

# ***Benchmark cross sections for heavy flavour production at HERA and LHC***

***(coord: M. Corradi, A. Dainese)***

- ◆ **Motivation** (M.Corradi)
- ◆ **Calculation frameworks and uncertainty bands** (M.Corradi)
- ◆ **Cross sections for HERA (PhP)** (M.Corradi, M.Cacciari, B.Kniehl et al., H.Jung)
- ◆ **Cross sections for HERA (DIS)** (E.Laenen, B.Kniehl et al., H.Jung, O.Behnke)
- ◆ **Cross sections for the LHC** (A.Dainese, M.Cacciari, K.Peters, G.Barbagli, B.Kniehl et al., N.Zotov?)
- ◆ **Beauty production in PYTHIA/JetWeb at SppS, Tevatron, HERA and LHC** (O.Gutsche, A.Geiser, A.Dainese)

# *Motivation*

- ◆ Produce a compilation of the present theoretical knowledge and produce a set of plots/numbers to be used for future comparison
- ◆ Compare directly different theoretical approaches in different environments (PhP, DIS, pp)
  - ⊕ possibly using a common definition of uncertainty bands

## *Which cross sections*

- ◆ Close to experimental observables, but with only simple acceptance-like cuts
- ◆ e.g.  $d\sigma/dp_T$  in given rapidity range(s)
- ◆ “critical” observables, as  $p_T$  and  $\phi$  correlations, for which models may differ
- ◆ basic results at quark and hadron level

# How and Who

Theory	Interaction	Program	Calulator	
Massive NLO	LHC	MNR	A. Dainese	✓
Massive NLO	HERA DIS	HVQDIS	E. Laenen	
Massive NLO	HERA PhP	FMNR	M. Corradi	✓
matched massive/massless	HERA PhP, LHC	FONLL	M. Cacciari	✓
matched massive/massless	HERA PhP, LHC	GM-VFNS	B. Kniehl	
VFNS PDFs	HERA DIS	-	B. Kniehl	
$K_T$ factorization	LHC	-	N. Zotov	
Non-lin $g(x)$ (Kohlinen...)	HERA DIS, LHC	MNR	A. Dainese	✓
CCFM uPDF MC	PhP, DIS, LHC	CASCADE	H. Jung	
MC@NLO	LHC	MC@NLO	G. Barbagli	
LO+PS MC	HERA PhP	Pythia	A. Geiser, O. Gutsche	
LO+PS MC	LHC	Pythia	A. Dainese	✓
LO+PS MC	DIS	Rapgap	O. Behnke	

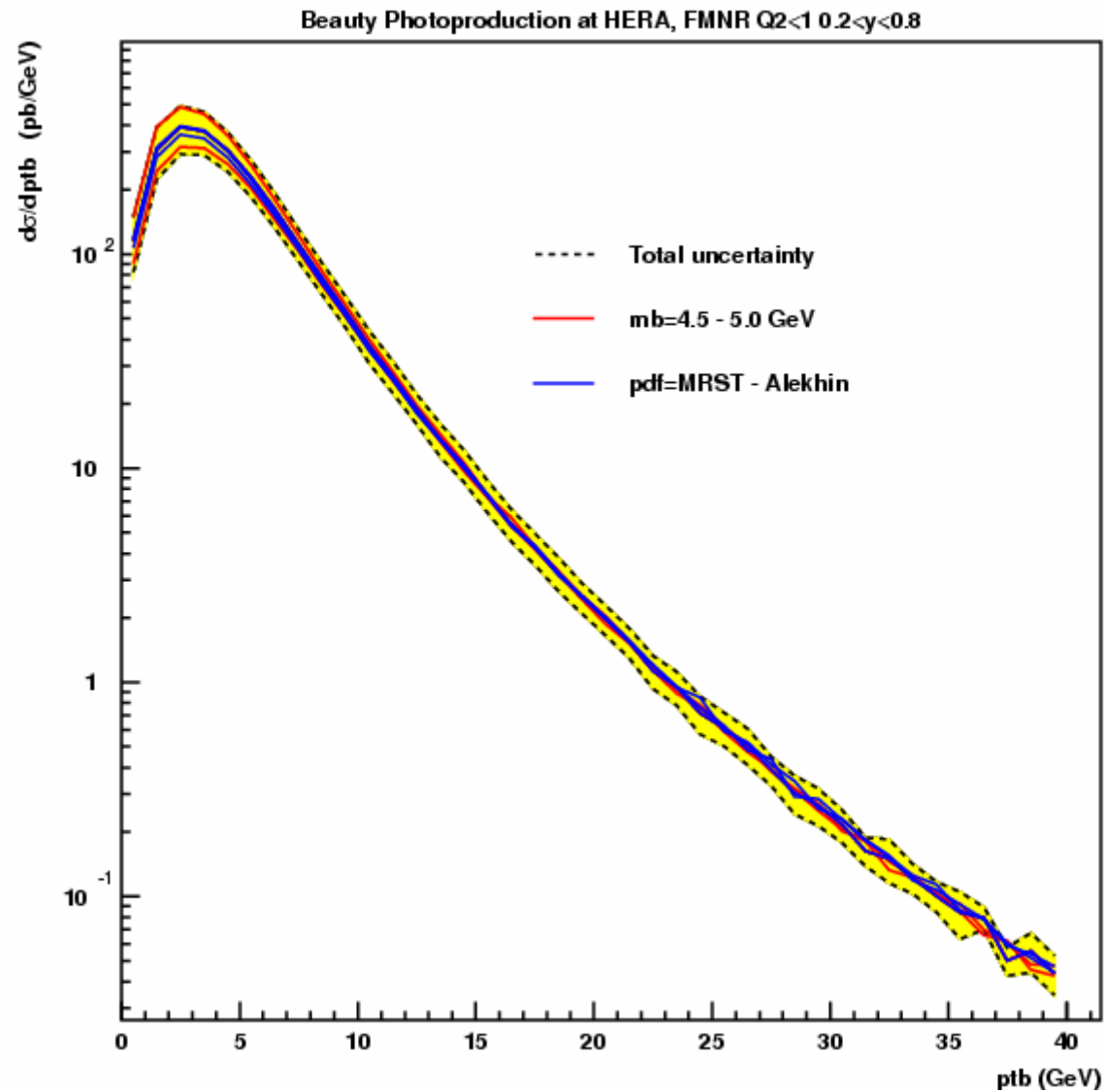
# Variation of parameters

Proposed parameters and systematics (at least for FO programs)

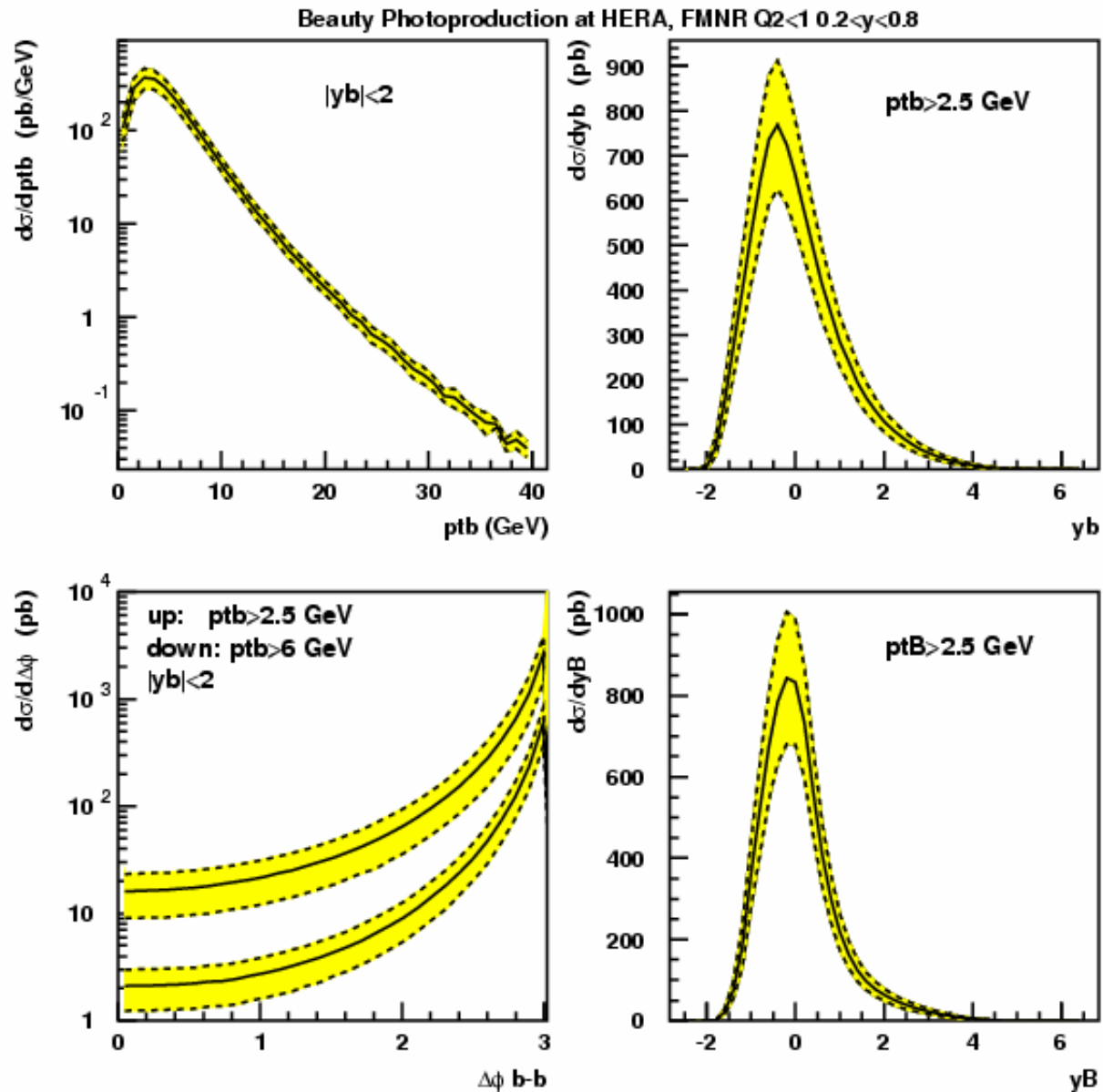
Parameter	nominal	variation
PDF	CTEQ6.1	do “error analysis” or use Alekin/MRST ?
$\alpha_S$	$\alpha_S(M_Z) = 0.1182$ ( $\Lambda_5^{MS} = 0.226$ )	$\pm 0.0020$
$\mu_R$	$\sqrt{m_T^2 + Q^2}$	$\times 2, \times 1/2$
$\mu_F$	$\sqrt{m_T^2 + Q^2}$	$\times 2, \times 1/2$
$m_c$	<b>1.5 GeV</b>	<b>1.3 - 1.7 GeV</b>
$m_b$	<b>4.75 GeV</b>	<b>4.5 - 5.0 GeV</b>
$\epsilon_c$	<b>0.04</b>	<b>0.02 - 0.06</b>
$\epsilon_b$	<b>0.0035</b>	<b>0.002 - 0.005</b>

- Total uncertainty band as quadratic sum of single-parameter bands

# Beauty PhP at HERA – FMNR (M. Corradi)

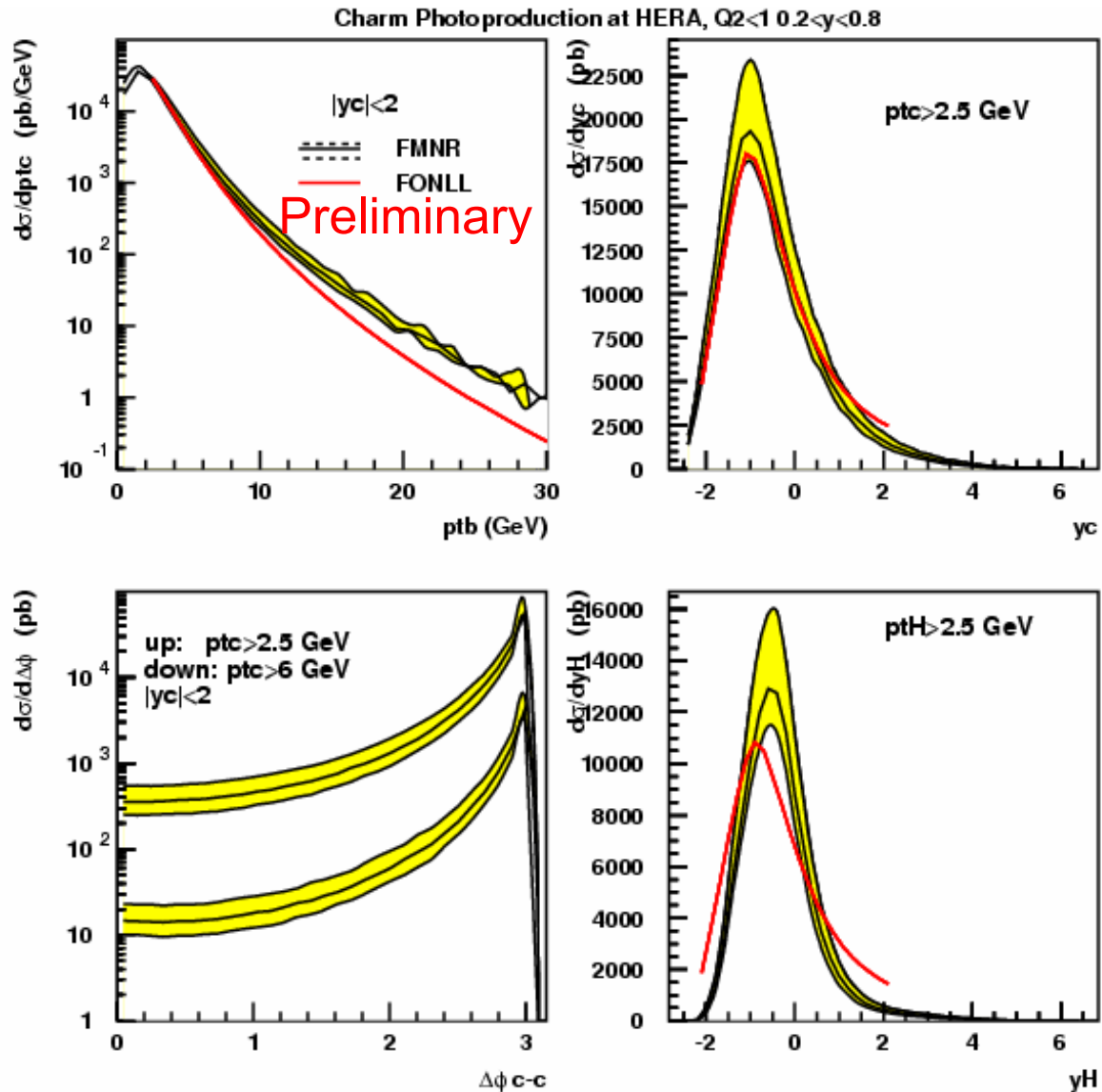


# Beauty PhP at HERA – FMNR (M. Corradi)



# Beauty PhP at HERA

## FMNR (M. Corradi) – FONLL (M. Cacciari)





# Charm at LHC – MNR (A.Dainese)

Parameters and resulting total cross sections are:

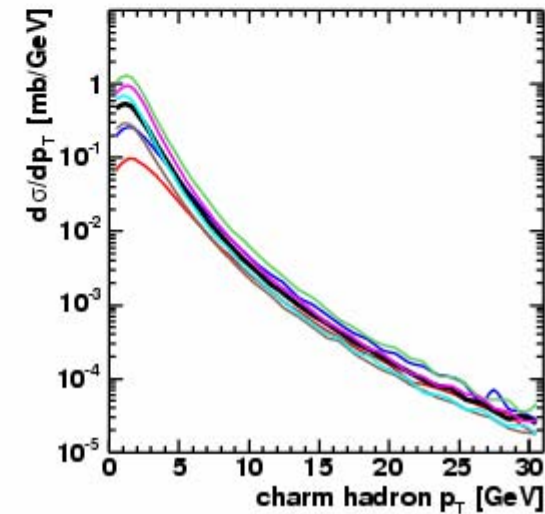
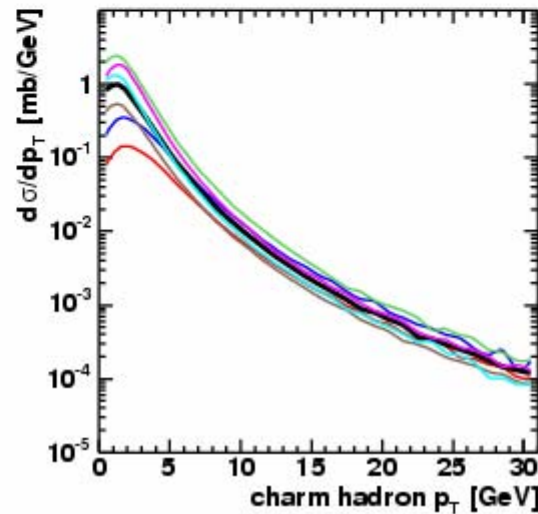
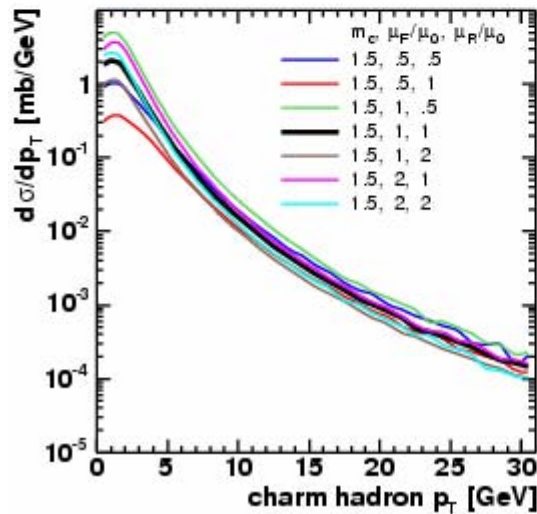
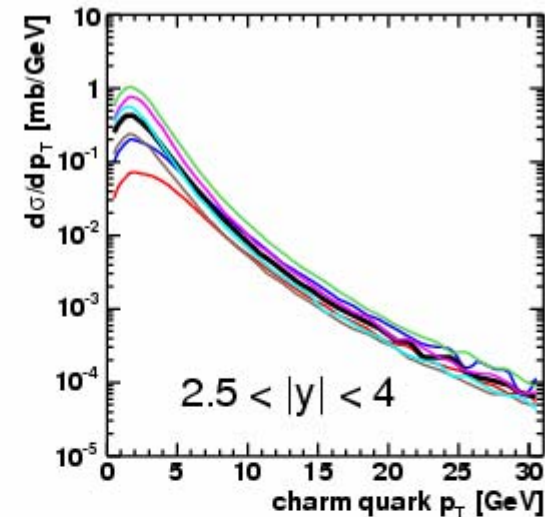
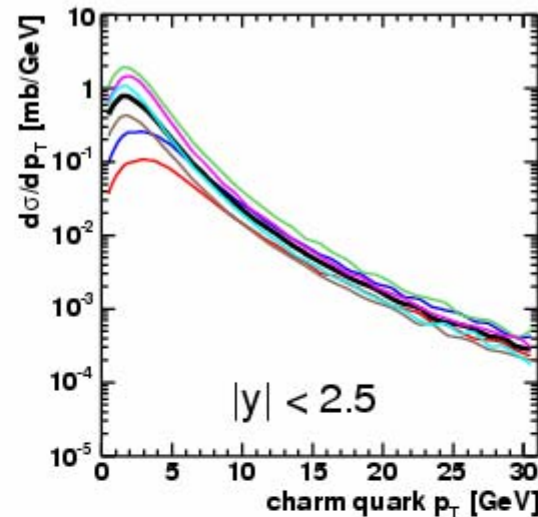
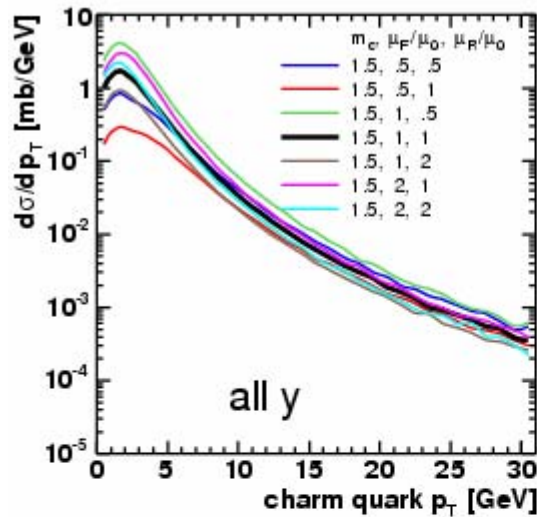
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$\langle kt^2 \rangle = 1 \text{ GeV}^2$

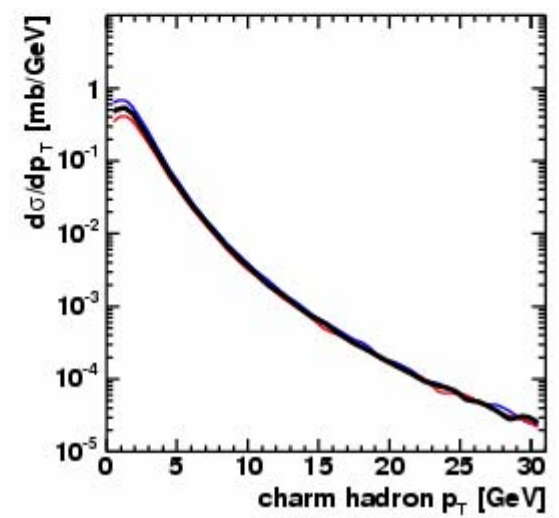
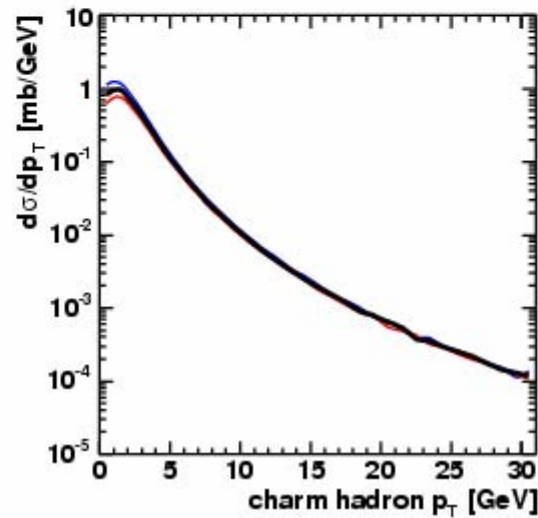
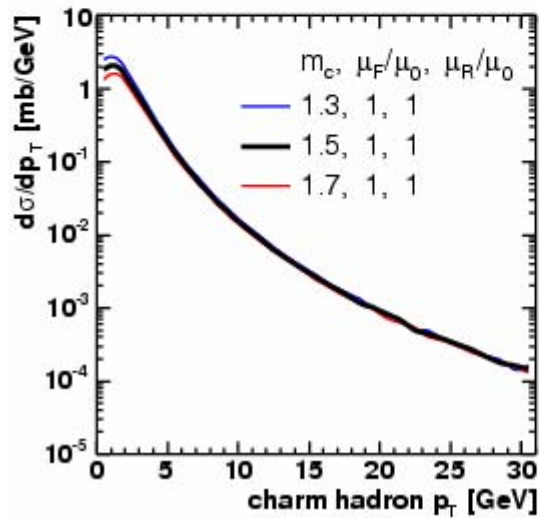
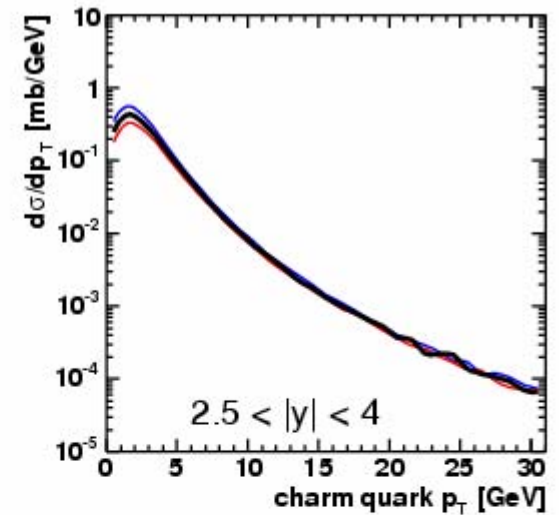
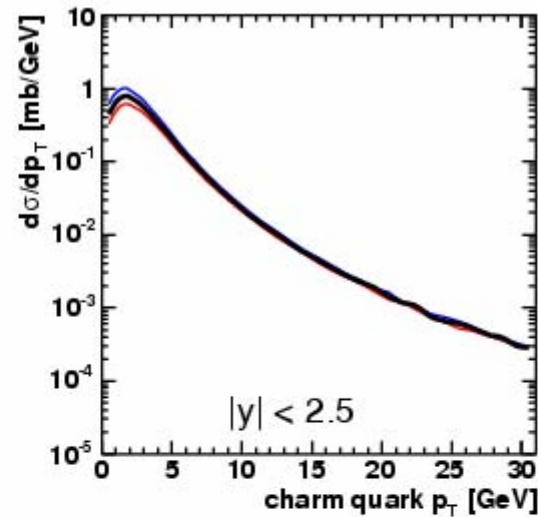
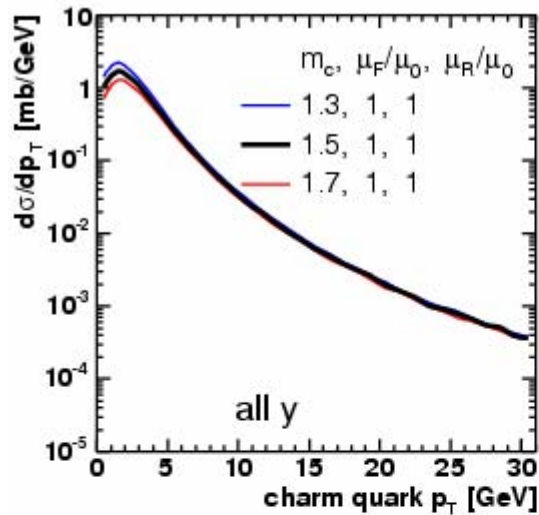
mc[GeV]	muF/mu0	muR/mu0	eps_Peterson	sigma_ccbar [mb]
***** This is the baseline *****				
1.5	1	1	0.03	6.06
***** Variation of scales *****				
1.5	0.5	0.5	0.03	3.67
1.5	0.5	1	0.03	1.52
1.5	1	0.5	0.03	14.09
1.5	1	1	0.03	6.06
1.5	1	2	0.03	3.38
1.5	2	1	0.03	10.37
1.5	2	2	0.03	7.22
***** Variation of charm mass *****				
1.3	1	1	0.03	7.69
1.7	1	1	0.03	4.81
***** Variation of eps_Peterson *****				
1.5	1	1	0.01	6.06
1.5	1	1	0.06	6.06

[ where  $\mu_0 = \sqrt{mc^2 + (p_{tc}^2 + p_{t\bar{c}}^2)/2}$  ]

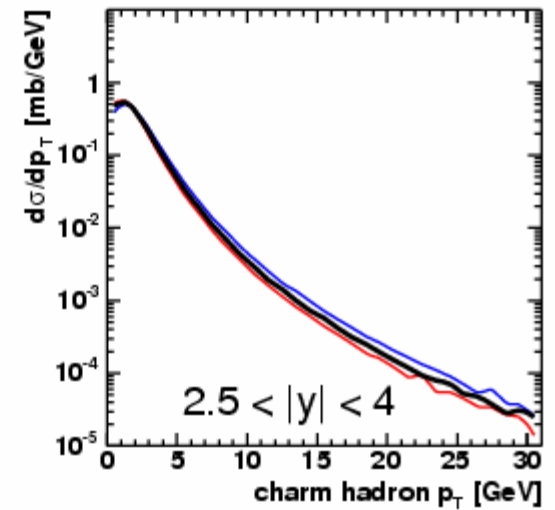
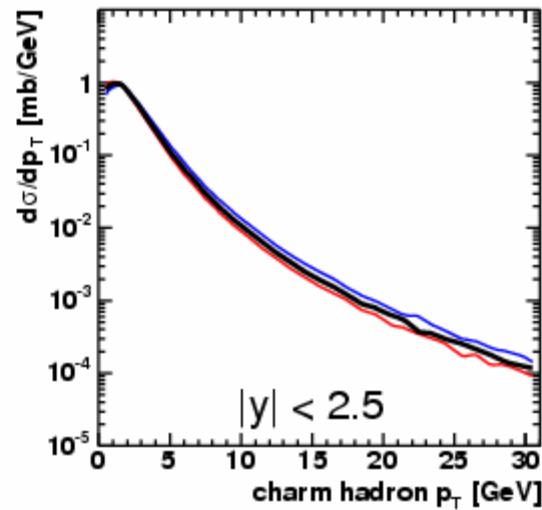
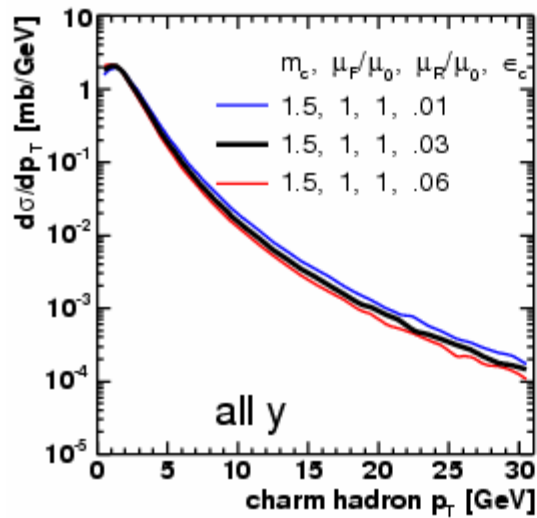
# Charm at LHC – MNR (A.Dainese)



# Charm at LHC – MNR (A.Dainese)

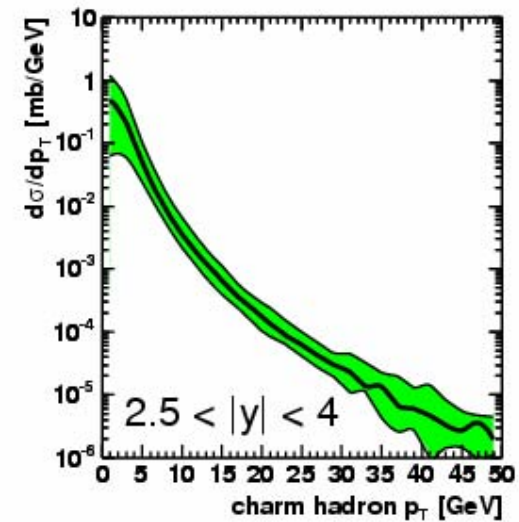
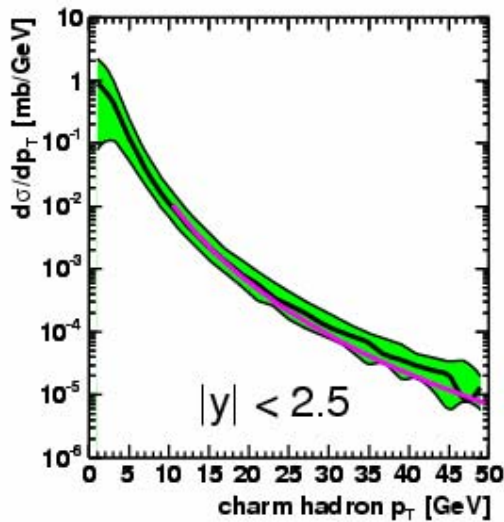
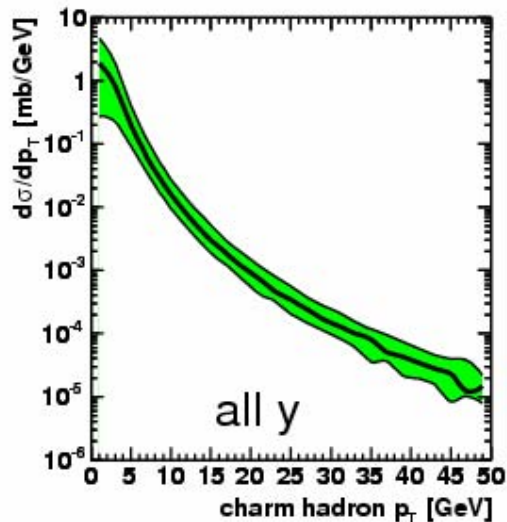
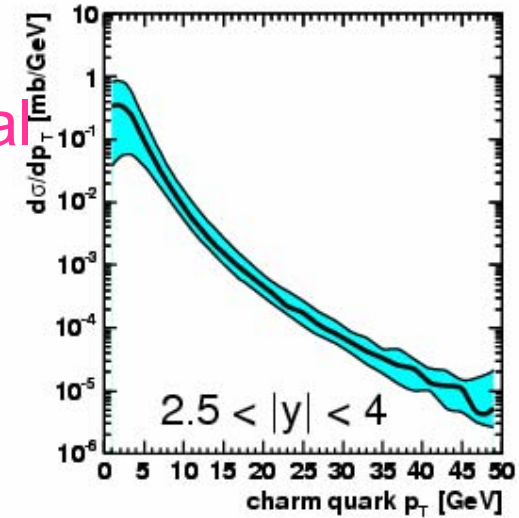
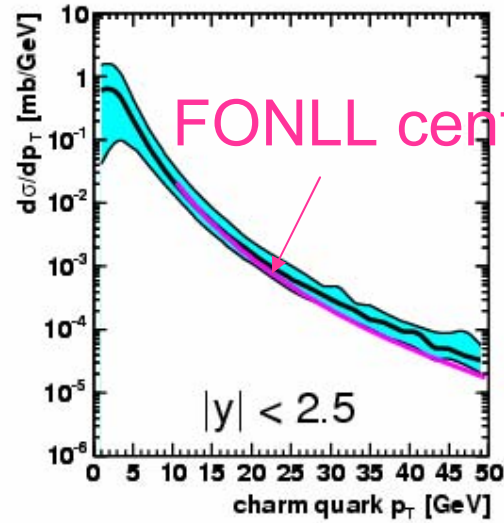
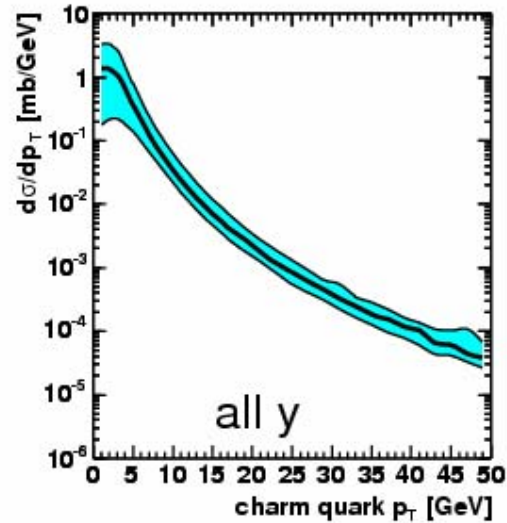


# Charm at LHC – MNR (A.Dainese)

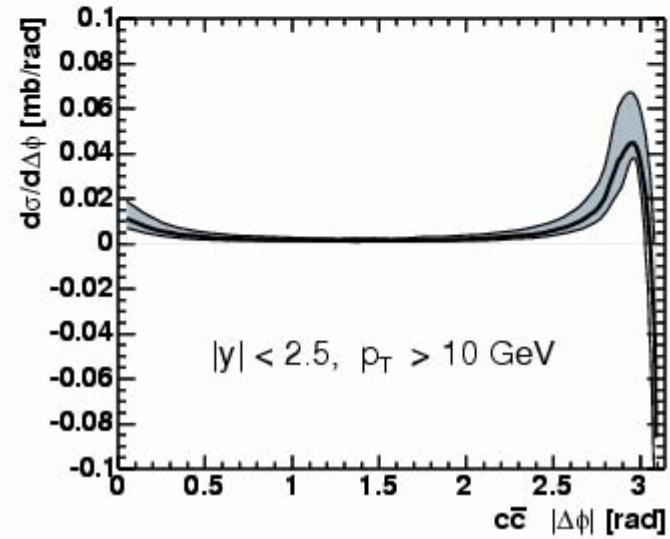
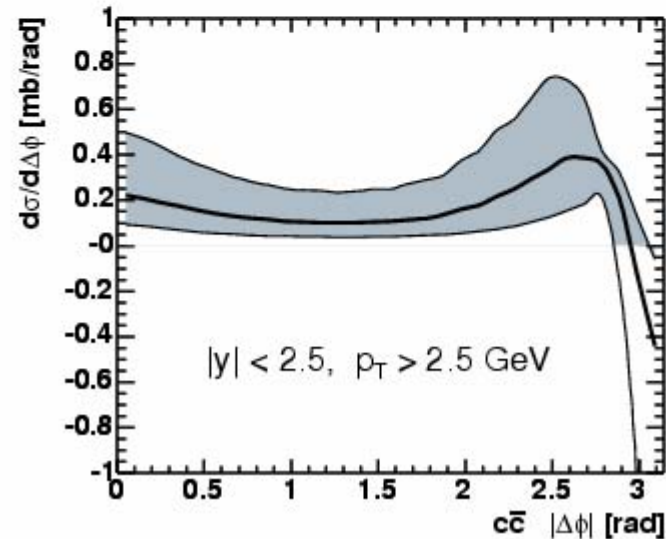
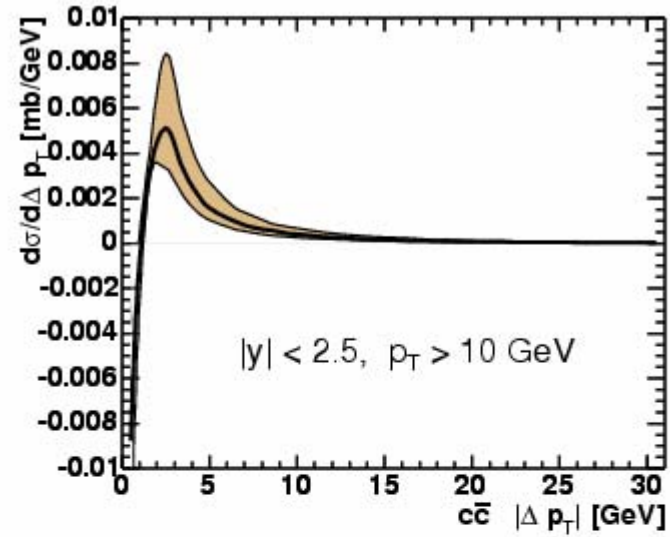
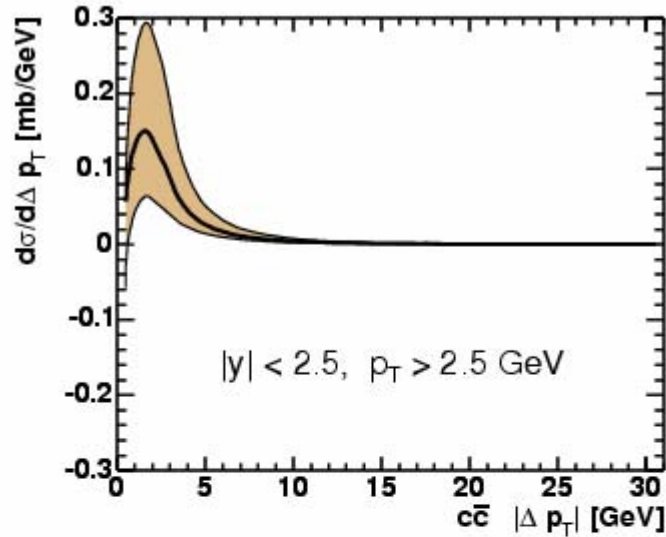


# Charm at LHC

*MNR* (A.Dainese) – *FONLL* (M.Cacciari)



# Charm at LHC – MNR (A.Dainese)



# Beauty at LHC – MNR (A.Dainese)

Parameters and resulting total cross sections are:

PDF set = CTEQ6M

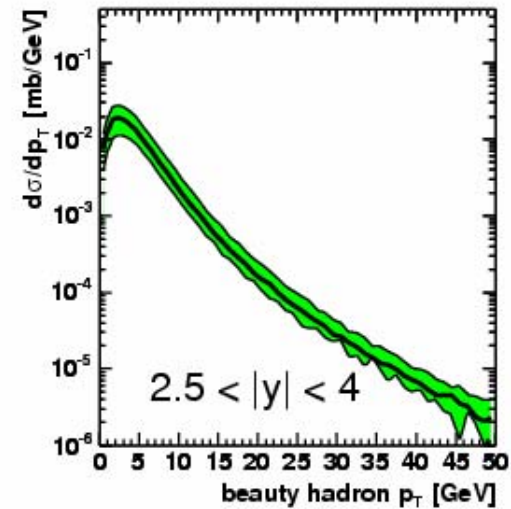
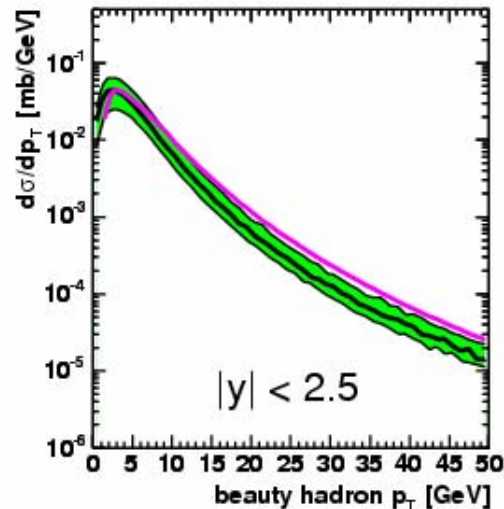
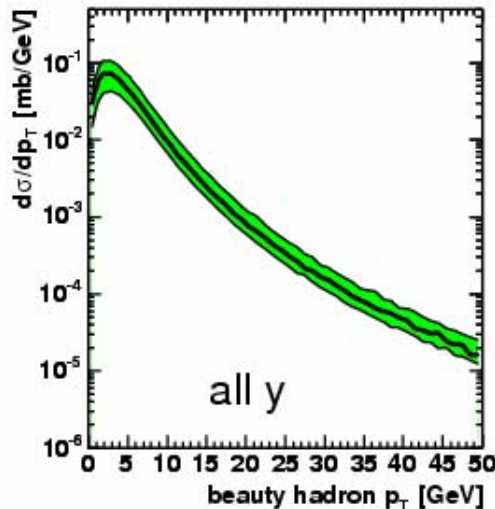
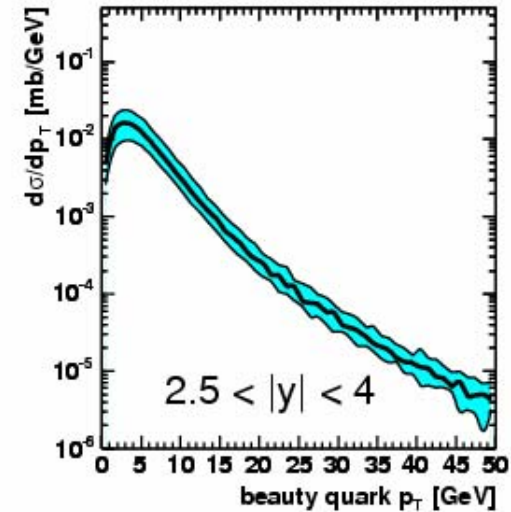
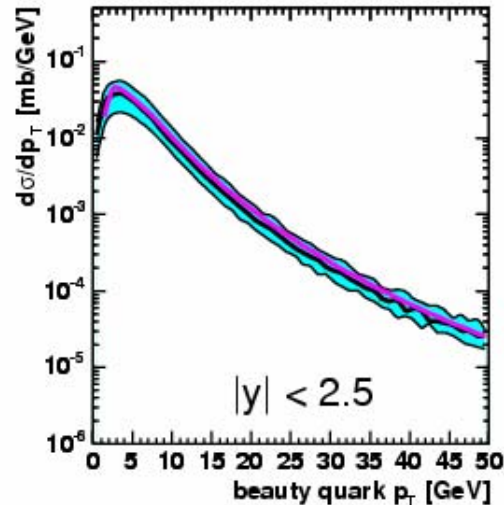
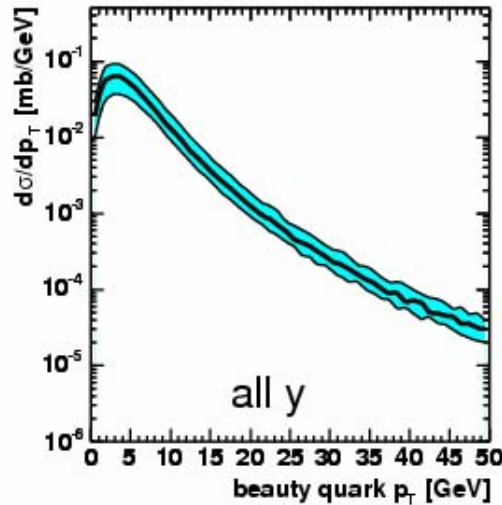
$\langle kt^2 \rangle = 1 \text{ GeV}^2$

mb[GeV]	muF/mu0	muR/mu0	eps_Peterson	sigma_bbbar [mb]
***** This is the baseline *****				
4.75	1	1	0.004	0.445
***** Variation of scales *****				
4.75	0.5	0.5	0.004	0.475
4.75	0.5	1	0.004	0.294
4.75	1	0.5	0.004	0.648
4.75	1	1	0.004	0.445
4.75	1	2	0.004	0.324
4.75	2	1	0.004	0.536
4.75	2	2	0.004	0.420
***** Variation of beauty mass *****				
4.50	1	1	0.004	0.518
5.00	1	1	0.004	0.384
***** Variation of eps_Peterson *****				
4.75	1	1	0.001	0.445
4.75	1	1	0.006	0.445

[ where  $\mu_0 = \sqrt{mb^2 + (pt_b^2 + pt_{\bar{b}}^2)/2}$  ]

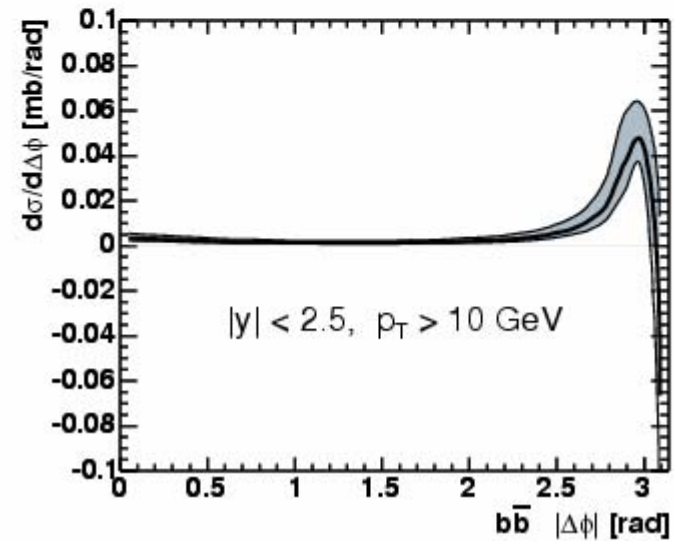
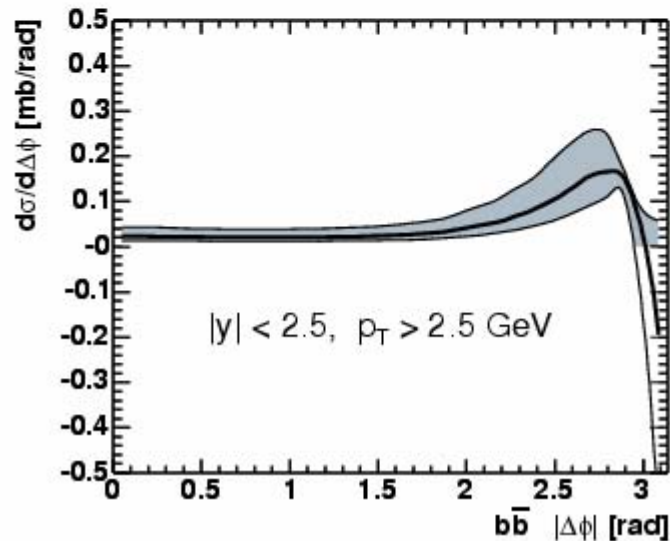
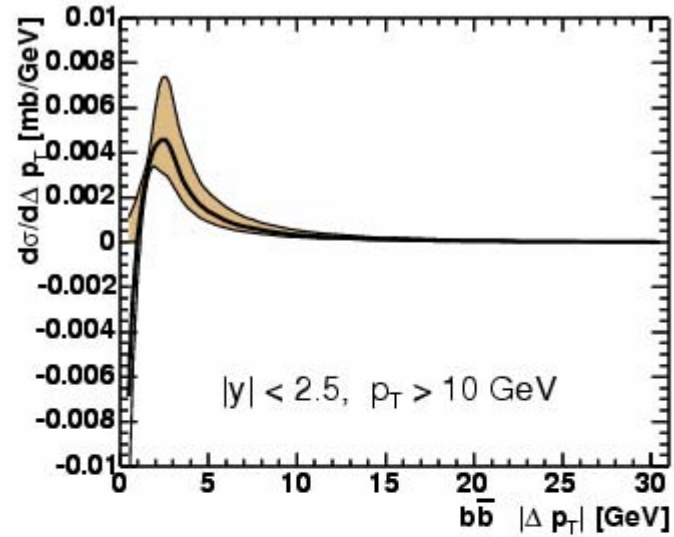
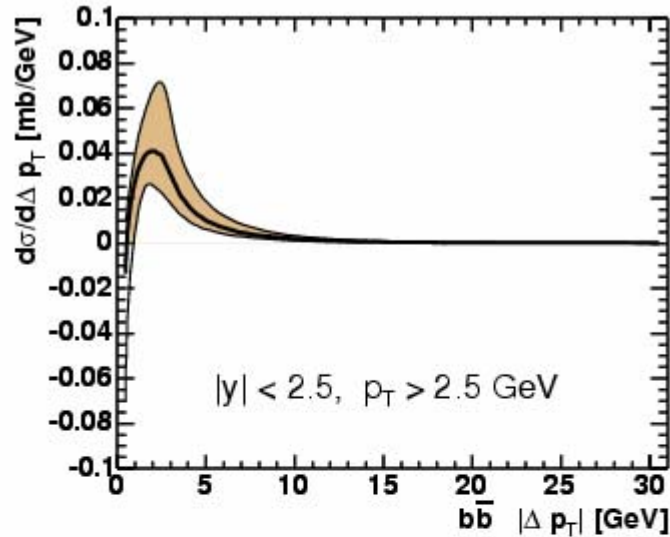
# Beauty at LHC

## MNR (A.Dainese) – FONLL (M.Cacciari)

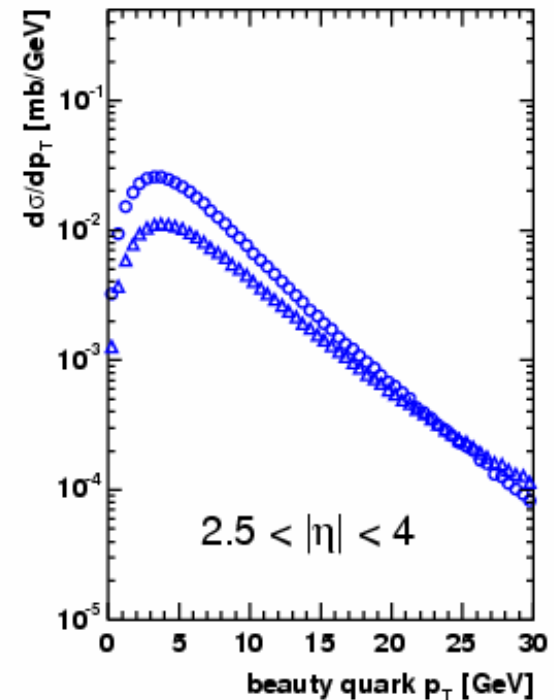
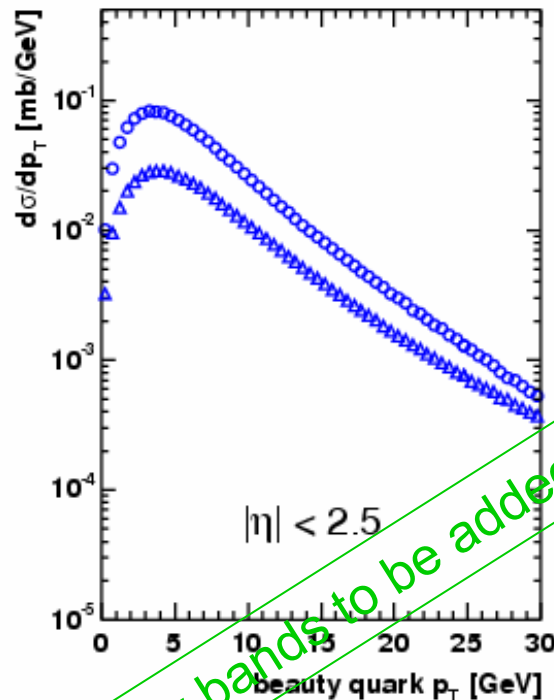
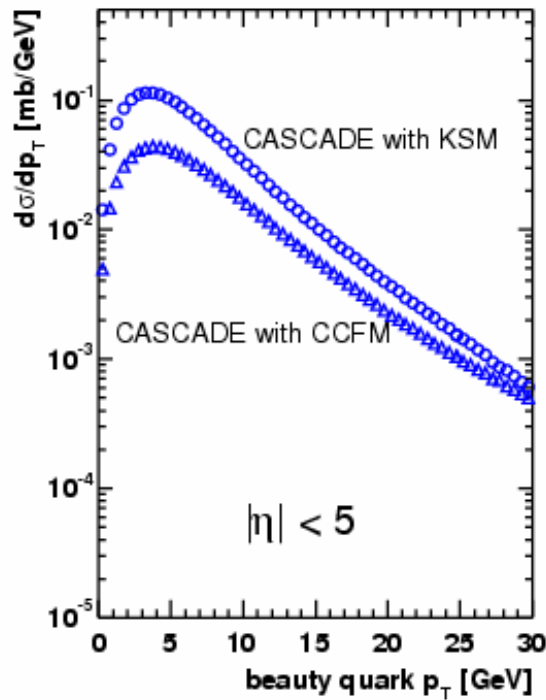




# Beauty at LHC – MNR (A.Dainese)



# Beauty at LHC – Cascade (K.Peters)

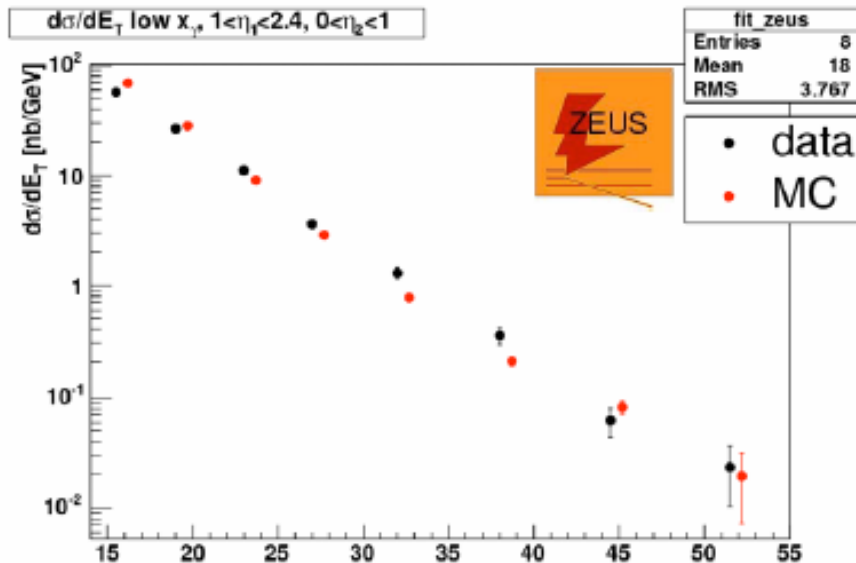


uncertainty bands to be added

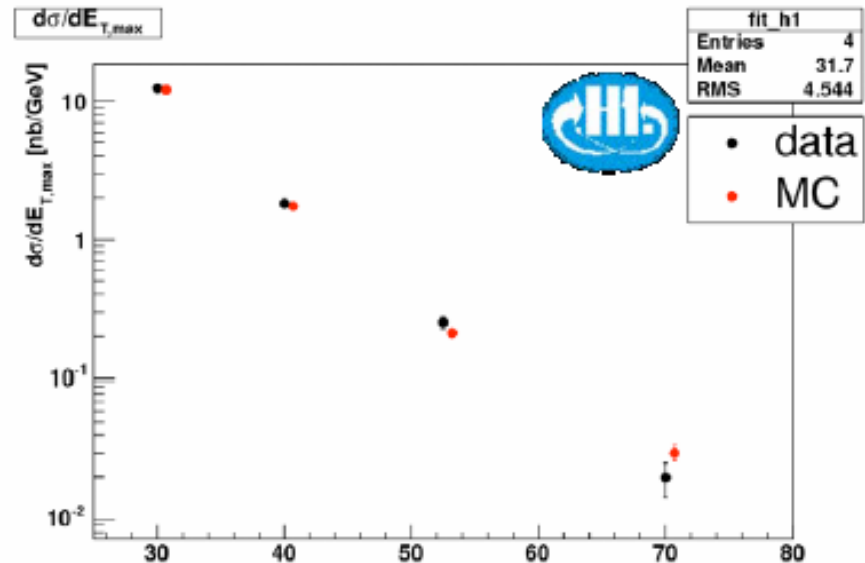
# Beauty with *PYTHIA*/JetWeb at SppS, Tevatron, HERA (O.Gutsche, A.Geiser)

- Generator: **PYTHIA**
  - inclusive mode
  - Proton PDF: CTEQ5L
  - Photon PDF: GRV LO
  - min. trans. momentum: 3 GeV/c
  - JetWeb scale = **1.45**

**MC normalization ( $\times 1.45$ ) fixed from high  $E_T$  jets at HERA**

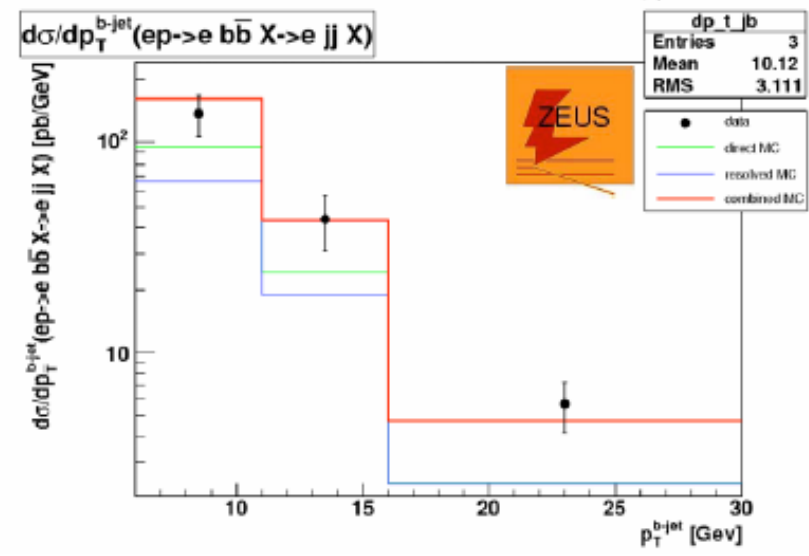
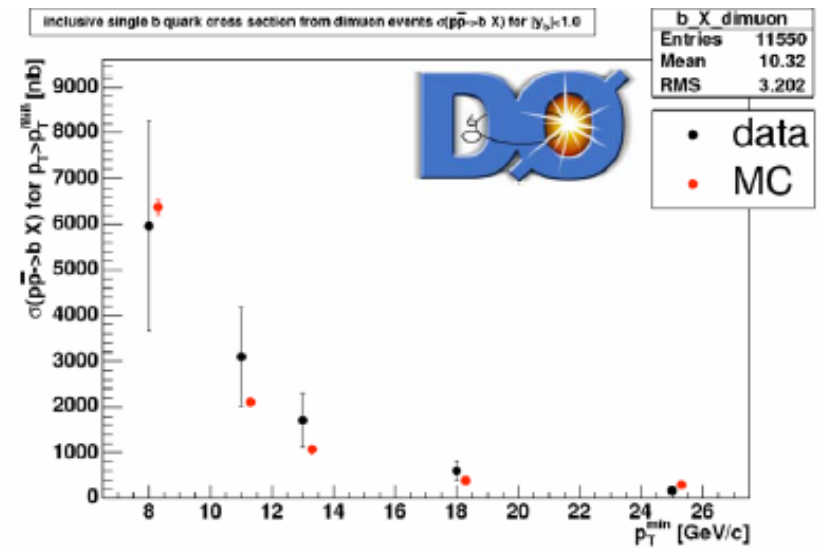
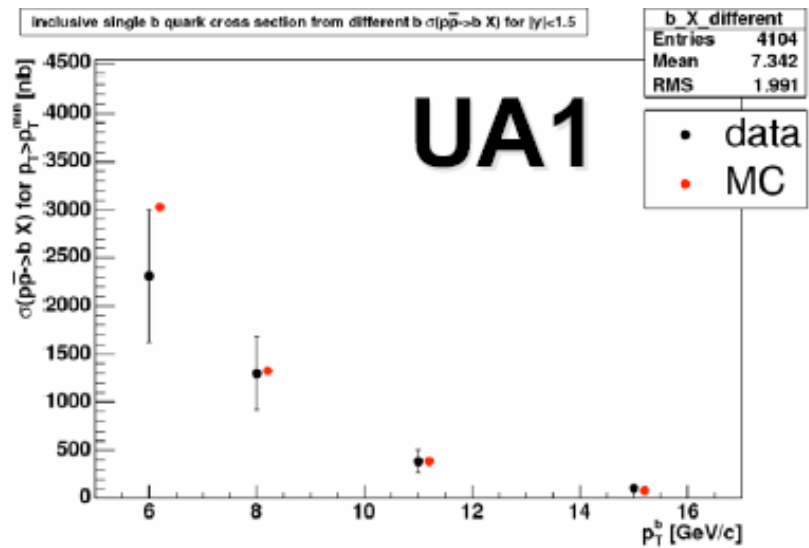


Dijet photoproduction at HERA and the structure of the photon (Eur.Phys.J.C23:615-631,2002)



Measurement of Dijet Cross Sections in Photoproduction at HERA (Eur.Phys.J.C25:13-23,2002)

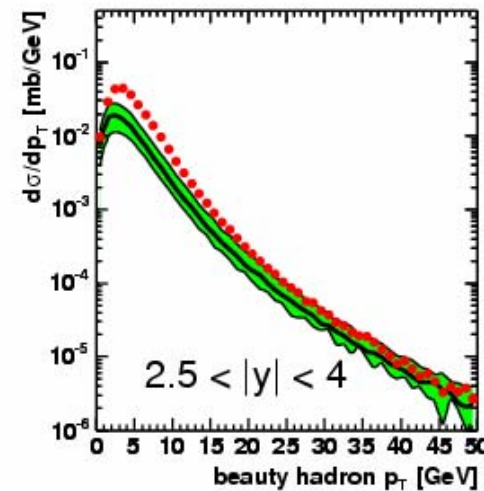
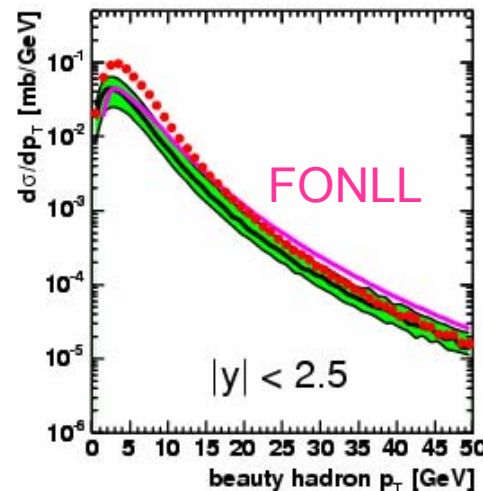
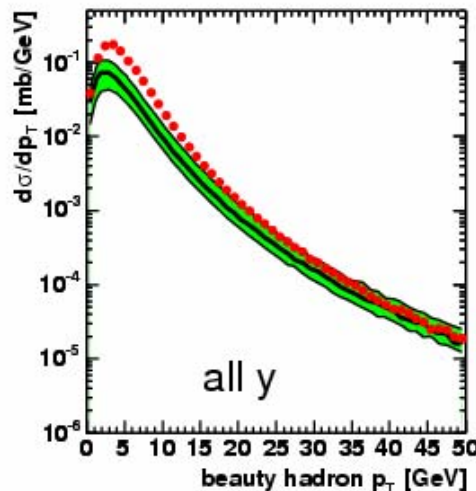
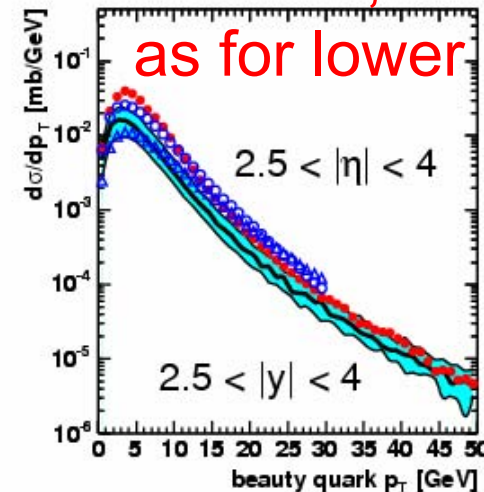
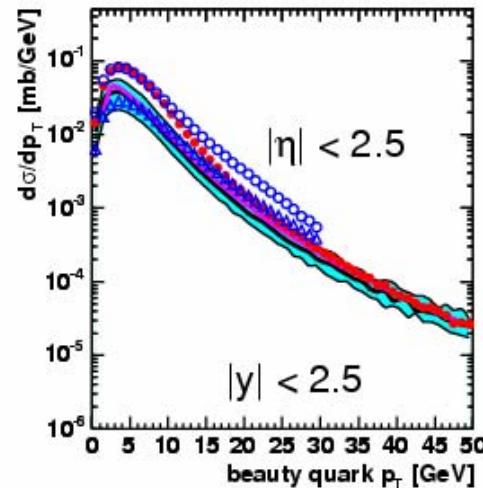
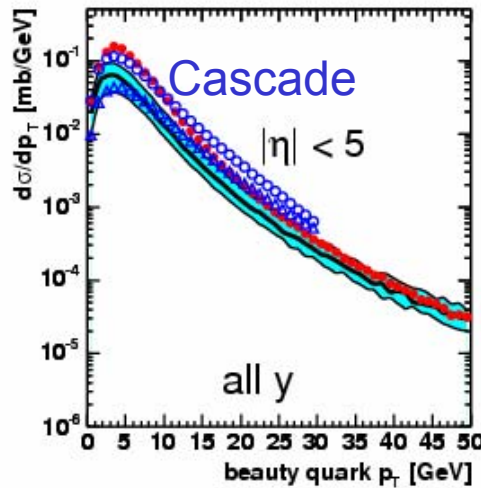
# Beauty with PYTHIA/JetWeb at SppS, Tevatron, HERA (O.Gutsche, A.Geiser)



Simultaneous description of UA1, D0 and ZEUS beauty production data.  
**Reliable baseline for LHC?**

# Beauty with PYTHIA/JetWeb at SppS, Tevatron, HERA ... and LHC (A.Dainese)

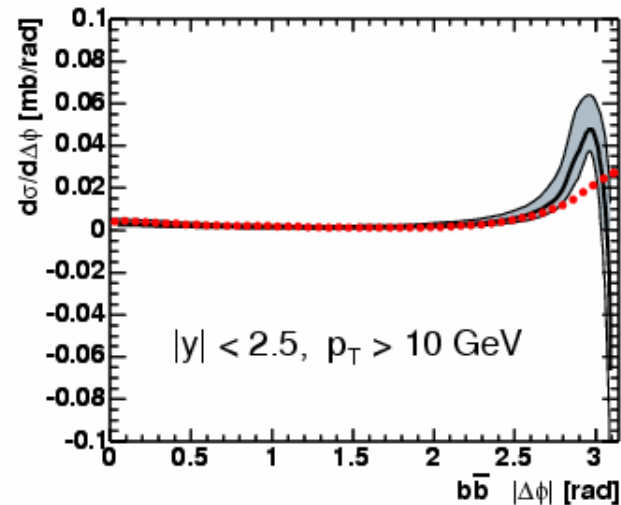
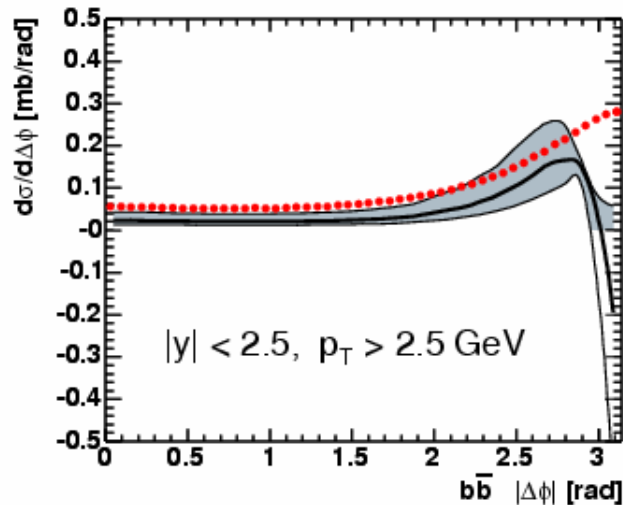
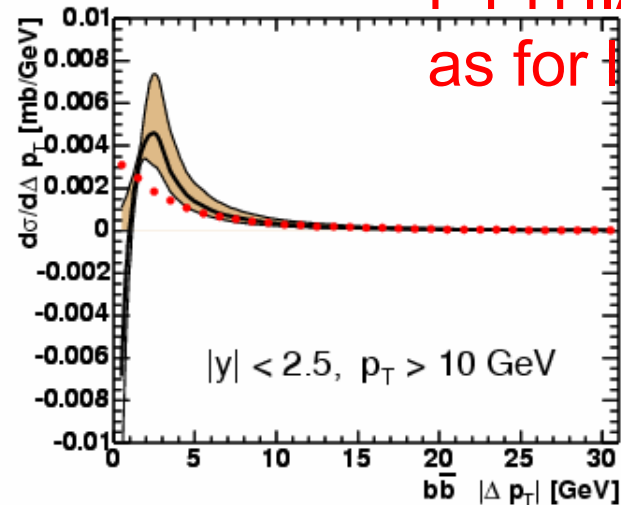
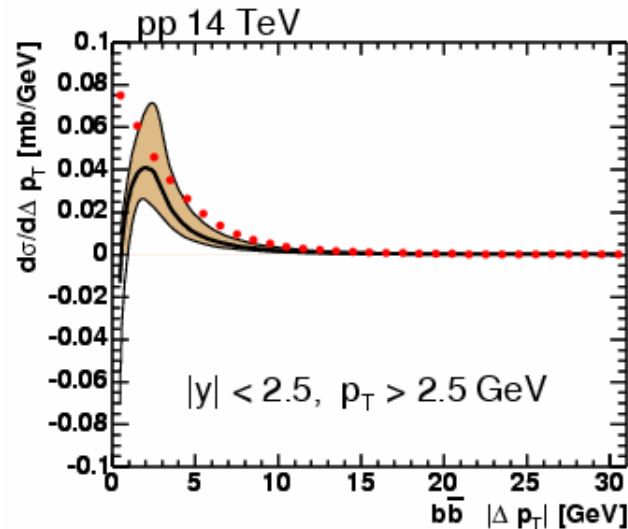
PYTHIA, same params  
as for lower energies



**PYTHIA normalization ( $\times 1.45$ ) fixed from high  $E_T$  jets at HERA**

# Beauty with PYTHIA/JetWeb at SppS, Tevatron, HERA ... and LHC (A.Dainese)

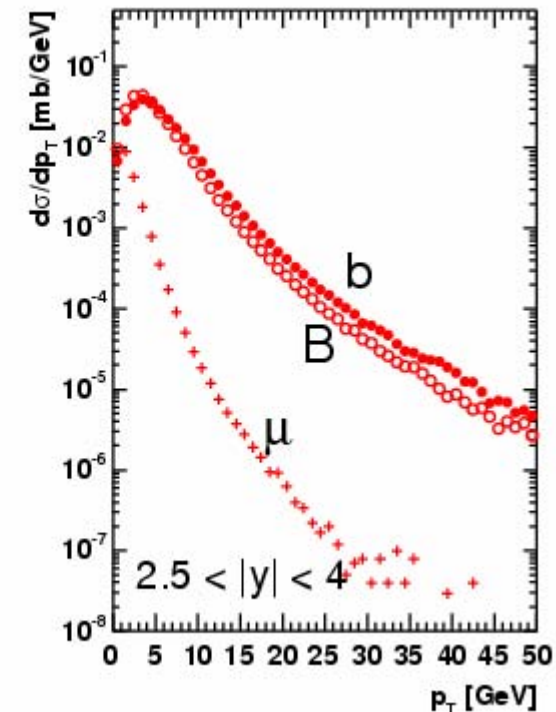
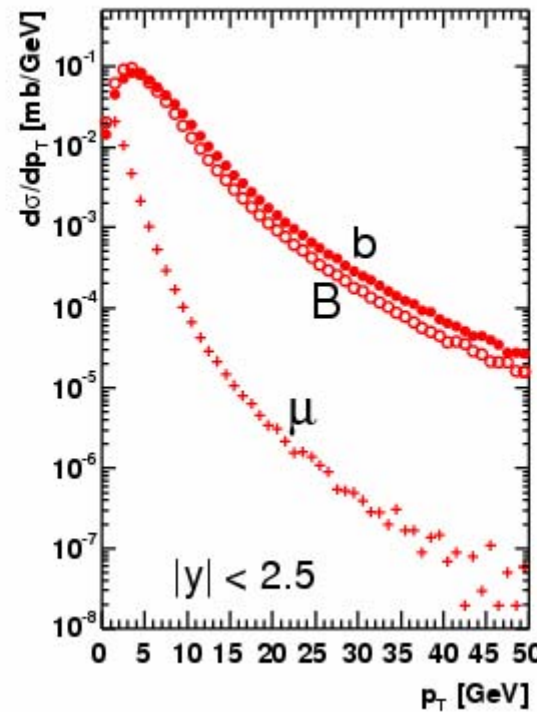
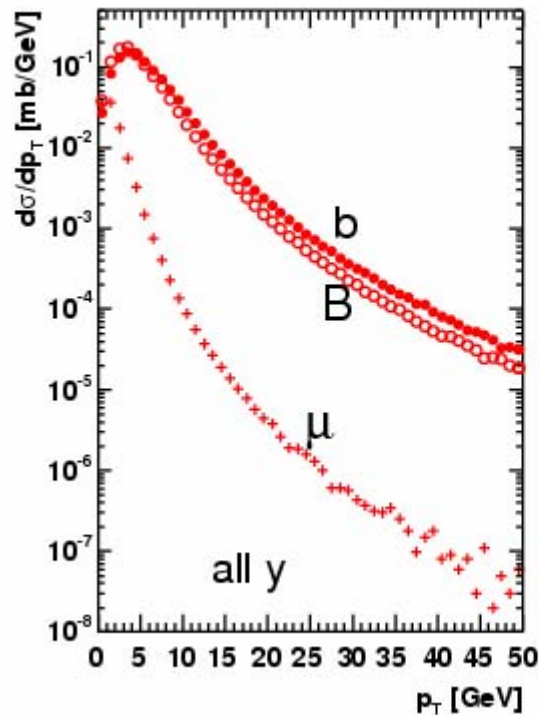
PYTHIA, same params  
as for lower energies



**PYTHIA normalization ( $\times 1.45$ ) fixed from high  $E_T$  jets at HERA**

# Beauty with PYTHIA/JetWeb at SppS, Tevatron, HERA ... and LHC (A.Dainese)

PYTHIA, same params  
as for lower energies

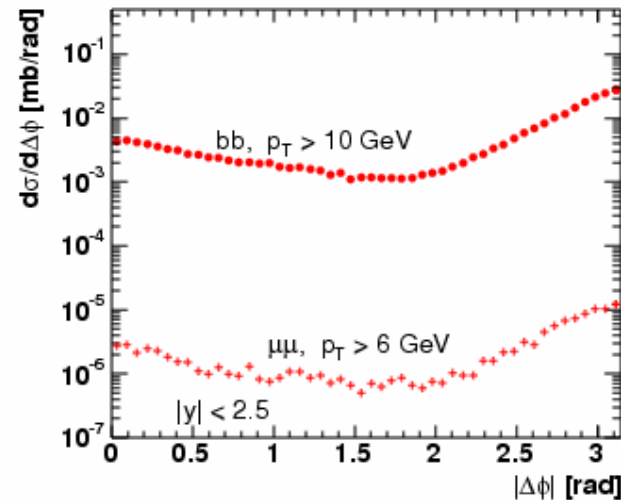
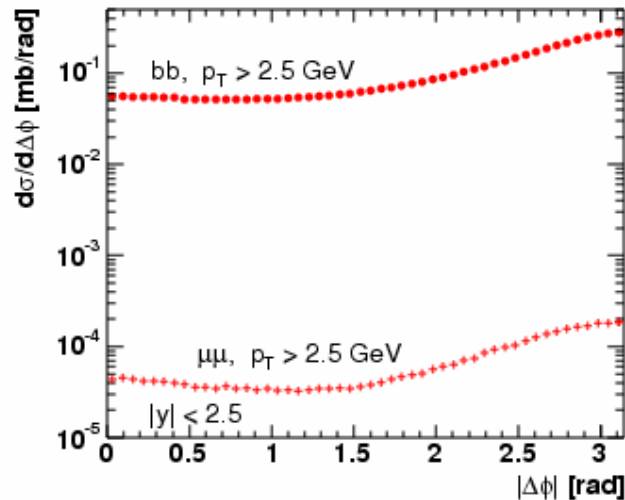
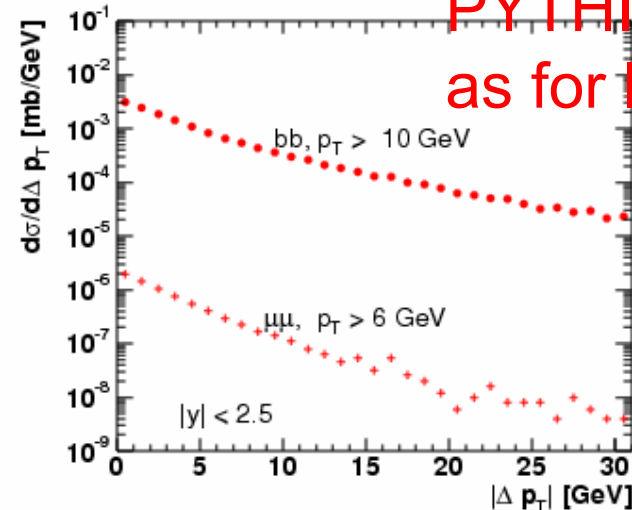
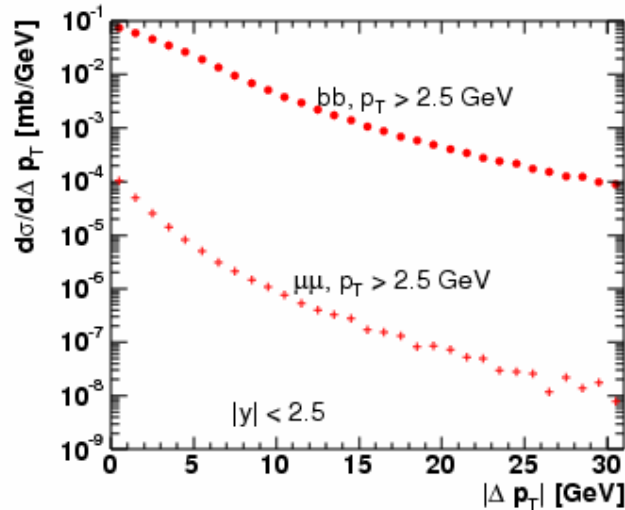


(only direct muons from B, B.R. 10%)

**MC normalization ( $\times 1.45$ ) fixed from high  $E_T$  jets at HERA**

# Beauty with PYTHIA/JetWeb at SppS, Tevatron, HERA ... and LHC (A.Dainese)

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**PYTHIA normalization ( $\times 1.45$ ) fixed from high  $E_T$  jets at HERA**