Reconstruction of narrow resonances decaying into jets with the ATLAS detector

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Introduction

The LHC physics program requires good mass resolution for objects decaying into jets:

$\rightarrow$ resonance identification

$\rightarrow$ background rejection capabilities

$\Rightarrow$ Expected performances for the following decays:

- $W \rightarrow j\,j$
- $t \rightarrow W\,b \rightarrow j\,j\,b$
- $H \rightarrow b\bar{b}$
- $H \rightarrow b\bar{b}b\bar{b}$
- $H/A \rightarrow \tau\tau$, and τ-jet identification

W mass reconstruction through W → j j decays

Mass reconstruction procedure:

→ the resolution on the reconstructed mass depends upon:

- physics effects (jet fragmentation,…)
- detector effects (calorimeter response,…)

→ these effects depend upon pT(W) ⇒ different reconstruction strategies

⇒ three methods:

1- mass calculated from the 4-momenta of the 2 jets

2- mass calculated from the 4-momentum of each calorimeter tower

3- as 2- but the energy is collected in a single cone (high pT(W) events)

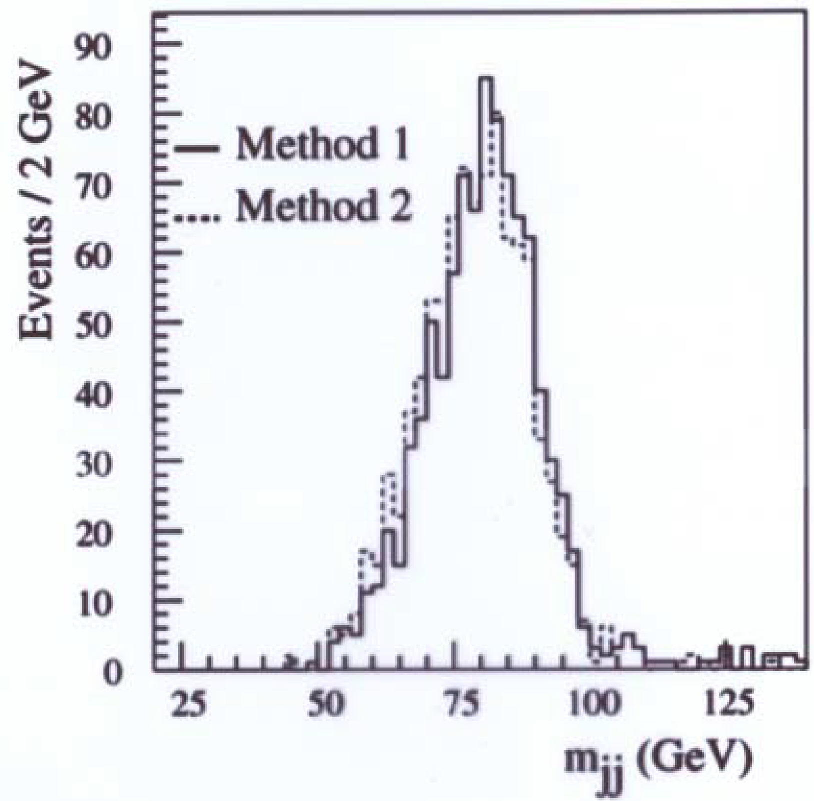
Events sample - 3 pT(W) ranges:

- low pT: pT(W) < 50 GeV
- mid-pT: 100 < pT(W) (GeV)< 200
- hight pT: 200 < pT(W) (GeV) < 700

W mass reconstruction - low pT sample

Jet reconstruction:

- jets well separated (⟨ΔR⟩≈3)
- method 1 and 2 with a fixed cone algorithm
- jet energy corrected by ⟨E(parton)/E(jet)⟩



Mass resolution:

- m(jj) distribution fitted by a gaussian
  - → no pile-up: $\sigma = 9.5$ GeV
  - → pile-up: $\sigma = 13.8$ GeV
  - → reconstructed mass ≈ generated mass
- m(jj) resolution dominated by jet energy resolution

mass resolutions: σ = 7.7 GeV (M1) σ = 8.3 GeV (M2)
(low luminosity)

⇓

low mass tails (small opening angle between jets)

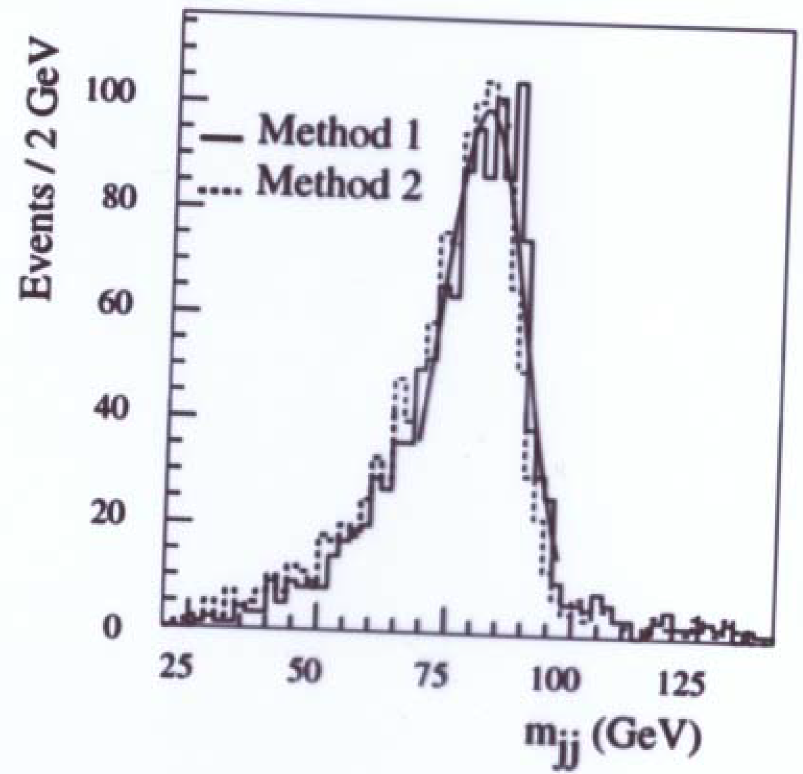
⇓

different jet algorithms tested on method 1:

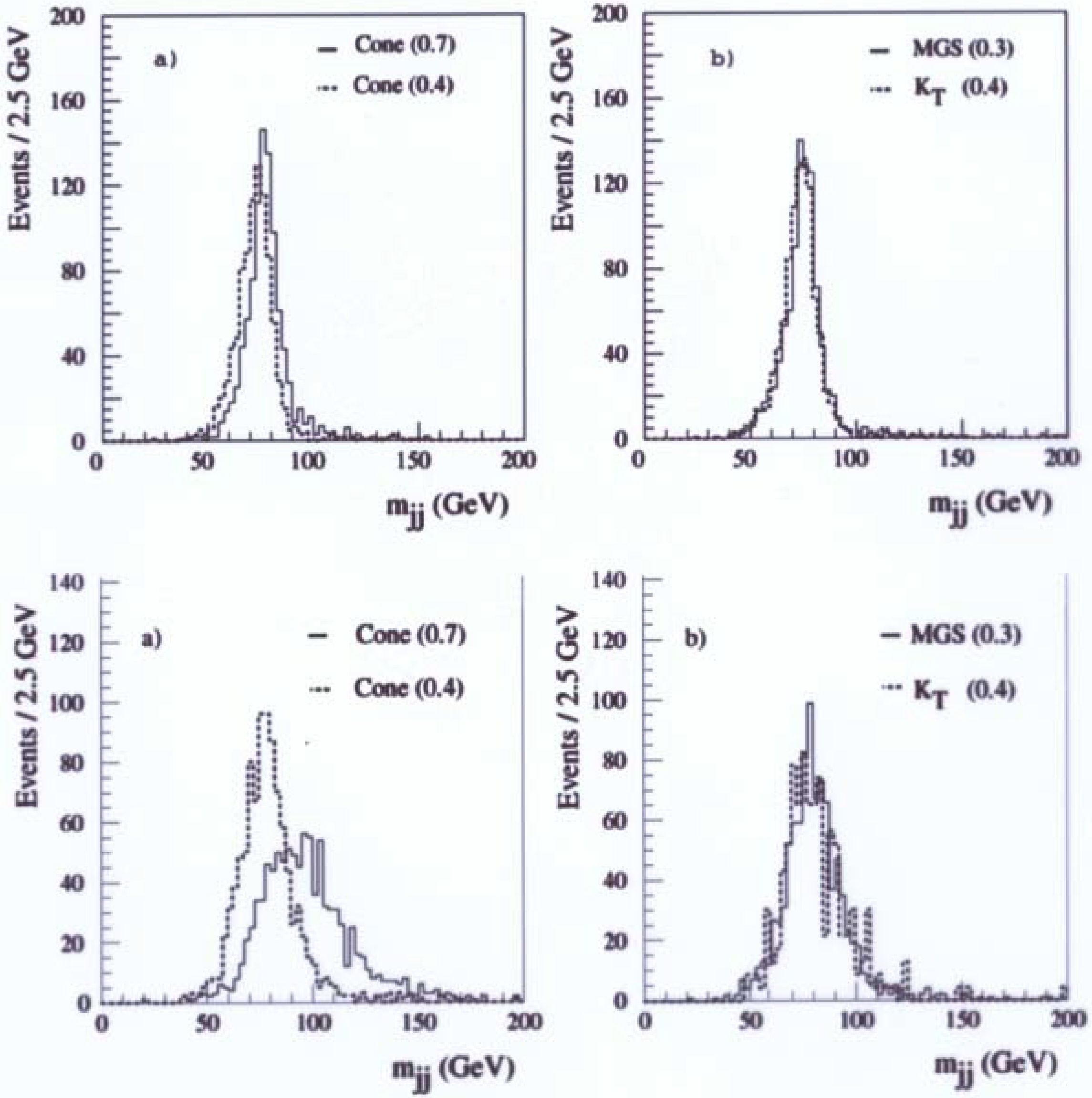
- fixed cone with $\Delta R = 0.4$
- fixed cone with $\Delta R = 0.7$
- Kt algorithm
- MGS algorithm

(for low and high luminosity scenarios)

Low Luminosity



W mass reconstruction - mid-pT sample

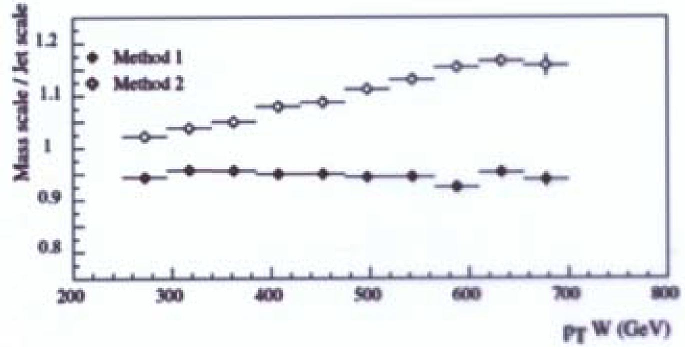


Low Luminosity

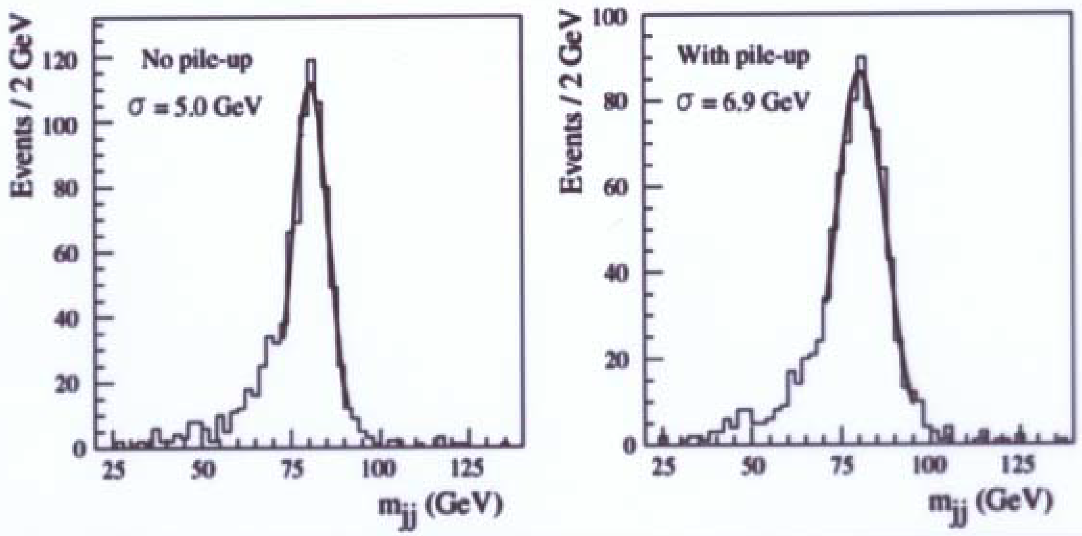
High Luminosity

W mass reconstruction - high pT sample

mass scale: M(rec)/M(gen) →



⇒ linear correction on the reconstructed mass:



Top mass reconstruction through $t \rightarrow W\, b \rightarrow j\, j\, b$ decays

Event sample:

$pp \rightarrow t\bar{t} \rightarrow l\nu bjjb$ 30K fully simulated events

$\rightarrow$ M(top) = M(jjb)

Jet reconstruction:

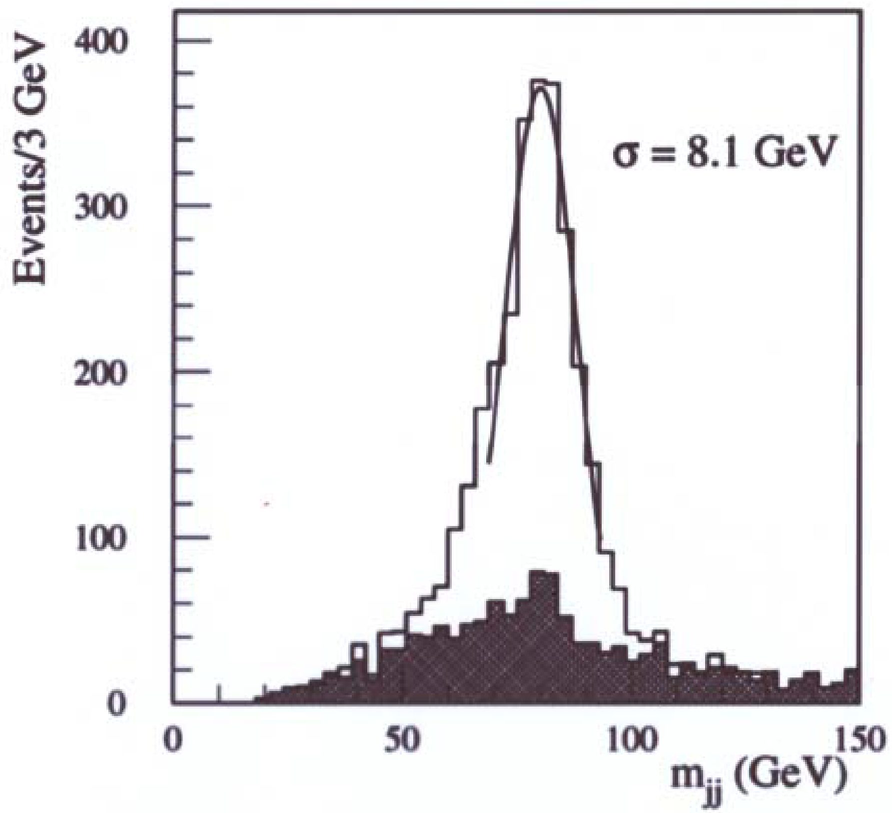
- fixed cone algorithm with $\Delta R = 0.4$
- jet energy calibration: factor: $\langle pT(parton)/pT(jet) \rangle$

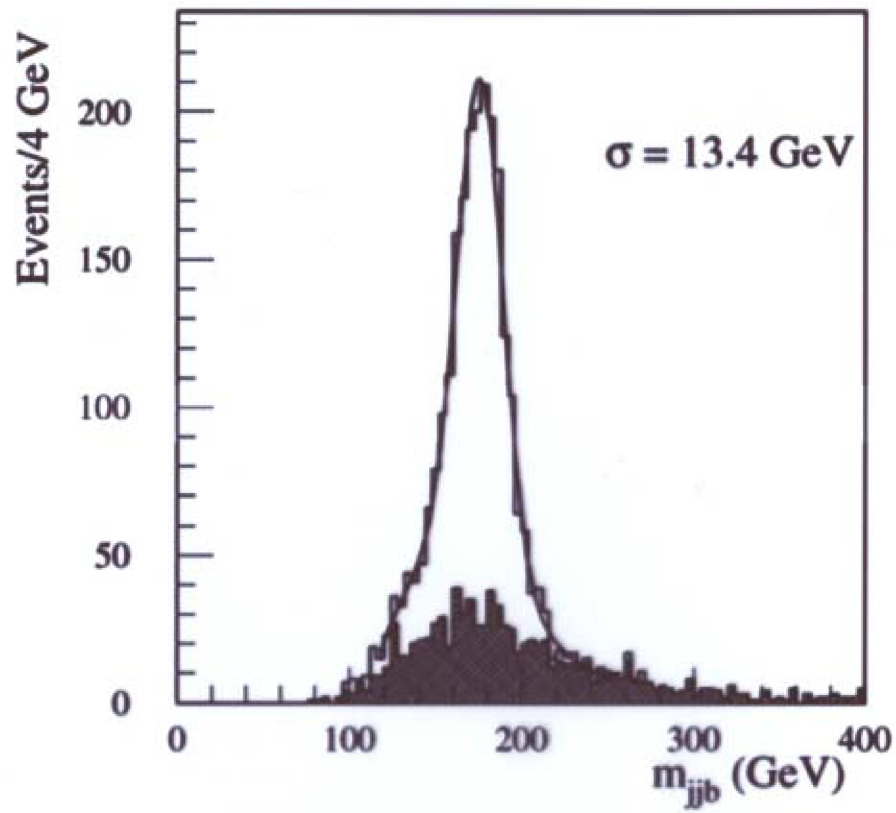
Event selection/reconstruction:

- ≥ 4 jets ($pT > 40$ GeV, $|\eta| < 2.5$), ≥ 2 b-tagged jets
- $W \rightarrow jj$ decay reconstructed (jet pair having M(jj) closest to M(W))
- $|M(jj) - M(W)| < 20$ GeV
- $t \rightarrow jjb$ decay reconstruction: b-jet association (take b-jet giving highest pT(jjb))

Top mass reconstruction through $t \to W\,b \to j\,j\,b$ decays

(Low Luminosity)



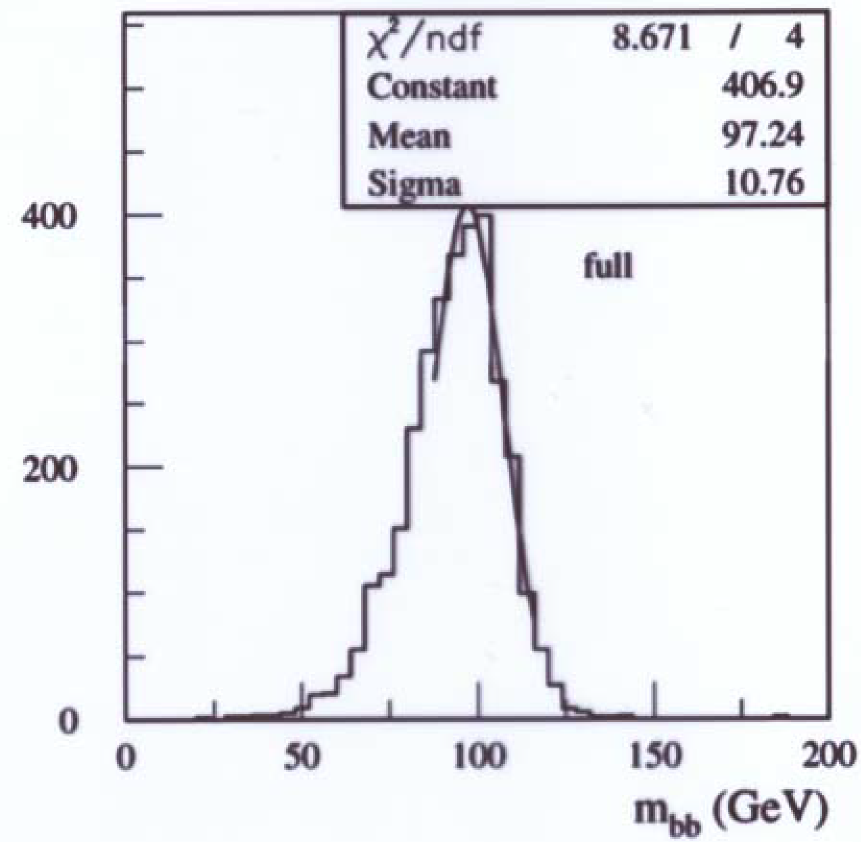


$H \rightarrow b\,b$ decay

Promising channel to observe low mass Higgs bosons (from WH and $t\bar{t}H$ production)

$h \rightarrow b\bar{b}$ decays: clean signature for SUSY final states

Mass distribution



Event sample/reconstruction:

- 900 WH fully simulated events ($W \rightarrow l\nu, H \rightarrow b\bar{b}$), with $m_H = 100$ GeV
- fixed cone algorithm with ΔR=0.7
- 2 b-tagged jets (pT>15 GeV and $|\eta|$<2.5)
- ε(1 b-jet)=83%, ε(2 b-jets)=69%

$H \rightarrow hh \rightarrow b\,b\,b\,b$ decay

MSSM promising channel for small tanβ and Higgs mass below threshold for $H \rightarrow t\bar{t}$

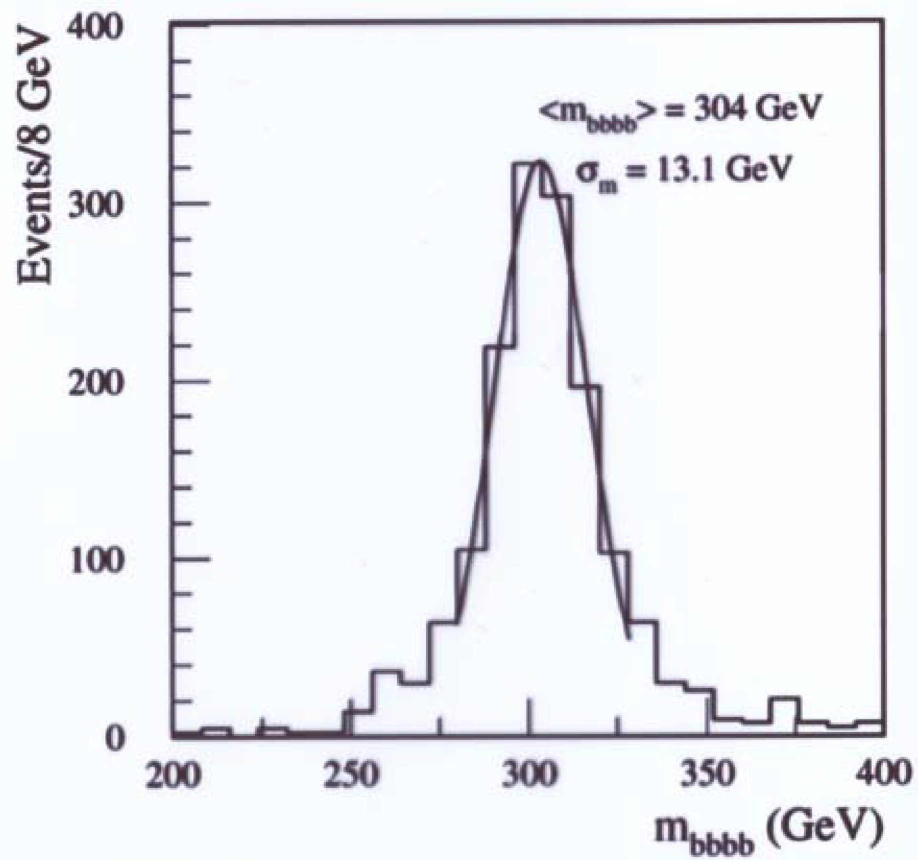
Event sample:

- fully simulated events with $m_H = 300$ GeV and $m_h = 80$ GeV
- fixed cone algorithm with ΔR=0.7
- 4 b-tagged jets with pT>30 GeV and |η|<2.5

h decays reconstruction:

- assuming h boson discovered
- 2 h→bb decays reconstructed choosing the comb which minimizes $X^2 = (m_{b\bar{b}} - m_h)^2 + (m_{b\bar{b}} - m_h)^2$

$\rightarrow \sigma(m_h) = 11$ GeV



H decay reconstruction:

- both $m_{b\bar{b}}$ within +/- 2σ
- b-jets re-calibrated using $m_{b\bar{b}} = m_h$

$\rightarrow \sigma(m_H) \approx 13$ GeV

H/A mass reconstruction through H/A → $\tau\tau \rightarrow j\,\nu\ l\,\nu\,\nu$)

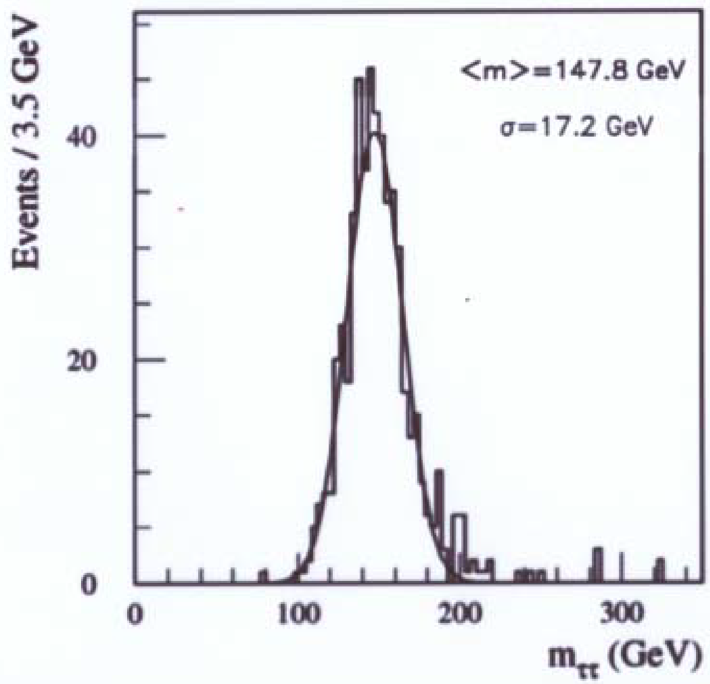
Method: under some assumptions: $m_{\tau\tau} = \sqrt{2(E_1+E_{\nu1})(E_2+E_{\nu2})(1-\cos\theta)}$

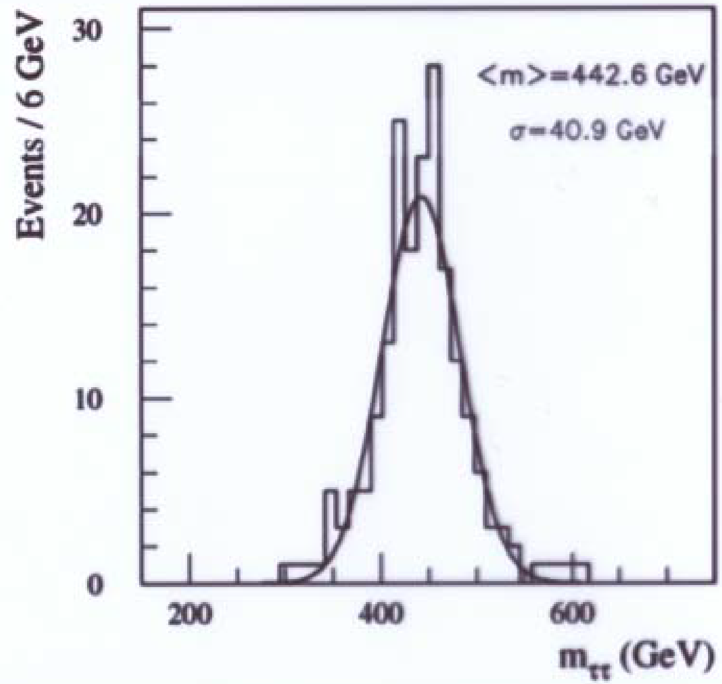
where: E_1, E_2 : energy of the detected products

$E_{\nu1}, E_{\nu2}$: energy of the two neutrino systems; θ: angle between directions of the detected products

$E_{\nu1}, E_{\nu2}$:obtained by solving: $P_x^{miss}(P_y^{miss}) = (E_{\nu1}\overline{u_1})_{x(y)} + (E_{\nu2}\overline{u_2})_{x(y)}$ → solved if sinΔϕ(j,l) ≠0

Results:
- fully simulated events with: m_A = 150 GeV and 450 GeV
- selection cuts: events with 2.9<Δϕ<3.4 rejected





τ-jet identification

τ-jets have low multiplicity

→ collimated calorimeter cluster

→ small number of tracks

↓

3 variables:

- Rem, "electromagnetic jet radius": $\dfrac{\sum_{i=1}^{n} E_{Ti}\sqrt{(\eta_i-\eta_{cluster})^2+(\phi_i-\phi_{cluster})^2}}{\sum_{i=1}^{n} E_{Ti}}$
- ΔE_T^{12} fraction of E_T in the EM and HAD, within 0.1<ΔR<0.2 around the cluster barycentre
- N_{tr} number of tracks matching the cluster within ΔR<0.3

Example: τ/jet separation for A→ττ

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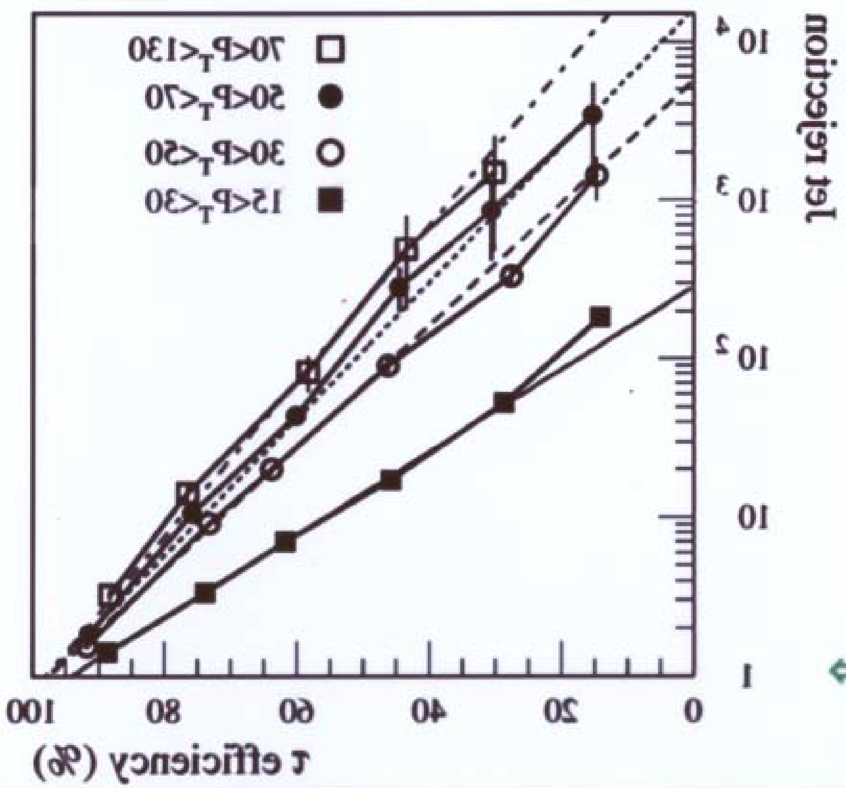
Rejection vs. τ identification efficiency ⇒



Conclusions

Expected resolutions depend on decay channel and on kinematics.

↳ different strategies for the reconstruction have to be considered

W mass resolution:

- (low-mid)-pT(W) → 8 GeV (low L) and 13 GeV (high L)
- high-pT(W) → effects due to jet overlap

top mass resolution:

- 13 GeV

Higgs mass resolution:

- $H \rightarrow b\bar{b}$: 11 GeV (for m_H = 100 GeV)
- $H \rightarrow b\bar{b}b\bar{b}$: 13 GeV (for m_H = 300 GeV)
- $A \rightarrow \tau\tau$: 10%

Jet algorithms

Cone algorithm :

- jet seed = tower with highest Et
- builds a cone around that seed
- fixed cone size
- parameters: Et(seed), ΔR, Et(jet) min.

KT clustering algorithm :

- input: all energetic towers

→ pairs the closest ones

- ending of merging process: different ways (cut on the distance,…)
- no predefined jet size

Mulguisin algorithm (MGS):

- towers classified by decreasing Et

→ first tower assigned to first cluster

→ next tower assigned to the same cluster or a new cluster is started (depending on the distance ΔR)

- parameter: ΔR(min) between two jets
- no predefined jet size (can set one)