DIS 2010

Parton Shower Effects in Heavy Flavour Production at Tevatron

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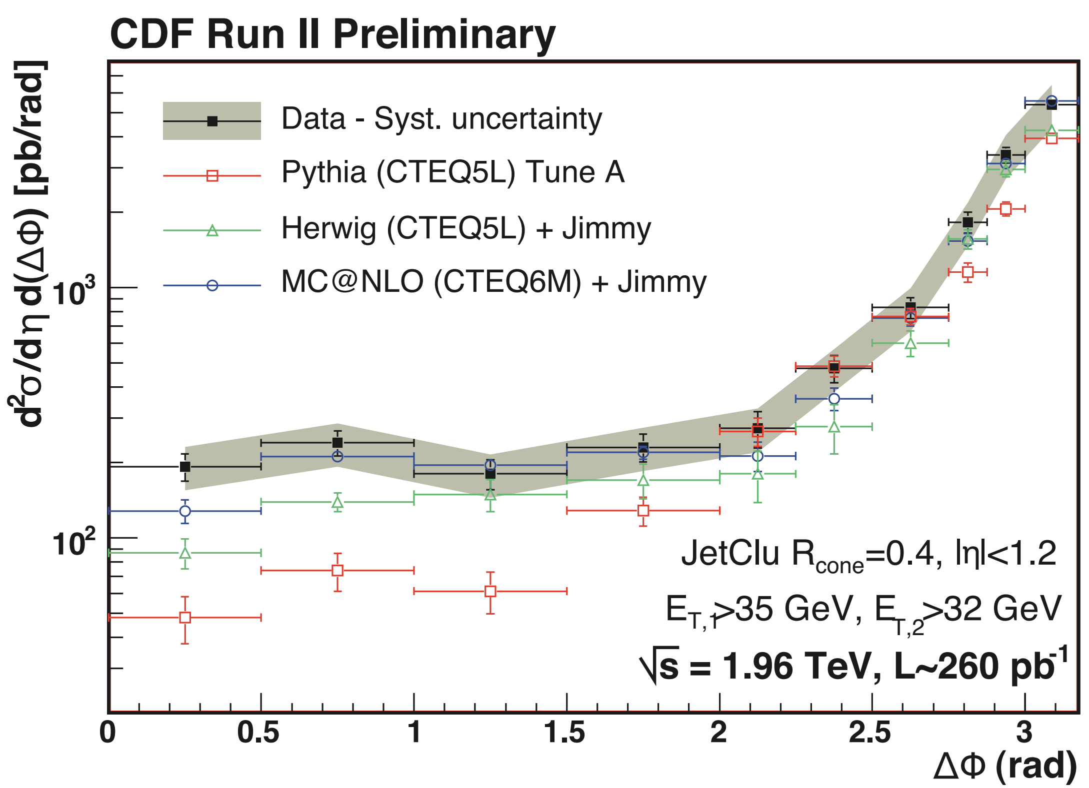
Motivation

Why Heavy Flavour production at Tevatron?

- In general good description of measurements using collinear approach
- But: non-collinear gluon evolution dynamics fully understood?



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Overview

➡ Compare Heavy Flavour production at Tevatron to predictions using the non-collinear approach:

- Hadron-level Monte Carlo Generator CASCADE
  (H. Jung, M. Krämer)
- Numerical Calculations on parton-level
  (A.V. Lipatov, N.P. Zotov)

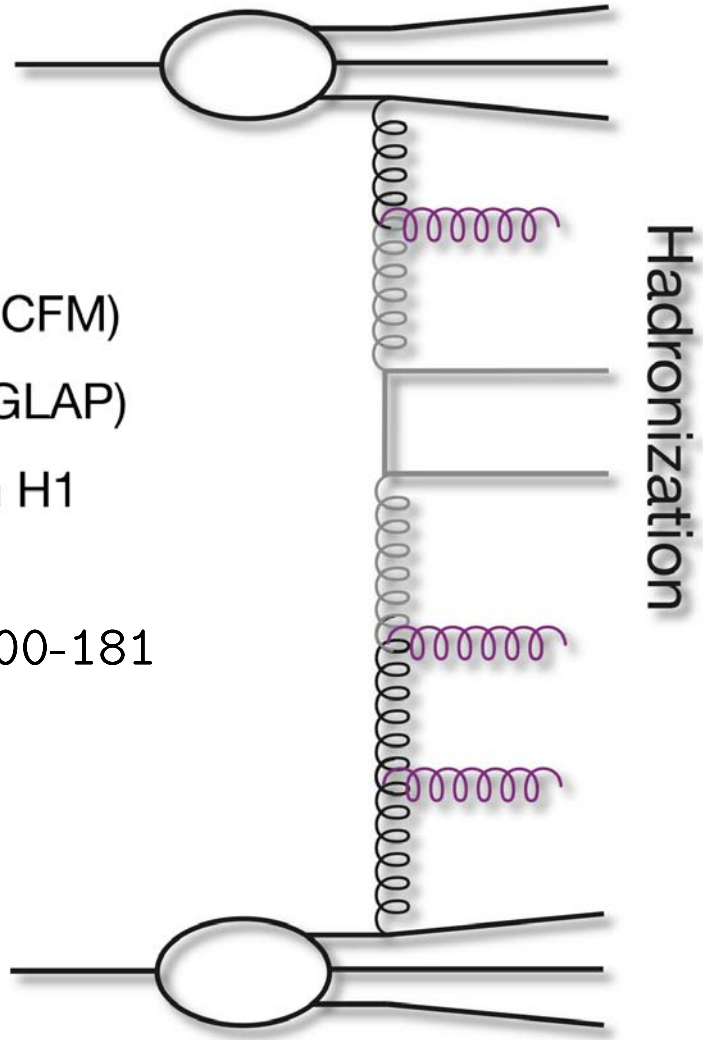
- Angular correlations in Heavy Flavour production provide further insights
  - Playground for tests of unintegrated gluon densities
  - Sensitivity to parton showers can be investigated

Note: References given below histograms denote the source of the data analyses

Theoretical Predictions I

http://www.desy.de/~jung/cascade

- CASCADE Monte Carlo Generator:
  - Angular ordered initial state parton showers (CCFM)
  - Final state parton showers angular ordered (DGLAP)
  - unintegrated PDFs: fit to $F_2(x, Q^2)$ data from H1
    $x < 0.005,\ Q^2 > 5\mathrm{GeV}^2$
    H1 Eur. Phys. J. C21 (2001) 33-61, DESY 00-181



See talk of A. Knutsson for new fitted PDFs, this conference

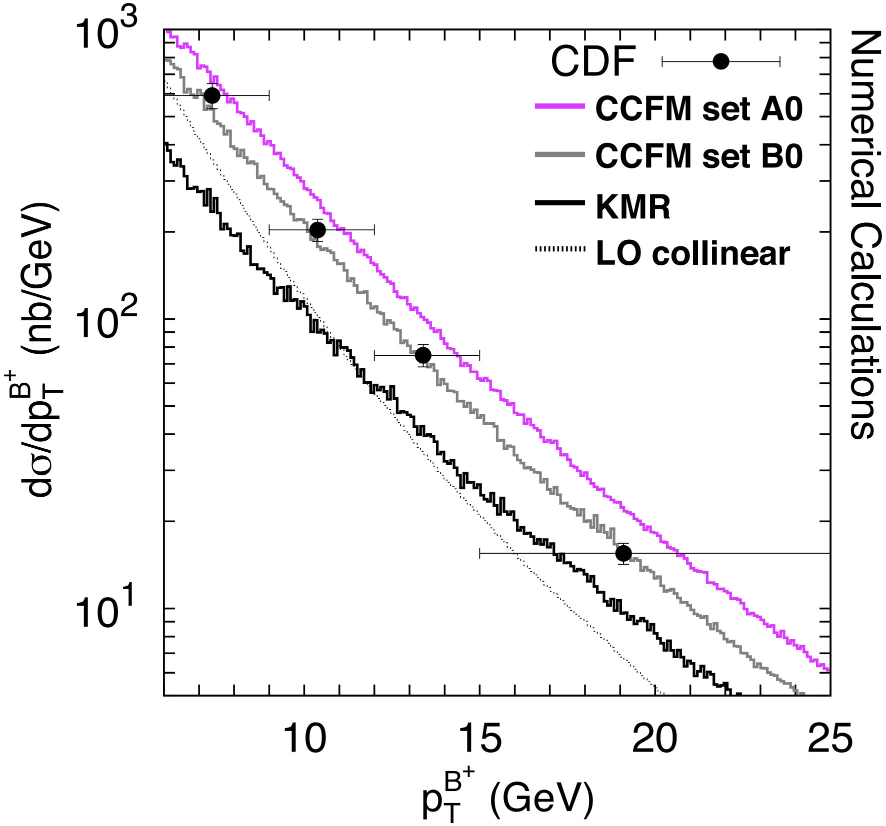
Theoretical Predictions II

- Numerical Calculations:
  - Convolution of off-shell partonic cross section $\hat{\sigma}$
    and unintegrated gluon distributions in a proton $\mathcal{A}(x, \mathbf{k}_T^2, \mu^2)$
  - Analytic expression for the Matrix element $|\bar{\mathcal{M}}(g^* g^* \to q\bar{q})|^2$ derived in
    $\texttt{N.P. Zotov, A.V. Lipatov, V.A.Saleev, hep-ph/0112114}$
  - unintegrated PDFs: numerical solution of CCFM evolution equations,
    Parameters were fitted to describe the proton structure function $F_2(x, Q^2)$

Numerical Calculations performed by A.V. Lipatov and N.P. Zotov

Unintegrated PDFs

- Different unintegrated PDFs (uPDFs):
- CCFM set A0 and B0
- From collinear quark and gluon distributions: Kimber-Martin-Ryskin (KMR)
  - Resummation of small x logarithms is not taken into account for KMR



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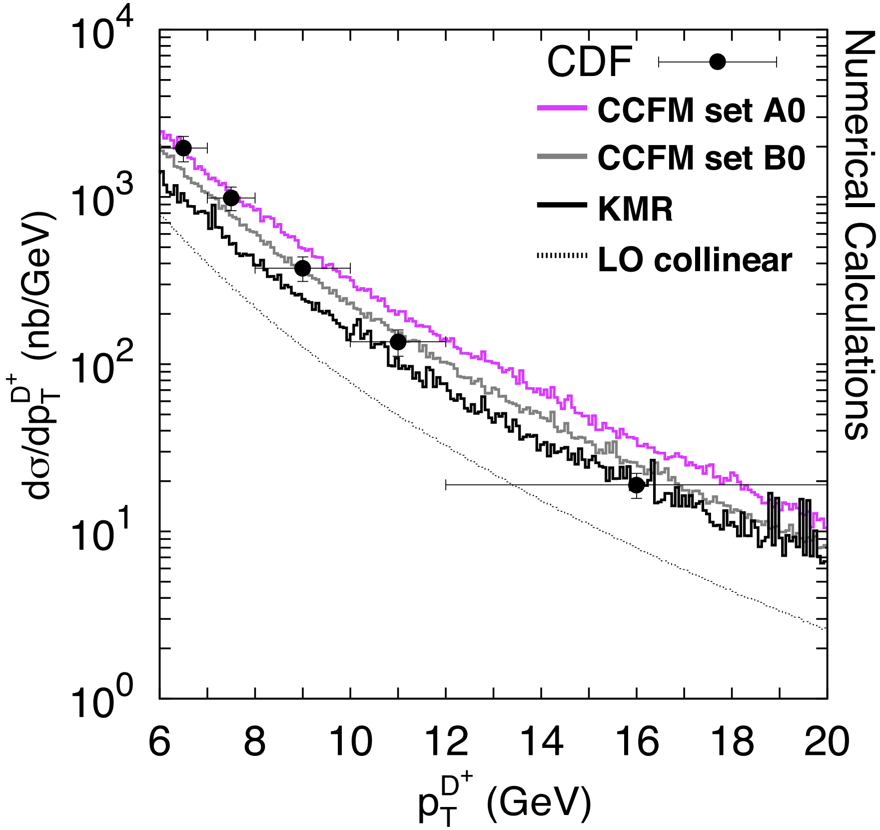
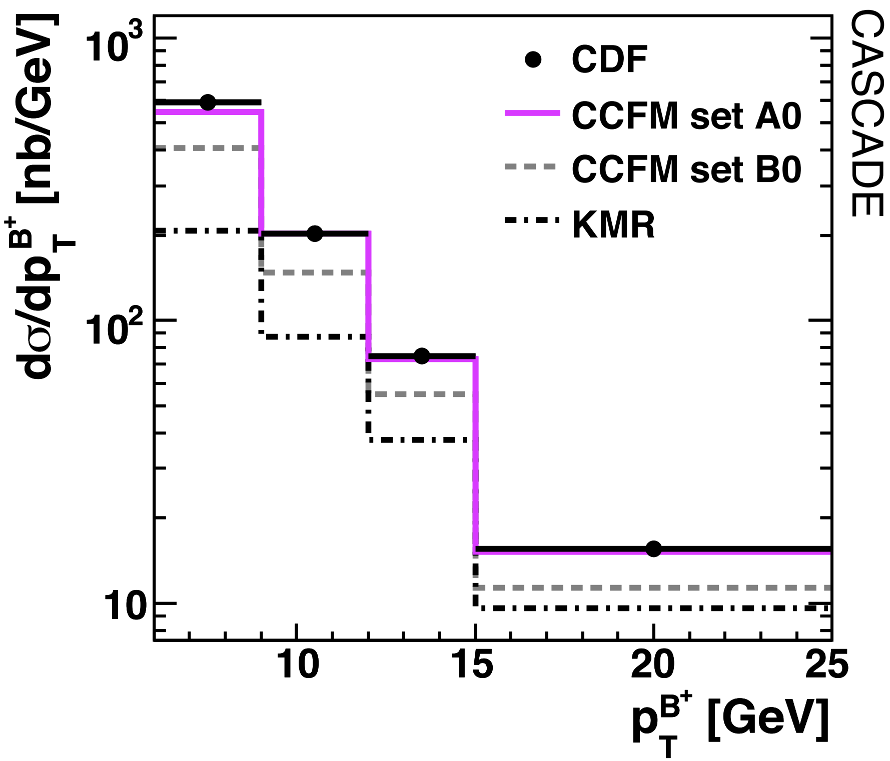


Phys.Rev.Lett.91 : 241804

Unintegrated PDFs

- Transverse momentum distributions of B and D mesons well described
- KMR predictions for charm are closer to the CCFM ones than for beauty production



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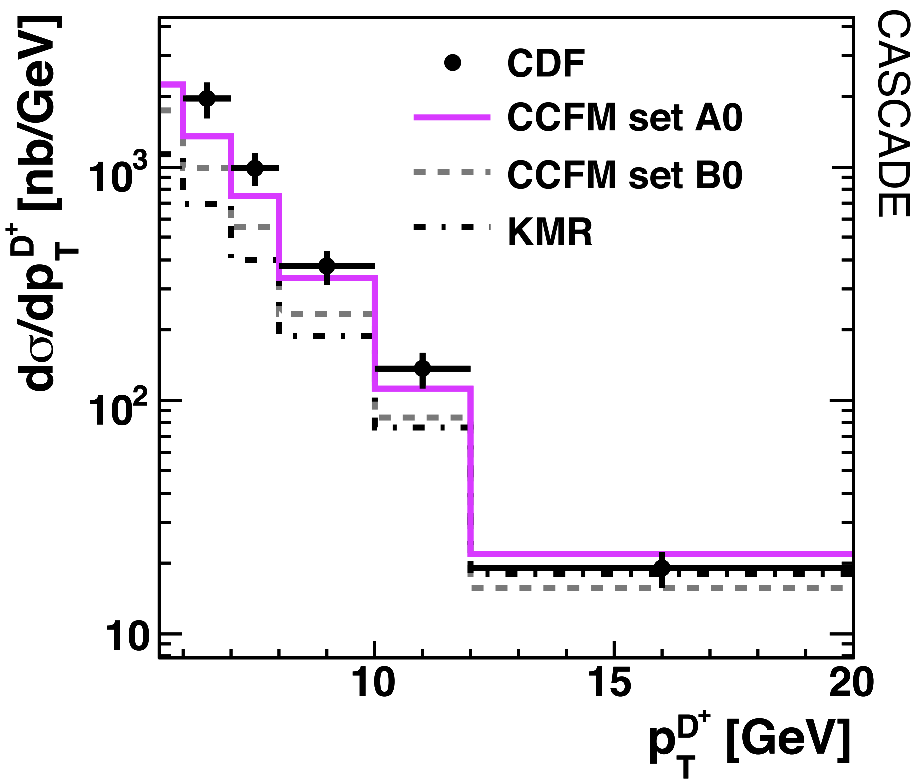
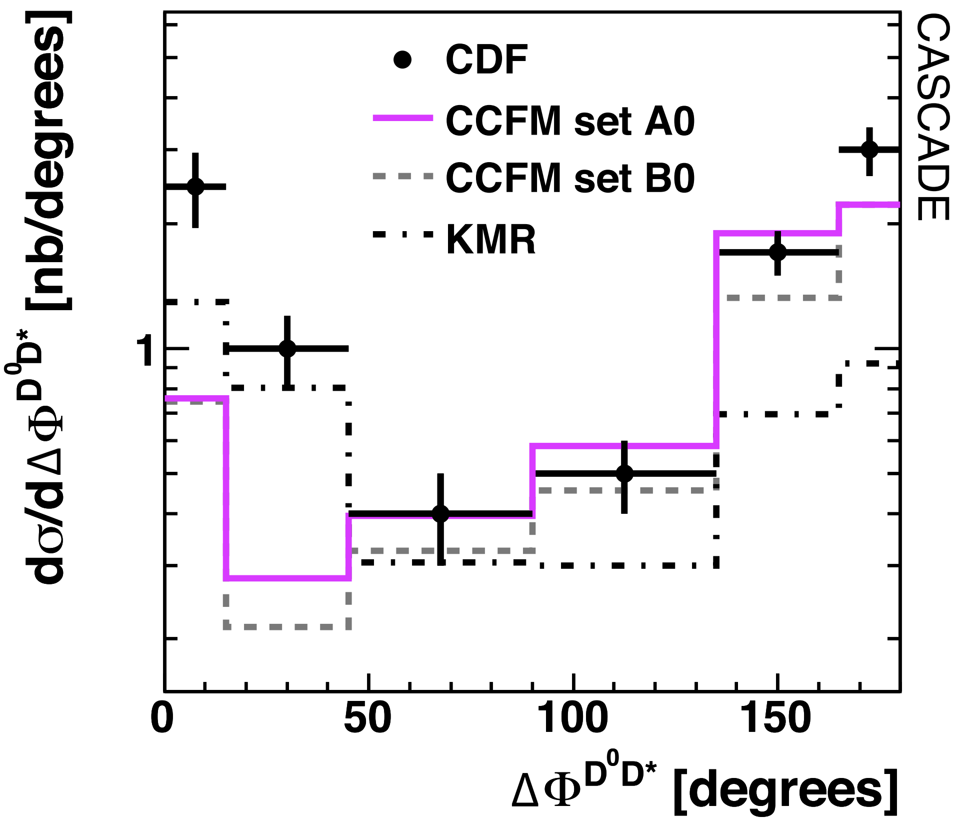


Phys.Rev.Lett.91 : 241804

Unintegrated PDFs

- Sensitive to non-collinear gluon evolution
- KMR describes data best at low $\Delta\Phi$, CCFM sets A0 and B0 are too low



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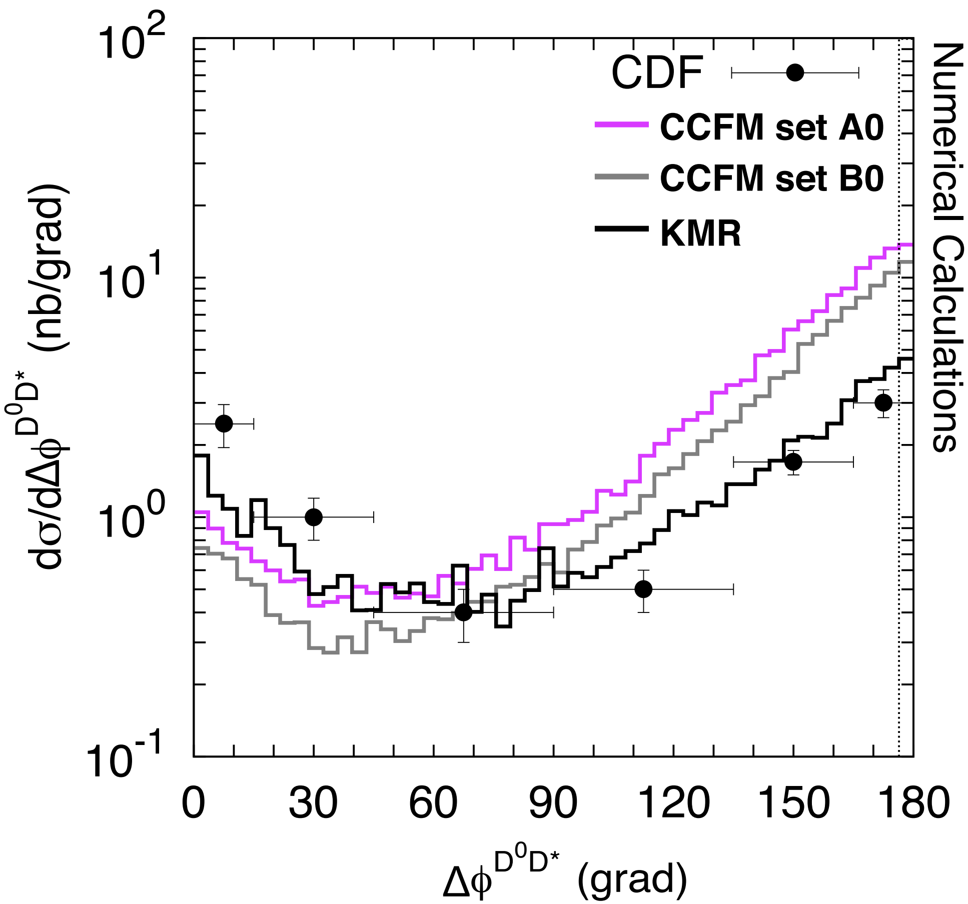
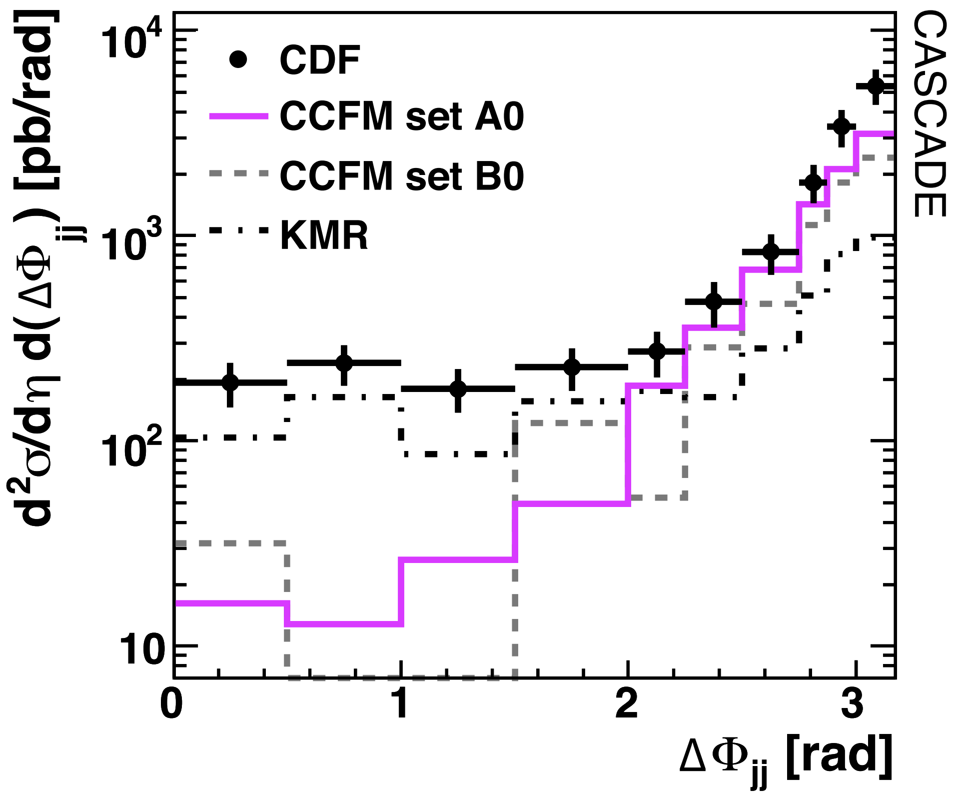


Unintegrated PDFs

- uPDFs in charm and beauty production show similar behaviour:
- Underestimation of the data at large and small angular correlations

➡ Solvable problem?



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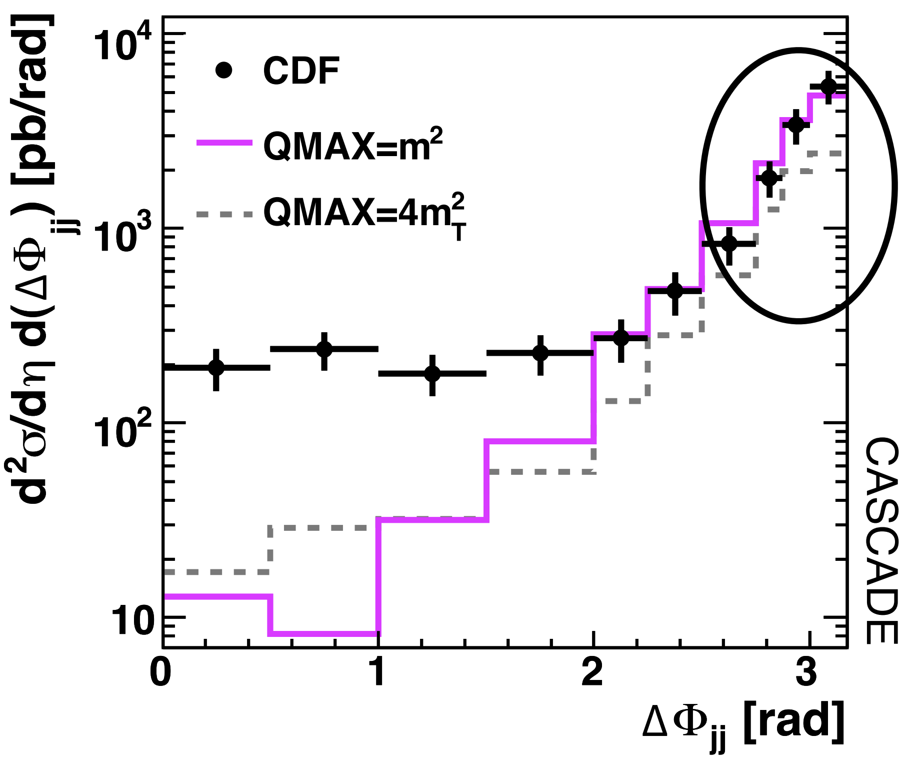
Final State Parton Shower I

- Here: only final state parton shower using CASCADE
- Change of final state parton shower scale:

$$\texttt{QMAX} = 4\mathrm{m}_\mathrm{T}^2 \rightarrow \texttt{QMAX} = \mathrm{m}^2, \text{ with m: quark mass}$$

➡ Lower scale: less gluon radiations lead to higher correlation of the jets



- But: tail not described
- Contributions of $gg \rightarrow gg$ are expected to be dominant here

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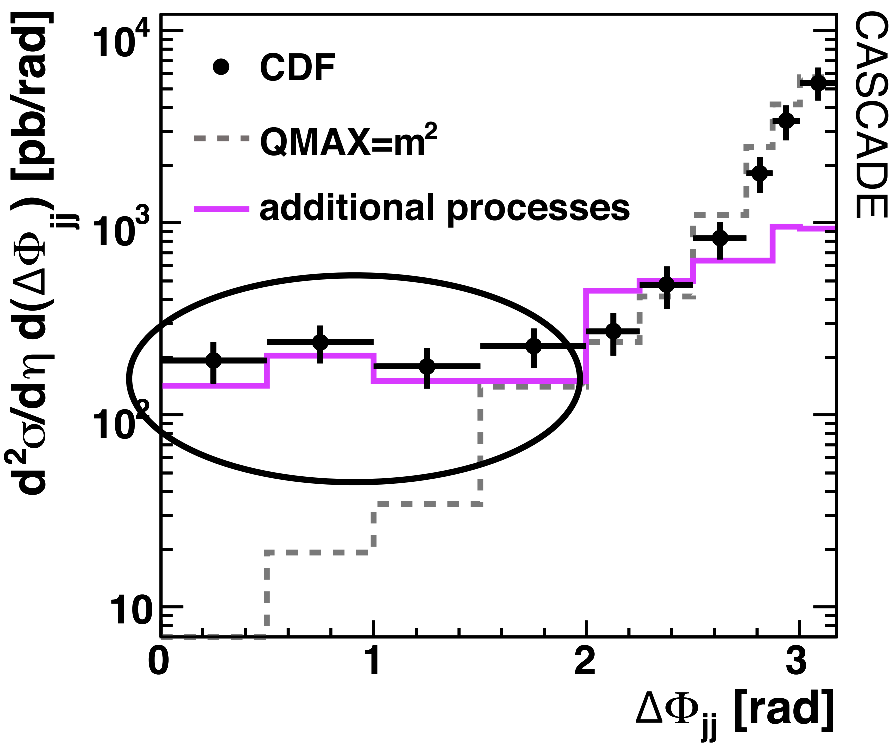
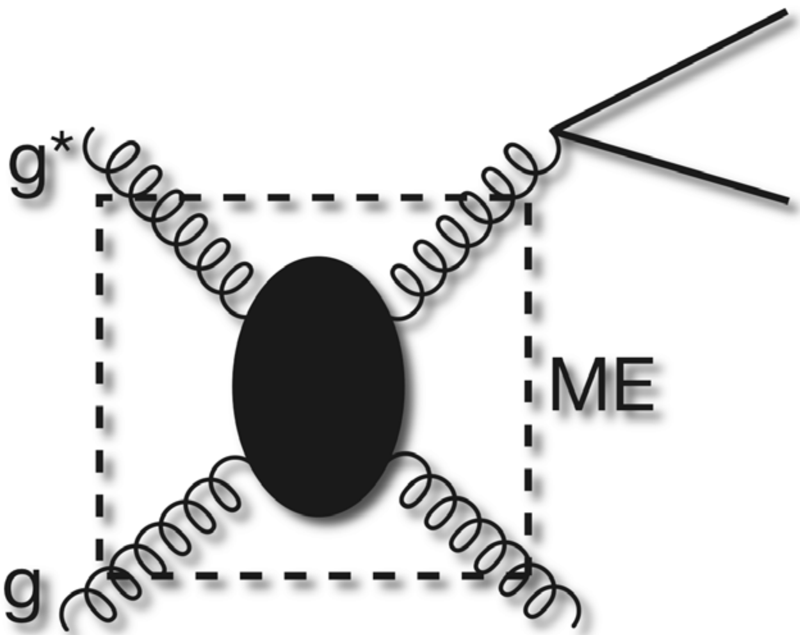
Final State Parton Shower II

- Additional processes: $gg \rightarrow gg,\ gq \rightarrow gq$
- See talk of M. Deak, K. Kutak, this conference

  M.Deak, F.Hautmann, H.Jung, K.Kutak, JHEP0909 : 121, 2009

➡ Small angular separations of the dijet system are now described as well





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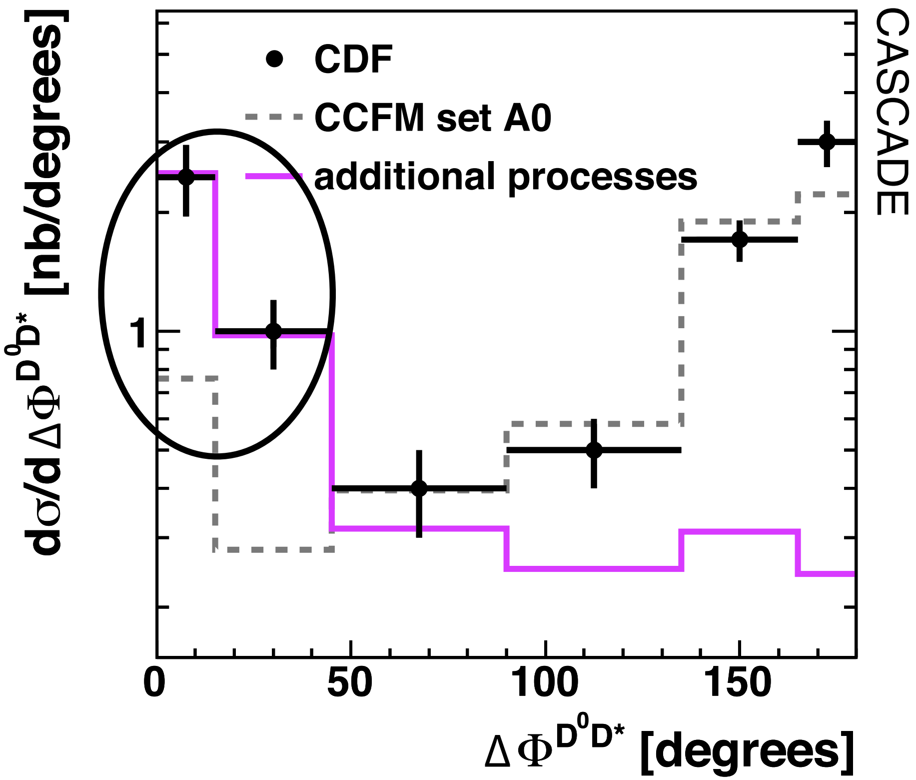
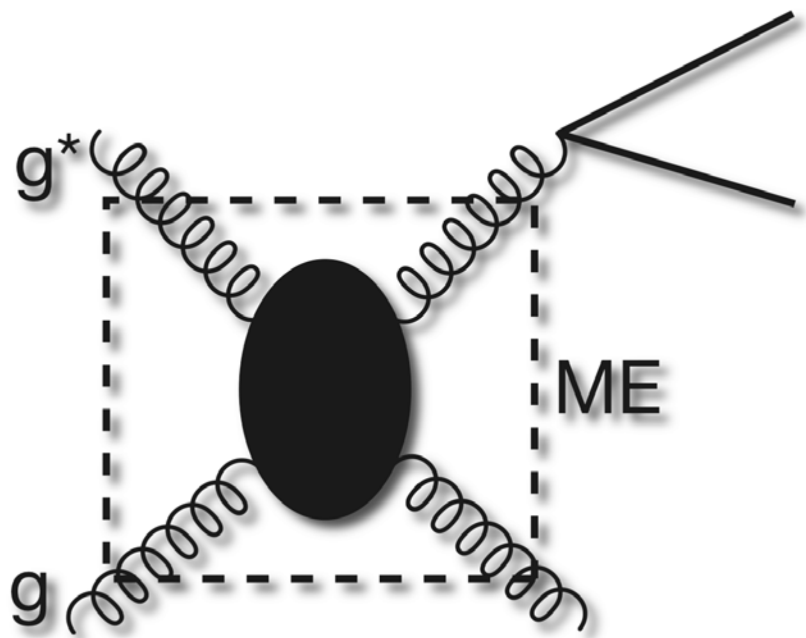
Final State Parton Shower III

- Additional processes: $gg \rightarrow gg,\ gq \rightarrow gq$

➡ Small angular separations are now described as well in charm production





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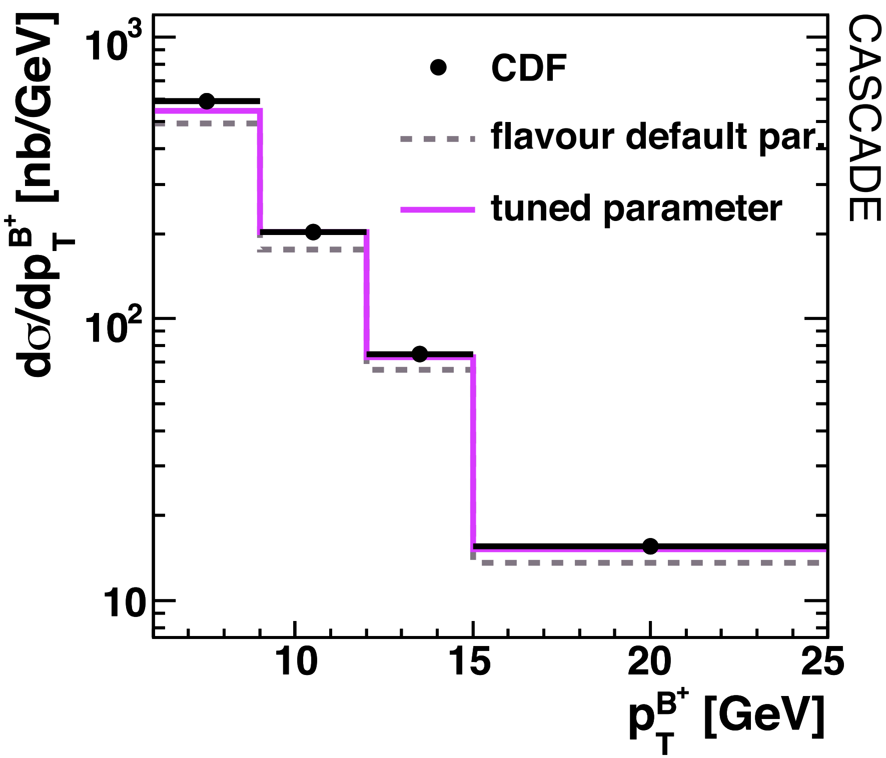
Systematic Uncertainties

- Used default and tuned fragmentation parameters from Professor
  $\mathtt{http://projects.hepforge.org/professor}$
- Table with parameters can be found in the backup

➡ Better description of the data for beauty and charm production



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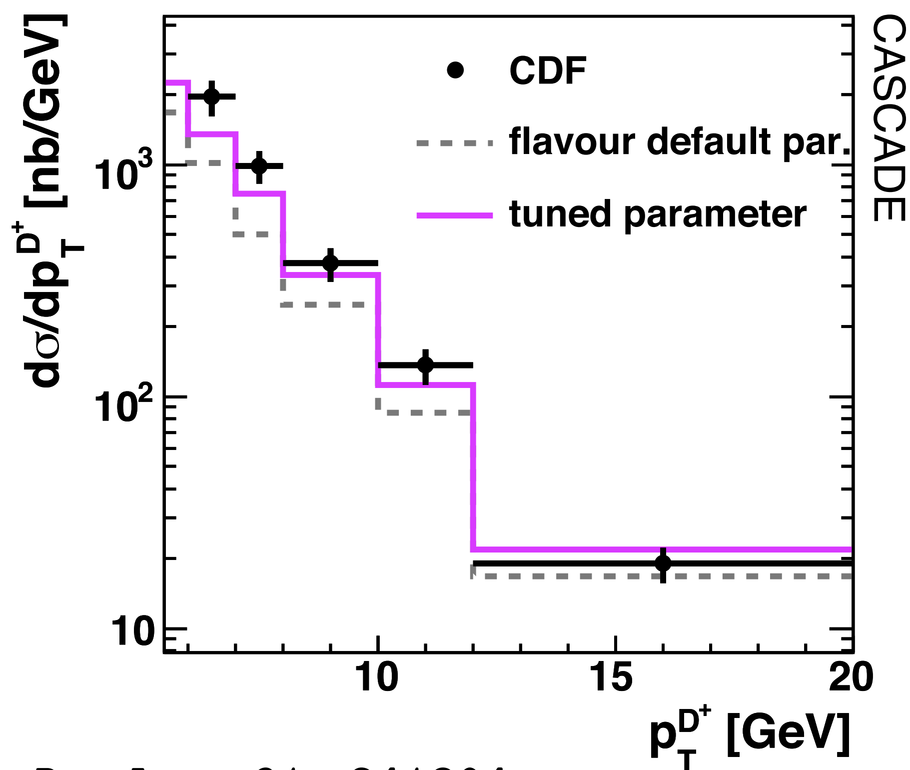
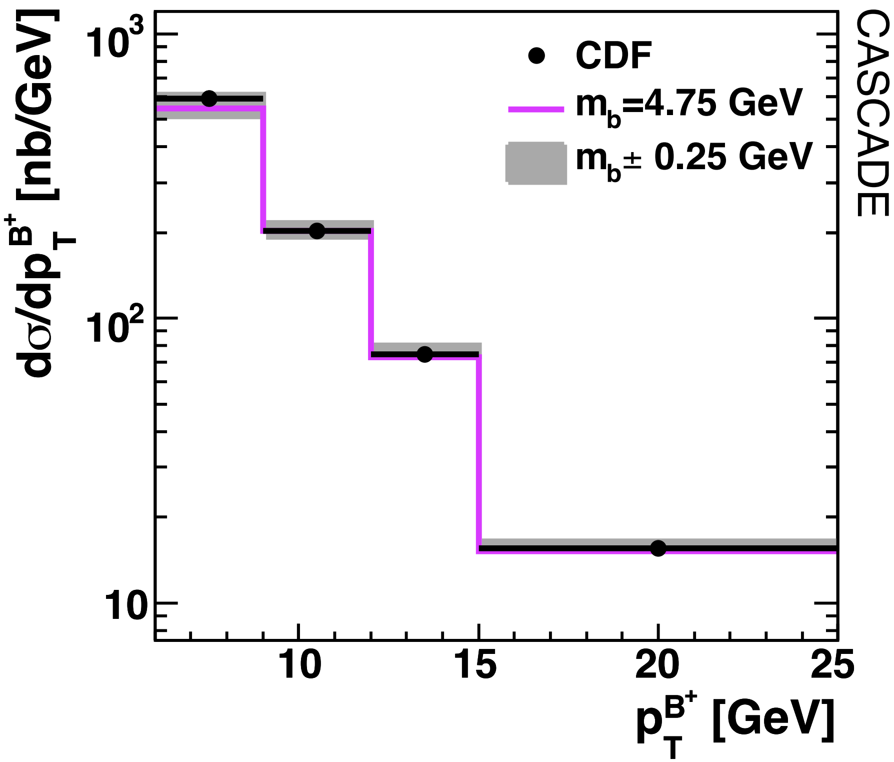


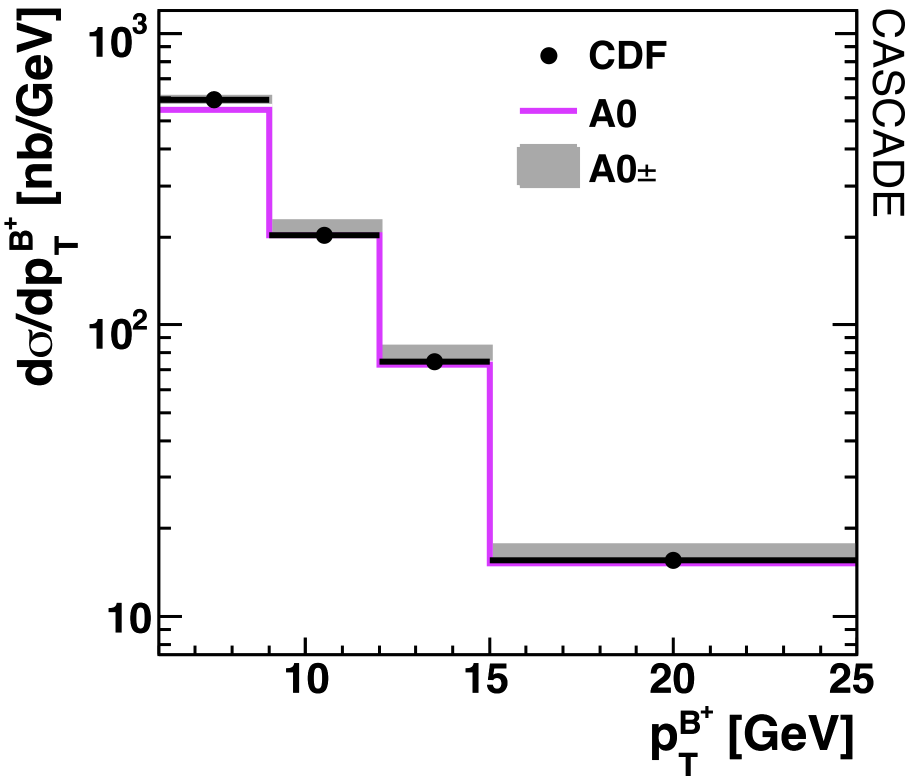
$\mathtt{Phys.Rev.Lett.91:241804}$

Systematic Uncertainties

- Variation of the beauty quark mass: $\mathrm{m_b} = 4.75\mathrm{GeV} \pm 0.25\mathrm{GeV}$
- Variation of the scale by a factor of 2 up and down

➡ Sensitivity to the beauty quark mass $\mp^{9\%}_{10\%}$ and the scale ~11%





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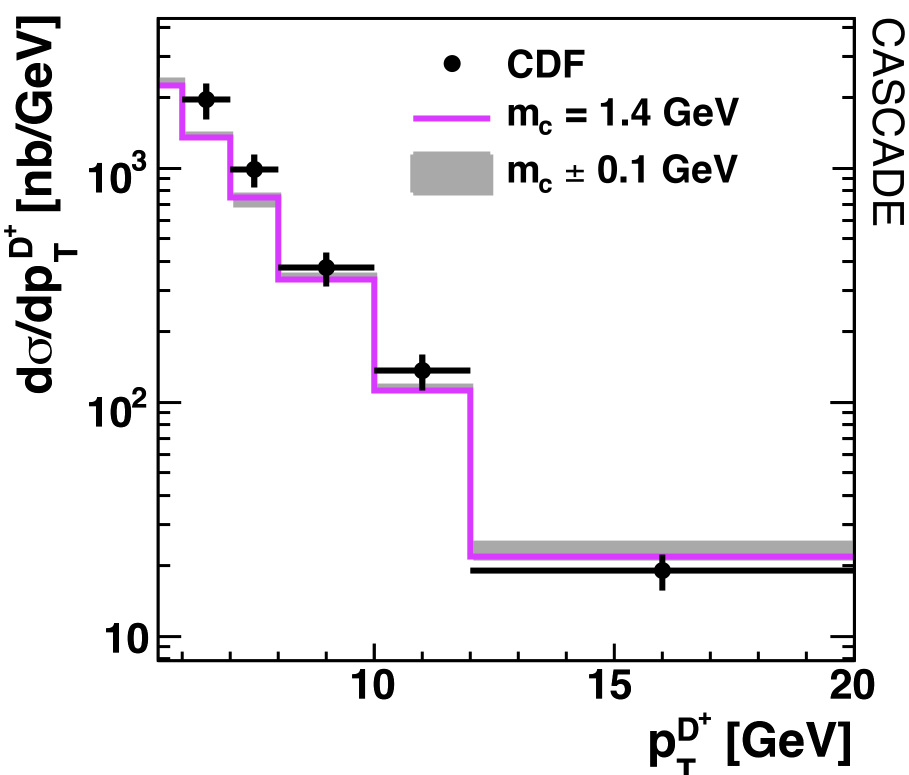
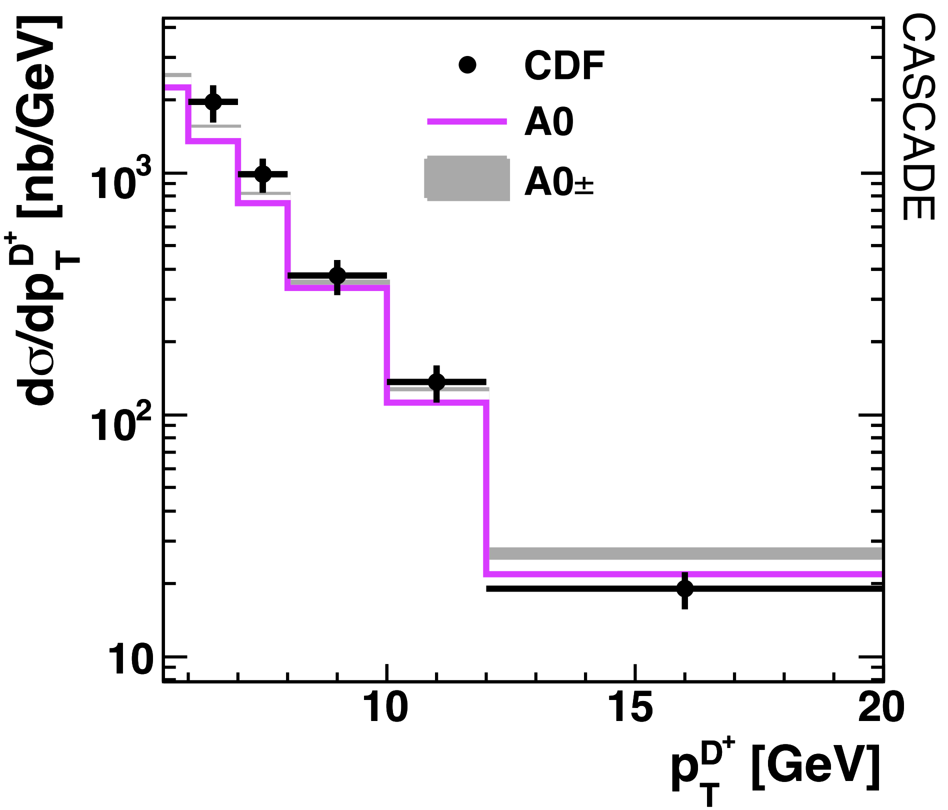
Systematic Uncertainties

- Variation of the charm quark mass: $\mathrm{m_c} = 1.4\mathrm{GeV} \pm 0.1\mathrm{GeV}$
- Variation of the scale by a factor of 2 up and down

➡ Sensitivity to the charm quark mass $\mp^{5\%}_{4\%}$ and to the scale ~13%





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Summary of Systematic Uncertainties

Source / Cross Section	$\sigma(B^+)$ [μb]	$\sigma(D^+)$ [μb]
CDF Data	2.78 ± 0.24	$4.31 \pm 0.1 \pm 0.7$
CCFM set A0	$2.62\pm^{0.39}_{0.37}$	$3.17\pm^{0.41}_{0.86}$
CCFM set A0+	$+11\%$	$+10\%$
CCFM set A0-	$+1\%$	$+8\%$
Quark Mass Variation up	-9%	-5%
Quark Mass Variation down	$+10\%$	$+4\%$
Flavour default parameter	-10%	-27%
Total	$\pm^{15\%}_{14\%}$	$\pm^{13\%}_{27\%}$

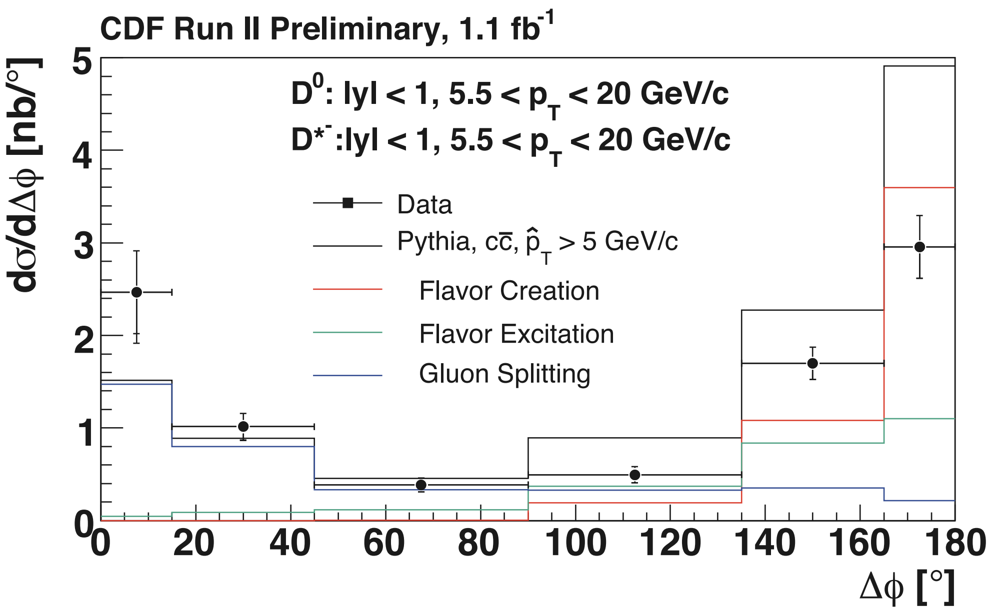
Summary

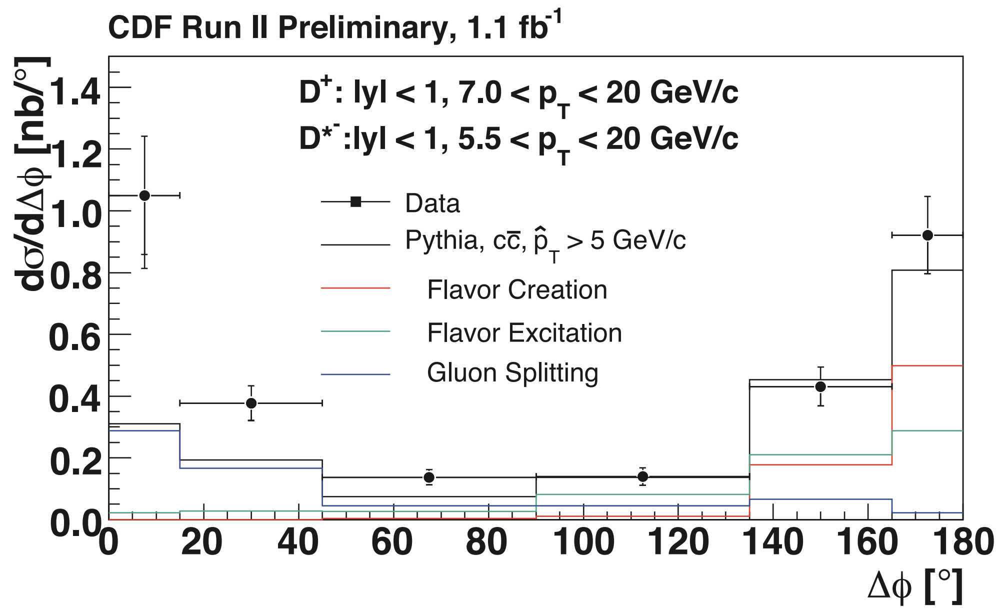
- Presented CASCADE predictions and numerical calculations for charm and beauty analyses sensitive to non-collinear gluon dynamics at Tevatron
- Differences of unintegrated gluon densities clearly visible in variables sensitive to higher order contributions
- Behaviour of final state parton shower plays an important role
  - obtain perfect description of the $\Delta\Phi_{\mathrm{jj}}$ peak in beauty production by decreasing the final state parton shower scale
- Additional processes $gg \rightarrow gg$
  - small angular correlations are now described for beauty and charm production

➡ Theoretical predictions using the CCFM approach are able to describe Heavy Flavour production at Tevatron within systematic errors

Backup

Charm Tevatron Analysis





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Professor Parameter

Flavour and Fragmentation Parameters tuned to LEP data

Tuned parameters

MSTJ(11)	5
PARJ(21)	0.325
PARJ(41)	0.5
PARJ(42)	0.6
PARJ(47)	0.67
PARJ(81)	0.29
PARJ(82)	1.65

Default parameters

MSTJ(11)	4
PARJ(21)	0.36
PARJ(41)	0.3
PARJ(42)	0.58
PARJ(47)	1.0
PARJ(81)	0.29
PARJ(82)	1.0

Tuned parameters

PARJ(1)	0.073
PARJ(2)	0.2
PARJ(3)	0.94
PARJ(4)	0.032
PARJ(11)	0.31
PARJ(12)	0.4
PARJ(13)	0.54
PARJ(21)	0.313
PARJ(25)	0.63
PARJ(26)	0.12

Default parameters

PARJ(1)	0.1
PARJ(2)	0.3
PARJ(3)	0.4
PARJ(4)	0.05
PARJ(11)	0.5
PARJ(12)	0.6
PARJ(13)	0.75
PARJ(25)	1.0
PARJ(26)	0.4

Additional settings

MSTJ(11)	5
PARJ(1)	0.073
PARJ(2)	0.2
PARJ(3)	0.94
PARJ(4)	0.032
PARJ(11)	0.31
PARJ(12)	0.4
PARJ(13)	0.54
PARJ(25)	0.63
PARJ(26)	0.12

http://projects.hepforge.org/professor