

Prompt yield extraction

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Ω_c^0 lifetime measurement meeting

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News

Data and simulation

Strategy to extract prompt yields

Fit to MC samples of signal, normalization and control modes

Sanity checks

Fit to D^0 data

Ongoing tests

- The problem is caused by the EventType
- Use 26104880 in the end
- Committed and merged

■ 2016 data and simulation samples available for this analysis

Modes	Data	MC	
signal	$\Omega_c^0 \rightarrow pK^-K^-\pi^+$	Turbo	ReDecay $\tau = 250$ fs, 500 fs
normalization	$\Xi_c^0 \rightarrow pK^-K^-\pi^+$	Turbo	ReDecay
control	$\Omega_b^- \rightarrow \Omega_c^0(\rightarrow pK^-K^-\pi^+) \pi^-$	Stripping	Full Sim.
control	$\Omega_b^- \rightarrow \Omega_c^0(\rightarrow pK^-K^-\pi^+) \mu^- \bar{\nu}_\mu$	Stripping	Full Sim. $\tau = 250$ fs
control	$\Xi_b^- \rightarrow \Xi_c^0(\rightarrow pK^-K^-\pi^+) \mu^- \bar{\nu}_\mu$	Stripping	Full Sim.
control	$D^{*+} \rightarrow D^0(\rightarrow K^-K^+\pi^-\pi^+)\pi^+$	Turbo	ReDecay
control	$B^+ \rightarrow \bar{D}^0(\rightarrow K^+K^-\pi^+\pi^-)\pi^+$	Stripping	Full Sim.

Strategy to extract prompt yields

- Contamination from b -hadron decays is evident in large decay time bins
- Use $\log_{10}(\chi^2_{\text{IP}})$ as discriminating variable
- Model the prompt and secondary components with the Bukin function

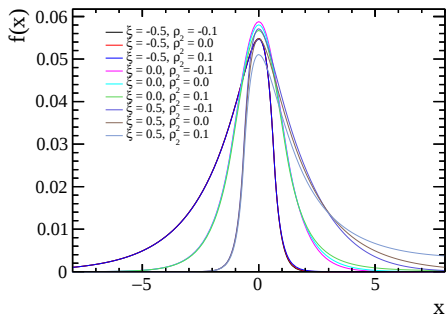
$$\mathcal{P}(x; \mu, \sigma, \xi, \rho_1, \rho_2) = \begin{cases} \exp \left\{ \frac{(x-x_1)\xi \sqrt{\xi^2+1} \sqrt{2 \ln 2}}{\sigma \left(\sqrt{\xi^2+1}-\xi \right)^2 \ln \left(\sqrt{\xi^2+1}+\xi \right)} + \rho_1 \left(\frac{x-x_1}{\mu-x_1} \right)^2 - \ln 2 \right\} & x \leq x_1, \\ \exp \left\{ - \left[\frac{\ln \left(1+2\xi \sqrt{\xi^2+1} \frac{x-\mu}{\sigma \sqrt{2 \ln 2}} \right)}{\ln \left(1+2\xi^2-2\xi \sqrt{\xi^2+1} \right)} \right]^2 \times \ln 2 \right\} & x_1 < x < x_2, \\ \exp \left\{ \frac{(x-x_2)\xi \sqrt{\xi^2+1} \sqrt{2 \ln 2}}{\sigma \left(\sqrt{\xi^2+1}-\xi \right)^2 \ln \left(\sqrt{\xi^2+1}+\xi \right)} + \rho_2 \left(\frac{x-x_2}{\mu-x_2} \right)^2 - \ln 2 \right\} & x \geq x_2. \end{cases}$$

where

$$x_1 = \mu + \sigma \sqrt{2 \ln 2} \left(\frac{\xi}{\sqrt{\xi^2+1}} - 1 \right)$$

Illustration of the Bukin functions

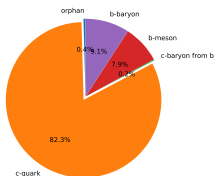
- Bukin functions with various asymmetry and tail parameters with $\mu = 0, \sigma = 1, \rho_1 = 0$



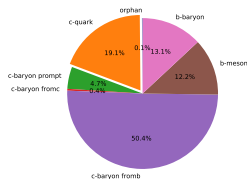
Prompt and secondary MC samples

- Prompt and secondary MC samples of Ω_c^0 , Ξ_c^0 and D^0 : acquired by apply MC_MOTHER_ID requirements to inclusive MC samples
- Components after all selections

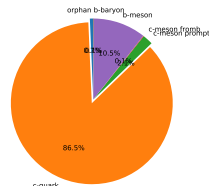
Components	orphan	c-quark	c-meson	c-baryon	b-meson	b-baryon
abs (MC_MOTHER_ID)	0	4	(400,500)	(4000,5000)	(500,600)	(5000,6000)



Ω_c^0



Ξ_c^0



D^0

- Validation needed with b -decay MC samples

The definition of the decay time

- Decay time t is defined as

$$t \equiv \frac{\vec{p} \cdot \vec{r}}{p^2} \times m$$

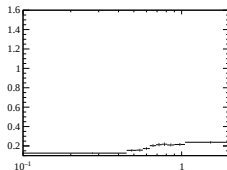
where $\vec{p}$ is the momentum vector, $\vec{r}$ the vector pointing from PV to decay vertex, and m the invariant mass of the charm hadron

Fit with all parameters free in all decay time bins

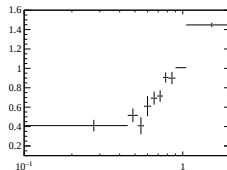
- All fits converge with accurate error matrix
- μ : dependent on t with clear pattern for prompt and secondary
- σ : vary with t for prompt and secondary
- ξ : vary with t for prompt and secondary
- ρ_1, ρ_2 : vary with t for prompt and secondary

Fit results in decay-time bins: μ

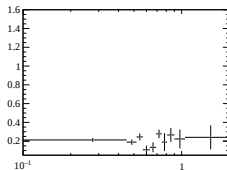
Prompt
 Ω_c^0



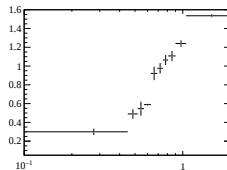
Secondary
 Ω_c^0



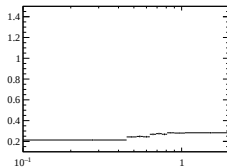
Prompt
 Ξ_c^0



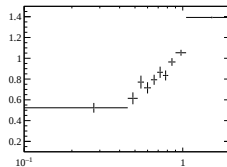
Secondary
 Ξ_c^0



Prompt
 D^0

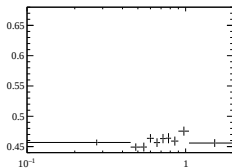


Secondary
 D^0

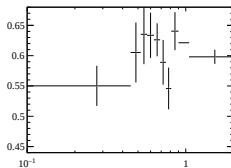


Fit results in decay-time bins: σ

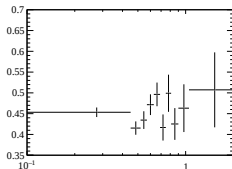
Prompt
 Ω_c^0



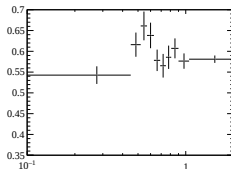
Secondary
 Ω_c^0



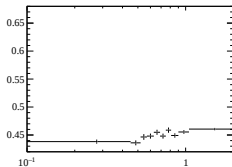
Prompt
 Ξ_c^0



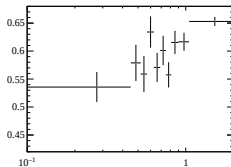
Secondary
 Ξ_c^0



Prompt
 D^0

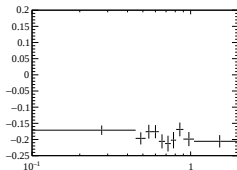


Secondary
 D^0

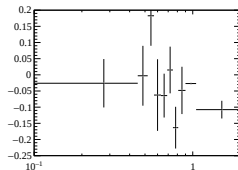


Fit results in decay-time bins: ξ

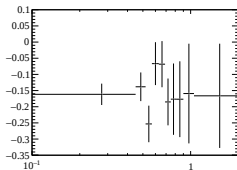
Prompt
 Ω_c^0



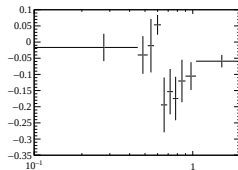
Secondary
 Ω_c^0



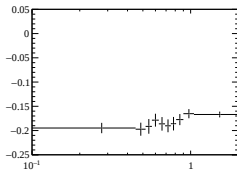
Prompt
 Ξ_c^0



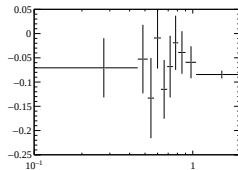
Secondary
 Ξ_c^0



Prompt
 D^0

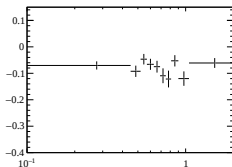


Secondary
 D^0

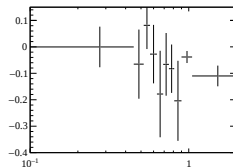


Fit results in decay-time bins: ρ_1

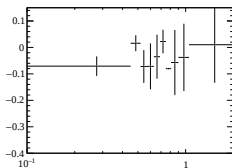
Prompt
 Ω_c^0



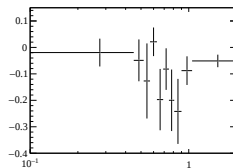
Secondary
 Ω_c^0



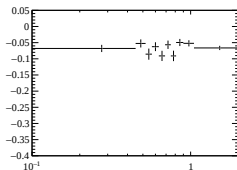
Prompt
 Ξ_c^0



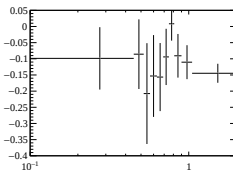
Secondary
 Ξ_c^0



Prompt
 D^0

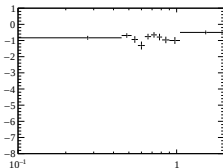


Secondary
 D^0

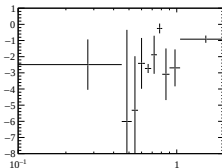


Fit results in decay-time bins: ρ_2

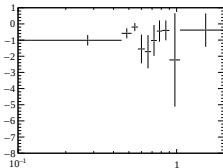
Prompt
 Ω_c^0



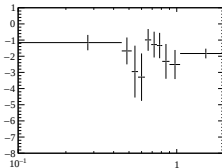
Secondary
 Ω_c^0



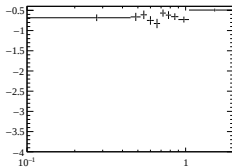
Prompt
 Ξ_c^0



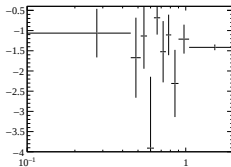
Secondary
 Ξ_c^0



Prompt
 D^0



Secondary
 D^0

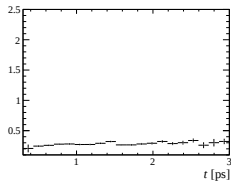


Fit D^0 MC in even decay time bins

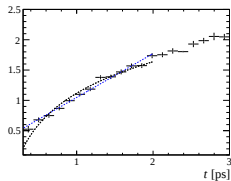
- Fit with all parameters free in equally-sized 20 decay time bins between 0.3 ps and 3 ps

D^0 results in even decay-time bins: μ

Prompt
 D^0

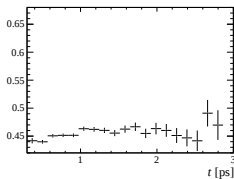


Secondary
 D^0

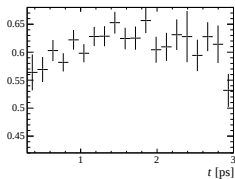


D^0 results in even decay-time bins: σ

Prompt
 D^0

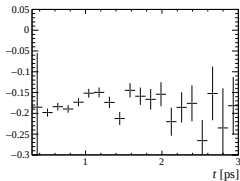


Secondary
 D^0

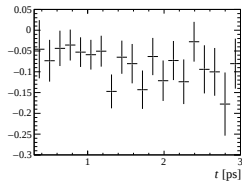


D^0 results in even decay-time bins: ξ

Prompt
 D^0

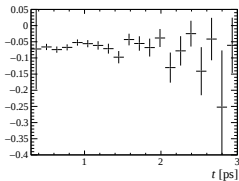


Secondary
 D^0

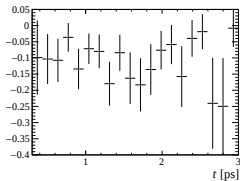


D^0 results in even decay-time bins: ρ_1

Prompt
 D^0

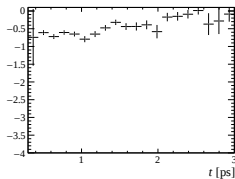


Secondary
 D^0

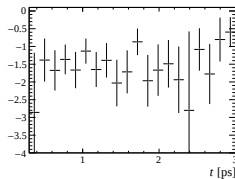


D^0 results in even decay-time bins: ρ_2

Prompt
 D^0



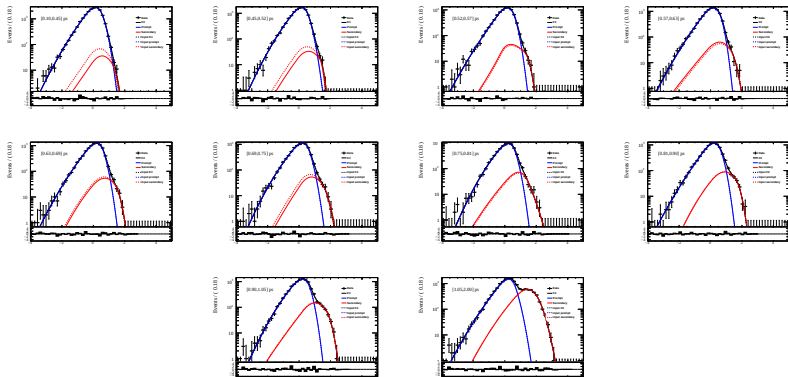
Secondary
 D^0



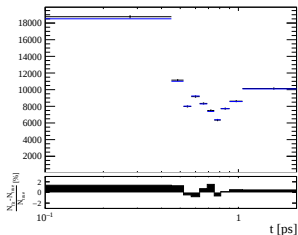
Sanity check: fit combined MC samples

- Check whether the fit can re-produce the input prompt fraction with MC samples
- Fit the combined (prompt+secondary) MC with free μ_{prompt} and $\mu_{\text{secondary}}$, while fixing other parameters to values of separate fits

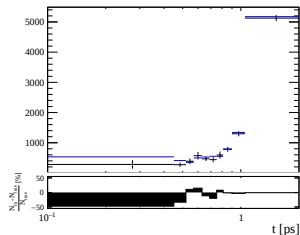
Fit results of combined MC samples: Ω_c^0



Comparison of input and extracted yield: Ω_c^0



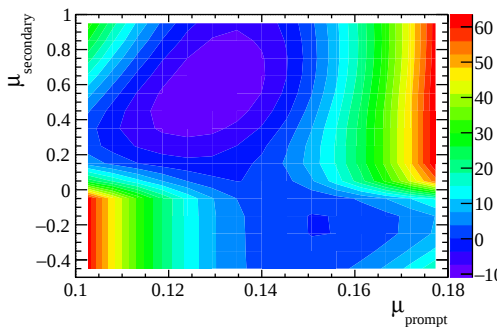
Prompt



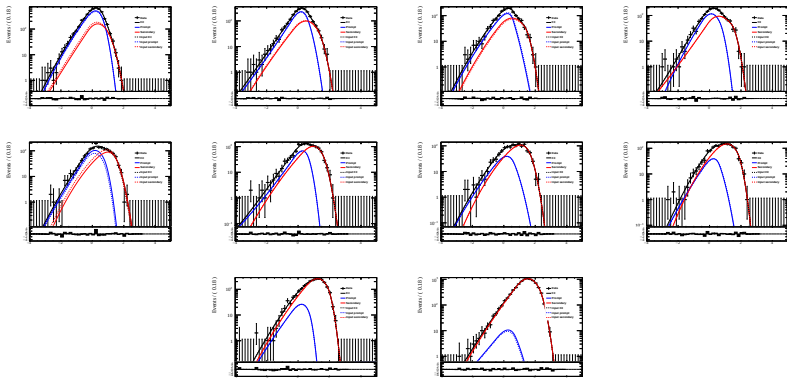
Secondary

Likelihood scan of μ_{prompt} and $\mu_{\text{secondary}}$

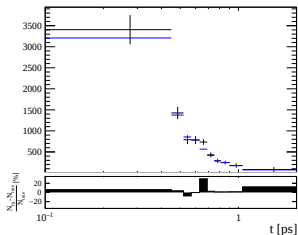
■ Ω_c^0 bin 0



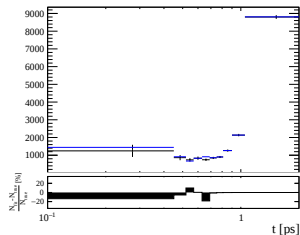
Fit results of combined MC samples: Ξ_c^0



Comparison of input and extracted yield: Ξ_c^0



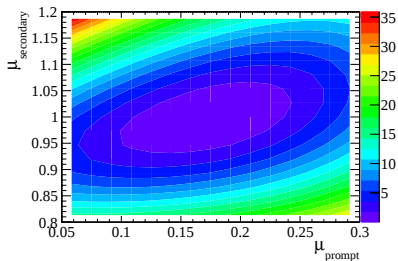
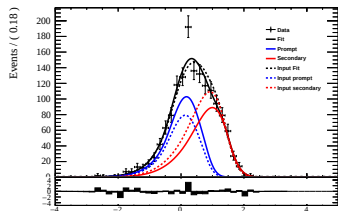
Prompt



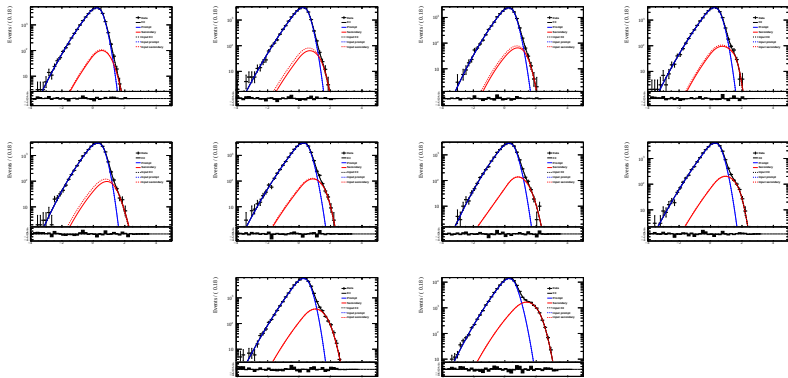
Secondary

Likelihood scan of μ_{prompt} and $\mu_{\text{secondary}}$

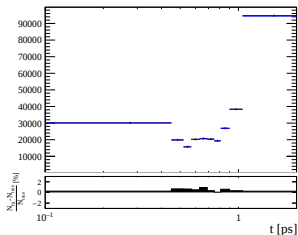
■ Ξ_c^0 bin 4



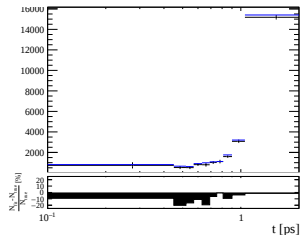
Fit results of combined MC samples: D^0



Comparison of input and extracted yield: D^0



Prompt

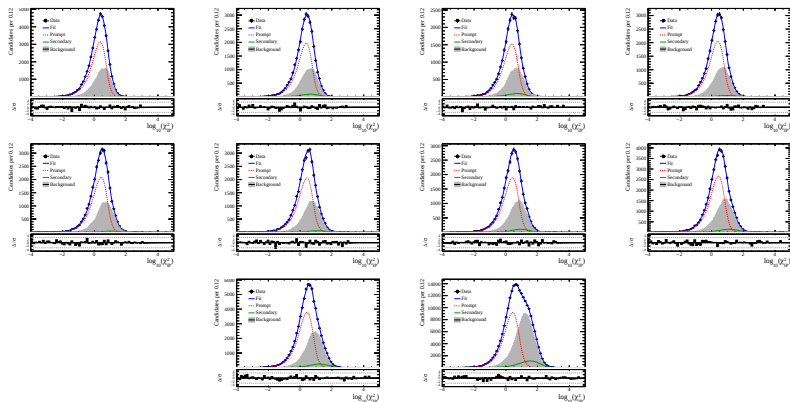


Secondary

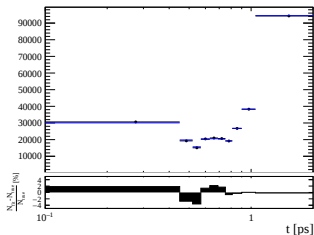
Sanity check: fit background-injected combined MC

- Check whether the fit can re-produce the input prompt fraction
- Fit the combination of prompt MC, secondary MC and background from data
 - Background sample is generated from the RooKeysPdf of mass-sideband data
 - Background sample size is determined from the signal/background ratio in data
 - logIPCHI2 of MC sample is shifted by 0.15 to match the data
- Fit configuration
 - μ_{prompt} and $\mu_{\text{secondary}}$ free to float
 - Other parameters fixed to separately-fit results
 - Number of background fixed to the input value

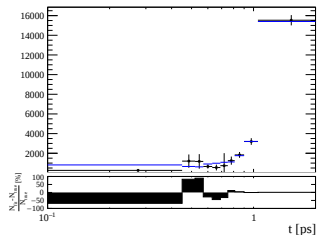
Fit results of background-injected combined MC



Comparison of input and extracted yield: D^0



Prompt



Secondary

Fit to $D^{*+} \rightarrow \pi^+ D^0 (\rightarrow K^- K^+ \pi^- \pi^+)$ data

■ Mass fit

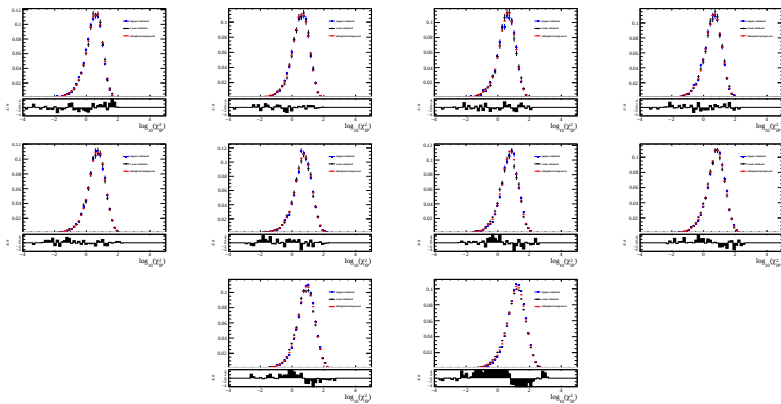
- In $1865 \pm 45 \text{ MeV}/c^2$ mass region
- Gaussian + 2nd-order Chebychev

■ IPCHI2 fit

- In $1865 \pm 2.5 \times 5.65 \text{ MeV}/c^2$ signal region
- Prompt and secondary signal components: μ_{prompt} and $\mu_{\text{secondary}}$ free and other parameters fixed to MC
- Background: kernel estimation with mass-sideband data
Lower sideband: $[1820, 1830] \text{ MeV}/c^2$
Upper sideband: $[1900, 1910] \text{ MeV}/c^2$
- The total number of backgrounds fixed to values from mass fit
- Binning scheme: the same as the signal mode

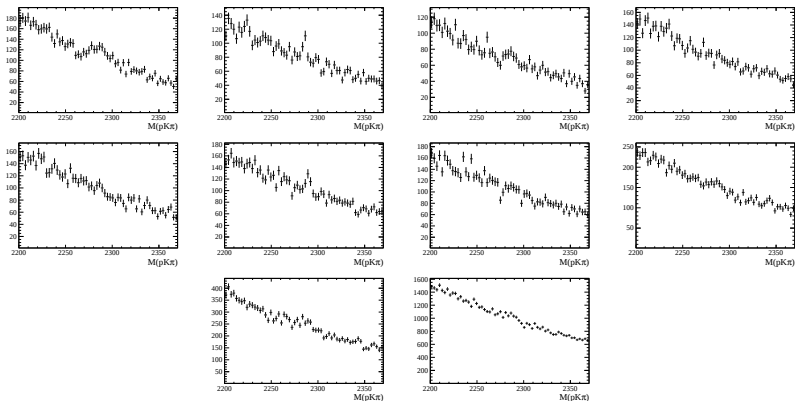
Comparison of background logIPCHI2

- MC cannot provide a large combinatorial background sample
- Real data is necessary for background studies



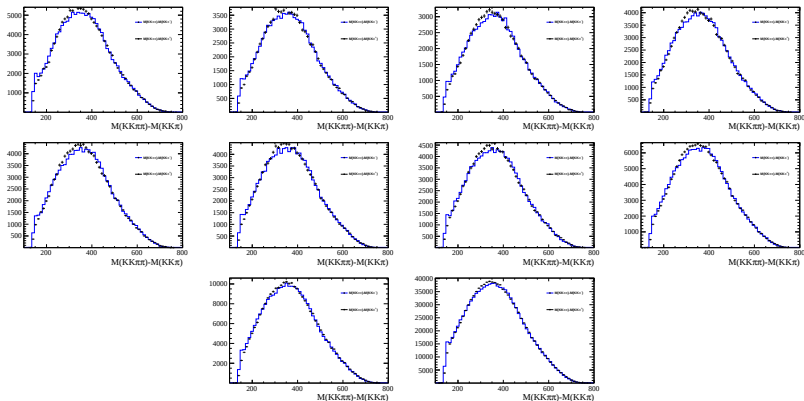
Physics backgrounds in $D^{*+} \rightarrow \pi^+ D^0 (\rightarrow K^- K^+ \pi^- \pi^+)$

- Λ_c^+ background: p mis-identified as K^-
- Suppressed by tight PID cuts



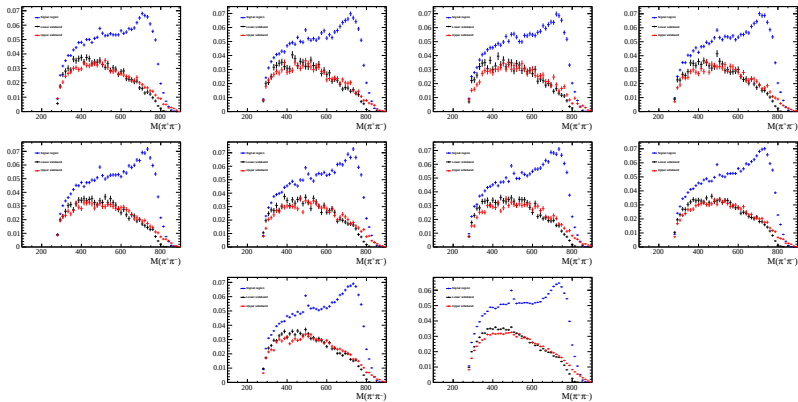
Physics backgrounds in $D^{*+} \rightarrow \pi^+ D^0 (\rightarrow K^- K^+ \pi^- \pi^+)$

- π swap: $D^{*+} \rightarrow \pi^+ D^0 (\rightarrow K^- K^+ \pi^- \pi^+)$
- Not significant due to tight χ^2_{IP} cuts

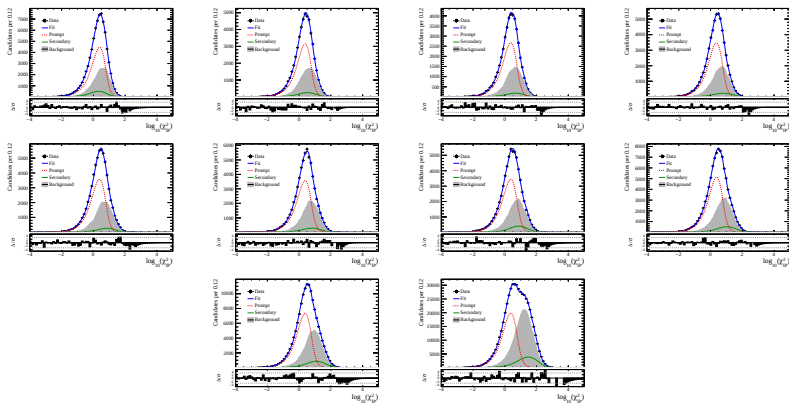


Physics backgrounds in $D^{*+} \rightarrow \pi^+ D^0 (\rightarrow K^- K^+ \pi^- \pi^+)$

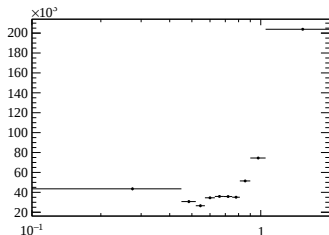
- K_S^0 background: $D^0 \rightarrow K^- K^+ K_S^0 (\rightarrow \pi^+ \pi^-)$
- Exist but not significant in the signal region



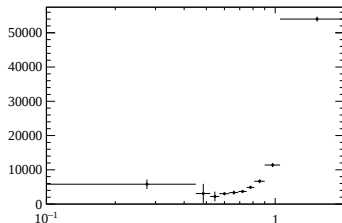
Fit results of D^0 data



Fit results of yields

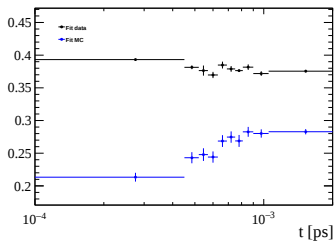


Prompt

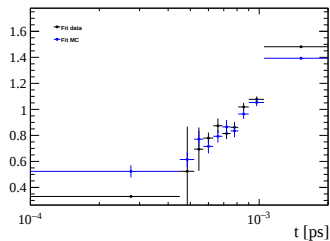


Secondary

Fit results of μ

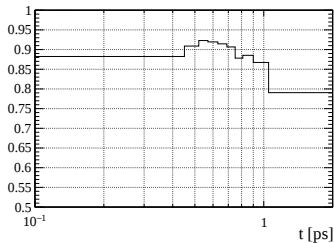


Prompt

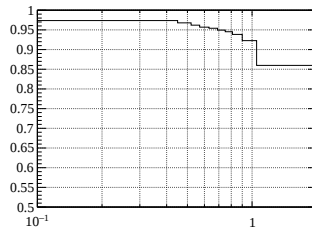


Secondary

Comparison of data and MC: prompt fraction

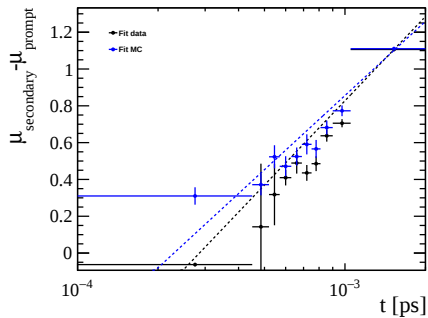


Data

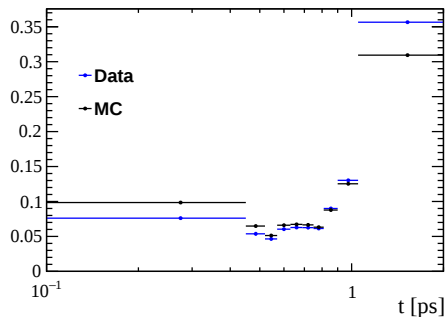


MC

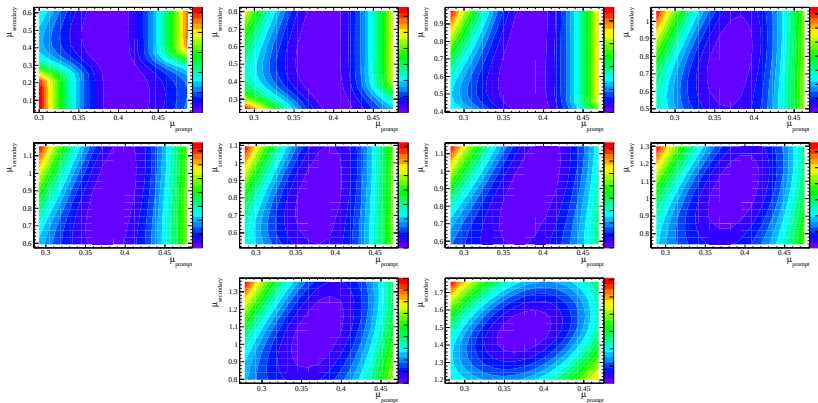
Comparison of data and MC: $\mu_{\text{prompt}} - \mu_{\text{secondary}}$



Comparison of data and MC: prompt yield

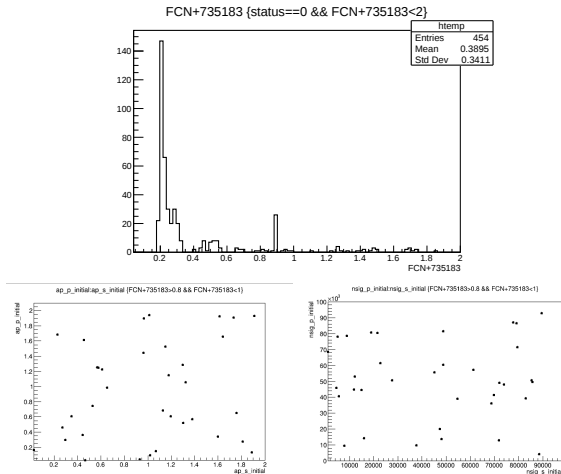


Likelihood scan of μ_{prompt} and $\mu_{\text{secondary}}$



Effect of initial values

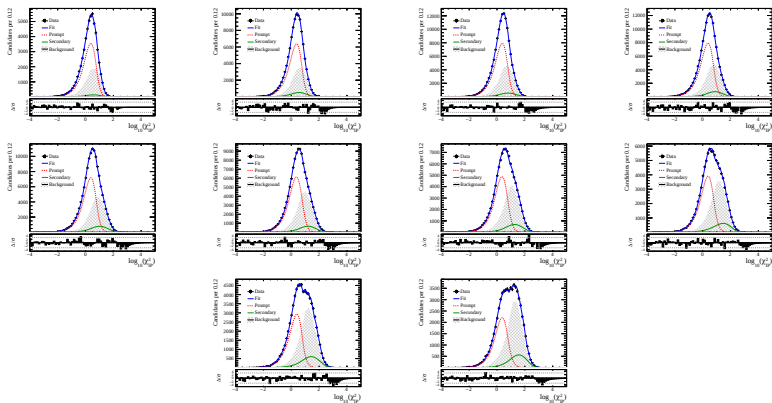
- Repeat the fit (bin 0) with random initial values in parameter space (μ_{prompt} , $\mu_{\text{secondary}}$, N_{prompt} , $N_{\text{secondary}}$)



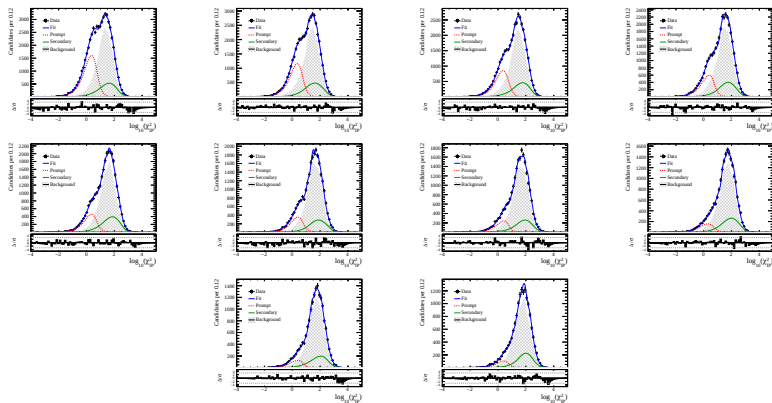
Fit D^0 data in even decay time bins

- Study the effect of unequal binning scheme
- Fit data in equally-sized 20 decay time bins between 0.3 ps and 3 ps

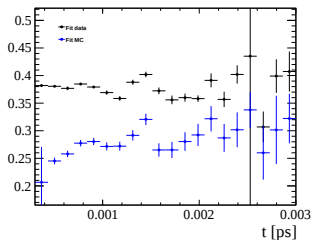
Fit results of D^0 data in even bins: bin 0-9



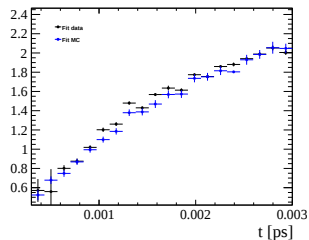
Fit results of D^0 data in even bins: 10-19



Fit results of μ in even bins

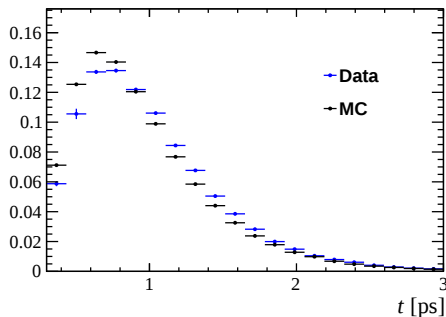


Prompt



Secondary

Comparison of prompt yield in even decay-time bins

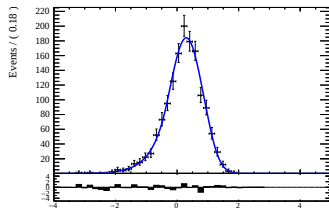
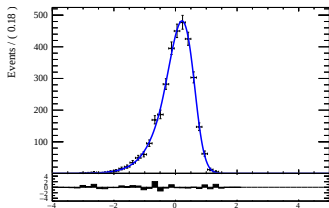
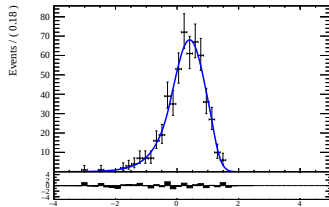
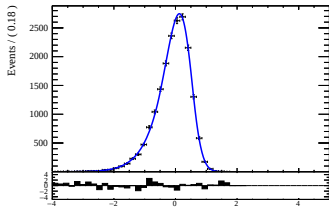


- D^0 decay time fit

BACKUP

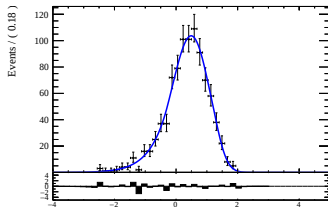
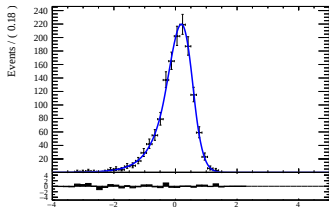
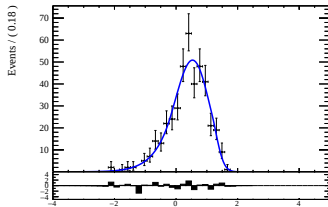
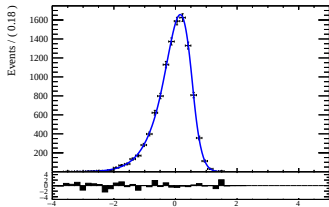
Fit with all parameters free: bin 0

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



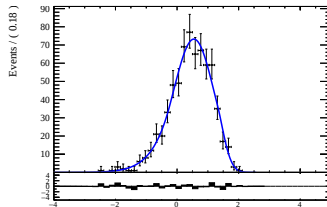
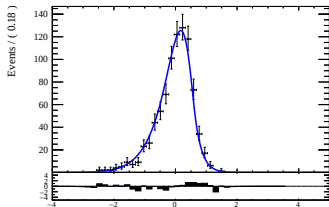
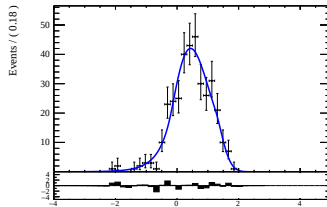
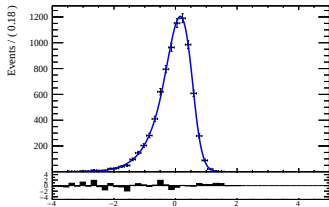
Fit with all parameters free: bin 1

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



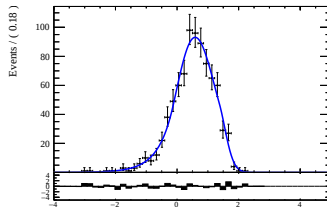
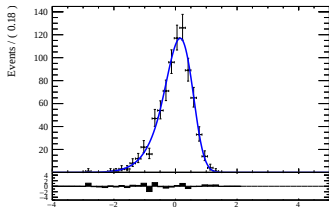
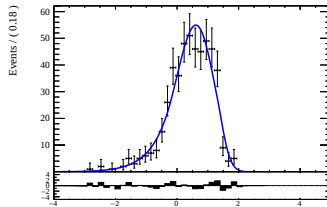
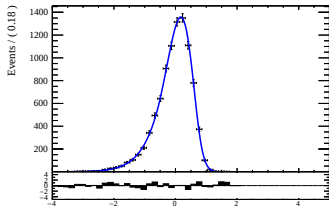
Fit with all parameters free: bin 2

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



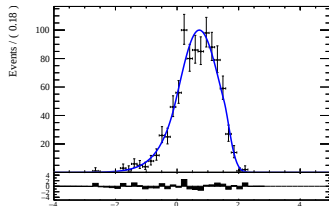
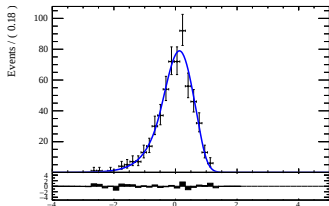
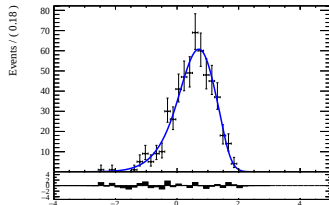
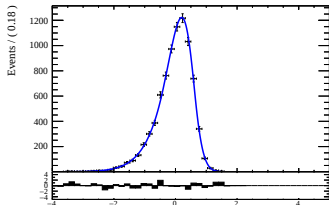
Fit with all parameters free: bin 3

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



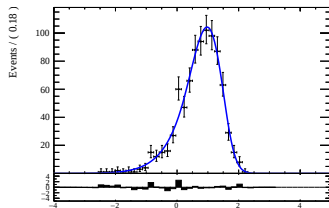
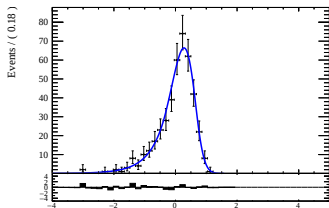
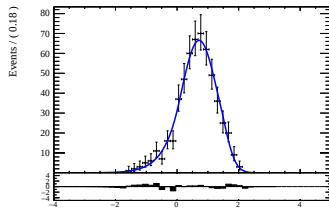
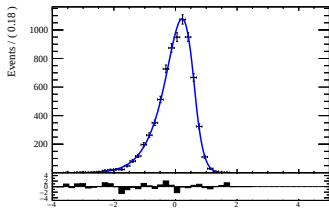
Fit with all parameters free: bin 4

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



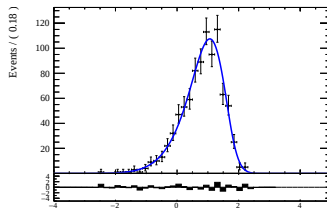
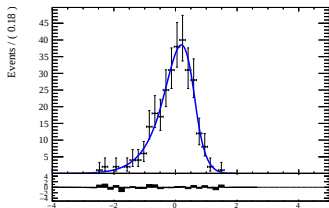
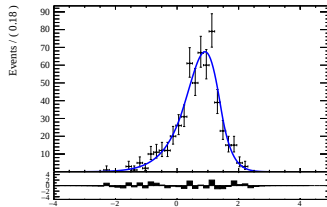
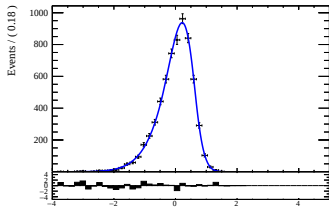
Fit with all parameters free: bin 5

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



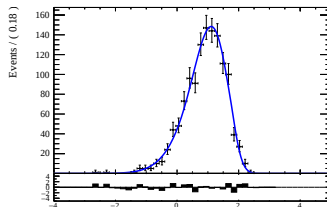
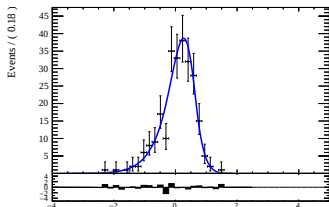
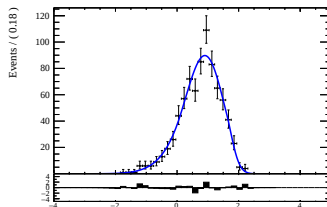
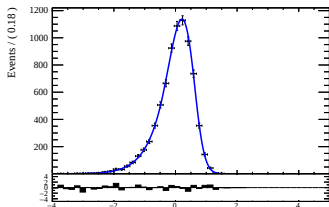
Fit with all parameters free: bin 6

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



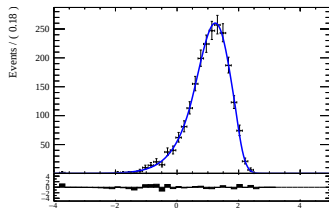
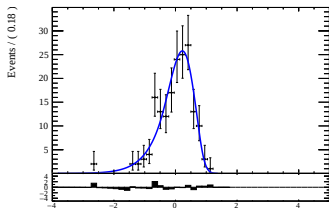
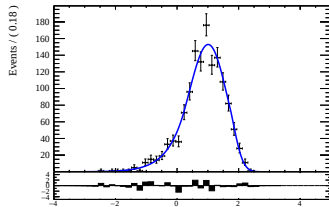
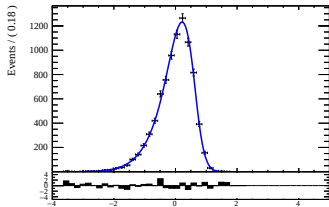
Fit with all parameters free: bin 7

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



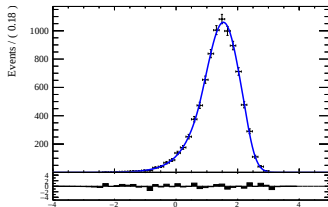
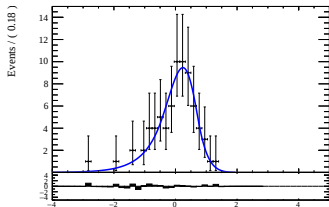
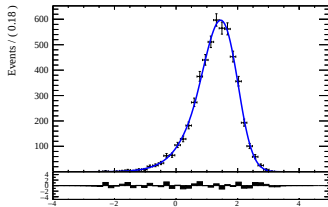
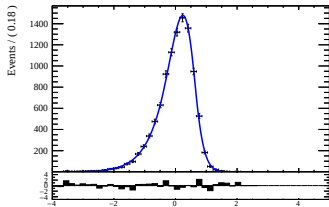
Fit with all parameters free: bin 8

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



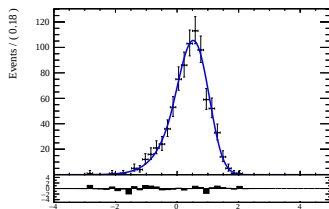
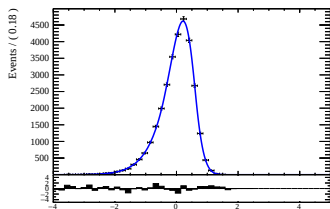
Fit with all parameters free: bin 9

- (left) Prompt and (right) secondary for (top) Ω_c^0 and (bottom) Ξ_c^0



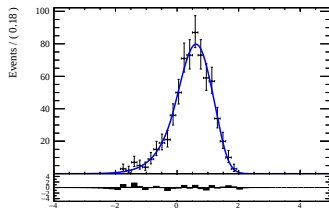
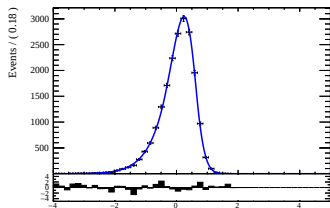
Fit D^0 MC with all parameters free: bin 0

- (left) Prompt and (right) secondary



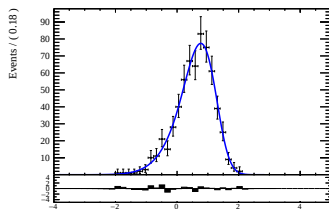
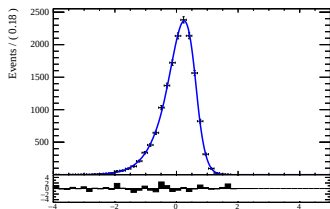
Fit D^0 MC with all parameters free: bin 1

- (left) Prompt and (right) secondary



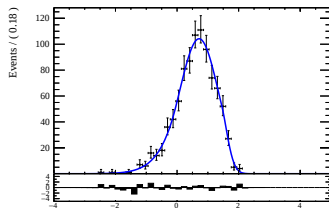
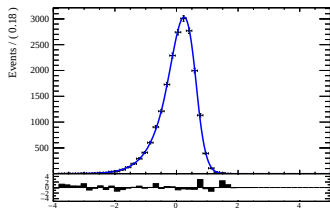
Fit D^0 MC with all parameters free: bin 2

- (left) Prompt and (right) secondary



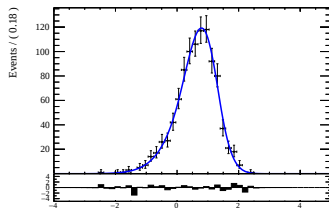
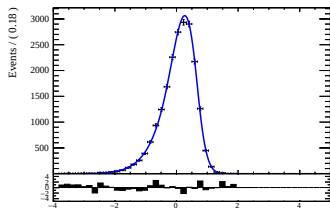
Fit D^0 MC with all parameters free: bin 3

- (left) Prompt and (right) secondary



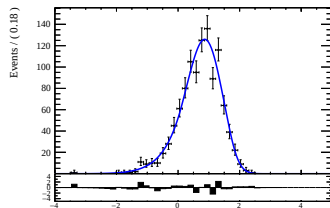
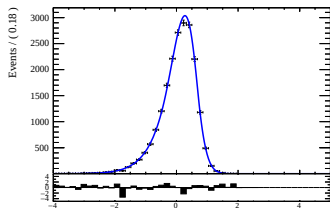
Fit D^0 MC with all parameters free: bin 4

- (left) Prompt and (right) secondary



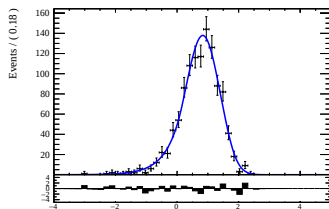
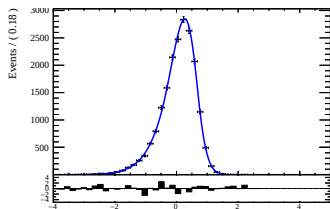
Fit D^0 MC with all parameters free: bin 5

- (left) Prompt and (right) secondary



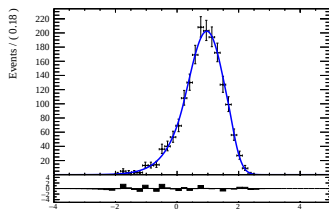
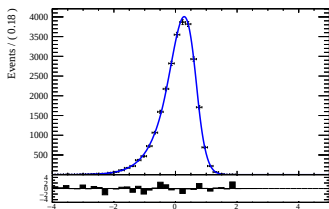
Fit D^0 MC with all parameters free: bin 6

- (left) Prompt and (right) secondary



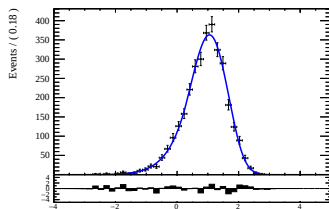
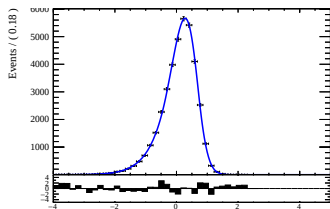
Fit D^0 MC with all parameters free: bin 7

- (left) Prompt and (right) secondary



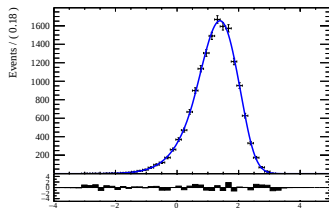
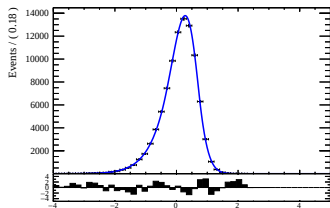
Fit D^0 MC with all parameters free: bin 8

- (left) Prompt and (right) secondary

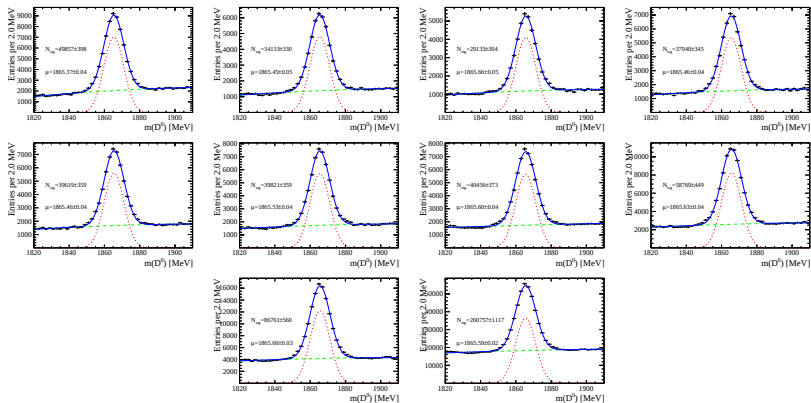


Fit D^0 MC with all parameters free: bin 9

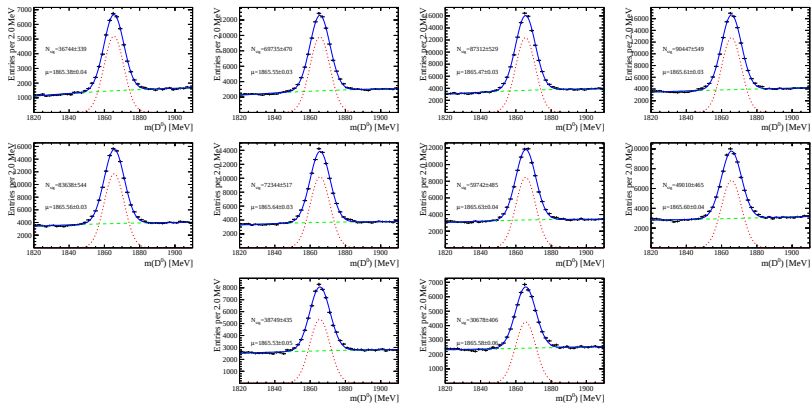
- (left) Prompt and (right) secondary



Fit mass of D^0 data



Fit mass of D^0 data in even bins: bin 0-9



Fit mass of D^0 data in even bins: bin 10-19

