Studies on ATLAS muon efficiency measurement with $Z \rightarrow \mu\mu$

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Outlook

1. Introduction: what are we measuring?
2. Muon trigger in ATLAS
3. Tag and Probe method
4. Results on MC samples
5. Plans for the first data and conclusions

1 - Introduction

- The knowledge of the actual detector performances will be crucial for all measurements at LHC experiments
- We are interested in the development of a method to measure trigger and reconstruction efficiency (including detector acceptance) using real data
- In the following we present the results of the Tag&Probe method to determine the muon spectrometer trigger efficiency

2 – ATLAS muon trigger

ATLAS trigger reduces the event rate from the initial 40 MHz to ~200 Hz affordable by the event storage system

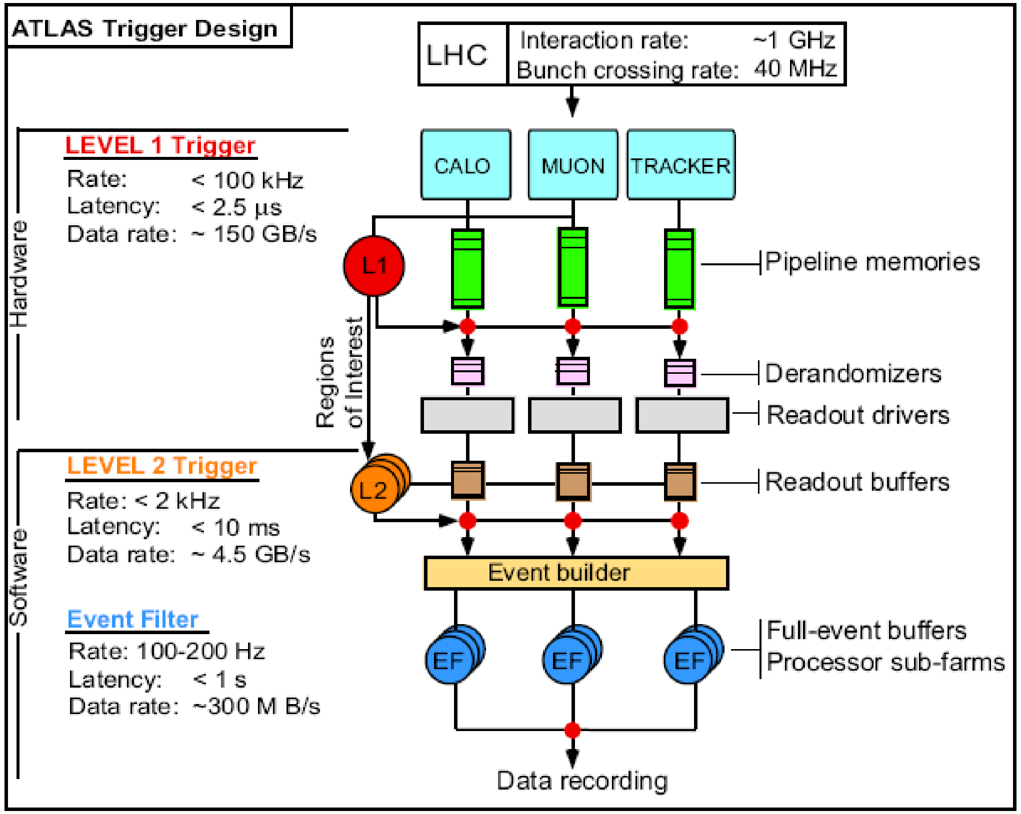
Muon trigger is organized over more levels:

– The first one has to operate a fast choice and identification of the Region of Interest (RoI) → hardware

– Following levels process a limited subset of data (only from the RoI) with higher granularity and better resolution → software

– Final level very close to offline reconstruction (Event Filter), runs online on RoI data.

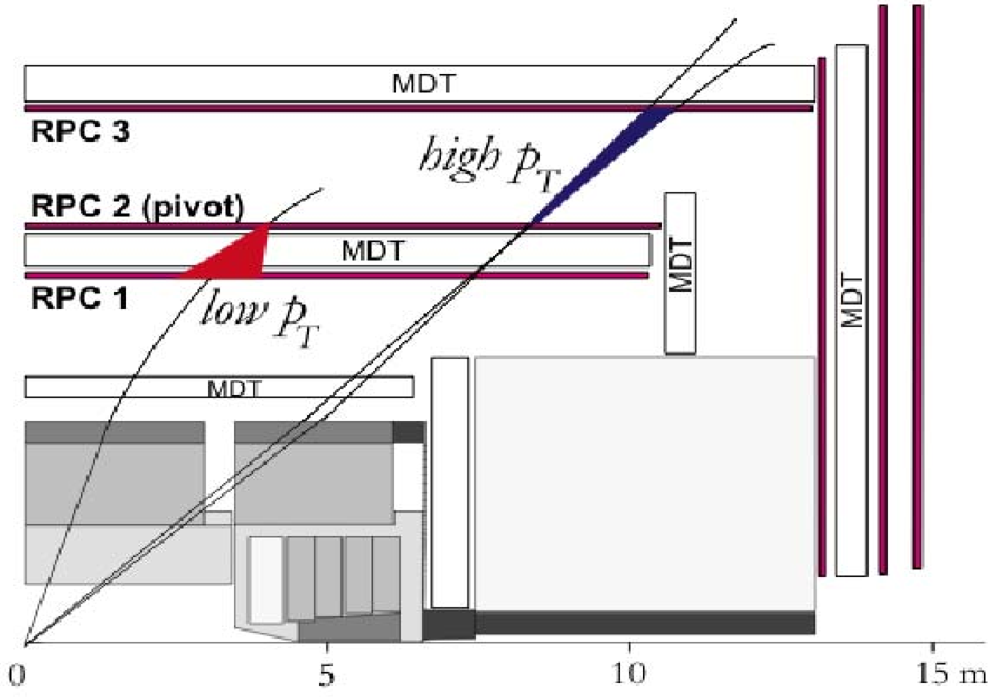
– Typical muon RoI size in eta – phi ~0.1x0.1



2 - Muon trigger in ATLAS

Level 1 uses dedicated detector system based on RPCs and TGCs

- Selection of events with muons above a given p_T threshold (up to six programmable thresholds) → e.g. 6, 10 and 20 GeV
- Coincidence of hits in space (both eta and phi) and time within geometrical windows in different trigger detector layers

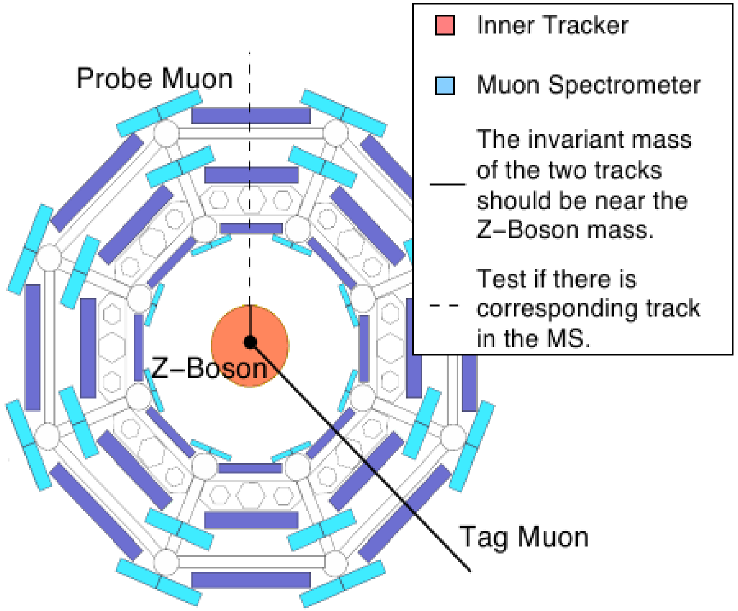


Level 2 and Event Filter based on software reconstruction algorithms

3 - Tag and Probe using the Z resonance

- The analysis goal is to provide a sample of muons selected independently of the Muon Spectrometer to measure MS trigger and reconstruction efficiency
- In $Z \rightarrow \mu\mu$ events is possible to identify a true self-triggering muon using all subdetectors (the tag) and search for the almost back-to-back muon (the probe) without using the MS
- Need to study on Monte Carlo samples:
  how many probes you can select → using signal sample
  how many background you have → using background samples

Tag and Probe method



3 - Tag and Probe Method

- Tag selection:
  - muon reconstructed using both inner detector and muon spectrometer with p_T and eta cut
  - self-triggering
  - coming from the primary vertex
  - isolated
- Probe selection:
  - inner detector track in the acceptance with p_T and eta cut
  - almost back-to-back to the tag in the transverse plane
  - coming from the same vertex
  - isolated
  - tag and probe combined mass in the Z mass range
  - identified as a muon by the calorimeter

3 - Tag and Probe Method

→ Once you have the probe selected: try probe – trigger matching, for various trigger thresholds and levels

$$\text{Efficiency} = \frac{\text{\# of probes that match the trigger}}{\text{\# of total probes selected.}}$$

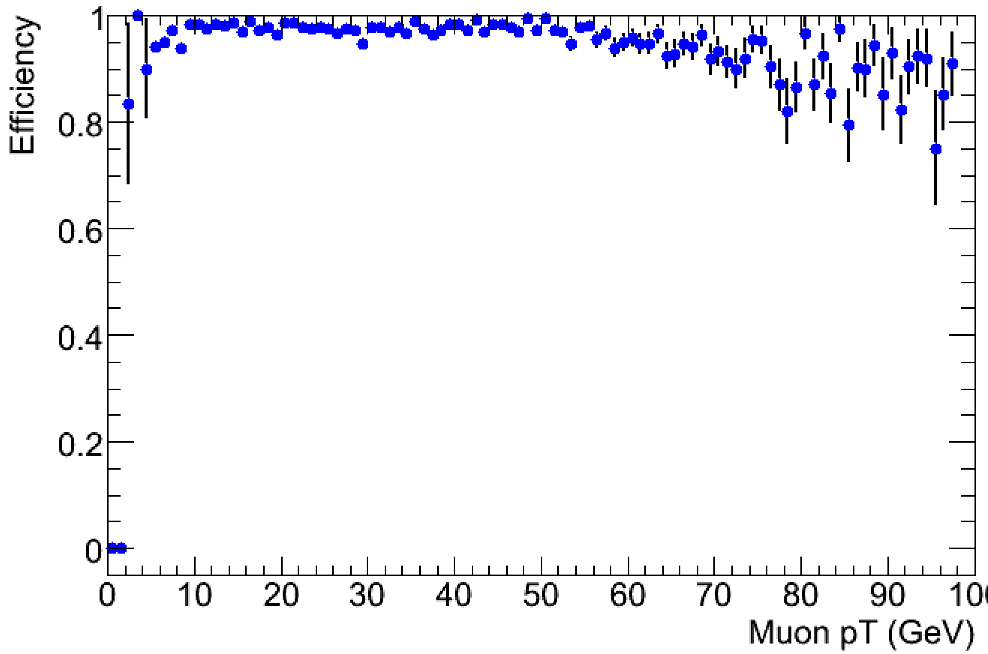
Efficiency is calculated vs pt, eta and phi

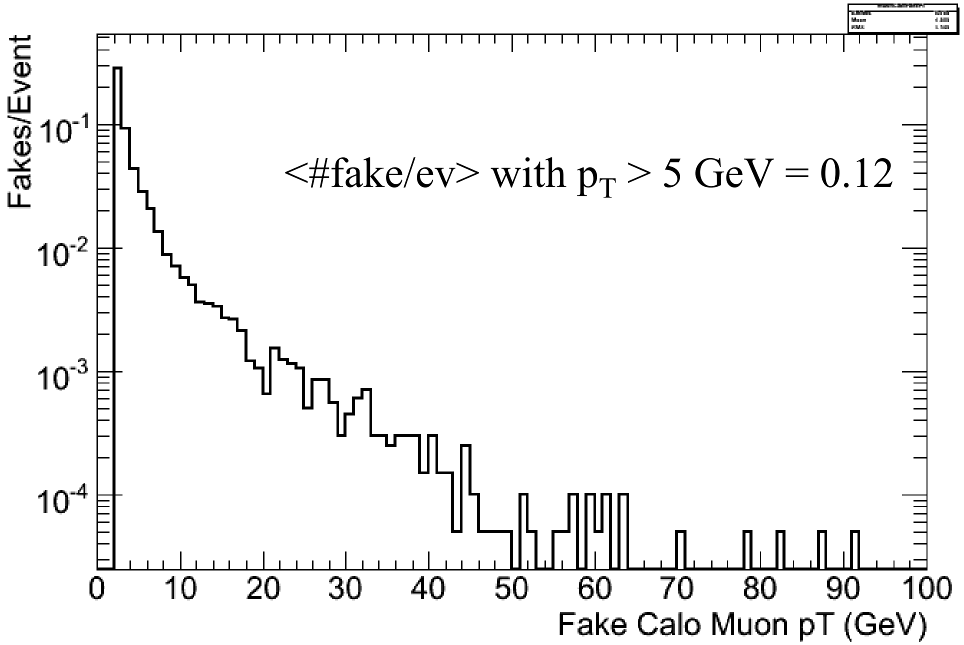
This is an absolute measurement, It's NOT dependent on the reconstruction efficiency!

3 – Main Backgrounds

For each tag there are ~35 muon candidate inner detector tracks. Sometimes one is passing the probe selection but it isn't a muon

- W → μν : this is the main background.
  - The xsec is ~10 times the signal one
  - It's reduced in particular by tagging the probe as a muon with the hadronic calorimeter (below performances of the tagging algorithm)



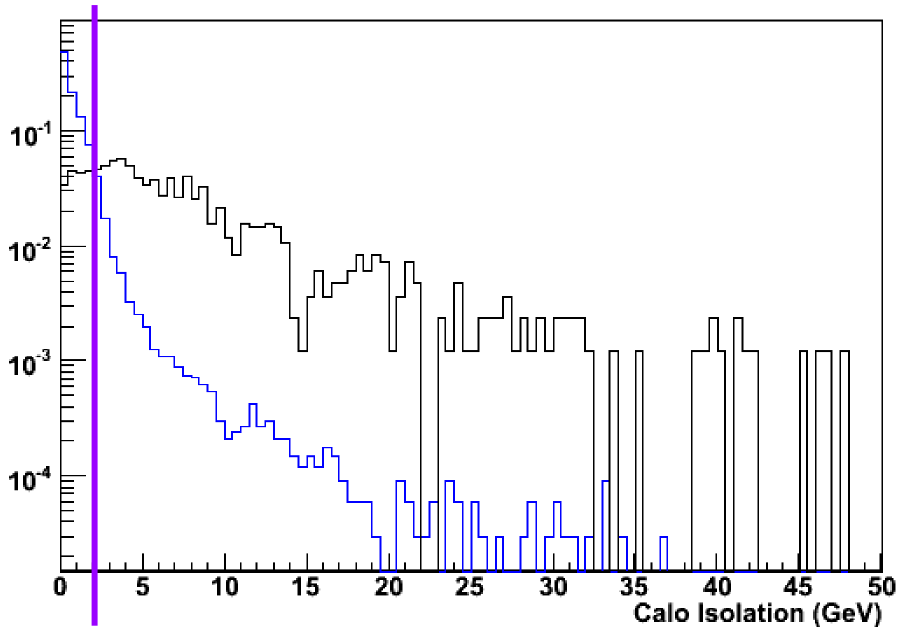


3 – Main Backgrounds

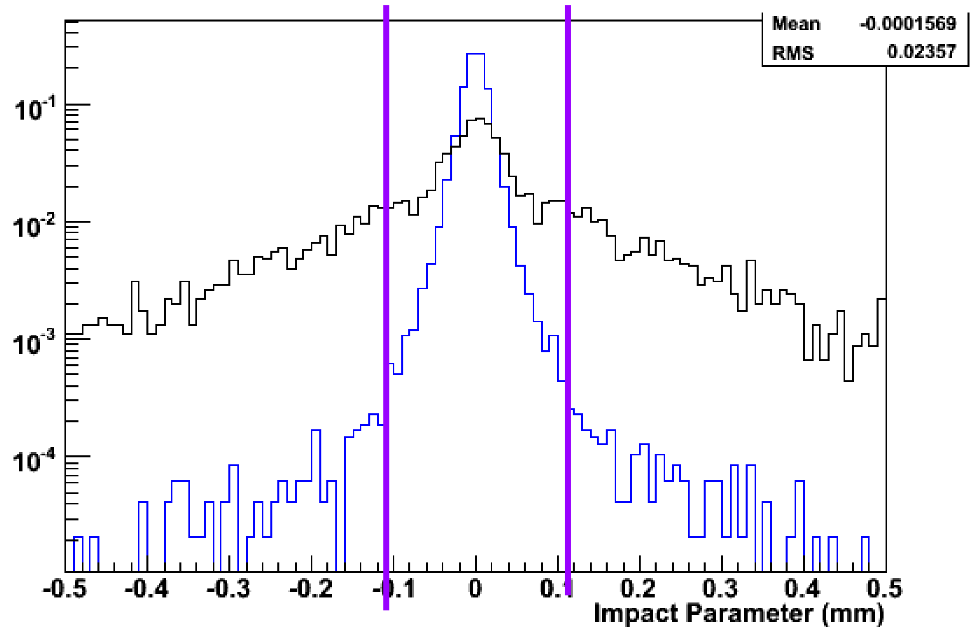
- bbar → μ + X:
  - The xsec is ~100 times the signal one
  - Here you have true muons from b that can pass the probe selection
  - It's reduced using isolation cut and impact parameter cut (the probe must come from the primary vertex)

Blue → signal   Black → bbar background

Track isolation



Transverse impact parameter distribution



4 – Analysis summary

Sample	Xsec [pb]	probe/pb^{-1} (pt > 5 GeV)	probe/pb-1 (pt > 20 GeV)
Z->mu mu	1854	1081	1042
W->mu nu	14490	4.2	< 1.1
bbar-> mu + X	270000	1.6	< 1.4
Z->tau tau	104	0.2	0.2
Zbbar->4l	1	0.2	0.1
ttbar	700	< 1.8	< 1.3

(NLO Xsec x filter efficiency (LO for bb samples))

- About 1000 probes/pb^{-1}
- About 1 probe/pb^{-1} in eta-phi bins 0.2x0.2
- Main background W → μν 0.4%

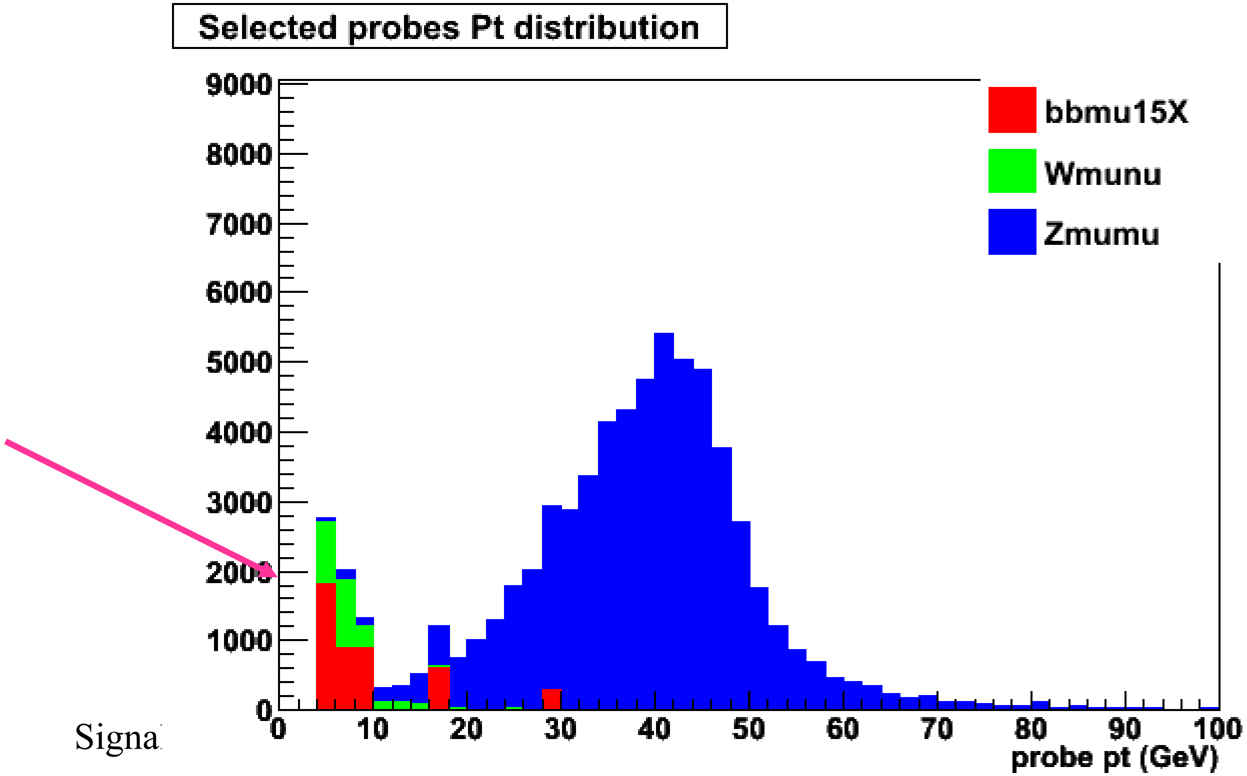
4 – Background contribution

The background level is not so high BUT is concentrated at low p_T

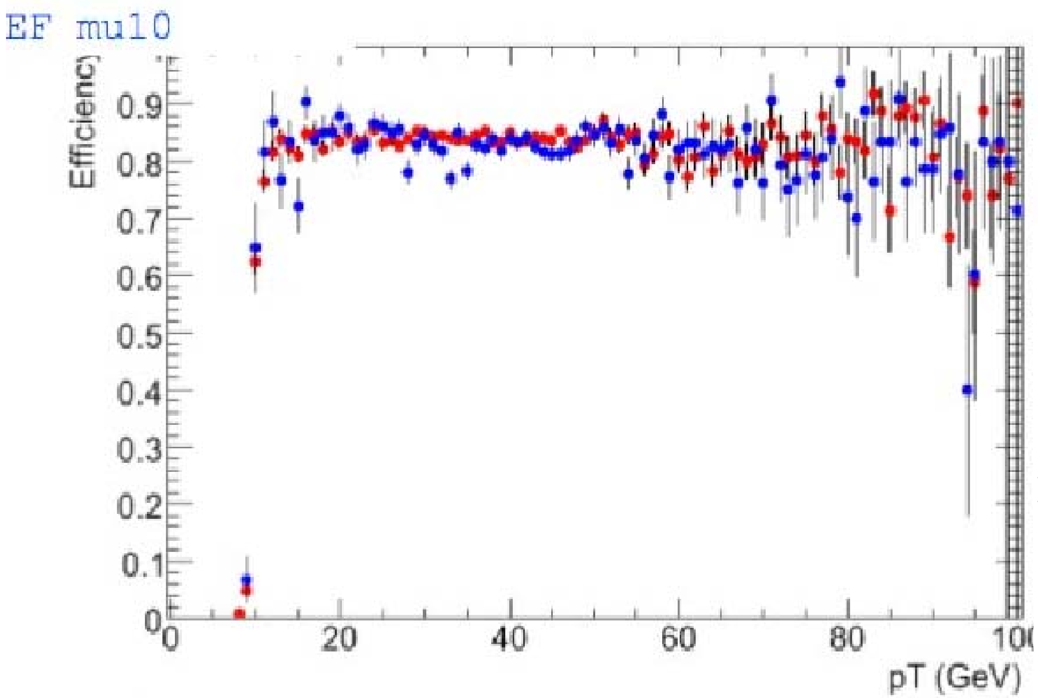
→ if you want to remove the tag-probe invariant mass cut to explore low p_T region it must be taken under control!

Probe pt distribution for signal and main backgrounds with 50 pb^{-1} removing the tag-probe invariant mass cut .

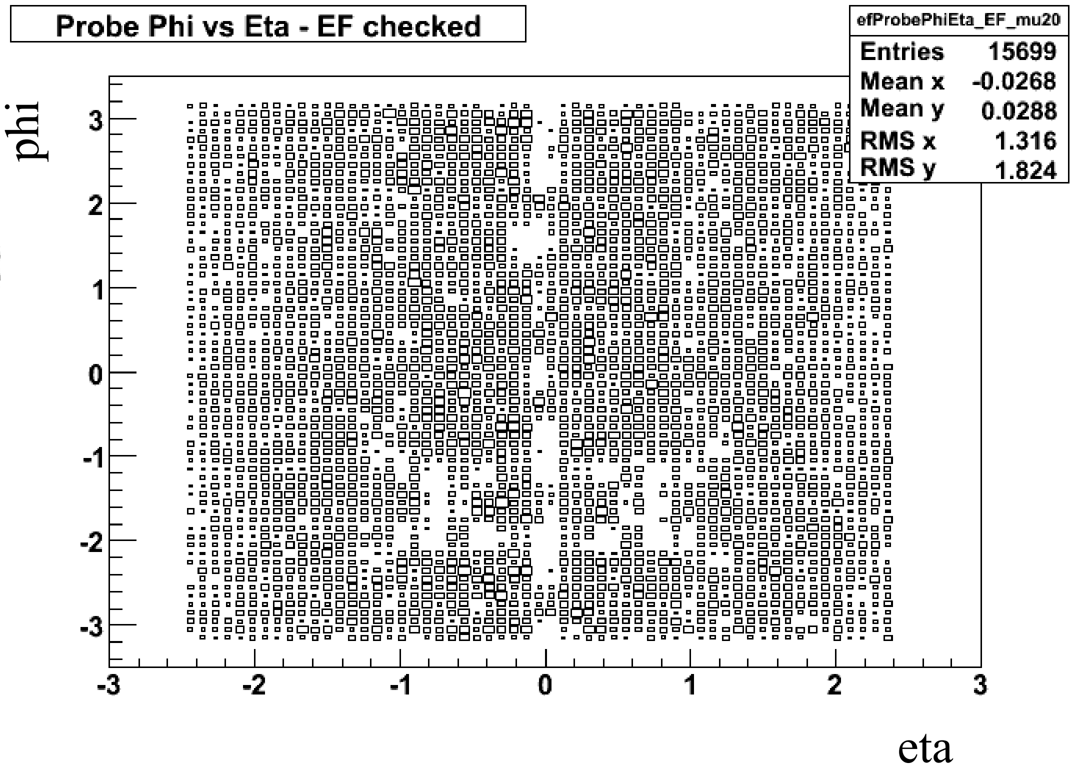
Very small statistics at low p_T: to study this region we need to use a Drell-Yan sample and check the actual level of background.



4 – Trigger Efficiency and acceptance



Example of trigger efficiency vs pt with 40 pb^{-1}. One can compare the measured efficiency (blue) with the one calculated using the Monte Carlo truth (red)



The overall efficiency is dominated by the muon spectrometer level 1 acceptance!

Eta – Phi distribution of selected probes that pass the trigger → here you see the geometrical acceptance but in real data could be worse.

5 – Conclusions and plans for the first data

- Trigger efficiency will be one of the first measurements to be done with the first LHC data

→ It is possible to measure the trigger efficiency from real data with a tag&probe method using $Z \rightarrow \mu\mu$ events.

- Assuming to have 50 pb^{-1}, the expected error is:
  - < 1% overall over ~50000 selected probes
  - 20% per trigger tower over ~50 selected probes

→ Background is reduced to an acceptable level BUT the statistics is limited expecially to measure the efficiency per trigger tower.

- The same method can be used to measure the offline reconstruction efficiency