ATLAS Experiment: The Analysis Activity of LNF Group

Claudio Gatti

Outline

- LNF Group Activity
- Data Preparation
- Commissioning with Cosmic Rays
- Measurement of W and Z Cross Sections
- Calibration and Performances with Physics Processes
- Search for New Heavy Gauge Bosons Z'→$\mu\mu$
- Search for SM and MSSM Higgs Bosons
- Summary

The LNF Group Activity (I)

1. MDT Chambers
   - Design
   - R&D
   - Assembly of 94 BML (Barrel Middle Large) for a total area of 600 m^2
   - Test beam data
   - Installation and commissioning
2. LNF Tier 2
3. Fast Track: Hardware Track Finder for Atlas Trigger

The LNF Group Activity (II)

4. Data Preparation: filtering for the Atlas Muon Performance group
5. Muon Spectrometer Performances with Cosmic Rays
6. Detector Performances and Calibration with Physics Processes
   - Dimuons from J/ψ and Z (MC studies)
   - E_T^{Miss} reconstruction on MC and first data
7. Analysis (MC studies)
   - Measurement of pp→Z→$\mu\mu$ and pp→W→$\mu\nu$ cross sections
   - Search for new heavy gauge bosons (Z′)
   - Search for SM and MSSM higgs (H/h/A)

I will talk about this second part

Data Preparation

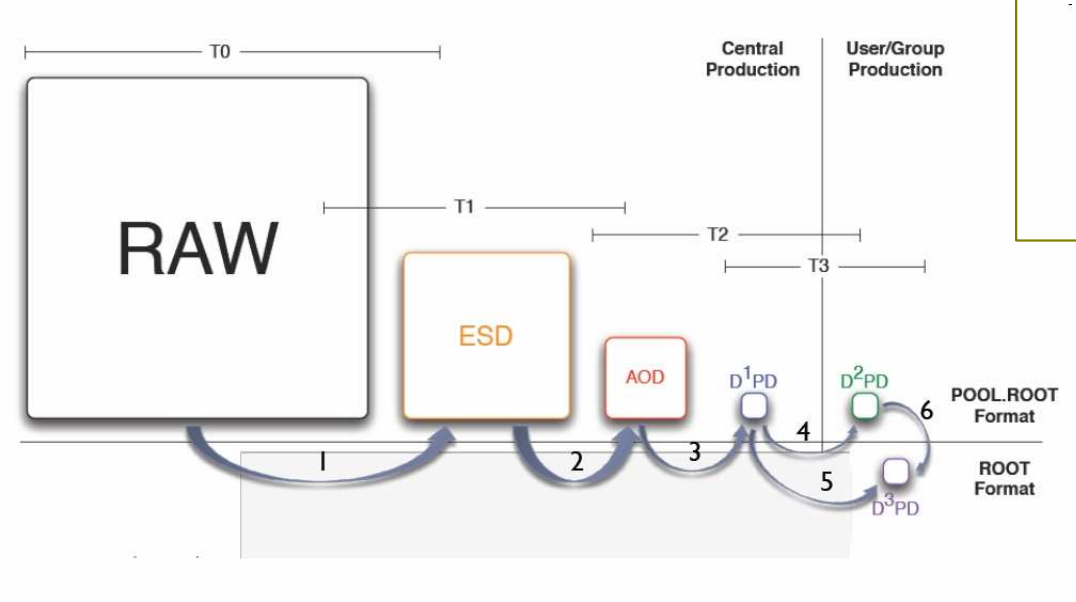
Data Preparation

RDO:
- Tier0: Tier1
- Content: Raw Data
- Size 1.5 MB/evt

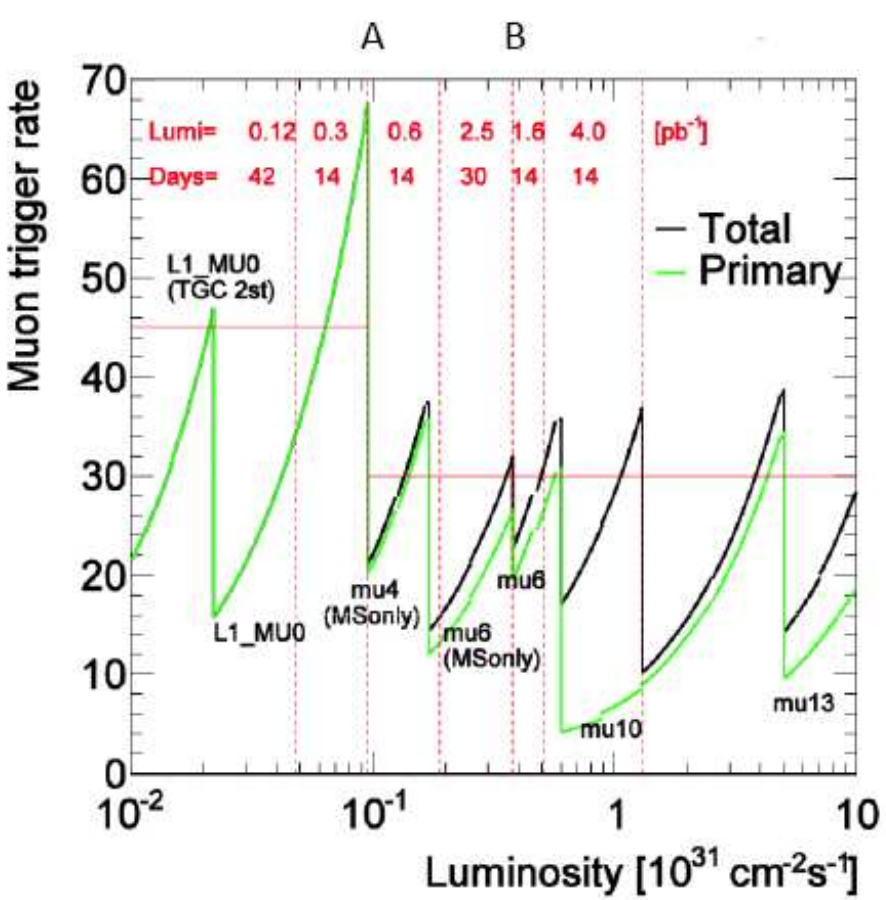
DESD (filtered ESD):
- Location: Tier2
- Size: 900 kB/evt
- Content: Identified particles + hits&cells

ESD:
- Location: Tier1
- Size: 900 kB/evt
- Content: Identified particles + hits&cells

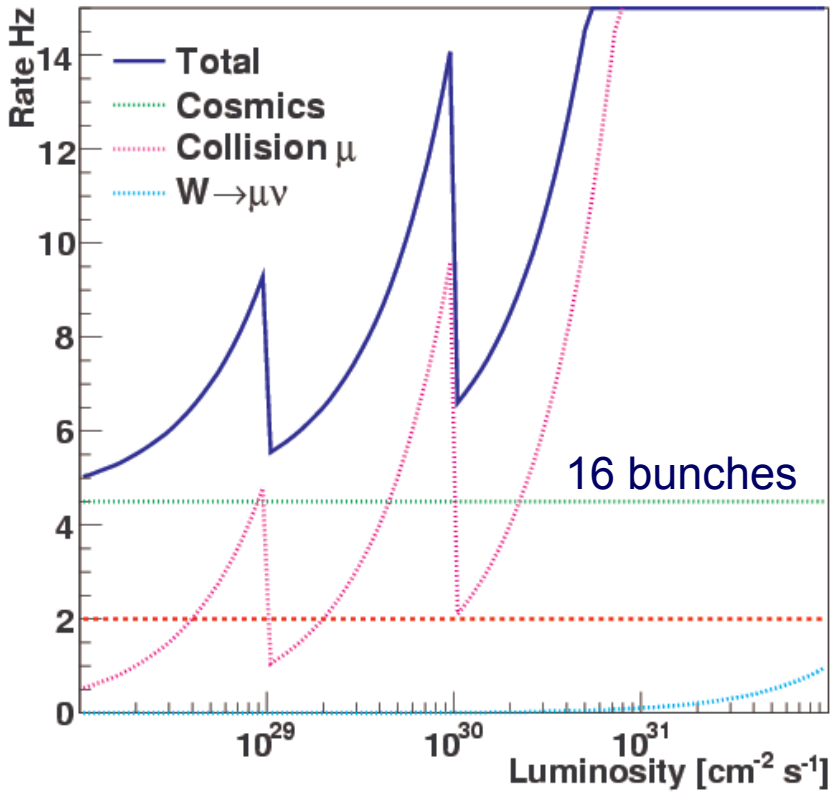
AOD:
- Location: Tier2
- Size 100 kB/evt
- Content: Identified particles



Data Preparation



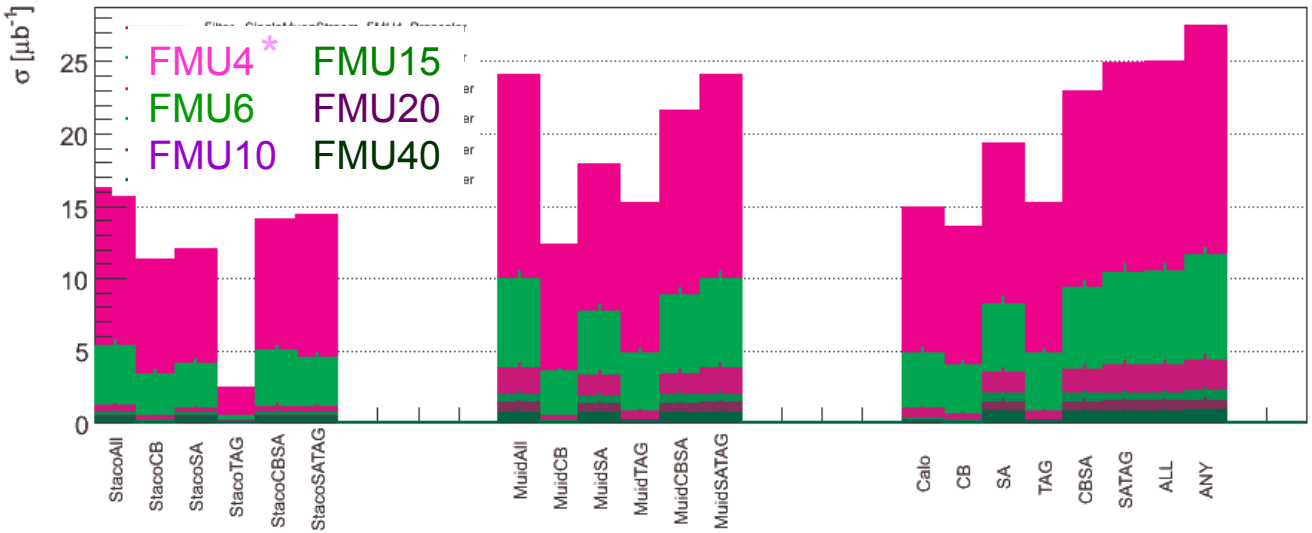
DESD expected rates

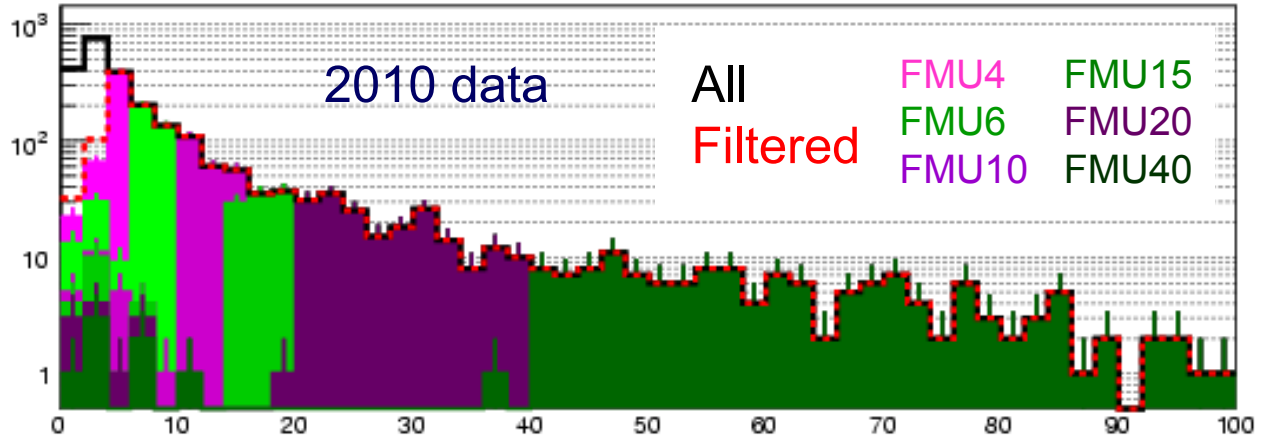


ESD Muon throughput up to 40 MB/s
Muon-DESD throughput ~ 4 MB/s (1 MB/evt → 4 Hz)

DESD will be the only format distributed at T2's with hit/cells information
LNF group responsible for filtering/monitoring/validating the muon stream

Data Preparation



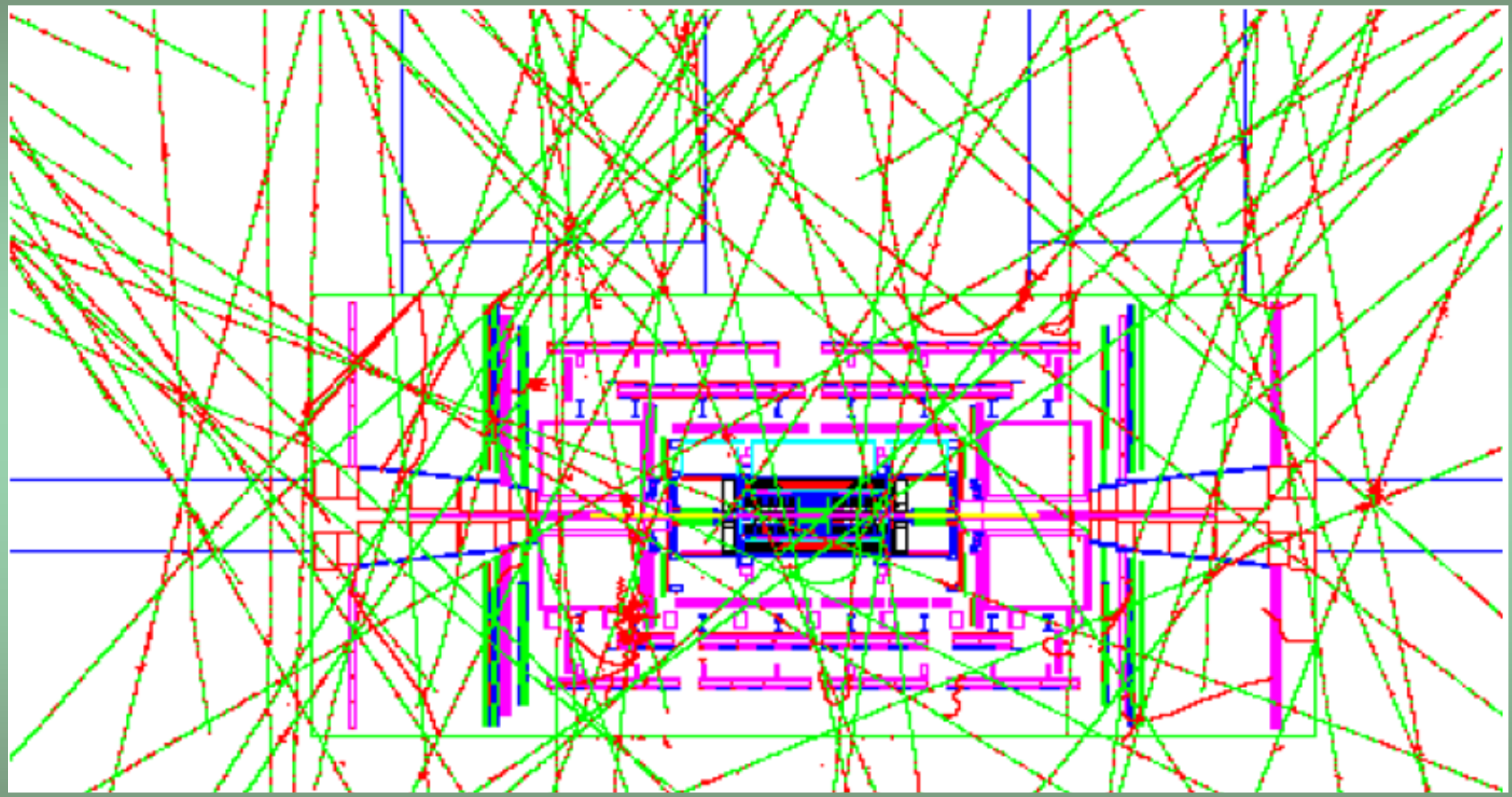


*Single muon filter name: FMU+(pT cut in GeV)

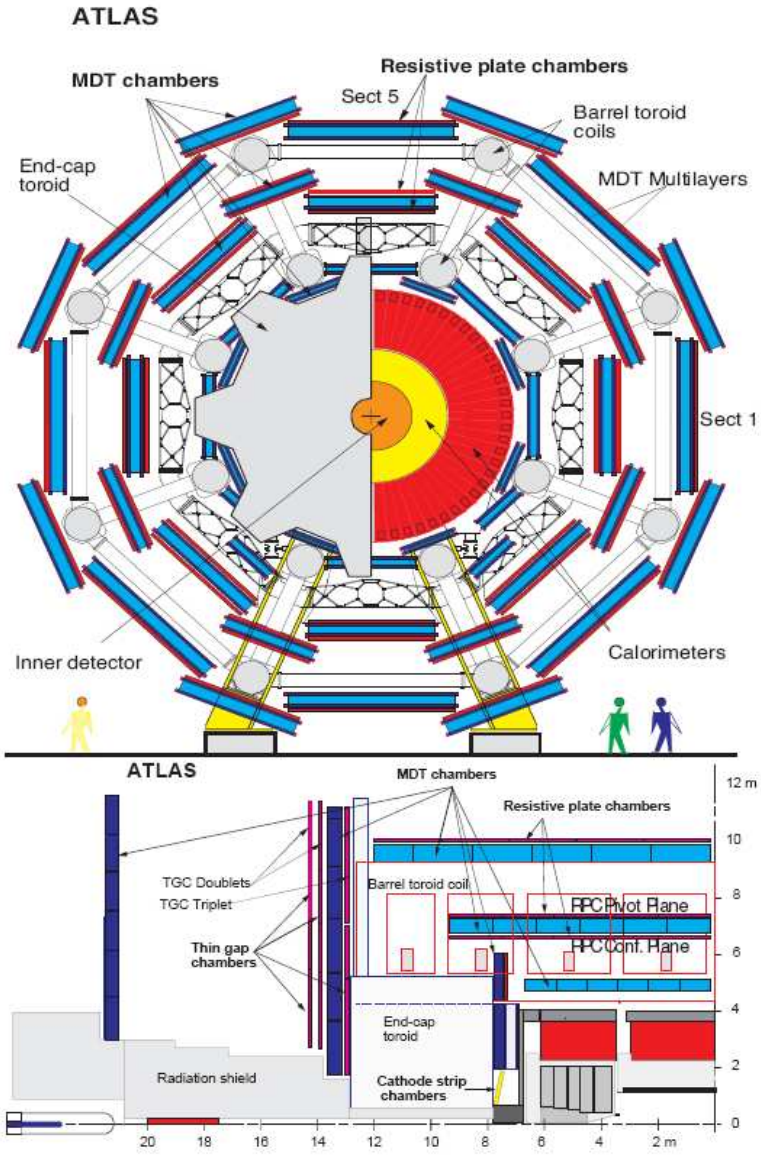
1. Set of Filters:
   - Single and di-muons
   - Isolated muons
   - SA/CB/TAG/Calo
2. Cosmic rejection
3. Fake rejection

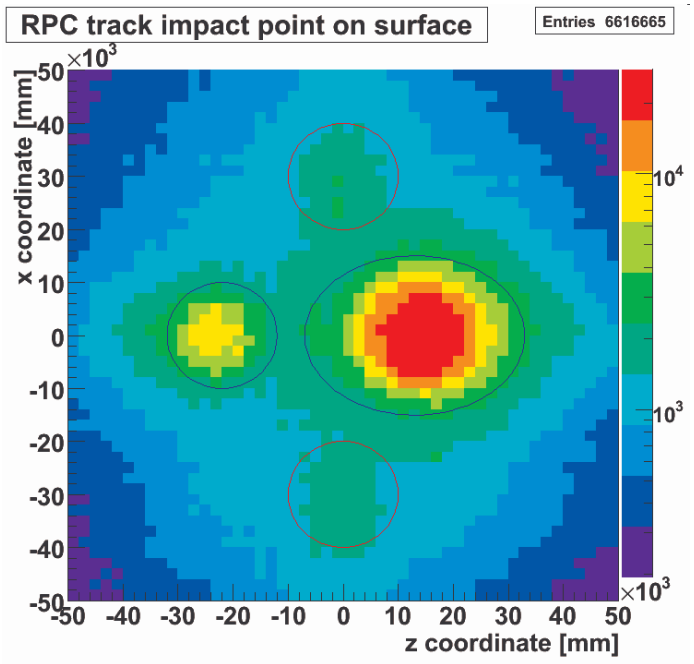
Simple selections
Easy to monitor
Bookkeeping
Easy to configure

Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays



Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays





- Based on 60M cosmic-rays
- Most of cosmics from shafts
- Mostly vertical and triggered in barrel
- Runs both with B field on and off

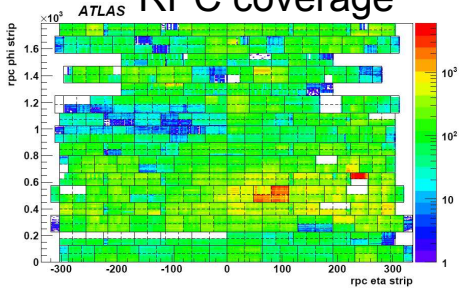
Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays

1. Performance of precision and trigger chambers
   - single element efficiency
   - resolutions
   - noise rates
2. Calibration methods
3. Track reconstruction
4. Alignment and momentum resolution

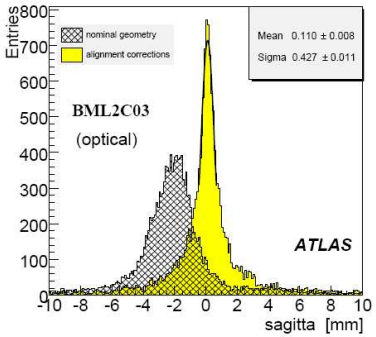
Submitted to EPJC

Leading role of LNF in coordination and paper editing.

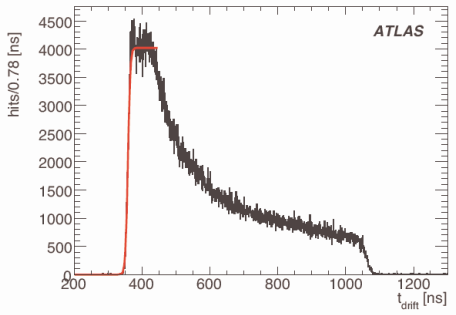
RPC coverage



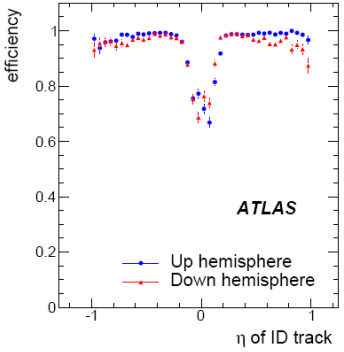
Optical alignment



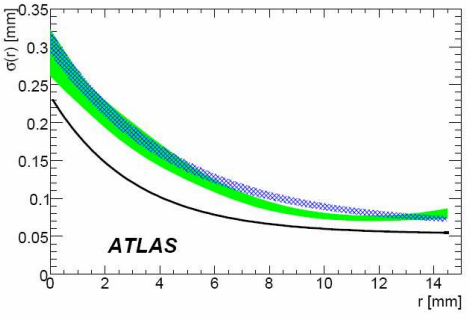
MDT drift-time



Track efficiency

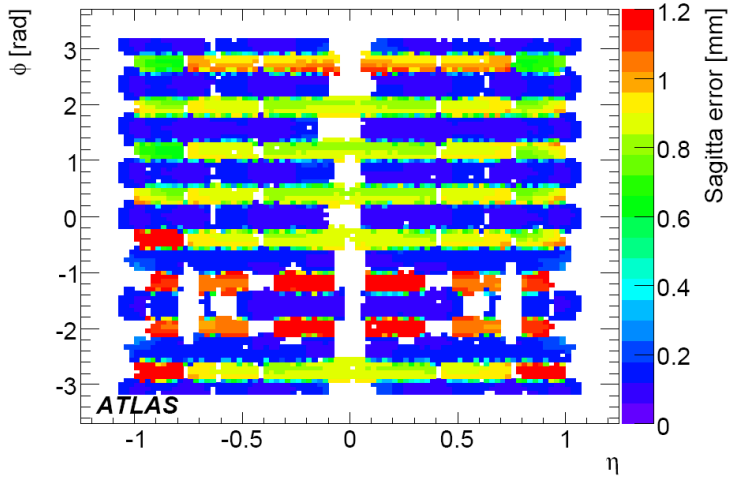


Single tube resolution

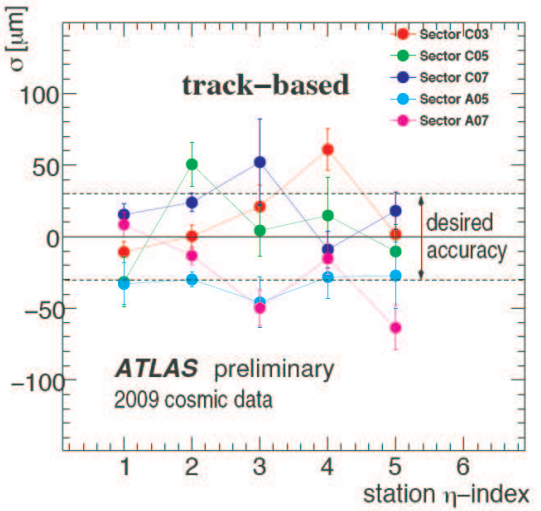


Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays

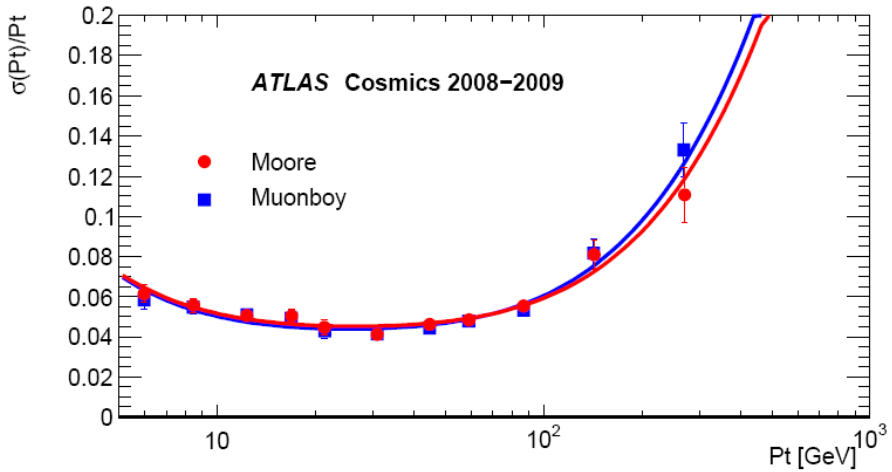
Optical alignment (absolute position)



Alignment based on cosmic tracks with toroid off and solenoid on.

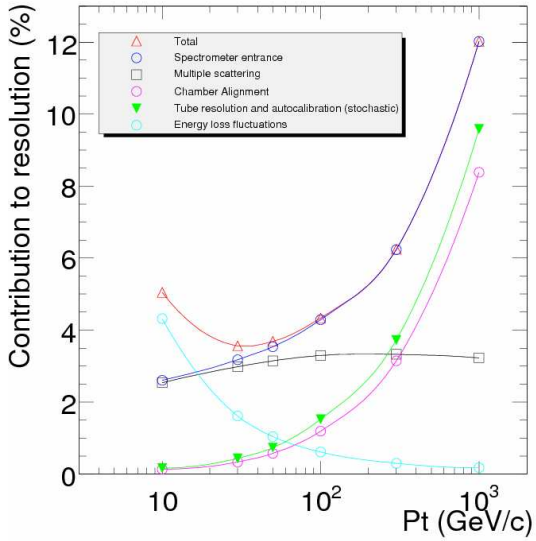


Momentum Resolution

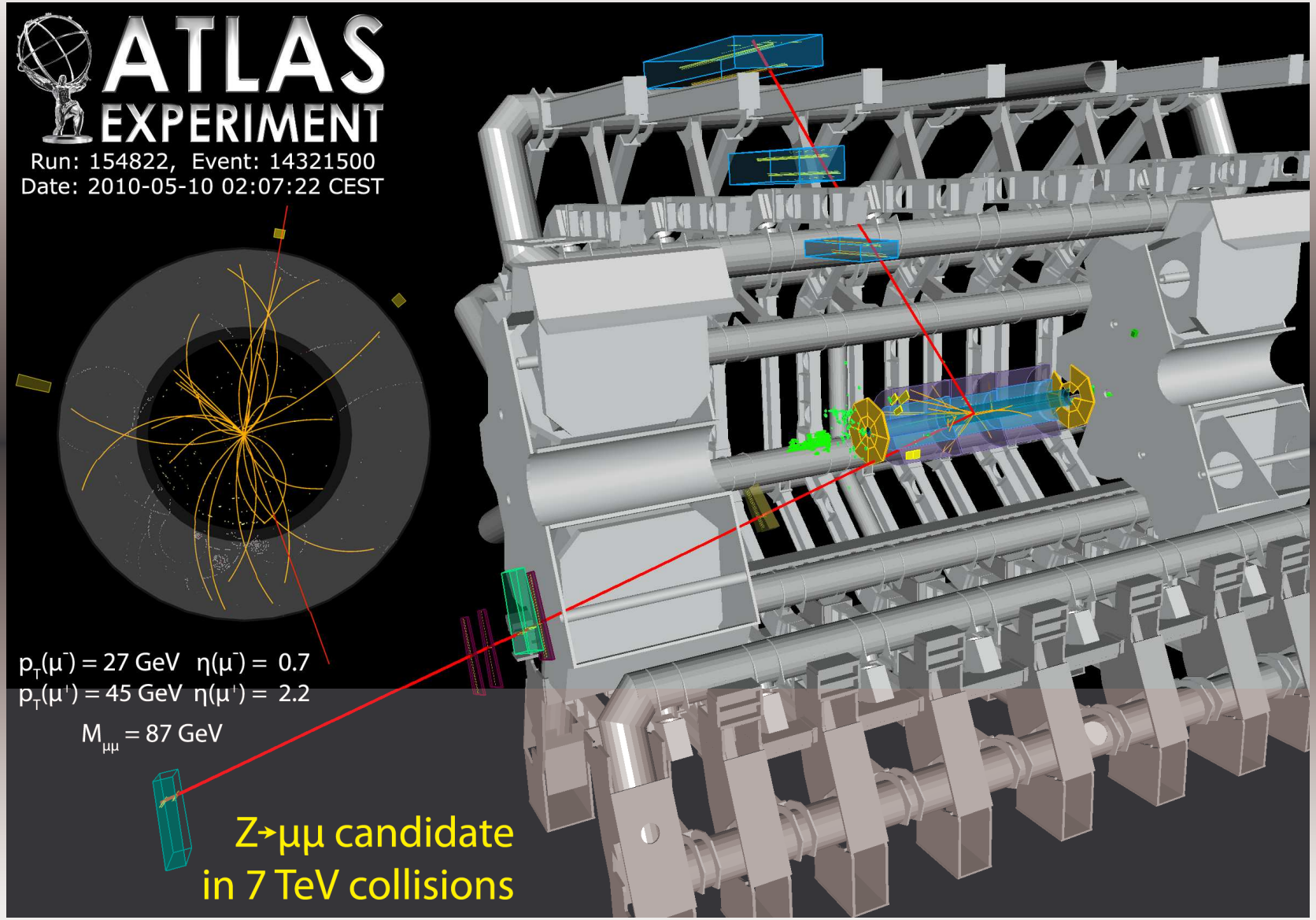


Measured by splitting the cosmic track into two independent tracks

Ideal alignment/calibration



Measurement of $\sigma(pp \rightarrow W \rightarrow \mu\nu)$ and $\sigma(pp \rightarrow Z \rightarrow \mu\mu)$



Measurement of $\sigma(pp \rightarrow W \rightarrow \mu\nu)$ and $\sigma(pp \rightarrow Z \rightarrow \mu\mu)$

ATL-PHYS-COM-2010-124

MC study at 10 TeV with 15 pb^{-1}

σ_z~1 nb σ_w~10 nb

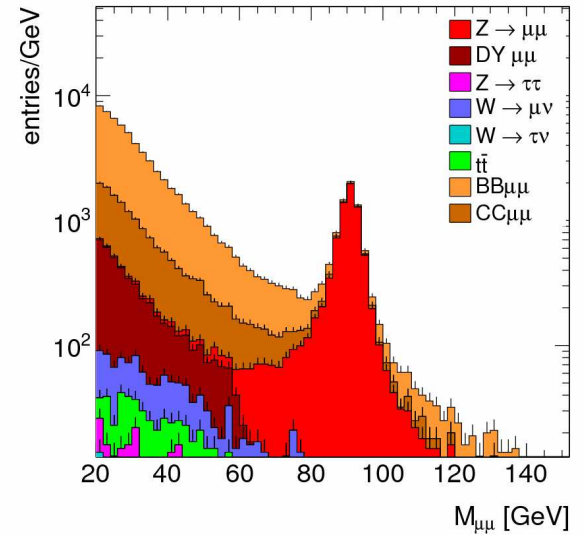
70,000 $W \rightarrow \mu\nu$

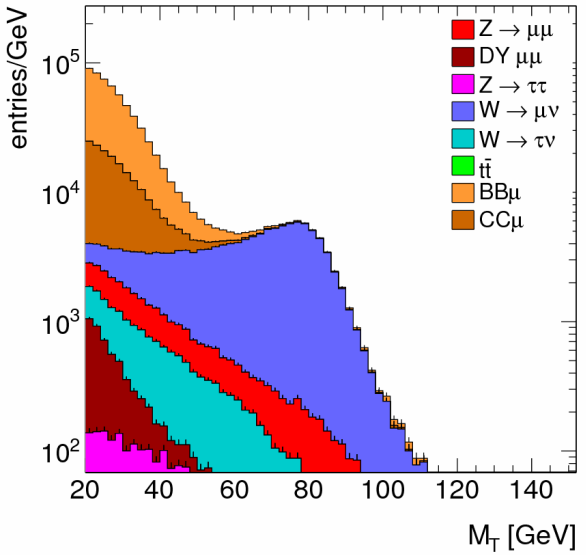
7,000 $Z \rightarrow \mu\mu$

$\delta(N_W/N_Z)$ ~1%

Full analysis on pseudo-data sample

- Signal selection
- Background subtraction and signal estimate
- Efficiency determination
- Impact of detector miscalibrations studied using pseudo data sample reconstructed with:
  - Misalignment of spectrometer from 50 to 500 μm
  - ID misalignments from 50 to 100 μm
  - Miscalibrated missing energy





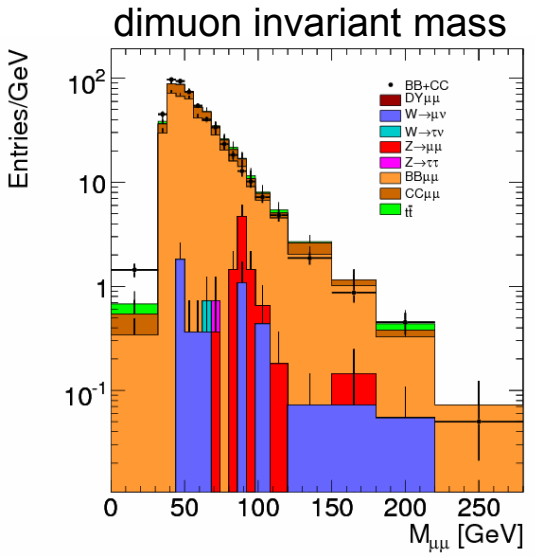
In collaboration with INFN Cosenza, Pavia, Roma2, Roma3

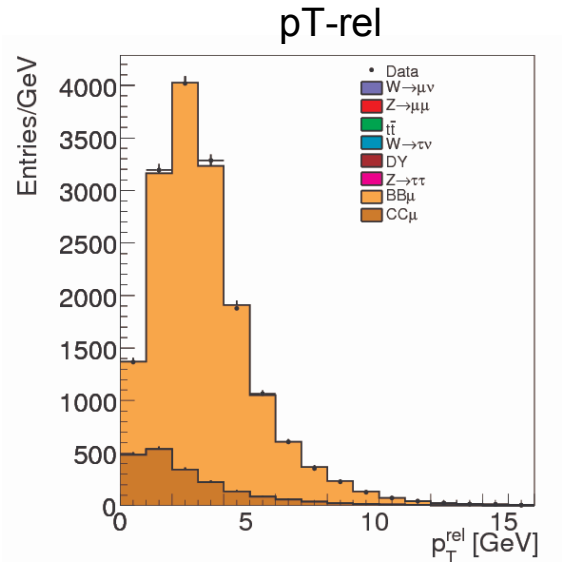
Z and W: Background Estimation

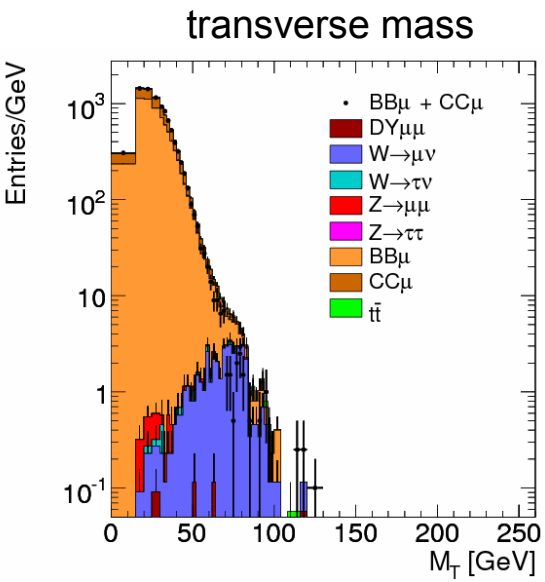
Data-driven techniques to estimate QCD background shape

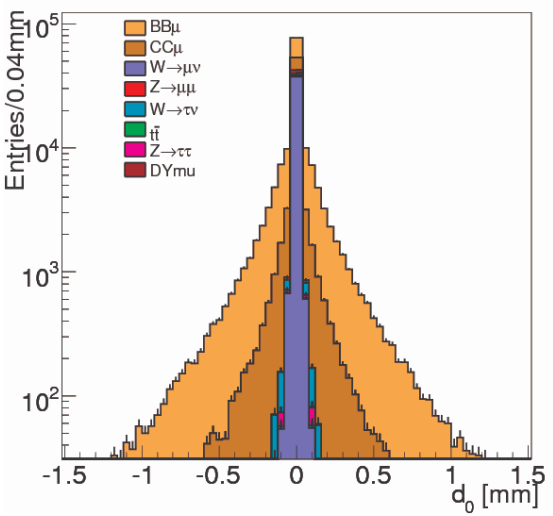
1. Isolated vs non isolated muons
2. Same sign vs opposite sign di-muons
3. b-tagging variables

All methods tested on calibrated and miscalibrated pseudo-data samples

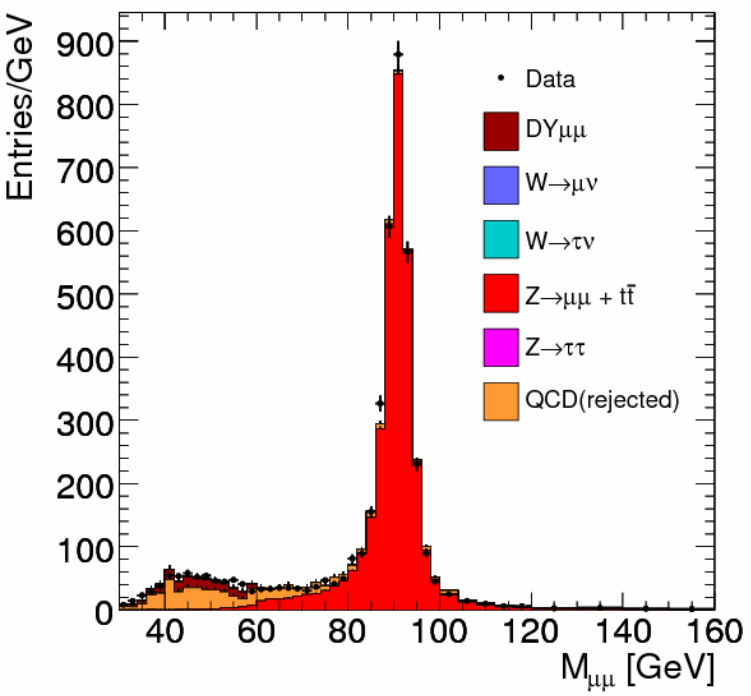


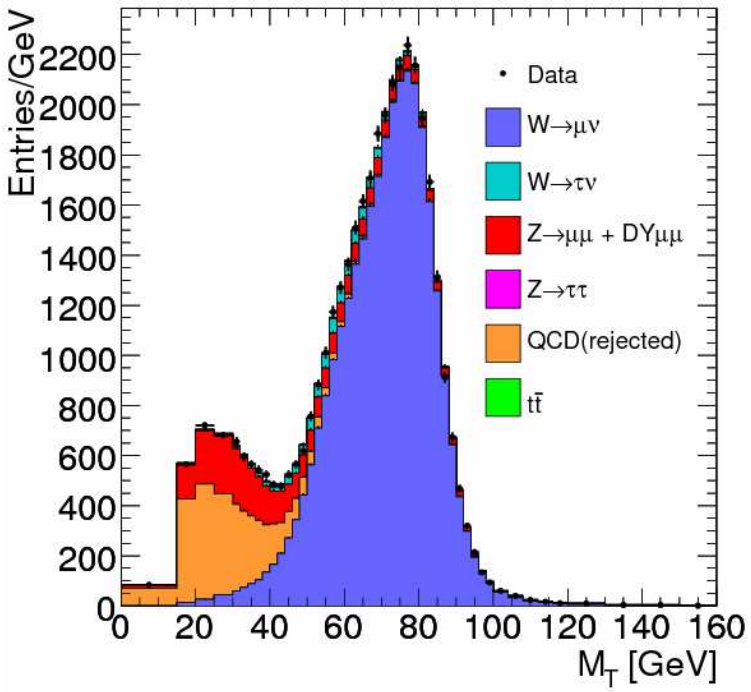






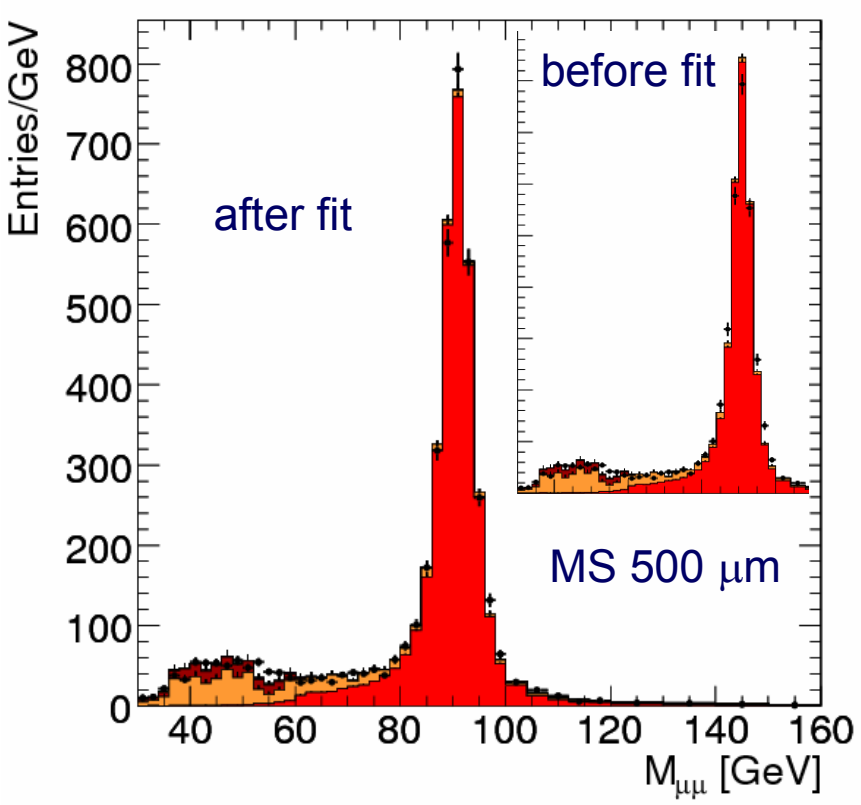
Z and W: Signal Extraction

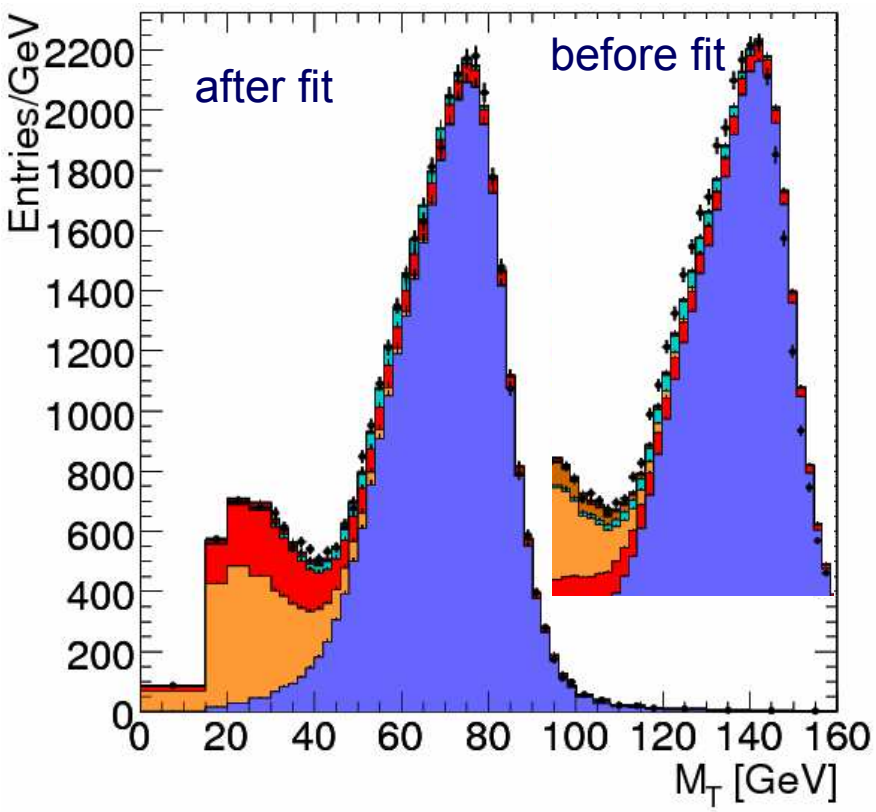




- Fits with template histograms. QCD shapes extracted from pseudo-data samples.
- Fits return expected number of signal events within statistical error
- Good stability with cut variation.

Z and W: Impact of Miscalibrations





Smearing of p_T and E_T^{Miss} included to take into account miscalibrations

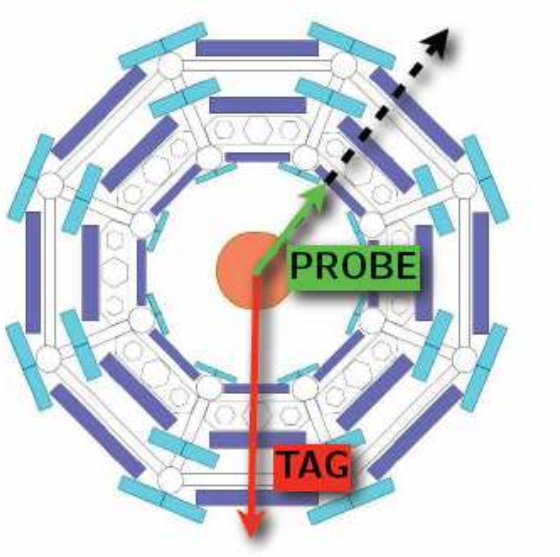
$$p_T^{new} = p_T^{old}(1 + g\Delta a p_T)$$

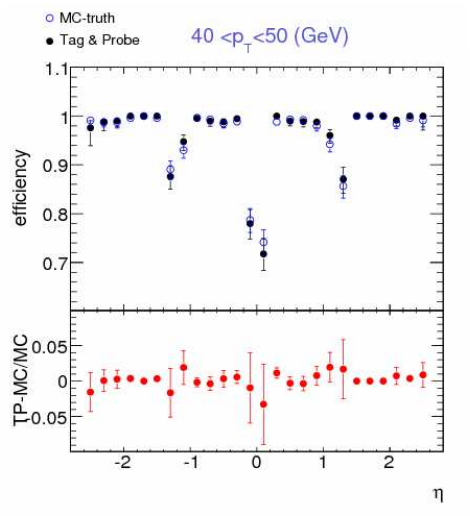
$$E_T^{Miss} = E_T^{Miss} m(1 + g\sigma\sqrt{\sum E_T})$$

g Gaussian number

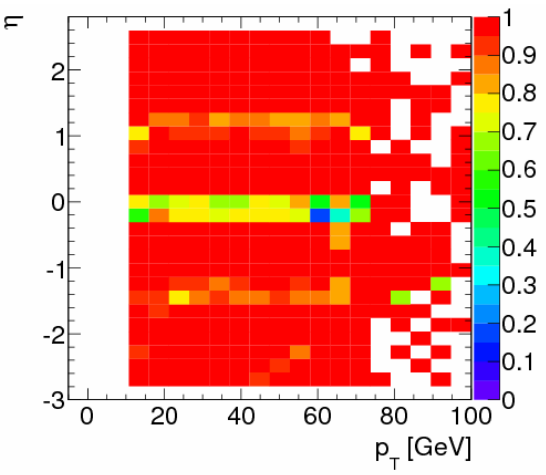
Δa can be used to extrapolate resolution to higher momenta (Z'→μμ)

Z and W: Efficiency Determination





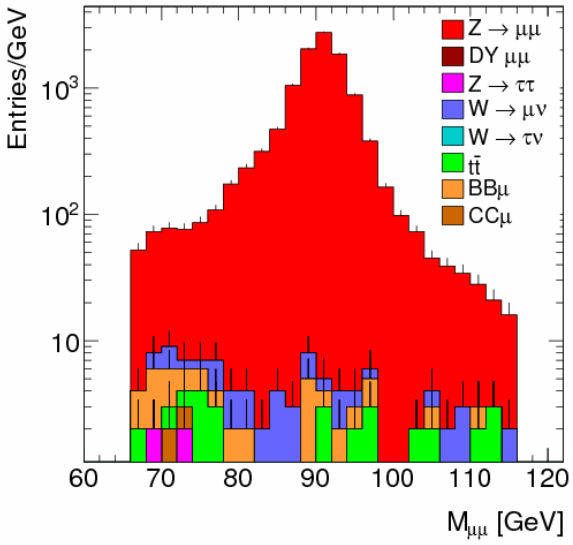
2D efficiency map



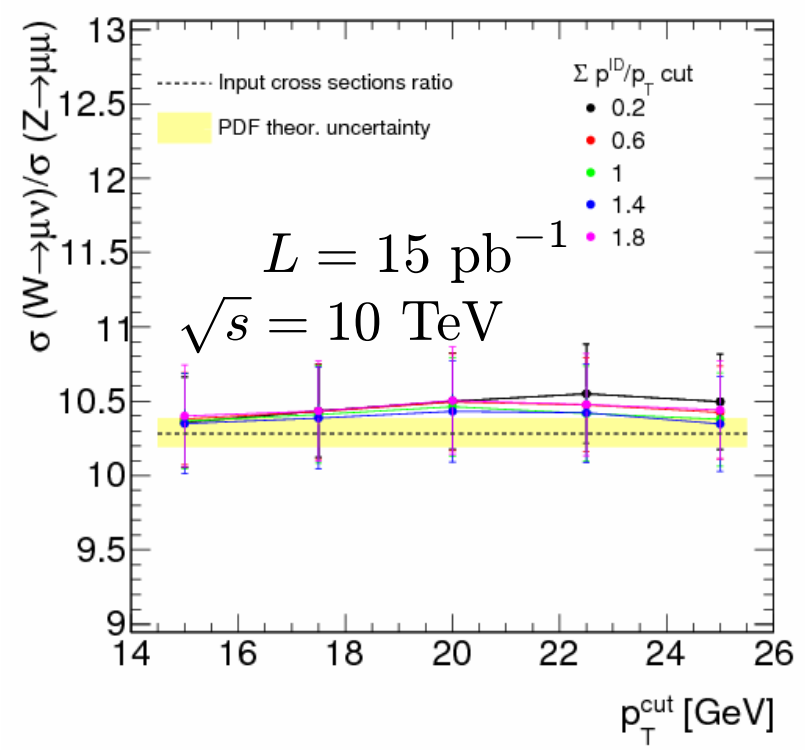
Background larger source of systematics

Reconstruction and trigger efficiencies determined from Z→μμ control sample.

- checks wrt MC truth
- checks on misaligned samples
- MC reweighting to obtain corrected efficiency
- all backgrounds included



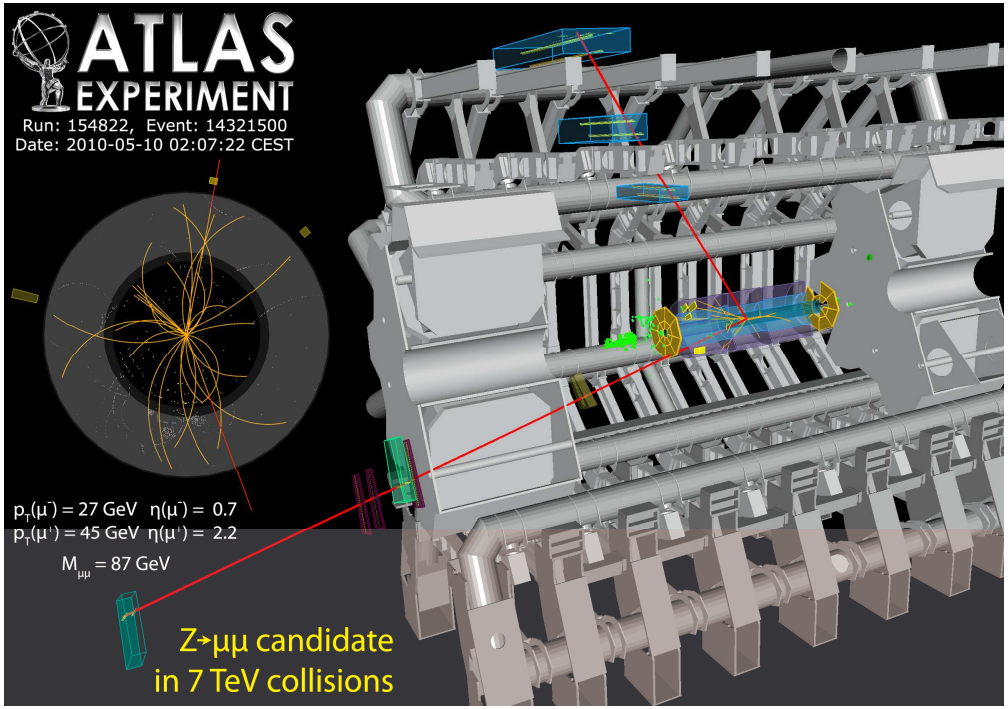
Z and W: Expected Precision and Accuracy

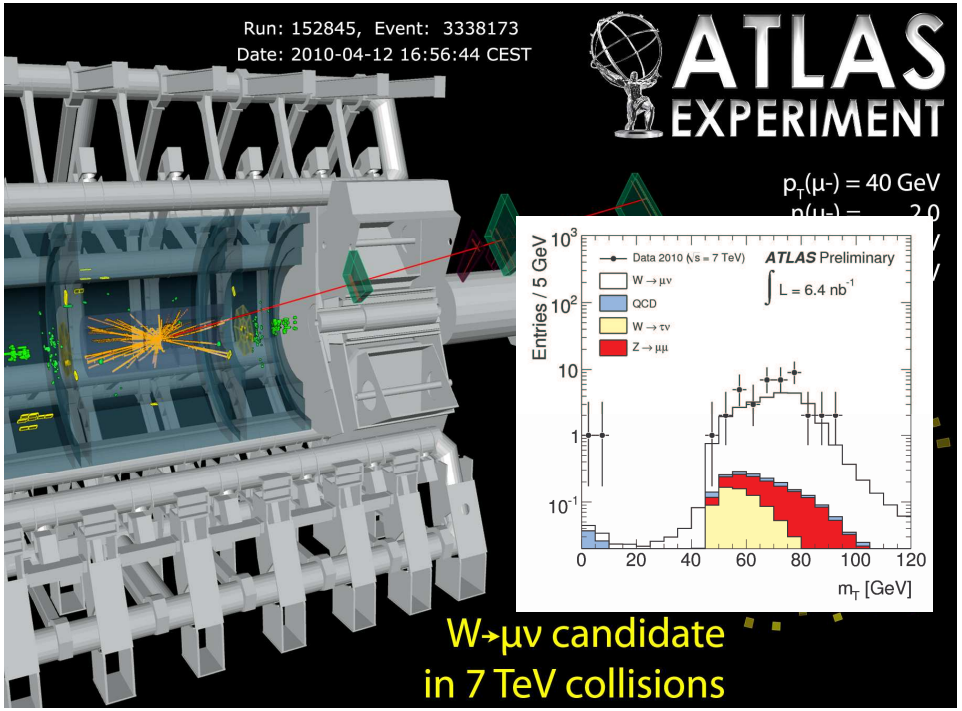


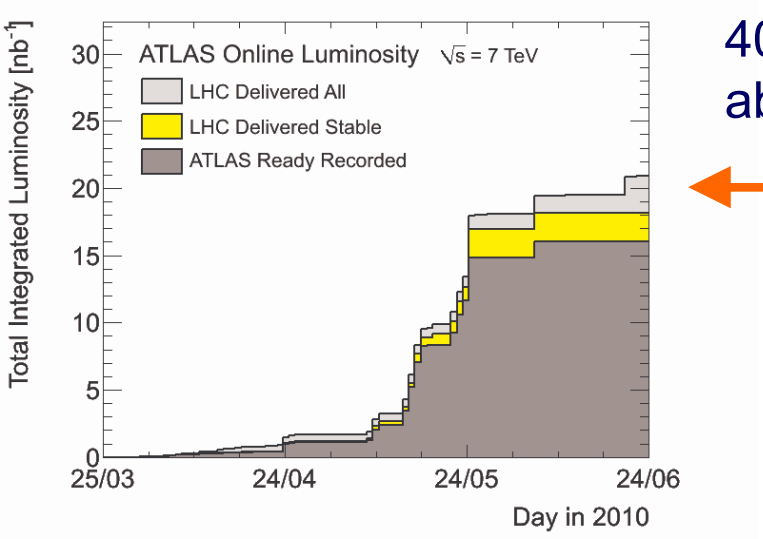
δ effect (%)	$W \to \mu\nu$		$Z \to \mu\mu$		$R_{W/Z}$	
	stat	syst	stat	syst	stat	syst
acceptance	∼0	1.2	∼0	2.0	∼0	2.6
tag-and-probe	-	0.1	-	0.7	-	0.7
efficiency	0.5	1.6	0.6	1.2	0.8	0.4
fit yield	0.5	0.4	1.4	0.7	1.4	0.8
μ scale/resol	-	1.0	-	1.0	-	1.4
$\not{E}_T$ scale/resol	-	1.0	-	-	-	1.0
stability	-	0.8	-	1.3	-	1.0
totals	0.7	2.6	1.5	3.0	1.6	3.5
	2.7		3.4		3.8	
luminosity	10		10		-	

- Theoretical error on acceptances 1-2%
- Efficiency affected up to 1.5% by background contamination
- Partial cancellation of systematic effects in the ratio of counted events
- Large cancellation (5→1%) of theoretical error in ratio of cross sections

Z and W Observation with First Data



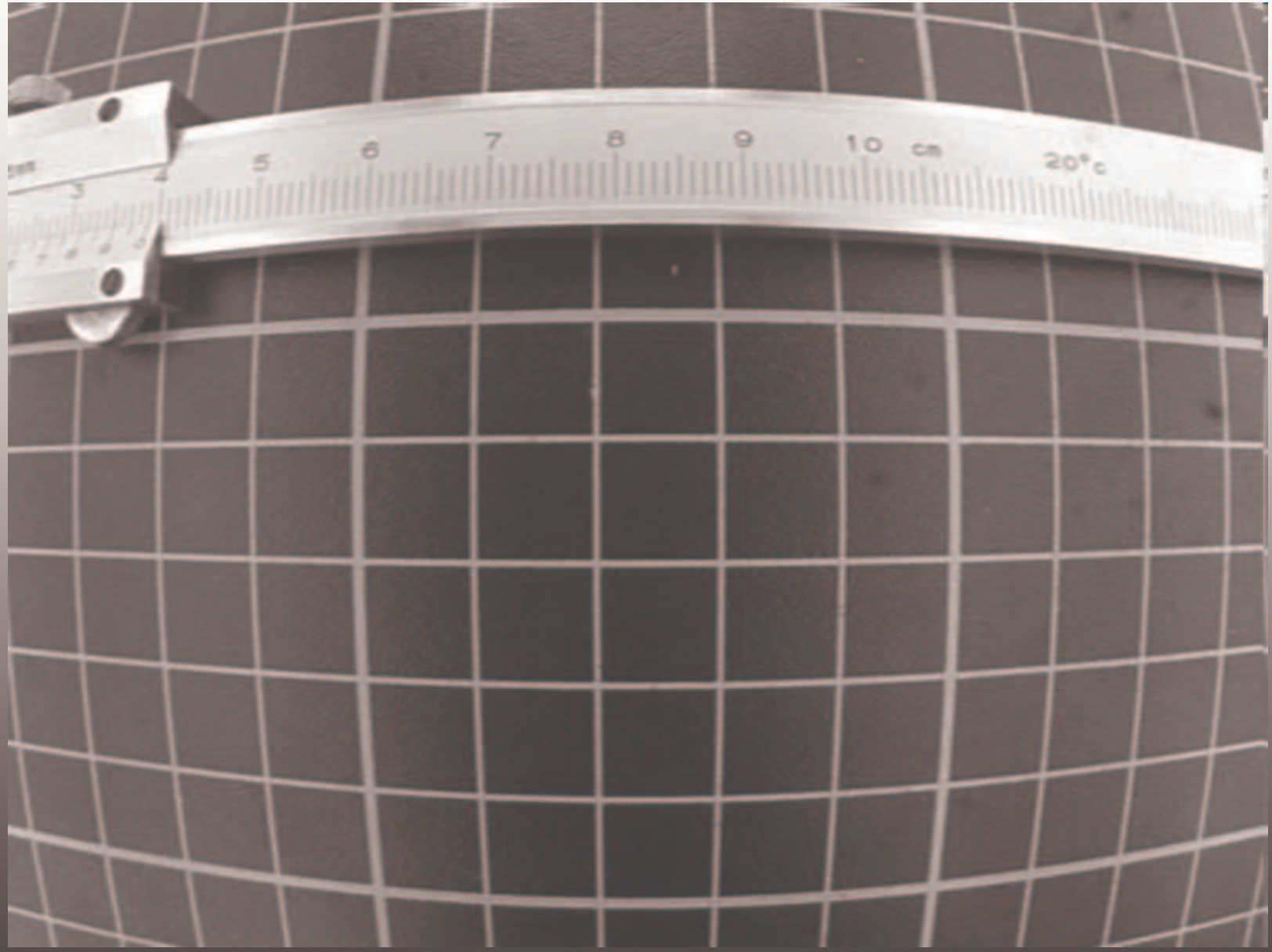




40 W candidates and 2 Z candidates observed with about 7 nb^{-1}

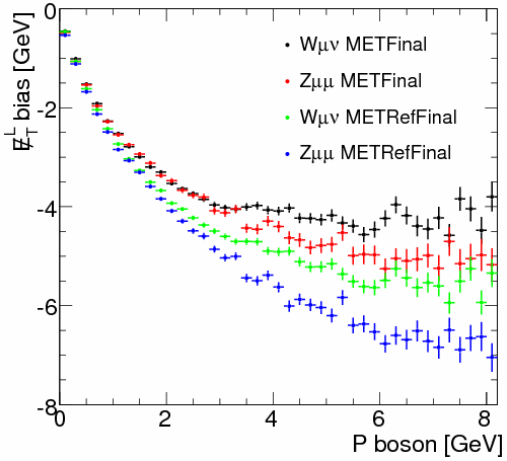
Need a factor 1000 luminosity for a measurement at % level

Calibration and Performances with Physics Processes

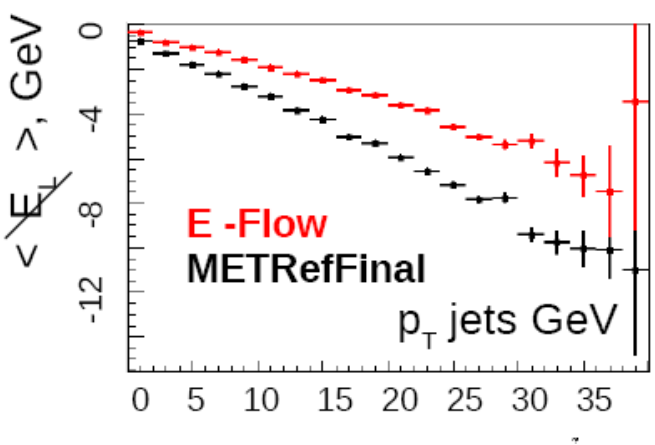


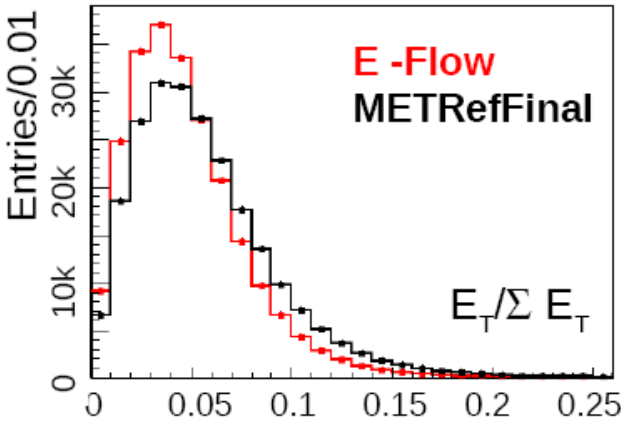
E_T^{Miss}: Energy-Flow Method

The projection of E_T^{Miss} along boson direction sensitive to unbalance between hadronic recoil and muons.



Data (L1 Calo stream) @ 7 TeV





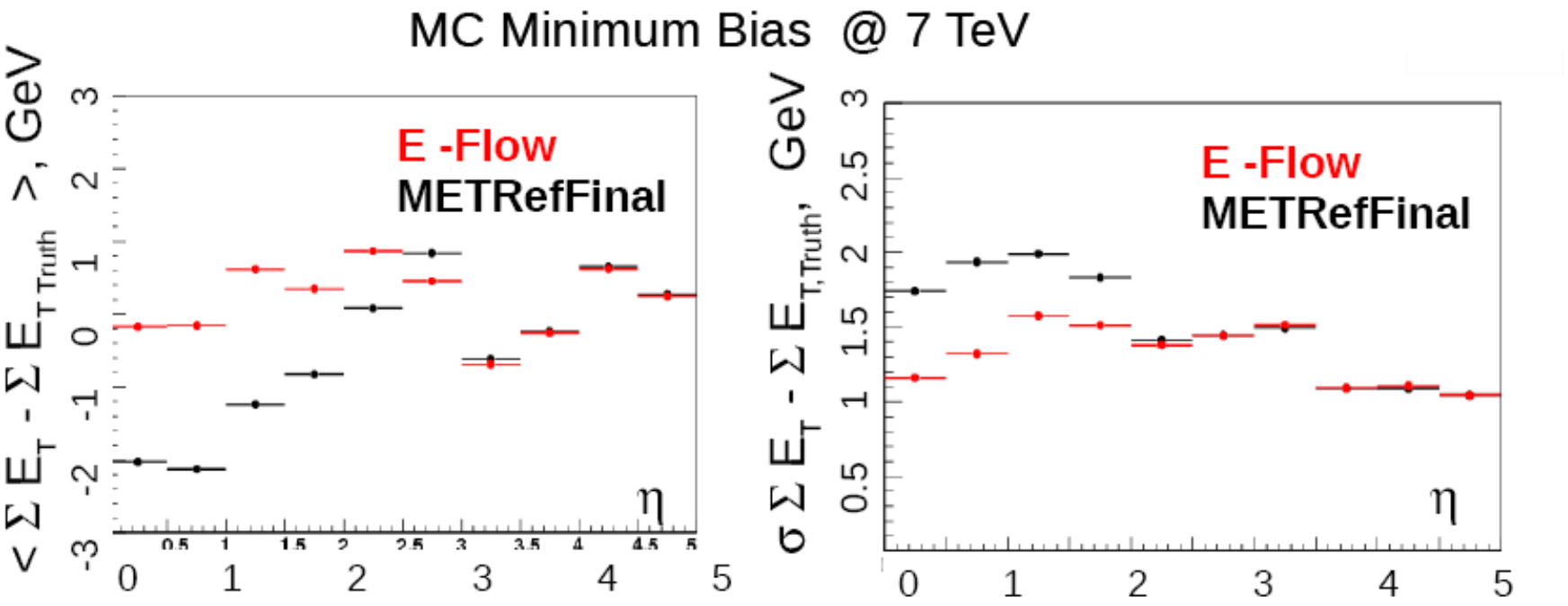
Similar effect observed in a jet sample from 7 TeV data.

Developed an energy-flow algorithm combining track and calorimeter information.
Substantial improvement in E_T^{Miss} linearity and resolution.

ATL-PHYS-COM-2010-184

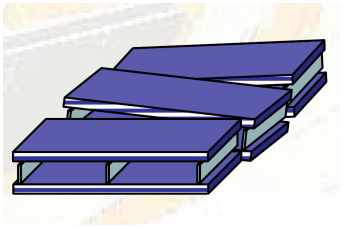
E_T^{Miss}: Energy-Flow Method

Better calibration and resolution also of ΣE_T
Improved agreement data/MC, good for W analysis

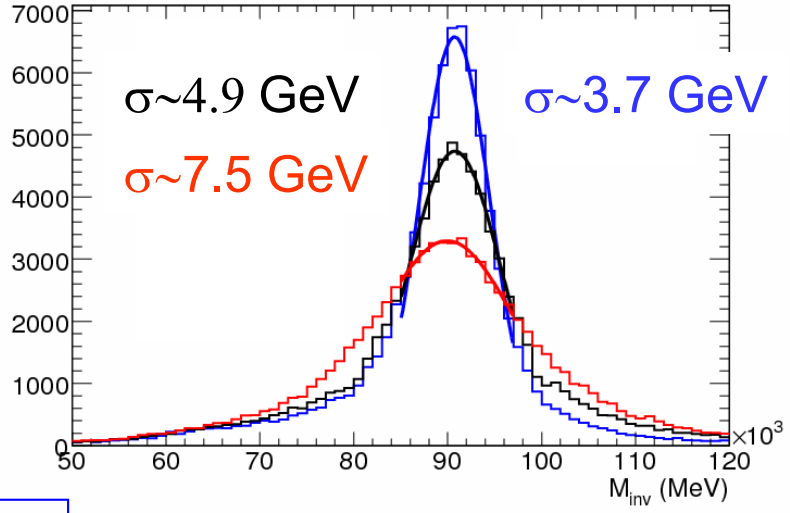


Calibration and Monitoring with Z→μμ

Exploit Z mass constraint to calibrate momentum scale at tower level.



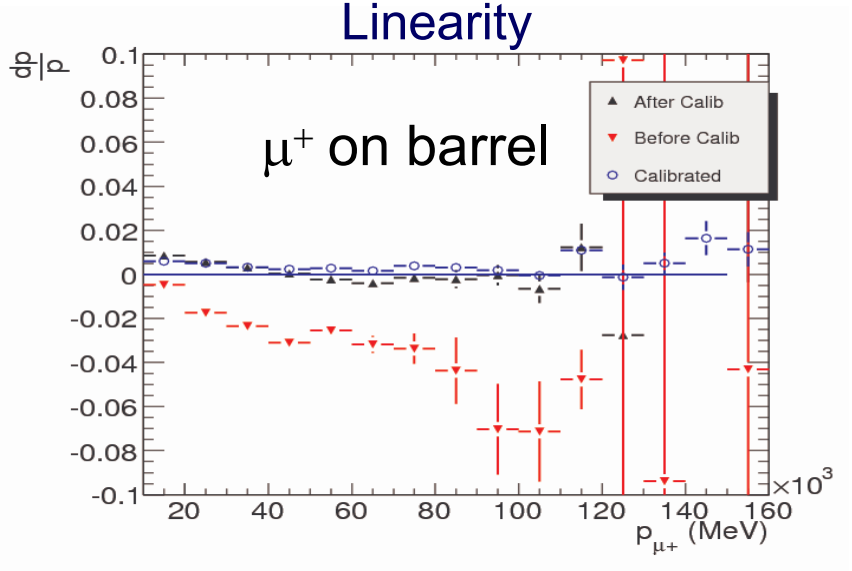
Test with large miscalibrations
- shifts 1mm
- rotations 1 mrad



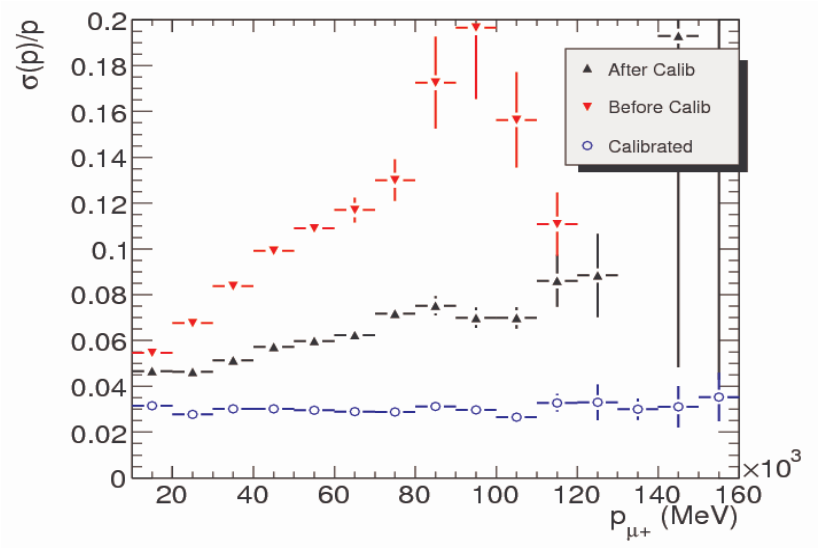
L~100 pb^{-1}

Before calibration
After calibration
Ideally calibrated detector

Linearity



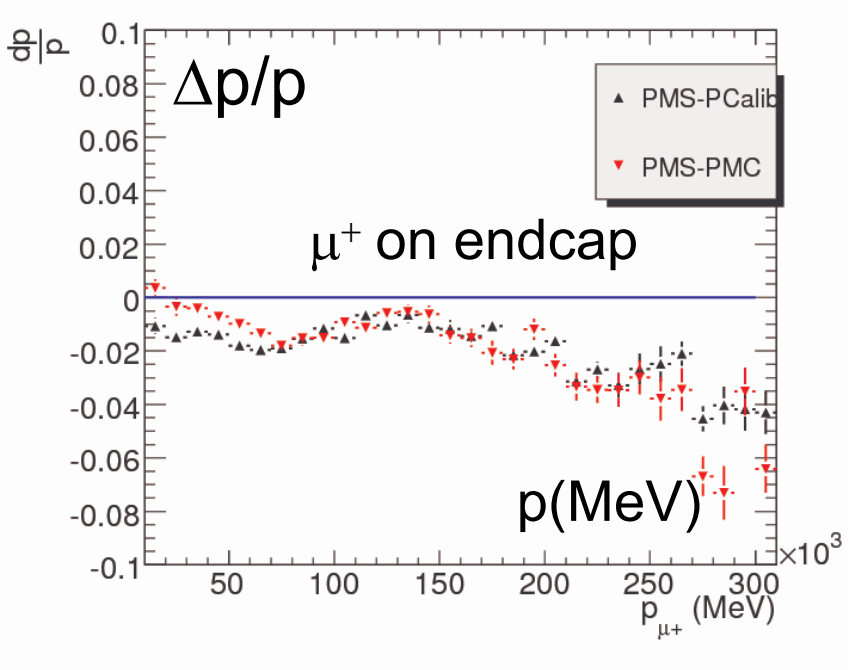
Resolution

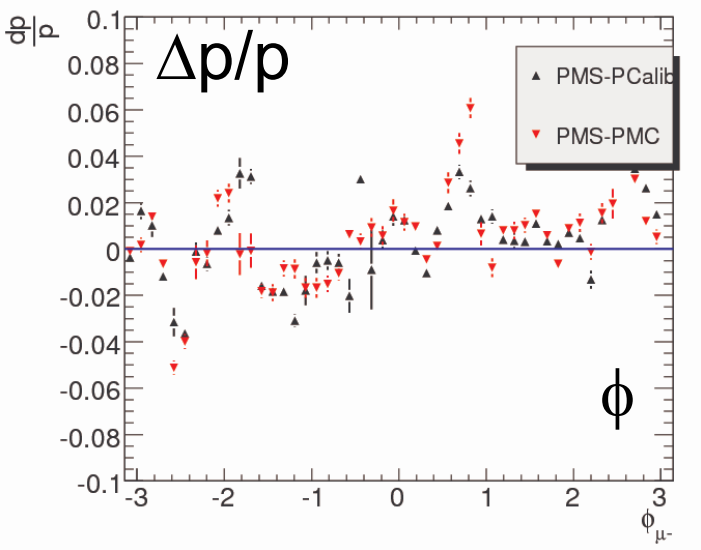


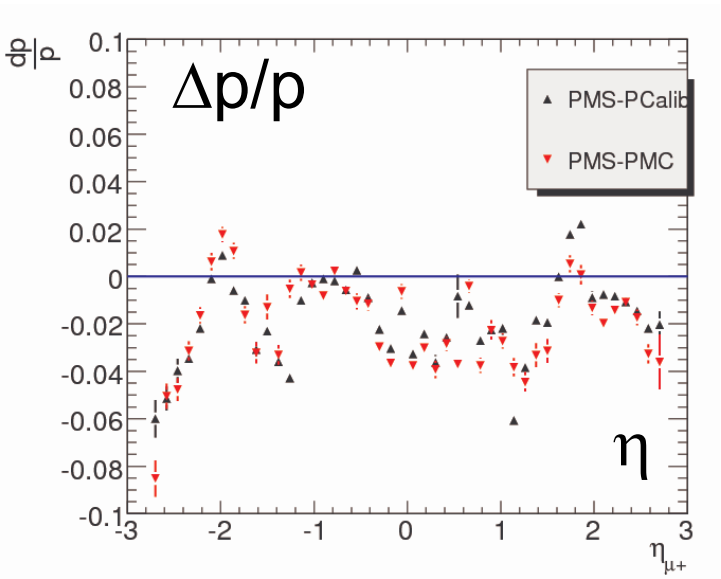
Calibration and Monitoring with Z→μμ

Use the new calibrated momenta to monitor the momentum linearity in the MS.

Δp=pMS-pMC
Δp=pMS-pCalib







Search for Exotics and Higgs

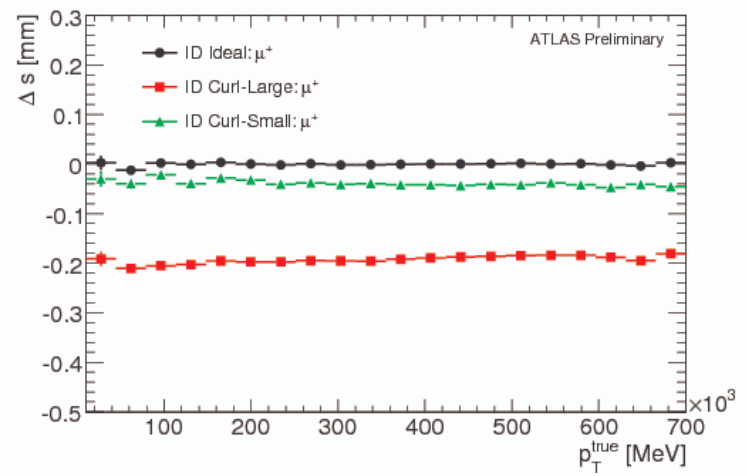
Impact of Miscalibrations on Discovery Potential of Z'→μμ

The impact of several detector misalignments on Z' discovery have been studied:

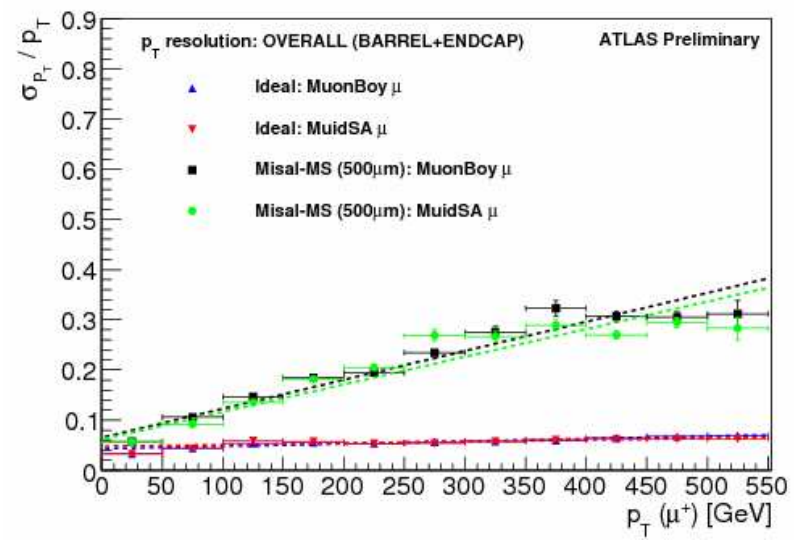
- MS random misalignments O(50→500 μm)
- ID random misalignments O(50→100 μm)
- ID "weak modes"

Study with large misalignments to check robustness of reconstruction.

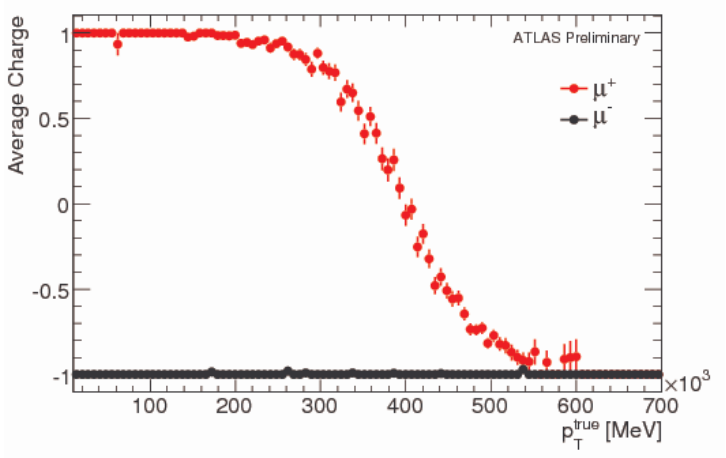
ID "weak modes"



500 μm misalignments in MS impact on SA muon resolution



Charge inversion due to large weak mode



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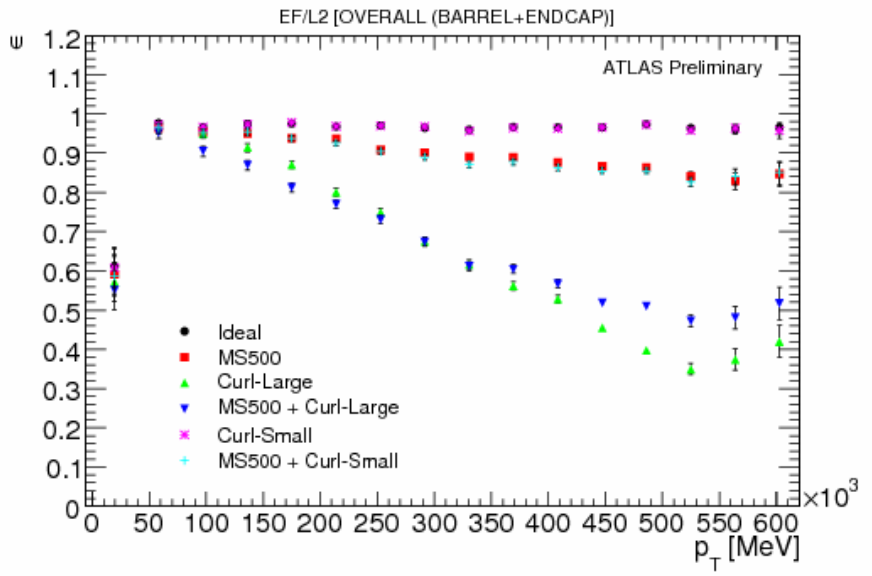
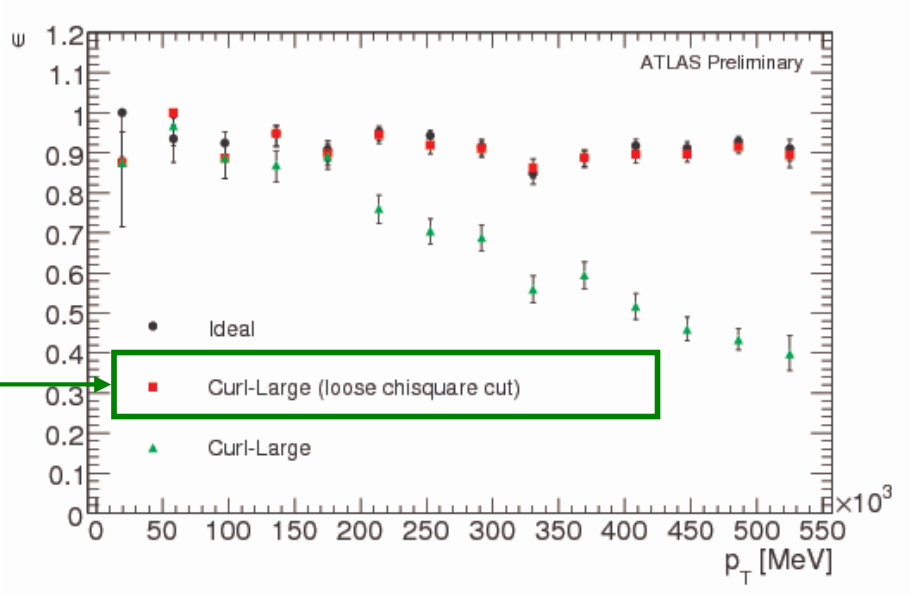
Impact of Miscalibrations on Discovery Potential of Z' →μμ

Large inefficiency, observed in combining ID and MS tracks, reflects on trigger efficiency.

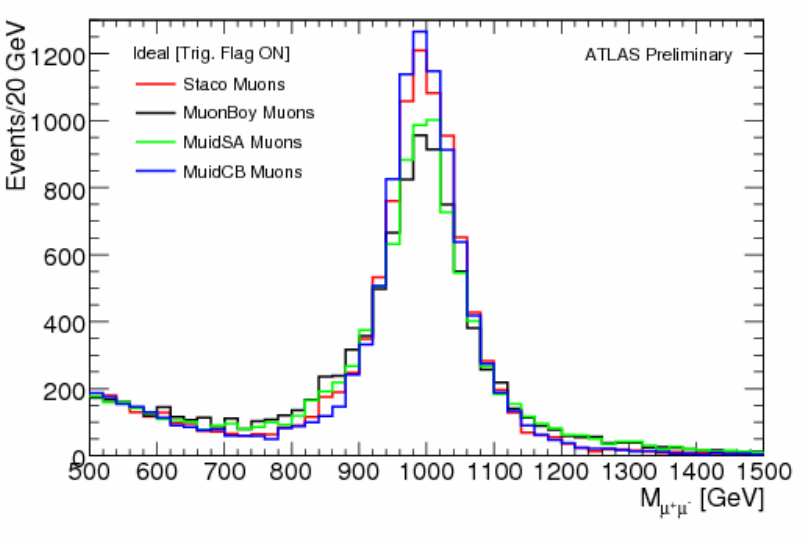


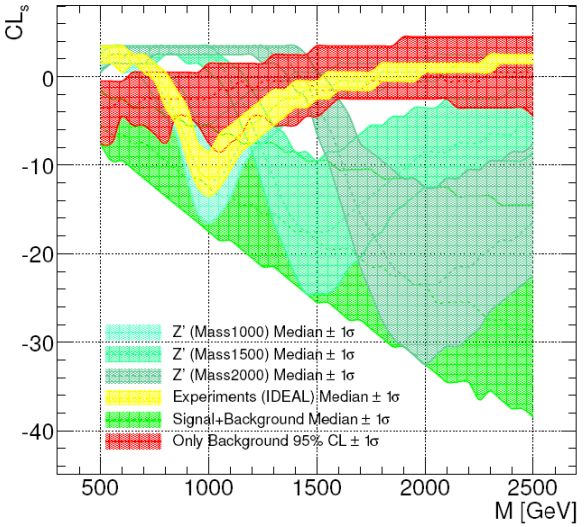
Cured by taking into account the alignment uncertainty in the error matrix.



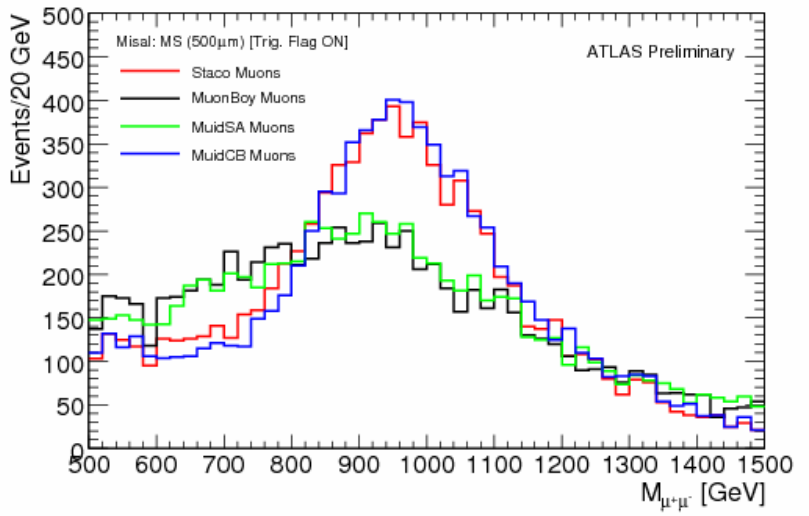
Impact of Miscalibrations on Discovery Potential of Z' →μμ

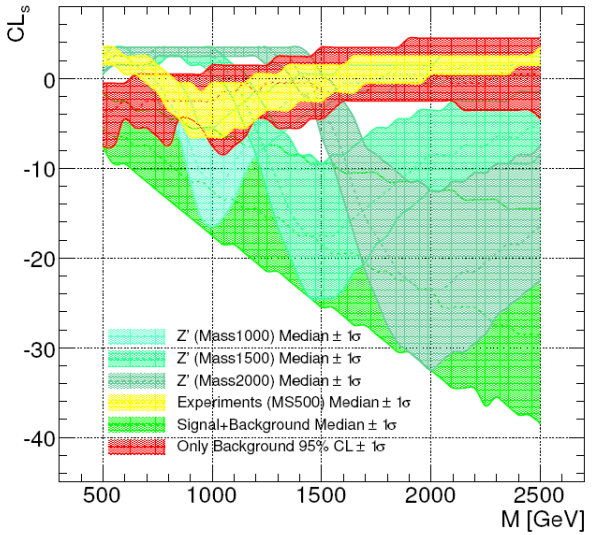
ideal alignment





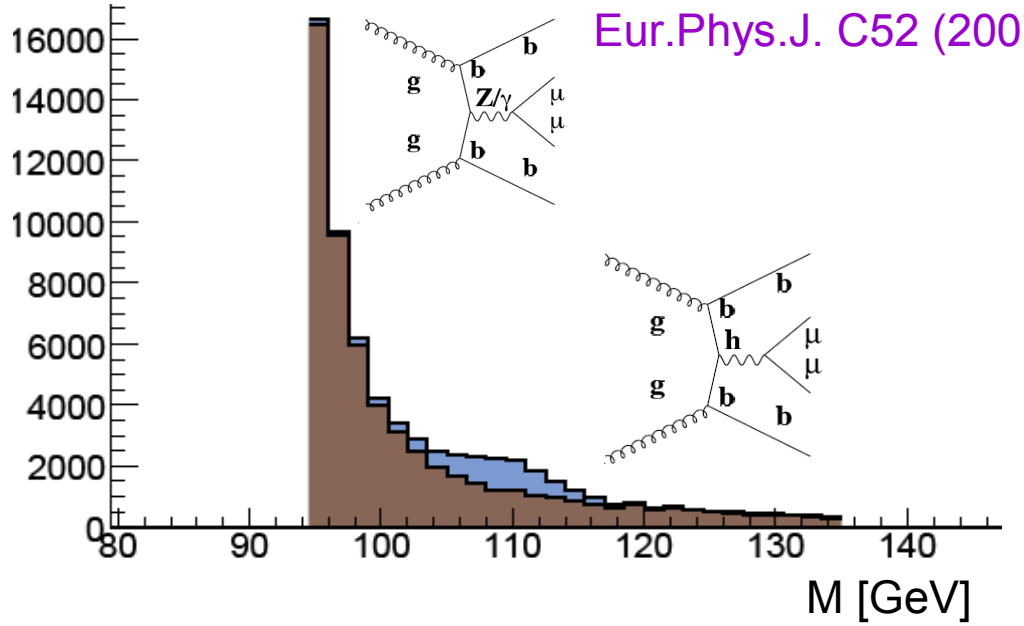
500 μm misalignments in MS





Possible discovery with 100 pb^{-1} @ 7 TeV

pp→bbh/A→bbμμ

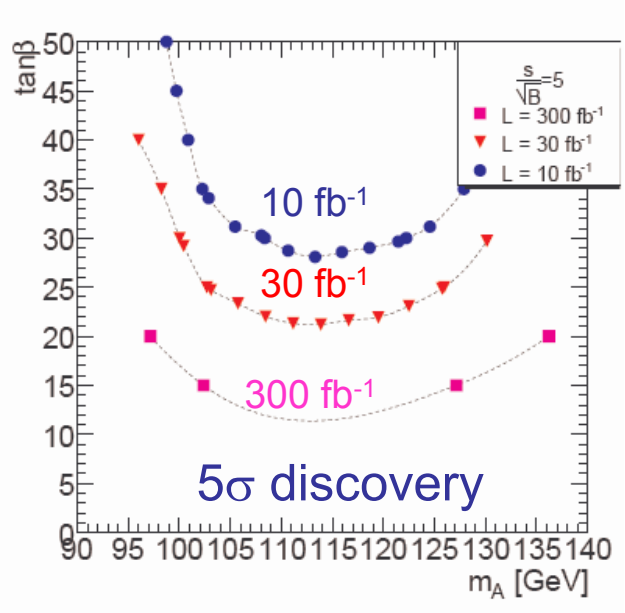


Eur.Phys.J. C52 (2007)

$tan\beta$	45
$m_{A/h}$	110 GeV
L	300 fb^{-1}
$\sqrt{s}$	14 TeV

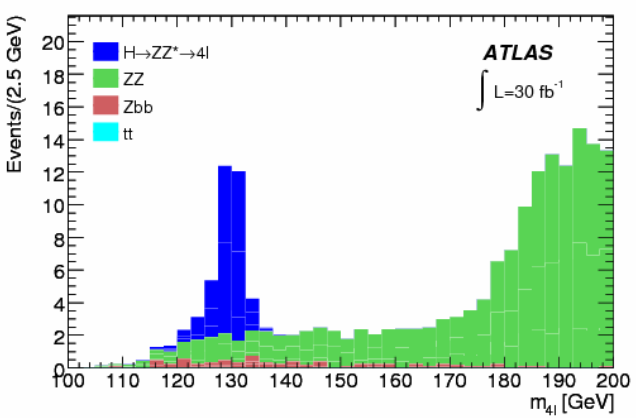
- MC study for discovery of MSSM h/A bosons in the large tanβ region and mass close to 100 GeV.
- Large pp→bbZ→bbμμ background (control samples from Z→ee decays)
- Select 2 muons (p_T>10 GeV) + 2 jets (≥1 b-jet)

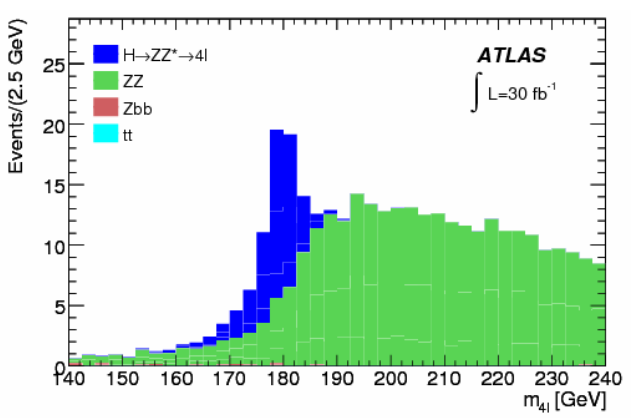
Possible discovery with large tanβ with L=10 fb^{-1} @ 14 TeV

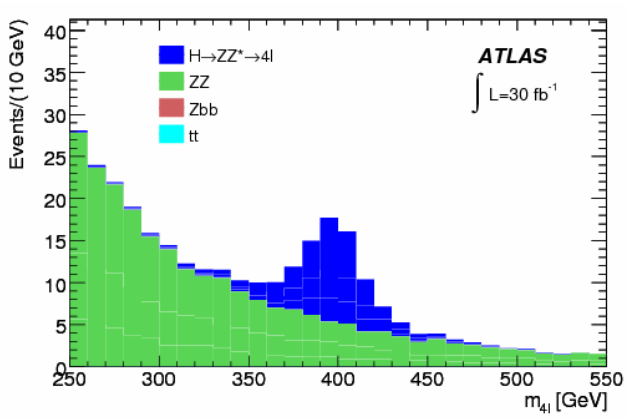


In collaboration with Roma1

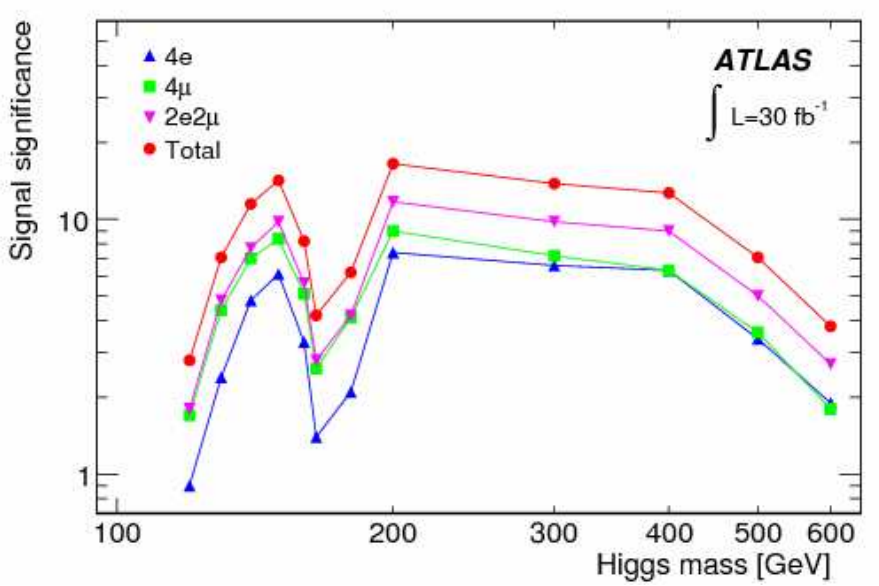
pp→H→ZZ*→4μ







L=30 fb-1 @ 14 TeV



Background from ZZ* continuum:

σ(pp→ZZ→4 leptons) = O(100 fb)

σ(pp→H→4 leptons) = O(1-10 fb)

CERN-OPEN-2008-020

In collaboration with Cosenza

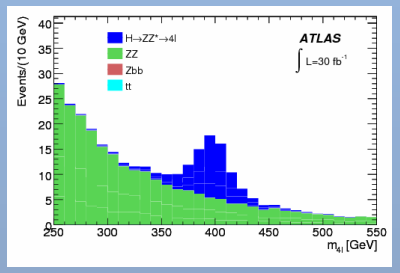
Summary

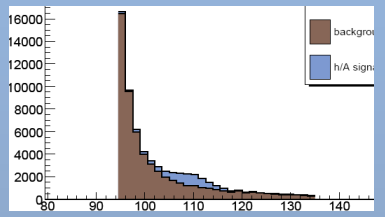
10^2 L(fb^{-1})

10^{-1}

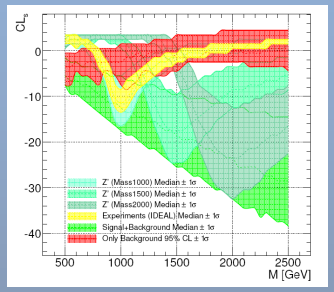
10^{-2}

0

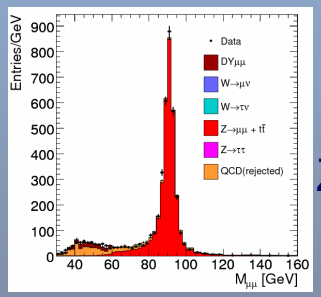




SM or MSSM Higgs

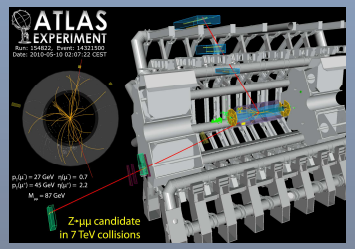


Z' exclusion/observation

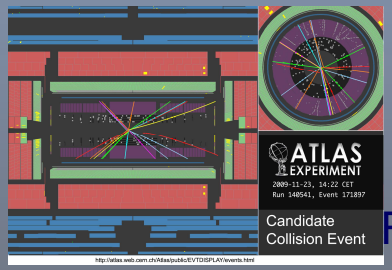


Z and W cross sections

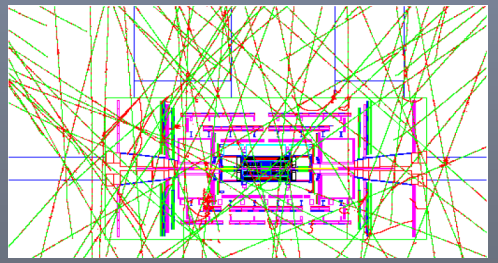
Data Preparation



First Z→μμ candidate



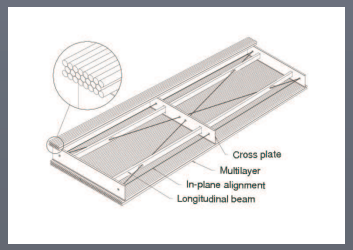
First Collision



Cosmic rays

Installation

Assembly



Design

Tier2