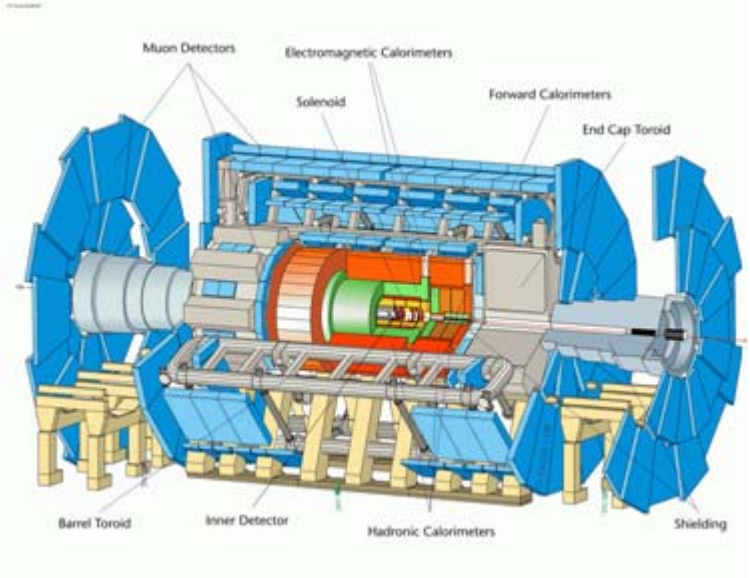
Prospects for physics with tau leptons (with ATLAS experiment at LHC)

- ✓ Tau leptons
- ✓ Taus reconstruction in ATLAS experiment
- ✓ Prospects for first physics with taus in final states
- ✓ Prospects for discoveries with taus in final states



Results presented here from „preliminary ATLAS CSC" or „ATLAS TDR".

Tau leptons: general

Tau lepton is one of the six fundamental leptons.

→ massive particle, electro-weak interaction only

→ Yukava coupling to SUSY particles, free from QCD effects

→ production and decay well separated in time, potential for measurement of the polarisation, spin correlations, parity

→ excellent knowledge about decay modes from low-energy experiments

ideal signature to probe "New Physics"

however .....

As the heaviest lepton, it may decay into both leptons and hadrons.

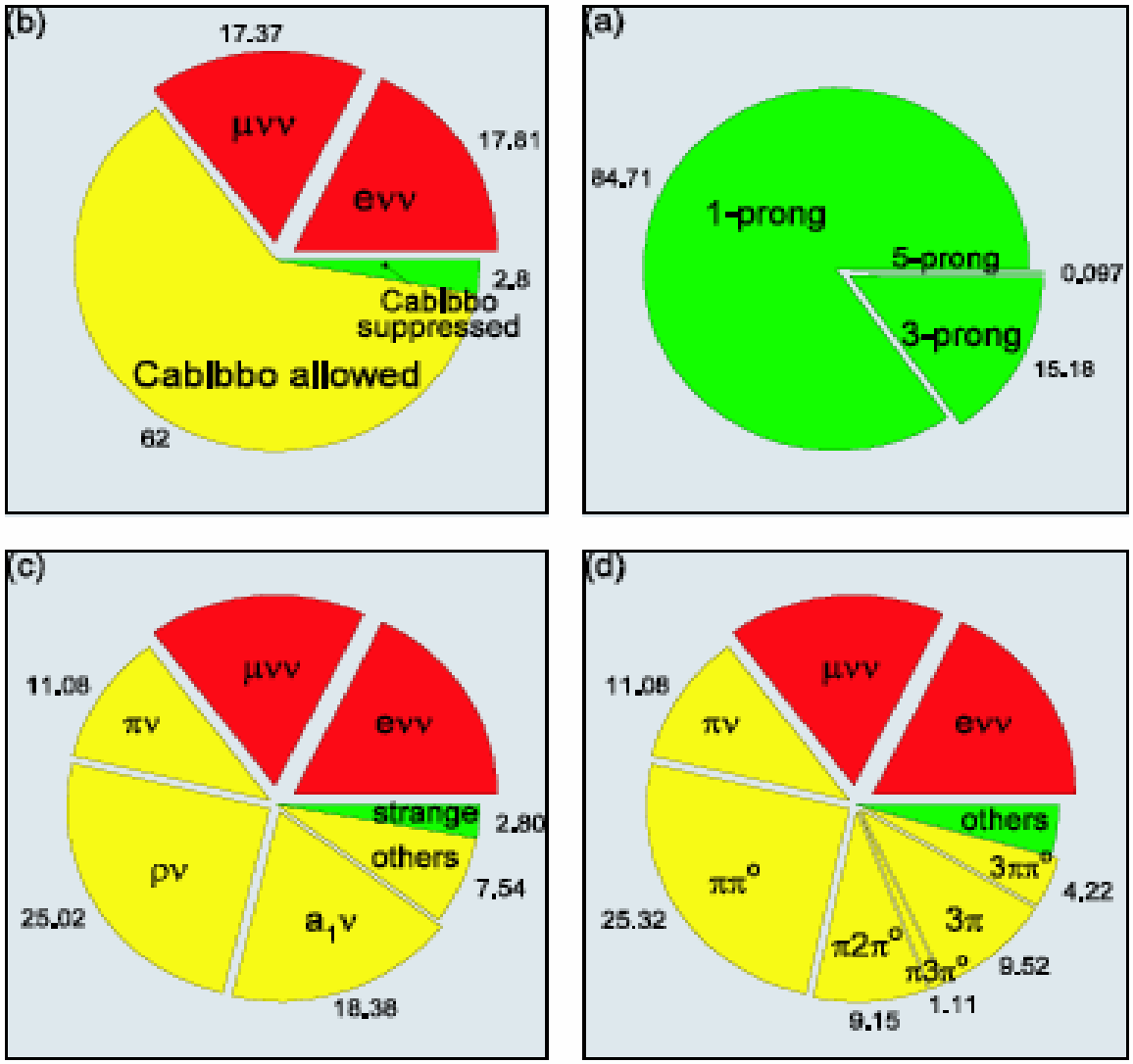
PDG-2006 lists more than 200 different tau decay channels

→ several decay modes possible

→ mini-jet like signature

Make it quite difficult because of huge QCD background for observing in the pp collision experimental environment

Tau leptons: general



Tau leptons: general

Tau lepton factories

Group	$\int L\,dt$, fb^{-1}	$N_{\tau\tau}$, 10^6
LEP (Z-peak)	0.34	0.33
CLEO (10.6 GeV)	13.8	12.6
BaBar (10.6 GeV)	384	350
Belle (10.6 GeV)	543	490
τ-c (4.2 GeV)	10	32
SuperB	50k	45k

BaBar (~530 fb^{-1}) and Belle (~800 fb^{-1}) collected together about 1.3 ab^{-1}
B-factory is also a τ factory producing 0.9 10^6 $\tau^+\tau^-$ pairs per each fb^{-1}

Tau lepton mass measurement

Group	m_τ, MeV
BES, 1996	$1776.96^{+0.18+0.25}_{-0.21-0.17}$
PDG, 2006	$1776.99^{+0.29}_{-0.26}$
KEDR, 2007	$1776.81^{+0.25}_{-0.23} \pm 0.15$
Belle, 2007	$1776.61 \pm 0.13 \pm 0.35$
PDG, 2008	1776.83 ± 0.18

Lepton universality is OK.
r = 1.0039 +- 0.0040 (0.99s)
The r sensitivity is six times higher than in 1992 (0.004 vs 0.025)

Tau-lepton properties were studied very extensively at previous and present experiments.
At LHC we will use them as an excellent probe for New Physics.

Experimental identification:
Algorithms and expected performance

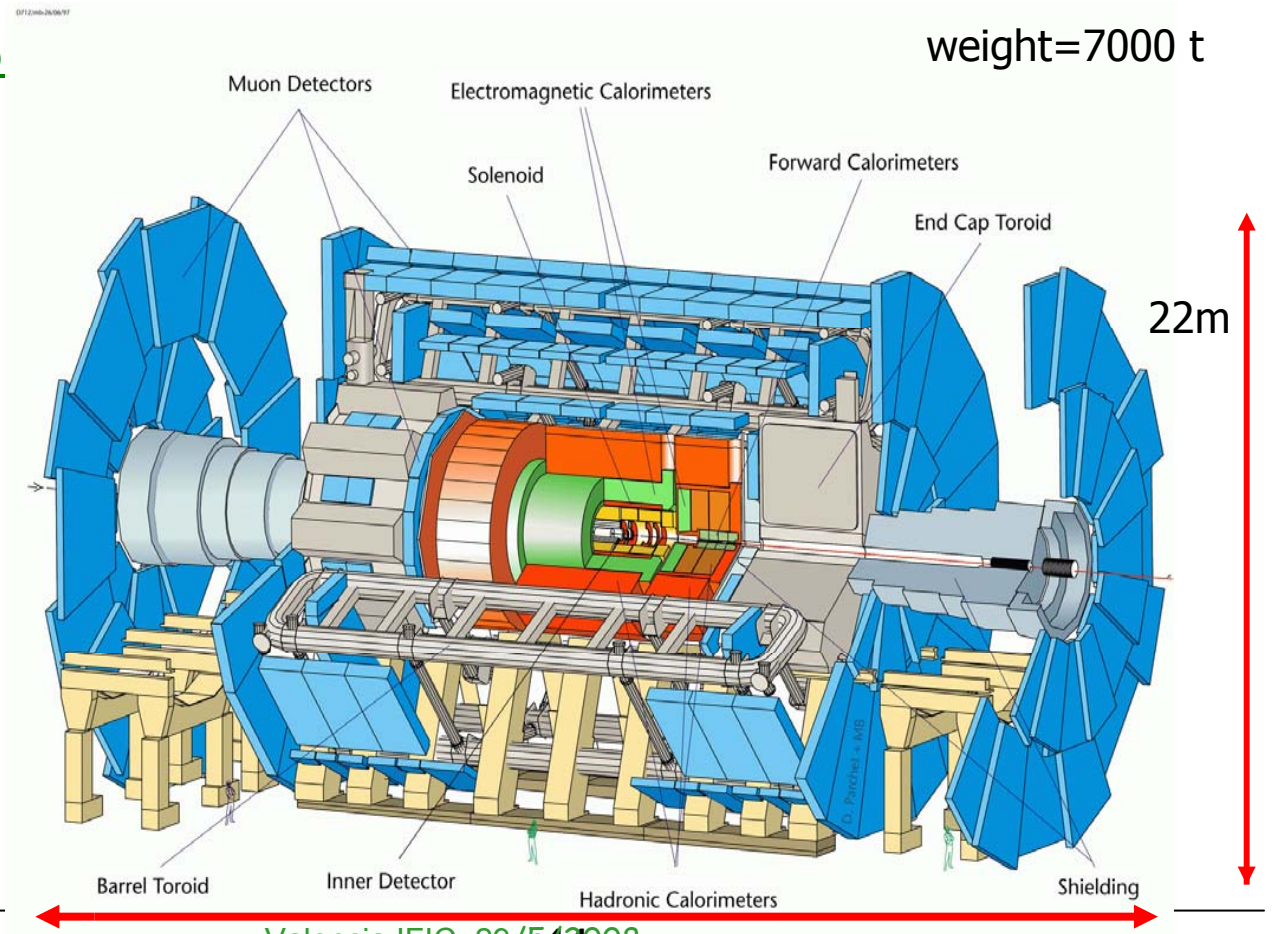
The ATLAS detector at LHC

γ-electrons, jets, E_t^{miss}, σ_E
$|\eta|$ coverage, b-tagging

Inner Detector :
Semiconductor Pixel and Strips
Straw Tube Tracking Detector (TRT)
$L \times R = 7m \times 1.15m$
$\sigma_{R\phi} = 12\text{-}16\mu m$, $\sigma_z = 66\text{-}580\mu m$

Thin Superconducting Solenoid
(B=2T)
LAr Electromagnetic Calo
$L \times R = 13.3m \times 2.25m$
$|\eta| \leq 3.2$ (4.9)
$\sigma_E / E = 10\% / \sqrt{E} \oplus 0.7\%$
Hadronic Calorimeter :
Endcaps LArg
Barrel Scintillator-tile
$L \times R = 12.2m \times 4.25m$
$\sigma_E / E = 50\% / \sqrt{E} \oplus 3\%$ ($|\eta$
Large Superconducting Air-Core Toroids

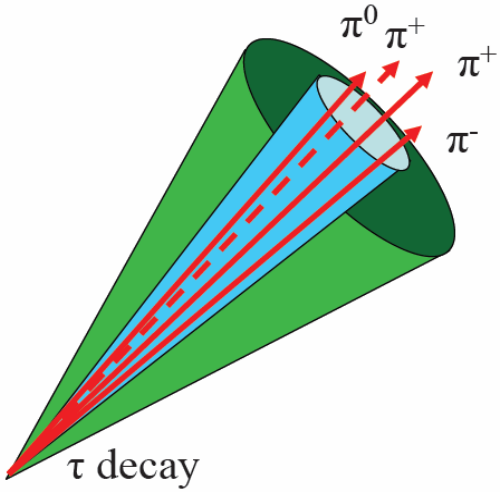
Muon Spectrometer
$L \times R = 25$ (46) $m \times 11m$



Hadronic taus: means for identification

Tracking:

→ object with low track multiplicity (1 $\pi^{\pm}$ or 3 $\pi^{\pm}$)
→ tracks more collimated than for "average jet",
(invariant mass, weighted width of tracks system)
→ decay length makes it possible to look
at secondary vertex (three-prong),
use impact parameter
→ isolation cone from other tracks



Calorimetry:

→ collimated deposition in EM (radius, width)
use shower shape variables
→ strong EM component for single prong (50% energy by π^0)
→ possibility to identify π^0 clusters using strip layers
→ isolation cone
→ both EM and HAD components

More "handles" for identification than eg. in case of b-tagging

Reconstruction of hadronic tau decays

Dedicated reconstruction algorithms, not a part of „flavour tagging" for jet objects

	τ-lepton	B-hadron (from b-quark)
Mass	1.78 GeV/c^2	5.2 - 5.7 GeV/c^2
Lifetime	0.29 ps	1.5 ps
Decay Length	87 μm	500 μm
Decay Channels	Hadronic: 65% ~ 77% "1-prong" ~ 23% "3-prong"	Fragmentation into jet with $\langle N_{ChTrack} \rangle > 5$ Jet has also tracks from fragmentation with "0" lifetime

Given complexity of the physics object two reconstruction schemes have been developed

Track-seeded reconstruction

Reconstruction

- use good quality tracks (pT>6 GeV) to seed tau candidate
- candidates with 1-8 quality tracks (pT>1 GeV) in $\Delta R<0.2$ from the seed
- define the η,φ using p_T weighting of tracks, checks charge consistency
- tau candidate E_T determined with energy-flow method
  (EM calo - separating neutral/charged sources of energy)

Identification:

- main discriminant is Neural Network but also available PDRS, cut-based, LLH
- combination of tracking and calorimeter variables for tau ID

Characteristics:

- rejection at reconstruction and identification steps
- good charge determination, minimize migration between 1-prong and 3-prong categories
- optimised for balanced efficiency for 1-prong and 3-prong categories
- very good performance at lower p_T regions

Calorimetry-seeded reconstruction

Reconstruction:

- use cone 0.4 TopoJets (>10 GeV) to seed tau candidates
- tracks (pT>2 GeV) in ΔR<0.3 from seeding TopoJet
- calibrates energy of cells in TopoJet using H1-calibration

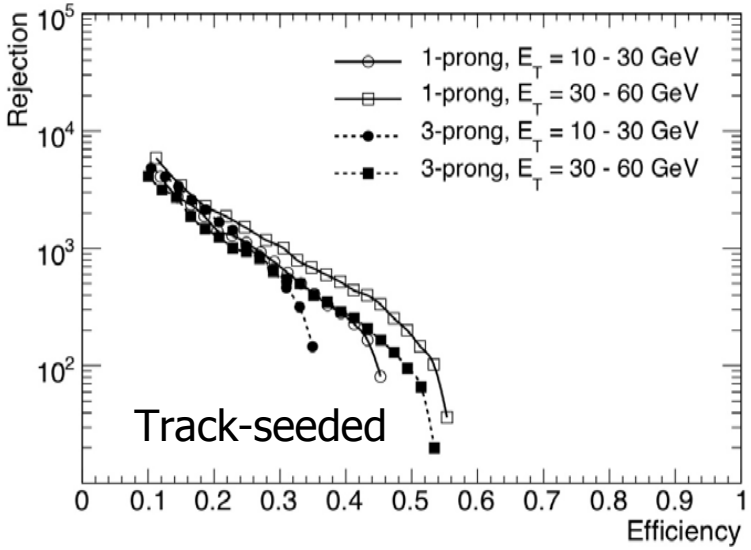
Identification:

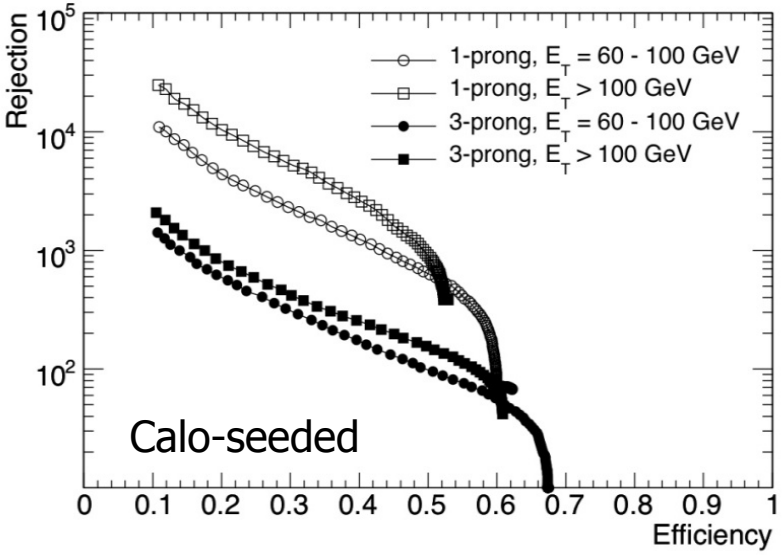
- use a Likelihood discriminant of 8 variables (assumes uncorrelated)
- variables exploit calorimeter shapes, track multiplicity
  η-strip layer, leading track properties

Characteristics:

- rejection power at identification, almost 100% efficient reconstruction
- optimized for 1-prong taus
- very good performance at higher p_T regions

Reference performance of the algorithms





Rejections at 30% efficiency

Tau CSC note

Algorithm	10-30 GeV	30-60 GeV	60-100 GeV	>100 GeV
track-seeded (neural net)	1p: 740±70 3p: 590±50	1p: 1030±160 3p: 590±70		
calo-seeded (likelihood)		1p: 1130±50 3p: 187±3	1p: 2240±140 3p: 310±7	1p: 4370±280 3p: 423±8

Both concepts integrated (year 2008)

Track-seeded candidates with matching topo-seed

- complete set of identification variables can be build,
- calculated energy from calorimetric and from energy-flow
- low level of misidentified charge
- low level of migration between 1-prong and 3-prong categories
- Pi0 subclusters reconstructed

Calo-seeded only candidates

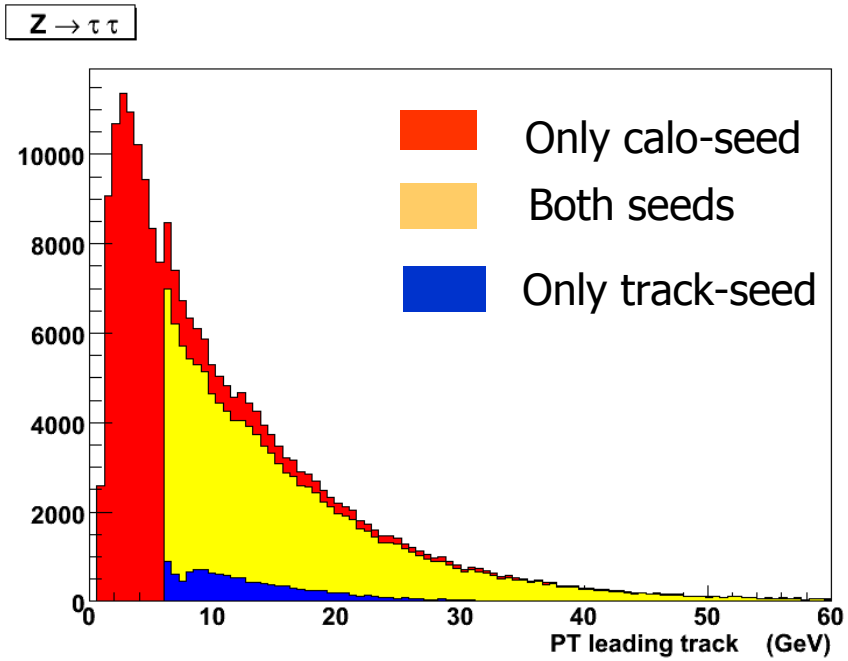
- energy from calorimetry
- more migrations, lower charge purity (tracks either do not pass quality selection or/and not leading
- Pi0 clusters reconstruction not yet integrated

Track-seeded only candidates

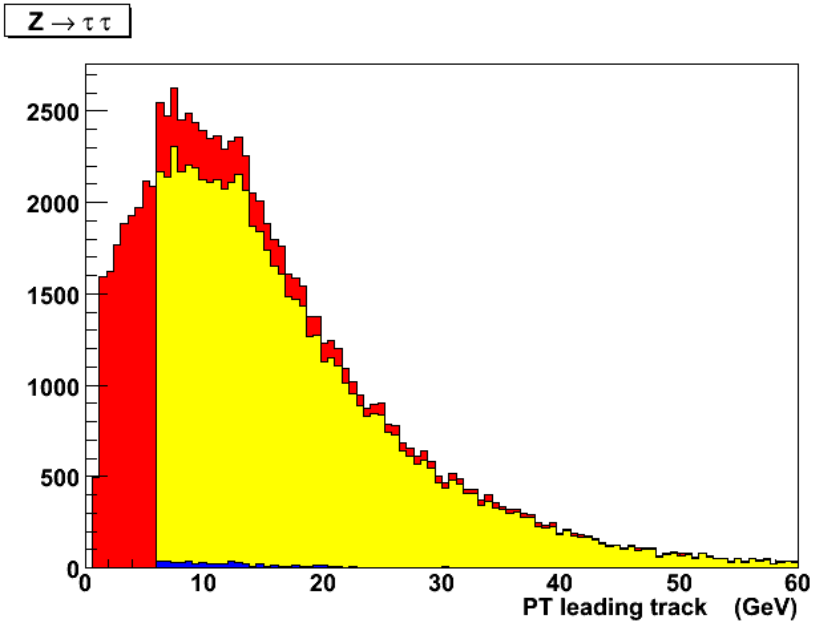
- small fraction, $\pi^{\pm}$ reconstructed in the Inner Detector and small energy deposition in calorimeter

In progress, integration of the identification procedures
(Likelihood, PDRS, NN, Boosted Decision Tree).

Both concepts integrated



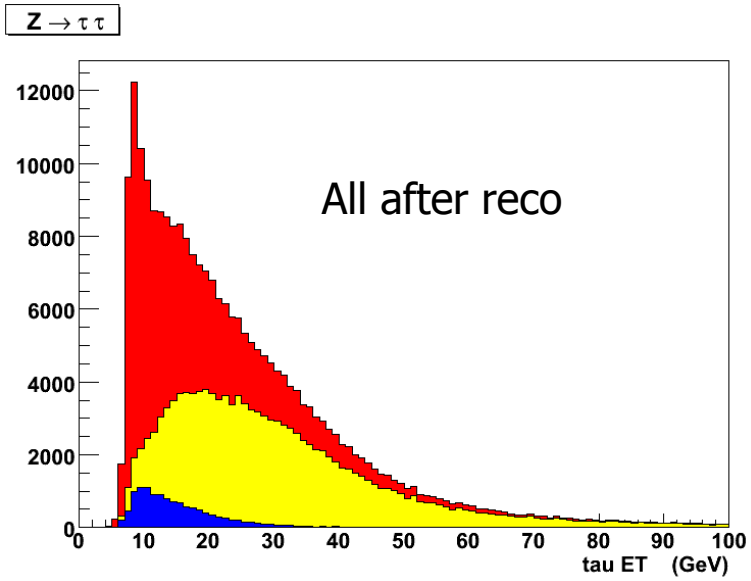
All reconstructed

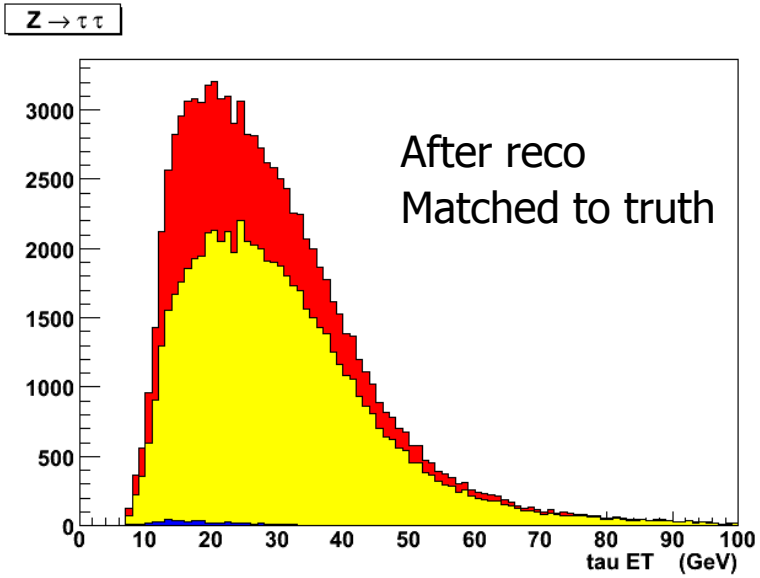


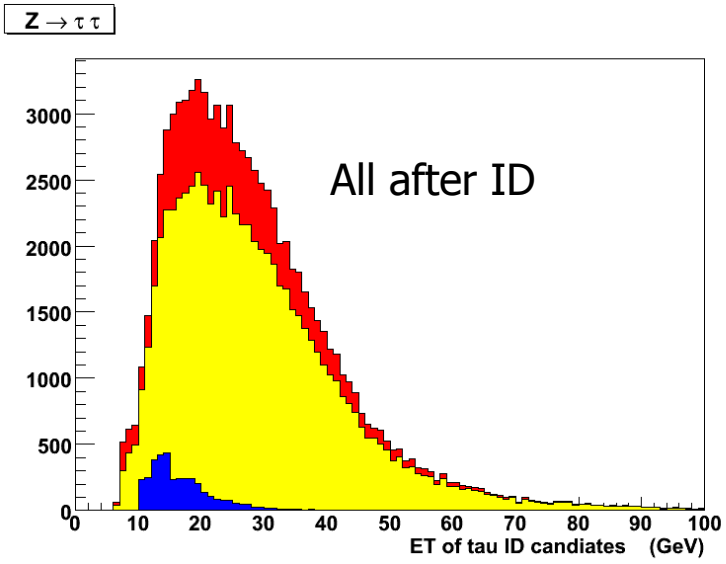
Only those matched to truth taus

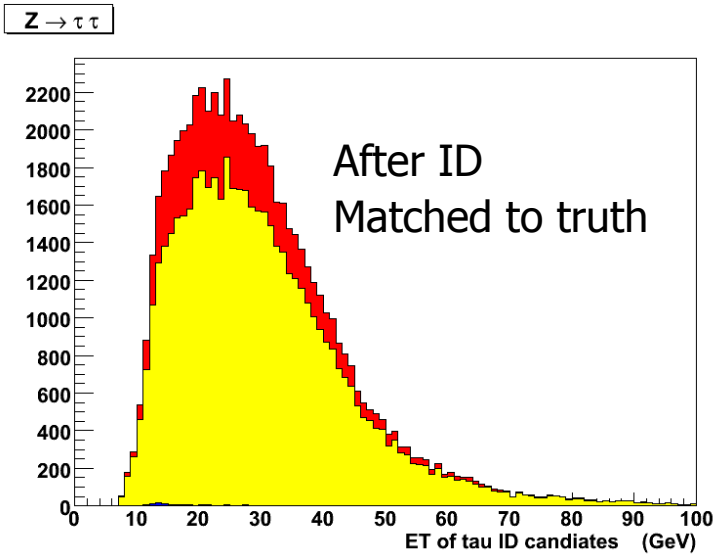
Categories for events Z->ττ and W->τν	Fraction of true taus reconstructed	Fraction of all candidates reconstructed (true + fake taus)
Track-seeded with matching calo-seed	74%	49%
Calo-seeded only	25%	45.5%
Track-seeded only	1%	5.5%

Both concepts integrated

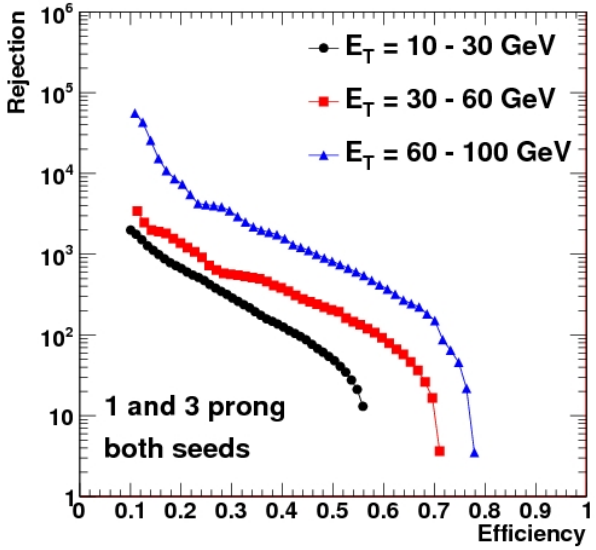


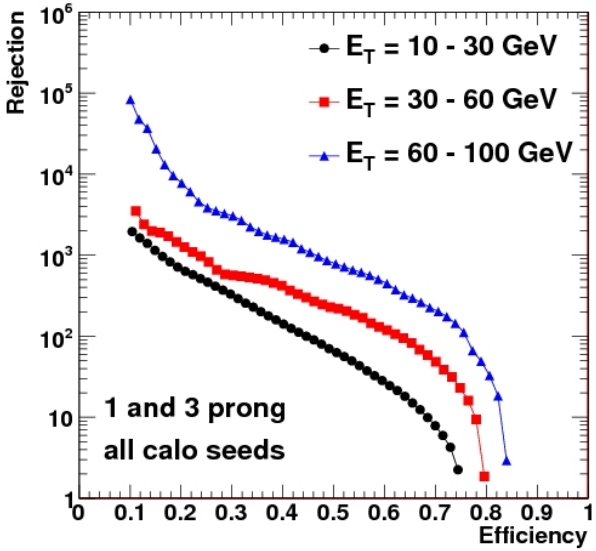






Reference performance of the algorithms





Rejections at 30% efficiency

Likelihood 2008

Algorithm	10-30 GeV	30-60 GeV	60-100 GeV
both-seeds (Likelihood2008)	1p: 470 3p: 520	1p: 700 3p: 2500	1p: 6400 3p: 4800
All calo-seeded (Likelihood2008)	1p: 510 3p: 460	1p: 710 3p: 2470	1p: 5050 3p: 4770

Few performance highlights (I)

Charge purity, migration between categories

Migration dominated by effects from combinatorics, not by charge misidentification of individual tracks

Tau CSC note

Track-seeded algorithm	Reconstructed as single-prong	Reconstructed as three-prong	Reconstructed as two-prong
Electron contamination (conversion)	1.5%	5.7%	2.9%
$\tau \rightarrow \pi^{+-}\, n\pi^0\, \nu$	96.1%	3.8%	23.8%
$\tau \rightarrow 3\pi^{+-}\, n\pi^0\, \nu$	3.9%	96.2%	76.2%
Charge misid (no had. interact.)	1.7% 0.4%	3.6% 2.1%	

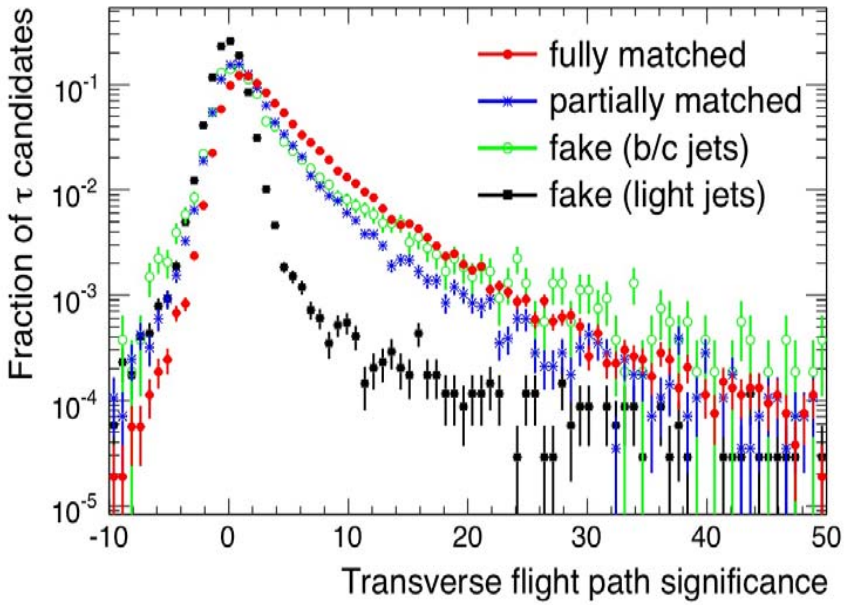
Few performance highlights (II)

Tau CSC note

Transverse flight path

Provides significant improvement in the rejection of candidates from light jets (multi-variate methods used: likelihood, neural network)

Important component for the life-time measurement (reconstruction of complete tau momenta including neutrino needed)



fully matched 3-prong	Resolution (μm)	Mean (μm)
transverse	10.2 ± 0.2	0.2 ± 0.1
parallel	593 ± 8	6 ± 6

Few performance highlights (III)

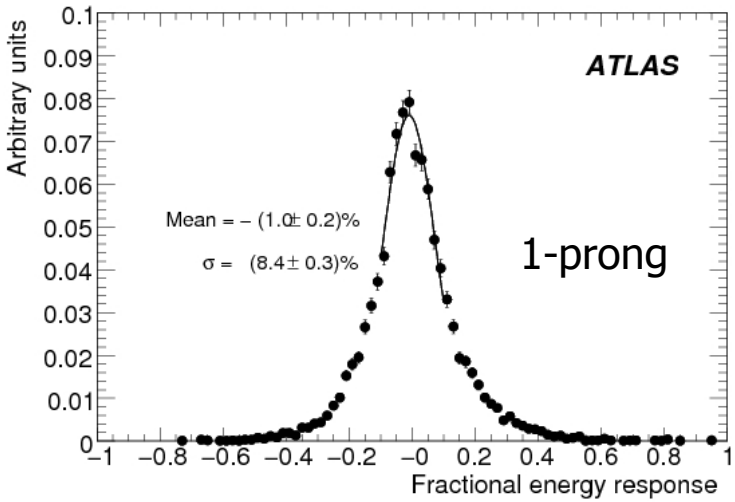
Tau CSC note

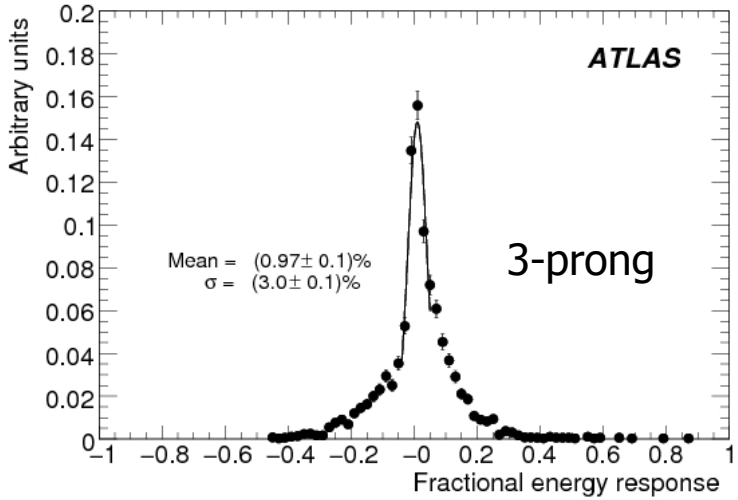
Energy flow

Transverse energy calculated from tracks transverse momenta and energy deposited in the cells of electromagnetic calorimeter (presampler, strips, middle) in cone of 0.2 around reco tau candidate. Cells in close vicinity to the track impact point are removed.

Correction terms for

- unsubtracted energy from track
- oversubtracted energy in case of overlying charged $\pi^{\pm}$ and neutral π^{0}



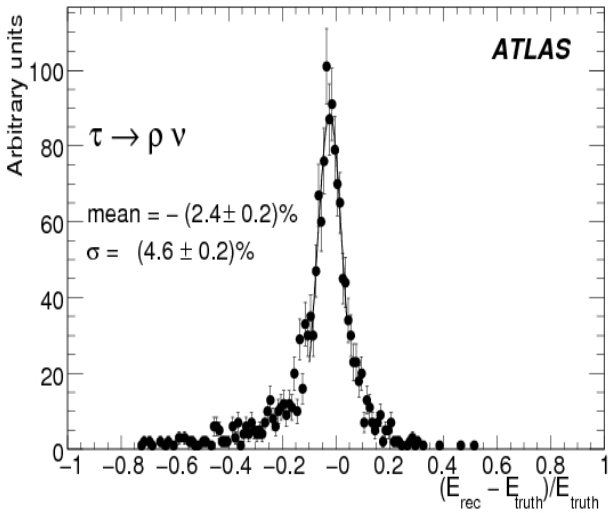


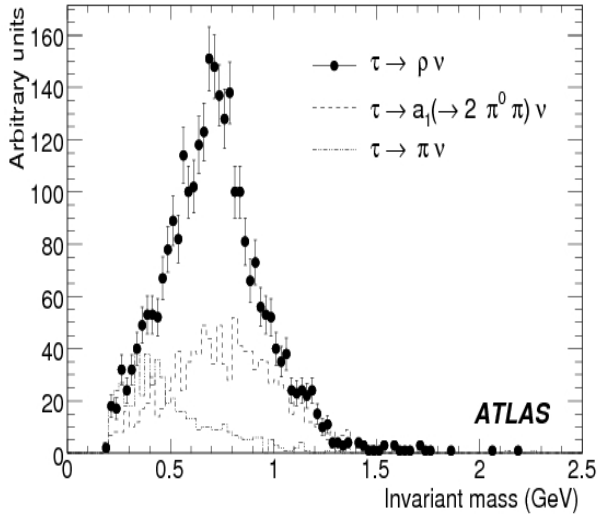
Few performance highlights (III)

Tau CSC note

Pi0 subclusters

Reconstructed using topological clustering of cells in electromagnetic calorimeter (strips, middle),
after subtracting cells in close vicinity to the track impact point





Single-prong only	no π^0 cluster	1 π^0 cluster	≥ 2 π^0 cluster
all $\tau\rightarrow$ had ν	**32 %**	**35 %**	**33 %**
$\tau\rightarrow\pi^{\pm}\nu$	**65 %**	**20 %**	**15 %**
$\tau\rightarrow\rho(\rightarrow\pi^{\pm}\pi^0)\ \nu$	**15 %**	**50 %**	**35 %**
$\tau\rightarrow a_1(\rightarrow 2\pi^0\pi^{\pm})\nu$	**9 %**	**34 %**	**57 %**

Tau Trigger Slice

- ✓ Triggering on hadronic tau decays will be difficult task (huge QCD bgd, high occupancy of the events). Intensive effort in ATLAS to develop algorithms and optimise performance
- ✓ Increases discovery potential for many physics channels, in few cases the only trigger (W->$\tau\nu$, charged Higgs in fully hadronic)
- ✓ Should be used with relatively high thresholds alone (tau60, tau100), or with more relaxed thresholds and combinations with other signature (E_T^{miss}, lepton, jet)

ATLAS Trigger System	Tau Trigger Slice
L1: (hardware) 40MHz->75kHz (2.5ms)	Calorimetry
L2: (software) 75kHz->2kHz (40ms)	Calorimetry + tracking
EF: (software) 2kHz -> 100 Hz (4s)	Same algorithms as off-line

LHC physics goals (pp collision)

Higgs boson is a keystone of Standard Model construction.
Elusive itself though interations is expected to define properties of all known particles. That is why search for the Standard Model Higgs boson over mas range $\sim 115 < m_H < 1000$ GeV is focusing point of the LHC experiments.

Explore the highly-motivated TeV-scale, search for physics beyond the SM (Supersymmetry (more than one Higgs boson), Extra-dimensions, q/l compositeness, leptoquarks, W'/Z', heavy q/l, etc.)

Precise measurements

- -- W mass
- -- Top mass, couplings and decay properties
- -- Higgs mass, spin, couplings (if Higgs found)
- -- B-physics (mainly LHCb): CP violation, rare decays,.....
- -- QCD jet cross-section and α_s
- -- etc....

Expected data samples (examples) with 100 pb^{-1}

Channels (examples …)	Events to tape for 100 pb^{-1} (ATLAS)	Total statistics from LEP and Tevatron
$W \to \mu\,\nu$	~ 10^6	~ 10^4 LEP, ~ $10^{6\text{-}7}$ Tevatron
$Z \to \mu\,\mu$	~ 10^5	~ 10^6 LEP, ~ $10^{5\text{-}6}$ Tevatron
$tt \to W\,b\,W\,b \to \mu\,\nu + X$	~ 10^4	~ $10^{3\text{-}4}$ Tevatron
QCD jets p_T > 1 TeV	> 10^3	---
$\tilde{g}\tilde{g}$ m = 1 TeV	~ 50	---

Goals in 2008-2009:

1. Commission and calibrate the detector **in situ using physics samples** e.g.
   - $Z \to ee, \mu\mu$ tracker, ECAL, Muon chamber calibration and alignment, etc.
   - $tt \to bl\nu\ bjj$ jet scale from $W \to jj$, b-tag performance, etc.

- "Rediscover" and measure SM physics at $\sqrt{s}$ = 14 TeV (10TeV?)
  W, Z, tt, QCD jets … (also backgrounds to New Physics)
- Early discoveries ?
  Potentially accessible: Z', SUSY, …. surprises ?

First $100pb^{-1}$

Physics measurements with taus

Efficiencies and rejections for physics channels

Tau CSC note

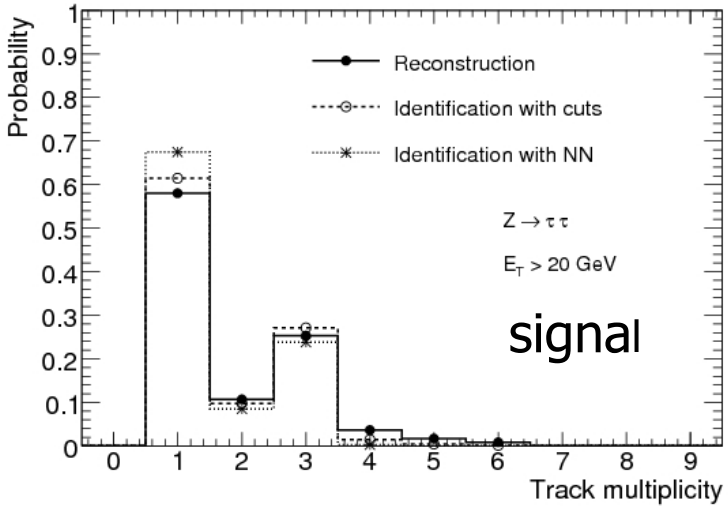
Process xsection	$Z \rightarrow \tau\tau$ 1.7 10^3 pb	$W \rightarrow \tau\nu$ 1.7 10^4 pb	QCD events 1.2 10^10 pb
track-based (cuts)	ε = 30.1%	ε = 26.2%	R = 550
track-based (Neural Net)	ε = 27.9%	ε = 22.6%	R = 1630
calo-based (LLH medium)	ε = 31.3%	ε = 25.8%	R = 1640
calo-based (LLH tight)	ε = 24.1%	ε = 17.5%	R = 3550

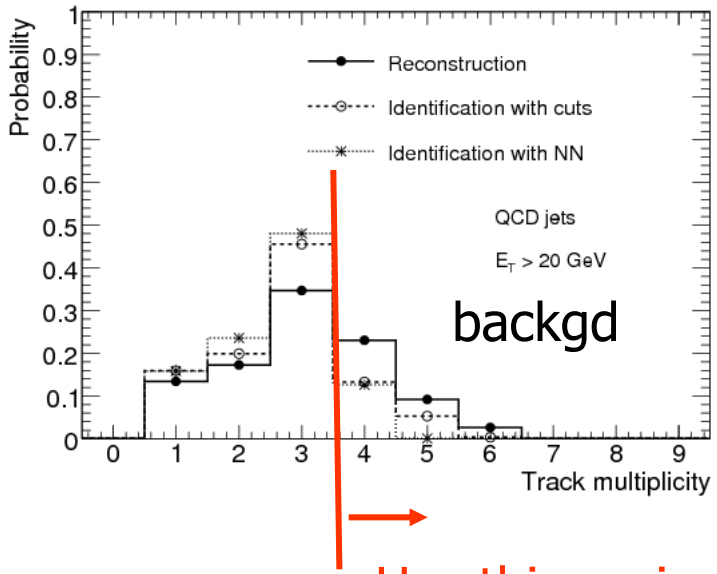
QCD background 6-7 orders of magnitude higher than the SM signals. Rejection of few hundred to few thousands against QCD jet events possible with τ identification only, more severe background suppression have to come from asking for isolated lepton and/or missing transverse energy in the event.

Track multiplicity spectra

A handle to control QCD background and establish evidence for τ observability.

For first evidence, strategy is to have efficiency well balance between single- and three-prong candidates (also minimise biases from trigger).





Ones tau identification well understood,
Optimisation for discoveries may become more inclusive i.e. optimise S/B (favour single-prong)

Use this region to control QCD normalisation

W -> $\tau\,\nu$ events with 100pb^{-1}

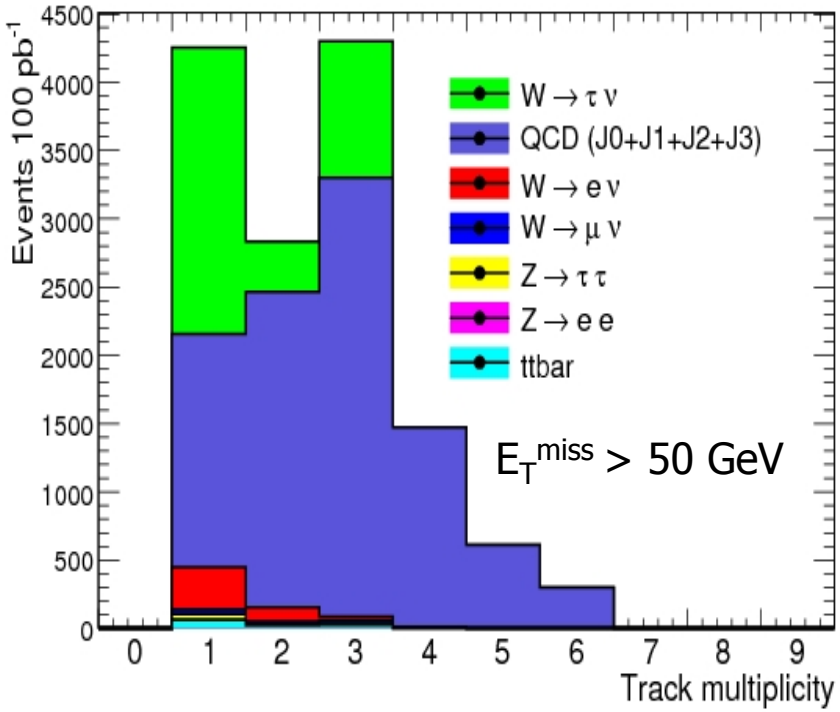
The most abundant source of taus in SM processes.
Triggered on single tau + $E_T^{miss.}$
Dominant bgd from QCD jets.
W$\rightarrow$eν important background, but also excellent control channel.
Observe excess of events in the track multiplicity spectrum of identified taus.

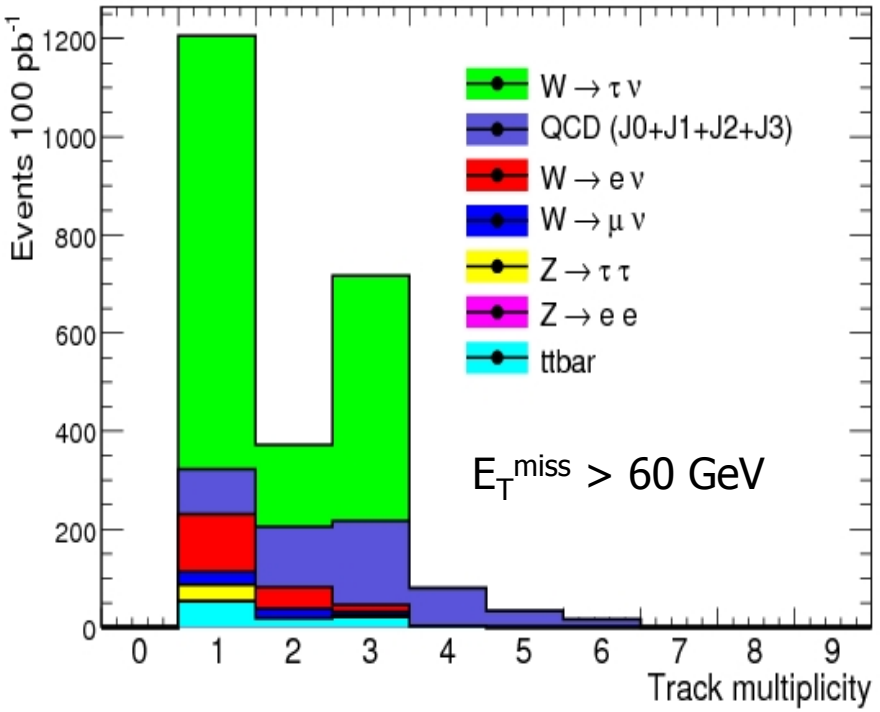
Tau CSC note

Events for 100pb-1	W->$\tau\nu$	W->eν	W->$\mu\nu$, tt, Z->ee, $\tau\tau$	QCD
In pp collisions	1.7 10^6	1.7 10^6	2.0 10^6	1.9 10^12
Trigger tau20i+xe30	8.8 10^4	4.4 10^5	3.3 10^5	8.6 10^7
medium tauID E_T^{miss} > 50 GeV 1 jet 15 GeV	3240	450	140	3200
E_T^{miss} > 60 GeV	1550	150	55	500

W -> τ ν events with 100pb^{-1}

Tau CSC note





Further reduction with increasing threshold on E_T^{miss}, tightening tauID, topological selection suppressing fake E_T^{miss} in QCD events.

Z -> ττ events (lep-had) with 100pb^{-1}

10 x smaller xsection but more interesting topology
Triggered on single lepton.
SS events (almost signal free) to control bgd in OS events (signal enriched).
Observe excess of events in invariant mass of visible decay products, then reconstruct complete invariant mass (collinear approximation).

Tau CSC note

Process (100pb^{-1})	Z→ττ	W→lν	QCD	Z->ll, ttbar
Isolated lepton	1.5 10^4	1.7 10^5	1.1 10^7	2.5 10^5
Before tauID	2780	2.4 10^4	2.7 10^4	2.7 10^3
After tauID + detphi cut	630±30	210±10	74±11	40±6
mass window 37-75GeV opposite sign events	520±30	45±5	29±5	15±5

Z -> ττ events (lep-had) with 100pb^{-1}

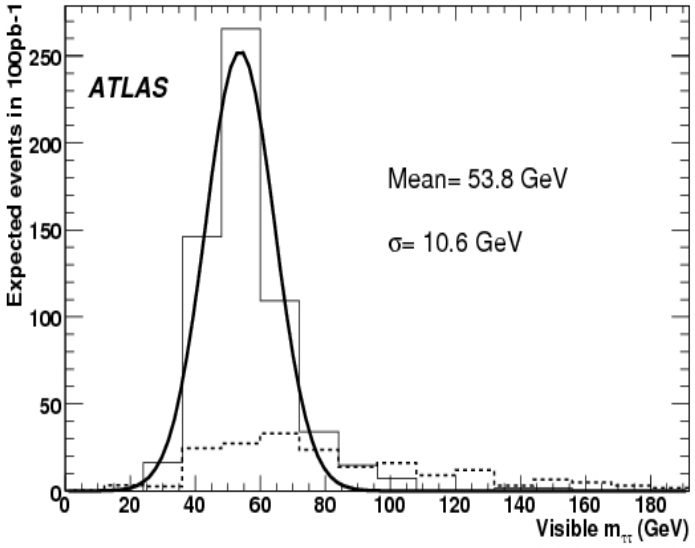
Taking into account only statistical uncertaintity

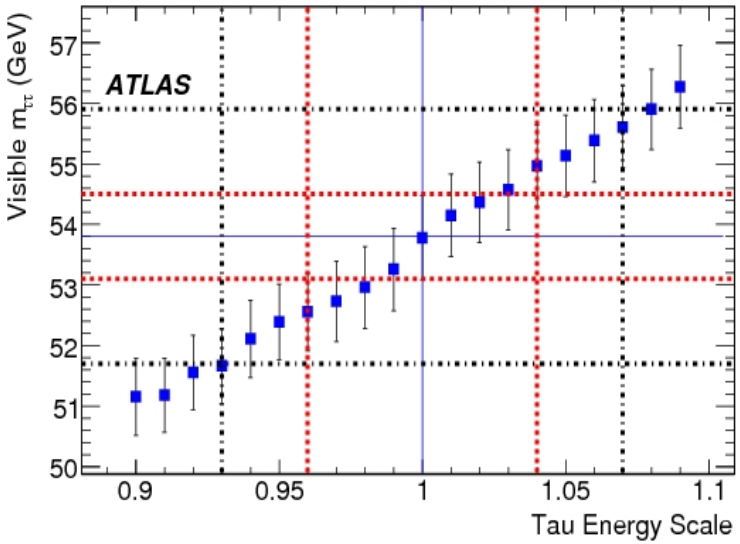
From visible mass

-- determine energy scale with ± 3% precision

-- determine xsection with with ± 6% precision

Tau CSC note

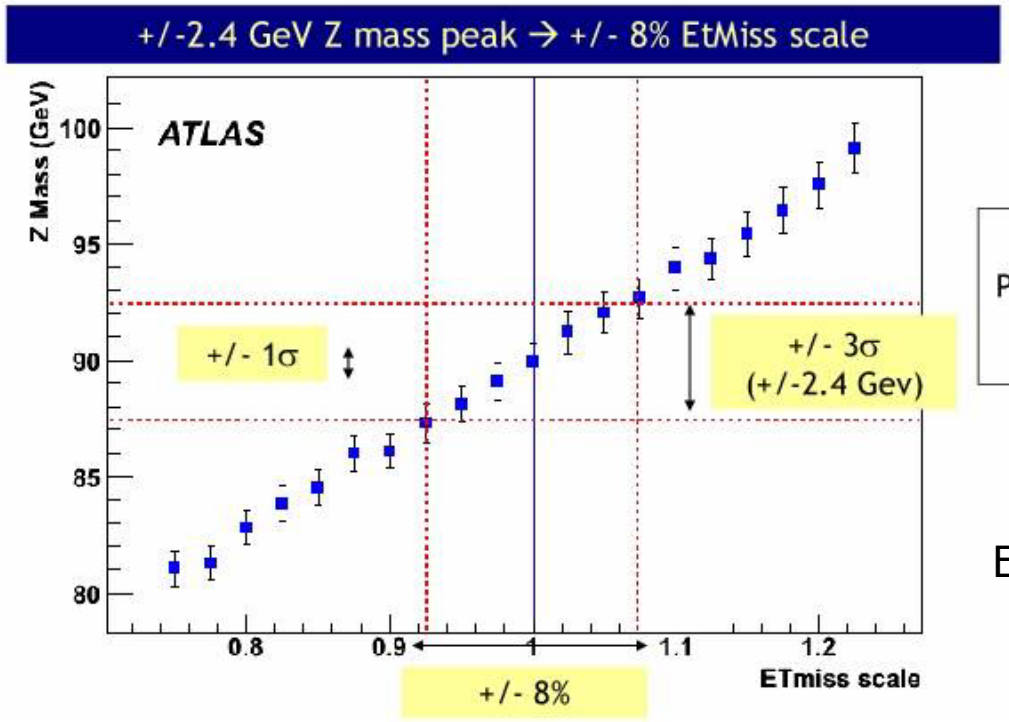




Z -> ττ events (lep-had) with 100pb^{-1}

Taking into account only statistical uncertaintity and assuming taus are well calibrated.

From invariant mass determine ETmiss scale
(additional selection, collinear approximation)



209 signal events
16 bgd events

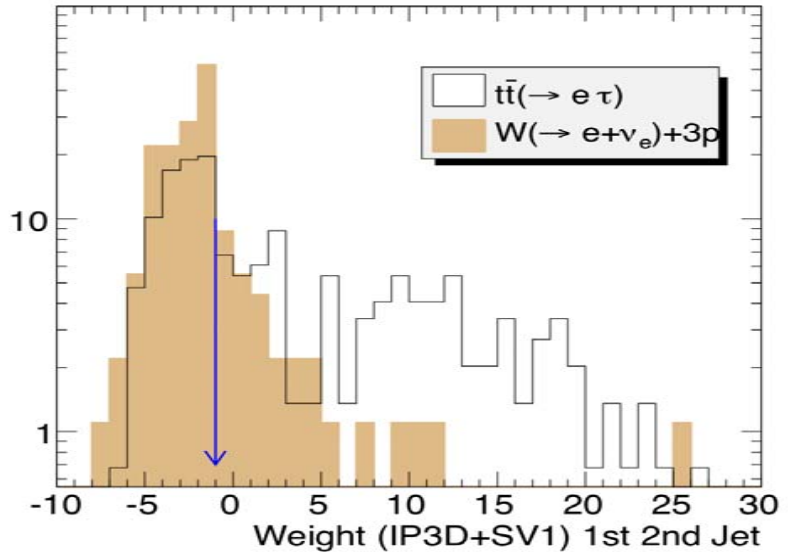
ETmiss CSC note

ttbar process with one W -> τν

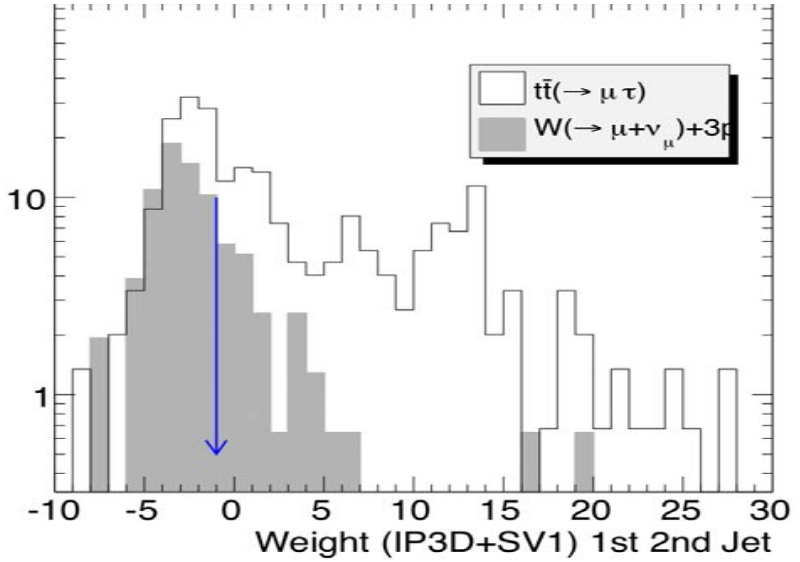
For ttbar with a $W \rightarrow \tau_{HAD}\nu$, σxBR = 870 pb (~2500 events in 100 pb^{-1})

- ✓ establish τ identification at higher p_T range
- ✓ b-tagging needed to suppress bgd
- ✓ τ+xe, τ+jet triggers for fully hadronic final state

Tau CSC note



Channel	Events in 100 pb^{-1}	S : B ratio
eτ	54±4	1 : 10
(with b-tag)	28±3	1: 1
μτ	77±5	1 : 4
(with b-tag)	40±4	1.5 : 1
qq'τ	~300	20 : 1



First $1fb^{-1}$

Discoveries with taus?

MSSM Higgs sector : $H^{\pm}$

Tau CSC note

Direct evidence for physics beyond SM

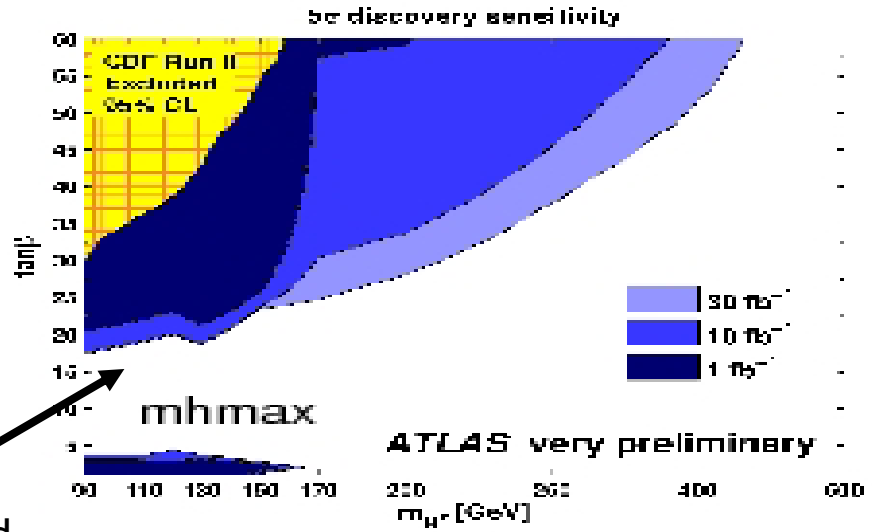
Two mass regions

$m_{H\pm} < m_t$

$m_{H\pm} > m_t$

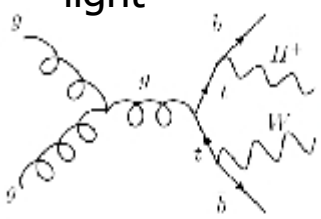
Main decay modes are fermionic.

Dominant observability potential from $H^{\pm} \rightarrow \tau\nu$



Should be also covered analysis in progress

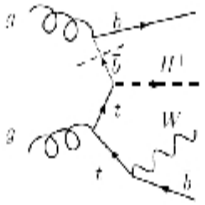
light



τ(had)υ

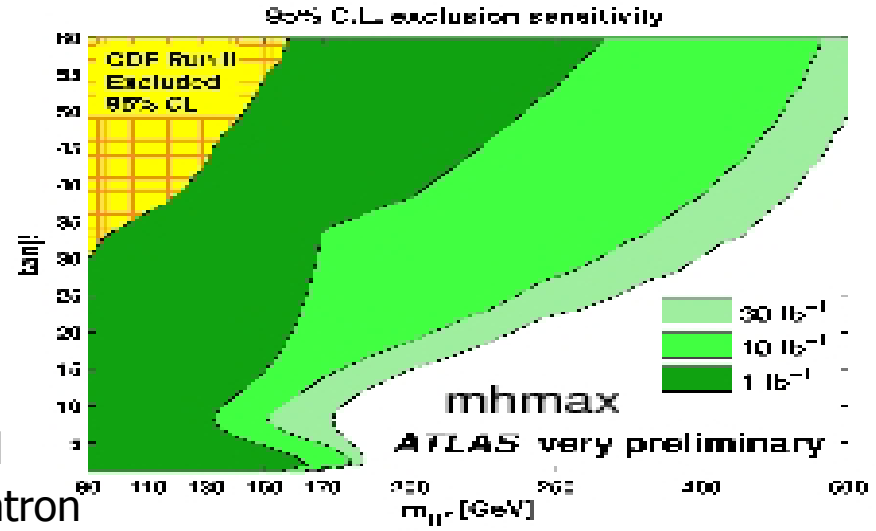
j j b , **lνb**

heavy



τ(had)υ

j j b



Already at $1fb^{-1}$ will extend discovery potential of Tevatron

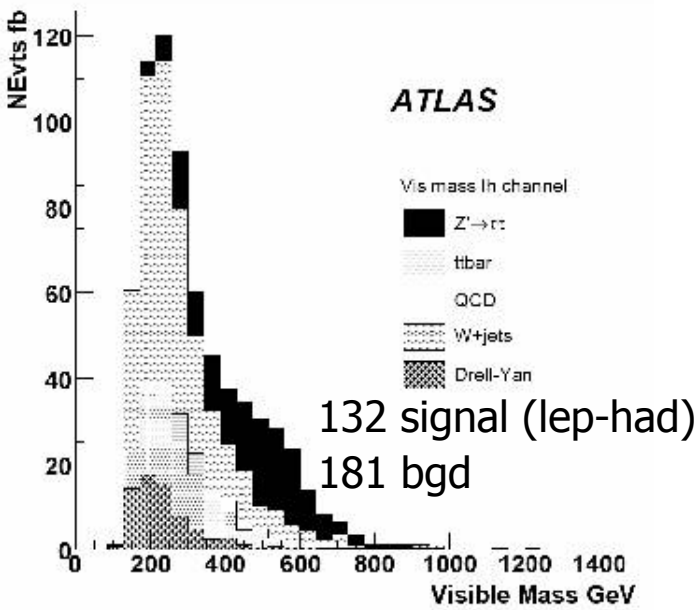
Heavy resonanses Z' -> ττ

Tau CSC note

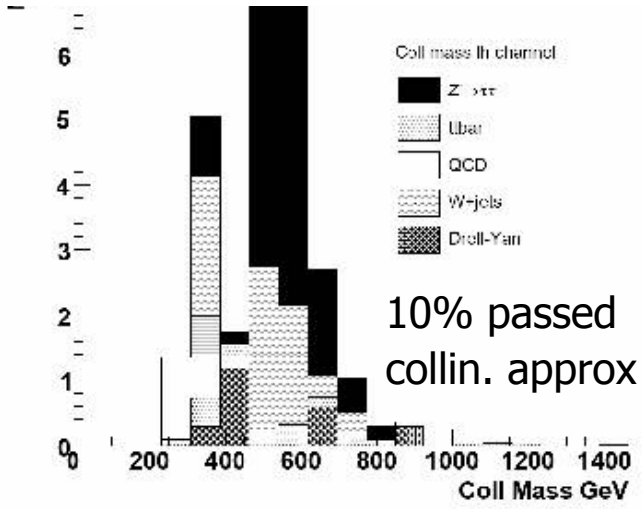
✓ Numbers of theories predict additional heavy gauge boson: E6, Extra dimensions,
✓ Studies can be interpreted/easily. extandable to several of them. In some models potential new resonanse couples preferentially to ττ final states.

Studied simple extension of SM,
mZ'=600 GeV , G = 13 GeV
s=3.64 pb, <pT> 63 GeV

Events 1fb-1 (coll. approx)	Signal	Bgd	S/sqrt(B) Incl. 10% syst
Lep-had	13.8	12.6	3.7
Ha-had	12.9	8.6	4.2
Both channels	26.9	23.4	5.3



132 signal (lep-had)
181 bgd

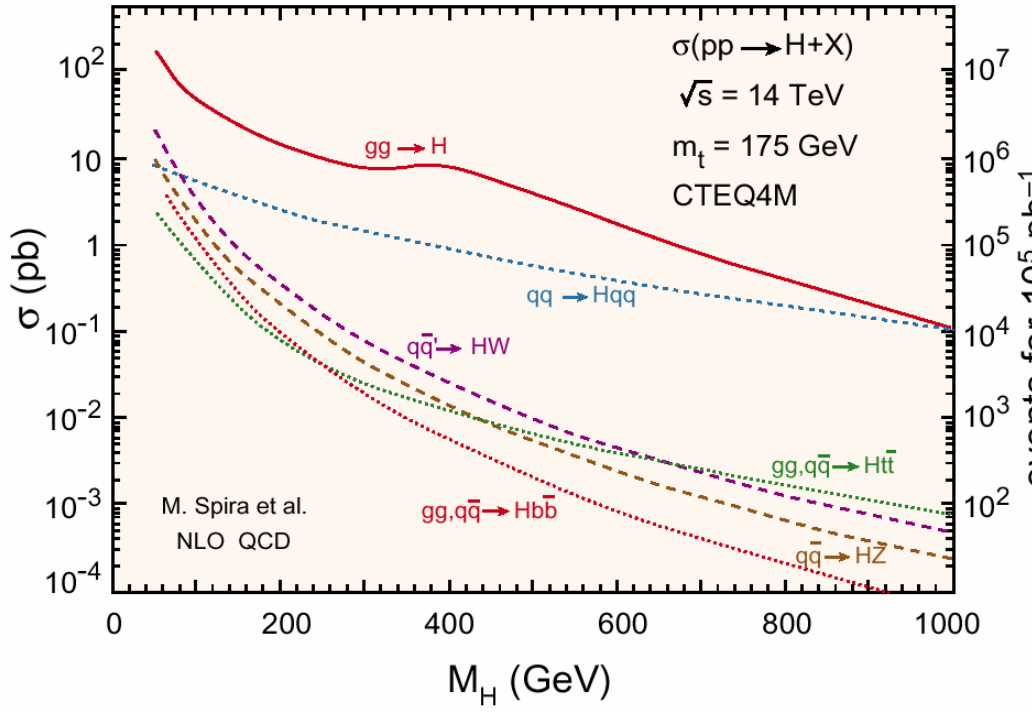


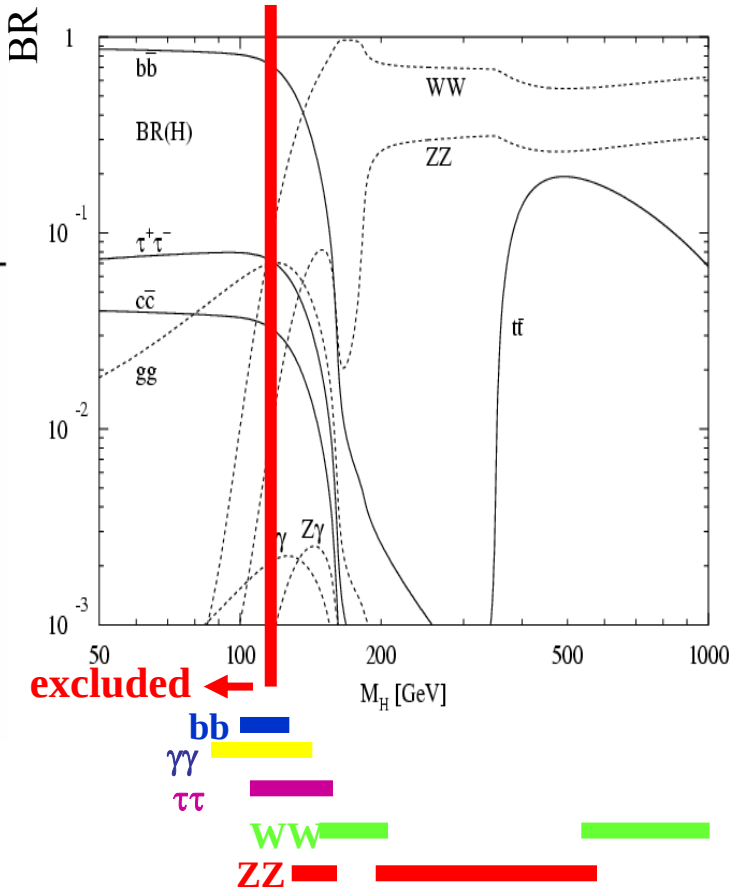
10% passed collin. approx

$10 fb^{-1}$ – $30\ fb^{-1}$
and more…

Exciting programme for discovery physics with taus

SM Higgs signal





m_H < 130 GeV : H → bb, ττ dominate

→ best search channels at the LHC : qqH→qq ττ, H → γγ, ttH → lbbX

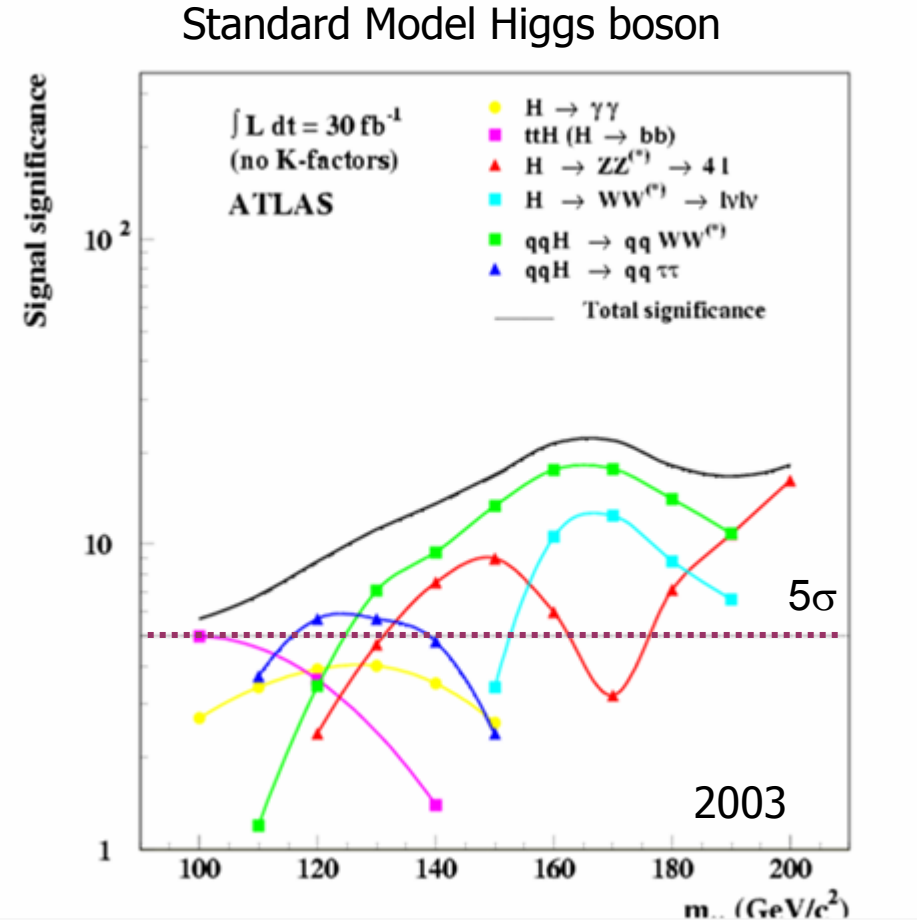
m_H > 130 GeV : H → $WW^{(*)}$, $ZZ^{(*)}$ dominate

→ best search channels at the LHC : H → $ZZ^{(*)}$ → 4l (gold-plated)

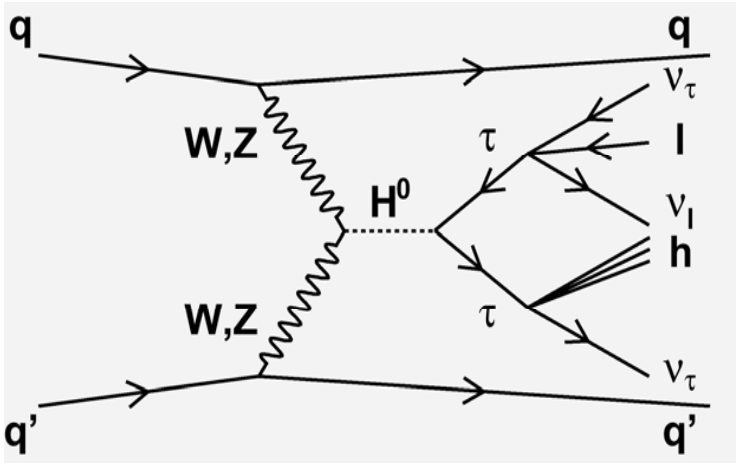
H → $WW^{(*)}$ → lν lν

SM Higgs boson discovery potential

Standard Model Higgs boson



qqH->qqττ



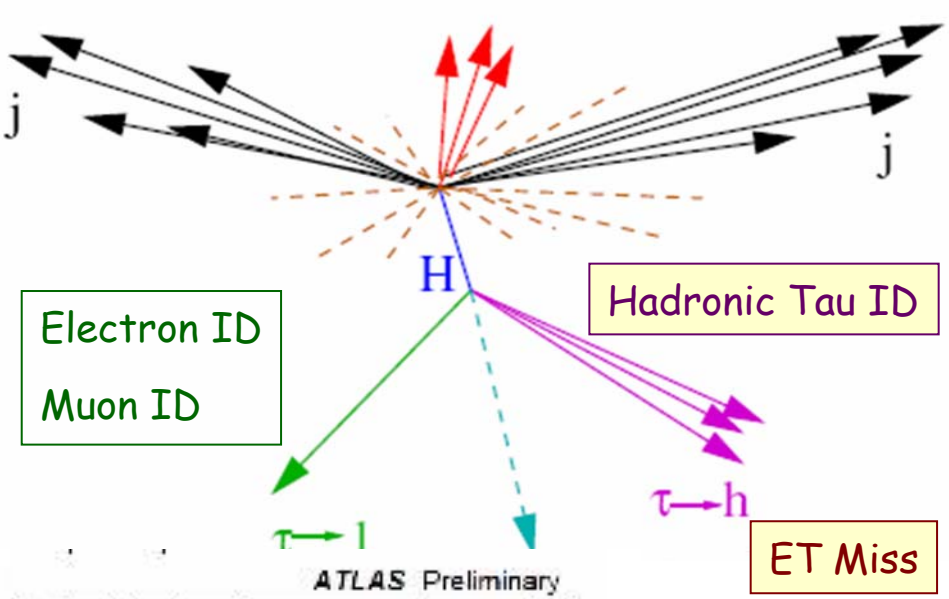
-> about 5 σ sensitivity for Higgs mass 110-140 GeV for $30fb^{-1}$

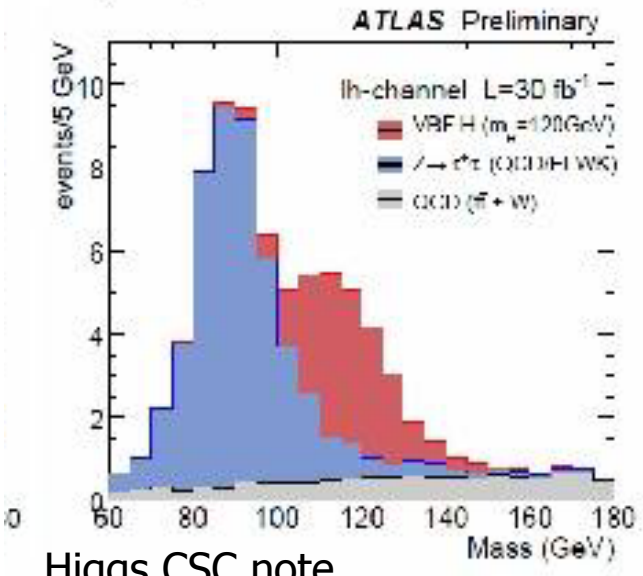
-> combined results for lepton-lepton and lepton-hadron decay modes

-> better performance for lepton-hadron (mass resolution, efficiencies)

-> gives access also to the measurement of the Higgs couplings: Hττ/HWW

Vector Boson Fusion: H→ττ





Higgs CSC note

Central Jet Veto:

- Sensible to PileUp

Forward Tagging Jets:

- Difficult Forward Region
- Jet Calibration

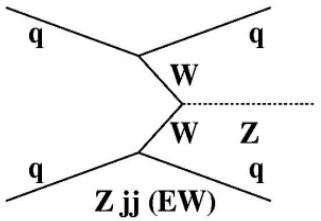
E_T^{Miss}:

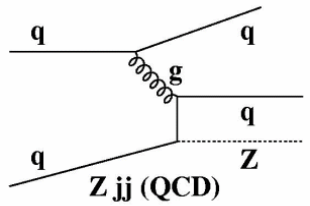
- Central to Tau Reconstruction
- Reconstructed Higgs Mass
- Dominant Experimental Issue

Dominant backgrounds:

Zjj, WWjj EW&QCD , tt production

$\sigma_M \sim 11\text{-}12$ GeV





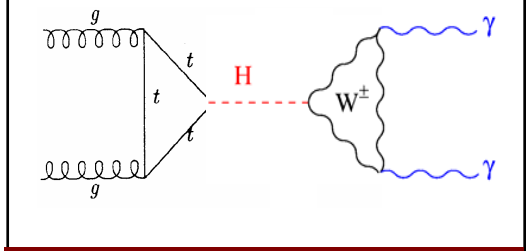
The most difficult low-mass region: m_H ~ 115-150 GeV…

ATLAS : m_H ~ 115 GeV 10 fb^{-1} : S/√B ≈ 4-5.5

range comes from H → γγ: LO vs NLO cross-section, cuts vs likelihood analysis

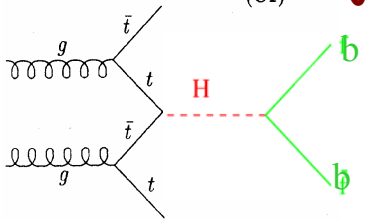
3 (complementary) channels with (similar) small significances:

H → γγ



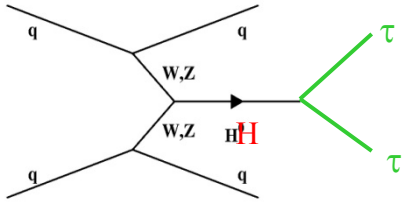
S=130, B=4300, S/√B= 2 - 4.4

ttH→ttbb → blνbjjbb



S/√B~2, being re-evaluated

qqH → qqττ



S=10, B=10, S/√B=2.7

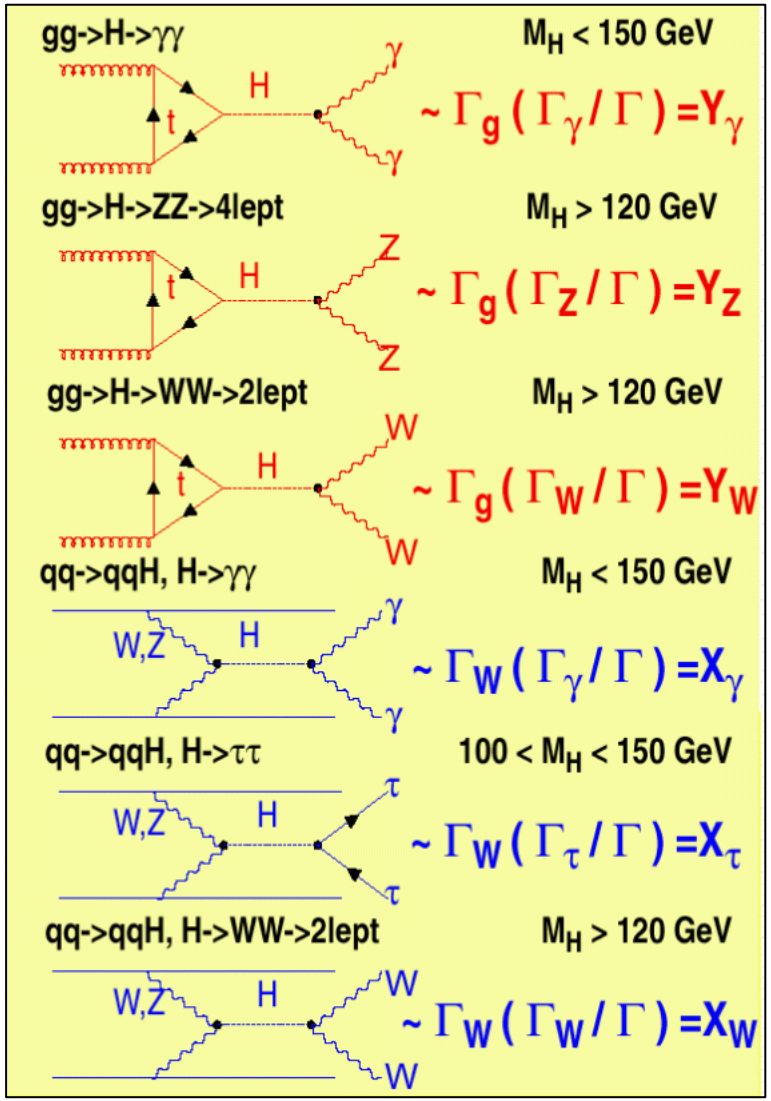
- different production and decay modes
- different backgrounds
- different detector/performance requirements:
  - -- ECAL crucial for H → γγ (in particular response uniformity) : σ/m ~ 1% needed
  - -- b-tagging crucial for ttH : 4 b-tagged jets needed to reduce combinatorics (background being re-evaluated)
  - -- efficient jet reconstruction over |η| < 5 crucial for qqH → qqττ : forward jet tag and central jet veto needed against background

5σ at 30fb-1
lep-had and lep-lep combined

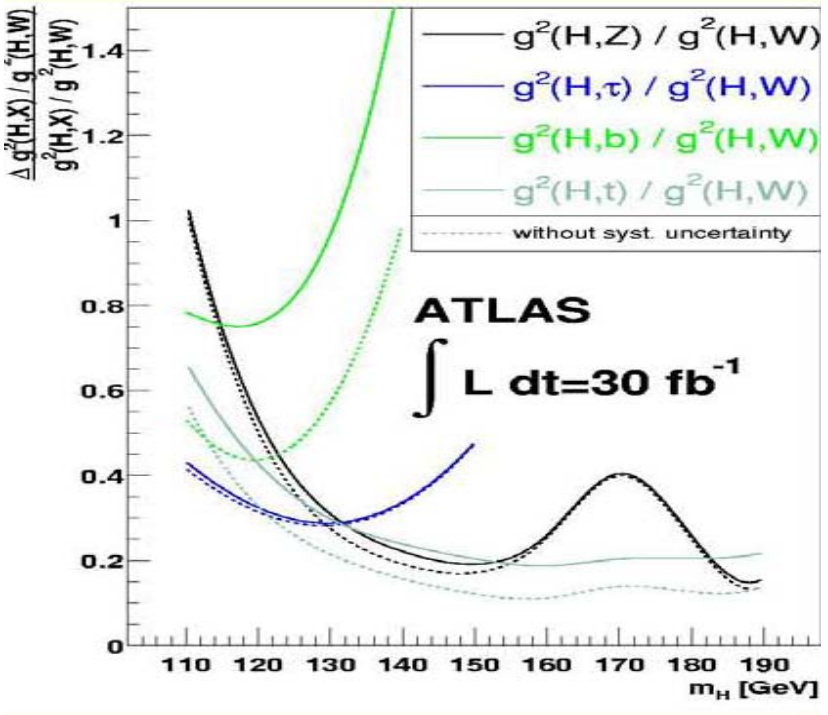
All three channels require very good understanding of detector performance and background control to 1-10% → convincing evidence likely to come mid-end 2009 …

Measurements of the SM Higgs boson couplings

2003



2003



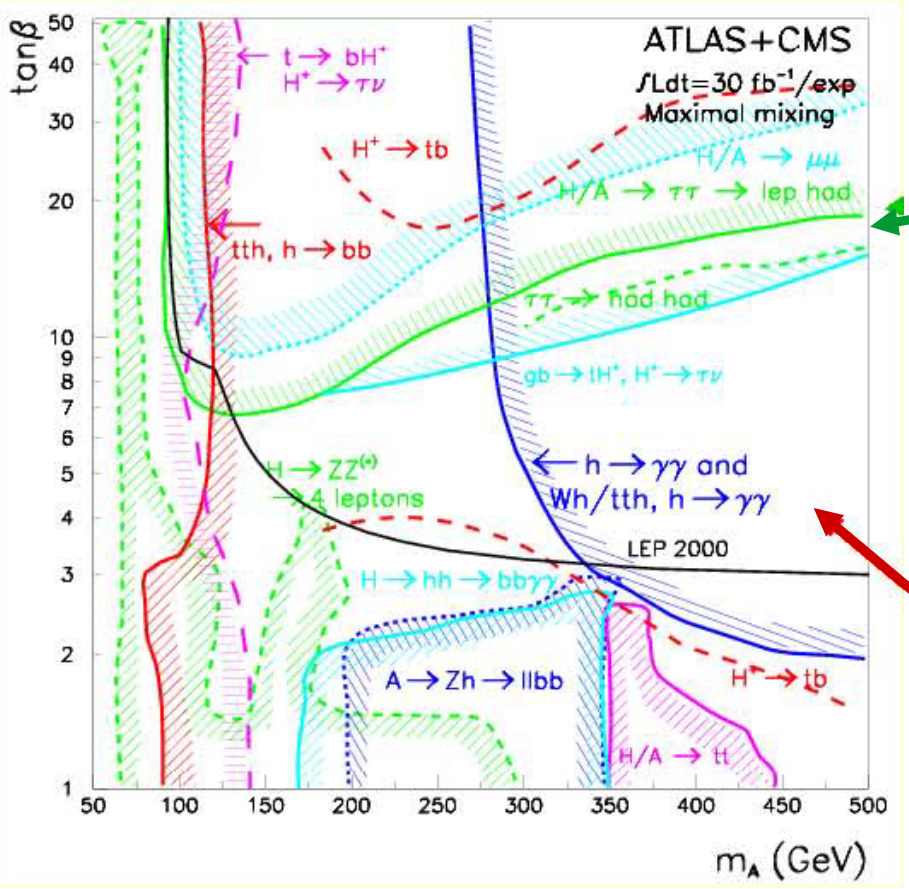
Mass will be measured with precision of 0.1% in mass range 130-450 GeV (gg, H->4l).

Angular discributions in in H->4l sensitive to spin and CP eigenvalue.

Relative couplings will be measured with precision of 20% at 300fb-1.

MSSM Higgs sector : h, H, A, $H^{\pm}$

(2001)



m_h < 135 GeV , $m_A \approx m_H \approx m_{H^{\pm}}$

A, H, H^+ cross-sections ~$\tan\beta^2$

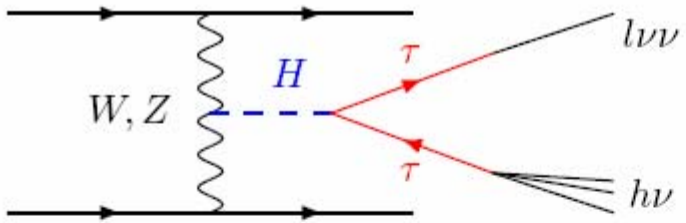
Best sentitivity from
A/H->ττ, H^+->τν
not easy the first year

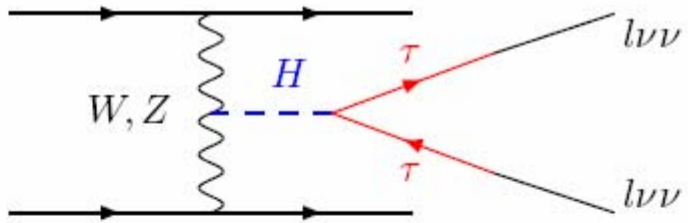
A/H->μμ experimentally easier
specially for the beginning

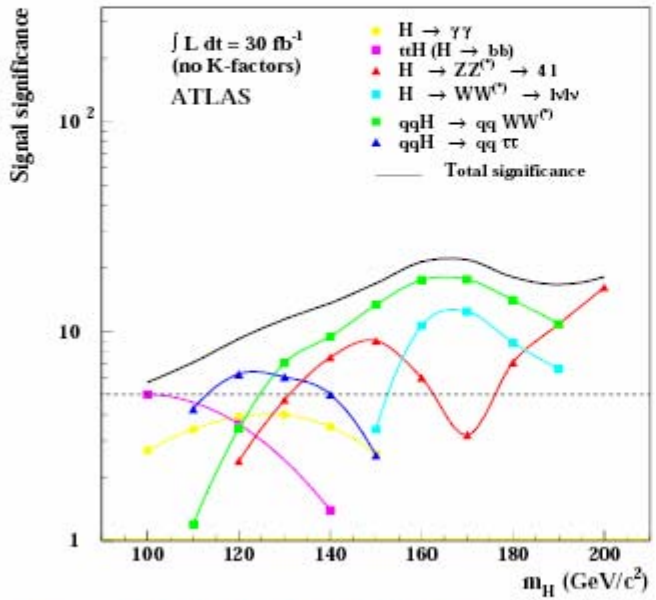
Here only SM-like observable
If SUSY particles neglected

BR(H,A → ττ) ~ 10%, BR($H^{\pm}$ → τν) ~ 100% below tb kinematical threshold

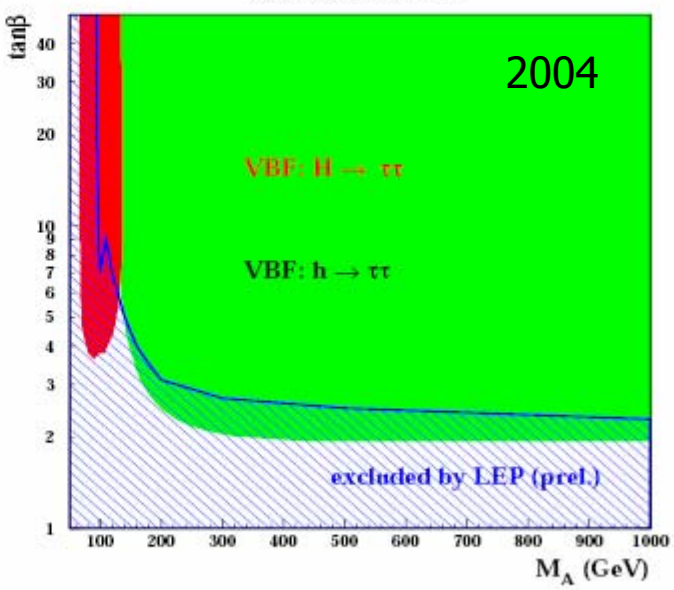
MSSM Higgs sector : h, H







Standard Model (Atlas Scientific Note)

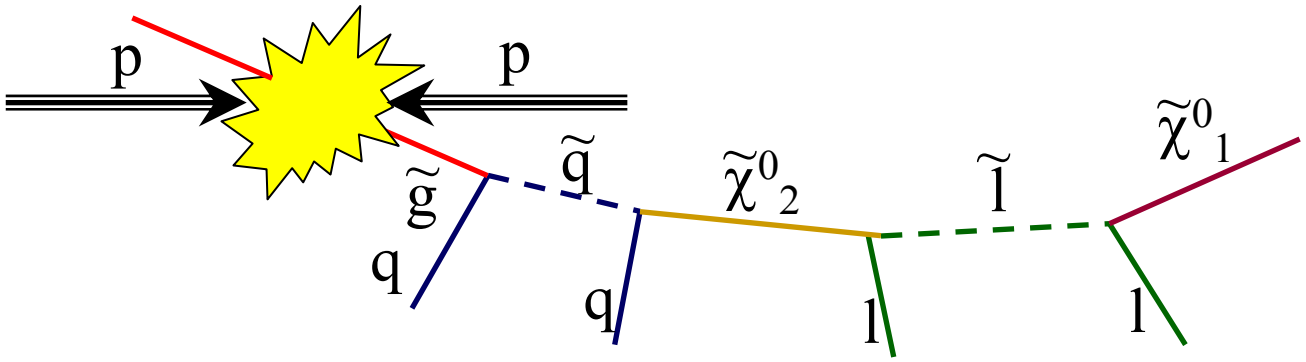


MSSM (M. Schumacher)

Most powerful channel near LEP limit and very important for MSSM.

SUSY Signatures at the LHC

A typical decay chain of supersymmetric particles in a proton-proton collision:



- ✓ Heavy strongly interacting sparticles (gluinos and squarks) produced in initial interaction
- ✓ Long decay chains and large mass differences between SUSY states; many high P_T objects are observed (lepton, jets, b-jets)
- ✓ If R-Parity is conserved cascade decays to stable undetected LSP (lightest SUSY particle; neutralino in mSUGRA); large E_T^{miss} signatures
- ✓ If the model is GMSB, LSP is gravitino. Additional signatures from NLSP (next-to-lightest SUSY particle) decays; for example photons $\tilde{\chi}_1^0 \to \gamma\tilde{G}$ and leptons from sleptons $\tilde{l} \to l\tilde{G}$
- ✓ If R-parity is not conserved LSP decays to 3-leptons, 2leptons+1jet, 3 jets; E_T^{miss} signature is lost

Taus in SUSY events (I)

SUSY CSC Note

✓ SUSY models generally violates e/μ/τ universality

✓Tau signatures important in much of the mSUGRA (minimal SuperGravity) parameter space, particularly at high tanβ (>10)

✓ Inclusive searches (SU3, SU6) with 1 lepton in final state

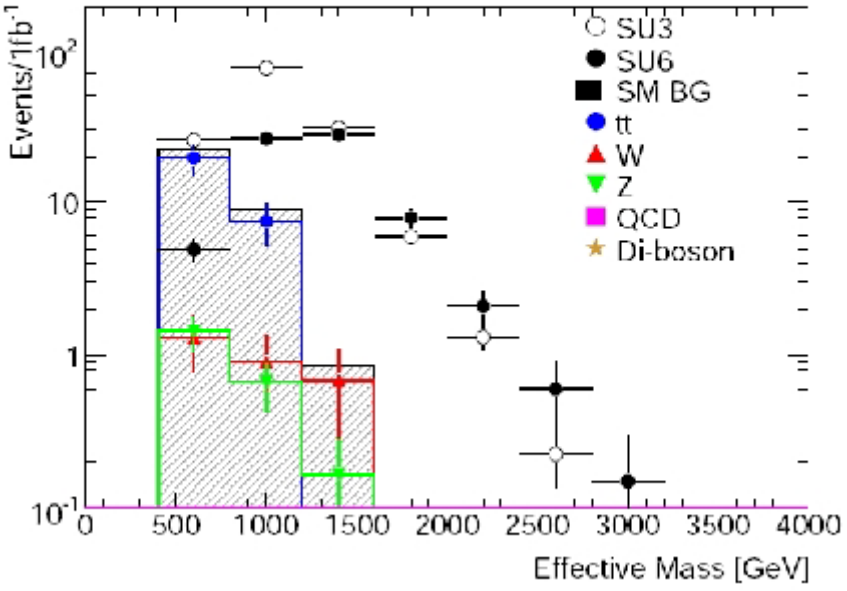
should be interesting in τ mode.

Branching ratio to taus in SU3, SU6

10xhigher than to e/μ.

Especially important for large tan β cases:

4 jets + ≥ 1 tau + missing E_T



Taus in SUSY events (II)

✓In mSUGRA R-parity conserved, all events contain 2 neutralinos escaping the detector -> one can measure kinematic endpoints in invariant mass distributions rather than mass peaks

✓ At some points in the parameter space (e.g. funnel) can only observe kinematic endpoints in τ invariant mass distributions,

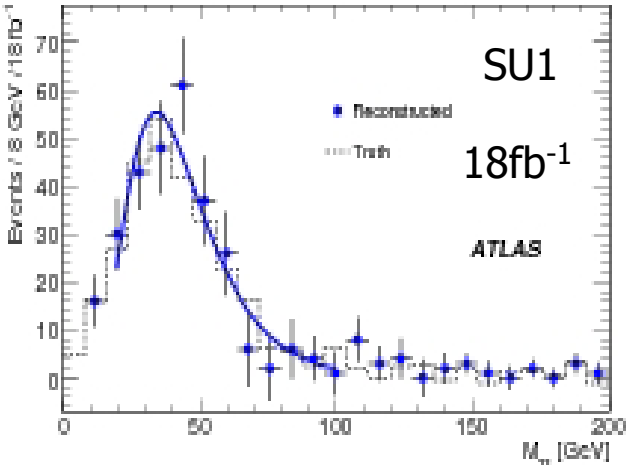
M_{max} = fn (masses involved SUSY particles)

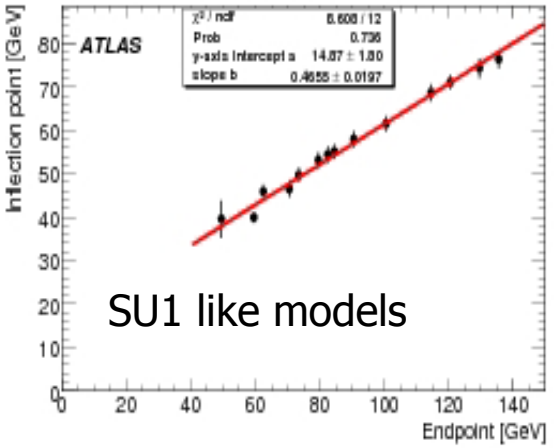
Only consider hadronic tau decays. No sharp edge because of ν, but end-point can still be measured. Shape different for diferent polarisation configuration, may dominate systematics

✓ In more exotic SUSY models stau lepton is LSP

✓ Can use tau polarization measurement to further constrain the underlying SUSY model. Tau is the only lepton which grant access to the polarisation information

SUSY CSC Note





Summary

→ Events with tau's will be observed with the first data of LHC, excellent possibility to understand detector performance.

→ Developed algorithm hopefully robust enough to be performant for large spectrum of analyses.

→ Identification of hadronicaly decaying tau leptons will be the key for New Physics discovery:

-> SM Higgs in VBV production, H->tau tau

-> MSSM Higgs, bbh/H/A , h/H/A -> tau tau

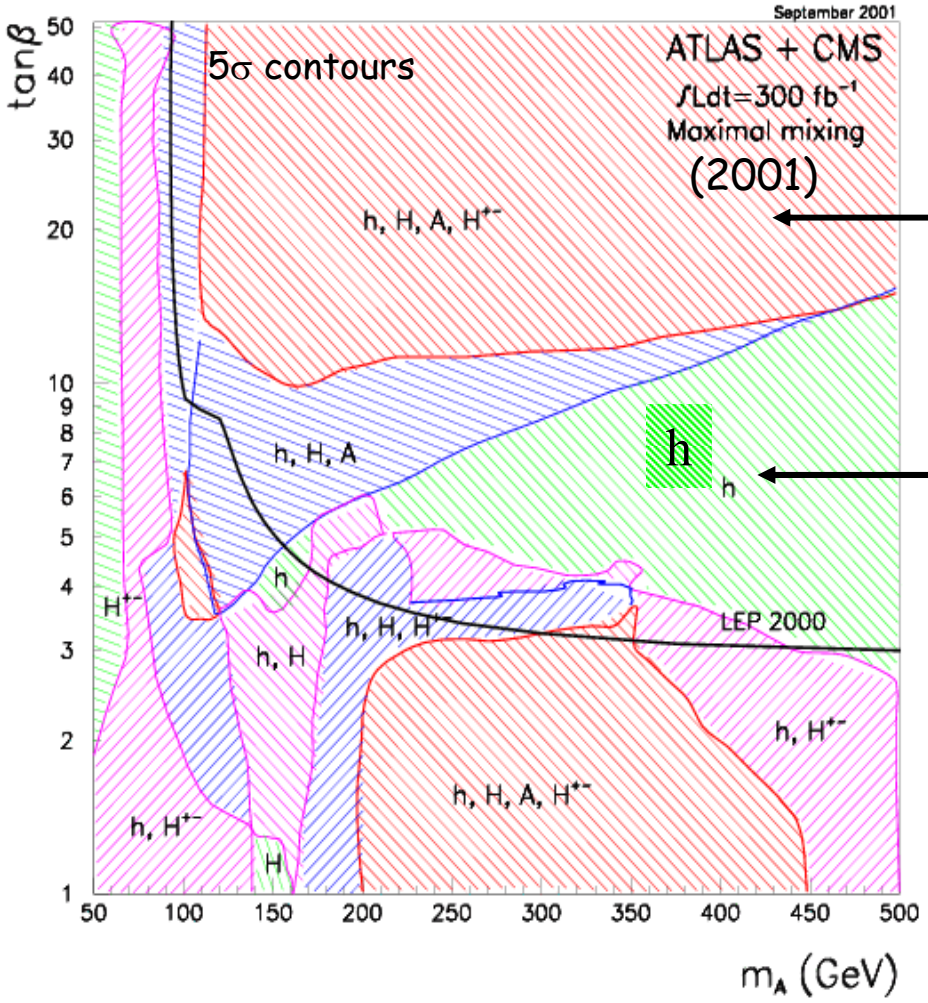
-> MSSM H+ in tt->H+b Wb, gb->bH+, H->tau nu

-> SUSY signatures with tau's in final states

-> extra dimentions(?)… new theories(?)…

→ Hopefully also probe for spin and/or parity related measurements

MSSM Higgs sector : h, H, A, $H^{\pm}$



$m_h < 135$ GeV , $m_A \approx m_H \approx m_{H^{\pm}}$

$H, A \rightarrow \mu\mu, \tau\tau$
$H^{\pm} \rightarrow \tau\nu$, tb

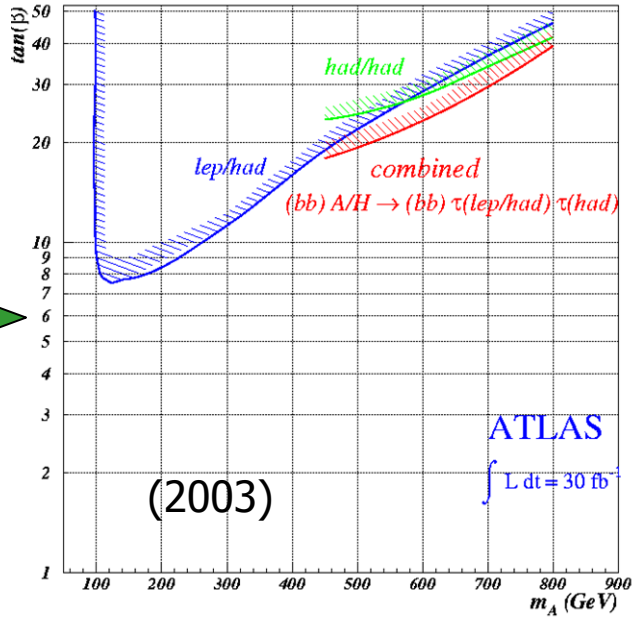
Here only h (SM - like) observable at LHC, unless A, H, $H^{\pm} \rightarrow$ SUSY
$\rightarrow$ LHC may miss part of the MSSM Higgs spectrum
Observation of full spectrum may require high-E ($\sqrt{s} \approx 2$ TeV) Lepton Collider

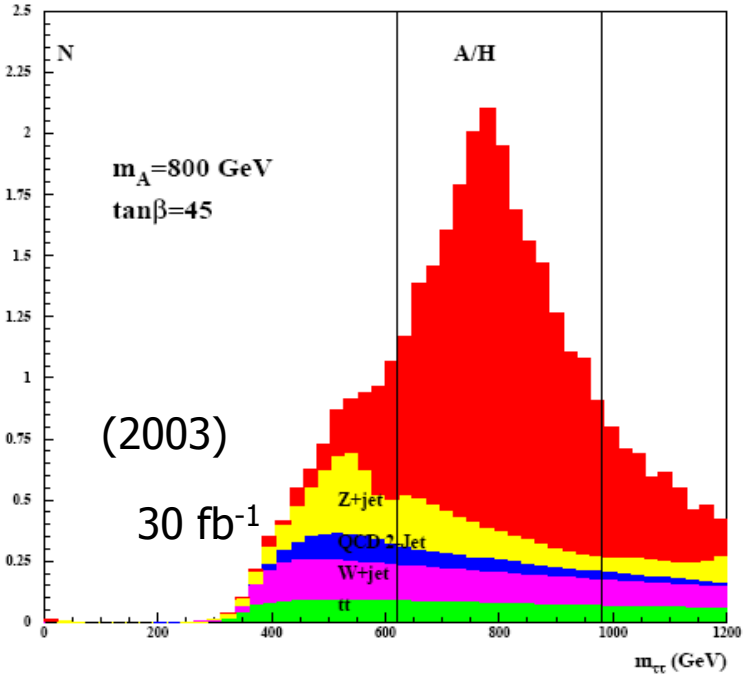
Assuming decays to SM particles only

MSSM Higgs sector : H, A

The tau decays provide the cleanest signature for the heavy Higgs discovery at high mass (and relatively high tanβ)

Investigated all the final states (ll, lh, hh). All of them contribute (at different M_A).





mass resolution: below 15% in had-had mode

Backgrounds:

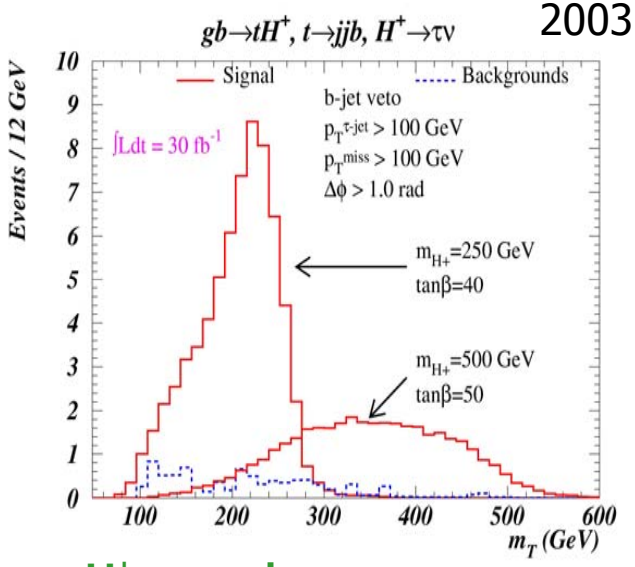
l-h: W+jets, Z+jets, tt, bb

h-h: W+jets, Z+jets, tt and QCD

the dominant bgd changes depending on the mA

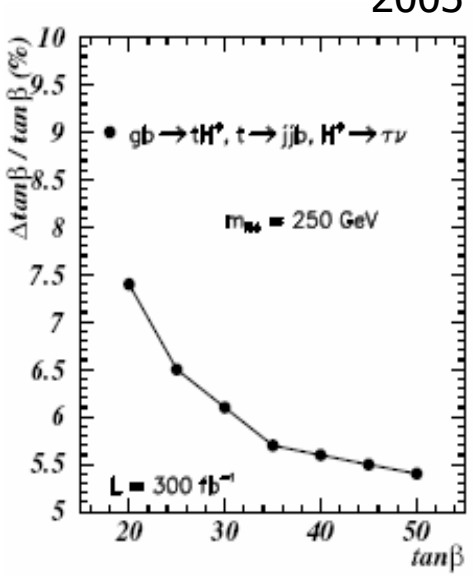
MSSM Higgs sector $H^{\pm} \to \tau\nu$

2003



$H^+ \to \tau\nu$ decay

2003



→ only transverse mass can be reconstructed

→ almost bgd free channel

→100% tau polarisation enhances signal observability above bgd from W events

$\Rightarrow$ precision improves as the rate of $H^{\pm} \to \tau^{\pm}\nu_{\tau}$ increases with $\tan\beta$

By measuring $\sigma \times BR$ in $H^{\pm} \to \tau^{\pm}\nu_{\tau}$.