STCF RICH detector design and R&D

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The 5th TIPP Conference
• **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

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

- Hadron form factors
- $\Upsilon(2175)$ 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 $f_{D_s}$
- $D_0$-$\bar{D}_0$ mixing
- Charm baryons

S.Olsen HIEPA 2015 Workshop
STCF Detector Concept

- PXD
  - \(0.15% X_0 \) / layer
  - \( \sigma_{xy} \approx 50 \) \( \mu m \)

- MDC
  - \( \sigma_{xy} \approx 130 \) \( \mu m \)
  - \( \sigma_p/p \approx 0.5\% \) @ 1 GeV
  - \( dE/dx \approx 6\% \)

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

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

- MUD
  - Down to \(< 0.4 \text{ GeV} \)
  - \( \pi \) suppression >10
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PID Detector Requirements

- Wide PID range
  - Cherenkov-based technology
  - Low p region (<0.6GeV) covered by trackers dE/dx measurement
- Compact (<20cm) 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 2GeV/c)
- Technology beyond $dE/dx$ + TOF is required for PID up to 2GeV

**PID**

- $\pi/K$ (and $K/p$) 3~4σ 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: $0.5\times 0.5\text{cm}^2$
- Expected Res: $<1.5\text{ mrad}$

- Proximity focusing RICH with CsI-coated MPGD readout
- Proximity gap $\sim 10\text{ cm}$, Sensor size $5\text{mm}\times 5\text{mm}$
- Radiator: liquid $\text{C}_6\text{F}_{14}$, $n\sim 1.3$
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Hard to find analytic equation ⇒ Likelihood method.

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

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

- Likelihood of h hypothesis:

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

- \( \pi, K \) separation:

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

\[ -2DLL_{\pi/K} \]

\[ 3.32\sigma \pi/K \] separation
Likelihood Method PID Power

PID efficiency for $\pi$ as $\pi$

$K/\pi$ 3.3$\sigma$ separation up to 2.0GeV/c
$K/p$ 3.3$\sigma$ 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

- **Track-VMM**
  - 0.4mm strip, 128*2

- **RICH-AGET**
  - 5mm pad, 32*32

- **Track-AGET**
  - 0.4mm strip, 128*2

**Single event**

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