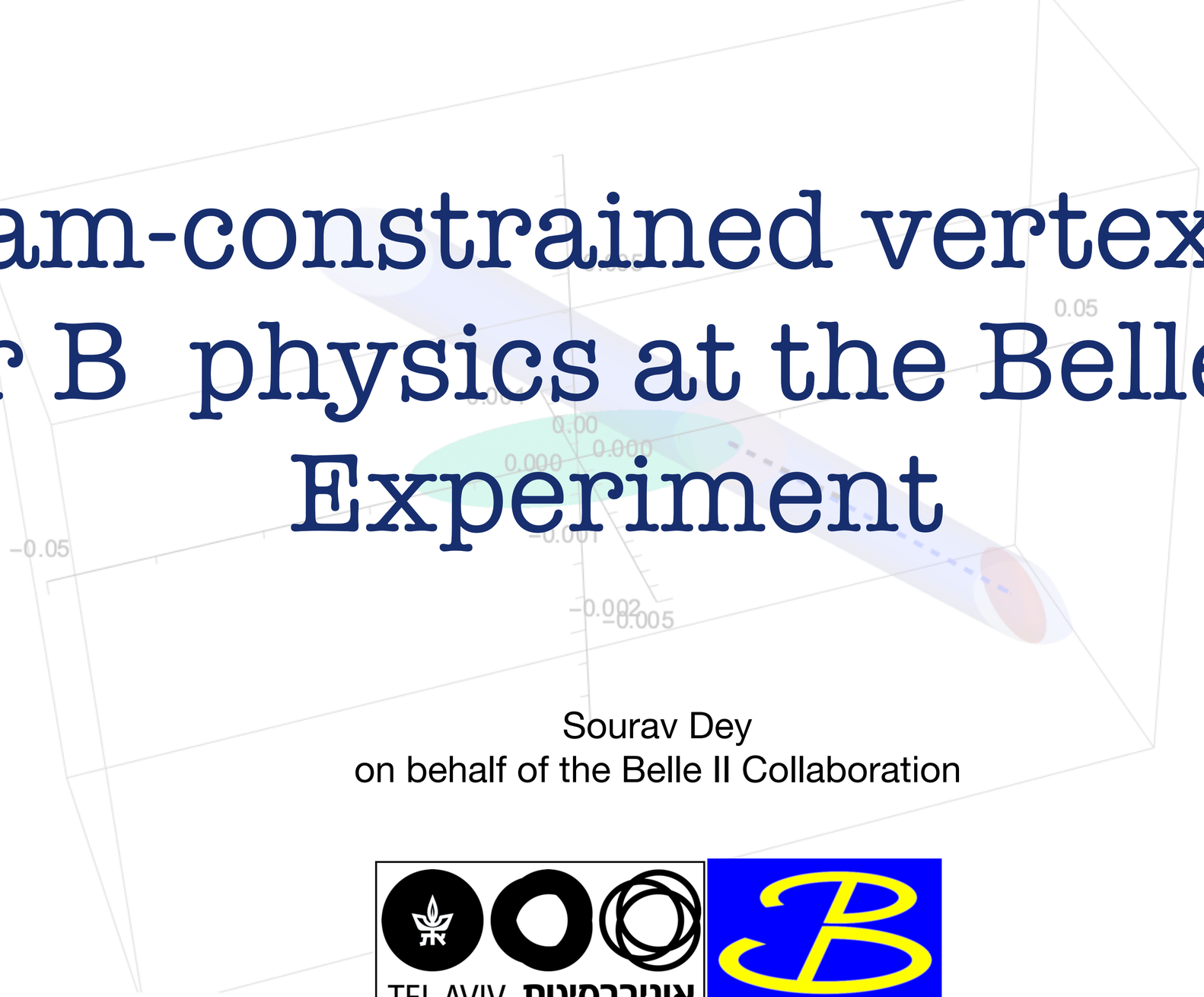
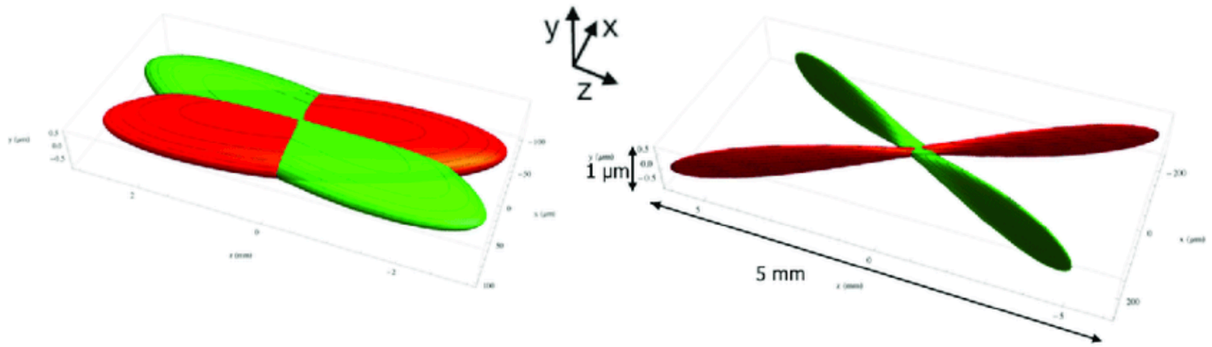
Beam-constrained vertexing for B physics at the Belle II Experiment

Sourav Dey
on behalf of the Belle II Collaboration



Introduction

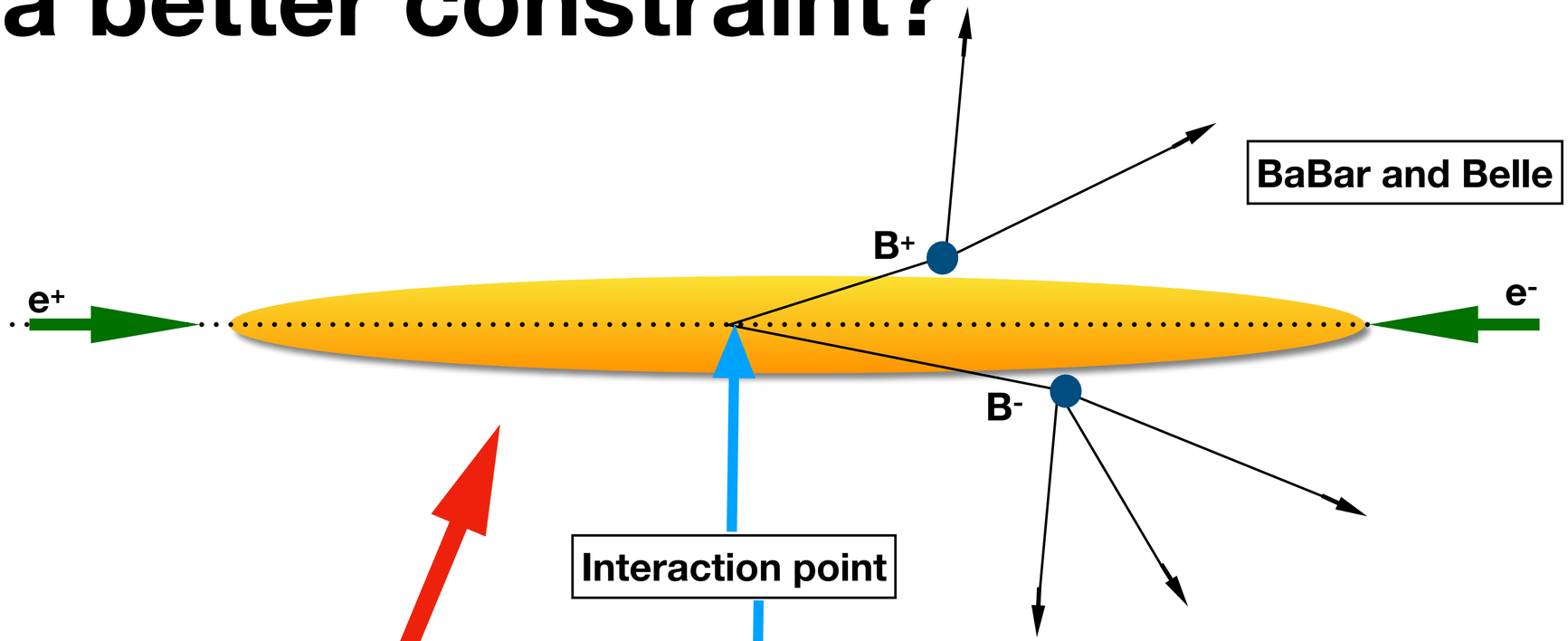
- In time-dependent analyses, the key ingredient is the difference between the time of decay of two B mesons. Determining B decay vertex positions correctly is necessary
- In BaBar, B^0 and B^+ average flight distance ~20 μm in transverse plane and ~260 μm in Z direction
- The beamspot size was ~(120 x 5 x 8000 μm^3), similar in Belle
- To obtain the B decay vertex position correctly, a vertex fit with interaction point(ip) constraint was sufficient
- In Belle II, the beamspot is smaller ~(6 x 0.06 x 150μm^3): thanks to nanobeam scheme. In addition, the tracking resolution is ~twice as good as at BaBar/Belle



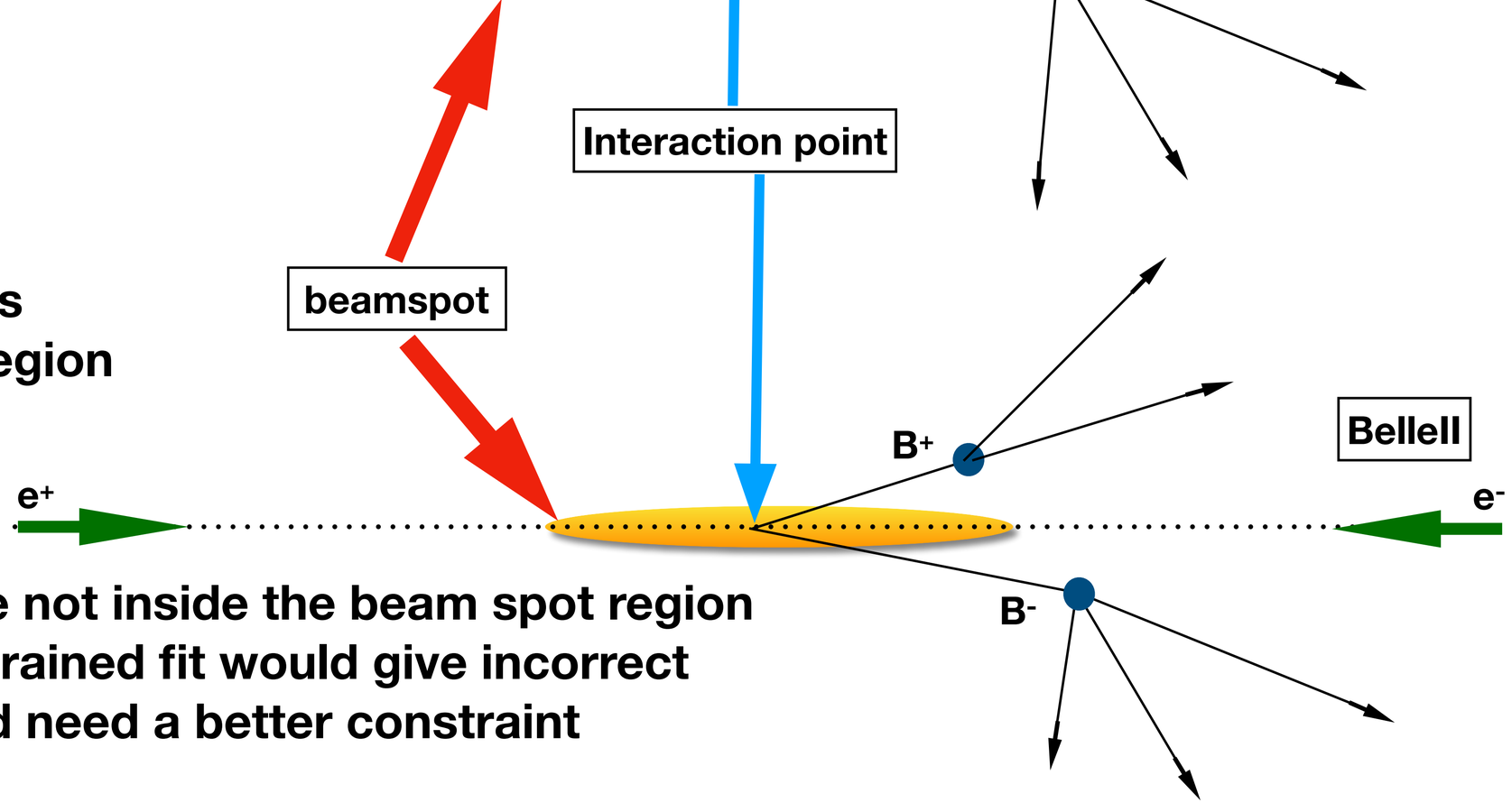
- In Belle II, an ip-constrained fit is not sufficient anymore. We need a better constraint

Why we need a better constraint?

In Babar and Belle, The B decay vertices resided inside the beamspot region : an ip-constrained fit used to give good result



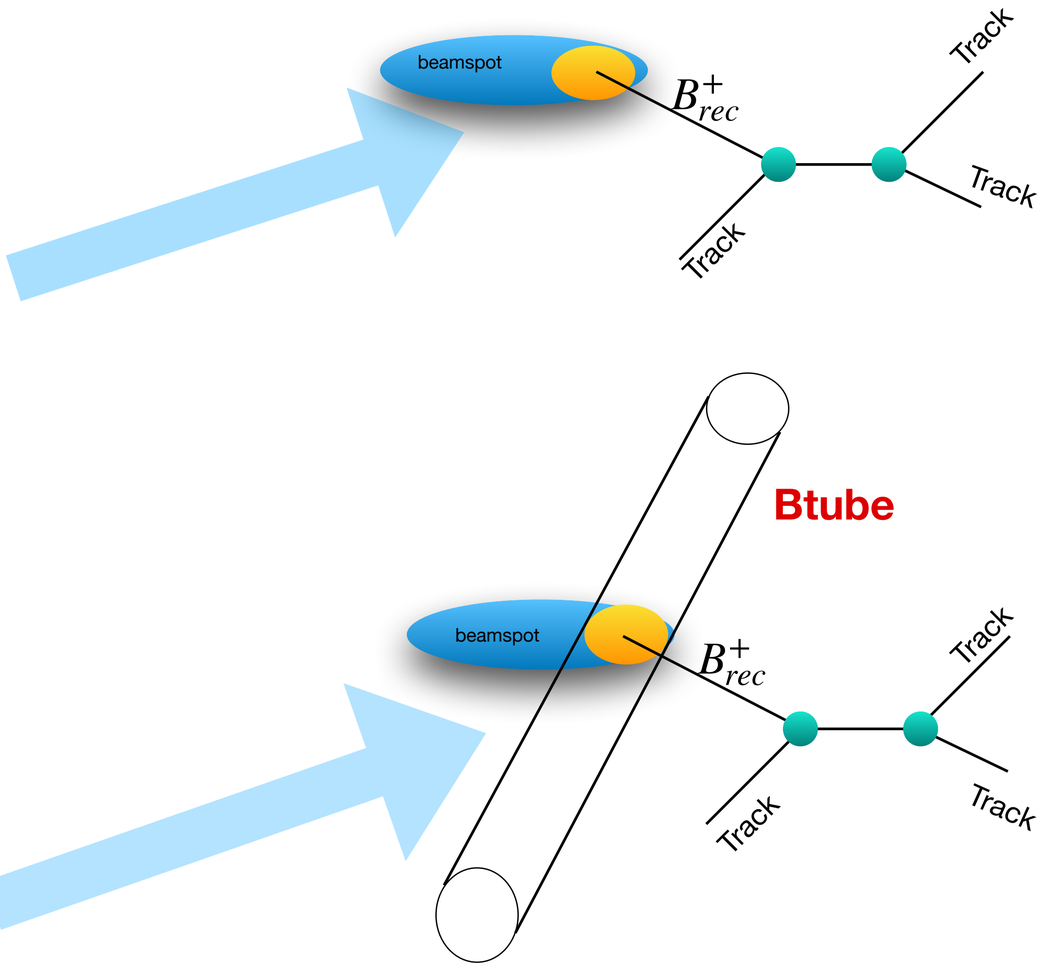
In Belle II, beamspot is much smaller : The B decay vertices come out of the beamspot region



The B decay vertices are not inside the beam spot region anymore. An ip-constrained fit would give incorrect result. We indeed need a better constraint

A new constraint: Btube

- Among two B mesons, we fully reconstruct one B (B_{rec})
- We propagate the B_{rec} track to the beamspot and apply a vertex fit. Result of this fit is a vertex which is the origin of both the B mesons.
- From four momentum conservation, we obtain the flight direction the other B .
- We then stretch the covariance matrix of the fully reconstructed B_{rec} vertex so that it has ~infinite size in the direction of the flight of the other B and use this tube-like object as the constraint of future other-B fits.



Procedure of creating the btube object and advantages of using it

Quality of fit using Btube: Event Generation

We generate some MC events. The fully reconstructed B and other B decays as follows

- We reconstruct the B_{rec} as

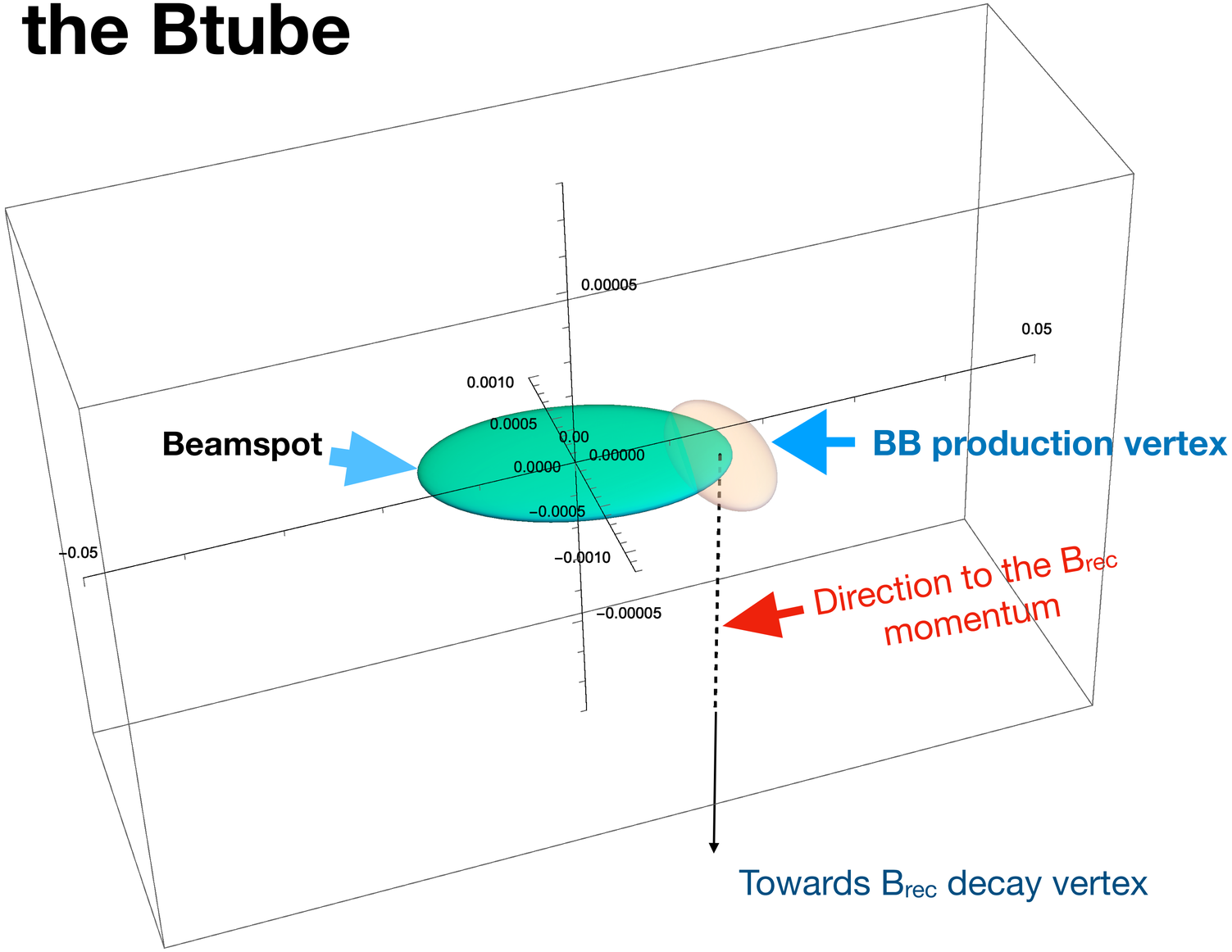
$$B^{+}_{rec} \rightarrow \bar{D}^{0}(\rightarrow K^{+}\pi^{-})\pi^{+}$$

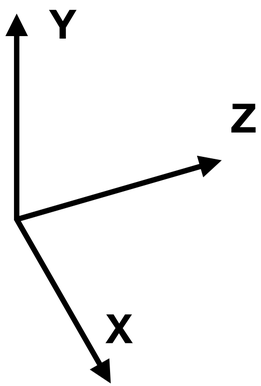
- The other B decays as

$$B^{-}_{other} \rightarrow J/\psi(\rightarrow \mu^{+}\mu^{-})K^{-}\pi^{+}\pi^{-}$$

We generated 1M mc events

Constructing the Btube

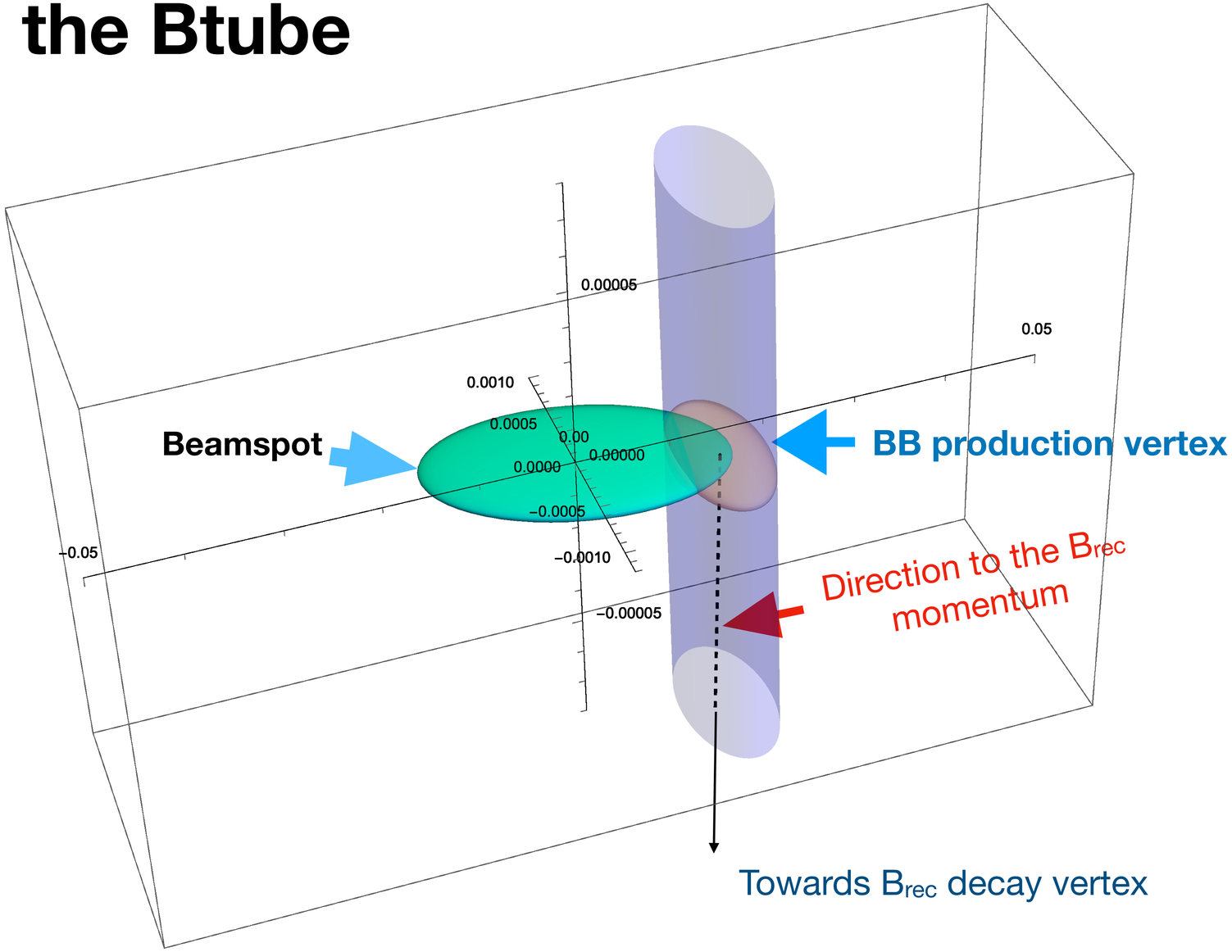




B_{rec} projectory is fitted to the beamspot
(scale in cm)

Graphics produced with Wolfram Mathematica

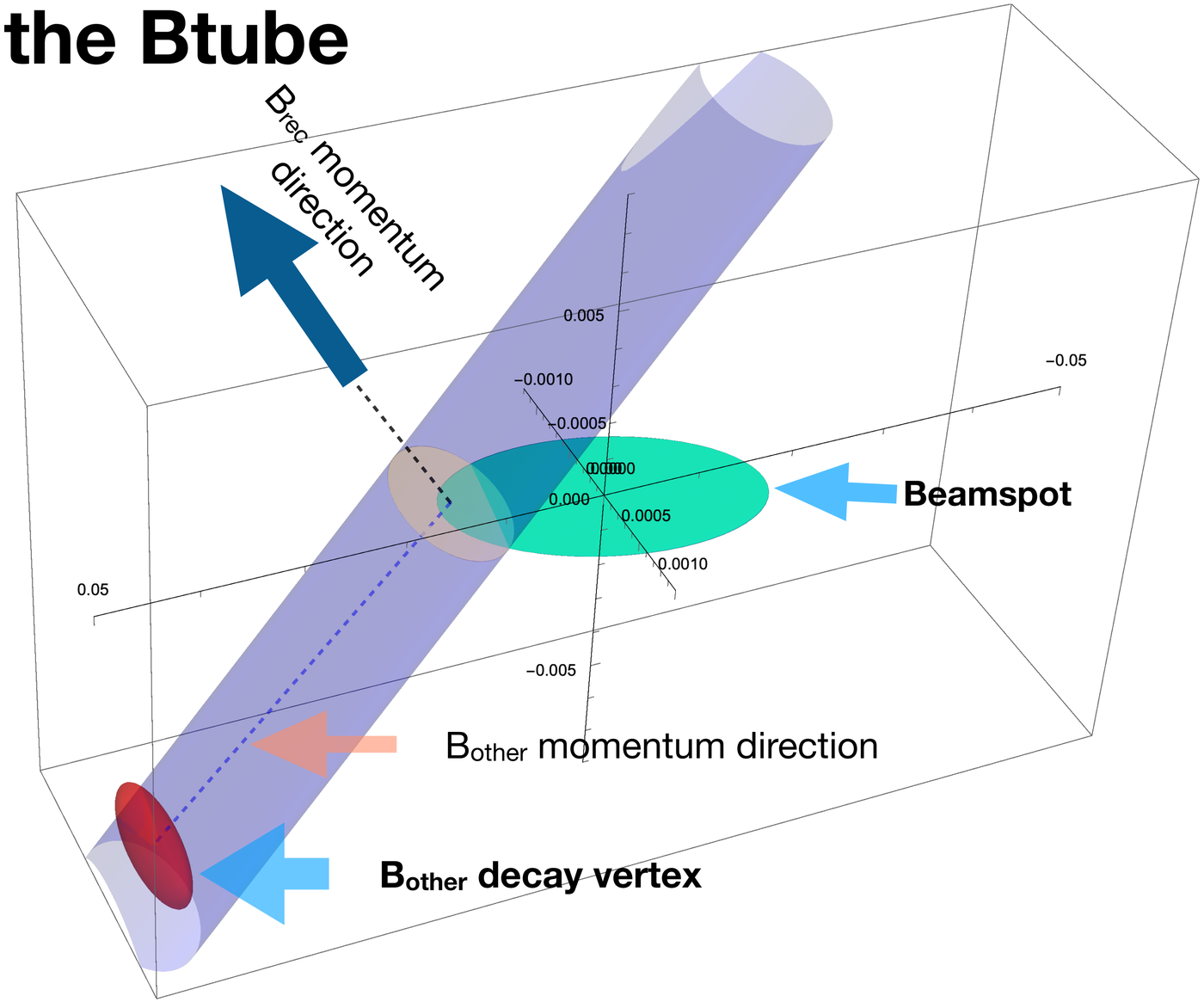
Constructing the Btube



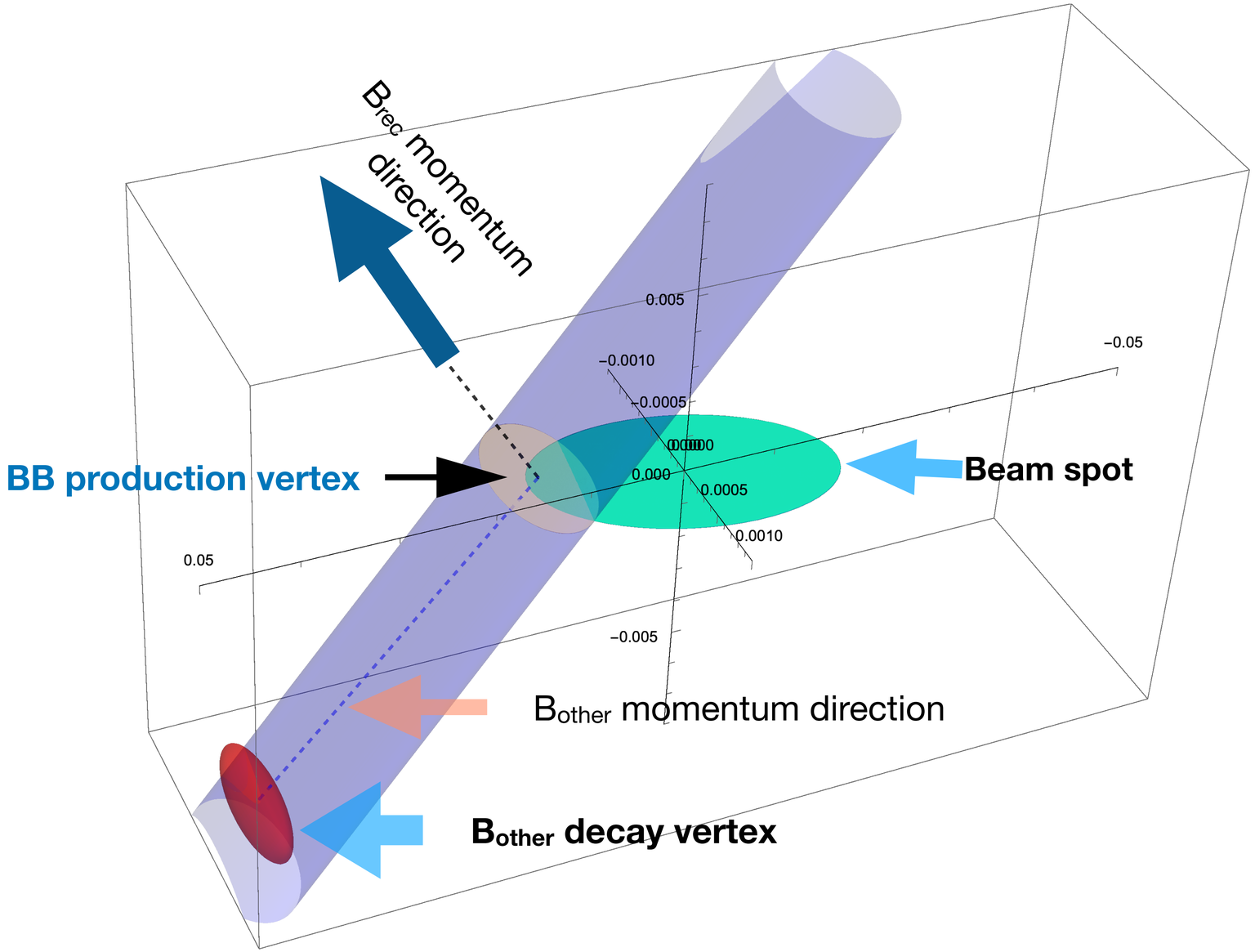
After estimating direction of B_{other}, the Btube is constructed

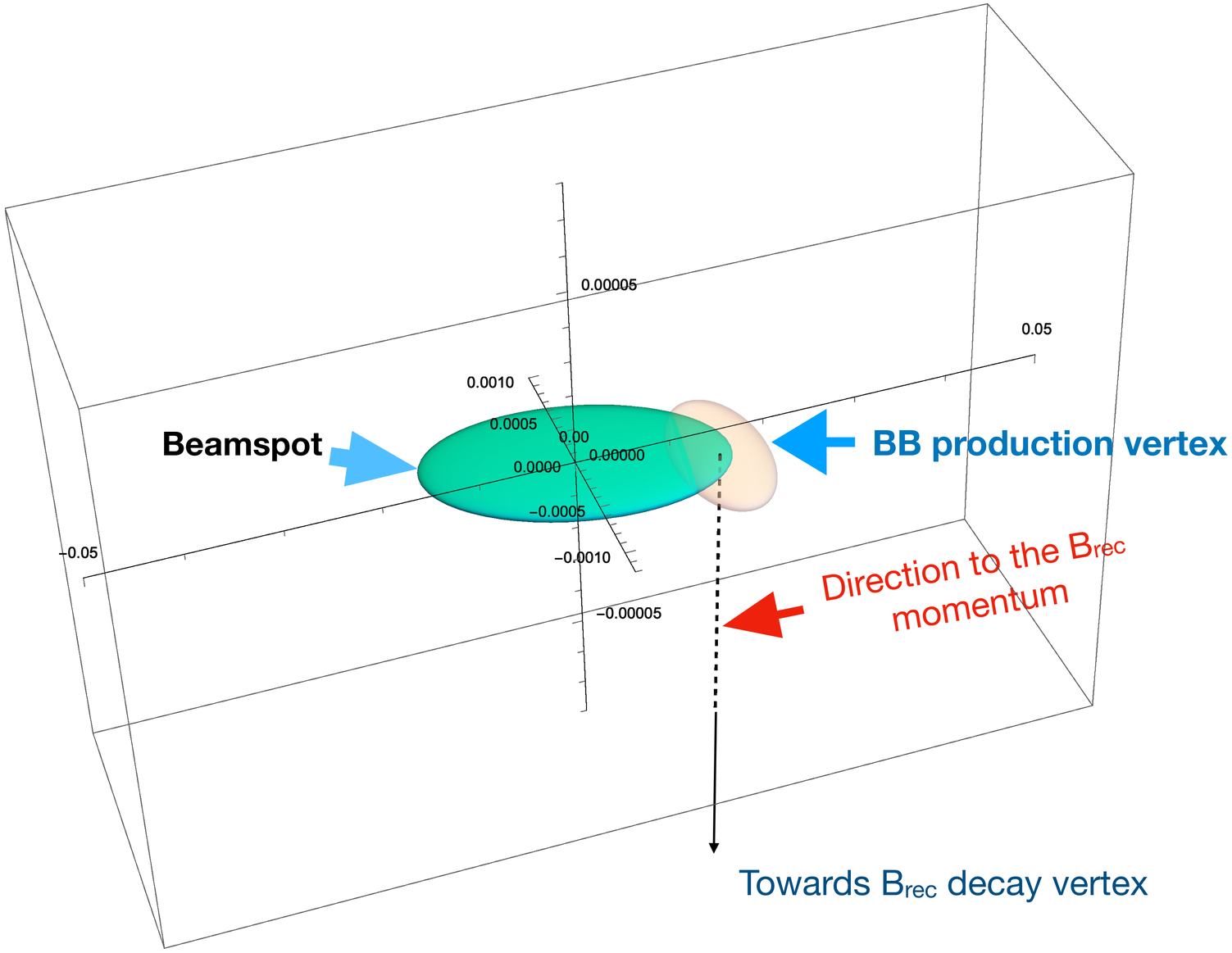
Graphics produced with Wolfram Mathematica

Constructing the Btube



After the other B is fitted with the tube constraint
(different y scale from previous slides)

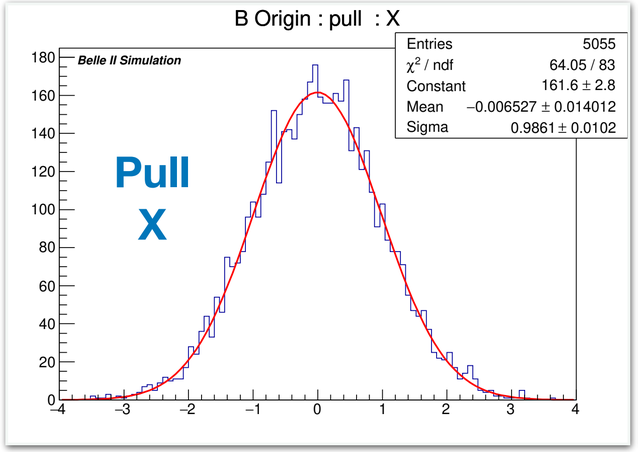

B_{rec} momentum direction
BB production vertex
Beam spot
B_{other} momentum direction
B_{other} decay vertex
0.005
−0.0010
−0.0005
0.000
0.0005
0.0010
−0.05
0.05
−0.005

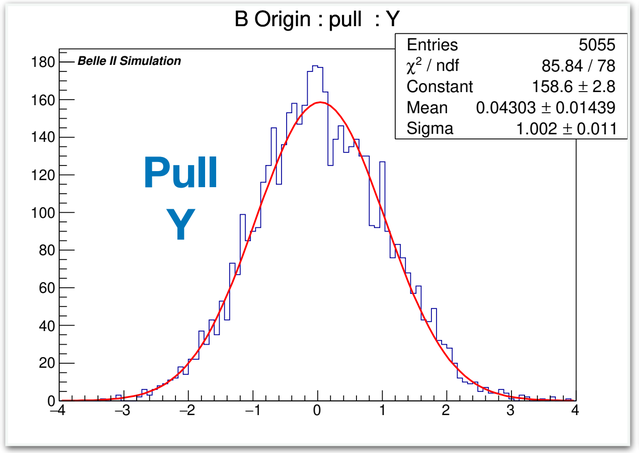


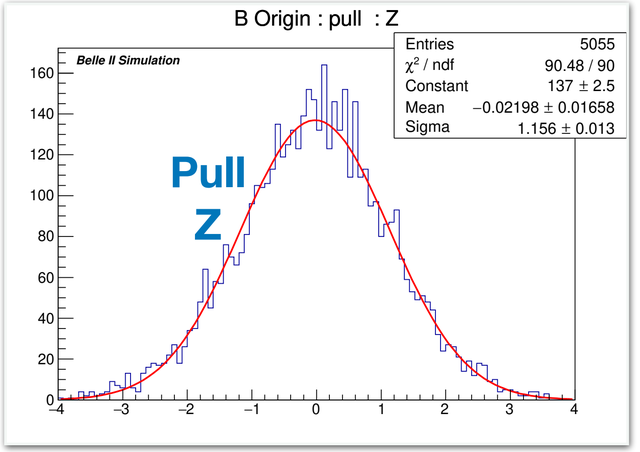
Next slide shows quality of BB production vertex fit

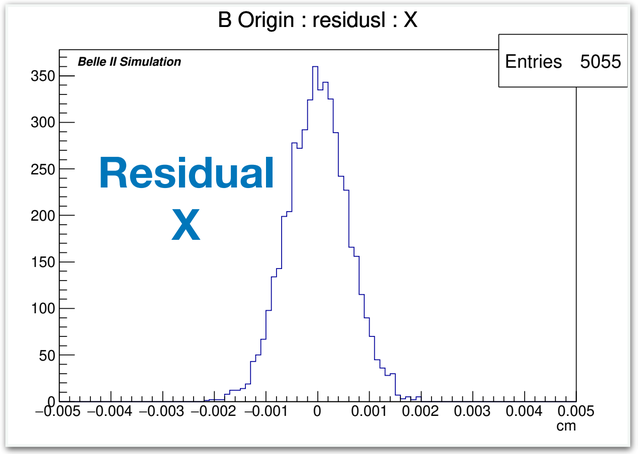
B origin uncertainties, residuals and pulls

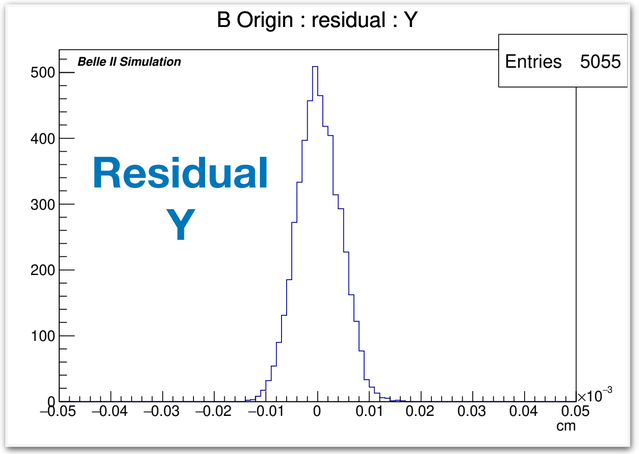
Key ingredient of btube

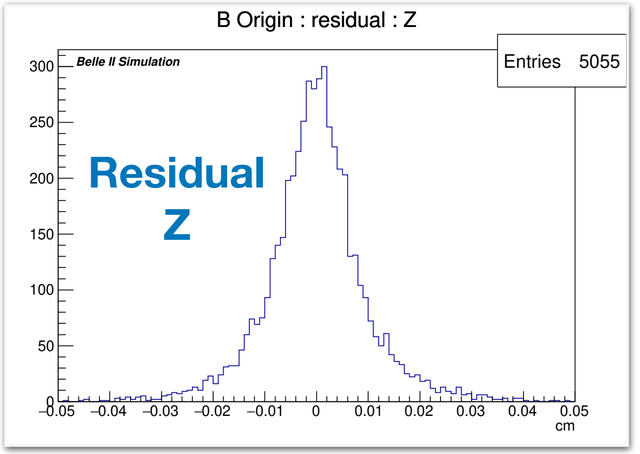


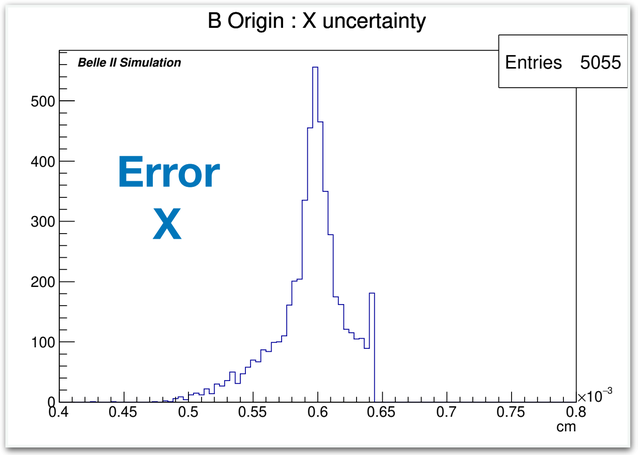


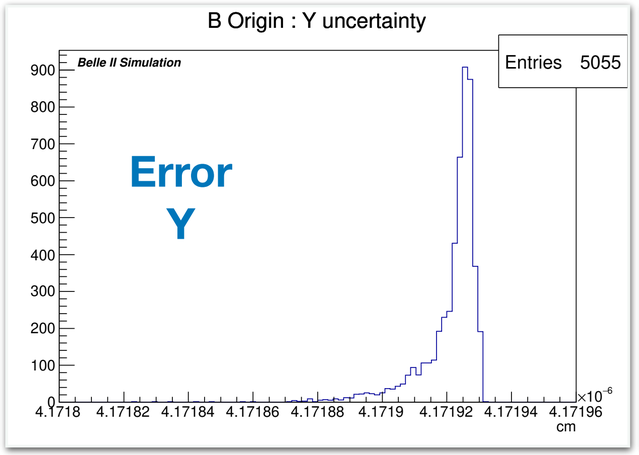


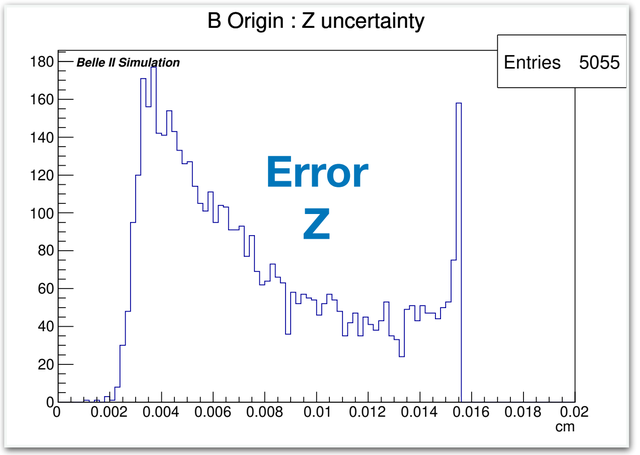












B origin uncertainties, residuals and pulls

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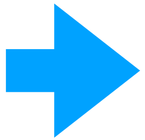
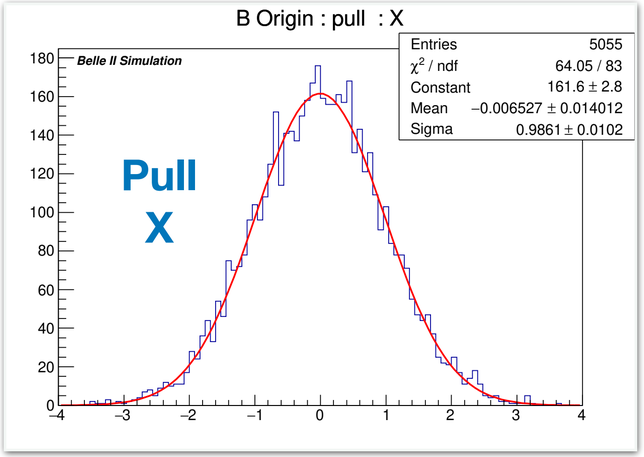
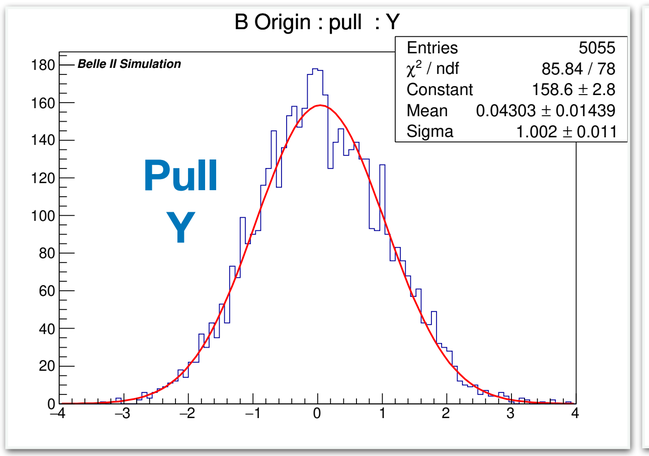
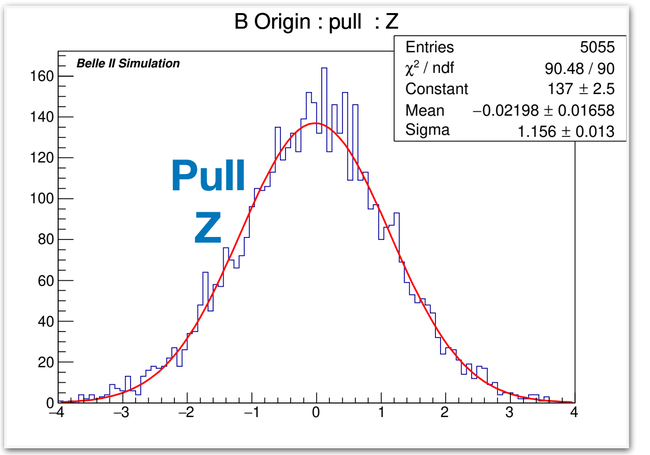
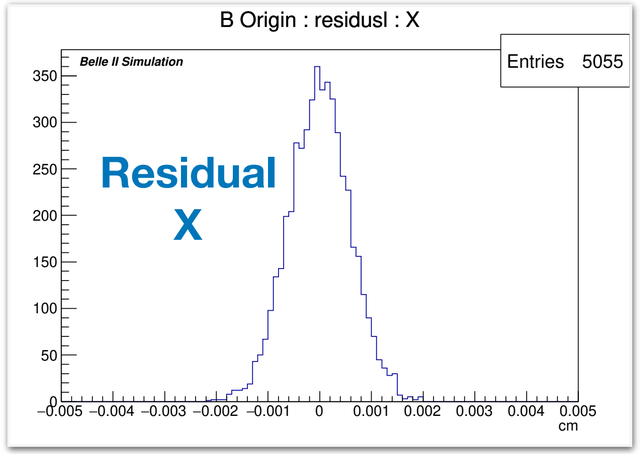
Pull Distributions are good

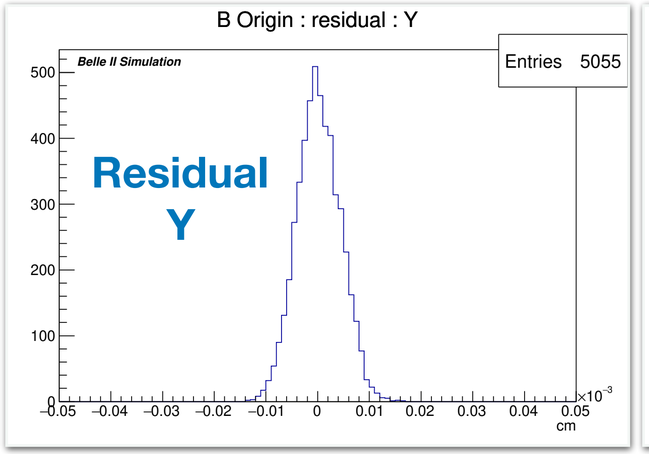


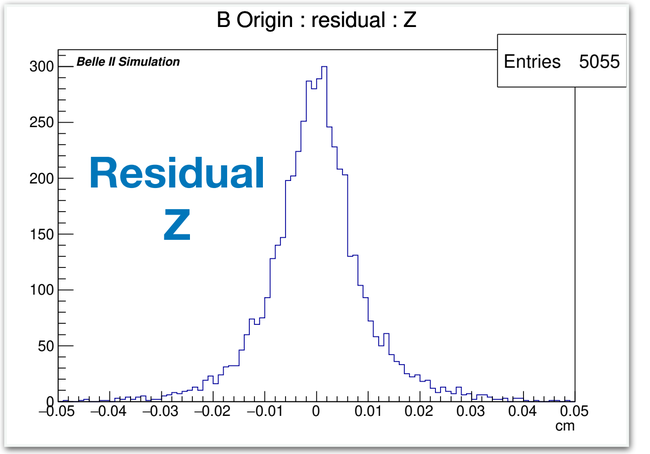


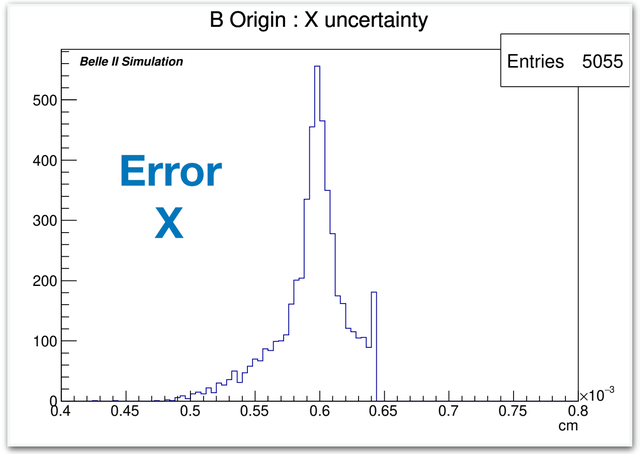


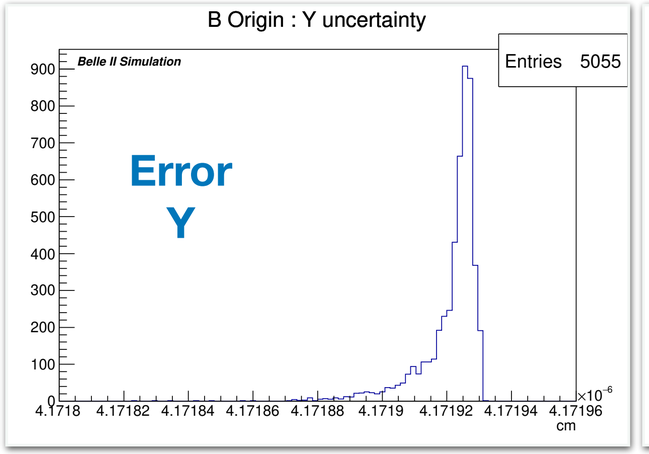


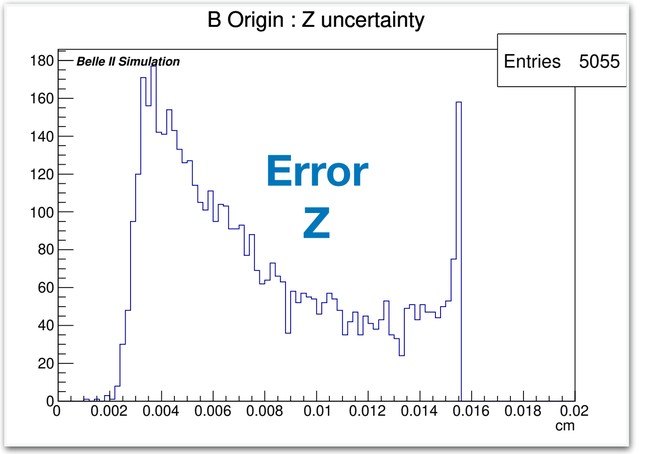




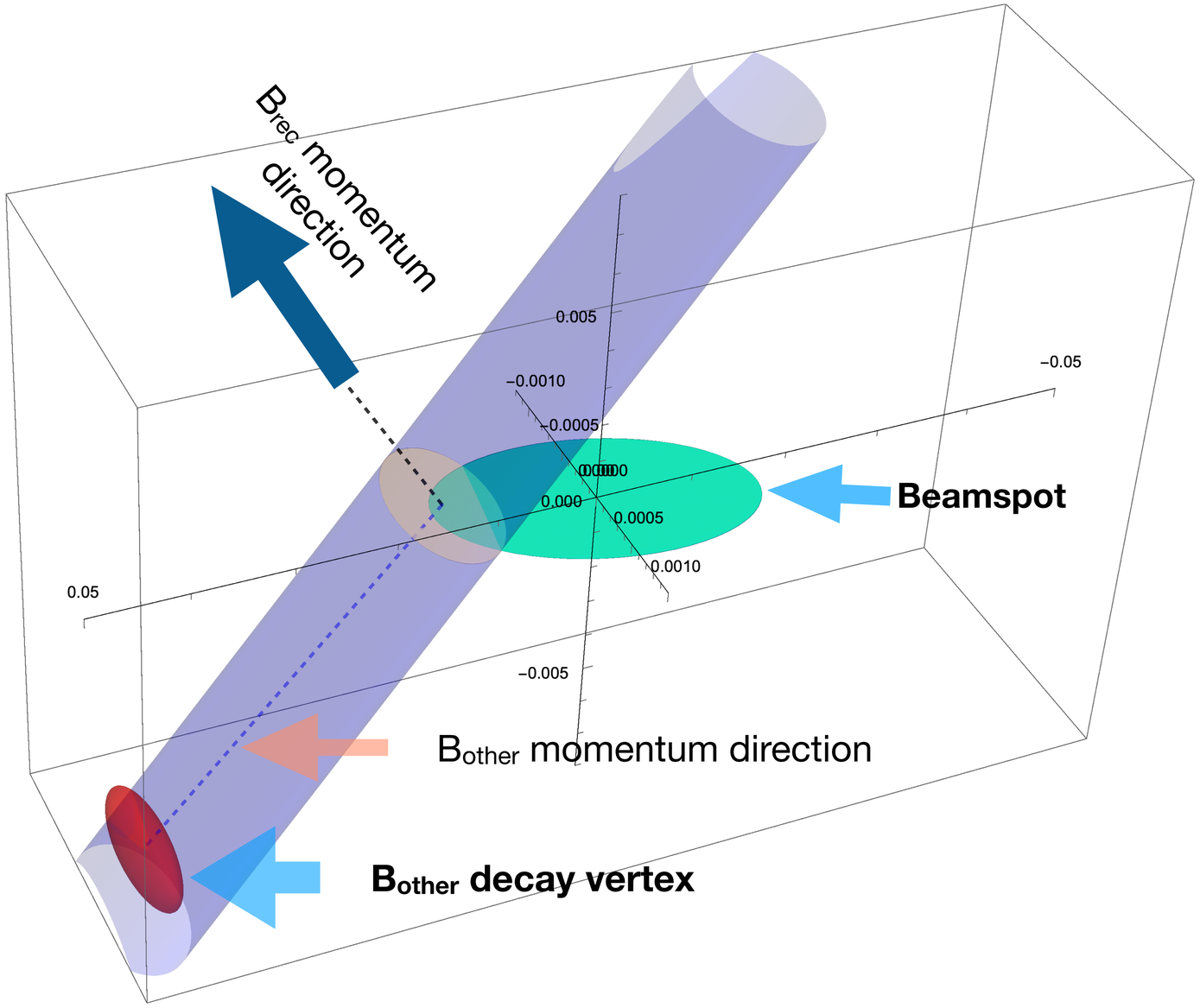








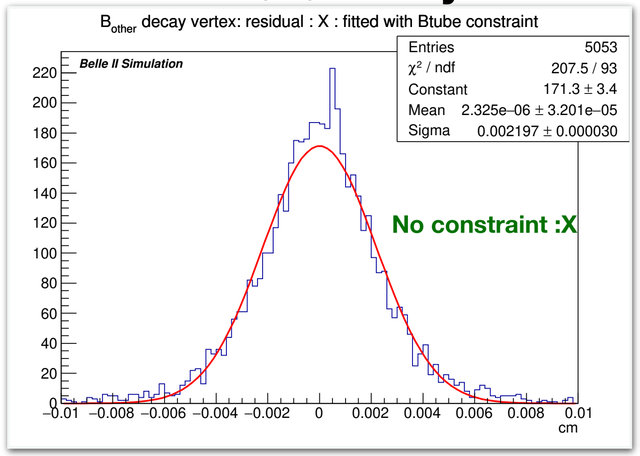
Distinct cut-off in X and Z component : small beam spot size

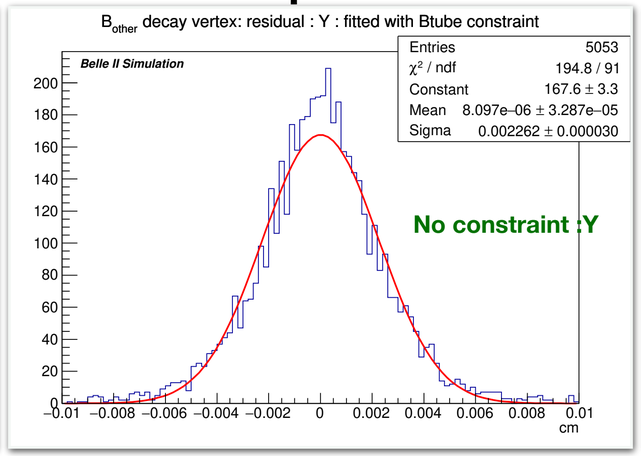


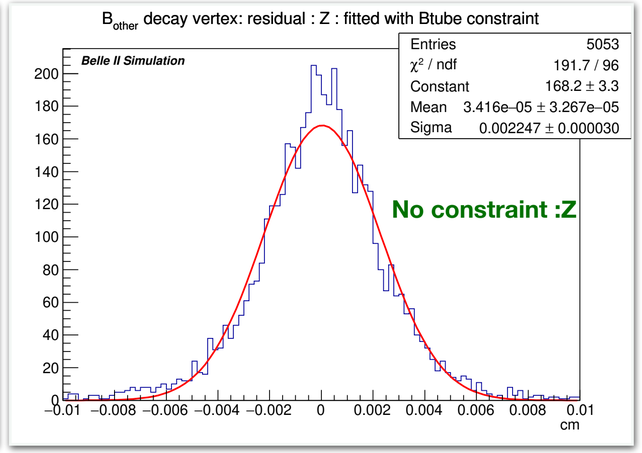
Next slides test the quality of the B_{other} vertex fit

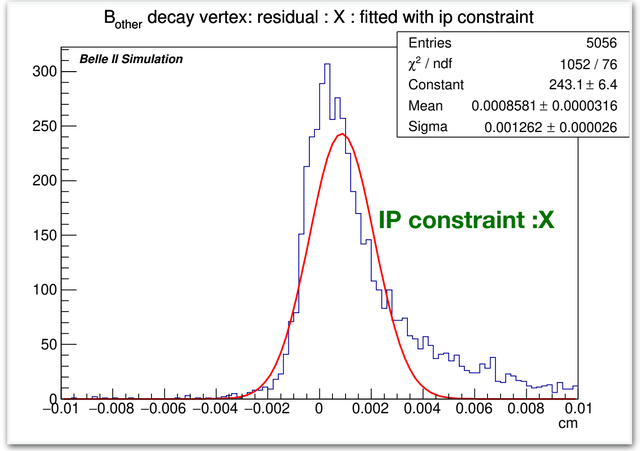
B_{other} decay vertex residuals : comparison

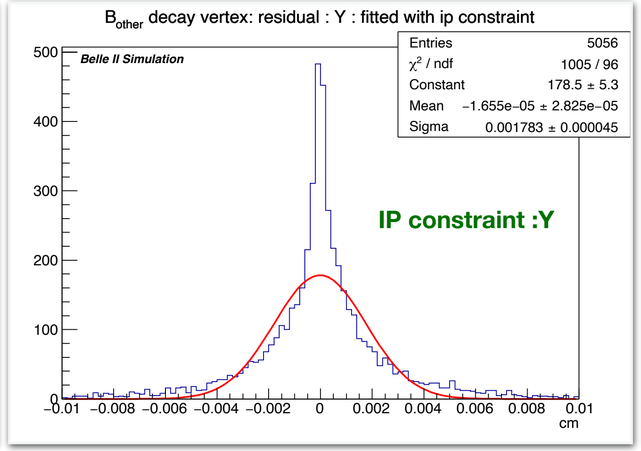
The tube constrained fit plots are most narrower

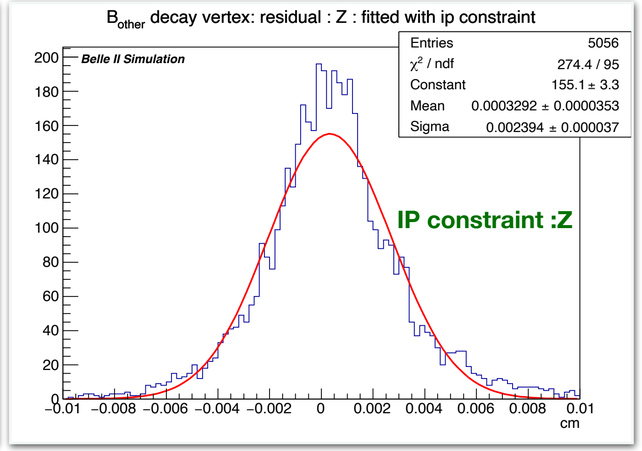


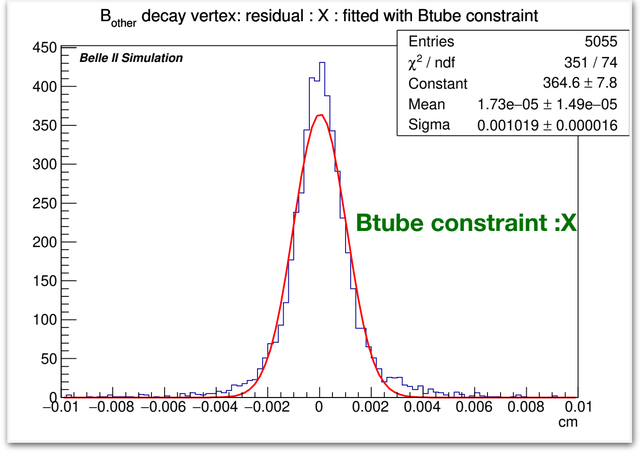


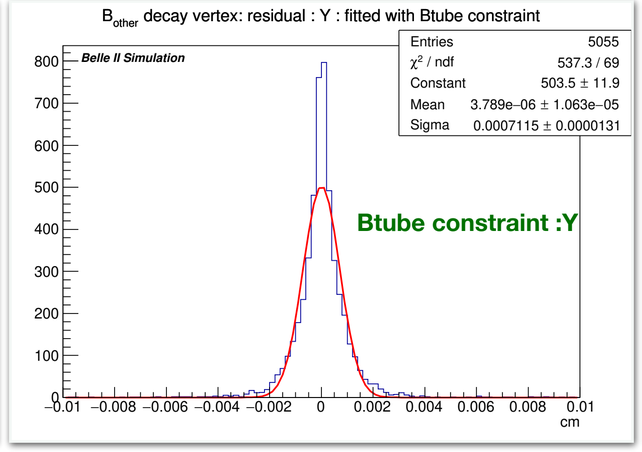


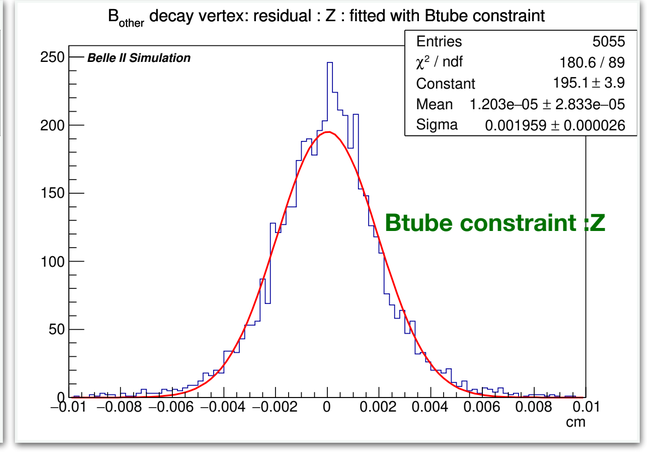




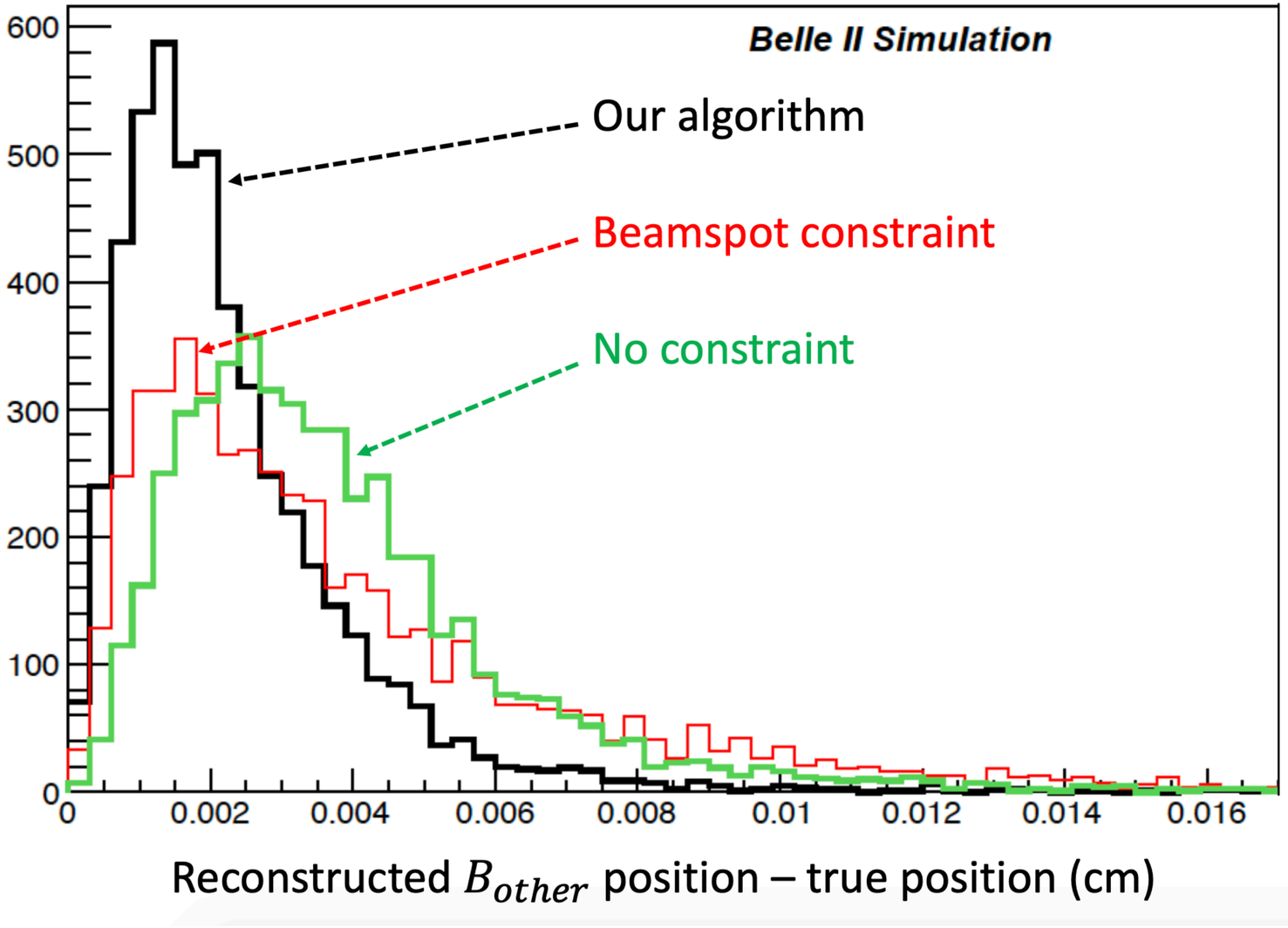








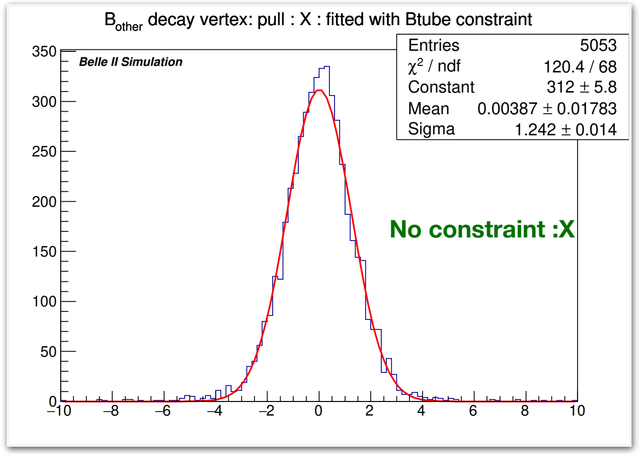
Other B decay vertex absolute residuals : comparison

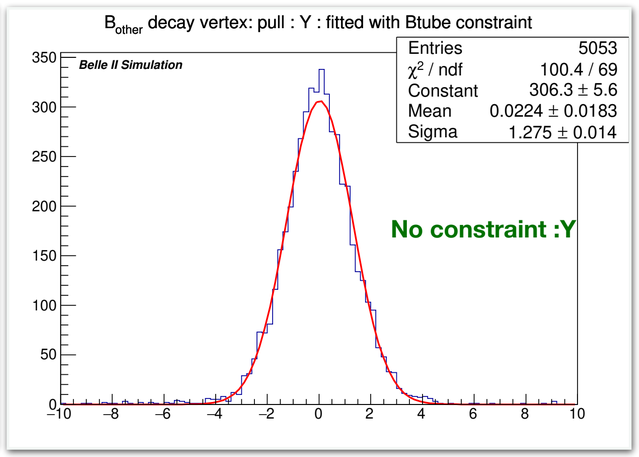


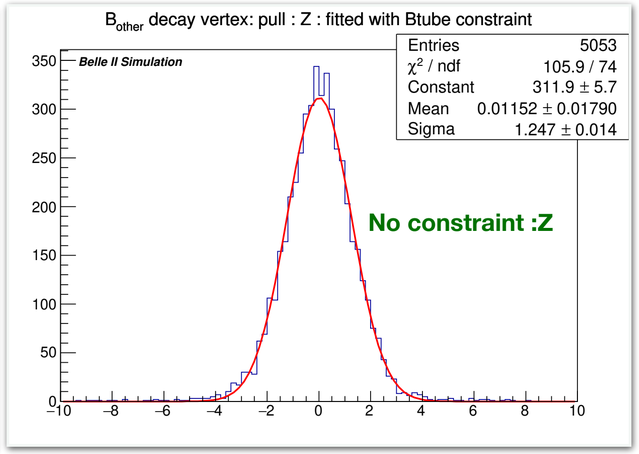
Using the btube constraint yields a B_{other} decay vertex that is closest to the true decay position.

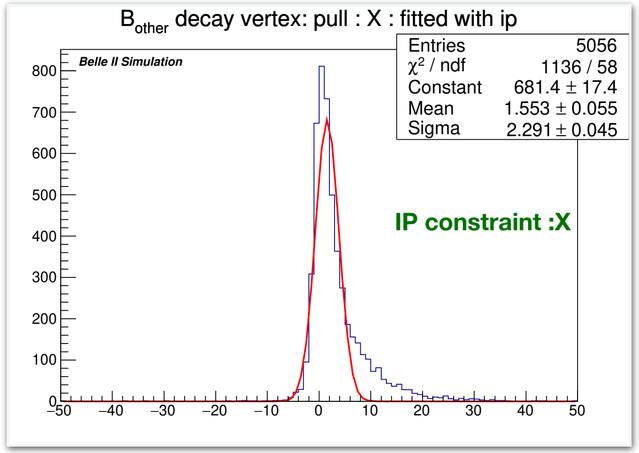
B_{other} decay vertex pulls : comparison

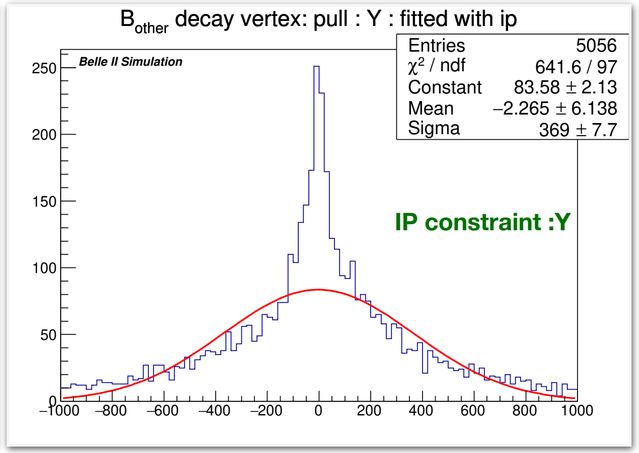
In ip-constrained fit, uncertainty in Y axis is too small to make a meaningful pull plot

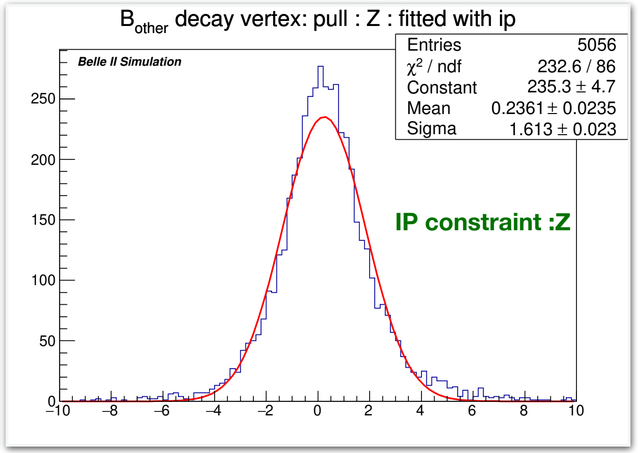


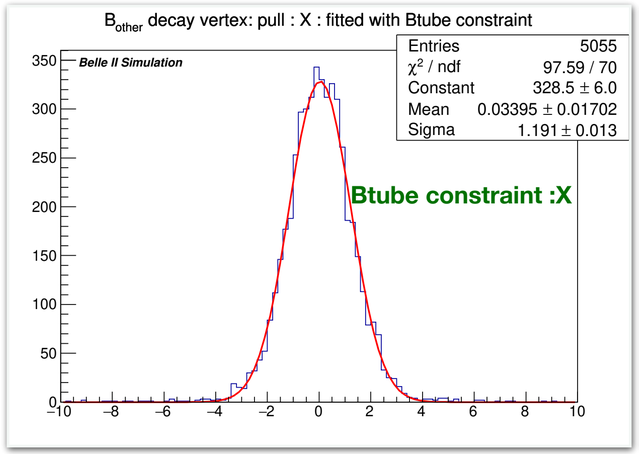


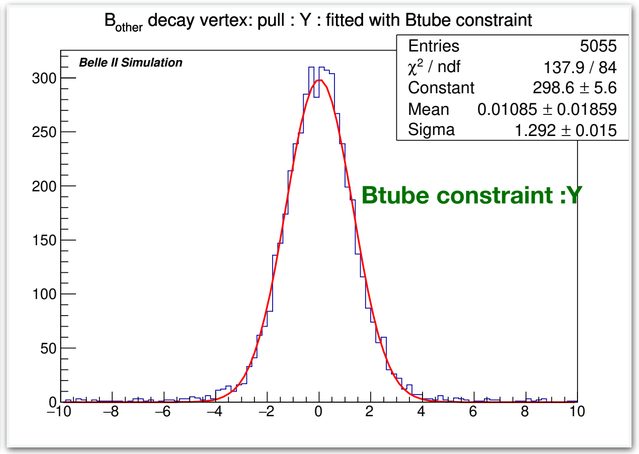


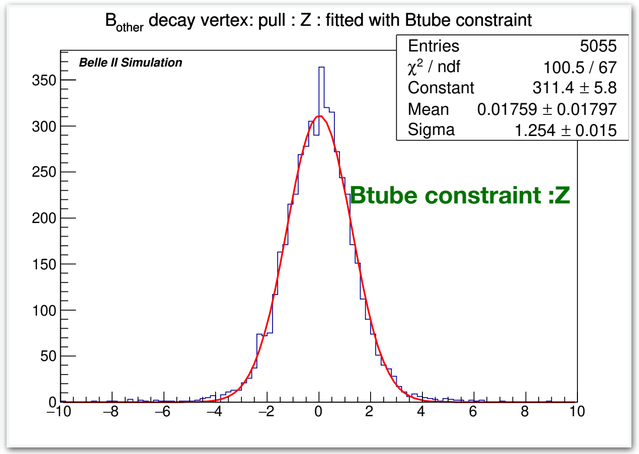












Conclusion

- Using the btube constraint yields a B_{other} decay vertex that is closest to the true decay position.

- Various potential usages
  - reduce bias in time-dependent measurements , improve Δt measurement
  - Provide background rejection in various B decays, e.g.: $B \to D\tau\nu$,$B \to \tau\nu$ where $\tau \to 3\pi\nu$, $B \to K^{(*)}\nu\bar{\nu}$, $B \to K^{(*)}\tau^{+}\tau^{-}$

Thank you for your attention

Backup

B_{other} decay vertex uncertainties : comparison

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