Bpm pedestal study
-- to check beam position

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BPM pedestal Study

- **Goal:** To help resolve the yields drift problems

- **Last time Studied**
  - Correlation map between different bpm channel
  - The uncertainty (contributed by pedestal) improved by a factor of three

- **Today**
  - Will beam position after remove the correlation?
  - Position jumps
### Pedestal Contribution to Target Uncertainty

**Before decoupling correlation**

<table>
<thead>
<tr>
<th>channel</th>
<th>Rms/channel</th>
<th>x/mm</th>
<th>y/mm</th>
<th>theta/mrad</th>
<th>Phi/mrad</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPMA1</td>
<td>323.81</td>
<td>-0.13</td>
<td>0.20</td>
<td>0.14</td>
<td>-0.18</td>
</tr>
<tr>
<td>BPMA2</td>
<td>299.10</td>
<td>0.09</td>
<td>-0.15</td>
<td>-0.11</td>
<td>0.14</td>
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<tr>
<td>BPMA3</td>
<td>2721.42</td>
<td>-0.76</td>
<td>-0.98</td>
<td>-0.71</td>
<td>-1.09</td>
</tr>
<tr>
<td>BPMA4</td>
<td>1969.06</td>
<td>0.67</td>
<td>0.89</td>
<td>0.59</td>
<td>0.97</td>
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<tr>
<td>BPMB1</td>
<td>291.87</td>
<td>0.14</td>
<td>-0.25</td>
<td>-0.24</td>
<td>0.15</td>
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<tr>
<td>BPMB2</td>
<td>798.75</td>
<td>-0.40</td>
<td>0.70</td>
<td>0.67</td>
<td>-0.42</td>
</tr>
<tr>
<td>BPMB3</td>
<td>845.37</td>
<td>-0.77</td>
<td>-0.44</td>
<td>-0.43</td>
<td>-0.80</td>
</tr>
<tr>
<td>BPMB4</td>
<td>378.10</td>
<td>0.25</td>
<td>0.14</td>
<td>0.13</td>
<td>0.26</td>
</tr>
<tr>
<td><strong>Square of sum</strong>&lt;br&gt;<strong>(Uncertainty)</strong></td>
<td>use RMS to estimate</td>
<td>1.38</td>
<td>1.60</td>
<td>1.26</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Square of sum</strong>&lt;br&gt;<strong>(case Triple peak)</strong></td>
<td>Use 1st and 3rd peak rough</td>
<td>2.34</td>
<td>2.94</td>
<td>2.13</td>
<td>3.23</td>
</tr>
</tbody>
</table>

**After decoupling correlation**

<table>
<thead>
<tr>
<th>channel</th>
<th>RMS *√2/channel</th>
<th>x/mm</th>
<th>y/mm</th>
<th>theta/mrad</th>
<th>Phi/mrad</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPMA1-BPMA2</td>
<td>459.9</td>
<td>-0.16</td>
<td>0.26</td>
<td>0.17</td>
<td>-0.23</td>
</tr>
<tr>
<td>BPMA1+BPMA2</td>
<td>415.4</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>-0.02</td>
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<tr>
<td>BPMA3-BPMA4</td>
<td>1055.4</td>
<td>-0.33</td>
<td>-0.42</td>
<td>-0.30</td>
<td>-0.47</td>
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<tr>
<td>BPMA3+BPMA4</td>
<td>4672.2</td>
<td>0.13</td>
<td>0.17</td>
<td>0.11</td>
<td>0.19</td>
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<td>BPMB1-BPMB2</td>
<td>956.1</td>
<td>0.41</td>
<td>-0.71</td>
<td>-0.69</td>
<td>0.44</td>
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<tr>
<td>BPMB1+BPMB2</td>
<td>890.5</td>
<td>0.02</td>
<td>-0.03</td>
<td>-0.03</td>
<td>0.02</td>
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<tr>
<td>BPMB3-BPMB4</td>
<td>690.2</td>
<td>-0.57</td>
<td>-0.32</td>
<td>-0.31</td>
<td>-0.59</td>
</tr>
<tr>
<td>BPMB3+BPMB4</td>
<td>1071.2</td>
<td>-0.04</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Square of sum</strong>&lt;br&gt;<strong>(Uncertainty)</strong></td>
<td>use RMS to estimate</td>
<td>0.80</td>
<td>0.94</td>
<td>0.84</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>Worst case square of sum</strong>&lt;br&gt;<strong>(Uncertainty)</strong></td>
<td>0.87</td>
<td>1.03</td>
<td>0.89</td>
<td>1.04</td>
<td></td>
</tr>
</tbody>
</table>

**Summary:** BPM Uncertainty improved by a factor of 3
Decouple correlation affect center beam position at target?

- Decouple the correlation between each channel signal

Basically rotate 45 degree to channel $A_{x+}$ and $A_{x-}$ (the two channel in same direction, eg in x direction), New coordinates $C_{x+}$ and $C_{x-}$

$$C_+ = A_+ \cdot \cos(45) - A_- \cdot (\sin 45) \cdot g_x$$
$$C_- = A_+ \cdot \sin(45) + A_- \cdot (\sin 45) \cdot g_x$$

Assume all calibration constant right, like $g_x$ (ratio factor), $b_+$, $b_-$ (offset due to unlinear respond)...

However: $E(X + Y) = E(X) + E(Y)$. It is easy to prove by mathematical induction that the **expected value** of the sum of any finite number of random variables is the **sum** of the **expected values** of the individual random variables

$$x_b = \frac{(A_+ - A_{\text{ped}} + b_+) - g_x(A_- - A_{\text{ped}} + b_-)}{(A_+ - A_{\text{ped}} + b_+) + g_x(A_- - A_{\text{ped}} + b_-)}$$

$$= \frac{(A_+ - A_- \cdot g_x) - (A_{\text{ped}} + A_{\text{ped}} - A_{\text{ped}} \cdot g_x) + b_+ - g_x \cdot b_-}{(A_+ - A_- \cdot g_x) + (A_{\text{ped}} + A_{\text{ped}} - A_{\text{ped}} \cdot g_x) + b_+ + g_x \cdot b_-}$$

$$= \frac{(A_{x+} - A_{x-} \cdot g_x) + b_+ - g_x \cdot b_- + \sqrt{2} C_x}{(A_{x+} - A_{x-} \cdot g_x) + b_+ + g_x \cdot b_- + \sqrt{2} C_x}$$

**Used the average pedestal**

**$x_b$ will not change**

Use the rotation coordinates will not affect the beam position calculation, but will improve the uncertainty estimation
Happex DAQ for BPMA trip Run 5898

Happex BPMA Channel 1

Raw ADC

Counts

Mean: 1.245e+4

Happex BPMA Channel 2

Raw ADC

Counts

Mean: 1.109e+4

Happex BPMA Channel 3

Raw ADC

Counts

Mean: 2.647e+4

Happex BPMA Channel 4

Raw ADC

Counts

Mean: 2.177e+4

Check: for bpma channel 1 and 2
Before rotation: $\overline{A_1} = 1.245e + 4$, $\overline{A_2} = 1.109e + 4$
After Rotation: $\overline{C_-} = 1061$, $\overline{C_+} = 1.65e+4$

Gx=0.987

Expected value checked

Happex DAQ for BPMA trip-Rotated Run 5898

BPMA Happex Channel 1 - 2

Entry

Raw ADC

Counts

Mean: 1061

BPMA Happex Channel 1 + 2

Entry

Raw ADC

Counts

Mean: 1.65e+4

BPMA Happex Channel 3 - 4

Entry

Raw ADC

Counts

Mean: 2953

BPMA Happex Channel 3 + 4

Entry

Raw ADC

Counts

Mean: 3.448e+4

Mean: 1.245e+4

Mean: 1.109e+4

Mean: 2.647e+4

Mean: 2.177e+4

Mean: 1.061

Mean: 1.65e+4

Mean: 2.953

Mean: 3.448e+4

$\overline{C_-} = A_1 \cdot \cos(45) - A_2 \cdot \sin(45) \cdot g_x$ ??

$\overline{C_+} = A_1 \cdot \cos(45) + A_2 \cdot \sin(45) \cdot g_x$ ??
Recall Beam Position Issue

Energy 2254 GeV -- beam information versus Run Number

Use Pengjia’s database

Two issues to check
- Current dependence
- Suddenly jumps
Recall Beam Position Issue

Energy 2254 GeV -- beam information versus Current

Use Pengjia’s database

Two issues to check

• Current dependence

• Suddenly jumps
Ebeam=2.2GeV, momentum 2.049GeV, Longitudinal 5T

new database after remove current dependence

choose the runs without yields to correct
Each mark stands for one run in the plot

Using the old database

Using the new database
Recall Beam Position Issue

Energy 2254 GeV -- beam information versus Run Number

How to deal with beam jumps here:

Two types of beam position jumps

a) Red circle part (after adding the carbon cover, run 5816), jump about 5mm or 5mrad? But yields no change

b) Blue circle part (run 5838-5851, continuous taking data, position jump back and forth, spread 3mm or 3mrad) yields change within 3%

Use Pengjia’s database
**Ebeam=2.2GeV, momentum 1.886GeV, Longitudinal 5T - 1st type jump**

<table>
<thead>
<tr>
<th>run</th>
<th>materialID</th>
<th>Momentum</th>
<th>current/nA</th>
<th>yield (use 6mm Raster cut)</th>
<th>BPMA x (mm)</th>
<th>BPMA y (mm)</th>
<th>BPMB x (mm)</th>
<th>BPMB y (mm)</th>
<th>Horizontal tg_x (mm)</th>
<th>Vertical tg_y (mm)</th>
<th>Horizontal tg_phi = dx/dz (mrad)</th>
<th>Vertical tg_theta = dy/dz (mrad)</th>
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<tr>
<td>5809</td>
<td>17</td>
<td>1.8857</td>
<td>44.07</td>
<td>1</td>
<td>-1.37</td>
<td>-2.35</td>
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<td>-3.41</td>
<td>-3.15</td>
<td>0.98</td>
<td>4.51</td>
</tr>
</tbody>
</table>

1.5 hours beam down (target anneal) between run 5816 and run 5818  
Carbon cover added after run 5816  
Calibrated Beam position Jump happened when beam back  
X jump -2.8mm; y jump 2.4mm  
Theta jump 5.5mrad; phi jump -2.3mrad  
Data Yields within 1% for the momentum setting  
Usually 1mm (1mrad) shift change yields ~3%
Ebeam=2.2GeV, momentum 1.469GeV, Longitudinal 5T - 2nd type jump

1. a linear current dependence for BPMB x from run 5838 to 5842? Due to unstable BPMB?
2. almost no yields change from run 5842-5843, and BPMA just drift 0.02mm in x, the calibrated horizontal x jumped from -4.54mm to -1.43mm from run 5842 to 5843
The offset is a factor in the formula

\[ x_b = \frac{A_+ - A_{ped} + b_+}{A_+ - A_{ped} + b_+} + g_x \frac{A_- - A_{ped} + b_-}{A_- - A_{ped} + b_-} \]

The offset has a very big shift.

How to deal with b factor:

b got from current dependence

What if has position dependence?
• Beam jumps has two types.
• Any suggestions?