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Technical note

The precision tracker of the OPERA detector

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Abstract

The Precision Tracker of the muon spectrometer of the OPERA detector consists of ~10000 aluminum drift tubes of 8 m length. They have an outer diameter of 38 mm and a wall thickness of 0.85 mm. The challenge of the detector design originates from the 8 m length of the drift tubes, a detector length, which has not been used before. Tight mechanical tolerances for positioning and alignment of the signal wires are required in order to make a significant measurement of the sign of the muon charge.

The detector is manufactured in modules, which are 50 cm wide, each consisting of four adjacent drift tube planes. This guarantees high efficiency and complete rejection of the left–right ambiguity. The details of the novel mechanical design are described in this paper.

For safety reasons, the drift tubes are operated with an Argon/CO_2 gas mixture. The gas volume of the drift tubes is entirely sealed with O-rings, in order to avoid ageing problems. The total gas volume amounts to about 80 m^3.

The front end electronics of the drift tubes consist of a bootstrap amplifier followed by a commercial ultrafast comparator. Thus only digital LVDS signals are transmitted over large distances.

We report on the development and performance of the first two prototype modules of the precision tracker including test measurements of the resolution and efficiency obtained.

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1. Introduction

OPERA consists of two massive lead-emulsion target sections followed by muon spectrometers, designed for a long-baseline neutrino oscillation experiment [1]. OPERA will search for ν_τ appearance originating from $\nu_\mu \longleftrightarrow \nu_\tau$ oscillations in the parameter region indicated by the atmospheric neutrino experiments. It exploits nuclear emulsions for the unambiguous detection of the decay of the τ produced in ν_τ CC interactions. This technique was successfully applied in Donut [2] and CHORUS [3]. OPERA will run at the LNGS[2] in the future CNGS[3] neutrino beam from CERN [4]. The detector target mass of ~1.8 kt is needed to reach the required sensitivity to measure 11ν_τ events in five years for $\Delta m^2 = 2.4 \times 10^{-3}\,eV^2$ and 4.5×10^{19} protons on target (pot) per year [5].

The spectrometers will be used for muon identification, the determination of the muon momentum and sign of the muon charge. The task of the muon spectrometer is to clarify the signature of the muonic τ decay and to remove the background originating from charmed particles produced in μ-neutrino interactions.

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[3]CERN Neutrinos to Gran Sasso.

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The muon spectrometers shown in Fig. 1 use warm iron core dipole magnets. Each magnet consists of two vertical walls of rectangular cross section having on top and bottom flux return paths surrounded by coils. The magnet walls are made of iron plates of 5 cm thickness interleaved with RPCs, which measure the range of the muons.

This novel muon spectrometer design has the advantage, that only one track coordinate has to be measured precisely, whereas for the commonly used toroidal muon spectrometers space points must be measured.

The precision tracker (PT) measures the muon track coordinates in the horizontal plane. It is made of drift tubes which are located in front and behind the magnet as well as between the two magnet walls (Fig. 1). The PT consists of 12 drift tube planes, each covering an area of 8 m × 8 m.

The present note describes the mechanical design of the Precision Tracker, its readout electronics and the test results of the first prototypes.

2. The specification of the precision tracker

2.1. Resolution

The structure of the muon spectrometer is defined by the task to measure the sign of the muon charge with a significance of at least 4σ. This means, that the momentum resolution of the spectrometer must be better than

$$\frac{\Delta p}{p} \leqslant 0.25 \quad (1)$$

for all muon momenta p up to a maximum of $p = 25\,\mathrm{GeV}/c$.

A muon traversing the spectrometer magnets is deflected twice by an angle $\theta/2$, forming an S-shaped track. The total deflection angle θ is the sum of the amounts of the two deflections. If the positions of the drift tube planes are chosen as shown in Fig. 2 the deflection angle θ

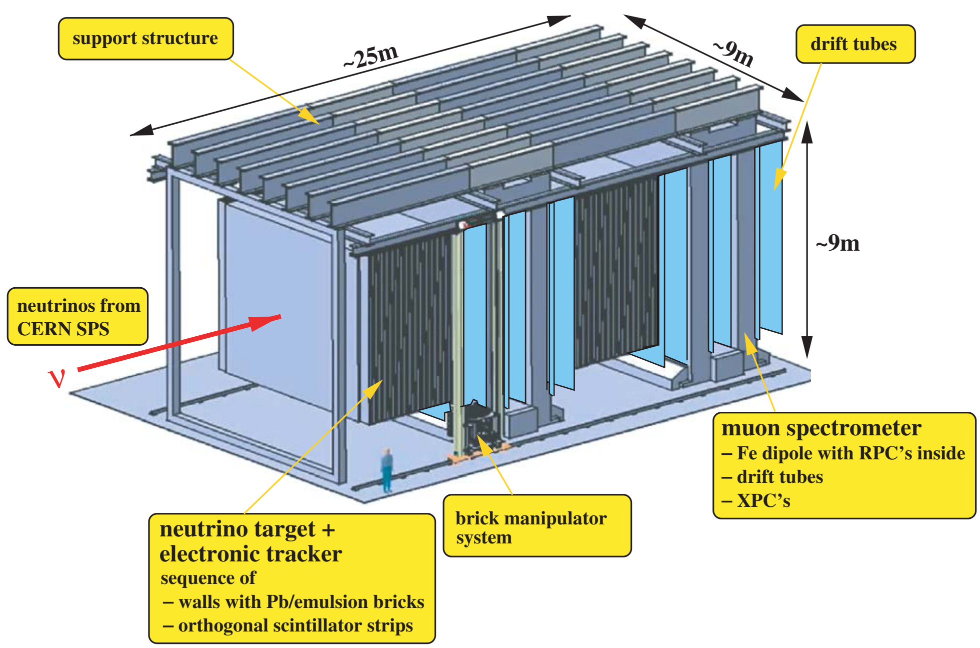

Fig. 1. The OPERA detector.

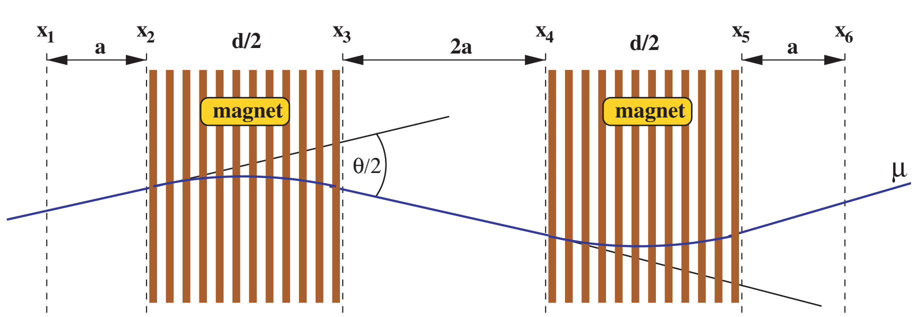

Fig. 2. Schematic layout of the OPERA muon spectrometer of one super module. The two iron core magnets are shown and the positions of the detector planes (dashed lines).