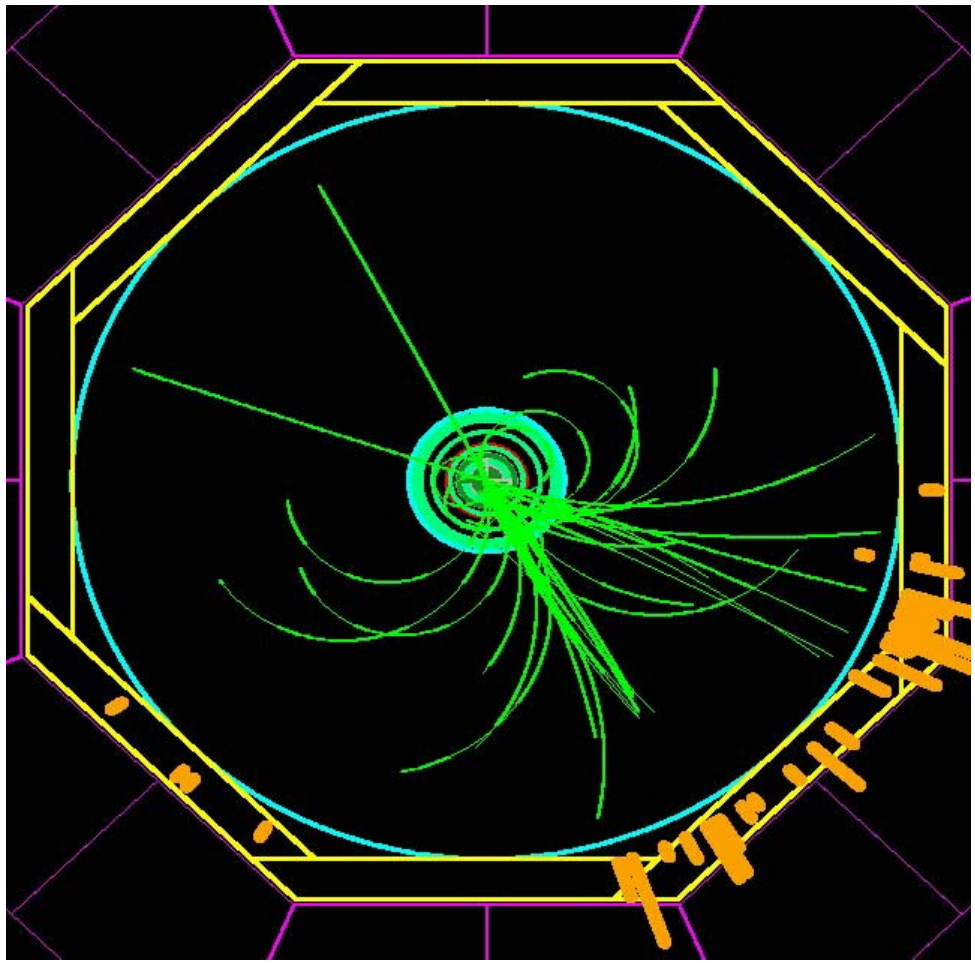
Mini-Review on Higgs Studies in the ECFA/DESY study



Klaus Desch, Hamburg
LCWS'02 – Jeju, Korea
28/08/02

General Remarks

2nd ECFA/DESY study on physics and detectors carried out the work for the Physics+Detector parts of the TESLA TDR

After the realease of TESLA TDR (Spring 2001) study has been extended for 2 years

Goals of the Study

The goals of the extended Study are:

1. to continue to build up the active community of experimenters, theorists and machine physicists who prepared the TDR, to be ready by 2003 to make firm proposals for a funded programme of linear e+e- physics up to about 1 TeV, if it is decided to go ahead.
2. to complete and extend feasibility studies on important physics channels.
3. to review the detector design in the light of results of the R&D programmes which are now getting under way.
4. to interact with the accelerator designers on questions relating to the machine/detector interface, including backgrounds, shielding, radiation levels, beam position monitoring, luminosity measurement and energy measurement.
5. to look at the physics potential and the technical possibilities for extensions of the programme to produce real photon-photon, electron-photon and e-e- collisions.
6. to extend the work of the "LoopVerein", developing new tools and techniques for calculating precise rates for Standard Model and supersymmetric processes that match the expected experimental precision.
7. to continue and extend contacts with physicists in North America, Asia and throughout the world. Wherever the collider is built the collaborations doing the experiments are likely to be composed of groups from all over the world - as they were at LEP and are at HERA, the Tevatron and the LHC.

General Remarks

Meetings/Milestones

Snowmass 2001
- triggered a lot of new ideas
- many contacts with North American physicists

Krakow Sept 2001

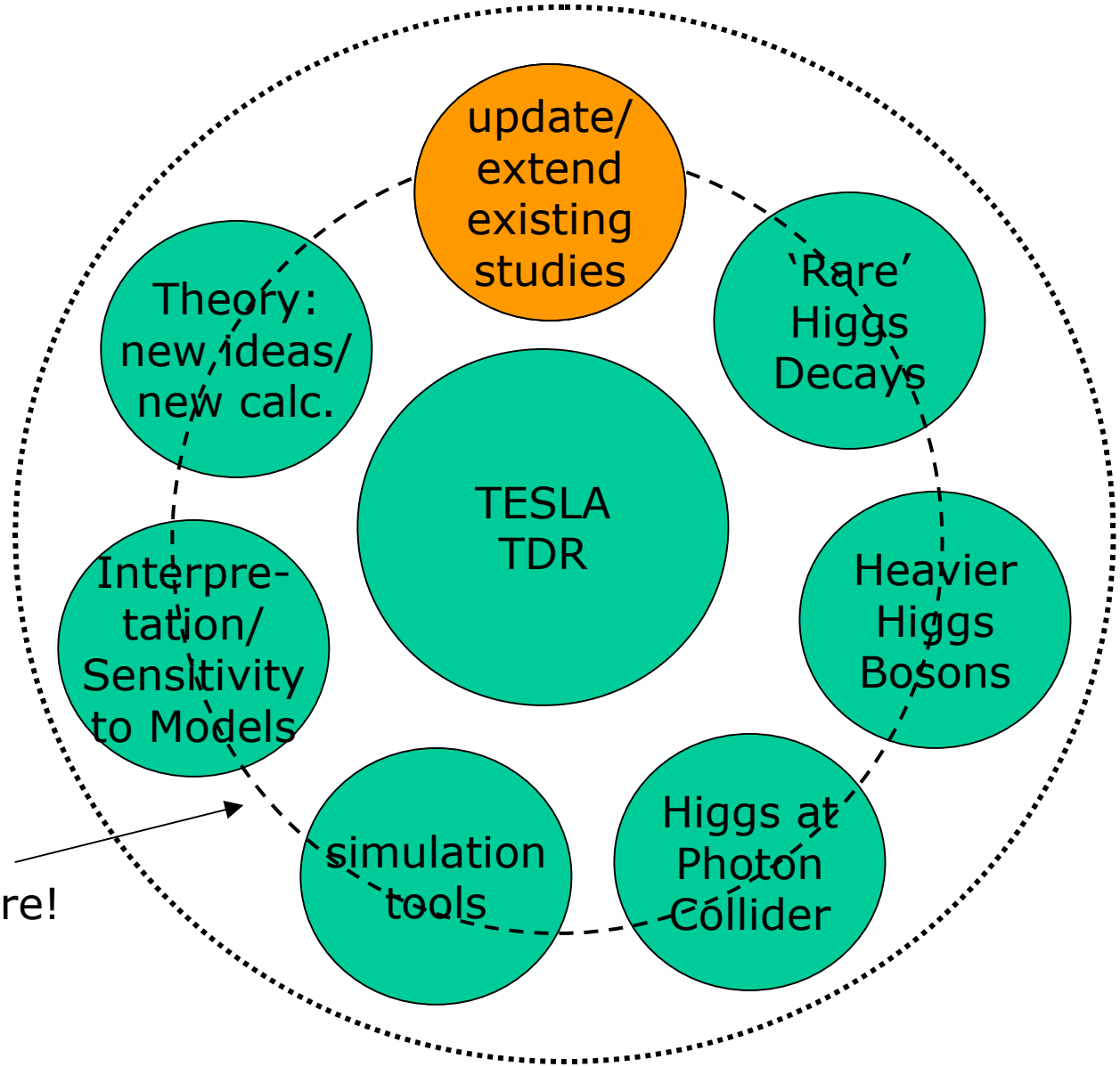
St.Malo April 2002

Jeju 2002
- opportunity to make closer contact with Asian colleagues!

Disclaimer:

This is rather a status report than a review!
Many results are preliminary, studies are ongoing…

ECFA/DESY Higgs study landscape



Light Higgs Branching Ratios: Binomial Approach

TESLA TDR study (Battaglia): obtain BR's from measuring

$$BR(H \to X) = \frac{\sigma(HZ \to X + Z)}{\sigma(HZ \to H\ell\ell) / BR(Z \to \ell\ell)}$$

J-C.Brient

Alternative approach: measure fraction of $H \to X$ events within an unbiased sample of $HZ \to H\ell\ell$ events
Disadvantage: smaller event sample
Advantage: binomial errors smaller than gaussian errors (one measurement instead of two)

$$\mathrm{BR(H \to I)} = \frac{\mathrm{N_I}(1 - \mathrm{F_I^{non-H}} - \mathrm{F_{non-I}^{H}})}{\mathrm{N_{sel.}}(1 - \mathrm{F^{non-H}})} \frac{1.}{\varepsilon^{\mathrm{H \to I}}}$$

Light Higgs Branching Ratios: Binomial Approach

Efficiencies, Backgrounds

'cross talk'

background

decays	efficiency (%)	$F^H_{otherchannels}$	$F^{non-H}_{channel}$
$b\bar{b}$	88.	0.01	0.039
$\tau\tau$	98	0.12	0.267
$c\bar{c}$	75	0.59	0.005
gluon-gluon	89	0.06	0.006
$\gamma\gamma$	46	0.00	0.30
WW*	91	0.07	0.005

J-C.Brient

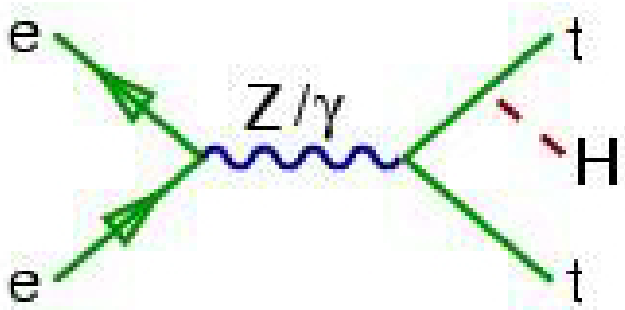
Result:

$\sqrt{s} = 350\,GeV$

$L = 500\ fb^{-1}$

decays	BR (%)	δB/B (%) direct method (this note)	δB/B (%) indirect method from ref. [2]	δB/B (%) combined
$b\bar{b}$	68.	1.9	2.4	1.5
$\tau\tau$	6.85	7.1	5.0	4.1
$c\bar{c}$	3.1	8.1	8.3	5.8
gluon-gluon	7.0	4.8	5.5	3.6
$\gamma\gamma$	0.22	35.	26	21.
WW*	13.3	3.6	4.2	2.7

New analysis of ttH



- reanalysis **A.Gay**
- extension to higher masses
- and inclusion of $H \to WW$
- ANN based selection
- event-wise IP-probability tag
- only one final state for $H \to WW$ so far:

"2 leptons of the same sign + 6 jets" channel

$e^+e^- \to t\bar{t}H \to W^+bW^-bW^+W^- \to$

$l^+\nu bqqbl^+\nu qq$ (+ c.c.)

$BR(2l^{+/-}2\nu 4q2b) \approx 10\% * BR(H \to W^+W^-)$

Assumptions:

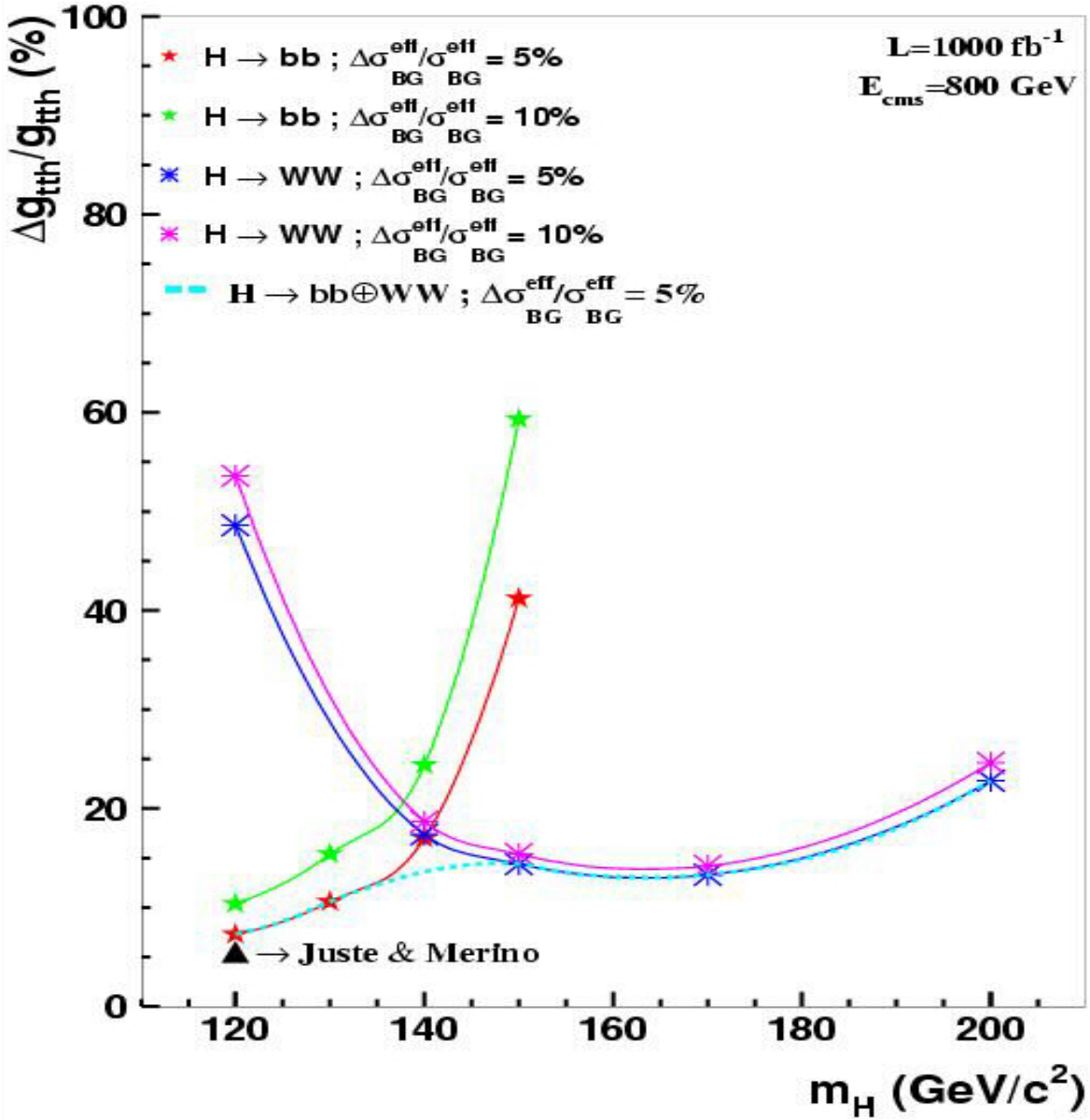
- $\sqrt{s} = 800$ GeV
- $L = 1000$ fb^{-1}
- $\frac{\Delta\sigma_{BG}^{eff}}{\sigma_{BG}^{eff}} = 5\%$ and 10%

m_H (GeV)	$BR(H \to b\bar{b})$	$BR(H \to W^+W^-)$	$\sigma_{t\bar{t}H}$ (fb)
120	67%	13%	2.5
160	3.1%	92%	1.4
200	0.23%	73%	0.8

New analysis of ttH

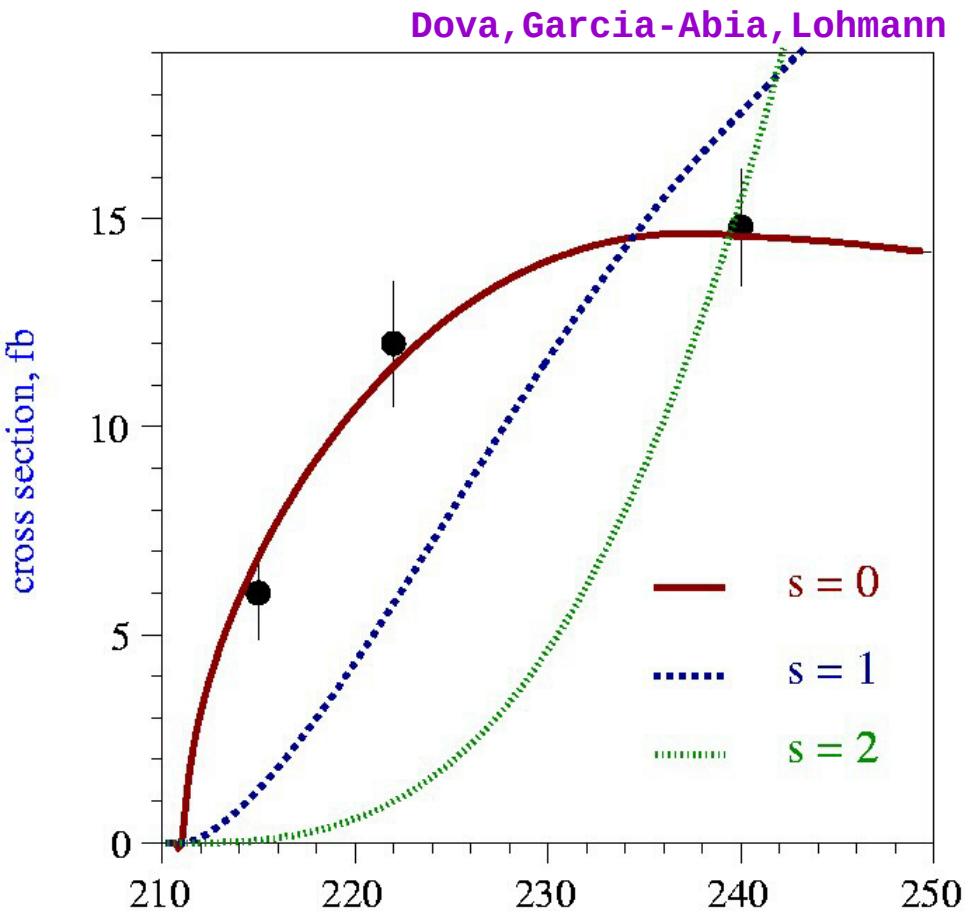
Result:

A.Gay



Higgs Spin

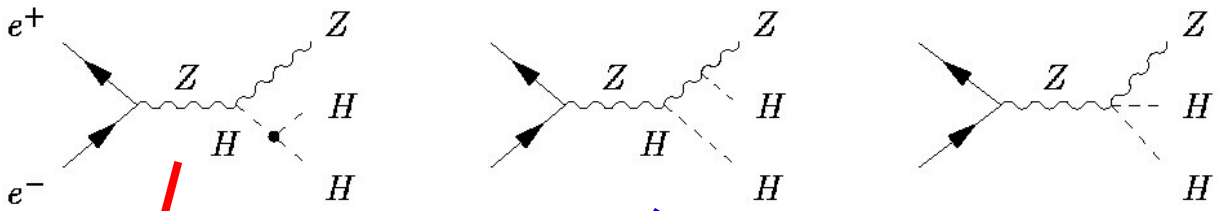
TDR analysis updated, see talks by
S.Y.Choi and W.Lohmann on thursday.

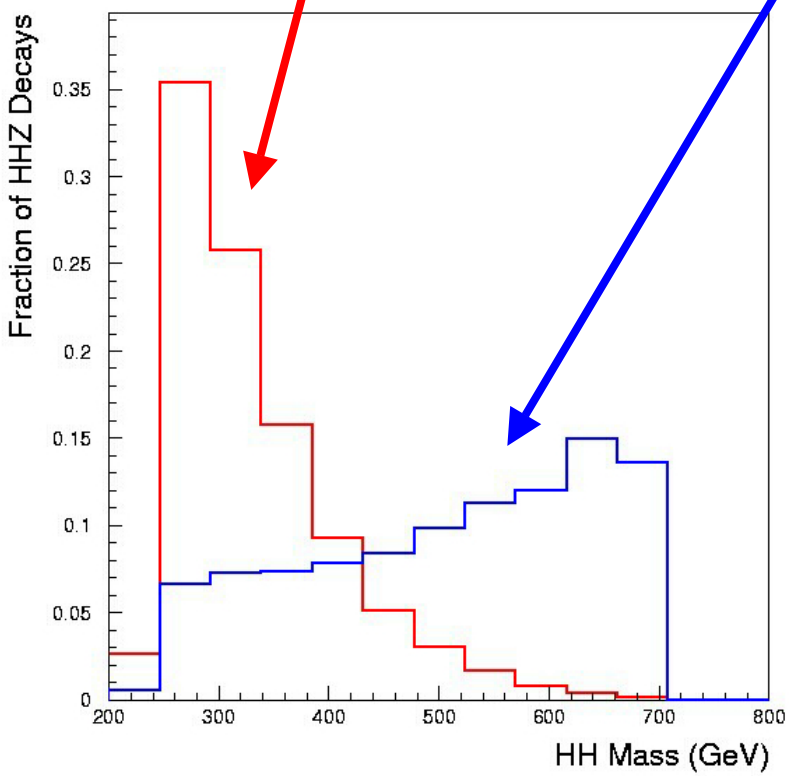


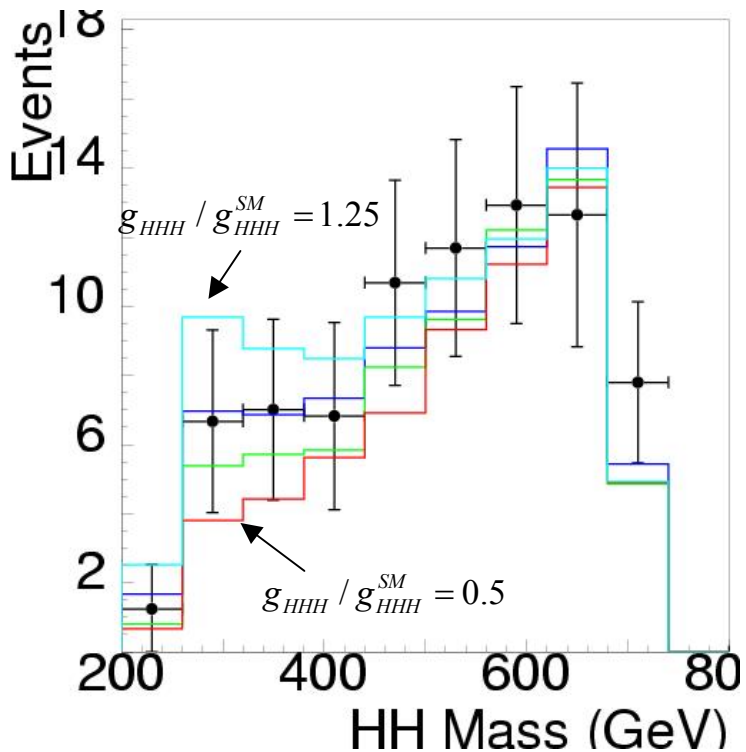
New Ideas for Higgs Self Coupling

Battaglia,Boos,Yao

Additional sensitivity from differential distributions:

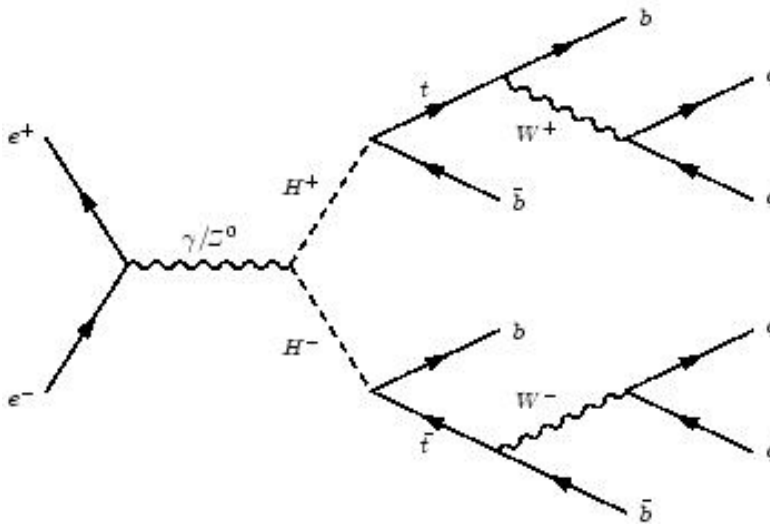






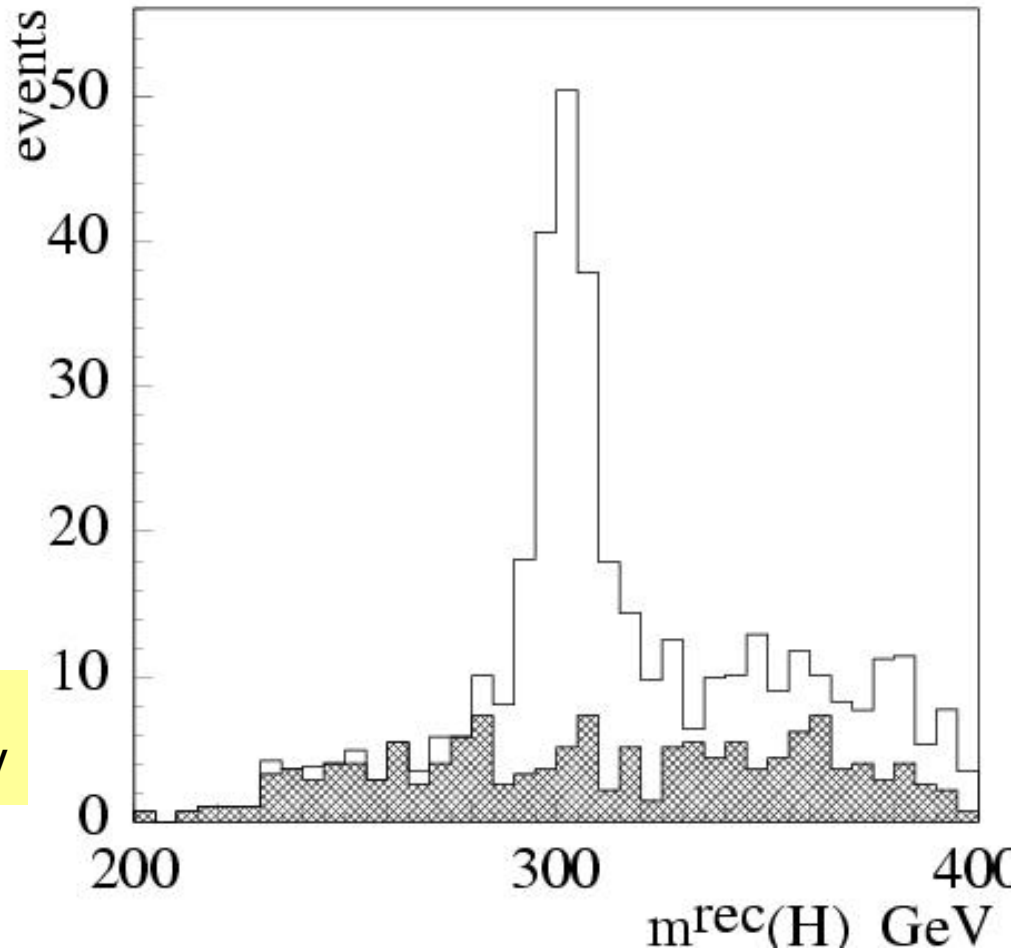
Update on Charged Higgs

new: now with genuine tbtb background

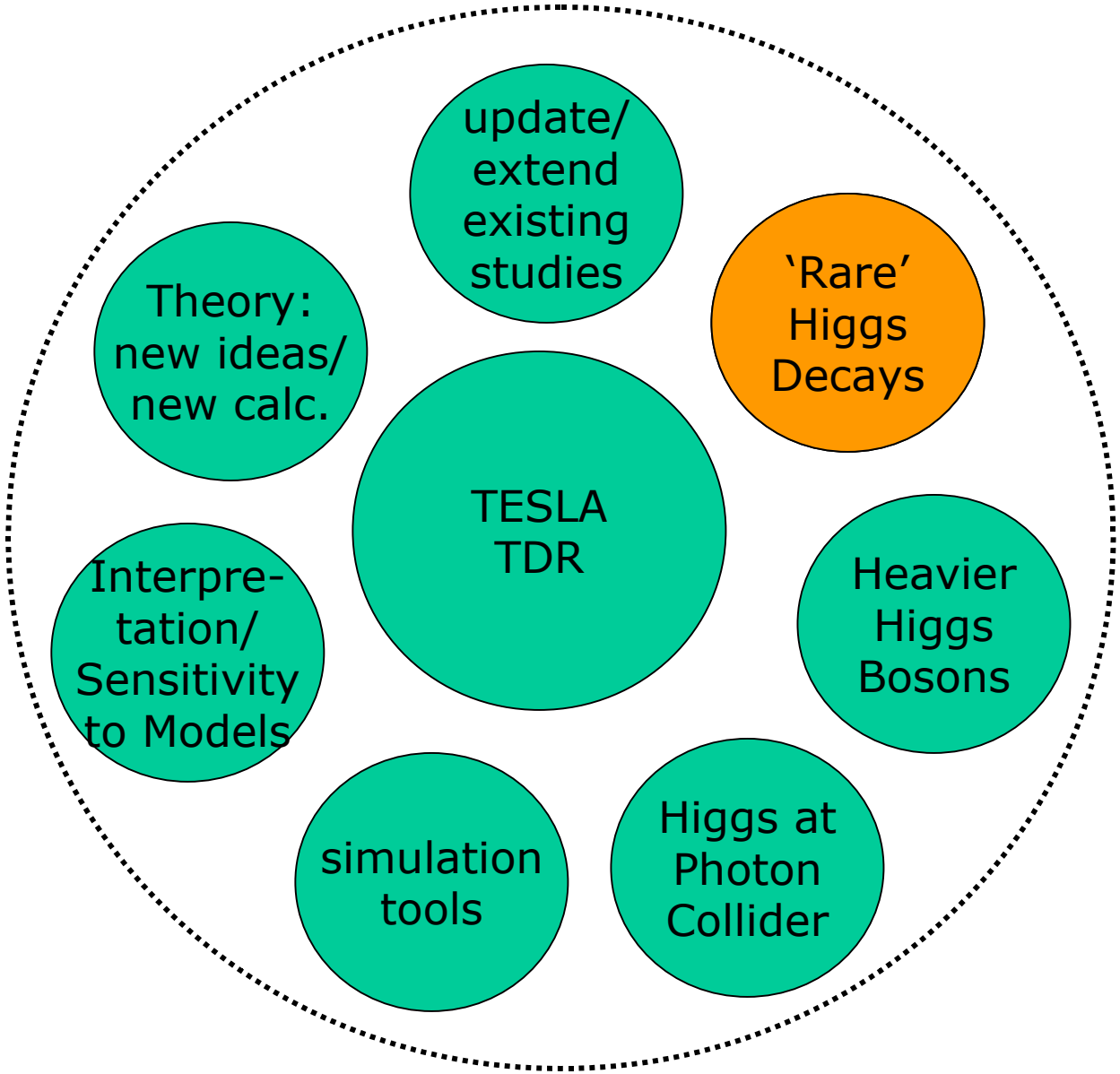


At 800 GeV:
5σ discovery up to m=350 GeV

Battaglia,Ferrari,Kiiskinen,Maki



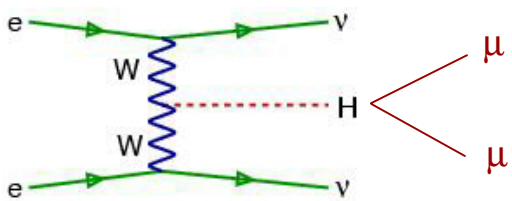
ECFA/DESY Higgs study landscape

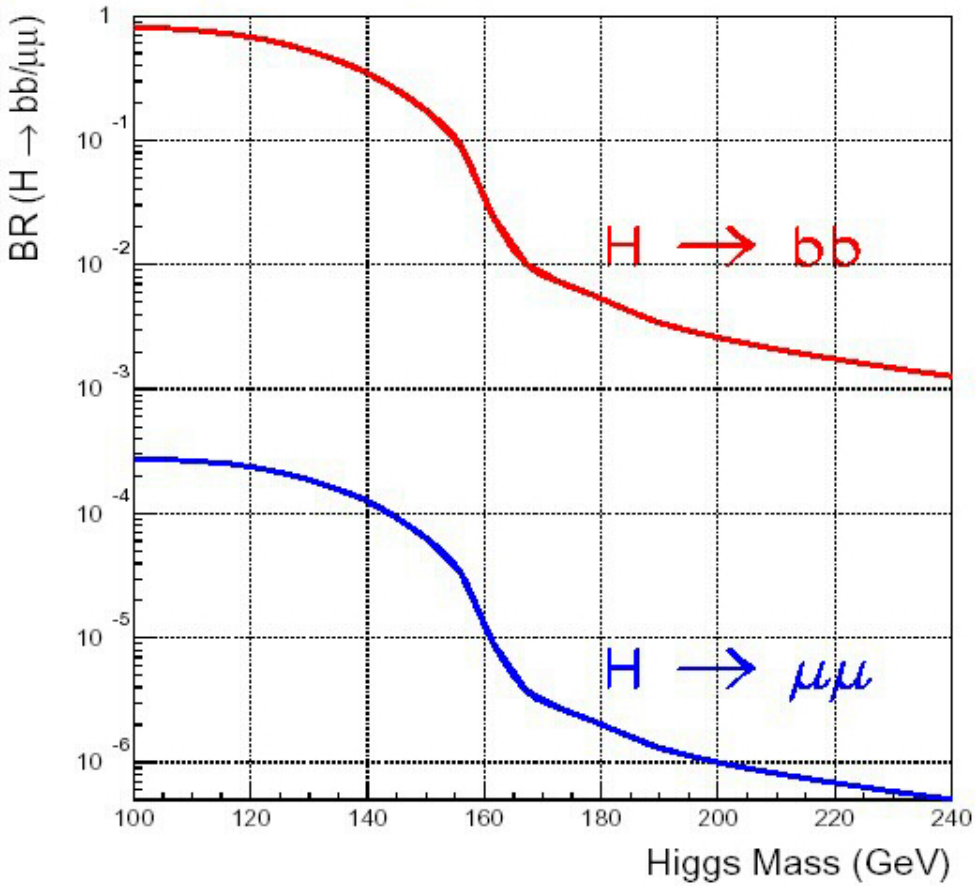


Rare decays

M.Battaglia

$H \to \mu^+\mu^-$





- rises with $\propto \ln s$
⇨ large number Higgs bosons at 800 GeV
- test of 'lepton universality in Higgs sector'
- select events with two muons and Missing energy: clean signature
- cut con recoil mass (remove ZZ)

Rare decays

M.Battaglia

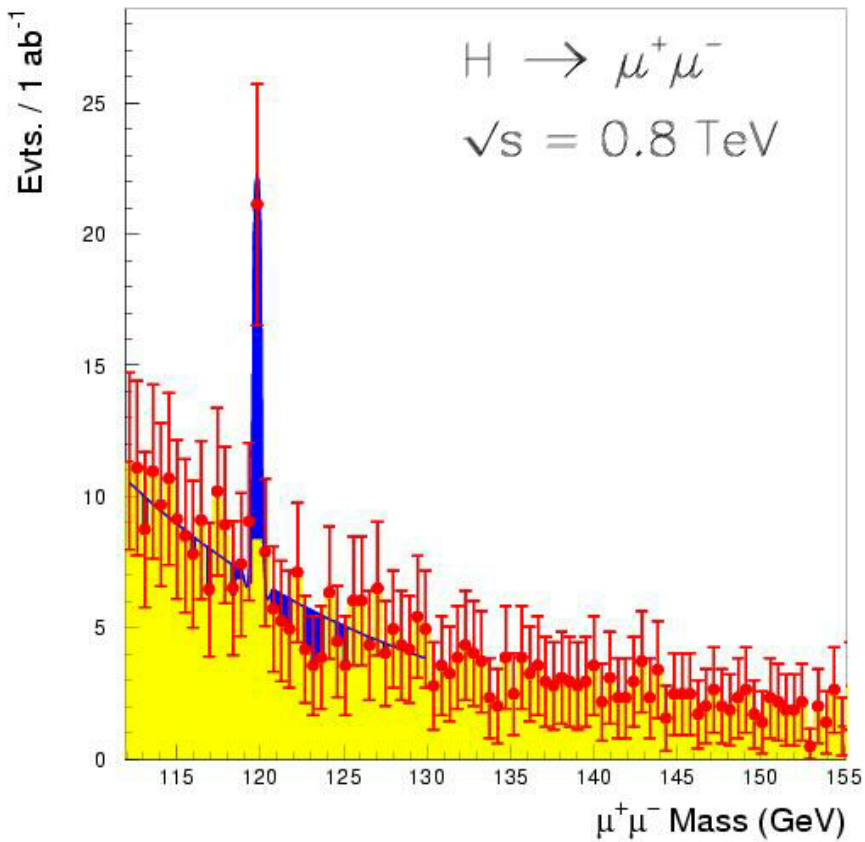
$H \to \mu^+\mu^-$

Result:

$\sqrt{s} = 0.8$ TeV
with $\int \mathcal{L} = 1$ ab^{-1}

M_H	120 GeV
δBR/BR	0.320

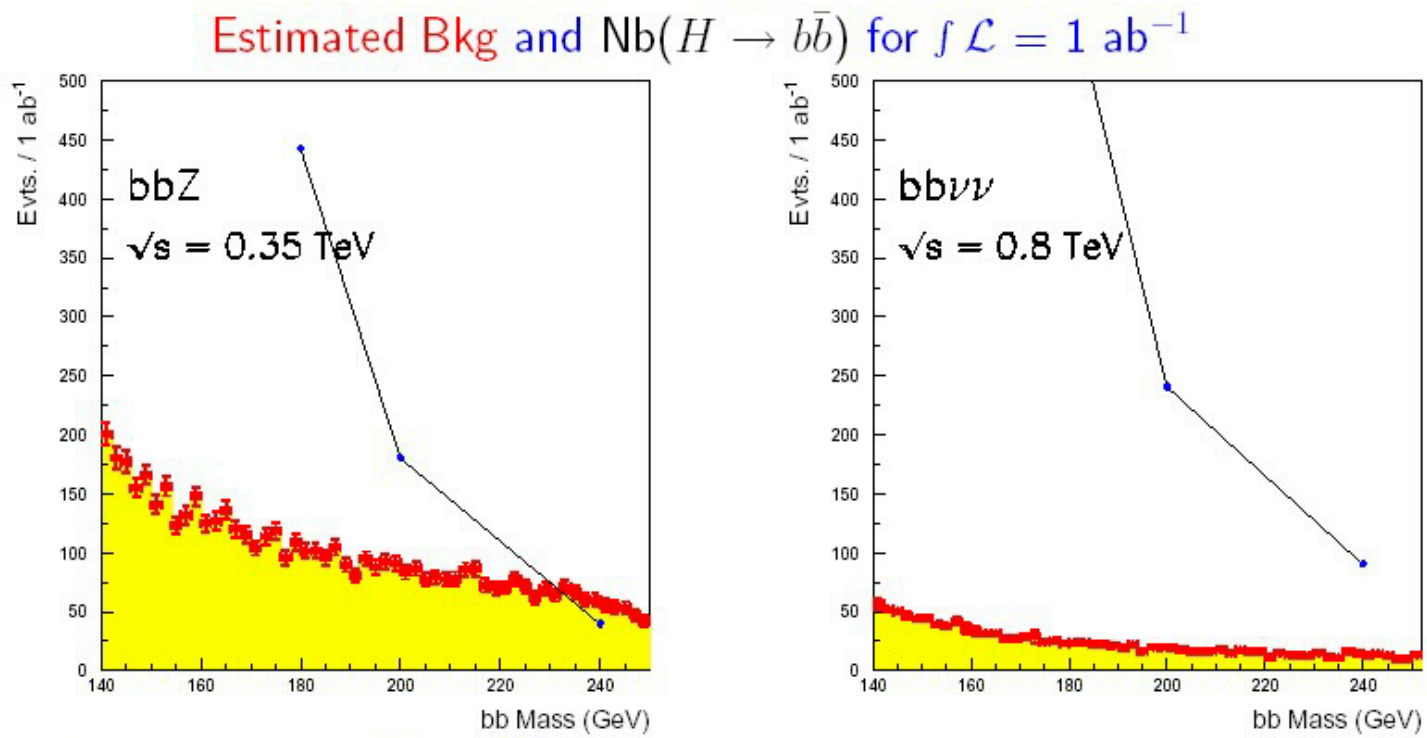
yields $\Delta g_{H\mu\mu} \approx 0.16$



Rare decays

M.Battaglia

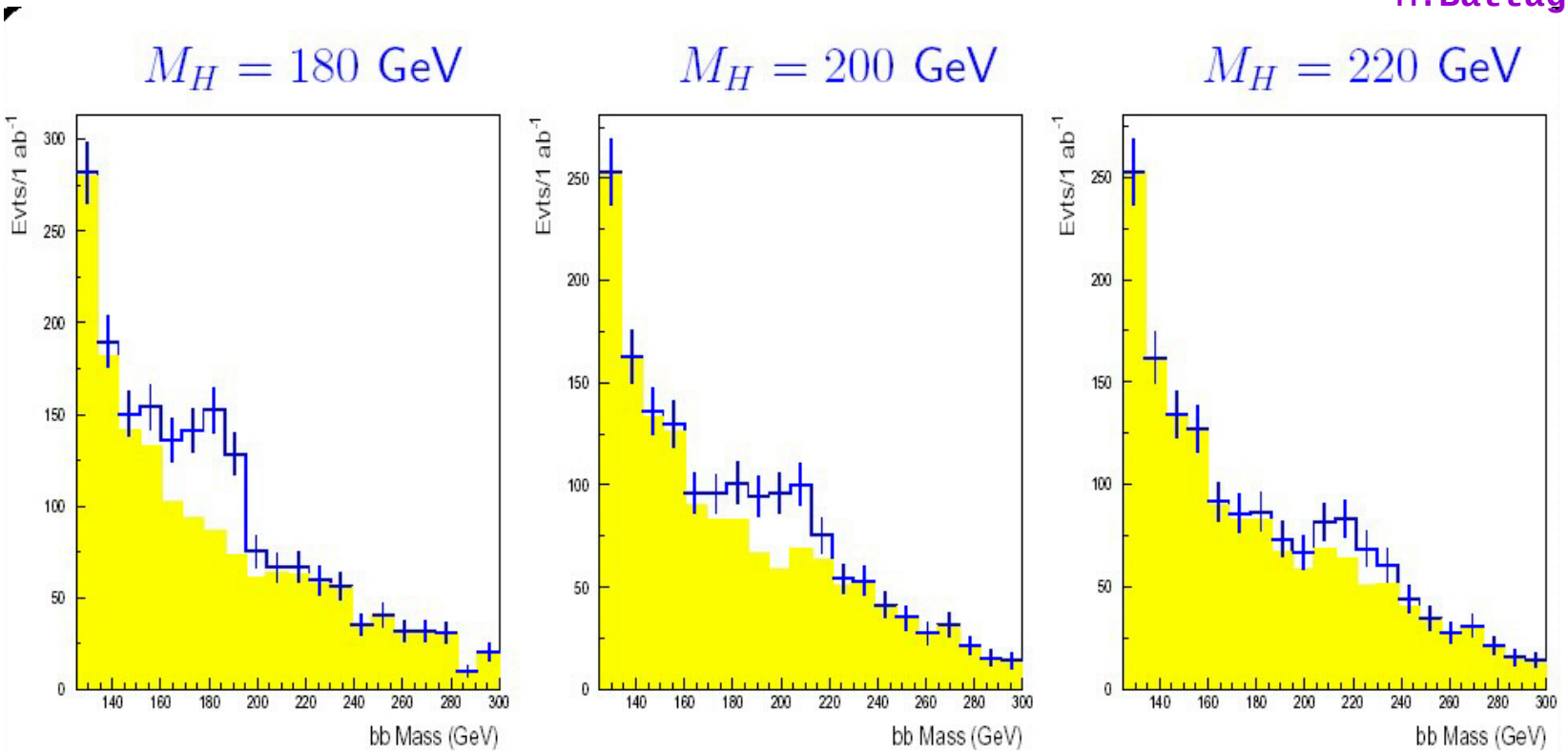
$H \to b\bar{b}$ as rare deacy ($m_H > 160\ GeV$)



Fusion(800GeV) preferred over Higgsstrahlung(350GeV)

Rare decays

M.Battaglia



RESULTS FOR $\sqrt{s} = 0.8$ TEV AND $\int \mathcal{L} = 1$ AB^{-1}

M_H (GeV)	$S/\sqrt{B}$	δ BR / BR
180	10.5	0.115
200	7.5	0.165
220	4.1	0.275

Rare decays

H.J.Schreiber et al

$$H \to \gamma Z$$

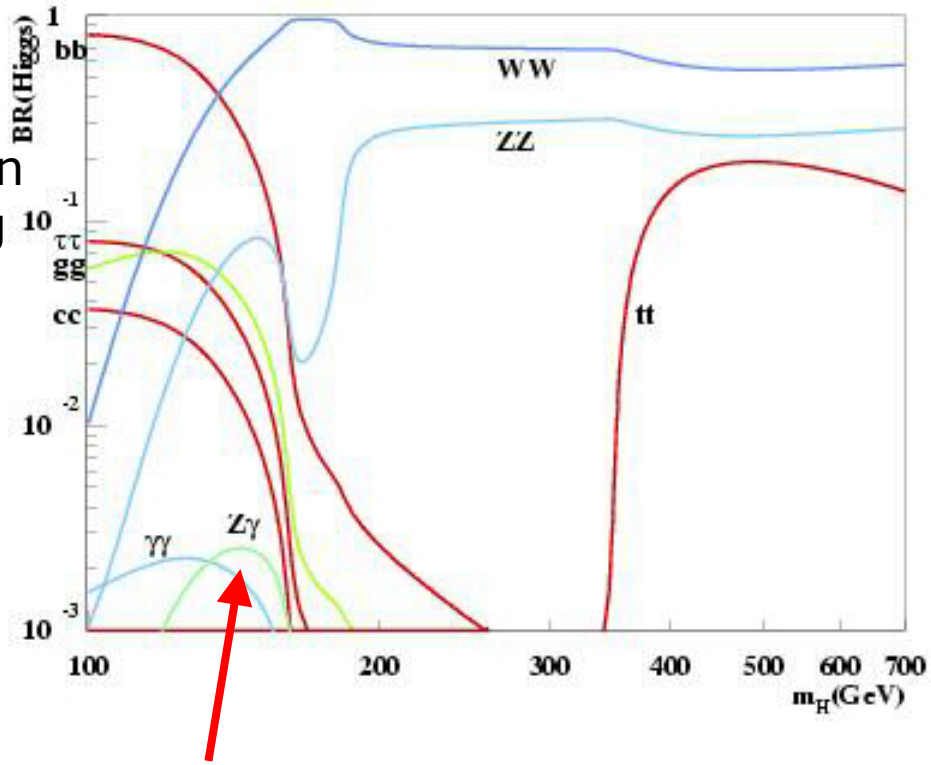
Might add interesting information
In case of anomalous $\gamma\gamma$ coupling

Study for:

$$\sqrt{s} = 500\,GeV, 1\,ab^{-1}$$

Most promising channel:

$$e^+e^- \to \nu\nu\gamma Z \to \nu\nu\gamma q\bar{q}$$



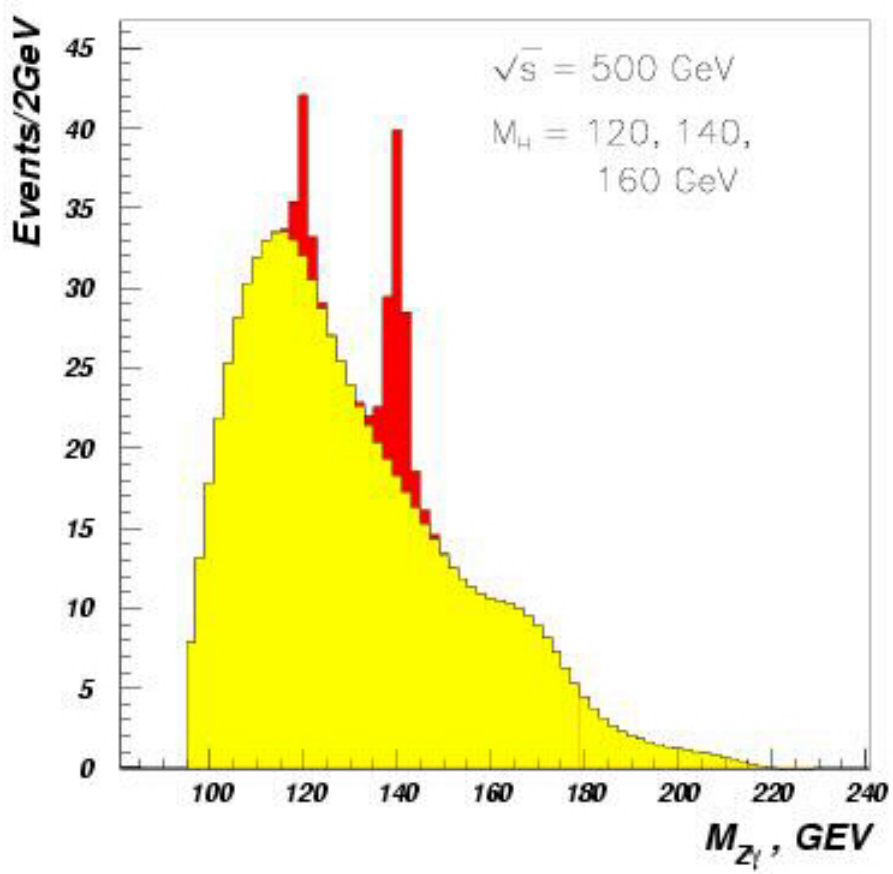
Rare decays

H.J.Schreiber et al

$$H \to \gamma Z$$

- backgrounds with CompHEP

- three analysis techniques (cuts and likelihood selection)



Preliminary result:

$$\Delta BR / BR(H \to Z\gamma) \approx 50\% \quad (120\ GeV)$$

$$\Delta BR / BR(H \to Z\gamma) \approx 20\% \quad (140\ GeV)$$

Invisible Higgs Decays

M.Schumacher

Many SM extensions predict invisible Higgs Decays, e.g.:

- MSSM $H \to \tilde{\chi}_1^0 \tilde{\chi}_1^0$
- Extra Dimensions
- Model with new singlets (NMSSM,Majoron Models)
- Stealthy Higgs

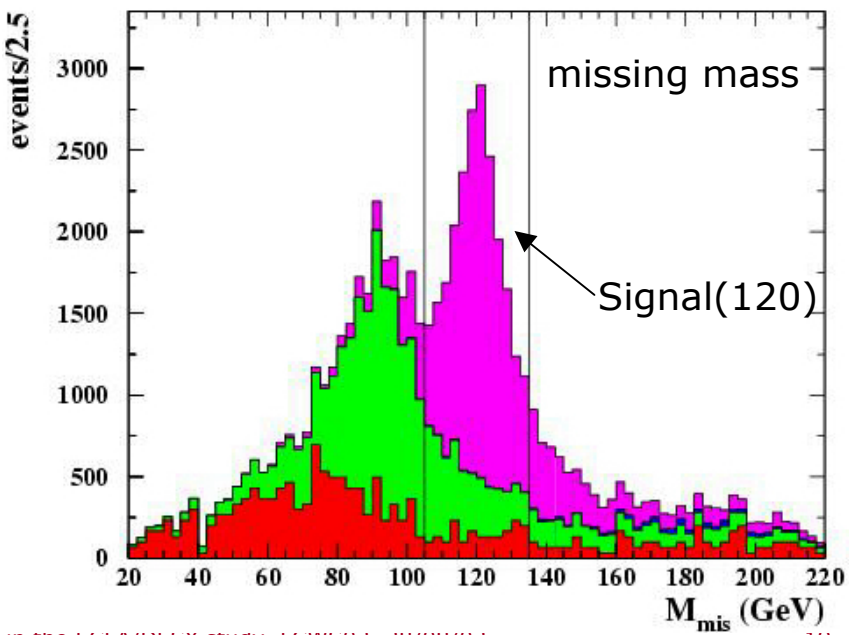
TDR: Estimate sensitivity from 1 = BR(vis) + BR(invis)

New study: explicit reconstruction in $e^+e^- \to ZH \to q\bar{q} + \not{E}$

Assumptions:

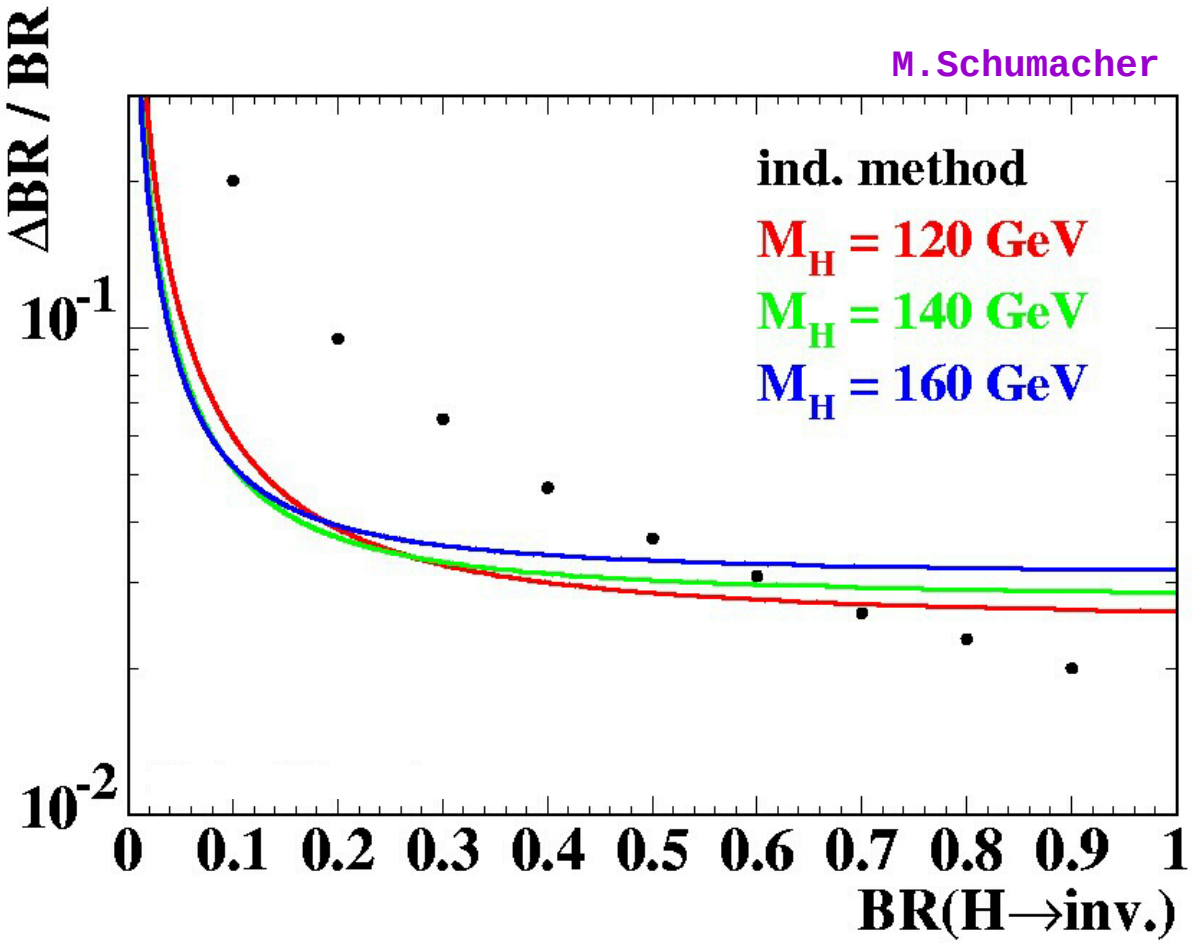
$\sqrt{s} = 350\,GeV, L = 500\,fb^{-1}$

$m_H = 120, 140, 160\,GeV$



Invisible Higgs Decays

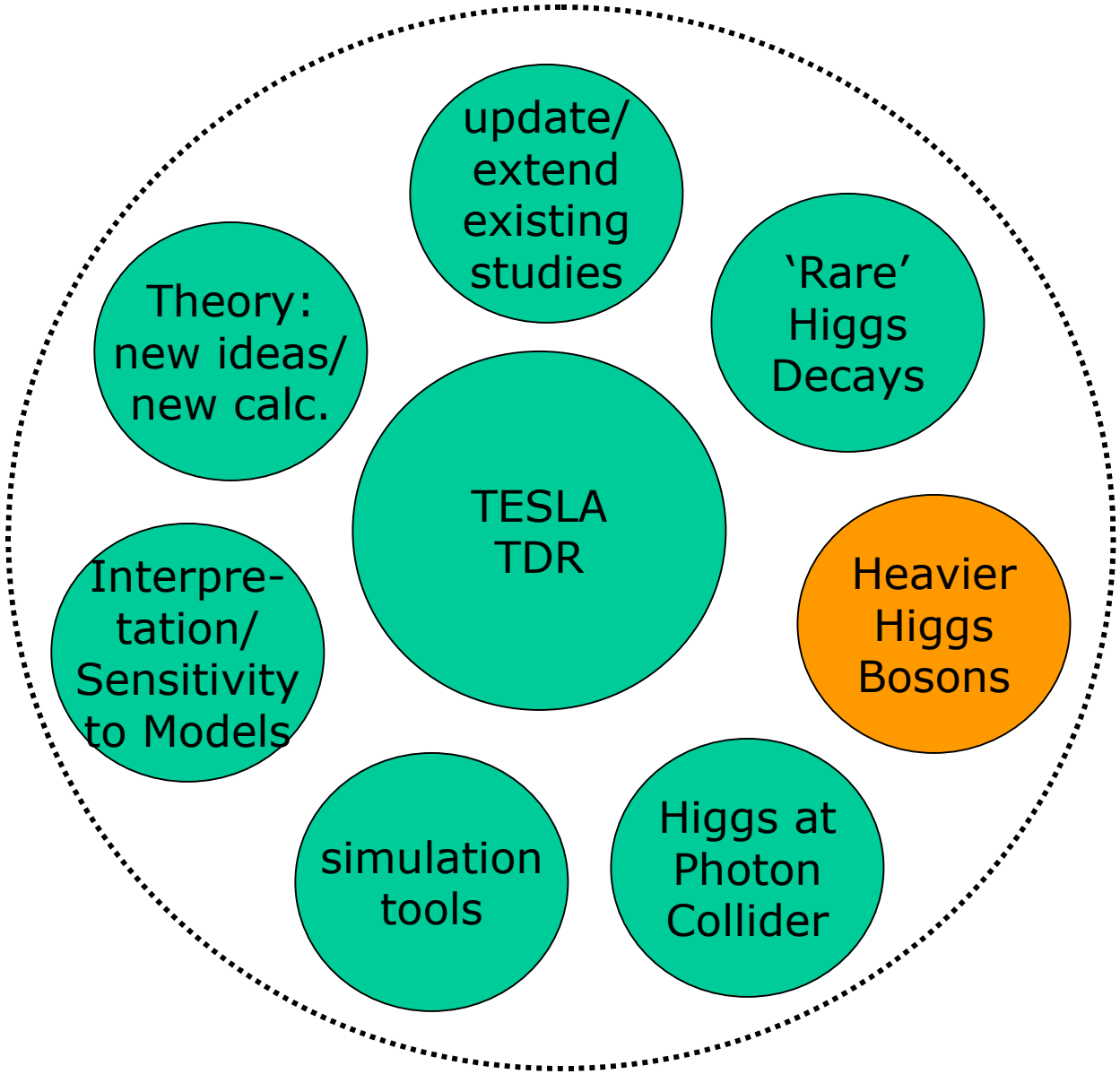
Result:



$\Delta BR/BR = 10\%(< 3\%)$ for $BR = 5\%(> 20\%)$

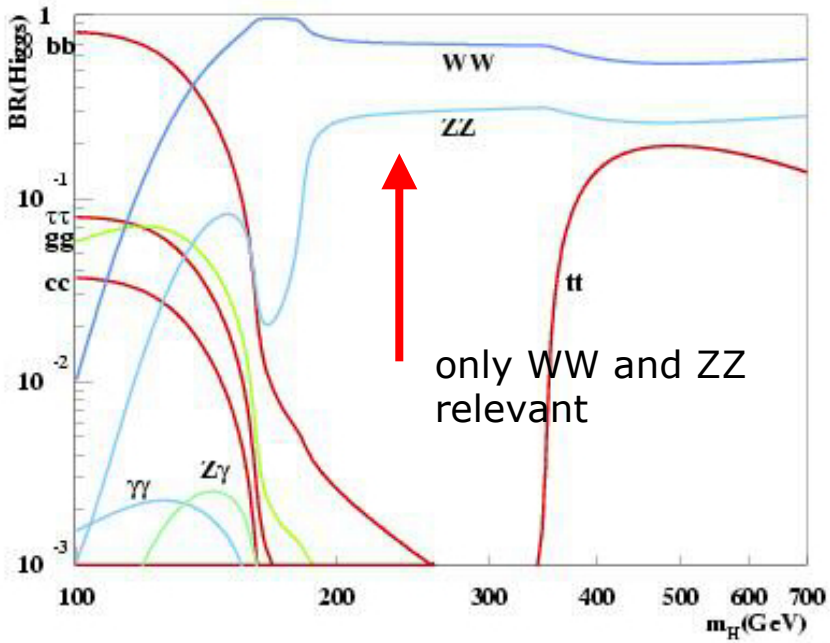
observation with 5σ down to $BR = 2\%$

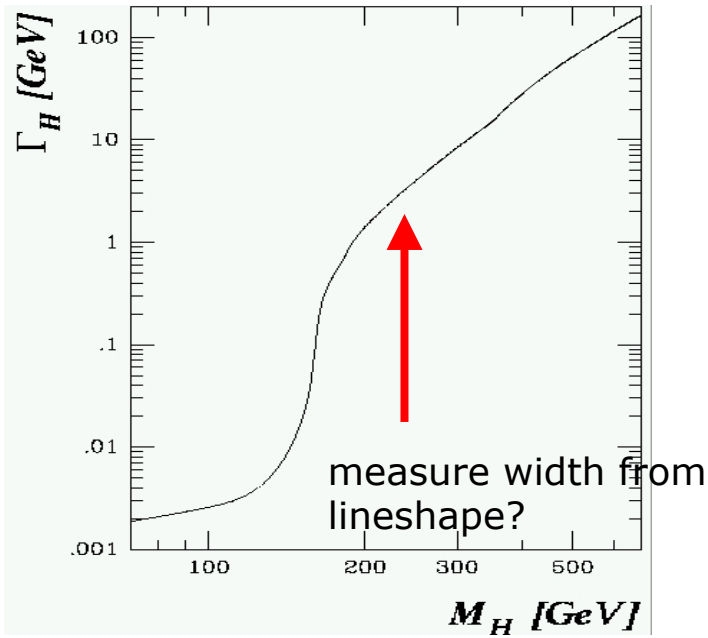
ECFA/DESY Higgs study landscape



Heavier than expected SM Higgs

What, if Higgs mass (somewhat) larger, than EW precision data tell?





Study of $e^+e^- \to ZH \to ZWW$ *and* ZZZ

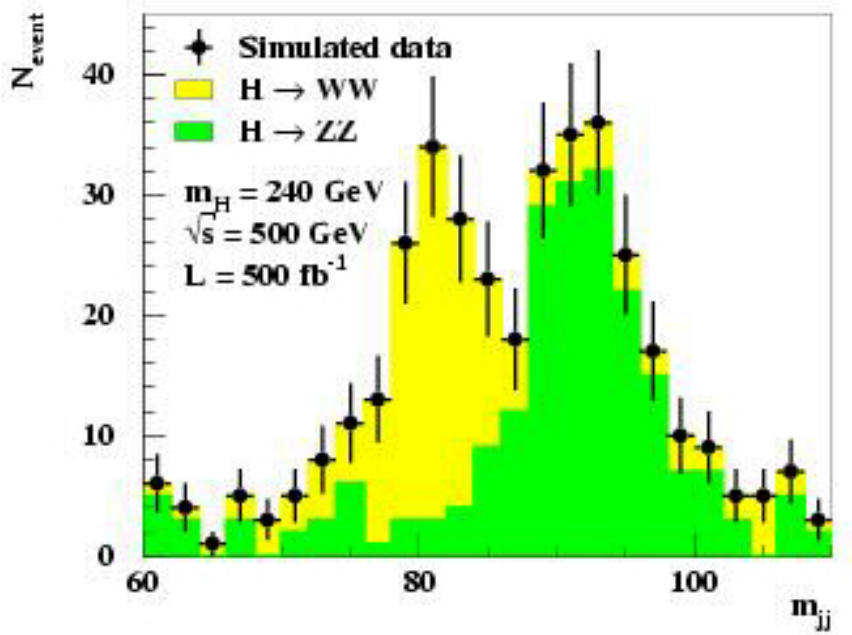
Most promising: $e^+e^- \to ZH \to \ell^+\ell^- q\bar{q}q\bar{q}$ final state

Heavier than expected SM Higgs

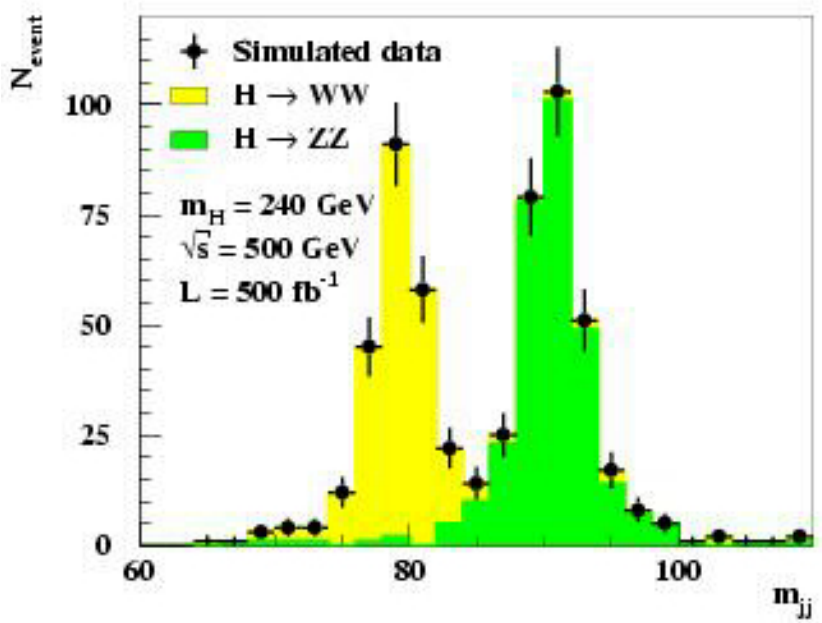
Critial task: disentangle $W \to q\bar{q}$ and $Z \to q\bar{q}$ N.Meyer, KD

Energy flow benchmark!

'raw' jets (30% jet energy res.)

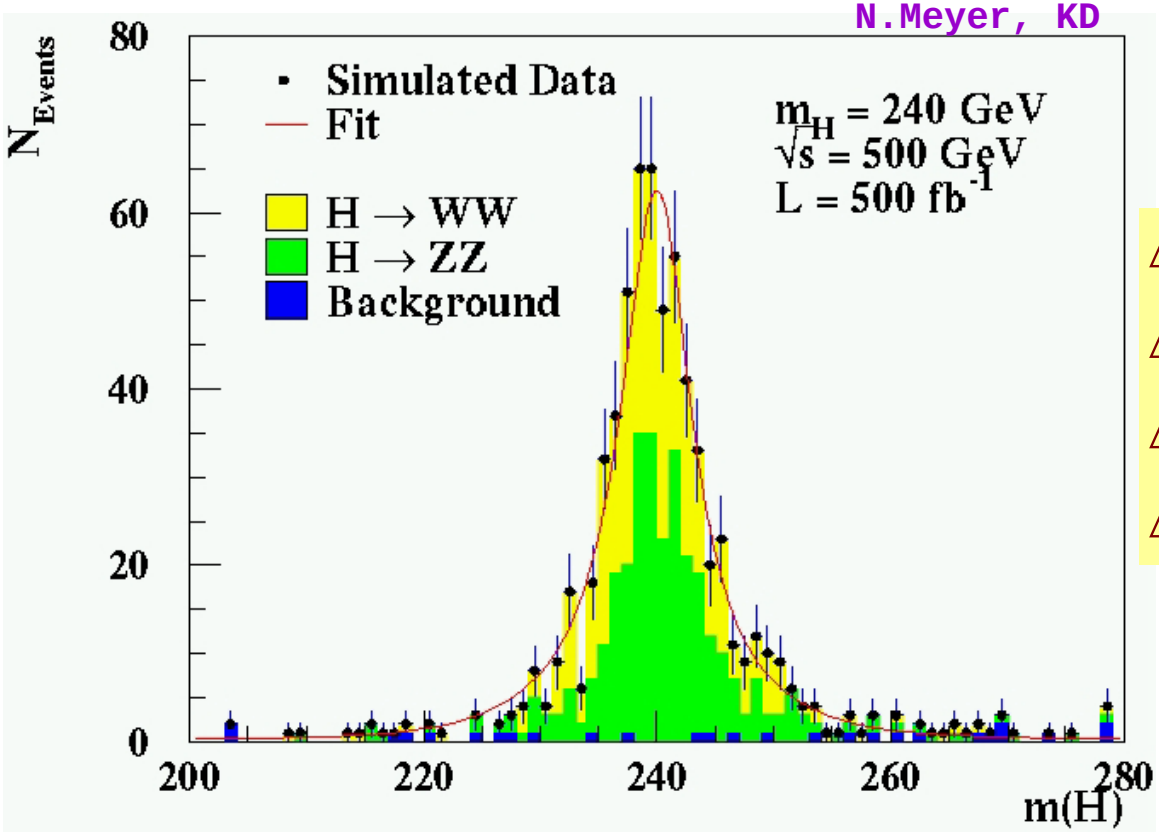


after kinematic fit



Heavier than expected SM Higgs

Result:



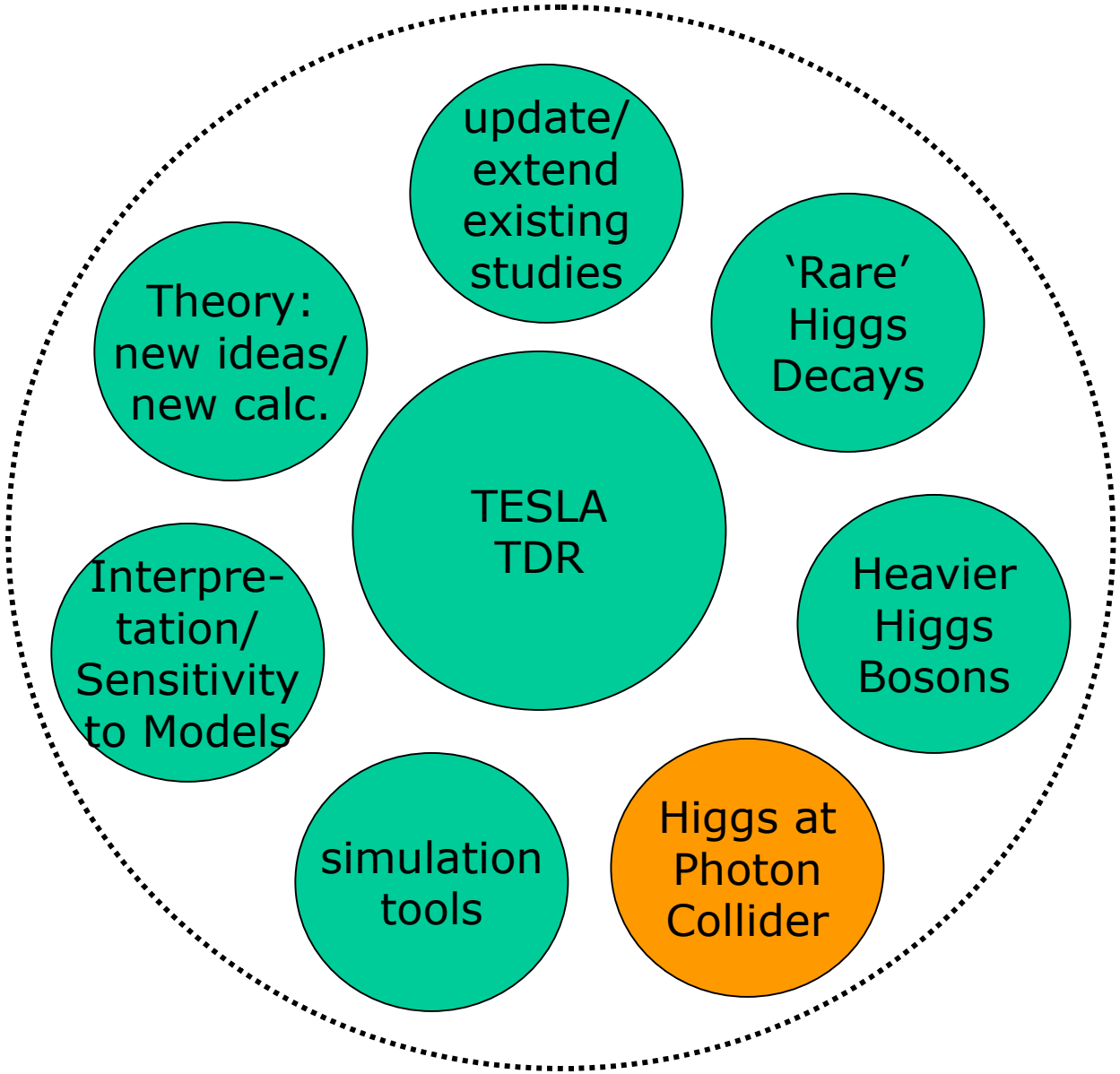
$$\Delta m_H = 200\ MeV$$

$$\Delta\Gamma_H / \Gamma_H = 11\%$$

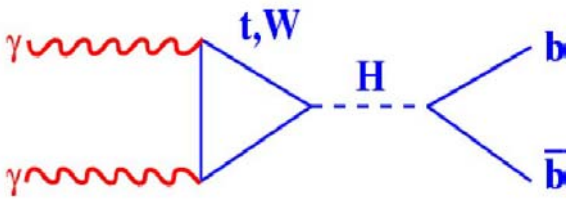
$$\Delta BR(WW) / BR(WW) = 6\%$$

$$\Delta BR(ZZ) / BR(ZZ) = 6\%$$

ECFA/DESY Higgs study landscape

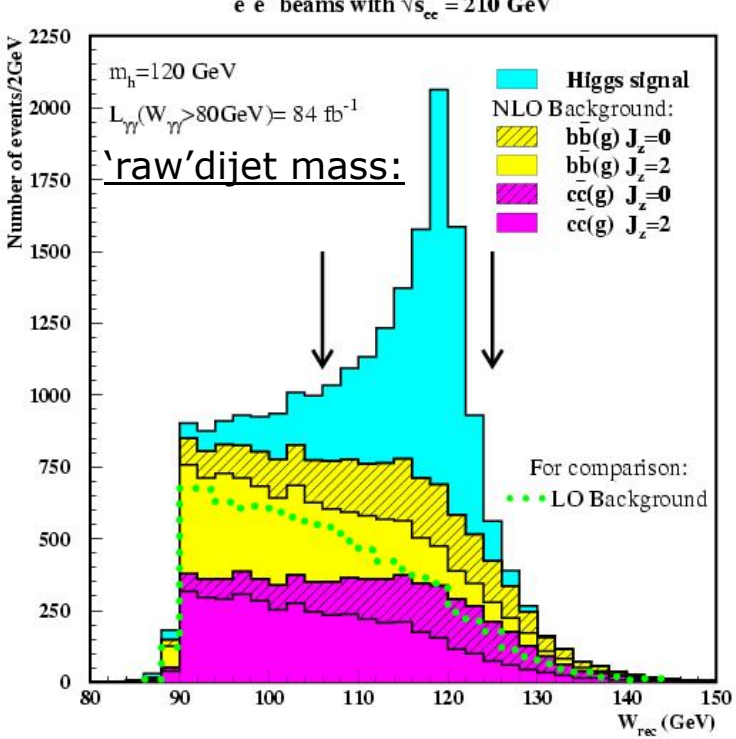


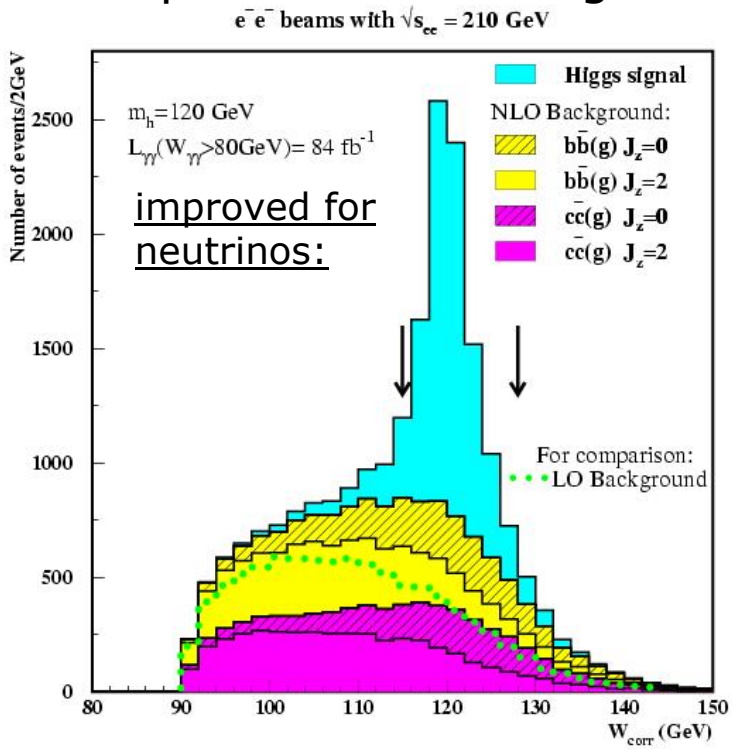
Higgs at photon collider



New simulation including
- NLO backgrounds
- realistic photon spectrum
- mass resolution improved for missing neutrinos

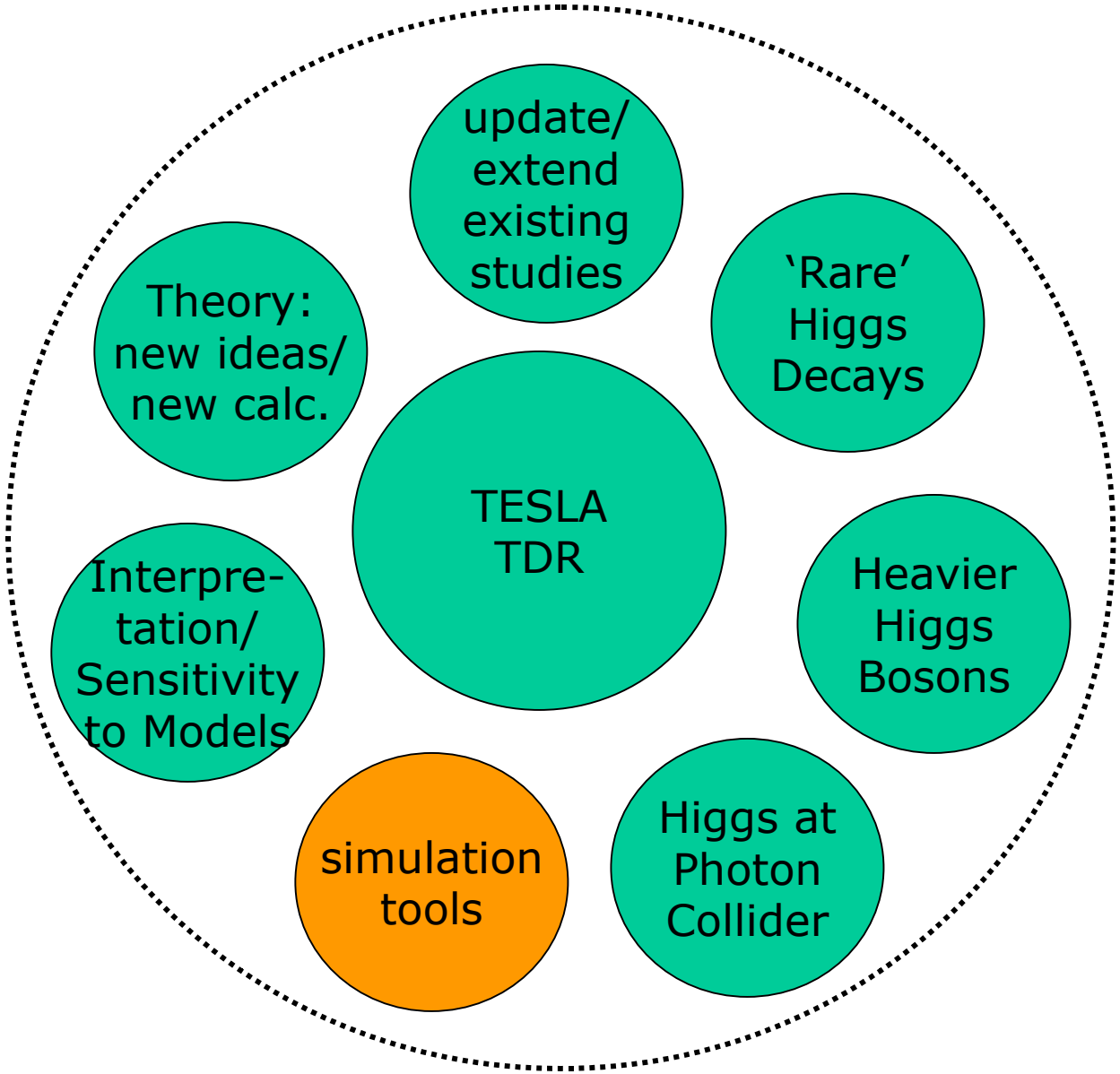
Krayczyk, Niezurawski Zarnecki





- also: study of $H \to WW$ (see talks by M.Krawczyk)
- also: experimental simulation of heavy H/A (S.Soldner-Rembold)
- also: report about US activities (D.Asner)

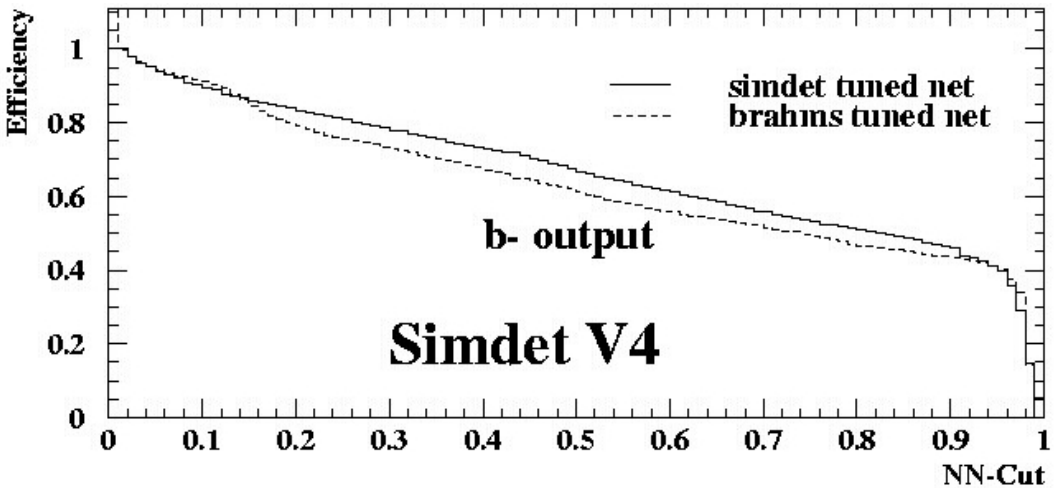
ECFA/DESY Higgs study landscape

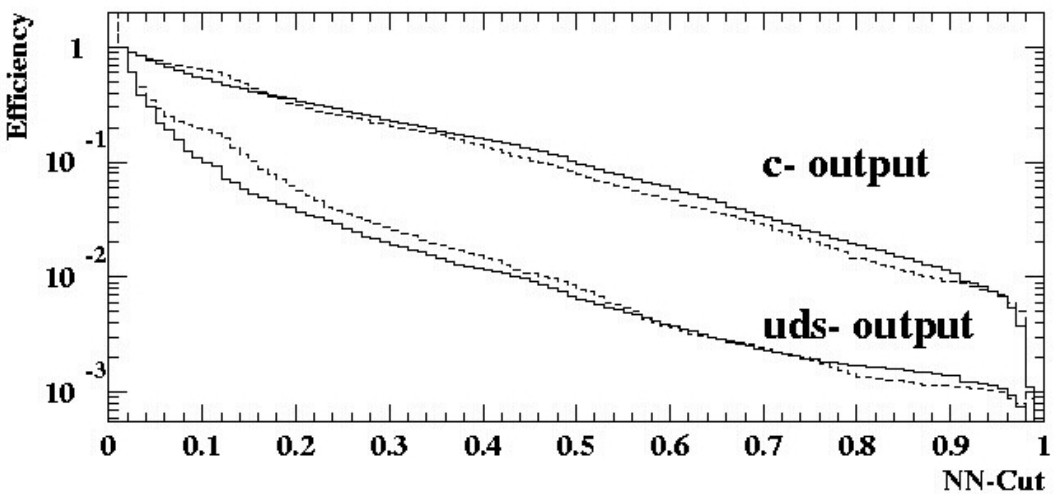


B-tagging in Fast Simulation

T.Kuhl

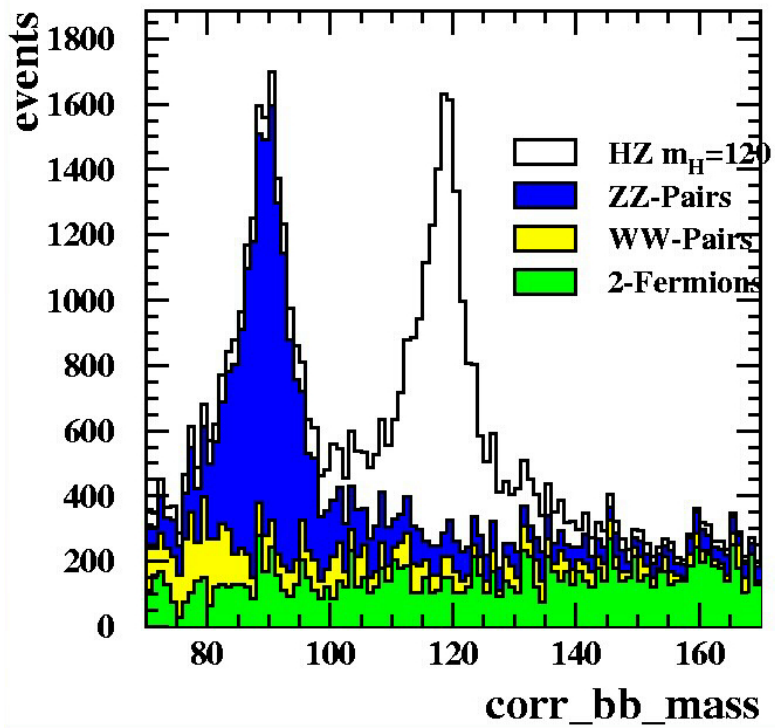
For TESLA-TDR: Many studies (not BR's!) used parametrized b-tag
Now: Event-by-event b-tag based on ZVTOP interfaced to SIMDET4



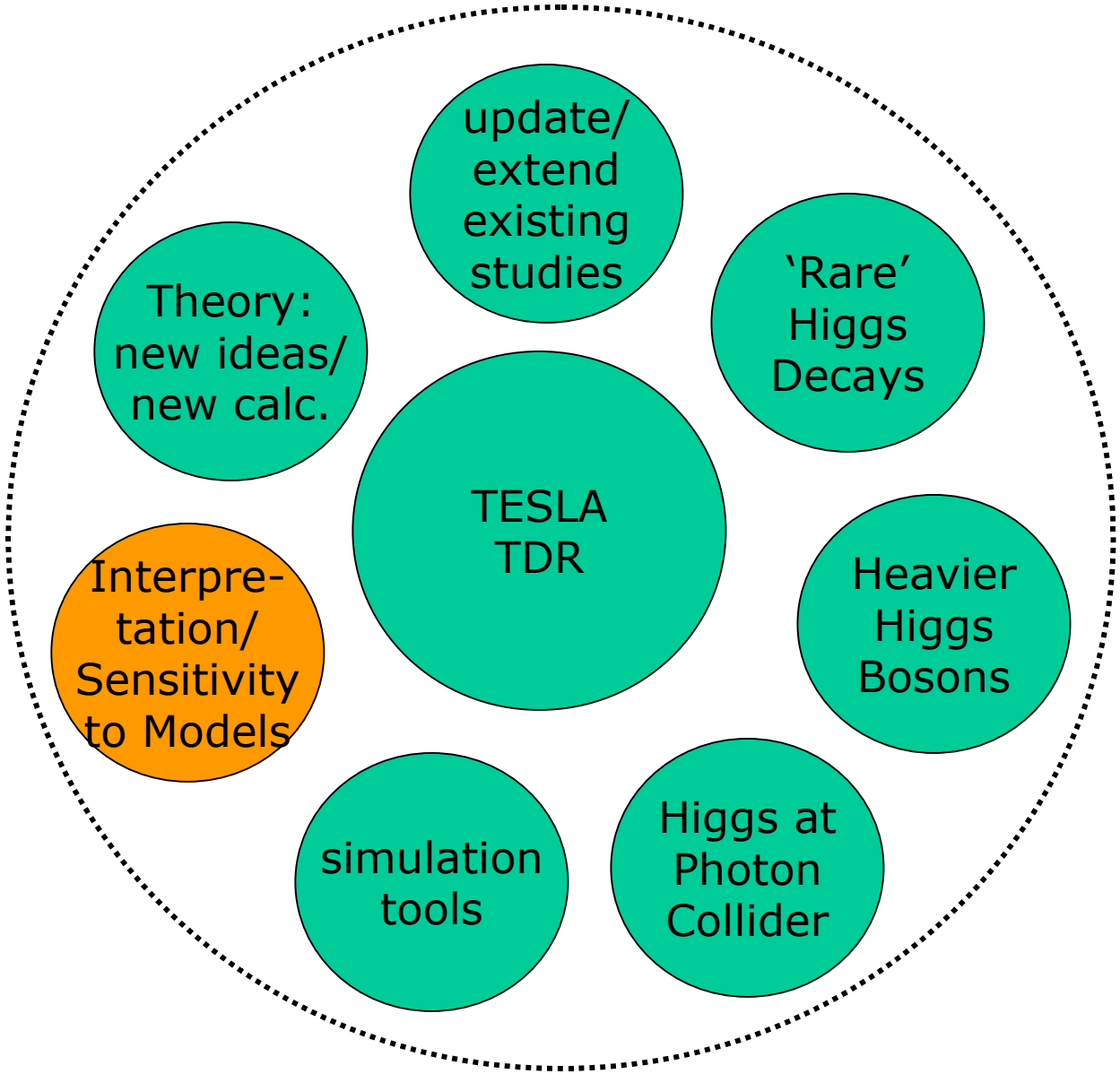


Sample analysis:

$$e^+e^- \to HZ \to b\bar{b}q\bar{q}$$



ECFA/DESY Higgs study landscape



Constraining the MSSM Higgs sector

Ultimate goal: extract the underlying SUSY parameters from Higgs sector measurements from a global fit

We're not there yet: difficult task since at higher orders, Higgs sectors depends on many parameters (stop mixing etc.)

Classical example: estimate m_A from BR-measurement

Yes! But, BR's also depend on $\tan\beta, m_{\tilde{t}}, m_t, A_t, \ldots, \Delta m_b (SUSY - QCD)$

We should try to bring the bits and pieces together!

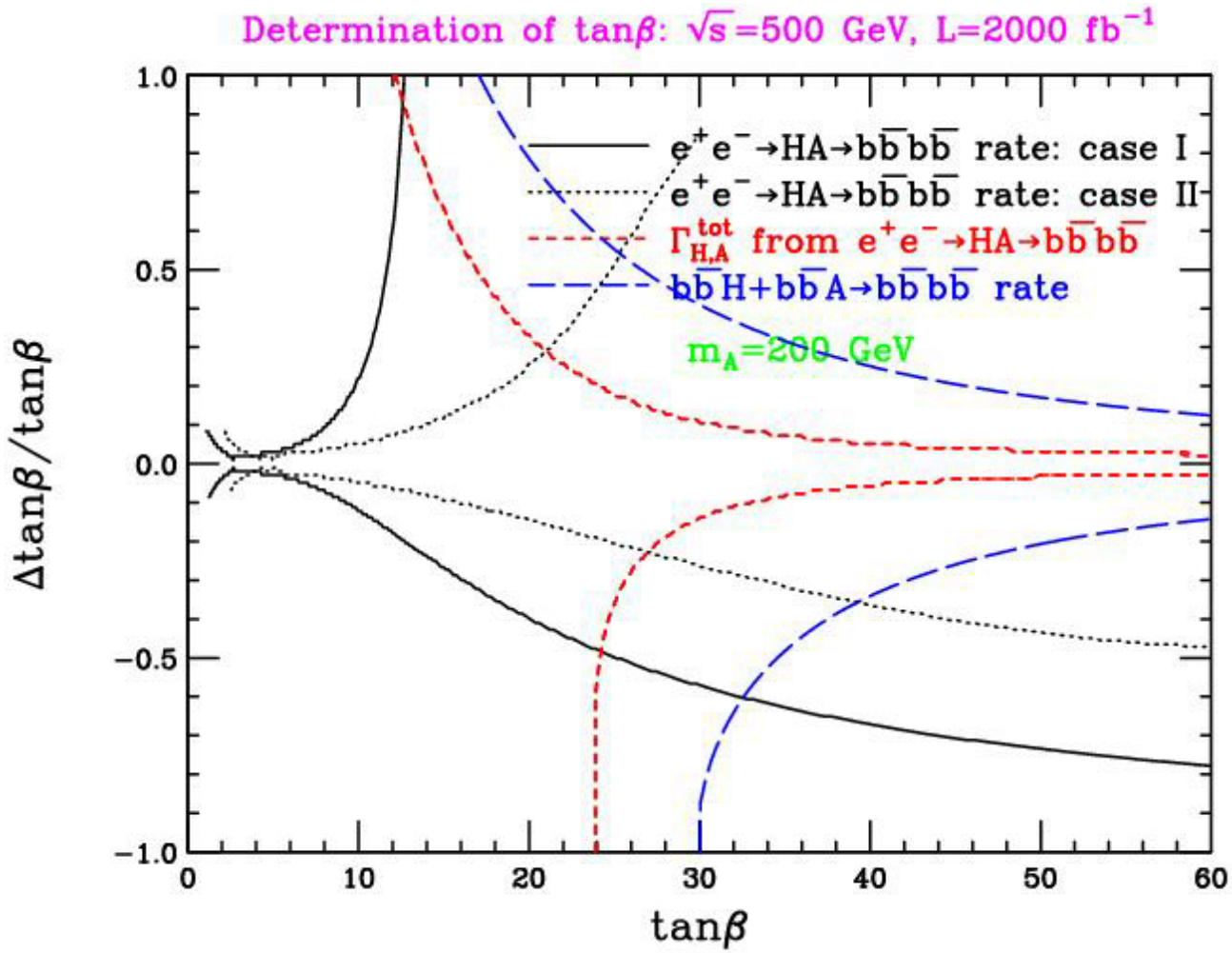
Some of them were presented in ECFA/DESY workshops…

Constraining the MSSM Higgs sector

tanβ from H/A

see talk by A.Sopczak

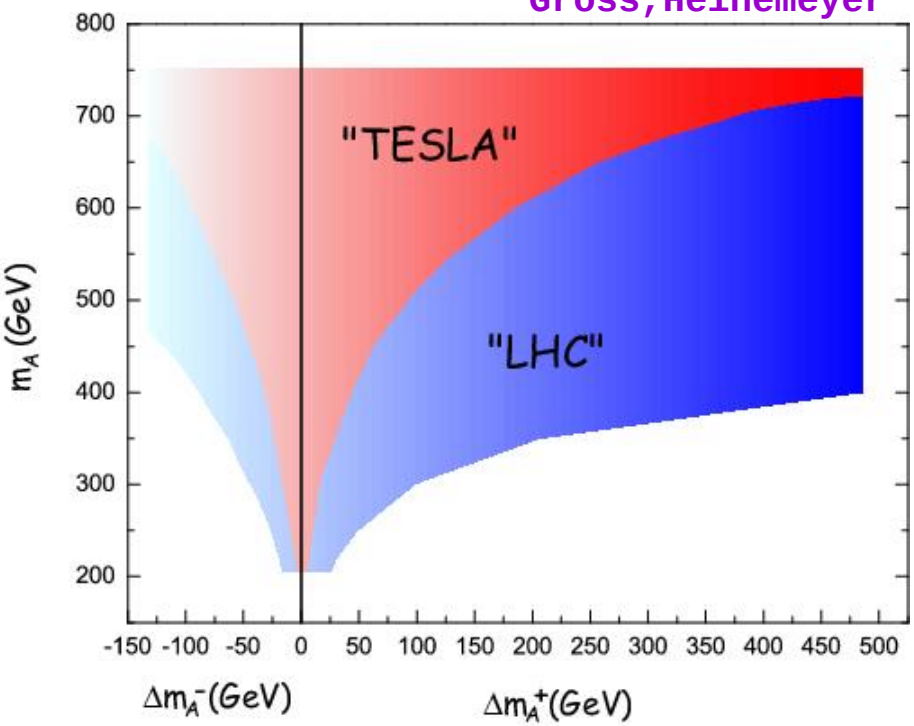
A.Spoczak



Constraining the MSSM Higgs sector

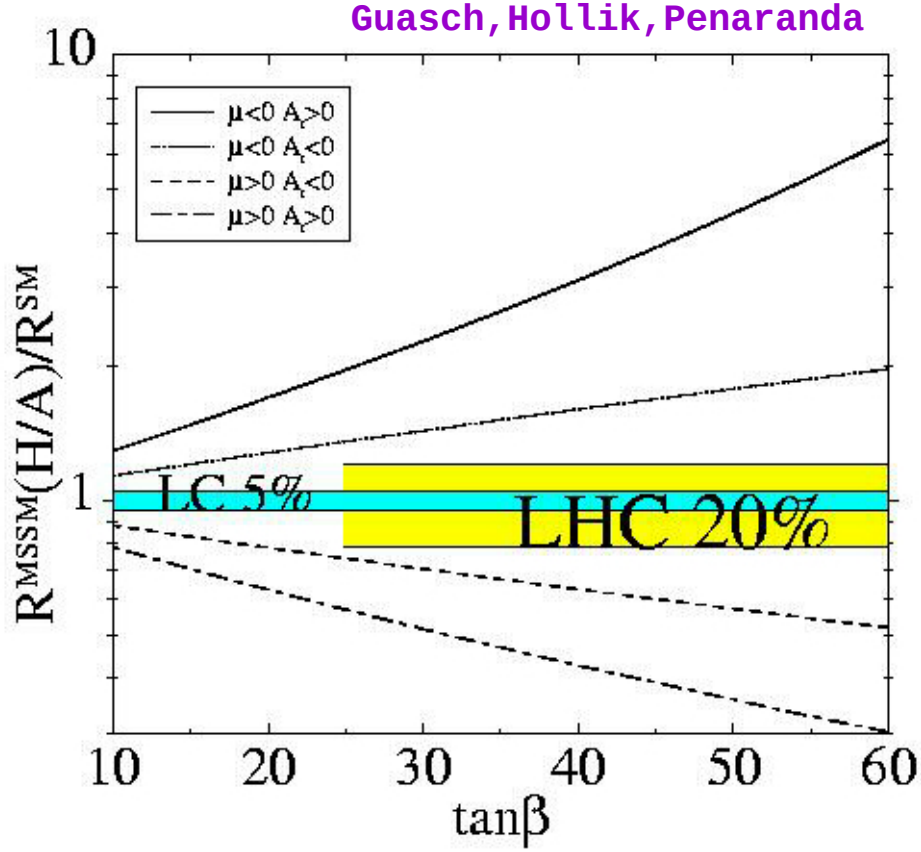
mA from bb/WW

Gross,Heinemeyer



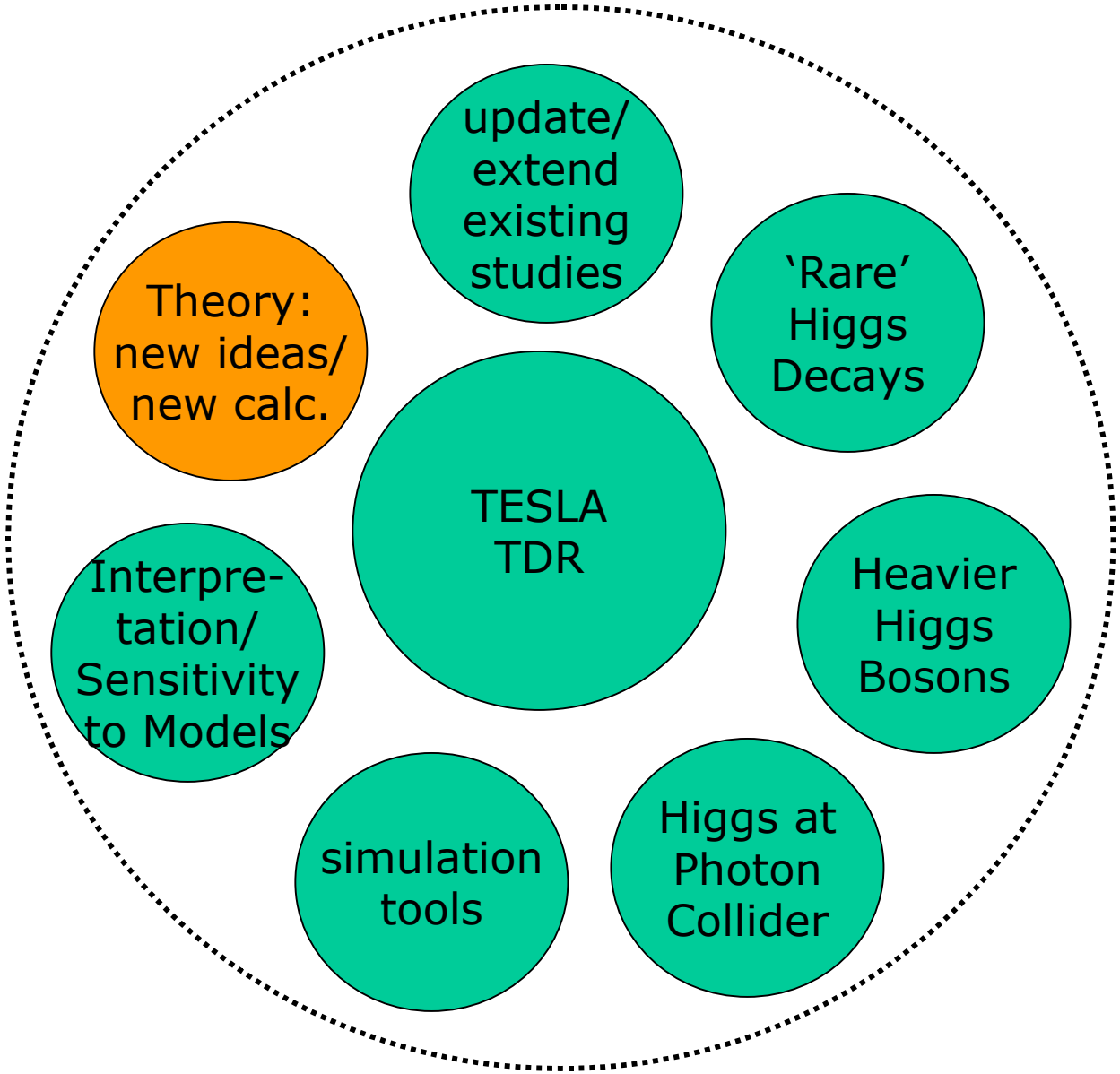
SUSY corrections (Δmb) from bb/$\tau\tau$

Guasch,Hollik,Penaranda



And many more ideas (Weiglein, Heinemeyer, ...)

ECFA/DESY Higgs study landscape



Theory: new ideas, new calculations…

This talk mainly focusses on experimental simulation

Close contact to theory is however highly appreciated!
I cannot cover all theoretical contributions we had in our workshops

Many of them trigger(ed) experimental work! That's good!

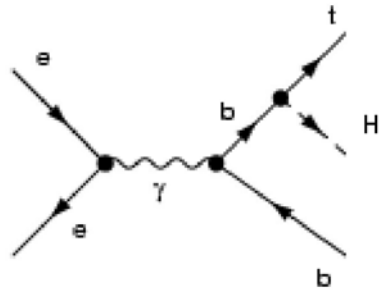
New ideas + new calculations:

- Radions and their mixing with the Higgs (J.Wells, J.Hewett)
- NMSSM Higgs sector (D.Miller)
- General Two Higgs Doublet model (P.Osland, M.Krawczyk)
- MSSM with CP violation (S.Heinemeyer)
- Higgs CP from tau decays (Z. Was)
- single charged Higgs associated with tb (B.Kniehl)
- single charged Higgs associated with $\tau\nu$ (S.Moretti)
- rad. Corrections to WW fusion (V.Spanos)
- bounds on Higgs mass (B.Grzadkowski)

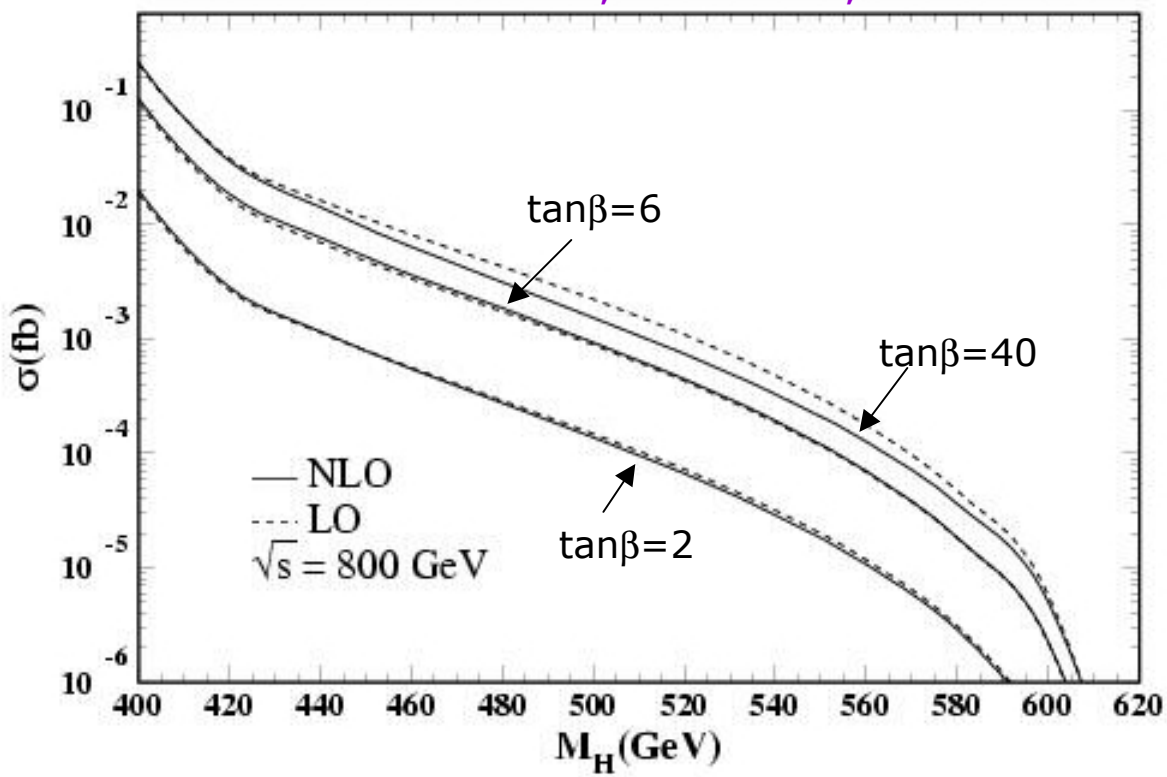
one example…->>

Theory: new ideas, new calculations…

single charged Higgs associated with tb
sizable QCD corrections



Kniehl,Madricardo,Steinhauser



Summary+Outlook

- TESLA TDR contains the core of our Higgs studies and contributed a lot to the accepted physics case for a linear collider
- This core is being currently extended in various directions, many things are under study
- Close collaboration of experiment and theory is very successful
- Closer contact to other regional studies started (could still be improved)
- Next meetings: November 2002, Prague
  Spring 2003, Amsterdam