A Forward TPC for STAR

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Two Forward Time Projection Chambers (FTPC) provide charge and momentum information in the pseudorapidity range between $2.5 < |\eta| < 4.0$. A radial TPC scheme is used, where ionisation electrons drift in an electric field perpendicular to the axial solenoidal magnetic field. Curved proportional wire chambers with pad readout record the track information via 19200 electronic channels. We report on measurements with various gas mixtures in a prototype chamber with and without magnetic field. The design and construction of a curved readout chamber is described. Based on the prototype measurements and the final layout of the detector the expected performance in measuring accuracy and two-track-separation is given.

Gas mixture in an E $\perp$ B enviroment

The use of a radial drift field was the only solution which allows us to resolve clusters in the inner region of the FTPC [1], in the predicted physics enviroment of RHIC collisions [2]. In a drift field which is perpendicular to the magnetic field the drifting electron cloud is deflected due to the Lorentz force with the deflection angle Ψ_D [3].

$$\Psi_D = \int_{r_0}^{r} \frac{\Psi_L(r)}{r} dr \tag{1}$$

For the FTPC one needs a gas mixture which has an appropriate total drift time ($\leq$ 60 μs) and a small Lorentz angle Ψ_L [4]. The tests of various gas mixtures finally show that using a cool gas like Ar/CO_2 (50/50) or Ar/DME (50/50) best fits the above given boundary conditions [5][6]. In figure 1 we show the dependence of the Lorentz angle on the magnetic field strength which is linear at a given drift field [4]. In additional measurements it has been shown that the perpendicular magnetic field has a minimal effect on the drift velocity and diffusion width for the described gas mixtures [4]. We will use Ar/CO_2 (50/50) as a chamber gas. It requires a lower cathode voltage compared to Ar/DME for the same drift time and it is non flammable which creates less safety and material selection problems.

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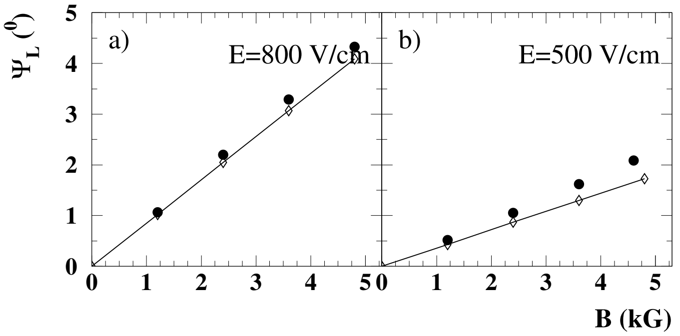

Figure 1.
Left plot :
Lorentz angle versus magnetic field for Ar/CO_2 (50/50) at an E-field of 800 V/cm for a fixed radius.
Right plot :
Lorentz angle versus magnetic field for Ar/DME (50/50) at an E-field of 500 V/cm for a fixed radius.
• Measured values.
⋄ MAGBOLTZ [7] calculation.

Final FTPC design

The final design of the FTPC is shown in figure 2. There are 10 padrows/FTPC with 960 pads/row. These rows are arranged in a six fold symmetry in ϕ and five such rings in longitudinal direction. Each of these thirty sectors holds one multi wire proportional chamber (MWPC) with two padrow segments. The readout is provided by a front-end electronic card which amplify, shape and digitize each pad signal [9].
Compared to a conventional TPC, as in the ALEPH experiment [10] the design of our FTPC differs in two major points.

1. The padrows are arranged on the cylinder wall and not on the endcaps.

2. The field cage has a radial E-field proportional to 1/r.

As a result we have a non-constant drift velocity over the drift volume. The area of equal drift time for different ϕ-positions of the electron cloud is a curved surface in comparison to a conventional TPC. For the design of the MWPC there are two possible solutions. A flat or a curved padplane for the MWPC. The advantage of a flat padplane is the known production scheme and the easier mechanical support structure. On the other hand one has to correct for the inhomogeneous E-field in the corners of the MWPC and the different drift time for identical radius at different ϕ-positions in the offline calibration. We decided to use a curved MWPC design to reduce the offline calibration effort in an already complicated inhomogeneous $E \perp B$ – field configuration.

The curved design is accomplished by using a sandwich of BendFlex material [2] for the padplane, which holds its shape after it has been bent. The sense wires are fixed with a conductive glue to the padplane with a gap of 1.5 mm before the sandwich is bent. In addition they are inclined by 17.4^o to the main symmetry axis of the pads. This is necessary

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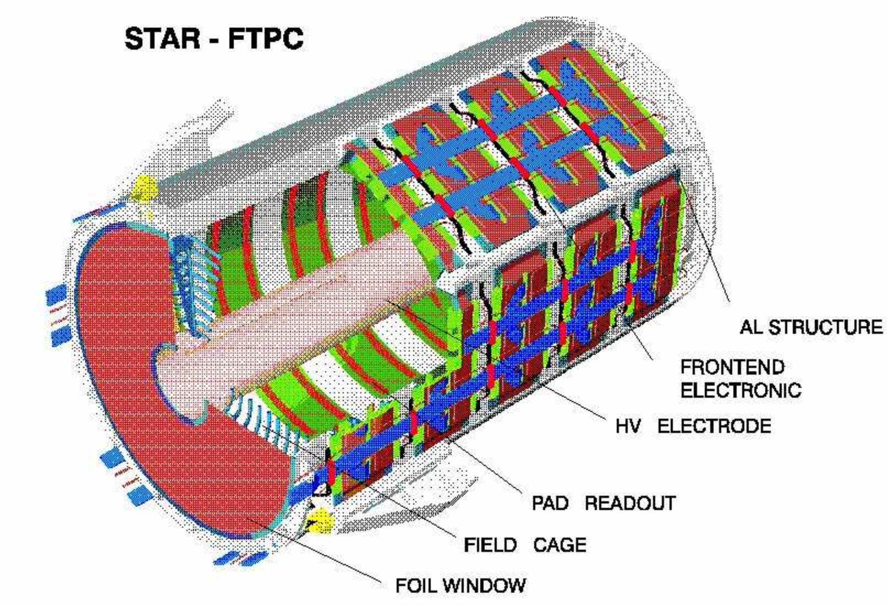

Figure 2.
The final layout of the FTPC has 10 padrows with 960 pads/row on the cylinder wall. Two padrow segments are combined in one MWPC in total 30 MWPC/FTPC. The front-end electronics [9] are directly mounted behind the MWPCs.

because focussing effects at the sense wires would give a step effect between the measured and the real position of the clusters [8]. Another advantage of the sandwich construction of the padplane is that it provides the gas tightness against the outer air region of the FTPC.

Prototype measurements

With the described final layout of the MWPC, we have built a prototype to measure chamber parameters like the pad-response-function (PRF) and the two-track-separation (TTS) for this design [8]. In figure 3 we show cluster width measurements. The PRF is determined by extrapolating the measured values to zero drift length. This analysis is done for two types of tracks, on the left side for muons and on the right side for laser tracks. Both measurements result in a PRF with a $\sigma_{PRF} \leq 1.4$ mm which is below the design goal of $\sigma_{PRF} \leq 1.5$ mm. These measurements also show that with the available gain of the MWPC it is possible to track minimum ionizing particles.

Another important parameter of the MWPC is the TTS (λ_ϕ). Due to the predicted occupancy of 30–35% at the inner radius of the FTPC an excellent separation capability

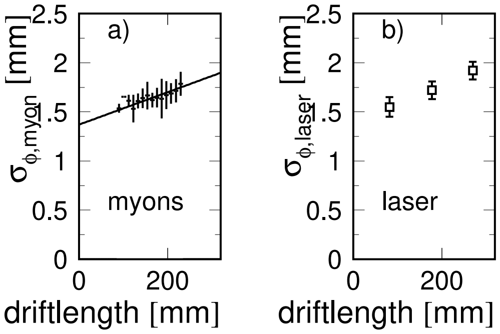

Figure 3.
Left plot:
Sigma of cluster width in ϕ direction versus the driftlength of the electron cloud produced by muons.
Right plot:
Sigma of cluster width in ϕ direction versus the drift length of the electron cloud produced by laser.

for two tracks $\lambda_\phi \leq 1.2$ mm is needed. Since our prototype chamber (Radial TPC) has a larger inner and outer diameter than the FTPC will have, we show in figure 4 the measured separation capability in the RTPC (black squares) and the calculated separation capability for the FTPC (black dots) using the values measured in the prototype chamber. Based on this estimate we should be able to resolve tracks with a separation capability of $\lambda_\phi \leq 1.0$ mm for the inner radius of 8.0 cm.

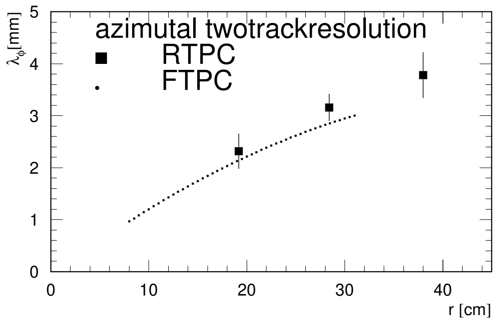

Figure 4.
Shown is the azimutal two-track separation capability λ_ϕ versus the radius of the prototype chamber (RTPC). The black squares are the measured separation capability using 2 crossed laser beams. The black dots show the calculated separation capability for the FTPC by using the measured resolution of the RTPC.

Final remarks

Based on the measured performance of the MWPCs we are confident that with our ambitious FTPC design, it will be possible to track particles in the forward region of an Au^{197} on Au^{197} collision at $\sqrt{s} = 200$ GeV/A. The goal is to complete one FTPC by the end of 1999 and install it in Spring 2000 at the STAR experiment.

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