



Charm-Beauty Separation in D meson final states



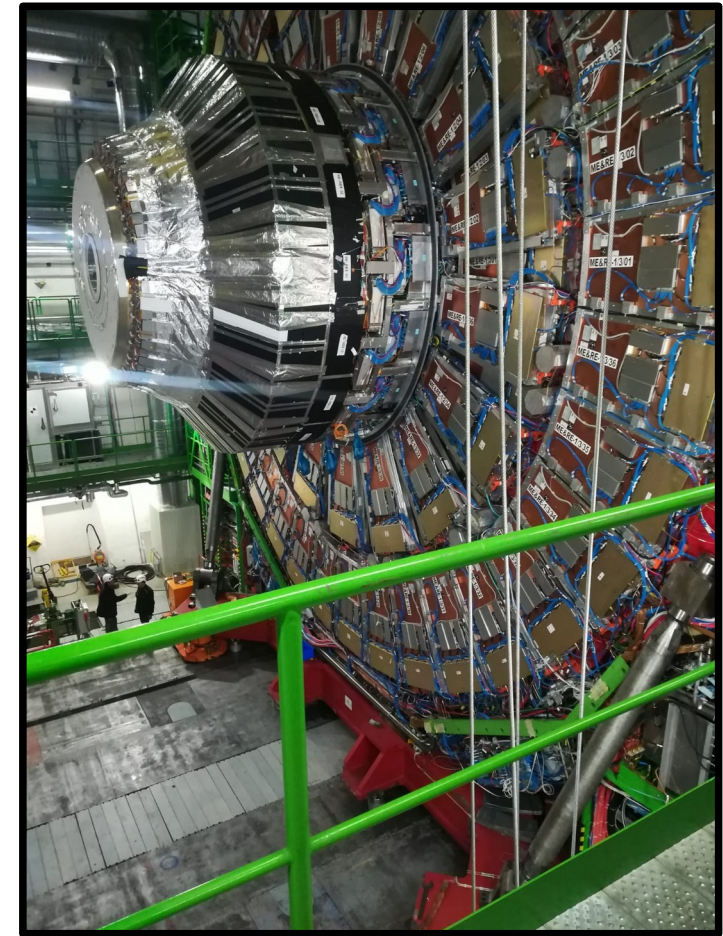
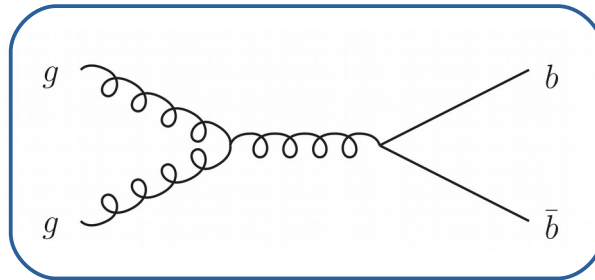
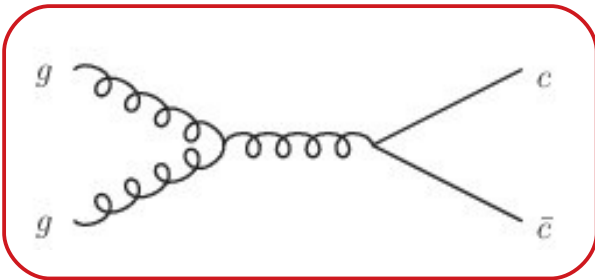
Josry Metwally, Achim Geiser - Hamburg, 26.03.2020



My PhD project

- Measure total **beauty** cross sections at different center of mass energies 0.9, 2.76, **5**, 7, 8, and 13 TeV, without theory extrapolation for the first time in →
- Measure cross sections in full phase space of D mesons **from b hadron decays** in small bins in p_T and $|Y|$ and integrate
- Decays:
$$B \rightarrow D^* X \rightarrow D^0 \pi_s X \rightarrow K \pi \pi_s X$$

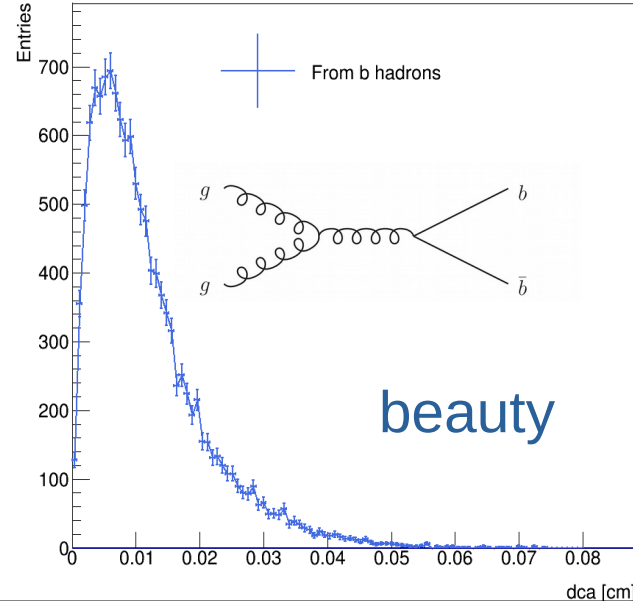
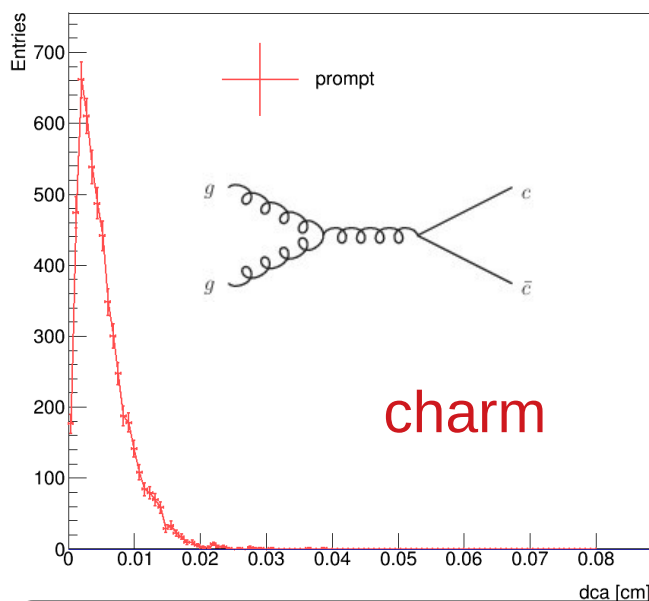
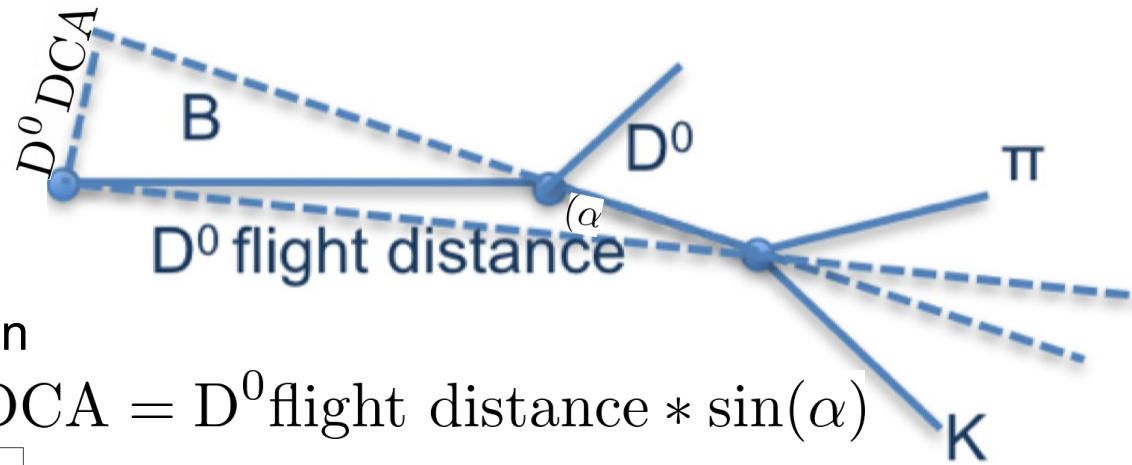
and $B \rightarrow D^0 X \rightarrow K \pi X$



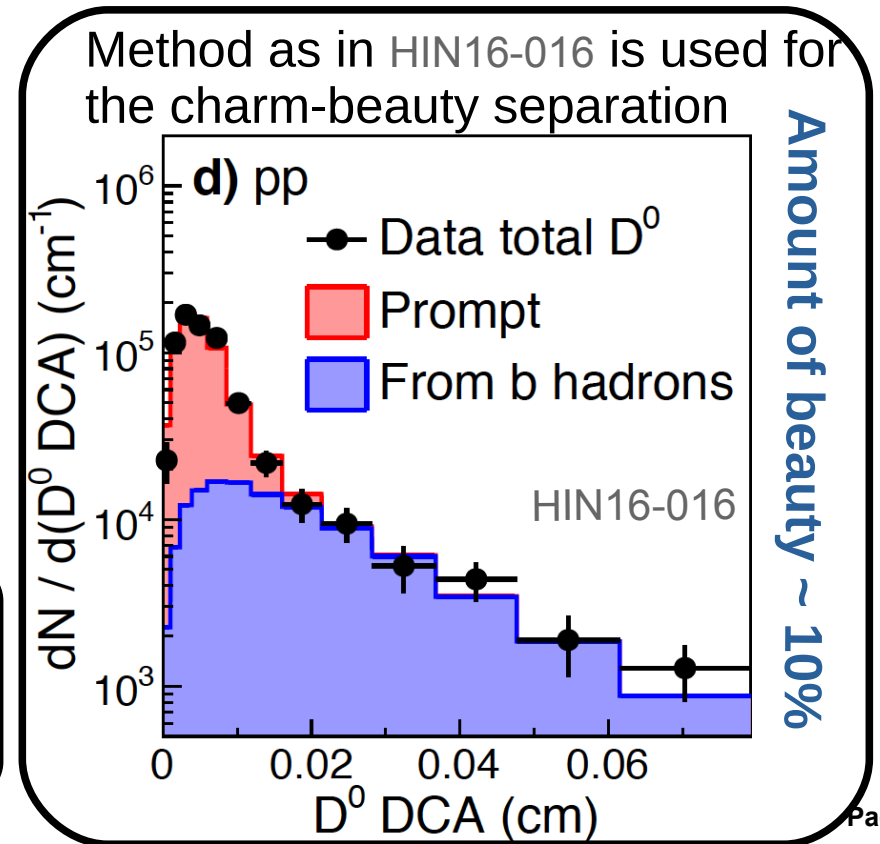
- **Challenge:** Separation of D mesons (**prompt** and **from b hadrons decays**) near the production threshold

Charm-Beauty Separation

- Trained with a MC (**prompt** and **non-prompt** D^0) how to distinguish statistical between **charm** and **beauty**
- Created Distance of Closest Approach (DCA) distribution

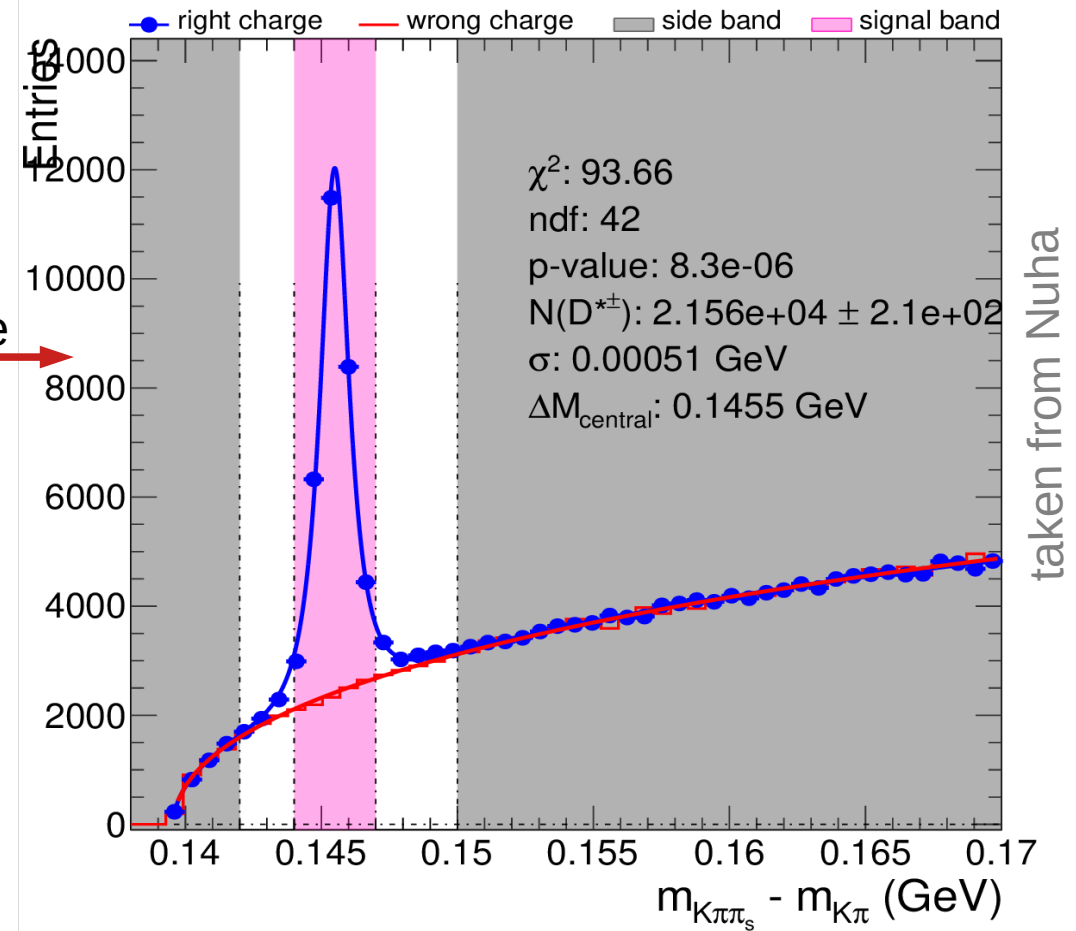
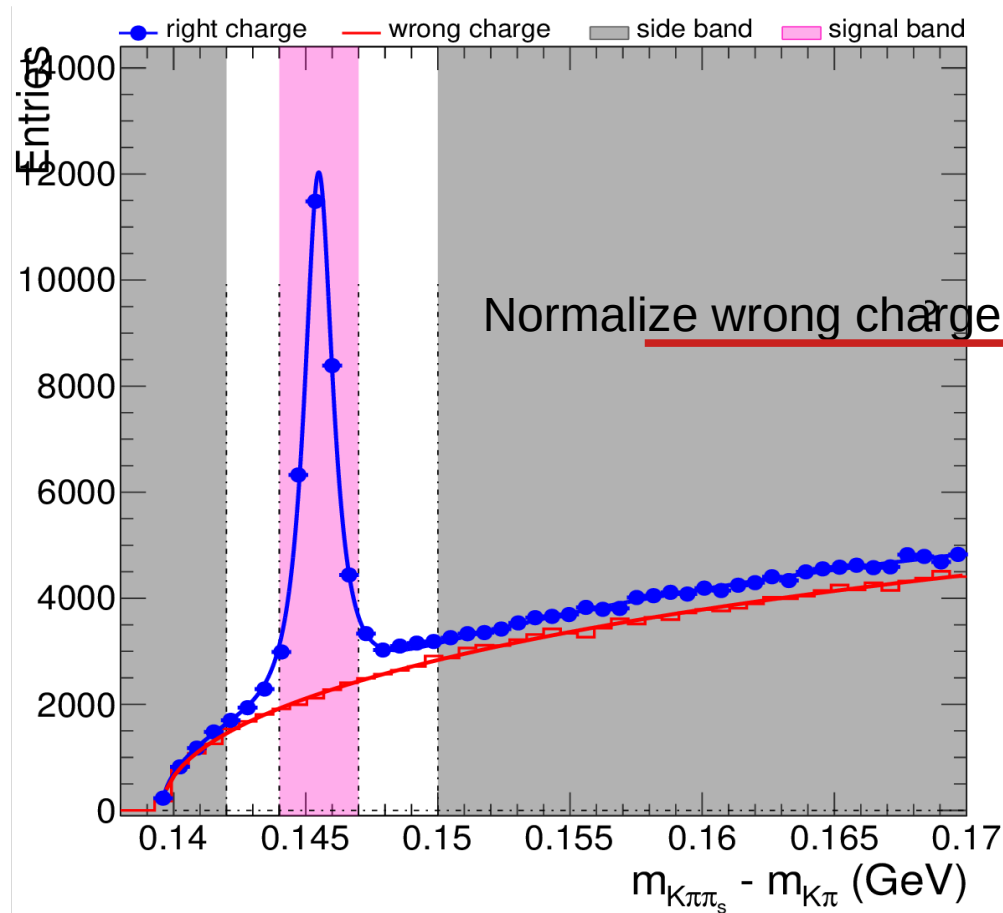


- Shapes are different and can be used to fit
- Used **MC15_PrmtD0pT0** & **MC15_NonPrD0pT0** (details in Backup)



Signal extraction on 5 TeV 2015 data

- We measure $D^* \rightarrow D^0 \pi$; shown distributions have the cuts: $p_T > 3,5 \text{ GeV}$, $|Y| < 1$



- We need to subtract the background in the signal region
- Normalize red to the blue (in grey area) leads to an scale factor of $SF = 1,09983$ in the signal region (pink)

Fitting templates to data

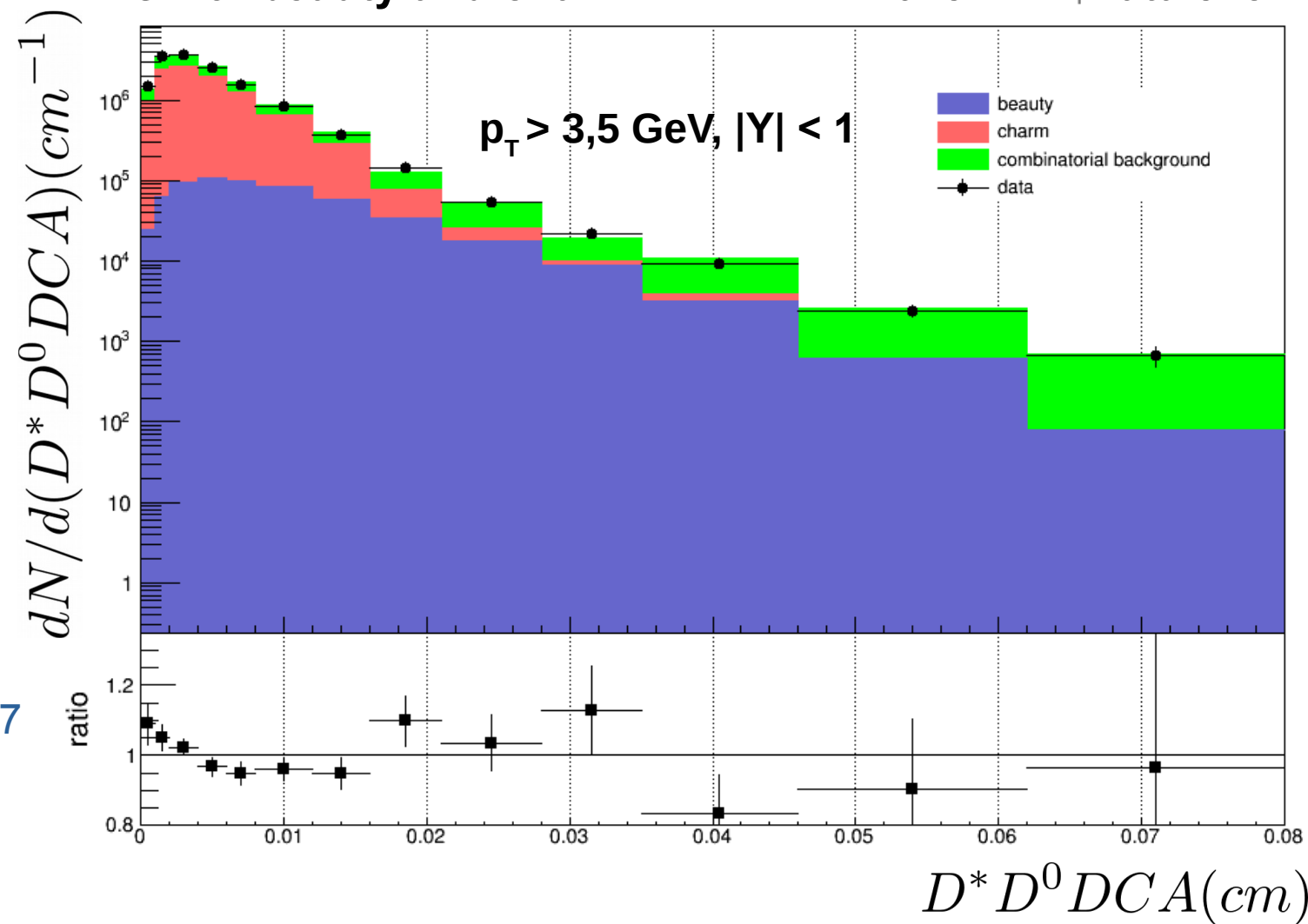
- Used the Higgs combine tool for fitting the templates to the data
- We got the fit parameter:

charm : $+3.884 \quad -0.079/+0.081$

beauty : $+0.142 \quad -0.018/+0.018$

- Integral of input MC **charm** is: $N_c = 4608$
- Integral of input MC **beauty** is: $N_b = 11797$

DCA of beauty and charm in $D^* D^0$ 2015 MinBData 5TeV

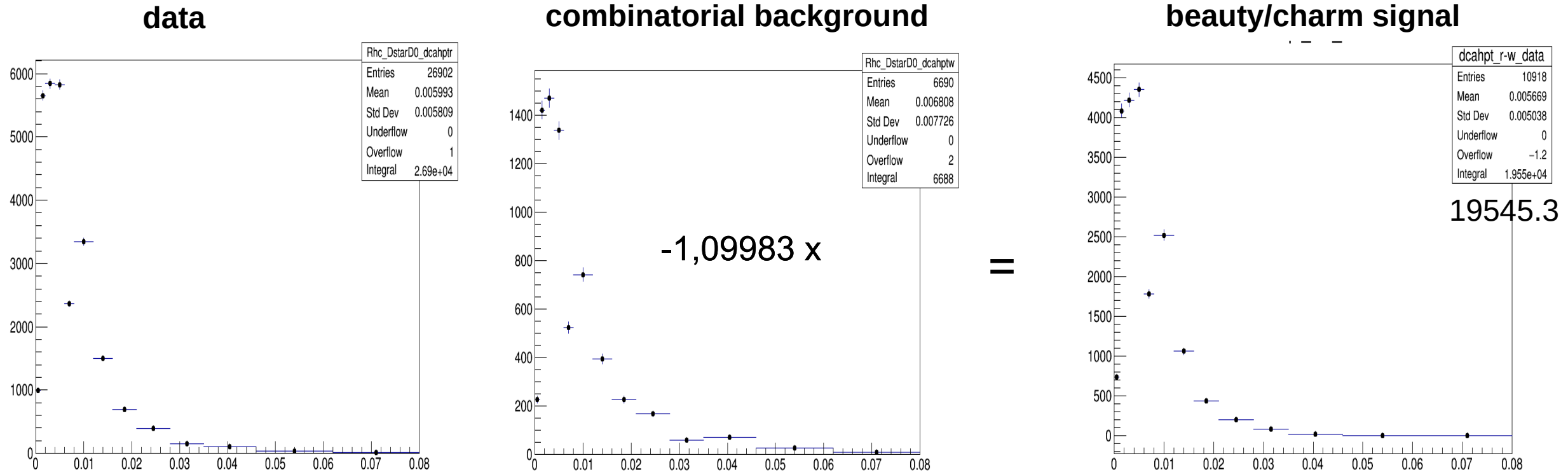


$$N_{c+b} = c \cdot N_c + b \cdot N_b = (3,884 \pm 0,080) \cdot N_c + (0,142 \pm 0,018) \cdot N_b$$

$$= c \cdot 4608 + b \cdot 11797 = \boxed{17897 \pm 369} + \boxed{1675 \pm 212} = 19572 \pm 426$$

The dca-data distributions

- For completeness the calculation of the beauty/charm signal



Charm-Beauty Separation

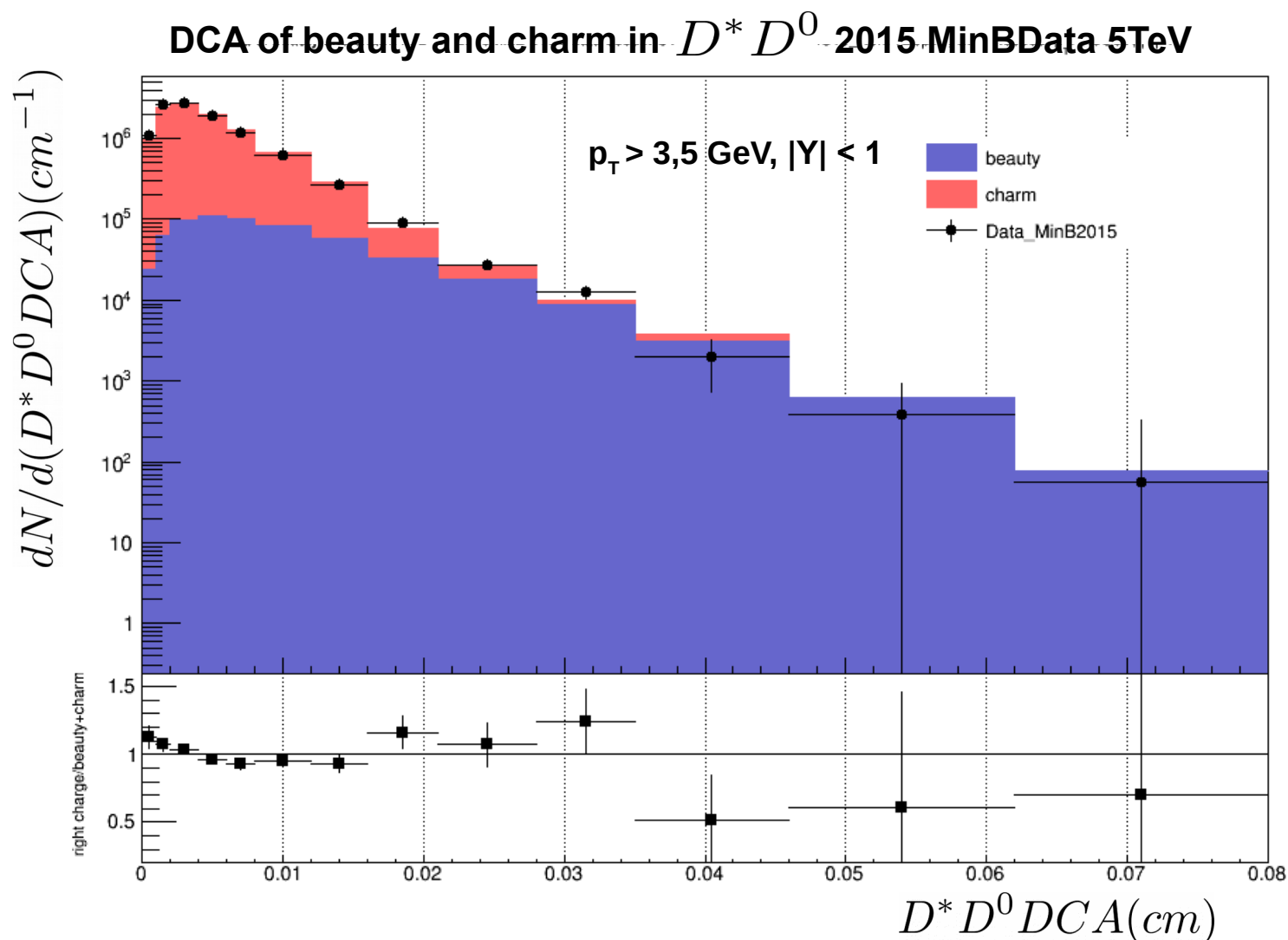
- We found:

→ Fraction of D^* from charm is
(91,4 $\pm$ 1,1)%

→ Fraction of D^* from beauty is
(8,5 $\pm$ 1,1)%

- By checking the MC we expected:
- 89,3% only c cbar
- 7,49% only b bbar
- 3,19% b bbar + c cbar

- charm-beauty separation is under control



Cross section calculation

Idea: calculate in one bin a par. total cross section by using only the information from the MC and in the second step compare it with the measurement from the data in the same bin

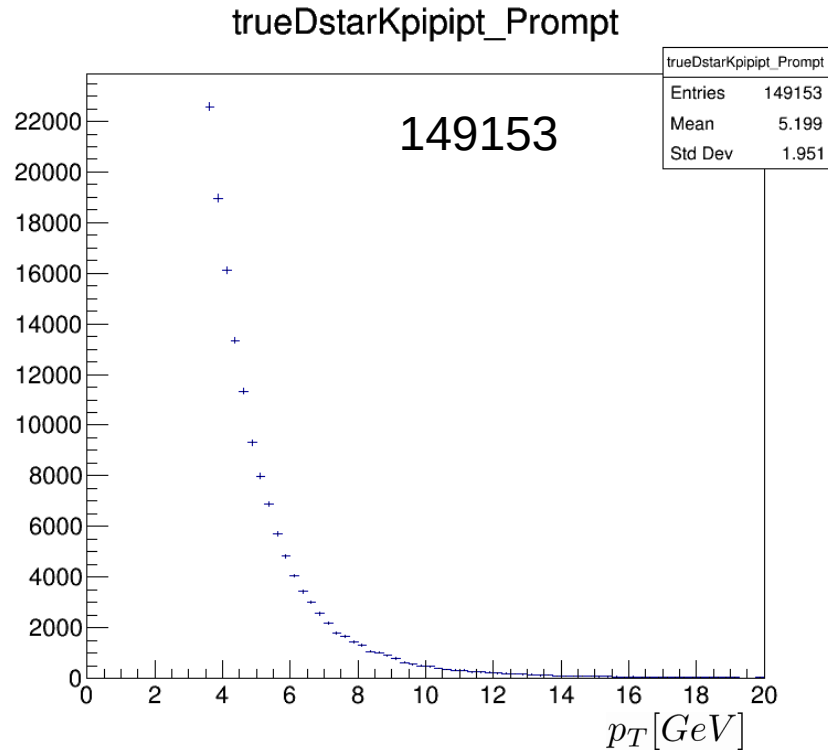
- Using our MC15_D0Kpi sample (details in back up)

$$\mathcal{L}_{eff} = \frac{N}{\sigma} = \frac{12077624}{298700000pb} = \frac{12077624}{298,7\mu b} = \boxed{40,43nb^{-1}}$$

got information from MCM: https://cms-pdmv.cern.ch/mcm/requests?dataset_name=D0Kpi_pT0toInf_TuneCUEP8M1_5TeV_pythia8-evtgen&page=0&shown=127

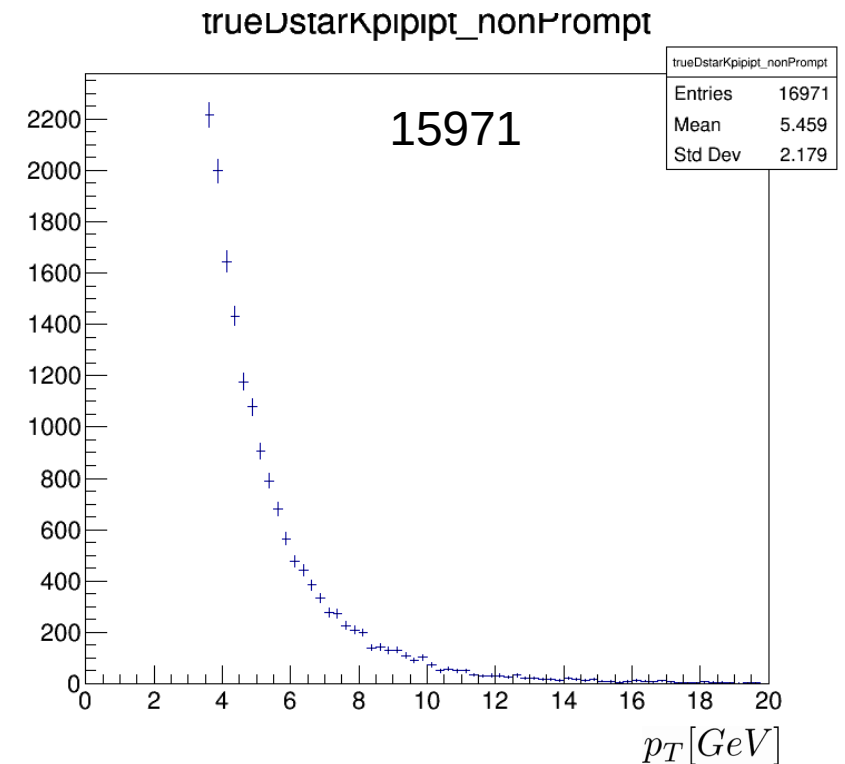
Calculate for $p_T > 3,5$ and $|Y| < 1$ par. total cross section for **charm/beauty** by using only the MC

- selected D^* full fill the decay chain: $D^* \rightarrow D^0 \pi \rightarrow K \pi \pi$ (used prompt/nonprompt flag at generator level)



$$\sigma_{pp \rightarrow D^*_{prompt} \rightarrow D^0 \pi \rightarrow K \pi \pi} = \frac{N_{D^*_{prompt}}}{\mathcal{L}_{eff}}$$

$$= \frac{149153}{40,43 nb^{-1}} = 3689,16 nb = 3,69 \mu b$$

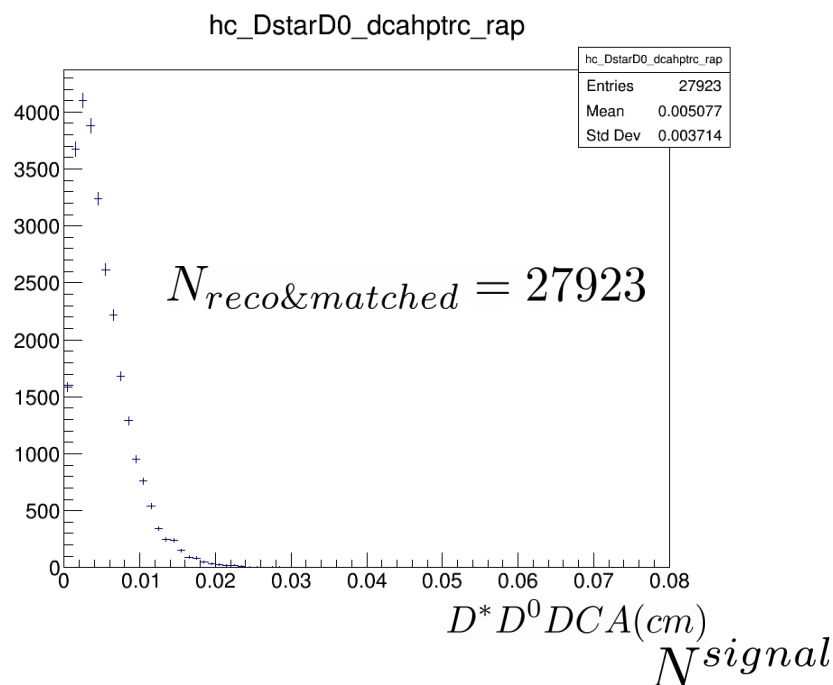


$$\sigma_{pp \rightarrow D^*_{nonprompt} \rightarrow D^0 \pi \rightarrow K \pi \pi} = \frac{N_{D^*_{nonprompt}}}{\mathcal{L}_{eff}}$$

$$= \frac{15971}{40,43 nb^{-1}} = 395,02 nb = 0,40 \mu b$$

Calculate for $p_T > 3,5$ and $|Y| < 1$ par. total cross section for **charm/beauty** in 2015 MinBData 5TeV

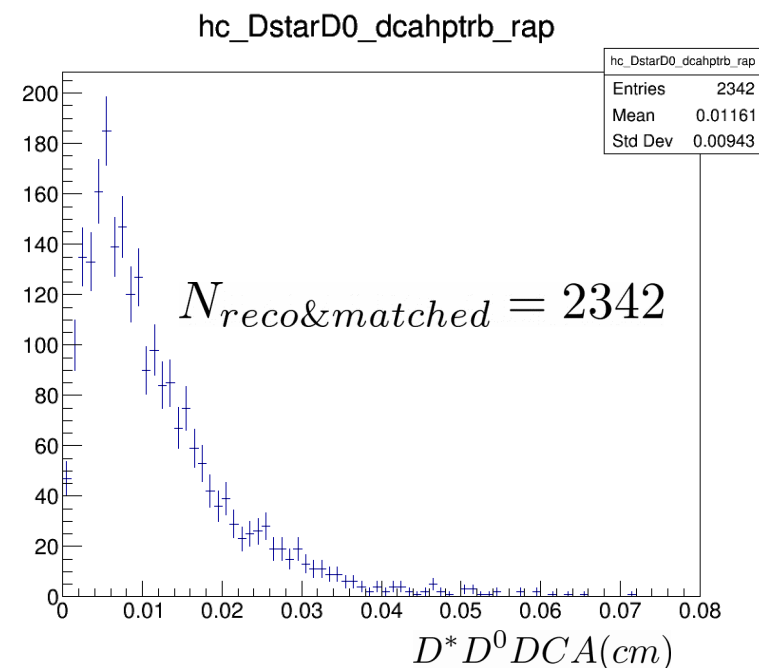
- Luminosity: used brilcalc $\mathcal{L}_{int} = 27,9nb^{-1}$ consistent with expectations
- Efficiency: $\epsilon = \frac{N_{reco\&matched}}{N_{true}}$ reconstructed true D^* at simulated vertex (used charm/beauty flag at reco level)



$$\sigma_{pp \rightarrow D^*_{prompt} \rightarrow D^0 \pi \rightarrow K \pi \pi} = \frac{N^{signal}}{\mathcal{L}_{int} \cdot \epsilon}$$

$$= \frac{17897}{27,95nb^{-1} \cdot \frac{27923}{149153}} = 3420,52nb = 3,42\mu b$$

from data dca fit
see page 5



$$\sigma_{pp \rightarrow D^*_{nonprompt} \rightarrow D^0 \pi \rightarrow K \pi \pi} = \frac{N^{signal}}{\mathcal{L}_{int} \cdot \epsilon}$$

$$= \frac{1675}{27,95nb^{-1} \cdot \frac{2342}{15971}} = 408,78nb = 0,41\mu b$$

Summary and outlook for 2015 5 TeV

- We will use the shown procedure bin by bin in full phase space
- Got luminosity $\mathcal{L} = 27,9 \text{ nb}^{-1}$
- Calculate efficiencies bin by bin in full phase space (on the way)
- Calculate cross sections for D^* from b hadron decays bin by bin in full phase space
- Get reference cross sections by using FONLL

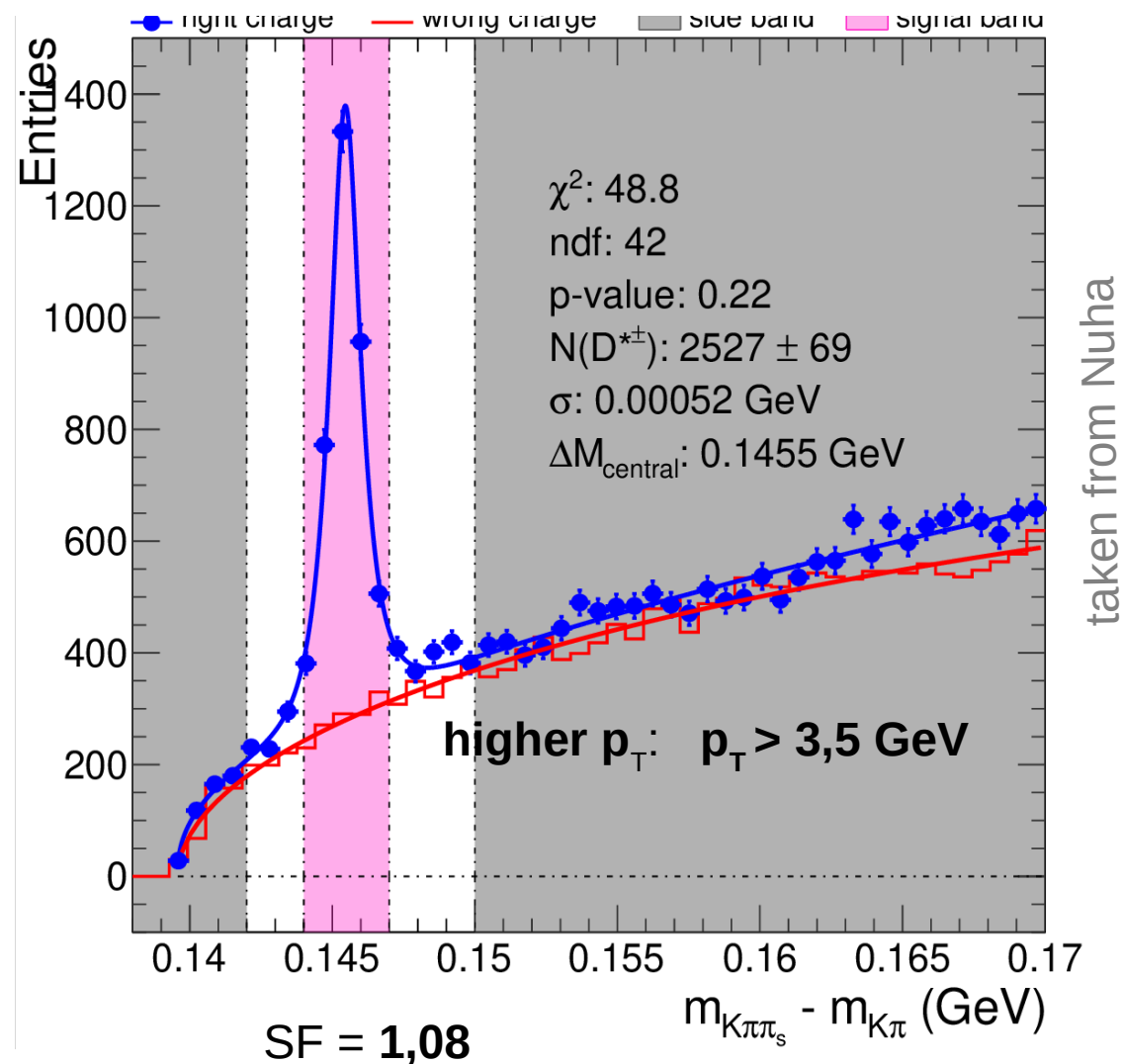
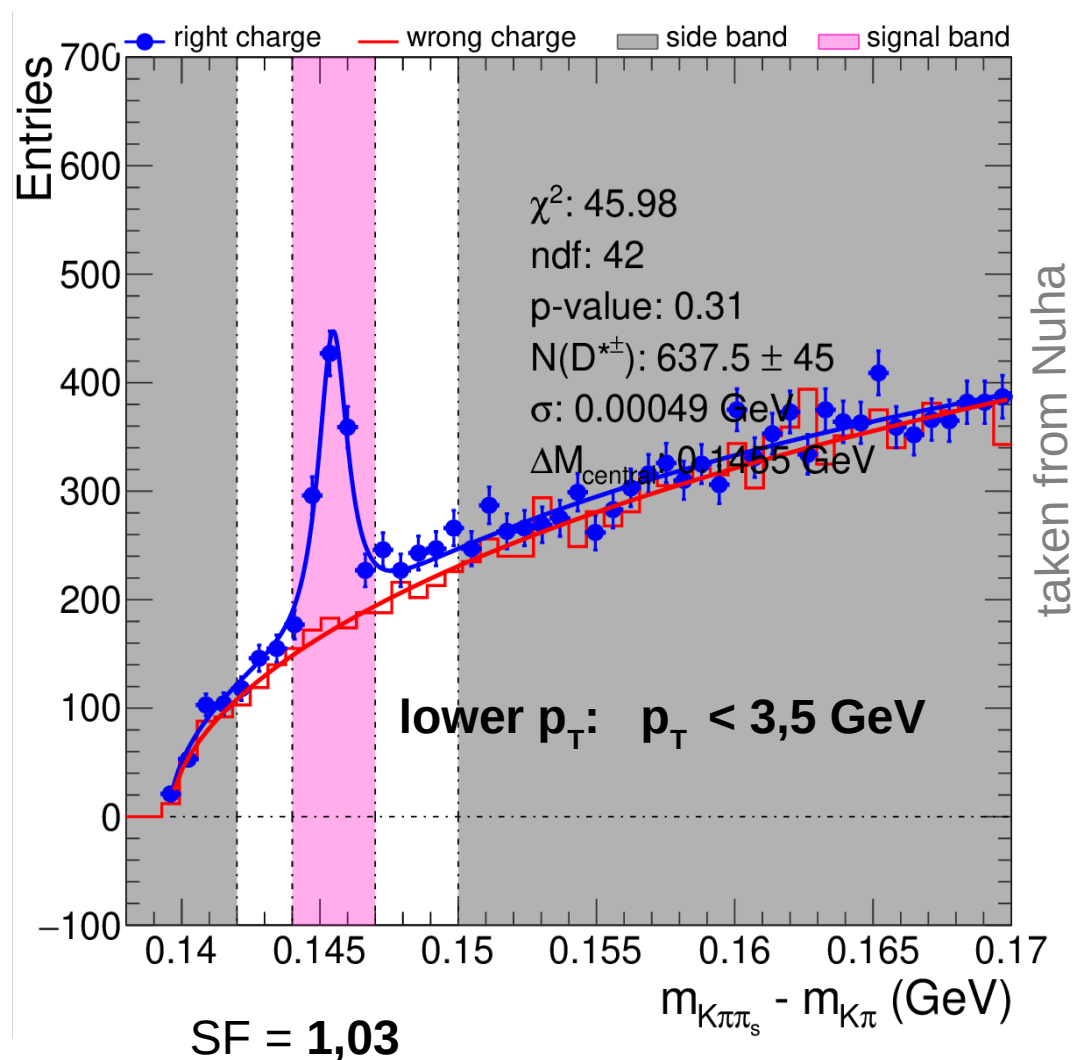
Is the Charm-Beauty Separation possible in 2010 7 TeV data

We look now in the phase space:

- $|Y| < 2,5$ and $p_T < 3,5$
- $|Y| < 2,5$ and $p_T > 3,5$

Signal extraction on 7 TeV 2010 data

Normalize red to the blue (in grey area) leads to a scale factor in the signal region (pink) for lower/higher p_T region of:



Charm-Beauty Separation in 2010 7 TeV data

- Used the Higgs combine tool for fitting the templates to the data

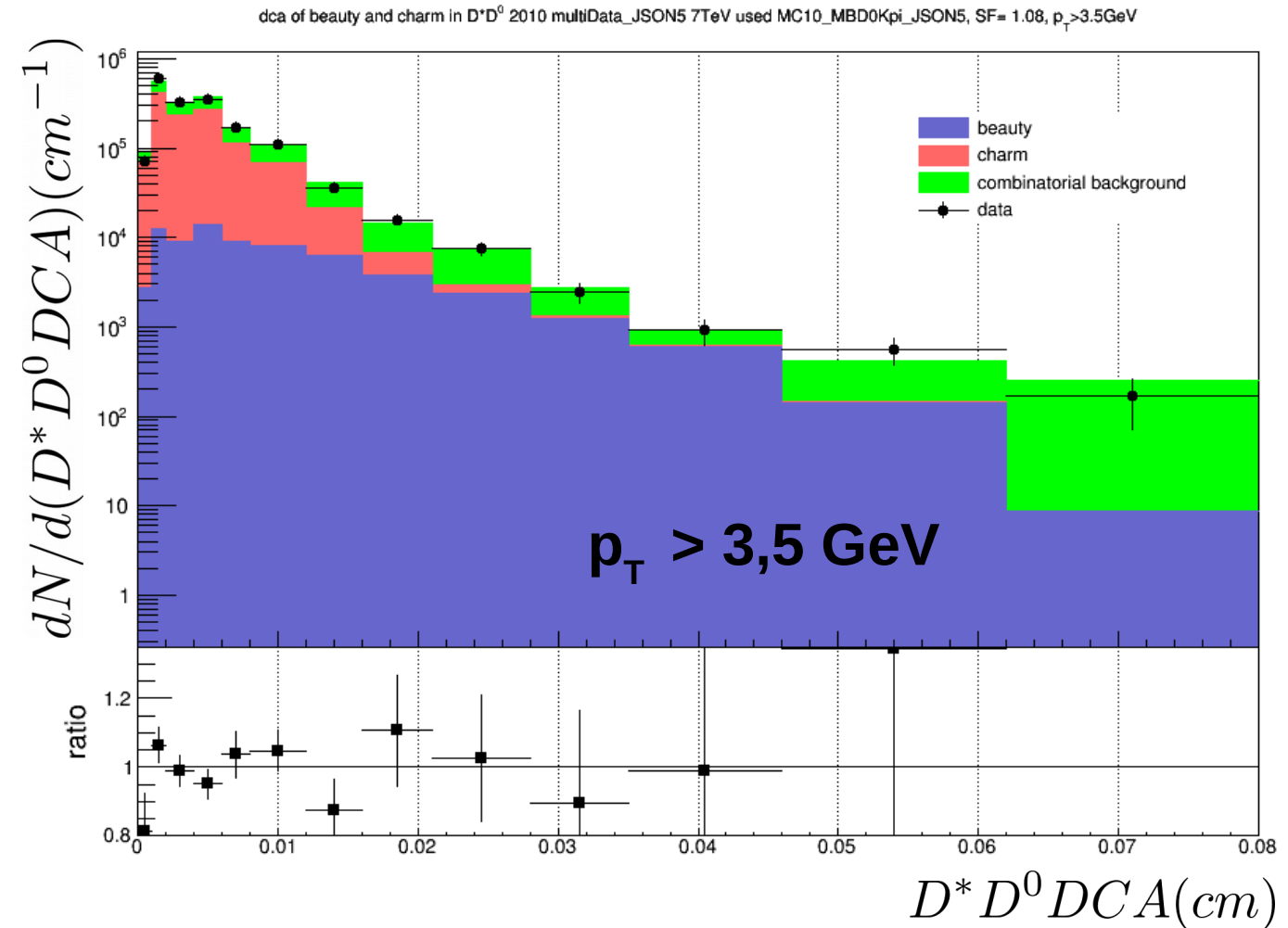
- Got the fit parameter:

charm : $+0,06 \quad -0.002/+0.002$

beauty : $+0.078 \quad -0.02/+0.02$

- Integral of input MC **charm** is: $N_c = 32583$

- Integral of input MC **beauty** is: $N_b = 2449$



$$N_{c+b} = c \cdot N_c + b \cdot N_b = (0,06 \pm 0,002) \cdot N_c + (0,078 \pm 0,02) \cdot N_b$$

$$= c \cdot 32583 + b \cdot 2449 = (1954,98 \pm 65,16) + (191,02 \pm 48,98) = 2146 \pm 81,52$$

Charm-Beauty Separation in 2010 7 TeV data

- Used the Higgs combine tool for fitting the templates to the data

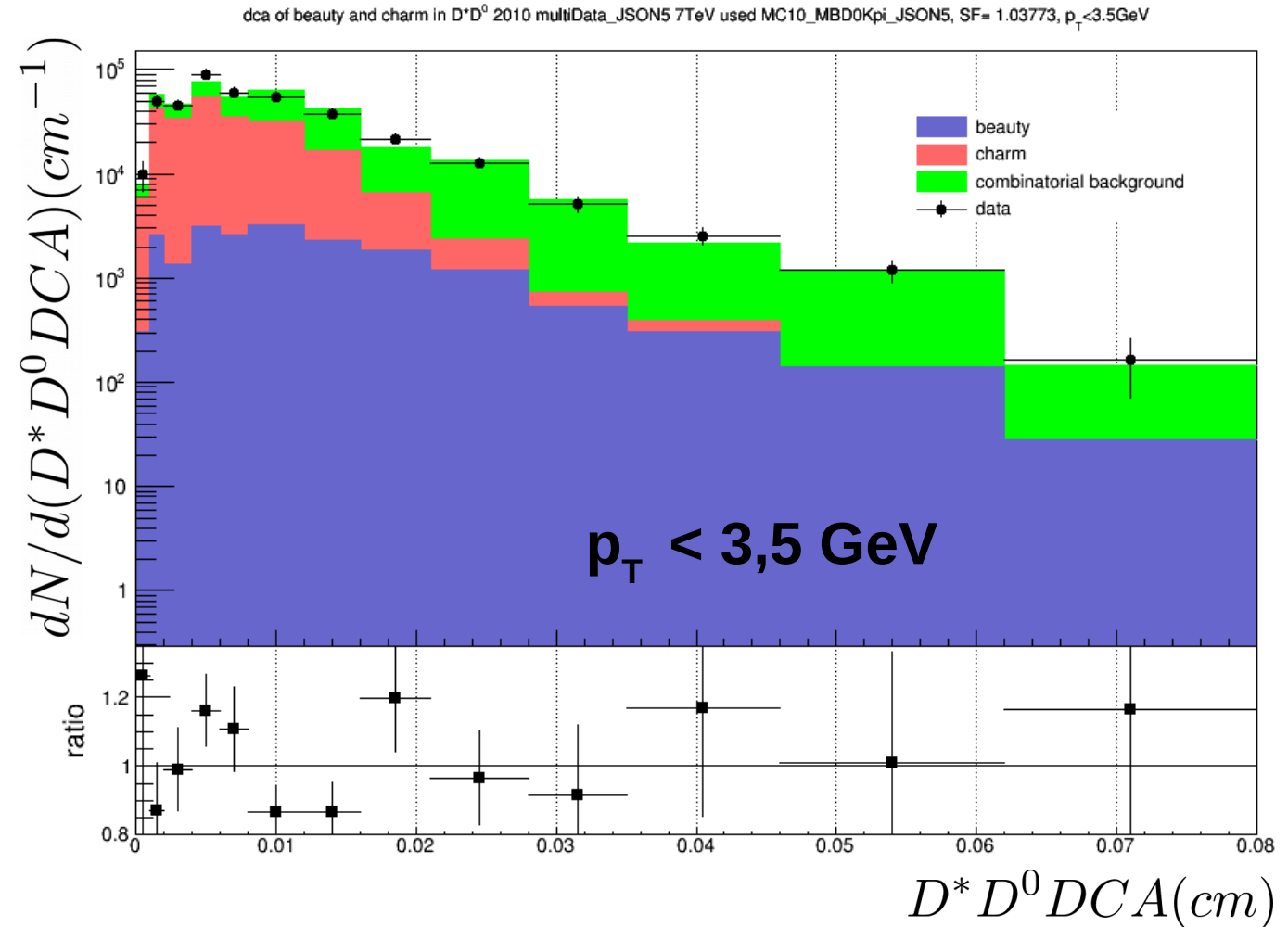
- Got the fit parameter:

charm : $+0,084 \pm 0,008$

beauty : $+0,101 \pm 0,082$

- Integral of input MC **charm** is: $N_c = 5810$

- Integral of input MC **beauty** is: $N_b = 660$



$$N_{c+b} = c \cdot N_c + b \cdot N_b = (0,084 \pm 0,008) \cdot N_c + (0,101 \pm 0,082) \cdot N_b$$

$$= c \cdot 5810 + b \cdot 660 = (488,04 \pm 46,48) + (66,66 \pm 54,12) = 554,70 \pm 71,34$$

Charm-Beauty Separation in 2010 7 TeV data

- Conclusion:
 - for $p_T > 3,5$:
 - → Fraction of D^* from charm is $(91,1 \pm 2,3) \%$
 - → Fraction of D^* from beauty is $(8,9 \pm 2,3) \%$
 - for $p_T < 3,5$:
 - → Fraction of D^* from charm is $(87,9 \pm 9,9) \%$
 - → Fraction of D^* from beauty is $(12,0 \pm 9,9) \%$
- charm beauty separation is possible in 2010 7 TeV data and useful for the calculation of the charm cross section in full phase space

**Thank you for
your attention**

Backup

- Trained with a MC (**prompt** and **non-prompt** D^0) how to distinguish statistical between **charm** and **beauty** and created Distance of Closest Approach (DCA) distribution (HIN16-016) , Used:
 - **MC15_PrmtD0pT0**: /PrmtD0_pThat-0_pT-0_pp_5p02-Pythia8/HINppWinter16DR-75X_mcRun2_asymptotic_ppAt5TeV_v3-v1/AODSIM, 1347186 events
 - **MC15_NonPrD0pT0**: /NonPrD0_pThat-0_pT-0_pp_5p02-Pythia8/HINppWinter16DR-75X_mcRun2_asymptotic_ppAt5TeV_v3-v1/AODSIM, 1942712 events
 - **MC15_D0Kpi**: /D0Kpi_pT0toInf_TuneCUPEP8M1_5TeV_pythia8-evtgen/HINppWinter16DR-75X_mcRun2_asymptotic_ppAt5TeV_v3-v3/AODSIM, "pdmv_evts_in_DAS": 12077624