STCF RICH
detector design and R&D

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• **Super Tau-Charm Facility**

  ▶ STCF: a natural extension of BEPCII and a viable option for a post-BEPCII HEP project in China

  • $E_{cm} = 2 - 7 \text{ GeV}, \ L \sim 0.5 \times 10^{35}\text{ cm}^{-2}\text{s}^{-1}@4\text{GeV}$
  • Symmetrical collision
  • double-ring, 600-800 m
  • Large Piwinski angle & Crab waist
  • Upgradable for polarized electron beam

A Super $\tau - C$ machine far beyond BEPCII
STCF Overview
Physics opportunities

- Hadron form factors
- \( Y(2175) \) resonance
- Multiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with \( \tau \) lepton

- XYZ particles
- D mesons
- \( f_D \) and \( f_{D_S} \)
- \( D_0 - D_0 \) mixing
- Charm baryons
STCF Detector Concept

PXD
- $\sim 0.15 \% X_0 / \text{layer}$
- $\sigma_{xy} \sim 50$ $\mu$m

MDC
- $\sigma_{xy} < \sim 130$ $\mu$m
- $\sigma_p/p \sim 0.5 \% @ 1$ GeV
- $dE/dx \sim 6\%$

PID
- $\pi/K$ (and K/p) $3-4 \sigma$ separation up to 2GeV/c

EMC
- E range: 0.02-2.5GeV
- At 1 GeV $\sigma_E (\%)$
  - Barrel: 2
  - Endcap: 4

MUD
- Down to $\sim 0.4$GeV
- $\pi$ suppression $>10$
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**PID Detector Requirements**

- Wide PID range
  - Cherenkov-based technology
    - Low p region (<0.6 GeV) covered by trackers dE/dx measurement
- Compact (<20 cm) and low material budget (< 0.5X₀)
  - Limited optical focusing methods
  - RICH/FTOF/DIRC
- Large solenoid angle coverage

- \( E_{cm} \) being up to 7 GeV calls for PID in a large momentum range (up to 2 GeV/c)
- Technology beyond \( dE/dx + TOF \) is required for PID up to 2 GeV

**PID**

- \( \pi/K \) (and \( K/p \)) 3~4\( \sigma \) separation up to 2 GeV/c
- \( \pi/\mu \) separation capacity for low momentum.
RICH Design

- $3\sigma \pi/K @ 2\text{GeV}$
- Material budget: $\sim 15\%$
- Thickness: $\sim 100\text{mm}$
- Rate: $<5\text{kHz/cm}^2@R>20\text{cm}$
- Gain: $\sim 10^5$
- IBF: $\sim 10^{-3}$
- Cum. Charge: $<2\text{uC/cm}^2@10\text{year}$
- Pad: $0.5\times0.5\text{cm}^2$
- Expected Res: $<1.5\text{ mrad}$

- Proximity focusing RICH with CsI-coated MPGD readout
- Proximity gap $\sim 10\text{ cm}$, Sensor size $5\text{mm}*5\text{mm}$
- Radiator: liquid $C_6F_{14}$, $n\sim 1.3$
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Hard to find analytic equation ⇒ Likelihood method.

- The photon collected in each anode pads follows the Poisson distribution

\[ pdf_{i,h} = \text{Poisson} \left( N_i + 10^{-3}, \text{mean}_{i,h} + 10^{-3} \right), \]

- Likelihood of h hypothesis:

\[ \ln L_h = \sum_i^{npads} \ln pdf_{i,h} \]

- \( \pi, K \) separation:

\[ DLL = \sum_i^{npads} \ln \frac{pdf_{i,\pi}}{pdf_{i,K}} \]

- Likelihood Method
Likelihood Method PID Power

PID efficiency for \( \pi \) as \( \pi \)

PID efficiency for \( K \) as \( K \)

\[
\frac{K}{\pi} \text{ 3.3}\sigma \text{ separation up to 2.0GeV/c}
\]

\[
\frac{K}{p} \text{ 3.3}\sigma \text{ separation up to 2.0GeV/c}
\]
Low Momentum $\mu/\pi$ Separation

$\pi$ efficiency

$\mu$ efficiency

$>90\%$ pid efficiency for momentum range (0.3GeV/c~0.5GeV/c) and polar angle (0°~40°)
Classification using CNN

Using CNN to classify three hadrons.

PID efficiency ~ similar level of likelihood method.

Highly accelerate the execution time to 2evt/ms (1 2080Ti).
Develop the RICH Prototype

- Effective area: 16X16 cm²
- Quartz as radiator (10mm) will be replaced by C6F14
- THGEM+CsI (700nm)
- Anode pad(5mm²)
- AGET FEE: 1024 channels
RICH prototype beam-test @DESY

a) RICH prototype

b) RICH in position

c) Test-beam
Spatial resolution

Trigger:
S1 & S2

T06 is getting worse due to the e-scattering
• Summary

- STCF PID requires 2GeV/c $\pi/K$ separation, and RICH can satisfy this requirement.
- Via the Likelihood method, $>3\sigma$ separation capability can be reached by RICH in STCF, and can offer $\pi/\mu$ PID in low momentum range.
- Test-beam @DESY shows the current base-line design is functional and can fulfill the requirements. Preliminary results are presented.

Thank you !!
• backup
counting rate extrapolated from BESIII

- Barrel: 400 Hz/cm²
- Endcaps: 4kHz/cm²
- May include significant contributions from detector/electronics noise since no clear dependence on beam current is seen