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The sensitivity for Δm_s and $\gamma + \phi_s$ from $\mathrm{B_s^0} \to \mathrm{D_s^-}\pi^+$ and $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$ decays

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The $B_s^0 \to D_s^- \pi^+$ and $B_s^0 \to D_s^\pm K^\pm$ decays will be used in LHCb to determine the B_s^0 oscillation frequency Δm_s and the CP angle $\gamma + \phi_s$. The study of the sensitivity for these CP parameters - that was performed in view of the LHCb TDR (Reoptimized Detector Design and Performance [1]) - is described in detail in this note. In the first section the formalism is given and the strategy for extracting Δm_s and $\gamma + \phi_s$ is explained. The following two sections give the details of the simulation and the results on the sensitivity for Δm_s and $\gamma + \phi_s$. Only a brief discussion of the formalism will be given, more details can be found for example in reference [2].

1 The extraction of Δm_s and $\gamma + \phi_s$.

If the heavy(B_H) and light(B_L) mass eigenstates of B-mesons are

$$|B_{H(L)}\rangle = \frac{1}{\sqrt{p^2+q^2}}[p|B\rangle + (-)q|\bar{B}\rangle], \tag{1}$$

the time evolution of the $|B_s\rangle$ and $|\bar{B}_s\rangle$ flavour eigenstates follow from

$$\begin{aligned}
\Gamma_{B\to f}(t) &= \frac{|A_f|^2}{2} e^{-\Gamma_s t}[I_+(t) + I_-(t)] \\
\Gamma_{\bar{B}\to f}(t) &= \frac{|A_f|^2}{2} \left|\frac{p}{q}\right|^2 e^{-\Gamma_s t}[I_+(t) - I_-(t)] \\
\Gamma_{\bar{B}\to \bar{f}}(t) &= \frac{|\bar{A}_{\bar{f}}|^2}{2} e^{-\Gamma_s t}[\bar{I}_+(t) + \bar{I}_-(t)] \\
\Gamma_{B\to \bar{f}}(t) &= \frac{|\bar{A}_{\bar{f}}|^2}{2} \left|\frac{q}{p}\right|^2 e^{-\Gamma_s t}[\bar{I}_+(t) - \bar{I}_-(t)],
\end{aligned} \tag{2}$$

where A_f is the instantaneous decay amplitude for a B_s-meson into a final state f,

$$\begin{aligned}
I_+(t) &= (1+|\lambda|^2)\cosh(\frac{\Delta\Gamma_s}{2}t) - 2\Re\lambda\sinh(\frac{\Delta\Gamma_s}{2}t), \\
I_-(t) &= (1-|\lambda|^2)\cos(\Delta m_s t) - 2\Im\lambda\sin(\Delta m_s t),
\end{aligned} \tag{3}$$

$\Delta\Gamma_s$ the decay width difference between the heavy and light B_s-meson eigenstates (for $\bar{I}_+$ and $\bar{I}_-$ replace λ by $\bar{\lambda}$), and

$$\lambda \equiv \frac{q}{p}\frac{\bar{A}_f}{A_f} \quad \text{and} \quad \bar{\lambda} \equiv \frac{p}{q}\frac{A_{\bar{f}}}{\bar{A}_{\bar{f}}} \quad . \tag{4}$$

The tree diagrams for the instantaneous $B_s^0 \to D_s^- K^+$ and $B_s^0 \to D_s^+ K^-$ decays are shown in figure 1. From the figure it can be seen that B_s^0 as well as $\bar{B}_s^0$ can decay instantaneously as $D_s^- K^+$ or $D_s^+ K^-$. The two different tree diagrams are represented by $T1$ and $T2$. For $B_s^0 \to D_s^- \pi^+$ this is not the case, only a single tree diagram exists. A B_s^0 decays instantaneously as $D_s^- \pi^+$ and a $\bar{B}_s^0$ as $D_s^+ \pi^-$. The $B_s^0 \to D_s^- \pi^+$ decay is therefore flavour specific and $A_{\bar{f}} = \bar{A}_f = 0$, thus $\lambda = \bar{\lambda} = 0$. With $\left|\frac{p}{q}\right| = 1$ a flavour asymmetry can be defined as

$$\mathcal{A}^{flav} = \frac{\Gamma_{\bar{B}\to f} - \Gamma_{B\to f}}{\Gamma_{\bar{B}\to f} + \Gamma_{B\to f}} = -D \cdot \frac{\cos(\Delta m_s t)}{\cosh(\Delta\Gamma_s t)}, \tag{5}$$

with D a dilution factor with contributions from wrong tagging (1-2w, with w the wrong tag fraction) and experimental resolutions. This asymmetry $\mathcal{A}^{flav}$ allows the extraction of Δm_s, w, and optionally $\Delta\Gamma_s$ from the decay rates $\Gamma_{B\to f}$ and $\Gamma_{\bar{B}\to f}$, and similarly from $\Gamma_{B\to \bar{f}}$ and $\Gamma_{\bar{B}\to \bar{f}}$.

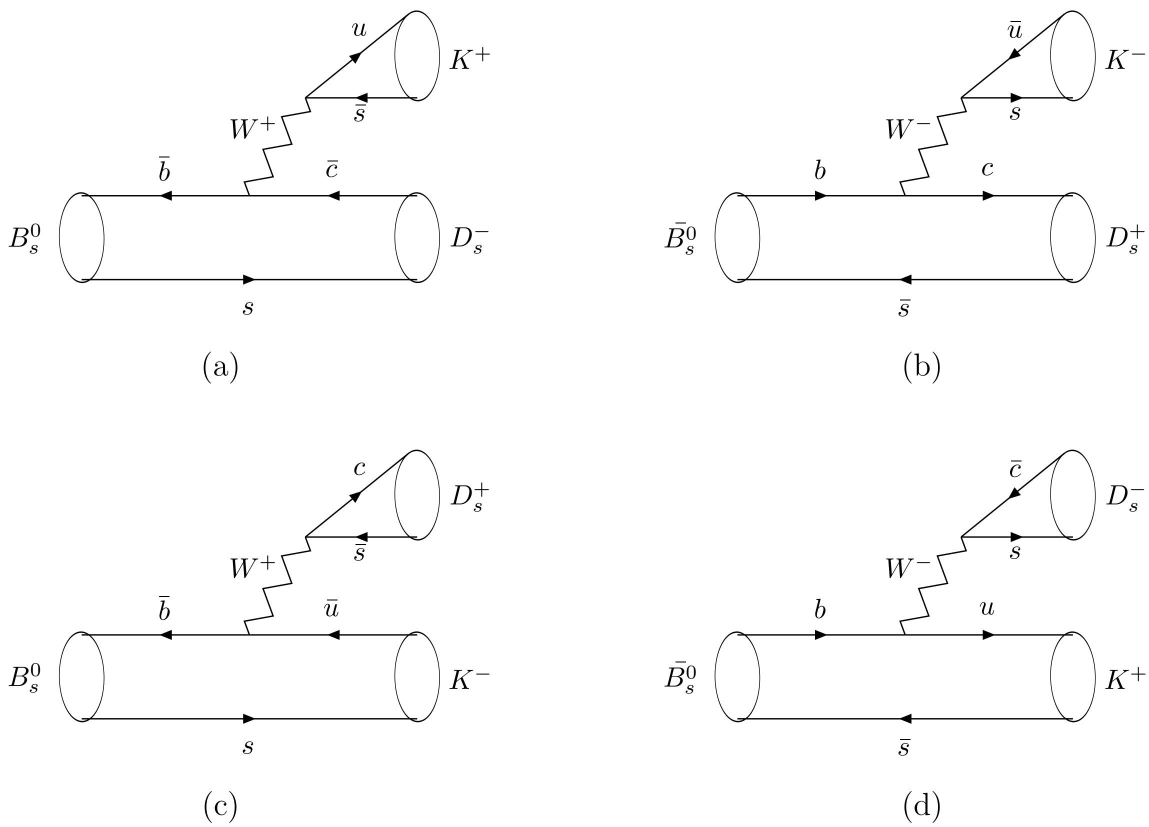

Figure 1: The tree diagrams for the $B_s^0 \to D_s^- K^+$ and $B_s^0 \to D_s^+ K^-$ decays. (a) The instantaneous decay amplitude A_f (or $T1$), (b) $\bar{A}_{\bar{f}}$, (c) $A_{\bar{f}}$, and (d) $\bar{A}_f$ (or $T2$).

For $B_s^0 \to D_s^\pm K^\pm$ it is expected that $A_f \approx \bar{A}_f$, therefore $|\lambda| = |\bar{\lambda}|$. Since B_s^0 as well as $\bar{B}_s^0$ can decay instantaneously as $D_s^- K^+$, there is an interference between the B_s^0 decays where the B_s^0 has or has not oscillated. The relevant quark processes are $\bar{b} \to \bar{c}u\bar{s}$ and $\bar{b} \to \bar{u}c\bar{s}$. Since the ratio

$$\left|\frac{A_f}{\bar{A}_f}\right| = \left|\frac{A_{\bar{f}}}{\bar{A}_{\bar{f}}}\right| = \left|\frac{V_{ub}V_{cs}}{V_{cb}V_{us}}\right| \approx 0.5, \tag{6}$$

the interference effects are large. This interference gives a sensitivity to $\gamma+\phi_s$ and the strong phase difference between $T1$ and $T2$ (i.e. A_f and $\bar{A}_f$), $\Delta_{T1/T2}$.

For $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$, λ can be defined as

$$\lambda_{D_s^- K^+} = \left(\frac{q}{p}\right)_{B_s} \left(\frac{\bar{A}_{D_s^- K^+}}{A_{D_s^- K^+}}\right) \propto \left(\frac{V_{tb}^* V_{ts}}{V_{tb} V_{ts}^*}\right) e^{i\Delta_{T1/T2}} \frac{V_{ub} V_{cs}^*}{V_{cb}^* V_{us}} \propto e^{-i(\Delta_{T1/T2}+(\gamma+\phi_s))} \tag{7}$$

$$\lambda_{D_s^+ K^-} = \left(\frac{p}{q}\right)_{B_s} \left(\frac{\bar{A}_{D_s^+ K^-}}{A_{D_s^+ K^-}}\right) \propto \left(\frac{V_{tb} V_{ts}^*}{V_{tb}^* V_{ts}}\right) e^{i\Delta_{T1/T2}} \frac{V_{ub}^* V_{cs}}{V_{cb} V_{us}^*} \propto e^{-i(\Delta_{T1/T2}-(\gamma+\phi_s))}, \tag{8}$$

where the first factor represents the $\mathrm{B_s^0}$ mixing, and the last factor the $\bar{b} \to \bar{c}u\bar{s}$ and $\bar{b} \to \bar{u}c\bar{s}$ decays. From the four time dependent decay rates λ and $\bar{\lambda}$ can be determined. The strong phase difference $\Delta_{T1/T2}$ and the CP angle $\gamma+\phi_s$ follow then from

$$\gamma+\phi_s = \frac{1}{2}[\arg(\lambda) - \arg(\bar{\lambda})] \tag{9}$$

$$\Delta_{T1/T2} = \frac{1}{2}[\arg(\lambda) + \arg(\bar{\lambda})]. \tag{10}$$

If ϕ_s is known (for example from $J/\psi\phi$ decays [3]) we can use this to determine the angle γ. For the extraction of $\gamma+\phi_s$ from $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$ the values for Δm_s, $\Delta\Gamma_s$, and w are required. As mentioned above these can be determined from $\mathrm{B_s^0} \to \mathrm{D_s^-}\pi^+$. In order to take into account the correlations on Δm_s, $\Delta\Gamma_s$, and w in the extraction of $\gamma+\phi_s$, the $\mathrm{B_s^0} \to \mathrm{D_s^-}\pi^+$ and $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$ decay rates are fitted simultaneously. The $\mathrm{B_s^0} \to \mathrm{D_s^-}\pi^+$ and $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$ decays are topologically very similar and the selection criteria in the event selection (details can be found in [4]) for the two decays are exactly the same, except for the requirement on the particle identification (PID) for the bachelor particle (pion or kaon). The w values can be therefore assumed to be equal for the two decays, as confirmed in the full GEANT detector simulation.

2 Simulation of $\mathrm{B_s^0} \to \mathrm{D_s^-}\pi^+$ and $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$ events and the likelihood description

In order to study the sensitivity for Δm_s and $\gamma+\phi_s$, the following approach was applied. Events are generated with a toy MC for different settings of the weak phase difference $\gamma+\phi_s$, the strong phase difference $\Delta_{T1/T2}$, Δm_s and $\Delta\Gamma_s/\Gamma_s$. The default value for $\Delta\Gamma_s/\Gamma_s$ is 0.1, following the expectation of Beneke et al. [5]. An experimental uncertainty on the reconstructed decay time ($\Delta\tau_{rec}$) is assigned to each generated event. The value for $\Delta\tau_{rec}$ is obtained from an event with the same true decay time (τ_{true}) as the toy event but that was simulated with a the full GEANT detector simulation. The decay time error distribution is shown in figure 2, where it can be seen that the uncertainties on the decay time range between 0.015 and 0.13 ps. Note that the full distribution of figure 2 is used in the toy simulation. The events are smeared according to the pull of the decay time as obtained from the full LHCb MC simulation. The pull distribution $(\tau_{rec} - \tau_{true})/\Delta\tau_{rec}$

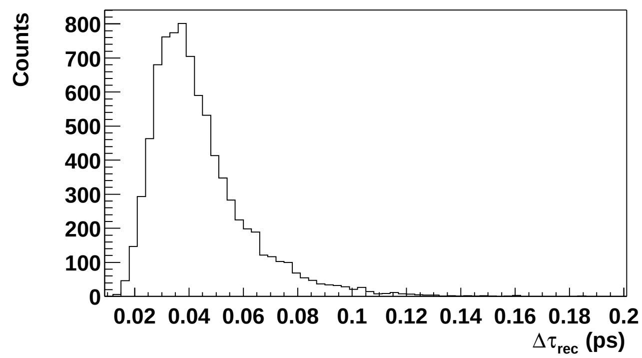

Figure 2: The decay time error distribution. This error is obtained from the full MC simulation and has contributions from the uncertainty on the momentum and the decay distance.

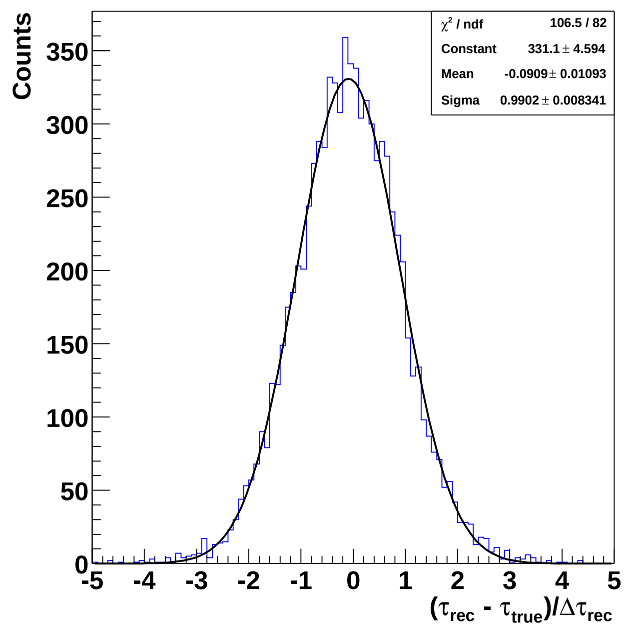

Figure 3: The pull, i.e. $(\tau_{rec} - \tau_{true})/\Delta\tau_{rec}$, of the proper time fitted with a Gaussian distribution.

is shown in figure 3. The figure demonstrates, since the σ of the Gaussian distribution equals about 1, that the uncertainty on the decay time is well estimated in the full MC study.

Background events are generated with a lifetime that is half the lifetime of B_s^0-meson decays. The events are used to maximize a likelihood ($\mathcal{L}$) function, which is given by

$$\mathcal{L}_{B\to f}(\overrightarrow{\alpha}, \overrightarrow{\beta}) = \prod_i^{B_s\to D_s\pi} \text{Prob}(\tau_{rec}, \Delta\tau_{rec}|\overrightarrow{\alpha}, S, w \cdot \prod_i^{B_s\to D_sK} \text{Prob}(\tau_{rec}, \Delta\tau_{rec}|\overrightarrow{\beta}, S, w) \quad (11)$$

with $\overrightarrow{\alpha}$=(Γ_s, Δm_s, $\Delta\Gamma_s$) and $\overrightarrow{\beta}$=(λ,$\bar{\lambda}$, Γ_s, Δm_s, $\Delta\Gamma_s$) the vectors of physics parameters used for the event generation.

$$\mathrm{Prob}(\tau_{rec}, \Delta\tau_{rec}|\overrightarrow{\alpha}, S, w) = \int_0^\infty [(1-f_{bg})m_{sig}\Gamma_{sig}(t|\overrightarrow{\alpha}, w) + f_{bg}m_{bg}\Gamma_{bg}(t)] \cdot A(t) \cdot G(t-\tau_{rec}, \Delta\tau_{rec}, S) \cdot dt \tag{12}$$

with

- $\Gamma_{sig}(t|\overrightarrow{\alpha}, w) = (1-w)\Gamma_{B\to f} + w\Gamma_{\bar{B}\to f}$ with w the wrong tag fraction.
- $\Gamma_{bg}(t) = 2\Gamma_s e^{-2t\Gamma_s}$
- $m_{sig} = \frac{1}{(\sigma_{m_{B_s}})\sqrt{2\pi}} e^{-(m_{rec}-m_{B_s})^2/2(\sigma_{m_{B_s}})^2}$, with $\sigma_{m_{B_s}} = 13.8$ GeV and m_{B_s} the $\mathrm{B_s^0}$-meson mass.
- m_{bg} = constant
- $A(t)$ is the time dependent efficiency as determined from the full LHCb simulation (figure 5)
- $G(t-\tau_{rec}, \Delta\tau_{rec}, S) = \frac{1}{(\Delta\tau_{rec}\cdot S)\sqrt{2\pi}} e^{-(\tau_{rec}-t)^2/2(S\cdot\Delta\tau_{rec})^2}$

The total likelihood is

$$\mathcal{L}(\overrightarrow{\alpha}, \overrightarrow{\beta}) = \mathcal{L}_{B\to f}(\overrightarrow{\alpha}, \overrightarrow{\beta}) \cdot \mathcal{L}_{\bar{B}\to f}(\overrightarrow{\alpha}, \overrightarrow{\beta}) \cdot \mathcal{L}_{B\to \bar{f}}(\overrightarrow{\alpha}, \overrightarrow{\beta}) \cdot \mathcal{L}_{\bar{B}\to \bar{f}}(\overrightarrow{\alpha}, \overrightarrow{\beta}). \tag{13}$$

The events are weighted according to the fraction of events with that mass that are selected in the event selection. This fraction follows from the reconstructed mass distribution (figure 4) as determined in the event selection [4] with the full LHCb simulation. A resolution scale factor S is introduced in the likelihood (i.e. a free parameter in the maximization) - allowing for a possible error in the determination of the uncertainty on the decay time - that is multiplied with $\Delta\tau_{rec}$. The result for this scale factor may not be equal to unity since in the event simulation we smear the events with the double Gaussian pull distribution of the decay time, while in the fit we use only a single Gaussian. However, since the pull distribution of the decay time is basically a perfect single Gaussian as shown in figure 3, this effect will be negligible.

The time dependent efficiency that was determined from the full MC study is shown in figure 5. Since there is no difference in the selection criteria for $\mathrm{B_s^0} \to \mathrm{D_s^-}\pi^+$ and $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$ decays, except for the requirement on the PID of the bachelor particle, the two data samples were added. The functional form of the time dependent efficiency is shown in the figure. The likelihoods for $\mathrm{B_s^0} \to \mathrm{D_s^-}\pi^+$ and $\mathrm{B_s^0} \to \mathrm{D_s^\pm K^\pm}$ are simultaneously maximized using the following free parameters: $|\lambda|$ ($= \left|\overline{\lambda}\right|$), $\arg(\lambda)$, $\arg(\bar{\lambda})$, w, and Δm_s. The values for $\gamma+\phi_s$ and the strong phase difference $\Delta_{T1/T2}$ follow from $\arg(\lambda) = -(\gamma+\phi_s)+\Delta_{T1/T2}$ and $\arg(\bar{\lambda}) = (\gamma+\phi_s)+\Delta_{T1/T2}$.

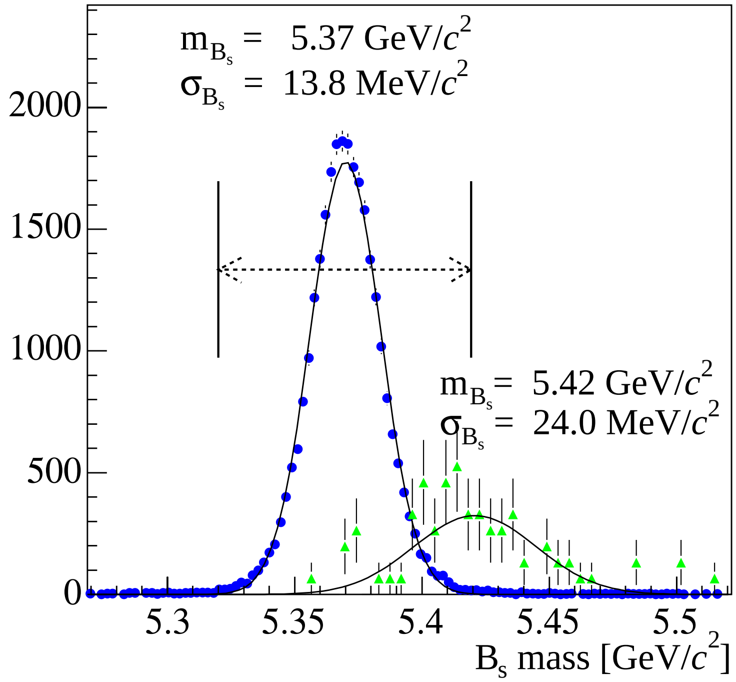

Figure 4: The B_s^0 mass distribution as determined from the full LHCb MC. The mass resolution is 13.8 MeV. Also shown is the mass distribution of $B_s^0 \to D_s^- \pi^+$ decays that have been reconstructed as $B_s^0 \to D_s^\pm K^\pm$ decays.

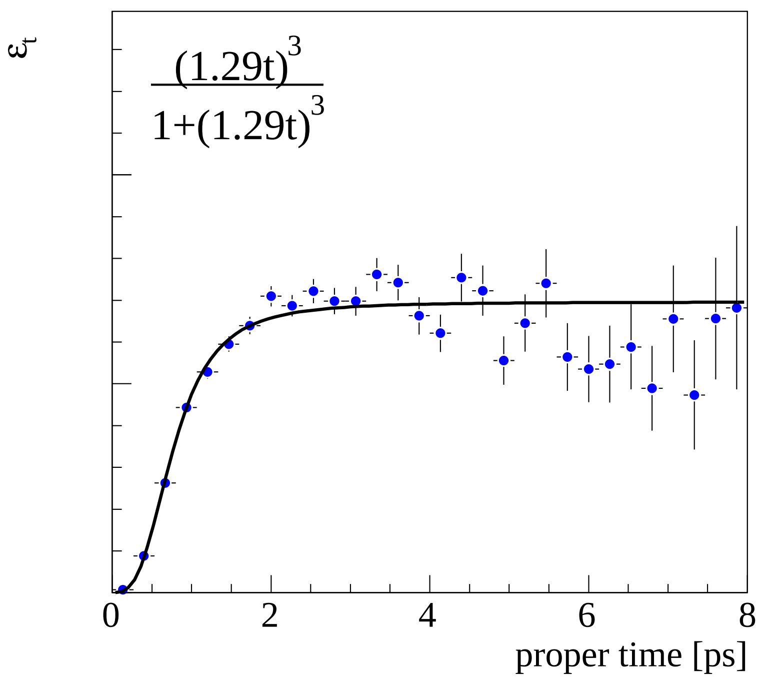

Figure 5: The time dependent efficiency of $B_s^0 \to D_s^- \pi^+$ and $B_s^0 \to D_s^\pm K^\pm$ events. The data were fitted with the equation shown in the figure.

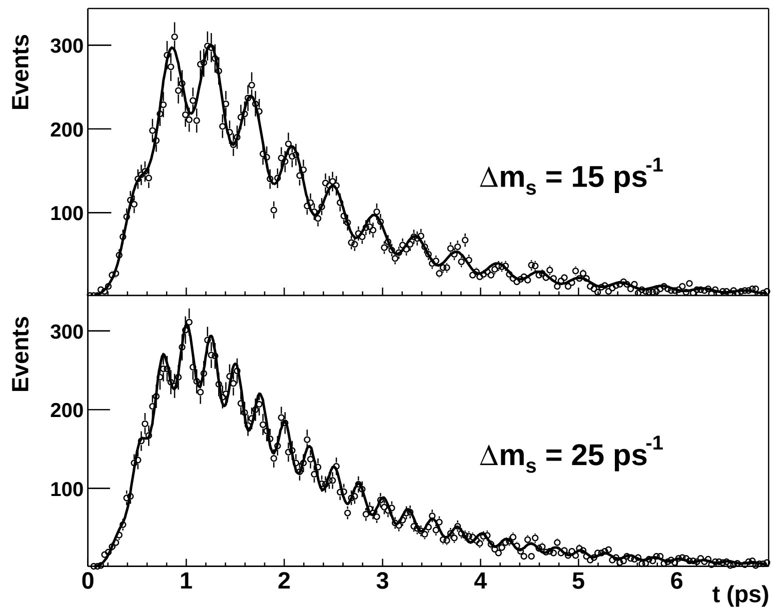

Figure 6: Simulated $B_s^0 \to D_s^- \pi^+$ decay rate for two different values of Δm_s. Only B_s decays which have been tagged as not having oscillated are included. The data represents one year of data taking, while the curve represents the probability as obtained with the likelihood maximization.

3 Results on Δm_s and $\gamma + \phi_s$

The results on the annual yield, the B/S ratios, and tagging performance as determined from the full MC simulation are summarized in table 1 [4, 1]. The results on the tagging efficiency (ϵ_{tag}) and the wrong tag fraction (w) are consistent for $B_s^0 \to D_s^- \pi^+$ and $B_s^0 \to D_s^\pm K^\pm$ therefore a weighted (with the uncertainty on w and ϵ_{tag}) average was used in the simulation, namely ϵ_{tag}=54.3% and w=32.8%. For the B/S ratio a value of 0.32 was used for $B_s^0 \to D_s^- \pi^+$, while for $B_s^0 \to D_s^\pm K^\pm$ the center value of the B/S interval was used, namely 0.5.

Table 1: Annual yields and B/S ratios for $B_s^0 \to D_s^- \pi^+$ and $B_s^0 \to D_s^\pm K^\pm$ decays.

Decay	Yield	B/S	ϵ_{tag} (%)	w (%)
$B_s^0 \to D_s^- \pi^+$	80k	0.32±0.10	54.6±1.2	30.0±1.6
$B_s^0 \to D_s^\pm K^\pm$	5.4k	<1.0	54.2±0.6	33.4±0.8

The $B_s^0 \to D_s^- \pi^+$ ($B_s^0 \to D_s^\pm K^\pm$) decay rate for one (five) year LHCb data is shown together with the maximized likelihood in figure 6 (7 and 8). The $B_s^0 \to D_s^\pm K^\pm$ asymmetry for 5 year LHCb data is shown in figure 9.

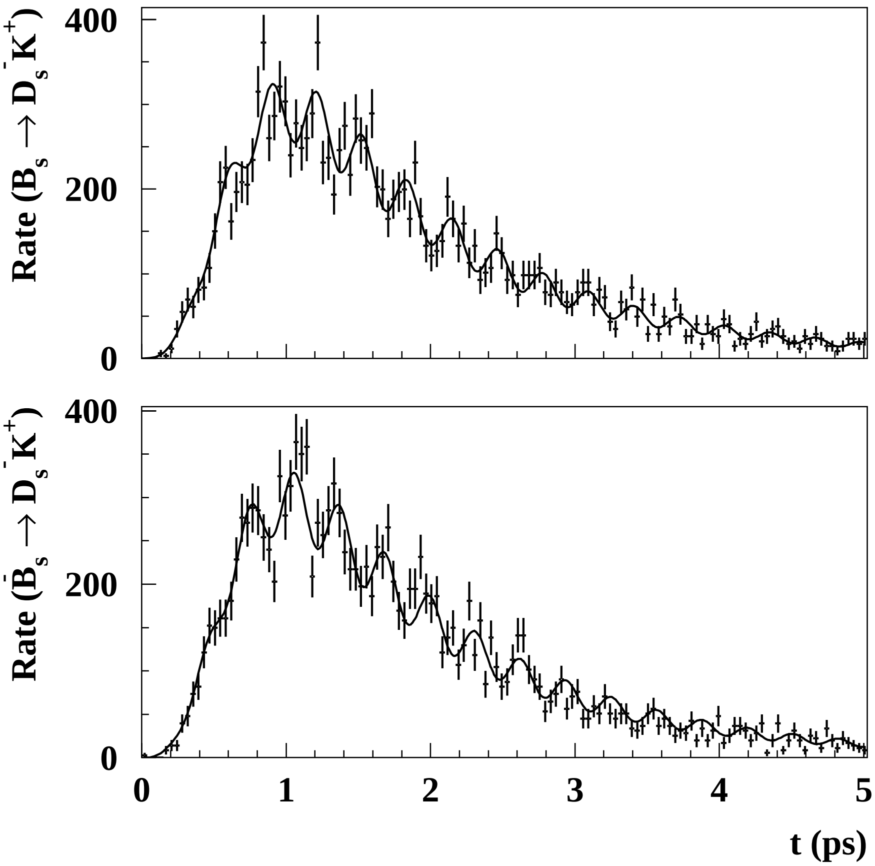

Figure 7: Simulated $B_s \to D_s^- K^+$ decay rate. The data represents five years of data taking, while the curve represents the probability as obtained with the likelihood maximization.

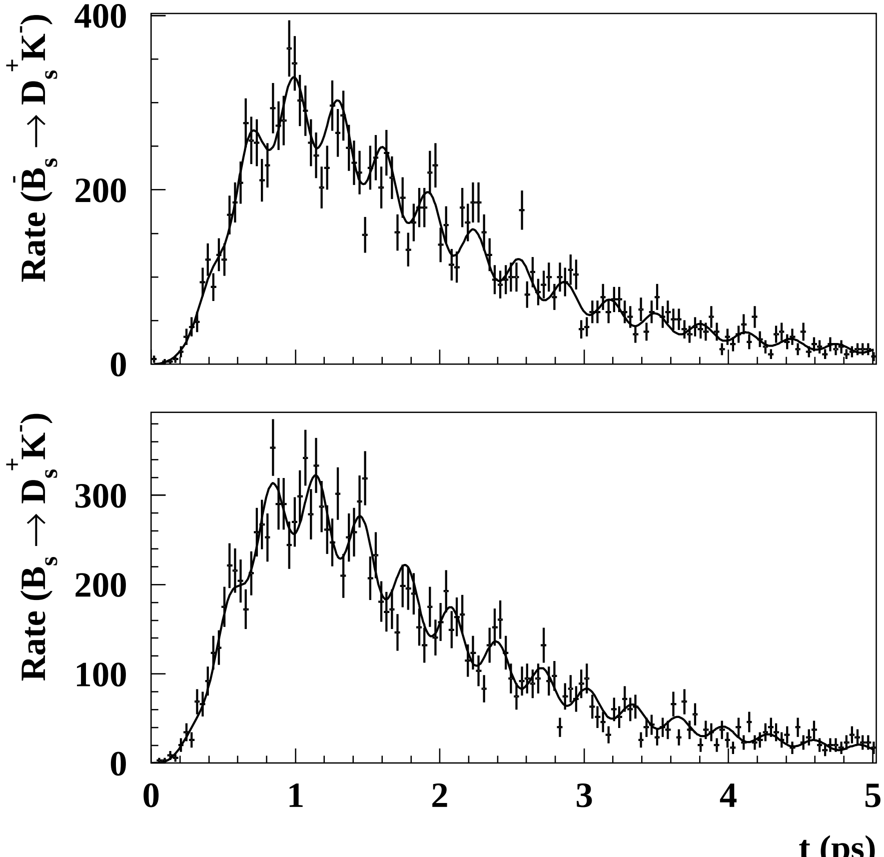

Figure 8: Simulated $B_s \to D_s^+ K^-$ decay rate. The data represents five years of data taking, while the curve represents the probability as obtained with the likelihood maximization.

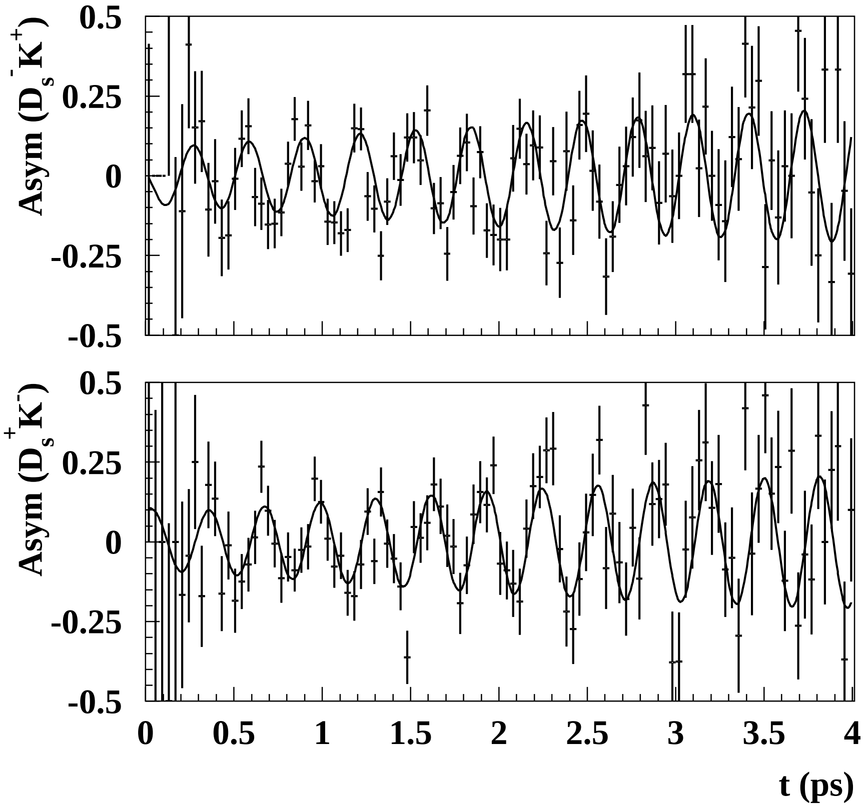

Figure 9: The $B_s^0 \to D_s^\pm K^\pm$ asymmetries for 5 year LHCb data.

The results of the maximization for the uncertainty on Δm_s for one year of $B_s^0 \to D_s^- \pi^+$ data are displayed in table 2. For each setting of Δm_s 100 'experiments' were performed. The average precissison of these experiments is given in the table. The mistag rate w is determined with a relative precision of 1.5%.

Table 2: Statistical precision on Δm_s (in ps^{-1}) with one year of data.

Δm_s	15	20	25	30
$\sigma(\Delta m_s)$	0.009	0.011	0.013	0.016

The results on Δm_s as shown in table 2 demonstrate that the uncertainty on Δm_s is small, around 0.06%. The relevant quantity to investigate is therefore the maximum value of Δm_s measurable in the experiment (sensitivity limit). To evaluate this limit the 'amplitude method', suggested and described in [7], is used. In this method the $\cos(\Delta m_s t)$ term of equation 5 is multiplied by a factor A. This amplitude can be a free parameter in the likelihood minimization, if the other parameters are fixed. The amplitude A can

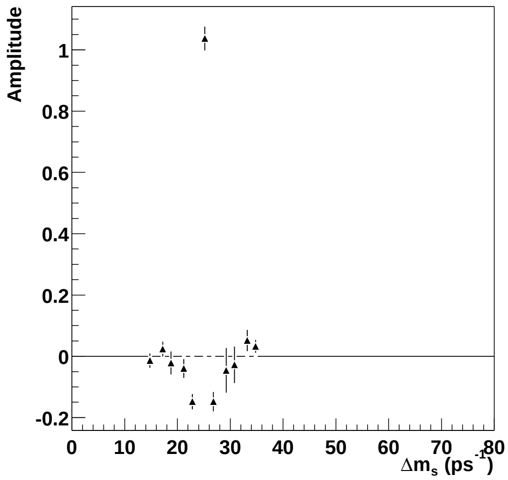

Figure 10: The amplitude factor A for different values of Δm_s. The MC data were generated with $\Delta m_s = 25\ ps^{-1}$. As expected A is equal to 1 for this Δm_s value.

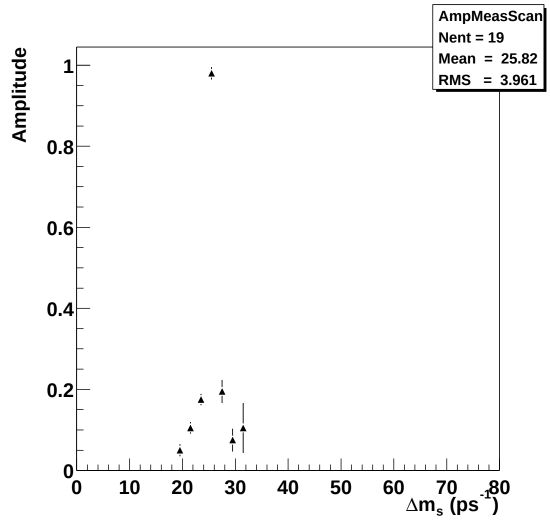

Figure 11: The amplitude factor A, as shown in figure 10, but with the assumption that the event selection efficiency is independent of the decay time. In this case all the fitted values for the amplitude are positive.

thus be determined for different values of Δm_s, when data is generated with a fixed value of Δm_s. Such a scan, where data is generated with Δm_s=25 ps^{-1}, is shown in figure 10. The error bars in the figure represent the statistical uncertainty on A (σ_A) from the likelihood maximization. As expected, A=1 is found for the Δm_s value of 25 ps^{-1}. The bins adjacent to that where the maximum is found show a negative amplitude. This is caused by the lower selection efficiency for small values of the decay time. Figure 6 shows that the statistically dominant region for the fit is indeed from 1 to 2 ps. A phase shift of π radians is therefore possible, resulting in a negative amplitude factor A. This effect is indeed absent when the selection efficiency is assumed to be independent of the decay time, as demonstrated in figure 11.

In order to obtain the sensitivity limit for Δm_s, data is generated with an 'infinite' value of Δm_s, in this case 400 ps^{-1}. For different values of Δm_s the amplitude A is determined from the likelihood maximization. The sensitivity limit for Δm_s is then defined as that value of Δm_s for which 5$\cdot\sigma_A$ equals the expected value of A=1. The result of 100 'experiments' for the sensitivity limit can be seen in figure 12. The $\sigma_A$values in the plot are the averages of the 100 uncertainties that are found for each value of Δm_s. The value of Δm_s where $5{\cdot}\sigma_A = 1$ is 68 ps^{-1}. If instead of $5{\cdot}\sigma_A = 1$ it is required that $1.645{\cdot}\sigma_A = 1$ (90% reliability interval) the limit is 100 ps^{-1}. The cases where the decay time resolution would be better or worse by 10% and 20% with respect to the full MC result are also shown.

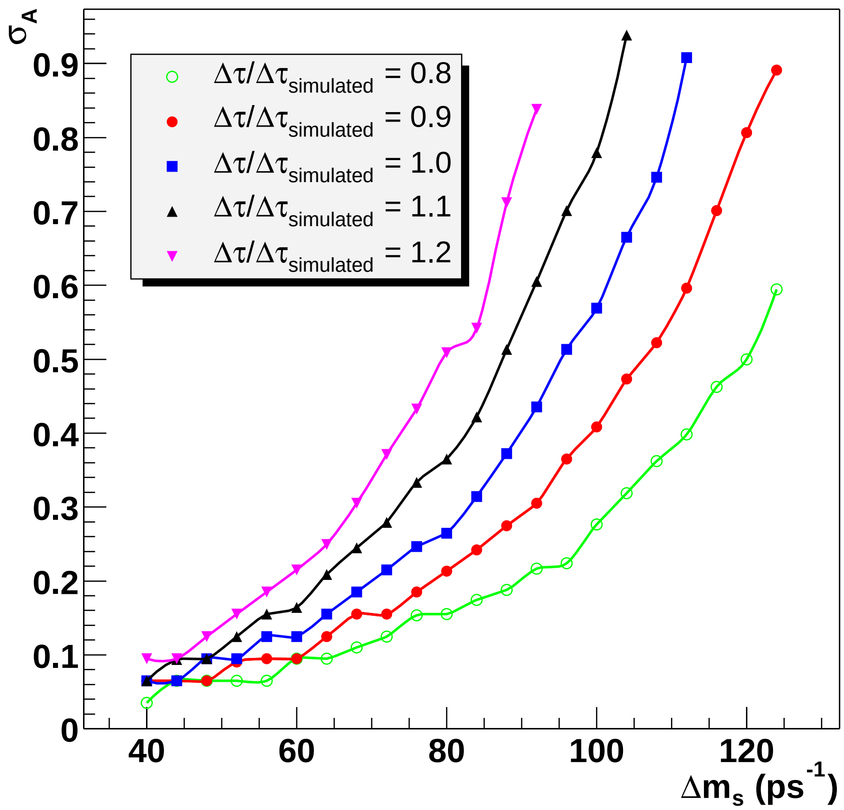

Figure 12: The uncertainty on the amplitude factor A as a function of Δm_s. For $5{\cdot}\sigma_A = 1$, Δm_s equals 68 ps^{-1}. Also shown are the cases where the decay time resolution would be better or worse by 10% and 20% with respect to the full MC result.

Table 3: Expected statistical uncertainty on $\gamma+\phi_s$ for one year of data. Unless otherwise specified, Δm_s=20 ps^{-1}, $\Delta\Gamma_s/\Gamma_s$=0.1, $\gamma+\phi_s$=65° and $\Delta_{T1/T2} = 0°$. All values are given in degrees, except Δm_s (ps^{-1}) and $\Delta\Gamma_s/\Gamma_s$.

Δm_s	15	20	25	30
$\sigma(\gamma+\phi_s)$	12.1	14.2	16.2	18.3

$\Delta\Gamma_s/\Gamma_s$	0	0.1	0.2
$\sigma(\gamma+\phi_s)$	14.7	14.2	12.9

$\gamma+\phi_s$	55	65	75	85	95	105
$\sigma(\gamma+\phi_s)$	14.5	14.2	15.0	15.0	15.1	15.2

$\Delta_{T1/T2}$	-20	-10	0	$+10$	$+20$
$\sigma(\gamma+\phi_s)$	13.9	14.1	14.2	14.5	14.6

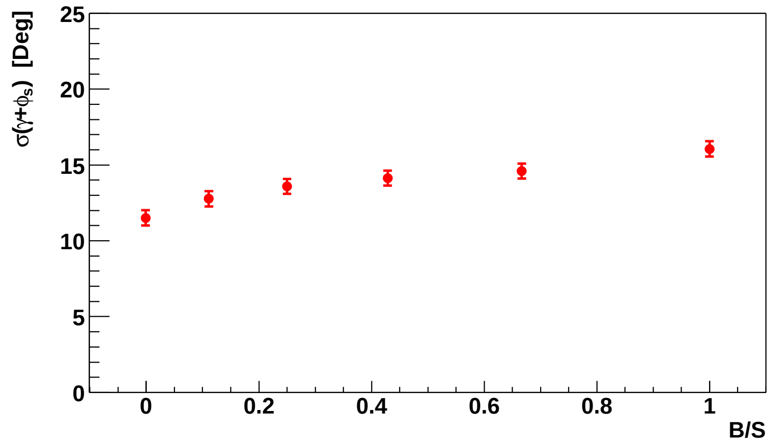

Figure 13: The uncertainty on $\gamma + \phi_s$ as a function of the B/S ratio. The data represents one year of LHCb data. For a B/S ratio that is equal to 0.5 the uncertainty on $\gamma + \phi_s$ is 14.2^0.

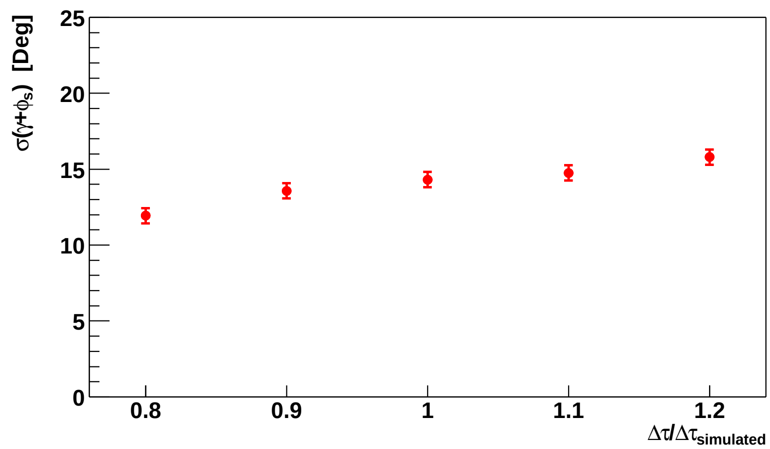

Figure 14: The uncertainty on $\gamma + \phi_s$ as a function of the decay time resolution. Shown are the sensitivities for the cases where the decay time resolution would be better and worse by 10% and 20%, with respect to the full MC result. The data represents one year of LHCb data.

The results of the likelihood maximization for the uncertainty on $\gamma + \phi_s$ for one year of $\mathrm{B_s^0} \to \mathrm{D_s^{\pm}K^{\pm}}$ data are given in table 3. For each setting of the physics parameters 100 experiments were performed and the average precision of these experiments is given in the table. The sensitivity for $\gamma + \phi_s$ was additionally studied as a function of the B/S ratio and the decay time resolution. These dependences are shown in figure 13 and figure 14.

As a cross-check the pull distributions $\frac{\arg(\lambda)_{true} - \arg(\lambda)_{fit}}{\sigma(\arg(\lambda))}$ and $\frac{\arg(\bar{\lambda})_{true} - \arg(\bar{\lambda})_{fit}}{\sigma(\arg(\bar{\lambda}))}$ are shown in figures 15 and 16.

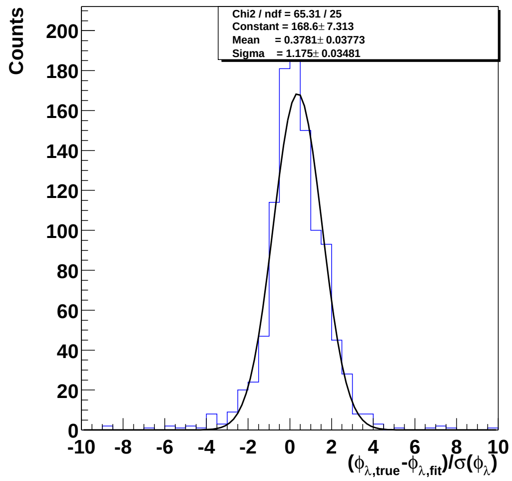

Figure 15: The pull of $\arg(\lambda) = \phi_\lambda$

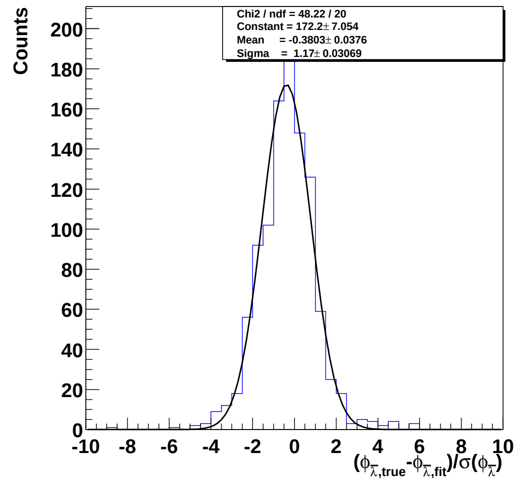

Figure 16: The pull of $\arg(\bar\lambda) = \phi_{\bar\lambda}$

4 Summary

The sensitivities for measuring Δm_s and $\gamma + \phi_s$ were evaluated by using as much as possible the full GEANT MC simulation of the LHCb detector. The uncertainty on Δm_s is very small, i.e. between 0.009 and 0.016 ps^{-1} for values of Δm_s ranging from 15 to 30 ps^{-1}. The highest value of Δm_s that can be measured is 68 ps^{-1}. The uncertainty for $\gamma + \phi_s$ is around 12 degrees for low values of Δm_s and increases to about 18 degrees for higher values of Δm_s.

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