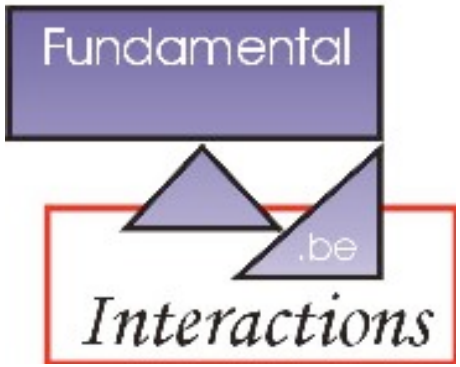


Search for new high mass resonances decaying into muons in the CMS experiment

Davide Pagano

Université Catholique de Louvain

- **Introduction**
- **Event selection**
  - Trigger
  - muon and dimuon selections
  - **isolation**
  - **cosmic rejection**
- **Comparison data and MC**
- **Systematic uncertainties**
  - detector resolution, efficiency
  - alignment
  - background modeling
- **Limit setting on $\sigma(Z')/\sigma(Z^0)$**
- **Improvement of high energy muon reconstruction (DYT algorithm)**
  - MC and data studies
  - Impact on Z' searches

Various models of physics beyond the Standard Model predict new gauge bosons Z' (spin 1):

- Models with a new U(1) gauge symmetry.
- All GUT's with gauge groups larger than SU(5) (for example SO(10), E_6,…).
- Little Higgs models.

…

Strategy of the search:

To select events with at least 2 muon candidates of opposite charge, passing some tight cuts, and reconstruct the dimuon invariant mass. We look at M>200 GeV/c^2.

- **no new resonance**: the resulting distribution should be a smooth distribution.

- **new resonance**: we expect to see a Breit-Wigner distribution convoluted with the detector resolution over a smooth shape.

Shape analysis by inspecting the mass spectrum such structure using an **unbinned maximum likelihood** fit. The output of the fit is used to set confidence limits as function of the unknown Z' mass. In particular **the limits on $\sigma(Z')/\sigma(Z^0)$**.

Event cuts

1. Scraping filter (to avoid beam background)
2. Good vertex filter (useful for cosmic rejection)
3. DQM certified good run list

Muon cuts

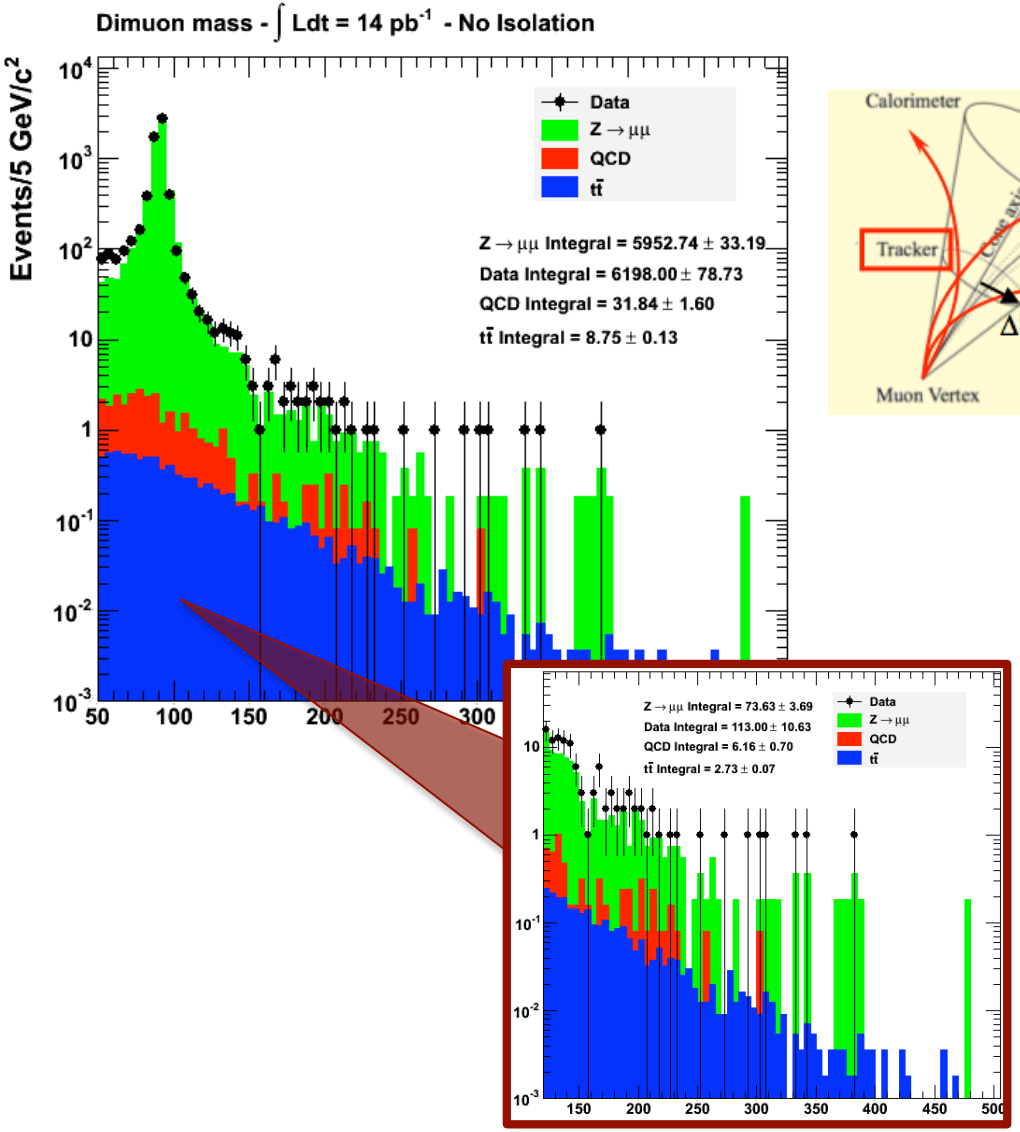
4. Global muons
5. p_T > 20 GeV/c
6. Number of valid tracker hits > 10

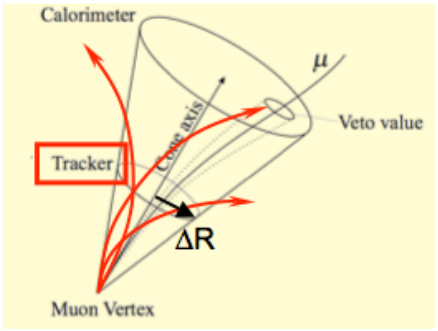
Cuts for both muons

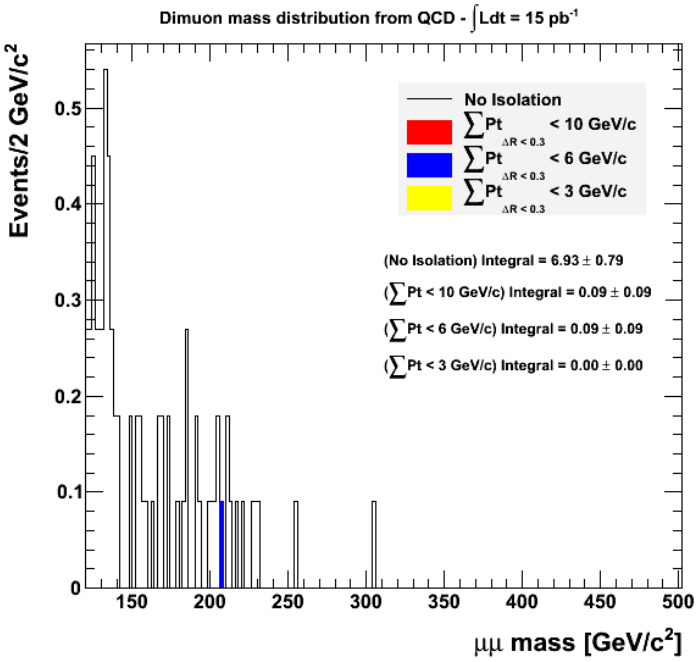
7. $|d_{xy}| < 0.2$
8. Global track fit χ^2/ndof < 10
9. Number of valid pixel hits ≥ 1
10. Number matched muon segments ≥ 2
11. Tracker muon
12. Dimuon vertex χ^2/ndof < 10
13. The 3d angle between muons > 0.02 rad
14. Isolation (sumPt < 10 GeV/c)
15. The muon must be matched in ΔR_{03} with the object that fired the HTL path

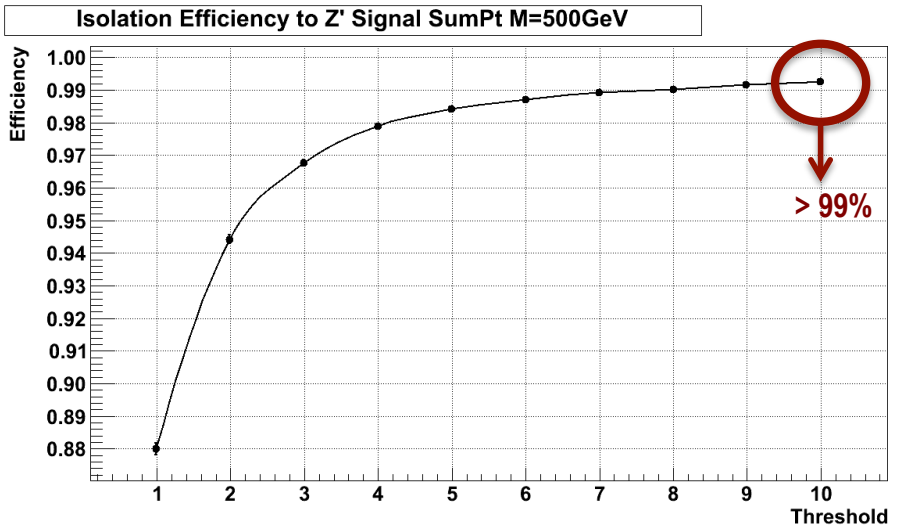
Cuts for at least one muon

Those cuts are inspired to the VBTF selection from EWK group



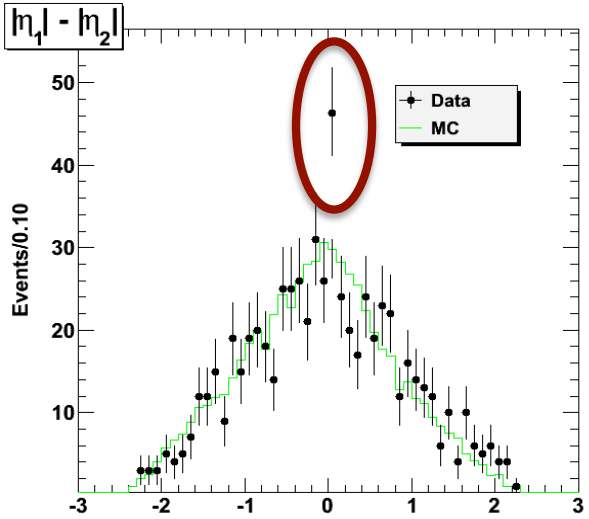


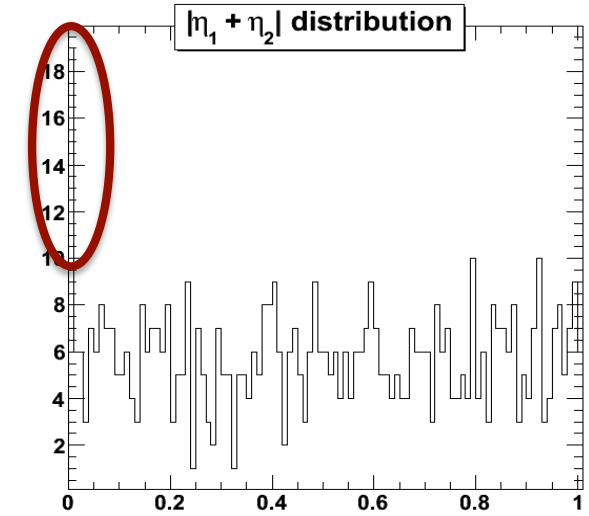




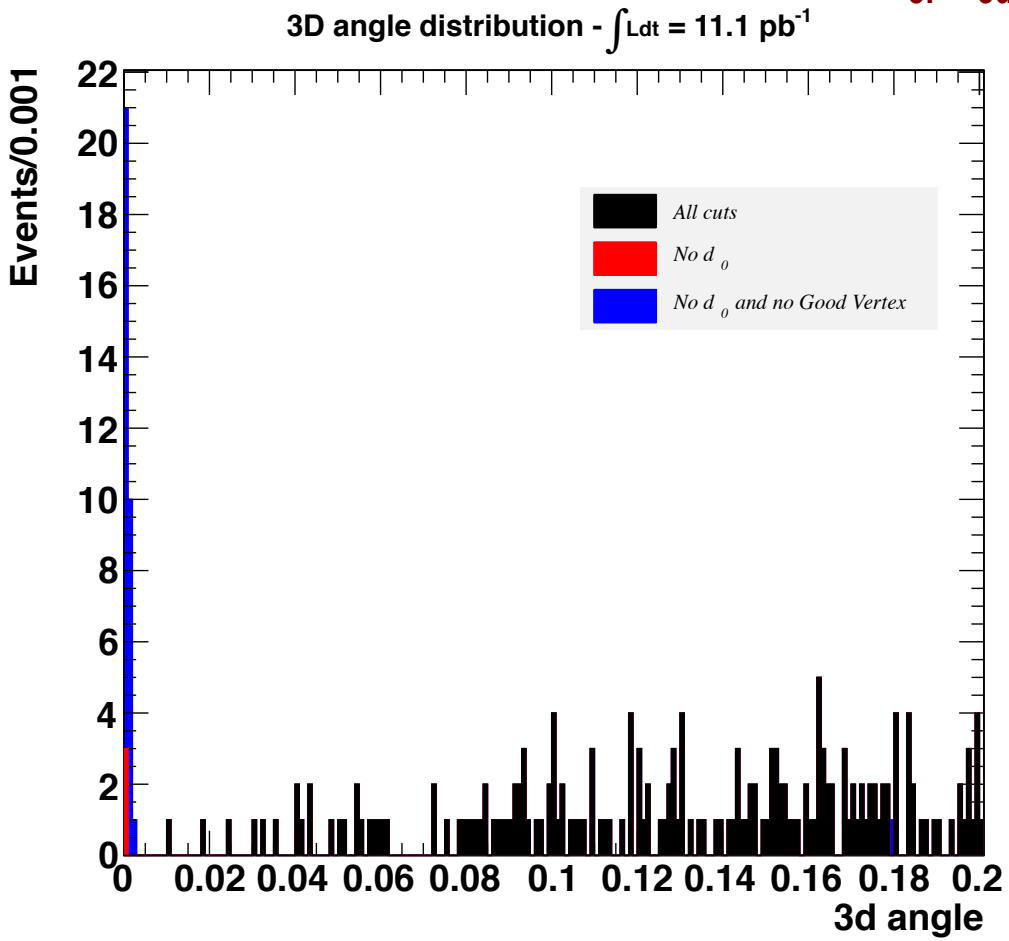
To find the loosest isolation cut reducing the QCD contribution to less than 0.1 in M > 200 GeV/c^2 region for 15pb^{-1}

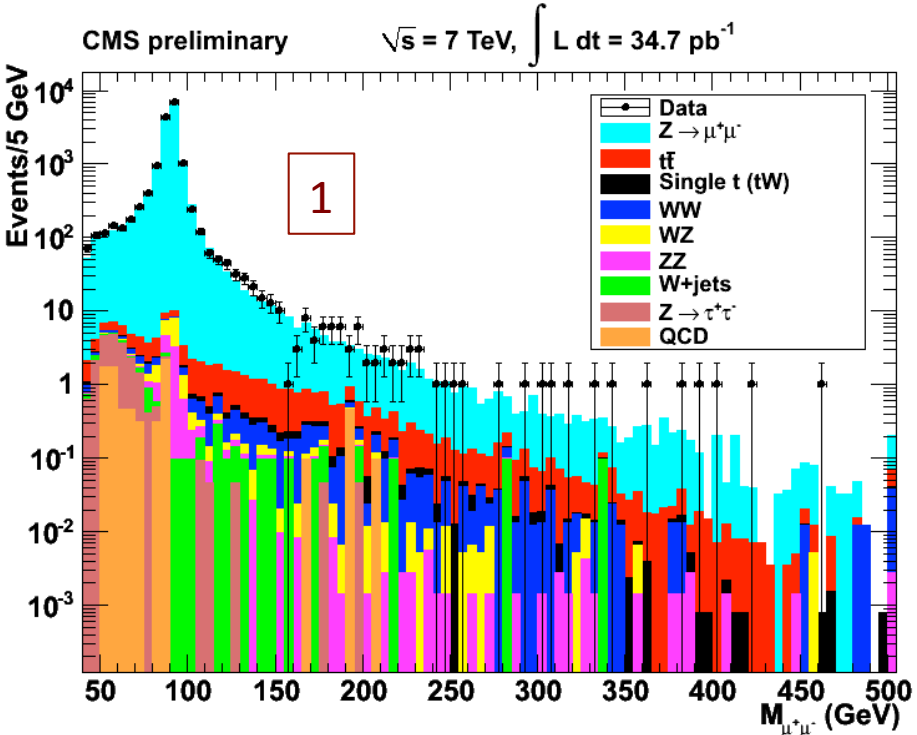
cosmic muons crossing the detector close to the beam can be reconstructed as a $\mu^+\mu^-$ pair

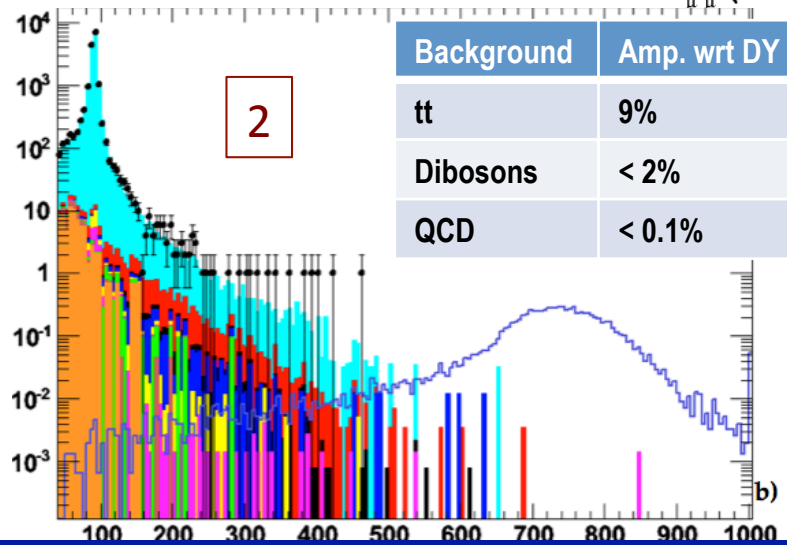




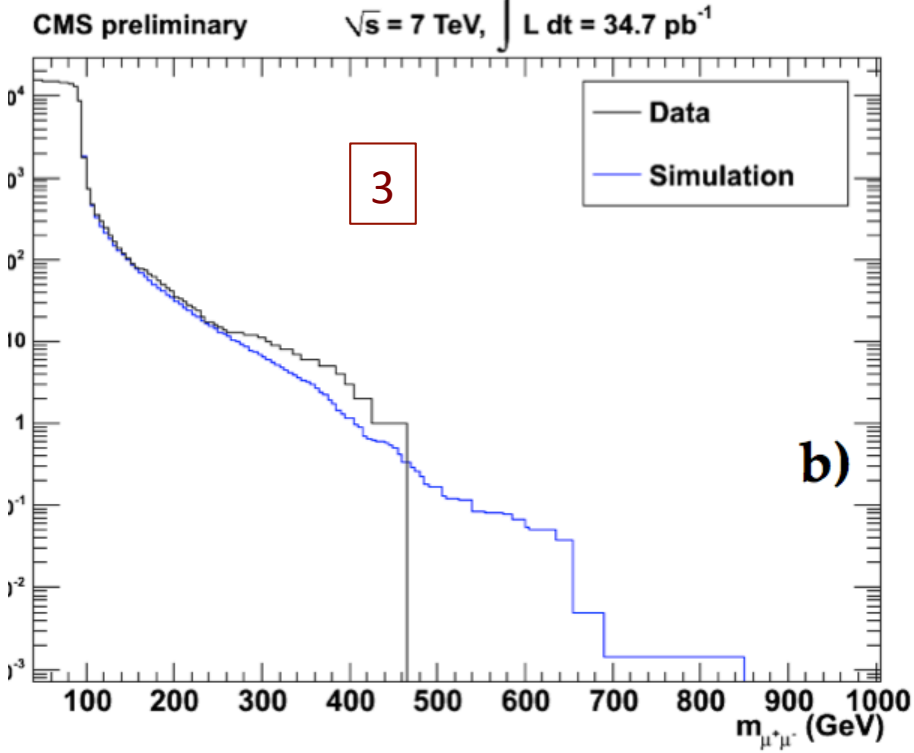
1. Good vertex
2. d_{xy}
3. 3d angle







Background	Amp. wrt DY
tt	9%
Dibosons	< 2%
QCD	< 0.1%



$M_{\mu\mu}$ > 200 GeV/c²

We also used data-driven methods to estimate/cross-check the background rates and shapes:

eμ method for tt, tW, etc…
same sign muons for mis-identified muons
muons matched to jets for QCD
dimuon from cosmic

This is not overview of our systemetics

Our goal is to set a limit on $\frac{\sigma(Z') \times BR(Z' \to \mu^+\mu^-)}{\sigma(Z^0) \times BR(Z^0 \to \mu^+\mu^-)} = \frac{\varepsilon(Z')}{\varepsilon(Z^0)} \times \frac{A(Z')}{A(Z^0)} \times \frac{N(Z')}{N(Z^0)}$

σ^* ε^* from EWK group

systematic uncertanties

We consider uncertainties on the following four quantities (from our side):

1. **efficiency and acceptance**: for efficiency and acceptance product we estimate a systematic uncertainty of 6%.
2. **mass resolution**: we estimate a total uncertainty of 6.3% at 500 GeV and 12.5% at 1 TeV.
    1. momentum resolution: the momentum resolution of high-pT muons is studied with cosmic rays.
    2. misalignment: the presence of distortion modes in the tracker that are not completely constrained by the alignment procedure (**weak modes**).
3. **integrated luminosity**: this is estimated to be 11%.
4. **number of background events expected**: above 200 GeV we estimate an uncertainty of 3% from parton distribution functions, 20% from higher order QCD corrections and 2% to account for shape uncertainties.

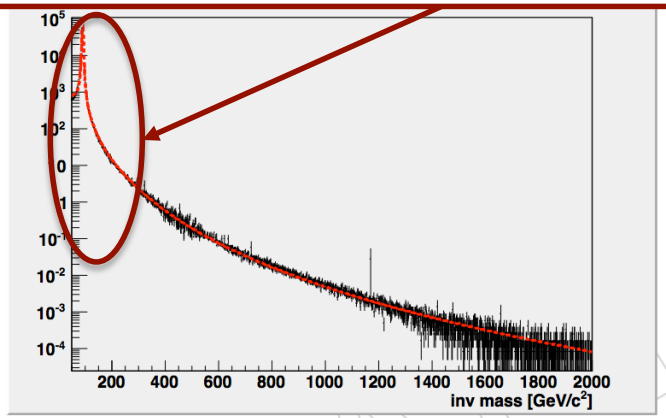
normalization to Z peak: we estimate a 5% overall uncertainty, arising from differing acceptance ratio between low and high dimuon masses for the Z boson and the selection efficiencies

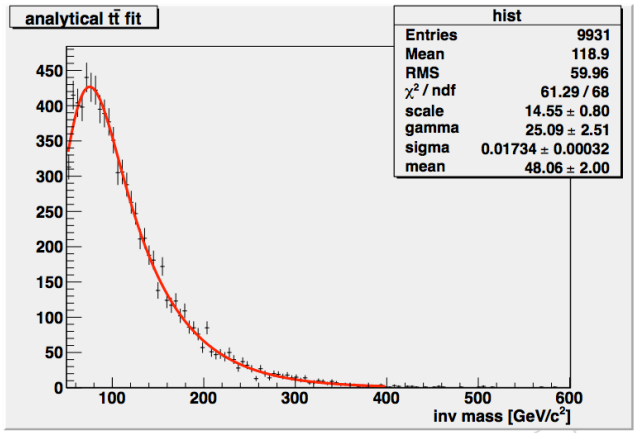
No evidence of resonances → set upper limit: it's based on outcomes of u.l. fits of data in region > 200 GeV/c²

- **Signal** Breit-Wigner convoluted with a Gaussian
- **Background**

$$p_S = \int \frac{A}{\sqrt{2\pi}\sigma} \exp\left(\frac{(m-\mu')^2}{2\sigma^2}\right) \frac{1}{(\mu'^2-\mu^2)^2+\mu^2\sigma_z^2} d\mu'$$

$$p(m \mid \mu,\Gamma,\sigma,\theta)_{POLE} = e^{-\theta m} A\mathrm{Voigt}(m-\mu,\Gamma,\sigma) + e^{-\theta m} B\mu \frac{(m^2-\mu^2)^2}{(m^2-\mu^2)^2+m^2\Gamma^2/\mu^2}$$





m > 200 GeV/c² → $p_{DY}(m \mid \alpha,k) = Ae^{-\alpha m^k}$

$$p_{t\bar{t}}(m \mid \mu,\sigma,\gamma) = G(m \mid \mu,\sigma) \otimes Ae^{-\gamma m}$$

negligible

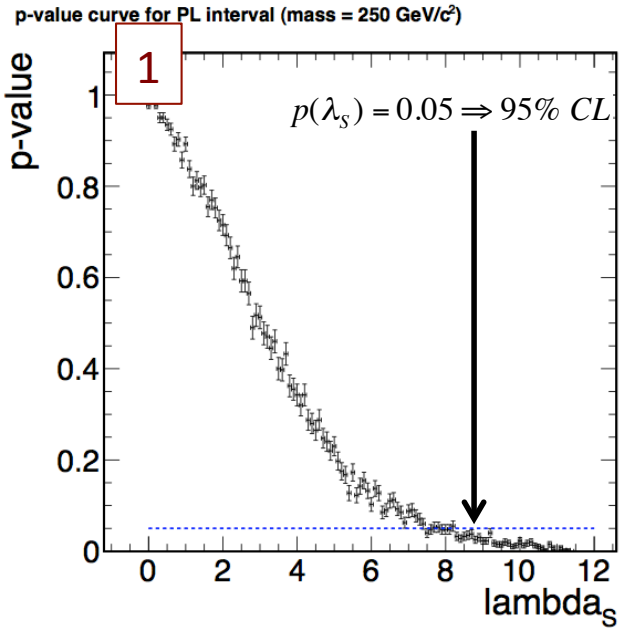
Likelihood

$$L(D \mid \lambda_S,\lambda_B,M) = \frac{(\lambda_S+\lambda_B)^N e^{-(\lambda_S+\lambda_B)}}{N!} \prod_{i=1}^{N}\left(\frac{\lambda_S}{\lambda_S+\lambda_B} p_S(m_i \mid \Gamma,M,w) + \frac{\lambda_B}{\lambda_S+\lambda_B} p_B(m_i \mid \alpha_i,k)\right)$$

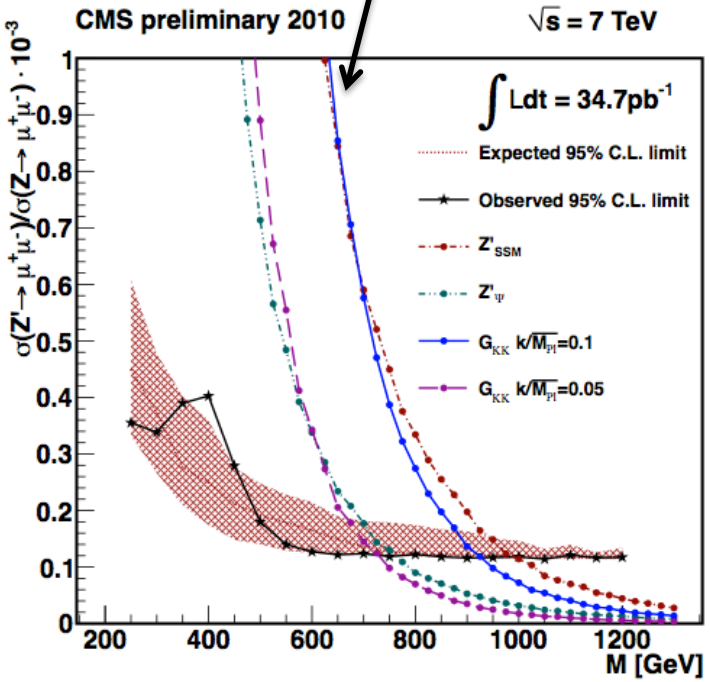
λ_S and λ_B are allowed to float in the fit with all other parameters fixed.

$$\lambda_S = \sigma^* \cdot \varepsilon^* \cdot N(Z^0) \text{ and } t_0 = \log\left(\frac{L(\lambda_S, \lambda_B)}{L(\lambda_S = 0, \lambda_B)}\right)$$

we eliminate the uncertainty from ∫Ldt and the dependence on experimental acceptance, trigger and offline efficiencies.



predicted ratios of cross sections



for every M, we generate toy pseudo experiments incrementing λ_S

$p(t_0^{data} > t_0^{toy})$

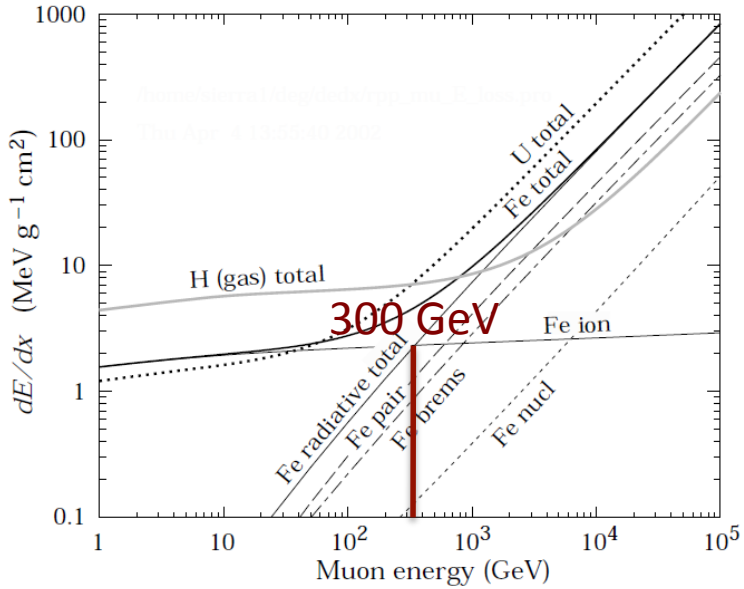
where the $p(\lambda_S)$ crosses $\alpha = 0.05$ → our 95% CL limit.

exclude Z' for all M where σ is larger than our limit.

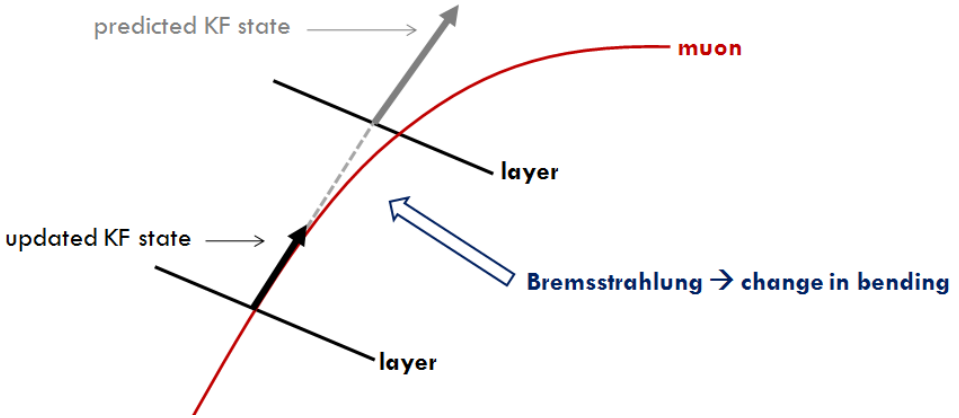
We can exclude Z'_{SSM} below 930 GeV and Z'_{ψ} below 875 GeV
…very close to Tevatron limit…

Improvement of high energy muon reconstruction

For high energy muons the energy loss due to radiative processes is dominant with to respect to ionization



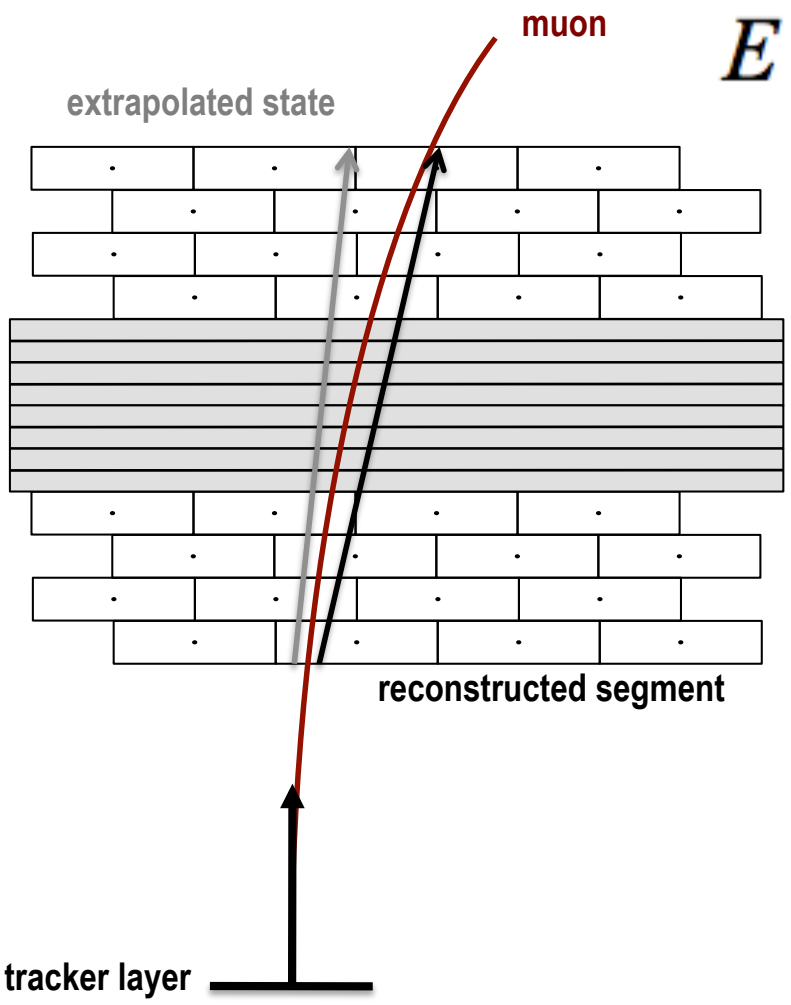
Problem: the Kalman Filter doesn't take into account radiative processes.



In case of muons, large energy losses (due to radiative processes) are likely to happen into calorimeters and iron. So, **reconstruction has to be stopped once a large energy loss is identified**.

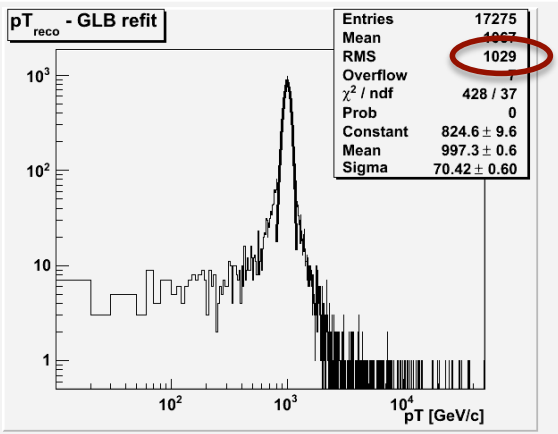
Methods based on shower identification is not effective

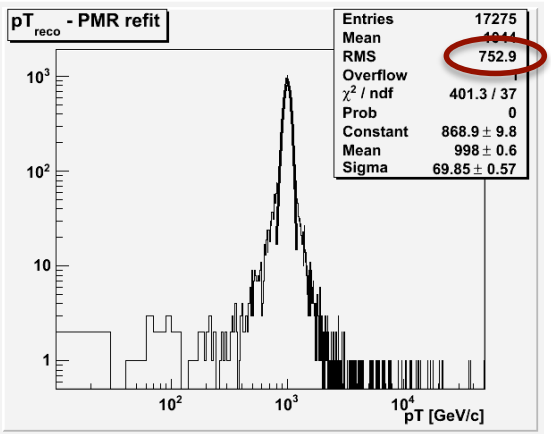
G. Bruno and I developed a new algorithm (called DYT) to recognize large energy loss by macthing the extrapolated track state and the reconstructed segment in the muon chambers.

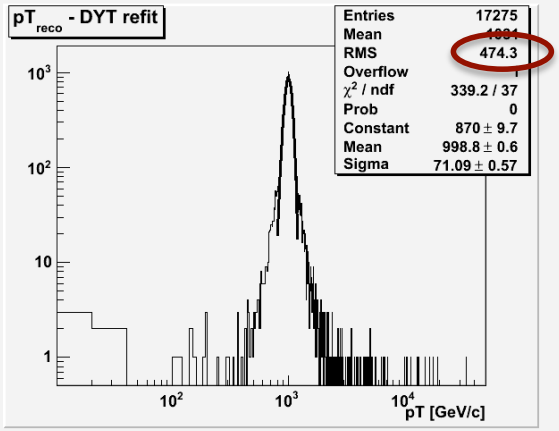


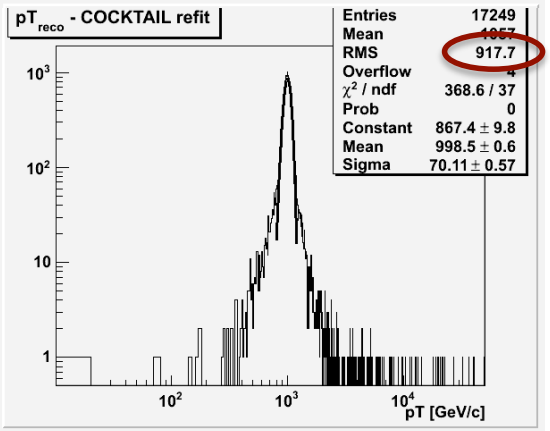
$$E = vMv^T$$

MC single muons pT 1 TeV/c





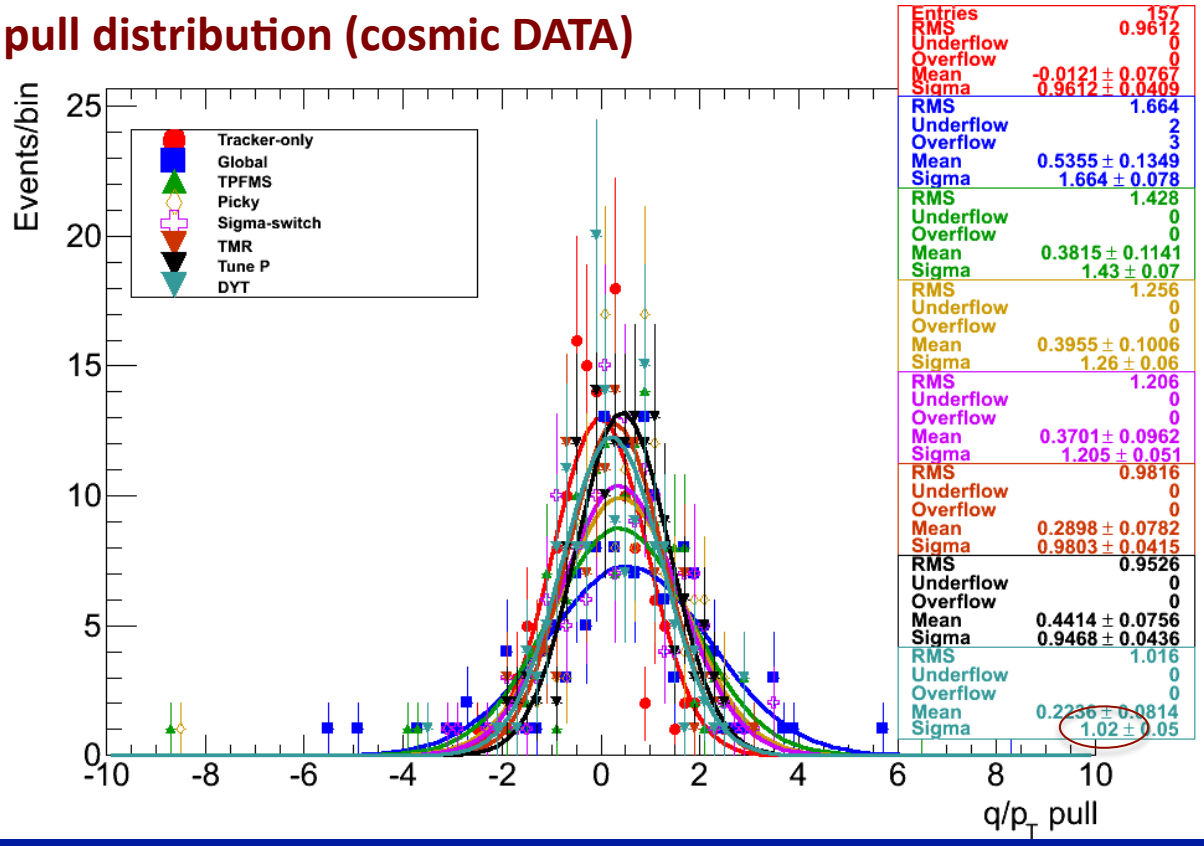




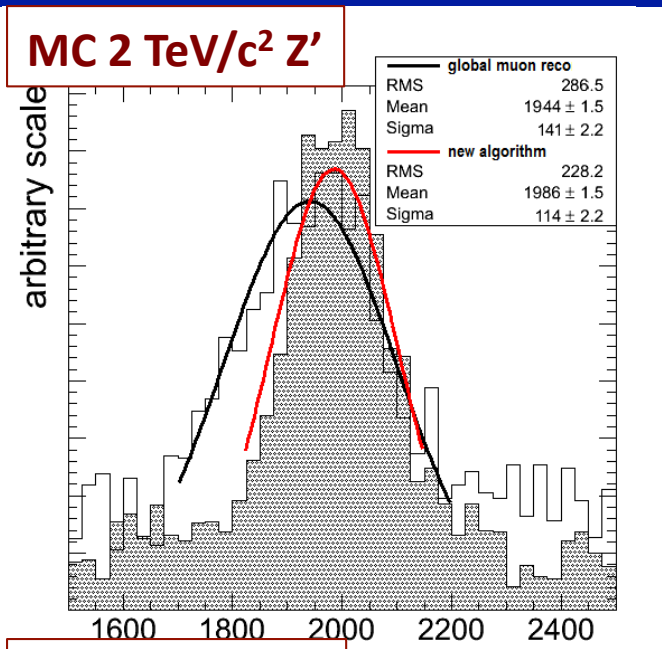
The DYT is planned to be used from 2011 in exotica analysis (when the new muon misalignment scenario will be available):

in case of misalignment the matrix M must misalignment information

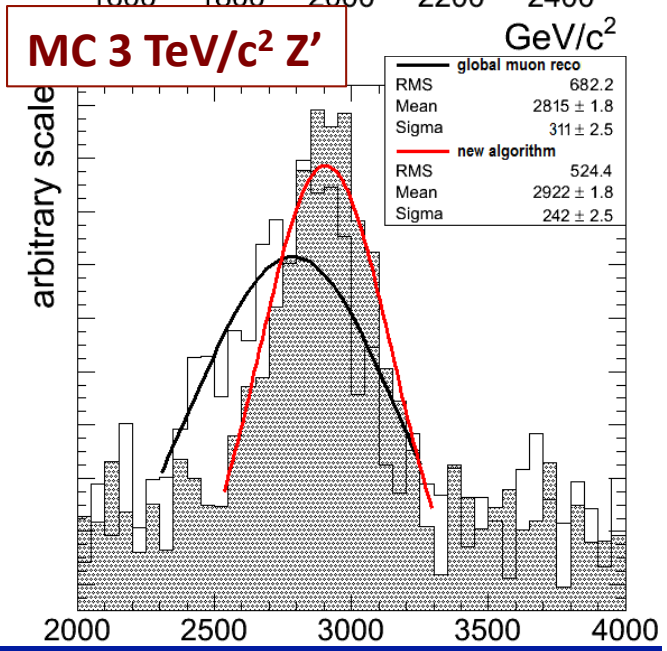
pull distribution (cosmic DATA)



MC 2 TeV/c² Z'



MC 3 TeV/c² Z'



• We have analyzed 35 pb^{-1} → no evidence of high mass resonances

• We set a limit on the ratio of production cross sections between the Z' and and Z_0 bosons for two Z' mass scenarios. …we plan to include other models…

• Here I showed the limit for the most optimistic model of Z' production (predicting the Z'_{SSM} boson) and for the narrower Z'_{ψ} from E_6:

we exclude Z'_{SSM} masses less than 930 GeV/c^2 and Z'_{ψ} less than 875 GeV/c^2

…so we're already getting very close to the Tevatron limits…

• It was shown (using data and MC) that DYT has a remarkable impact on high energy muon reconstruction and it also is expected to improve the mass reconstruction of high mass Z' in case of discovery.

For this reasons the Exotica Z'→μμ group
has planned to use the DYT in the search from 2011.
…also the W' group is interested…