

Vertex reconstruction with SST

Chi2 Vertex Fit

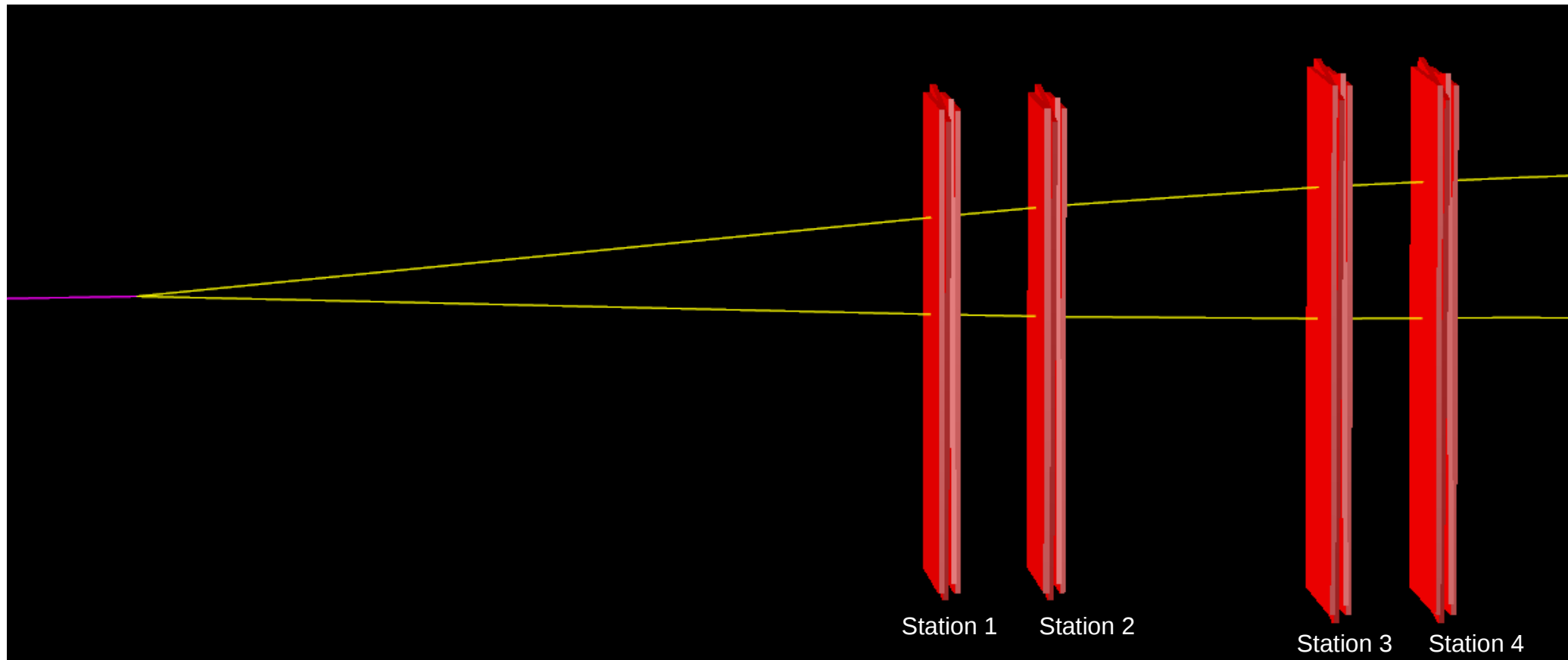
Ievgen Korol
for HU-Berlin team



11th SHiP Collaboration Meeting
08.06.2017

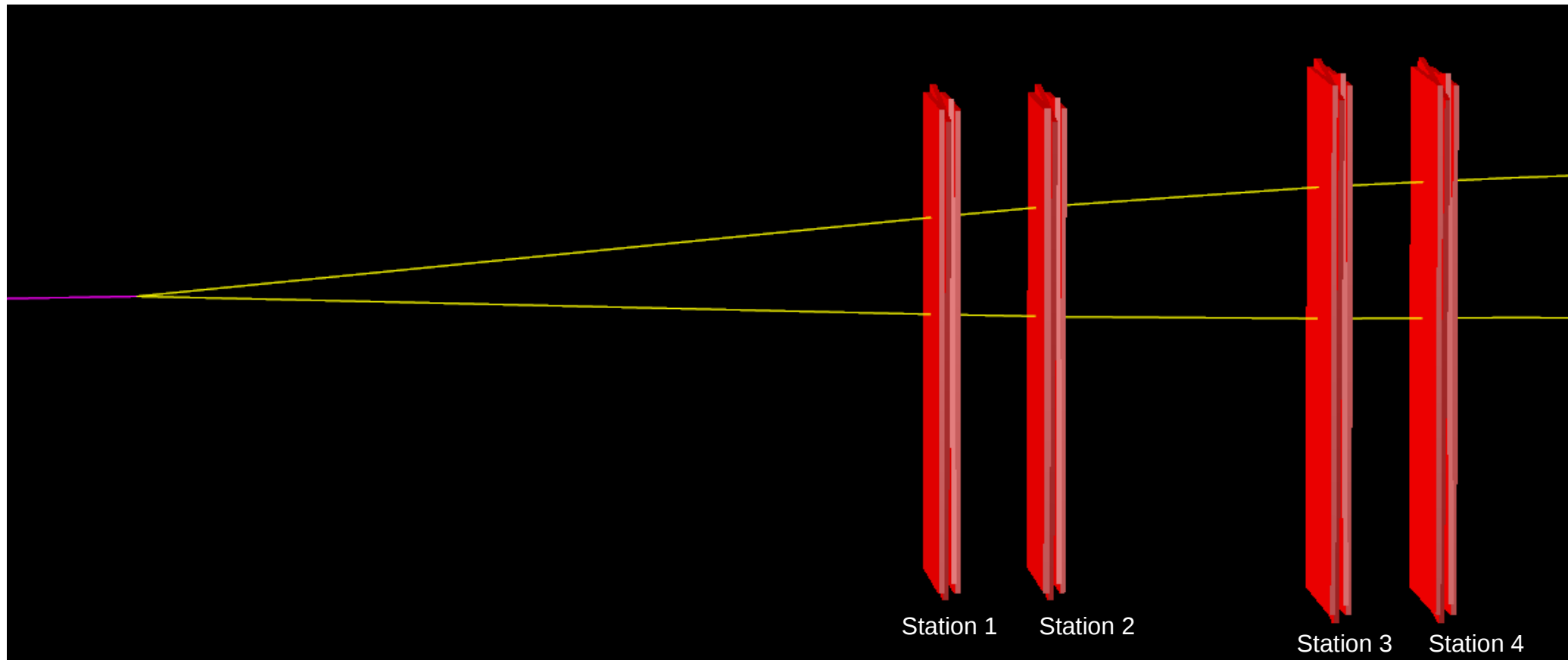


Vertex Reconstruction



Vertex Reconstruction

hits collection

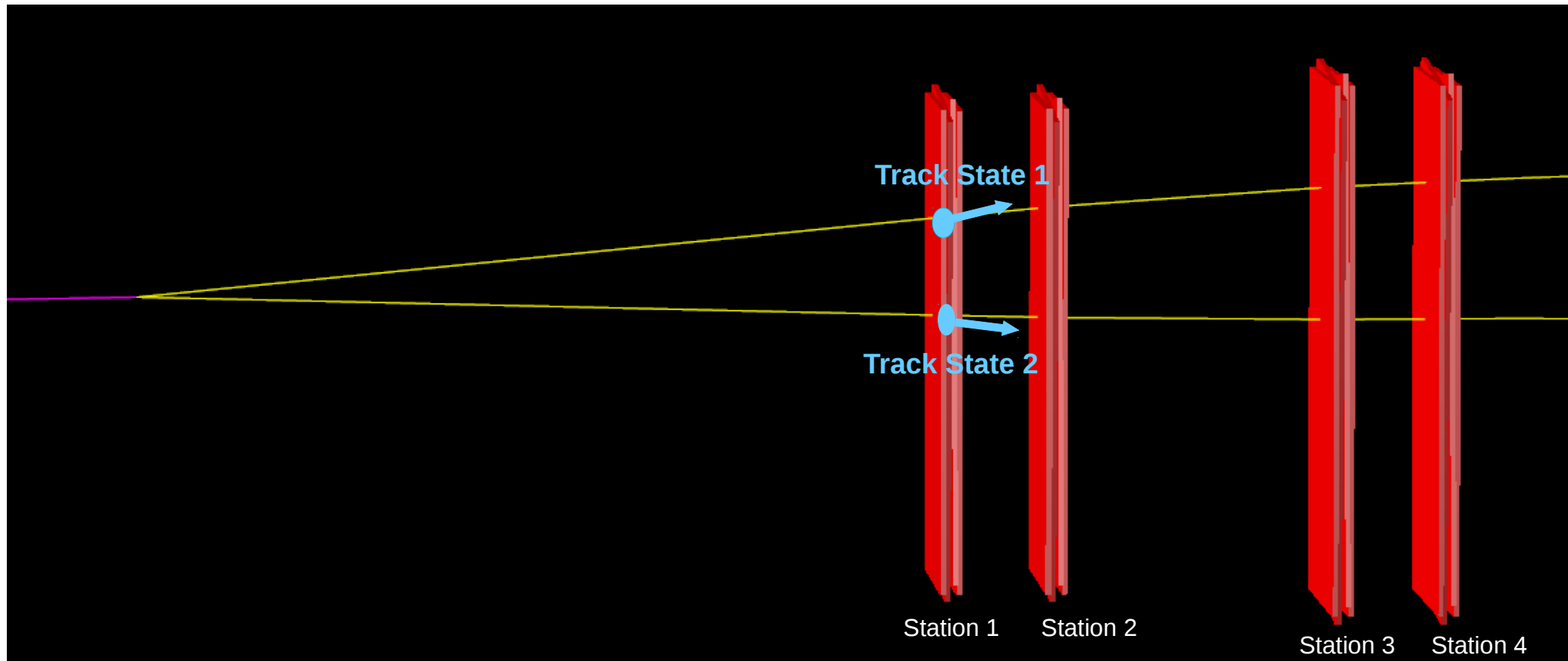


Vertex Reconstruction

hits collection

GENFIT

Set of parameters
with covariance
matrices describing
track at some Z position
- "Track State"



Vertex Reconstruction

hits collection

GENFIT

Set of parameters
with covariance
matrices describing
track at some Z position
- "Track State"

$M (q/p, u', v', u, v) @ Z$

q/p – charge over momentum
 u' – track direction with respect to X axis
 v' – track direction with respect to Y axis
 u – X position of the track
 v – Y position of the track

Track State 1

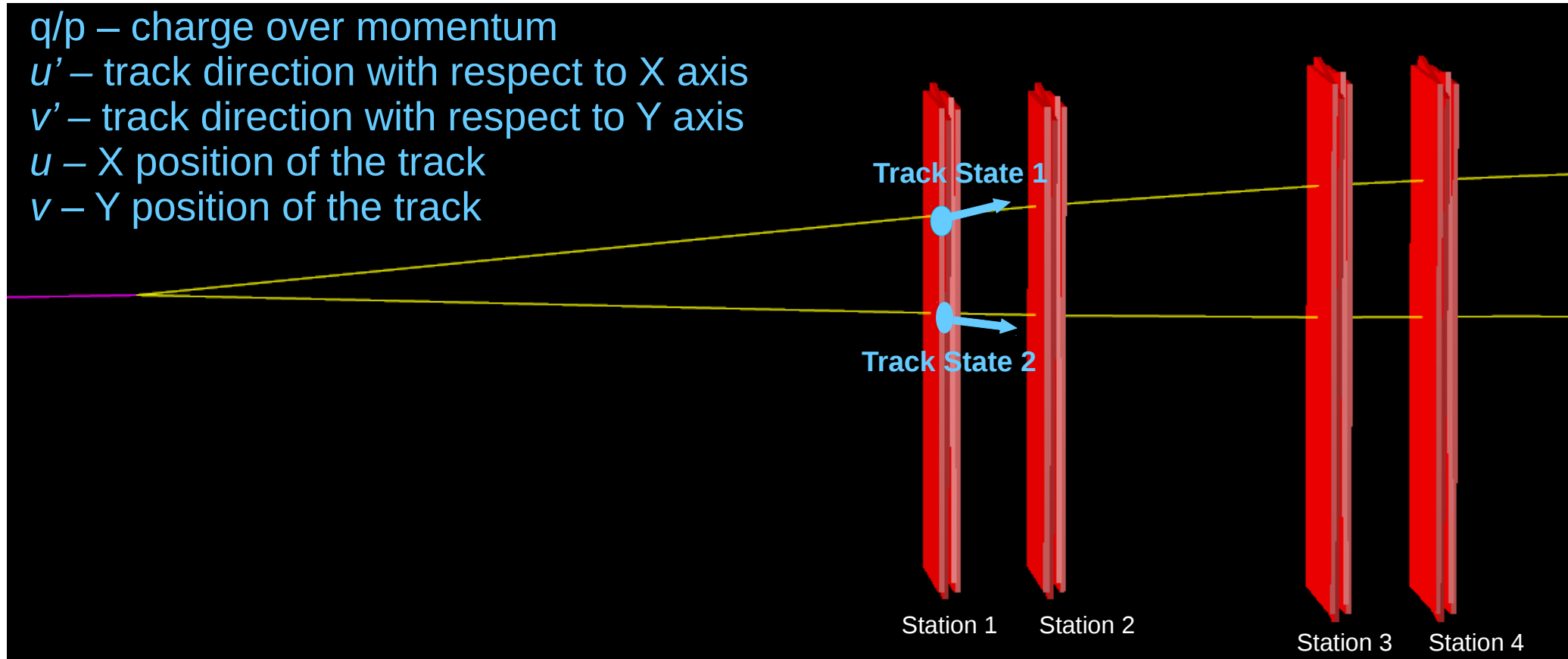
Track State 2

Station 1

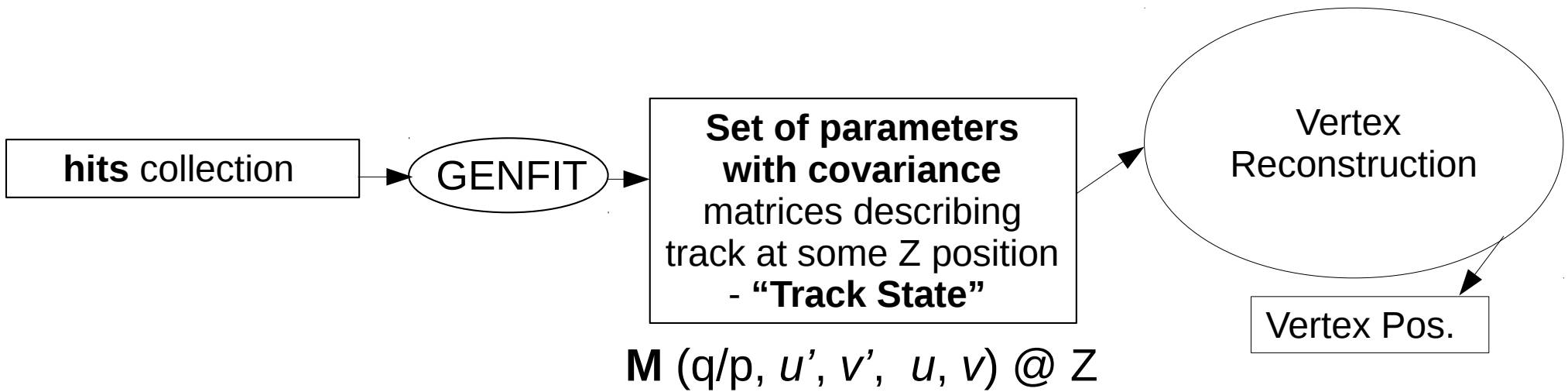
Station 2

Station 3

Station 4



Vertex Reconstruction



q/p – charge over momentum
 u' – track direction with respect to X axis
 v' – track direction with respect to Y axis
 u – X position of the track
 v – Y position of the track

Vertex Pos.

Track State 1

Track State 2

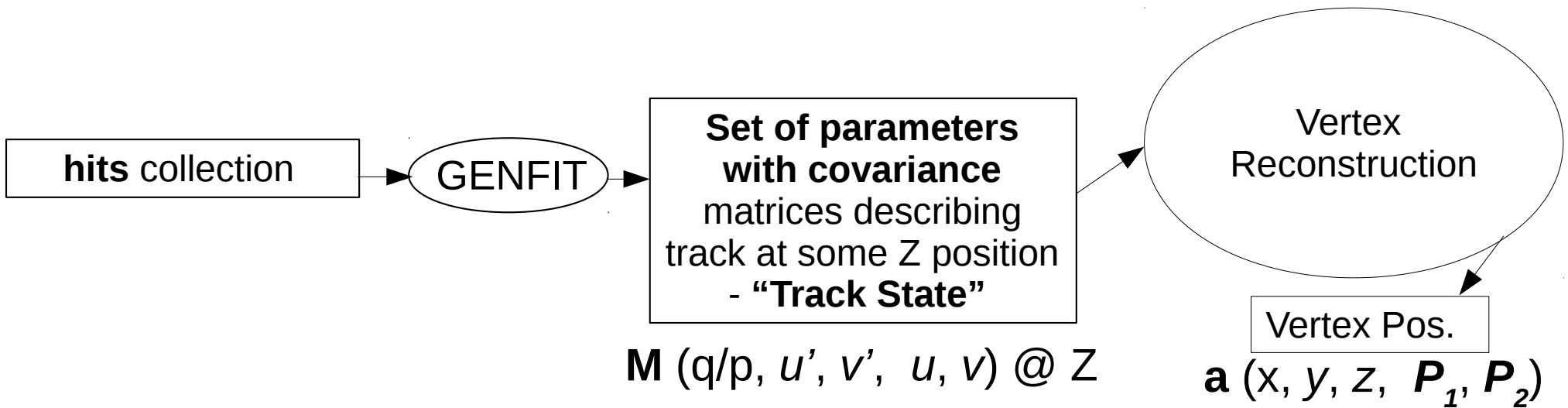
Station 1

Station 2

Station 3

Station 4

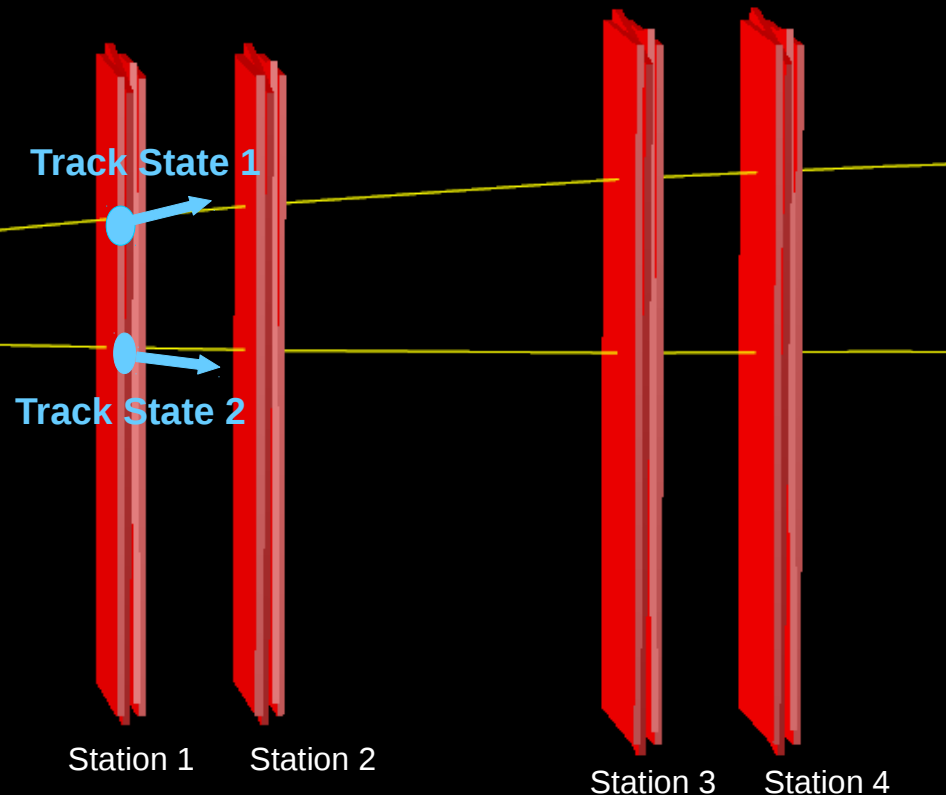
Vertex Reconstruction



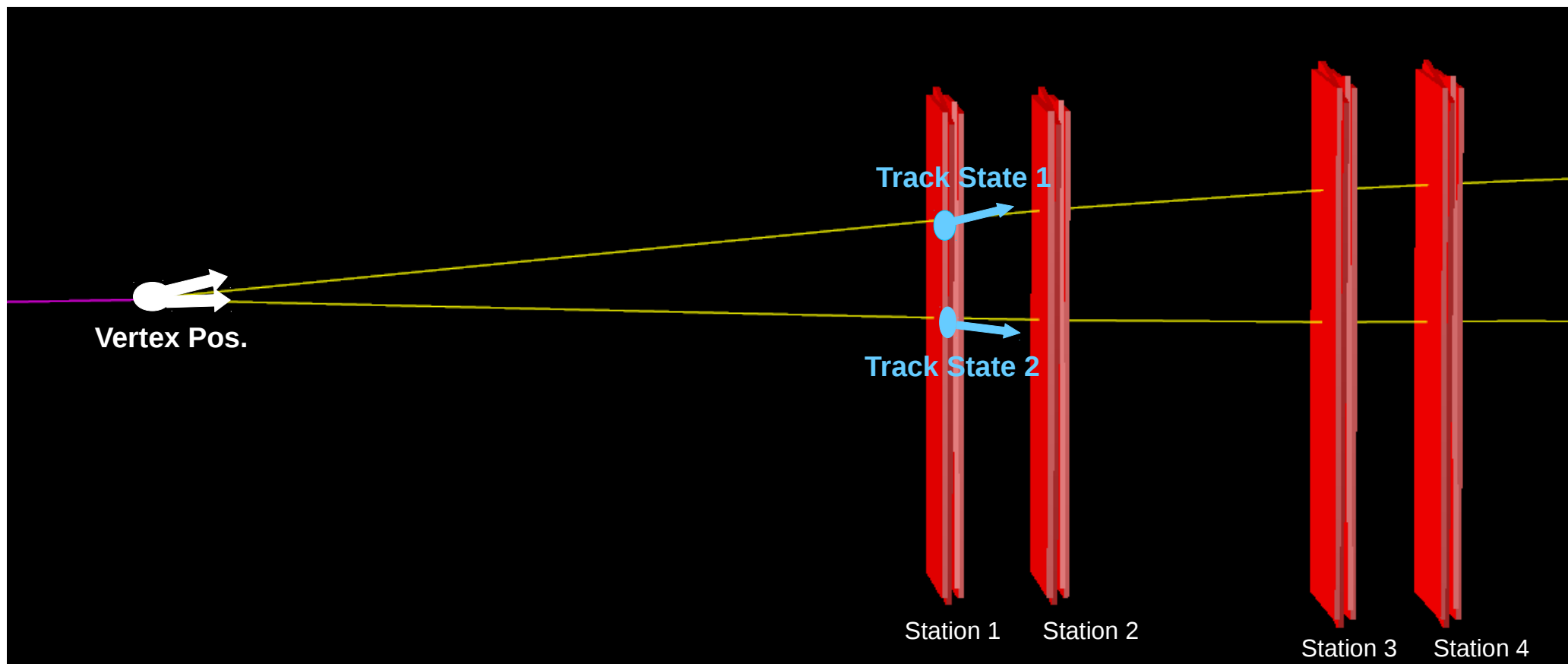
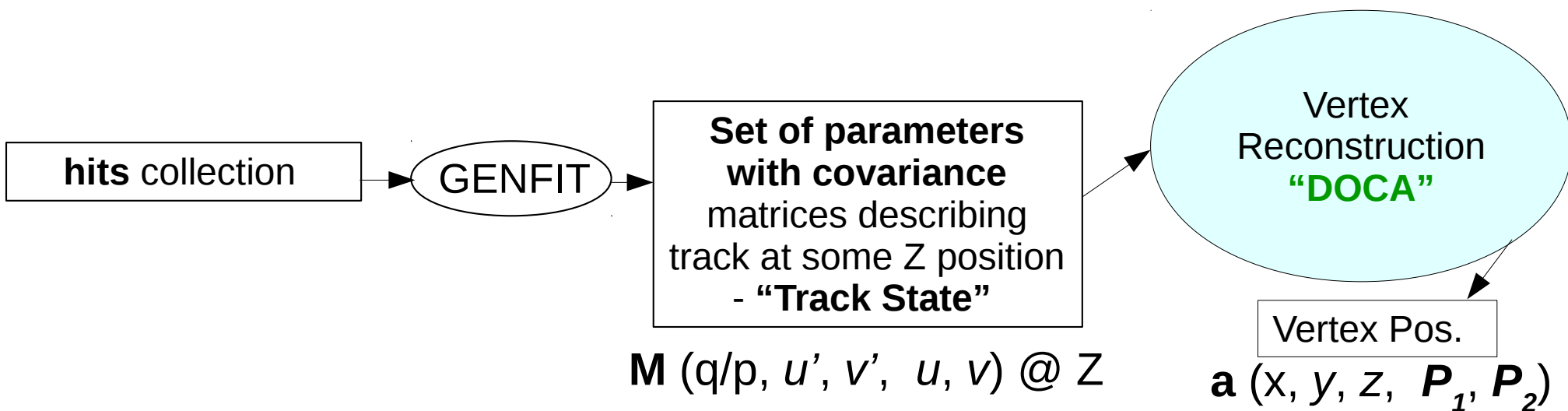
q/p – charge over momentum
 u' – track direction with respect to X axis
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 u – X position of the track
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Vertex Pos.

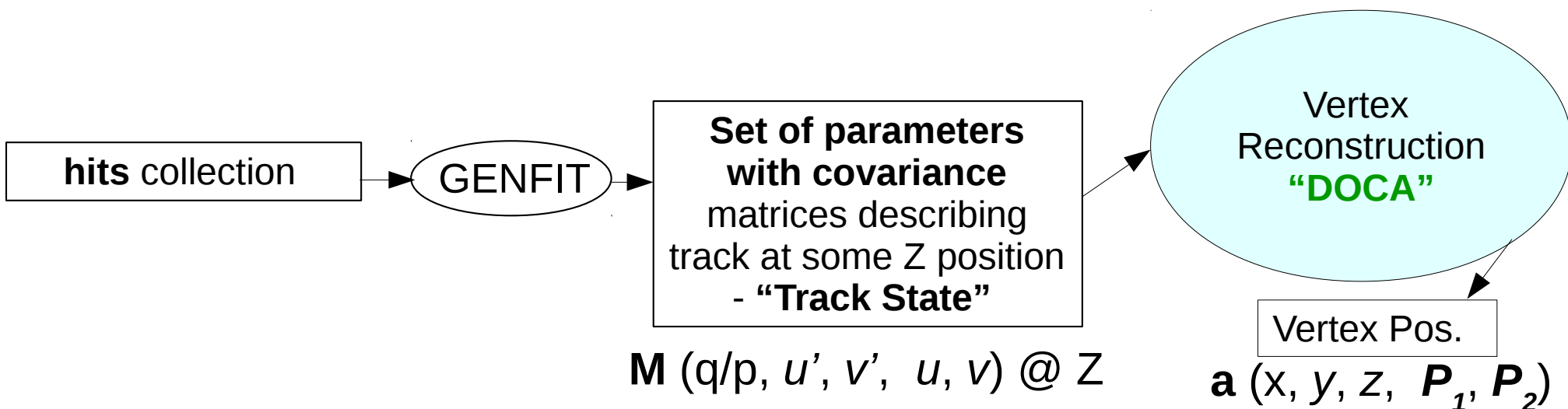
x, y, z – vertex position
 P_1, P_2 – track momentums



Vertex Reconst. - Current Procedure



Vertex Reconst. - Current Procedure



Vertex reconstruction scheme:

0. **extrapolate** as striate lines:
(starting Vertex Pos.)

Vertex Pos.

The diagram shows a white circle representing the **Vertex Pos.** with two white arrows pointing outwards. From this vertex, two yellow lines representing tracks extend to the right. These tracks pass through two vertical red bars representing **Station 1** and **Station 2**. At the intersection points, blue circles represent **Track State 1** and **Track State 2**, with blue arrows pointing to the right. The tracks continue to the right, passing through two more vertical red bars representing **Station 3** and **Station 4**.

Track State 1

Track State 2

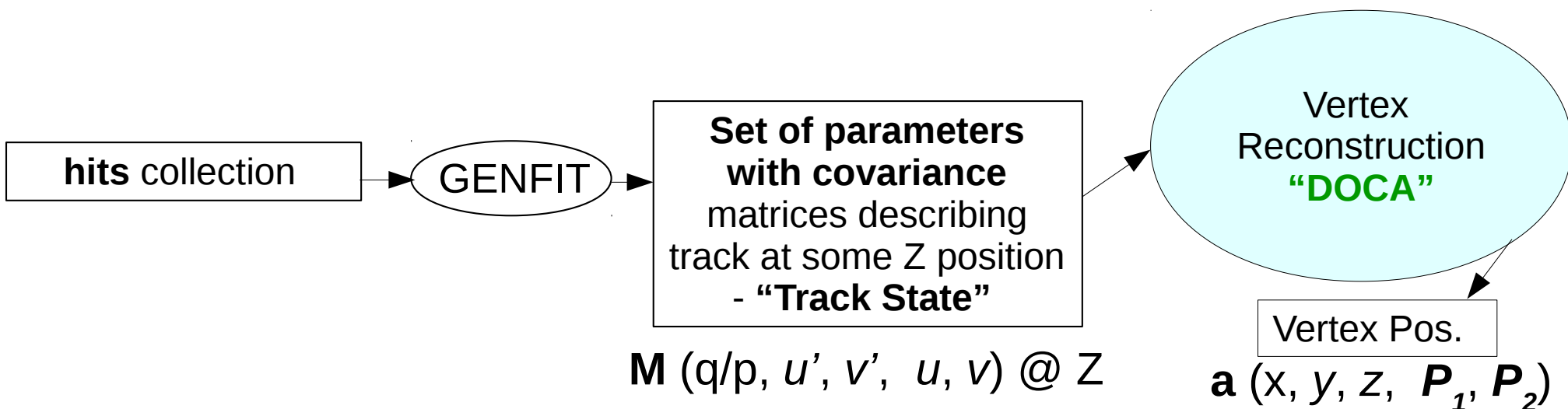
Station 1

Station 2

Station 3

Station 4

Vertex Reconst. - Current Procedure



Vertex reconstruction scheme:

0. **extrapolate** as striate lines:
(starting Vertex Pos.)



Track State 1

Track State 2

Iteratively (10 iterations or $dZ < 0.01$):

1. **propagate** to current Vertex Pos.
2. find **new** Vertex Pos. from DOCA
3. $dZ = \text{current} - \text{new}$, **current = new**

Station 1

Station 2

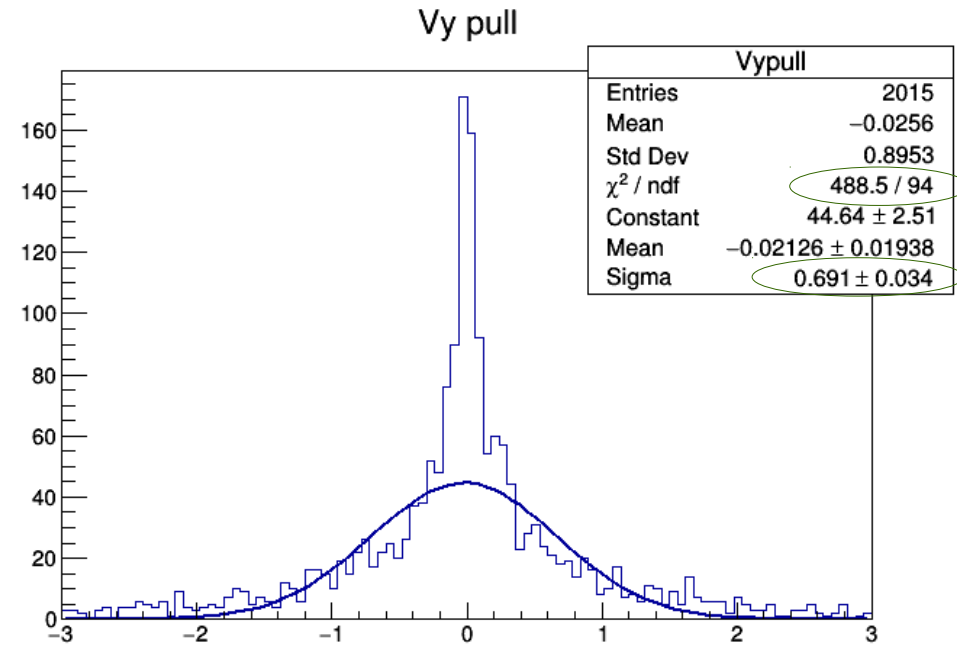
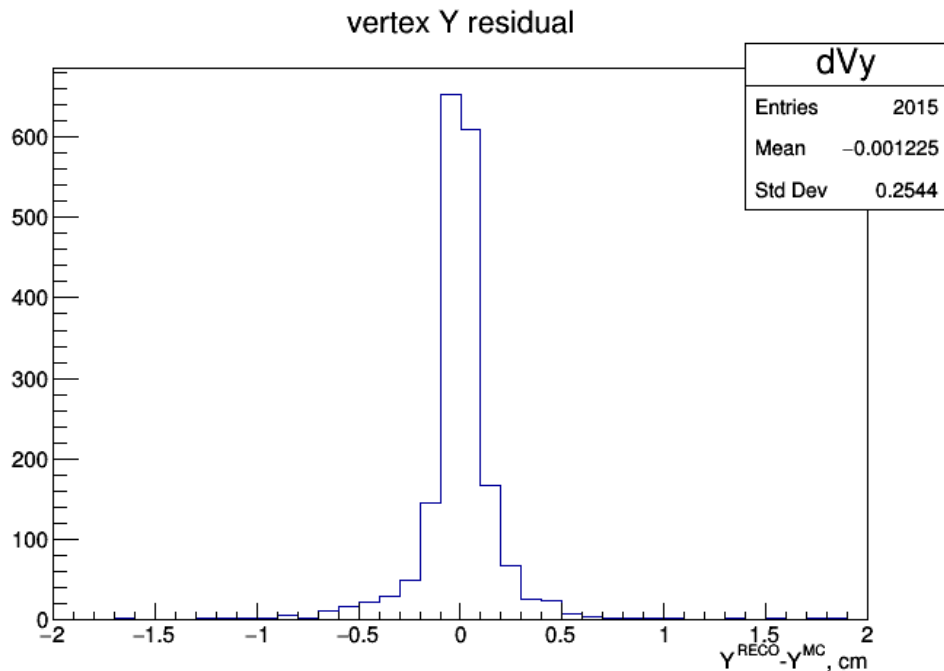
Station 3

Station 4

Y – residual and pull distribution

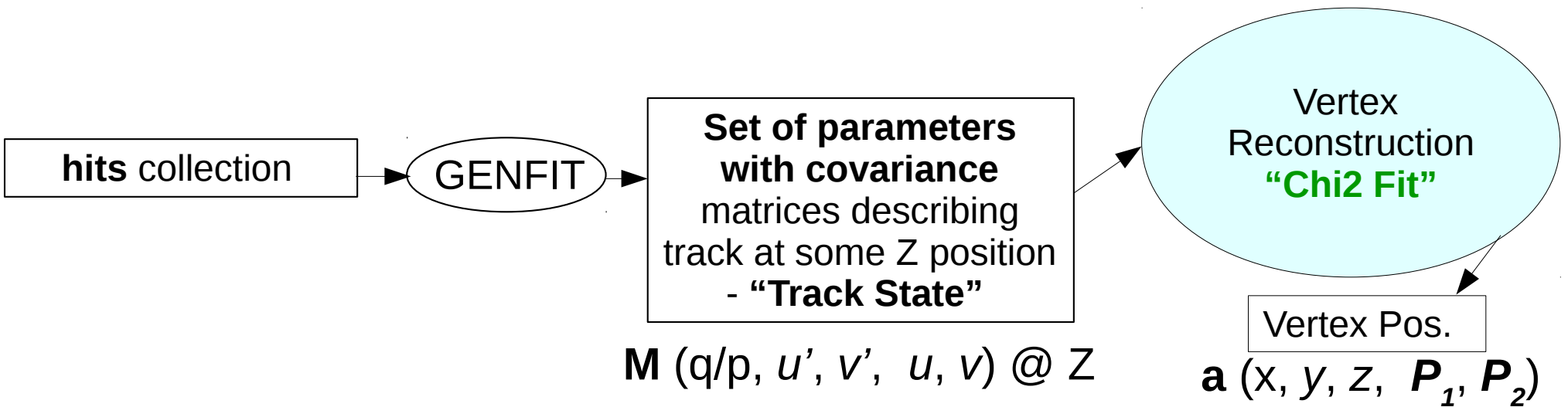
$$Y \text{ residual} = Y_{RECO} - Y_{TRUE}$$

$$Y \text{ pull} = \frac{Y_{RECO} - Y_{TRUE}}{\sigma(Y_{RECO})}$$



Measured errors of Y are over estimated

Vertex Reconst. - Chi2 Fit



Vertex reconstruction algorithm:

Obtain vector of parameters \mathbf{a} by minimizing the χ^2

Vertex Pos.

$$\chi^2 = (F(\mathbf{a}) - M_{1,2})^T COV_{M_{1,2}}^{-1} (F(\mathbf{a}) - M_{1,2})$$

10 measurements:

$$M_{1,2} (q/p_1, u'_1, v'_1, u_1, v_1, q/p_2, u'_2, v'_2, u_2, v_2)$$

9 fit parameters:

$$a(x, y, z, P_1, P_2)$$

Track State 1

Station 1

Station 2

Station 3

Station 4

Vertex Reconst. - Chi2 Fit

Vertex reconstruction algorithm:

Obtain vector of parameters \mathbf{a}
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$$\chi^2 = (F(\mathbf{a}) - M_{1,2})^T \text{COV}_{M_{1,2}}^{-1} (F(\mathbf{a}) - M_{1,2})$$

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$$M_{1,2}(q/p_1, u'_1, v'_1, u_1, v_1, q/p_2, u'_2, v'_2, u_2, v_2)$$

9 fit parameters:

$$\mathbf{a}(x, y, z, \mathbf{P}_1, \mathbf{P}_2)$$

Track State 1

Station 1

Station 2

Station 3

Station 4

$$F(\mathbf{a}) = C_1 \cdot \mathbf{a} + C_2 \cdot \mathbf{a} \cdot \mathbf{a}^T \cdot \mathbf{k} \quad , \text{ where}$$

C_1, C_2 – constant matrices
 \mathbf{k} – constant vector

Vertex Reconst. - Chi2 Fit

Vertex reconstruction algorithm:

Obtain vector of parameters \mathbf{a}
by minimizing the χ^2



$$\chi^2 = (F(\mathbf{a}) - M_{1,2})^T \text{COV}_{M_{1,2}}^{-1} (F(\mathbf{a}) - M_{1,2})$$

10 measurements:

$$M_{1,2}(q/p_1, u'_1, v'_1, u_1, v_1, q/p_2, u'_2, v'_2, u_2, v_2)$$

9 fit parameters:

$$\mathbf{a}(x, y, z, \mathbf{P}_1, \mathbf{P}_2)$$

Track State 1

Station 1

Station 2

Station 3

Station 4

$$F(\mathbf{a}) = C_1 \cdot \mathbf{a} + C_2 \cdot \mathbf{a} \cdot \mathbf{a}^T \cdot \mathbf{k} \quad , \text{ where } \quad C_1, C_2 - \text{constant matrices}$$

$$\mathbf{k} - \text{constant vector}$$

$$\chi^2 = (C_1 \cdot \mathbf{a} + C_2 \cdot \mathbf{a} \cdot \mathbf{a}^T \cdot \mathbf{k} - M_{1,2})^T \text{COV}_{M_{1,2}}^{-1} (C_1 \cdot \mathbf{a} + C_2 \cdot \mathbf{a} \cdot \mathbf{a}^T \cdot \mathbf{k} - M_{1,2})$$

Vertex Reconst. - Chi2 Fit

Vertex reconstruction algorithm:

Obtain vector of parameters \mathbf{a}
by minimizing the χ^2



$$\chi^2 = (F(\mathbf{a}) - M_{1,2})^T \text{COV}_{M_{1,2}}^{-1} (F(\mathbf{a}) - M_{1,2})$$

10 measurements:

$$M_{1,2}(q/p_1, u'_1, v'_1, u_1, v_1, q/p_2, u'_2, v'_2, u_2, v_2)$$

9 fit parameters:

$$\mathbf{a}(x, y, z, \mathbf{P}_1, \mathbf{P}_2)$$

Track State 1

Station 1

Station 2

Station 3

Station 4

$$F(\mathbf{a}) = C_1 \cdot \mathbf{a} + C_2 \cdot \mathbf{a} \cdot \mathbf{a}^T \cdot \mathbf{k} \quad , \text{ where } \quad C_1, C_2 - \text{constant matrices}$$

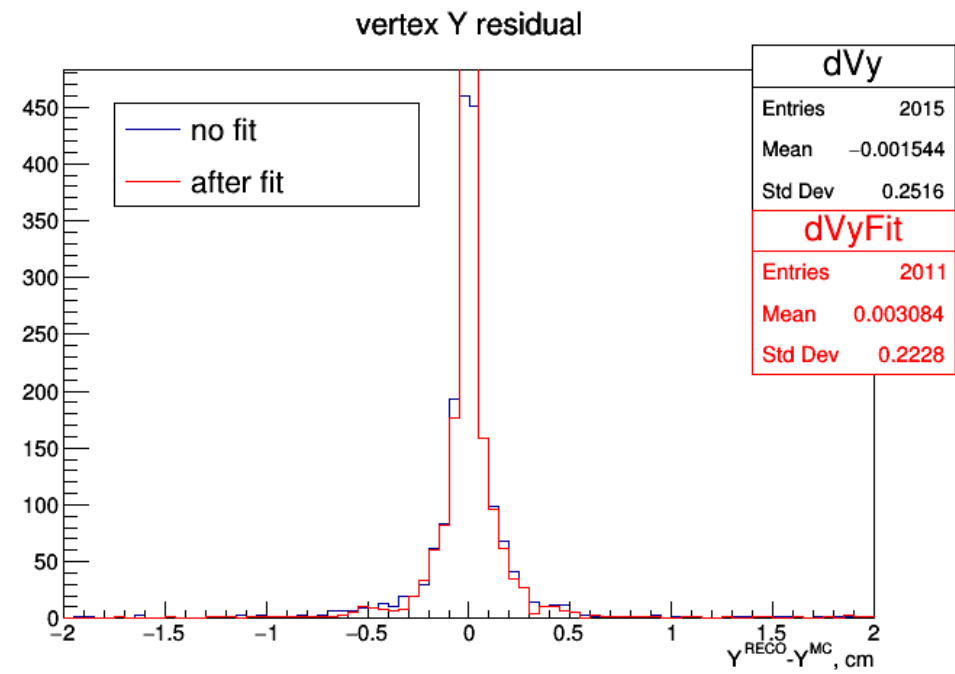
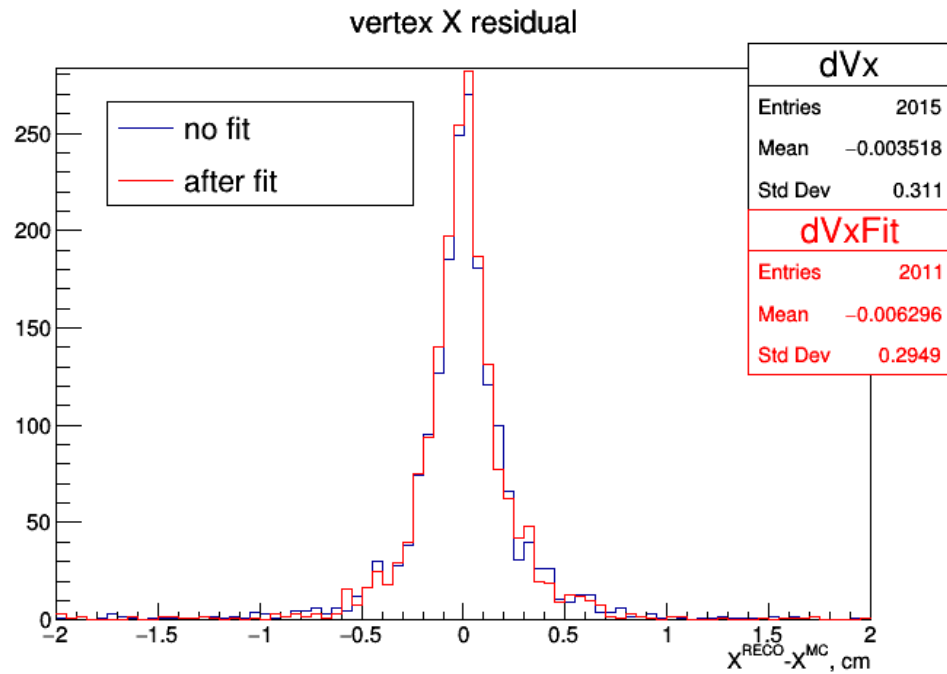
$$\mathbf{k} - \text{constant vector}$$

$$\chi^2 = (C_1 \cdot \mathbf{a} + C_2 \cdot \mathbf{a} \cdot \mathbf{a}^T \cdot \mathbf{k} - M_{1,2})^T \text{COV}_{M_{1,2}}^{-1} (C_1 \cdot \mathbf{a} + C_2 \cdot \mathbf{a} \cdot \mathbf{a}^T \cdot \mathbf{k} - M_{1,2})$$

Minimized with TMinuit

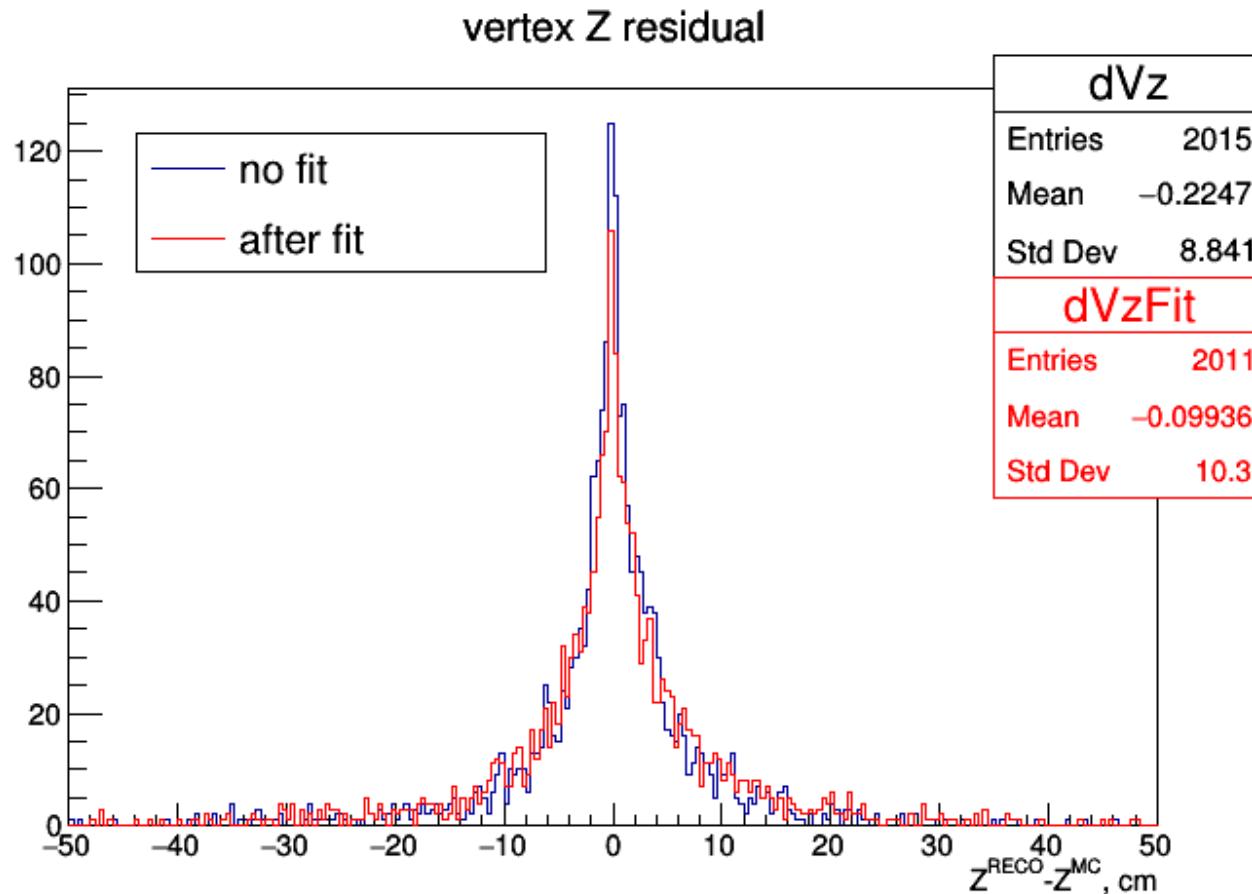
starting values: DOCA method

X, Y residuals



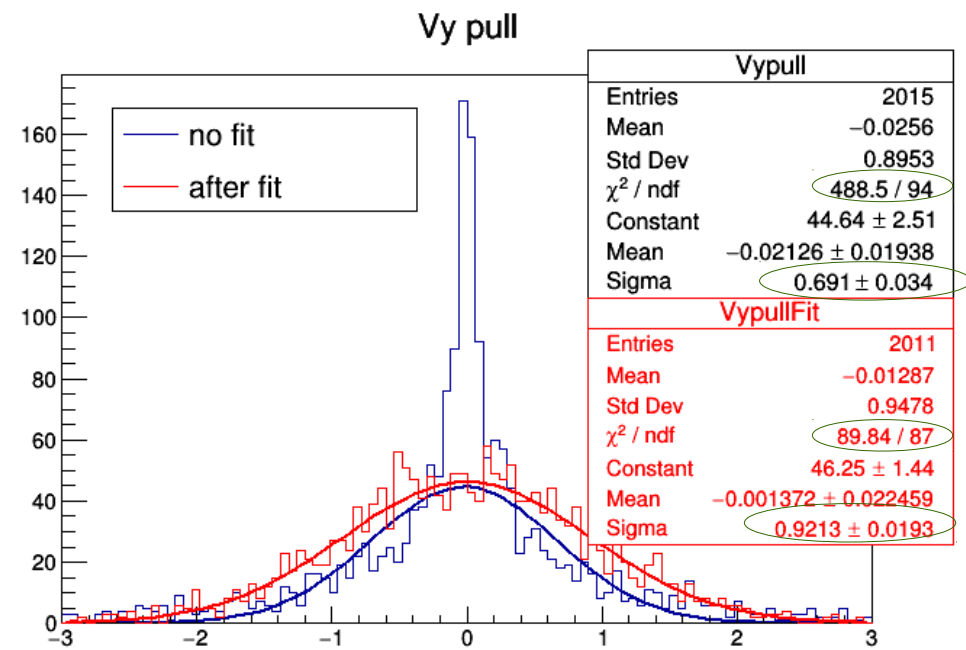
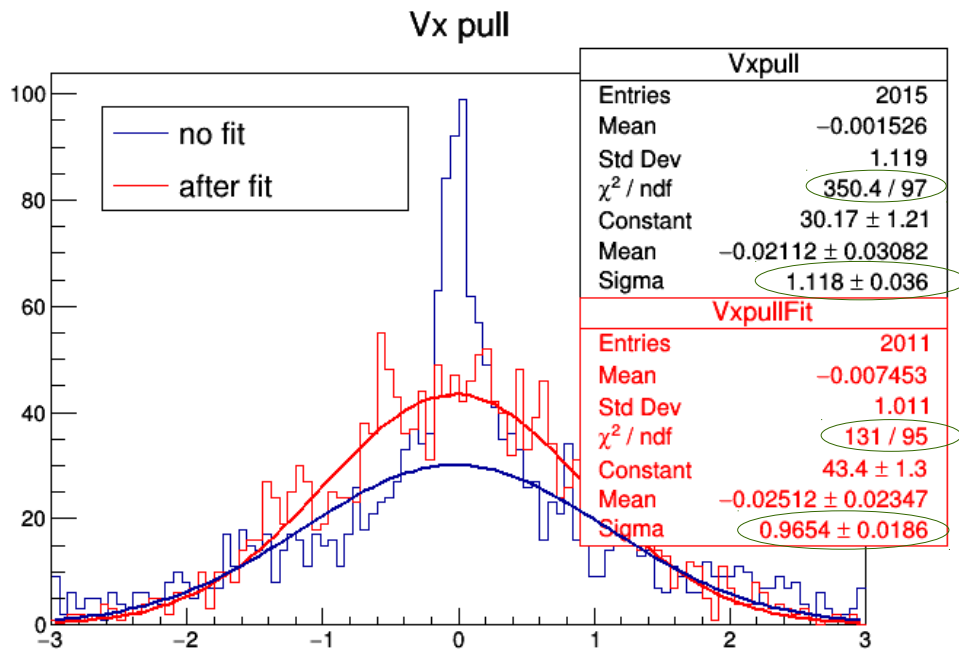
No significant changes are observed

Z residual



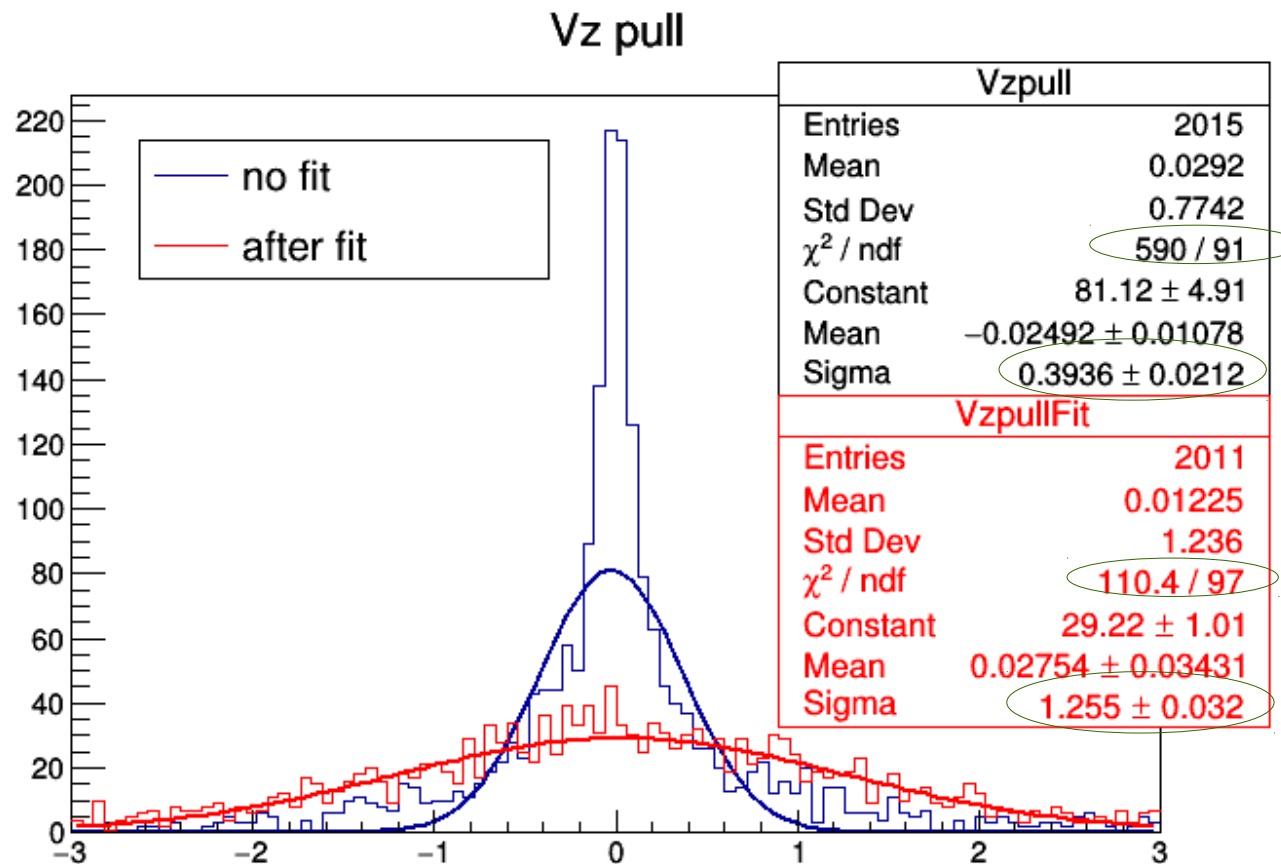
No significant changes are observed

X, Y pull distributions



pull dist. look better → correctly obtained errors

Z pull distribution



pull dist. looks better → correctly obtained errors

Conclusions

- Full chi2 fit was used to reconstruct HNL vertex from two charged tracks
 - as starting values parameters estimated from DOCA method were used
- Chi2 fit gives better estimate of the errors

Backup

HNL mass residual

