Performance of Drift Chambers for E906/SeaQuest Drell–Yan Experiment at Fermilab

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1. Introduction

- SeaQuest studies the structure of the proton.
  - the flavor asymmetry of anti-quarks in the proton.
- 120 GeV proton beam at Fermilab is used.
- We will measure $\bar{d}/\bar{u}$ in the region $0.1 < x < 0.45$ by Drell–Yan process
  ... $x$: Bjorken $x$
- We detect muons from Drell–Yan process.
  - momentum $\sim 40$ GeV

\[ q\bar{q} \rightarrow \gamma^* \rightarrow \mu^+ \mu^- \]
• Toward Run3, performance of drift chambers has been investigated with Run2 data.

• I will report on
  - position resolution of drift chambers and
  - single plane efficiency of drift chambers.

• The data were taken with $1 \times 10^{12}$ protons/s intensity beam.
  - The intensity will increase to $2 \times 10^{12}$ protons/s.
2. SeaQuest Spectrometer

- Target: proton, deuteron, carbon, iron, and tungsten
- Magnet: momentum determination of the muons
- There are four tracking stations for detecting muons; Station 1, 2, 3, and 4.
  - St. 3 consists of two parts;
    - St. 3+: upper half of St. 3
    - St. 3-: lower half of St. 3
  - Each of St. 1, 2, 3+, and 3- consists of a drift chamber and a hodoscope.
  - St. 4 consists of proportional tubes and a hodoscope.
X and X' planes are vertical.

V and V' planes are tilted by +14° from vertical direction.

U and U' planes are tilted by -14° from vertical direction.

Each drift chamber has six planes; X, X', V, V', U, and U'.

<table>
<thead>
<tr>
<th>Detector</th>
<th>Detector Name</th>
<th>Plane Width (cm)</th>
<th>Plane Height (cm)</th>
<th>Cell Width (mm)</th>
<th>Maximum Drift Time (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. 1 Drift Chamber</td>
<td>D1</td>
<td>102</td>
<td>122</td>
<td>6.4</td>
<td>110</td>
</tr>
<tr>
<td>St. 2 Drift Chamber</td>
<td>D2</td>
<td>231</td>
<td>269</td>
<td>20.8</td>
<td>280</td>
</tr>
<tr>
<td>St. 3+ Drift Chamber</td>
<td>D3p</td>
<td>222</td>
<td>160</td>
<td>20.0</td>
<td>270</td>
</tr>
<tr>
<td>St. 3- Drift Chamber</td>
<td>D3m</td>
<td>222</td>
<td>160</td>
<td>20.0</td>
<td>210</td>
</tr>
</tbody>
</table>
- We use 18 planes in total for tracking.
- In order to investigate chamber performance, “global tracks” are used.
  - “global track”: track reconstructed with all the chamber planes
- Goal of position resolution is calculated based on goal of mass resolution of $\mu^+$ and $\mu^-$.  
  - mass resolution < 0.24 GeV (contribution of multiple scattering is dominant)
  - position resolution < 400 $\mu$m
- Goal of single plane efficiency is calculated based on tracking efficiency.
  - single plane efficiency > 95%
  - tracking efficiency will be 90% with this single plane efficiency.
    ‣ assume a global track needs 5 or 6 hits per chamber
3. Position Resolution of Drift Chamber

Definition:
Position resolution = the standard deviation of the residual at the plane

- Track quality cuts are applied.
  - Number of hits associated with track = 18
  - Reduced $\chi^2$ of track < 3.0

Goal of resolution < 400 µm
• Position resolution vs Drift time of each drift chamber.
• Smooth curves have been obtained.
  - there is no very high or low point
  - a constant value is used in analysis
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• Smooth curves have been obtained.
  - there is no very high or low point
  - a constant value is used in analysis
## Summary of Position Resolution

<table>
<thead>
<tr>
<th>Plane Name</th>
<th>Goal</th>
<th>Result</th>
<th>Plane Name</th>
<th>Goal</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D1U</strong></td>
<td>400 µm</td>
<td>260 µm</td>
<td><strong>D3pV’</strong></td>
<td>400 µm</td>
<td>370 µm</td>
</tr>
<tr>
<td><strong>D1U’</strong></td>
<td>400 µm</td>
<td>240 µm</td>
<td><strong>D3pV</strong></td>
<td>400 µm</td>
<td>380 µm</td>
</tr>
<tr>
<td><strong>D1X</strong></td>
<td>400 µm</td>
<td>370 µm</td>
<td><strong>D3pX’</strong></td>
<td>400 µm</td>
<td>320 µm</td>
</tr>
<tr>
<td><strong>D1X’</strong></td>
<td>400 µm</td>
<td>350 µm</td>
<td><strong>D3pX</strong></td>
<td>400 µm</td>
<td>330 µm</td>
</tr>
<tr>
<td><strong>D1V</strong></td>
<td>400 µm</td>
<td>220 µm</td>
<td><strong>D3pU’</strong></td>
<td>400 µm</td>
<td>320 µm</td>
</tr>
<tr>
<td><strong>D1V’</strong></td>
<td>400 µm</td>
<td>220 µm</td>
<td><strong>D3pU</strong></td>
<td>400 µm</td>
<td>340 µm</td>
</tr>
<tr>
<td><strong>D2V</strong></td>
<td>400 µm</td>
<td>370 µm</td>
<td><strong>D3mV’</strong></td>
<td>400 µm</td>
<td>330 µm</td>
</tr>
<tr>
<td><strong>D2V’</strong></td>
<td>400 µm</td>
<td>320 µm</td>
<td><strong>D3mV</strong></td>
<td>400 µm</td>
<td>340 µm</td>
</tr>
<tr>
<td><strong>D2X’</strong></td>
<td>400 µm</td>
<td>380 µm</td>
<td><strong>D3mX’</strong></td>
<td>400 µm</td>
<td>420 µm</td>
</tr>
<tr>
<td><strong>D2X</strong></td>
<td>400 µm</td>
<td>370 µm</td>
<td><strong>D3mX</strong></td>
<td>400 µm</td>
<td>470 µm</td>
</tr>
<tr>
<td><strong>D2U</strong></td>
<td>400 µm</td>
<td>390 µm</td>
<td><strong>D3mU’</strong></td>
<td>400 µm</td>
<td>320 µm</td>
</tr>
<tr>
<td><strong>D2U’</strong></td>
<td>400 µm</td>
<td>390 µm</td>
<td><strong>D3mU</strong></td>
<td>400 µm</td>
<td>410 µm</td>
</tr>
</tbody>
</table>

- The position resolutions shown here are average values of the planes.
- Position resolution at each plane of D1, D2 and D3p is better than goal.
- Some planes on D3m are worse than goal but are tolerable.
4. Single Plane Efficiency of Drift Chamber

- Definition of single plane efficiency (of D1X, for example)
  - Track must have a hit on all planes except D1X
  - **Efficient** track: track which **does** have a hit on D1X
  - **In-efficient** track: track which **does not** have a hit on D1X
  - Efficiency of D1X
    \[
    \frac{\text{Number of efficient tracks}}{\text{Number of efficient and in-efficient tracks}}
    \]
  - Efficiency of other planes is obtained by the same method.

- Goal of efficiency > 95%
Efficiency

- Efficiency of each plane of D1 and D3m is better than goal.
- Efficiency of each plane of D3p is lower than goal.
  - HV was set lower to suppress rather-high leak current.
  - D3p >90%, the others >95% → the effect of in-efficiency of D3p is small.
  - We are optimizing the D3p now toward Run3.
    - Attach aluminum Mylar to D3p in order to avoid humidity going into the chamber.
• There are some remaining problems on the efficiency.

• The figure on the left shows local efficiency of D1U’.

• Horizontal axis: Wire position

• Vertical axis: Efficiency

• Efficiency is highest at the center of the plane.

• What causes such a phenomenon?

  - Wire hit rate dependence or performance of tracking might be the reason.

I’m investigating that now.
5. Summary

- SeaQuest studies the structure of the proton, especially studies the flavor asymmetry of anti-quarks in the proton.

- SeaQuest spectrometer has four tracking stations for detecting muons; Station 1, 2, 3, and 4.
  - Station 1, 2, and 3 have drift chamber(s).

- The position resolution of each plane of drift chambers is better than goal (400 µm) except three planes of D3m, but they are tolerable.

- The single plane efficiency of each plane of D1 and D3m is larger than goal (95%).
  - Efficiencies of two planes of D2 and all the planes of D3p are less than goal, but the effect is not very large because the efficiencies of the other planes are high.

- There are some remaining problems on efficiency to be studied.
  - Effect of wire hit rate and effect of performance of tracking on the single plane efficiency will be investigated.
Backup
Backup: humidity and leak current

D3p — I (μA)

leak current

HH — Humidity by HXX Sensor (%)

humidity
Backup: St. 3 chambers

D3p
- Clear mylar is attached.
  - useful when wire repairing

D3m
- aluminized mylar
Backup: multiplicity dependence

- Noise hit removal is applied for tracking.
  - It would remove true hit accidentally.
    → efficiency drops happen more at higher multiplicity region.

- Investigation of the behavior at low multiplicity region is ongoing.
  - It would be due to tracking?
  - The highest efficiency would be the true chamber efficiency.
Backup: Iteration analysis

- Position resolution and relation between drift time and drift distance are required for track reconstruction, but they are unknown at first. For track reconstruction, they are assumed.

- After track reconstruction, position resolution and relation between drift distance and drift time are obtained.

  - They are results of the track obtained by assumed values, so it is not obvious if they are correct values.

- Using them, the track reconstruction is done again. Position resolution and relation between drift distance and drift time are obtained again.

- Doing such things again and again, the values get closer to the true values.
Backup: RT curve

RT curve: relation between the drift distance (R) and drift time (T)

No iteration

After the analysis iterated four times
Backup: Residual