Status of charm and beauty cross sections at 5 TeV

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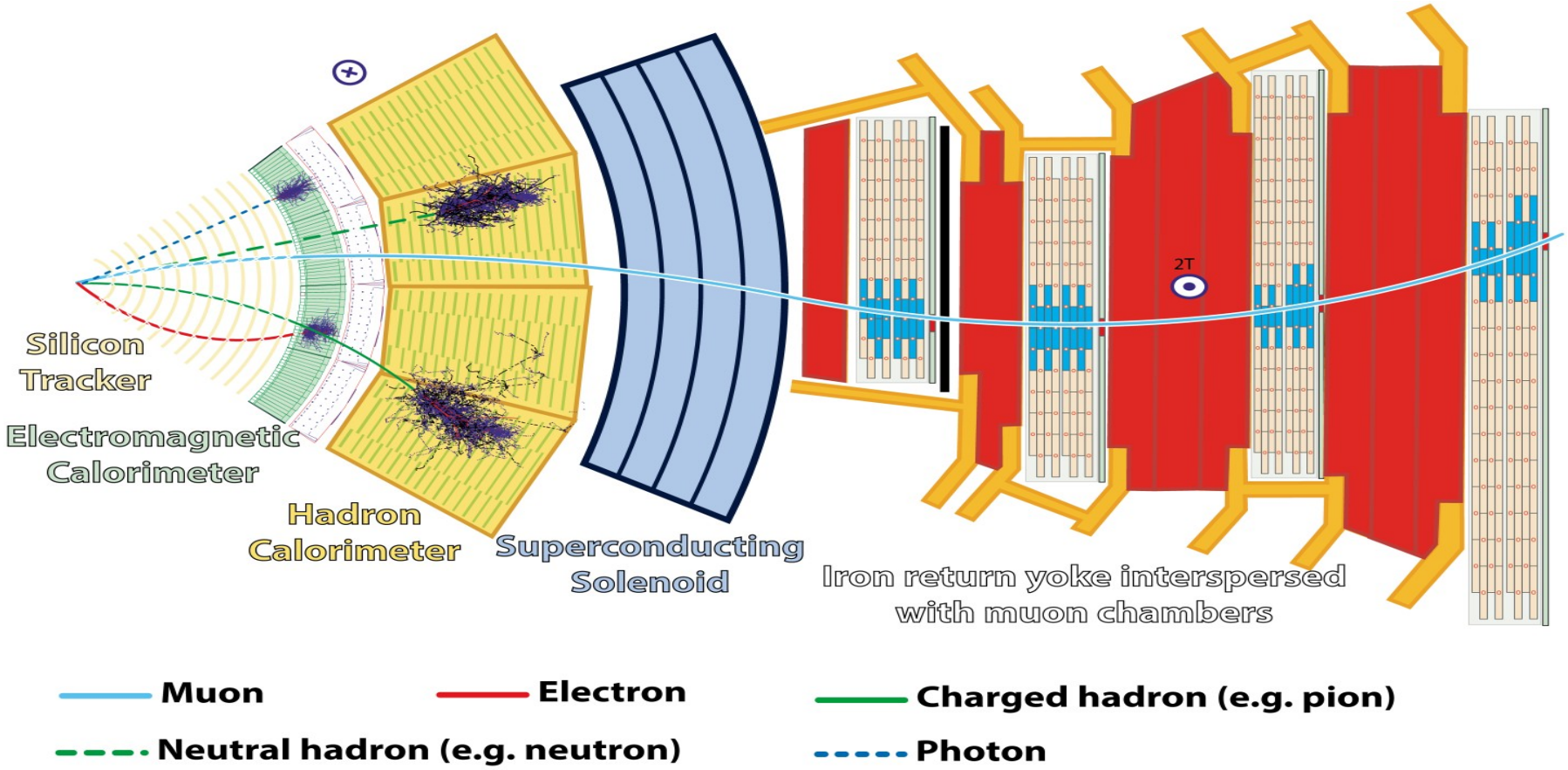
Introduction to CMS

- The CMS detector consists of a silicon tracker detector (largest of the world) electromagnetic calorimeter, hadron calorimeter and muon detectors

- Total weight: 12 500 t
- Diameter: 15m
- Total Length: 21m
- Collision Rate: 40 MHz
- Magnetic Field:
  - Solenoid: 4T
  - Yoke: 2T

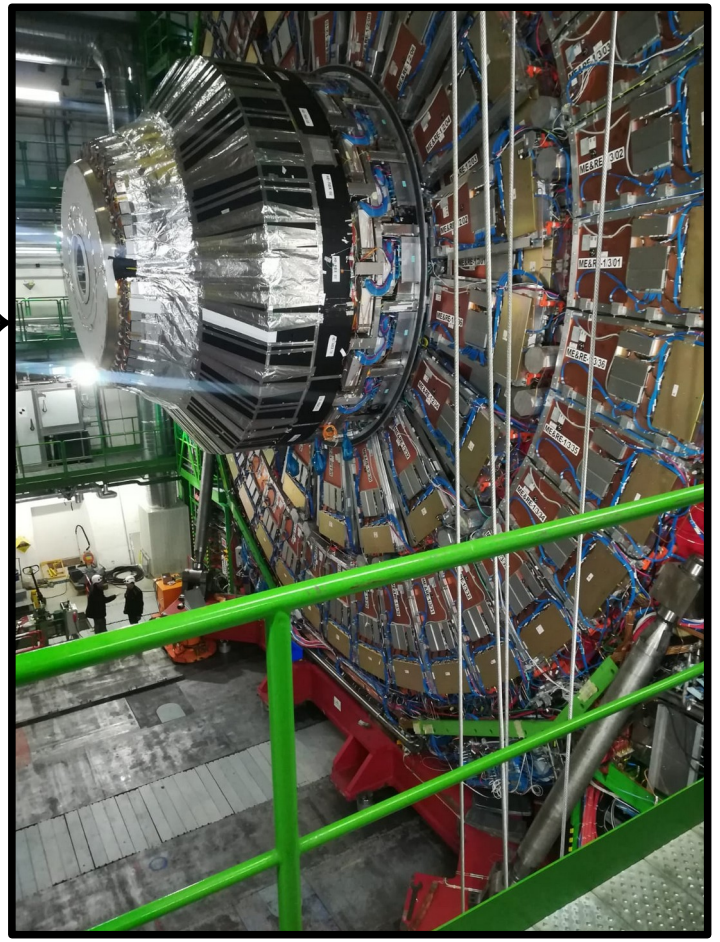


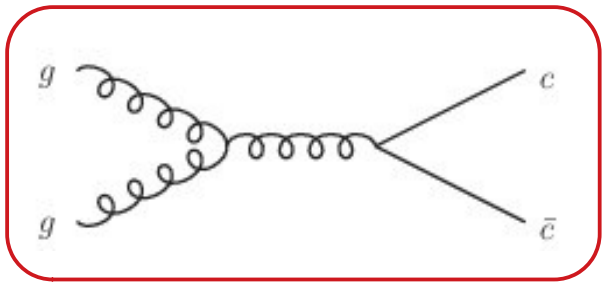
My PhD project

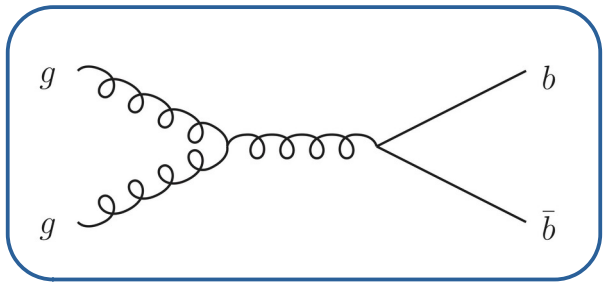
- Measure total beauty cross sections at different center of mass energies 0.9, 2.76, **5**, 7, 8, and 13 TeV, smallest theory extrapolation for the first time in →
- Measure cross sections in full phase space of D mesons from b hadron decays in small bins in p_T and |y| (rapidity) and integrate
- Decays:

$$B \to D^* X \to D^0 \pi_s X \to K\pi\pi_s X$$

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





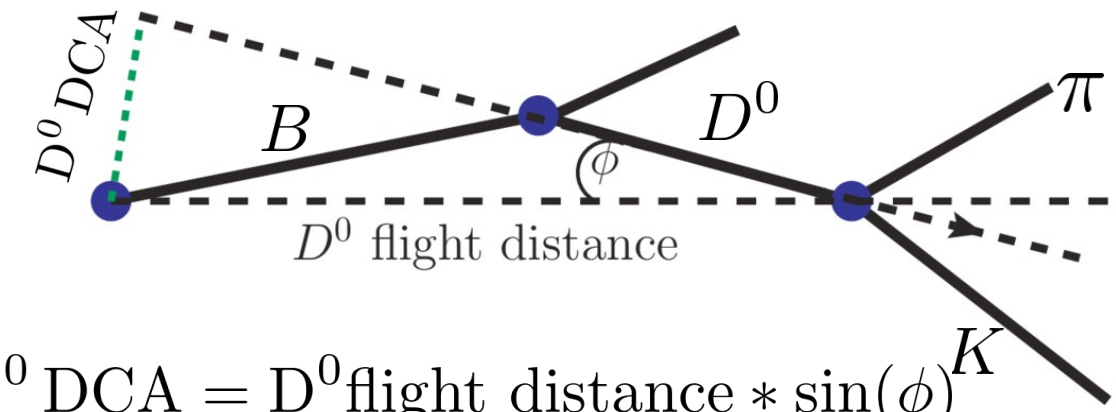


- **Challenge**: Separation of D mesons (prompt and from b hadrons decays) near the production threshold

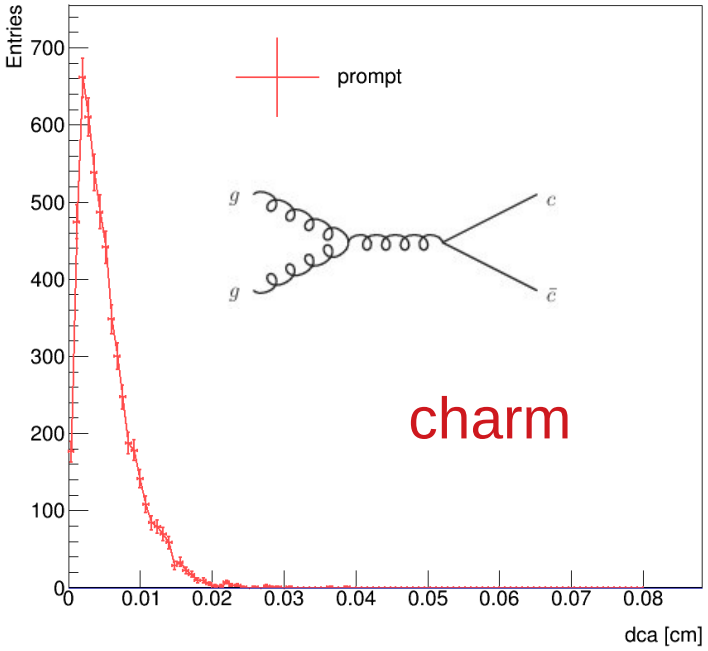
Charm-Beauty Separation

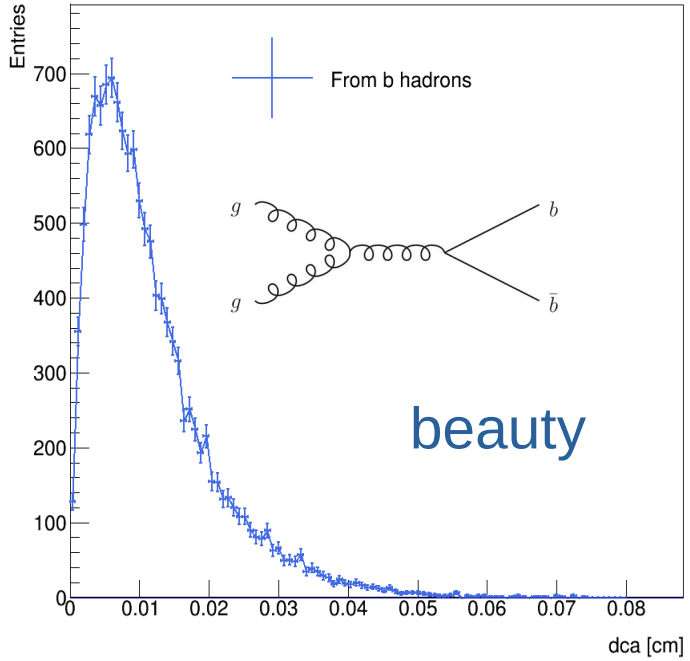
- Trained with MC (prompt and non-prompt D^0) how to distinguish statistical between charm and beauty

- Distance of Closest Approach (DCA) distribution



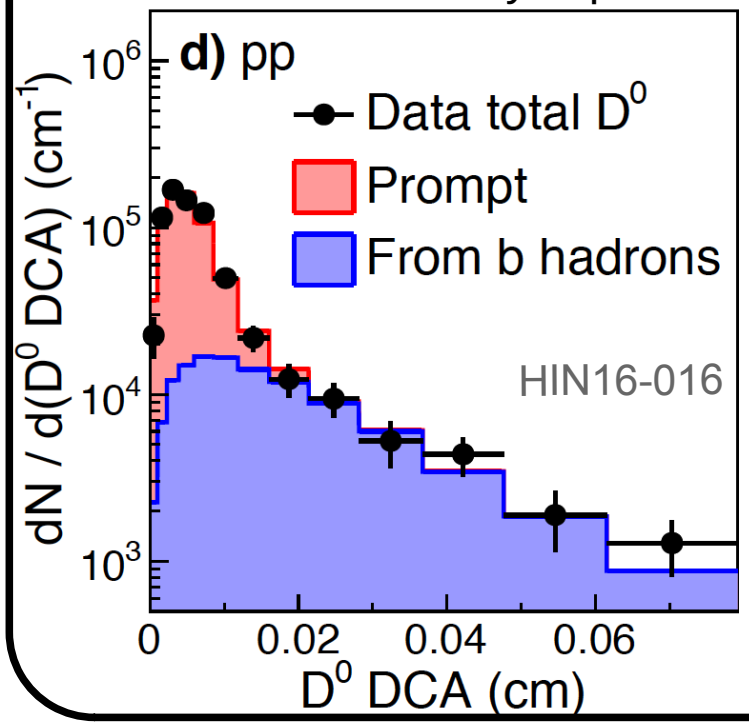
$$\mathrm{D^0\ DCA} = \mathrm{D^0 flight\ distance} * \sin(\phi)$$





Shapes are different and can be used to fit

Method as in CMS-HIN-16-016 is used for the charm-beauty separation



Used cuts for selection of $D^{*\pm} \to D^0 \pi_s^{\pm} \to K^{\mp}\pi^{\pm}\pi_s^{\pm}$

the D^* system

right charge $K^{\mp}\pi^{\pm}\pi_s^{\pm}$ with a real D⁰	wrong charge $K^{\mp}\pi^{\mp}\pi_s^{\pm}$ comb bg

use both to extract a very clear signal

- Track p_T cut: $p_T^{K,\pi} > 0.5\ GeV$ none for slow pion π_s
- D⁰ mass cut: $1.836 < m_{D^0} < 1.892\ GeV$
- We define our cuts in two p_T regions differently:
  - in the **higher** p_T region $p_T^{D^*} > 3.5\ GeV$

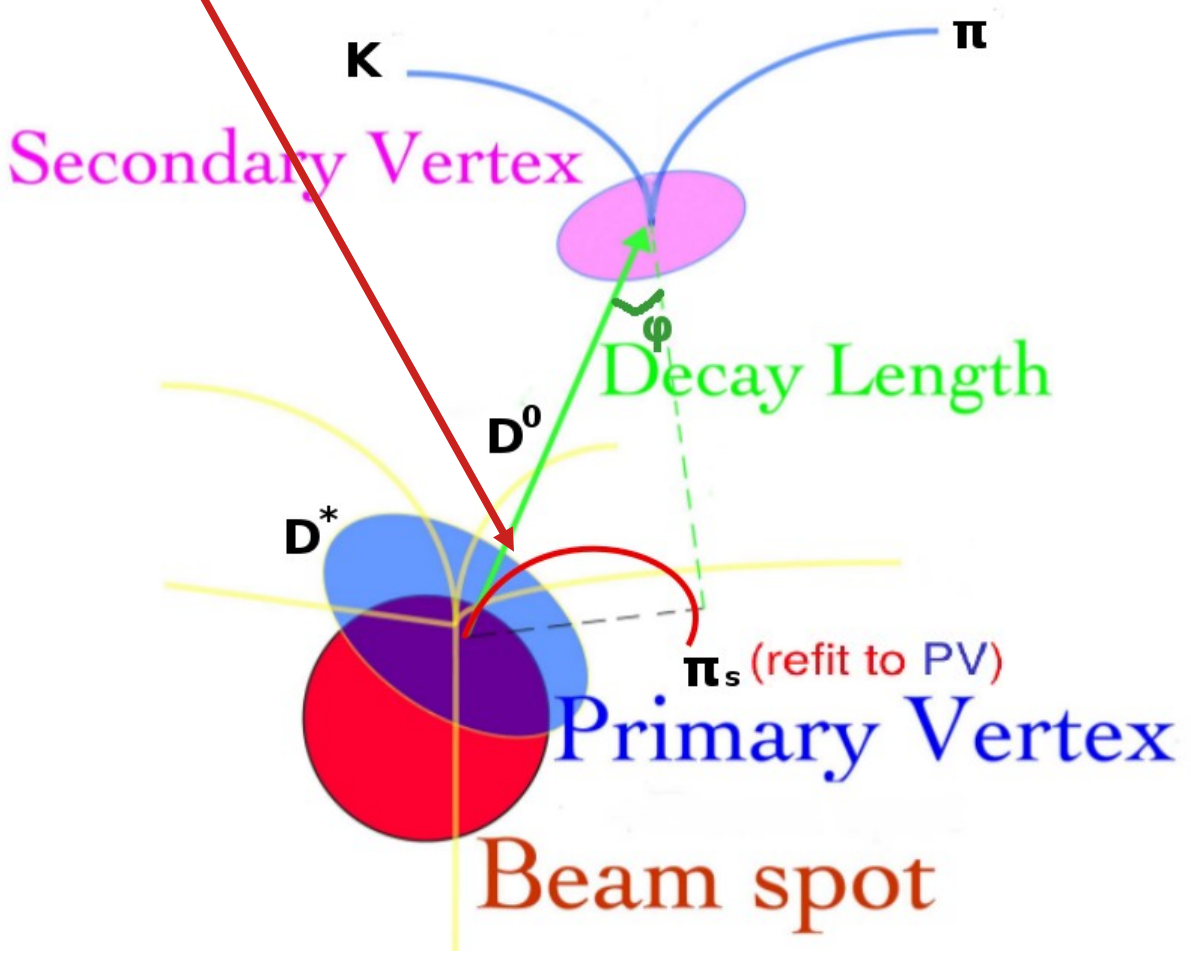
$$\left(dl_{sig}^{D^0} > 0 \ \ \& \ \ pt_{Tfrac}^{D^*} > 0.15 \ \ \& \ \ \cos(\phi) > 0.8\right) or\ dl_{sig}^{D^0} > 2$$

  - in the **lower** p_T region $p_T^{D^*} < 3.5\ GeV$

$$\mathrm{pt}_{Tfrac}^{D^0} > 0.1 \ \ \& \ \ \cos(\phi) > 0.8 \ \ \&$$

$$\left\{\left(dl_{sig}^{D^0} > 1.5\ \&\ pt_{Tfrac}^{D^*} > 0.15\right) \ or \ \left(dl_{sig}^{D^0} > 2\ \&\ \cos(\phi_{D^0}) > 0.995\right) \ or\ dl_{sig}^{D^0} > 3\right\}$$

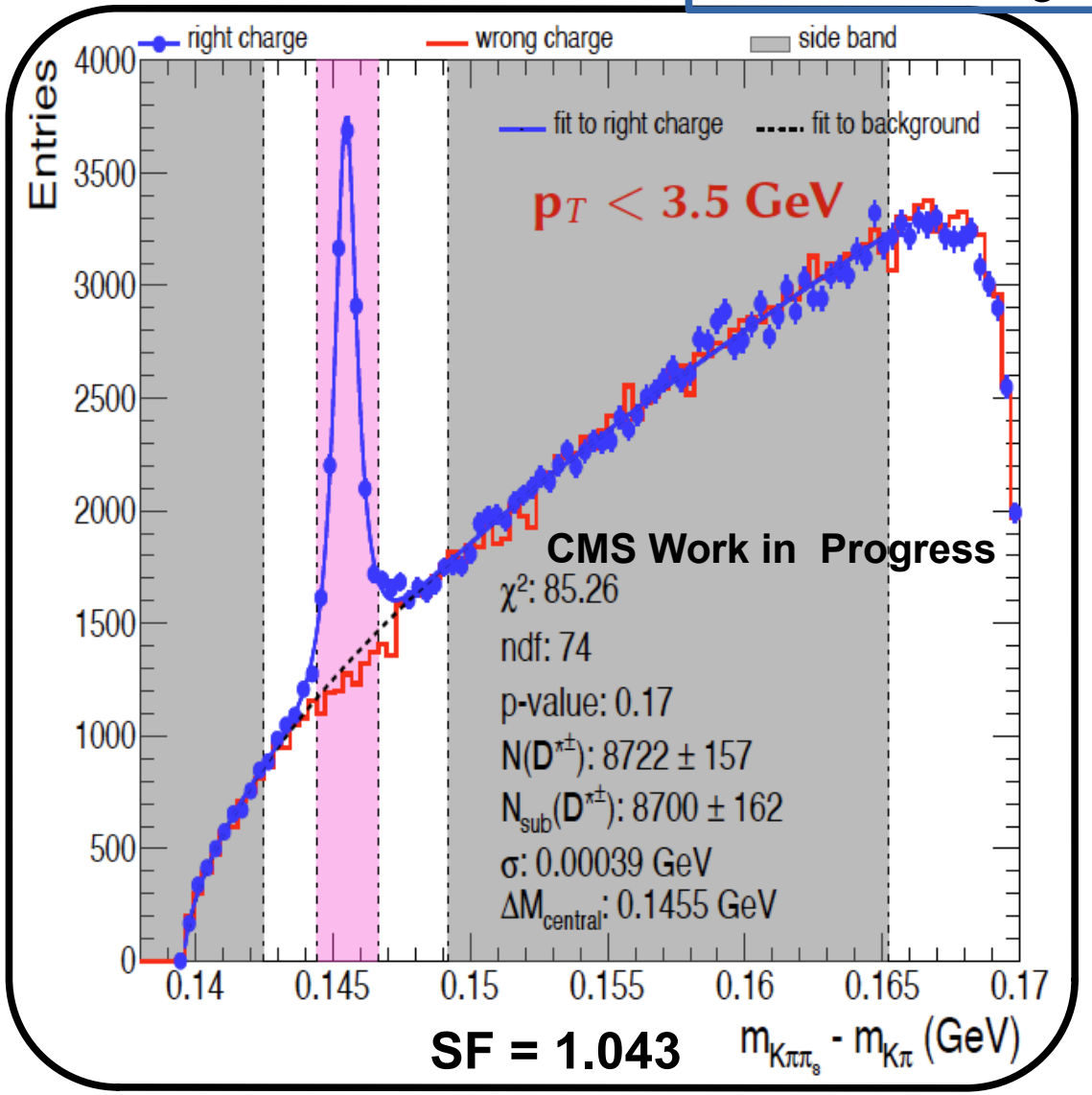
- With: $p_{Tfrac} = \dfrac{p_T\ of D\ meson}{p_T\ of \Sigma_{\text{at respective PV}}^{\text{all tracks}}}$ $\qquad dl_{sig}^{D^0} = \dfrac{dl^{D^0}}{dl_{err}^{D^0}}$



Signal extraction on 5 TeV 2015 data

right charge $K^{\mp}\pi^{\pm}\pi_s^{\pm}$ with a real D^0	wrong charge $K^{\mp}\pi^{\mp}\pi_s^{\pm}$ comb bg
use both to extract a very clear signal	

- We measure $D^{*\pm} \rightarrow D^0\pi_s^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi_s^{\pm}$ and need to subtract the background in the signal region
  - Normalize red to the blue (in grey area) leads to an scale factor (SF)
  - Apply the scale factor to red and subtract it in the signal region (pink) from blue to get a clear signal



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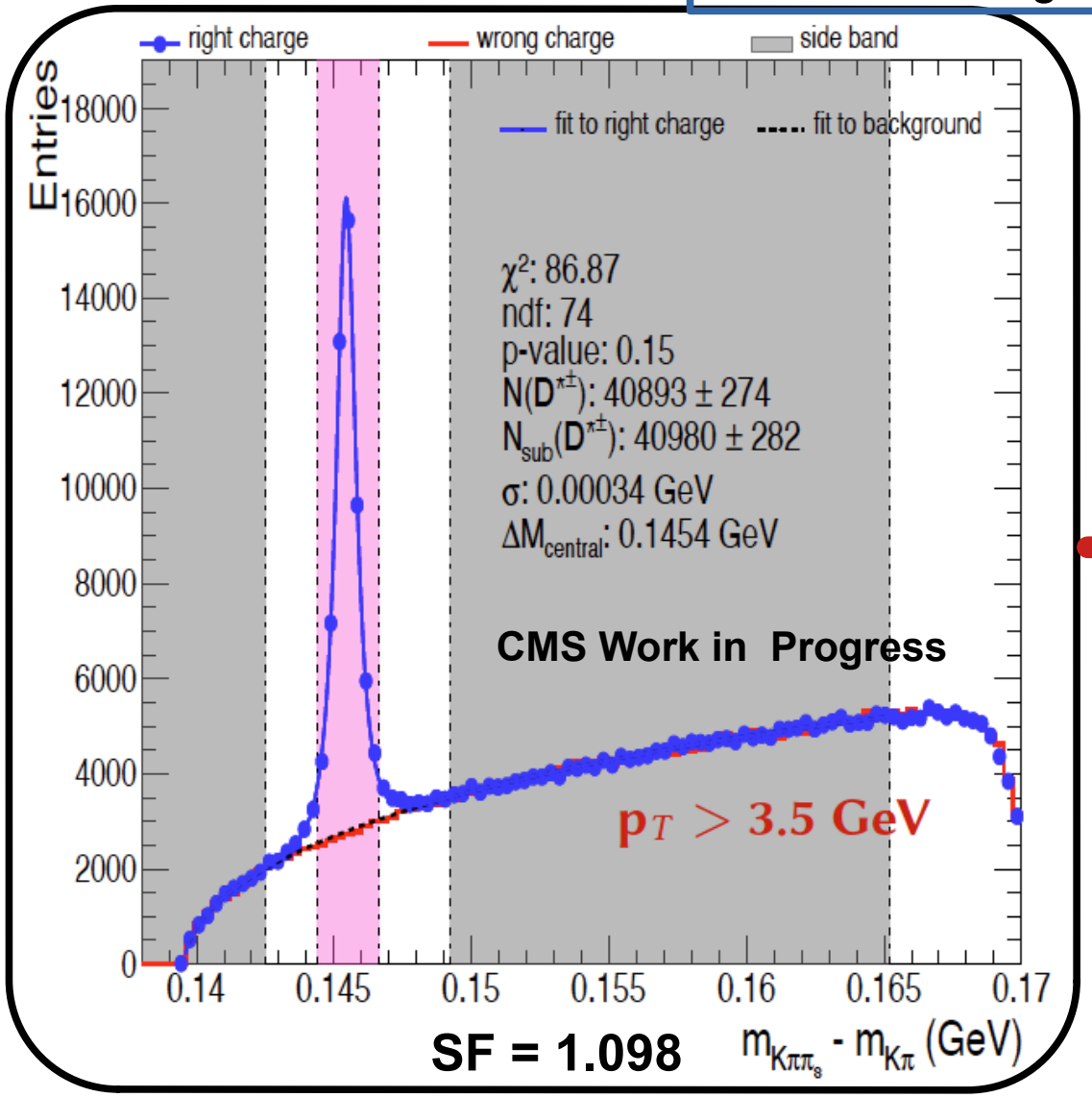


next slide

Fitting to data

- Fit the MC templates to the data
  - $N_c^{signal} = 38346.7^{+377.8}_{-377.7}$
  - $N_b^{signal} = 2665.7^{+280.8}_{-271.6}$
- Partial total cross section in phase space:

$$p_T > 3.5\,GeV \quad |y| < 2.5$$

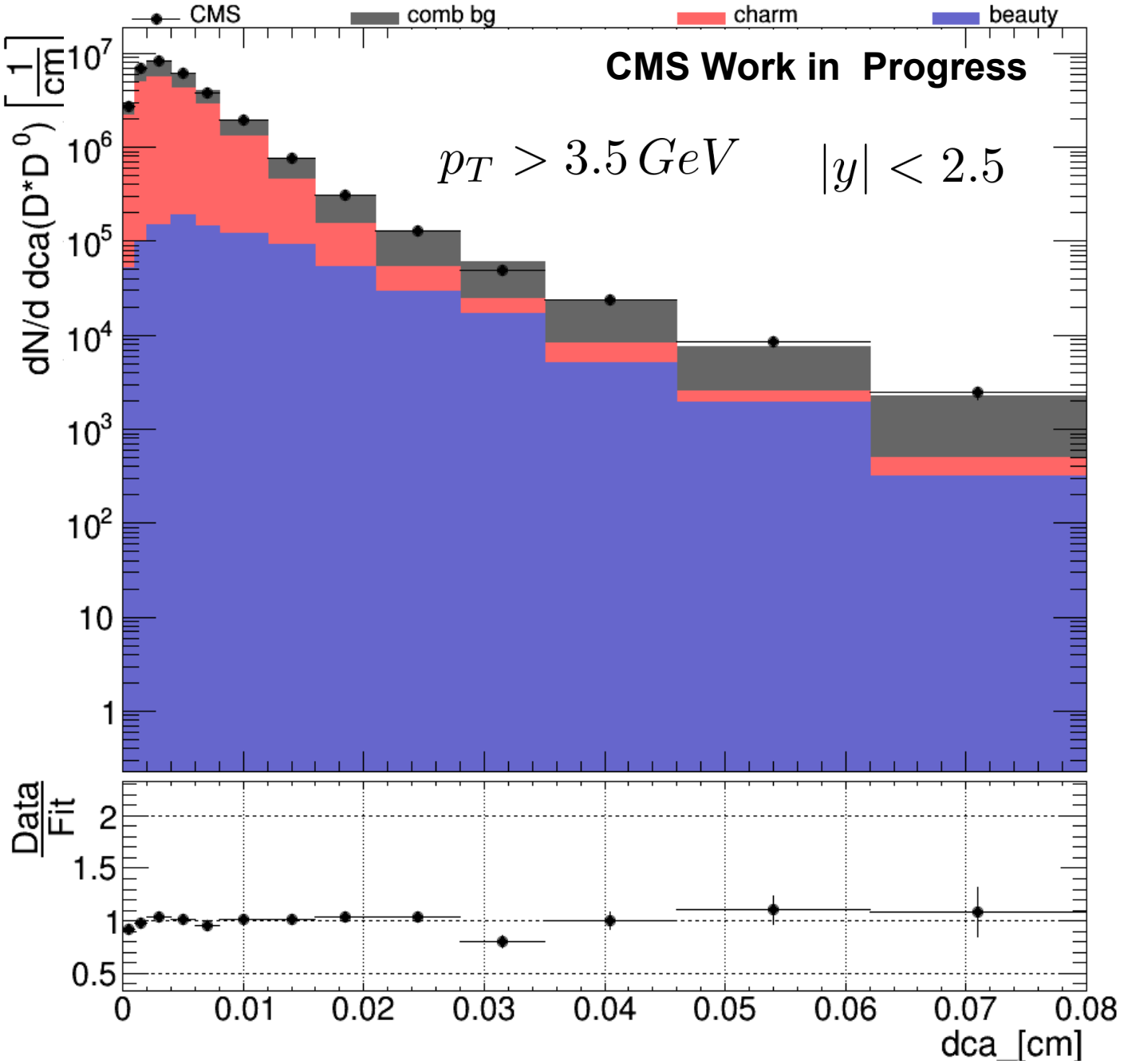
$\sigma_{pp \to D^*_{prompt}} = 246.06^{+2.42}_{-2.42}\,\mu b$

PYTHIA:$301.08\mu b$

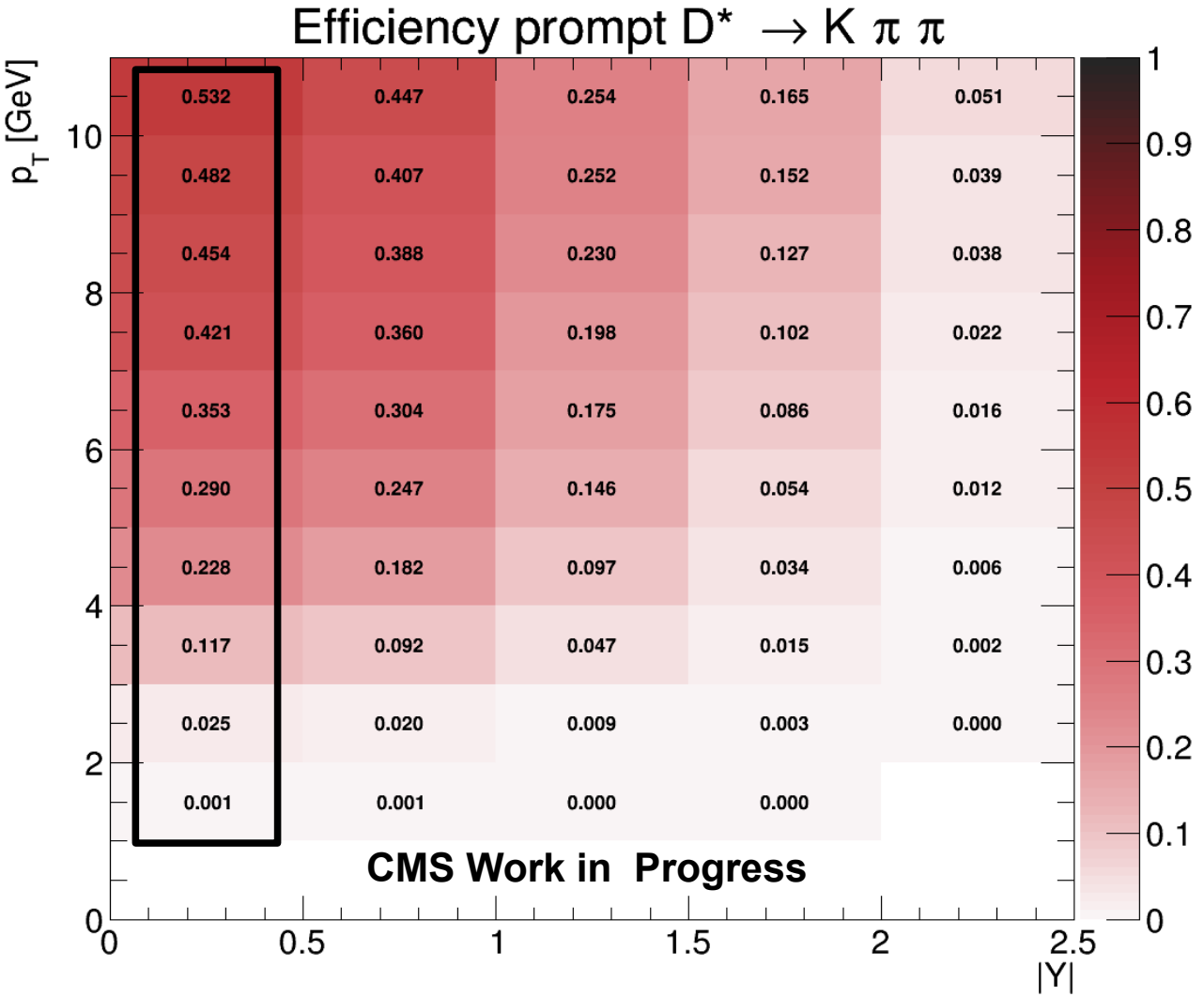
$\sigma_{pp \to D^*_{nonprompt}} = 17.94^{+1.89}_{-1.83}\,\mu b$

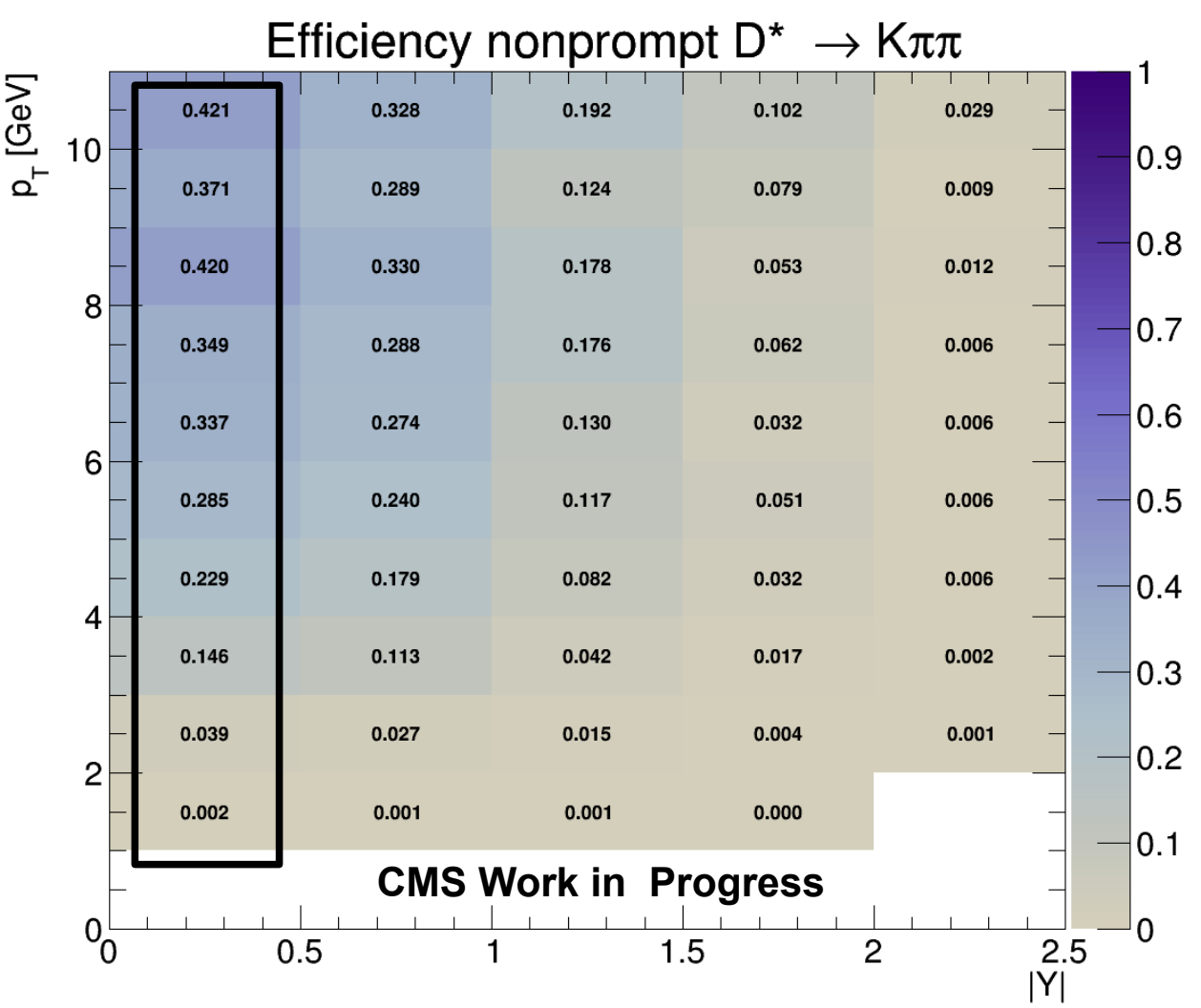
PYTHIA: $30.77\mu b$

only statistical uncertainties



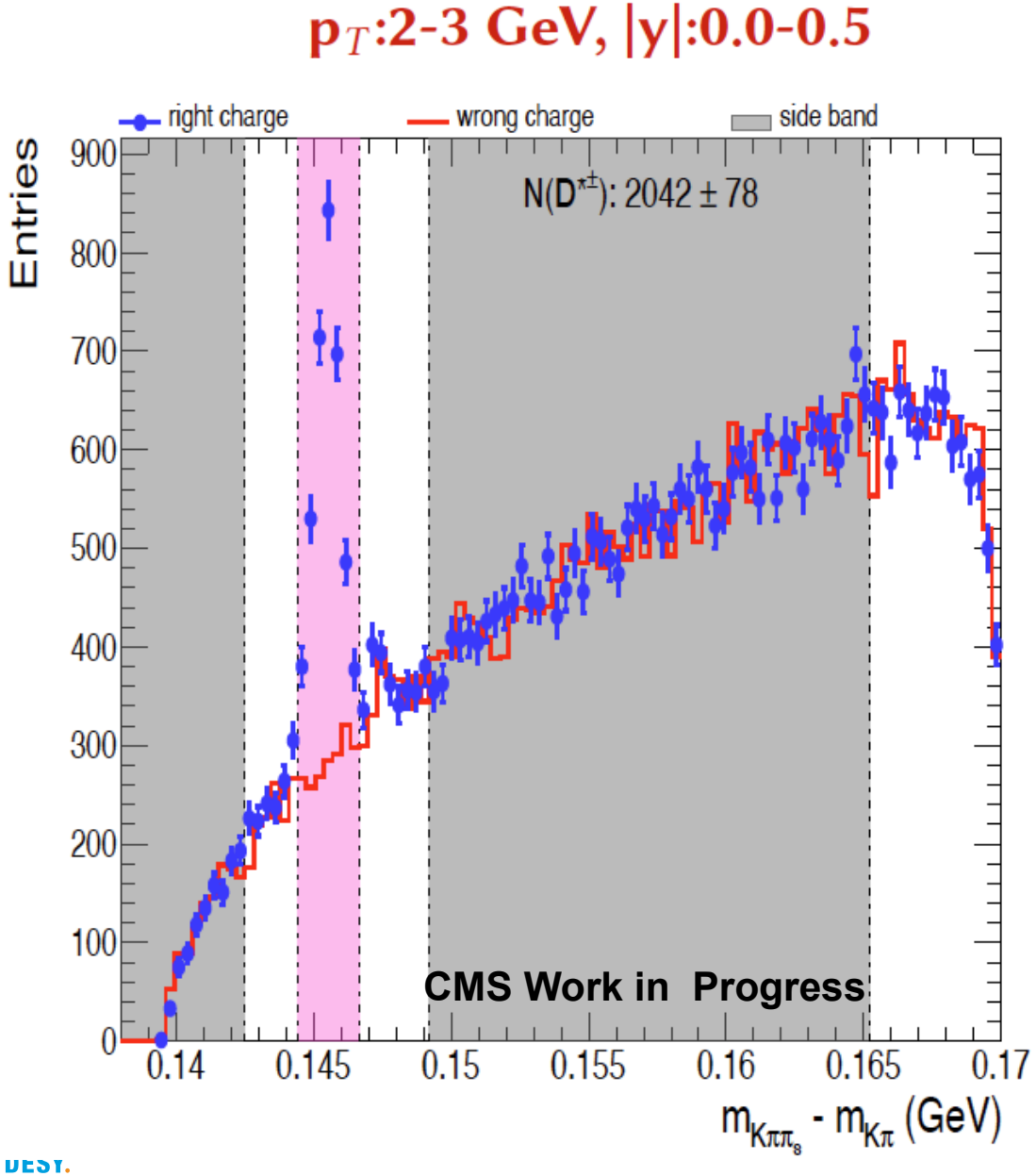
Double differential efficiency table for (non)prompt D*

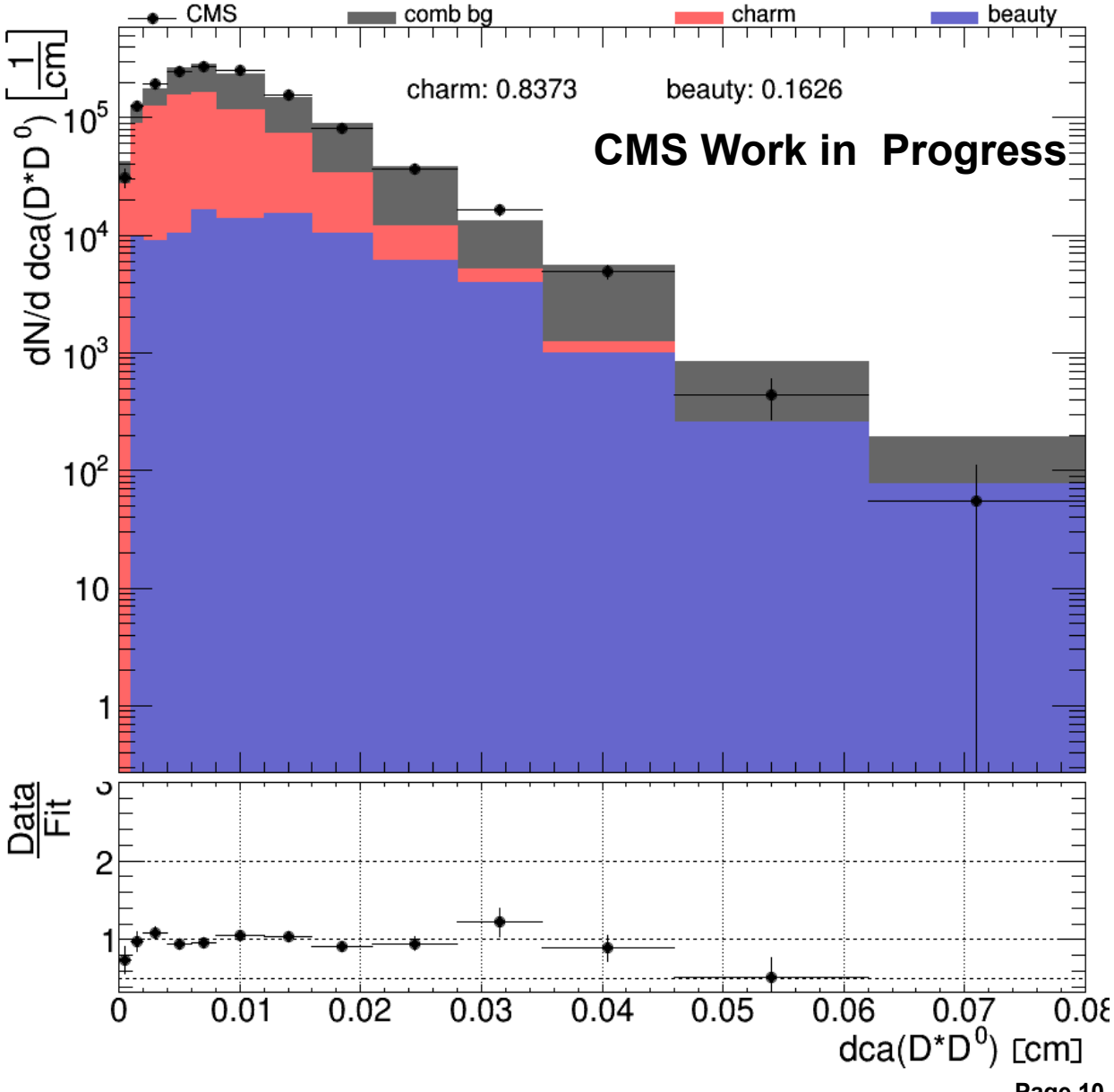




- Focus on phase space region |y| < 0.5

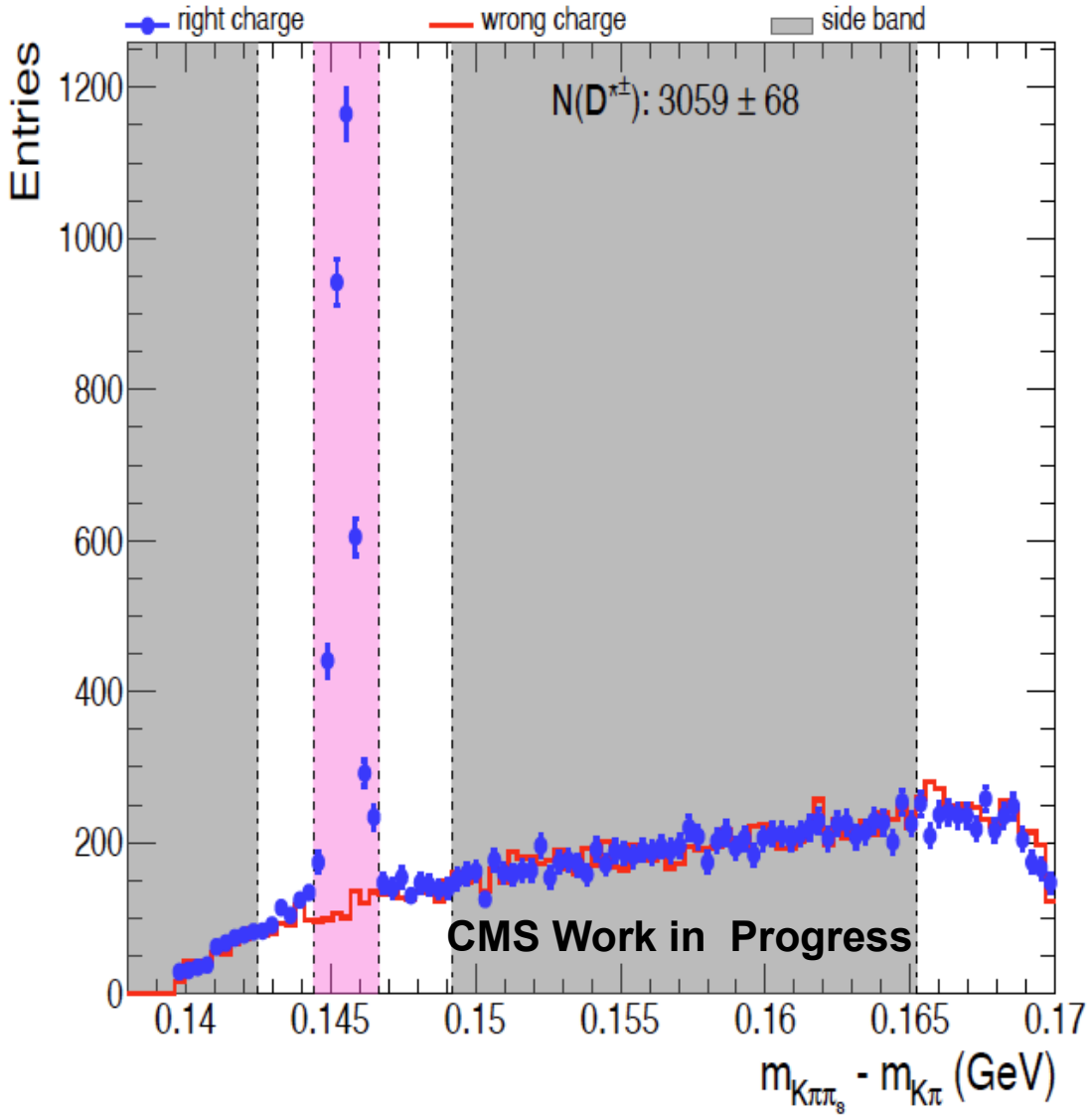
Charm-Beauty Separation example

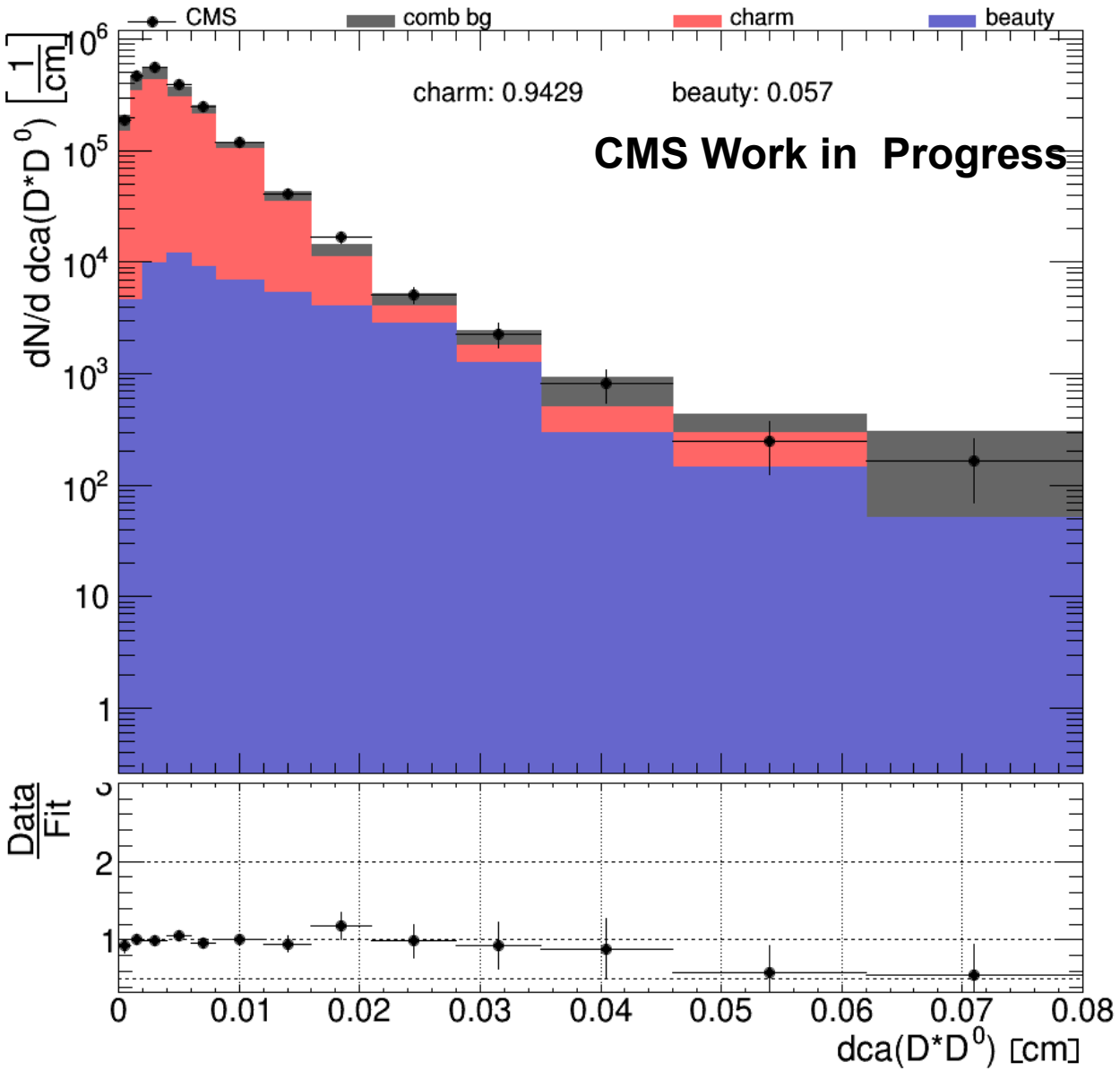




Charm-Beauty Separation example

p_T:5-6 GeV, |y|:0.0-0.5

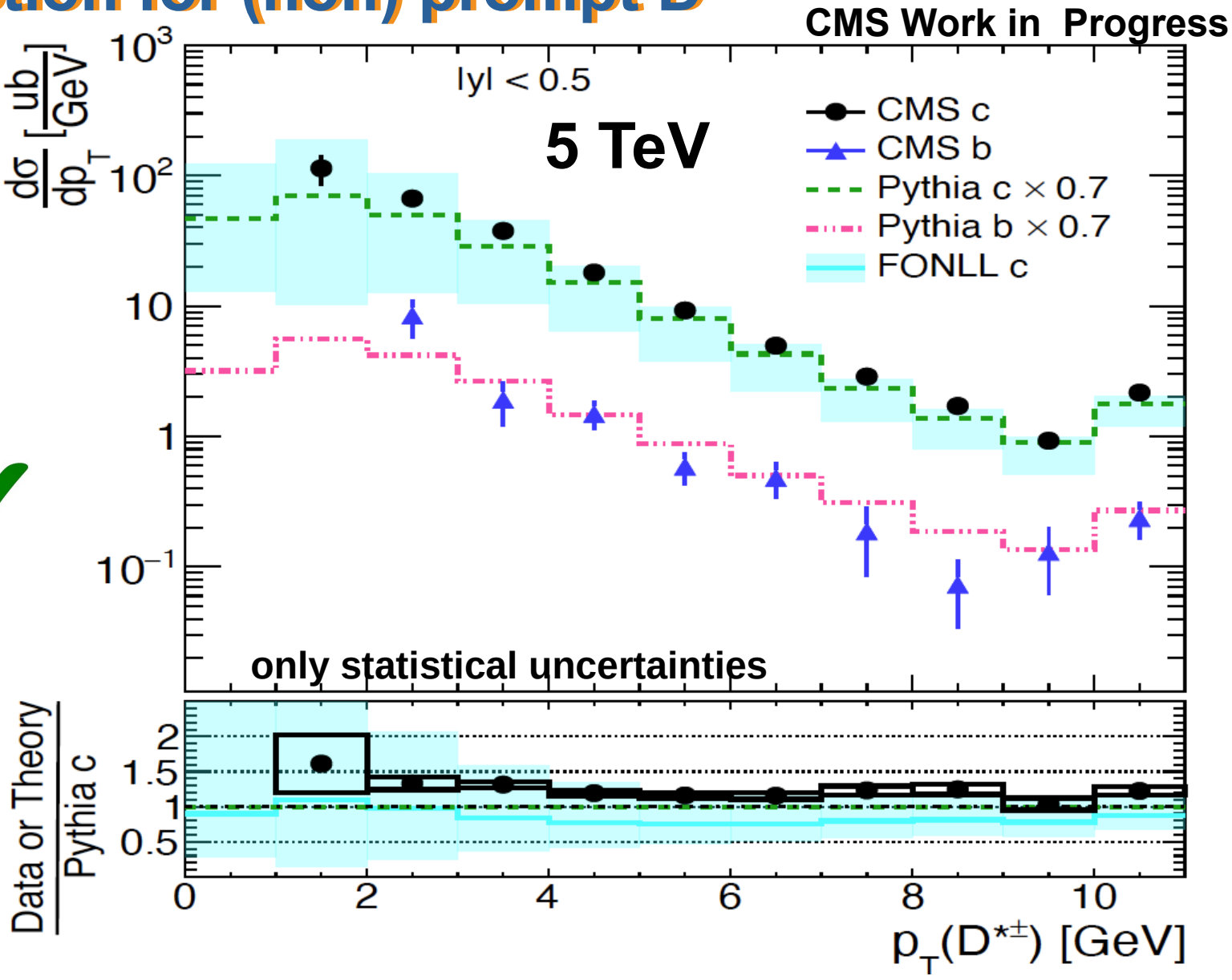




Differential cross section for (non) prompt D*

First measurement of D* from charm and beauty in this phase space in CMS

- Agreement with NLO + NLL prediction (FONLL) and with shape from Pythia ✓
- Remainder of phase space & comparison to other measurements in progress



Summary

- Measured D mesons $D^{*\pm} \rightarrow D^0 \pi_s^{\pm} \rightarrow K^{\mp} \pi^{\pm} \pi_s^{\pm}$
- Separation of D mesons (prompt and from b hadrons decays) near the production threshold
- First measurement of D* cross sections from charm and beauty at 5 TeV in CMS

- Continue measurement in the remainder of the phase space to get the total beauty cross section

Backup

References

[1] Siona Ruth Davis. **“Interactive Slice of the CMS detector”**. In: (Aug. 2016). url: https://cds.cern.ch/record/2205172.

[2] https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults#Run_2_annual_charts_of_luminosit

Fixed Order Next to Leading Log

- We used FONLL for the prediction of heavy quark production and chose D* as hadronic final state
- We used the following set of parameters for charm production
  - the fragmentation factor for charm $f_c = 0.236$
  - the PDF set CTEQ6.6 (PDF uncertainty summed in quadrature to mass und scale uncertainty)
  - central value for mass $m_c = 1.5$ GeV (mass uncertainty $m_c = 1.3$, 1.7 GeV summed in quadrature to scales uncertainties)
  - central value $\mu_R = \mu_F = \mu_0 = \mathrm{sqrt}(m^2 + p_T^2)$
  - scale uncertainties: $\mu_0/2 < \mu_R$ and $\mu_F < 2\mu_0$ with $1/2 < \mu_R/\mu_F < 2$
- We variate the mass, PDF, renormalisation and factorization scale and got and uncertainty band by the lower and upper values of this variation

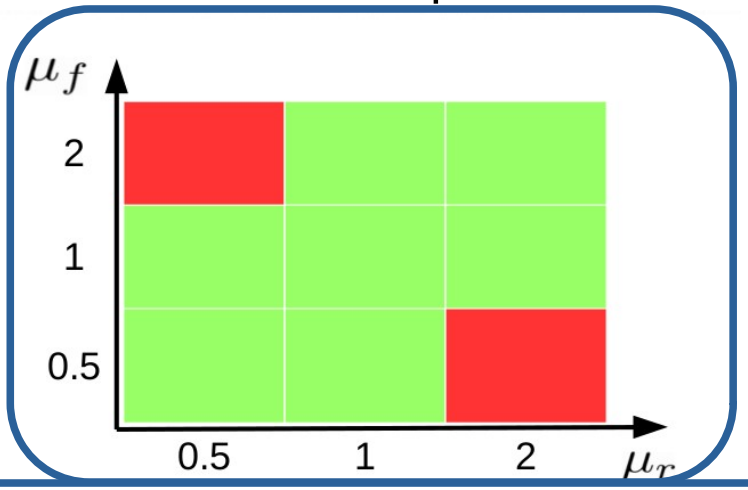
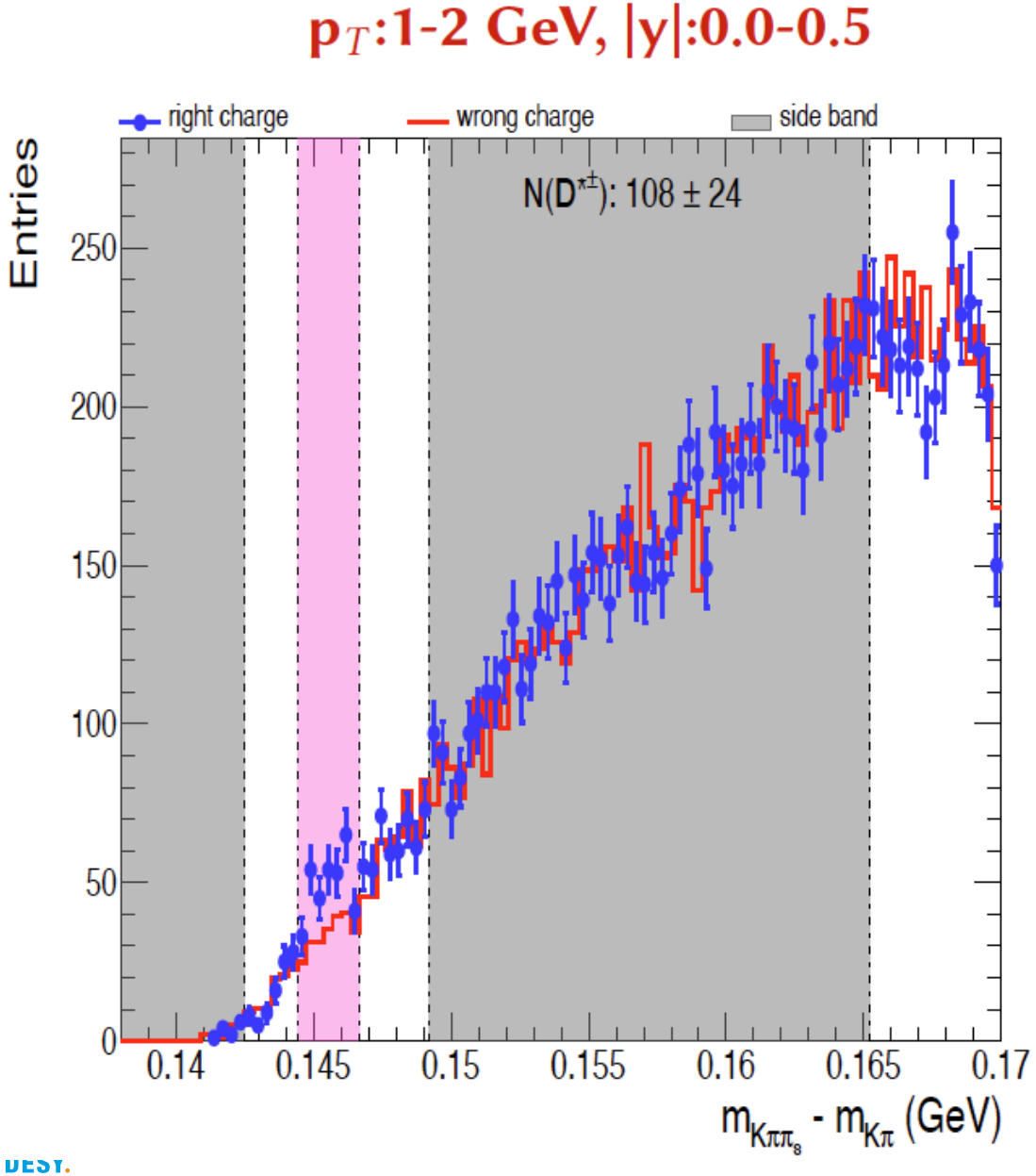
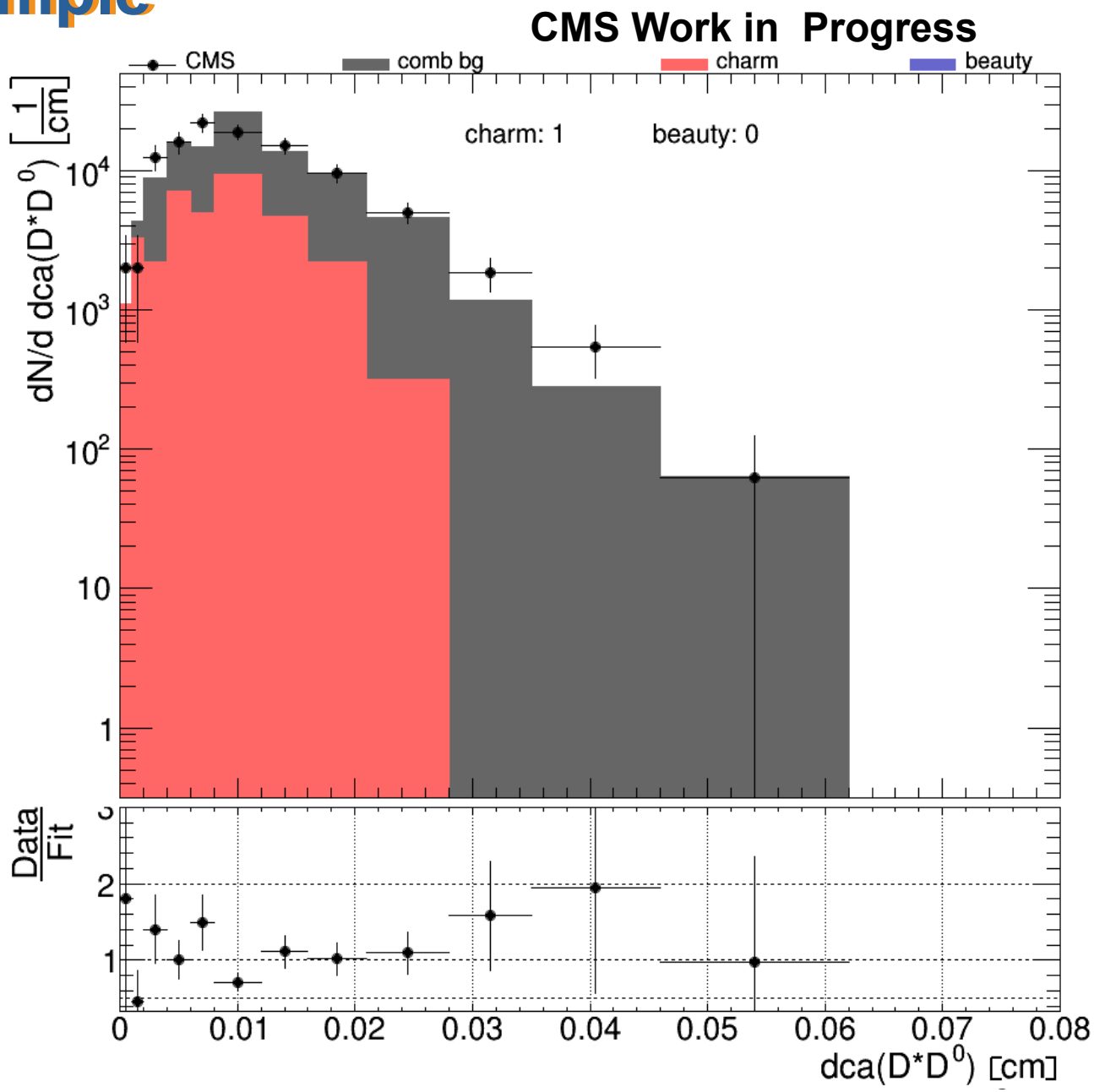


Illustration of the seven combinations of the variation of the renormalisation scale μ_r and factorization scale μ_f

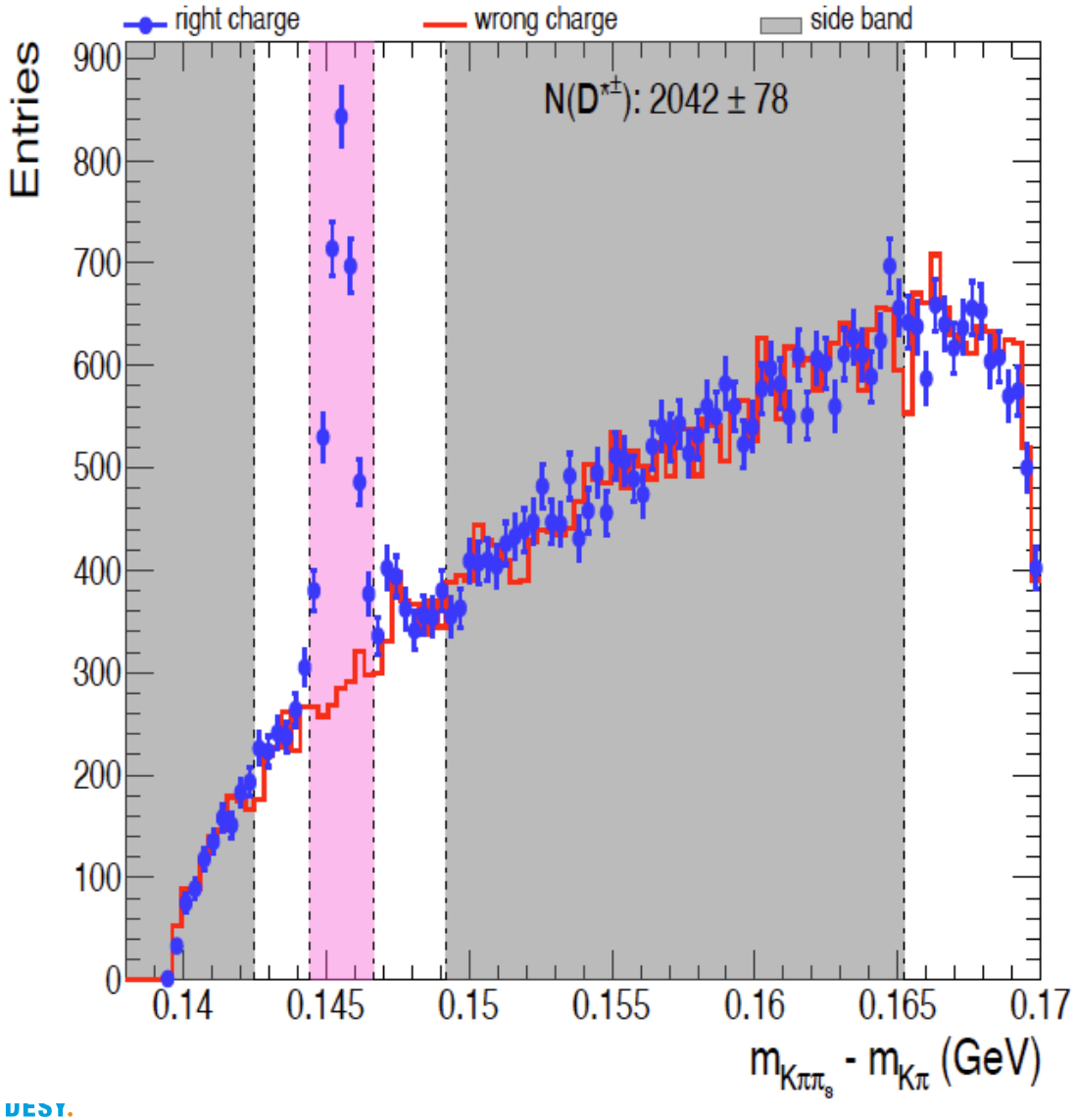
Charm-Beauty Separation example



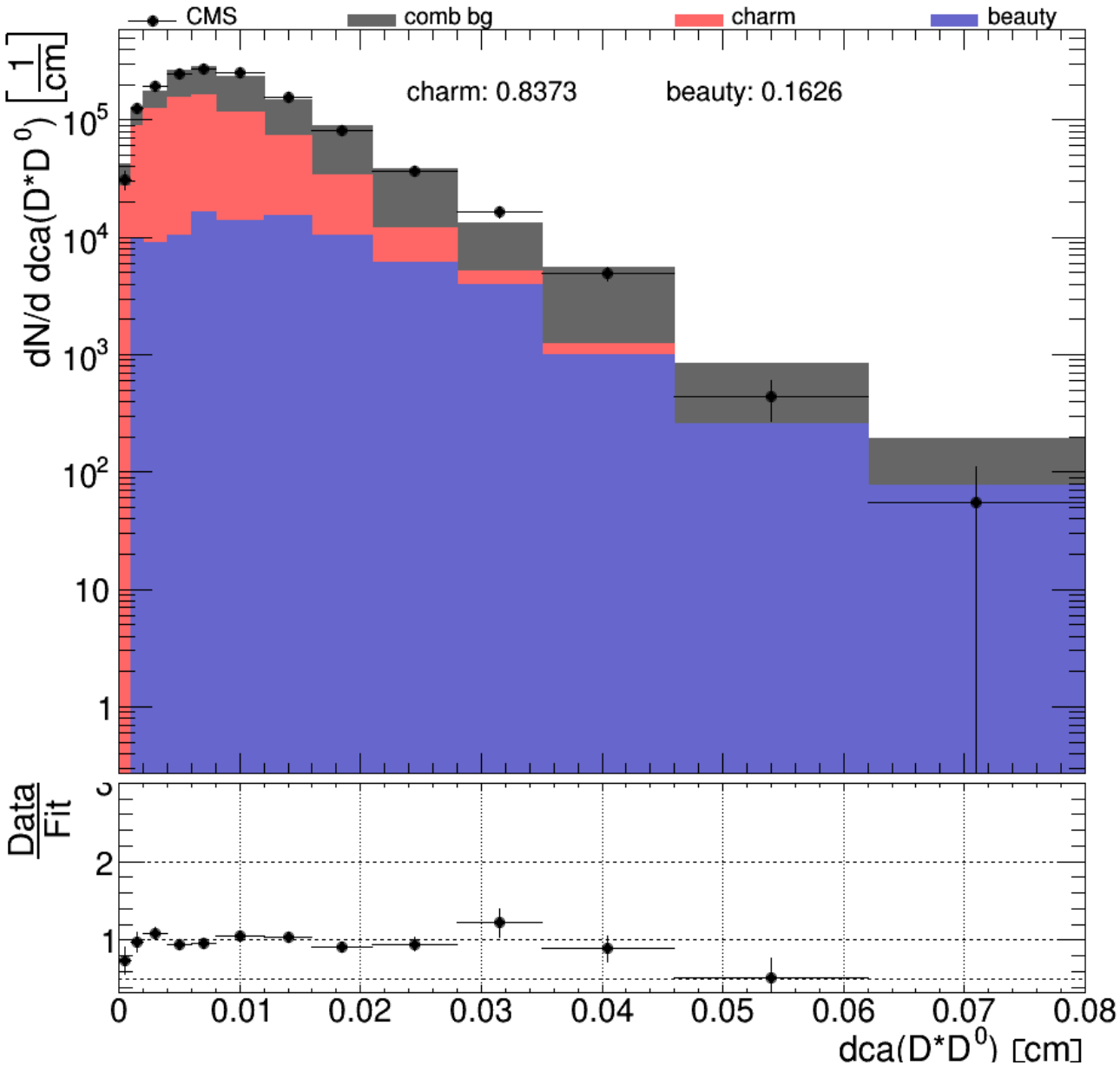


Charm-Beauty Separation example

p_T:2-3 GeV, |y|:0.0-0.5

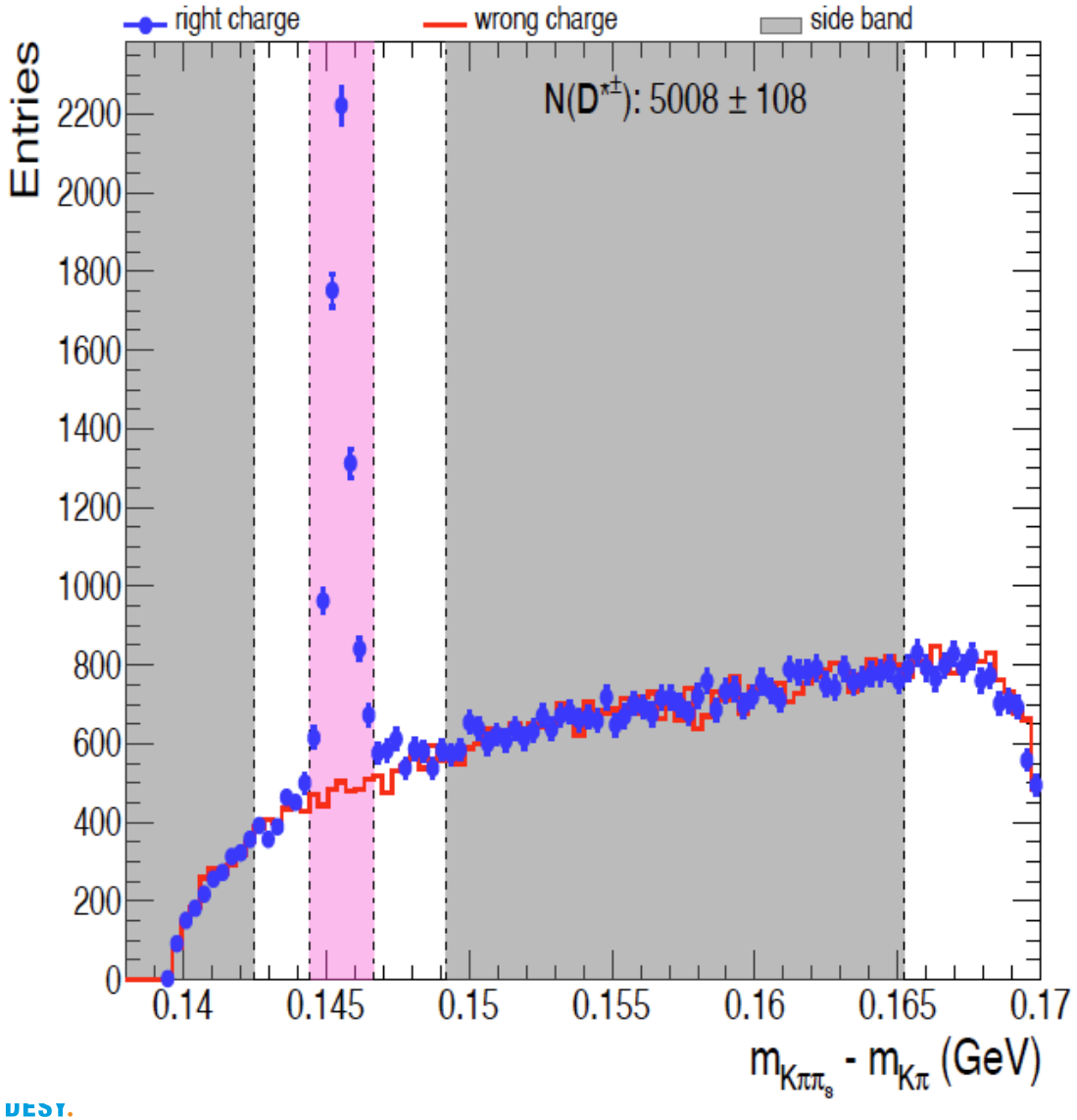


CMS Work in Progress



Charm-Beauty Separation example

p_T:3-4 GeV, |y|:0.0-0.5



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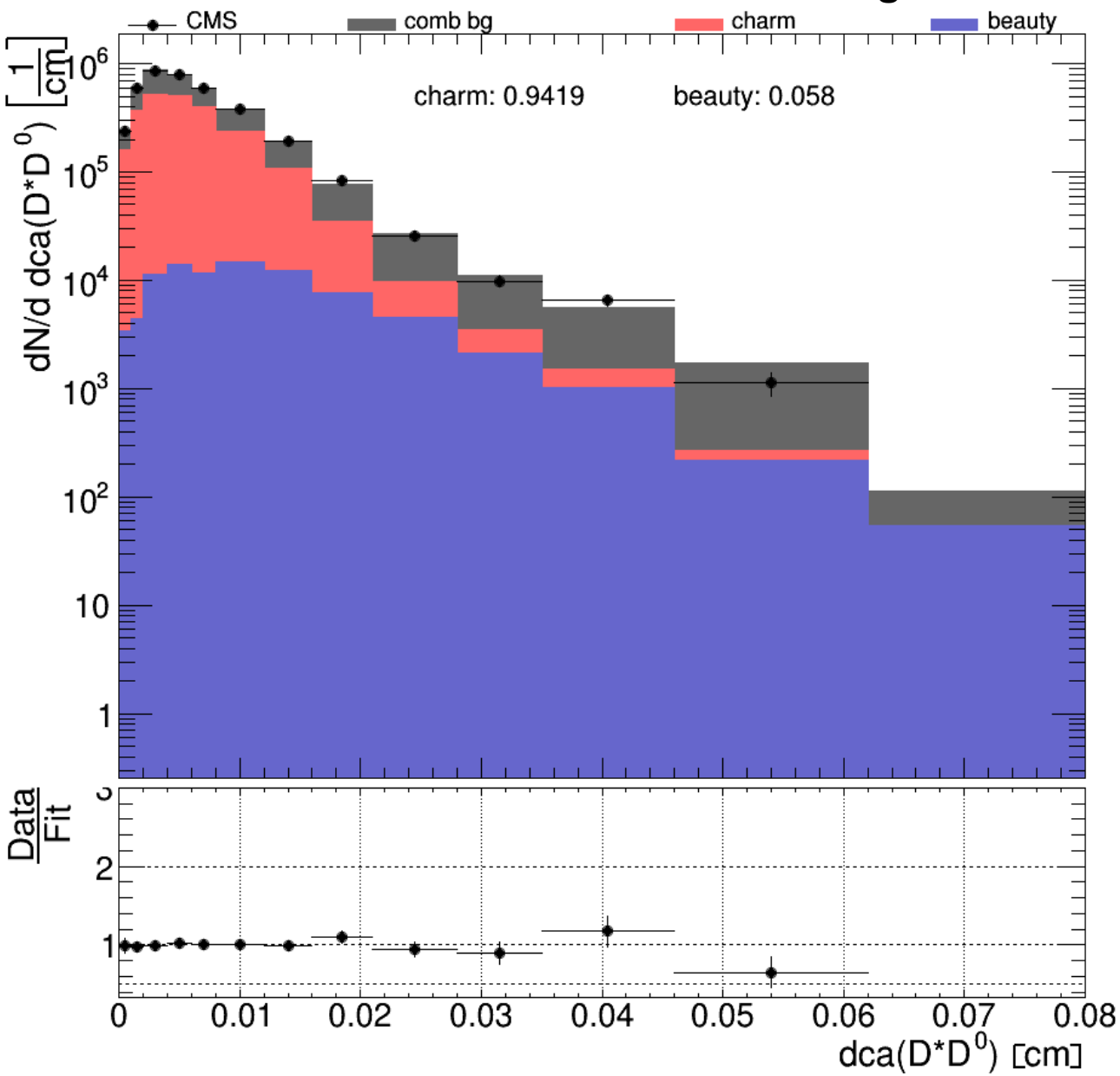
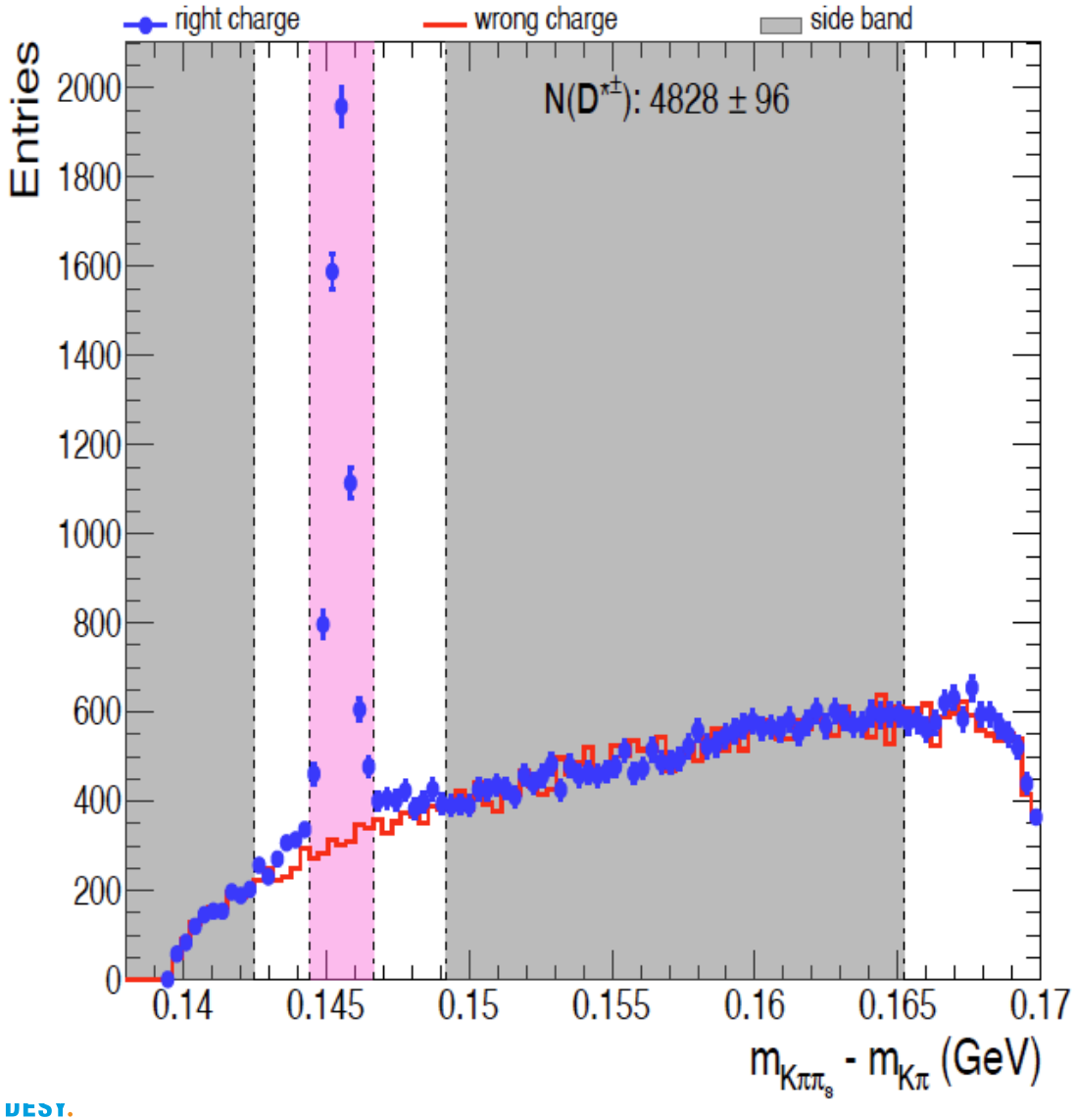
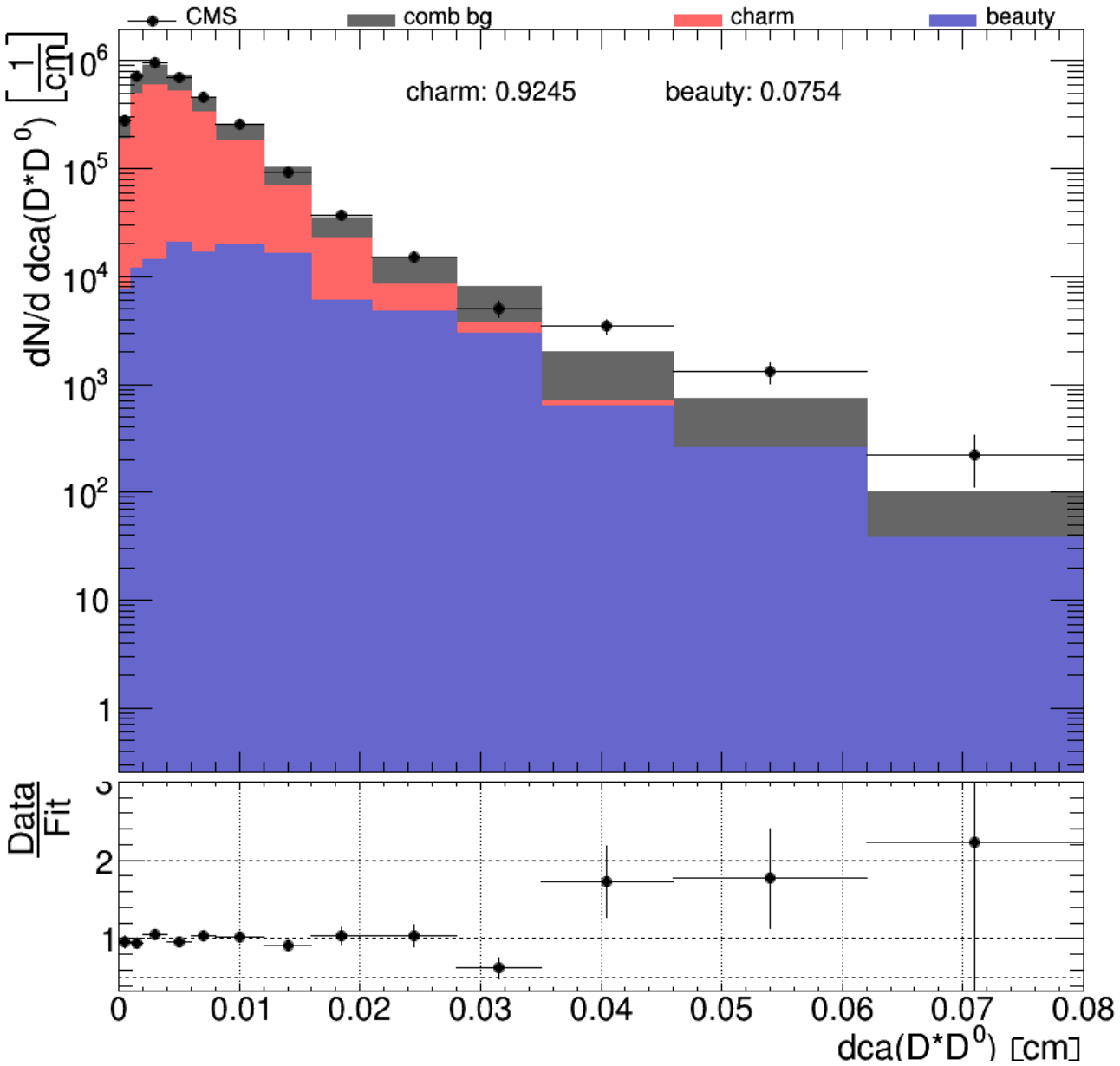


Charm-Beauty Separation example

p_T:4-5 GeV, |y|:0.0-0.5

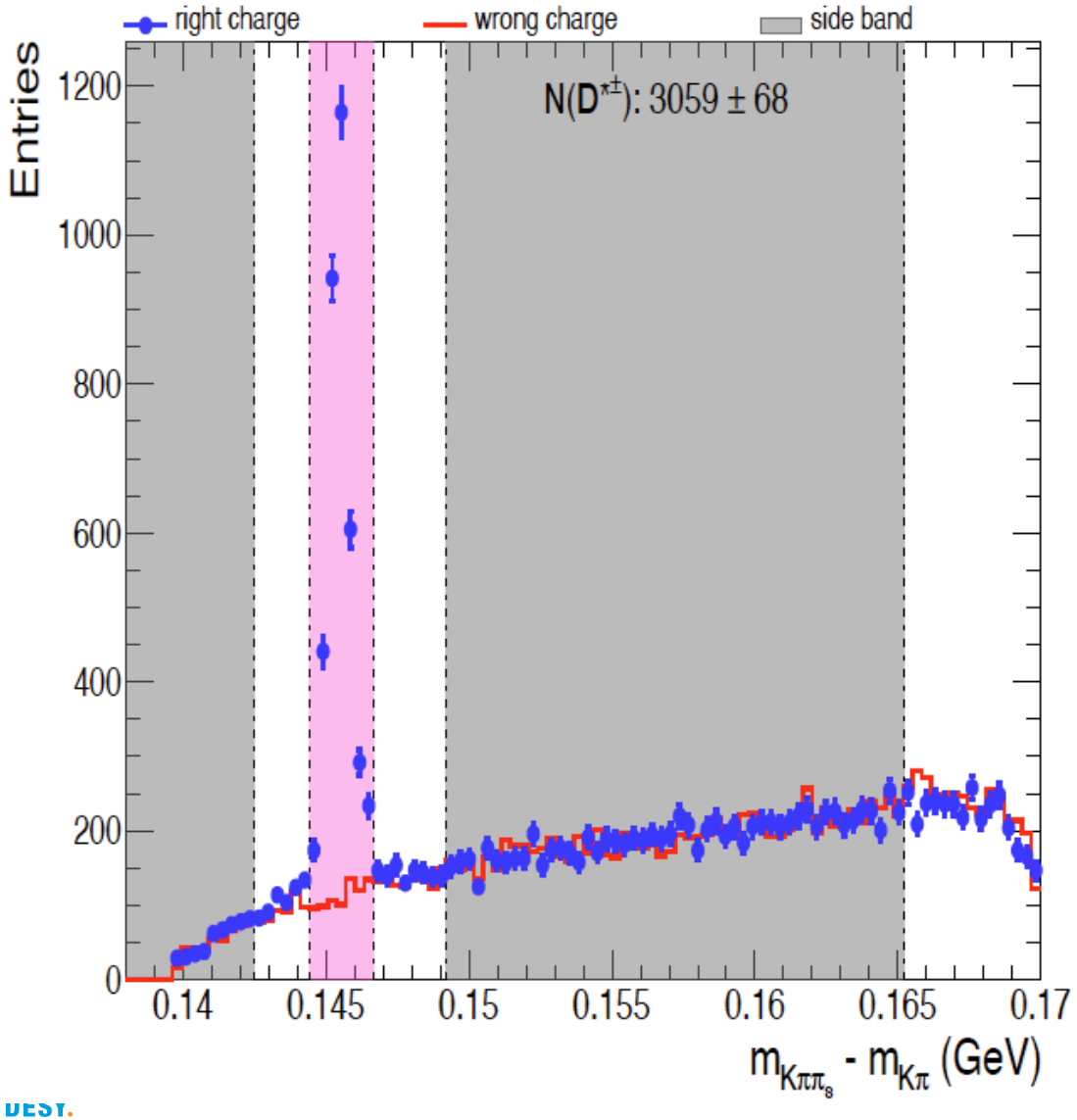


CMS Work in Progress



Charm-Beauty Separation example

p_T:5-6 GeV, |y|:0.0-0.5



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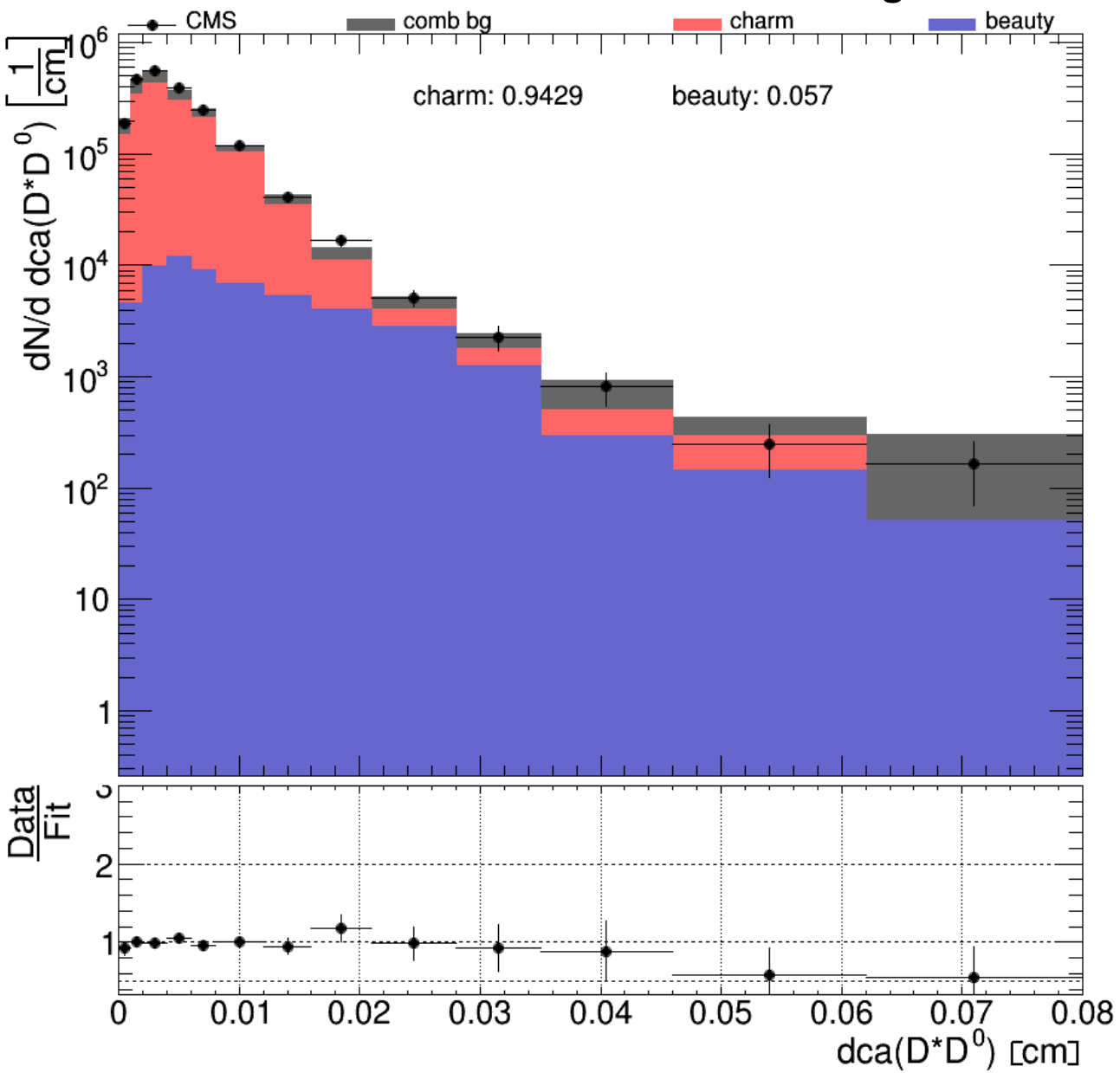
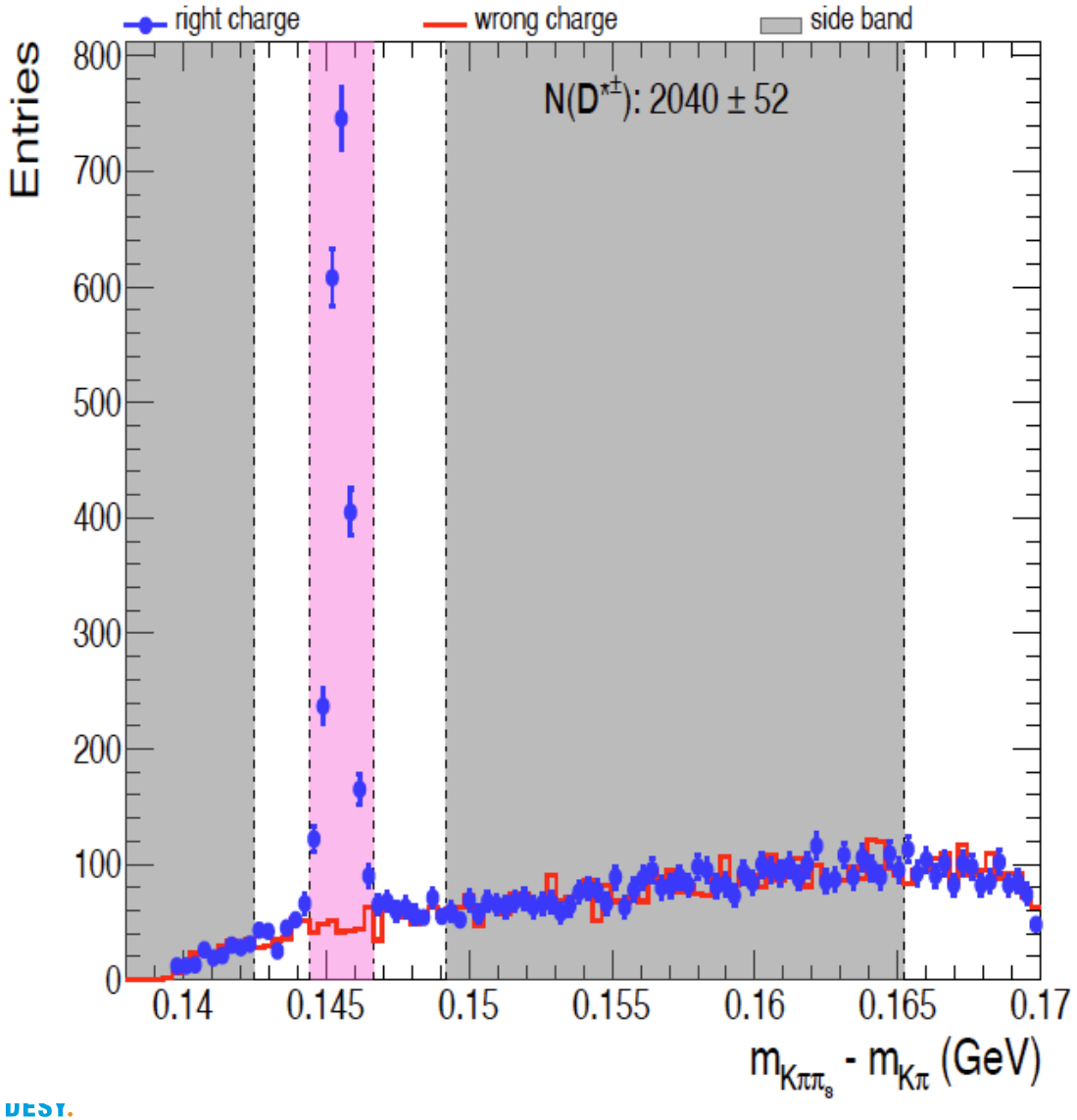
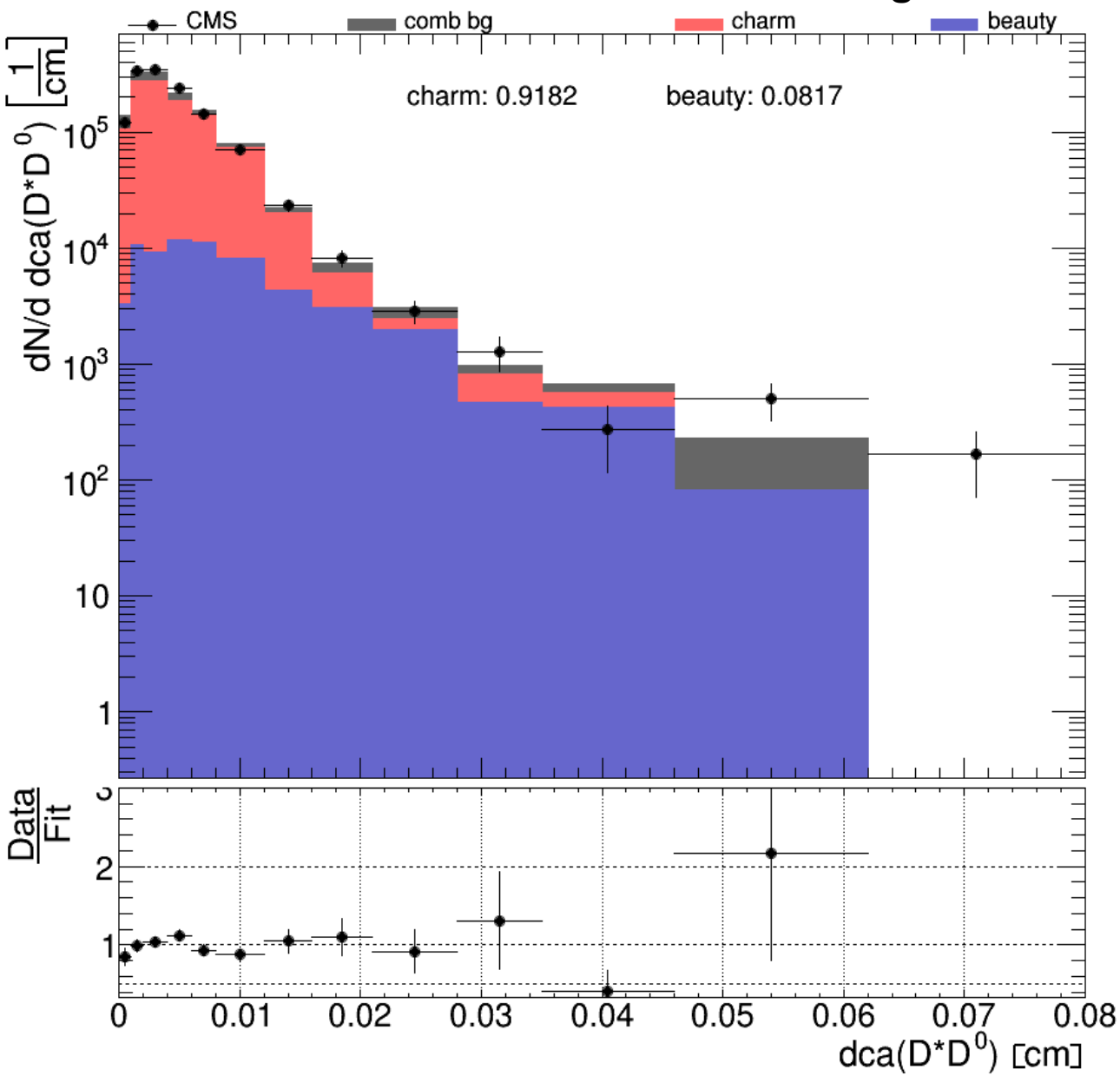


Charm-Beauty Separation example

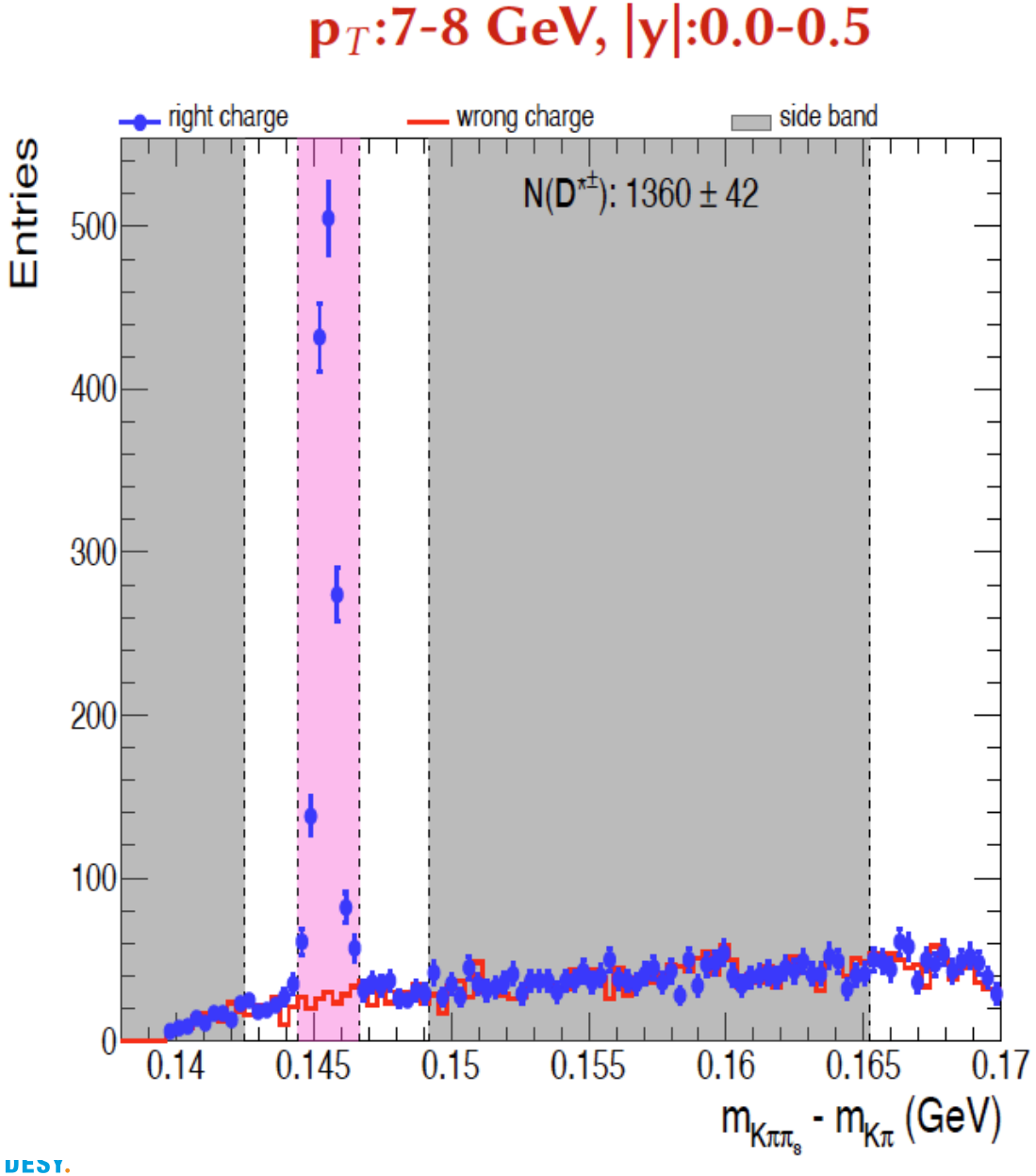
p_T:6-7 GeV, |y|:0.0-0.5

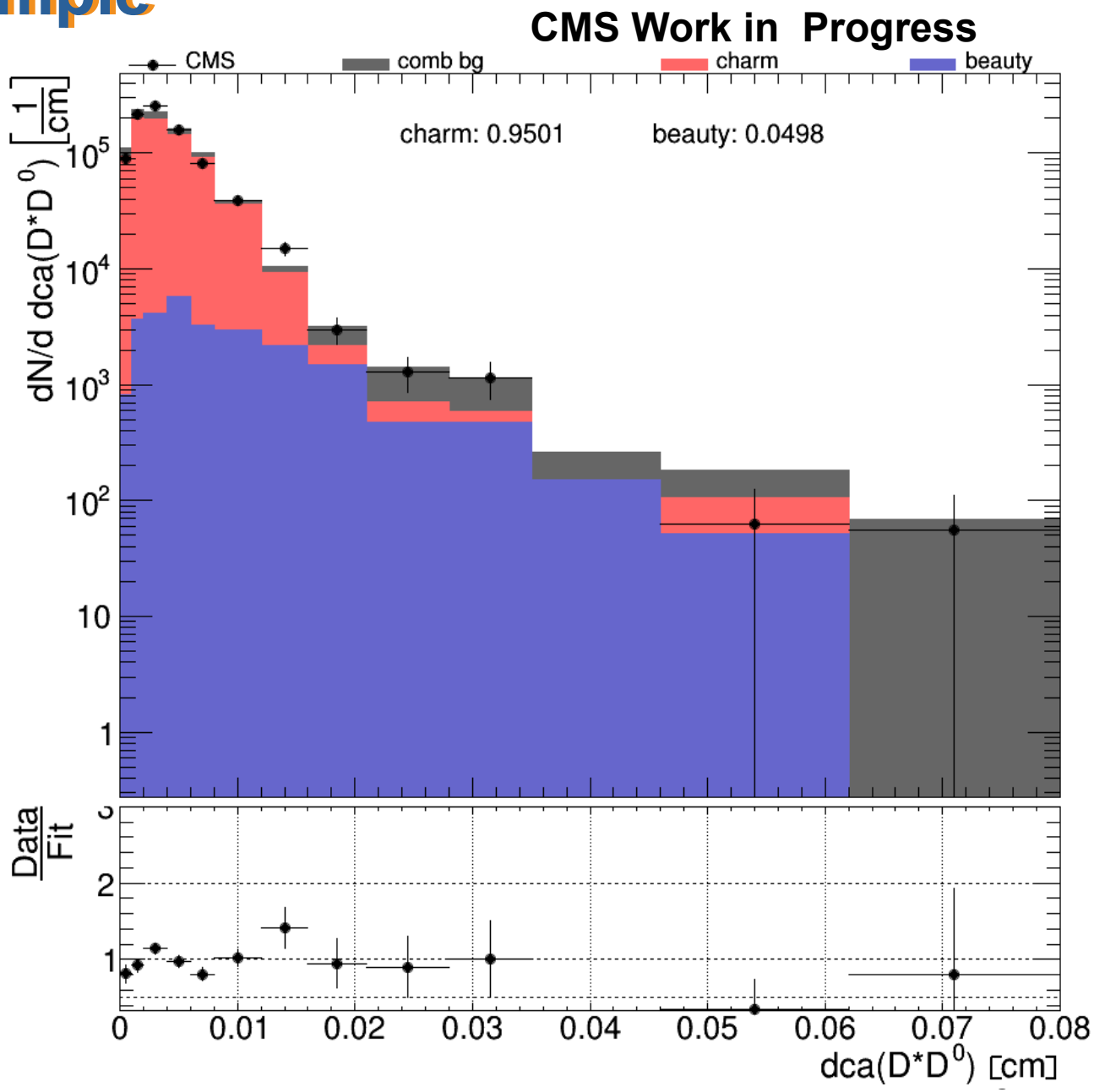


CMS Work in Progress



Charm-Beauty Separation example





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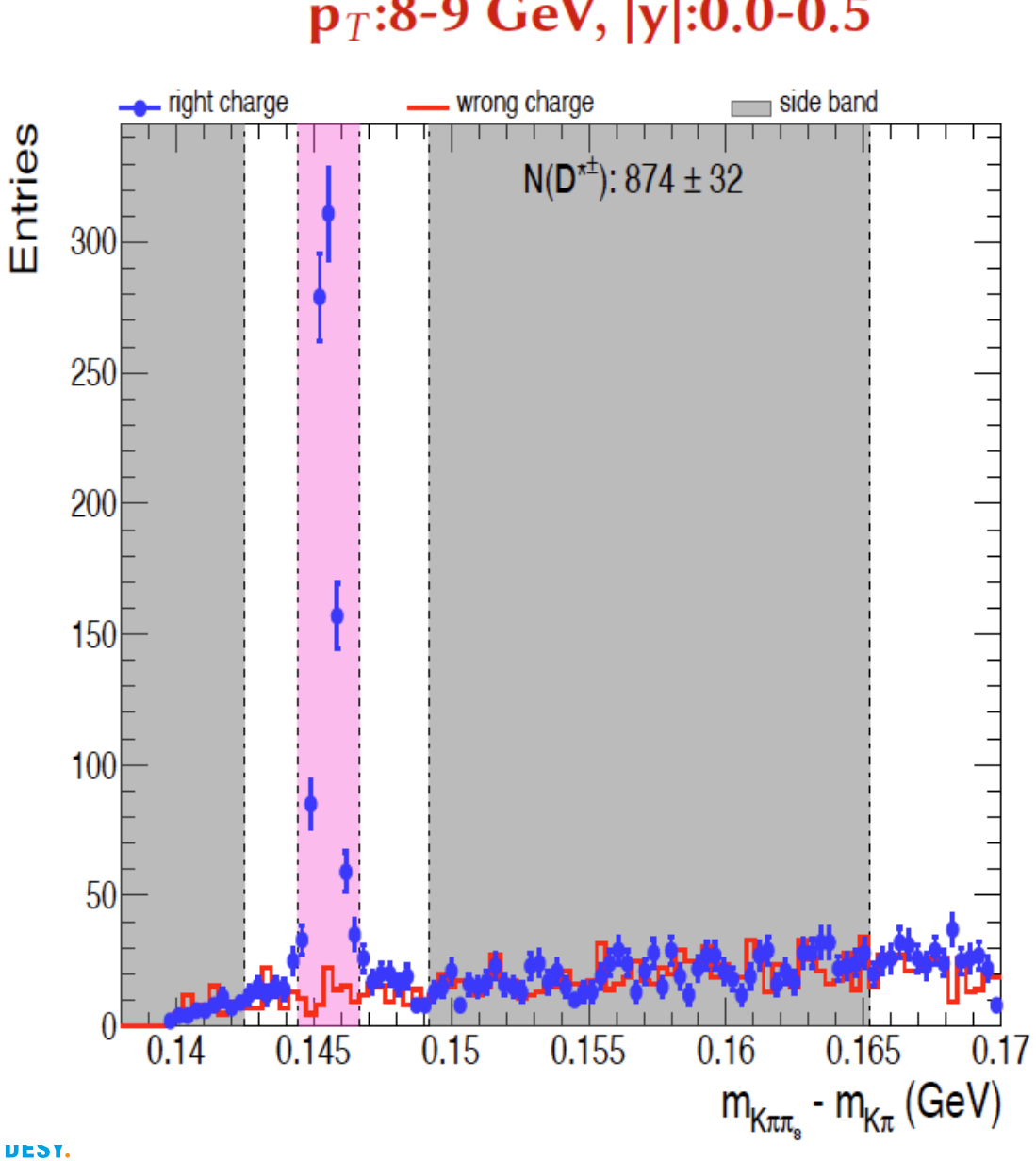
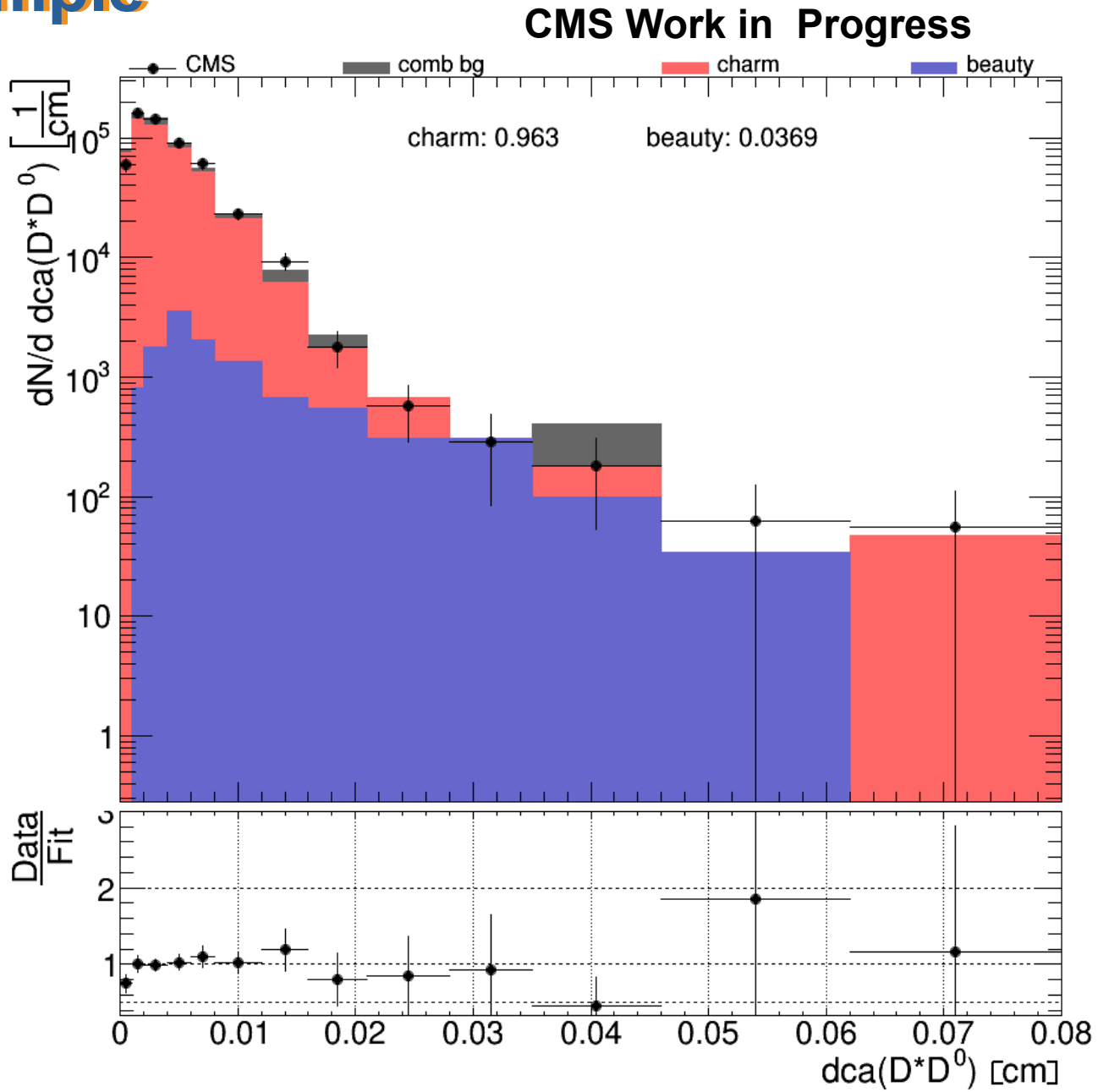
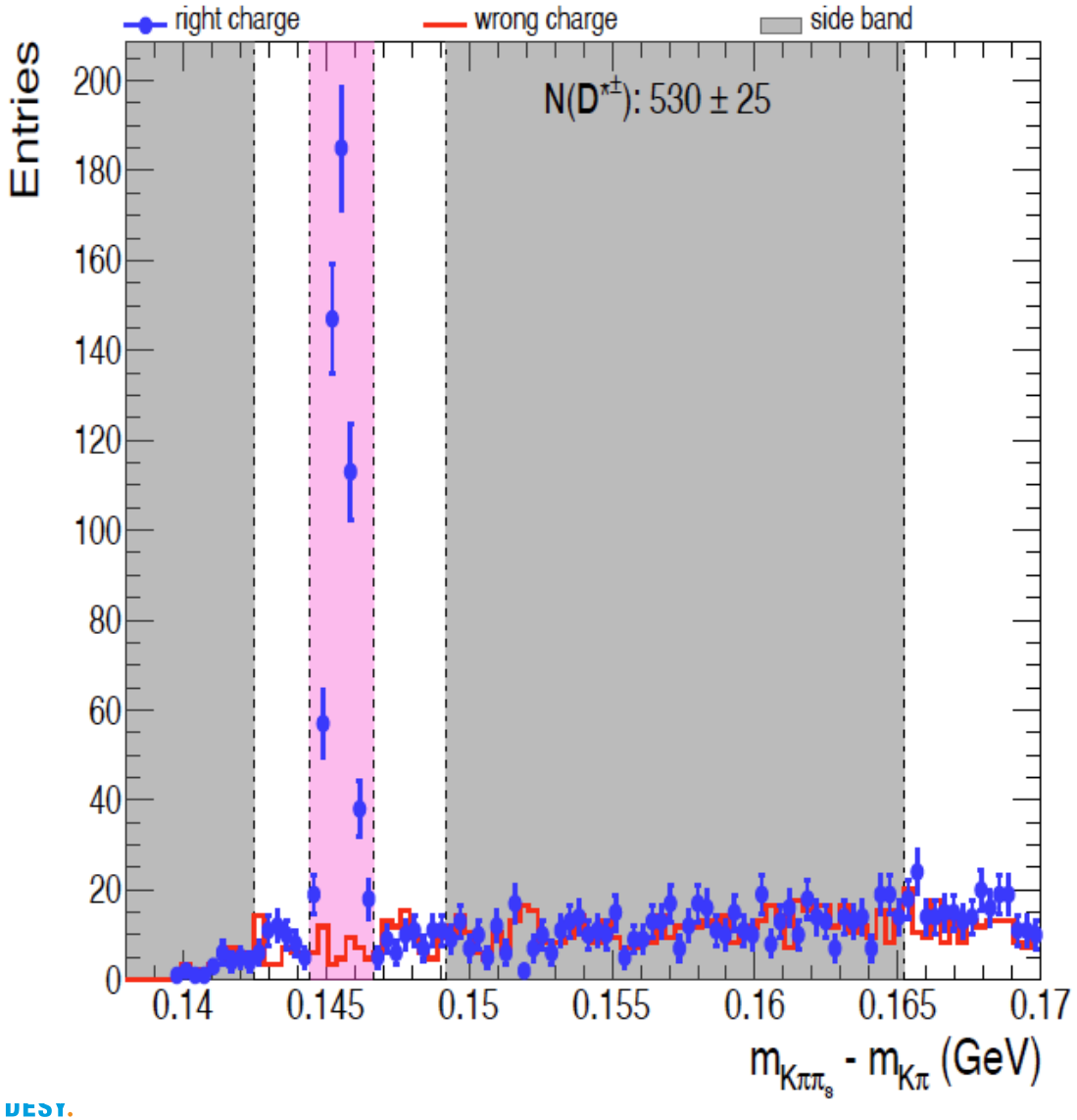


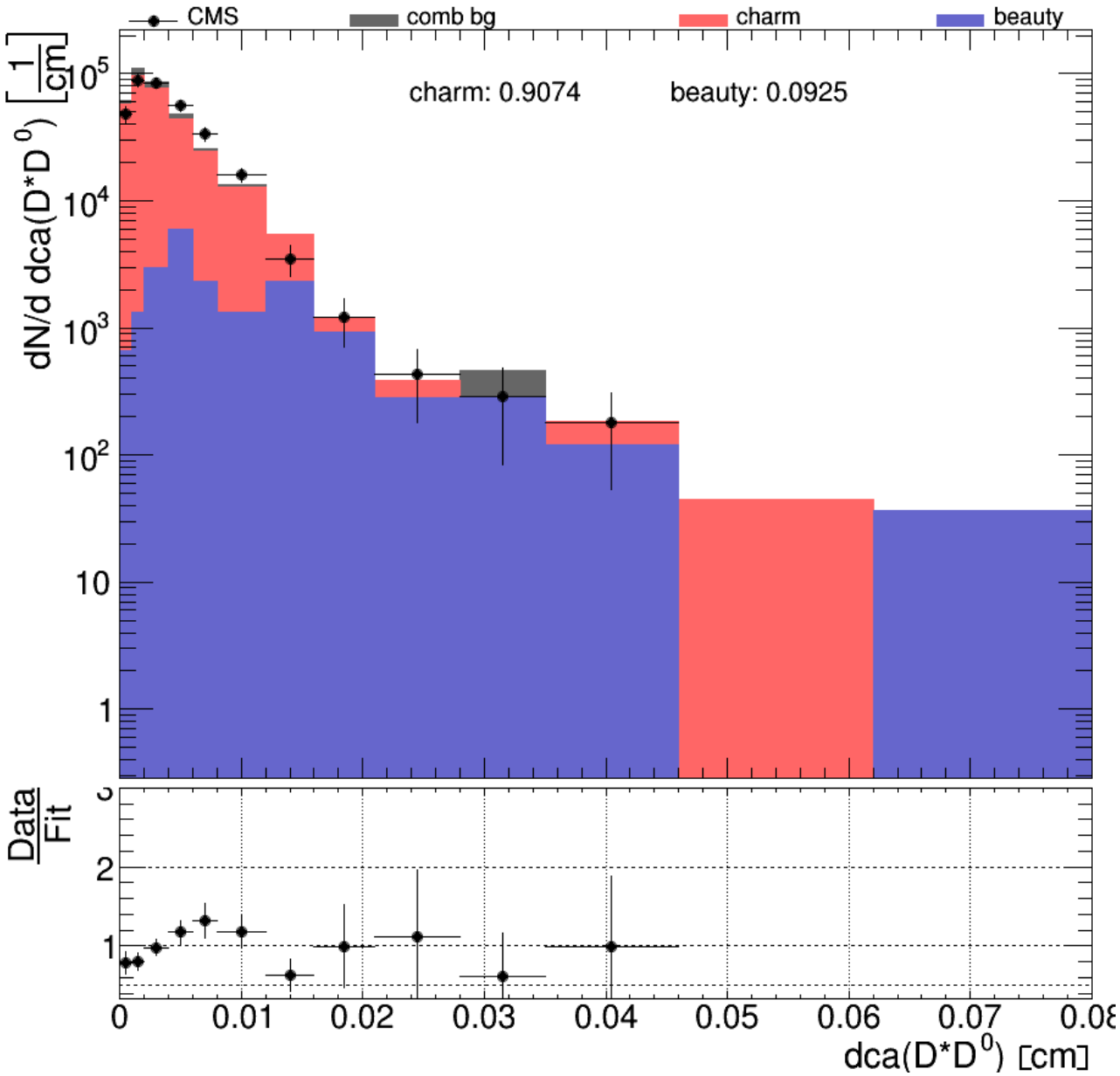


Charm-Beauty Separation example

p_T:9-10 GeV, |y|:0.0-0.5

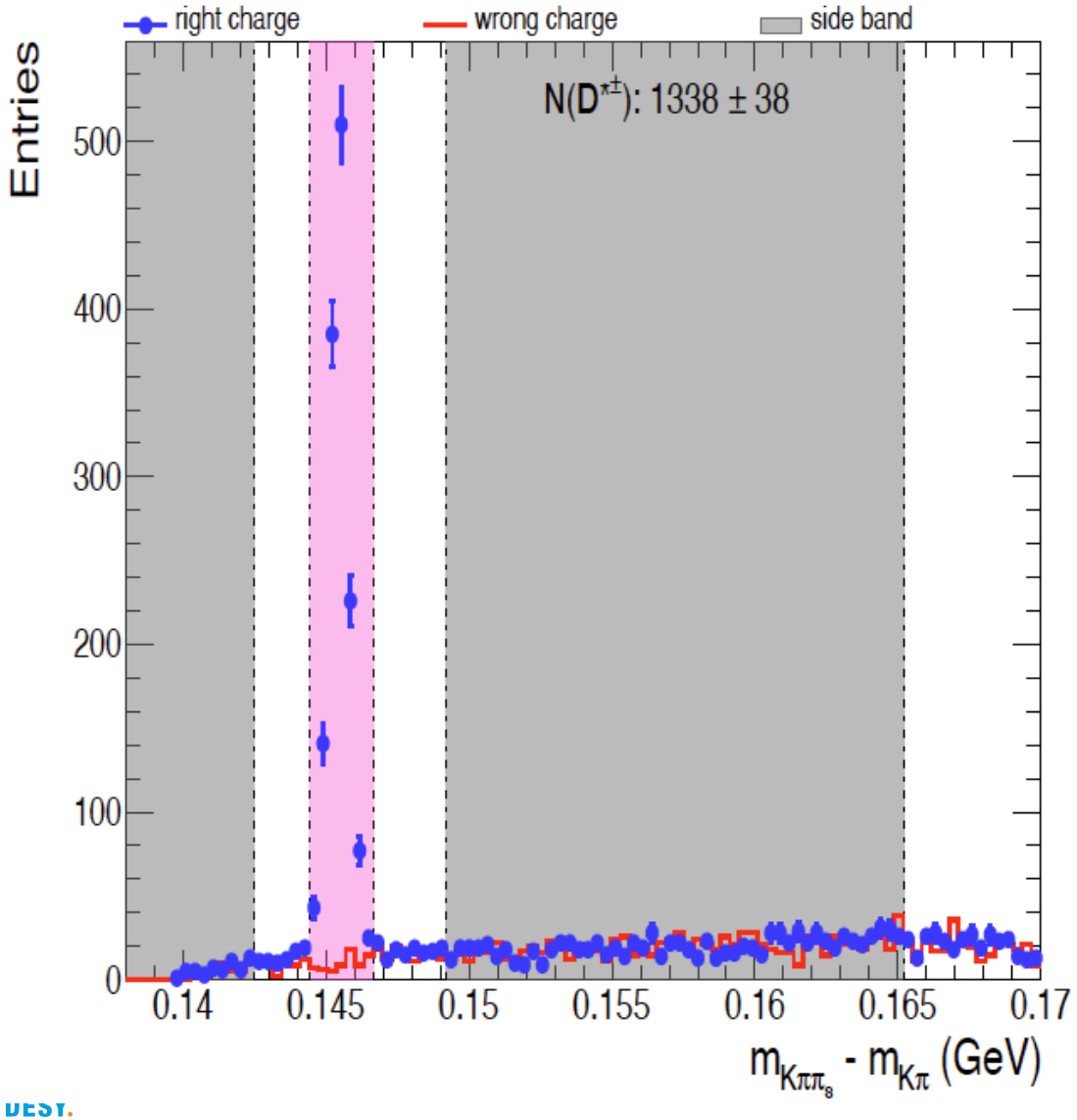


CMS Work in Progress

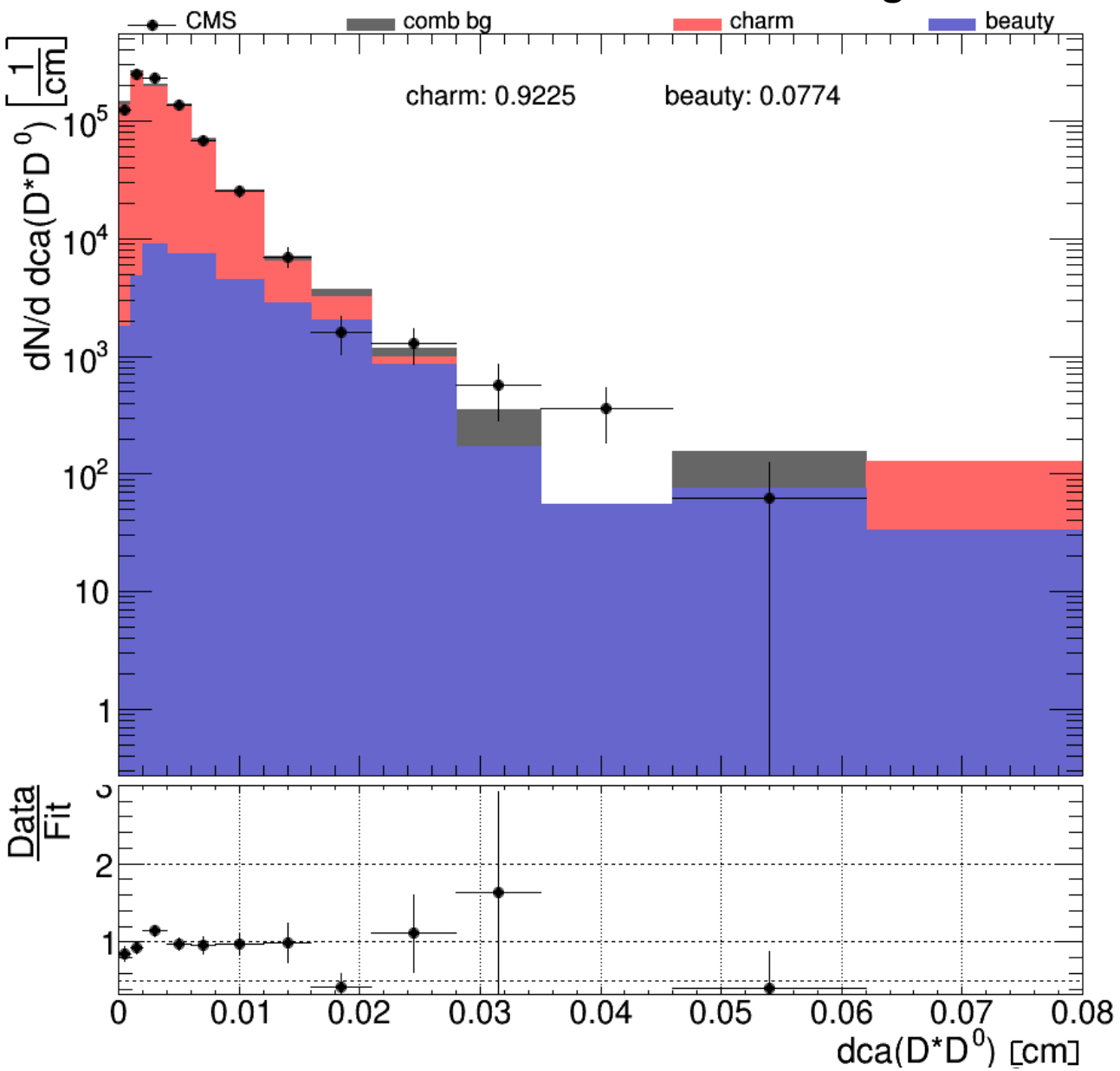


Charm-Beauty Separation example

p_T:10-11 GeV, |y|:0.0-0.5

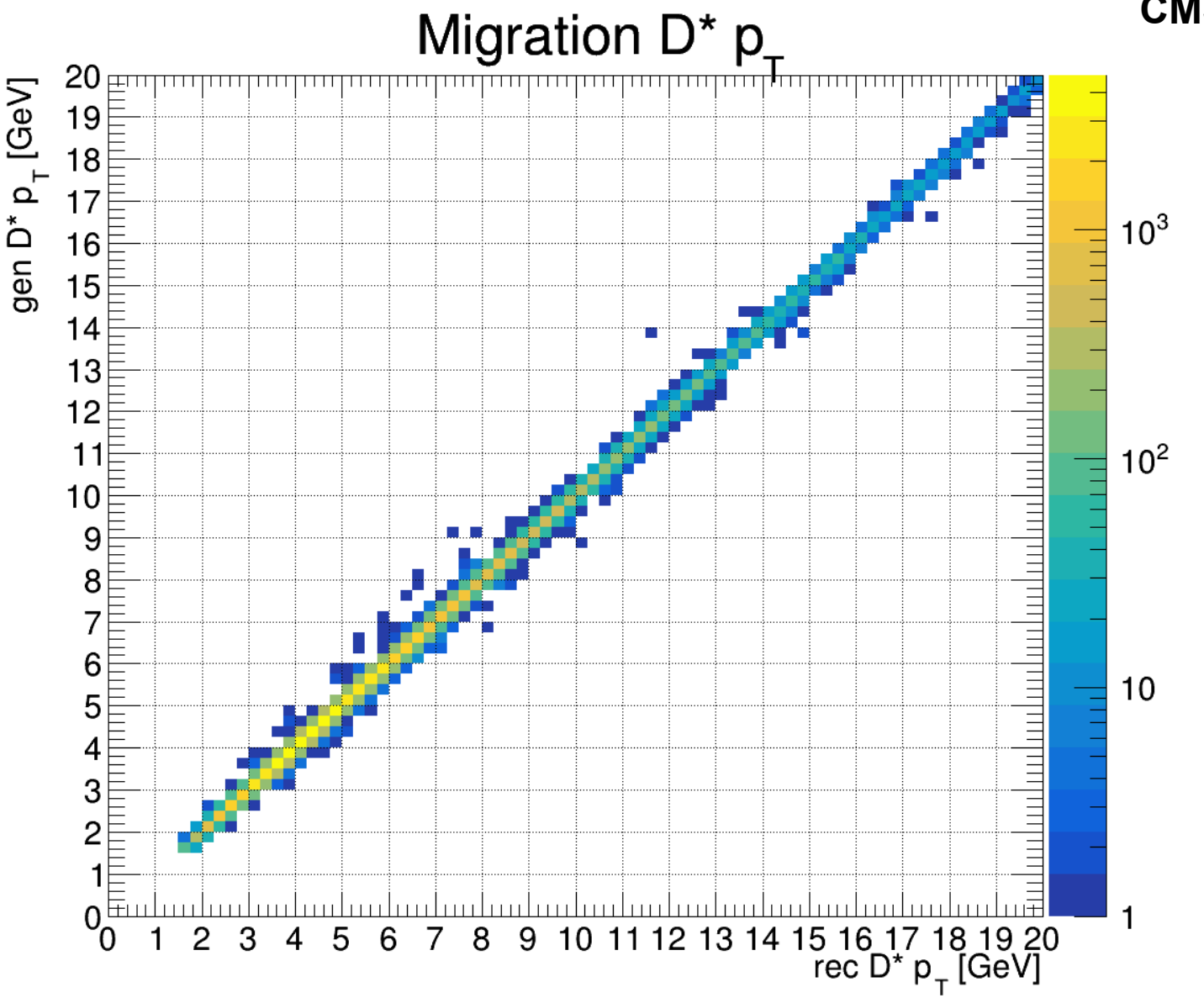


CMS Work in Progress



Migration plot

CMS Work in Progress



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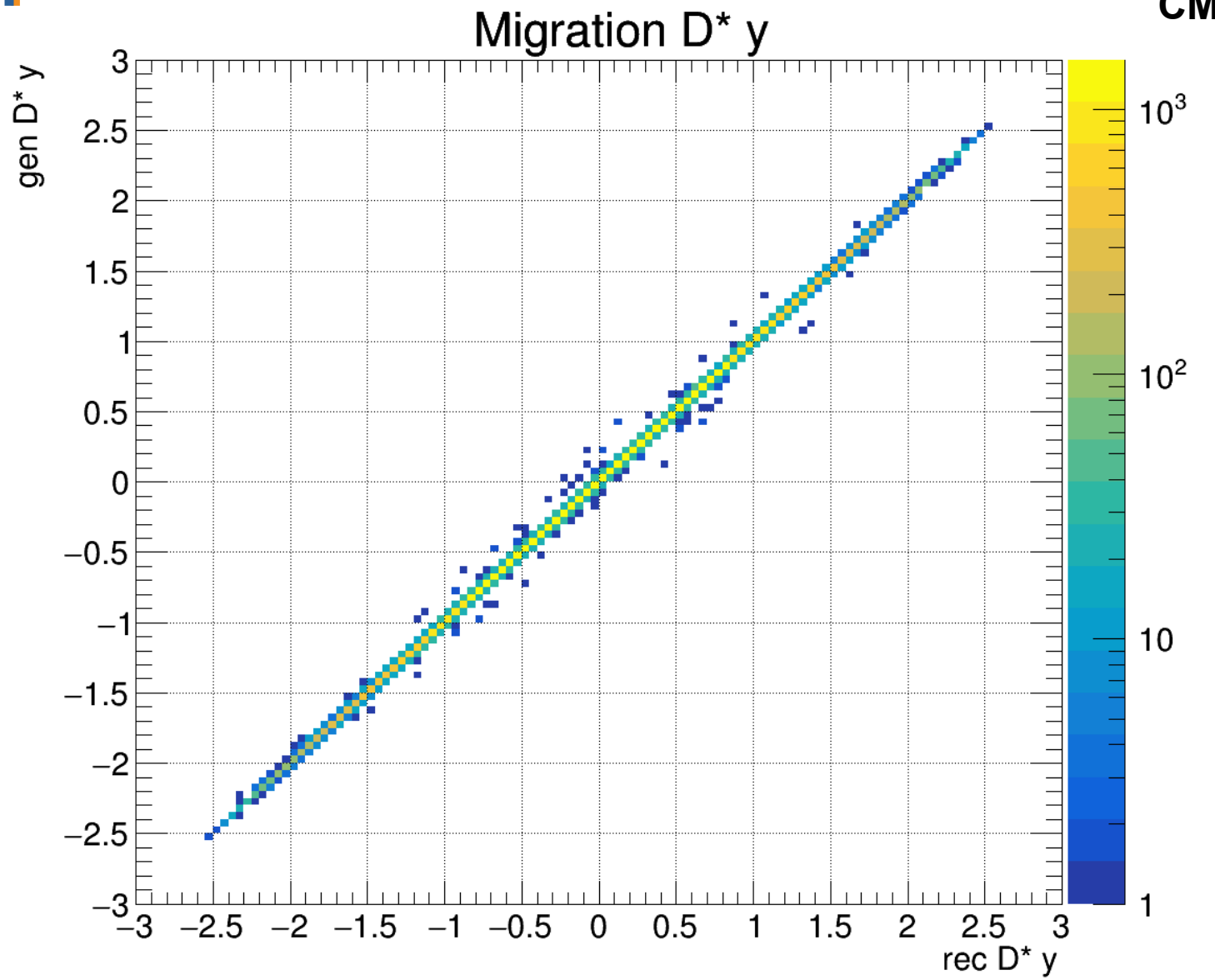

Migration plot

CMS Work in Progress