Studies of electroweak boson production in the forward region with LHCb.

James Keaveney, UCD (on behalf of the LHCb collaboration)

Deep Inelastic Scattering (DIS) 2010, Firenze

This talk

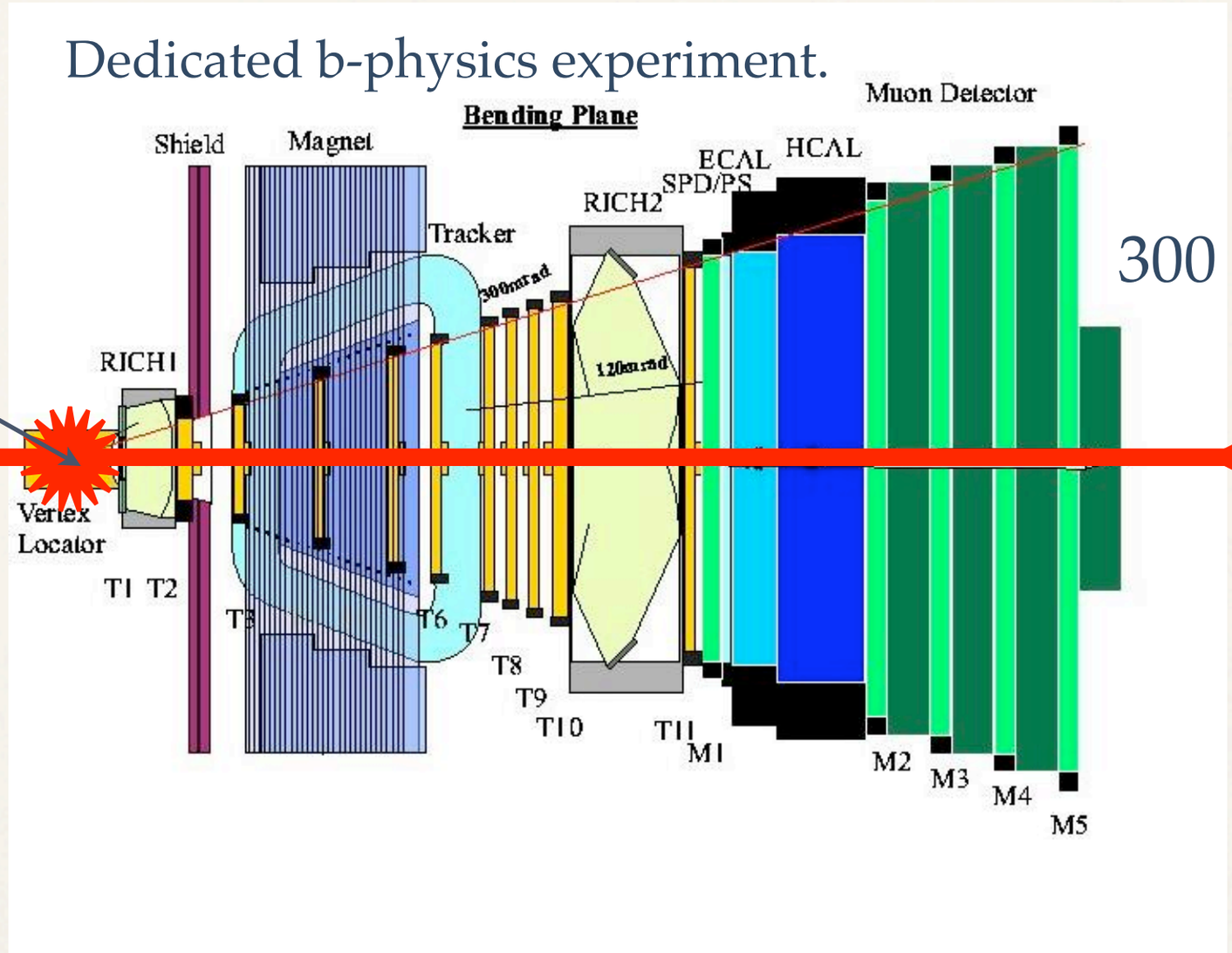
- LHCb

- Electroweak boson measurements at LHCb : W, Z, γ^*
  => motivations and expected impact.

- Selections and expected yields.

LHCb : a forward spectrometer

Dedicated b-physics experiment.



INTERACTION POINT

300 mrad

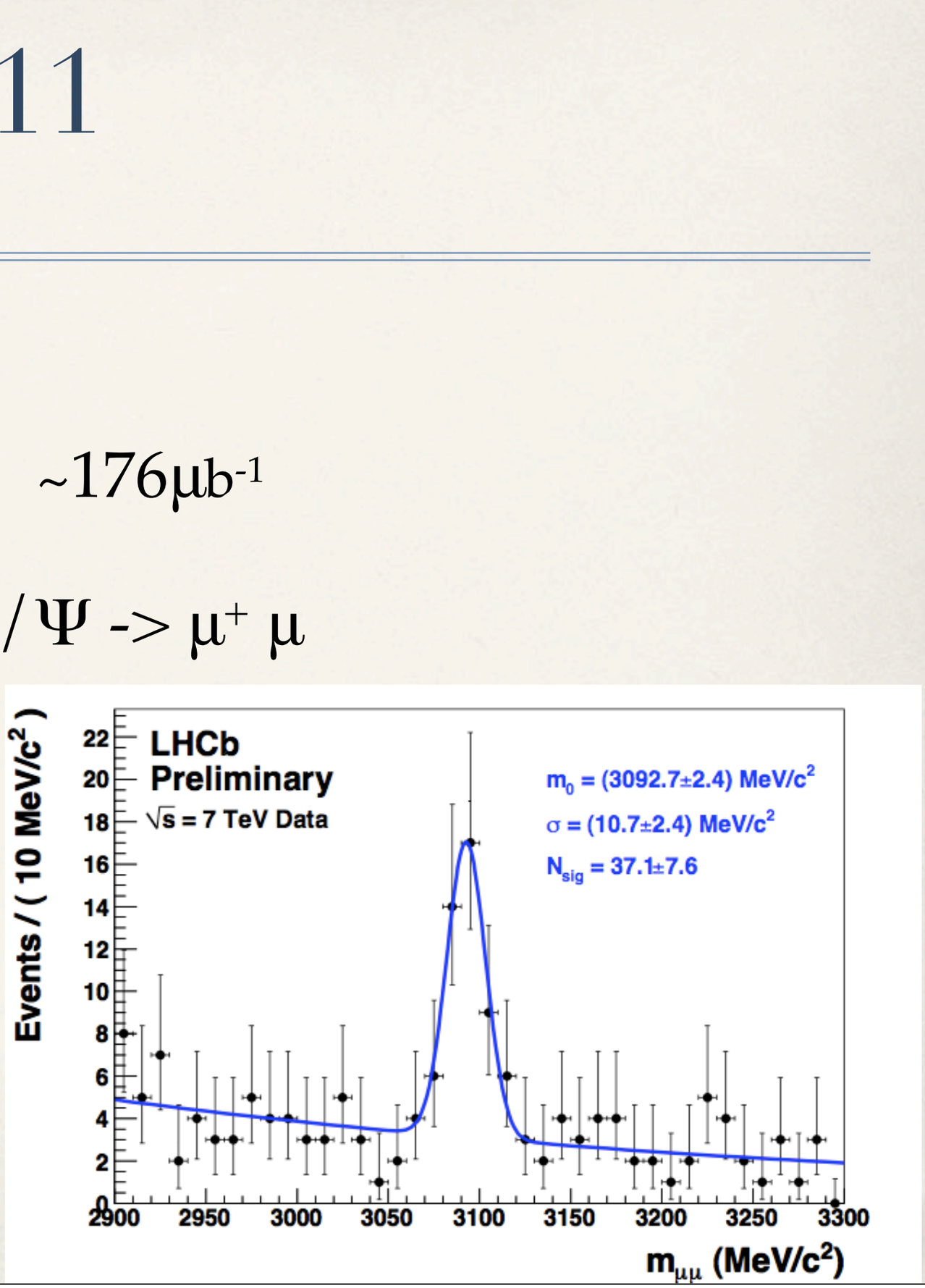
BEAMLINE

Sophisticated trigger system includes ability to trigger / reconstruct low momentum muons.

Pseudorapidity range : $1.9 < \eta < 4.9$, $p_\mu > 6$ GeV, $pt_\mu > 1$ GeV

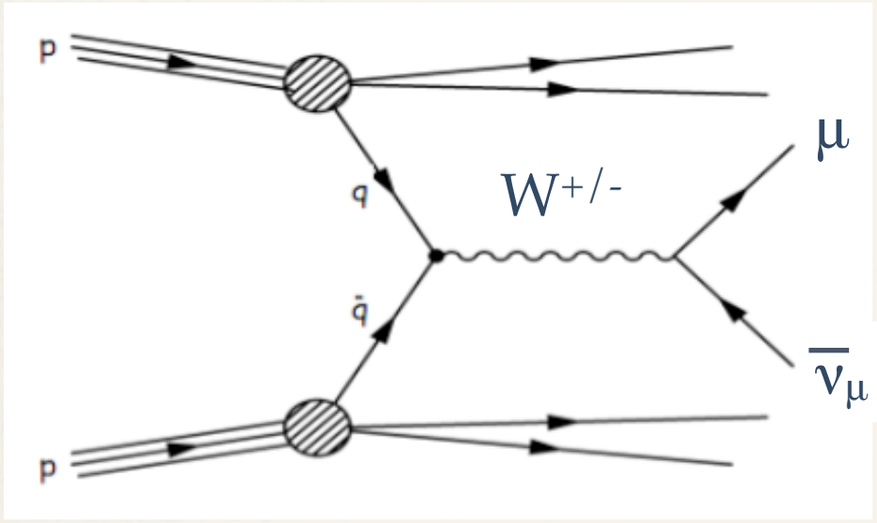
LHCb in 2010/2011

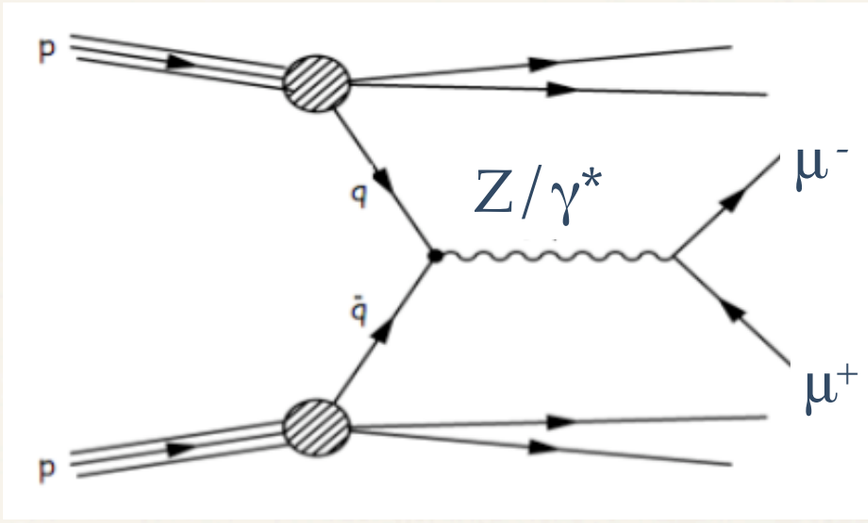
- Data taking at $\sqrt{s} = 7$TeV has begun.
- Integrated luminosity so far in 2010 ~$176 \mu b^{-1}$
- Resonances already observed, e.g. $J/\Psi \rightarrow \mu^+ \mu$
- See talk by E.Polycarpo (Thurs.)



Electroweak bosons at LHCb

Channels of interest :





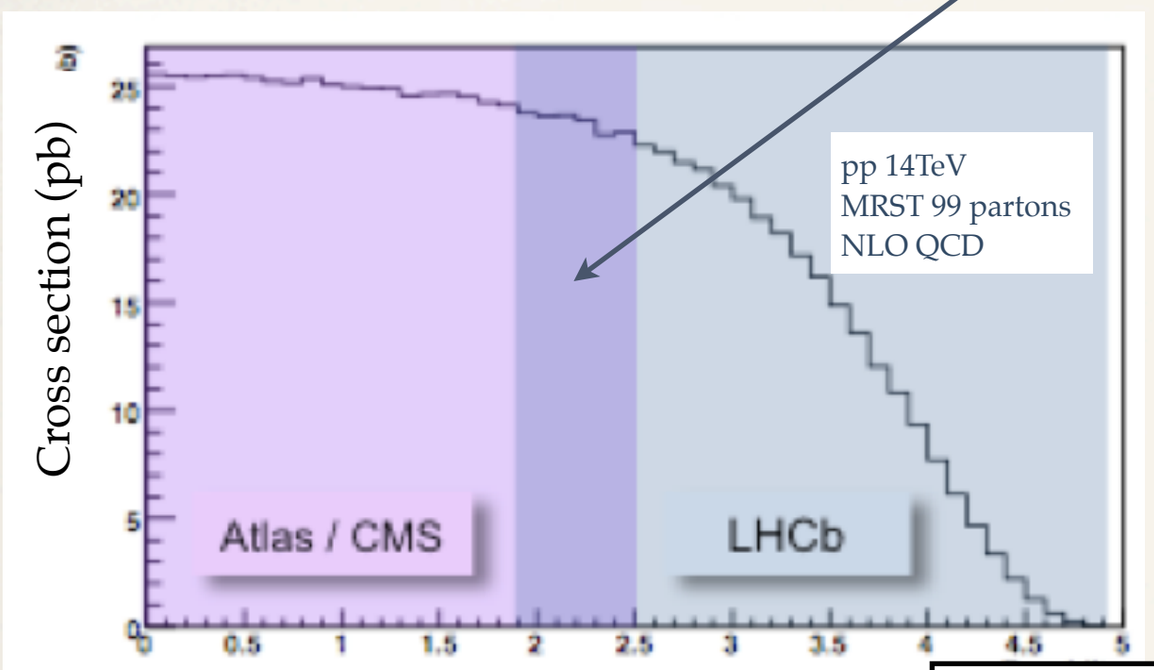
$W -> \mu \overline{\nu}_\mu$

$Z/\gamma^* -> \mu^+ \mu^-$

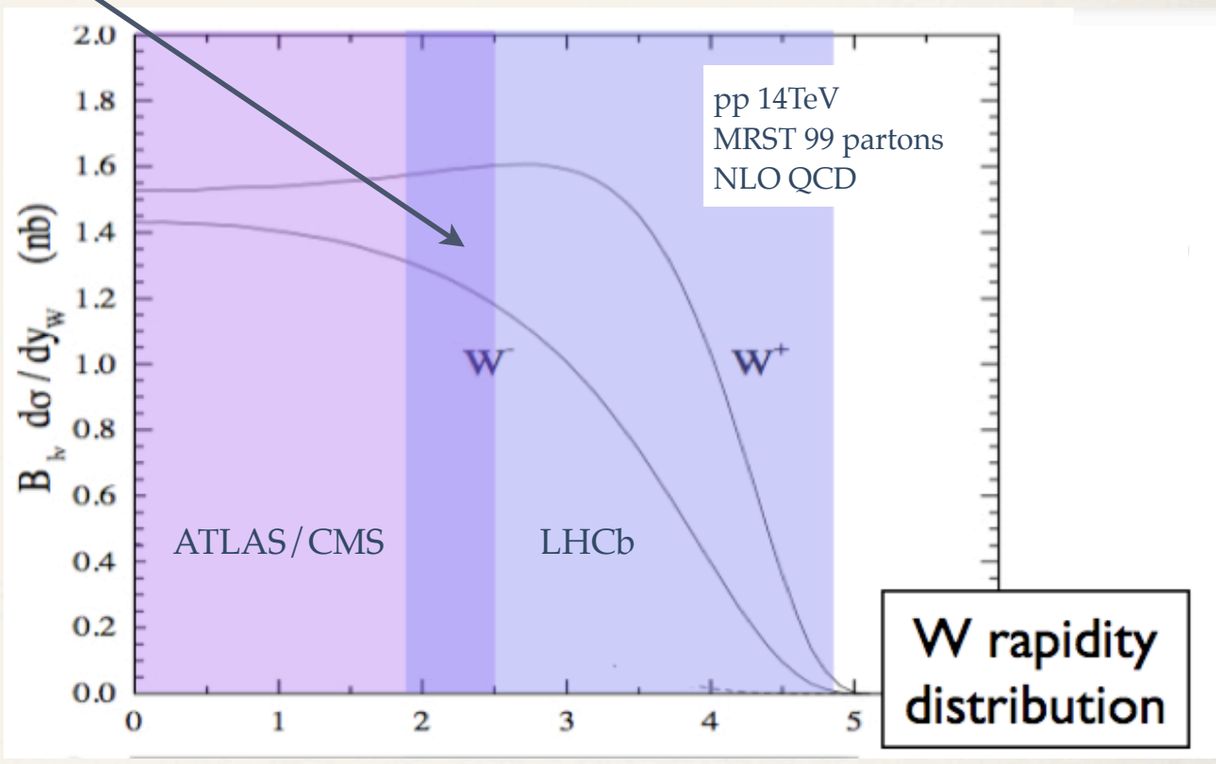
- Cross section measurements provide accurate test of standard model in new energy regime.
- Cross section and rapidity distributions can constrain PDFs (see talk from F. de Lorenzi).

LHCb : Kinematic coverage

Overlap region



Z rapidity distribution



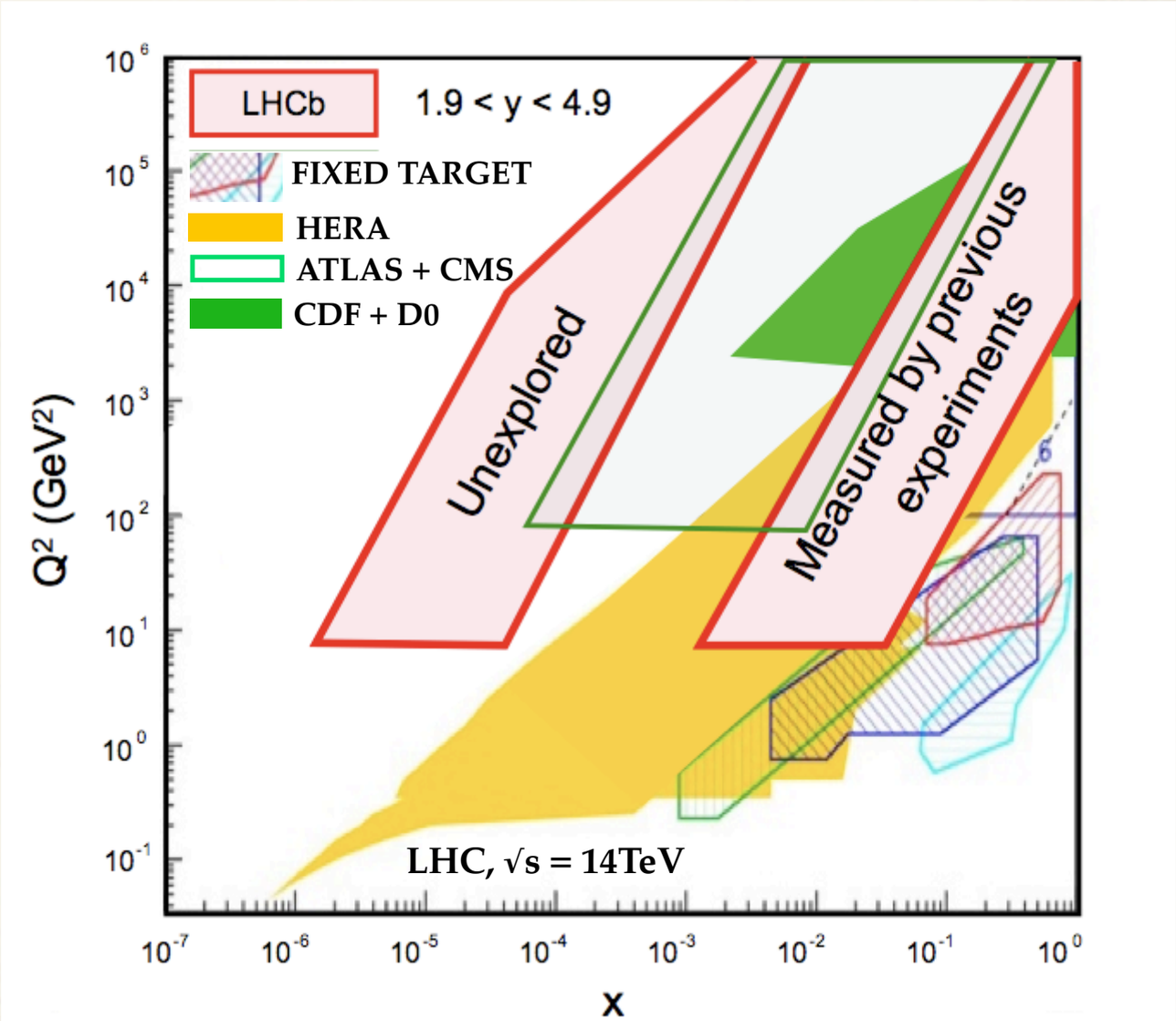
W rapidity distribution

- Complementary rapidity range to ATLAS/CMS, LHCb can provide crosscheck.
- LHCb has unique access to forward region ($y > 2.5$).
- We expect ~10^6 Z and W events at LHCb in 2010/2011.

LHCb : Kinematic coverage

- Angular acceptance and triggering capabilities of LHCb provides unique coverage of <u>two</u> distinct regions in (x, Q^2) space.

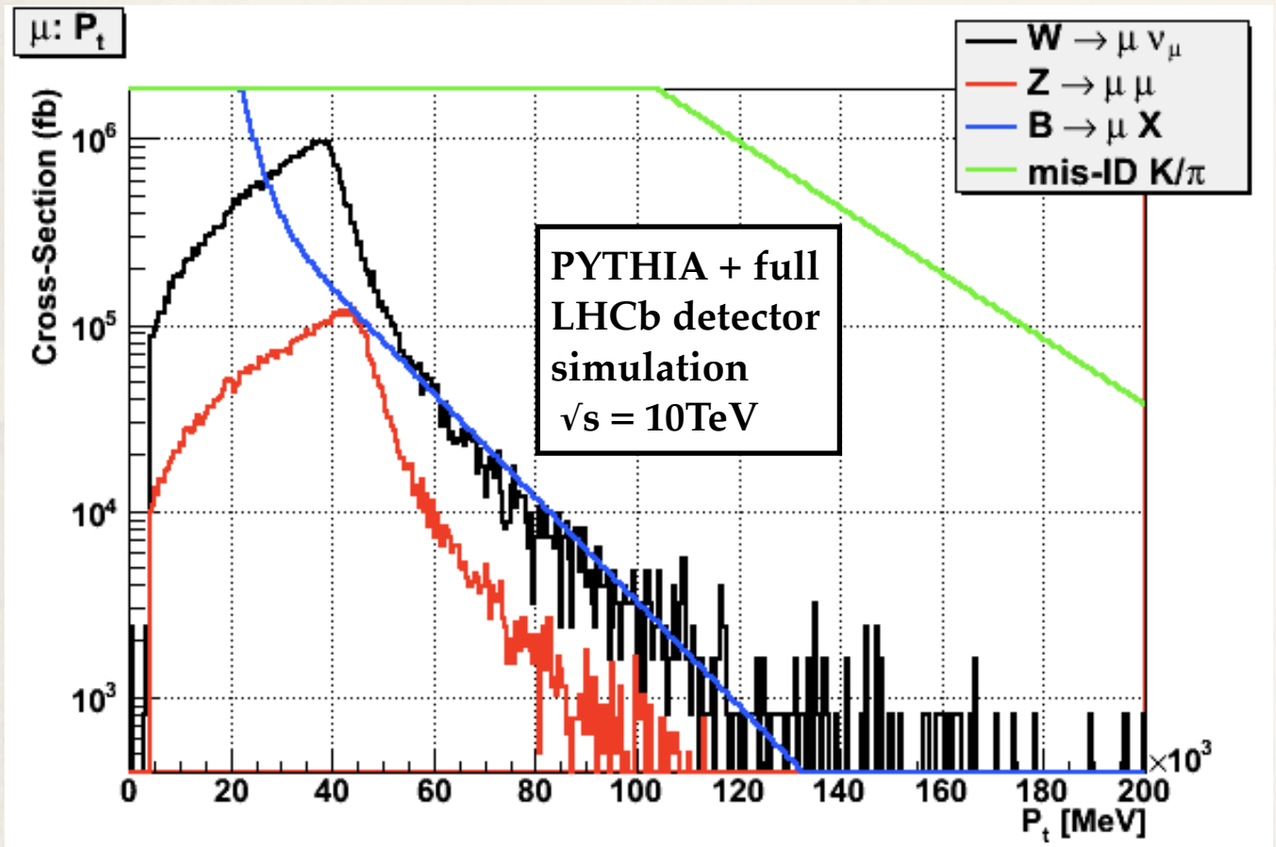
- One region (low x) previously unexplored.



Selection studies

$W \rightarrow \mu \nu_\mu$

Signal event characteristics -
->Single isolated high Pt Muon
->Little other energy in event



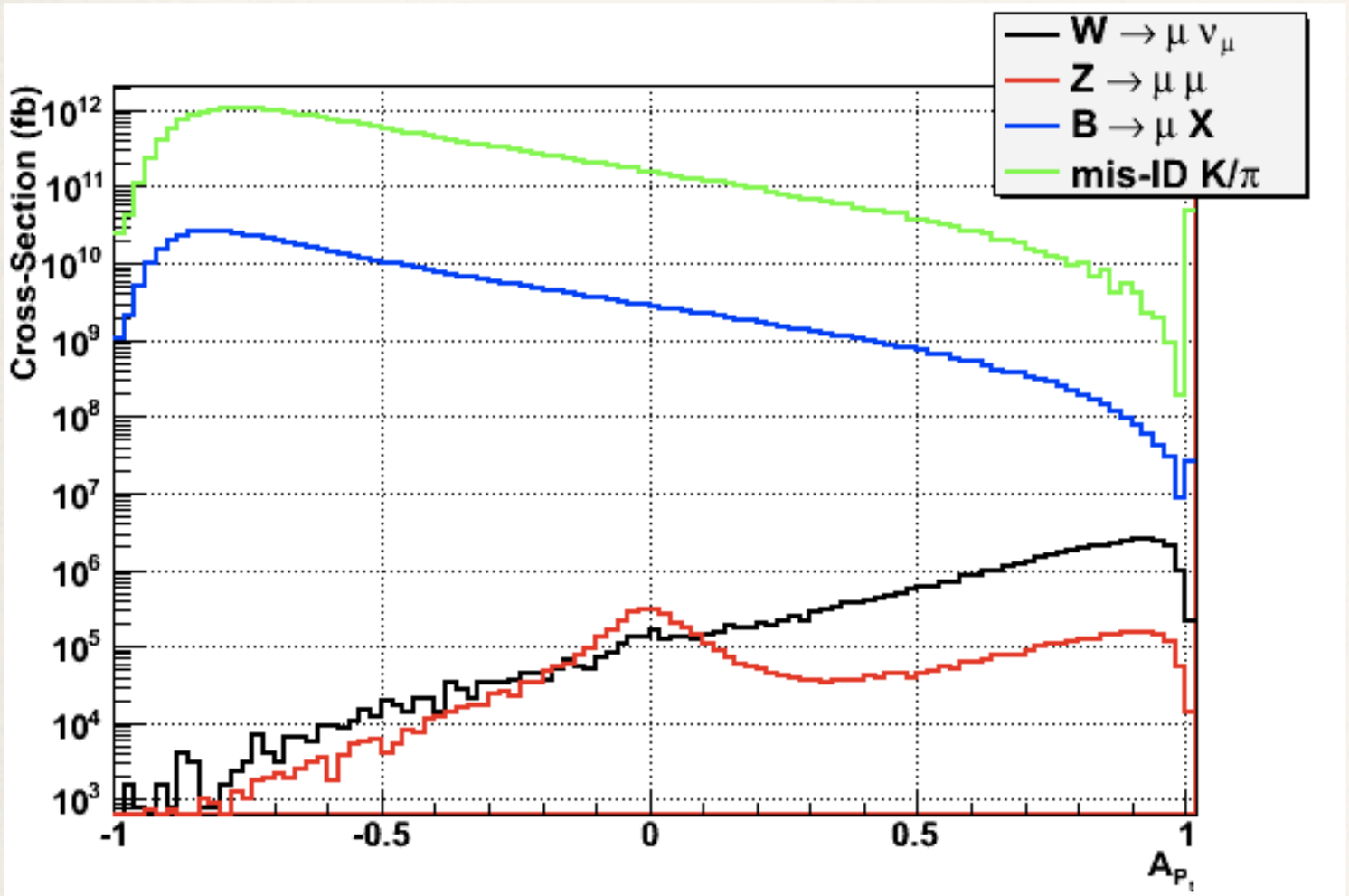
Largest backgrounds :
Mis-ID of π/K
$Z/\gamma^* \rightarrow \mu^+ \mu^-$
$B \rightarrow \mu + X$

Mis-ID component extrapolated to high Pt region using exponential fit, agrees well with theoretical expectation.

Mis-ID in this Pt region mainly due to Pion punchthrough.

Selection studies

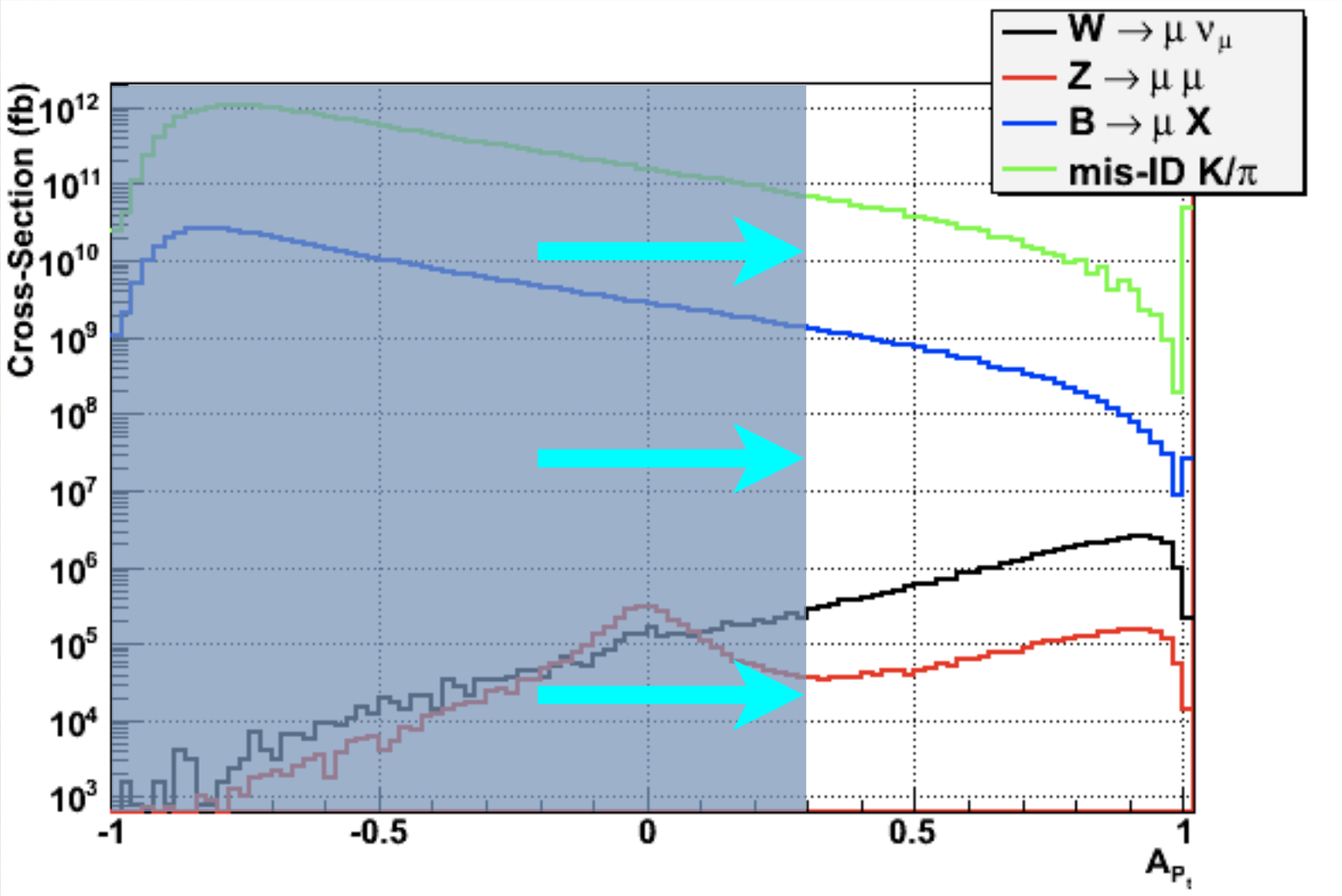
W -> $\mu\,\nu_\mu$



$$A_{pt} = \frac{pt_\mu - pt_{rest}}{pt_\mu + pt_{rest}}$$

Selection studies

W - > μ ν_μ



$$A_{pt} = \frac{pt_\mu - pt_{rest}}{pt_\mu + pt_{rest}}$$

Require $A_{Pt} > .3$

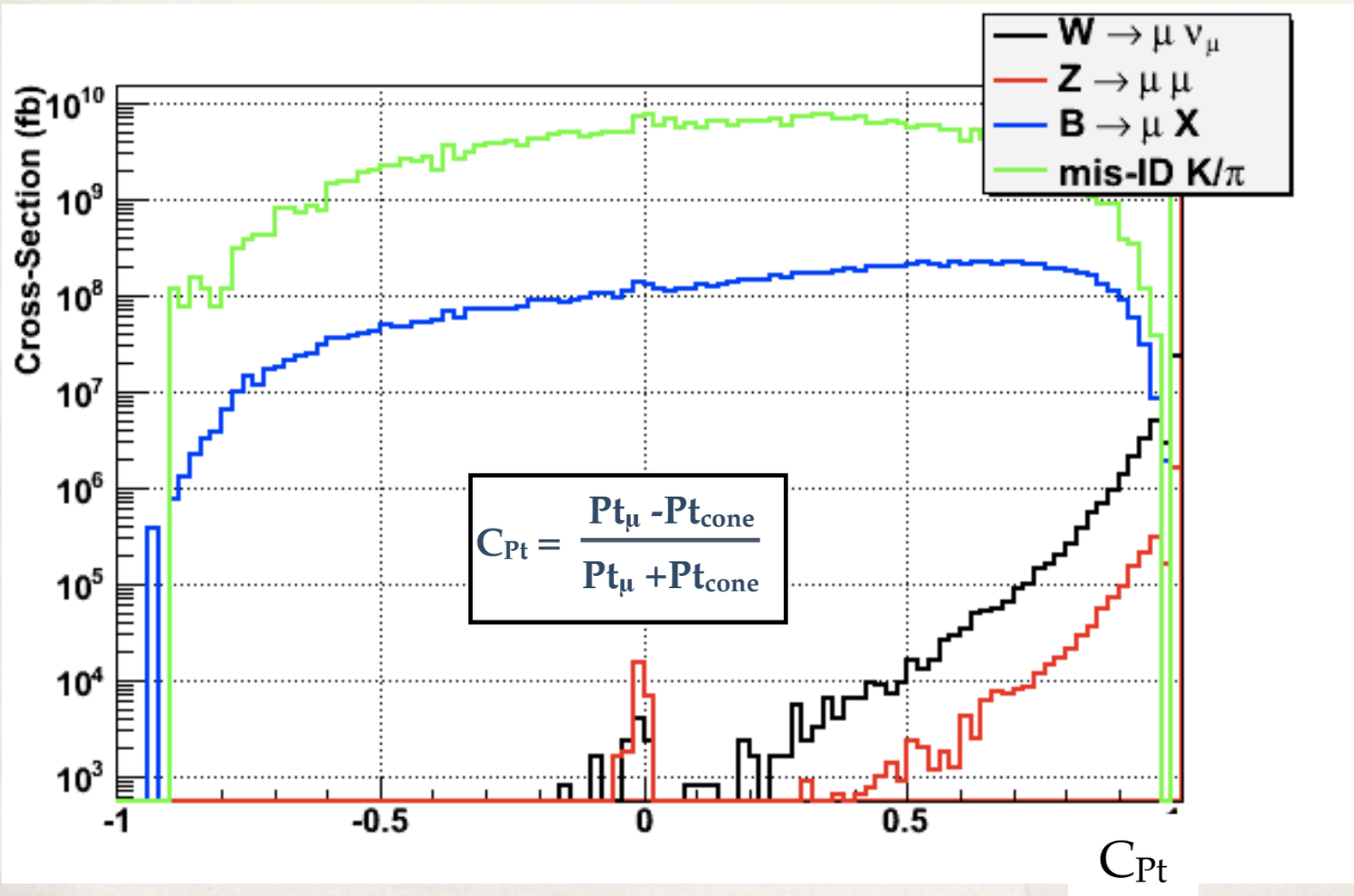
process	rejection factor
W - > μ ν_μ	0.09
Z/γ^* -> μ^+ μ	0.54
Mis-ID	0.98
B -> μ + X	0.99

Selection studies

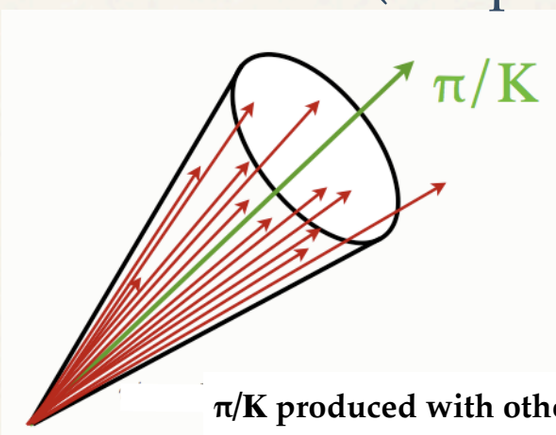
$W \rightarrow \mu \nu_\mu$

To further suppress Mis-ID background we use a cone based selection.

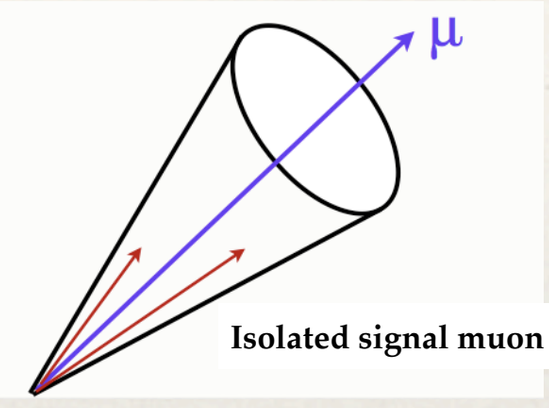
Cut on asymmetry between Pt_μ and summed Pt in cone around μ.



Cone size= 1 (eta-phi space)



π/K produced with other particles

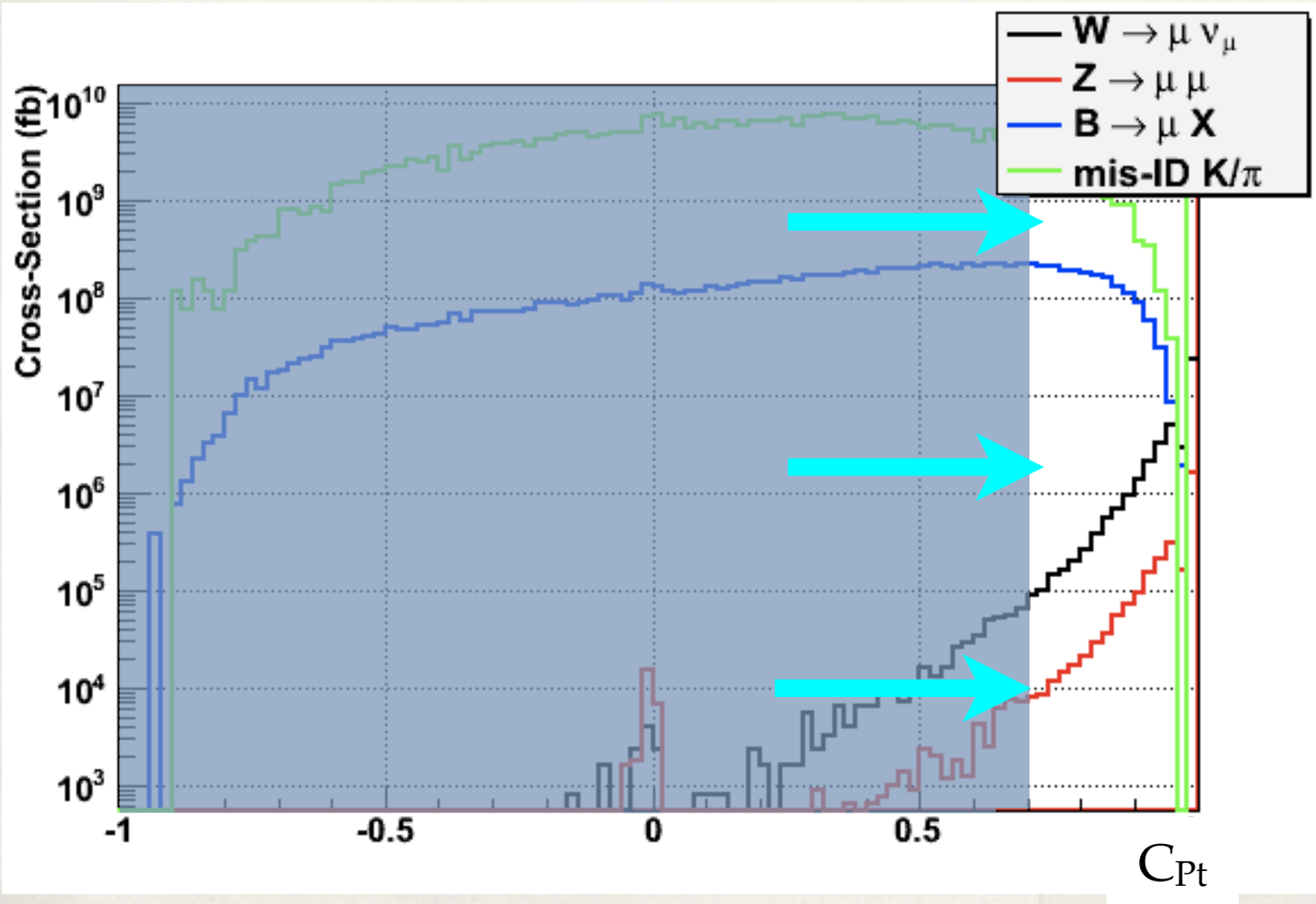


Isolated signal muon

Selection studies

$W \rightarrow \mu \nu_\mu$

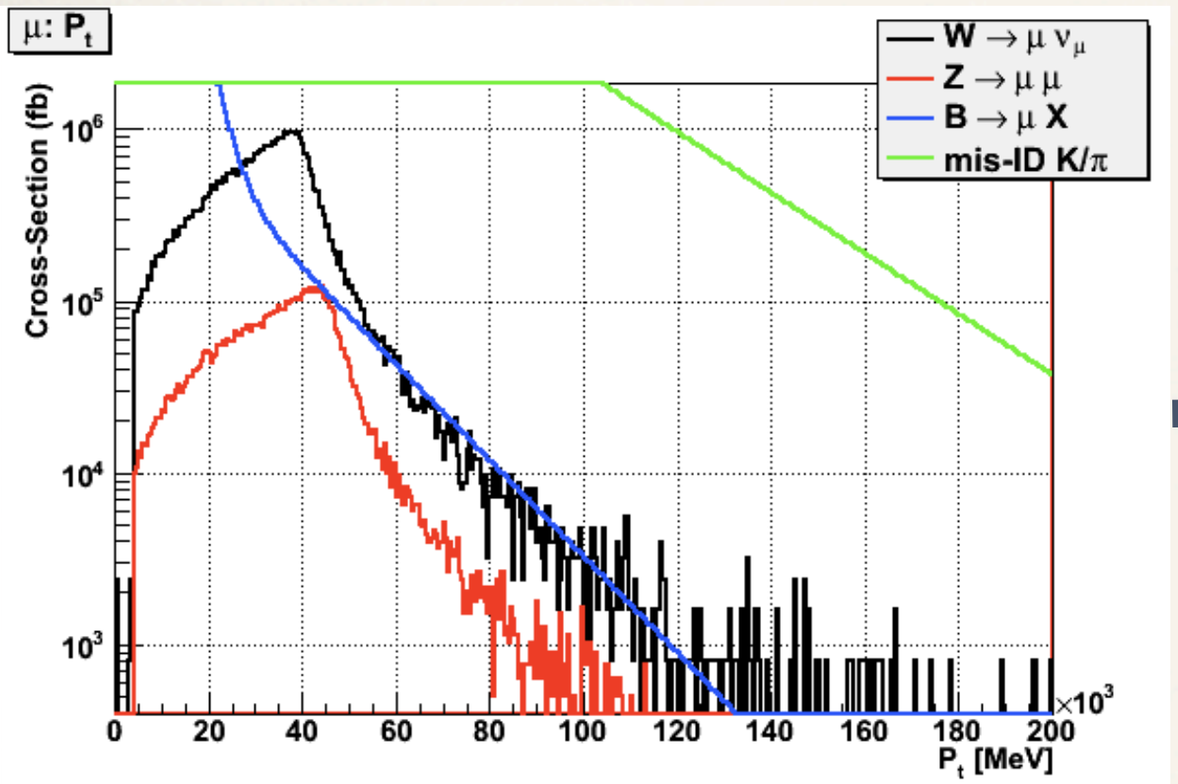
Require $C_{Pt} > .7$

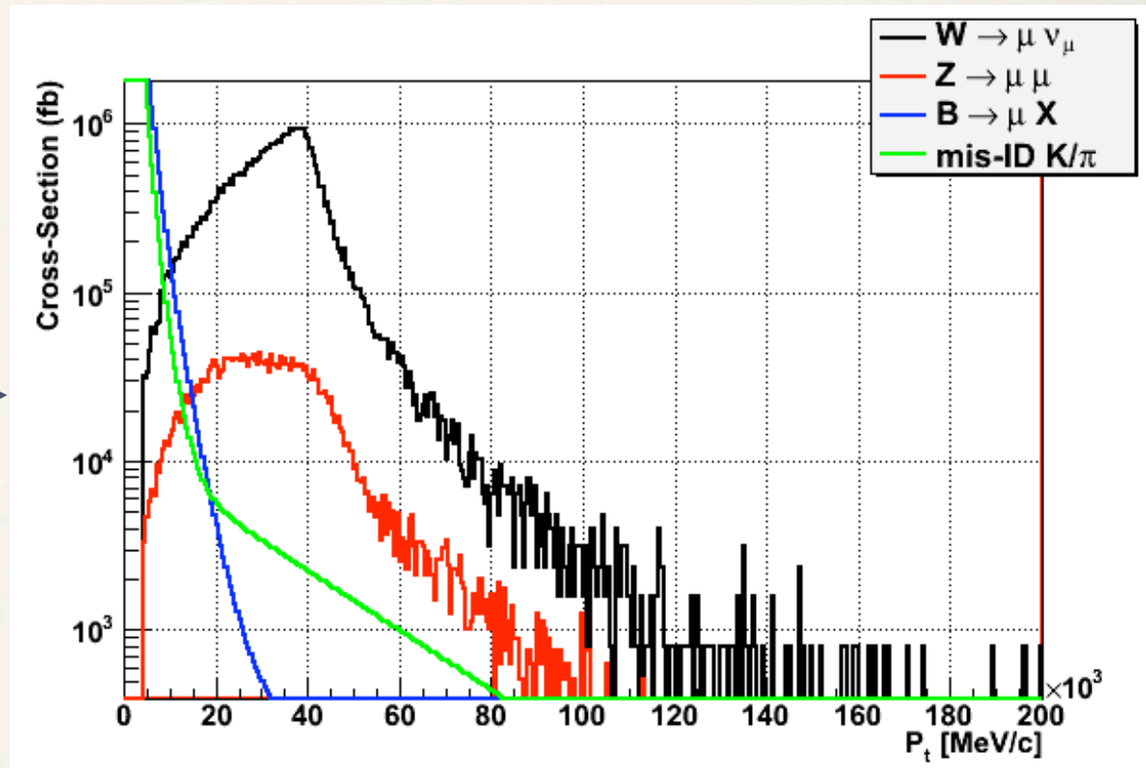


process	rejection factor
$W \rightarrow \mu \nu_\mu$	0.02
$Z/\Upsilon^* \rightarrow \mu^+ \mu$	0.03
Mis-ID	0.3
$B \rightarrow \mu + X$	0.48

Selection studies

W -> μ ν_μ



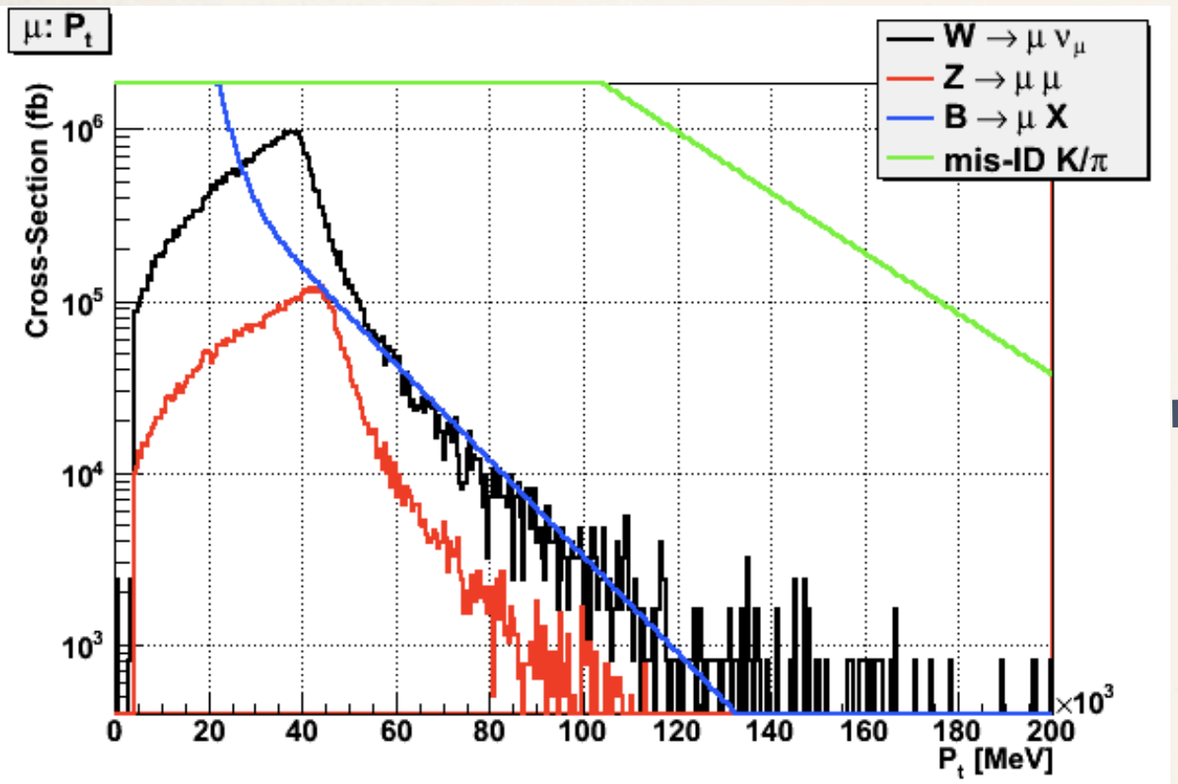


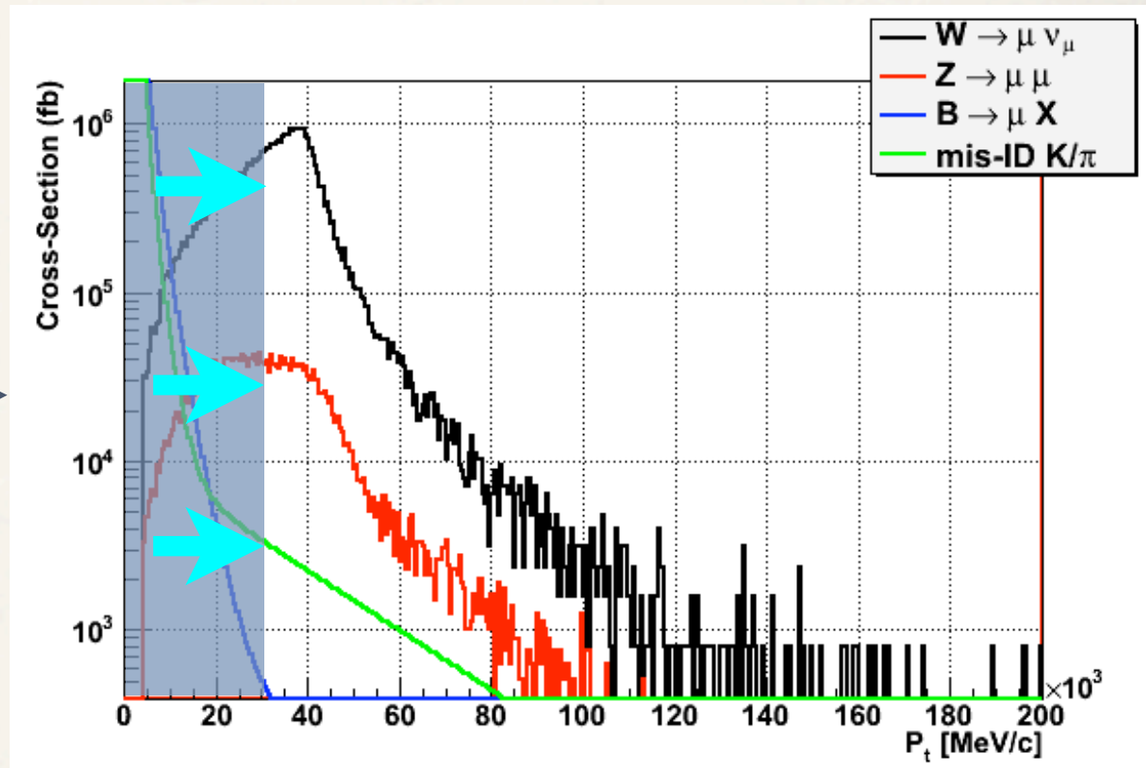
before isolation cuts

after isolation cuts

Selection studies

$W \rightarrow \mu \nu_\mu$





before isolation cuts

after isolation cuts

require Pt > 30GeV

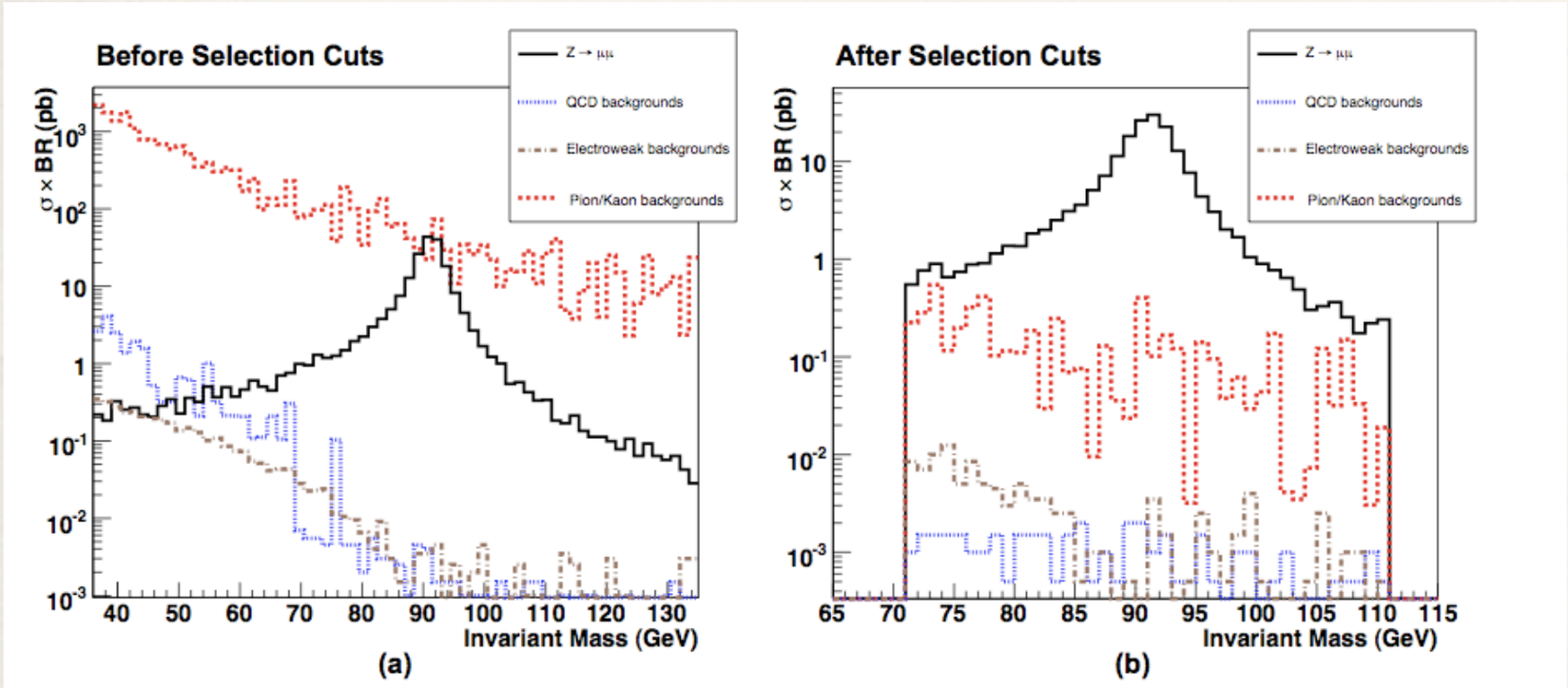
W sample purity ~92%

Selection studies

$Z -> \mu^+ \mu^-$

Thorough analysis in Monte Carlo presented previously*

I will present recent refinements.



Signal selected with simple kinematic cuts:

Muon Pt > 20GeV;

$40GeV < M_{\mu\mu} < 130GeV$;

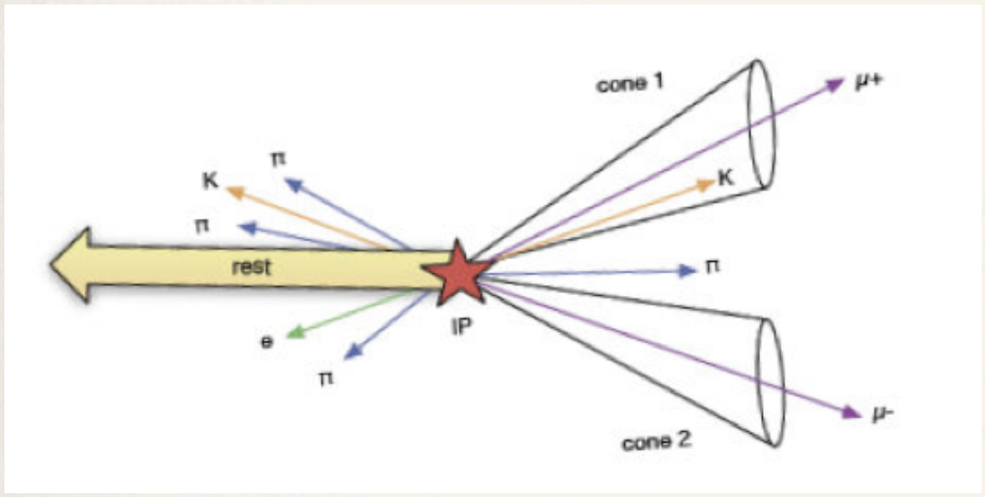
$E_{hadronic}$ Tracks < 50GeV

Largest remaining background arises from hadron Mis-ID.

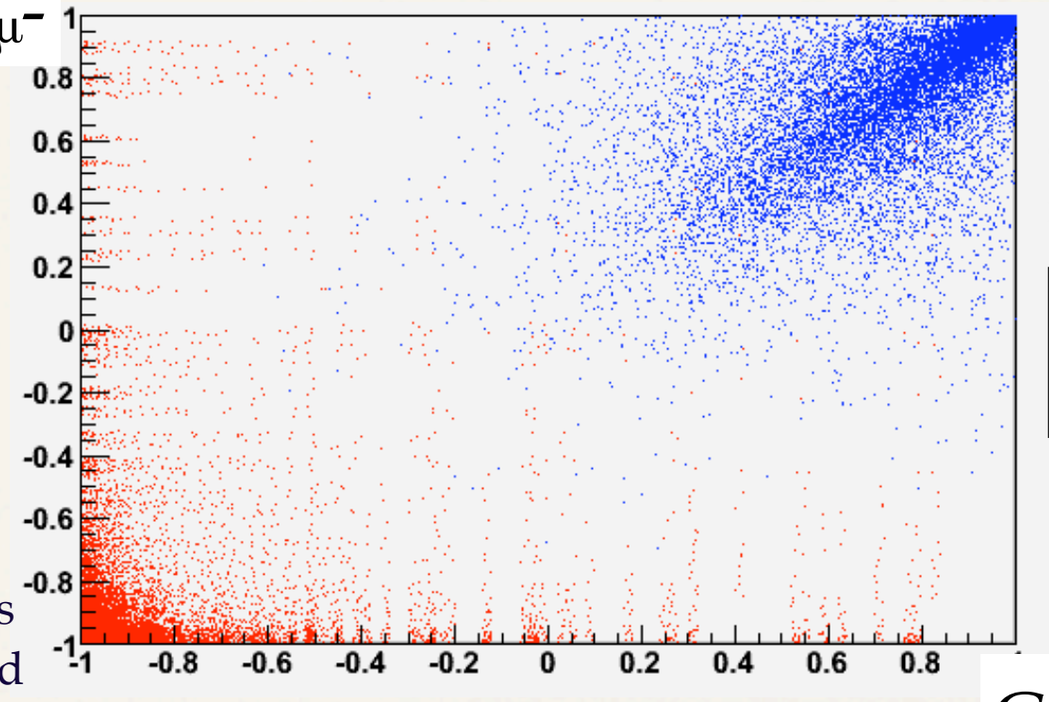
*J. Anderson (CERN-**THESIS**-2009-020).

Selection studies $Z -> \mu^+ \mu^-$

- Similar approach to W selection forseen to further suppress Mis-ID background



$C_{Pt\mu^-}$



(1,1) = event with two completely isolated muons

(-1,-1) = event with two muons both surrounded by many other particles

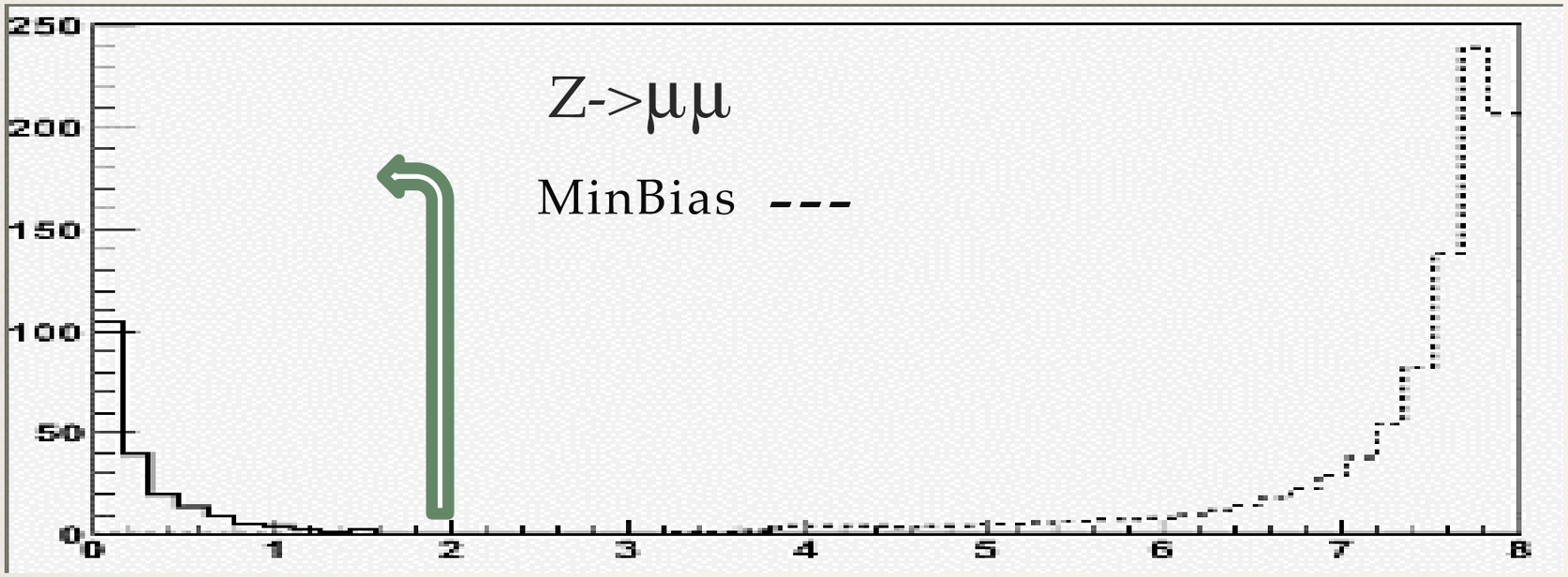
$C_{Pt\mu^+}$

-> can require <u>two</u> isolated muons, background suppression easier.

->Cut on the squared distance of each event from (1,1) in ($C_{Pt\mu^-}$, $C_{Pt\mu^+}$) space.

Selection studies

$Z -> \mu^+ \mu^-$



4-vector level

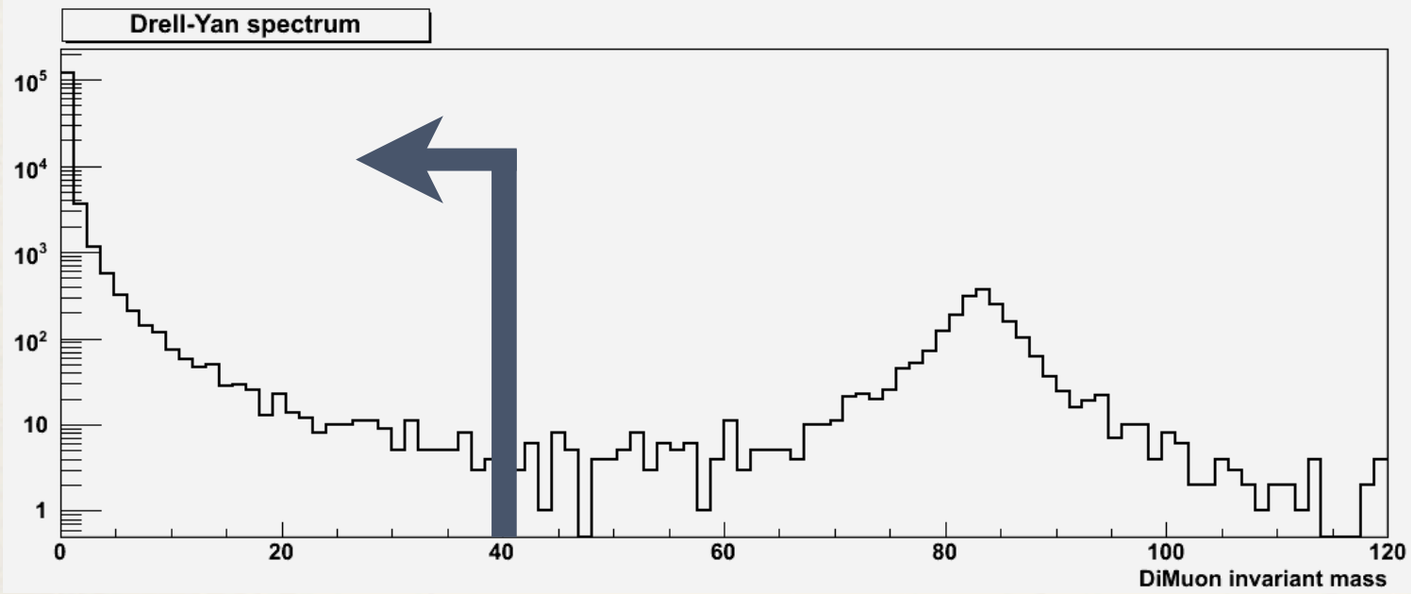
- Requiring (I<2) rejects 99.9% of background while retaining 95% signal.

For both Z/γ^* and W, isolation distributions will be measured/calibrated with real data.

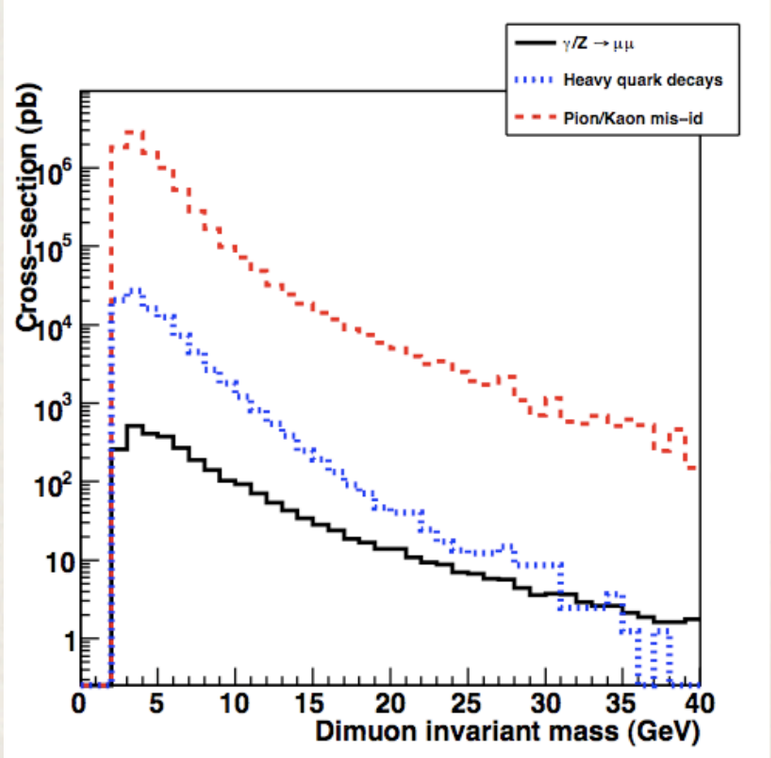
Monte Carlo cuts only an estimation.

Selection studies

$\gamma^* -> \mu^+ \mu^-$



Drell-Yan dimuons with $M_{\mu\mu} < 40$GeV classified as $\gamma^* -> \mu^+ \mu^-$



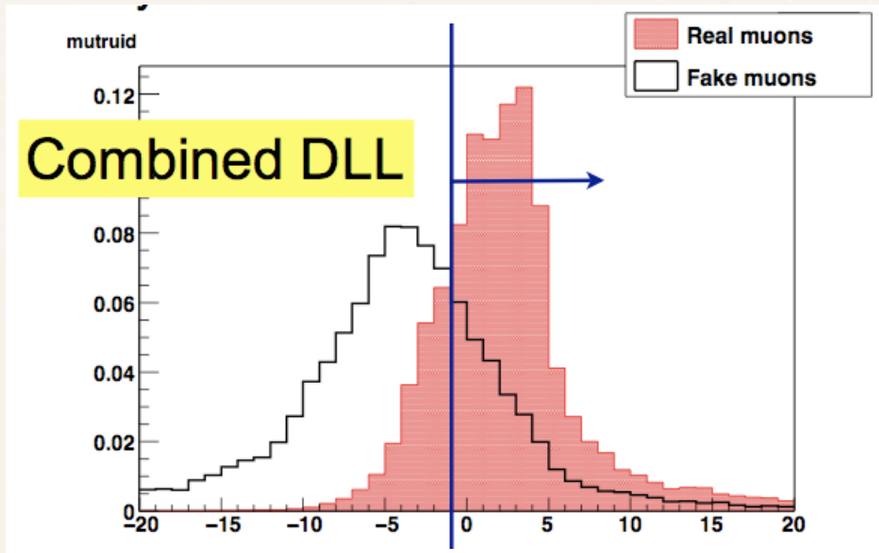
Similar backgrounds as for Z region

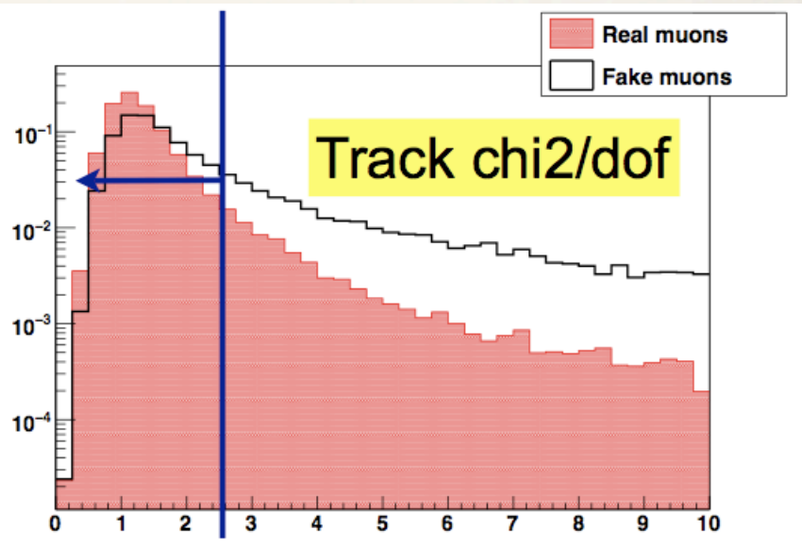
Backgrounds more dominant here!

More complex selection scheme required.

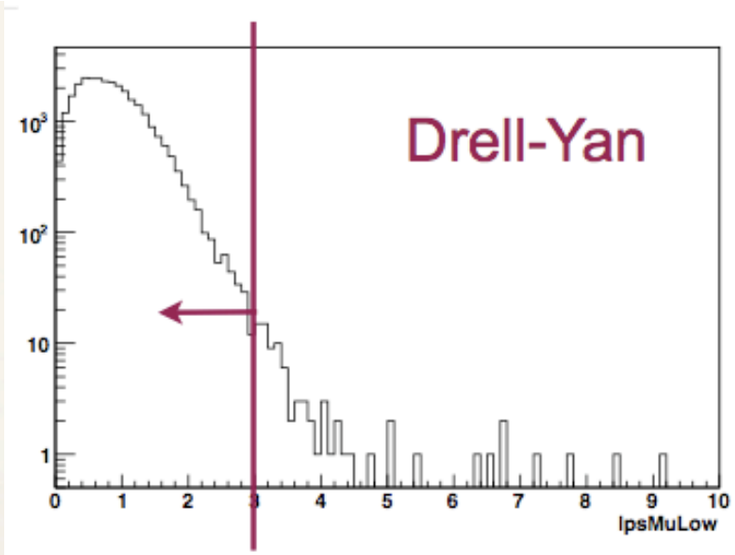
Selection studies $\gamma^* -> \mu^+ \mu^-$

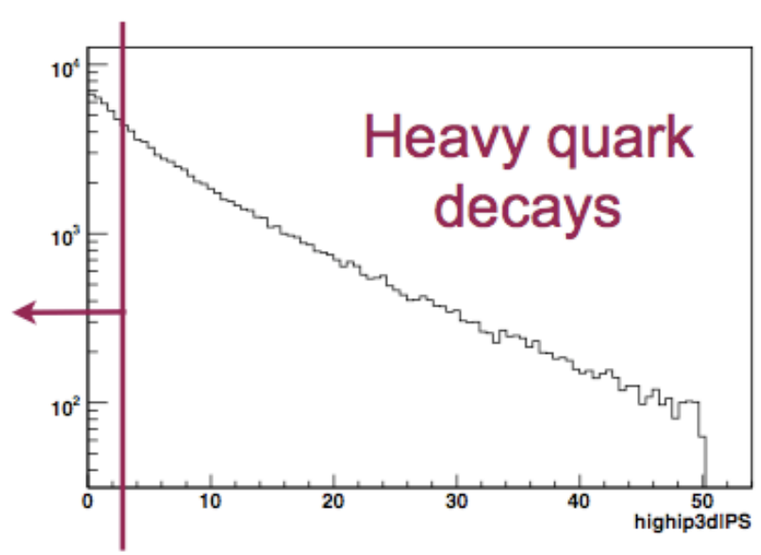
Additional variables are used to reject Mis-ID component:





IPS





Can achieve a factor of 10 reduction on Mis-ID, with ID efficiency 90%->70%

Selection studies

$\gamma^* -> \mu^+ \mu^-$

A cone based selection is now applied to further suppress Mis-ID.

$$A(x,y) = \frac{x-y}{x+y}$$

$A(P_{\mu 1}, P_{cone1})$

$A(P_{\mu 2}, P_{cone2})$

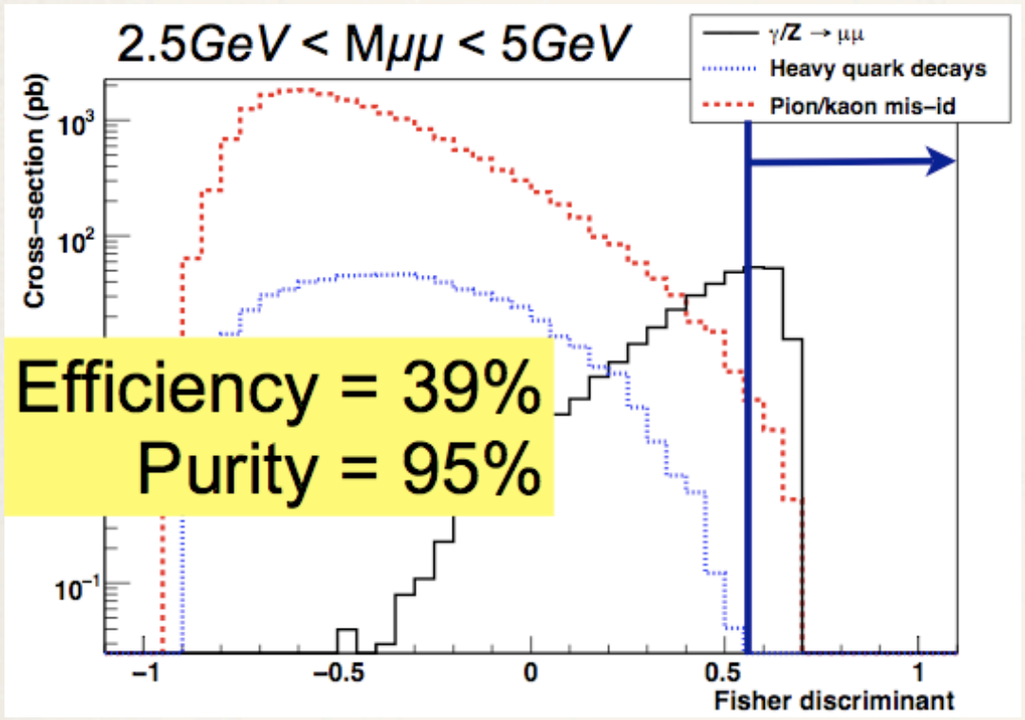
$A(P_{\mu 1} + P_{\mu 2}, P_{rest})$

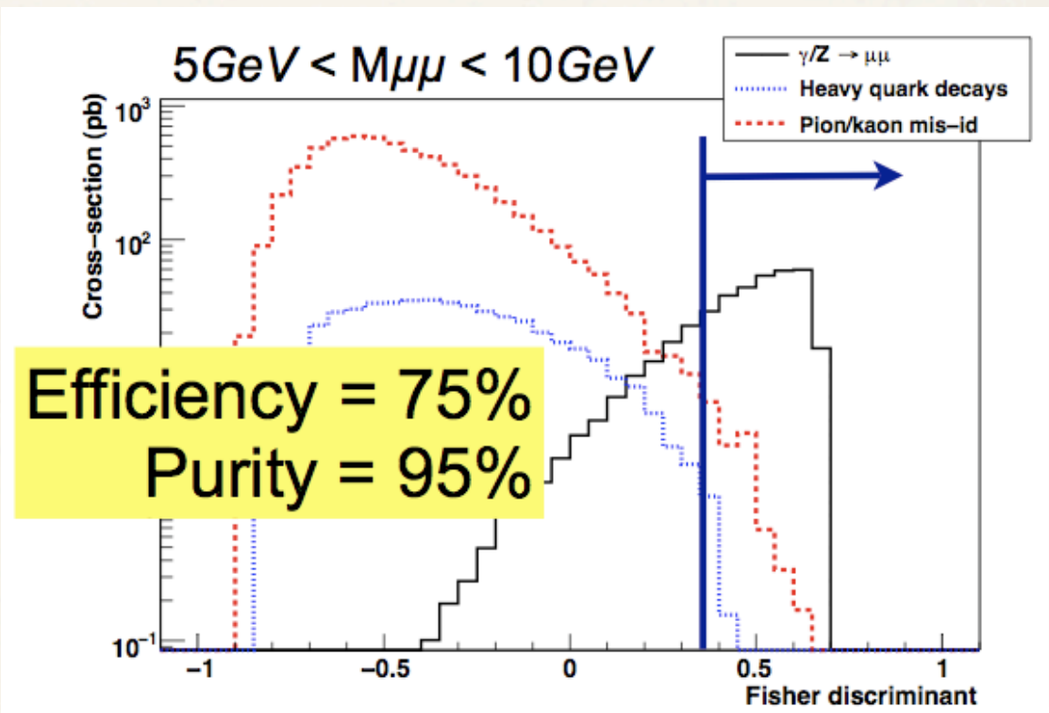
$A(P_{cone1} + P_{cone2}, P_{rest})$

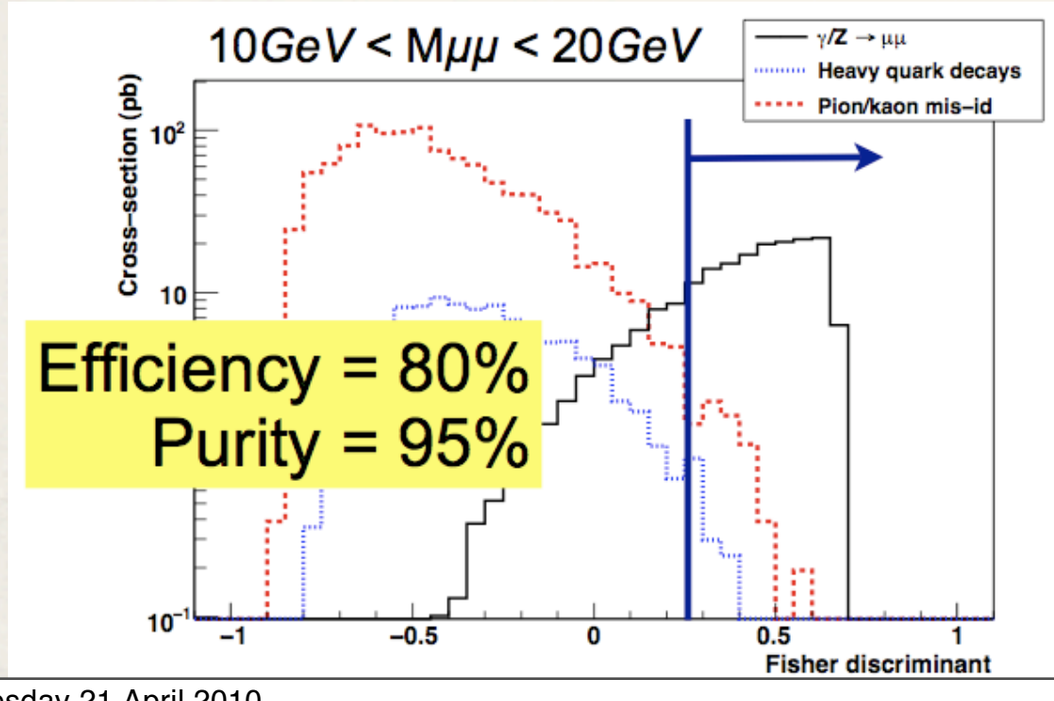
Combine 4 variables into Fisher discriminant and optimise cuts.

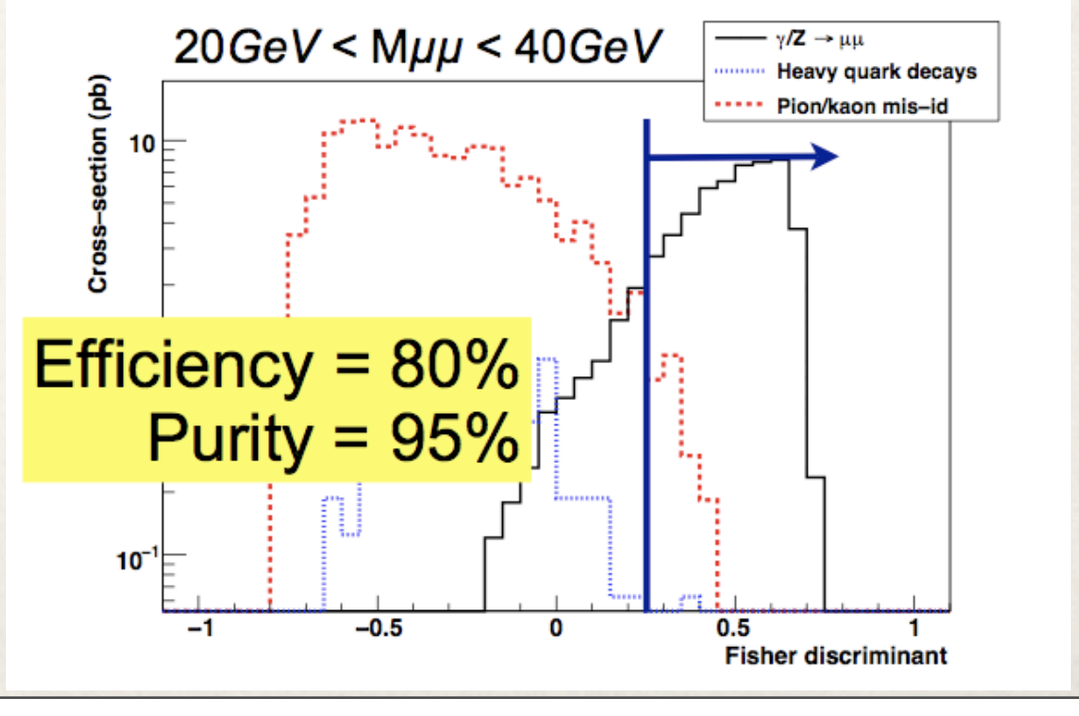
Selection studies

$\gamma^* -> \mu^+ \mu^-$









Estimated yields

In 2010/2011, LHCb will collect ~1fb^{-1} of data

channel	# events in LHCb	Total Efficiency	# events recorded	Purity
$W -> \mu \nu_\mu$	$3.47 * 10^6$	0.81	$2.81 * 10^6$	0.94
$Z -> \mu^+ \mu^-$	$8.52 * 10^5$	0.79	$6.73 * 10^5$	0.99
$\gamma^* -> \mu^+ \mu^-$ (2.5GeV<M<5GeV)	$6.26 * 10^5$	0.19	$1.19 * 10^5$	0.95
$\gamma^* -> \mu^+ \mu^-$ (5GeV<M<10GeV)	$7.76 * 10^5$	0.37	$2.87 * 10^5$	0.95
$\gamma^* -> \mu^+ \mu^-$ (10GeV<M<20GeV)	$3.76 * 10^5$	0.39	$1.47 * 10^5$	0.95
$\gamma^* -> \mu^+ \mu^-$ (20GeV<M<40GeV)	$1.08 * 10^5$	0.39	$4.23 * 10^4$	0.95

% Measurement uncertainties

*see talk by D.Moran tomorrow

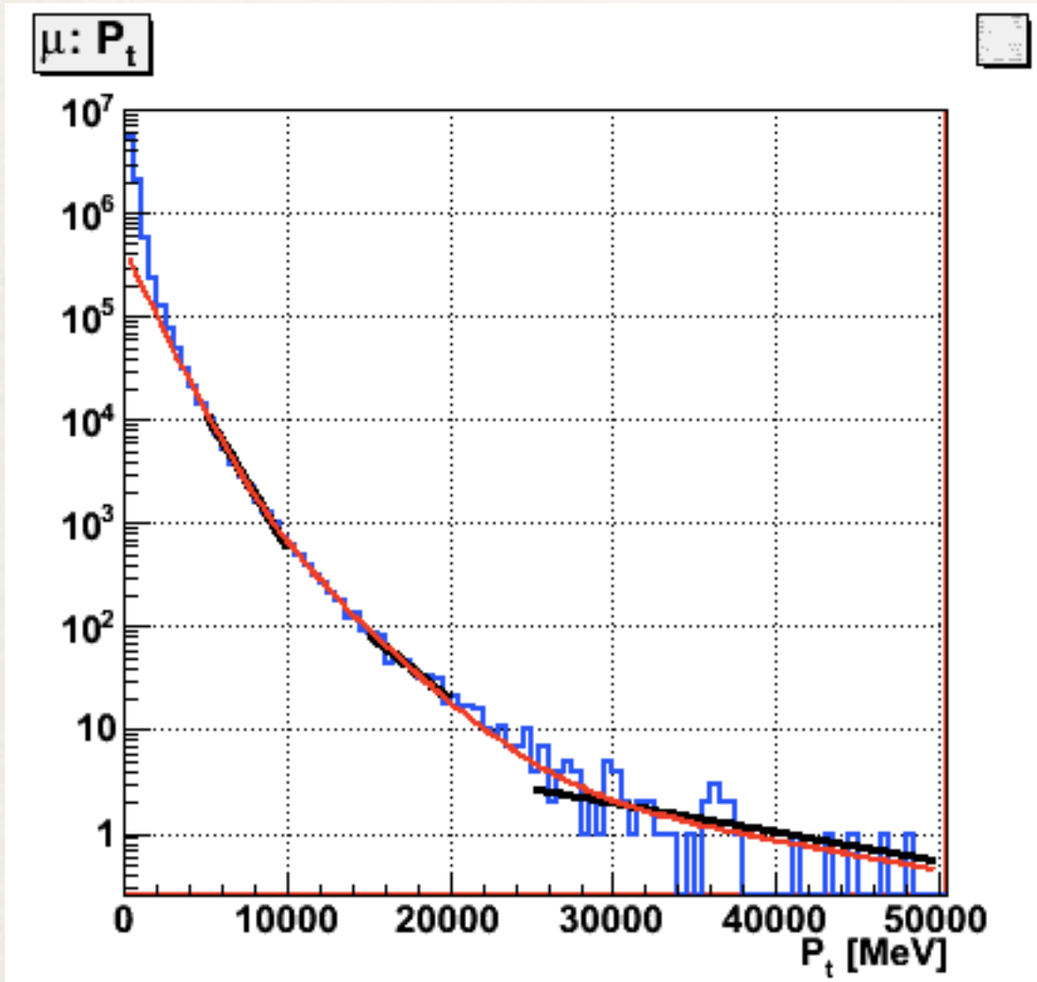
channel	statistical	background	reconstruction/ selection	trigger	Luminosity*
$W^{+/-}$	0.05	0.3	0.2	0.1	5-10
Z	0.07	0.2	0.3	0.1	5-10
γ^* (2.5GeV<M<5GeV)	0.2	0.2	0.3	0.1	5-10
γ^* (5GeV<M<10GeV)	0.6	0.2	0.3	0.1	5-10
γ^* (10GeV<M<20GeV)	0.5	0.2	0.3	0.1	5-10
γ^* (20GeV<M<40GeV)	1	0.2	0.3	0.1	5-10

Conclusions

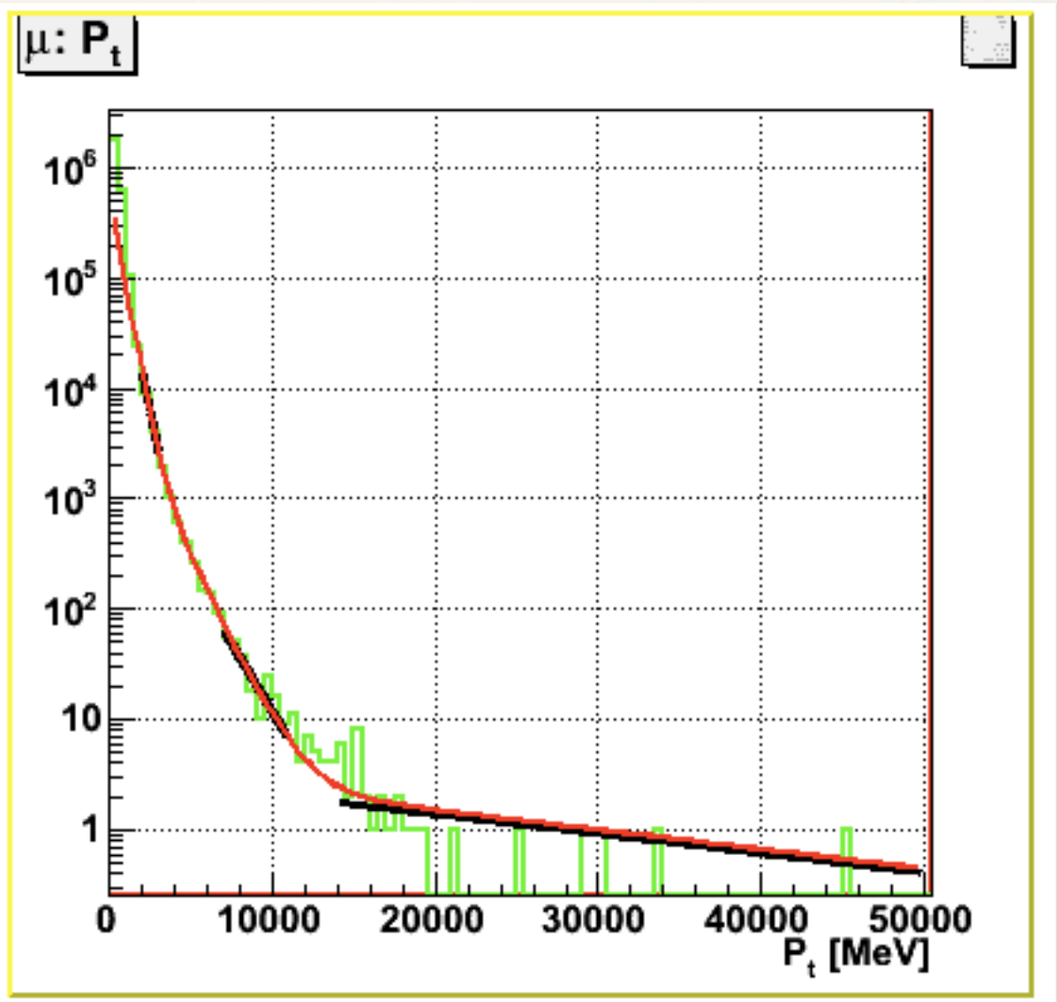
- LHCb expects 1fb^{-1} in 2010.
- We have developed a set of methods to extract pure samples of Z, W and γ^* events in Monte Carlo.
- Data-driven methods desirable in from now on.
- PDF work, further electroweak measurements in progress.

BACKUPS

Fitting Mis-ID Pt distribution

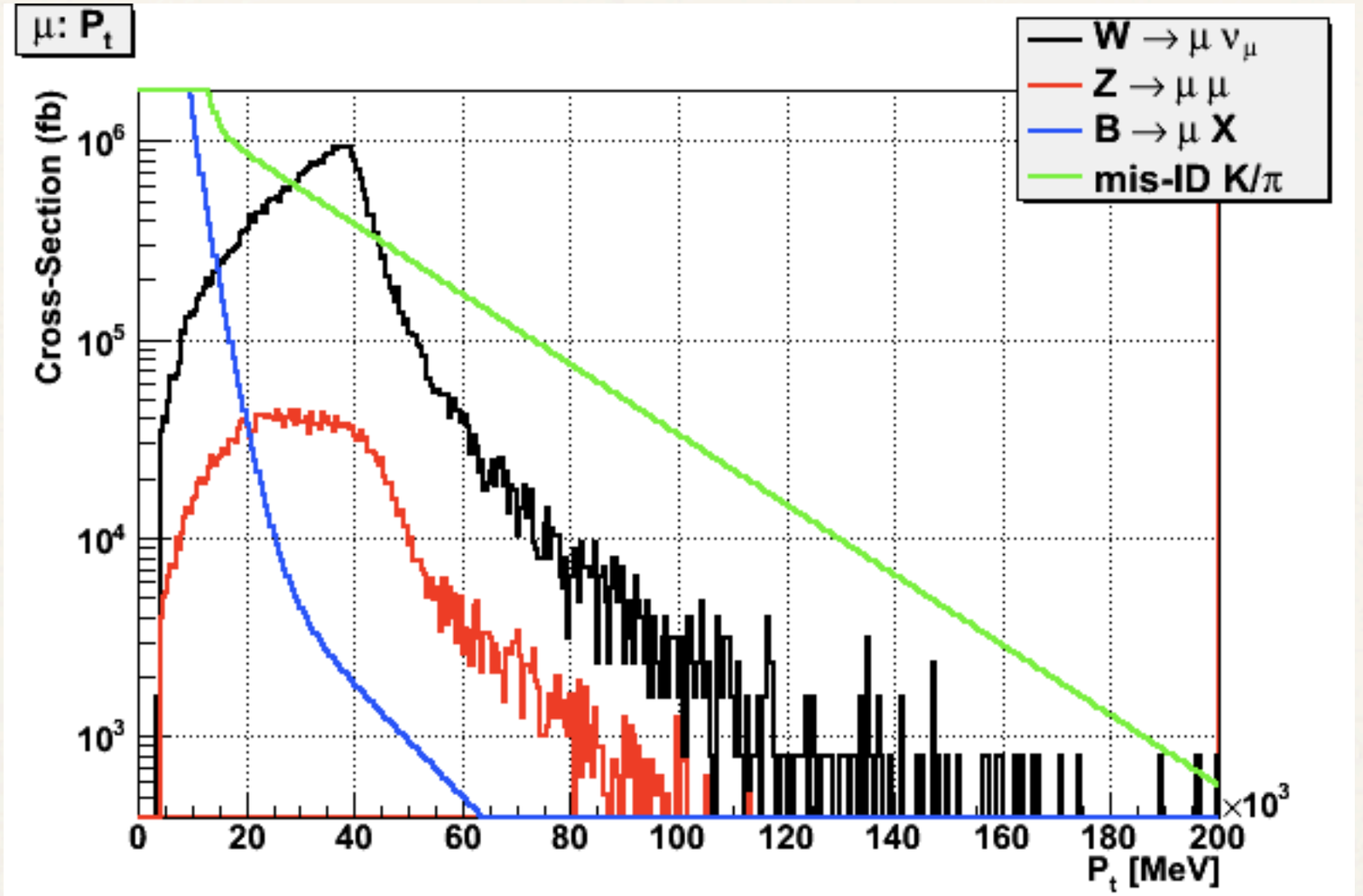


B-> μ +X



Mis-ID

Background suppression



After 1st asymmtery cut