$B_s \to D_s K\pi\pi$: γ measurement

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Status

A lot of progress since last update:

- re-optimized selection for γ measurement
- added 2015 & 2016 Run2 data
- use Meerkat PID sampling to control misID contributions
- developed time dependent MINT version
- integrated time acceptance and resolution in TD-MINT
- New MC request, a lot more statistics needed

Re-optimized Selection

We now use specific phasespace cuts during preselection to suppress background:
plot here

$$m(K\pi\pi) < xXxGeV$$

The reduced background level allows us to loosen the BDT cut and significantly improve $\frac{S}{\sqrt{S+B}}$

New data!

Data from 2015 & 2016 now added to analysis

Slightly reorganized mass fits, now fit simultaneously in every year and D_s final state:

- years: 2011, 2012, 2015, 2016
- $D_s \to \phi\pi \to KK\pi$
- $D_s \to K^*K \to KK\pi$
- $D_s \to KK\pi$ (non-resonant)
- $D_s \to \pi\pi\pi$

Fit components

Components we model in the invariant mass distributions:

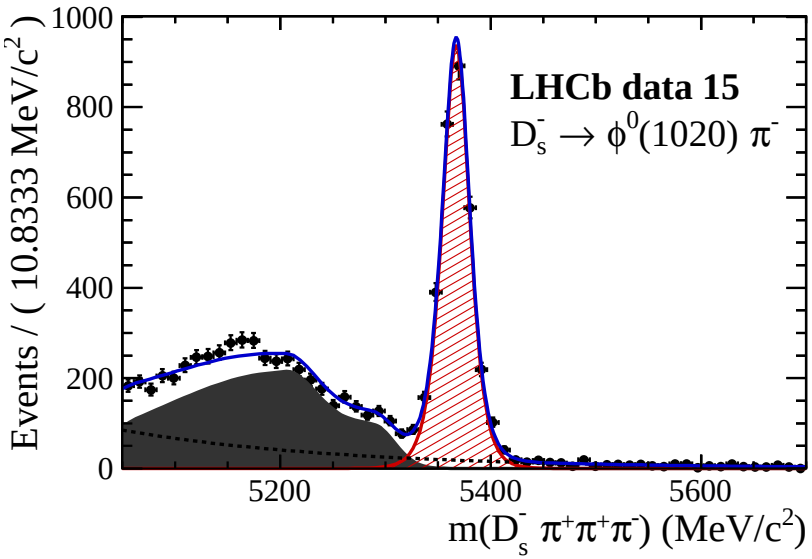
$B_s \to D_s\pi\pi\pi$:

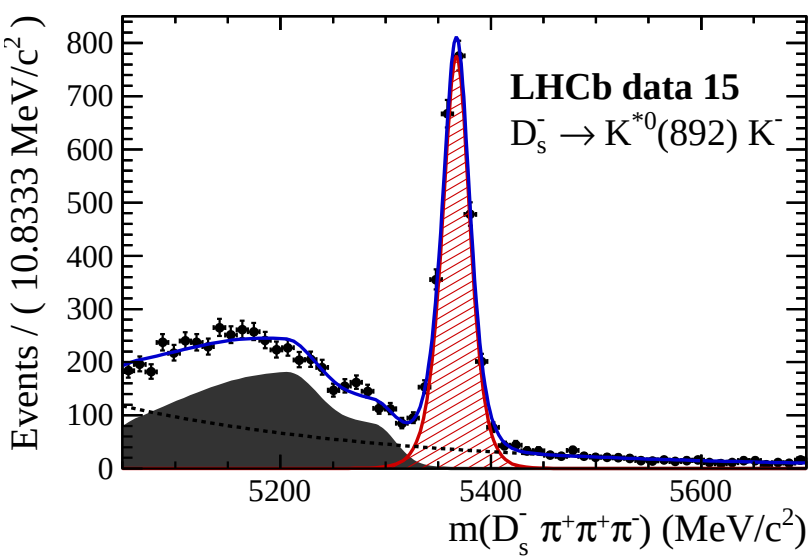
- B_s signal
- $B_s \to D_s^*\pi\pi\pi$ partial reconstructed background combinatorial
- combinatorial background

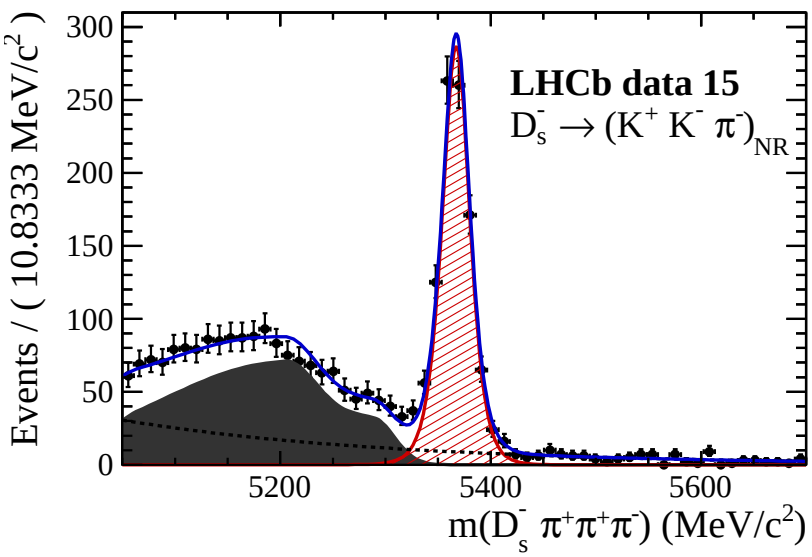
$B_s \to D_sK\pi\pi$:

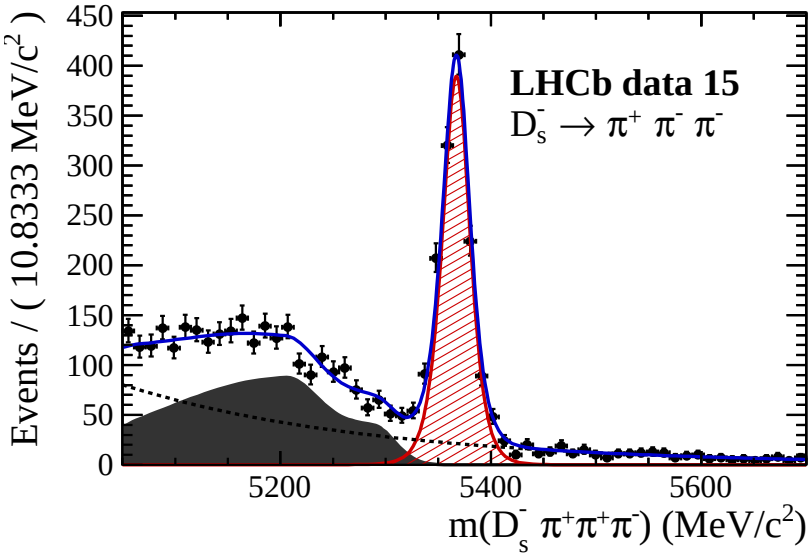
- B_s/B^0 signal
- $B_s/B^0 \to D_s^*K\pi\pi$ partial reconstructed background
- $B_s \to D_s\pi\pi\pi$ mis-ID background
- combinatorial background

Massfits norm 15

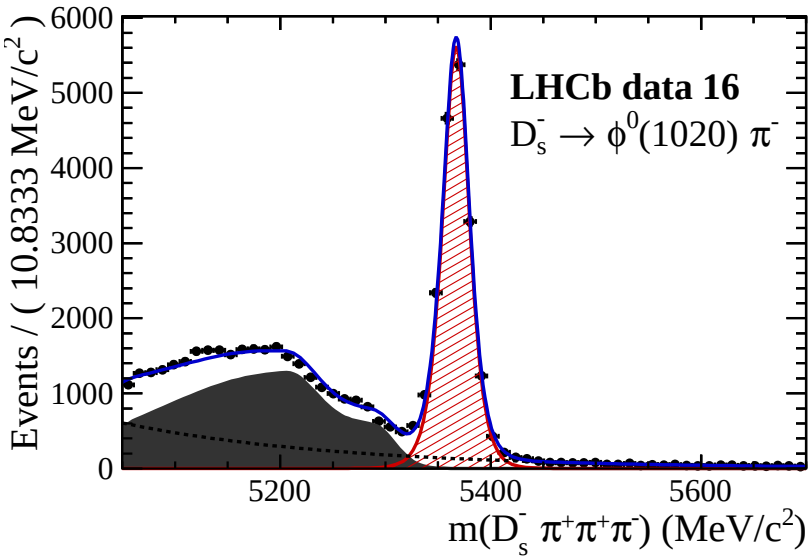


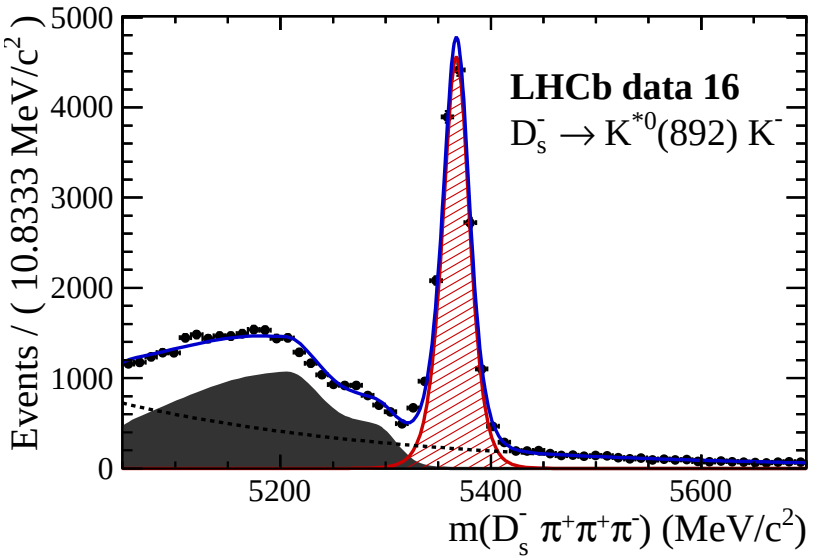


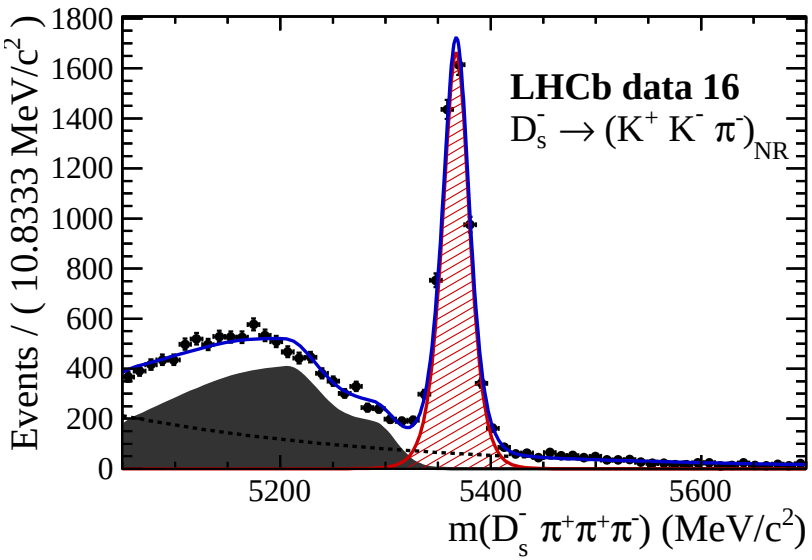


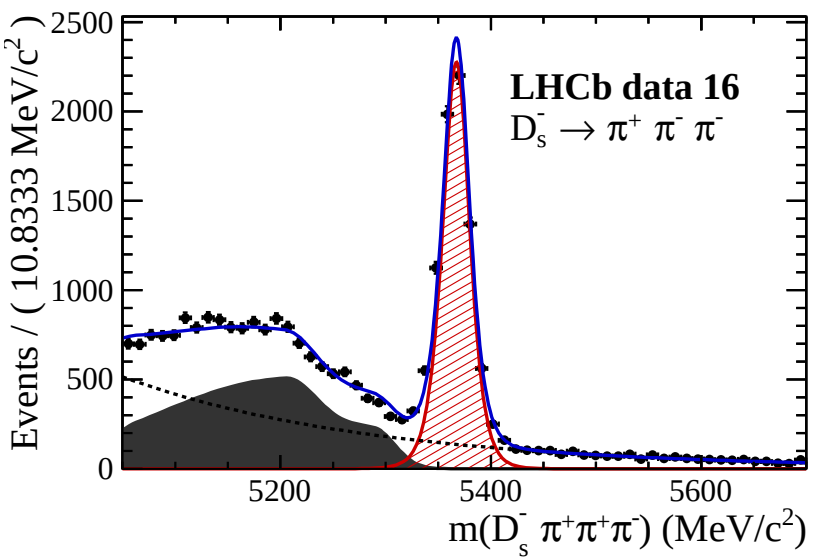


Massfits norm 16

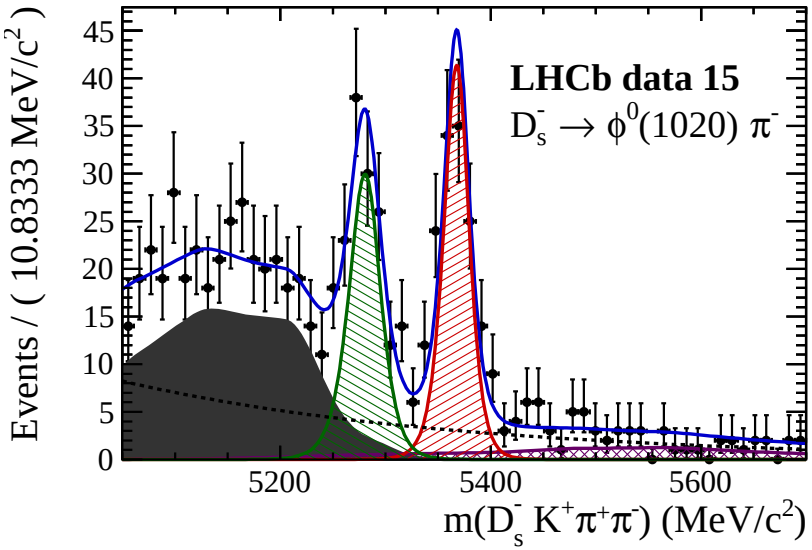


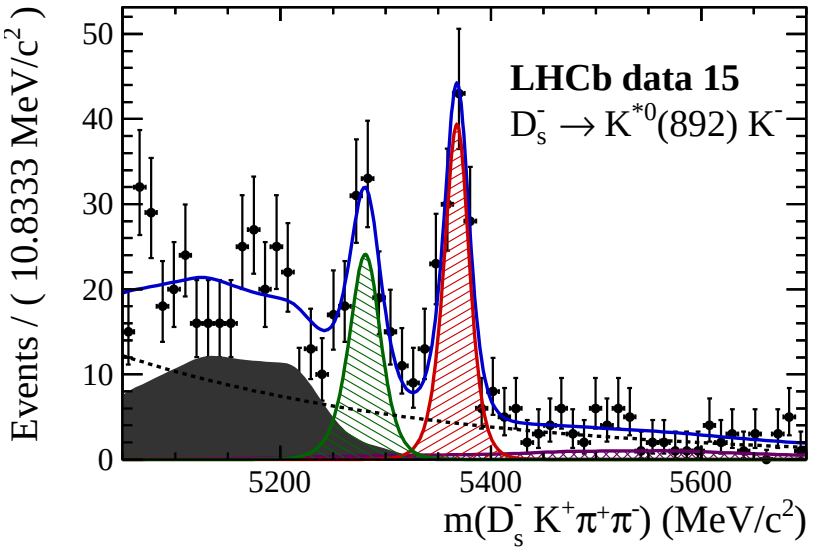


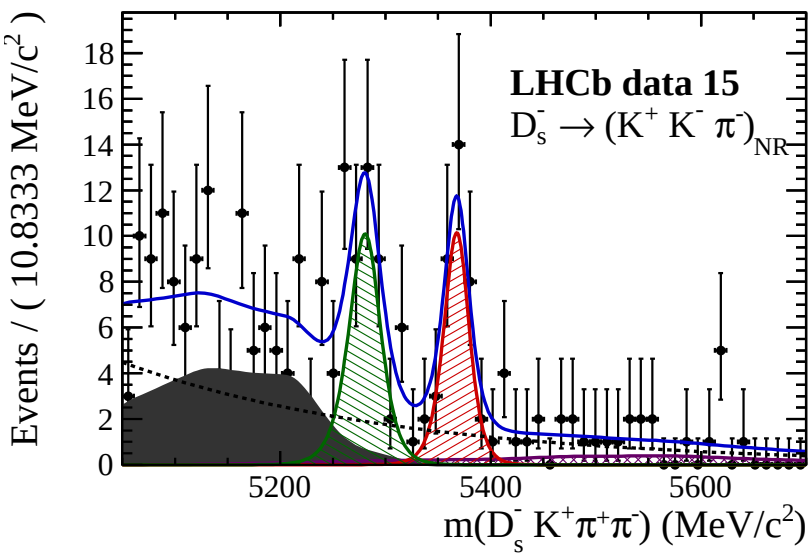


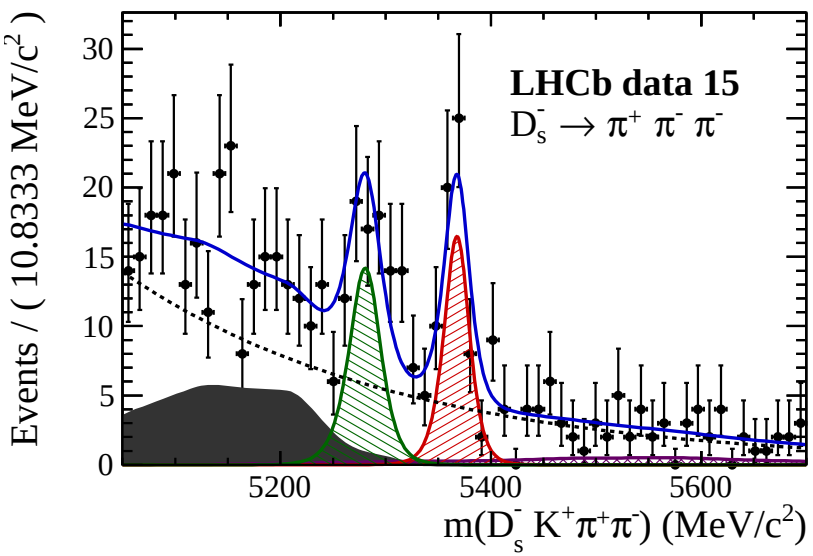


Massfits signal 15

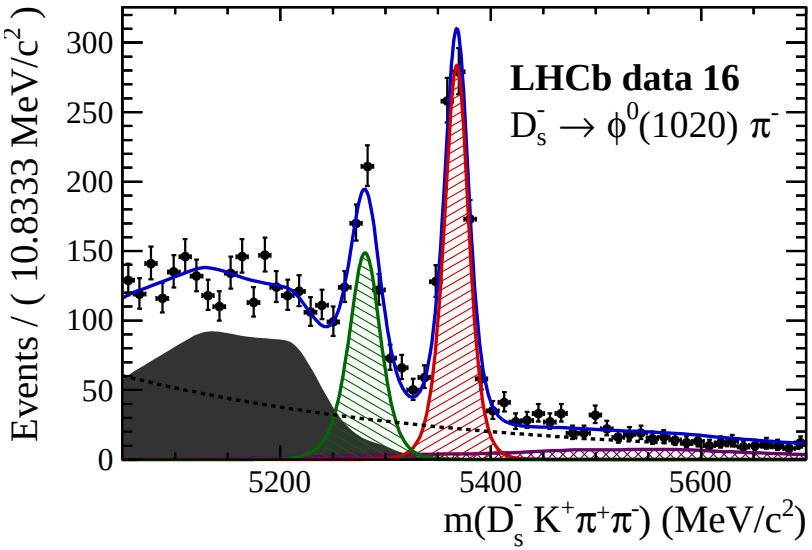


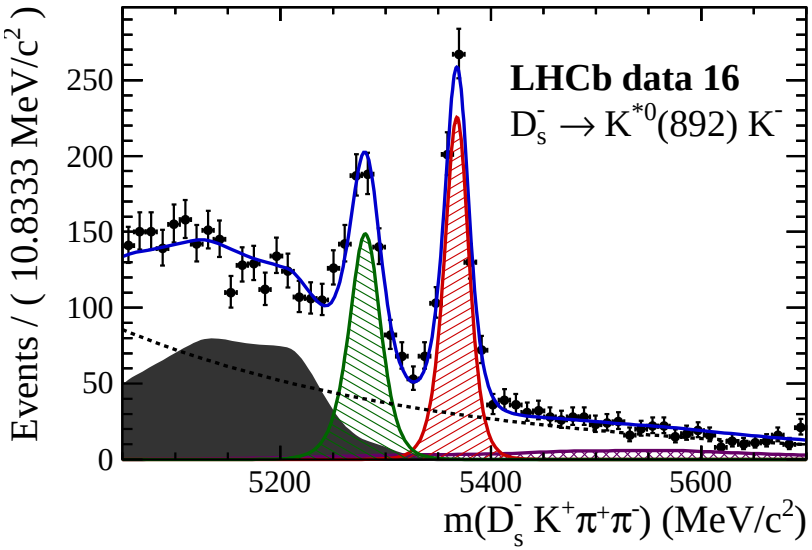


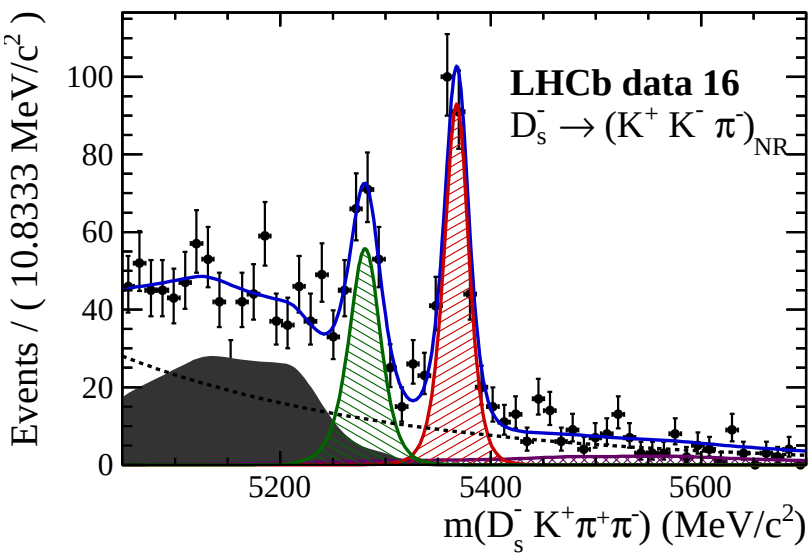


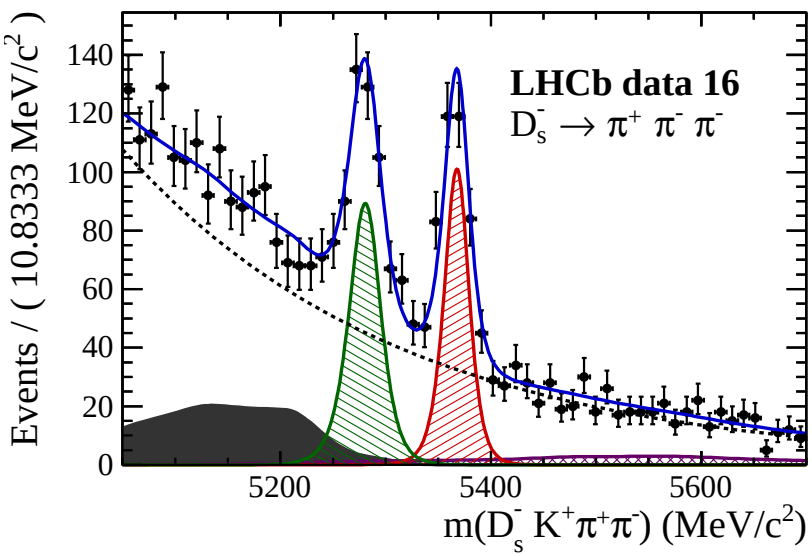


Massfits signal 16

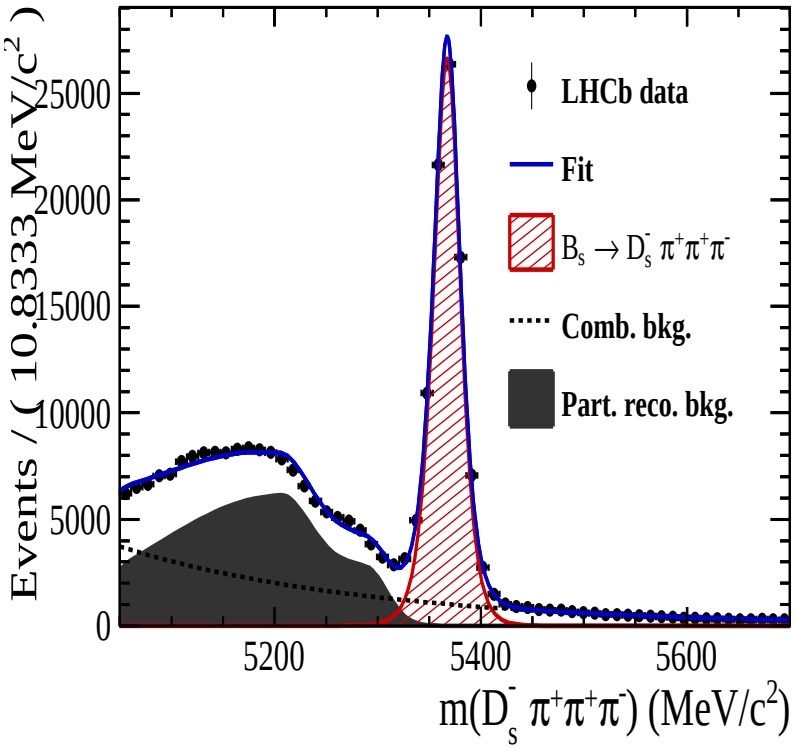


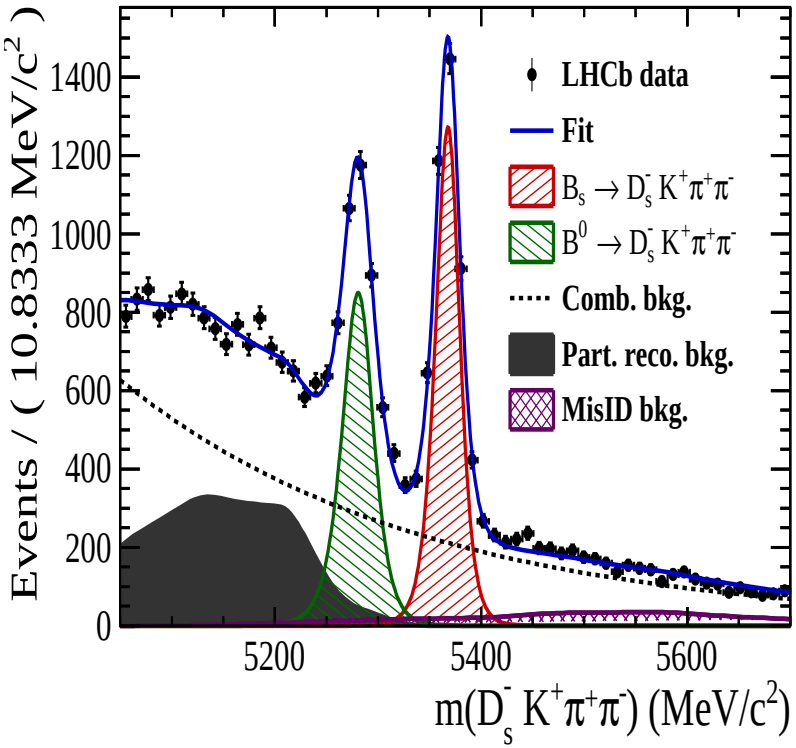






Run1 & 2 Data combined





fit component	yield 2011	yield 2012	yield 2015	yield 2016
$B_s \to D_s\pi\pi\pi$	9554 $\pm$ 204	22940 $\pm$ 316	7839 $\pm$ 185	45186 $\pm$ 452
$B_s \to D_sK\pi\pi$	426 $\pm$ 57	909 $\pm$ 71	319 $\pm$ 38	2049 $\pm$ 104

$\to$ 3700 Signals in total !

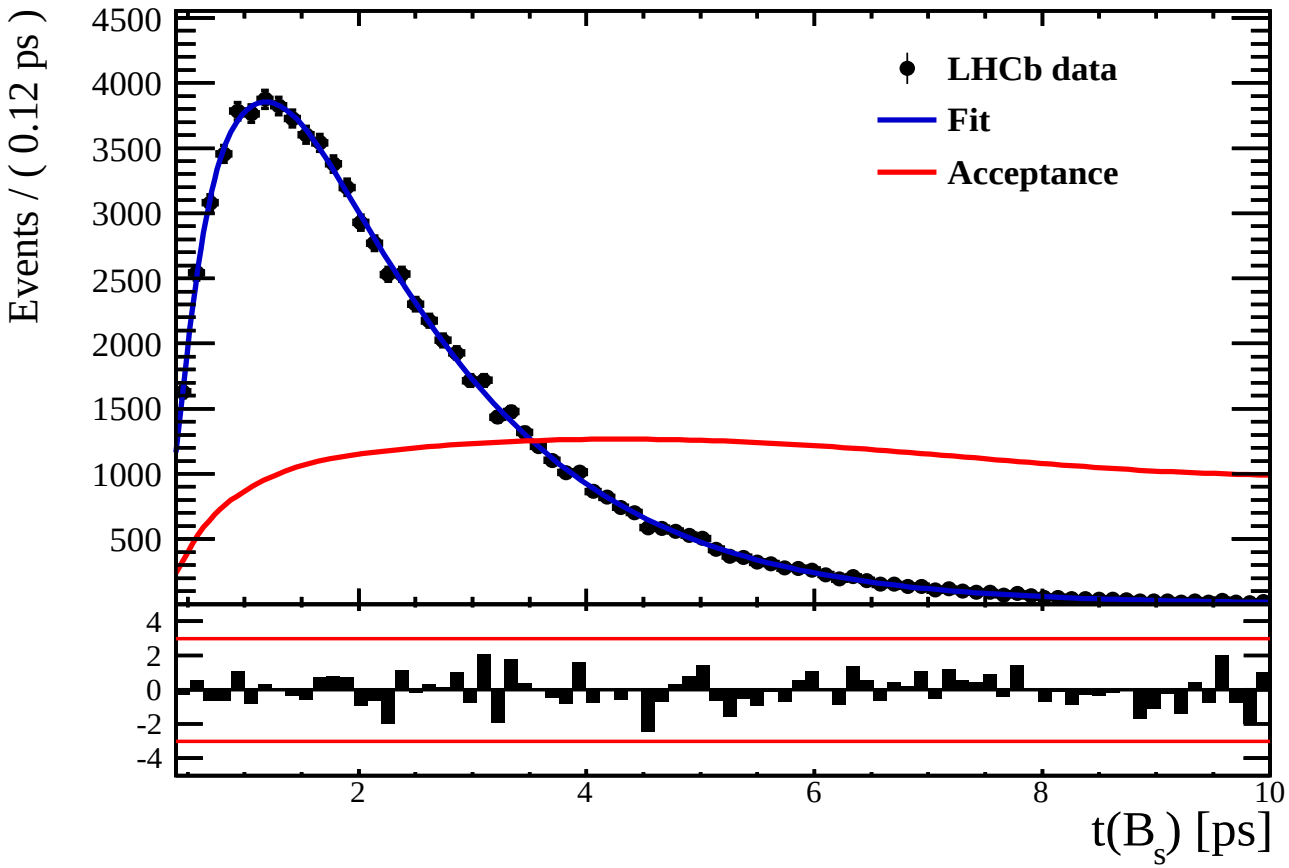
Time-Acceptance

- $\frac{\Gamma(t)^{observed}}{dt} = \frac{\Gamma(t)^{theory}}{dt} \cdot \epsilon(t)$
- Use control channel $B_s^0 \to D_s^+ \pi^- \pi^+ \pi^-$
- describe $\epsilon(t)$ using cubic splines
- fit flavour averaged t-distribution, e.g.

$$\mathcal{P}(t', \vec{\lambda}) = \left[(e^{\Gamma_s t} \cdot cosh(\frac{\Delta\Gamma_s t}{2}) \times \mathcal{R}(t - t') \right] \cdot \epsilon(t', \vec{\lambda})$$

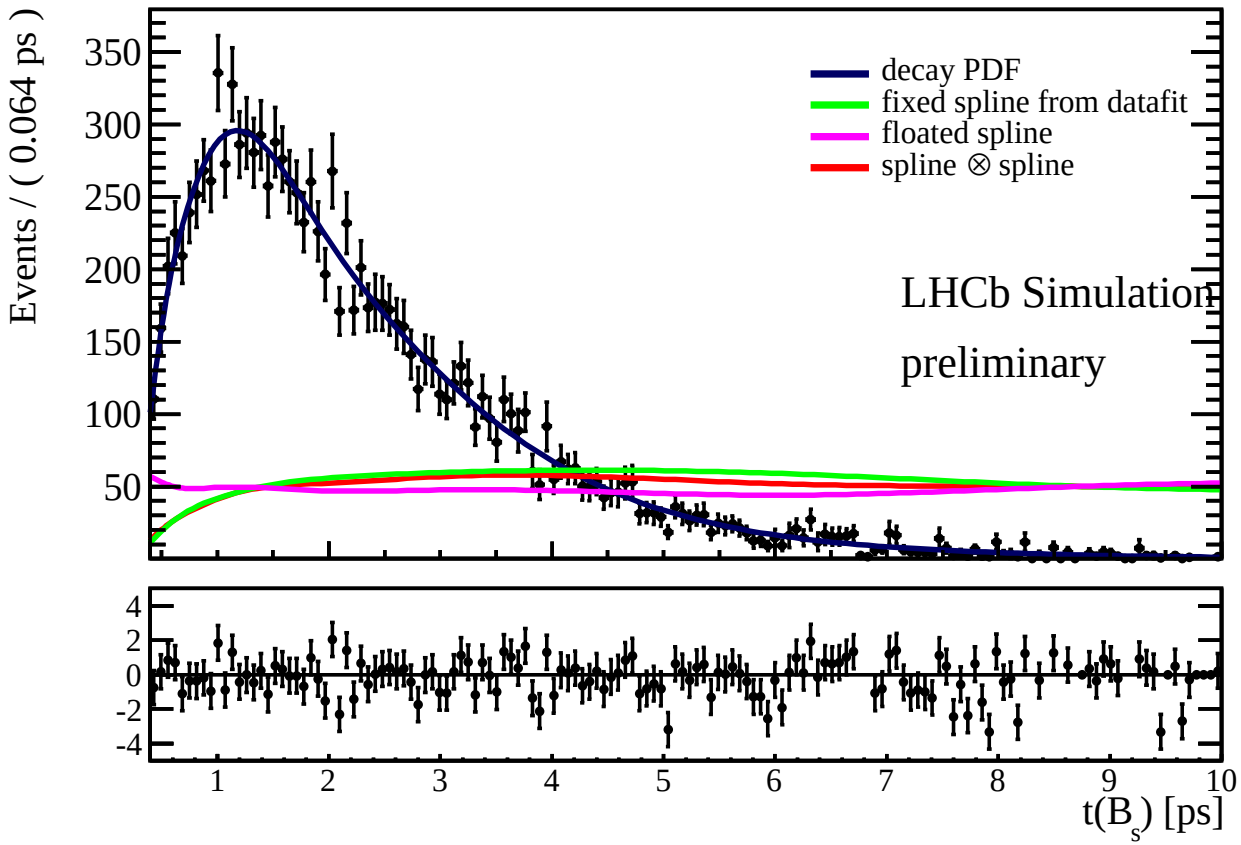
- fix $\Delta\Gamma$ and Γ to PDG, float polynomials

Time-Acceptance



knots at 0.5, 1, 1.5, 2, 3, 6. 9.5, 10 ps

Spline Products



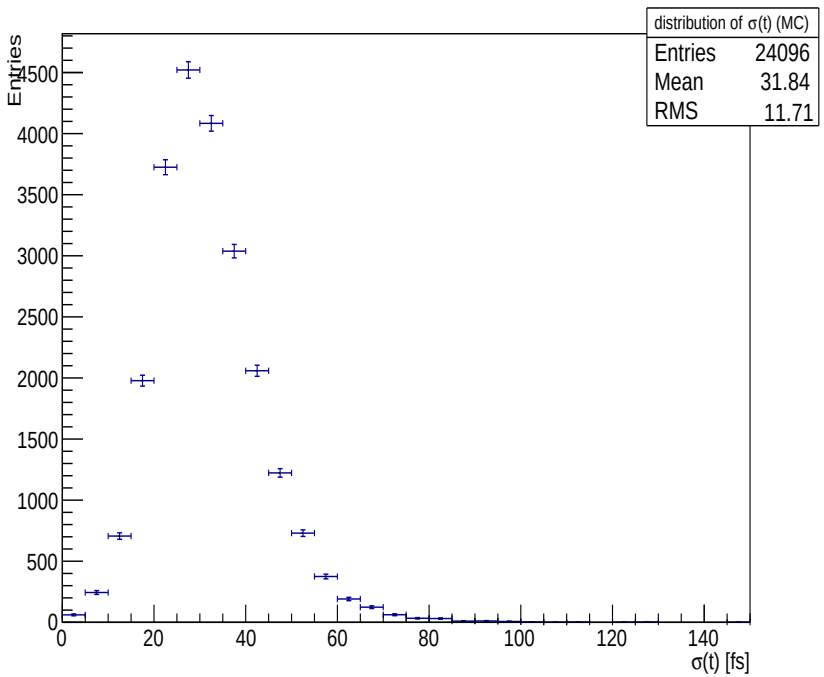
We also imported the Spline Product class (see talk by Agnieszka) to check corrections between $B_s \to D_s\pi\pi\pi$ and $B_s \to D_s K\pi\pi$

need more MC statistic for this fit

Resolution

Per-event decay-time error σ_t estimated by the decay tree fitter

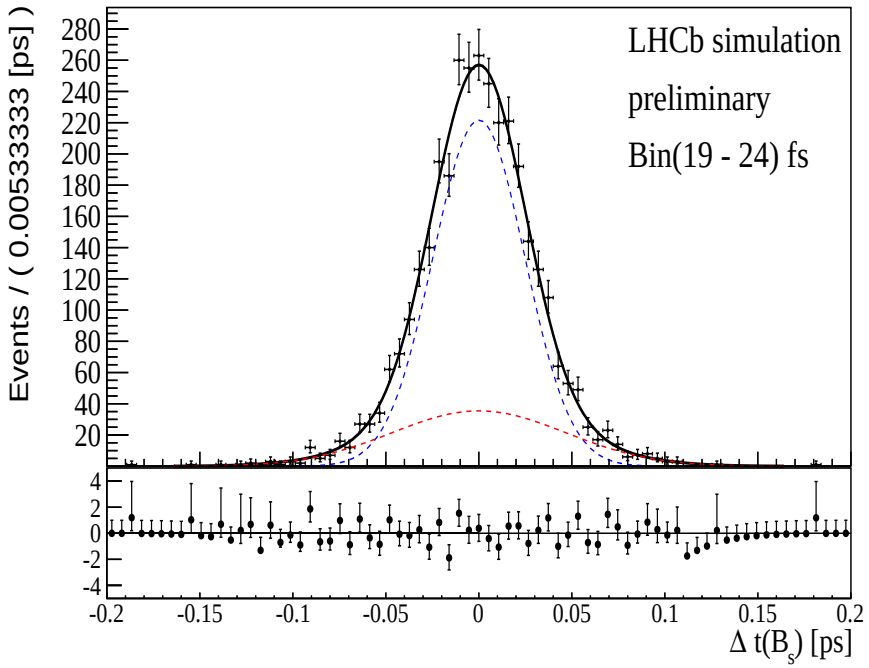
Problem: Not calibrated, real decay-time error will be shifted



Fit double Gaussian to distribution of $\Delta t = t_{true} - t_{observed}$ in every Bin, on MC

Derive effective resolution from Dilution of CP-observables

Resolution

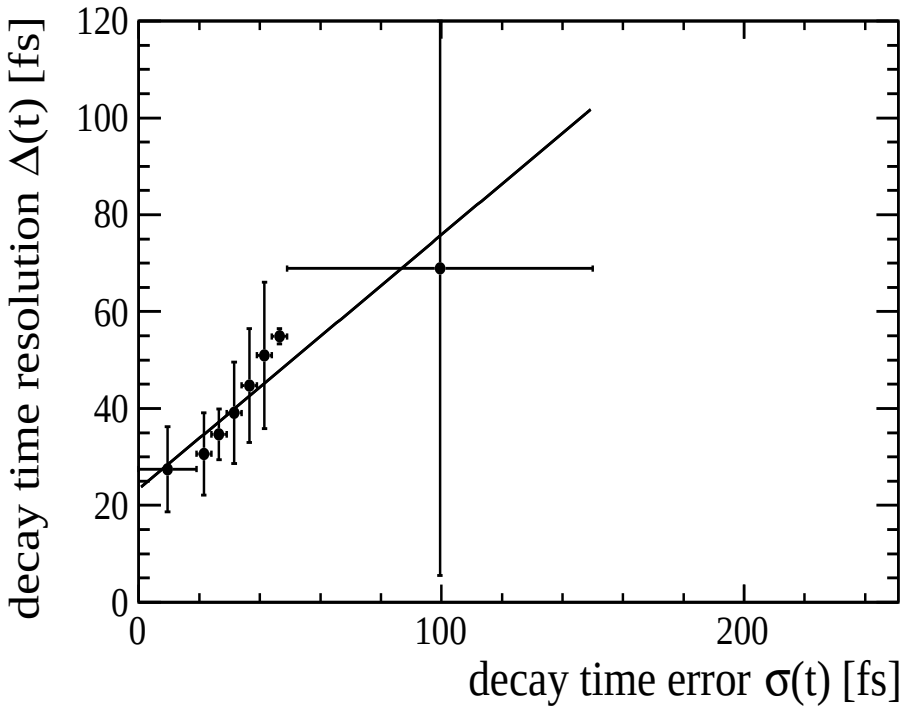


$$\mathcal{D} = f_1 e^{-\sigma_1^2 \Delta m_s^2/2} + (1 - f_1) e^{-\sigma_1^2 \Delta m_s^2/2}, \mathcal{D} \in [0, 1]$$

$$\sigma_{eff} = \sqrt{(-2/\Delta m_s^2) \ln D}$$

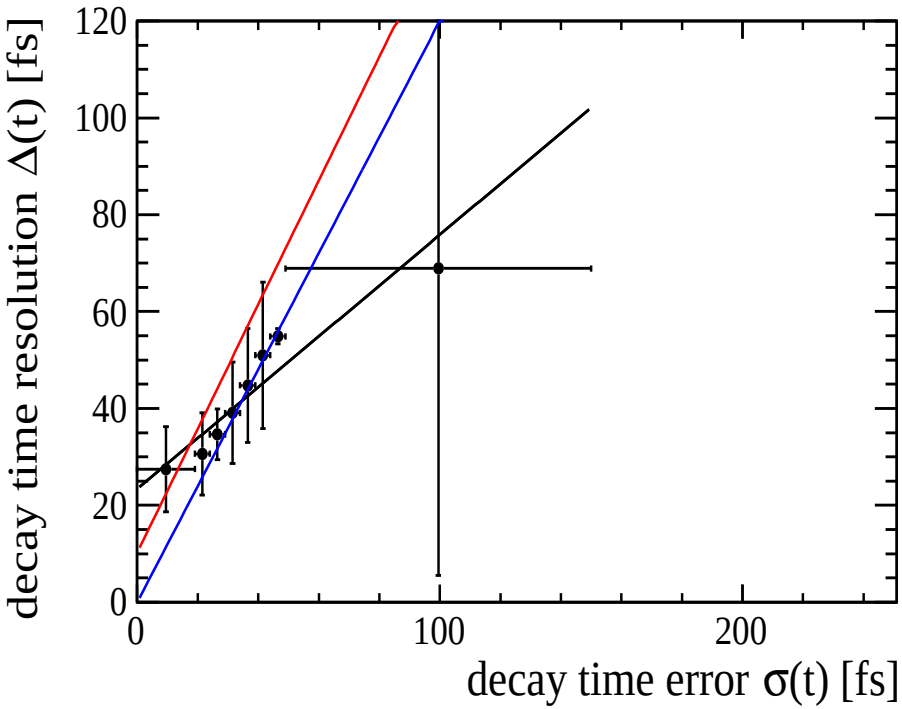
Resolution

Plot σ_t from decay tree fitter against σ_{eff} from Gaussian fits



Fitted with first order polynomial

Resolution



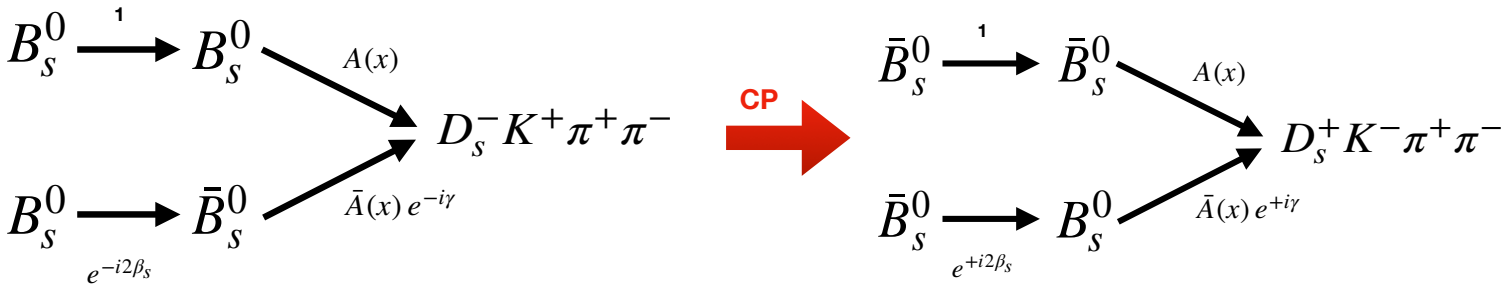
comparison of
$B_s \to D_s K\pi\pi$,MC
$B_s \to D_s K$,MC
$B_s \to D_s K$,Data

$$\to \text{assume } \frac{\sigma_{eff}(\sigma_t)_{D_sK,Data}}{\sigma_{eff}(\sigma_t)_{D_sK,MC}} \approx \frac{\sigma_{eff}(\sigma_t)_{D_sK\pi\pi,Data}}{\sigma_{eff}(\sigma_t)_{D_sK\pi\pi,MC}}$$

$$\Leftrightarrow \sigma_{eff}(\sigma_t)_{D_sK\pi\pi,Data} \approx \frac{\sigma_{eff}(\sigma_t)_{D_sK,Data}}{\sigma_{eff}(\sigma_t)_{D_sK,MC}} \cdot \sigma_{eff}(\sigma_t)_{D_sK\pi\pi,MC}$$

Might be able to get LTU data by re-stripping due to HLT bug !

TD-Amplitude Fit using MINT



Full time-dependent amplitude PDF:

$$
\begin{aligned}
P(x,t,q_t,q_f) \propto [&\left(|A(x)|^2 + |\bar{A}(x)|^2\right) \cosh\left(\frac{\Delta\Gamma\, t}{2}\right) \\
&+ q_t q_f \left(|A(x)|^2 - |\bar{A}(x)|^2\right) \cos\left(\Delta m_s\, t\right) \\
&- 2\mathrm{Re}\left(A(x)^* \bar{A}(x)\, e^{-iq_f(\gamma - 2\beta_s)}\right) \sinh\left(\frac{\Delta\Gamma\, t}{2}\right) \\
&- 2q_t q_f \mathrm{Im}\left(A(x)^* \bar{A}(x)\, e^{-iq_f(\gamma - 2\beta_s)}\right) \sin\left(\Delta m_s\, t\right)] e^{-\Gamma t}
\end{aligned}
$$

$q_t = +1, 0, -1$ for a B_s^0, no-, ($\bar{B}_s^0$) tag
$q_f = +1$ (-1) for $D_s^- K^+ \pi\pi$ ($D_s^+ K^- \pi\pi$) final states.

Phasespace-integrated PDF:

$$\begin{aligned}\int P(x,t,q_t,q_f)\mathrm{d}x \propto & \left[\cosh\left(\frac{\Delta\Gamma\, t}{2}\right)\right. \\ & + q_t q_f \left(\frac{1-r^2}{1+r^2}\right)\cos\left(m_s\, t\right) \\ & - 2\left(\frac{\kappa\, r\cos(\delta - q_f(\gamma - 2\beta_s))}{1+r^2}\right)\sinh\left(\frac{\Delta\Gamma\, t}{2}\right) \\ & \left. - 2q_t q_f \left(\frac{\kappa\, r\sin(\delta - q_f(\gamma - 2\beta_s))}{1+r^2}\right)\sin\left(m_s\, t\right)\right] e^{-\Gamma t} \\ = & \left[\cosh\left(\frac{\Delta\Gamma\, t}{2}\right) + q_t q_f\, \mathbf{C}\cos\left(m_s\, t\right)\right. \\ & \left. - \kappa\, \mathbf{D}_{q_f}\sinh\left(\frac{\Delta\Gamma\, t}{2}\right) - q_t\, \kappa\, \mathbf{S}_{q_f}\sin\left(m_s\, t\right)\right] e^{-\Gamma t}\end{aligned}$$

$$r \equiv \frac{\sqrt{\int |\bar{A}(x)|^2 \mathrm{d}x}}{\sqrt{\int |A(x)|^2 \mathrm{d}x}},\ \kappa\, e^{i\delta} \equiv \frac{\int A(x)^* \bar{A}(x)\mathrm{d}x}{\sqrt{\int |A(x)|^2 \mathrm{d}x}\sqrt{\int |\bar{A}(x)|^2 \mathrm{d}x}}$$

Amplitude Analysis

Time-integrated, flavor averaged PDF:

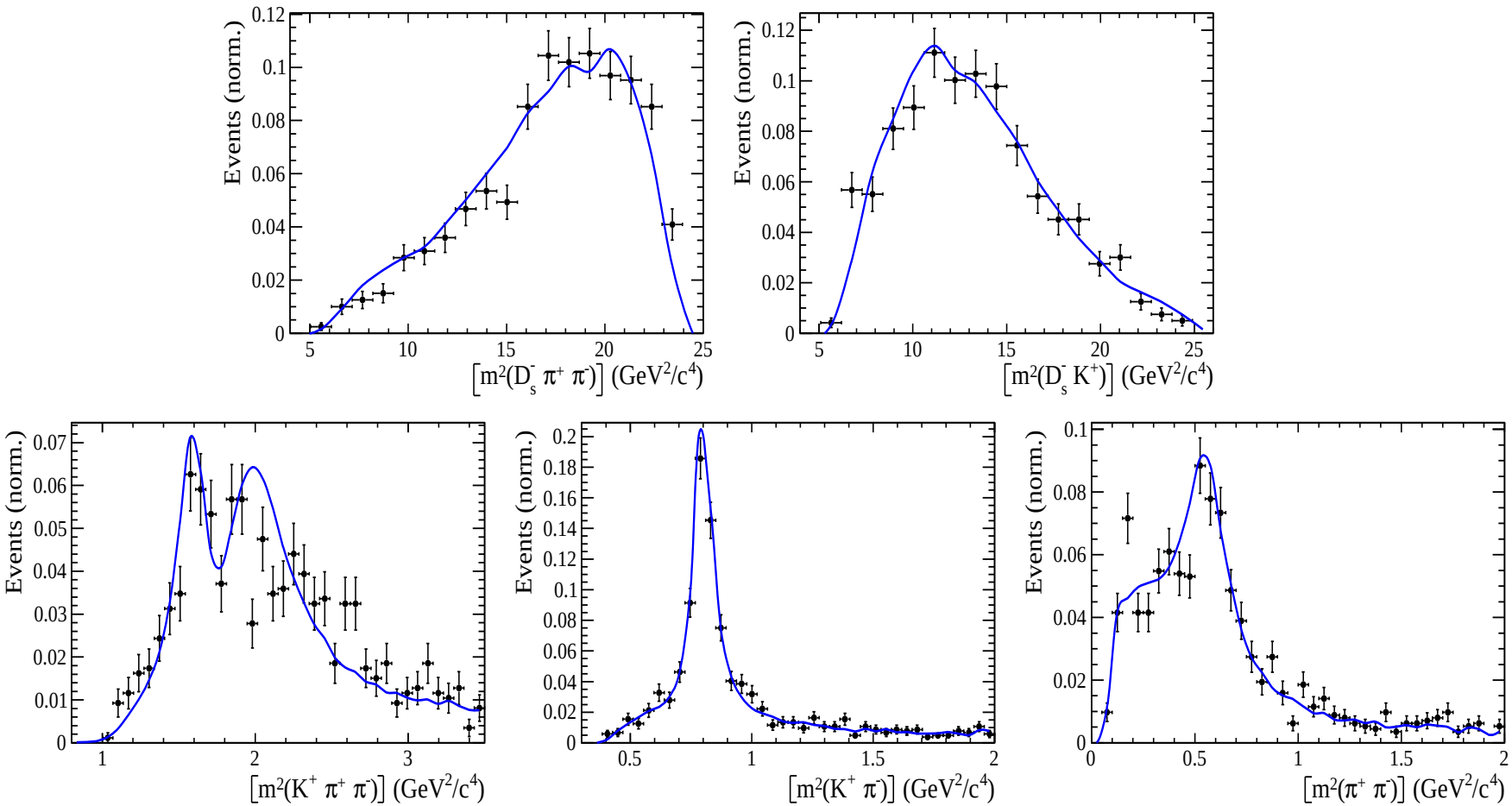
$$\int P(x, t, q_t, q_f)\, \mathrm{d}t\, \mathrm{d}q_t\, \mathrm{d}q_f \propto \left(|A(x)|^2 + |\bar{A}(x)|^2\right) \equiv |A^{eff}(x)|^2$$

- No sensitivity to γ
- Useful to identify contributing amplitude components

TD-MINT

- We implemented time-dependence + acceptance + resolution into MINT
- Now want to generate toys and validate the fitter
- First, take time-integrated MINT to fit contributing amplitude components
- Use fitted amplitudes to generate toys with TD-MINT
- Fit toys, examine results and compare phasespace-integrated to full fit
- additional tests of acceptance + resolution implementation possible, by comparing results to B2DX fitter package

Time integrated amplitude fit



Fit fractions

$$F_i^{eff} = \frac{\int |a_i^{eff} A_i^{eff}(x)|^2 \, dx}{\int |A^{eff}(x)|^2 \, dx}$$

```
(1) Bs0->K(1)(1270)+(->K(0)*(1430)0(->K+,pi-),pi+),Ds- = 0.0520926 +/- 0.0145326
(2) Bs0->K(1)(1270)+(->K*(892)0(->K+,pi-),pi+),Ds- = 0.090921 +/- 0.0214
(3) Bs0->K(1)(1400)+(->K*(892)0(->K+,pi-),pi+),Ds- = 0.315657 +/- 0.0320033
(4) Bs0->K*(1410)+(->K*(892)0(->K+,pi-),pi+),Ds- = 0.127998 +/- 0.0175661
(5) Bs0->NonResS0(->Ds-,pi+),K*(892)0(->K+,pi-) = 0.0265594 +/- 0.0114541
(6) Bs0[D]->NonResV0(->Ds-,pi+),K*(892)0(->K+,pi-) = 0.0108669 +/- 0.0069929
(7) Bs0->NonResA0(->sigma10(->pi+,pi-),Ds-),K+ = 0.0715845 +/- 0.0247102
(8) Bs0->NonResV0(->Ds-,K+),sigma10(->pi+,pi-) = 0.139525 +/- 0.0321404
(9) Bs0->K(1)(1270)+(->rho(770)0(->pi+,pi-),K+),Ds- = 0.16488 +/- 0.0379784
(10) Bs0->K(1)(1400)+(->rho(770)0(->pi+,pi-),K+),Ds- = 0.071005 +/- 0.0218139
(11) Bs0->K*(1410)+(->rho(770)0(->pi+,pi-),K+),Ds- = 0.0766048 +/- 0.014699
(12) Bs0->NonResA0(->rho(770)0(->pi+,pi-),Ds-),K+ = 0.0210193 +/- 0.0104696
 sum = 1.16871 +/- 0.0595647(fit)
```

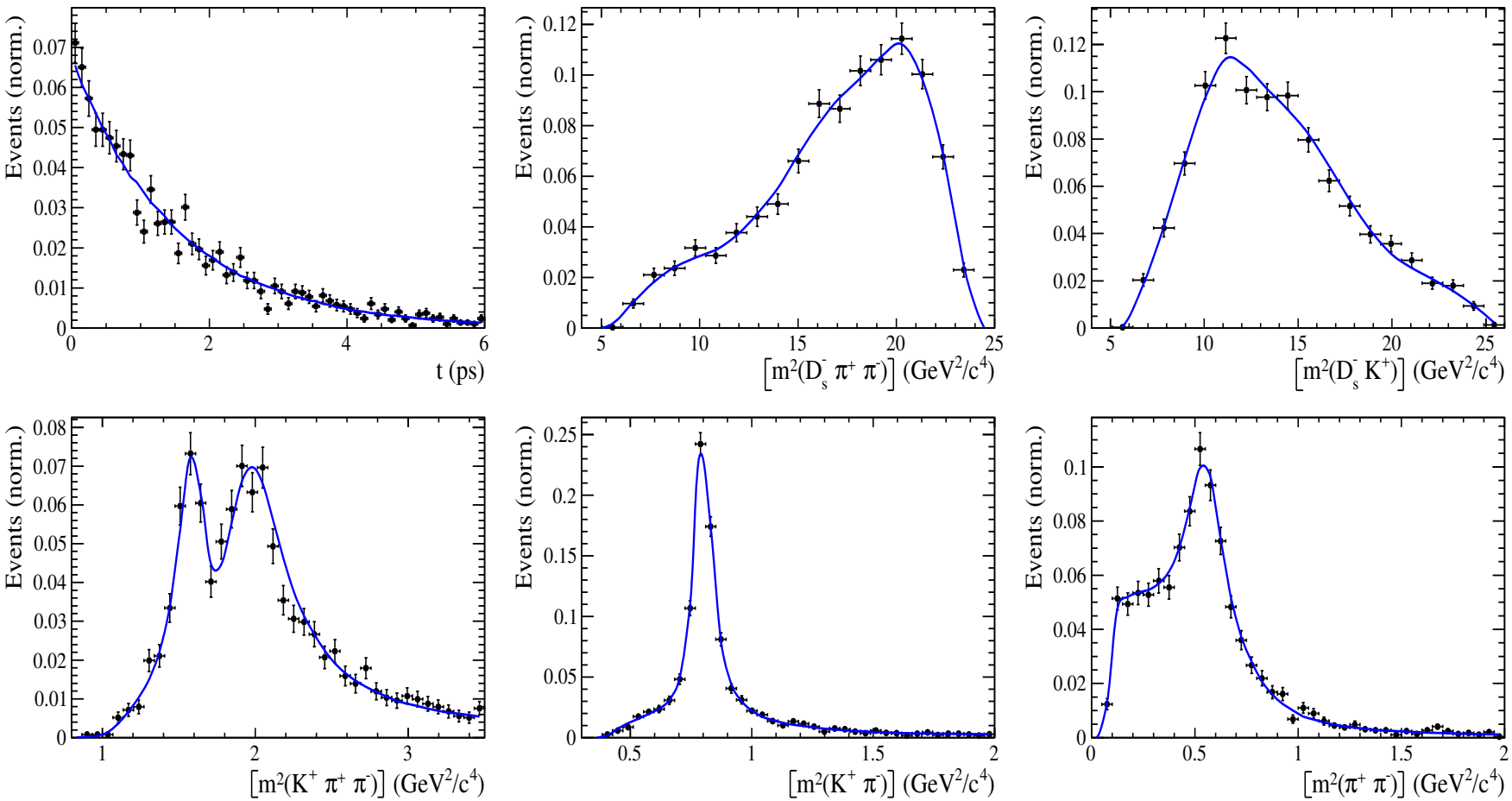
Time dependent amplitude fit

- Now time-dependent MINT extension
- Generate toys with different values for κ
- Compare sensitivity to γ fitting with **full PDF** and with **phasespace-integrated PDF**

Assumptions

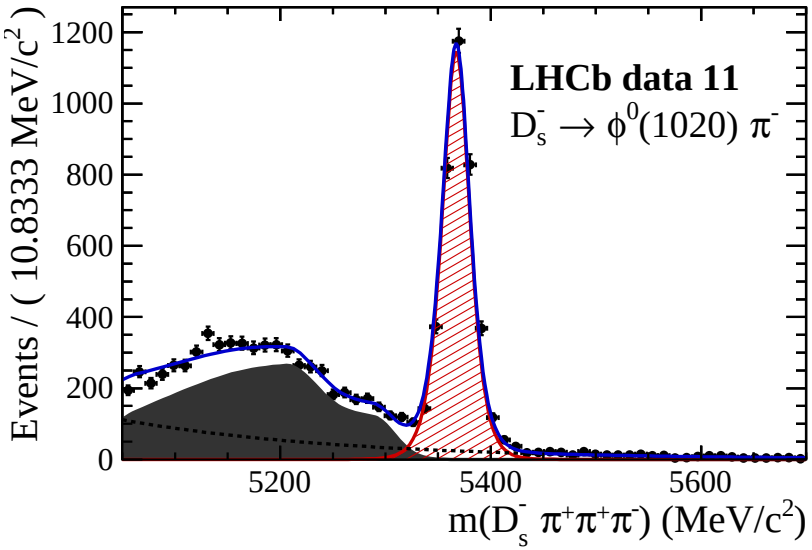
- Use amplitudes from flavor-averaged, time-integrated fit
- $r = 0.4$ (ratio of CKM elements)
- PDG values for: $\tau, \Delta m_s, \Delta\Gamma, \beta_s$
- $\epsilon(x,t) = const.$, including resolution and acceptance
- $\epsilon_{Tag} = 0.66, < \omega >= 0.4$
- $N_{signal} = 3000$ (Run1+15/16 data)

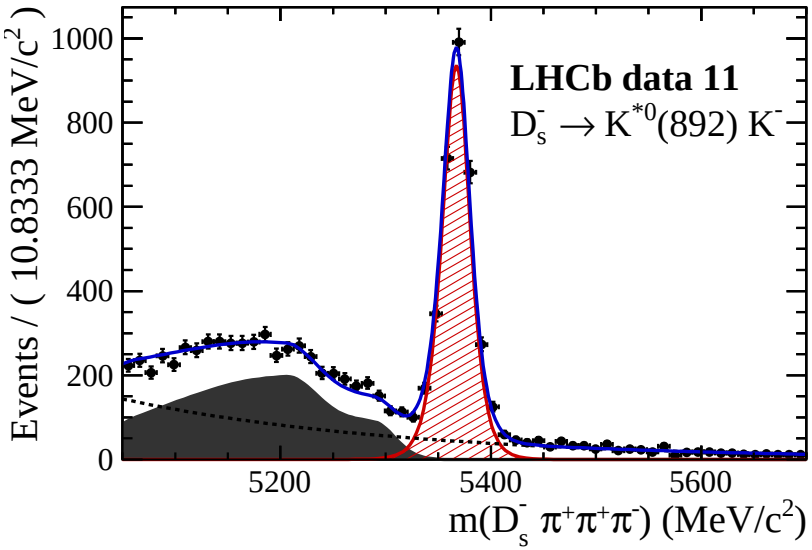
Example Toy-Fit: $B_s \to D_s K \pi\pi$

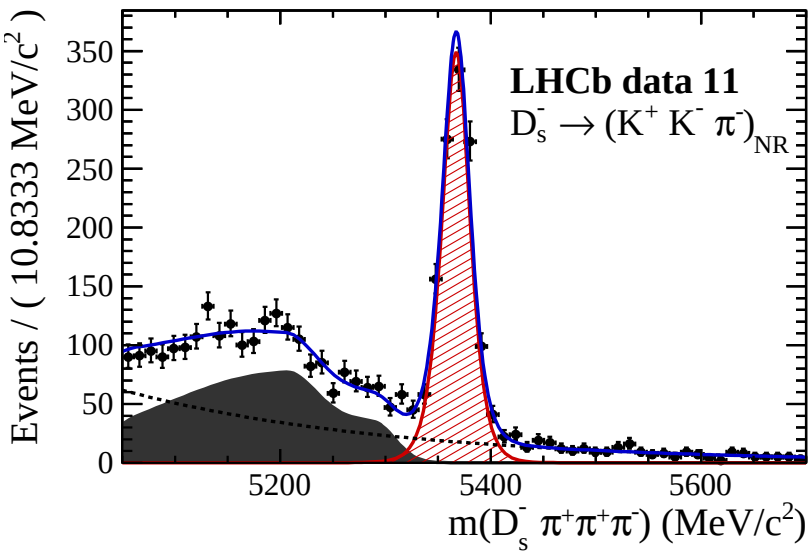


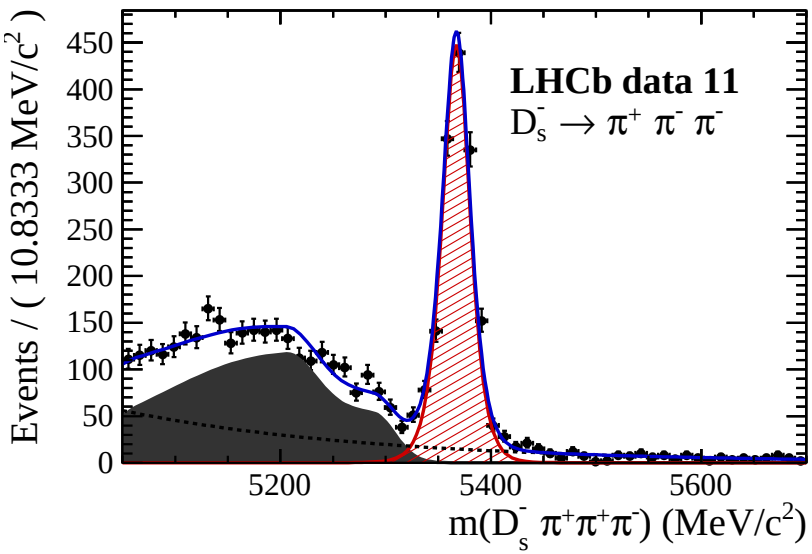
Appendix

Massfits norm 11

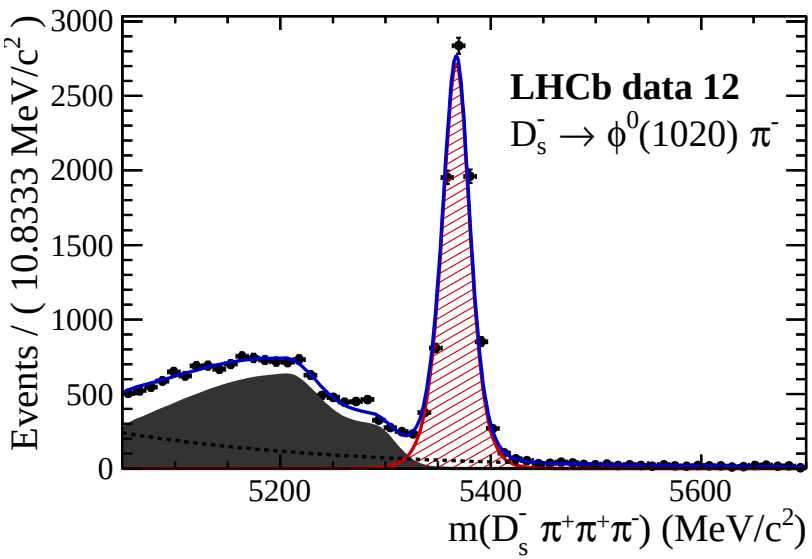


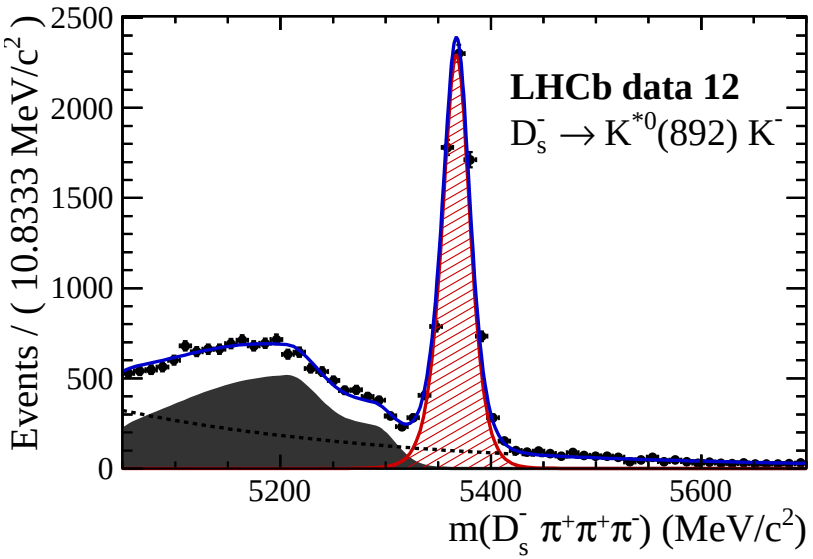


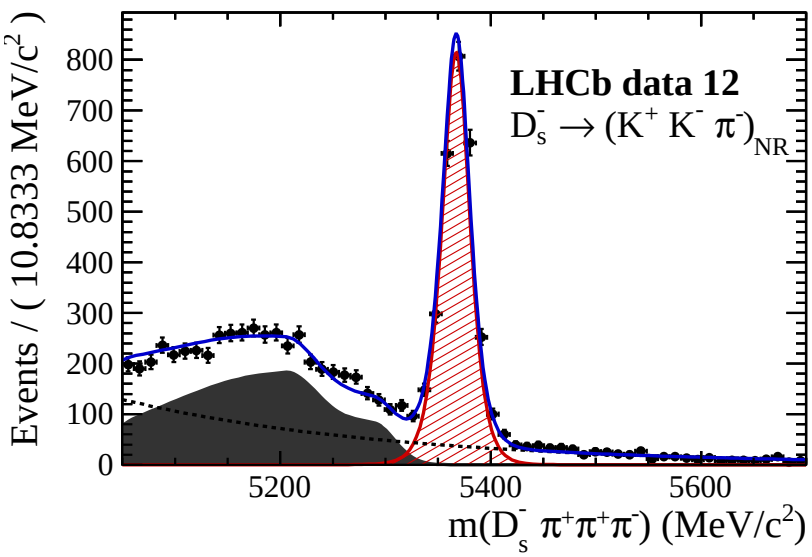


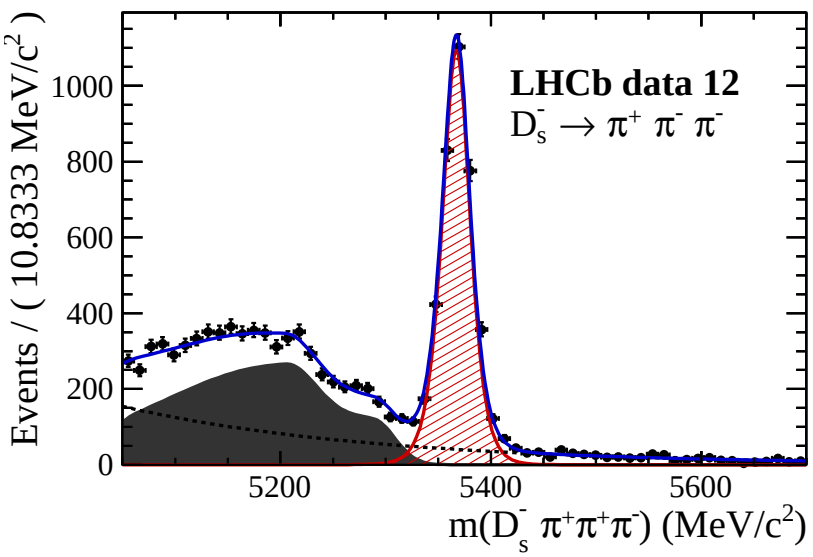


Massfits norm 12

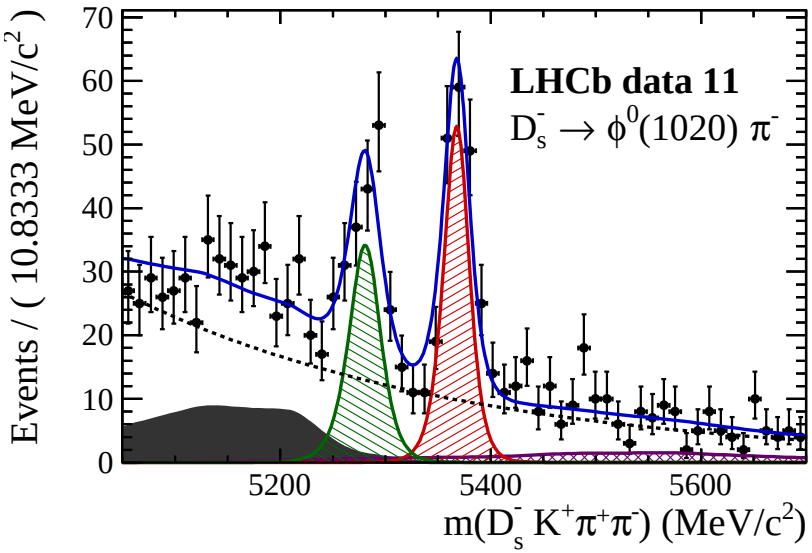


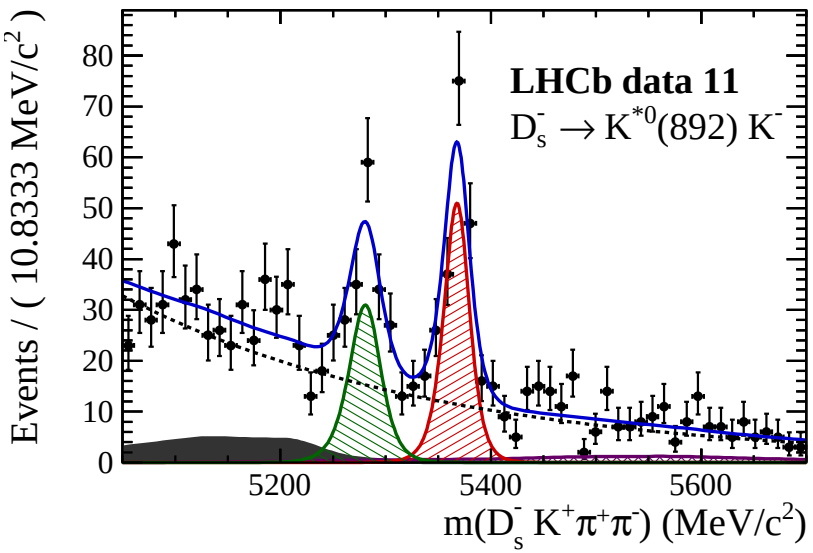


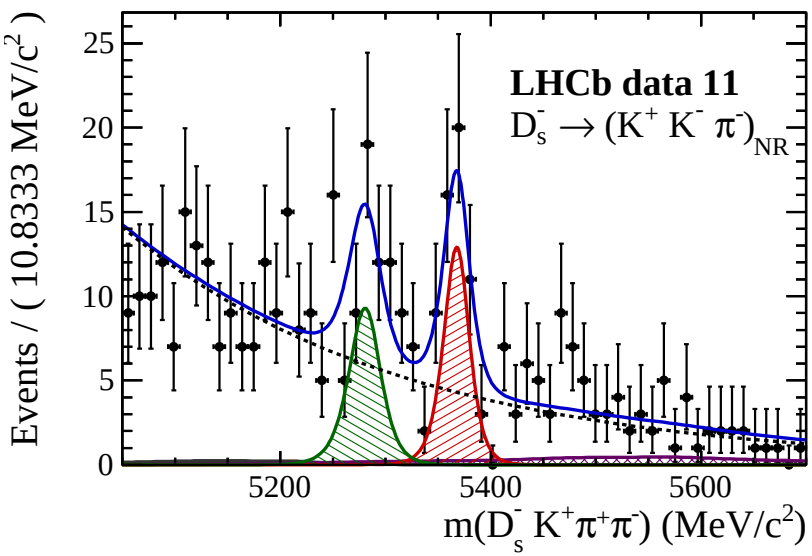


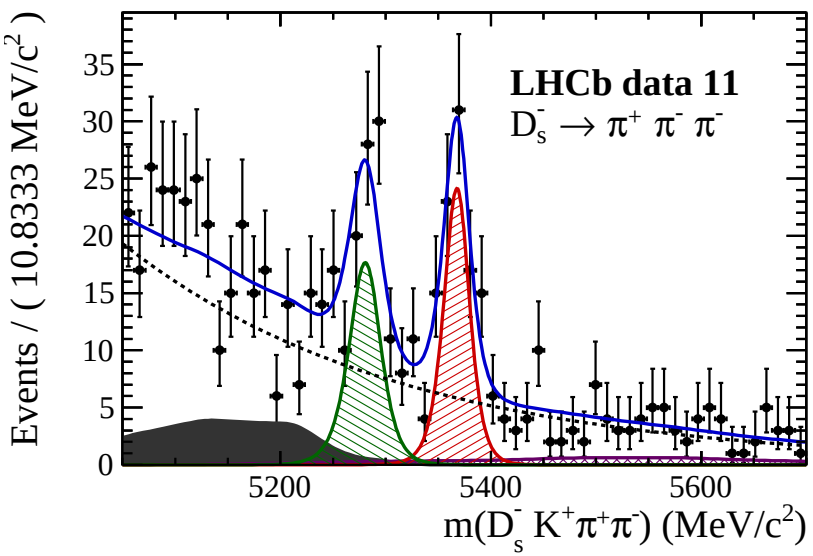


Massfits signal 11









Massfits signal 12