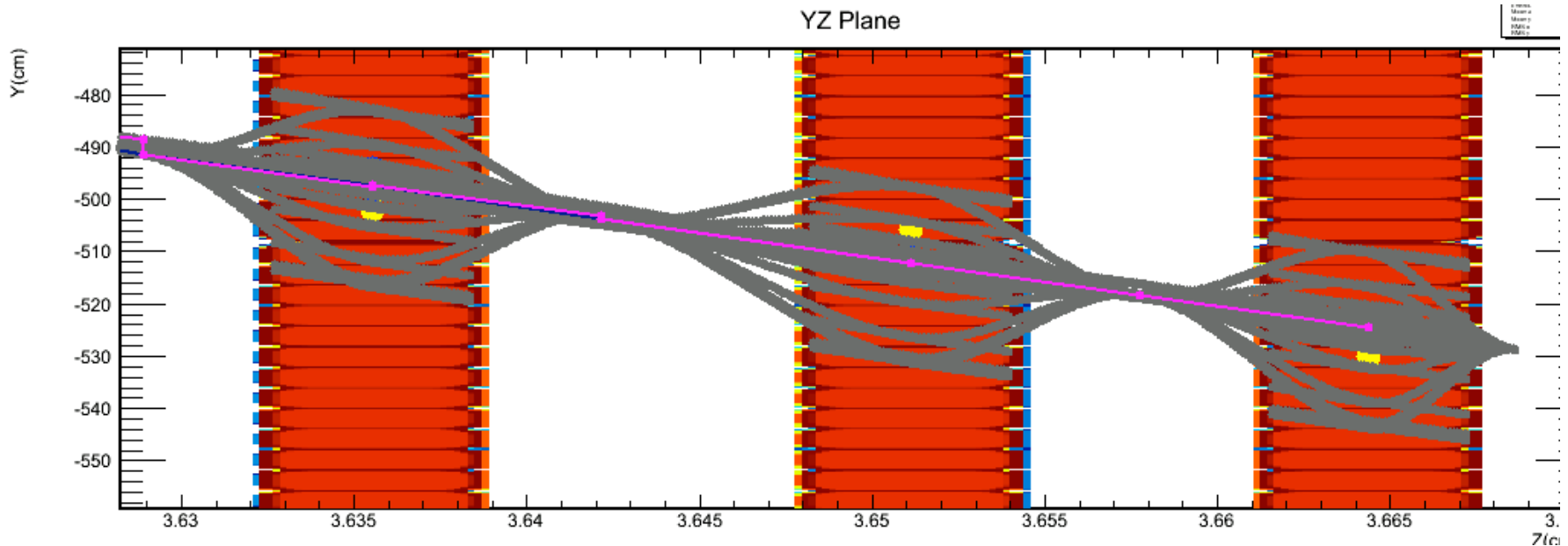
Kalman filters

Kalman Filter is an algorithm for determining **the best estimate** of the “current” state of a dynamic system.





KalmanFilter3D



This algorithm minimizes a chi-square function that takes in account predictions and measurements.



KalmanFilter3D efficiency: energy and position



Energy measurement

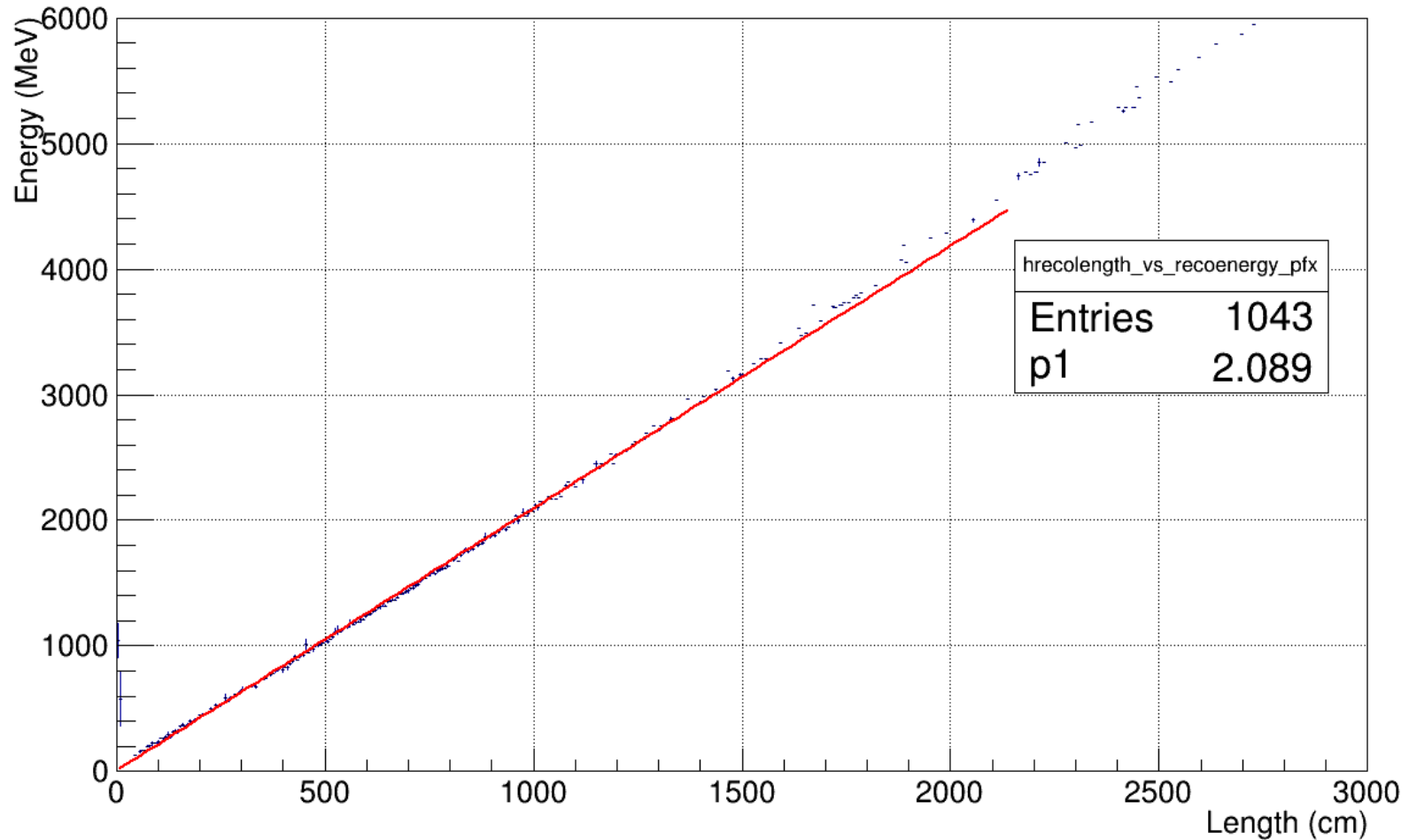
There are two ways to measure the energy of a particle from its track:

- *Slower*: Integrating energy loss step by step (using dE/dl in the current material)
- *Faster*: Extrapolating it from track length (with average dE/dl)



Average dE/dl

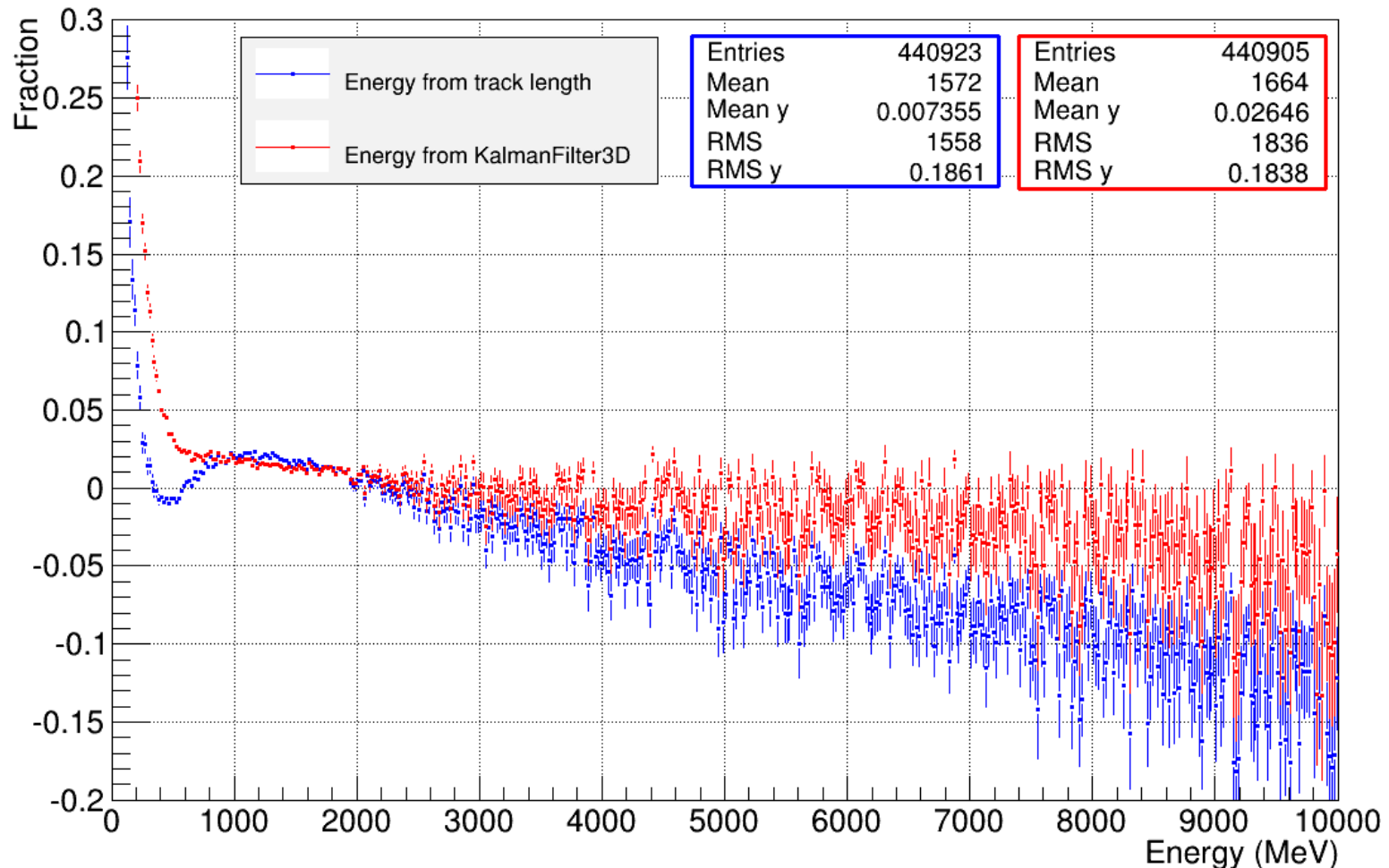
reco length vs reco energy





FD: Energy resolution

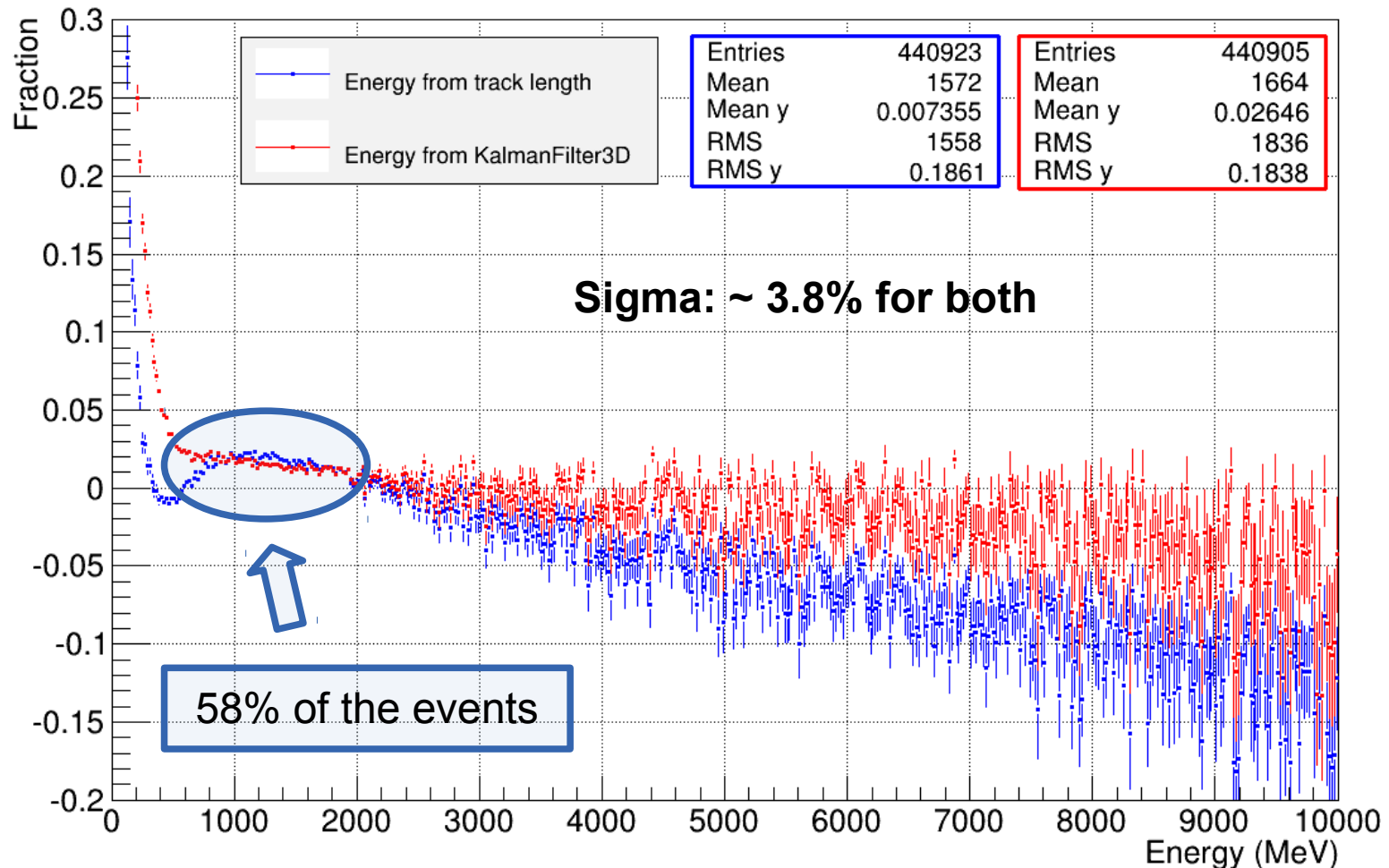
True energy vs Fraction (FD)





FD: Energy resolution

True energy vs Fraction (FD)





Near detector

Main differences between near detector and far detector:

	ND	FD
Mass (t)	330	14,600
Dimension (m)	4 x 4 x 14	15 x 15 x 60
Muon catcher	yes	no



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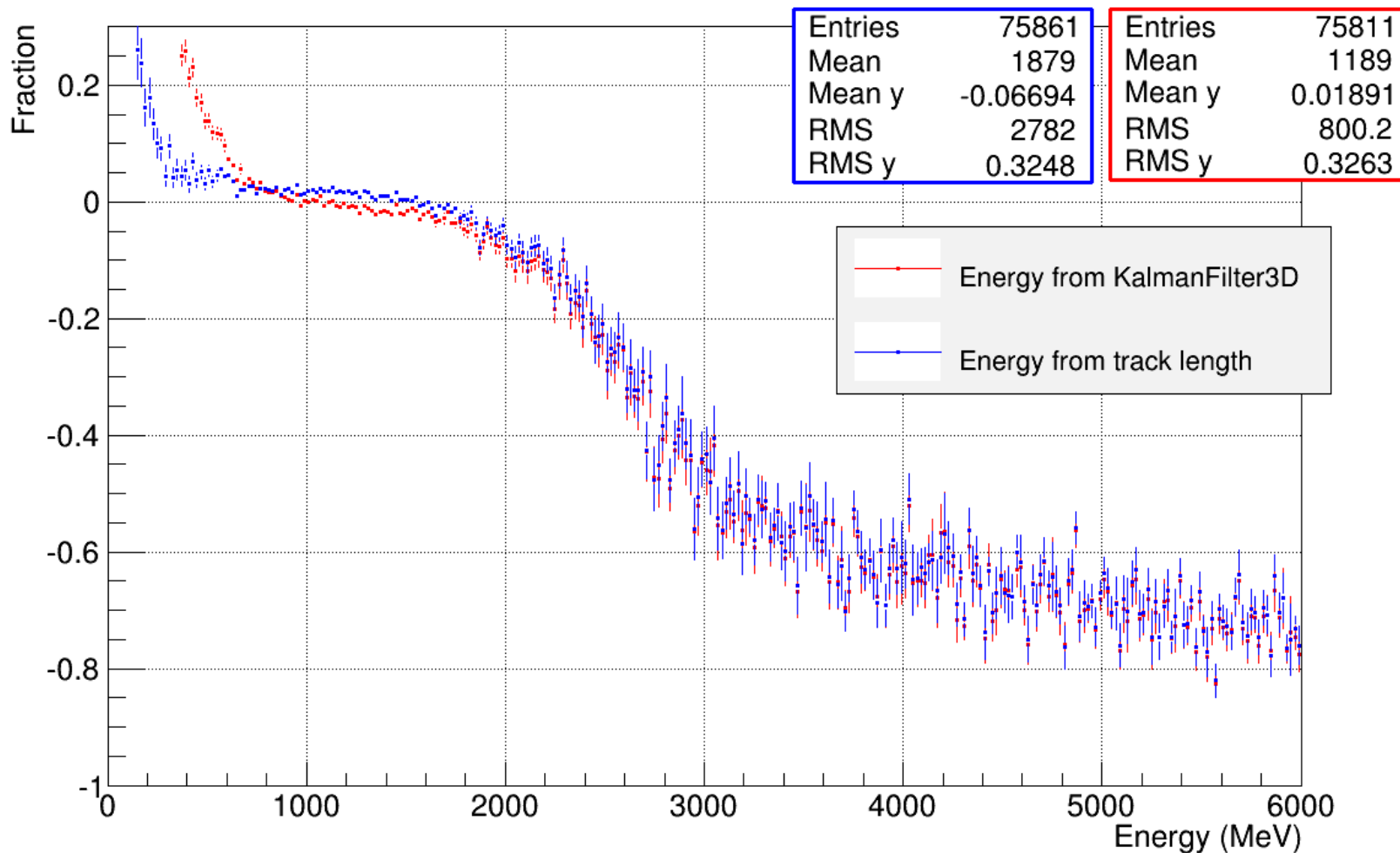


There are steel plates: non-uniform dE/dl



ND: Energy resolution

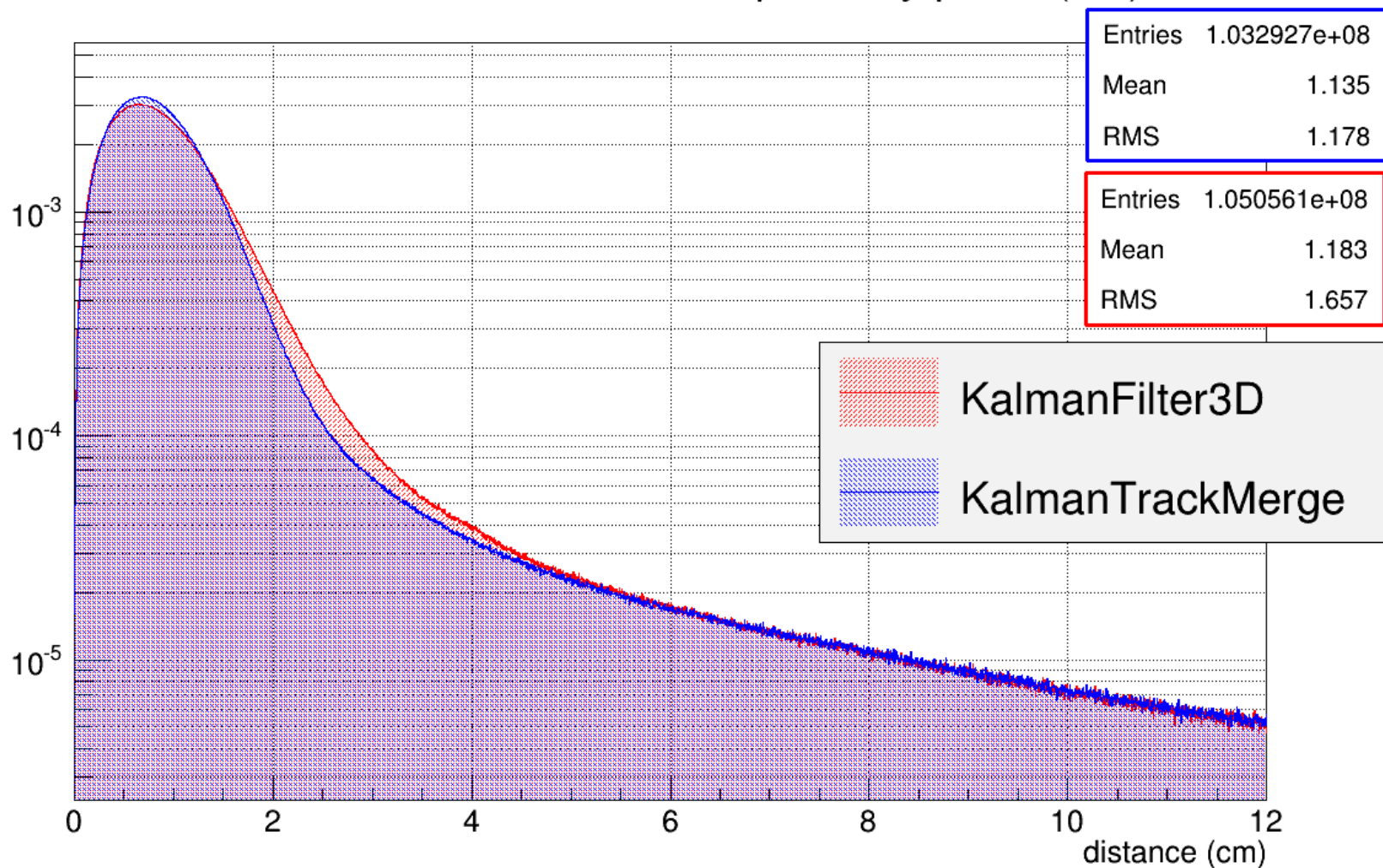
True energy vs fraction (ND)





FD: position resolution

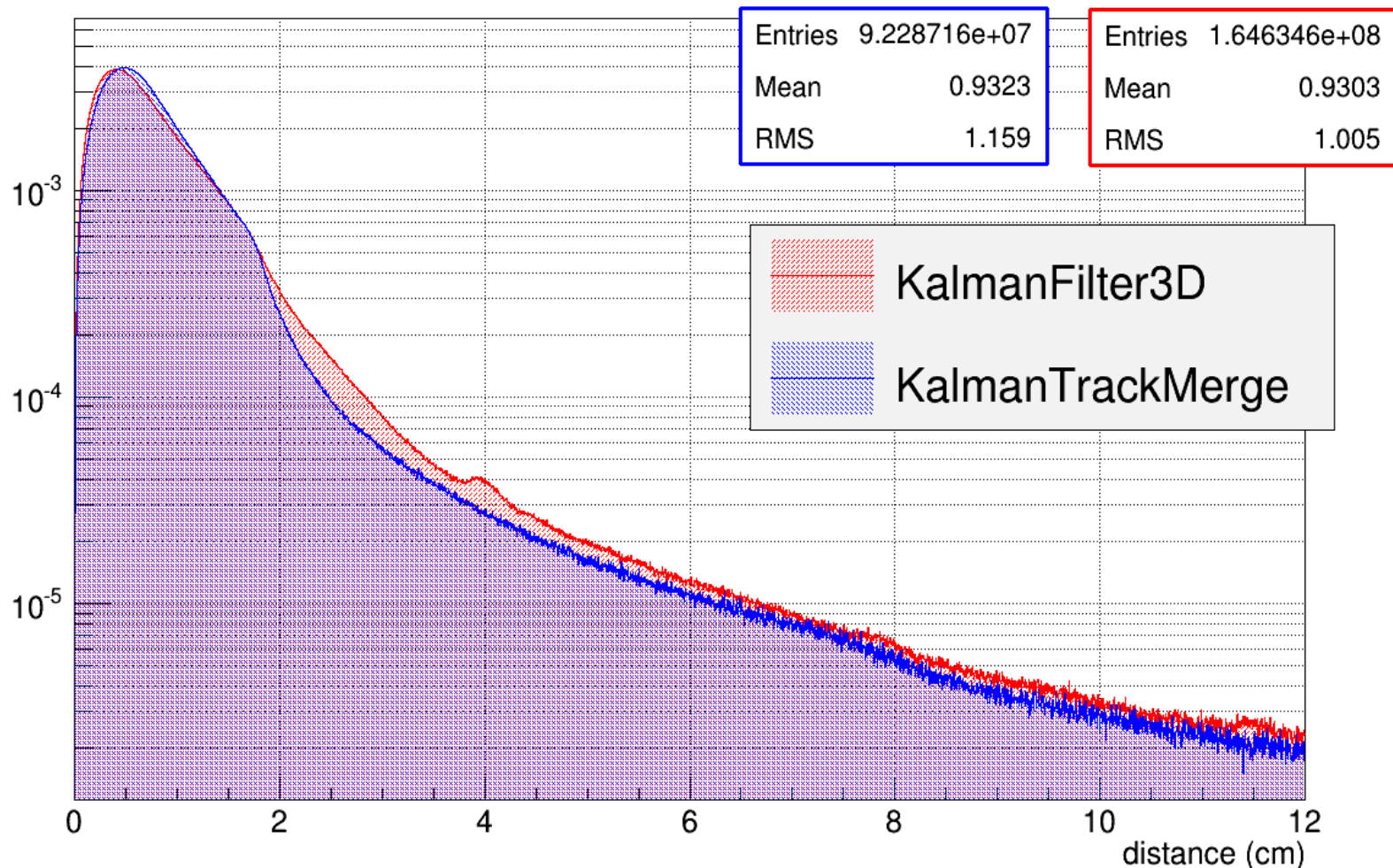
Distance from real track plane by plane (FD)





ND: position resolution

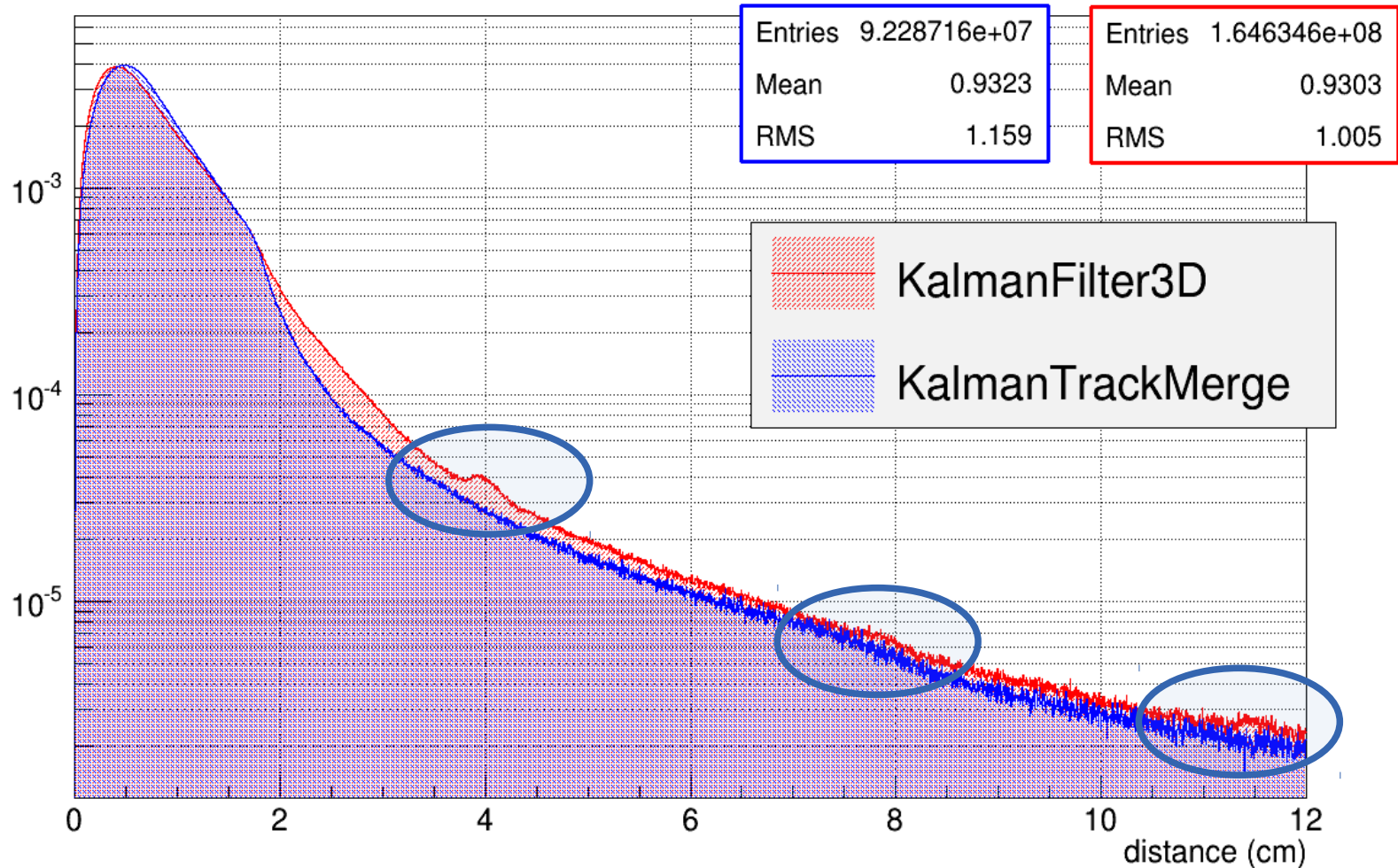
Distance from real track plane by plane (ND)





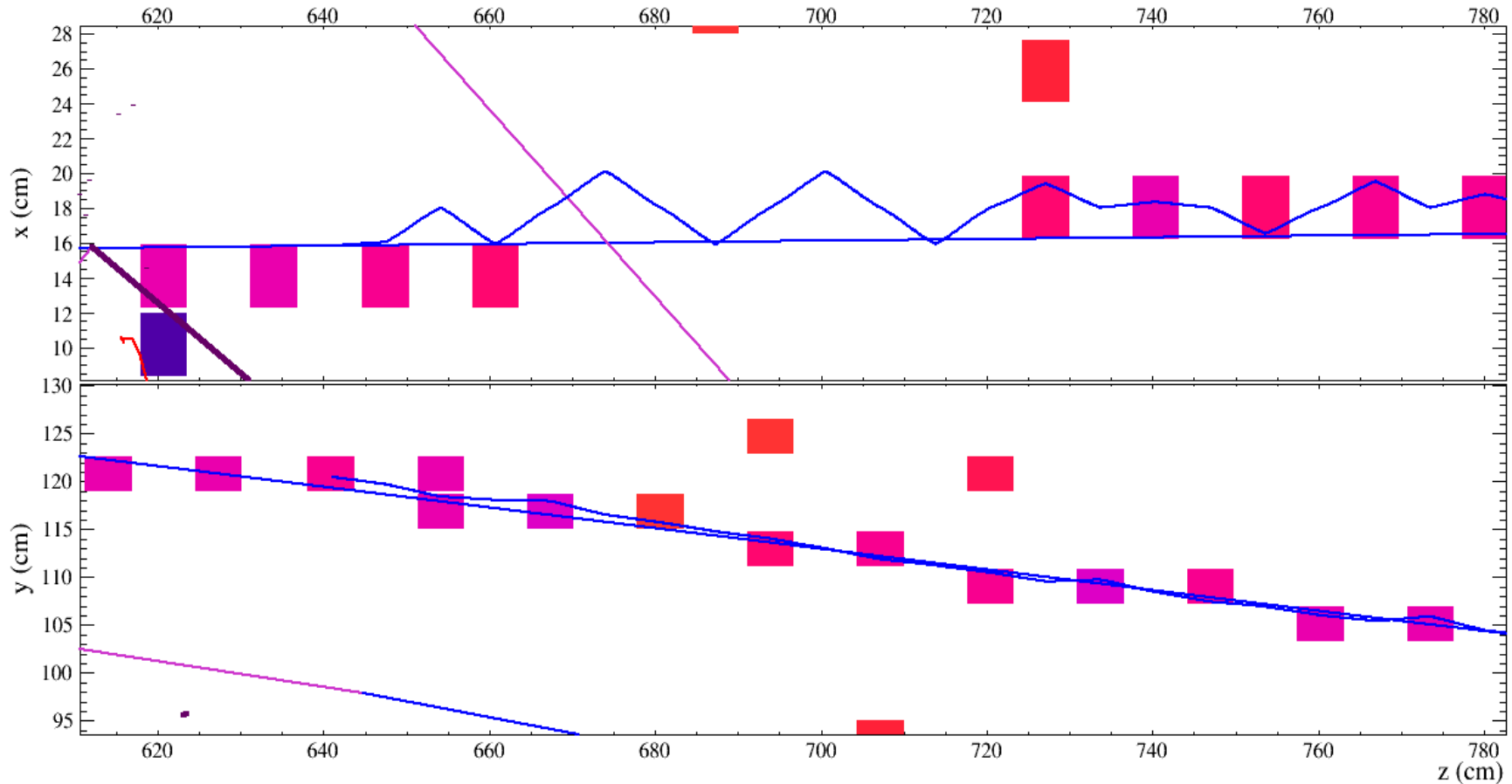
ND: position resolution

Distance from real track plane by plane (ND)





ND: position resolution



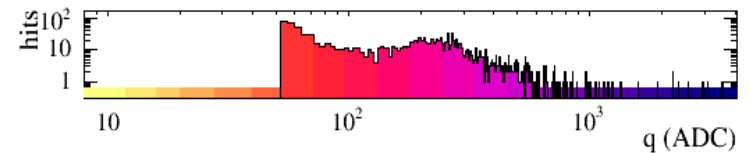
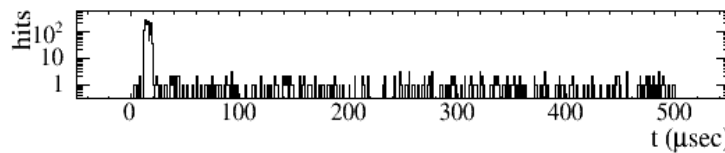
NOvA - FNAL E929

Run: 1 / 12

Event: 18 / NuMI

UTC Thu Jan 1, 1970

00:00:0.090000000



9/26/13

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Conclusion

We know the efficiency of KalmanFilter3D in the reconstruction of muon tracks (energy and position), both in far detector and in near detector.



Questions?

