Measurement of $D^{(*)}$ production cross sections

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Outline :

Introduction & Motivation

$D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$ reconstruction (ATLAS-CONF-2010-034)

Towards x-section measurement

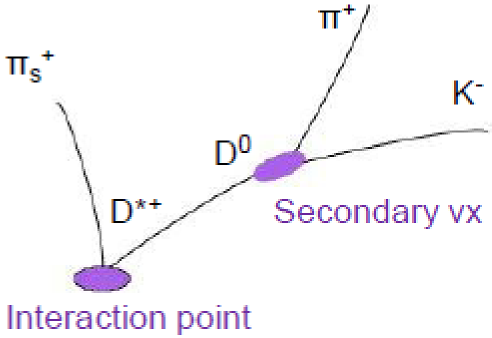
$D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$ production x-sections (ATLAS-CONF-2011-XXX)

Summary & Plans

Introduction & Motivation

D-mesons are produced in c and b fragmentation
c and b quark production are hard processes ($m_Q >> \Lambda_{QCD}$)
Theoretical calculations available till NLO+NLL level
Still large theoretical uncertainties (scales, multiple interactions)

Reconstruction of *D*-mesons already feasible with first ATLAS data due to
- large cross-section values
- clean *D*-meson signatures
- precise ATLAS tracking and vertexing



Important to measure production of D-mesons
- to evaluate and calibrate tracking performance
- to compare production in pp and heavy ion collisions
- to test theoretical calculations
- to verify m_c value and proton structure functions
- to realistically estimate charm contribution to backgrounds and trigger rates

$D^{(*)}$-mesons reconstruction at 7 TeV

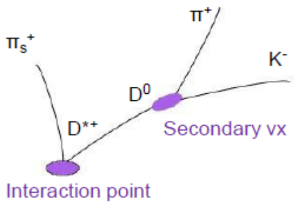
For D-meson reconstruction: 1.1 nb^{-1}
(March-July, minimum-bias triggers after prescale)

No *dE/dx* particle identification (not effective for high-p_T tracks)

Selection Strategy:

To select D-mesons one can utilise:

- hard nature of charm production $(p_T(D^{(*)}), p_T(K,\pi))$
- hard nature of charm fragmentation $(p_T(D^{(*)})/E_T)$
- relatively large D-mesons' life-times (l_{XY})
- "spin" angular behaviours of D-mesons' decays $(\cos\theta^*, \cos\theta')$



Goals:

- use widest kinematic range where signals can be measured

$$p_T(D^{(*)}) > 3.5\,\mathrm{GeV}, \quad |\eta(D^{(*)})| < 2.1$$

- make signals as clean (significant) as possible in the kinematic range
- use cuts (their values) which do not produce large systematic uncertainties

To tune actual cut values realistic MC has been used

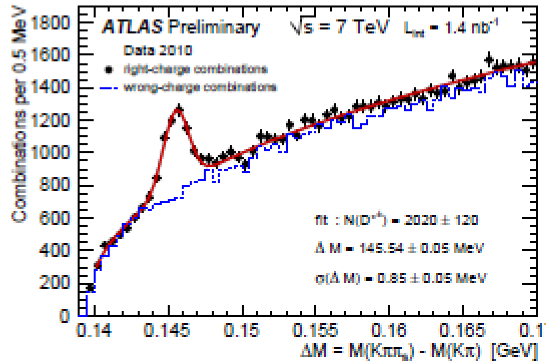
Figures from ATLAS-CONF-2010-034

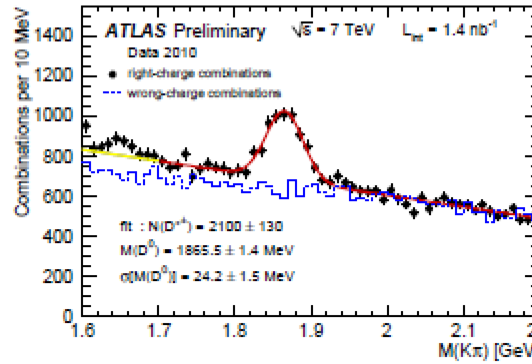
$D^{*+} \rightarrow D^0\ \pi_s^+ \rightarrow (K^-\ \pi^+)\ \pi_s^+$

$f(c \rightarrow D^{*+}) = 23.5 \pm 0.7\,\%$

$\mathcal{B} = 2.63 \pm 0.04\,\%$

$c\tau_{D^0} = 123\ \mu\mathrm{m}$



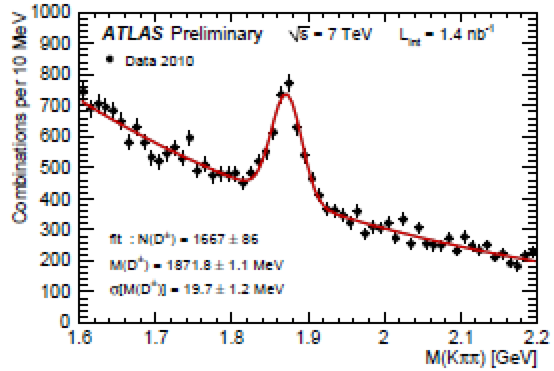


$D^+ \rightarrow K^-\ \pi^+\ \pi^+$

$f(c \rightarrow D^+) = 22.2 \pm 1.0\,\%$

$\mathcal{B} = 9.4 \pm 0.4\,\%$

$c\tau_{D^+} = 312\ \mu\mathrm{m}$

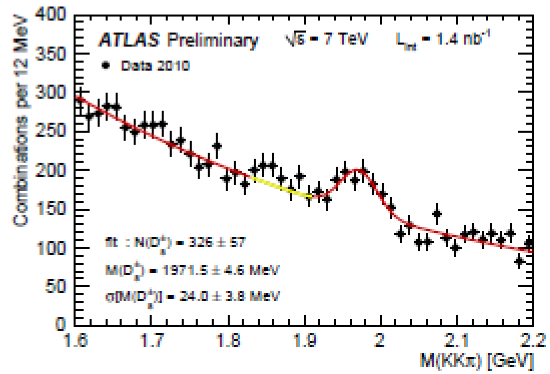


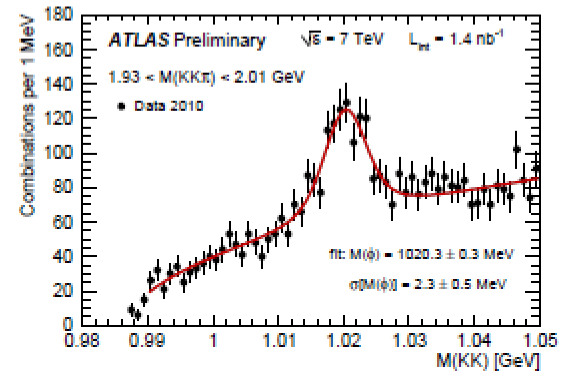
$D_s^+ \rightarrow \phi\ \pi^+ \rightarrow (K^-\ K^+)\ \pi^+$

$f(c \rightarrow D_s^+) = 8.7 \pm 0.9\,\%$

$\mathcal{B} = 2.32 \pm 0.14\,\%$

$c\tau_{D_s^+} = 150\ \mu\mathrm{m}$





Unbiased trigger selection

For data starting from period B,
EF slots should be used to take into account all prescales

Largest biased slot in MinBias stream:

EF_mbSpTrkMh_MB2 ($\Longrightarrow$ L1_MBTS_2) high-multiplicity selection

Largest unbiased slot in MinBias stream:

EF_L1ItemStreamer_L1_MBTS_1 ($\Longrightarrow$ L1_MBTS_1)

Second useful unbiased slot in MinBias stream:

EF_mbSPTrk ($\Longrightarrow$ L1_RD0_FILLED), add $10 - 15\%$ to the previos one

Other slots are marginal and not 100% efficient
($\Longrightarrow$ L1_MBTS_1_1, L1_MBTS_4_4)

We can use:
EF_L1ItemStreamer_L1_MBTS_1 || EF_mbSpTrk

$$\mathcal{L}_{1||2} = \mathcal{L}_{tot} * (1. - (1. - 1./N_1^{presc}) \cdot (1. - 1./N_2^{rand}/N_2^{presc}))$$

Data sample and luminosity

DATA selection for x-section measurement

GRL BPhys.tracking_noBS

Period A, runs 152166-153200, May's reprocessing

L1_MBTS_1

$\mathcal{L} = 417.8\,\mu\text{b}^{-1}$, OflLumi-7TeV-002

Period B, runs 153565-155160, May's reprocessing

EF_L1ItemStreamer_L1_MBTS_1 || EF_mbSpTrk

$\mathcal{L} = 514.6\,\mu\text{b}^{-1}$, OflLumi-7TeV-002

Period C, runs 155228-156682, T0 processing

EF_L1ItemStreamer_L1_MBTS_1 || EF_mbSpTrk

$\mathcal{L} = 73.3\,\mu\text{b}^{-1}$, OflLumi-7TeV-002

Period D1, runs 158045-158392, T0 processing

EF_L1ItemStreamer_L1_MBTS_1 || EF_mbSpTrk

$\mathcal{L} = 31.2\,\mu\text{b}^{-1}$, OflLumi-7TeV-002

Period D2, runs 158443-158582, T0 processing

EF_L1ItemStreamer_L1_MBTS_1 || EF_mbSpTrk

$\mathcal{L} = 35.3\,\mu\text{b}^{-1}$, OflLumi-7TeV-002

$\mathcal{L}_{ABCD1/2} = 1072.1\,\mu\text{b}^{-1}$

Periods D3 ($12.3\,\mu\text{b}^{-1}$), D4 ($13.1\,\mu\text{b}^{-1}$), D5 ($4.7\,\mu\text{b}^{-1}$) and D6 ($3.4\,\mu\text{b}^{-1}$) not used

$D^{*+} \rightarrow D^0 \pi_s^+ \rightarrow (K^- \pi^+) \pi_s^+$ (+c.c.) reconstruction

$N_{hits}^{pixel}(K, \pi, \pi_s) \geq 1$

$N_{hits}^{SCT}(K, \pi, \pi_s) \geq 4$

$p_T(\pi_s) > 0.25\,\mathbf{GeV}$, $p_T(K, \pi) > 1.0\,\mathbf{GeV}$, $|\eta(K, \pi, \pi_s)| < 2.5$

$d_0^{PV}(\pi_s) < 2.0\,\mathbf{mm}$, $z_0^{PV}(\pi_s)\sin\theta < 2.0\,\mathbf{mm}$

$M(K\pi)$ **window:** $(1.82 - 1.91) \Longrightarrow (1.80 - 1.93)$ **for** $p_T(D^*) > 12\,\mathbf{GeV}$ **or** $|\eta(D^*)| > 1.3$

D^0 **vertexing:**

VKalVrt, $\chi^2(D^0) < 5$, $l_{XY} > 0$

$d_0^{PV}(D^0) < 0.2\,\mathbf{mm}$, $z_0^{PV}(D^0)\sin\theta < 0.5\,\mathbf{mm}$ ($z_0^{PV}(D^0) == z$ **at 2D DCA (ATLAS default)**)

kinematic range:

$p_T(D^{*\pm}) > 3.5\,\mathbf{GeV}$, $|\eta(D^{*\pm})| < 2.1$

"hard fragmentation" cleaning:

$\frac{p_T(D^{*\pm})}{E_T} > 0.02$

$D^+ \rightarrow K^- \pi^+ \pi^+$ (+c.c.) reconstruction

$N_{hits}^{pixel}(K, \pi_{1,2}) \geq 1, \;\; N_{hits}^{SCT}(K, \pi_{1,2}) \geq 4$

$p_T(K) > 1.0\,\mathbf{GeV}, \;\; p_T(\pi_{1,2}) > 0.8\,\mathbf{GeV}, \;\; max(p_T(\pi_{1,2})) > 1.0\,\mathbf{GeV}, \;\; |\eta(K, \pi_{1,2})| < 2.5$

$\cos\theta^*(K) > -0.8$

suppression of $D^{*\pm}$ and $D_s^+ \rightarrow \phi\,\pi^+ \rightarrow (K^- K^+)\,\pi^+$ (+c.c.) reflections:

remove $\Delta M_{1,2} < 153\,\mathbf{MeV}$ **and** $|M(K^{\pm}, \text{"}K^{\mp}\text{"}) - M(\phi)_{\mathrm{PDG}}| < 8\,\mathbf{MeV}$

$D^{\pm}$ vertexing:

VKalVrt, $\chi^2(D^{\pm}) < 6$, $l_{XY} > 1.2\,\mathbf{mm}$

$d_0^{PV}(D^{\pm}) < 0.15\,\mathbf{mm}, \;\; z_0^{PV}(D^{\pm})\sin\theta < 0.3\,\mathbf{mm}$ ($z_0^{PV}(D^{\pm}) == z$ **at 2D DCA (ATLAS default)**)

kinematic range:

$p_T(D^{\pm}) > 3.5\,\mathbf{GeV}, \;\; |\eta(D^{\pm})| < 2.1$

"hard fragmentation" cleaning:

$\frac{p_T(D^{\pm})}{E_T} > 0.02$

$D_s^+ \rightarrow \phi\, \pi^+ \rightarrow (K^-\, K^+)\, \pi^+$ (+c.c.) reconstruction

$N_{hits}^{pixel}(K_{1,2}, \pi) \geq 1, \;\; N_{hits}^{SCT}(K_{1,2}, \pi) \geq 4$

$p_T(K_{1,2}) > 0.7\,\mathbf{GeV}, \;\; p_T(\pi) > 0.8\,\mathbf{GeV}, \;\; |\eta(K_{1,2}, \pi)| < 2.5$

$\cos\theta^*(\pi) < 0.4, \;\; |\cos\theta'(K)|^3 > 0.2$

$$\frac{d\,N}{d\,\cos\theta'(K)} \propto \cos^2\theta'(K) \Longrightarrow \frac{d\,N}{d\,\cos^3\theta'(K)} \propto const$$

select $|M(K^+K^-) - M(\phi)_{\mathrm{PDG}}| < 6\,\mathrm{MeV}$

$D_s^{\pm}$ vertexing:

VKalVrt, $\chi^2(D_s^{\pm}) < 6, \; l_{XY} > 0.4\,\mathrm{mm}$

$d_0^{PV}(D_s^{\pm}) < 0.15\,\mathrm{mm}, \;\; z_0^{PV}(D_s^{\pm}) \sin\theta < 0.3\,\mathrm{mm}$ ($z_0^{PV}(D_s^{\pm}) == z$ **at 2D DCA (ATLAS default)**)

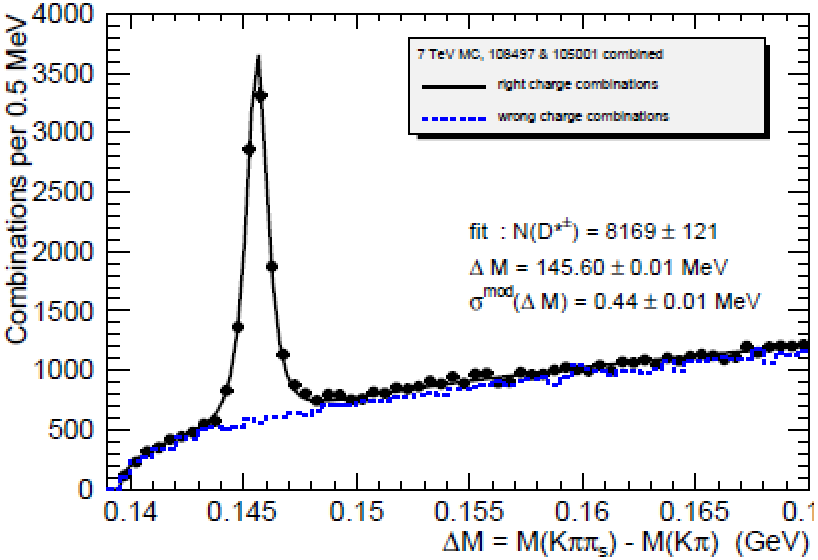
kinematic range:

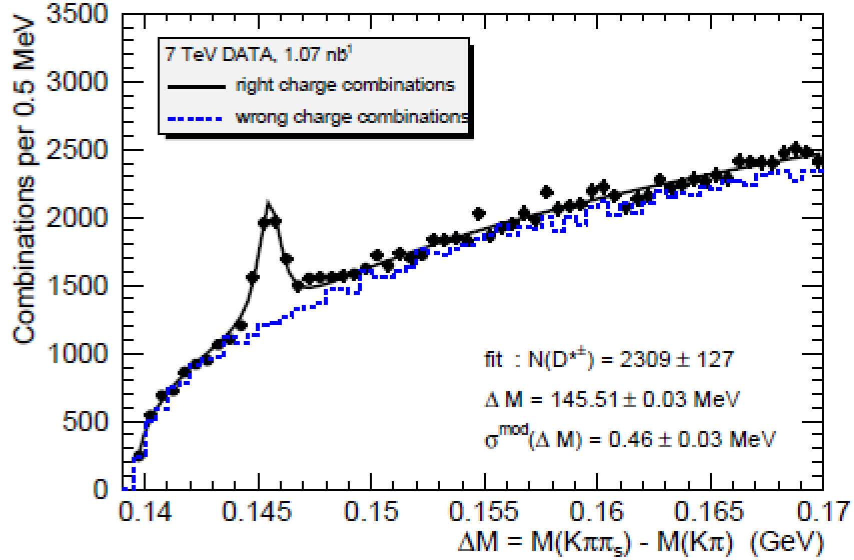
$p_T(D_s^{\pm}) > 3.5\,\mathbf{GeV}, \;\; |\eta(D_s^{\pm})| < 2.1$

"hard fragmentation" cleaning:

$\frac{p_T(D_s^{\pm})}{E_T} > 0.02$

Cross section of $D^{*\pm}$ production





kinematic range: $pT > 3.5\,\mathrm{GeV},\ |\eta| < 2.1$

$$Acc = 28.7 \pm 0.4\,\%$$

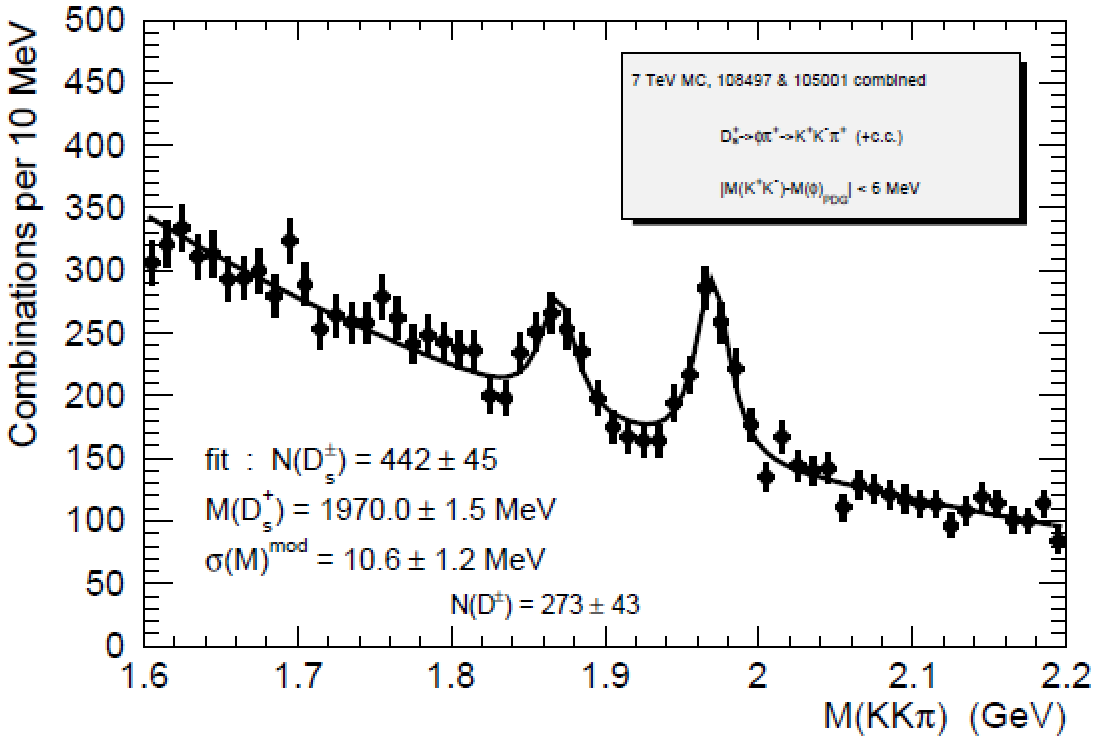
$$\sigma = 284.5 \pm 16.3\,\mu\mathrm{b}$$

signal: Gauss$^{\mathrm{mod}}$

backgr: $A \cdot (x - m_{\pi^+})^B \cdot \exp^{C \cdot (x - m_{\pi^+})}$

exponential term is used if needed (integrated, 2nd p_T bin, 3rd and 4th η bins)

$D_s^{\pm}$ with combined MC sample



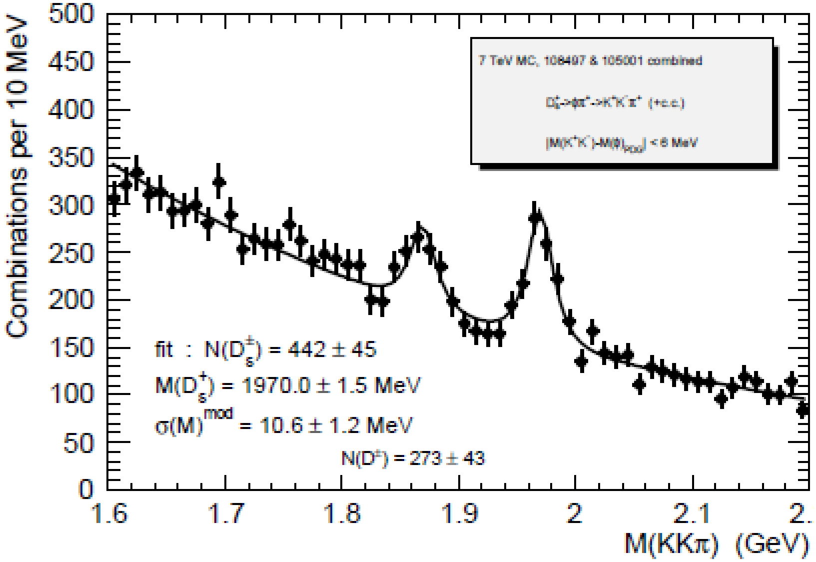
signals: Gauss$^{\text{mod}}$, backgr: exp

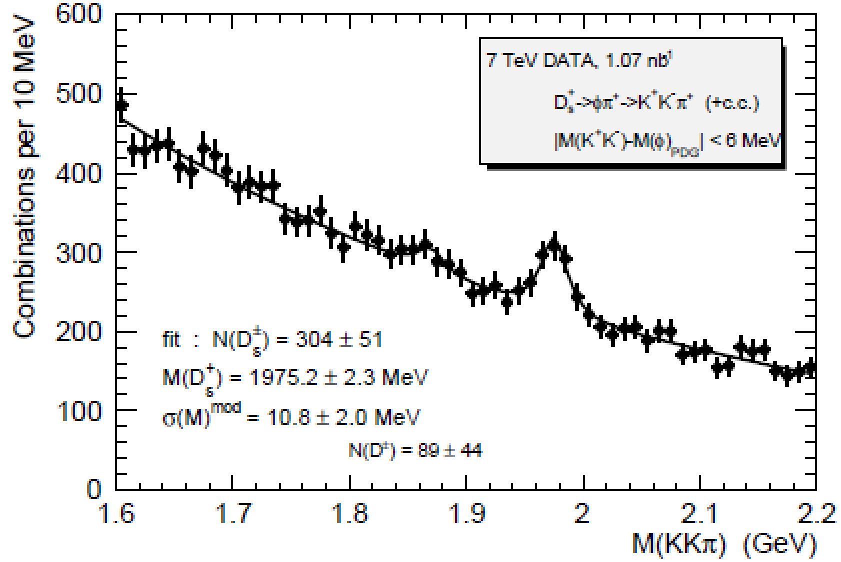
$M(D^+) \equiv M(D^+)^{\text{PDG}}$, $\sigma(D^{\pm}) \equiv \sigma(D_s^{\pm})$

free fit: $\sigma(D^{\pm}) = 11.6 \pm 1.8\,\text{MeV}$, $\sigma(D_s^{\pm}) = 10.3 \pm 1.5\,\text{MeV}$

matched: $\sigma(D^{\pm}) = 11.3 \pm 0.7\,\text{MeV}$, $\sigma(D_s^{\pm}) = 10.9 \pm 0.7\,\text{MeV}$

Cross section of $D_s^{\pm}$ production





kinematic range: $pT > 3.5\,\mathbf{GeV},\ |\eta| < 2.1$

$$Acc = 7.28 \pm 0.75\,\%$$

$$\sigma = 168 \pm 34\,\mu\mathrm{b}$$

signals: Gauss$^{\mathrm{mod}}$, **backgr:** exp

$M(D^+) \equiv M(D^+)^{\mathrm{PDG}}, \quad \sigma(D^{\pm}) \equiv \sigma(D_s^{\pm})$

Subtraction of $D_s^{\pm}$ reflection from $D^+ \rightarrow K^- \pi^+ \pi^+$

$D_s^{\pm}$ reflection to $D^+ \rightarrow K^- \pi^+ \pi^+$ signal :

$\mathcal{B}_{D_s^+ \rightarrow \phi\pi^+, \phi \rightarrow K^+K^-} = 2.32 \pm 0.14\,\%$: removed by veto on $M(KK)$

$\mathcal{B}_{D_s^+ \rightarrow K^+K^-\pi^+} = 5.50 \pm 0.27\,\%$: $> 3\%$ can distort $D^{\pm}$ signal

How to remove the reflection ?

MC : by matching to true level

DATA : shape from the matched MC reflection

normalisation =

$$\frac{N^{DATA}(D_s^{\pm})}{N^{MC}(D_s^{\pm})} \cdot \frac{r_B^{PDG}}{r_B^{MC}}$$

$$\text{where } r_B = \frac{\mathcal{B}_{D_s^+ \rightarrow K^+K^-\pi^+} - \mathcal{B}_{D_s^+ \rightarrow \phi\pi^+, \phi \rightarrow K^+K^-}}{\mathcal{B}_{D_s^+ \rightarrow \phi\pi^+, \phi \rightarrow K^+K^-}}$$

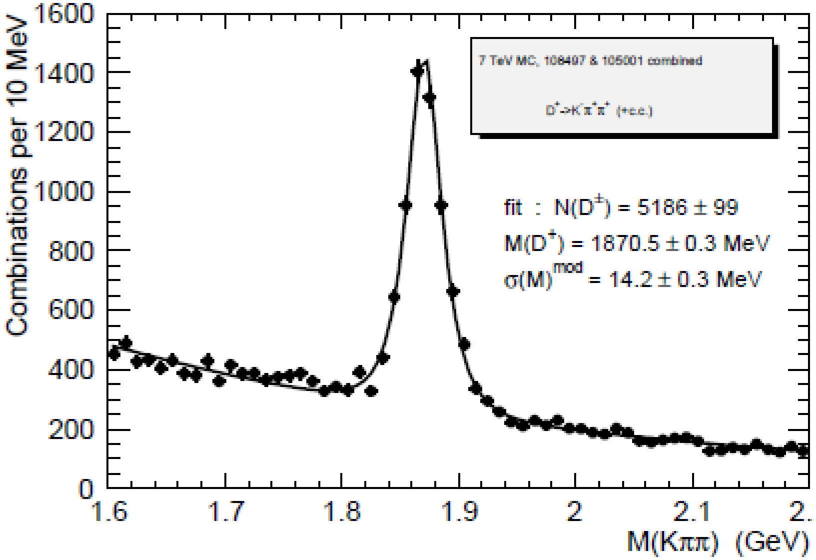
$$\frac{N^{DATA}(D_s^{\pm})}{N^{MC}(D_s^{\pm})} = \frac{304}{442}$$

$$\frac{r_B^{PDG}}{r_B^{MC}} = \frac{1.37}{1.92}$$

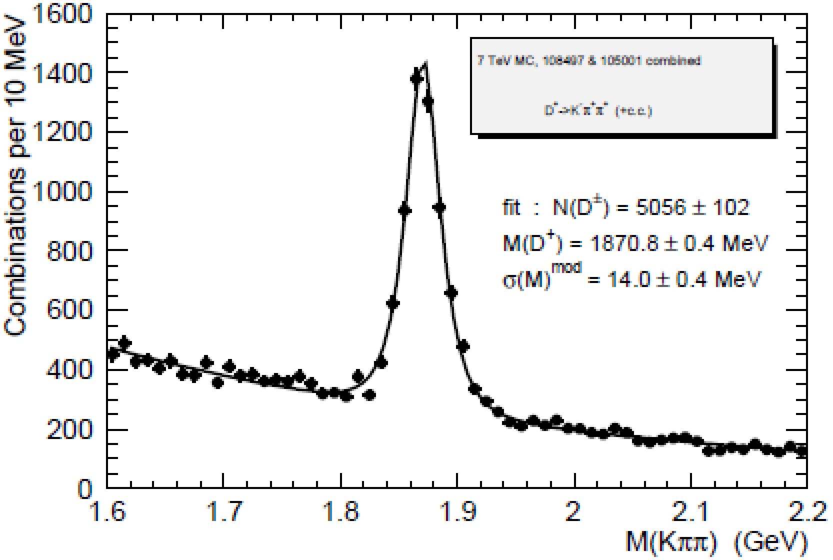
r_B^{MC} is taken from the MinBias MC (105001)

$D^{\pm}$ with combined MC sample

before $D_s^{\pm}$ subtraction



after $D_s^{\pm}$ subtraction



kinematic range: $pT > 3.5\,\text{GeV},\ |\eta| < 2.1$

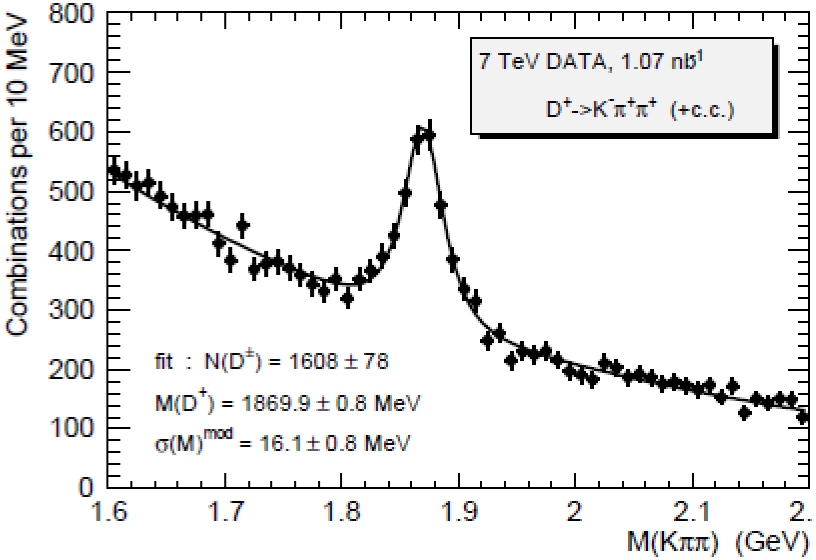
$$Acc = 6.43 \pm 0.13\,\%$$

signal: Gauss$^{\text{mod}}$

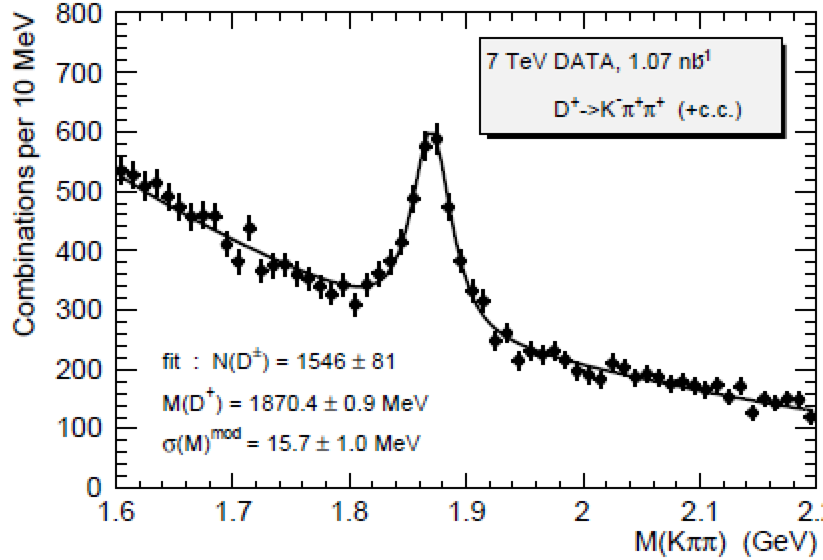
backgr: exp

Cross section of $D^{\pm}$ production

before $D_s^{\pm}$ subtraction



after $D_s^{\pm}$ subtraction



kinematic range: $pT > 3.5\,\mathrm{GeV},\ |\eta| < 2.1$

$$\sigma = 238 \pm 13\,\mu\mathrm{b}$$

signal: Gauss$^{\mathrm{mod}}$

backgr: exp

Binning for $D^{*\pm}$ and $D^{\pm}$ diff. x-sections

p_T : 3.5 - 5.0 - 6.5 - 8.0 - 12. - 40.

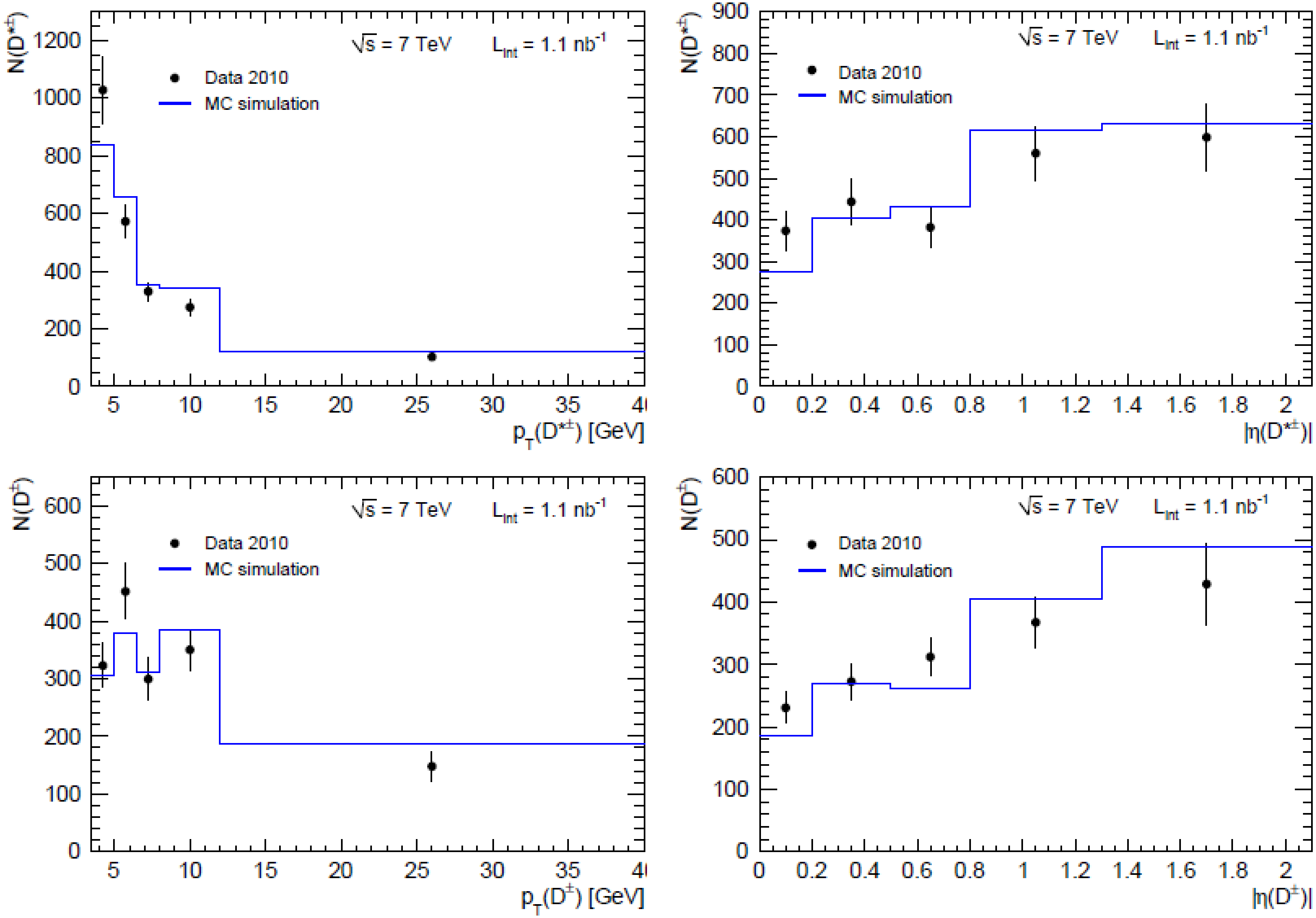
$|\eta|$: 0.0 - 0.2 - 0.5 - 0.8 - 1.3 - 2.1

$$\sigma_{pp\to D^{(*)}X} = \frac{N(D^{(*)})}{\mathscr{A}\cdot\mathscr{L}\cdot\mathscr{B}},$$

where $N(D^{(*)})$ is the number of reconstructed charmed mesons, $\mathscr{A}$ is the reconstruction acceptance obtained from the MC sample, $\mathscr{L}$ is the integrated luminosity and $\mathscr{B}$ is the branching fraction or the product of the branching fractions [11] for the decay channel used in the reconstruction.

The differential cross sections $d\sigma/dp_T$ and $d\sigma/d|\eta|$ were calculated for $D^{*\pm}$ and $D^{\pm}$ production in five bins in p_T ($3.5-5$; $5-6.5$; $6.5-8$; $8-12$; $12-40$ GeV) and five bins in $|\eta|$ ($0-0.2$; $0.2-0.5$; $0.5-0.8$; $0.8-1.3$; $1.3-2.1$). To obtain the differential cross sections in a given bin, the visible

Control plots from CONF-note



Systematic uncertainties

1) trigger: $eff = 100\%$, $\delta = 0.0\%$ (only this analysis)

2) luminosity: $\delta = 11\%$ ($\rightarrow$ 5% soon ?)

3) branchings: $\delta = 1.5\%,\ 4.3\%,\ 6.0\%$ (PDG 2010)

4) track reconstruction efficiency

   4.1) MC material description: $\delta = 6.0 - 9.3\%$ (ATLAS-CONF-2010-046)

   4.2) tracks selection: $\delta = 3\%$ (ATLAS-CONF-2010-046)

5) D-meson reconstruction

   basic cuts variations (χ^2, p_T/E_T, L_{XY}, ...) (next slide)

6) D-meson signals extraction (fits)

   variations of backgr. functions (+1 par.) and

   ranges (-2 bins from one or another edge) for all signals and bins

   in addition for $D_s^{\pm}$: $\sigma(D^{\pm})$ to 0.9 and 1.1 of $\sigma(D_s^{\pm})$

   in addition for $D^{\pm}$: subtraction of $D_s^{\pm}$ admixture by $\pm 1\sigma$ ($\sim 30\%$)

7) model dependence

   7.1) variations of p_T and η MC spectra

   (within compatibility with data, see slide)

   7.2) variations of beauty contribution (by factor 2)

NLO predictions to confront with data

Used : MC@NLO, POWHEG-HERWIG, POWHEG-PYTHIA (NLO+PS MC, public codes)

To be involved : FONLL (NLO+NLL), GM-VFNS (variable flavour number)
Expected : MC@NLO+PYTHIA, NNLO ?

Is it the same "NLO" in all predictions ?

$\sqrt{s} = 14\,\mathrm{TeV}$, CTEQ6m, $m_b = 4.75\,\mathrm{GeV}$, $m_c = 1.5\,\mathrm{GeV}$

MC@NLO 3.41:

$$\sigma_{b\bar{b}} = 0.457 \pm 0.001\,\mathrm{mb} \quad \sigma_{c\bar{c}} = 6.539 \pm 0.020\,\mathrm{mb}$$

$$\mu^2 = m_Q^2 + \frac{(p_{T,Q} + p_{T,\bar{Q}})^2}{4}$$

POWHEG-hvq 1.01:

$$\sigma_{b\bar{b}} = 0.464 \pm 0.001\,\mathrm{mb} \quad \sigma_{c\bar{c}} = 5.312 \pm 0.010\,\mathrm{mb}$$

$$\mu^2 = m_Q^2 + (M_{Q\bar{Q}}^2/4 - m_Q^2) \cdot \sin^2(\theta_Q)$$

Comment from Stefano Frixione:

MC@NLO returns a total cross section identical to that computed by the underlying NLO computation. This is not the case for Powheg; extra terms, beyond NLO, are included. These are NOT, however, the result of a proper NNLO computation (or beyond). Thus, large differences between MC@NLO and Powheg reflect our ignorance on the predictions beyond NLO.

The above difference is due to differences in the scale choice
Total x-sections with fixed scale (m_Q) agree within 1%

Hadronisation and theoretical uncertainties

Hadronisation : HERWIG cluster model or Bowler modification of Lund symmetric fragmentation function

Fragmentation fractions set to LEP data :

	LEP data	
	stat.$\oplus$syst.	br.
$f(c \to D^{*+})$	0.235 ± 0.007	± 0.003
$f(c \to D^{+})$	0.222 ± 0.010	± 0.009
$f(c \to D_s^{+})$	0.087 ± 0.009	± 0.005
$f(b \to D^{*\pm})$	0.175 ± 0.020	± 0.001
$f(b \to D^{\pm})$	0.227 ± 0.016	± 0.010
$f(b \to D_s^{\pm})$	0.140 ± 0.016	± 0.008

Theoretical uncertainties :

- scale uncertainty. The uncertainty was determined by varying μ_r and μ_f independently to $\mu/2$ and 2μ, with the additional constraint $1/2 < \mu_r/\mu_f < 2$, and selecting the largest positive and negative variations;
- m_Q uncertainty. The uncertainty was determined by varying the charm and bottom quark masses independently by 0.2 GeV and 0.25 GeV, respectively. The total m_Q uncertainty was obtained by adding the positive and negative cross-section variations in quadrature;
- PDF uncertainty. The uncertainty was determined by using the CTEQ6.6 PDF error eigenvectors. The total PDF uncertainty was obtained by adding the positive and negative cross-section variations in quadrature;
- hadronisation uncertainty. This uncertainty was obtained for each $D^{(*)}$ meson as a sum in quadrature of the corresponding fragmentation fraction uncertainty and the fragmentation function uncertainty. The latter uncertainty was determined in frame of the POWHEG-PYTHIA predictions by using the Peterson fragmentation function [26] with extreme choices of the fragmentation parameter: 0.02 and 0.1 for charm fragmentation, and 0.002 and 0.01 for beauty fragmentation. The uncertainties of the fragmentation fractions originating from the uncertainties in the charm meson decay branching ratios were not included into the total hadronisation uncertainties because they affect experimental and theoretical cross-section calculations in the same way and can be ignored in the comparison.

Fragmentation Fractions

The heavy quark hadronisation was performed using the cluster model [16] in case of HERWIG. In PYTHIA, the Lund string model [17] with the Bowler modification [18] of the Lund symmetric fragmentation fucntion [19] for heavy quarks was used. Fragmentation fractions of heavy quarks hadronising as a particular charm meson, $f(Q \to D^{(*)})$, were set to experimental values. The c-quark fragmentation fractions, obtained by averaging of the LEP measurements as in [20], and the b-quark fragmentation fractions, measured by ALEPH [21] and OPAL [22], were recalculated using updated values [24] of the relevant charm-meson decay branching ratios. They are summarised in Table 1.

	LEP data		
		stat.$\oplus$syst.	br.
$f(c \to D^{*+})$	0.235	± 0.007	± 0.003
$f(c \to D^{+})$	0.222	± 0.010	± 0.009
$f(c \to D_s^{+})$	0.087	± 0.009	± 0.005
$f(b \to D^{*\pm})$	0.175	± 0.020	± 0.001
$f(b \to D^{\pm})$	0.227	± 0.016	± 0.010
$f(b \to D_s^{\pm})$	0.140	± 0.016	± 0.008

Table 1: The fractions of c and b quarks hadronising as a particular charm meson, $f(Q \to D^{(*)})$, obtained using the LEP measurements (see text).

[23] L.Gladilin, Charm Hadron Production Fractions, hep-ex/9912064

Charm Hadron Production Fractions

The probabilities that a charm quark fragments into D^{*+}, D_s^+ and other charm hadrons are not calculable in perturbative QCD. To obtain them one can use data on charm production in e^+e^- annihilations. The most comprehensive charm measurements were performed by the CLEO [1, 2] and ARGUS [3, 4, 5] collaborations at centre-of-mass energies of about 10 GeV and by the OPAL [6, 7], ALEPH [8] and DELPHI [9, 10] collaborations in

Only LEP measurements used for current averaging because CLEO and ARGUS results are rather old and close to threshold

Particle	OPAL $\frac{\Gamma_{c\bar{c}}}{\Gamma_{had}} \cdot f(c \to D, \Lambda) \cdot B$ (%)	ALEPH $\frac{\Gamma_{c\bar{c}}}{\Gamma_{had}} \cdot f(c \to D, \Lambda) \cdot B$ (%)	DELPHI $\frac{\Gamma_{c\bar{c}}}{\Gamma_{had}} \cdot f(c \to D, \Lambda) \cdot B$ (%)
D_s^+	$0.056 \pm 0.015 \pm 0.007$	$0.072 \pm 0.012 \pm 0.004$	$0.076 \pm 0.007 \pm 0.007$
D^0	$0.389 \pm 0.027 ^{+0.026}_{-0.024}$	$0.370 \pm 0.011 \pm 0.023$	$0.360 \pm 0.010 \pm 0.021$
D^+	$0.358 \pm 0.046 ^{+0.025}_{-0.031}$	$0.368 \pm 0.012 \pm 0.020$	$0.349 \pm 0.012 \pm 0.021$
Λ_c^+	$0.041 \pm 0.019 \pm 0.007$	$0.067 \pm 0.007 \pm 0.004$	$0.074 \pm 0.015 \pm 0.009$

Charm hadron production fractions can be obtained dividing the measured products by the branching ratios and the Standard Model value of $\frac{\Gamma_{c\bar{c}}}{\Gamma_{had}}$ [13]:

$$\frac{\Gamma_{c\bar{c}}}{\Gamma_{had}} = 0.1719 \pm 0.0017 \,. \qquad (7)$$

There are four LEP measurements which can be used for the $f(c \to D^{*+})$ calculation. The OPAL collaboration has done a double tagged measurement of

Two OPAL's $f(c \to D^{*+})$ measurements are statistically and systematically correlated. To calculate the correlations one can use the result for $\frac{\Gamma_{c\bar{c}}}{\Gamma_{had}}$ obtained by the OPAL collaboration [6] from the measurements (8) and (12):

$f(b \to D^{\pm})$ Fragmentation Fractions

$f(b \to D^{*\pm})$	0.175	± 0.020	± 0.001
$f(b \to D^{\pm})$	0.227	± 0.016	± 0.010
$f(b \to D_s^{\pm})$	0.140	± 0.016	± 0.008

OPAL with new branching ratios
ALEPH with new branching ratios
ALEPH with new branching ratios

PDG 2010: $B^{\pm}/B^{0}/B_s^{0}/b$-baryon ADMIXTURE

Γ_{38}	$D^{*}(2010)^{+}$ anything	(17.3 ± 2.0) %	branching ratio not updated
Γ_{36}	D^{+} anything		
Γ_{37}	D^{-} anything	(22.7 ± 1.8) %	old branching ratio uncertainty
Γ_{46}	D_s^{-} anything	(14.7 ± 2.1) %	misinterpretation
Γ_{47}	D_s^{+} anything	(10.1 ± 3.1) %	

Visible cross sections

The visible cross sections for $D^{(*)}$ mesons in the kinematic range $p_T(D^{(*)}) > 3.5$ GeV and $|\eta(D^{(*)})| < 2.1$ are

$$\sigma^{vis}(D^{*\pm}) = 285 \pm 16(\text{stat.})^{+32}_{-27}(\text{syst.}) \pm 31(\text{lum.}) \pm 4(\text{br.})\,\mu\text{b},$$

$$\sigma^{vis}(D^{\pm}) = 238 \pm 13(\text{stat.})^{+35}_{-23}(\text{syst.}) \pm 26(\text{lum.}) \pm 10(\text{br.})\,\mu\text{b},$$

$$\sigma^{vis}(D_s^{\pm}) = 168 \pm 34(\text{stat.})^{+27}_{-24}(\text{syst.}) \pm 18(\text{lum.}) \pm 10(\text{br.})\,\mu\text{b},$$

where the last two uncertainties are due to those on the luminosity measurement and the charmed meson decay branching fractions.

The POWHEG-PYTHIA predictions are

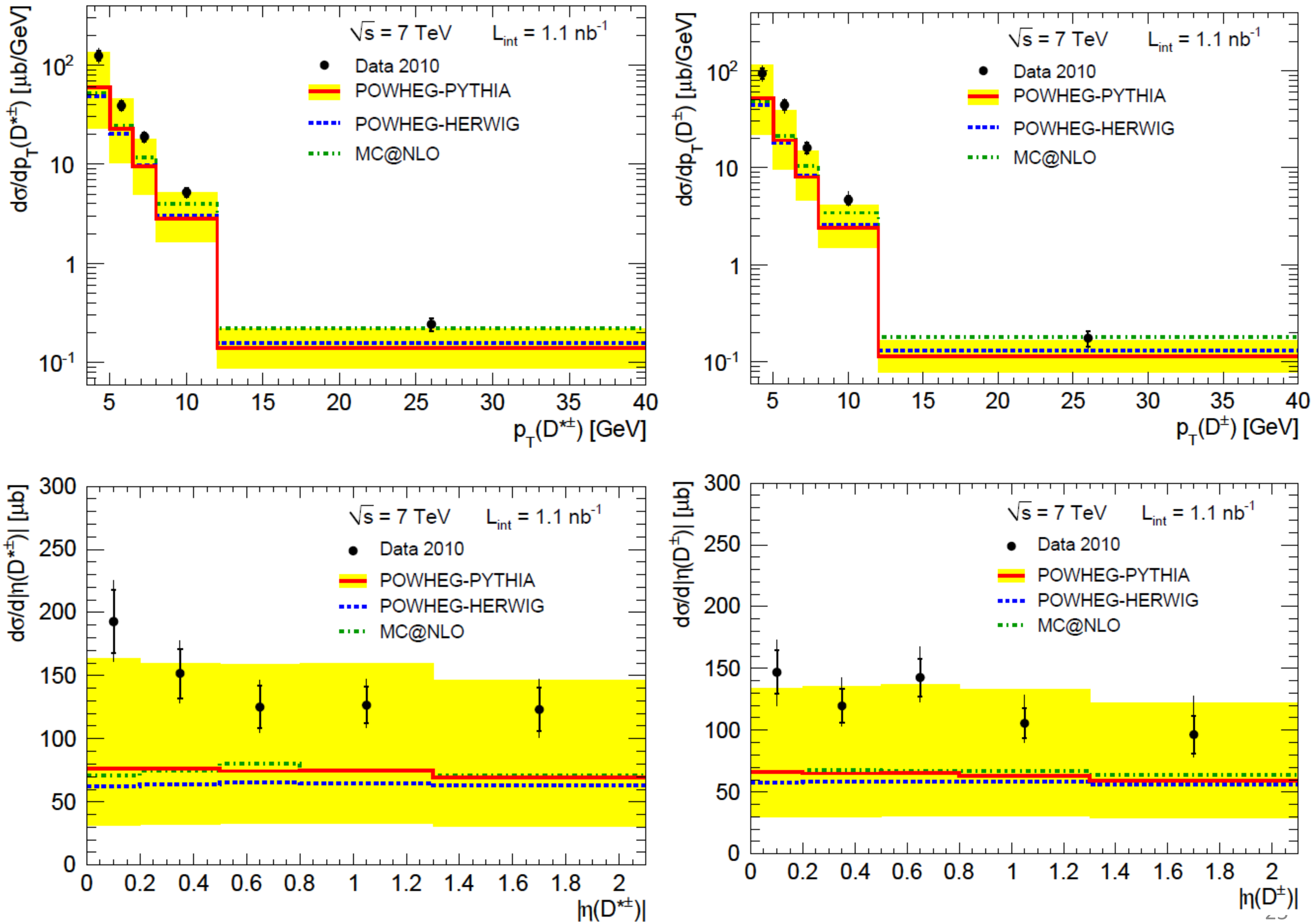
$$\sigma(D^{*\pm}) = 153^{+169}_{-80}(\text{scale})^{+13}_{-15}(m_Q)^{+24}_{-21}(\text{PDF})^{+20}_{-16}(\text{hadr.})\,\mu\text{b},$$

$$\sigma(D^{\pm}) = 132^{+137}_{-65}(\text{scale})^{+11}_{-10}(m_Q)^{+20}_{-18}(\text{PDF})^{+21}_{-11}(\text{hadr.})\,\mu\text{b},$$

$$\sigma(D_s^{\pm}) = 59^{+57}_{-28}(\text{scale})^{+4}_{-6}(m_Q)^{+9}_{-8}(\text{PDF})^{+7}_{-8}(\text{hadr.})\,\mu\text{b}.$$

The corresponding POWHEG-HERWIG predictions are $\sigma(D^{*\pm}) = 135\,\mu\text{b}$, $\sigma(D^{\pm}) = 121\,\mu\text{b}$ and $\sigma(D_s^{\pm}) = 50\,\mu\text{b}$, while MC@NLO predicts $\sigma(D^{*\pm}) = 155\,\mu\text{b}$, $\sigma(D^{\pm}) = 138\,\mu\text{b}$ and $\sigma(D_s^{\pm}) = 57\,\mu\text{b}$.

Differential cross sections



Extrapolation, fragm. ratios and and total $c\bar{c}$ x-section

$$\sigma_{tot}(D^{(*)}) = \sigma_{pp\to c\bar{c}X\to D^{(*)}X'} = \sigma_{vis}^{DATA}(D^{(*)}) \frac{\sigma_{vis}^{NLO,c\bar{c}}}{\sigma_{vis}^{NLO,c\bar{c}}+\sigma_{vis}^{NLO,b\bar{b}}} f_{extr}^{NLO,c\bar{c}}$$

$f_{extr}^{NLO,c\bar{c}} \sim 14-16$ **(relatively stable)**

$$\sigma_{tot}(D^{*\pm}) = 3.36 \pm 0.19\,\mathrm{mb}$$

$$\sigma_{tot}(D^{\pm}) = 3.10 \pm 0.17\,\mathrm{mb}$$

$$\sigma_{tot}(D_s^{\pm}) = 1.90 \pm 0.38\,\mathrm{mb}$$

$$\sigma^{dir}(D^{\pm}) = \sigma_{tot}(D^{\pm}) - \sigma_{tot}(D^{*\pm}) \cdot (1 - \mathcal{B}_{D^{*+}\to D^0\pi^+})$$

$$\gamma_s = \frac{\sigma_{tot}(D_s^{\pm})}{\sigma^{dir}(D^{\pm})+\sigma_{tot}(D^{*\pm})} = 0.35 \pm 0.07$$

$$P_{\mathrm{v}} = \frac{\sigma_{tot}(D^{*\pm})}{\sigma^{dir}(D^{\pm})+\sigma_{tot}(D^{*\pm})} = 0.63 \pm 0.03$$

$$\sigma_{c\bar{c}} = \sigma_{tot}(D^{(*)})/f(c\to D^{(*)})\ /\ \mathbf{2.}$$

weighted mean from $D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$:

$$\sigma_{c\bar{c}} = 7.13 \pm 0.28\,\mathrm{mb}$$

Extrapolated cross sections

The visible $D^{(*)}$ cross section were extrapolated to the cross sections in the full kinematic phase space after subtraction of the cross sections fractions originating from beauty production. To calculate the fractions and extrapolation factors the POWHEG-PYTHIA calculations were used. The combined uncertainty of the beauty-fraction subtraction and the extrapolation to the full kinematic phase space was determined by adding in quadrature results differences originating from all sources of the theoretical uncertainty (Section 7) and differences due to using POWHEG-HERWIG and MC@NLO calculations.

The total cross sections of the $D^{(*)}$ production in charm hadronisation are

$$\sigma_{cc}^{tot}(D^{*\pm}) = 3.36 \pm 0.19(\text{stat.})^{+0.38}_{-0.32}(\text{syst.}) \pm 0.40(\text{lum.}) \pm 0.05(\text{br.})^{+1.76}_{-0.82}(\text{extr.})\,\text{mb},$$

$$\sigma_{cc}^{tot}(D^{\pm}) = 3.10 \pm 0.17(\text{stat.})^{+0.46}_{-0.30}(\text{syst.}) \pm 0.34(\text{lum.}) \pm 0.13(\text{br.})^{+1.70}_{-0.89}(\text{extr.})\,\text{mb},$$

$$\sigma_{cc}^{tot}(D_s^{\pm}) = 1.90 \pm 0.38(\text{stat.})^{+0.30}_{-0.27}(\text{syst.}) \pm 0.21(\text{lum.}) \pm 0.11(\text{br.})^{+1.23}_{-0.55}(\text{extr.})\,\text{mb},$$

where the last uncertainties are the combined uncertainties due to the beauty-fraction subtraction and the extrapolation procedure.

To calculate the total cross section of charm production, the total cross sections of a given $D^{(*)}$ meson production should be divided by the doubled value of the corresponding charm fragmentation fraction from Table 1. The weighted mean of three values calculated from $D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$ cross sections is

$$\sigma_{cc}^{tot} = 7.13 \pm 0.28(\text{stat.})^{+0.89}_{-0.66}(\text{syst.}) \pm 0.78(\text{lum.})^{+3.82}_{-1.90}(\text{extr.})\,\text{mb},$$

where uncertainties of the fragmentation fractions were included into the extrapolation uncertainties. The common for measured cross sections and fragmentation fractions branching-fraction uncertainties do not affect the calculation of the total cross section of charm production.

Charm fragmentation ratios

The strangeness-suppression factor was calculated as the ratio of the $\sigma_{cc}^{tot}(D_s^{\pm})$ to the sum of $\sigma_{cc}^{tot}(D^{*\pm})$ and that part of $\sigma_{cc}^{tot}(D^{\pm})$ which originates not from $D^{*\pm}$ decays:

$$\gamma_{s/d} = \frac{\sigma_{cc}^{tot}(D_s^{\pm})}{\sigma_{cc}^{tot}(D^{*\pm}) + \sigma_{cc}^{tot}(D^{\pm}) - \sigma_{cc}^{tot}(D^{*\pm}) \cdot (1 - \mathscr{B}_{D^{*+}\to D^0\pi^+})} = \frac{\sigma_{cc}^{tot}(D_s^{\pm})}{\sigma_{cc}^{tot}(D^{\pm}) + \sigma_{cc}^{tot}(D^{*\pm}) \cdot \mathscr{B}_{D^{*+}\to D^0\pi^+}},$$

where $\mathscr{B}_{D^{*+}\to D^0\pi^+} = 0.677 \pm 0.005$ [10] is the branching ratio of the $D^{*+} \to D^0\pi^+$ decay. Using the extrapolated cross sections, the strangeness-suppression factor is

$$\gamma_{s/d} = 0.35 \pm 0.07(\text{stat.}) \pm 0.03(\text{syst.}) \pm 0.03(\text{br.})^{+0.04}_{-0.03}(\text{extr.}).$$

The fraction of D mesons produced in a vector state was calculated as the ratio of $\sigma_{cc}^{tot}(D^{*\pm})$ to the sum of $\sigma_{cc}^{tot}(D^{*\pm})$ and that part of $\sigma_{cc}^{tot}(D^{\pm})$ which originates not from $D^{*\pm}$ decays:

$$P_v = \frac{\sigma_{cc}^{tot}(D^{*\pm})}{\sigma_{cc}^{tot}(D^{*\pm}) + \sigma_{cc}^{tot}(D^{\pm}) - \sigma_{cc}^{tot}(D^{*\pm}) \cdot (1 - \mathscr{B}_{D^{*+}\to D^0\pi^+})} = \frac{\sigma_{cc}^{tot}(D^{*\pm})}{\sigma_{cc}^{tot}(D^{\pm}) + \sigma_{cc}^{tot}(D^{*\pm}) \cdot \mathscr{B}_{D^{*+}\to D^0\pi^+}}.$$

Using the extrapolated cross sections, the fraction P_v is

$$P_v = 0.63 \pm 0.03(\text{stat.})^{+0.02}_{-0.03}(\text{syst.}) \pm 0.02(\text{br.})^{+0.04}_{-0.03}(\text{extr.}).$$

The measured charm fragmentation ratios can be compared with those obtained in e^+e^- annihilations at LEP. The LEP fragmentation ratios were calculated using fragmentation fractions from Table 1:

$$\gamma_{s/d}^{\text{LEP}} = \frac{f(c \to D_s^+)}{f(c \to D^+) + f(c \to D^{*+}) \cdot \mathscr{B}_{D^{*+}\to D^0\pi^+}} = 0.23 \pm 0.02(\text{stat.} \oplus \text{syst.}) \pm 0.02(\text{br.}),$$

$$P_v^{\text{LEP}} = \frac{f(c \to D^{*+})}{f(c \to D^+) + f(c \to D^{*+}) \cdot \mathscr{B}_{D^{*+}\to D^0\pi^+}} = 0.62 \pm 0.02(\text{stat.} \oplus \text{syst.}) \pm 0.02(\text{br.}).$$

Summary & Plans

- Clean $D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$ signals reconstructed
- Performance ATLAS-CONF note released for Physics@LHC and reported in many conferences (by author in ICHEP 2010, IHEP-LHC 2010, LHC Physics day on HQ)
- New ATLAS-CONF note on $D^{(*)}$ production cross sections is ready and under review by the ATLAS editorial board and B-physics group

Plans:

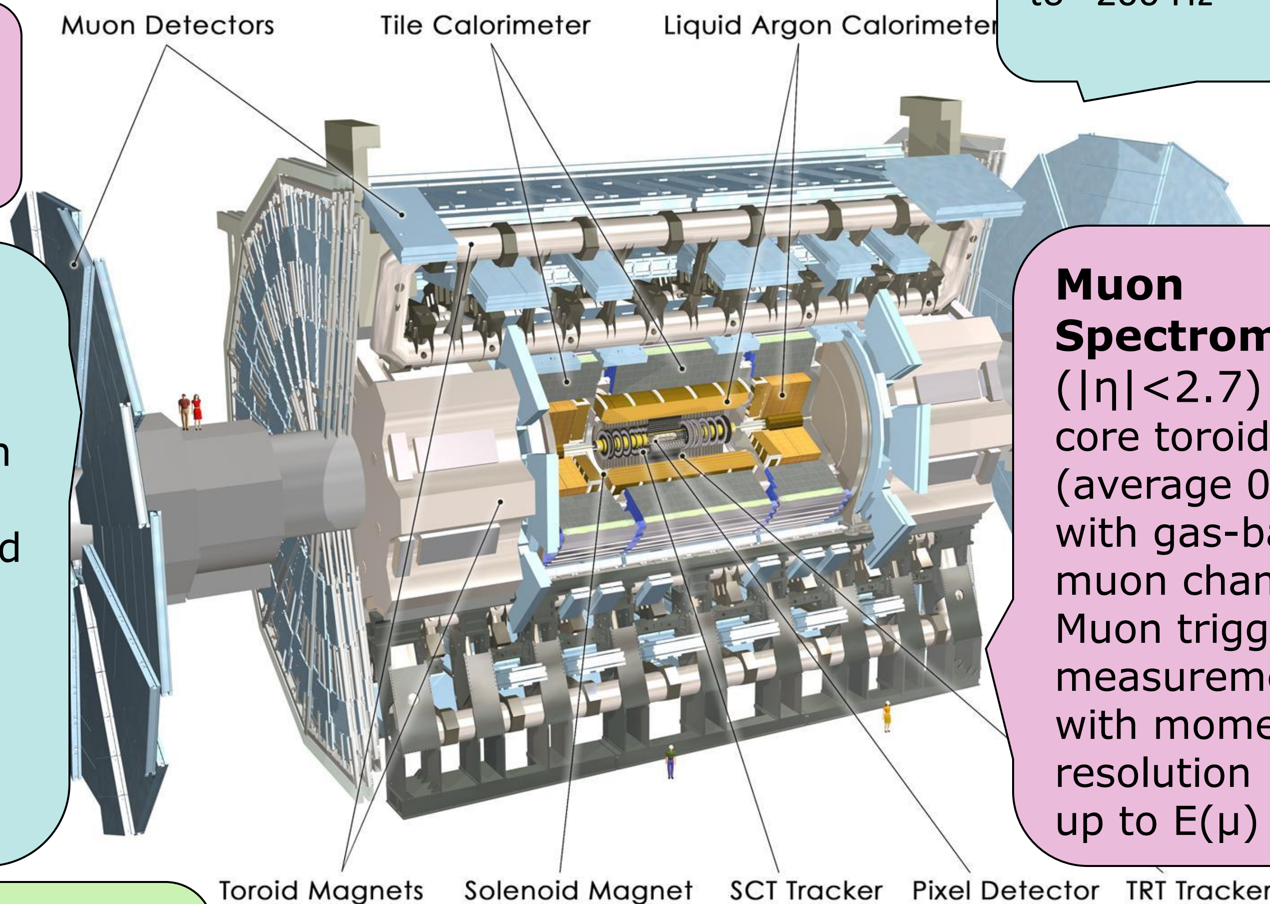
- release the new ATLAS-CONF note for winter conferences
- try to extend the measurement to high-p_T range using lowest L1Calo triggers – another note and, then, combined journal paper
- use $D^{(*)}$ reconstruction methodic for *W+c* measurement

Back-up Slides

The ATLAS detector

3-level trigger reducing the rate from 40 MHz to ~200 Hz

Length: ~46 m
Radius: ~12 m
Weight: ~7 Ktons



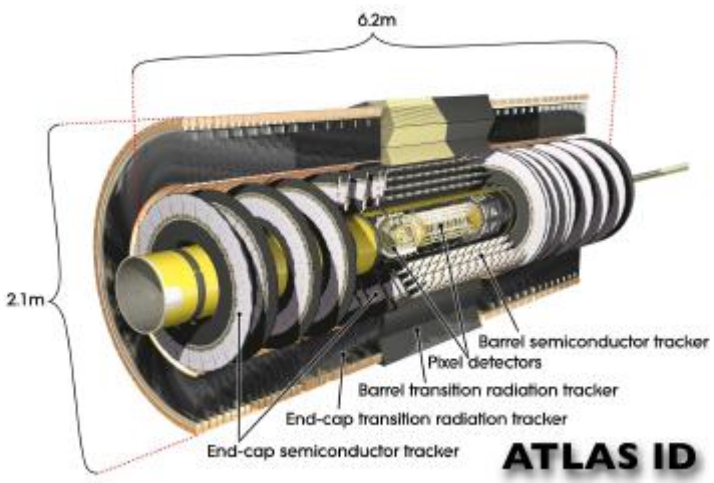
Inner Detector ($|\eta|<2.5$, B=2T): Si Pixels, Si strips, Transition Radiation Tracker (straws). Precise tracking and vertexing, e/π separation. p_t resolution: $\sigma/p_t \sim 3.8\times10^{-4}\ p_t$ (GeV) $\pm$ 0.015

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids (average 0.5T) with gas-based muon chambers. Muon trigger and measurement with momentum resolution < 10% up to E(μ) ~1 TeV

EM calorimeter: Pb-LAr Accordion. e/γ trigger, identification and measurement. E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

HAD calorimetry ($|\eta|<5$): Fe/scintillator Tiles (central), Cu/W-LAr (fwd). Trigger and measurement of jets and missing ET. E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \pm 0.03$

Tracking with ATLAS Inner Detector



- Pixel Detector:

3 barrel layers, 2 x 3 end-cap discs

$\sigma_{r\phi} \sim 10\ \mu m$, $\sigma_z \sim 115\ \mu m$

- Silicon Strip Detector (SCT)

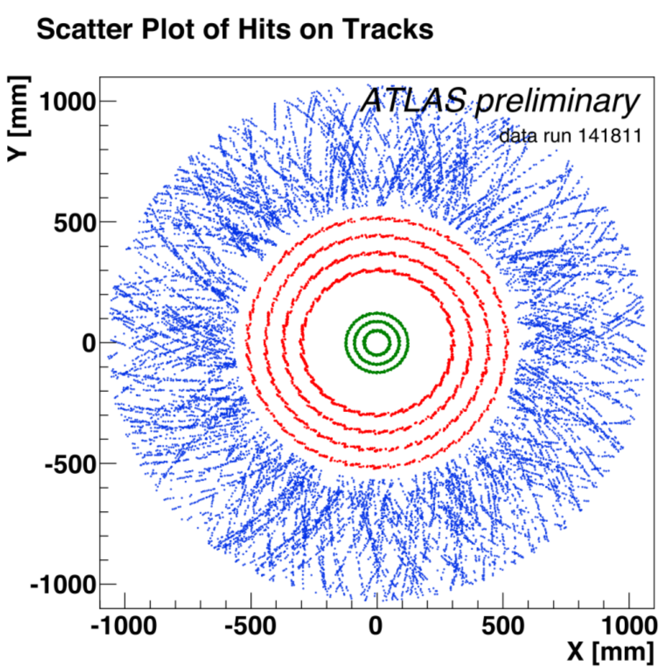
4 barrel layers, 2 x 9 end-cap discs

$\sigma_{r\phi} \sim 17\ \mu m$, $\sigma_z \sim 580\ \mu m$

- Transition Radiation Tracker(TRT)

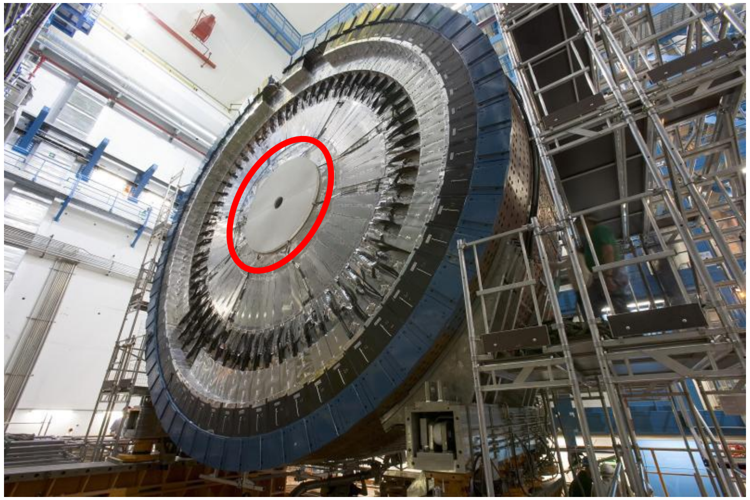
73 barrel straw layers, 2x160 end-cap radial straw discs

$\sigma_{r\phi} \sim 130\ \mu m$

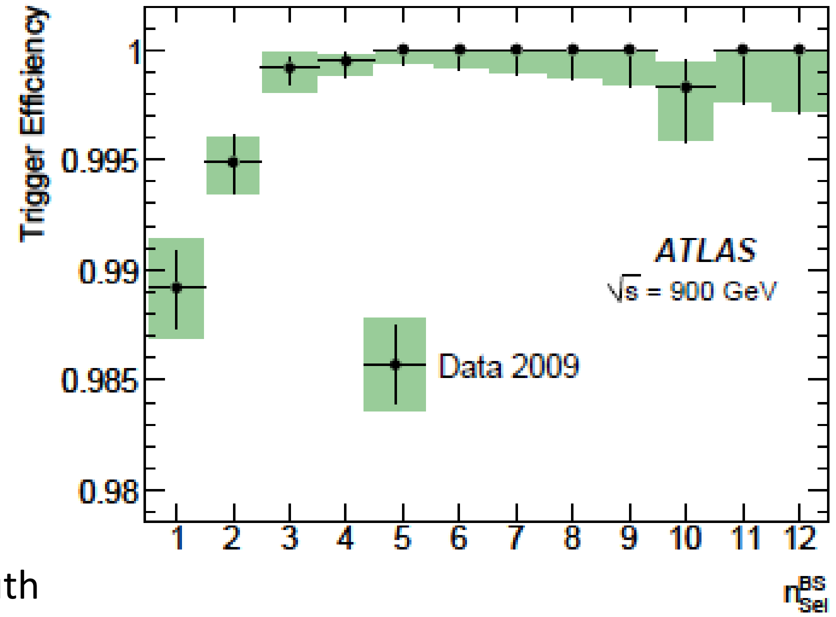


In this analysis:
tracks with at least 1 hit in Pixel and 4 hits in SCT and pT>250 MeV and |η|<2.5

Minimum-Bias Trigger



MinBias Trigger Scintillator at z=±3.56 m
on LAr cryostat; 2 rings with 8 sector in azimuth
2.09<|η|<2.82, 2.82<|η|<3.84

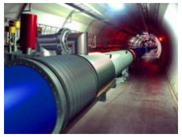


At least one hit above threshold in the Minimum-Bias Trigger Scintillators at each end of the detector

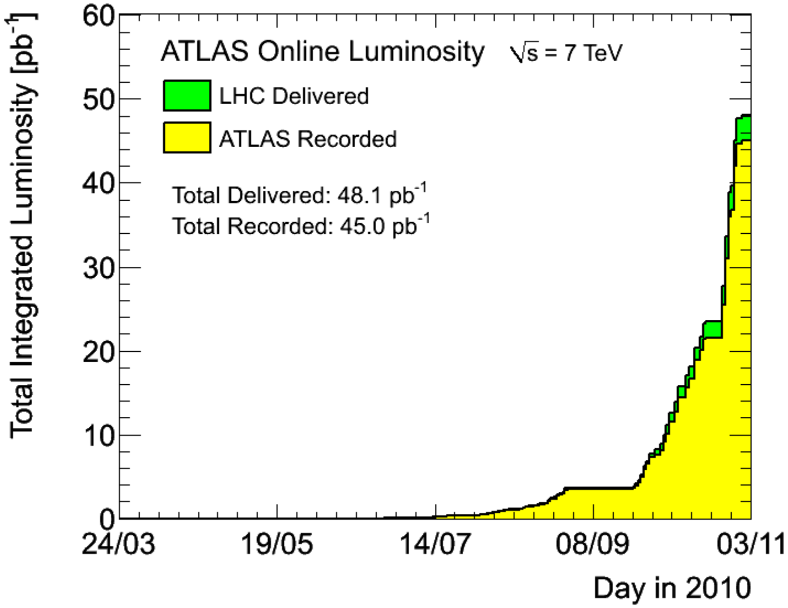
Efficiency is ~100% for events with at least 2 tracks passing beam-spot region

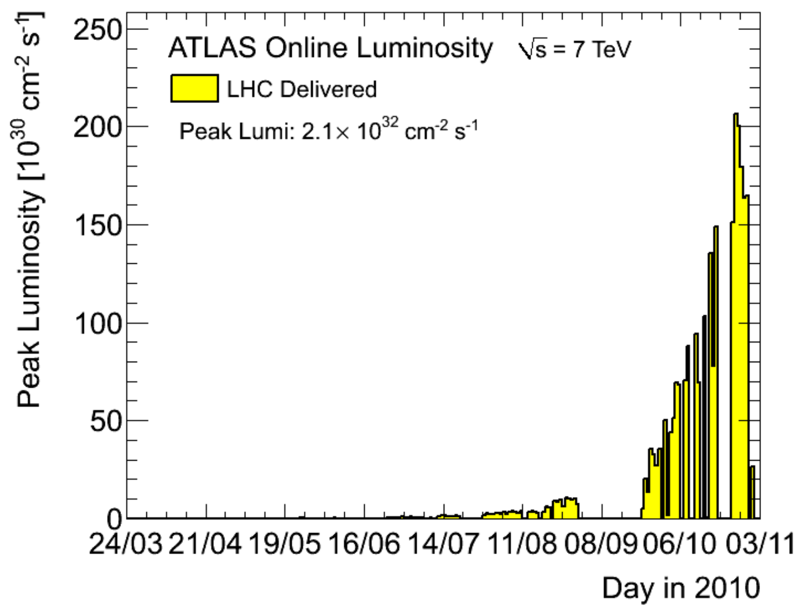
MBTS trigger allow us to measure *D*-mesons production cross-sections without uncertainty originating from trigger efficiency

The trigger is heavily prescaled with luminosity increase



Luminosity and Data Taking



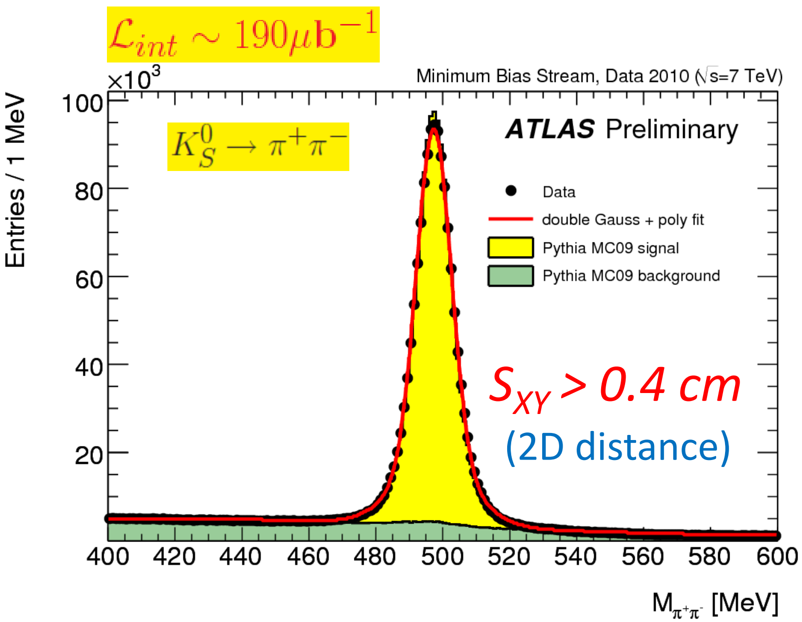


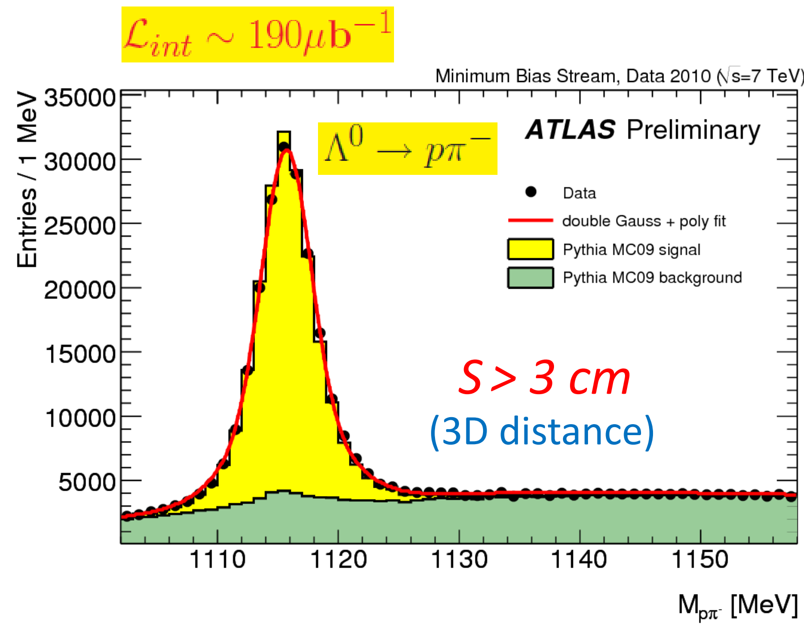
All ID components operational > 97%

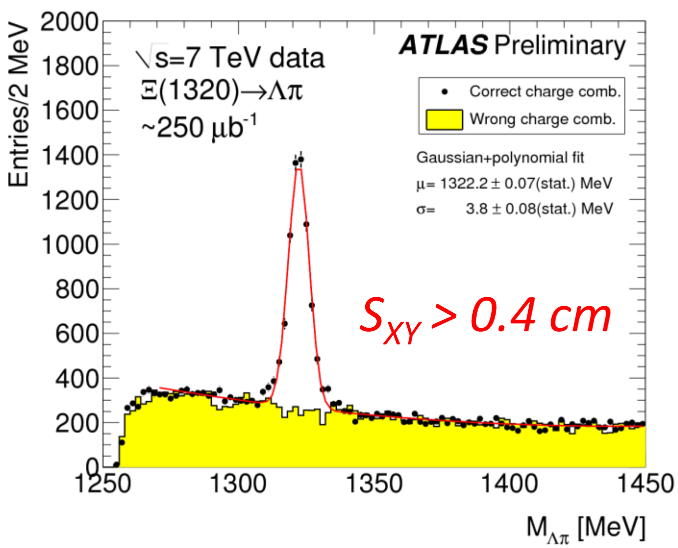
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%

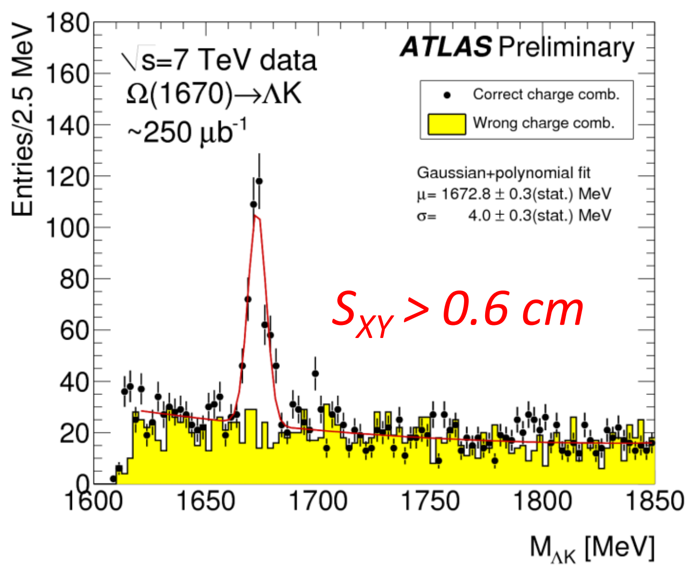
For *D*-meson reconstruction: 1.4 nb^{-1}
(March-May, minimum-bias trigger after prescale)

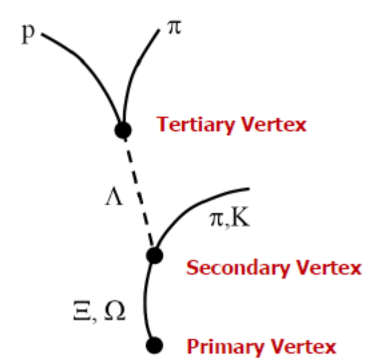
Resonance reconstruction with secondary and tertiary vertexes











Fitted masses and widths agree with MC and PDG mass values

Predictions and expected cross sections

Monte Carlo with LO matrix elements and LL parton showering (PYTHIA)

- flavor creation ($gg \rightarrow Q\bar{Q}$, $q\bar{q} \rightarrow Q\bar{Q}$)
- flavor excitation ($gQ \rightarrow gQ$, $qQ \rightarrow qQ$)
- gluon splitting ($gg \rightarrow Q\bar{Q}$)

PYTHIA with ATLAS Geant4 simulation (arXiv:1005.4568)

- detector level comparisons
- efficiencies and corrections

NLO+PS codes:

MC@NLO 3.41 $\Longrightarrow$ HERWIG

POWHEG-hvq 1.01 $\Longrightarrow$ HERWIG, PYTHIA

and for PDFs: LHAPDF 5.8.1

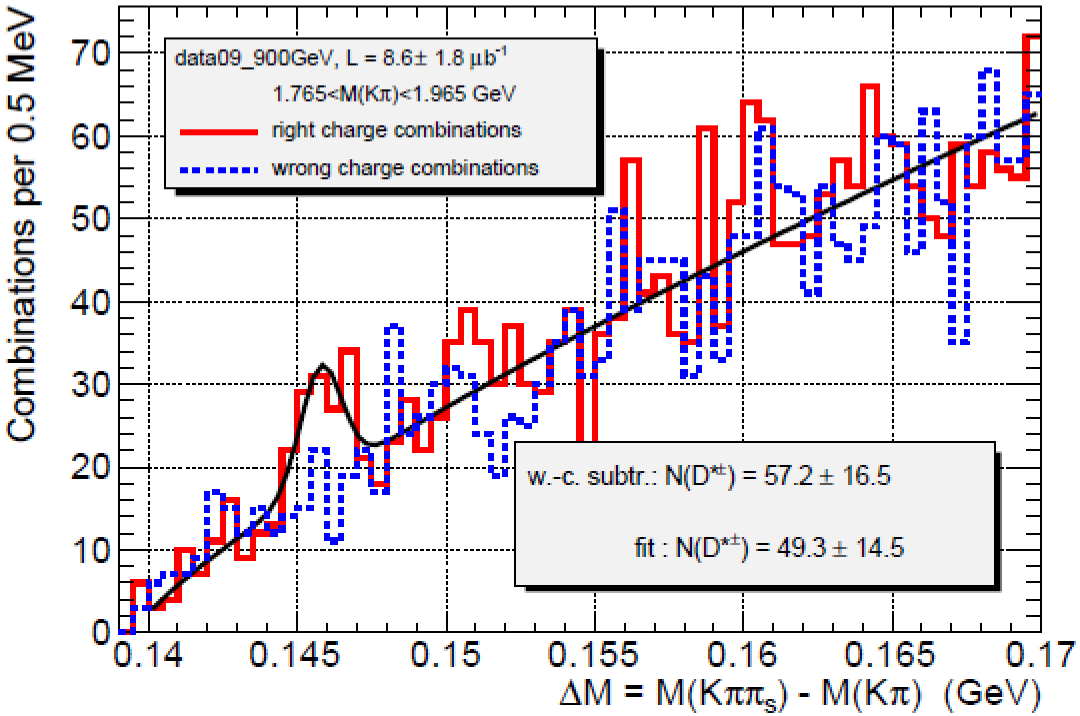
MC@NLO, CTEQ6.6, $m_b = 4.75\,\text{GeV}$, $m_c = 1.5\,\text{GeV}$, $\mu_r = \mu_f = m_T = \sqrt{m_Q^2 + p_T^2}$

$\sqrt{s}$ dependence:

$\sqrt{s}[TeV]$	$\sigma_{b\bar{b}}[mb]$	$\sigma_{c\bar{c}}[mb]$
0.9	0.0225	0.891
2.36	0.757	1.95
7.0	0.243	4.40
10.	0.345	5.68
14.	0.475	7.18

Theor. Uncertainties are large

$D^{*\pm}$ production x-section at $\sqrt{s} = 900\,\mathrm{GeV}$



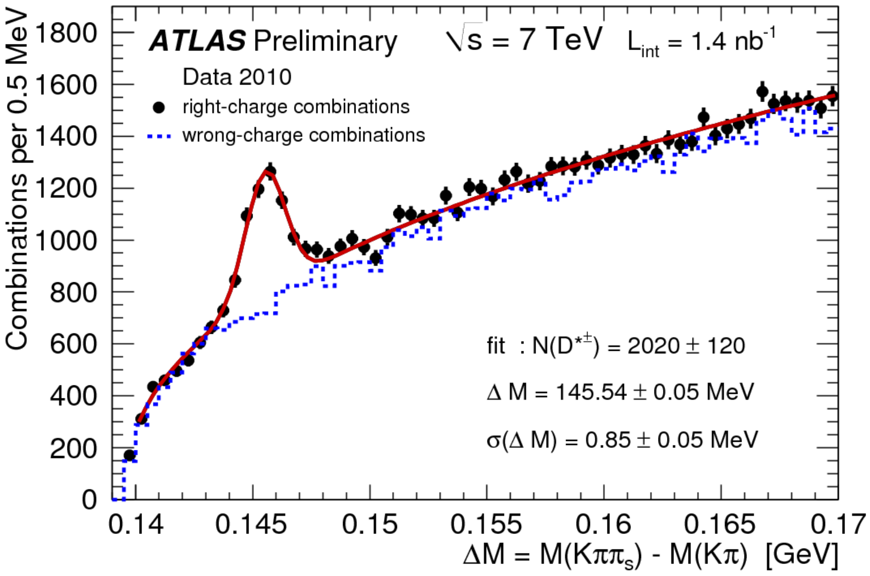
$\mathcal{L} = 8.6 \pm 1.8\,\mu\mathrm{b}^{-1}, \quad \mathcal{A} = 13.0 \pm 1.3\,\%, \quad \mathcal{B}_{D^{*+}\to(K^-\pi^+)\pi^+} = 2.57 \pm 0.05\,\%$

In the kinematic range: $p_T(D^{*\pm}) > 1.8\,\mathbf{GeV}, \ |\eta(D^{*\pm})| < 2.$

$\sigma_{pp\to D^{*\pm}X} = 1.6 \pm 0.5\,\mathbf{mb}$ **(stat.)**

(MC: $c\bar{c}/b\bar{b} = 95\%/5\%$)

$D^{*+} \to D^0\pi^+ \to (K^-\pi^+)\pi^+$ (+c.c.) reconstruction



Kinematic range:

$p_T(D^{*\pm}) > 3.5\,\mathrm{GeV}$, $|\eta(D^{*\pm})| < 2.1$

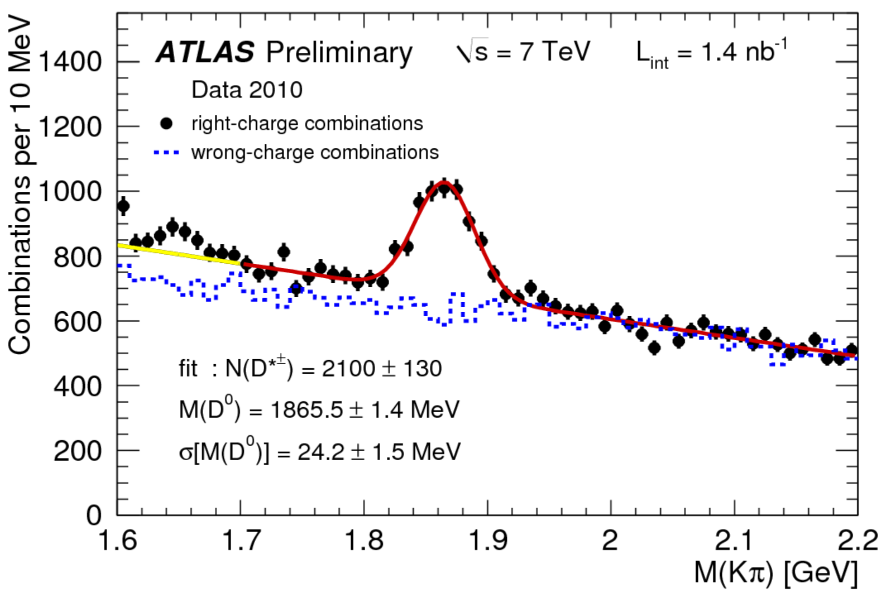
$p_T(D^{*\pm})/\sum E_T > 0.02$ $\Leftarrow$ **hard fragmentation**

$L_{XY}(D^0) > 0$ $\Leftarrow$ $c\tau(D^0) = 123\,\mu\mathrm{m}$

$p_T(K,\pi) > 1\,\mathrm{GeV}$, $p_T(\pi_s) > 0.25\,\mathrm{GeV}$

$\Leftarrow$ $1.83 < M(K\pi) < 1.90\,\mathrm{GeV}$

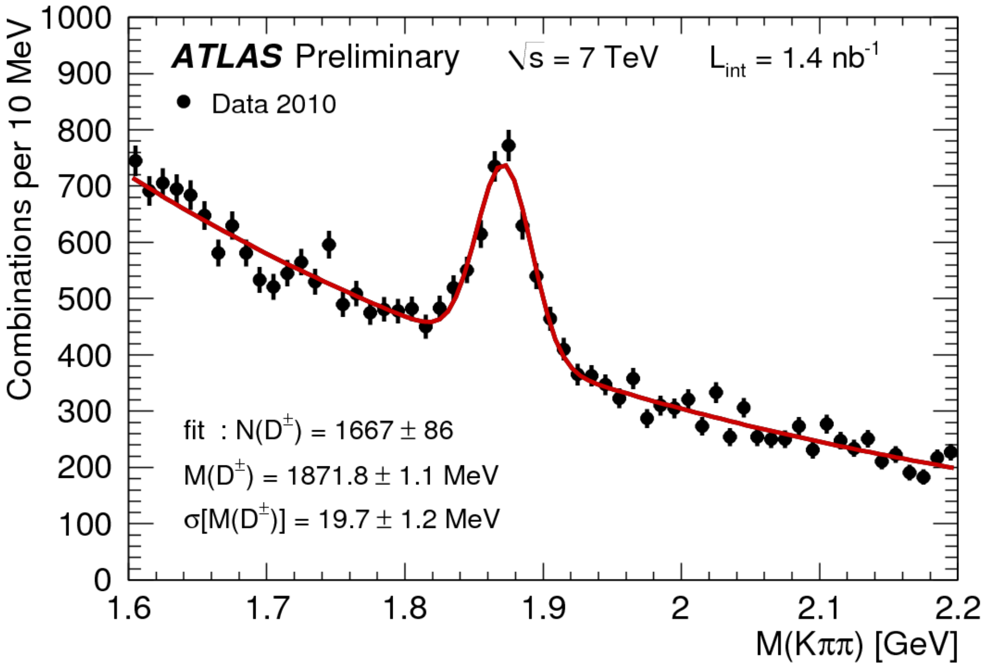
Wrong-charge combinations: $(K^+\pi^+)\pi_s^-$ (+ c.c.)



$\Leftarrow$ $144 < M(K\pi\pi) - M(K\pi) < 147\,\mathrm{MeV}$

Fitted masses and widths consistent with MC and PDG mass values

$D^+ \to K^- \pi^+ \pi^+$ (+c.c.) reconstruction



Kinematic range:

$p_T(D^\pm) > 3.5\,\mathrm{GeV},\ |\eta(D^\pm)| < 2.1$

$p_T(D^\pm)/\sum E_T > 0.02$ $\Leftarrow$ hard fragmentation

$L_{XY}(D^\pm) > 1.3\,\mathrm{mm}$ $\Leftarrow$ $c\tau(D^+) = 312\,\mu\mathrm{m}$

$p_T(K) > 1\,\mathrm{GeV}$

$p_T(\pi_{1,2}) > 0.8\,\mathrm{GeV},\ p_T(\pi_{1,2}^{\max}) > 1\,\mathrm{GeV}$

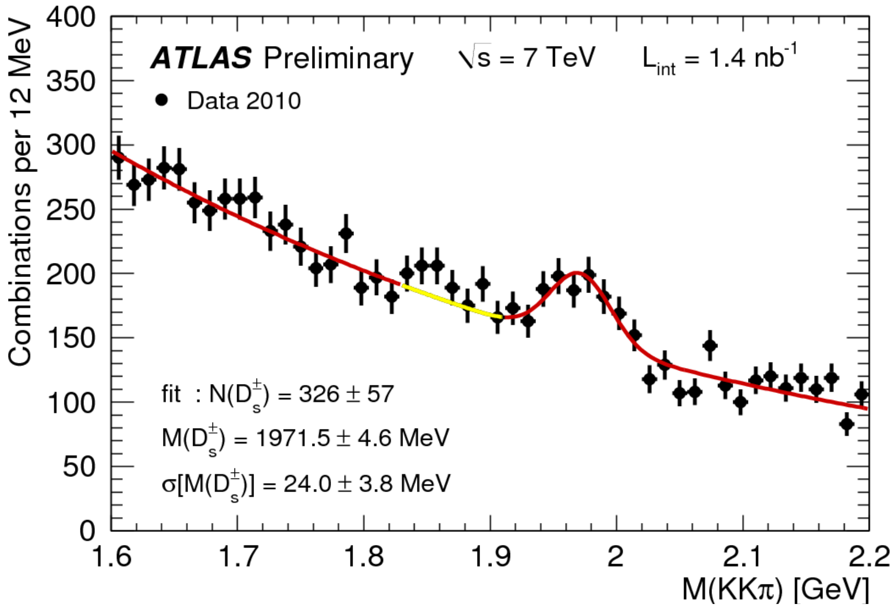
suppression of $D^{*\pm}$ and $D_s^+ \to \phi\,\pi^+ \to (K^-\,K^+)\,\pi^+$ (+c.c.) reflections:

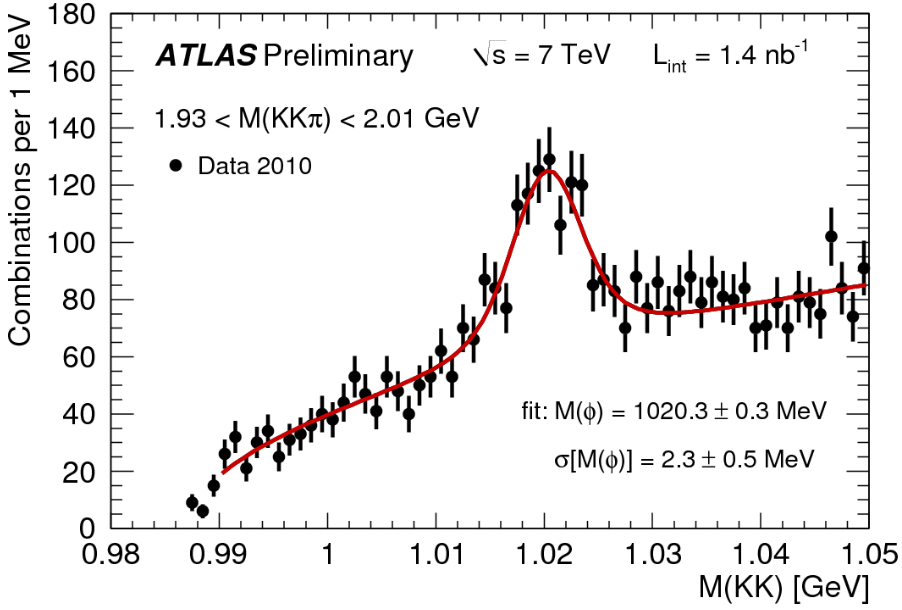
remove $\Delta M_{1,2} < 150\,\mathrm{MeV}$ and $|M(K^\pm,``K^\mp") - M(\phi)_{\mathrm{PDG}}| < 8\,\mathrm{MeV}$

$\cos\theta^*(K) > -0.8$ (angle between $\vec{p}(K)$ in $D^\pm$ rest frame and $\vec{p}(D^\pm)$ in the lab)

Fitted mass and width consistent
with MC and PDG mass value

$D_s^+ \to \phi\pi^+ \to (K^-K^+)\pi^+$ (+c.c.) reconstruction





Kinematic range:

$p_T(D_s^\pm) > 3.5\,\text{GeV},\ |\eta(D_s^\pm)| < 2.1$

$p_T(D_s^\pm)/\sum E_T > 0.04$ $\Longleftarrow$ **hard fragmentation**

$L_{XY}(D_s^\pm) > 0.4\,\text{mm}$ $\Longleftarrow c\tau(D_s^+) = 150\,\mu\text{m}$

$p_T(K_{1,2}) > 0.7\,\text{GeV},\ p_T(\pi) > 0.8\,\text{GeV}$

$\Longleftarrow |M(KK) - M(\phi)_{\text{PDG}}| < 6\,\text{MeV}$

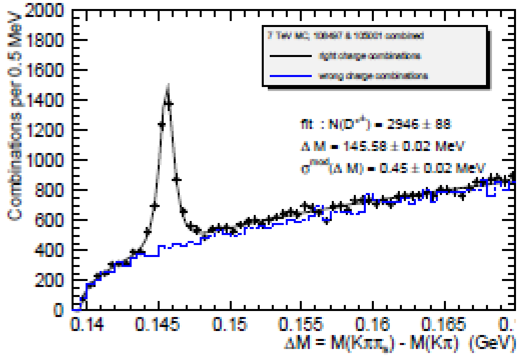
$\cos\theta^*(\pi) < 0.4$
($\angle$ between $\vec{p}(\pi)$ in $D_s^\pm$ r.f. and $\vec{p}(D_s^\pm)$ in the lab)

$|\cos\theta'(K)|^3 > 0.2$
($\angle$ between $\vec{p}(K)$ and $\vec{p}(\pi)$ in K^+K^- r.f.)

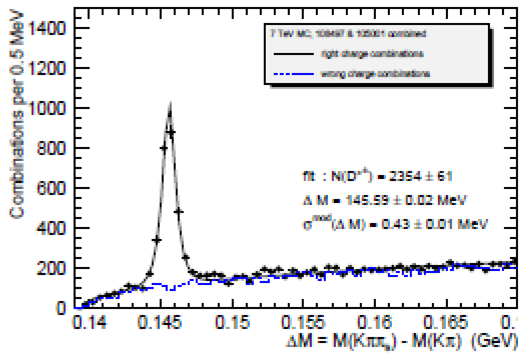
$\Longleftarrow 1.83 < M(KK\pi) < 1.91\,\text{GeV}$

Fitted masses and widths consistent with MC and PDG mass values

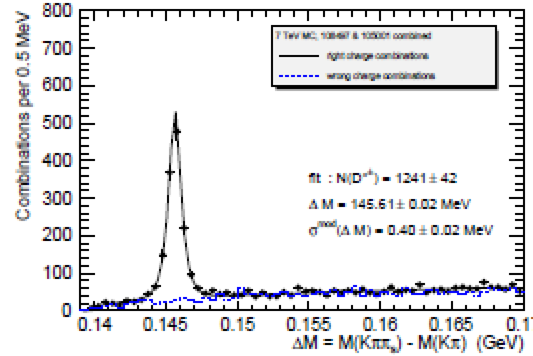
$D^{*\pm}$ acceptances in p_T bins



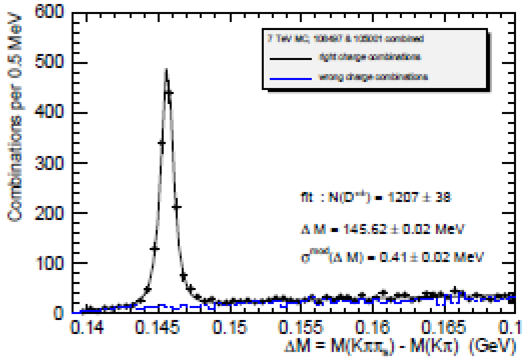
$Acc = 19.4 \pm 0.6\,\%$



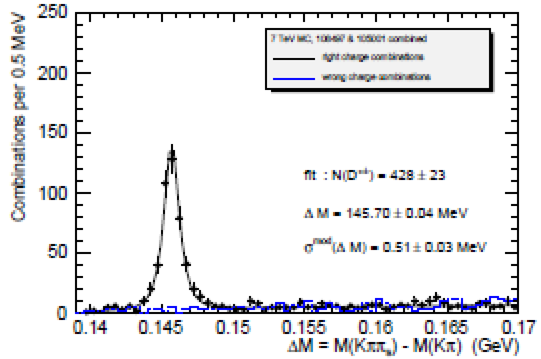
$Acc = 35.2 \pm 0.7\,\%$



$Acc = 40.9 \pm 1.4\,\%$

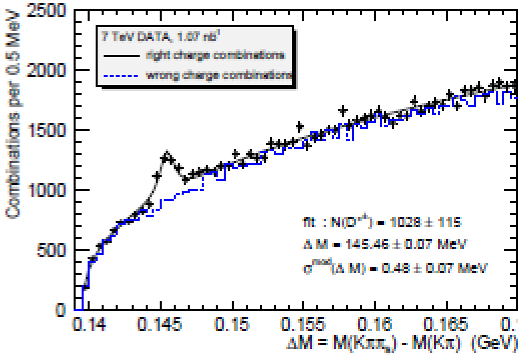


$Acc = 46.8 \pm 1.5\,\%$

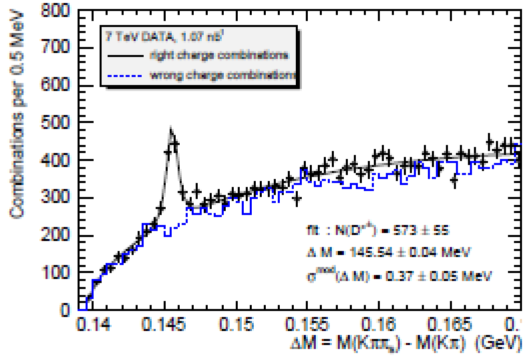


$Acc = 53.5 \pm 2.9\,\%$

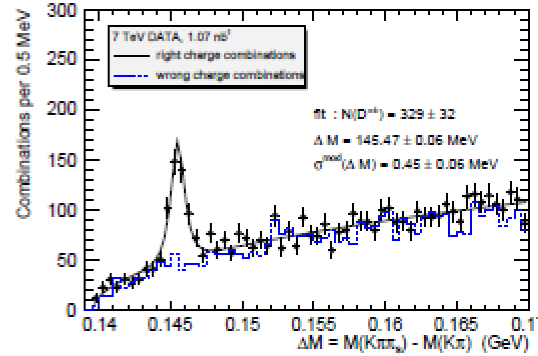
$D^{*\pm}$ x-sections in p_T bins



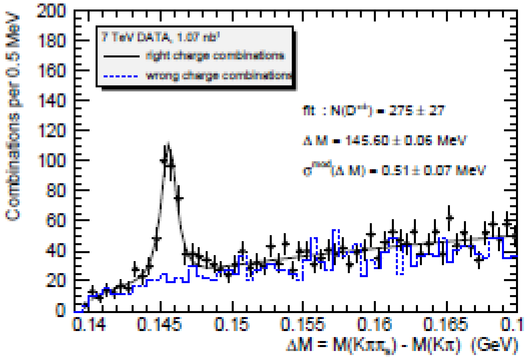
$\sigma = 187.3 \pm 21.8\,\mu\text{b}$



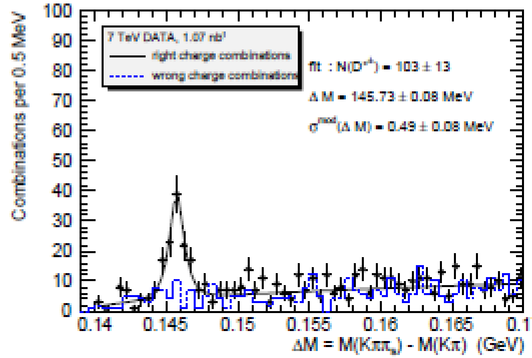
$\sigma = 58.6 \pm 5.9\,\mu\text{b}$



$\sigma = 28.5 \pm 2.9\,\mu\text{b}$



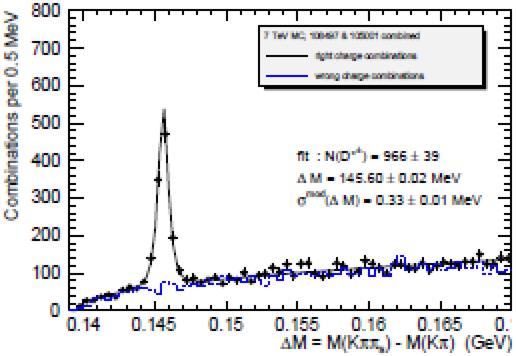
$\sigma = 20.8 \pm 2.1\,\mu\text{b}$



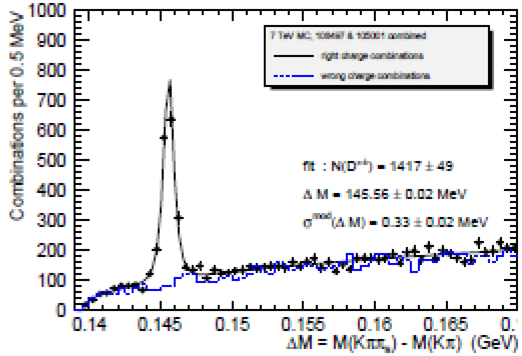
$\sigma = 6.8 \pm 1.0\,\mu\text{b}$

$\sum_5 = 302.0 \pm 22.8\,\mu\text{b}$ $\quad (\Longleftarrow 284.5 \pm 16.3\,\mu\text{b})$

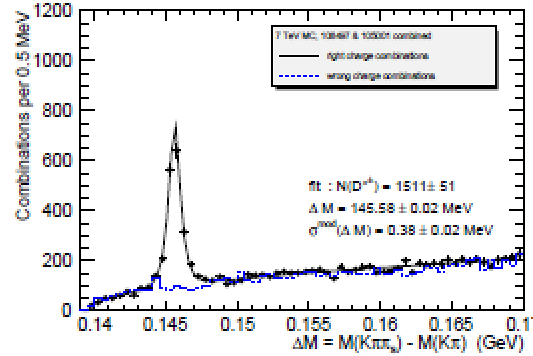
$D^{*\pm}$ acceptances in $|\eta|$ bins



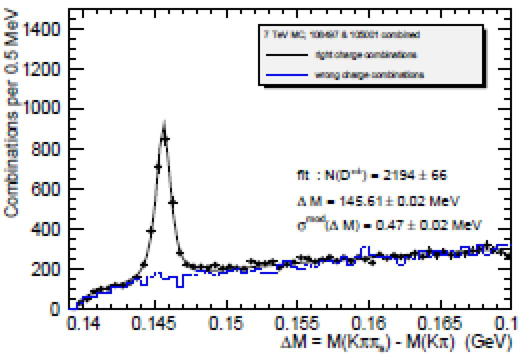
$Acc = 34.3 \pm 1.4\,\%$



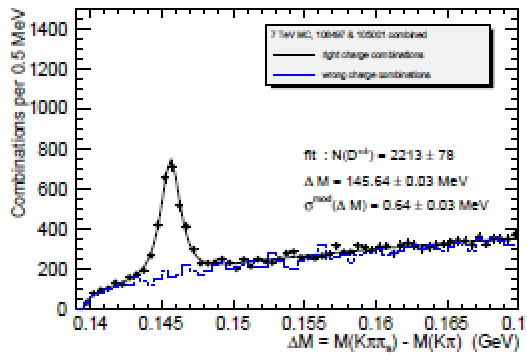
$Acc = 34.5 \pm 1.2\,\%$



$Acc = 36.0 \pm 1.2\,\%$

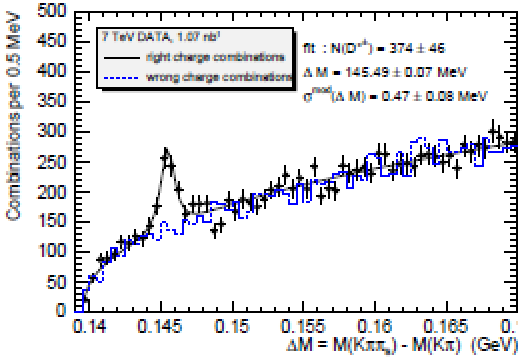


$Acc = 31.9 \pm 1.0\,\%$

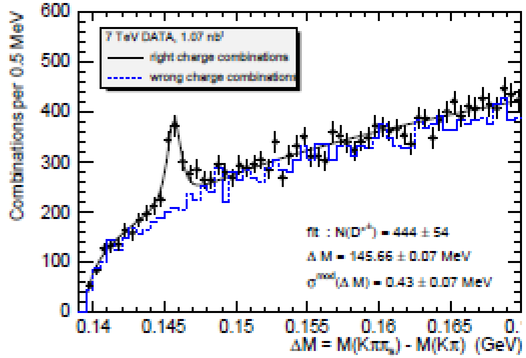


$Acc = 21.5 \pm 0.8\,\%$

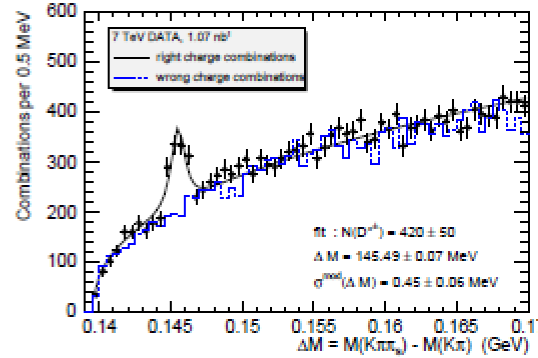
$D^{*\pm}$ x-sections in $|\eta|$ bins



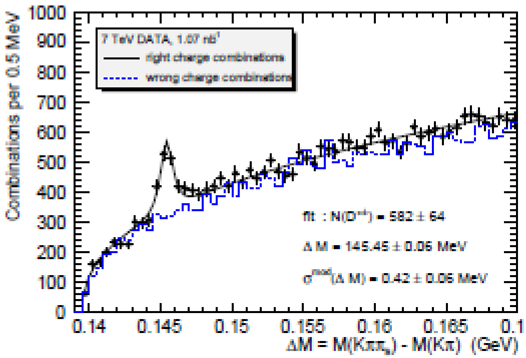
$\sigma = 38.6 \pm 5.1\,\mu$b



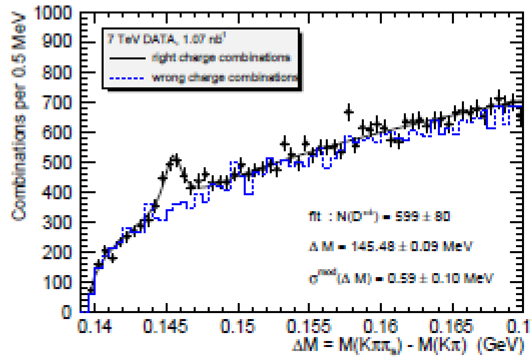
$\sigma = 45.6 \pm 5.9\,\mu$b



$\sigma = 37.5 \pm 5.1\,\mu$b



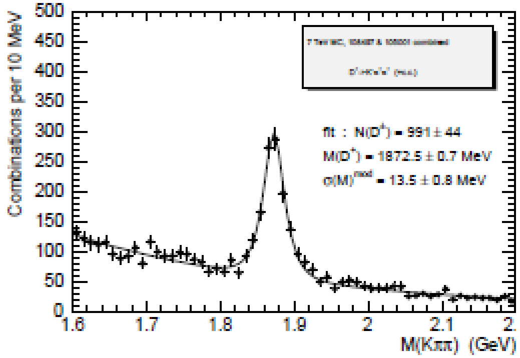
$\sigma = 63.3 \pm 7.3\,\mu$b



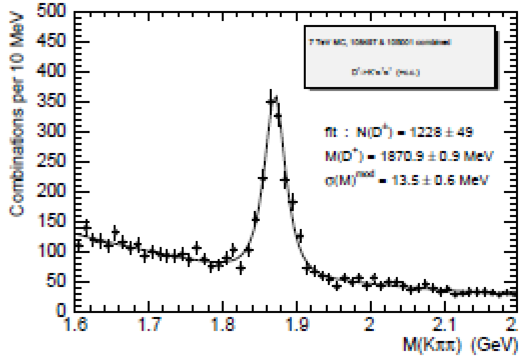
$\sigma = 98.5 \pm 13.7\,\mu$b

$\sum_5 = 283.5 \pm 18.1\,\mu$b $\quad (\Longleftarrow 284.5 \pm 16.3\,\mu$b)

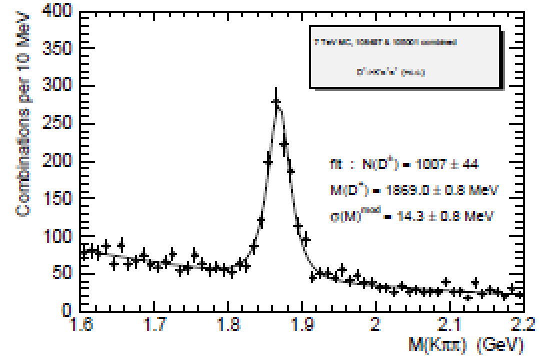
$D^{\pm}$ acceptances in p_T bins



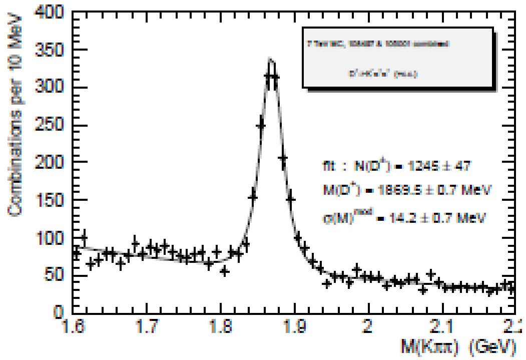
$Acc = 2.28 \pm 0.10\,\%$



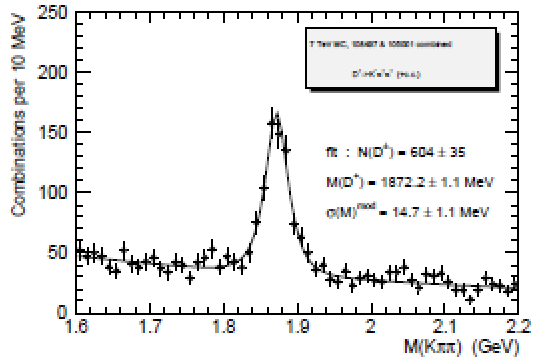
$Acc = 6.70 \pm 0.27\,\%$



$Acc = 12.4 \pm 0.5\,\%$

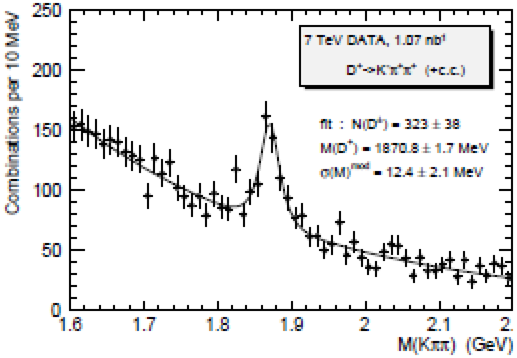


$Acc = 18.6 \pm 0.7\,\%$

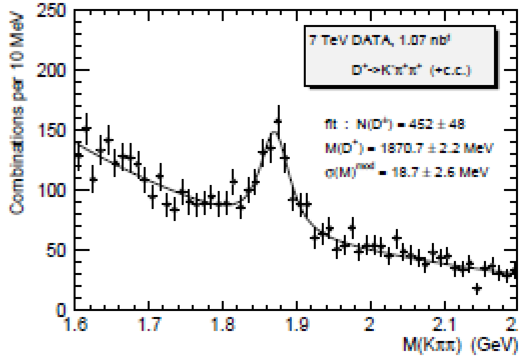


$Acc = 29.9 \pm 1.8\,\%$

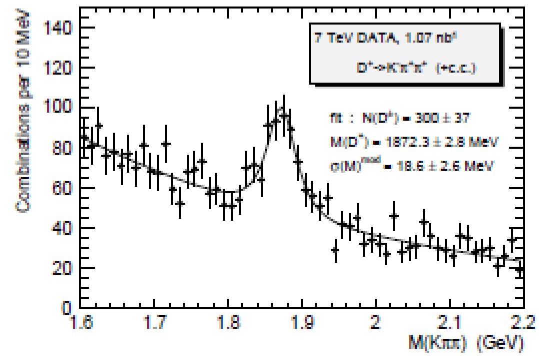
$D^{\pm}$ x-sections in p_T bins



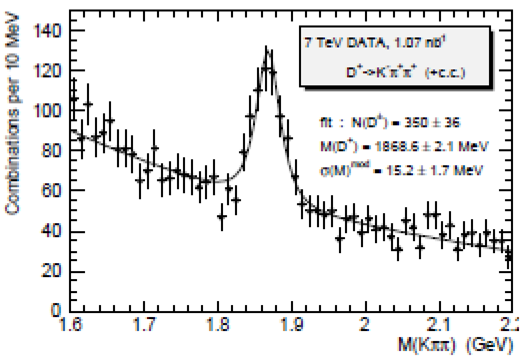
$\sigma = 140.6 \pm 17.8\,\mu\text{b}$



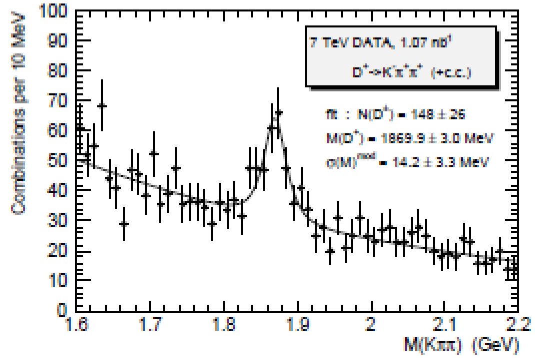
$\sigma = 66.9 \pm 7.6\,\mu\text{b}$



$\sigma = 24.1 \pm 3.1\,\mu\text{b}$



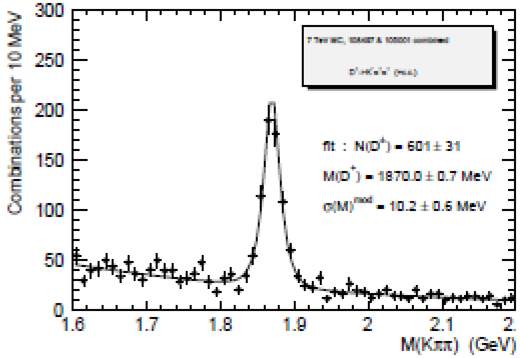
$\sigma = 18.7 \pm 2.1\,\mu\text{b}$



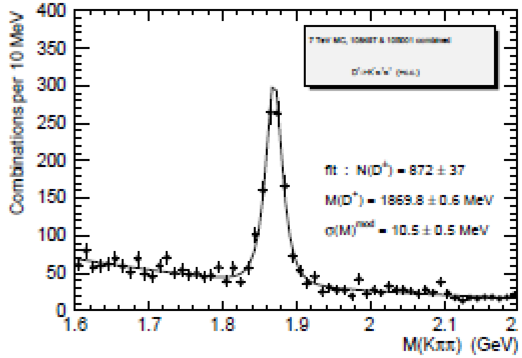
$\sigma = 4.9 \pm 0.9\,\mu\text{b}$

$\sum_5 = 255.2 \pm 19.7\,\mu\text{b}$ $(\Longleftarrow 238.5 \pm 13.4\,\mu\text{b})$

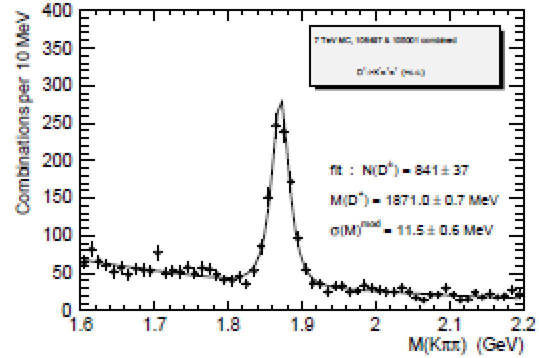
$D^{\pm}$ acceptances in $|\eta|$ bins



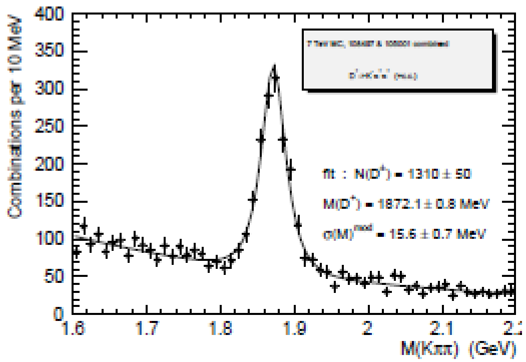
$Acc = 7.79 \pm 0.40\,\%$



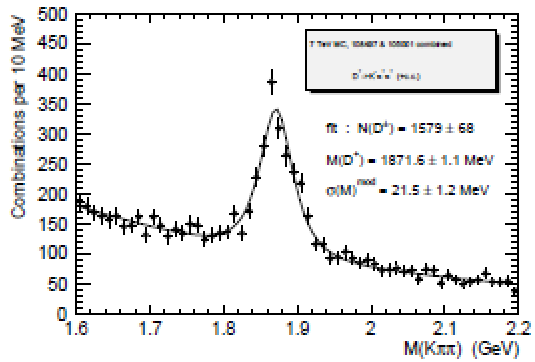
$Acc = 7.52 \pm 0.32\,\%$



$Acc = 7.24 \pm 0.32\,\%$

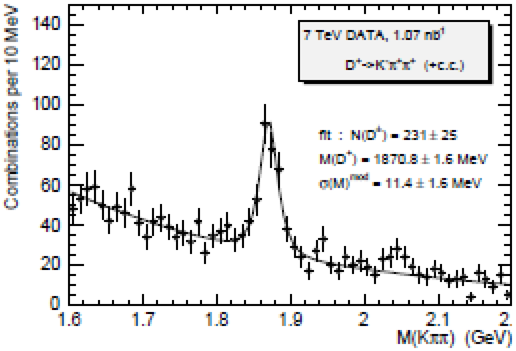


$Acc = 6.89 \pm 0.26\,\%$

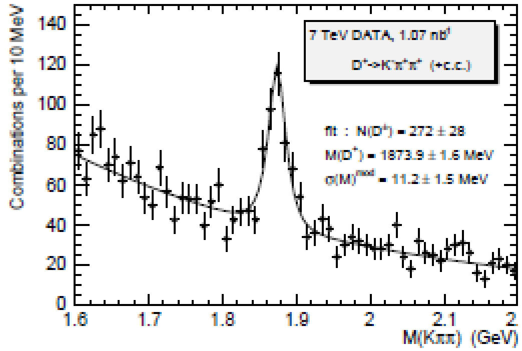


$Acc = 5.51 \pm 0.24\,\%$

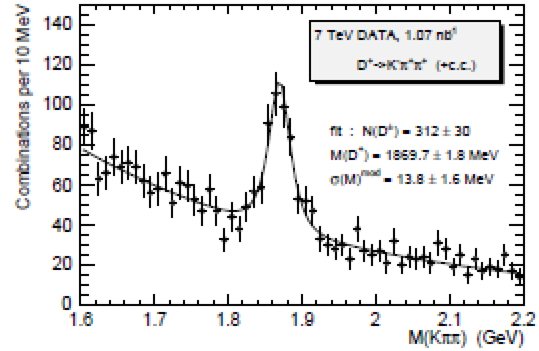
$D^{\pm}$ x-sections in $|\eta|$ bins



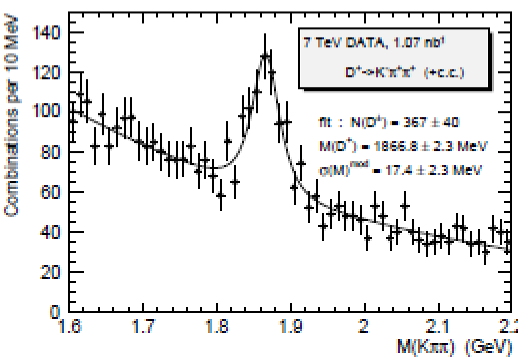
$\sigma = 29.4 \pm 3.5\,\mu$b



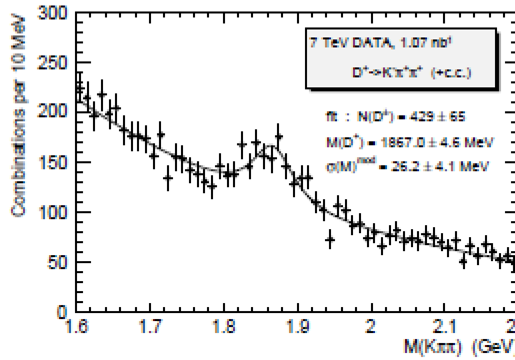
$\sigma = 35.9 \pm 4.0\,\mu$b



$\sigma = 42.8 \pm 4.6\,\mu$b



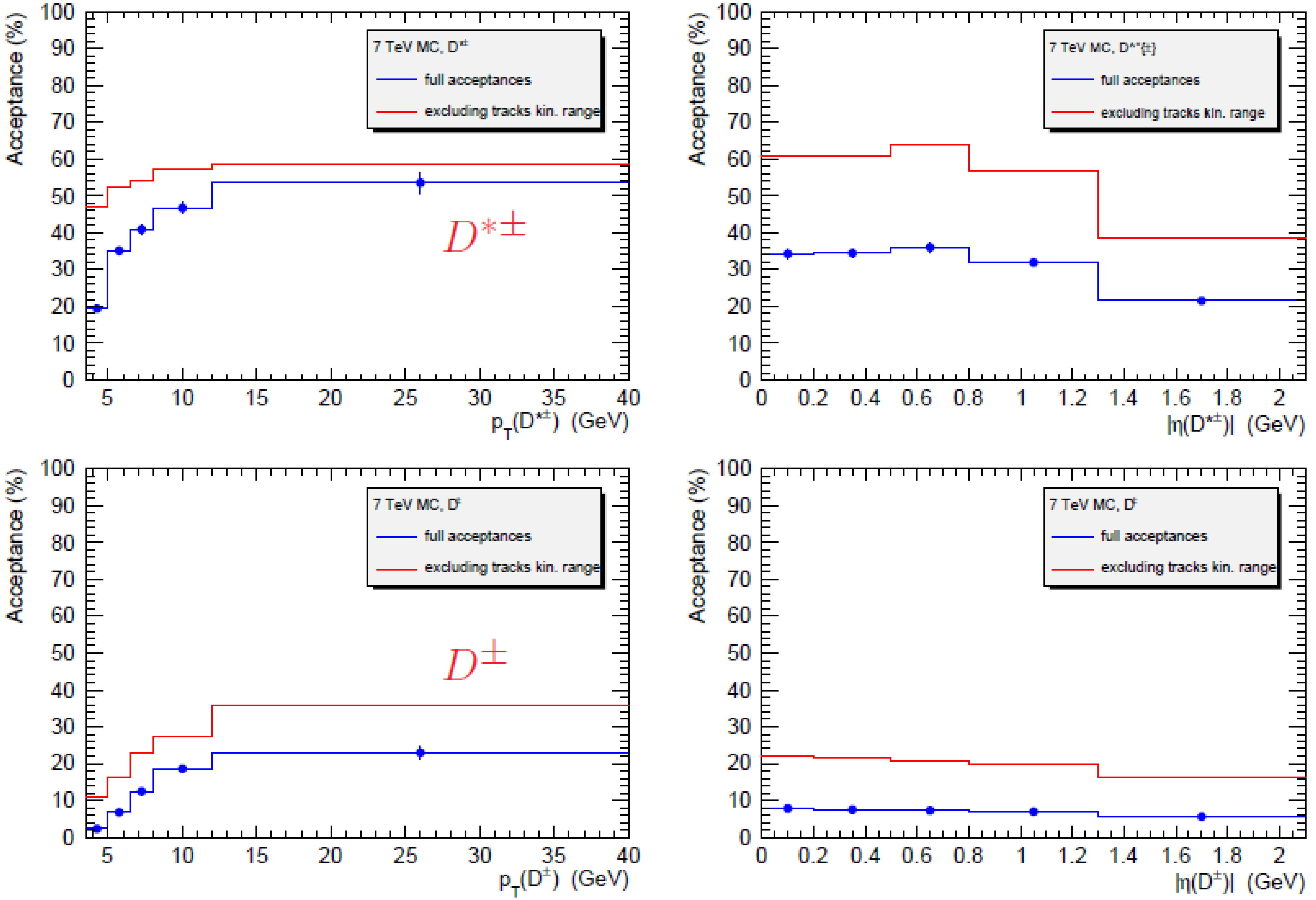
$\sigma = 52.9 \pm 6.2\,\mu$b



$\sigma = 77.3 \pm 12.1\,\mu$b

$\sum_5 = 238.3 \pm 15.3\,\mu$b $\quad (\Longleftarrow 238.5 \pm 13.4\,\mu$b)

Differential $D^{*\pm}$ and $D^{\pm}$ acceptances



Systematic uncertainties

1) trigger: $eff = 100\%$, $\delta = 0.0\%$ (only this analysis)

2) luminosity: $\delta = 11\%$ ($\rightarrow$ 5% soon ?)

3) branchings: $\delta = 1.5\%,\ 4.3\%,\ 6.0\%$ (PDG 2010)

4) track reconstruction efficiency

4.1) MC material description: $\delta = 6.0 - 9.3\%$ (ATLAS-CONF-2010-046)

4.2) tracks selection: $\delta = 3\%$ (ATLAS-CONF-2010-046)

5) D-meson reconstruction

basic cuts variations (χ^2, p_T/E_T, L_{XY}, ...) (see slide)

6) D-meson signals extraction (fits)

variations of backgr. functions (+1 par.) and

ranges (-2 bins from one or another edge) for all signals and bins

in addition for $D_s^{\pm}$: $\sigma(D^{\pm})$ to 0.9 and 1.1 of $\sigma(D_s^{\pm})$

in addition for $D^{\pm}$: subtraction of $D_s^{\pm}$ admixture by $\pm 1\sigma$ ($\sim 30\%$)

7) model dependence

7.1) variations of p_T and η MC spectra

(within compatibility with data, see slide)

7.2) variations of beauty contribution (by factor 2)

Track reconstruction uncertainties

from ATLAS-CONF-2010-046 and corresponding internal note:

Table 4: Summary of all tracking efficiency systematics. The tracking efficiency systematics are given in bins of track p_T and η. All numbers are in percent and relative to the corresponding tracking efficiencies. The total uncertainty is the sum in quadrature of the listed components: MC material description, track selection, and (if given) the p_T turn-on systematic.

p_T bin [MeV]	$\lvert\eta\rvert < 1.3$	$1.3 < \lvert\eta\rvert < 1.9$	$1.9 < \lvert\eta\rvert < 2.1$	$2.1 < \lvert\eta\rvert < 2.3$	$2.3 < \lvert\eta\rvert < 2.5$
$100 < p_T \leq 150$	$8 \oplus 1 \oplus 5$	$8 \oplus 1 \oplus 5$	$10 \oplus 1 \oplus 5$	$10 \oplus 1 \oplus 5$	$15 \oplus 1 \oplus 5$
$150 < p_T \leq 200$	$4 \oplus 1$	$6 \oplus 1$	$7 \oplus 1$	$9 \oplus 1$	$13 \oplus 1$
$200 < p_T \leq 250$	$3 \oplus 1$	$5 \oplus 1$	$6 \oplus 1$	$7 \oplus 1$	$12 \oplus 1$
$250 < p_T \leq 300$	$2 \oplus 1$	$4 \oplus 1$	$6 \oplus 1$	$6 \oplus 1$	$11 \oplus 1$
$300 < p_T \leq 350$	$2 \oplus 1$	$4 \oplus 1$	$5 \oplus 1$	$6 \oplus 1$	$9 \oplus 1$
$350 < p_T \leq 400$	$2 \oplus 1$	$4 \oplus 1$	$5 \oplus 1$	$5 \oplus 1$	$8 \oplus 1$
$400 < p_T \leq 450$	$2 \oplus 1$	$3 \oplus 1$	$4 \oplus 1$	$5 \oplus 1$	$8 \oplus 1$
$450 < p_T \leq 500$	$2 \oplus 1$	$3 \oplus 1$	$4 \oplus 1$	$4 \oplus 1$	$7 \oplus 1$
$500 < p_T$	$2 \oplus 1$	$3 \oplus 1$	$4 \oplus 1$	$4 \oplus 1$	$7 \oplus 1$

3.2) tracks selection: $\delta = 1\%$ for all tracks used: 3% for 3-tracks D-mesons

3.1) MC material description: $\delta = 2 - 11\%$ for tracks in our range

the above table has been ported to the MC and correlated uncert. evaluated:

Integrated $D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$ x-sections : $^{+7.7}_{-6.6}\%$, $^{+7.7}_{-6.6}\%$ and $^{+7.6}_{-6.6}\%$

$p_T(D^{*\pm})$: $^{+7.9}_{-6.8}\%$, $^{+7.6}_{-6.6}\%$, $^{+7.4}_{-6.5}\%$, $^{+7.5}_{-6.5}\%$, $^{+7.4}_{-6.4}\%$ $\quad |\eta(D^{*\pm})|$: $^{+6.4}_{-5.7}\%$, $^{+6.4}_{-5.7}\%$, $^{+6.4}_{-5.7}\%$, $^{+6.8}_{-6.0}\%$, $^{+10.9}_{-8.9}\%$

$p_T(D^{\pm})$: $^{+7.7}_{-6.7}\%$, $^{+7.7}_{-6.6}\%$, $^{+7.7}_{-6.6}\%$, $^{+7.6}_{-6.6}\%$, $^{+7.6}_{-6.6}\%$ $\quad |\eta(D^{\pm})|$: $^{+6.4}_{-5.7}\%$, $^{+6.4}_{-5.7}\%$, $^{+6.4}_{-5.7}\%$, $^{+6.8}_{-6.0}\%$, $^{+10.2}_{-8.5}\%$

Uncertainties of D-meson reconstruction

only MC is varied $\rightarrow$ check for mismatches between data and MC

1) invariant mass resolution

   1.1) $M(D^0)$ window: $\pm 5\,\mathrm{MeV}$ on both sides

   1.2) $M(\phi)$ window: $\pm 0.5\,\mathrm{MeV}$ on both sides

2) L_{XY} selections: $\pm 50\,\mu\mathrm{m}$

3) χ^2 selections: ± 0.5

4) $d_0(D)$ selections: $\pm 10\%$

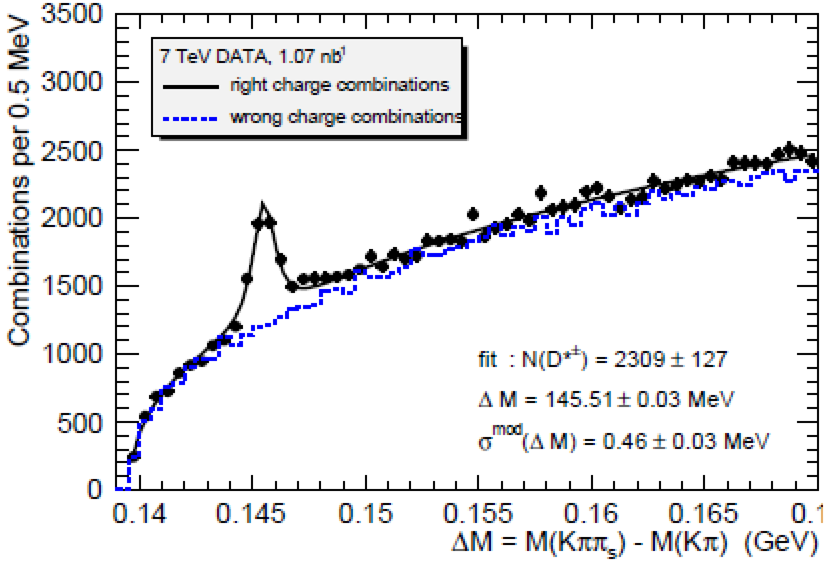
5) $z_0 \cdot \sin\theta(D)$ selections: $\pm 10\%$

6) p_T/E_T selections: $+25\%, -100\%$ of it's value

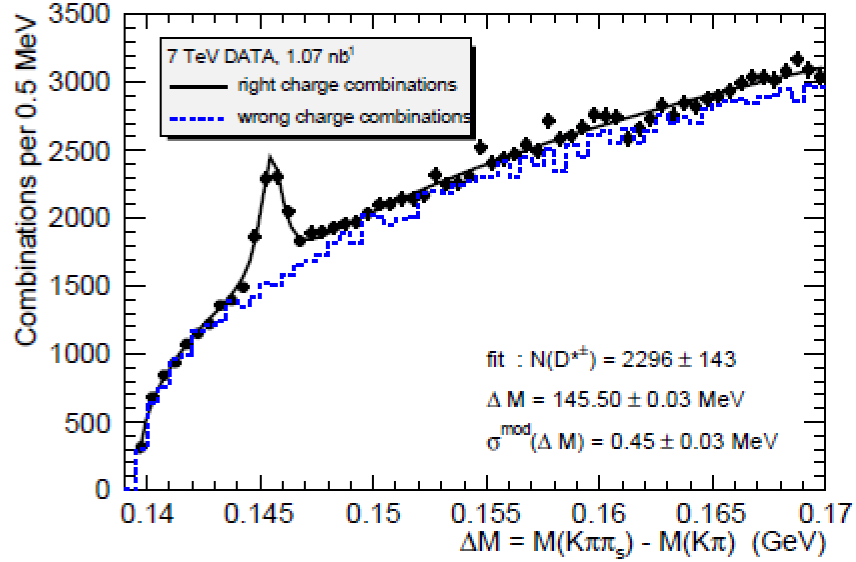
MC shows that the cut $p_T(D^{(*)})/E_T > 0.02$ removes
0.7%, 0.2% and 0.4% of true (matched) $D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$, respectively
Let's re-check the cut effect for data (see slides)

Effect of $p_T(D^{*\pm})/E_T > 0.02$ in data

with the cut (nominal)



without the cut



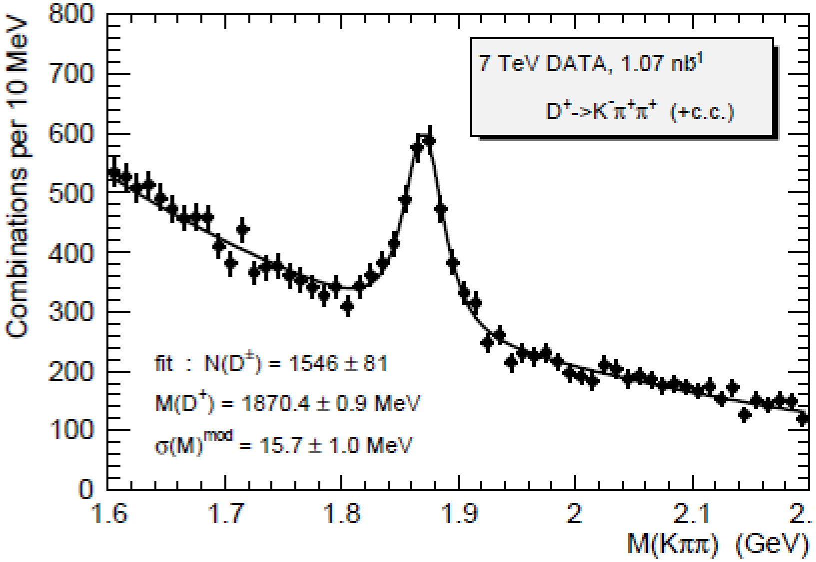
no significant signal reduction

$\sim 20\%$ background reduction

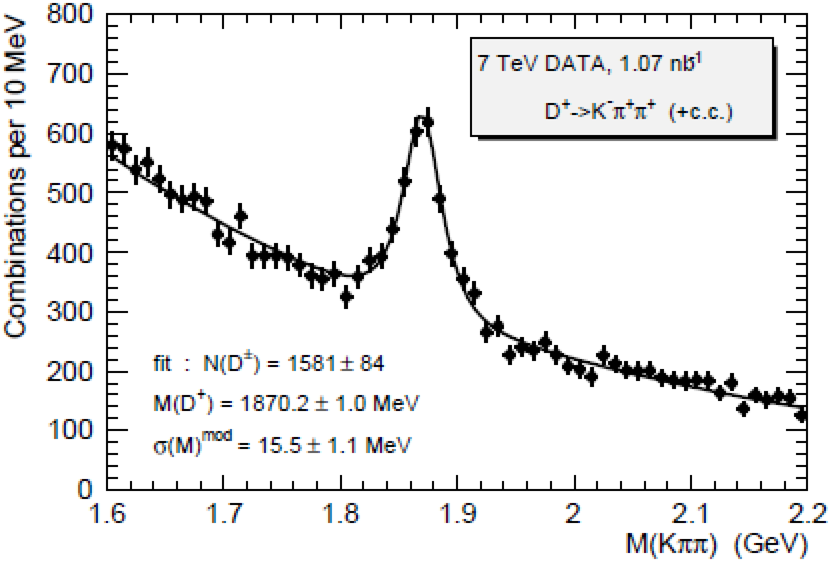
$\sim 12\%$ $\sigma(N(D^{*\pm}))$ reduction

Effect of $p_T(D^{\pm})/E_T > 0.02$ in data

with the cut (nominal)



without the cut



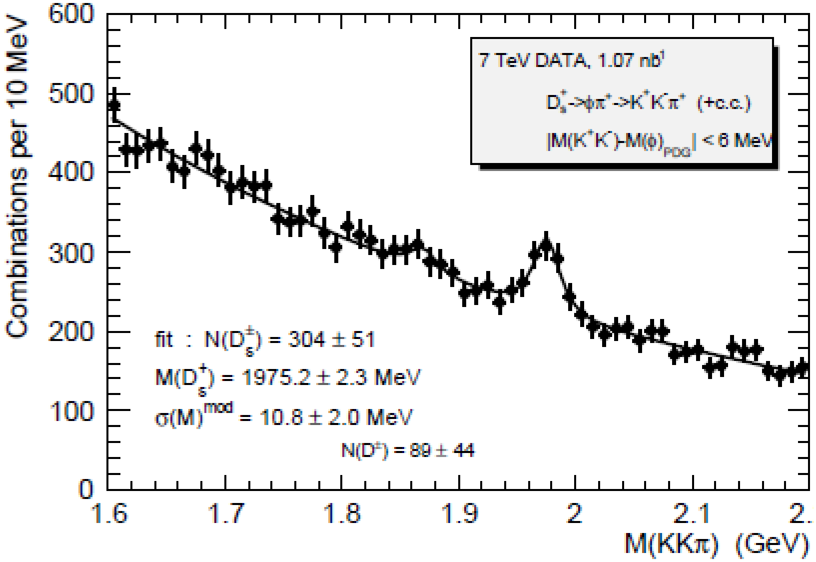
no significant signal reduction

$\sim 5\%$ background reduction

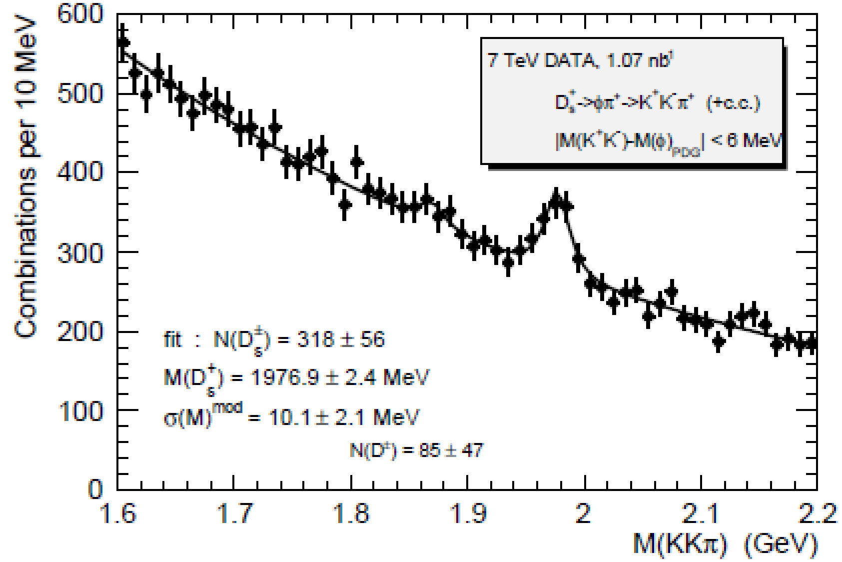
$\sim 3\%$ $\sigma(N(D^{\pm}))$ reduction

Effect of $p_T(D_s^\pm)/E_T > 0.02$ in data

with the cut (nominal)



without the cut

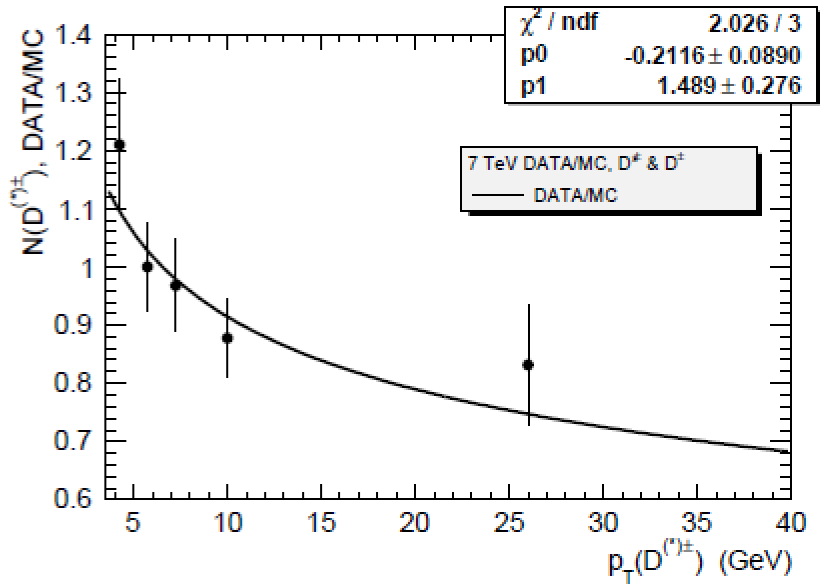


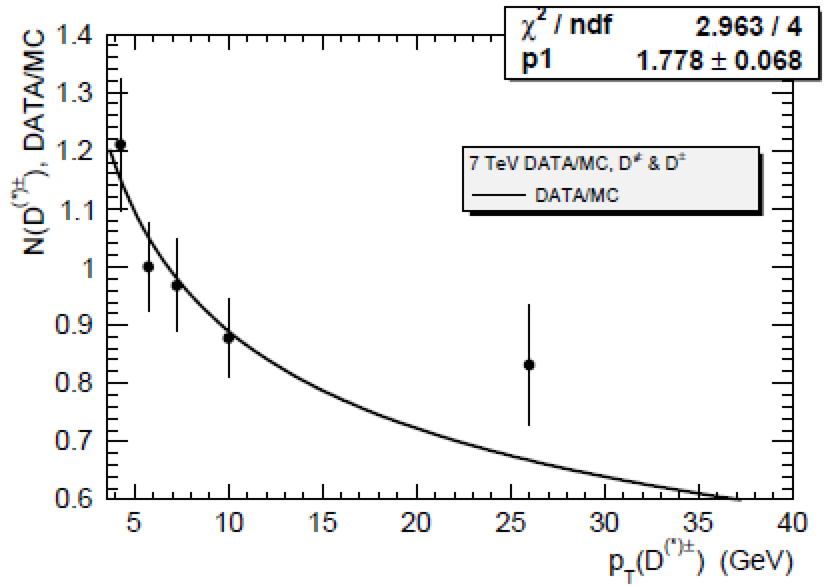
no significant signal reduction

$\sim 20\%$ background reduction

$\sim 10\%$ $\sigma(N(D_s^\pm))$ reduction

MC reweighting in $p_T(D^{(*)})$ (systematics)





fit with $p1 \cdot (p_T)^{p0}$

central fit : $p0 = -0.2116 \pm 0.0890$

(could be used for central calculations)

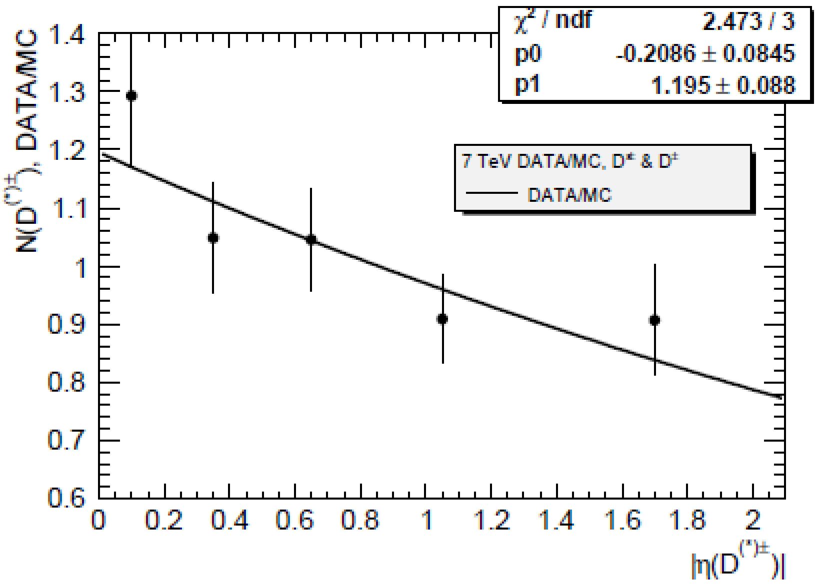
used for systematics:

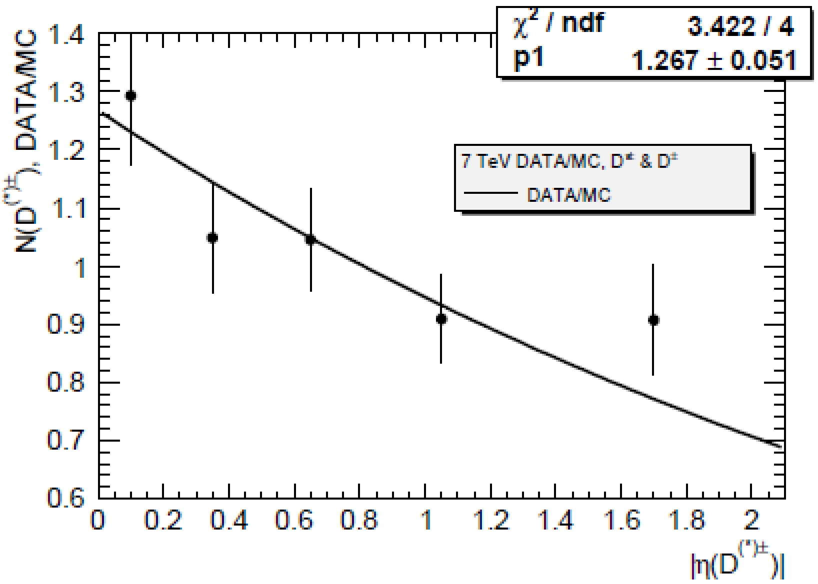
$p0 = -0.3006$

applied as function of true p_T

at both rec. and true levels

MC reweighting in $|\eta(D^{(*)})|$ (systematics)





fit with $p1 \cdot e^{p0 \cdot |\eta|}$

central fit : $p0 = -0.2086 \pm 0.0845$

(could be used for central calculations)

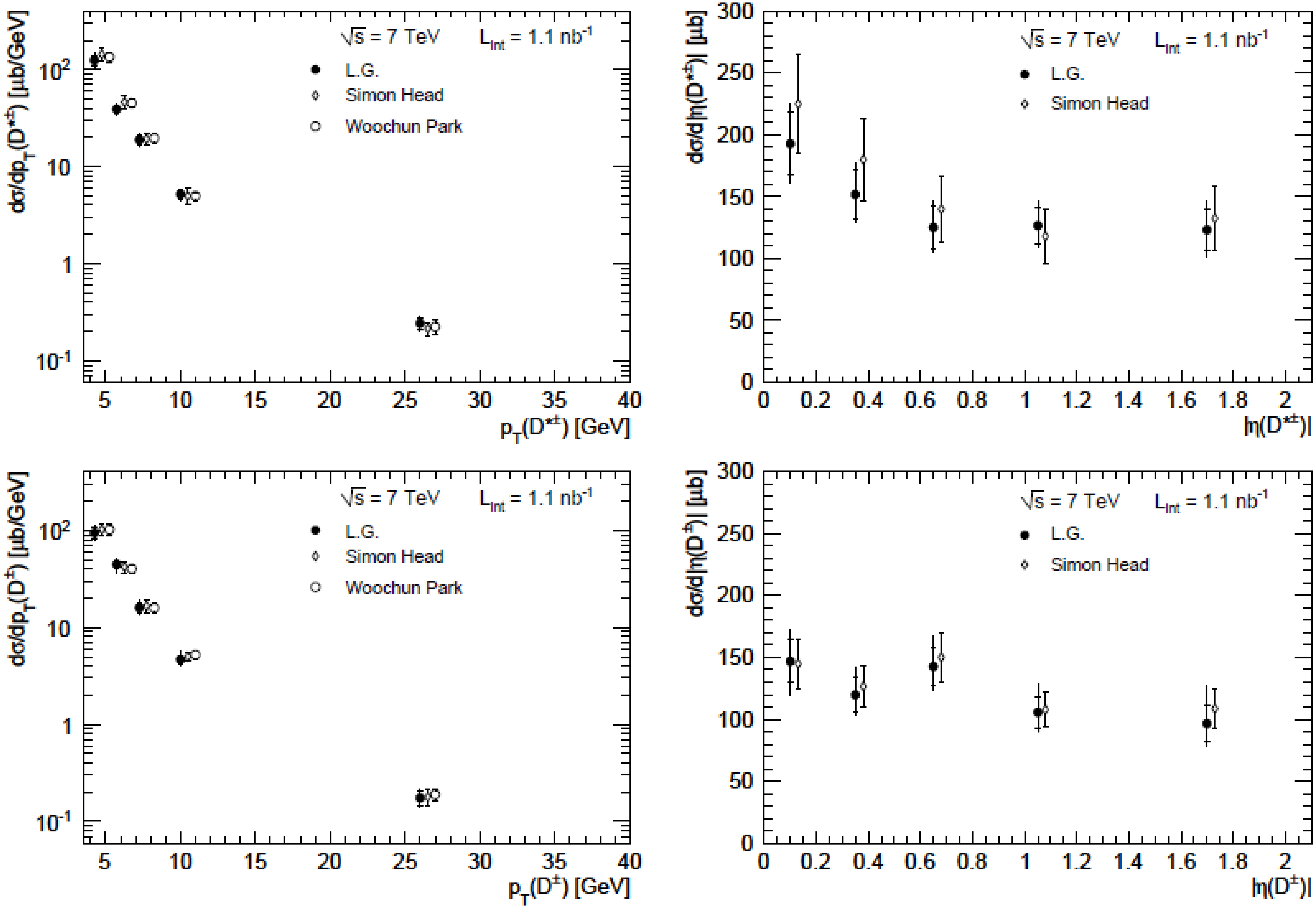
used for systematics:

$p0 = -0.2921$

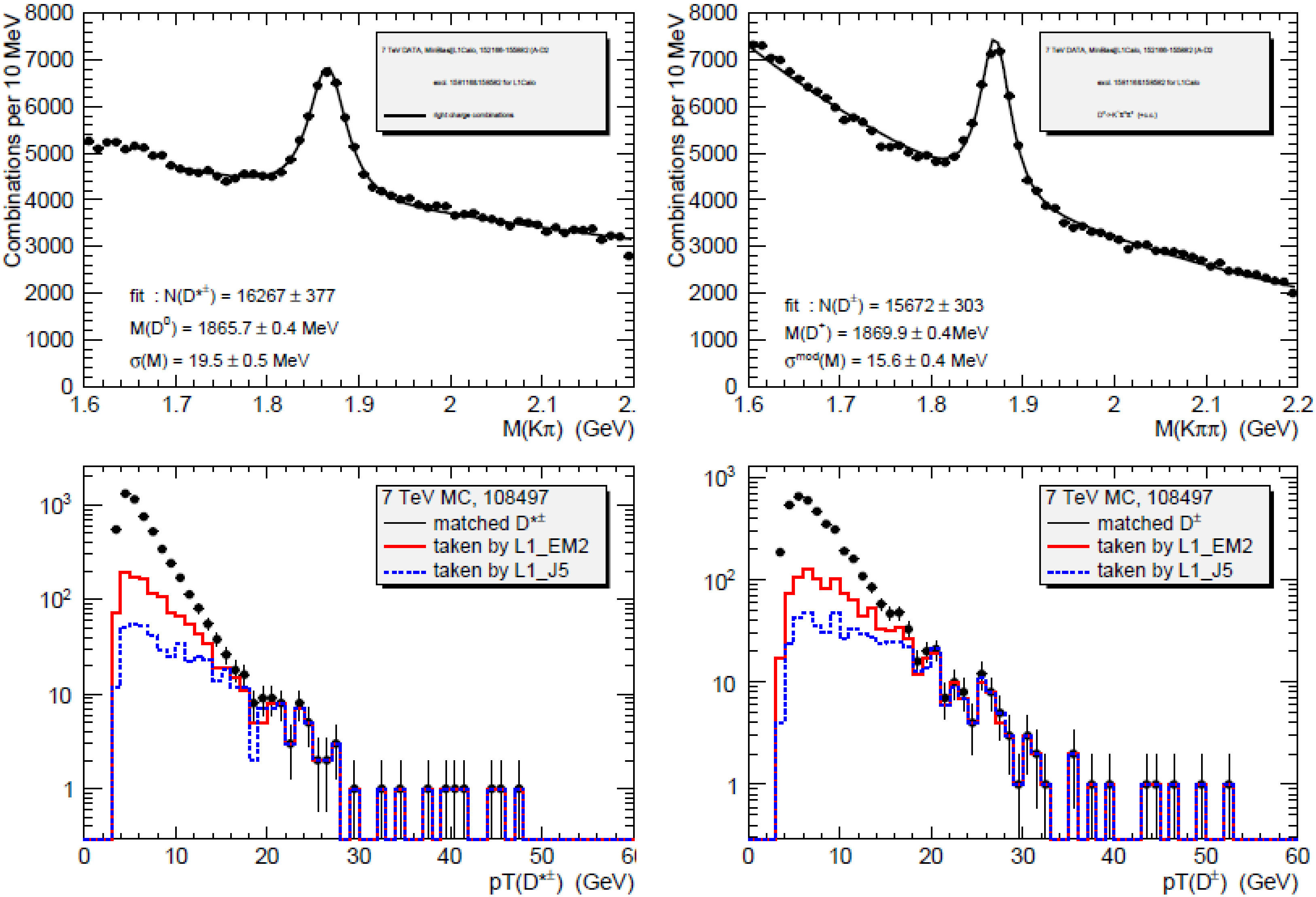
applied as function of true $|\eta|$

at both rec. and true levels

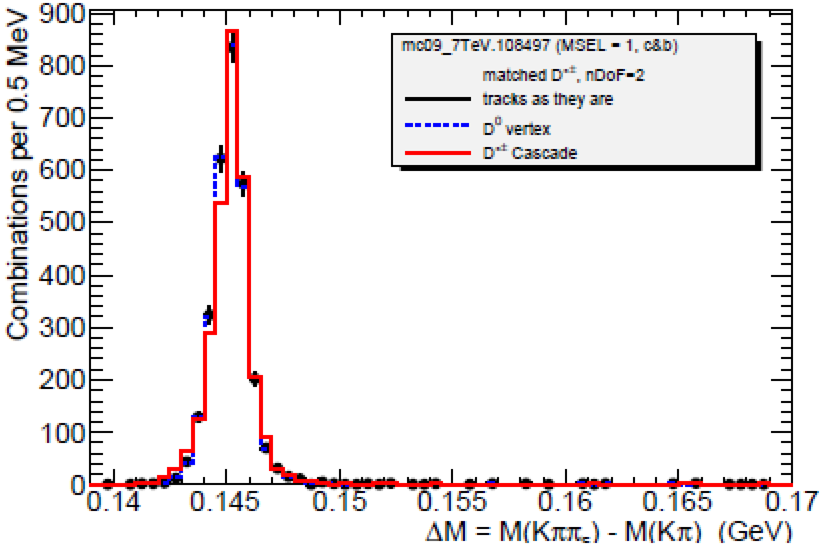
Results from independent analyses



$M(D^0)$ and $M(D^+)$ in "MinBias || L1Calo" streams



ΔM with nDoF=2 (Cascade) and nDoF=3 (3-tracks vertex)

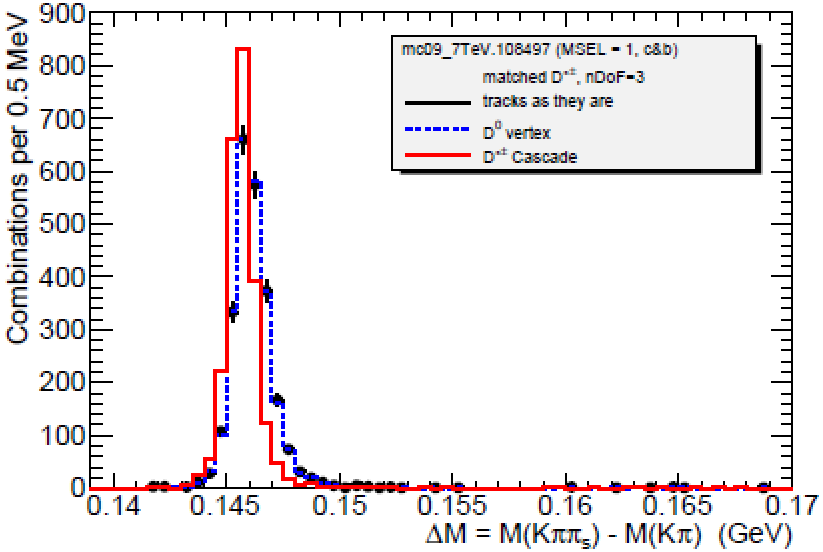


nDoF=2 (actual Cascade)

$D^{*\pm}$ vertex is before D^0 vertex

small shift to larger values

marginal improvement in resolution



nDoF=3 (3-tracks vertex)

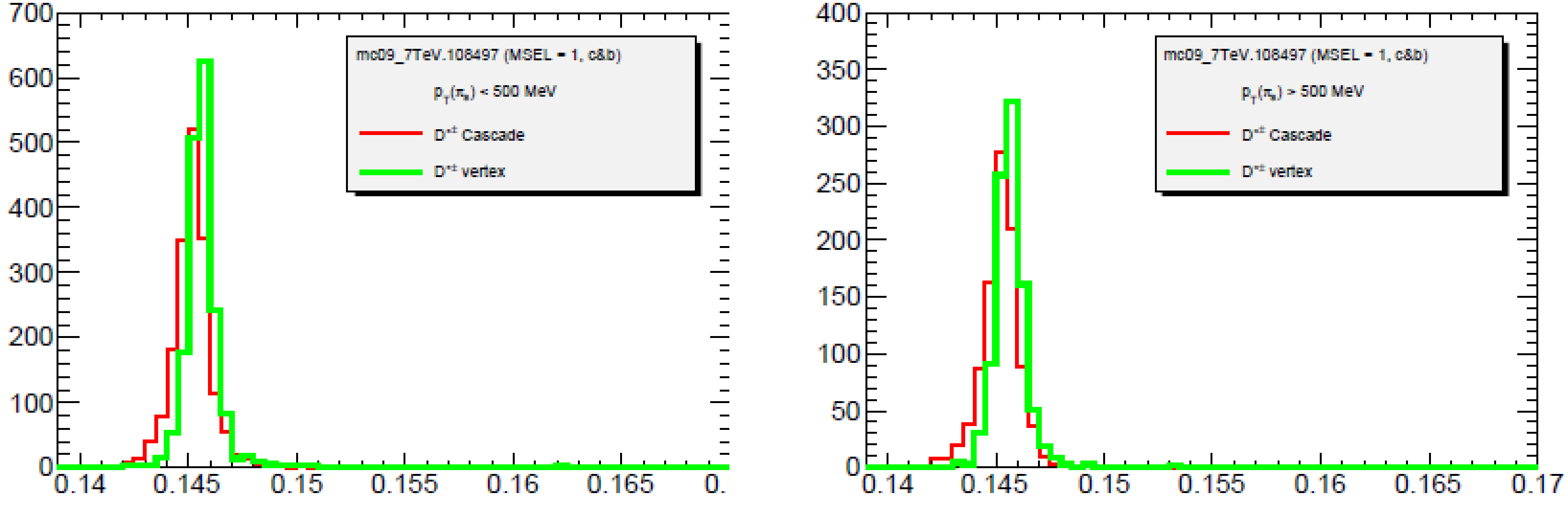
$D^{*\pm}$ vertex is after D^0 vertex

sizable shift to smaller values

great improvement in resolution

Should we also use 1-vertex approx. for cases when $D^{*\pm}$ vertex is insignificantly before D^0 vertex ?

ΔM with Cascade and 1-Vertex for low- and high-p_T slow pions



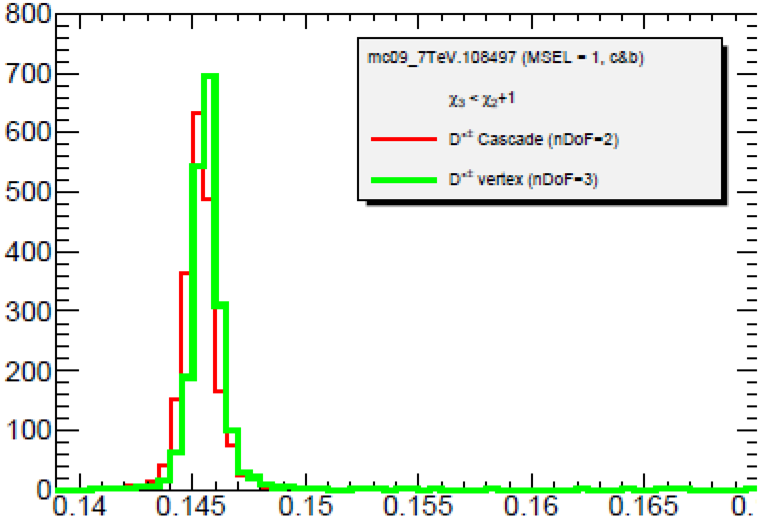
1-vertex approx. works for both low- and high-p_T slow pions

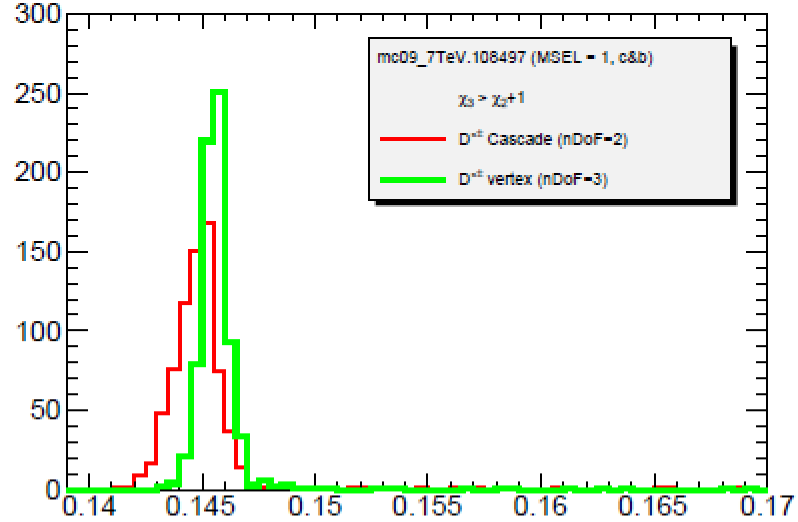
Statistical expectations for χ_3 (1-Vertex) and χ_2 (Cascade):

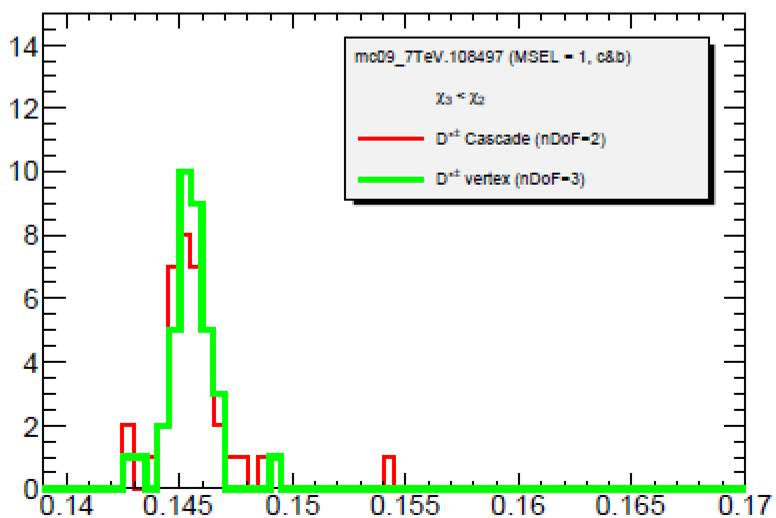
$\chi_3 < \chi_2 + 1$: 1-Vertex is expected to be better

$\chi_3 > \chi_2 + 1$: Cascade is expected to be better

ΔM with Cascade and 1-Vertex for various χ^2 changes

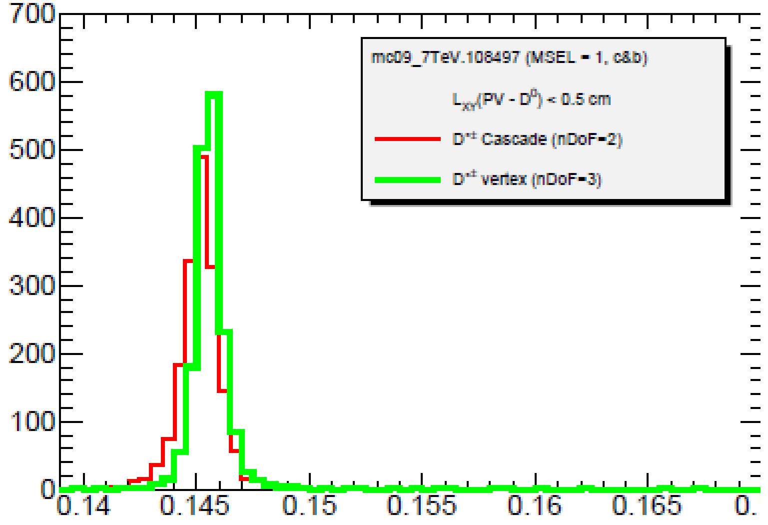


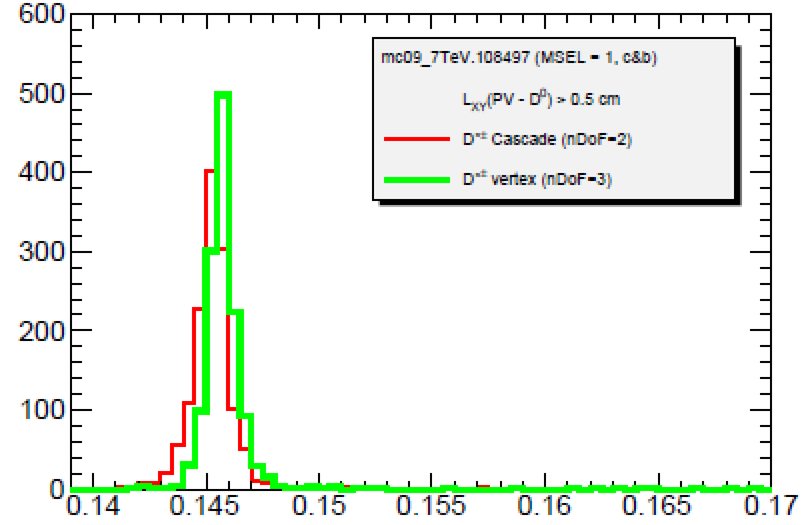


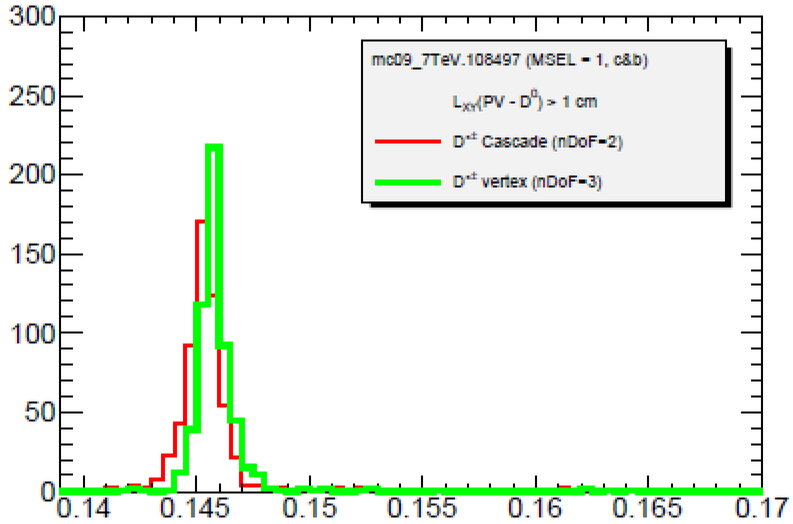


1-vertex approx. works better in all cases

ΔM with Cascade and 1-Vertex for various $L_{XY}(PV - D^0)$

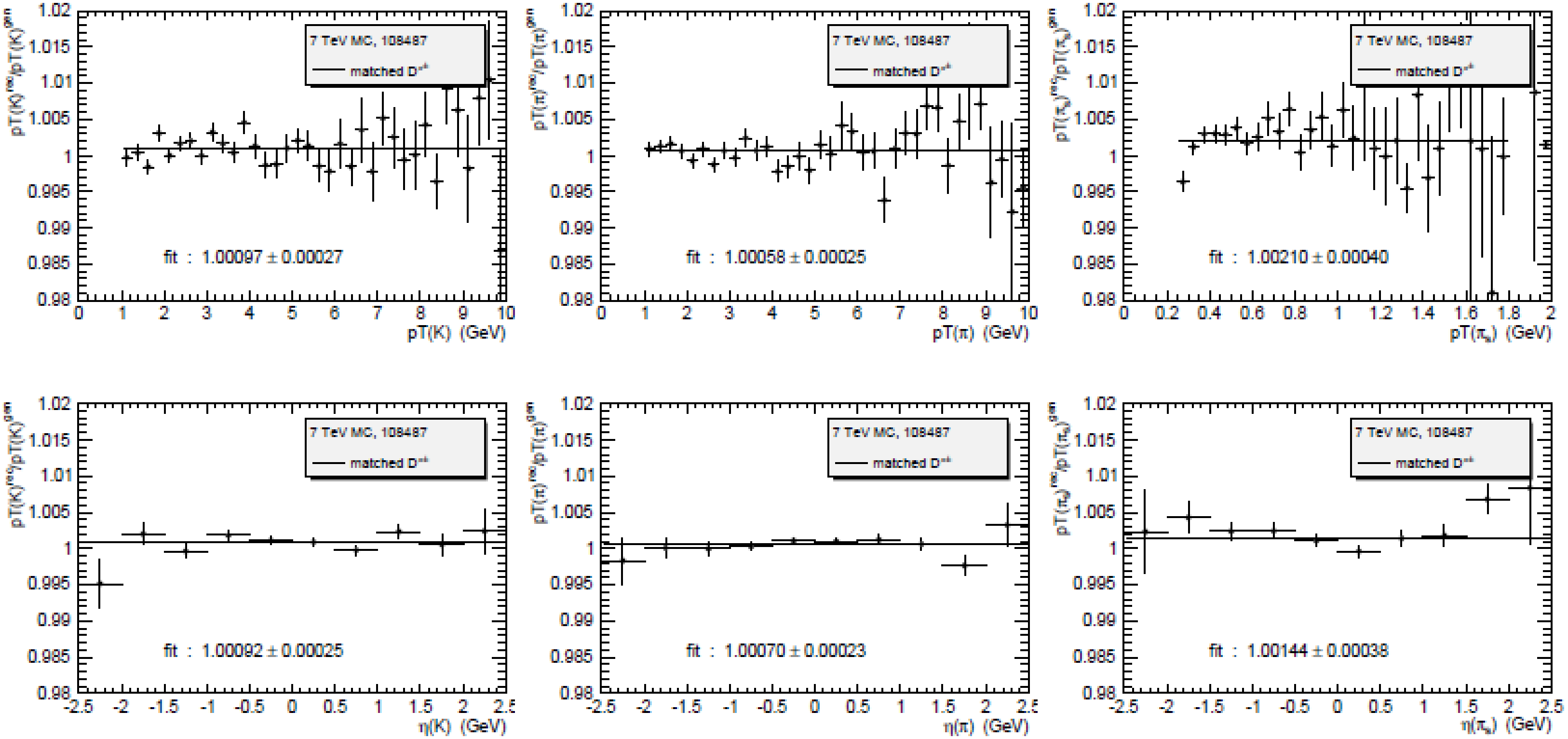




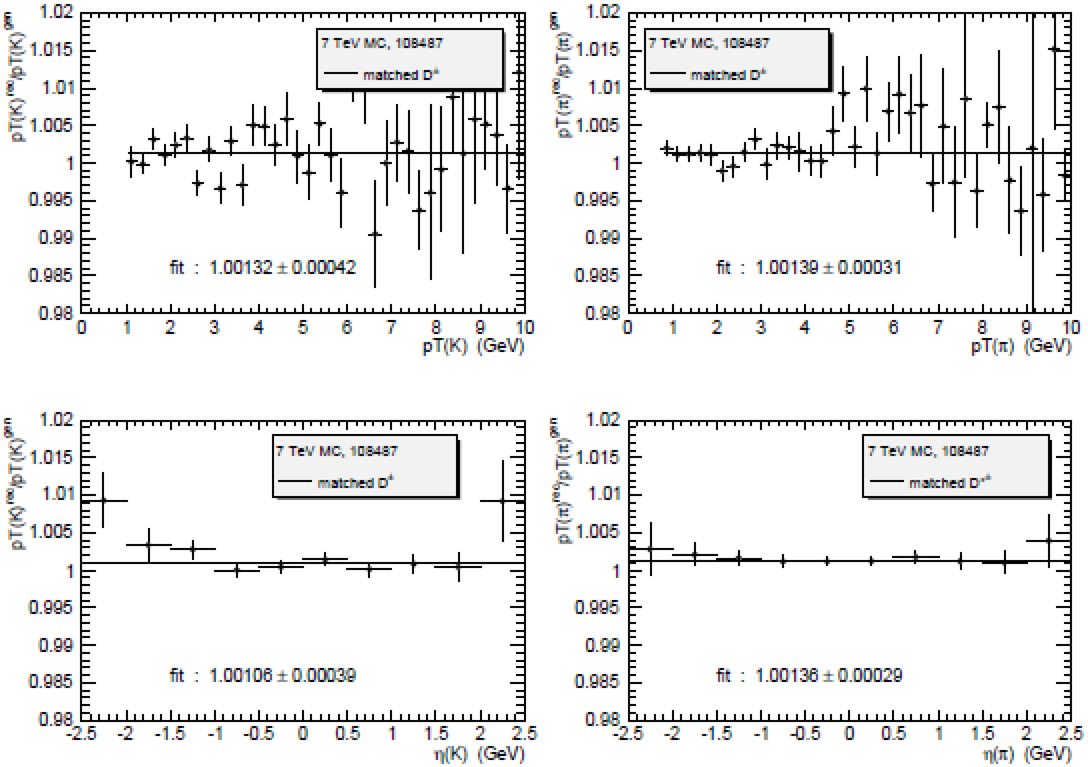


1-vertex approx. works better in all cases

Momentum scale for $D^{*\pm}$ tracks in MC



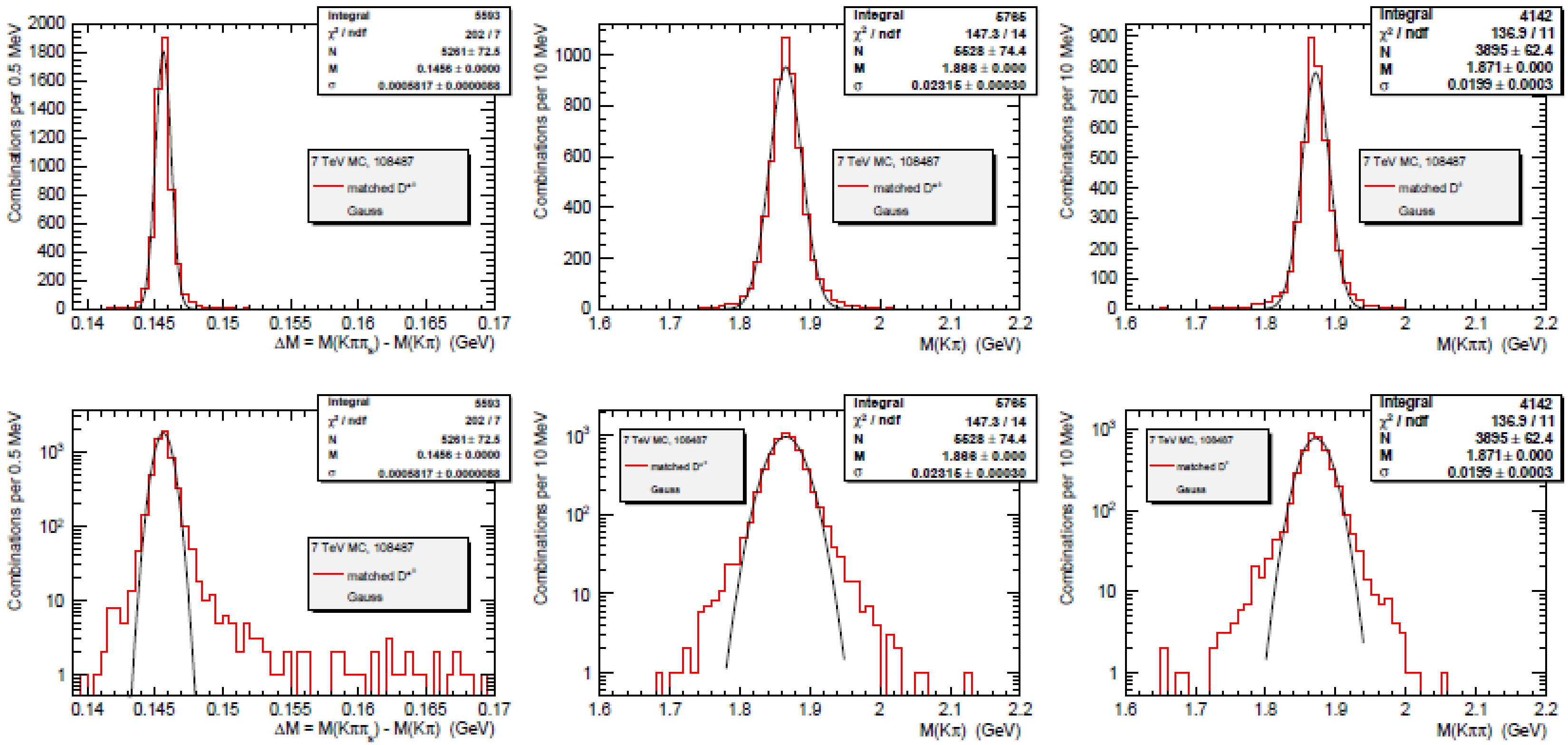
Momentum scale for $D^{\pm}$ tracks in MC



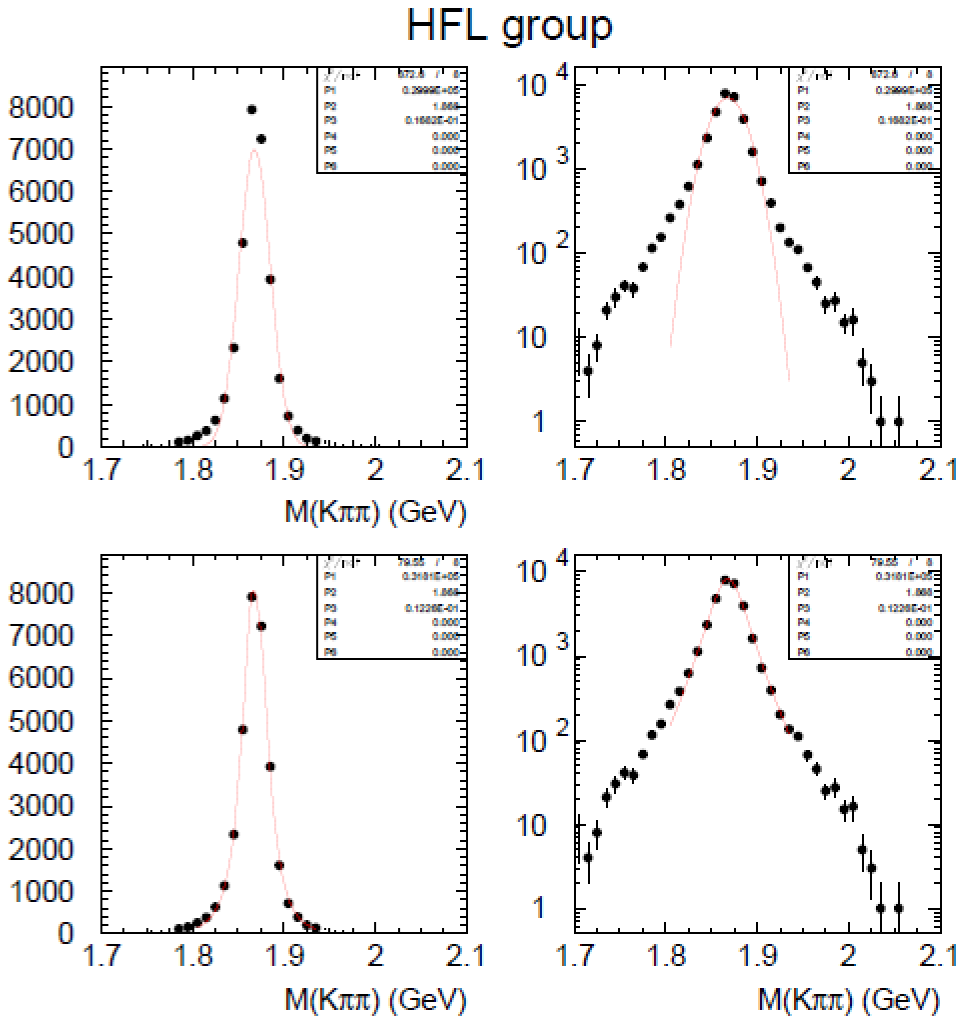
	nominal	sc = 0.999	sc = 0.998	MC input
$M(D^0)$	1867.62 ± 0.32	1866.04 ± 0.32	1864.57 ± 0.32	1864.50 **MeV**
$M(D^{\pm})$	1872.17 ± 0.33	1870.86 ± 0.33	1869.41 ± 0.33	1869.30 **MeV**

MC suggests reconstructed tracks momenta are overestimated by at least 0.1% (for systematics: $0.1 \pm 0.1\%$)

Description of $D^{(*)}$ signals' shapes by Gauss



Signal fitting (matched $D^{\pm}$ in another exp. as example)



Gaussian function :

$$\propto e^{-0.5\cdot x^2},$$

$$x = \frac{M - M_0}{\sigma}$$

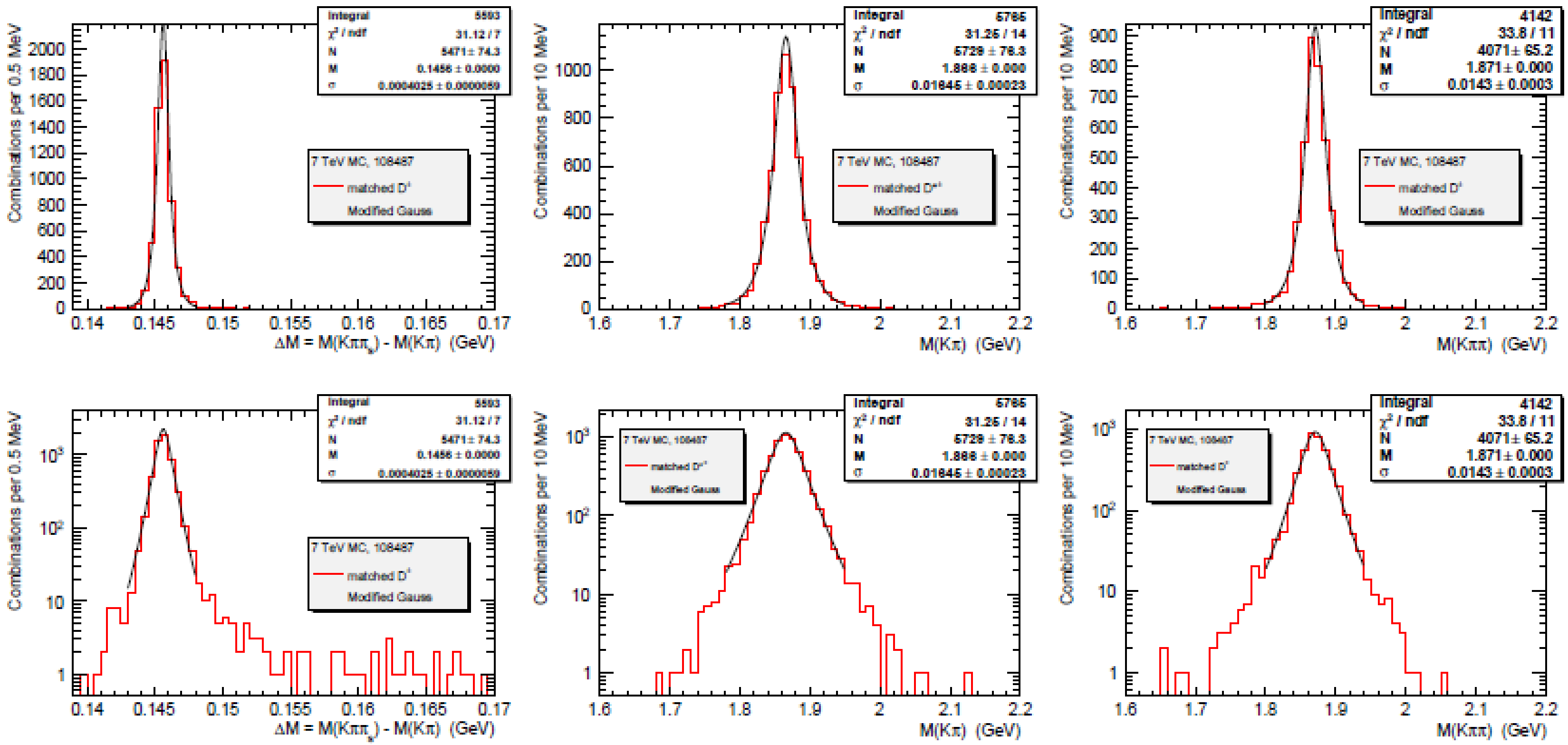
"Modified" Gaussian :

$$\propto e^{-0.5\cdot x^{1+\frac{1}{1+0.5\cdot x}}},$$

$$x = \left|\frac{M - M_0}{\sigma}\right|$$

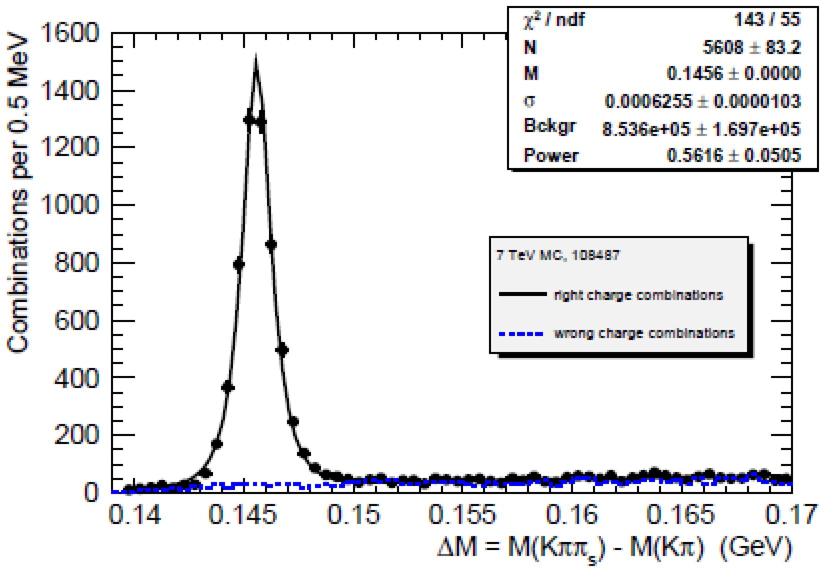
~ 1 order improvement in χ^2

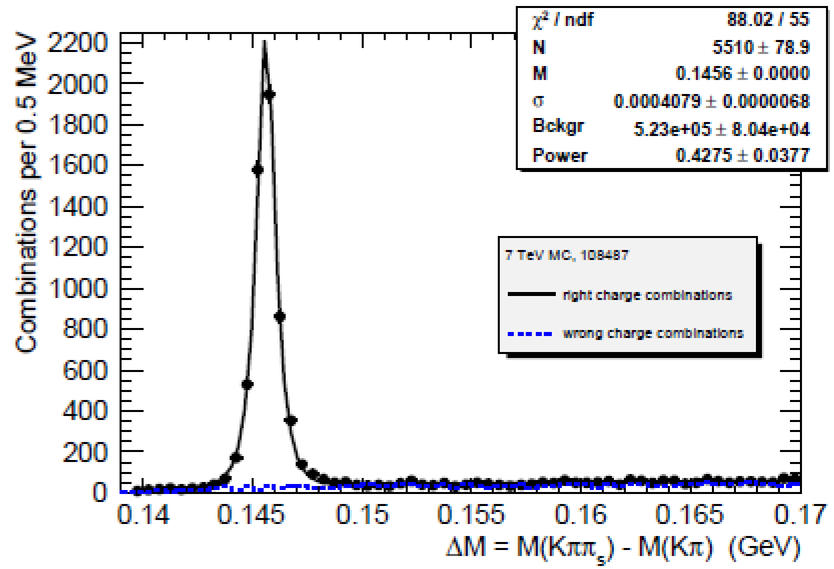
Description of $D^{(*)}$ signals' shapes by Modified Gauss



Shapes of $D^{(*)}$ signals are described much better
by the Modified Gaussian function
than by usual Gaussian function

Reconstruction and position of $\Delta M(D^{*\pm})$ signal





	rec. (sc = 0.999)	MC input	Δ_{cor}
ΔM (unbiased)	145.581 ± 0.013	145.50	81 ± 13 keV
ΔM (1-vertex)	145.616 ± 0.009	145.50	116 ± 9 keV

$\Delta_{\text{shift due to 1-vert.}} = 35 \pm 16$ keV

Possible fix:

2-vertex fit with the distance between $D^{*\pm}$ and D^0 vertices fixed to the expected (from momentum) median distance