# A Hybrid Muon Detector Design with RPC and Plastic Scintillator for the Experiment at the Super Tau-Charm Facility

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## 1. Introduction

The Super Tau-Charm Facility (STCF) is proposed as a natural successor to the BEPCII in the τ-Charm region, which provides a luminosity of at least 0.5 × $10^{35}$ /cm$^2$/s. The Muon Detector (MUD) is the outermost part of the STCF detector, dedicated to separating muons from pions, and identifying neutral hadron as well. The momenta final state of muons and pions produced at the STCF experiment are mostly below 1.7 GeV, and the challenge lies in low momentum region (<0.7 GeV/c) in which muons have short track length in the MUD. Also, due to the promotion of luminosity, the MUD need to have a high rate capability and excellent background suppression power. The Resistive Plater Chamber (RPC) and plastic scintillator are the two main alternative choices for MUD, with different sensitivity to photon and neutron, leading to different detection performance:

**RPC:**

- **Low background counting rate.**
- **Low sensitivity to cluster generated by hadron showed pions.**

**Plastic scintillators:**

- **High detection efficiency to neutral particles.**
- **High background counting rate.**

To this end, a hybrid Muon detector design consisting in bakelite-RPCs and scintillator strips is proposed, to make a balance between muon identification, background rejection and the overall cost.

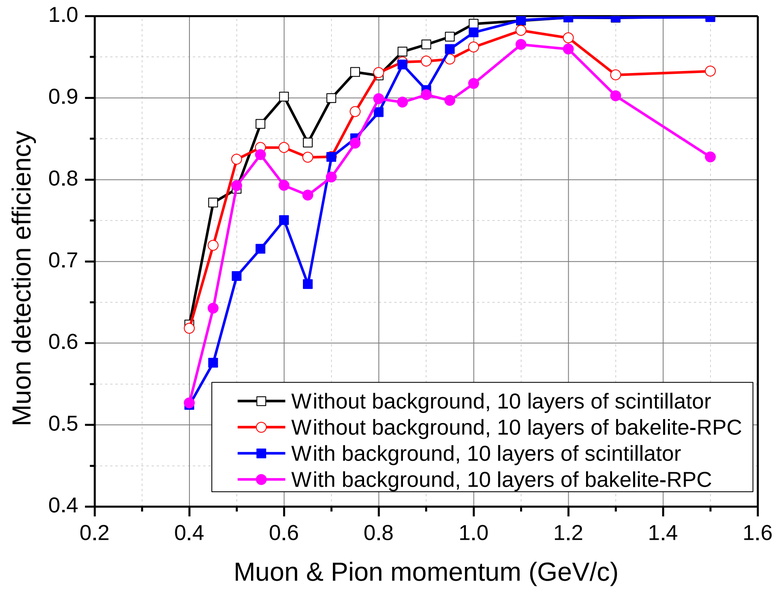


Fig. 1 The muon detection efficiency curve @pion rejection rate = 97% with or without background, in the direction of θ=90 deg, ϕ=90 deg (θ: polar angle, ϕ: azimuth angle).

## 2. Hybrid MUD Parameters Optimization

The hybrid MUD is designed as the combination of bakelite-RPC and plastic scintillator, asking for optimizations to improve performance. The detector layer amount, the iron yoke setting, the layout of bakelite-RPC and plastic scintillators, and the granularity of detector are the main parameters and get optimized.

### Iron yoke setting and detector layer amount

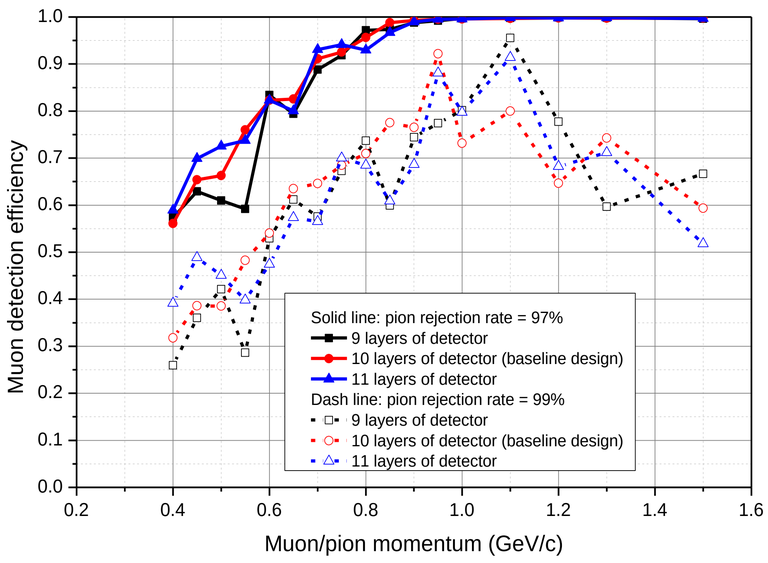


Fig.2 The Geant4 simulated muon detection efficiency curves with different layers of detector, and 51 cm yoke.

### Arrangement of bakelite-RPC and plastic scintillator

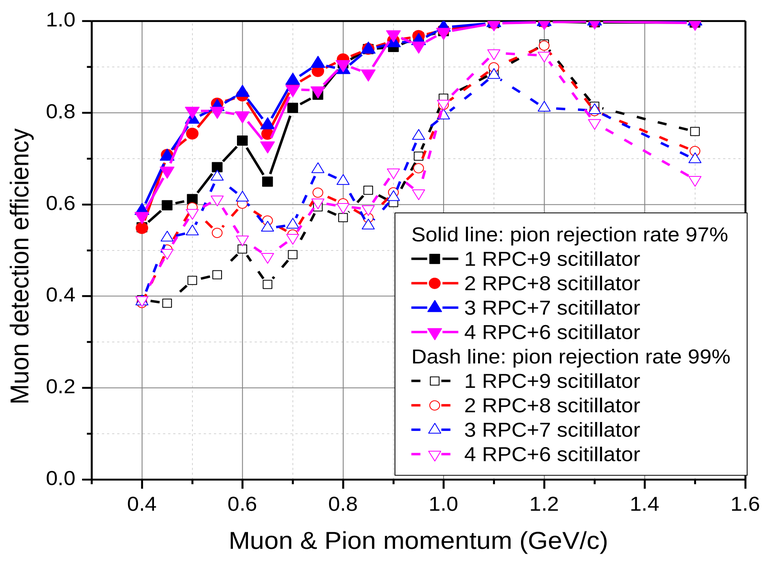


Fig.3 The muon detection efficiency curves with different bakelite-RPC and plastic scintillator combinations in the MUD design in zenith direction, under background.

### Granularity of bakelite-RPC and plastic scintillator strips

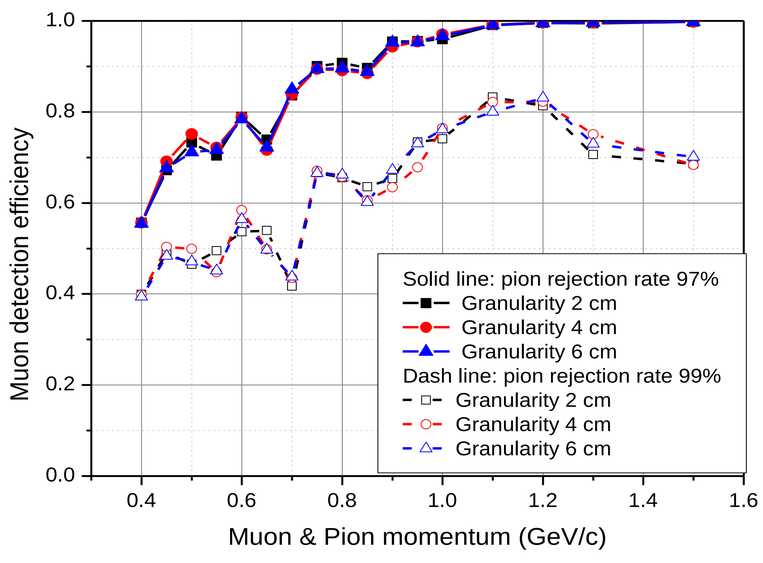


Fig.4 The Geant4 simulated muon detection efficiency, with different granularities, in the zenith direction.

## 3. Hybrid MUD Design and Performance

The hybrid MUD consists of 3 layers of bakelite-RPC and 7 layers of polystyrene plastic scintillator with the granularity of 4 cm, besides the additional neutron shielding and Endcap yoke component.

By matching the hits in the MDC, the ECAL and the MUD, the potential track-like (muon/pion separation) and cluster-like (neutral hadron identification) MUD hits can be separated to a certain extent and analyzed by the special Boosted Decision Tree (BDT) algorithms. The Geant4 simulation shows that the identification efficiency for muons with momenta above 0.8 GeV/c can be higher than 95%@pion rejection rate = 97%. Also, when the neutral hadron deposit less than 40 MeV in the ECAL, the detection efficiency of MUD can be up to 95%@photon rejection rate = 97%.




Fig.5 The schematic of hybrid MUD structure.

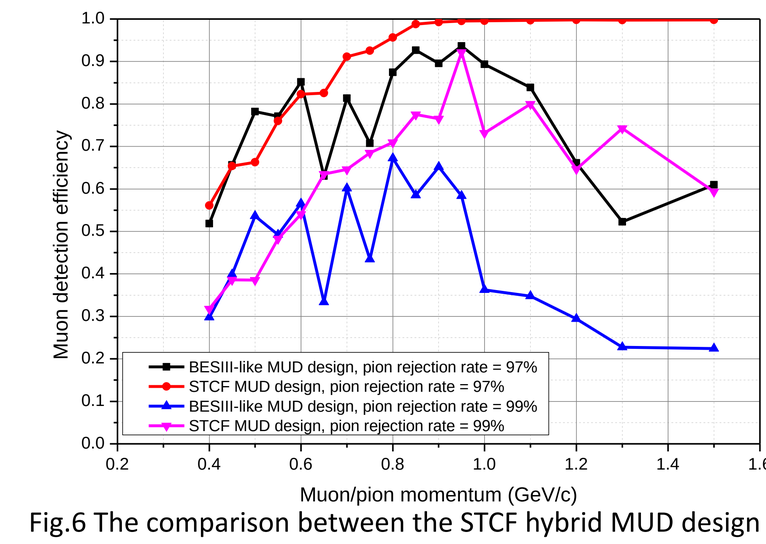


Fig.6 The comparison between the STCF hybrid MUD design and the BESIII-like MUD design with the same BDT algorithm, in the zenith direction and no background included.

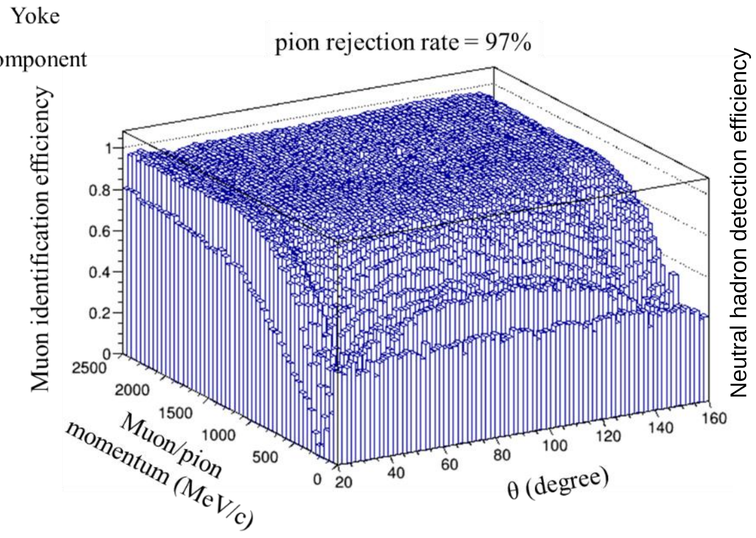


Fig.7 The Geant4 simulated muon detection efficiency distribution, with the pion rejection rate = 97%.

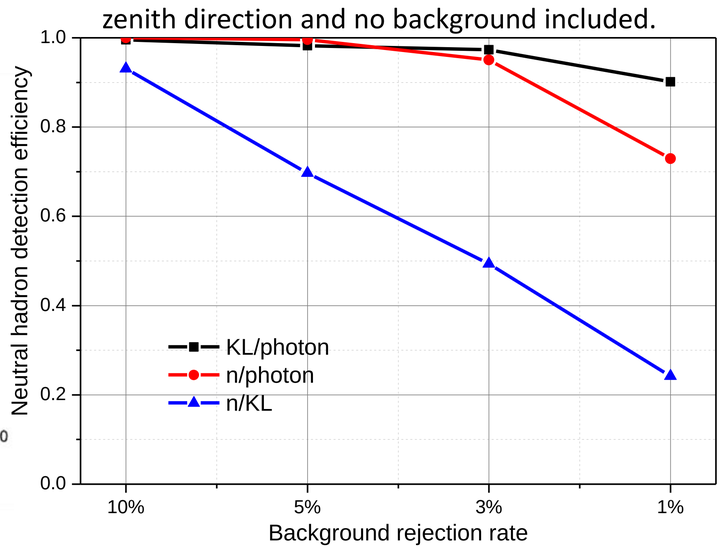


Fig.8 The detection efficiency curve with different categories of neutron, in the zenith direction.

## 4. Conclusion

To make a good balance between particle detection, identification and background suppression power, a new hybrid MUD design with 3 layers of bakelite-RPC and 7 layers of scintillator detector is proposed. The Geant4 simulation results indicate the particle detection efficiency:

- **muon: 95%@pion rejection rate=97%, when $p_T$>0.8 GeV/c**
- **Neutron and $K_L$: 95%@photon rejection rate=97%, when $E_{dep\ in\ ECAL}$ < 40 MeV**

**Acknowledgement:**

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