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Impact of the Higgs width at large tan β on bH searches

- Introduction
- Problem
- Breit Wigner Resonance
- BH Production Cross Section at NLO for a 0 width Higgs boson
- Event Spectrum
- P_{Tb} Dependence of the Cross Section for a 0 width Higgs boson
- Event Spectrum by P_{Tb} Bins
- Effect on the Analysis :
  - * Invariant Mass
  - * Limits

Introduction

- MSSM : 2 Higgs doublets
  - * 5 Higgs bosons : 3 neutral A, h, H and 2 charged H^+, H^-
  - * At LO, 2 parameters are needed to describe the Higgs sector :

eg m_A and $\tan\beta = v_1/v_2$ where v_1 and v_2 are the vevs of the 2 Higgs doublets

- The bA/h/H production is greatly enhanced compared to the MS

  Cross sections increase like $\tan^2\beta$

- In 90% of the case, A/h/H -> bb

  We look for 3 or 4 btagged jets by events

- Analysis was done on 260 pb^{-1} taken by DØ from November 02 to July 04

  The invariant mass peak of the 2 leading jets was reconstructed

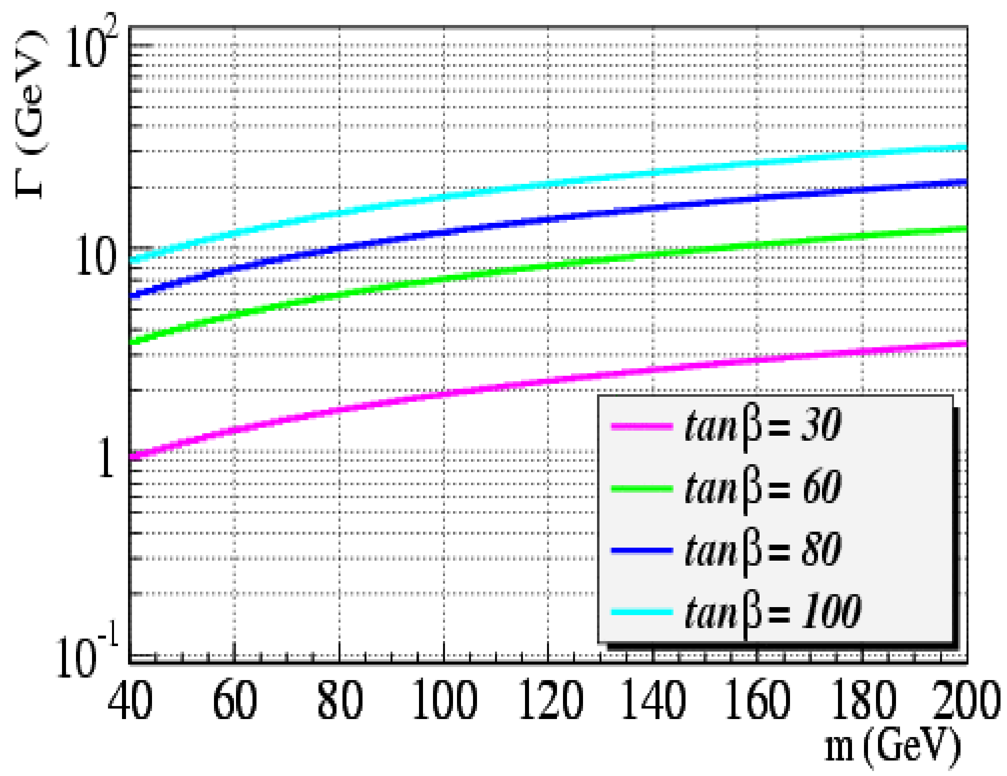
  => as no excess in data was seen, limits in the plan $\tan\beta$ – m_A were set.

cf Andy Haas' talk

Problem I looked at

- Given the integrated luminosity used in DØ bbH analysis, it is sensitive to the production of Higgs boson only at high tan β : for a Higgs mass of 150 GeV, the tan β excluded at 95% CL are above 93

Higgs Width from HDECAY



- The Higgs width, which goes like tan β^2, is sizable and its influence has to be studied :

  m_H = 150 GeV

  expected tan β limit = 93

  Γ(150 GeV, 93) = 22 GeV

Relativistic Breit Wigner

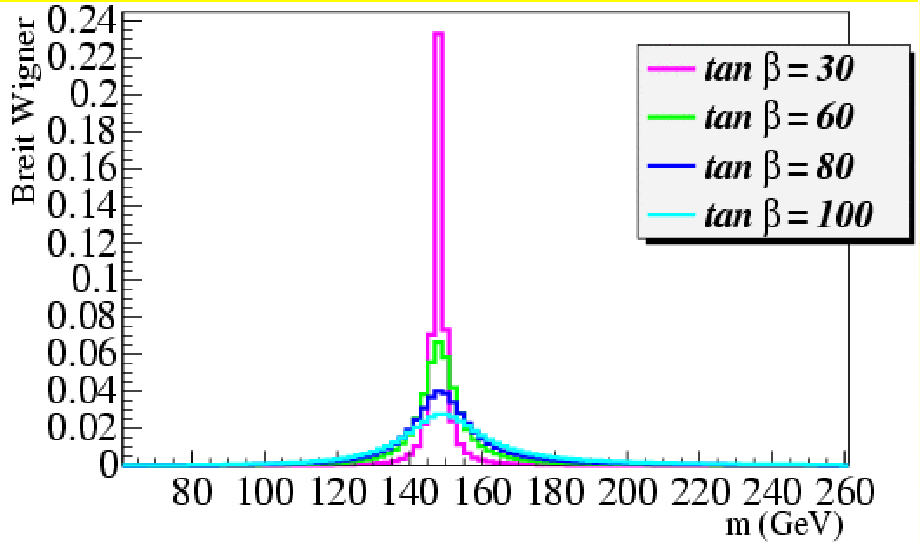
Relativistic BW for a Higgs boson of mass m_H and width Γ:

$$\mathrm{BW}(m_H, m, \tan\beta) \propto \frac{m\,\Gamma(m, \tan\beta, m_H)}{(m^2 - m_H^2)^2 + \Gamma(\tan\beta, m_H)^2 m_H^2}$$

where Higgs boson's width at the scale m is given by :

$$\Gamma(m, \tan\beta, m_H) = \Gamma(m_H, \tan\beta)\left(1 - 4\frac{m_b^2}{m^2}\right)^{\frac{3}{2}} \frac{m}{m_H}$$

Relativistic BW for m_H = 150 GeV



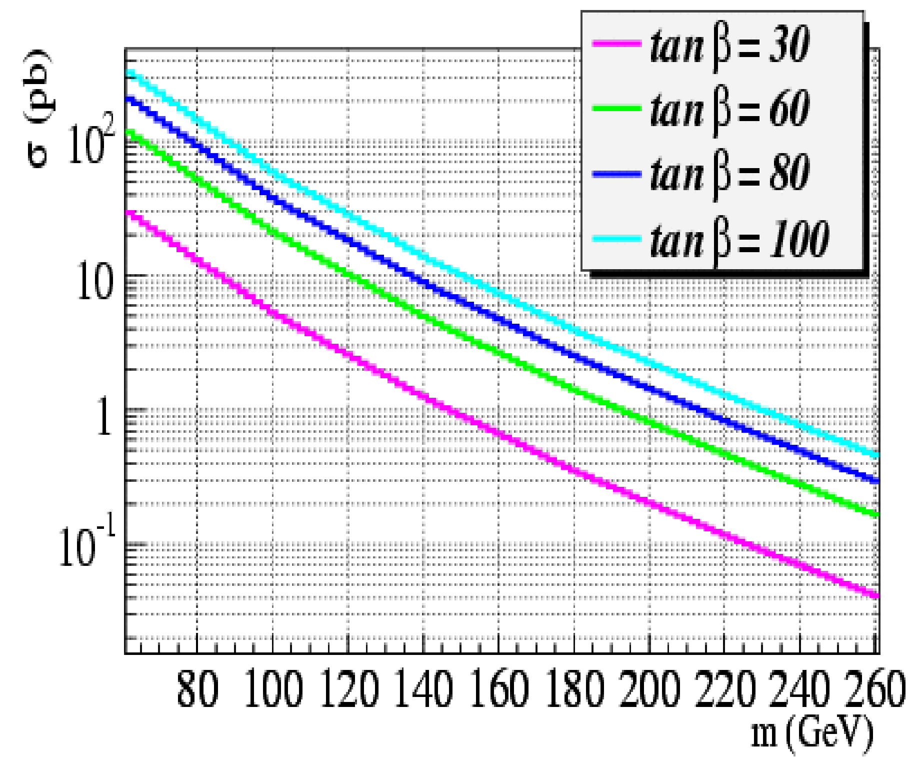
Cross section for bH process for a 0 width Higgs boson

$$\sigma(\mathrm{m}, \tan\beta, \mathrm{p_{T\,b}})$$

Hb production cross section for a 0 width Higgs boson

Transverse momentum of the b quark produced in association with the Higgs

Cross section for a 0 width Higgs (pb)



Cross section integrated over P_{Tb}

- Computed at NLO using MCFM code (Monte Carlo for FeMtobarn process from Campbell and Ellis)
- Requirement : $P_{Tb} > 15$ GeV, $|\eta_b| < 2$

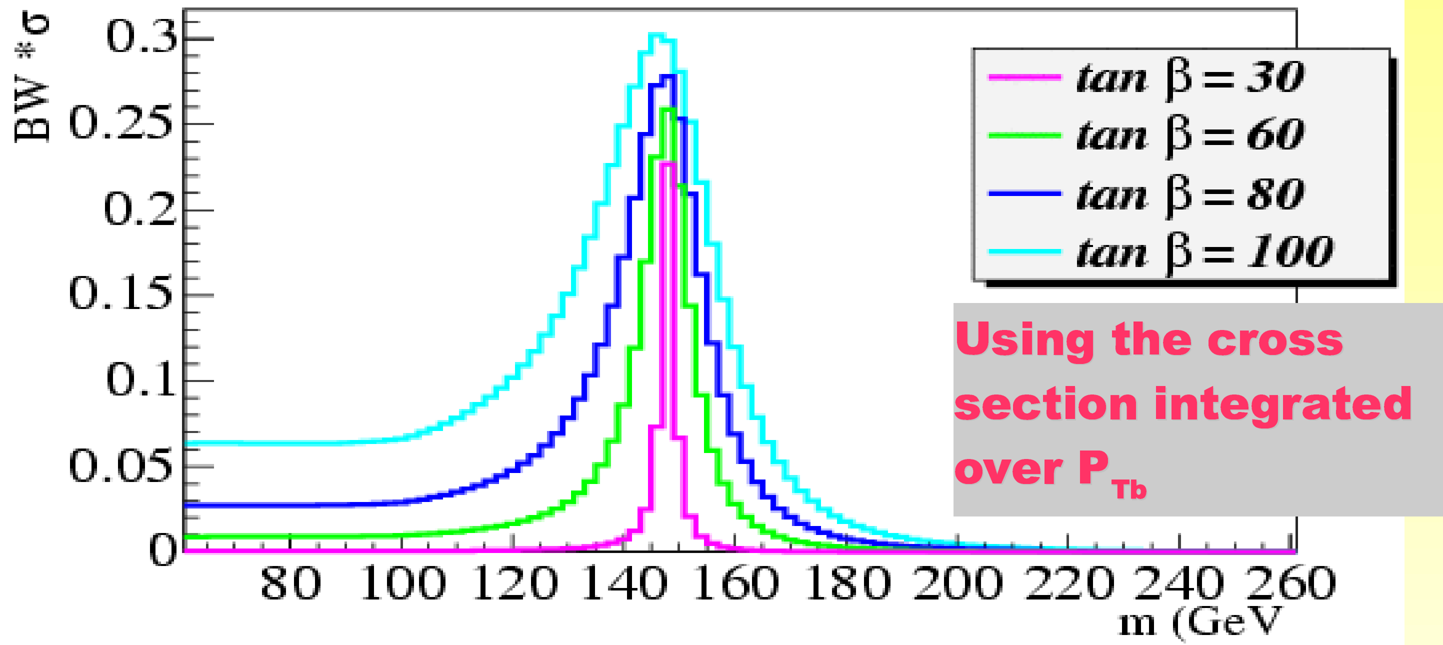
My cross section is in agreement with predictions of Willenbrock (hep-ph/204093)

Event Spectrum using the cross section integrated over P_{Tb}

The event spectrum is obtained by weighting the Breit Wigner by the bH cross section :

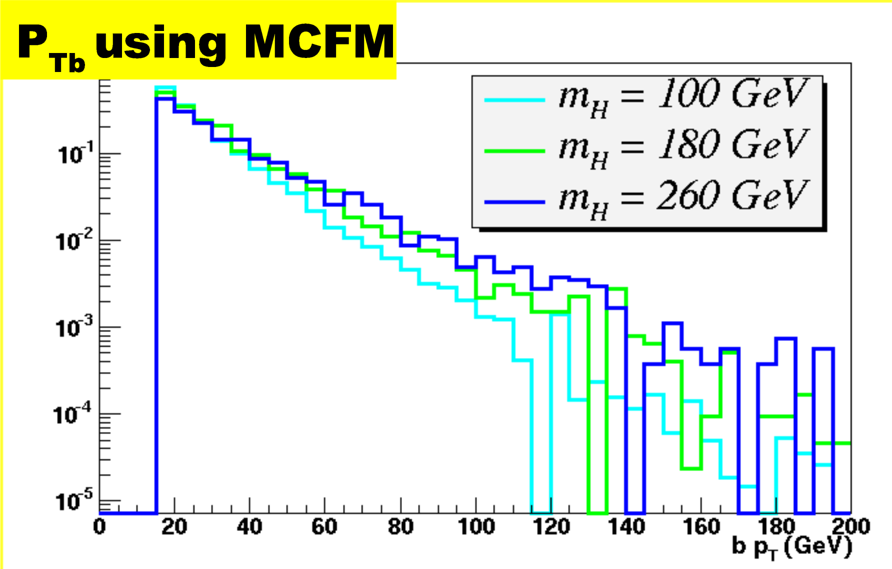
$$\mathrm{BW}(\mathrm{m_H}, \mathrm{m}, \tan\beta)\sigma(\mathrm{m}, \tan\beta, \mathrm{p_{T\,b}})$$

BW·σ for a Higgs mass of 150 GeV



Since bH production cross section varies by 2 orders of magnitude between 60 and 120 GeV, the event spectrum show a tail at low mass for tan β > 60 that can yield a loss in signal acceptance due to Higgs fluctuating low in mass.

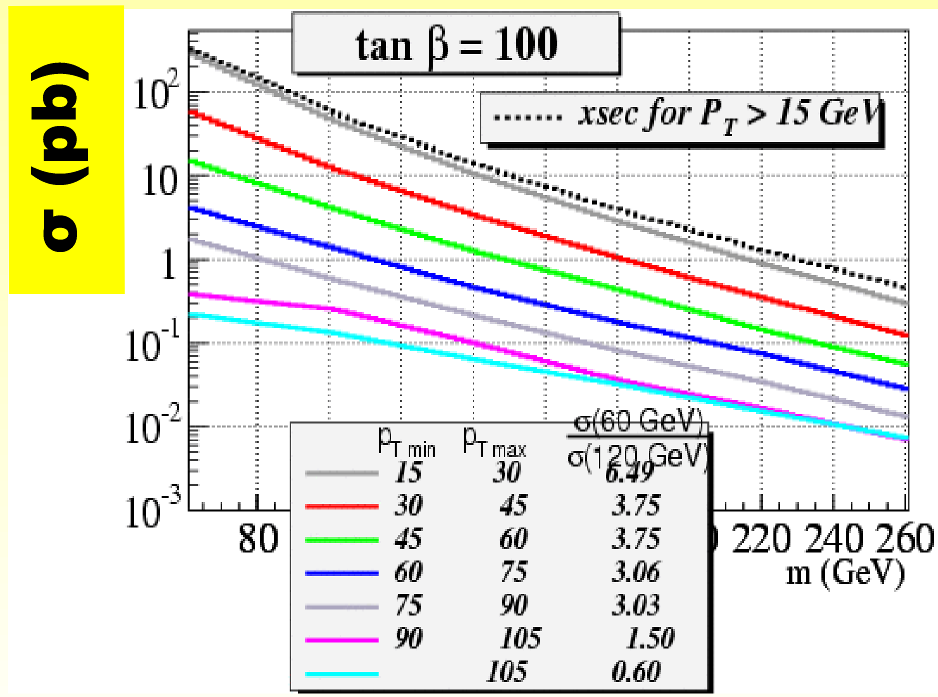
P_{Tb} dependence of bH production cross section for a 0 width Higgs boson



Heavier higgs meaning harder b's momenta spectrum, one must use a differential cross section instead of an integrated one.

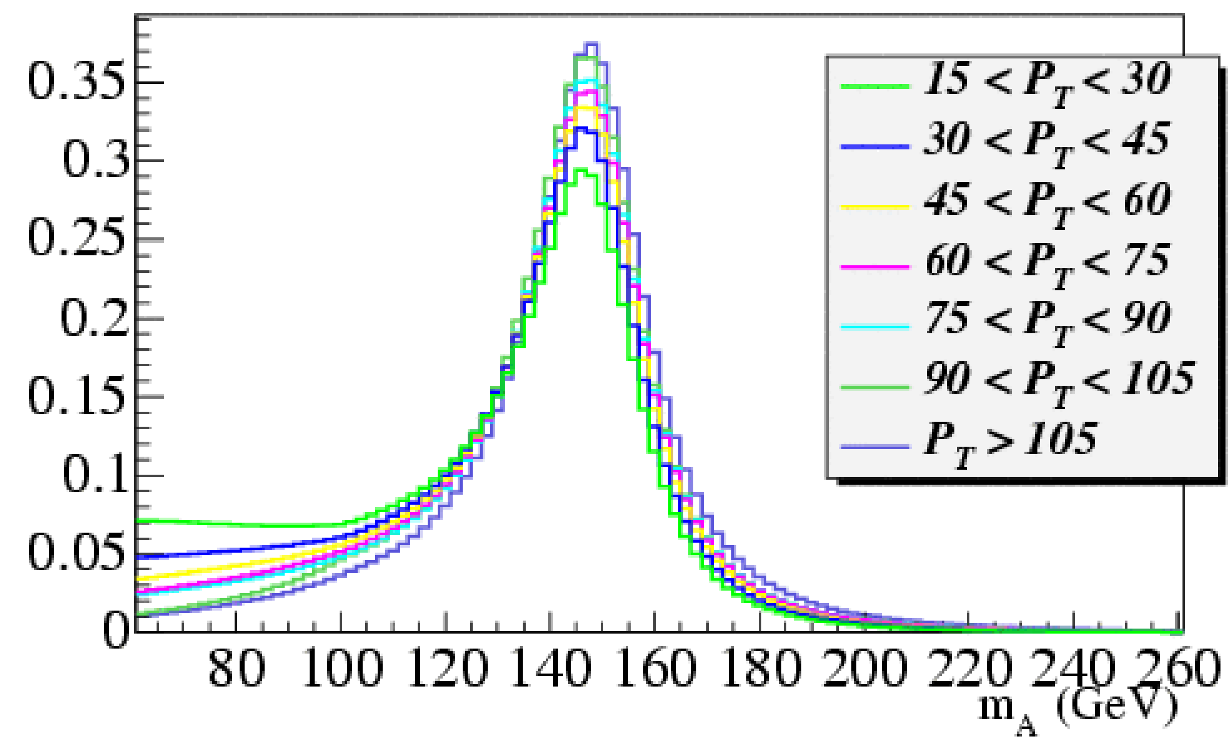
The cross section was computed for 7 P_{Tb} bins using MCFM (15-30, 30-45, 45-60, 60-75, 75-90, 90-105, > 105 GeV)

Cross section varies less with Higgs mass for higher p_{Tb}.



Event spectrum using the differential cross section

For a Higgs mass of 150 GeV and tan β = 100



Tail is smaller for high P_{Tb} events.

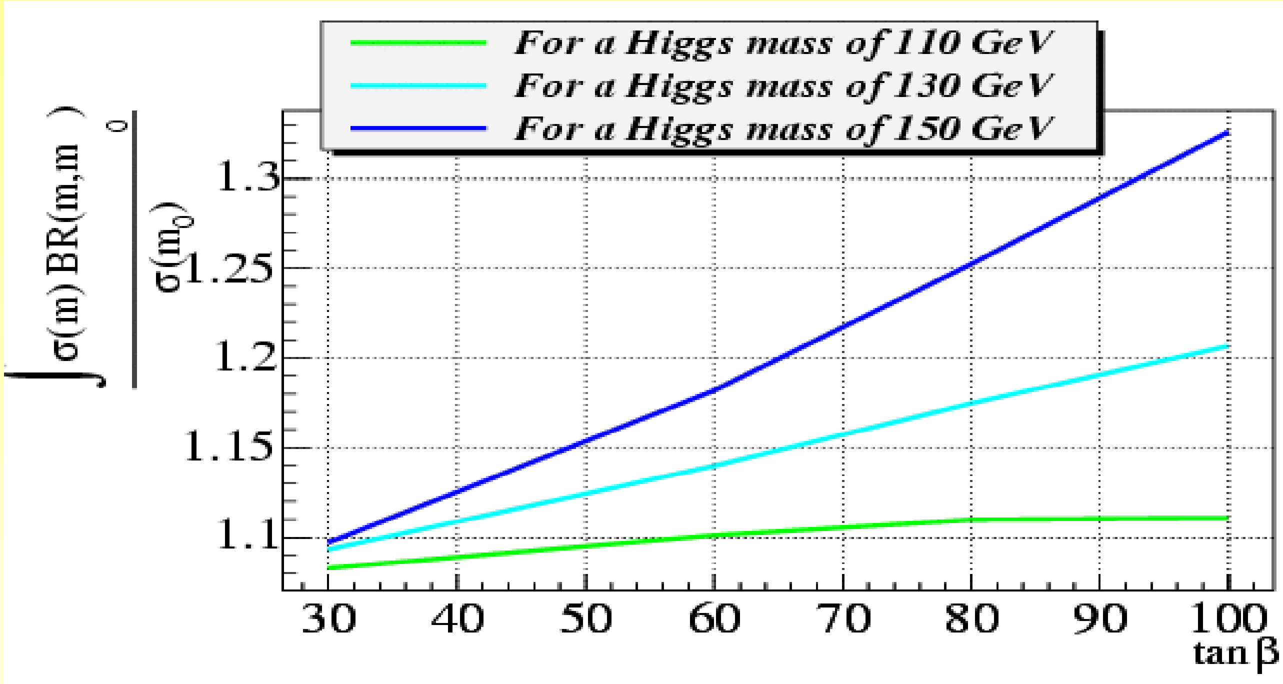
So the width effect that tends to be larger for heavy Higgs because of the larger width is toned down by the harder P_{Tb} spectrum.

Cross section if Higgs width is taken into account

- The cross section if we don't neglect the Higgs width is given by :

$$\int \mathrm{BW}(\mathrm{m}, \mathrm{m_H})\sigma(\Gamma = 0, \mathrm{m})\, \mathrm{dm}$$

- The ratio between the cross section with a non 0 Higgs width and the one with a 0 Higgs width (versus tan β):



Cross section is always increased if taking Higgs width into account. The possible loss in signal acceptance is then soften by this larger cross section.

A bit more on bbH analysis

- Signal : 3 or 4 b-tagged jets
- Background :
  - * multijet production jjj(j), bbj(j), bbbb
  - * other : Z+jets production, Top pair production
- Analysis cut :

We look only at events that pass a multijet trigger and satisfy :

- quality cuts on jets
- taggability criteria
- at least 3 and at most 5 jets with $|\eta|<2.5$
- kinematic cuts on the 3 leading jets P_T's (optimized for each Higgs mass)

eg for m_H=120 GeV $P_T(1^{st})>45$ GeV, $P_T(2^{nd})>25$ GeV, $P_T(3^{rd})>15$ GeV

- 3 or 4 b-tagged jets

- Look at the invariant mass of the 2 leading jets : search for an excess of events consistent with a Higgs signal shape.

Effect on the analysis (1)

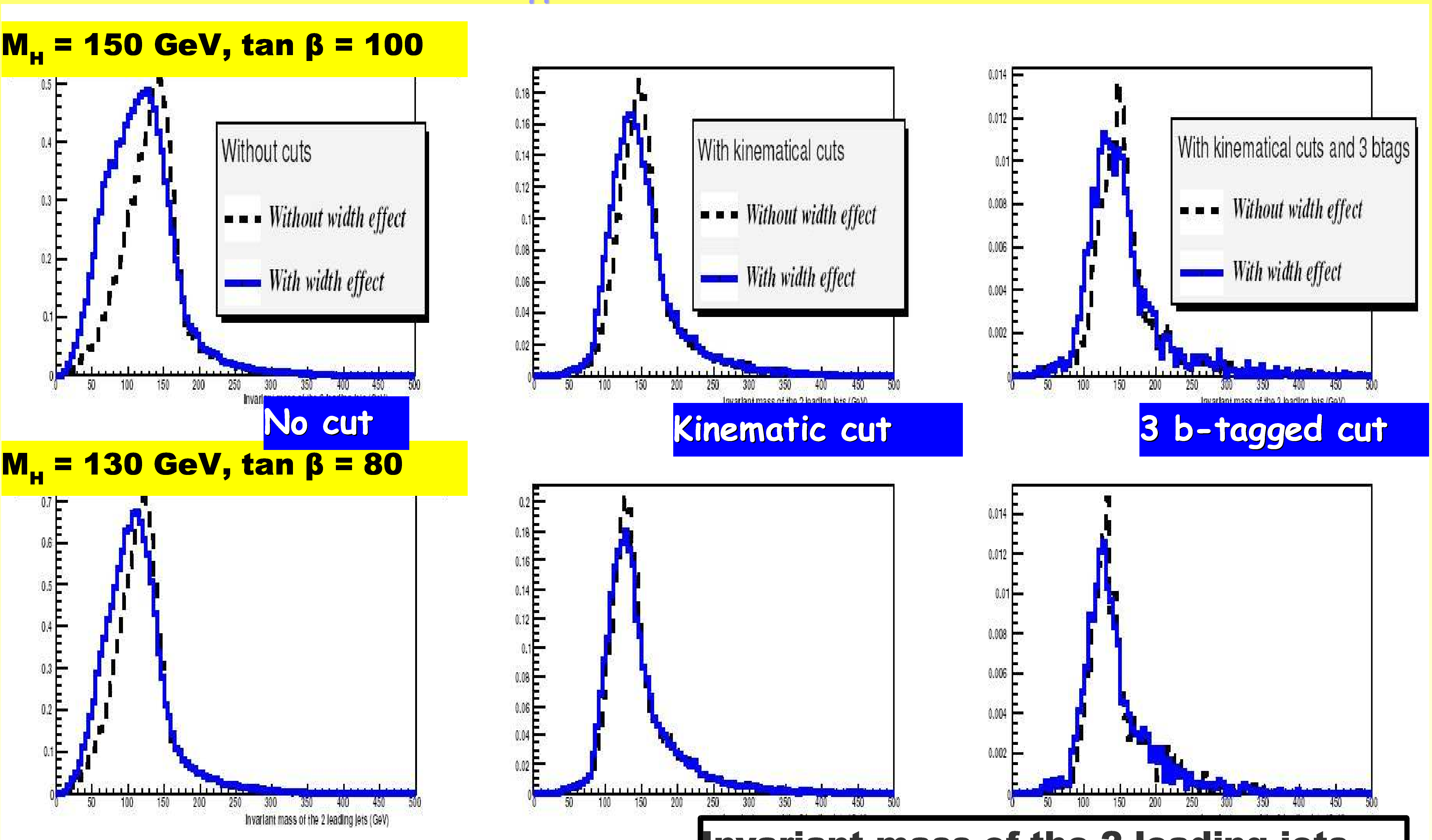
- The Monte Carlo was smeared using the spectra

$$\mathrm{BW}(\mathrm{m_H}, \mathrm{m}, \tan\beta)\sigma(\mathrm{m}, \tan\beta, \mathrm{p_{T\,b}})$$

* We assume that the 2 leading jets come from the Higgs, and the 3rd leading jet comes from the b produced in association with the Higgs.
* Depending on the 3rd jet P_{Tb}, the associated spectrum BW.σ(P_{Tb}) was used to rescale the P_T's of the 2 leading jets in each event, by randomly picking a scale following the BW.σ(P_{Tb}) distribution.
* It was checked that smearing at the reconstructed level, as opposed to the parton level, yields to similar invariant mass spectrum.

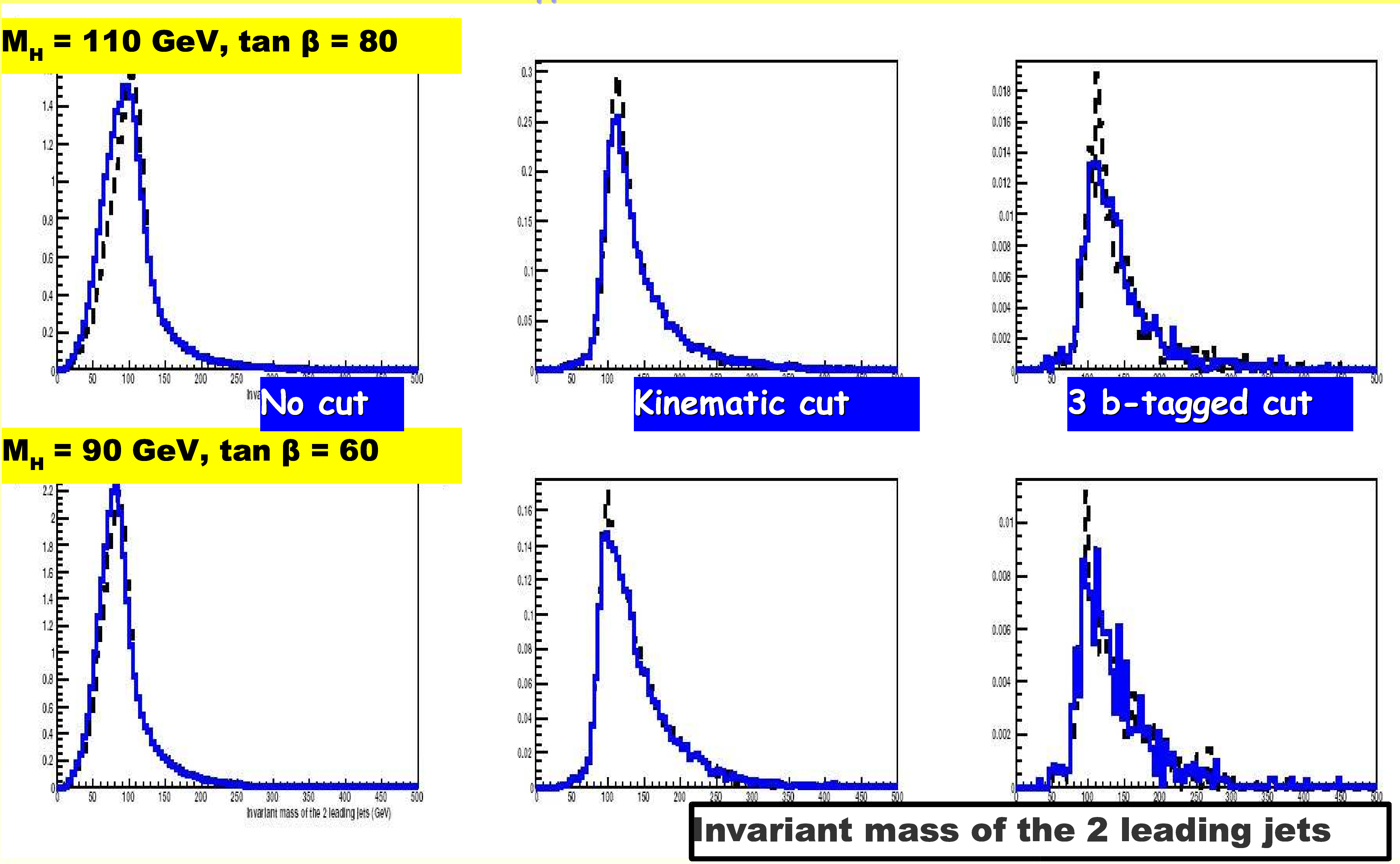
- We then compared the invariant mass of the 2 leading jets with and without Higgs boson width, as well as the limits obtained in both case.

Effect on the analysis (2): Invariant mass peak for m_H = 150 and 130 GeV



Invariant mass of the 2 leading jets

Effect on the analysis (3): Invariant mass peak for m_H = 110 and 90 GeV



Effect on the analysis (4): limits

Limits are set using the previous invariant mass peak, and compared to the limits obtained neglecting the Higgs width :

Shift in tan β expected limit induced by the Higgs width:

Higgs mass (GeV)	Higgs width (GeV)	Shift of $\tan\beta$ limit
150	25	1
130	22	1
110	13	2
90	11	0.5

Limits are always slightly weaker if taking Higgs width into account.

Conclusion

3 effects are seen :

- the event spectrum tail at low mass due to the large variation of the bH cross section at law mass

=> can lead to loss in signal acceptance due to Higgs fluctuating low in mass

- the variation of the cross section with the 3rd b jet P_T : the cross section at high P_{Tb} varies less

=> the event spectrum tail is smaller for high P_{Tb} that is for high Higgs mass

- the bH cross section taking the Higgs width into account is always higher than the one for a 0 width Higgs boson

=> the possible loss in efficiency is compensated with a higher cross section

With our analysis cuts, the events that are added through the Higgs width effect are cut.

The Higgs width can be neglected with the current analysis cuts, until at least a Higgs mass of 150 GeV and tan β = 100.