Development on Ultra-Long Wiring for Drift Chamber

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Abstract

A drift-chamber-based design has been chosen and implemented as a possible alternative to the TPC, in order to contribute to the PID performance in the design of the CEPC reference detector[1].

On the one hand, the goal is to study and optimize the resolution of dN/dx with the advanced electronics and the multilayer DC prototype. Thanks to the fruitful collaboration with the Italian group[2], after the study of the simulation and the preliminary test, two short multilayer drift chamber prototypes have been developed and tested with the cosmic ray and the beam at CERN PS, respectively.

On the other hand, the goal is to explore conceptually long wiring, since there hasn't been any records or experience in the known experiments with such a 5.8-meter ultra-long drift chamber, especially used as fine as 20 μm Tungsten wire for the sense wire.

This work focuses on the latter and reports the progress on DC's ultra-long wiring. The following topics are addressed:

1) Mechanical tooling for measuring the ultimate tension has been optimized.
2) A tooling for ultra-long wiring has been designed and machined.
3) Unit arrays of wires as long as 5.3m have been wired, and the creep of the wires has been calculated.

Introduction

IHEP Drift Chamber:

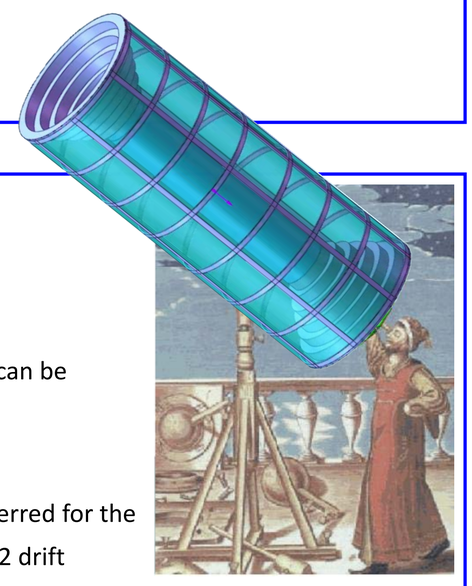
- BES-I MDC (1989)
- BES-II MDC (1996) [3]
- BES-III MDC (2007) [4]
- BES-III Inner-DC (2014) [5]
- CEPC prototype (2025)

The CEPC Drift Chamber

- **Requirement for standalone momentum resolution: 10^{-4} (GeV/c)$^{-1}$ with a magnetic field of 3 T**
- Total Length : 5800mm
- Radial span : from 600 mm to 1800 mm
- Two CF cylinders + two endplates as a multi-stepped tilted profile
- Cell number : 27623 in total in 64 wire layers
- Cell size : 18 mm x 18 mm
- Ratio of field wires to sense wires: 3:1
- Wire: Tungsten 20 μm， Aluminum 80μm
- Gas mixture: He/iC4H10=90:10

- Use of cluster counting for particle identification

1. Simulation: shows that 3σ K/π separation at 20GeV/c can be achieved with 1.2m track length.
2. Electronics & prototype - scale DAQ: ready.
3. Construction: feed through and wire crimping are preferred for the wire anchoring system, as used in the BESIII and KLOE-2 drift chambers [6], both in operation for over 19 years.
4. Prototypes: two short multilayer ones are under study. Cluster counting reconstruction algorithm is under progress[7].



ZHAO Guang's talk & PAN Wenyu's poster

Wire

Wire

Wires:

- LUMA Tungsten NI-AU-PLT:20μm
- CFW Al5056 NI-AU-PLT: 80μm



Wiring

- Wire deflection :
  - ***Sag***: the maximum vertical drop of the wire, decided by the tension with this formula. $T(c) = \lambda L^2/(8S_{ag})$ (λ : Linear density, S_{ag} : Wire sag, L :Wire length)
  - ***Creep***: tendency of a solid material to deform permanently (stretch or change shape) under a sustained mechanical stress.
- Sagitta of ultra-long wiring: for the short chamber, tension can be performed from the designed sag, whereas the ultra-long wire chamber, the ultimate tension and creep, must be considered, and the deflection is then derived inversely, with the resulting sagitta affecting the spatial resolution.

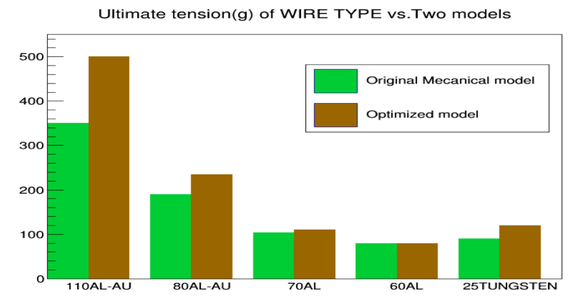
Ultra-long wiring: ultimate tension

1. The mechanical model for measuring the ultimate tension was machined as shown. However, after taking the measured values from this model into account, the optimal sag was around 700μm.

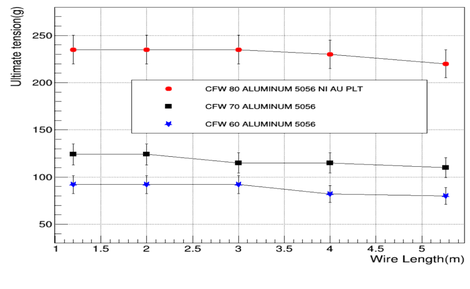
Importantly, in the BESIII MDC, the sag is approximately 80μm, compared with a spatial resolution of 130μm. The reconstruction algorithm and the overall DC design - by adding the stereo wire layers as in the BESIII MDC [4], to provide longitudinal measurements - help to minimize the impact of the sagitta on the spatial resolution.

2. Optimization was performed by replacing the wire supports on both sides, which significantly enhanced the ultimate tension, and corresponded to an optimal sag of about 300μm for a single wire.





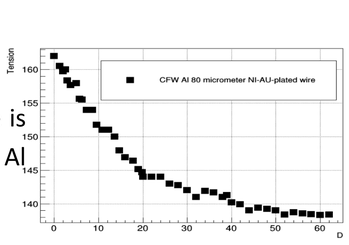
- The ultimate tension was measured for several wire lengths.
- Preliminary conclusion: within the range 1 - 5.3m, the ultimate tension is roughly constant，but decreases slightly as the length becomes ultra-long.
- The reason is not the material properties, but presumably to the weakening of the wire strength after slight damage, during the ultra-long wiring process .

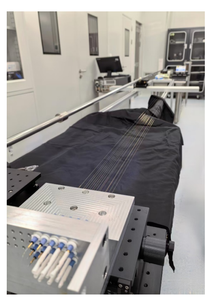


Ultra-long wiring: creep

- A tooling for ultra-long wiring has been designed and machined.
- Unit arrays of wires as long as 5.3m has been wired.
- The set tension and the tension after two months are 162 and 138g, respectively.
- For CFW Al 80μm NI-AU-plated wire，the creep ratio is less than 15%, creep time is around 2 months which is much shorter than that of the BESIII MDC wire(CFW Al 110μm NI-AU-PLT).
- It could be derived inversely by the final wiring，as shown in this formula:

$T(ι) = T(Ultimate) \times C_2 \times (1+C_1)$， *where C_1 and C_2 correspond the creep and safety coefficient*, respectively.





Acknowledgments

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Conclusion

1) For ultra-long wiring, the optimal sag of a single wire is around 300μm, which was greatly improved by optimizing the tooling. The creep of the field wire in the TDR[1] is less than 15%. Taking into account these numbers, the reconstruction algorithm and the future detailed design of CEPC DC - by adding the stereo wire layers to provide longitudinal measurements - will help to minimize the impact of the deflection on the resolution.
2) The feed through is reliable, since this is the first time that such a high tension achieved over such a long time. To meet the spatial resolution required by the CEPC design, the copper pin of the feed through may need to be optimized to achieve better anchoring.
3) Hand wiring is still unavoidable thanks to the feed through anchoring, but at least a robot for transferring the wire will be definitely necessary.
4) The creep of more type of wire will be calculated if needed, such as CFW-Al 60μmand CFW-Al 70μm wires used for the prototypes.

References

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