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Influence of the TPC Field Cage Design Changes on the Detector Performance

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Abstract

A modified TPC field cage design is compared with the 'old' one of the TDR in terms of tracking efficiency, momentum and angular resolution as well as of the additional space-charge created in the drift volume.

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1 Introduction

The TPC field cage design principle presented in the TPC Technical Design Report [1] was to provide a highly uniform electrostatic field in a cylindrical gas volume. This requires low-mass and high mechanical stability of the detector vessels under their own weight and subject to external loads from the weight of the ITS and its services. Despite satisfactory results of a stability analysis of the inner containment vessel based on finite element methods [2], and from the outcome of detailed studies on material properties [3], specific changes were recently proposed for the design and composition of the TPC field cage. Thus, in this note we compare the prime performance criteria for the TPC, such as its tracking efficiency, momentum and angular resolution and the magnitude of the space-charge generated in the drift volume for both, the original (TDR) and proposed modified design.

2 Layout and Material Budget

The entire construction of the TPC field cage, besides the two end-plates, consists of four vessels: the inner and outer field-cage vessels defining the drift volume, and the inner and outer containment vessels providing a protective envelope around the actual field cage. The two designs are shown by comparison in Table 1. Table 2 shows the material of the field cage vessels in terms of radiation length (X/X_0) for both designs.

3 Tracking Efficiency, Momentum and Angular Resolution

In Fig. 1 we show the tracking efficiency of the TPC 'stand-alone' for both designs. As one can see, no significant differences can be ascertained. Resolution of momentum and of azimuthal and polar angles is shown in Figs. 2, 3 and 4, respectively. Also in these cases, with the TPC taken 'stand-alone', the differences between the two designs have no particular effect on the resolution.

It should be noted, however, that in case of 'global tracking' the increased radiation length of the modified cylinders does result in a deteriorated overall resolution. From our analysis we estimate the increase in relative momentum error $\frac{\Delta p}{p}$ for high P_t (1 - 5 GeV/c) tracks to 0.1% (absolute), which results in a degraded mass resolution $\frac{\Delta m}{m} \approx 5\%$ in the Υ region. However, this change of resolution seems to be irrelevant.

4 Space-charge in the Drift Volume

The larger thickness and different choice of materials of the vessels are expected to slightly increase the space-charge due to particles interacting with the cylinder walls. This would lead to increased track distortions and thus to a global loss in detector performance. To show the effect, we have plotted in Fig. 5 the total charge in the region of the innermost 30 cm detection layer of the TPC as a function of z. One notices a small increase of charge due to the modifications, yet outside the TPC acceptance, where most of the material changes were introduced (aluminium conical sections of the inner containment vessel). This, consequently, does not affect the particle tracks produced within the nominal acceptance of the detector.

5 Conclusion

Our detailed simulations demonstrate that the proposed design modifications of the TPC field cage do not affect the detector in terms of its physics performance. A new study on the global stability of the field cage can thus be launched in order to verify also its mechanical integrity prior to construction.

Old design	Modified design
Inner Containment Vessel - cones	
aluminium - 50 μm Tedlar - 50 μm Kevlar - 2×300 μm Nomex honeycomb - 20 mm Kevlar - 2×300 μm Tedlar - 50 μm aluminium - 50 μm	aluminium - 3 mm
Inner Containment Vessel - central drum	
aluminium - 50 μm Tedlar - 50 μm Kevlar - 2×100 μm Nomex honeycomb - 5 mm Kevlar - 2×100 μm Tedlar - 50 μm aluminium - 50 μm	aluminium - 50 μm epoxy glue - 100 μm Tedlar - 38 μm carbon fiber - 2×100 μm Nomex honeycomb - 5 mm carbon fiber - 2×100 μm Tedlar - 38 μm epoxy glue - 100 μm aluminium - 50 μm
Outer Containment Vessel	
aluminium - 50 μm Tedlar - 50 μm Kevlar - 2×300 μm Nomex honeycomb - 30 mm Kevlar - 2×300 μm Tedlar - 50 μm aluminium - 50 μm	aluminium - 50 μm epoxy glue - 100 μm Tedlar - 38 μm fiber glass - 3×250 μm Nomex honeycomb - 30 mm fiber glass - 3×250 μm Tedlar - 38 μm epoxy glue - 100 μm aluminium - 50 μm
Inner Field-cage Vessel	
everywhere	*central part (within the acceptance)*
Tedlar - 50 μm Kevlar - 2×100 μm Nomex honeycomb - 20 mm Kevlar - 2×100 μm Tedlar - 50 μm	Tedlar - 38 μm fiber glass - 3×100 μm Nomex honeycomb - 20 mm fiber glass - 3×100 μm Tedlar - 38 μm
	reinforced part (outside the acceptance)
	Tedlar - 38 μm fiber glass - 7×100 μm Nomex honeycomb - 20 mm fiber glass - 7×100 μm Tedlar - 38 μm
Outer Field-cage Vessel	
Tedlar - 50 μm Kevlar - 2×100 μm Nomex honeycomb - 20 mm Kevlar - 2×100 μm Tedlar - 50 μm	Tedlar - 38 μm fiber glass - 2×100 μm Nomex honeycomb - 20 mm fiber glass - 2×100 μm Tedlar - 38 μm

Table 1: Comparison of mechanical parameters for the two TPC designs.

Vessel	Old design	Modified design
Inner Containment Vessel:		
Cones	0.714% of X_0	3.380% of X_0
Drum	0.332% of X_0	0.408% of X_0
Inner Field Cage Vessel:		
Central part	0.324% of X_0	0.520% of X_0
Outer part	0.324% of X_0	0.976% of X_0
Outer Field Cage Vessel	0.324% of X_0	0.406% of X_0
Outer Containment Vessel	0.791% of X_0	1.279% of X_0

Table 2: Material in terms of fractional radiation length for both TPC designs.

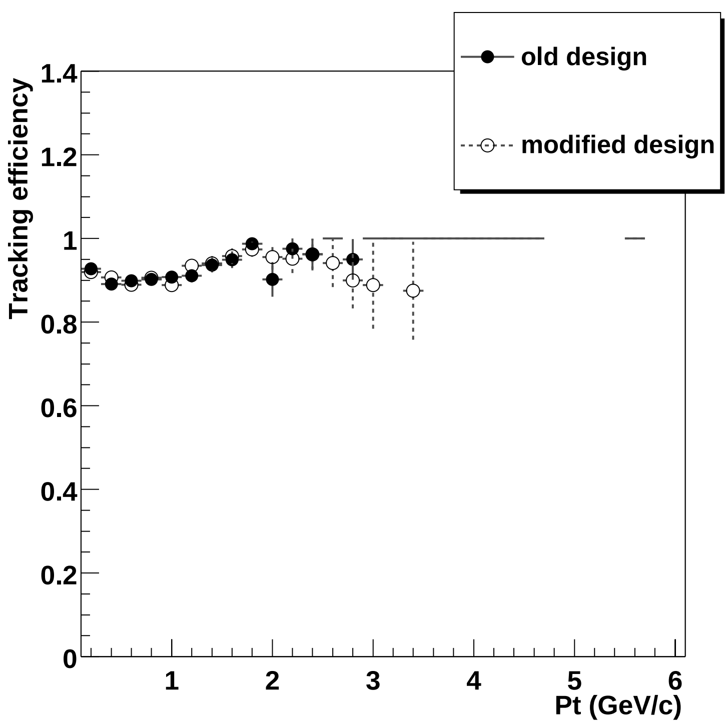

Figure 1: Tracking efficiency for the old and modified field cage design.

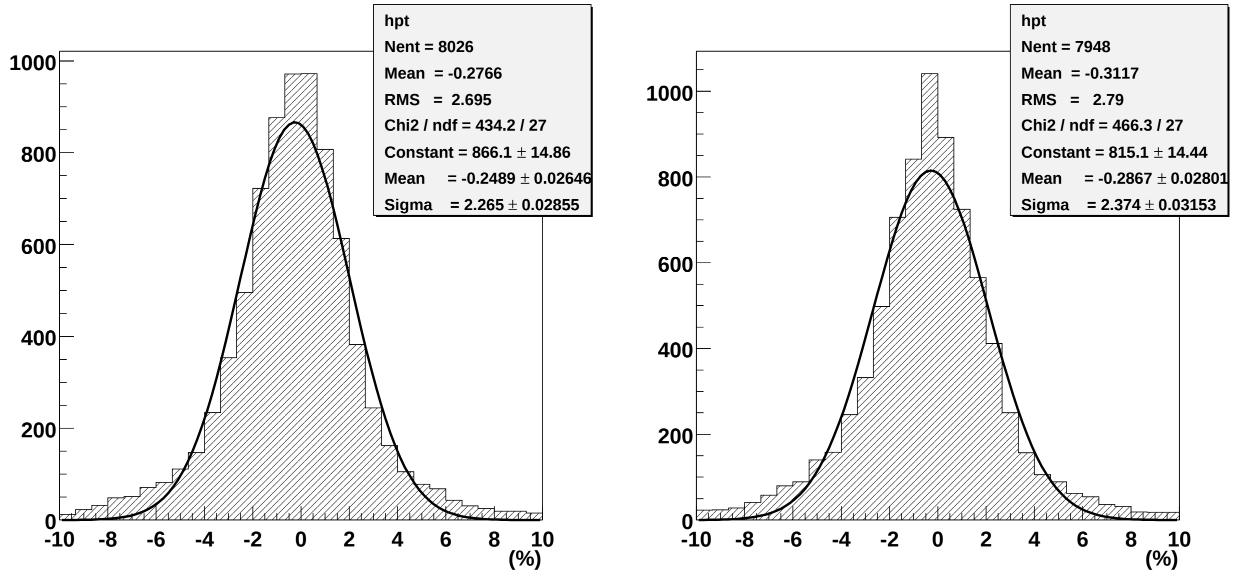

Figure 2: Transverse momentum resolution for the old (left) and modified (right) vessels design.

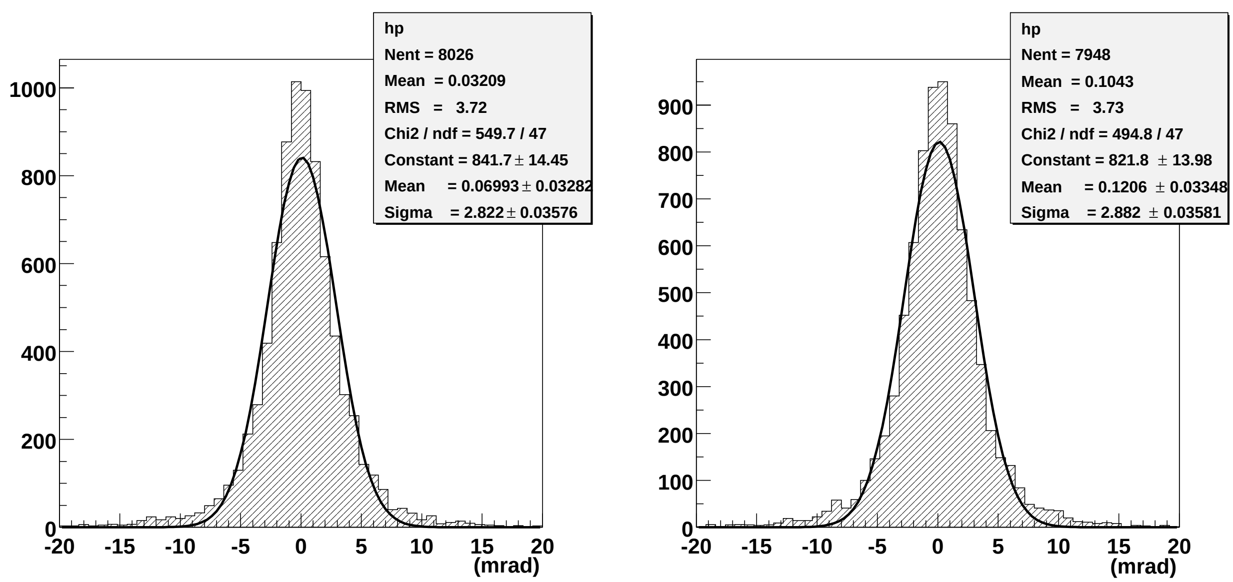

Figure 3: Azimuthal angle resolution for old (left) and modified (right) design.

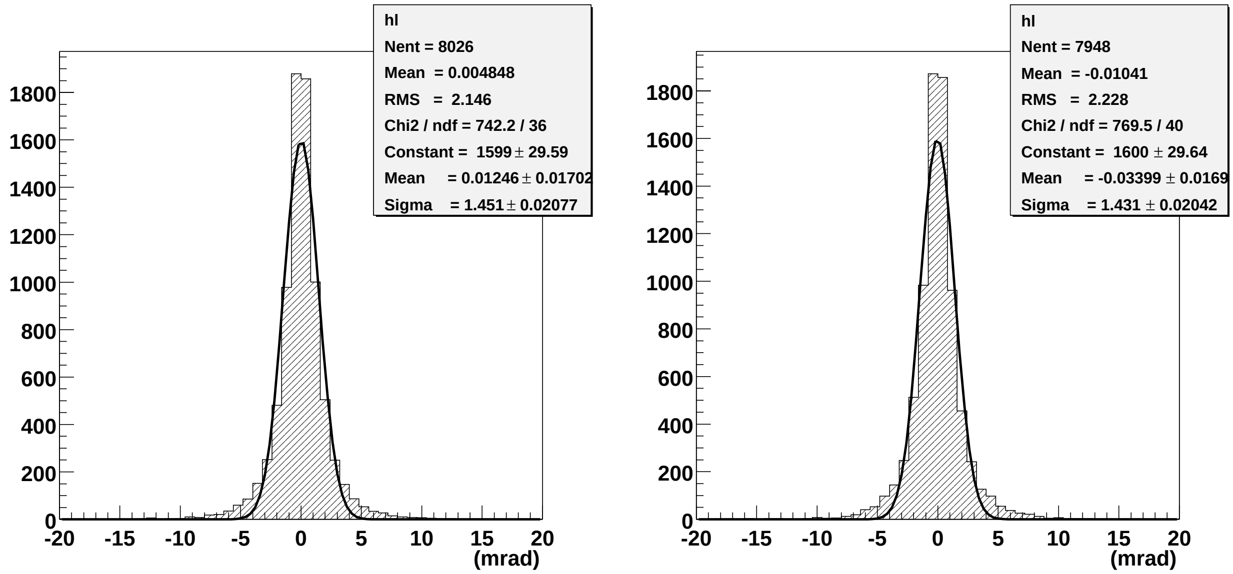

Figure 4: Polar angle resolution for old (left) and modified (right) design.

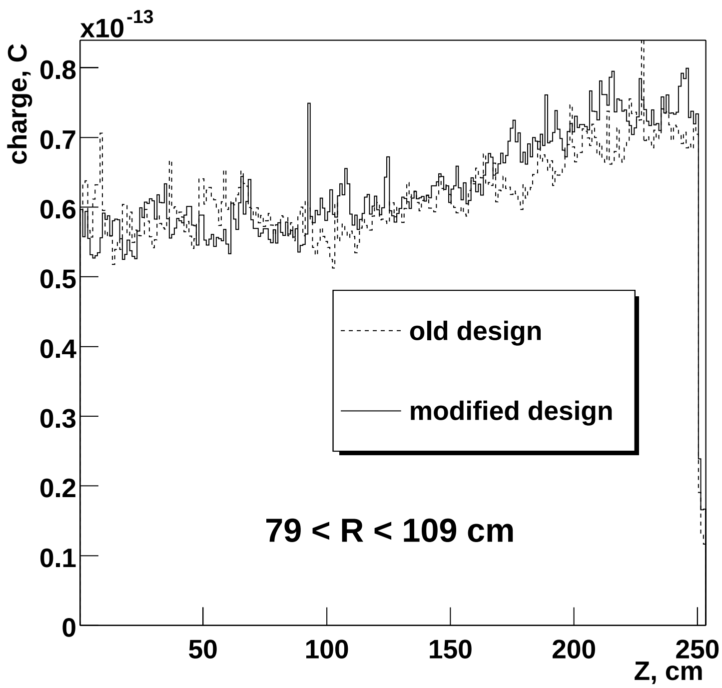

Figure 5: Total space-charge in the innermost (30 cm) TPC detection layer as a function of z; dashed line is for old design, solid line is for modified design.

References

[1] ALICE TDR 7, CERN/LHCC 2000-001, 7 January 2000.
[2] A. Wróblewski, T.C. Meyer, ALICE-INT-2001-08.
[3] Note to be published.