Measurement of the muon inclusive cross section up to p_T = 100 GeV

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Groups working on the analysis

Roma Tre

T. Baroncelli, F. Ceradini, B. Di Micco, A. Farilla, M. Iodice, F. Petrucci

data driven track efficiency , trigger efficiency, background determination, cross section evaluation, data/MC comparison

Pavia

S. Franchino (acceptance and MC track efficiency studies, contamination evaluation)

Frascati

M. Antonelli, A. Sibidanov - data driven track efficiency

Analysis reviewers

R. Ferrara (Pavia), C. Amelung, K. Tokushuku

Analysis based on the EWPA-00-04-14 analysis framework and MCP ntuples.
Ntuples produced on Italian tier-2 and locally analysed at Roma-3 Tier-3 (20 TB).

The measurement

$$\frac{d\sigma_\mu}{dP_T}=\frac{1}{L}\frac{dN_\mu}{dp_T} \qquad \frac{dN_\mu}{dp_T}=\frac{f_{prompt}(p_T)}{\epsilon_{trig}(p_T)\,\epsilon_{track}(p_T)}\frac{dN_{\mu\, reconstructed}}{dP_T}$$

$f_{prompt}(p_T)$ Fraction of muons not coming from π and K decays evaluated on data using Monte Carlo shapes

$\epsilon_{trig}(p_T)$ Trigger efficiency evaluated on DATA;

$\epsilon_{track}(p_T)$ Track efficiency evaluated on Monte Carlo and corrected for DATA/MC discrepancies.

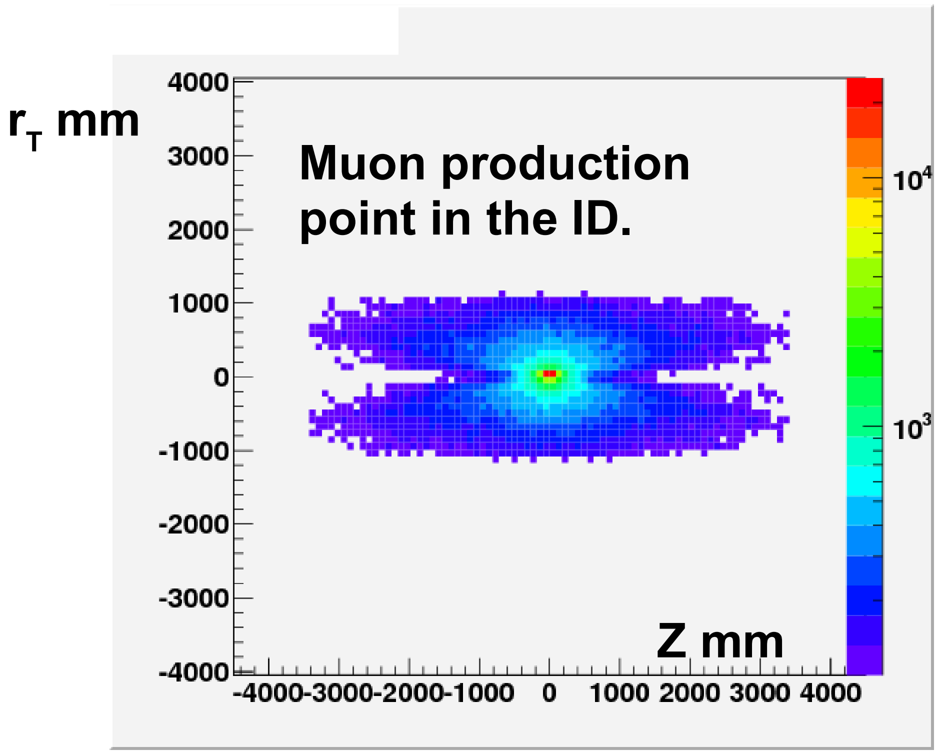
L Integrated luminosity of the data sample

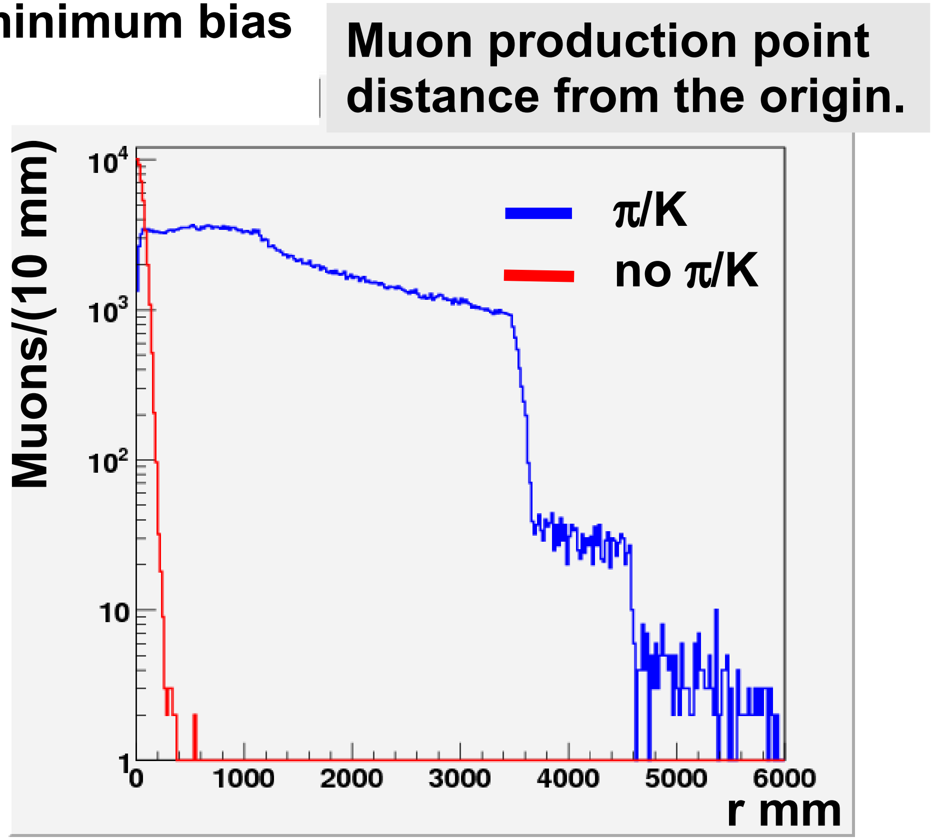
Prompt muon component

Muons from π and K are produced almost everywhere in the I.D. and calorimeter, Their rate is material and geometry dependent. No muons from π/K at the I.P.

Remaining muons come from particles with short decay length, almost detector independent, production yield in pp collision is a physics measurable quantity.

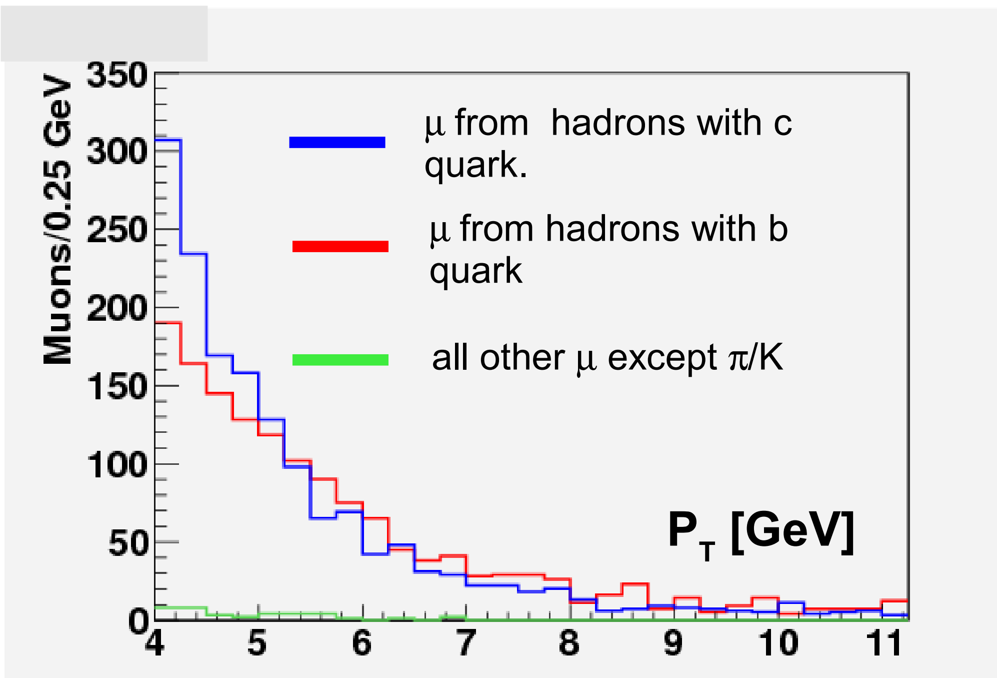
Non diffractive minimum bias



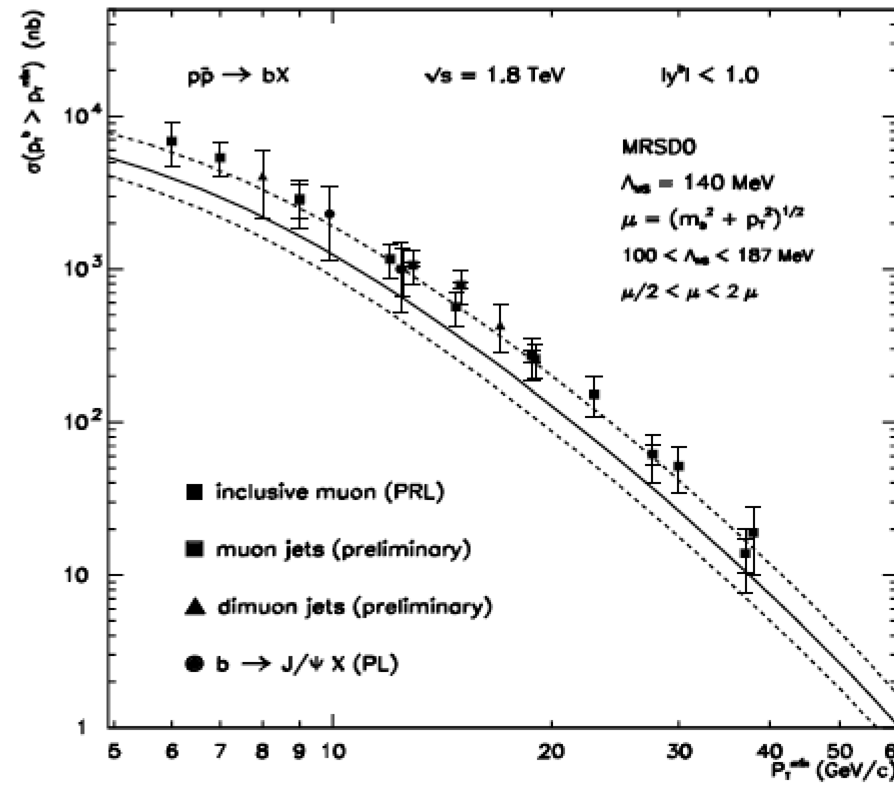


Physics of the prompt muon cross section.

Non diffractive minimum bias



b quark integrated cross section from D0.



At low p_T the prompt muon spectrum measures the heavy quark production cross section.

At high p_T (> 25 GeV) W/Z contribution becomes important.

Analysis selection

1) Identification of collision events using MBTS pads times;

2) Staco combined muons
(Inner Detector track + Muon Spectrometer Track matched each in angle and momentum, the best matched combination is taken)

3) $|\eta| < 2.5$ (inside inner detector acceptance), the cross section will be evaluated in this η range (no acceptance correction)

Triggers and data samples.

Data sample	Trigger	Luminosity nb^{-1}	P_T range
Run Range: 152777 – 158392			
152777 switch of Muon Trigger to 3 BC 158393 HLT rejection applied at L1_MU0	L1_MU0	46.3	4-16 GeV
Run Range: 158443 – 159224 ICHEP STATISTIC	L1_MU10	282	16-100 GeV
Run Range: 160387 – 161948 period E > 161948 HLT rejection applied to all chains	L1_MU10	1002.2	16-100 GeV

Trigger efficiency - L1_MU0/L1_MBTS_1

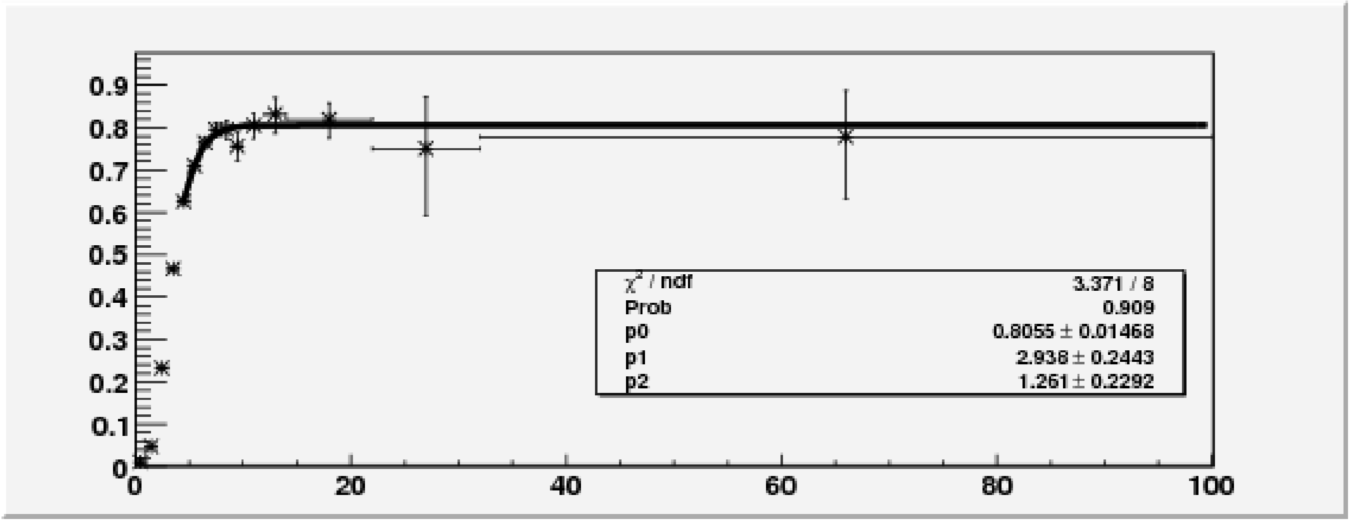
1) L1_MBTS_1 trigger efficiency has been evaluated on data on the Random stream respect to collision event selection (ε>0.99999) 819/819 triggered events;

2) measure the spectrum on L1_MBTS_1 triggered events;

3) measure the spectrum on L1_MU0 and L1_MBTS_1 triggered events;

4) The ratio of the two is the L1_MU0 trigger efficiency on our sample;

Minimum Bias stream run range 152777-155697

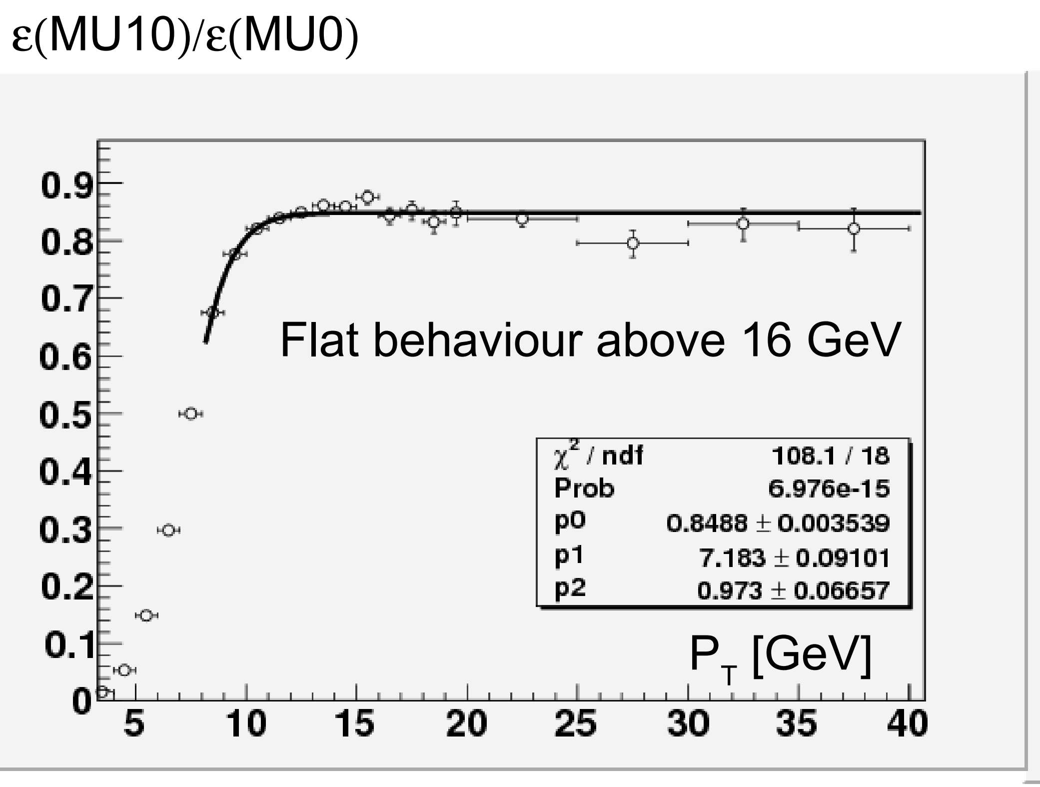


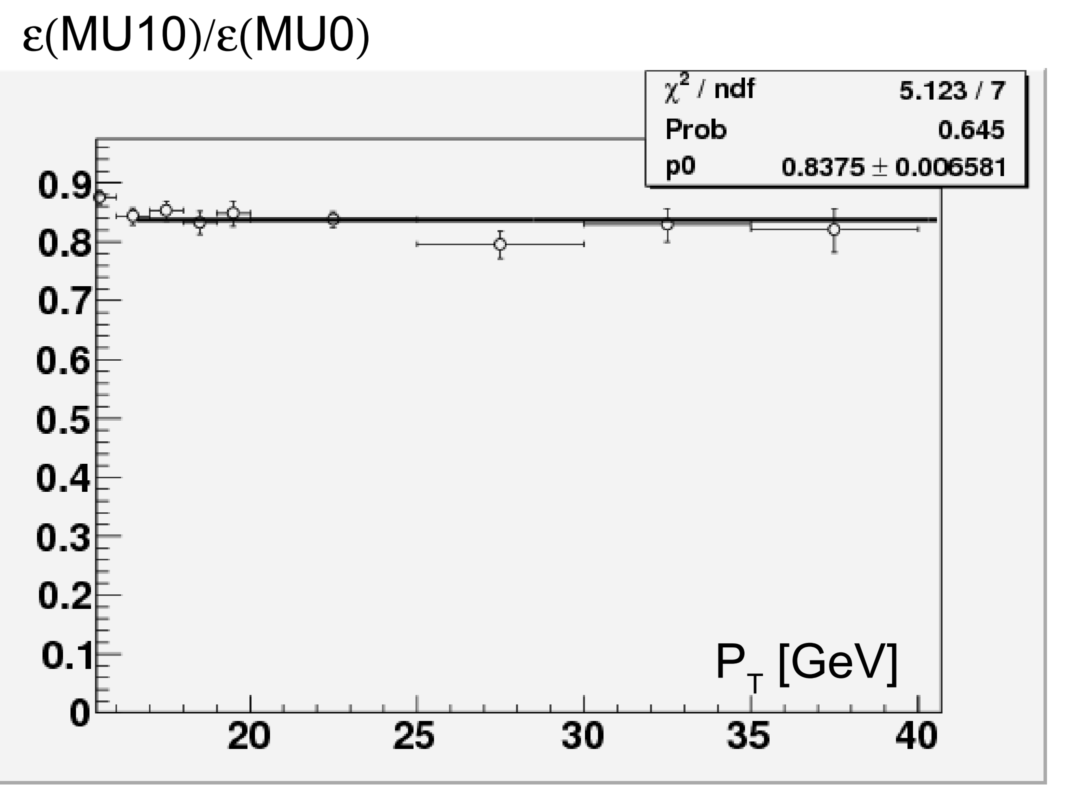
Fermi-Dirac fitting function

$$\frac{p_0}{1+e^{\frac{-(P_T-p_1)}{p_2}}}$$

Trigger efficiency – L1_MU10/L1_MU0

Efficiency evaluated in the Run Range: 152777 – 158392





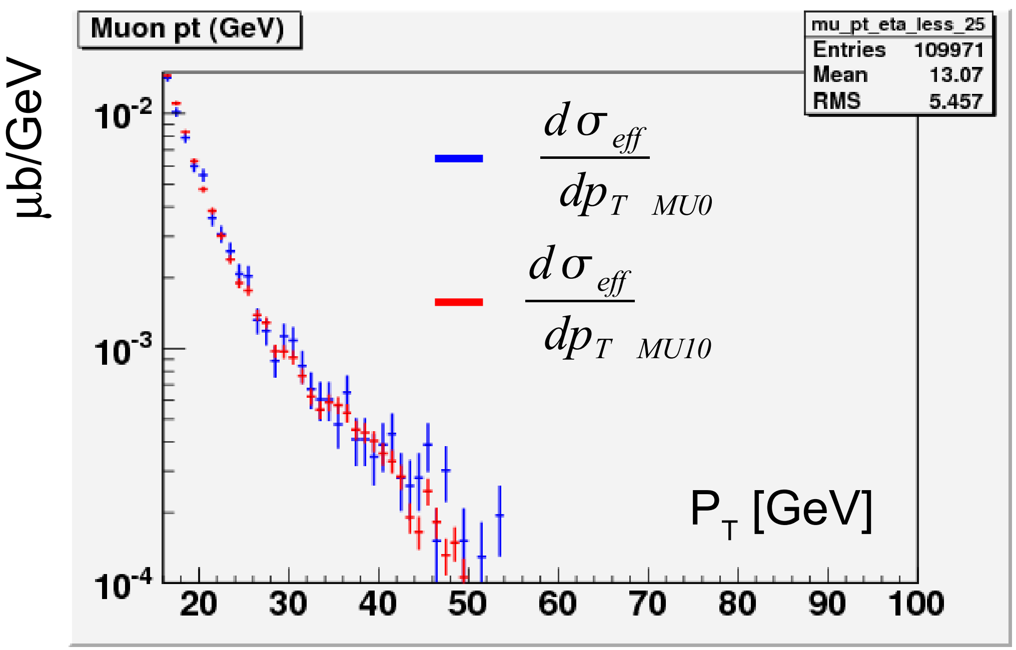
Effective cross section comparison ICHEP statistics

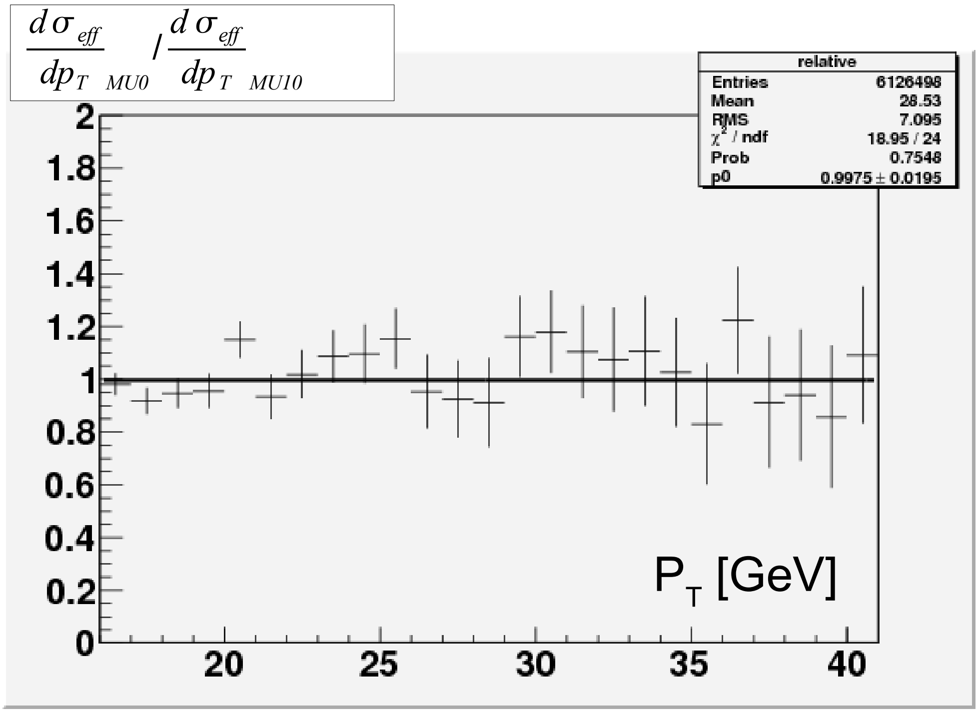
$$\left.\frac{d\sigma_{eff}}{dp_T}\right|_{MU0} = \frac{N_\mu}{L_{MU0}}$$

Run Range:
152777 – 158392
L_{int} = 46320 μb^{-1}

$$\left.\frac{d\sigma_{eff}}{dp_T}\right|_{MU10} = \frac{N_\mu}{\epsilon_{MU10/MU0} L_{MU10}}$$

Run Range:
158443 – 159224
L_{int} = 281700 μb^{-1}





Effective cross section period E

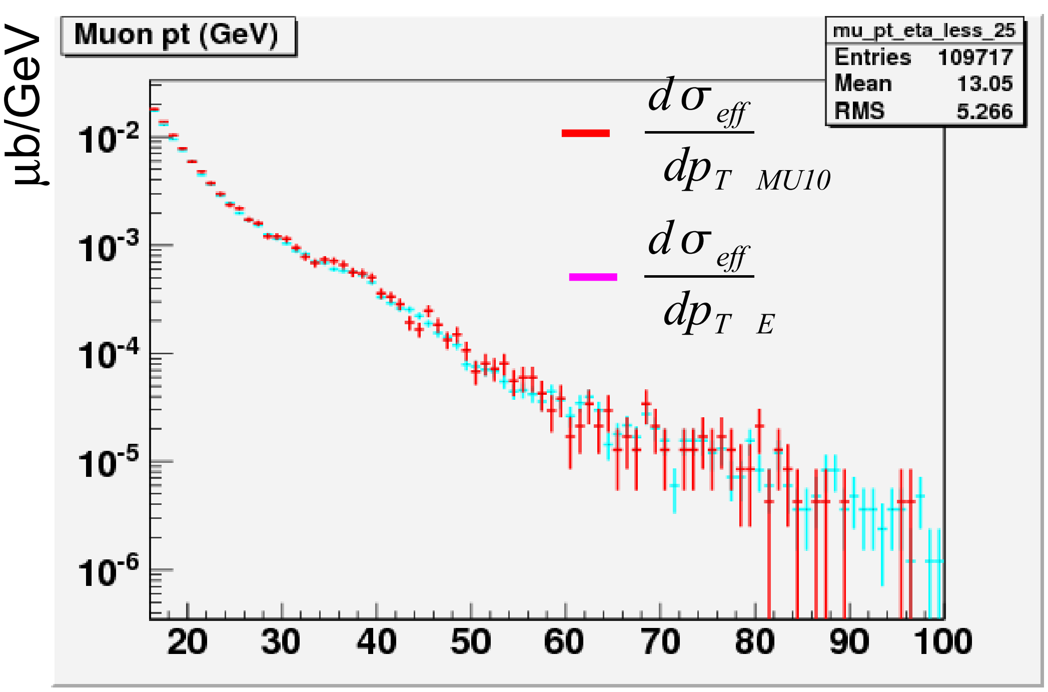
$$\left.\frac{d\sigma_{eff}}{dp_T}\right|_{MU10} = \frac{N_\mu}{\epsilon_{MU10/MU0} L_{MU10}}$$

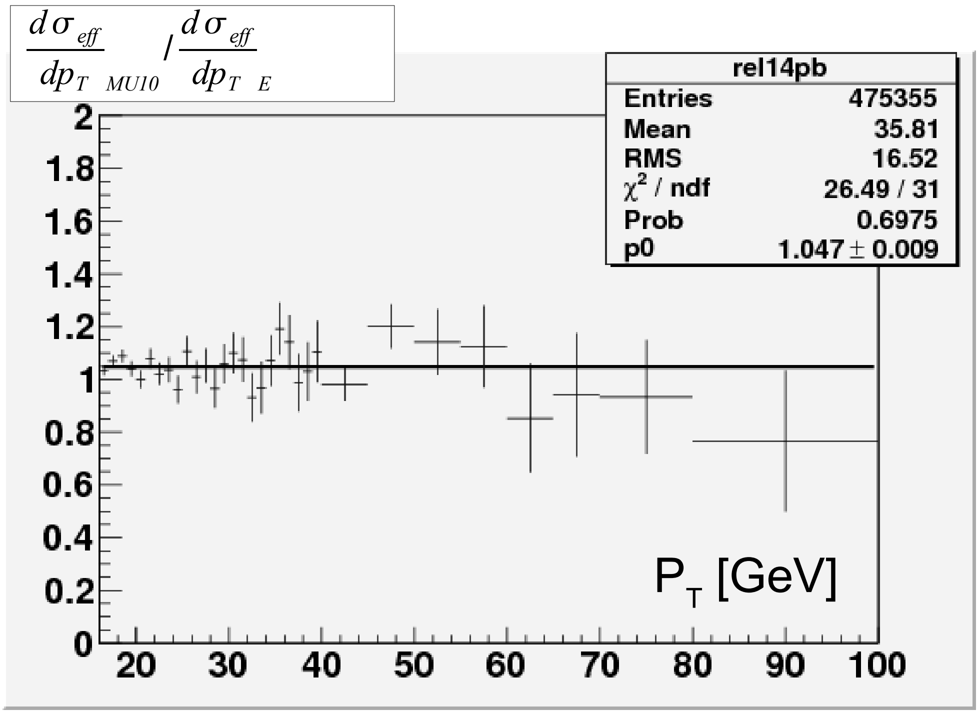
Run Range:
158443 – 159224
L_{int} = 281700 μb^{-1}

$$\left.\frac{d\sigma_{eff}}{dp_T}\right|_{E} = \frac{N_\mu}{\epsilon_{MU10/MU0} L_{E}}$$

Run Range:
160387 – 161948
L_{int} = 1002200 μb^{-1}

5% reduction in the yield, trigger efficiency under investigation with JetTauEtMiss and L1Calo streams





MC evaluated track efficiency

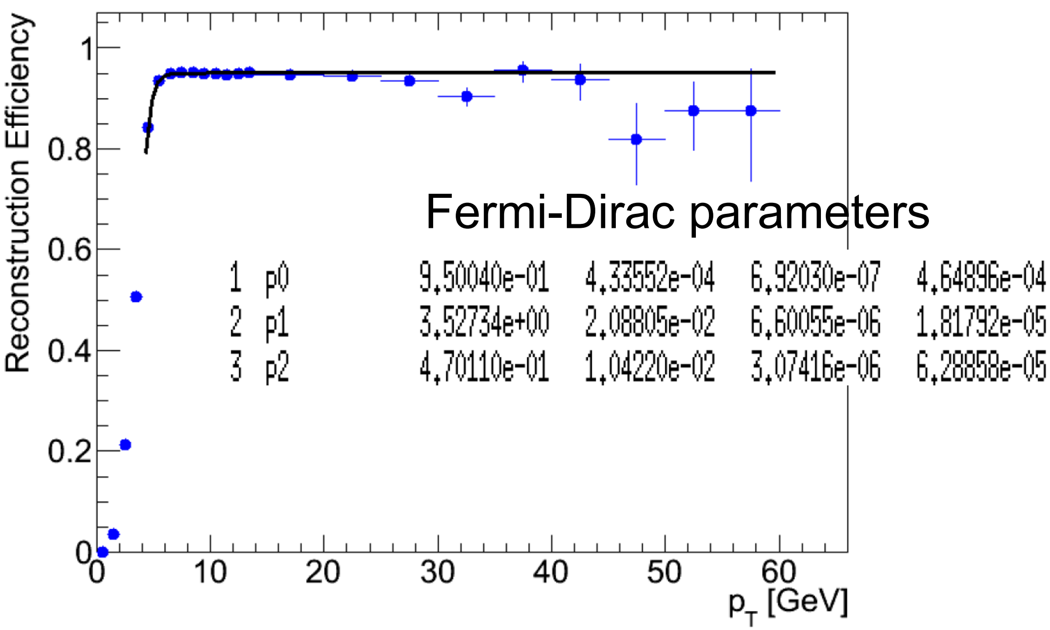
PythiaB bbmu4

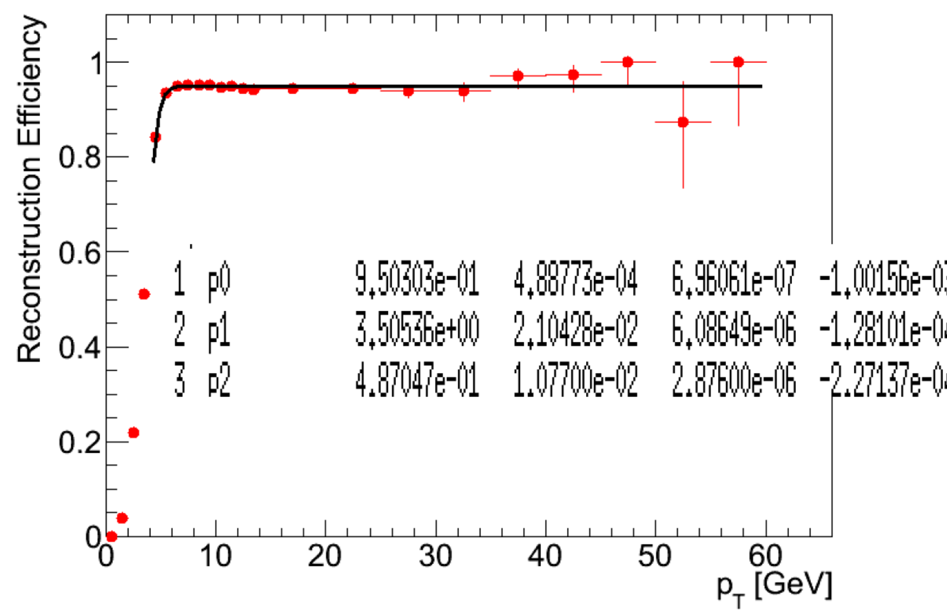
Event with a quark
b in $|\eta| < 4.5$ and $p_T > 5$ GeV
and a muon (before GEANT
simulation) with $|\eta| < 2.5$ $p_T > 4$ GeV

PythiaB ccmu4

Event with a quark
c in $|\eta| < 4.5$ and $p_T > 4$ GeV
and a muon (before GEANT
simulation) with $|\eta| < 2.5$ $p_T > 4$ GeV

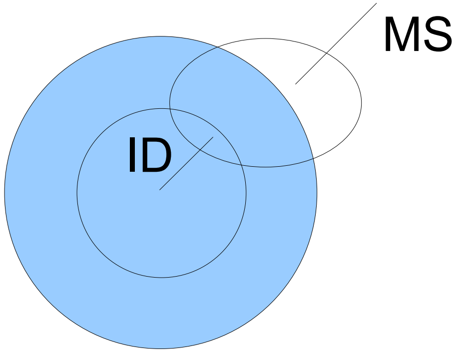
Reconstruction efficiency is flavour independent, we can measure directly the sum of the two contributions.





DATA/MC correction for the track efficiency.

MS reconstruction and matching



$\varepsilon = \varepsilon_{ID} \times \varepsilon_{MS} \times \varepsilon_{Match}$

Evaluated in one step.

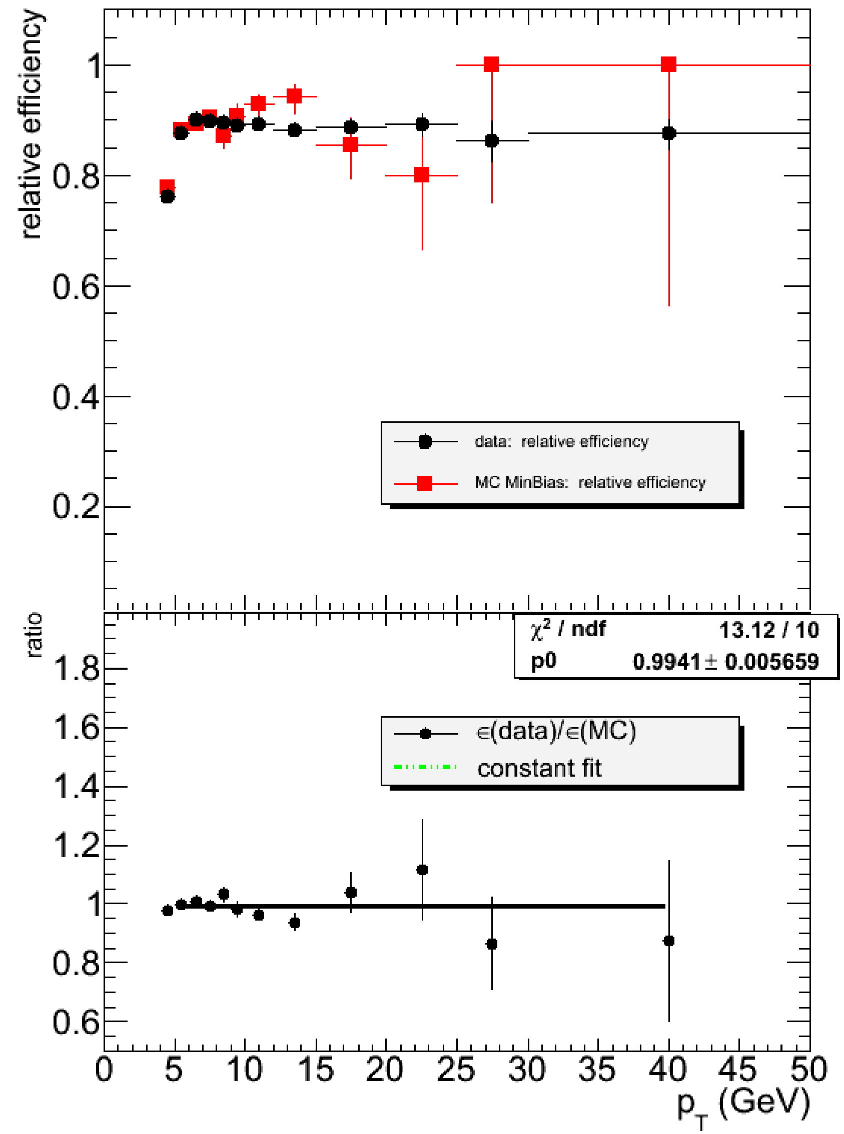
The problem is the determination of a pure muon sample without using MS track informations.

Method 1

Look for an ID track that matches an L1_MU0 ROI in ΔR.

Selection

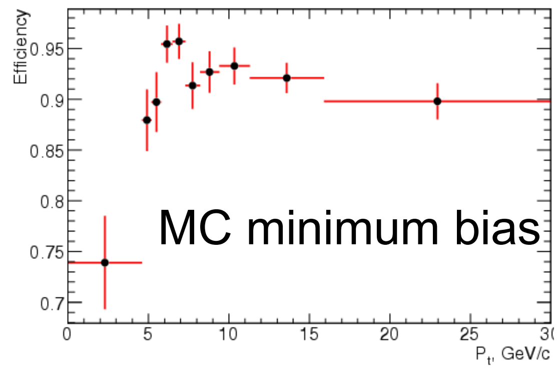
- $|\eta| < 2.5$, $p_T > 4$ GeV
- $n_{pixel} > 1$; $n_{SCT} > 5$;
- ΔR (ID-ROI) < $-0.0087 * p_T + 0.235$ $\quad p_T < 20$ GeV
  0.06 $\quad p_T > 20$ GeV

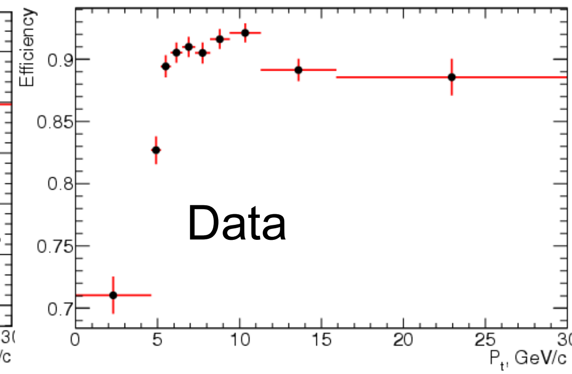


DATA/MC correction for the track efficiency - Method 2

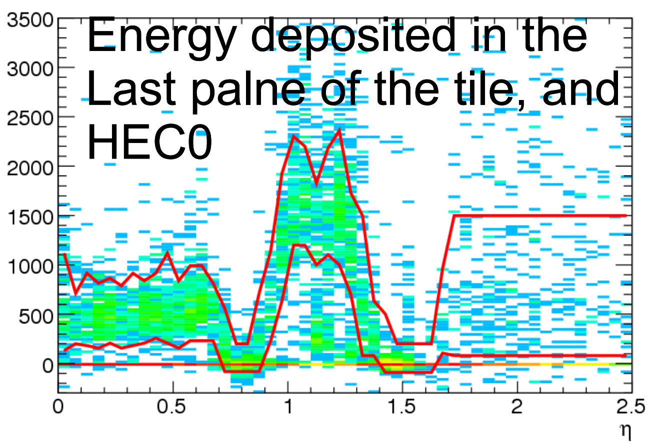
We select good ID tracks associated with jet using the following criteria:

- $\sqrt{(\eta_{\rm jet} - \eta_{\rm trk})^2 + (\phi_{\rm jet} - \phi_{\rm trk})^2} < 0.4$
- $|\eta| < 2.5$
- $p_t > 4$ GeV/c
- $d_{PV}/\sigma_d > 3$
- $\chi^2/{\rm ndf} < 1.25$
- $+$ sliding quality cuts
- $E_\mu > 1.4$ GeV in B in jet+μ rest frame
- TopoCluster with energy release in layers closest to MIP close to track extrapolation, with correction of calorimeter granularity in η.

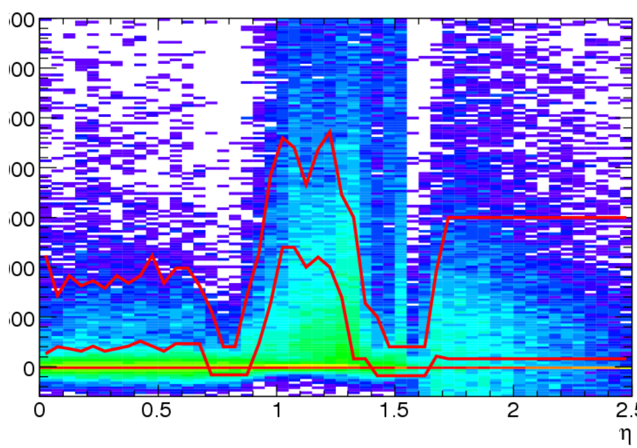


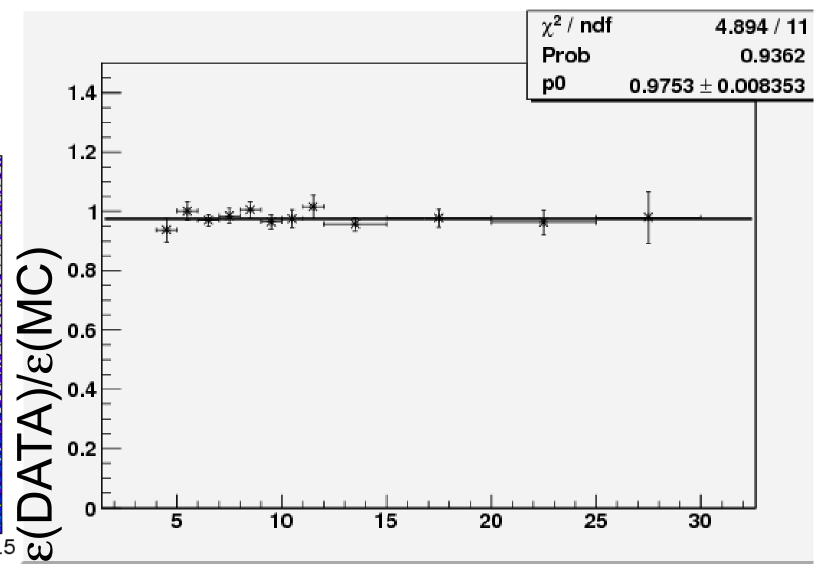


Muon



Fake Muon





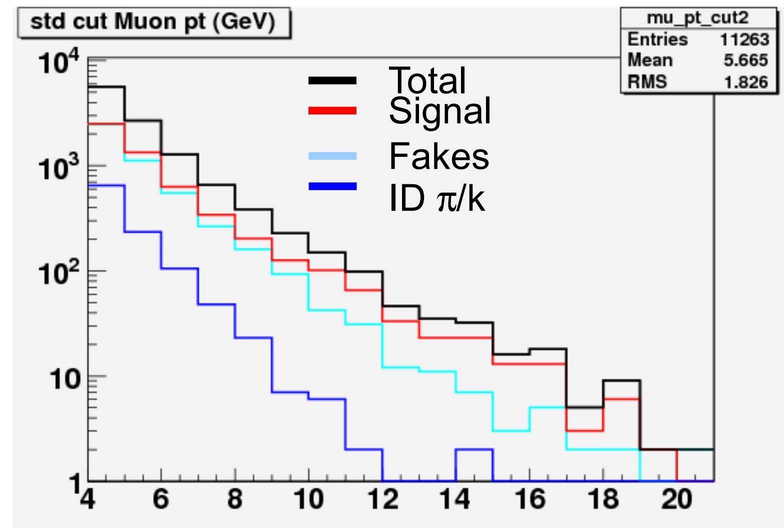
Signal fraction determination

Muons from pi/K decay in calorimeter and punch through

The ID track is the pi/K momentum, the MS track is the muon momentum, at high P, ΔP measures the energy taken by the neutrino at low P large kink are possible

ΔP_T most sensitive variable

Non diffractive minimum bias

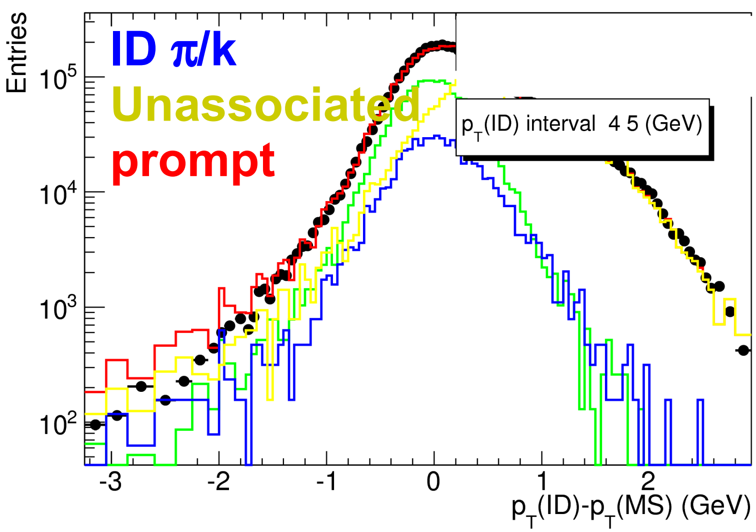


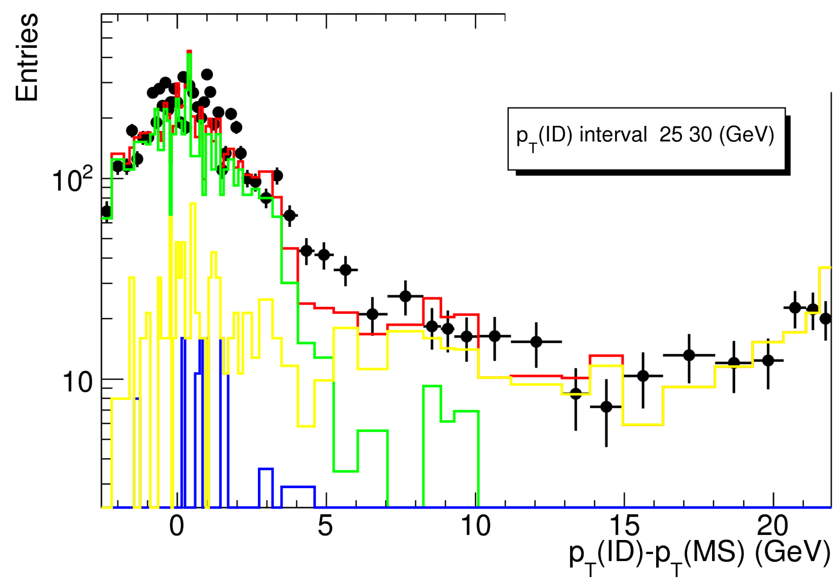
The relative MS-ID miscalibration is taken into account by scaling and smearing the Monte Carlo MS momentum

$$P_T(MS) \to \alpha P_T(MS) + \beta r P_T(MS)$$

r normally distributed number

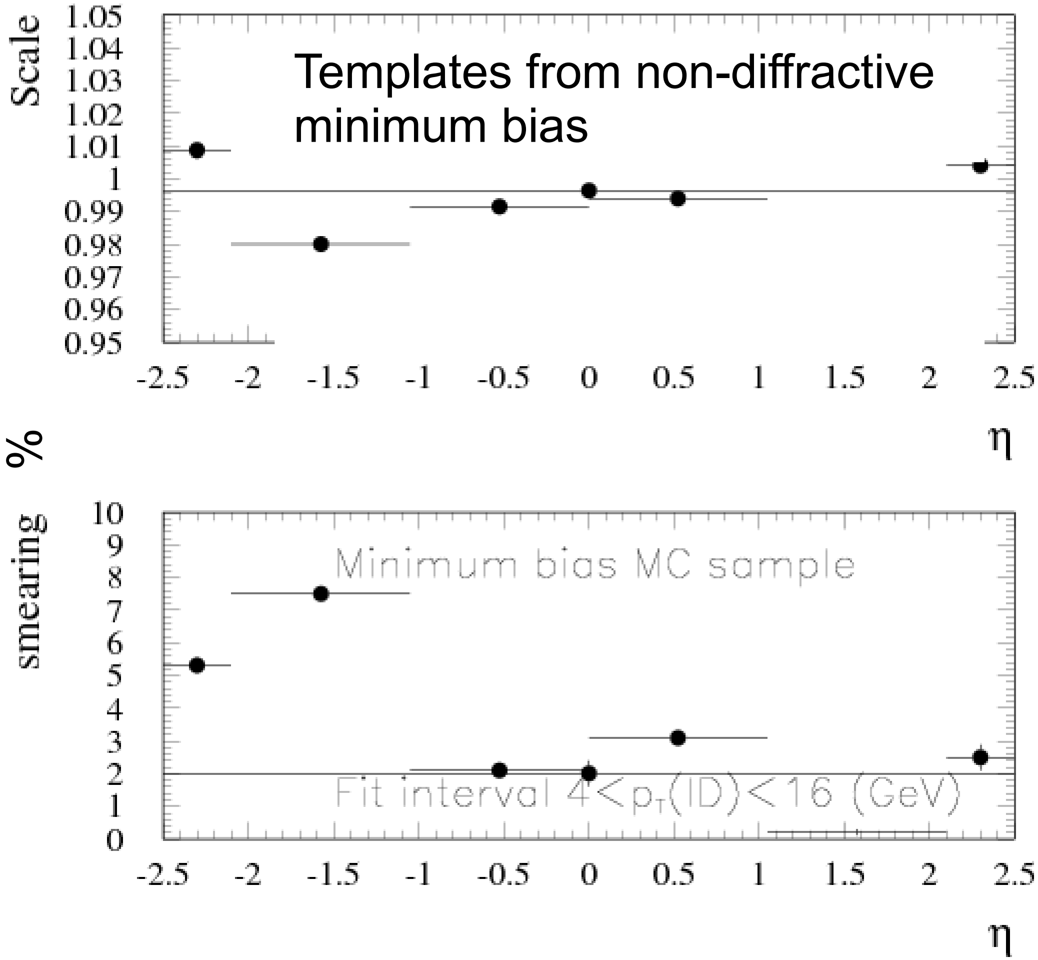
The MC is templated event by event and the scale and smearing are applied at each minimization step





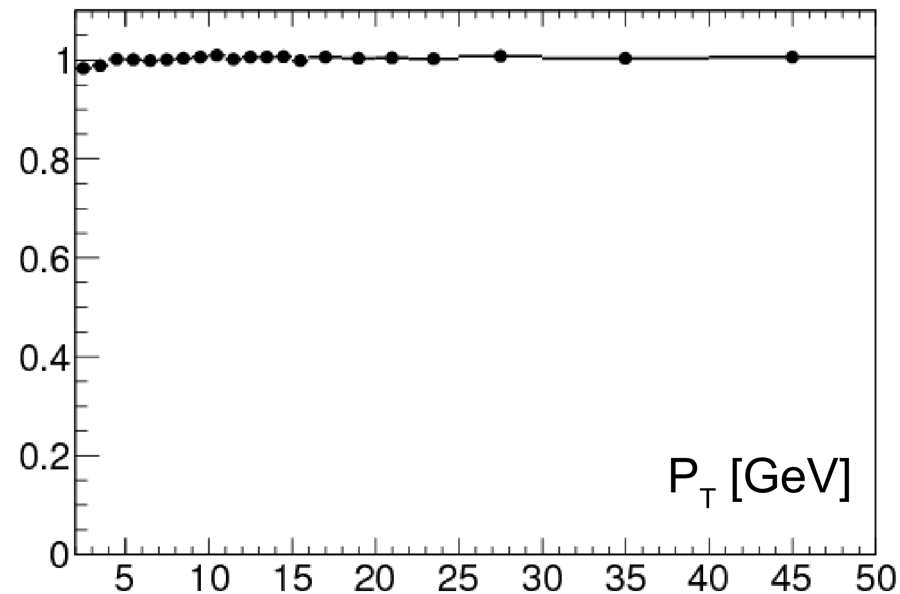
Scale and smearing η dependence

MS condition strongly η dependent, determination of the smearing and scale as a function of η using non-diffractive Minimum Bias for $4 < p_T < 16$ GeV

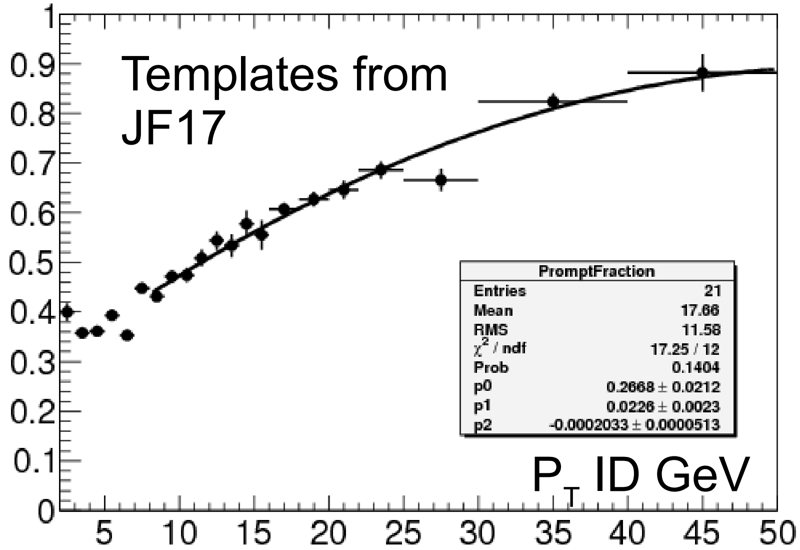


η independent scale correction factor as a function of p_T (super-scale)

Fit performed with MC JF17



Signal fraction determination.

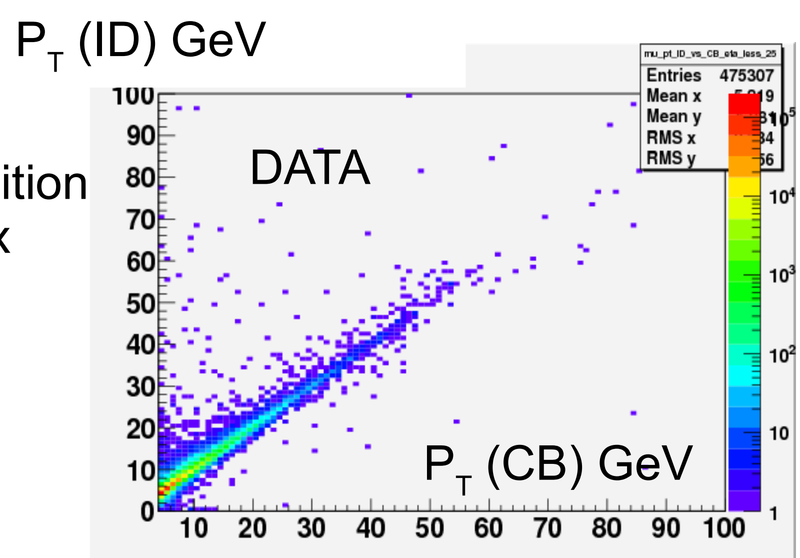


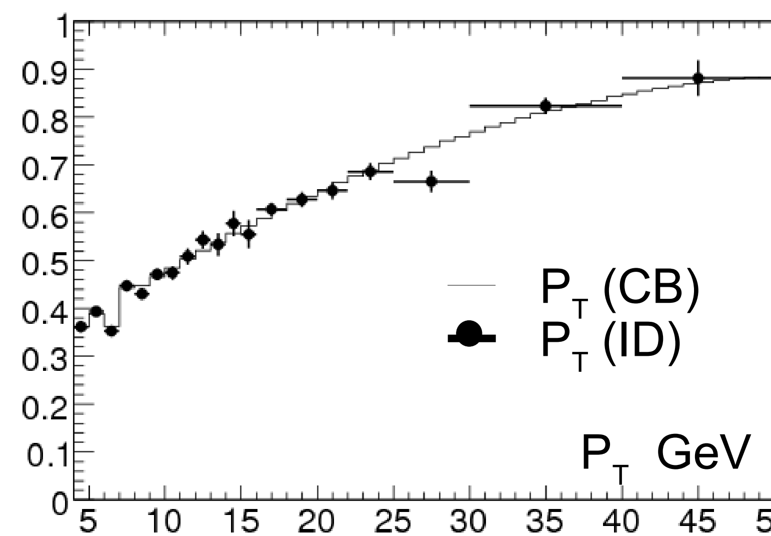
Irregular behaviour up to 8 GeV
Pol2 fit for $p_T > 8$ GeV.

Study performed in p_T (ID), p_T combined results in an unphysical value on fakes (the average between the π/K and the muon momenta)

Need weighting matrix to have contribution in P_T (CB).

Transition matrix





Cross section evaluation

$$\frac{dN_{\mu}}{dp_T}=\frac{f_{prompt}(p_T)}{\epsilon(p_T)}\frac{dN_{\mu\,reconstructed}}{dP_T}$$

$$f_{prompt}(p_{T\,CB})=\int_{p_{T\,ID}}\overset{\text{DATA}}{g(p_{T\,CB},p_{T\,ID})}\cdot \overset{\text{DATA}}{f_{prompt}(p_{T\,ID})}\,dp_{T\,ID}$$

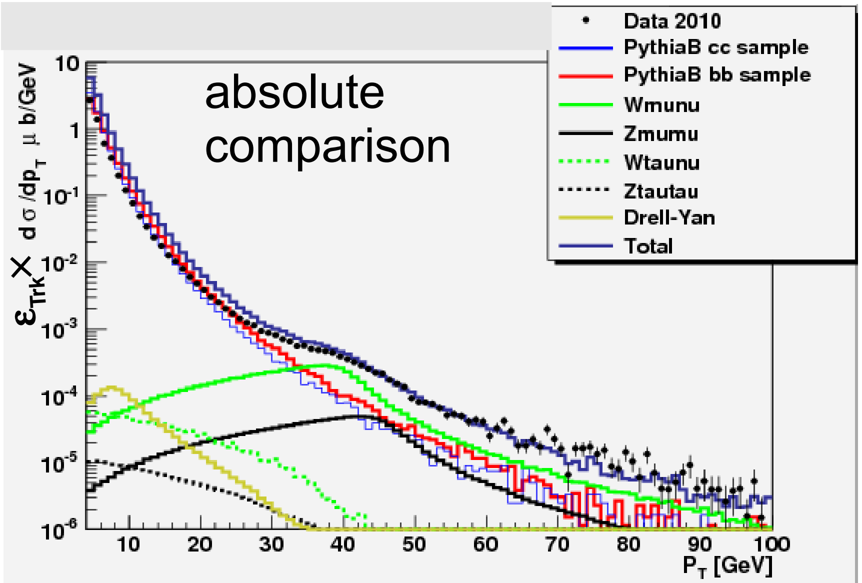
$$\epsilon(p_T)=\frac{N_{trk}(reco\wedge triggered)}{N_{\mu\,produced}}=\frac{N_{trk}(reco\wedge triggered)}{N_{trk}(reco)}\cdot\frac{N_{trk}(reco)}{N_{\mu\,produced}}=\epsilon_{trig}\cdot\overset{\text{DATA}}{\epsilon_{trk}}=\epsilon_{trig}\cdot\overset{\text{DATA}}{\frac{\epsilon_{trk}}{\epsilon_{trk\,MC}}}\cdot\epsilon_{trk\,MC}$$

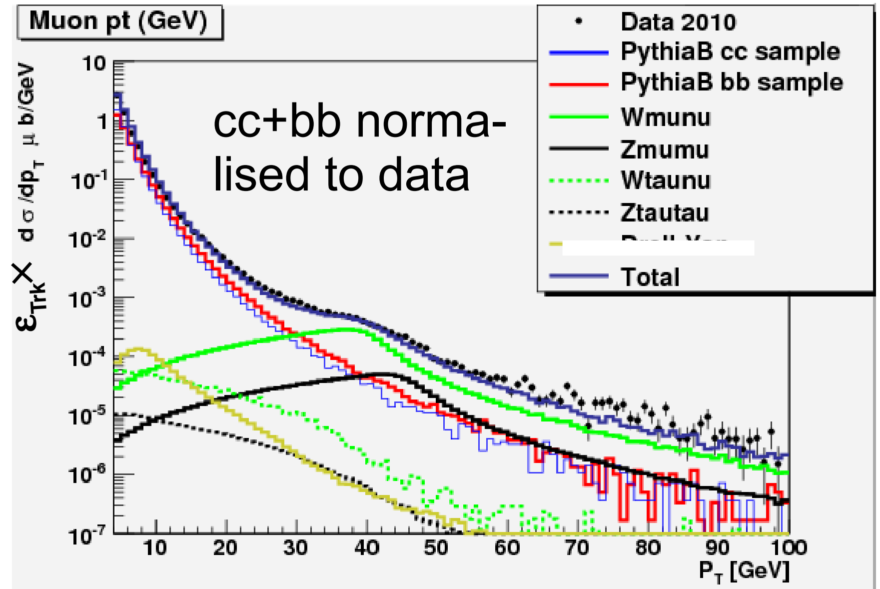
$$\epsilon_{trig}=\overbrace{\frac{\epsilon_{MU10}}{\epsilon_{MU0}}\cdot\frac{\epsilon_{MU0}}{\epsilon_{MBTS1}}}^{\text{DATA}}\cdot\overset{1}{\epsilon_{MBTS_1}}$$

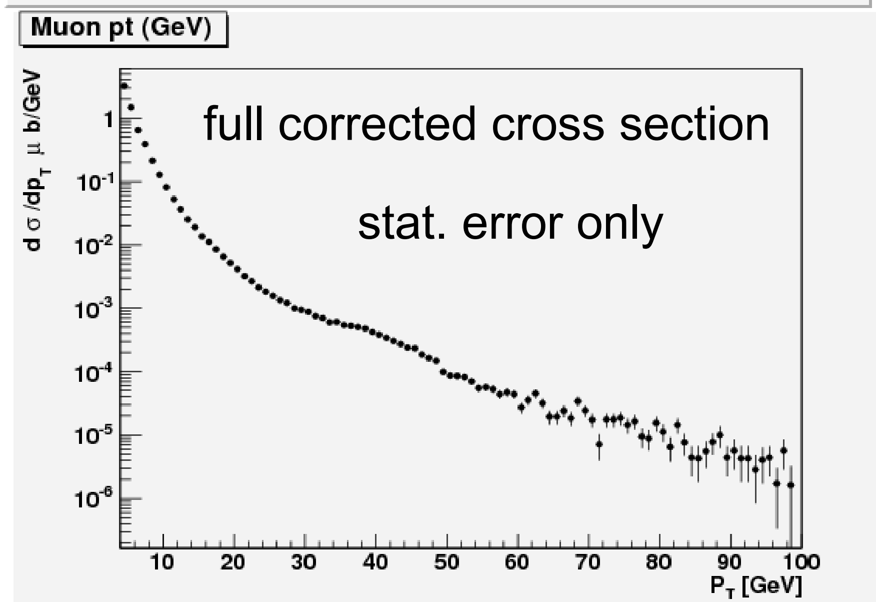
$$\frac{d\sigma_{\mu}}{dP_T}=\frac{1}{L}\frac{dN_{\mu}}{dp_T}$$

$$\frac{\epsilon_{MU10}}{\epsilon_{MU0}}=1$$ for $p_T < 16$ GeV

The muon inclusive cross section





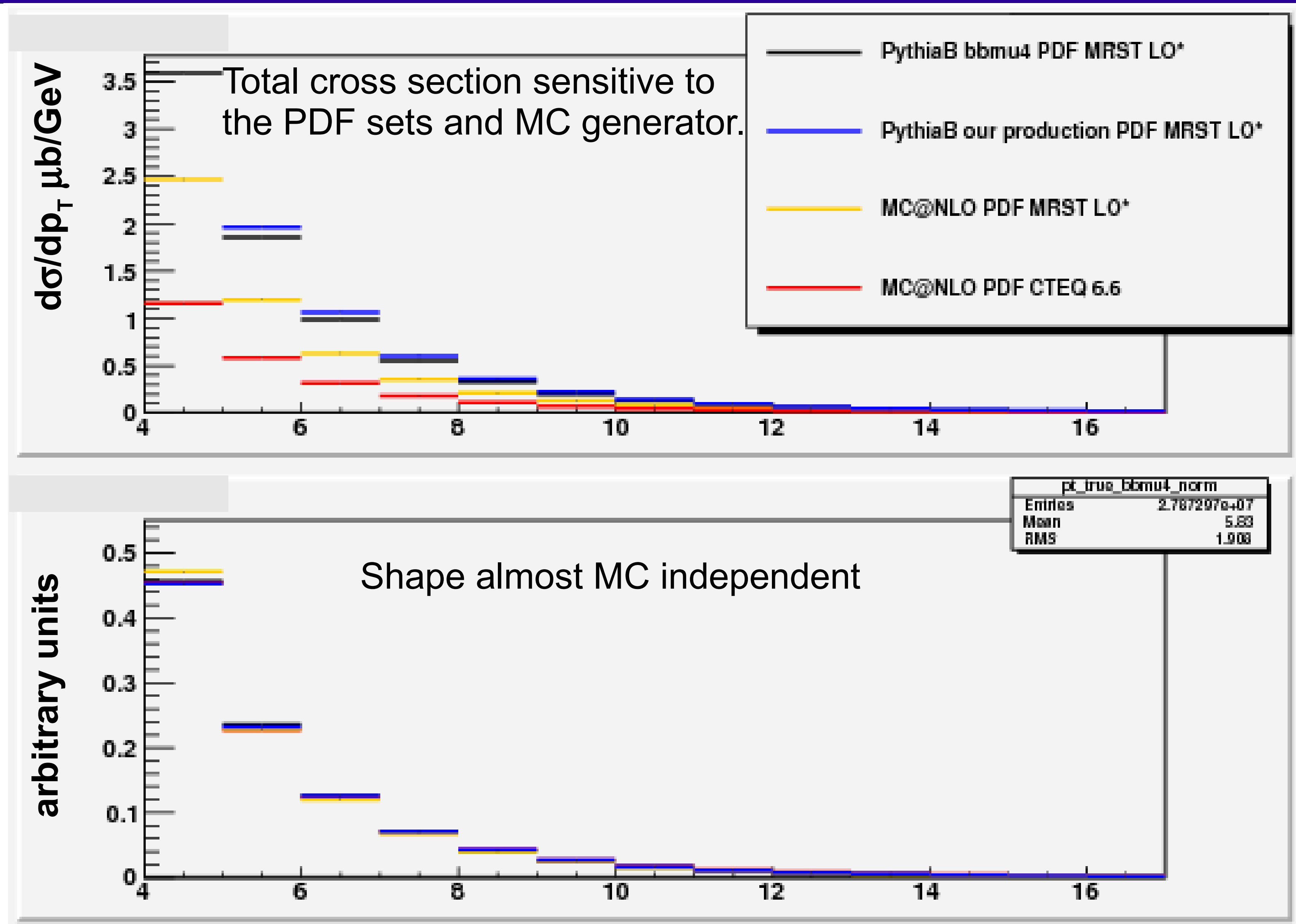


$4 < p_T < 20$ GeV

$\sigma^{\mu}_{\ \mathrm{DATA}} = 5.5\ \mu b$

$\sigma^{\mu}_{\ bb} + \sigma^{\mu}_{\ cc} = 13\ \mu b$

MC predictions for μ in bb events



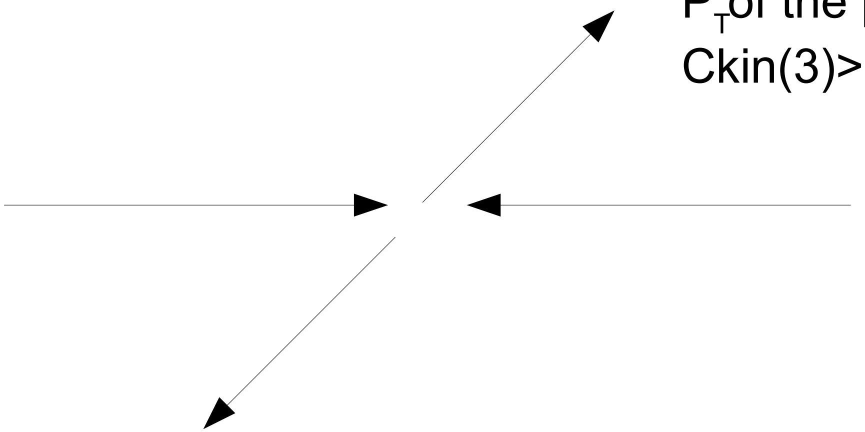
MC produced at EVGEN level at Roma-Tre Tier-3

Conclusions

- Trigger efficiency have to be recomputed period by period using calo streams;
- Inner Detector DATA/MC correction have to be computed;
- Determination of the CB muon resolution need to be performed and the spectrum need to be unfolded (Gatti,Dreucci method?)
- Systematics under evaluation
- We point to have a preliminary result with 1.4 pb^{-1}
- Extract the heavy quark production cross section, W,Z and W/Z production cross section from the fit to the spectrum;
- Constraint the PDF set in the given experimental uncertainties and fragmentation model uncertainities.

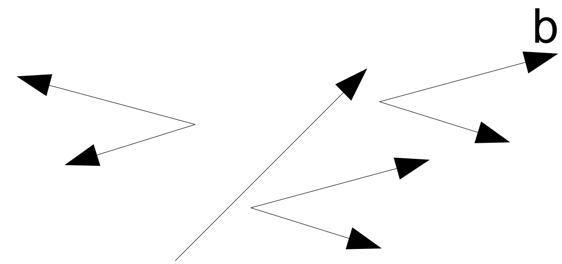
Generation and filtering...

Primary interaction



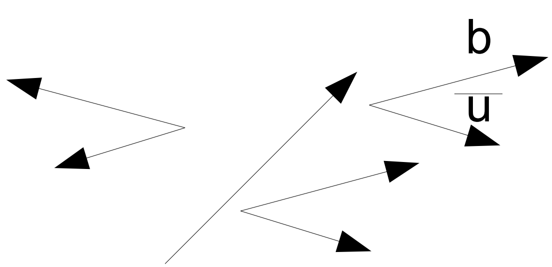
P_T of the primary parton
Ckin(3)>6 GeV

showering



cutbqp p_T of the b quark > 5 GeV
Cutbqeta eta of the b quark < 4.5

Fragmentation and decays



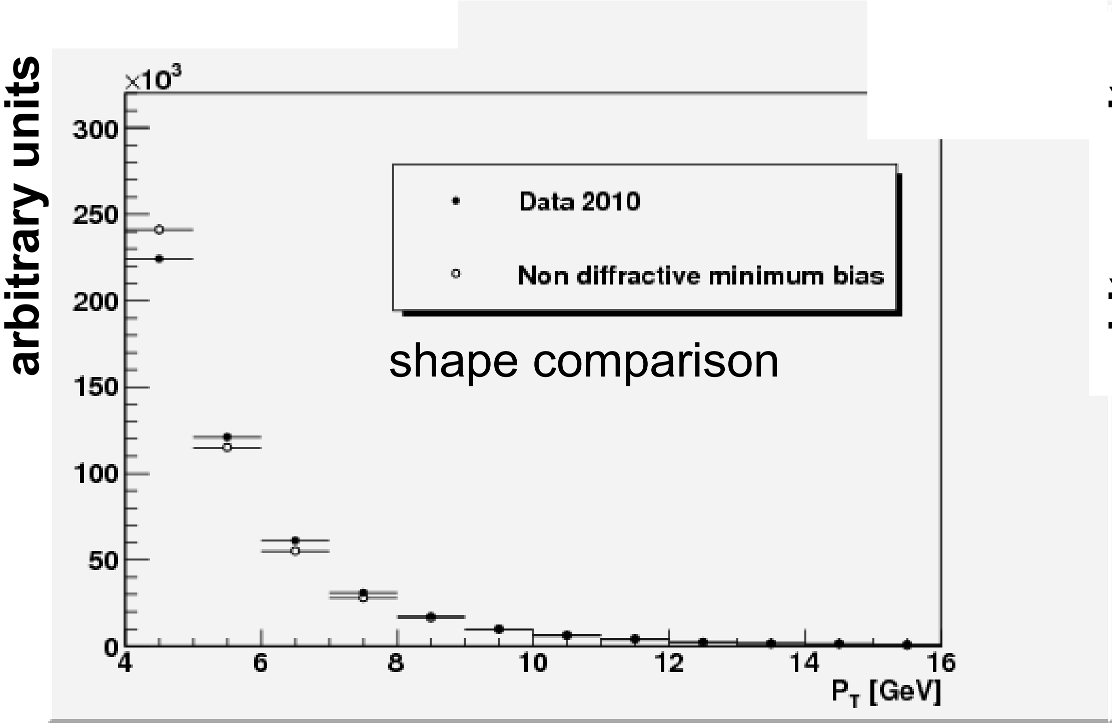
$B^- \to \mu^- \bar{\nu}$

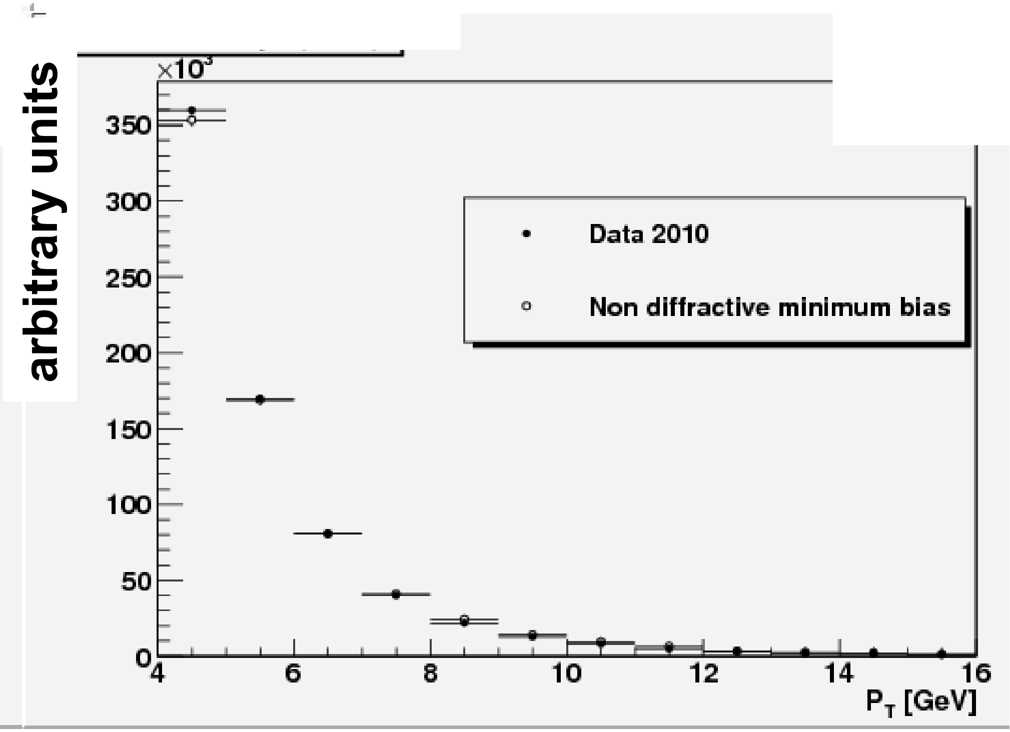
μ p_T > 4 GeV
eta of the μ < 2.5

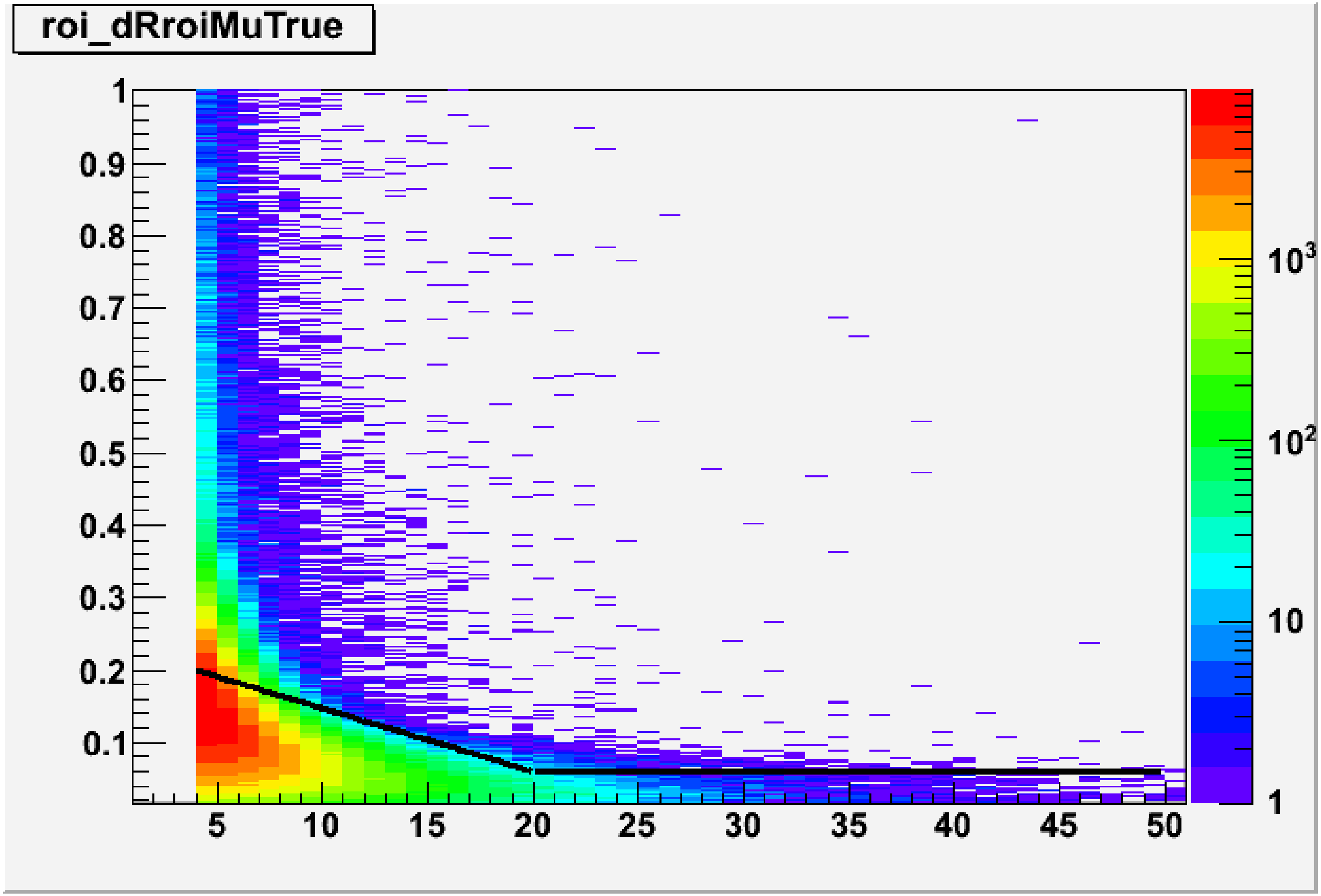
Trigger efficiency – L1_MU0/L1_MBTS_1 (DATA/MC comparison)

Data MC comparison without L1_MU0 trigger efficiency correction

Data are corrected for trigger efficiency. In MC trigger is not required.






roi_dRroiMuTrue
1
0.9
0.8
0.7
0.6
0.5
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5
10
15
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30
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10^3
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1