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The Muon-Tracking-System of the OPERA Experiment

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The main goal of the OPERA experiment is to detect the oscillation of ν_μ into ν_τ. The appearance of a ν_τ is identified by the decay signature of the short living τ lepton created in a charged current interaction of the ν_τ in the detector. However, ν_μ charged current interactions may produce charmed particles which can mimic the decay signature of the τ. In order to suppress this background it is crucial to identify the charge sign of the μ. Therefore a spectrometer with good spatial resolution and robust track reconstruction algorithms is needed. The OPERA detector has a magentic spectrometer consisting of drift tubes called Precision Tracker (PT) and resistive plate chambers (RPCs) in a magnetic field. An improved charge sign reconstruction algorithm is presented and tested on real data. Also, an alternative read-out scheme for drift tubes to remove ambiguities in the track reconstruction is shown.

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1. Introduction

The OPERA experiment searches for $\nu_\mu \rightarrow \nu_\tau$ oscillation in appearance mode. The ν_τ interact in the detector and produce a short lived τ.

The muon tracking system of the OPERA experiment called Precision Tracker (PT) was designed to measure the charge sign and the momentum of the crossing muons with a high accuracy to identify background events produced in ν_μ charged current interactions [1]. An improved charge sign reconstruction method and a different electronic read-out for drift tubes allowing a 3D reconstruction of the intersection point of the track with the tube will be presented.

2. The OPERA Muon Tracking System - Precision Tracker

Drift tubes allow to reconstruct radial drift circles, indicating the distance of the crossing particle from the central wire. If several drift tubes are stacked, the projection of the crossing muon in the plane orthogonal to the tubes axis can be reconstructed by fitting the track which matches best to all drift circles.

The OPERA Precision Tracker (PT) consists of 9504 vertical drift tubes in total, each 8 m long with a diameter of 38 mm. The spatial resolution of a single tube is better than 300 μm (RMS). The tubes are arranged in modules, made of 4 layers of 12 tubes each. Thus each module consists of 48 tubes. In front of and behind the magnetic field region, two PT walls consisting of 15 or 17 modules respectively, measure the muon track in the horizontal plane before and after the bending. The bending angle is proportional to the momentum, the direction of the bending angle indicates the charge sign of the muon. The momentum resolution $\frac{\Delta p}{p}$ is better than 0.25 for p_μ under 25 GeV/c [2].

The OPERA drift tubes are read-out only at one side. For a precise drift circle measurement it is necessary to know the intersection point of the track with the tube along the wire to subtract the propagation time along the wire of the signal from the measured drift time.

For the OPERA PT, this intersection point along the tube wire is provided by the RPC measurements. Follow description in [1].

3. Improved Muon Charge Sign Reconstruction (AMM)

The charge sign of the muon is correlated with the sign of the deflection angle. Neglecting energy loss, the projected trajectory inside the magnetic field describes an arc of a circle in the horizontal plane. In this plane, the tangent vector of the trajectory at the entry point and the reverse tangent vector of the trajectory at the exit point should have equal angles with the secant between these points (for more details see [3]).

From the collected drift tube data, straight muon track segments in front of and behind the magnetic field are reconstructed. The improved muon charge sign reconstruction method called the Angular Matching Method (AMM) [3] allows to check the consistency of the two reconstructed track segments: The angles between the secant and the tangents of the arc of the assumed circle which the muon track describes in the magnetic field are compared. A weight is then calculated from the difference of the two angles that indicates the matching of these two track segments. With

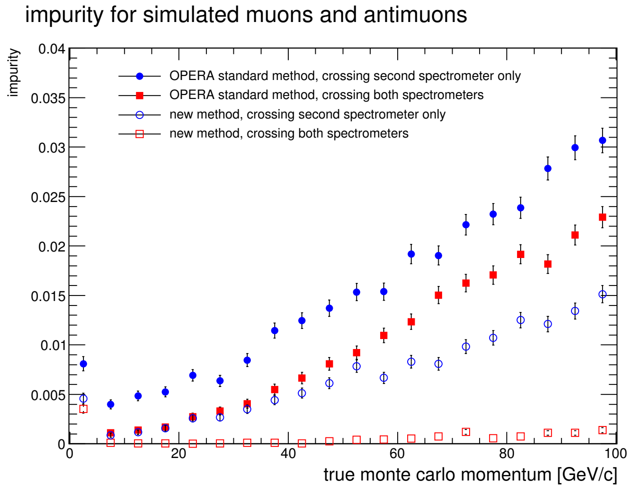

Figure 1: Impurity depending on the momentum of the Monte Carlo truth. The impurity is the number of wrong charge sign determinations divided by the number of charge sign assignments. Taken from [3].

this method, it is possible to find events containing showered or scattered particles by their low weight. By mismatches of the two track segments, wrongly reconstructed events can be identified as well. With the weight, it is possible to classify the quality of the charge sign measurement on an event-by-event basis. Furthermore, the AMM has a weaker momentum dependency compared to the standard method used in the OPERA experiment (see Figure 1). If several charge sign measurements per event are available, the momentum dependency is even weaker [3].

4. Drift Tube Development: Read-Out from Both Sides

The read-out of drift tubes at one side is a standard technique. However, the measured time will be the sum of the true drift time and the propagation time along the wire. To get a high accuracy for the reconstructed track, the intersection point of the track along the drift wire is necessary to know, especially for long tubes. If the drift tube is read-out at one side only, the information about this intersection point has to be provided by another detector or the accuracy in time will be smeared by the propagation time of the signal along the wire.

On the other hand, if the drift tube is read-out at both sides, it is possible to calculate the position of the crossing muon along the wire from the two measured times at both ends (see Figure 2). It is thus possible to get 3D track information from drift tubes without using multiple crossed layers of drift tubes. Also ambiguities in the mapping between layers of crossed drift tubes can be solved. For the test setup with read-out at both sides, electronic components and test modules from the original OPERA PT were used. Using this setup a spatial resolution along the tube wire of 50 cm was reached using only first hits.

In Figure 3, the difference of the measured times at both ends of the tube versus the position along the wire is shown. The linear correlation between the position along the tube and the time difference is clearly visible. With optimized hardware, an improved spatial resolution along the wire will be possible [4], the electronic modules used in this study were not designed for this purpose.

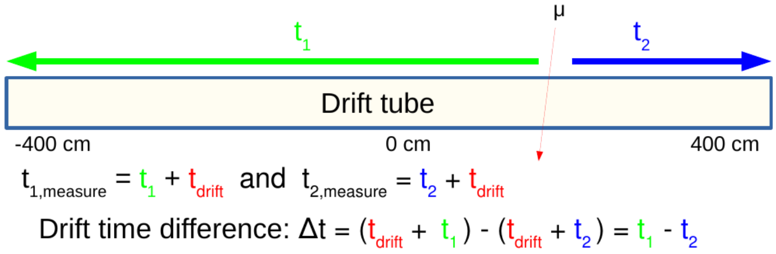

Figure 2: Schematic view of a drift tube that is read-out at both sides: t_{drift} is the drift time, t_1 and t_2 are the propagation times along the wire to both end of the drift tube, $t_{1,measure}$ and $t_{2,measure}$ are the measured times at both ends and Δt is the difference of the two propagation times from the intersection point of the muon to both ends of the tube.

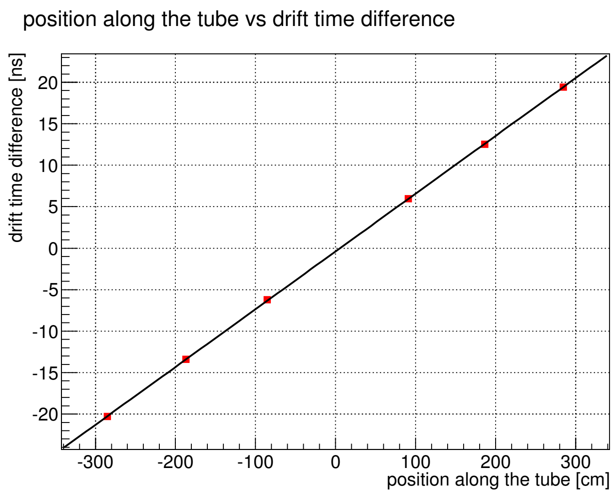

Figure 3: The position along the tube versus the measured time difference at the six different positions along the tube wire (red rectangles) and the linear fit is shown (black solid line). Taken from [4].

5. Conclusion

Two different techniques have been presented to improve the analysis both in OPERA as well as in future experiments using drift tubes. The upcoming SHiP experiment [5], for example will reuse parts of the OPERA PT and profit from these developments.

References

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