Search for the VBF $H \rightarrow \tau\tau$ decays with the ATLAS Detector at the LHC

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On behalf of the ATLAS Collaboration

International Conference on Particle Physics

In Memoriam Engin Arık and Her Colleagues

Boğaziçi University, İstanbul, Turkey

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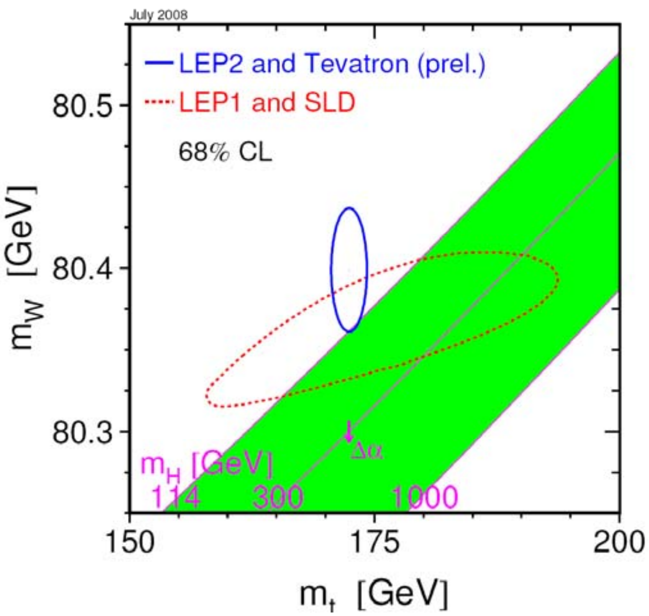
Outlines

- Higgs production at the LHC
- VBF qqH→qq $\tau\tau$ Signal Reconstruction
  - Triggers
  - Leptons reconstruction
- Background Estimation
  - MC and data-driven estimations
- Systematics
- Pile-up effects

Experimental Constraints on SM Higgs

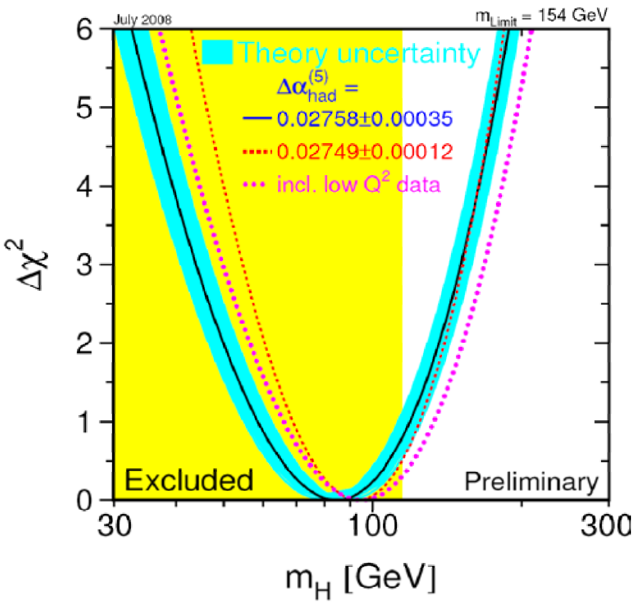


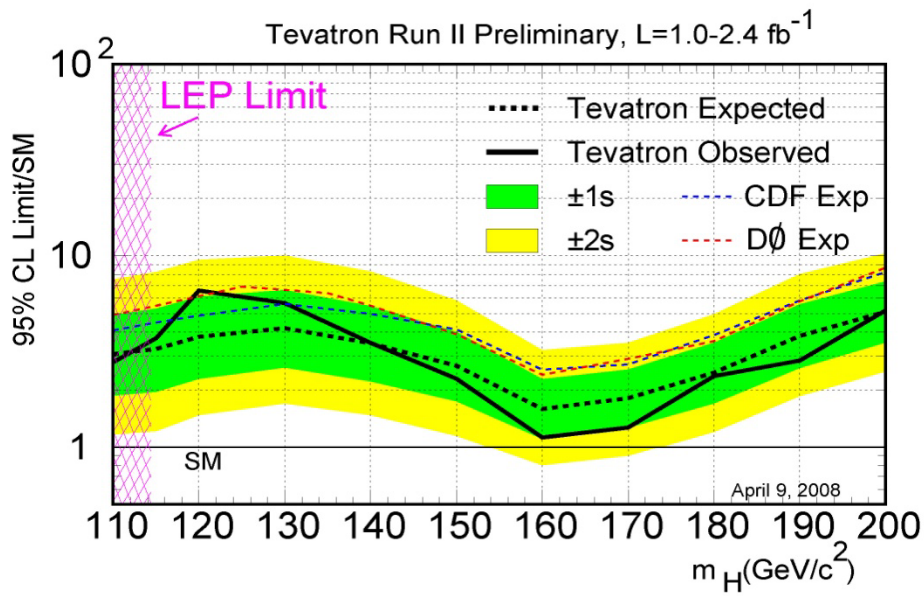
- **Electroweak symmetry breaking needed to explain e.g. masses of fundamental fermions and W/Z bosons**
- **Simplest model of EW symmetry breaking predicts the existence of a Higgs scalar**
  - **Higgs boson mass is only free parameter in theory**
- **Masses of Higgs, top and W connected through loop diagrams → precision electroweak fits sensitive to Higgs mass**

  $m_H = 87 +34 -26$ GeV/c²; including LEP: $m_H < 185$ GeV/c²

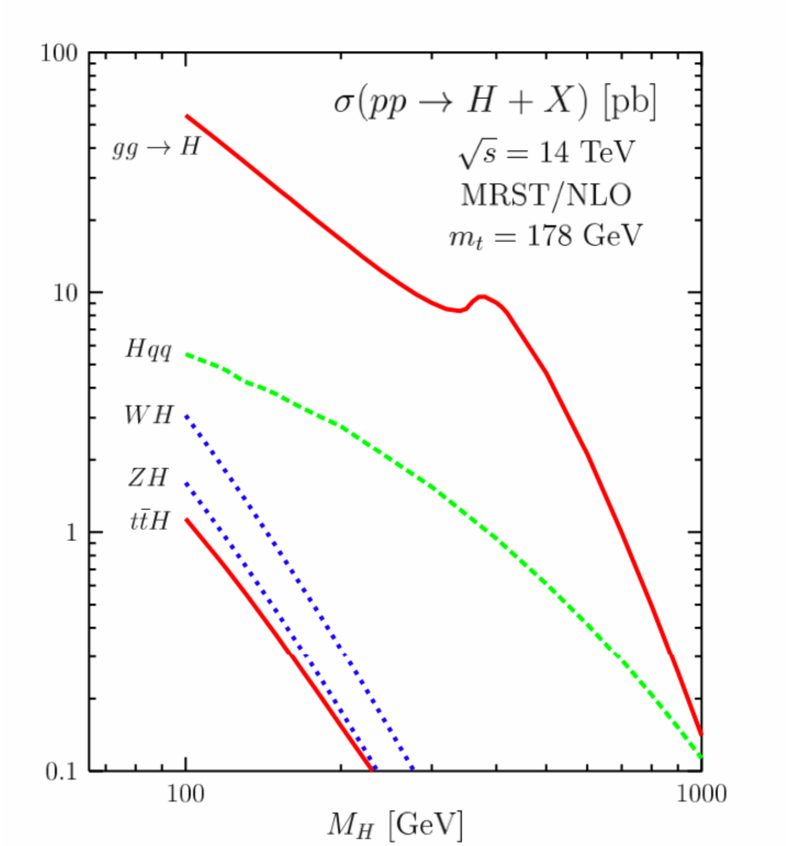
- **From LEP: $m_H > 114.4$ GeV/c² @ 95% CL**

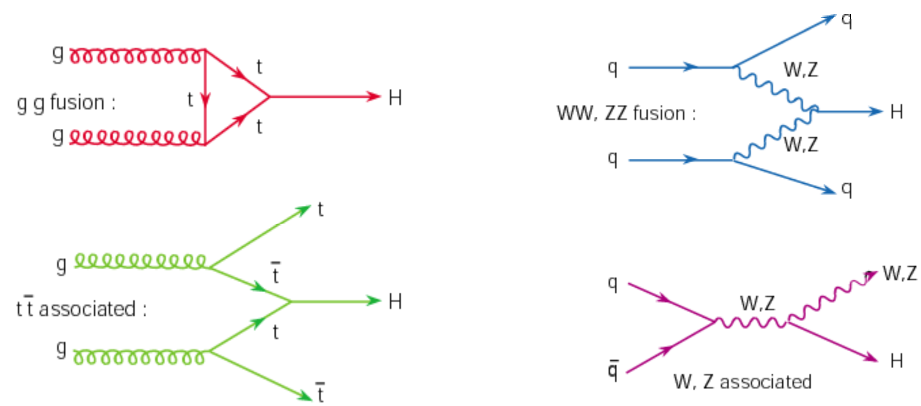
- **Tevatron experiments expected to be able to exclude SM Higgs @ 95%CL up to $m_H \approx 200$ GeV/c² or make 3σ observation?**





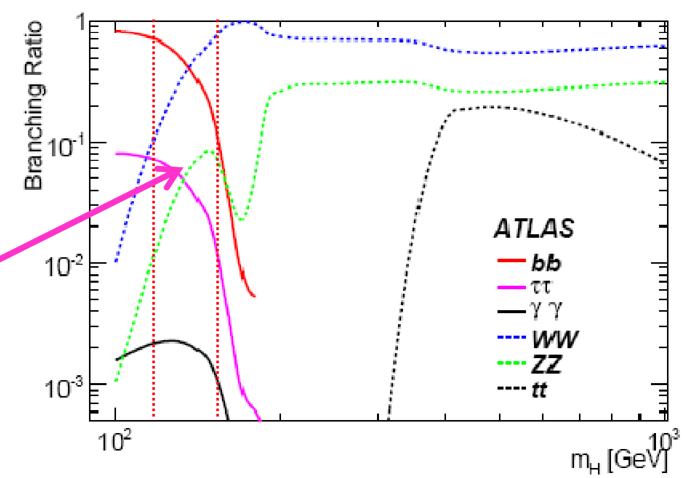
Higgs Production and Decay @ LHC





Typical uncertainties on the cross sections

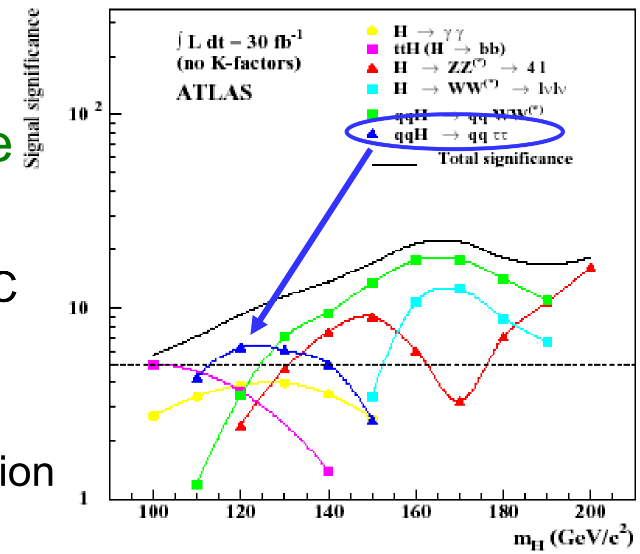
gg fusion: ~ 10% NNnLO
VBF : ~ 5% NLO
ttH : ~ 10-15 % NLO
WH,ZH : ~ 5% NNLO



- High BR for ττ decay mode is around [110-140] GeV
- Only channel to measure Higgs Yukawa coupling to leptons

Higgs Discovery Potential with ATLAS

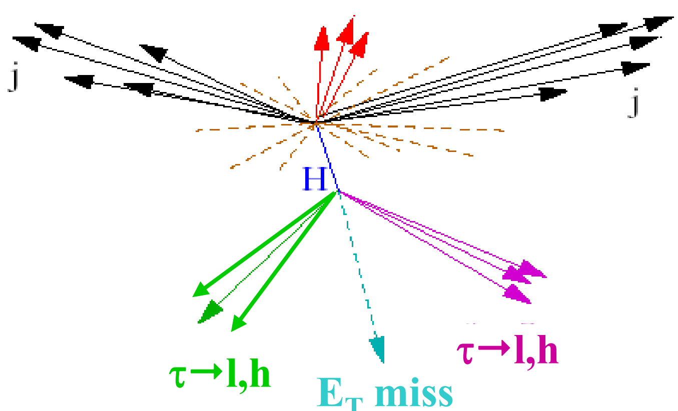
SN-ATLAS-2003-024



- Previous Monte Carlo studies in ATLAS have showed a discovery potential for SM Higgs boson over a large mass spectrum:
  - A 5σ significance could be reached within the first $30 fb^{-1}$ of LHC nominal luminosity
  - Several channels for each mass point
  - VBF modes plays a crucial role in the [115-130] GeV mass region
- Improved analysis in 2008
  - full GEANT4 simulation with realistic detector geometry and misalignment / distortion effects , large statistics (Computing System Commissioning)
  - Detailed trigger simulation (including lvl1 firmware trigger) most recent reconstruction and identification methods
  - LO/NLO ME generators (Alpgen, Sherpa, MC @ NLO) matched to PS generators (Herwig) for backgrounds
  - All tau decay final states combinations considered
    - Feasibility of trigger for hadron-hadron chanel

VBF qqH→qq ττ Signal

- Focus on ττ final state with all τ decay modes considered for the first time.
  - Cross section x Br = 0.4 - 0.5 pb



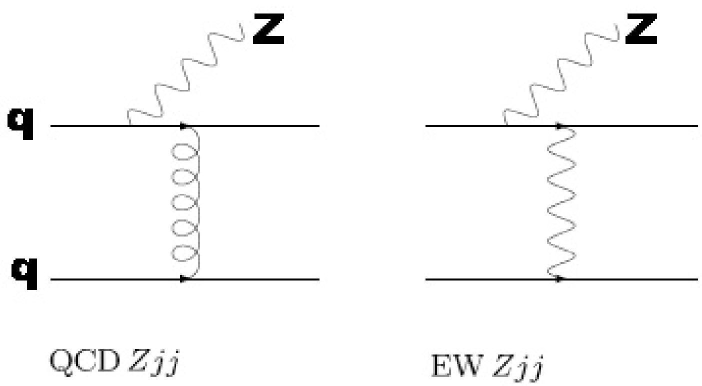
Signal signature :

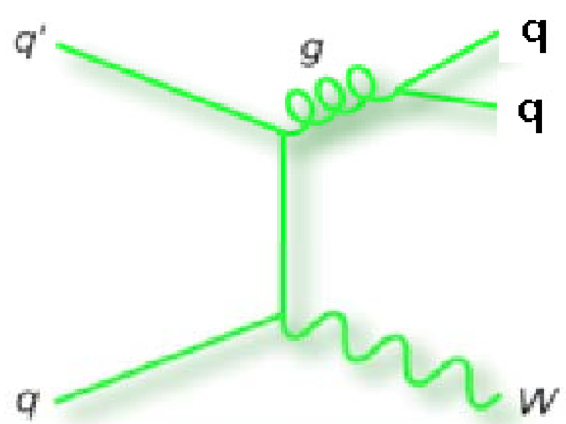
- 2 high pt forward jets
- decay products:
  - 2 central leptons (ll)
  - 1 central lepton + 1 central tau jet (lh)
  - 2 centrals tau jets (hh)
  - E_T^{miss}

- Main Background:
  - Z→ ττ +jets, Z→ll+jets, W+jets, WW+jets, ttbar, multijet QCD
- Experimental issues:
  - Good lepton (e, μ) identification.
  - Good efficiency for the reconstruction of forward jets.
  - very good τ jet identification and rejection of fakes from e, μ and QCD jets.
  - Good E_T^{miss} measurement for mass resolution of tau-pairs.

Main Backgrounds to qqH, H $\rightarrow\tau\tau$

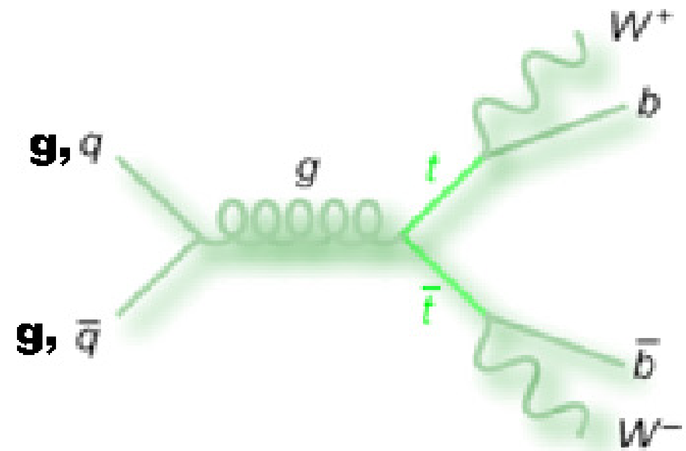
Z+jets : 2 taus and jets as in signal
Handle : different kinematic

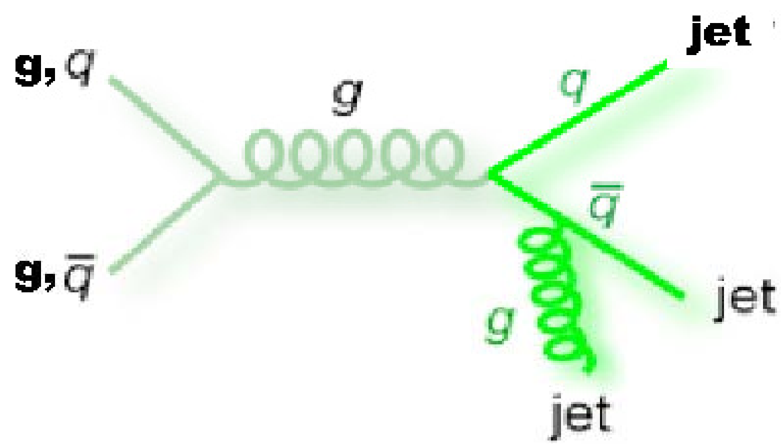




W+jets : 1 tau and q(g) jets as in signal.
Handle : different kinematic and tau identification

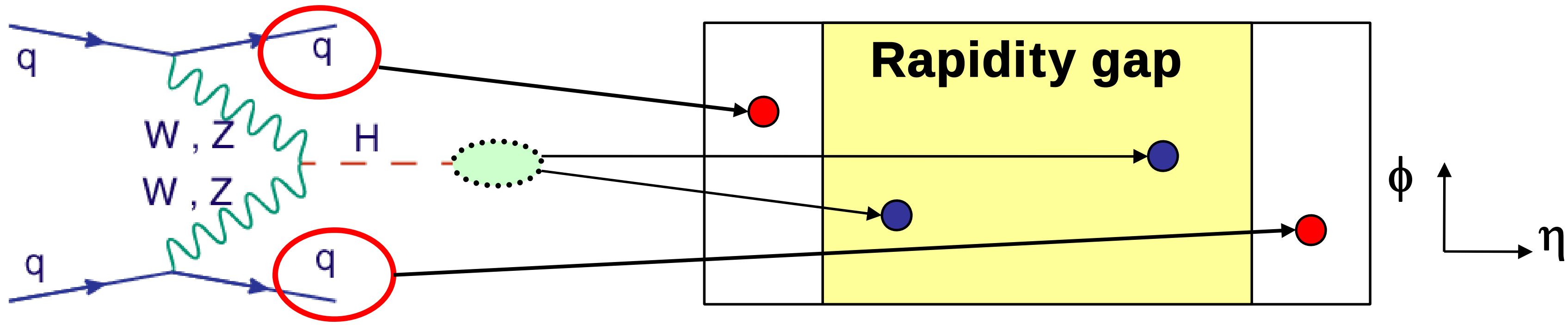
tt : 2 taus as in signal, but no q,g jets
Handle : different kinematic and jet flavour



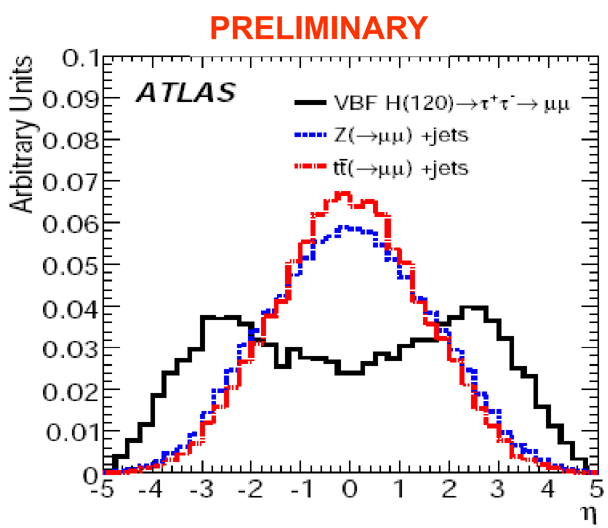


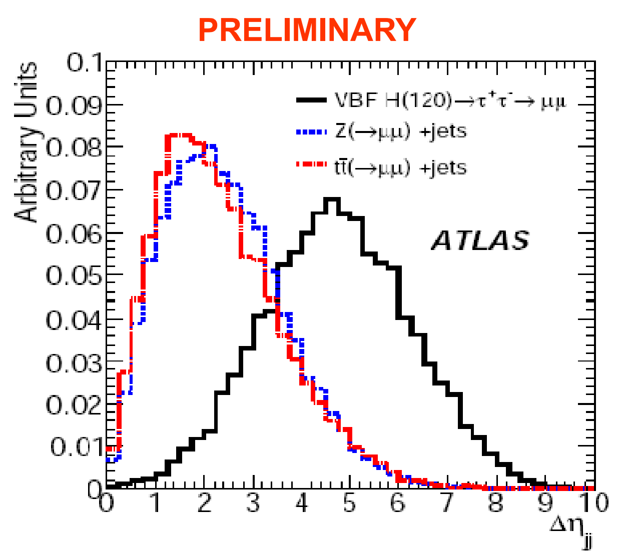
Pure QCD : all q,g initiated jets, no real taus
Handle : different kinematic (missing ET), tau identification

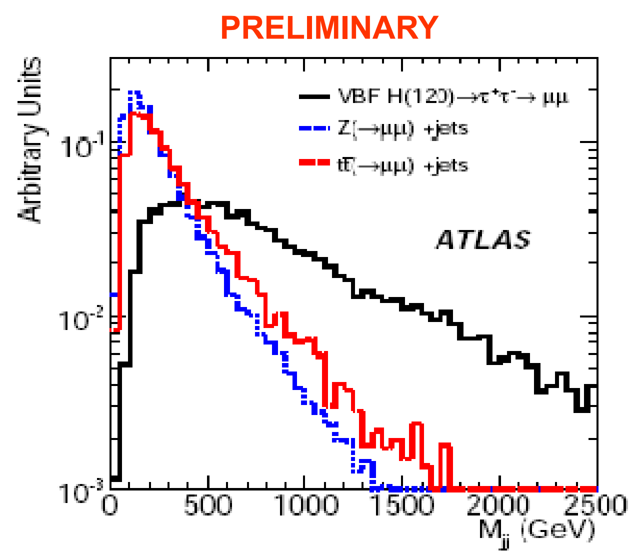
Signatures of VBF qqH



- Use of VBF configuration for background rejection:
  - Two forward “tag” jets (large η separation with high p_T) with large Mjj
  - No jet activity in the central region (no color flow between tag jets): central jet veto.
  - Higgs decay products produced between the two tagging jets.

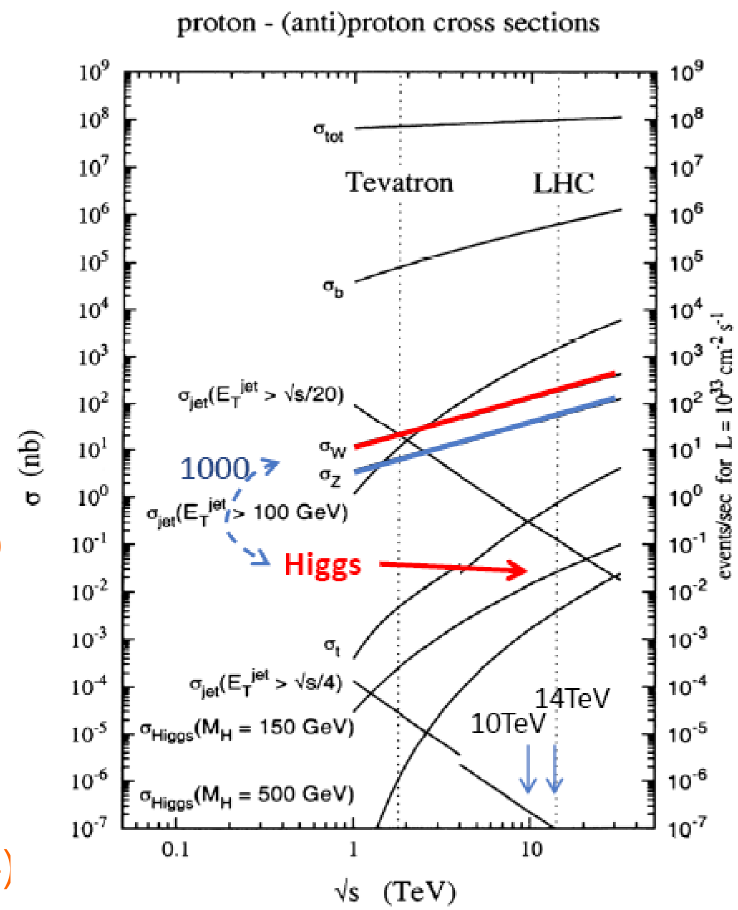






Analysis Strategy

- Given the large cross section of background processes, Higgs signal extraction requires large rejection factors:
  - W/Z: 10^5
  - QCD: 10^{11}
- Against QCD dijets:
  - (ll) channel:
    - $(10^3$ (e/mu)$)^2$ x 10^2 (VBF jets) x 10^3 (missing E_T)
  - (lh) channel:
    - 10^3 (e/mu) x 10^2 (VBF jets) x 10^2 (tau jet) x 10^3 (missing E_T) x high p_T tau jet
  - (hh) channel:
    - 10^2 (VBF jets) x $(10^2$ (tau jet)$)^2$ x 10^3 (missing E_T) x (high p_T tau jet$)^2$

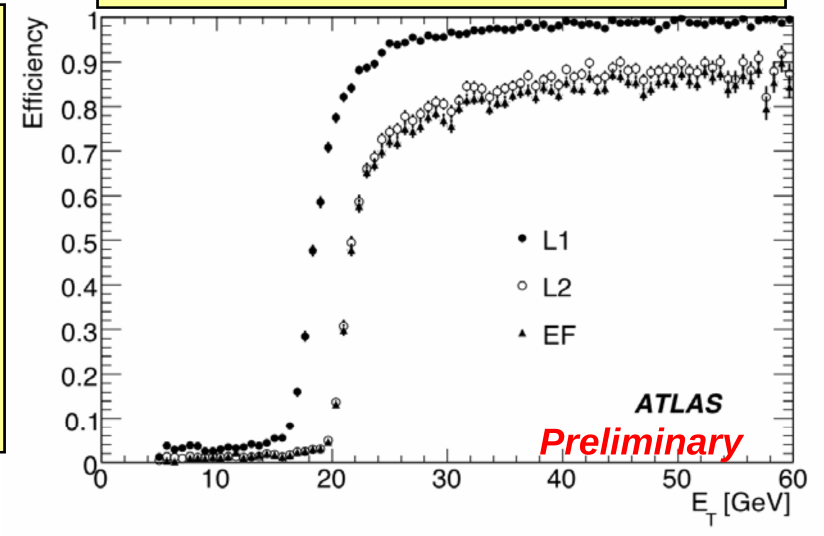


Lepton Triggers

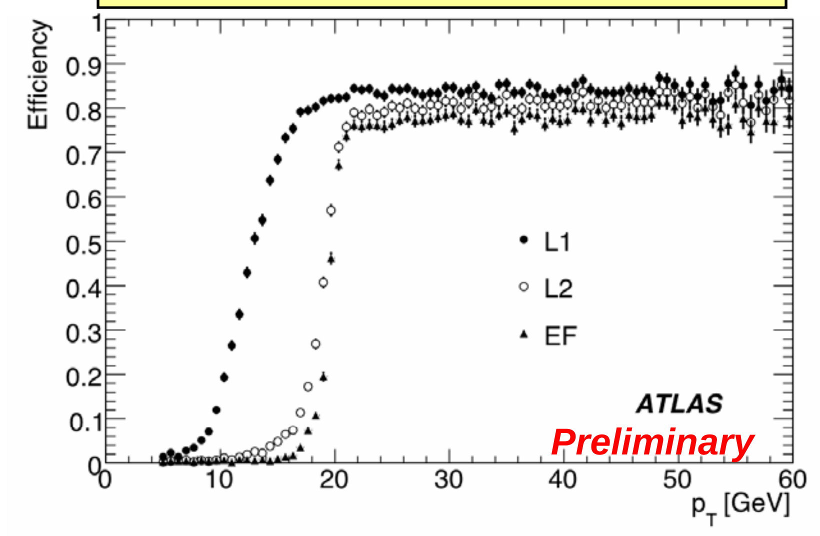
- Level-1: Selects $\Delta\eta\times\Delta\varphi$ regions of interest where a lepton satisfying the given criteria is found
  - Muons: p_t^{Thresh} range 4 GeV/c to 40 GeV/c, Electrons: E_t^{Thresh} = 15, 22 GeV
- High Level Trigger (Level-2): Validation of selected leptons using fast reconstruction algorithms.
  - Leptons passing the quality cuts and fixed energy thresholds are retained.
- High Level Trigger (Event Filter): Reconstruction of pre-selected leptons with the same algorithms used for offline reconstruction.

Trigger efficiency

Electrons E_t^{thres} = 22 GeV



Muons p_t^{thres} = 20 GeV/c

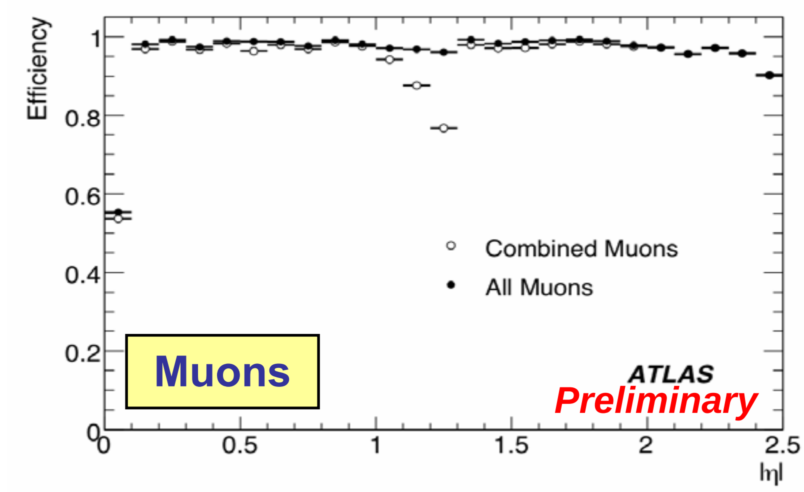


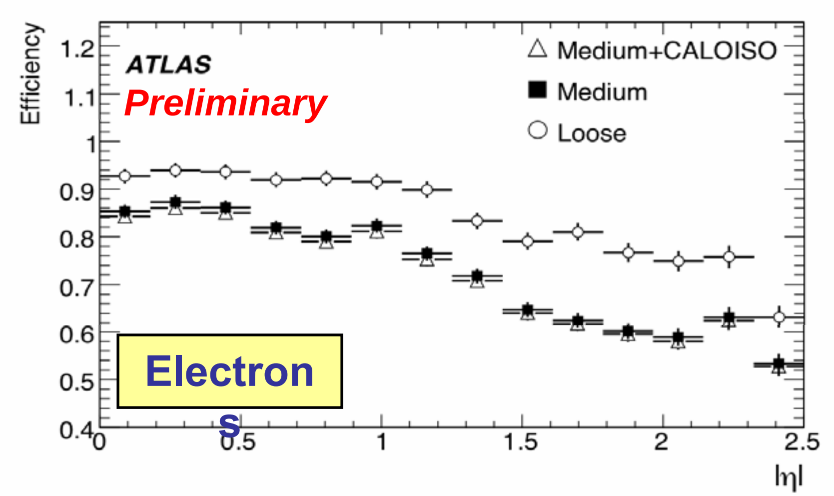
Electron/Muon Reconstruction

- Electrons
  - A cluster in the LAr EM Calorimeter associated with a track in the Inner Detector.
  - Consistency of the shower shape with an electron.
  - Inconsistency of the shower shape with $\pi^0 \rightarrow \gamma\gamma$ decay.
  - Track quality requirements: number of hits in the Pixel and SCT detectors and small transverse impact parameter: d_0<0.1mm.

- Muons
  - Muon tracks are reconstructed separately in the Muon Spectrometer and Inner Detector.
  - The Inner Detector tracks are combined with nearest MS tracks in a certain cone $\Delta R = \sqrt{(\Delta\eta^2 + \Delta\varphi^2)}$. Combinations with best χ^2 are kept.

Reconstruction efficiency



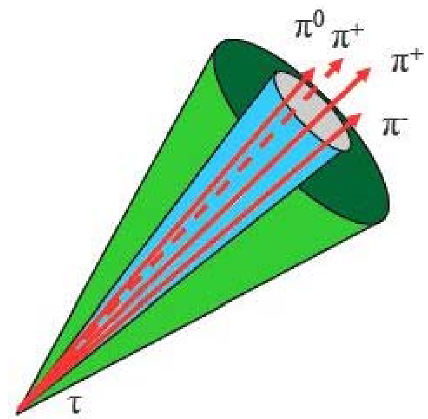


τ Decay Modes

- Leptonic decay modes: ~35%
  - $\tau \rightarrow \nu_\tau + \nu_e + e$ (17.4%)
  - $\tau \rightarrow \nu_\tau + \nu_\mu + \mu$ (17.8%)

  } Identification of Electron/muon from τ

- Hadronic decay modes: ~65% (**tau-jet**)
  - 1 prong: ~77%
    - $\tau \rightarrow \nu_\tau + \pi^\pm$ (11.0%)
    - $\tau \rightarrow \nu_\tau + \pi^\pm + \pi^0$ (25.4%)
    - $\tau \rightarrow \nu_\tau + \pi^\pm + \pi^0 + \pi^0$ (10.8%)
    - $\tau \rightarrow \nu_\tau + \pi^\pm + \pi^0 + \pi^0 + \pi^0$ (1.4%)
    - $\tau \rightarrow \nu_\tau + K^\pm + n\pi^0$ (1.6%)
  - 3 prong: ~23%
    - $\tau \rightarrow \nu_\tau + 3\ \pi^\pm + n\pi^0$ (15.2%)



<u>Identification of tau-jet</u>

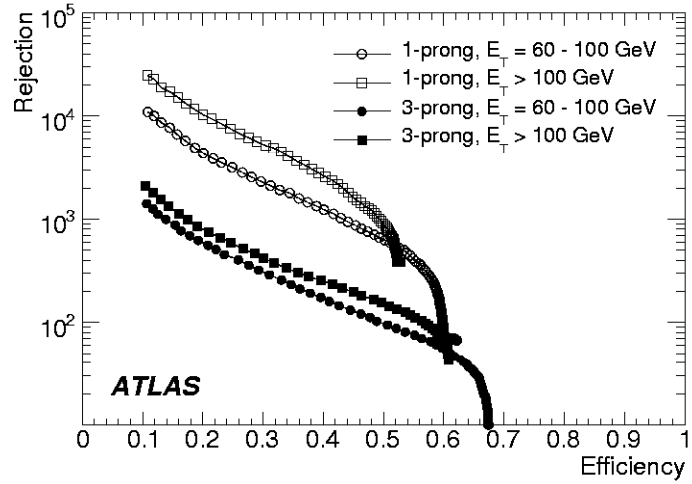
- 1-3 tracks ,
- Impact parameter,
- Shower shape,
- Secondary vertex,
- Energy sharing of neutral and charged pion component

Tau-jet Reconstruction

- ATLAS uses 2 hadronic τ-jet reconstruction algorithms, both require calorimeter clusters matching a track
  - Track-based algorithm
    - high quality leading hadronic track: pT>6 GeV,
    - look for other tracks with pT>1 GeV in cone dR<0.2 around the leading track
      - no additional tracks – single prong candidate
      - up to two additional tracks -three prong candidate
    - tau candidate energy is estimated using the energy flow approach:
      - calorimeter deposits from charged particles are replaced by the tracks momenta
      - contribution from $\pi 0$ included, and the effects of $\pi 0$ and $\pi \mp$ depositing energy in the same calorimeter cells are corrected
  - Calorimeter-based algorithm, used for qqH, $H \rightarrow \tau\tau$ analysis:
    - a jet with transverse energy E_T > 10GeV, is the seed for the tau reconstruction.
    - energy estimate is obtained from for all the cells within $\Delta R < 0.4$ of the barycenter.
    - cells are calibrated using H1 calibration method. The energy of the cells is calibrated to the jet energy scale
    - tracks within $\Delta R < 0.3$ with p_T >1 GeV from the cluster centre are assigned to the tau candidate

Tau-jet Identification

- Both algorithms provides a large if reconstruction variables to be used in a variety of identification techniques:
  - R_{EM} - radius of EM cluster
  - Isolation Fraction: E_T in isolation region ($0.1<\Delta R<0.2$) dived by the energy in cone $\Delta R<0.4$
  - EM and Hadronic energies of cluster
  - Ntrack - track multiplicity of tau candidate,...
- Identification methods:
  - Cut based identification
  - Logarithmic likelihood
  - Neural Network
  - Boosted Decision Tree,…

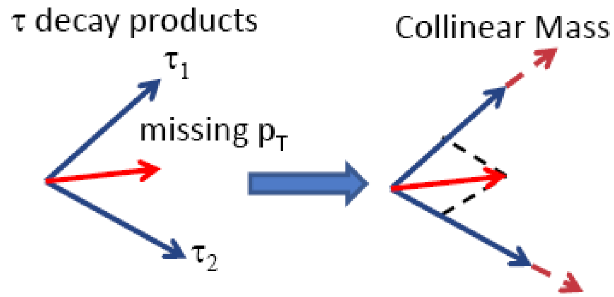


Selection	Efficiency	Rejection cuts	Rejection TMVA cuts	Rejection NN	Rejection PDRS
	E_T=10 -30 GeV				
One-prong	0.33	225±10	435±30	**510±40**	460±40
Three-prong	0.28	360±25	470±40	**740±70**	670±60
	E_T=30-60 GeV				
One-prong	0.42	140±10	170±10	**440±40**	320±30
Three-prong	0.45	60±2	90±10	**160±10**	130±10

Benchmarks for qqH, H $\rightarrow\tau\tau$:
ε = 0.4-0.5
Rejection =100-200

Signal Reconstruction

- Use of collinear approximation for τ–τ mass reconstruction:

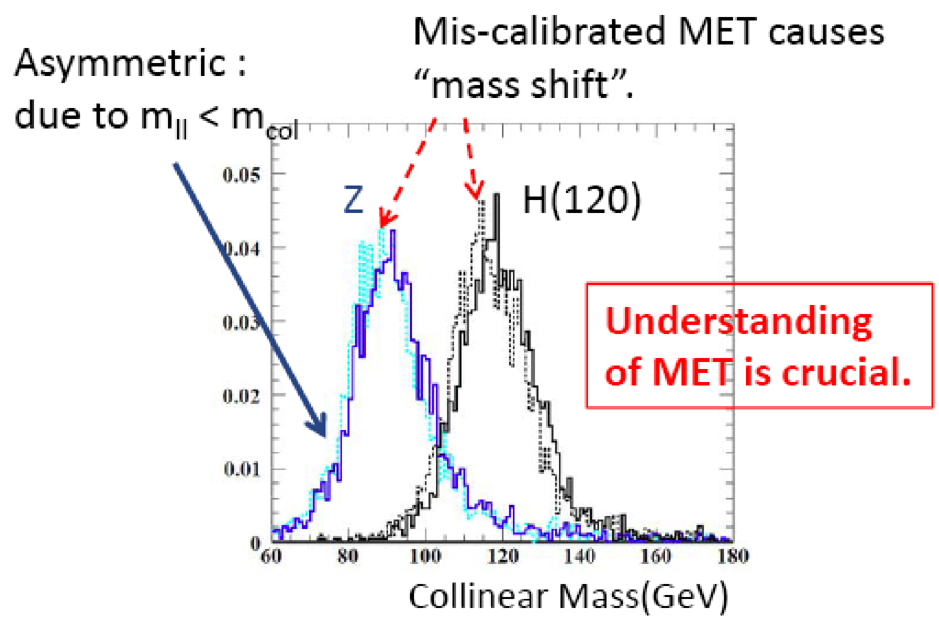


$$M_{\tau\tau} = \sqrt{2(E_h+E_{\nu h})(E_l+E_{\nu l})(1-\cos\theta_{\tau\tau})}.$$

$$\Rightarrow \quad M_{\tau\tau} = \frac{M_{lh}}{\sqrt{x_{\tau l}x_{\tau h}}} \qquad \text{for } x_\tau > 0$$

where,

$$\begin{cases} x_{\tau h} = \dfrac{E_h}{E_h+E_{\nu h}} = \dfrac{h_x l_y - h_y l_x}{h_x l_y + \not{E}_x l_y - h_y l_x - \not{E}_y l_x} = \dfrac{N}{D_h} \\ x_{\tau l} = \dfrac{E_l}{E_l+E_{\nu l}} = \dfrac{h_x l_y - h_y l_x}{h_x l_y - \not{E}_x h_y - h_y l_x + \not{E}_y h_x} = \dfrac{N}{D_l}, \end{cases}$$



- In addition to VBF and E_T^{miss} cuts, thresholds for e/μ/τ identification are optimized for identification efficiency and fake rejection.
- Low $M_T(l\text{-}E_T^{miss})$ to reduce the W+jet background.
- jet veto (uncertainty on the robustness of the jet veto with respect to radiation in the underlying event and to the presence of pile-up: so far VBF channels studied at low luminosity only).

Signal Yield and Trigger efficiency

- All trigger levels efficiencies have been fully simulated and taken into account in signal estimation

Trigger menu	Efficiency × Acceptance(%)
e22i	9.08 ± 0.03
mu20	9.88 ± 0.04
L1_TAU30_xE40_softHLT	3.67 ± 0.02

- Signal yield for the 3 final states:

ll channel, mH=120 GeV

Cross section (fb)	309.1
Trigger	57.2(1)
Trigger lepton	49.5(1)
Dilepton	5.46(3)
Missing $E_T \geq 40$ GeV	3.17(3)
Collinear Approx.	2.15(2)
N jets ≥ 2	1.77(2)
Forward jet	1.34(2)
B-jet veto	1.16(2)
Jet kinematics	0.63(1)
Central jet veto	0.56(1)
Mass window	0.45(1)

lh channel, mH=120 GeV

Cross section (fb)	309.1
Trigger	57.2(1)
Trigger lepton	49.5(1)
Dilepton veto	43.4(1)
Hadronic τ	8.02(7)
Missing $E_T \geq 30$ GeV	4.96(5)
Collinear Approx.	3.34(5)
Transverse mass	2.46(4)
N jets ≥ 2	2.02(4)
Forward jet	1.52(3)
Jet kinematics	0.82(2)
Central jet veto	0.72(2)
Mass window	0.61(2)

hh channel, mH=120 GeV

Cross section (fb)	309.1
Trigger tau & MET	11.4(1)
2 Hadronic τs	1.83(4)
Missing $E_T \geq 40$ GeV	1.43(3)
Collinear Approx.	1.03(3)
Di-tau Transverse mass	1.03(3)
N jets ≥ 2	0.86(3)
Total p_T	0.83(3)
Forward jet	0.72(2)
Jet kinematics	0.45(2)
Central jet veto	0.39(2)
Mass window	0.34(2)

Some Details on Background Estimation on MC

- Full simulation statistics not enough to test the full rejection factor on backgrounds ➡ factorization method applied:
  - 3 categories of selection cuts:
    1. tau decays
    2. forward jets
    3. Correlated tau decays - forward jets
- Total rejection rate is product of three categories.
  - Effect on signal (strongest expected) shows agreement between sequential and factorized within 50%. Discrepancy smaller for background (30% Z, 50% tt)
- Additionally, for (hh) final state:
  - No tau identification applied, parametrized efficiency -> event weight factor
  - Pythia vs ME : factor 2-3 difference in VBF jet cuts => factor 5 (x2 safety factor)
- Uncertainty on this affects only current estimates of significance, real measurement will not be affected by lack of background sample statistics
- Data-driven methods for background estimation has also been developed for QCD and $Z \rightarrow \tau\tau$

Background Yields

	$Z \to \tau^+\tau^-$+jets(≥ 1) QCD	ELWK	$t\bar{t}$ Full	Fast	$Z \to l^+l^-$+n jets ($n \geq 1$)	$W \to l\nu$+n jets ($n \geq 1$)	diboson $WW/ZZ/WZ$
Cross section (fb)	168.4×10^3	1693	833×10^3		768.6×10^3	8649×10^3	174.1×10^3
Trigger	$51.5(1)\times10^3$	230(1)	$209.8(2)\times10^3$		$633.8(4)\times10^3$	$4411(9)\times10^3$	$32.0(1)\times10^3$
Trigger lepton	$42.7(1)\times10^3$	190(1)	$179.1(2)\times10^3$		$588.0(4)\times10^3$	$3815(9)\times10^3$	$28.0(1)\times10^3$
Dilepton	$4.25(5)\times10^3$	19.2(4)	$21.7(1)\times10^3$		$369.9(5)\times10^3$	$2.5(2)\times10^3$	$3.95(6)\times10^3$
Missing $E_T \geq 40$ GeV	744(18)	9.9(3)	16847(99)		2683(67)	1148(176)	1744(49)
Collinear Approx.	454(14)	6.2(2)	1817(33)	Atlfast	104(12)	46(21)	73(9)
N jets ≥ 2	262(8)	5.8(2)	1722(32)	1699(4)	73(8)	14(6)	51(8)
Forward jet	39(2)	2.0(1)	294(13)	324(1)	10(3)	$\geq$1.2(2)*	8(3)
B-jet veto	30(2)	1.5(1)	89(7)	90.3(9)	9(3)	$\geq$1.0(2)*	5(2)
Jet kinematics	2.71(5)	0.57(5)	11.8(3)*	26.7(5)	0.66(3)*	0.19(4)*	0.33(5)*
Central jet veto	1.24(3)	0.43(4)	1.9(1)*	2.6(1)	0.27(1)*	0.10(2)*	0.18(4)*
Mass window	0.23(1)	0.04(1)	0.10(2)*	0.06(2)	0.058(3)*	0.01(1)*	0.002(1)*

ll ~ 0.5

lh ~ 0.2

	$Z \to \tau^+\tau^-$+jets(≥ 1) QCD	ELWK	$t\bar{t}$ Full	Fast	$Z \to l^+l^-$+n jets ($n \geq 1$)	$W \to l\nu$+n jets ($n \geq 1$)	diboson $WW/ZZ/WZ$
Cross section (fb)	168.4×10^3	1693	833×10^3		768.6×10^3	8649×10^3	174.1×10^3
Trigger	$51.5(1)\times10^3$	230(1)	$209.8(2)\times10^3$		$633.8(4)\times10^3$	$4411(9)\times10^3$	$32.0(1)\times10^3$
Trigger lepton	$42.7(1)\times10^3$	190(1)	$179.1(2)\times10^3$		$588.0(4)\times10^3$	$3815(9)\times10^3$	$28.0(1)\times10^3$
Dilepton veto	$38.4(1)\times10^3$	171(1)	$156.4(2)\times10^3$		$216.5(4)\times10^3$	$3811(9)\times10^3$	$23.7(1)\times10^3$
Hadronic τ	3062(42)	19.3(4)	5224(56)		20250(156)	32537(1012)	704(30)
Missing $E_T \geq 30$ GeV	850(20)	12.1(3)	4251(50)		468(26)	21001(801)	474(26)
Collinear Approx.	514(15)	7.8(2)	606(19)		17(3)	324(46)	32(6)
Transverse mass	415(13)	6.5(2)	176(10)	Atlfast	11(2)	67(18)	14(3)
N jets ≥ 2	235(7)	6.0(2)	162(9)	167(1)	8(1)	49(11)	7(1)
Forward jet	40(3)	2.3(1)	32(4)	26.1(4)	1.3(6)	$\geq$2.9(3)*	3(1)
Jet kinematics	2.7(1)	0.72(6)	1.8(1)*	3.6(1)	0.10(1)*	0.7(1)*	0.06(1)*
Central jet veto	1.2(1)	0.49(5)	0.25(4)*	0.43(5)	0.047(6)*	0.43(6)*	0.02(1)*
Mass window	0.11(2)	0.04(1)	0.012(5)*	0.03(1)	0.008(1)*	0.020(6)*	0.001(1)*

	$Z \to \tau^+\tau^-$ $+jets(\geq 1)$ QCD	ELWK	$t\bar{t}$	$W \to \tau\nu + n\,jets$ $(n \geq 1)$	QCD di-jet ($\times$ 5)
Cross section (fb)	40.3×10^3	1693	833×10^3	922×10^3	~~19.1 10^{12}~~
Trigger tau & MET	1756(15)	126(1)	78177(232)	39600(400)	
2 Hadronic τs	161(4)	4.9(2)	373(16)	317(33)	2.756(3) 10^6*
Missing $E_T \geq 40$ GeV	108(4)	3.7 (2)	335(15)	243(29)	0.97(3) 10^3*
Collinear Approx.	72(3)	2.3 (1)	43(5)	20(7)	1.7(2) 10^2*
Di-tau Transverse mass	72(3)	2.3(1)	39(5)	18(7)	1.6(2) 10^2*
N jets ≥ 2	46(2)*	2.1(1)	34(5)*	8(3)*	0.86(4) 10^2*
Total p_T	40(2)*	1.9(1)	24(4)*	8(3)*	0.75(3) 10^2*
Forward jet	17(1)*	1.1(1)	9(2)*	3(1)*	23(3)*
Jet kinematics	1.4(1)*	0.43(6)	0.6(2)*	0.5(4)*	8(3)*
Central jet veto	0.7(1)*	0.36(6)	0.16(9)*	0.3(3)*	4(1)*
Mass window	0.08(3)*	0.03(1)	0.03(3)*	0.1(1)*	1(1)*

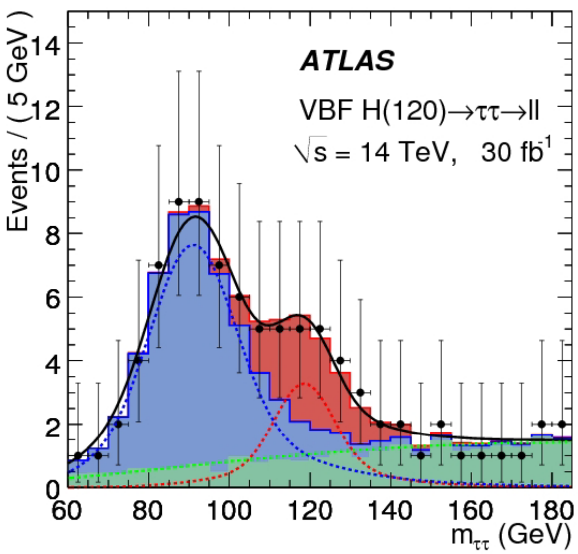
Data driven models needs to be carefully checked

hh ~ 1.2

Final Mass Distribution

- After all cuts, extract signal significance using a simultaneous fit which includes background shapes from control regions

PRELIMINARY



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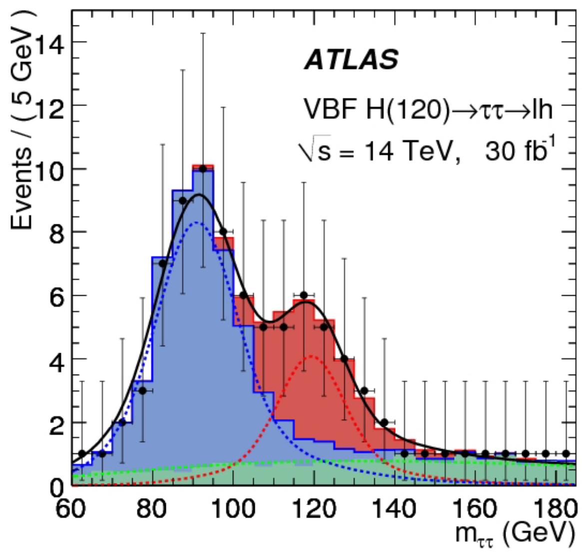

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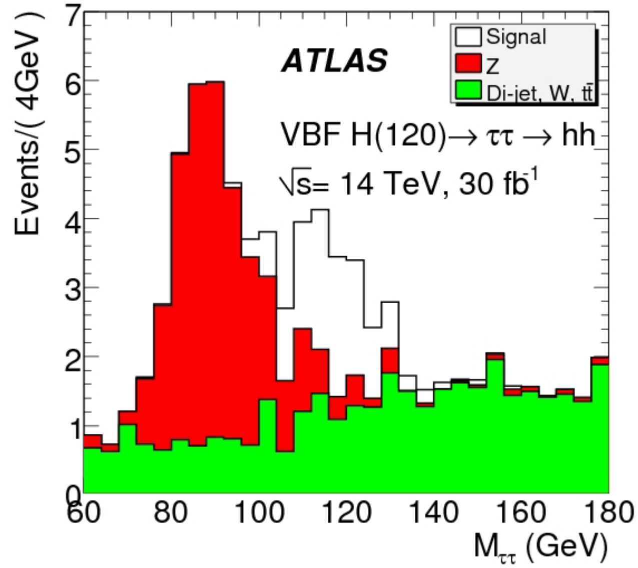
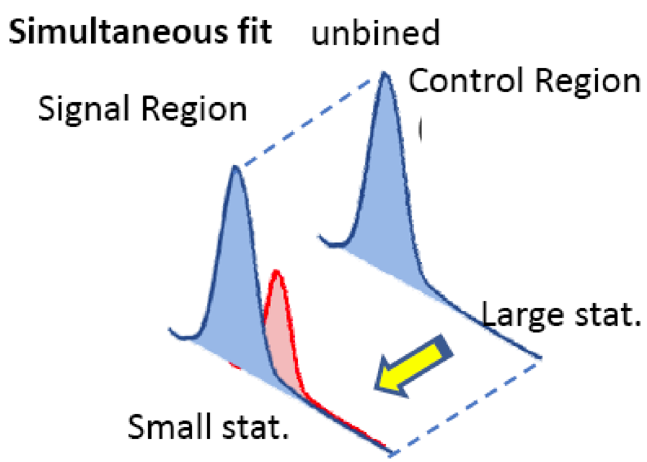




Likelihood function:

$$
\begin{aligned}
L(data|\mu, M_H, \nu) \;=\; & L_{track}(\text{track multiplicity}|r_{QCD}) \\
\times\; & L_Z(Z+\text{jets control}|\sigma_Z) \\
\times\; & L_{QCD}(\text{QCD control}|a_0, a_1, a_2, a_3) \\
\times\; & L_{s+b}(\text{signal candidates}|\mu, M_H, \sigma_H, \sigma_Z, r_{QCD}, a_0, a_1, a_2, a_3),
\end{aligned}
$$

Systematics on Mass Reconstruction and Signal Efficiency

- Both experimental and theoretical systematic effect s have been addressed

Source	Relative uncertainty	Effect on signal efficiency
luminosity	$\pm 3\%$	$\pm 3\%$
muon energy scale	$\pm 1\%$	$\pm 1\%$
muon energy resolution	$\sigma(p_T) \oplus 0.011 p_T \oplus 1.7\ 10^{-4} p_T^2$	$\pm 0.5\%$
muon ID efficiency	$\pm 1\ \%$	$\pm 2\%$
electron energy scale	$\pm 0.5\%$	$\pm 0.4\ \%$
electron energy resolution	$\sigma(E_T) \oplus 7.3\ 10^{-3} E_T$	$\pm 0.3\ \%$
electron ID efficiency	$\pm 0.2\%$	$\pm 0.4\%$
tau energy scale	$\pm 5\%$	$\pm 4.9\%$
tau energy resolution	$\sigma(E) \oplus 0.45\sqrt{E}$	$\pm 1.5\%$
tau ID efficiency	$\pm 5\%$	$\pm 5\%$
jet energy scale†	$\pm 7\%$ ($\lvert\eta\rvert \leq 3.2$) $\pm 15\%$ ($\lvert\eta\rvert \geq 3.2$) $\pm 5\%$ (on $\not{E}_T$)	$^{+16\%}/_{-20\%}$
jet energy resolution	$\sigma(E) \oplus 0.45\sqrt{E}$ ($\lvert\eta\rvert \leq 3.2$) $\sigma(E) \oplus 0.67\sqrt{E}$ ($\lvert\eta\rvert \geq 3.2$)	$\pm 1\%$
b-tagging efficiency	$\pm 5\%$	$\pm 5\%$
forward tagging efficiency	$\pm 2\ \%$	$\pm 2\%$
central jet reconstruction efficiency	$\pm 2\ \%$	$\pm 2\%$
total summed in quadrature		$\pm 20\%$

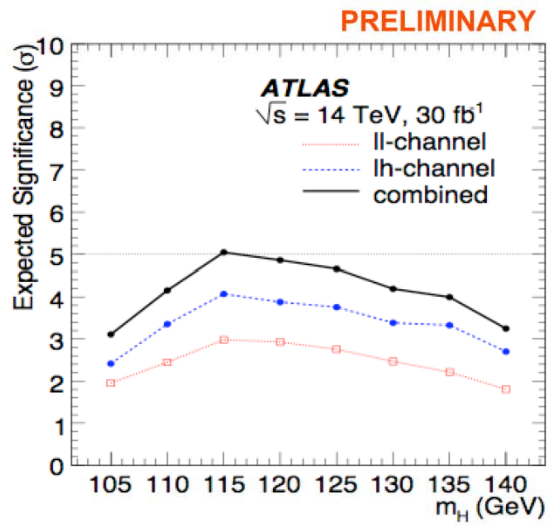
Source	Relative uncertainty	Effect on signal efficiency
PDF uncertanties	$\pm 3.5\%$	$\pm 3.5\%$
scale dependence on cross-section	$\pm 3\%$	$\pm 3\%$
scale dependence CJV efficiency	$\pm 1\%$	$\pm 1\%$
parton-shower and underlying event	$\pm \leq 10\%$	$\pm < 10\%$
total summed in quadrature		$\pm < 10\%$

Significance using ll and lh final states

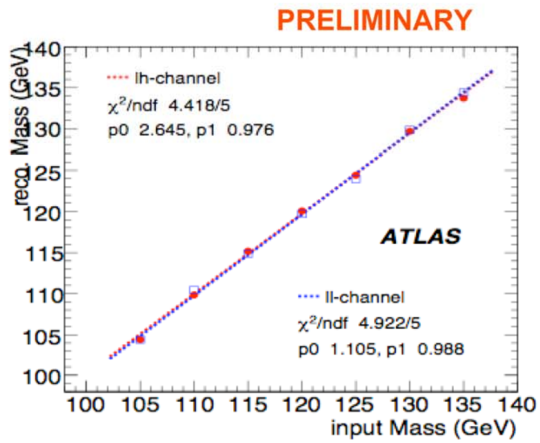
- Only ll and lh final states were used for signal significance

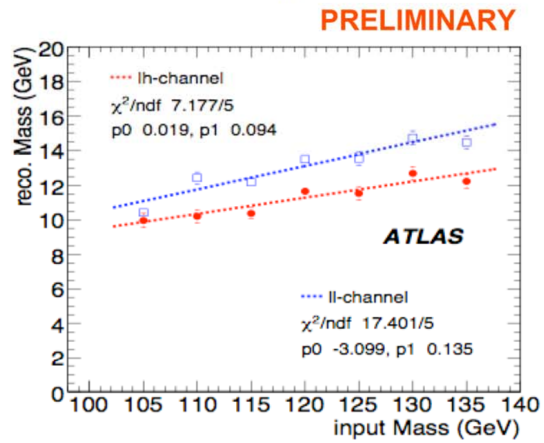
No pile-up

m_H	ll-channel	lh-channel	combined
105	1.95	2.41	3.10
110	2.44	3.35	4.15
115	2.98	4.07	5.04
120	2.92	3.87	4.85
125	2.75	3.75	4.65
130	2.46	3.38	4.18
135	2.21	3.32	3.99
140	1.80	2.70	3.24



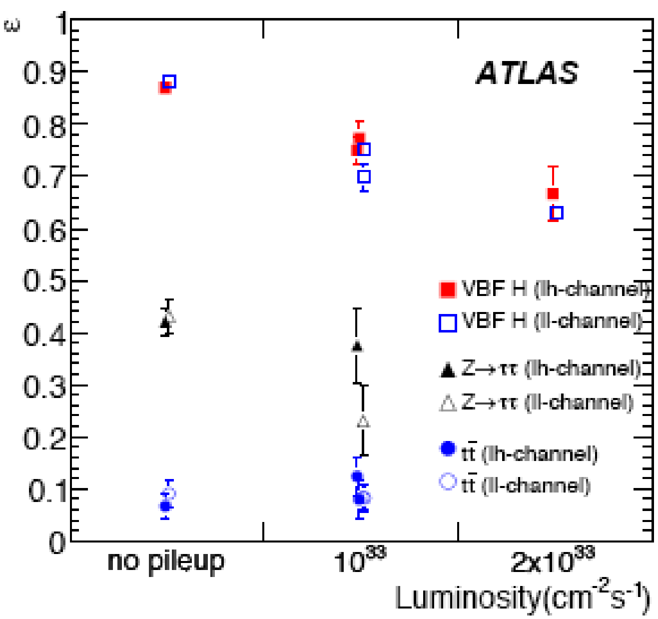
Mass determination reliability

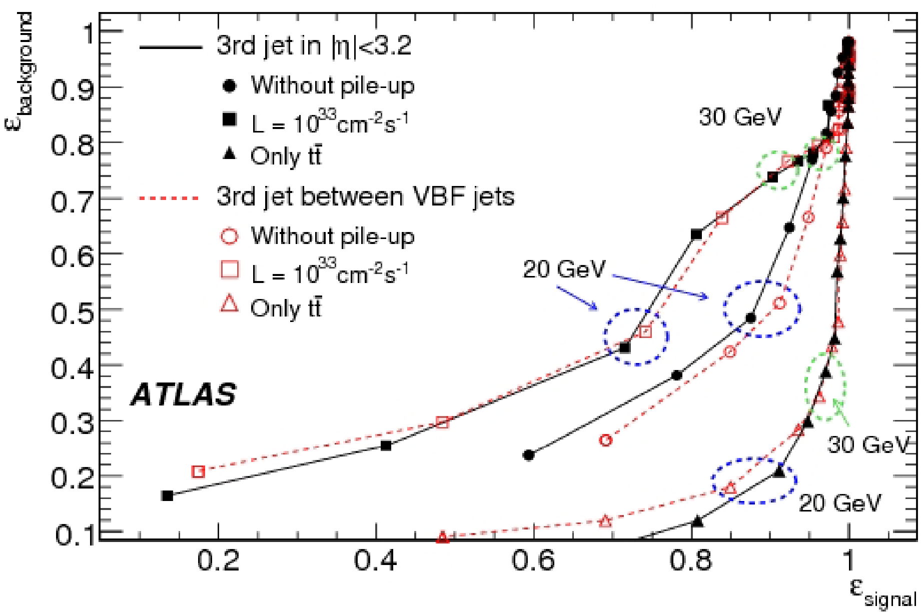




Pile-up Effects

- Pile-up could even at low luminosity LHC run (10^{32} -10^{33}cm-^{2}s^{-1}). We could expect 2-6 minimum-bias events per bunch crossing
- Overall effects:
  - Additional p-p interactions can produce hadronic activity in central region, signal events fail the jet veto cut
  - pile-up interactions degrade the missing E_T determination, hence the mass distribution
  - pile-up degrades the tau identification performance
- Scale will be measured in early data.





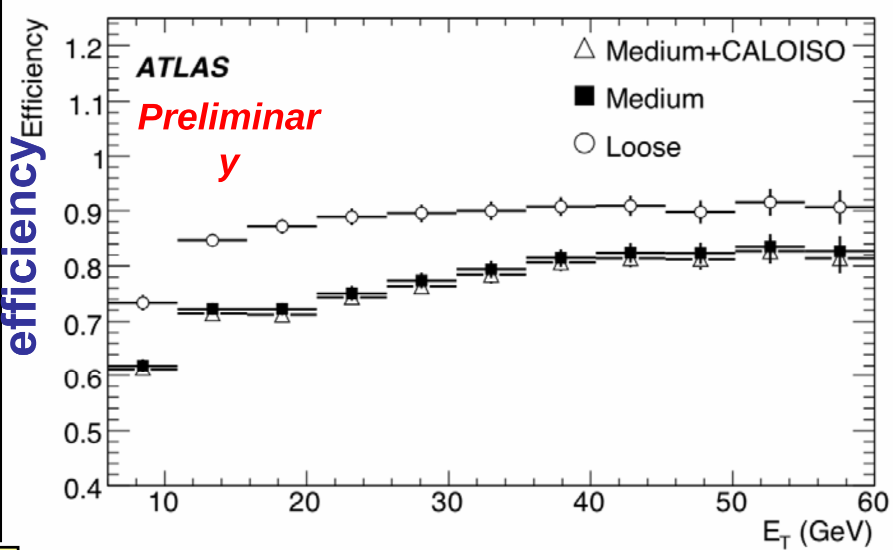
Conclusion and Outlook

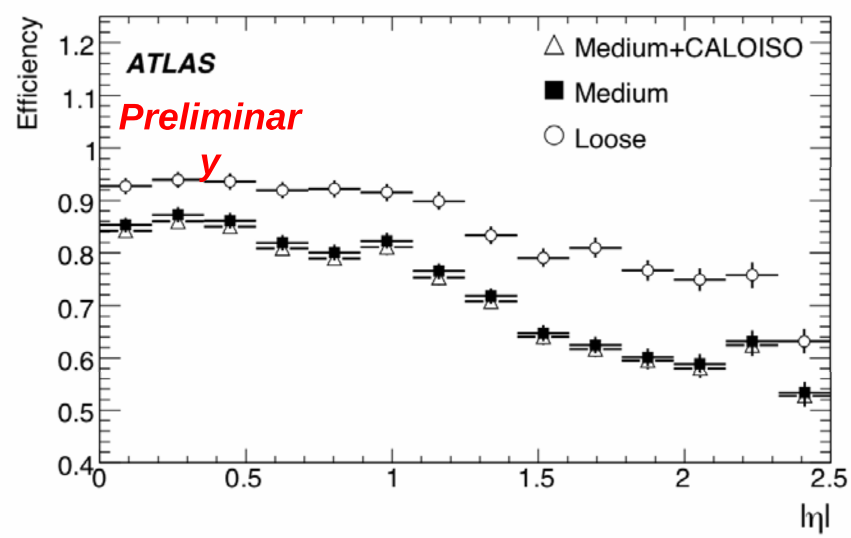
- Updated studies of VBF SM Higgs production with tau leptons in final state has been performed in ATLAS
  - Full simulation including correct material budget and realistic misalignment and noise effects has been used for this review, together with most recent reconstruction and identification tools
  - Final states from all ta decay modes are considered, and most up-to-date trigger simulation is used
  - Strategy for determining most important backgrounds from data is in place and will be tested with early SM measurements.
- ATLAS can discover as a 5 sigma effect the existence of a SM Higgs boson with mass around 120GeV within the first 3 years of operation at peak luminosity 10^{33} cm^{-2} s^{-1}
  - SM Higgs could be also excluded with within this mass region
- SM measurements with early data will be crucial for Higgs discovery or exclusion

Back-up

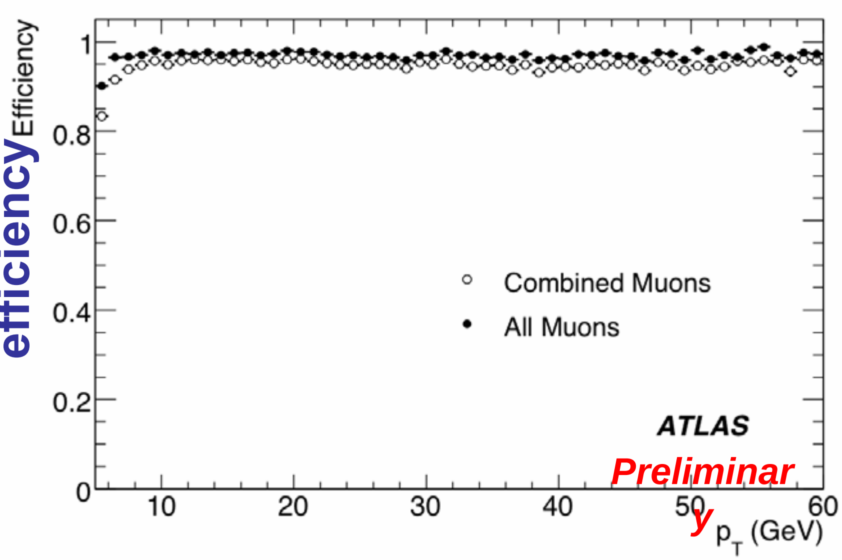
Electron/Muon Reconstruction

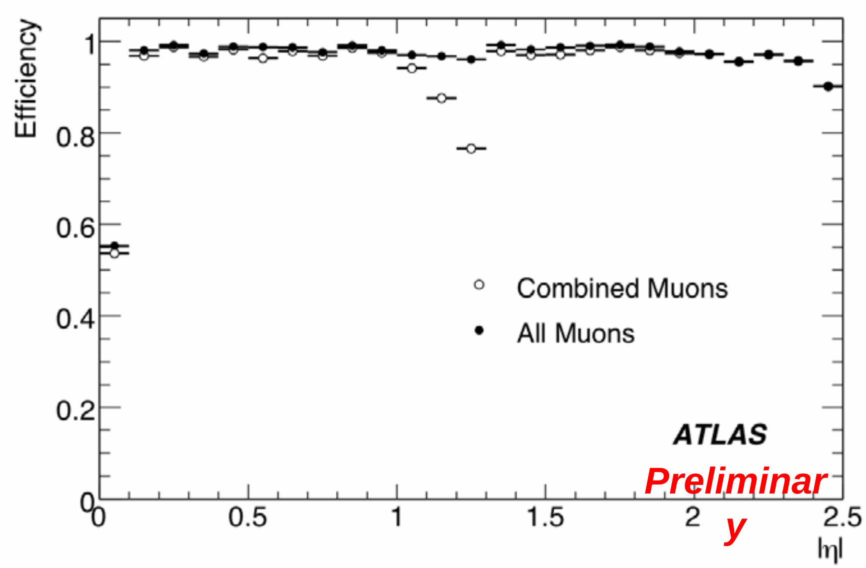
Reconstruction efficiency





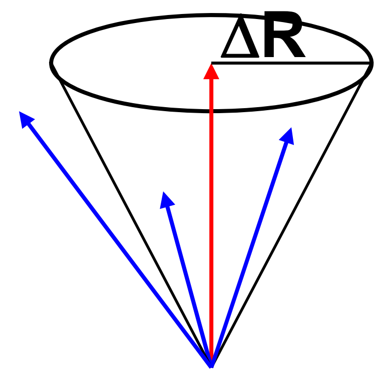
Reconstruction efficiency



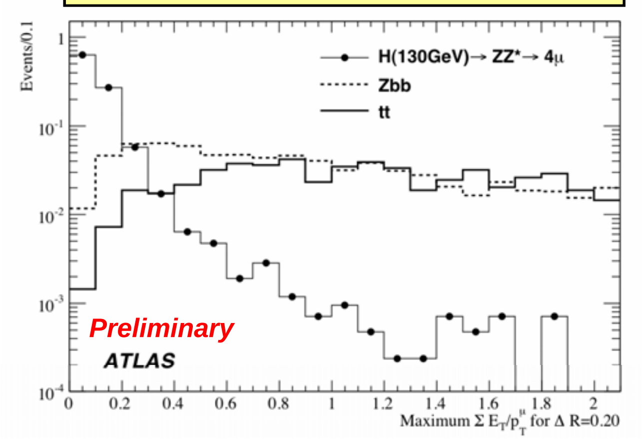


Lepton Isolation

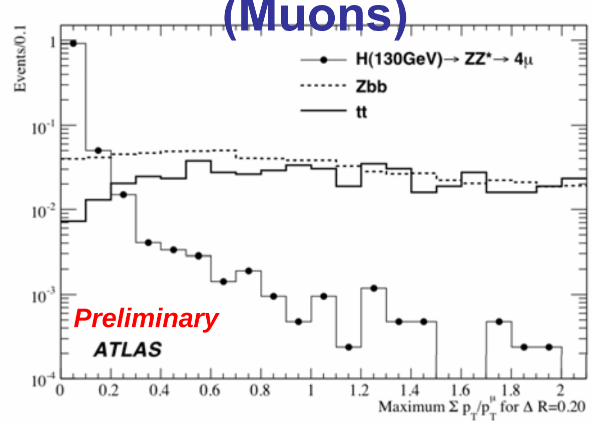
- Isolation cuts reduces contamination from semi-leponic b-decays
- 2 isolation cuts can be used
  - Calorimeter: $\Sigma E_t/p_t^l$ in a cone $\Delta R = \sqrt{(\Delta\eta^2 + \Delta\varphi^2)}$
    - ΔR=0.2 for muons; ΔR=0.4 for electrons.
  - Inner Detector: $\Sigma p_t/p_t^l$ in a cone ΔR =0.2



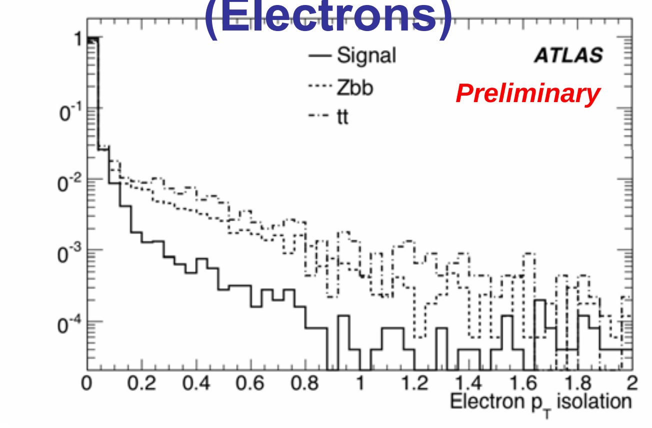
Calorimeter (Muons)



Inner Detector (Muons)

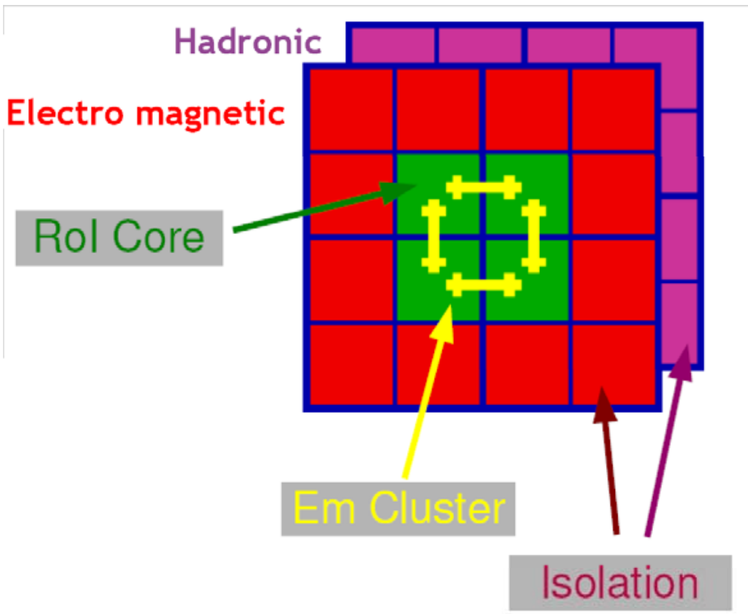


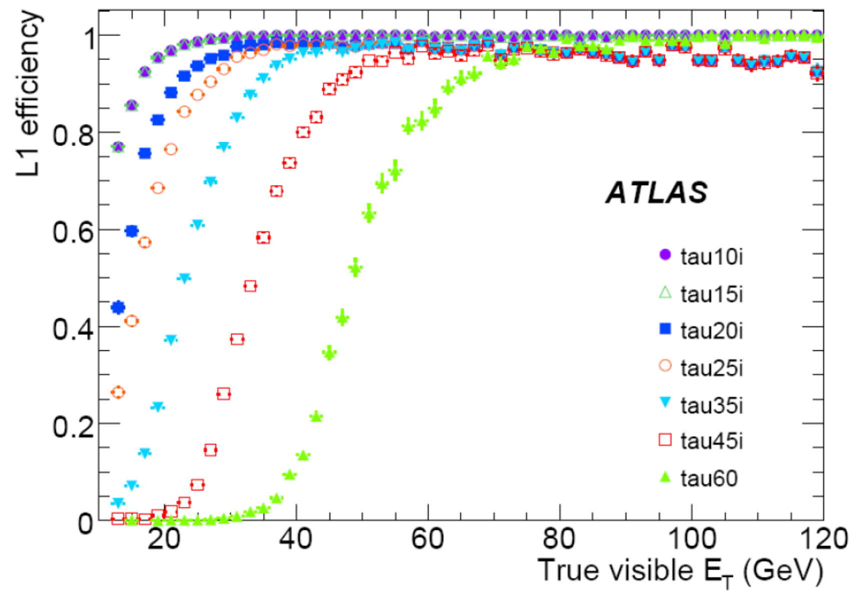
Inner Detector (Electrons)



Level-1 Tau trigger

- Central 2x2 core of both e.m. and hadronic towers
- Tau cluster=two most energetic neighboring e.m towers+ central 2x2 hadronic towers
- EmIsol=energy in the isolating ring 2x2 to 4x4 in e.m. calorimeter
- HadIsol=energy in the isolating ring 2x2 to 4x4 inhadronic calorimeter

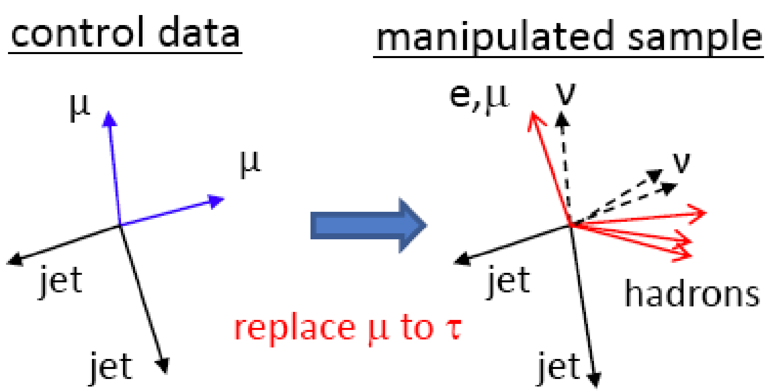




- Combined menus for specific signatures:
  - Tau + missing ET, for single tau decay (H+/-): XE30_L1_TAU13)
  - Tau + lept + jet , for double tau decay (Z, A/H): L1_TAU30_XE40_softHLT
  - Tau + tau + jet for all hadronic double tau decays

Examples of Data-Driven Methods for Background Estimation

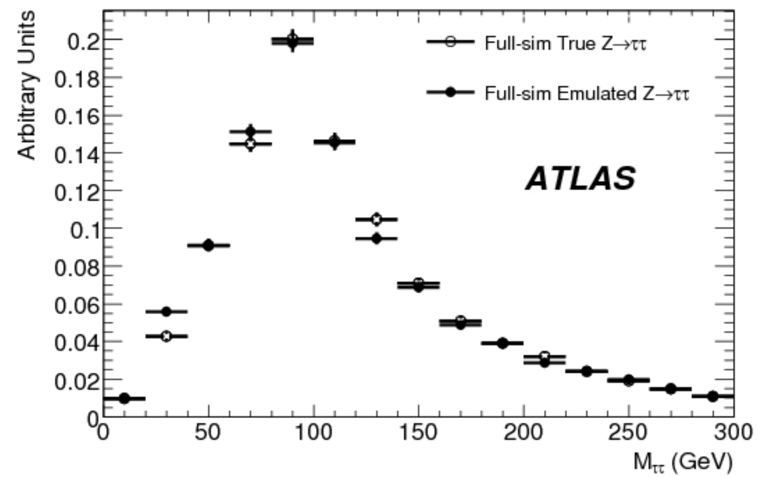
- Example : $Z \rightarrow \tau\tau$ + jets
  - Assume tau decay is well modeled by MC



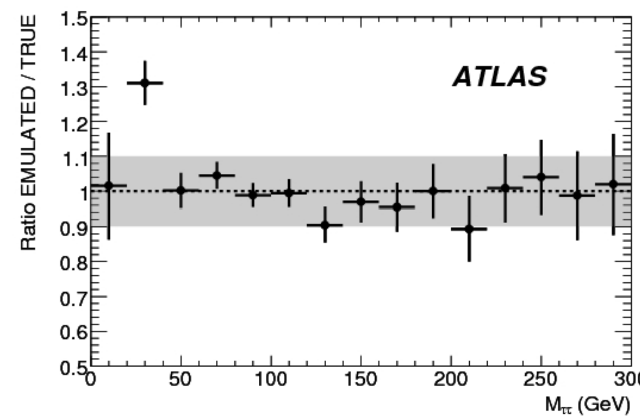
- **Replace muon with tau**
- **Rerun Tauola**
- **Resimulate again**

Missing E_T modelled by data
-> tails well described

PRELIMINARY

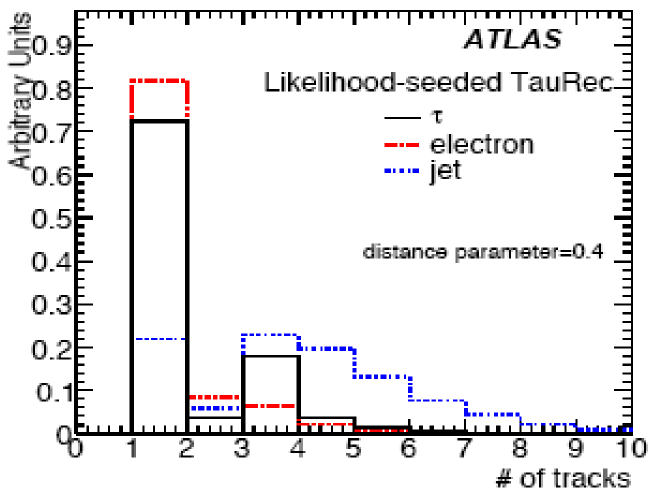


PRELIMINARY



- QCD: OS = SS
  - this can have large difference and systematic (eg Tevatron, W+jets, 40%)

QCD Fake Rate from Data



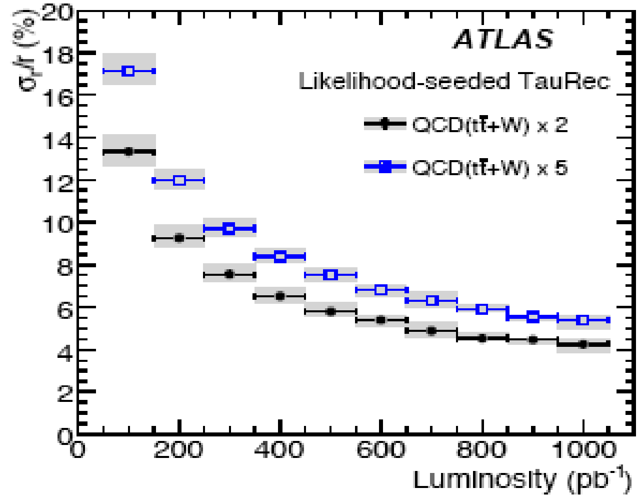


Figure 11: Track multiplicity distribution for QCD fake events and electron-fake events as well as the τ signal.

Figure 12: Expected errors of the fraction r_{tau} as a function of luminosity. The QCD events are scaled to $\times 2$ and $\times 5$.

Given a sample of tau candidates, the relative abundance of taus, electrons, and jets can be found by fitting the track multiplicity distribution with the extended likelihood function

$$L_{track}(r_{QCD}, r_{tau}) = \Pi_i^N Pois(n_{exp}^{tot} \times (r_{tau} f_{tau}^i + r_{QCD} f_{jet}^i + (1 - r_{tau} - r_{QCD}) f_{lep}^i) | N_{obs}^i)$$
$$\times Gaus(N_{obs}^{tot} | n_{exp}^{tot}, \sqrt{n_{exp}^{tot}}) \quad (10)$$
$$\times Gaus(N_{lep}^{measured} | n_{exp}^{tot}(1 - r_{tau} - r_{QCD}), \Delta_{lep} n_{exp}^{tot}(1 - r_{tau} - r_{QCD}))$$

where n_{exp}^{tot} is the total number of events estimated by the fit, r_{tau} (r_{QCD}) is the fraction of the tau (jet) contribution with respect to the estimated total number of events, $\Delta_{lep} = 10\%$ is the relative uncertainty on lepton measurement, and f^i is the normalized probability for the i^{th} bin of the track multiplicity distribution. The second term constrains the normalization, and the third term is an additional constraint term for the lepton contribution estimated by an independent analysis. The fit is performed to find the