Measuring the Higgs Self Coupling Somewhere

Tilman Plehn

UW Madison, CERN

(with Uli Baur and David Rainwater)

Higgs Bosons at the LHC

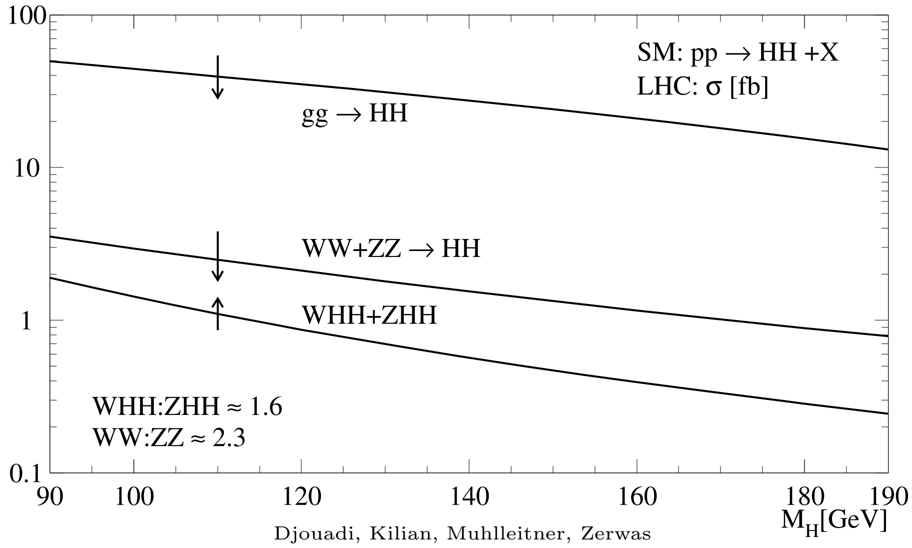
The Missing Piece:

– multitude of discovery channels in gluon and weak boson fusion
  [CMS: Nikitenko, ATLAS: Jacobs]

– measurement of couplings

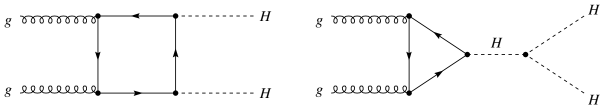
– determination of Higgs coupling structure and spin
  [TP, Rainwater, Zeppenfeld; Choi, Miller, Muhlleitner, Zerwas]

– Higgs potential: $V = -\lambda v^2(\Phi^\dagger\Phi) + \lambda(\Phi^\dagger\Phi)^2$
  relationship beween mass and self coupling: $\lambda = m_H^2/(2v^2)$?



Djouadi, Kilian, Muhlleitner, Zerwas

One-Loop Amplitude $gg \to HH$:



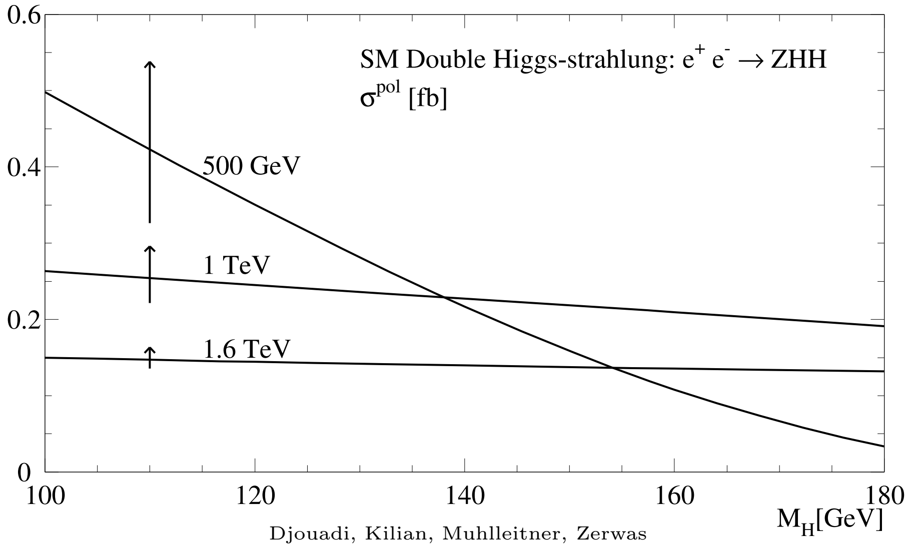
– single off-shell Higgs production
  (destructively) interfering with four point continuum graphs

– convenient effective theory $\mathcal{L}_{\text{eff}} \sim H^n G_{\mu\nu} G^{\mu\nu}$
  links $ggHH$ vertex to gluon self energy (top loop)

– approximation good for $m_H < 2m_t$, total rate

WHAT DO OTHERS SAY?

Rate at TESLA: $e^+e^- \to ZHH$



Djouadi, Kilian, Muhlleitner, Zerwas

$\to$ limited number of events

$\to$ low Higgs mass, decays $H \to b\bar{b}$ [Castanier, Gay, Lutz, Orloff]

$\to$ S/B detector simulation, neural net analysis

m_h [GeV]	$\sigma_{\rm hhZ}$(fb)	$N^{500}_{\rm hhZ}$	$\epsilon_{\rm hhZ}$	$\Delta\sigma/\sigma$		
				L = 500fb^{-1}	1000fb^{-1}	2000fb^{-1}
120	0.186	93.	43%	24.1%	17.3%	11.6%
130	0.149	74.	43%	26.6%	19%	17.7%
140	0.115	57.	39%	32%	23%	17%

$\to$ measurement of λ through total cross section ($m_h = 120$ GeV)

selection	variable	$\Delta\lambda/\lambda$		
		L = 500fb^{-1}	1000fb^{-1}	2000fb^{-1}
B	$\not{B}^{\rm recoil}$	42.2%	30.3%	20.3 %
D	NN output	35.7%	22.6%	18.0%

$\Rightarrow$ TESLA can do something

Higgs Pairs at the LHC

Signal Extraction:

– signal $gg \to HH \to (W^+W^-)(W^+W^-) \to (jj\ell^\pm\nu)(jj\ell'^\pm\nu)$

$\Pi\,\mathrm{BR} \lesssim 1/30$ [c.f. Mangano... hep-ph/0204087]

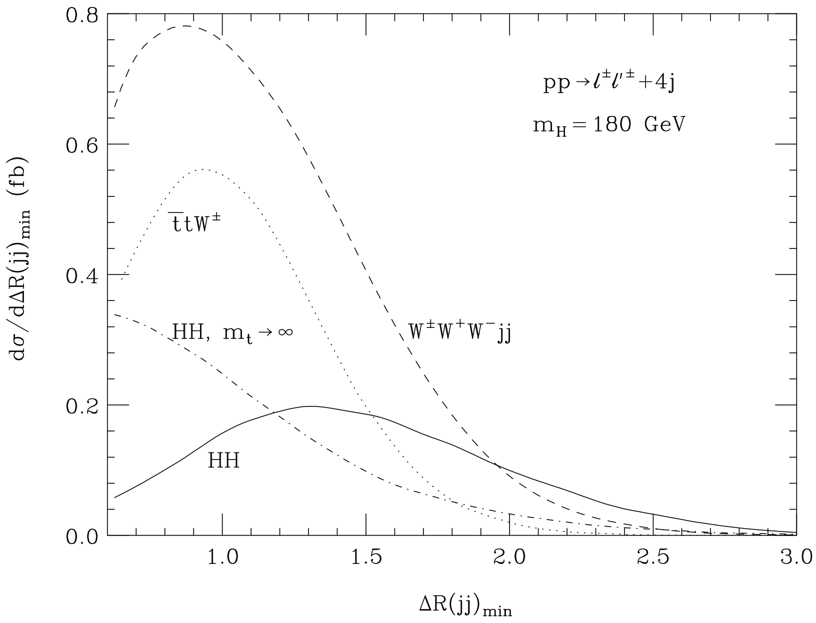
– parton level MC, one cut $\Delta R_{\mathrm{jj,min}} > 1$ only

– dominant backgrounds: $WWWjj, t\bar{t}W$

additional backgrounds: $WWZjj, t\bar{t}W, t\bar{t}Z, t\bar{t}j, WZ4j, WW4j, 4t$

[$VV4j \equiv VV2j + 2j$, all others hard matrix element]

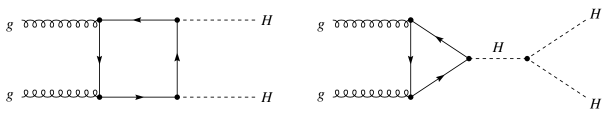
– large top mass approximation completely useless!



Signal & Backgrounds [fb]:

m_h [GeV]	signal	$\mathrm{N}^{2\times300}$	$WWWjj$	$t\bar{t}W$	$t\bar{t}Z$	$t\bar{t}j$	$WZ4j$	$WW4j$	$t\bar{t}t\bar{t}$
150	0.074	44	0.361	0.222	0.054	0.082	0.148	0.0052	0.0018
160	0.194	116	0.486						
180	0.177	106	0.404						
200	0.083	50	0.292						

Higgs Self Coupling



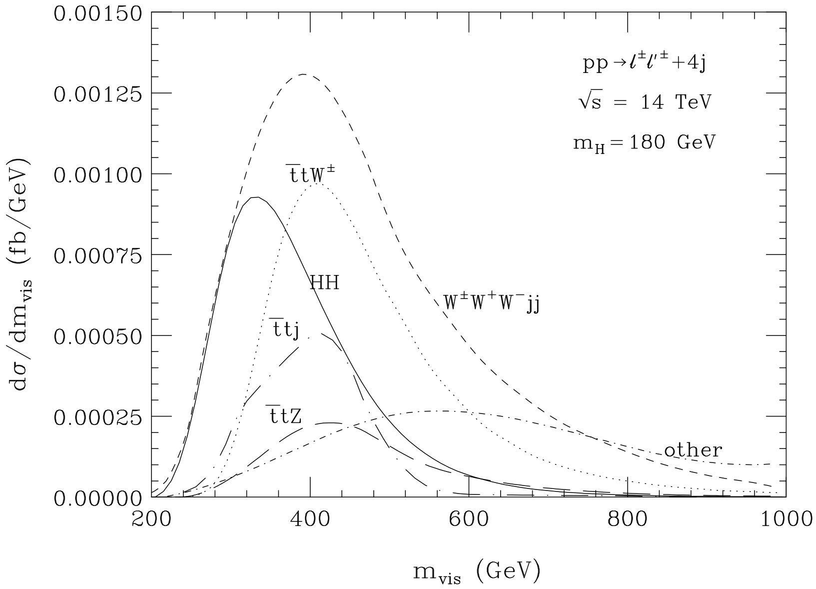
Intermediate Higgs vs. Continuum:

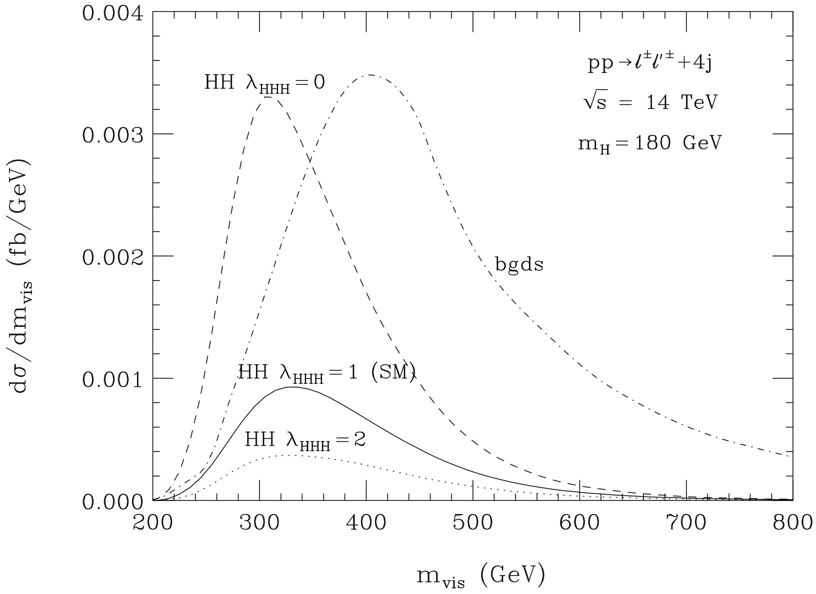
– useful distribution from visible mass $[(\Sigma_{j,\ell}\, p^{\mu})^2$; small for HH signal]

– could be used for background suppression

– instead used to fit self coupling λ [best cancellation at threshold]

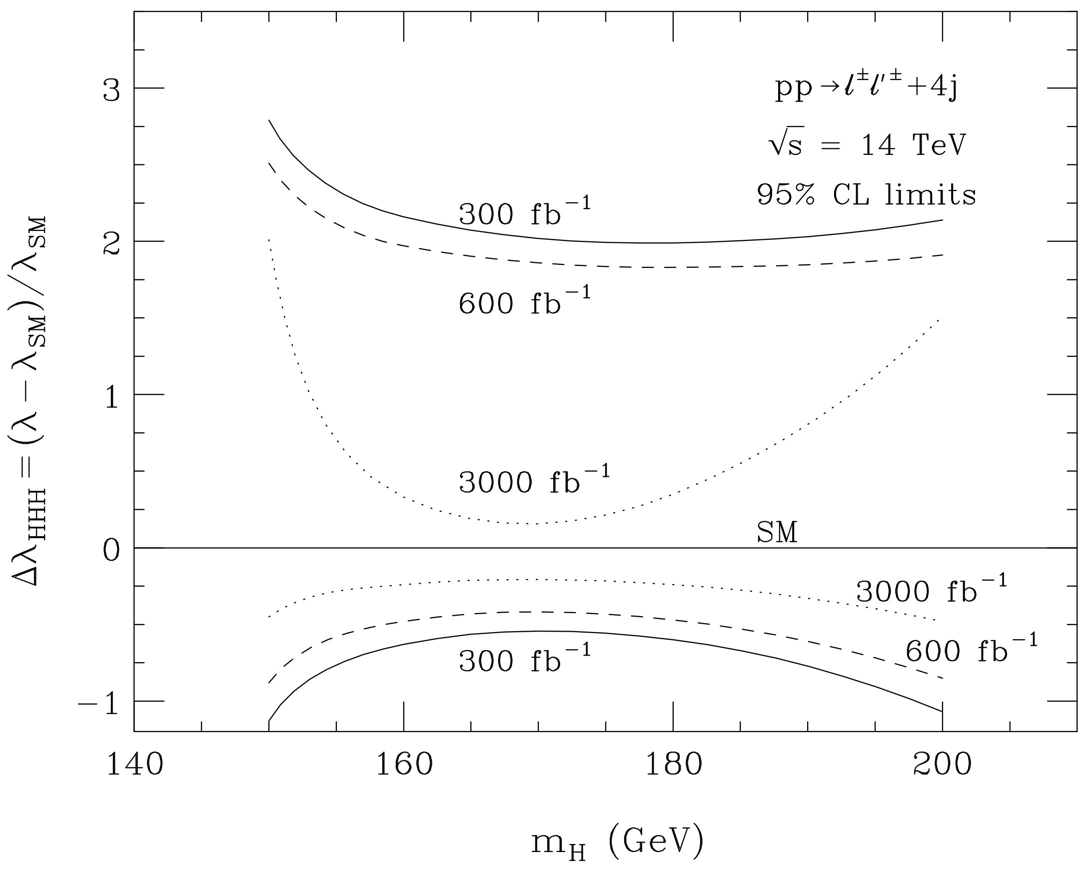
$\Rightarrow$ measurement of λ should be possible at LHC





n.b.: Extraction from total rate not a good idea at LHC

CONCLUSIONS



So What About the Complementarity?

TESLA	LHC
double-Higgs strahlung	gluon fusion (one-loop)
limited by rate	limited by backgrounds
low mass region 120...140 GeV	intermediate $m_H = 150...200$ GeV
decay $H \to b\bar{b}$	decay $H \to WW$
λ_{HHH} from rate	λ_{HHH} from visible mass
neural net analysis available	parton level, one cut, χ^2analysis
how about CLIC?	how about the vLHC?

Outlook: vLHC