Multi-muon signal with early CMS data

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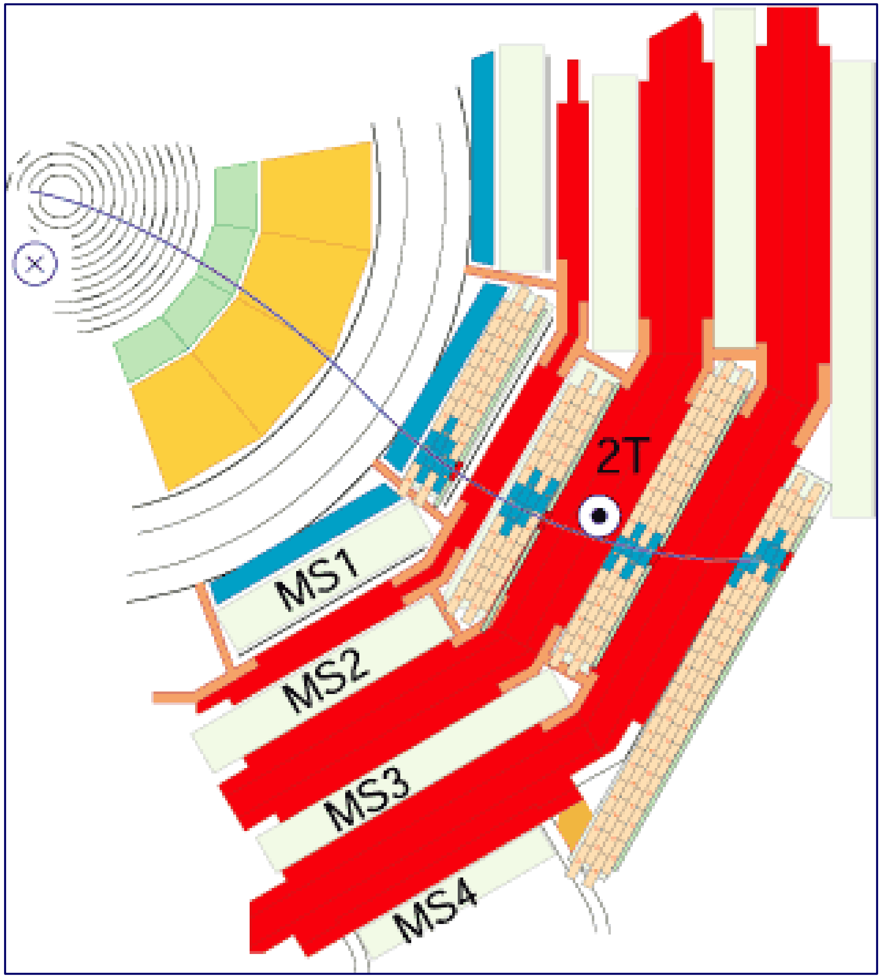


Talk outline

- Our main idea is to study the CDF multi-muon events in CMS detector with early data
- To reach the goal a deep, multi-purpose detector response study is needed:
  - Expected sources of large impact parameter muons
  - Quantification of relative/absolute contributions from them
- Show our first steps on:
  - Measuring muon reco efficiency vs Impact Parameter and decay radius
  - Understanding of fake muons with MC and data-driven techniques
    - Hadron punch through (PT)
    - Decays in flight (DiF) of $K^{\pm}$,$\pi^{\pm}$
  - Computing preliminary estimate of CMS sensitivity for CDF anomaly

CDF analysis highlights

- Motivations
  - Large $\sigma_{b\bar{b}}$ compared to NLO QCD expectation when measured with muons **PRD 69, 072004 (2004)**
  - Time-integrated mixing probability χ larger than e^+e^- result **PRD 69, 012002 (2004)**
  - Low-mass dilepton spectrum inconsistent with QCD expectations from heavy flavor **PRD 72, 072002 (2005)**

- Results
  - There is an unexpected sample of muons which do not give hits in the first two silicon layers (r<2.5 cm) and which have a very large impact parameter (IP); hereafter called "**ghost**" muons (fanciful term).
  - The size of the ghost sample is about the same as the bb sample.
  - Around ghost muons, additional ones are found with similar characteristics

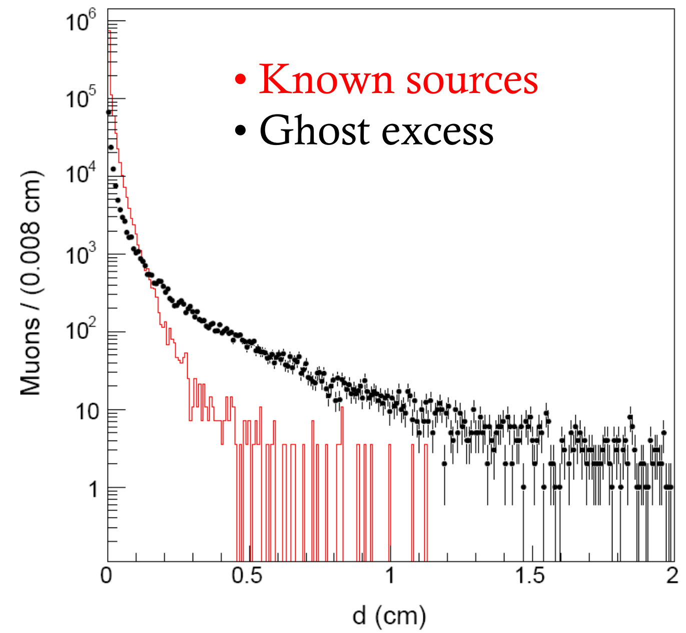
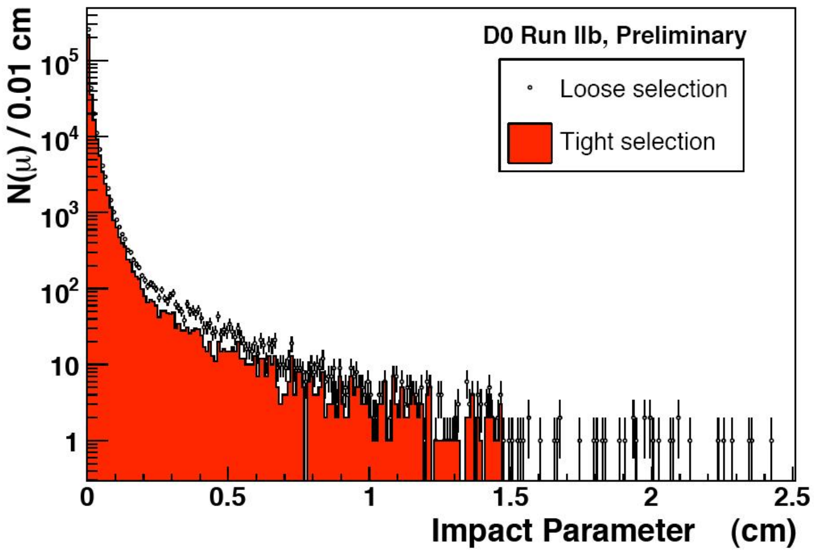


FIG. 7: Impact parameter distribution of muons contributed by ghost (•) and QCD (histogram) events. Muon tracks are selected with loose SVX requirements. The detector resolution is $\simeq 30\ \mu$m, whereas bins are 80 μm wide.

D0 analysis

- D0 recently performed a CDF-like analysis trying to confirm or exclude the presence of multi-muon events in their data.
- They used well-measured muon tracks produced within the beampipe (**tight** silicon requirements) to predict yield of dimuons with **looser** cuts with both MC simulation and control samples of real data
  - Caveat: reconstrucion efficiency falls rapidly at large impact parameter
- **D0 does not see any muon excess in the loose sample**



Analysis Plan (I)

- Check track reconstruction efficiency for tracks with large Impact Parameter (IP)
  - MC study of track reconstruction efficiency vs IP, vs radius of production point
  - Validation on data using tracks from Ks decay
- Check resolution in IP determination
  - Measure in data with dimuon resonances
- Check IP, P_t distribution from most relevant sources of reconstructed muons
  - Punch through (PT)
  - Decays in flight
  - Semileptonic B,D decays

} Data control samples

$K^0_s \rightarrow \pi^+\pi^-$
$\phi \rightarrow K^+K^-$
$\Lambda \rightarrow p\pi$
$D^0 \rightarrow \pi^+K^-$

Analysis Plan (II)

- Study secondary tracks from nuclear interactions and their contributions to IP tails
- Compute expected background rate in well-defined IP/P_t region
- Jump on data!

- Technical points:
  - there is no impact parameter for genPs
    - We used linear extrapolation back to primary vertex
  - GenPs are reconstructed before GEANT detector simulation
    - We used K. Ulmer private code to recover DIF and nuclear interactions

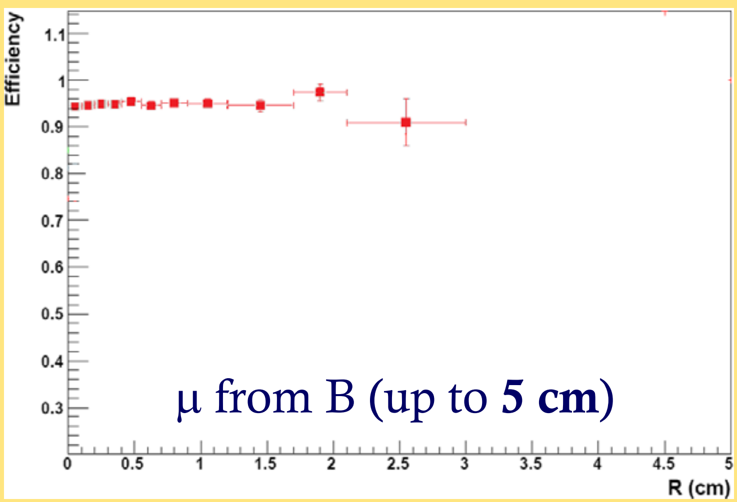
Framework and data sample

- CMSSW_2_2_9 using PATtuples
- Inclusive pp→μX
  - /InclusivePPmuX/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO
  - At least 1 generated muon with $P_t(\mu) > 2,5$ GeV
    - This requirement rises decay in flight fake rate
    - Punch Through rate is not affected by this requirement
  - $\sigma = 5,16 \cdot 10^{10}$ pb
  - Filter efficiency = 0.0061
  - No trigger requirements
  - 5M events used (L= 0.056 pb^{-1})
- Different Muon selectors used:
  - GlobalMuonPromptTight
  - TMLastStation

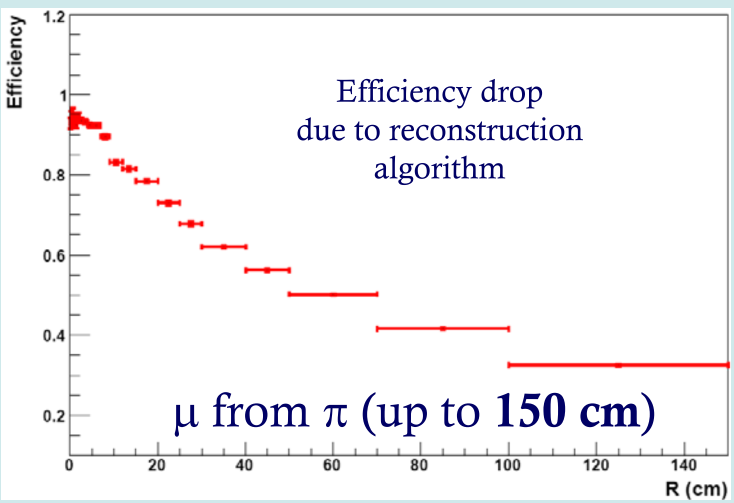
Muon reco efficiency vs R_{decay}

- Efficiency of the current tracking reco algorithm drops after few (~10) centimeters
  - This affects reco efficiency fo muons coming from long-lived particles
    - Improvements in CMSSW_3_X

“Prompt” muons



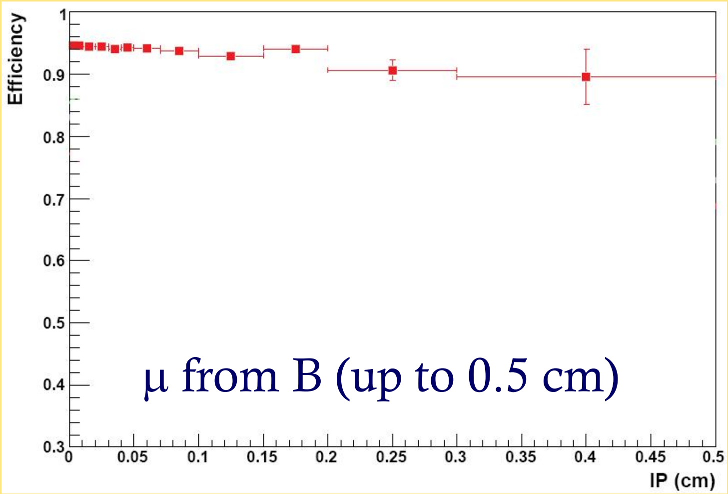
“Delayed” muons



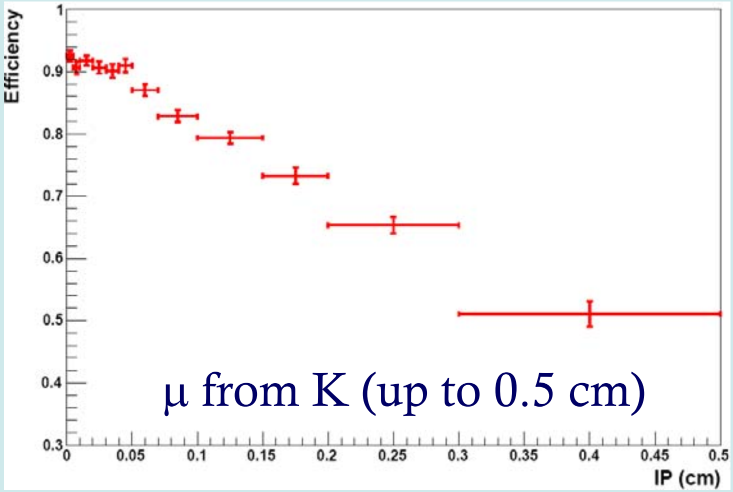
Muon reco efficiency vs IP

- Very high efficiency for "prompt" muons
- Slight efficiency drop for muons coming from long-lived particles (related to efficiency vs R_{decay})

"Prompt" muons

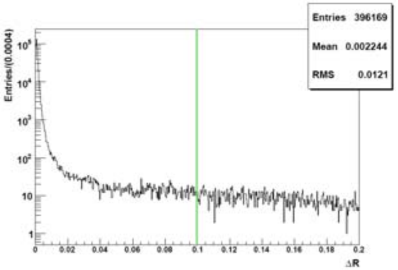


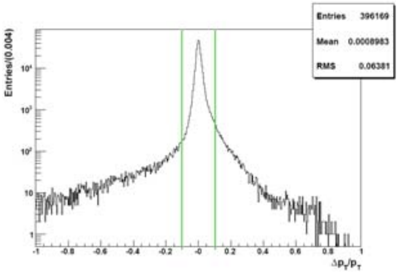
"Delayed" muons



Fake rate estimation based on MC-truth

- Track basic requirements
  - $Pt > 5$ GeV , $|\eta| < 2.5$
- Reco-MC tracks association criteria
  - Tight cuts applied to obtain high purity (no matter about efficiency loss)
    - $\Delta R < 0.1$
    - $|\Delta Pt/Pt| < 0.1$





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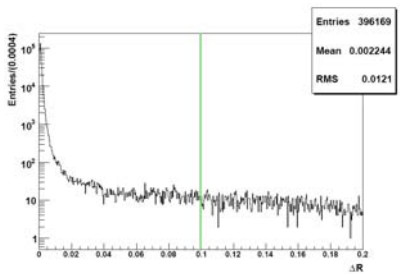
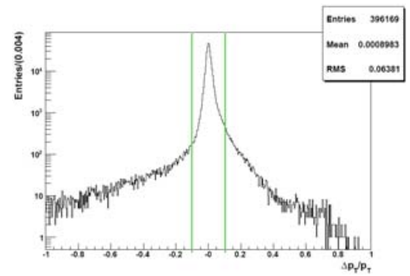




- We define the Muon Fake Rate as the sum of two effects: hadron punch-throughs and hadron in flight decays
  - Current estimate of Muon Fake Rate is biased because used sample requires at least 1 muon with Pt > 2,5 GeV per event
    - D.I.F. is over-estimated, P.T. is fine
- Different muon selectors used
  - TMLastStationTight (TML), GlobalMuonPromptTight (GmuP)

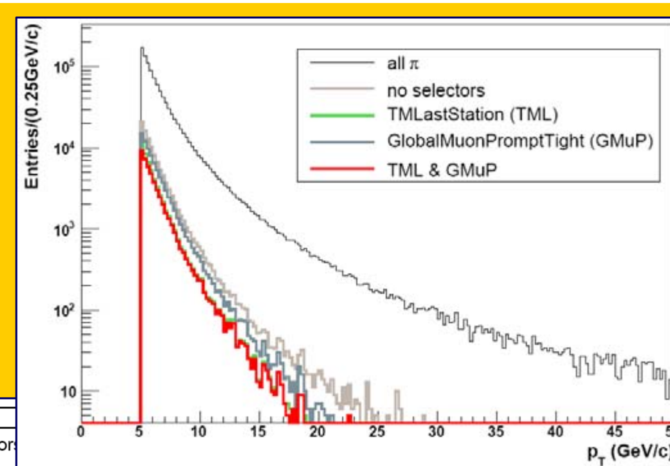
Muon fake rates from pions (DIF+PT)

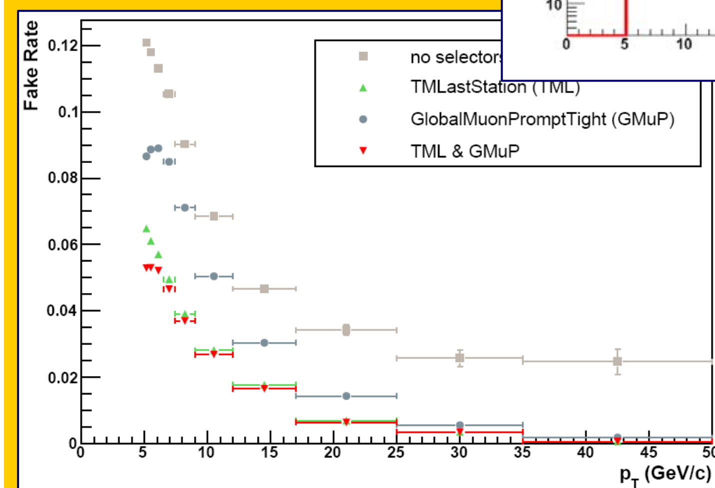
General Procedure:

- Pick up generated pions and associate reco track using ΔR, ΔP_t cuts
- Check if associated track is assigned also to a reco muon candidate
  - If so is a fake muon
- Divide fake muons sample by the associated reco tracks to obtain muon fake rate

- If we use ALL the pions we overestimate the fake rate due sample used)

P_t distribution





P_t fake rate

Muon selector	Fake rate
TML+GMuP	4.59 %

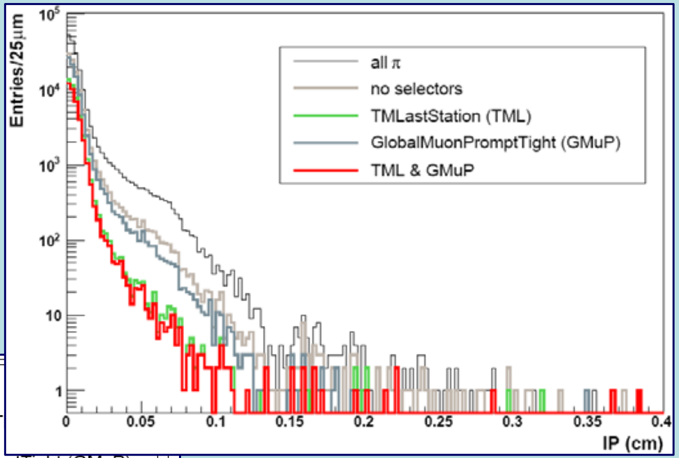
← OVERESTIMATED DUE TO D.I.F.!!!

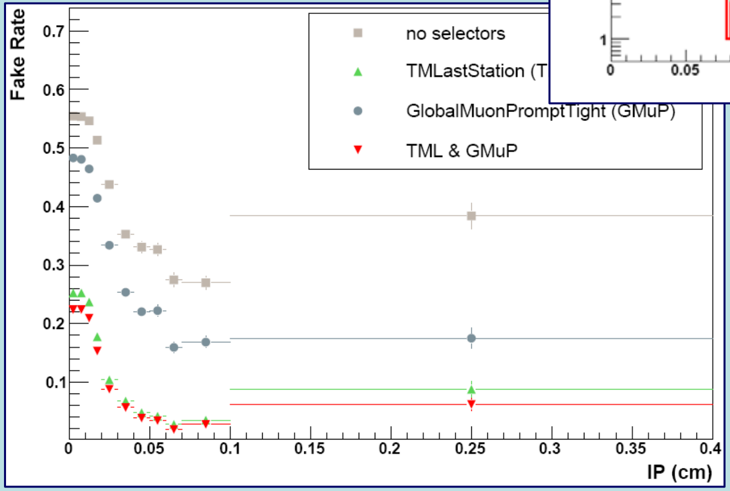
Muon fake rates from kaons (only DIF)

- The same effect can be seen using the Kaon sample
- Selecting only in-flight-decayed kaons the muon fake rate is highly overestimated

- More statistics is needed to deeply understand distributions behavior

Impact parameter distribution





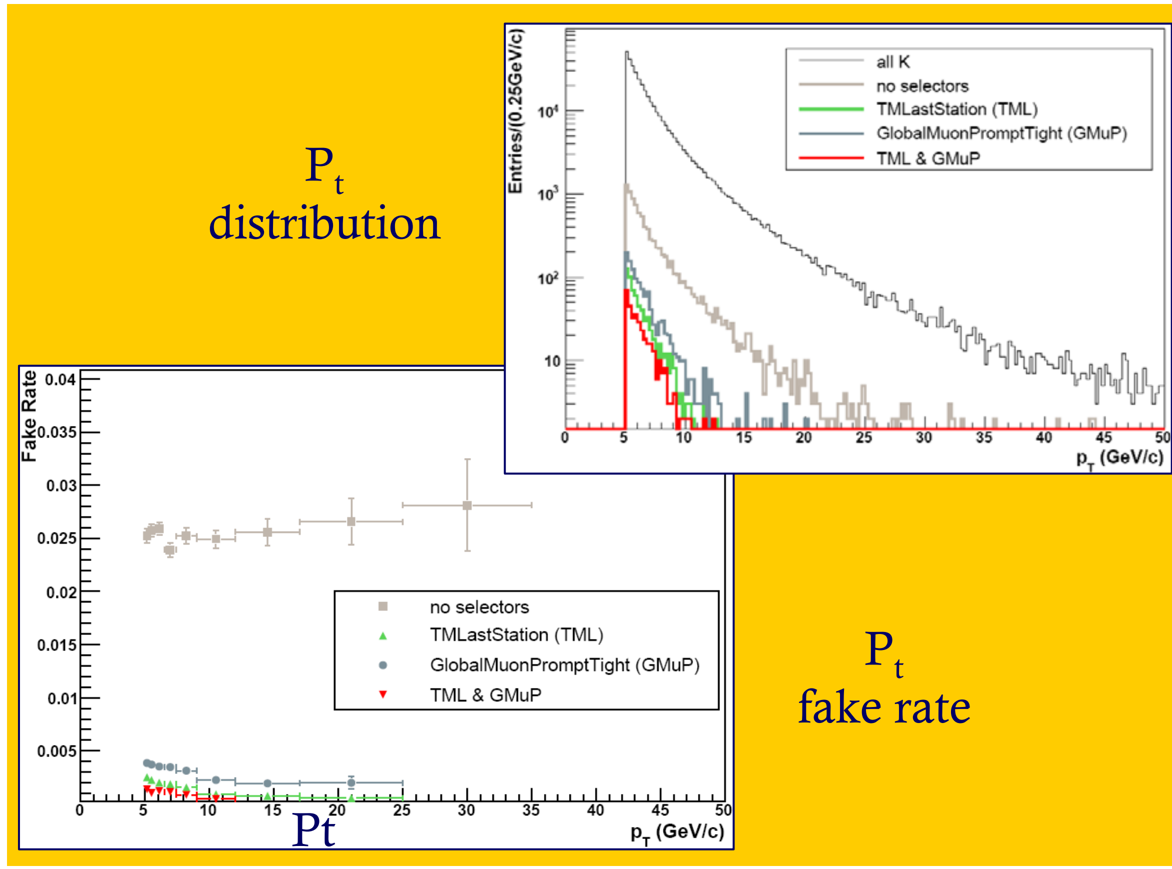
Impact parameter fake rate

Muon selector	Fake rate
TML+GMuP	38,6 %

← OVERESTIMATED!!!

Muon fake rates from kaons only (PT)

- Selecting only punch-through kaons the muon fake rate is as expected because is not biased by generation cuts



- More statistics is needed to deeply understand distributions behavior

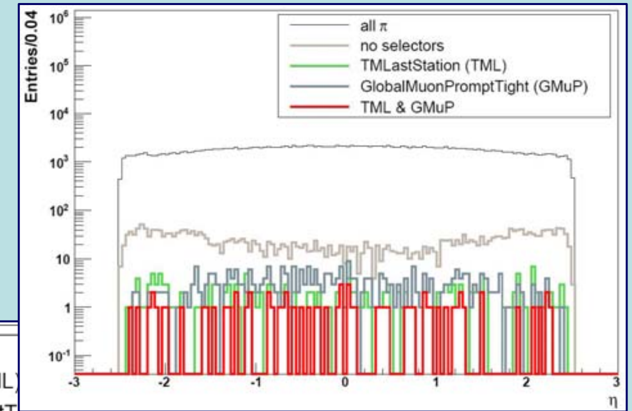
Muon selector	Fake rate
TML+GMuP	0,06 %

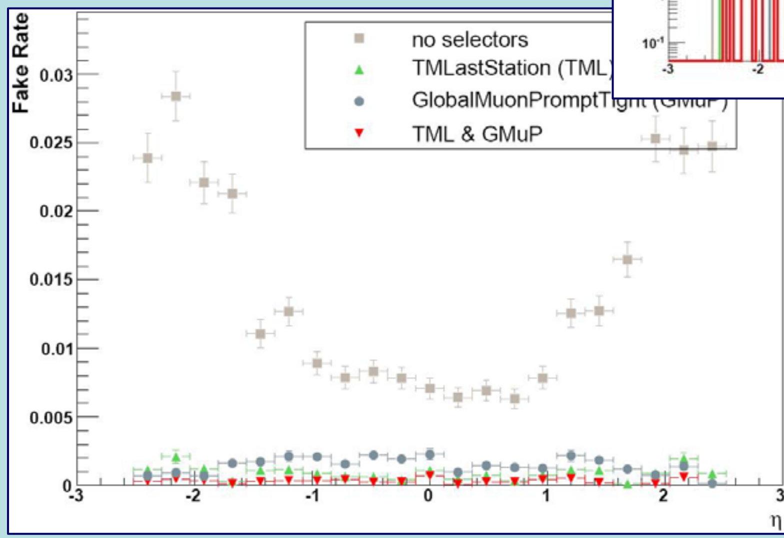
← AS EXPECTED

Muon fake rates from protons

- Protons do not decay so only punch-through can be observed

η distribution





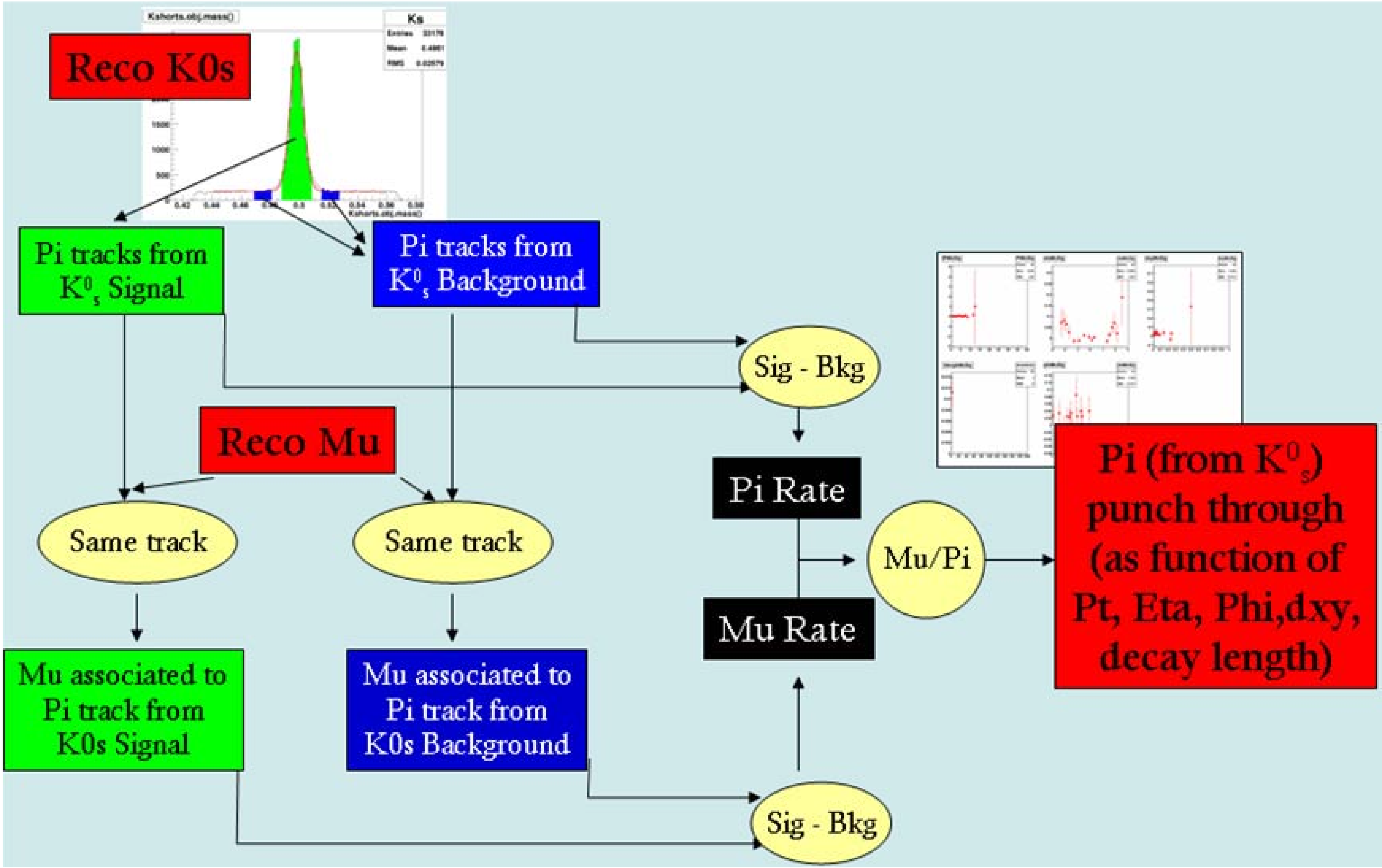
η fake rate

- More statistics is needed to deeply understand distributions behavior

Muon selector	Fake rate
TML+GMuP	0,03 %

← AS EXPECTED

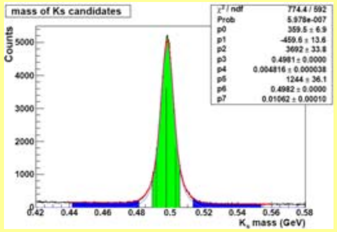
Data-driven muon fake rates from resonances (I)

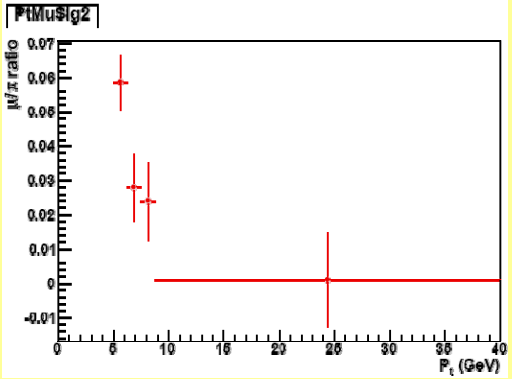


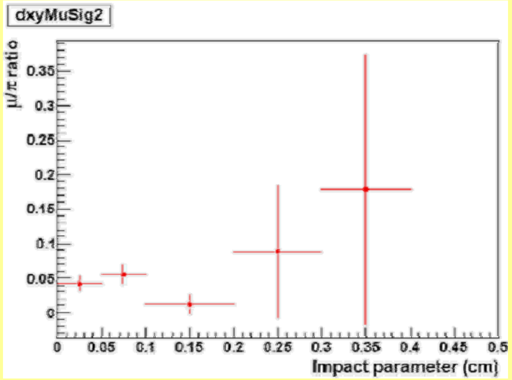
Data-driven muon fake rates from resonances (II)

- Long lived resonances muon fake rates

$K^0_s \rightarrow \pi\pi$



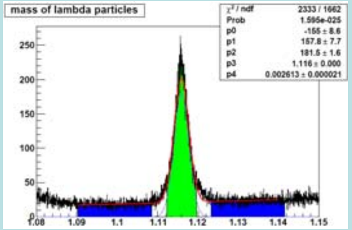


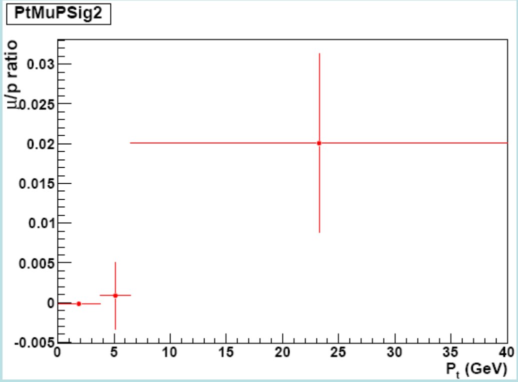


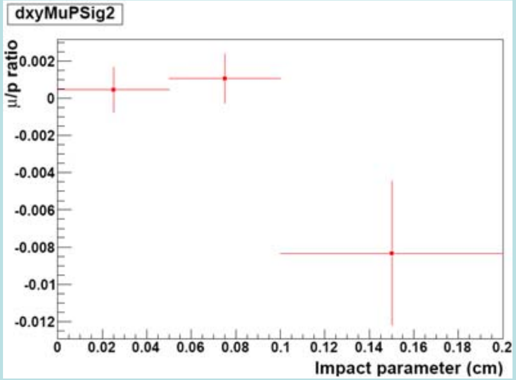
Data-driven pion fake rate: (4.7 ± 0.6)%

MC-driven pion fake rate 4.6%

$\Lambda^0 \rightarrow p\pi$





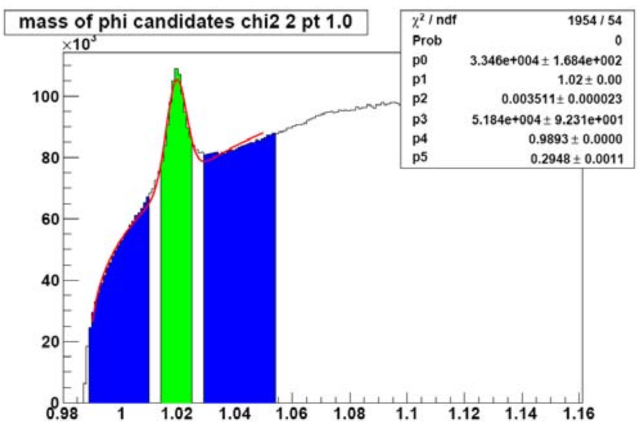


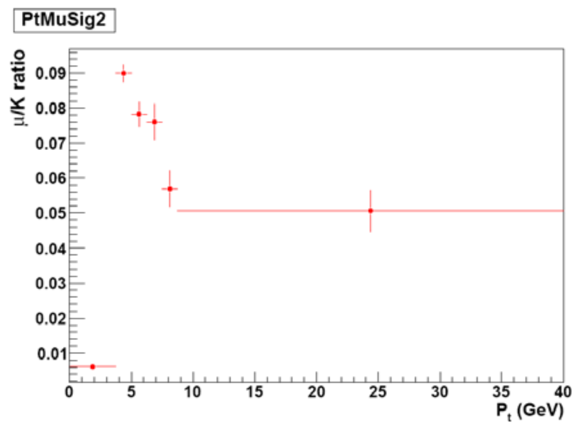
Data-driven proton fake rate: (0.05 ± 0.03)%

MC-driven proton fake rate 0.03%

Data-driven muon fake rates from resonances (III)

- Short lived resonances muon fake rates
  - Ex: $\phi^0 \rightarrow KK$ (cut on IP to optimize S/B)





Data-driven kaon fake rate: ~2 %

MC-driven kaon fake rate 7%

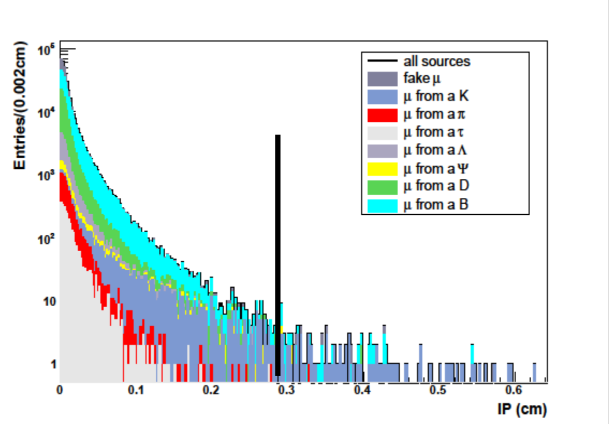
- In this case backgound is dominating and not linear
- Data-driven and MC-driven fake rates do not match (possible error in computing backgound)

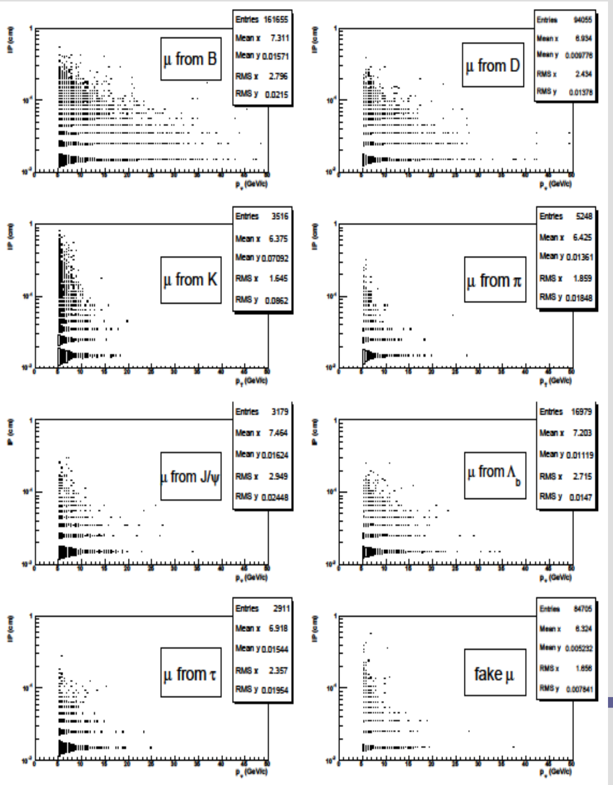
Preliminary estimate of CMS sensitivity for CDF-like signal (Method)

No model is avaible. → Need to rely only upon our understanding of the Standard Model background, for a possible exclusion.

1. Classification of all relevant Standard Model sources of muons and analysis of the kinematic features:
   - *semileptonic decays of heavy flavor mesons;*
   - *in-flight decays of light hadrons and punch-through (fake muons);*
   - *J/ψ decays;*
   - *Λ_b decays;*
   - *Υ decays;*
   - *τ decays.*
2. Definition of a search region in p_T and impact parameter, where a possible CDF-life signal is expected;
3. Estimate of the cross-section σ_b of background from Standard Model processes within this region;
4. Discussion of the possibility to exclude a CDF-like signal from collision data collected with given integrated luminosity L.

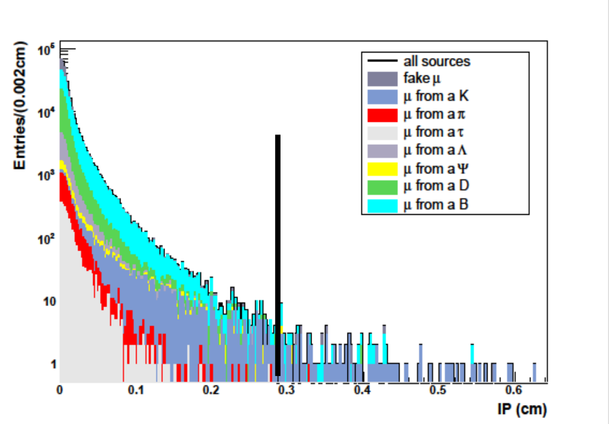
Background estimate and signal exclusion (I)

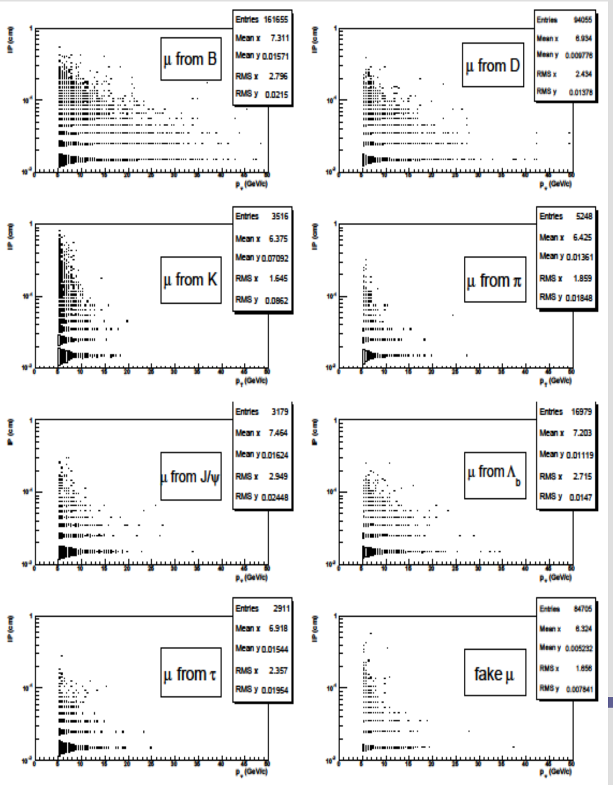




1. Classification of all relevant SM sources (background).
2. Definition of the search region:
   - $pT > 5\ GeV/c$
   - $|\eta| < 2.5$
   - $IP > 0.3\ \ cm.$
3. $N_b = 129 \pm 11$ events found within this region, from integrated luminosity $L_s = 0.056\ pb^{-1}$.
4. Estimated background $\sigma_b = N_b / L_s = (2303 \pm 196)\ pb$.

Background estimate and signal exclusion (I)





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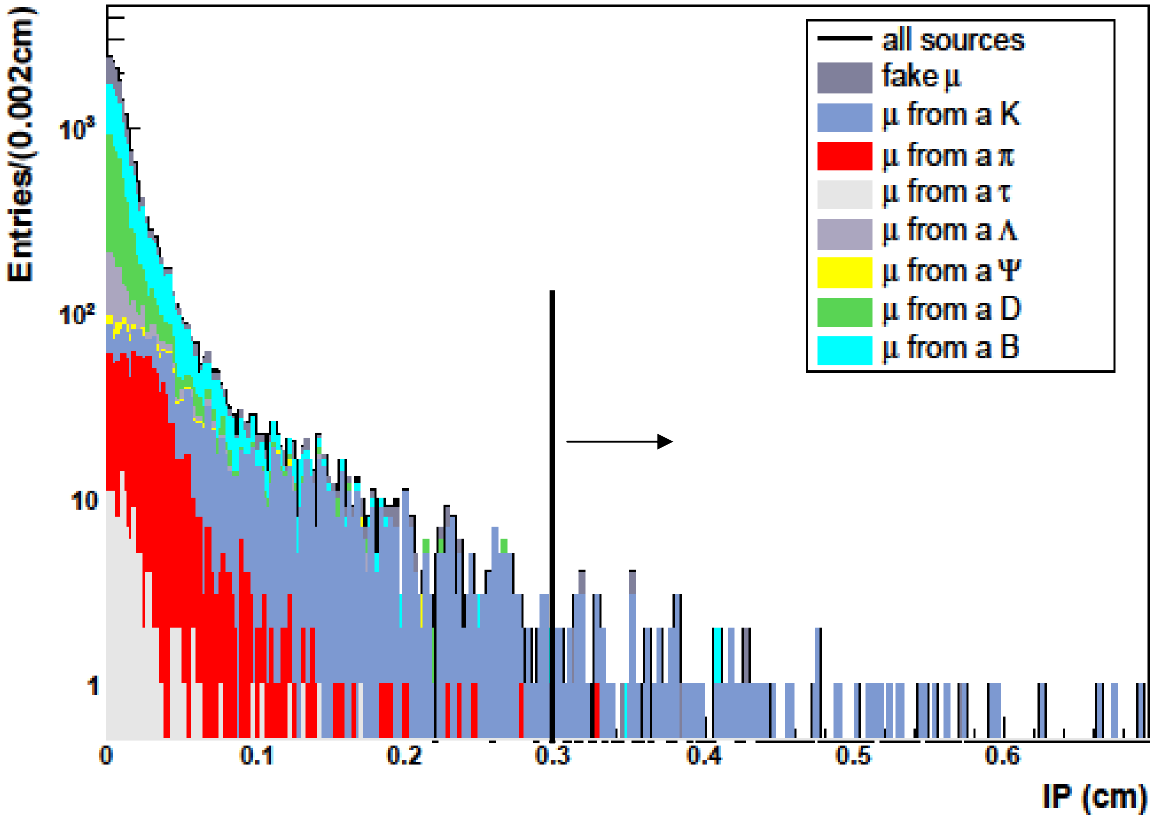
4. Estimated background $\sigma_b = N_b / L_s = (2303 \pm 196)\ pb$.
5. $N_s = 1.96 \cdot \sqrt{\sigma_b L}$ signal events can be excluded at 95% C.L. on data collected with integrated luminosity L.
6. Corresponding to a signal cross-section $\sigma_s = \frac{94}{\sqrt{L}}$ pb

L (pb^{-1})	N_s^{lim}	σ_s (pb)
1	94	94
10	297	30
100	941	9

Background estimate and signal exclusion (II)

- Selection of a sample of muons without hit in the innermost layer of the tracker (R = 4.4 cm).
- Supposed to reproduce the sample of displaced muons used by CDF, in which the excess is found.



$\mathcal{L}$ (pb^{-1})	N_s^{lim}	σ_s (pb)
1	85	85
10	270	27
100	850	8

Conclusions

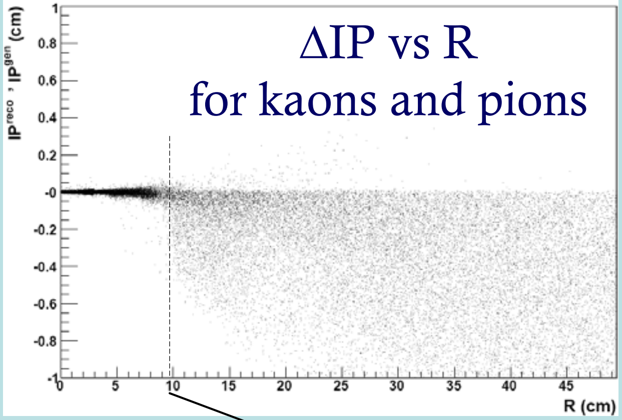
- We are putting together the tools to understand and size up the different contributions to large IP muons, in order to check the CDF signal of anomalous muon production.
- Still a lot of work is foreseen
  - Anybody is welcome to join our efforts!

BACKUP SLIDES

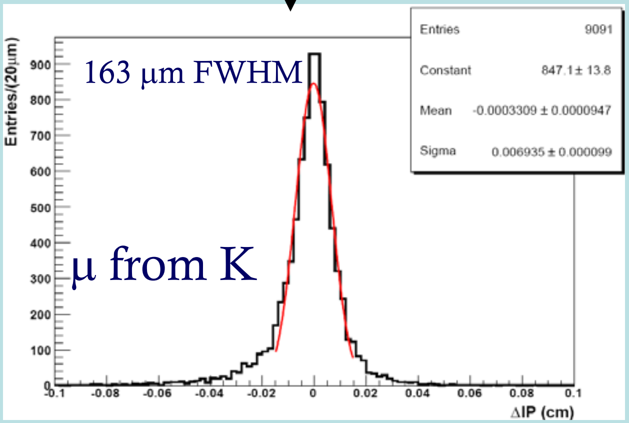
IP resolution

- Prompt muons have the best IP resolution
- Muons coming from in flight decays have worse resolution due to decay kink
- On data IP resolution can be estimated from J/Psi resonance

"Delayed" muons



R < 10 cm



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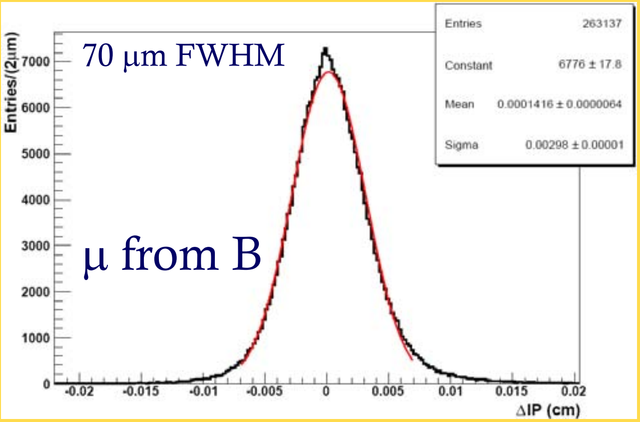
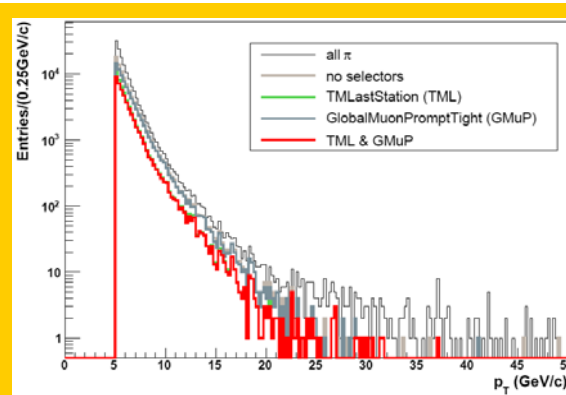
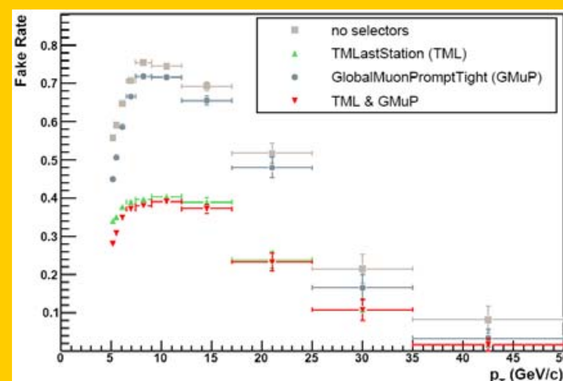


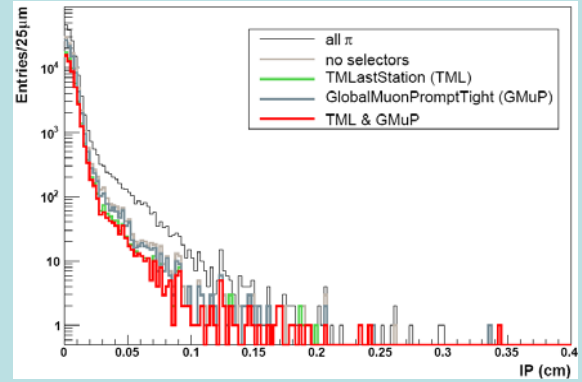
Muon fake rates from pion (only DIF)

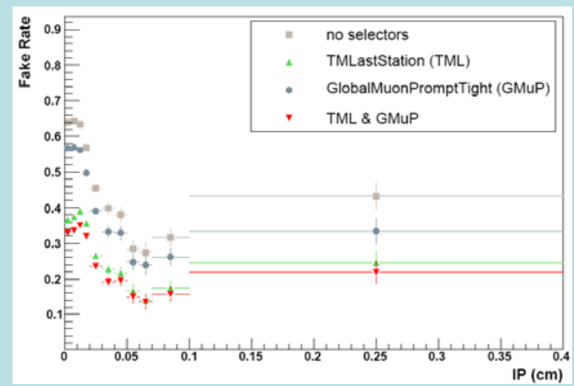
- Selecting only in-flight-decayed pions the muon fake rate is highly overestimated





Pt





Impact parameter

- More statistics is needed to deeply understand distributions behavior

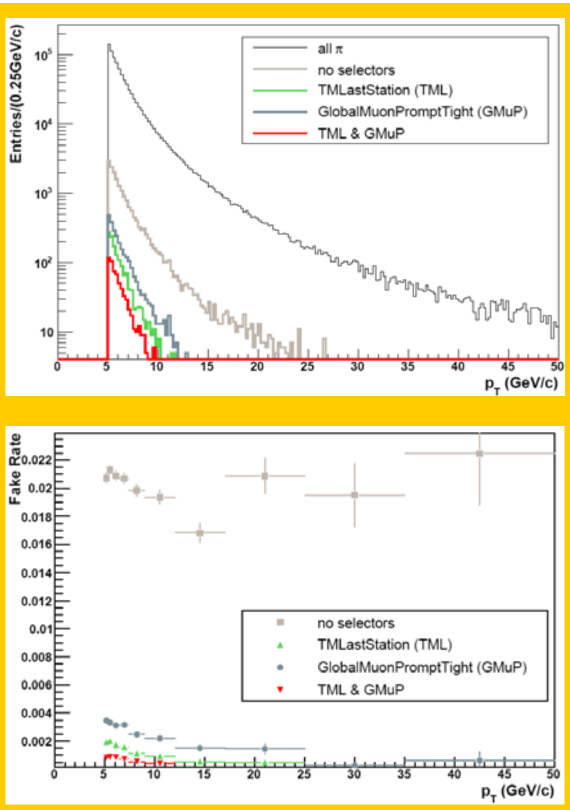
Muon selector	Fake rate
TML+GMuP	32,8 %

← OVERESTIMATED!!!

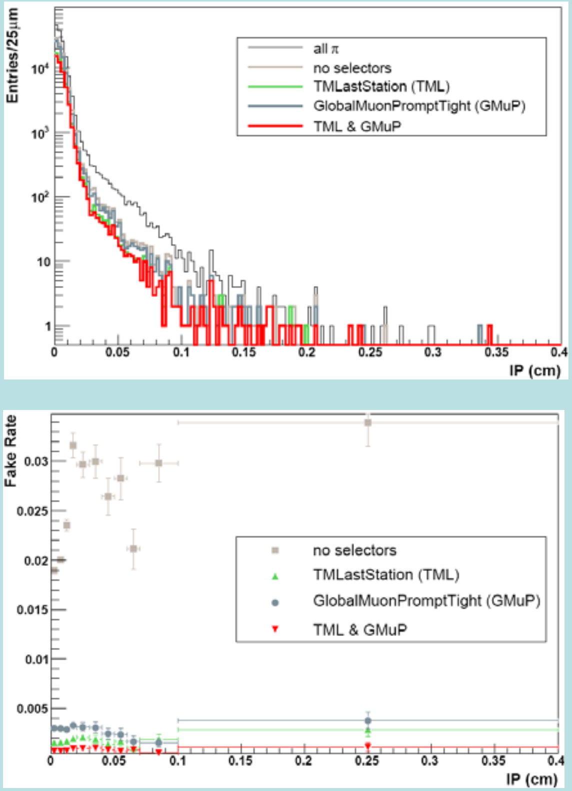
Muon fake rates from pion (only PT)

- Selecting only punch-through pions the muon fake rate is as expected because is not biased by generation cuts

- More statistics is needed to deeply understand distributions behavior



Pt



Impact parameter

Muon selector	Fake rate
TML+GMuP	0,07 %

← AS EXPECTED