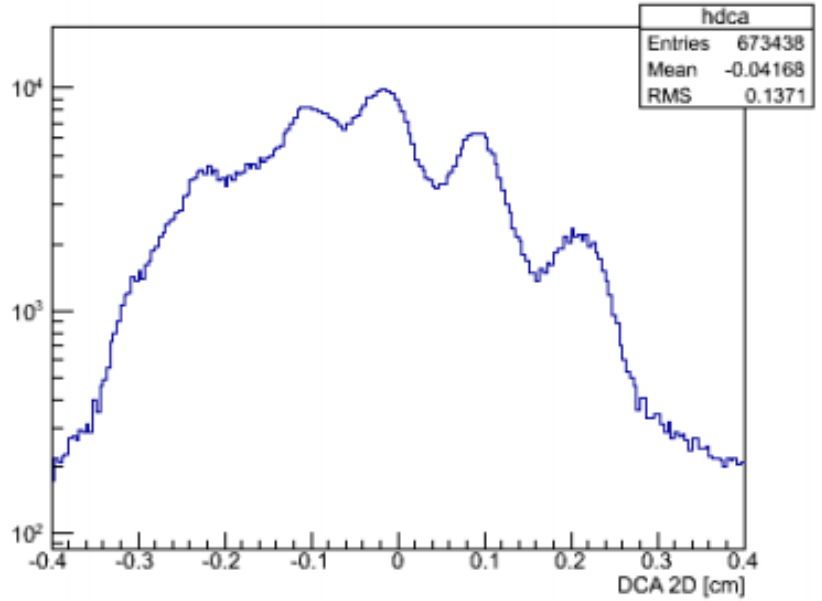
Alignment of the PHENIX Silicon Vertex Tracker (VTX) in 2014

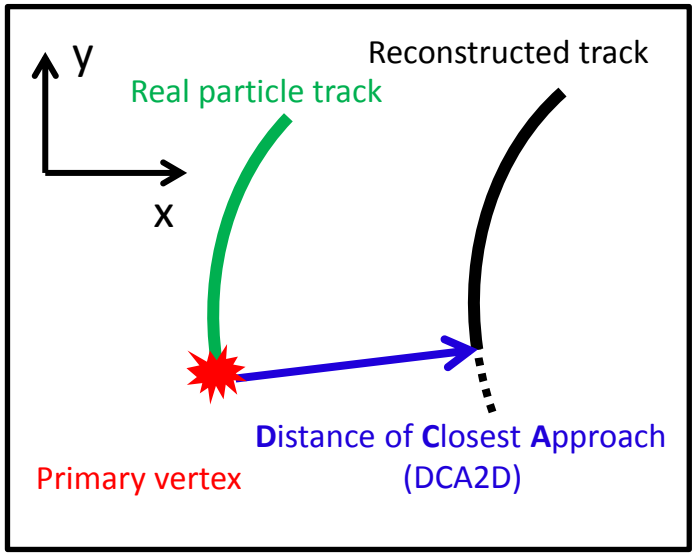
Yasuyuki Akiba
Takashi Hachiya
Hidemitsu Asano
Taebong Moon

Yonsei Univ./RIKEN
Nov. 27th 2014

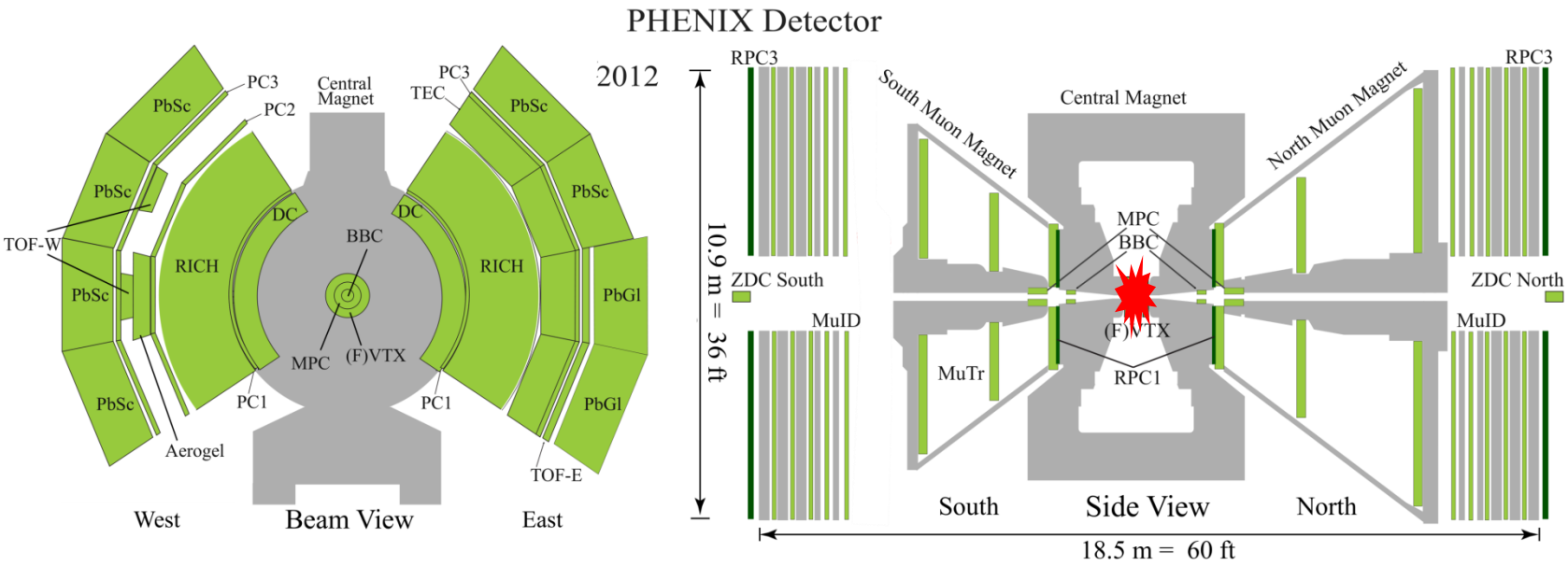
Motivation of the alignment

- Alignment:
  - Equalizing the expected detector position to the installed position.
- Mis-alignment:
  - will degrade quality of measurement.
    - ex) **DCA**, pT, invariant mass, primary vertex and etc..
  - can lead to ineffective/wrong physical conclusion.





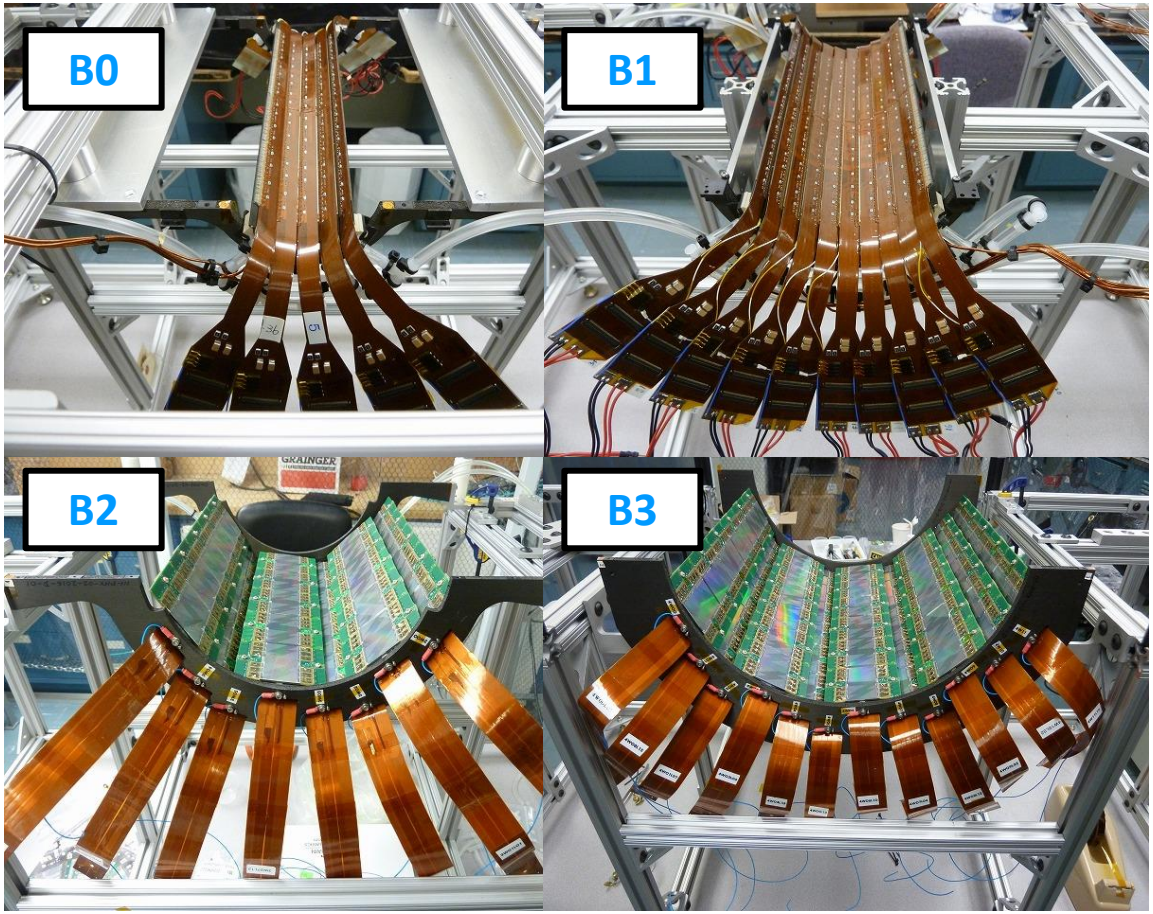
PHENIX detector

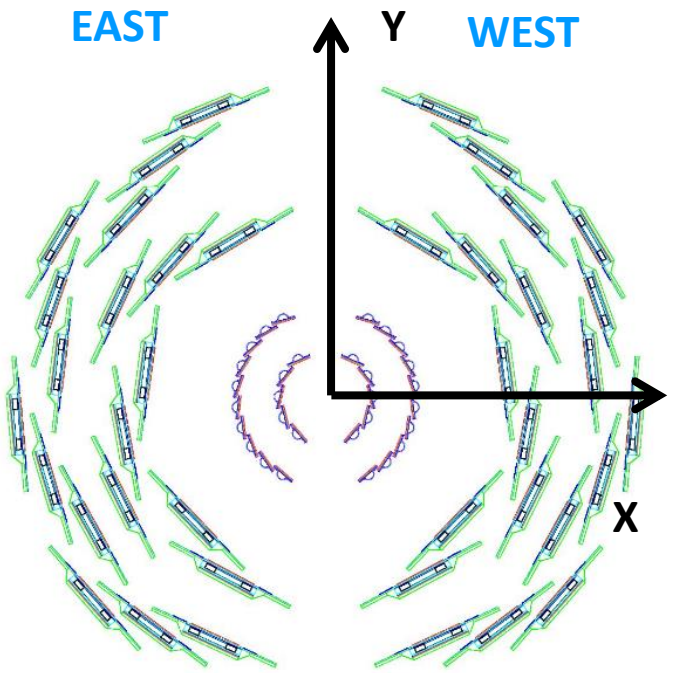


- **Silicon Vertex Tracker (VTX)**
  - Primary/secondary vertex
  - Global/standalone tracking
  - DCA measurement

- **Drift Chamber (DC)**
  - Charged paritcle tracking
  - Momentum measurement
  - $|\eta| < 0.35 \quad \Delta\phi = \pi/2$

Silicon Vertex Tracker (VTX)





$|\eta| < 1.2$ $\Delta\phi \sim 2\pi$

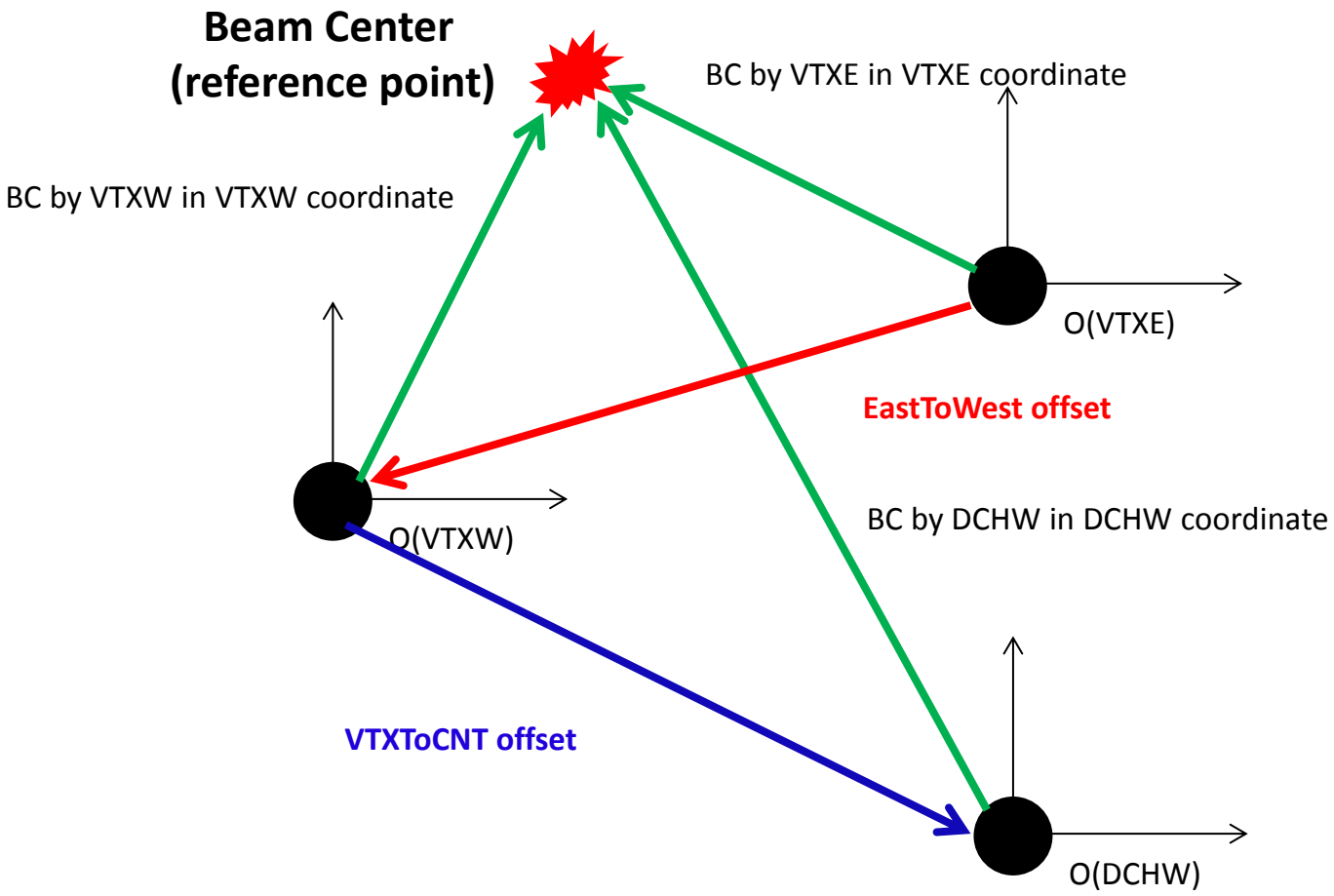
Layer	Kind	R (cm)	Z (cm)	RO Channel	# Ladders
0	Pixel	2.5	±10	1,310,720	10
1	Pixel	5	±10	2,671,440	20
2	Strip-pixel	11.7	±16	122,880	16
3	Strip-pixel	16.6	±19	221,184	24

Alignment procedure

- Offset calibration
  - VTX and DCH of both west and east have their own coordiante systems.
  - The origins of the detector don’t coinside with each other.
  - Should take account of the relative positions first.

- VTX ladder by ladder alignment
  - The expected location of the ladders is different from the installed location.
  - Should equalize them.

Offset calibration using field-off run



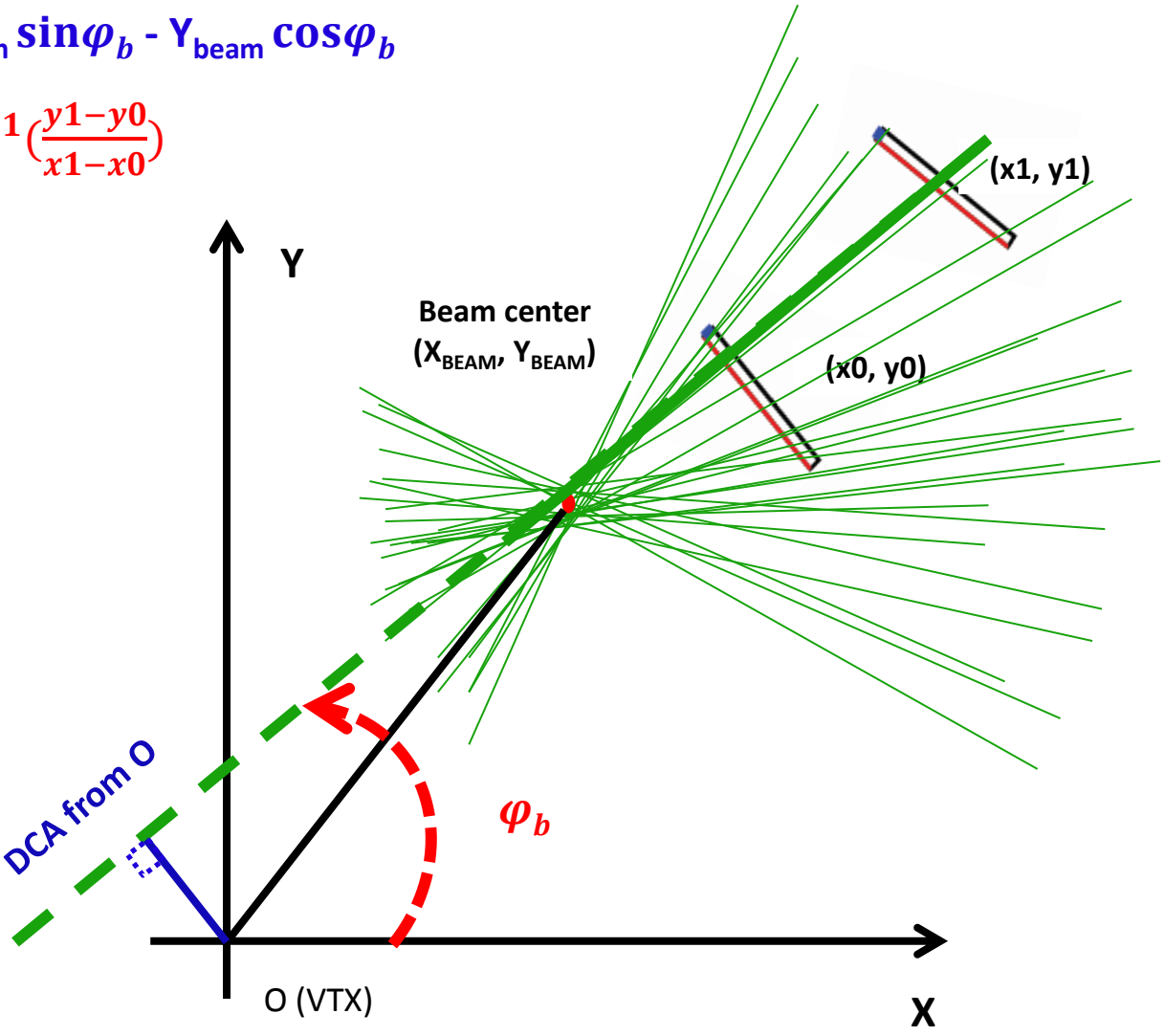
Relative positions can be calculated if we know <u>BCs in their own internal coordinates</u>.

Beam center in the VTX

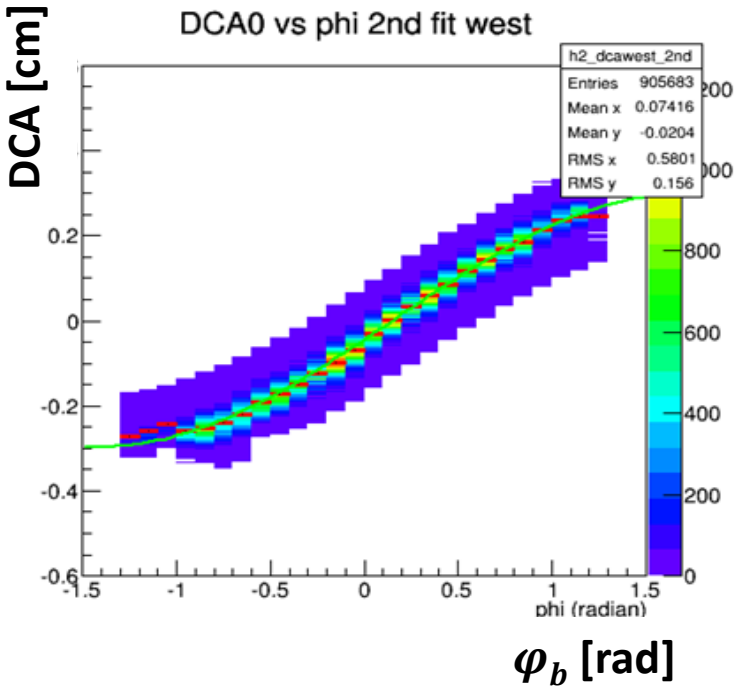
- BC in the VTX can be represented by the following formula.

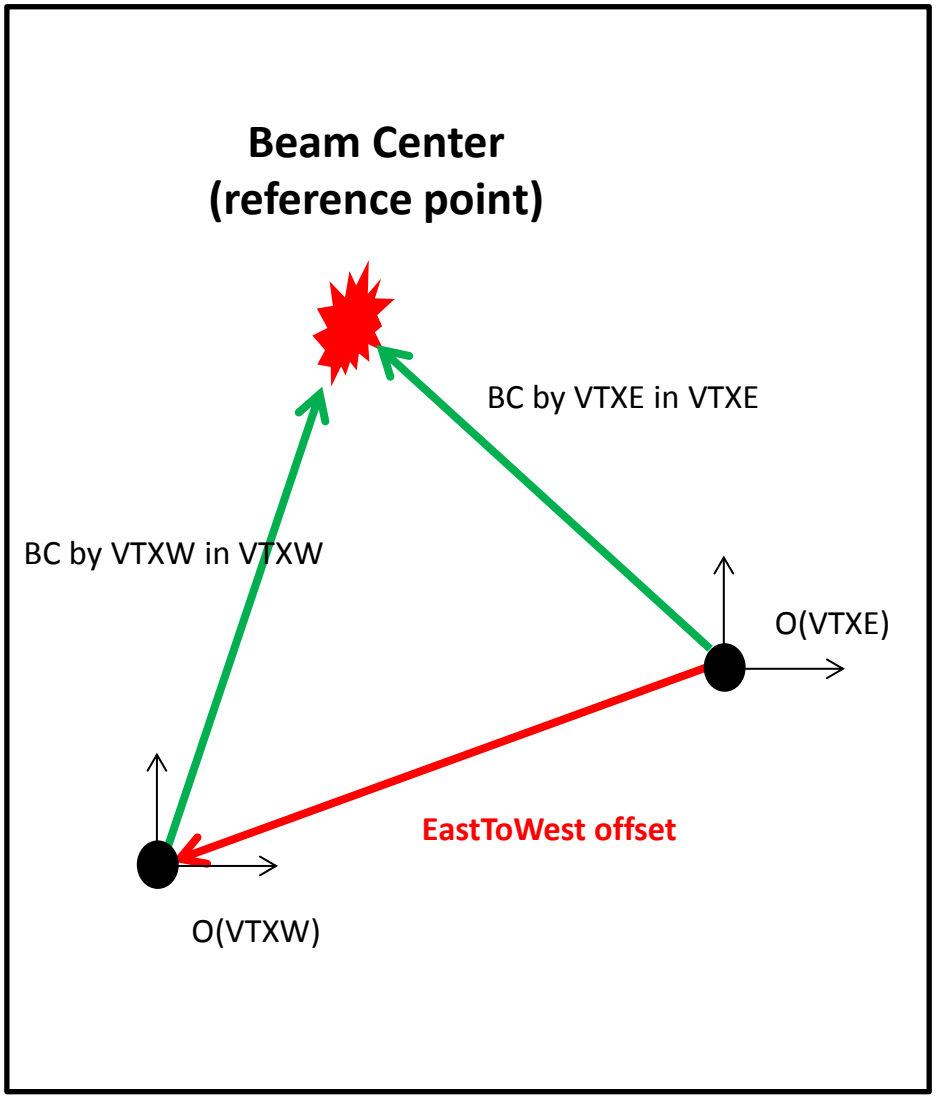
- $\mathbf{DCA = X_{beam} \sin\varphi_b - Y_{beam} \cos\varphi_b}$

- $\varphi_b = tan^{-1}\left(\frac{y1-y0}{x1-x0}\right)$



Beam center in the VTX





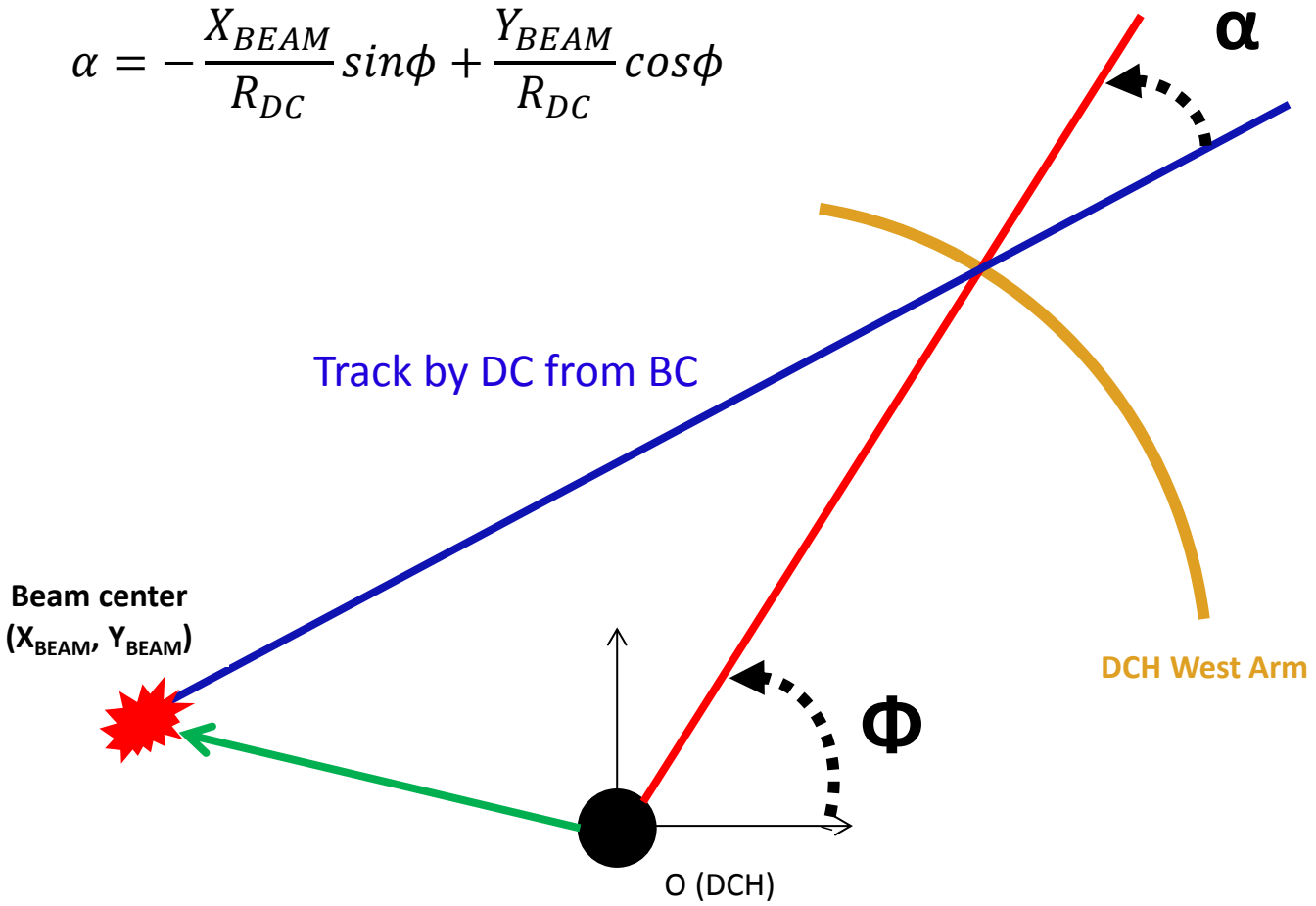
Fit using the following formula.

- DCA = P1 * $\sin\varphi_b$ + P2 * $\cos\varphi_b$
- P1 = X_{BEAM} = 0.293613 cm
- P2 = -Y_{BEAM} = 0.047278 cm

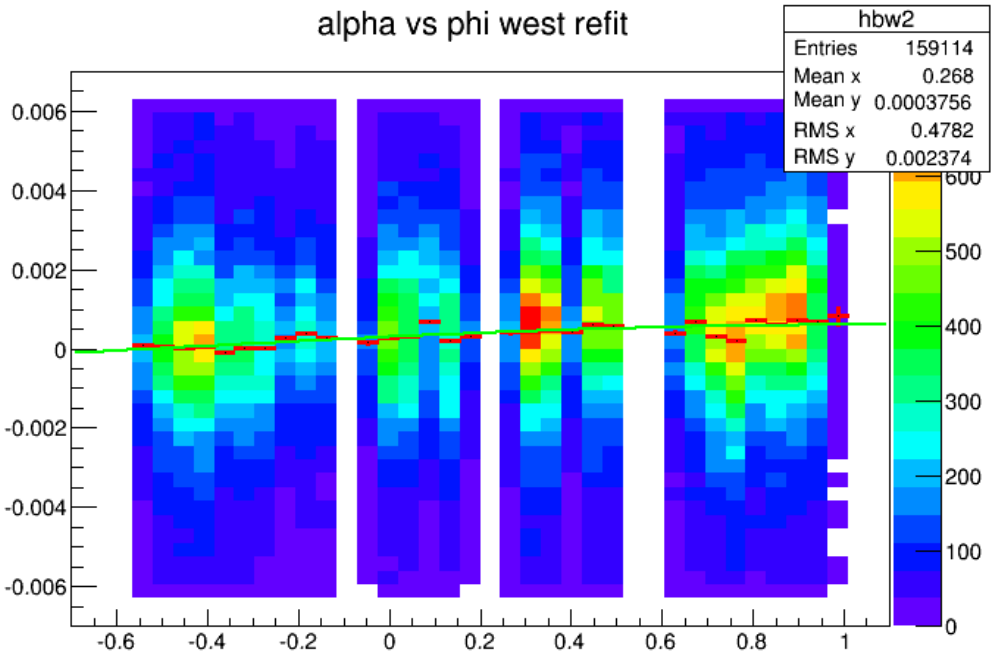
Beam center by DCH

- Due to offset btw beam center and the origin of DC, α is not 0 and represented by following formula.

$$\alpha = -\frac{X_{BEAM}}{R_{DC}} sin\phi + \frac{Y_{BEAM}}{R_{DC}} cos\phi$$

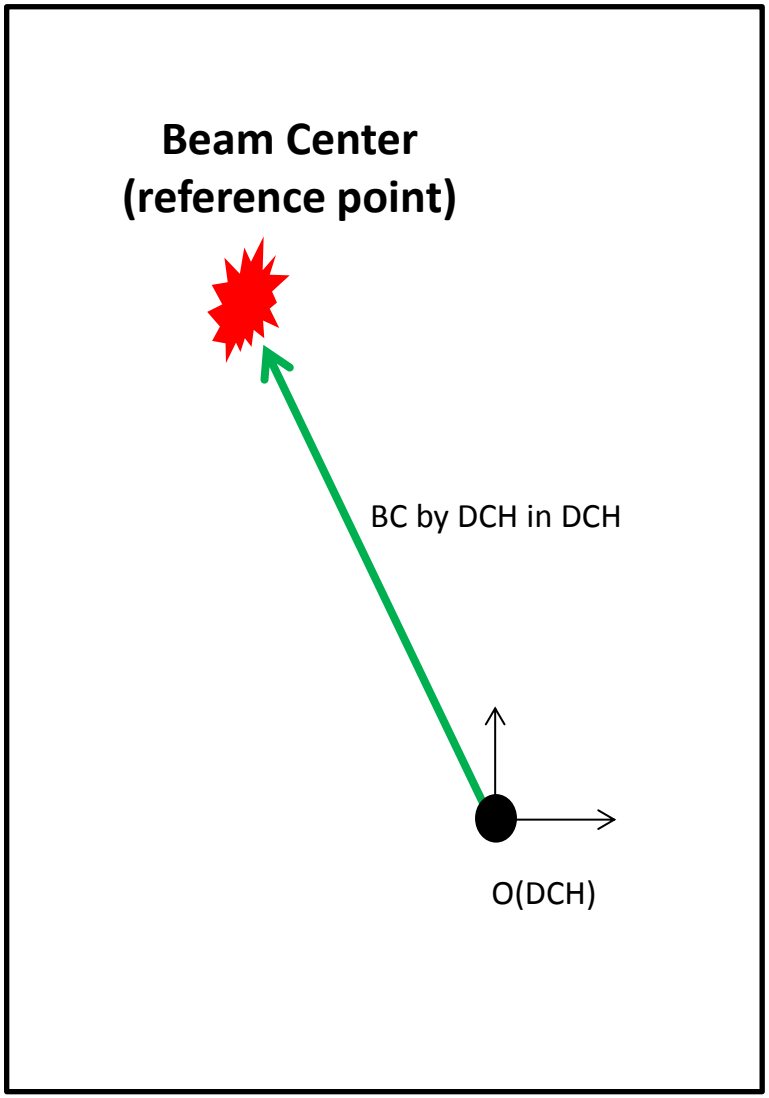


Beam center in the DCH

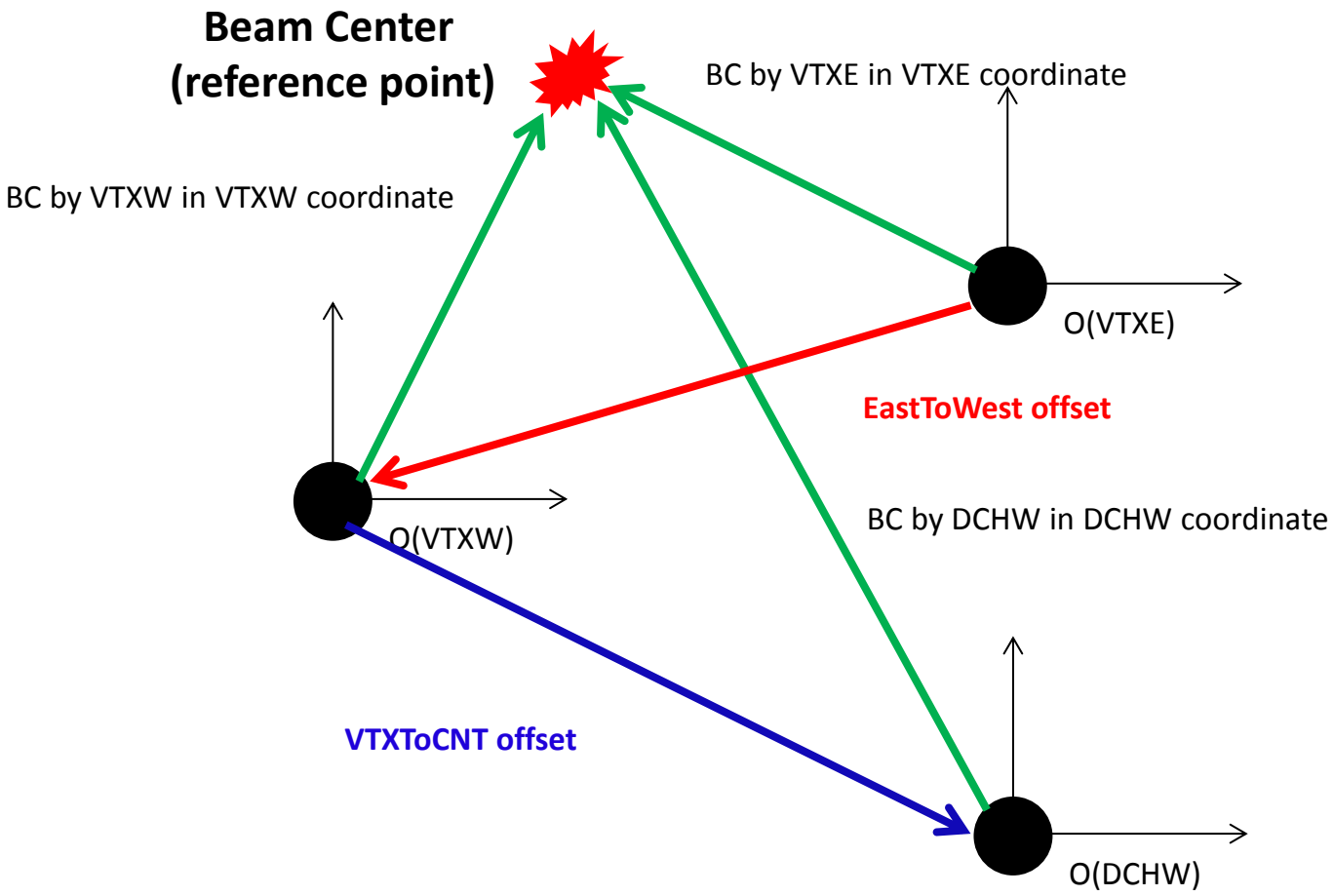


$$X_{BEAM} = -0.115619cm$$

$$Y_{BEAM} = 0.0641195cm$$



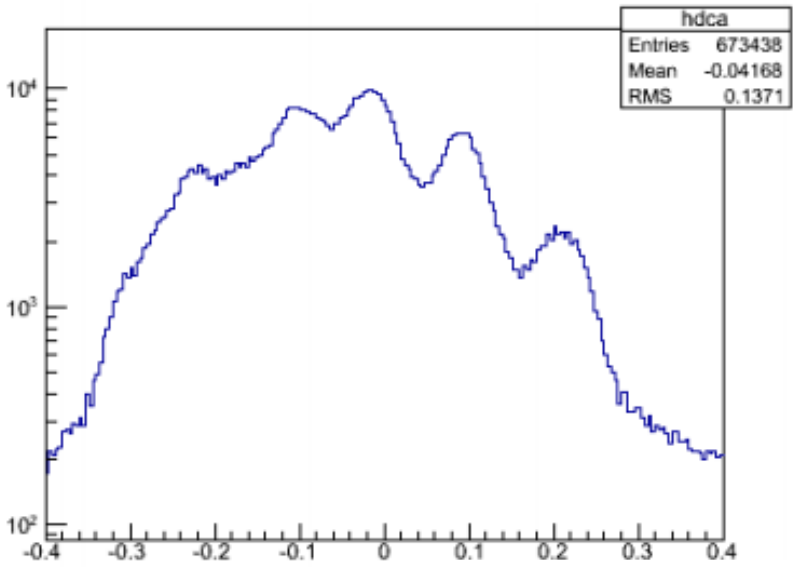
Offset calibration using field-off run



Relative positions can be calculated if we know BCs in their own internal coordinates.

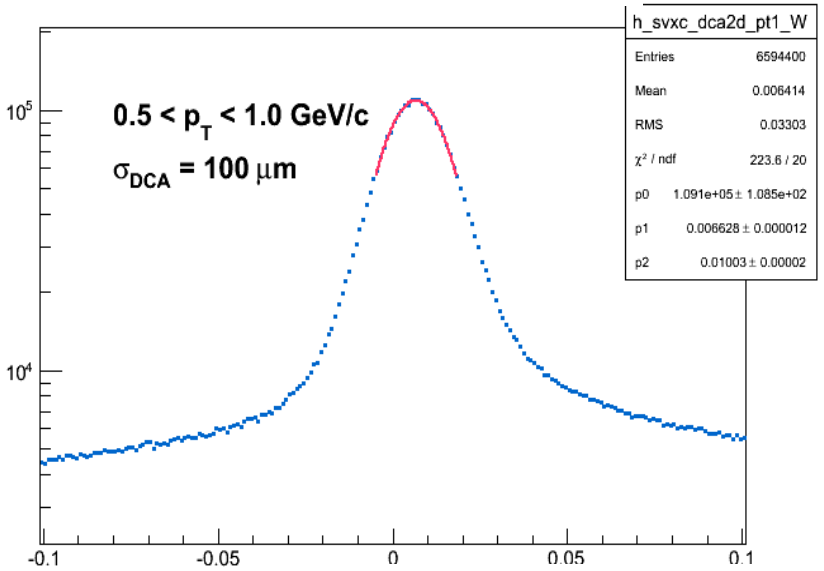
After offset calibration using field-off and -on run

Before offset calib



DCA in X-Y plane (cm)

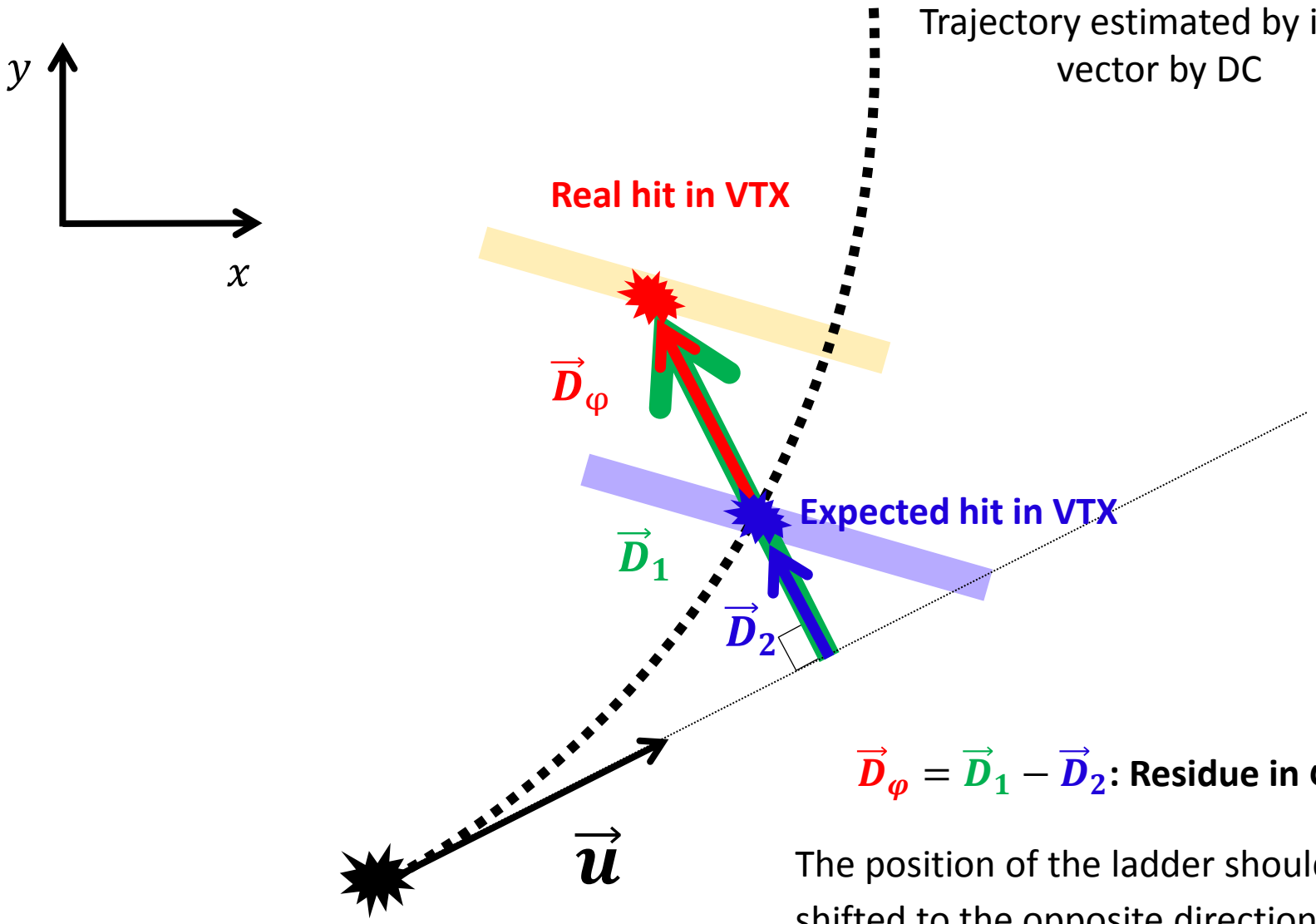
After offset calib



DCA in X-Y plane (cm)

- DCA in X-Y plane became a Gaussian distributin after offset calib.
- The problem still exists.
  - The mean of Gaussian is shifted to the right.
  - A poor DCA resolution.
- VTX ladder by ladder alignment is requred.

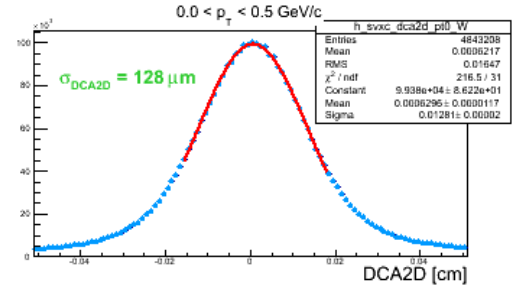
Alignment in φ (ladder by ladder)

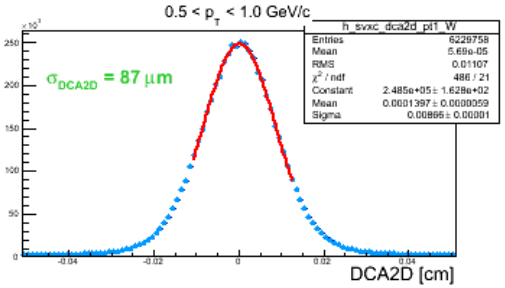


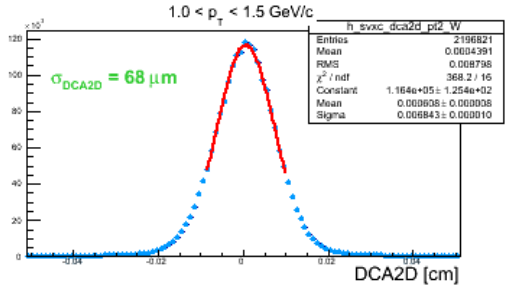
$\vec{D}_\varphi = \vec{D}_1 - \vec{D}_2$: **Residue in φ.**

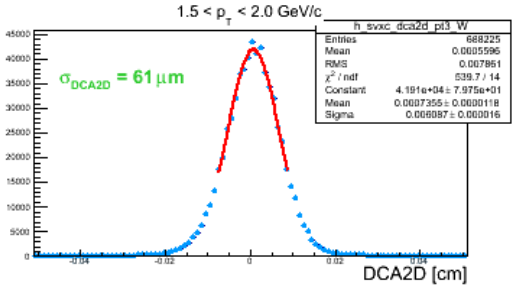
The position of the ladder should be shifted to the opposite direction by $\vec{D}_\varphi$

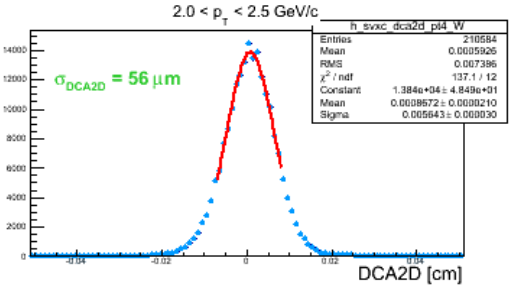
DCA in X-Y plane

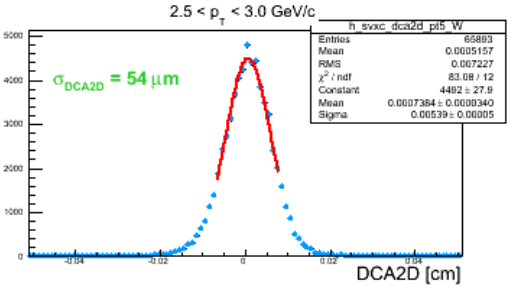


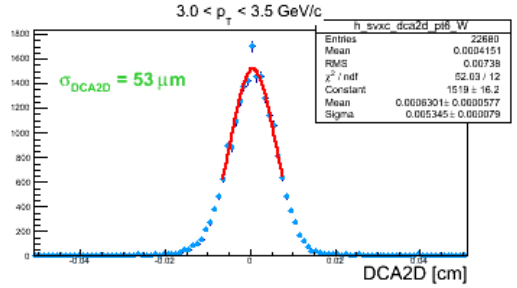


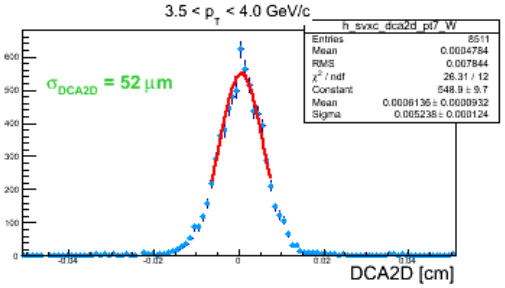


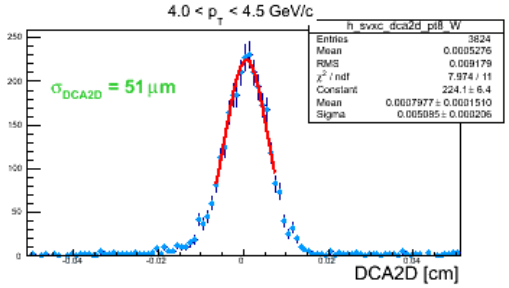




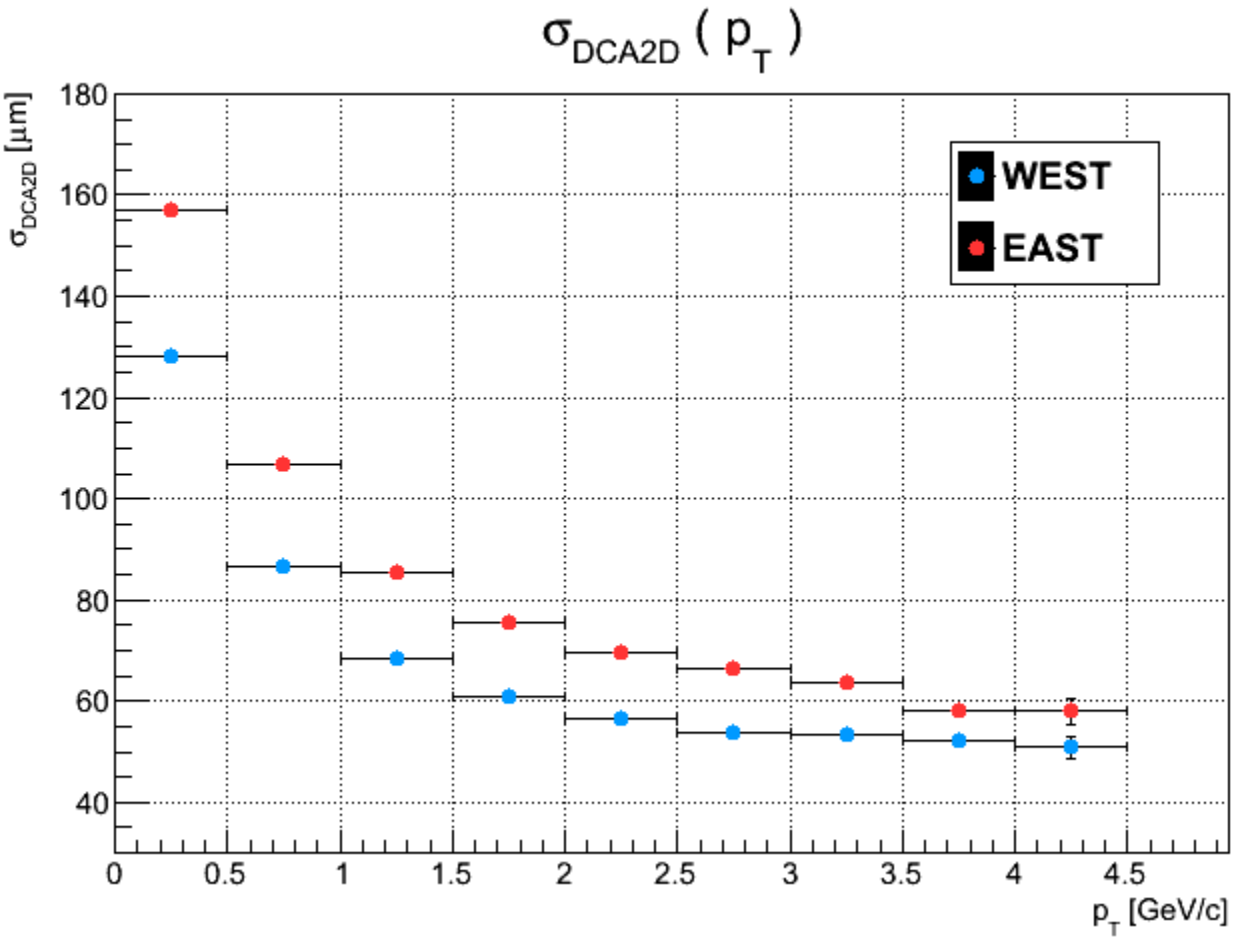








DCA resolution in X-Y plane



DCA resolution becomes better as pT increased.

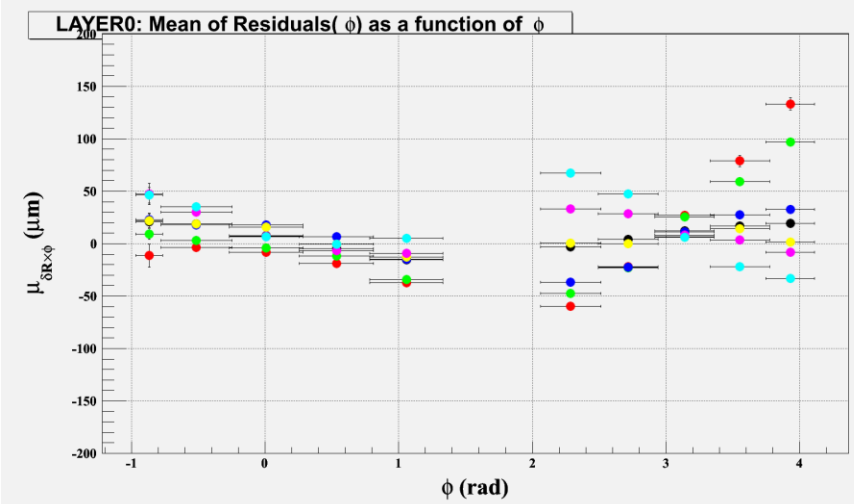
History for run 14 ^{3}HeAu 200GeV

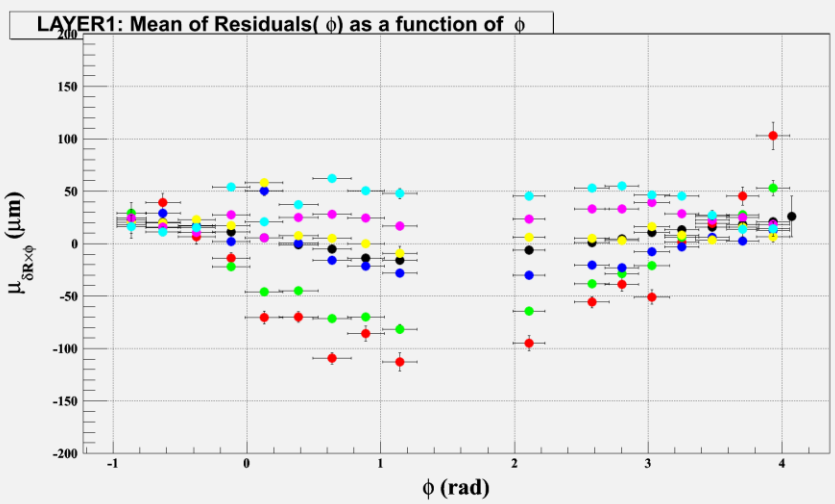
First run 415370	2014-06-19 20:20:26	**June 19th: Run14 3HeAu run started**
DCH Period 1		
Last run 415498	2014-06-21 7:27:39	**No Calibration due to missing DCH**
First run 415550	2014-06-21 20:53:28	**June 21st: East and West carriage moved**
DCH Period 2		**415835** and **416230** used for zero field and physics run respectively
Last run 416238	2014-06-30 2:59:42	
First run 416361	2014-06-30 22:39:59	**June 30th: West carriage moved**
DCH Period 3		**416379** and **416381** used for zero field and physics run respectively
Last run 416382	2014-07-01 11:43:08	
First run 416429	2014-07-01 20:00:27	**July 1st: West carriage moved**
DCH Period 4		**416442** and **416742** used for zero field and physics run respectively
Last run 416893	2014-07-06 5:37:51	

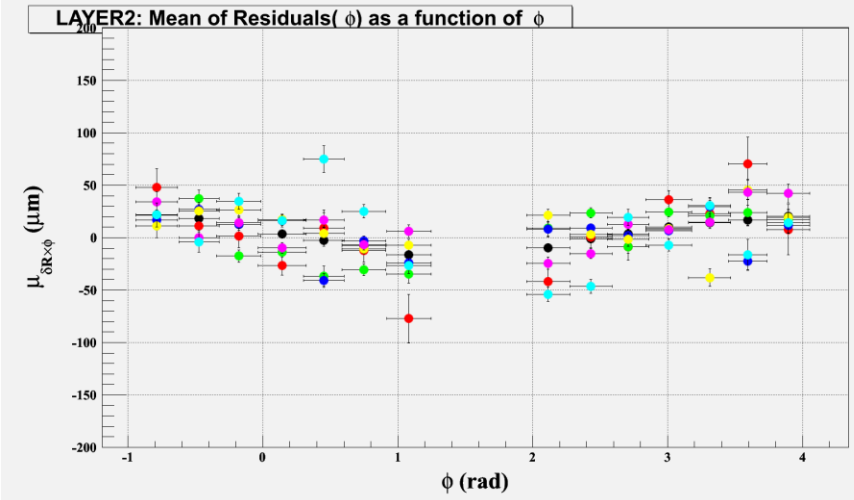
DCH moving

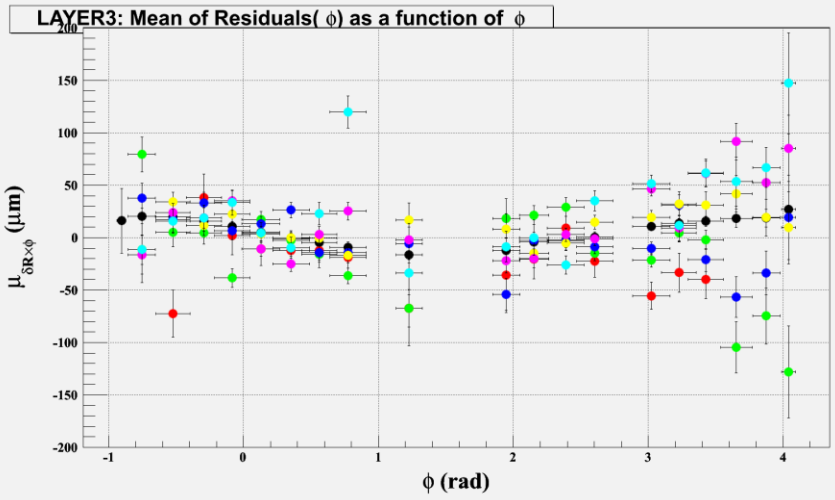
VTX moving

Further study









Black: no primz cut **Red: primz < -8** **Green: -8 < primz < -4** **Blue: -4 < primz < 0**

Yellow: 0 < primz < 4 **Pink: 4< primz < 8** **Bright blue: primz > 8**

/direct/phenix+user06/phnxreco/Takashi_VTX_LbyL/tmoon/dsts/5.Akiba/2.p2Out/macros

Summary

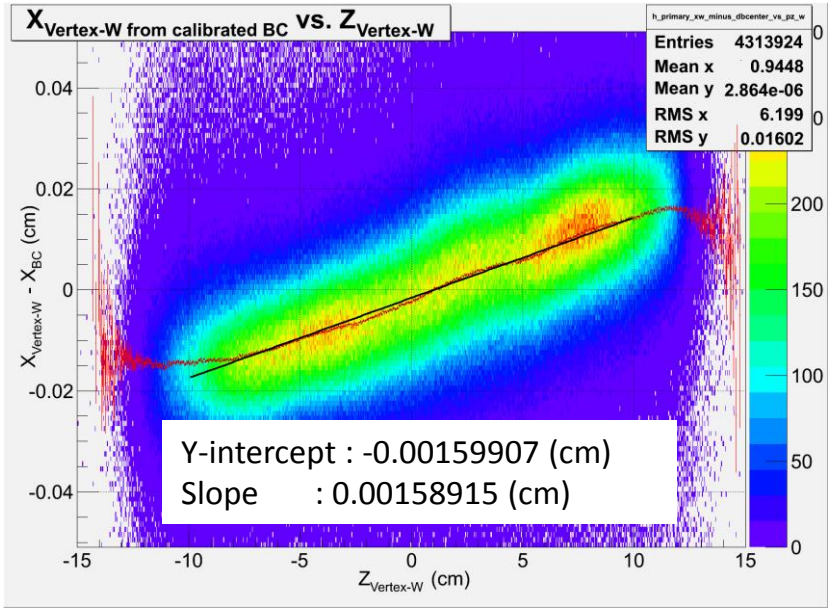
- Alignment finished and we chieved a good DCA resolution less than 70 micron when pT is 1GeV/c.

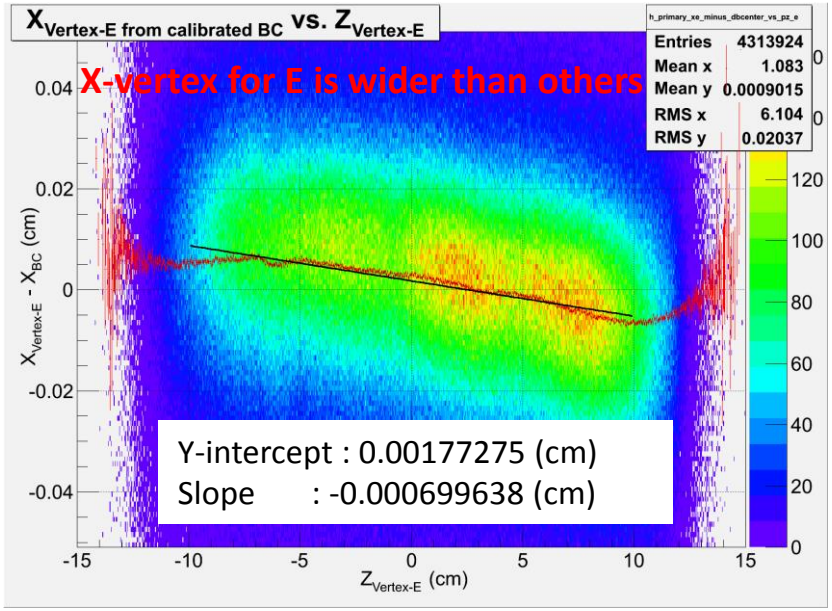
- There is room for improvement of DCA.
  - Rotation of the coordinate and/or the ladder in VTX
  - Cosideration of the DCHE coordinate system.

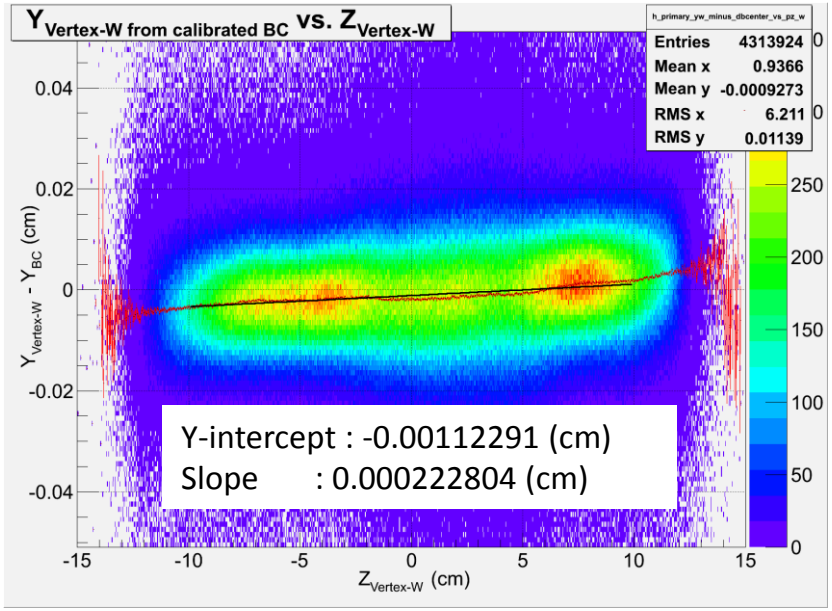
Thanks!

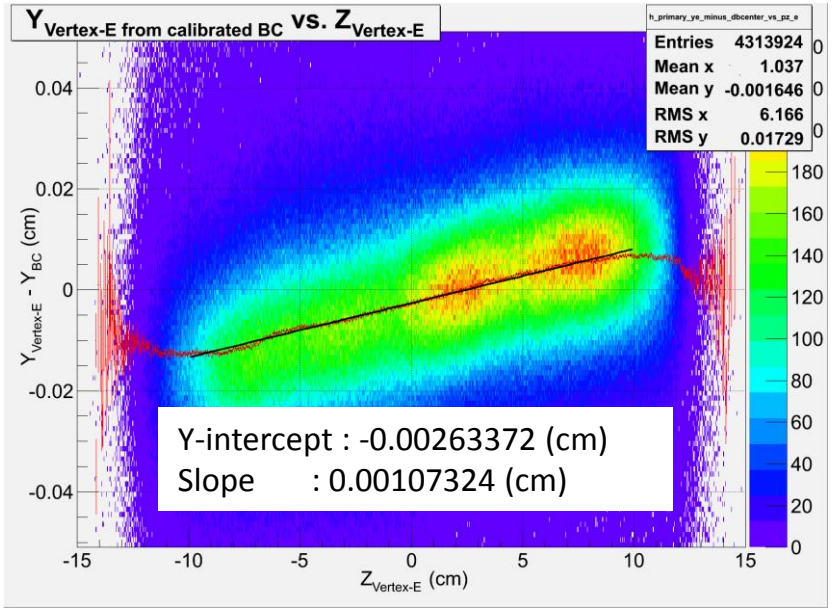
Get paramenters from linear fit.

*523 PRDFs used.



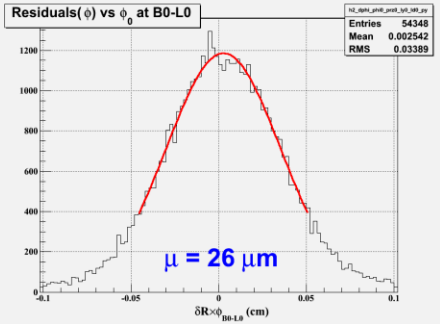


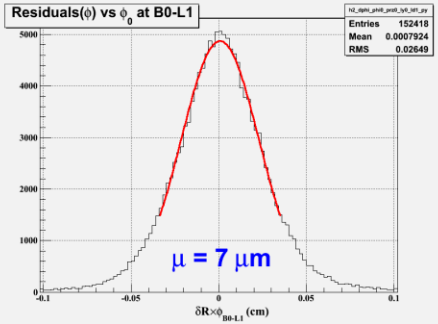


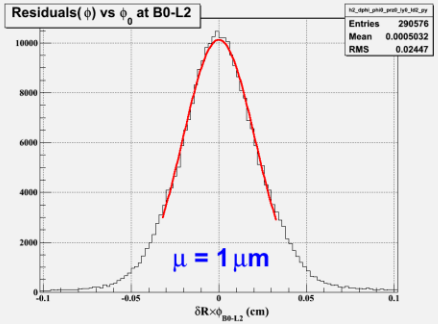


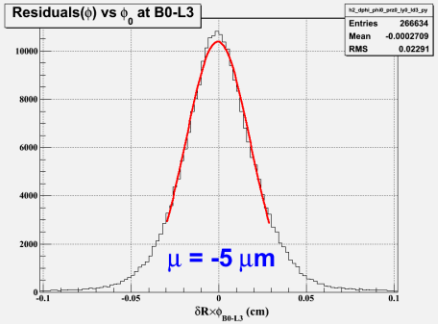
/direct/phenix+user06/phnxreco/Takashi_VTX_LbyL/tmoon/dsts/3.Akiba/4.p2Out/rootfiles/ana.C

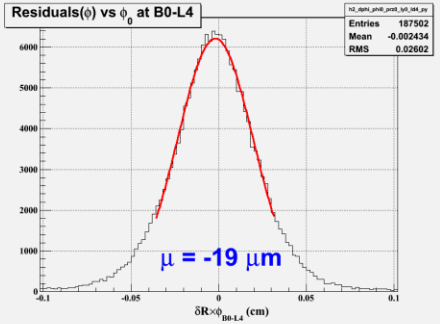
Residue in phi for B0

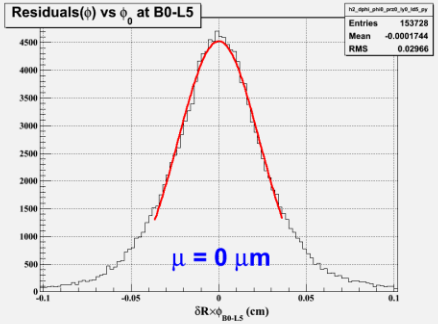


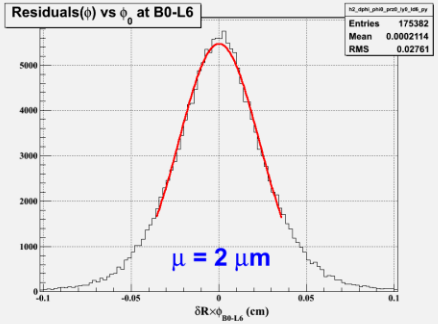


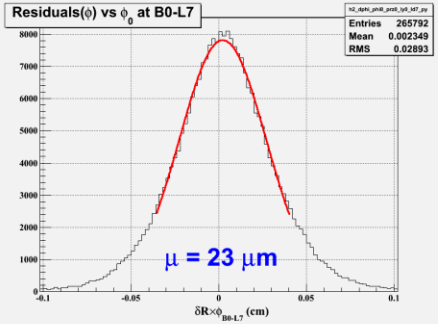


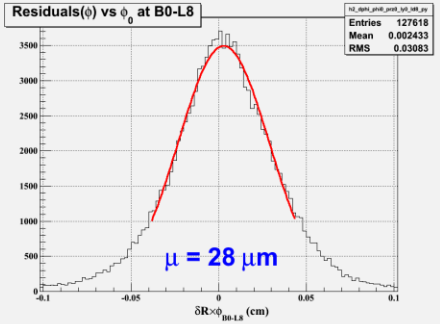


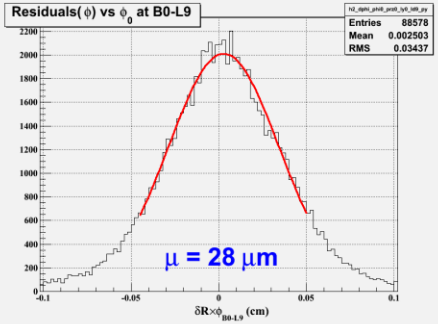




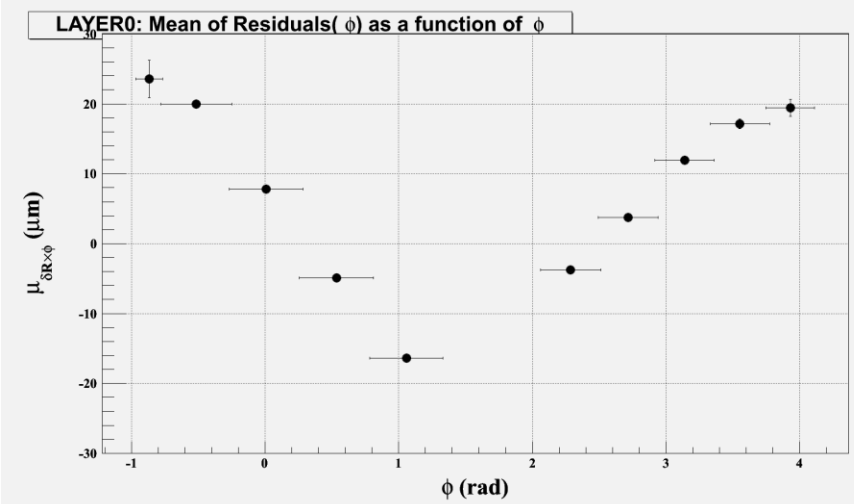


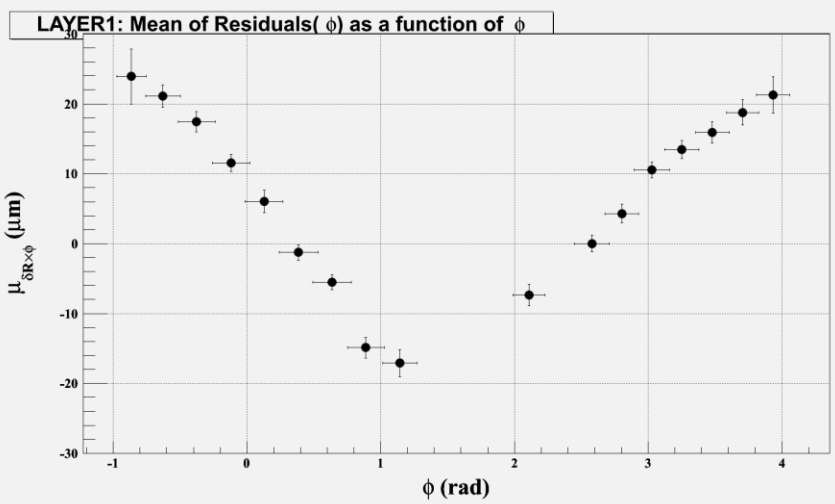


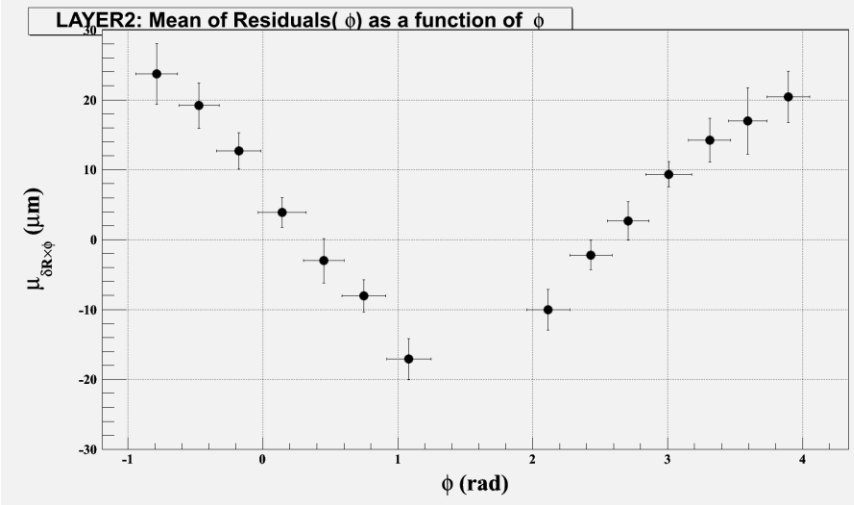


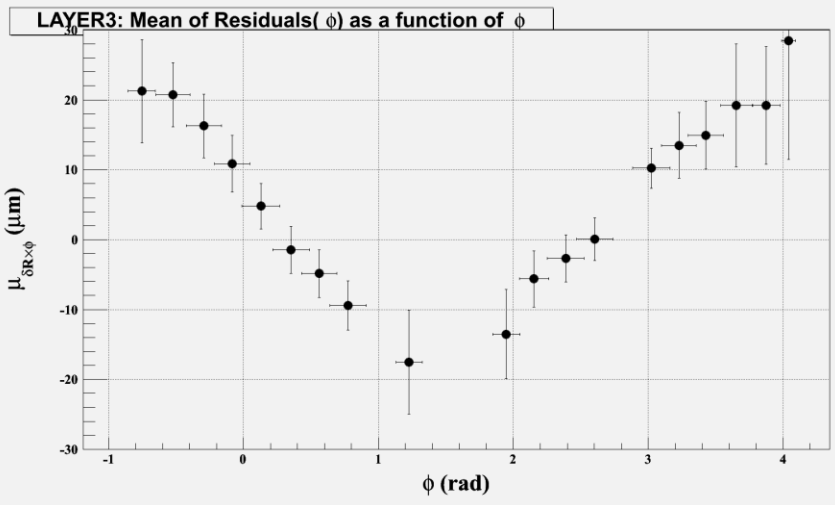


Mean of residue in phi



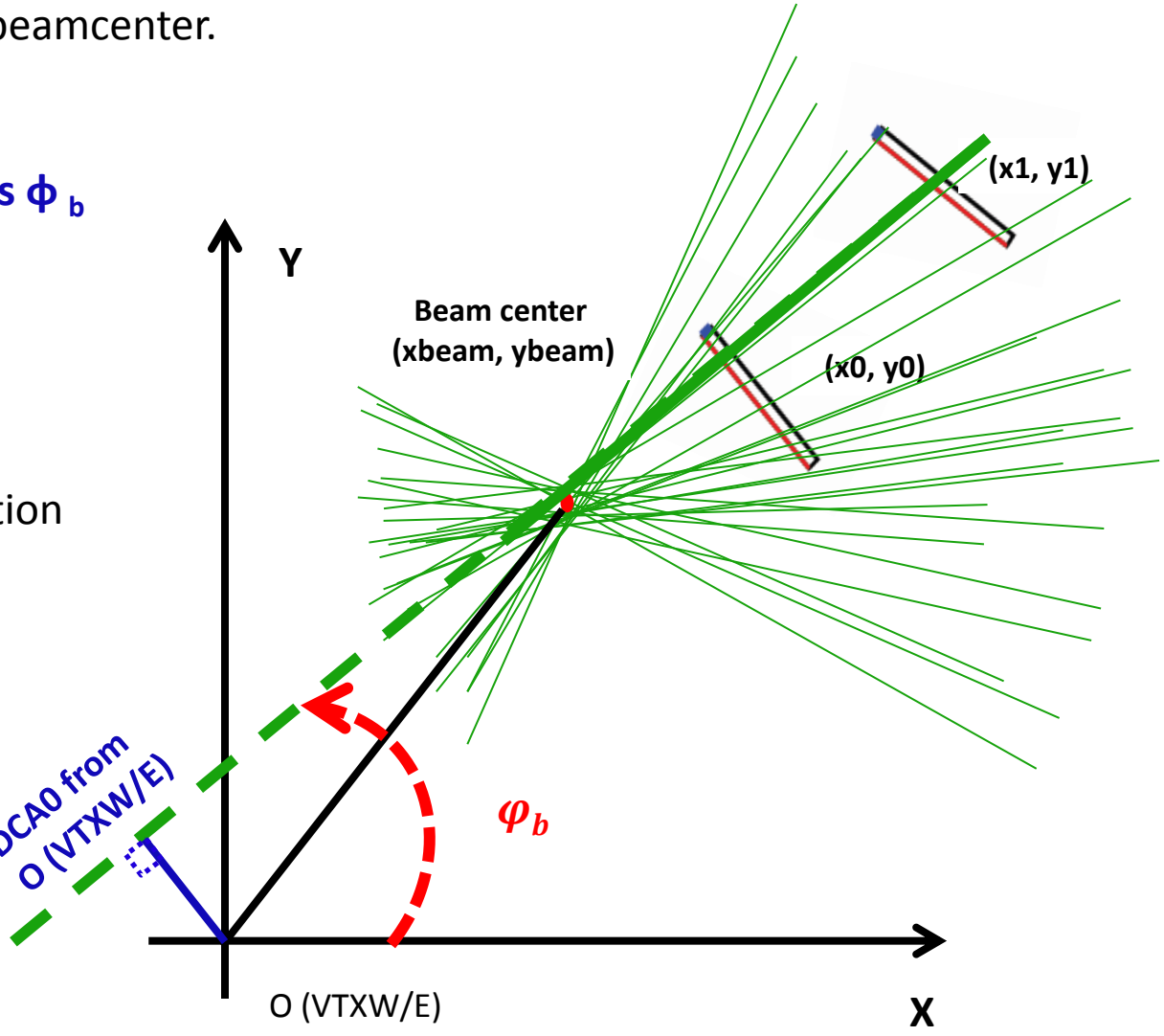






DCA0 formula for fitting

- DCA0 can be represented by beamcenter.
- **For fitting,**
  DCA0 = X_{beam} sin ϕ_b - Y_{beam} cos ϕ_b
- $\varphi_b = tan^{-1}(\frac{y1-y0}{x1-x0})$
- Before fitting, DCA0 as a function of φ_b should be known.

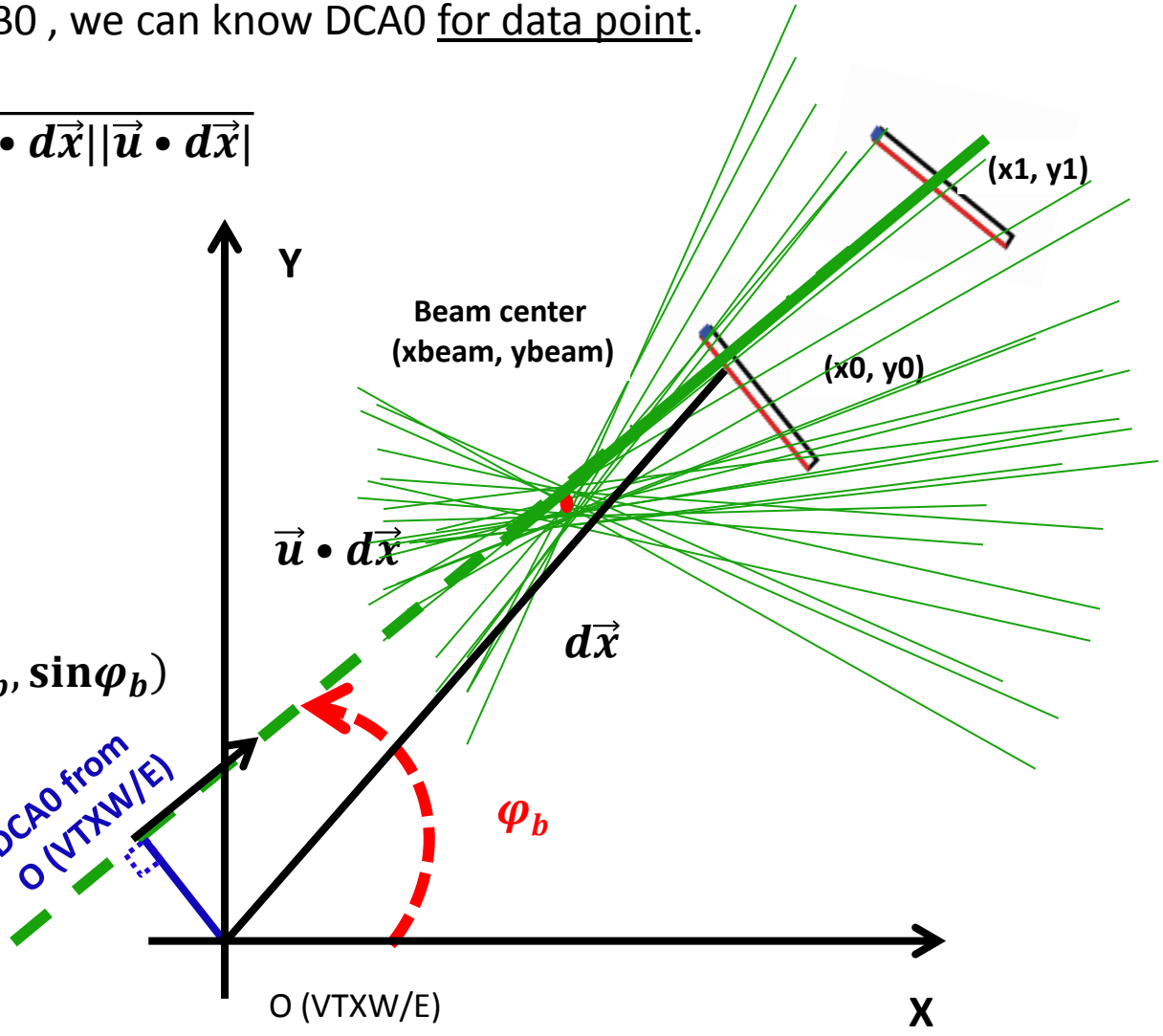


This is calculated in VTX internal coordinate

DCA0 formula for data point

- By using position of hits in B0 , we can know DCA0 for data point.
- $|DCA0| = \sqrt{d\vec{x} \bullet d\vec{x} - |\vec{u} \bullet d\vec{x}||\vec{u} \bullet d\vec{x}|}$
- $d\vec{x} = (x0, y0)$
- $\vec{u} = (\cos\varphi_b, \sin\varphi_b)$
- $\varphi_b = tan^{-1}(\frac{y1-y0}{x1-x0})$

$\vec{u} = (\cos\varphi_b, \sin\varphi_b)$



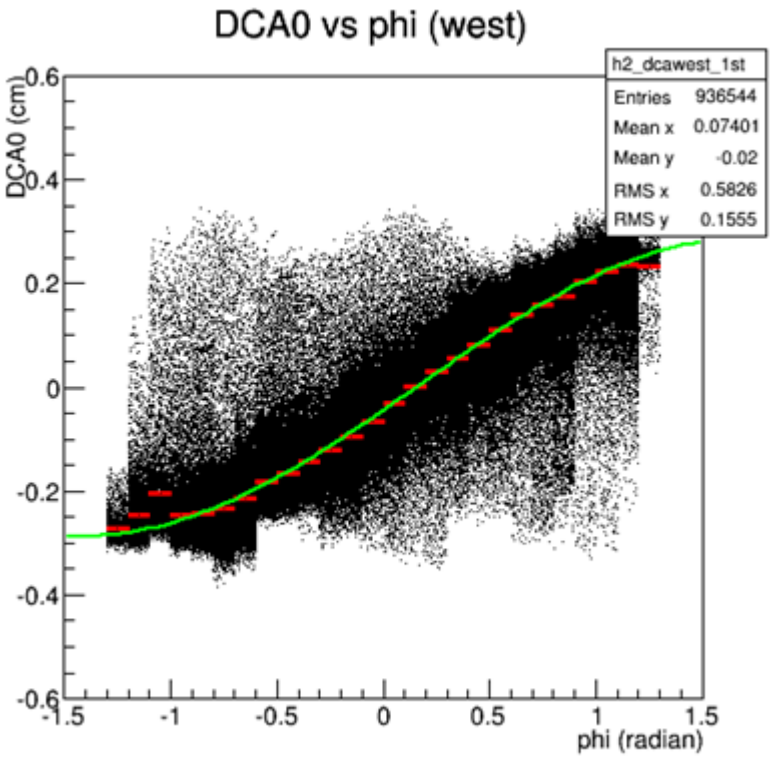
This is calculated in VTX internal coordinate

Beam center by VTX : fit DCA0 vs Φ_b

- Plot 2-D distribution of DCA0 vs φ_b.
- Do Fitting using below function.
  - DCA0 = par[0]sin Φ_b + par[1]cos Φ_b
  - par[0] = X_{BC} = 0
  - par[1] = Y_{BC} = 0

  Parameters should not be fixed
- After fitting, it return beamcenter in the VTX West coordinate.
  - par[0] = 0.285206+E-4
  - par[1] = 0.0465125+E-5

  Those will be used as initial parameters for next fitting.



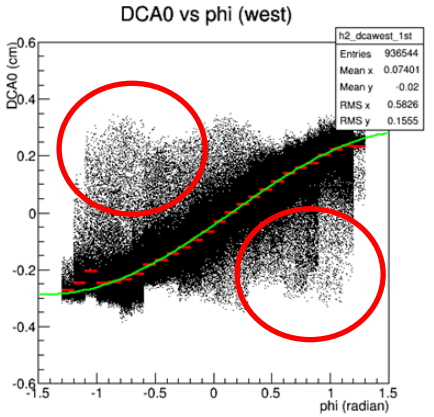
ZEROFDATA_P00_0000405836_000(0~19).PRDFF
Run Number : 406541
Energy : 200 GeV
Number of events : 1.315M

Beam center by VTX : background reduction

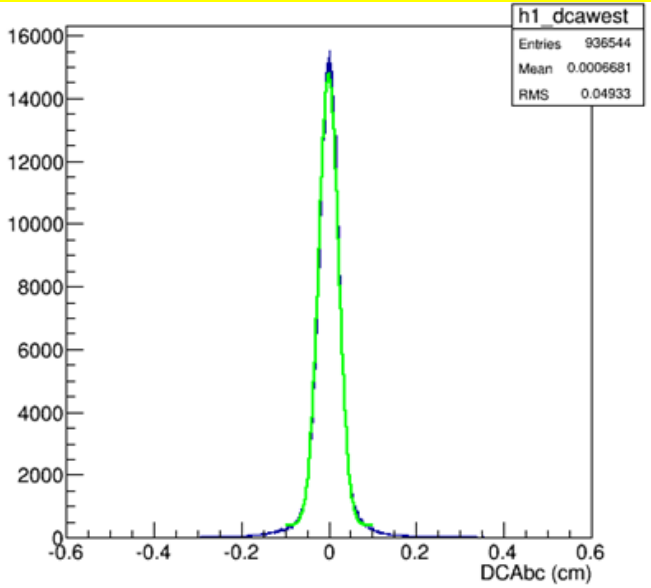
- Before 2nd iteration, let's eliminate background.
- Calculate DCA0 - par[0]sin Φ_b - par[1]cos Φ_b.
  - par[0] = 0.285206
  - par[1] = -0.0465125
- Fitting function.

$$y = \frac{A}{\sqrt{2\pi}\sigma}\exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right) + C$$

- Get σ from fitting.
- Apply 5-sigma cut
  - lDCA0 - par[0]sin Φ_b - par[1]cos Φ_bl < 5σ

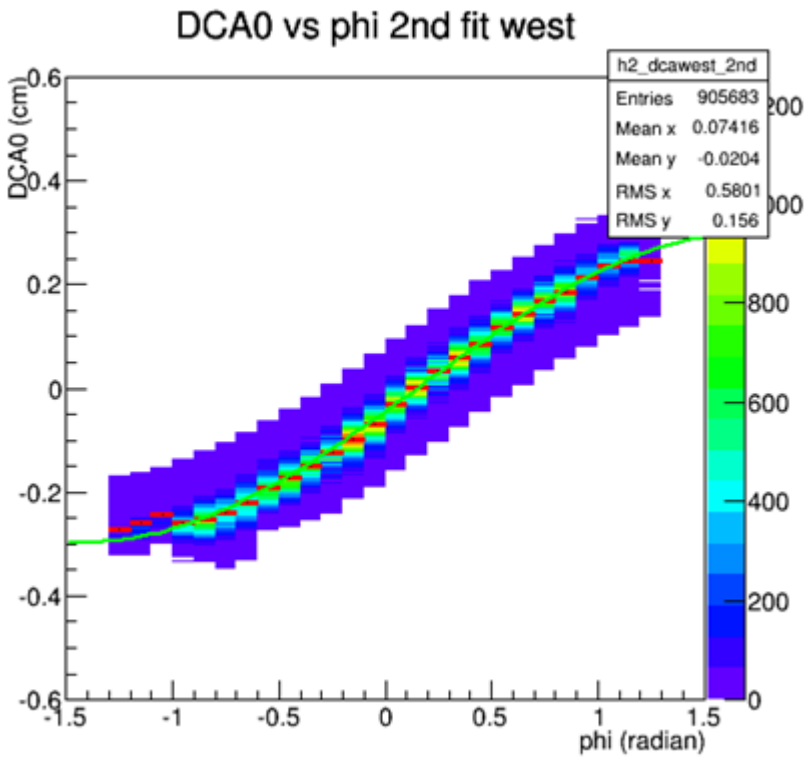


DCA0 - par[0]sin Φ_b - par[1]cos Φ_b



Beam center by VTX : refit DCA0 vs Φ_b

- Plot 2-D distribution of DCA0 vs φ_b again.
- Fit function again.
  - DCA0 = par[0]sin Φ_b +par[1]cos Φ_b
  - par[0] = 0.293506+-E-5
  - par[1] = -0.0471569+E-5
- Final result.
  - par[0] = X_{offset} = 0.293613+E-5 cm
  - par[1] = -Y_{offset} = 0.0472786+-E-5 cm

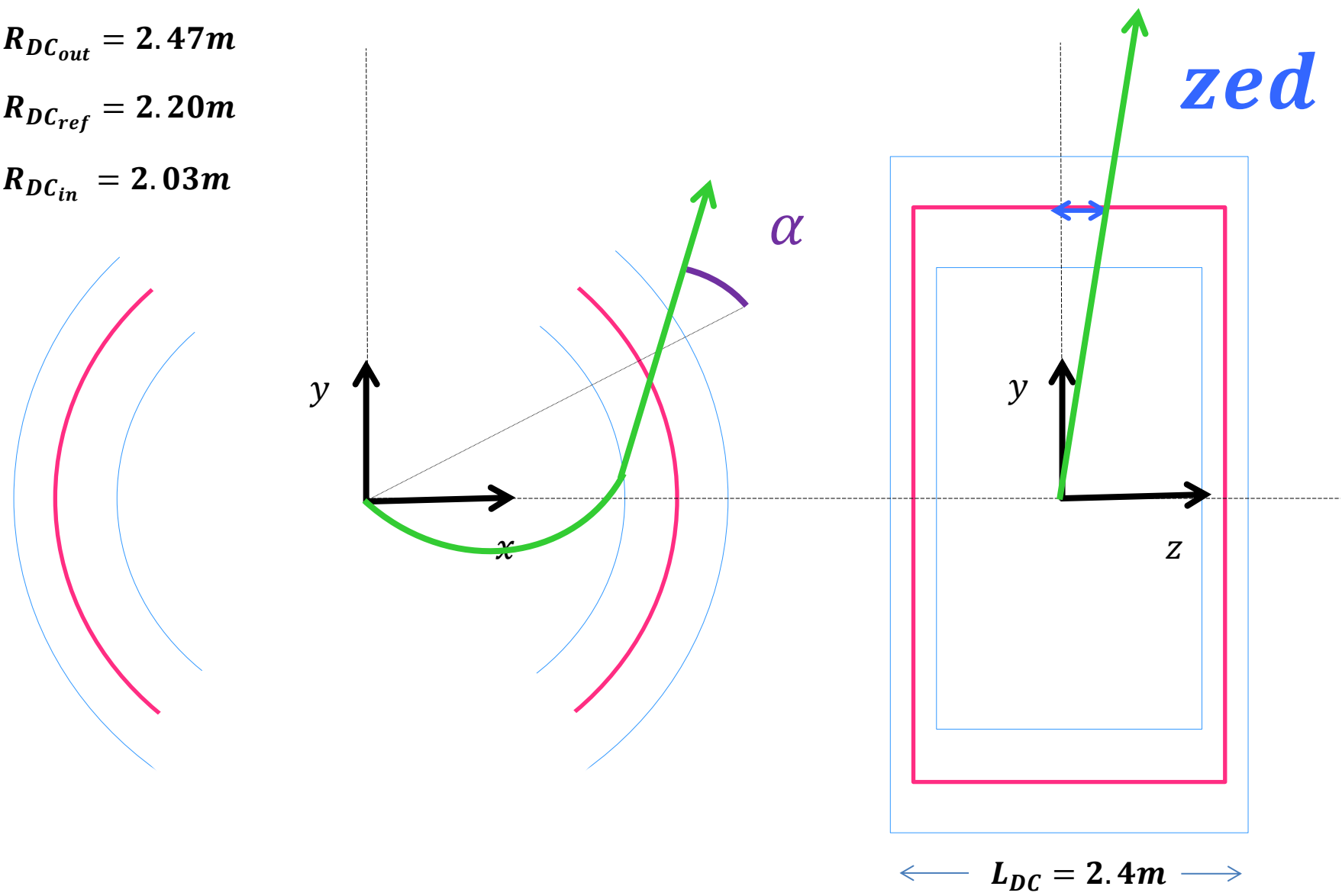


What is zed ?

$R_{DC_{out}} = 2.47m$

$R_{DC_{ref}} = 2.20m$

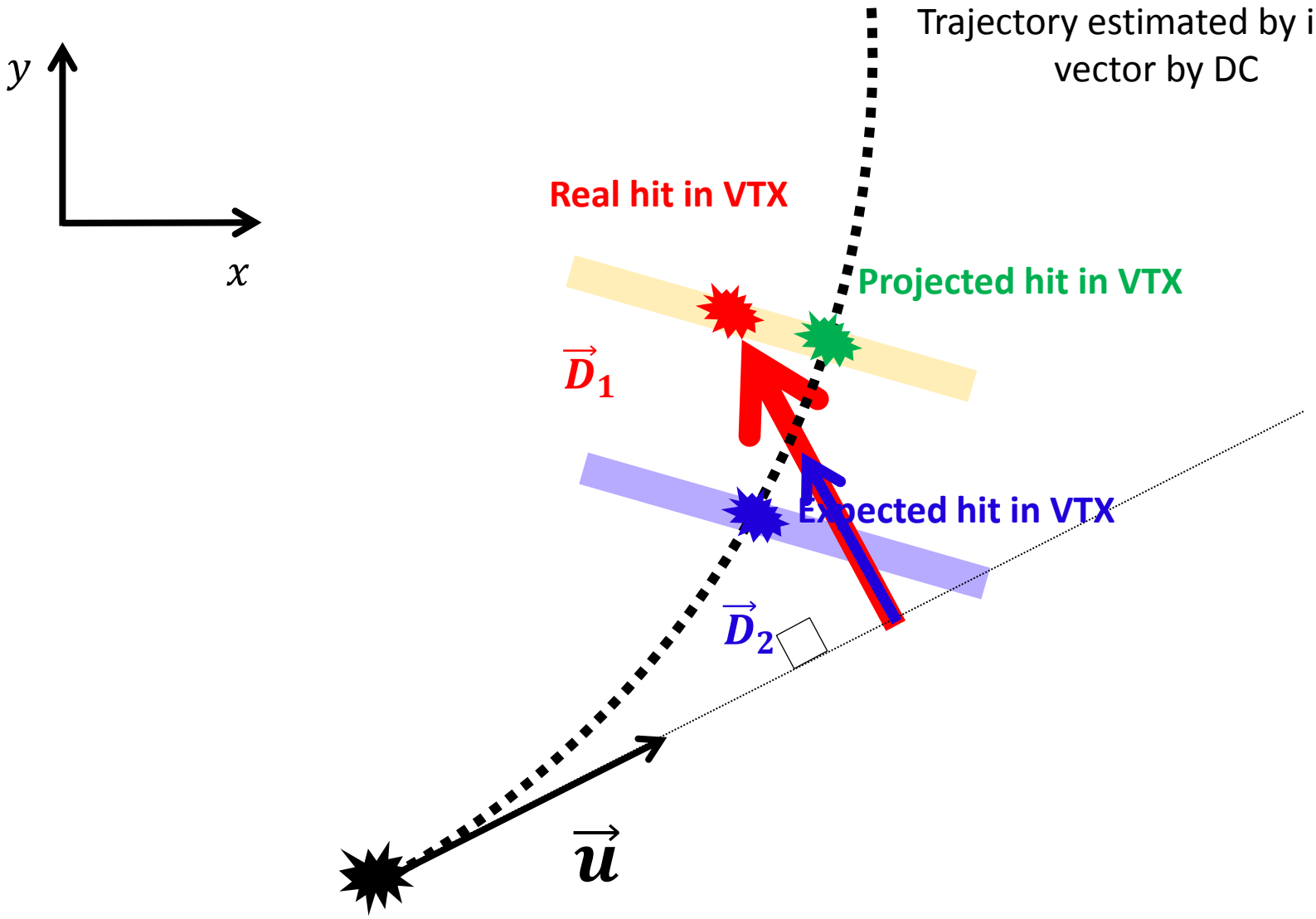
$R_{DC_{in}} = 2.03m$



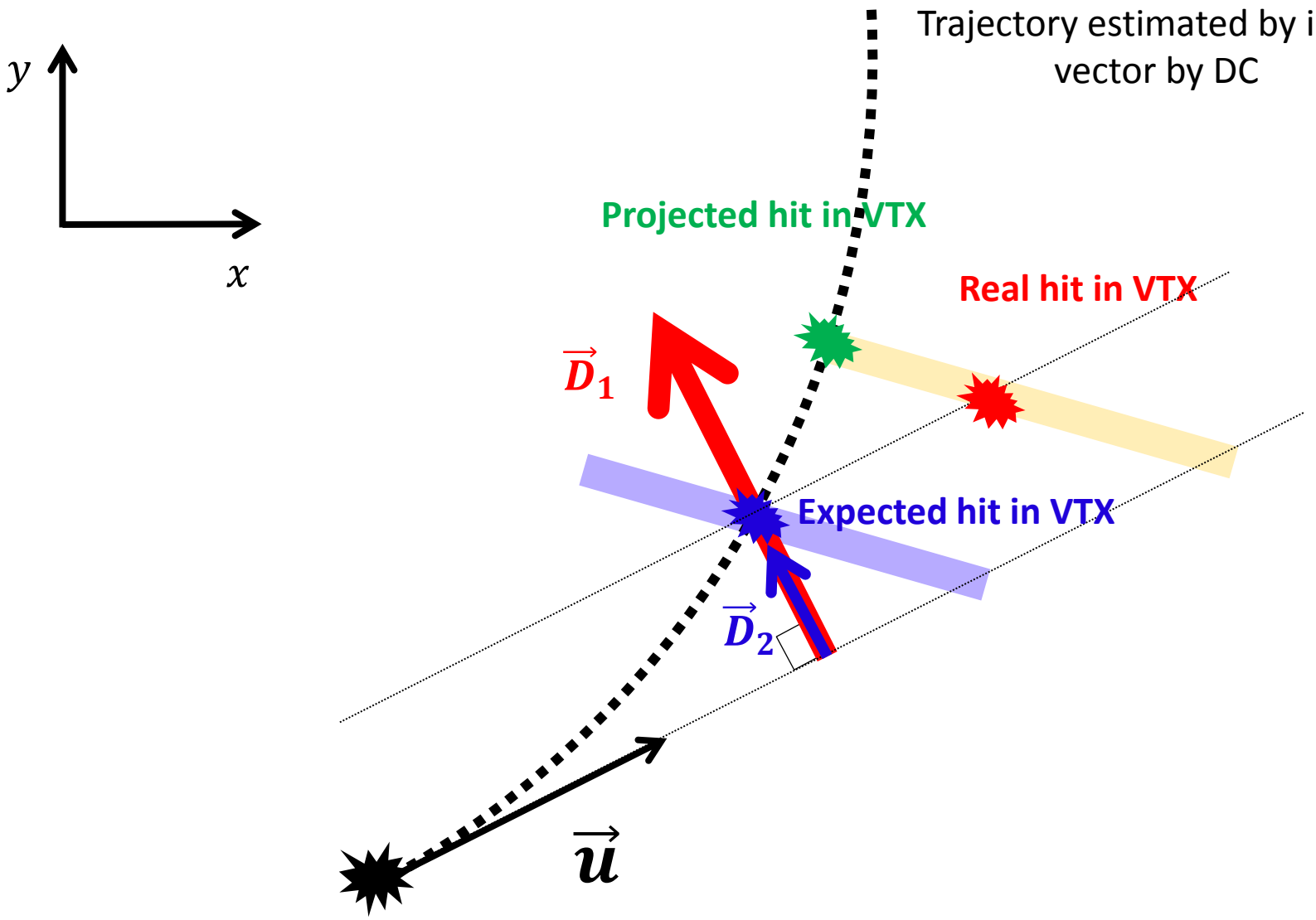
Beam View

Side View

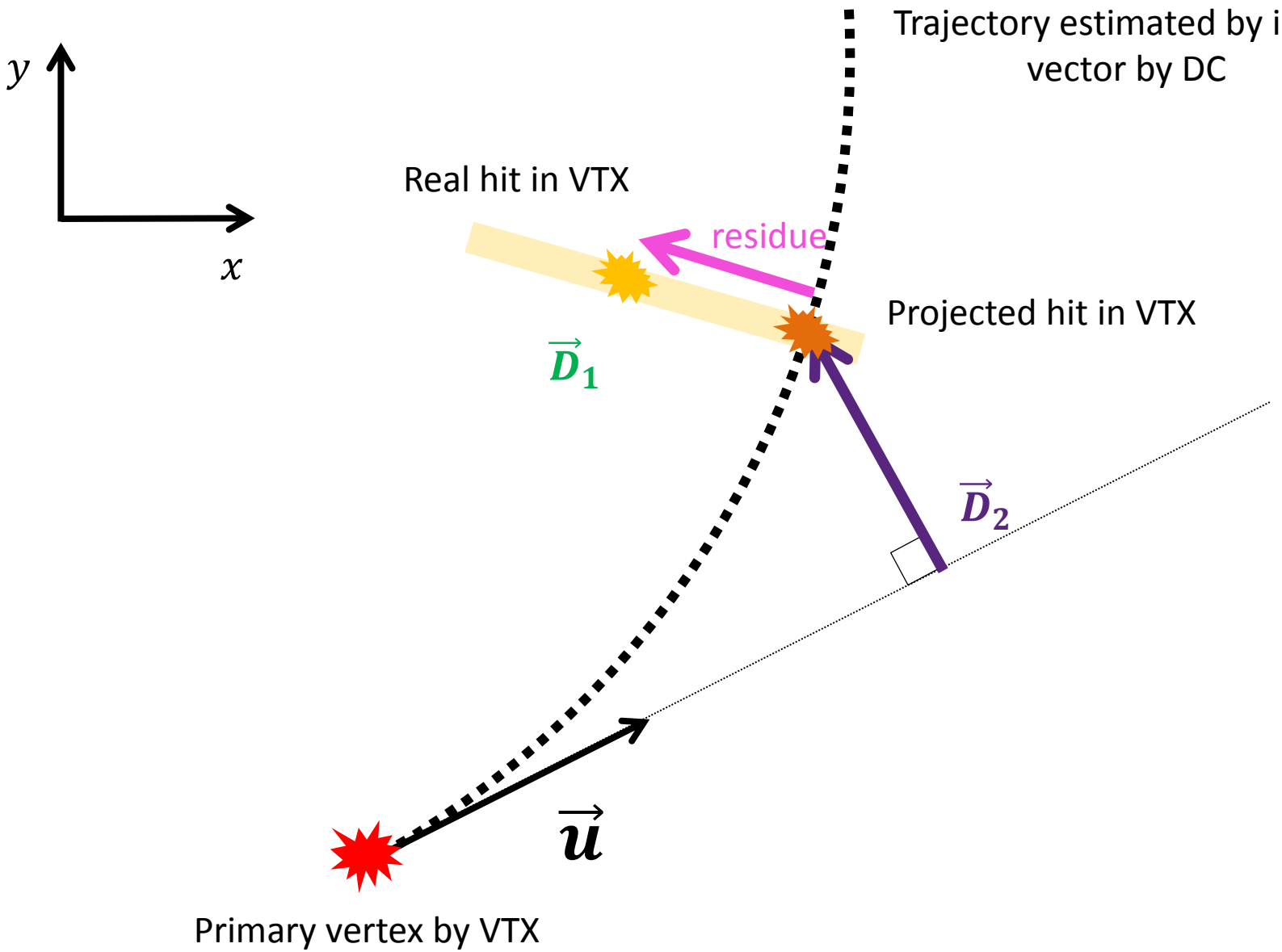
Alignment in u_N (ladder by ladder)

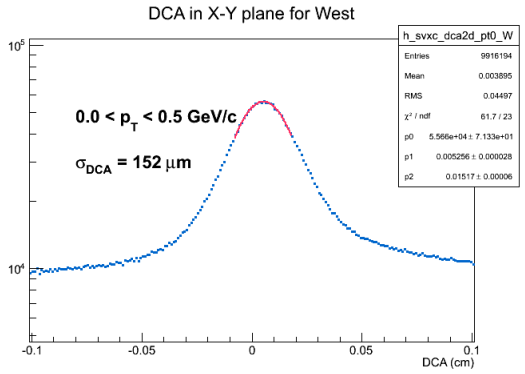


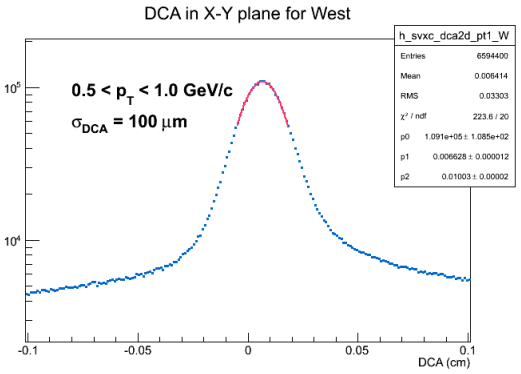
Alignment in u_T (ladder by ladder)

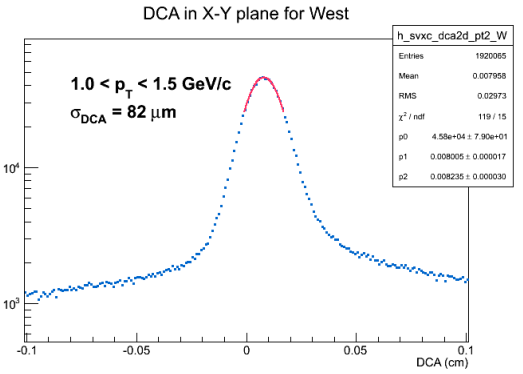


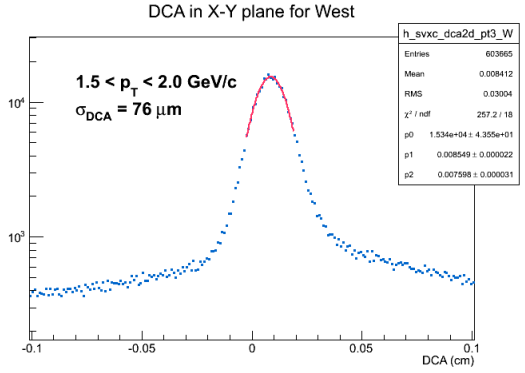
Alignment in φ (Ladder by Ladder(

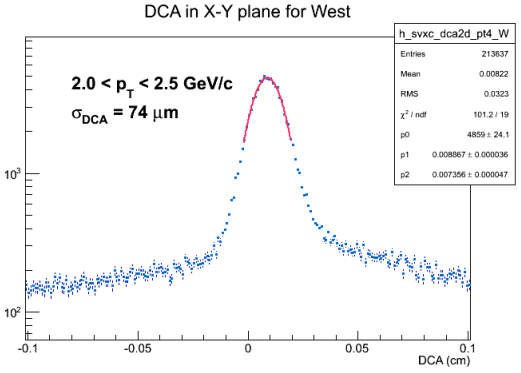


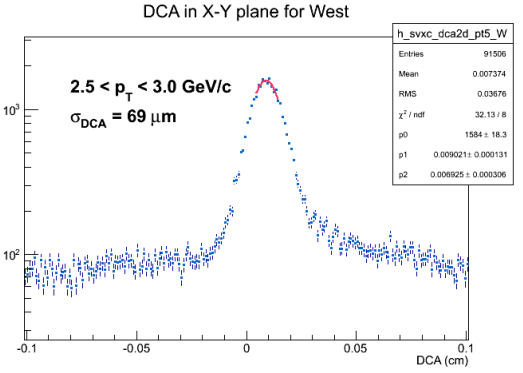

DCA in X-Y plane for West
h_svxc_dca2d_pt0_W
Entries 9916194
Mean 0.003895
RMS 0.04497
χ² / ndf 61.7 / 23
p0 5.566e+04 ± 7.133e+01
p1 0.005256 ± 0.000028
p2 0.01517 ± 0.00006
0.0 < p_T < 0.5 GeV/c
σ_DCA = 152 μm
DCA (cm)

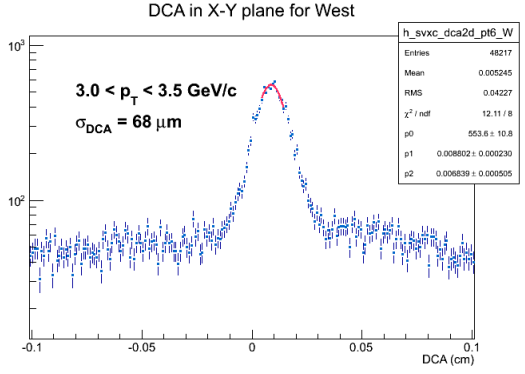

DCA in X-Y plane for West
h_svxc_dca2d_pt1_W
Entries 6594400
Mean 0.006414
RMS 0.03303
χ² / ndf 223.6 / 20
p0 1.091e+05 ± 1.085e+02
p1 0.006628 ± 0.000012
p2 0.01003 ± 0.00002
0.5 < p_T < 1.0 GeV/c
σ_DCA = 100 μm
DCA (cm)

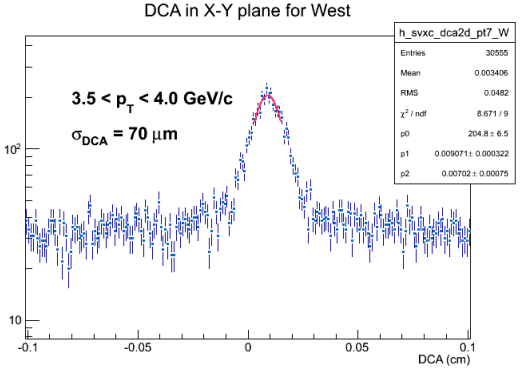

DCA in X-Y plane for West
h_svxc_dca2d_pt2_W
Entries 1920065
Mean 0.007958
RMS 0.02973
χ² / ndf 119 / 15
p0 4.58e+04 ± 7.90e+01
p1 0.008005 ± 0.000017
p2 0.008235 ± 0.000030
1.0 < p_T < 1.5 GeV/c
σ_DCA = 82 μm
DCA (cm)

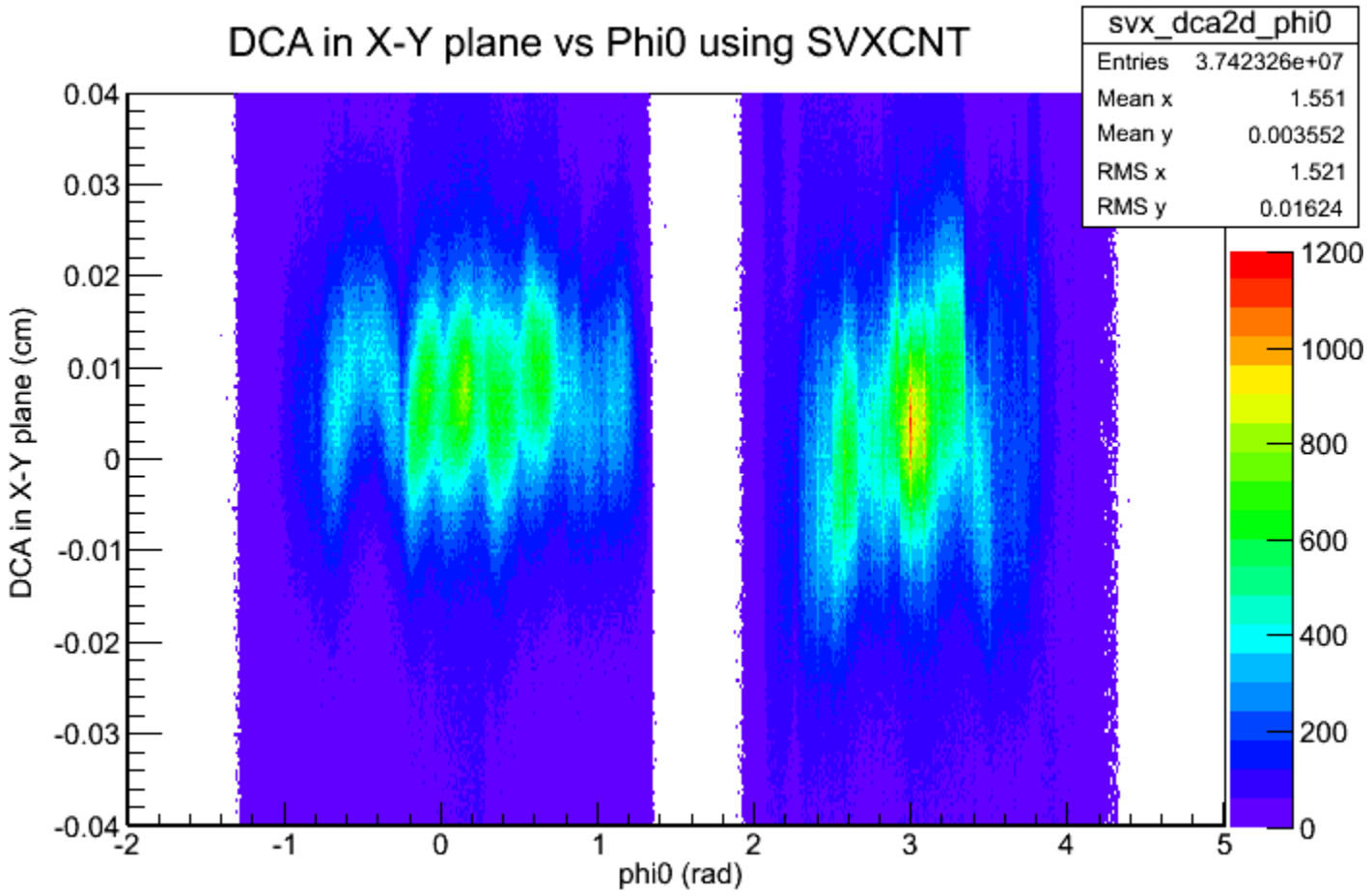

DCA in X-Y plane for West
h_svxc_dca2d_pt3_W
Entries 603665
Mean 0.008412
RMS 0.03004
χ² / ndf 257.2 / 18
p0 1.534e+04 ± 4.355e+01
p1 0.008549 ± 0.000022
p2 0.007598 ± 0.000031
1.5 < p_T < 2.0 GeV/c
σ_DCA = 76 μm
DCA (cm)


DCA in X-Y plane for West
h_svxc_dca2d_pt4_W
Entries 213637
Mean 0.00822
RMS 0.0323
χ² / ndf 101.2 / 19
p0 4859 ± 24.1
p1 0.008867 ± 0.000036
p2 0.007356 ± 0.000047
2.0 < p_T < 2.5 GeV/c
σ_DCA = 74 μm
DCA (cm)

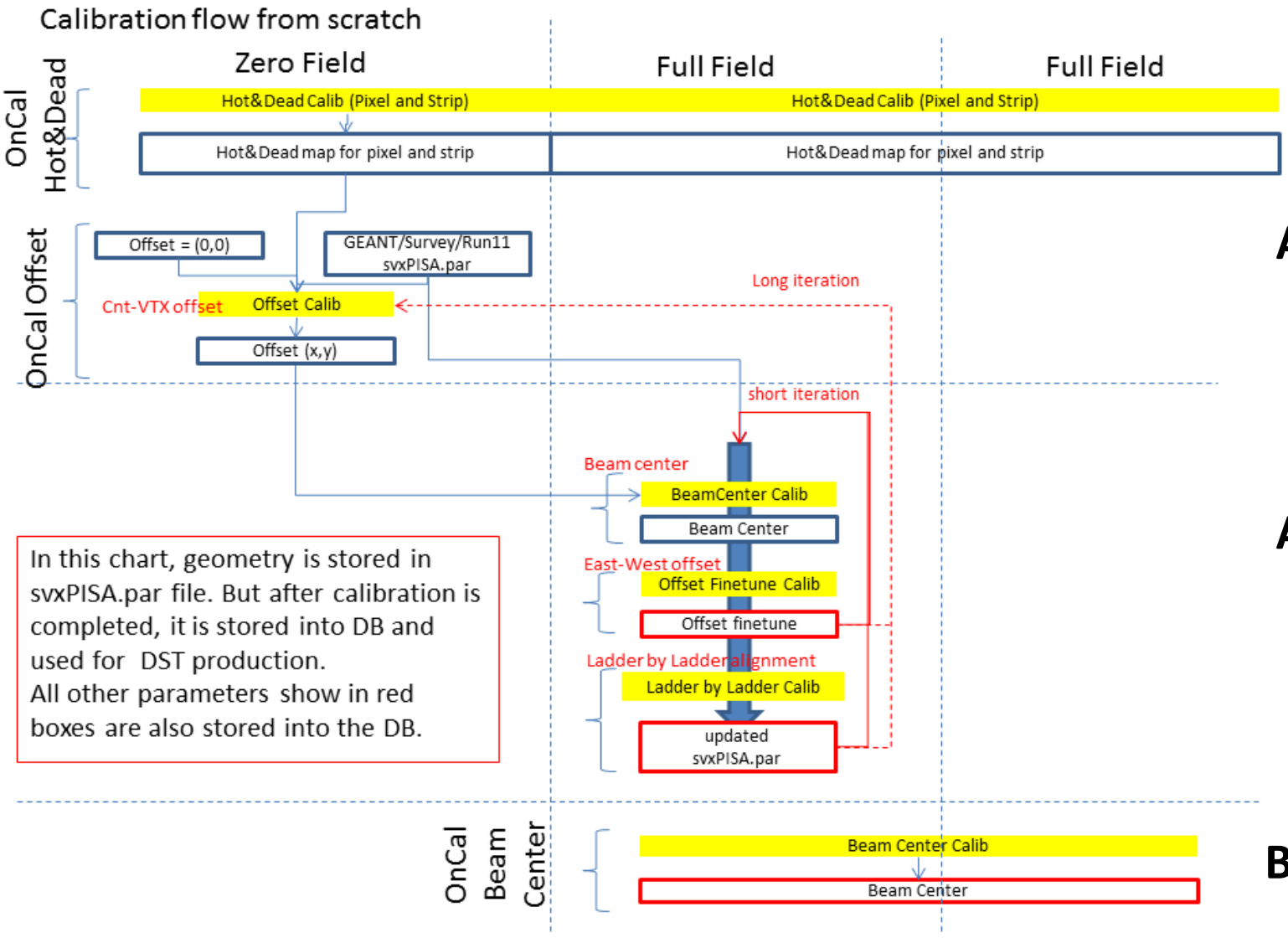

DCA in X-Y plane for West
h_svxc_dca2d_pt5_W
Entries 91506
Mean 0.007374
RMS 0.03676
χ² / ndf 32.13 / 8
p0 1584 ± 18.3
p1 0.009021 ± 0.000131
p2 0.006925 ± 0.000306
2.5 < p_T < 3.0 GeV/c
σ_DCA = 69 μm
DCA (cm)


DCA in X-Y plane for West
h_svxc_dca2d_pt6_W
Entries 48217
Mean 0.005245
RMS 0.04227
χ² / ndf 12.11 / 8
p0 553.6 ± 10.8
p1 0.008802 ± 0.000230
p2 0.006839 ± 0.000505
3.0 < p_T < 3.5 GeV/c
σ_DCA = 68 μm
DCA (cm)


DCA in X-Y plane for West
h_svxc_dca2d_pt7_W
Entries 30555
Mean 0.003406
RMS 0.0482
χ² / ndf 8.671 / 9
p0 204.8 ± 6.5
p1 0.009071 ± 0.000322
p2 0.00702 ± 0.00075
3.5 < p_T < 4.0 GeV/c
σ_DCA = 70 μm
DCA (cm)


DCA in X-Y plane vs Phi0 using SVXCNT
svx_dca2d_phi0
Entries 3.742326e+07
Mean x 1.551
Mean y 0.003552
RMS x 1.521
RMS y 0.01624
DCA in X-Y plane (cm)
phi0 (rad)
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
-1
0
1
2
3
4
5
1200
1000
800
600
400
200
0

Introduction to calibration

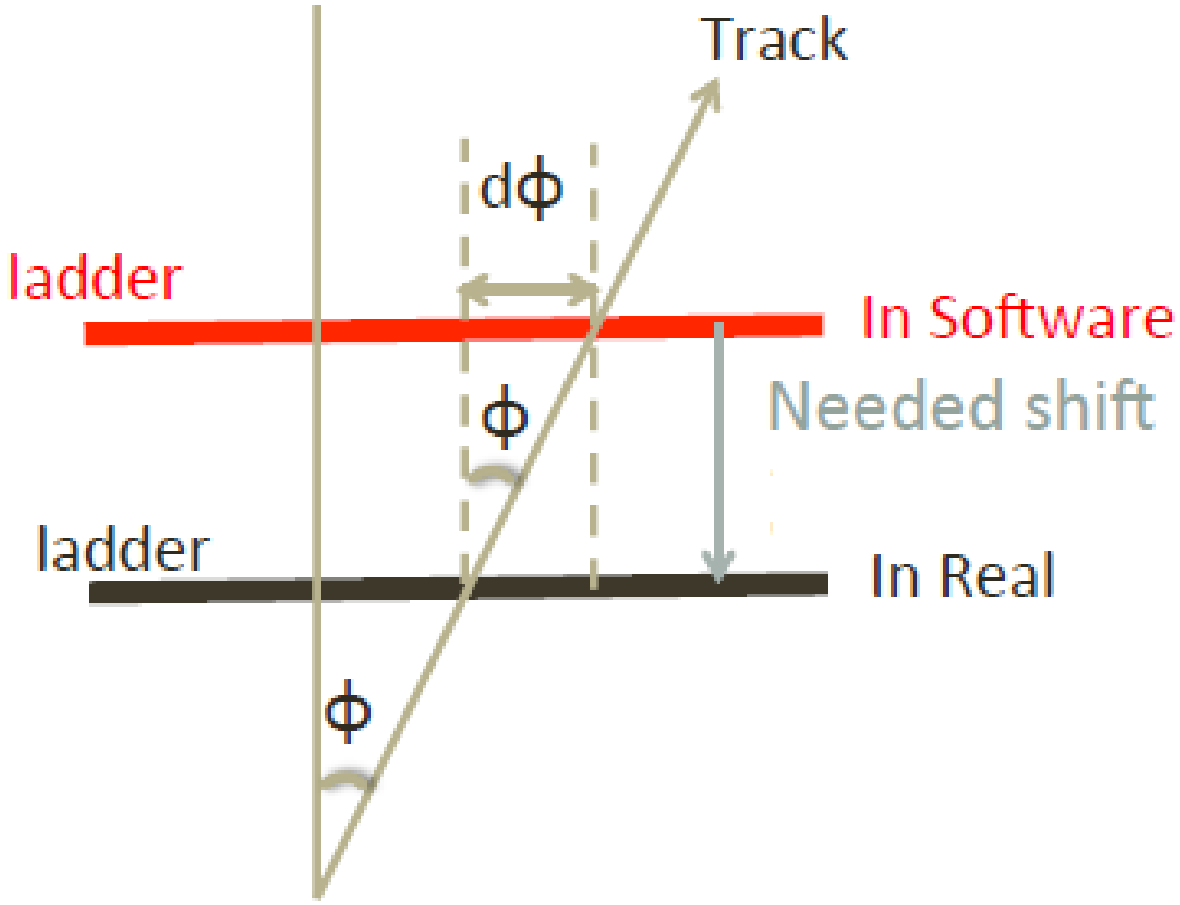


Alignment 1st STEP

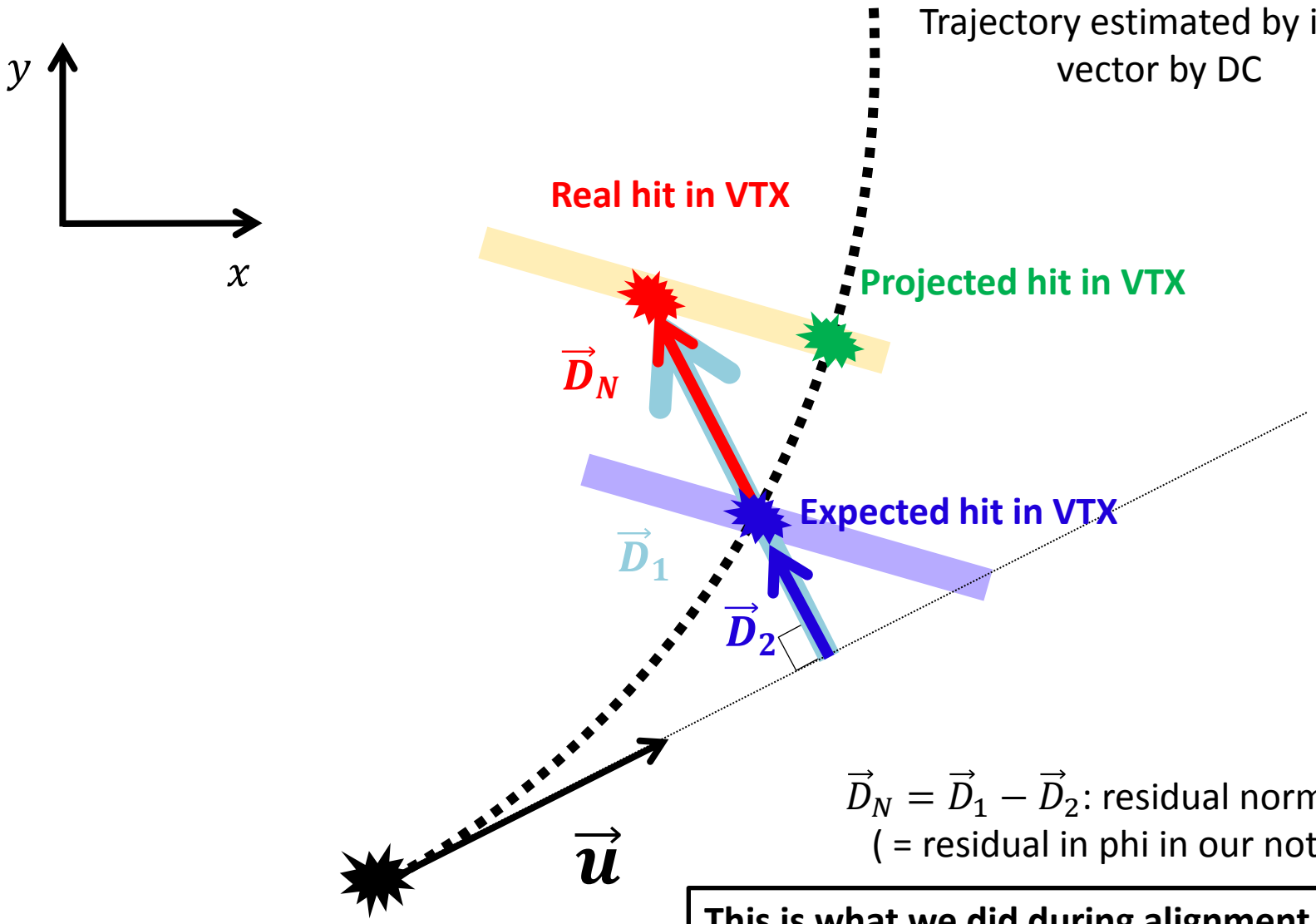
Alignment 2nd STEP

BeamCenter STEP

2) Alignment Ladder by Ladder in φ and z



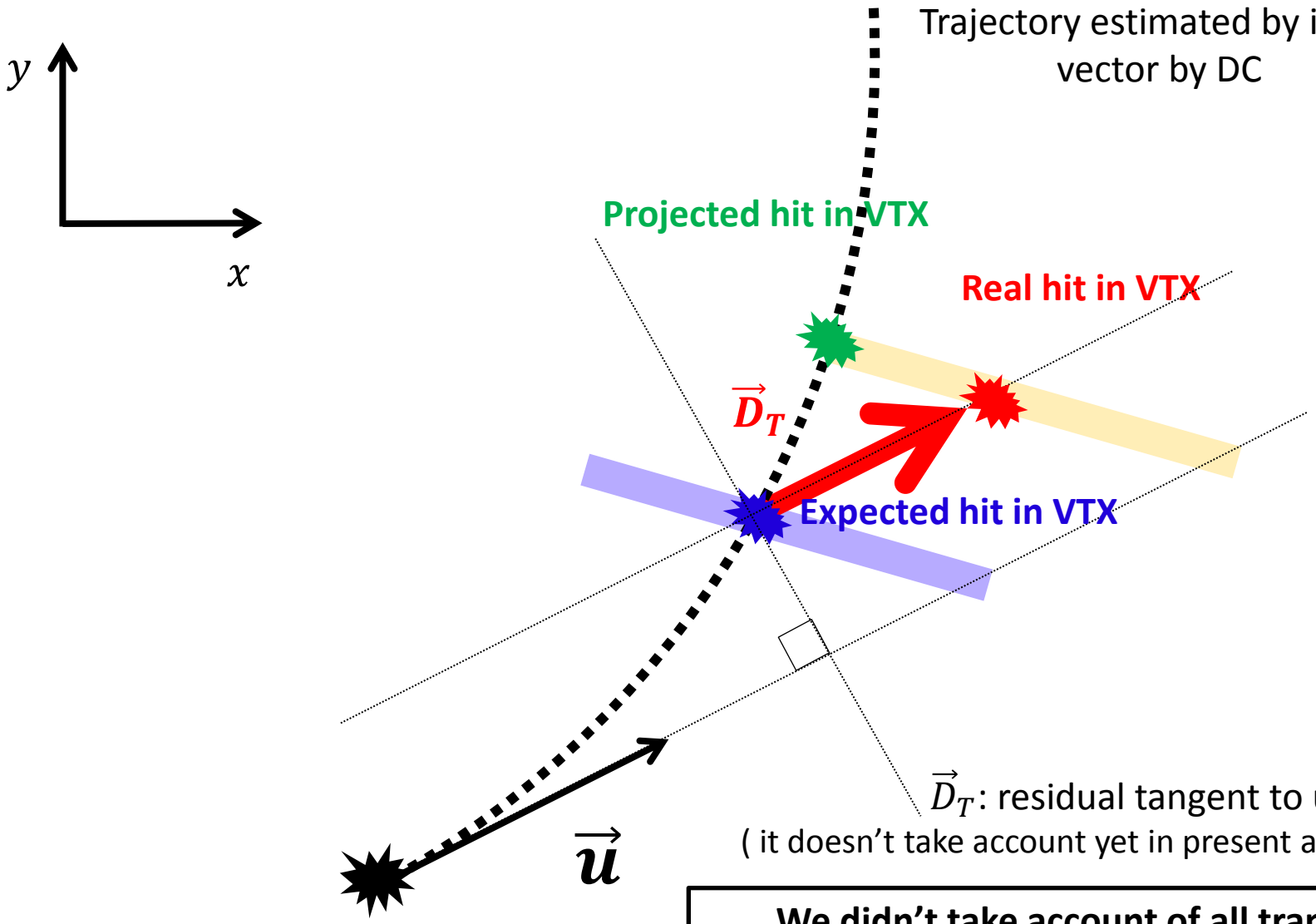
Alignment in u_{Normal} (ladder by ladder)



$\vec{D}_N = \vec{D}_1 - \vec{D}_2$: residual normal to u.
(= residual in phi in our notation)

This is what we did during alignment in phi so far.

Alignment in $u_{Tangent}$ (ladder by ladder)



$\vec{D}_T$: residual tangent to u.
(it doesn't take account yet in present alignment step)

We didn't take account of all translation.

Feb. 14: East carriage moved into run position, ready for physics.
Feb. 18: Zero-field runs 402340 and 402338 with a total of ~780k events.
Feb. 19: Access, East carriage moved out and in.
Feb. 20: Zero-field run 402765 with a total of ~590k events.
Feb. 24: Access and move of East carriage out and in.
Feb. 24: Zero-field run 403312, 403318, 403319, 403322, 403324, 403329 with a total of ~3M events. Note: extended runs because of possible timing shift.
Mar. 05: Access (maintenance day) and move of East and West Carriage.
Mar. 08: Zero-field runs 404895, 404891, 404892, 404893, 404894 with a total of ~1.4M events.
Mar. 11: End of LE run, maintenance day, East carriage moved.

Mar. 15: 200 GeV Au+Au, Zero-field runs 405836, 405837, 405838 with a total of ~13M events.
Mar. 19: West carriage moved, Zero-field run 406541 with ~1.5M events
Apr. 02: East/West carriage moved, Zero-field run 408185 with a total of ~ 2M events.
Apr. 04: East carriage moved, Zero-field run 408327 with about 2M events.
Apr. 16: West carriage moved, Zero-field run 409446 with about 9M events.
Apr. 25: West carriage moved, Zero-field run 410113 with about 11M events.
Apr. 30: West carriage moved, Zero-field runs 410660, 410661 with about 2.5M events.
May 05: West carriage moved, Zero-field run 410925 with about 8.8M events.
May 12: East carriage moved, Zero-field runs 411562, 411653, 411654, and 411655 with about 7.5M events.
May 14: East carriage moved, Zero-field run 411768 with about 3.8M events.
May 28: East and West carriage moved, Zero-field run to be performed.

VTX W/E Beamcenter

Run Number	Begin Run Time	VTX_W_BC_X (cm)	VTX_E_BC_X (cm)	VTX_W_BC_Y (cm)	VTX_E_BC_Y (cm)
411768	2014-05-14 22:27:56	0.321894	0.311514	0.0604457	0.0731154
		4.21E-05	6.42E-05	2.54E-05	3.22E-05
410925	2014-05-05 20:47:26	0.316704	0.30741	0.0554225	0.0696703
		3.50E-05	4.87E-05	2.10E-05	2.51E-05
410660	2014-05-02 17:09:52	0.318525	0.309431	0.0530202	0.0671689
		3.65E-05	5.13E-05	2.23E-05	2.63E-05
410113	2014-04-25 23:55:47	0.311066	0.302995	0.0543635	0.0692437
		3.54E-05	4.95E-05	2.14E-05	2.59E-05
409446	2014-04-17 08:02:40	0.304156	0.300362	0.0474877	0.0624171
		2.77E-05	3.36E-05	1.64E-05	1.79E-05
408327	2014-04-05 02:01:02	0.296781	0.297015	0.0473594	0.0627811
		2.97E-05	3.79E-05	1.77E-05	1.95E-05
408185	2014-04-03 21:54:15	0.300461	0.298614	0.04552	0.0613181
		3.66E-05	5.42E-05	2.46E-05	2.70E-05
406541	2014-03-19 22:03:44	0.293613	0.290074	0.0472786	0.0632157
		5.69E-05	7.52E-05	3.52E-05	4.10E-05
405836	2014-03-15 15:24:12	0.293506	0.28705	0.0471569	0.0631874
		8.62E-05	1.19E-04	5.33E-05	6.70E-05

DCH W/E Beamcenter

Run Number	Begin Run Time	DCH_W_BC_X (cm)	DCH_E_BC_X (cm)	DCH_W_BC_Y (cm)	DCH_E_BC_Y (cm)
411768	2014-05-14 22:27:56	-0.0934428	0.175698	0.0709698	-0.00224814
		2.58E-03	3.42E-03	1.48E-03	1.80E-03
410925	2014-05-05 20:47:26	-0.098038	0.164632	0.0692345	0.000193448
		2.00E-03	2.70E-03	1.13E-03	1.42E-03
410660	2014-05-02 17:09:52	-0.170679	0.167384	0.0649218	-0.00871519
		2.06E-03	2.79E-03	1.17E-03	1.45E-03
410113	2014-04-25 23:55:47	-0.149458	0.227087	0.0649649	0.00391081
		2.58E-03	2.86E-03	1.30E-03	1.50E-03
409446	2014-04-17 08:02:40	-0.114017	0.187738	0.0589805	-0.012743
		1.48E-03	1.91E-03	9.08E-04	1.01E-03
408327	2014-04-05 02:01:02	-0.120571	0.178991	0.0599652	-0.0122251
		1.30E-03	1.80E-03	7.46E-04	9.50E-04
408185	2014-04-03 21:54:15	-0.112316	0.17537	0.058528	-0.0150966
		2.16E-03	3.02E-03	1.25E-03	1.60E-03
406541	2014-03-19 22:03:44	-0.115619	0.197408	0.0641195	-0.012895
		2.82E-03	3.84E-03	1.63E-03	2.06E-03
405836	2014-03-15 15:24:12	-0.0932499	0.1871	0.0640048	-0.0119661
		4.54E-03	6.40E-03	2.67E-03	3.39E-03

CNT East To West

Run Number	Begin Run Time	CNT_East2West_X (cm)	CNT_East2West_Y (cm)
411768	2014-05-14 22:27:56	-0.2691408	0.07321794
410925	2014-05-05 20:47:26	-0.26267	0.069041052
410660	2014-05-02 17:09:52	-0.338063	0.07363699
410113	2014-04-25 23:55:47	-0.376545	0.06105409
409446	2014-04-17 08:02:40	-0.301755	0.0717235
408327	2014-04-05 02:01:02	-0.299562	0.0721903
408185	2014-04-03 21:54:15	-0.287686	0.0736246
406541	2014-03-19 22:03:44	-0.313027	0.0770145
405836	2014-03-15 15:24:12	-0.2803499	0.0759709

VTX To CNT Offset

Run Number	Begin Run Time	VtxToCnt_X (cm)	VtxToCnt_Y (cm)
411768	2014-05-14 22:27:56	-0.4153368	0.0105241
410925	2014-05-05 20:47:26	-0.414742	0.013812
410660	2014-05-02 17:09:52	-0.489204	0.0119016
410113	2014-04-25 23:55:47	-0.460524	0.0106014
409446	2014-04-17 08:02:40	-0.418173	0.0114928
408327	2014-04-05 02:01:02	-0.417352	0.0126058
408185	2014-04-03 21:54:15	-0.412777	0.013008
406541	2014-03-19 22:03:44	-0.409232	0.0168409
405836	2014-03-15 15:24:12	-0.3867559	0.0168479

VTX East To West

Run Number	Begin Run Time	VTX_East2West_X (cm)	VTX_East2West_Y (cm)
411768	2014-05-14 22:27:56	0.01038	-0.0126697
410925	2014-05-05 20:47:26	0.009294	-0.0142478
410660	2014-05-02 17:09:52	0.009094	-0.0141487
410113	2014-04-25 23:55:47	0.008071	-0.0148802
409446	2014-04-17 08:02:40	0.003794	-0.0149294
408327	2014-04-05 02:01:02	-0.000234	-0.0154217
408185	2014-04-03 21:54:15	0.001847	-0.0157981
406541	2014-03-19 22:03:44	0.003539	-0.0159371
405836	2014-03-15 15:24:12	0.006456	-0.0160305