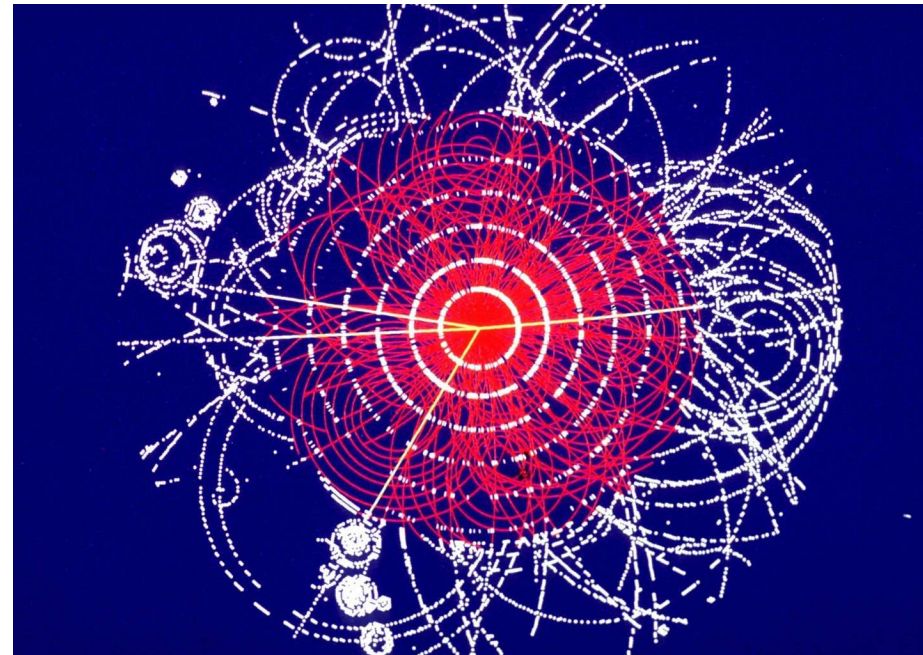


HIGGS BOSON PHYSICS

Dieter Zeppenfeld
Karlsruhe Institute of Technology (KIT)

Pheno 2009 Symposium, Madison, May 11 - 13, 2009

- Introduction
- Search channels at the LHC
- Higgs coupling measurements
- QCD and EW corrections
- Hjj events: VBF vs gluon fusion
- Higgs CP measurements
- Conclusions



Goals of Higgs Physics

Higgs Search = search for dynamics of $SU(2) \times U(1)$ breaking

- Discover the Higgs boson
- Measure its couplings and probe mass generation for gauge bosons and fermions

Fermion masses arise from Yukawa couplings via $\Phi^\dagger \rightarrow (0, \frac{v+H}{\sqrt{2}})$

$$\begin{aligned} \mathcal{L}_{\text{Yukawa}} &= -\Gamma_d^{ij} \bar{Q}'_L{}^i \Phi d'_R{}^j - \Gamma_d^{ij*} \bar{d}'_R{}^i \Phi^\dagger Q'_L{}^j + \dots = -\Gamma_d^{ij} \frac{v+H}{\sqrt{2}} \bar{d}'_L{}^i d'_R{}^j + \dots \\ &= -\sum_f m_f \bar{f} f \left(1 + \frac{H}{v}\right) \end{aligned}$$

- Test SM prediction: $\bar{f} f H$ Higgs coupling strength = m_f/v
- Observation of $H f \bar{f}$ Yukawa coupling is no proof that v.e.v exists

Higgs coupling to gauge bosons

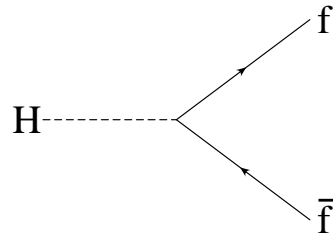
Kinetic energy term of Higgs doublet field:

$$(D^\mu \Phi)^\dagger (D_\mu \Phi) = \frac{1}{2} \partial^\mu H \partial_\mu H + \left[\left(\frac{g v}{2} \right)^2 W^{\mu+} W_\mu^- + \frac{1}{2} \frac{(g^2 + g'^2) v^2}{4} Z^\mu Z_\mu \right] \left(1 + \frac{H}{v} \right)^2$$

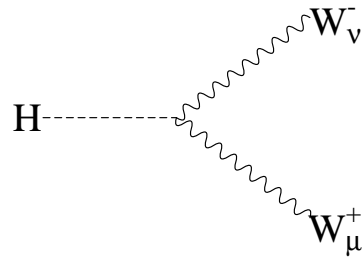
- W, Z mass generation: $m_W^2 = \left(\frac{g v}{2} \right)^2$, $m_Z^2 = \frac{(g^2 + g'^2) v^2}{4}$
- WWH and ZZH couplings are generated
- Higgs couples proportional to mass: coupling strength = $2 m_V^2 / v \sim g^2 v$ within SM

Measurement of WWH and ZZH couplings is essential for identification of H as agent of symmetry breaking: Without a v.e.v. such a trilinear coupling is impossible at tree level

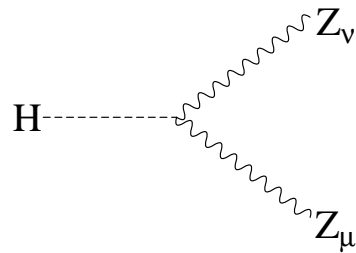
Feynman rules for SM Higgs couplings



$$-i \frac{m_f}{v} \mathbf{1}$$



$$ig m_W g_{\mu\nu}$$

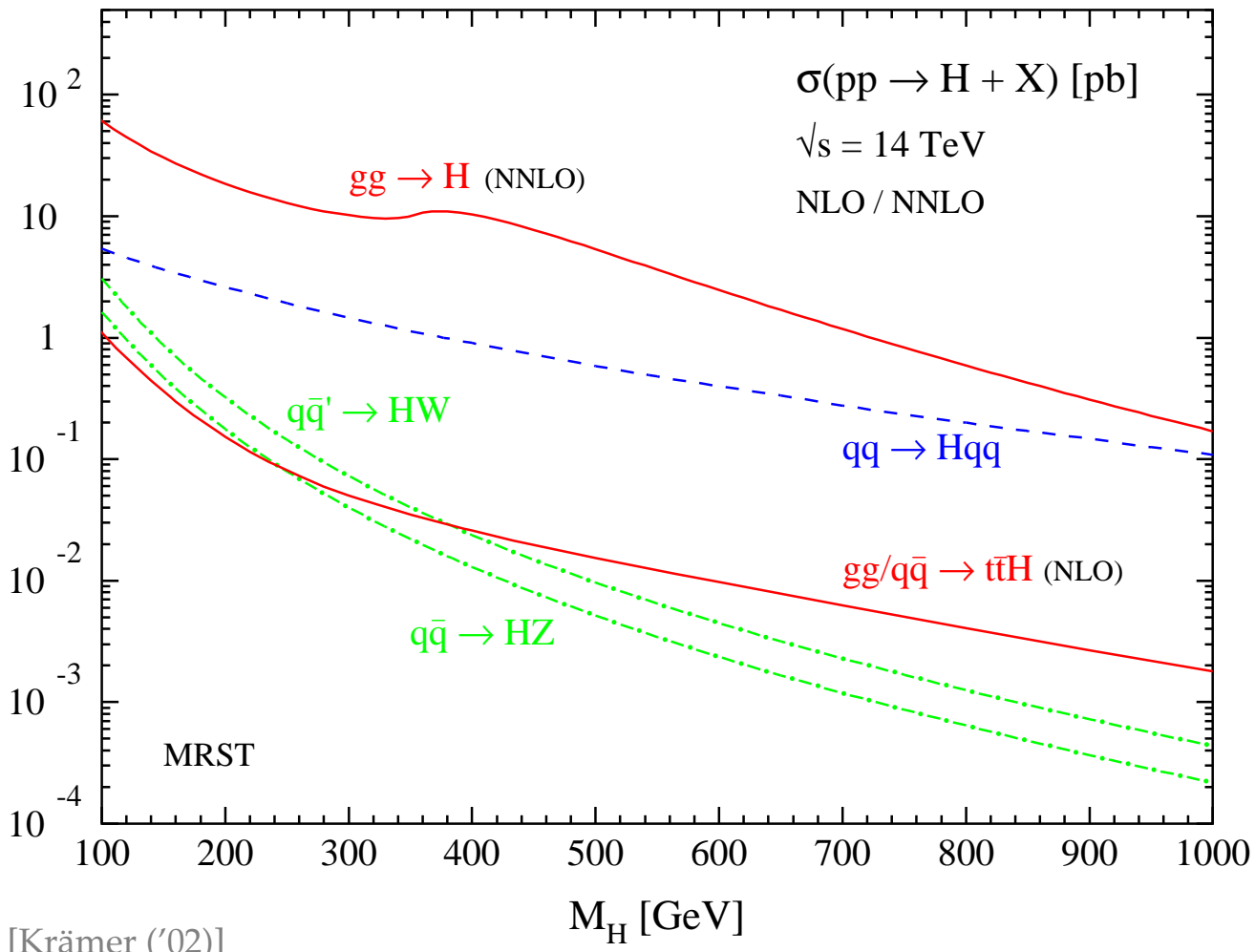


$$i g \frac{1}{\cos \theta_W} m_Z g_{\mu\nu}$$

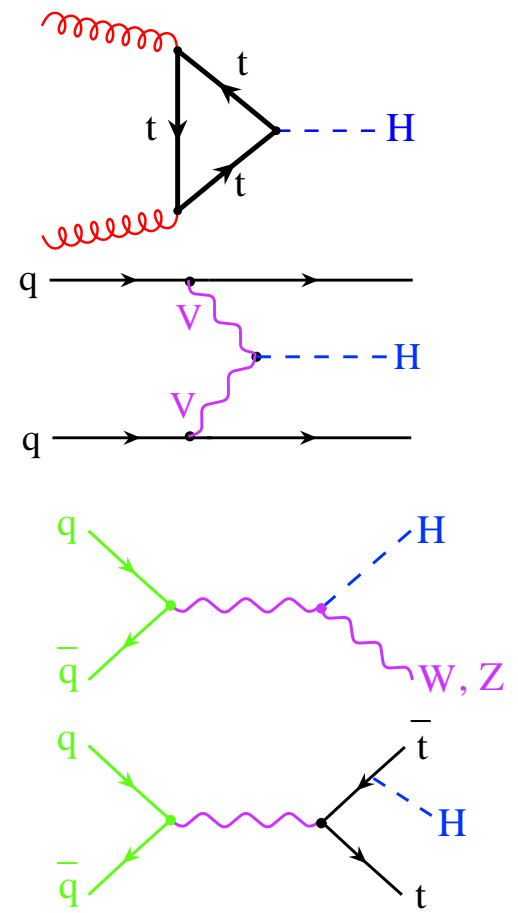
Verify tensor structure of HVV couplings. Loop induced couplings lead to $HV_{\mu\nu}V^{\mu\nu}$ effective coupling and different tensor structure: $g_{\mu\nu} \rightarrow q_1 \cdot q_2 g_{\mu\nu} - q_{1\nu}q_{2\mu}$

Distinguish scalar from pseudoscalar Higgs couplings to fermions.

Total cross sections at the LHC



[Krämer ('02)]



Inclusive search channels

- inclusive search for

$$H \rightarrow \gamma\gamma$$

invariant-mass peak, for $m_H < 150$ GeV

- inclusive search for

$$H \rightarrow ZZ^* \rightarrow \ell^+ \ell^- \ell^+ \ell^-$$

for $m_H \geq 130$ GeV and $m_H \neq 2m_W$.

- inclusive search for

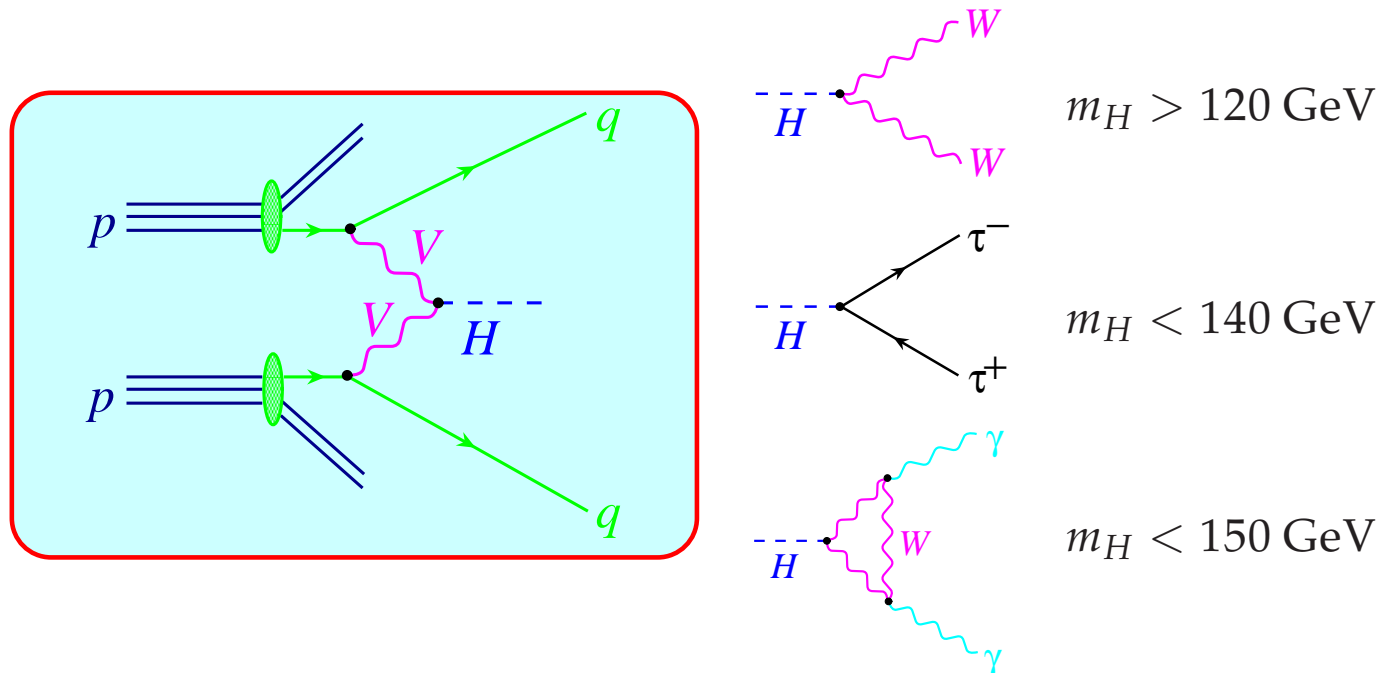
$$H \rightarrow W^+W^- \rightarrow \ell^+ \bar{\nu} \ell^- \nu$$

for $140 \text{ GeV} \leq m_H \leq 200 \text{ GeV}$

Inclusive searches dominated by gluon fusion production

probe ttH coupling (or ggH effective vertex)

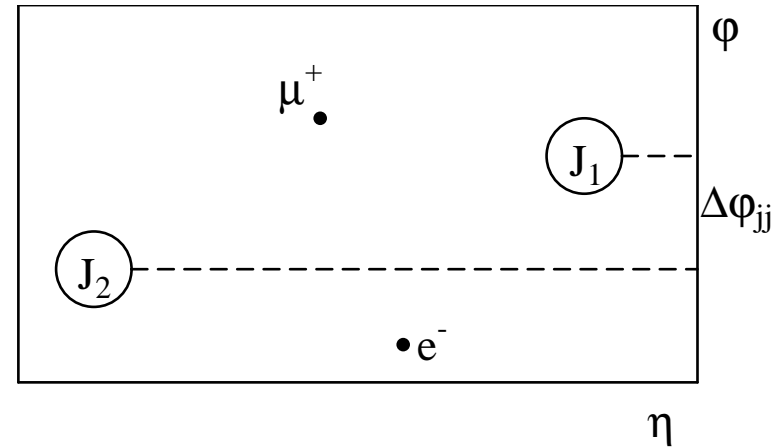
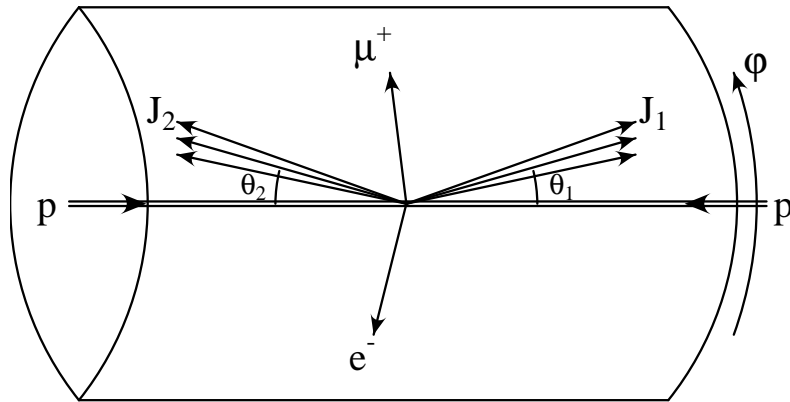
Vector Boson Fusion (VBF)



[Eboli, Hagiwara, Kauer, Plehn, Rainwater, D.Z. ...]

Most measurements can be performed at the LHC with **statistical accuracies** on the measured cross sections times decay branching ratios, $\sigma \times \text{BR}$, of **order 10%** (sometimes even better).

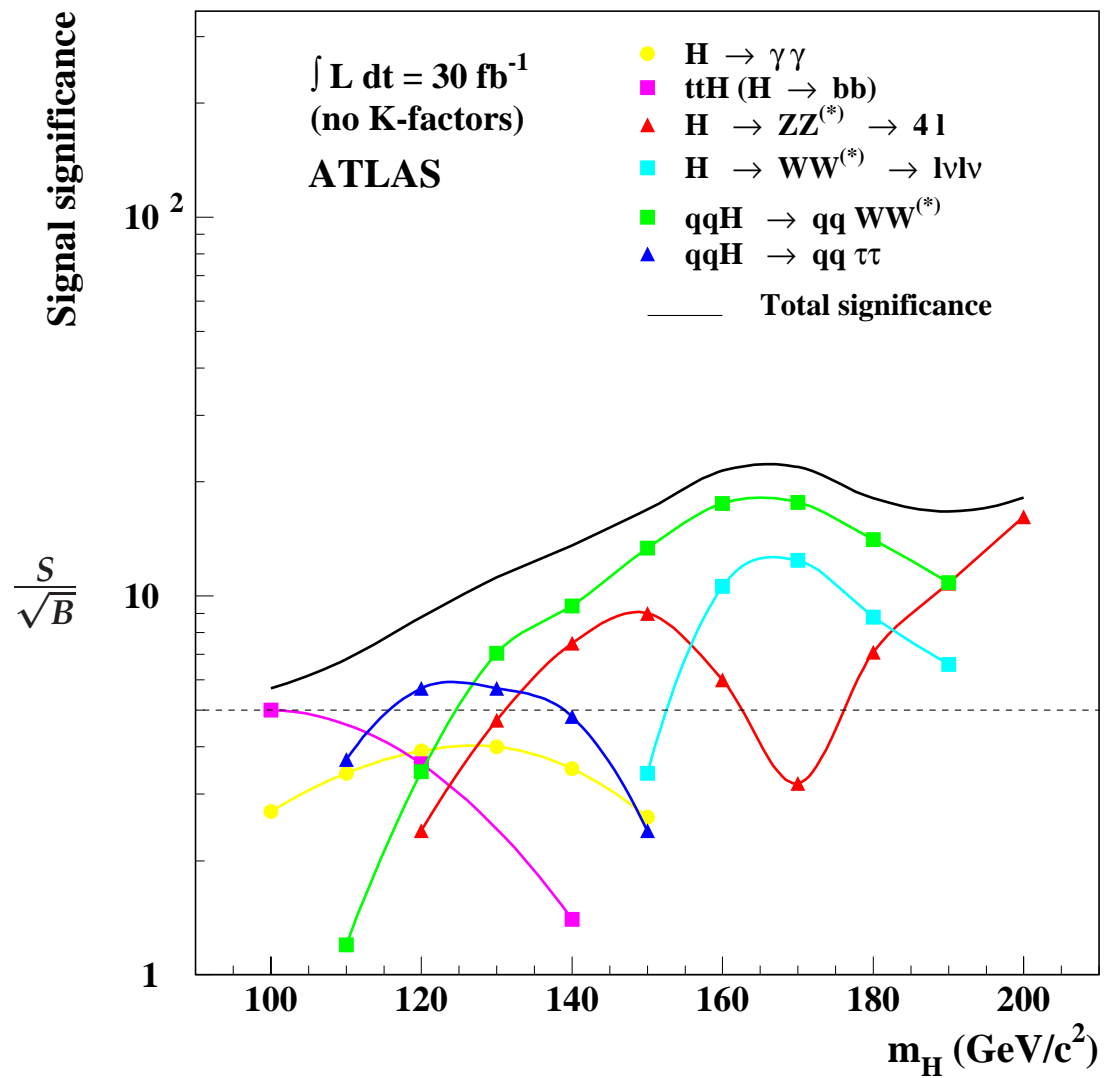
VBF signature



Characteristics:

- energetic jets in the **forward** and **backward** directions ($p_T > 20$ GeV)
- large **rapidity separation** and large **invariant mass** of the two tagging jets
- **Higgs decay products between** tagging jets
- Little gluon radiation in the central-rapidity region, due to **colorless** W/Z exchange (**central jet veto**: no extra jets between tagging jets)

Higgs discovery potential



Associated production search channels

- $pp \rightarrow t\bar{t}H \rightarrow t\bar{t}b\bar{b}$
for $m_H < 120 - 130$ GeV

- $q\bar{q} \rightarrow WH, ZH$ **New and improved:** Butterworth, Davison, Rubin, Salam, arXiv:0802.2470
trigger on leptonic decay of W or Z , look for $H \rightarrow b\bar{b}$

New idea for WH and ZH associated production: concentrate on high $p_T(H) \gtrsim 200$ GeV:

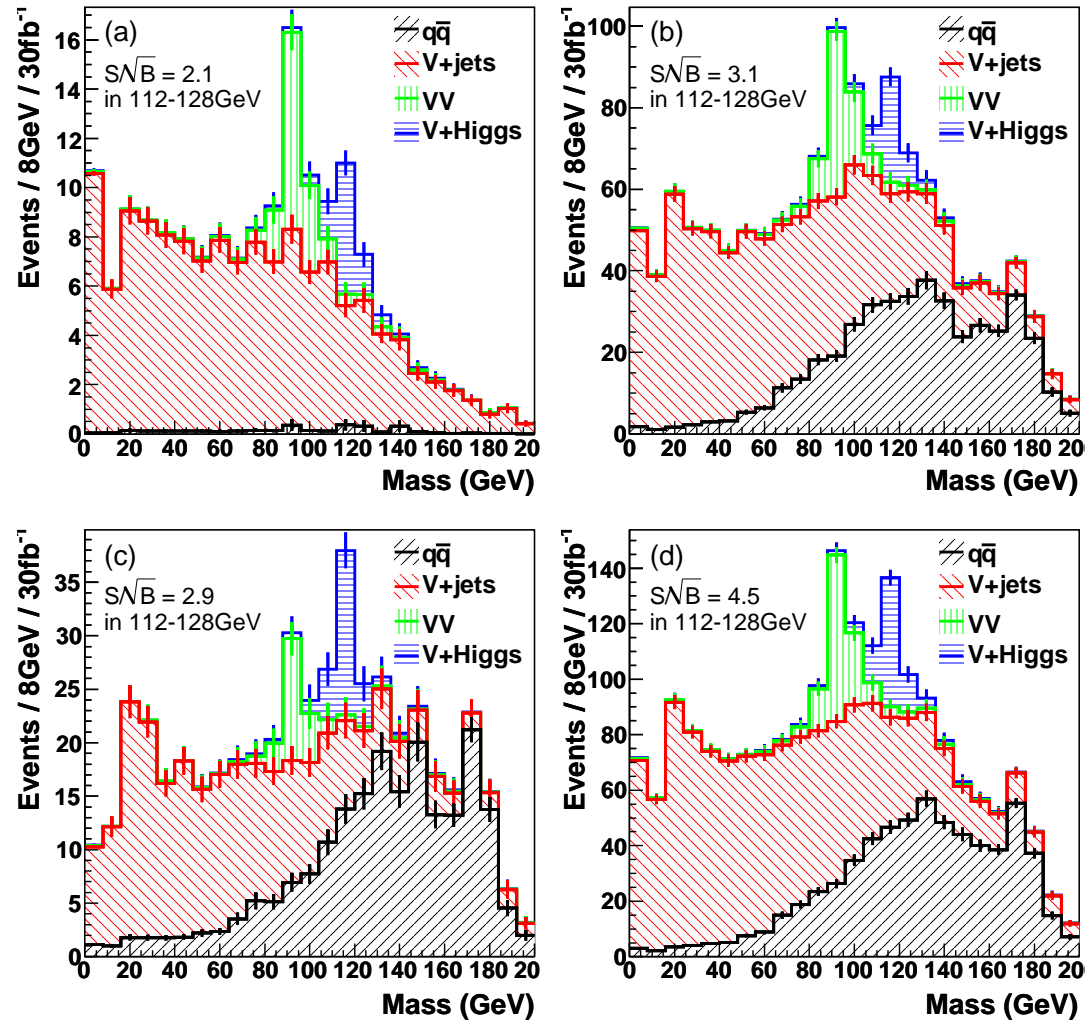
- \implies fat Higgs jet with $b\bar{b}(g)$ subjet structure
- small separation of b -quark jets from $H \rightarrow b\bar{b}$ decay \implies better $b\bar{b}(g)$ invariant mass resolution
- lower background fraction than at low $p_T(H)$

Expected signal in HZ and HW at $p_T(H) > 200$ GeV

Example: $m_H = 120$ GeV,
 $\int L dt = 30 \text{ fb}^{-1}$

- Need excellent b tagging and non- b rejection efficiencies (assumed: 60% and 2% respectively)
- Search in
 - (a) HZ with $Z \rightarrow ll$
 - (b) HZ with $Z \rightarrow \nu\nu$ and
 - (c) $WH \rightarrow l\nu b\bar{b}$ samples
- Promising signal with 30 fb^{-1} when combining all 3 channels

Detailed studies with full detector simulation on the way



Measuring Higgs couplings at LHC

LHC rates for partonic process $pp \rightarrow H \rightarrow xx$ given by $\sigma(pp \rightarrow H) \cdot BR(H \rightarrow xx)$

$$\sigma(H) \times BR(H \rightarrow xx) = \frac{\sigma(H)^{\text{SM}}}{\Gamma_p^{\text{SM}}} \cdot \frac{\Gamma_p \Gamma_x}{\Gamma},$$

Measure products $\Gamma_p \Gamma_x / \Gamma$ for combination of processes ($\Gamma_p = \Gamma(H \rightarrow pp)$)

Problem: rescaling fit results by common factor f

$$\Gamma_i \rightarrow f \cdot \Gamma_i, \quad \Gamma \rightarrow f^2 \Gamma = \sum_{obs} f \Gamma_i + \Gamma_{rest}$$

leaves observable rate invariant \implies no model independent results at LHC

Loose bounds on scaling factor:

$$f^2 \Gamma > \sum_{obs} f \Gamma_x \quad \implies \quad f > \sum_{obs} \frac{\Gamma_x}{\Gamma} = \sum_{obs} BR(H \rightarrow xx) (= \mathcal{O}(1))$$

Total width below experimental resolution of Higgs mass peak ($\Delta m = 1 \dots 20$ GeV)

$$f^2 \Gamma < \Delta m \quad \implies \quad f < \sqrt{\frac{\Delta m}{\Gamma}} < \mathcal{O}(10 - 40)$$

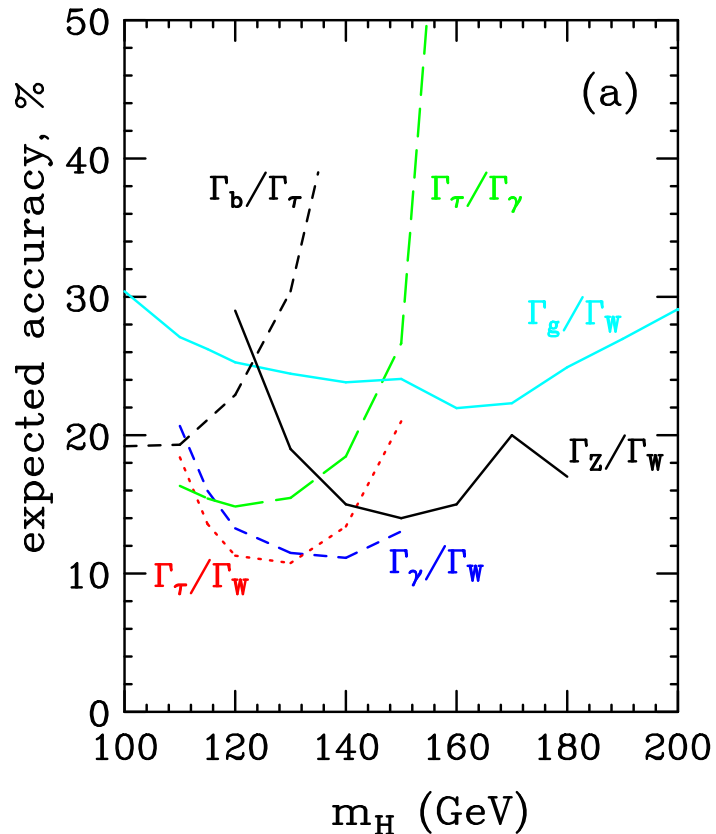
Fit LHC data within constrained models

• $\frac{g_{H\tau\tau}}{g_{Hbb}} = \text{SM value}$

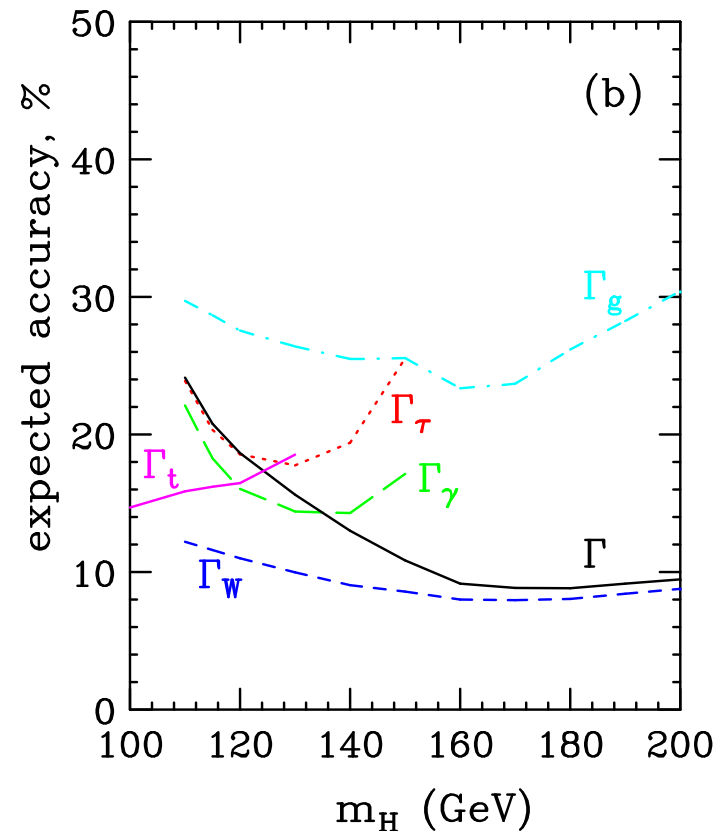
• $\frac{g_{HWW}}{g_{HZZ}} = \text{SM value}$

• no exotic channels

width ratios



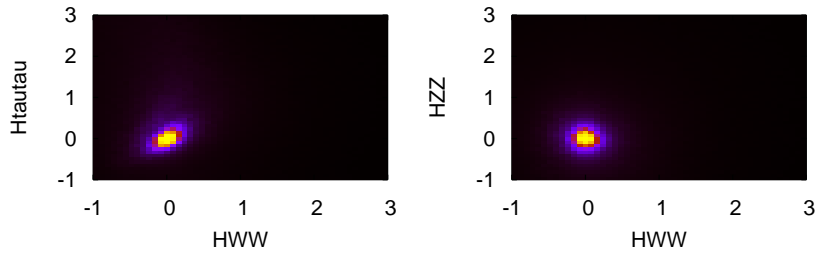
(partial) widths



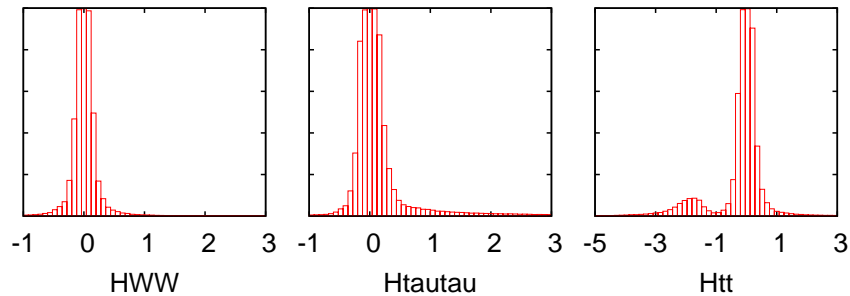
With 200 fb^{-1} measure partial width with 10–30% errors, couplings with 5–15% errors

New analysis: Lafaye et al., arXiv:0904:3866

Correlations $m_H = 120 \text{ GeV}$ and 300 fb^{-1}



$1/\Delta\chi^2$



- theoretical and experimental errors including correlations. Study relative errors

$$g_{Hxx} = g_{Hxx}^{SM} (1 + \Delta_{Hxx})$$

- sophisticated statistical analysis in SFitter framework
- Results for $m_H = 120 \text{ GeV}$ and 30 fb^{-1}

	RMS	σ_{symm}	σ_{neg}	σ_{pos}
Δ_{WWH}	± 0.31	± 0.23	-0.21	$+0.26$
Δ_{ZZH}	± 0.49	± 0.36	-0.40	$+0.35$
$\Delta_{t\bar{t}H}$	± 0.58	± 0.41	-0.37	$+0.45$
$\Delta_{b\bar{b}H}$	± 0.53	± 0.45	-0.33	$+0.56$
$\Delta_{\tau\bar{\tau}H}$	± 0.47	± 0.33	-0.21	$+0.46$

Corrections for Higgs production cross sections

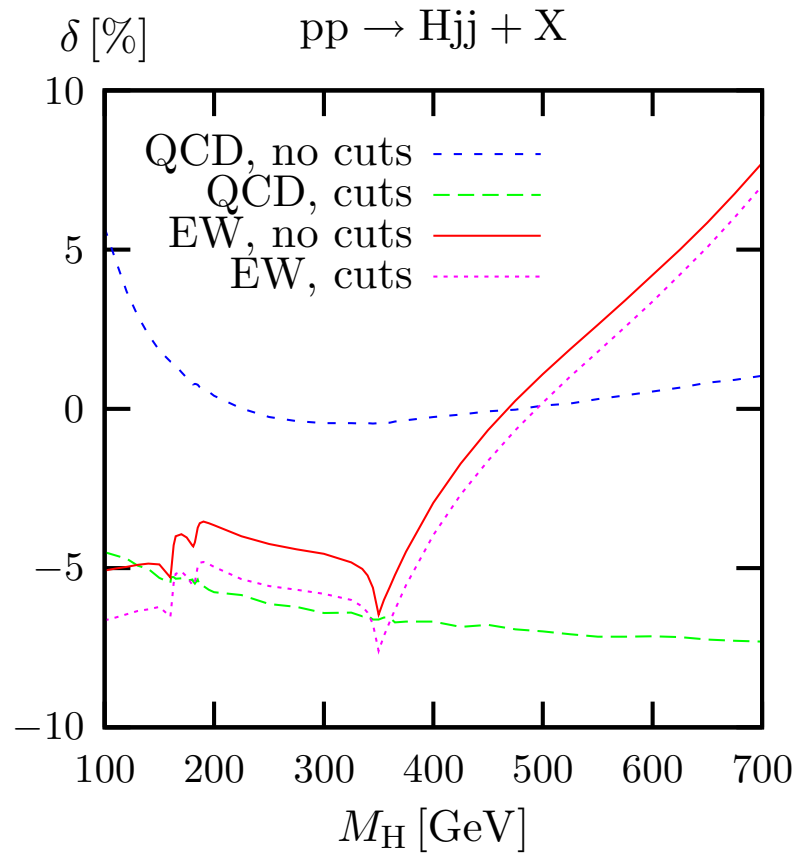
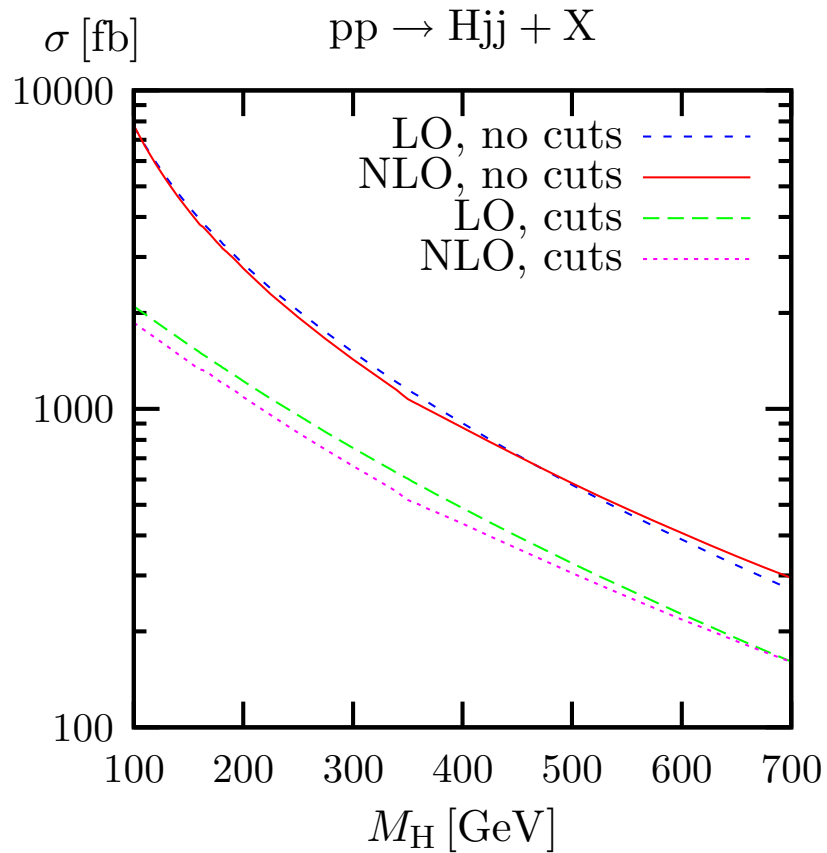
Measurement of **partial widths** at **10–20% level** or **couplings** at **5–10% level** requires **predictions** of SM production cross sections at **10% level or better**

⇒ need QCD corrections to production cross sections. **Much progress in recent years**

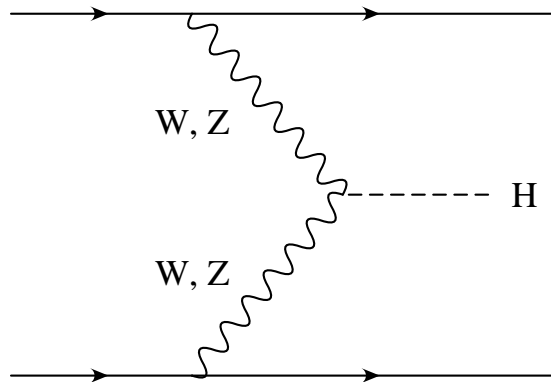
- $gg \rightarrow H$ (all but NLO in $m_t \rightarrow \infty$ limit)
 - NNLO: **Harlander, Kilgore (2001); Anastasiou, Melnikov (2002); Ravindran, Smith, van Neerven (2003)**
 - N³LO in soft approximation: **Moch, Vogt (2005)**
- Hjj by gluon fusion at NLO: **Campbell, Ellis, Zanderighi (2006)**
- weak boson fusion
 - total cross section at NLO: **Han, Willenbrock (1991)**
 - distributions at NLO: **Figy, Oleari, D.Z (2003); Campbell, Ellis, Berger (2004)**
 - 1-loop EW corrections: **Ciccolini, Denner, Dittmaier (2007)**
 - approx. NLO QCD to $Hjjj$: **Figy, Hankele, D.Z (2007)**
- $\bar{t}tH$ associated production at NLO: **Beenakker et al.; Dawson, Orr, Reina, Wackerroth (2002)**
- $\bar{b}bH$ associated production at NLO: **Dittmaier, Krämer, Spira; Dawson et al. (2003)**

QCD + EW corrections to Hjj production

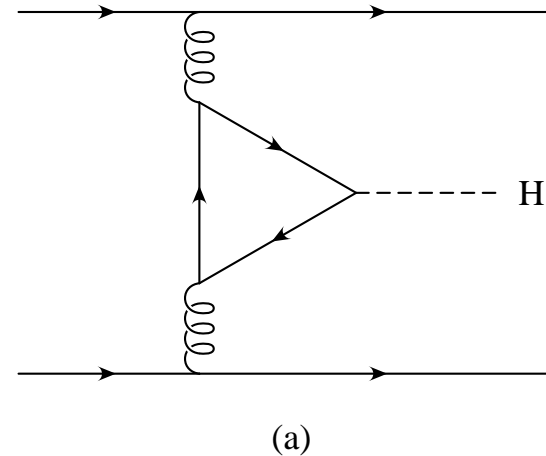
Cross sections without and with VBF cuts: $p_T(j) > 20 \text{ GeV}$ $|y_{j_1} - y_{j_2}| > 4$, $y_{j_1} \cdot y_{j_2} < 0$



How to distinguish VBF and gluon fusion?



vs.



Double real corrections to $gg \rightarrow H$ can “fake” VBF

⇒ we need to **investigate the phenomenology** of these two processes and understand the differences that can be exploited to **distinguish** between gluon fusion and VBF

⇒ derive **cuts** to be applied to **enhance VBF** with respect to gluon fusion.

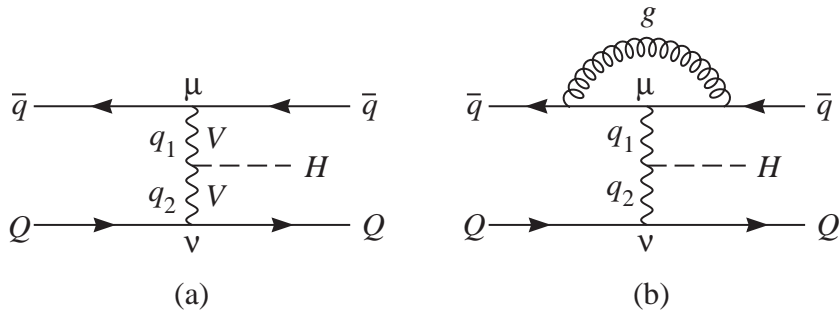
Measure **HWW and HZZ coupling**

⇒ derive **cuts** to be applied to **enhance gluon fusion** with respect to VBF.

Measure **effective Hgg coupling** or **Htt coupling**

Tensor structure of the HVV coupling

Most general HVV vertex $T^{\mu\nu}(q_1, q_2)$



$$T^{\mu\nu} = a_1 g^{\mu\nu} + a_2 (q_1 \cdot q_2 g^{\mu\nu} - q_1^\nu q_2^\mu) + a_3 \varepsilon^{\mu\nu\rho\sigma} q_{1\rho} q_{2\sigma}$$

The $a_i = a_i(q_1, q_2)$ are scalar form factors

Physical interpretation of terms:

SM Higgs $\mathcal{L}_I \sim HV_\mu V^\mu \longrightarrow a_1$

loop induced couplings for neutral scalar

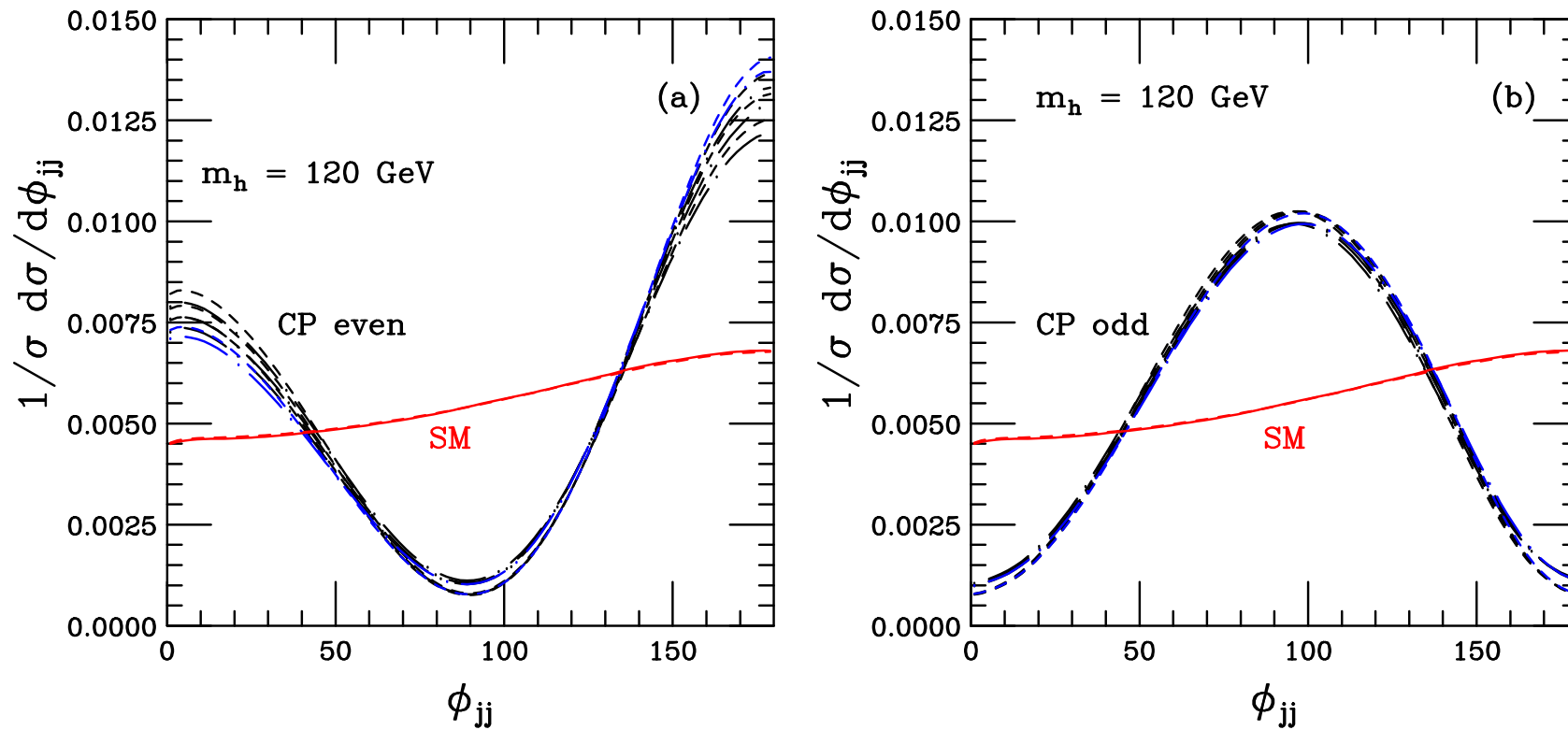
CP even $\mathcal{L}_{eff} \sim HV_{\mu\nu} V^{\mu\nu} \longrightarrow a_2$

CP odd $\mathcal{L}_{eff} \sim HV_{\mu\nu} \tilde{V}^{\mu\nu} \longrightarrow a_3$

Must distinguish a_1, a_2, a_3 experimentally

Azimuthal angle correlations

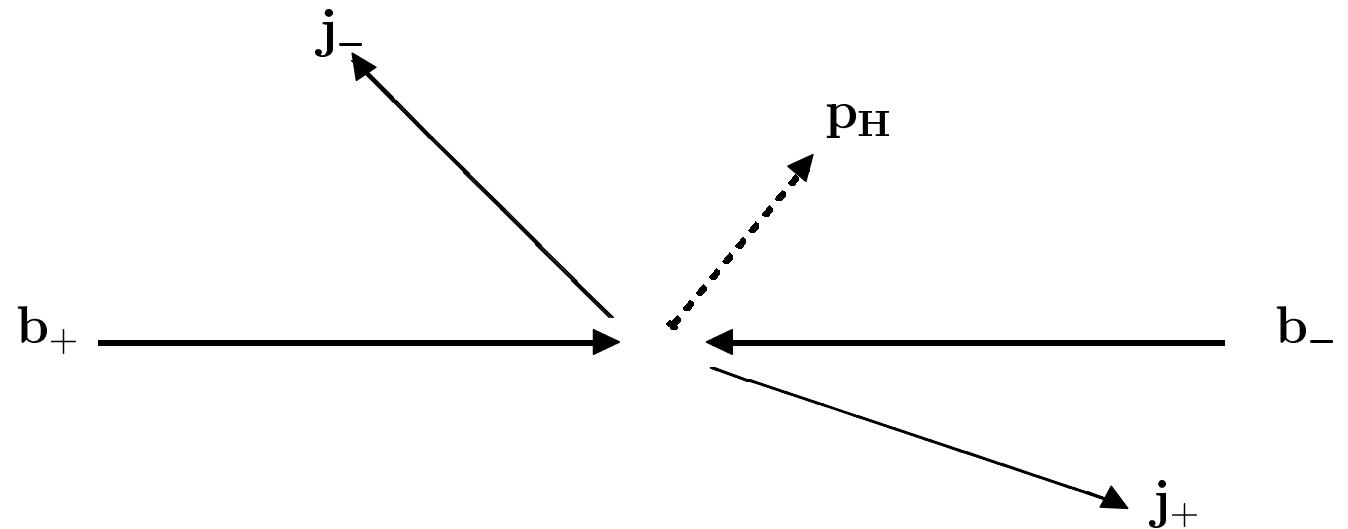
Tell-tale signal for non-SM coupling is azimuthal angle between tagging jets



Dip structure at 90° (CP even) or $0/180^\circ$ (CP odd) only depends on tensor structure of HVV vertex. Very little dependence on form factor, LO vs. NLO, Higgs mass etc.

Azimuthal angle distribution and Higgs CP properties

Kinematics of Hjj event:

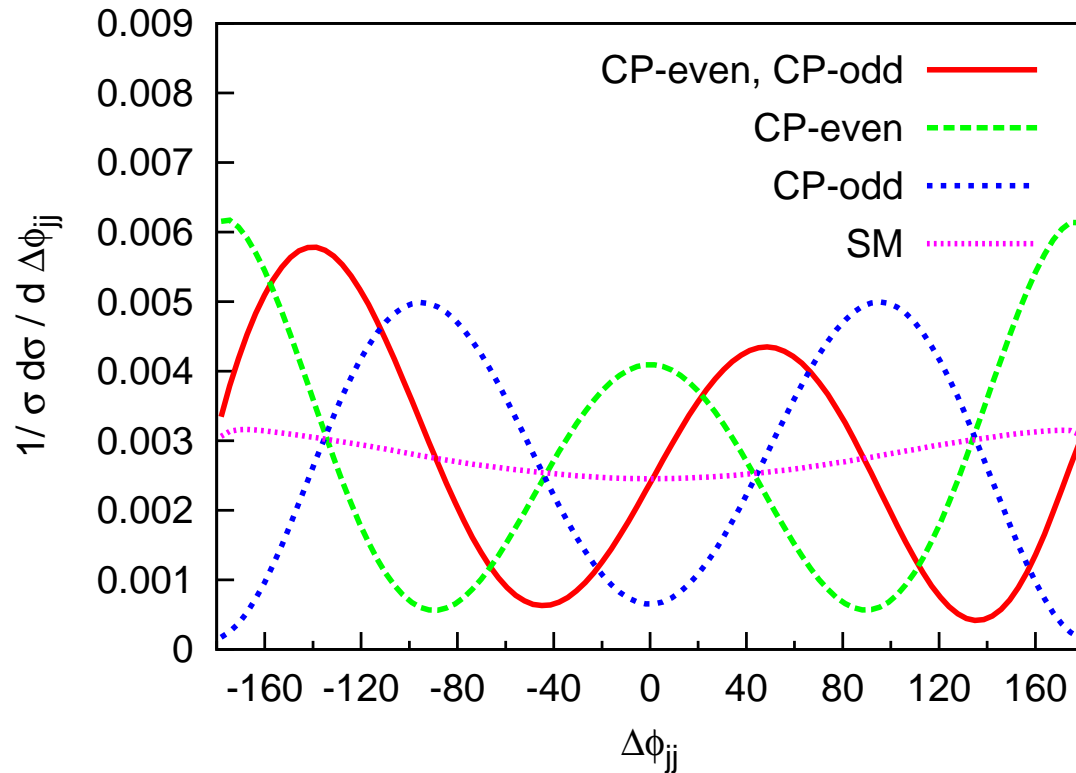


Define azimuthal angle between jet momenta j_+ and j_- via

$$\varepsilon_{\mu\nu\rho\sigma} b_+^\mu j_+^\nu b_-^\rho j_-^\sigma = 2p_{T,+} p_{T,-} \sin(\phi_+ - \phi_-) = 2 p_{T,+} p_{T,-} \sin \Delta\phi_{jj}$$

- $\Delta\phi_{jj}$ is a parity odd observable
- $\Delta\phi_{jj}$ is invariant under interchange of beam directions $(b_+, j_+) \leftrightarrow (b_-, j_-)$

Signals for CP violation in the Higgs Sector



mixed CP case:

$$a_2 = a_3, a_1 = 0$$

pure CP-even case:

a_2 only

pure CP odd case:

a_3 only

Position of **minimum of $\Delta\phi_{jj}$ distribution** measures relative size of CP-even and CP-odd couplings. For

$$a_1 = 0,$$

$$a_2 = d \sin \alpha,$$

$$a_3 = d \cos \alpha,$$

\Rightarrow **Minimum at $-\alpha$ and $\pi - \alpha$**

From VBF to gluon fusion

- Loop induced HVV couplings are almost certainly too small to give observable azimuthal angle modulation at the LHC in VBF. Interest for VBF is in experimentally confirming the structure of the tree level HVV coupling as coming from $(D^\mu \Phi)^\dagger (D_\mu \Phi)$
- The a_2 and a_3 terms naturally arise for Φgg couplings from top quark triangles and lead to effective Lagrangians

$$\text{CP – even :} \quad i \frac{m_Q}{v} \quad \rightarrow \quad \mathcal{L}_{eff} = \frac{\alpha_s}{12\pi v} H G_{\mu\nu}^a G^{\mu\nu,a}$$

$$\text{CP – odd :} \quad - \frac{m_Q}{v} \gamma_5 \quad \rightarrow \quad \mathcal{L}_{eff} = \frac{\alpha_s}{8\pi v} A G_{\mu\nu}^a \tilde{G}^{\mu\nu,a} = \frac{\alpha_s}{16\pi v} A G_{\mu\nu}^a G_{\alpha\beta}^a \varepsilon^{\mu\nu\alpha\beta}$$

- Study gluon fusion induced Φjj events to distinguish CP-even and CP-odd couplings

Effective Lagrangian and full top and bottom loops implemented in VBFNLO:

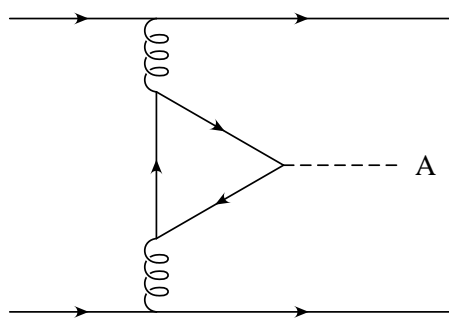
parton level Monte Carlo for $Hjj, Wjj, Zjj, W^+W^-jj, ZZjj, VVV$ production by Bozzi, Figy,

Hankele, Jäger, Klämke, Kubocz, Oleari, Worek, DZ, ...

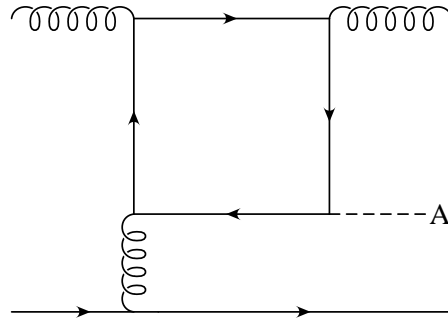
Available at <http://www-itp.physik.uni-karlsruhe.de/~vbfnlweb/>

Feynman graphs for (pseudo)scalar Higgs production

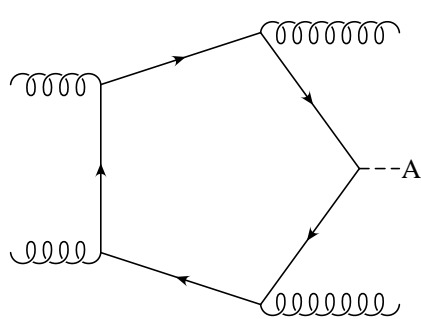
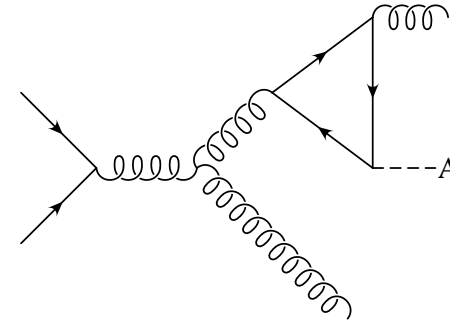
$pp \rightarrow \Phi jjX$ including top and bottom loops + interference [Michael Kubocz, DZ]



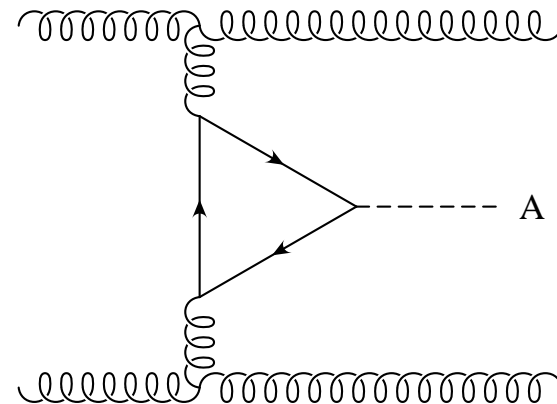
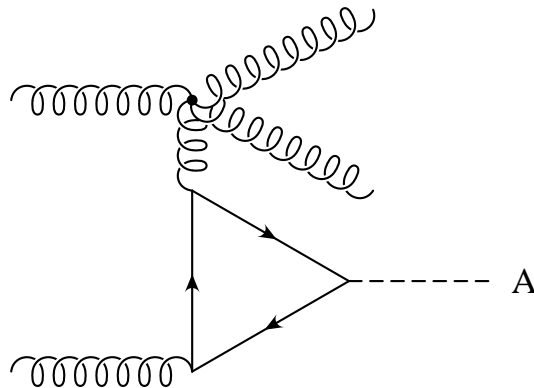
(a)



(b)



(c)



Gluon Fusion as a signal channel

Heavy quark loop induces effective Hgg vertex:

$$\text{CP – even :} \quad i \frac{m_Q}{v} \rightarrow \mathcal{L}_{eff} = \frac{\alpha_s}{12\pi v} H G_{\mu\nu}^a G^{\mu\nu,a}$$

$$\text{CP – odd :} \quad - \frac{m_Q}{v} \gamma_5 \rightarrow \mathcal{L}_{eff} = \frac{\alpha_s}{8\pi v} A G_{\mu\nu}^a \tilde{G}^{\mu\nu,a} = \frac{\alpha_s}{16\pi v} A G_{\mu\nu}^a G_{\alpha\beta}^a \varepsilon^{\mu\nu\alpha\beta}$$

Azimuthal angle between tagging jets probes difference

- Use gluon fusion induced Φjj signal to probe structure of Hgg vertex
- Find **cuts** to enhance gluon fusion over VBF and other backgrounds

\implies Study by **Gunnar Klämke** in $m_Q \rightarrow \infty$ limit (hep-ph/0703202)

Gluon fusion signal and backgrounds

Signal channel (LO):

- $pp \rightarrow Hjj$ in gluon fusion with $H \rightarrow W^+W^- \rightarrow l^+l^-\nu\bar{\nu}$, ($l = e, \mu$)
- $m_H = 160 \text{ GeV}$

dominant backgrounds:

- W^+W^- -production via VBF (including Higgs-channel): $pp \rightarrow W^+W^-jj$
- top-pair production: $pp \rightarrow t\bar{t}, t\bar{t}j, t\bar{t}jj$ (N. Kauer)
- QCD induced W^+W^- -production: $pp \rightarrow W^+W^-jj$

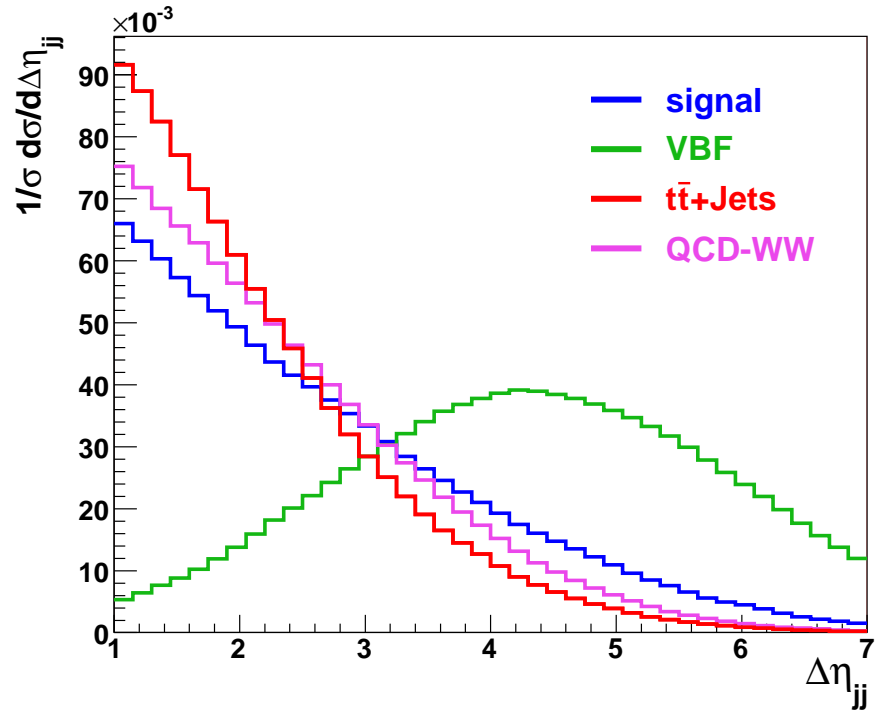
applied inclusive cuts (minimal cuts):

- 2 tagging-jets
 $p_{Tj} > 30 \text{ GeV}, \quad |\eta_j| < 4.5$
- 2 identified leptons
 $p_{Tl} > 10 \text{ GeV}, \quad |\eta_l| < 2.5$
- separation of jets and leptons
 $\Delta\eta_{jj} > 1.0, \quad R_{jl} > 0.7$

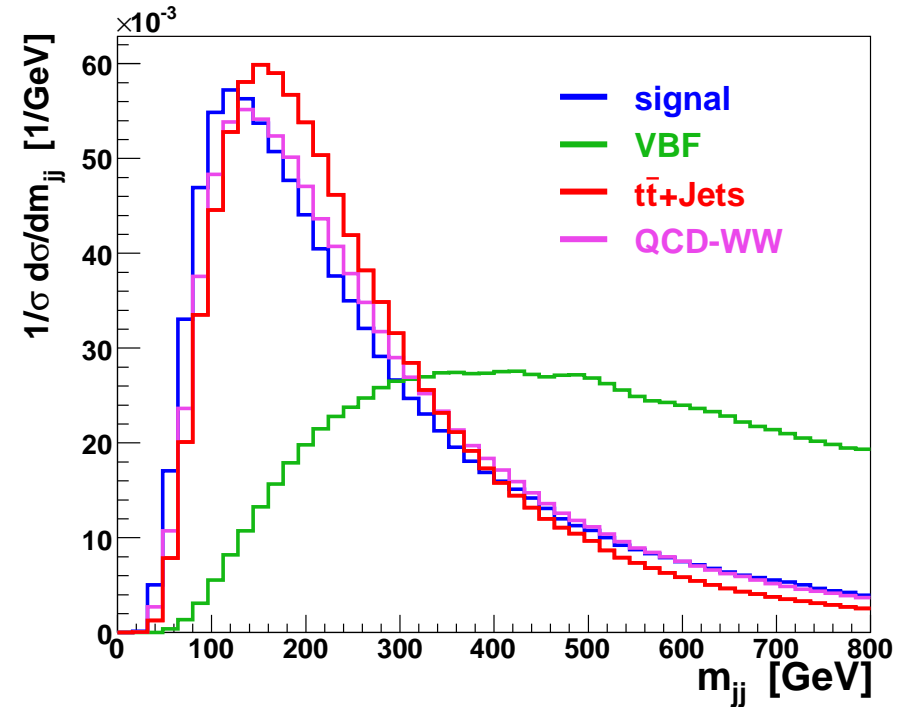
process	σ [fb]
GF $pp \rightarrow H + jj$	115.2
VBF $pp \rightarrow W^+W^- + jj$	75.2
$pp \rightarrow t\bar{t}$	6832
$pp \rightarrow t\bar{t} + j$	9518
$pp \rightarrow t\bar{t} + jj$	1676
QCD $pp \rightarrow W^+W^- + jj$	363

Characteristic distributions

tagging jet rapidity separation



dijet invariant mass



Separation of **VBF Hjj signal** from QCD background is much easier than separation of **gluon fusion Hjj signal**

Selection continued

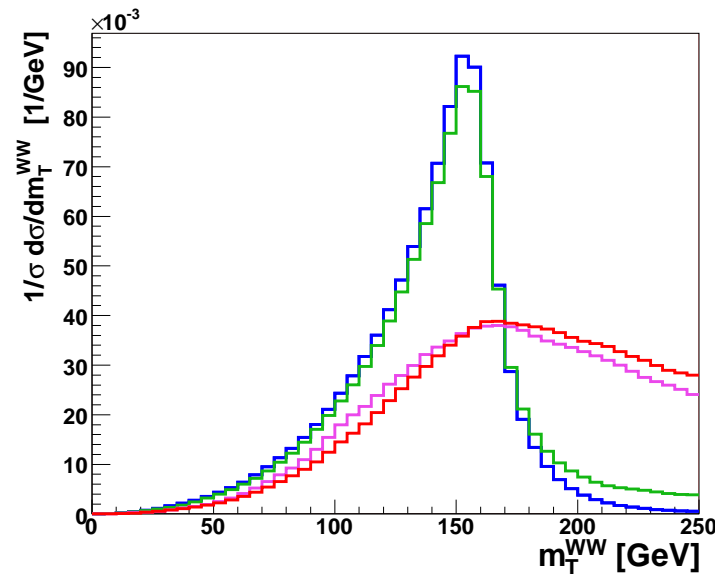
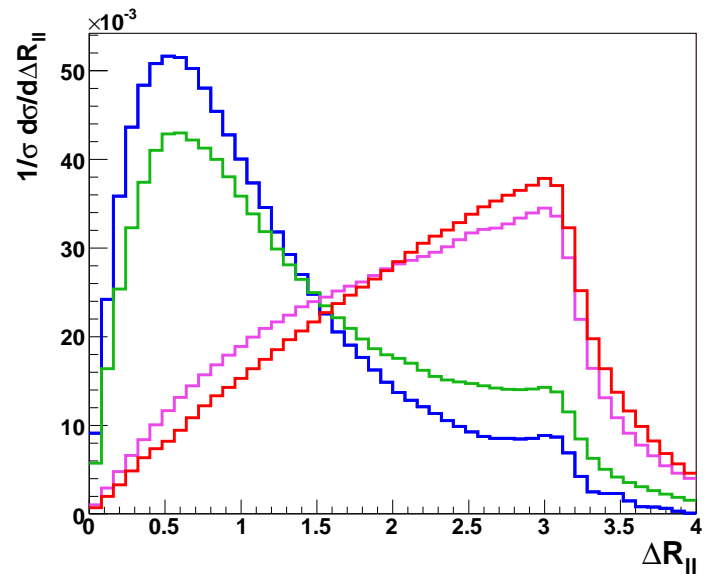
- **b-tagging** for reduction of top-backgrounds. *(CMS Note 06/014)*
 - (η, p_T) - dependent tagging-efficiencies (60% - 75%) with 10% mistagging - probability

- selection cuts:

$$R_{ll} < 1.1, \quad M_{ll} < 75 \text{ GeV}, \quad M_{ll} < 0.44 \cdot M_T^{WW}, \quad p_{Tl} > 30 \text{ GeV},$$

$$M_T^{WW} < 170 \text{ GeV}, \quad \cancel{p}_T > 30 \text{ GeV}$$

$$M_T^{WW} = \sqrt{(\cancel{E}_T + E_{Tll})^2 - (\vec{\cancel{p}}_{Tll} + \vec{\cancel{p}}_T)^2}$$



signal

VBF

$t\bar{t}$ +Jets

QCD-WW

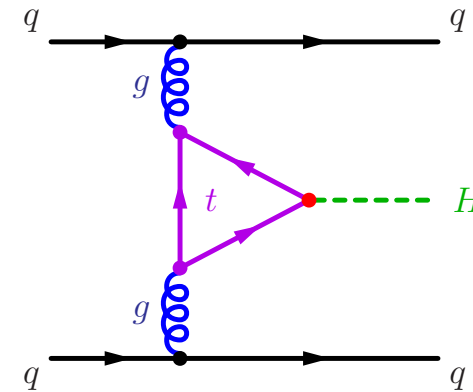
Results

process	σ [fb]	events/ 30 fb^{-1}
GF $pp \rightarrow H + jj$	31.5	944
VBF $pp \rightarrow W^+W^- + jj$	16.5	495
$pp \rightarrow t\bar{t}$	23.3	699
$pp \rightarrow t\bar{t} + j$	51.1	1533
$pp \rightarrow t\bar{t} + jj$	11.2	336
QCD $pp \rightarrow W^+W^- + jj$	11.4	342
Σ backgrounds	113.5	3405

$$\Rightarrow \mathbf{S/\sqrt{B}} \approx \mathbf{16.2} \text{ for } 30 \text{ fb}^{-1}$$

Higgs + 2 Jets in Gluon Fusion, $H \rightarrow \tau\tau \rightarrow \ell^+ \ell^- \nu \bar{\nu}$

- this channel has not been studied so far
- interesting for SM Higgs (≈ 120 GeV) and SUSY scenario with large $\tan \beta$ ($m_H \approx m_A \gtrsim 150$ GeV)
- x-section times branching ratio of ≈ 50 fb looks promising (SM)
- has potential for study of Higgs CP-properties



Studied so far (by [Gunnar Klämke](#)):

- Study of signal and SM backgrounds for $m_H = 120$ GeV case (simple cut based analysis)
- same for one MSSM scenario $m_A = 200$ GeV, $\tan \beta = 50$

Questions:

- How many signal and background events are there after cuts (what's the statistical significance)
- What are the prospects of CP-measurements via jet-jet azimuthal angle correlation

SM case with $m_H = 120$ GeV

a b-veto was applied to reduce the top backgrounds.

$$R_{\ell\ell} < 2.4, \quad \cancel{p}_T > 30 \text{ GeV}, \quad m_{\ell\ell} < 80 \text{ GeV}, \quad 110 \text{ GeV} < m_{\tau\tau} < 135 \text{ GeV}, \quad 0 < x_i < 1$$

process	σ [fb]	events / 600 fb ⁻¹
GF $pp \rightarrow H + jj \rightarrow \tau\tau jj$	4.927	2956
GF $pp \rightarrow A + jj \rightarrow \tau\tau jj$	11.43	6860
VBF $pp \rightarrow H + jj \rightarrow \tau\tau jj$	2.523	1514
QCD $pp \rightarrow Z + jj \rightarrow \tau\tau jj$	27.62	16573
VBF $pp \rightarrow Z + jj \rightarrow \tau\tau jj$	0.475	285
$pp \rightarrow t\bar{t}$	3.86	2316
$pp \rightarrow t\bar{t} + j$	8.84	5306
$pp \rightarrow t\bar{t} + jj$	3.8	2283
QCD $pp \rightarrow W^+W^- + jj$	1.48	887
VBF $pp \rightarrow W^+W^- + jj$	0.147	88
Σ backgrounds	48.84	29300

for cp-even higgs: $S/\sqrt{B} \approx 17$ (600 fb⁻¹)

this corresponds to: $S/\sqrt{B} \approx 5$ (50 fb⁻¹)

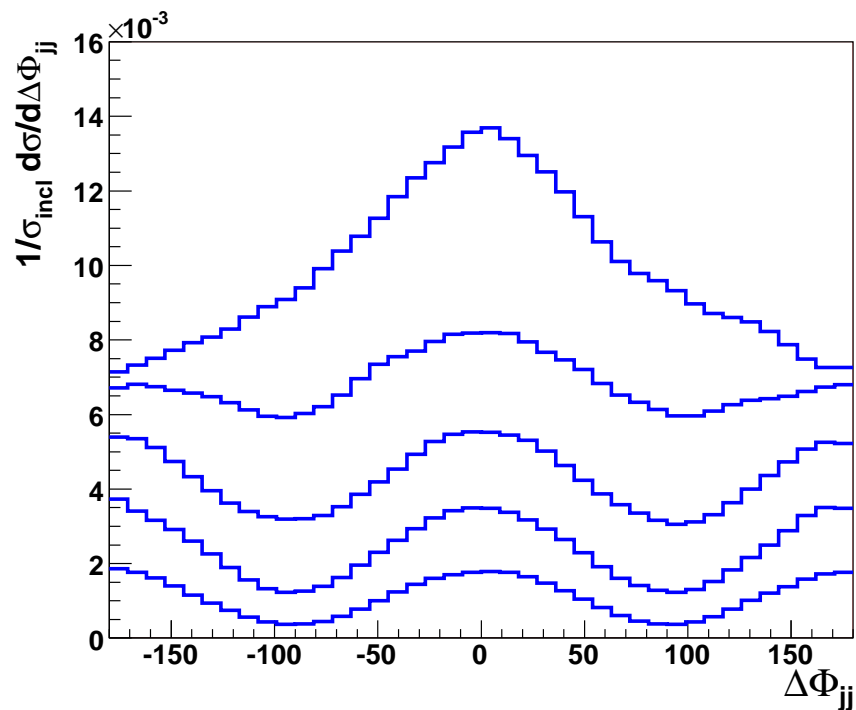
for cp-odd higgs: $S/\sqrt{B} \approx 40$ (600 fb⁻¹)

this corresponds to: $S/\sqrt{B} \approx 5$ (10 fb⁻¹)

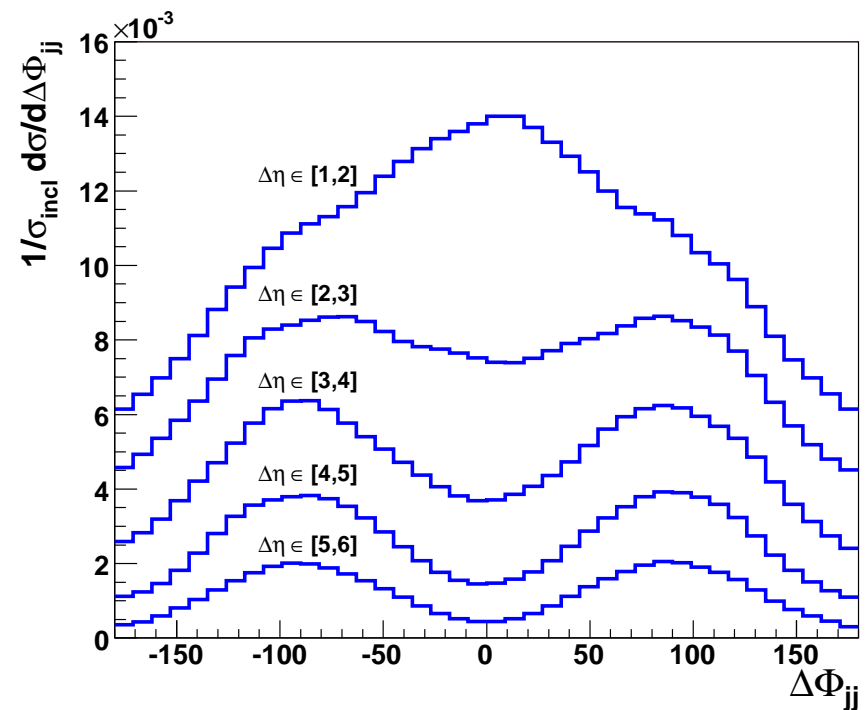
Sensitivity of gluon fusion to structure of Hgg vertex

Sensitivity of the $\Delta\phi_{jj}$ distribution to the structure of the effective Hgg coupling **increases with the rapidity separation of the two tagging jets**

CP-even coupling

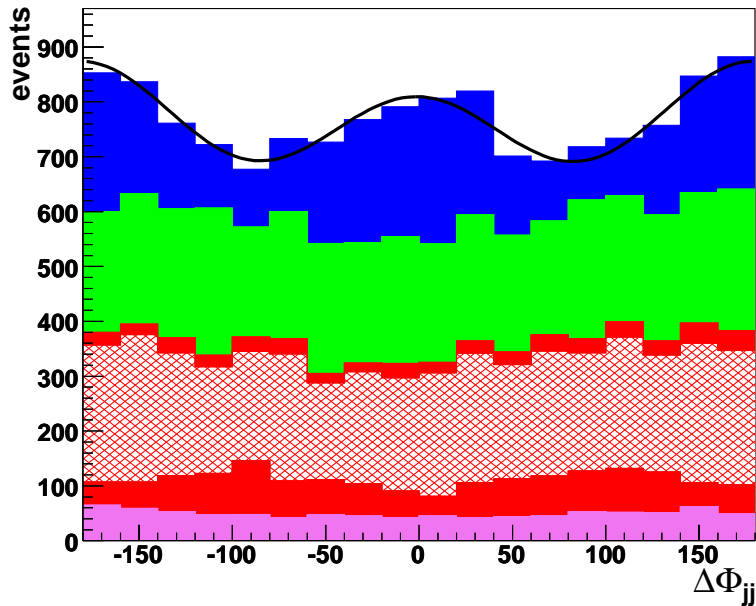


CP-odd coupling



$\Delta\Phi_{jj}$ -Distribution in gluon fusion: WW case

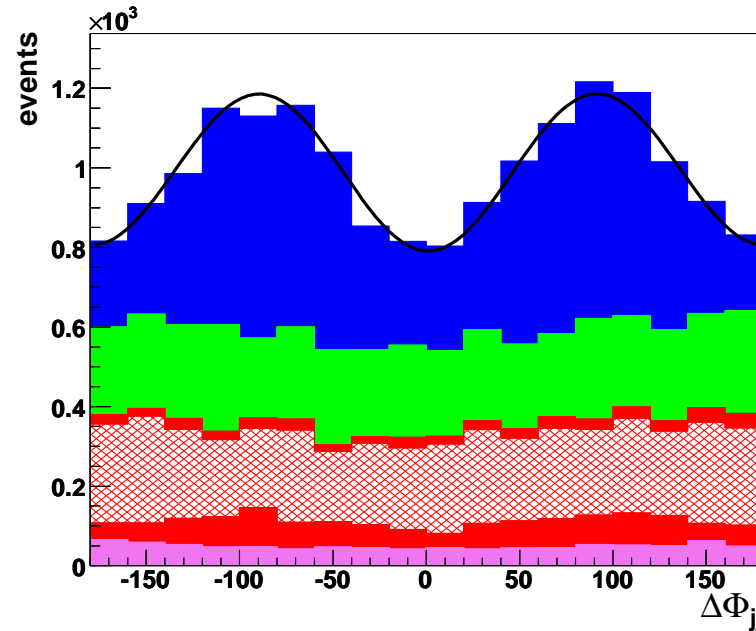
Fit to Φ_{jj} -distribution with function $f(\Delta\Phi) = N(1 + A \cos[2(\Delta\Phi - \Delta\Phi_{max})] - B \cos(\Delta\Phi))$



CP-even

$$A = 0.100 \pm 0.039$$

$$\Delta\Phi_{max} = 5.8 \pm 15.3$$



CP-odd

$$A = 0.199 \pm 0.034$$

$$\Delta\Phi_{max} = 93.7 \pm 5.1$$

Signal

VBF

t \bar{t} +Jets

QCD-WW

$L = 300 \text{ fb}^{-1}$

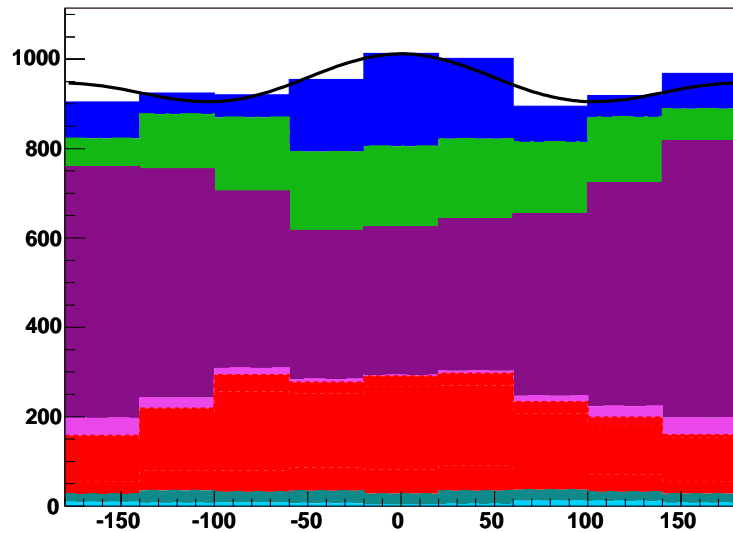
$(\Delta\eta_{jj} > 3.0)$

fit of the background only : $A = 0.069 \pm 0.044$ and $\Delta\Phi_{max} = 64 \pm 25$

(mean values of 10 independent fits of data for $L = 30 \text{ fb}^{-1}$ each)

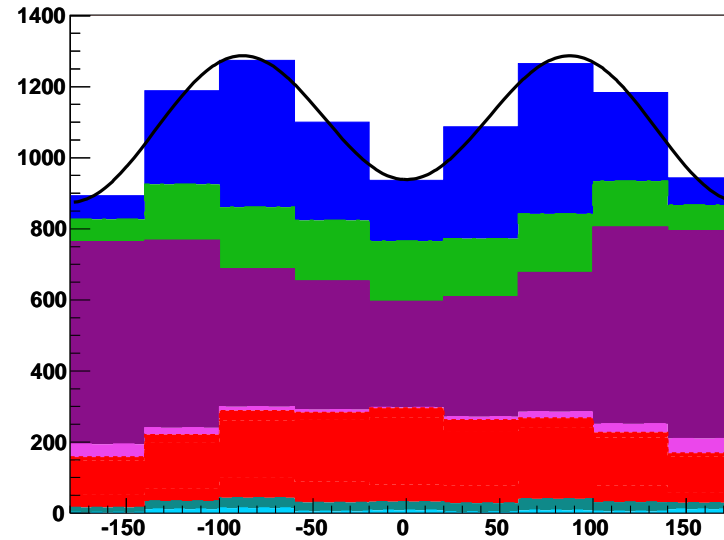
$H \rightarrow \tau\tau$ case: $\Delta\Phi_{jj}$ -distribution with backgrounds

Fit to Φ_{jj} -distribution with function $f(\Delta\Phi) = N(1 + A \cos[2(\Delta\Phi)] - B \cos(\Delta\Phi))$



CP-even

$$A = 0.004 \pm 0.015$$



CP-odd

$$A = -0.161 \pm 0.014$$

Signal
VBF-H
QCD-Z
EW-Z
t \bar{t} +Jets

$L = 600 \text{ fb}^{-1}$
 $(\Delta\eta_{jj} > 3.0)$

fit of the background only : -0.043 ± 0.016
 \Rightarrow significance for CP-even vs. CP-odd ≈ 8

Conclusions

- LHC will observe a SM-like Higgs boson in multiple channels, with 5...20% statistical errors
⇒ great source of information on Higgs couplings
- Gauge boson fusion processes provide important facets of this information, both on absolute values of couplings but also on their tensor structure.
- Loop corrections on signal processes provide SM predictions with 10% accuracy or better.
- Beside weak boson fusion also the gluon fusion process $pp \rightarrow Hjj$ is an interesting analysis channel which deserves more work.
- Higgs boson CP properties and structure of the HVV and Hgg vertices from jet-angular correlations in VBF and gluon fusion