extension muon performance for (H->)ZZ->4l

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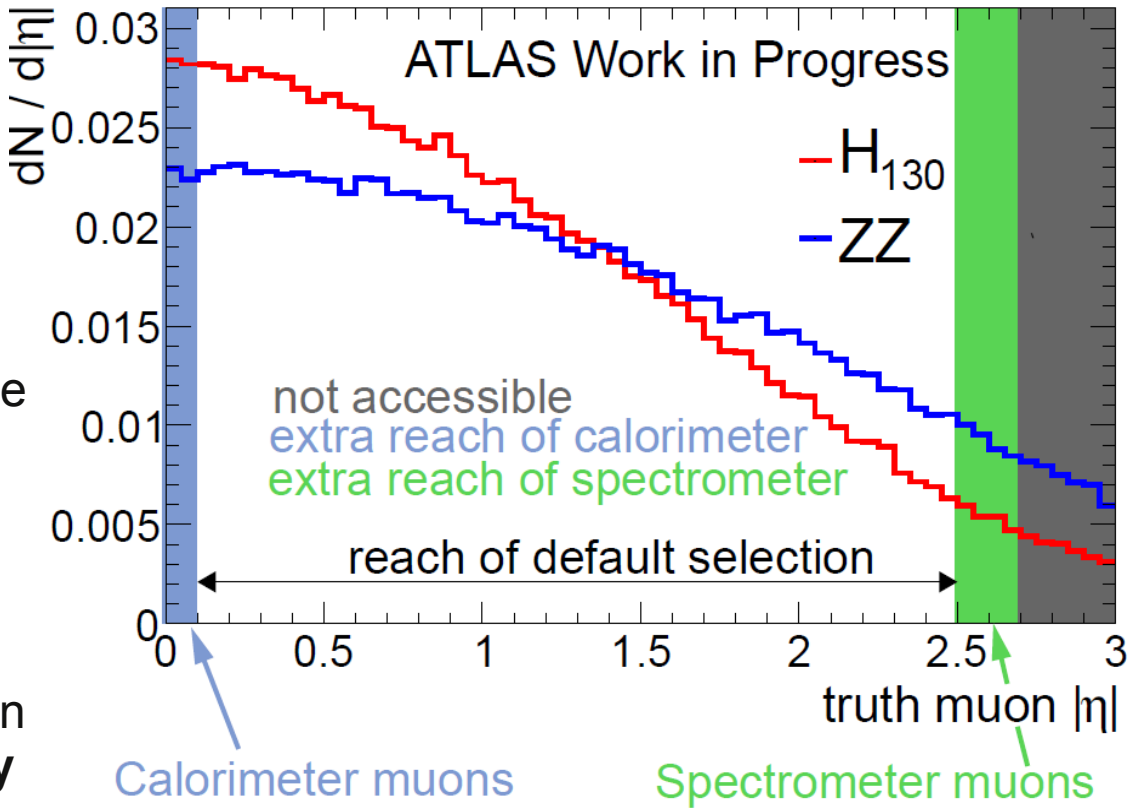
MPI Higgs informal meeting

12.07.2011

REMINDER: Extension muons for the ZZ analyses

Interesting because

4 leptons in the final state mean ε^4 **dependency** on lepton reconstruction efficiency!



•Combined muons: highly efficient if we have them, but...

- |η| ~0: MS acceptance hole (instrumentation)
- |η| > 2.5: no ID coverage
  - ➔ **no combined muons there**
- fall back on other reconstruction types in these regions to **recover the efficiency loss**
  - Calorimeter muons in the centre
    - tag ID tracks as muons using the Calorimeter
  - Standalone muons in the forward region
    - rely on the MS reconstruction

➔ need **careful performance studies**

- convince physics conveners that we can work with only half the usual detector in these regions...
- H->ZZ$^{(*)}$->4l, SM ZZ->4l have expressed interest

Status of the extension Muons

- **Smearing functions** and **Scale factors** provided by MCP for both types

- **Selection criteria** for both found for physics analyses
  - use combination of ID track quality and calo muon tagger output for the Calos, add relative Etcone20
  - EtCone < 6 GeV and high pt for the standalones

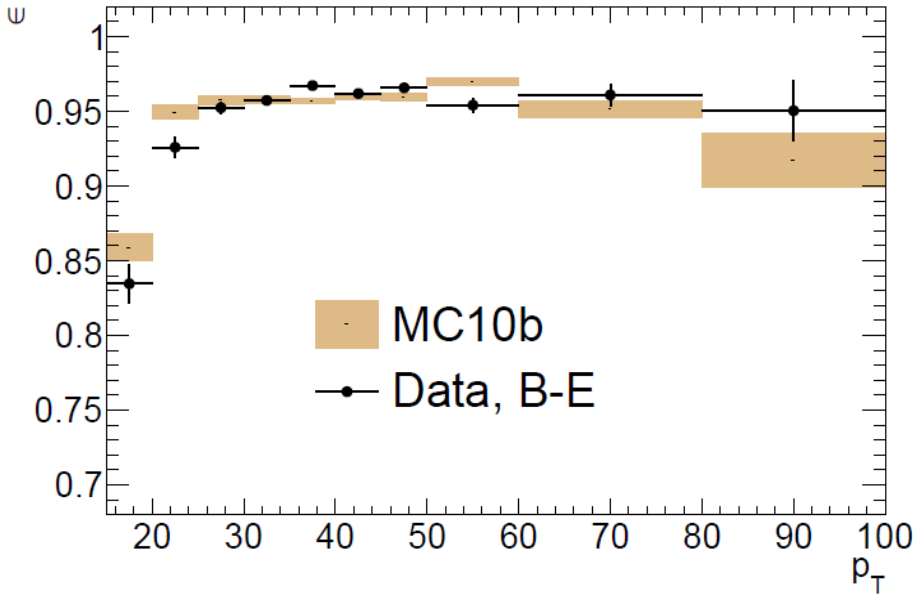
- now, more or less **ready for use**
  - plan: include them for the LPC ZZ->4l CONF note if time permits
  - perform final studies

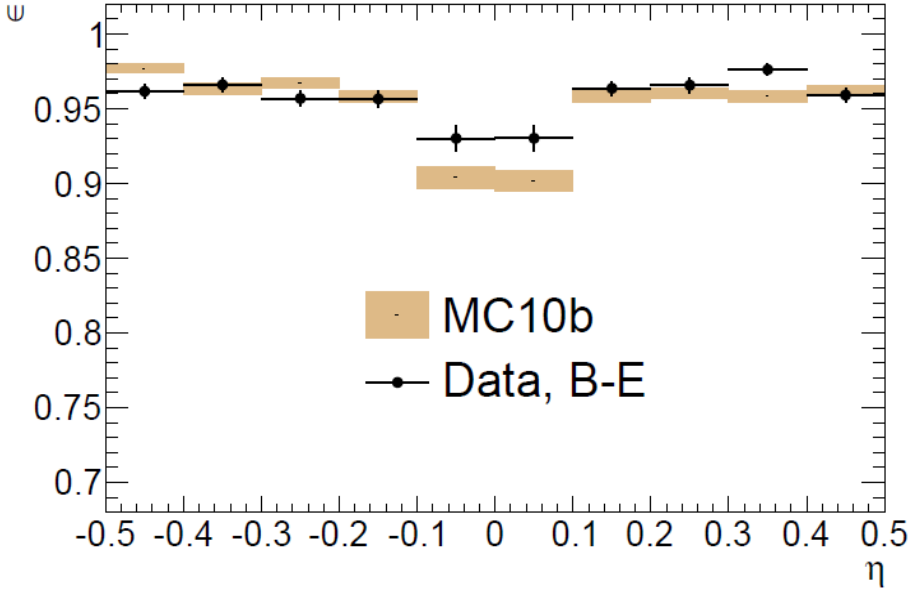
Calo Muons

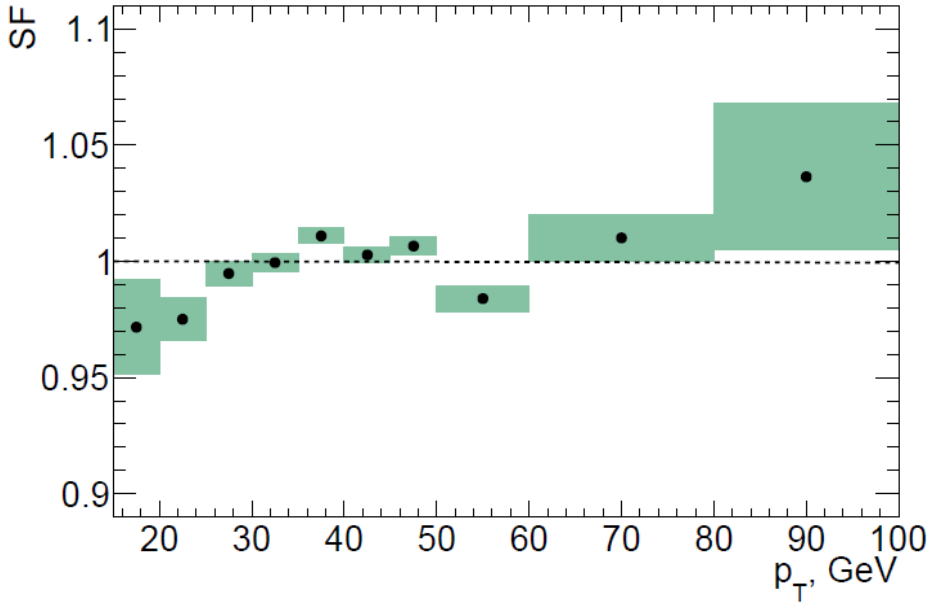
Tag-and-Probe efficiencies

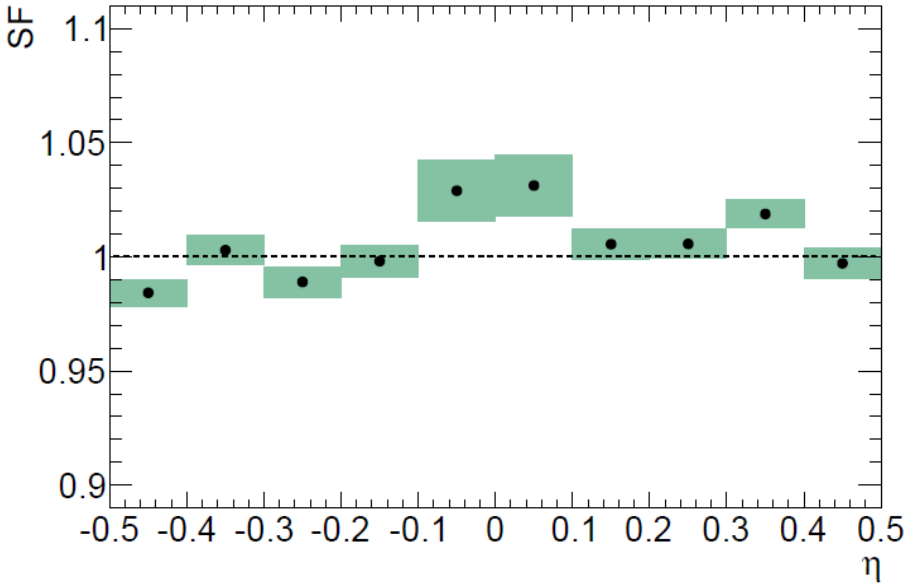
- Selection:
  - Tag: p_T > 20 GeV, trigger-matched, isolated combined muon
  - Probe:
    - standalone muon (isolated) for absolute efficiencies
    - OR ID track (MCP hits requirement, p_T > 15 GeV, track isolation) for validation
  - must form a Z ($q_1 q_2 < 0$, $|M_{ll} - M_Z| < 10$ GeV)
- Use the standalone probes to extract scale factors for the corresponding MCP package
- Use the ID track based method to look more closely at the central region and validate the standalone based method

Efficiency Scale Factors from SA probes



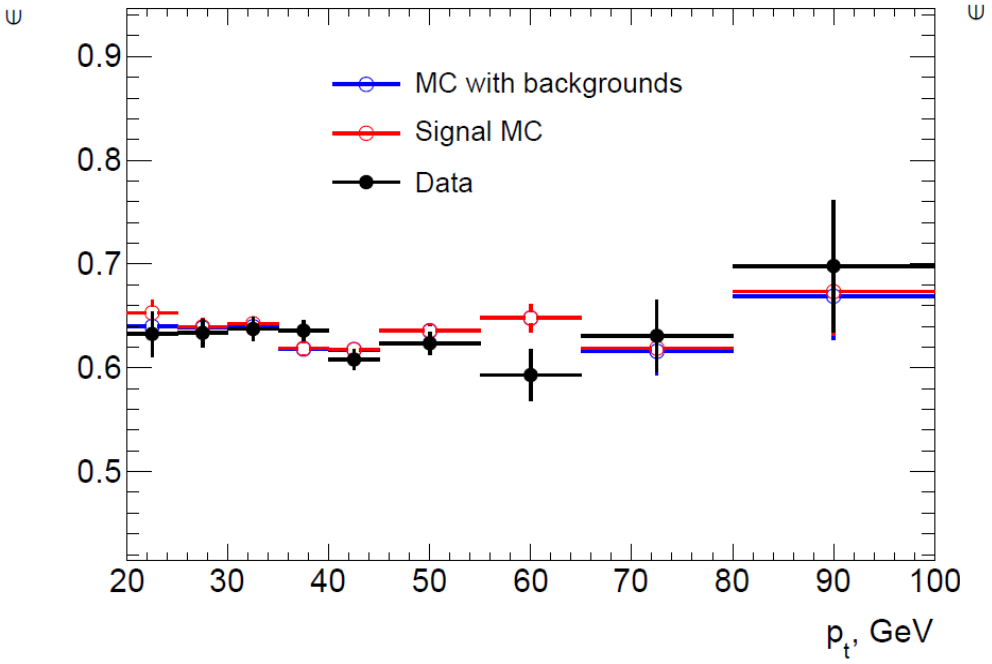


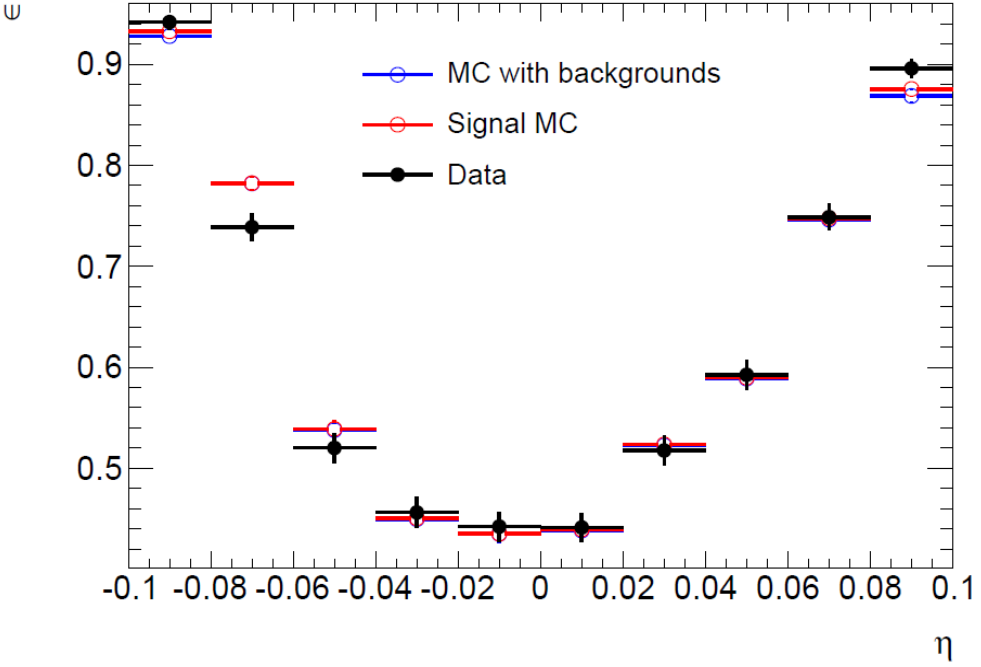




Tag-And-Probe efficiencies

STACO Combined muons (for comparison!)

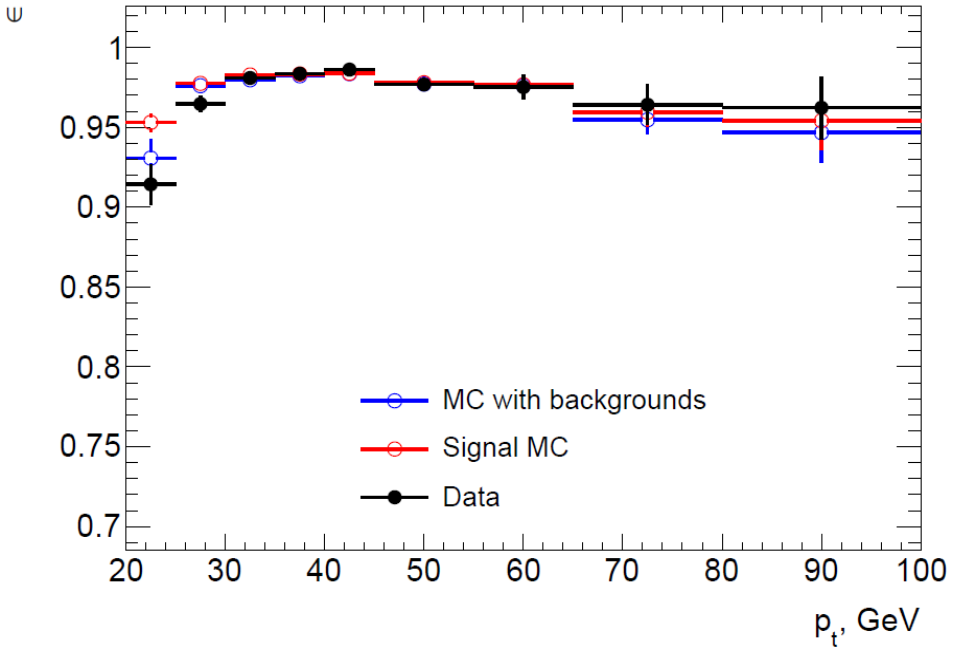


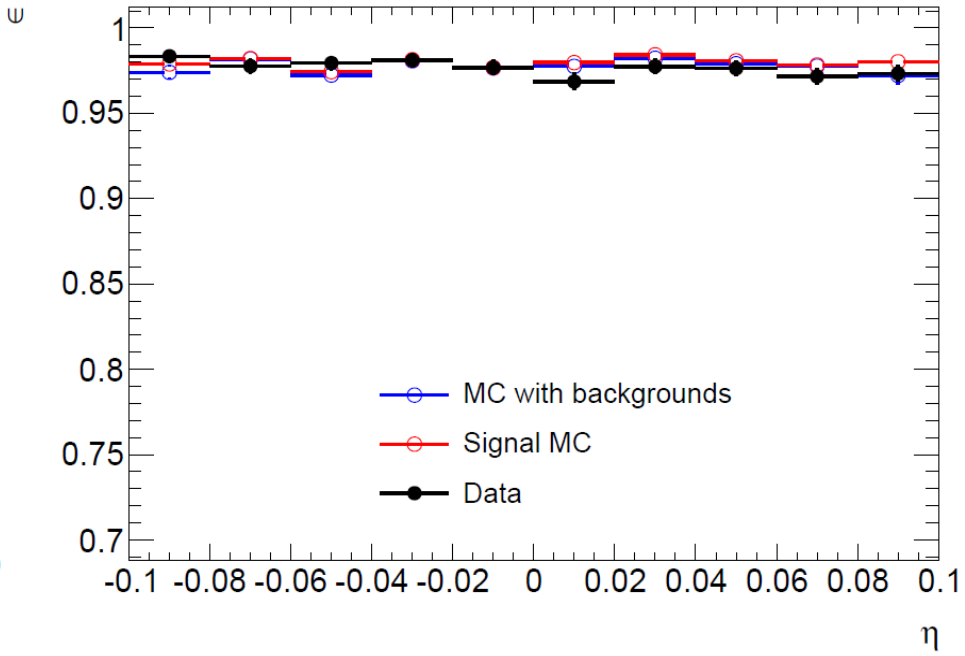


- efficiency loss clearly visible!
  - MS acceptance holes in the eta-phi-plane
  - reason for looking at CaloMuons
- remaining efficiency ~ 65% averaged over the region

Tag-And-Probe efficiencies

all CaloTag muons



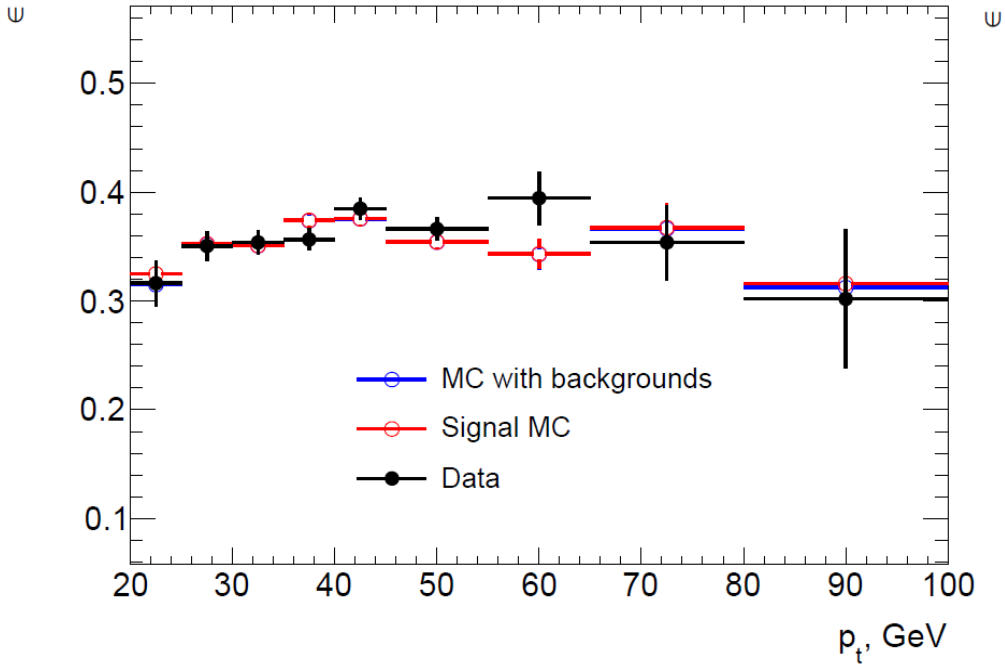


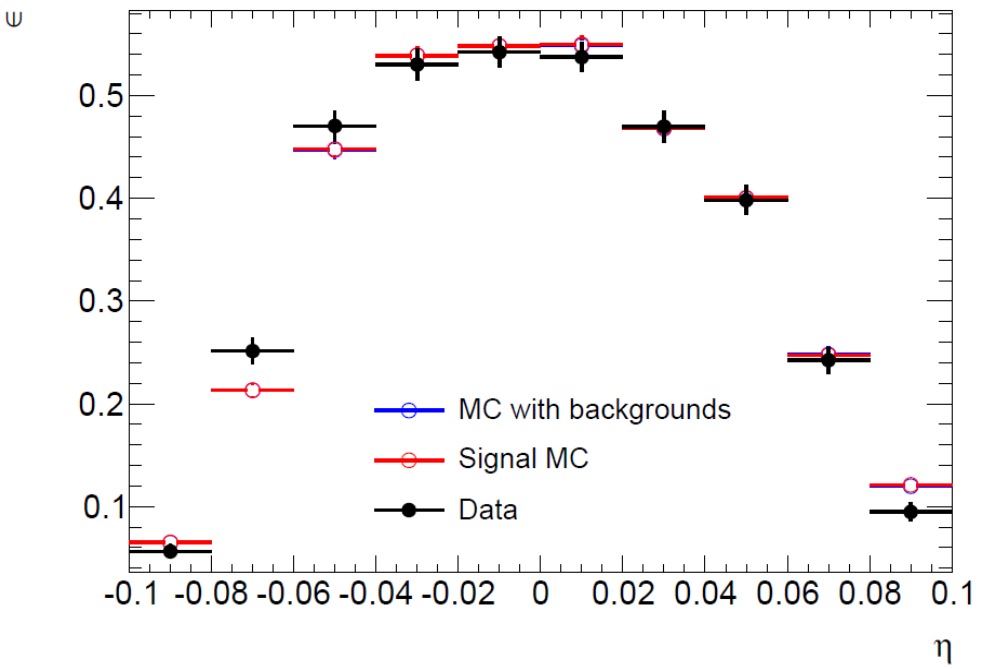
- no problems for the CaloTag muons

- careful when comparing to the standalone probes!
  - these efficiencies already assume an ID track!
    - need to correct for ID efficiency before comparing

Tag-And-Probe efficiencies

Unique CaloTag Muons (no combined match)



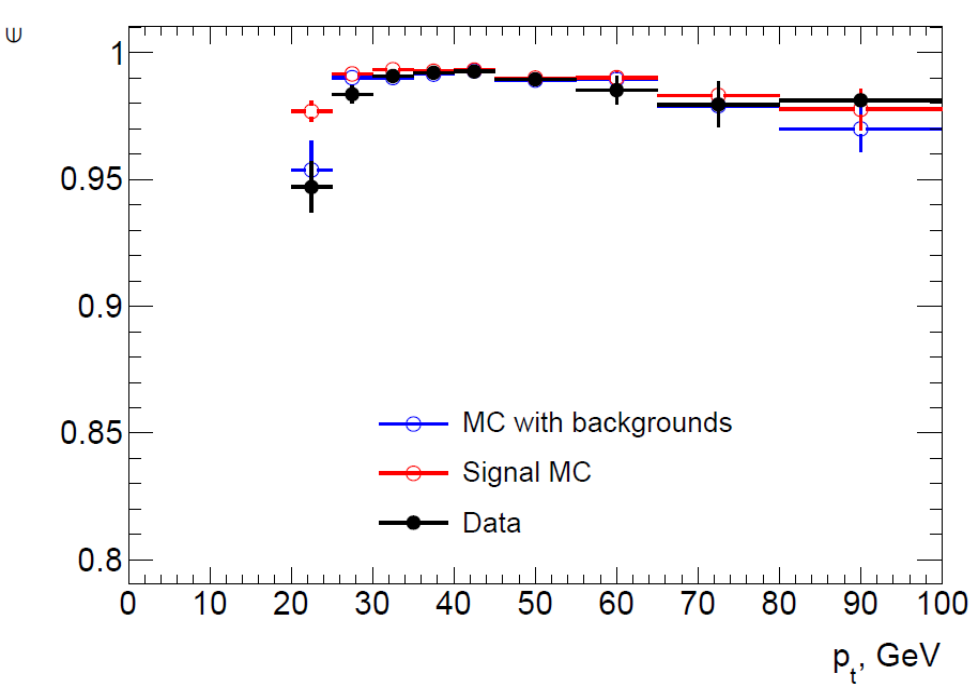


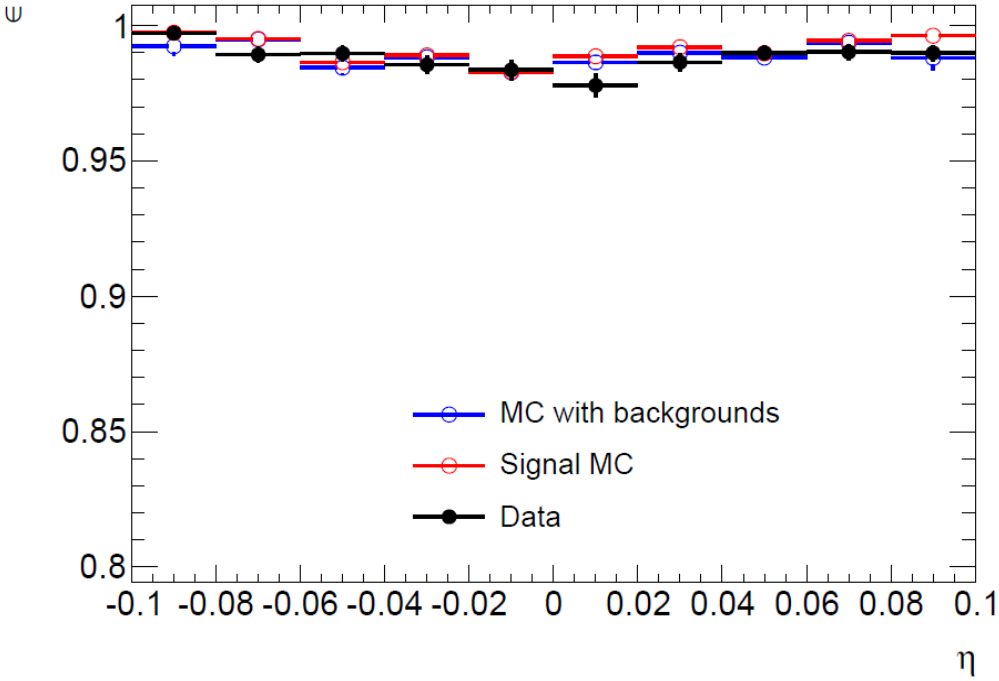
„unique“ Calo efficiency: complementary to combined efficiency

- this is the efficiency gain in eta/pt from including CaloMuons

Tag-And-Probe efficiencies

Combined and CaloTag Muons together





➔ **plugged the efficiency hole!**

Validation of the methods

- CaloTag efficiencies have been measured using two methods:
  - IDTrack Track and Probe (tagger efficiency)
  - Standalone Track and Probe (absolute efficiency)
- **Are these compatible?**
  - Compare results (for maximum statistics: average over eta, pt>15 GeV)
- IDTrack T&P: yields CaloTagger efficiencies, needs to be corrected for the ID efficiency!

Standalone T&P:

$\varepsilon_{ID} = 0.9421 \pm 0.0040$

$\varepsilon_{CaloMuon} = 0.9288 \pm 0.0063$

$\rightarrow \varepsilon_{CaloTagger} = 0.9859 \pm 0.0052$

IDTrack T&P:

$\varepsilon_{CaloTagger} = 0.9834 \pm 0.0038$

Compatible within 1Sigma!

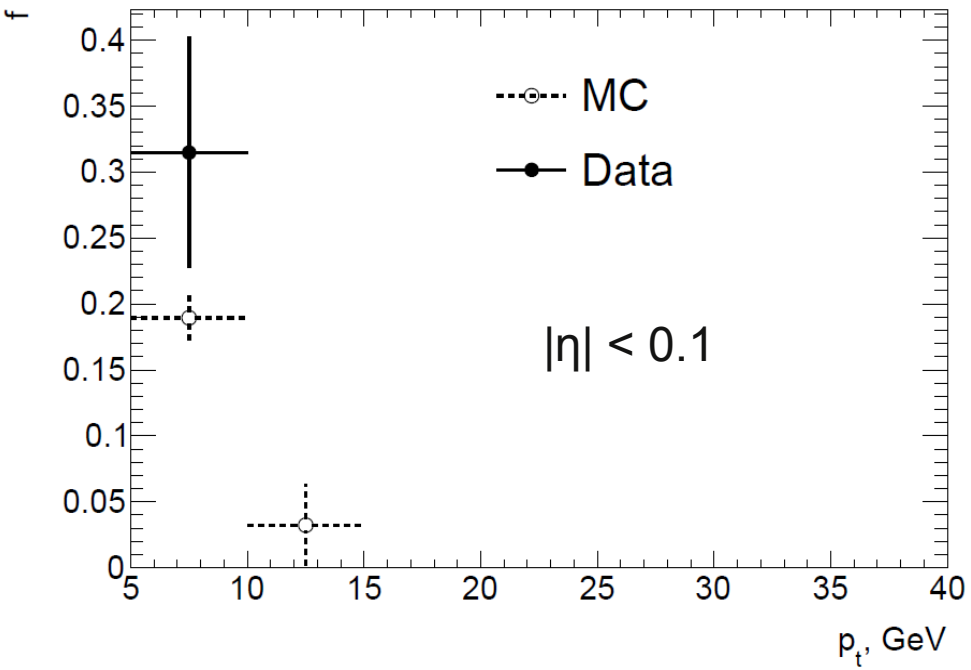
Fake Estimation on Data

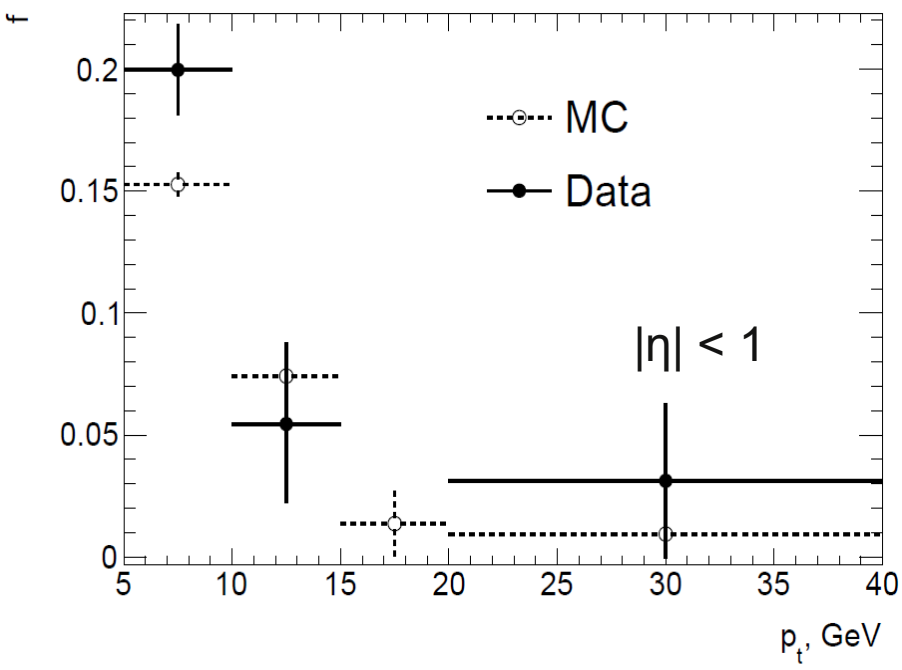
- Use **Z+X Tag Fake rate method**:
- Choose a sample of **fake muons from Z+jets**
  - Z->μμ selection, with Anticuts on Et_{Miss} <25 GeV (cut away WZ) and $|m_{34} - M_Z| > 30$ GeV(if 4 leptons in event - cut away ZZ)
  - select leptons reconstructed in addition to the ones from Z
    - ➔ quite solid sample for an estimate!
- For these muons from jets, derive the **Fake Factor**

$$f = \frac{N_{CaloTag}\left(P_T^{cone20} < 0.15\ pt \wedge E_T^{cone20} < 0.15\ pt\right)}{N_{CaloTag}\left(P_T^{cone20} > 0.15\ pt \vee E_T^{cone20} > 0.15\ pt\right)}$$

- Look for events with CaloMuons passing the **loosened quality requirements** (see denominator) on data
- **scale the found events** using the fake factor!

Fake Factor





- even at 1 fb^-1, **lack of statistics** for this method
- use eta region **up to 1.0** to get entries into bins above 15 GeV
- For the analysis: **average for pt > 15 GeV** (proposed cut for the CaloMuon selection)
  - for safety: **add 50%** (see 5 GeV bin) to the resulting factor to compensate for extrapolation

Fake estimation on data

- result using this method:
  - f ~ 0.020 ± 0.021 @ pt > 15 GeV
  - → **f_{corr} ~ 0.03 ± 0.03**
- run ZZ -> 4l selection on data - allow CaloTag muons to fail the isolation cut
  - found **0** such „ZZ->“4l events on data (B-H1)
  - → derive **upper Limit (90% CL)**: **$N_{fake,\ loose\ Calos}$ < 2.3**
    - → conservative poisson estimate
    - → Profile Likelihood PCL upper limit would yield ***1.17 @ 90%***
  - → use fake factor to scale this upper limit:
    - **$N_{Fake,\ real\ Calos}$ < 0.074 ± 0.074 (90% CL)**

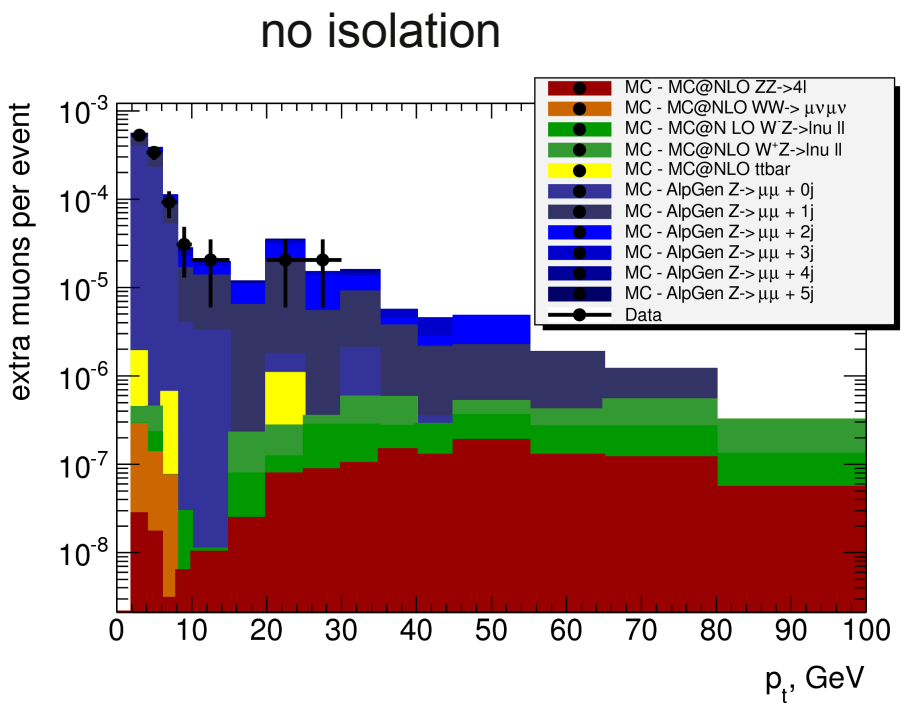
→ **do not expect significant contamination from fakes**

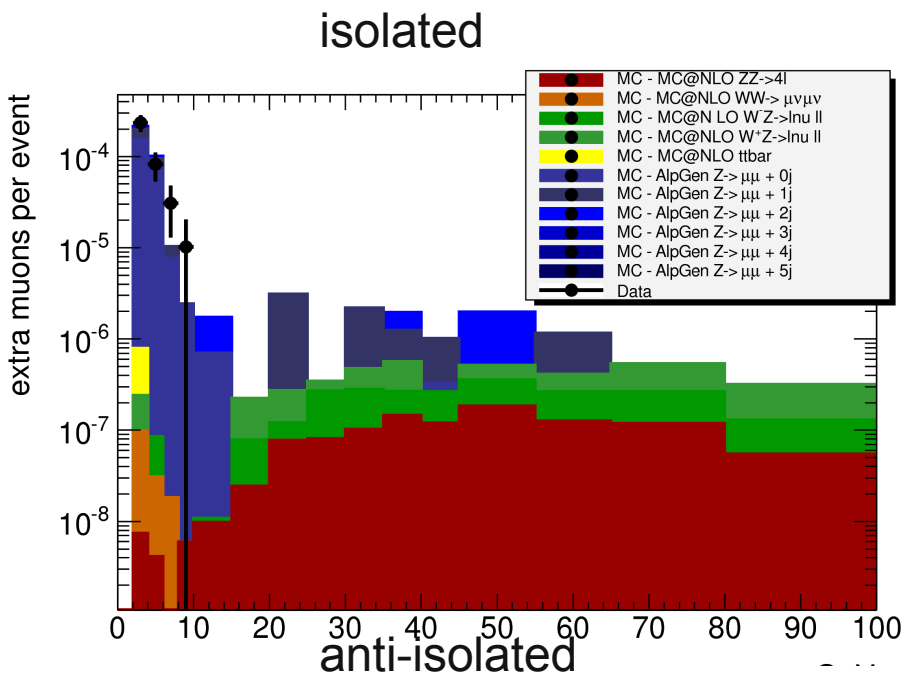
Fake estimation #2

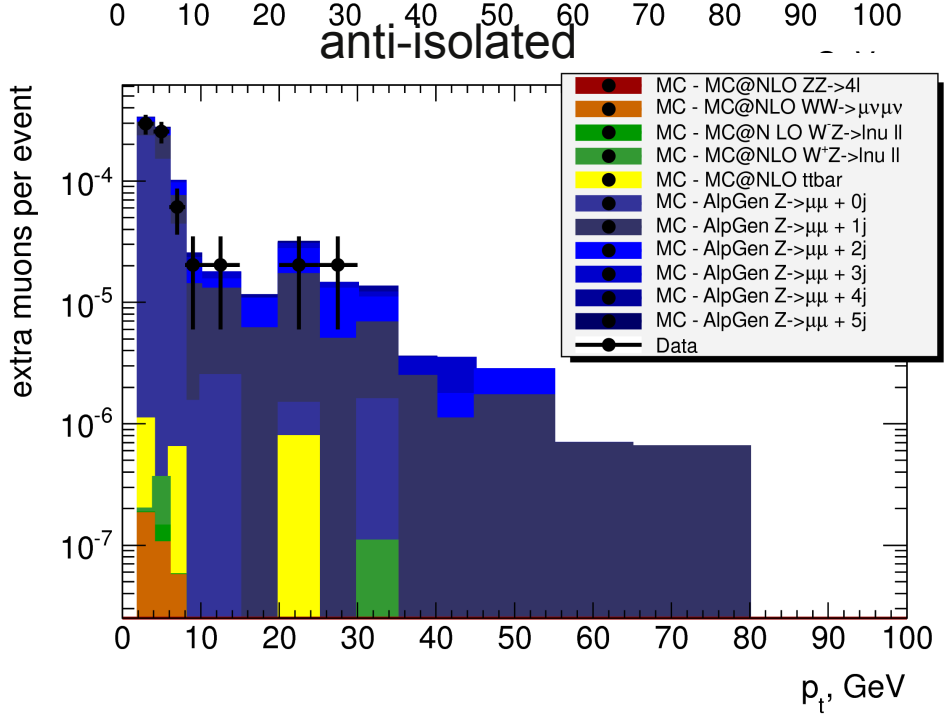
- **better suited to current statistics**, but less accurate, not for published results
- **Z+jets selection** as before
  - do **not** use the Anticuts - able to look at **composition** of the extra muons
    - includes fakes and good muons from diboson events

- what can we do with this?
- → **validate the MC description** of the fakes
  - → if description is okay, we can trust MC results for background gains in analyses (as a first estimate)
- **easy to adapt** to other lepton types, **more general** than fake factor analysis
  - used to check MuTag fakes for WW

Fake estimation #2

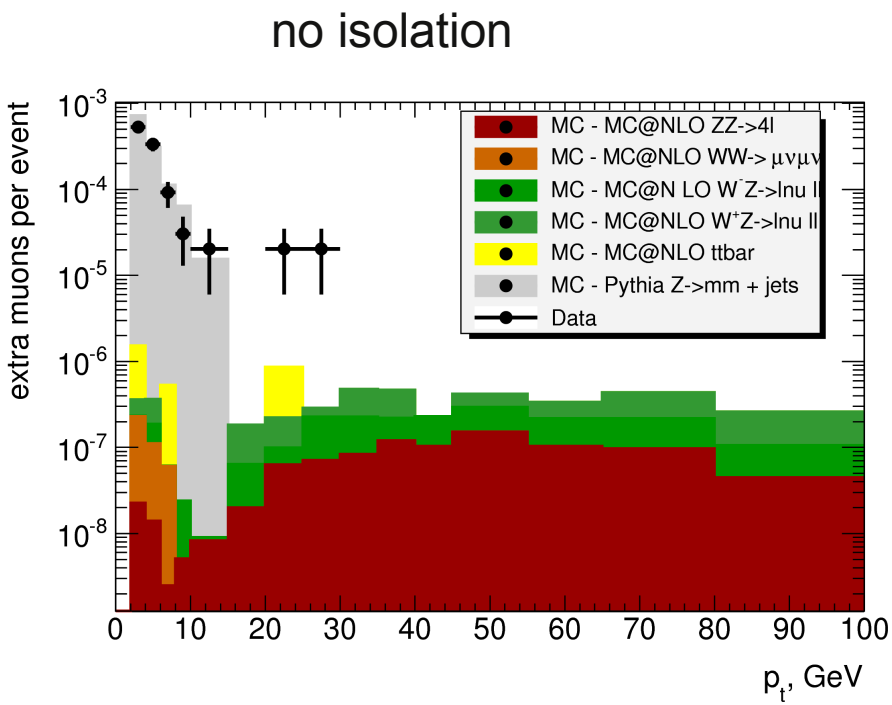


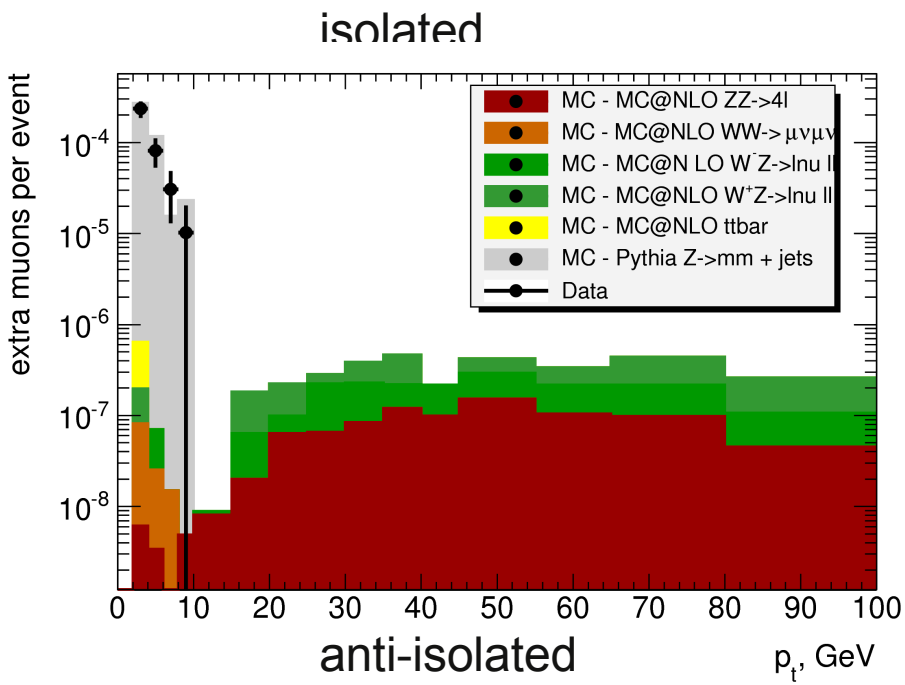


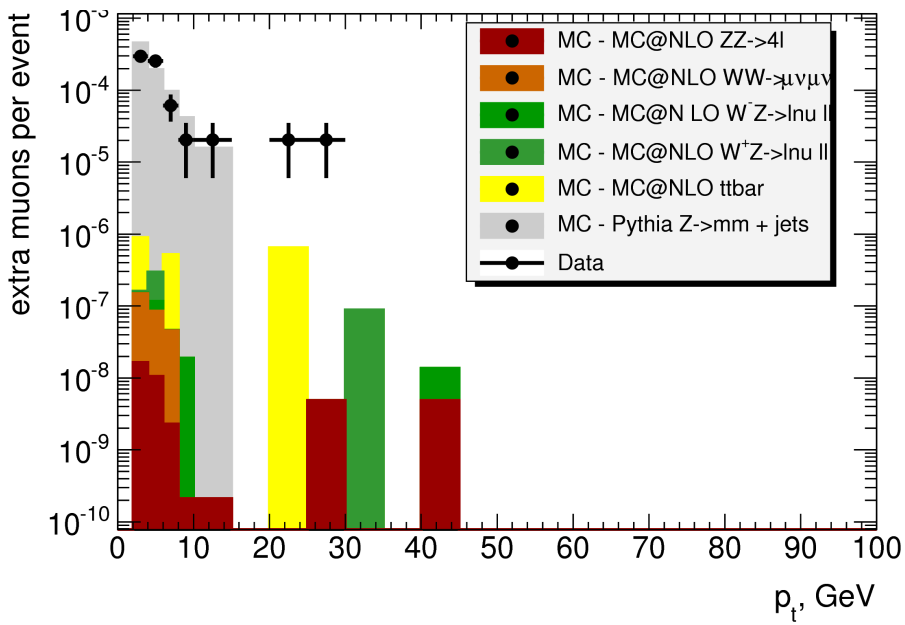


- MC description „fair“
  - Alpgen: rather solid
  - *Pythia does not access the high pt fake region*
- Isolation cut: removes almost no signal

Fake estimation #2







- MC description fails at high pt
  - *Alpgen: rather solid*
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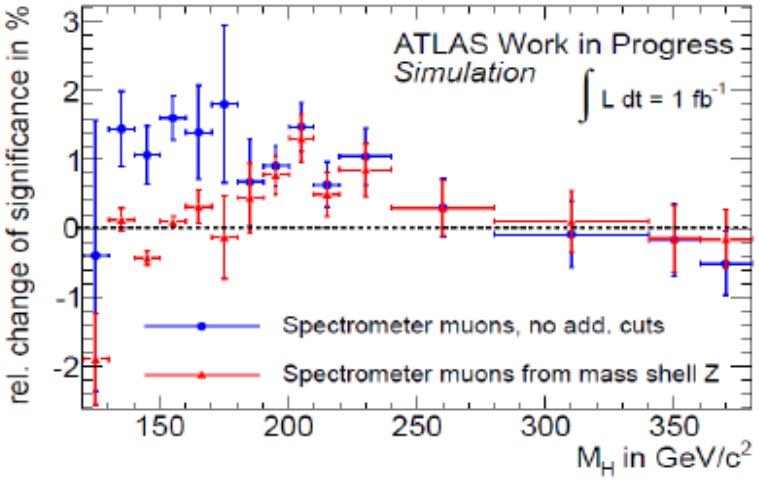
Standalone Muons

standalone muons

- for H->4l: **not as attractive** as the Calomuons because they reduce s/b



- SM ZZ->4l: **no „ZZ background“**
  - happy to have them
- Unlike CaloMuons: Already **1 candidate** ZZ->4l with a standalone muon!

Run 182486, event 21528951
$M_{\mu\mu}$ = 90.8 GeV, m_{ee} = 90.3 GeV, m_{4l} = 344.7 GeV

- Being worked on by Konstantinos Bachas
  - MCP-approved efficiencies and scale factor provided
  - next steps: make the standalones ready for SM ZZ LPC note

Strategy for reconstruction efficiency SF in 2.5<|η|<2.7

Typical tag & probe cannot be applied in this region

1st approach (Normalize to L)

- Select Z candidates in data and mc with 1 high eta muon ("probe") and 1 CB muon in |η|<2.5 ("tag")
  - Apply same cuts as for resolution study to the combined muon
  - No cuts on the high eta muon
- Extract Z yields from data and mc appropriately normalized to same luminosity
- Efficiency SF_1 given as:

$$SF_1 = \frac{\text{DATA: Z Yield } 1\mu\ (|\eta|>2.5) + 1 \text{ CB } \mu}{\text{MC :Z Yield } [1\mu\ (|\eta|>2.5) + 1 \text{ CB } \mu]}$$

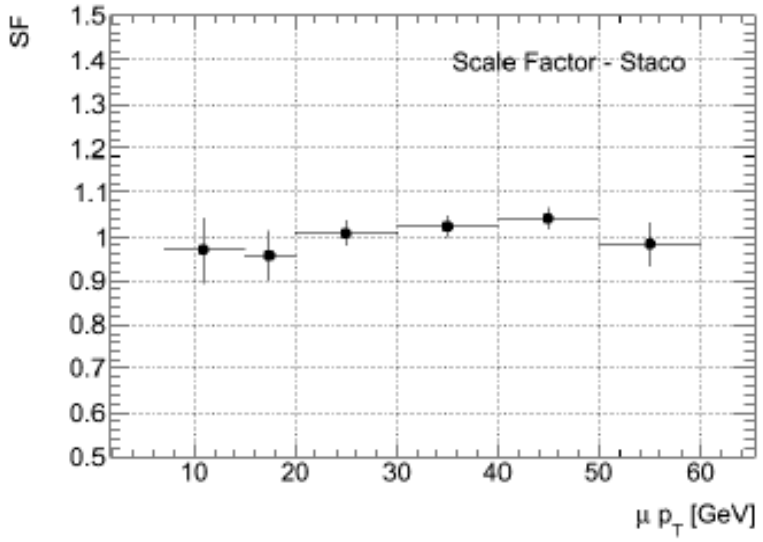
2nd approach (Normalization independent of L) proposed by Oliver

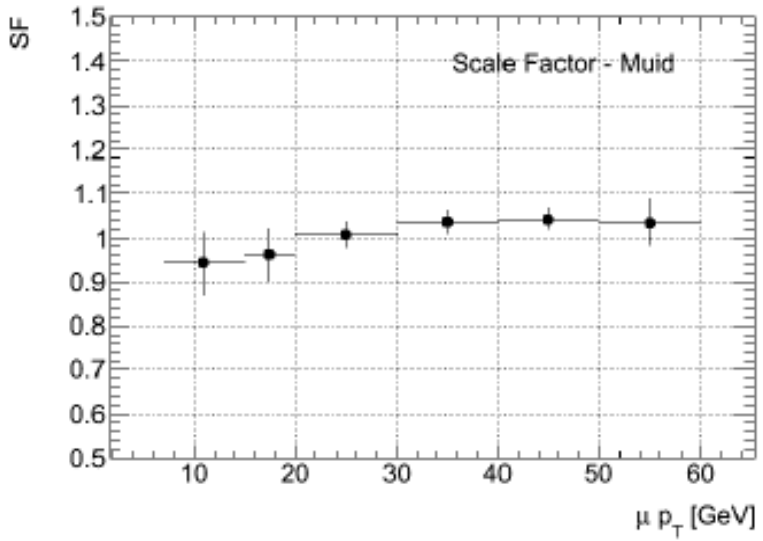
- Select Z candidates in data and mc with 1 muon in 2.2 <|η|<2.5 ("probe") and 1 muon in |η|<2.2 ("tag")
  - Apply same cuts as for resolution study to the combined muon
  - No cuts on the "probe" muon
- Extract Z yields from data and mc
- Efficiency SF_2 given as:

$$SF_2 = SF_1 \times \frac{\text{MC: Z Yield } 1\mu\ (2.2<|\eta|<2.5) + 1\mu\ (|\eta|<2.2)}{\text{DATA:Z Yield } [\text{Yield } 1\mu\ (2.2<|\eta|<2.5) + 1\mu\ (|\eta|<2.2]}$$

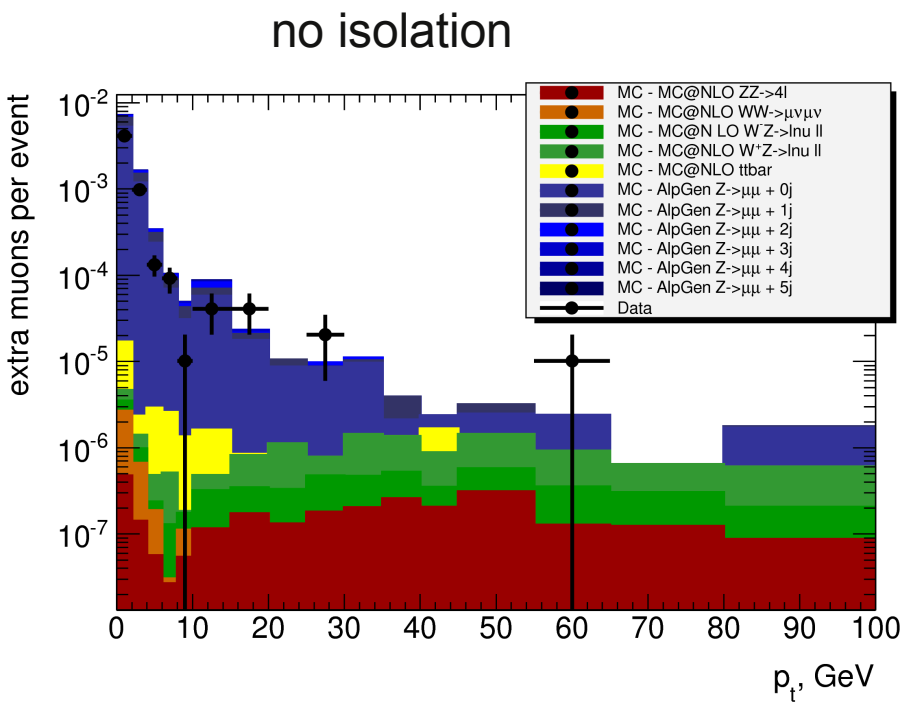
Efficiency Scale Factor in high η muon pt bins

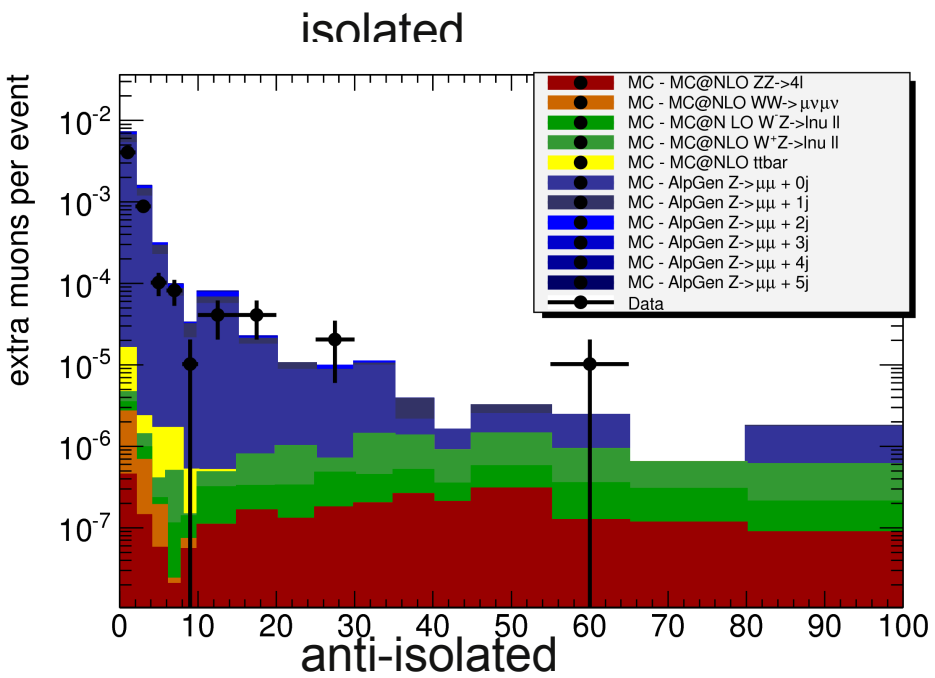
- No dependence on luminosity in this case
- Lower statistics in first and last bins
- Max variation in worse case is ~ 5%
- Only statistical error shown on the plots
  - Systematics (see next slide)

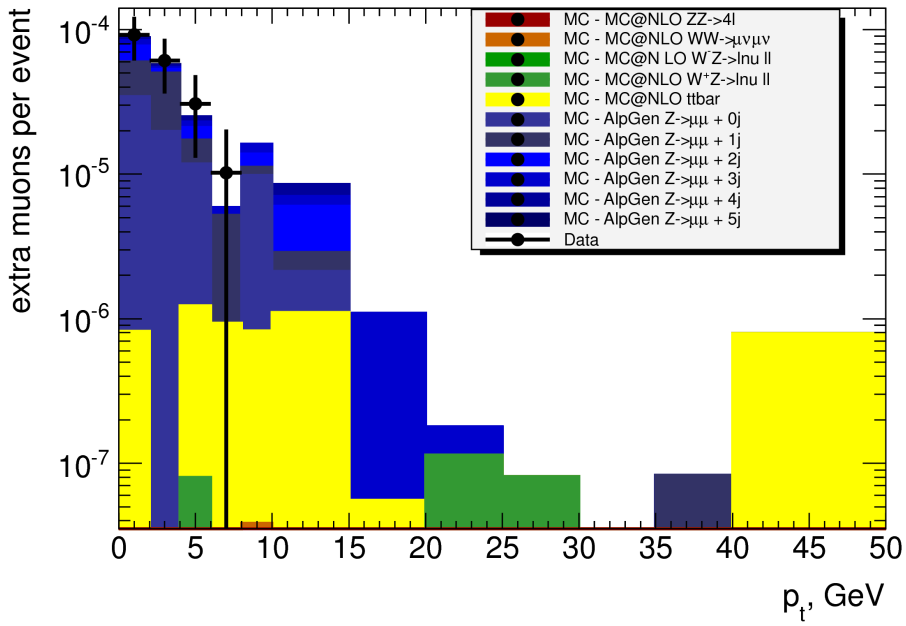




Fake estimation - simple method

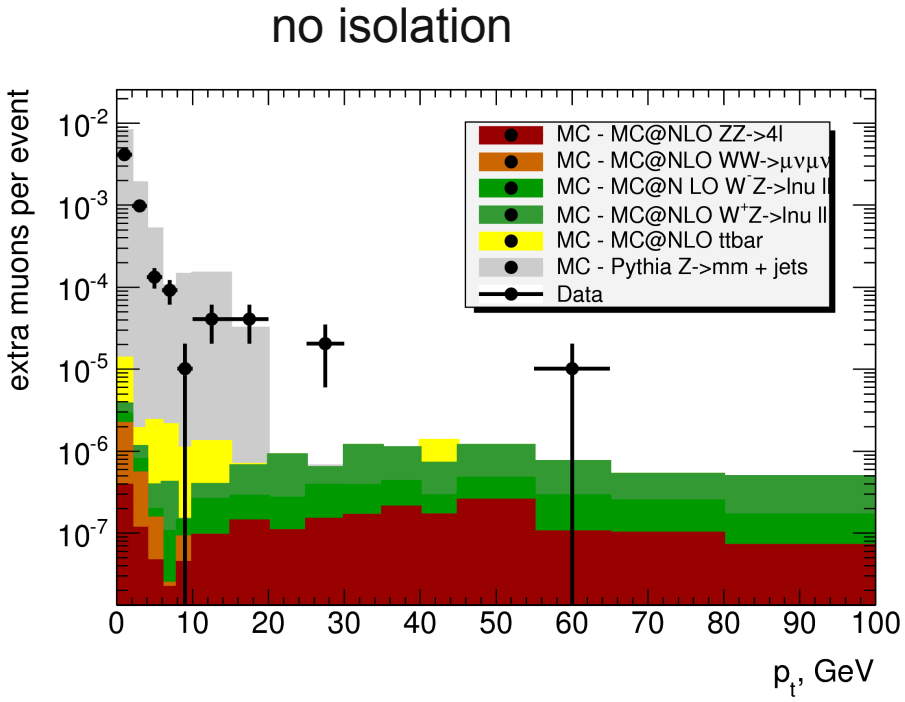


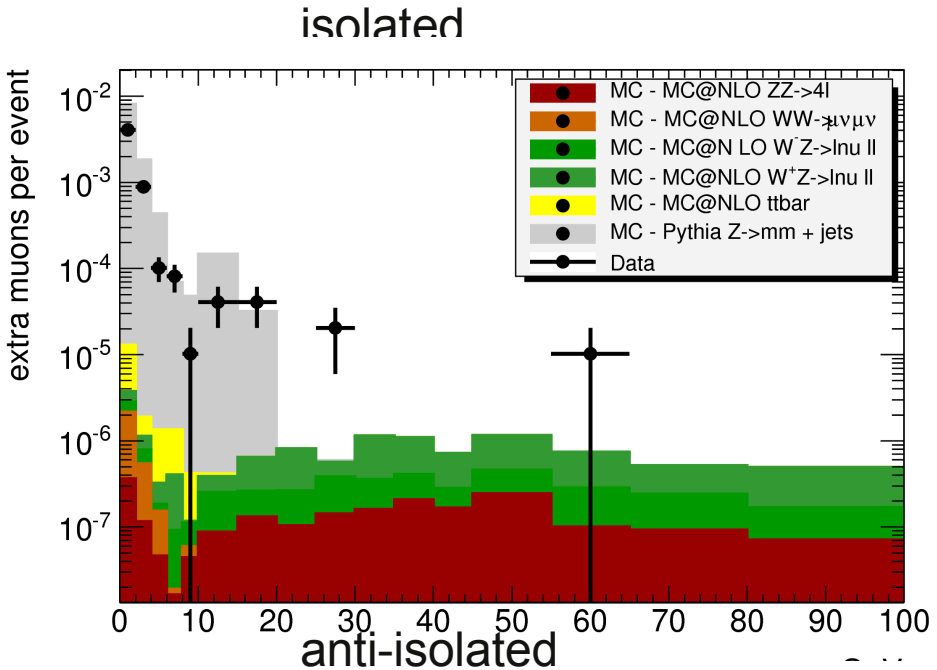


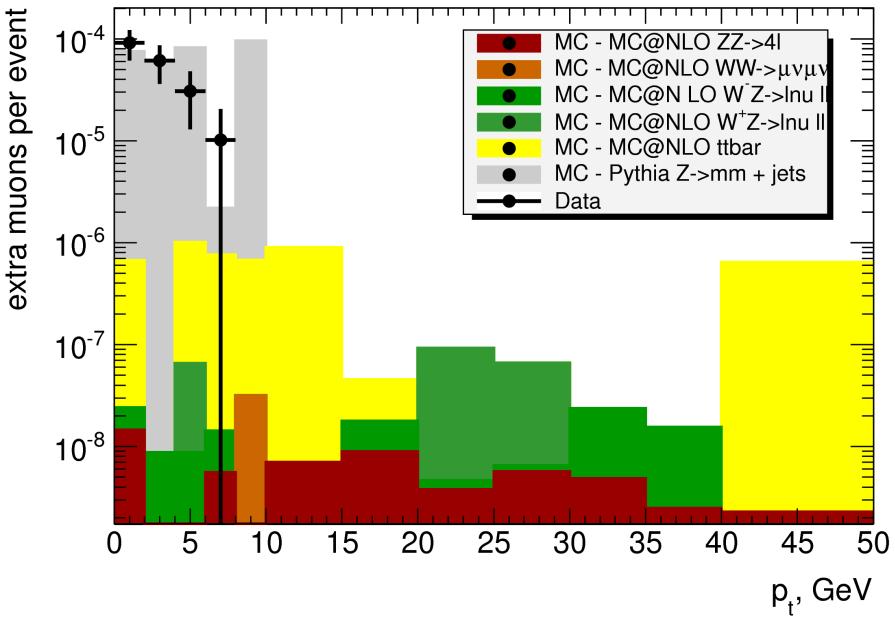


- MC description: again „fair“
  - Alpgen: problems especially with isolated fakes
  - *Pythia does not access the high pt fake region, not better than AplGen at low pt*
- Isolation cut: use EtCone40 < 6

Fake estimation - simple method







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Summary/Conclusions

- **Efficiency** measurements carried out, **scale factors** available
  - **acceptance hole can be plugged** using CaloTag
  - acceptance can be **extended to |η| < 2.7** using standalones

- **Fake rates** have been analyzed
  - MC not perfect for this
    - Alpgen: problems but does the job as a first-order estimate
    - Pythia: forget it...
  - ➔ nice to have **data-based** estimate!
    - ➔ need **statistics**!!
    - ➔ Needs to be run for the standalone muons

- MCP has **approved** the use of extension Muons for ZZ analyses
  - finish selling them to the conveners, include them in the code...