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

Last Time Pedestal Contribution to Target Uncertainty

Before decoupling correlation

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

After decouple correlation

channel		RMS *$\sqrt{2}$ /channel	x/mm	y/mm	Theta /mrad	Phi /mrad
BPMA1 –BPMA2		459.9	-0.16	0.26	0.17	-0.23
BPMA1+BPMA2		415.4	-0.01	0.03	0.01	-0.02
BPMA3 –BPMA4		1055.4	-0.33	-0.42	-0.30	-0.47
BPMA3+BPMA4		4672.2	0.13	0.17	0.11	0.19
BPMB1-BPMB2		956.1	0.41	-0.71	-0.69	0.44
BPMB1+BPMB2		890.5	0.02	-0.03	-0.03	0.02
BPMB3-BPMB4		690.2	-0.57	-0.32	-0.31	-0.59
BPMB3+BPMB4		1071.2	-0.04	-0.02	-0.02	0.01
Square of sum (Uncertainty)			0.80	0.94	0.84	0.92
Worst case square of sum (Uncertainty)			0.87	1.03	0.89	1.04

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-}

$$C_+ = A_+ * cos(45) - A_- * (sin45) * g_x$$
$$C_- = A_+ * \sin(45) + A_- * (sin45) * g_x$$

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

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

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

Used the average pedestal

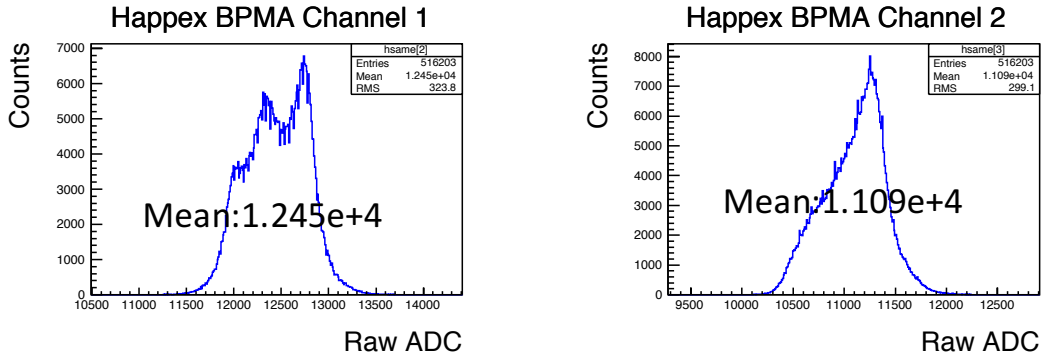
$$= \frac{(A_{x+} - A_{x-}*g_x) + b_+ - g_x*b_- + \sqrt{2}C_{x-}}{(A_{x+} - A_{x-}*g_x) + b_+ + g_x*b_- + \sqrt{2}C_{x+}}$$

x_b *will not change*

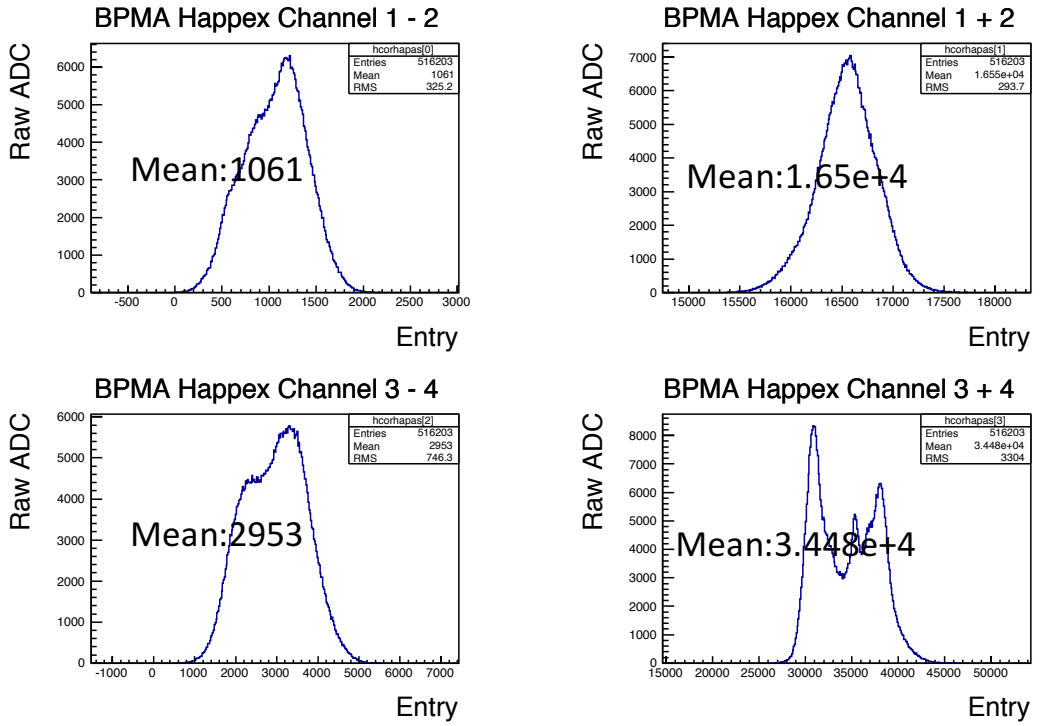
→ Use the rotation coordinates will not affect the beam position calculation, but will improve the uncertainty estimation

Expected value checked

Happex DAQ for BPMA trip Run 5898



Happex DAQ for BPMA trip-Rotated Run 5898



Check: $for\ bpma\ channel\ 1\ and\ 2$

Before rotation: $\overline{A_1} = 1.245e+4$, $\overline{A_2} = 1.1.09e+4$

After Rotation: $\overline{C_-}$ =1061, $\overline{C_+}$ =1.65e+4

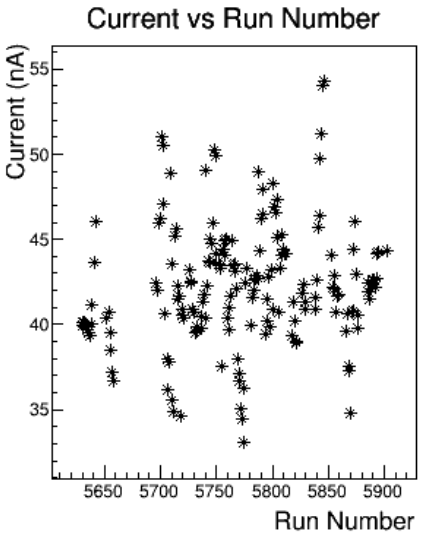
Gx=0.987

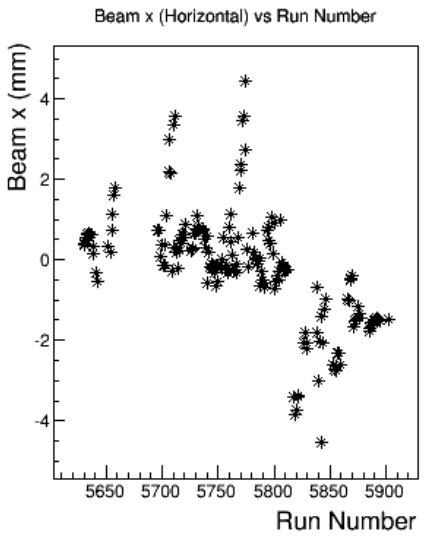
$$\overline{C_-} = \overline{A_1} * \cos(45) - \overline{A_2} * \sin(45) * g_x ??$$

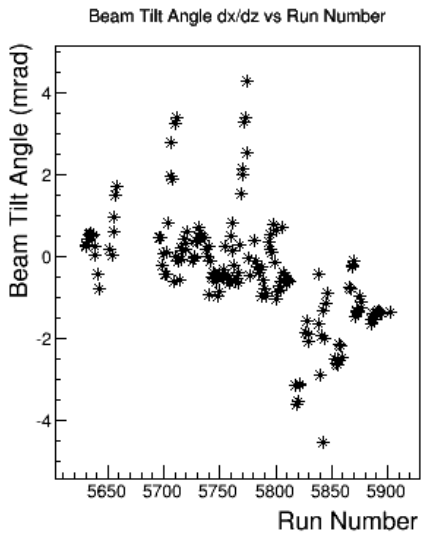
$$\overline{C_+} = \overline{A_1} * \cos(45) + \overline{A_2} * \sin(45) * g_x ??$$

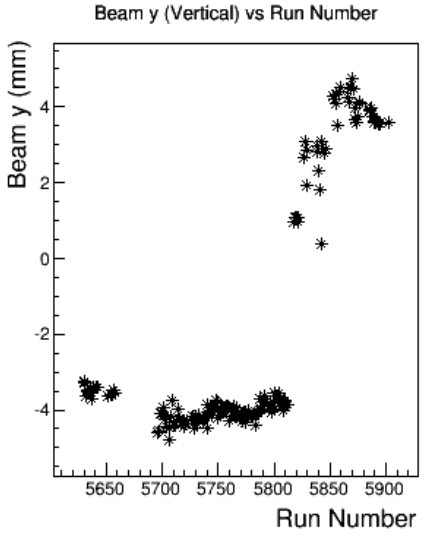
Recall Beam Position Issue

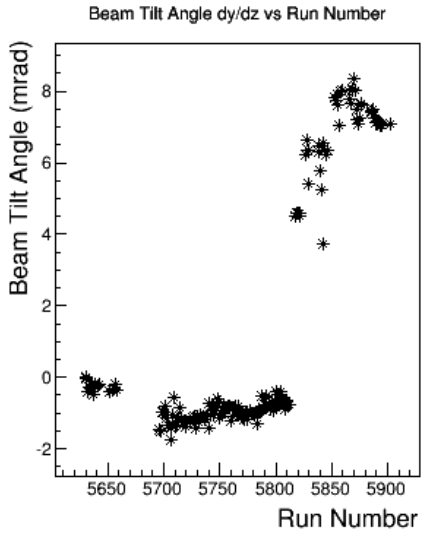
Energy 2254 GeV -- beam information versus Run Number











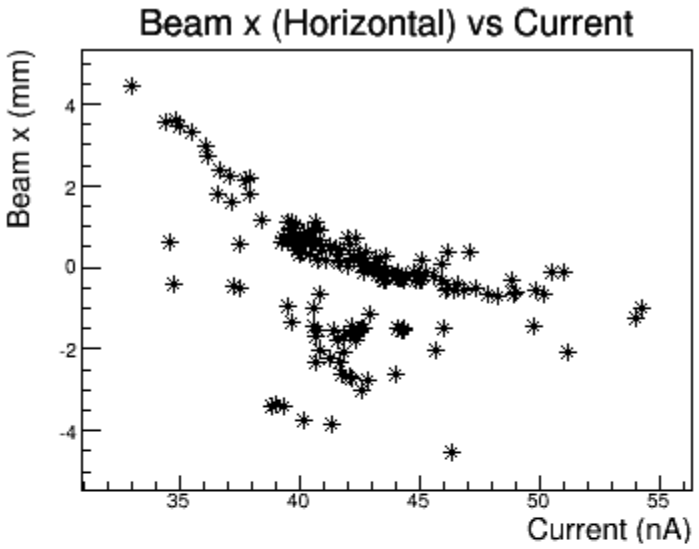
Use Pengjia's database

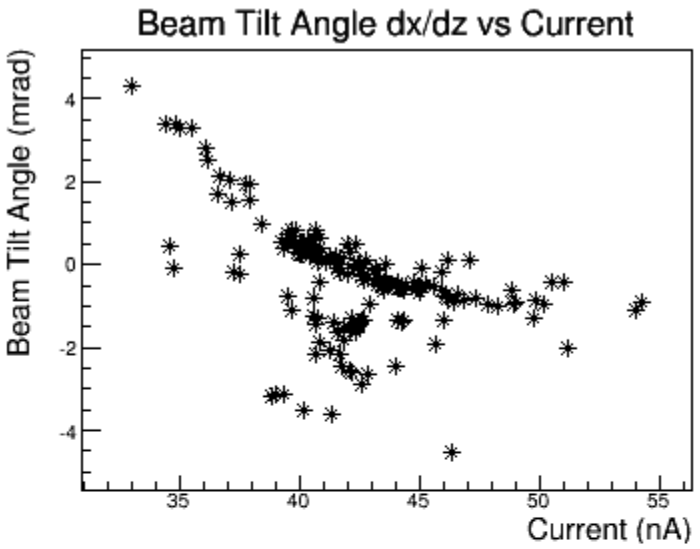
Two issues to check

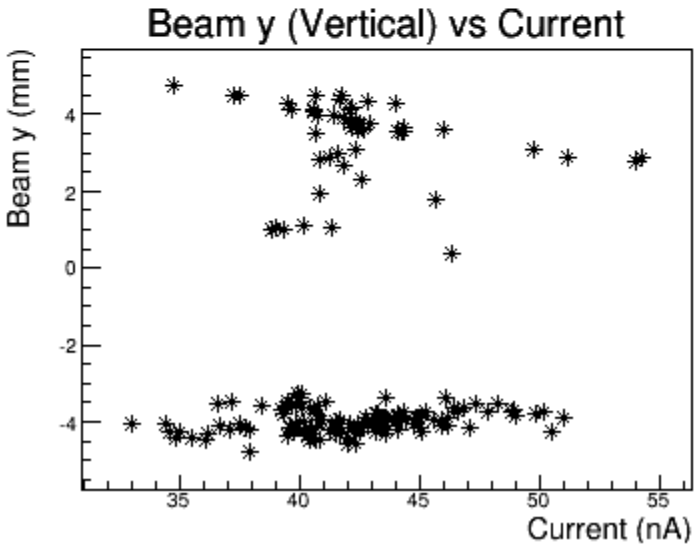
- Current dependence
- Suddenly jumps

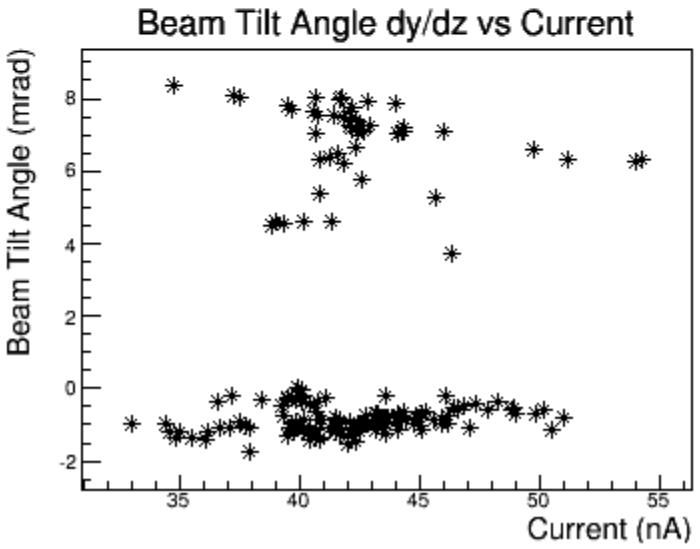
Recall Beam Position Issue

Energy 2254 GeV -- beam information versus Current









Use Pengjia's database

Two issues to check

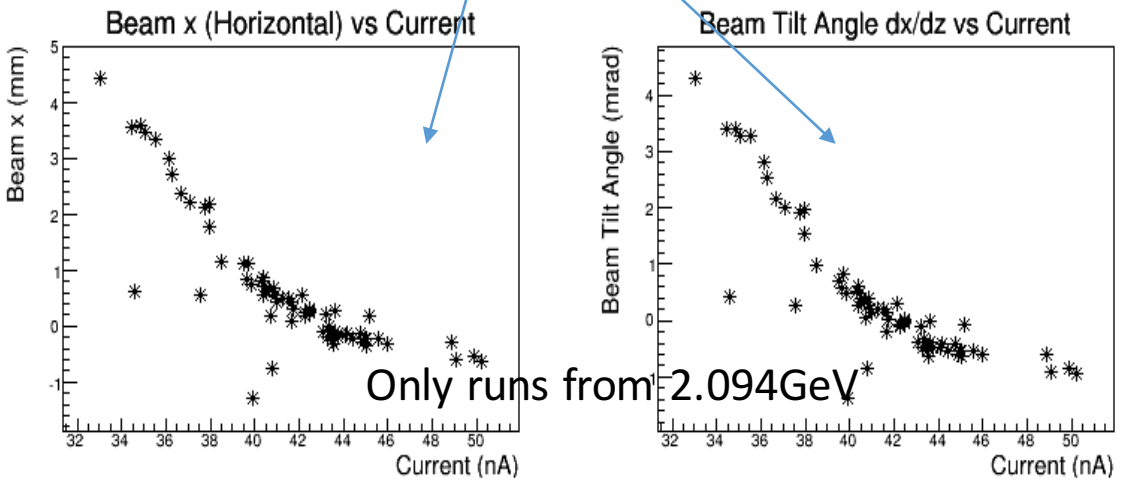
- Current dependence
- Suddenly jumps

Ebeam=2.2GeV, momentum 2.049GeV, Longitudinal 5T
new database after remove current dependence

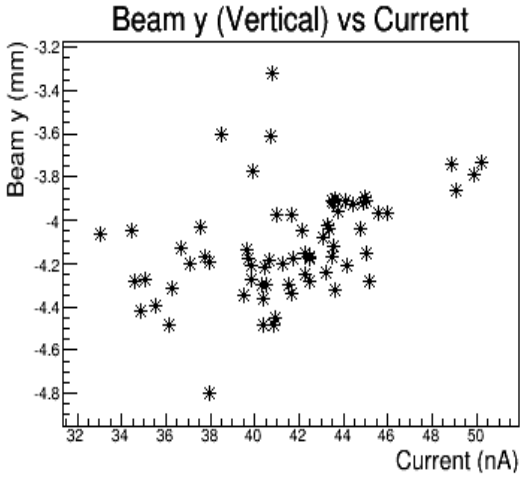
choose the runs without yields to correct

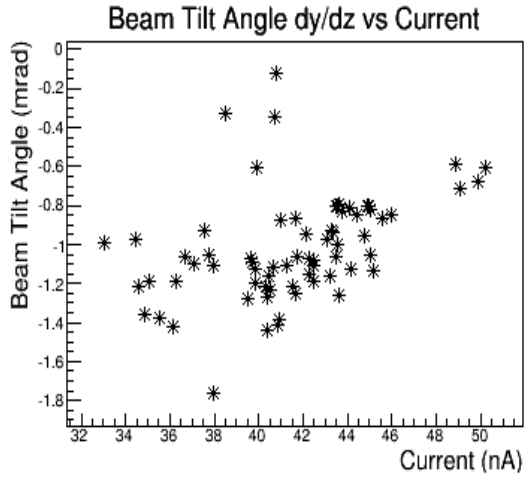
Each mark stands for one run in the plot

Using the old database

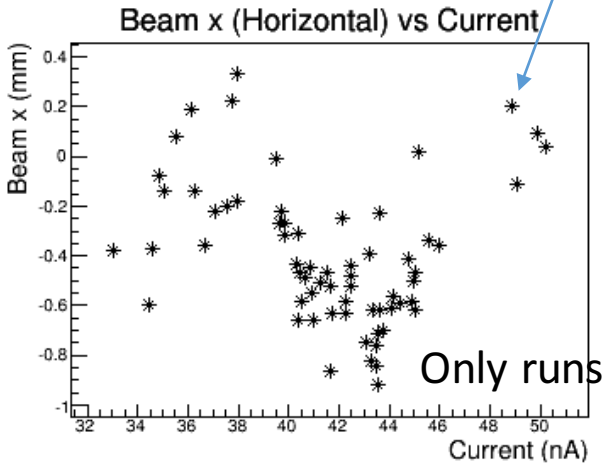


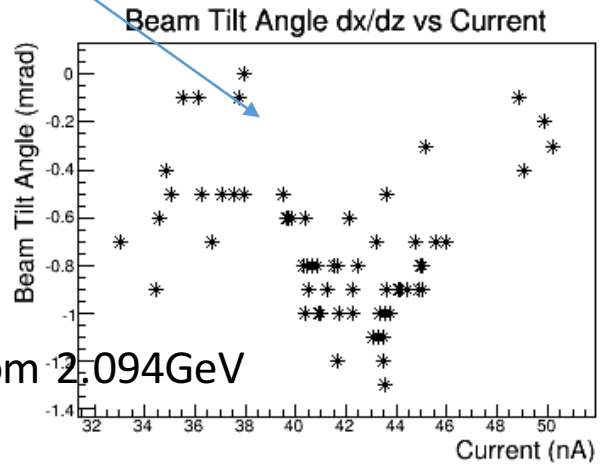
Only runs from 2.094GeV





Using the new database





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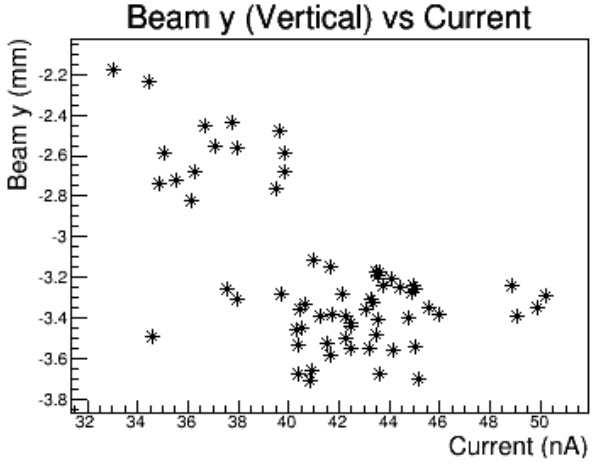
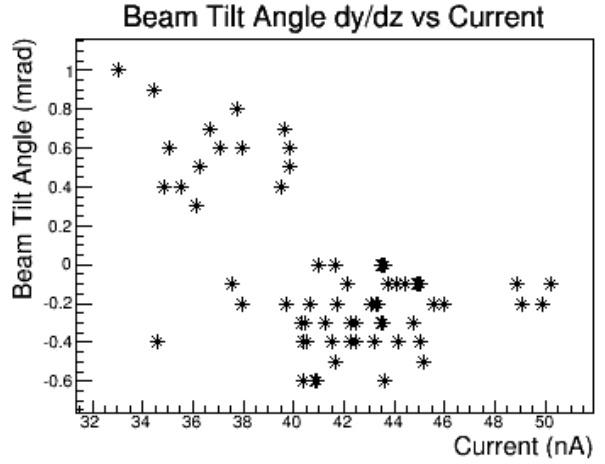
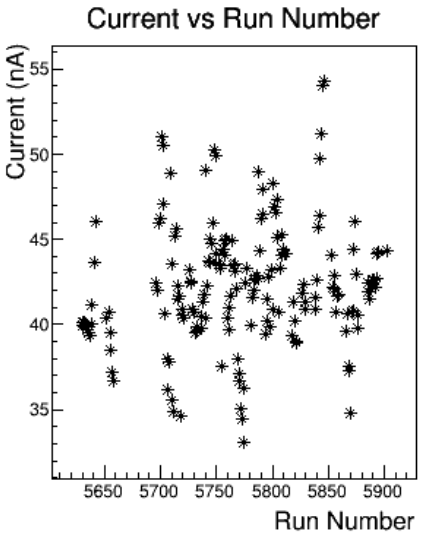
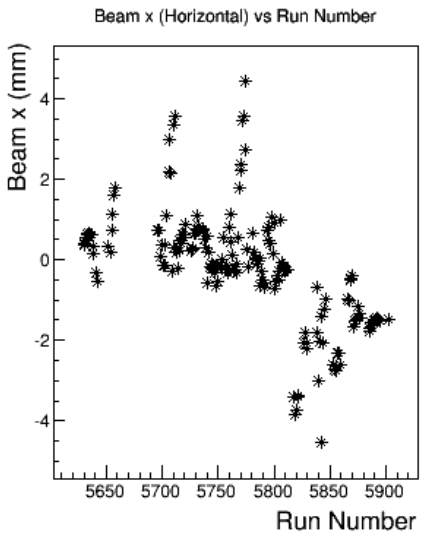


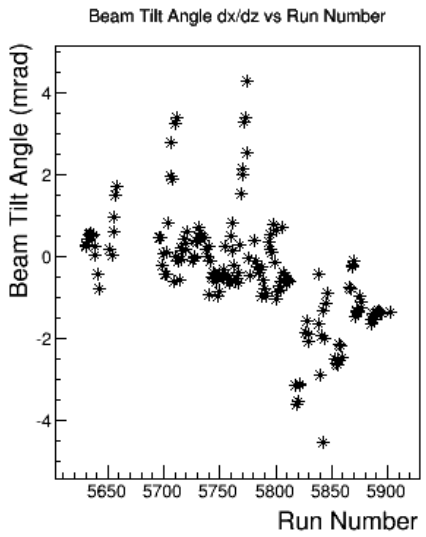


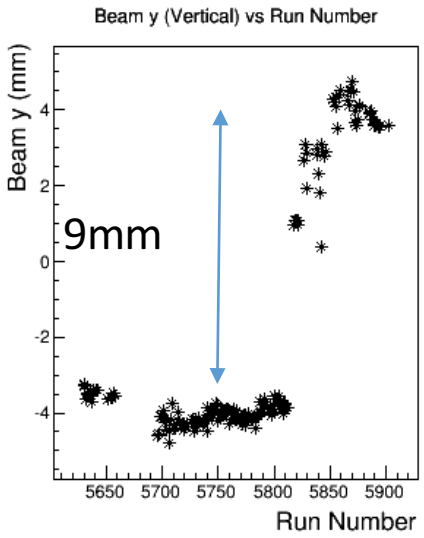
Recall Beam Position Issue

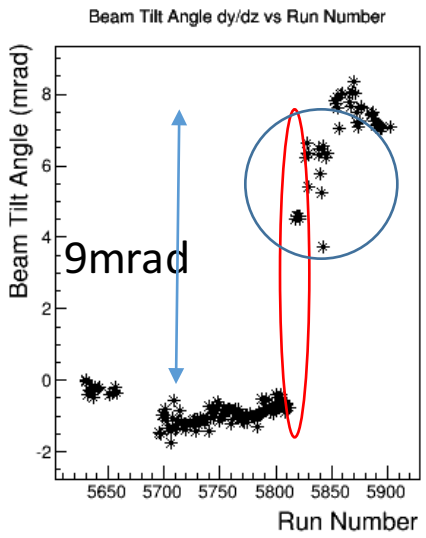
Energy 2254 GeV -- beam information versus Run Number











Use Pengjia's database

How to deal with beam jumps here:

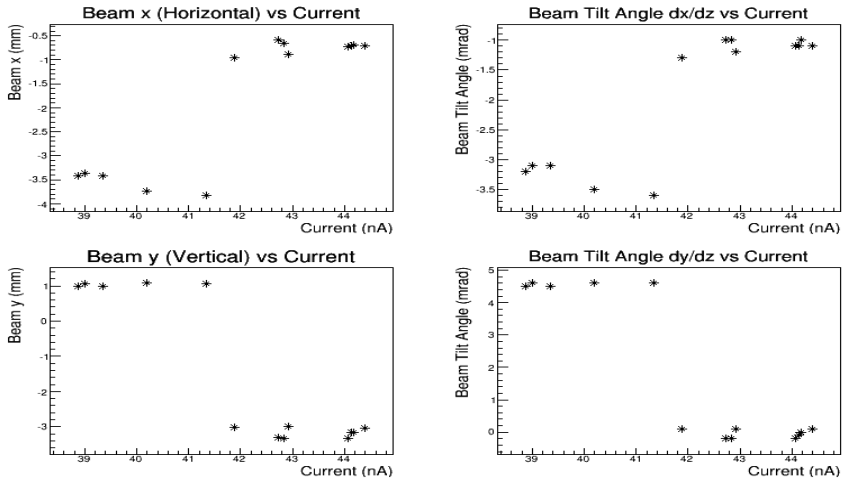
Two types of beam position jumps

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%

Ebeam=2.2GeV, momentum 1.886GeV, Longitudinal 5T – 1st type jump

run	materialID	Momentum	current/nA	yield(use 6mm Raster cut)	BPMA x (mm)	BPMA y (mm)	BPMB x (mm)	BPMB y (mm)	Horizontal tg_x (mm)	tg_phi=dx/dz (mrad)	Vertical tg_y (mm)	tg_theta =dy/dz (mrad)
5809	17	1.8857	44.07	1	-1.37	-2.35	-1.21	-2.65	-0.72	-1.05	-3.34	-0.22
5810	17	1.8857	44.39	1.005	-1.35	-2.34	-1.16	-2.58	-0.71	-1.06	-3.05	0.07
5811	17	1.8857	44.12	1.003	-1.35	-2.34	-1.17	-2.61	-0.71	-1.05	-3.16	-0.06
5812	17	1.8857	44.17	1.001	-1.35	-2.34	-1.17	-2.61	-0.7	-1.05	-3.16	-0.05
5813	17	1.8857	42.92	0.997	-1.34	-2.35	-1.17	-2.54	-0.88	-1.25	-3	-1.25
5814	17	1.8857	41.89	1.01	-1.36	-2.35	-1.21	-2.54	-0.95	-1.3	-3.02	-1.3
5815	17	1.8857	42.84	1.005	-1.38	-2.36	-1.2	-2.67	-0.65	-0.98	-3.33	-0.98
5816	17	1.8857	42.72	1.004	-1.35	-2.37	-1.16	-2.68	-0.59	-0.95	-3.32	-0.95
5818	17	1.8857	39.35	1.002	-2.02	-2.02	-1.7	-1.11	-3.41	-3.14	0.98	4.53
5819	17	1.8857	41.33	1.006	-2	-2.02	-1.77	-1.02	-3.83	-3.6	1.07	4.6
5820	17	1.8857	40.19	1.005	-1.98	-2.02	-1.74	-1.03	-3.74	-3.51	1.08	4.6
5821	17	1.8857	39	1.021	-1.99	-2.01	-1.66	-1.09	-3.36	-3.11	1.07	4.6
5822	17	1.8857	38.88	1.006	-2.01	-2.02	-1.69	-1.11	-3.41	-3.15	0.98	4.51



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

run	materialID	Momentum	current/nA	yield(use 6mm Raster cut)	BPMA x (mm)	BPMA y (mm)	BPMB x (mm)	BPMB y (mm)	Horizontal tg_x (mm)	tg_phi=dx/dz (mrad)	Vertical tg_y (mm)	tg_theta =dy/dz (mrad)
5838	17	1.4684	40.88	1	-1.85	-2.03	-0.67	-1.08	-0.67	-0.42	2.8	6.31
5839	17	1.4684	41.61	0.992	-1.82	-2.04	-0.89	-0.87	-1.81	-1.63	2.97	6.48
5840	17	1.4684	42.59	0.993	-1.82	-2.03	-1.26	-0.84	-3	-2.87	2.32	5.78
5841	17	1.4684	45.7	0.977	-1.78	-2.06	-1.08	-1.12	-2.02	-1.9	1.8	5.24
5842	17	1.4684	46.39	0.973	-1.78	-2.06	-1.88	-1.08	-4.54	-4.54	0.37	3.74
5843	17	1.4684	49.78	0.966	-1.76	-2.06	-0.73	-0.9	-1.43	-1.3	3.09	6.57
5844	17	1.4684	51.21	0.969	-1.73	-2.07	-0.89	-0.86	-2.07	-2	2.88	6.34
5845	17	1.4684	54.02	0.969	-1.73	-2.08	-0.71	-1.02	-1.23	-1.12	2.79	6.25
5846	17	1.4684	54.27	0.985	-1.71	-2.09	-0.62	-1.03	-0.99	-0.89	2.88	6.33
5850	17	1.4684	45.98	0.973	-1.79	-2.05	-0.78	-0.79	-1.71	-1.56	3.37	6.87
5851	17	1.4684	43.05	0.983	-1.8	-2.02	-0.74	-0.63	-1.85	-1.68	3.91	7.42

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

BPMB Database

BPMB Database for run 5776-5816

```
avail run period:5690-5705,5709-5710,5713-5730,5734-5736,5738-5768,5776-5816
avail curr(nA):42
target z position(mm,support multi):-14.135 0 14.135 -10.81 -13.6271
pedestal peak:9932.568435 27050.689090 37947.382798 12518.264860
offset:-7001.92140914 -11182.52819187 -19240.20734696 -7534.04559374
bpmb ar,gx,gy:34.924999999999997 0.846000000000000 1.094000000000000
fitorder:1 1
bpmb x a,b,c:1.7669720580957626 0.969356883774036 0.012141489078902175
bpmb y a,b,c:-1.7711933198053358 1.082135970322633 -0.07618325031862734
fval:0.7345050 1.0104276
bpmb x err:0.2 0.019434 0.022899
bpmb y err:0.2 0.021511 0.025433
```

BPMB Database for run 5817-5920

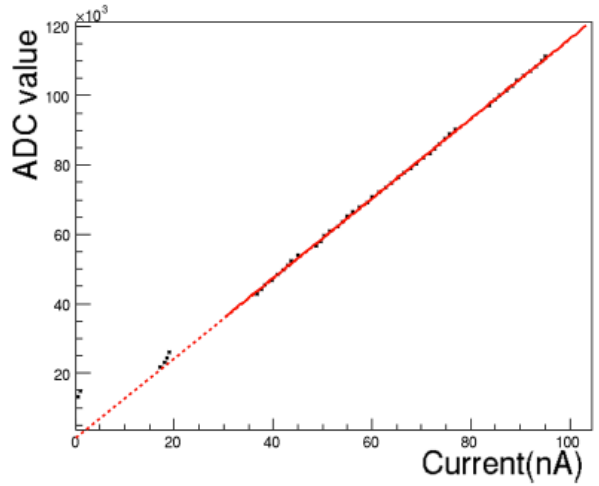
```
avail run period:5817-6218
avail curr(nA):88 50
target z position(mm,support multi):-14.135 0 14.135 -10.81 -13.6271 -12.5476
pedestal peak:9932.455078 26819.394531 37714.996094 12536.925781
offset:-12325 -15779 -10565 -7666
bpmb ar,gx,gy:34.924999999999997 0.826000000000000 1.094000000000000
fitorder:1 1
bpmb x a,b,c:0.033272652288621 1.096324079373919 0.029047078500277
bpmb y a,b,c:0.048720993507263 1.202920412827341 -0.078819129281960
fval:0.0739224 0.0863825
bpmb x err:0.130851 0.019434 0.022899
bpmb y err:0.146220 0.021511 0.025433
```

The offset is b factor in the formula

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

The offset has a very big shift

How to deal with b factor:
b got from current dependence



ADC value of BPM raw signal $(A - A_{ped})$ V.S. beam current

what if has position dependence?

- Beam jumps has two types.
- Any suggestions?