Higgs Physics at the Linear Collider

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DESY

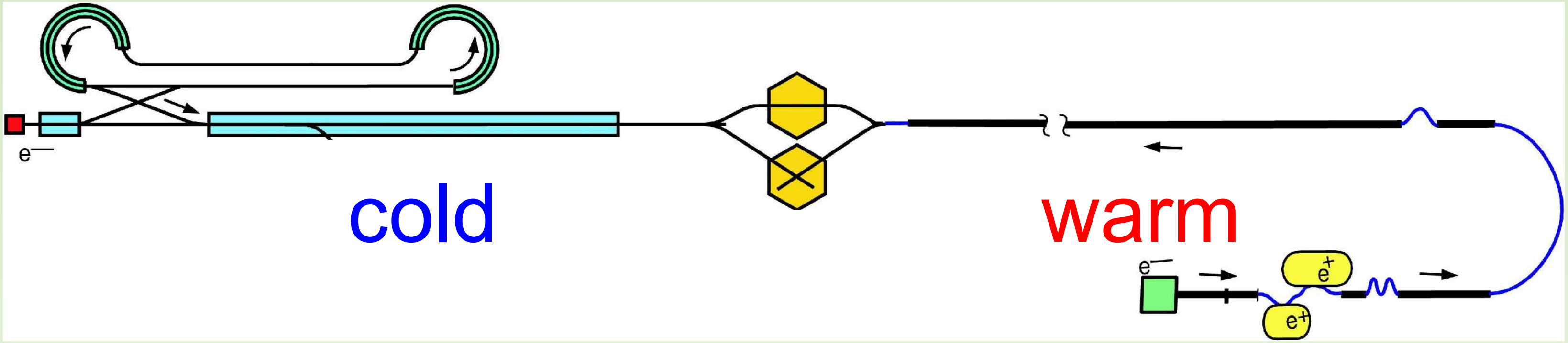
Content:

- Introduction
- Model independent : recoil mass
- SM like Higgs boson: mass, branching ratios, CP, self coupling
- Higgs pair production

New: Physics, machine, detector and tools performance

Linear Collider

e^+e^--Linear Collider $\sqrt{s}$=350 ... 1000 GeV, Luminosity ≈ 500fb^{-1}



Detector:

Momentum resolution:

$\delta(1/p) = 7 \times 10^{-5}$/GeV (1/10×LEP, LHC)

Jet energy resolution:

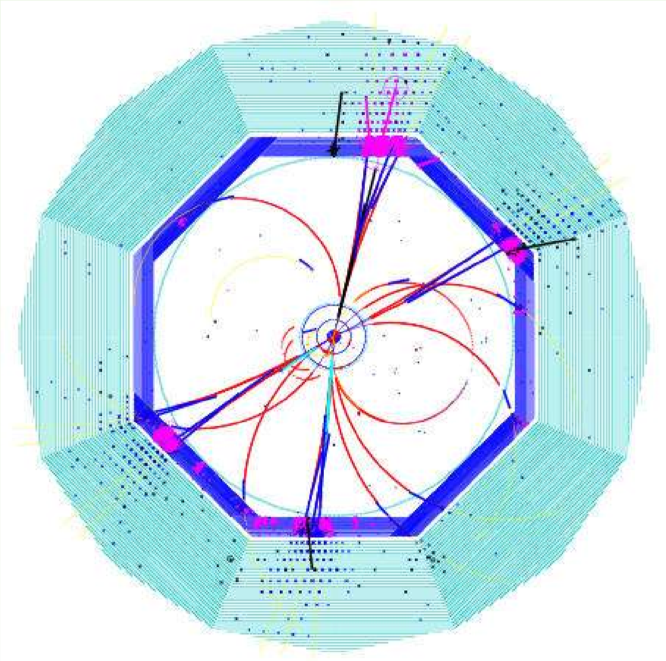
$\delta E/E = 0.3/\sqrt{E(\text{GeV})}$ (<1/2×LEP)

Impact parameter resolution:

$\delta d=(5\oplus 10/p(\text{GeV}))\mu m$ (1/3×SLD)

Hermeticity:

up to ≈ 25 mrad



Physics at the LC

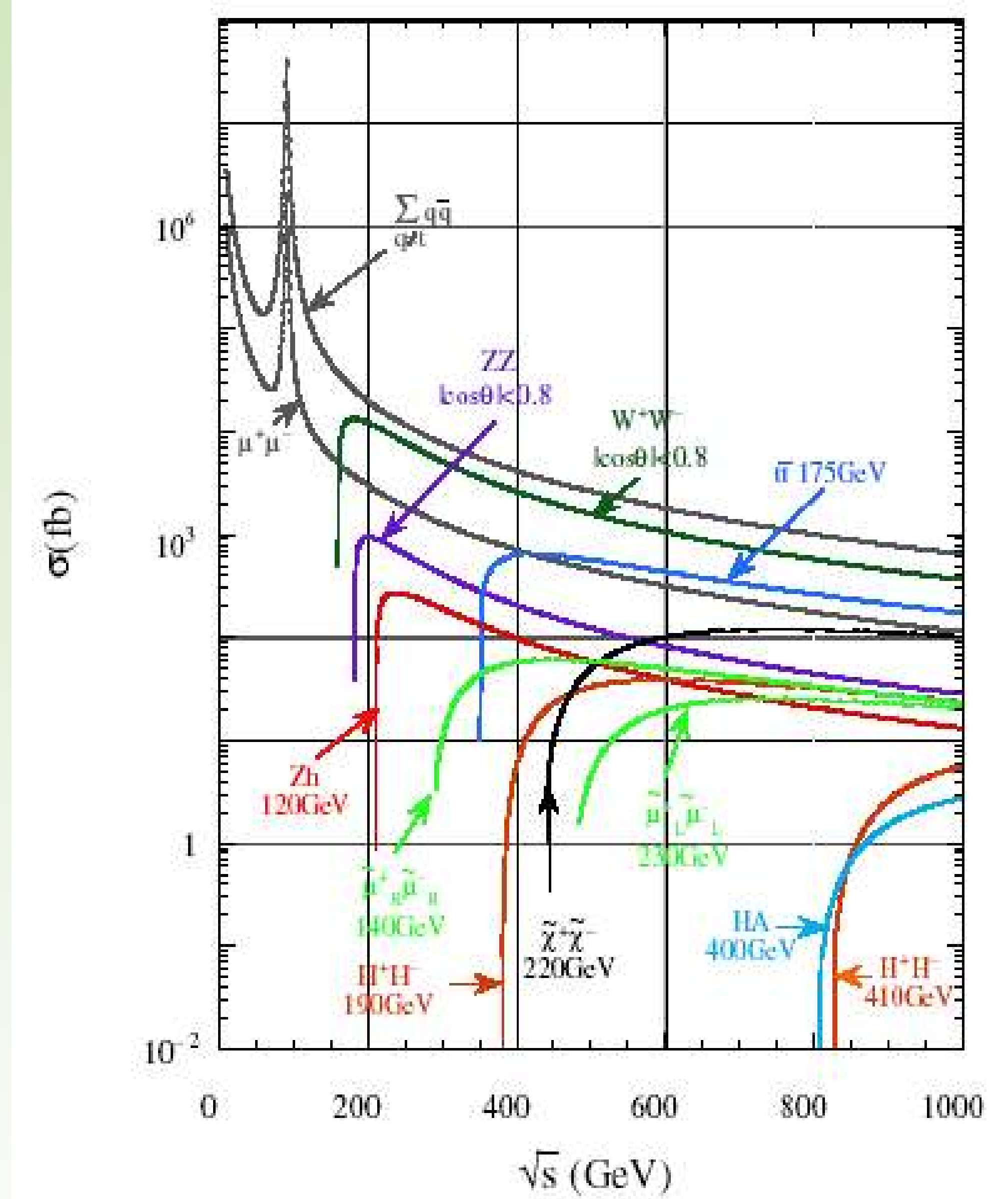
Higgs:

Cross section fb ....pb

$\Rightarrow$O(10^4-10^5) event per 500 fb^{-1}

Standard Model Background:

O(few 10^7) events



EWSB Higgs

Most possible scenario if Higgs exist:

Discovery and first measurements at LHC

Linear Collider:

High precision measurements to

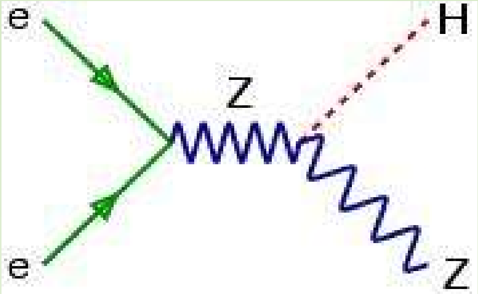
Establish Higgs mechanism as the mechanism responsible for electro-weak symmetry breaking

- Is it a Higgs-Boson ?
- Is it responsible for mass generation ?
- Does the Higgs field have a non-zero v.e.v. ?
- Structure of Higgs sector ?

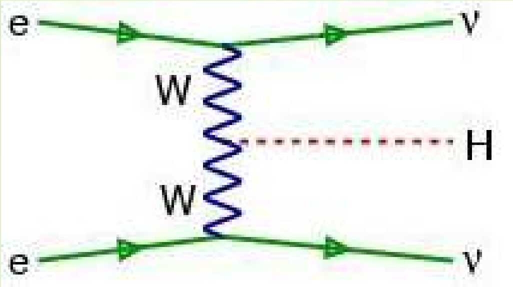
Higgs production at the LC

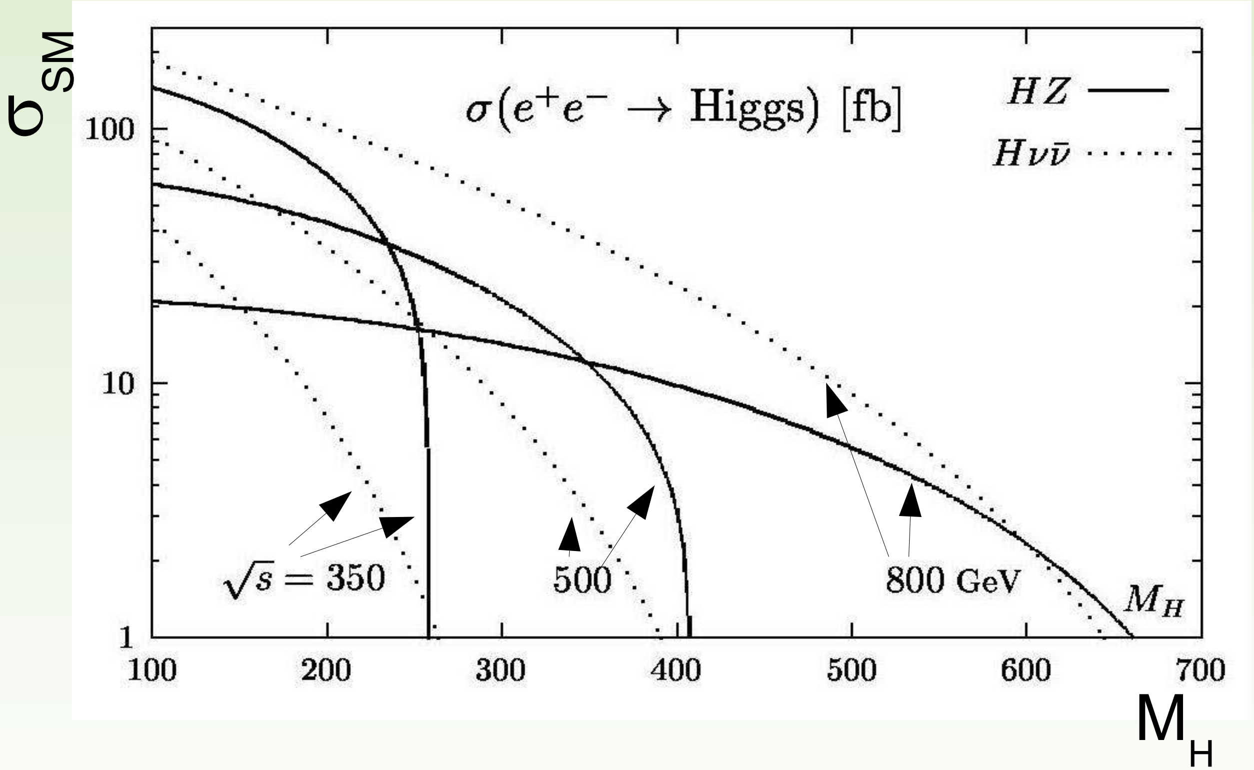
Dominant production processes at LC:

Low Energy:



High Energy:



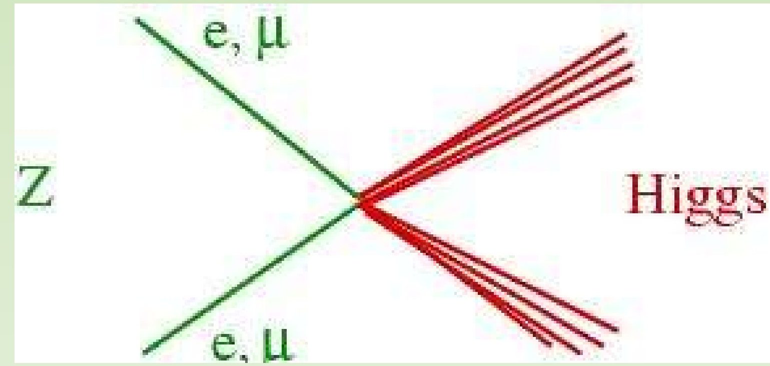


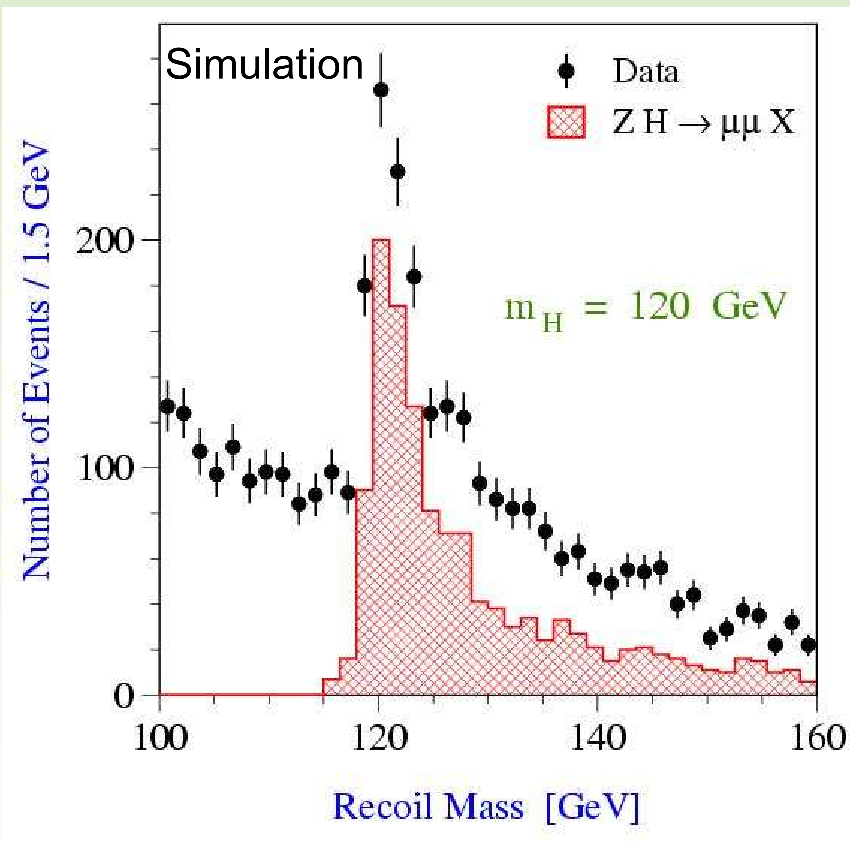
Recoil mass

Model independent:

"seeing it without looking at it"

Recoil mass spectrum: HZ $\rightarrow$ Xll (l=μ,e)





$\Delta\sigma/\sigma \approx 3\%$

$\Delta m \approx 110$ MeV

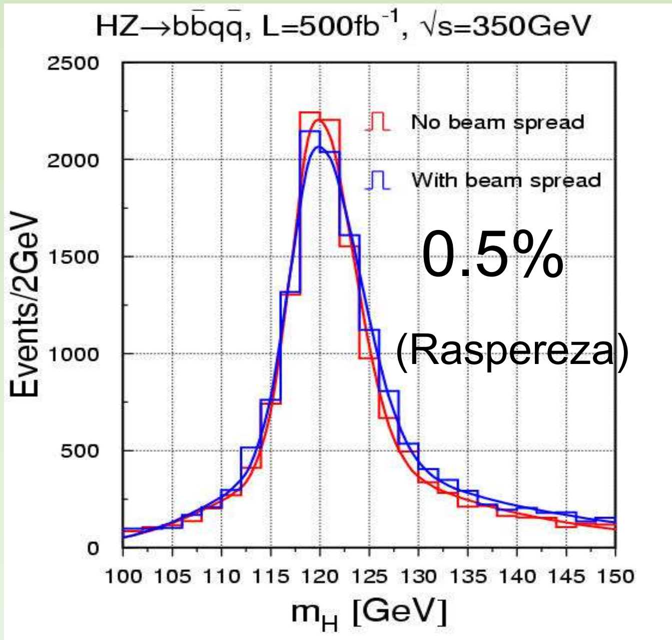
Benchmark for momentum resolution:

$\delta(1/p) = 7 \times 10^{-5}$/GeV

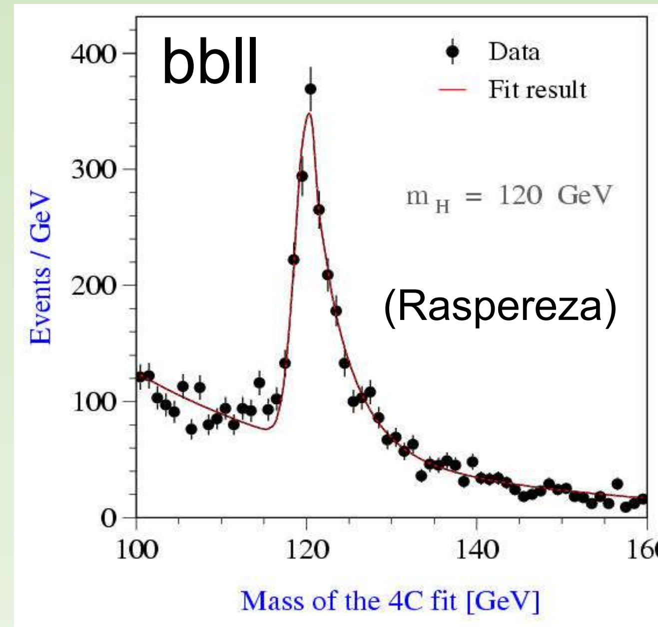
$\Rightarrow$ High precession measurement

Mass measurements

Measurement of bbqq and bbll using kinematic Fits



$\sigma(m_H)$=45 MeV



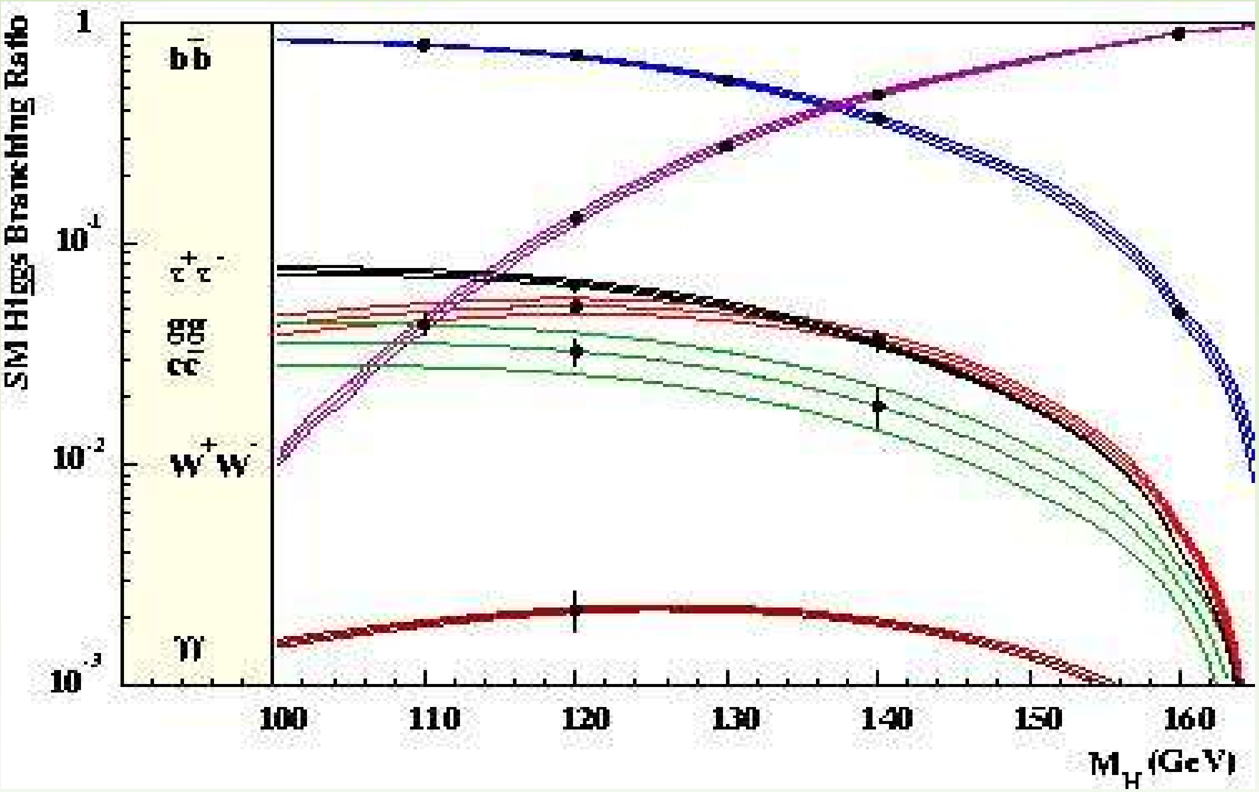
$\sigma(m_H)$=70 MeV

Studied:
- Combined accuracy: 40 MeV
- Energy shift ⇒mass shift (linear)
- Beam Energy spread (table)
- Theoretical uncertainties:
  3 GeV (today) ⇒ 0.5 GeV

	δM_h in MeV		
	TESLA	TESLA	NLC
Decay mode	$\delta E/E=0$	$\delta E/E=0.1\%$	$\delta E/E=0.3\%$
recoil mass	110	117	143
$ZH \to l^+l^- q\bar{q}$	70	72	76
$ZH \to q\bar{q}b\bar{b}$	45	46	48
Combined	38	39	40

Higgs branching ratios

Higgs field responsible for particle masses
⇒ couplings proportional to masses



Tesla Design Report
ΔBR/BR

bb	2.4%
cc	8.3%
gg	5.5%
ττ	6.0%
γγ	23.0%
WW	5.4%

For
350 GeV;500 fb^{-1}
M_H = 120 GeV

Start to redo analysis with better detector description

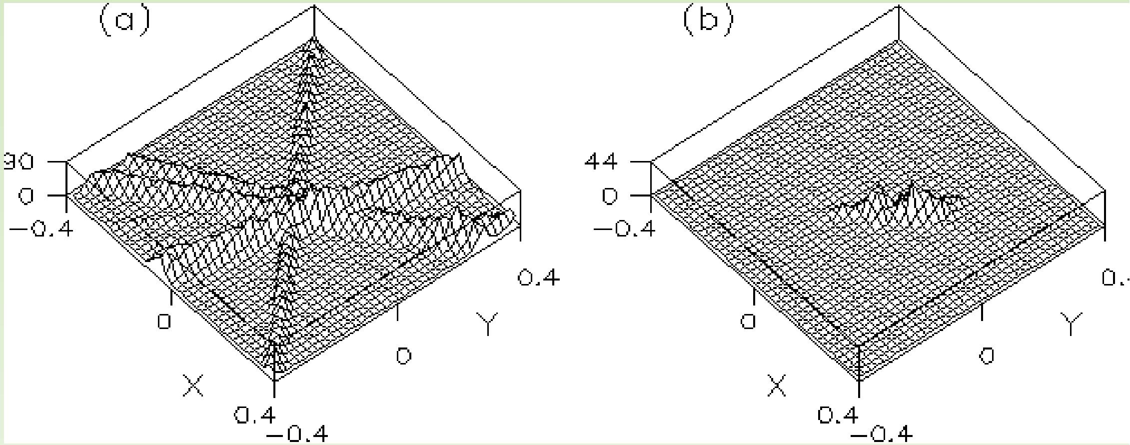
⇒ results converging

Hadronic Higgs BR

Reanalyzed with much more realistic flavour tag

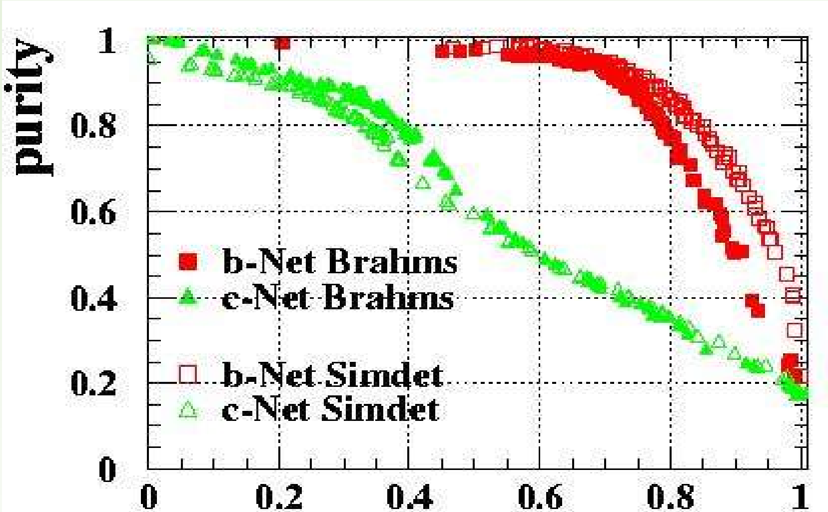
TESLA Design Report (TDR):
jet wise b-tag parametrization

Now: Using track wise vertex finding (ZVTOP) and NNet



Tracks in jet as probability desity tubes

Vertex: overlap



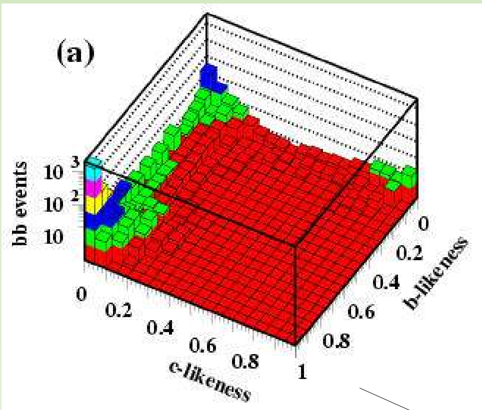
(Xella-Hansen, Kuhl)

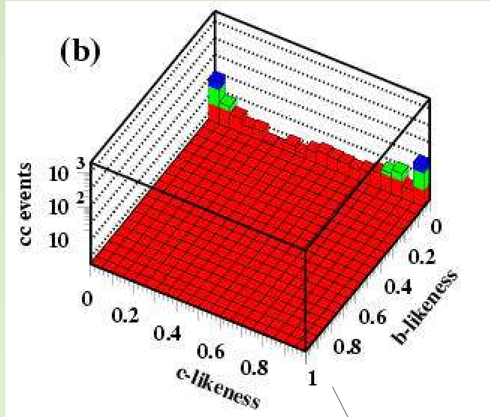
Comparison (qq at 91.2 GeV):

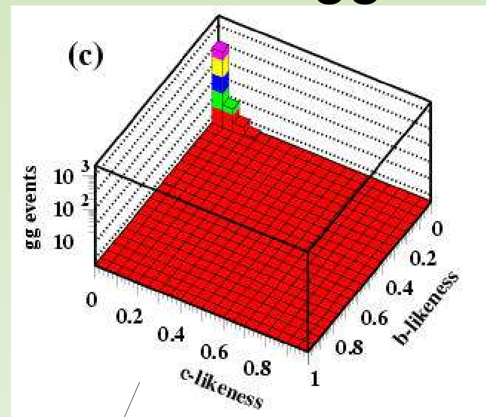
Full : Geant 3 (Brahms)
Open: Fast simulation (Simdet)

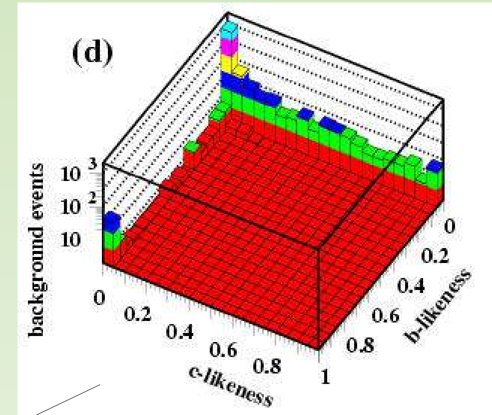
Hadronic branching ratio

$H \rightarrow bb$ + $H \rightarrow cc$ + $H \rightarrow gg$ + background



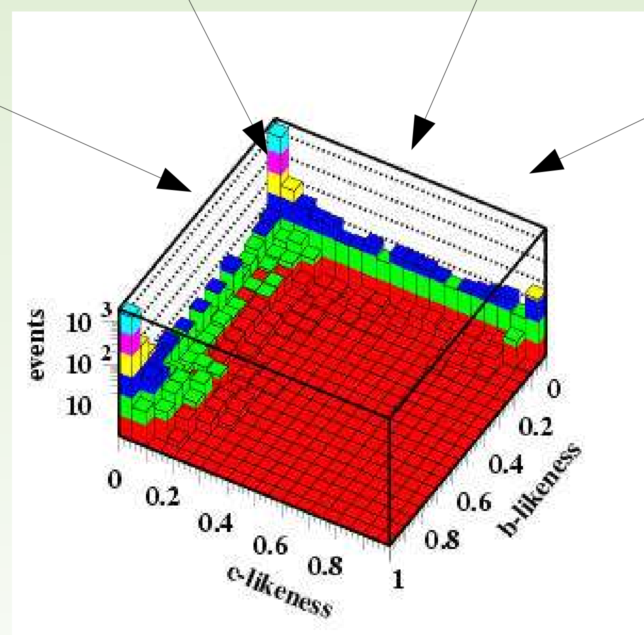






Maximum likelihood fit:

Simultaneous extraction of σBR(bb), σBR(cc) and σBR (gg)



Results:

	New	TDR
BR(bb) =	2.5%	(2.4%)
BR(cc) =	12.0%	(8.0%)
BR(gg) =	8.0%	(5.5%)

Using σ from recoil mass

Result: same order but more realistic detector description

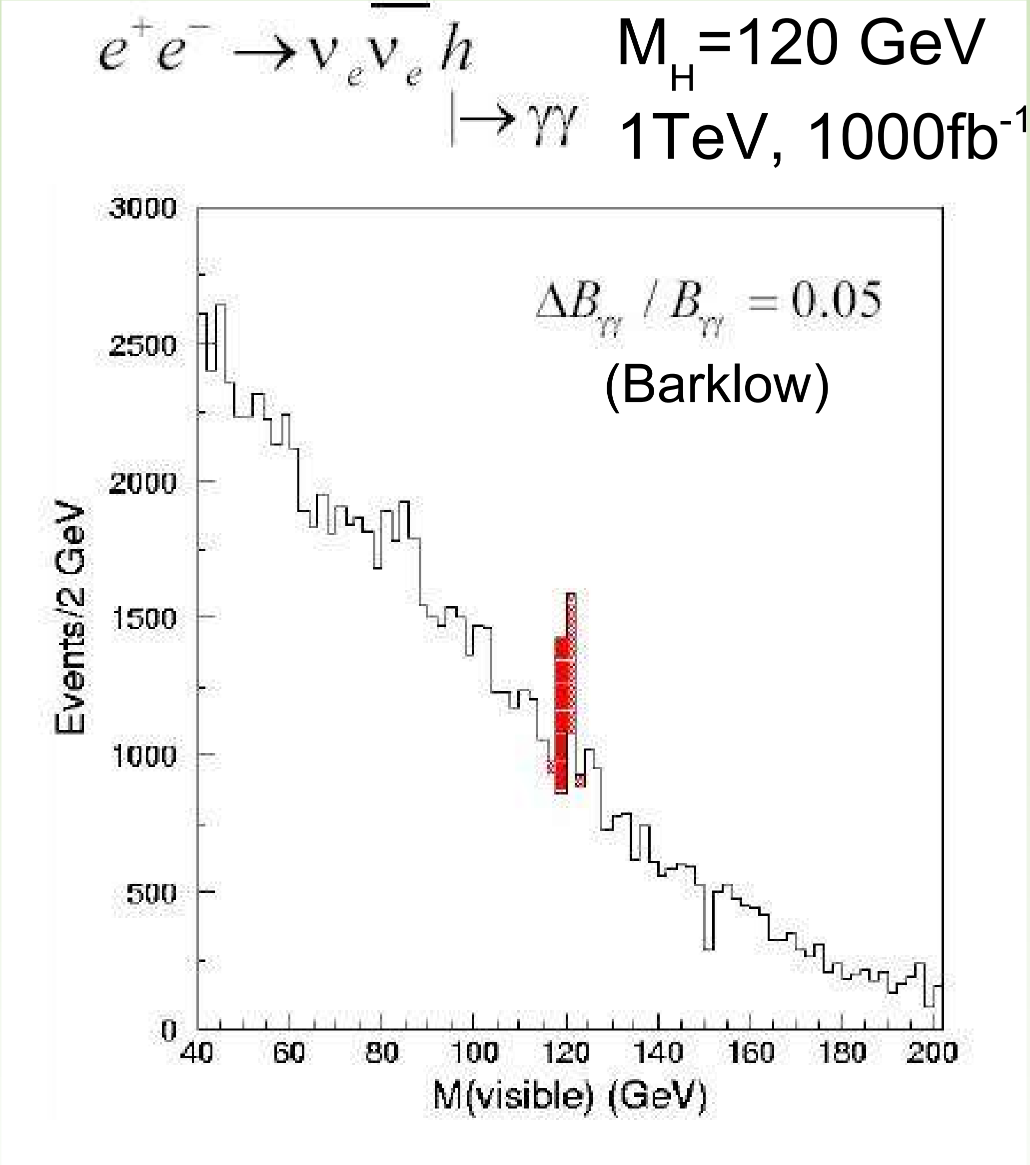
$H \to \gamma\gamma$

Looking for:

- two photons
- missing energy
- transverse momentum

Full background up to 8 fermions included: mostly $\nu\nu\gamma\gamma$

Accuracy: 5%



What can we learn from BR ?

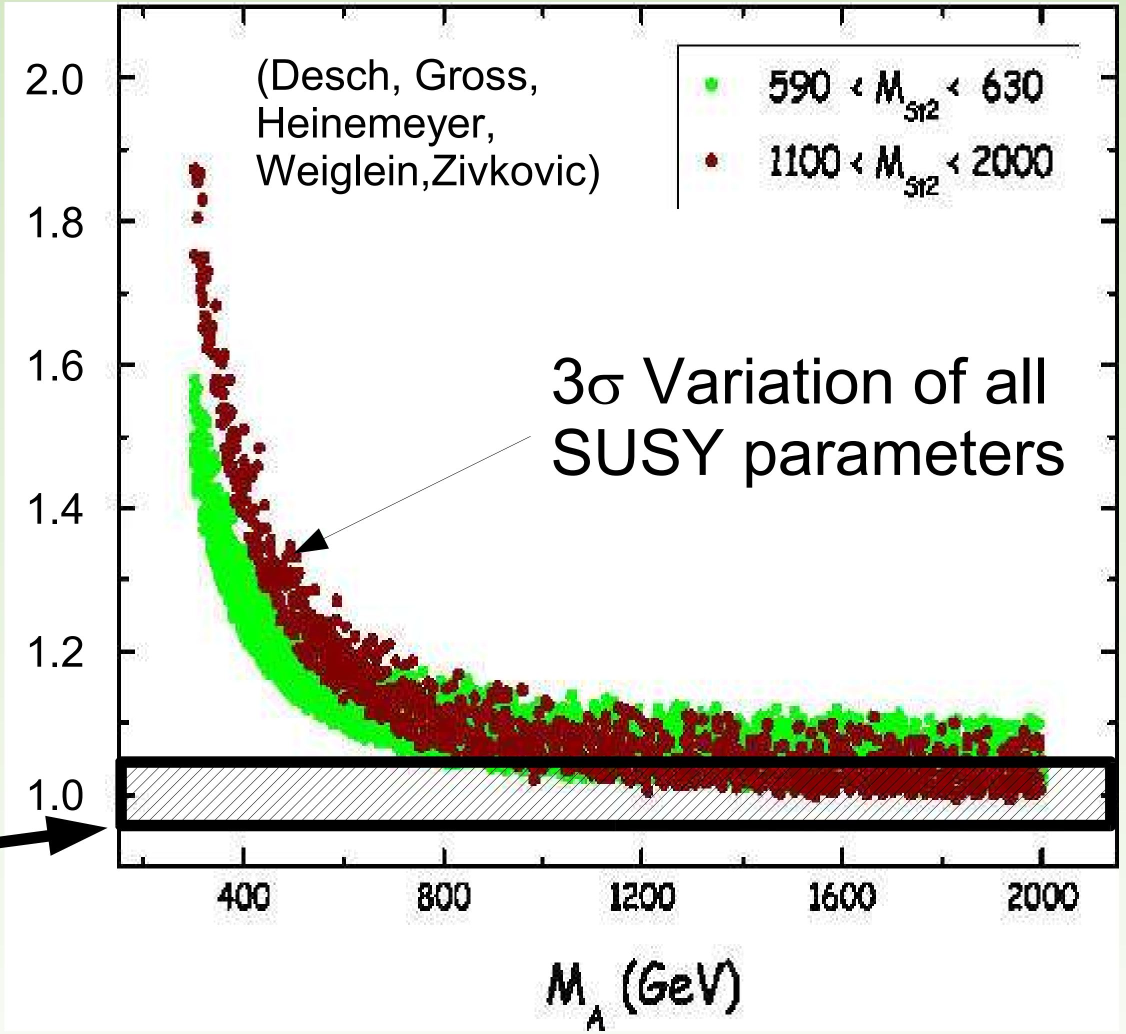
Branching ratios model dependent:

MSSM vs SM

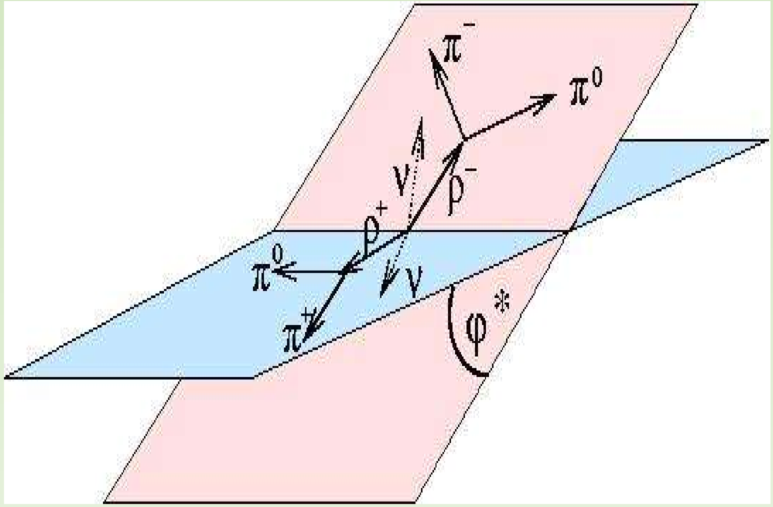
$$r = \frac{BR(bb)/BR(WW)}{BR(bb)_{SM}/BR(WW)_{SM}}$$

Accuracy: √s=350GeV, 500fb^{-1}

SPS1a, different Stop2 masses



H^0 or A^0



Using $H \to \tau\tau$ with $\tau \to \rho\nu$

τ decay plane $\Rightarrow$ τ spin information

$\tau\tau$ correlation $\Rightarrow$ Higgs CP

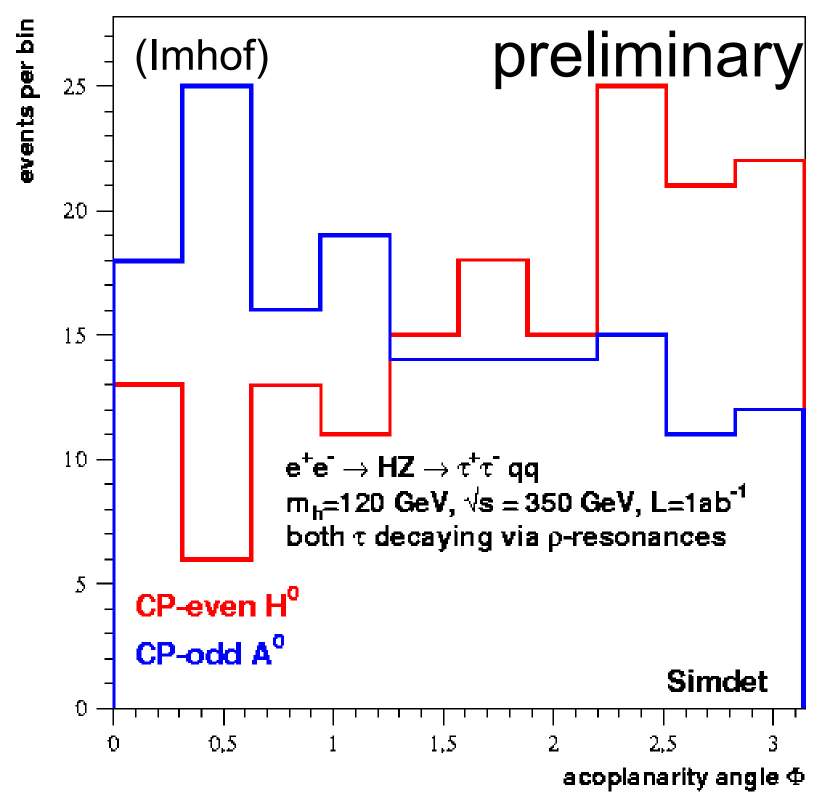
From simulated detector signals, luminosity of 1 ab^{-1}:

Reconstructed acoplanarities:

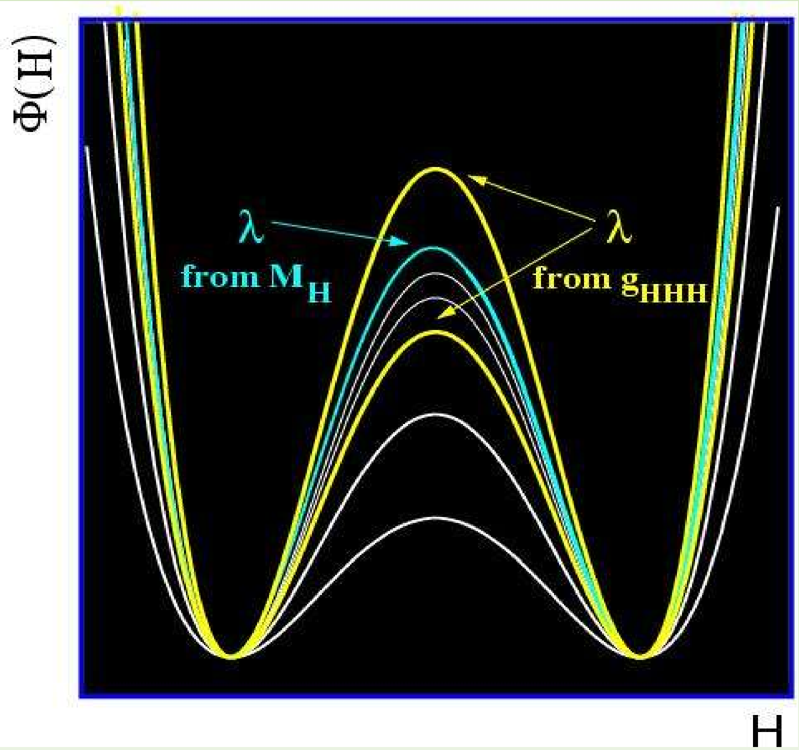
A^0: 0.270 ± 0.076

H^0: -0.165 ± 0.078

Clear differentiation between H^0 and A^0

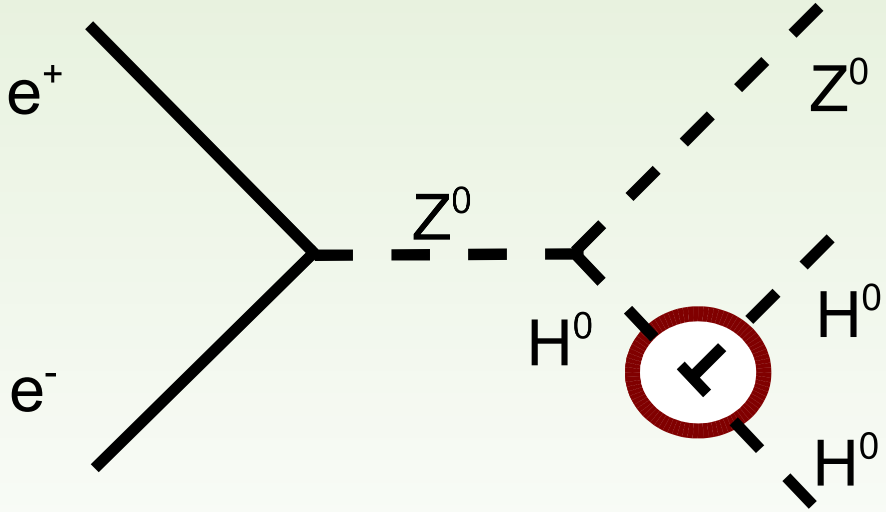


Higgs potential reconstruction



$L(H) = \lambda v^2 H^2 + \lambda v H^3 + 1/4 \lambda H^4$
SM: $g_{HHH} = 6\lambda v$, fixed by M_H

Measurement of g_{HHH}:



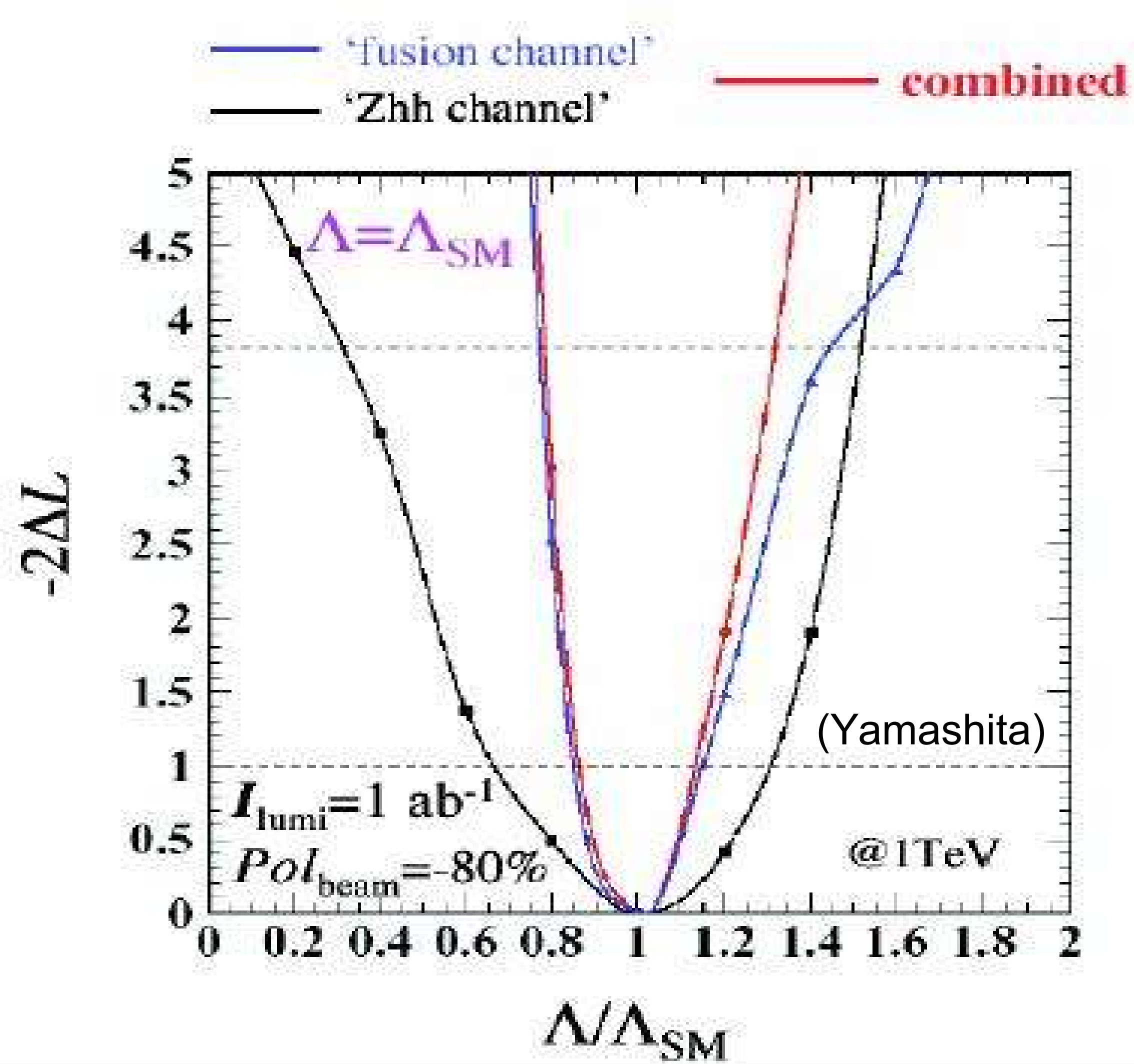
Higgs self coupling cont.

m_H=120 GeV; $\sqrt{s}$=1 TeV

Likelihood curves for $\Lambda=\Lambda_{SM}$:

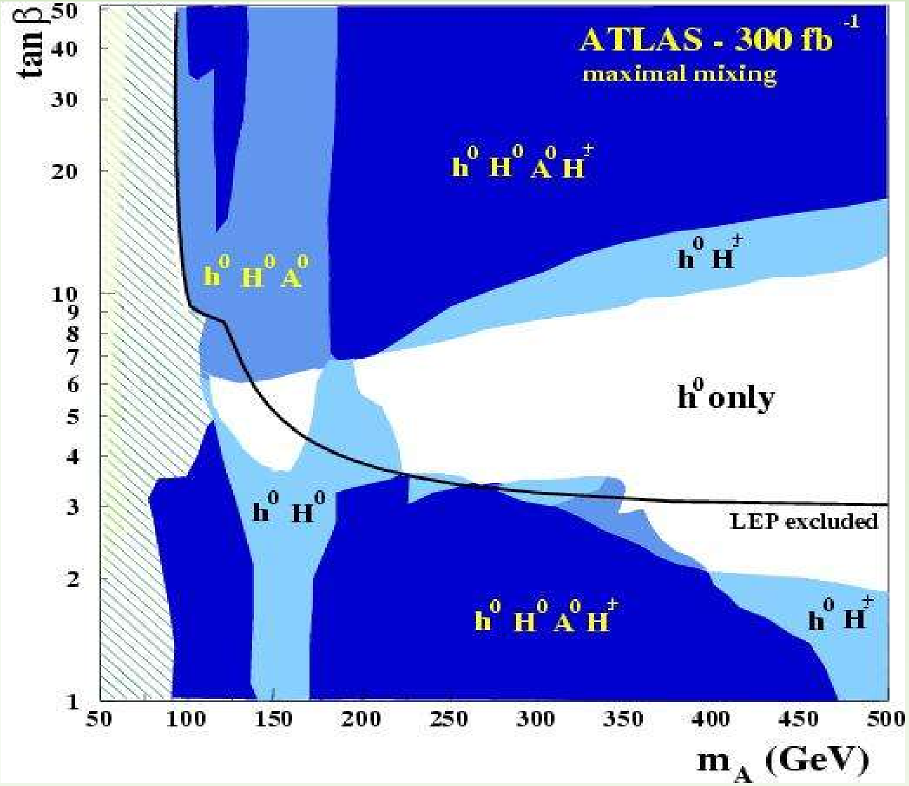
Result (CL=95%):

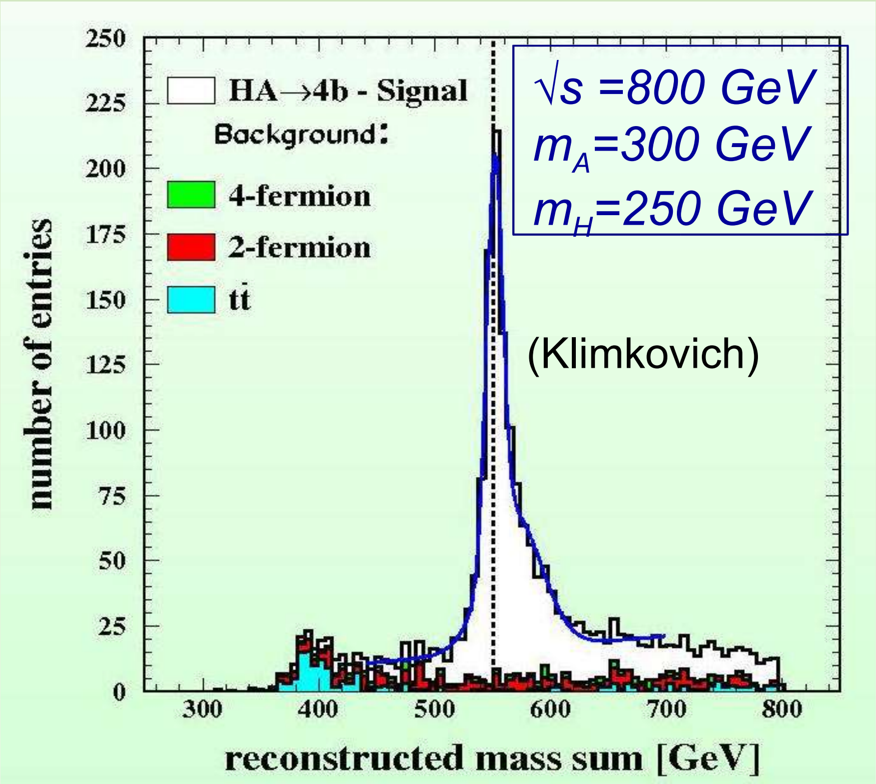
Λ/Λ_{SM}= 1.00 +0.13 -0.11



Higgs pair production

Heavy SUSY Higgs at LHC:





HA→bbbb and HA→ bbττ/ττbb:

5σ discovery possible

up to Σ m = √s – 30 GeV

Observation and mass/BR/width(?) measurements deep into the LHC wedge region at 800-1000 GeV LC

Summary

(Together with LHC measurements)

LC crucial to establish the

- Higgs mechanism
- origin of mass generation
- character of the Higgs boson

High precision measurement of the Higgs properties

- mass and cross sections
- branching ratios
- self couplings
- CP quantum numbers

Study detector and beam related issues