The limitation of TOF

- TOF over the short ~2.2m baseline inside the SHMS hut will be of little use for most of the momentum range anticipated for the SHMS.
- Even over a 22.5m distance from the target to the SHMS detector stack, TOF is of limited use.

Effect of finite timing resolution ($\pm 1.5\sigma$ with $\sigma=200\text{ps}$). Separation <3$\sigma$ to the right of where lines intersect.

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Non-TOF techniques

- Efficient, high-confidence PID requires extensive use of non-TOF techniques such as Čerenkov detectors.

- Good PID can be obtained with a series of Čerenkov detectors:
  - $e^-/\pi^-$ ⇒ Noble Gas Čerenkov $(n-1 < 10^{-4})$
  - $\pi^+/K^+$ ⇒ Heavy Gas Čerenkov $(n-1 \leq 10^{-3})$
  - $K^+/$ ⇒ Aerogel Čerenkov $(n-1 \leq 0.05)$

- Lead Glass Calorimeter also plays a critical role in $e^-, e^+$ identification.
Hall-C SHMS Detector System

**Noble Gas Čerenkov:**
e/π separation at high momenta, where multiple-scattering is less of an issue.

**Trigger Hodoscopes:**
Time-of-Flight at low momenta; insensitive to photon or low-energy background.

**Heavy Gas Čerenkov:**
π/K separation for P>3.4 GeV/c.

**Aerogel Čerenkov(s):**
Depending on the n used, K/p separation or π/K separation at low momenta.

**Lead Glass Calorimeter:**
e/π separation.
Calorimeter: e/π separation

- Lead-Glass Block / PMT / Base Assemblies from HERMES.
- Expect >200:1, based on HMS Calorimeter performance.
Noble Gas Cerenkov: $e/\pi$ (or $\pi/K$) separation at high momenta

2.5 m long gas radiator at atmospheric pressure.
- Argon: $\pi$ threshold $\sim$ 6 GeV/c.
- Adding Neon: $\pi$ threshold may be varied up to 12 GeV/c.
- Para-Terphenyl PMT window over-coating.
- Performance 20 photoelectrons (worst case: pure Neon).

At low momenta: remove mirrors, insert coupling so that the tank becomes part of the vacuum system – reduces MCS.
Heavy Gas Cerenkov: $\pi$ /K separation for momenta > 3.4 GeV/c

To maintain good $\pi$/K separation, it is necessary to reduce the gas pressure above 7 GeV/c.

Lowest $\pi^\pm$ identification efficiency occurs at 3.4 GeV/c (~10 p.e.).

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Electron-Pion Discrimination

- The most stringent requirements arise when the SHMS is set to negative polarity.
- Both $e^-/\pi^-$ and $\pi^-/e^-$ separations are required:

<table>
<thead>
<tr>
<th>Expt</th>
<th>$P_{\text{SHMS}}$ (GeV/c)</th>
<th>Worst Fore/Bkd Rate Ratio</th>
<th>Noble Gas Č</th>
<th>Pb-G Cal</th>
<th>Total $e:\pi$ Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_\pi$ (E12-06-101)</td>
<td>5.1, 6.5</td>
<td>1 ($\pi^-$):1000(e-)</td>
<td>50:1</td>
<td>200:1</td>
<td>10000:1</td>
</tr>
<tr>
<td>SIDIS $p_T$ (PR12-09-017)</td>
<td>1.5-5.0</td>
<td>1 ($\pi^-$):10 (e-)</td>
<td>Not used for lowest $P$.</td>
<td>250:1</td>
<td>250:1</td>
</tr>
<tr>
<td>$x&gt;1$ (E12-06-105)</td>
<td>4.8-10.6</td>
<td>1(e-):50($\pi$- )</td>
<td>50:1</td>
<td>100:1</td>
<td>5000:1</td>
</tr>
<tr>
<td>DIS-Parity (E12-07-102)</td>
<td>4.9-6.7</td>
<td>3(e-):1($\pi$-)</td>
<td>10:1</td>
<td>100:1</td>
<td>1000:1</td>
</tr>
</tbody>
</table>
Pion-Kaon Discrimination

- Equally applicable for positive or negative SHMS polarity.
- Supplemental Aerogel or TOF must supplement Heavy Gas Čerenkov at low momentum.

<table>
<thead>
<tr>
<th>Expt</th>
<th>$P_{SHMS}$ (GeV/c)</th>
<th>Worst Fore/Bkd Rate Ratio</th>
<th>Heavy Gas Č P&gt;3.4 GeV/c</th>
<th>Aerogel Č P&lt;3.4 GeV/c (n=1.010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_\pi$ (E12-06-101)</td>
<td>2.2-8.1</td>
<td>2(π):3(K+p)</td>
<td>1000:1</td>
<td>300:1</td>
</tr>
<tr>
<td>CT (E12-06-107)</td>
<td>5.1-9.6</td>
<td>1(π):1(K+p)</td>
<td>1000:1</td>
<td>NA</td>
</tr>
<tr>
<td>$\pi$ Factorization (E12-07-102)</td>
<td>2.4-8.5</td>
<td>2(π):3(K+p)</td>
<td>1000:1</td>
<td>300:1</td>
</tr>
<tr>
<td>K Factorization (PR-09-011)</td>
<td>2.6-7.1</td>
<td>1(K):30(π)</td>
<td>1000:1</td>
<td></td>
</tr>
</tbody>
</table>
Aerogel Čerenkov

- Reliable $K/p$ separation over a wide momentum range is a challenge.
- Although only one aerogel Čerenkov is required at any particular momentum, two detectors would allow flexibility over a greater range.
- $K/p$ separation gets progressively more difficult as $(n-1)$ is reduced at higher momenta.

<table>
<thead>
<tr>
<th>$P_{SHMS}$ (GeV/c)</th>
<th>$n$ (10cm)</th>
<th>K p.e.</th>
<th>p p.e.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5-3.0</td>
<td>1.030</td>
<td>13-46</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>3.1-3.7</td>
<td>1.020</td>
<td>12-31</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>3.8-4.3</td>
<td>1.015</td>
<td>13-24</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>4.4-5.1</td>
<td>1.010</td>
<td>5.5-</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>5.2-6.2</td>
<td>1.0075</td>
<td>5.5-13</td>
<td>&lt;1</td>
</tr>
<tr>
<td>6.4-7.3</td>
<td>1.0055</td>
<td>6-9</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

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Kaon-Proton Discrimination

- Only relevant for SHMS positive polarity.
- Several experiments have similar stringent requirements:

<table>
<thead>
<tr>
<th>Expt</th>
<th>Momenta (GeV/c)</th>
<th>Worst Fore/Bkd Rate Ratio</th>
<th>Aerogel Č (worst case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT (E12-06-107)</td>
<td>5.1-9.6</td>
<td>1(K):10(p)</td>
<td>100:1</td>
</tr>
<tr>
<td>SIDIS $p_T$ (PR12-09-017)</td>
<td>1.5-5.0</td>
<td></td>
<td>200:1</td>
</tr>
<tr>
<td>K Factorization (PR12-09-011)</td>
<td>2.6-7.1</td>
<td>1(K):3(p)</td>
<td>100:1</td>
</tr>
</tbody>
</table>
Supplementary $K/\pi$ 7 GeV/c

- pCDR includes a supplemental $K/\pi$ identification technique utilizing the dE/dx distribution of particles traversing the wire chambers.
- Requires analog readout for groups of wires.

Cut placed at 75% likelihood results in 200:1 $\pi$:K sep. separation with 95% efficiency.
Summary

- Particle identification requirements of approved and proposed SHMS experiments are largely met by the planned detector package.
- At least one Aerogel Čerenkov is required for $\pi^\pm$ identification at $P<3.4$ GeV/c and for $K^\pm$ identification up to at least 5 GeV/c.
- The need to supplement $K$ identification at higher momenta seems clear.
  - Addition of pulse-height info to the wire chamber readout is a particularly attractive option.
  - Requires new readout electronics, but cost is offset by the need for fewer sets of aerogel (different $n$) and less overhead when changing momentum.
  - Likely cost effective over the longer term.