Double differential σ of D* at 7TeV 2010

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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 PVs in the event. More details can be found in backup
- Today (double differential σ 7 TeV):
  - Analysis setup
  - Signal determination
  - Efficiency
  - Luminosity
  - σ

Analysis setup

Analysis setup

- The Ntuples were produced using Virtual Machine (VM) from CMS Open Data with CRAB job (SLC5 to compile and el7 to submit the job)
- The input datasets for data are available publicly in CMS Open Data portal
- For MC, currently the MC used was only charm MC (w/o separation with beauty)
- The input datasets that are used for the results:
  - /ZeroBias/Run2010A-Apr21ReReco-v1/AOD
  - /MinimumBias/Run2010A-Apr21ReReco-v1/AOD
  - /MinimumBias/Run2010B-Apr21ReReco-v1/AOD
  - /ZeroBias/Commissioning10-May19ReReco-v1/RECO
  - /MinimumBias/Commissioning10-May19ReReco-v1/RECO
  - /MinBias_charmfilter_TuneZ2star_7TeV-pythia6-evtgen/LowPU2010DR42-NoPU2010_DR42_START42_V17B-v2/AODSIM
- Previously, the results used only ZeroBias trigger
- Now, used ZeroBias and MinimumBias triggers. The details for triggers list can be found in AN-18-284 pg. 28

Signal determination

Signal determination

- There are two methods used to get the number of signals
- 1. Used fitting function
- 2. Used background substraction
- Currently we are using method 2 for double differential σ

Background subtraction

- 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
- Substract right charge sign to the normalized wrong charge to get Nsignal

Fitting function

Modified gaussian function for signal

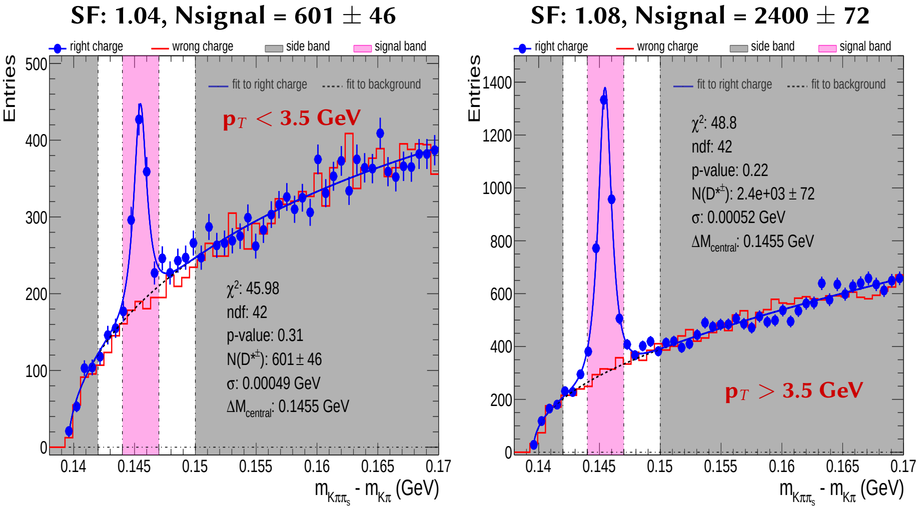
$$\mathrm{Gauss}^{\mathrm{mod}} \propto \exp[-0.5 \cdot x^{1+1/(1+0.5\cdot x)}]$$

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

Threshold function for background

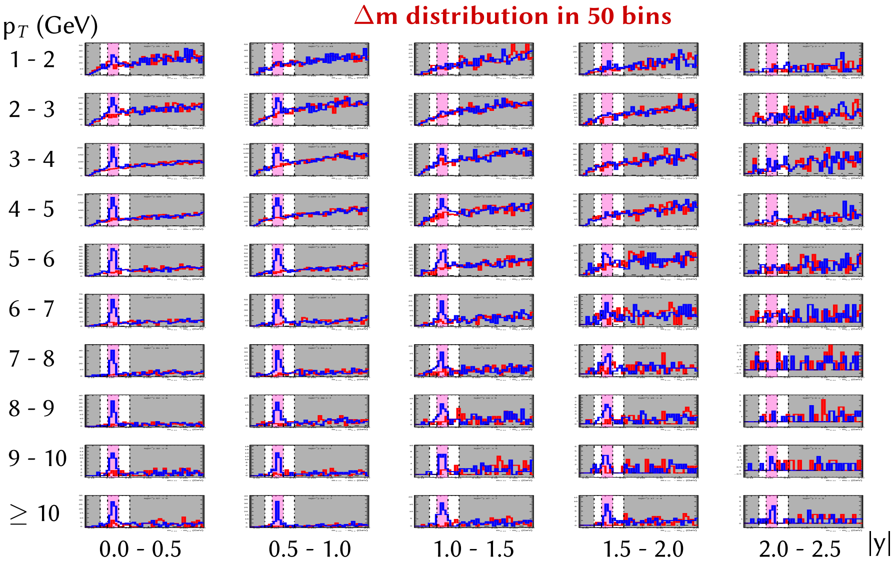
$$A \cdot (\Delta m - m_{\pi^+})^B \cdot \exp[C \cdot (\Delta m - m_{\pi^+}) + D \cdot (\Delta m - m_{\pi^+})^2]$$

Nsignal at lower and higher p_T region

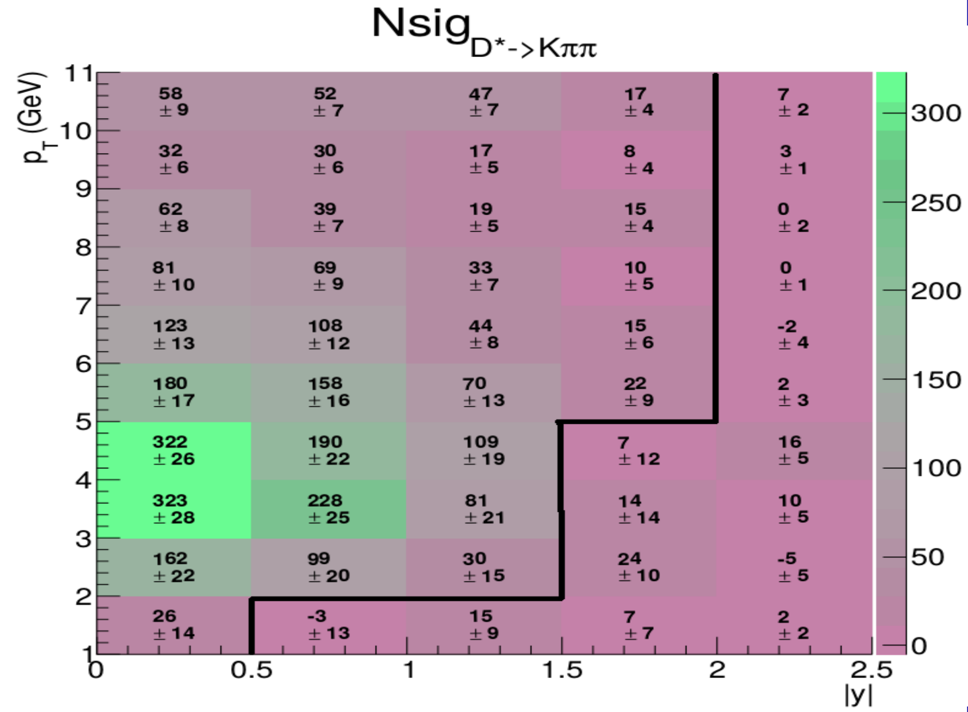


Δm distribution at lower and higher p_T regions using fitting method looks ok

Δm in p_T and y phase space



D* peak can be seen in most region except in $|y| > 1.5$. Individual plots in backup



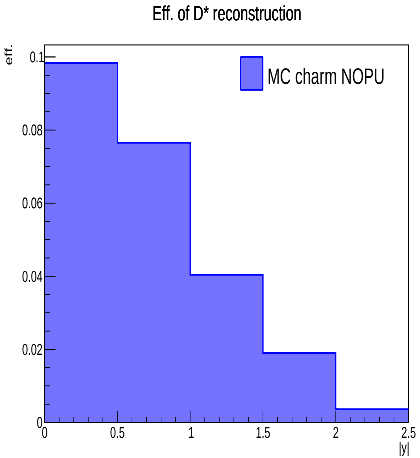
Nsig D*->Kππ
p_T (GeV)
|y|
0
0.5
1
1.5
2
2.5
1
2
3
4
5
6
7
8
9
10
11
0
50
100
150
200
250
300
58 ± 9
52 ± 7
47 ± 7
17 ± 4
7 ± 2
32 ± 6
30 ± 6
17 ± 5
8 ± 4
3 ± 1
62 ± 8
39 ± 7
19 ± 5
15 ± 4
0 ± 2
81 ± 10
69 ± 9
33 ± 7
10 ± 5
0 ± 1
123 ± 13
108 ± 12
44 ± 8
15 ± 6
-2 ± 4
180 ± 17
158 ± 16
70 ± 13
22 ± 9
2 ± 3
322 ± 26
190 ± 22
109 ± 19
7 ± 12
16 ± 5
323 ± 28
228 ± 25
81 ± 21
14 ± 14
10 ± 5
162 ± 22
99 ± 20
30 ± 15
24 ± 10
-5 ± 5
26 ± 14
-3 ± 13
15 ± 9
7 ± 7
2 ± 2

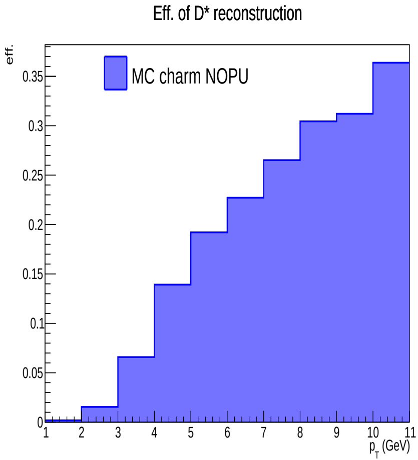
Efficiency

Calculating efficiency of $D^* \to K\pi\pi$

- Branching ratio (BR) from PDG:
  - $D^* \to D^0\pi = 0.68$
  - $D^0 \to K\pi = 0.039$
- D* eff. for MC charm filter:
  - $\frac{N_{reco\&true}}{N_{true}} / (0.039 * 0.68)$

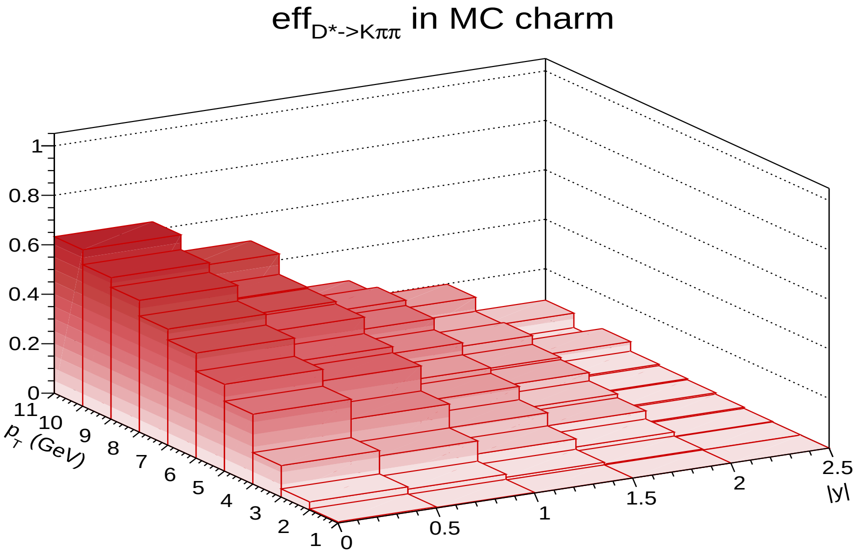
1D D^* efficiency



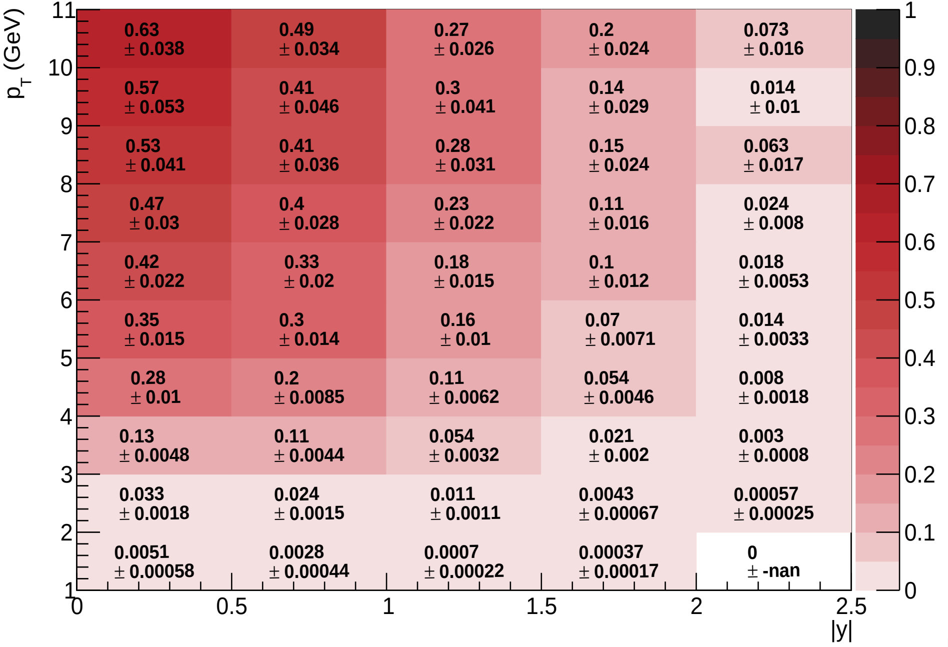


D^* efficiency decreases when rapidity going higher but increases as p_T going higher

2D D* efficiency



$eff_{D^{*}\to K\pi\pi}$ in MC charm

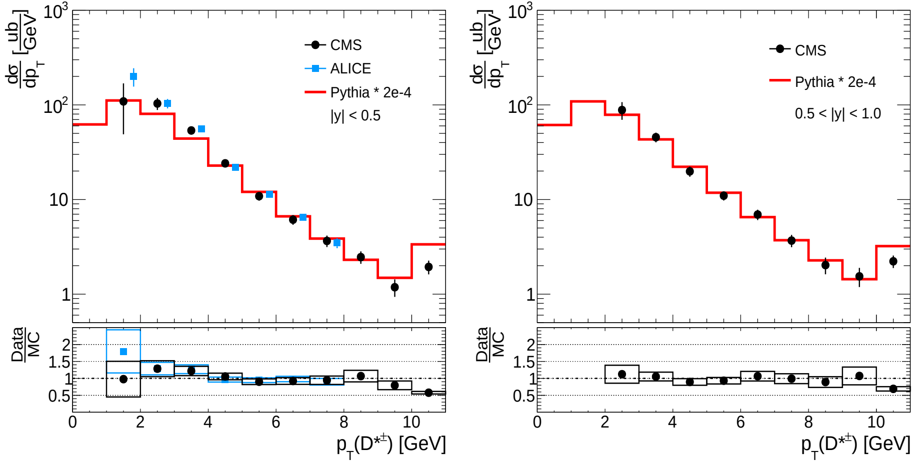


Luminosity

- For this result, estimated luminosity was used: $1.75 nb^{-1}$
- The correct luminosity is almost done but not ready for this presentation
- More details regarding the ongoing luminosity calculation can be found in AN pg. 14 & 30

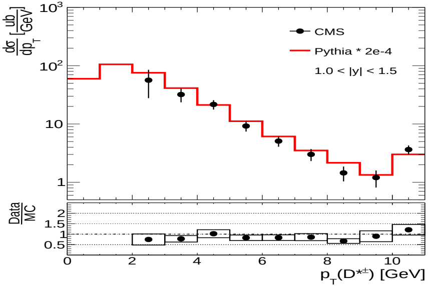
$D^* \sigma$

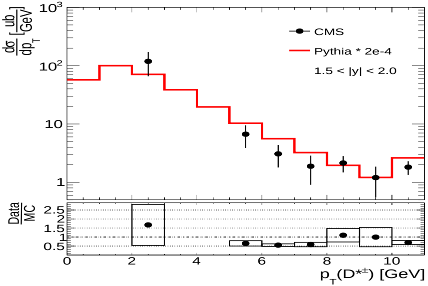
σ as a function of p_T

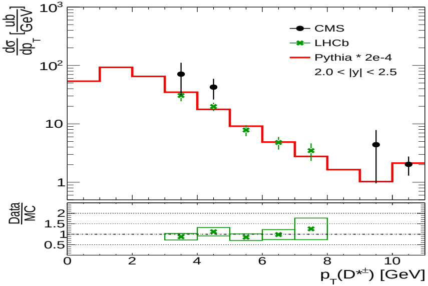


On the left: σ compared with ALICE looks comparable

σ as a function of p_T

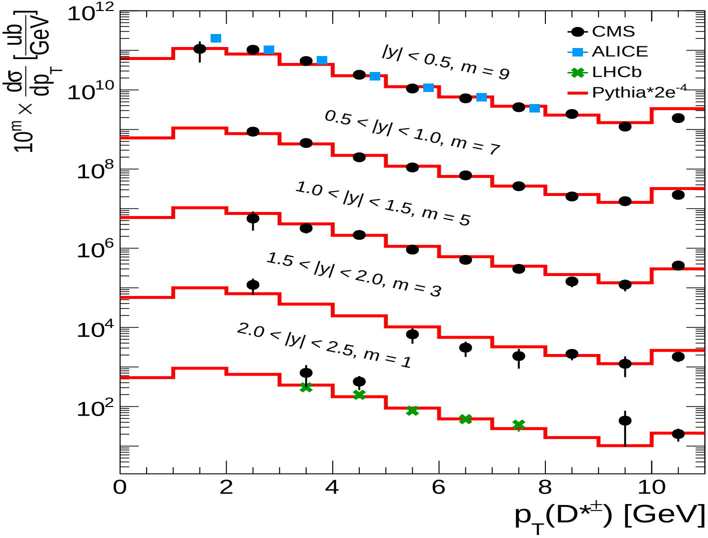






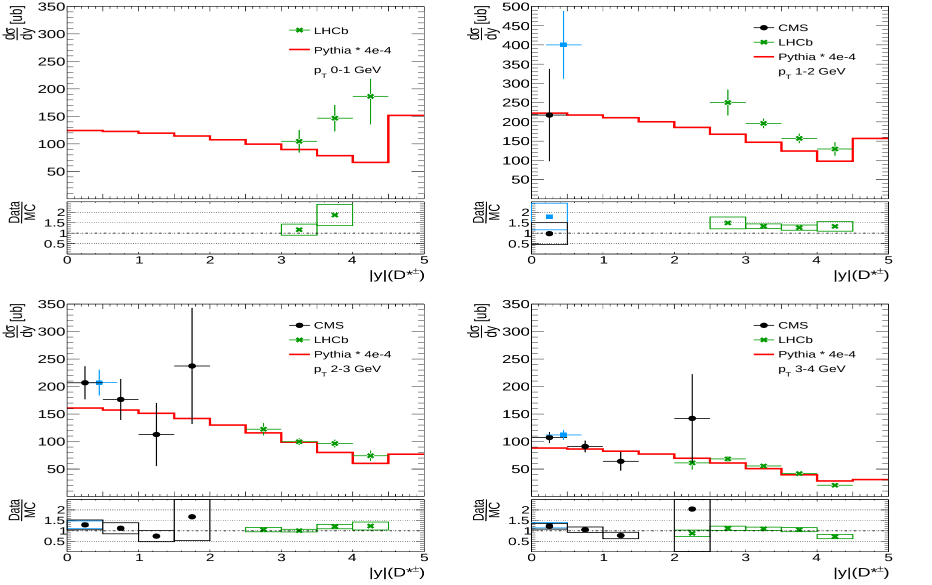
- Comparison with LHCb result
- It agreed with the MC
- For this phase space
  we will use the measurement
  from LHCb

double differential σ as a function of p_T

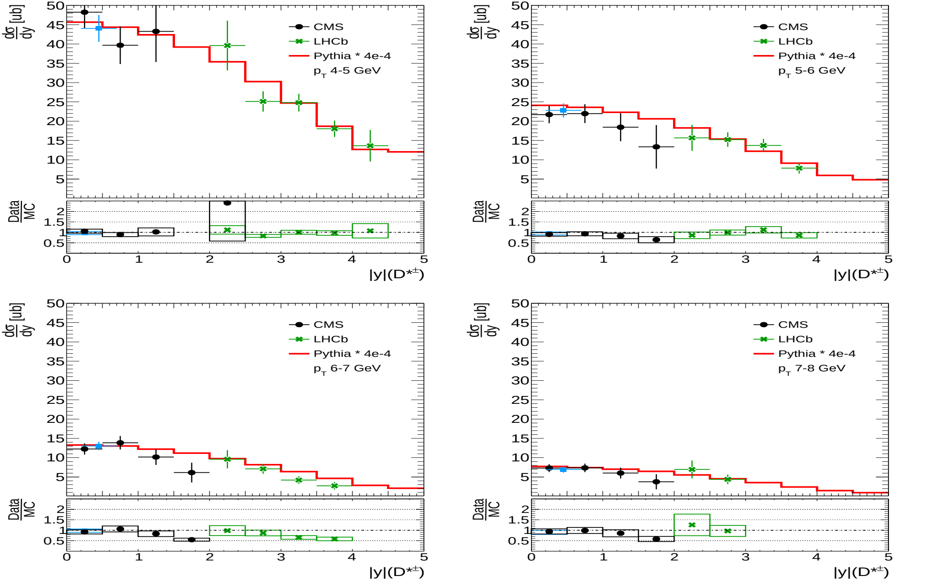


The σ was compared with ALICE and LHCb result for each p_T bin

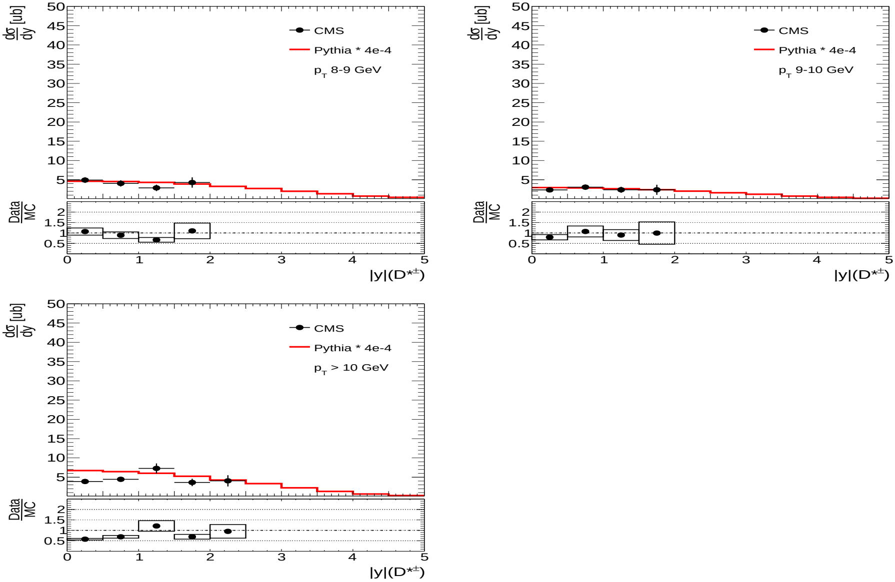
σ as a function of |y|



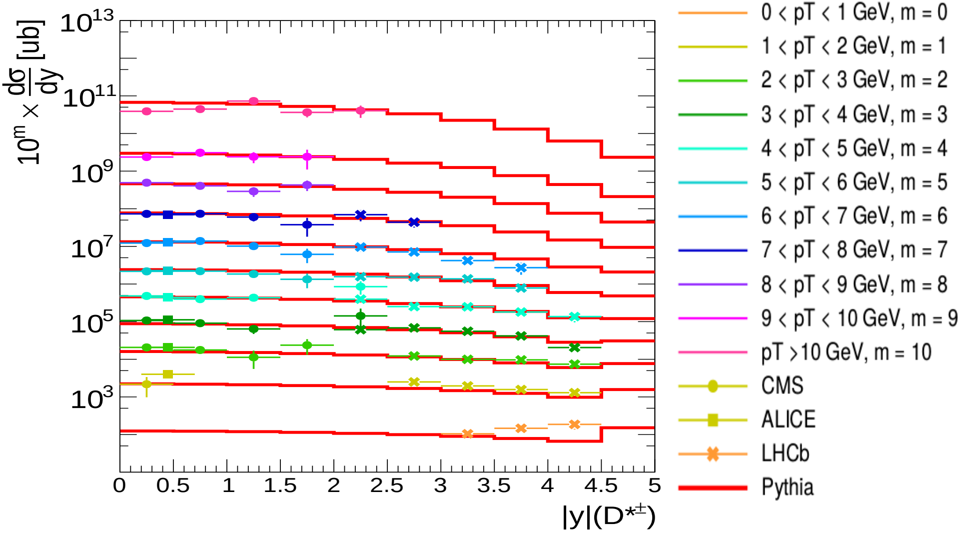
σ as a function of |y|



σ as a function of |y|



double differential σ as a function of |y|



The σ was compared with ALICE and LHCb result for each |y| bin

Conclusion

- More statistics was added to the results. There will be a further increase of statistics by a factor 2 or so from pileup in the muon and electron samples (being worked on)
- Luminosity calculation is almost done
- Double differential σ compared with ALICE, LHCb and Pythia looks reasonable
- Next would be combined 3 bins of rapidity (0.5-2.0)
- Same procedure will be done for D^0
- Systematics studies will start soon

Backup

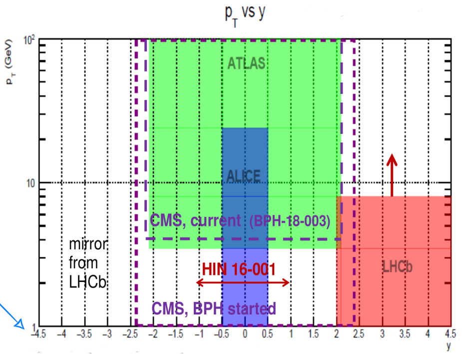
Introduction overview

- 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 $\sigma^{tot}_{c\bar{c}}$
- Challenge: Acceptance of D mesons at low p_T

$\boxed{\sigma^{tot}_{c\bar{c}} \text{ expected to be} \sim 10 \text{ mb!}}$

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

Goal:
Measure D mesons down to p_T 1 GeV

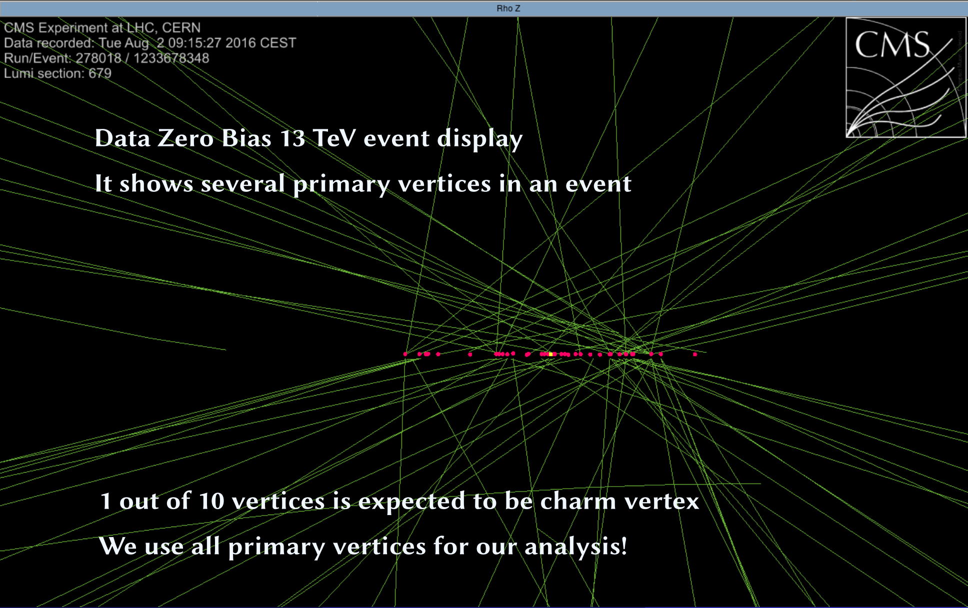


ATLAS (7 TeV)
arXiv:1512.02913v2

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



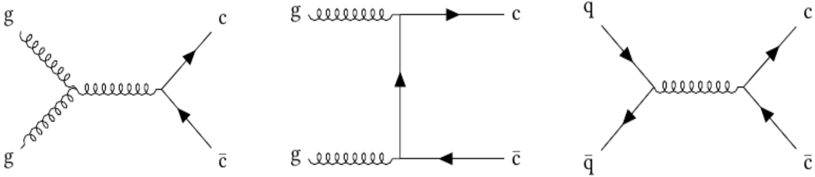
Data Zero Bias 13 TeV event display

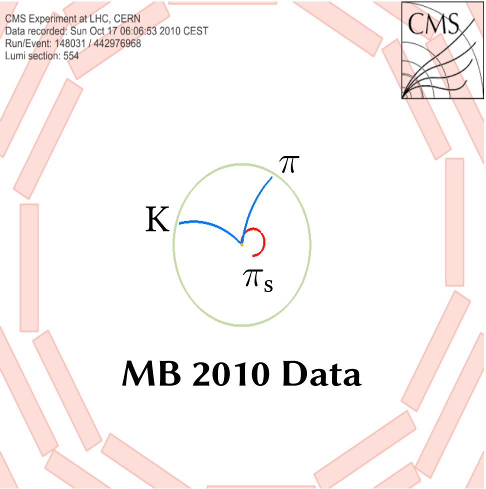
It shows several primary vertices in an event

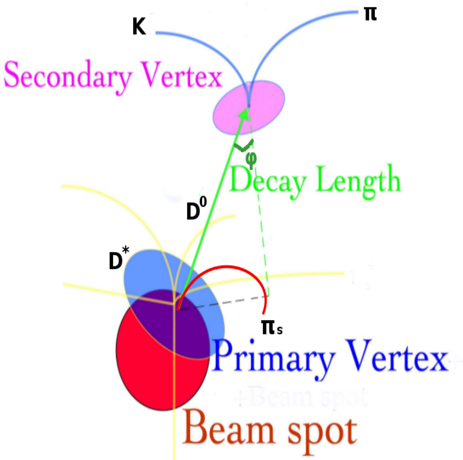
1 out of 10 vertices is expected to be charm vertex

We use all primary vertices for our analysis!

D meson reconstruction


g
g
c
c̄
g
g
c
c̄
q
q̄
c
c̄


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


K
π
Secondary Vertex
φ
Decay Length
D0
D*
πs
Primary Vertex
Beam spot

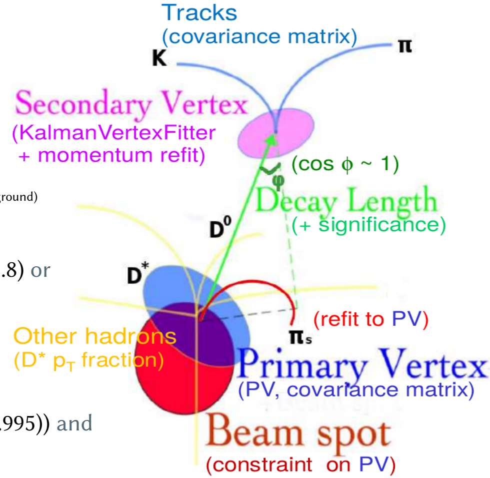
$D^{*\pm} \to D^0\pi^\pm \to K^\mp\pi^\pm\pi^\pm$ selection

optimized for low p_T charm

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

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

- Track p_T cut
  - $p_T^{K,\pi} > 0.5$ GeV, none for π_s
- D^0 mass cut
- Possible combination:
  - Right charge: $K^\mp\pi^\pm\pi_s^\pm$
  - Wrong charge: $K^\mp\pi^\mp\pi_s^\pm$ (combinatorial background)
- For higher p_T ($p_T^{D^*} > 3.5$ GeV):
  - ($dl^{D^0}_{Sig} > 0$ & $p^{D^*}_{Tfrac} > 0.15$ and $\cos\phi > 0.8$) or $dl^{D^0}_{Sig} > 2$
- For lower p_T ($p_T^{D^*} < 3.5$ GeV):
  - (($dl^{D^0}_{Sig} > 1.5$ & $p^{D^*}_{Tfrac} > 0.15$) or $dl^{D^0}_{Sig} > 3$ or ($dl^{D^0}_{Sig} > 2$ and $\cos\phi_{D^0} > 0.995$)) and $p^{D^0}_{Tfrac} > 0.1$ and $\cos\phi > 0.8$

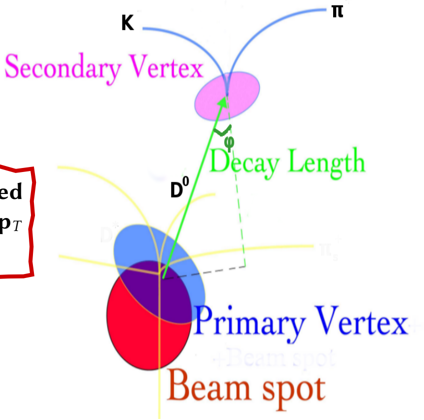


D^0 / $\overline{D}^0 \to K^{\mp}\pi^{\pm}$ selection

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

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

optimized for low p_T charm

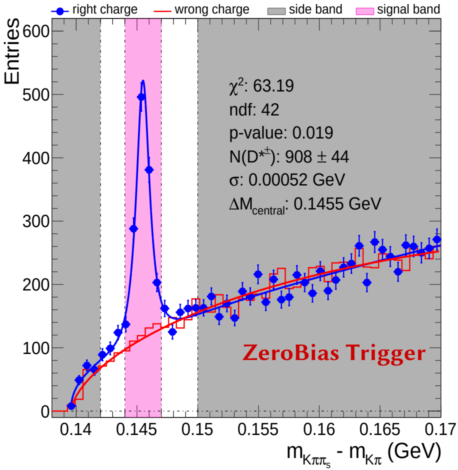


Signal determination cont.

- comparison with ZeroBias Trigger
- higher and lower p_T region using background substraction method
- background substraction method for each phase space
- fitting function method for each phase space

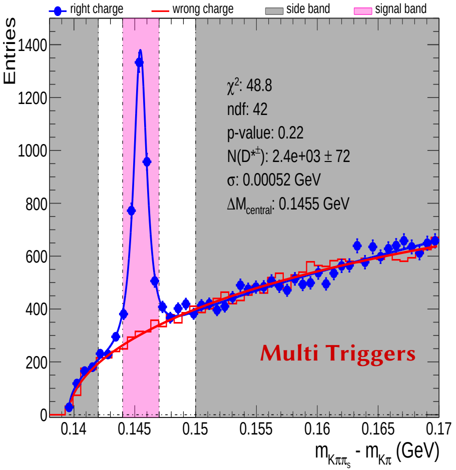
Nsignal at higher p_T region

SF: 1.09, Nsignal = 908 $\pm$ 44



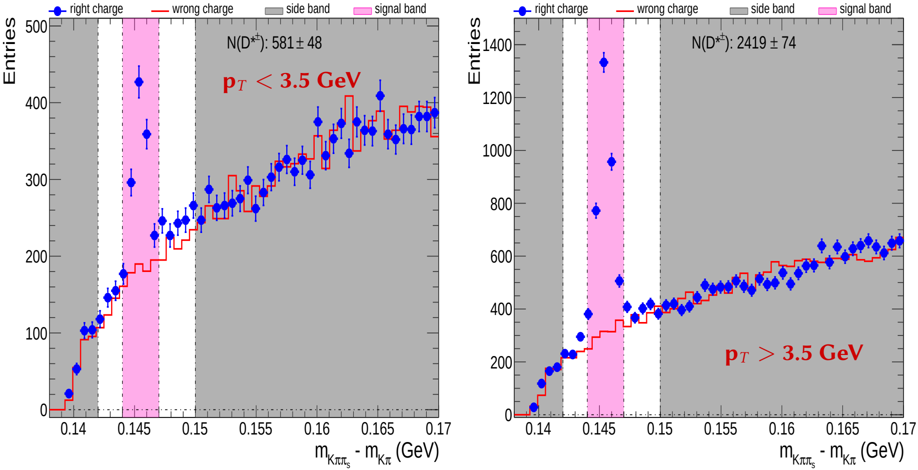
$p_T > 3.5$ GeV, 0.7nb^{-1}

SF: 1.08, Nsignal = 2400 $\pm$ 72



$p_T > 3.5$ GeV, 1.75nb^{-1}

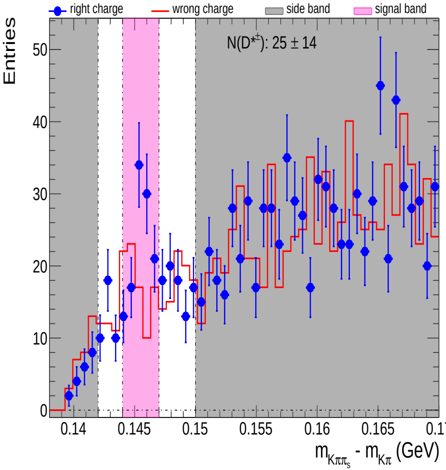
Nsignal at lower and higher p_T region



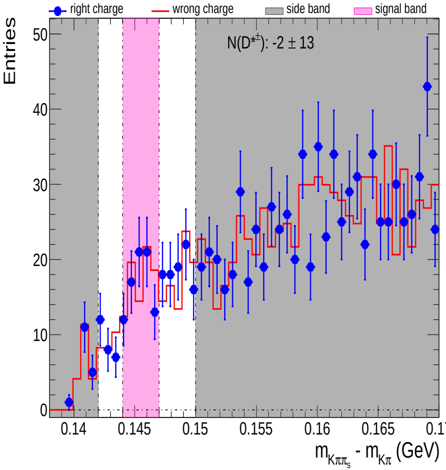
Δm distribution at lower and higher p_T regions using background substraction method looks comparable with fitting method

Nsignal using background substraction

p_T:1-2 GeV, |y|:0.0-0.5

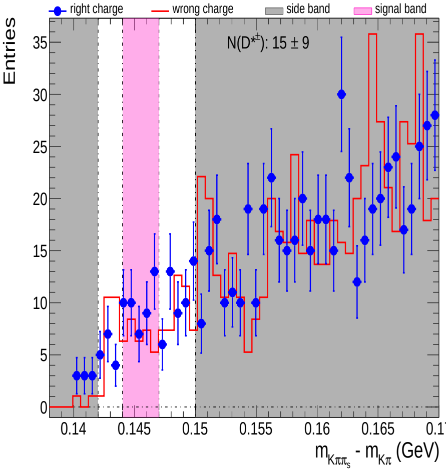


p_T:1-2 GeV, |y|:0.5-1.0

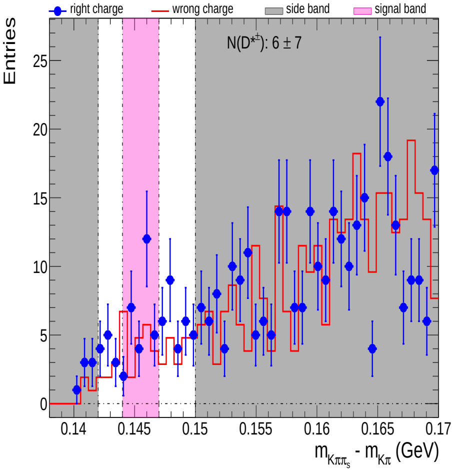


Nsignal using background substraction

p$_T$:1-2 GeV, |y|:1.0-1.5

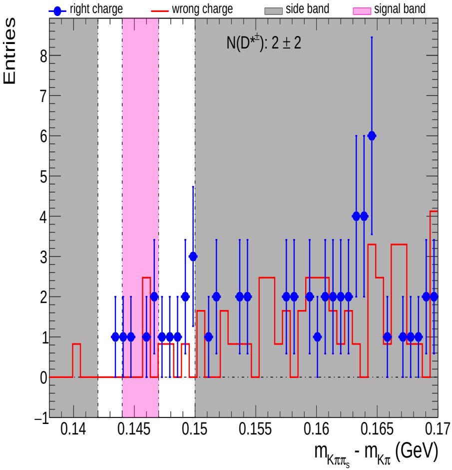


p$_T$:1-2 GeV, |y|:1.5-2.0



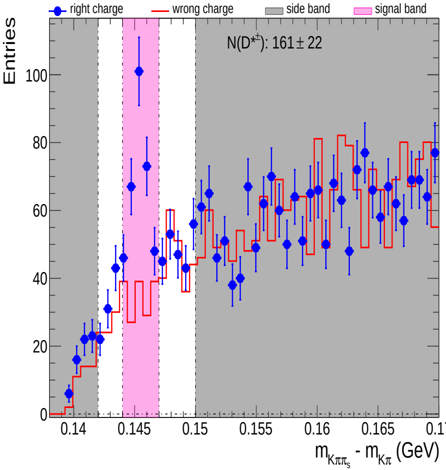
Nsignal using background substraction

p_T:1-2 GeV, |y|:2.0-2.5

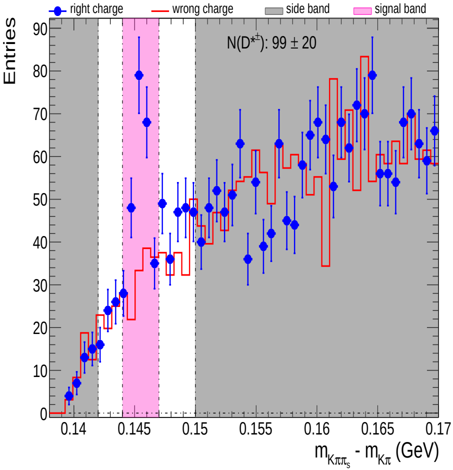


Nsignal using background substraction

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

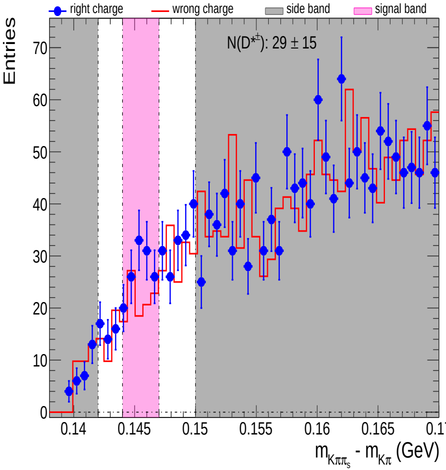


p_T:2-3 GeV, |y|:0.5-1.0

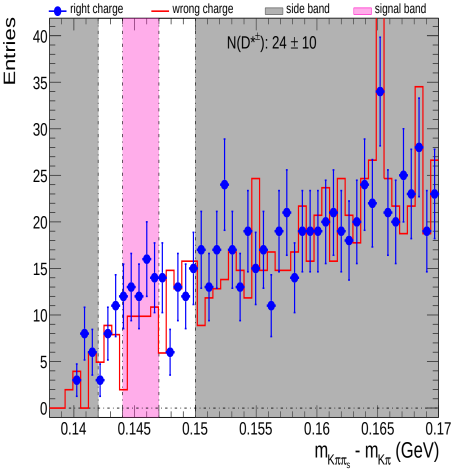


Nsignal using background substraction

p_T:2-3 GeV, |y|:1.0-1.5

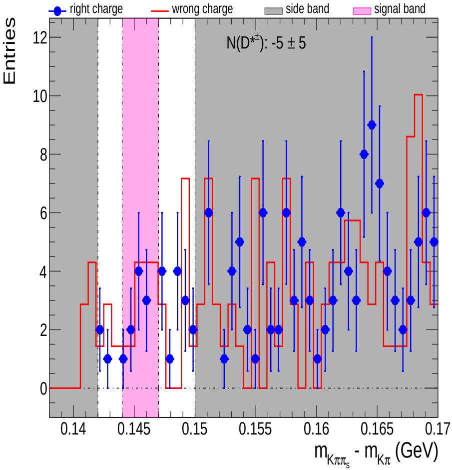


p_T:2-3 GeV, |y|:1.5-2.0



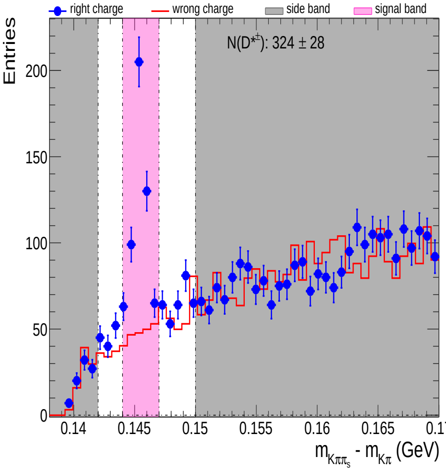
Nsignal using background substraction

p_T:2-3 GeV, |y|:2.0-2.5

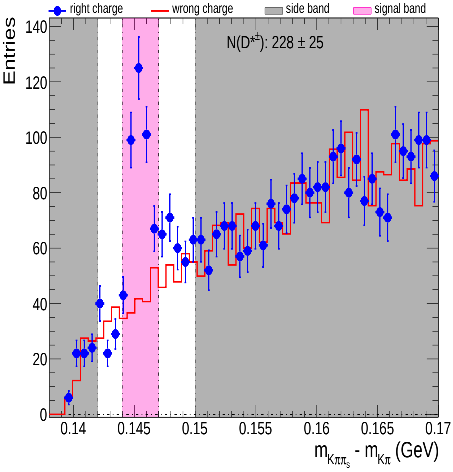


Nsignal using background substraction

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

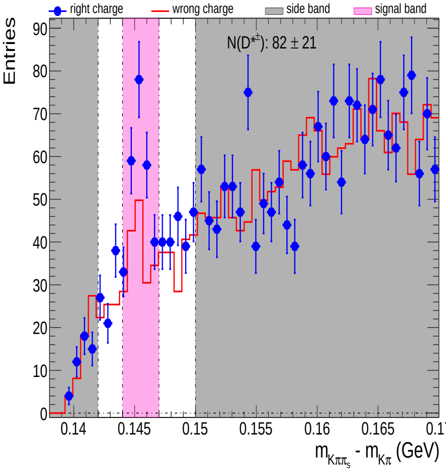


p_T:3-4 GeV, |y|:0.5-1.0

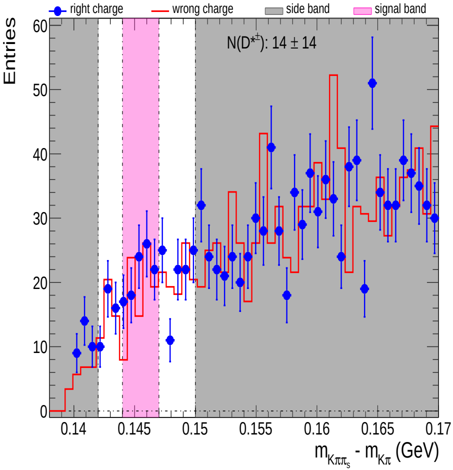


Nsignal using background substraction

p_T:3-4 GeV, |y|:1.0-1.5

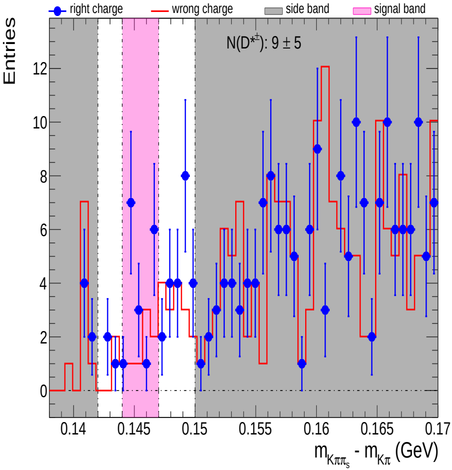


p_T:3-4 GeV, |y|:1.5-2.0



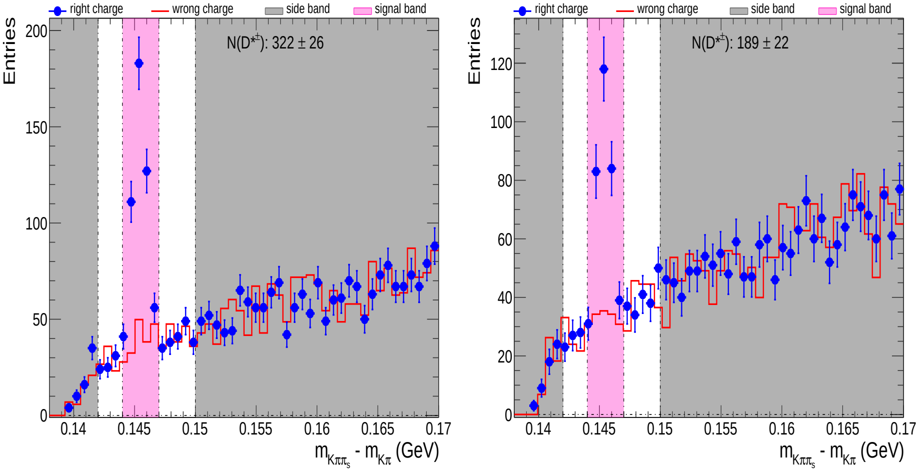
Nsignal using background substraction

p_T:3-4 GeV, |y|:2.0-2.5



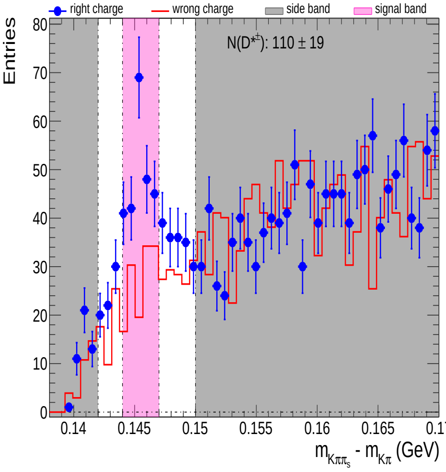
Nsignal using background substraction

p_T:4-5 GeV, |y|:0.0-0.5 **p_T:4-5 GeV, |y|:0.5-1.0**

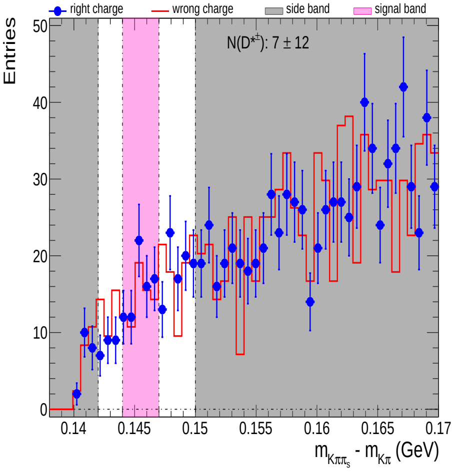


Nsignal using background substraction

p_T:4-5 GeV, |y|:1.0-1.5

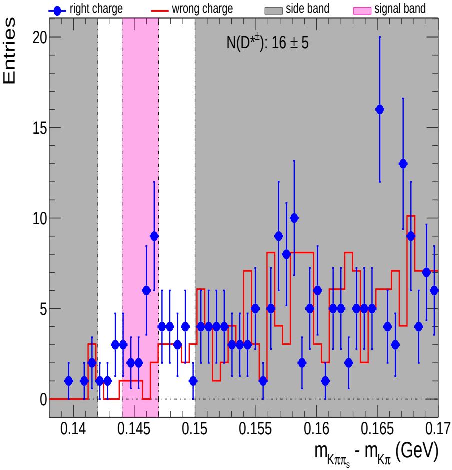


p_T:4-5 GeV, |y|:1.5-2.0



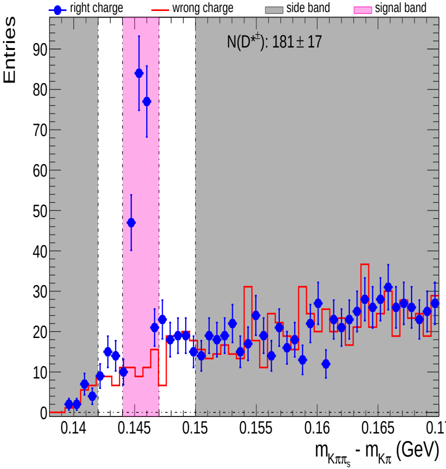
Nsignal using background substraction

p_T:4-5 GeV, |y|:2.0-2.5

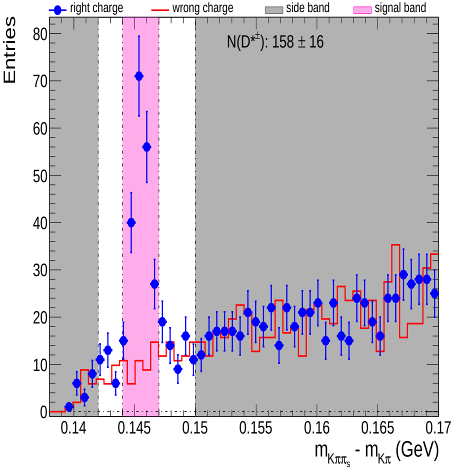


Nsignal using background substraction

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

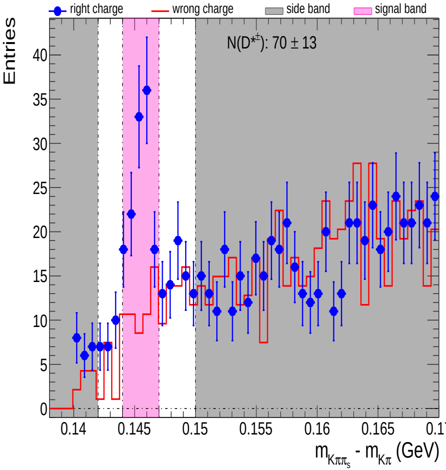


p_T:5-6 GeV, |y|:0.5-1.0

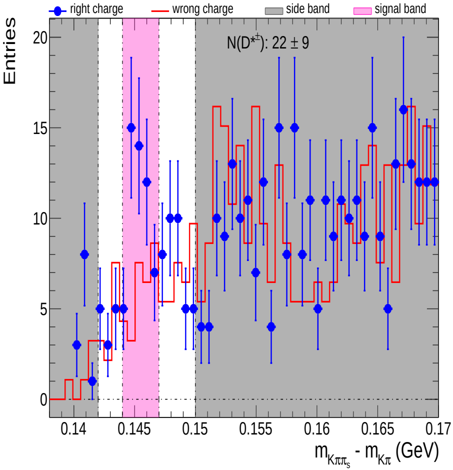


Nsignal using background substraction

p_T:5-6 GeV, |y|:1.0-1.5

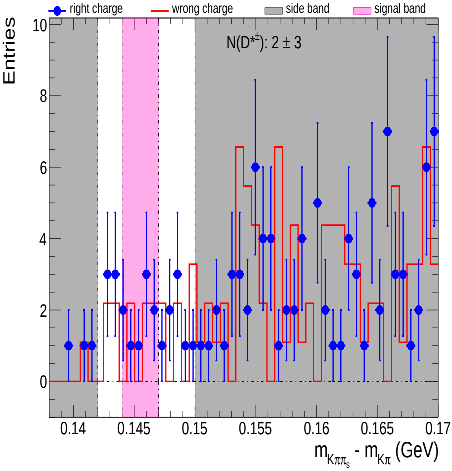


p_T:5-6 GeV, |y|:1.5-2.0

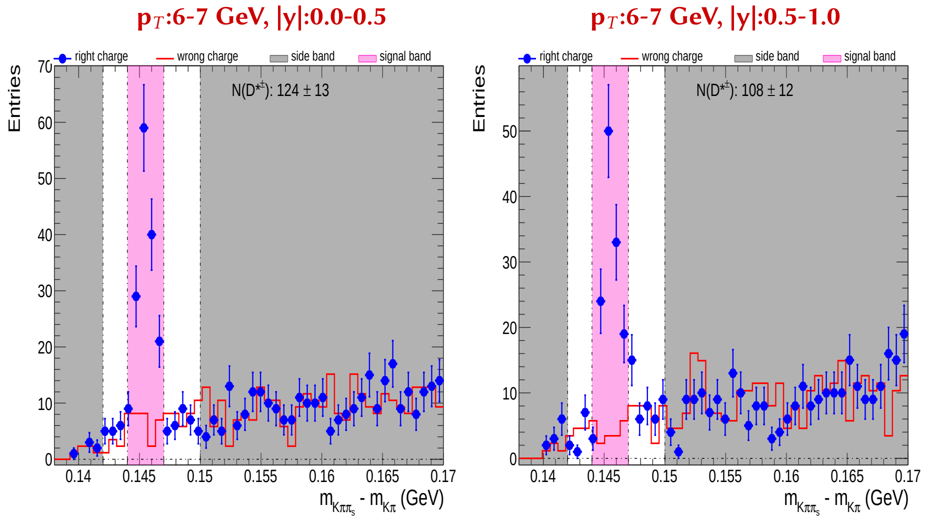


Nsignal using background substraction

p_T:5-6 GeV, |y|:2.0-2.5

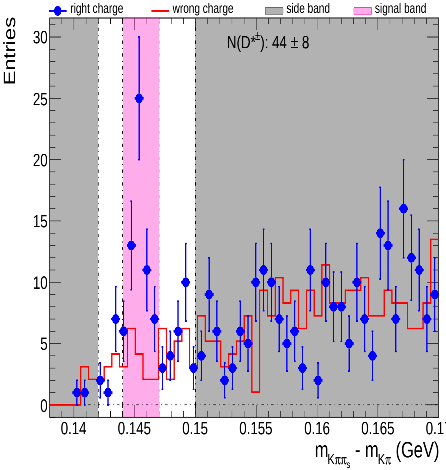


Nsignal using background substraction

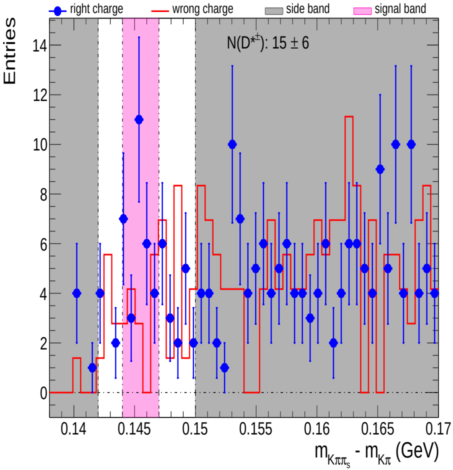


Nsignal using background substraction

p_T:6-7 GeV, |y|:1.0-1.5

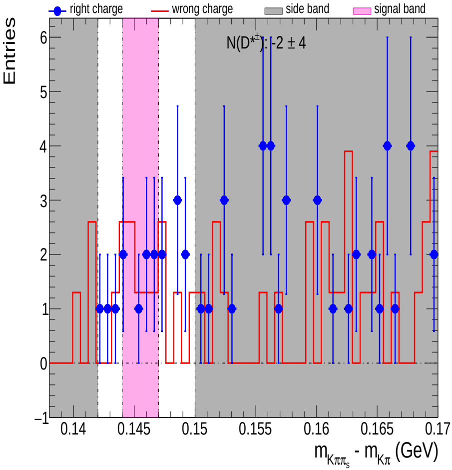


p_T:6-7 GeV, |y|:1.5-2.0



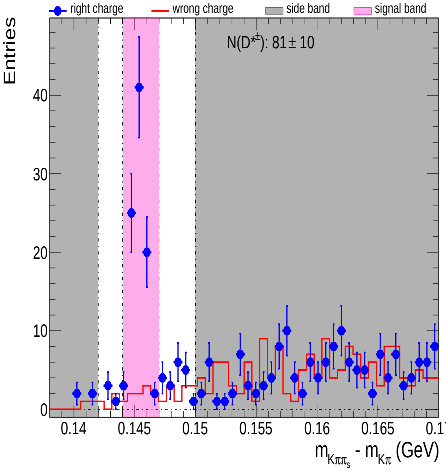
Nsignal using background substraction

p_T:6-7 GeV, |y|:2.0-2.5

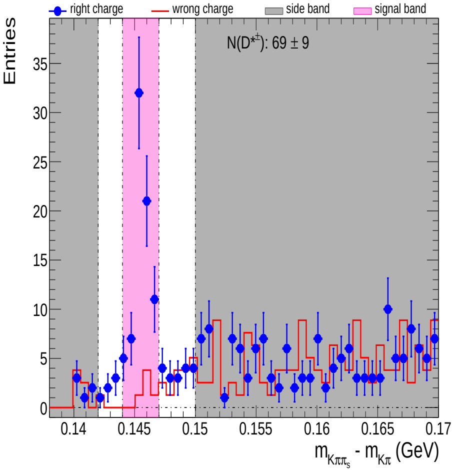


Nsignal using background substraction

p_T:7-8 GeV, |y|:0.0-0.5

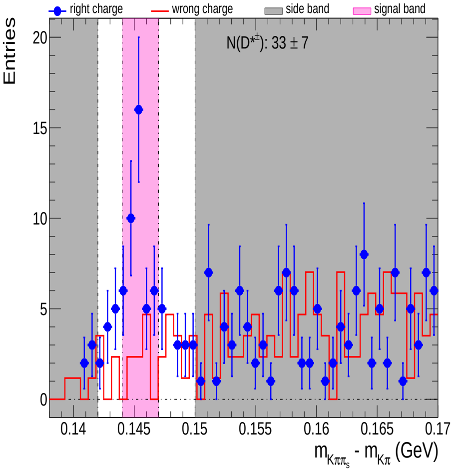


p_T:7-8 GeV, |y|:0.5-1.0

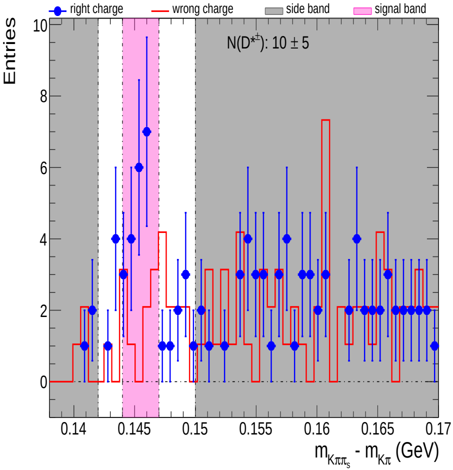


Nsignal using background substraction

p_T:7-8 GeV, |y|:1.0-1.5

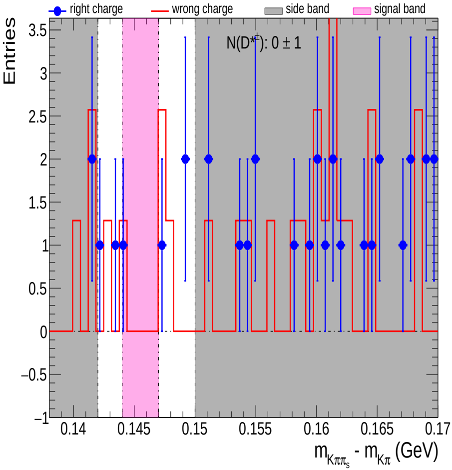


p_T:7-8 GeV, |y|:1.5-2.0



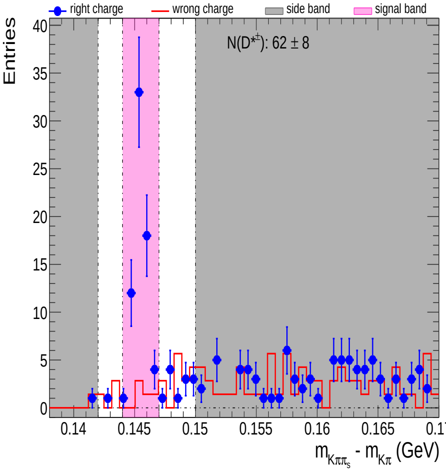
Nsignal using background substraction

p_T:7-8 GeV, |y|:2.0-2.5

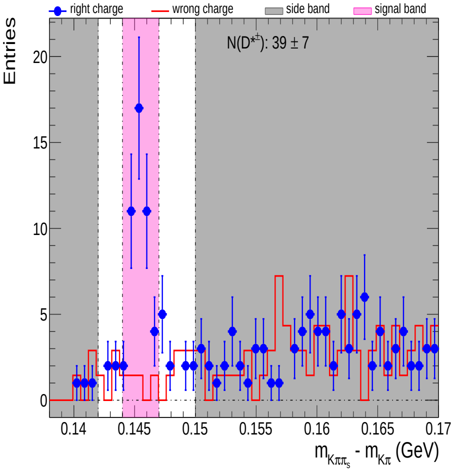


Nsignal using background substraction

p_T:8-9 GeV, |y|:0.0-0.5

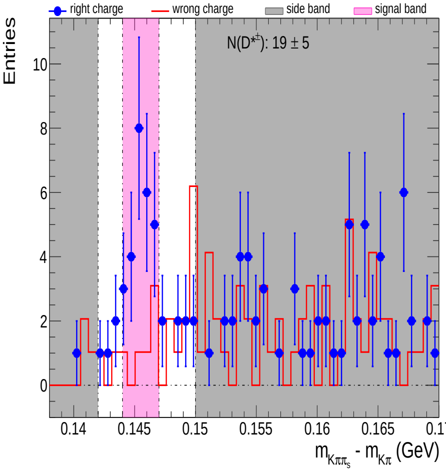


p_T:8-9 GeV, |y|:0.5-1.0

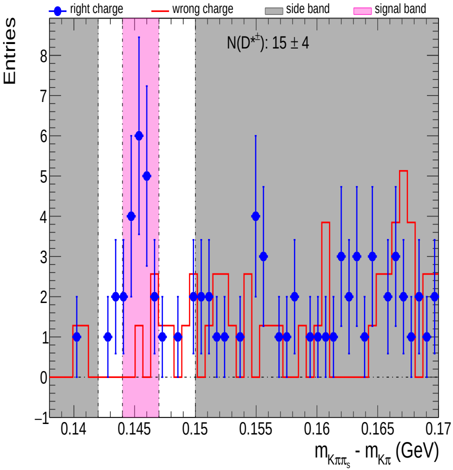


Nsignal using background substraction

p_T:8-9 GeV, |y|:1.0-1.5

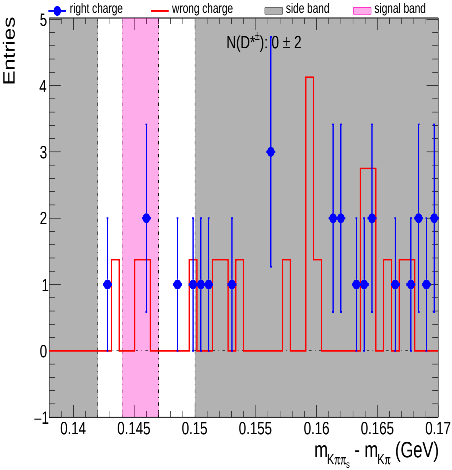


p_T:8-9 GeV, |y|:1.5-2.0



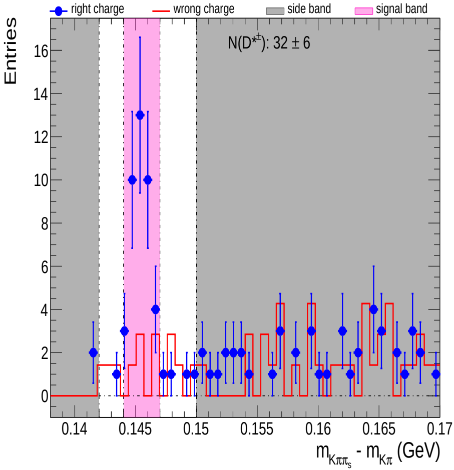
Nsignal using background substraction

p_T:8-9 GeV, |y|:2.0-2.5

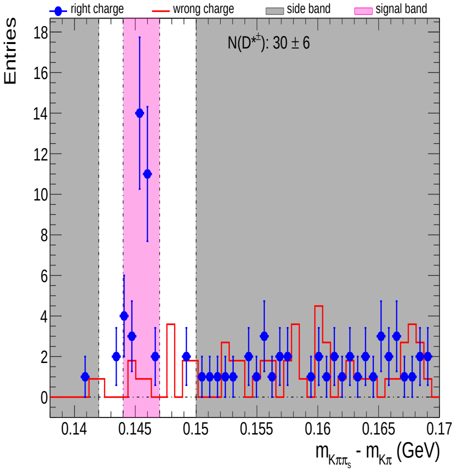


Nsignal using background substraction

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

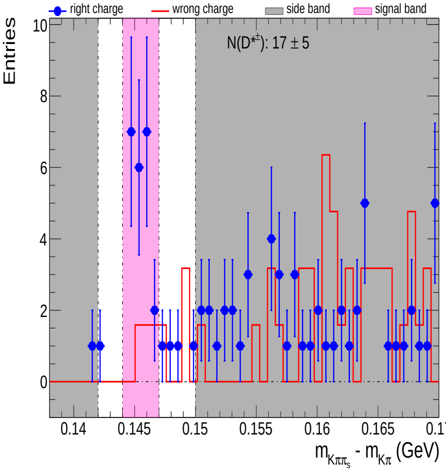


p_T:9-10 GeV, |y|:0.5-1.0

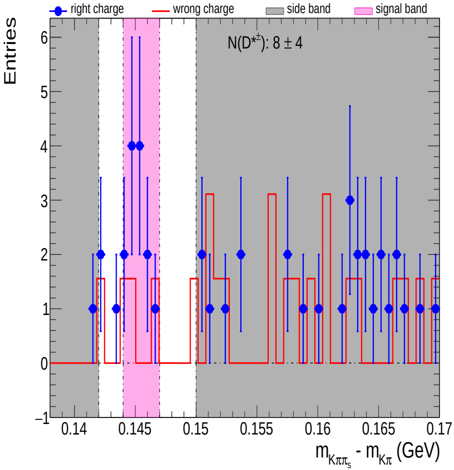


Nsignal using background substraction

p_T:9-10 GeV, |y|:1.0-1.5

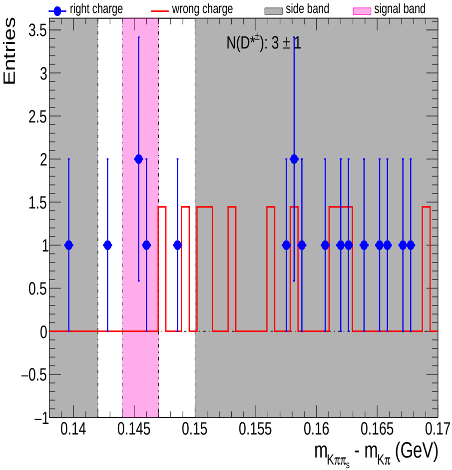


p_T:9-10 GeV, |y|:1.5-2.0



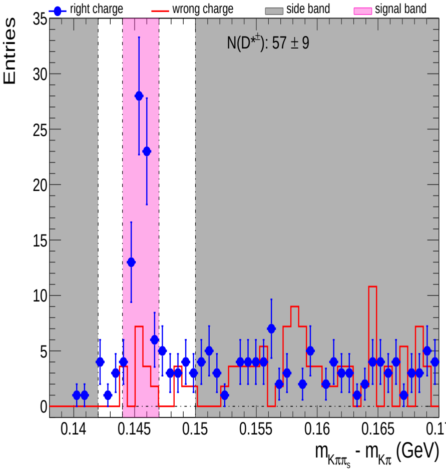
Nsignal using background substraction

p_T:9-10 GeV, |y|:2.0-2.5

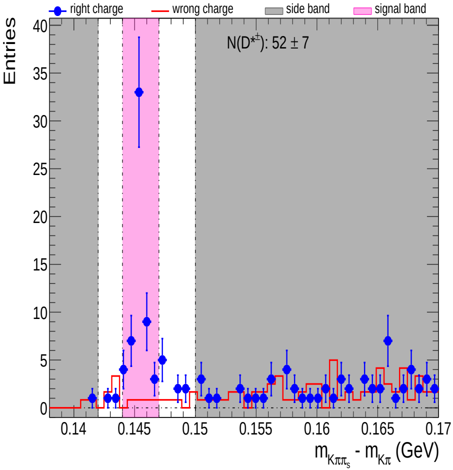


Nsignal using background substraction

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

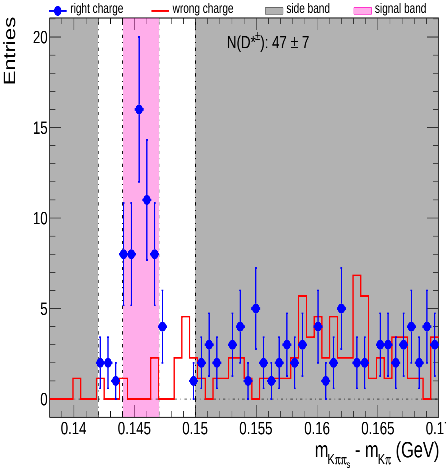


p_T:10-11 GeV, |y|:0.5-1.0

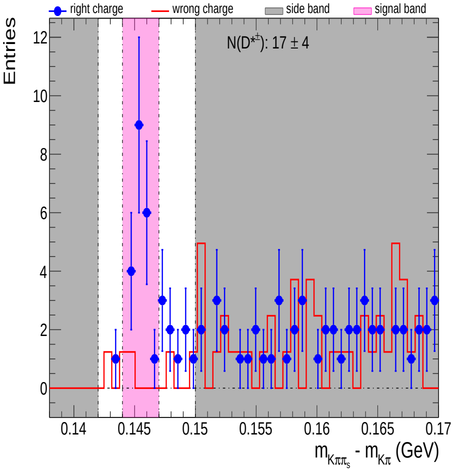


Nsignal using background substraction

p_T:10-11 GeV, |y|:1.0-1.5

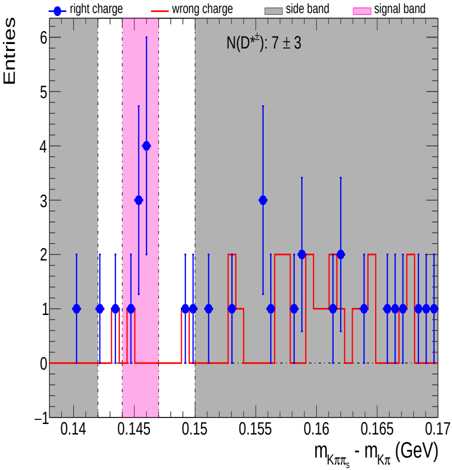


p_T:10-11 GeV, |y|:1.5-2.0



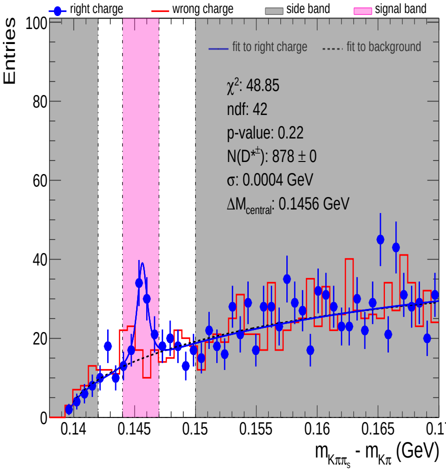
Nsignal using background substraction

p_T:10-11 GeV, |y|:2.0-2.5

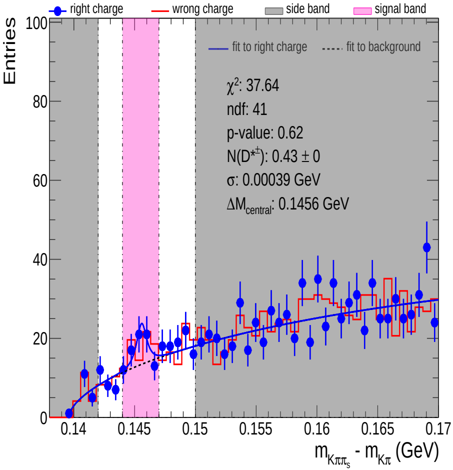


Nsignal using fitting function

p_T:1-2 GeV, |y|:0.0-0.5

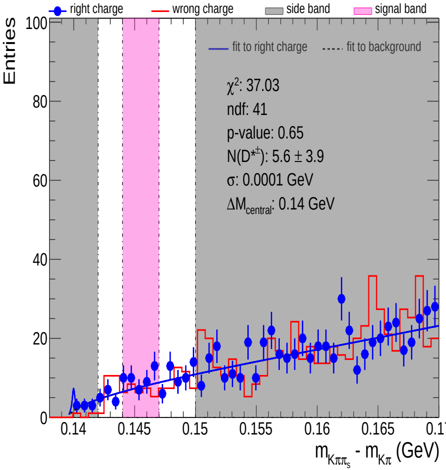


p_T:1-2 GeV, |y|:0.5-1.0

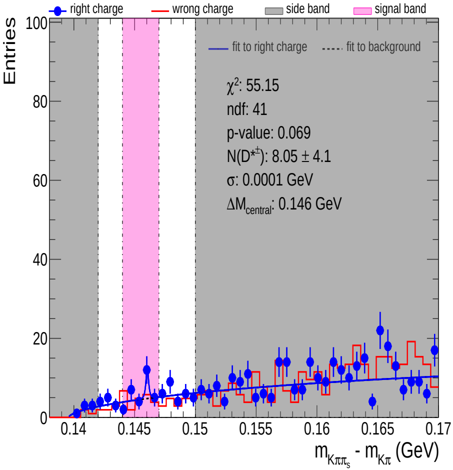


Nsignal using fitting function

p_T:1-2 GeV, |y|:1.0-1.5

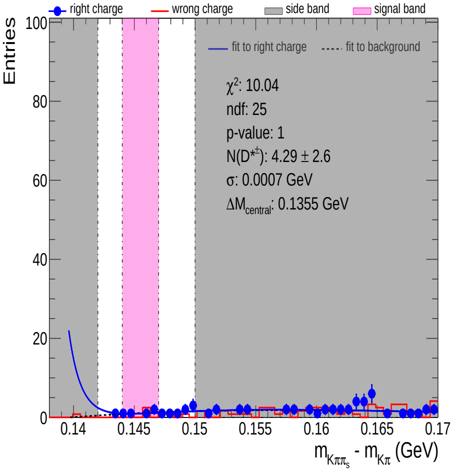


p_T:1-2 GeV, |y|:1.5-2.0



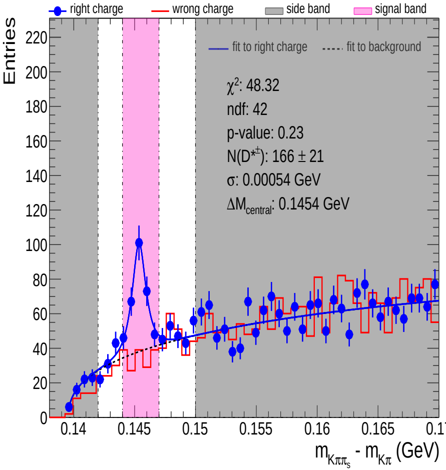
Nsignal using fitting function

p_T:1-2 GeV, |y|:2.0-2.5

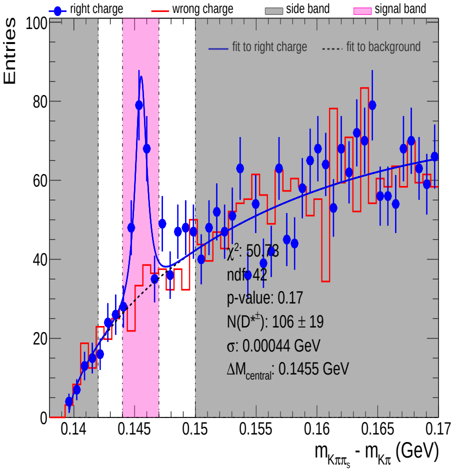


Nsignal using fitting function

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

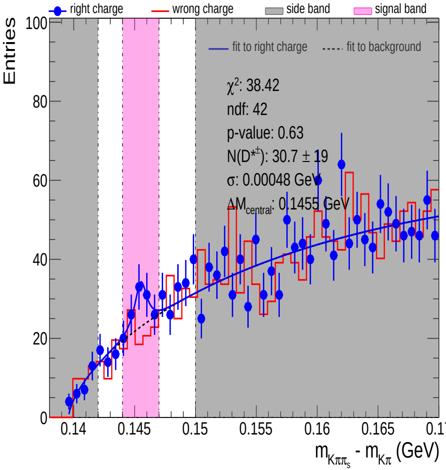


p_T:2-3 GeV, |y|:0.5-1.0

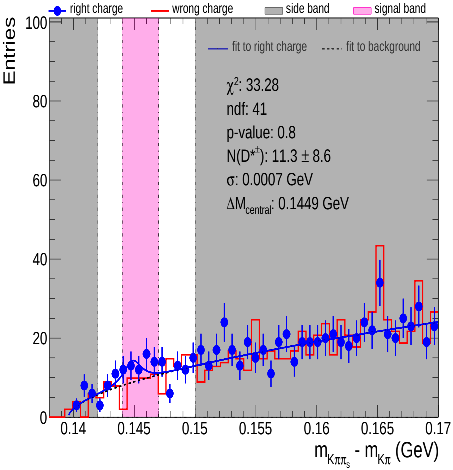


Nsignal using fitting function

p_T:2-3 GeV, |y|:1.0-1.5

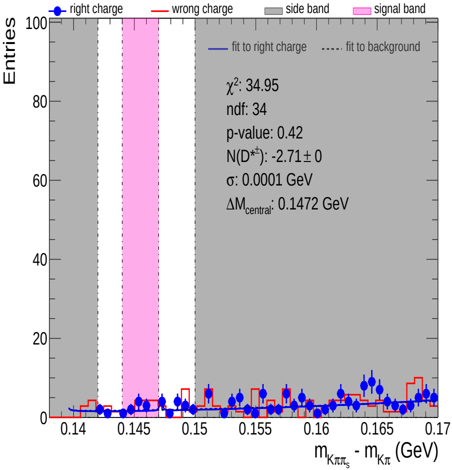


p_T:2-3 GeV, |y|:1.5-2.0



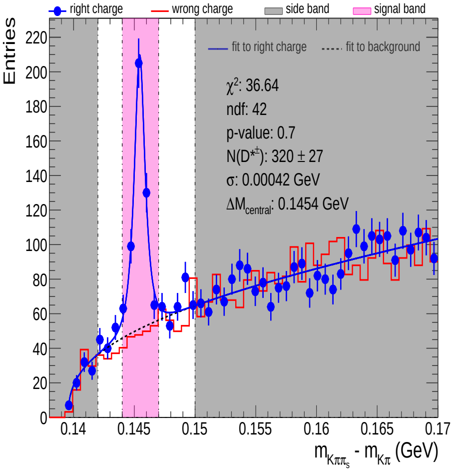
Nsignal using fitting function

p_T:2-3 GeV, |y|:2.0-2.5

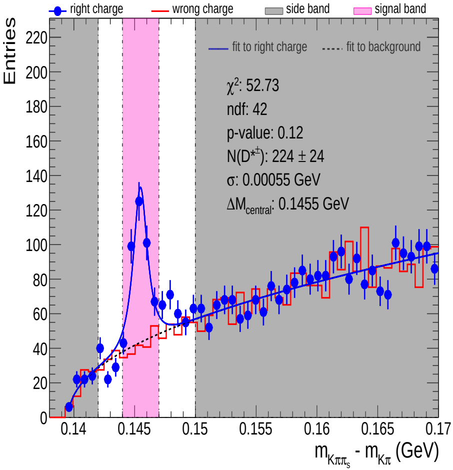


Nsignal using fitting function

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

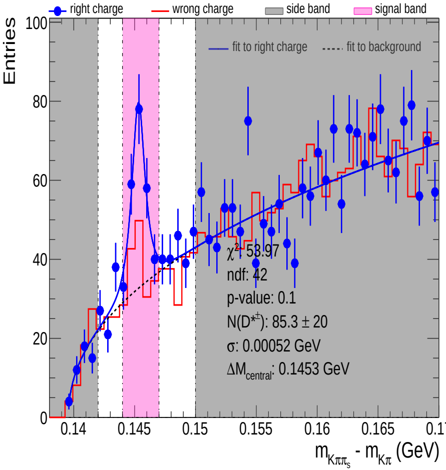


p_T:3-4 GeV, |y|:0.5-1.0

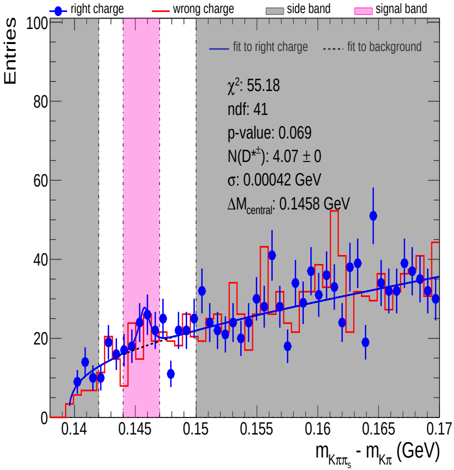


Nsignal using fitting function

p_T:3-4 GeV, |y|:1.0-1.5

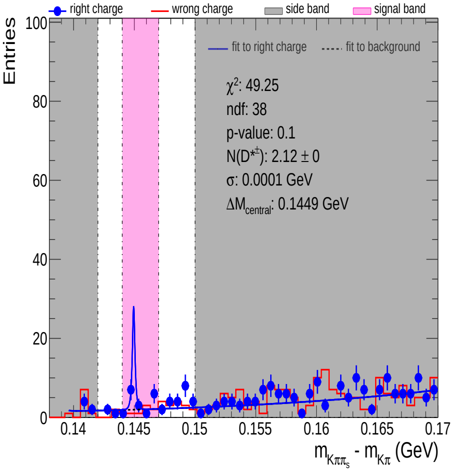


p_T:3-4 GeV, |y|:1.5-2.0



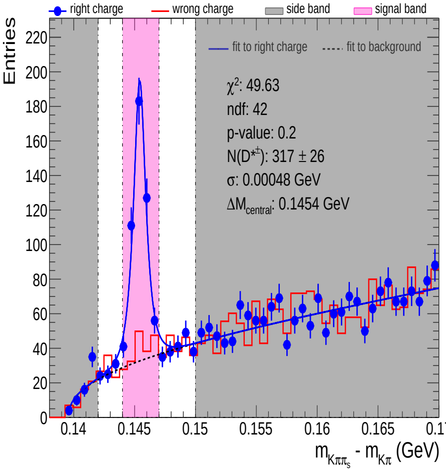
Nsignal using fitting function

p_T:3-4 GeV, |y|:2.0-2.5

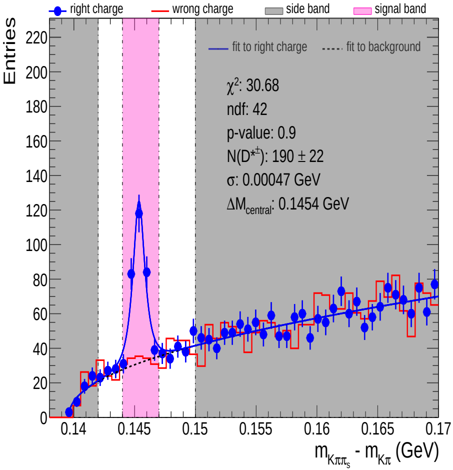


Nsignal using fitting function

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

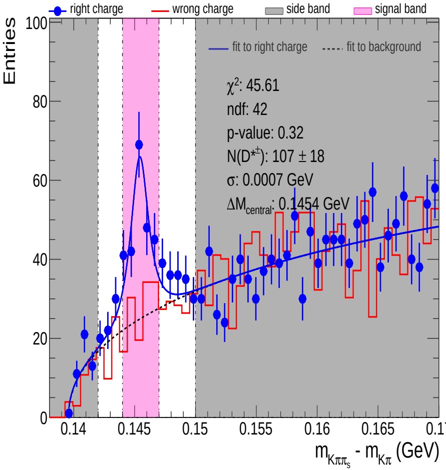


p_T:4-5 GeV, |y|:0.5-1.0

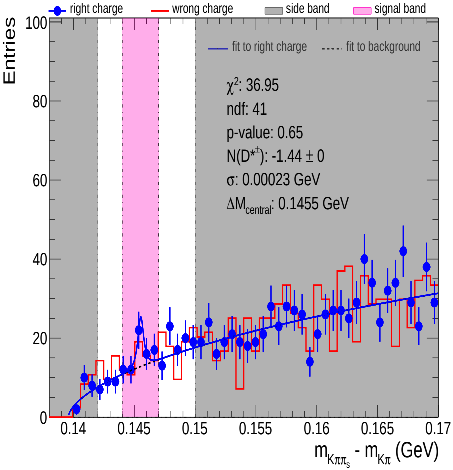


Nsignal using fitting function

p_T:4-5 GeV, |y|:1.0-1.5

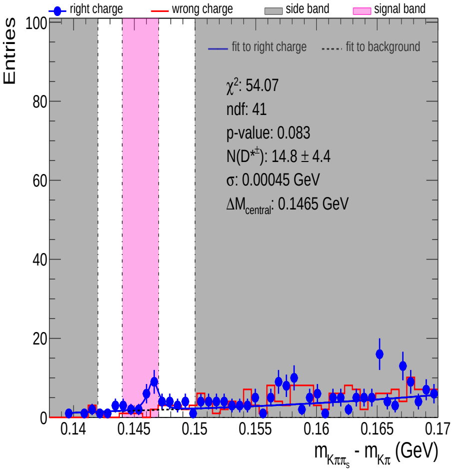


p_T:4-5 GeV, |y|:1.5-2.0



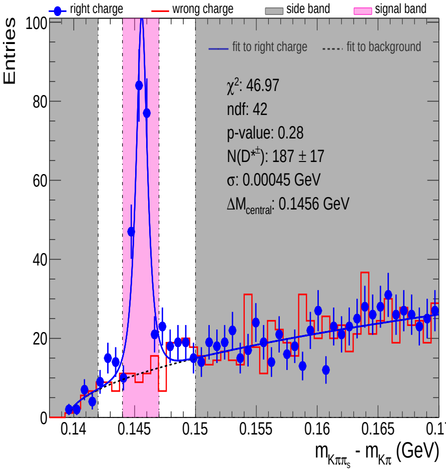
Nsignal using fitting function

p_T:4-5 GeV, |y|:2.0-2.5

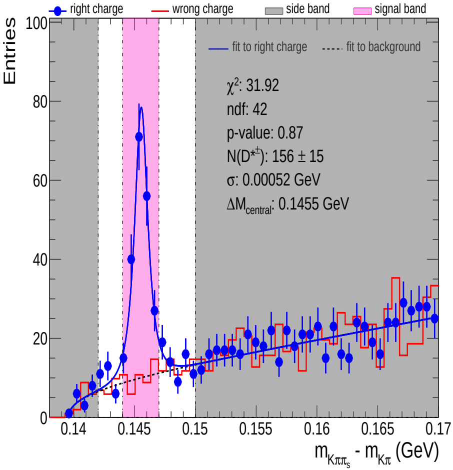


Nsignal using fitting function

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

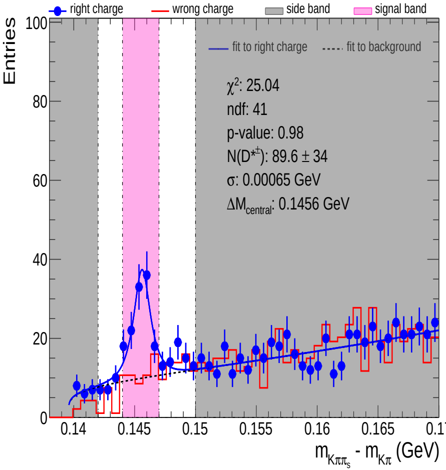


p_T:5-6 GeV, |y|:0.5-1.0

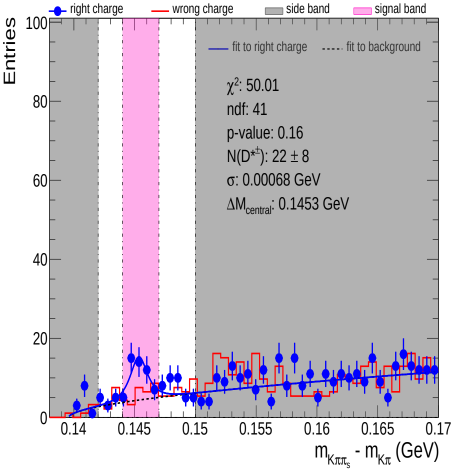


Nsignal using fitting function

p_T:5-6 GeV, |y|:1.0-1.5

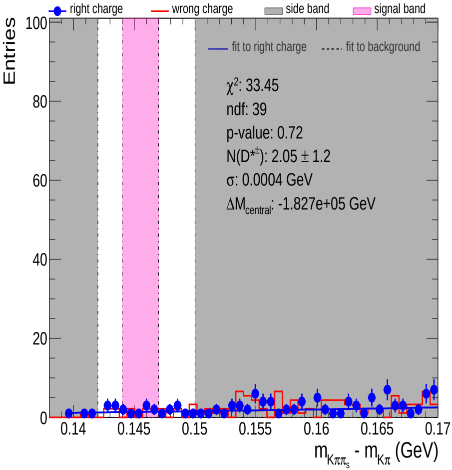


p_T:5-6 GeV, |y|:1.5-2.0



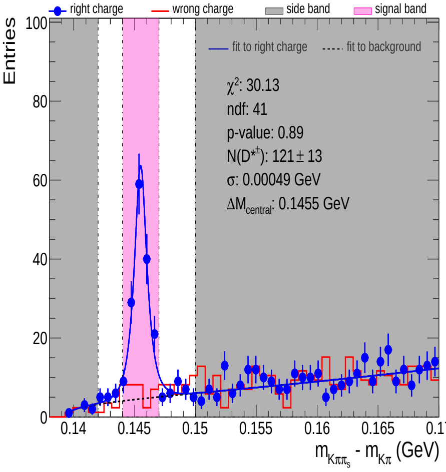
Nsignal using fitting function

p_T:5-6 GeV, |y|:2.0-2.5

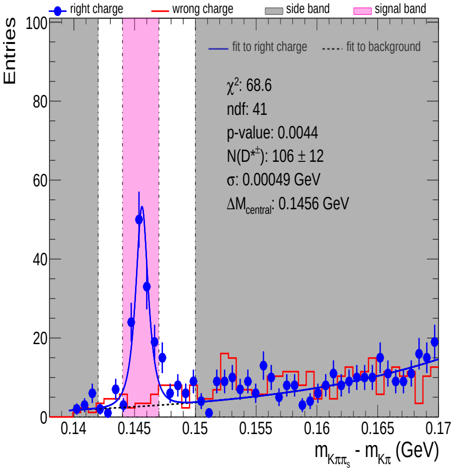


Nsignal using fitting function

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

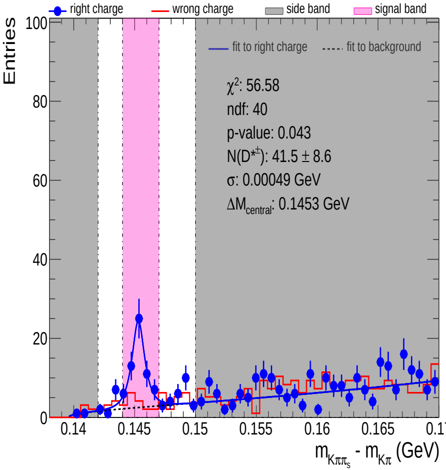


p_T:6-7 GeV, |y|:0.5-1.0

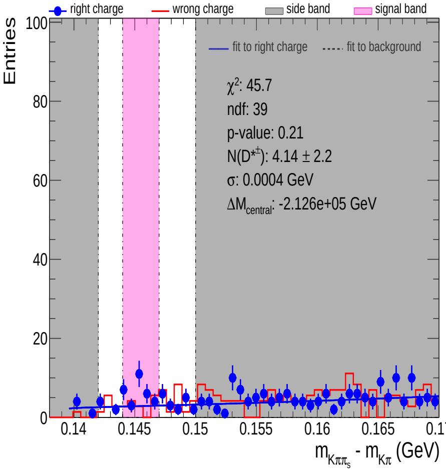


Nsignal using fitting function

p_T:6-7 GeV, |y|:1.0-1.5

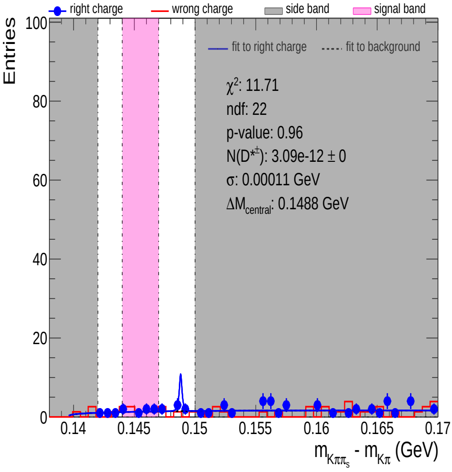


p_T:6-7 GeV, |y|:1.5-2.0



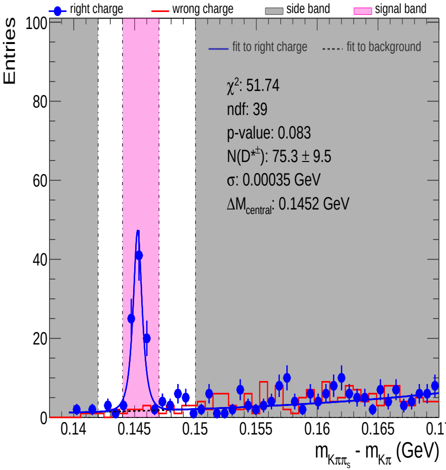
Nsignal using fitting function

p_T:6-7 GeV, |y|:2.0-2.5



Nsignal using fitting function

p_T:7-8 GeV, |y|:0.0-0.5



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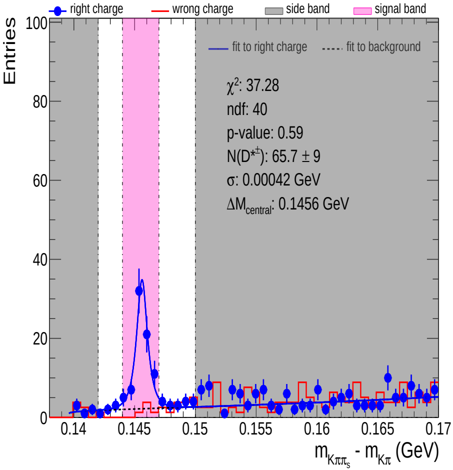
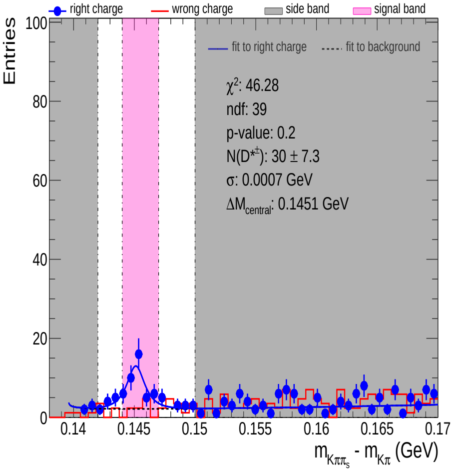
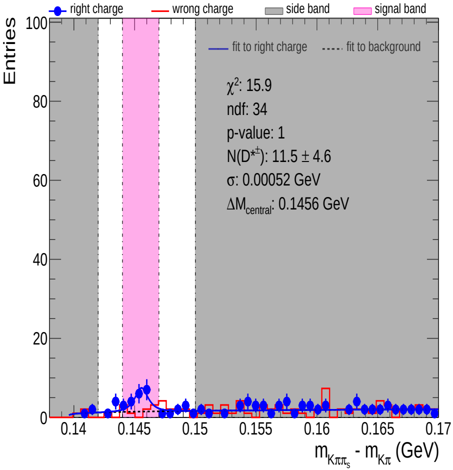


Nsignal using fitting function

p_T:7-8 GeV, |y|:1.0-1.5

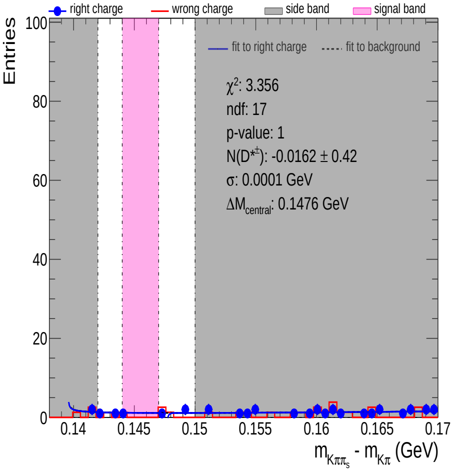


p_T:7-8 GeV, |y|:1.5-2.0



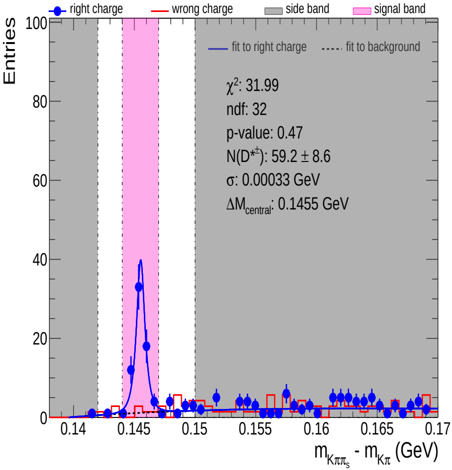
Nsignal using fitting function

p_T:7-8 GeV, |y|:2.0-2.5

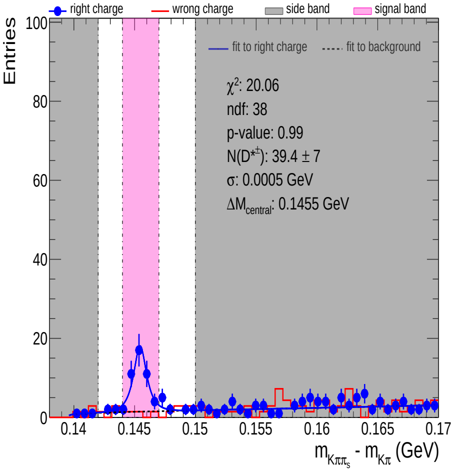


Nsignal using fitting function

p_T:8-9 GeV, |y|:0.0-0.5

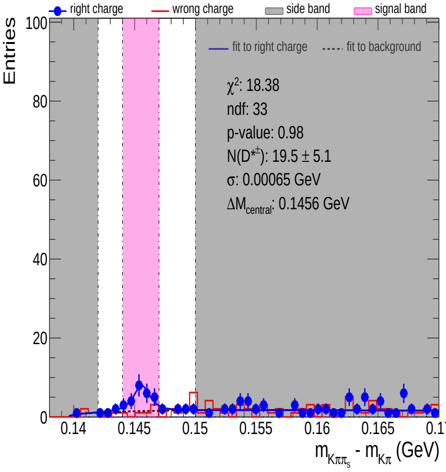


p_T:8-9 GeV, |y|:0.5-1.0

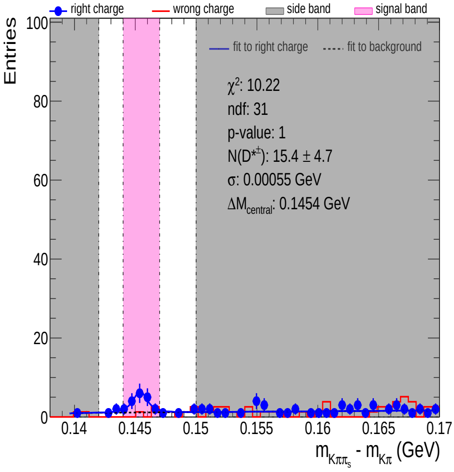


Nsignal using fitting function

p_T:8-9 GeV, |y|:1.0-1.5

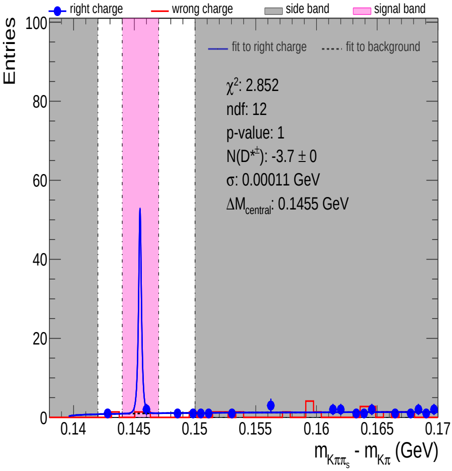


p_T:8-9 GeV, |y|:1.5-2.0



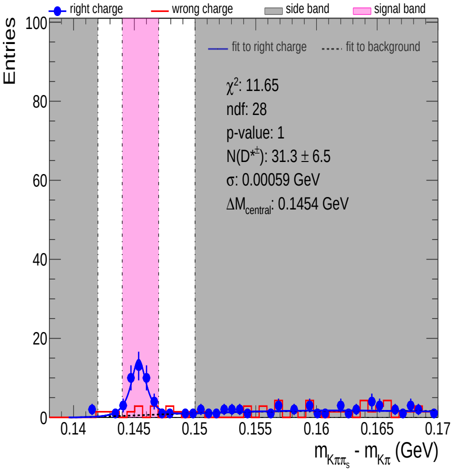
Nsignal using fitting function

p_T:8-9 GeV, |y|:2.0-2.5

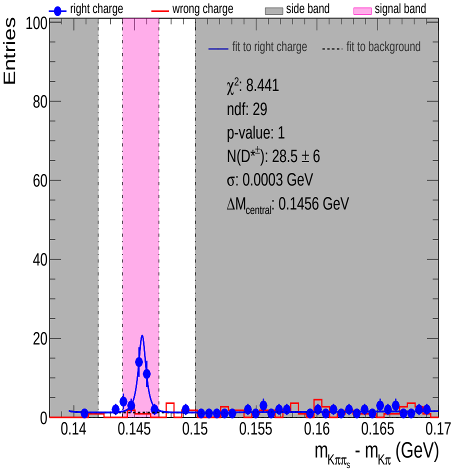


Nsignal using fitting function

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

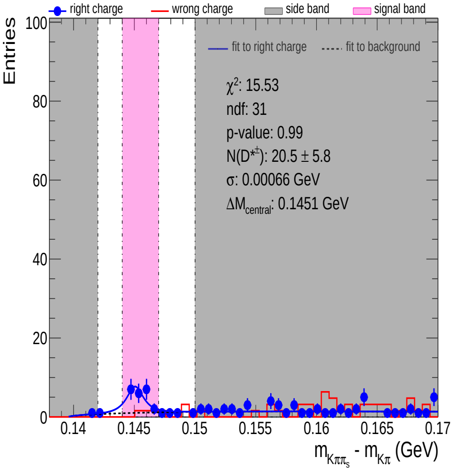


p_T:9-10 GeV, |y|:0.5-1.0

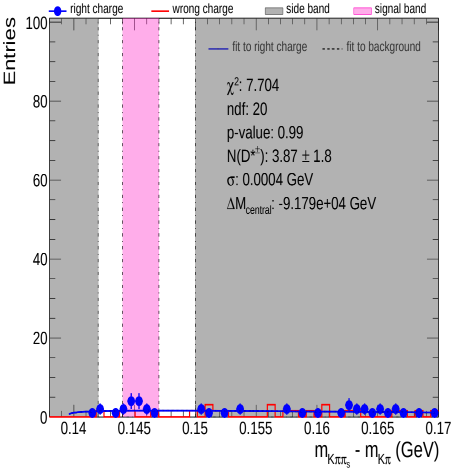


Nsignal using fitting function

p_T:9-10 GeV, |y|:1.0-1.5

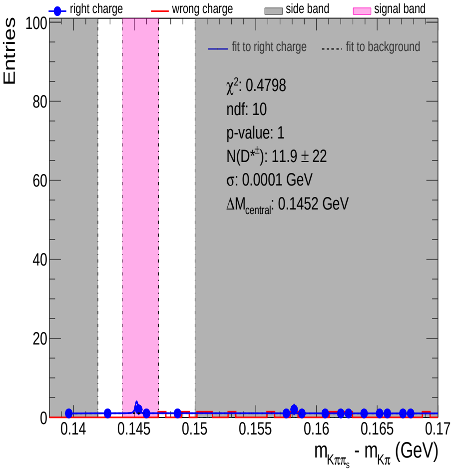


p_T:9-10 GeV, |y|:1.5-2.0



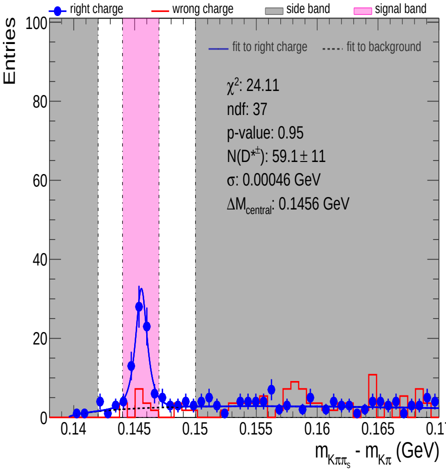
Nsignal using fitting function

p_T:9-10 GeV, |y|:2.0-2.5

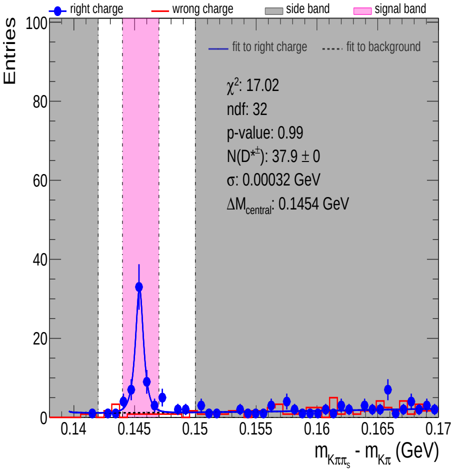


Nsignal using fitting function

p$_T$:10-11 GeV, |y|:0.0-0.5

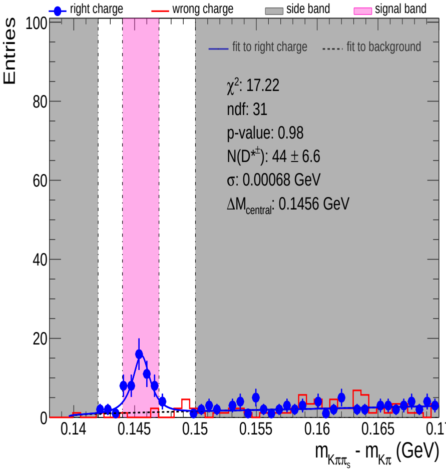


p$_T$:10-11 GeV, |y|:0.5-1.0

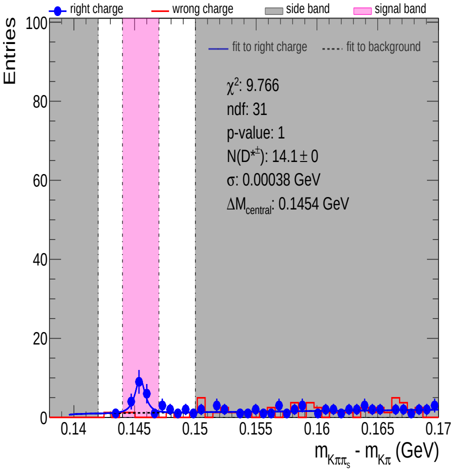


Nsignal using fitting function

p_T:10-11 GeV, |y|:1.0-1.5

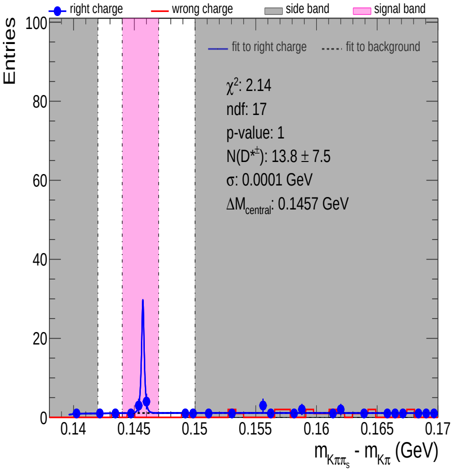


p_T:10-11 GeV, |y|:1.5-2.0

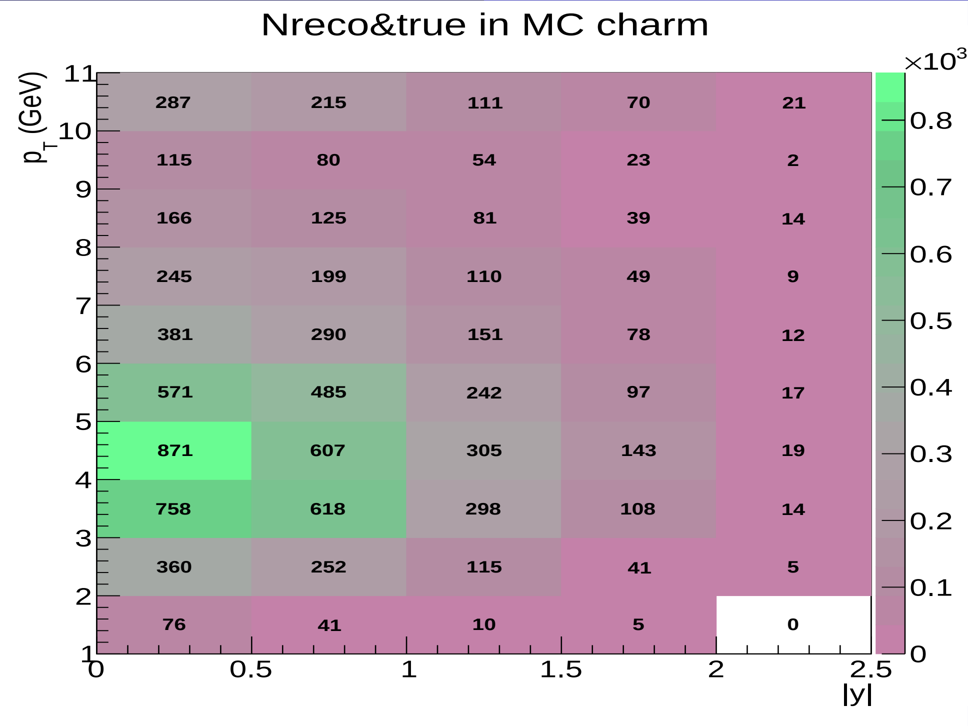


Nsignal using fitting function

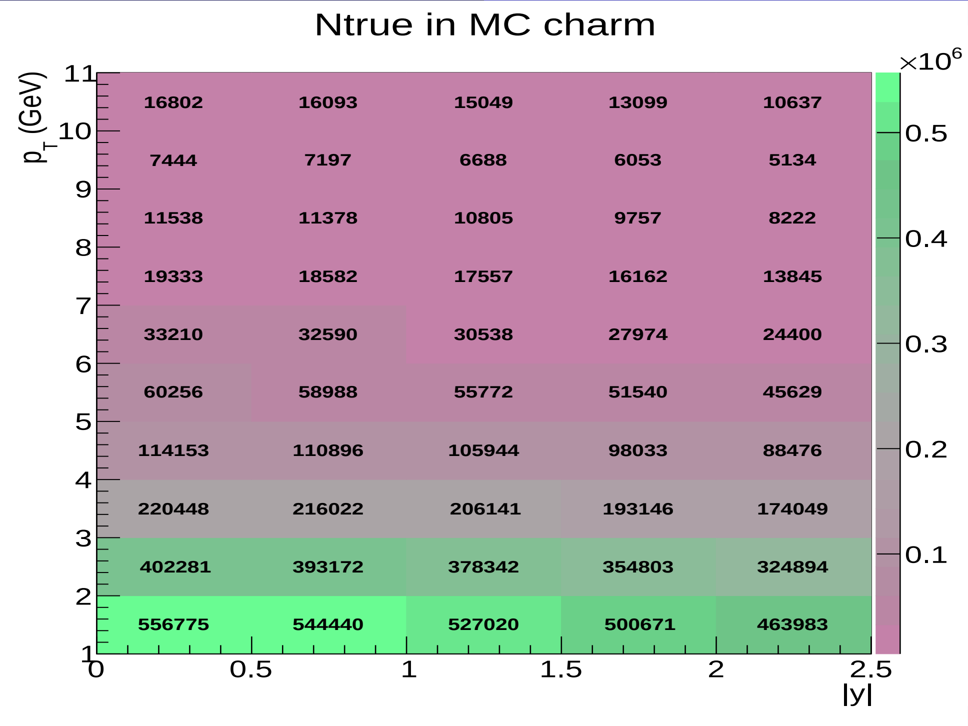
p_T:10-11 GeV, |y|:2.0-2.5



Nreco match true


Nreco&true in MC charm
p_T (GeV)
|y|
$\times10^3$
287 215 111 70 21
115 80 54 23 2
166 125 81 39 14
245 199 110 49 9
381 290 151 78 12
571 485 242 97 17
871 607 305 143 19
758 618 298 108 14
360 252 115 41 5
76 41 10 5 0

Ntrue



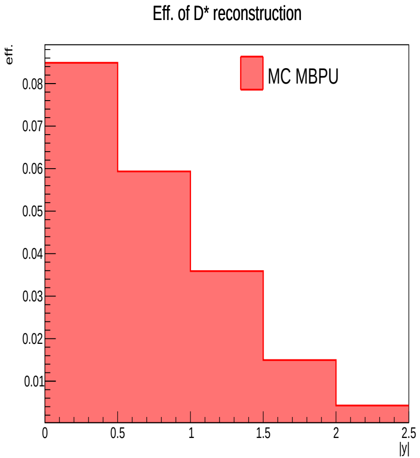
Ntrue in MC charm
p_T (GeV)
|y|
$\times10^6$
16802
16093
15049
13099
10637
7444
7197
6688
6053
5134
11538
11378
10805
9757
8222
19333
18582
17557
16162
13845
33210
32590
30538
27974
24400
60256
58988
55772
51540
45629
114153
110896
105944
98033
88476
220448
216022
206141
193146
174049
402281
393172
378342
354803
324894
556775
544440
527020
500671
463983

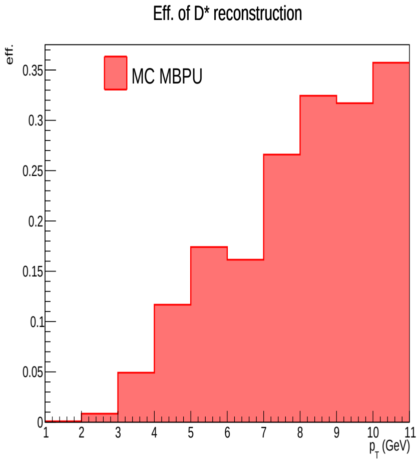
Efficiency

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

- 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($c \to D^*$) = 0.23
  - f($c \to D^0$) = 0.61
- Branching ratio (BR):
  - $D^* \to D^0\pi$ = 0.68
  - $D^0 \to K\pi$ = 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 D0)

1D D^* efficiency





D^* efficiency decreases when rapidity going higher but increases as p_T going higher