First Results from an Experimental Study of $\tan\beta$ Measurement in $\tau\tau$ Fusion Process

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Outline

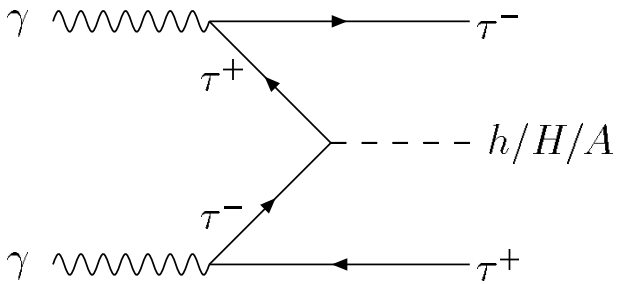
- Motivation
- Generator level results
- Detector level results

Motivation

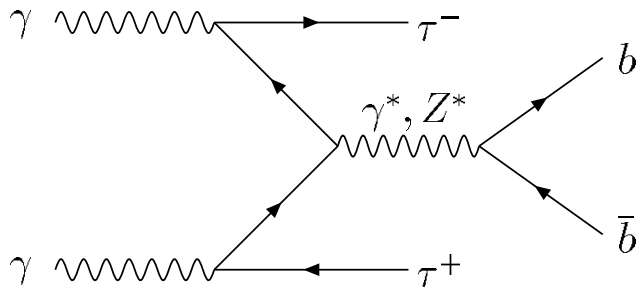
Measurement of $\tau\tau$ fusion process has been suggested for the precise determination of $\tan\beta$, for large $\tan\beta$ values

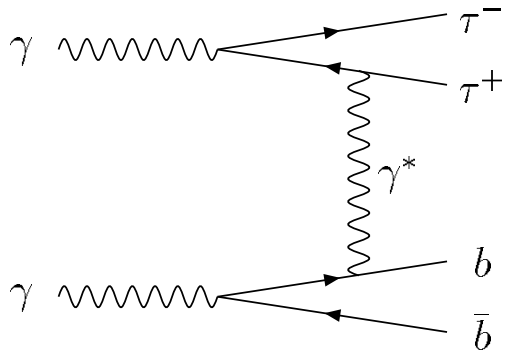
S.Y.Choi et al. hep-ph/0404119

$$\sigma(\gamma\gamma \to \tau^+\tau^- h) \sim \tan^2\beta$$



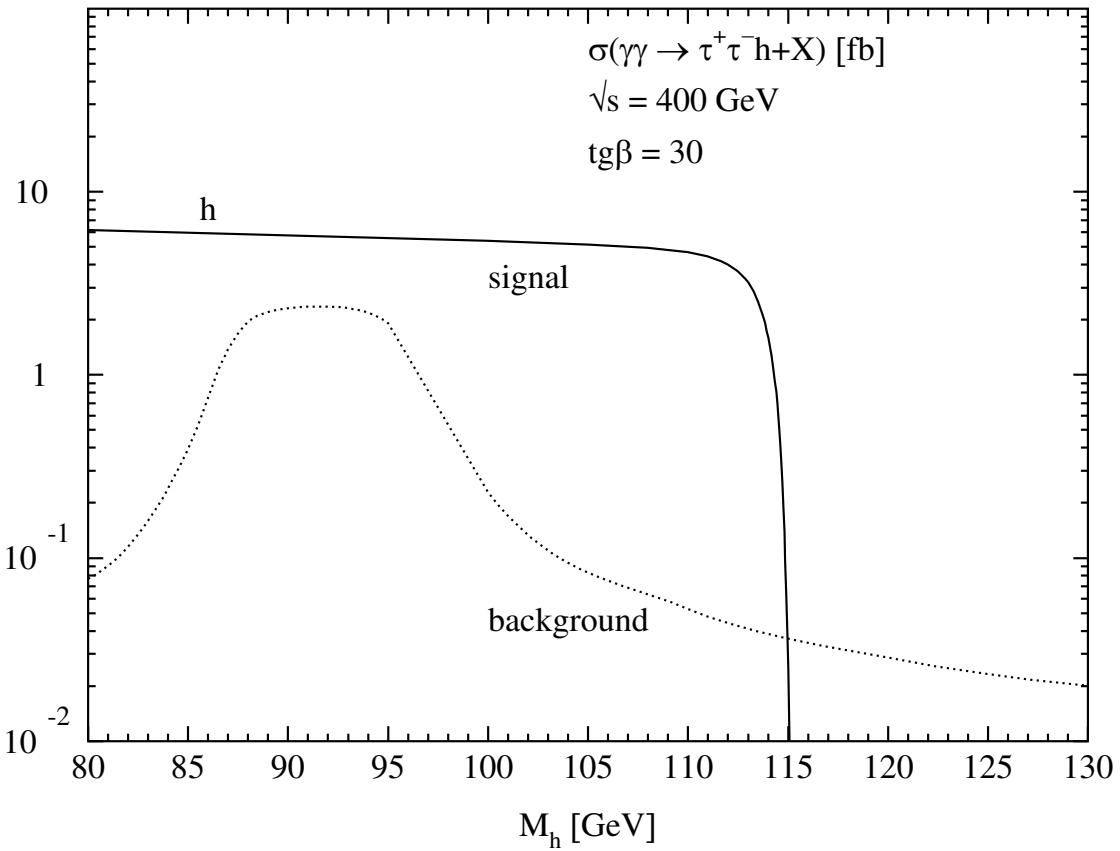
Irreducible background of four fermion production is small





Motivation

For $100\,fb^{-1}$ of data collected at $\sqrt{s_{\gamma\gamma}}$=400 GeV (monochromatic photon beams !)
assuming signal event selection efficiency of 70% ($b\bar{b}$) $\times$ 50% ($\tau\tau$) = 35%



From number of events reconstructed in the $\pm$5 GeV mass window:

$$\Delta \tan\beta \approx 0.9 \div 1.3$$

S.Y.Choi et al. hep-ph/0404119

Event generation

Signal events $\gamma\gamma \to \tau\tau h \to \tau\tau b\bar{b}$
and background events $\gamma\gamma \to \tau\tau b\bar{b}$ (excluding h exchange)
were generated using CompHEP 33.23 (A.Pukhov et al. hep-ph/9908288)

Realistic luminosity spectra for Photon Collier was included with CompAZ
(A.F.Zarnecki, Acta Phys.Polon. B34 (2003) 2741)

Photon polarization was taken into account.

For $\sqrt{s_{ee}} = 500$ GeV, integrated luminosity expected after one year is $1000\,fb^{-1}$

About $130\,fb^{-1}$ in the high energy peak ($W_{\gamma\gamma} > 300$ GeV)

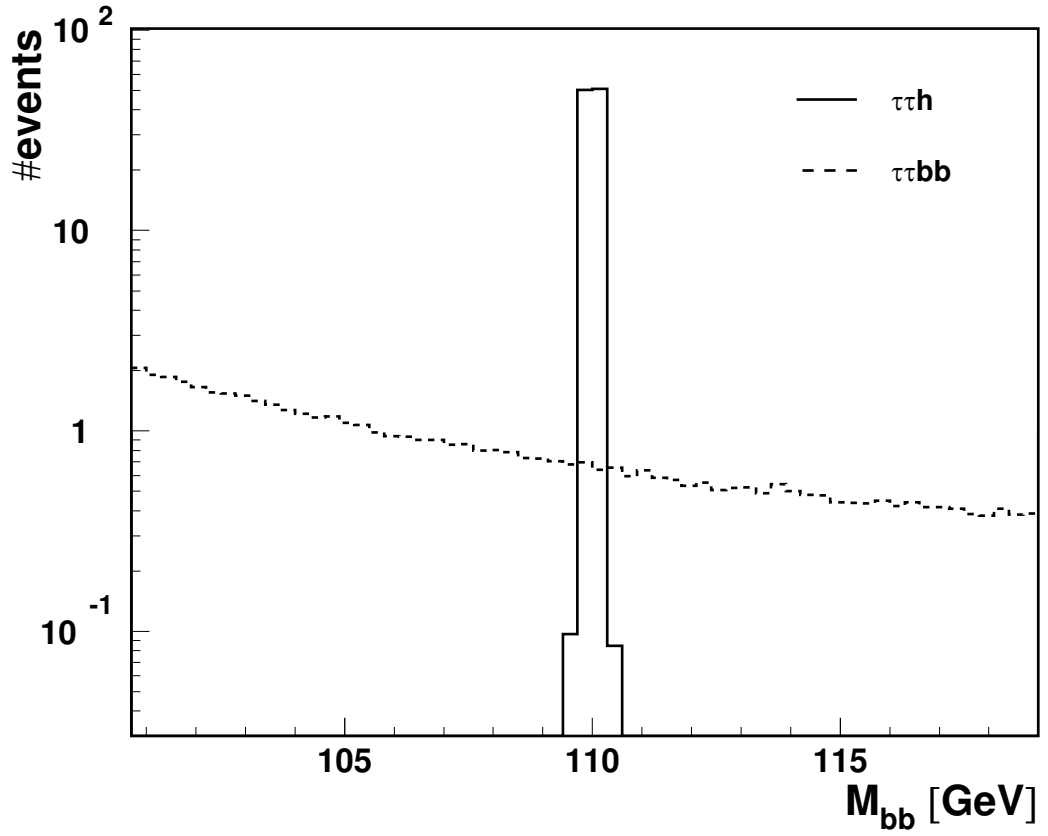
Cuts imposed on generator level:

- $b\bar{b}$ invariant mass $80 < M_{bb} < 150$ GeV
- For both τ: energy $E_\tau > 5$ GeV
- For all particles: production angle $|\cos\theta| < 0.99156$ (130 mrad)

Generator level results

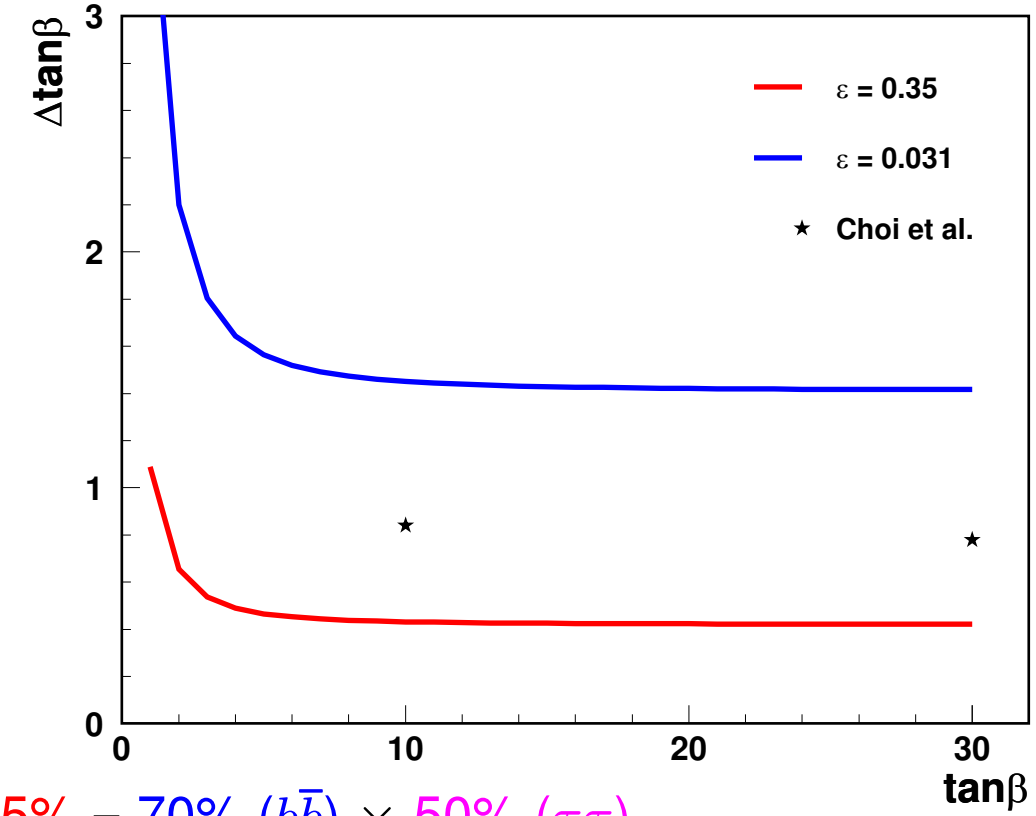
Invariant mass distribution on generator level

$M_h = 110$ GeV, $\tan\beta = 5$



Generator level results

From number of events reconstructed in the ± 5 GeV mass window:



35% = 70% $(b\bar{b})$ $\times$ 50% $(\tau\tau)$

3.1% = 70% $(b\bar{b})$ $\times$ 70% $(\tau\tau)$ $\times BR^2(\tau \to l\nu\bar{\nu})$

Cross section for M_h =110 GeV and $\tan\beta = 30$

$$\sigma(\gamma\gamma \to \tau\tau h \to \tau\tau b\bar{b}) \approx 3.6 fb$$

about 25% lower than or monochromatic beam, but total luminosity is an order of magnitude higher !

Experimental analysis

The analysis follows the approach developed in $\gamma\gamma \to h \to b\bar{b}$ analysis.

$\Rightarrow$ for details see: P.Niezurawski, hep-ph/0503295.

Experimental details taken into account:

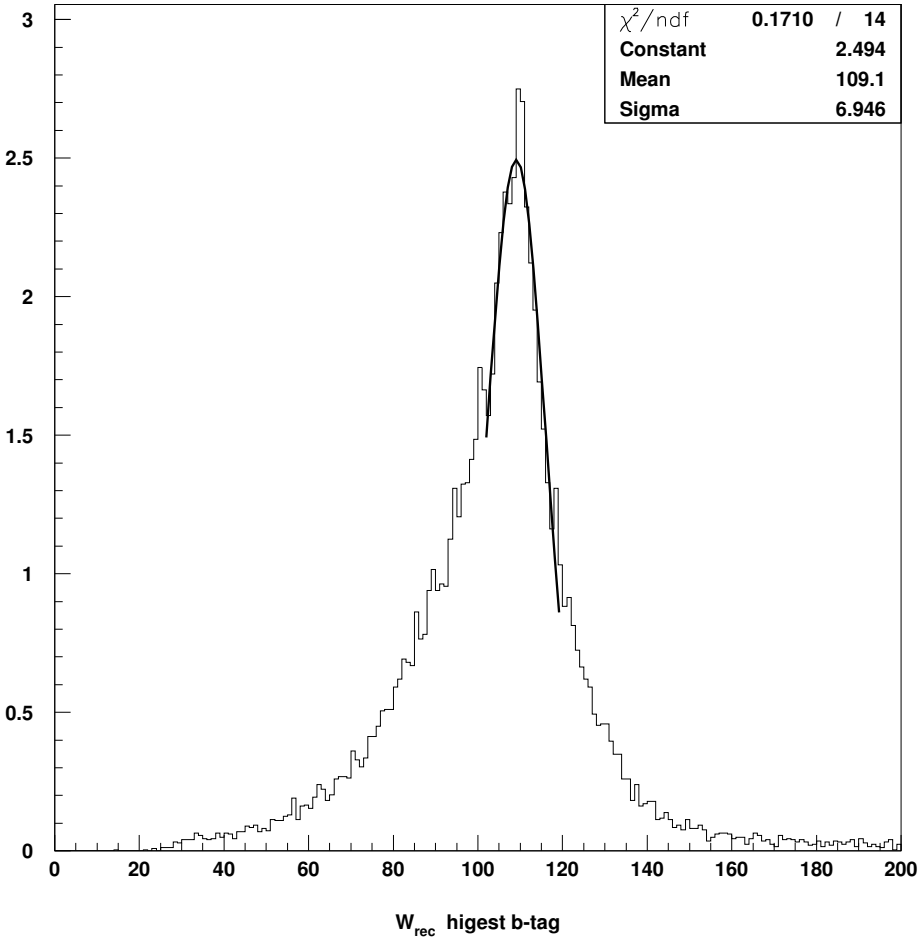
- crab-wise crossing of the beams, $\theta_c = 34$ mrad
- primary vertex distribution
- overlaying events $\gamma\gamma \to hadrons$ (OE)
  generated with PYTHIA using realistic $\gamma\gamma$-luminosity spectrum (V. Telnov)

- Description of detector performance: Simdet 4.01
- ZVTOP-B-HADRON-TAGGER package used for b-tagging
- Jets reconstructed using Durham algorithm

Event selection

Reconstructed invariant mass of two b-tagged jets (M_h= 110 GeV, $\tan\beta = 10$)

Tag value $P_b > 0.6$ and $|cos\theta_j| < 0.75$



Selection efficiency $\sim$ 20% only !

Mainly due to large boost of $b\bar{b}$ system

Mass resolution affected by

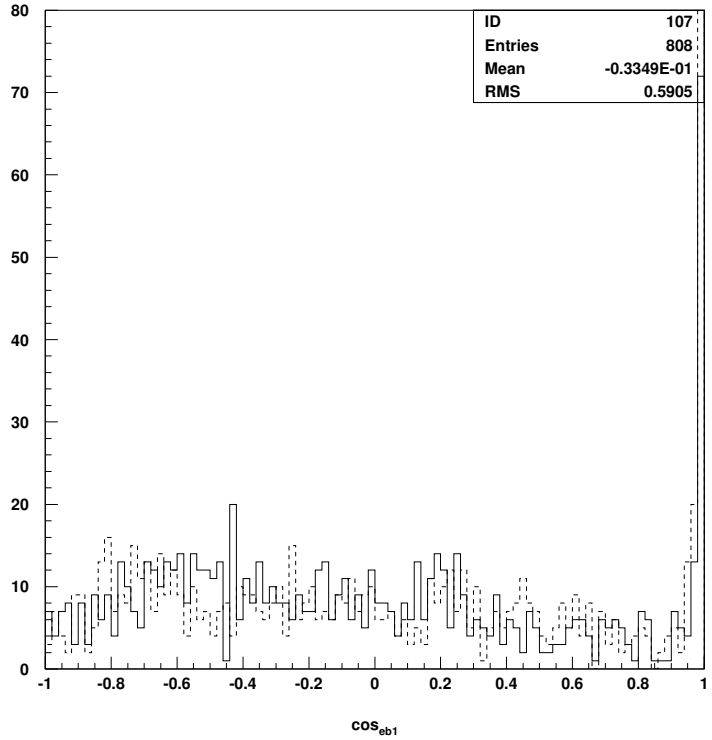
- boost of $b\bar{b}$ system
- overlying events
  (2 per bunch crossing, on average)
- escaping neutrinos
  from semi-leptonic b decays

Event selection

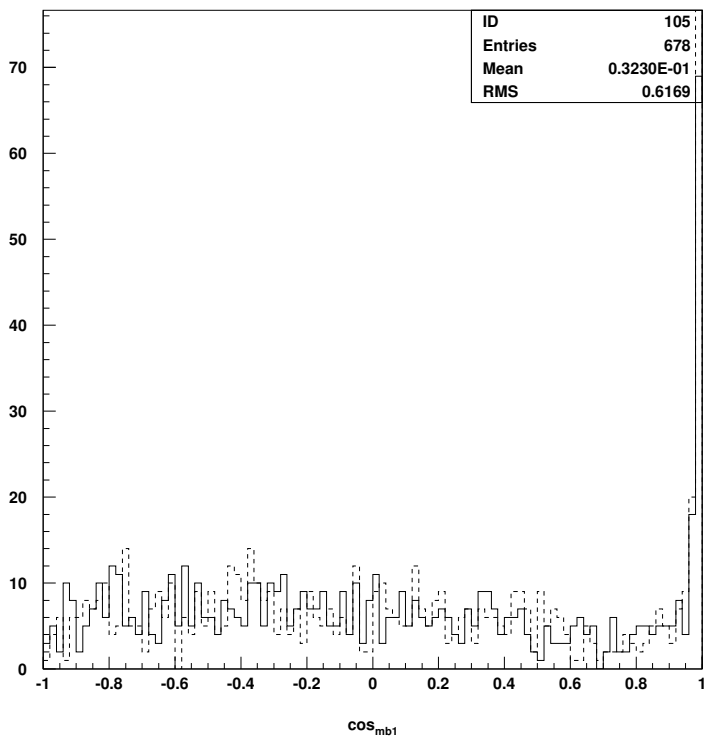
Semi-leptonic b decays can be identified by reconstructing leptons in b-tagged jets.

Cosine of the angle between reconstructed lepton and b-jet:

electrons

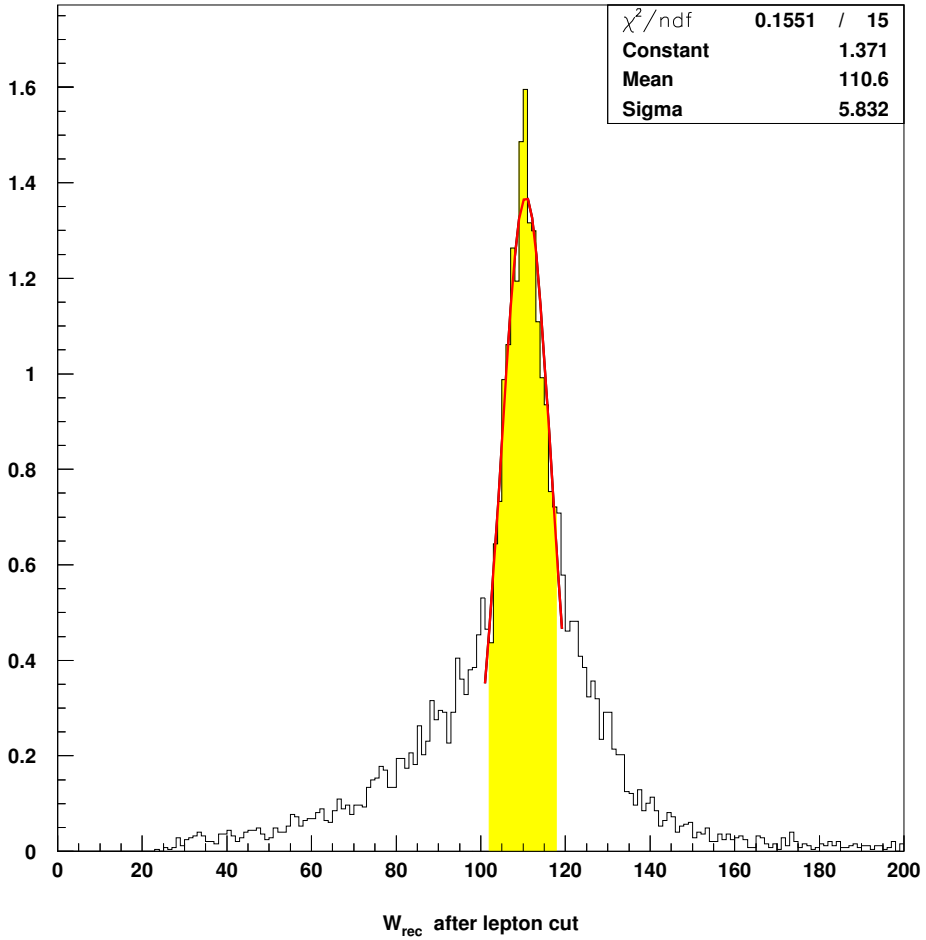


muons



Event selection

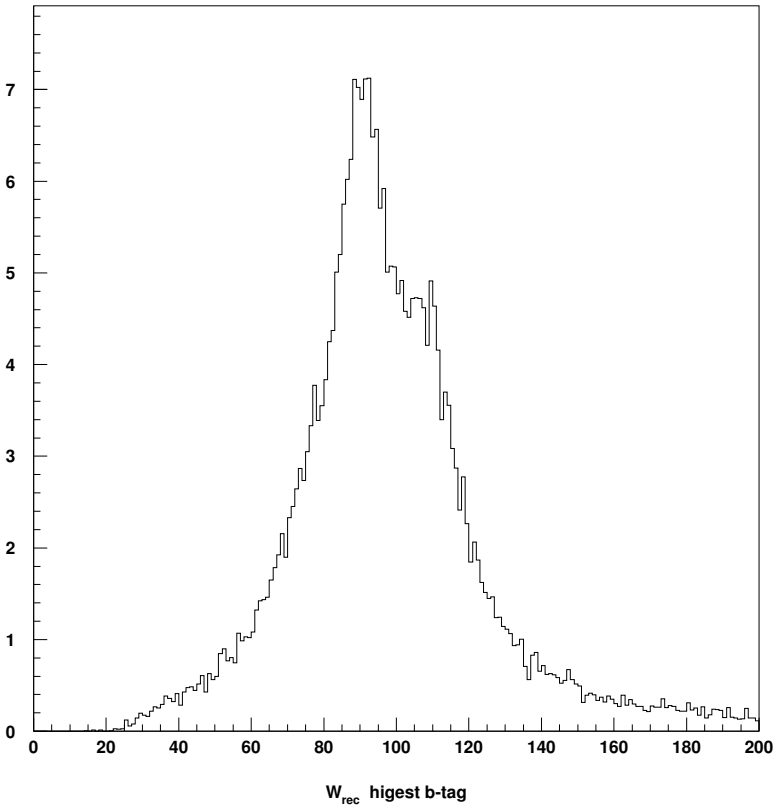
Reconstructed invariant mass for two b-tagged jets: $P_b > 0.6$ and $|cos\theta_j| < 0.75$,
after additional requirement $\cos\theta_{lb} < 0.9$: selection efficiency down to $\sim$ 10% !



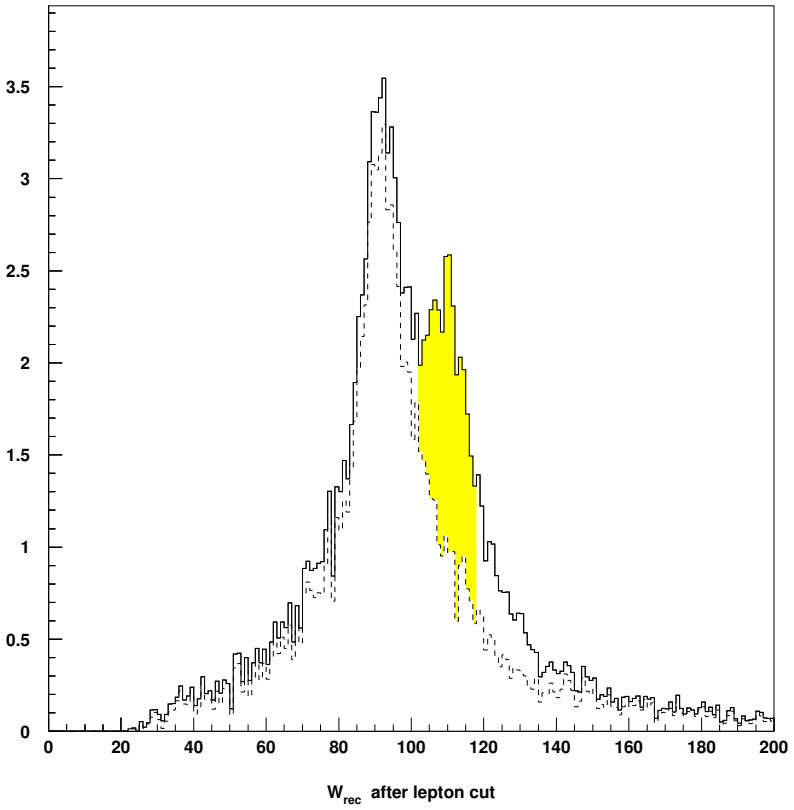
Detector level results

Reconstructed invariant mass distribution for two b-tagged jets, for signal (M_h=110 GeV, $\tan\beta = 10$) and background events

without lepton cut



with lepton cut



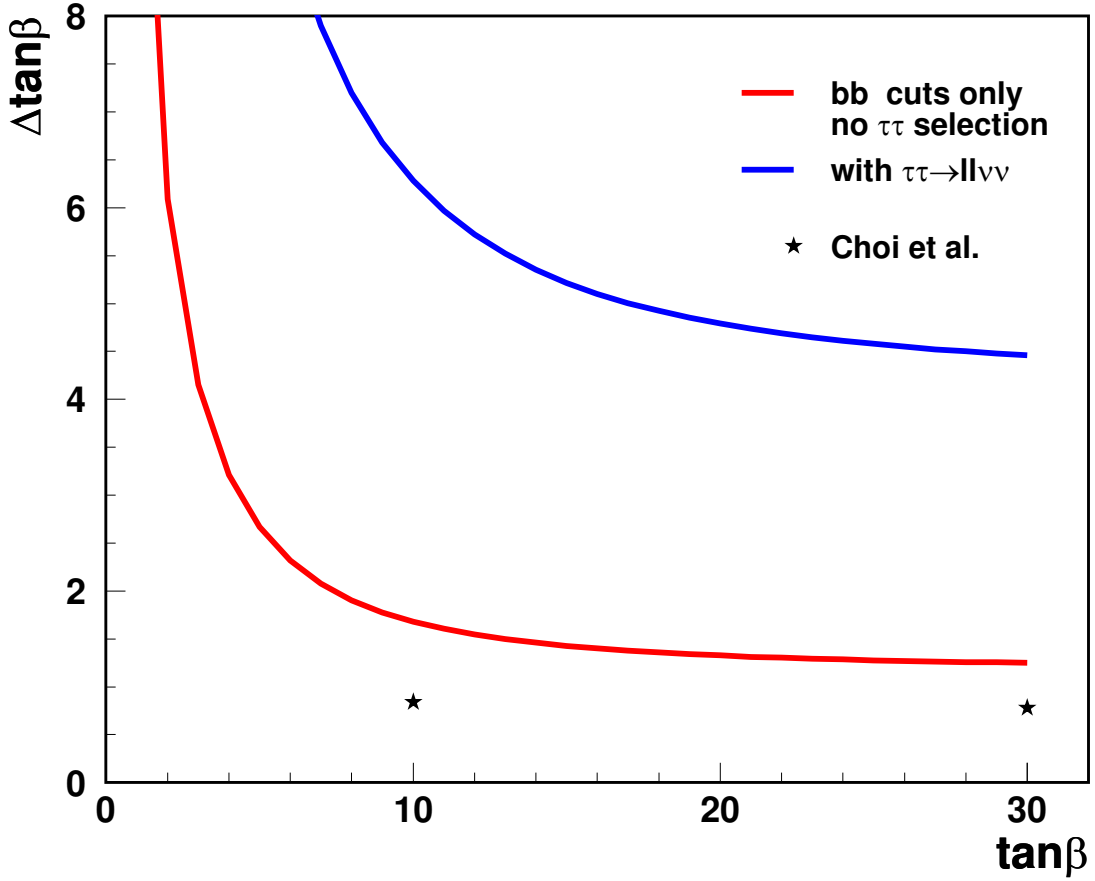
$\Rightarrow$ cut against semi-leptonic b decays allows to separate h and Z° peaks

Detector level results

Expected precision of $\tan\beta$ determination:

after b selection cuts only and after tagging of leptonic τ decays

using $\pm$10 GeV mass window



Conclusions

First experimental study of $\gamma\gamma \to \tau\tau h$ process

Preliminary results not very promising, but:

- No $b\bar{b}$ selection optimization (!)
- Simple mass window approach
- No τ identification algorithm (hadronic decays)

  $\Rightarrow$ room for improvements
- No reducible background simulation

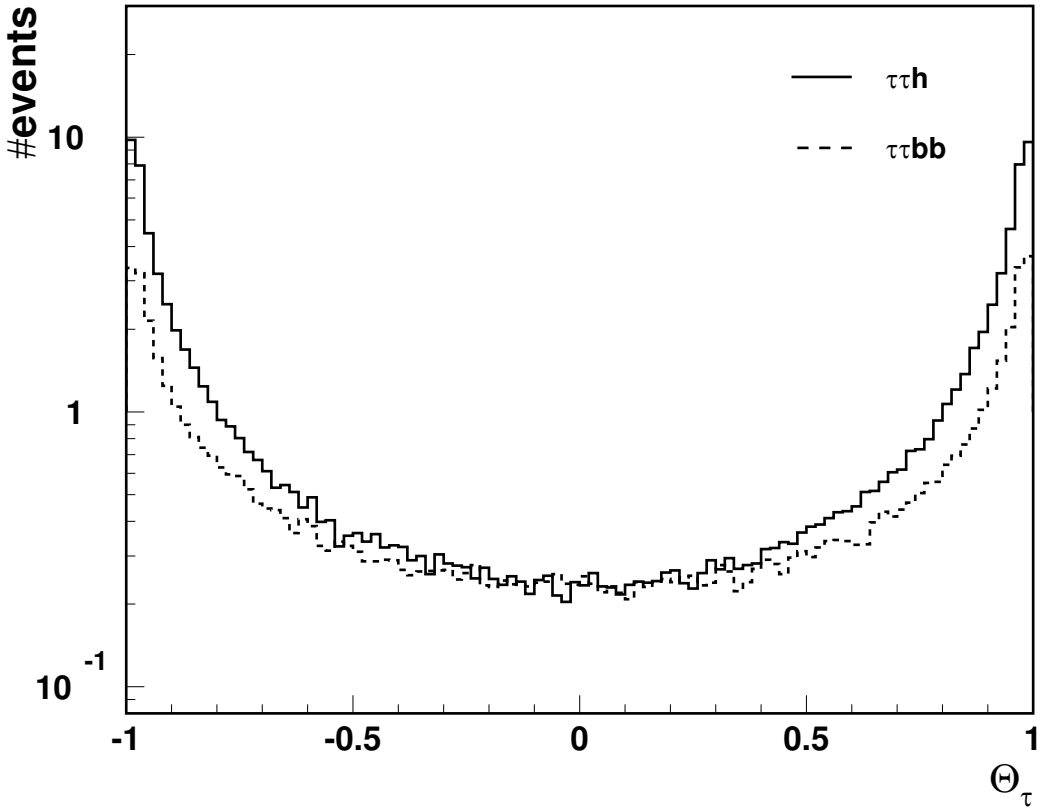
  e.g. $\gamma\gamma \to b\bar{b}$ with OE

  $\Rightarrow$ is it possible to reconstruct hadronic τ decays in the forward region?

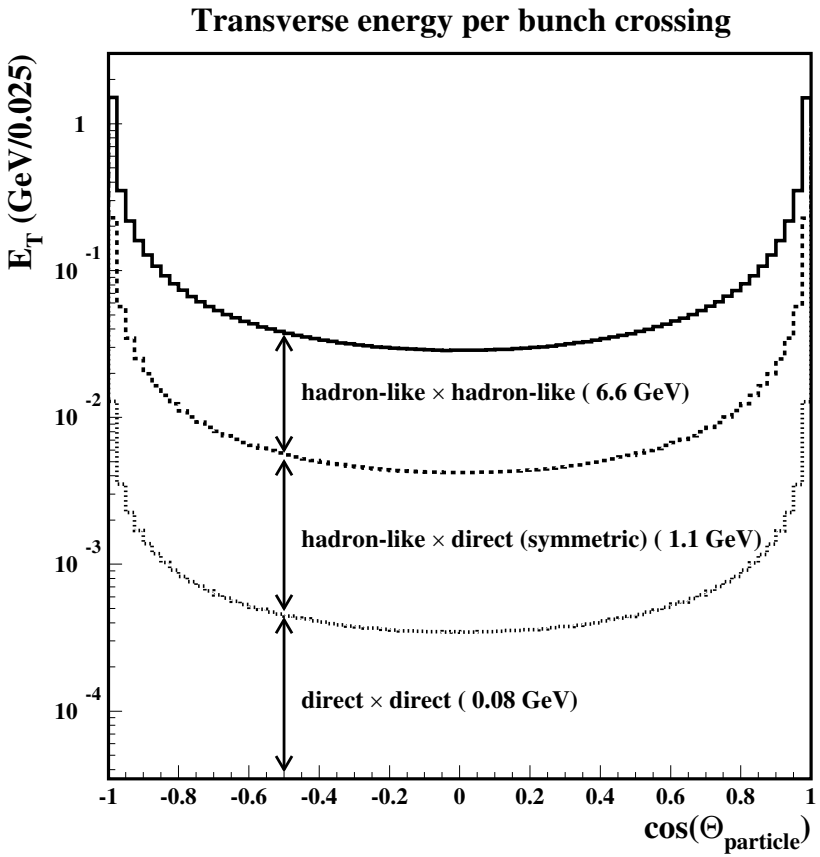
τ identification

Angular distributions of:

signal and background τ



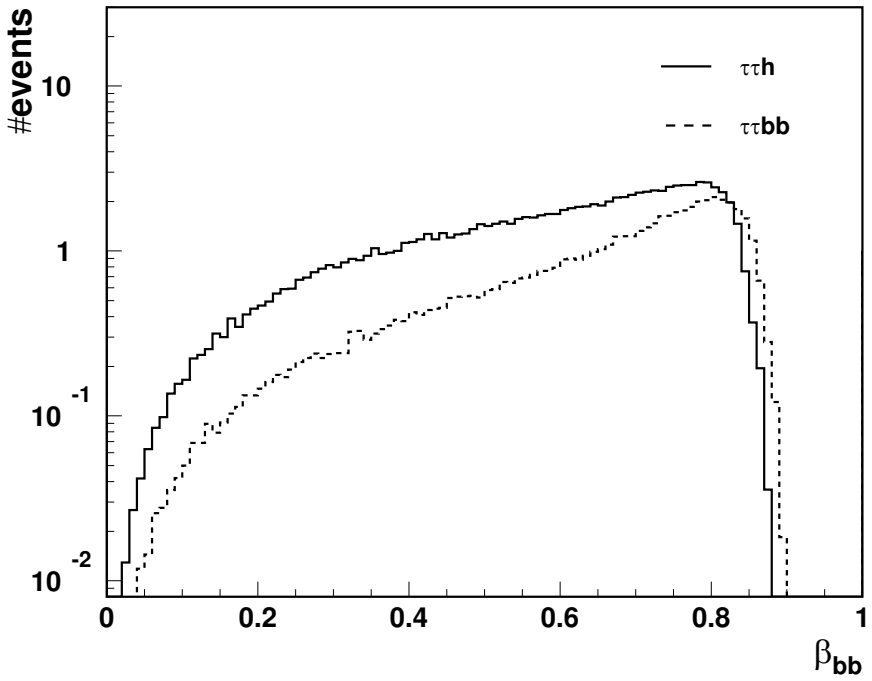
hadrons from OE



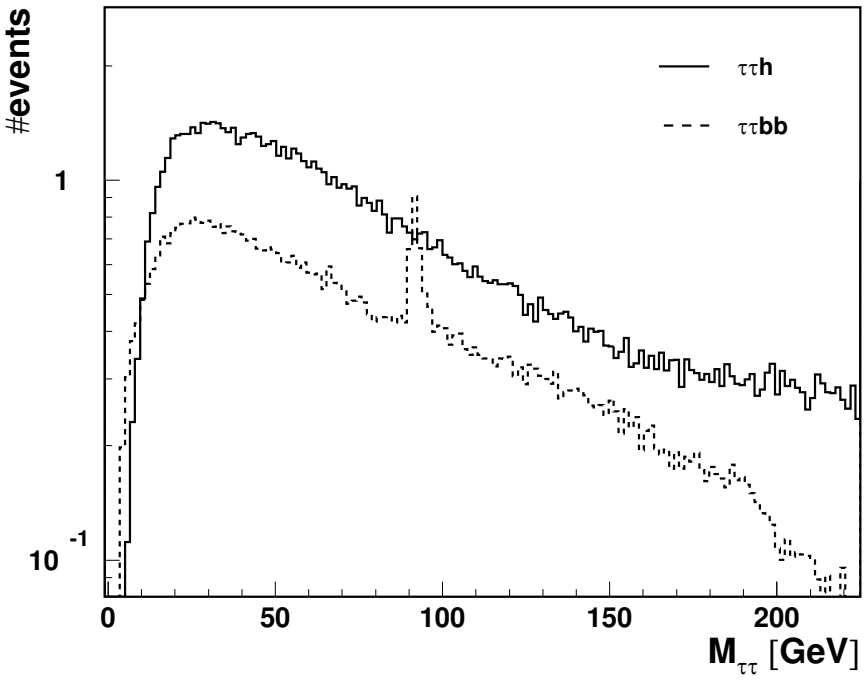
Identification of hadronic τ decays can be very difficult...

Generator level results

Boost of $b\bar{b}$ system



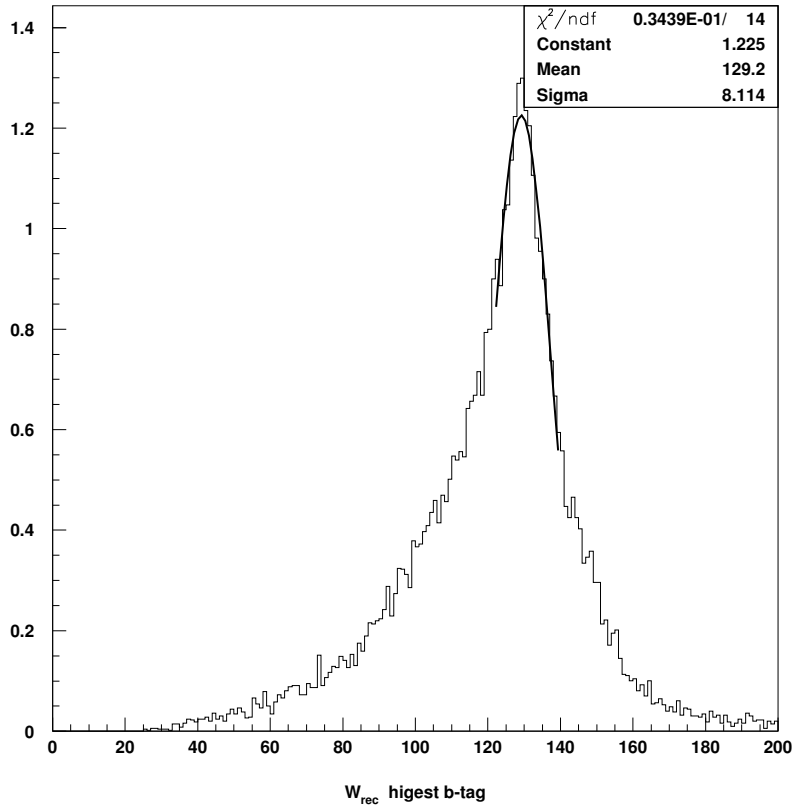
Invariant mass of $\tau^+\tau^-$ pair



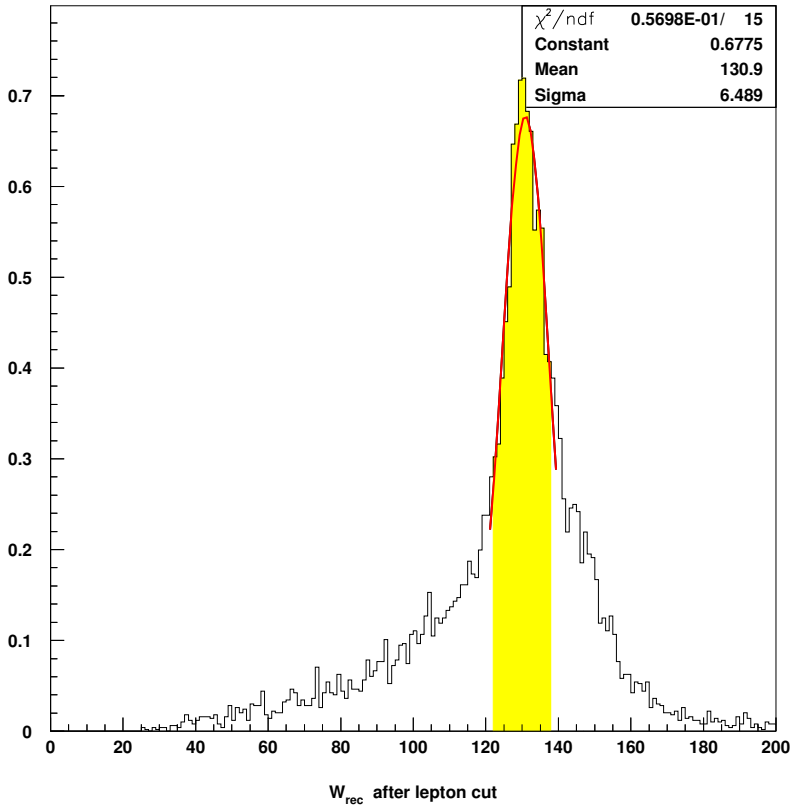
Detector level results

Reconstructed invariant mass of two b-tagged jets for signal events (M_h= 130 GeV)

without lepton cut



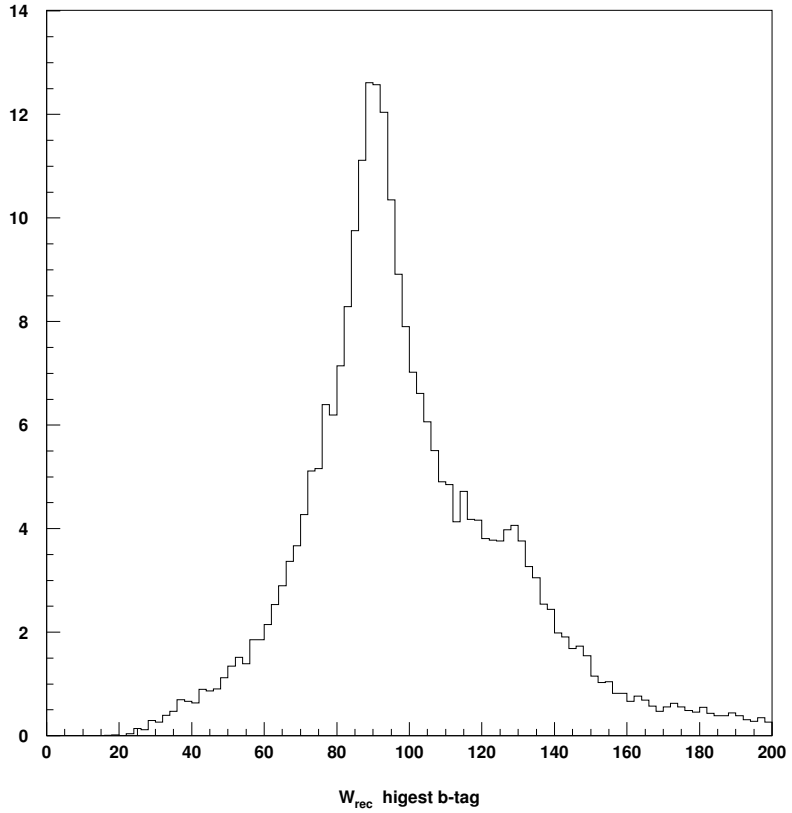
with lepton cut



Detector level results

Reconstructed invariant mass of two b-tagged jets
for signal and background events (M_h= 130 GeV)

without lepton cut



with lepton cut