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Oxford
March 20th
(1999)

HIGGS self couplings

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* Conclusion(s) ?

hep-ph/9903229
DESY 99/001
TTP99-02
PM/99-01

Testing Higgs Self-couplings at e^+e^- Linear Colliders

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Abstract

To establish the Higgs mechanism *sui generis* experimentally, the self-energy potential of the Higgs field must be reconstructed. This task requires the measurement of the trilinear and quadrilinear self-couplings, as predicted, for instance, in the Standard Model or in supersymmetric theories. The couplings can be probed in multiple Higgs production at high-luminosity e^+e^- linear colliders. Complementing earlier studies to develop a coherent picture of the trilinear couplings, we have analyzed the production of pairs of neutral Higgs bosons in all relevant channels of double Higgs-strahlung, associated multiple Higgs production and WW/ZZ fusion to Higgs pairs.

CERN-TH/98-189
hep-ph/9806351

Measuring the Trilinear Couplings of MSSM Neutral Higgs Bosons at High-Energy e^+e^- Colliders

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Abstract

We present a detailed analysis of multiple production of the lightest CP-even Higgs boson (h) of the Minimal Supersymmetric Standard Model (MSSM) at high-energy e^+e^- colliders. We consider the production of the heavier CP-even Higgs boson (H) via Higgs-strahlung $e^+e^- \to ZH$, in association with the CP-odd Higgs

University of Bergen, Department of Physics
Scientific/Technical Report No.1999-01
ISSN 0803-2696
hep-ph/9902270
February 1999

Measuring Trilinear Higgs Couplings in the MSSM

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Abstract

Trilinear couplings of the neutral CP-even Higgs bosons in the Minimal Supersymmetric Standard Model (MSSM) can be measured through the multiple production of the lightest CP-even Higgs boson (h) at high-energy e^+e^- colliders. This includes the production of the heavier CP-even Higgs boson (H) via $e^+e^- \to ZH$, in association with the CP-odd Higgs boson (A) in $e^+e^- \to AH$, or via $e^+e^- \to \nu_e\bar{\nu}_e H$, with H subsequently decaying through $H \to hh$. These processes can enable one to measure the trilinear Higgs couplings λ_{Hhh} and λ_{hhh}, which can be used to theoretically reconstruct the Higgs potential. We delineate the regions of the MSSM parameter space in which these trilinear Higgs couplings could be measured.

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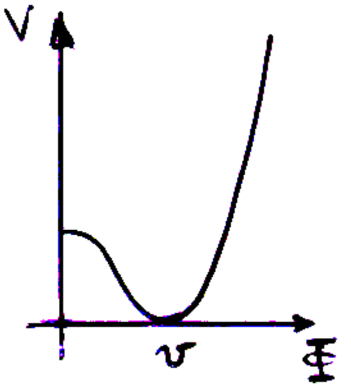
Introduction

Higgs potential has to be tested
(ultimate proof of the nature of H)

★ 

SM exemple

$$V(\Phi) = \lambda(\Phi^\dagger\Phi - v^2)^2$$

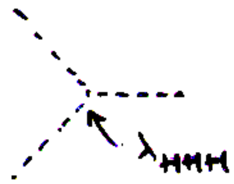
↑ quartic coupling

with $v = 174$ GeV

Thus

Higgs mass $\quad M_H^2 = 4\lambda v^2$

trilinear self coupling $\quad \lambda_{HHH} = 6\sqrt{2}\,\lambda v = 3M_H^2/\sqrt{2}\,v$



quartic linear self coupling $\quad \lambda_{HHHH} = 6\lambda = 3M_H^2/2v^2$

★ **MSSM case** much more complicated!

- 4 different λs in the potential
- All trilinear couplings exist!

$$\lambda_{hhh},\ \lambda_{hhH},\ \lambda_{hHH},\ \lambda_{HHH},\ \lambda_{hAA},\ \lambda_{HAA}$$
$$\lambda_{hH^+H^-},\ \lambda_{HH^+H^-}$$

functions of α, β

★ It's very important (fundamental) to measure these trilinear couplings.

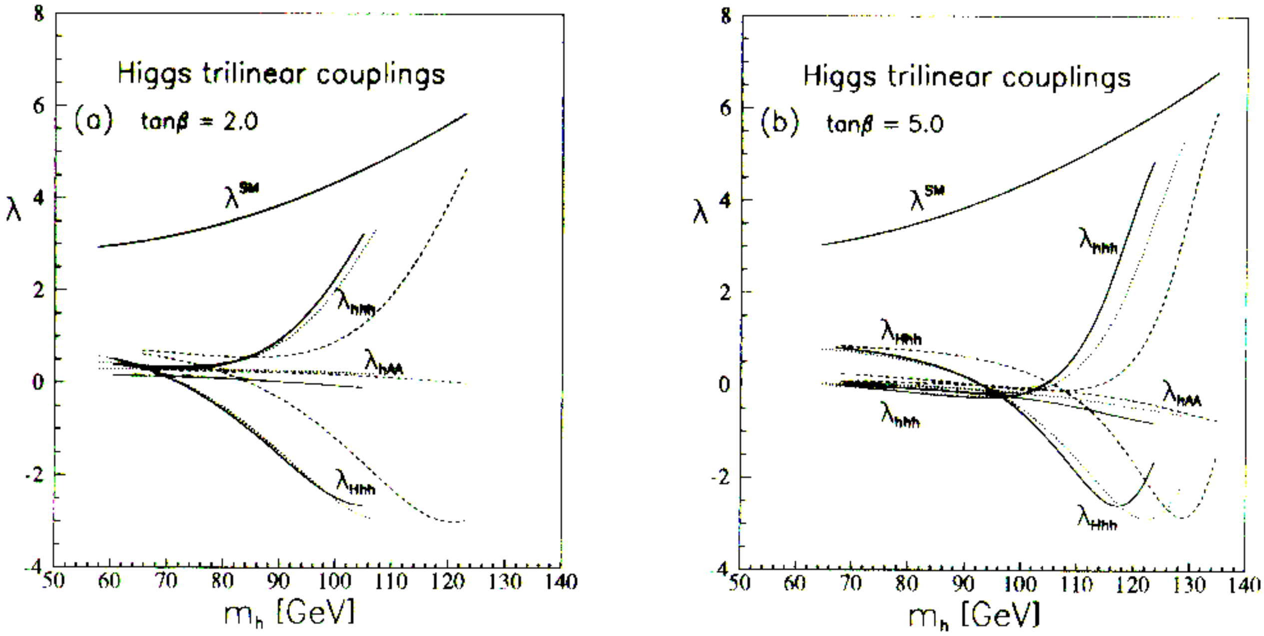


Figure 1: Trilinear Higgs couplings λ_{Hhh}, λ_{hhh} and λ_{hAA} as functions of m_h for two values of $\tan\beta$: (a) $\tan\beta = 2.0$, (b) $\tan\beta = 5.0$. Each coupling is shown for three cases of the mixing parameters: no mixing ($A = 0$, $\mu = 0$, solid), mixing with $A = 1$ TeV and $\mu = -1$ TeV (dotted), as well as $A = 1$ TeV and $\mu = 1$ TeV (dashed).

from Osland / Pandita

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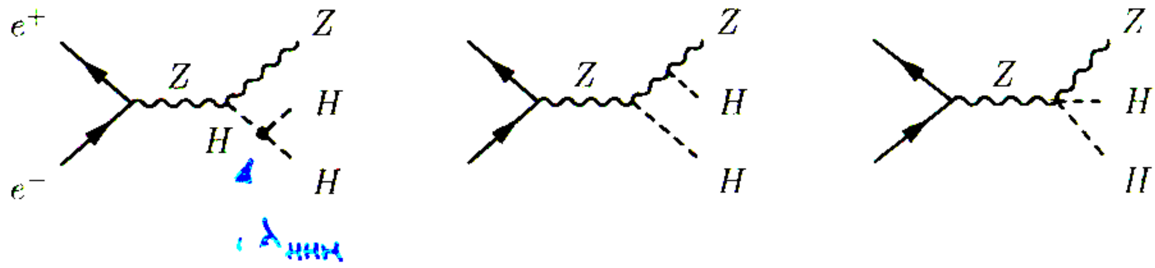
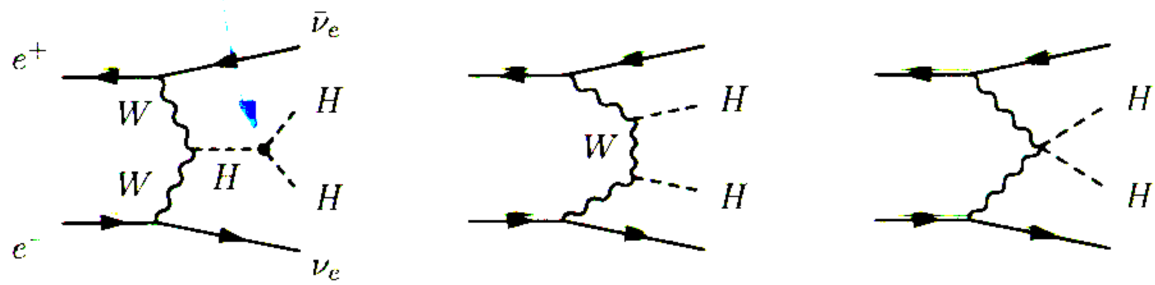
The simplest case

SM !

double Higgs-strahlung: $e^+e^- \to ZHH$



WW double-Higgs fusion: $e^+e^- \to \bar{\nu}_e \nu_e HH$



ZHH important for $\sqrt{s} \lesssim 500$ GeV

fusion dominant $\sqrt{s} > 500$ GeV

X-sections for $M_H = 110$ GeV

ZHH @ $\sqrt{s} = 500$ GeV : ~ 0.2 fb

fusion @ $\sqrt{s} = 1$ TeV : ~ 0.1 fb

ZHH feasibility study @ $\sqrt{s} = 500$ GeV with $M_H = 100$ GeV

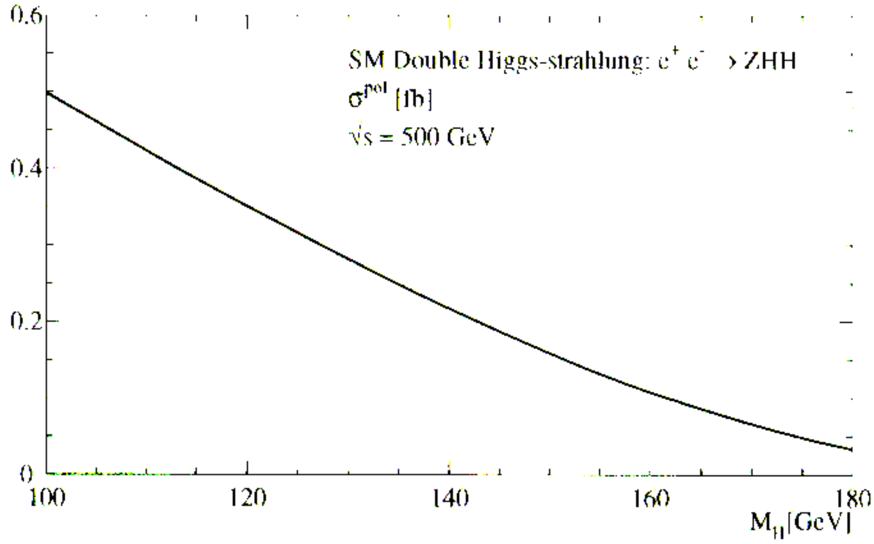


Figure 1: The cross section for double Higgs-strahlung in the SM at the collider energy $\sqrt{s}$ = 500 GeV. The electron-positron beams are taken oppositely polarized.

↑ important.

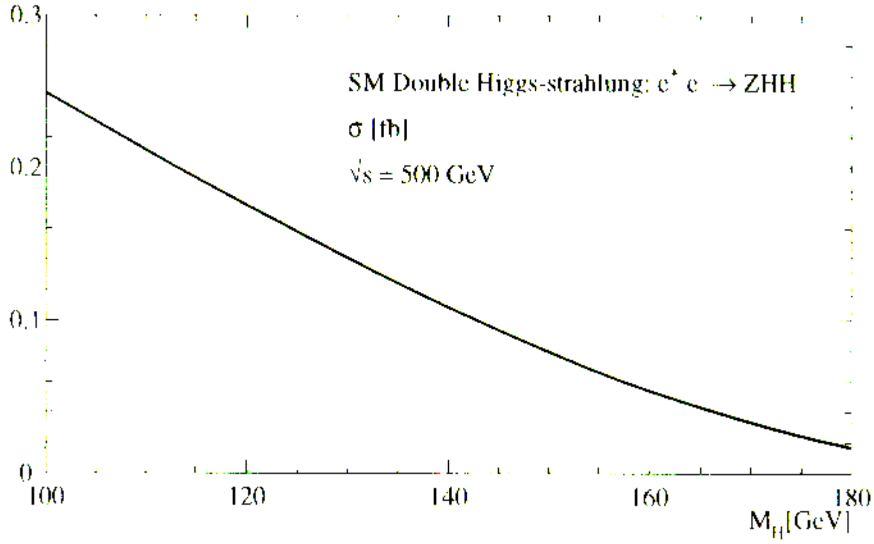


Figure 2: The cross section for double Higgs-strahlung in the SM at the collider energy $\sqrt{s}$ = 500 GeV. The electron-positron beams are unpolarized.

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SM, $\sqrt{s}$ = 500, M_H = 100, HHZ channel

signal : x-section : 0.25 fb

signature : 1Z and 2H

(GRACE) 6 jets, kin. fits, btag)

background(s)

			x-section
"2 fermion"	$q\bar{q}(\gamma)$ including $t\bar{t}$!	↑	8200 fb
"4 fermion"	W^+W^-	(PYTHIA)	7700 fb
	Z^0Z^0		550 fb
	Ze^+e^-/$We\nu$	↓	12700 fb
	HZ	(HZHA)	70 fb
"6 fermion"	WWZ	(GRACE)	20 fb
	ZZZ		0.53 fb

most difficult background : $Zb\bar{b}b\bar{b}$! $\gtrsim$ 0.02 fb

reducible only thru kin. fit !

generator level study ! simple sequential analysis.

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Summary: x-sections, in fb.

	Initial	cut #1 (multihadron)	cut #2 (multi-jet)	cut #3 (rough kin. compatibility)	cut #4 (btag)
Signal	0.175	0.172	0.169	0.129	0.014
$q\bar{q}(\gamma)$	8200	164	110	38	–
WW	7700	1740	154	8	–
ZZ	550	148	20	5	–
Weν/Zee	12700	2	2	–	–
HZ	70	33	4	2	–
ZZZ	0.53				
WWZ	20				
Total bgd	~ 29 pb	~ 2 pb	< 300 fb	~ ?	?
s/b	$< 10^{-5}$	$\sim 10^{-4}$	$\sim 8.10^{-4}$	?	?

8 ÷ 10% efficiency.

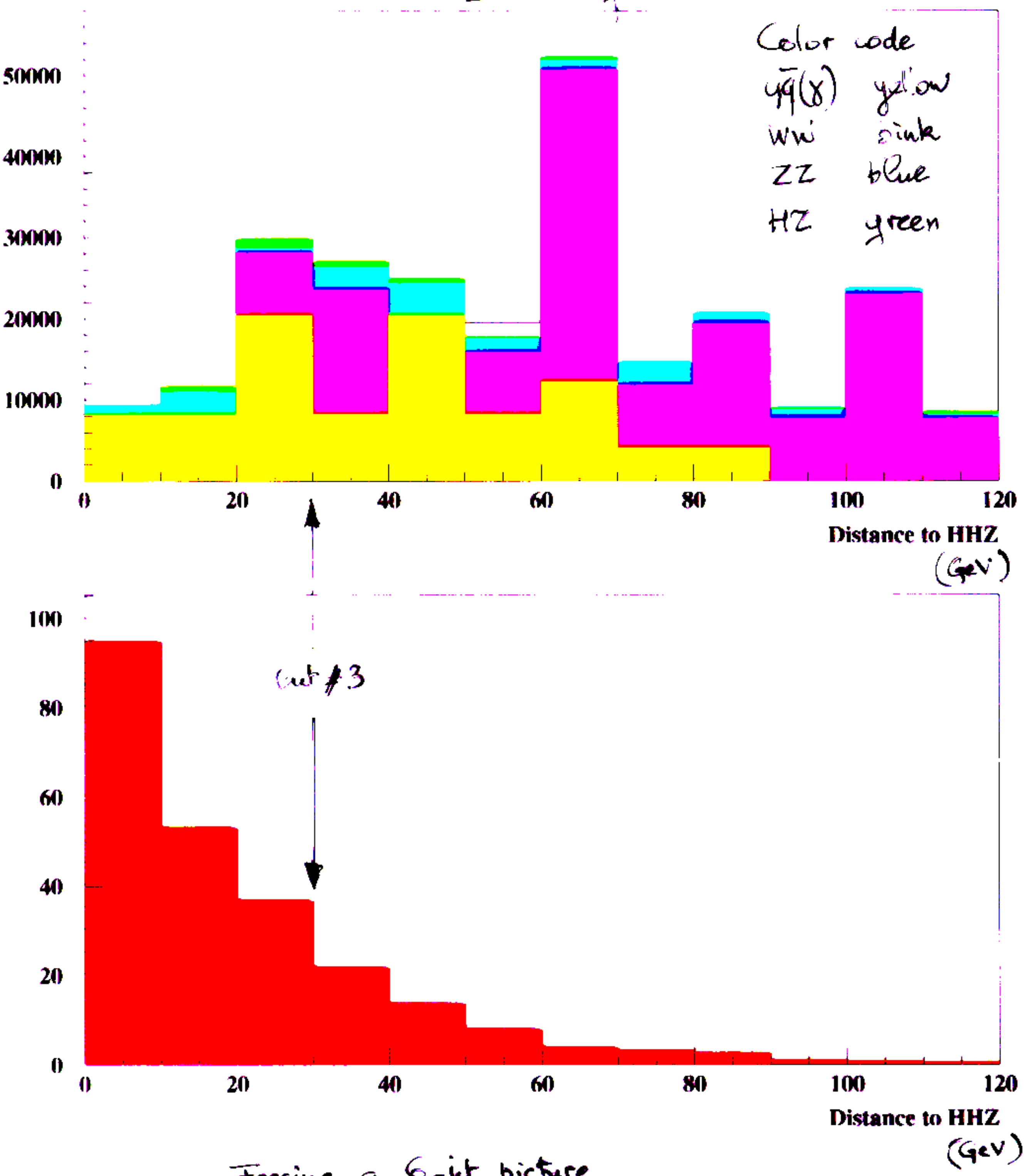
caveat: 1) statistics not enough

2) major backgrounds (WWZ and ZZZ) not generated yet!

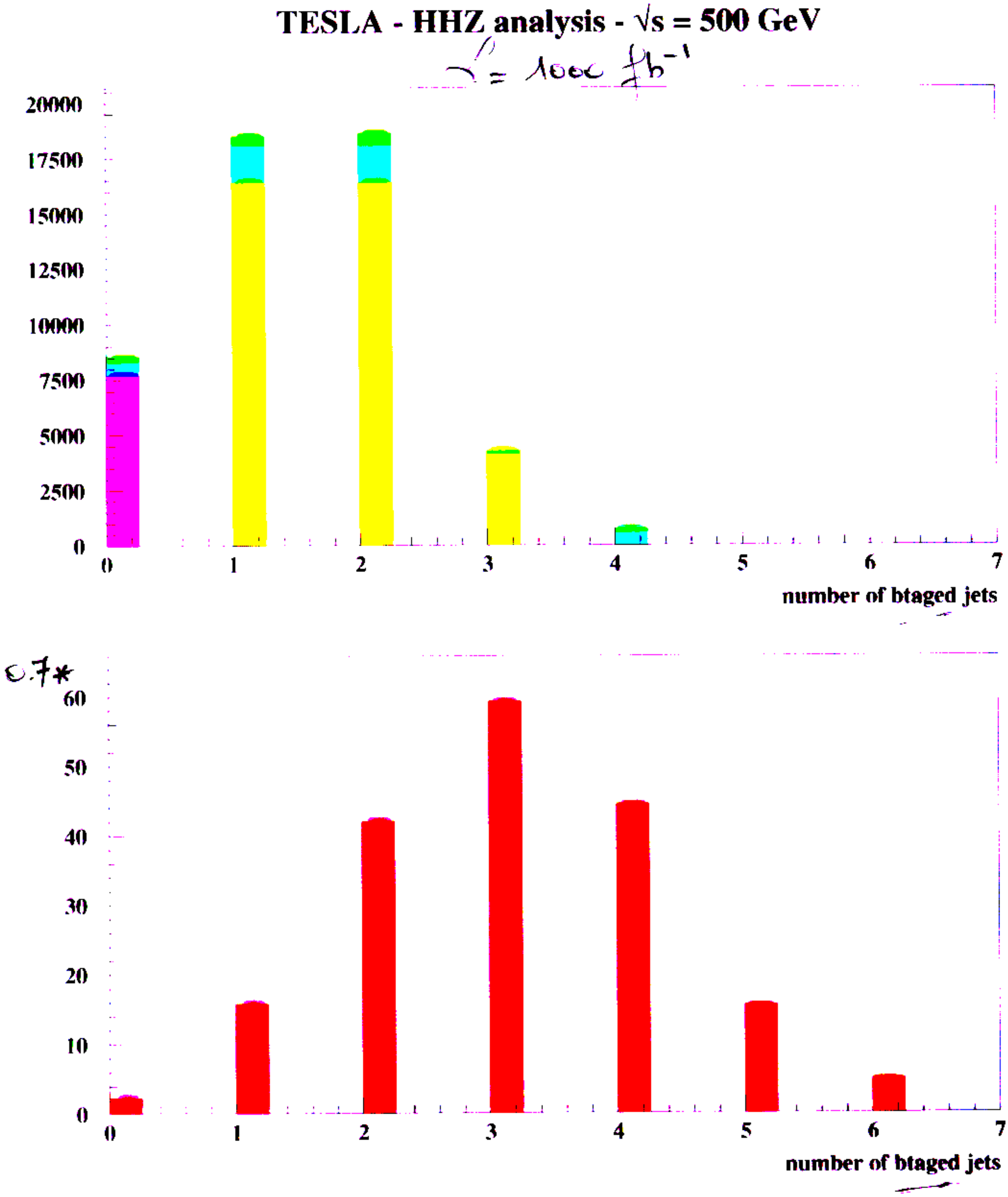
1) and 2) will be covered before SITGES!
Together with an overall optimisation of this set of cuts
No hope for a SGV/SIMDET/BRAHMS simulation...

TESLA - HHZ analysis - √s = 500 GeV

$\mathcal{L} = 1000\ fb^{-1}$

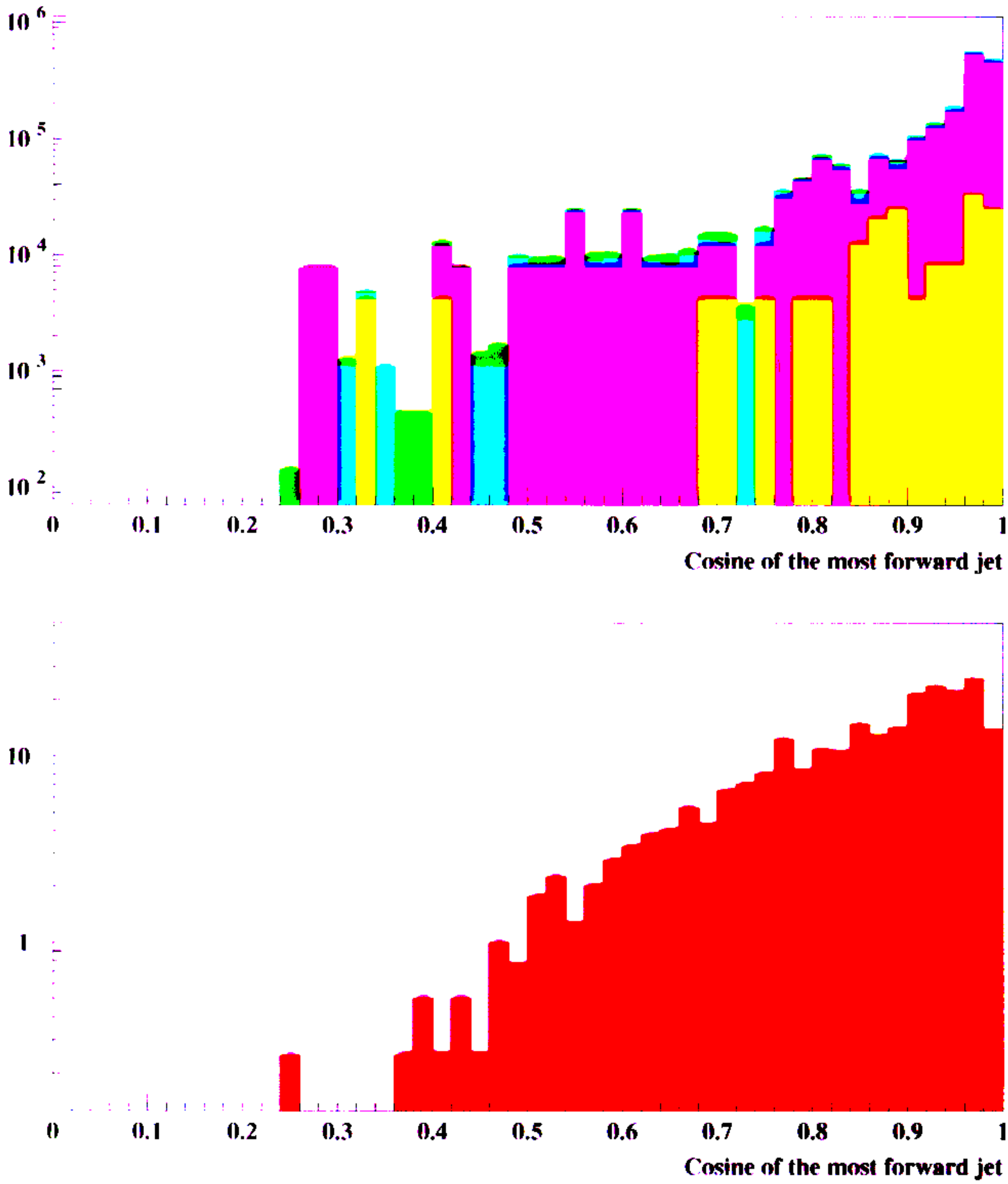


Forcing a 6-jet picture
15 bijets , 15 triplets of bijets
compute the min. (euclidian) distance to
(100., 100., 91.2)



cut #4 : selecting a high number of b-jets.

TESLA - HHZ analysis - √s = 500 GeV



We need : – a very good forward acceptance
– a very good forward btag !
vertex detector coverage up to
$\cos\theta \sim .94$

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Conclusions

- It seems feasible to
  - * claim evidence for (SM) HHZ events ($\hookrightarrow q\bar{q}$)
  - * measure the cross-section (errors ?)
  - * deduce a value for λ_{HHH} (precision ? $\lesssim 20\%$)

- under a (few) mandatory conditions.
  - * ~ low $\sqrt{s}$, but very high luminosity !

→ $\mathcal{L} \gtrsim 500\ fb^{-1}$ (SM)
   $\mathcal{L} \sim 1000\ fb^{-1}$ (MSSM)

  - * with a detector with a good forward accept.

→ jet reconstruction down to < 10°
   btagging capability down to < 20°

Challenging, but rewarding.