Recherche du boson de Higgs se désintegrant en 4-leptons dans ATLAS

Isolation calorimétrique des muons

Bruno Lenzi

CEA - Saclay

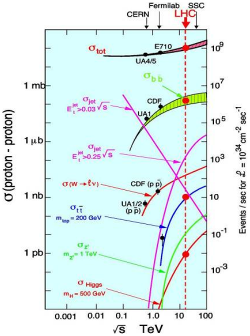
Journées des jeunes chercheurs
05/12/08

Outline

Outline

Large Hadron Collider (LHC)

- 27.6 km accelerator
- p + p collisions at 14 TeV (also Pb + Pb @ 5.5 TeV)
- 4 experiments
  - 2 general purpose: ATLAS, CMS
  - B-physics: LHC-b
  - Heavy ions: ALICE

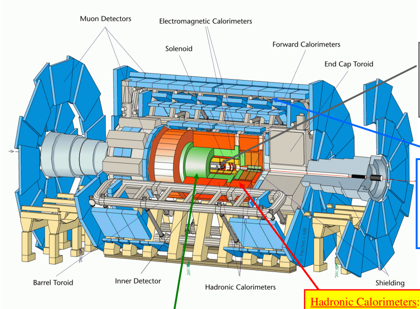


- Designed to look for the Higgs boson and any evidence of new physics BSM
- Precision measurements (m_{top}, m_W)
- Dealing with (very) rare processes, cannot miss interesting events!

A Toroidal LHC ApparatuS (ATLAS)

Length ~45 m , Weight ~7000 tonnes

Height ~22m



Inner Detector: (Silicon pixels + strips +TRT→particle ID (e/π))
B=2T , $\sigma/p_T \sim 10\% \, p_T \oplus 1\%$
(e.g. H → bb)

Muon system: (precision chambers + triggers in air core toroids B=0.5T mean value) ,
σ/pT ~ 10 % at 1 TeV standalone
(e.g. H,A→μμ, H→4μ)

Hadronic Calorimeters: (Fe scint Cu-liquid argon)
$\sigma/E \sim 50\%/\sqrt{E} \oplus 3\%$
Jet, E_{Tmiss} performance **(e.g. H →ττ, H→bb)**

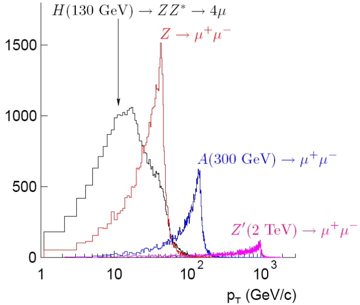
Electromagnetic Calorimeters: (Pb liquid argon)
$\sigma/E \sim 10\%/\sqrt{E} \oplus 0.7\%$, Uniform longitudinal segmentation
Provides: e/γ identification, energy and angular resolution,
γ/jet , γ /π0 separation **(e.g. H→γγ)**

Energy-scale: e/γ~0.1%, μ~0.1%, Jets~1%

- Inner Detector (ID), Calorimeters, Muon Spectrometer (MS)
- Solenoidal (ID) and toroidal (MS) magnets
- 10^8 readout channels
- More than 2k physicists

Muons in LHC

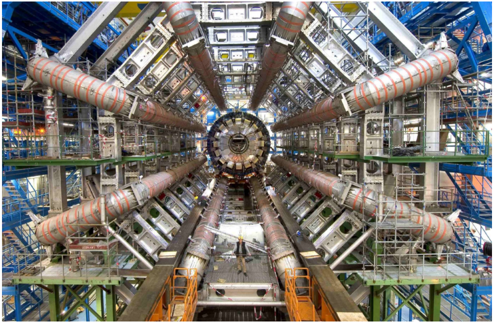
- Muons are the only particles that can traverse large quantity of material (calorimeters)
- Present in several physical processes (clean signature)
- Usually low branching ratios



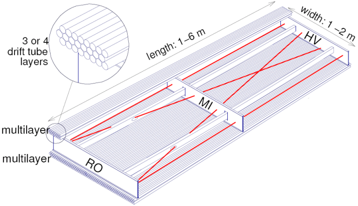
Requirements

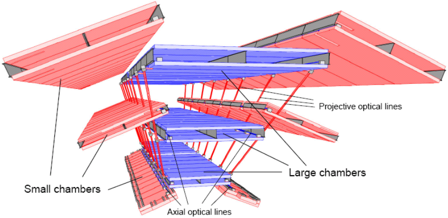
- Excellent reconstruction efficiency and momentum resolution over wide range
- Very low fake rates
- Efficient trigger capability

ATLAS Muon Spectrometer



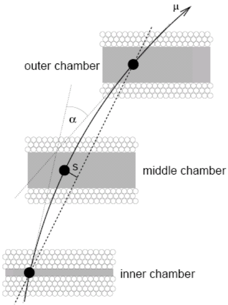
- Trigger and precision chambers in air core toroids
  - Independent trigger system and momentum measurement
  - Muons bent in the polar direction
- 4 different chamber technologies
- 16 sectors, 3 stations, $\approx$ 2k chambers, 10^6 channels, 10^3 m^2
- Optical alignment aiming 30 μm precision

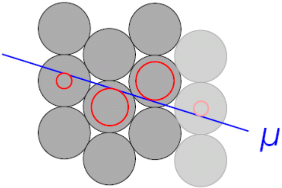




ATLAS Muon Spectrometer - muon measurement

- Hit position defined by tube and drift radius
- Momentum determined by sagitta measurement (s)
- 2nd coordinates measured in trigger chambers (not shown)



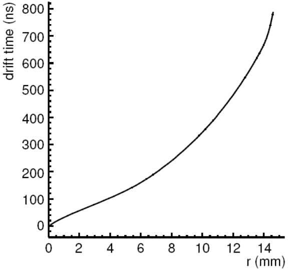


Goal: $\sigma_{p_T} \approx 10\%$ @ 1 TeV

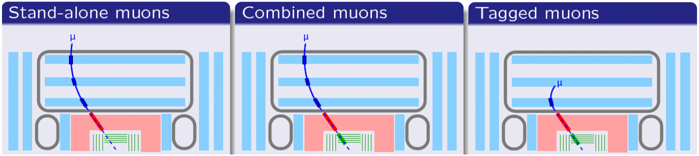
Sagitta $\approx 500\mu m$

Spatial resolution $\approx 40\mu m$

$\sigma_{\text{align}} = \sqrt{(50\ \mu\text{m})^2 - (40\ \mu\text{m})^2}$

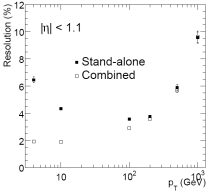


ATLAS Muon Spectrometer - muon measurement

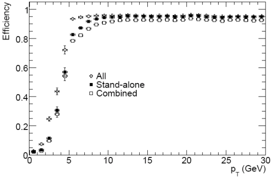


MS
Calo
ID

Taking into account E-loss

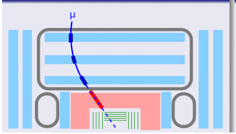


- Standalone muons: not seen by Inner Detector
  - MS coverage ($|\eta| < 2.7$) exceeds ID ($|\eta| < 2.5$)
- Combined muons: measured by Inner Detector and Muon Spectrometer
  - Improved momentum measurement
  - Efficiency around 95%
  - Very low fake rates $\approx 10^{-3}$/event
- Tagged muons: by MS or calorimeter
  - Low-pt muons do not reach outer stations
  - Regions without 3 stations

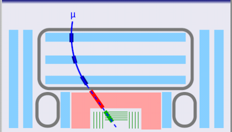


ATLAS Muon Spectrometer - muon measurement

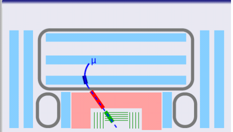
Stand-alone muons



Combined muons



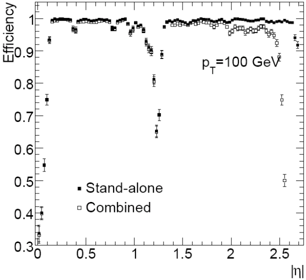
Tagged muons



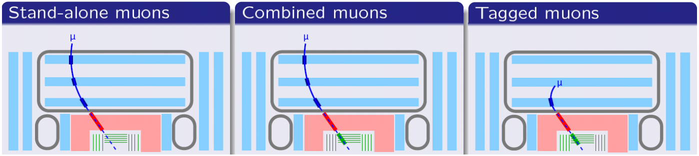
MS
Calo
ID

Taking into account E-loss

- Standalone muons: not seen by Inner Detector
  - MS coverage ($|\eta| < 2.7$) exceeds ID ($|\eta| < 2.5$)
- Combined muons: measured by Inner Detector and Muon Spectrometer
  - Improved momentum measurement
  - Efficiency around 95%
  - Very low fake rates $\approx 10^{-3}$/event
- Tagged muons: by MS or calorimeter
  - Low-pt muons do not reach outer stations
  - Regions without 3 stations



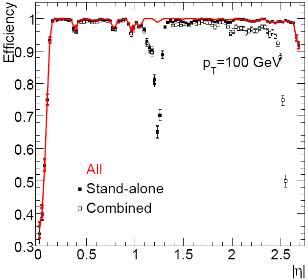
ATLAS Muon Spectrometer - muon measurement



MS
Calo
ID

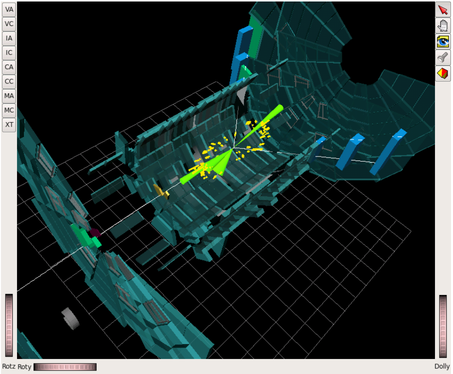
Taking into account E-loss

- Standalone muons: not seen by Inner Detector
  - MS coverage ($|\eta| < 2.7$) exceeds ID ($|\eta| < 2.5$)
- Combined muons: measured by Inner Detector and Muon Spectrometer
  - Improved momentum measurement
  - Efficiency around 95%
  - Very low fake rates $\approx 10^{-3}$/event
- Tagged muons: by MS or calorimeter
  - Low-pt muons do not reach outer stations
  - Regions without 3 stations



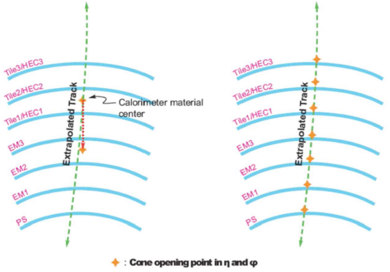
ATLAS Muon Spectrometer - muon energy loss and isolation

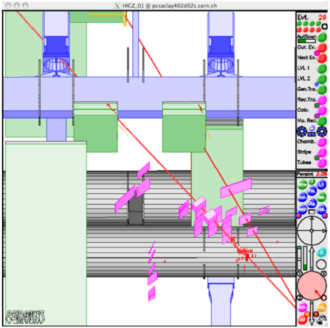
- Isolation is related to detector activity around a given particle
  - One of the main features used to separate signal and backgrounds in SM analysis, Higgs searches and beyond
  - Used to separate muons from W,Z and inside jets (b,c)



ATLAS Muon Spectrometer - muon energy loss and isolation

- Muons also loose energy in the calorimeters (impact on momentum resolution)
- Studying optimizations to better describe E-loss and consequently isolation
  - Minimum number of cells to consider for E-loss
  - Size of the region around the muon that maximizes S/B

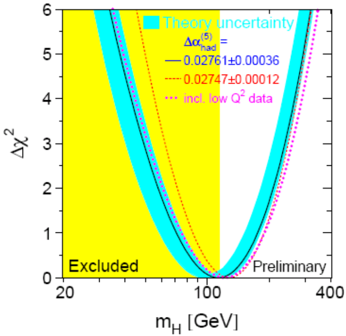


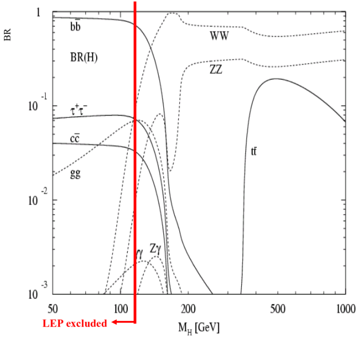


Outline

Higgs boson

- Search for the Higgs boson is the main objective of ATLAS and LHC
- Constrains by direct (> 114.4 GeV - LEP) and indirect searches ($\lesssim$ 180 GeV - LEP / Tevatron) (95% CL)
  - **But we have to look all over!**
- Many production / decay modes, but in particular H $\rightarrow$ ZZ
  - One the highest branching ratios
  - H $\rightarrow$ ZZ $\rightarrow$ 4-leptons (e, μ) is the so called "golden channel"

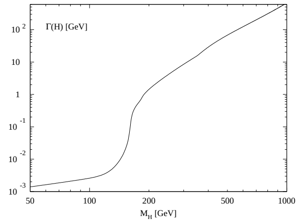


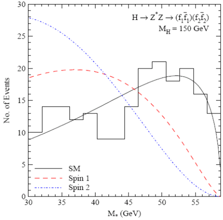


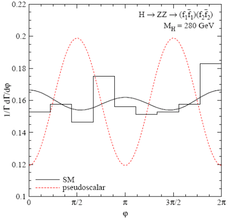
Higgs to ZZ

We see a peak! But is it the (SM) Higgs?

- Apart from Higgs mass, SM predicts width, spin, parity, couplings...
- ZZ is suitable for measuring Higgs properties
  - Mass with good precision
  - Width for high masses
  - Spin and parity, high statistics needed



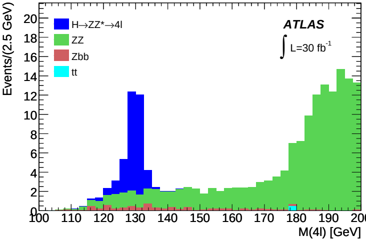




Higgs to 4-leptons

Why "golden channel"?

- Clear peak over smooth background
- Significant discovery potential for $m_H > 130$ GeV
- Precise mass measurement



Higgs to 4-leptons

Why "golden channel"?

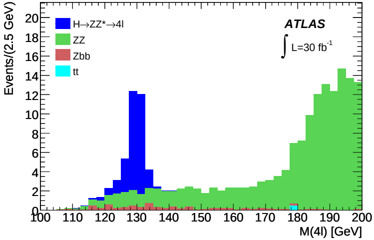
- Clear peak over smooth background
- Significant discovery potential for $m_H > 130$ GeV
- Precise mass measurement

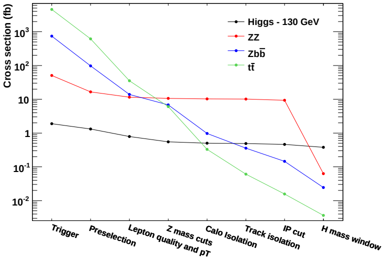
However...

- Very low b.r. for $Z \rightarrow ll$ (3% each)
- Low cross section when WW becomes on-shell (160 GeV)
- Soft leptons for low m_H (Z off-shell)

Process	Cross-section
$H \rightarrow 4l$ (120 - 200 GeV)	1.6 - 15.5 fb
$ZZ^{(*)} \rightarrow 4l$	57.2 fb
$Zb\bar{b} \rightarrow 4l + X$	812 fb
$t\bar{t} \rightarrow 4l + X$	6064 fb

4-leptons with $p_T > 5$ GeV and $|\eta| < 2.5$





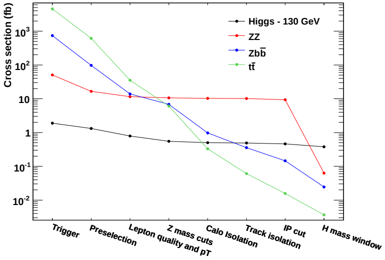
Higgs to 4-leptons

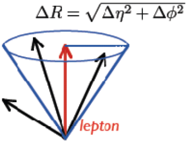
However...

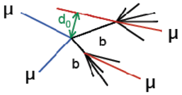
- Very low b.r. for Z → ll (3% each)
- Low cross section when WW becomes on-shell (160 GeV)
- Soft leptons for low m_H (Z off-shell)

Process	Cross-section
H → 4l (120 - 200 GeV)	1.6 - 15.5 fb
$ZZ^{(*)}$ → 4l	57.2 fb
$Zb\bar{b}$ → 4l + X	812 fb
$t\bar{t}$ → 4l + X	6064 fb

4-leptons with p_T > 5 GeV and $|\eta|$ < 2.5







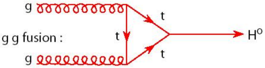
Leptons from bottom decays

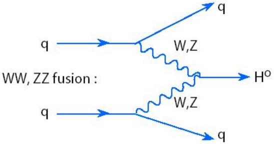
- Are softer (p_T)
- Are less isolated (track and calorimeter isolation)
- Have a displaced vertex (impact parameter (IP))
- Do not form resonance (di-lepton mass)

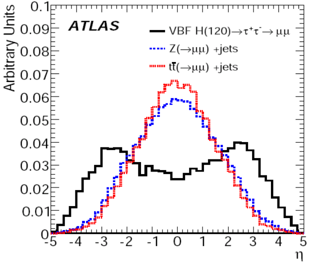
Same effect on signal and ZZ!

Higgs production modes

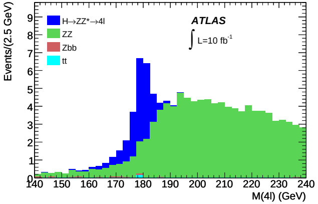
On LHC Higgs is mainly produced by gluon-fusion and Vector-Boson-Fusion (VBF)







- VBF has a clear experimental signature: two forward jets with high-p_T and high separation in η
  - Used when gg-fusion is not feasible ($H \to \tau\tau$) or to reduce QCD backgrounds ($H \to WW$)
- Advantages: can measure Higgs coupling to W,Z, etc.
- Drawback: relatively small fraction of the production ($\approx 20\%$)



Started to investigate feasibility of VBF analysis in $H \to 4l$ channel

- Can be used to reduce "ireducible" ZZ bg

VBF analysis in H $\rightarrow$ 4l channel

Cross sections and expected events (30 fb^{-1})

Higgs mass	σ_{NLO} (fb) H $\rightarrow$ 4l	gluon-fusion events	VBF events
165	2.29	42	6
180	5.38	102	16
200	20.53	397	66
300	13.32	267	46

- Dealing with (very) low statistics
- Started with VBF H $\rightarrow \tau\tau$
  - Not efficient enough for this analysis
- Studying optimizations on tagging and cuts for VBF jets

Do not have a good simulation for the moment, but it looks promising...

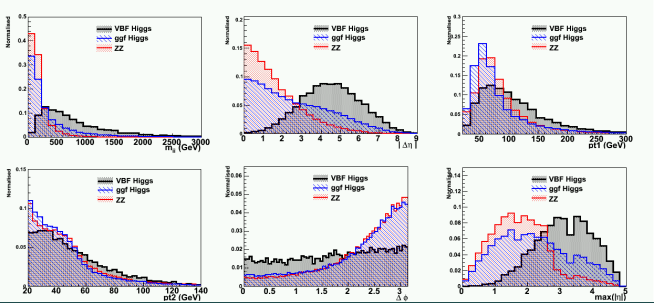
VBF analysis in $H \to 4l$ channel

Cross sections and expected events (30 fb^{-1})

Higgs mass	σ_{NLO} $H \to 4l$ (fb)	gluon-fusion events	VBF events
165	2.29	42	6
180	5.38	102	16
200	20.53	397	66
300	13.32	267	46

- Dealing with (very) low statistics
- Started with VBF $H \to \tau\tau$
  - Not efficient enough for this analysis
- Studying optimizations on tagging and cuts for VBF jets

Do not have a good simulation for the moment, but it looks promising...



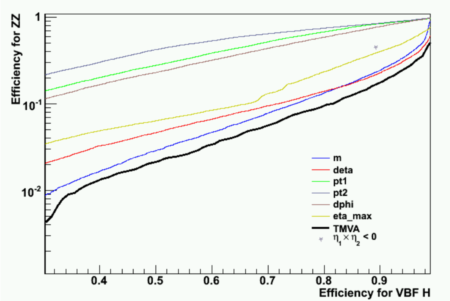
VBF analysis in H $\rightarrow$ 4l channel

Cross sections and expected events (30 fb^{-1})

Higgs mass	σ_{NLO} (fb) H $\rightarrow$ 4l	gluon-fusion events	VBF events
165	2.29	42	6
180	5.38	102	16
200	20.53	397	66
300	13.32	267	46

- Dealing with (very) low statistics
- Started with VBF H $\rightarrow \tau\tau$
  - Not efficient enough for this analysis
- Studying optimizations on tagging and cuts for VBF jets

Do not have a good simulation for the moment, but it looks promising...



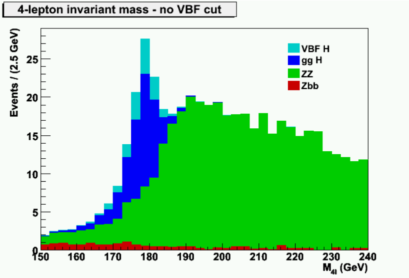
VBF analysis in H $\rightarrow$ 4l channel

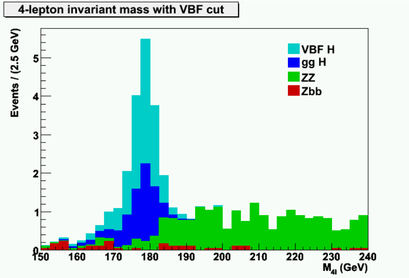
Cross sections and expected events (30 fb^{-1})

Higgs mass	σ_{NLO} (fb) H $\rightarrow$ 4l	gluon-fusion events	VBF events
165	2.29	42	6
180	5.38	102	16
200	20.53	397	66
300	13.32	267	46

- Dealing with (very) low statistics
- Started with VBF H $\rightarrow \tau\tau$
  - Not efficient enough for this analysis
- Studying optimizations on tagging and cuts for VBF jets

Do not have a good simulation for the moment, but it looks promising...





Outline

Summary and future plans

- ATLAS Muon Spectrometer
  - Very precise and complex system
  - Muons give a clean signature for many physical processes
  - Studying calorimetric isolation $\longrightarrow$ used on Higgs searches, SM and BSM analyses
- Higgs boson and the 4-lepton channel
  - $H \longrightarrow ZZ$ can measure Higgs properties
  - 4-leptons is the "golden channel" but not that easy
  - Started VBF $H \longrightarrow 4l$ analysis

Plans:

- Continue with H analysis on simulation
- Muon isolation with simulation and real data (collisions or cosmics)

Muon trigger