Update of Ω_c^0 lifetime measurement

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Ω_c^0 lifetime measurement meeting

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Outline

- Study of $D^{*+} \to D^0(\to K^-K^+\pi^-\pi^+)\pi^+$ control mode
  - Event selection
    - Turbo selection
    - Pre-selection
    - BDT
  - Prompt yield extraction
    - Mass fit
    - $\log\chi^2_{IP}$ modelling
    - Fit to MC sample
    - Fit to data
    - $\log\chi^2_{IP}$ in decay time bins
- MC request

Samples of $D^{*+} \to D^0(\to K^-K^+\pi^-\pi^+)\pi^+$ mode

- Data sample
  - 2016 Collision data collected by `Hlt2CharmHadDstp2D0Pip_D02KmKpPimPipTurbo`
- 2016 MC sample
  - EventType: 27165003
  - Identify prompt contribution with D^{*+} MOTHER ID

Turbo selection

DaughtersCuts	`TRCHI2DOF < 3.0`
	`PT > 250.0`
	`P > 1000.0`
	`MIPCHI2DV(PRIMARY) > 3.0`

K	`PIDK > 5`
π	`PIDK < 5`

CombinationCuts	`(APT1+APT2+APT3+APT4) > 1800.0`
	`AP > 25000.0`
	`ADOCA(i,4) < 100.0, i=1,2,3`
	`ACHI2DOCA(i,4) < 10.0, i=1,2,3`

MotherCuts	`CHI2VXNDOF < 12.0`
	`PT > 2000.0`
	`P  > 30000.0`
	`BPVDIRA > cos( 0.02 )`
	`BPVLTIME() > 0.0001`
	`BPVVDCHI2 > 25`

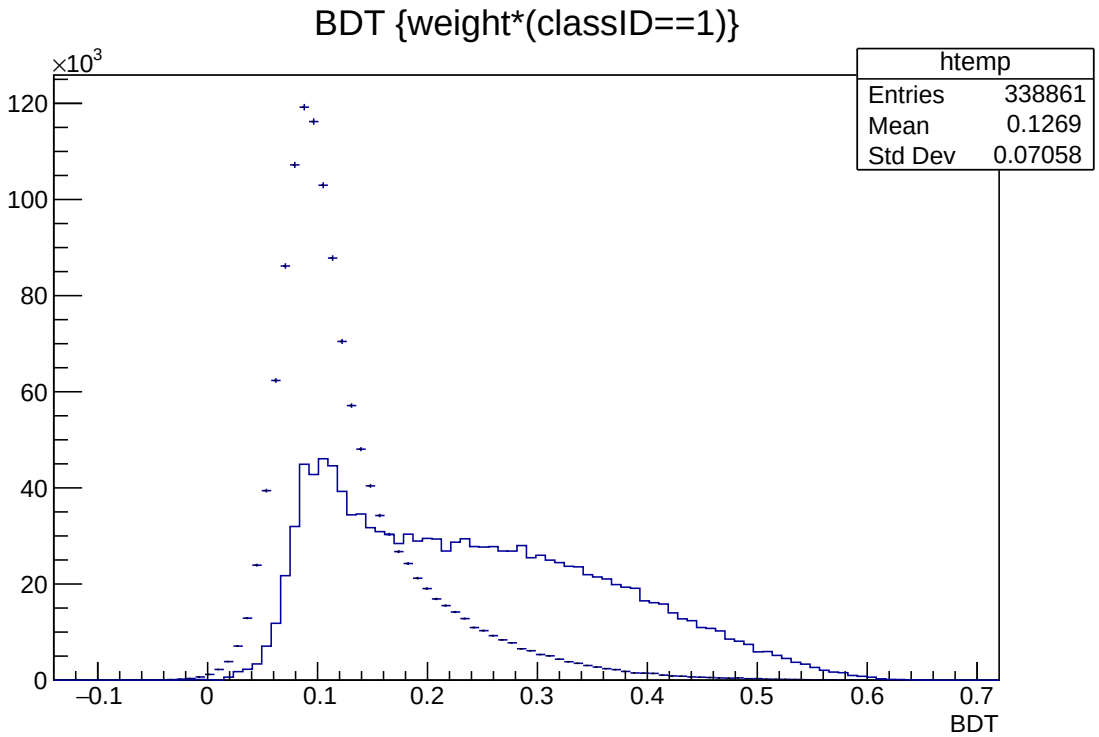
Pre-selections

- Additional PT cuts due to generator-level cuts in MC sample
- Further PID cuts to be consistent to signal channel

Variable	Cuts
D0_PT	> 2900 MeV
Daughters' PT	> 300 MeV
Daughters' P	2900 MeV
K PIDK	> 10
π PIDK	< 0

BDT with sWeighted data sample as signal

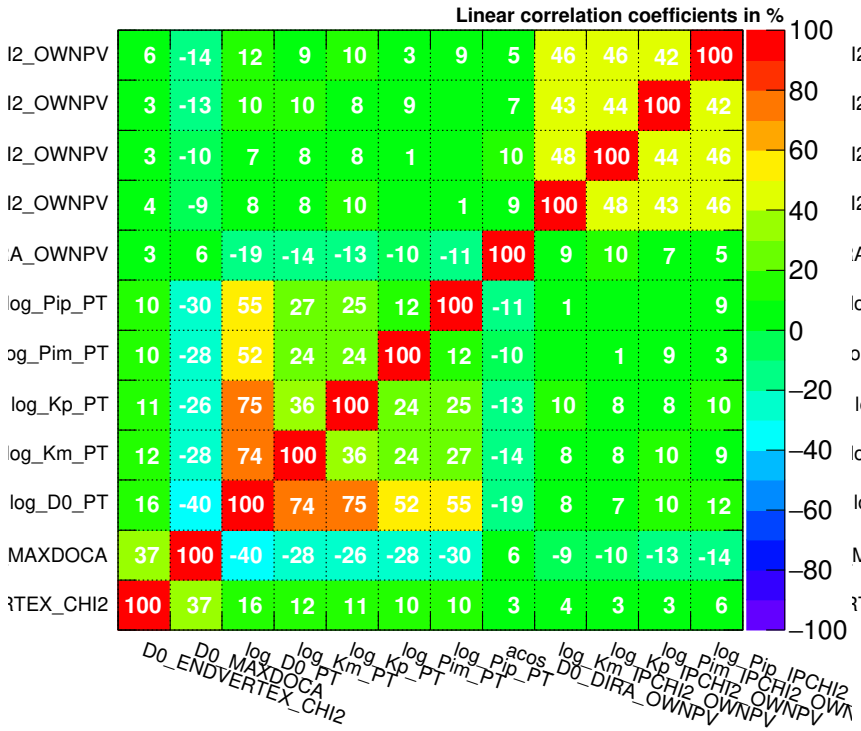
- Try to train with sWeighted data sample as signal and sideband data sample as background
- Similar training variables as signal mode: Vertex quality, PT, IPCHI2, ProbNNx
- Stange response distributions (need to be understood)



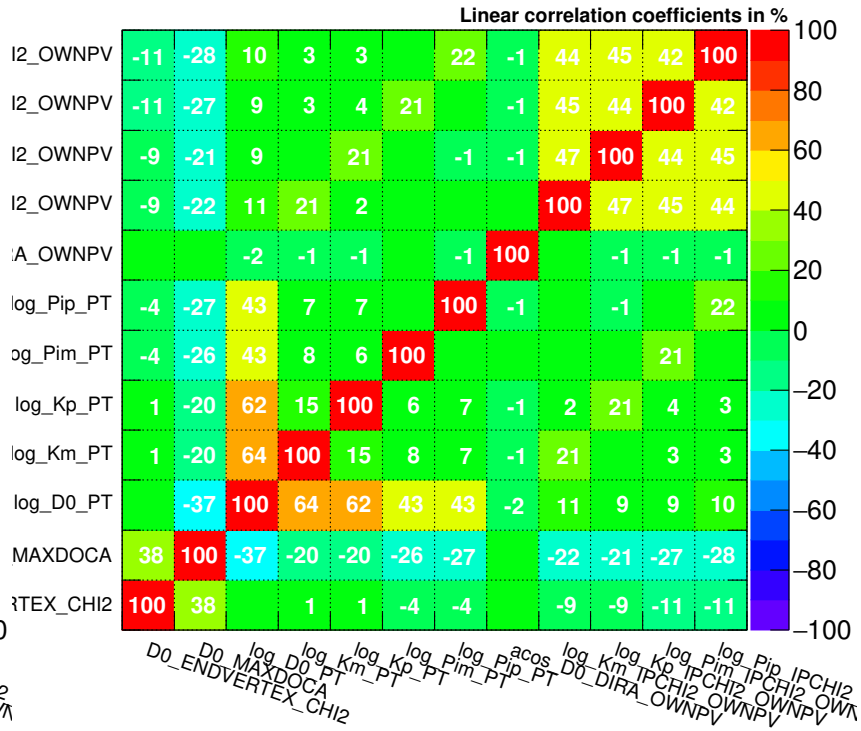
BDT with MC sample as signal

- Try to train with MC sample as signal and sideband data sample as background
- Similar training variables as signal mode: Vertex quality, PT, IPCHI2 (not include PID variables)
- Correlation matrices below

Correlation Matrix (signal)

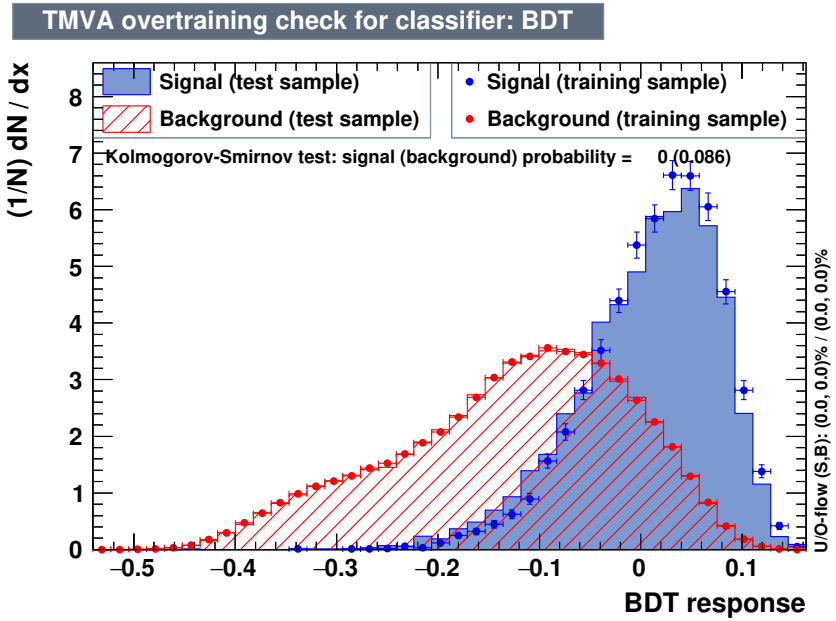


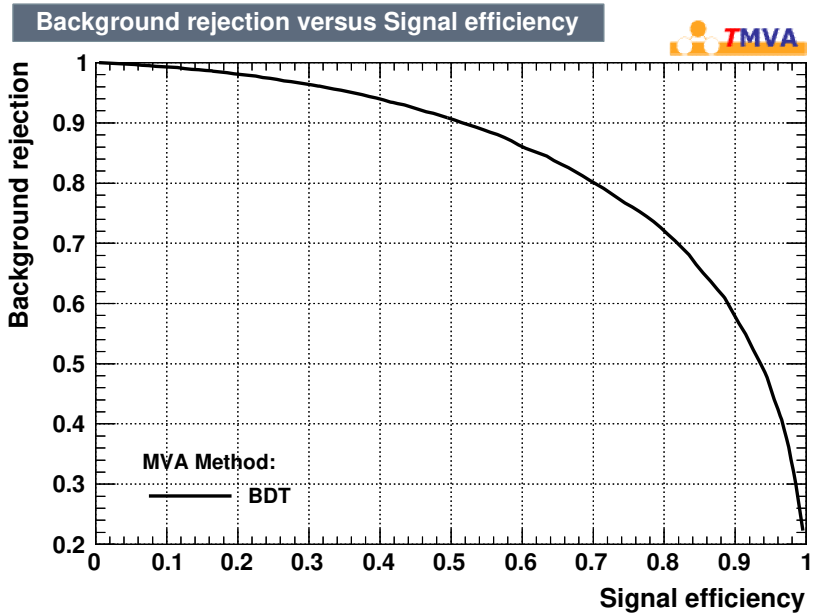
Correlation Matrix (background)



BDT performance

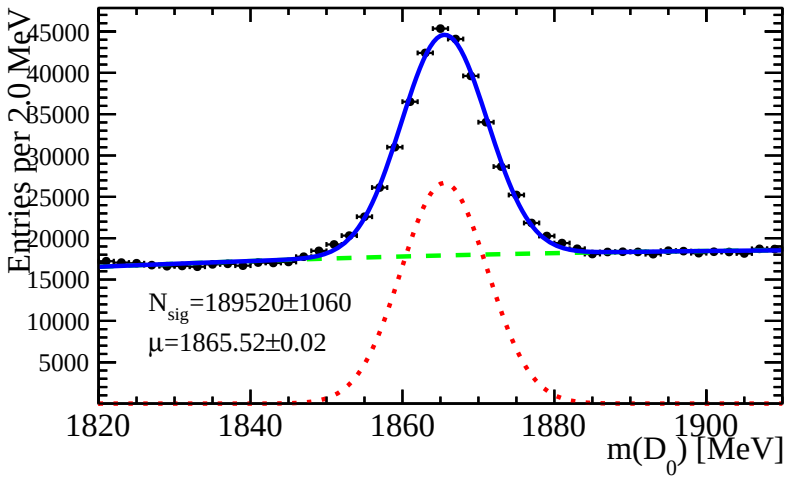
- BDT response (left) and ROC curve (right)
- Choose BDT> -0.1 to get high signal efficiency and improved signal/background ratio





Mass fit

- Define diffrent mass regions in the mass spectrum
  - Sideband: $[1820, 1830] \cup [1910, 1920]$
  - SignalWindow: $[1865 - 2.5 \times \sigma, 1865 + 2.5 \times \sigma]$
- Fit to the D0_M of data sample that passed all selctions
- For background: SignalWindow/Sideband $= 1.439$
- For signal: SignalWindow/TotalRegion $= 0.987$



$\log \chi^2_{IP}$ modelling

- Bukin function, a modified Novosibirsk function with extended tail parameters

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

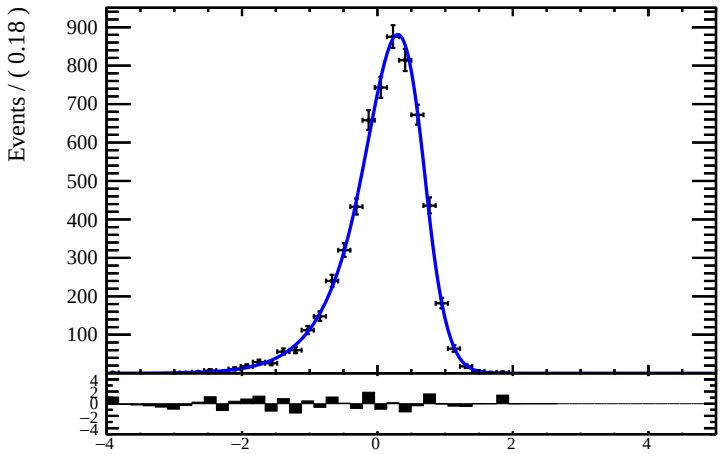
where

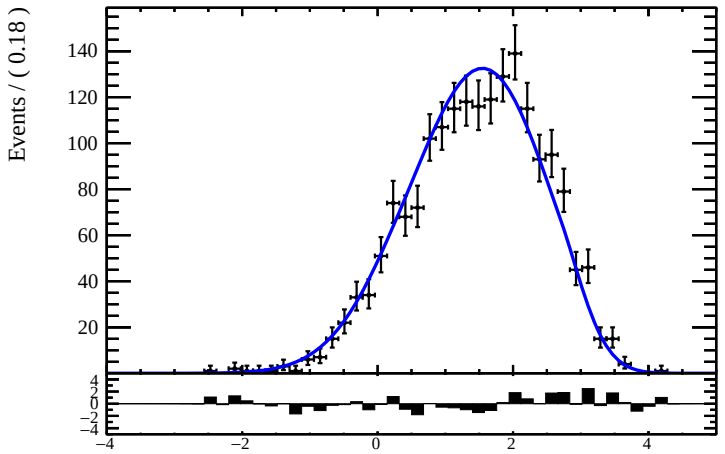
$$x_1 = \mu + \sigma\sqrt{2\ln 2}\left(\frac{\xi}{\sqrt{\xi^2+1}} - 1\right)$$

$$x_2 = \mu + \sigma\sqrt{2\ln 2}\left(\frac{\xi}{\sqrt{\xi^2+1}} + 1\right)$$

Fit to IPCHI2 of MC sample

- Fit with all parameters free
- Prompt component (left) and secondary component (right)

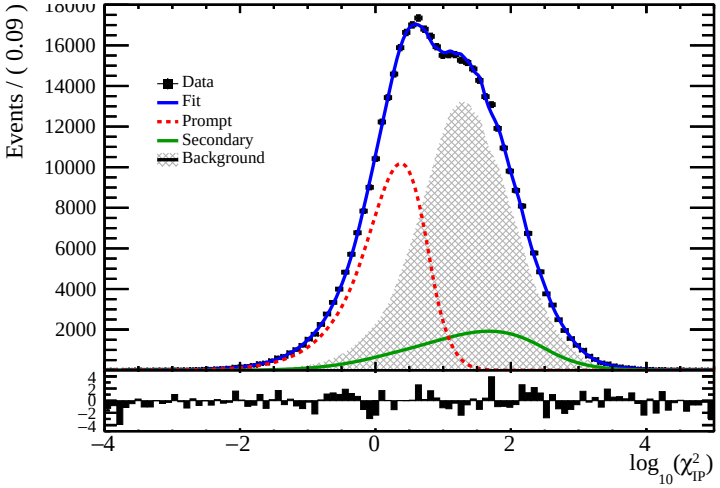


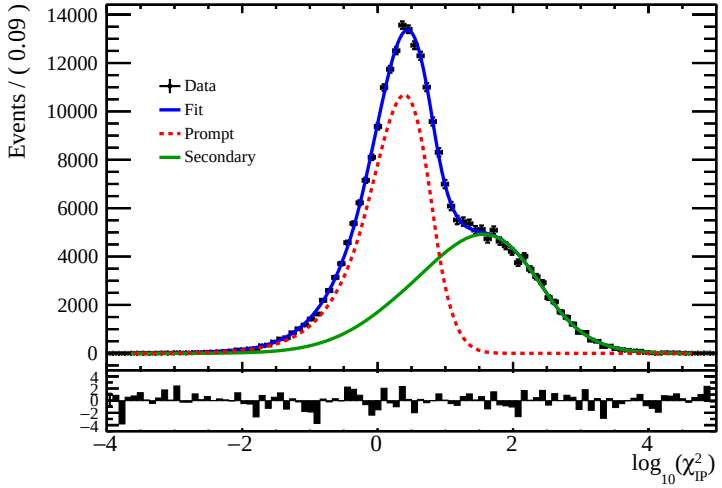


Fit to IPCHI2 of data sample

- Approach 1: Fit to sWeighted data
  - Fixed parameters: prompt shape parameters
- Approach 2: Fit to data in the SignalWindow
  - Fixed parameters: prompt shape parameters
  - Fix background contribution with shape of sideband data and number of backgrounds normalized to SignalWindow

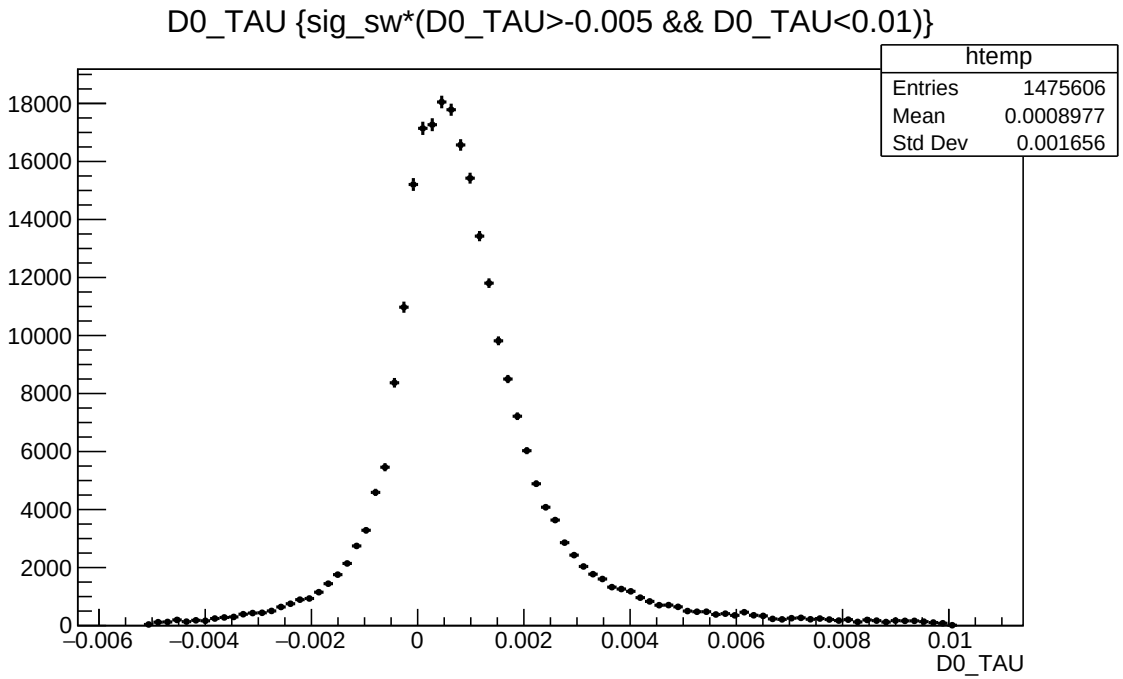
Fit results





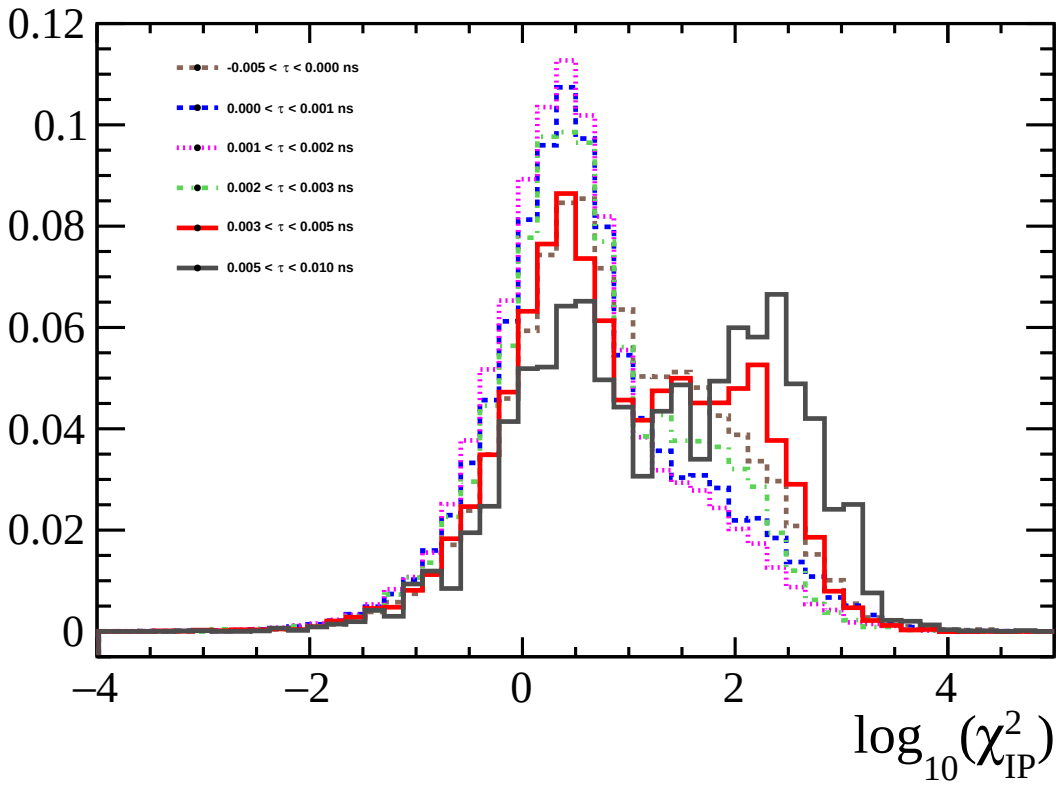
Sample	MC	MC	KeysPdf	KeysPdf	sWeight	sWeight
Component	prompt	secondary	prompt	secondary	prompt	secondary
μ	0.30 ± 0.02	1.55 ± 0.09	0.38 ± 0.00	1.68 ± 0.04	0.40 ± 0.02	1.56 ± 0.14
σ	0.45 ± 0.01	1.04 ± 0.03	0.45	0.93 ± 0.06	0.45	0.92 ± 0.08
ξ	-0.17 ± 0.02	-0.05 ± 0.07	-0.17	-0.19 ± 0.04	-0.17	-0.13 ± 0.12
ρ_1	-0.05 ± 0.02	-0.83 ± 0.31	-0.05	-0.86 ± 0.39	-0.05	-0.65 ± 0.89
$\rho 2$	-0.62 ± 0.17	-2.62 ± 0.95	-0.62	-0.67 ± 0.15	-0.62	-0.61 ± 1.71
N_{prompt}	5938 ± 77	-	137359 ± 1978	-	144032 ± 7612	-
$N_{secondary}$	-	1597 ± 40	-	49450 ± 2022	-	127270 ± 7784

Signal decay time distribution



IPCHI2 in different decay time bins

- Binning: [-0.005, 0., 0.001, 0.002, 0.003, 0.005, 0.01] ns
- Signal IPCHI2 distribution



Next to-do

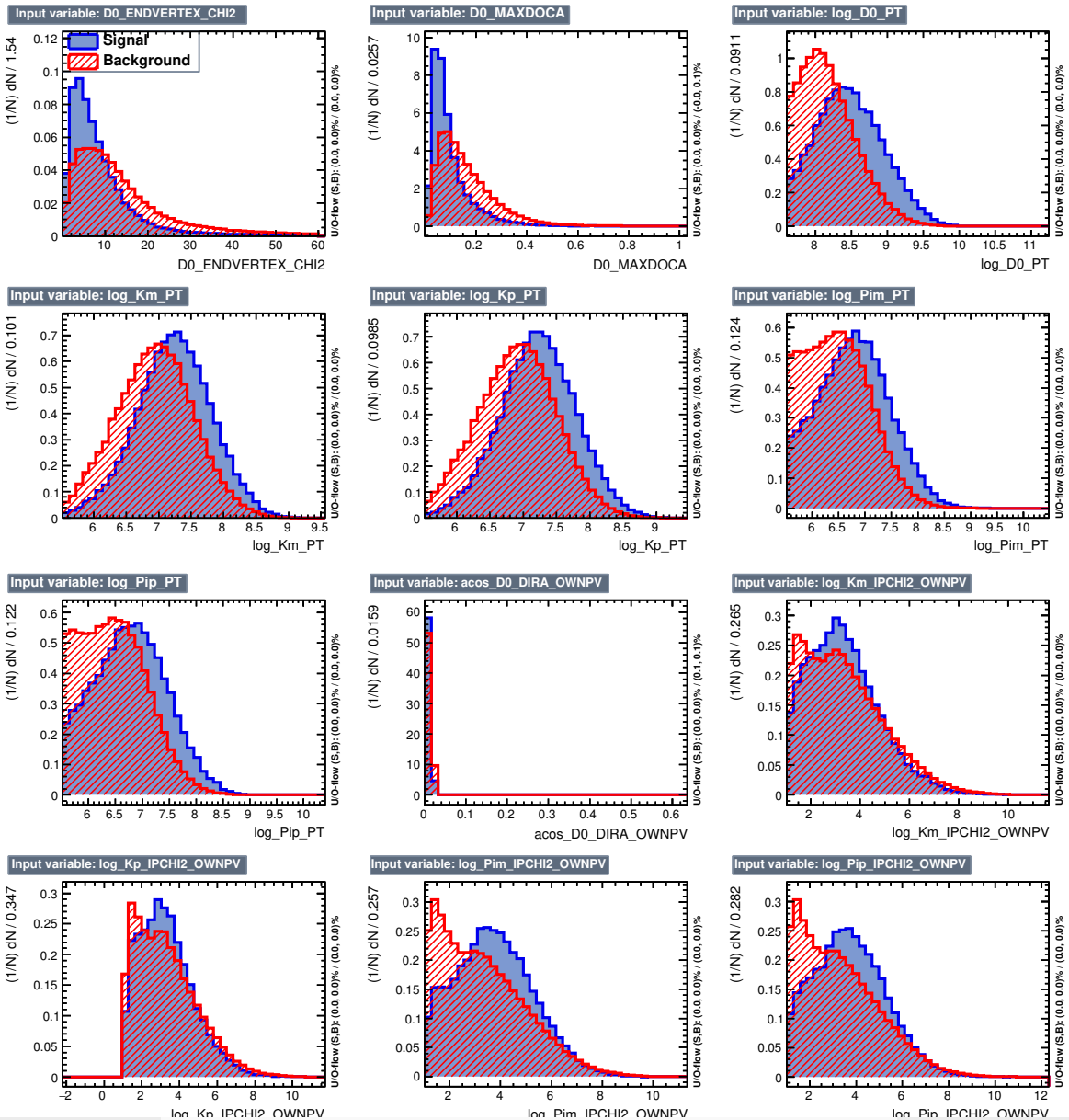
- Relate mass fit to IPCHI2 fit
- Test the fit stability
  - Toy studies: generate samples according to the fitted shape, examine the pull plots of parameters
- Try to fit in decay time bins

MC request

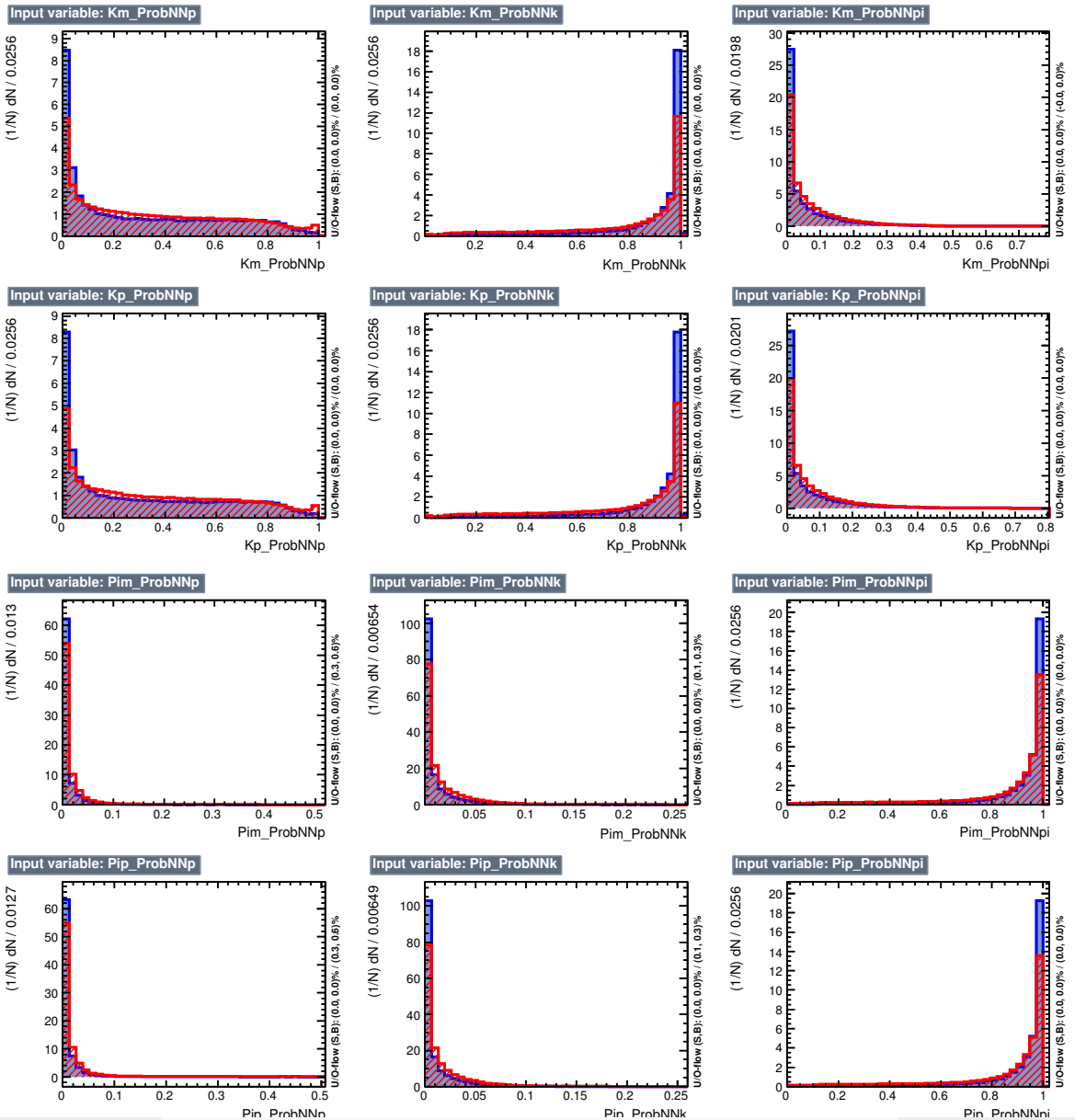
- Possible fast simulation option: Re-use the underlying event many times with different signal decay
  - Procedure
    1. Generate a full event
    2. Find and split off what should be re-decayed
    3. Simulate the underlying event and make it persistent across multiple event
    4. Create particle-gun-like event
    5. Reattach the signal particle to the correct vertex in the event
    6. Write out the event
    7. Repeat 3. to 6. $N_{redecay}$ times before going back to 1.
  - Pros: Fast (depending on $N_{redecay}$) and complexity of a full event
  - Cons: No disk space saving and statistical uncertainty more difficult
- Additional option to improve the statistics
  - Add generator-level PT and P cuts on the final-state tracks (cuts exist in Turbo but not currrent DECFILEs)
  - PT$>400\,\mathrm{MeV}$: 28%;
    PT$>400\,\mathrm{MeV}$ and P$>800\,\mathrm{MeV}$: 21%

Backup

Training variables with sWeighted sample as signal



Training variables with sWeighted sample as signal



Turbo selections of $\Omega_c^0 \to pK^-K^-\pi^+$

Items	Cuts
Daughter K	(TRCHI2DOF<3) (PT>500.) (P>1000.) (PIDK>10.) (MIPCHI2DV(PRIMARY) > 4.0)
Daughter π	(TRCHI2DOF<3) (PT>500.) (P>1000.) (PIDK<0.) (MIPCHI2DV(PRIMARY) > 4.0)
Daughter p	(TRCHI2DOF<3) (PT>500.) (P > 10000.) (PIDp > 10.0) & ((PIDp-PIDK) > 5.0) (MIPCHI2DV(PRIMARY) > 4.0)
CombinationCut	(in_range(2386.0, AM, 2780.0)) ((APT1+APT2+APT3+APT4) > 3000.0) (AHASCHILD(PT > 1000.0)) (ANUM(PT > 500.0) >= 2) (AHASCHILD((MIPCHI2DV(PRIMARY)) > 8.0)) (ANUM(MIPCHI2DV(PRIMARY) > 6.0) >= 2)
MotherCut	(VFASPF(VCHI2PDOF) < 10.0) (BPVDIRA > cos(0.01)) (BPVLTIME() > 0.0001) (BPVVDCHI2 > 10.0)