Update on $B^0 \to K^{*0}\tau\tau$ at FCC-ee

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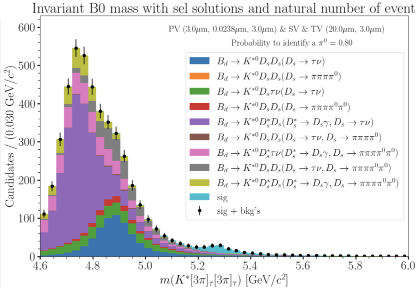
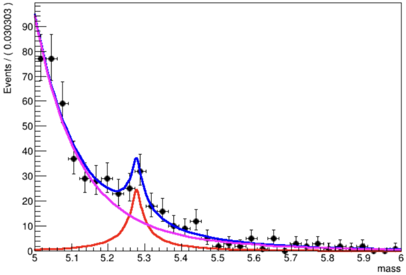
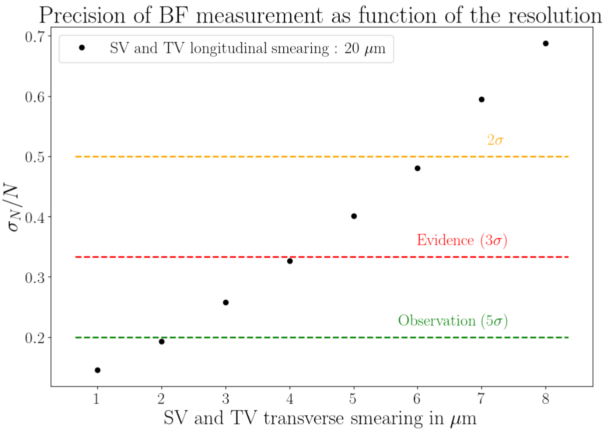
Quick summary until precision of the measurement determination

- Aim of this work : determine the vertex detector requirements in order to measure $B^0 \to K^{*0}\tau\tau$ with $\tau \to 3\pi\nu$ at FCC-*ee*.
- Signal and dominant backgrounds simulated with the momentum resolution given by the IDEA drift chamber tracking system.
- Fast (gaussian) secondary vertex resolutions emulated, in the Longitudinal-Transverse plan of the decaying particle, in order to check the feasibility of the measurement in several working points.
- Selection of the signal build on a reference vertex resolution working point.
- The precision of the measurement determined from an Unbinned ML fit of the data for each working point.







- Precision on BF measurement for fully emulated vertexing working points have been determined.
- Next step = confront this to an actual state of the art vertex detector we have at hand → the IDEA vertex detector.

- Resolutions determined from 10^6 signal events.
- Reconstructed PV position fitted from reconstructed tracks with the FCCAnalyses VertexFitterSimple tools (Beam Spot Constraints set at $(4.5, 20e^{-3}, 300)$ μm).
- Displacement of the reconstructed PV w.r.t. the MC truth PV is built in cartesian coordinates.
- The IDEA resolution is determined for each coordinate by a fit of the displacement :
  - double gaussian model on (x,z) [i],
  - simple gaussian model on y.
- Resolutions $\mathcal{O}(3\,\mu\text{m})$ for (x,z).
- Resolution $\mathcal{O}(20\,\text{nm})$ for y.

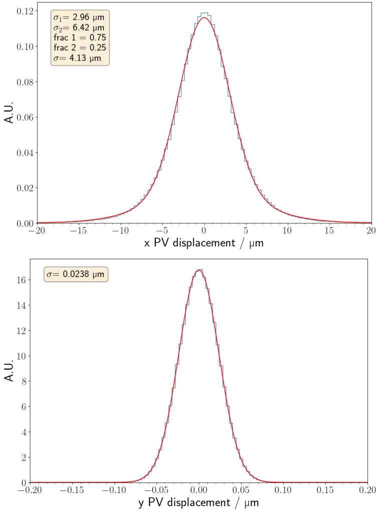


Figure – PV displacement and fit of the resolution for x (top) and y (bottom).

i. In appendix.

- Reconstructed SV ($K^{*0} \rightarrow K\pi$) and TV ($\tau \rightarrow 3\pi$) positions fitted from MC matched reconstructed tracks via FCCAnalyses VertexFitterSimple tools.
- Displacement of the reconstructed SV and TV w.r.t. to the MC truth projected on decay plan (L-T).
- The IDEA resolution is determined for each coordinate by a fit of the displacement :
  - triple gaussian model on L,
  - simple CB model on T.
- The performances are a bit better[ii] on the TV (3 tracks) comparing to the SV (2 tracks) despite the lower daughters momenta on average.

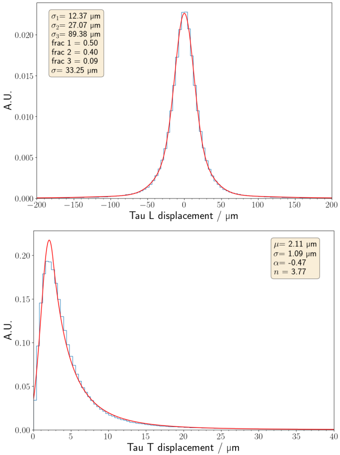


Figure – TV displacement and fit of the resolution for L (top) and T (bottom), T not signed because there is no reference T direction (not as it is in our smearing).

ii. In appendix.

- Emulation of the PV resolutions with 3D-gaussian smearing that follow the combined σ of the fits among each axis.
- SV and TV smearing via the IDEA fitted resolutions.
- Smearing emulated on each direction via accept/reject algorithms.
- SV and TV L smeared from there respective pdf's.
- SV and TV T smeared from an opportunistic 3 gaussians pdf ($\mu = 0, \sigma_1 = 2.7\,\mu\text{m}, f_1 = 50\%, \sigma_2 = 7\,\mu\text{m}, f_2 = 40\%, \sigma_3 = 20\,\mu\text{m}, f_3 = 10\%$), which reproduces fairly the IDEA T displacement distribution when emulated in 2D on the transverse plan.

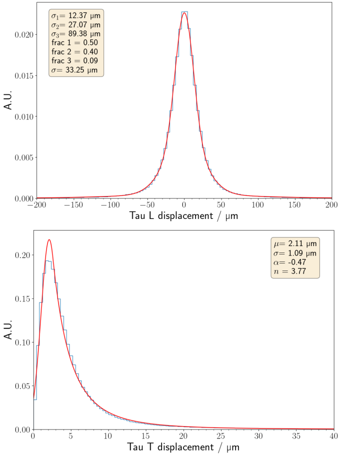
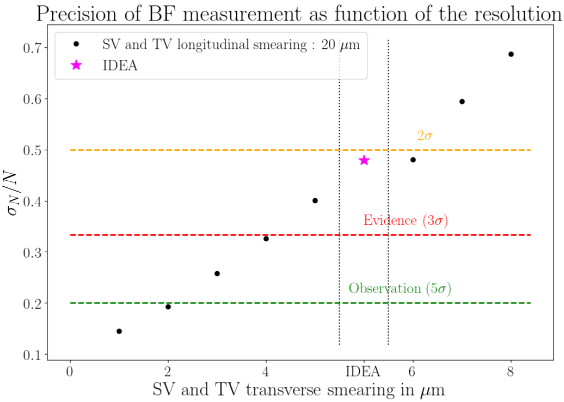


Figure – TV displacement and fit of the resolution for L (top) and T (bottom), T not signed because there is no reference T direction (not as it is in our smearing).



Emulation of the vertex resolution performances in order to look for the feasibility of the search of $B^0 \to K^{*0}\tau\tau$ at FCC-*ee* :

- Hint of the signal with the state-of-the-art vertex detector,
- not far from evidence neither.

The IDEA working point : new emulation

- The SV and TV transverse smearing used previously was opportunistic $\rightarrow$ 2D model that reproduces the transverse displacement built by hand.
- New version : two orthogonal directions in the transverse plan are picked up randomly via a circle parameterised in the transverse plan itself.
- Projection of the displacement on these new directions $\rightarrow$ signed decomposition of the transverse displacement on a (x', y') basis.
- Directions built randomly $\rightarrow$ x' and y' directions are equivalent $\Rightarrow$ combination of the two to determine the resolution.
- Fit of the resolutions with a 3 gaussians model for SV transverse resolution and TV transverse resolution separately.
- Emulation of the IDEA point in the same way as previously, but with these more educated models.

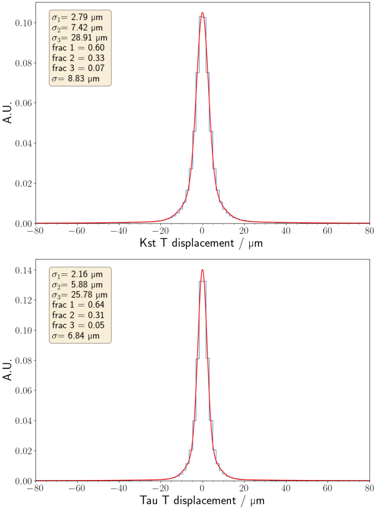
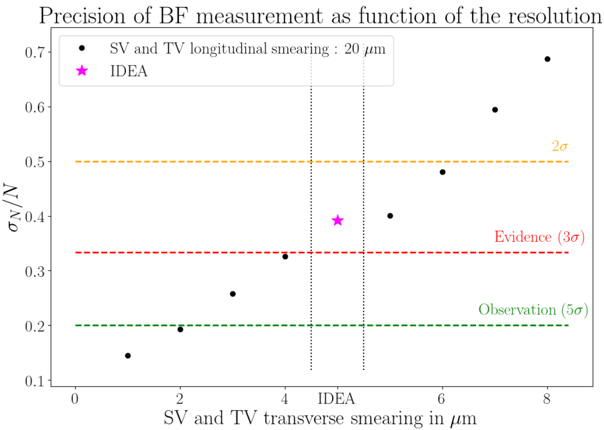


Figure – SV (top) and TV (bottom) signed transverse displacement and fit of the transverse resolution.



- Only a slight change (resulting in small improvement) with this new IDEA emulation $\rightarrow$ IDEA point is closer to the 3σ line.
- A last question : how the picture is changed by improving the IDEA vertexing performances ?

- The use of the SmearObjects.SmearedTracks tools allows to use IDEA vertexing with improved tracks.
- 4 new IDEA working points examined :
  - $2\times$ better Ω (momentum)
  - $2\times$ better $d_0 - z_0$ (IP)
  - $1.5\times$ better $d_0 - z_0$ (IP)
  - $1.2\times$ better $d_0 - z_0$ (IP)
- PV, SV and TV displacements fitted as previously to determine resolutions.
- Emulations of these 4 various IDEA working points.

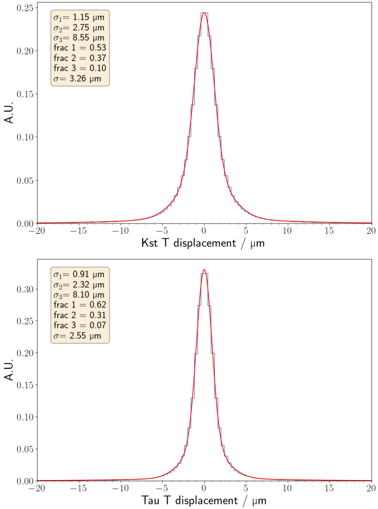
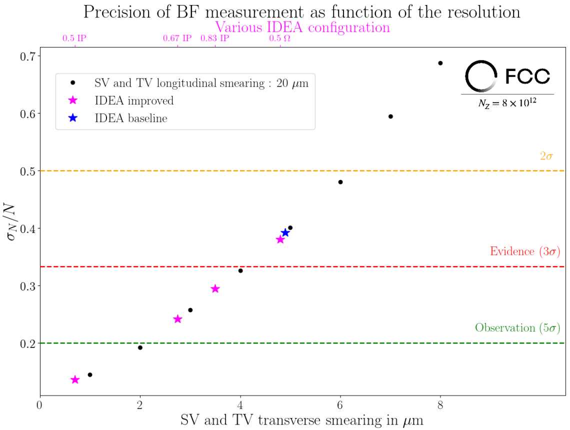


Figure – SV (top) and TV (bottom) signed transverse displacement and fit of the transverse resolution with twice better IP.

Final picture



- IDEA points placed at interpolated position w.r.t. others.
- The momentum measurement improvement has as expected a modest role.
- By contrast, significant improvements on Physics with better IP resolutions !

- The objectives of the study are met : assessment of the required vertex detector performance for $b \to s\tau^+\tau^-$ physics.
- Next step : filling the ANAnote for midterm review report and publication.

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Thanks !

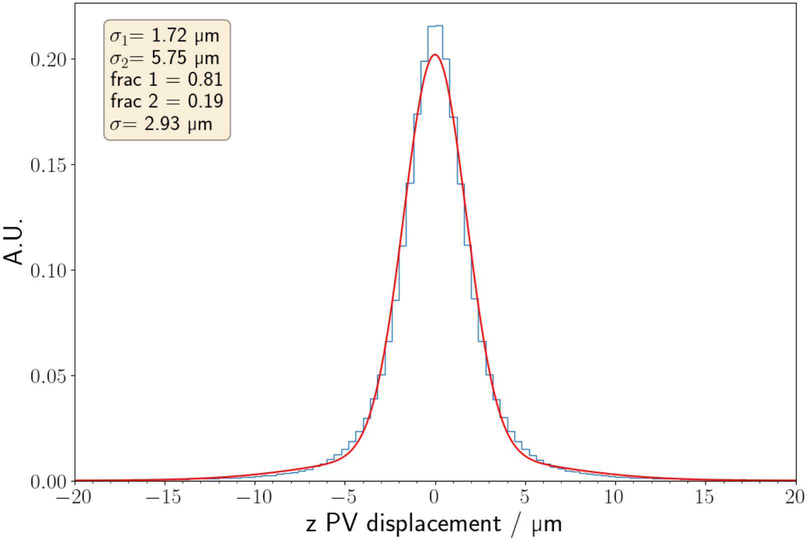

Figure – PV displacement and fit of the resolution for z

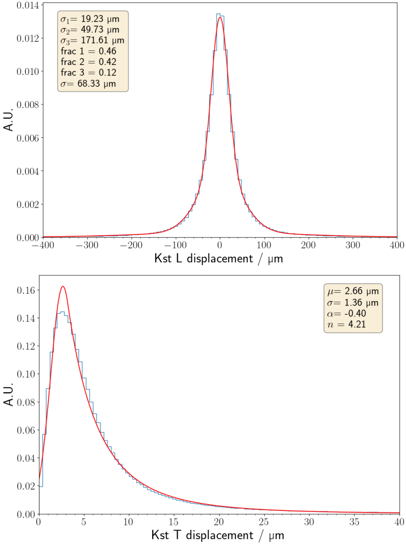

Figure – SV displacement and fit of the resolution for L (top) and T (bottom).