Study of MPGD based photon detectors for the STCF-RICH system

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Abstract: The Super τ-Charm Facility (STCF) is a high-luminosity electron-positron collider under development in China. STCF requires excellent particle identification for charged hadrons within its energy range, necessitating a ≥4σ separation for π/K identification at momentum ranges of 2GeV/c and below. To meet these stringent requirements, a Cherenkov detector, Ring Imaging Cherenkov detector (RICH), has been selected as the baseline candidate for STCF. Our research focuses on a cascaded micro-pattern gas detector based on THGEM + Micromegas. This setup fulfills the RICH's demands for a photon detector, providing high gain, large area coverage, and high counting rate capabilities. Furthermore, we are exploring the feasibility of a novel photon detector based on a double micro-mesh gaseous structure (DMM).

Introduction

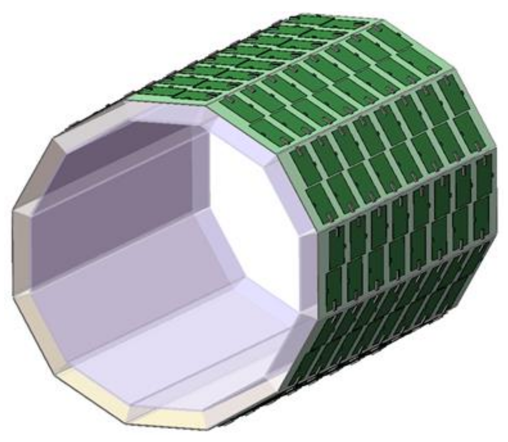

Figure.1 Conceptual design of STCF-RICH system

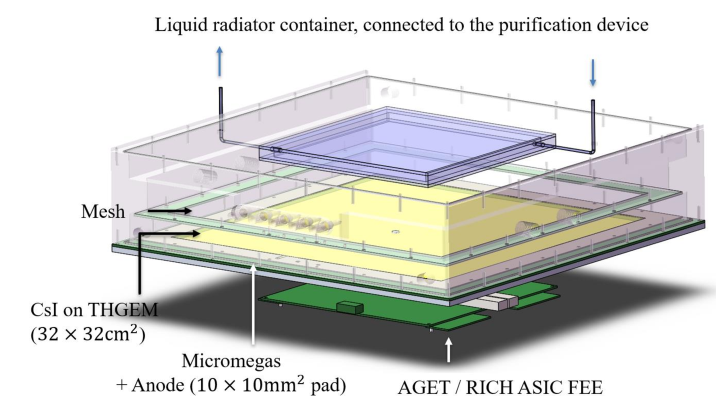

Figure.2 Design of RICH detector prototype

◻Requirements of photon detector in RICH system

- ✓High gain >10^5
- ✓Large area(12×2×45cm×135cm)
- ✓High QE and photo-electron collection efficiency

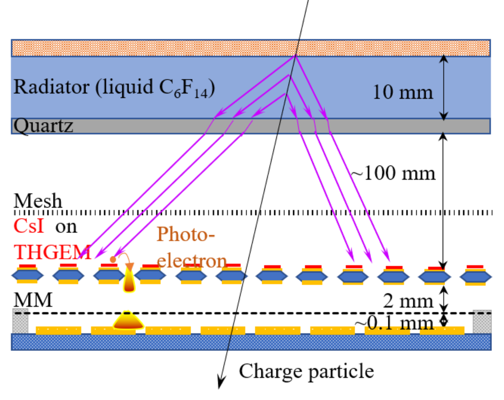

Figure.3 RICH detector based on THGEM + Micromegas

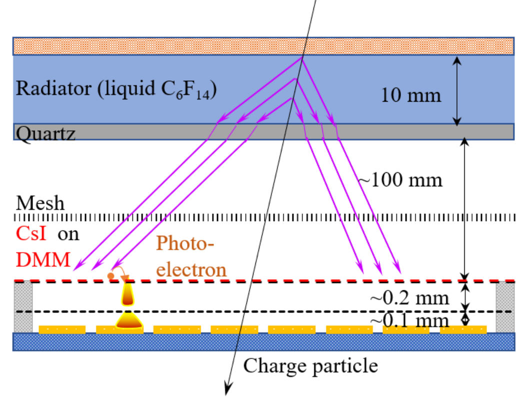

Figure.4 RICH detector based on DMM

RICH detector based on THGEM + Micromegas

The Micromegas detector has been developed using a thermal bonding technique[1], and the THGEM utilizes a copper reduction process in order to enhance voltage resistance and increase the surface area of the photocathode coating.

We have successfully developed a RICH detector which a sensitive area of 32×32cm², achieving a gain of up to 10^5 with a gain uniformity (RMS/Mean) better than 20%. Cherenkov radiation photons can be detected by plating CsI on the THGEM as a photocathode.

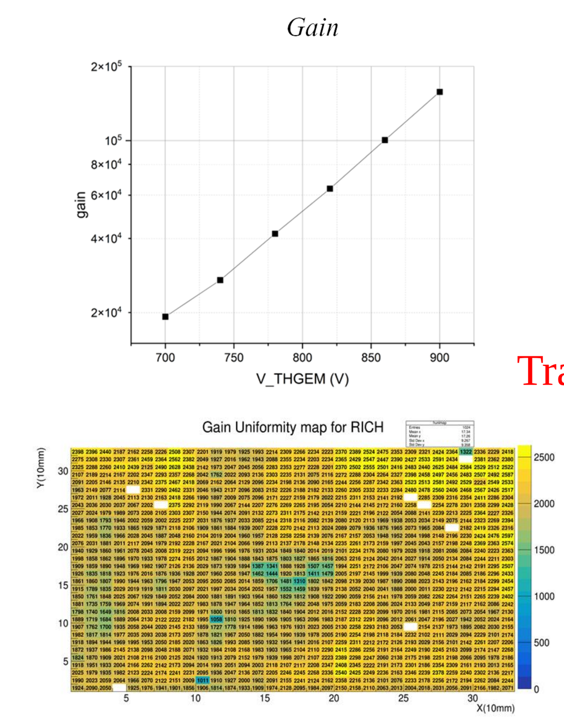

Figure.5 Performance test of RICH prototype

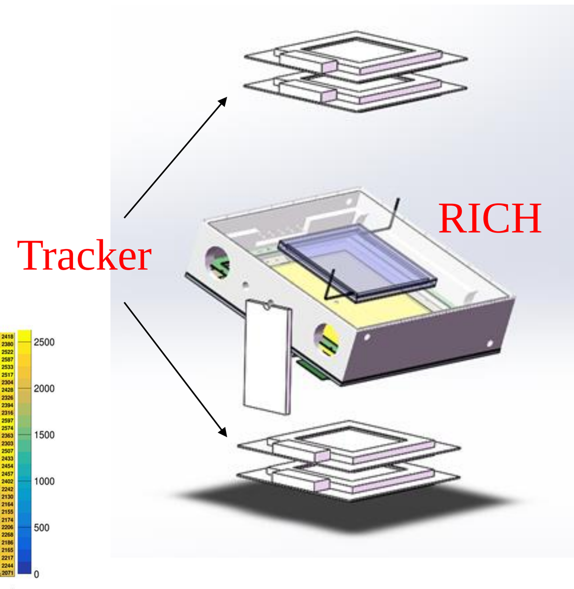

Figure.6 Cosmic ray test

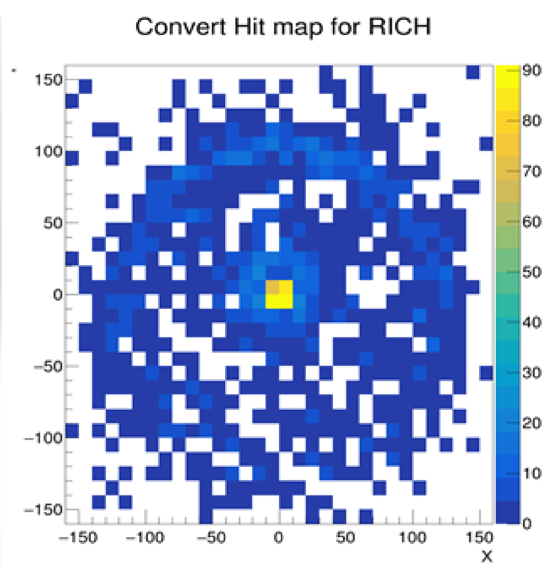

Figure.7 Cosmic hit map for RICH detector

New photon detector: DMM

Advantages

- **High gain:** a gain of up to 10^6 for single electrons, and the gain of a large-area DMM better than 10^5
- **Compact structure and good time resolution:** reducing the need for complex mechanical designs, and a good time resolution of single-photon (< 300ps) [2]
- **Low ion backflow:** IBF ratio as low as 0.025% [3]
- **Low out-gas:** not release gases, benefit for the preparation and operation of CsI photocathode

Performance of large area DMM

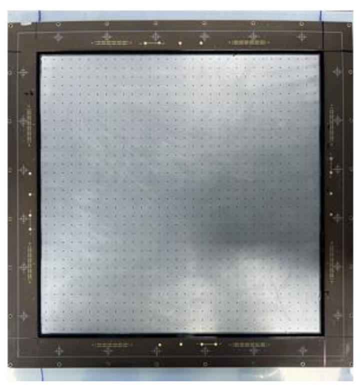

Figure.8 a large area DMM(32×32cm²)

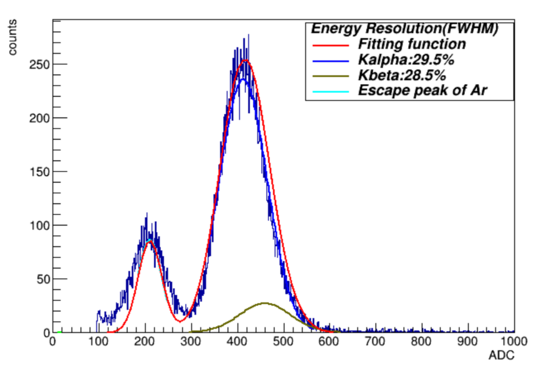

Figure.9 energy resolution of DMM ,test with ^{55}Fe

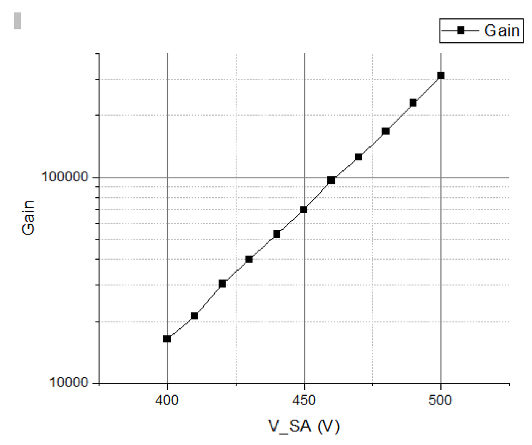

Figure.10 gain of DMM >3×10^5 , test with ^{55}Fe

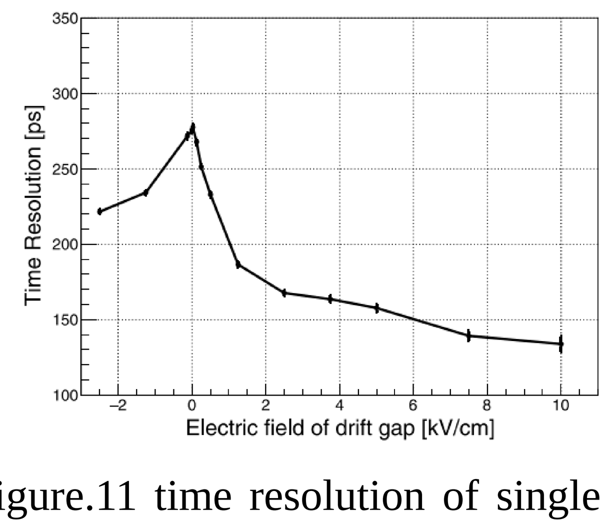

Figure.11 time resolution of single photon, using a reflecting photocathode[2]

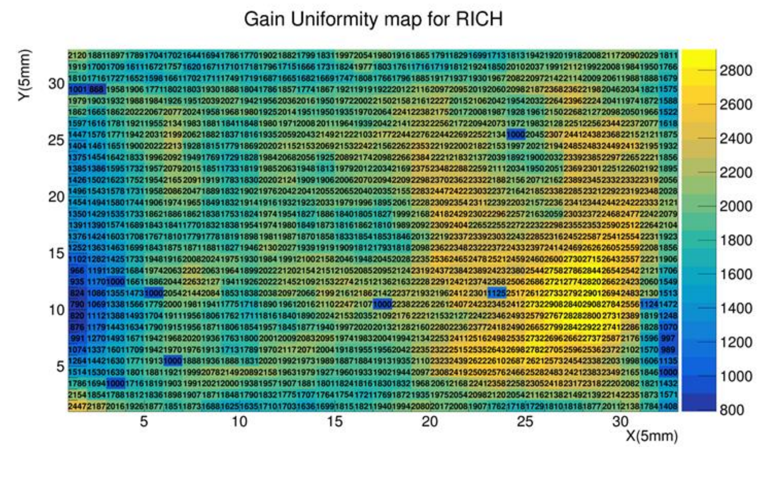

Figure.12 the gain uniformity of this large area DMM is 16.3%, batter than 20%

CsI photocathode Coating

Figure.13 CsI plated on stainless steel mesh as a reflective photocathode

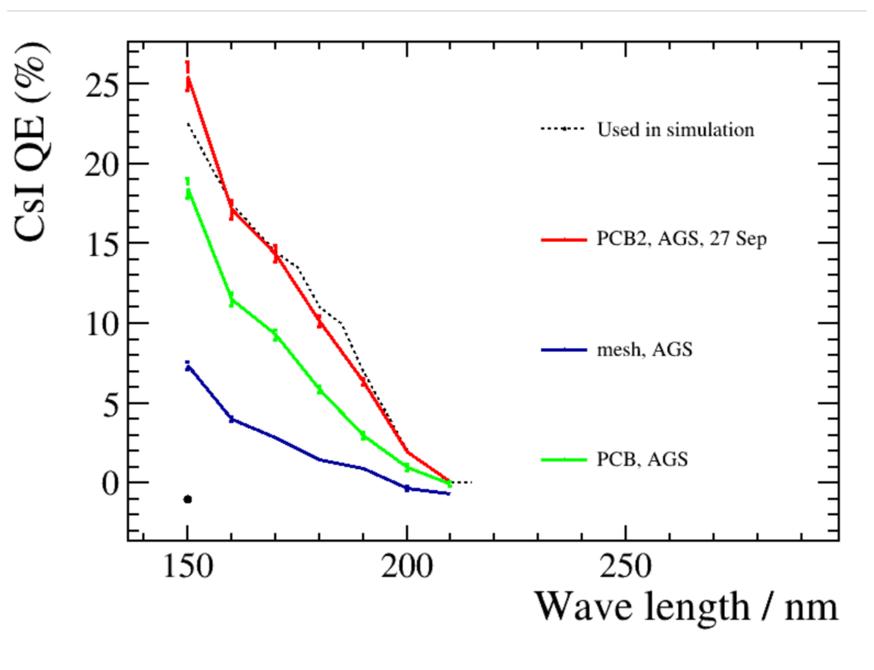

Figure.14 Quantum efficiency of CsI photocathode coating on mesh, with a window opening rate of 48%

Conclusions

- ◻ The development of RICH prototype based on THGEM combined with Micromegas has been achieved, and the Cherenkov radiation photon signals have been successfully tested.
- ◻ A large-area DMM has been developed, with a gain uniformity better than 20%.
- ◻ The coating experiment on the stainless steel mesh has been completed, verifying the relationship between quantum efficiency and the coated area.

References

[1] Jianxin Feng, Zhiyong Zhang et al., A thermal bonding method for manufacturing Micromegas detectors, Nuclear Inst. and Methods in Physics Research A, 989 (2021) 164958.
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[3] Binbin Qi, Kunyu Liang et al., Optimization of the double micro-mesh gaseous structure (DMM) for low ion-backflow applications，Nuclear Inst. and Methods in Physics Research A, 976 (2020) 164282.

Acknowledgement

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