# *Status of vertexing*

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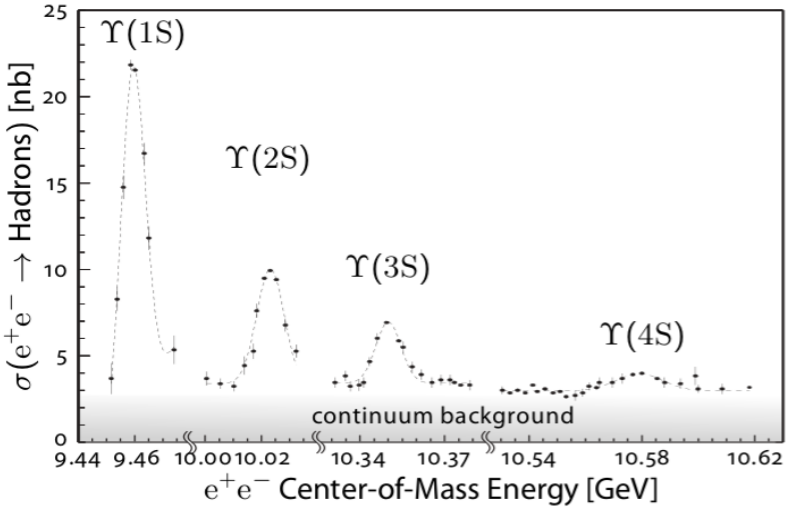
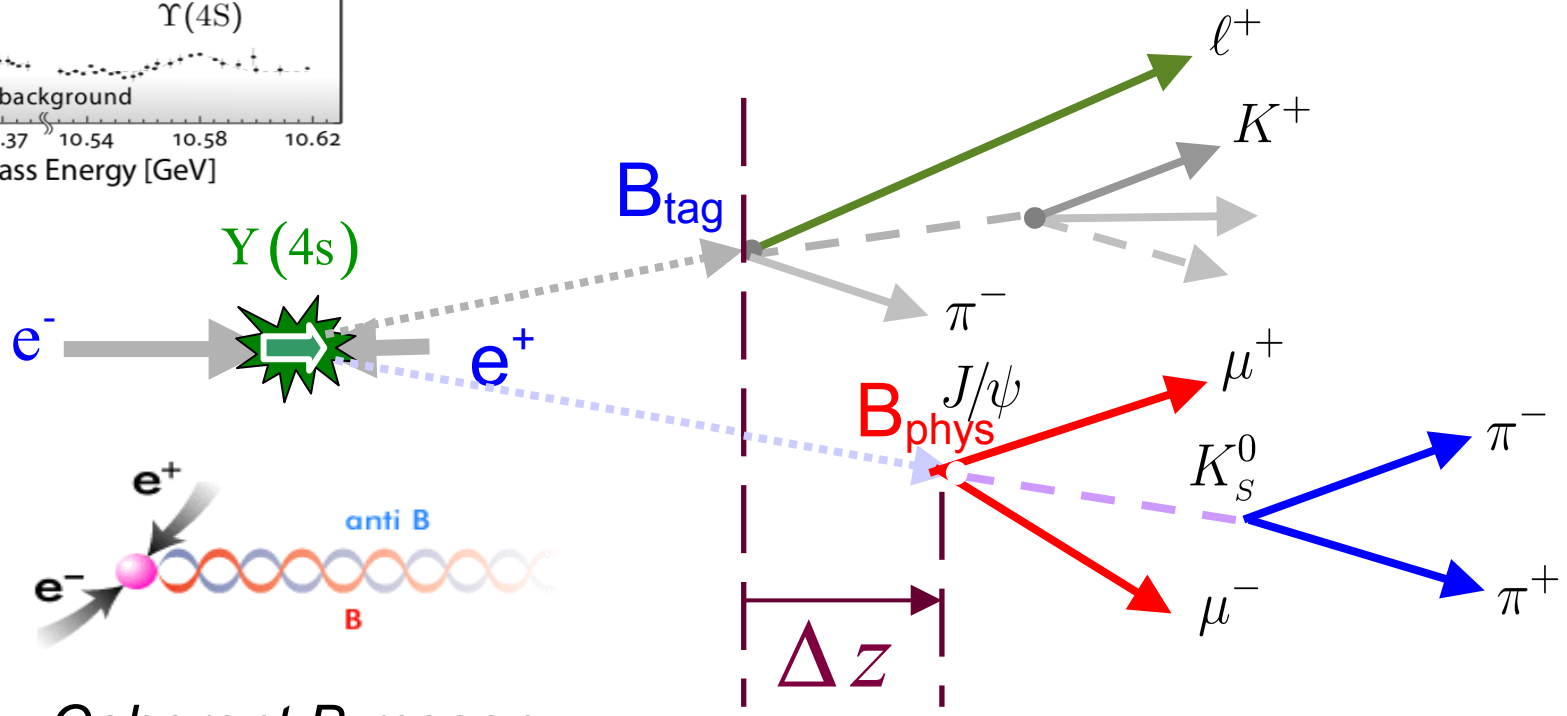
# Time dependent measurements




- Y(4S) is the first resonance just above the $B\bar{B}$ production threshold
- Only $B\bar{B}$ pairs are produced, and are at rest in the Y(4S) frame

$$\Delta t = \frac{\Delta z}{\beta \gamma c}$$

Resolution on Δt will be dominated by the resolution of the tagging side vertex







*Coherent B meson pair production*

Belle ~ 200 μm
Belle II ~ 130 μm

Δt probability parametrization $\mathcal{P}(\Delta t, q) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}\left[1 + q\left(\mathcal{A}_{CP}\cos\Delta m_d \Delta t + \mathcal{S}_{CP}\sin\Delta m_d \Delta t\right)\right]$

# Software versions

Different behaviour from different releases in the last 3 months

200 k $B^0 \rightarrow J/\psi$ Ks events generated:

- First introduction of the VXD hits: r14967 (20/01/2015)
- Recent release: r16924 (04/04/2015)

- New release produces a 30.7% higher efficiency.
- Maybe Due to new Ks reconstruction/selection

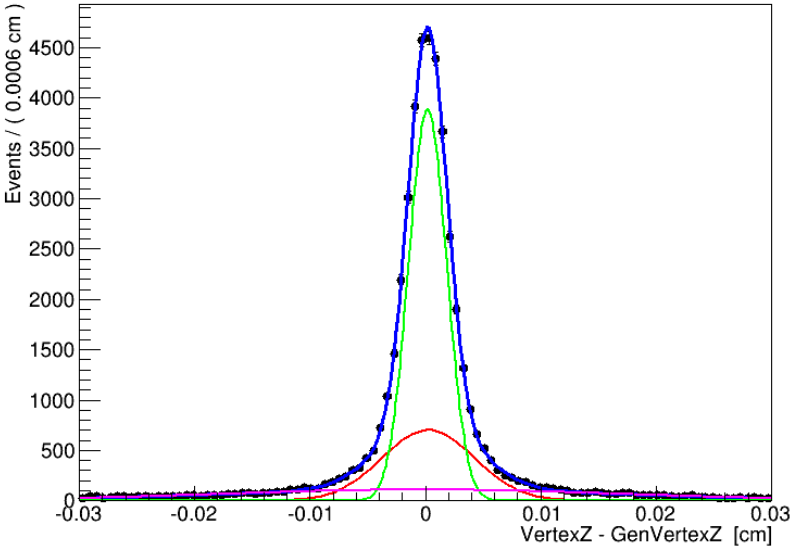
- Used rave release 0.6.16: present version in the externals
- Release 0.6.21 available:
  - no differences in performances
  - To be checked if it solves the memory leak

Ks loading using a recent release doesn't work for events generated with r14967:

[ERROR] Uncaught exception encountered: Out-of-range access in StoreArray::operator[], for array 'TrackFitResults' (durability: event), index -1 { module: ParticleLoader_K_S0 }

# J/ψ → μ μ: SVN r14967 (20/01/2015)

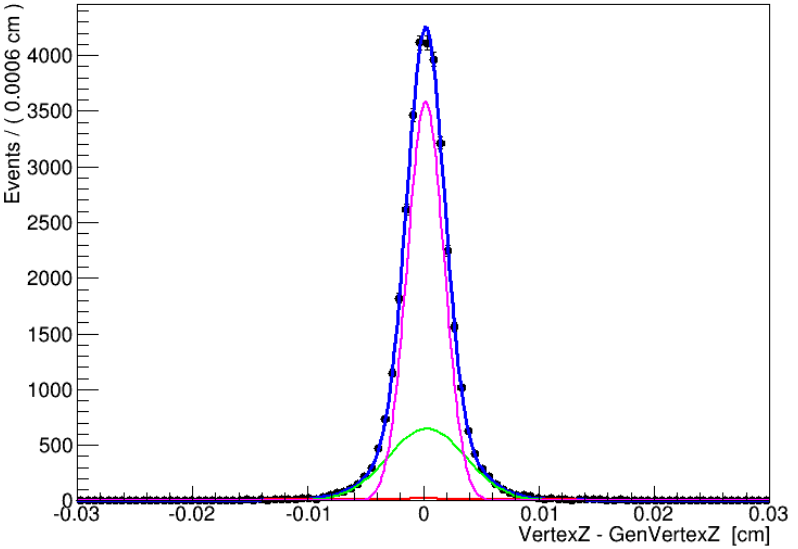
All events




| Floating Parameter | FinalValue +/- | Error |
|---|---|---|
| Mu1 | 2.5705e-04 +/- | 5.92e-05 |
| Mu2 | 1.8774e-04 +/- | 1.47e-05 |
| Mu3 | -2.8753e-04 +/- | 2.65e-04 |
| Sigma1 | 4.0189e-03 +/- | 1.69e-04 |
| Sigma2 | 1.6504e-03 +/- | 2.96e-05 |
| Sigma3 | 1.7471e-02 +/- | 5.23e-04 |
| frac1 | 2.5689e-01 +/- | 1.65e-02 |
| frac2 | 5.8353e-01 +/- | 1.89e-02 |

Shift (micron) = 1.297
Resolution (micron) = 47.8343

both μ with at least one PXD hit



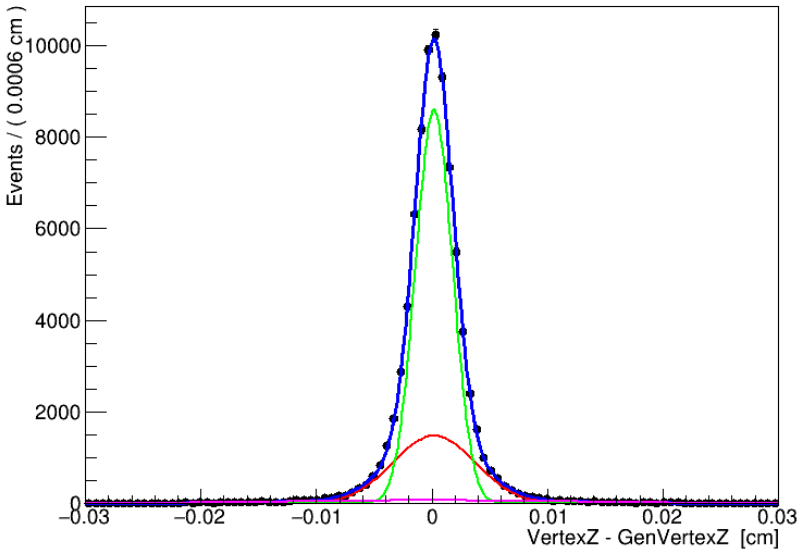

| Floating Parameter | FinalValue +/- | Error |
|---|---|---|
| Mu1 | -1.0460e-04 +/- | 4.38e-04 |
| Mu2 | 2.8470e-04 +/- | 4.95e-05 |
| Mu3 | 1.8751e-04 +/- | 1.47e-05 |
| Sigma1 | 1.0821e-02 +/- | 5.60e-04 |
| Sigma2 | 3.3875e-03 +/- | 1.01e-04 |
| Sigma3 | 1.5937e-03 +/- | 2.32e-05 |
| frac1 | 2.3581e-02 +/- | 2.64e-03 |
| frac2 | 2.7205e-01 +/- | 1.82e-02 |

Shift (micron) = 2.07061
Resolution (micron) = 22.9927

Efficiency = 73.7 %

# J/ψ → μ μ: SVN r16924 (04/04/2015)

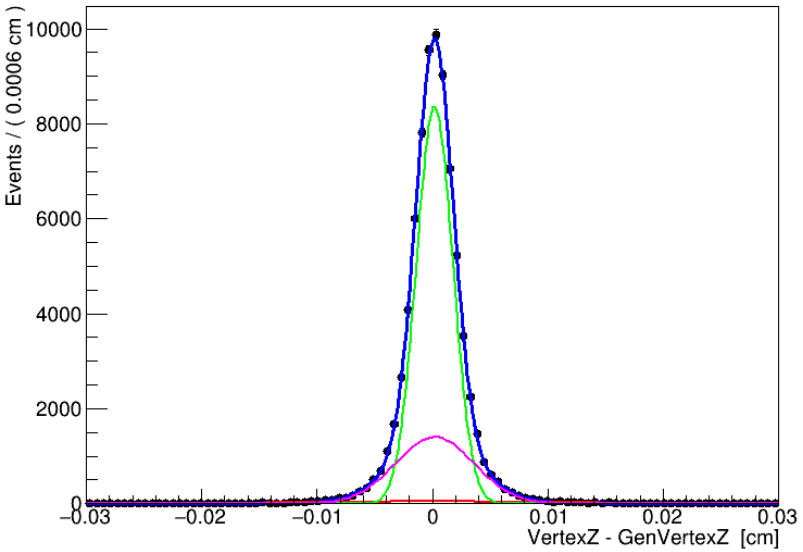
All events




| Floating Parameter | FinalValue +/- | Error |
|---|---|---|
| Mu1 | 1.8952e-04 +/- | 3.42e-05 |
| Mu2 | 1.7944e-04 +/- | 9.43e-06 |
| Mu3 | -2.4185e-04 +/- | 2.51e-04 |
| Sigma1 | 3.5677e-03 +/- | 8.30e-05 |
| Sigma2 | 1.6034e-03 +/- | 1.70e-05 |
| Sigma3 | 1.3178e-02 +/- | 3.79e-04 |
| frac1 | 2.6547e-01 +/- | 1.23e-02 |
| frac2 | 6.9003e-01 +/- | 1.34e-02 |

Shift (micron) = 1.63371
Resolution (micron) = 26.3987

both μ with at least one PXD hit




| Floating Parameter | FinalValue +/- | Error |
|---|---|---|
| Mu1 | 4.1073e-05 +/- | 2.81e-04 |
| Mu2 | 1.8466e-04 +/- | 9.48e-06 |
| Mu3 | 2.0418e-04 +/- | 3.41e-05 |
| Sigma1 | 1.1054e-02 +/- | 3.78e-04 |
| Sigma2 | 1.5909e-03 +/- | 1.58e-05 |
| Sigma3 | 3.4082e-03 +/- | 7.67e-05 |
| frac1 | 2.6013e-02 +/- | 1.90e-03 |
| frac2 | 7.1625e-01 +/- | 1.34e-02 |

Shift (micron) = 1.85956
Resolution (micron) = 23.0547

Efficiency = 92.9 %

# Rave: Adaptive Vertex Fitter

Down-weights outliers dynamically, instead of using hard cutoffs (important for 3+ track vertices).

Minimization of the weighted least sum of squares

Journal of Physics G, 34:N343–N356, 2007.

square of the standardized residual

$$w_i\left(\chi_i^2\right) = \frac{\exp(-\chi_i^2/2T)}{\exp(-\chi_i^2/2T) + \exp(-\sigma_{\text{cut}}^2/2T)}$$

Weight

"temperature" parameter
"softness" of the weight function

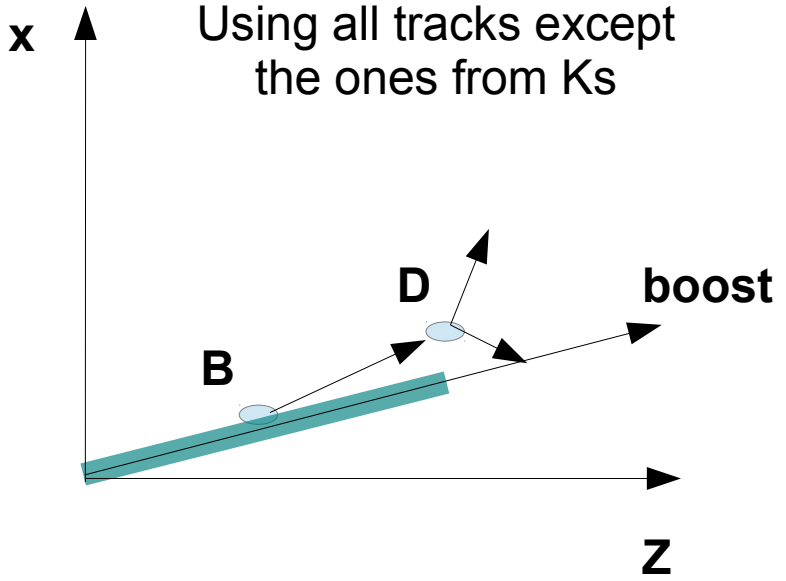
cutoff parameter

in each iteration step
the temperature parameter is lowered

$$T_i = 1 + r \cdot (T_{i-1} - 1)$$

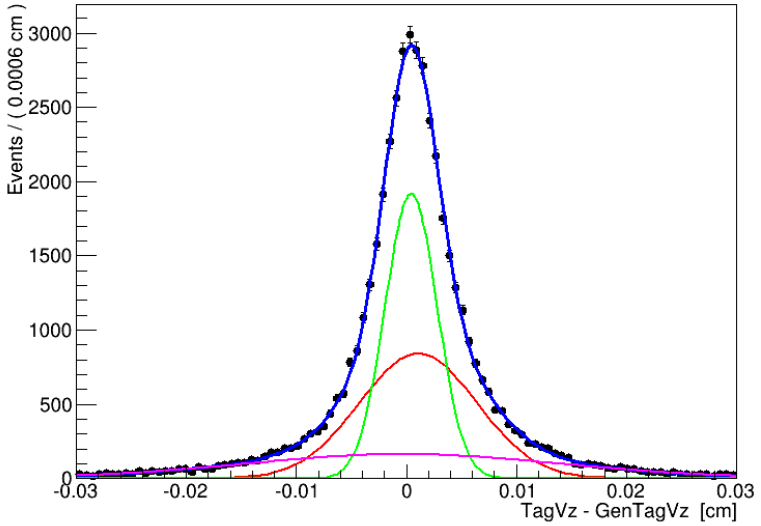
0<r<1

Using all tracks except the ones from Ks



# Tag side vertex resolution

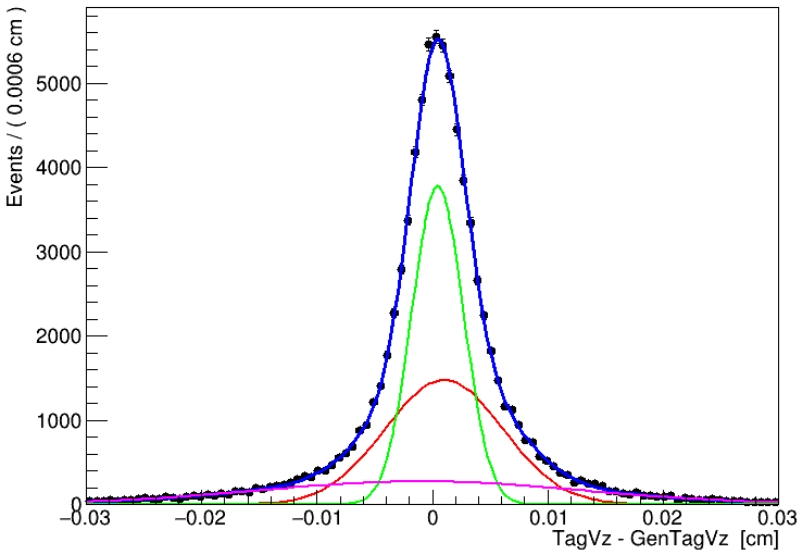
SVN r14967




| Floating Parameter | FinalValue +/- Error |
|---|---|
| Mu1 | 1.0701e-03 +/- 7.98e-05 |
| Mu2 | 4.2252e-04 +/- 3.64e-05 |
| Mu3 | -2.8536e-04 +/- 2.16e-04 |
| Sigma1 | 5.3486e-03 +/- 2.56e-04 |
| Sigma2 | 2.3626e-03 +/- 8.75e-05 |
| Sigma3 | 1.4404e-02 +/- 4.55e-04 |
| frac1 | 3.9808e-01 +/- 2.45e-02 |
| frac2 | 4.0063e-01 +/- 3.15e-02 |

Shift (micron) = 5.37808
Resolution (micron) = 59.7502

SVN r16924

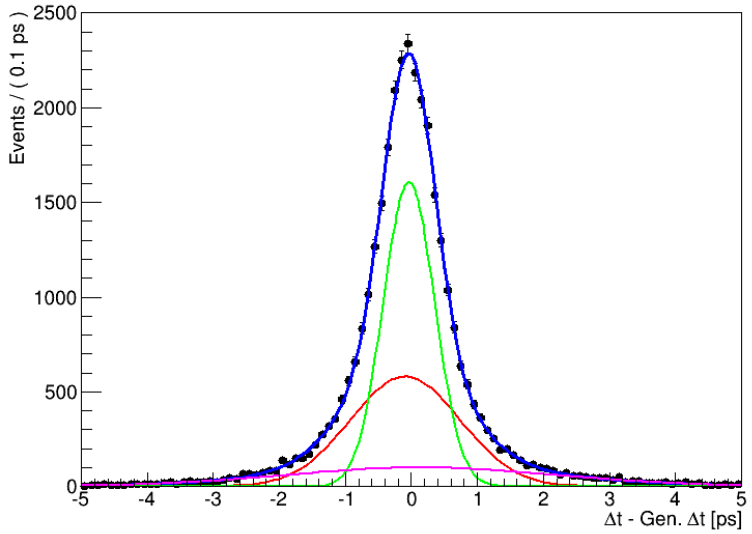



| Floating Parameter | FinalValue +/- Error |
|---|---|
| Mu1 | 1.0093e-03 +/- 5.35e-05 |
| Mu2 | 4.4940e-04 +/- 2.31e-05 |
| Mu3 | -1.0572e-03 +/- 1.69e-04 |
| Sigma1 | 5.1318e-03 +/- 1.51e-04 |
| Sigma2 | 2.2401e-03 +/- 4.68e-05 |
| Sigma3 | 1.4222e-02 +/- 2.95e-04 |
| frac1 | 3.8306e-01 +/- 1.52e-02 |
| frac2 | 4.2685e-01 +/- 1.86e-02 |

Shift (micron) = 3.77463
Resolution (micron) = 56.2535

# Δt resolution

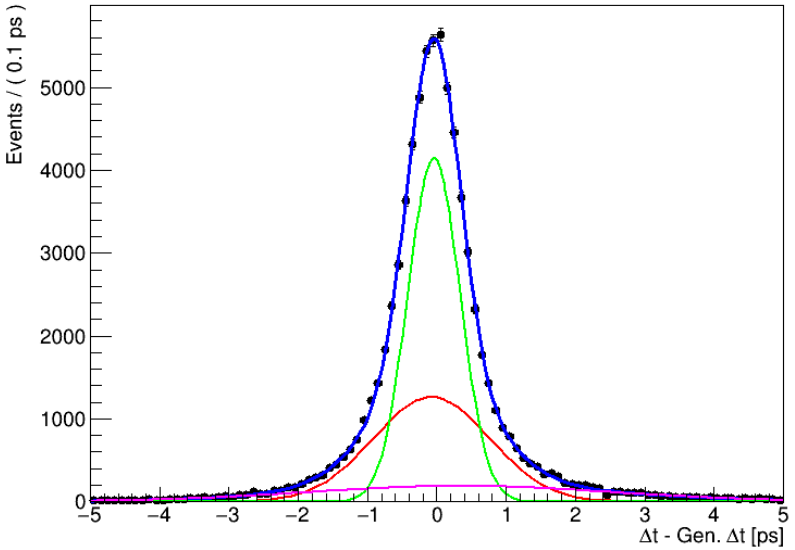
SVN r14967




| Floating Parameter | FinalValue +/- | Error |
|---|---|---|
| Mu1 | -9.2781e-02 +/- | 1.42e-02 |
| Mu2 | -3.8090e-02 +/- | 5.91e-03 |
| Mu3 | 1.4541e-01 +/- | 4.50e-02 |
| Sigma1 | 8.3397e-01 +/- | 6.00e-02 |
| Sigma2 | 3.8951e-01 +/- | 1.69e-02 |
| Sigma3 | 2.0614e+00 +/- | 8.10e-02 |
| frac1 | 3.6846e-01 +/- | 3.71e-02 |
| frac2 | 4.7676e-01 +/- | 4.81e-02 |

Shift (ps) = -0.0298379
Resolution (ps) = 0.812055

SVN r16924

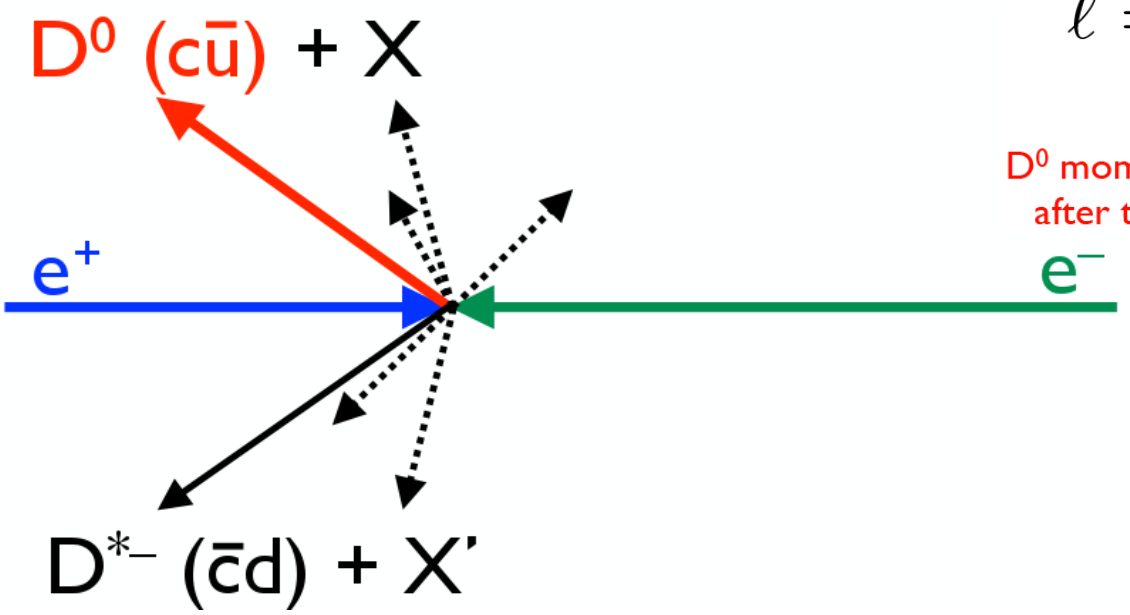



| Floating Parameter | FinalValue +/- | Error |
|---|---|---|
| Mu1 | -7.8199e-02 +/- | 8.87e-03 |
| Mu2 | -4.3422e-02 +/- | 3.38e-03 |
| Mu3 | 3.4051e-01 +/- | 3.73e-02 |
| Sigma1 | 8.4145e-01 +/- | 3.22e-02 |
| Sigma2 | 3.7806e-01 +/- | 7.94e-03 |
| Sigma3 | 2.2043e+00 +/- | 5.90e-02 |
| frac1 | 3.4952e-01 +/- | 1.84e-02 |
| frac2 | 5.1614e-01 +/- | 2.33e-02 |

Shift (ps) = -0.00400102
Resolution (ps) = 0.785354

Belle
- Shift = 0.2 ps
- Resolution = 0.92 ps

# CPV measurements in D mesons



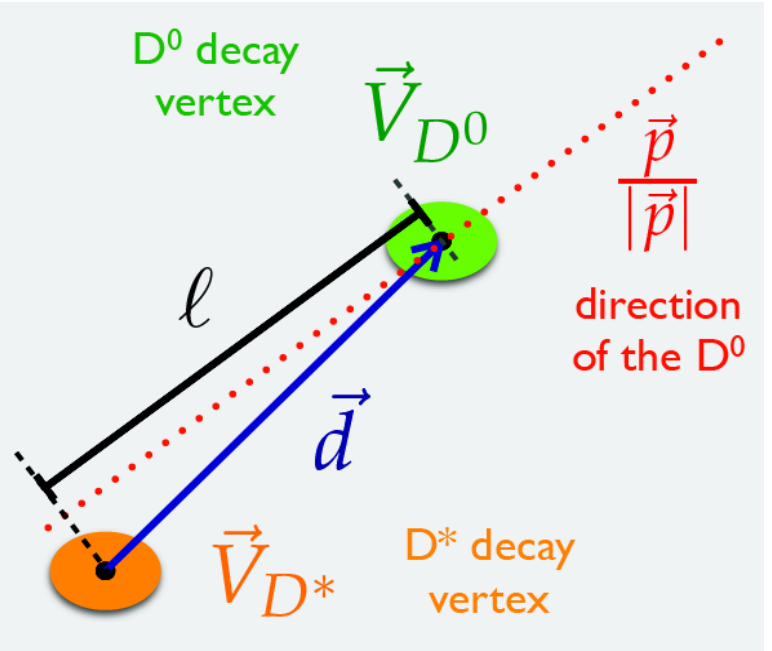

$$\ell = \frac{\vec{d}\cdot\vec{p}}{|\vec{p}|} \quad , \quad \vec{d} = \vec{V}_{D^0} - \vec{V}_{D^*}$$

$\vec{p}$: $D^0$ momentum after the fit

$\vec{V}_{D^0}$: from a mass constrained fit

$\vec{V}_{D^*}$: from a beam-spot constrained fit

Flight time $t = \frac{\ell}{c}\frac{m_D}{|\vec{p}|}$



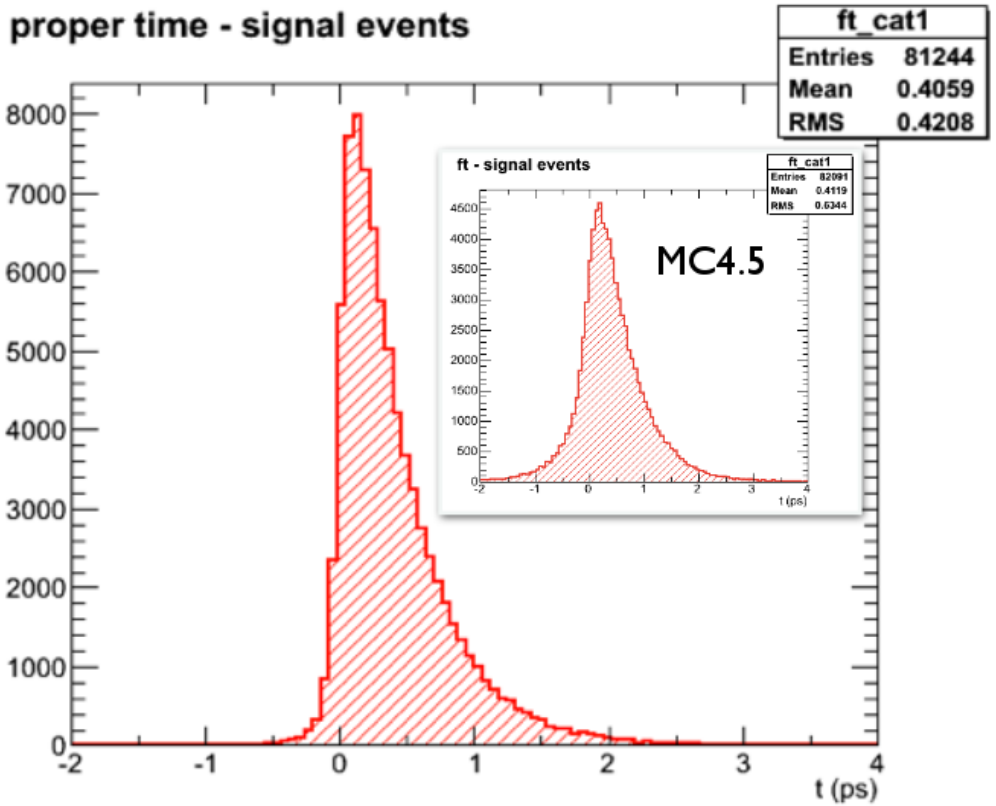

No coherent production of the $D^0 - \overline{D}^0$ state
flavour tagging with $D^{*+} \rightarrow D^0 \pi^+$ decays

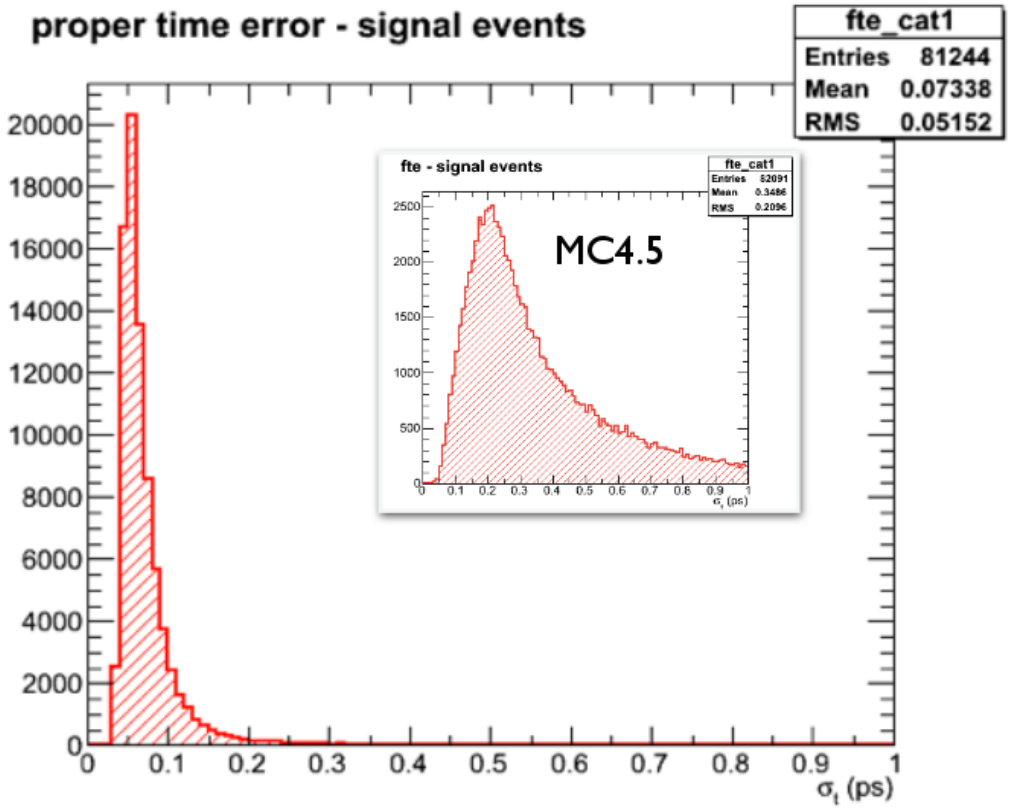
Removal of D from B decays (p* cut):

- reduce combinatoric background
- allows to assume that D* are produced at the interaction point
  - precise reconstruction of decay and production vertices required for time-dependent analyses

# Proper time & proper time error

Courtesy by G. Casarosa

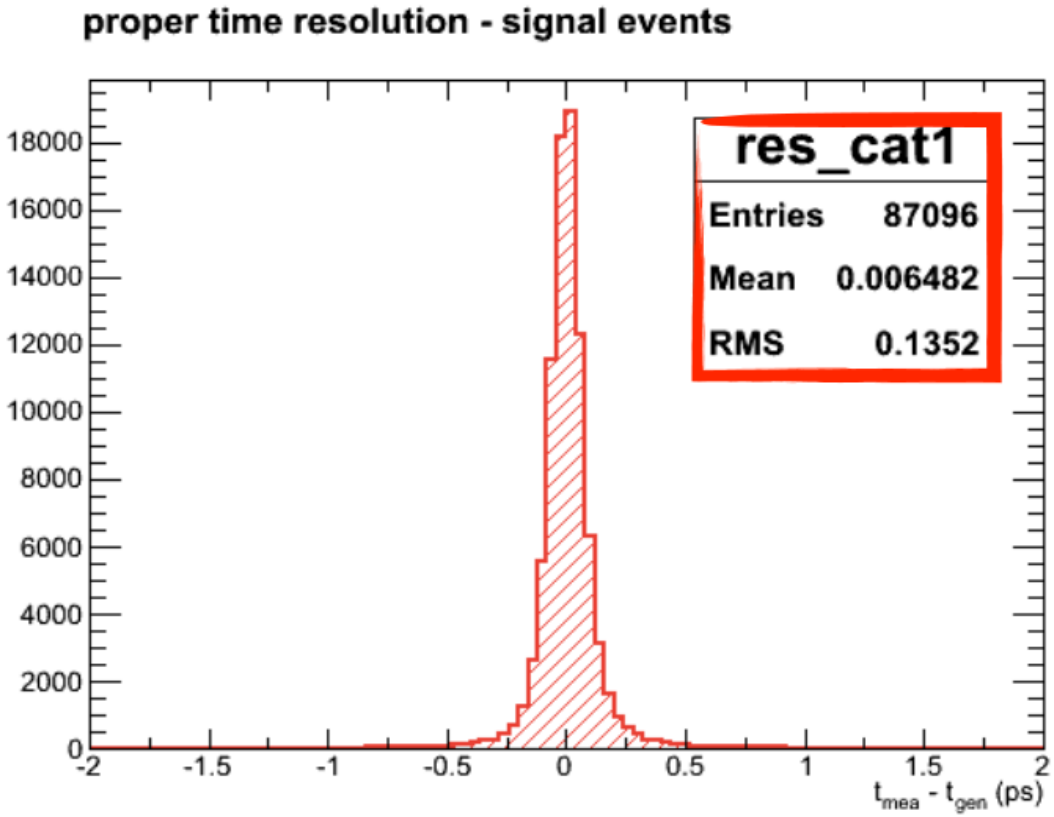


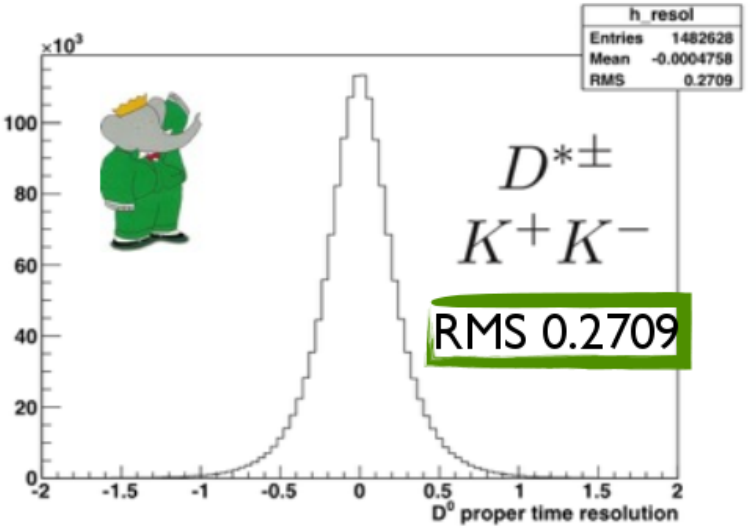



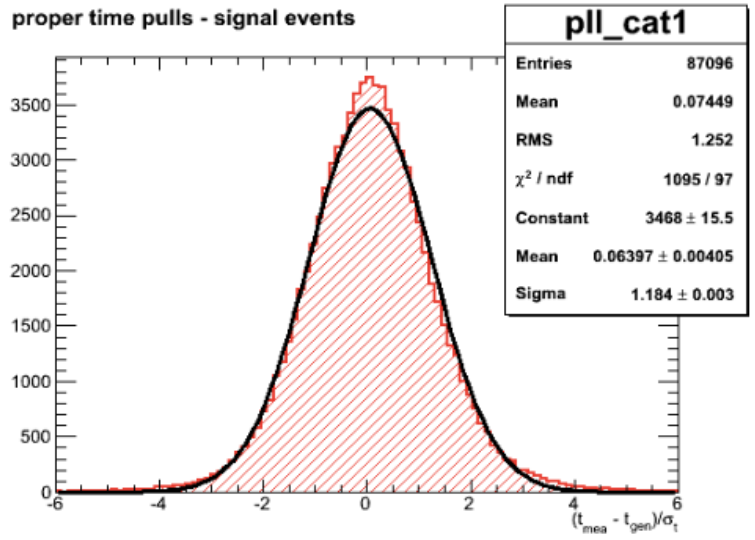

- tremendous improvement in the computation of $\sigma_t$ w.r.t. MC4.5 (plot in the box)
  - average $\sigma_t$ = 0.07 ps VS 0.35 ps in MC4.5
- tremendous improvement in the computation of *t* w.r.t. MC4.5 (plot in the box)
  - RMS t = 0.421 ps VS 0.634 ps in MC4.5

# Proper time resolution

Courtesy by G. Casarosa




- **$D^0$ proper time resolution = 0.135 ps**
- factor 2 improvement w.r.t *BABAR* and Belle (0.28 ps)
- pulls distribution is OK:
  - error correctly estimated within 18%
  - bias of 6% of the error

# Outlook

New tracking provides better vertexing performance

- $\Delta t$ distribution better than Belle (considering the lower boost)
- Important improvement in charm physics too.
- Still a shift in $J/\psi \rightarrow \mu\,\mu$ vertex fit

Rave needs further development:

- Memory leak: test release 0.6.21
- More than one instance at the same time
- Kinematic vertex fit:
  - Daughters update
  - Multi-constrained fit
  - Decay tree fit