$B_0 \to \eta' K_0$: study on ΔT resolution.

and first test of TreeFitter

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Outline

Will talk about:

- ΔT resolution
  - analysis of structures of ΔT resolution
  - study of ΔT dependencies from other variables
  - test of advanced ΔT resolution model with B^0 lifetime τ_B
  - analysis of *per-event* $\sigma_\Delta T$
- First test with TreeFitter
  - Efficiency
  - resolution

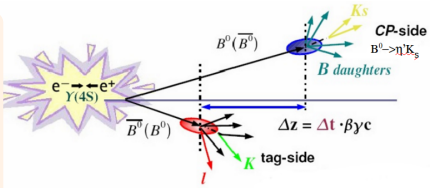
Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state

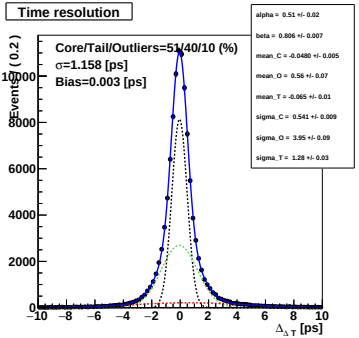
Motivations:

- we want to study the ΔT resolution for $B^0 \to \eta' K^0$ final state
- assess the systematic uncertainties due to limited knowledge of ΔT resolution
- provide a better definition of ΔT reso to be used in the ML fit to extract the TDCPV parameters
- study the B^0 lifetime in the same channel τ;
  - can be studied also in control channel $B^{\pm} \to \eta' K^{\pm}$
- So far, used a single tri-gaussian pdf

Channel: $B^0 \to \eta'(\to \pi^+\pi^-\eta(\to \gamma\gamma))K^0(\to \pi^{\pm})$

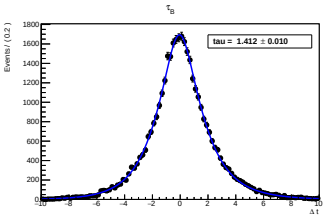
Tech. details: MC9, BGx0, `Rel 00-09-02` with patch





τ_B tests - remind from last B2GM

Reco-level



$\tau_B = 1.412 \pm 0.010$ ps

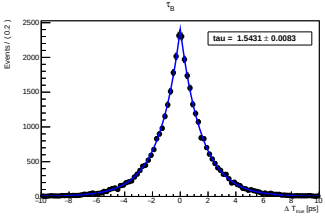
τ_B from fit to ΔT **PDF**: double sided decay function convoluted with ΔT resolution model

There's a non negligible underestimation of the τ_B, for both channels ($\tau_B^{gen} = 1.534$ ps)

Two possible causes:

- bias due to selection or reconstruction is ruled out
- symptomatic of a wrong estimation of ΔT resolution

Gen-level

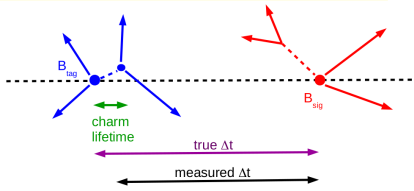


$\tau_B = 1.543 \pm 0.008$ ps

ΔT resolution in Belle

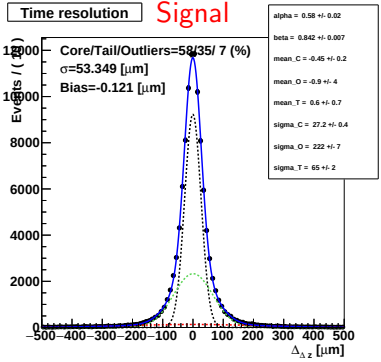
In Belle documented in [Tajima et al., 2004]

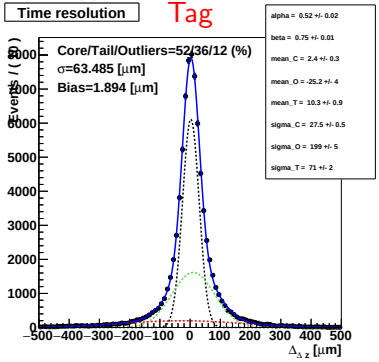
- ΔT reso is a convolution of four contributions:
  1. z reso for B^0 vertex for signal
  2. and tag side;
  3. smearing due to additional non-primary tracks (K^0, charm);
  4. approx that B^0 is at rest in the cms of Belle;
- and it is a (complex) function of:
  - no. of tracks used in vertex fit (both signal and tag side);
  - error on vertex fit positions;
  - $\chi^2/NDoF$ of vertices fit;



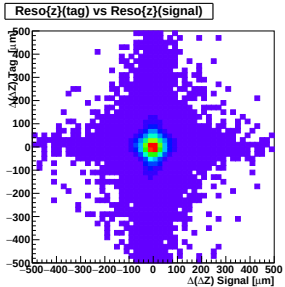
In Babar datasample was split in different categories of Flavor Tagging variable, and each category fitted separately

Δz resolution: Tag and signal side



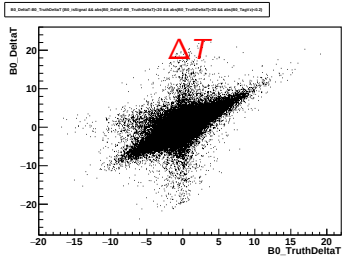


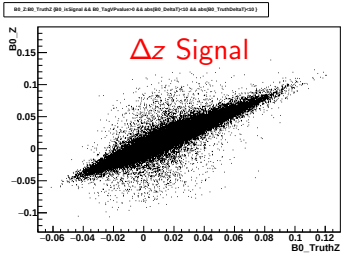
No correlation

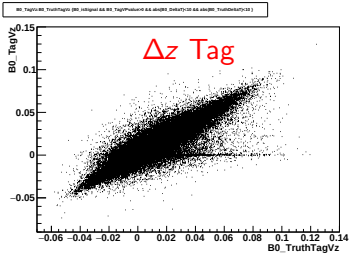


Signal side resolution depends on channel, not tag side

$\Delta T/\Delta z$ vs Truth



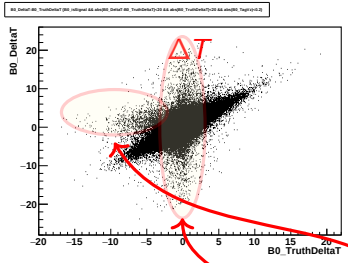


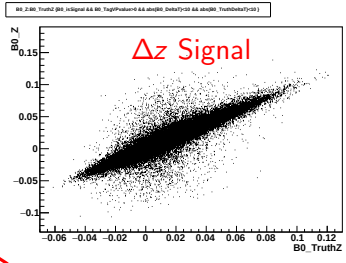


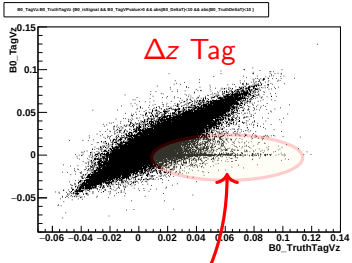
Structures visible:

- at $\Delta T_{truth} \sim 0$ and $\Delta T_{truth} < 0$
  - origin not so clear, not so visible in Δz signal
- at $z_{reco} \sim 0$
  - known vertex reco artifact
  - sometime the fit does not move from starting point

$\Delta T/\Delta z$ vs Truth







Structures visible:

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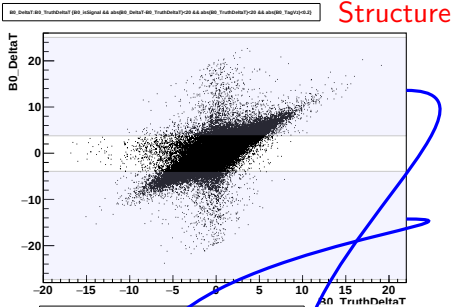
  - origin not so clear, not so visible in Δz signal
- at $z_{reco} \sim 0$
  - known vertex reco artifact
  - sometime the fit does not move from starting point

ΔT structures

Structure more visible if we look at ΔT_{truth} for tails of ΔT_{reco}



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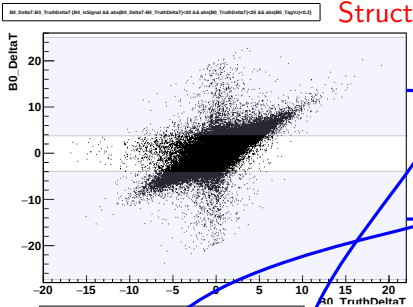
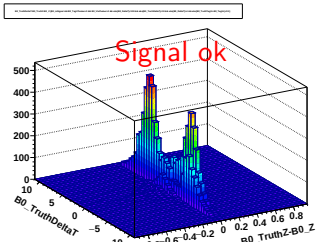
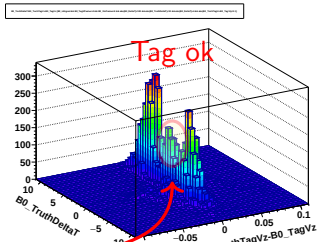


Look separately at Δz for signal and tag for tails in ΔT

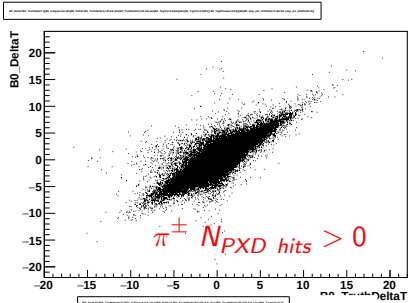


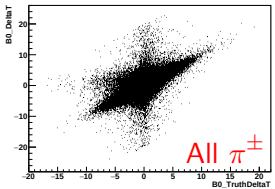


Sometime ΔT is wrong even if Δz_{tag} is correct.
Problem is on signal side

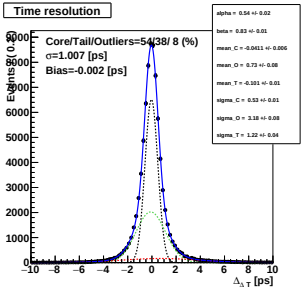
Origin of tails

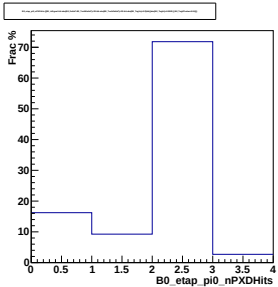
If we requires that $\pi^{\pm}$ from η' has > 0 PXD hits





ΔT resolution improves (was 1.15 ps)





but $> 15\%$ of ϵ drop for each track!

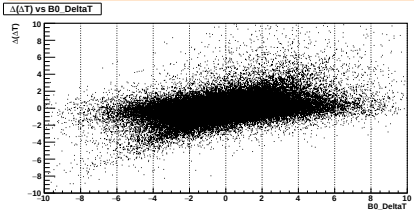
Channel	VXDTF1 Overall reconstruction ε	VXDTF1 PXD hit association ε	VXDTF2 Overall reconstruction ε	VXDTF2 PXD hit association ε
$\phi[K^+K^-]\ K^0_S[\pi^+\pi^-]$	24.0%	68.6%	30.1%	82.0%
$\phi[\pi^+\pi\pi^0]\ K^0_S[\pi^+\pi^-]$	18.1%	78.9%	22.0%	92.7%

A. Gaz

ϕK^0_S

Is a single tri-gaussian enough to model the ΔT resolution?

No! Clear dependence on ΔT_{reco}



- Divide distribution in slices (10)
- fit each with a tri-gaussian

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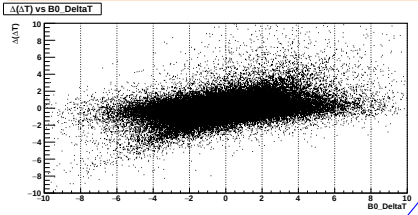
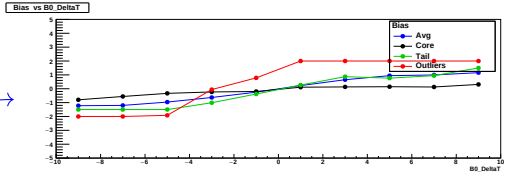
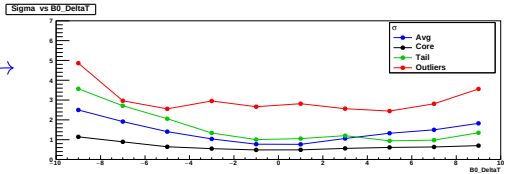
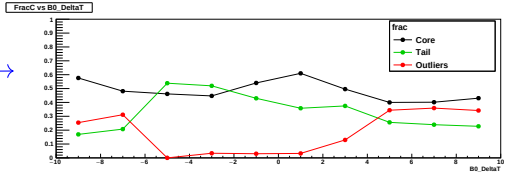


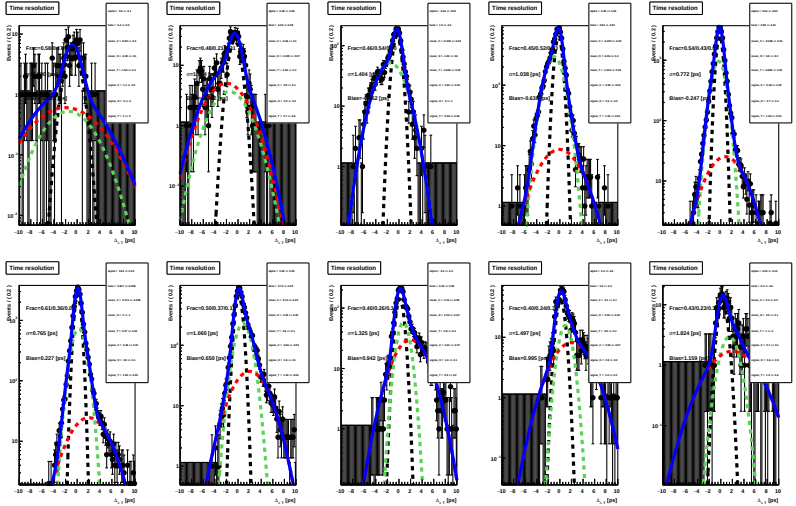
- Divide distribution in slices (10)
- fit each with a tri-gaussian
- right plot shows for (Core/Tail/Outliers/Avg):
  - biases
  - sigmas
  - fractions
- clear trend for biases and sigmas





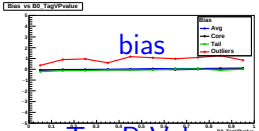


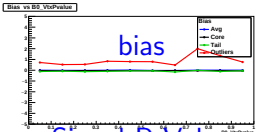
$\Delta(\Delta T)$ vs B0‘¨DeltaT: slices fit

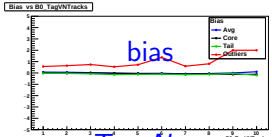


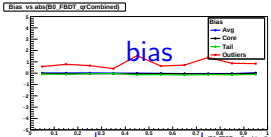
Other correlations?

- search for correlation with other variables:
  - Tag/Signal Vertex P-value;
  - Number of tracks used in Tag Vertex;
  - Flavor Tagging output (á la BaBar);
  - ...
- nothing significant found







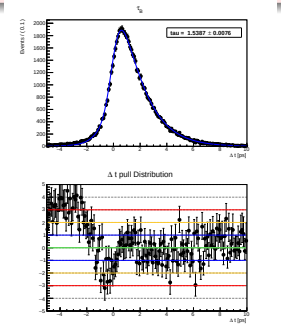


NB: Red is for outliers, always $\sim$ negligible fraction

τ_B fit with ΔT-dependent time resolution function

how to take use correlation between resolution parameters and $\Delta T_{reco(true)}$

- RooDecay can convolute exp. with gaussian resolution functions, also parametric
- nevertheless it fails if the parameters of the resolution are left as functions of ΔT
- eventually the whole function has been written down by hand and coded



- Fit to the reconstructed one sided ΔT distribution
- resolution parameters from simultaneous fit in ΔT_{true}
- result seem ok: $\tau_B = 1.539 \pm 0.008$...
- but a strong dependence on the tails and outliers components is observed

Still some work is needed for a deeper understanding

ΔT-dependent time resolution function - Main issues

1. tried modelling the resolution as a function of ΔT_{reco} or ΔT_{truth}
   - in principle the two approaches should be equivalent, but results differs
2. how properly evaluate the ΔT resolution parameters
   - some parameters $\sim$constant (σ, fractions)
   - compute the functional dependence of bias: two approaches under study
     - ★ bin dataset wrt $\Delta T_{reco(true)}$ and perform independent
     - ★ simultaneous fit in those categories

resolution parameters vs ΔT_{reco}

- core and outlier params consistent between the two methods
- Not so for tail
- fraction of core component is consistent, larger difference in tail/outlier components

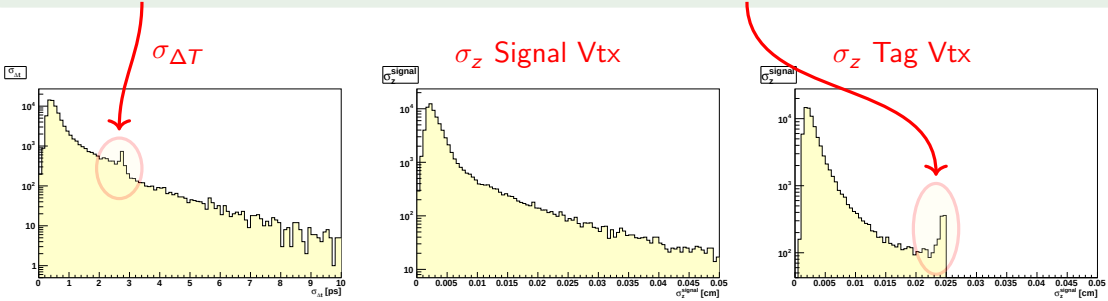
	fit in bins	simultaneous fit
μ_C [ps]	$0.09 \cdot \Delta T - 0.05$	$0.07 \cdot \Delta T - 0.06$
μ_T [ps]	$0.34 \cdot \Delta T - 0.04$	$0.72 \cdot \Delta T - 0.06$
μ_O [ps]	$0.57 \cdot \Delta T + 1.92$	$0.51 \cdot \Delta T + 0.8$
σ_C [ps]	0.55	0.60
σ_T [ps]	1.01	0.73
σ_O [ps]	3.00	2.54
f_C	0.70	0.73
f_T	0.27	0.20

Per event ΔT error

since some release, ΔT error is available *per event*

- computed propagating the signal/tag vertex uncert. from vertex fit taking into account all correlation
- Warning: bug present in `rel-00-09-xx` fixed in `rel-01-00-xx` and patched for this work

Strange peak structure in distribution: coming from Tag-Side vertex error

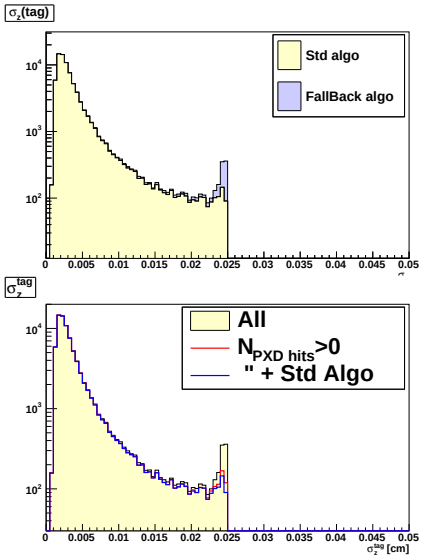


Peak origin

Tag vertex fit (`breco`) is performed using all RoE tracks

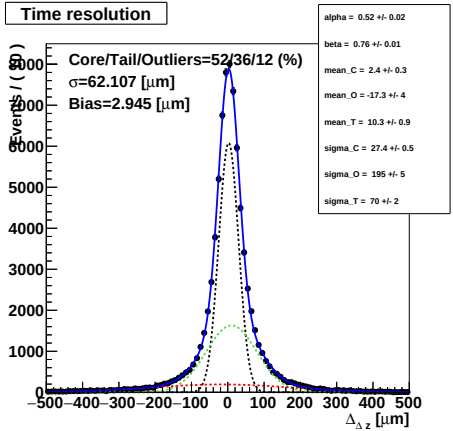
- iterative process, trying to add one track at a time;
  - possible to exclude tracks based on N_{PXD} hits
  - default no cut: $N_{PXD} >= 0$
  - (only modifying the code)*
- it also perform a vertex constraint (`iptube`);
- if the constraint fails, a non constrained fit algo is used as a fall-back
  - (algo actually used not available at user level)*

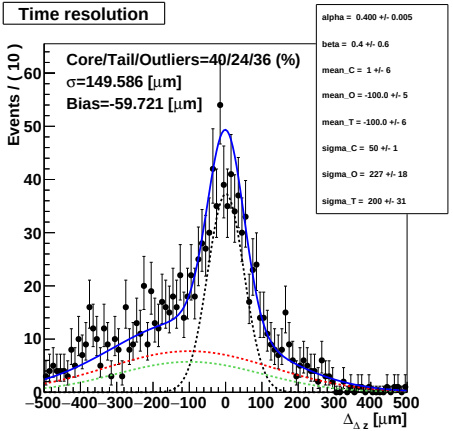
peak for tag-side due fit with fall-back algo
requiring $N_{PXD} > 0$ also remove peak
To be investigated by expert



Impact on Tag-vertex resolution

Only 1.6% of events fitted with fall-back algo, but vertex resolution is significantly worse

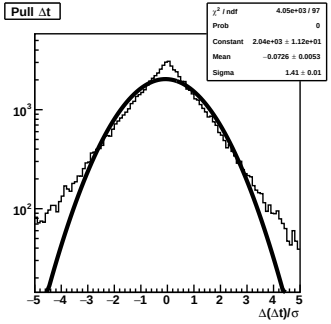


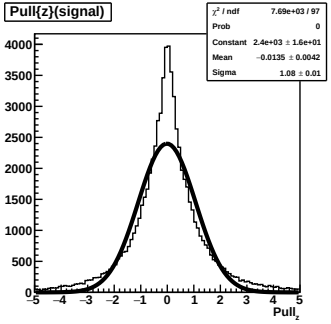


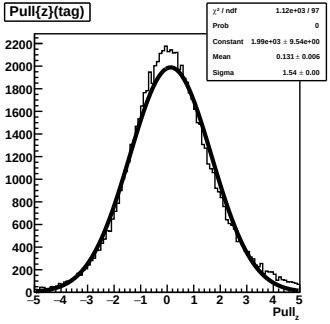
$\sigma_{\Delta T}$ in the τ_B fit?

Can we use the *per-event* $\sigma\Delta T$ in the ML fit? Technically yes.
We need to check that the pull $(\Delta T/\sigma_{\Delta T})$ is reasonably gaussian ($mean = 0, \sigma = 1$)

- Not gaussian for ΔT;
- $\sigma \sim 1$ for z_{signal}, but large tails;
- good gaussian for z_{tag} but $\sigma = 1.5$;





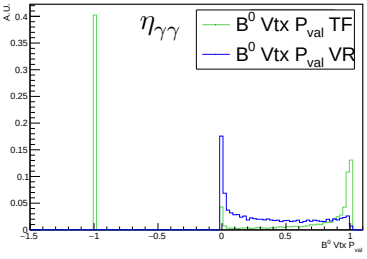


First test with TreeFitter: efficiencies

Started with default configuration (no constraints on intermediate state masses)

ε (%)	$\eta_{\gamma\gamma}$
VR all	36.4
VR B0_VtxPvalue > 0.001	31.7
TF all	39.4
TF B0_VtxPvalue > 0.001	22.1

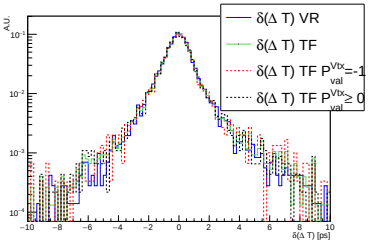
head release: 20000 events

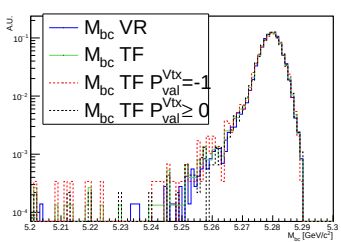


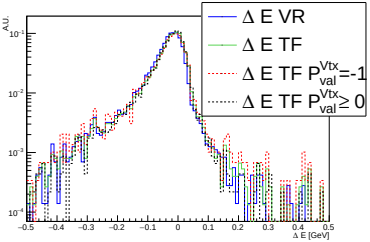
Issue with efficiency

- The default cut on the Vtx P-value is 0.001 $\Rightarrow$ efficiency drop $\sim$ 50%
- efficiency recovered (and slight improved) once all events are kept
- need to understand who are those guys with vtx P-val=-1: bug, wrong tool configuration
- had a look at some distributions but nothing relevant spotted (next slides)
- in contact with authors

ΔT resolution, M_{bc}, ΔE



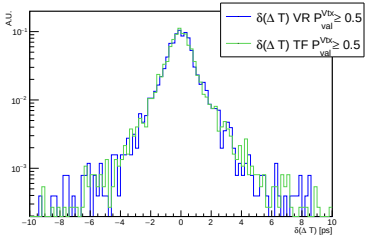


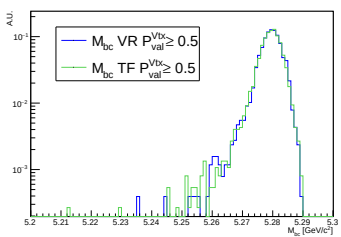


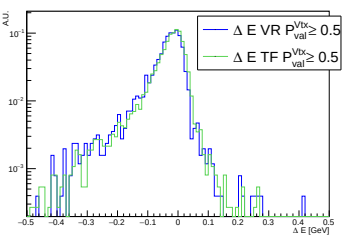
- overall comparable performances with both Vertex Rave method (VR) and Tree Fitter (FT)
- no appreciable differences are observed between events with vxt P_{Val}=-1 or ≥ 0
- a slight shift in ΔE is observed when using TF
- likely to be improved when intermediate masses constraints will be added

ΔT resolution, M_{bc}, ΔE - Only good quality events

Looking at events with vtx $P_{val} \geq 0.5$







- also for good quality events comparable performances are observed with both Vertex Rave method (VR) and Tree Fitter (FT)
- likely to be improved when intermediate masses constraints will be added

Summary

Still work in progress, no conclusion yet: hopefully for next B2GM

- ΔT resolution has several structures related to reconstruction/vertexing
  - Some identified, some still unclear
  - need to test `VXDTF2` reconstruction to see if improves `PXD` hits usage for prompt tracks
- τ_B fit with ΔT dependent resolution function tried
  - still technical difficulties
  - preliminary results promising
- per event $\sigma_\Delta T$ has still many issues, mostly on tag side
  - also pulls are not so good
  - will test anyway in the τ fit
- first test with `TreeFitter`
  - Issues with efficiency
  - vertex P-value interpretation

Additional stuff

Additional or backup slides

Bibliography I

[Tajima et al., 2004] Tajima, H., Aihara, H., Higuchi, T., Kawai, H., Nakadaira, T., Tanaka, J., Tomura, T., Yokoyama, M., Hazumi, M., Sakai, Y., Sumisawa, K. and Kawasaki, T. (2004). Proper-time resolution function for measurement of time evolution of B mesons at the KEK B-Factory. NIM *533*, 370 – 386. doi:https://doi.org/10.1016/j.nima.2004.07.199.