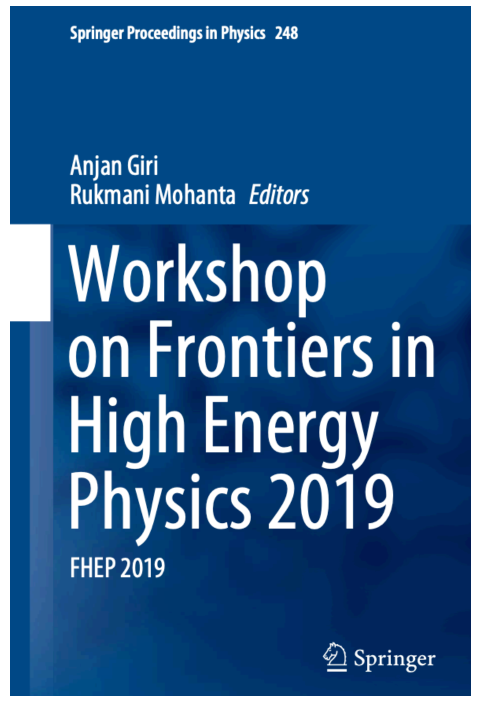
Btube and performance paper meeting

B2GM, 10 Oct, 2024

Sourav Dey

Documentation already available for Btube:

- Talk given at FHEP2019: https://docs.belle2.org/record/1764/files/BELLE2-TALK-CONF-2019-159.pdf
- A conference proceeding based on the above note: https://doi.org/10.1007/978-981-15-6292-1_52

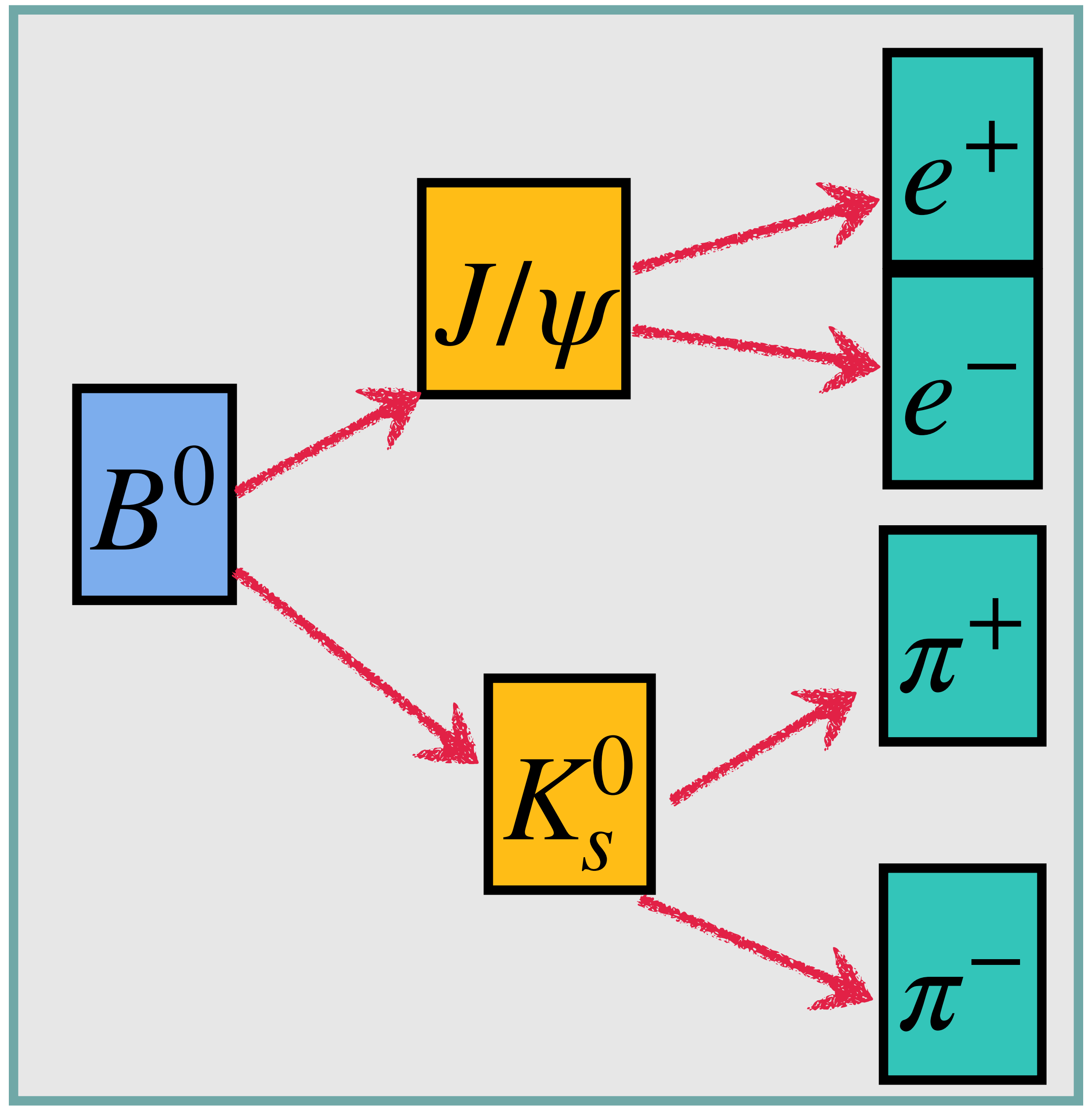


- additional talk at a previous B2GM

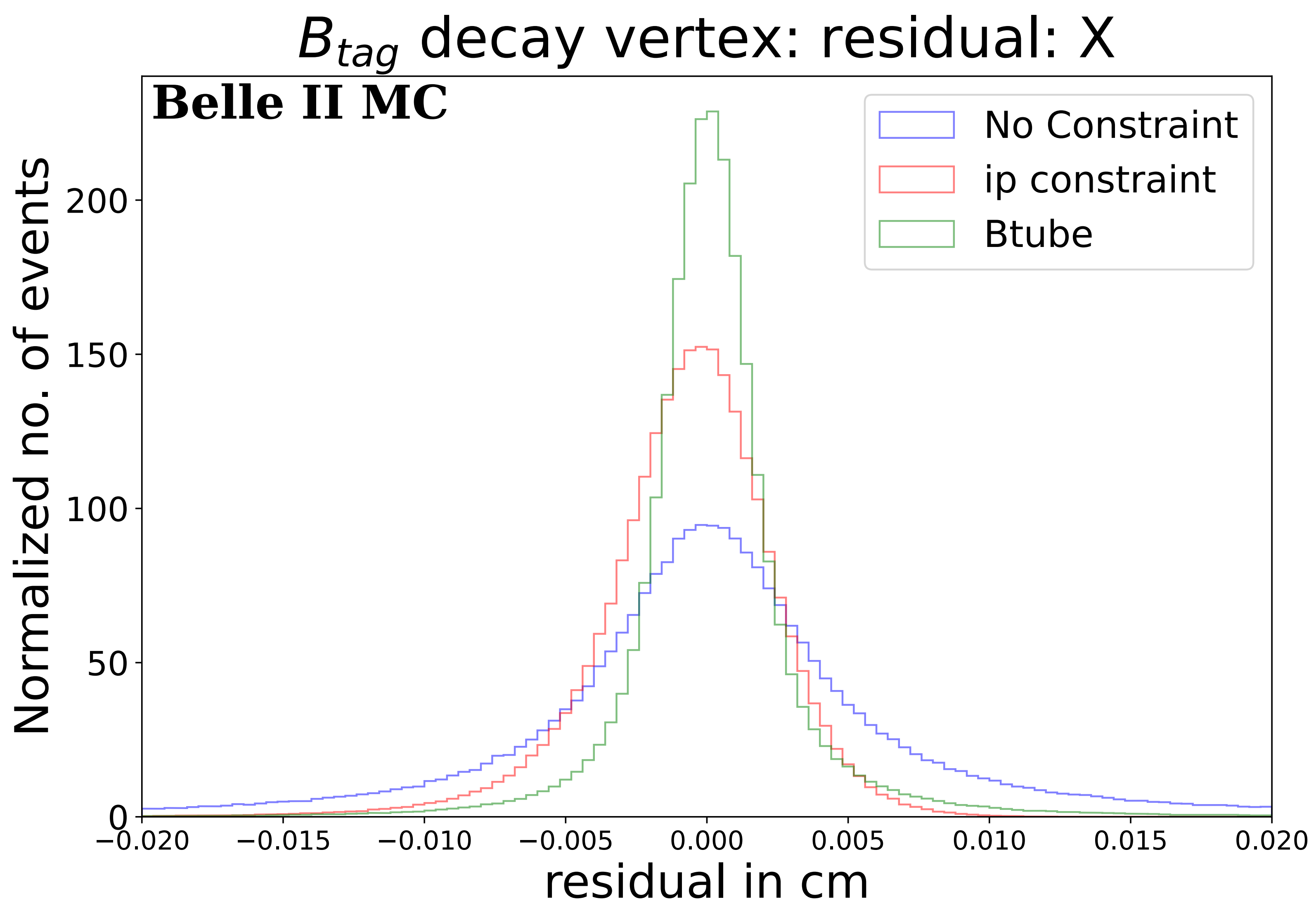
We would like to have a collaboration authored algorithm paper for proper citation

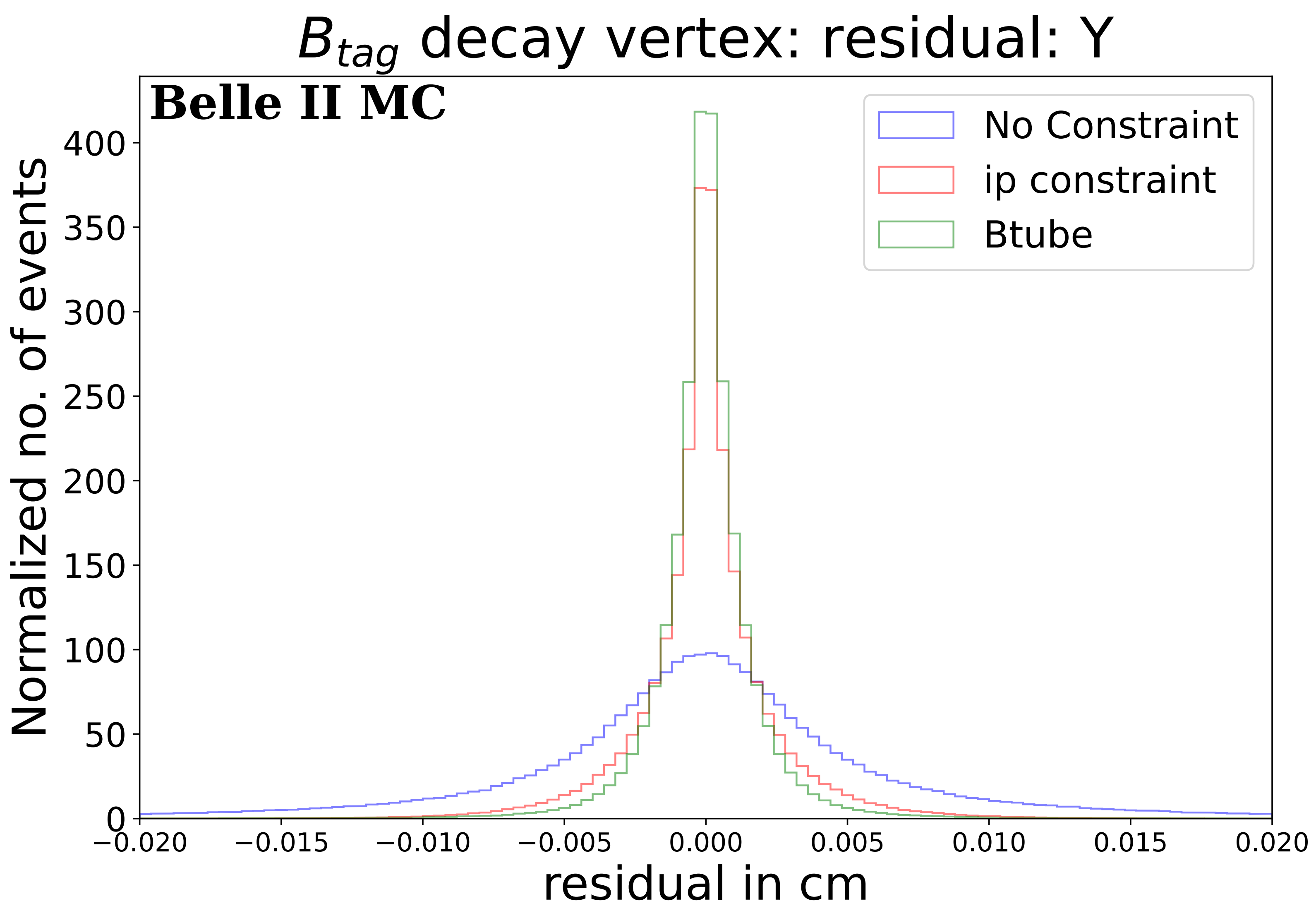
Signal MC

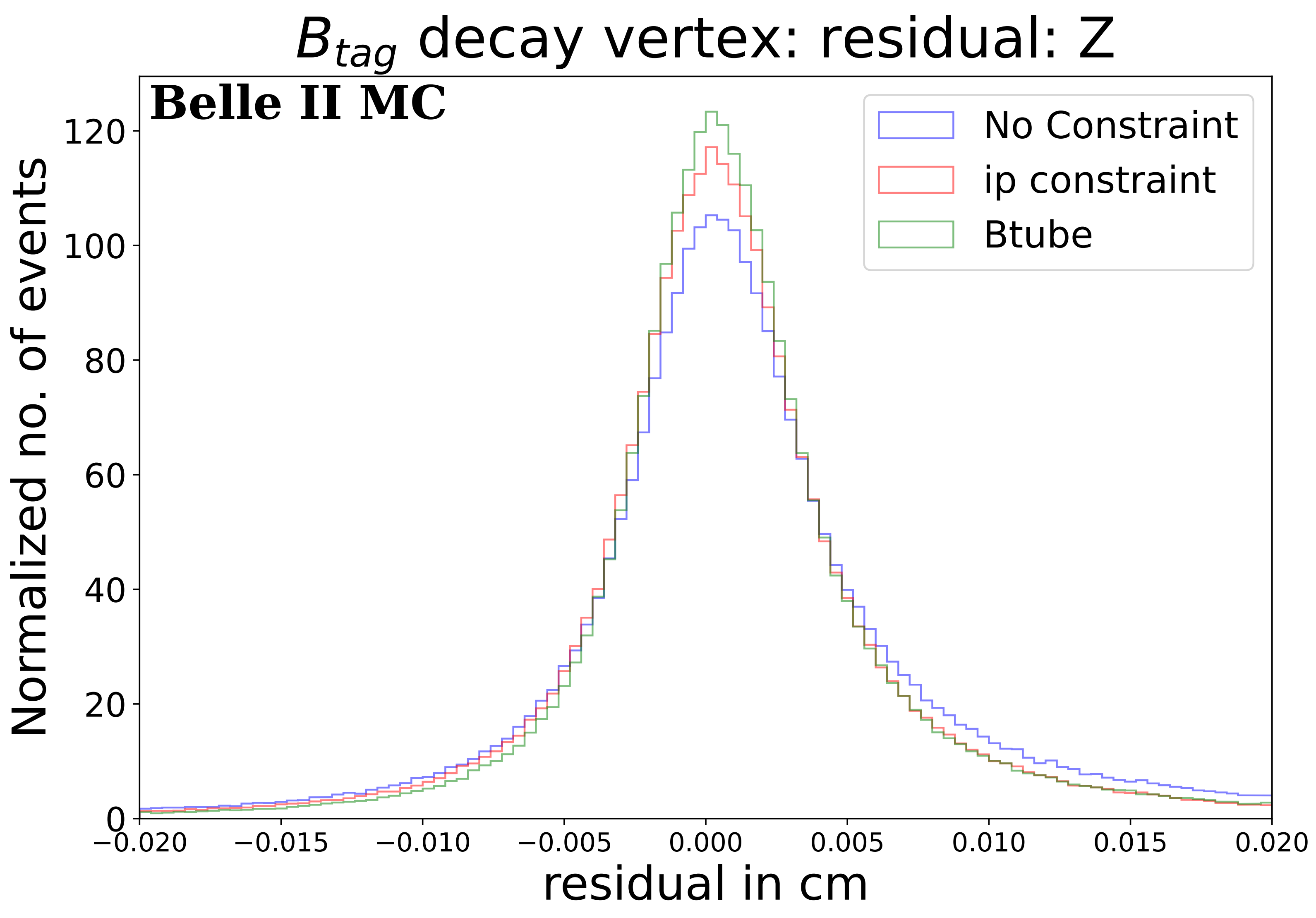
- MC event type: `1111540100` :
    - $B^0 \to J/\psi[e^+e^-]K_s^0[\pi^+\pi^-]$
    - dec: https://gitlab.desy.de/belle2/software/basf2/-/blob/main/decfiles/dec/1111540100.dec
- campaign MC15ri_b
- Ntuples are produced with release-06-02-00
- n_events = 2000000

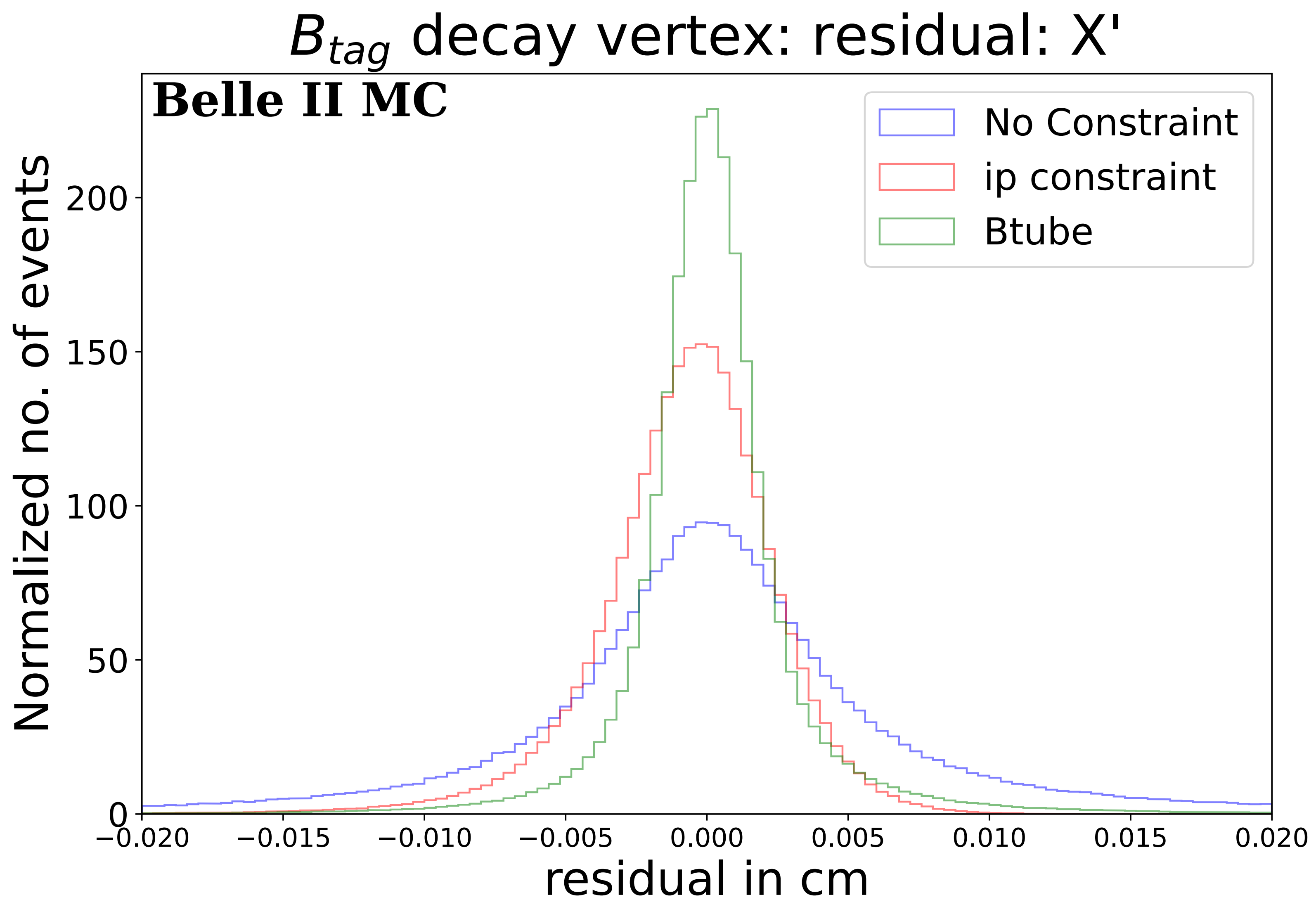


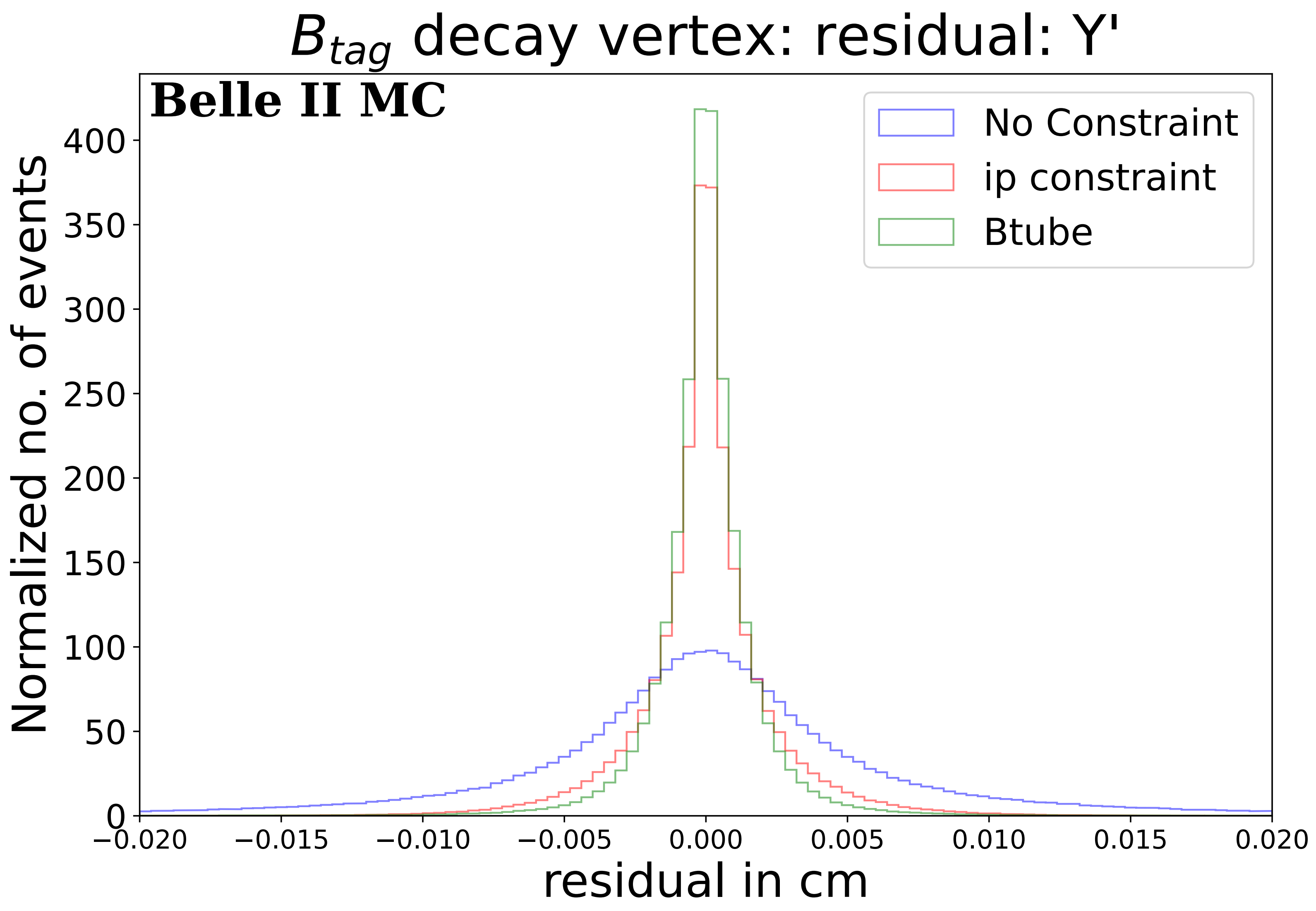
Tag B properties

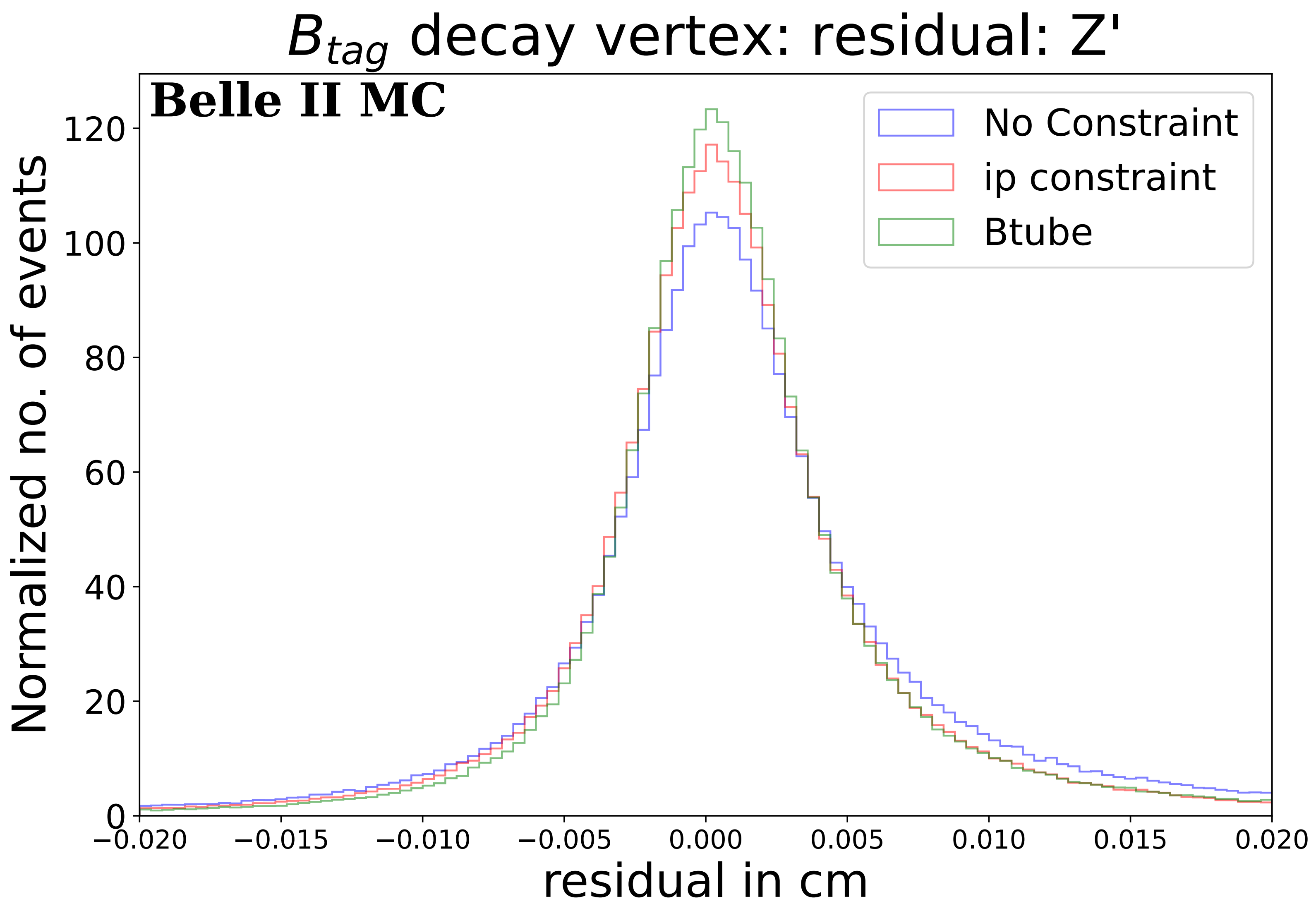




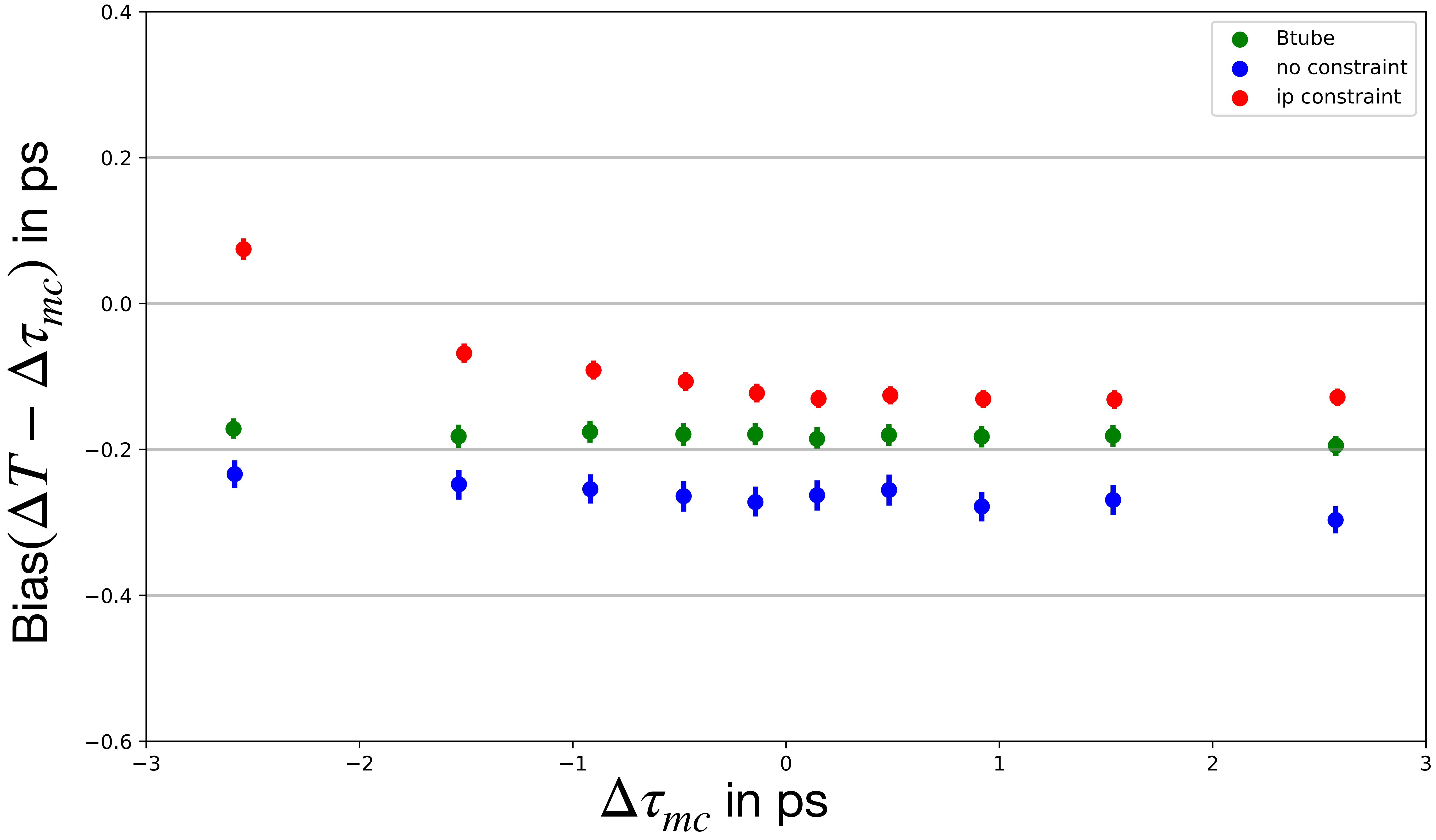








$$B^0 \to J/\psi[e^+e^-]K_s^0[\pi^+\pi^-]$$



I was stuck at this point, thanks to Michele for providing recommended cuts which eventually solved the problem

Collision point properties From the BTube algorithm

Plans for the paper

- Description of the algorithm with graphics : Done

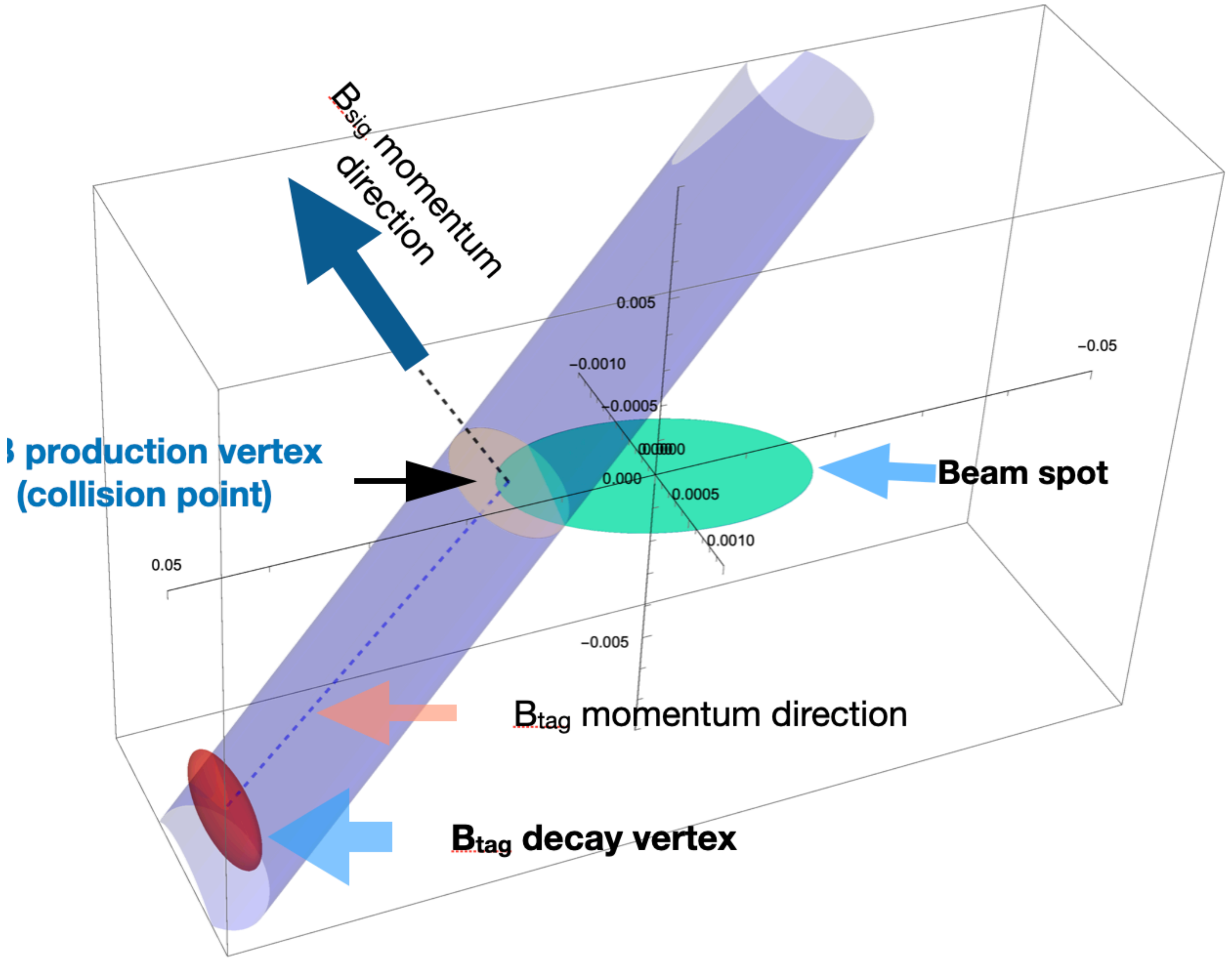
  (Graphics produced with Mathematica from an actual MC event)

- all the tests : with newer basf2 release : Done with 06-02-00

- Include in the text : how Δt is calculated : explain briefly and cite a proper paper?

- Performance plots : Done

- Target journal : NIM A



Questions on Beamspot

Hi all,

I had a question about the knowledge of the beamspot in SuperKEKB. The BaBar luminous region paper assumes the following:

- Negligible x-y coupling at the IP for both rings
- Negligible dispersion
- Beam-beam effects are negligible (so bunches are Gaussian)
- RF effects are negligible (so bunches are Gaussian)

Do we know if these assumptions are good approximations for SuperKEKB? I thought it would be worth asking by e-mail in case the answer was no, as that would give us some time to talk to machine colleagues to try and understand the details.

Best wishes,

Adrian

We need Radek's expertise here

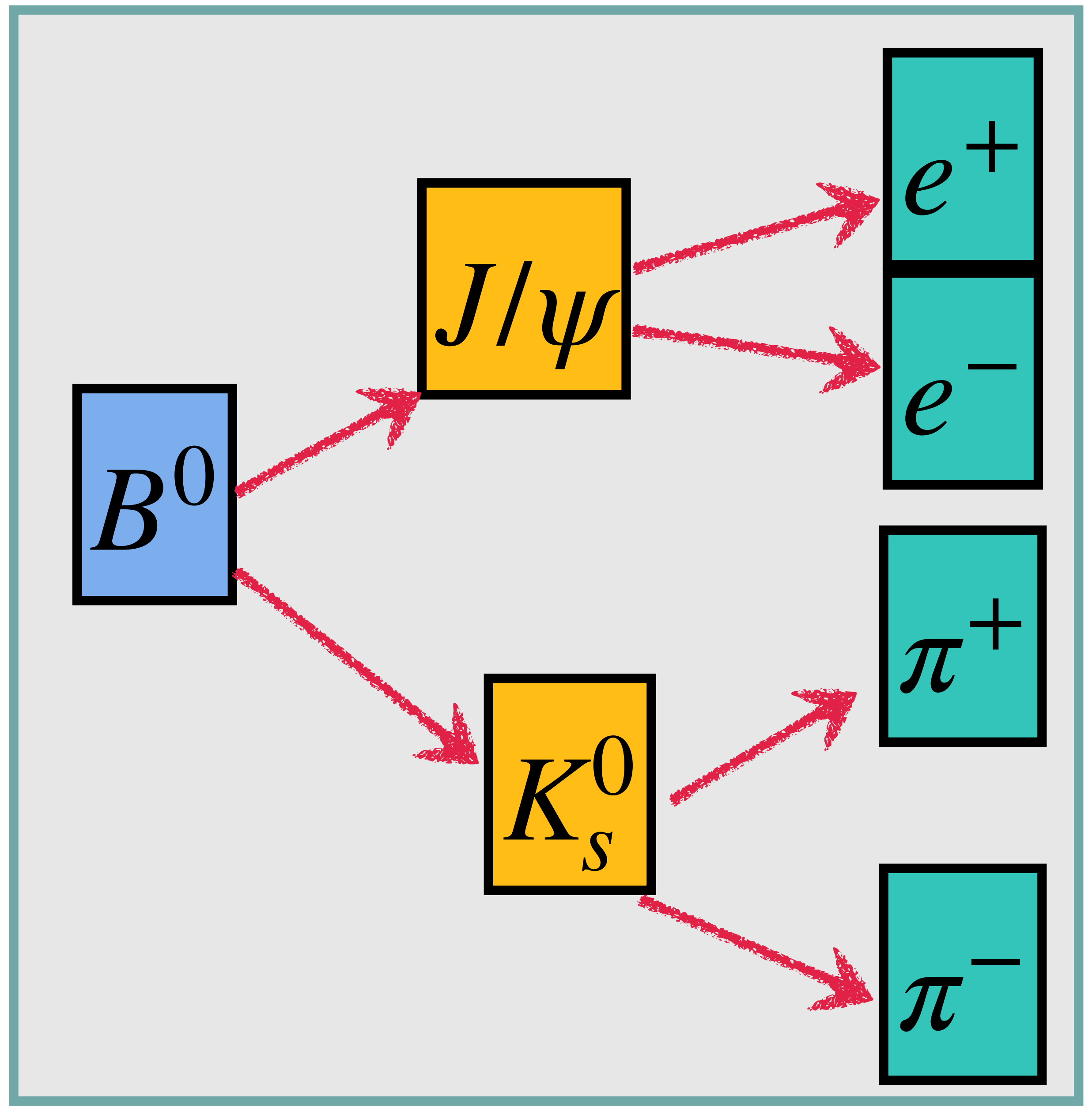
We also need to finalize...

- Who is going to write the beamspot part of the paper : timeline ?
- Should we ask to form a review comity now?

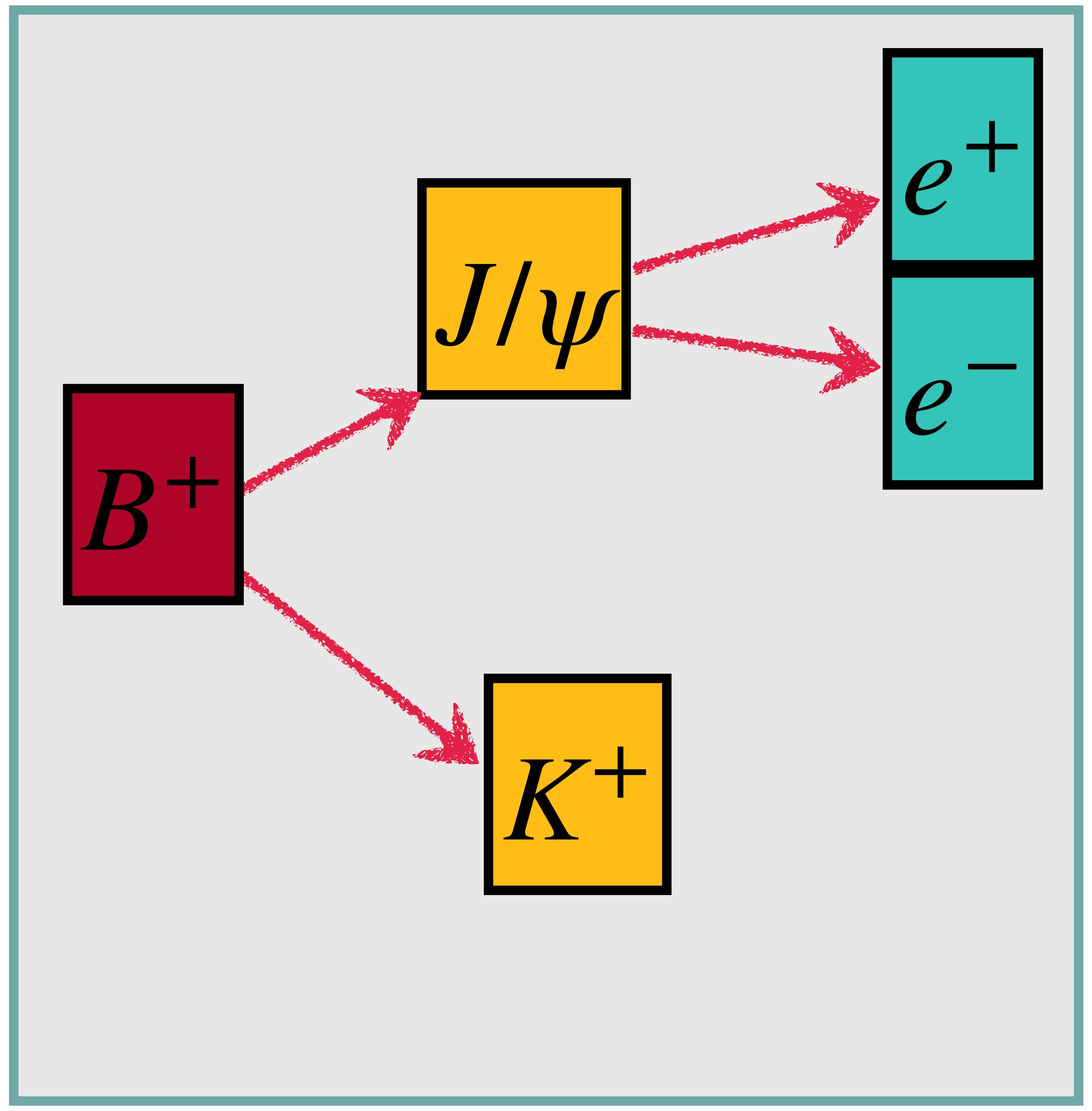
backup

Signal MC

- MC event type: 1111540100 :
    - $B^0 \to J/\psi[e^+e^-]K_s^0[\pi^+\pi^-]$
    - dec: https://gitlab.desy.de/belle2/software/basf2/-/blob/main/decfiles/dec/1111540100.dec



- MC event type: 1211530000 :
    - $B^+ \to J/\psi[e^+e^-]K^+$
    - dec: https://stash.desy.de/projects/B2/repos/software/browse/decfiles/dec/1211530000.dec

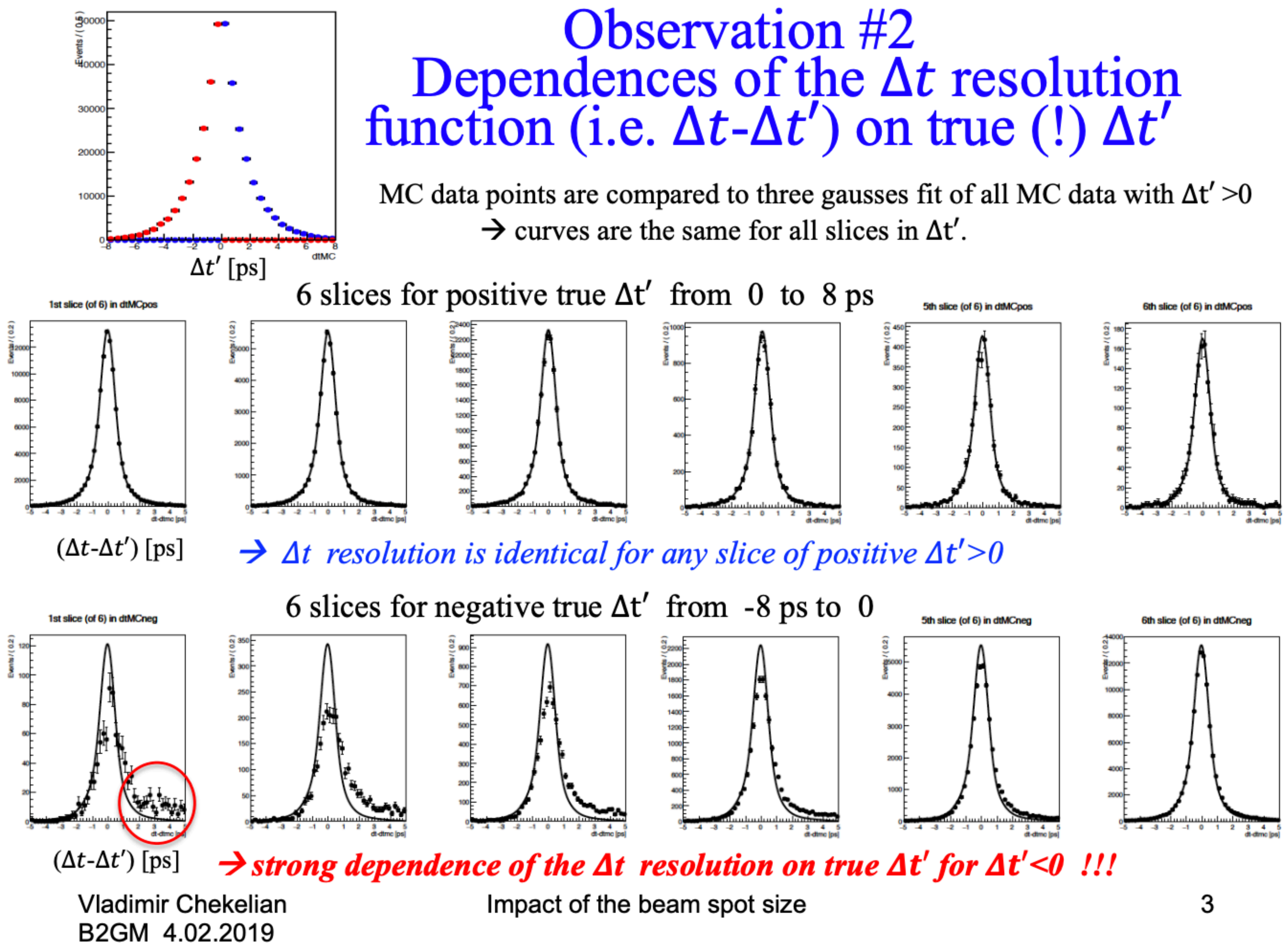


We generate some MC events. The fully reconstructed B and other B decays as follows

- We reconstruct the B_{rec} as $B^+_{rec} \to \bar{D}^0(\to K^+\pi^-)\pi^+$

- The other B decays as $B^-_{other} \to J/\psi(\to \mu^+\mu^-)K^-\pi^+\pi^-$

The Bias



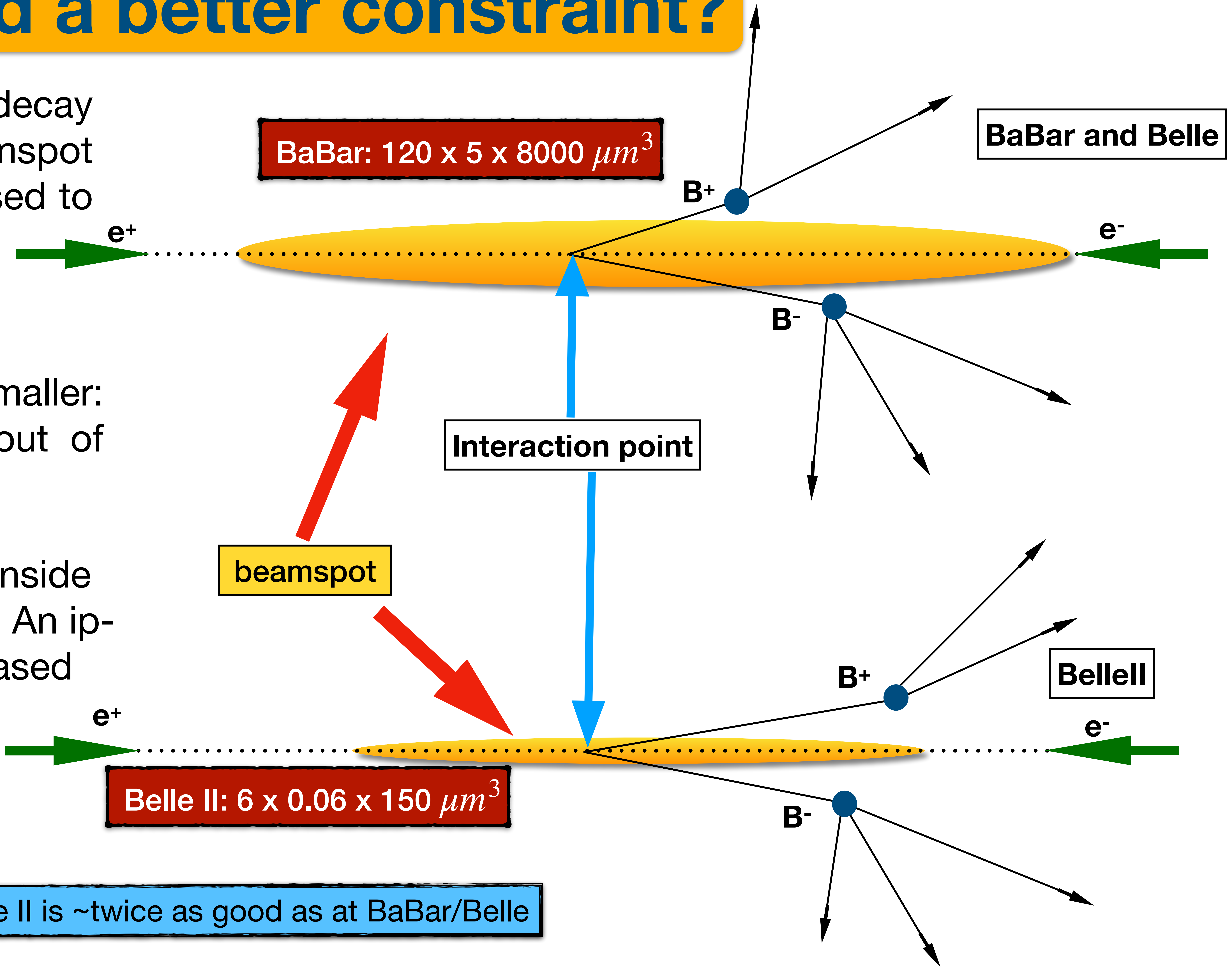
- Vladimir Chekelian first reported the problem of bias

Why do 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 biased result.



Also: the tracking resolution of Belle II is ~twice as good as at BaBar/Belle

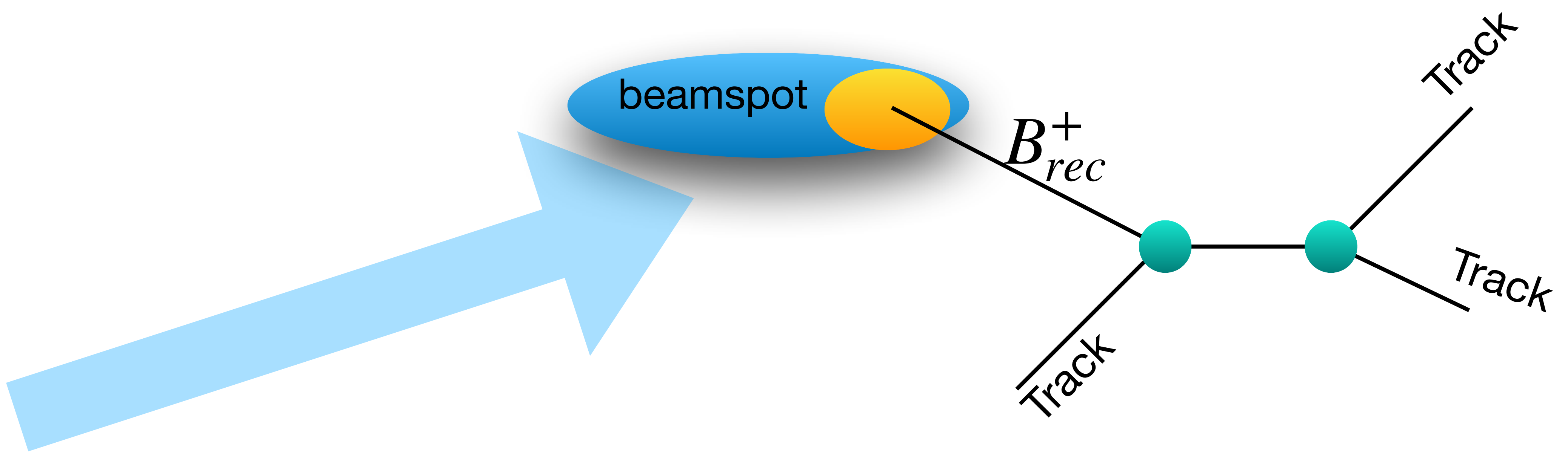
A new constraint: Btube

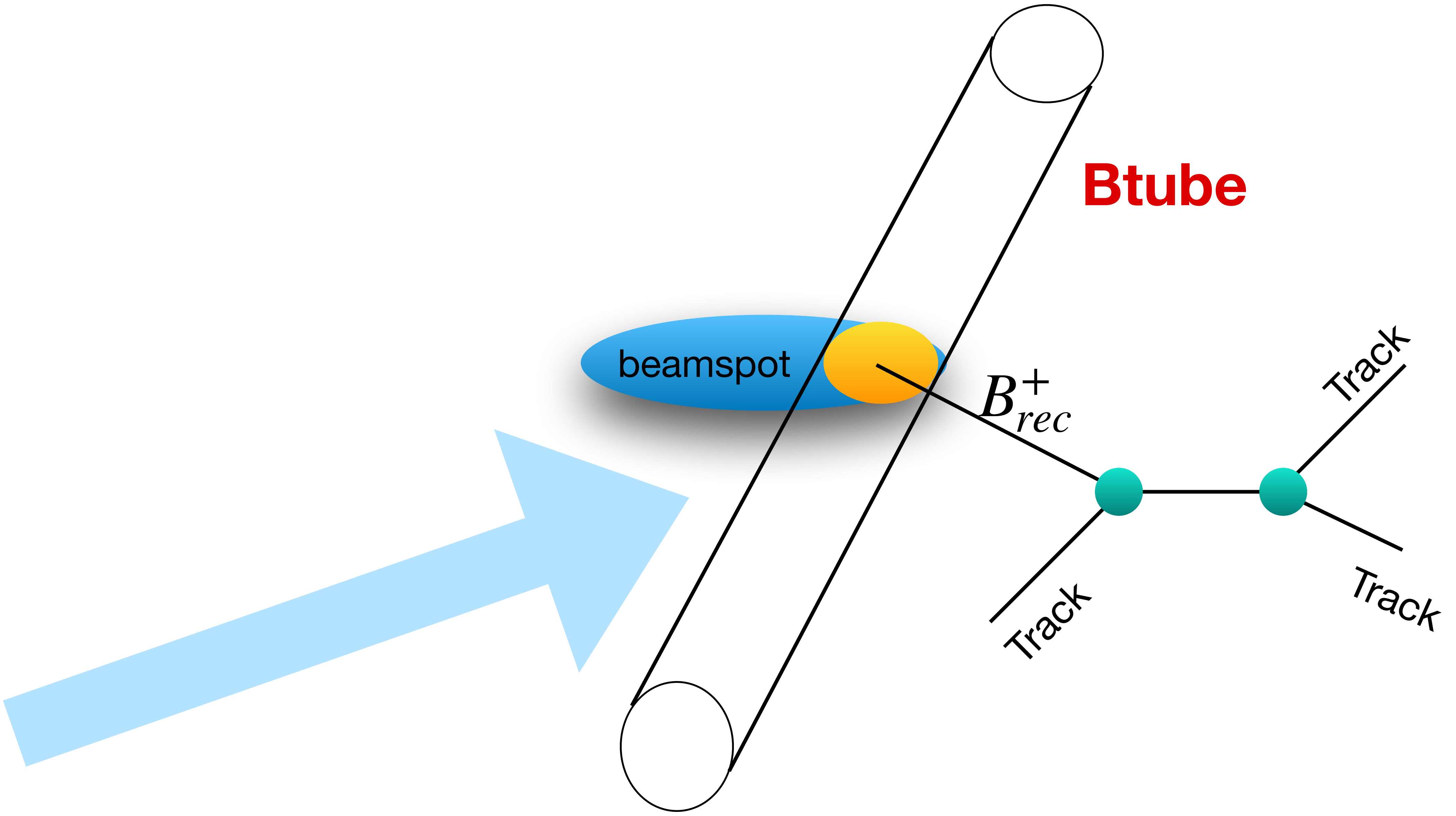
- Among two B mesons, we fully reconstruct one B (B_{rec})

- 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.

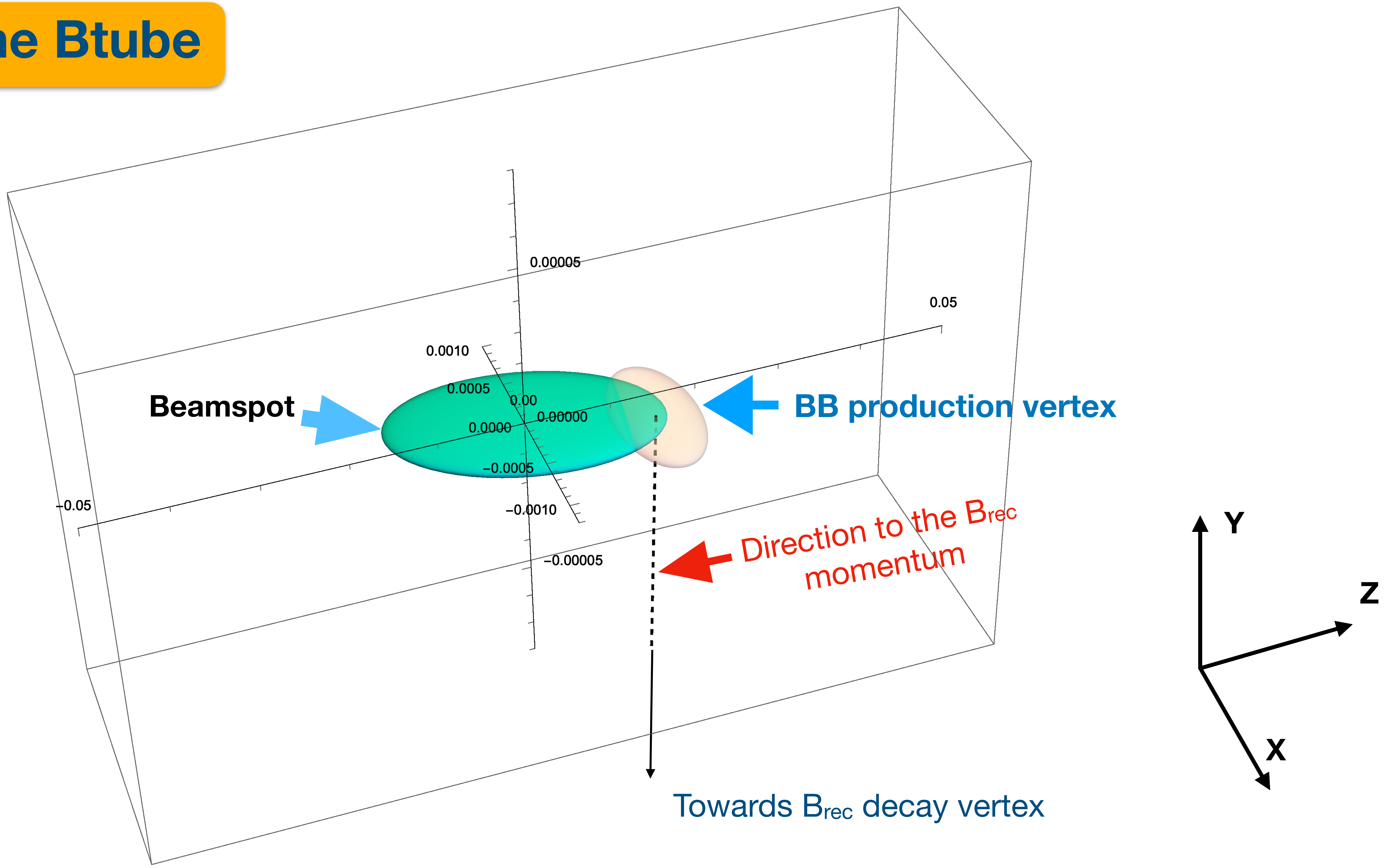
- From four momentum conservation, we obtain the flight direction the other B .

- 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.





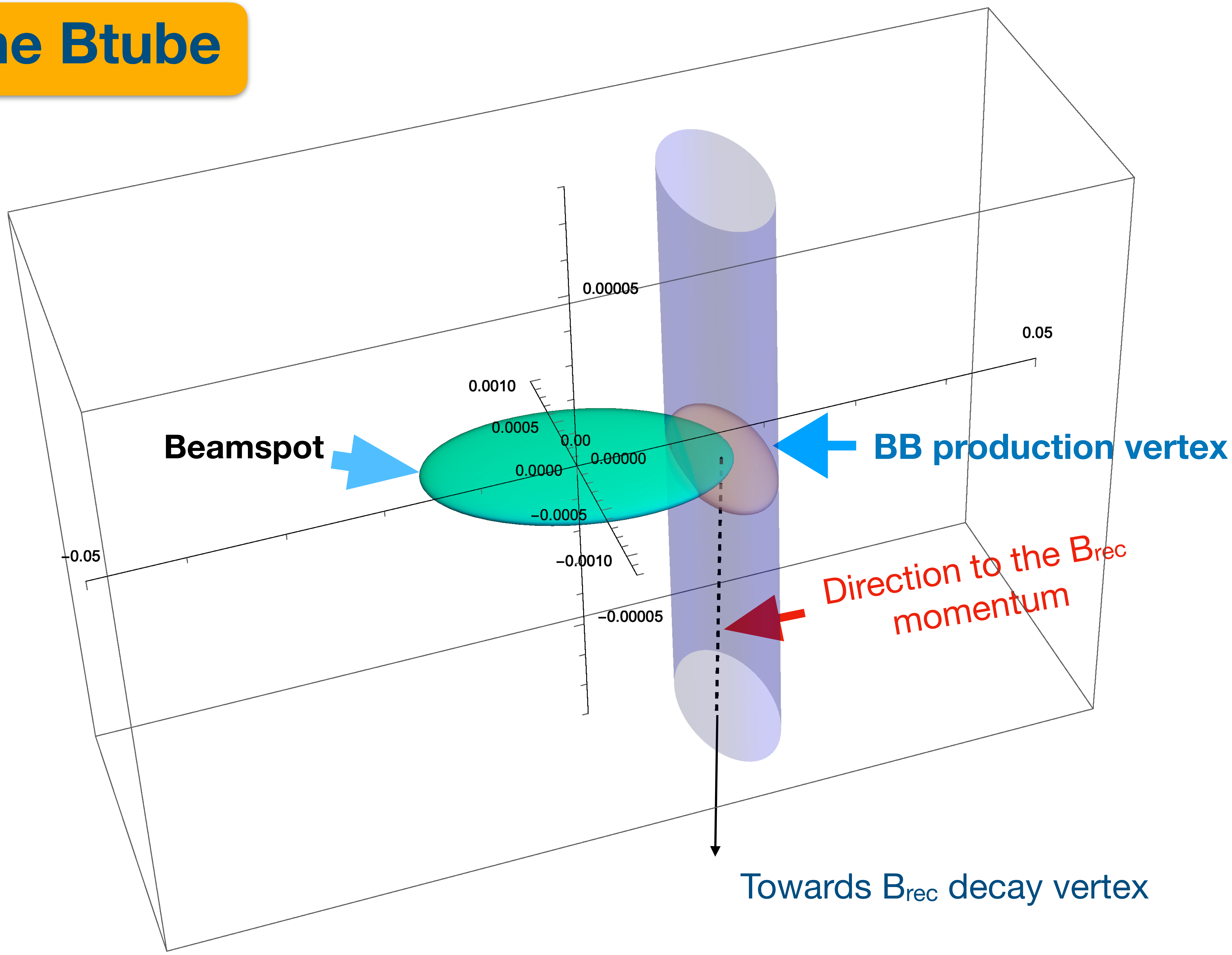
Constructing the Btube



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

Graphics produced with Wolfram Mathematica

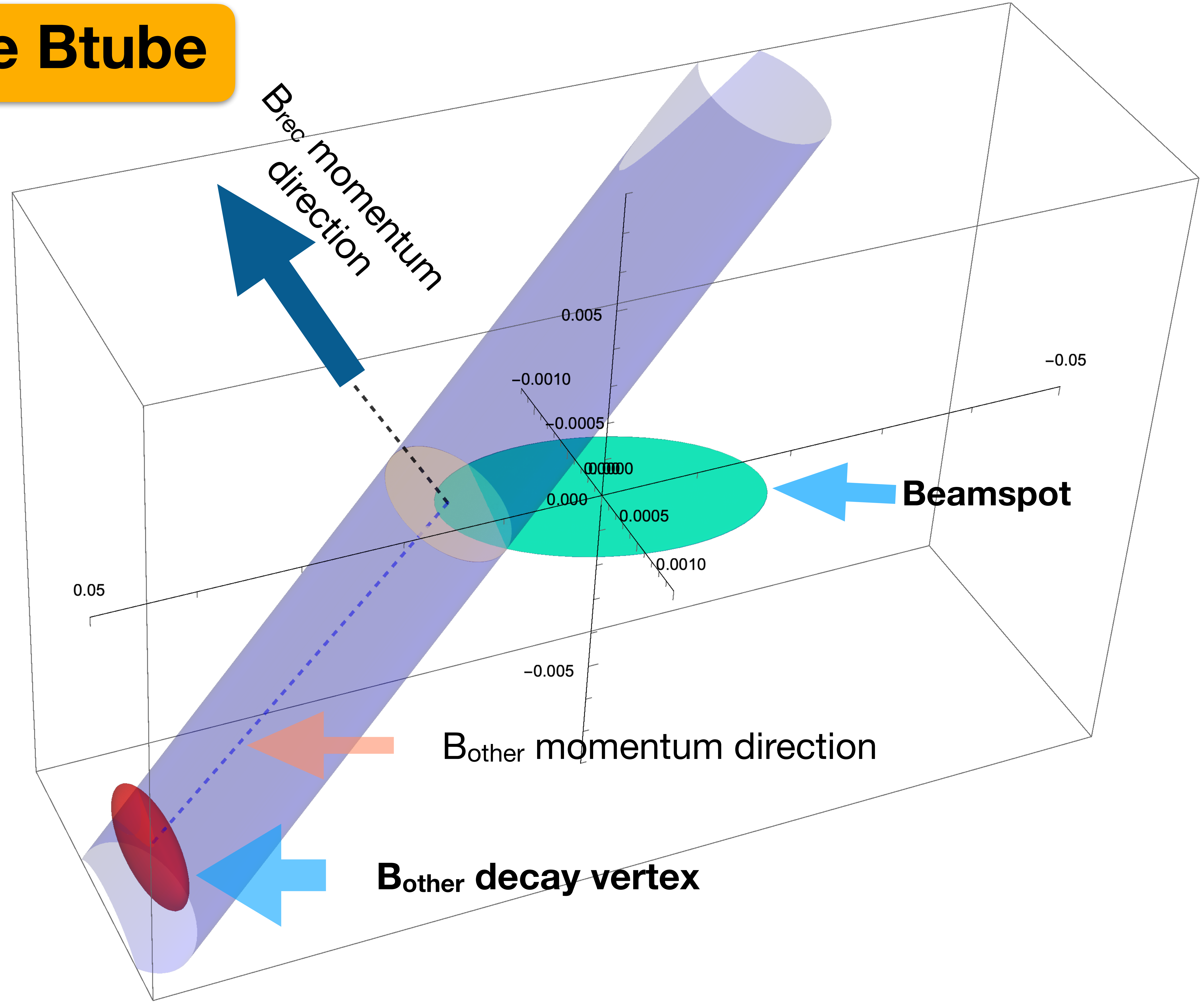
Constructing the Btube



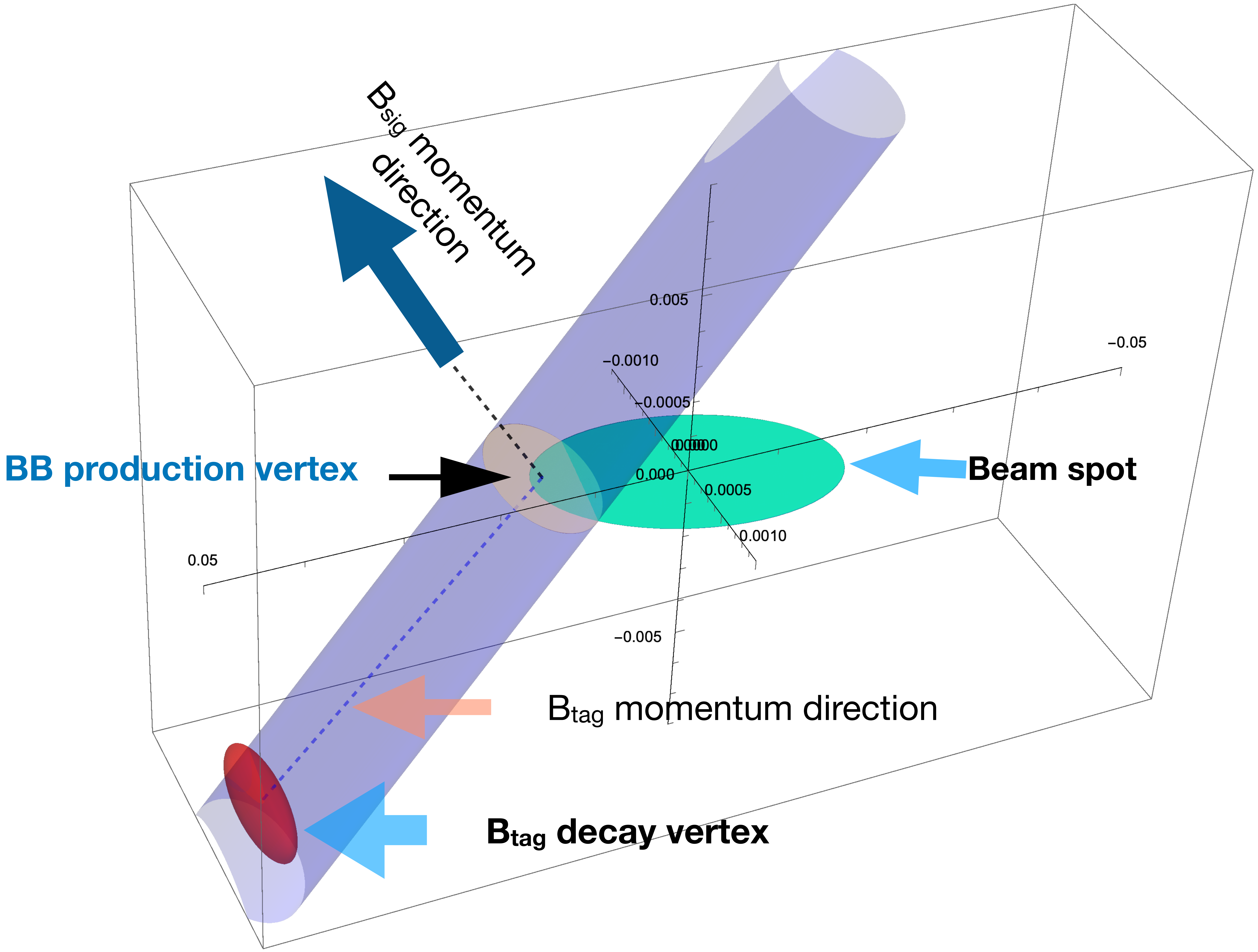
After estimating direction of B_{other}, the Btube is constructed

Graphics produced with Wolfram Mathematica

Constructing the Btube

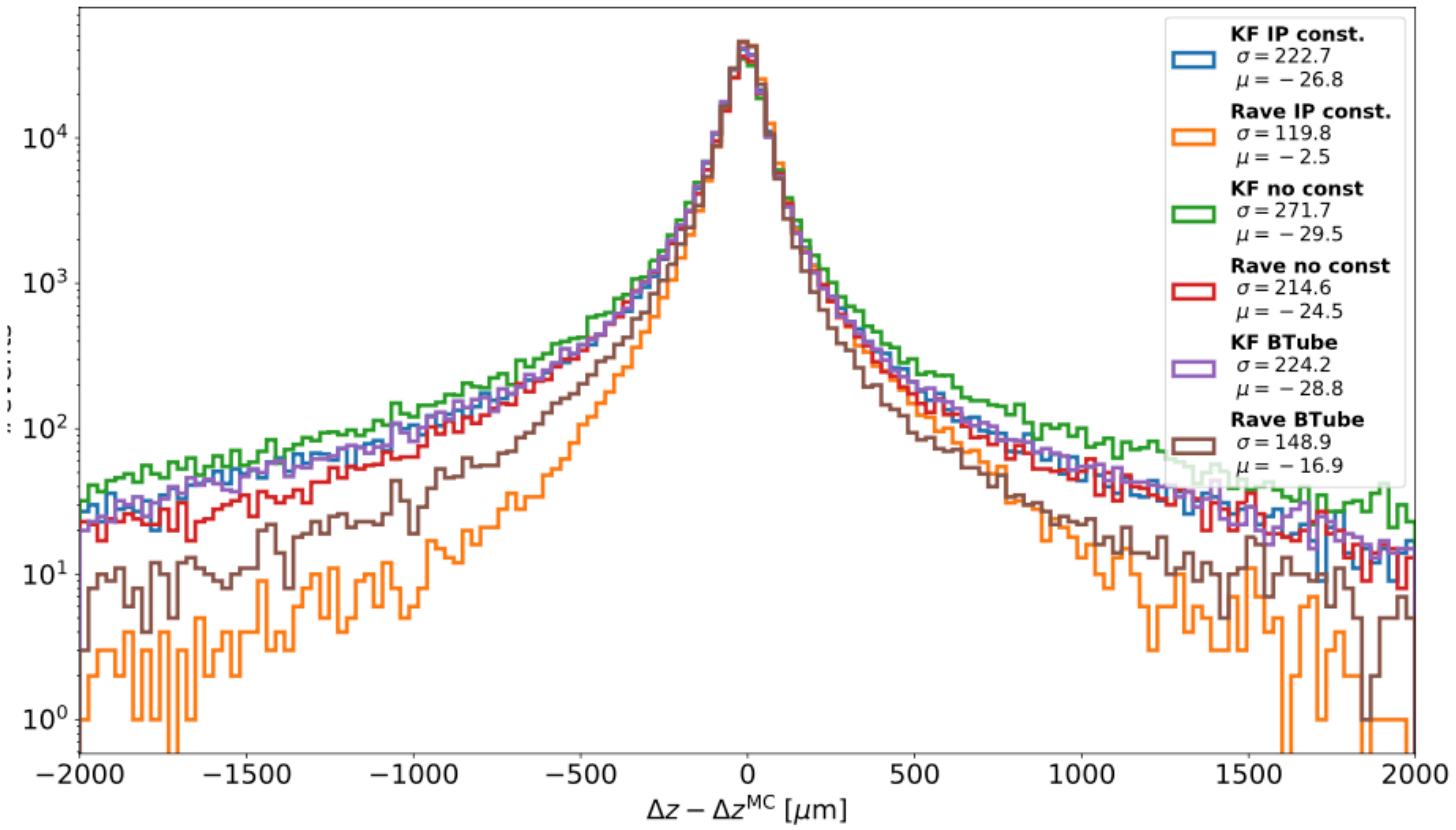


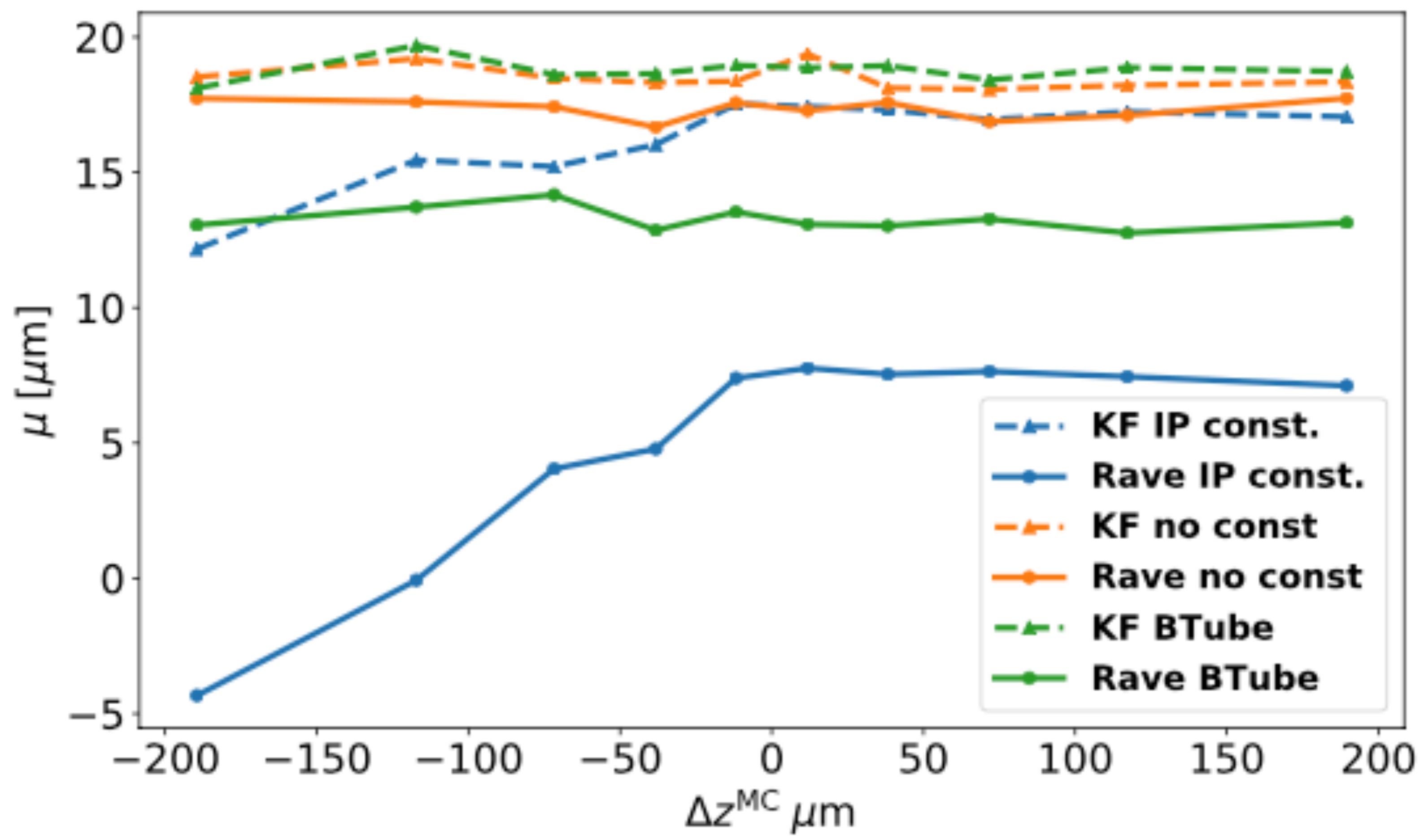
After the other B is fitted with the tube constraint
(different y scale from the previous slides)

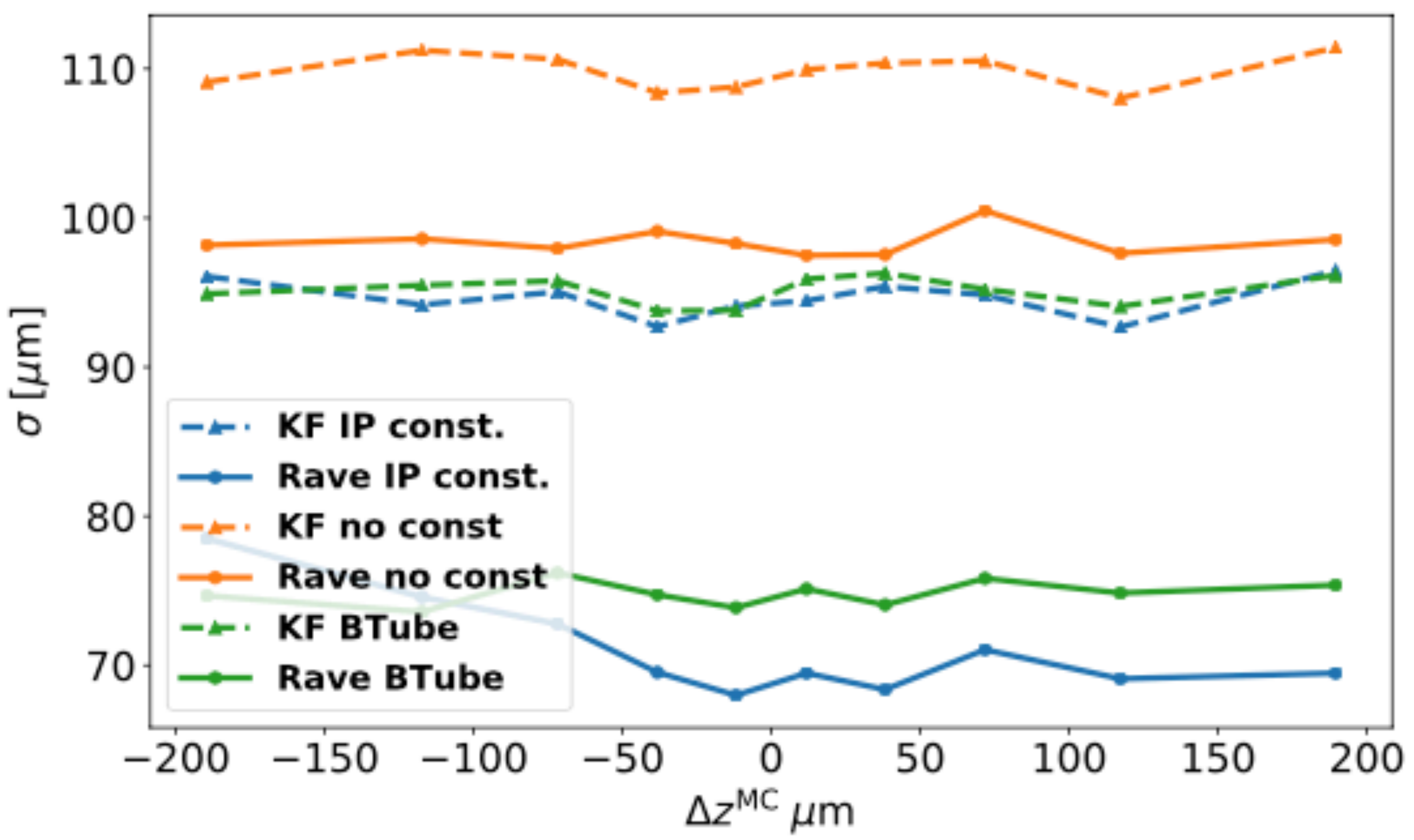


Constructing the Btube

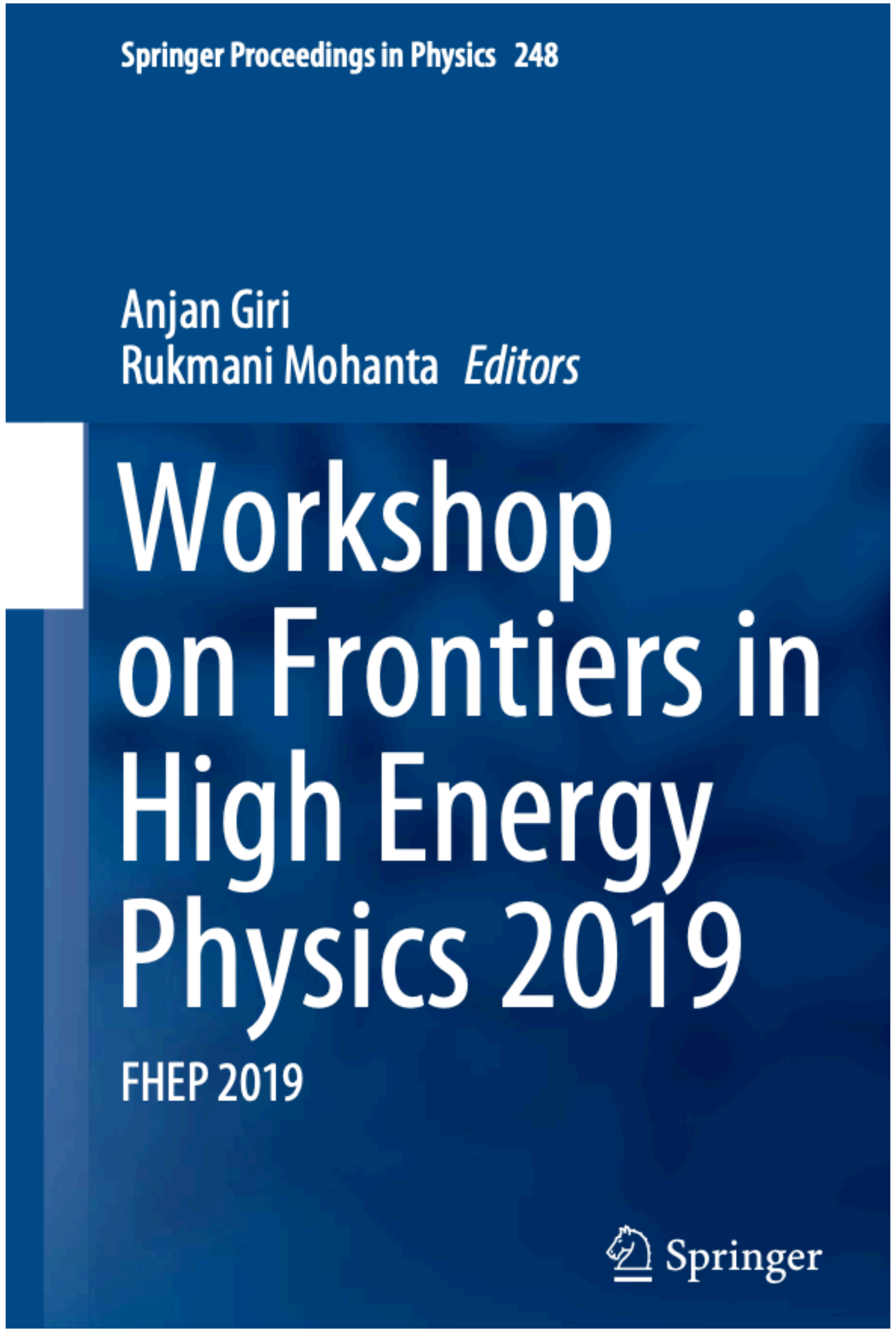
Study done by Thibaud







Do we need all these comparisons? Which is the standard fitter to work with?



Chapter 52
Beam-Constrained Vertexing for *B* Physics at the Belle II Experiment

S. Dey and A. Soffer

Abstract The Belle II experiment, which recently began collecting e^+e^- collision data, will extend the successful physics program of BABAR and Belle with a 30-fold increase in integrated luminosity and an improved detector. In particular, the vertex position resolution of Belle II is better than that of its predecessors by about a factor of two. The high resolution and the very small e^+e^- collision region provide a powerful constraint that can be used in a number of B-physics analyses. This contribution will cover studies performed with this method, as well as the performance of the Belle II experiment.

52.1 Introduction

In time-dependent analyses in B factories, the key ingredient is the difference between the time of decay of two B mesons that come from the decay of the same $\Upsilon(4S)$. To measure this difference, a precise determination of the B decay vertex positions is of utmost importance. In the BABAR and the Belle experiments, the beam spot size was much larger than Belle II. For example, in the BABAR experiment the beam spot size was $(120 \times 5 \times 8000)\ \mu\text{m}^3$, where each value is the width of the Gaussian beam profile in the x, y and z directions, respectively. Here, the x, y and z axes are toward the center of the accelerator, upward out of the plane of the accelerator and along the beam direction, respectively. The average distance travelled by the B meson in the z direction is approximately 260 μm at BABAR (similar to Belle). So, the B mesons decay within the beamspot if we only consider the z direction. Hence, in these cases, to find the decay vertex of the B meson correctly, a fit where the vertex was constrained to be within the beam spot was sufficient.

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In Belle II, the use of the nano-beam scheme reduces the beam spot size drastically. In Belle II, the beam spot size is $(6 \times 0.06 \times 150)\ \mu\mathrm{m}^3$. Now, as the B meson would decay at a significant distance from the beam spot, a beam-spot-constrained vertex fit could introduce unnecessary bias and the B decay vertex position could not be measured correctly. Thus, in the remainder of this contribution we describe a new constraint that removes this bias.

52.2 A New Constraint: Btube

The constraint applies to events in which there is a fully reconstructed one B meson, which we refer to as B_{rec}. The other B meson is referred to as B_{other}. The decay chain can be summarised as $\Upsilon(4S) \to B_{\mathrm{rec}} B_{\mathrm{other}}$. Now, we can propagate the B_{rec} momentum to the beam spot and apply a vertex fit, such as the adaptive vertex fitter from RAVE [1]. The result of this fit is a vertex from which both the B mesons originated. From four-momentum conservation we obtain the direction in which the B_{other} flies. We then stretch the covariance matrix of the fully reconstructed vertex so that it effectively has infinite size in the direction of the flight of the B_{other}. This tube-like object we call "Btube", which we use as a constraint in further B_{other} fits. The construction of the Btube constraint is shown schematically in Fig. 52.1.

52.3 Analysis

To study the Btube constraint, we use a Monte Carlo (MC) sample that is produced using the EVTGEN [2] package to generate the decays and the GEANT4 [3] package to simulate the detector response. The sample contains one million events with the following decay chain: $B^+_{\mathrm{rec}} \to \bar{D}^0(\to K^+\pi^-)\pi^+$ and $B^-_{\mathrm{other}} \to J/\psi(\to \mu^+\mu^-)K^-\pi^+\pi^-$. We reconstruct the events, then only consider those in which the full decay tree is correctly reconstructed for further analysis. In the selected events, we fit the B_{other} decay vertex with RAVE including the Btube constraint. An example event from our generated samples is shown in Fig. 52.2.

52.4 Results

52.4.1 *Quality of BB Production Vertex*

In order to check how the Btube constraint performs, first we evaluate the correctness the BB production vertex. In Fig. 52.3 we show the pull distributions and fit them with Gaussian pdfs. The quality of the fits clearly show that the BB production vertex

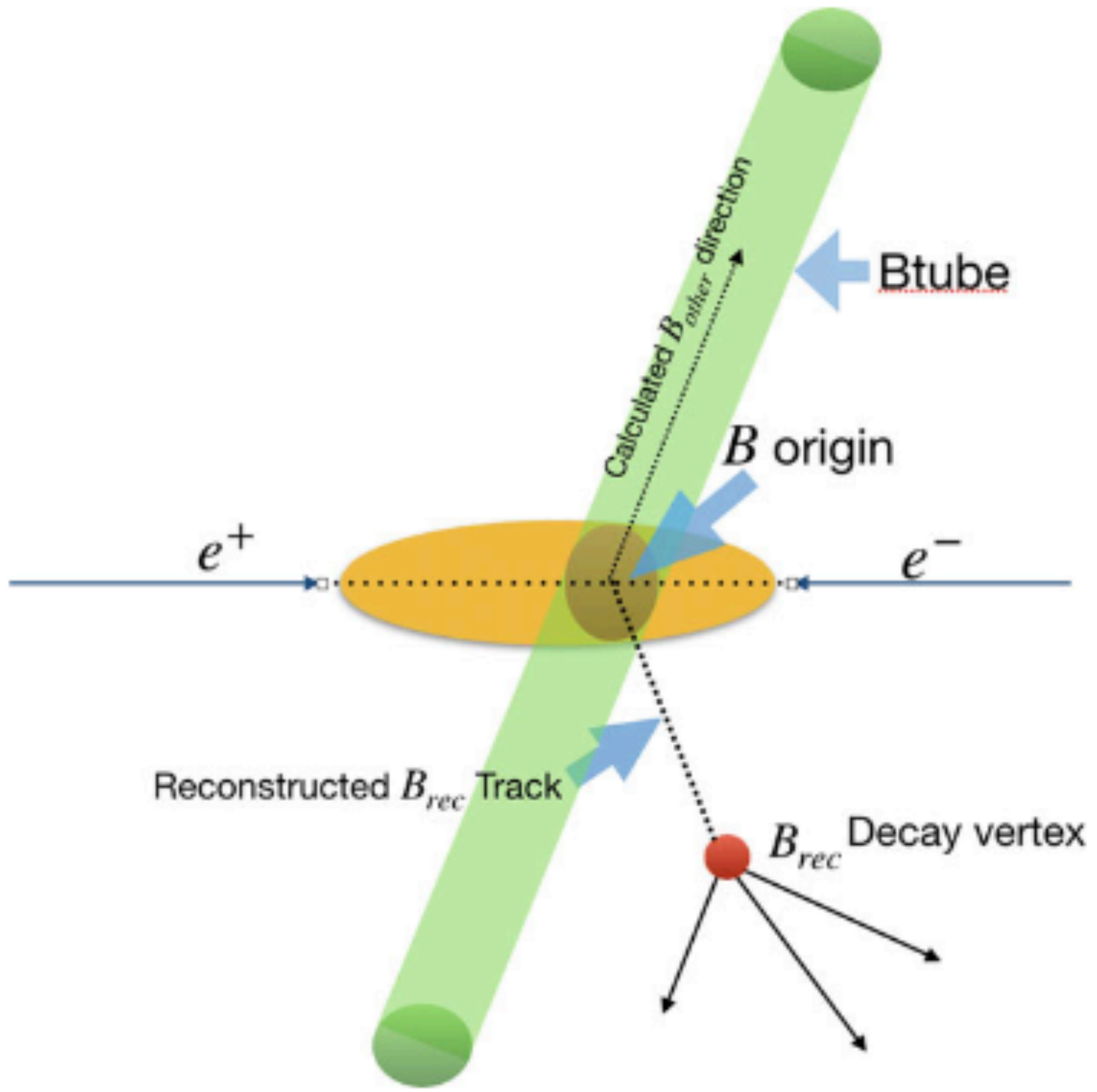

Fig. 52.1 Schematic of the Btube constraint

is reconstructed correctly. In Fig. 52.4 uncertainties of this vertex position is shown. The truncation points at the right hand sides of all the plots are determined by the beam spot size itself.

52.4.2 *Comparison of B_{other} Decay Vertex Residuals Obtained with Three Different Constraints*

In the Fig. 52.5, we plot the residual distribution of the B_{other} decay vertex fitted using no constraint, using the beamspot constraint and using the Btube constraint. This plot clearly shows an improved fit can be achieved using the Btube constraint.

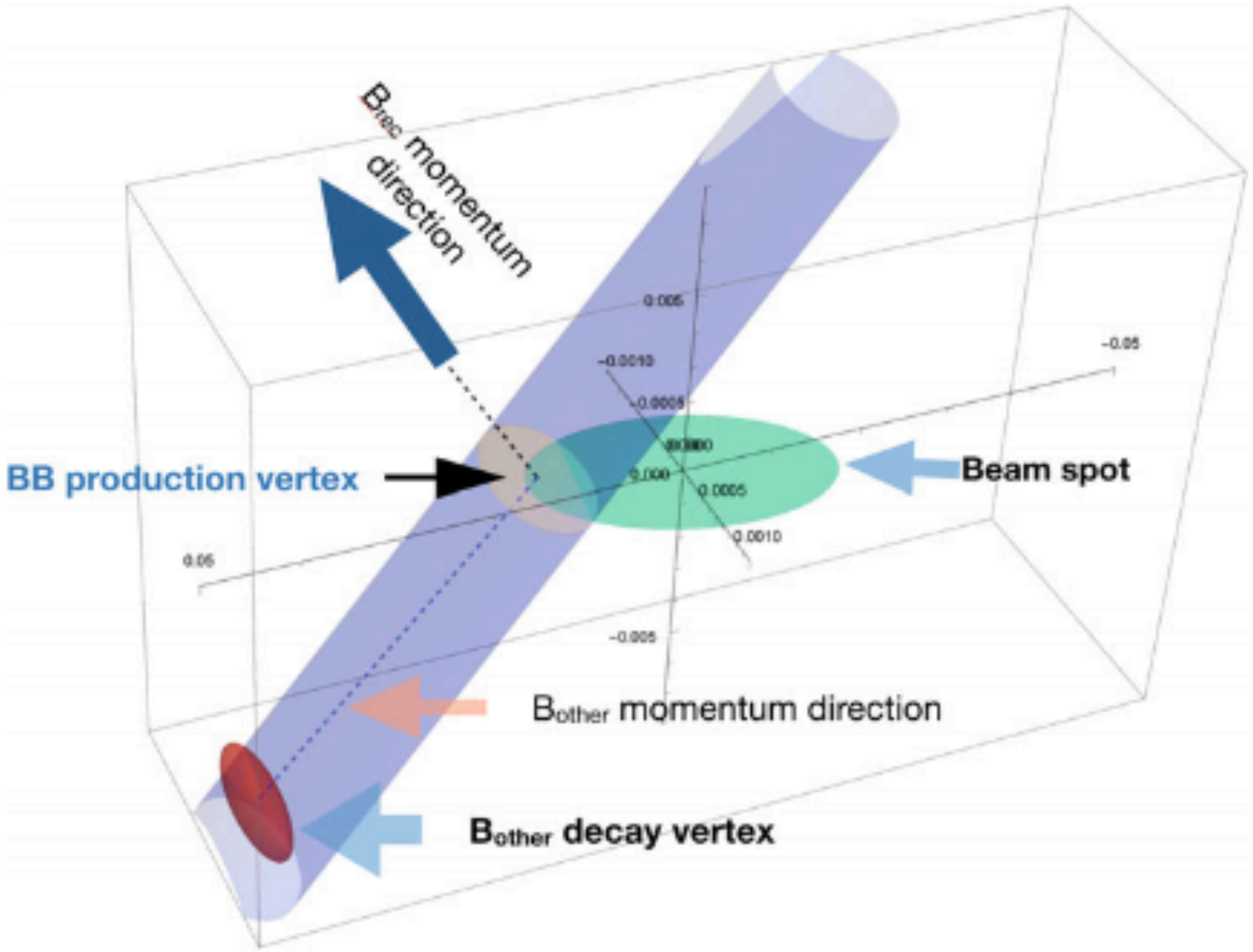

Fig. 52.2 B_{other} decay vertex fitted with Btube constraint. Beam spot, BB production vertex and the B_{rec} momentum direction are shown. The figure is generated with Mathematica

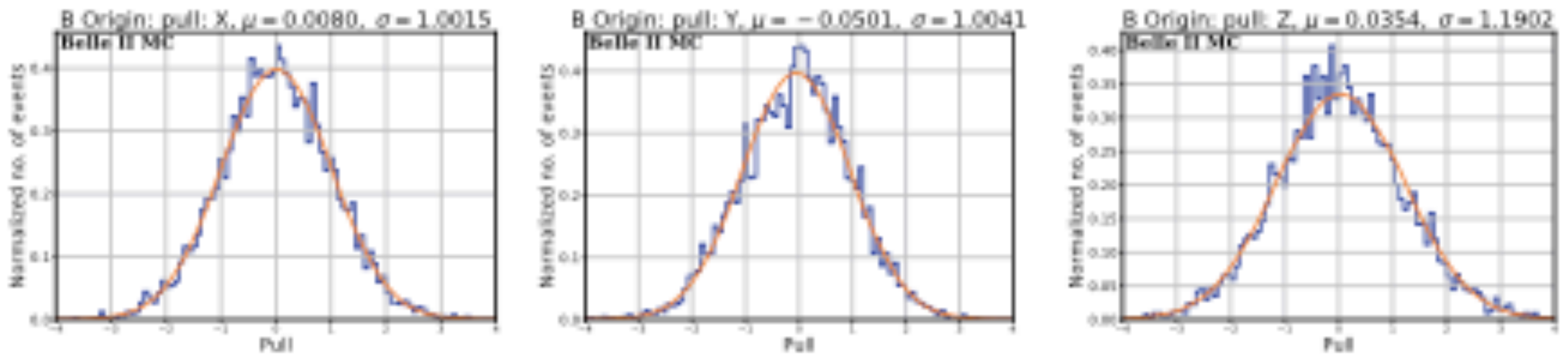

Fig. 52.3 Pull distributions of the $B\bar{B}$ production vertex position in (left) x, (middle) y and (right) z

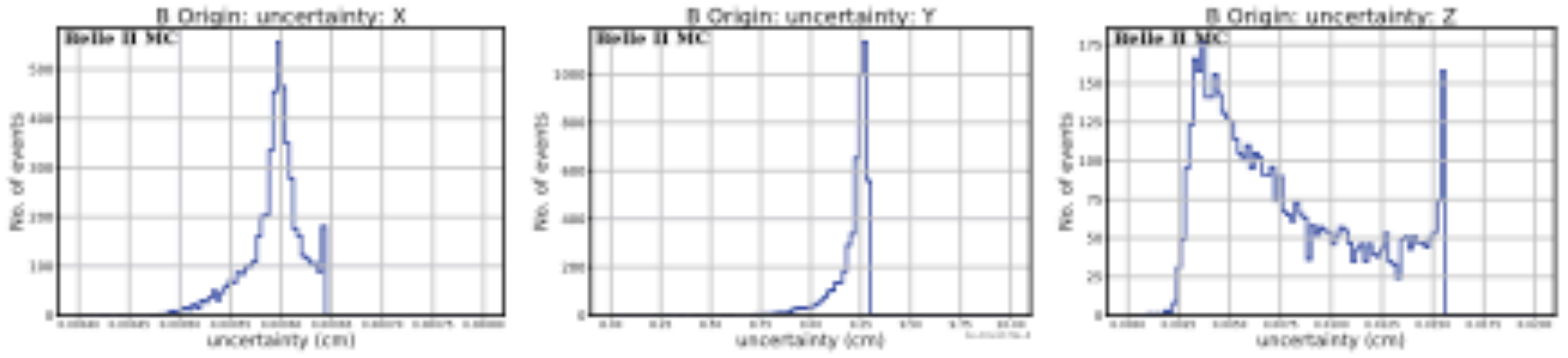

Fig. 52.4 Distributions of the uncertainty on the $B\bar{B}$ production vertex position in (left) x, (middle) y and (right) z

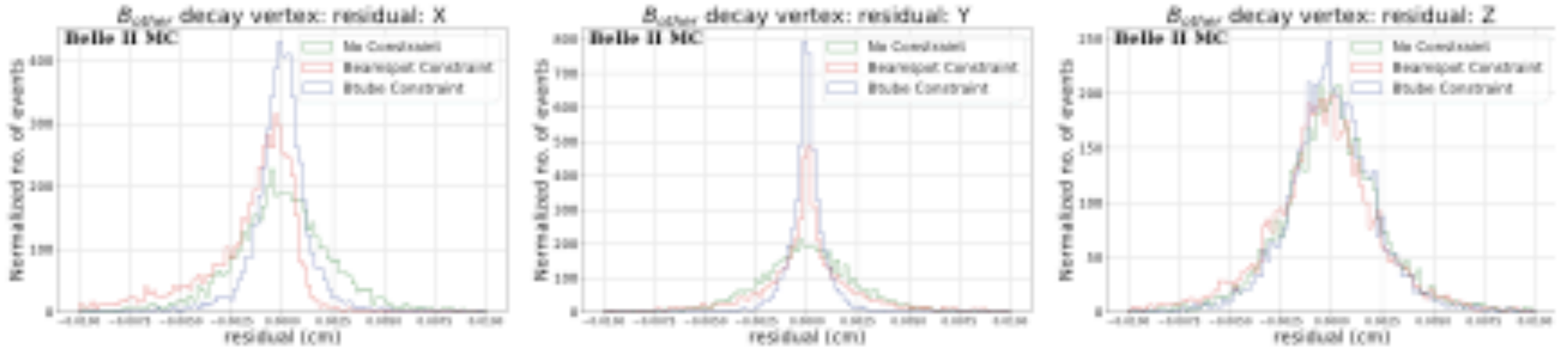

Fig. 52.5 B_{other} vertex position residuals in (left) x, (middle) y and (right) z comparing the use of the Btube constraint, beam-spot constraint and no constraint

52.5 Conclusion

Figure 52.5 shows that using the Btube constraint improves the determination of the B decay position, compared to using either the beam-spot constraint or no constraint. Therefore, using the Btube constraint will reduce bias in Δt measurements and other time-dependent studies. In addition, a Btube constrained fit can be used to improve background rejection in decays like $B \to D\tau\nu$, $B \to K^{(*)}\nu\bar{\nu}$, $B \to \tau\nu$ where $\tau \to 3\pi\nu$ or $\tau \to l\nu$.

References

1. W. Waltenberger et al., IEEE Trans. Nucl. Sci. **58**, 434–444 (2011)
2. D.J. Lange, Nucl. Instrum. Meth. **A462**, 152–155 (2001)
3. T. Abe, Belle II (2010), arXiv:1011.0352