7 June '06

# Sensitivity of the muon isolation cut efficiency to the underlying event uncertainties

Salavat Abdullin (FNAL)
Darin Acosta (UF)
Paolo Bartalini (UF)
Rick Cavanaugh (UF)
Alexey Drozdetskiy (UF)
Andrey Korytov (UF)
Guenakh Mitselmakher (UF)
Yuriy Pakhotin (UF)
Bobby Scurlock (UF)
Alexander Sherstnev (Cambridge)

Corresponding paper:

- CMS Note 2006/033
- CERN server: link

# Introduction

- ▷ isolation cut (ISOL) plays the key role
  - ▷ suppressing tt, Zbb
- ▷ ISOL affects signal and ZZ-bckg as well
  - ▷ need to know ISOL efficiency well
- ▷ Two questions to be answered

1. How well can we predict the isolation cut efficiency using the current Monte Carlo generators?
2. Can we measure the isolation cut efficiency using the experimental data themselves and, if yes, would the associated experimental systematic errors be smaller than the Monte Carlo based theoretical uncertainties?

- ▷ Tracker based ISOL is used
- ▷ Results may be of general interest

- ▷ UE (CMS Note 2005/013): *is all the remnant activity from the same proton-proton interaction*

# Technicalities

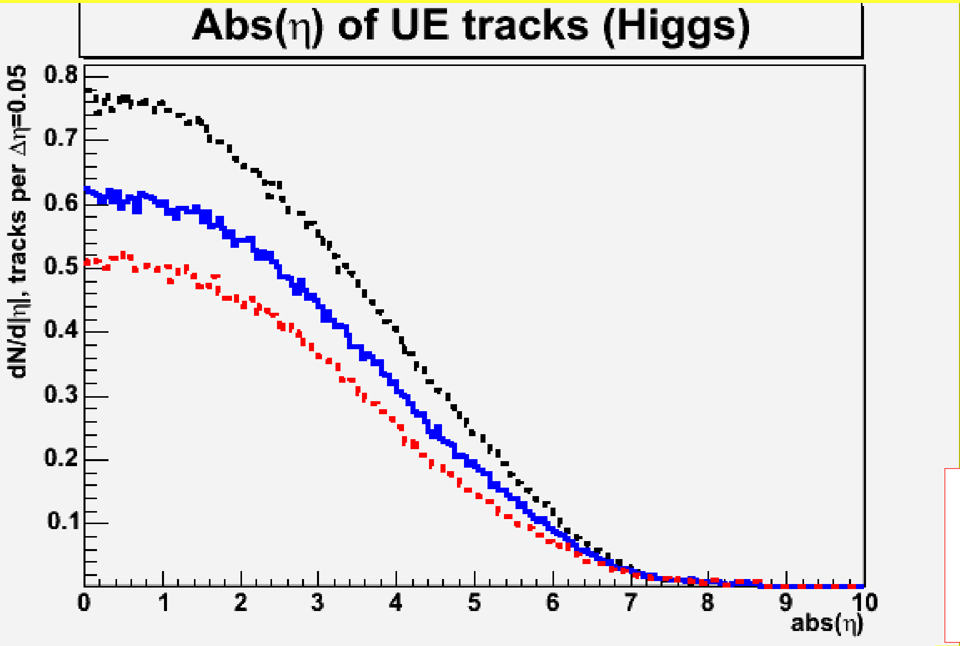
- DC04/05 parameters used
  - for UE $PT_{cut\text{-}off}$ a special set of parameters and their variations used (see the Note and referenced there 2005/013 CMS Note as well)
  - In PYTHIA: $PT_{cut\_off}$ = PARP(82)*(14000/PARP(89))$^{PARP(90)}$
    - we use PARP(89) = 14000
    - PARP(82) = 2.9 → $PT_{cut\_off}$ = 2.9 GeV – default scenario
    - PARP(82) = 2.4 → $PT_{cut\_off}$ = 2.4 GeV – pessimistic scenario (-3σ)
    - PARP(82) = 3.4 → $PT_{cut\_off}$ = 3.4 GeV – optimistic scenario (+3σ)
  - Difference in $PT_{cut\_off}$ values 0.5 GeV is about 3σ of corresponding variation of the parameter (tuned and extrapolated from data)
    - for more details look at CERN Yellow report 2000/004
- Samples used in analysis
  - signal ($M_H$=150 GeV), tt, ZZ, Z-inclusive
  - to increase selection efficiency an additional cut PT>7 GeV for at least 4 muons was used at generator pre-selection level (for signal and tt)

# Conditions. Cuts.

## ▷ Details

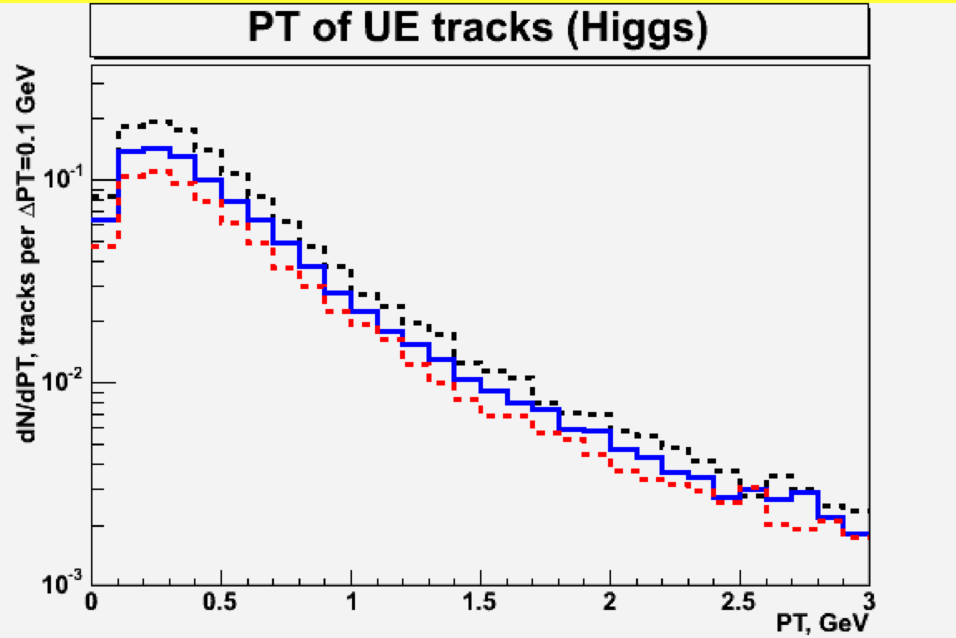
- ▷ 'Good muon' cuts applied for efficiency 'per muon'
  - ▷ pt>7 in barrel, P>9 in endcap ($|\eta|$=1.1 – is a border)
- ▷ A la full simulation analysis cuts applied for efficiency 'per muon' for mh150 signal
  - ▷ in addition to 'good muon' cuts
  - ▷ cuts on 4 selected muons PT>10 GeV
  - ▷ inv. masses of $\mu+\mu-$ pairs > 12 GeV (for all permutations)
  - ▷ $110 < m_H < 700$
  - ▷ a la tracker isolation cuts: 0, 0, 1, 2 GeV (on four selected muons, sorted by ISOL parameter)
  - ▷ no IP parameter cuts
- ▷ Isolation parameter is a sum of PT of tracks inside cone dR
  - ▷ dR($\eta$,$\varphi$) cone size = 0.3
  - ▷ PT of considered tracks in a cone > 0.8 GeV (default in ORCA)
  - ▷ muons are excluded from isolation parameter calculation

# Tracks multiplicity



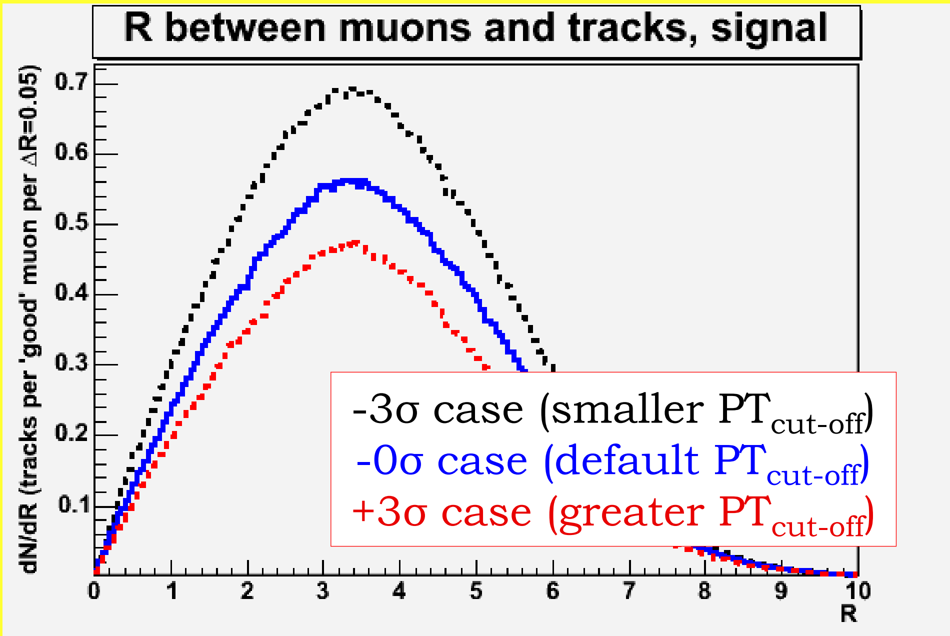

multiplicity changed

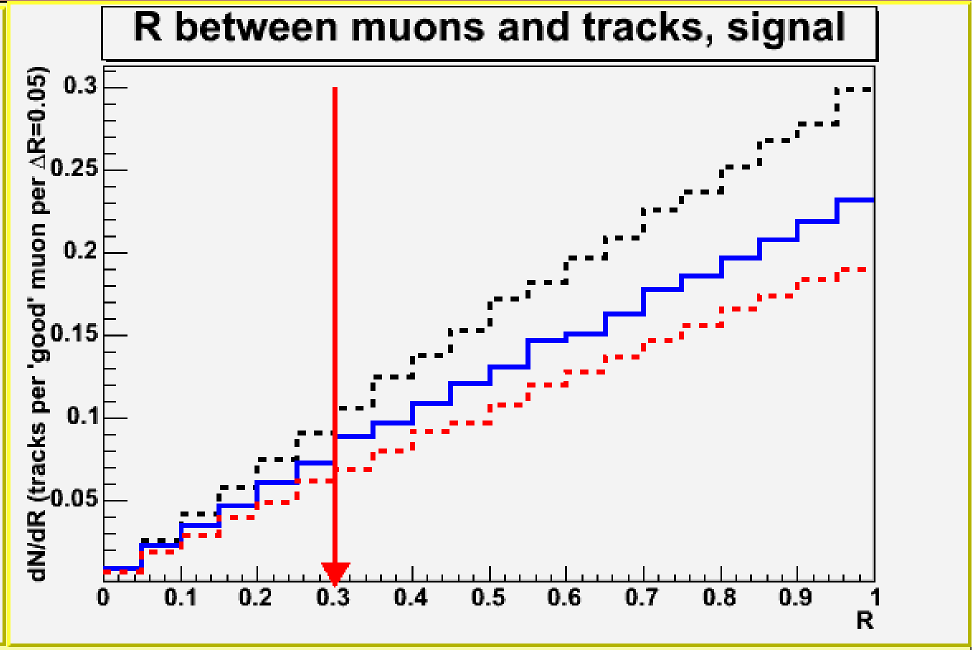
-3σ case (smaller $PT_{cut-off}$)
-0σ case (default $PT_{cut-off}$)
+3σ case (greater $PT_{cut-off}$)

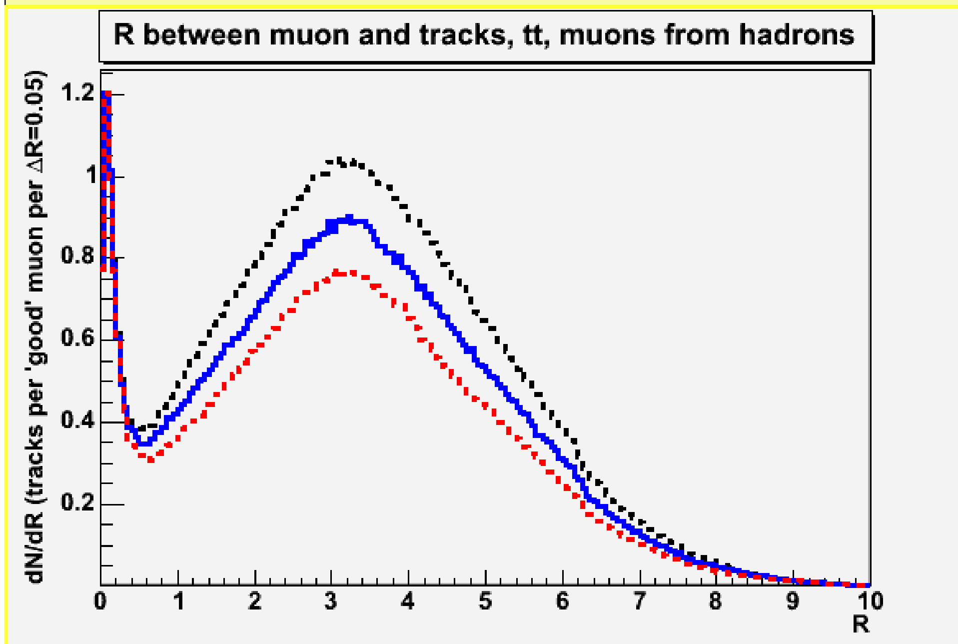


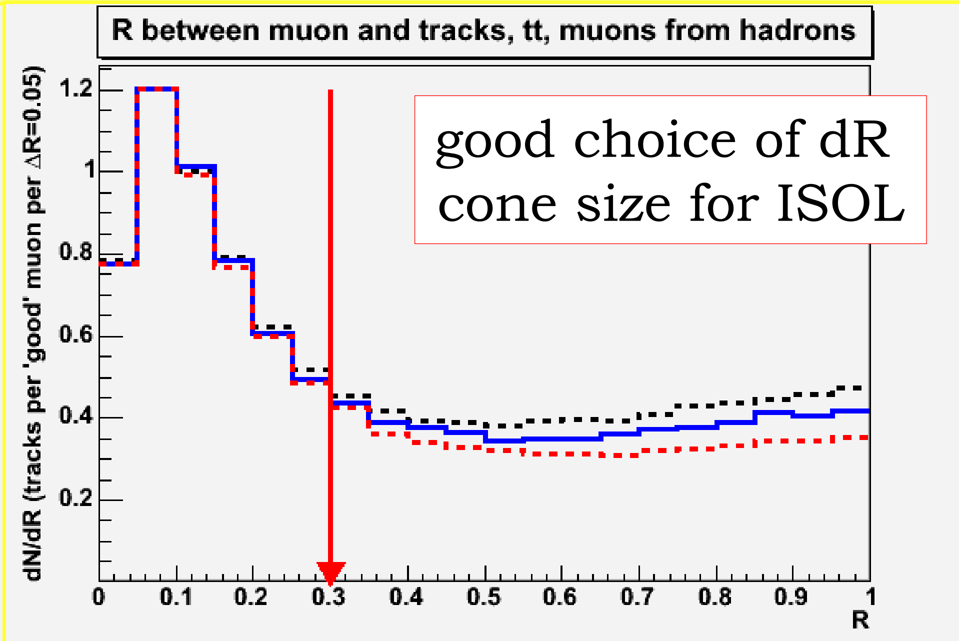

PT spectrum unchanged

# dR distributions (multiplicity and cone size)

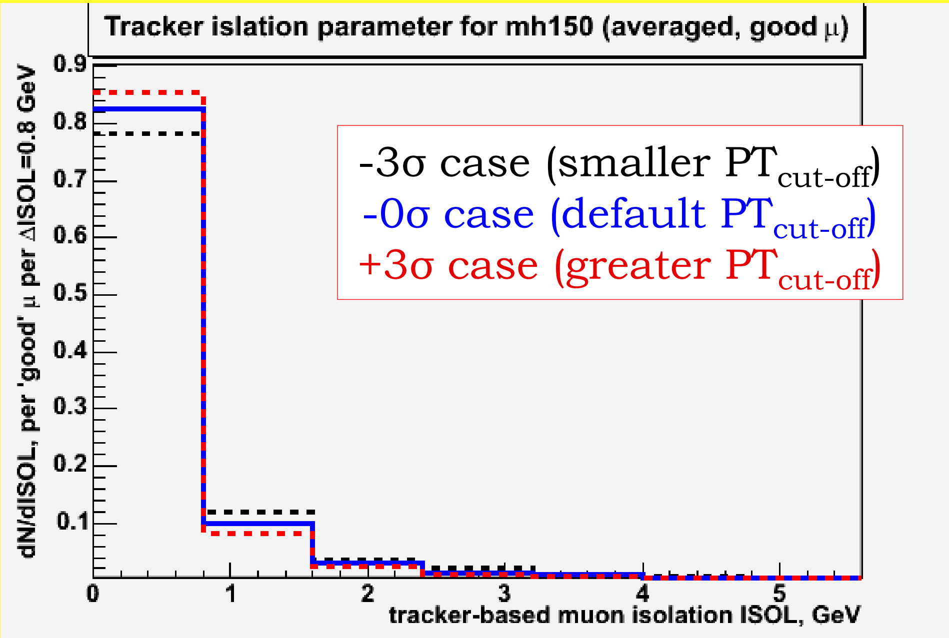


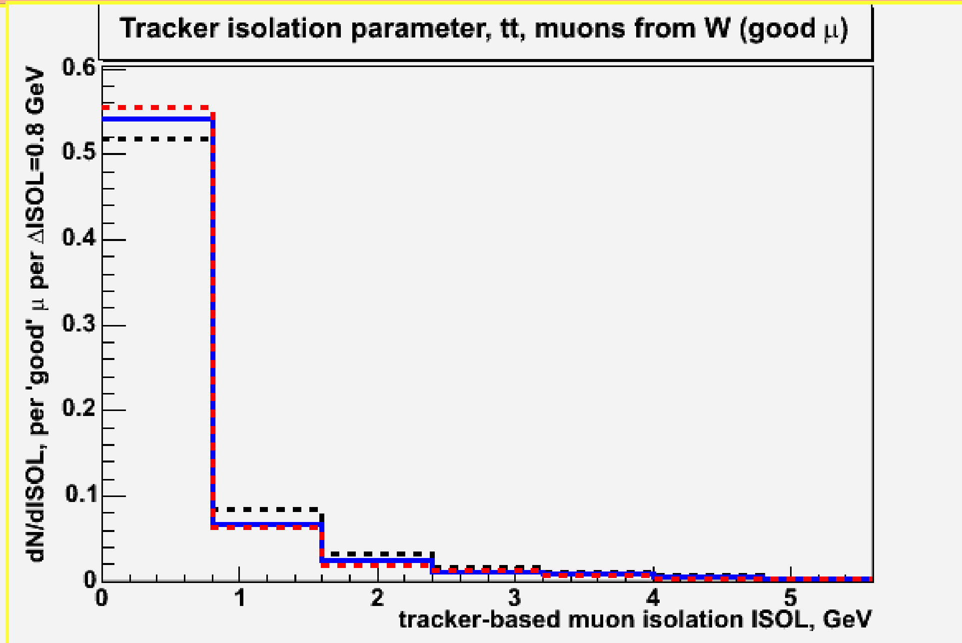



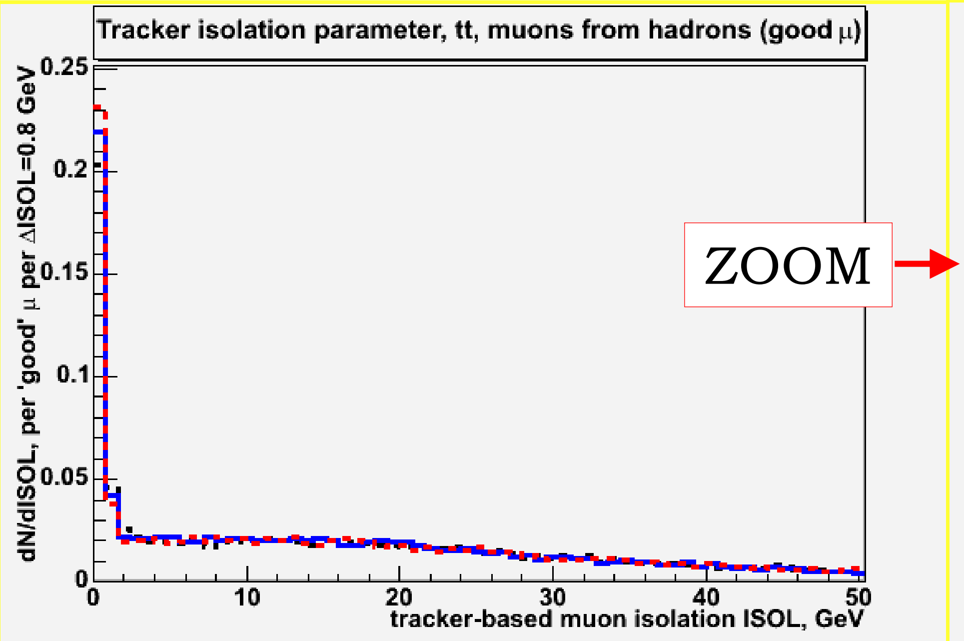



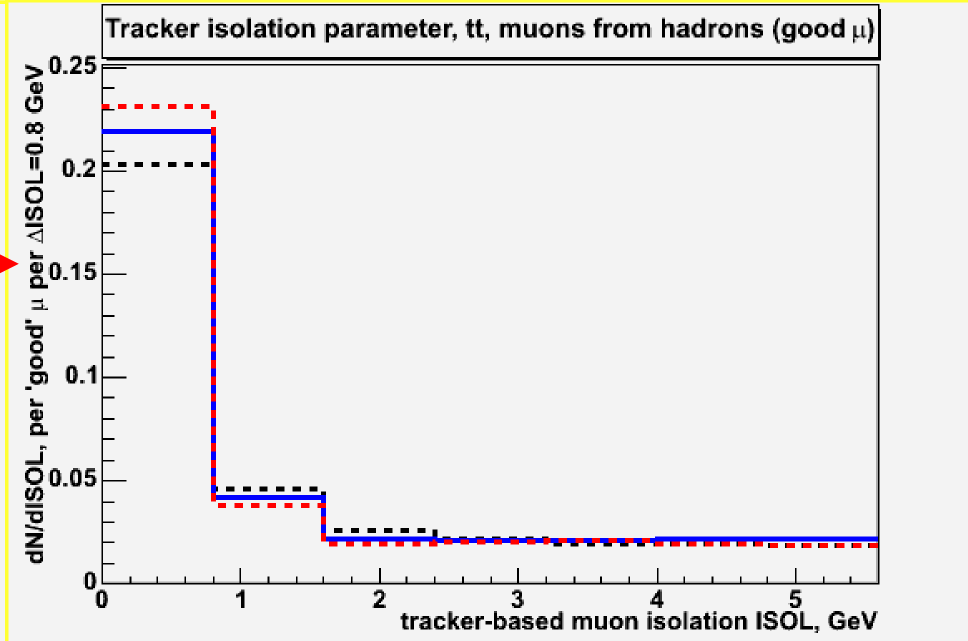



# ISOL and its variations



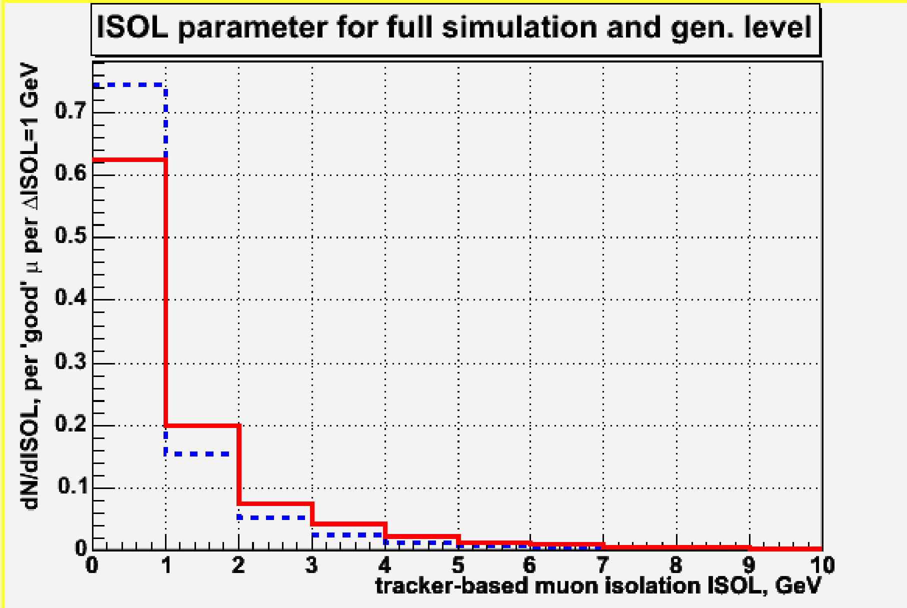



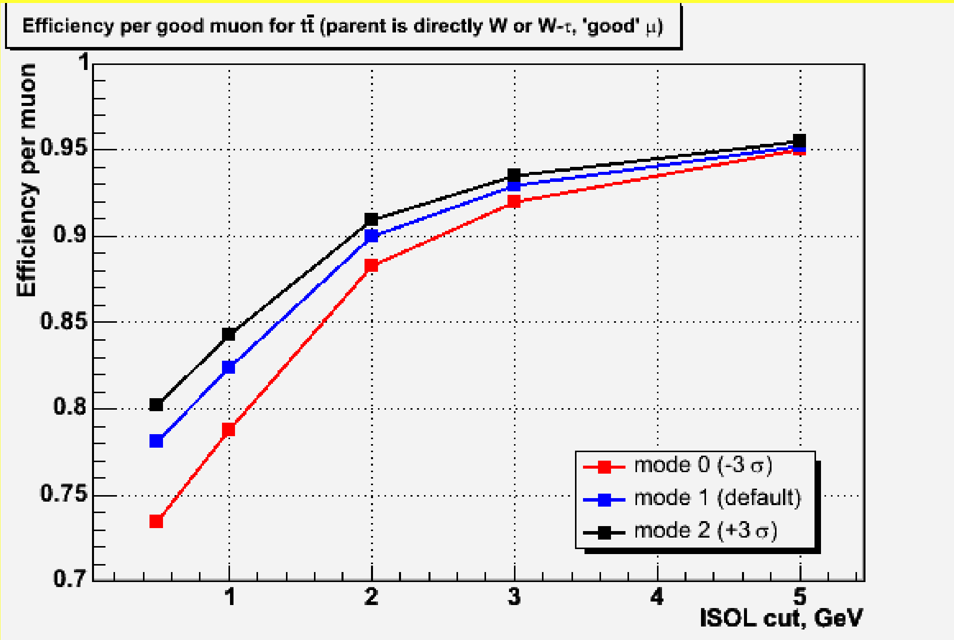
# Full simulation and gen. level comparison

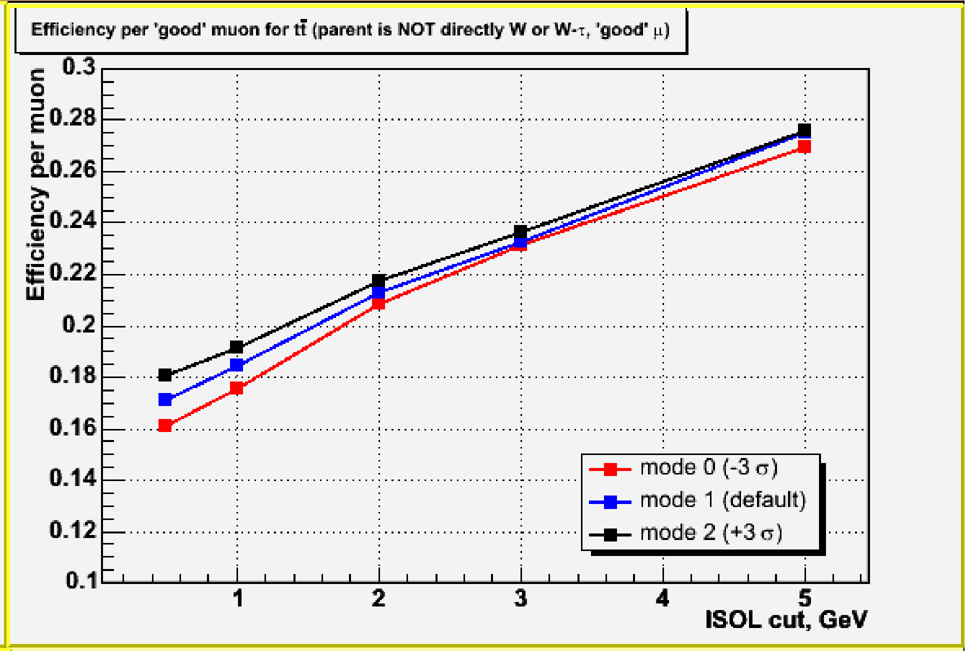
- Comparison of the tracker isolation parameter distributions
  - full detector simulation (blue)
    - $m_H = 150$ signal sample
  - this generator level study (red)
    - $m_H = 150$ signal sample
  - default UE simulation settings

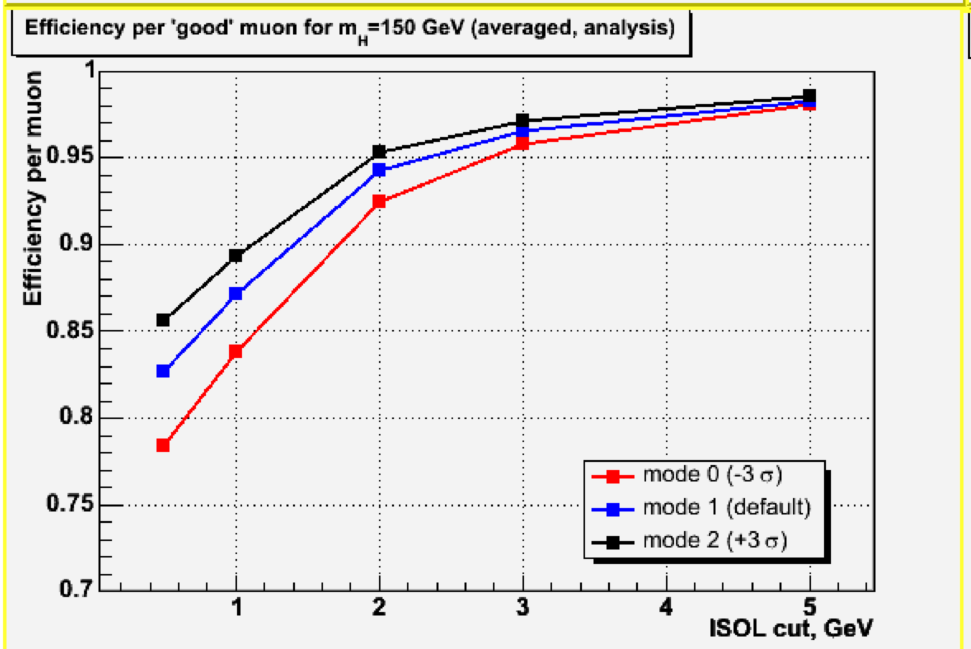


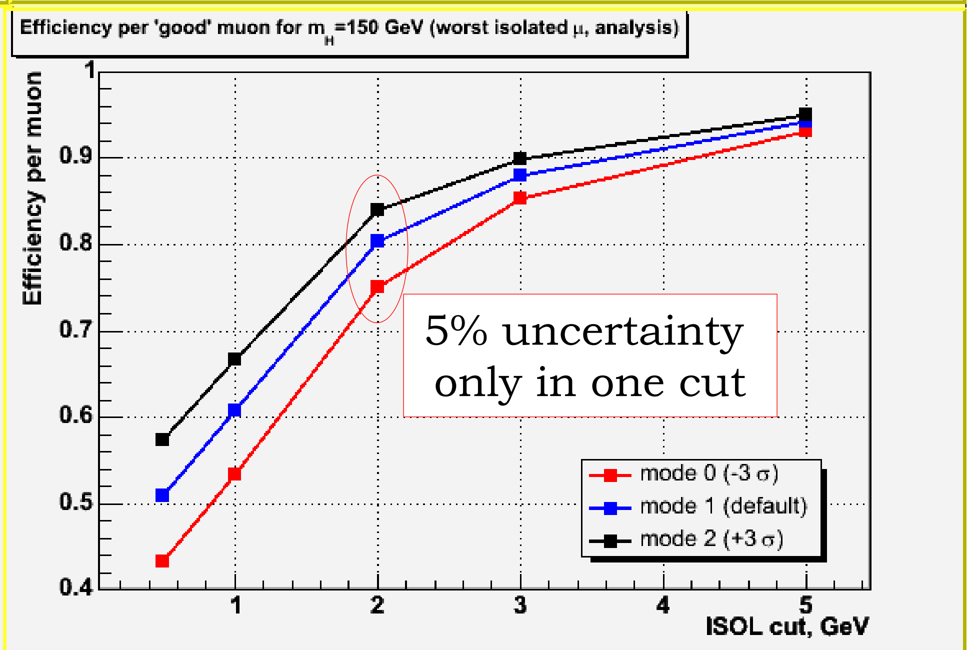

- Plus final event selection efficiencies (analysis cuts):
  - about 23% in the full simulation analysis
  - about 21% in these generator level studies

# ISOL cut efficiencies. Prediction uncertainties.

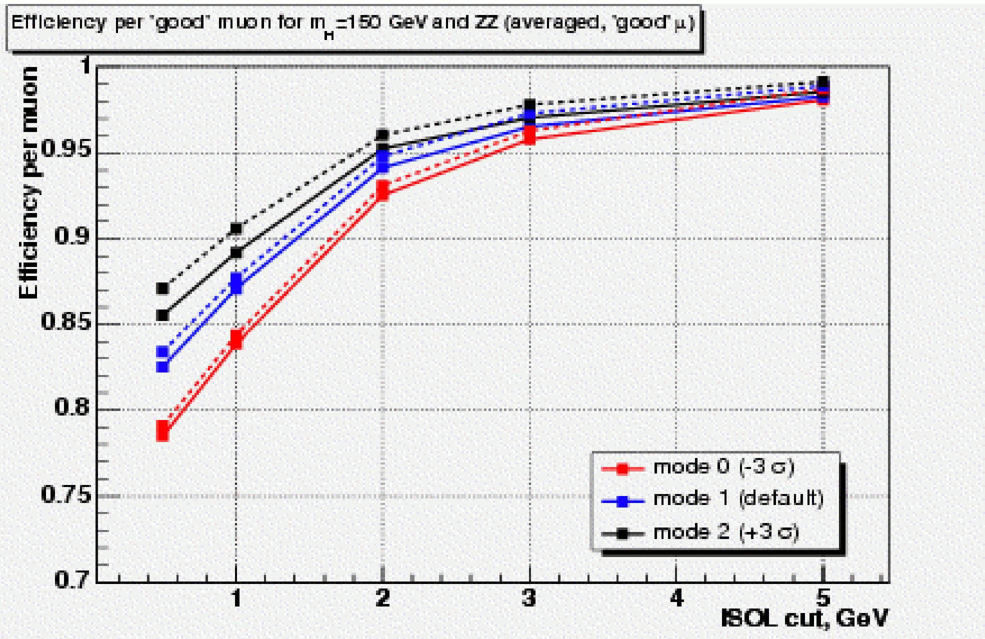


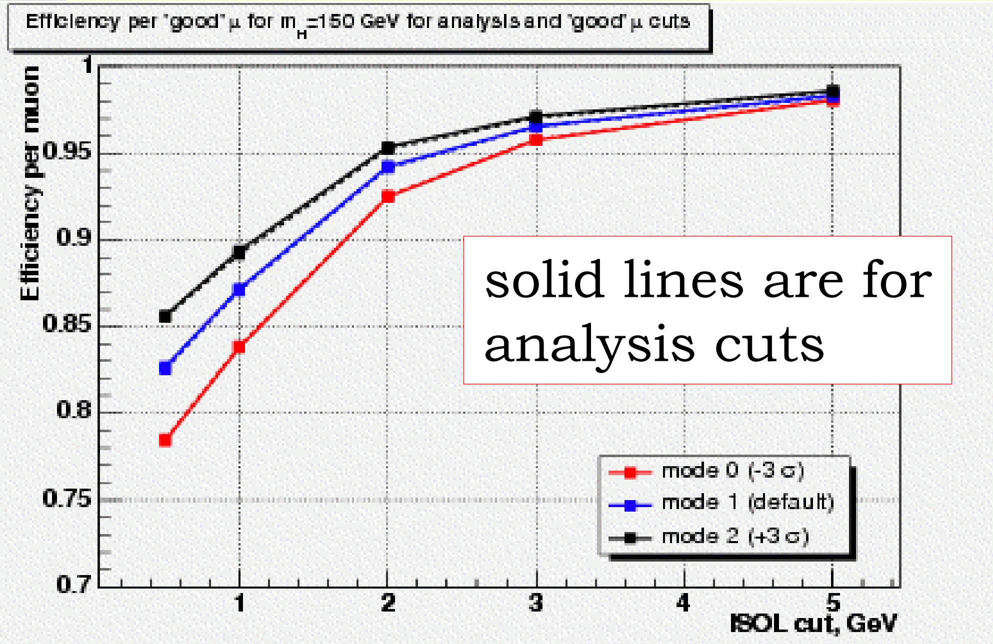



# ISOL cut efficiencies. Prediction uncertainties. (2)




Results for ZZ-background and signal are similar (dashed lines – for ZZ)

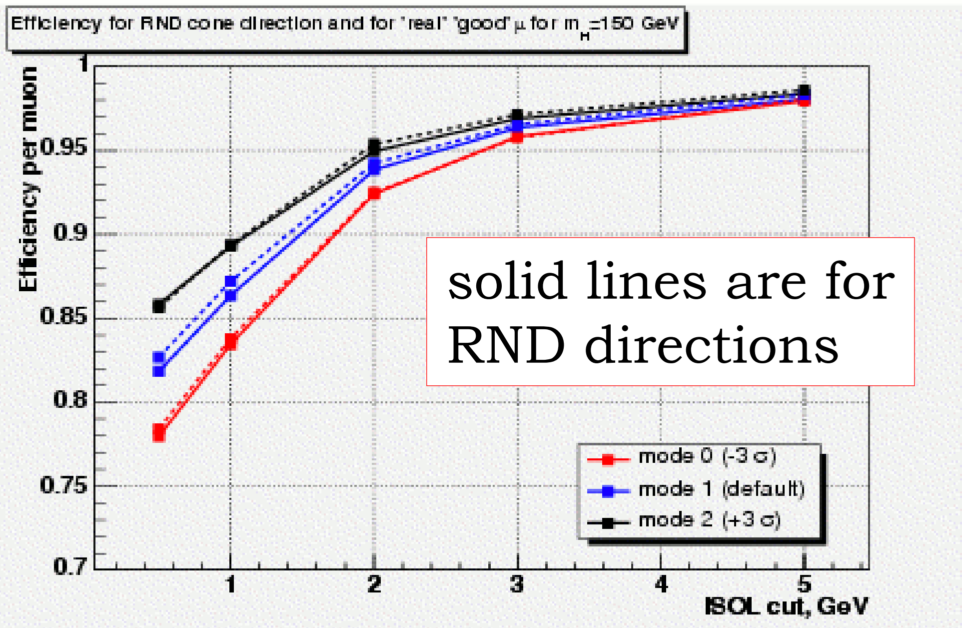


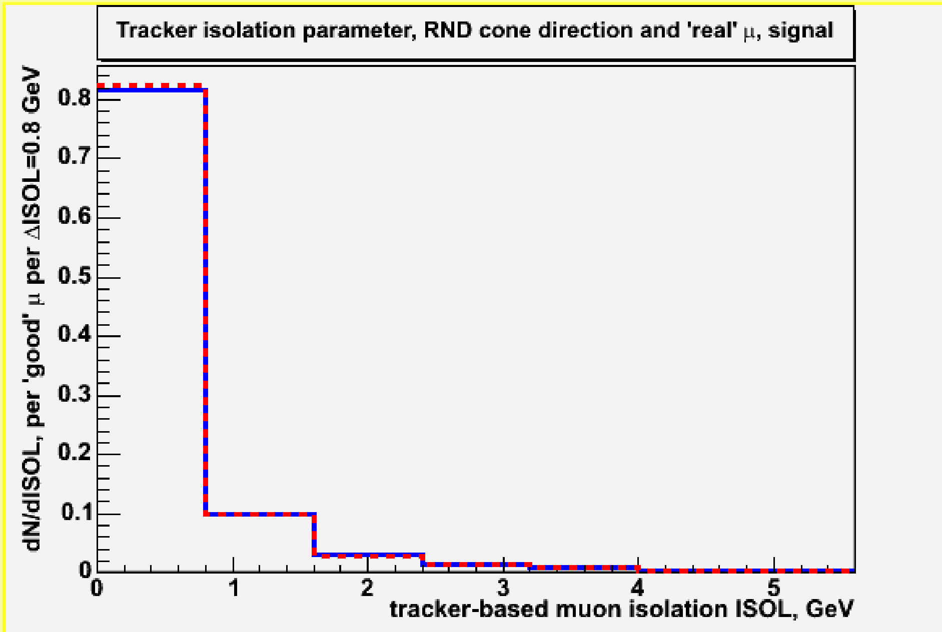

solid lines are for analysis cuts

Up to the statistical precision there is no difference for efficiencies before and after analysis cuts

# ISOL efficiency from data.

## ▷ Idea is to use Random cone direction.



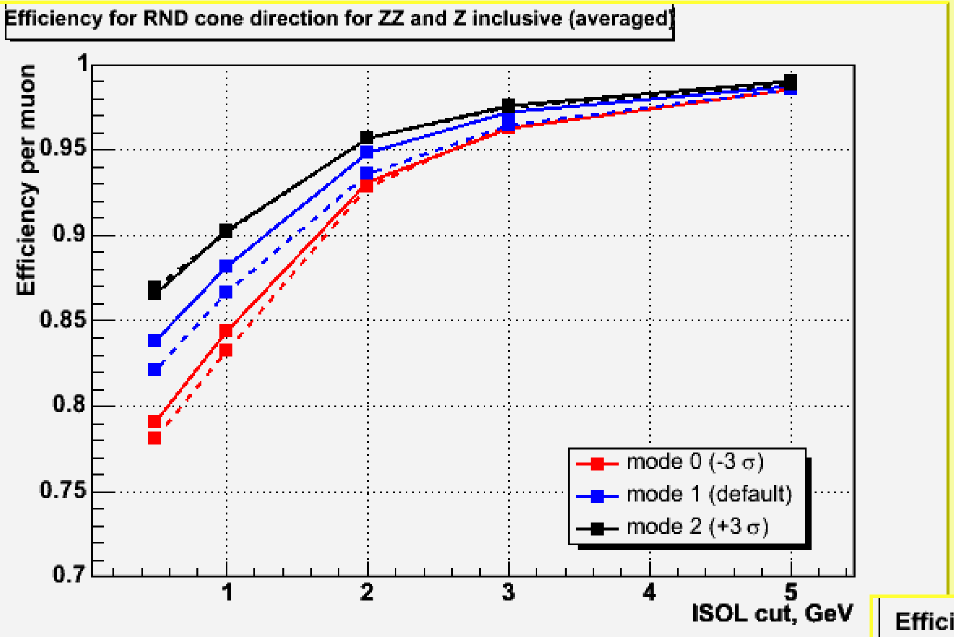

Random cone direction: all the calculations for ISOL efficiency done for uniformly distributed random directions in event instead of directions for 'real' (MC) muons.

can measure the isolation cut efficiency by using some distinct reference data sample and applying the random cone technique

- big cross section
- similar UE structure as ZZ/signal
- relatively clean from backgrounds

→ trying Z-inclusive sample

# ISOL efficiency from data. (2)




Very close to ZZ "real" μ (dashed – Z-inclusive)

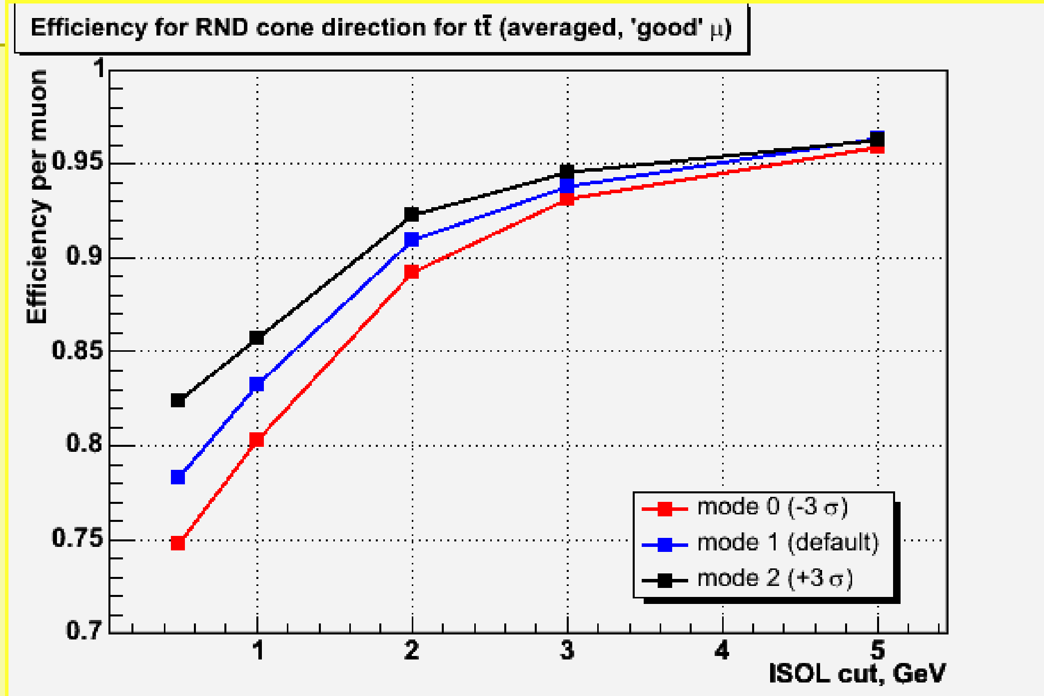



Illustration (not every sample is suitable): tt is too different.

# ISOL efficiency from data. (3) Efficiency per event.

| process/case | efficiency (default) | efficiency ($-3\sigma$) | efficiency ($+3\sigma$) |
|---|---|---|---|
| signal, $m_H = 150$ GeV | $0.775 \pm 0.004$ | $0.707 \pm 0.005$ | $0.812 \pm 0.004$ |
| $ZZ$ background | $0.780 \pm 0.004$ | $0.721 \pm 0.005$ | $0.838 \pm 0.004$ |
| 4 RND muons, Z-inclusive events | $0.762 \pm 0.007$ | $0.706 \pm 0.007$ | $0.821 \pm 0.006$ |
| $t\bar{t}$ background | $0.016 \pm 0.001$ | $0.013 \pm 0.001$ | $0.015 \pm 0.001$ |

- ▷ numbers for Signal, ZZ and Z-inclusive samples are in agreement with each other for all the three different tested UE scenarios
- ▷ range of efficiencies for the ZZ spans from ~0.72 to ~0.84
  - ▷ prediction uncertainties!!! (from theoretical uncertainties in the UE physics)
- ▷ from data: shift is ~2% and not dependant on UE scenario
  - ▷ smaller than other known uncertainties

# Summary

- ISOL per muon due to uncertainties in the UE models can vary as much as 5%
  - the efficiency itself and the uncertainty strongly depend on how tight the ISOL cut is
- The 4-muon isolation cut efficiency per event for ZZ ~78±6%
- Elimination of these large uncertainties
  - calibration the isolation cut efficiency from data using Z-inclusive events with the random cone technique
    - eliminates uncertainties associated with the poor understanding of the UE physics
    - might be ~2% systematic shift in the 4-muon isolation cut efficiencies obtained this way, already very small
- The results and described techniques in this note may be of interest for all analyses relying on lepton isolation cuts.
- We would like to thank: *CIEMAT group, T.Ferguson, U.Gasparini, N.Neumeister, M.Konecki, A.Nikitenko, F.Palla, I.Vorobiev* for useful discussions.