ATLAS LNF activity
Status Report

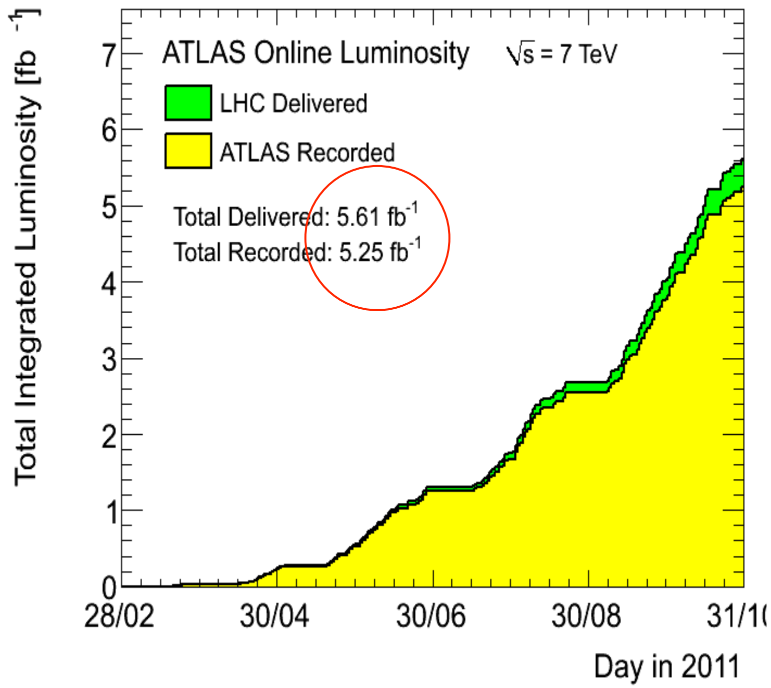
LNF Scientific Committee, Frascati, 19 Jan 2012

M. Testa on behalf of ATLAS LNF group

Annovi A., Antonelli M., Bilokon H., Cerutti F., Chiarella V., Curatolo M., Dreucci M., Esposito B., Gatti C., Laurelli P., Maccarrone G., Sansoni A., Testa M., Di Nardo R., Castagnaro A., Volpi G., Beretta M., Martini A., Nicoletti G., Vilucchi E.

Status of LHC and ATLAS

	2010	2011
ATLAS recorded integrated luminosity	45 pb^{-1}(pp) 9 μb^{-1}(PbPb)	5.25 fb^{-1} 200nb^{-1}(PbPb)
Peak Luminosity $cm^{-2}s^{-1}$	$2.1 \cdot 10^{32}$	$3.65 \cdot 10^{33}$
Mean interactions / bunch crossing	~2	6.3 / 11.6



Fraction of non-operational detector channels: few permil to 3.5%
(depends on the sub-detector)

Data taking eff. in 2011: 93.5%
Fraction of good quality data: 90-96%

Introduction

In the last two years ATLAS had excellent performances
and published several analyses (~110 published/submitted papers)

The ATLAS LNF has given in the last 20 years a relevant contribution to:

- Project, construction, test and installation, commissioning and management of the μ spectrometer
- Trigger DAQ

The Group has a leading role in the determination and optimization of the μ spectrometer performances in ATLAS (Muon Analysis Task Force chair person)

The Group has contributed to several analyses mostly involving muons the final states

- H->WW->lνlν, H->ZZ->4l, μ inclusive cross section, J/Ψ, WW->lνjj, W/Z inclusive, minimum bias

The Group is deeply involved in

- Reconstruction algorithms (μ,E_T^{miss})
- In Computing Activity: Tier2
- In the detector upgrade:
    - Trigger upgrade with fast tracks reconstruction (FTK)
    - Muon spectrometer upgrade

Physics and Performances

- Ks and Λ production
- μ inclusive cross section
- J/Ψ and Z suppression in Pb-Pb collisions
- W/Z inclusive (not covered in this talk)
- μ reconstruction
- E_T^{miss} reconstruction
- $H \rightarrow WW \rightarrow l\nu l\nu$
- $H \rightarrow ZZ \rightarrow 4l$
- $WW \rightarrow l\nu jj$ (not covered in this talk)

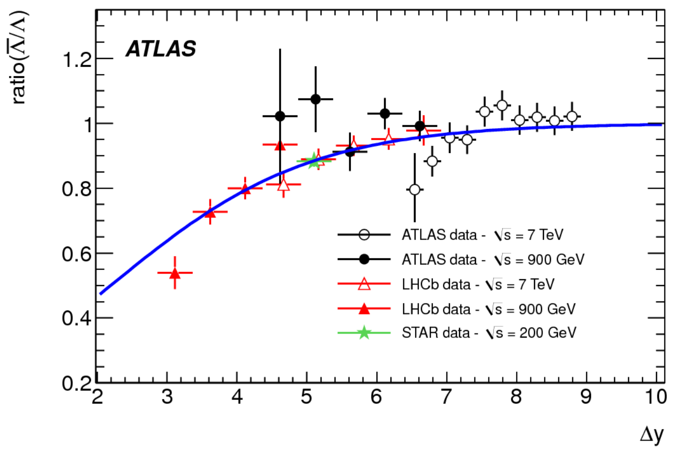
Study of K_S and Λ productions

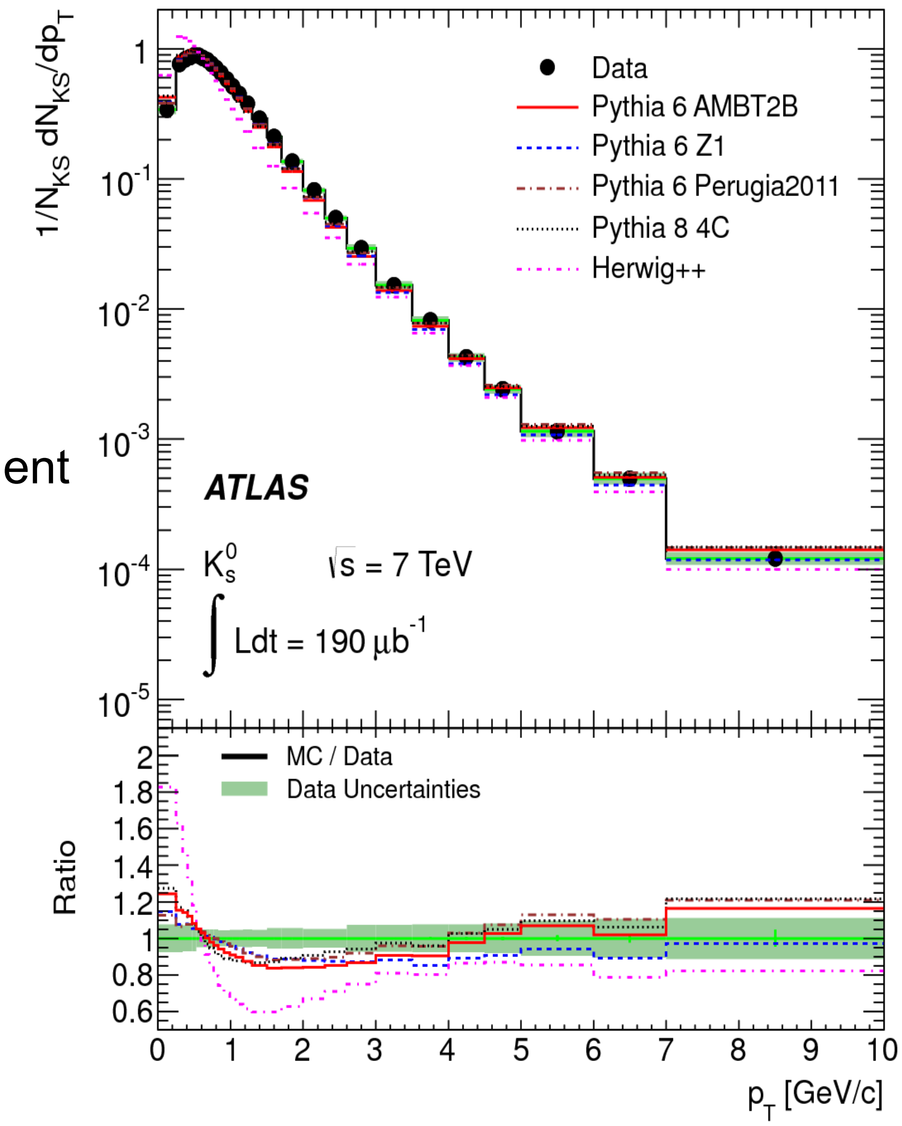
Both the distribution of p_T and y of K_S and Λ are
- Important for tuning MC generators
- Models strongly disagree
  ➔ experimental input needed

$\bar{\Lambda}/\Lambda$ production ratio correlated with baryon-number transport away from the beam remnant in pp collisions

No model agrees both in p_T and multiplicity Simultaneously ➔ MC further model development
$\bar{\Lambda}/\Lambda$ in agreement with the expectations and other experiments

PRD 75 (2012) 012001



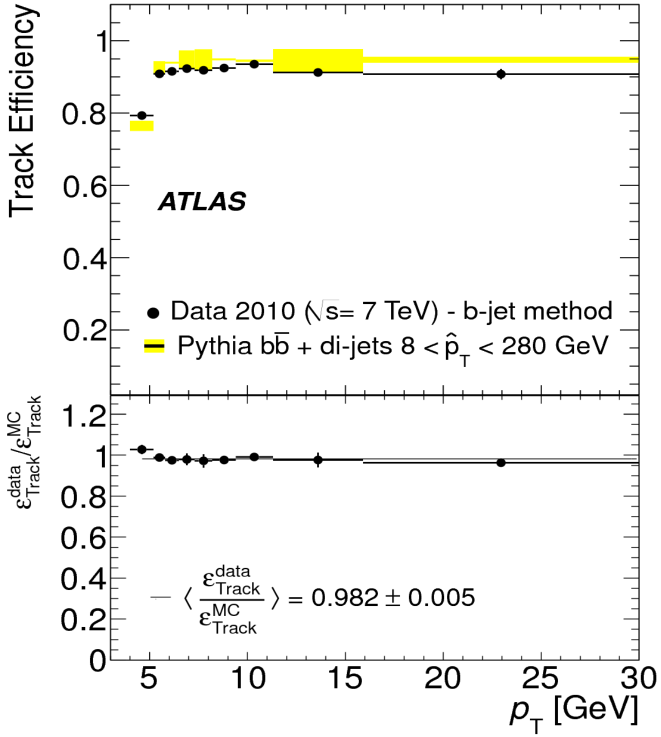


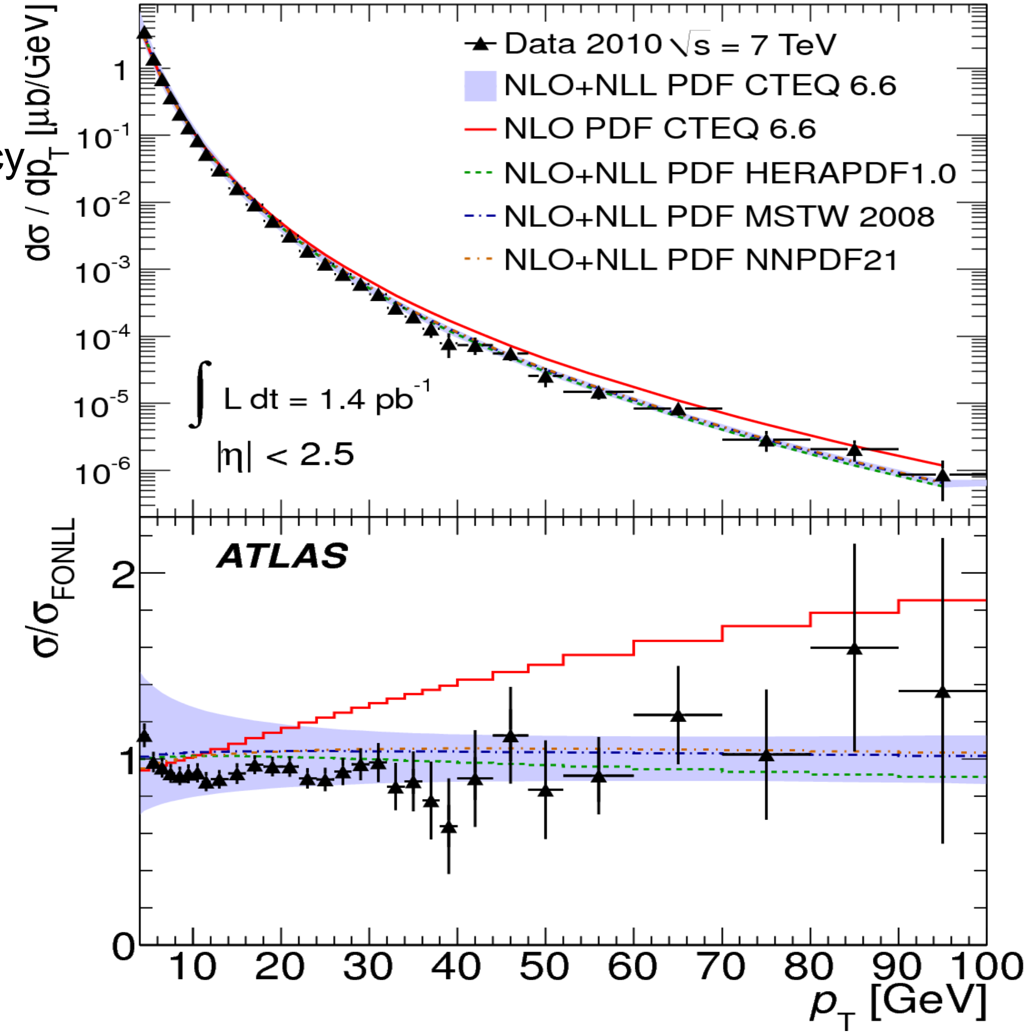
Accepted by PLB

Measurement of the inclusive μ cross section

At low p_T dominated by b and c decays
→Constrain the theoretical predictions for heavy flavour productions
First time in hadronic colliders data show sensitivity in the muon channel to NLL high-pt resummation in the heavy flavour production

Frascati's contribution in tracking efficiency determination at low pt using muons from B decay

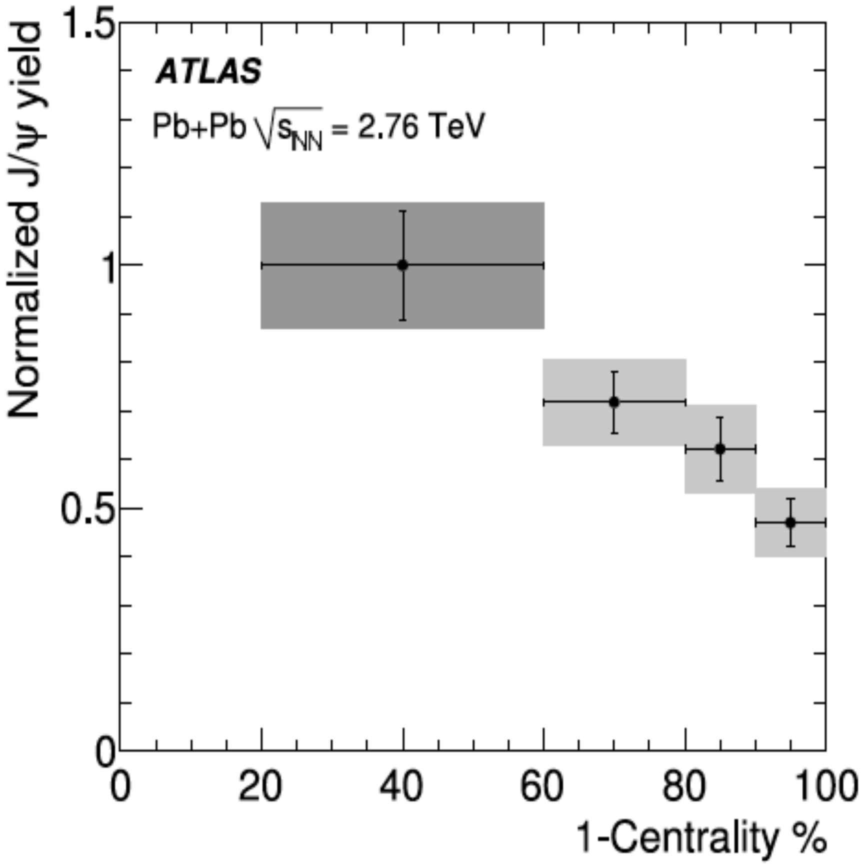


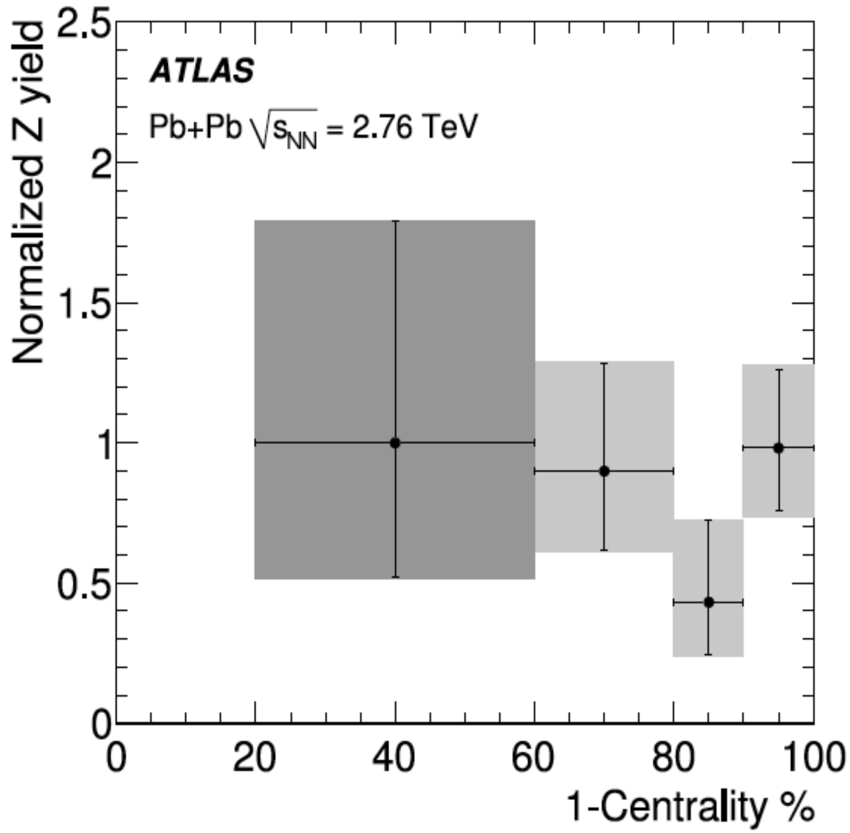


Measurement of the centrality dependence of J/Ψ yields and observation of Z production in lead-lead collisions

If QGP is formed, Quark Deconfinement suppress quarkonium production via color screening

Published on PLB:
Relevant contribution and paper editing





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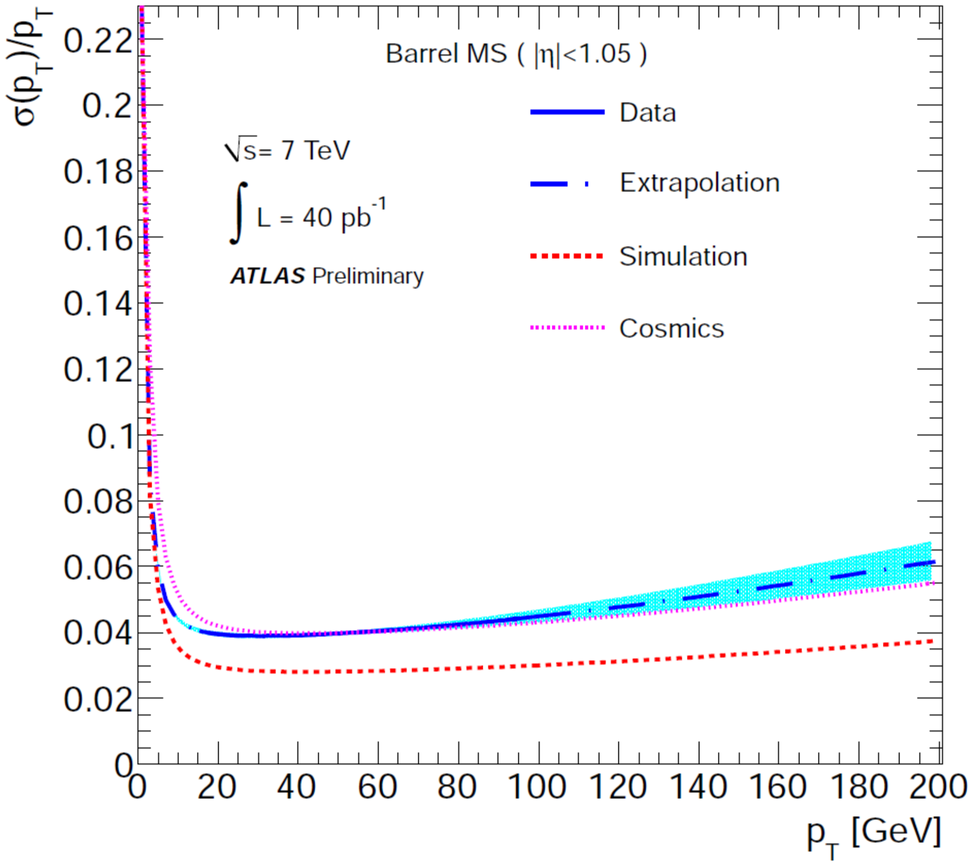
Study on Muons performances (I)

Relevant contribution to performance studies :
efficiency, calibration, resolution (Z, J/Ψ, cosmics)
Muon Analysis Task Force coordination



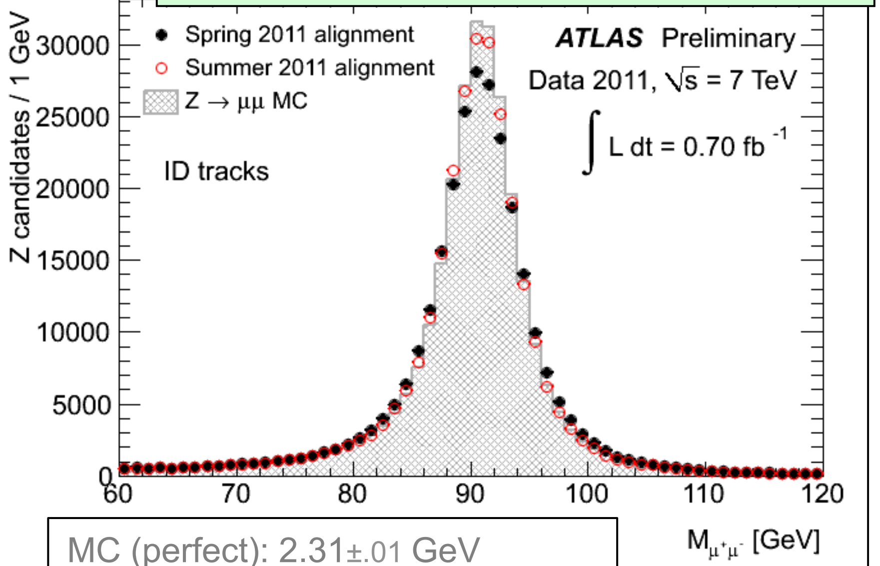
ATLAS-CONF-2011-046
EPJC 70 (2010) 875
Leading role paper editing
and coordinating

Improvement in alignment will
give better data-MC agreement
(see later)

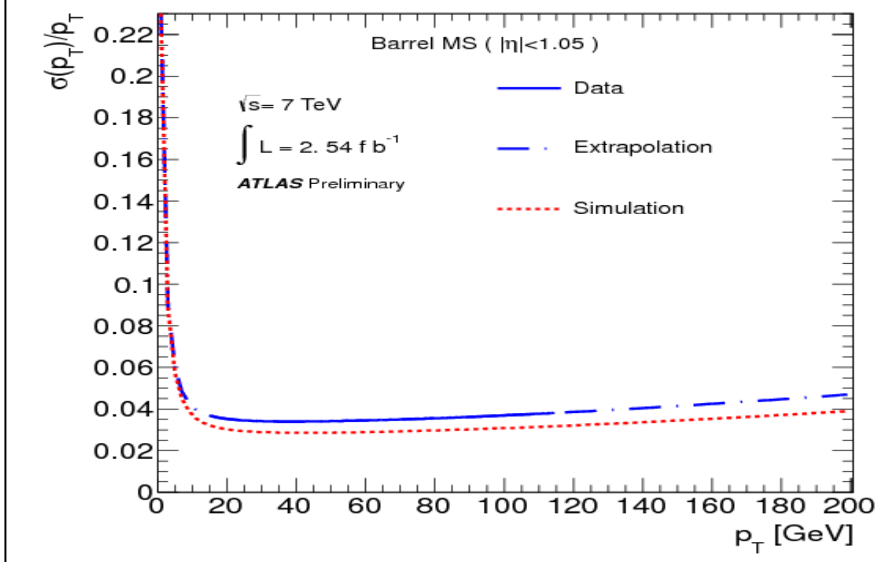
Study on Muons performances (II)

Improvement of the alignment with respect to 2010 → Improved agreement with MC with respect to 2010

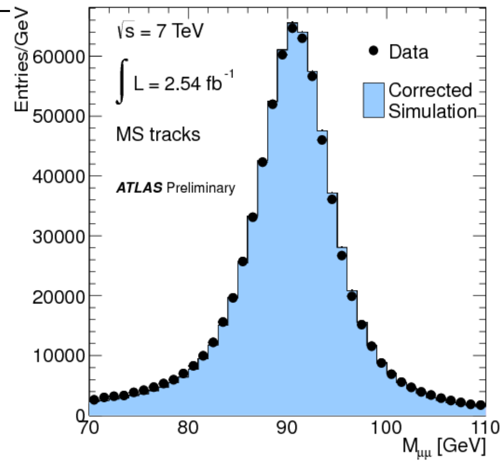
Improving Z→μμ mass resolution



MC (perfect): 2.31±.01 GeV
Data Spring 2011 : 2.89±.01 GeV
Data Summer 2011: 2.45±.01 GeV

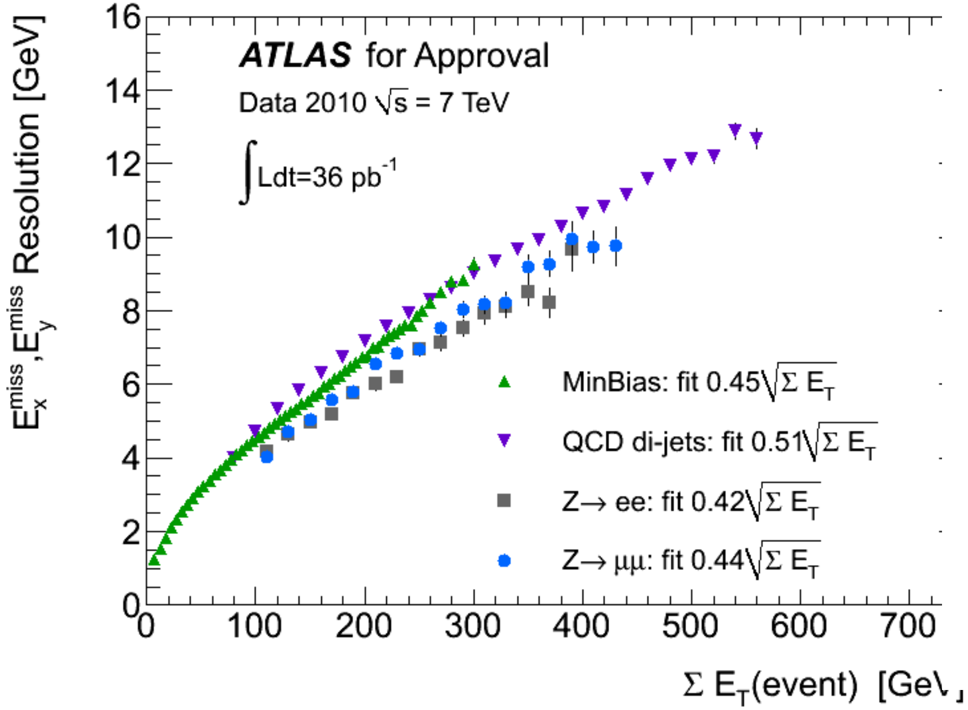


LNF group active in the measurement of the resolution parameters from fit to the Z lineshape →

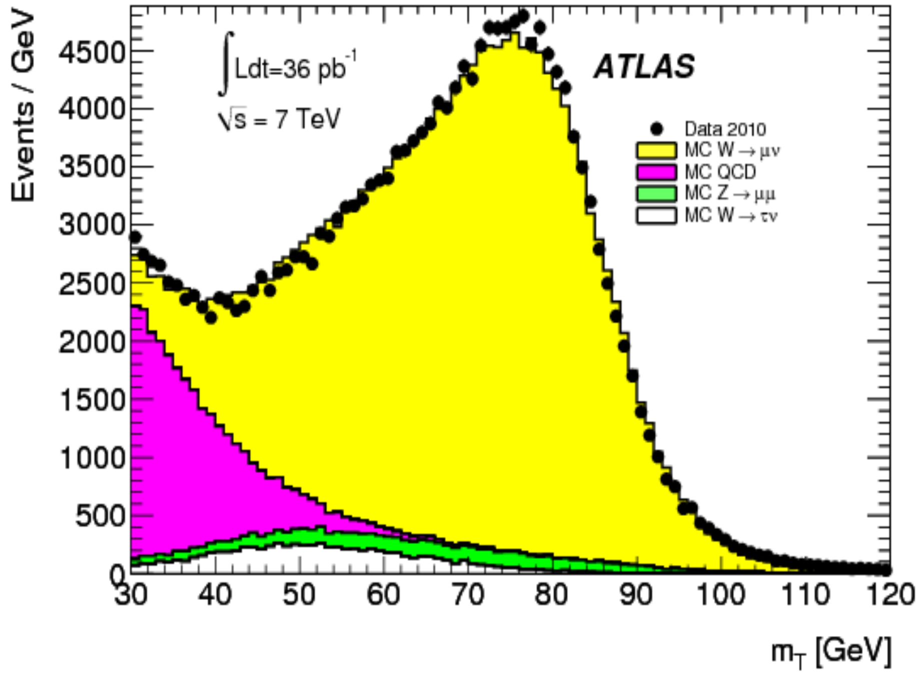


E_T^{miss} Reconstruction

Relevant contributions to E_t^{miss} reconstruction
Energy Flow package responsibility for the "low pt" E_T^{miss} component

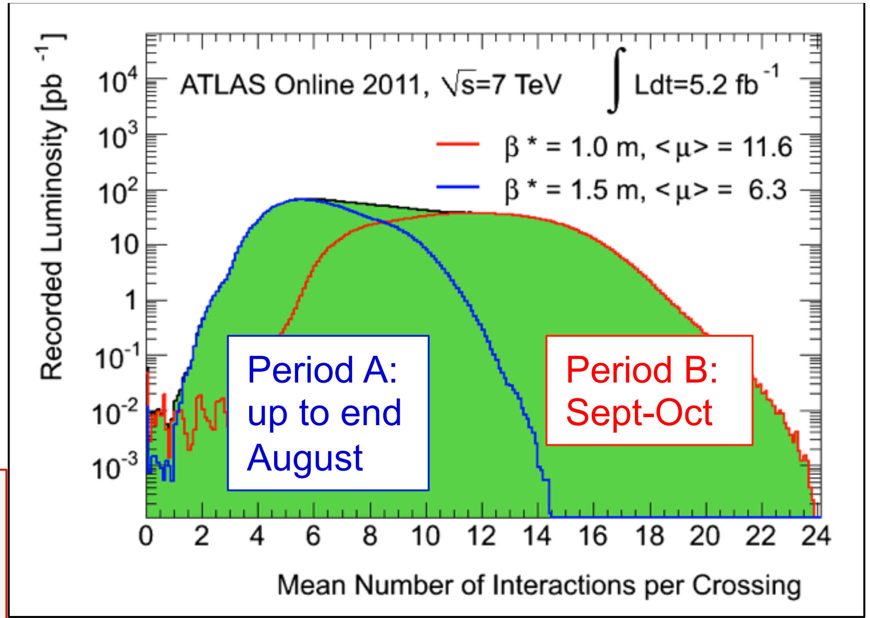


E_T^{miss} scale determination @1.5% very important for systematics in many analysis



CERN-PH-EP-2011-114 submitted to EPJ
ATL-COM-PHYS-2011-495
Important role in conf/note and papers

2011: Facing Pile-Up

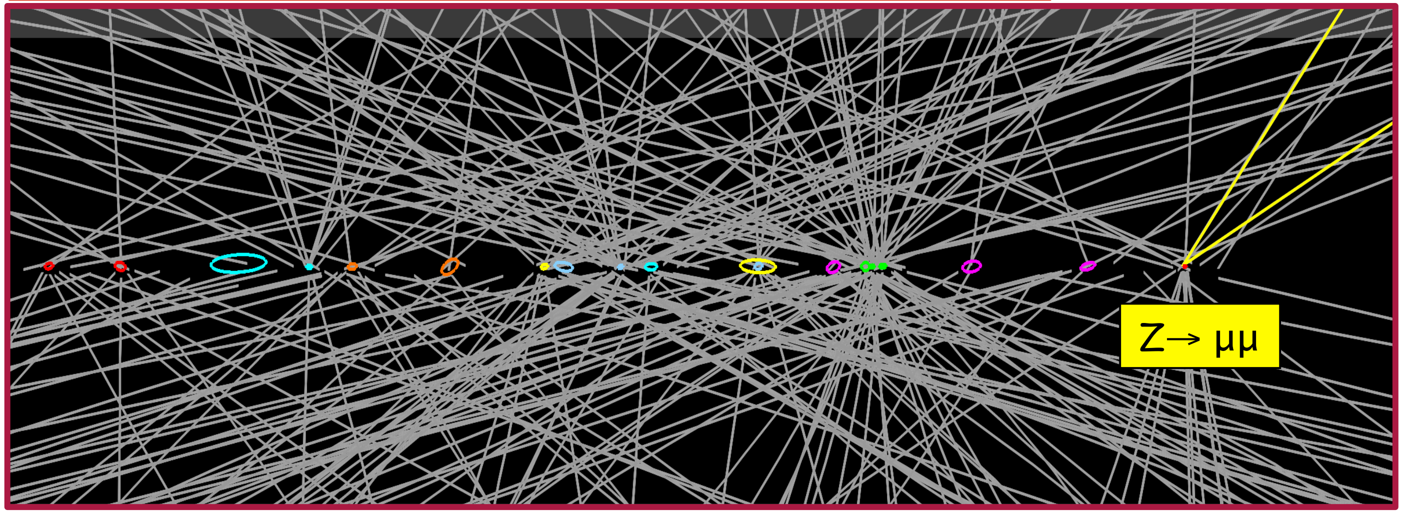


Price to pay for the high luminosity: larger-than-expected pile-up

Pile-up = number of interactions per crossing

Tails up to ~20 → comparable to design luminosity

(50 ns operation; several machine parameters pushed beyond design)



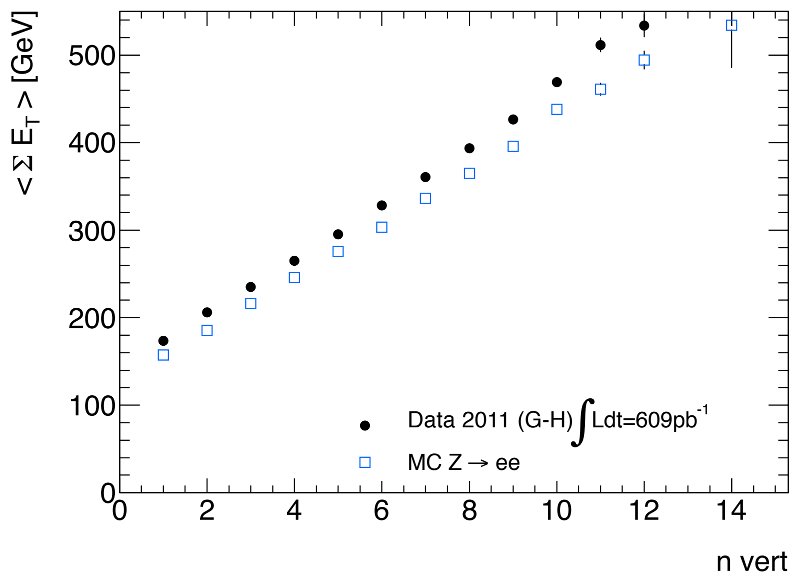
Event with 20 reconstructed vertices

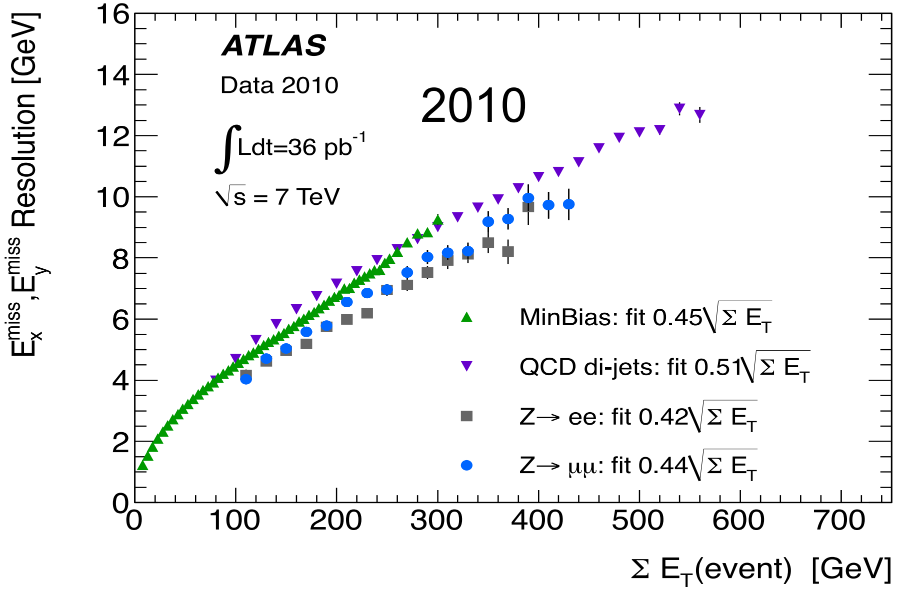
(ellipses have 20 σ size for visibility reasons)

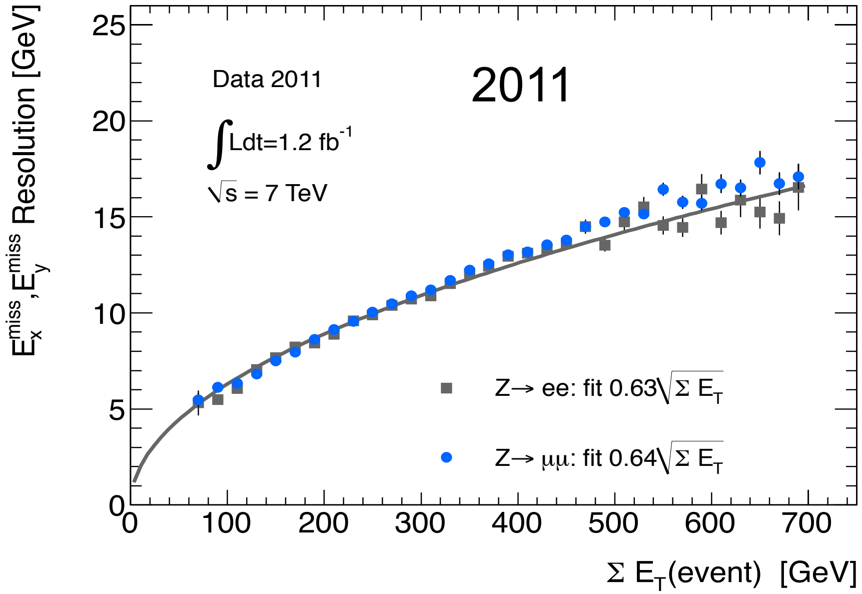
Challenging for trigger, computing resources, reconstruction of physics objects (in particular ETmiss, soft jets, ..)

Precise modeling of both in-time and out-of-time pile-up in simulation is essential

Effect of PileUp on E_T^{miss}





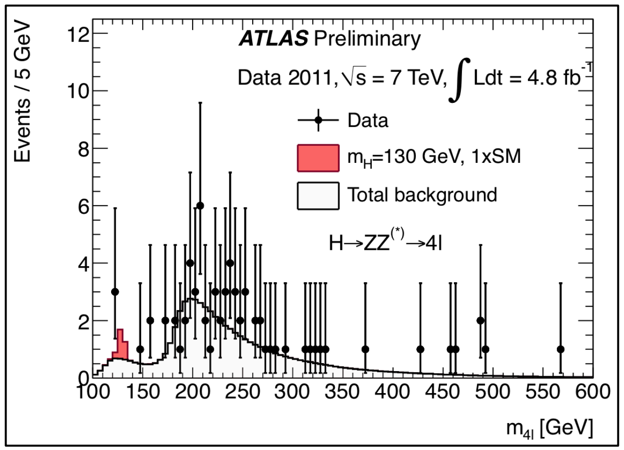


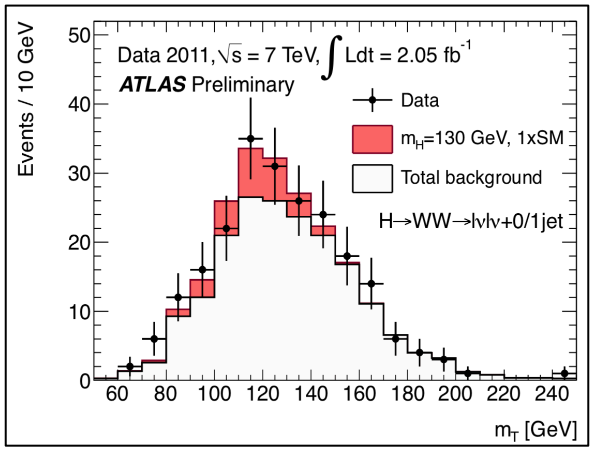
- Increase of $\sum E_T$, mostly due to the increase of the "low pt" component (underlying event)→ worse resolution (in time pile-up contribution)
- Worsening of E_T^{miss} resolution:
  2010 $0.43 \sqrt{\sum E_T}$
  2011 $0.61 \sqrt{\sum E_T}$
  (out of time pile up contribution)
- Harder work for MC model

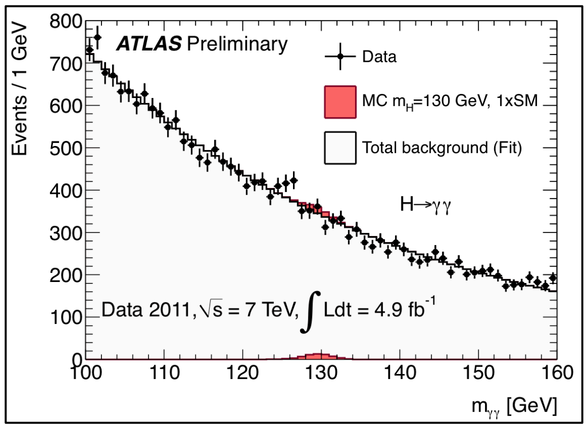
Higgs search

Very well known results presented on December 13th at CERN public seminar

LNF contribution:
$H \rightarrow ZZ(*) \rightarrow 4l$ and $H \rightarrow WW(*) \rightarrow l\nu l\nu$ channels
exploite mostly the high experience of the group in μ and E_T^{miss} reconstruction







H →WW(*) → lνlν (eνeν, μνμν, eνμν)

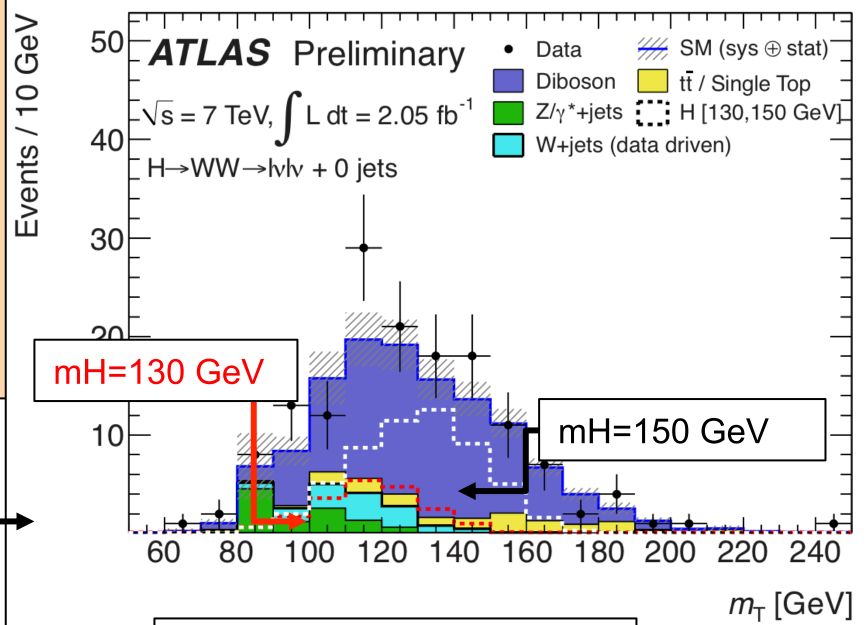
- Most sensitive channel over ~ 125-180 GeV (σ ~ 200 fb) **110 < mH < 300 GeV**
- However: challenging: 2ν ->no mass reconstruction/peak -> "counting channel"
- 2 isolated opposite-sign leptons, large ETmiss
- Main backgrounds: WW, top, Z+jets, W+jets
  - mll ≠ mZ, b-jet veto, …
  - Topological cuts against "irreducible" WW background:
    - pTll, mll, Δϕll (smaller for scalar Higgs), mT (ll, ETmiss)

Crucial experimental aspects:

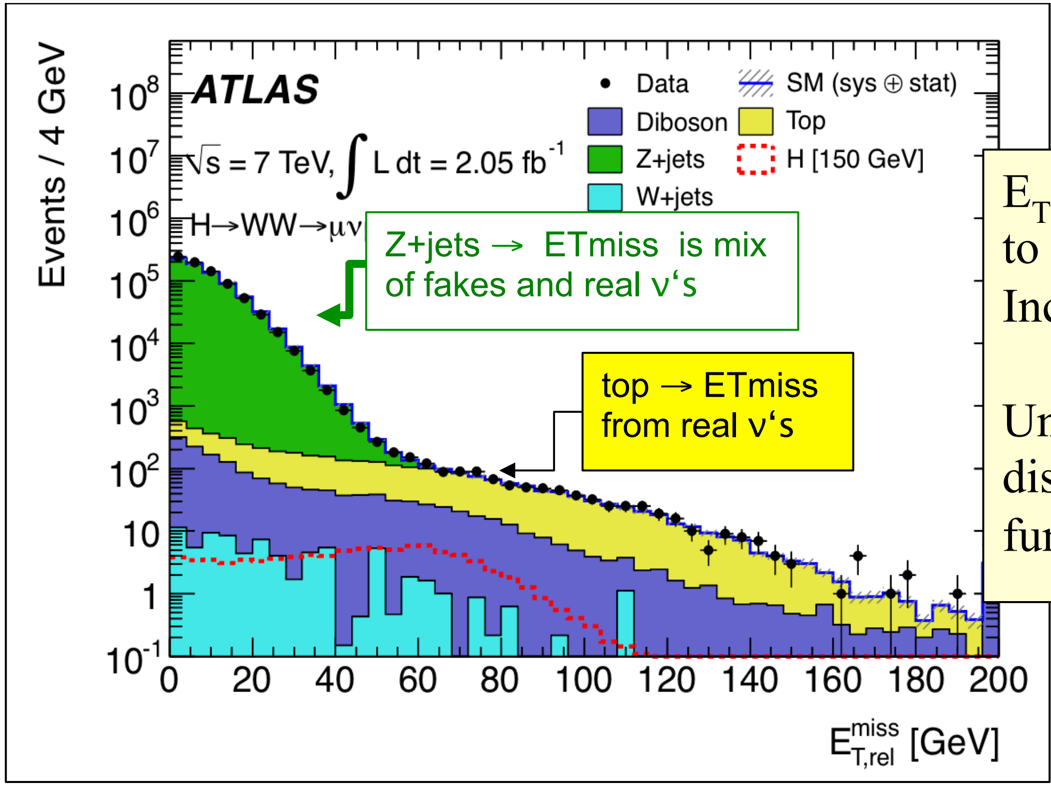
- understanding of E_T^{miss} (genuine and fake) (experience of Frascati group)
- excellent understanding of background in signal region → use signal-free control regions in data to constrain MC → use MC to extrapolate to the signal region

After all cuts (selection for mH=130 GeV)

Observed in data 2.1 fb-1	94 events 10 ee, 42 eμ, 42 μμ
Expected background	76 (±11)
Expected signal mH=130 GeV	19 (±4)



$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{miss})^2 - (\mathbf{P}_T^{\ell\ell} + \mathbf{P}_T^{miss})^2}$$



E_T^{miss} spectrum and resolution very sensitive to pile-up
Increase of resolution → tighten cut
→ loss signal
Understanding sources on data-MC disagreement on E_t^{miss} distribution is fundamental especially with high pileup

LNF group is active in:

- E_T^{miss} studies:
  Evaluate data driven systematic uncertainties due the soft components
- Drell-Yan bkg suppression
- Theoretical studies on the impact of PDF's uncertainty on the Drell-Yan and WW background

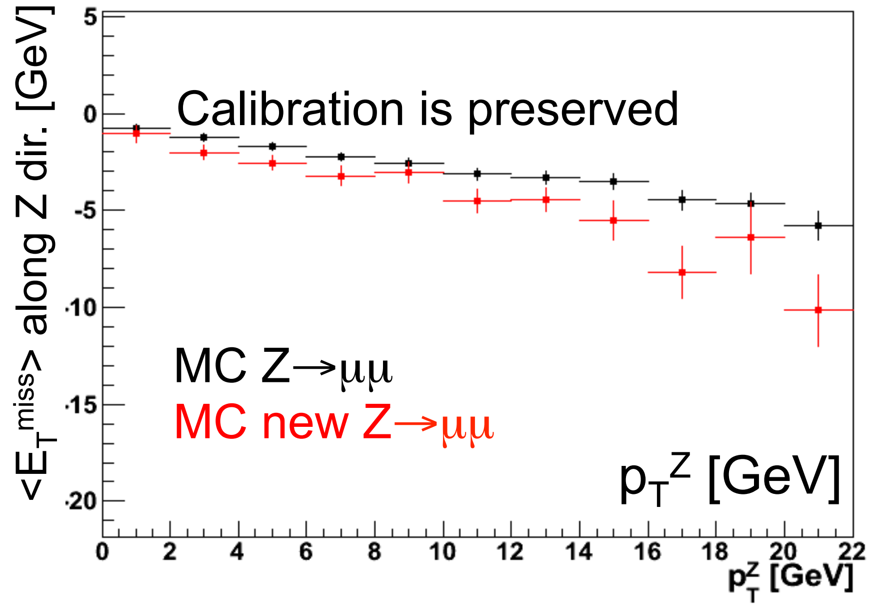
Important role in the 4.7 fb^{-1} analysis:
ATL-COM-PHYS-2011-1757,
ATL-COM-PHYS-2011-1729

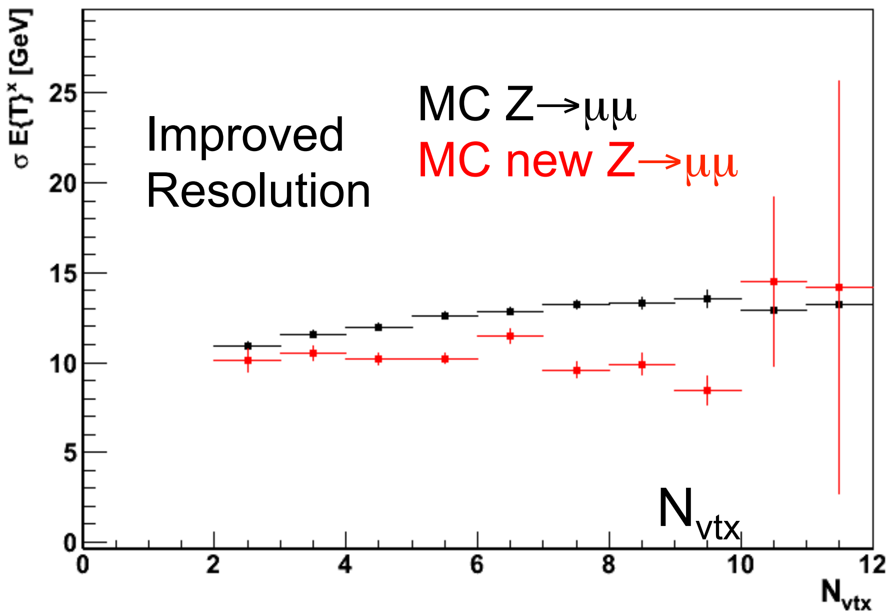
Perspectives for 2012:
~ 20 fb^{-1} integrated luminosity
Improve sensitivity of the analysis
Pileup suppression algorithm is crucial
Improves in the modeling

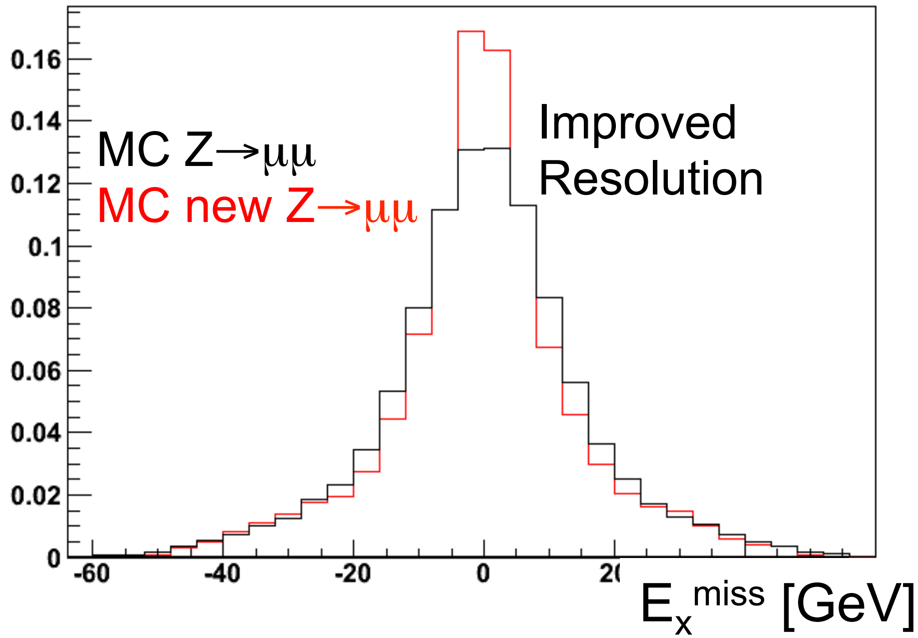
Study of PileUp Suppression in E_T^{miss} reconstruction

Fundamental for 2012:
50ns bunch spacing , ~2 × L➔ ~30 <μ>

Reduce the dependence on the number of PV using tracks
➔ select tracks at the primary vertex and "companion" cluster around tracks (mini-jets like)







$H \rightarrow ZZ^{(*)} \rightarrow$ 4l (4e, 4μ, 2e2μ)

110 < mH < 600 GeV

- σ ~ 2-5 fb
- However:
  -- mass can be fully reconstructed → events would cluster in a (narrow) peak
  -- pure: S/B ~ 1
- 4 leptons: pT1,2,3,4 > 20,20,7,7 GeV; m12 = mZ ± 15 GeV; m34 > 15-60 GeV (depending on mH)
- Main backgrounds:
  -- ZZ(*) (irreducible)
  -- mH < 2mZ : Zbb, Z+jets, tt with two leptons from b/q-jets
- → Suppressed with isolation and impact parameter cuts on two softest leptons
- Signal acceptance x efficiency: ~ 15 % for mH~ 125 GeV

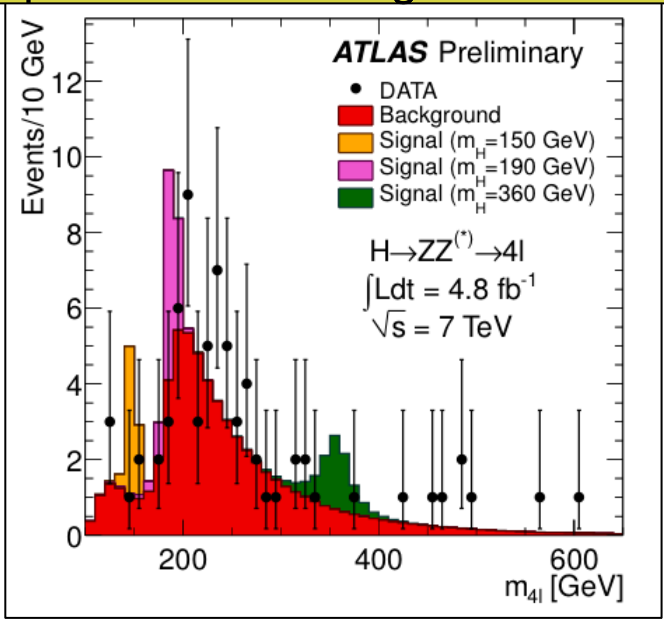
Crucial experimental aspects:

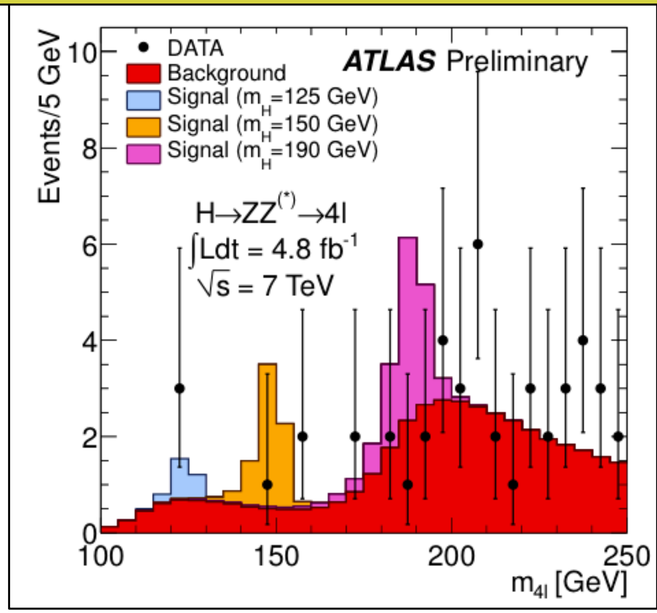
- High lepton reconstruction and identification efficiency down to lowest pT
- Good lepton energy/momentum resolution (experience of LNF group)
- Good control of reducible backgrounds (Zbb, Z+jets, tt) in low-mass region:
  ◊ cannot rely on MC alone (theoretical uncertainties, b/q-jet →l modeling, ..)
  ◊ need to compare MC to data in background-enriched control regions (but: low statistics ..)

After all selections: kinematic cuts, isolation, impact parameter

Full mass range
Observed: 71 events: 24 4μ + 30 2e2μ + 17 4e
Expected from background: 62±9

m(4l) < 180 GeV
Observed: 8 events: 3 4μ + 3 2e2μ + 2 4e
Expected from background: 9.3±1.5





In the region mH < 141 GeV (not already excluded at 95% C.L.) 3 events are observed: two 2e2μ events (m=123.6 GeV, m=124.3 GeV) and one 4μ event (m=124.6 GeV)

In the region 117< m4l <128 GeV
(containing ~90% of a mH=125 GeV signal):

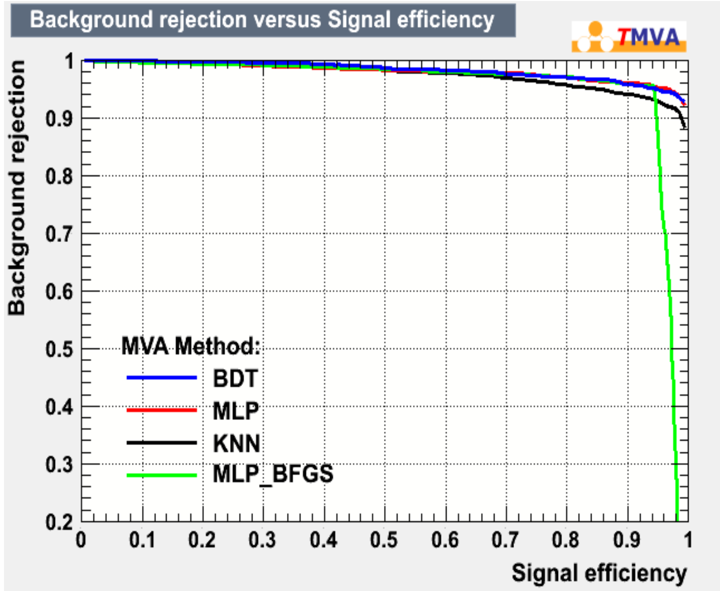
- similar contributions expected from signal and background: ~ 1.5 events each
- S/B ~ 2 (4μ), ~ 1 (2e2μ), ~ 0.3 (4e)
- Background dominated by ZZ* (4μ and 2e2μ), ZZ* and Z+jets (4e)

Main systematic uncertainties

Higgs cross-section	: ~ 15%
Electron efficiency	: ~ 2-8%
ZZ* background	: ~ 15%
Zbb, +jets backgrounds	: ~ 40%

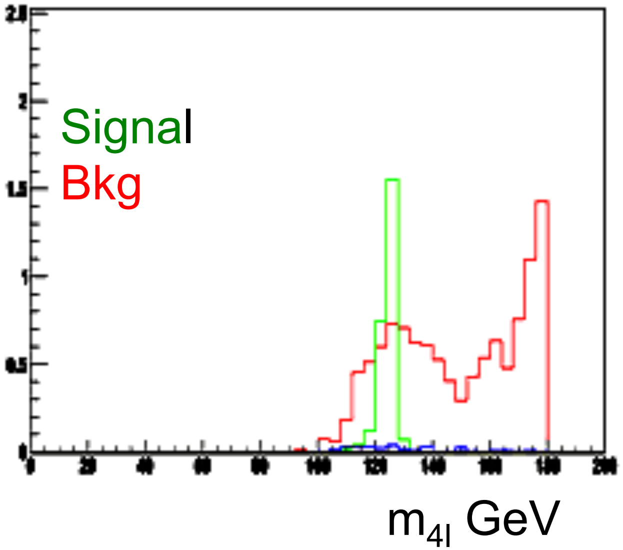
Low Mass H →ZZ(*)→ 4μ analysis optimization

LNF group is working on
- Optimizing kinematic cuts (Pt leptons, M12, M34,..)
- Use of stand-alone and Calo-Tag muons
- Use of MVA techniques with 4 muons kinematic variables

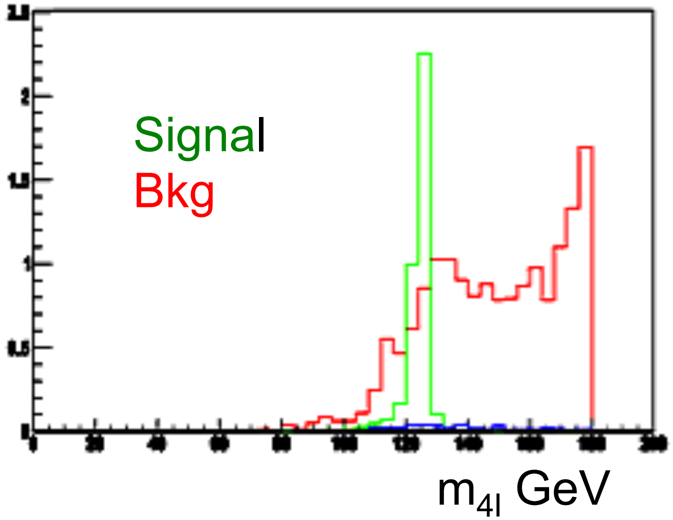


With simple cut optimization:
CLs(Poisson) = 4.7 %
(it was 10.5% with "official" cuts)

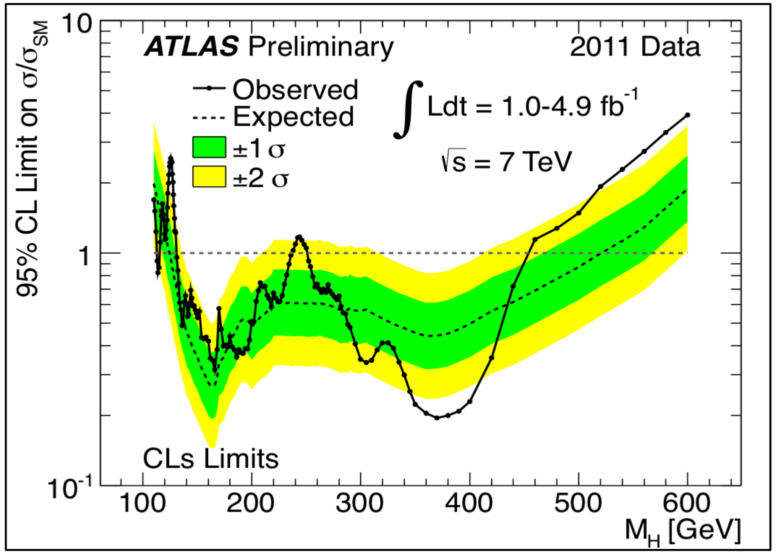
Before simple cut optimization

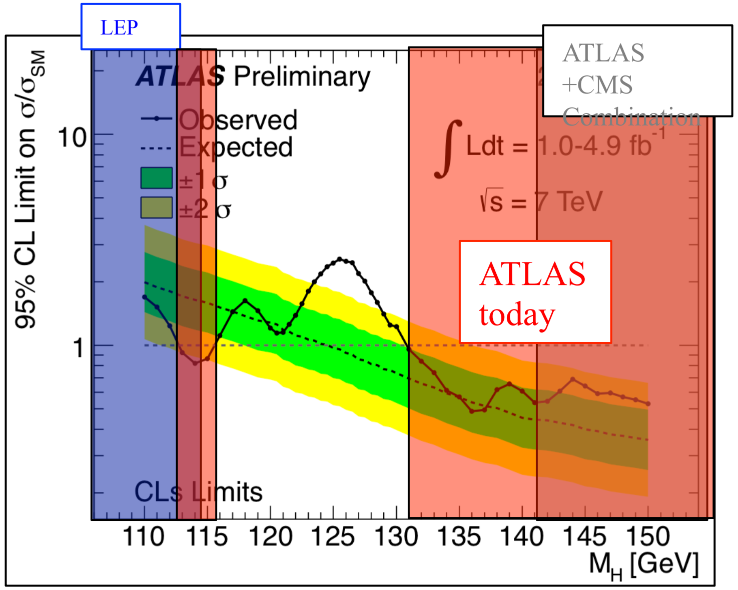


After simple cut optimization



Higgs searches: putting all channel together





Excluded at 95% CL: 112.7 < mH < 115.5 GeV
131 < mH < 453 GeV, except 237-251 GeV

Excluded at 99% CL: 133 < mH < 230 GeV,
260 < mH < 437 GeV

Expected if no signal

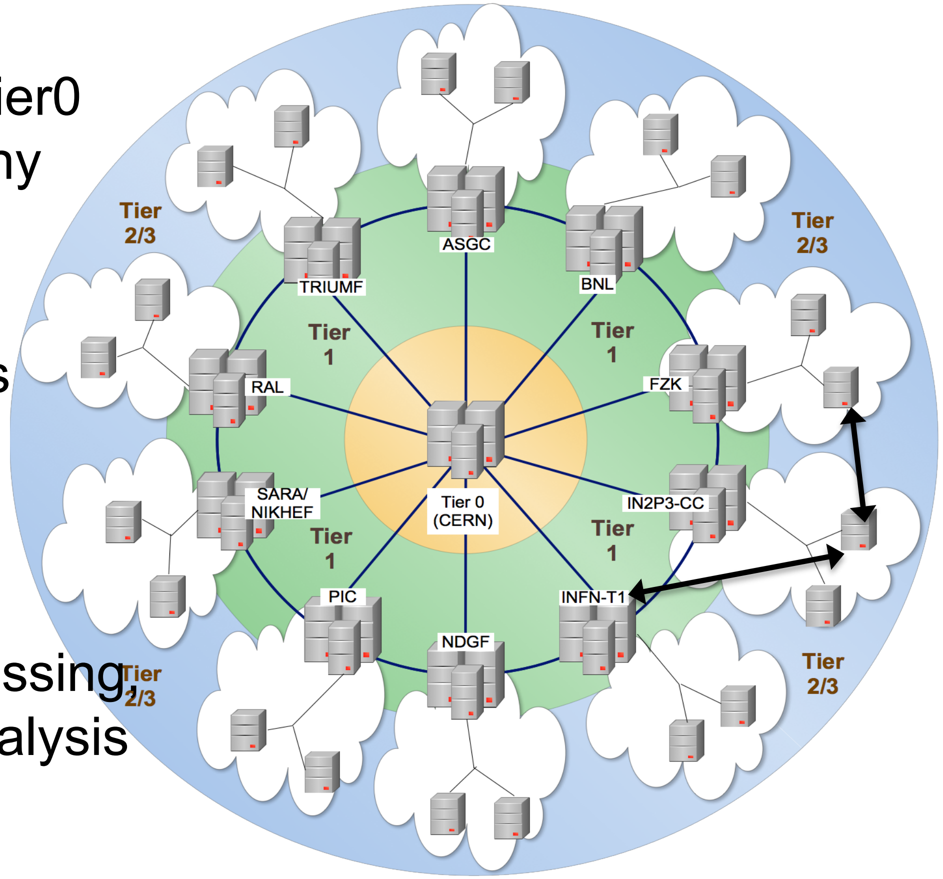
124.6-520 GeV

MORE DATA → 2012 run:
~ 20 fb^{-1} more per experiment of delivered luminosity needed for:
5σ discovery at mH~ 125 GeV with ~ 3σ per channel (ATLAS alone)
5σ discovery down to ~ 116 GeV (ATLAS+CMS combined)
"Contingency": analysis improvements; √s=8 TeV (brings ~ 10% sensitivity gain)

Tier2 Activity

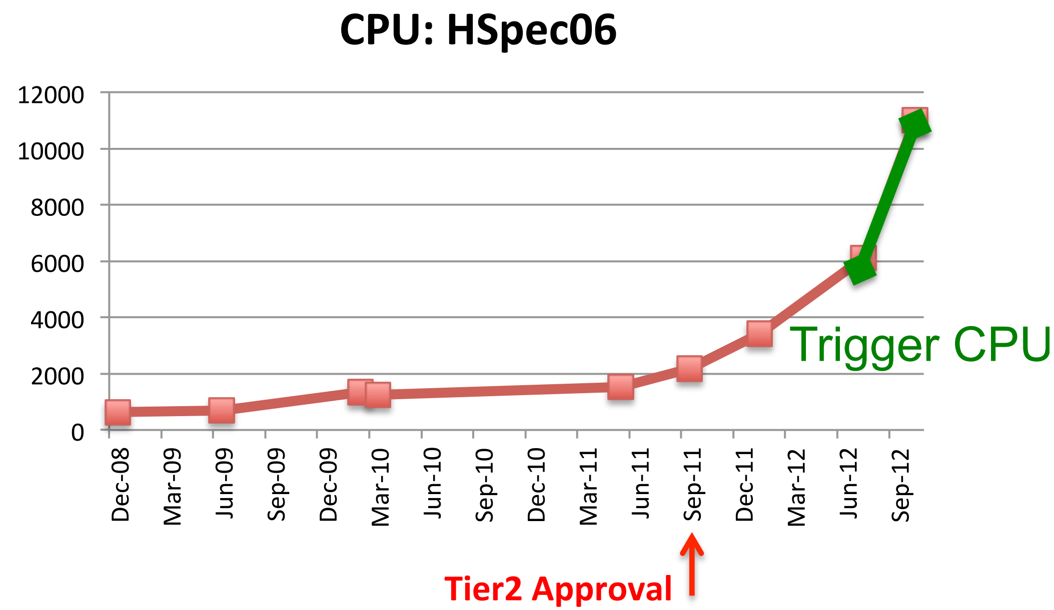
ATLAS Computing Model

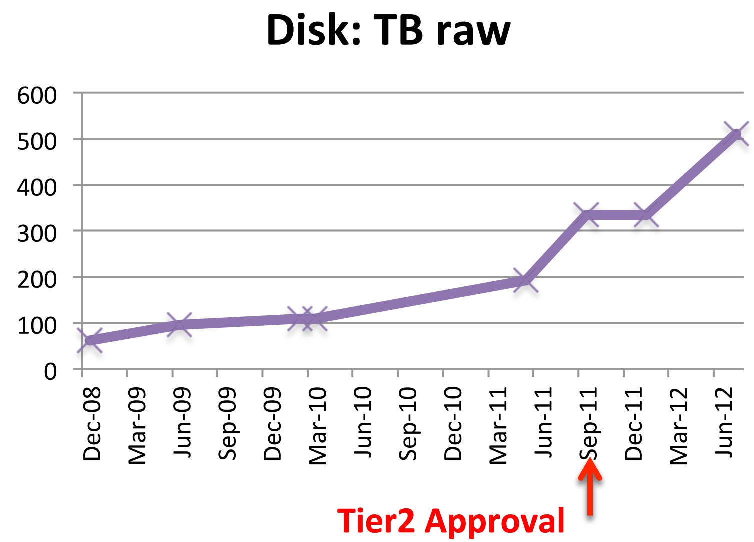
- Hierarchical computing model based on Grid paradigm.
- 3 levels of computing centers: 1 Tier0 (Cern), 10 Tier1s, ~70 Tier2s, many Tier3s, with different roles and dimensions.
- Data are distributed between Tiers on the base of their popularity
- A cloud is made of a Tier1 and its associated Tier2
- Computing activities: data reprocessing, MC simulation, user and group analysis
- IT cloud: Tier1 at CNAF, Tier2s: Frascati, Milano, Roma1, Napoli
- **September 2011: INFN official approval for Frascati Tier2**



Farm resources evolution: from 2008 to 2012

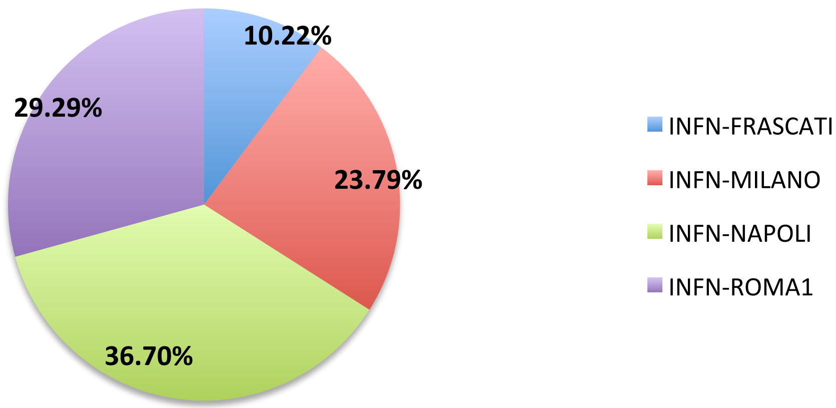
- Frascati's farm has been small up to now, but, being an official INFN Tier2, from 2012 it will be funded like the other Tier2s
- In addition, a further expansion is expected through the acquisition of some ATLAS Trigger CPU (560 job slots) Present computing farm:
  - 2616 Hspec06
  - 336 TBr disk space



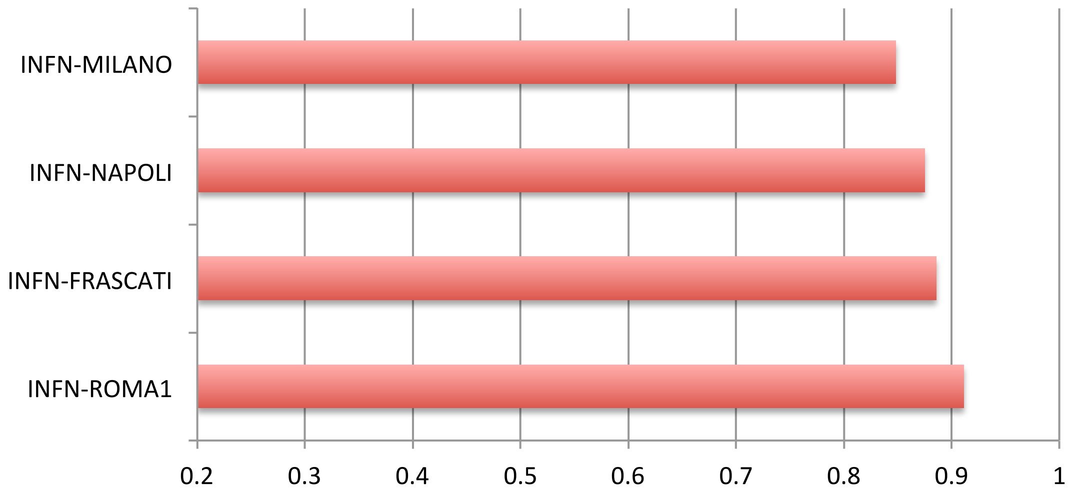


Tier2 performancy

CPU consumption Good Jobs (in seconds)



Average Efficiency All Jobs



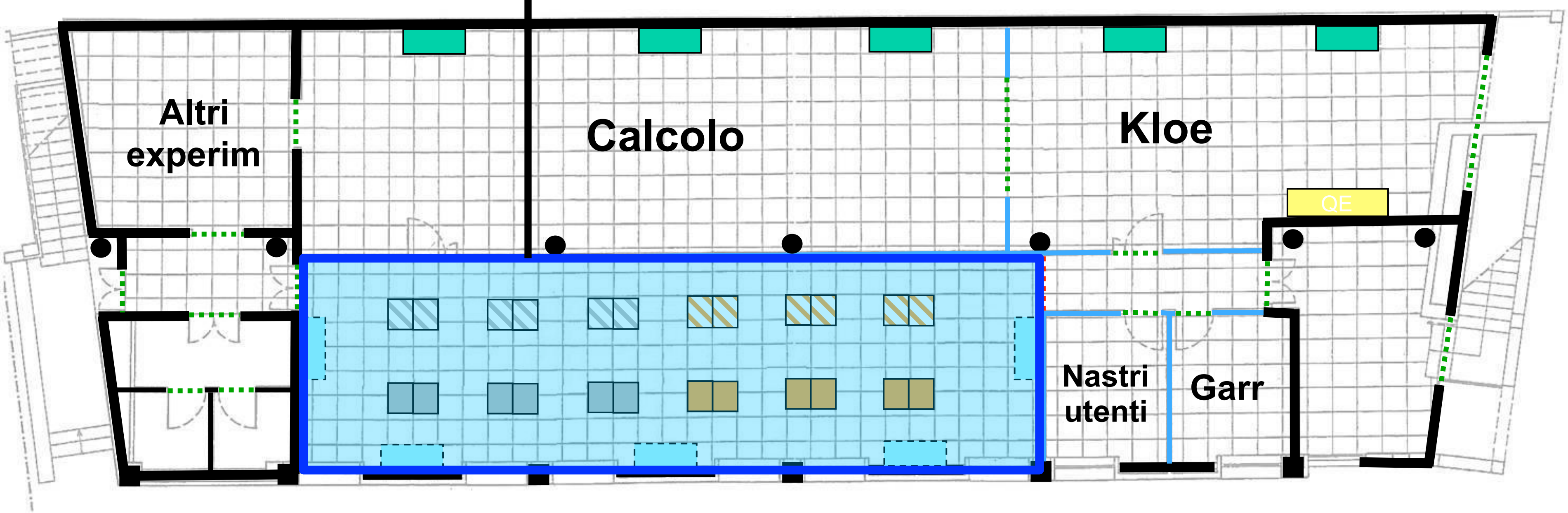
- Very good usage of the resources: ~11% of use wrt 9% of size (considering only Italian Tier2s, plot for the last 10 months)
- Very high job efficiency:
  - 99.5% for analysis jobs of the last month
  - Plot of the last 10 months
- Frascati, between sites of the same dimension, is in the highest performance category

News: Softwares, Infrastructure

- Expansion of the computing room:
  - Space doubling and electrical upgrade is ready
  - upgrade of air conditioning is in pre-qualification phase
  - ready by September 2012.

- Parallel ROOT on the Grid (Proof on Demand) will allow the final steps of analysis to be performed on the Grid.

- SuperB simulation jobs and storage access tests running on the farm.

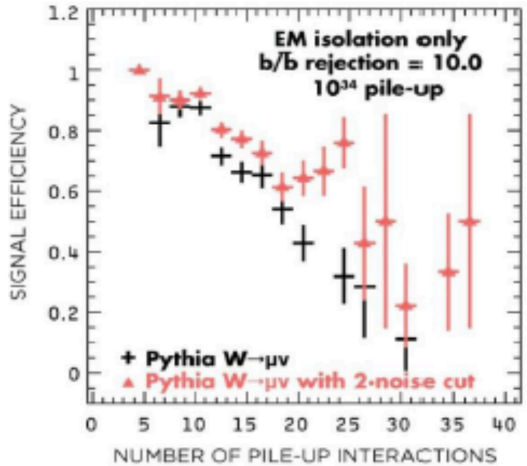


Contribution to ATLAS upgrades

- FTK
- Muon upgrade

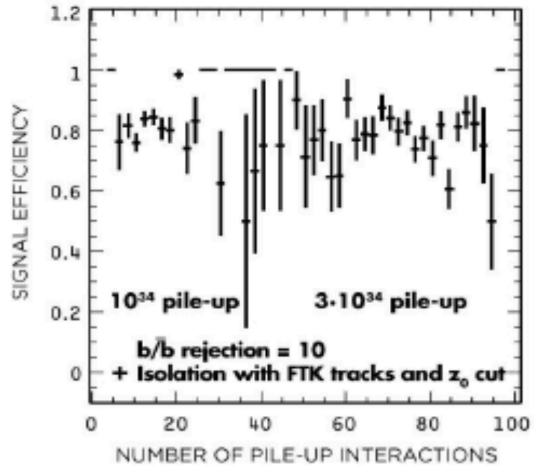
Fast Tracker FTK: Motivation

- **Many/most new physics scenarios: final state with heavy flavor**
  - **Select *b*-jets and *τ*-jets from enormous QCD background ⇒ tracking**
- **Selection of leptons using calorimeter isolation fails at high luminosity because of the pile-up. Solution is tracking isolation using tracks pointing to the lepton at the beamline.**



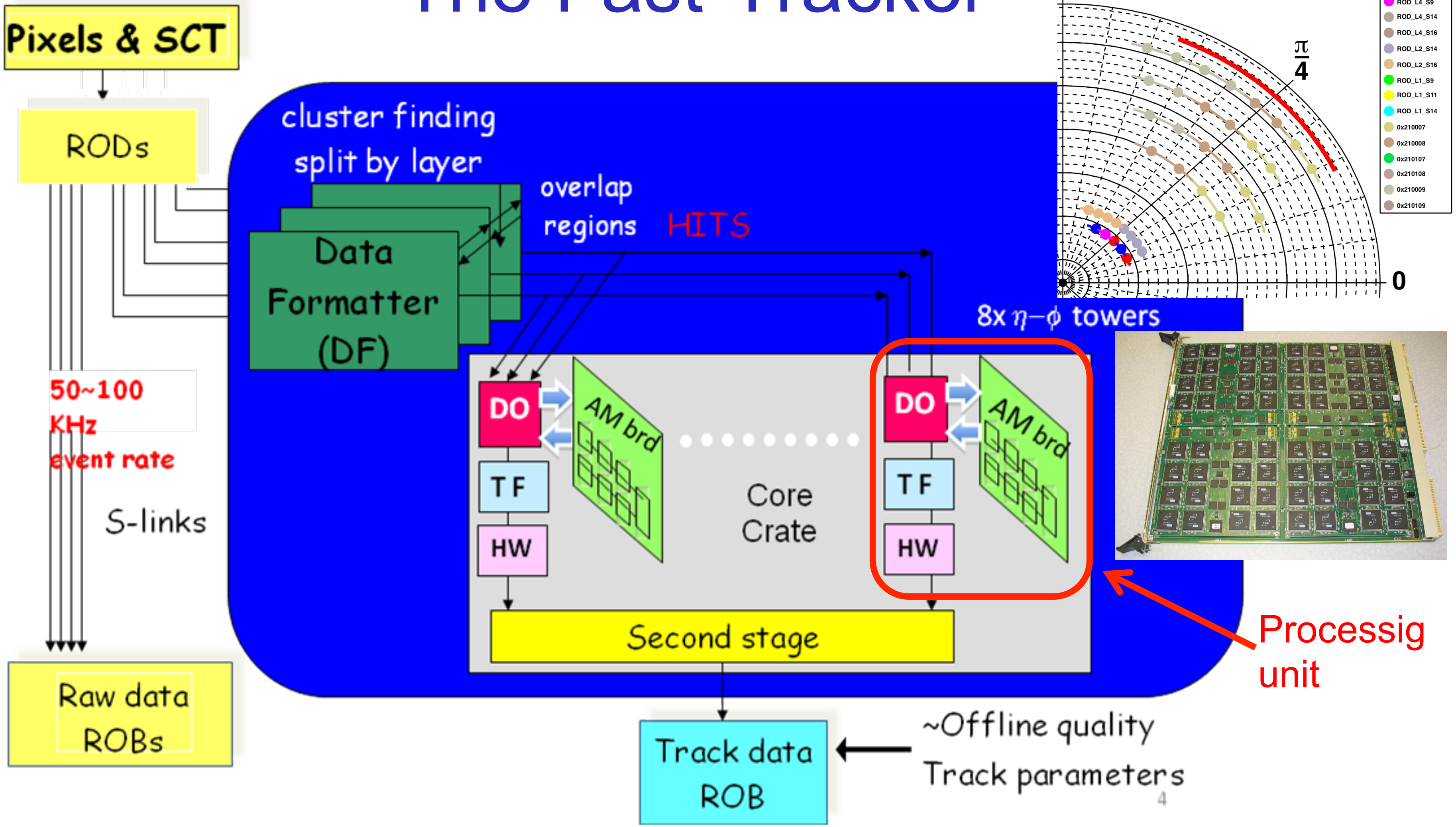
Calorimeter isolation

Tracking isolation



- **At SLHC, track many jets & leptons ⇒ near-global tracking**
- **Large hit density ⇒ big increase in tracking execution time**
- **Larger backgrounds ⇒ time consuming trigger algorithms**

The Fast-Tracker

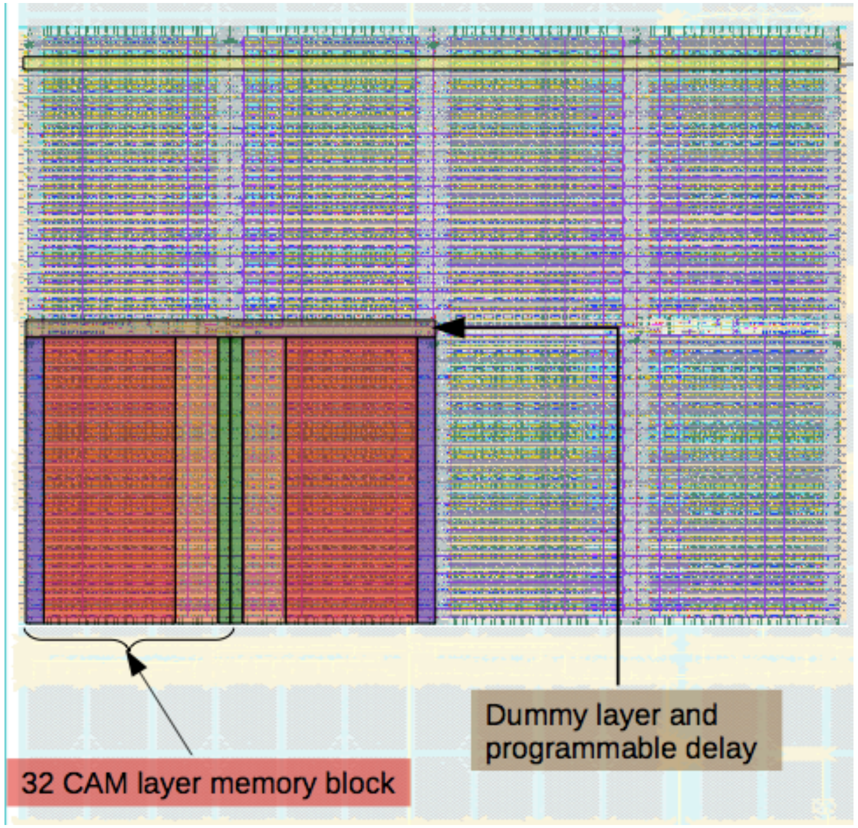


- Global tracking within 100μs after a Level-1 trigger.
- Highly parallel data flow: 64 η -ϕ towers in 8 core crates and 8-fold parallelism within each tower (for inst. Lum. $3{\times}10^{34}$)
- Pattern recognition: 10^9 patterns in parallel (8 layers).
- Second stage: extrapolate into stereo SCT layer. Include stereo hits in final fit.

Associative Memory chip

LNF coordination

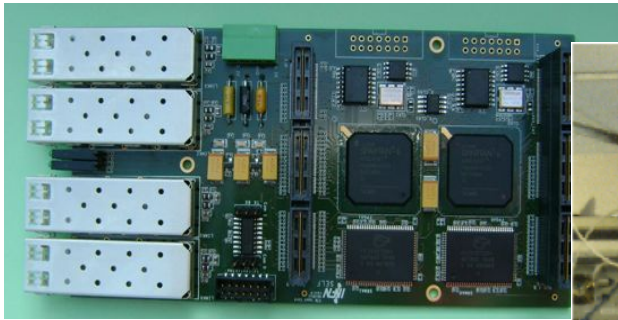
- Increase the pattern density x20
- Keep similar power consumption
  - despite x2.5 speed
  - would be x50 with same design/technology
  - switch to full custom design (core only)
  - need smart ideas



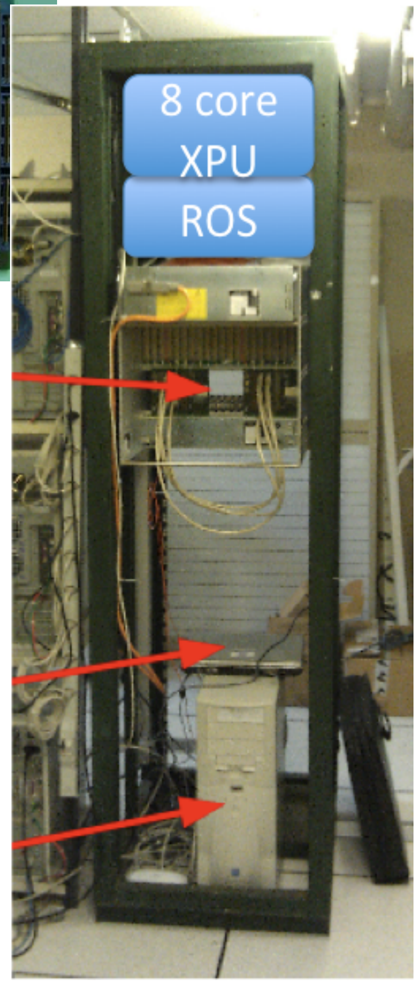
Associative Memory Design for the FastTrack Processor (FTK) at ATLAS
ATL-DAQ-PROC-2011-045 https://cdsweb.cern.ch/record/140465?ln=en

Clustering card & vertical slice

Preparing to test the system on a “vertical slice” of the apparatus



- FTK clustering mezzanine
  – Performs clustering in the pixels
- S-Link communication tested @ CERN
- Clustering firmware in progress
- Vertical slice with FTK prototypes @ CERN
  - Clustering card being integrated with AMBoard (Pisa) and EDRO board (Bologna)
  - Ready to produce 10 mezzanines for vertical slice



Crate with boards

FPGA programmer

Data source

ATL-DAQ-PROC-2011-018 to be published on NIM A
https://cdsweb.cern.ch/record/1382040/

FTK Simulation

LNF coordination

The FTK simulation is a complex system

- > 2 main goals:
  - Test and optimize the algorithms and the logic of the boards
  - Study the uses of FTK tracks in the HLT algorithms

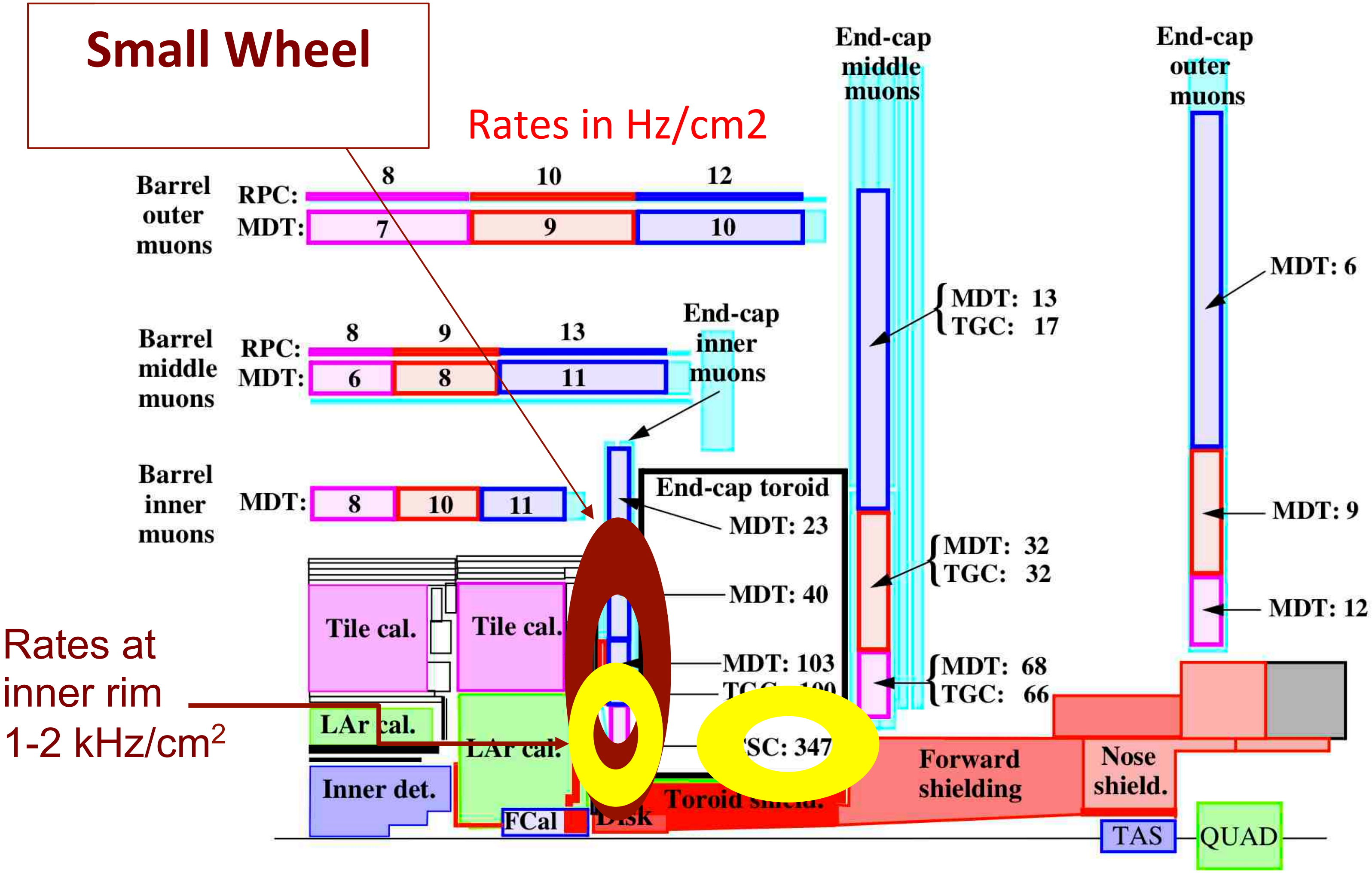
- Integration in the ATLAS software environment
- Continuously updating the configuration to follow the detector/accelerator changes
  - Updating the physics case studies with the most recent MC
- Preparing the HW configuration and the tools for the "vertical slice" test monitoring

<u>**A new "Variable Resolution Associative Memory" for High Energy Physics**</u>

ATL-UPGRADE-PROC-2011-004 https://cdsweb.cern.ch/record/1352152

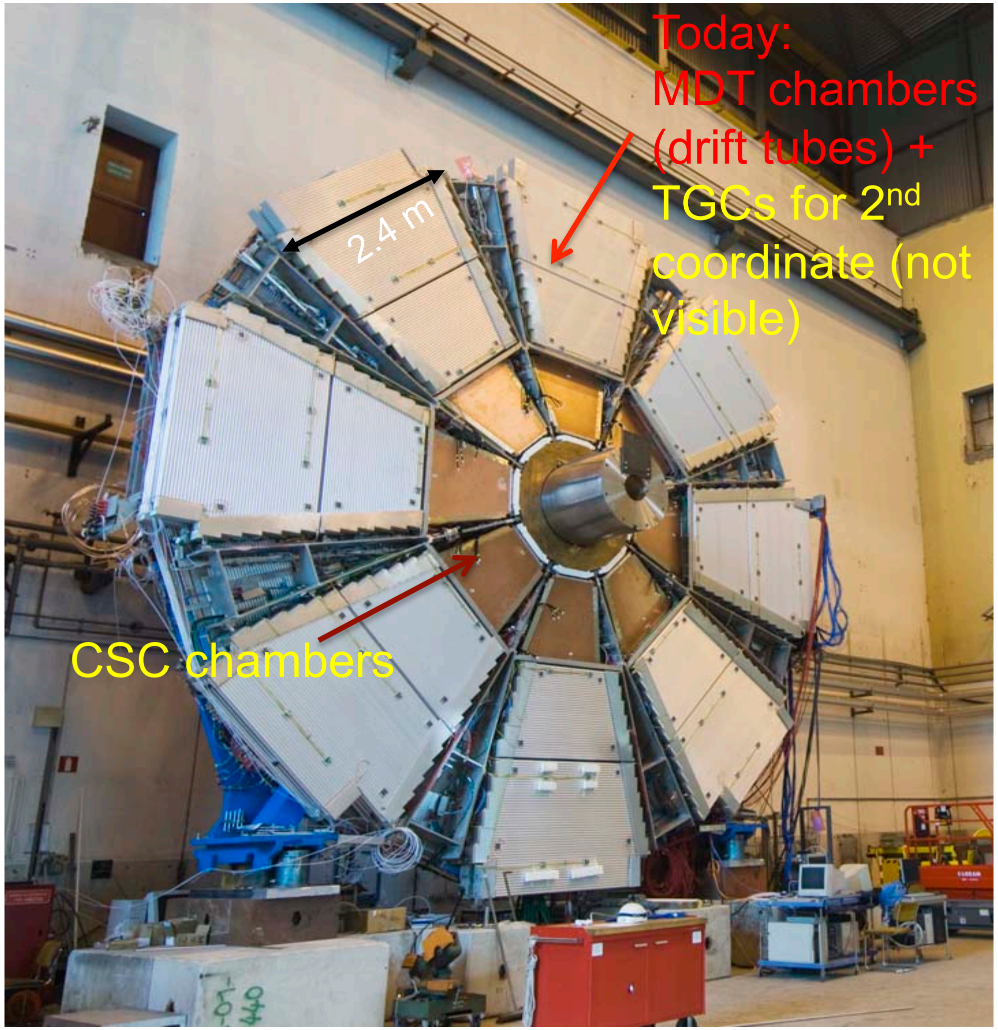
The ATLAS Muon System Upgrade Phase I (2018)

Count rates*) in the ATLAS Muon System at $\sqrt{s}$ = 14 TeV for L = 10^{34} $cm^{-2}s^{-1}$



*) ATLAS Detector paper, 2008 JINST 3 S08003

ATLAS Small Wheel upgrade proposal



Requirements:

- Rate capability 15 kHz/cm^2 (L ≈ 5 x 10^{34} cm^{-2}s^{-1})
- Efficiency > 98%
- Spatial resolution ≤100 μm (Θ_{track}< 30°)
- Good double track resolution
- Trigger capability (BCID, time resolution ≤ 5–10 ns)
- Radiation resistance
- Good ageing properties

Candidates:

- Micromega (tracks + trigger)
- sMDT(tracks)+TGC(trigger)
- sMDT(tracks)+RPC(trigger)

Small Wheel upgrade LNF activity

Strong interest for the tracking part:

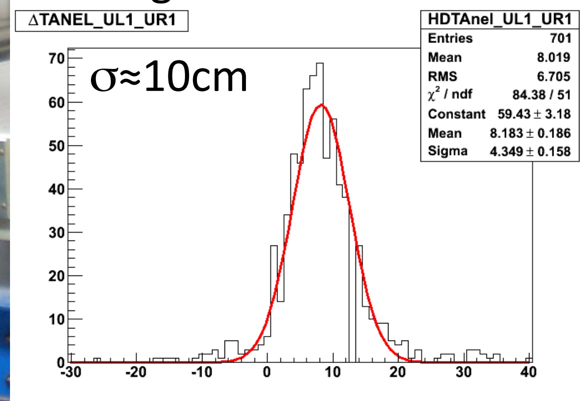
- LNF has solid experience on MDTs
- Approaching to test Micromegas in next months

Revision of various options by an ATLAS panel by beginning of 2012

LNF test system:

- 2 MDT BML chambers
- 14 scintillators 20x150cm^2
- 1 scintillating fiber counter 20x300 cm^2 (8+1 PM's)
- Tunable Iron absorber ~50 cm

Longitudinal resolution



Conclusions

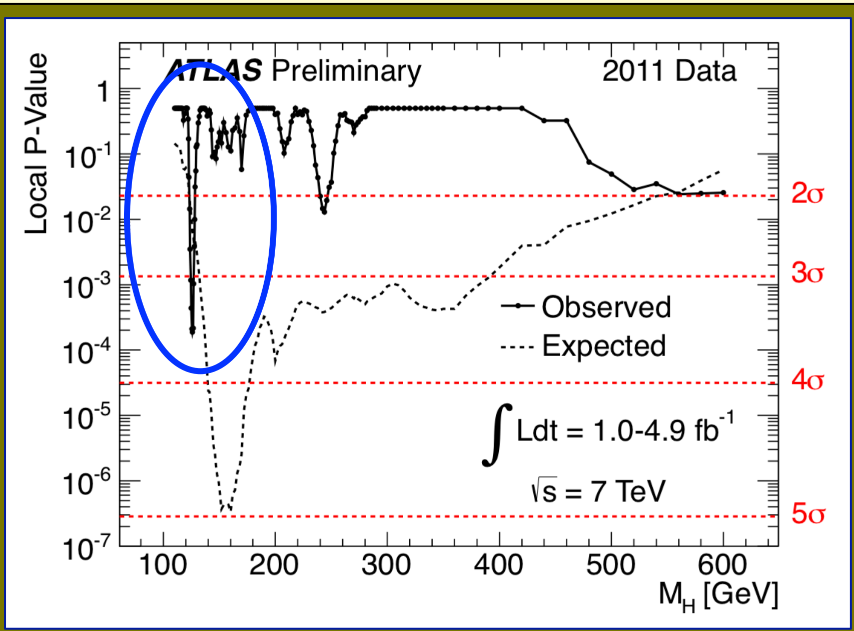
- Excellent performances of LHC and ATLAS in 2011
- Huge improvements in Higgs searches: final word expected in 2012

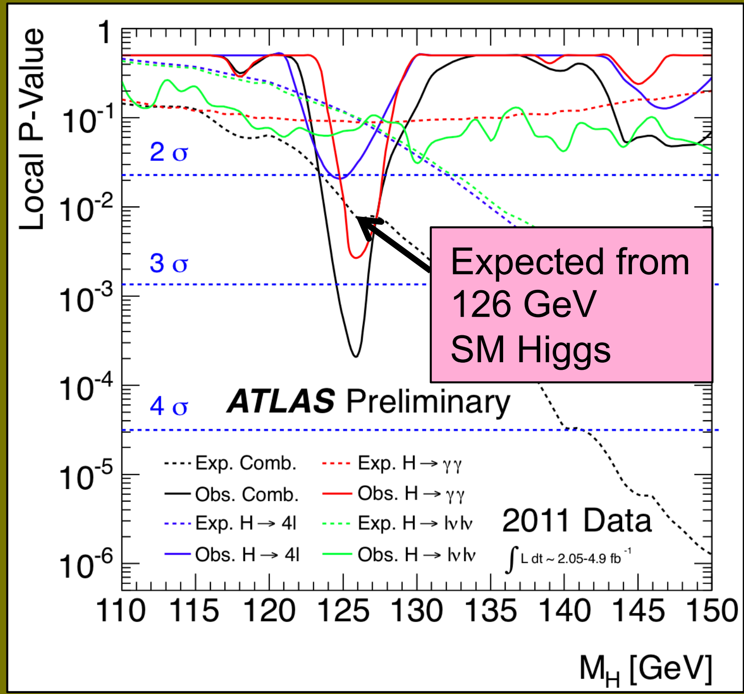
- LNF group is a very active and experienced one in ATLAS:
  - Active in relevant reconstruction and analysis channels
  - Tier 2 INFN approval thanks to site excellent performances. Size will soon reach that of the other italian Tier2

- Upgrade Activity
  - FTK: Activities in good shape and proceeding fast
  - Muon Upgrade: ready to test at LNF the selected option

Spares

Consistency of the data with the background-only expectation





Maximum deviation from background-only expectation observed for m_H~126 GeV

Local p_0-value: 1.9 10^{-4}
→ local significance of the excess: 3.6σ
~ 2.8σ H→ γγ, 2.1σ H→ 4l, 1.4σ H→ lνlν

Expected from SM Higgs: ~2.4σ local (~1.4σ per channel)

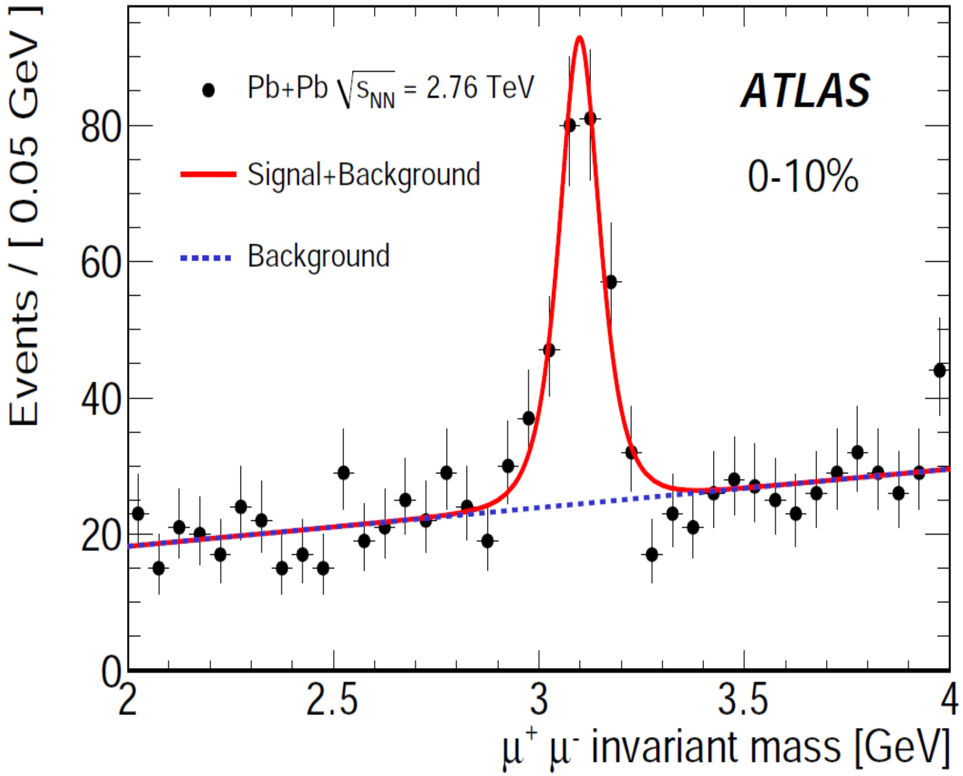
Global p_0-value : 0.6% →2.5σ LEE over 110-146 GeV
Global p_0-value : 1.4% →2.2σ LEE over 110-600 GeV

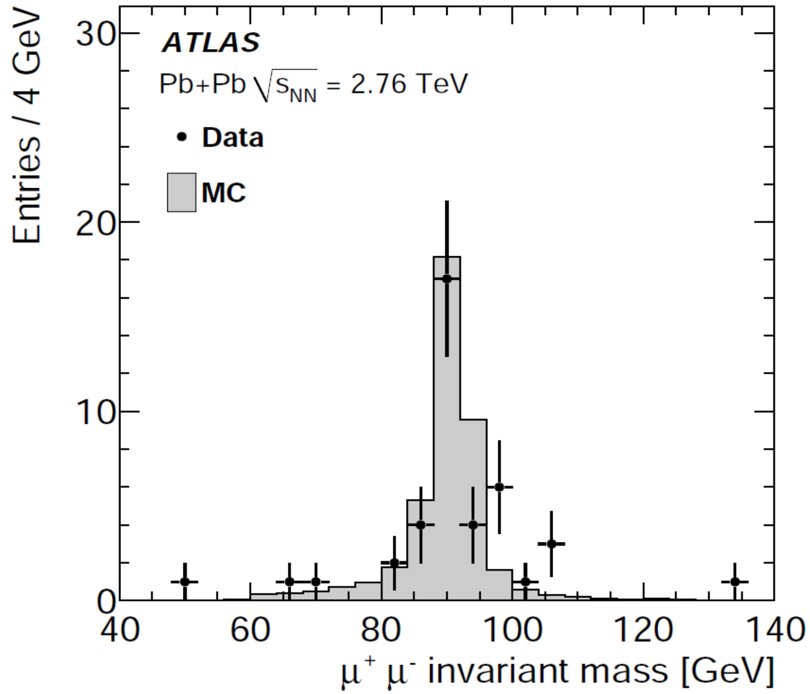
Measurement of the centrality dependence of J/Psi yields and observation of Z production in lead-lead collisions

Relevant contribution and paper editing for the measurement of J/Ψ suppression in Pb-Pb collisions

If QGP is formed, Quark Deconfinement suppress quarkonium production via color screening

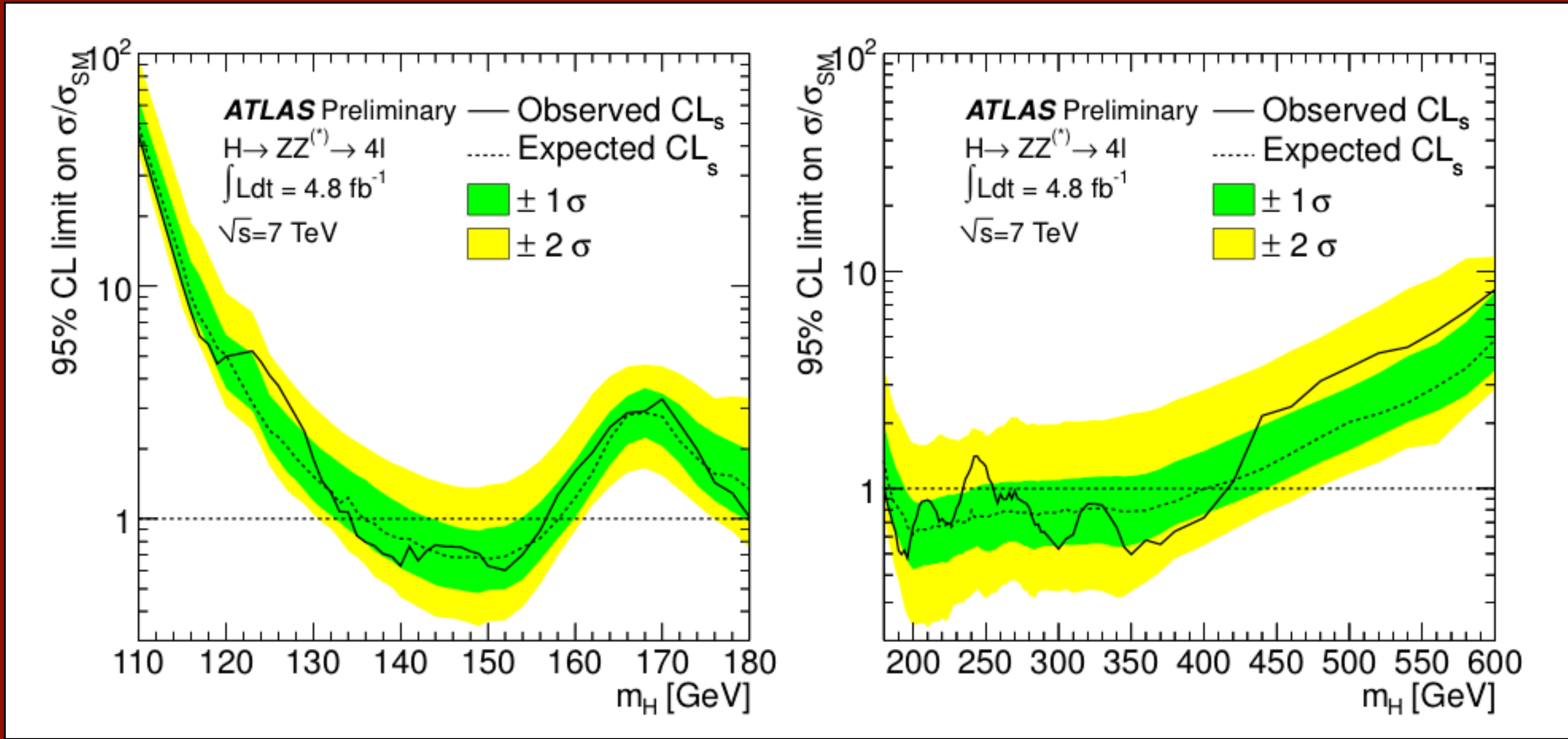
Phys.LettB.697(2011) 294-312





DATA: analyzed **~7 mb-1**

From fit of signal and background expectations to 4l mass spectrum



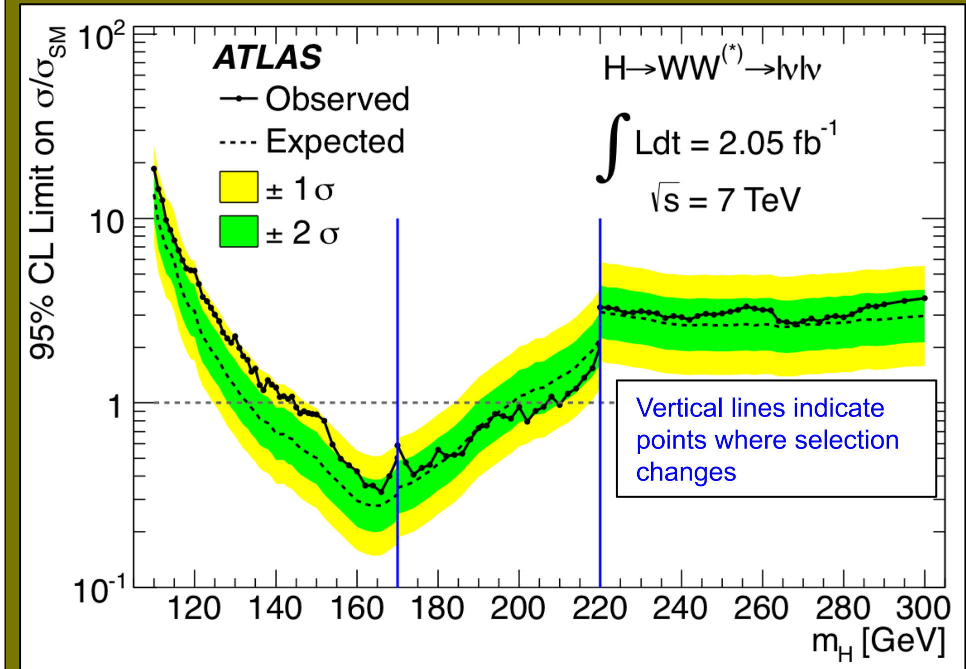
Excluded (95% CL): $135 < m_H < 156$ GeV and $181 < m_H < 415$ GeV (except 234-255 GeV)
Expected (95% CL): $137 < m_H < 158$ GeV and $185 < m_H < 400$ GeV

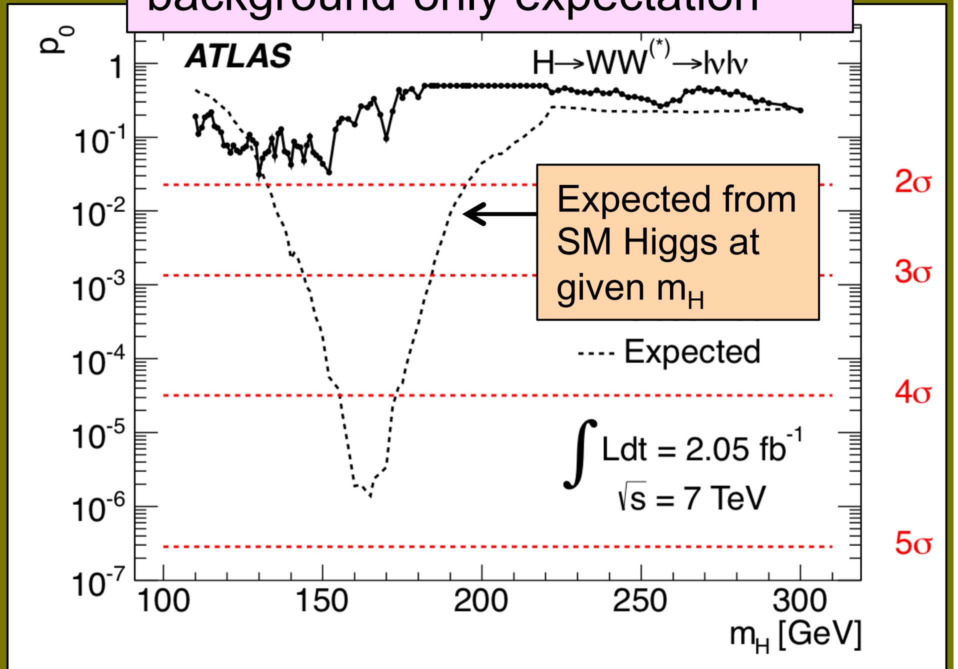
After all cuts (selection for m_H=130 Ge

2.1 fb^{-1}

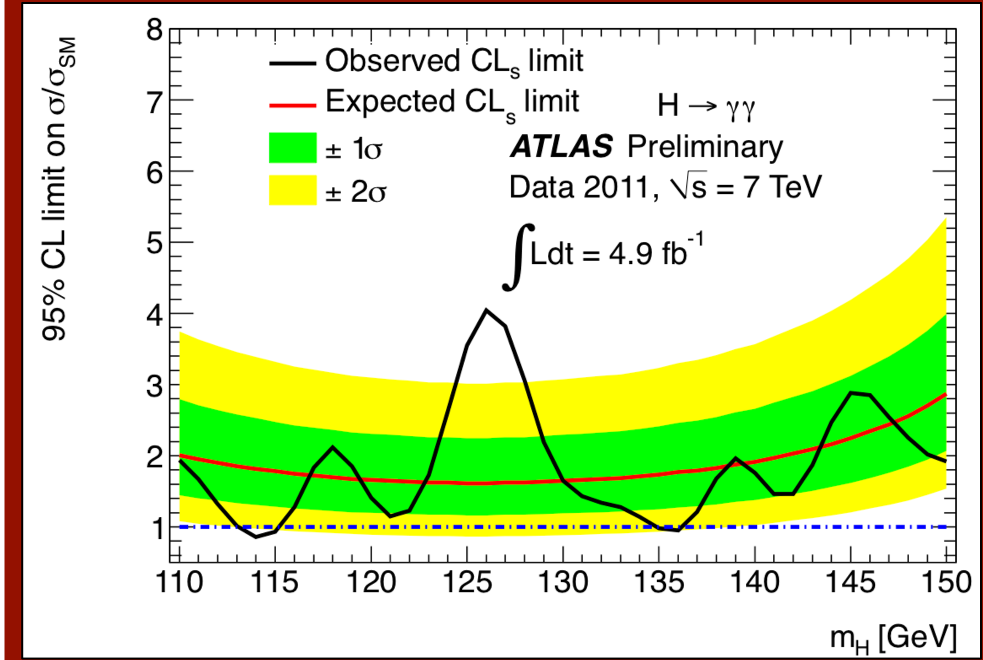
Observed in data	94 events 10 ee, 42 eμ, 42 μμ
Expected background	76 (±11)
Expected signal m_H=130 GeV	19 (±4)

Consistency of the data with the background-only expectation



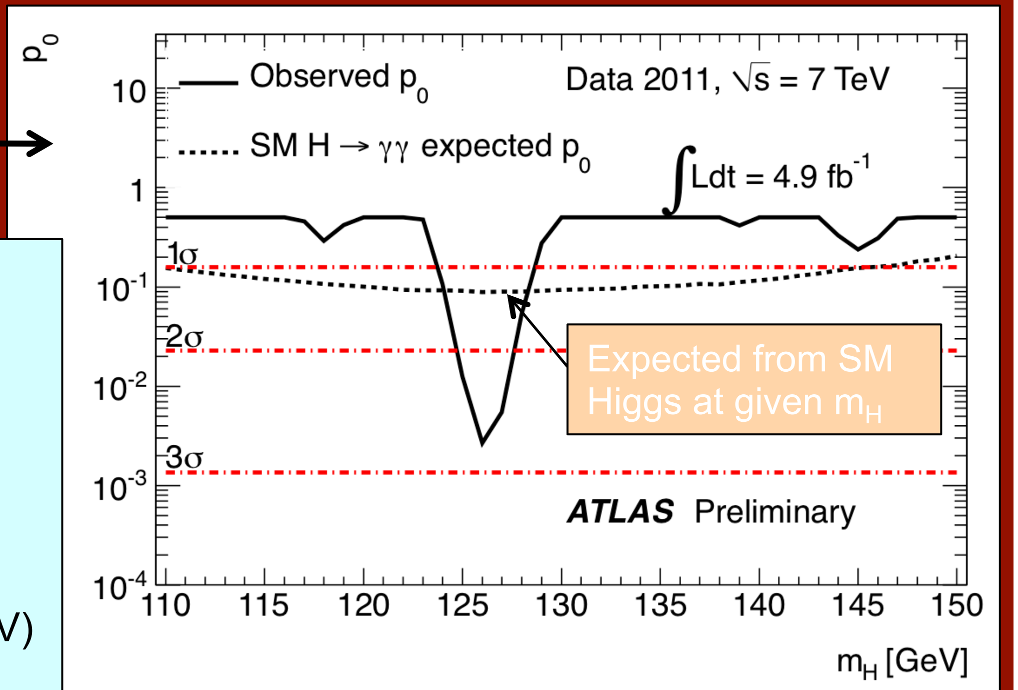


- Excluded (95% CL): 145 < m_H < 206 GeV (expected: 134-200 GeV)
- Observed limit within 2σ of expected: max deviation 1.9 σ for m_H ~ 130 GeV



Excluded (95% CL):
$114 \leq m_H \leq 115$ GeV, $135 \leq m_H \leq 136$ GeV

Consistency of the data with the background-only expectation



Expected from SM Higgs at given m_H

Maximum deviation from background-only expectation observed for m_H~126 GeV:

- ❑ local p_0-value: 0.27% or 2.8σ
- ❑ *expected from SM Higgs*: ~ 1.4σ local
- ❑ global p_0-value: includes probability for such an excess to appear anywhere in the investigated mass range (110-150 GeV) ("Look-Elsewhere-Effect"): ~7% (1.5σ)