Reconstruction of decay time differences of correlated D^0–$\overline{\mathrm{D}}^0$ pairs

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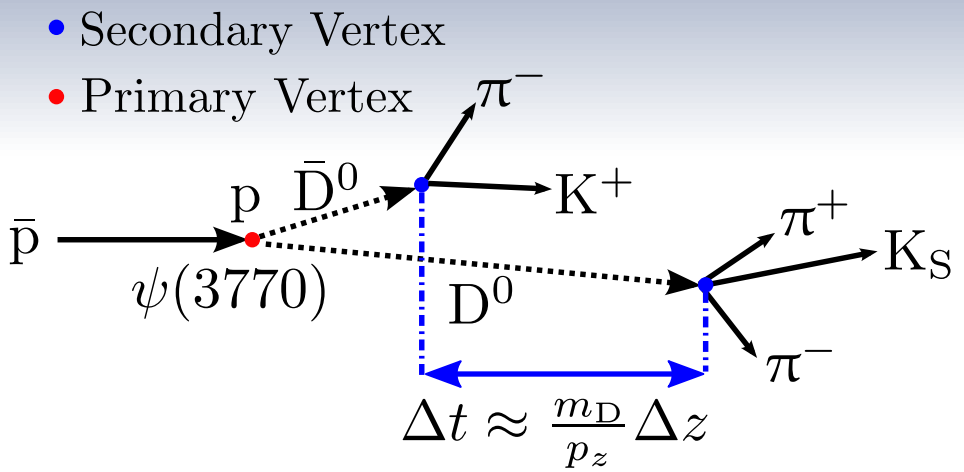
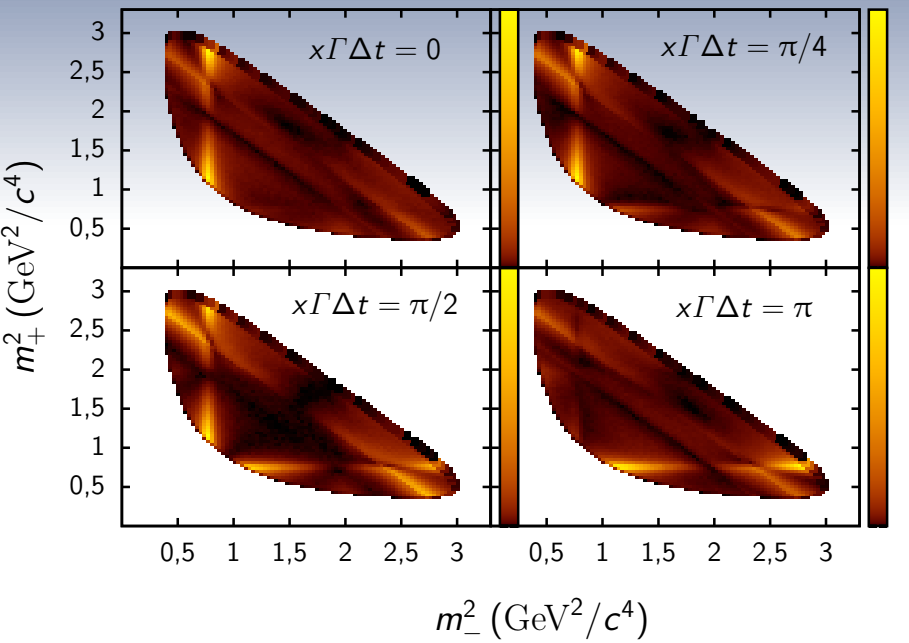
Overview

Measurement of D^0–$\overline{\mathrm{D}}^0$-Mixing

Decay channel: $\bar{\mathrm{p}}\mathrm{p} \to \psi(3770) \to \mathrm{D}^0\,\overline{\mathrm{D}}^0 \to (\mathrm{K_S}\,\pi^+\,\pi^-)(\mathrm{K}^+\,\pi^-)$





- The Dalitz-plot of the $\mathrm{D}^0 \to \mathrm{K_S}\pi^+\pi^-$ decay depends on the decay time difference between $\overline{\mathrm{D}}^0$- and D^0-decay.
- A time dependant analysis allows the determination of mixing and *CP*-violating parameters.
- Of mayor importance is therefore a good resolution of the decay time difference.

Link of space and time resolution

Reconstructed vertices

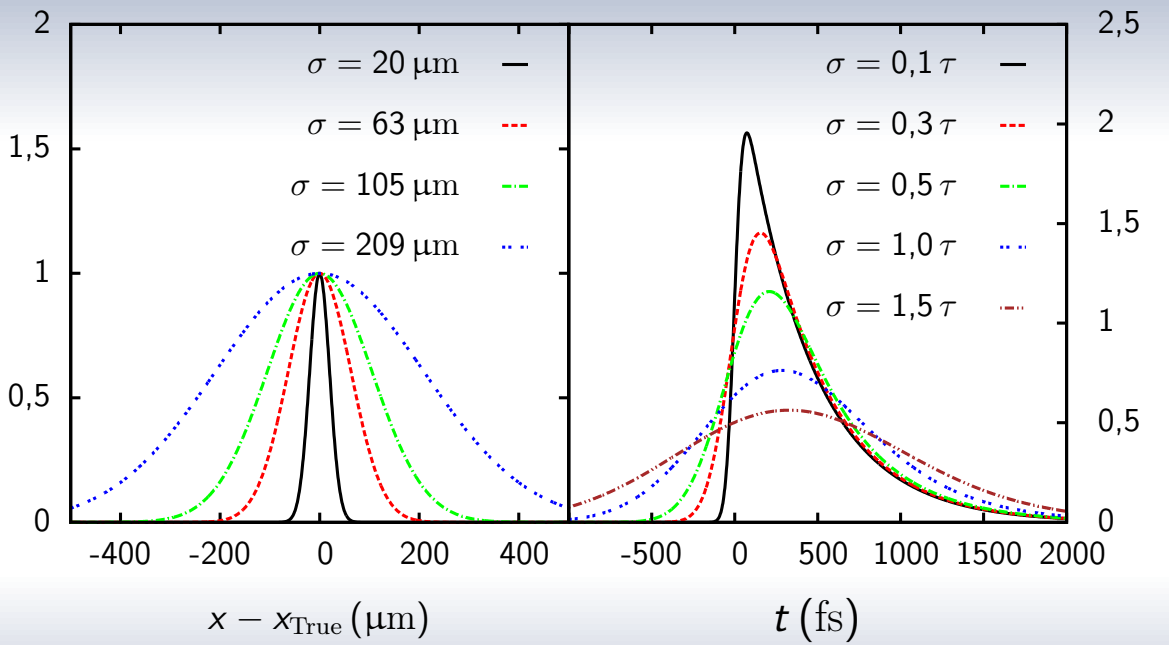
By charged tracks:

$\mathrm{D}^0 \to \mathrm{K_S}\,\pi^+\,\pi^-$

$\overline{\mathrm{D}}^0 \to \mathrm{K}^+\,\pi^-$

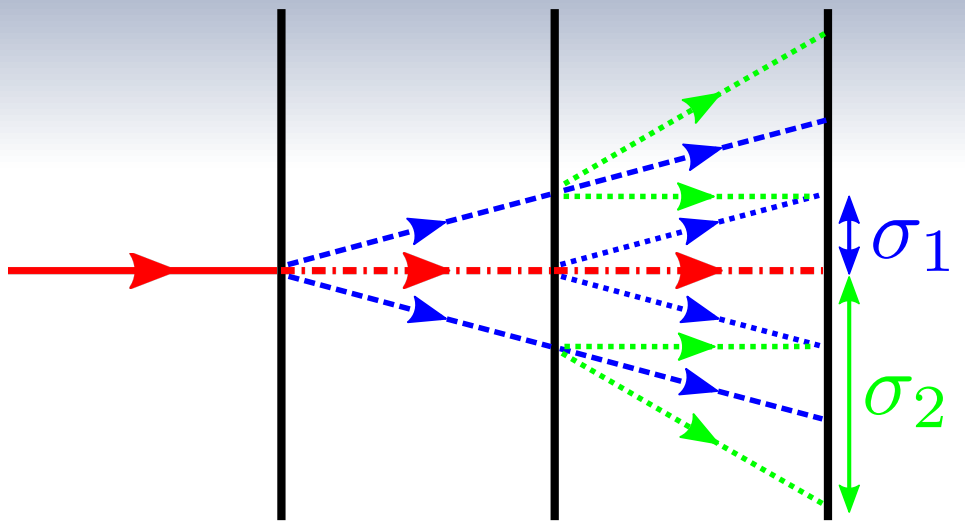
Reconstructed lifetime

$$t = \frac{m_\mathrm{D}}{p}\left(\frac{\boldsymbol{p}}{p}\right)\cdot(\boldsymbol{L}-\boldsymbol{L}_0)$$



- The decay time distribution can be described by a convolution of an exponential lifetime distribition and a gaussian resolution function.

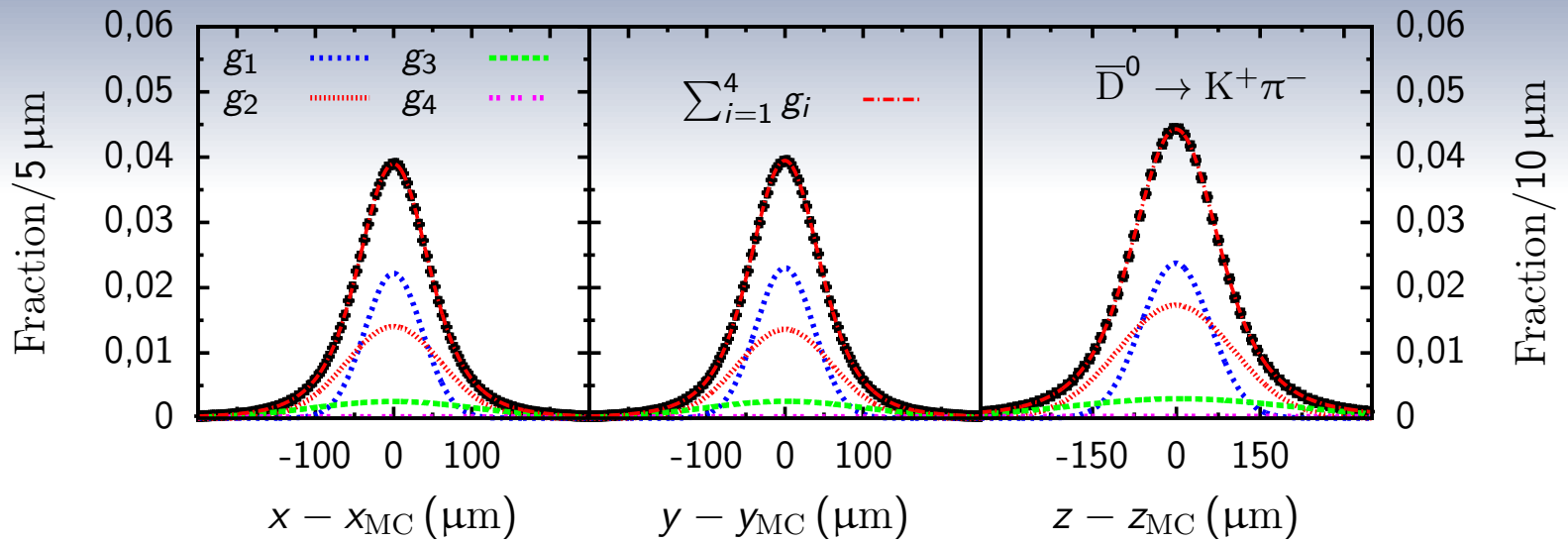
Resolution function in case of multiscattering



- In case of multiscattering the vertex resolution does **not** follow a normal distribution.
- Approximately a sum of gaussians can be used.
- Resolution function: $\mathcal{R} = \sum_{i=1}^{4} g_i$.

Resolution of $\overline{\mathrm{D}}^0$-vertex

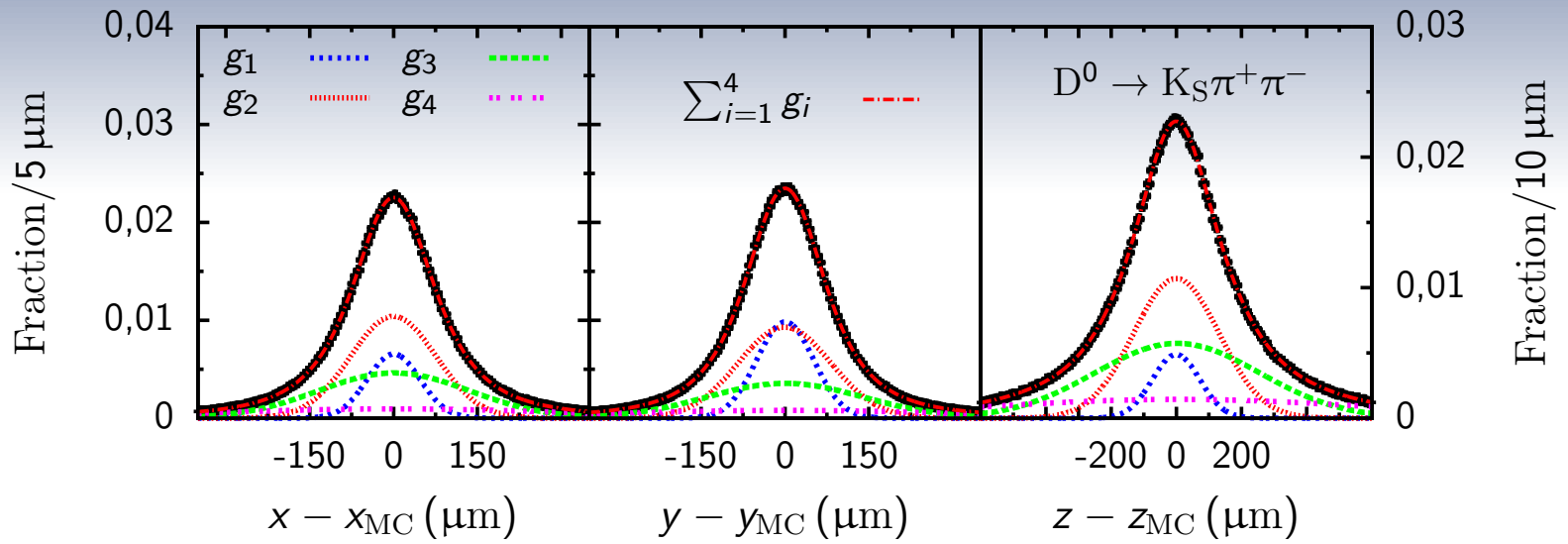
Simulation with Pandaroot Release Oct14



Parameter	x	y	z
$\sigma_1\,(\mu\mathrm{m})$	$36,69 \pm 0,22$	$37,01 \pm 0,24$	$61,88 \pm 0,46$
$\sigma_2\,(\mu\mathrm{m})$	$60,73 \pm 0,75$	$59,80 \pm 0,83$	$102,67 \pm 1,08$
$\sigma_3\,(\mu\mathrm{m})$	$104,91 \pm 1,71$	$103,09 \pm 1,69$	$198,64 \pm 2,24$
$\sigma_4\,(\mu\mathrm{m})$	$308,24 \pm 5,98$	$300,72 \pm 5,40$	$590,37 \pm 8,81$

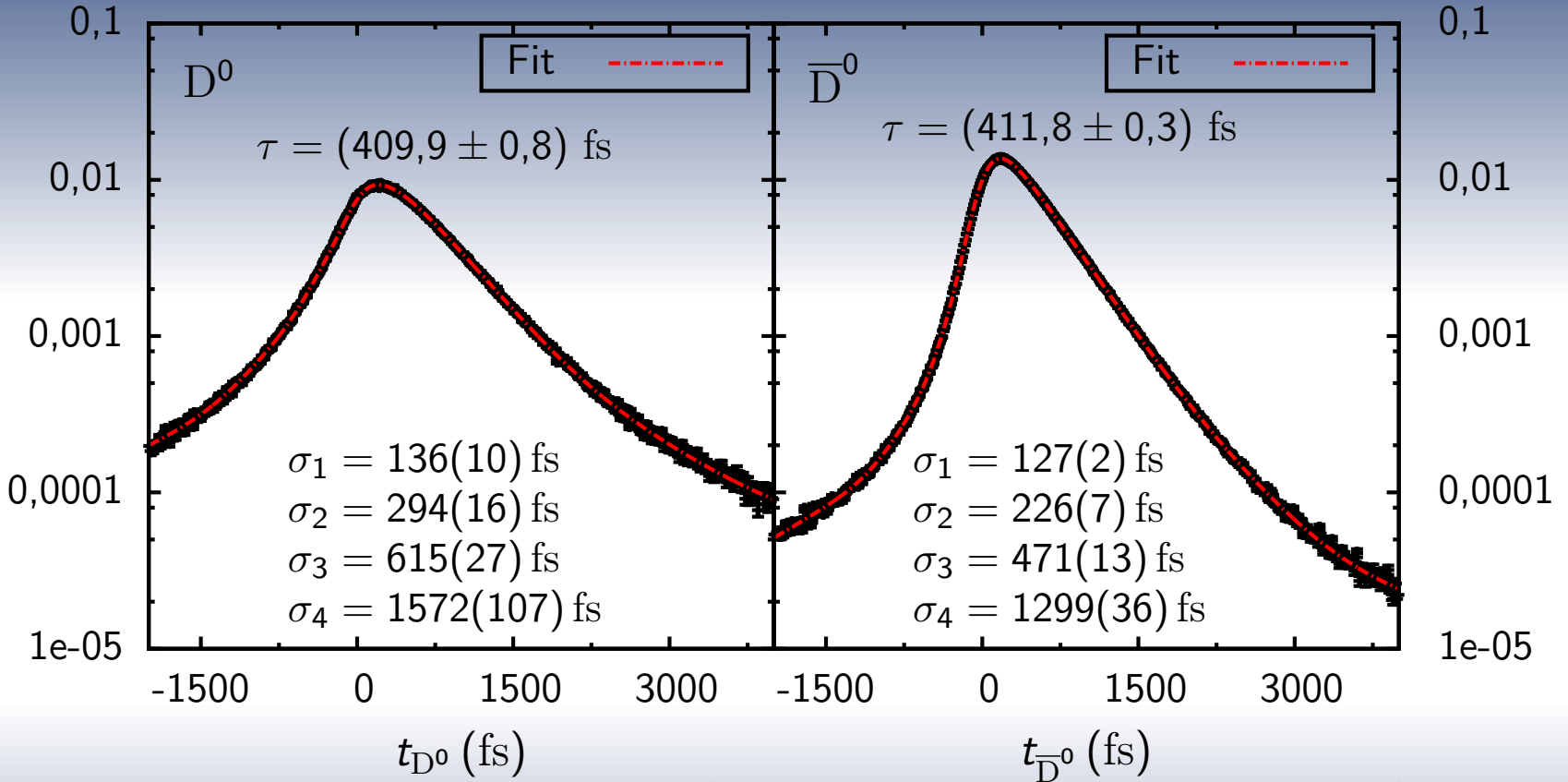
Resolution of D^0-vertex

Simulation with Pandaroot Release Oct14



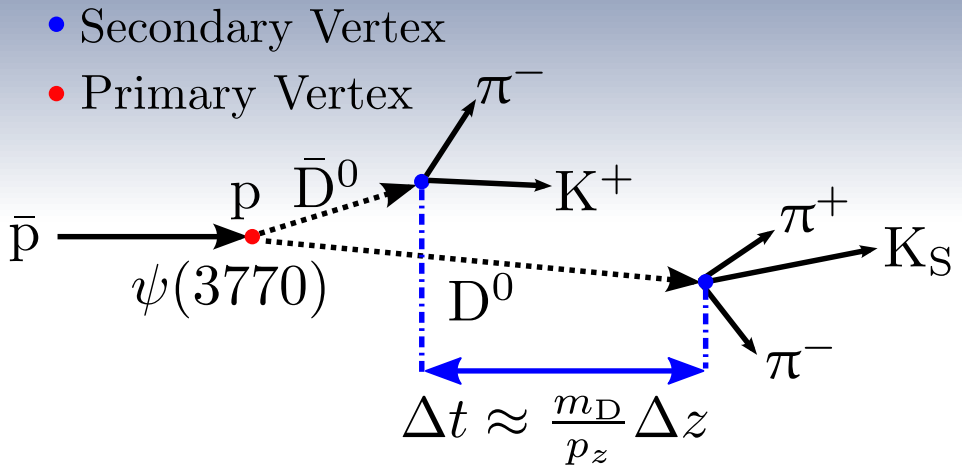
Parameter	x	y	z
$\sigma_1\,(\mu\mathrm{m})$	$47,20 \pm 2,13$	$51,12 \pm 1,34$	$73,13 \pm 3,49$
$\sigma_2\,(\mu\mathrm{m})$	$76,75 \pm 4,07$	$83,15 \pm 4,98$	$131,54 \pm 4,36$
$\sigma_3\,(\mu\mathrm{m})$	$134,96 \pm 7,37$	$139,91 \pm 11,81$	$252,42 \pm 6,90$
$\sigma_4\,(\mu\mathrm{m})$	$308,57 \pm 18,45$	$314,05 \pm 26,43$	$596,08 \pm 15,83$

Mean Lifetime



- Also in later experiment such a fit will allow an approximation of the decay time resolution.
- τ_{D^0} is in agreement with $\tau_{\mathrm{MC}} = 410,1\,\mathrm{fs}$.
- $\tau_{\overline{\mathrm{D}}^0}$ is slightly overestimated (syst. Error).

Decay Time Difference



Used Approximation

- $|\boldsymbol{L}_{\mathrm{D}^0} - \boldsymbol{L}_{\overline{\mathrm{D}}^0}| \approx \Delta z$
- $|\boldsymbol{p}_{\mathrm{D}^0}| \approx |\boldsymbol{p}_{\overline{D}^0}| \approx \frac{p_z(\bar{\mathrm{p}})}{2}$

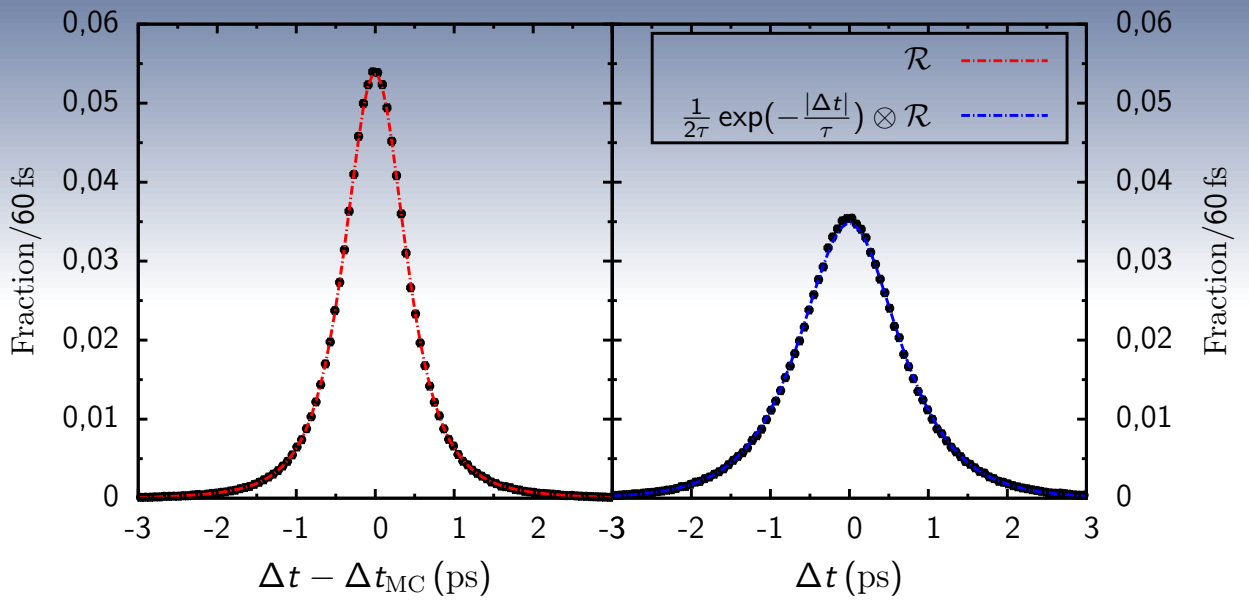
- The resolution of $\boldsymbol{L_0}$ is in the order of $\sigma_z \approx 1\,\mathrm{mm}$ (POCA).
- Transverse momenta are small: $m_\psi \approx 2m_\mathrm{D}$.

Dependance of primary vertex can be removed

$$\Delta t = t_{\mathrm{D}^0} - t_{\overline{\mathrm{D}}^0} = \frac{m_\mathrm{D}}{p_{\mathrm{D}^0}} \left(\frac{\boldsymbol{p}_{\mathrm{D}^0}}{p_{\mathrm{D}^0}}\right) \cdot (\boldsymbol{L}_{\mathrm{D}^0} - \boldsymbol{L}_0) - \frac{m_\mathrm{D}}{p_{\overline{\mathrm{D}}^0}} \left(\frac{\boldsymbol{p}_{\overline{\mathrm{D}}^0}}{p_{\overline{\mathrm{D}}^0}}\right) \cdot \left(\boldsymbol{L}_{\overline{\mathrm{D}}^0} - \boldsymbol{L}_0\right)$$

$$\Delta t \approx \frac{m_\mathrm{D}}{p_z} \Delta z$$

Decay Time Difference



Fit of Residuals

- $\sigma_1 = 199(6)\,\mathrm{fs}$
- $\sigma_2 = 325(5)\,\mathrm{fs}$
- $\sigma_3 = 561(6)\,\mathrm{fs}$
- $\sigma_4 = 1120(5)\,\mathrm{fs}$

- Resolution without cuts: $\sigma_{\Delta t} = (1159,9 \pm 11,9)\ \mathrm{fs}$

$\rightarrow$ Cut on event-based error ($< 1200\,\mathrm{fs}$) and $\Delta t = [-3000\,\mathrm{fs},\ 3000\,\mathrm{fs}]$

Resolution after cuts (RMS)

$\sigma_{\Delta t} = 612,8\,\mathrm{fs}$

Comparison to other experiments

- Decay time difference $\Delta t \approx \frac{1}{c\beta\gamma}\Delta z$.
- Comparison to mixing studies via $(\mathrm{e^+e^-} \to \Upsilon(10860) \to \mathrm{B^0\overline{B}^0})$.
- $\tau_{\mathrm{B^0}} \approx 3\tau_{\mathrm{D^0}}$.
- Shorter mean lifetime but bigger boost and better decay time resolution.

Experiment	$\beta\gamma\,(\psi, \Upsilon)$	$\sigma_{\Delta t}\,(\mathrm{fs})$
$\overline{\mathrm{P}}\mathrm{ANDA}$	1,74	612,8
BaBar	0,55	1092
Belle	0,425	1560

Summary

- The vertex resolution is within the technical design goals.
- Good knowledge of the detector resolution is mandatory for time dependant measurements.
- Within the examined channel the decay time resolution is $\sigma_{\Delta t} = 612{,}8\,\mathrm{fs}$.
- Comparison with other experiments indicate that mixing studies are feasible.