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

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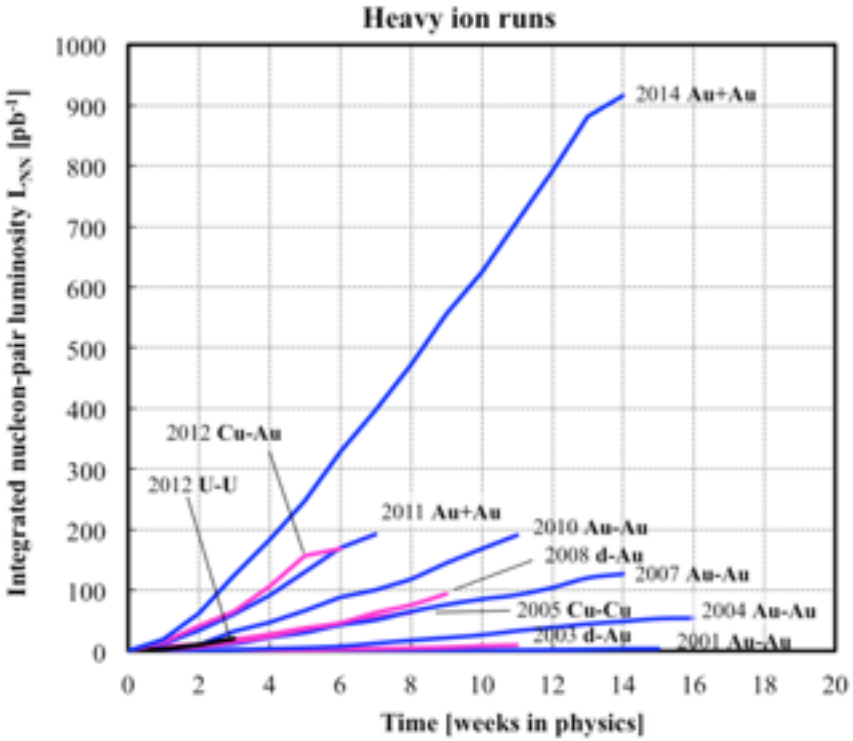
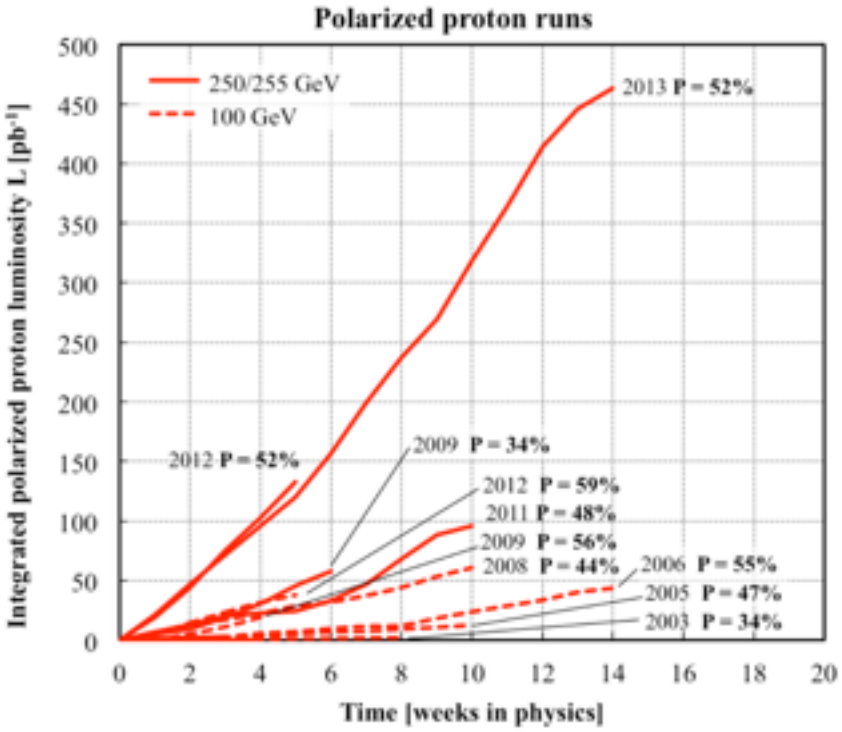
for the PHENIX collaboration

Yonsei Univ./RIKEN
April 24th 2015

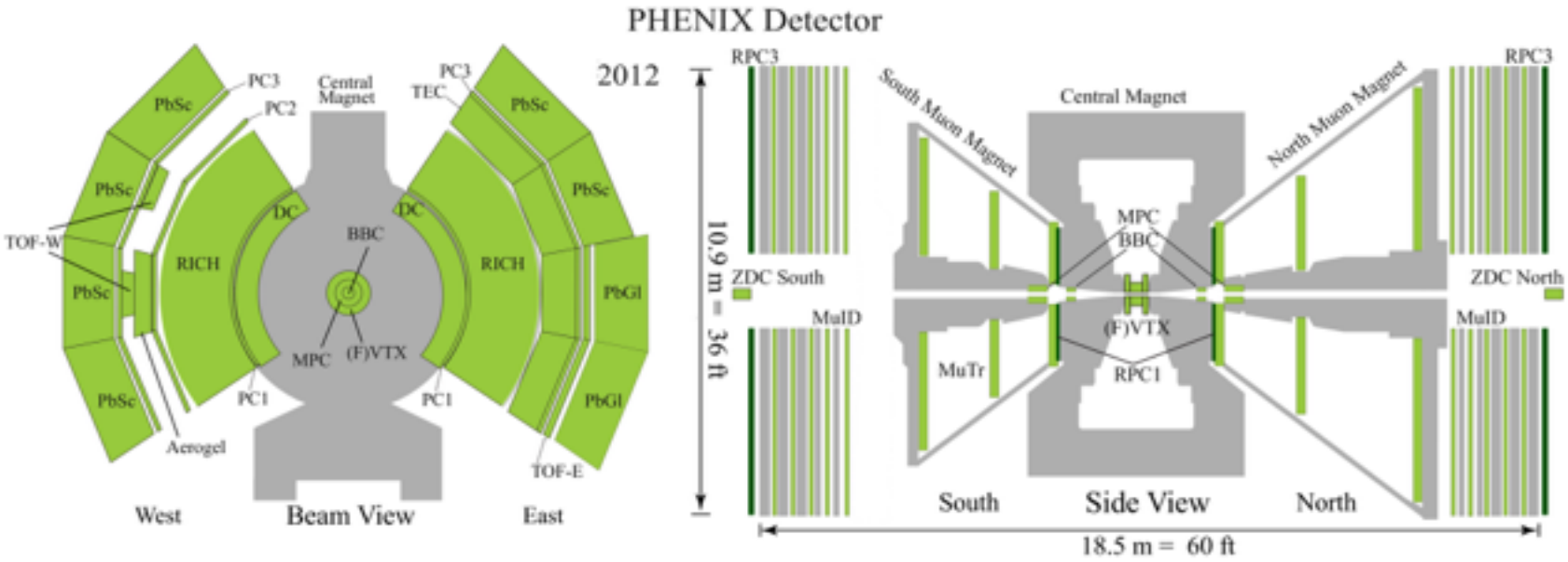
PHENIX data record





- During the 2014 Run, PHENIX has recorded a large number of events with Silicon Vertex Tracker (VTX) and Forward VTX (FVTX) together.
- The best quality dataset of VTX since it was installed in 2011.

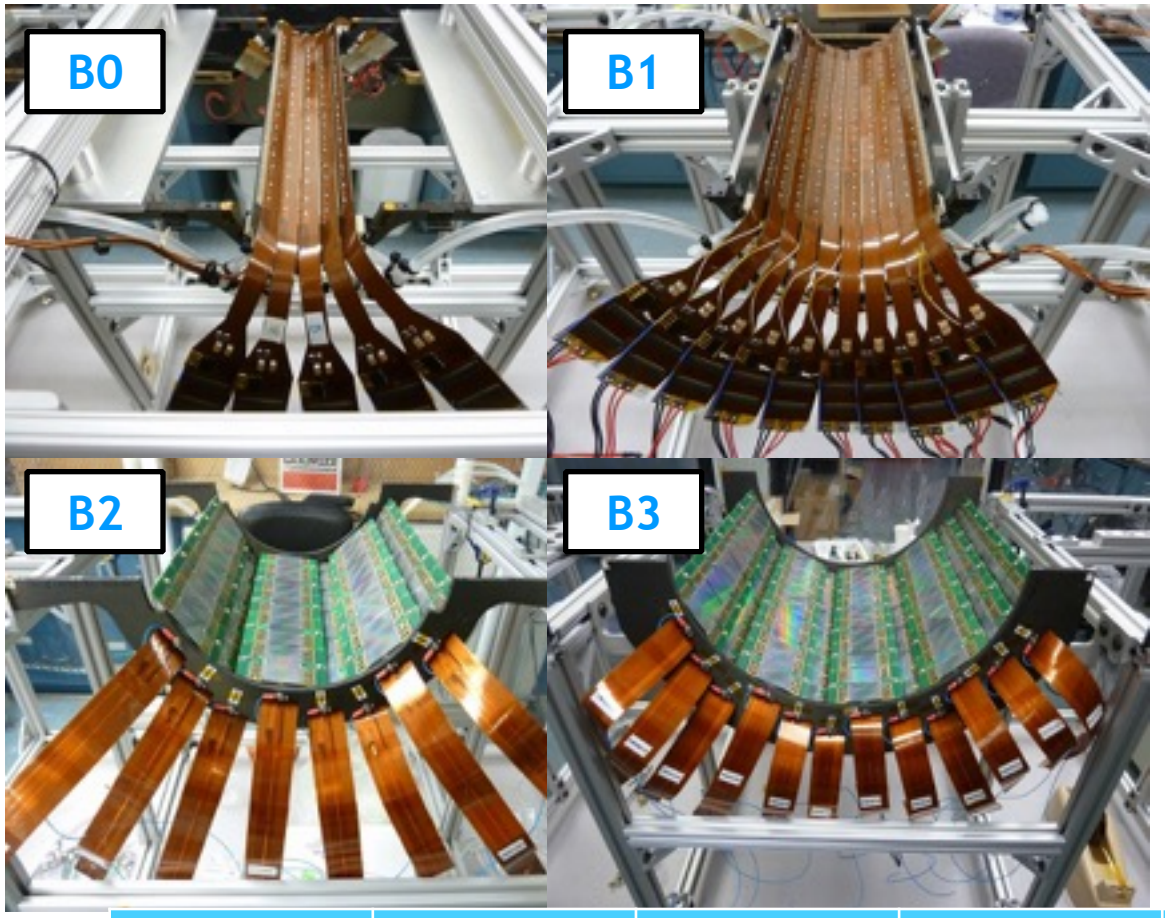
PHENIX Detectors

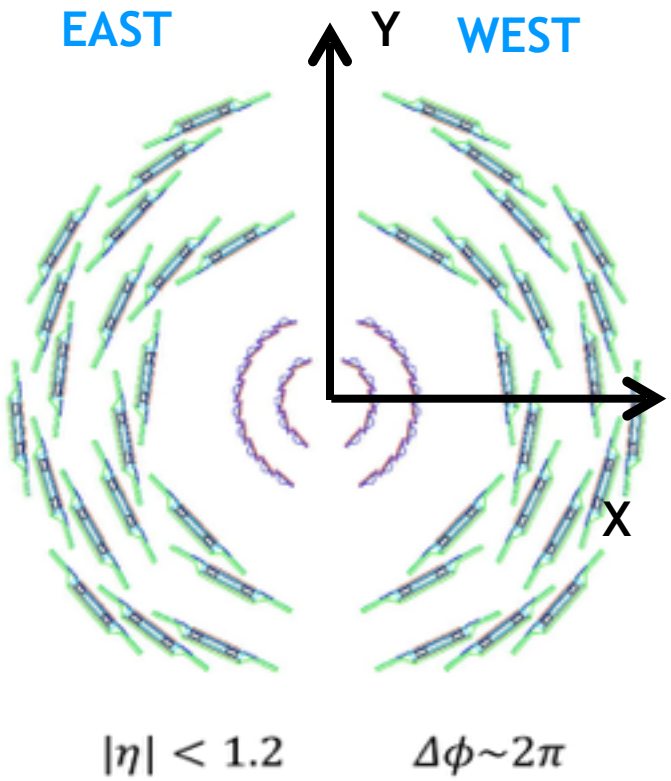


$|\eta|<0.35,\ \Delta\Phi=\pi/2$

- Drift/Pad Chambers (DC/PC)
  - Charged particle tracking
  - Momentum measurement
- Beam Beam Counter (BBC)
  - Triggering and Z-Vertexing
- Ring Cherenkov Detector (RICH)
  - Triggering and eπ ID
- EM Calorimeter (EMCal)
  - Energy measurement
  - Triggering and PID (with Time Of Flight)
- Silicon Vertex Tracker (VTX)
  - Vertexing, Tracking and DCA measurement

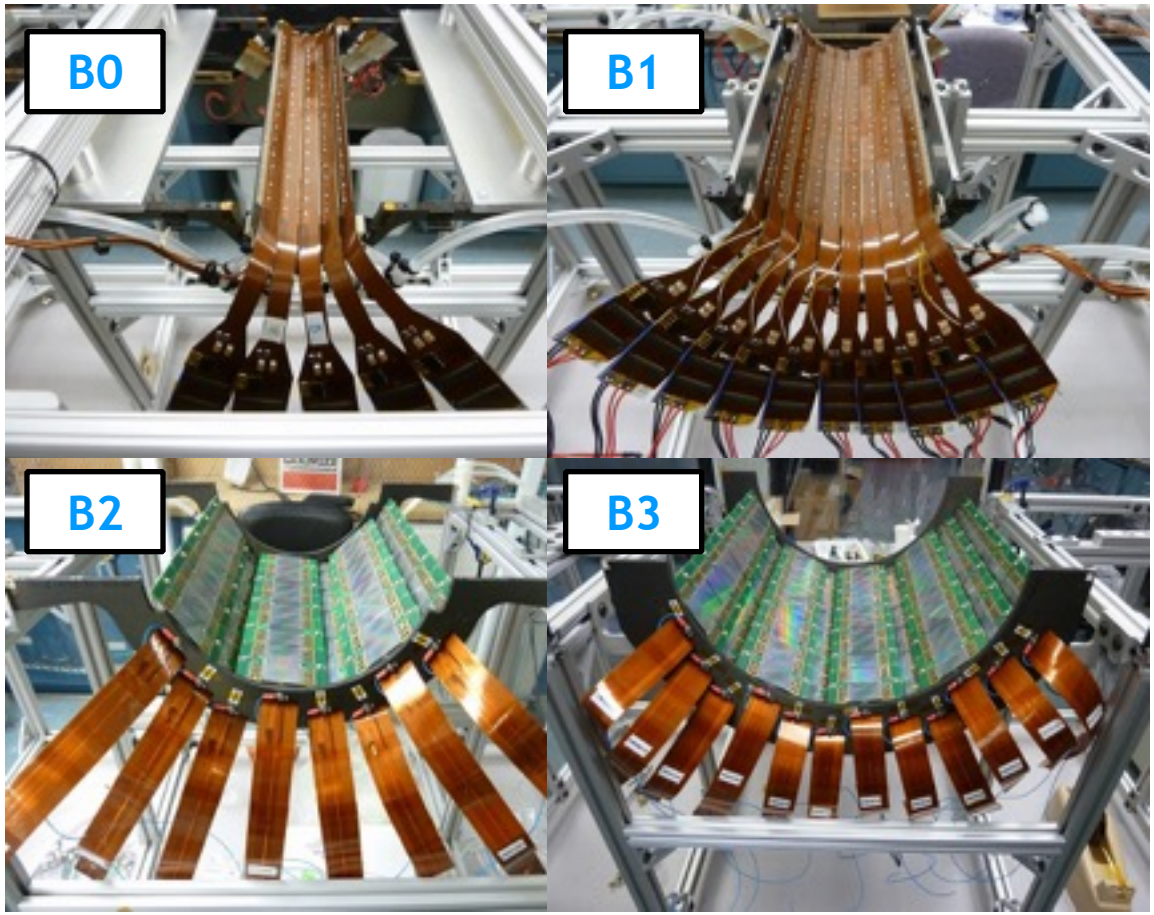
Silicon Vertex Tracker (VTX)

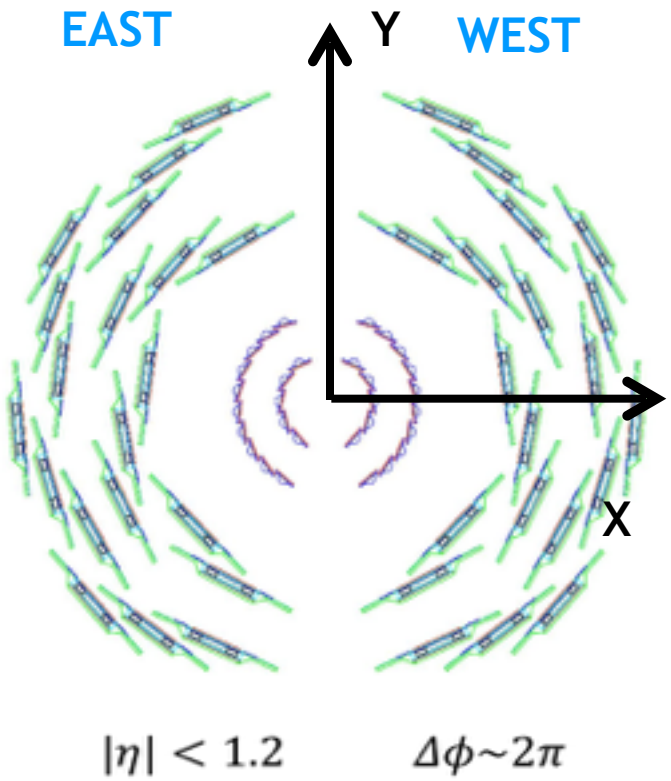




Layer	Kind	R (cm)	Z (cm)	RO Channel	# Ladders
0	*Pixel*	*2.5*	*±10*	*1,310,720*	*10*
1	*Pixel*	*5*	*±10*	*2,671,440*	*20*
2	*Strip-pixel*	*11.7*	*±16*	*122,880*	*16*
3	*Strip-pixel*	*16.6*	*±19*	*221,184*	*24*

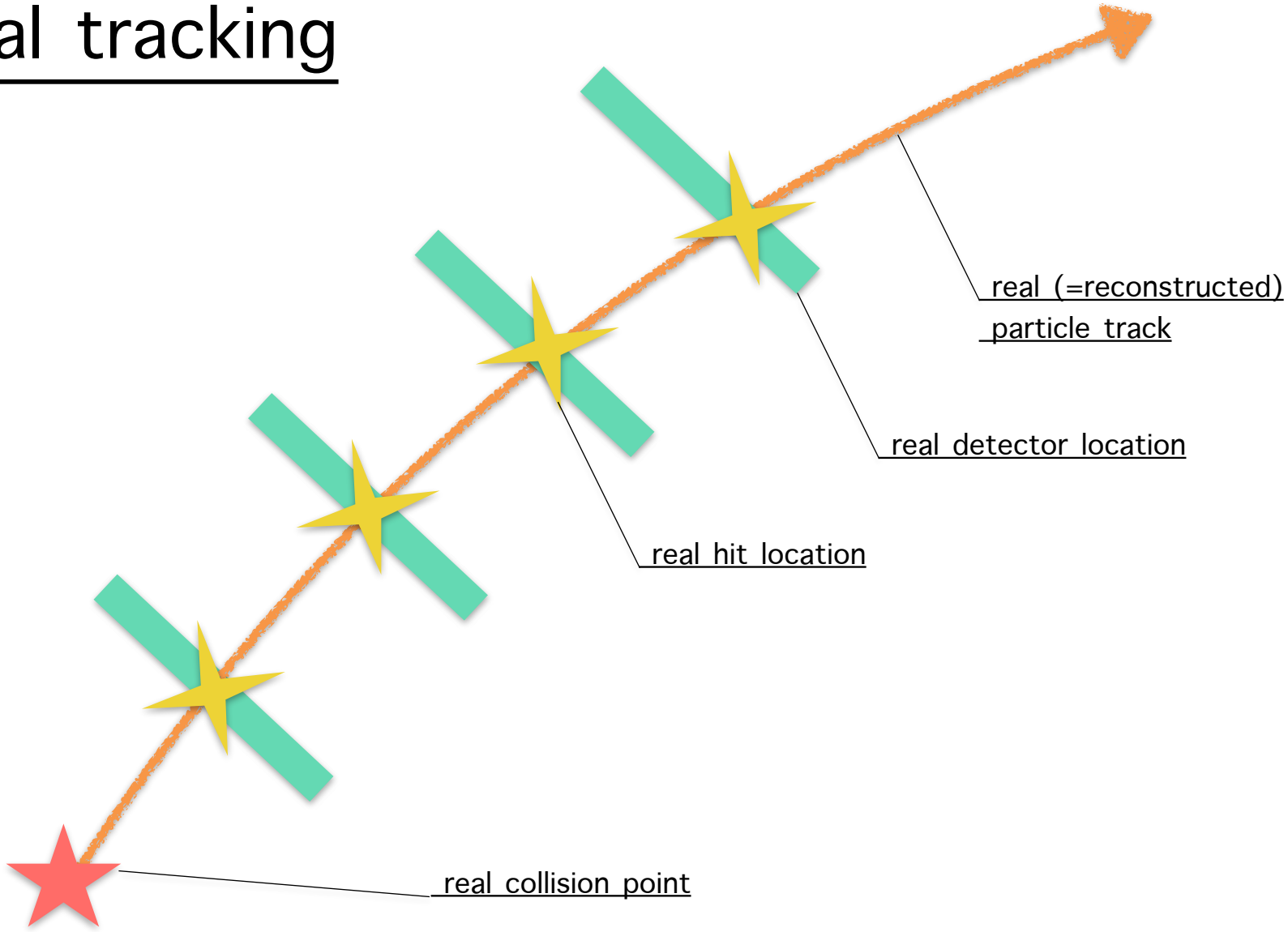
Silicon Vertex Tracker (VTX)



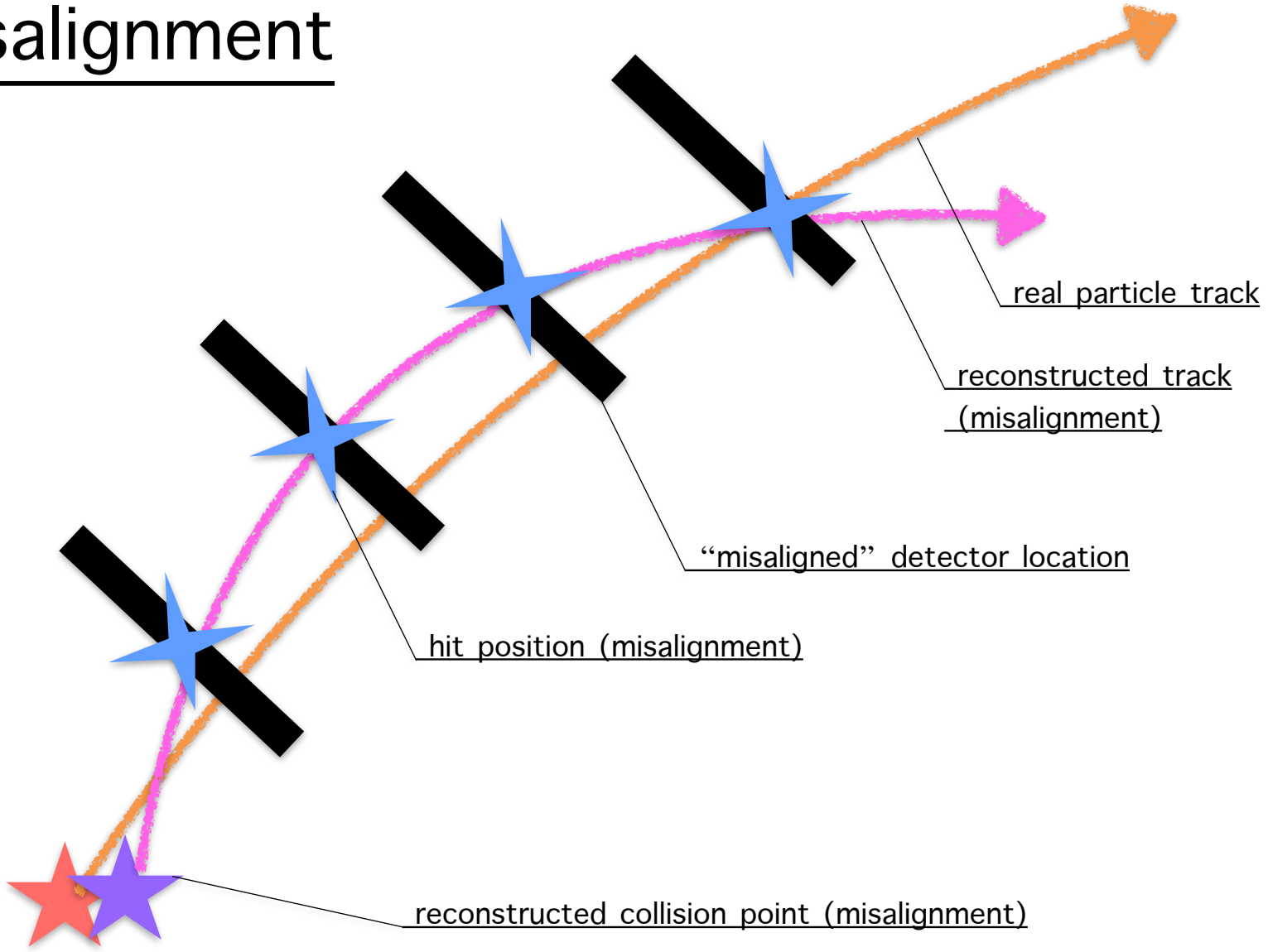


- Primary and secondary vertices with a high resolution (<100μm for p_T>1GeV/c).
- Tracking performance in conjunction with PHENIX main central tracker.

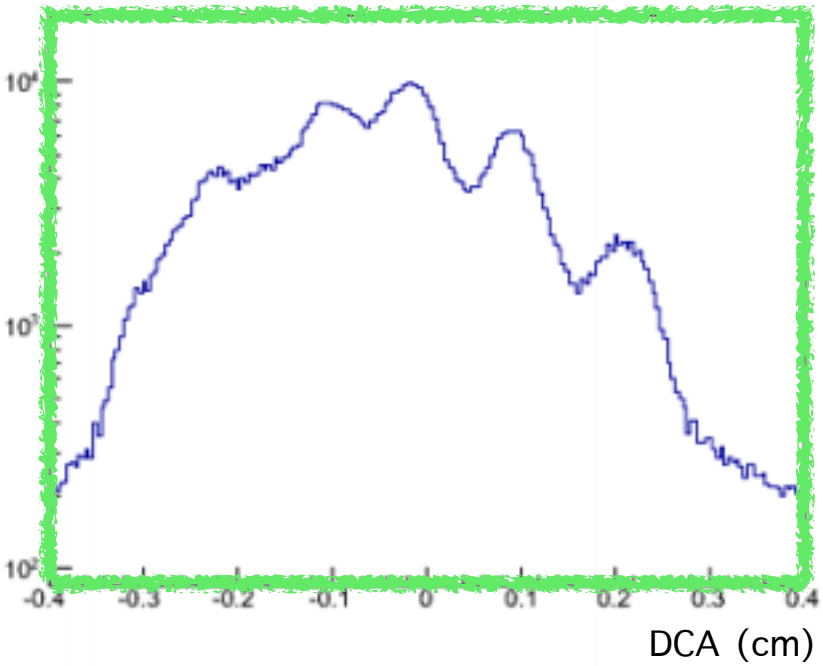
Ideal tracking



Misalignment



DCA w/ misalignment



real particle track

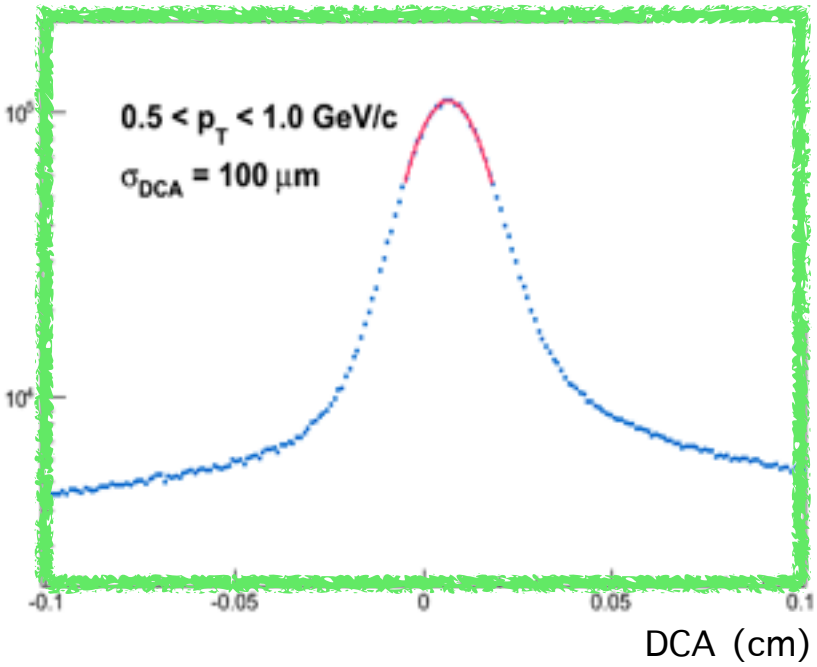
reconstructed track

Distance of Closest Approach (DCA)

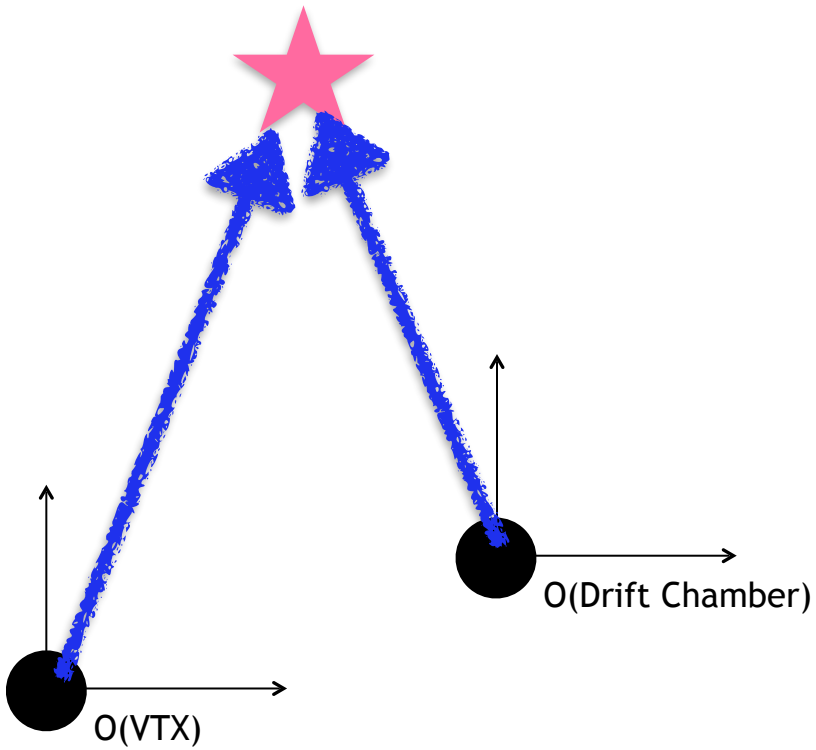
collision point

DCA w/ misalignment

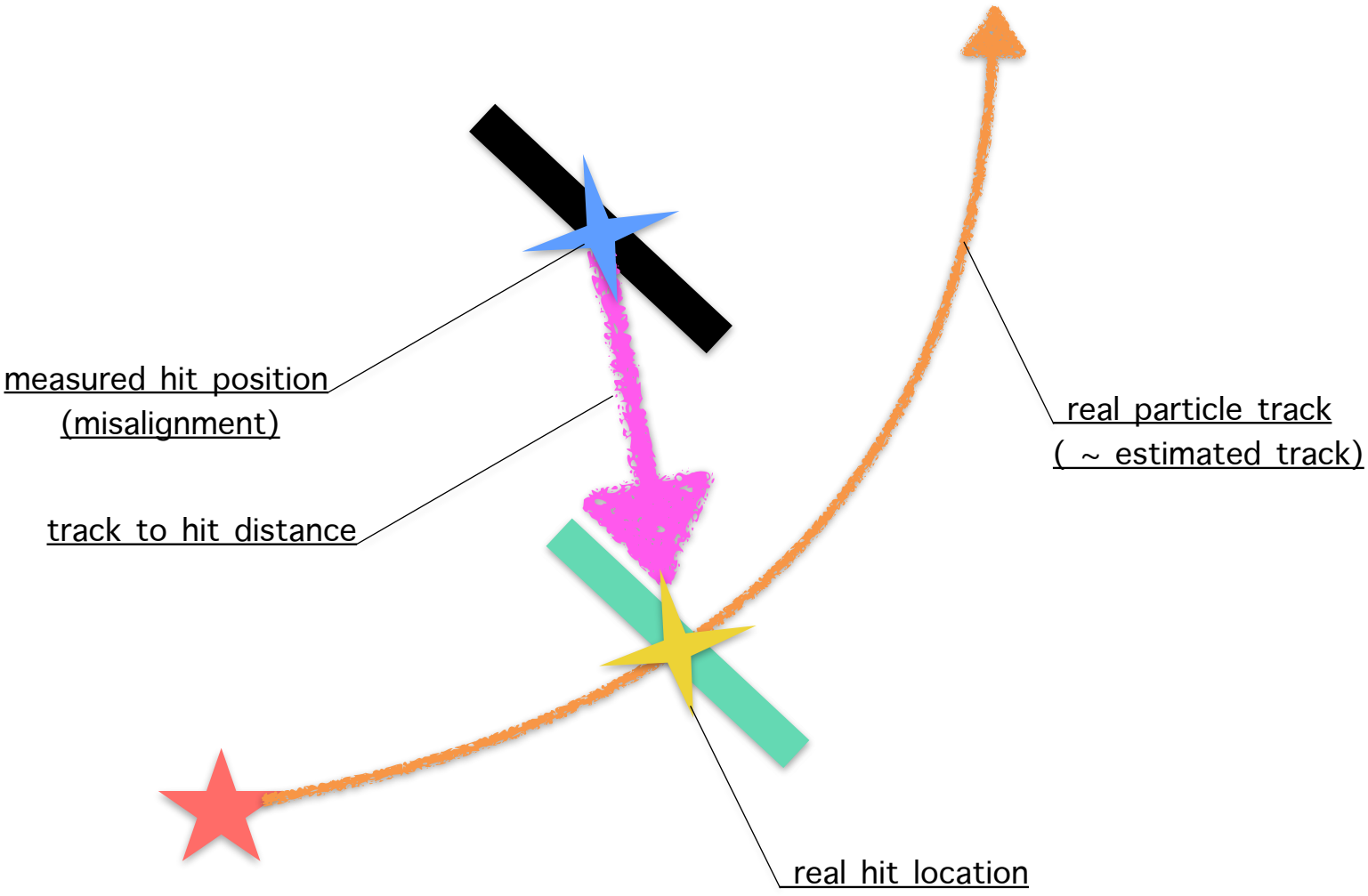
Offset Calibration



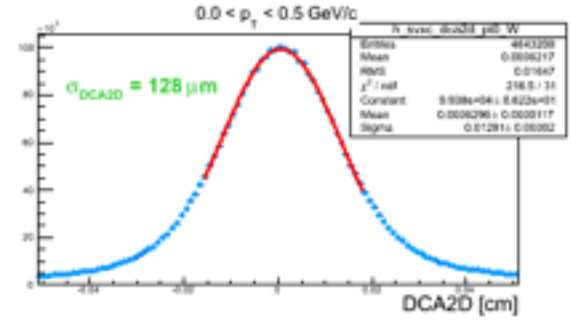
Beam Center
(reference)

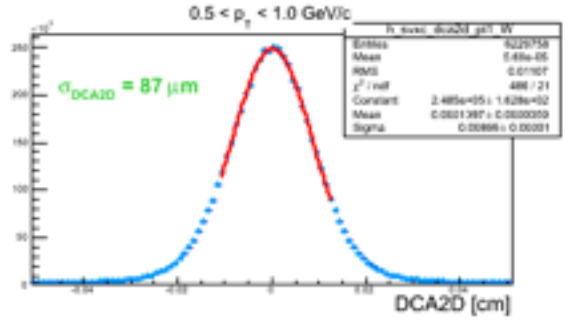


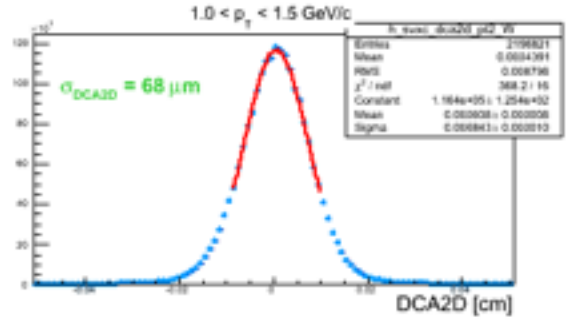
Basic idea of alignment

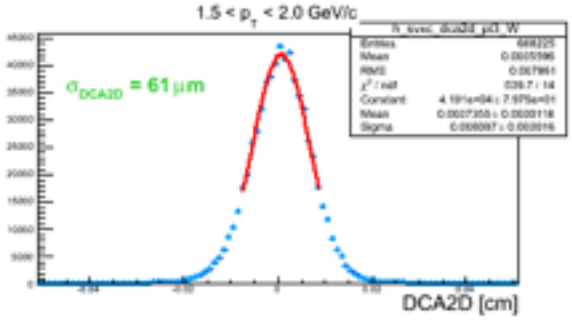


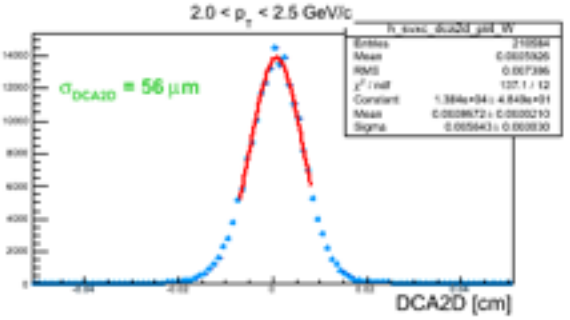
Final result of DCA

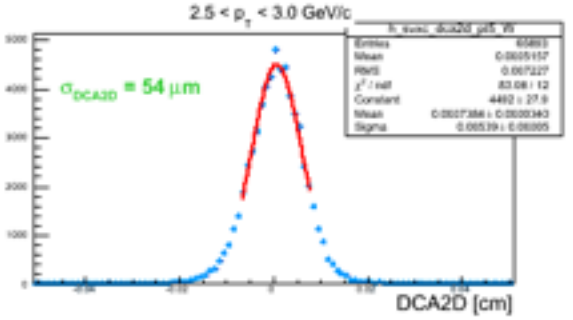


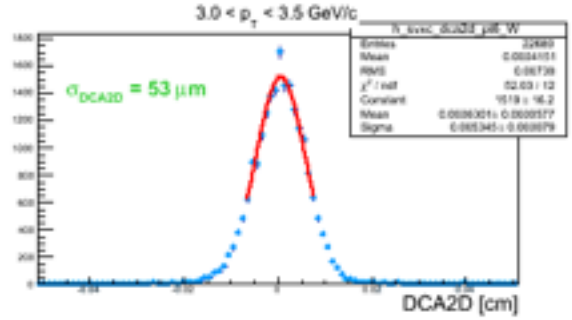


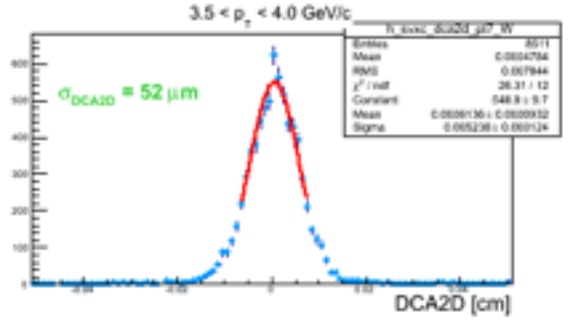


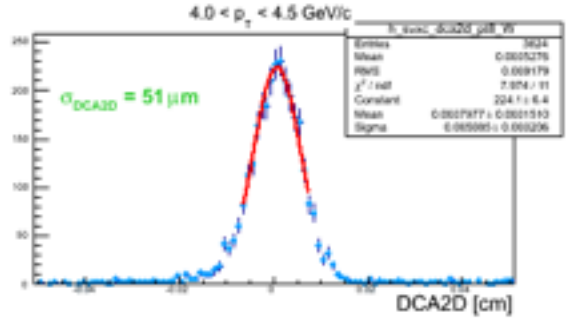




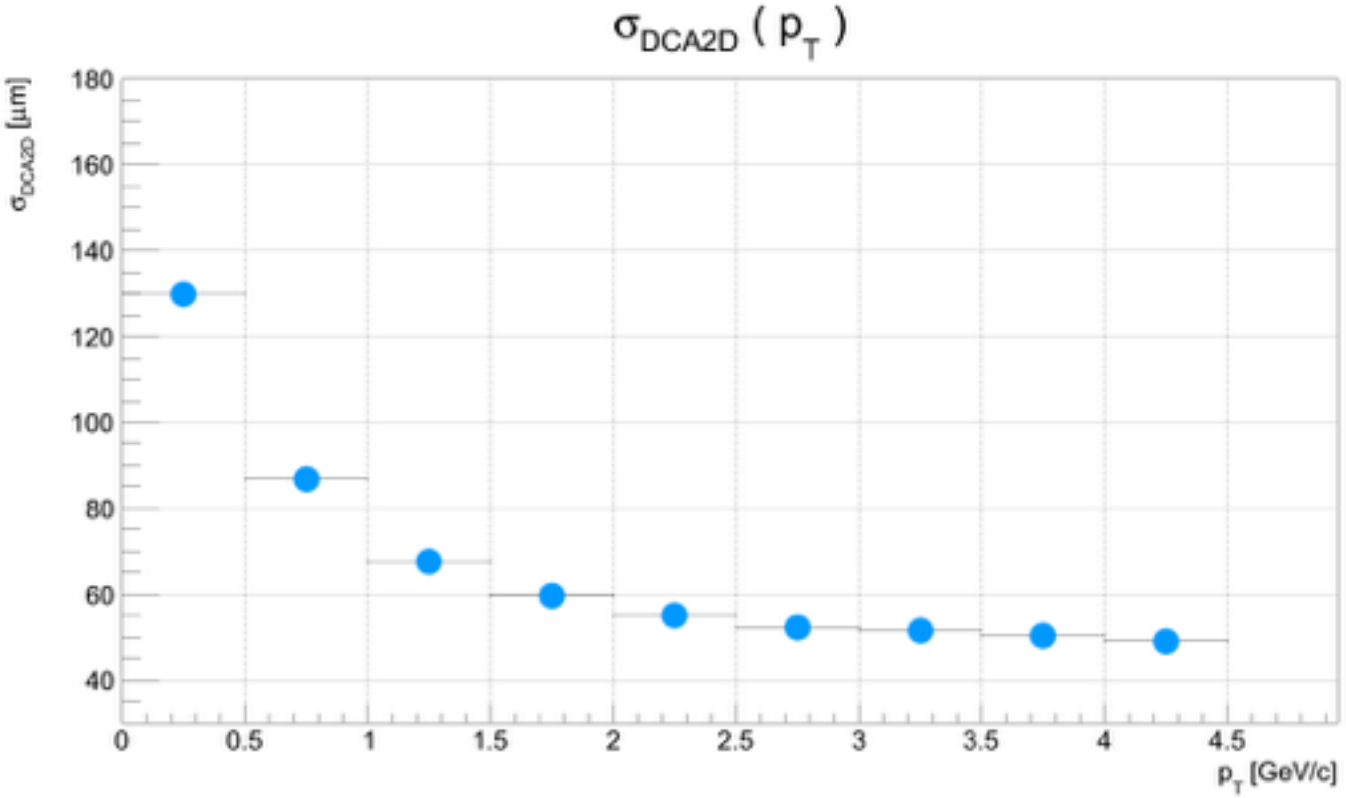




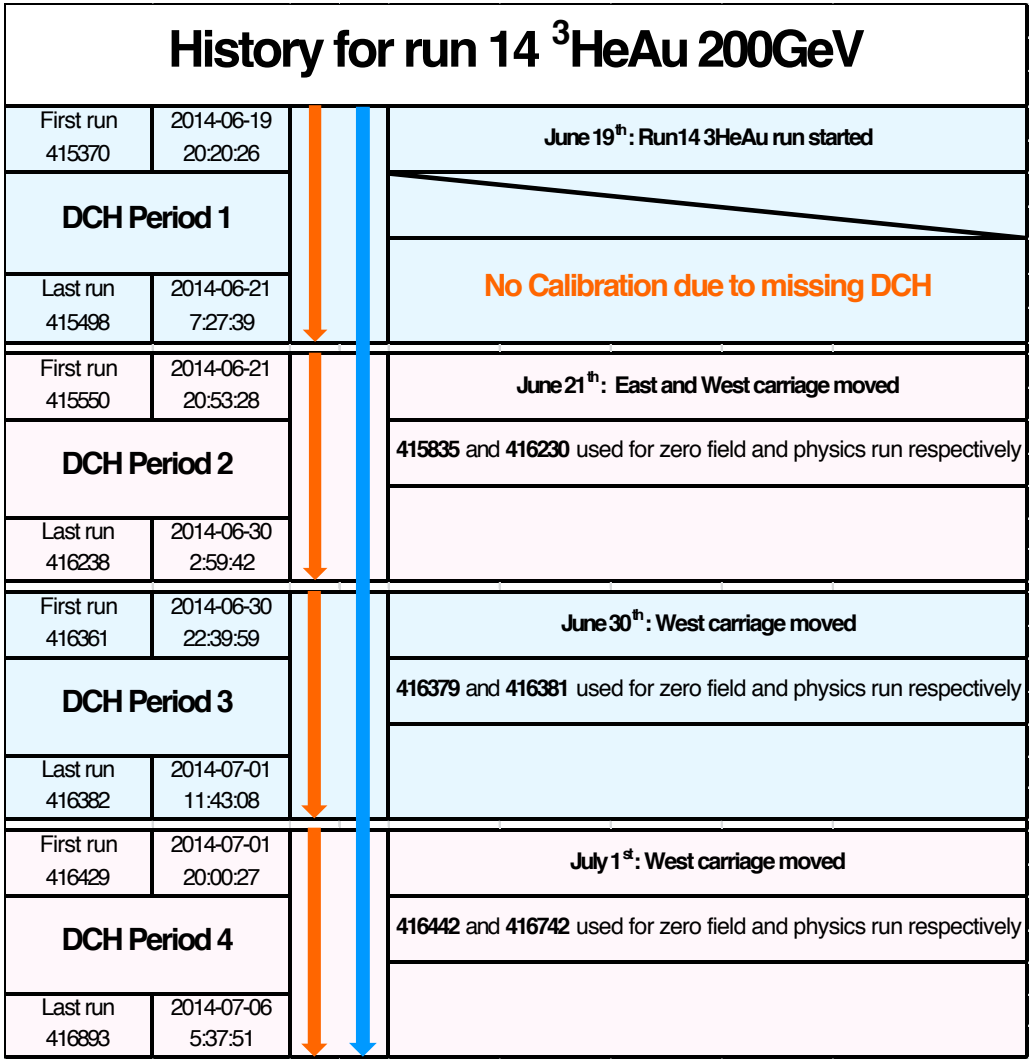




Final result of DCA



Calibration period



DCH moving

VTX moving

Summary

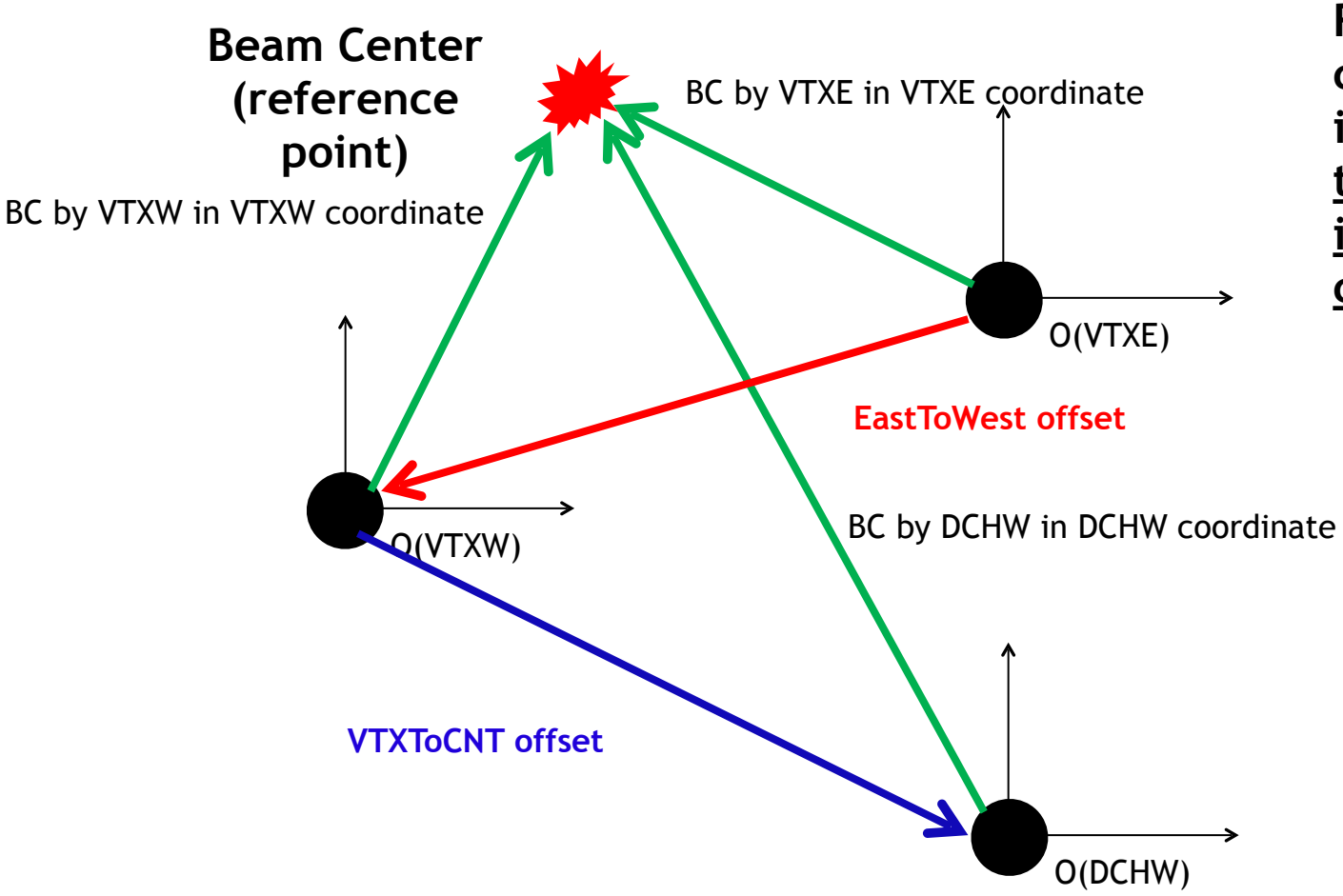
- PHENIX has achieved the DCA resolution < 70μm for 1GeV/c of p_T.
- It enables us to precisely investigate charm and bottom physics.

Thank You !!!

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



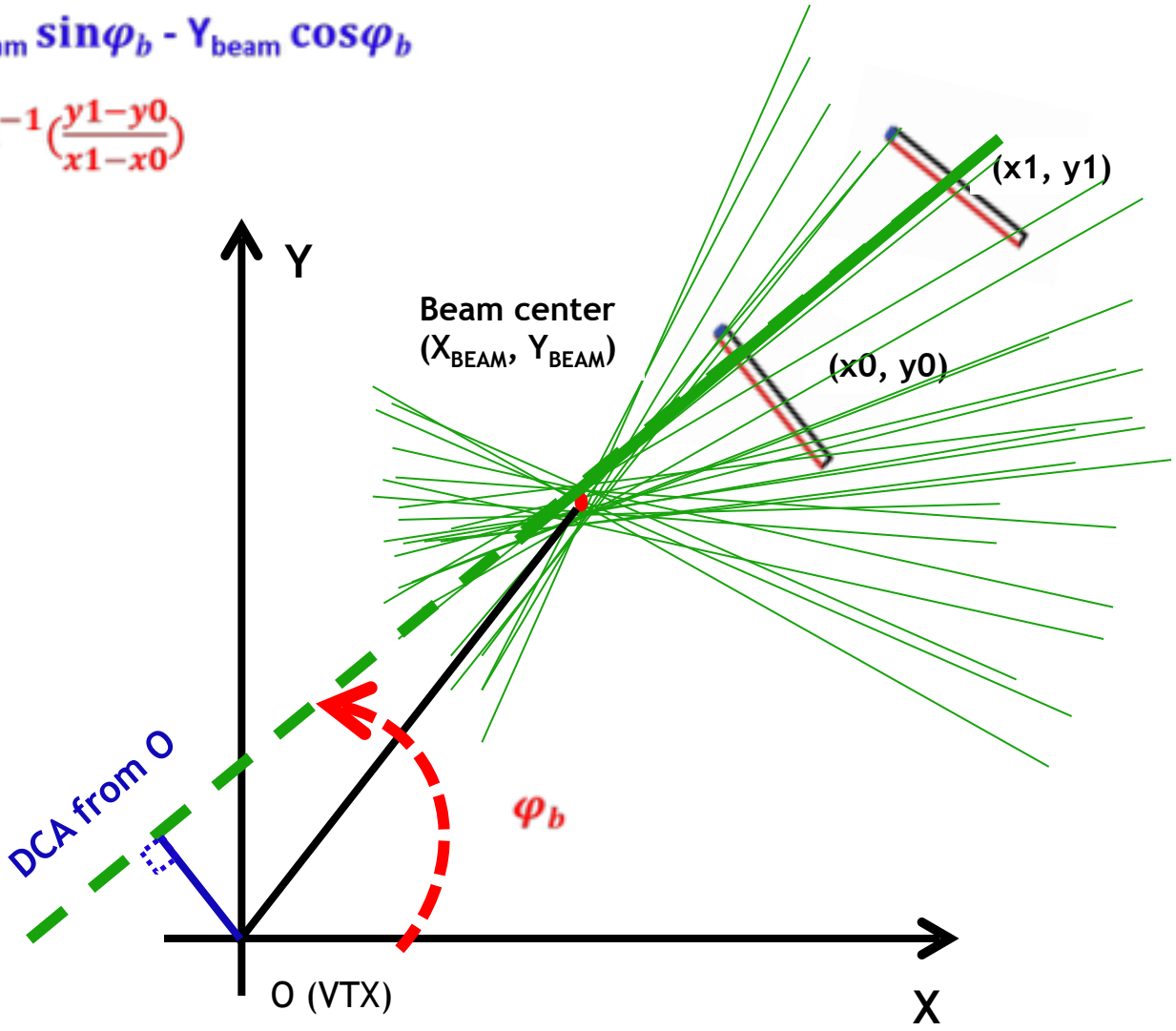
Relative positions can be calculated if we know BCs in their own internal coordinates.

Beam center in the VTX

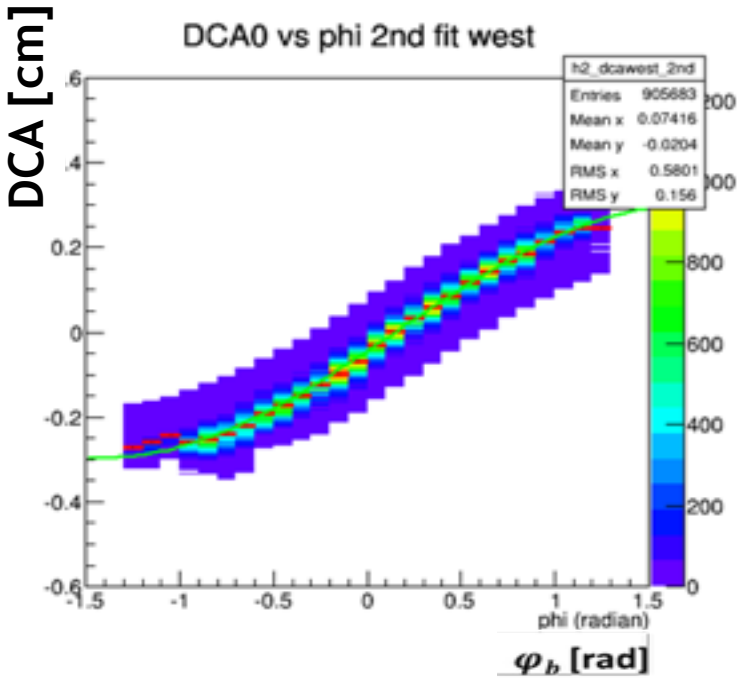
- BC in the VTX can be represented by the following formula.

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

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

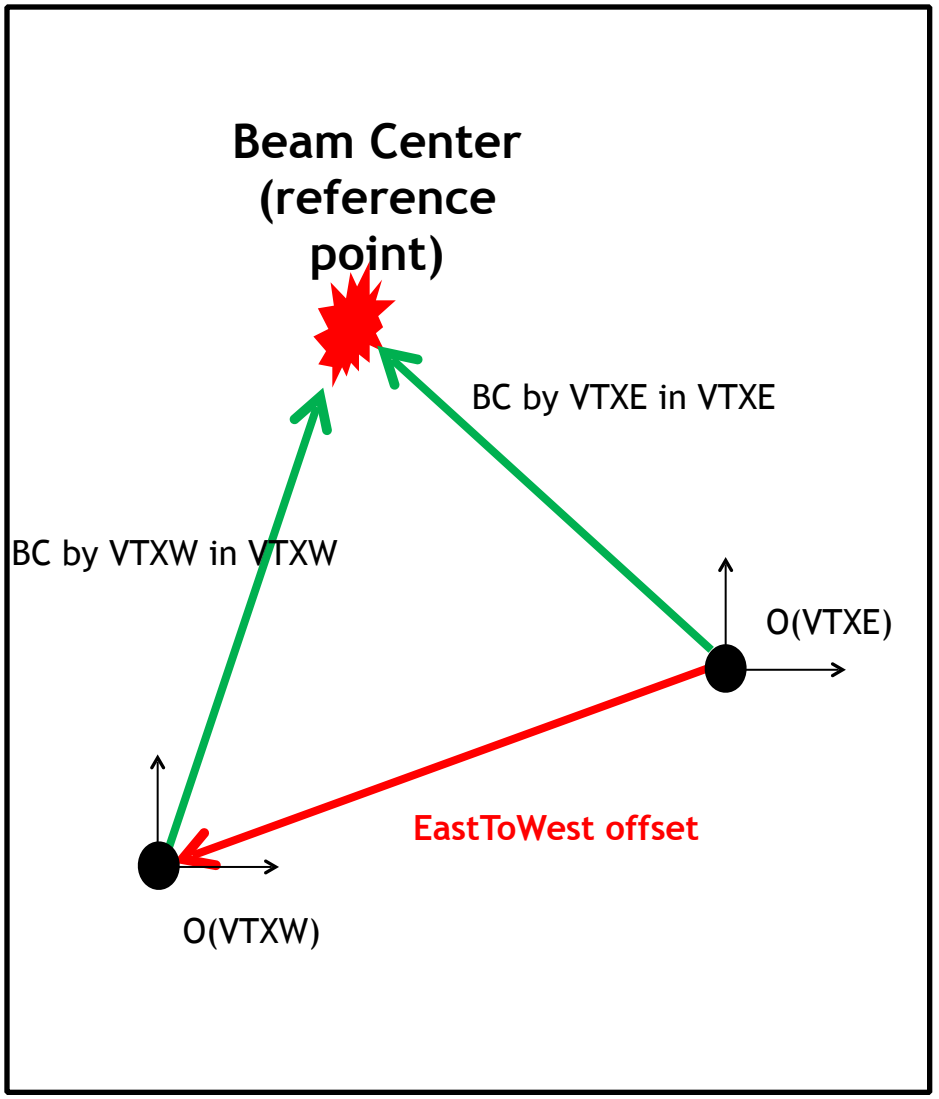


Beam center in the VTX



Fit using the following formula.

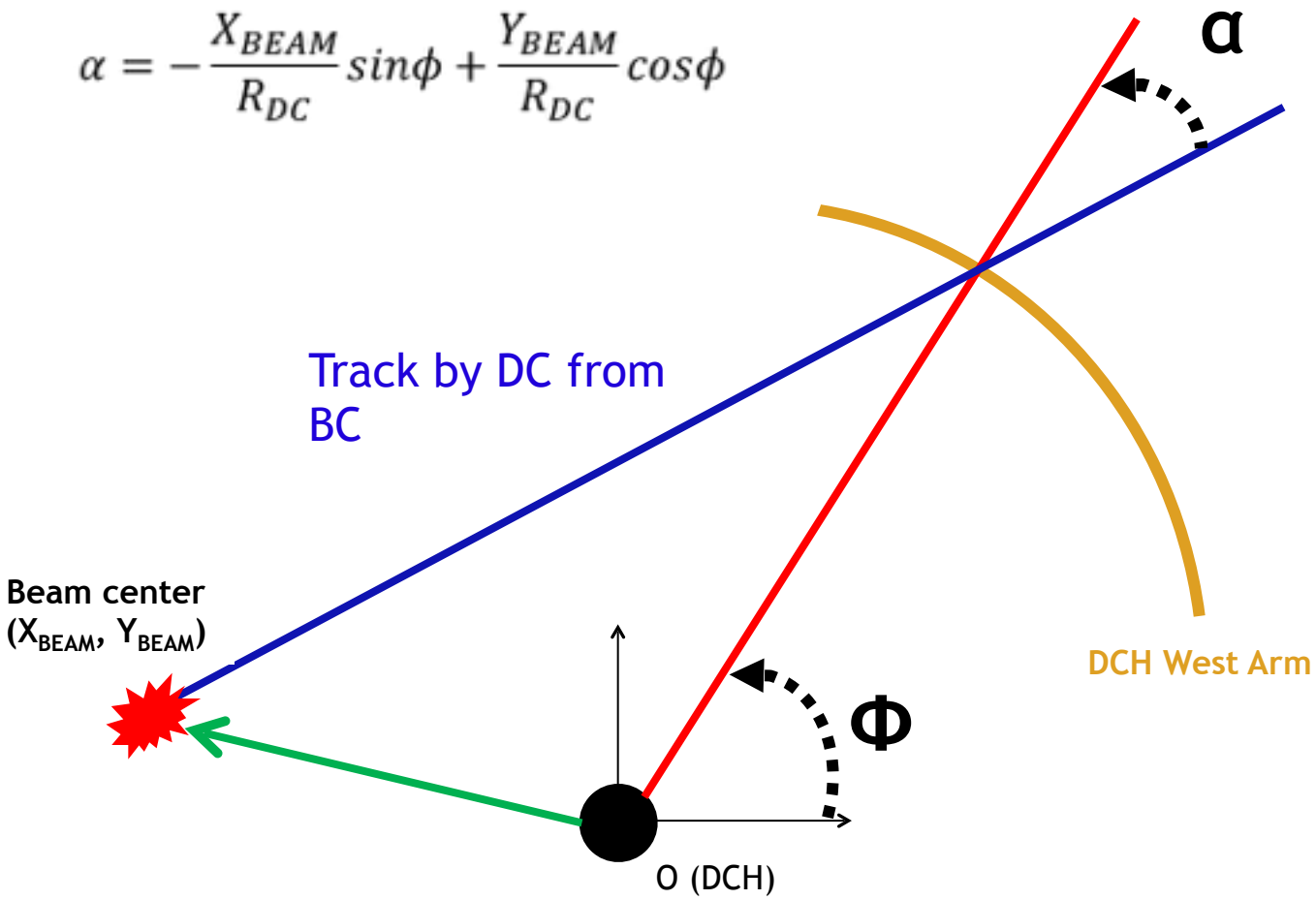
- DCA = P1 * $\sin\varphi_b$ + P2 * $\cos\varphi_b$
- P1 = X_{BEAM} = 0.293613 cm
- P2 = -Y_{BEAM} = 0.047278 cm



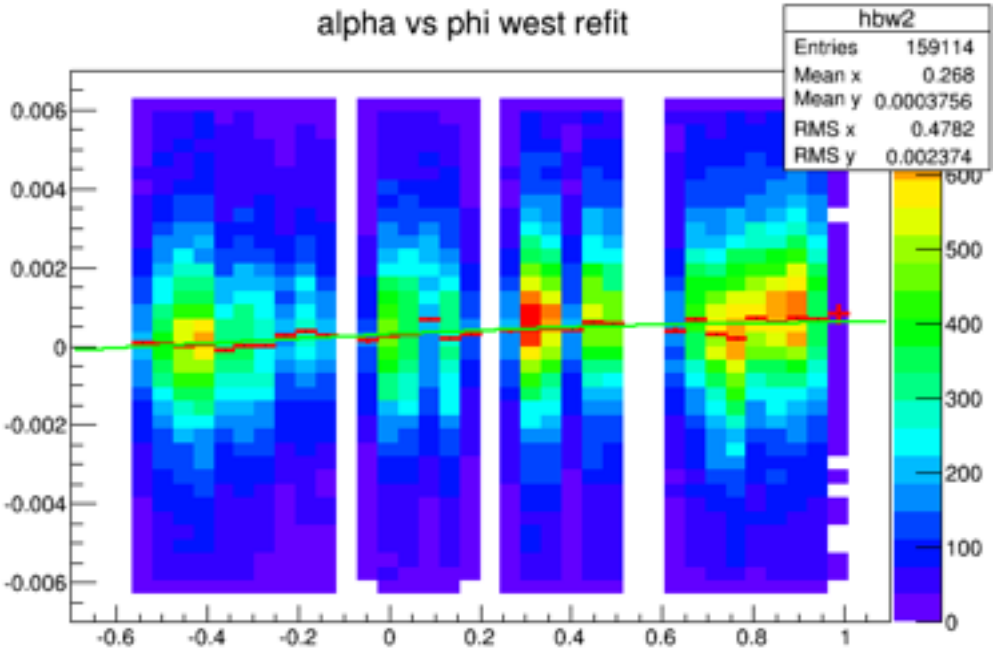
Beam center by DCH

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

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

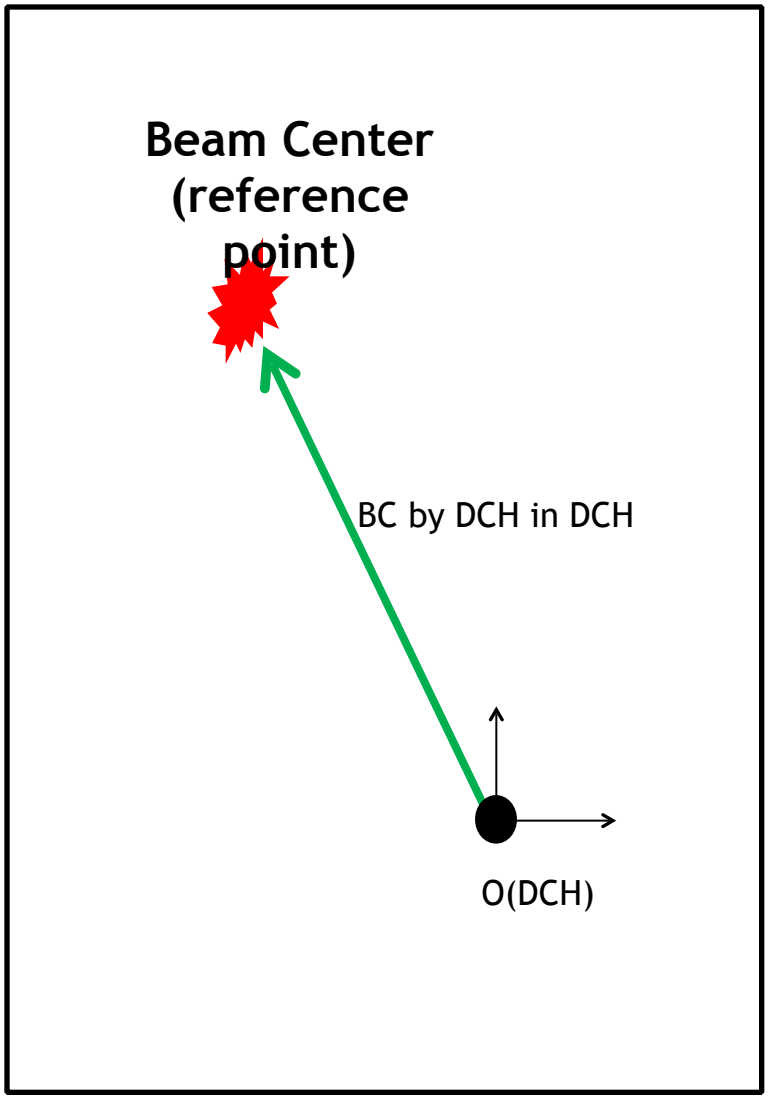


Beam center in the DCH

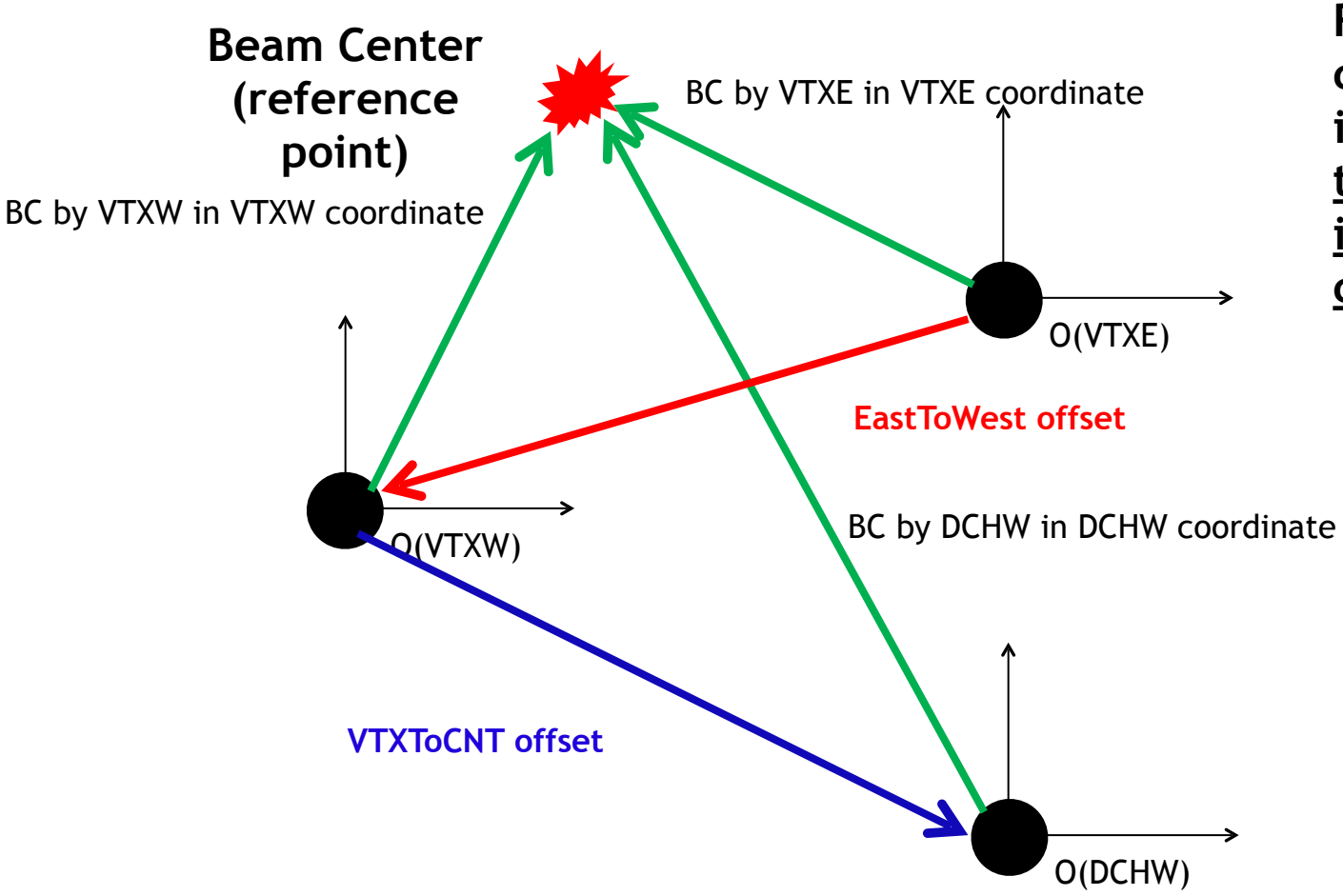


$$X_{BEAM} = -0.115619cm$$

$$Y_{BEAM} = 0.0641195cm$$



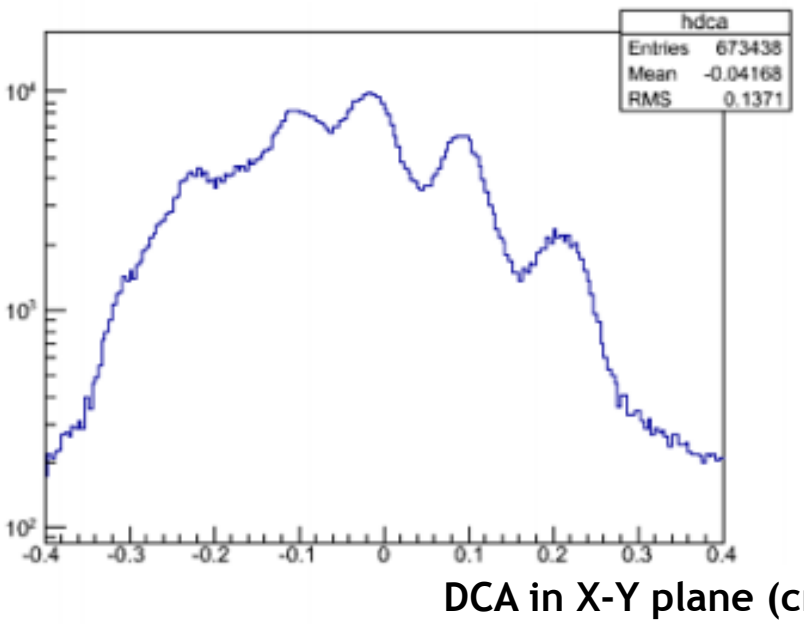
Offset calibration using field-off run



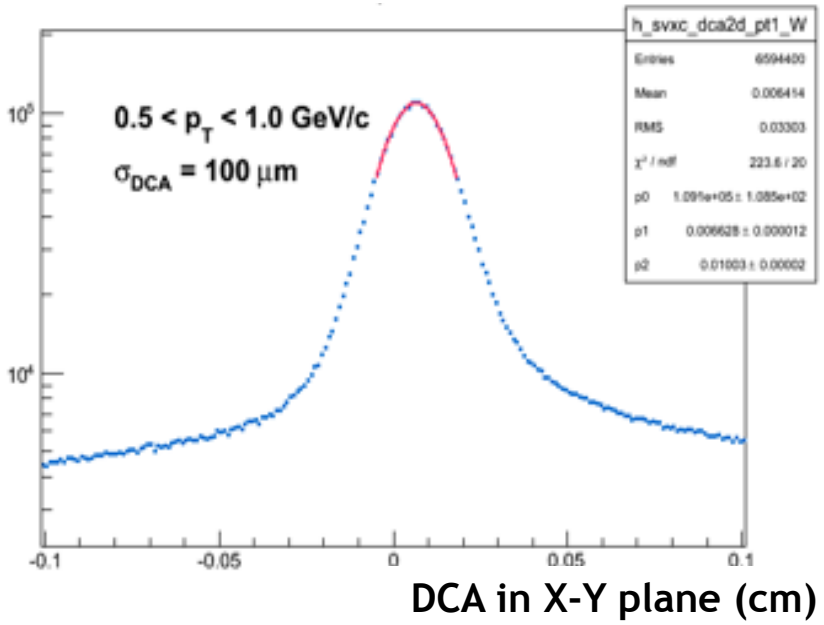
Relative positions can be calculated if we know <u>BCs in their own internal coordinates</u>.

After offset calibration using field-off and -on run

Before offset calib

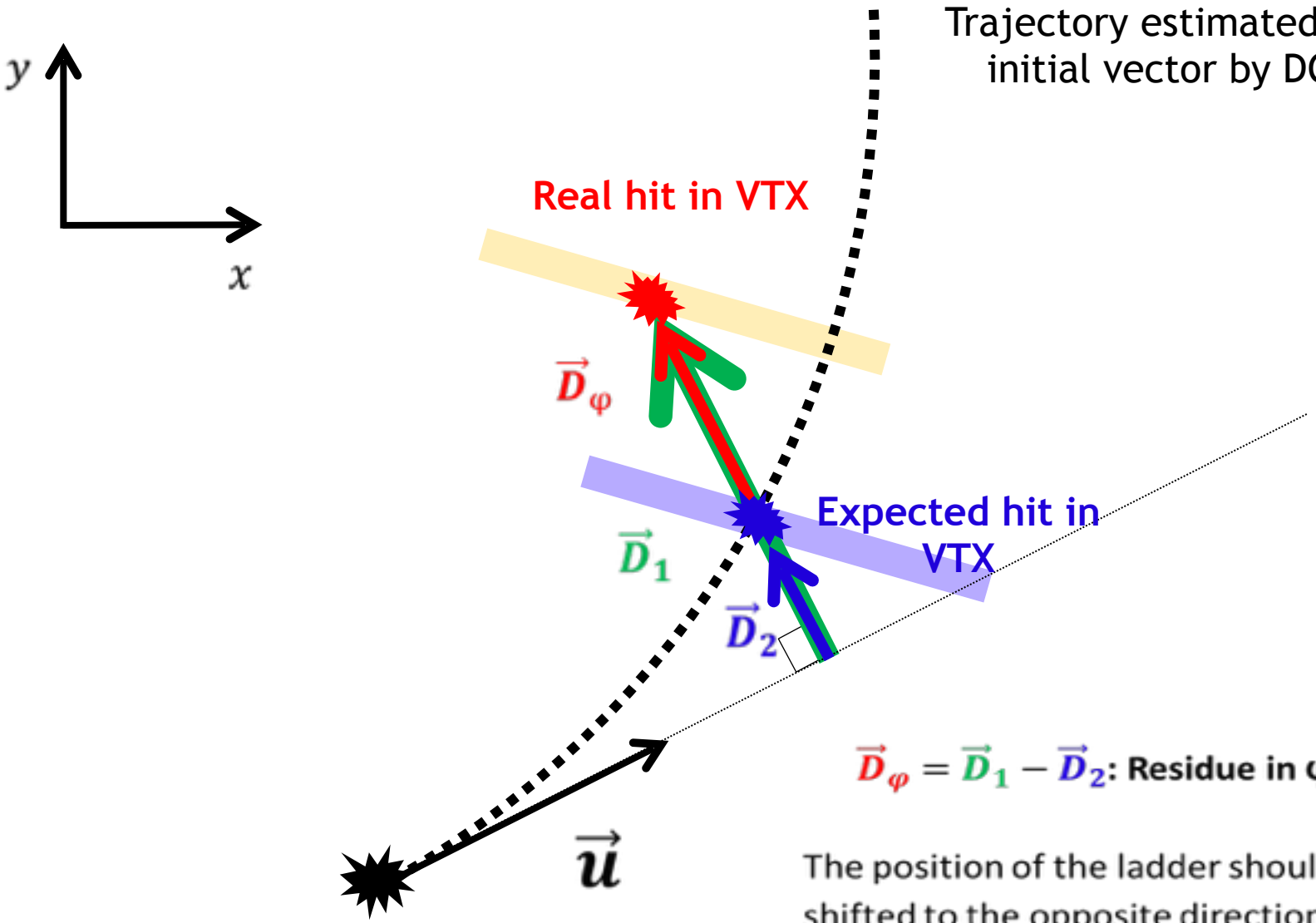


After offset calib



- 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.

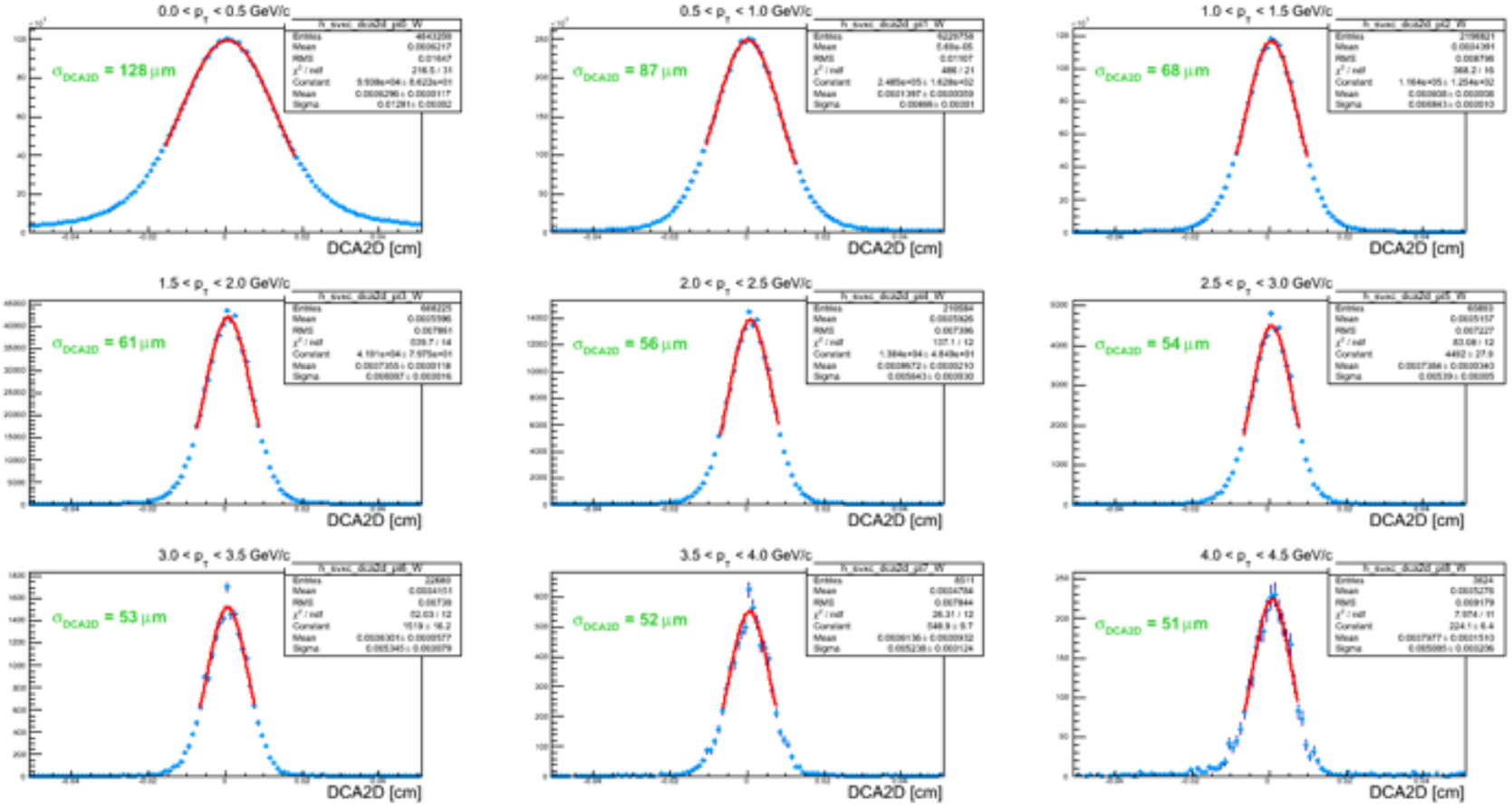
Alignment in φ (ladder by ladder)



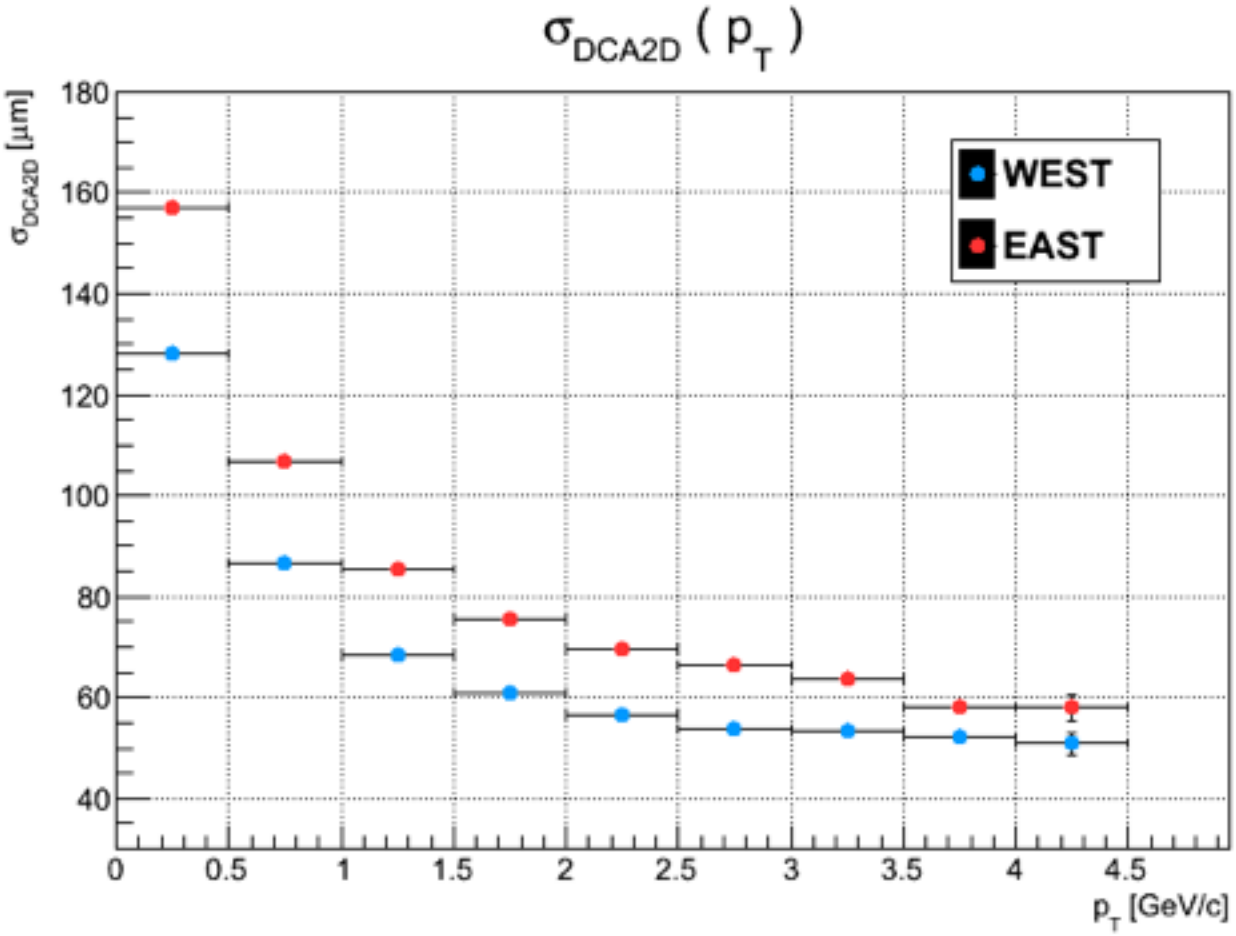
$\vec{D}_\varphi = \vec{D}_1 - \vec{D}_2$: Residue in φ.

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.

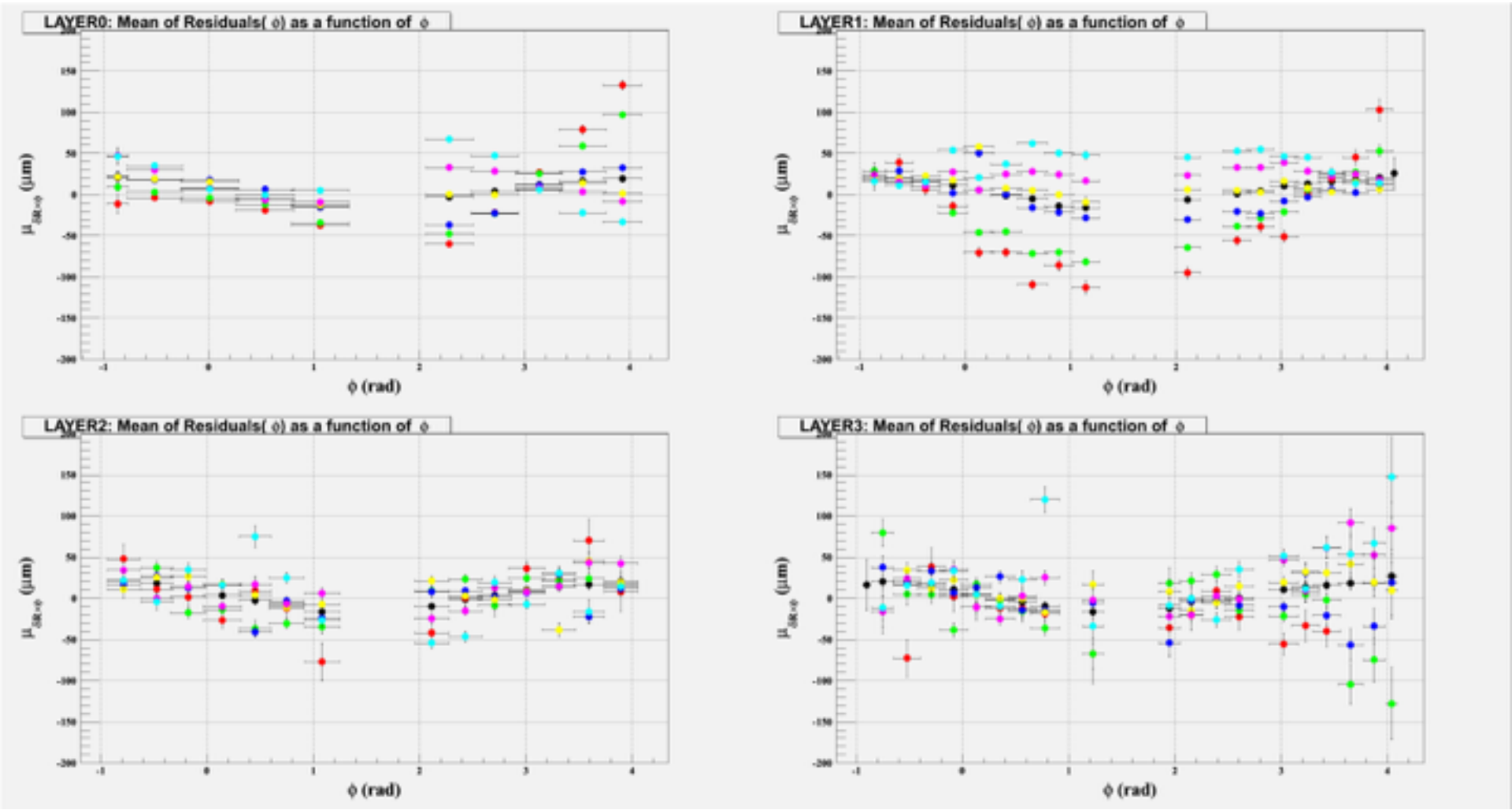
History for run 14 ^{3}HeAu 200GeV

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 21th: 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+user26/phnxreco/Takashi_VTX_libyl/tmoon/dsts/5_Akiba/2_p2Out/macros

Summary

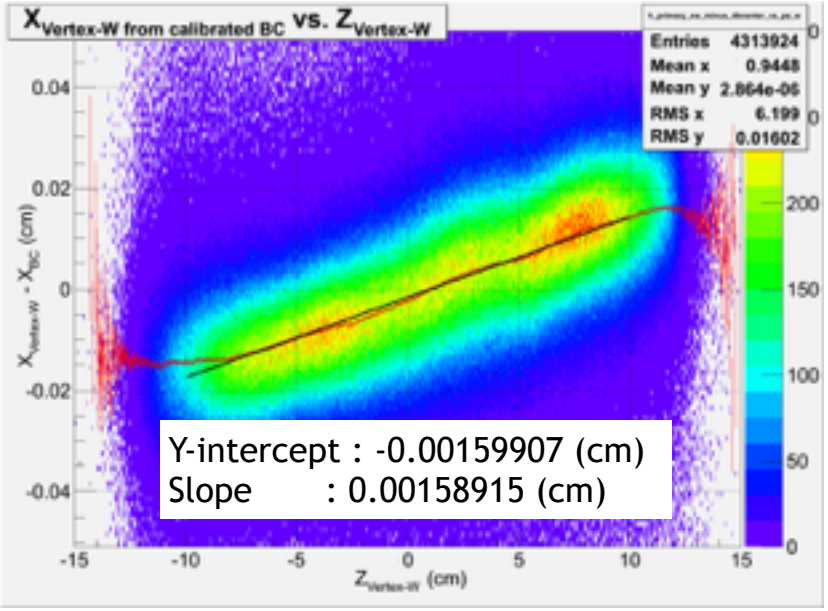
- Alignment finished and we chieved a good DCA resolution less than 70 micron when pT is 1GeV/c.

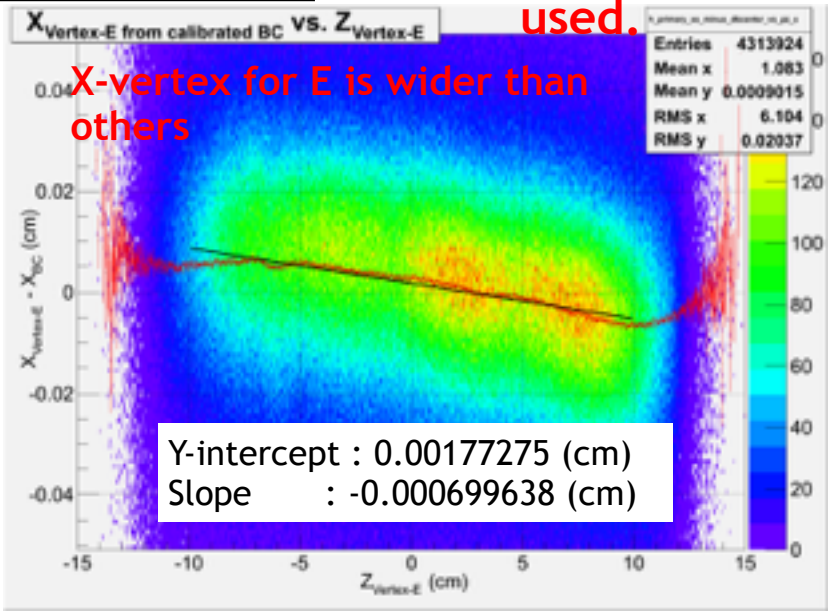
- There is room for improvement of DCA.
  - Rotation of the coordinate and/or the ladder in VTX
  - Cosideration of the DCHE coordinate system.

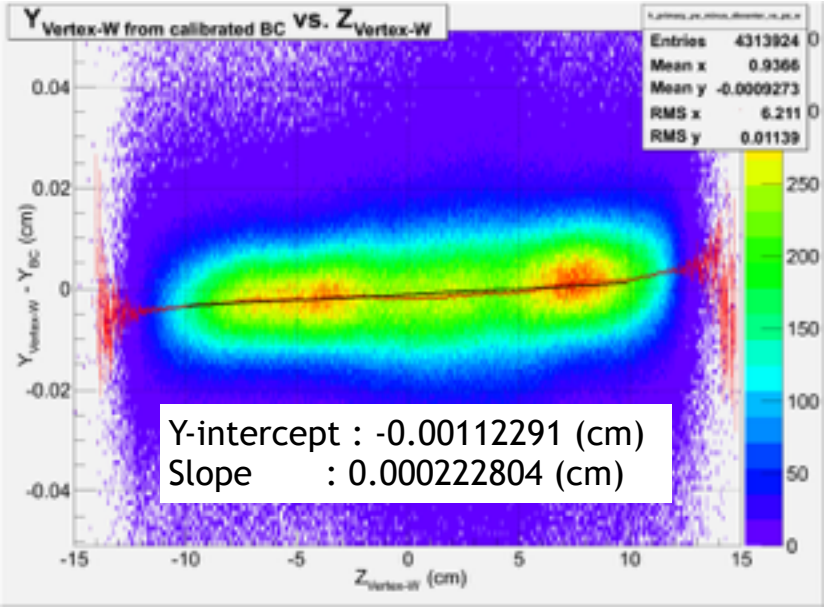
Thanks!

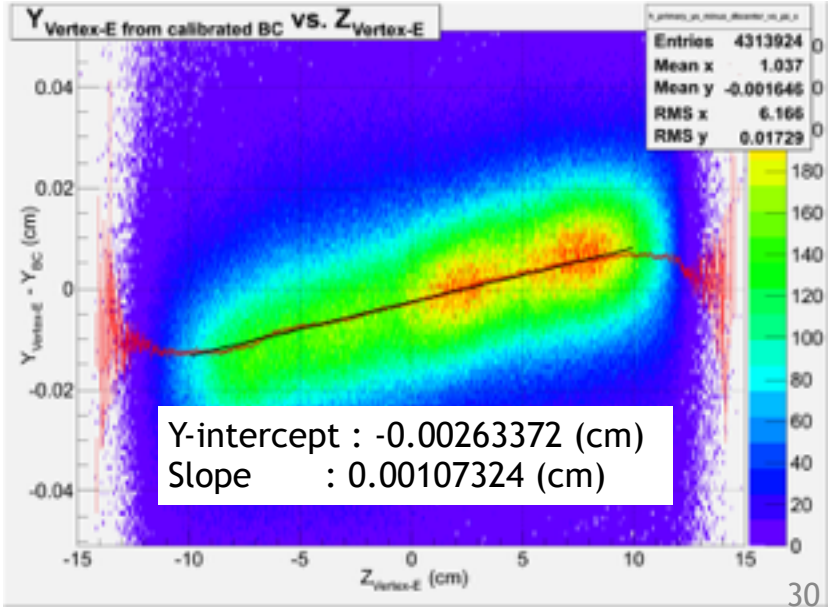
Get paramenters from linear fit.

*523 PRDFs used.









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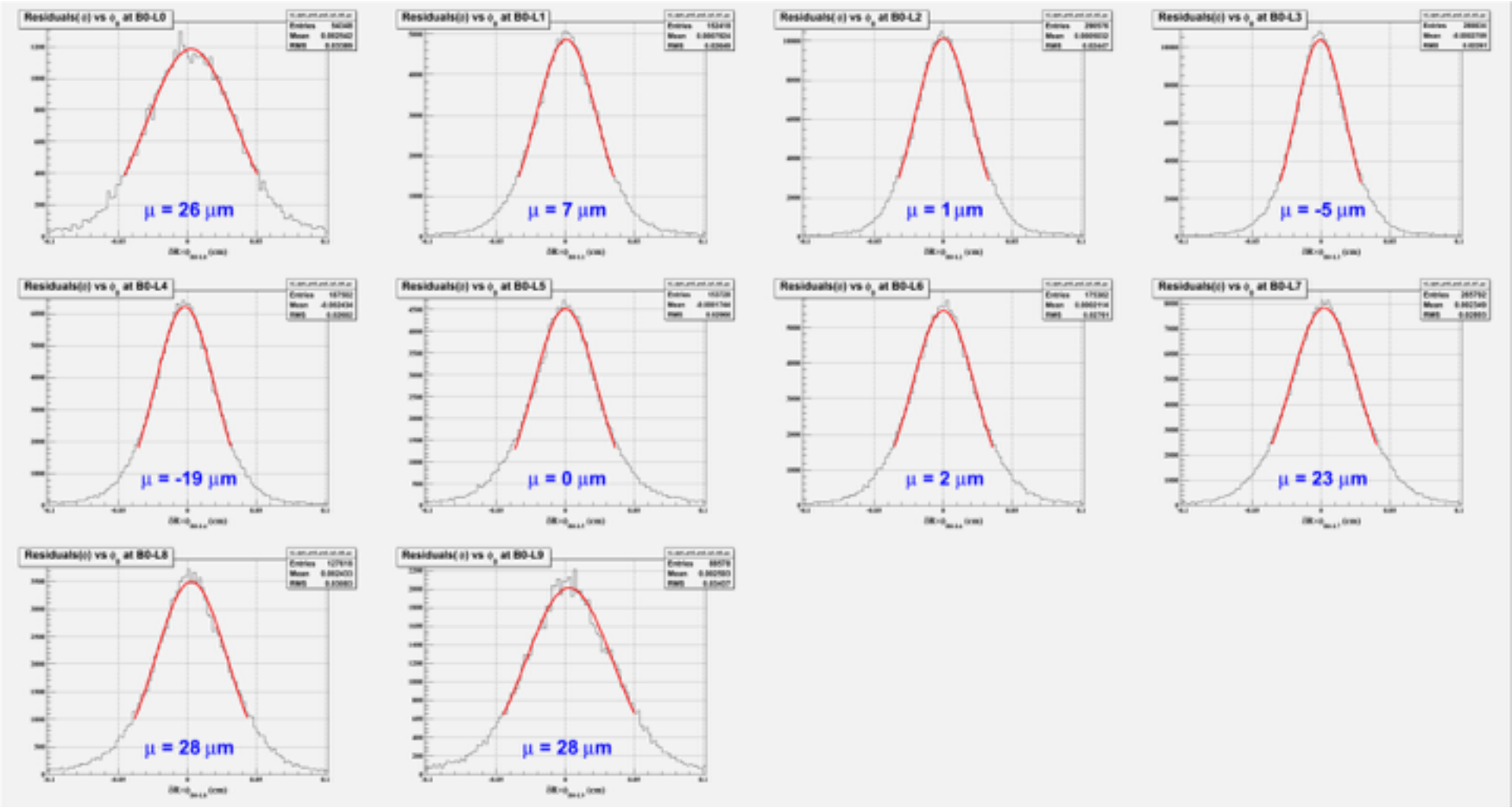
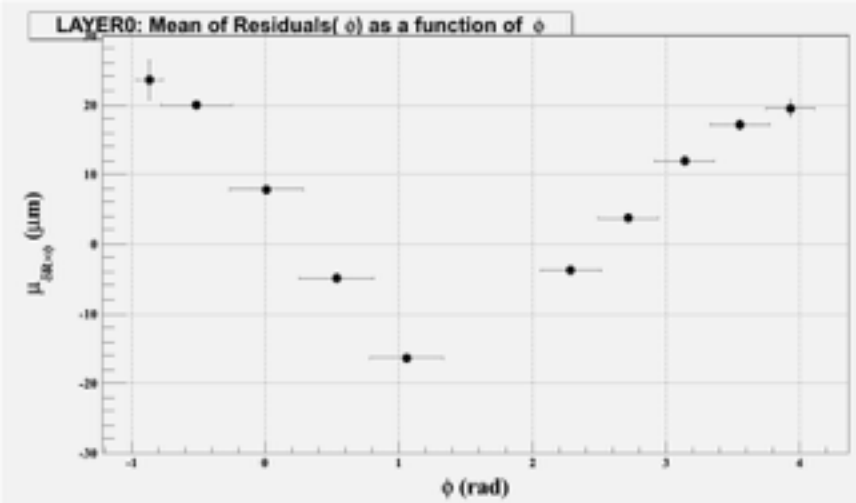
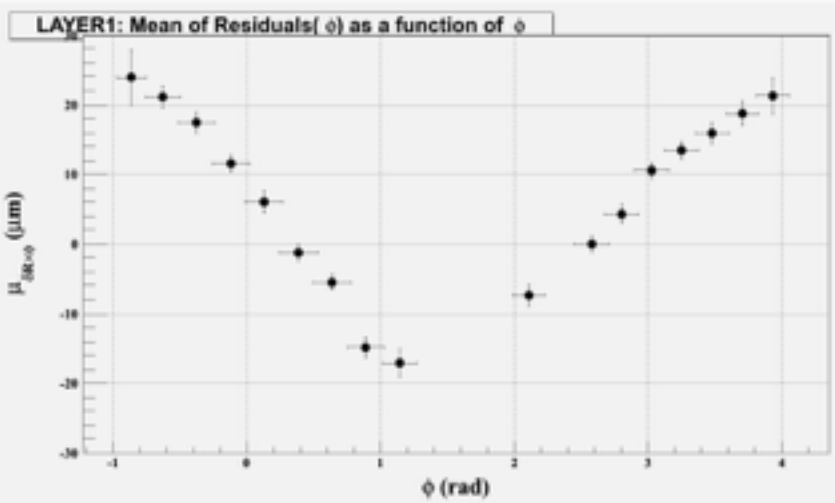
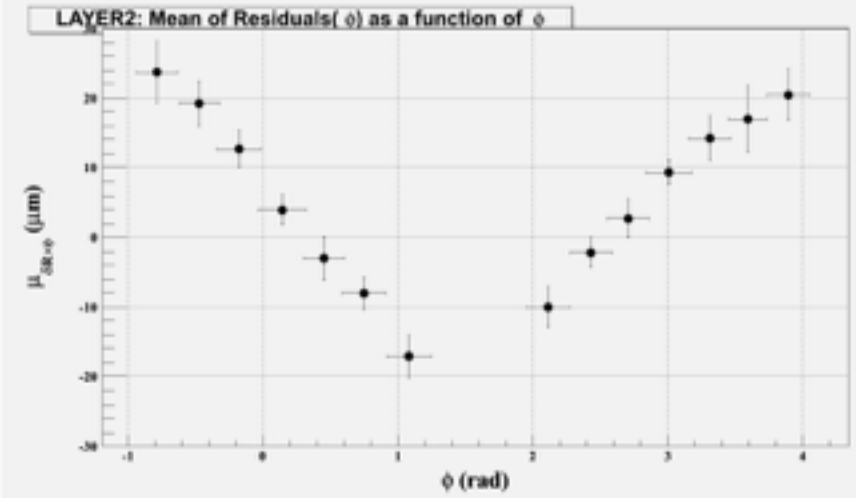
Residue in phi for B0

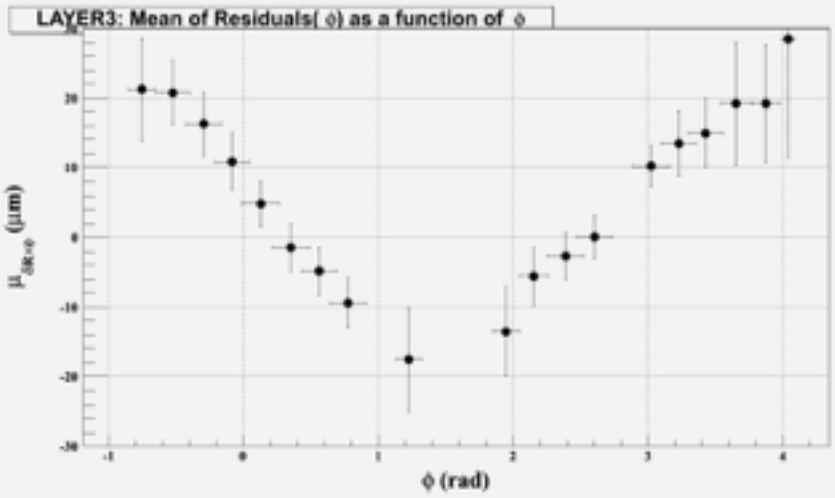


Mean of residue in phi



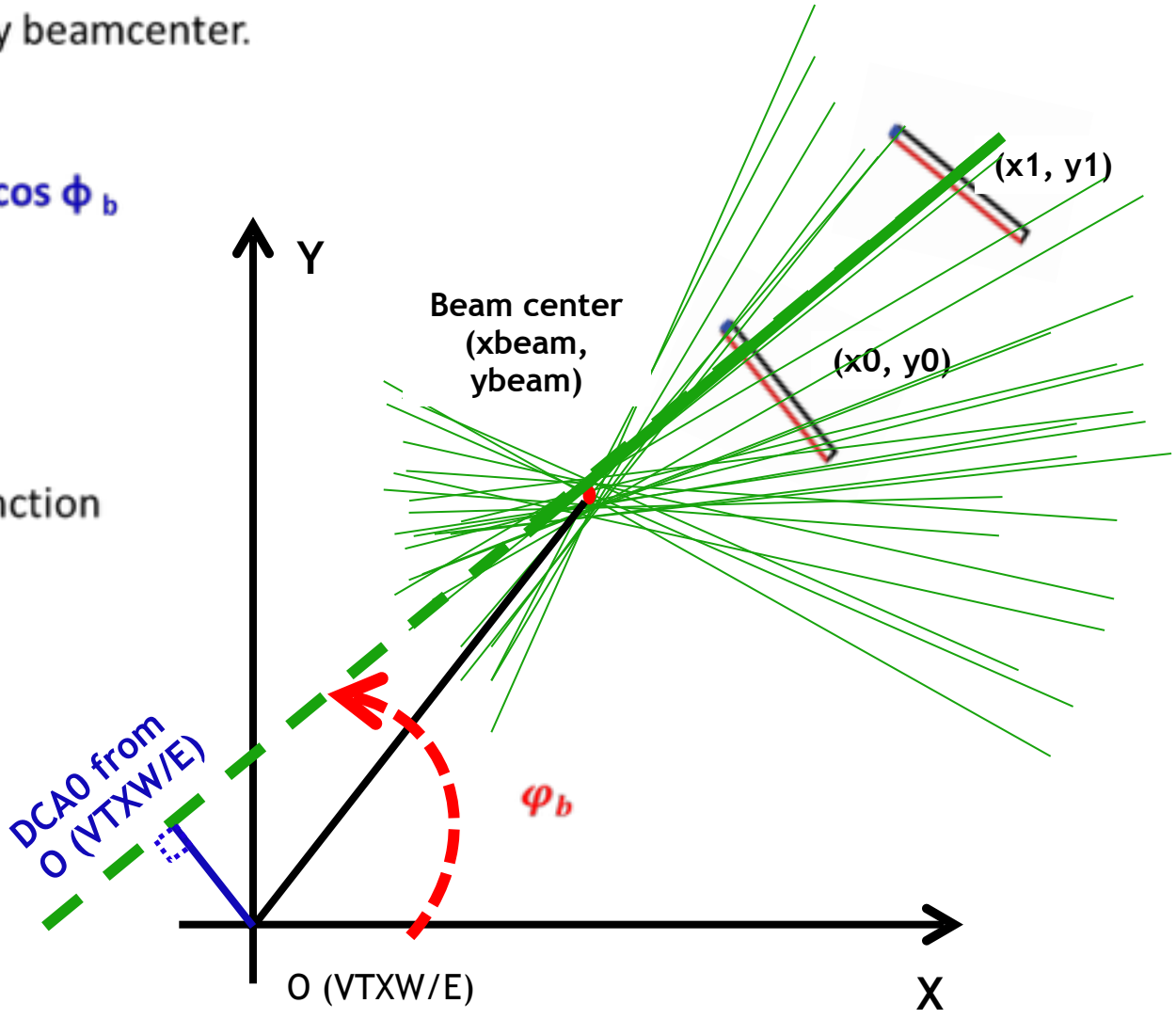






DCA0 formula for fitting

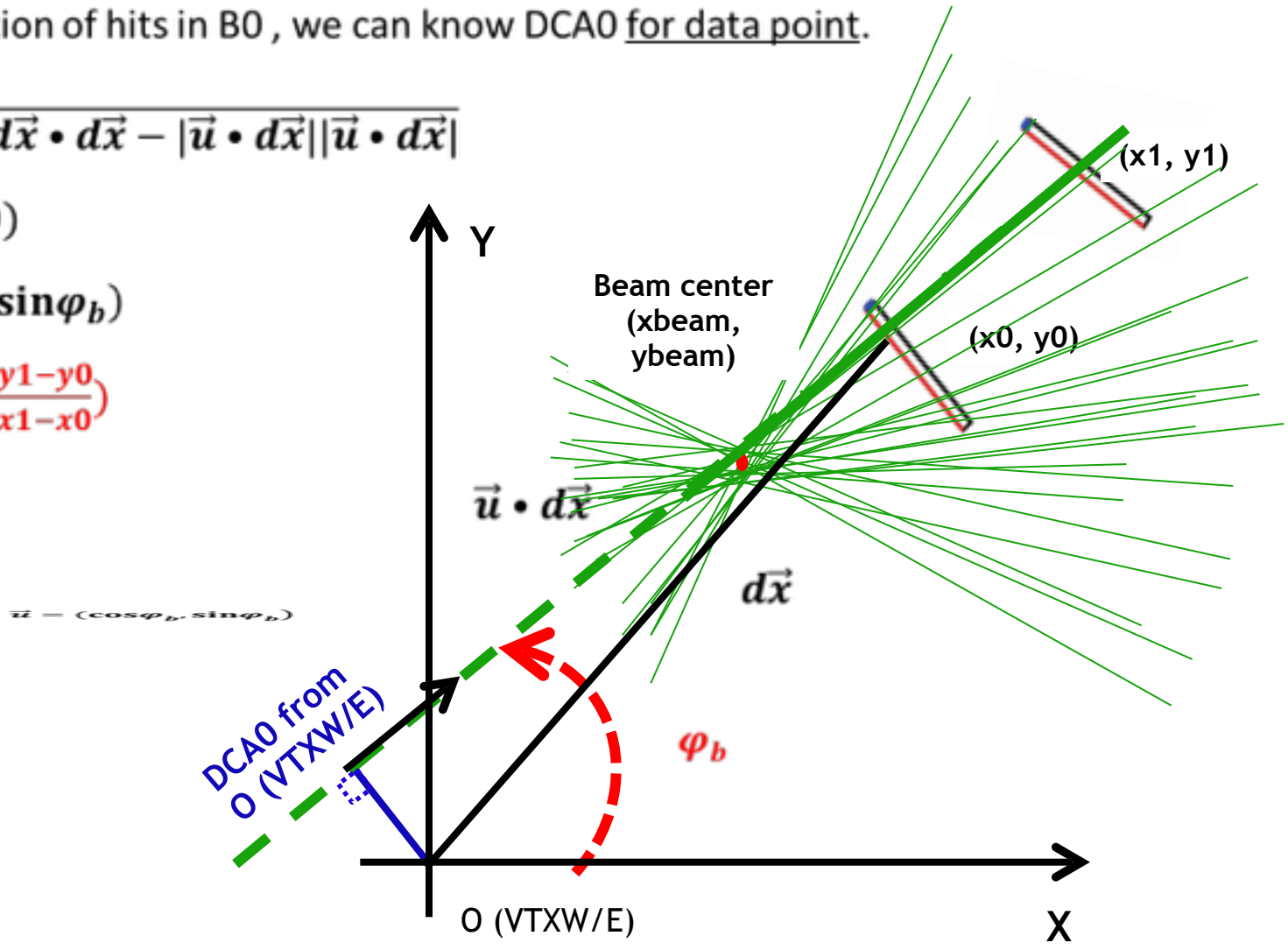
- DCA0 can be represented by beamcenter.
- **For fitting,**
  $DCA0 = X_{beam} \sin \phi_b - Y_{beam} \cos \phi_b$
- $\varphi_b = tan^{-1}(\frac{y1-y0}{x1-x0})$
- Before fitting, DCA0 as a function of φ_b should be known.



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.
- $|DCA0| = \sqrt{d\vec{x} \bullet d\vec{x} - |\vec{u} \bullet d\vec{x}||\vec{u} \bullet d\vec{x}|}$
- $d\vec{x} = (x0, y0)$
- $\vec{u} = (\cos\varphi_b, \sin\varphi_b)$
- $\varphi_b = tan^{-1}(\frac{y1-y0}{x1-x0})$



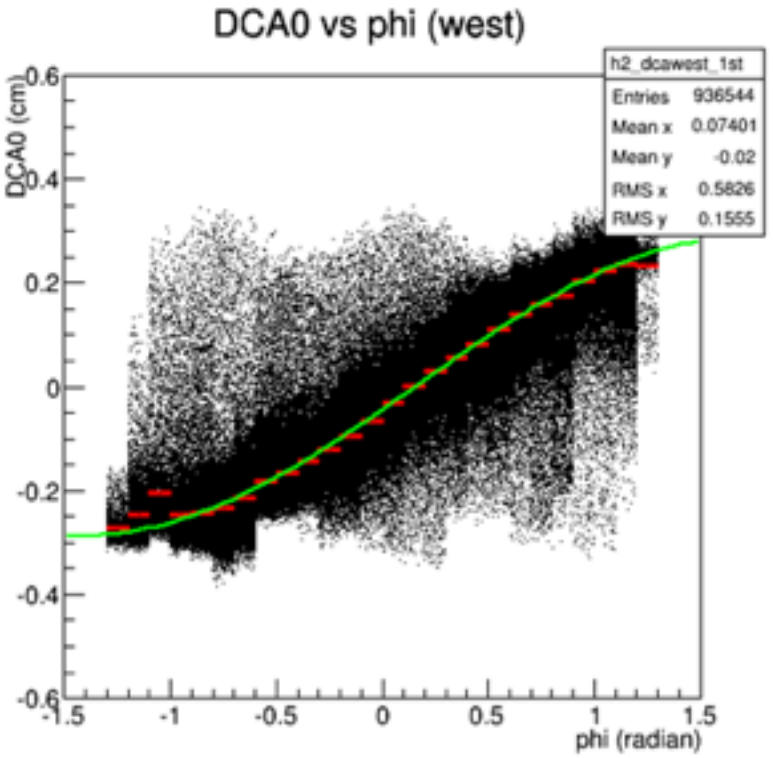
This is calculated in VTX internal coordinate

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.



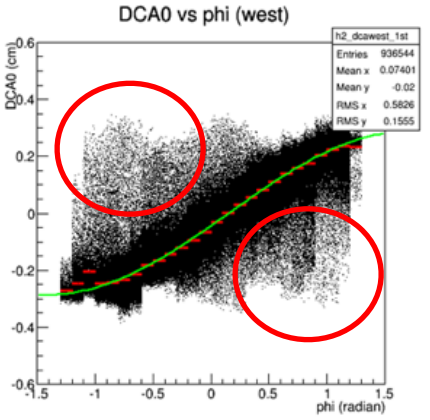
ZEROFDATA_P00_0000405836_000(0~19).PRDFF
Run Number : 406541
Energy : 200 GeV
Number of events : 1.315M

Beam center by VTX : background reduction

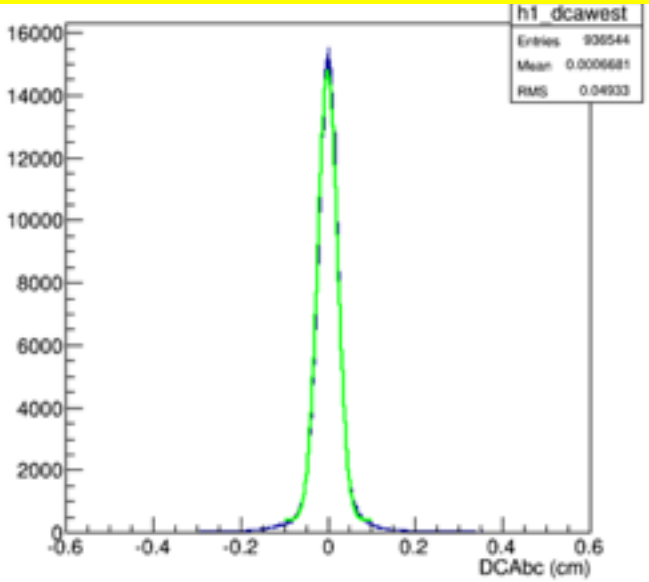
- Before 2nd iteration, let's eliminate background.
- Calculate DCA0 - par[0]sin Φ_b - par[1]cos Φ_b.
  - par[0] = 0.285206
  - par[1] = -0.0465125
- Fitting function.

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

- Get σ from fitting.
- Apply 5-sigma cut
  - |DCA0 - par[0]sin Φ_b - par[1]cos Φ_b| < 5σ

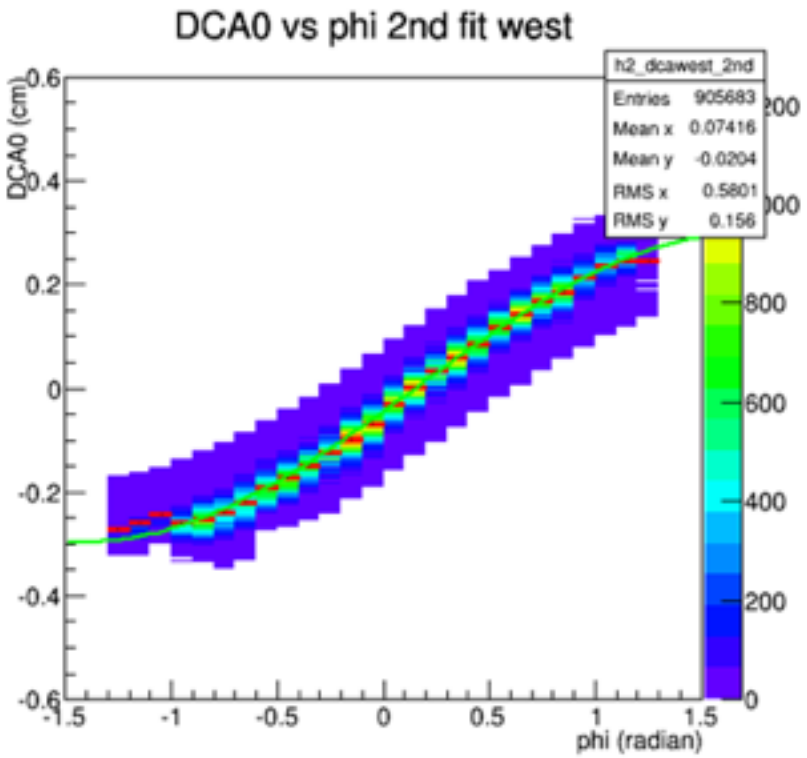


DCA0 - par[0]sin Φ_b - par[1]cos Φ_b



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

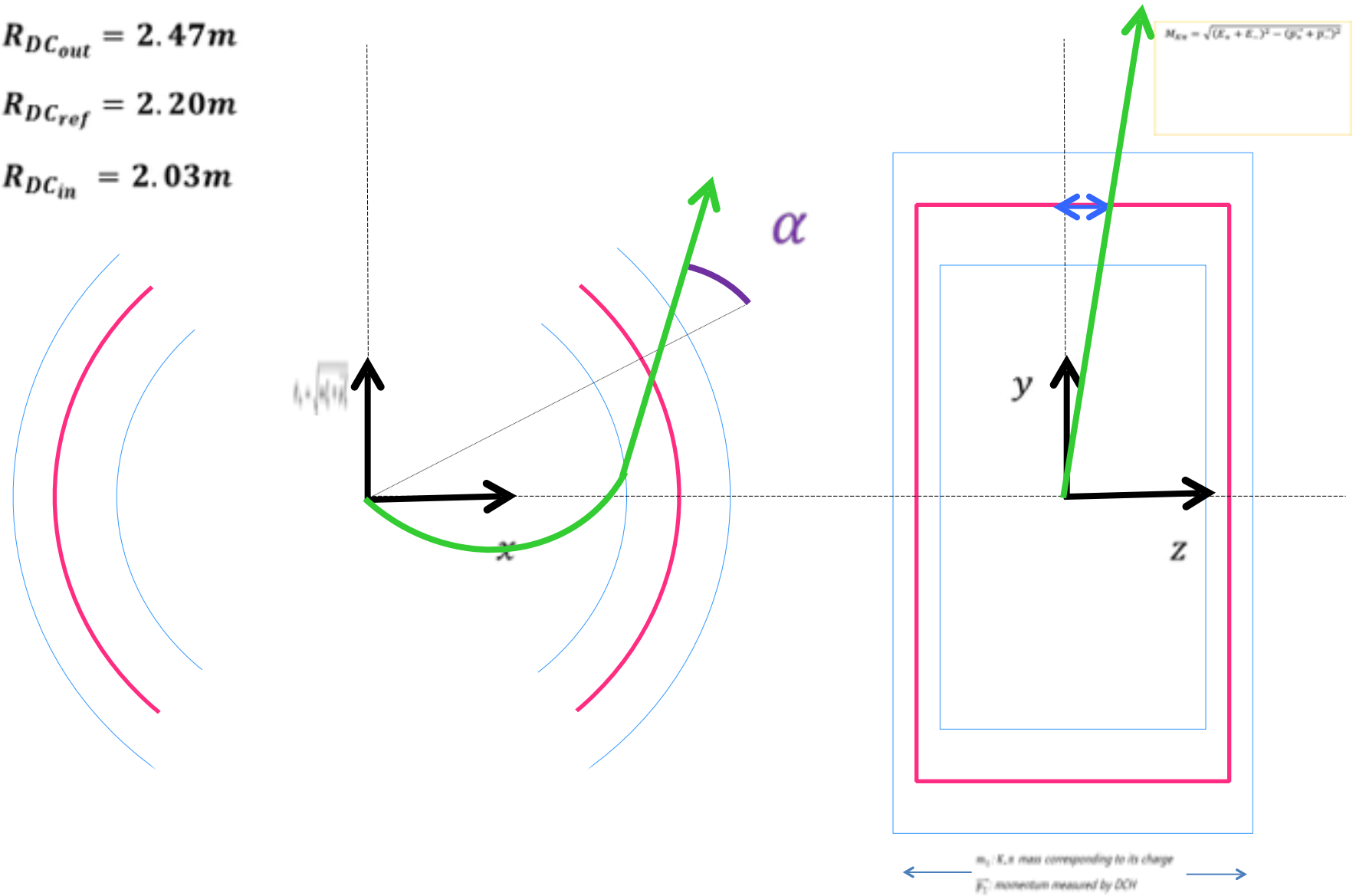


What is zed ?

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

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

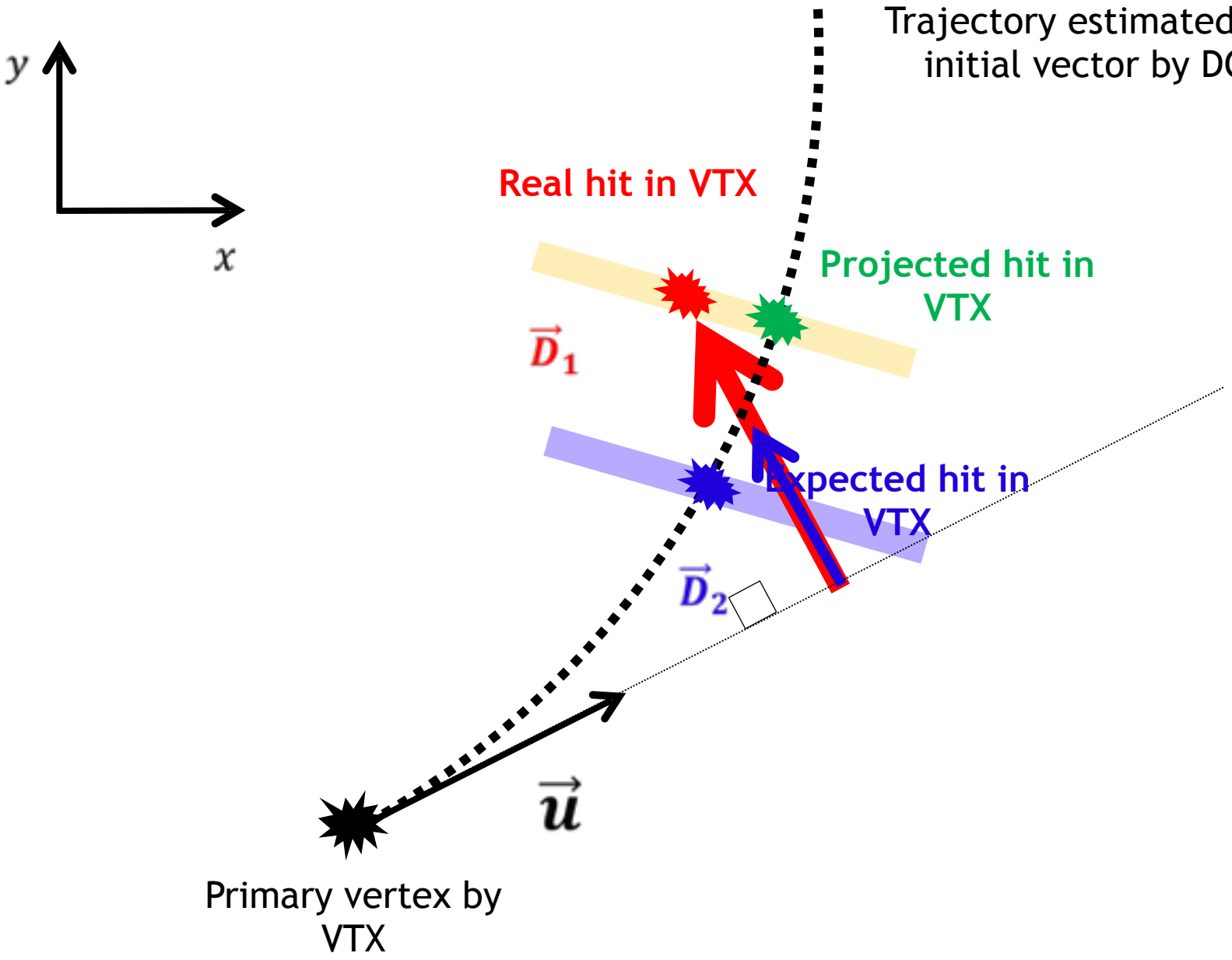
$R_{DC_{in}} = 2.03m$



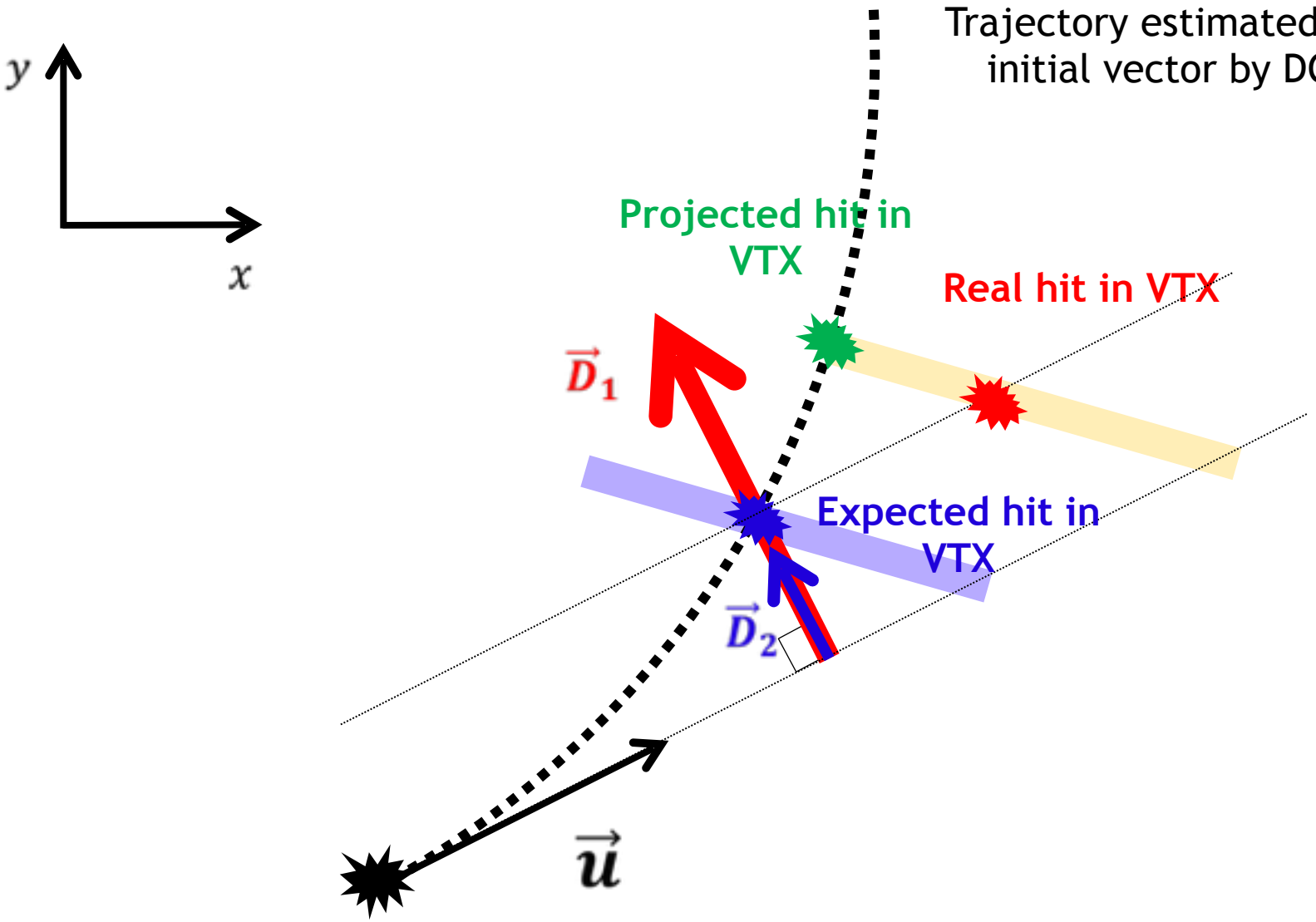
Beam View

Side View

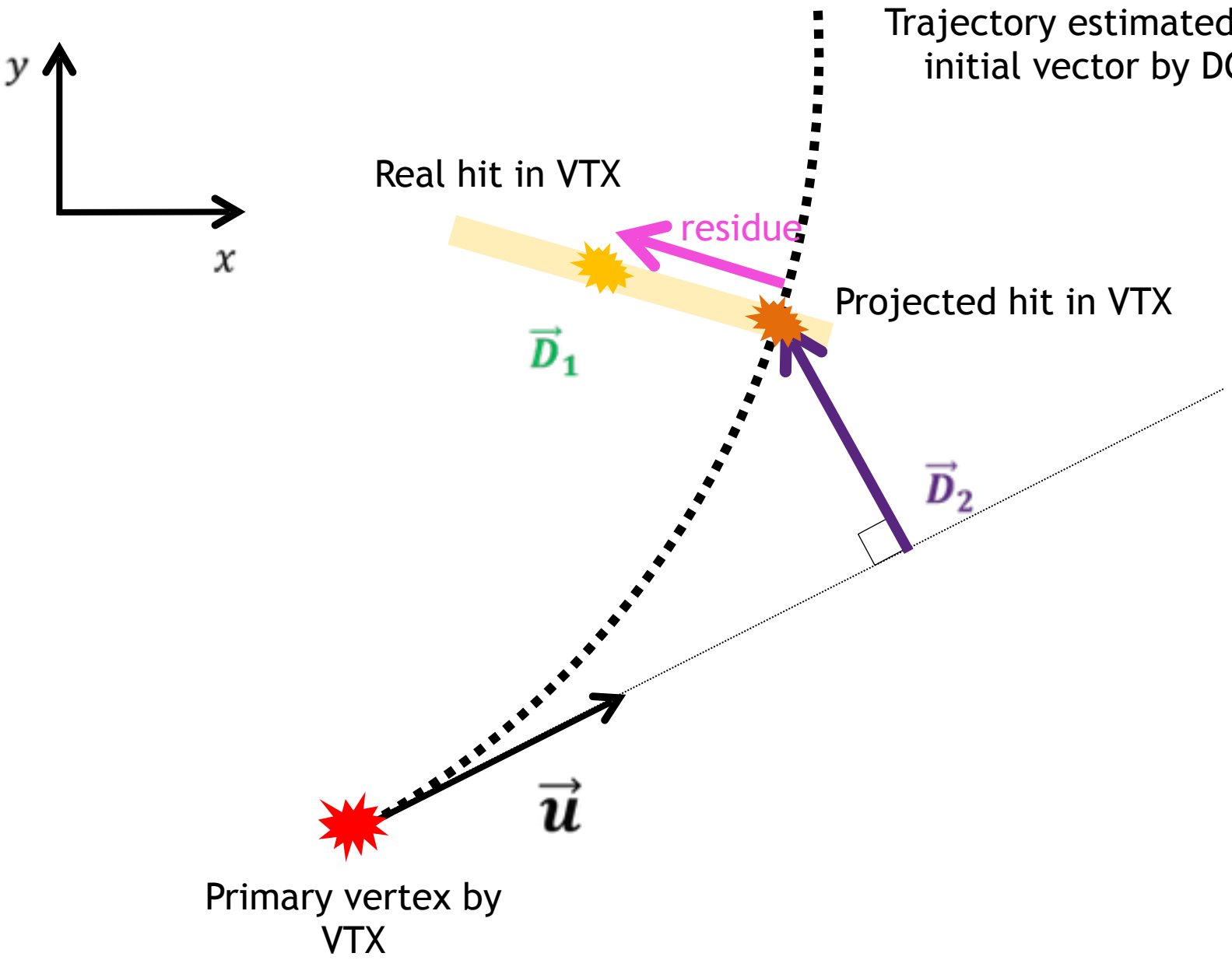
Alignment in u_N (ladder by ladder)

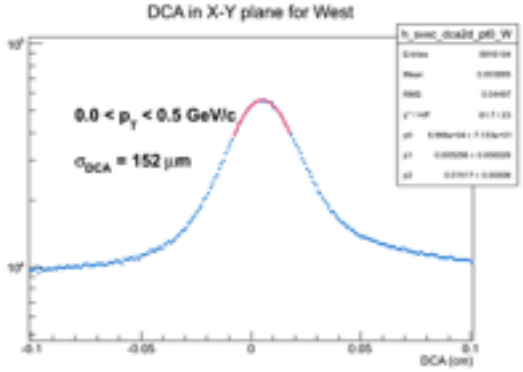


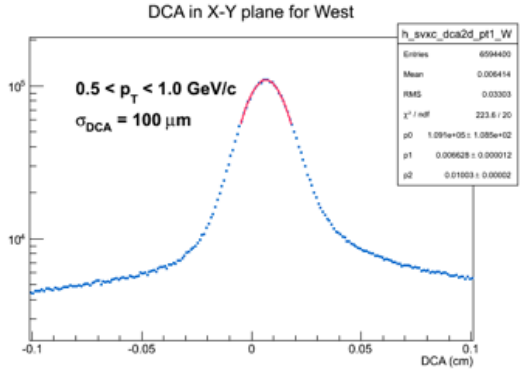
Alignment in u_T (ladder by ladder)

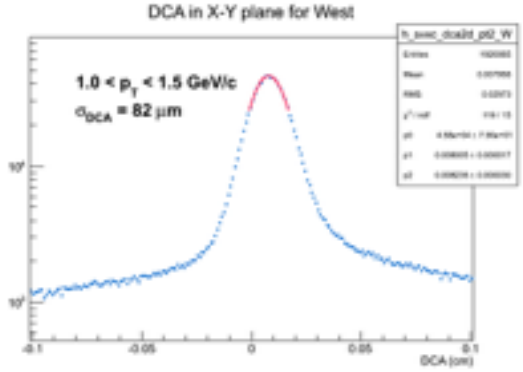


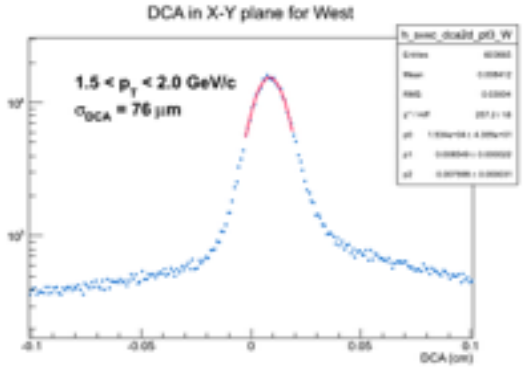
Alignment in ϕ (Ladder by Ladder(

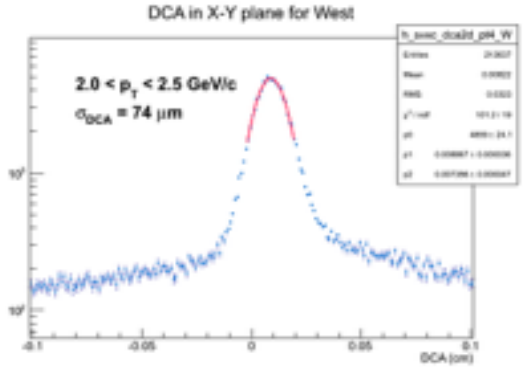


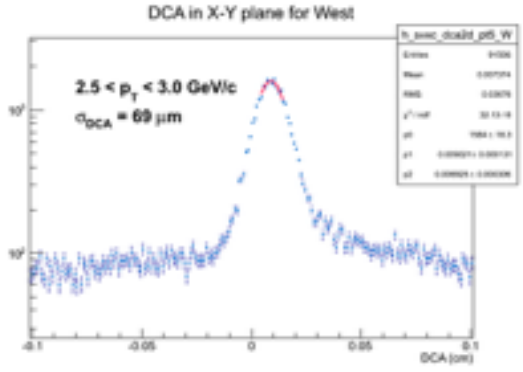

DCA in X-Y plane for West
0.0 < p_T < 0.5 GeV/c
σ_{DCA} = 152 μm
DCA (cm)

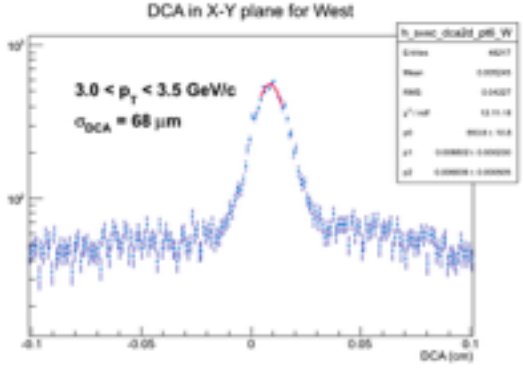

DCA in X-Y plane for West
0.5 < p_T < 1.0 GeV/c
σ_{DCA} = 100 μm
DCA (cm)

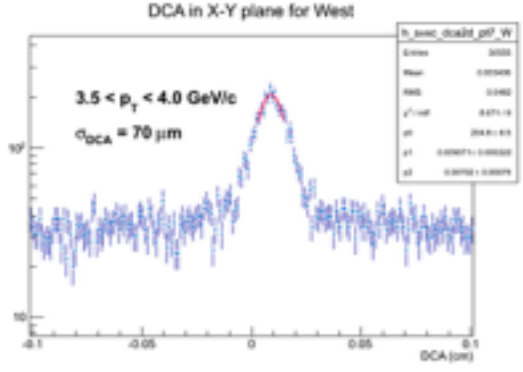

DCA in X-Y plane for West
1.0 < p_T < 1.5 GeV/c
σ_{DCA} = 82 μm
DCA (cm)

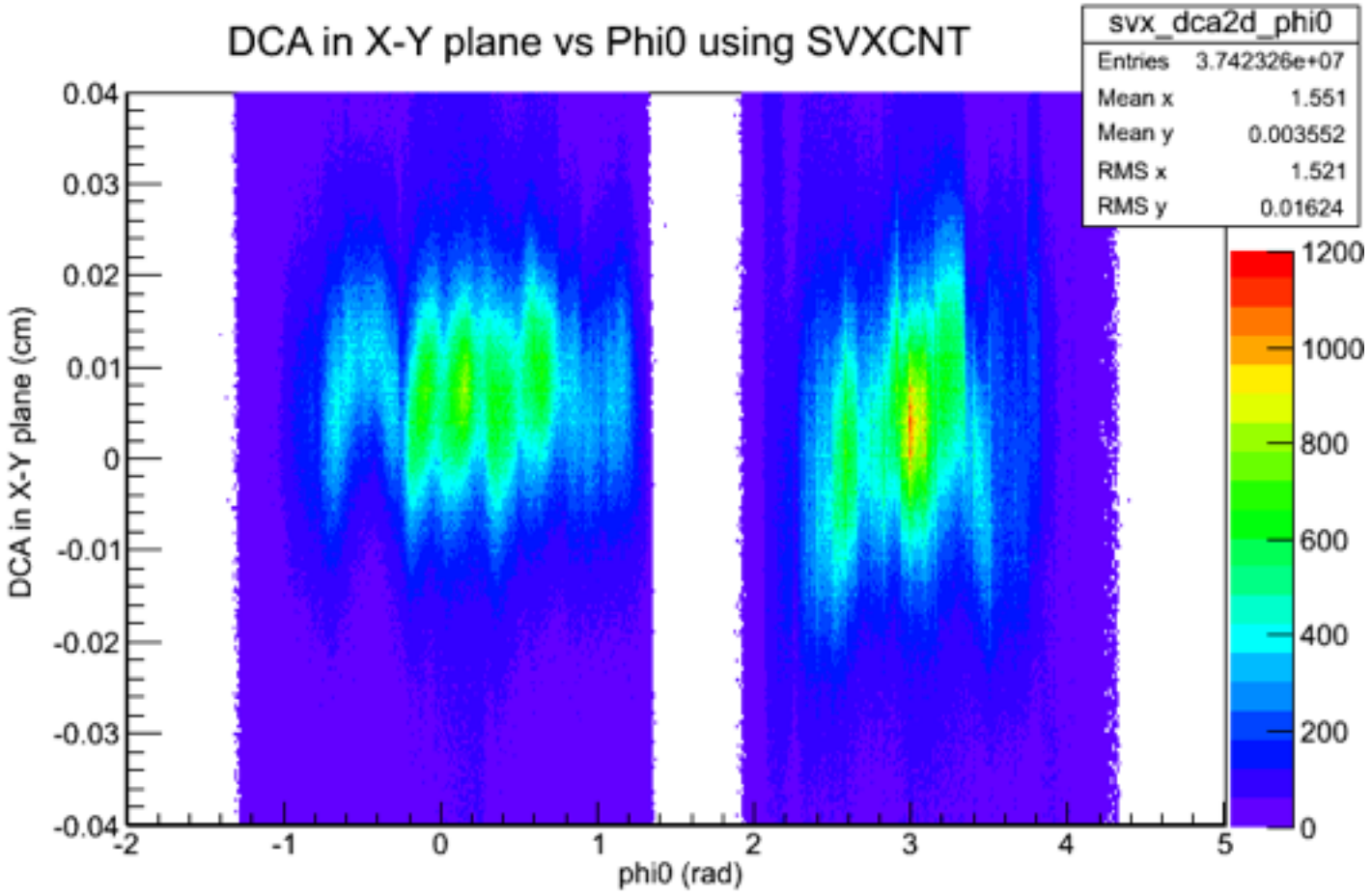

DCA in X-Y plane for West
1.5 < p_T < 2.0 GeV/c
σ_{DCA} = 76 μm
DCA (cm)


DCA in X-Y plane for West
2.0 < p_T < 2.5 GeV/c
σ_{DCA} = 74 μm
DCA (cm)

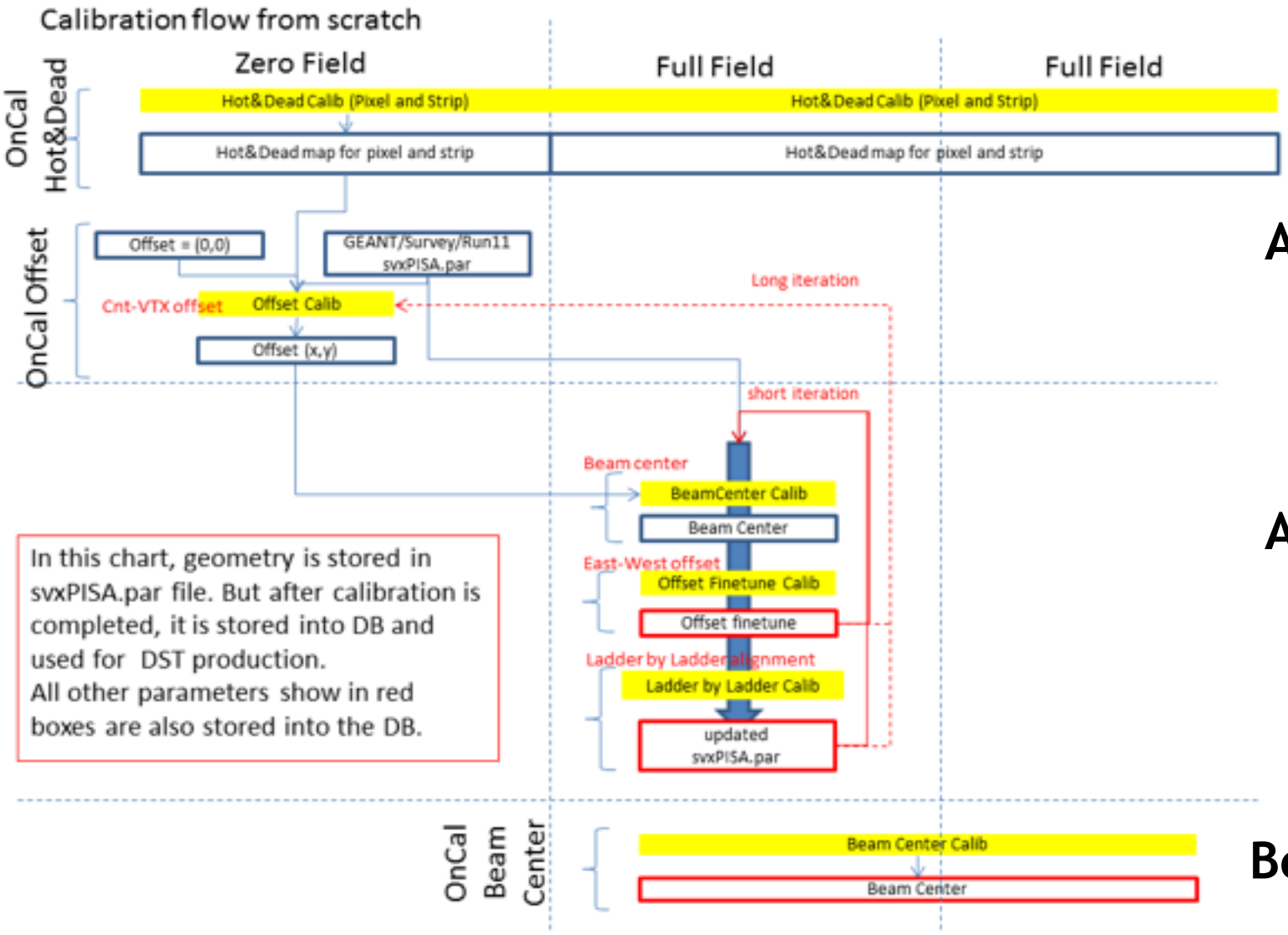

DCA in X-Y plane for West
2.5 < p_T < 3.0 GeV/c
σ_{DCA} = 69 μm
DCA (cm)


DCA in X-Y plane for West
3.0 < p_T < 3.5 GeV/c
σ_{DCA} = 68 μm
DCA (cm)


DCA in X-Y plane for West
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)
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
phi0 (rad)
1200
1000
800
600
400
200
0

Introduction to calibration

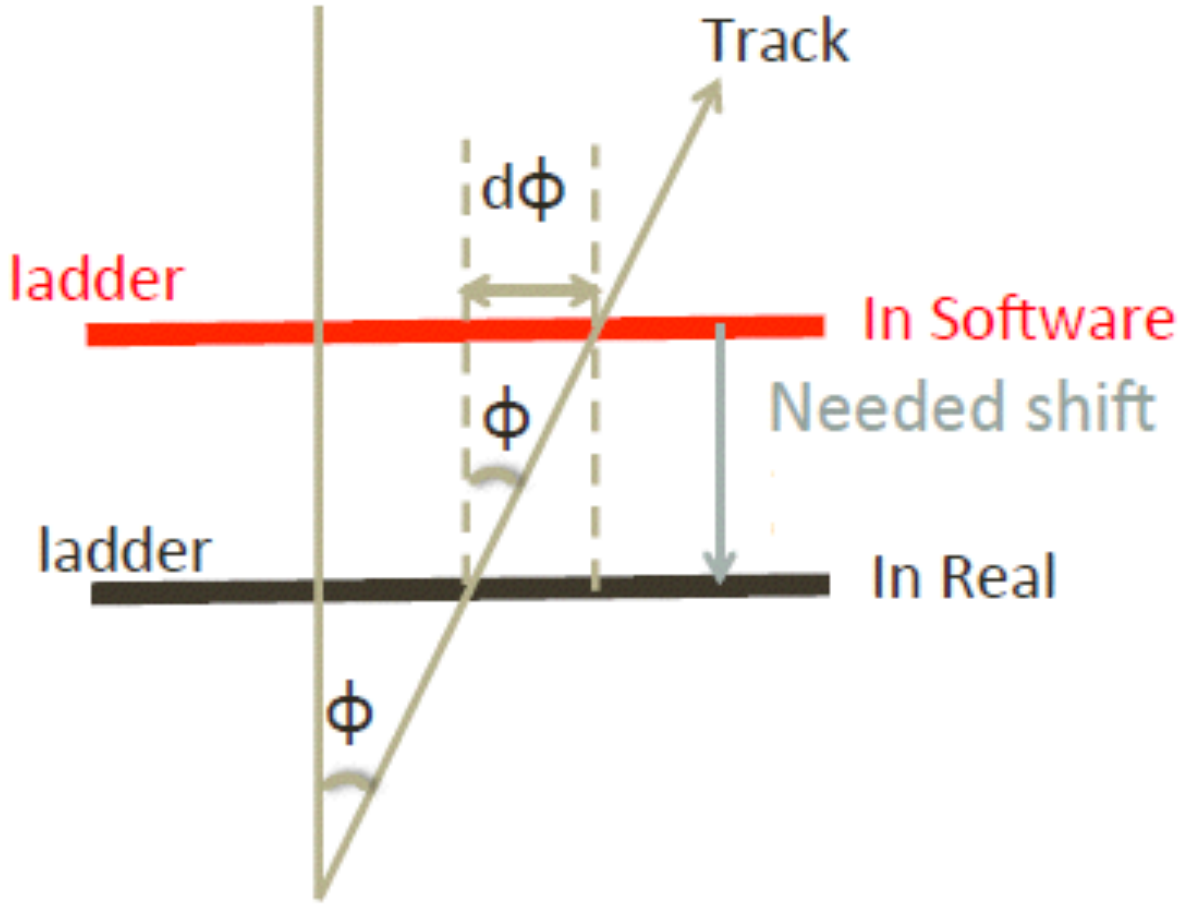


Alignment 1st STEP

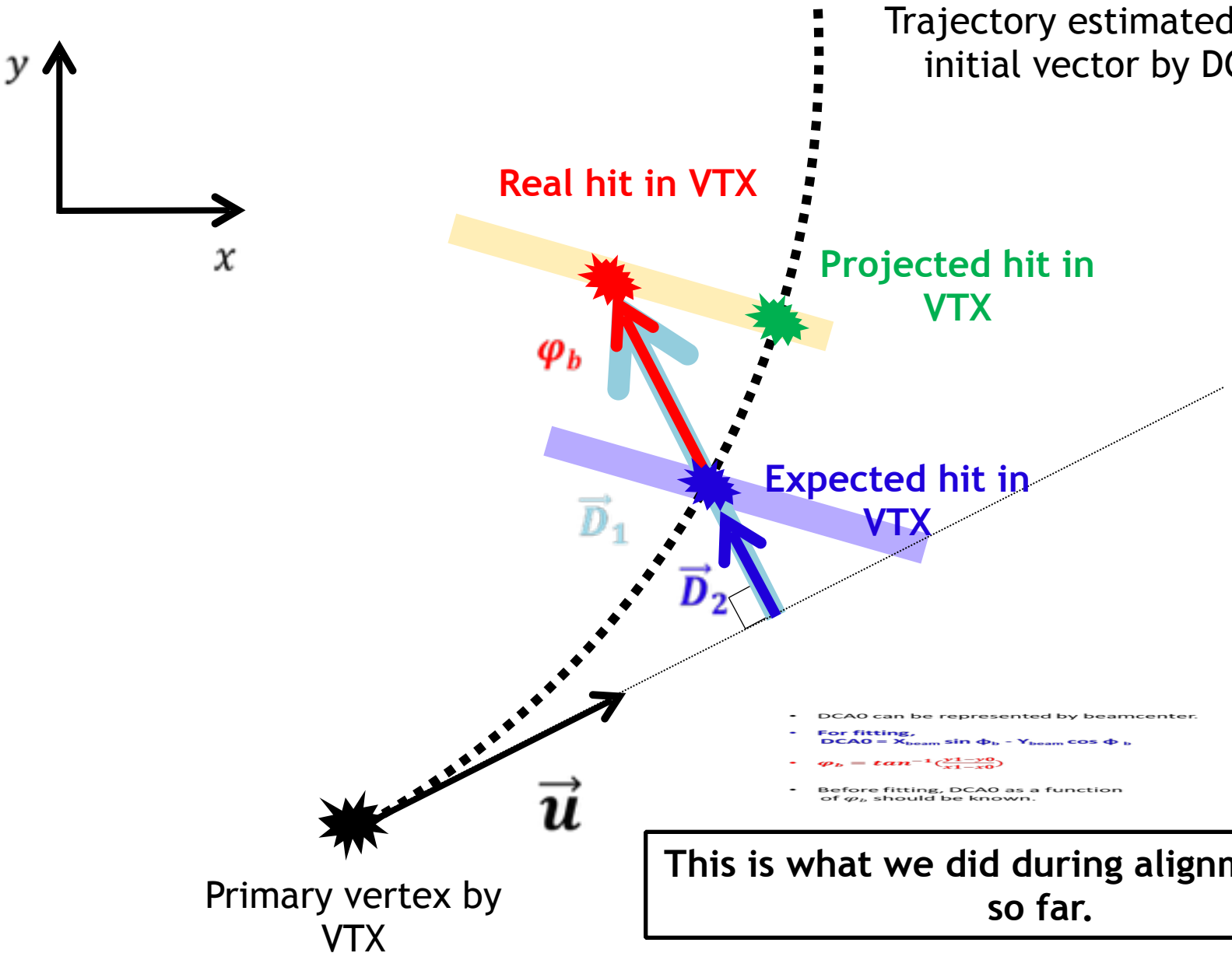
Alignment 2nd STEP

BeamCenter STEP

2) Alignment Ladder by Ladder in ϕ and z

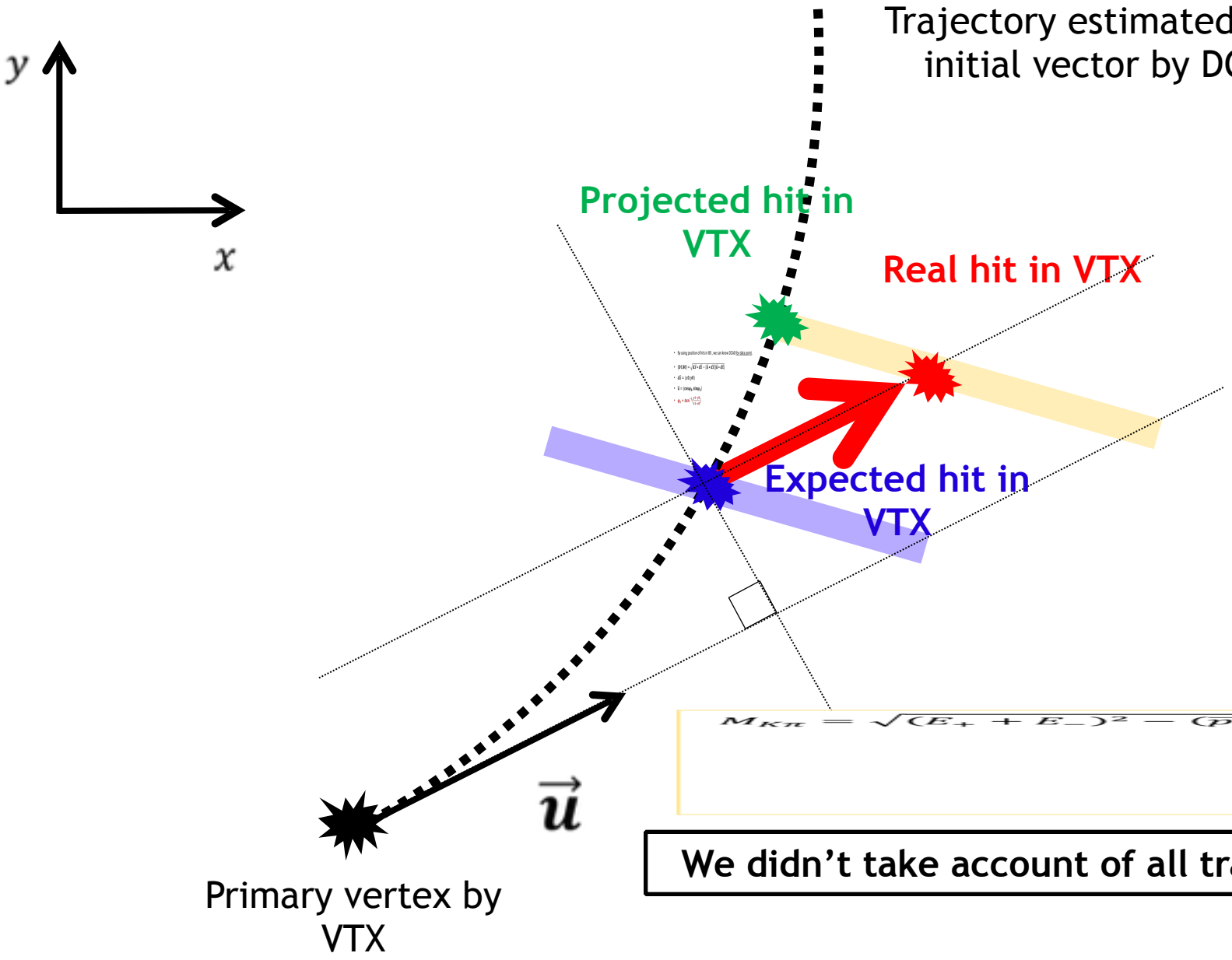


Alignment in u_{Normal} (ladder by ladder)



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

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



$$M_{K\pi} = \sqrt{(E_+ + E_-)^2 - (\vec{p}_+ + \vec{p}_-)^2}$$

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