$W \rightarrow \mu\nu_\mu$ Selection

A look at backgrounds, efficiency and purity based on 1042 pb^{-1} of 2011 data at LHCb

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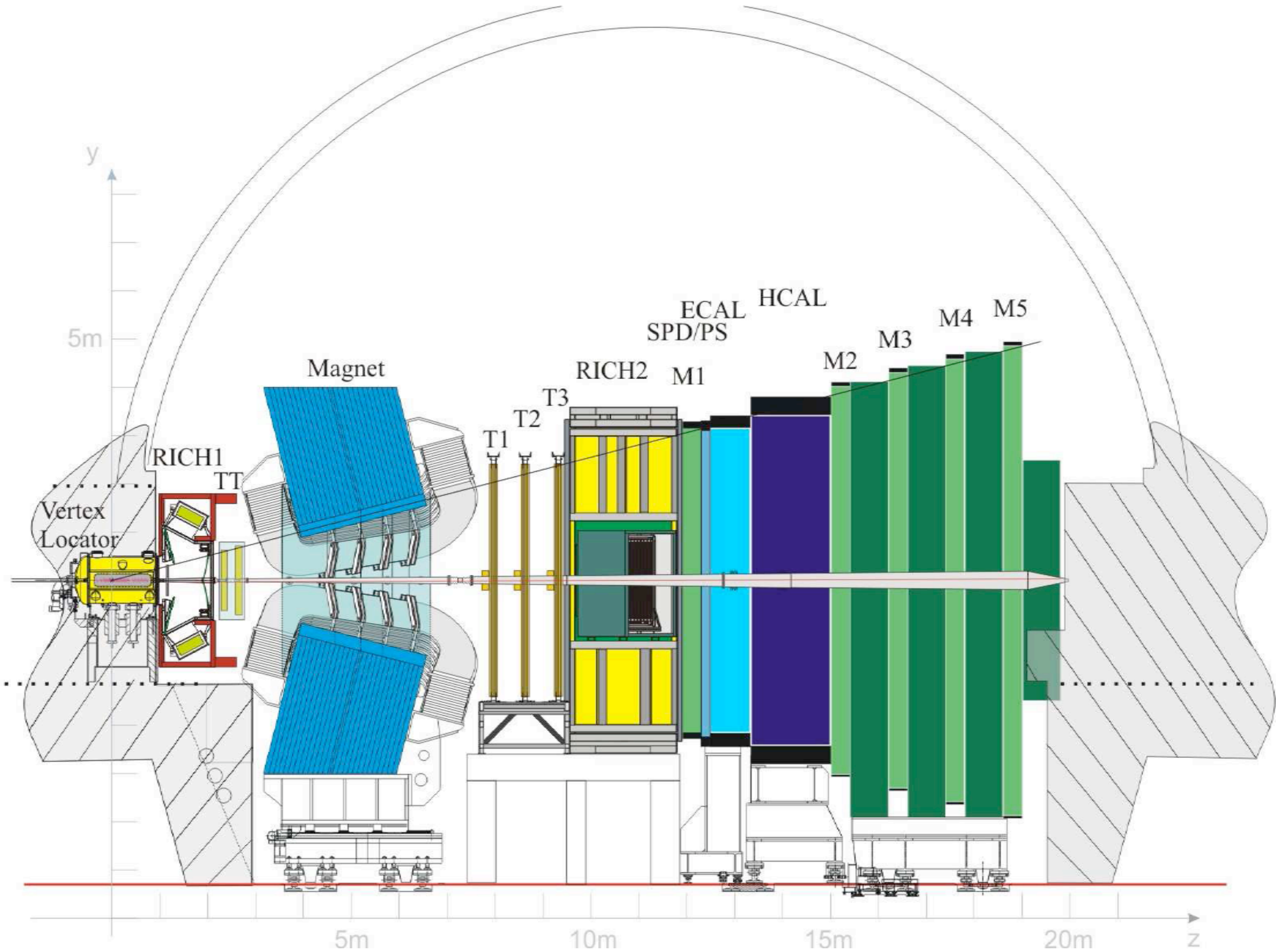
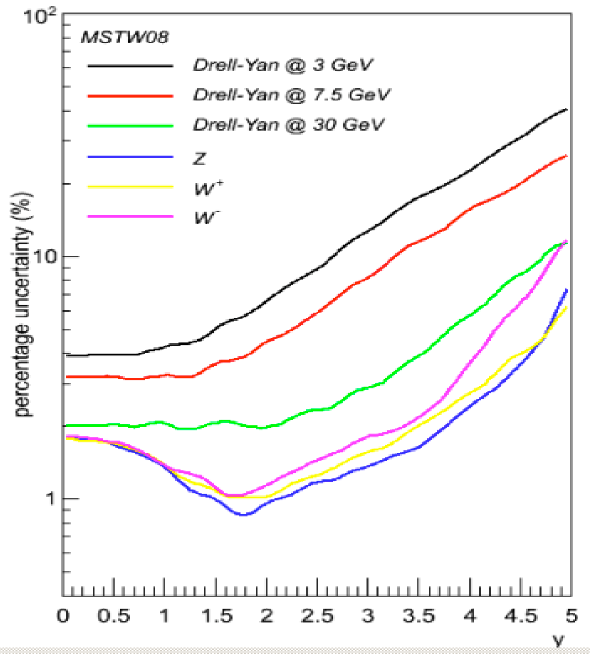
HEPP/APP Conference 03/04/12

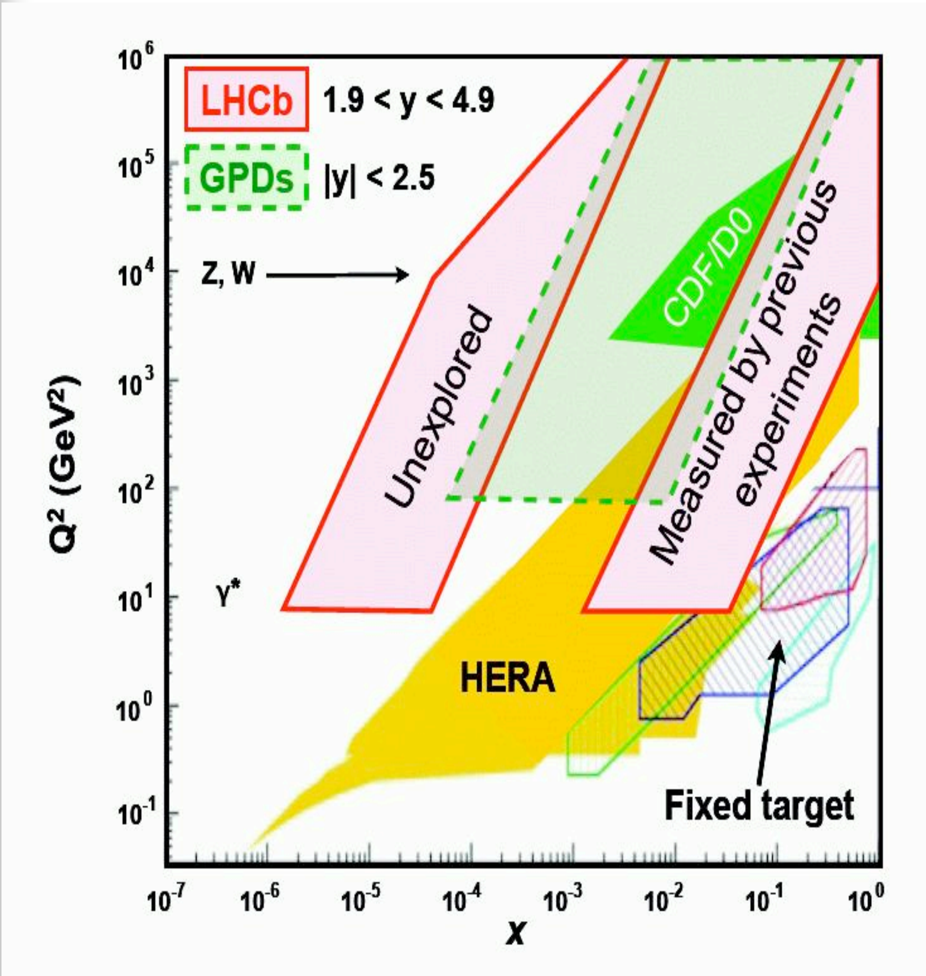
The LHCb Experiment



Motivation

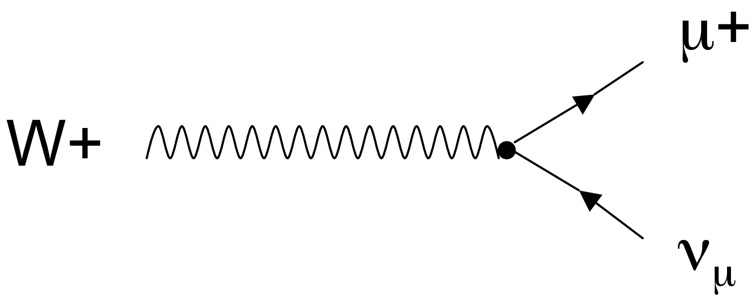
Theoretical uncertainty on cross-section

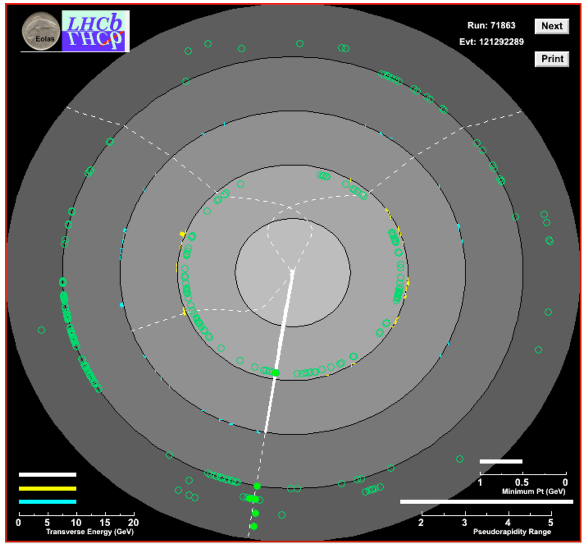




- Looking for cross-section and briefly at W+/W- asymmetry
- LHCb covers currently unexplored region
- Measurements will be complimentary to ATLAS and CMS

$W \rightarrow \mu\nu_\mu$ at LHCb

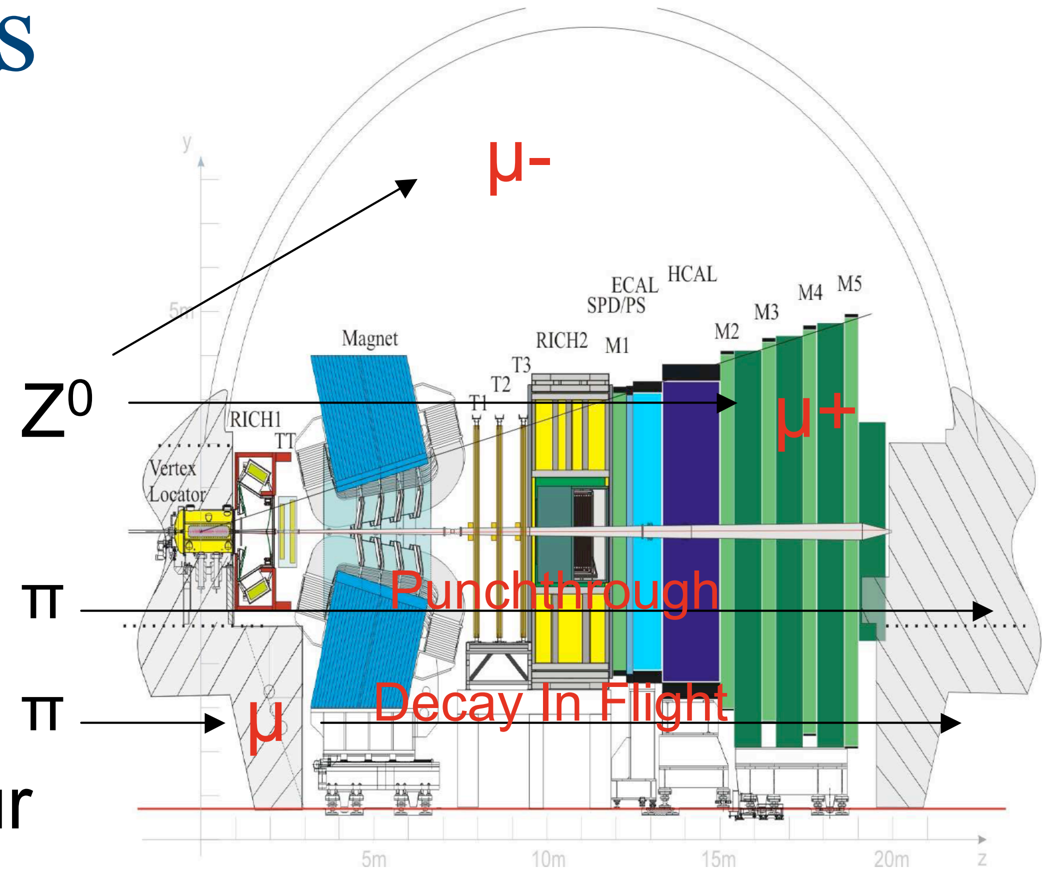




- Signal - 1 isolated muon with no IP
- Numerous backgrounds
- Fortunately, relatively large production rate

Backgrounds

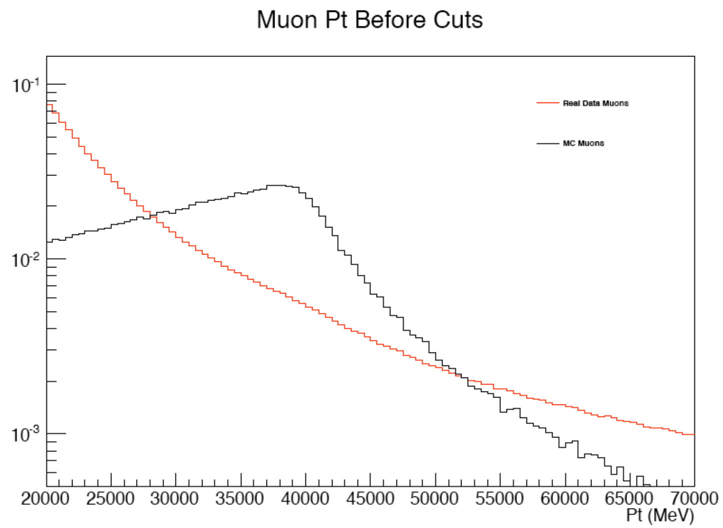
- Ewk
  - $Z^0 \to \mu+ \mu-$
  - $Z^0 \to \tau+ \tau-$
  - $W^\pm \to \tau^\pm \nu_\tau$
- QCD
  - Heavy flavour
  - Pion/Kaon mis-id



Refining Signal

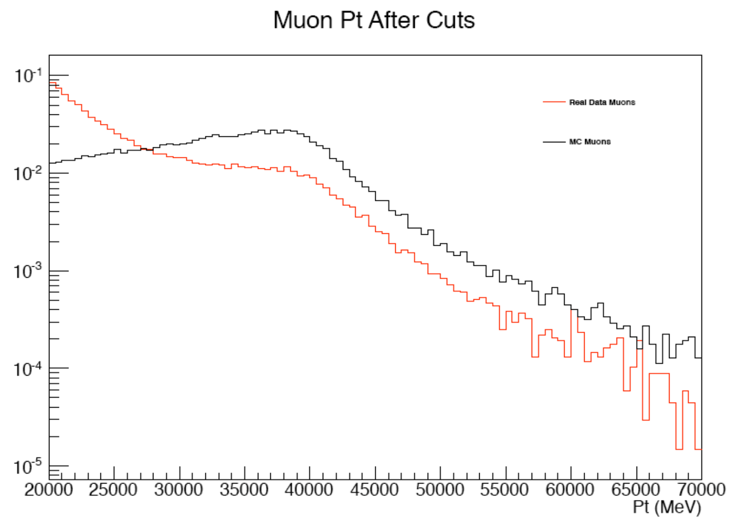
Cuts

- No other muon with Pt > 2GeV
- Pt > 20 GeV
- IP < 0.08 mm
- Hcal E / P < 0.04
- Isolation cuts
  - Cone ($R=\sqrt{\eta^2+\phi^2}=0.5$) Pt < 2GeV
  - Event Pt < 10 GeV
  - Event IM < 20 GeV
- Track Quality Cuts
  - χ^2 Probability > 0.01
  - $(\sigma P)/P < 0.1$



Plots normalised to unit area

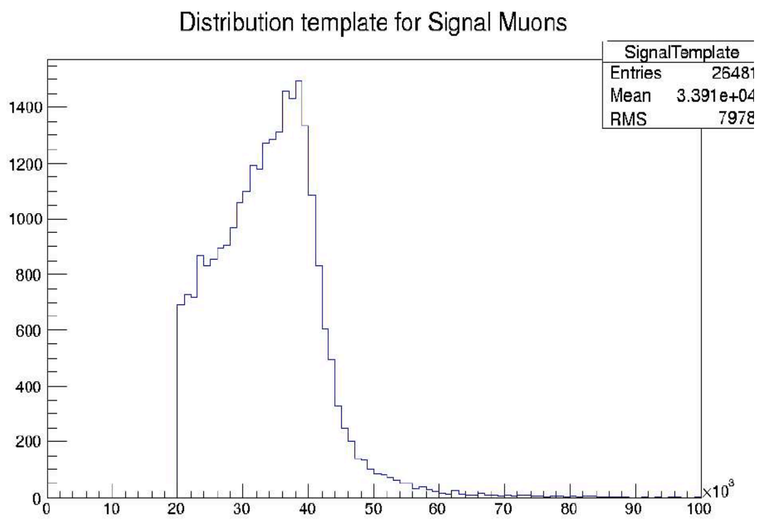
LHCb Unofficial

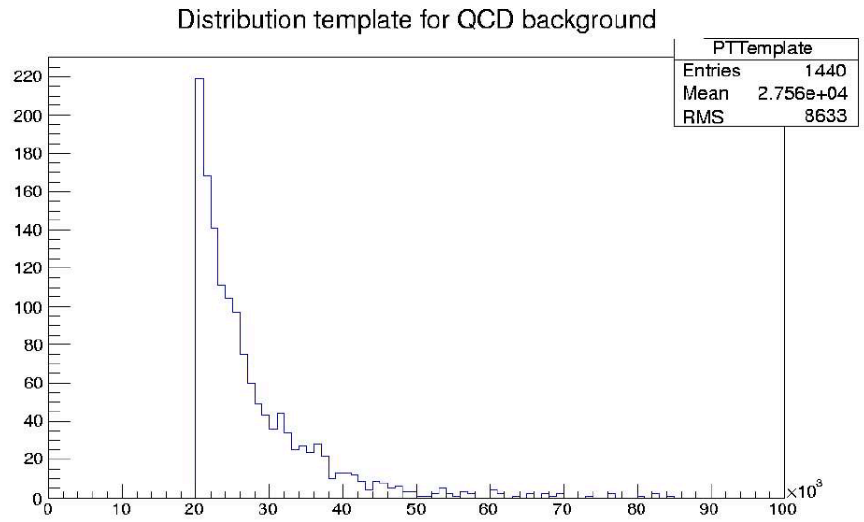


General method for finding signal candidates

- Generate a ‘template’ for each distribution in Pt
- Apply Constraints
- Perform global fit to real data

LHCb Unofficial



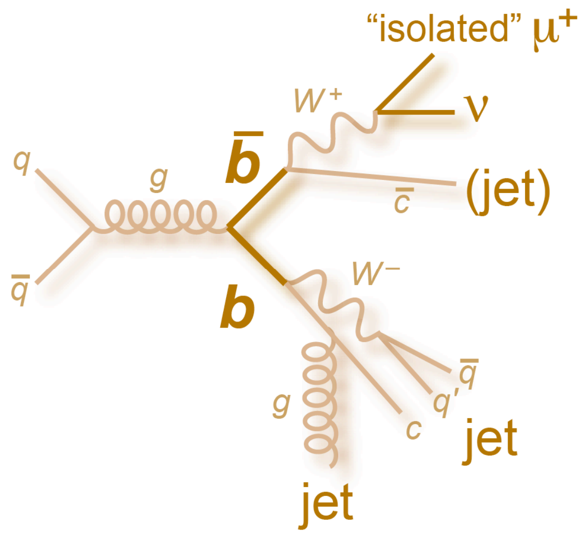


Template Generation

- For signal and electroweak backgrounds use MC templates
- Normalise background candidates to real data numbers using MC ratios
- For QCD backgrounds :
  - Separate into different contributions
    - Heavy flavour use anti-cuts on isolation variables
      - IP > 0.08, Cone Pt > 2 GeV, Evt IM >40 GeV, Evt Pt > 15GeV
    - Punchthrough use anti-cuts on hadronic calorimeter E/P
      - E/P > 0.08
    - Decay in flight - take final state pions and kaons and explicitly boost them back to r.f., and propagate them as muons
      - Very complicated
  - Or choose 1 template and add systematic error

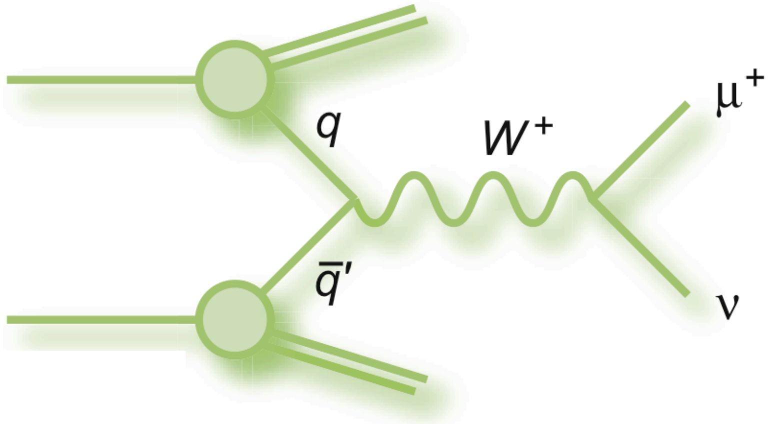
QCD Backgrounds

- Difficult to define π/K mis-id
- Either :
  - Use separate contributions which are more difficult to understand
  - Use one template with systematic of 1.38% (W+) and 2.83% (W-)



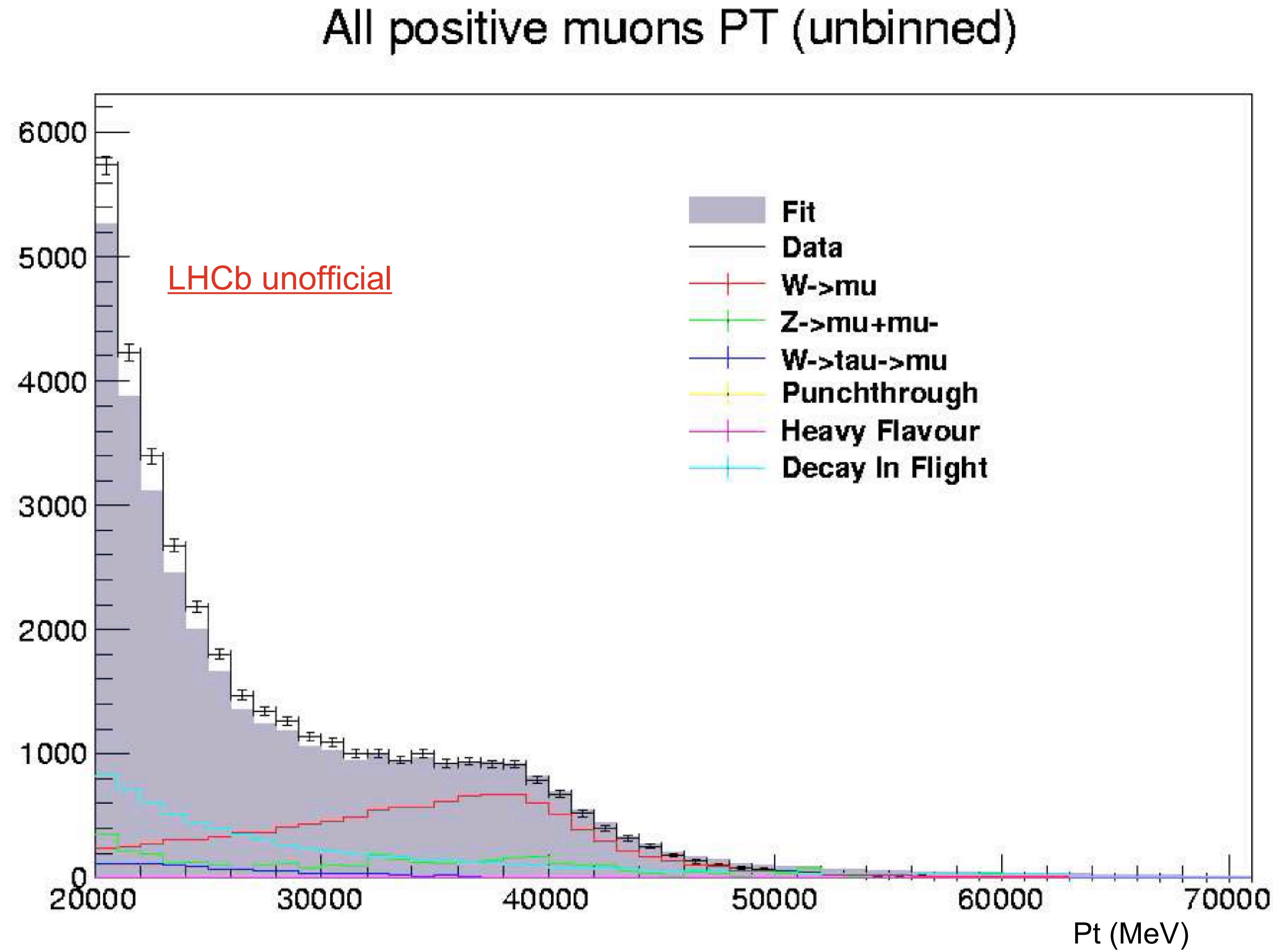
The following results use three separate templates

Final Fit

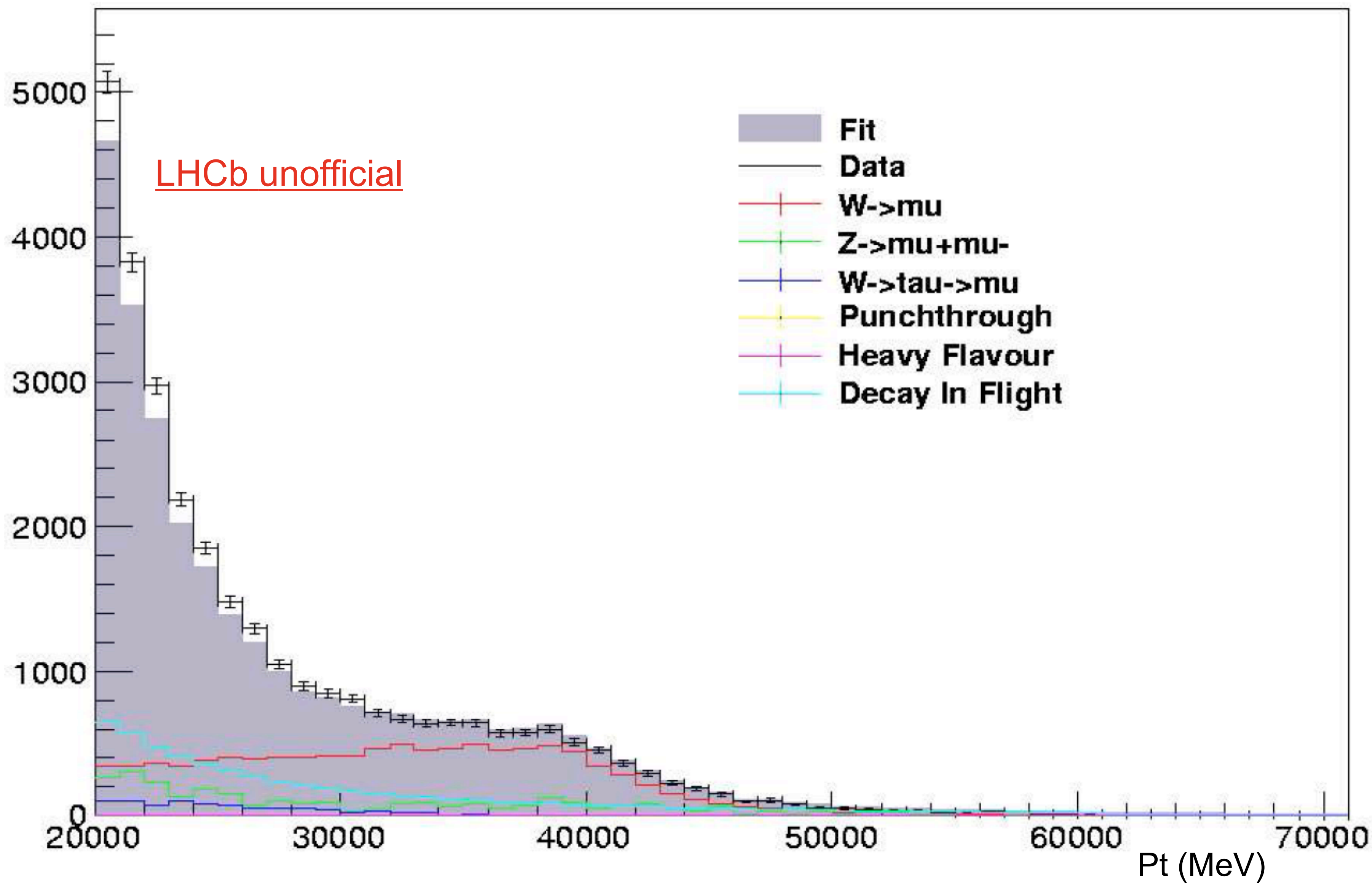


- Fit in 4 η bins
- Improves fit stability
- Separate for + and -
- 30274 ± 174 W- and 37910 ± 195 W+ candidates so far
- W+ (30.65 ± 0.08)%*
- W- (33.13 ± 1.1)%*

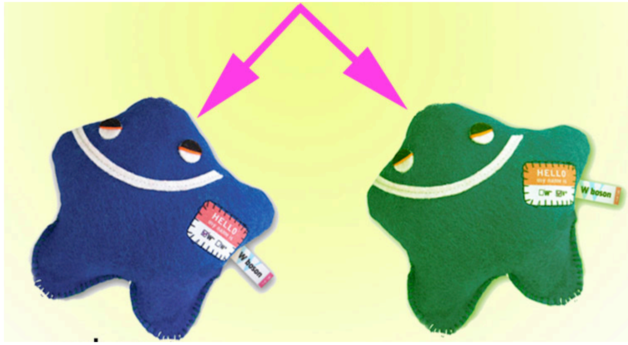
*This is the percentage purity given by the global fit


All positive muons PT (unbinned)
LHCb unofficial
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight
6000
5000
4000
3000
2000
1000
0
20000
30000
40000
50000
60000
70000
Pt (MeV)

All Negative Muons PT (unbinned)



To do:



- Re-optimise cuts to further reduce background
- Improve fit :
  - Change QCD background templates
  - Look into other generators to improve understanding of signal
- Calculate underlying efficiencies
- Calculate asymmetry and W+/W- cross-section ratio to further compare to theory

Thankyou for listening, any questions?

Backup

Cut Efficiencies

- χ^2 *Probability >0.01 :* 100%
- σ*P/P < 0.1 :* 100%
- *IP < 0.08 :* 92%
- *Cone Pt < 2GeV :* 92%
- *Event IM < 20GeV :* 86 %
- *Event Pt < 10GeV :* 64%
- *HCal E/P < 0.04 :* 98%

Constraints on templates used in fit

- $Z^0 \rightarrow \mu^+ \mu^-$: 9.74 ± 0.28 %
- $Z^0 \rightarrow \tau^+ \tau^-$: < 0.01 %
- $W^\pm \rightarrow \tau^\pm \nu_\tau$: 3.90 ± 0.15 %
- Punchthrough : 0.02 ± 0.01 %
- Heavy Flavour : 0.4 ± 0.2 %

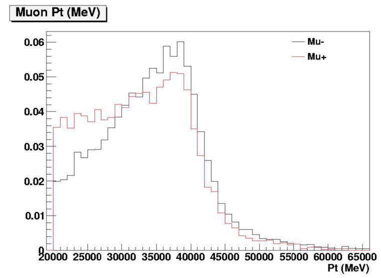
K/π DIF Template

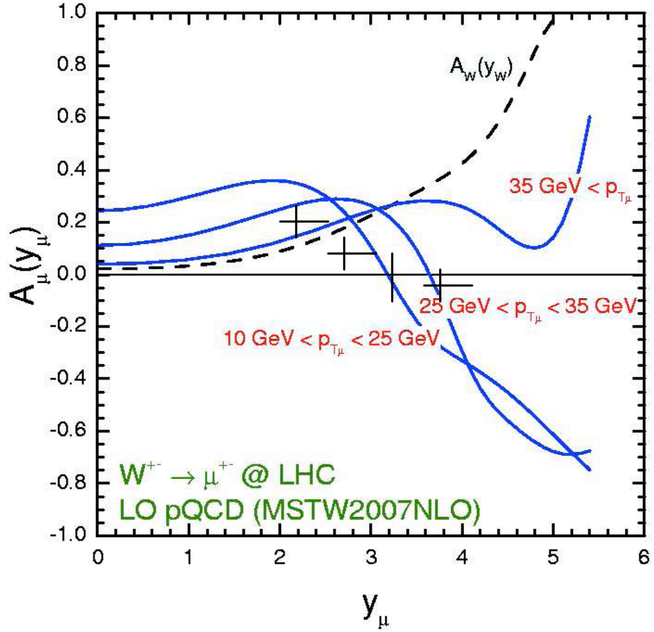
- Includes the following processes with b.r from PDG* :

Process	Branching Ratio (%)
$K^{\pm} \longrightarrow \mu^{\pm} + \nu_{\mu}$	63.55 ± 0.11
$K^{\pm} \longrightarrow \pi^{\pm} + \pi^{0}$	20.66 ± 0.08
$K^{\pm} \longrightarrow \pi^{\pm} + \pi^{0} + \pi^{0}$	1.761 ± 0.022
$K^{\pm} \longrightarrow \pi^{\pm} + \pi^{\pm} + \pi^{\mp}$	5.59 ± 0.04
$\Pi^{\pm} \longrightarrow \mu^{\pm} + \nu_{\mu}$	99.98770 ± 0.00004

http://pdglive.lbl.gov/Rsummary.brl?nodein=S010&exp=Y&sub=Yr&return=MXXX020
http://pdglive.lbl.gov/Rsummary.brl?nodein=S008&exp=Y&sub=Yr&return=MXXX005

W+ / W- Pt Asymmetry





Asymmetries :

(μ+ - μ-)/(μ+ + μ-)

-2< η <2.5 : 0.219

-2.5<η<3 : 0.096

-3< η<3.5 : -0.011

-3.5< η<4 : -0.134

-4< η<4.5 : 0 (statistical)

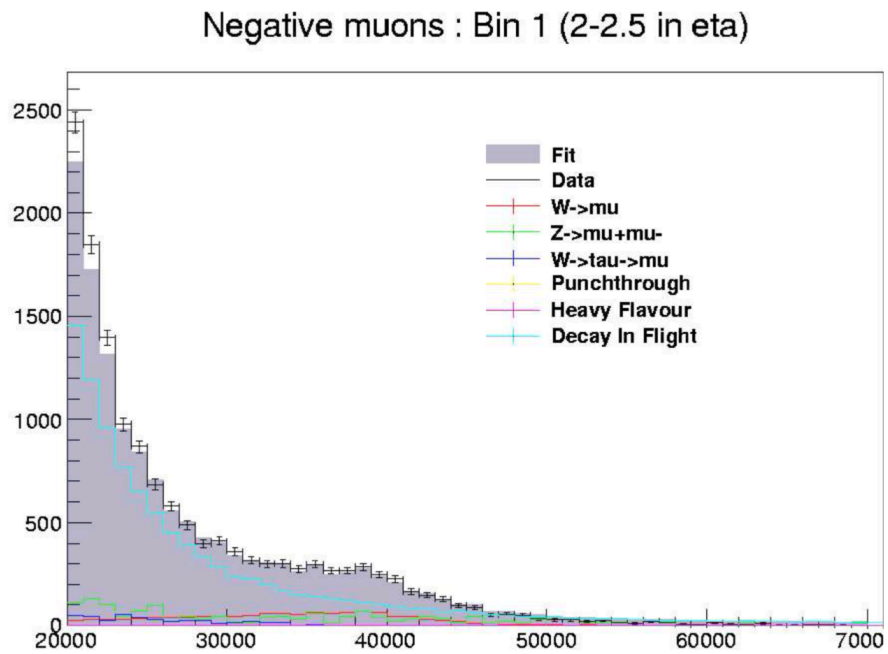
μ+ and μ- have different Pt spectra as shown above. This leads to asymmetries in the η bins used for this fit.

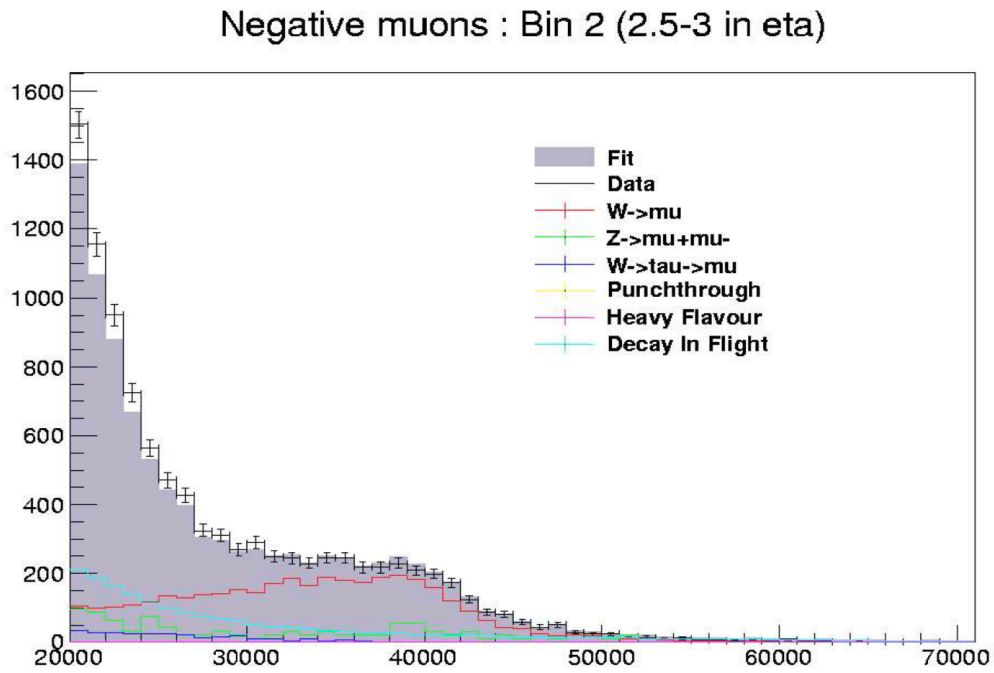
http://projects.hepforge.org/mstwpdf/

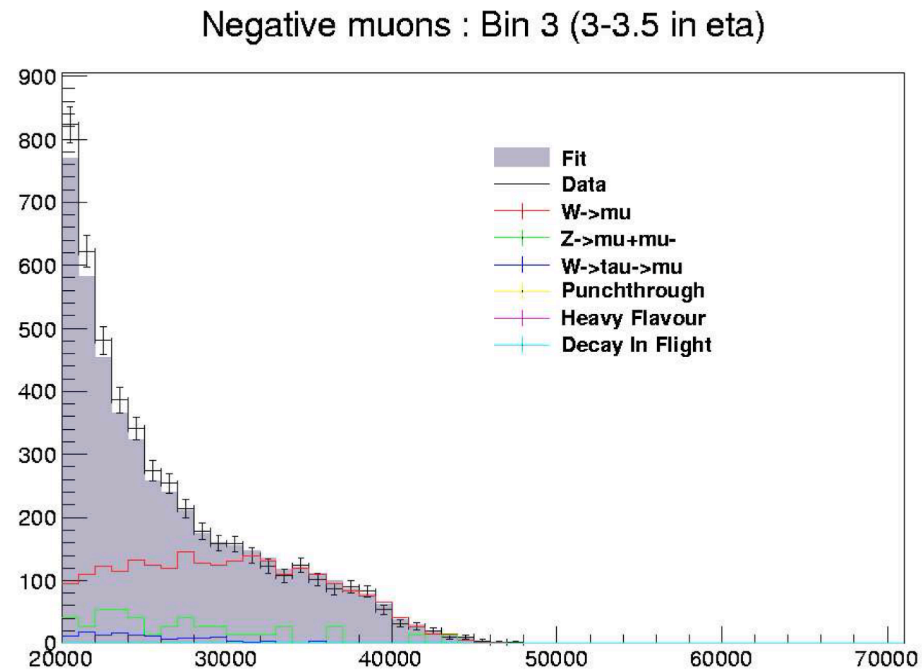
Comparison to 2010 paper

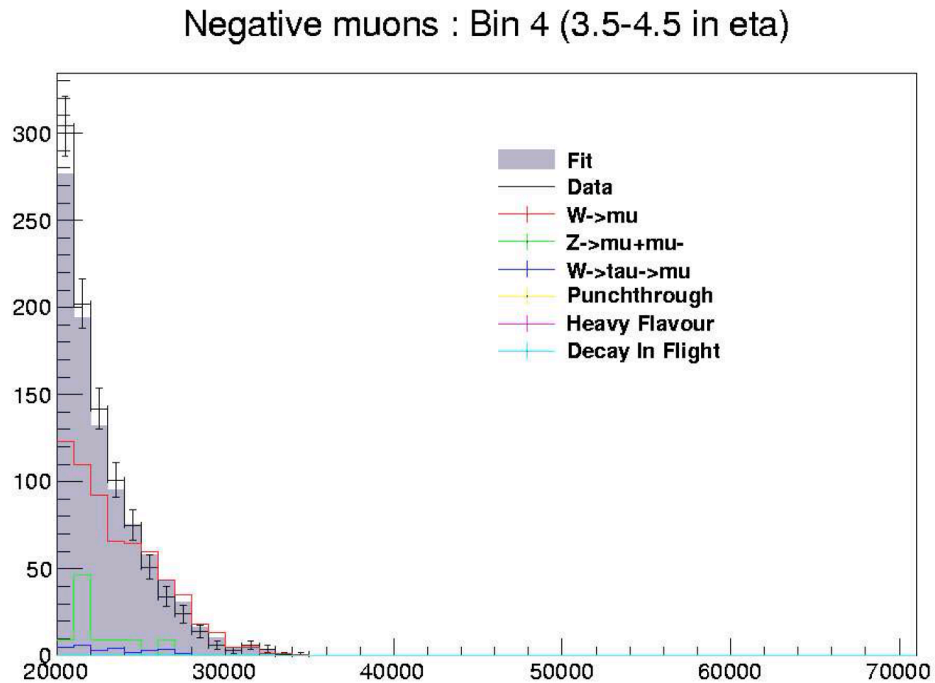
	Paper	Present Analysis
Integrated Lumi	37 pb^{-1}	1042 pb^{-1}
No of Candidates	14660 + / 11618 -	37910 + / 30274 -
Purity of fit	(78.8 ± 2.1)% / (78.4 ± 2.5)%	(30.65 ± 0.08)% / (33.13 ± 1.1)%
No η bins	5	4
DIF template	Probability distribution	Smeared $\pi^{\pm}$s and $K^{\pm}$s
Constraints on : ***$Z \to \mu^- \mu^+$***	(9.3 ± 0.4)%	(9.74 ± 0.28)%
$W \to \tau$ and $Z \to \tau^+ \tau^-$ together	2.7%	W : (3.90 ± 0.15)% Z : <(0.01)%
Heavy Flavour	(0.4 ± 0.2)%	(0.4 ± 0.2)%

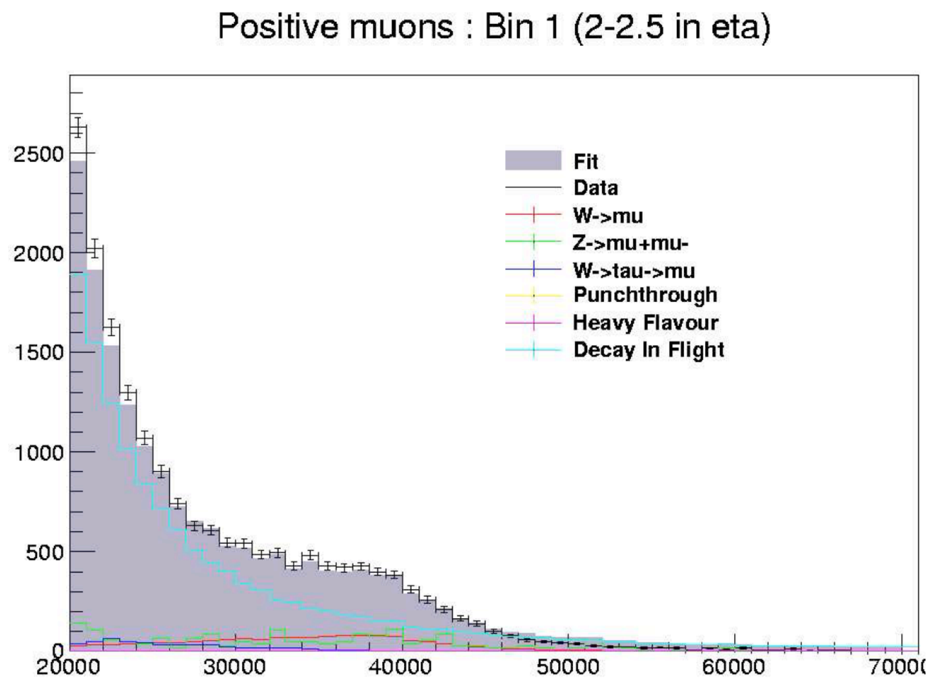
Binned Fits Follow

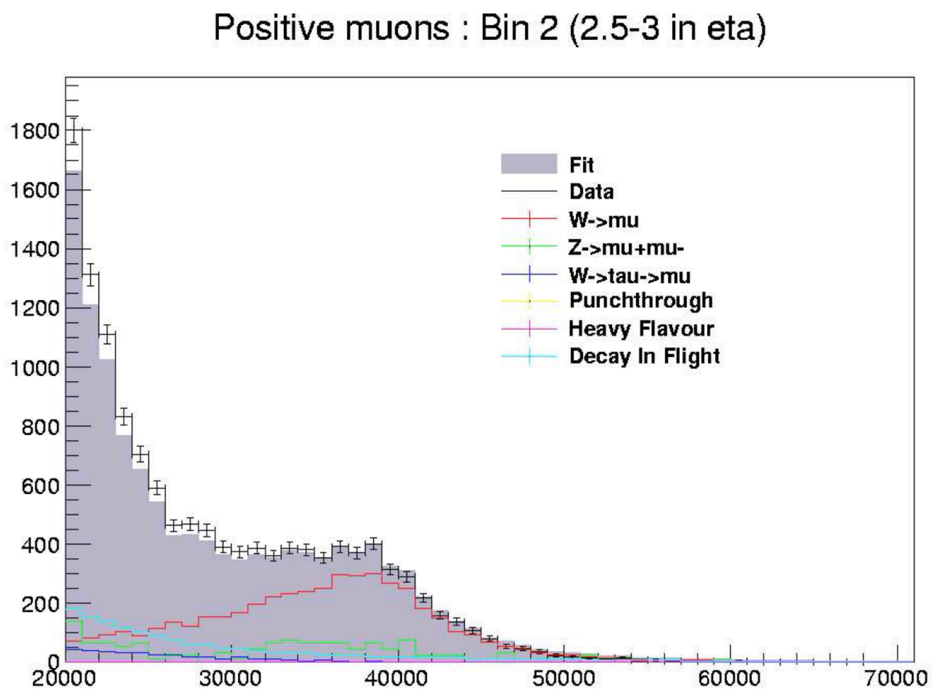

Negative muons : Bin 1 (2-2.5 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight
0
500
1000
1500
2000
2500
20000
30000
40000
50000
60000
7000

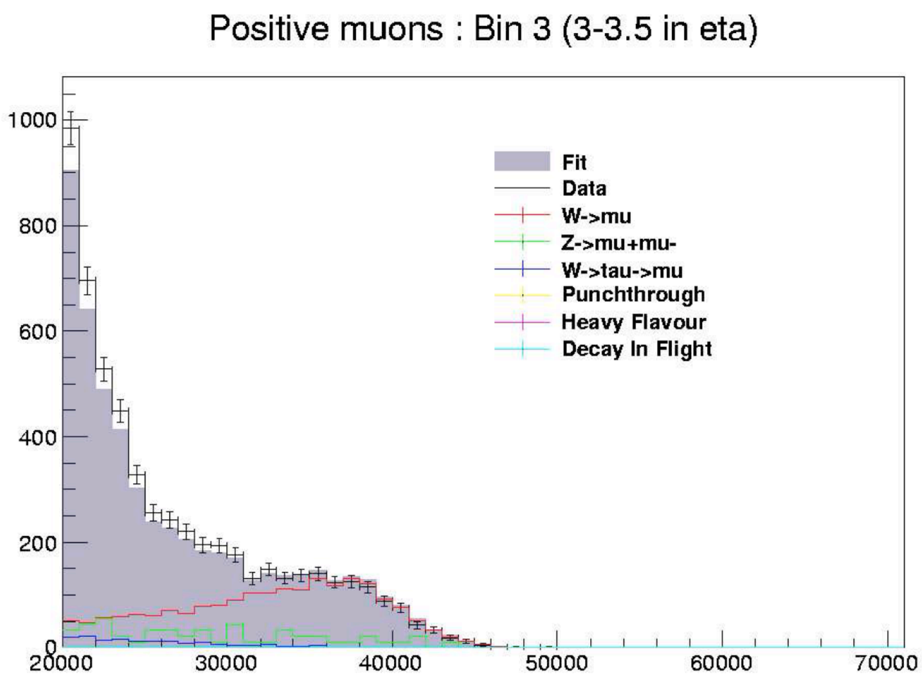

Negative muons : Bin 2 (2.5-3 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight
0
200
400
600
800
1000
1200
1400
1600
20000
30000
40000
50000
60000
70000

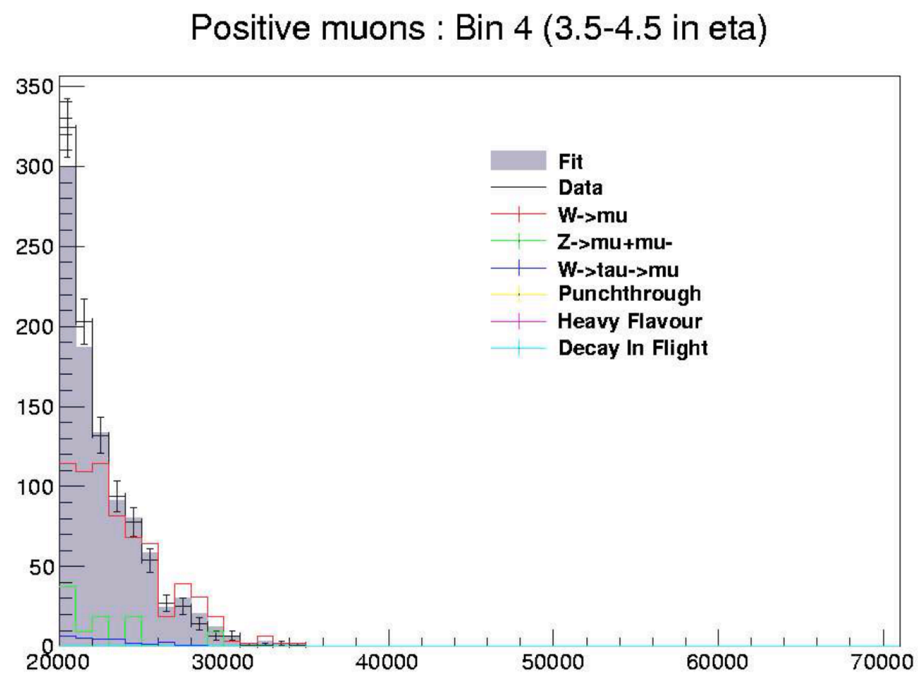

Negative muons : Bin 3 (3-3.5 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight
0
100
200
300
400
500
600
700
800
900
20000
30000
40000
50000
60000
70000


Negative muons : Bin 4 (3.5-4.5 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight
0
50
100
150
200
250
300
20000
30000
40000
50000
60000
70000


Positive muons : Bin 1 (2-2.5 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight


Positive muons : Bin 2 (2.5-3 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight


Positive muons : Bin 3 (3-3.5 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight


Positive muons : Bin 4 (3.5-4.5 in eta)
Fit
Data
W->mu
Z->mu+mu-
W->tau->mu
Punchthrough
Heavy Flavour
Decay In Flight