Produzione di b al Tevatron

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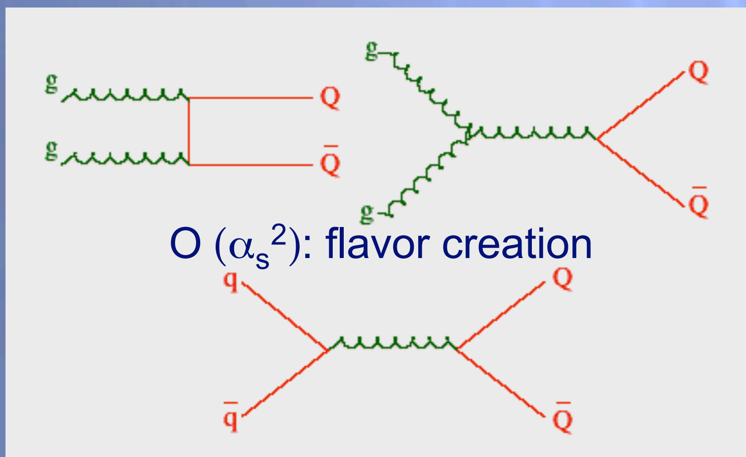
Introduction

- CDF/D0 RUN I: b-quark production higher then expected from NLO theory
- Big theoretical effort to understand discrepancies:
  1. NLO+resummation of $\log(p_T/m_b)$ (NLL) -> FONLL
  2. PDF fit improvements (CTEQ6M, MRST, …)
  3. New fragmentation functions from LEP and SLC
  4. FONLL + PDF + Frag. Fun. -> New prediction for Tevatron in 2002 [1]
     - Theory and measurement are now compatible
     - Predictions affected by large uncertainties on renormalization and factorization (~40%)
- Still some discrepancies between different measurements
- Tevatron RUN II: huge production of b quarks
  - Precise measurement of the cross section in different modes
  - Check the pattern of the different experimental results

[1] M.Cacciari and P.Nason, PRL 89, 122003 (2002)

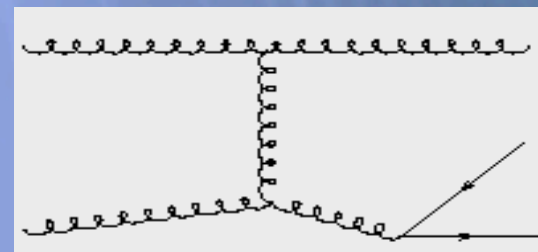
Heavy Flavor Production at $p\bar{p}$

Leading Order Diagrams

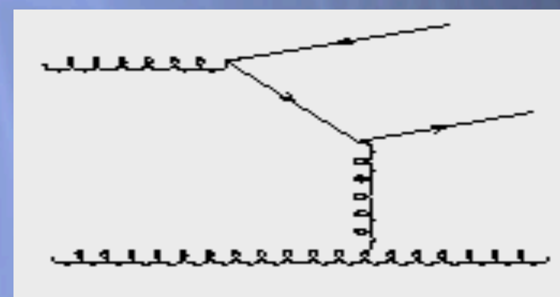


O (α_s^2): flavor creation

Next to Leading Order Diagrams



O (α_s^3): gluon splitting



O (α_s^3): flavor excitation

σ_b is inferred from the measurement of the production rate as a function of p_T of the *B_u* hadrons or some of their decay products:

$$\frac{d\sigma\left(p\bar{p}\rightarrow B\rightarrow J/\psi,l\right)}{dp_T\left(B,J/\psi,l\right)}=\frac{d\sigma\left(qq/gg/qg\rightarrow bX\right)}{dp_T\left(b\right)}\otimes PDF^{p,\bar{p}}\otimes D^{b\rightarrow B}\otimes QQ$$

measured | parton level calculation (NLO, FNLLO) | *p* structure | frag | decay

Single b production [2]

channel (ex.)	R for p_T^{min} (GeV/c) = 6	8-10	12-15	19-21	≈29	≈40
J/ΨK$^+$ (CDF)		4.0±15%	(3.4)			
J/ΨK$^+$ (CDF)		2.9±23%	(1.9)			
μX (CDF)				2.5±26%	(1.9)	
eX (CDF)			2.4±23%			
eD^o (CDF)				2.1±34%		
J/ΨX (CDF)		4.0±10%	(3.4)			
J/ΨX (CDF2)		3.1±9%	(2.7)			
μX (DØ)	2.1±27%		(1.7)			
μX (DØ)	2.5±25%		(3.5)			
b jets(μ) (DØ)				2.4±20%		(2.0)

$\langle R \rangle = \sigma(\text{data})/\sigma(\text{NLO}) = 2.8,\ \ RMS = 0.7$

Excluing J/Ψ $\langle R \rangle = 2.33,\ \ RMS = 0.19$

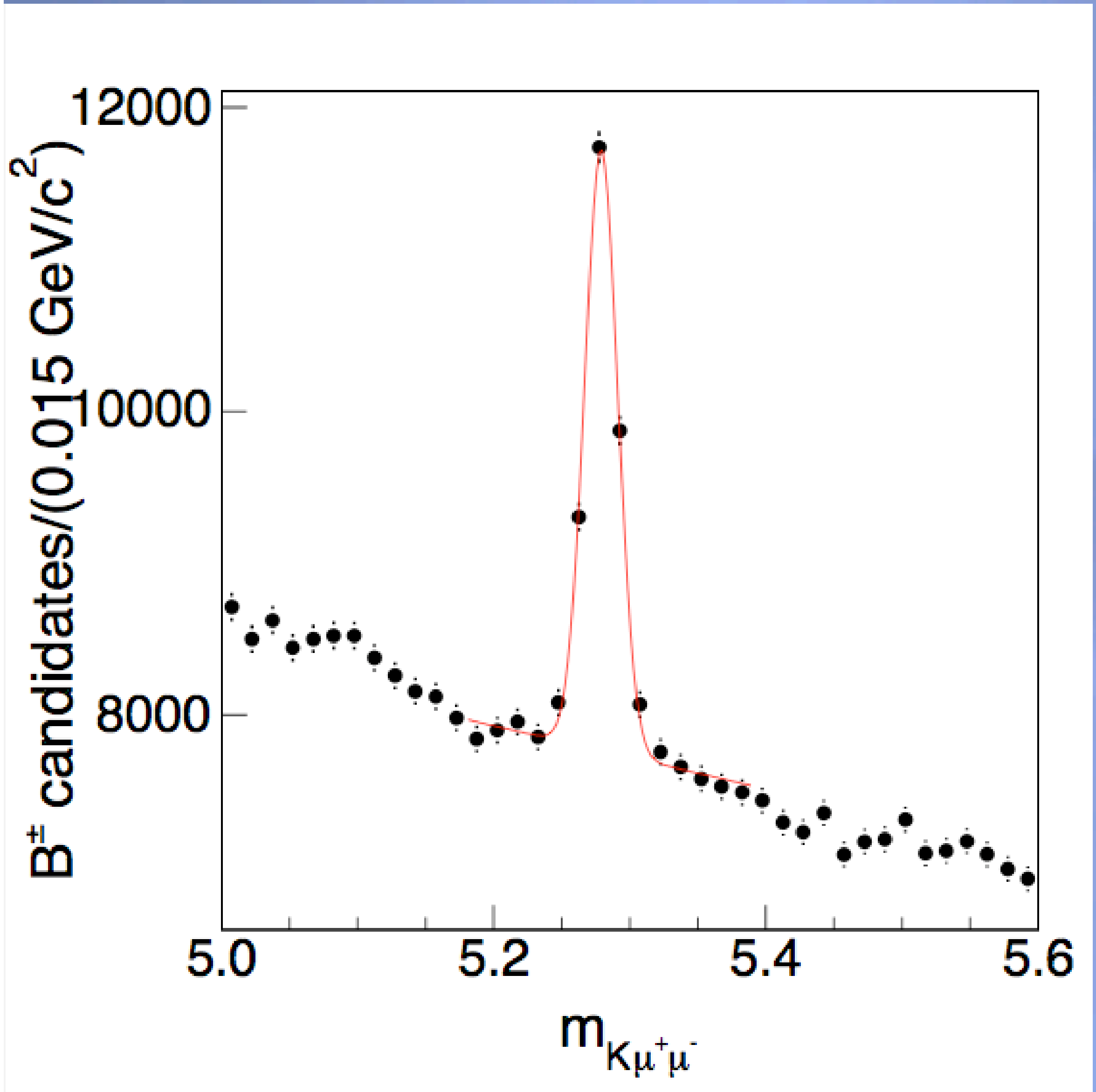
[2] F.Happacher www-conf.kek.jp/dis06/doc/WG5/hfl20-happacher.ps

$B^+ \to J/\psi + K^+$ [3]

- Very clean mode low uncertainties
- Exploit higher RUNII statistics
- Reduce systematics as much as possible
  - No L_{xy} cut systematics
  - calculate eff. & acc. with MC
  - correct with eff. & acc. measured on Data
- Kinematical cuts
  - $p_T(B^+) > 6$ GeV/c | $p_T(\mu) > 2$ GeV/c | $p_T(K) > 1.25$ GeV/c
  - Muon detector $|\eta| < 0.8$
  - Tracking $|\eta| < 1.3$
  - $\Rightarrow$ B candidates have $|y| < 1$

[3] CDF Collaboration, PRD 75, 012010 (2007)

B candidates



B cand. = 8197 ± 239

Fit Systematics: 2%
(evaluated by varying fit range and bkg shape)

Acceptance and efficiency

- MC: NLO + MRSD0
- Divide sample in 5 $p_T(B^+)$ bins
- In each bin correct efficiency and acceptance
  - Use samples of unbiased J/ψ to correct
    - Muon detector acceptance and efficiency
    - Trigger primitive generation efficiency
  - Correct for tracking efficiency
  - Interaction of kaon with detector material
- Systematics: 2.5% (Luminosity syst.: 6%)

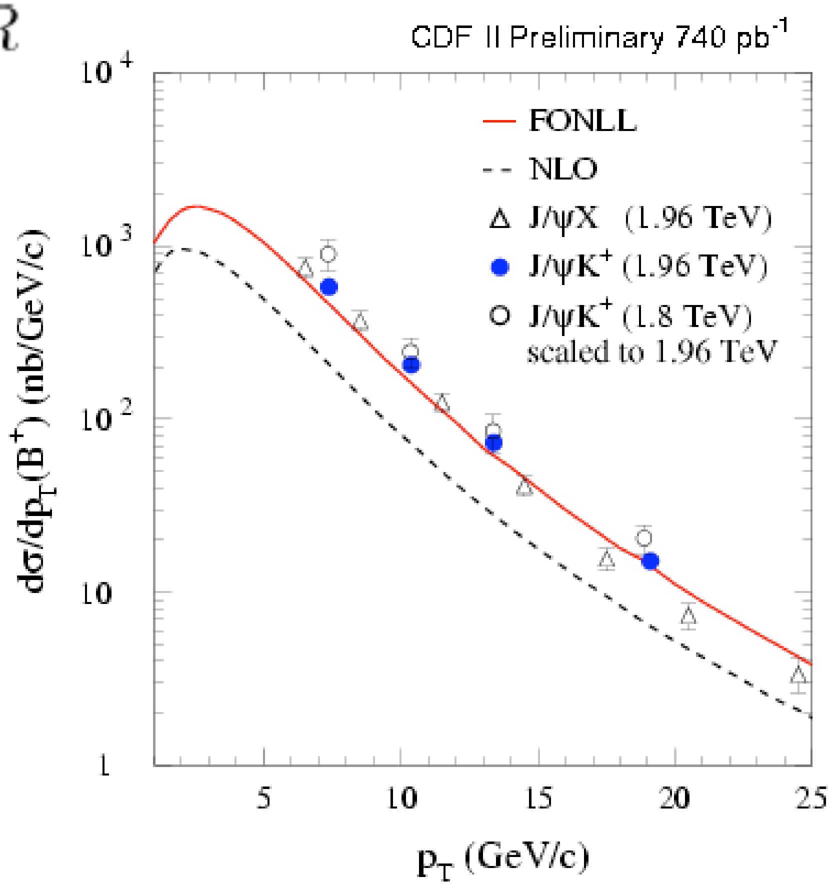
Cross Section

$$\frac{d\sigma(B^+)}{dp_T} = \frac{N/2}{\Delta p_T \times \mathcal{L} \times \mathcal{A}_{\rm corr} \times BR}$$

$\sigma_{B^+}(p_T \geq 6$ GeV/c, $|y| < 1) =$ (2.78 ± 0.24) μb (4% stat)

R = 2.80 ± 0.24 (NLO)

- In agreement with RUN II J/ψX measurement
- Within values predicted by the FONLL calculation



$b\bar{b}$ correlations review

- Mostly b from Direct Production (LO) contribute to the measurement
- Disentangle LO and next-to-LO

channel	(experiment)	R_{2b} for p_T^{min} (GeV/c)= 6-7	10	15	~20
$b+\bar{b}$ jets	CDF			1.2±25%	
$b+\bar{b}$ jets	CDF				1.0±32%
μ+b jet	CDF		1.5±10%		
$\mu^+ + \mu^-$	CDF	3.0±20%			
$\mu^+ + \mu^-$	DØ	2.3±33%			

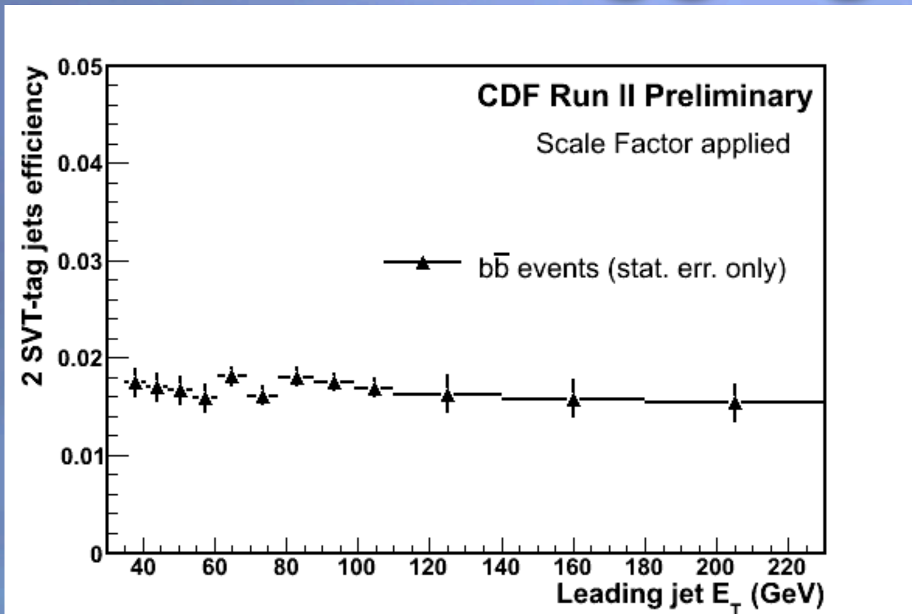
$<R_{2b}> 1.8$ with RMS = 0.8

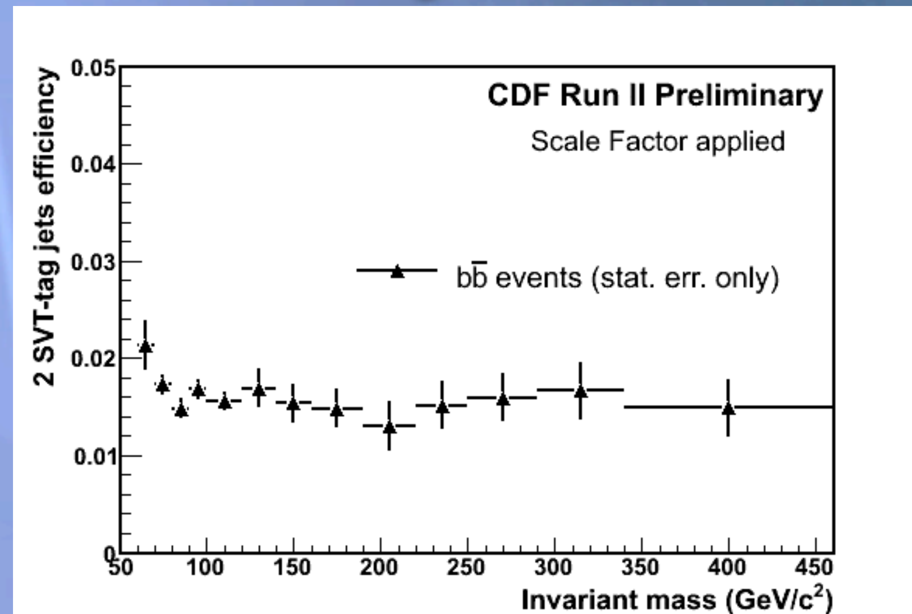
$b\bar{b}$ di-jet Production [4]

- Use events selected from displaced track trigger
  - High statistics in no-prescaled triggers
  - Bias from the Silicon Vertex Trigger (SVT): Tight offline selection to remove trigger bias
  - Measure trigger and b-tagging eff. in one single step in the MC
- Calculate efficiencies and acceptance using Pythia MC and correcting by scale factors

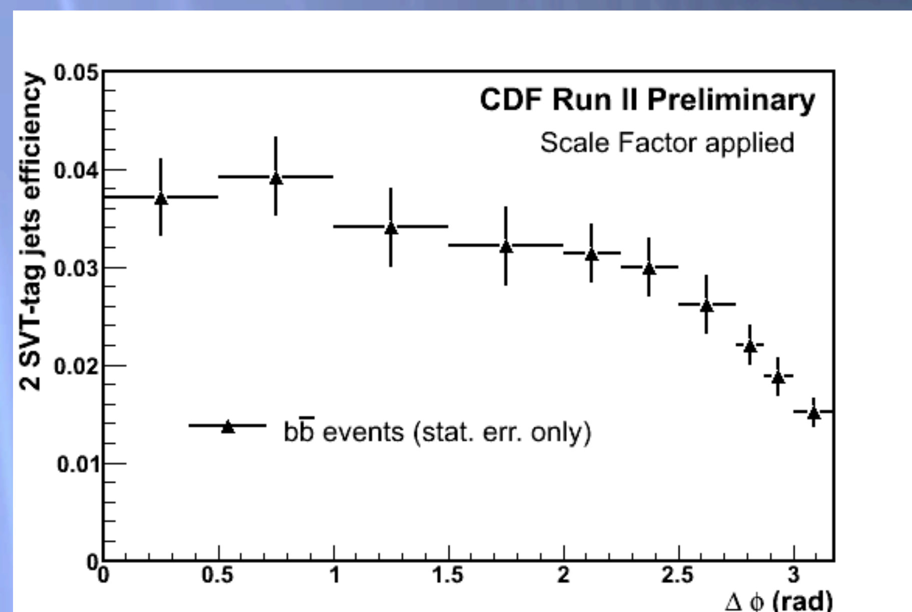
[4] http://www-cdf.fnal.gov/physics/new/qcd/bb_SVT_07/bbcross.html

Tagging efficiency

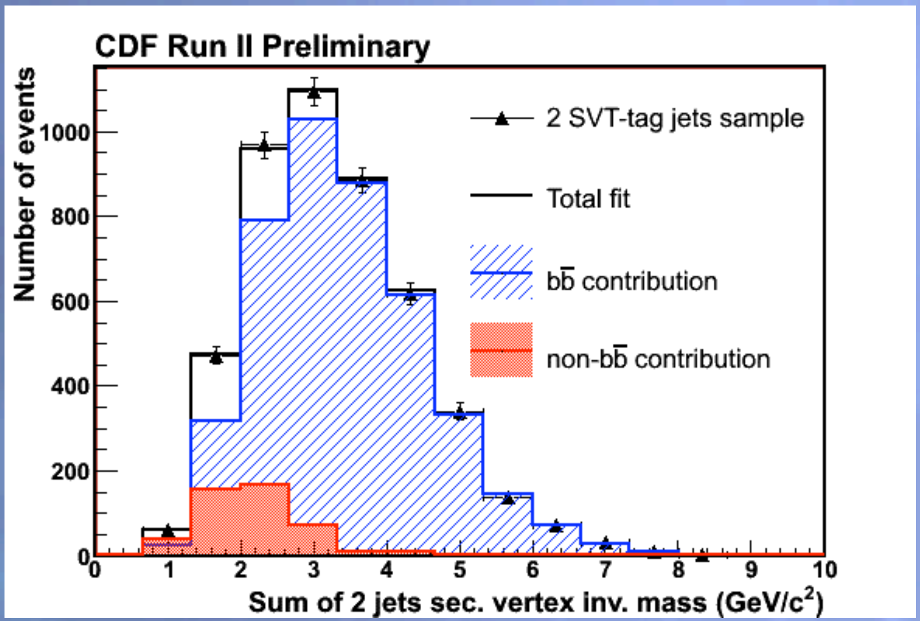


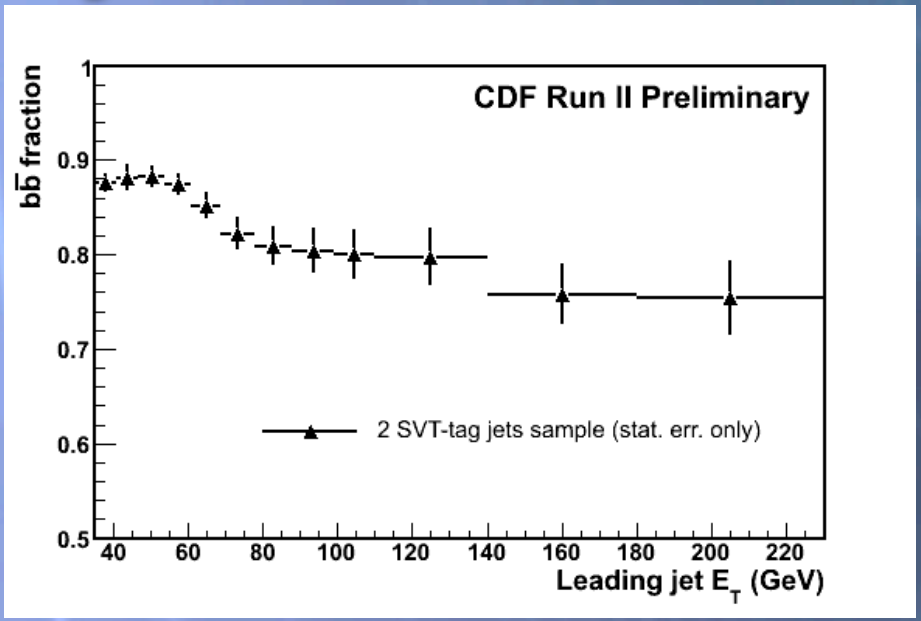


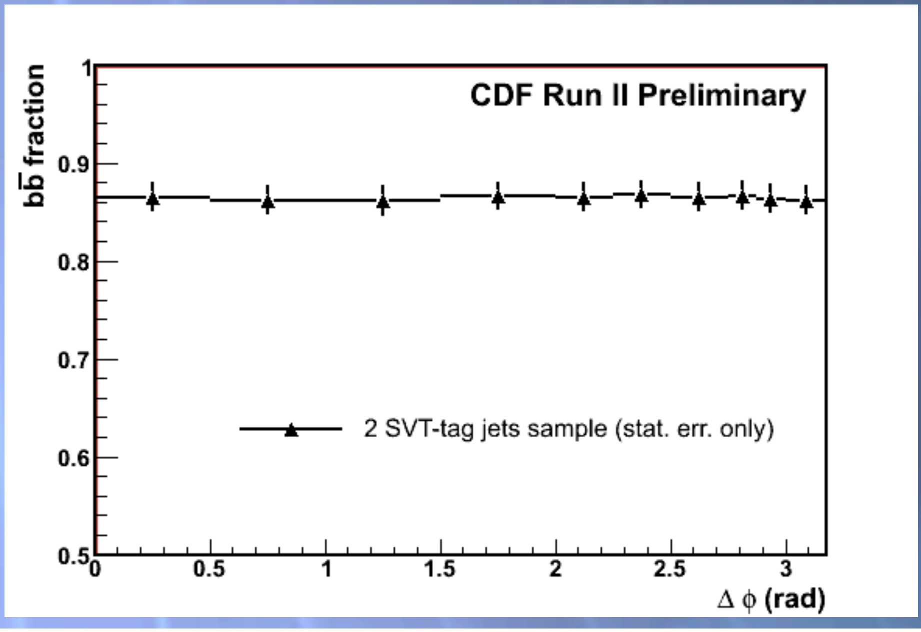
- SecVtx tagged Jet with
  - E_T>30 GeV
  - |η|<1.2
- Jet associated to a SVT track with
  - P_T>2 GeV
  - $|d_0|$>120 μm



Purity







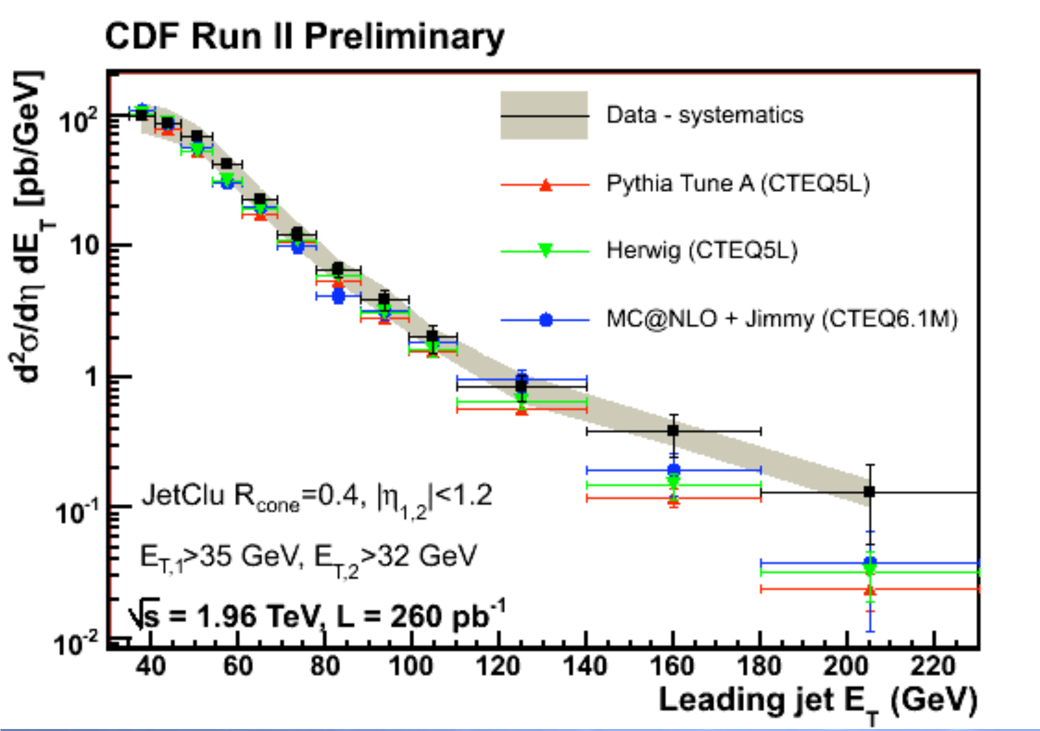
- Contamination from b+q/g
- Use invariant mass of tracks associated to sec. vertex in the Jet
- Fit data with templates from MC

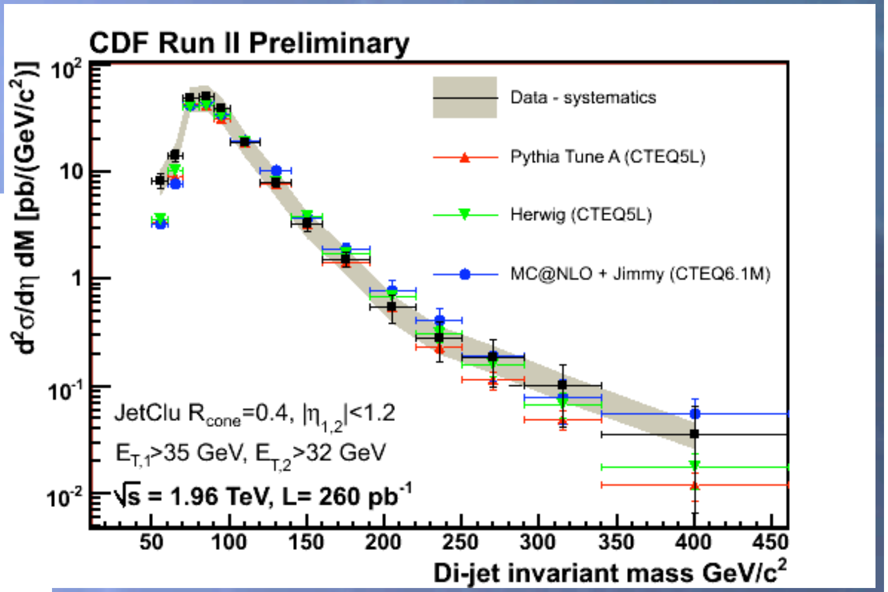
Integral Cross Section

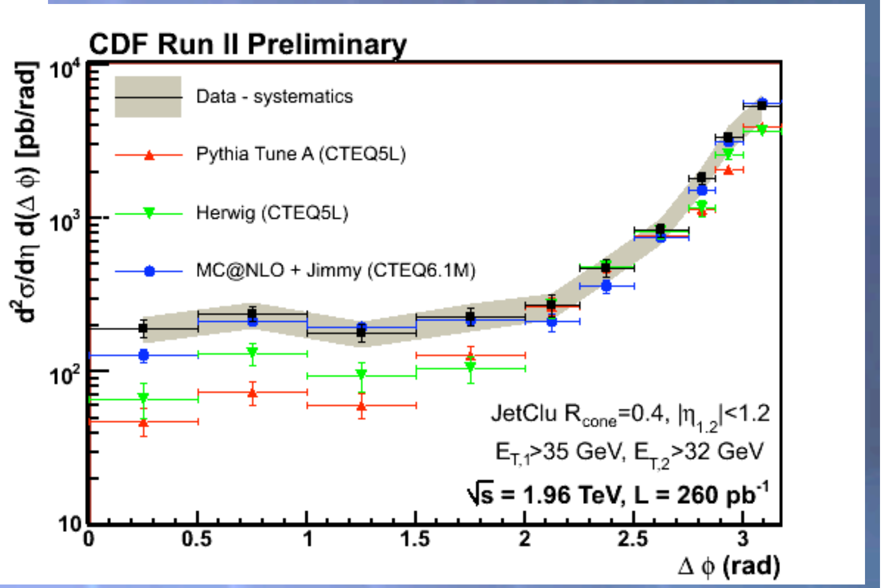
- Systematics:
  - Luminosity: 6%
  - Jet energy corrections: 13-20%
  - Others
    - SVT b-tagging efficiency
    - B-jet purity determination: mass template sensitivity to tracking inefficiency

CDF Run II Preliminary	σ [pb] $\lvert\eta_{1,2}\rvert < 1.2$, $E_{T,1} > 35$ GeV, $E_{T,2} > 32$ GeV
Data	$\sigma = 2360 \pm 70$ (stat.) ± 530 (syst.)
Pythia	$\sigma = 2140 \pm 22$ (stat.)
Herwig	$\sigma = 2201 \pm 29$ (stat.)
MC@NLO+Jimmy	$\sigma = 2259 \pm 44$ (stat.)

Differential Cross Section







Summary

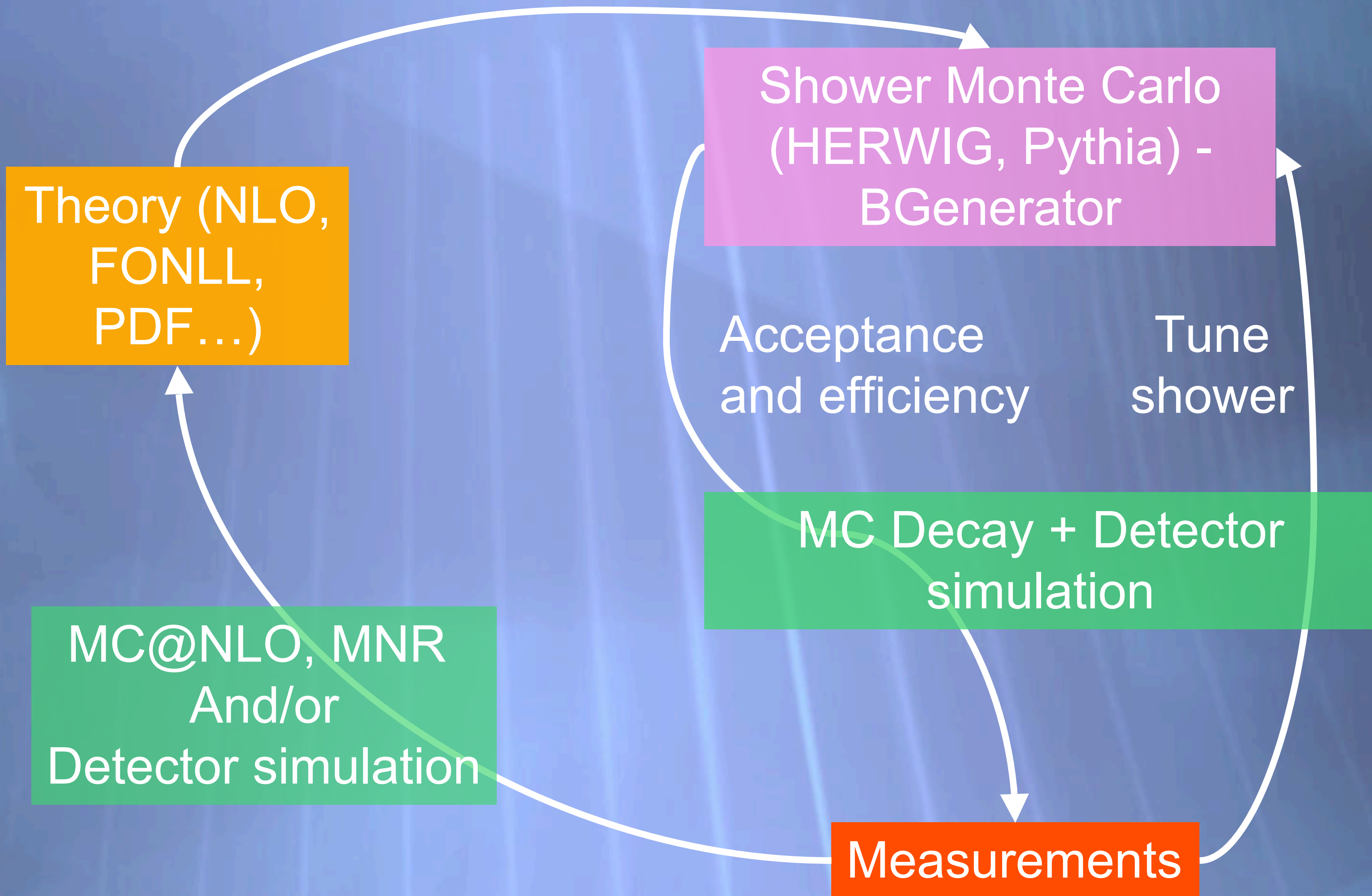
- b quark production measurement in RUN I found rates higher than theoretical expectations
- Interplay between theory and measurement fundamental to understand nature
- Different measurements provide different results, providing weak constraints to theory -> improving!
- New Tevatron measurements, thanks to higher statistics and better theory, will allow to clarify the general picture
- New modes need to be checked
- Understand production rates at 2TeV will be a starting point for the upcoming 14TeV data

BACKUP

NLO - FONLL

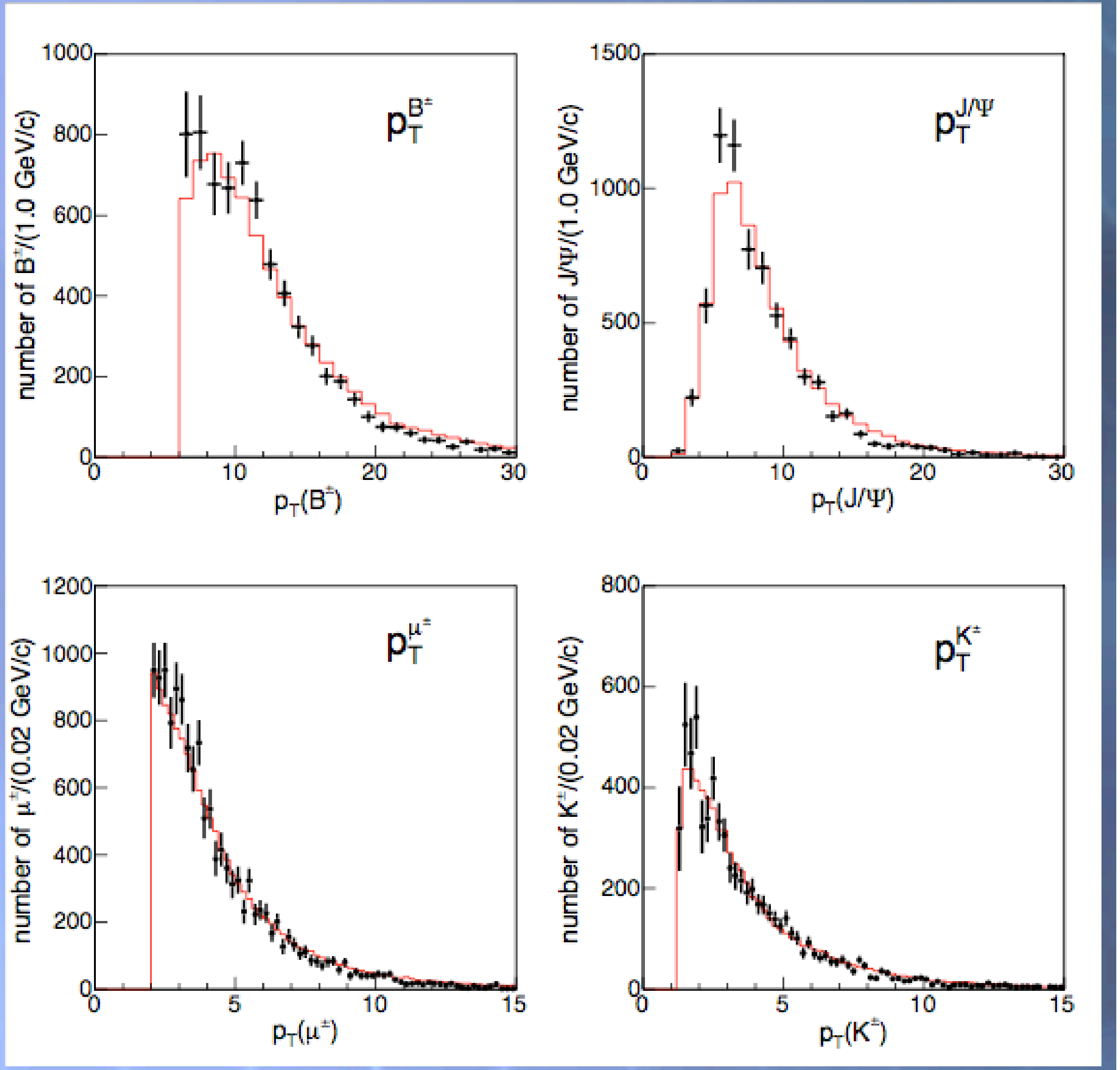
- NLO
  - Uses Peterson fragmentation function ($\varepsilon = 0.006$)
  - MRSD0 fits to the PDF
- FONLL
  - NLO + NLL (20%)
  - CTEQ6M fits to the PDF (20%)
  - Fragmentation functions consistent with the accuracy of calculation (30-40%)

The players of the game



MC

- Generate events based on NLO calculation
- PDF: MRSD0
- Decay B using EvtGen for B decays
- GEANT simulation of CDF
- Simulation of L1 and L2 primitives and algorithms



Acceptances and efficiencies

p_T range (GeV)	$<p_T>$ (GeV)	Acc x ε (%) from MC	Acc x ε (%) Data corrected
6-9	7.37	1.53	1.73 ± 0.04
9-12	10.38	3.78	4.28 ± 0.11
12-15	13.39	5.94	6.74 ± 0.18
15-25	19.10	8.81	9.98 ± 0.26
≥25		13.20	14.96 ± 0.40

- *Acc x* ε obtained from MC for B with Pt>6 and |y|<1
- correction factor ($DATA_{eff}/MC_{eff}$) = 1.134±0.034
- $<p_T>$ is defined as $\sigma(<p_T>)$ = average σ over p_T bin

Eff. & Acc. correction table

Source	Data	MC	Corr
COT tracking	$(0.996 \pm 0.006)^3$	$(0.998 \pm 0.002)^3$	1.00 ± 0.02
CMU acc. & eff.	$(0.625 \pm 0.007)^2$	$(0.6426 \pm 0.0004)^2$	0.945 ± 0.022
CMU & XFT prim.	$(0.9247 \pm 0.0004)^2$	$(0.8362 \pm 0.0004)^2$	1.223 ± 0.002
L1 eff.	0.9925±0.0009	1	0.9925±0.0009
L2 eff.	0.9948±0.0001	1	0.9948±0.0001
L3 eff.	$(0.997 \pm 0.002)^2$	1	0.994±0.004
Total	0.324±0.009	0.2853 ± 0.001	1.134±0.034

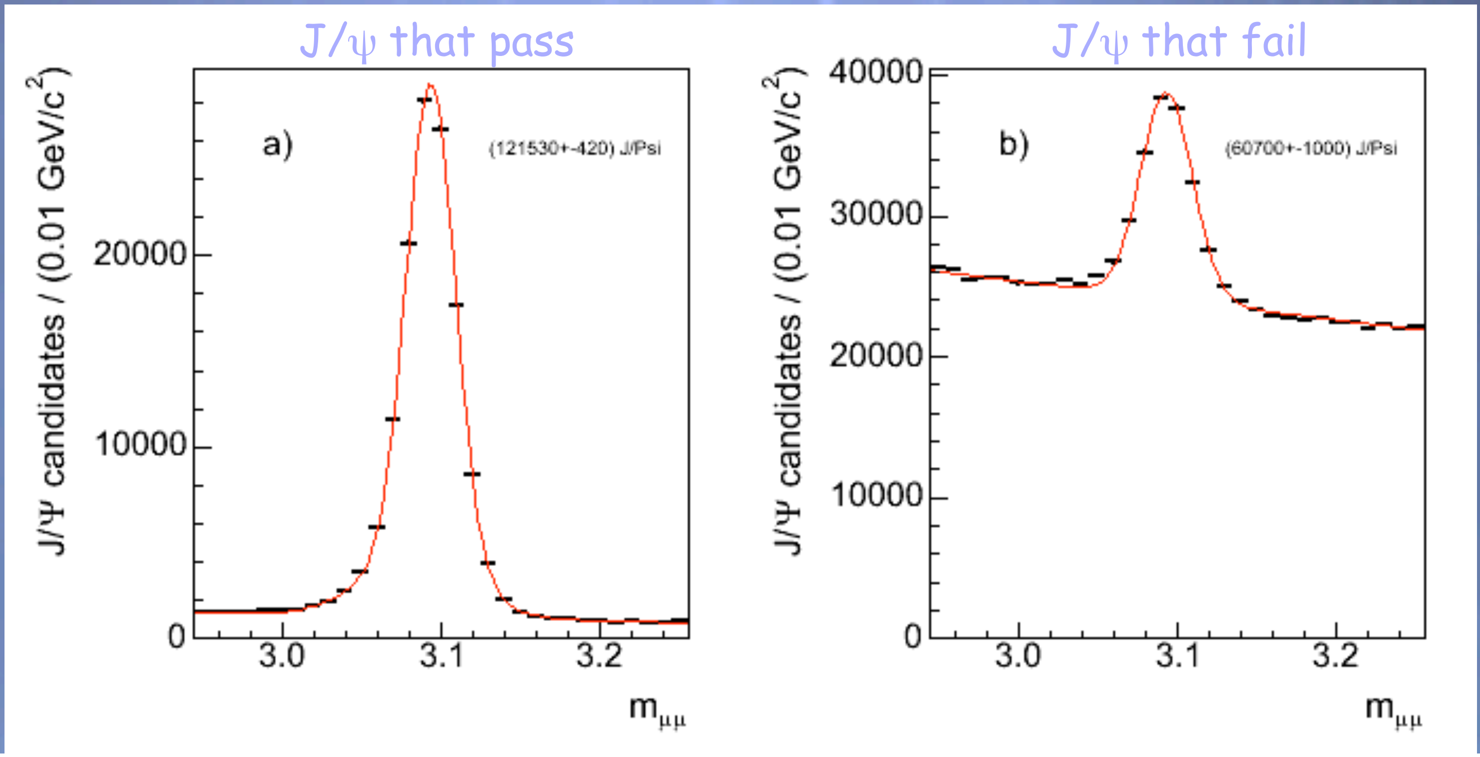
Final scale factor $(DATA_{eff}/MC_{eff})$ = 1.134±0.034

Correction to efficiencies (1)

- COT track reconstruction efficiency
  - MC 0.998 ± 0.002 (per track)
  - Data: 0.996 ± 0.006 [J/ψ xsec paper: Phys. Rev. D71, 032001 (2005)]
    - MC hits embedding in J/ψ data
- L3 efficiency (data only)
  - 0.997± 0.002 (per muon track) [J/ψ xsec paper]

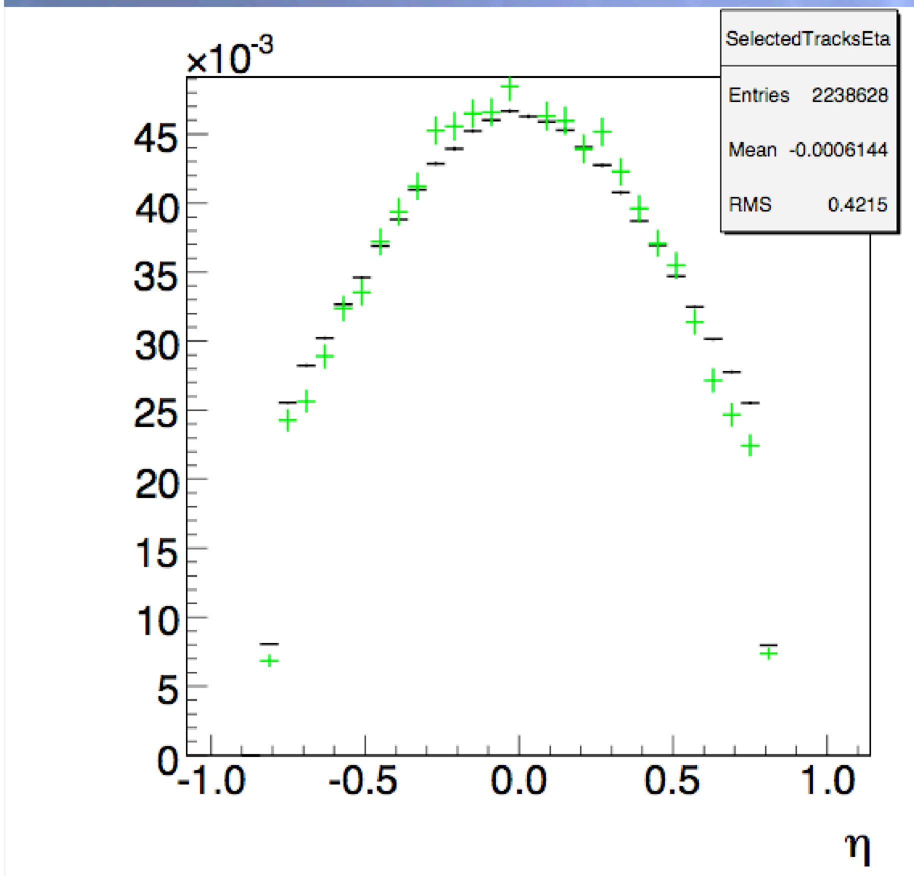
Correction to CMU acc. time eff.

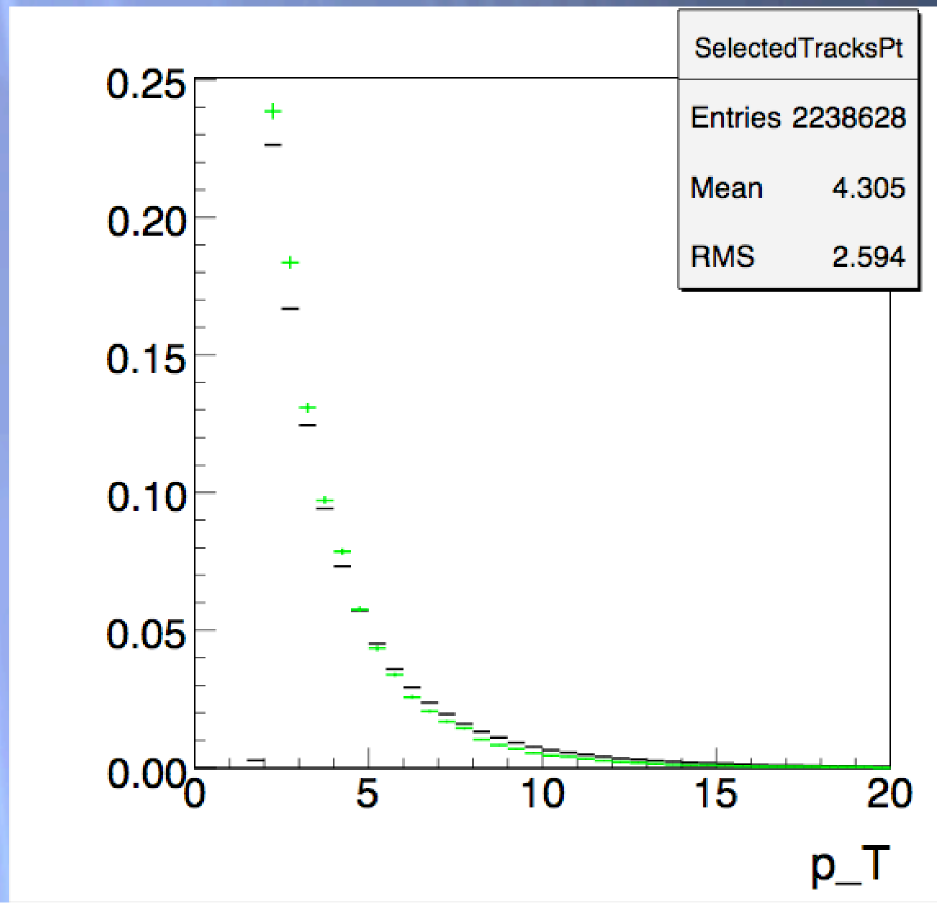
- CMU detector acceptance and eff. (for tracks w/ Pt> 2GeV & $|\eta| < 0.8$)
- MC 0.6426 ± 0.0004 (per muon)
- In μ+SVT data we count all J/ψ made w/ trigger CMU & SVT track
  - then we count all J/ψ that have a second offline CMU
  - events reweighed to reproduce MC distributions (next slide)
  - Data 0.625 ± 0.007 (no reweigh 0.632 ± 0.006)



Base distribution for CMU acc. times eff.

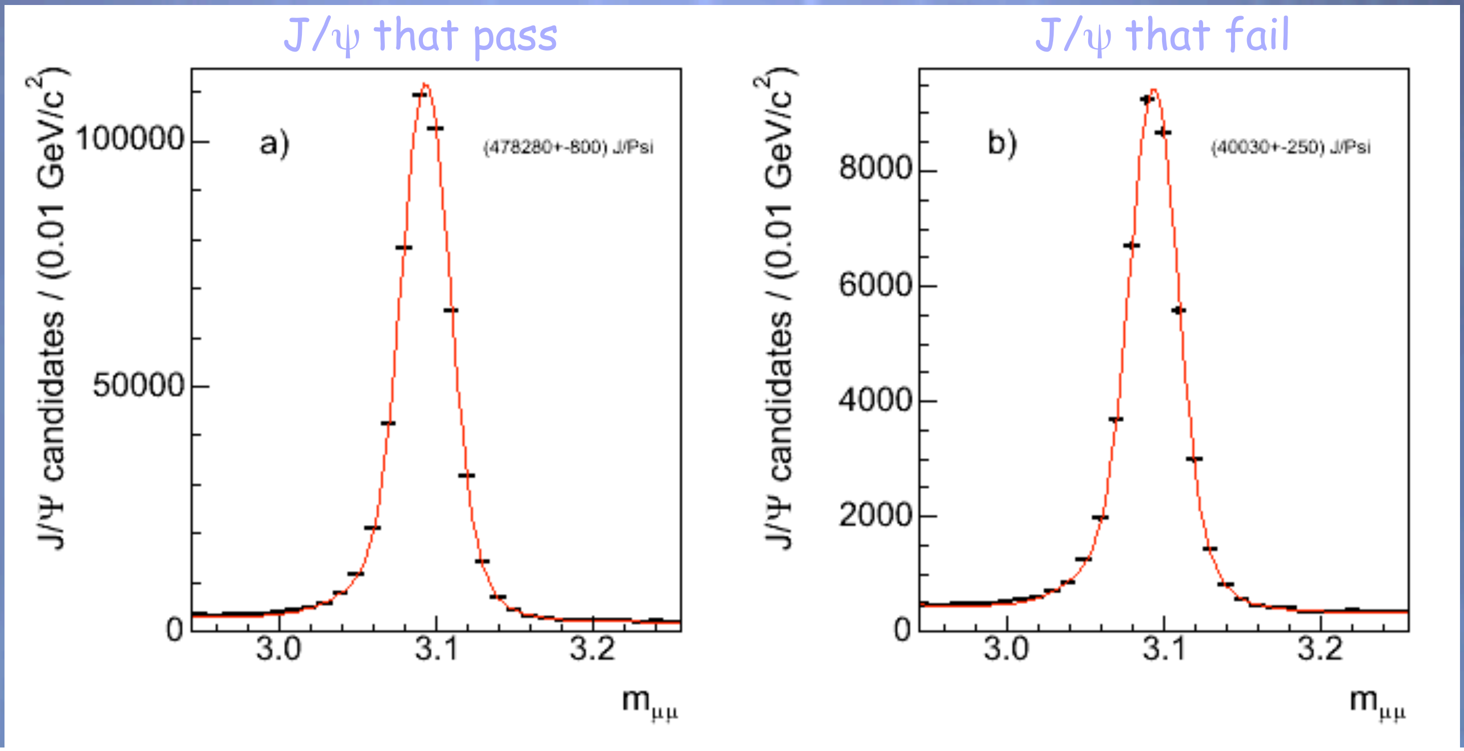
- Compare data vs MC eta/pt distributions of probe SVT track
- green is data: (μ+SVT) enter plot for unbiased leg only (bkg subtract.)
- black is MC: enter plot for both legs
- ratio of distributions is used to reweigh data





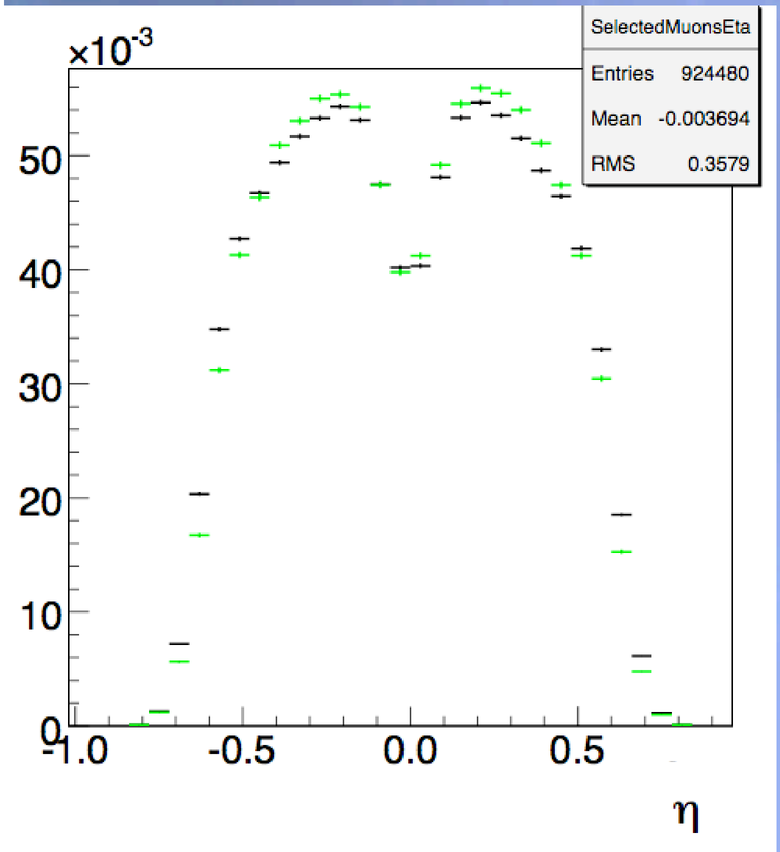
Correction to trigger efficiency

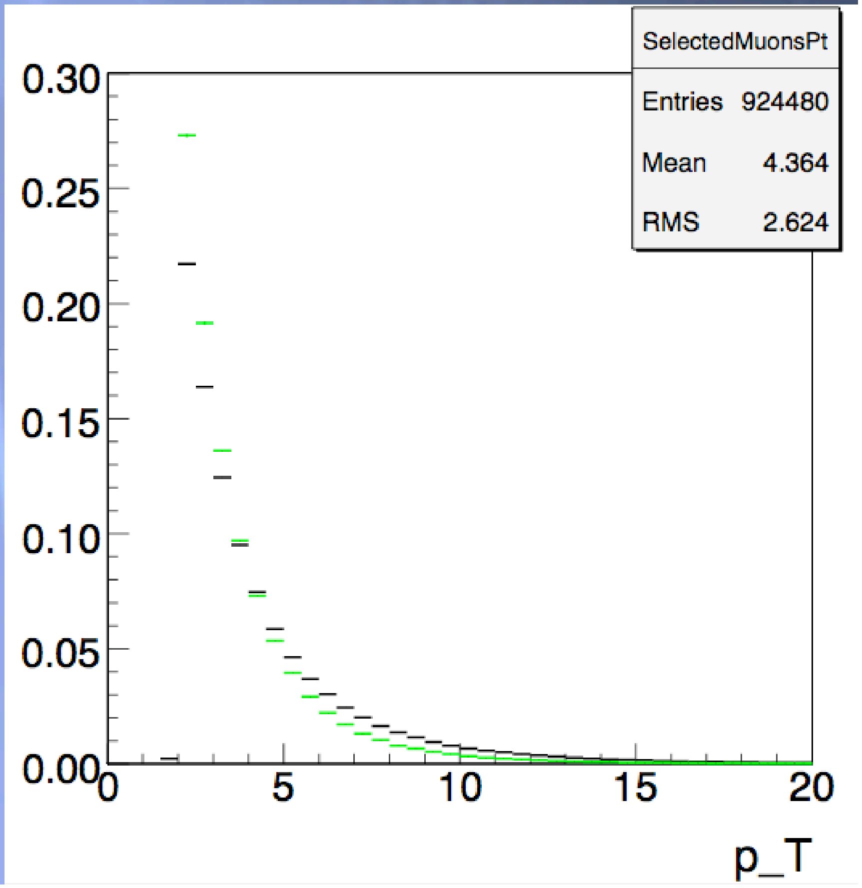
- CMU L1 primitive efficiency (for CMU muons w/ Pt> 2GeV & $|\eta| < 0.8$)
- MC 0.8362 ± 0.0004 (per muon)
- JPSI CMUP4 data: count J/ψ with CMU&XFT primitive Pt>4GeV & CMU
    - then count J/ψ with two primitives Pt>4 & Pt>2 GeV
    - events reweighed to reproduce MC distributions (next slide)
    - Data 0.9247 ± 0.0004 (no reweigh 0.9228 ± 0.0004)



Correction to CMU trigger eff.

- Compare data vs MC eta/pt distributions of probe CMU muon
- green is data: (JPSI_CMUP4) enter plot for unbiased leg (bkg subtract.)
- black is MC: enter plot for both CMU muons
- ratio of distributions is used to reweigh data





Uncertainties summary

Uncertanity source	Relative uncertanity (%)
Luminosity	6
BR	4.3
statistical	4.2
Acc. time eff. systematic	3.0
Total	9.0