Higgs → ZZ* → 4 leptons ($e^{\pm}$,$\mu^{\pm}$)

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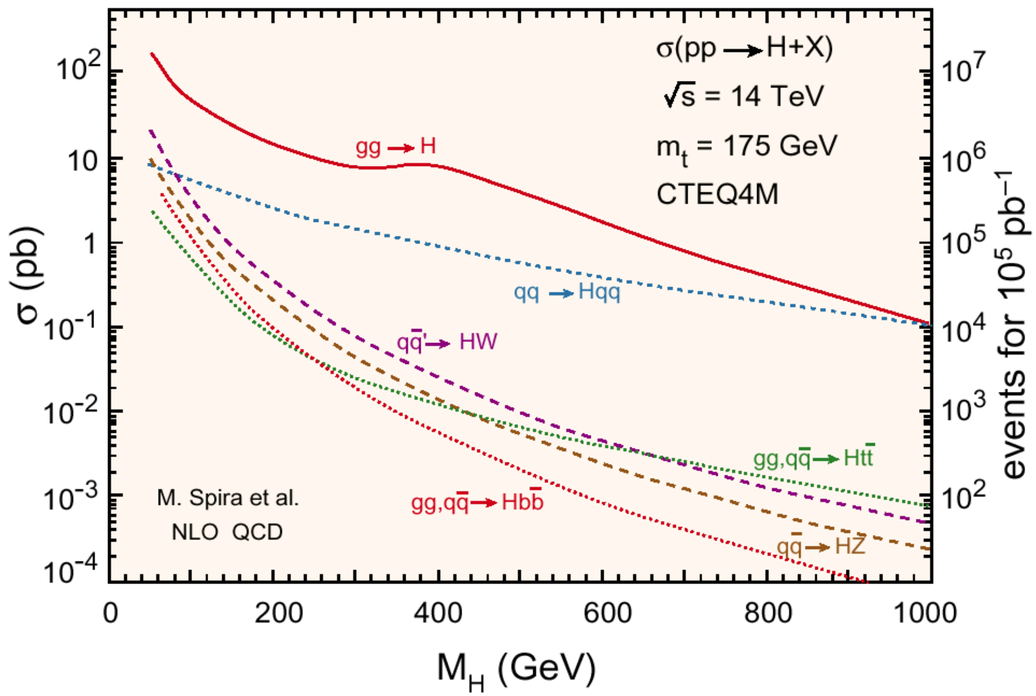
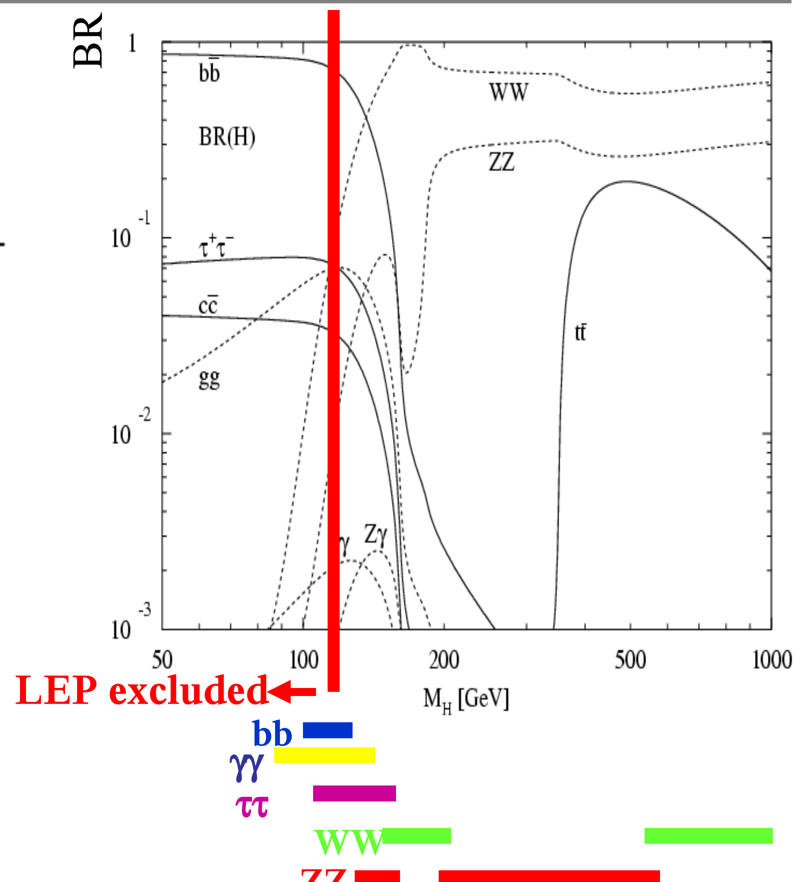
Outline

- Introduction
- Analysis
  - framework
  - data samples
  - Current status
  - Performance studies
- Conclusions, future plans

Introduction: SM Higgs (cross sections and BRs)





$H \to ZZ^{(*)} \to 4l\ (e,\mu)$: clear signature on top of low background

Studies are focused on the mass region: 130 GeV < m_H < $2m_Z$

For m_H < 180 GeV Higgs is narrow → good detector resolution essential

Introduction: Signal and Backgrounds

Signal:

- **H → ZZ(*) → 4l** (l=e,μ)

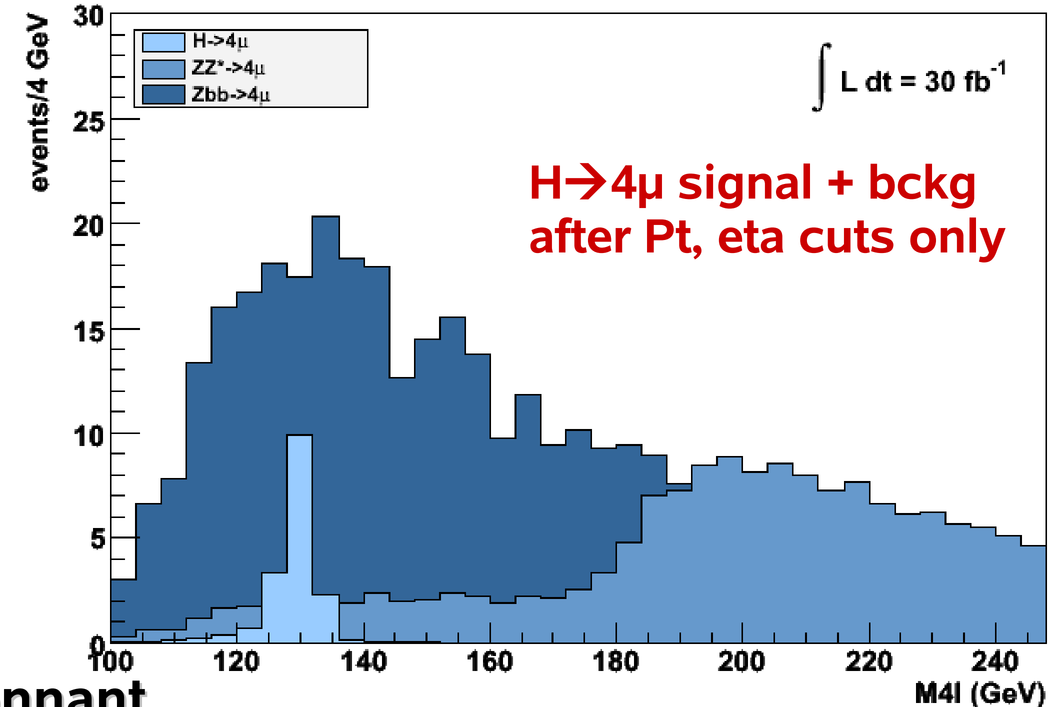
Backgrounds:

Irreducible

- ZZ(*) /γ (*) → 4l
- ZZ(*) /γ (*) → 2l 2τ

Reducible

- Zbb → 4lX **resonant**
- tt →WbWb →4lX **non resonant**



X-sections and generators used in ATLAS

type	H→4l mH=150 GeV (NLO calculations)	ZZ→4l LO calculation / Kfactor ~1.3	Zbb→4l LO calculation / no Kfactor	tt→4l NLO calculation
generator	Pythia	Pythia	AcerMC	MC@NLO
x-section	10.5 fb	X 15 Higgs x-section	X 5000 Higgs x-section	X 80000 Higgs x-section

Analysis Framework and Tools

- Use/test/validation of ATLAS standard tools
  - EV_H4lPreselector: EventView based code
    - Under cvs /offline/PhysicsAnalysis/HiggsPhys/HiggsToFourLeptons
    - Loops on AOD collections of e, μ
      - (no overlap removals for μ)
    - Dump of AOD variables in an Athena Aware Ntuple
  - Final Analysis in root
    - Both Higgs analysis and performance studies

- Development of common tools for the analysis shared among the ARTEMIS group.

- Contribution to the relevant "CSC" note

Analysis Strategy

- Signal selection

  Aim: trigger on the signal

  – Cuts on Pt distribution of leptons → (to trigger the signal)
  – Cuts on di-lepton mass m_{ll} → (against the reducible bckg tt, Zbb, Zγ* + cascade decays)

- Background Rejection

  Aim: Reject the reducible background of a factor ~100 after kinematic cuts to keep it at 10% of irreducible background (protection against theoretical uncertainties)

  – Isolation cuts
    - Isolation based on the Inner Detector
    - Isolation based on the Calorimeters
  – Impact Parameters of leptons, χ^2 of common vertex of 4l

- Higgs mass reconstruction

  Aim: Improve the mass resolution

  – Combined reconstruction (calo+ID, Muon Spectrometer +ID)
  – Mass constraint of Z^0

Lepton Identification

In this analysis we have used:

electrons:

- *Loose "IsEm" : Cut on* calorimeter observables (e.g energy cuts in 1st , 2nd sampling in various eta bins, cuts on the leakage of the tile)

muons:

- *"STACO" + "MuTag"*
  - STACO: Combined muon reconstruction using Inner Detector (new tracking package) tracks with Muon Spectrometer tracks (Muonboy package)
  - Mutag: Tagging ID tracks with segments (part of tracks in the Inner /Medium stations) from the Muon Spectrometer

Note: We have also compared the performances of the "STACO" to the "MUID" package which provides combined reconstruction of the Muon Spectrometer tracks ("MOORE" package) with the ID tracks ("IpatRec" package)

MC samples and analysis procedure

- Samples used:
  - Signal (~40K events)

trig1_misal1_csc11.005300.PythiaH130zz4l.recon.AOD.v12000601_tid007180

Release used for reconstruction

  - ZZ (~79K events)

trig1_misal1_csc11_V1.005980.Pythiazz4l.recon.AOD.v12000601_tid007884

  - Zbb (~97K events)

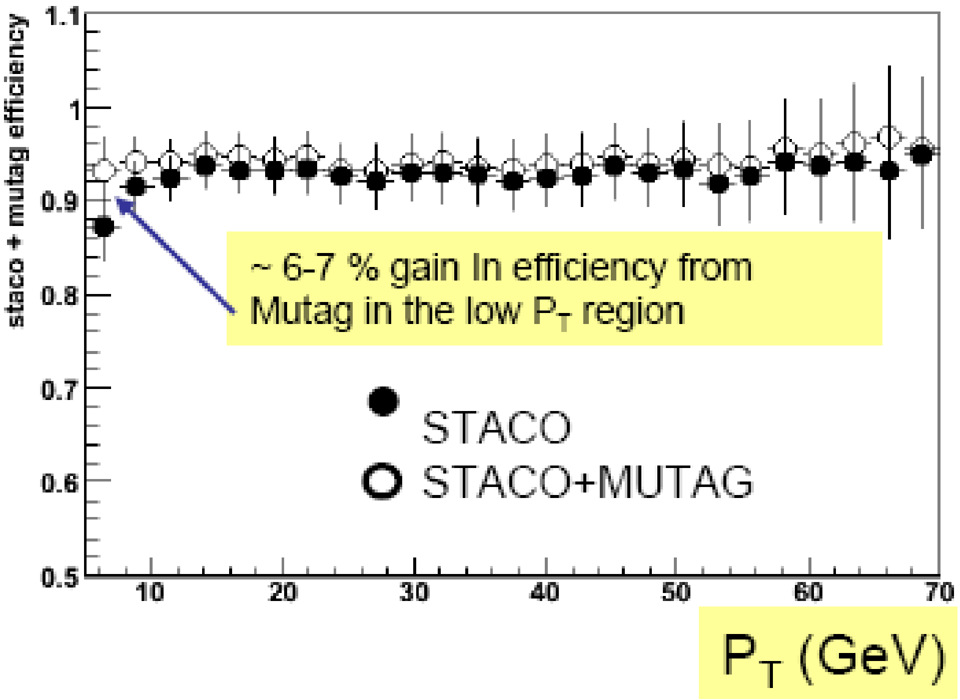
trig1_misal1_mc12.005177.AcerMC_Zbb_4l.recon.AOD.v12000604_tid009504/8746

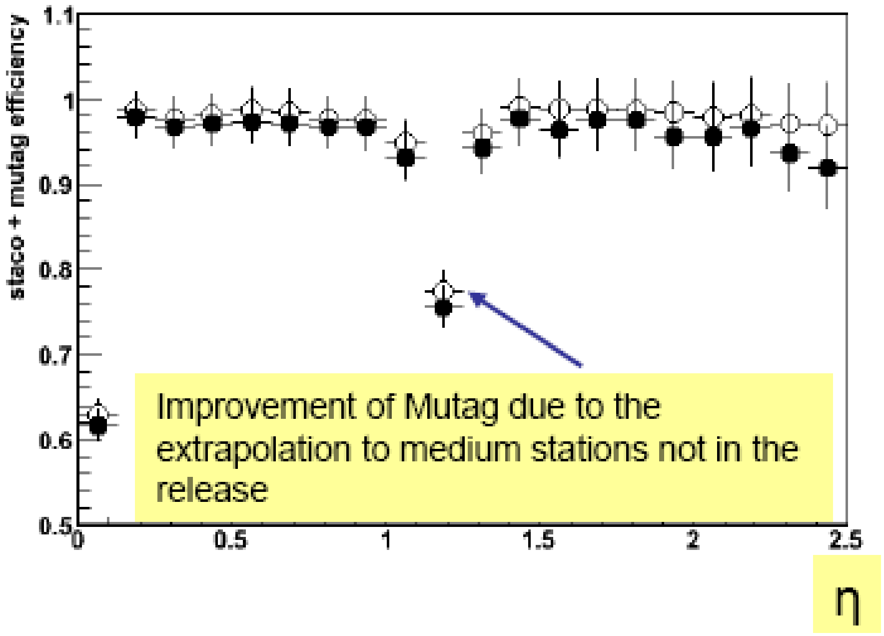
- "misal1" data processed with geometry ATLAS-CSC-01-02-00
  - New magnetic field, misaligned geometry with distortions
  - "sf05": cavern background, 5x ATLAS nominal

- Analysis procedure
  - Copy of all AOD files to a local disk using a grid tool
    - Fast, no particular problems encountered.
  - Perform analysis in our local machine.

Performance Studies (H→4μ)

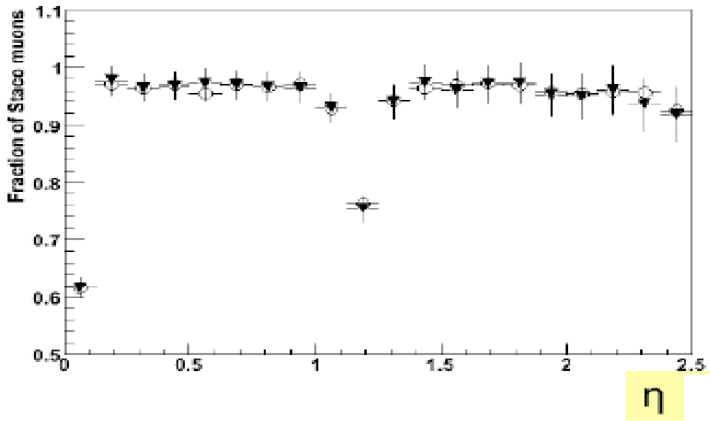
Efficiency of "STACO" and "STACO+MuTag" packages as a function of eta, Pt from H→4l samples with pileup and cavern background

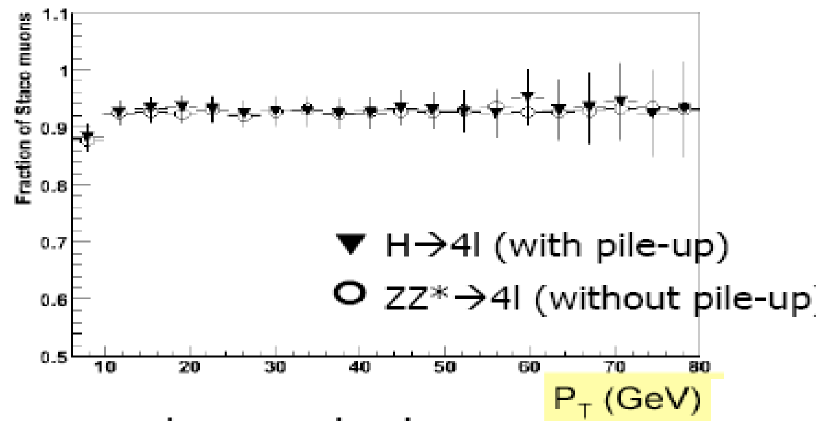




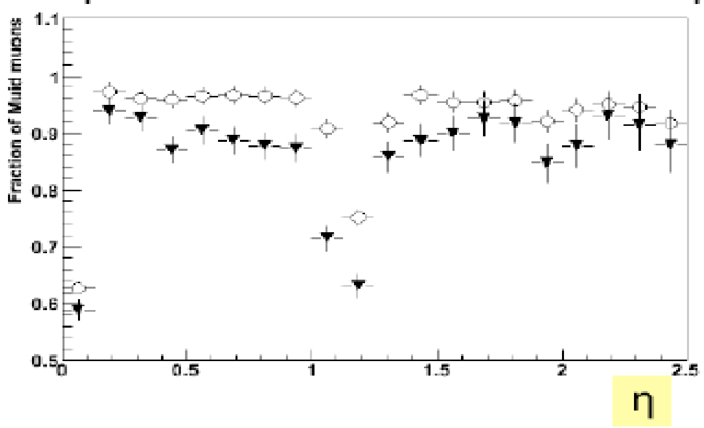
Performance Studies (H→4μ)

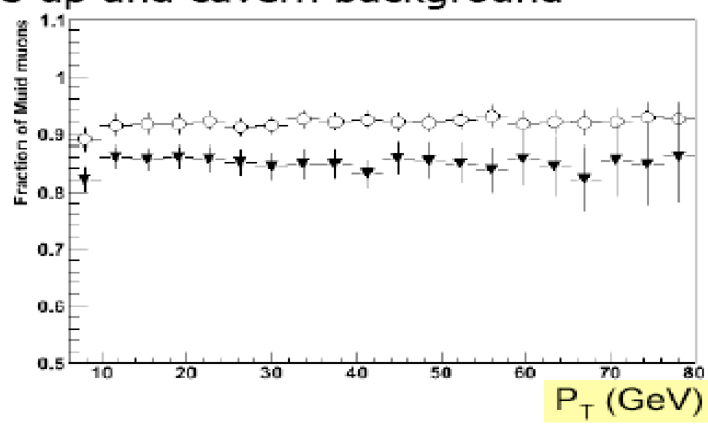
- STACO performance with and without pile-up and cavern background





- Muid performance with and without pile-up and cavern background



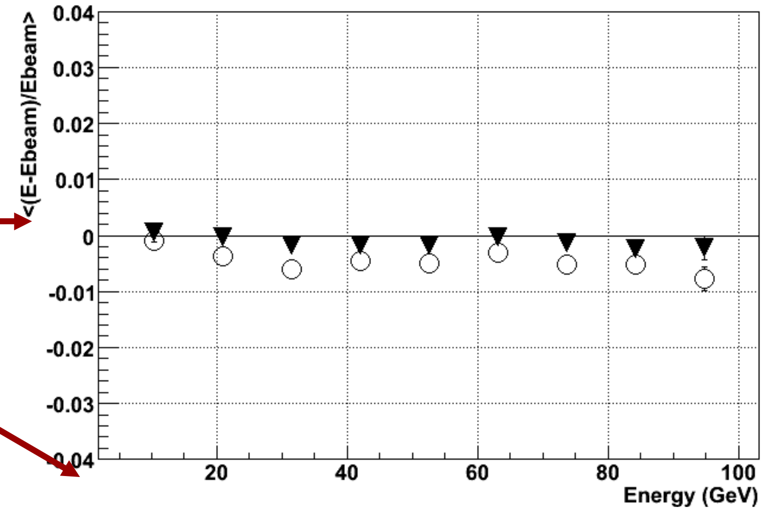


STACO: same performance in samples with/without pile-up, cavern background
MUID: sensitive to pileup + cavern bckg samples

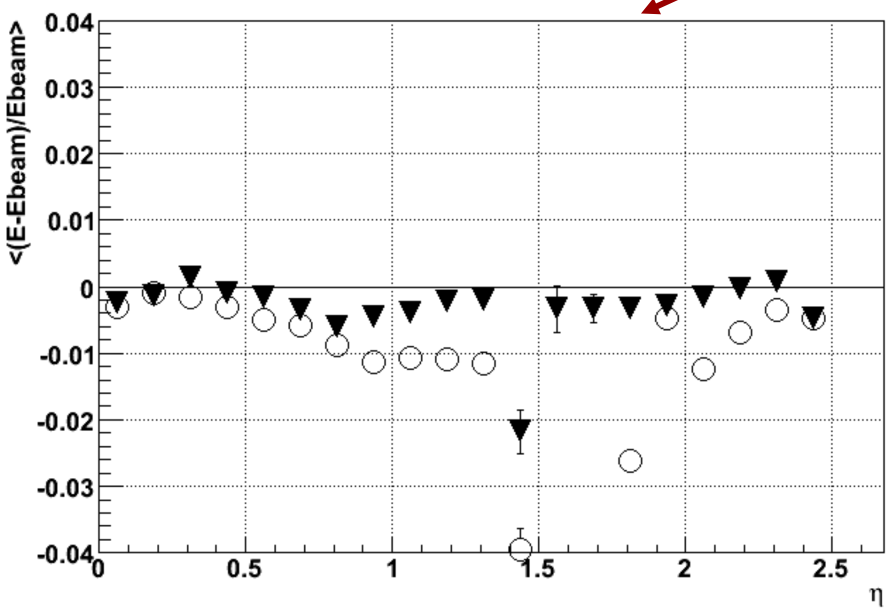
Performance Studies (H→4e)

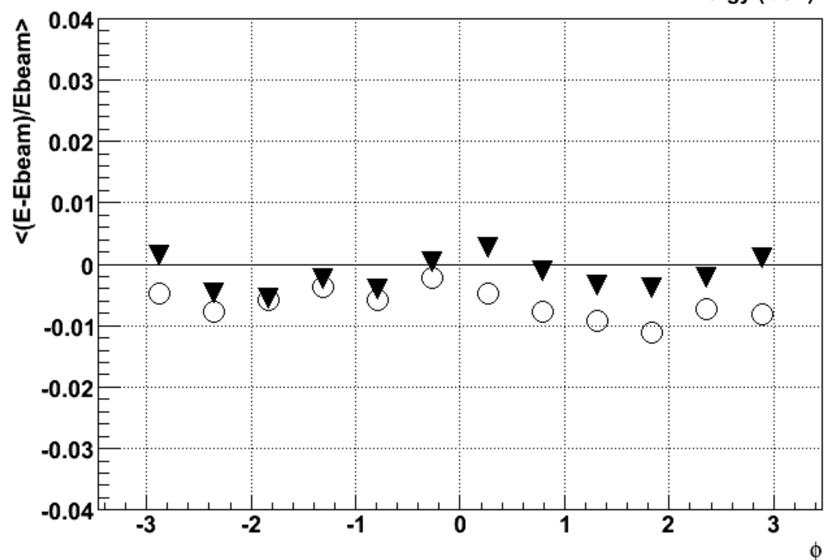
▼ samples with ideal geometry
○ samples of misaligned geometry

Linearity



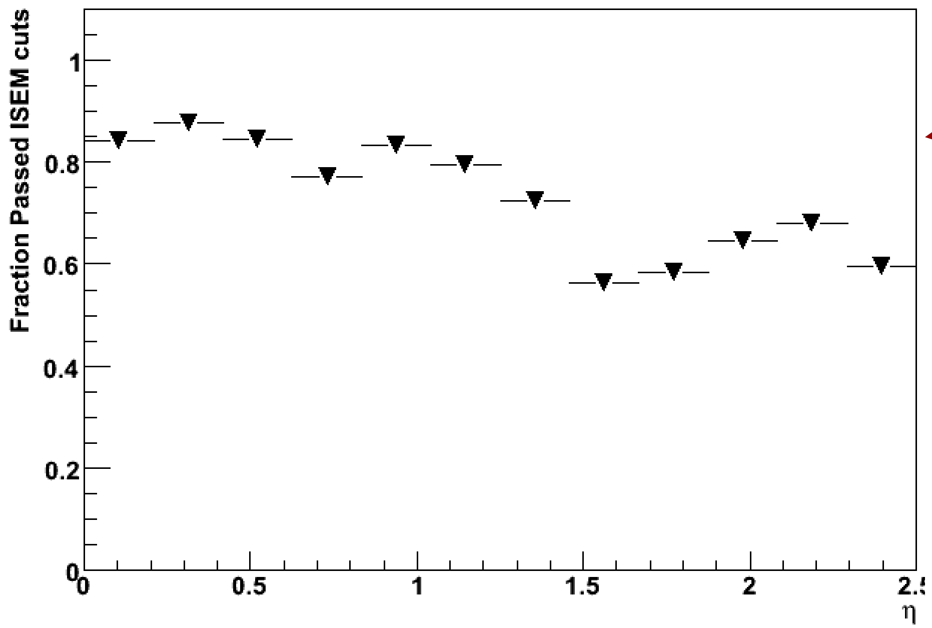
Uniformity versus η , ϕ

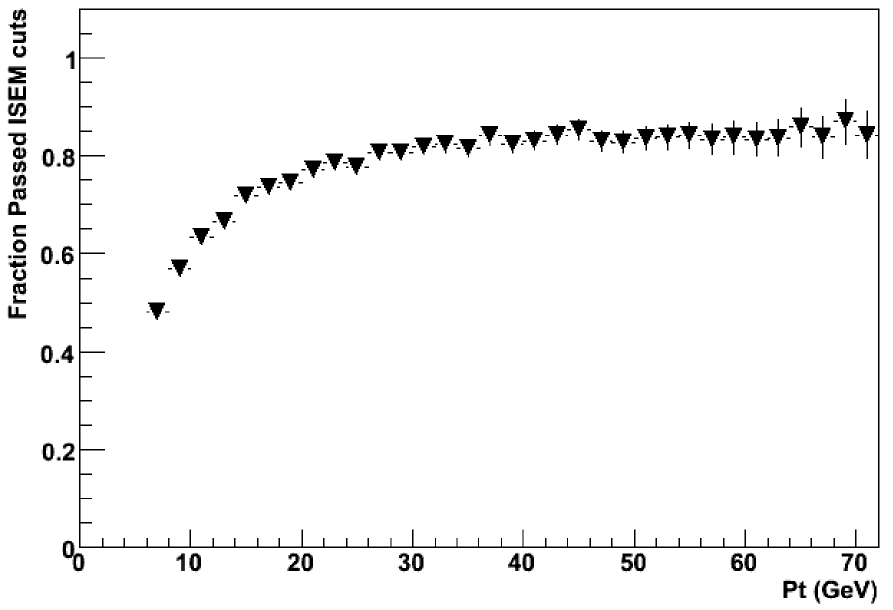




Performance Studies (H→4e)

"IsEm" efficiency versus **η** ,P_t

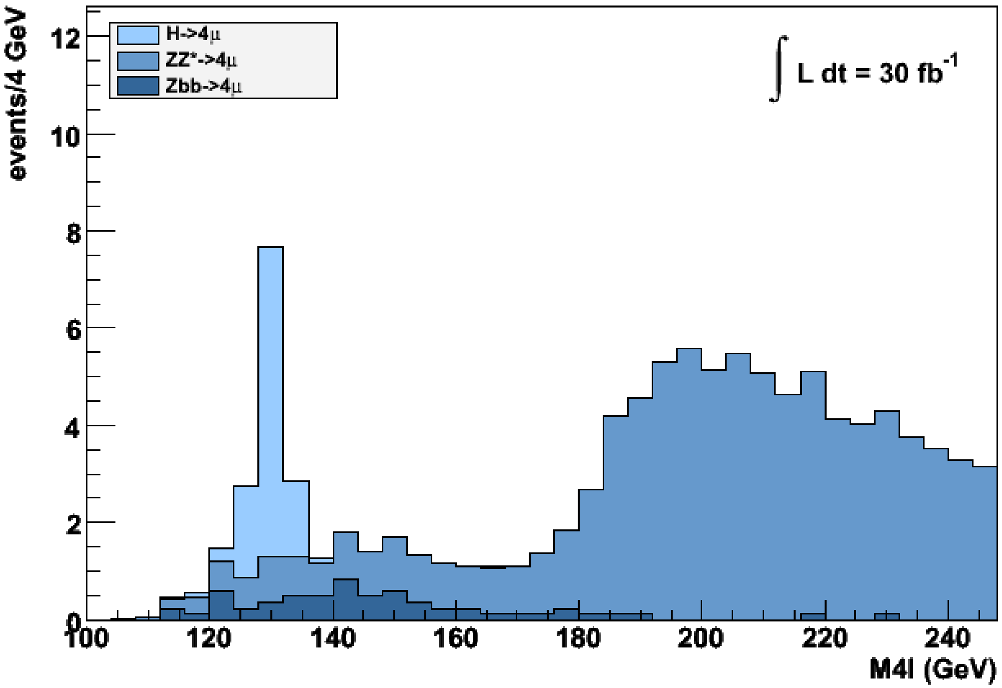




Cut Flow (H→4μ)

Relative efficiencies (%) for signal + bckg starting from a 4l (l=e,μ) sample

Cuts	H→4μ	ZZ*→4μ	Zbb→4μ
4μ combined in η range	18%	16%	8%
4μ combined Pt>7 GeV	88%	92%	51%
2μ combined Pt>20 GeV	94%	98%	86%
Calo isolation	89%	85%	14%
Track isolation	95%	97%	49%
Impact Parameter cuts	96%	94%	56%
Z mass reconstruction	72%	92%	33%
Higgs mass window	92%	1%	11%
Total events per fb^{-1}	**0.31**	**0.08**	**0.02**

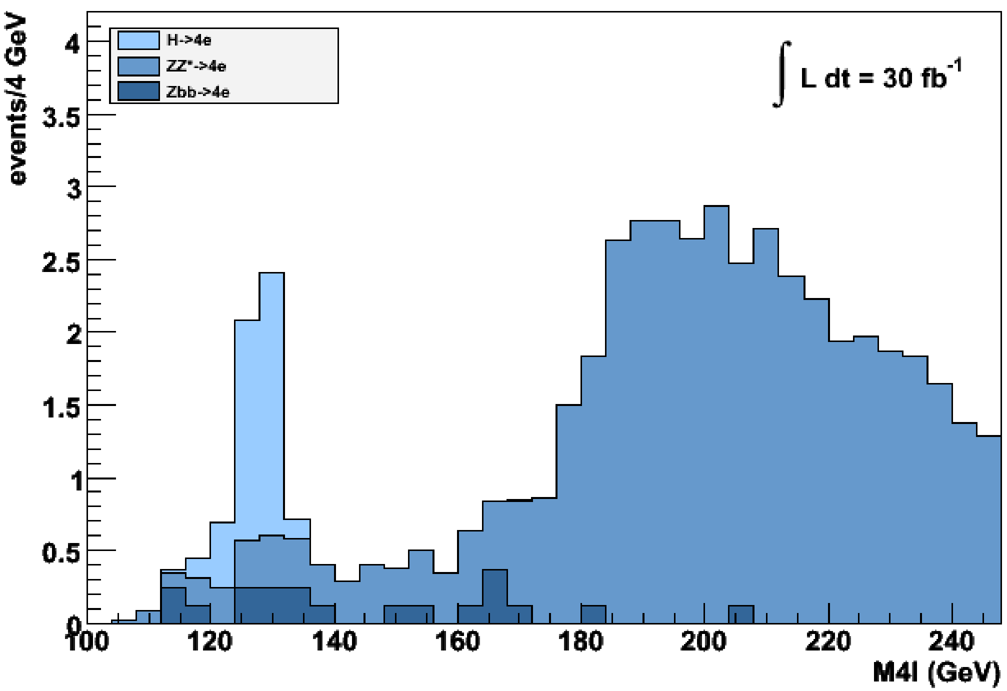


expect ~10 signal events in the mass window ±5 GeV from the Higgs mass of 130 GeV

Cut Flow (H→4e)

Relative efficiencies (%) for signal + bckg starting from a 4l (l=e,μ) sample

Cuts	H→4e	ZZ*→4e	Zbb→4e
4e combined in η range	8%	8%	0.6%
4e combined Pt>7 GeV	90%	96%	50%
2e combined Pt>20 GeV	95%	99%	84%
Calo isolation	96%	98%	74%
Track isolation	91%	88%	46%
Impact Parameter cuts	86%	83%	60%
Z mass cuts	66%	92%	36%
Higgs mass window	79%	1%	21%
Total events per fb^{-1}	**0.1**	**0.04**	**0.02**

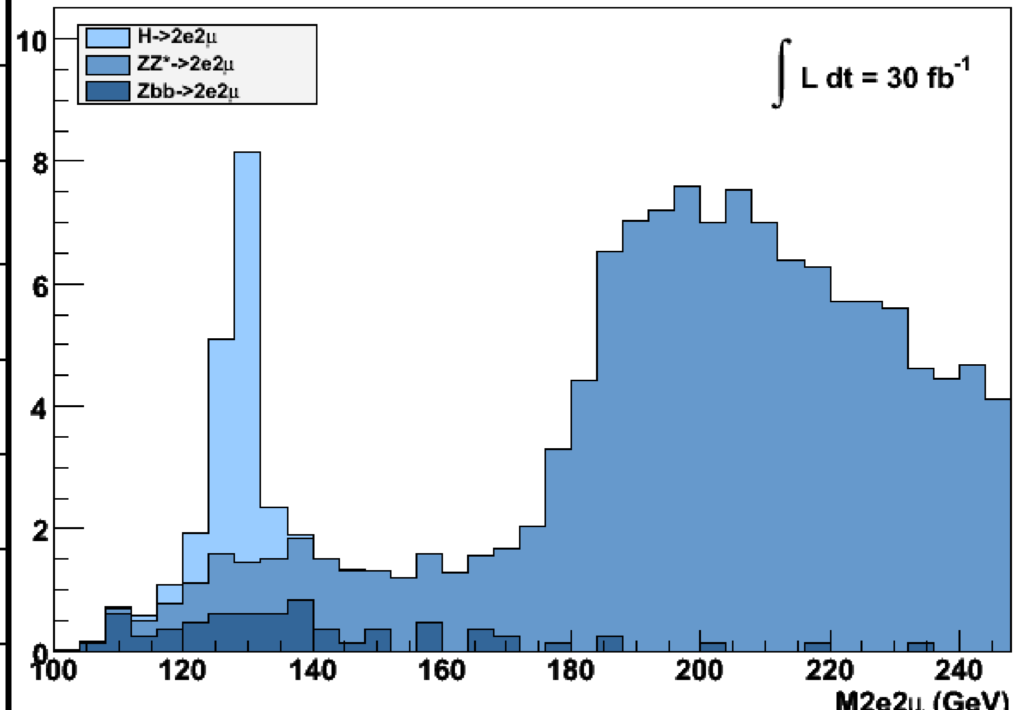


expect ~3 signal events in the mass window ±5 GeV from the Higgs mass of 130 GeV

Cut Flow (H→2e2μ)

Relative efficiencies (%) for signal + bckg starting from a 4l (l=e,μ) sample

Cuts	H→ 2μ2e	ZZ*→ 2μ2e	Zbb→ 2μ2e
2μ2e combined in η range	26%	26%	17%
4l combined Pt>7 GeV	83%	84%	26%
2l combined Pt>20 GeV	95%	98%	87%
Calo isolation	88%	89%	18%
Track isolation	94%	93%	47%
IPcuts	90%	88%	55%
Zmass cuts	68%	92%	42%
Higgs mass window	86%	1%	18%
Total events per fb^{-1}	**0.35**	**0.09**	**0.04**



expect ~10 signal events in the mass window ±5 GeV from the Higgs mass of 130 GeV

H→4l CSC note

https://twiki.cern.ch/twiki/bin/view/Atlas/HiggsToFourLeptonsCSCnote

~14 institutes, ~40 people participating to the analysis

• Technical analysis: To ensure the consistency all analyses that (independent and based (in general) on different data formats,) a "test" of the analysis software implementing a "technical" set of selection cuts complemented by a set of reference plots.

Cross checks of results proved to be very useful;

Very good strategy to apply during real data taking period.

e.g of results, tables produced out of this technical analysis

H-->2e2mu (Staco)

Cut	Artemis	Athens	Cosenza	Madrid	Orsay	Roma	SMU	Wisc AOD	Wisc AAN
none	39250	39250		39250		39250	39250	39250	39250
1.1	8133	7781				7781	7781	7782	7782
1.2	6413	6427				6427	6427	6444	6444
2.1-2.4	4353	4358				4357	4358	4358	4358
3.1		2306		2138		2306	2306	2306	2306
3.2	3653	3654		3357		3654	3654	3654	3654
3.3		4158		3834		4157	4158	4158	4158
4.1		3404		3319					
4.2		3265		3595					
5.x		2803		2696					

Contributions with early data

Main focus in two areas

Performance

- **Muon identification**
  - Muon Spectrometer / Inner Detector
    - measure resolution, efficiency, fake rate from the data
      - Studies with J/Psi, Z samples
- **Electron identification**
  - Calorimeters / Inner Detector
    - check linearity, uniformity, efficiency
      - e.g minimum bias events for uniformity checks versus phi
      - Zs for uniformity checks versus eta, efficiency checks

Background rejection

Contribution to the Standard Model group

- ZZ
- Zbb (e.g process with cross section calculation with large theoretical uncertainties, direct measurement from the data very useful)

Conclusions & Future plans

Within this analysis we are focusing our interest on the following areas /open issues:

- Concerning the backgrounds:
  - Not enough statistics for the reducible backgrounds (tt, Zbb); need tighter filter cuts at generation level
  - Zbb background needs to be checked carefully with various generators in order to estimate the theoretical uncertainties on the calculation of cross sections
- Concerning the performance:
  - Studies, checks, validation of e,μ samples
- Concerning the software tools:
  - Try to have an analysis program flexible enough to adapt to the official ATLAS output scheme (DPD, root access e.t.c)

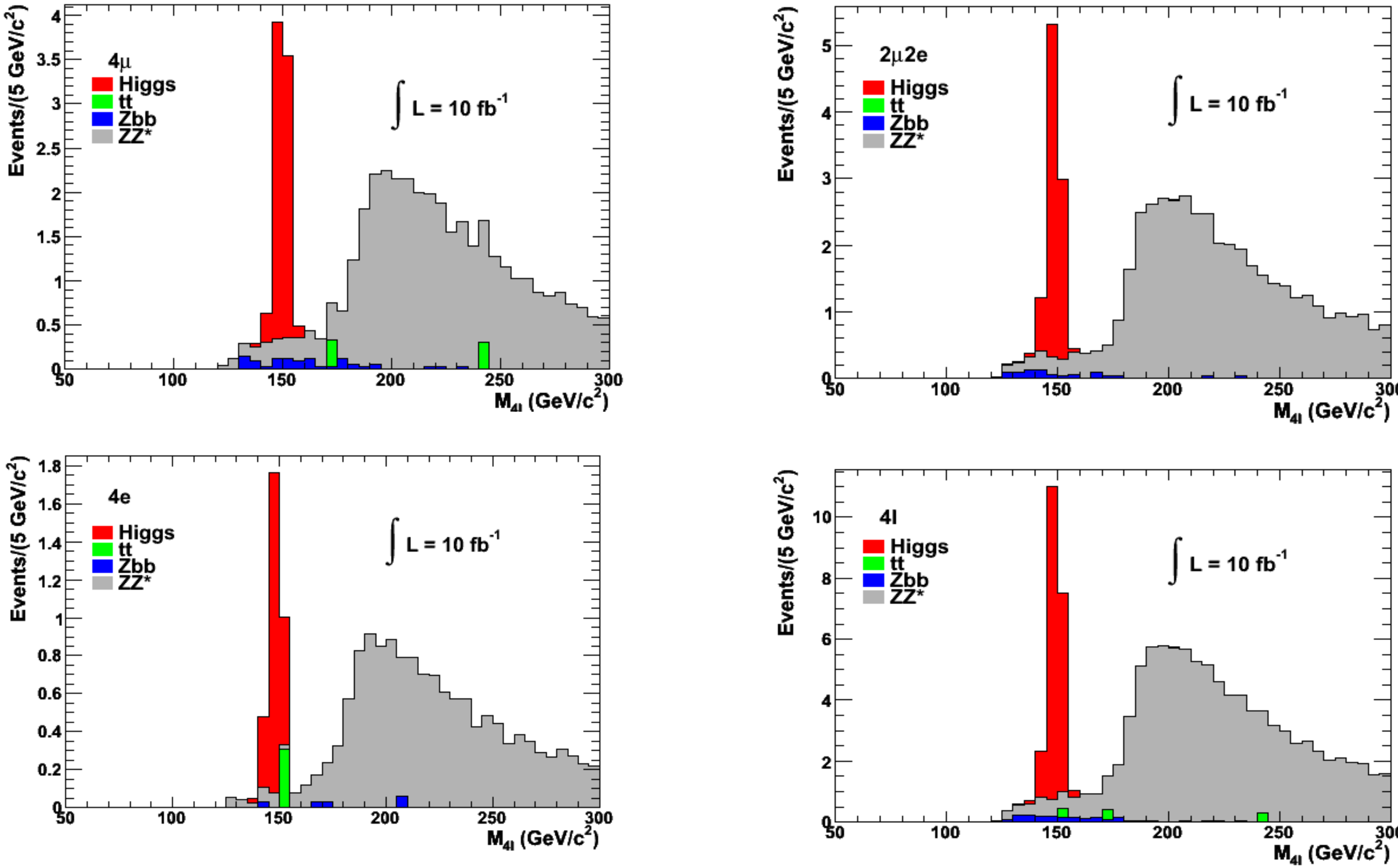
BACKUP SLIDES

Outline

- Mass Plots with 10 fb^{-1}
- Luminosity Overview
- Electron Identification

Signal + Background with 10 fb^{-1}

Plots from H→4lepton working group shown
by F. Gianotti on the 12th of September at the SPC meeting



Luminosity Overview

- What can do in this channel with different $\mathcal{L}$?
  - 1fb^{-1} : Concentrate on performance studies
  - 10 fb^{-1} : H→4l channel already feasible…
  - 30 fb^{-1} : H→4l channel clearly feasible

Number of expected events in the Higgs mass window ± 5 GeV from the Higgs mass of 130 GeV.

Integrated Luminosity	H→4l (mH=130Gev)	ZZ→4l	Zbb→4l
1 fb^{-1}	0.8	0.2	0.08
10 fb^{-1}	8	2.1	0.8
30 fb^{-1}	24	6.3	2.4

Electron Identification

- cut on fraction of energy deposited in 1st sampling

PhysicsElectronTester.CutF1 = [0.005]

- cut on hadronic energy

PhysicsElectronTester.CutHadLeakage = [0.018, 0.018, 0.020, 0.045, 0.030, 0.025, 0.015]

- cut on ratio e237/e277

PhysicsElectronTester.CutReta37 = [0.800, 0.800, 0.600, 0.850, 0.910, 0.910, 0.910]

- cut on shower width in 2nd sampling

PhysicsElectronTester.CutWeta2c = [0.0140, 0.0140, 0.020, 0.0150, 0.0140, 0.0140,0.0125]

- cut on Delta Emax2 in 1st sampling

PhysicsElectronTester.CutDeltaEmax2 = [0.25, 0.45, 0.45, 0.53, 0.40, 0.40, 0.30]

- cut on Emax2 - Emin in 1st sampling

PhysicsElectronTester.CutDeltaE = [150., 150., 100., 300., 200., 150., 150.]

- cut on total width in 1st sampling

PhysicsElectronTester.CutWtot = [4.00, 4.00, 3.00, 3.10, 2.10, 1.55, 1.40]

- cut on width in 1st sampling

PhysicsElectronTester.CutWeta1c = [0.80, 0.80, 0.75, 0.75, 0.68, 0.65, 0.60]

- cut on Fside in 1st sampling

PhysicsElectronTester.CutFracm = [0.35, 0.48, 0.47, 0.48, 0.27, 0.25, 0.20]