Tau leptons as a probe for New Physics at LHC

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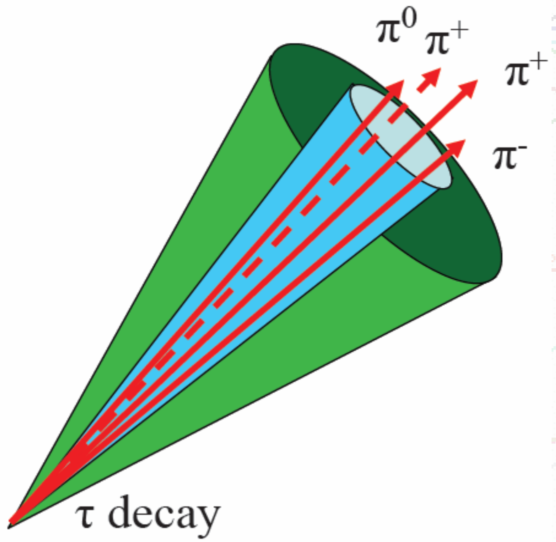
(On behalf of the ATLAS collaboration)



1. Motivation
2. ATLAS experiment
3. Early physics: $Z \to \tau\tau$, $W \to \tau\nu$
4. Taus in searches for:
   - -SM and MSSM Higgs
   - -SUSY
   - -XD
5. Conclusions

Why tau leptons are an important signature at LHC experiments

Taus

- massive particles, EW 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 .....

- several decay modes possible
- jet-like signature
- difficult because of huge QCD bkg

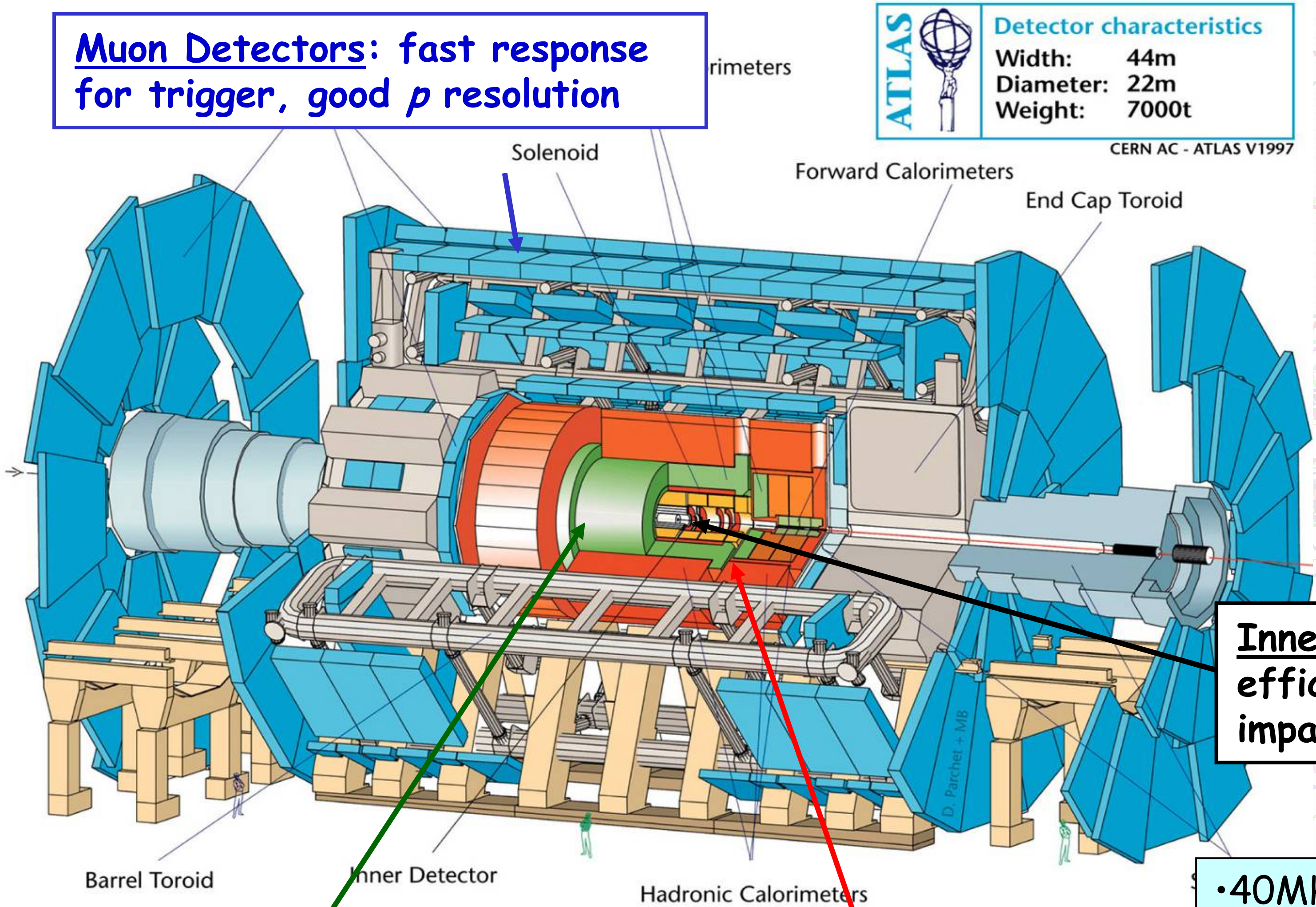
Make it quite difficult for observing in the pp collision experimental environment

At the LHC

- Large statistics already in the first data: $W \to \tau\nu$, $Z \to \tau\tau$
  - detector calibration, bkg normalisation, algorithms tuning, control channels
- Signature for Higgs boson(s) discovery
- Signature for SUSY discovery
- Polarisation sensitive to SUSY parameters
- Signature for "extra dimensions"

ATLAS (A Toroidal LHC ApparatuS)

Muon Detectors: fast response for trigger, good *p* resolution



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

Inner Detector: high efficiency tracking, good impact parameter resolution

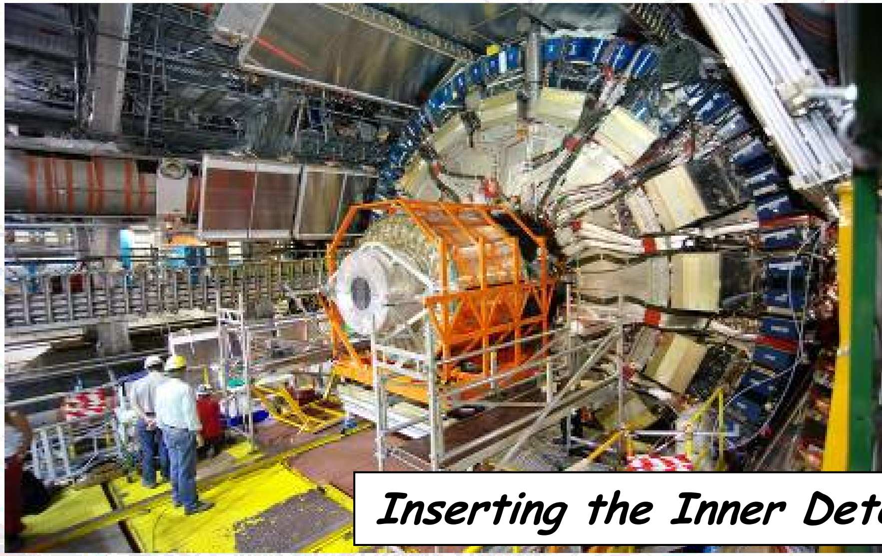
Electromagnetic Calorimeters: excellent e/γ identification, E and angular resolution, response uniformity

Hadron Calorimeters: Good jet and E_T miss performance

- 40MHz beam crossing
- Readout: 160M channels (3000 km cables)
- Raw data = 320Mbyte/sec (1TB/hour)

Machine start up scenario

LHC Magnets in place



Inserting the Inner Detector

~ March 2007 - last LHC magnet installed
~ August 2007 - machine and experiments closed
~ November 2007 - first collisions ($\sqrt{s}$ = 900 GeV, $L \sim 10^{29}$ $cm^{-2}s^{-1}$)
Commissioning run at injection energy until end 2007, then shutdown (3 months ?)
~ June 2008 - first collisions at $\sqrt{s}$=14 TeV (followed by first physics run), $L \sim 10^{32}$ $cm^{-2}s^{-1}$

Goal : deliver integrated luminosity of few fb^{-1} by end 2008 (with 50% efficiency of data taking)

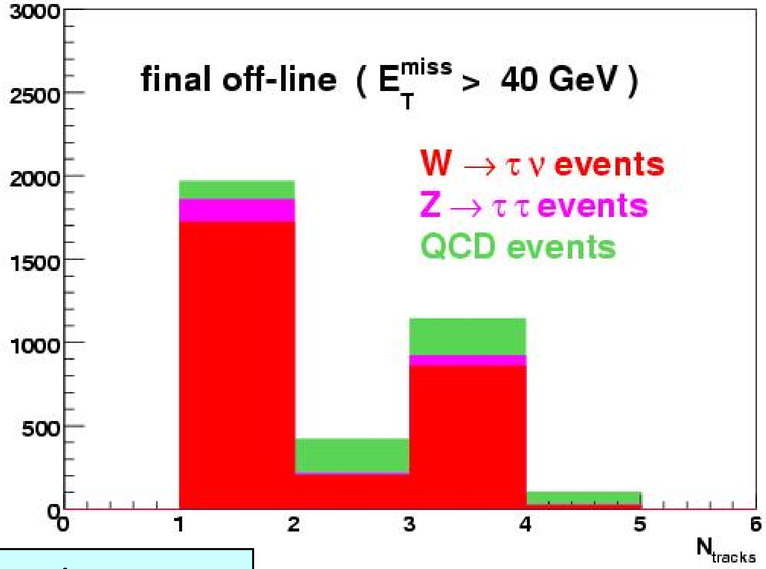
First data: $W \to \tau\nu$ events

Prospects for taus with 10-100 pb^{-1} at L~ 10^{31-32} over the first weeks of running: extract signal from most abundant sources of τ leptons as early as possible → requires a performant τ and E_T^{miss} trigger from the very start

Expected rates for 100 pb^{-1}	$W \to \tau\nu$, $\tau \to$hadron	$W \to e\nu$	$Z \to \tau\tau$, $1\tau \to$hadron
σ.B (pb)	11200	17300	1500
τ30i + xE35	~ 15 000	~ 250 000	~ 1300
τ20i + xE25	~ 60 000	~ 560 000	~ 3500

Assuming eff ~ 80% for τ trigger, ~ 50% for τ reco/id

Events exp in 100pb^{-1} vs N Tau tracks



preliminary

It will be "counting" experiment: evidence in the N_{Track} spectrum. Signal x 10 and bgd x 100 with respect to 2 TeV collisions.

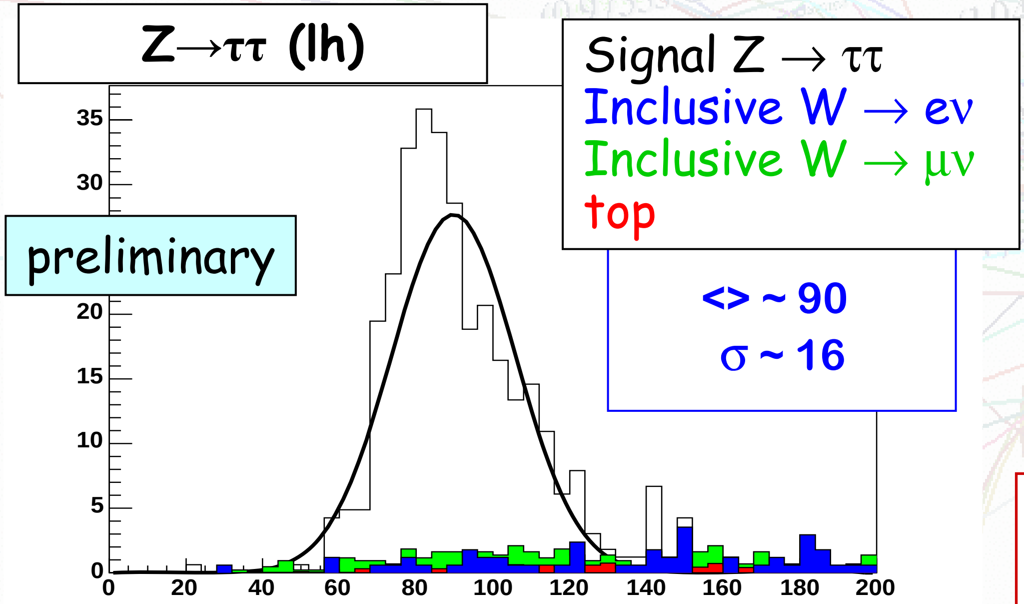
Profit from low-luminosity operation to trigger at lowest possible thresholds (E_T τ15i), raise E_T^{miss} cut as luminosity goes up.

Require QCD jet rejection of 10^3- 10^4 at 50% efficiency and p_T ~ 20 GeV

First data: $Z \to \tau\tau$ events

Observation of $Z \to \tau\tau$ events will be "easier", but 10x less events produced

- → trigger on lepton (electron, muon)
- → use same-sign (lep,tau) events to control bgd for the signal events, which are opposite-sign
- → evidence in Ntrack spectrum and Mvis (lep-had) system
- → reconstruct invariant mass of the $\tau\tau$ system (collinear approximation)



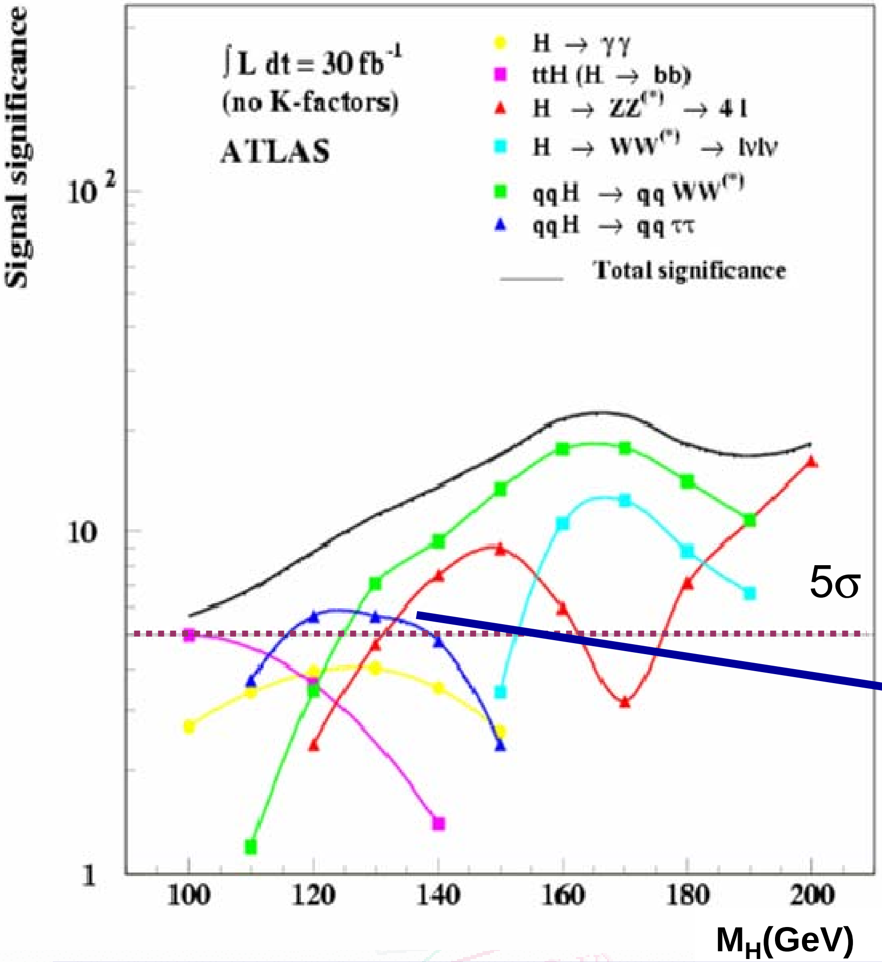
Expect in $100pb^{-1}$ about 300 evt observed (e,μ) with 20% bgd possibility to loosen cuts? bb bkg still to be included/checked

With 10^{31} luminosity, lower threshold on lepton and tau to 15 GeV. Tighten selection to improve resolution of invariant mass.

Sensitivity of the measured Z-mass to the absolute energy scale on reconstructed missing energy: ± 10% variation on E_T^{miss} results in shift of about 3% of the measured mass

Prospects for discovery of Standard Model Higgs boson

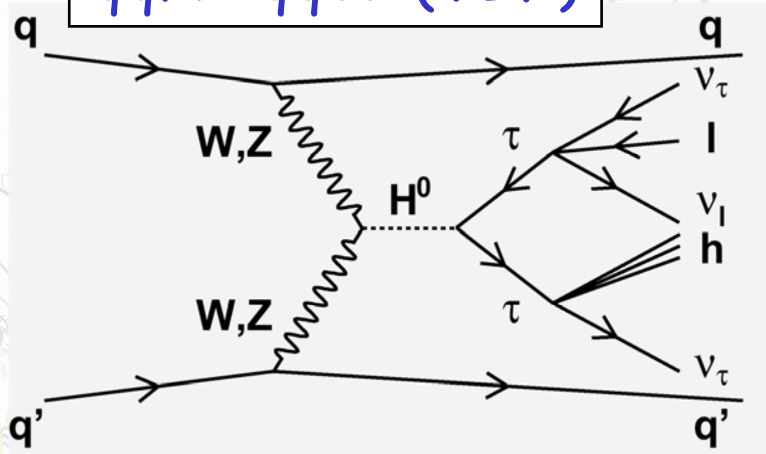
Standard Model Higgs boson
(first few years of operation)



σ : 300-64 fb for M_H=120-150 GeV

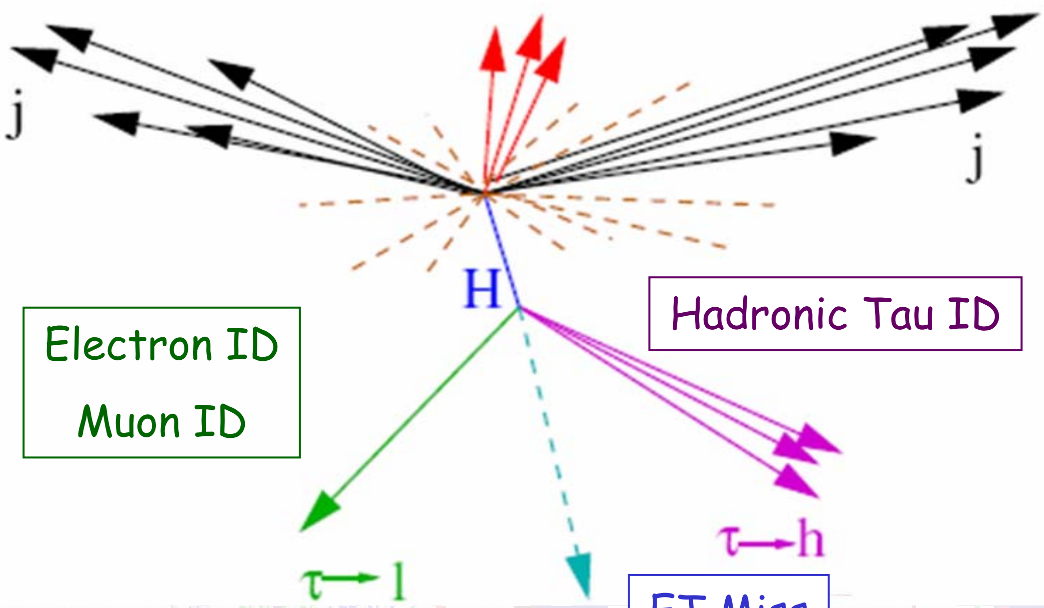
BR($H \to \tau\tau$) ~ few %

qqH->qqττ (VBF)



- VBF ~20% of tot σ for $m_H < 2m_Z$ but event characteristics can be exploited to suppress large bkg
- about 5 σ sensitivity for Higgs mass 110-140 GeV for 30fb^{-1}
- combined results for l-l and l-h modes
- better performance for l-h (mass resolution, efficiencies)
- gives access also to the measurement of the Higgs couplings: Hττ/HWW

Vector Boson Fusion: $H\to\tau\tau$



Electron ID

Muon ID

Hadronic Tau ID

ET Miss

Central Jet Veto:

-Sensible to PileUp

Forward Tagging Jets:

-Difficult Forward Region

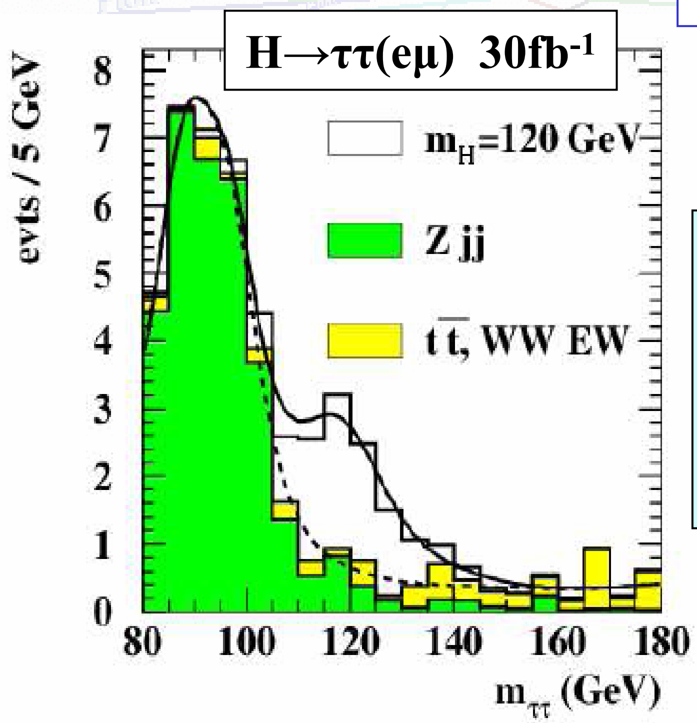
-Jet Calibration

E_T Miss:

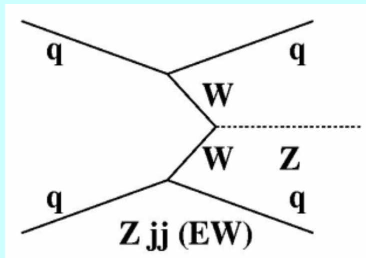
-Central to Tau Reconstruction

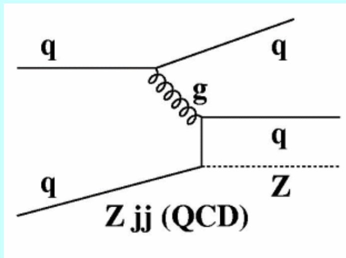
-Reconstructed Higgs Mass

-Dominant Experimental Issue



Dominant backgrounds:
Zjj, WWjj EW&QCD
tt production

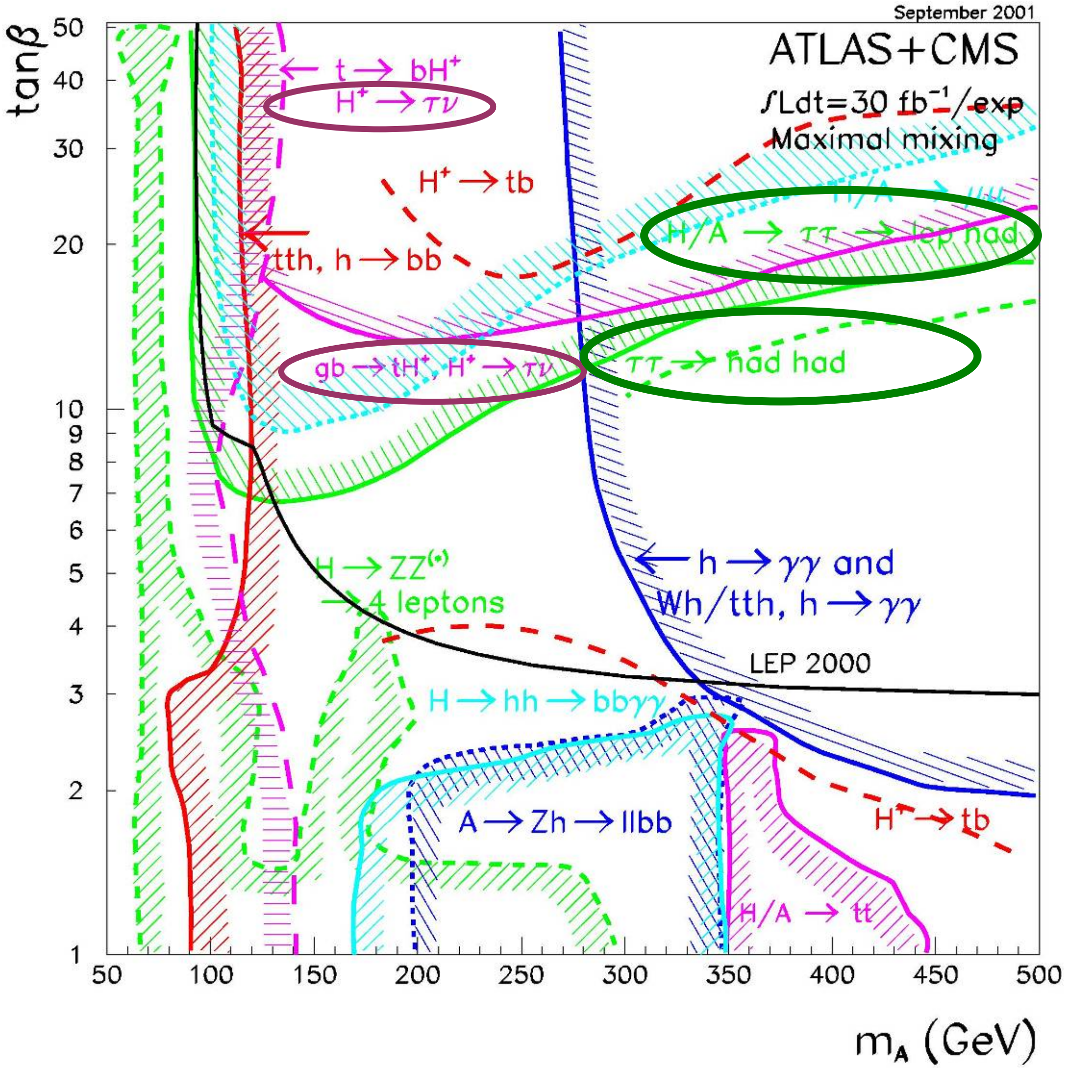




σ_M ~ 11-12 GeV

Prospects for discovery of MSSM Higgs boson

Minimal Supersymmetric Standard Model



Neutral H and A

- prod: gg->H/A and gg->bbH/A (for high tanβ)
- BR(H/A->ττ) ~ 10%
- BR(H/A->bb) ~ 90%

Charged Higgs

-prod:

$m_H < m_t$: tt->Wb b H^{+-}

mt>mt: gb→t H^{+-}, gg(qq)→tb H^{+-}, qq→H^{+-}

-decay modes: H^{+-}->τν, H^{+-}-> tb for $m_H > m_t$

-BR($H^\pm \to \tau\nu$) ~ 100% below tb kinematical threshold

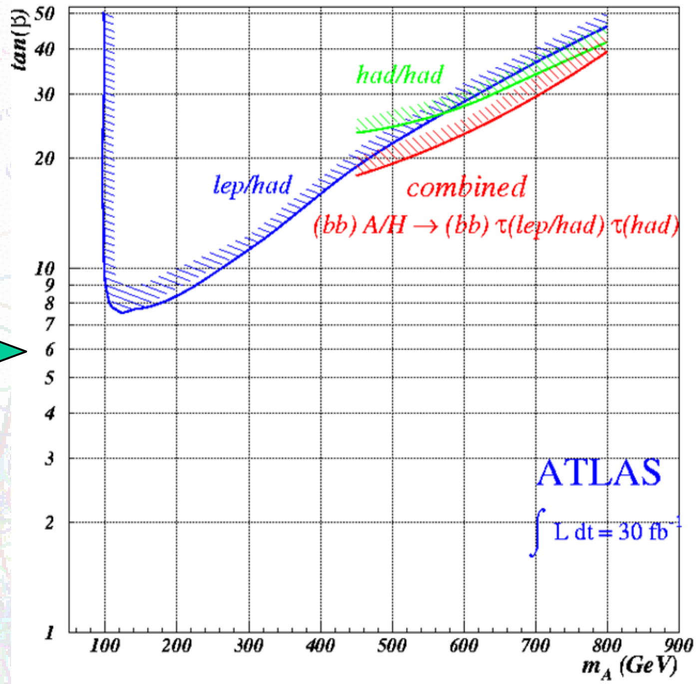
-> discovery modes for large and moderate tanβ
-> measurement of tanβ

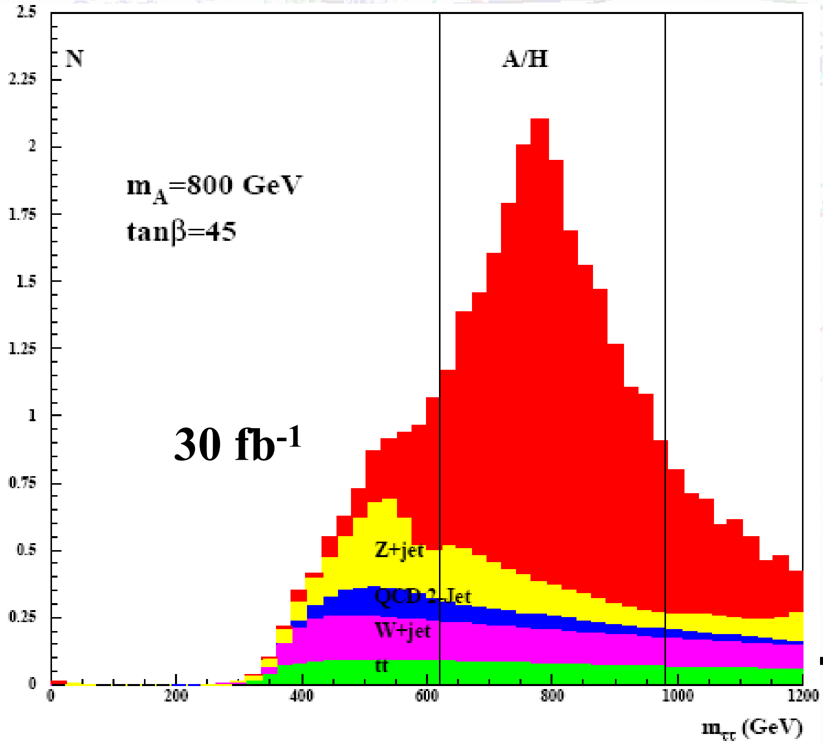
Closer look at neutral H/A → ττ

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).

The associated production (bbA/H) provides additional rejection against the main backgrounds: Z+jet, W+jet, QCD (h-h only)





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

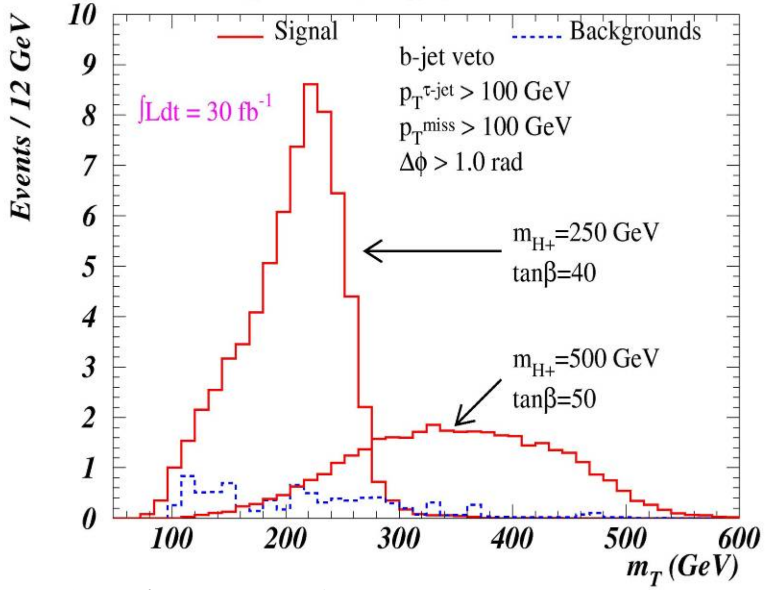
the dominant bgd changes depending on the mA

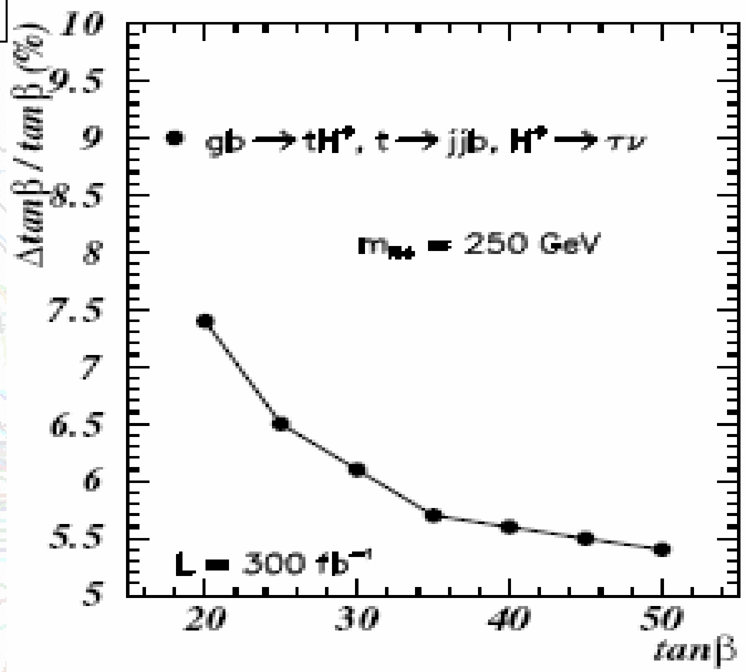
Closer look at charged $H^{\pm} \to \tau\nu$

Mass reconstruction

gb→tH⁺
t→ jjb, H⁺ →τν

tanβ measurement





→ final state: hadronic tau, 3 jets, E_T^{miss}

→ only transverse mass can be reconstructed (as ν in final state) but m_H can be obtained with likelihood method

→ almost bgd free channel (tt,Wt)

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

→ determination of tanβ by measuring of the rate in this channel

$\sigma(gb \to tH^{+-}) \times BR(H^{+-} \to \tau\nu) \sim \tan^2\beta$

→ precision improves as the rate of $H^{+-} \to \tau\nu$ improves with tanβ

If large "extra dimensions" exist .....?

- In 2-Higgs Doublet Model of type II, 2HDM-II (MSSM)

$H^- \to \tau_R^- \bar{\nu}$, H^- to τ_L^- suppressed

- In Large Extra Dimensions $H^- \to \tau_L^- \psi$ can be enhanced by large number of Kaluza-Klein states. Thus:

$$H^- \to \tau_R^- \bar{\nu} + \tau_L^- \psi$$

Bulk neutrino

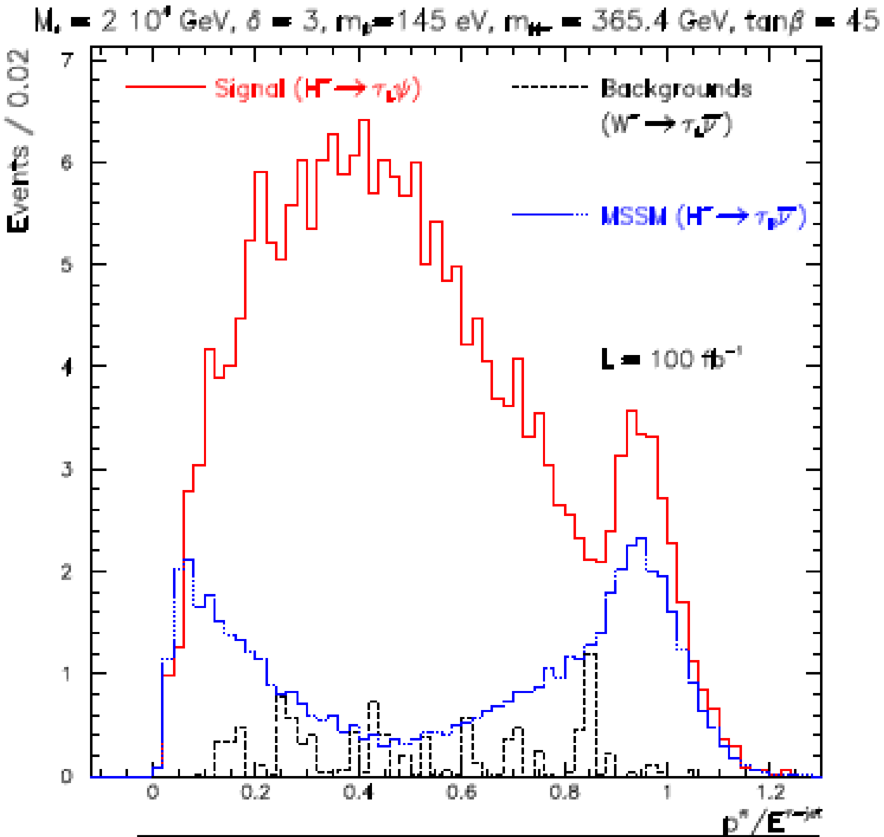
- Measurement of the polarisation asymmetry can be used (A~func (model parameters))

$$A = \frac{\Gamma(H^- \to \tau_L^- \psi) - \Gamma(H^- \to \tau_R^- \bar{\nu})}{\Gamma(H^- \to \tau_L^- \psi) + \Gamma(H^- \to \tau_R^- \bar{\nu})}$$

-Observation of signal in m_T distribution is not sufficient to distinguish between 2HDM and L.E.D.

-The reconstruction of p_π/E_{jet} should determine the scenario: 2HDM or L.E.D.

- Further measurement of the asymmetry may provide a distinctive signature for L.E.D.



fraction of E carried by the charged track in 1P decays

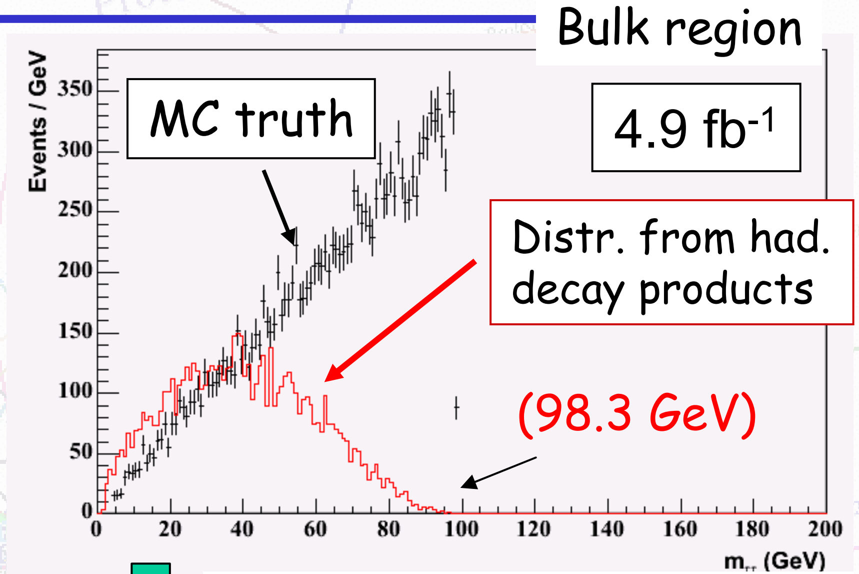
Interesting prospects in SUSY events

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

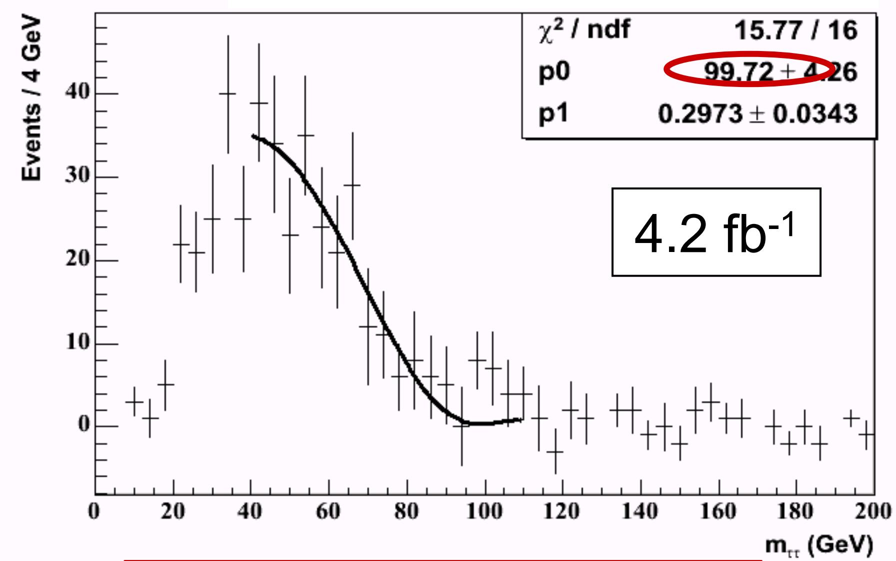
$$\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_1^{\pm}\tau^{\mp} \rightarrow \tilde{\chi}_1^0\tau^{\pm}\tau^{\mp}$$

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.
- Can use tau polarization measurement to further constrain the underlying SUSY model.



Can fit distorted distribution, and apply this MC fit to the reconstructed distribution



$$m_{vis}(\tau^{\pm}\tau^{\mp}) - m_{vis}(\tau^{\pm}\tau^{\pm})$$

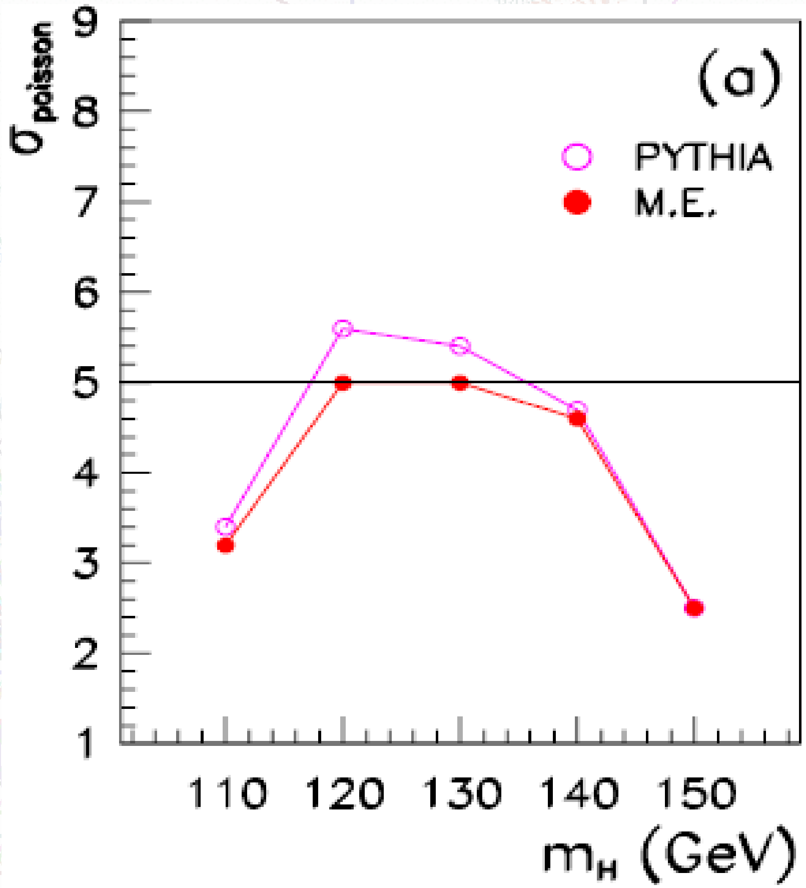
Conclusions

- Events with tau's will be observed with the first data of LHC, excellent possibility to understand detector performance.
- Identification of tau leptons will be the key for New Physics discovery:
  - SM Higgs in VBF production, $H \to \tau\tau$
  - MSSM Higgs, bbH/A , $H/A \to \tau\tau$
  - MSSM H^+ in $tt \to H^+b$ Wb, $gb \to bH+$, $H \to \tau\nu$
  - SUSY signatures with tau's in final states
  - extra dimentions(?)... new theories(?)...
- Polarisation measurements should be possible
- Given large dynamic range of required observability in hadronic channel mandatory development of several dedicated algorithms for reconstruction and identification (see Fabien Tarrade talk).

Backup Slides

Vector Boson Fusion: H→ττ

A number of systematic effects need to be considered.
-uncertainties arise in the simulation of the level of the backgrounds. QCD Zjj events produced with M.E. calculations yield a higher contribution, by at least a factor of two relative to PYTHIA, to the final number of background events.
-uncertainties in detector performance, such as tau-jet and lepton reconstruction efficiencies and rejection factors
-other systematic errors relating to calibration, pileup effects, luminosity measurement,



With M.E. QCD Z+jet bkg estimation
30 fb-1

$H/A \rightarrow \tau\tau$ Systematic uncertainties

• **Detector resolution:** A worse resolution in the reconstruction of ETmiss results in a broader distribution of the reconstructed mass. In order to estimate this effect, the mass window has been increased by 20%. The signal acceptance has been kept at the value of the standard analysis.

• **Identification of the τ and b-jets:** An efficiency of the tau-ID of 55% has been used. This values has been decrease to 40%, while the jet rejection values remain unchanged. The b-tagging efficiency has been lowered from *eff* = 0.7 to 0.6, while keeping the same rejection factors.

• **Jet energy scale:** The absolute jet energy scale at the ATLAS are estimated to be known with 3% accuracy. Therefore, all jet energies in the study have been raised by 3% to estimate the effect of this uncertainty, which alters the acceptance due to the cuts of the transverse energy of jets used in the event selection.

	$m_{A/H}$	$\tan\beta$	Signal	Background	Significance
Standard analysis	600	30	20.4	7.4	5.8 σ
	800	45	19.6	6.8	5.8 σ
Detector resolution	600	30	20.4	9.4	5.2 σ
	800	45	19.6	8.3	5.3 σ
τ identification	600	30	14.9	7.5	4.3 σ
and b-tagging	800	45	13.8	5.7	4.4 σ
jet energy scale	600	30	18.6	8.6	5.0 σ
	800	45	16.7	7.3	4.8 σ

Table 10: Study of the influence of systematic uncertainties of the significance of the channel $(b\bar{b})A/H \rightarrow (b\bar{b})\,\tau\,(had)\,\tau\,(had)$.

Closer look at charged $H^{\pm} \rightarrow \tau\nu$

Table 1: The statistical precision on the mass determination in the $H^{\pm} \rightarrow \tau\nu$ channel. The reference masses are listed in the first column. The reconstructed masses $< m >$ (GeV) and the corresponding precision δm (GeV) are calculated for 100 and 300 fb^{-1}. We take $\tan\beta = 45$. The statistical precision deteriorates as the Higgs mass increases because of the reduction in rate.

$m_{H^{\pm}}$ (GeV)	$\mathcal{L} = 100\ fb^{-1}$		$\mathcal{L} = 300\ fb^{-1}$	
m_0	$< m >$	δm	$< m >$	δm
225.9	226.4	3.0	226.4	1.7
271.1	271.0	3.4	271.1	2.0
317.8	318.3	5.2	318.3	3.0
365.4	365.5	7.8	365.7	4.6
413.5	413.6	7.7	413.8	4.5
462.1	462.3	10.2	462.6	6.0
510.9	511.5	13.0	511.9	7.4

Table 2: The systematic effects on the mass determination in the $H^{\pm} \rightarrow \tau\nu$ channel are small. Columns 2 and 3 show the statistical uncertainties for an integrated luminosity of 300 fb^{-1}. Columns 4 and 5 include the systematic uncertainties. The total uncertainties are dominated by the statistical errors.

$m_{H^{\pm}}$ (GeV)	No systematics		With systematics	
	$< m >$	δm	$< m >$	δm
225.9	226.4	1.7	225.9	1.7
271.1	271.1	2.0	270.9	2.3
317.8	318.3	3.0	319.9	3.5
365.4	365.7	4.6	365.2	4.7
413.5	413.8	4.5	414.9	4.7
462.1	462.6	6.0	460.8	6.3
510.9	511.9	7.4	511.7	9.2

Systematic uncertainties:
- the shape of the background
- the background rate (known to 5%)
- the energy scale -1% for jets and 0.1% for photons, electrons and muons.

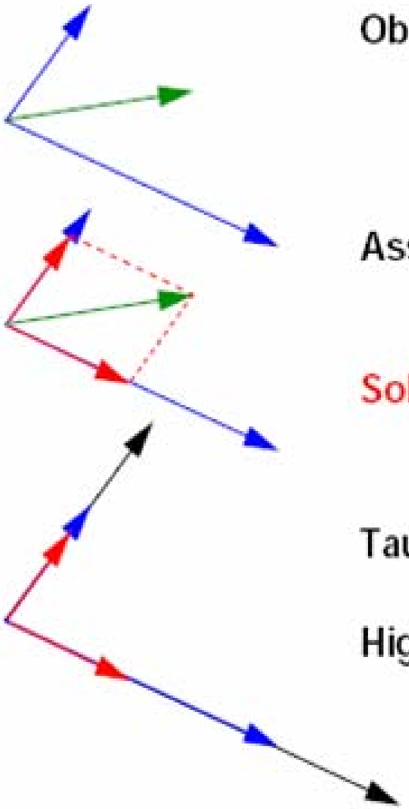
Closer look at charged $H^{\pm} \to \tau\nu$

Table 4: The overall precisions on the rate determination in the $H^{\pm} \to \tau\nu$ channel for $\mathcal{L} = 30$, 100 and 300 fb^{-1}. The total number of background events is $B = 6.7$ for 30 fb^{-1} [10]. The number of signal events listed in the second column correspond to an integrated luminosity of 30 fb^{-1} [10].

$(m_{H^{\pm}}$ [GeV], $\tan\beta)$	$S \equiv$ Signal events	$\Delta(\sigma \times BR)/(\sigma \times BR)$ (%)		
	30 fb^{-1}	30 fb^{-1}	100 fb^{-1}	300 fb^{-1}
200, 30	46.3	18.6	14.2	11.6
250, 40	60.3	16.9	13.3	11.2
300, 45	70.5	16.0	12.8	11.0
350, 25	18.8	28.7	19.9	14.1
400, 35	30.6	22.3	16.2	12.4
450, 60	66.9	16.3	12.9	11.1
500, 50	36.2	20.7	15.3	12.0

The main systematic error would come from the knowledge of the luminosity (+-10%.)

Mass can be reconstructed in collinear approximation



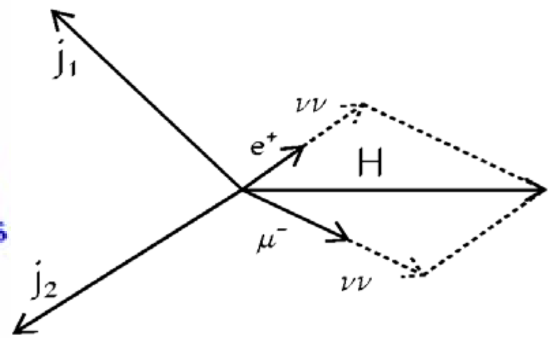
Observe
missing transverse momentum
and visible Tau-decay products

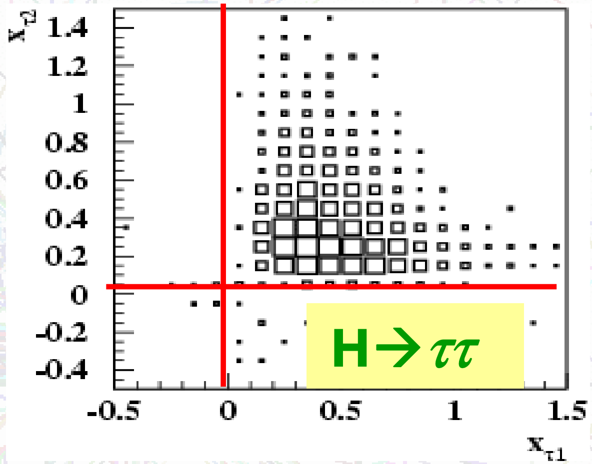
Assume Tau decay products
collinear with original Tau

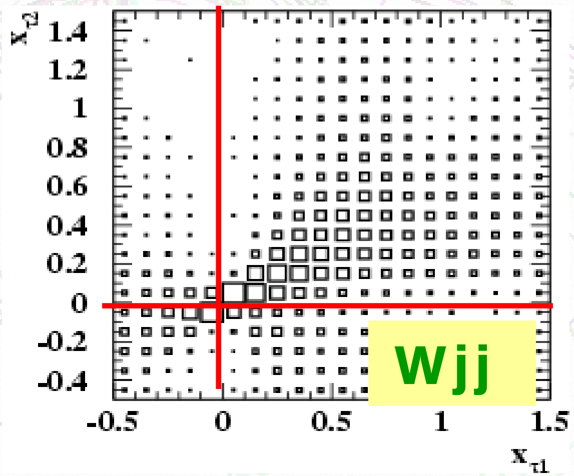
Solve 2 linear equations
for the neutrinos

Taus can be reconstructed

Higgs can be reconstructed







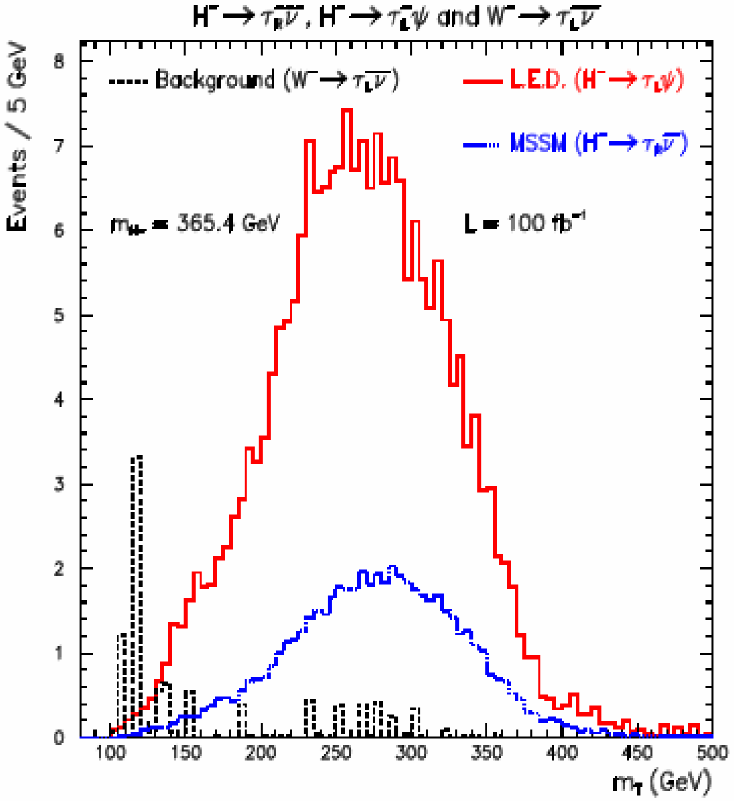
$$x_{\tau h} = \frac{h_x l_y - h_y l_x}{h_x l_y + \not{p}_x l_y - h_y l_x - \not{p}_y l_x}$$

$$x_{\tau l} = \frac{h_x l_y - h_y l_x}{h_x l_y - \not{p}_x h_y - h_y l_x + \not{p}_y h_x}$$

x_τ = momentum fraction carried by tau decay products

Reconstruction of the transverse mass

$$m_T = \sqrt{2 p_T^{\tau} \not{p}_T \left[1 - \cos(\Delta\phi)\right]}$$



⇒ Observation of signal in m_T distribution is not sufficient to distinguish between 2HDM (MSSM) and L.E.D.

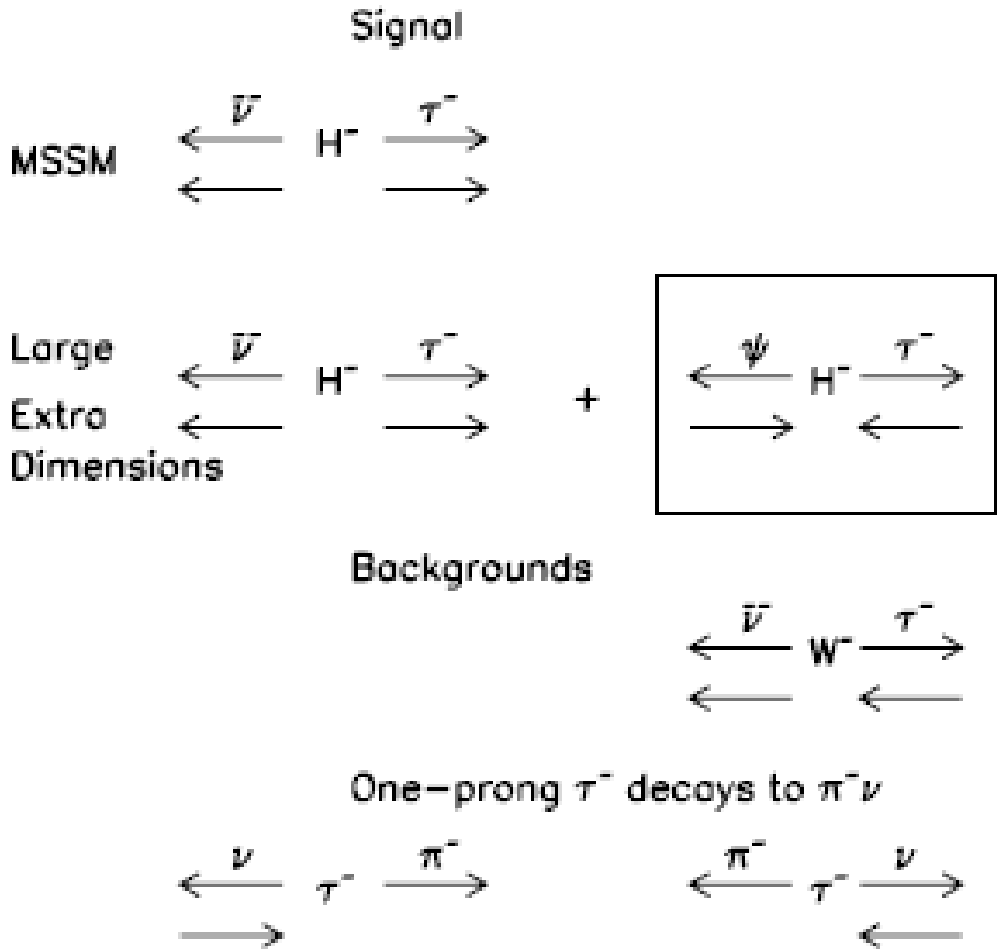
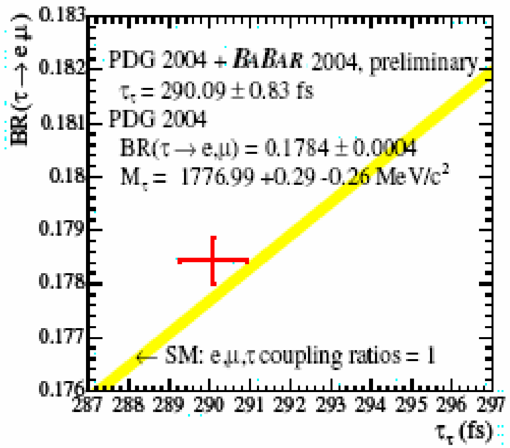


FIG. 6: Polarization of the decay τ from $H^{\pm}$ in MSSM and in models with a singlet neutrino in large extra dimensions. In the latter case, both left and right handed τ's can be produced with some polarization asymmetry. In the backgrounds, the τ comes from the decay of the $W^{\pm}$. The signal to be studied is in the box — the polarization of the decay τ in this signal is the same as in the background. Thus, τ polarization effects would not help in suppressing the backgrounds but they may help distinguish between the 2HDM and other models.

Last but not least: life-time measurement

SLAC-PUB -11317



measurement compatible with universality assumptions

The tau lepton lifetime:

$289.4 \pm 0.91(\text{stat}) \pm 0.90\ (\text{syst})$ fs
(preliminary) BABAR, SLAC-PUB-11317

$290.9 \pm 1.4\ (\text{stat}) \pm 1.0\ (\text{syst})$ fs
DELPHI, Nucl. Phys. Proc. Suppl. 144 (2005) 105

With ATLAS, use $Z\to\tau\tau$ or $W\to\tau\nu$ events, three-prong decays,

D. Cavalli & B. Osculati, ATL-PHYS-2000-014

$Z\to\tau\tau$ events: → statistical error of 1.8fs,
not competitive with other measurements

$W\to\tau\nu$ events: → statistical error of 0.25-0.35 fs,
competitive with measurements at e^+e^- colliders
→ expect 780 000 hadronic tau-decay events for $30fb^{-1}$
→ not proven yet that systematic error can be kept under control

$\tilde{\tau}_1^{\pm}$ NLSP in large part of MSSM parameter space

Decay chains often end with:

$$\tilde{\tau}_1^{\pm} \to \tau^{\pm} \tilde{Z}_1$$

$$\hookrightarrow \pi^{\pm}\nu(12.5\%),\ \rho^{\pm}\nu(26\%),\ a_1^{\pm}\nu(7.5\%)$$

- Hadronic decays: sensitive to tau polarization
- 1-prong decays: good tau identification

Tau polarization depends on composition of LSP

LSP composition dependence of tau polarization:

Polarization $P_\tau = \frac{\left(a_{11}^R\right)^2 - \left(a_{11}^L\right)^2}{\left(a_{11}^R\right)^2 + \left(a_{11}^L\right)^2},$

with
$$a_{11}^R = -\frac{2g}{\sqrt{2}} N_{11} \tan\theta_W \sin\theta_\tau - \frac{g m_\tau}{\sqrt{2} m_W \cos\beta} N_{13} \cos\theta_\tau,$$
$$a_{11}^L = \frac{g}{\sqrt{2}} \left[N_{12} + N_{11} \tan\theta_W\right] \cos\theta_\tau - \frac{g m_\tau}{\sqrt{2} m_W \cos\beta} N_{13} \sin\theta_\tau,$$

LSP composition $\tilde{Z}_1 = N_{11}\tilde{B} + N_{12}\tilde{W} + N_{13}\tilde{H}_1 + N_{14}\tilde{H}_2,$

$\tilde{\tau}_1^{\pm}$ composition $\tilde{\tau}_1 = \tilde{\tau}_R \sin\theta_\tau + \tau_L \cos\theta_\tau$

- Universal SUGRA models:
$$P_\tau \simeq +1$$
- For most non-universal SUGRA models:
$$P_\tau \simeq \cos^2\theta_\tau - \sin^2\theta_\tau$$
- AMSB models:
$$P_\tau \simeq -1$$
- For many GMSB models ($\tilde{\tau}_1 \to \tau\tilde{G}$ decay):
$$P_\tau = \sin^2\theta_\tau - \cos^2\theta_\tau$$

Sugra models

- Reminder:
  - Minimal Sugra (mSUGRA) has 4 parameters + a sign:
    - m_0 : common scalar mass at GUT scale
    - $m_{1/2}$: common gaugino mass at GUT scale
    - A: common trilinear Higgs sfermion-sfermion coupling at GUT scale
    - tg β: ratio of the Higgs vacuum expectation values
    - sgn(μ): μ being the SUSY conserving Higgsino mass

mSUGRA: selected points

- DC1 bulk region point (new underlying event in generation)
  - m_0 =100 GeV, $m_{1/2}$ = 300 GeV, A_0 = -300 GeV, $\tan\beta$ = 6, sgn(μ) = +
  - LSP is mostly bino, light l_R enhance annihilation. 'Bread and butter' region for the LHC experiments
  - llq distributions, tau-tau measurements, third generation squarks (both tau identification and B tagging improved)
- Coannihilation point
  - m_0 =70 GeV, $m_{1/2}$ = 350 GeV, A_0 = 0 GeV, $\tan\beta$ = 10, sgn(μ) = +
  - LSP is pure bino. LSP/sparticle coannihilation. Small slepton-LSP mass difference gives soft leptons in the final state
- Focus point
  - m_0 = 3350 GeV, $m_{1/2}$ = 300 GeV, A_0 = 0 GeV, $\tan\beta$ = 10, sgn(μ) = +
  - LSP is Higgsino, near μ^2=0 bound. Heavy sfermions; all squarks and sleptons have mass >2 TeV, negligible FCNC, CP, g_μ-2, etc. Complex events with lots of heavy flavor
- Funnel region point
  - m_0 = 320 GeV, $m_{1/2}$ = 375 GeV, A_0 = 0 GeV, $\tan\beta$ = 50, sgn(μ) = +
  - wide H, A for $\tan\beta$ >> 1 enhance annihilation. Heavy Higgs resonance (funnel); main annihilation chain into bb pairs
  - dominant tau decays
- Low mass point at limit of Tevatron RunII reach
  - m_0 = 200 GeV, $m_{1/2}$ = 160 GeV, A_0 = -400 GeV, $\tan\beta$ = 10, sgn(μ) = +
  - big cross section, but events rather similar to top
  - measure SM processes in presence of SUSY background to show detector is understood

Inclusive analysis

Select events with at least 4 jets and Missing E_T

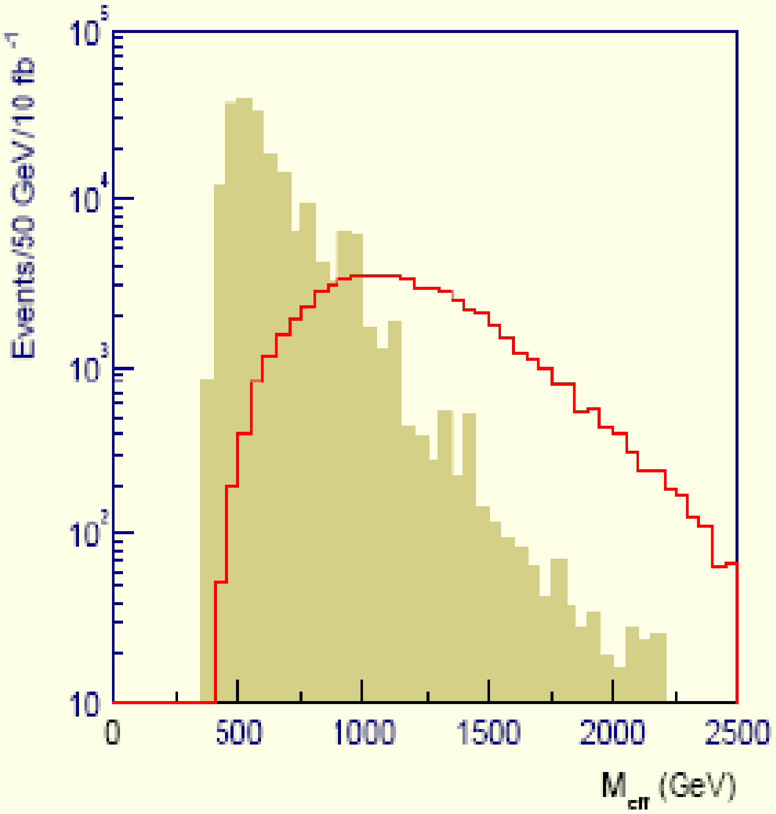
A simple variable

$M_{\rm eff} = P_{t,1} + P_{t,2} + P_{t,3} + P_{t,4} + \not{E}_T$

At high $M_{\rm eff}$ non-SM signal rises above background note scale

Peak in $M_{\rm eff}$ distribution correlates well with SUSY mass scale

$M_{\rm SUSY} = \min(M_{\bar{u}}, M_{\bar{g}})$



Will determine gluino/squark masses to $\sim 15\%$

Tau decay modes

- $c\tau \sim= 87\mu m$, $m_\tau = 1.78$ GeV/c^2
- Leptonical decays
  - $\tau \to e(\mu)\,\nu\,\nu$: ~ 35.2 %
    - Identification done through the final lepton
- Hadronical decays
  - 1 prong
    - $\tau \to \nu_\tau + \pi^{+/-} + n(\pi^o)$: 49.5 %
  - 3 prongs
    - $\tau \to \nu_\tau + 3\pi^{+/-} + n(\pi^o)$: 15.2 %
  - **"τ–jet" is produced**

Quite often taus are produced in pairs: 42% of final states contains two "tau-jet"

$\tau\tau$ decay mode	BR
$\ell\ell\,\nu$	12 %
ℓjet ν	46 %
jet jet ν	42 %

- tau jets at LHC:
  - very collimated
    - **90% of the energy is contained in a 'cone' of radius R=0.2 around the jet direction for ET>50 GeV**
  - Low multiplicity
    - **One, three prongs**
  - Hadronic, EM energy deposition
    - **Charged pions**
    - **Photons from π^o**

The ATLAS detector at LHC

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

Thin Superconducting Solenoid
(B=2T)

LAr EM Calorimeter:
$L \times R$ = 13.3m×2.25m
$|\eta| \leq 3.2$ (4.9)
$\sigma_E / E = 10\%/\sqrt{E} \oplus 0.7\%$
PB-LAr

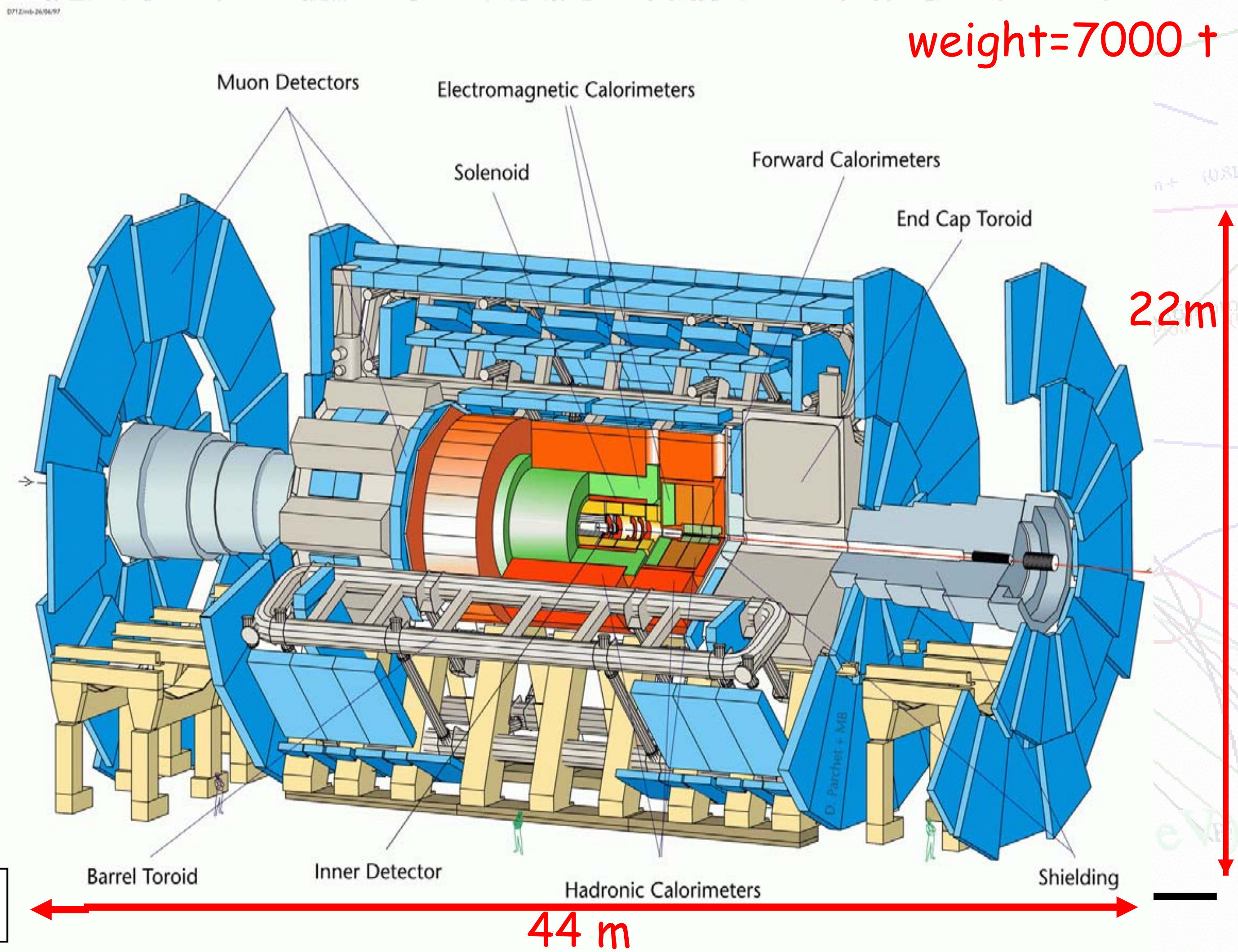
Hadronic Calorimeter :
Endcaps LArg
Barrel Scintillator-tile
$L \times R$ = 12.2m×4.25m
$\sigma_E / E = 50\%/\sqrt{E} \oplus 3\%$ ($|\eta| \leq 3$)

Large Superconducting Air-Core Toroids

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

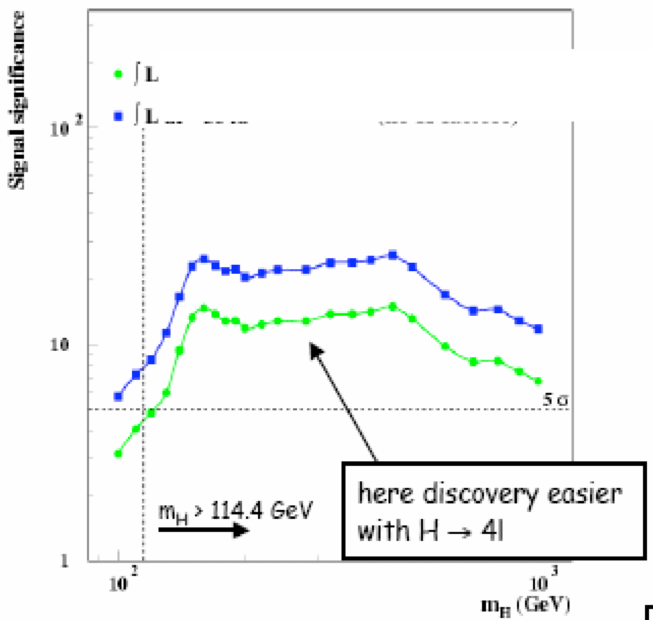
σ(EtMiss)=0.46*sqrt(SumET))

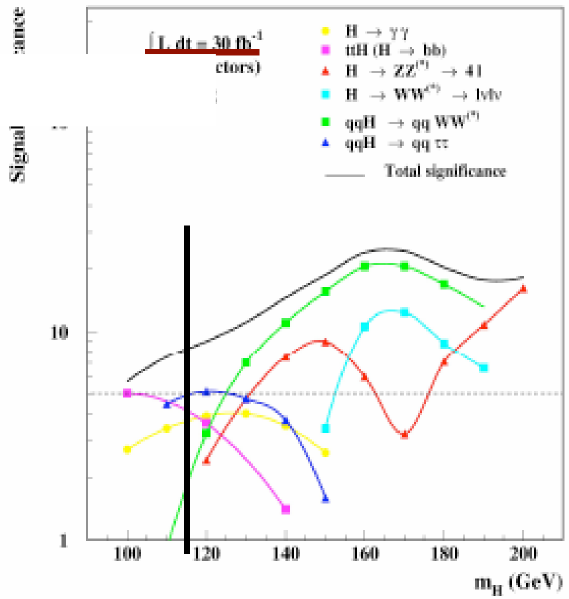
Inner Detector :
Semiconductor Pixel and Strips
Straw Tube Tracking Detector (TRT)
$L \times R$ = 7m×1.15m
$\sigma_{R\phi}$=12-16µm, σ_Z=66-580µm



SM Higgs with mass below 200 GeV

A difficult case: a light Higgs (m_H ~ 115 GeV) ...





BR(H→ττ) ~ few %

m_H ~ 115 GeV	10 fb^{-1}

ATLAS	H → γγ	ttH → ttbb	qqH → qqττ (ll + l-had)
S	130	15	~ 10
B	4300	45	~ 10
S/ √B	2.0	2.2	~ 2.7

total S/ √B ≈ $4^{+2.2}_{-1.3}$

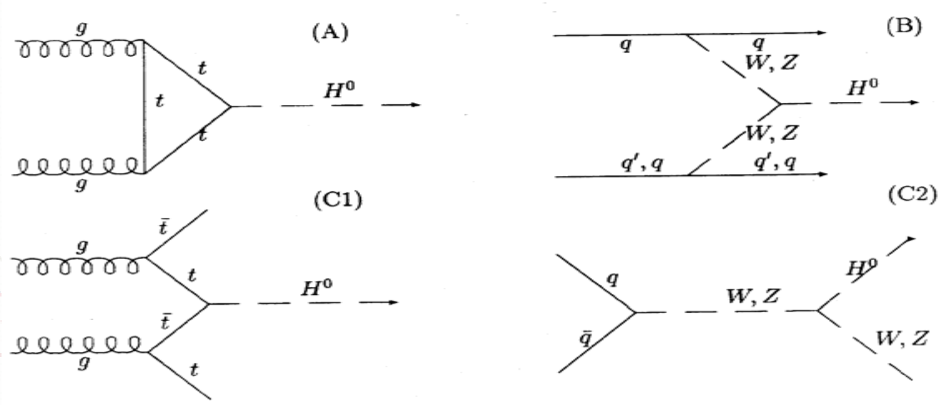
K-factors ≡ σ(NLO)/σ(LO) ≈ 2 not included

Full GEANT simulation, simple cut-based analyses

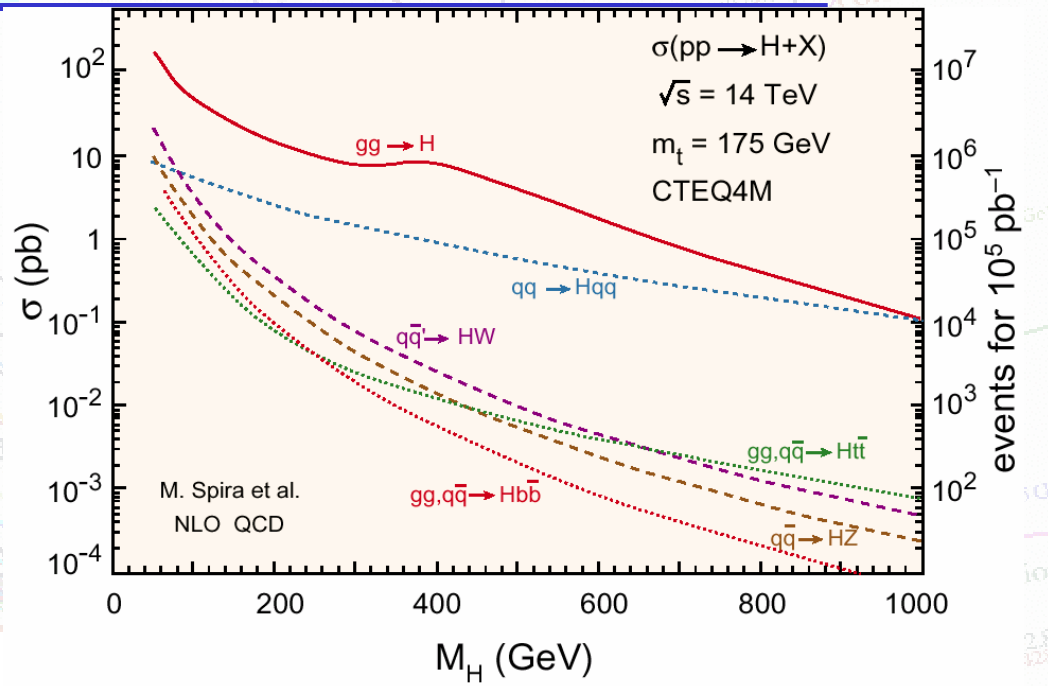
If clean had-had channel observable, sensitivity to Higgs parity might be established but which production process use to allow to trigger such events?

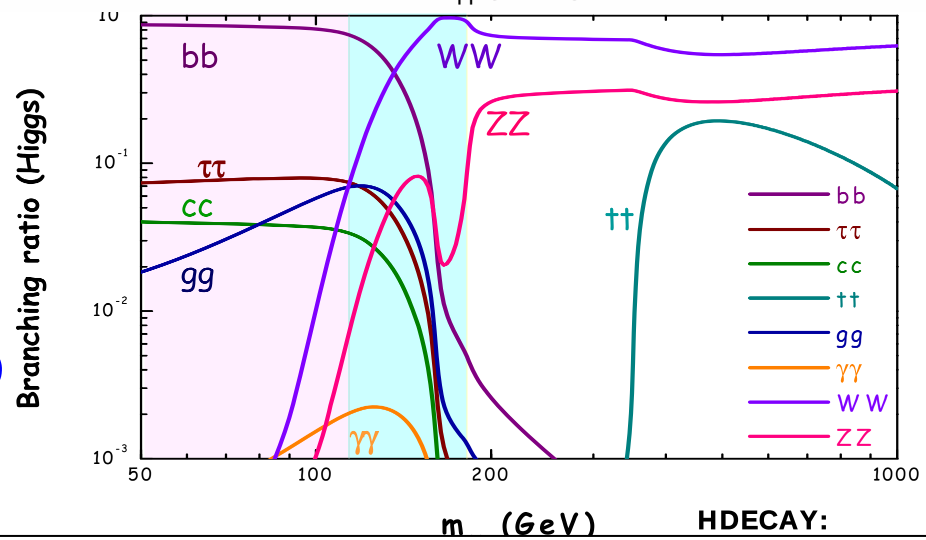
SM Higgs production at LHC

gg fusion WW/ZZ fusion



associated ttH associated WH,ZH





- $m_H < 2 m_Z$:
  - $H \to \gamma\gamma$
  - $ttH \to \ell\nu bb + X$
  - $H \to ZZ^* \to 4\ell$
  - $H \to WW^* \to \ell\nu\ell\nu$
  - $WH \to WWW^* \to \ell\nu\ell\nu\ell\nu, \ell^\pm\ell^\pm\nu\nu jj$
- $m_H > 2 m_Z$:
  - Main channel is $H \to ZZ \to 4\ell$ (gold-plated)
  - $H \to ZZ \to \ell\ell\nu\nu$ $m_H > 300$ GeV
  - $H \to ZZ \to \ell\ell jj$ forward
  - $H \to WW \to \ell\nu jj$ jet tag

fully hadronic final states dominate but cannot be extracted from large QCD backgrounds

MSSM Higgs searches

Two Higgs Doublets with 5 physical states

• 2 CP-even neutral Higgs bosons	h^0, H^0
• 1 CP-odd neutral Higgs boson	A^0
• 2 charged Higgs bosons	$H^{\pm}$
• free parameters	$\tan\beta = \upsilon_1 / \upsilon_2$
	m_A

tree level: $m_h \leq m_Z$
$m_A \leq m_H$
$m_W \leq m_{H\pm}$

rad. corrected: $m_h < 130$ GeV

many possible search channels @ LHC

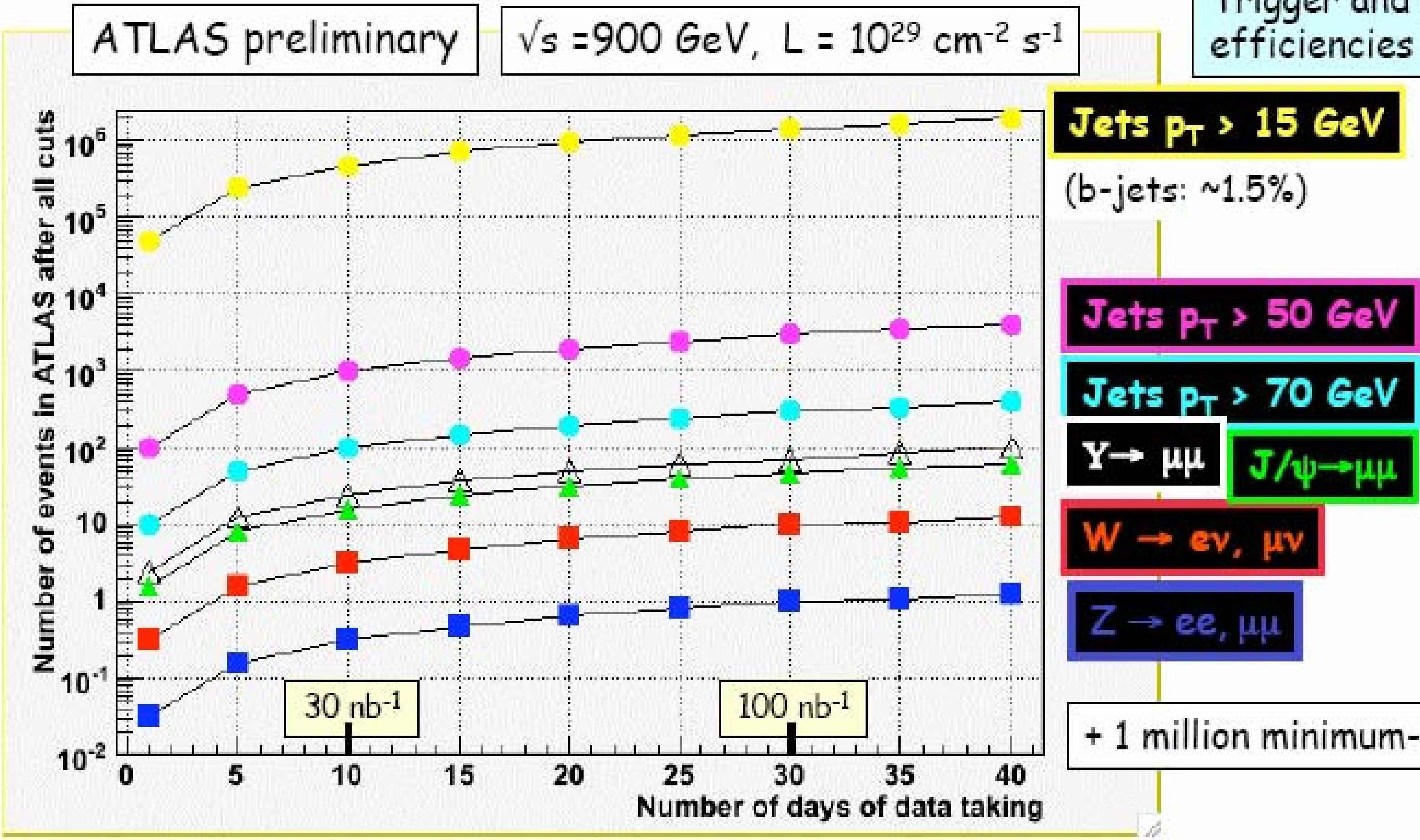
$h \to \gamma\gamma$, $tt\,h \to tt\,bb$, $H \to Z\,Z^{(*)} \to 4\ell$ like SM

$A/H \to \mu\mu, \tau\tau, tt$, $H^{\pm} \to \tau\nu, cs, tb$
$H \to hh$, $A \to Z\,h$
} typical for MSSM

$A/H \to \chi^0_2\,\chi^0_2$
$\chi^0_2 \to h\,\chi^0_1$
if SUSY particles accessible

What data samples in 2007 ?

30% data taking efficiency included (machine plus detector)
Trigger and analysis efficiencies included



- Start to commission triggers and detectors with collision data (minimum bias, jets, ..) in real LHC environment
- Maybe first physics measurements (minimum-bias, underlying event, QCD jets, …) ?
- Observe a few $W \to l\nu$, $\Upsilon \to \mu\mu$, $J/\psi \to \mu\mu$?

F. Gianotti, ICHEP06, Moscow, 02/08/2006

F. Gianotti, ICHEP06,
Moscow, 02/08/2006

With the first physics run in 2008 ($\sqrt{s}$ = 14 TeV) ...

1 fb^{-1} (100 pb^{-1}) ≡ 6 months (few days) at L= 10^{32} $cm^{-2}s^{-1}$
with 50% data-taking efficiency
→ may collect a few fb^{-1} per experiment by end 2008

Channels (examples ...)	Events to tape for 100 pb^{-1} (per expt: ATLAS, CMS)	Total statistics from some of previous Colliders
$W \rightarrow \mu\nu$	~ 10^6	~ 10^4 LEP, ~ 10^6 Tevatron
$Z \rightarrow \mu\mu$	~ 10^5	~ 10^6 LEP, ~ 10^5 Tevatron
tt → W b W b → $\mu\nu$ +X	~ 10^4	~ 10^4 Tevatron
QCD jets p_T > 1 TeV	> 10^3	---
$\tilde{g}\tilde{g}$ m = 1 TeV	~ 50	---

With these data:

- Understand and calibrate detectors in situ using well-known physics samples
  - e.g. - Z → ee, μμ   tracker, ECAL, Muon chambers calibration and alignment, etc.
  - - tt → blν bjj   jet scale from W → jj, b-tag performance, etc.
- Measure SM physics at $\sqrt{s}$ = 14 TeV : W, Z, tt, QCD jets ...
  (also because omnipresent backgrounds to New Physics)

→ prepare the road to discovery ...... it will take time ...

Experimental conditions

- Proton-Proton collisions @ 14 TeV
- Luminosity:
  - First run in 2007 at 900 GeV
  - First run @ 14 TeV in 2008, luminosity increasing to reach ~$10^{33}cm^{-2}s^{-1}$ "low luminosity" phase

    => ~ *30 fb^{-1} between 2008 and 2010/2011*
  - ~$10^{34}cm^{-2}s^{-1}$ "high luminosity" phase

    => *~300 fb^{-1} by 2014/2015*
- Pile-up: ~ 2 (low luminosity) to 20 (high luminosity) pp interactions ("minimum bias") per bunch crossing (every 25 ns)
- Trigger to go from 40 MHz interaction rate to ~200Hz to disk for offline analysis