

Updates on inclusive charm cross section

N. Z. Jomhari, A. Geiser

DESY Hamburg
QCD meeting

Dec 06, 2019

Recap

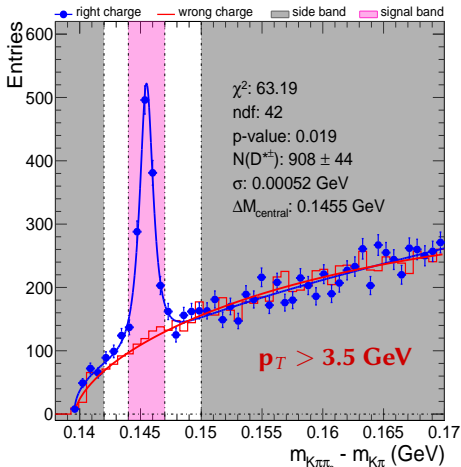
- **Objective:** To measure the total cross section of inclusive charm at different pp center of mass energies (0.9, 2.7, 5, 7, 8, 13 (from PU in BParking) TeV)
- **How?:** By using all PV in the event. More details can be found in backup
- **Today (7 TeV):**
 - Determination of N_{signal} and fitting D^* mass distribution
 - Detector Efficiency
 - Luminosity
 - First look at the cross section of D^*

Steps towards cross section

$$\sigma = \frac{N}{L_{int} \cdot \epsilon \cdot a}$$

Nsignal in higher p_T region

SF: 1.09, Nsignal = 908 \pm 44



Nsignal

- Normalized the wrong charge (WC) sign to the right charge sign in the side bands to get the scale factor (SF)
- Use the SF to normalize WC sign in signal band
- Subtract right charge sign to the normalized wrong charge to get Nsignal

Modified gaussian function for signal

$$\text{Gauss}^{\text{mod}} \propto \exp[-0.5 \cdot x^{1+1/(1+0.5 \cdot x)}]$$

$$x = |(\Delta m - m_0)/\sigma|$$

Threshold function for background

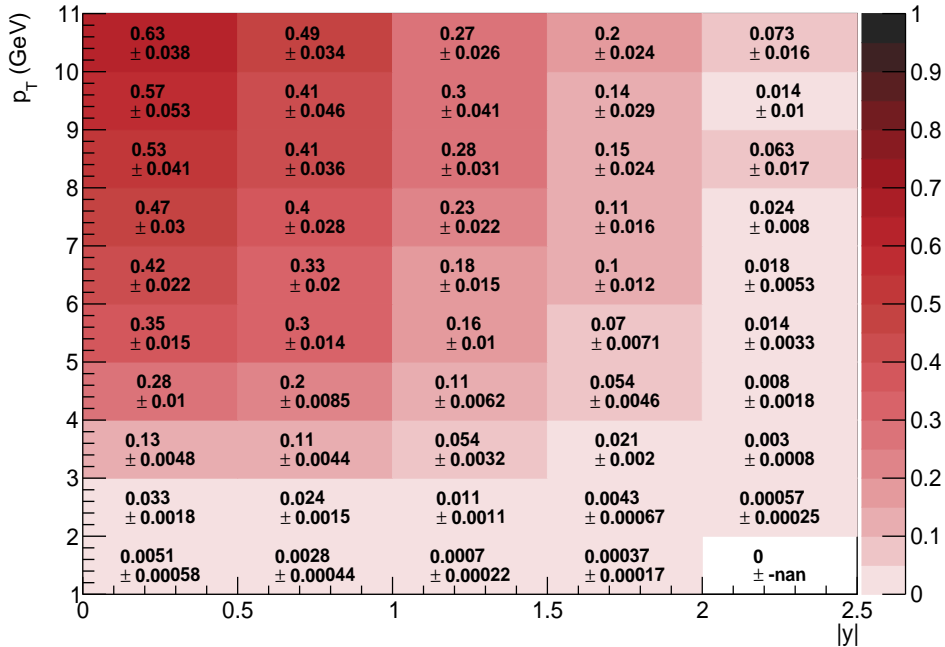
$$A \cdot (\Delta m - m_{\pi^+})^B \cdot \exp[C \cdot (\Delta m - m_{\pi^+}) + D \cdot (\Delta m - m_{\pi^+})^2]$$

Efficiency of D^*

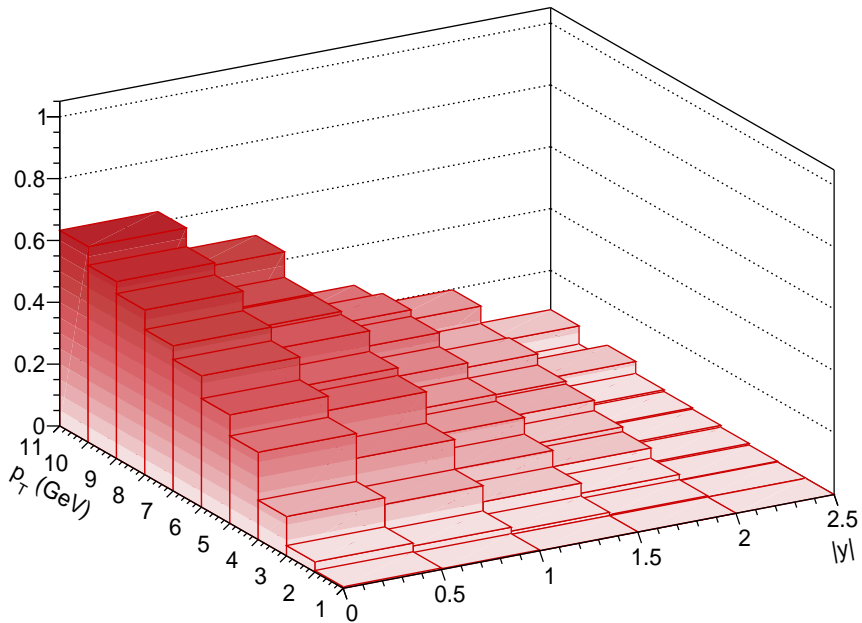
Information related to efficiency $D^* \rightarrow D^0 \pi$

- The requested MC datasets 7TeV are available at DESY site:
 - /MinBias_charmfilter_TuneZ2star_7TeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_START42_V17B-v2/AODSIM $\sim 20M$
 - /MinBias_beautyfilter_TuneZ2star_7TeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_START42_V17B-v2/AODSIM $\sim 2M$
 - /D0Kpi_pT0toInf_TuneZ2star_7TeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_START42_V17B-v2/AODSIM $\sim 6M$
 - /DplusKpipi_pT0toInf_TuneZ2star_7TeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_START42_V17B-v2/AODSIM $\sim 5M$
- Charm fragmentation fraction:
 - $f(c \rightarrow D^*) = 0.23$
 - $f(c \rightarrow D^0) = 0.61$
- Branching ratio (BR):
 - $D^* \rightarrow D^0 \pi = 0.68$
 - $D^0 \rightarrow K \pi = 0.039$
- For MC charm filter:
 - $\frac{N_{reco\&true}}{N_{true}} / (0.039 * 0.68)$ (For D^*)
 - $\frac{N_{reco\&true}}{N_{true}} / (0.039/2)$ (For D^0)

eff_{D*⁻→Kππ} in MC charm



eff_{D^{*}->Kππ} in MC charm



Luminosity

Luminosity

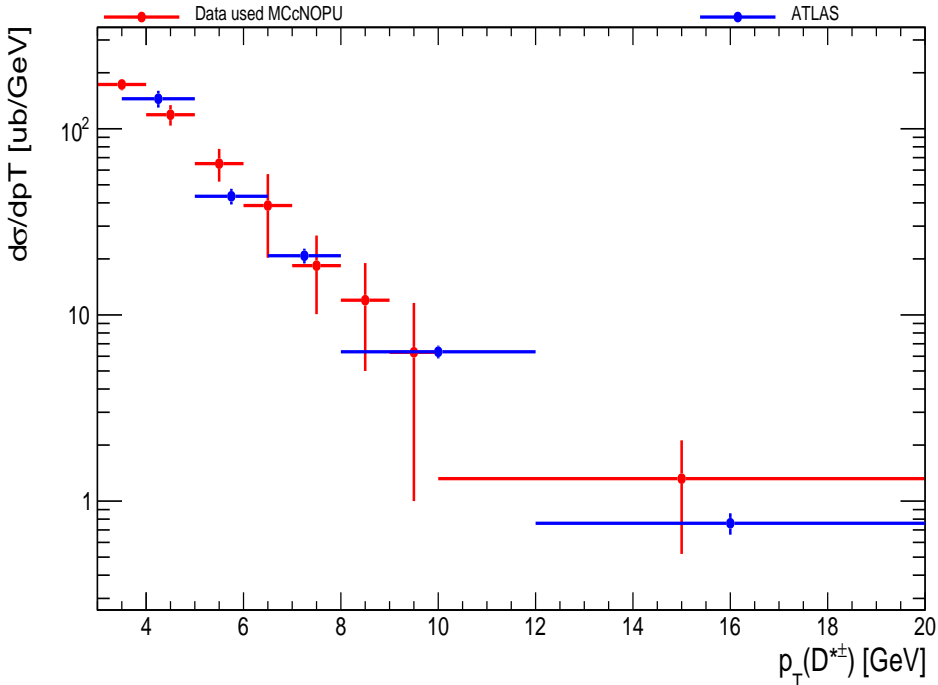
- The calculation of luminosity using brilcalc was conducted
- Command that I used as recommended in Lumi twiki in [here](#):
 - `brilcalc lumi -type hfoc -i
Cert_136033-149442_7TeV_Apr21ReReco_Collisions10_JSON_v2.txt -hltpath
HLT_ZeroBias`
- However, the information is not quite right
- Investigation and some discussion with other people is ongoing
- Therefore, estimate luminosity was used to calculate this cross section

```

#Summary:
+-----+-----+-----+-----+-----+-----+
| hltpath      | nfill | nrun | ncms | totdelivered(/ub) | totrecorded(/ub) |
+-----+-----+-----+-----+-----+-----+
| HLT_ZeroBias | 76    | 272  | 71876 | 283101.916047805  | 277327.126526316 |
+-----+-----+-----+-----+-----+-----+
#Sum delivered : 283101.916047805
#Sum recorded  : 277327.126526316

```

Cross section of D^*



Conclusion

- N_{signal} was determined using background subtraction method
- Fitting will be used for systematic later on
- The efficiency in MC charm looks reasonable
- At this moment, luminosity is the estimate luminosity. Need to investigate more on this
- First look at the cross section is successful
- The shape of the cross section looks correct
- For charm and beauty separation, see Josry's presentation

Any suggestions and questions are welcome!

Backup

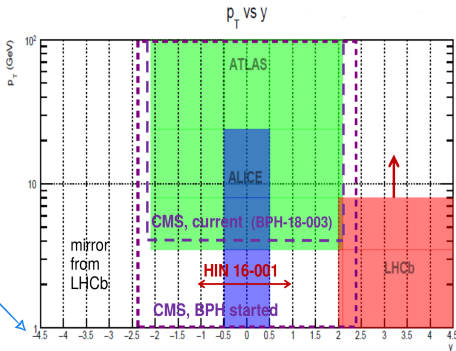
Introduction overview

- **Objective:** To measure the total cross section of inclusive charm at different pp center of mass energies (0.9, 2.7, 5, 7, 8, 13 (from PU in BParking) TeV)
- **Why?** Test NNLO QCD, constraints on PDFs, measurement of charm quark mass
- So far, only parts of phase space are measured at LHC
- **CMS + LHCb** together can **cover** essentially **full phase space** of $\sigma_{c\bar{c}}^{tot}$
- **Challenge:** Acceptance of D mesons at low p_T

$\sigma_{c\bar{c}}^{tot}$ expected to be ~ 10 mb!

CMS (5 & 13 TeV)
arXiv:1708.04962
BPH-18-003

Goal:
Measure D mesons
down to p_T 1 GeV



ATLAS (7 TeV)
arXiv:1512.02913v2

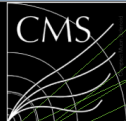
LHCb (5, 7 & 13 TeV)
arXiv:1610.02230v2
arXiv:1302.2864v1
arXiv:1510.01707v6

ALICE (2.76, 5 & 7 TeV)
arXiv:1205.4007v3
arXiv:1901.07979
arXiv:1111.1553v3

Analysis strategy in general

Rho Z

CMS Experiment at LHC, CERN
Data recorded: Tue Aug 2 09:15:27 2016 CEST
Run/Event: 278018 / 1233678348
Lumi section: 679



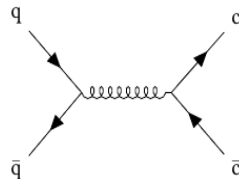
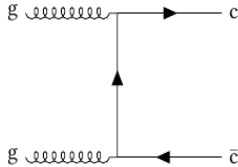
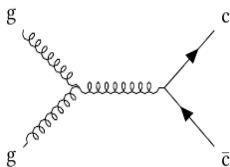
Data Zero Bias 13 TeV event display

It shows several primary vertices in an event

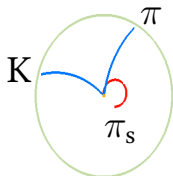
1 out of 10 vertices is expected to be charm vertex

We use all primary vertices for our analysis!

D meson reconstruction



CMS Experiment at LHC, CERN
 Data recorded: Sun Oct 17 06:06:53 2010 CEST
 Run/Event: 148031 / 442976968
 Lumi section: 554



MB 2010 Data



Primary Vertex

Beam spot

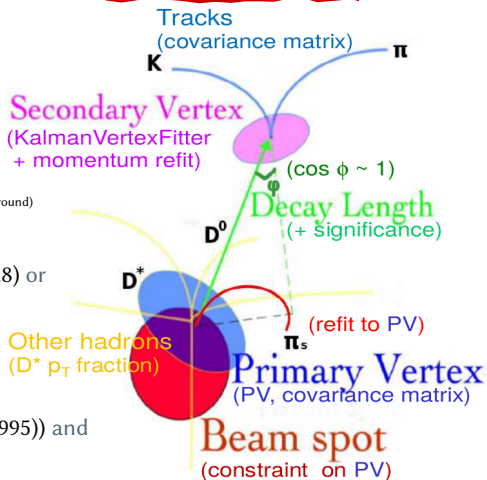
D*[±] → D⁰π[±] → K[∓]π[±]π[±] selection

optimized for
low p_T charm

$$p_{Tfrac} = \frac{p_T \text{ of D meson}}{\sum p_T \text{ of all tracks at respective PV}}$$

$$dl_{Sig}^{D^0} = \frac{dl^{D^0}}{dl_{err}^{D^0}}$$

- Track p_T cut
 - p_T^{K,π} > 0.5 GeV, none for π_s
- D⁰ mass cut
- Possible combination:
 - Right charge: K[∓]π[±]π_s[±]
 - Wrong charge: K[∓]π[∓]π_s[±] (combinatorial background)
- For higher p_T (p_T^{D*} > 3.5 GeV):
 - (dl_{Sig}^{D⁰} > 0 & p_{Tfrac}^{D*} > 0.15 and cosϕ > 0.8) or dl_{Sig}^{D⁰} > 2
- For lower p_T (p_T^{D*} < 3.5 GeV):
 - ((dl_{Sig}^{D⁰} > 1.5 & p_{Tfrac}^{D*} > 0.15) or dl_{Sig}^{D⁰} > 3 or (dl_{Sig}^{D⁰} > 2 and cosϕ_{D⁰} > 0.995)) and p_{Tfrac}^{D⁰} > 0.1 and cosϕ > 0.8

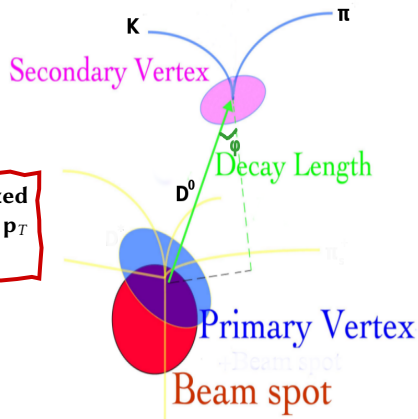


D⁰ / $\bar{D}^0 \rightarrow K^\mp \pi^\pm$ selection

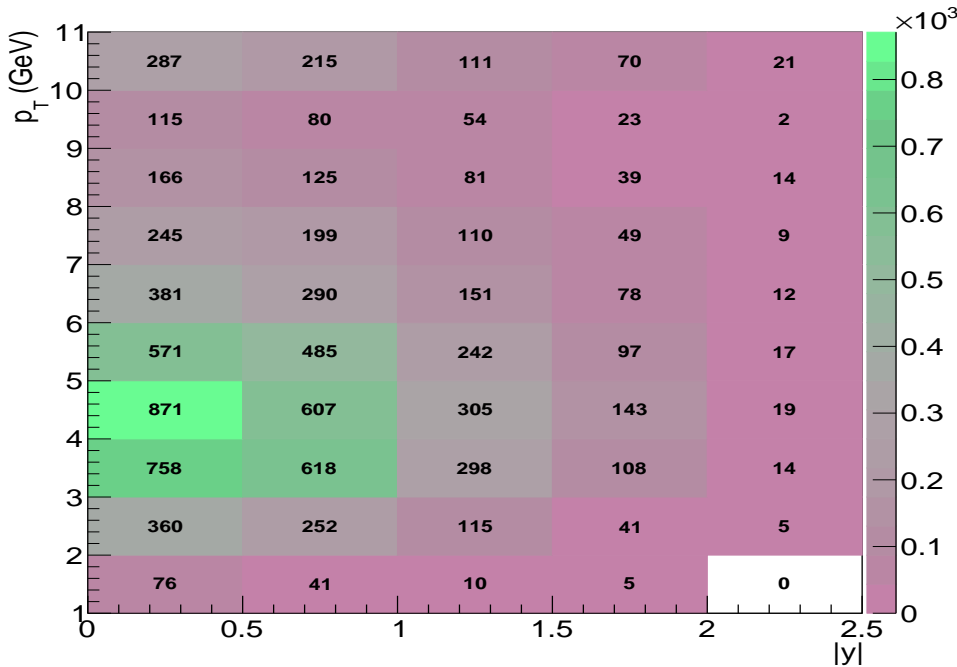
- $p_T^K > 0.5 \text{ GeV}$, $p_T^\pi > 0.5 \text{ GeV}$
- $1.68 < m_{D^0} < 2.05 \text{ GeV}$
- For higher p_T ($p_T^{D^0} > 3.5 \text{ GeV}$):
 - $dl_{Sig}^{D^0} > 4$
 - $\cos\phi^{D^0} > 0.99$
- For lower p_T ($p_T^{D^0} < 3.5 \text{ GeV}$):
 - $dl_{Sig}^{D^0} > 3.5$
 - $\cos\phi^{D^0} > 0.99$

optimized
for low p_T
charm

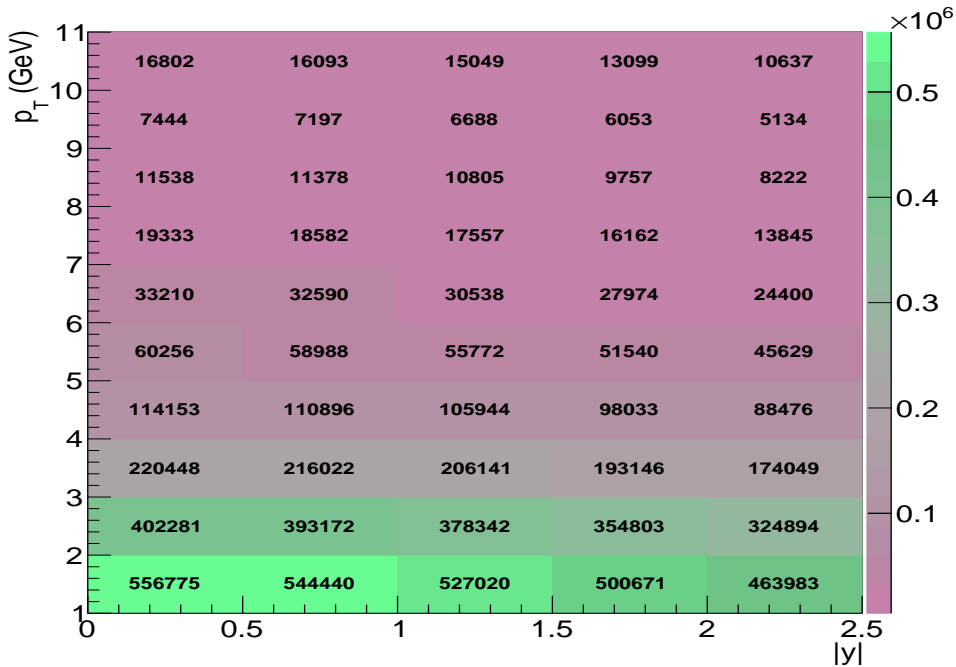
$$dl_{Sig}^{D^0} = \frac{dl^{D^0}}{dl_{err}^{D^0}}$$



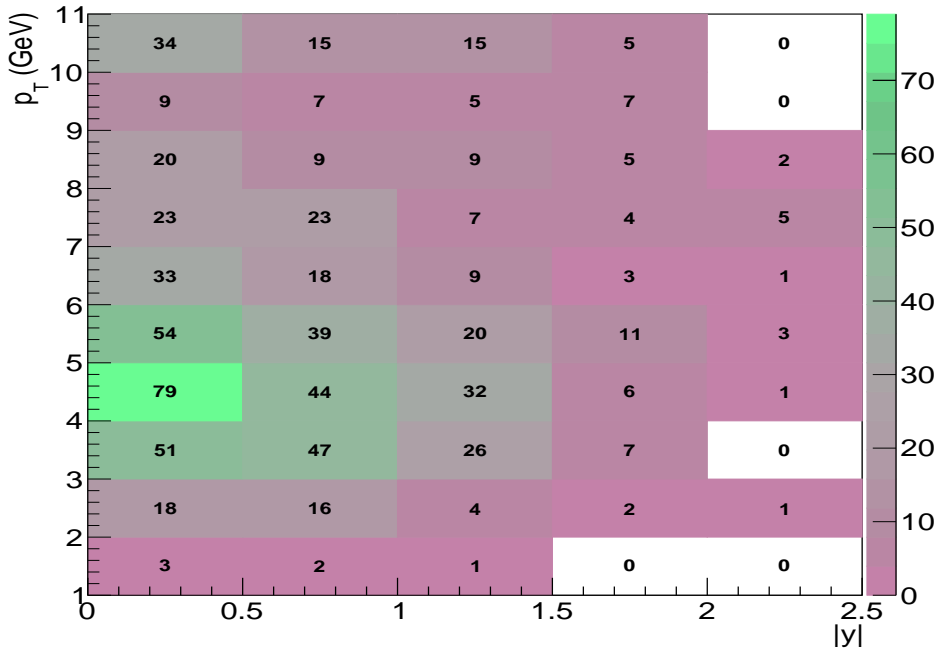
Nreco&true in MC charm



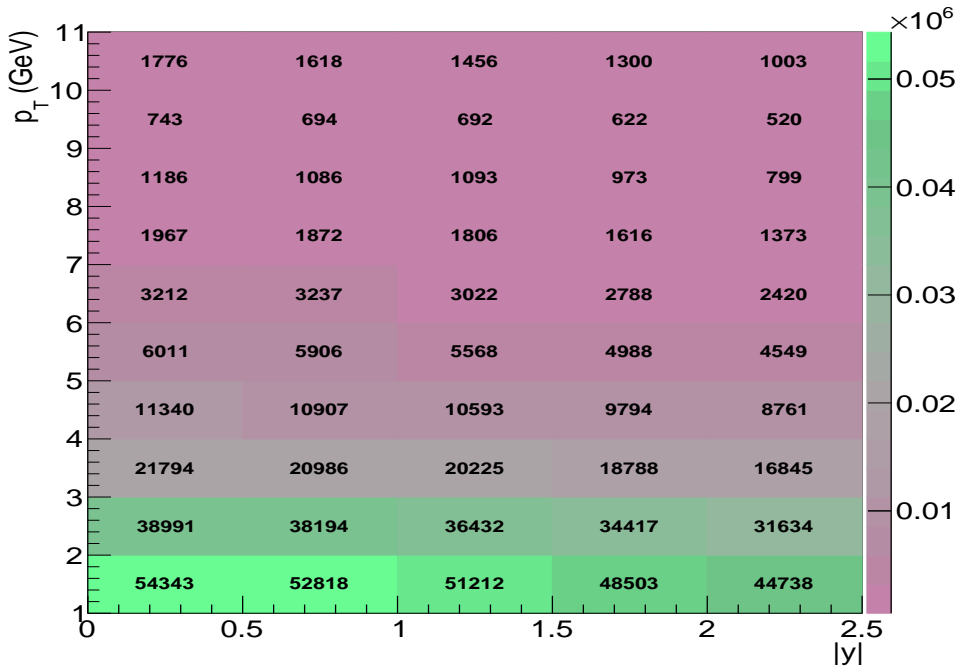
Ntrue in MC charm



Nreco&true in MC MBPU



Ntrue in MC MBPU



ATLAS: Calculated cross section of D^* with kinematic phase space, $|\eta| < 2.1$ and $3.5 < p_T < 100$ GeV

Experiment	Trigger	Integrated lumi	Nsignal	Cross section
$3.5 < p_T < 20$ GeV (low p_T)	- Triggers: first level trigger MB & second level trigger random triggers (these triggers are unbiased for the evt of interest)	- take into account prescale, so integrated lumi = 1.04 nb ⁻¹	- Nsig of $D^{*\pm} = 2140 \pm 120$ (stat)	- cross section of $D^{*\pm} = 331 \pm 18$ (stat)
$20 < p_T < 100$ GeV	- Triggers: first level trigger jet trigger with threshold 5, 10, 15 GeV for $20 < p_T < 30$, $30 < p_T < 40$ and $40 < p_T < 100$ GeV respectively.	- take into account prescale for 5 & 10 GeV, so integrated lumi = 28 and 90 nb ⁻¹ respectively. For 15 GeV, no prescale, so lumi = 280 nb ⁻¹	- Nsig of $D^{*\pm} = 732 \pm 34$	- cross section of $D^{*\pm} = 988 \pm 45$ (stat)

DIFFERENTIAL CROSS SECTIONS OF $D^{*\pm}$

As a function of η , $ \eta < 2.1$		As a function of p_T , $3.5 < p_T < 20$ GeV		As a function of p_T , $20 < p_T < 100$ GeV	
p_T range [GeV]	D_{cross} / dp_T [ub / GeV]	$ \eta $ range	$D_{\text{cross}} / d \eta $ [ub / GeV]	$ \eta $ range	$D_{\text{cross}} / d \eta $ [nb / GeV]
3.5 – 5.0	145 ± 15	0.0 – 0.2	176 ± 21	0.0 – 0.2	591 ± 66
5.0 – 6.5	43.4 ± 4.2	0.2 – 0.5	158 ± 17	0.2 – 0.5	585 ± 54
6.5 – 8.0	20.8 ± 1.9	0.5 – 0.8	149 ± 15	0.5 – 0.8	638 ± 55
8.0 – 12	6.34 ± 0.5	0.8 – 1.3	156 ± 14	0.8 – 1.3	446 ± 43
12 – 20	$(757 \pm 101)e-3$	1.3 – 2.1	171 ± 23	1.3 – 2.1	358 ± 49
20 – 30	$(78.8 \pm 5.6)e-3$				
30 – 40	$(13.3 \pm 1.2)e-3$				
40 – 60	$(2.52 \pm 0.21)e-3$				
60 – 100	$(131 \pm 31)e-6$				

CMS: Calculating cross section of $D^{*\pm}$ for higher and lower pT (no pT and eta cut)

$N_{\text{signal}} = \text{cross section} * \text{integrated lumi} * \text{efficiency} * \text{acceptance}$ | $\text{cross section} = N_{\text{signal}} / (\text{integrated lumi} * \text{efficiency} * \text{acceptance})$

Variables that have fix values		
Charm fragmentation fraction		Integrated lumi [ub-1]
c → D ^{*+}	0.2	500 (not final)
c → D ⁰	0.6	
Branching fraction		
D ^{*+} → D ⁰ [Γ] = 0.68, D ⁰ → K [Γ] = 0.039,		
D ^{*+} BR = 0.68 * 0.039 = 0.026		

MC	MC Description	hc_Dstar_deltamhptr/w	trueDstartp
/MinBias_TuneZ2star_HFshowerLibrary_7TeV_pythia6/Summer12-LowPU2010_DR42_PU_S0_START42_V17B-v2/AODSIM	#events: 19,868,000 events, Minimum bias events with single and double diffractive process	if (DstarD0_simlidx[ee]>1 && Dstar_simlidx[ee]>1) { DstarD0_simlidx; // matched true D0 in genparticle list Dstar_simlidx; // associated true D* in Genpart, if any DstarD0_simlidx.push_back(simidD0); simidD0 = idD0sim[id0];	Truth D* pdg 413 w/o any specific decay & w/o coming from any trueDstartp_noBeauty_noCharm Truth D* pdg 413 w/o any specific decay & has no beauty & charm
/D0Kpi_pT0toInf_TuneZ2star_900GeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_900GeV_START42_V17B-v2/AODSIM	#events: 4,857,763 events, Minimum bias events with D0 → Kpi filter		trueDstartp_beauty_charm Truth D* pdg 413 w/o any specific decay & has beauty & charm
/MinBias_charmfilter_TuneZ2star_7TeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_START42_V17B-v2/AODSIM	#events: 19,444,773 events, Minimum bias events with charm filter		trueDstartp_beauty Truth D* pdg 413 w/o any specific decay & has beauty but not charm
/MinBias_beautyfilter_TuneZ2star_7TeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_START42_V17B-v2/AODSIM	#events: 1,827,530 events, Minimum bias events with beauty filter		trueDstartp_charm Truth D* pdg 413 w/o any specific decay & has charm but not beauty

Some information:

*all Nsig, reco, true is the integral

<https://twiki.cern.ch/twiki/bin/view/CMS/TWikiLUM#TabLum>

In MuDhistos4:

#bin, xmin, xmax: 100, 0.138, 0.17

hc_Dstar_deltamhptr/w: with pT cut > 3.5 GeV, no eta cut

hc_Dstar_deltamhptr/w: with pT cut > 3.5 GeV, no eta cut

#bin, xmin, xmax: 80, 0, 20.

trueDstartp: no pT and eta cut, fill the truth Dstar particle

all histograms are rebin 2

Eff n Xsec xkira mesin lg. Guna tgn. nk dptkn value Nreco tu sama dgn nsignal.tukar nm histogram and input is MC. Ntrue pulak dpt drp printout integral pT > 3.5

Higher pT, > 3.5 [GeV]

	Data	MC	
	ZeroBias data	MB HFshower with PU	Charm filter
Nsignal (Data) hc_Dstar_deltamhptr/w	908 ± 44		
Nreco match true hc_Dstar_deltamhptr/w		565 ± 24	6491 ± 80
Ntrue trueDstarpt		228419 ± 478	2321820 ± 1524
Eff		0.0025 ± 0.00011	0.0028 ± 0.0015
Eff detector		9.6%	10.8%
Cross section [ub]		728 ± 28	651 ± 153

1.5 < Lower pT, < 3.5 [GeV]

	Data	MC	
	0B RunA + MB RunA&B	MB HFshower with PU	Charm filter
Nsignal (Data) hc_Dstar_deltamhptr/w	207 ± 30		
Nreco match true hc_Dstar_deltamhptr/w		80 ± 9	1265 ± 9
Ntrue trueDstarpt		1046720 ± 1023	10846700 ± 3293
Eff		0.000076 ± 8.49e-6	0.00011 ± 12.2e-6
Eff detector		0.2%	0.4%
Cross section [ub]		2723 ± 518	1881 ± 282

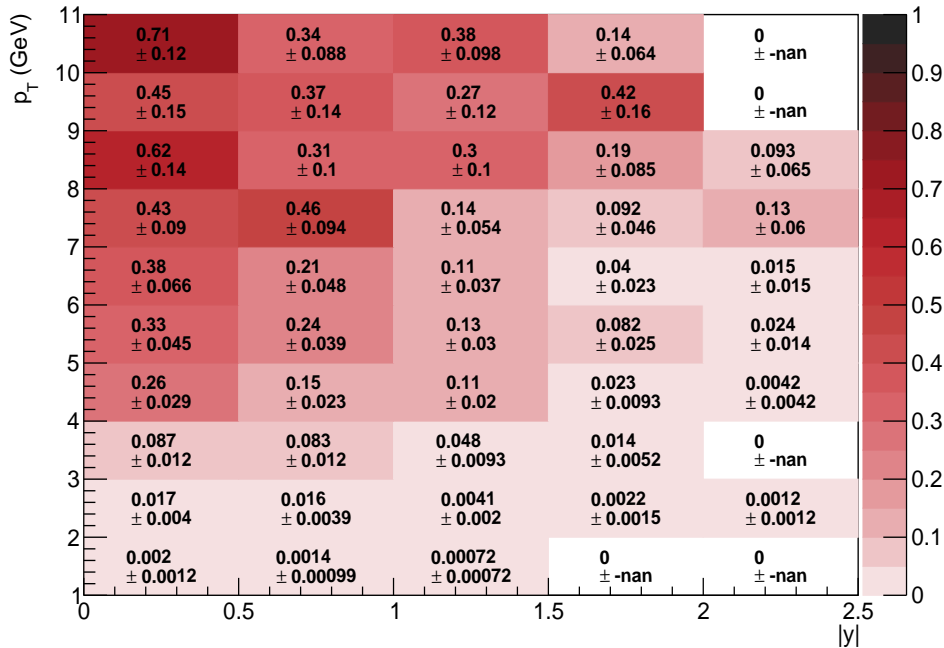
CMS: Calculating cross section of D^* with kinematic phase space, $|\eta| < 2.1$ and p_T

 DIFFERENTIAL CROSS SECTIONS OF $D^{*\pm}$ AS A FUNCTION OF

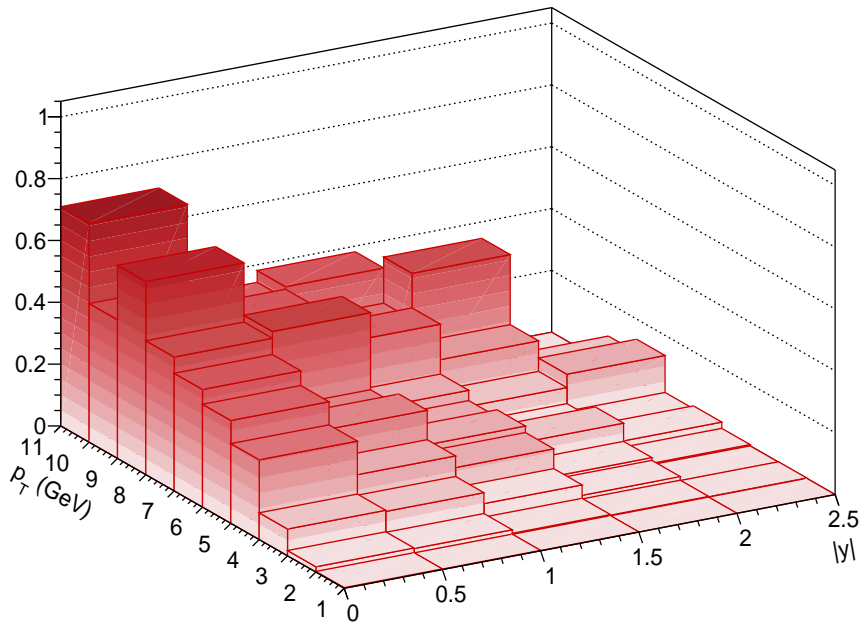
pT range [GeV]	Nsignal (Data) hc_Dstar_deltam_ptr/w	Nreco match true (MC MBPU) hc_Dstar_deltam_ptr/w	Ntrue (MC MBPU) trueDstarptetacut	Eff (MC MBPU)
0 - 1	0	0	59674	0
1 - 2	0	0	167501	0
2 - 3	0	0	137727	0
3 - 4	156 ± 12	104 ± 10	80263 ± 283	$0.0013 \pm 1.3e-5$
4 - 5	238 ± 15	147 ± 12	42780 ± 207	$0.0034 \pm 2.7e-4$
5 - 6	175 ± 13	114 ± 11	22838 ± 151	$0.0050 \pm 4.8e-4$
6 - 7	122 ± 11	57 ± 8	12520 ± 112	$0.0045 \pm 6.3e-4$
7 - 8	69 ± 8.3	56 ± 7	7434 ± 86	$0.0075 \pm 9.4e-4$
8 - 9	49 ± 7	35 ± 6	4469 ± 67	$0.0078 \pm 1.3e-3$
9 - 10	28 ± 5.3	25 ± 5	2844 ± 53	$0.0088 \pm 1.8e-3$
10-20	65 ± 8	60 ± 8	6328 ± 80	$0.0095 \pm 1.3e-3$

DIFFERENTIAL CROSS SECTIONS OF D*± AS A FUNCTION OF ETA, ETA < 2.1						
pT range [GeV]	Nsignal (Data) hc_Dstar_deltam_ptr/w	Nreco match true (MC MBc) hc_Dstar_deltam_ptrt/w	Ntrue (MC MBc) trueDstartetacut	Eff (MC MBc)	Integrated lumi [ub-1]	dcross / dpT [ub / GeV]
0 - 1	0	0	612545	0	500 ± 36 (not final)	0
1 - 2	0	104	1.71978e+06	0		0
2 - 3	0	635	1.42355e+06	0		0
3 - 4	156 ± 12	1486 ± 39	819539 ± 905	0.0018 ± 4.7e-5		173 ± 12
4 - 5	238 ± 15	1635 ± 40	430673 ± 656	0.0040 ± 9.8e-5		119 ± 15
5 - 6	175 ± 13	1234 ± 35	230199 ± 480	0.0054 ± 1.5e-4		65.0 ± 13
6 - 7	122 ± 11	803 ± 28	127183 ± 357	0.0063 ± 2.2e-4		38.7 ± 11
7 - 8	69 ± 8.3	550 ± 23	73564 ± 271	0.0075 ± 3.1e-4		18.4 ± 8.3
8 - 9	49 ± 7	365 ± 19.	44768 ± 212	0.0082 ± 4.3e-4		12.0 ± 7
9 - 10	28 ± 5.3	251 ± 16	28261 ± 168	0.0089 ± 5.6e-3		6.30 ± 5.3
10-20	65 ± 8	620 ± 25	63087 ± 251	0.0098 ± 4.0e-4	1.32 ± 0.8	

eff_{D*⁻→Kππ} in MC MBPU



eff_{D^{*}->Kππ} in MC MBPU



Eff. of D^* reconstruction

