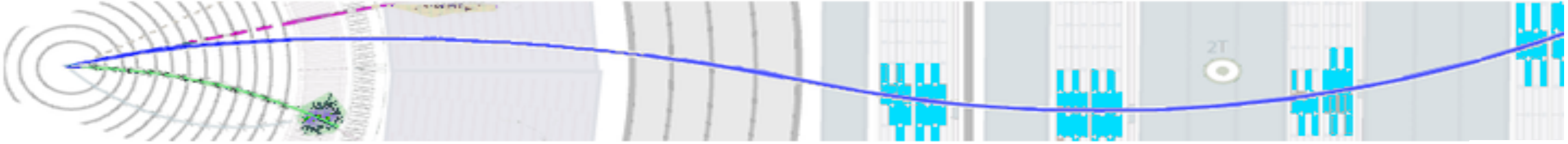

EPS 2013:
W+Heavy Flavor Jets at CMS

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On Behalf of the CMS Collaboration

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Overview

Recent CMS results on W + Heavy Flavored Jets

→Measurements performed at 7Tev with 5 fb^{-1} of data

W+c

W+ 1 c-jet identified by D-Meson/semi-leptonic decays

Compared to MCFM with a variety of PDFs

Probe the strange content of the proton at the EWK scale

W+bb

W+ 2 b-Jets which are well separated in Delta R

Compared to MCFM

First Measurement of this phase space

Irreducible background to WH with H→bb, also BSM

Advertisement: *More CMS W/Z boson+Jets measurements tomorrow (12:25 QCD) and at the poster session!*

W+C & the strange quark

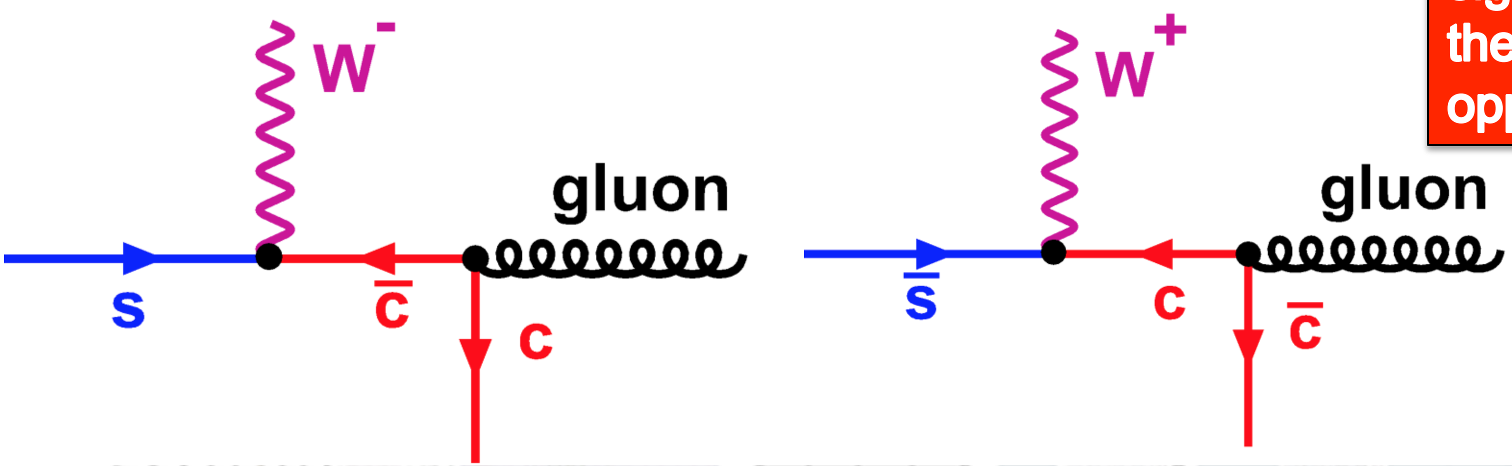
Measurement of the W plus charm quark production provides direct access the strange quark content of the proton at the EWK scale

Precise measurements of this process at the LHC may significantly reduce the uncertainties on the strange parton density function (PDF)

Cross section and cross section ratios measured in the fiducial region:

- **Charm quark: $p_T(c) > 25$ GeV, $|\eta(c)| < 2.5$**
- **$W \rightarrow l\nu$: $p_T(\text{lepton}) > 25$ (35) GeV, $|\eta(\text{lepton})| < 2.1$**

Here, true W+c signature requires the W and c to be opposite signs



Signatures & Strategy

W→lν + a leading jet with charm content, identified as:

Displaced secondary vertex

→with 3 tracks consistent with a $D^{\pm}$ decay

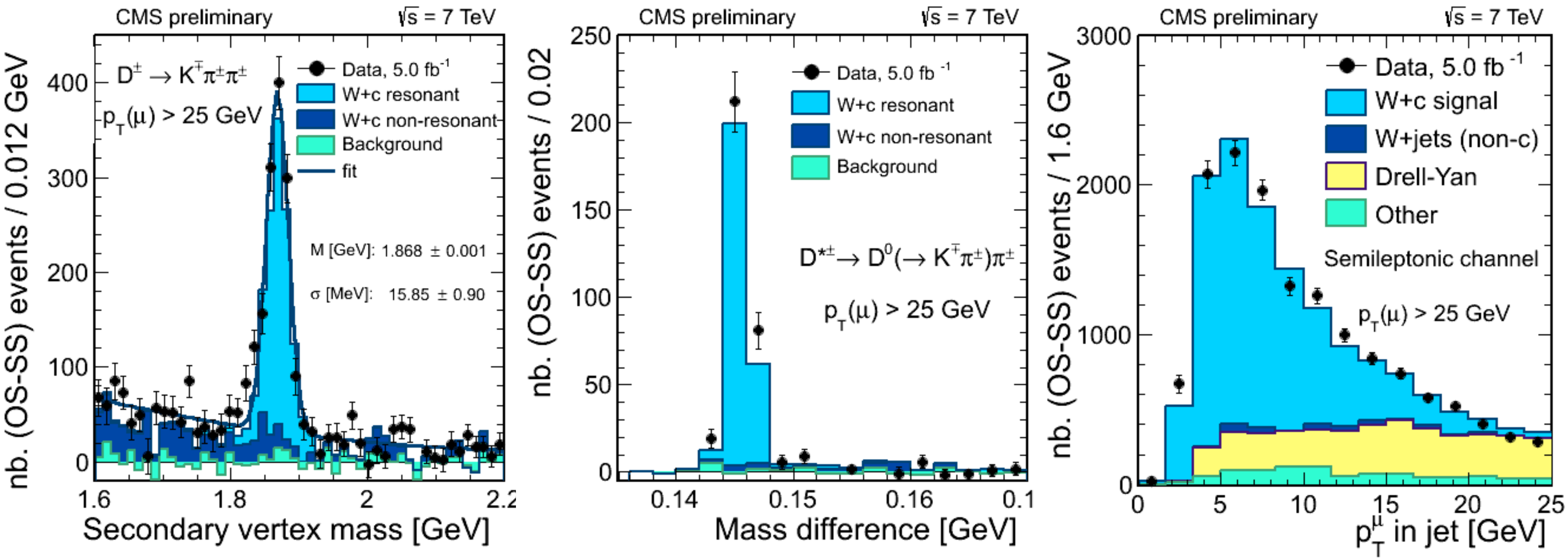
→with 2 tracks, consistent with a D^0 decay associated to a previous D* decay

→Semi-Leptonic decay leading to a well identified muon

Why restrict the measurement to these three channels?

The **charge of the c quark is unequivocally determined** in the three signatures ($c^{\pm} \to D^{\pm}$, $c^{\pm} \to D^{*\pm} \to D0+\pi^{\pm}$, $c^{\pm} \to l^{\pm}$) → **Enables OS –SS Subtraction**

Identified decay → **correct Branching Ratio from LEP**

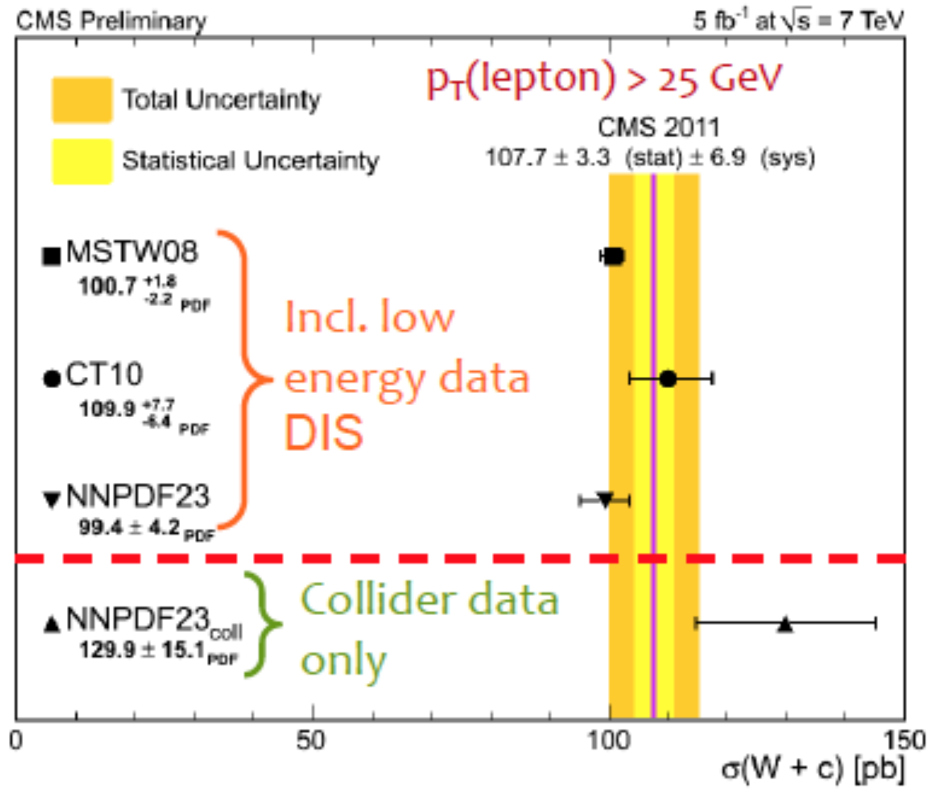


Cross Section Results

Compared to MCFM 6.1 at NLO: CT10, MSTW08, NNPDF2.3 (also collider only)

Charm jet ($\Delta R=1$): $p_T(c) > 25$ GeV, $|\eta(c)| < 2.5$; $W \rightarrow l\nu$: $p_T(l) > 25$ (35) GeV, $|\eta(l)| < 2.1$

$$\sigma(W+c) = \frac{N_{sel} - N_{bkg}}{\mathcal{L}_{\text{int}}\,\mathcal{B}\,\mathcal{A}\,\epsilon}$$



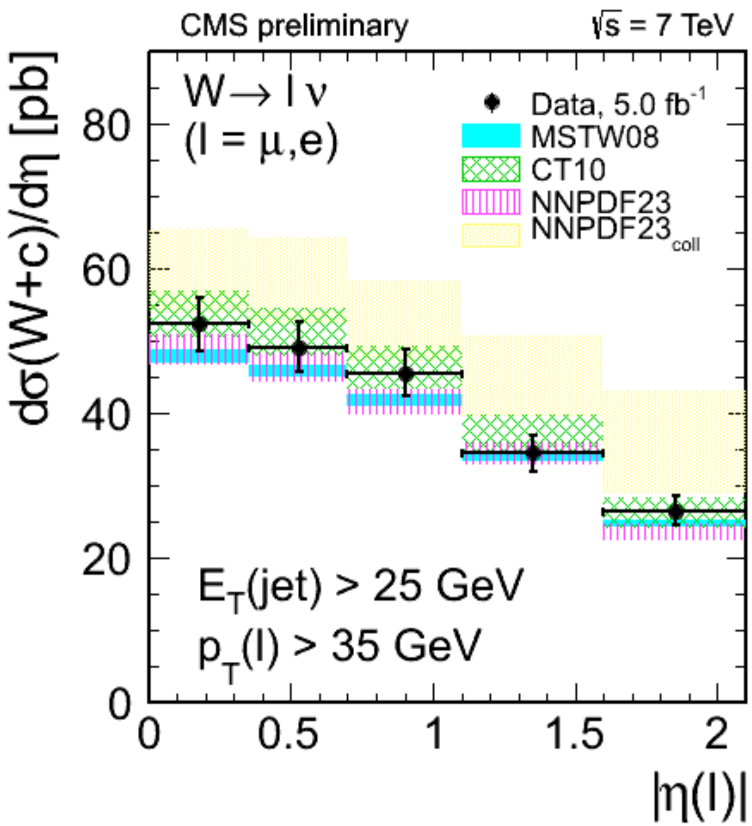
Size of the PDF uncertainties depend on the different methodology used by the various groups

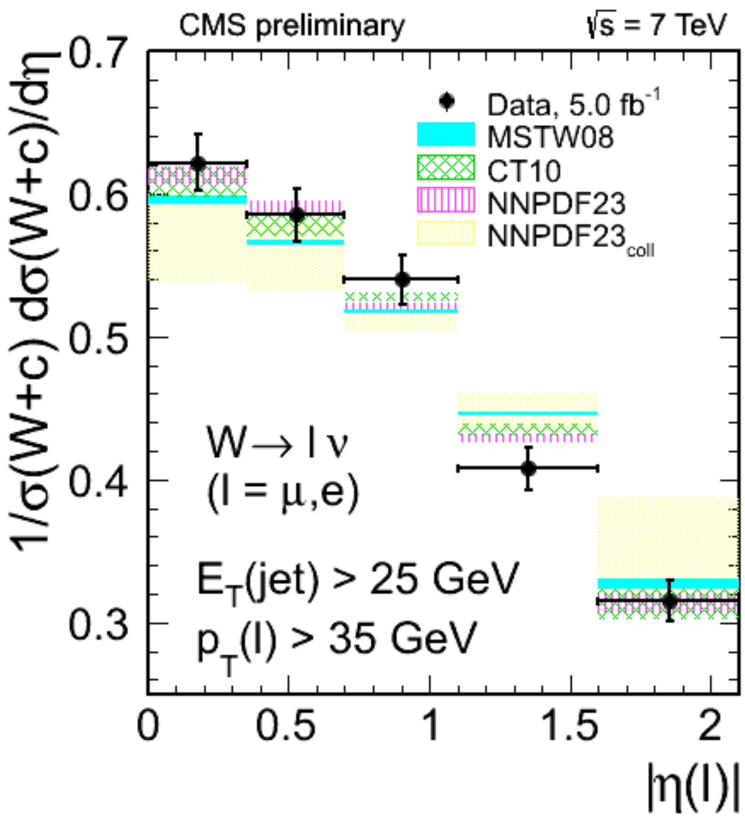
Differential Cross Section

Theoretical predictions (MSTW, CT10, NNPDF23) reproduce the experimental measurement well

Normalized differential cross section (right) shown in bins of lepton pseudorapidity probe the shape of the strange quark PDF

→Systematic Uncertainty comes almost entirely from total cross section

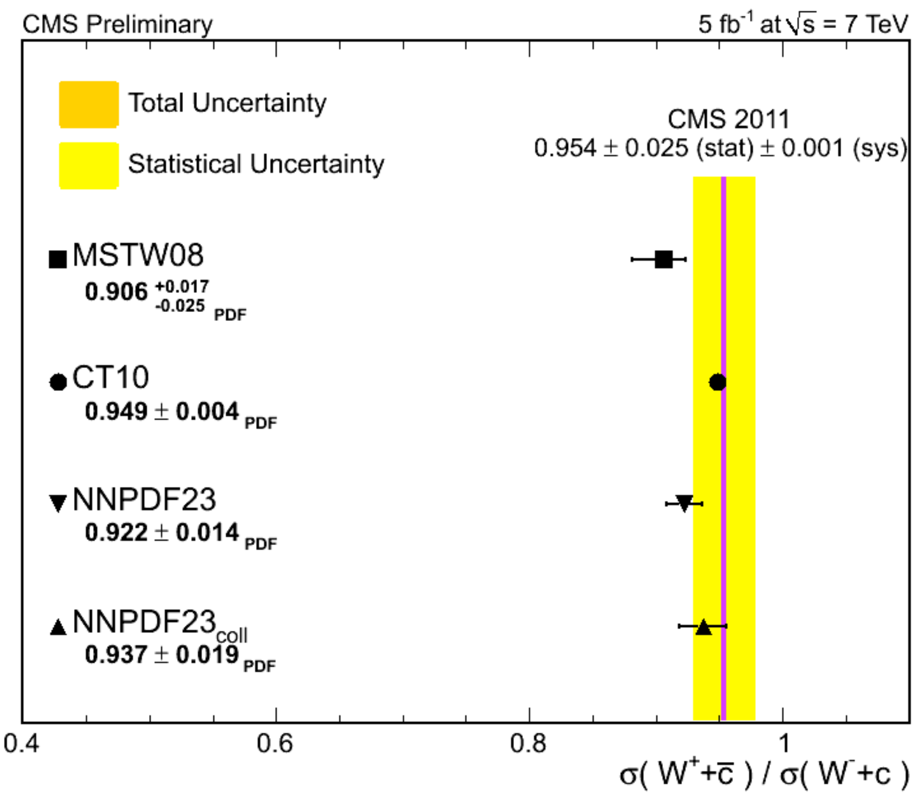


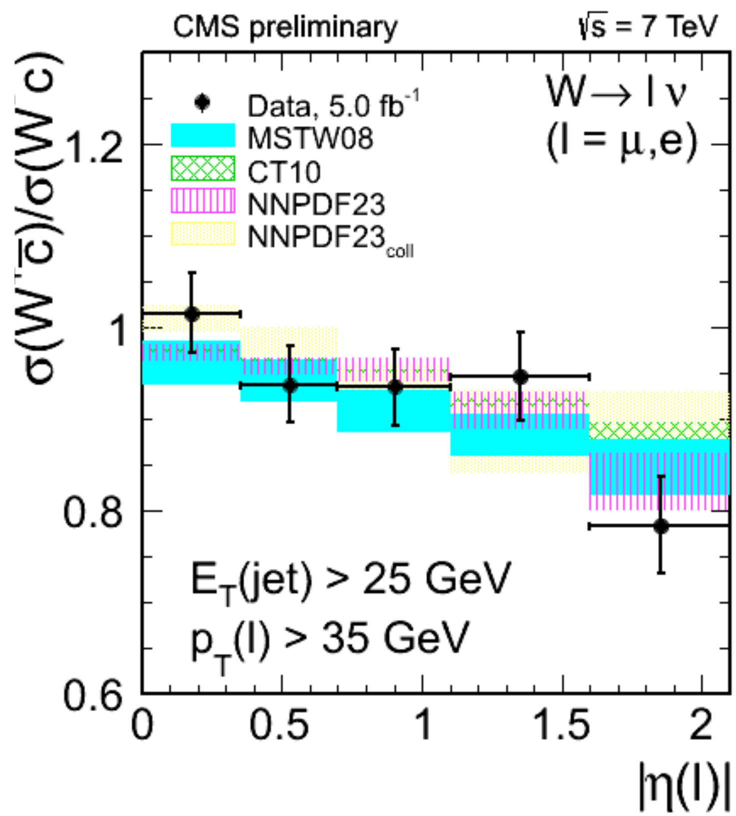


Cross Section Charge Ratio

$$R_c^{\pm} = \frac{\sigma(W^+ + \bar{c})}{\sigma(W^- + c)} = \frac{(N^+{}_{OS} - N^+{}_{SS})}{(N^-{}_{OS} - N^-{}_{SS})}$$

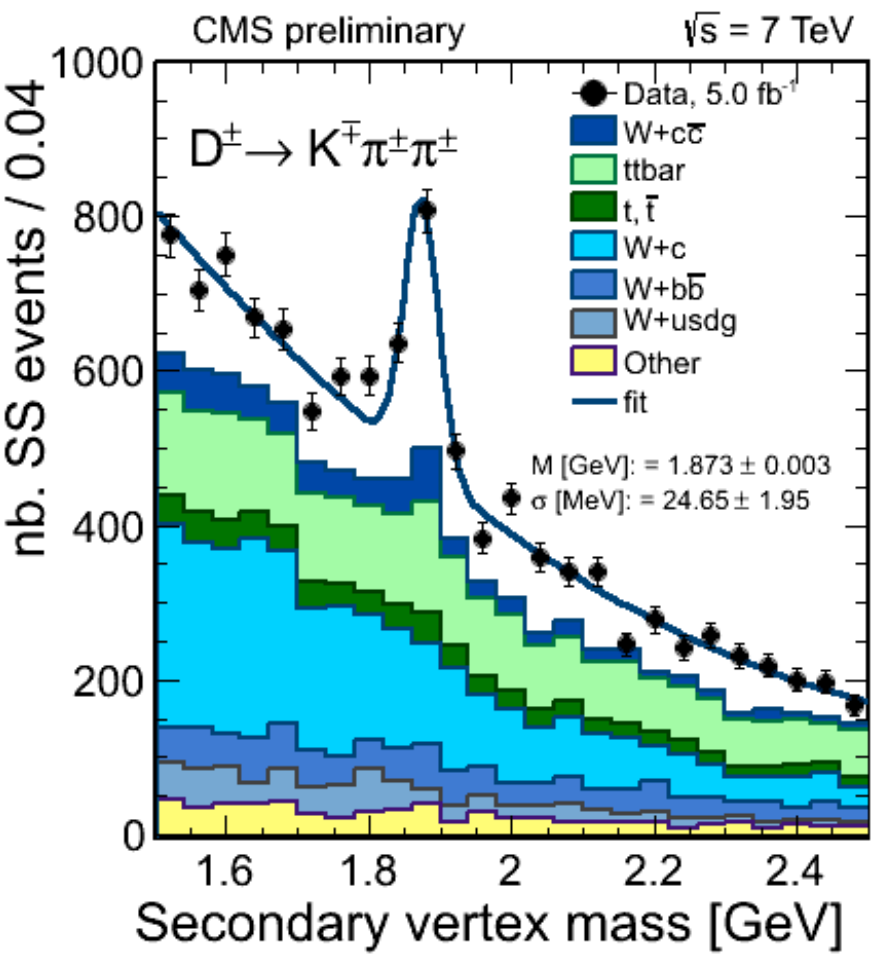
- Binned measurement: in 5 bins of lepton pseudorapidity
- Agreement with theoretical prediction



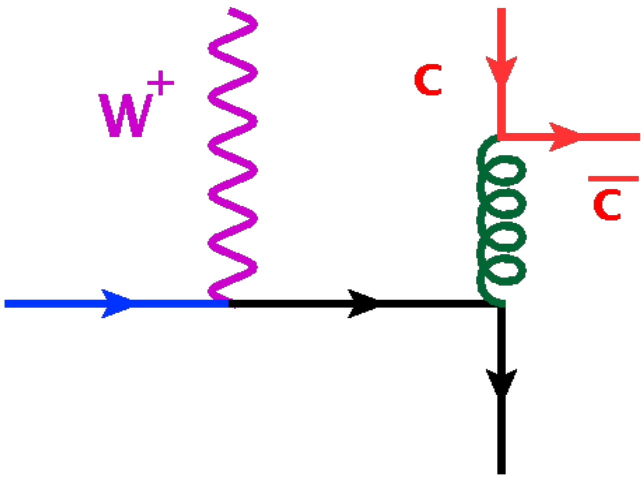


Observation on W + 1 SV

(Essentially W+1 bTag)



Sample enriched in c$\bar{c}$/b$\bar{b}$ events



Comparison with the reference Madgraph+Pythia Monte Carlo

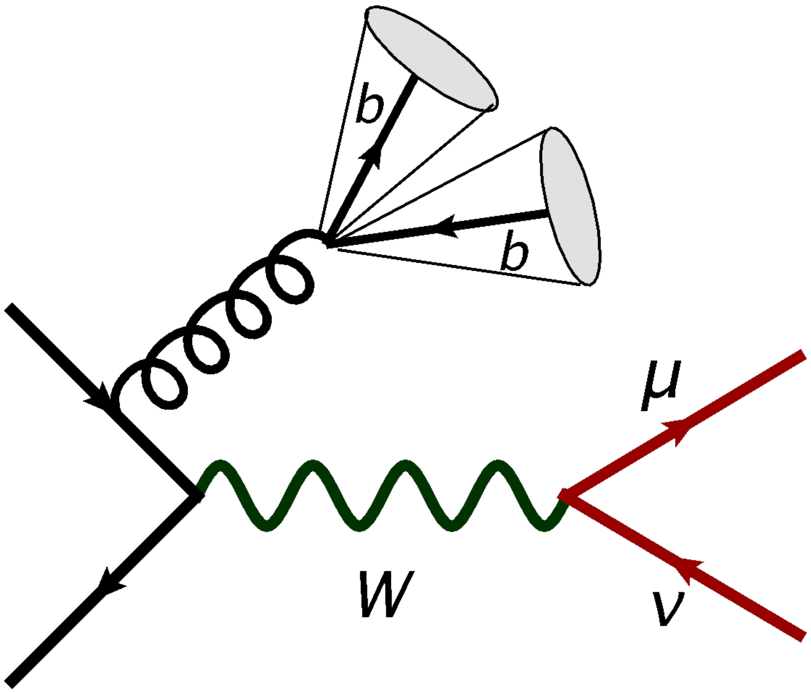
Significant deficit observed in MC

Hypothesis: collinear production mis-modeling in MG+Pythia?

W plus $b\bar{b}$

Gluon→$b\bar{b}$ where b quark forms a b-jet which is **well separated** in Delta R

This signal selection is intrinsic of a hard interaction where the gluon is produced in association with the W-boson (Minimal effects due to collinear mis-modelling)



Major background for searches (**WH with H→$b\bar{b}$**; but also BSM)

→A thorough understanding of W+$b\bar{b}$ in the same kinematic region as is used in searches is crucial

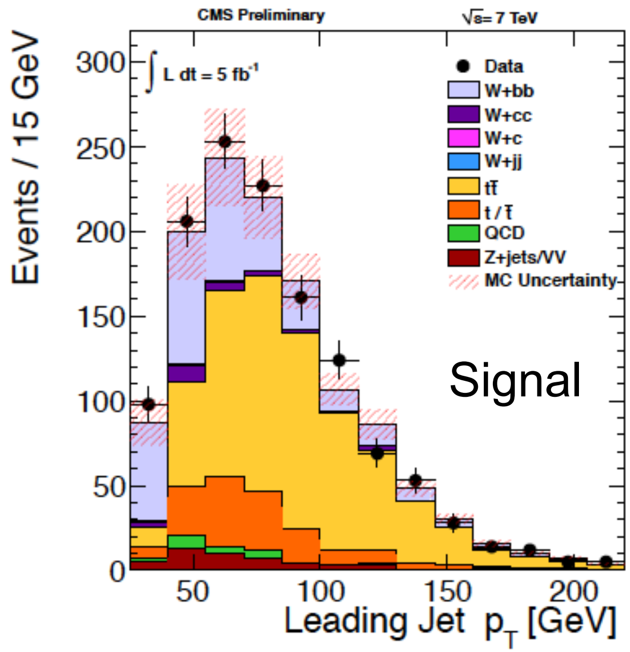
Cross section measured in the fiducial region, and unfolded to the level of final state particles:

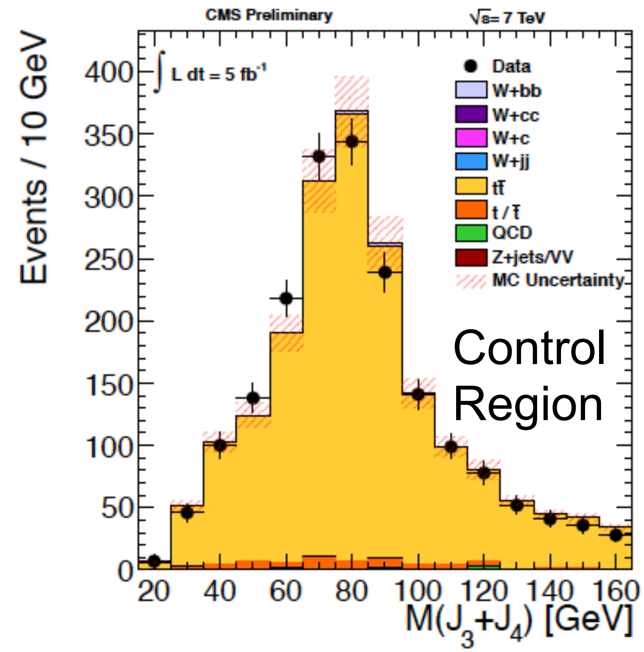
- **W→lν: p_T(lepton) > 25 GeV, |η(lepton)| < 2.1**
- **2 B Jets: p_T(b jet) > 25 GeV, |η(b jet)| < 2.4**

Signal Extraction

Combined Secondary Vertex algorithm used to distinguish b-Jets from udcsg

Veto on $t\bar{t}$-like events in the signal region





Binned Maximum Likelihood Fit

Signal Region: 2 b-Tagged jets

Fit simultaneously with

Ttbar Control Region: 4 jets, 2 b-Tag

→Agreement with Madgraph+Pythia

Process	Prediction	Fitted Yield
$W+b\bar{b}$	332 ± 66	300 ± 60
$W+c$, $W+c\bar{c}$	21 ± 4	20 ± 4
W+usdg	1.5 ± 0.2	1 ± 1
Z+jets	31 ± 3	32 ± 3
$t\bar{t}$	596 ± 35	647 ± 52
Single top	160 ± 13	170 ± 13
WW, WZ	19 ± 3	17 ± 3
QCD	33 ± 17	33 ± 16
Total	1194 ± 78	1220 ± 82
Observed Events	1230 ± 35	

Cross Section Measurement

$$\sigma(pp \to W + b\bar{b}) = \frac{N_{Data} - N_{Bckg}}{\mathcal{L}_{int}\,\epsilon_{sel}}$$

L=5 fb^{-1}

ε_{sel} =11±1% (MG+Pythia)

Measured in a fiducial region, unfolded to the level of final state particles with:

$p_T(\mu) > 25$ GeV, $|\eta(\mu)| < 2.1$; 2 B Jets: p_T(b jet) > 25 GeV, $|\eta$(b jet)$| < 2.5$

→Matched to a B-hadron

$$\sigma(pp \to W + b\bar{b}, p_T^b > 25\ \text{GeV}, |\eta^b| < 2.4) \times \mathcal{B}(W \to \mu\nu, p_T^\mu > 25\ \text{GeV}, |\eta^\mu| < 2.1) = \\ = 0.53 \pm 0.05\,(\text{stat.}) \pm 0.09\,(\text{syst.}) \pm 0.06\,(\text{theo.}) \pm 0.01\,(\text{lum.})\ \text{pb.}$$

MCFM NLO prediction: **σ(W+bb)=0.52±0.03 pb**

Measurement is Systematics dominated (**20% relative sys unc**)

Leading Systematic Uncertainties: b-Tagging, Jet Energy Scale

Hadronization correction (MG+Pythia, 5F & 4F): **C(b→B) = 92±1%**

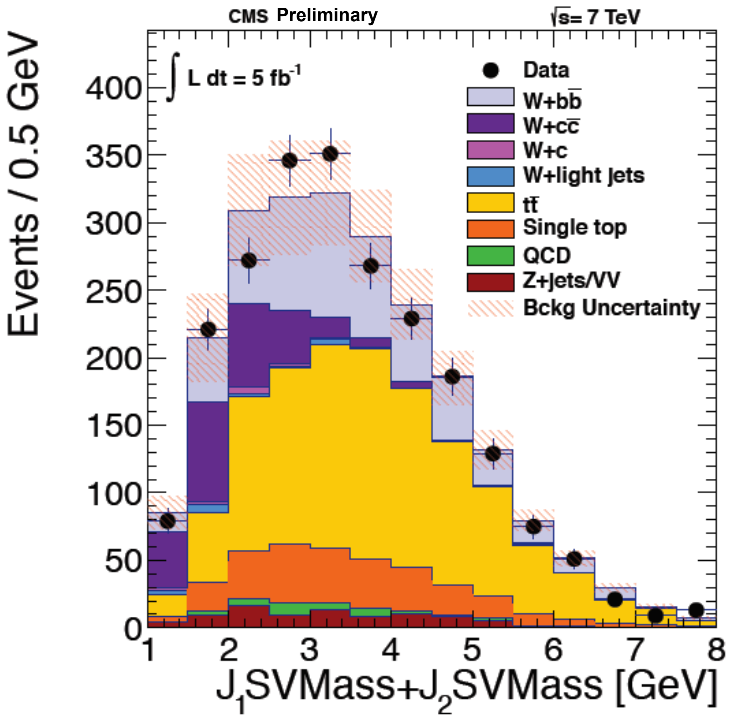
DPS is found to be sufficiently modeled in MG+Pythia

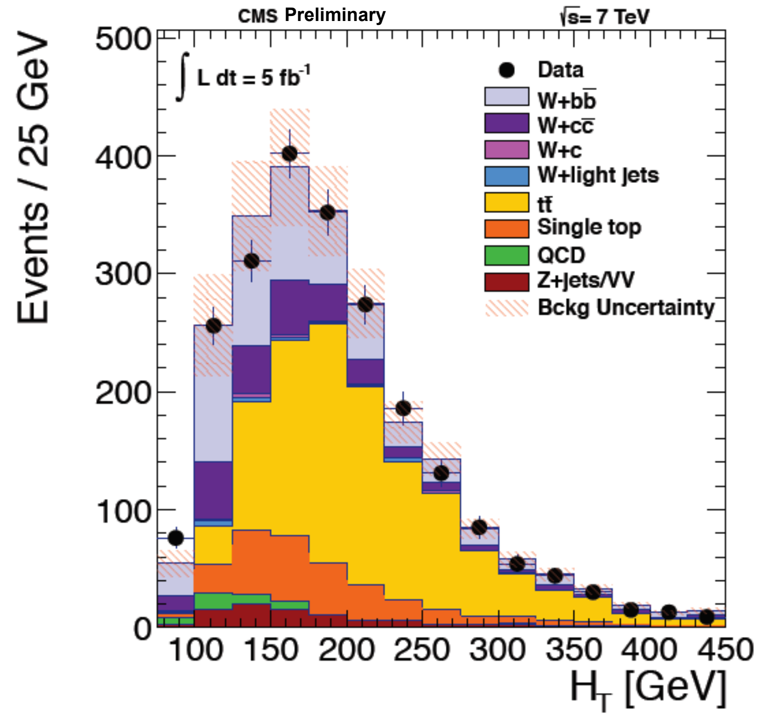
Alternative Phase Space

Loosen b-tag selection and separate W+c$\bar{c}$ from W+b$\bar{b}$

Two dimensional fit using H_T of the event and the addition of the secondary vertex found in Jet 1 and Jet 2

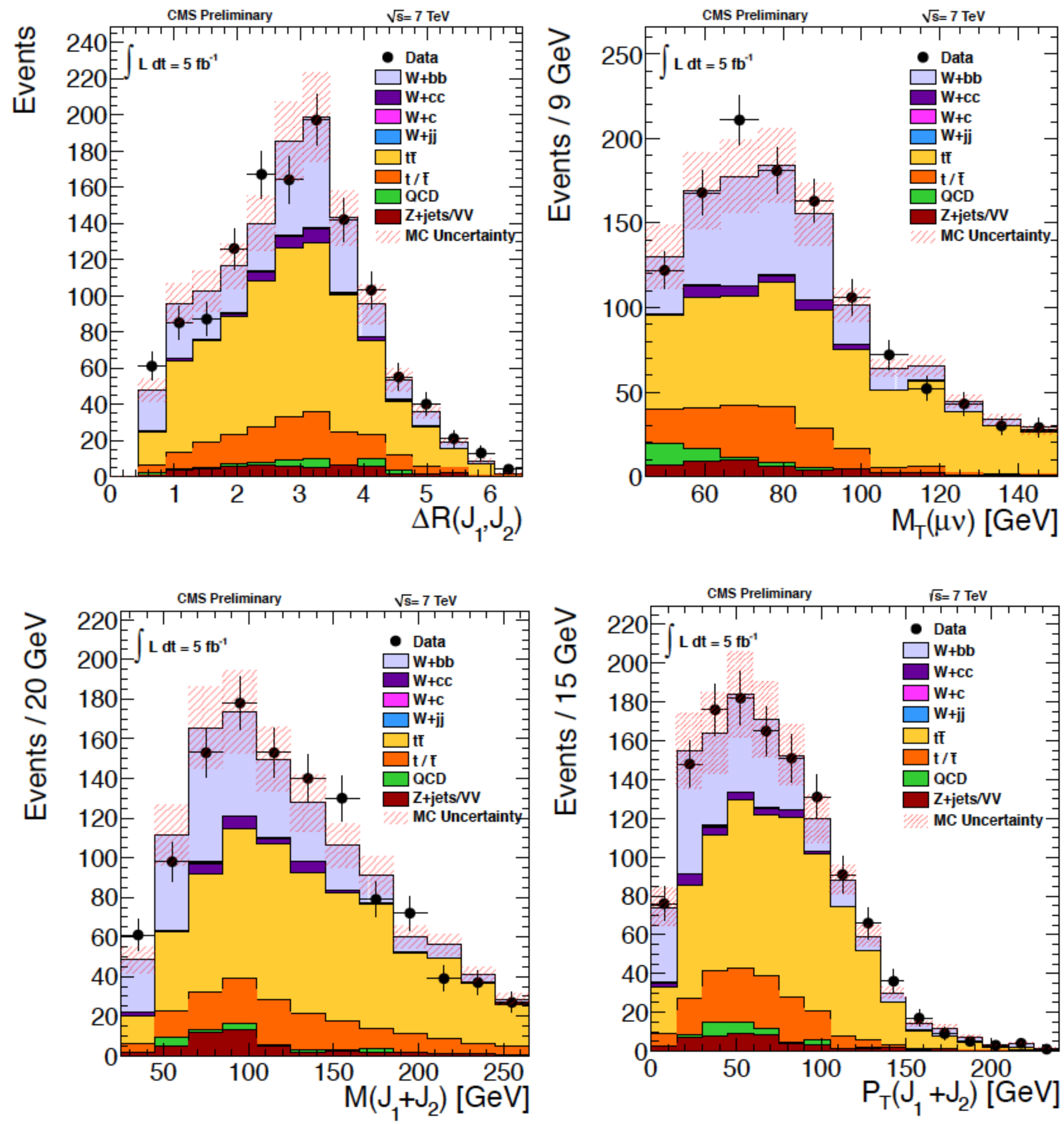
This J1SVMass+J2SVMass variable provides separation for W+c$\bar{c}$ and W+b$\bar{b}$ (futher work on Jet Sub-Structure can improve these measurements)





W+bb Kinematic Properties

Kinematic properties of the W+b$\bar{b}$ system are shown to be in good agreement with Madgraph+Pythia



Conclusions

W+b$\bar{b}$ and W+c are found to be in good agreement with Standard Model Predictions as modeled by Madgraph+Pythia

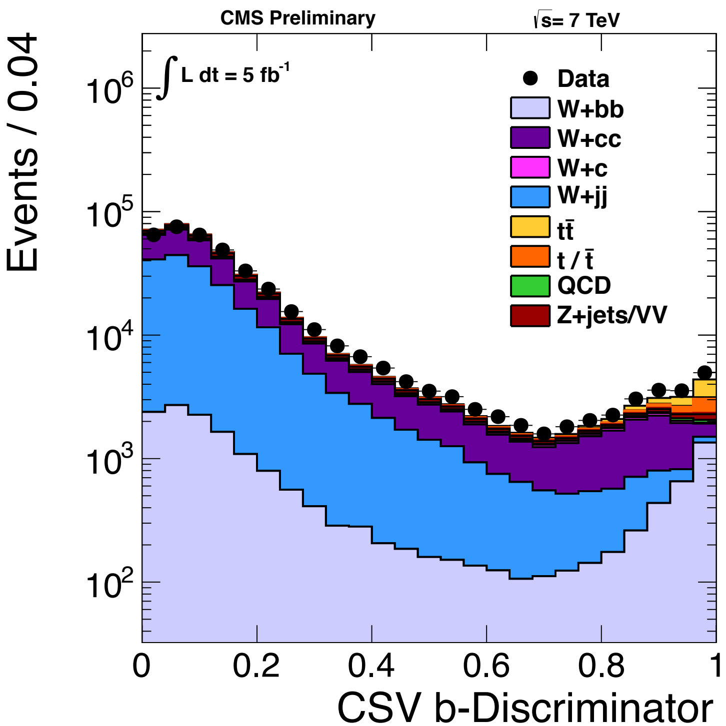
The W + 2 b-Jet measurement is the first ever performed at the LHC!

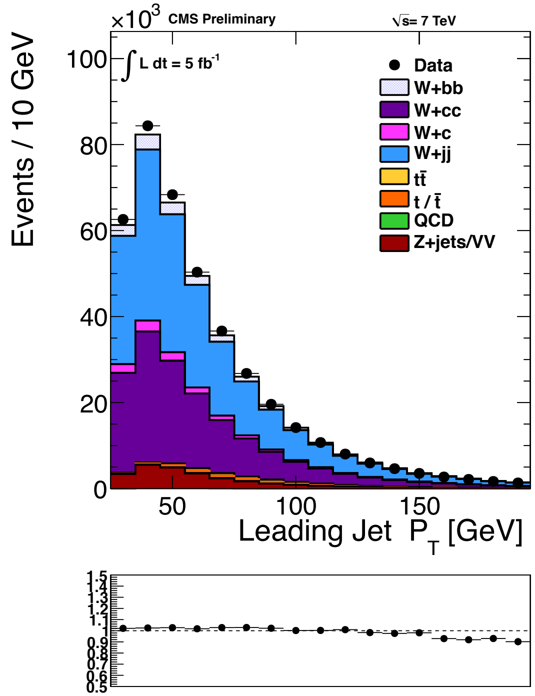
The W+c precision cross section measurement provides a direct probe to the strange quark content of the proton

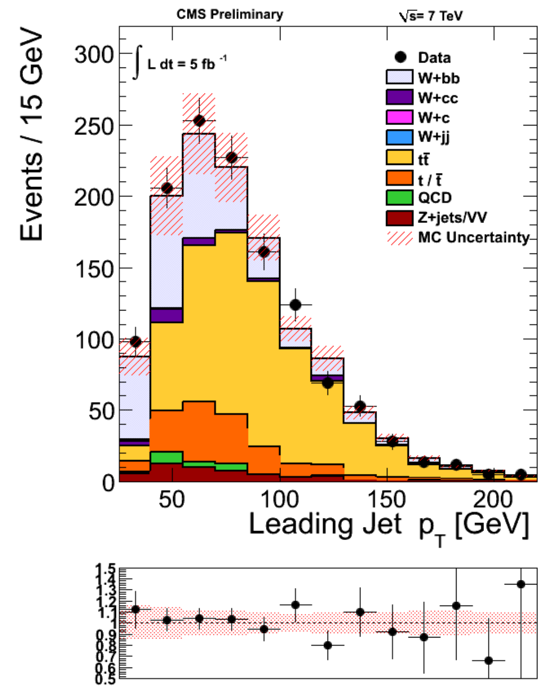
Exciting prospects for 8TeV studies with increased Luminosity!

Thank you for your time!

Combined Secondary Vertex







Start with two jets that **exhibit qualities of b-Jets**

CSV Algorithm is

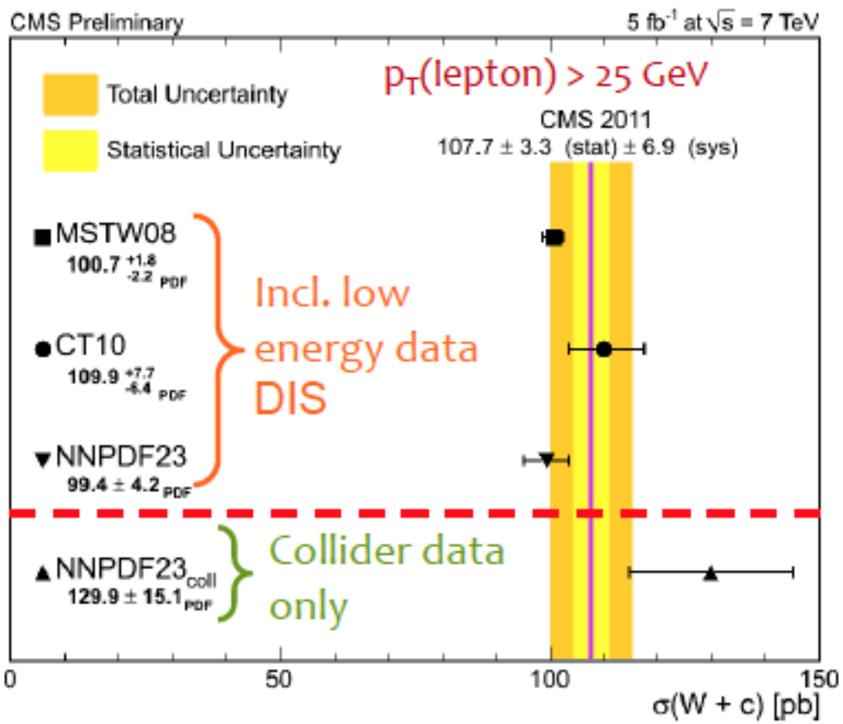
> The CSV b-tagging algorithm combines the following variables into a single discriminating variable using a Likelihood ratio technique: **secondary vertex mass**, **multiplicity of charged particles associated to the secondary vertex**, the **flight significance associated to the secondary vertex**, **the energy of charged particles associated to the SV divided by the energy of all charged particles associated to the jet, the rapidities of charged particle tracks associated to the secondary vertex**, and the t**rack impact parameter significance exceeding the charm threshold**.

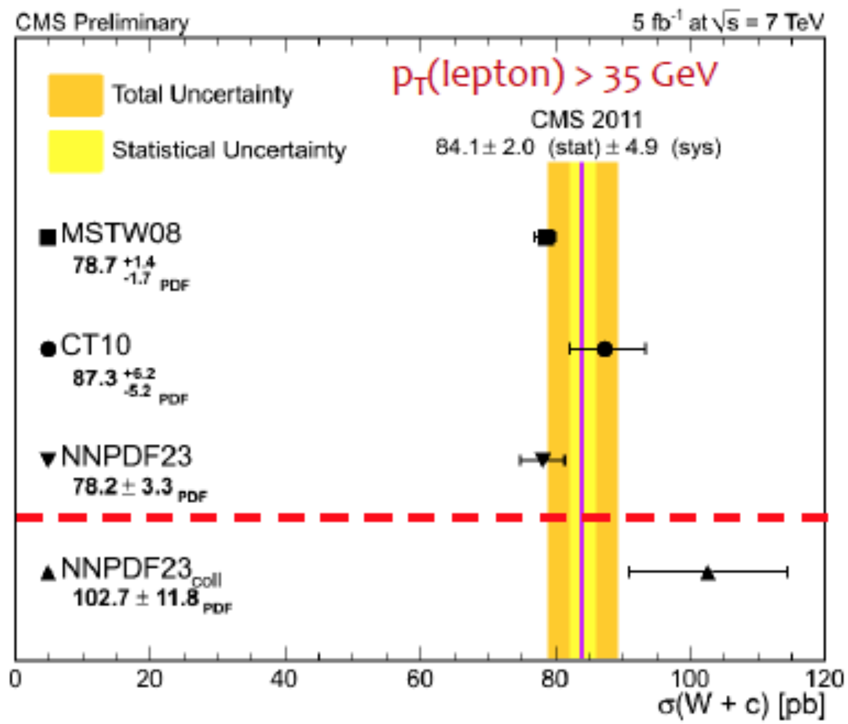
If a jet does not have an SV then CSV algorithm computes “pseudo Vertex” and “No-Vertex” values

Cross Section Results

MCFM 6.1 at NLO: CT10, MSTW08, NNPDF2.3 (also coll. only)

Charm jet (ΔR=1): $p_T(c) > 25$ GeV, $|\eta(c)| < 2.5$; W→lν: $p_T(l) > 25$ (35) GeV, $|\eta(l)| < 2.1$





Measured cross section with pt(lepton)>25Gev and pt(lepton>35GeV)