

Higgs bosons production in association with a photon at LHC

Emidio Gabrielli
CERN PH-TH

based on:

EG, F.Maltoni, B. Mele, M.Moretti, F.Piccinini, R.Pittau, NP B781 (2007), 64

EG, B.Mele, J.Rathsman, PR D77 (2008) 055020

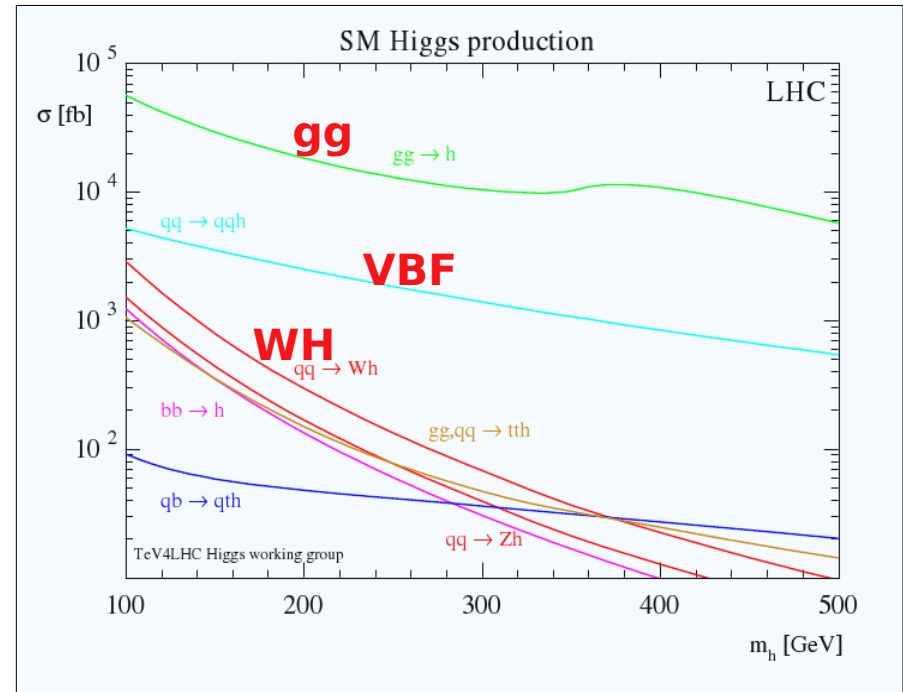
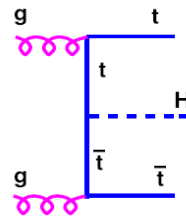
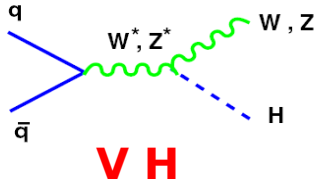
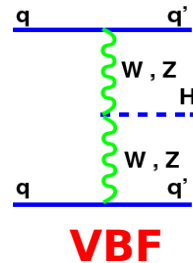
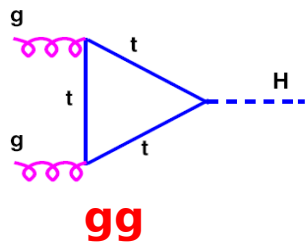
EG, B. Mele, F. Piccinini (in preparation)

CPT Marseille 16/04/2010

Higgs boson physics at the Large Hadron Collider

- Higgs boson search is one of main tasks of LHC
- range of Higgs boson mass is not predicted
 - $m_H > 114.5 \text{ GeV}$ (LEP2)
 - $m_H < 800 \text{ GeV}$ theoretical upper bound
- SM precision tests favor a light Higgs Boson, with mass below 200 GeV
- discovery of a light Higgs boson is challenging at LHC due to the huge background (bckg) in $b\bar{b}$
- discovery channels of Higgs boson at LHC strongly depend on the actual Higgs mass

Higgs boson production mechanisms



inclusive x-sections

- **gluon-gluon fusion: main mechanism in the whole range**
(**gg cross-section $\sim O(10)$ pb for $m_H < 200$ GeV**)
- **Vector boson fusion (VBF) is also sizeable**
- **WH and ttH: interesting at low Higgs masses**

Higgs discovery channels at LHC

• $m_H = [115-130] \text{ GeV}$

$H \rightarrow \gamma \gamma$ golden channel

$H \rightarrow \tau \tau$ silver channel

• $m_H = [130-150] \cup [180-800] \text{ GeV}$

$H \rightarrow Z Z \rightarrow 4l \text{ (} l=\mu, e \text{)}$ golden channel

$H \rightarrow W W \rightarrow 2l 2\nu \text{ (} l=\mu, e \text{)}$ silver channel

• $m_H = [150-170] \text{ GeV}$

$H \rightarrow W W \rightarrow 2l 2\nu \text{ (} l=\mu, e \text{)}$ golden channel

Light Higgs boson scenario

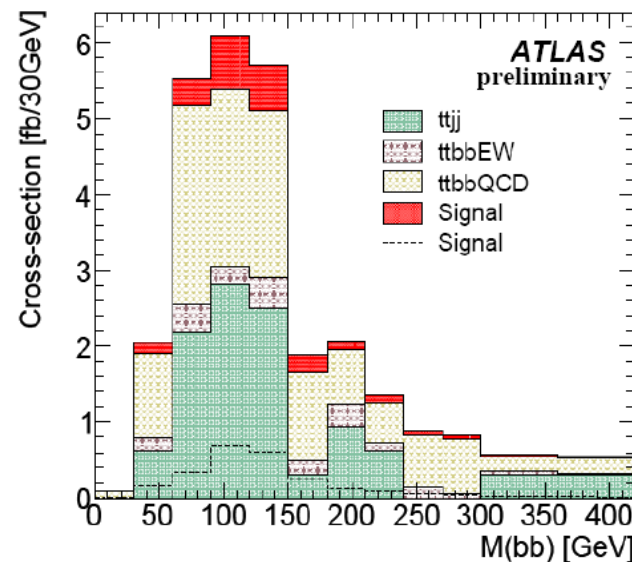
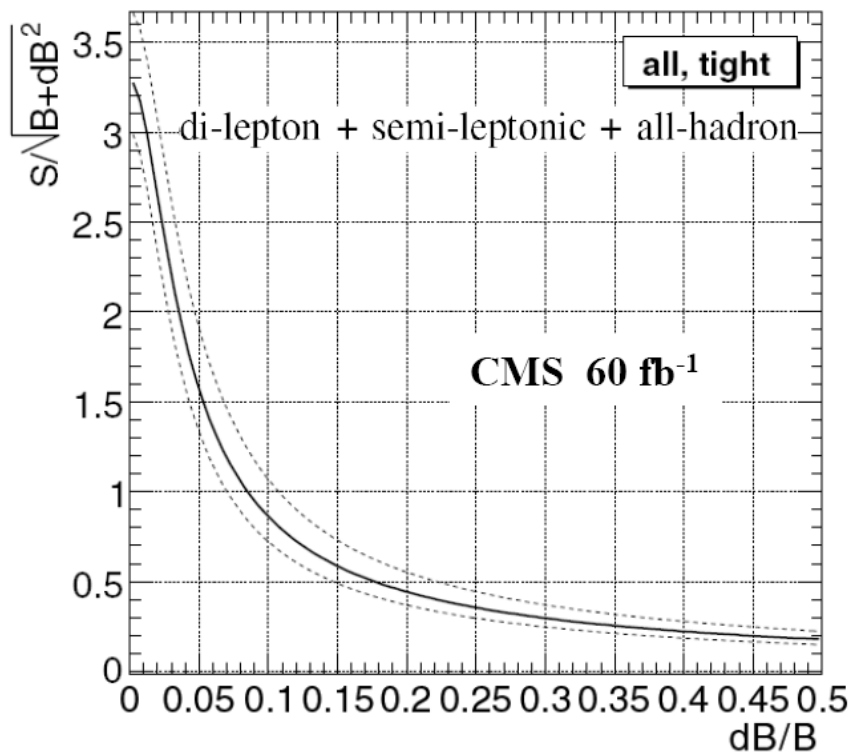
how to measure Hbb coupling

- Information on Higgs couplings to fermions and gauge bosons is crucial for unravelling the origin of the Higgs mechanism (SM, MSSM, technicolor, extra-dimensions)
- at low m_H , important to determine both Hbb and $H\tau\tau$ couplings, e.g. $Hbb/H\tau\tau$ is sensitive to the nature of the SM extension
- discovery channels for $m_H=115-130$ GeV:
 $H \rightarrow \gamma\gamma$ (and $H \rightarrow \tau\tau$)
- $H\gamma\gamma$ coupling: 1-loop vertex (as ggH)
 - sensitive to the UV sector of the theory
 - problems ?
- discovery channels don't constrain Hbb coupling
- difficult to measure Hbb due to large QCD bckg

ttH, $H \rightarrow bb$

new ATLAS I.Ludwig ← **semileptonic top decay**
CMS TDR S.Cucciarelli,A.Schmidt,C.Weiser,
C.Riccardi,P.Torre, D.Benedetti,A.Santocchia,C.Hill, ← **semileptonic ,**
J.Incandela and S.Koay CMS note 2006/119 **dileptonic and**
J.Phys.G:Nucl.Part.Phys. 34 (2007) N221-N250 **all hadronic**
channels

Very difficult
large background , similar to signal

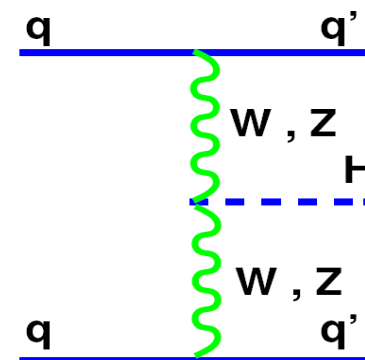


$H \rightarrow b\bar{b}$ in VBF

basic partonic process: $qq \rightarrow qq H(\rightarrow b\bar{b})$

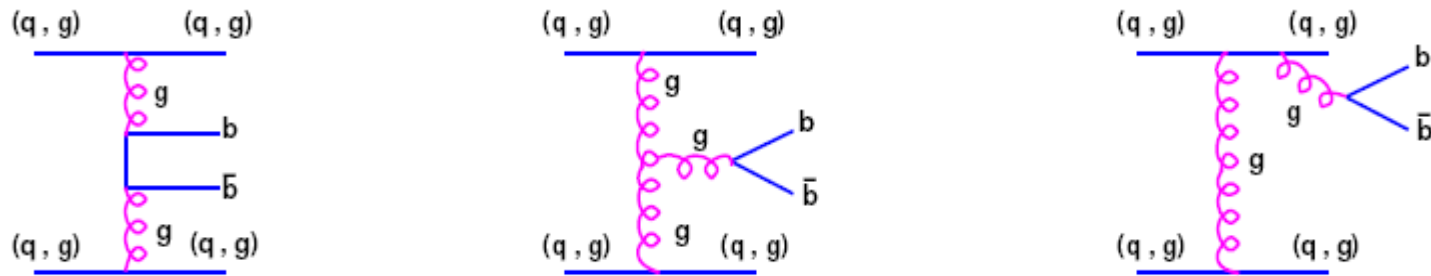
Mangano, Moretti, Piccinini,
Pittau, Polosa (2003)

$$p_T(j) \approx 40 \text{ GeV}$$

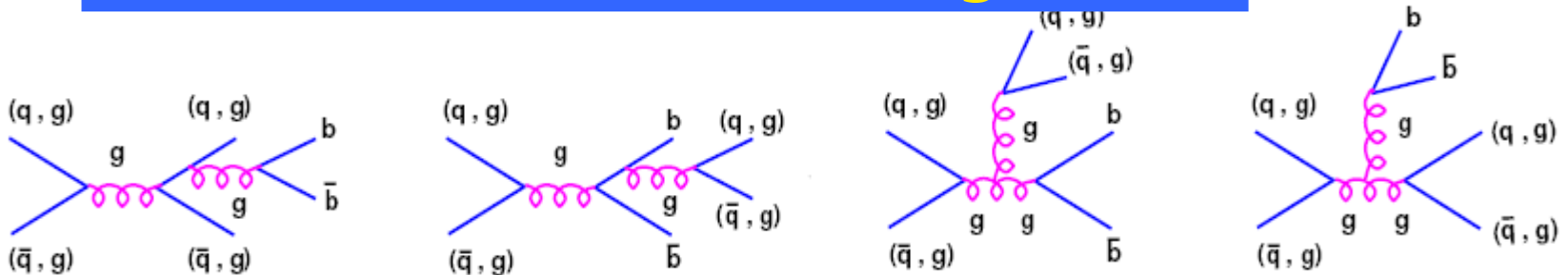


- **signature: $pp \rightarrow H(\rightarrow b\bar{b}) + j j$**
- **large x-section, but...**
- **VERY DIFFICULT** to control the huge QCD bckg
- **potential problems with trigger efficiency**

QCD bckg at partonic level for $pp \rightarrow bb\ jj$



a set of t,u-channel diagrams



s-channel diagrams suppressed by $m(jj) > \text{TeV}$

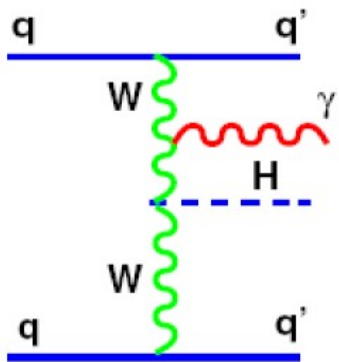
■ large contribution of gluons in external legs

A new promising channel to measure bbH coupling at the LHC

E.G., F. Maltoni, B. Mele, M. Moretti, F. Piccinini, R. Pittau

Nucl.Phys. B781 (2007), 64

VBF



$pp \rightarrow H \gamma + jj$

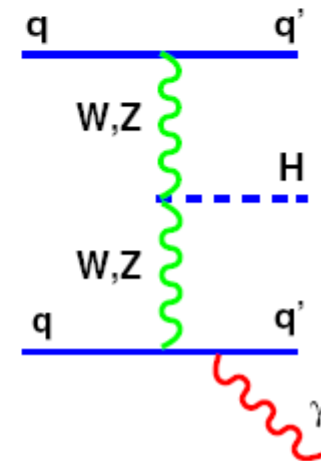
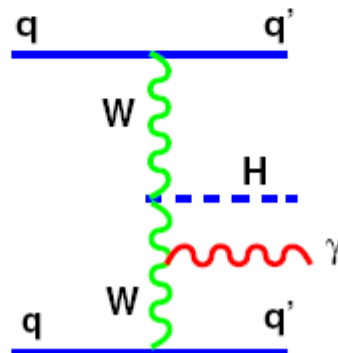
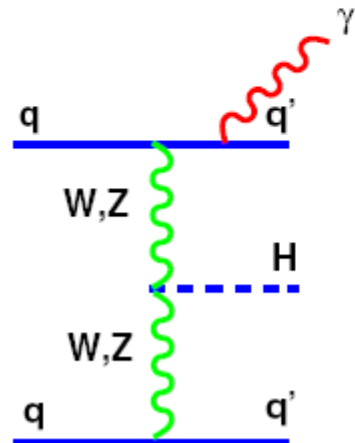
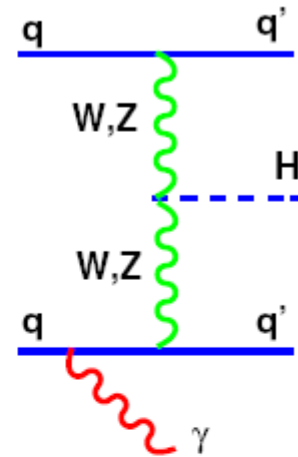
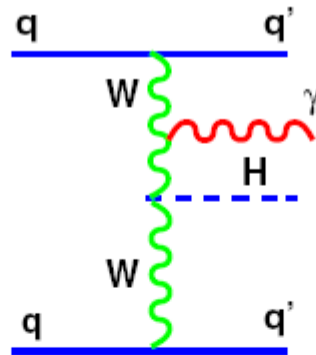
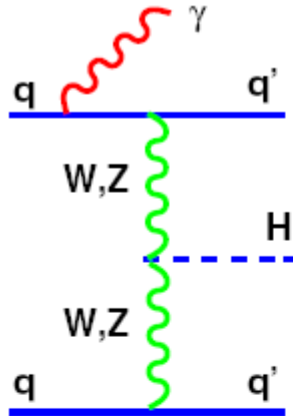
$\downarrow$
 bb

the same characteristics of VBF still hold !

- two jets with large invariant mass
- widely separated in rapidity (forward/backward)
- typical transverse momenta of jets $p_T(j) \sim 40 \text{ GeV}$
- H decay products lying at intermediate rapidity

signal at partonic level

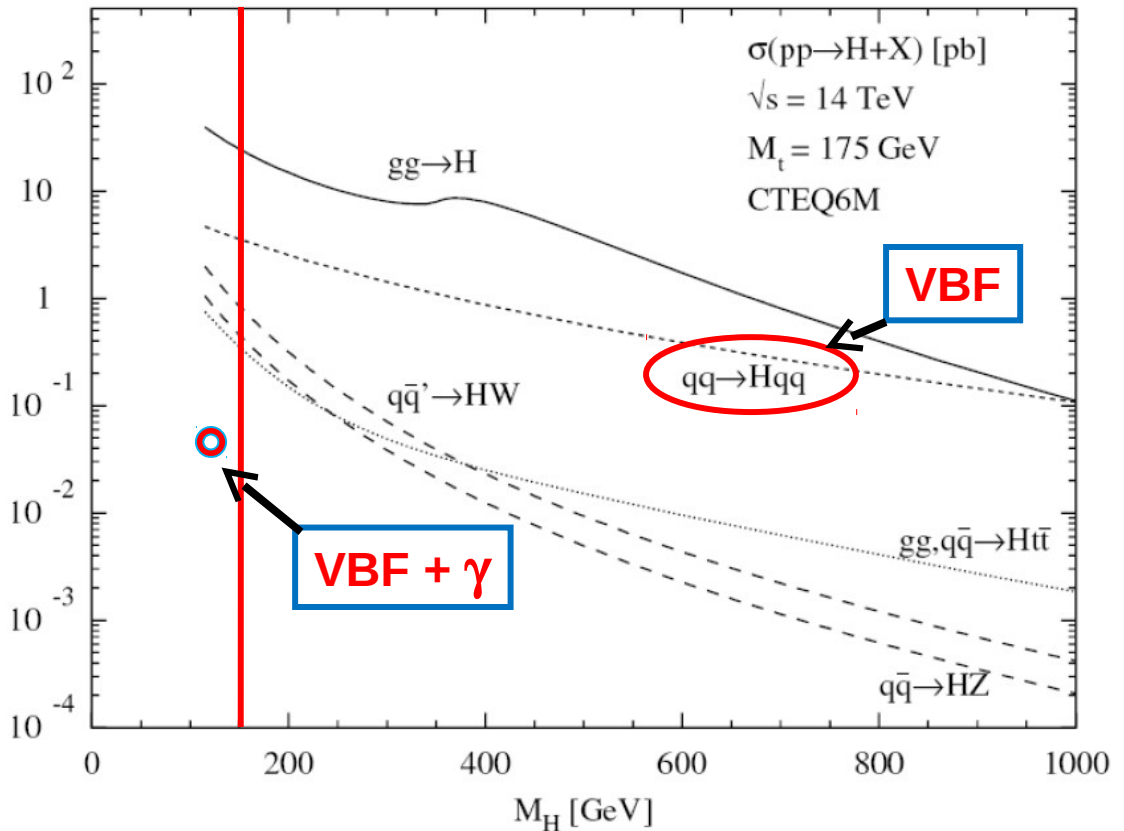
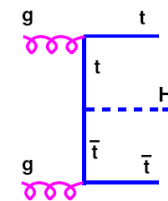
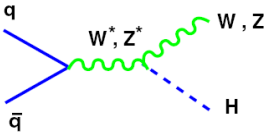
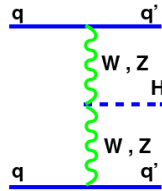
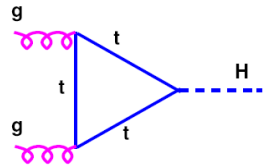
$$qq \rightarrow qq H + \gamma$$



main advantages

- trigger on photon at high p_T
- the large gluon component in QCD bckg is idle in radiating a photon
- dynamical effects (coherence) **dramatically suppress** radiation of central photon in QCD bckg
- **x-section ~ 65 fb** with $p_T(\gamma) > 20$ GeV
- could provide a new independent test not only of **Hbb** but also of **HWW** coupling

Higgs production: inclusive x-sections in pb



■ $\sigma(H+jj+\text{gamma}) \sim 1/100 \times \sigma(H+qq)$, $p_T(\gamma) > 20$ GeV

■ BUT: VBF + γ doesn't pay any suppression for $\text{BR}(H \rightarrow b\bar{b})$ (cfr $\text{BR}(H \rightarrow \gamma\gamma) \sim 0.002$)

signal cross section $pp \rightarrow H \gamma jj$

minimal set of kinematical cuts

$$\Delta R_{ij} > 0.4$$

$$p_T^{\gamma} \geq 20 \text{ GeV}$$

$$m_{ij} > 100 \text{ GeV}$$

m_H (GeV)	110	120	130	140
$\sigma(H\gamma jj)$ [fb]	67.4	64.0	60.4	56.1
$\mathcal{BR}(H \rightarrow b\bar{b})$	0.770	0.678	0.525	0.341

- full EW tree-level matrix element to $pp \rightarrow H \gamma jj$
computed with both ALPGEN and MADEVENT
- ◆ PDF set is CTEQ5L

$$\Delta R_{ij} = \sqrt{(\Delta \eta_{ij})^2 + (\Delta \phi_{ij})^2}$$

how a γ emission affects the bckg

- one would expect by naive QED rescaling

$$S(\gamma \text{ Hjj}) \sim \alpha S(\text{Hjj}) \quad (\alpha = \text{fine structure constant})$$

$$B(\gamma \text{ Hjj}) \sim \alpha B(\text{Hjj})$$

$$(S/\sqrt{B})|_{H\gamma jj} \sim \sqrt{\alpha} (S/\sqrt{B})|_{Hjj} \quad \sqrt{\alpha} \approx 1/10$$

- if so $\longrightarrow$ no interest in requiring γ emission

...but this is not the case

- QED naive rescaling holds for **inclusive processes**
not always for restricted regions of phase space !
- requirement of photon centrality **dramatically suppresses bckg**

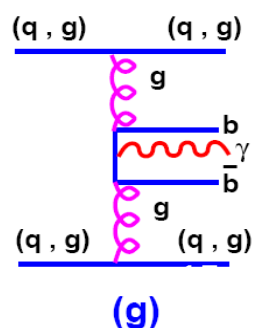
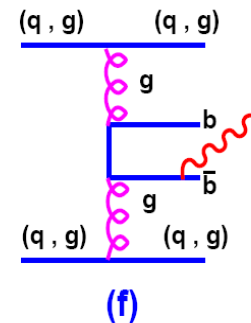
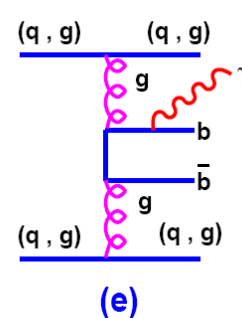
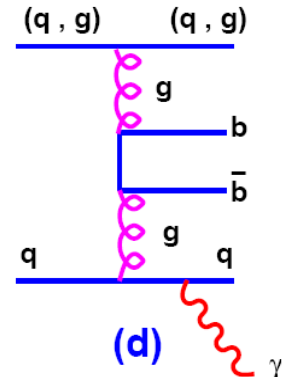
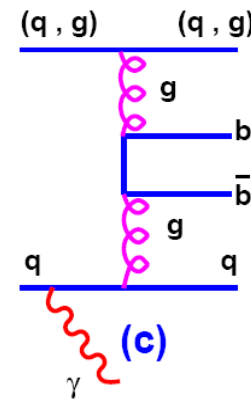
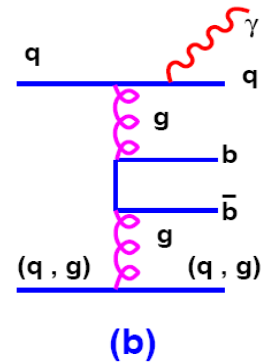
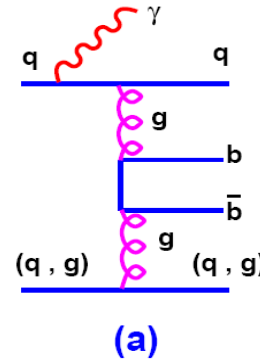
main bckg to $pp \rightarrow H \gamma + jj$

t and u type diagrams dominant

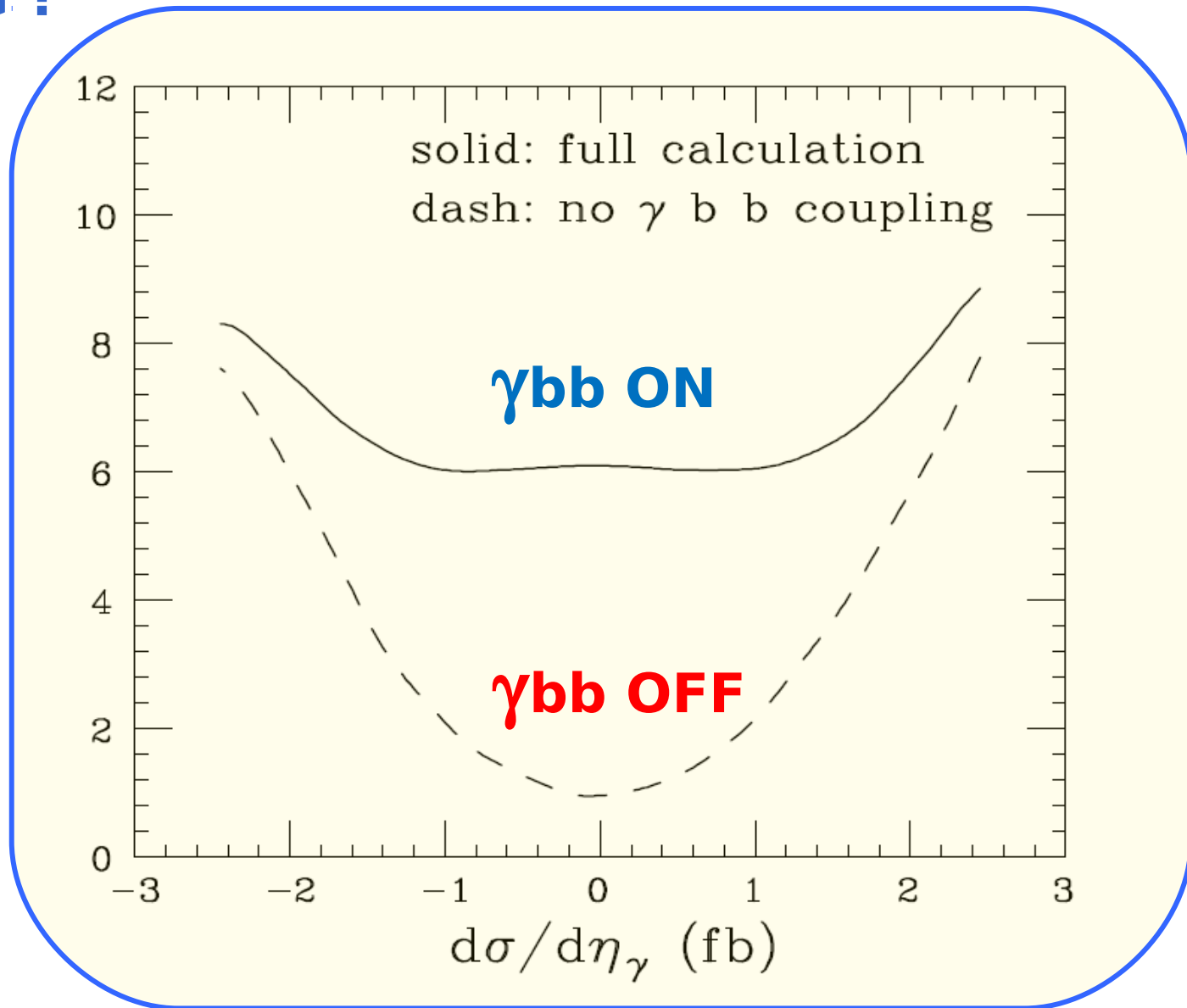
bckg is less active by requiring a central γ

dynamical effect: $\longrightarrow$
for γ at large angles
destructive interference
(a) + (b) and (c) + (d)

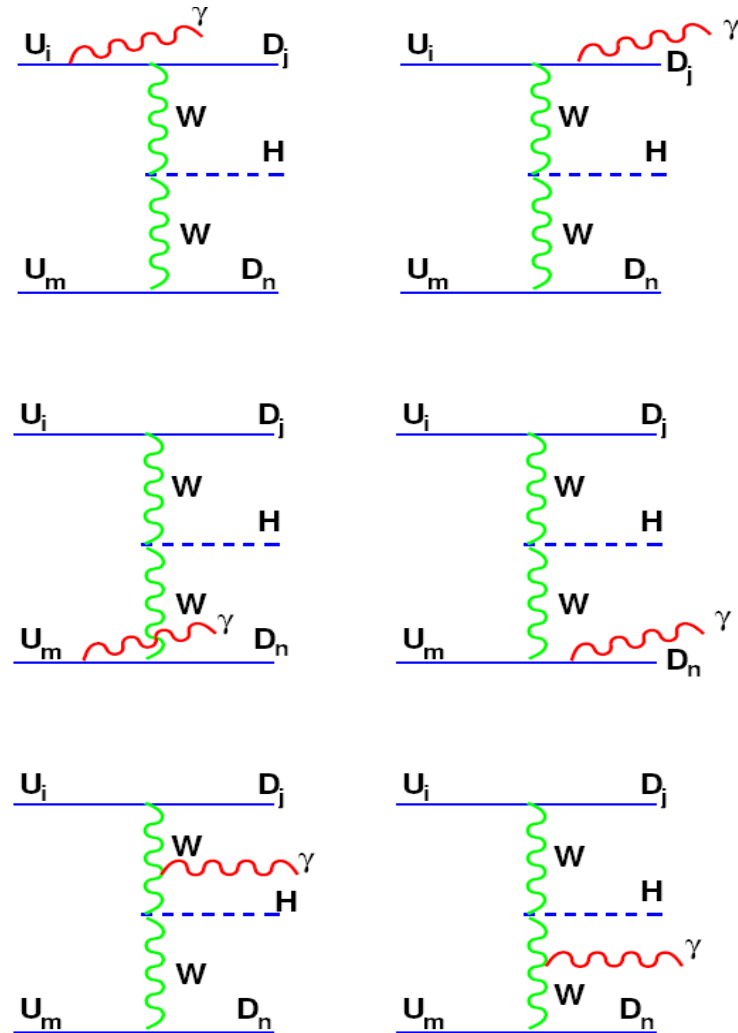
dominant contrib. $\longrightarrow$
(is small being suppressed by b-quark electric charge 2)



what if the $\gamma b b$ coupling is switched off in the BCKG ?



on the contrary
SIGNAL
 has no destructive
 interference at large
 angle, due to the
 charged currents



● no suppression at large angle for the signal

S/B versus optimization of kinematical cuts

- cuts made at partonic level (partonic shower effects added in a second stage)
- we obtained (optimized cuts follow)

$$B(\gamma \text{ bbjj}) / B(\text{bbjj}) \sim 1/3000$$

$$S(\gamma \text{ bbjj}) / S(\text{bbjj}) \sim 1/100$$

$$S(\gamma) / B(\gamma) \sim 30 \text{ S/B}$$

basic cuts

$$\begin{aligned} p_T^j &\geq 30 \text{ GeV}, & p_T^b &\geq 30 \text{ GeV}, & \Delta R_{ik} &\geq 0.7, \\ |\eta_\gamma| &\leq 2.5, & |\eta_b| &\leq 2.5, & |\eta_j| &\leq 5, \\ m_{jj} &> 400 \text{ GeV}, & m_H(1-10\%) &\leq m_{b\bar{b}} \leq m_H(1+10\%) \\ 1) \quad p_T^\gamma &\geq 20 \text{ GeV}, \\ 2) \quad p_T^\gamma &\geq 30 \text{ GeV}, \end{aligned}$$

after looking at:

$$\frac{d\sigma}{dm_{jj}}, \quad \frac{d\sigma}{dp_T^{j1}}, \quad \frac{d\sigma}{dp_T^{b1}}, \quad \frac{d\sigma}{dm_{\gamma H}}, \quad \frac{d\sigma}{|\Delta\eta_{jj}|},$$

optimized cuts follow:

$$m_{jj} \geq 800 \text{ GeV}, \quad p_T^{j1} \geq 60 \text{ GeV}, \quad p_T^{b1} \geq 60 \text{ GeV}, \\ |\Delta\eta_{jj}| > 4, \quad m_{\gamma H} \geq 160 \text{ GeV}, \quad \Delta R_{\gamma b/\gamma j} \geq 1.2,$$

$$S = L \sigma_S \text{BR} \varepsilon(b) \varepsilon(\bar{b}) \varepsilon(bb)$$

$$B = L \sigma_B \varepsilon(b) \varepsilon(\bar{b})$$

$$\text{sign} \neq \frac{S}{\sqrt{B}}$$

we used

$$L = 100 \text{ fb}^{-1}$$

$$\varepsilon(b) = 60\% \rightarrow \text{eff. b-tag}$$

$$\varepsilon(bb) = 70\% \rightarrow \text{due to } (+/-10\%) \text{ bb mass resolution}$$

partonic contributions to bckg

no photon

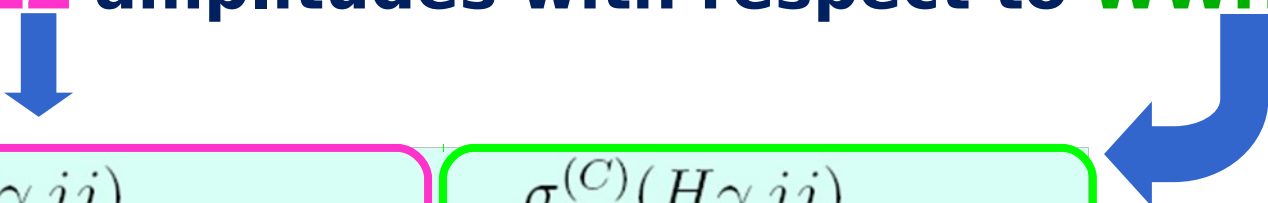
with photon

sub-processes	σ_i (pb)	σ_i/σ	σ_i^γ (fb)	$\sigma_i^\gamma/\sigma^\gamma$
$gq \rightarrow b\bar{b} gq (\gamma)$	57.2(1)	55.3 %	17.3(1)	51.6 %
$gg \rightarrow b\bar{b} gg (\gamma)$	25.2(1)	24.4 %	3.93(3)	11.7 %
$qq' \rightarrow b\bar{b} qq' (\gamma)$	7.76(3)	7.5 %	4.04(2)	12.1 %
$qq \rightarrow b\bar{b} qq (\gamma)$	6.52(2)	6.3 %	4.49(3)	13.4 %
$q\bar{q}' \rightarrow b\bar{b} q\bar{q}' (\gamma)$	4.60(2)	4.4 %	2.28(2)	6.8 %
$q\bar{q} \rightarrow b\bar{b} q\bar{q} (\gamma)$	2.13(2)	2.1 %	1.21(2)	3.6 %
$gg \rightarrow b\bar{b} q\bar{q} (\gamma)$	0.0332(7)	0.03 %	0.124(3)	0.37 %
$q\bar{q} \rightarrow b\bar{b} gg (\gamma)$	0.0137(2)	0.01 %	0.094(2)	0.28 %
$q\bar{q} \rightarrow b\bar{b} q'\bar{q}' (\gamma)$	0.000080(3)	0.00007 %	0.00080(8)	0.002 %

further advantages of requiring a central photon

■ VBF is sensitive to both WWH and ZZH

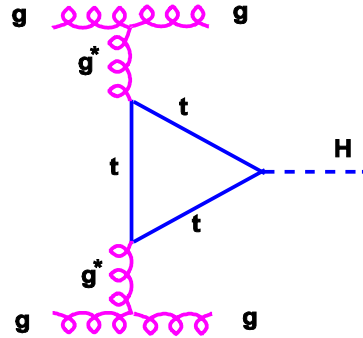
γ depletes HZZ amplitudes with respect to WWH


$$\frac{\sigma^{(N)}(H\gamma jj)}{\sigma^{(N)}(H jj)} = 0.0016, \quad \frac{\sigma^{(C)}(H\gamma jj)}{\sigma^{(C)}(H jj)} = 0.013$$

$$p_T^\gamma \geq 20 \text{ GeV}, \quad |\eta_\gamma| \leq 2.5, \quad \text{and} \quad \Delta R_{j\gamma} \geq 0.7$$

■ requiring a central photon in VBF increases sensitivity to WWH coupling

■ suppresses contaminations from $g^* g^* \rightarrow H$
induced by loop of top



basic kinematical cuts (see next slide)

- ▶ with $p_t > 20 \text{ GeV} \rightarrow$ reduction factor of 8×10^{-4}
for $\sigma (H \gamma jj)$ with respect to $\sigma (H jj)$
(induced by $g^* g^* \rightarrow H$)
- ▶ cross section $\sim 0.21 \text{ fb}$ (negligible !)

Cross sections

	$p_T^{\gamma, cut}$	$m_H = 120 \text{ GeV}$	$m_H = 130 \text{ GeV}$	$m_H = 140 \text{ GeV}$
$\sigma[H(\rightarrow b\bar{b})\gamma jj]$	20 GeV	3.59(7) fb	2.92(4) fb	1.98(3) fb
	30 GeV	2.62(3) fb	2.10(2) fb	1.50(3) fb
$\sigma[b\bar{b}\gamma jj]$	20 GeV	33.5(1) fb	37.8(2) fb	40.2(1) fb
	30 GeV	25.7(1) fb	27.7(1) fb	28.9(2) fb
$\sigma[H(\rightarrow b\bar{b})jj]$		320(1) fb	254.8(6) fb	167.7(3) fb
$\sigma[b\bar{b}jj]$		103.4(2) pb	102.0(2) pb	98.4(2) pb

L=100 fb⁻¹	$p_T^{\gamma, cut}$	$m_H = 120 \text{ GeV}$	$m_H = 130 \text{ GeV}$	$m_H = 140 \text{ GeV}$
$S/\sqrt{B} _{H\gamma jj}$	20 GeV	2.6	2.0	1.3
$S/\sqrt{B} _{H\gamma jj}$	30 GeV	2.2	1.7	1.2
$S/\sqrt{B} _{Hjj}$		3.5	2.8	1.9

(before shower)

H($\rightarrow$ bb)+jj+ γ

S/B $\sim$ 1/10

H($\rightarrow$ bb)+jj

S/B $\sim$ 1/300

cfr.

gg $\rightarrow$ H($\rightarrow$ $\gamma\gamma$)

S/B $\sim$ 1/20

Reducible backgrounds

- $pp \rightarrow \gamma + 4 \text{ jets}$ with two light-jets tagged as b-jets
- $pp \rightarrow bb + 3 \text{ jets}$ with one light-jet misidentified as γ
- $pp \rightarrow 5 \text{ jets}$ with one light-jet misidentified as γ and two light-jets tagged as b-jets

Efficiencies of mistagging

$$\varepsilon_{bj} = 1/100$$

$$\varepsilon_{\gamma j} = 1/5000 \quad (\text{ATLAS})$$

number of events ($m_H=120$ GeV) Signal versus Bckg

	$p_T^\gamma \geq 20$ GeV	$p_T^\gamma \geq 30$ GeV
$pp \rightarrow \gamma H(\rightarrow b\bar{b}) + 2j$	90	66
$pp \rightarrow \gamma b\bar{b} + 2j$	1206	925
$pp \rightarrow \gamma + 4j$	23	17
$pp \rightarrow b\bar{b} + 3j$	440	324
$pp \rightarrow 5j$	14	11
$S/\sqrt{B}$	2.2	1.8

(before shower)

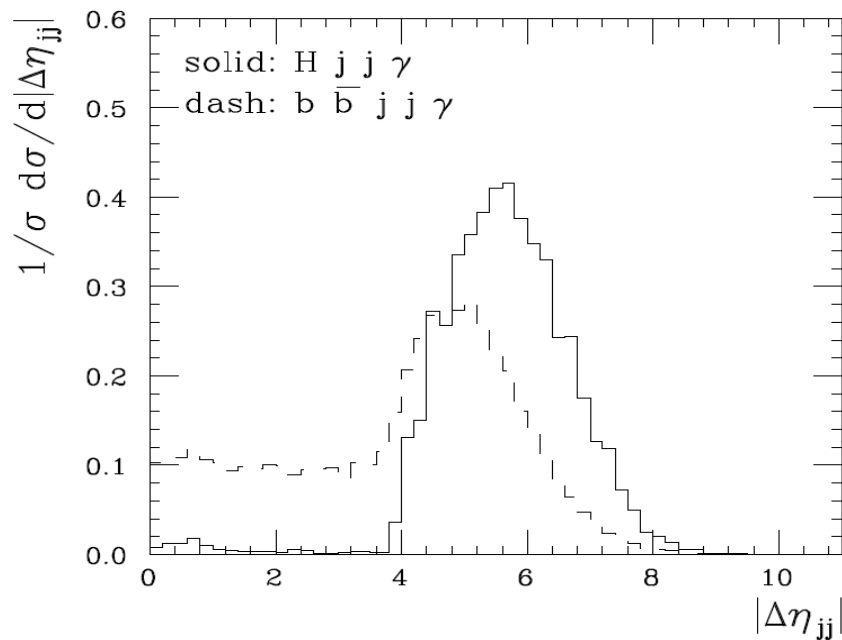
Irreducible bckg has a dominant role !

Parton shower effects and central jet veto

- no color is exchanged in the signal between initial and final fermionic lines
- on the contrary, bckg is characterized by the presence of t-channel virtual gluons

QCD radiation pattern is similar to the plane VBF process ➡ **central jet veto drastically enhances S/B**

- **invariant mass and rapidity separation** between the tagging jets are expected to decrease in the bckg events respect to partonic configurations. (smaller effect in the signal)
- **Kin. Cuts get more effective in enhancing S/B**



Algorithm1:

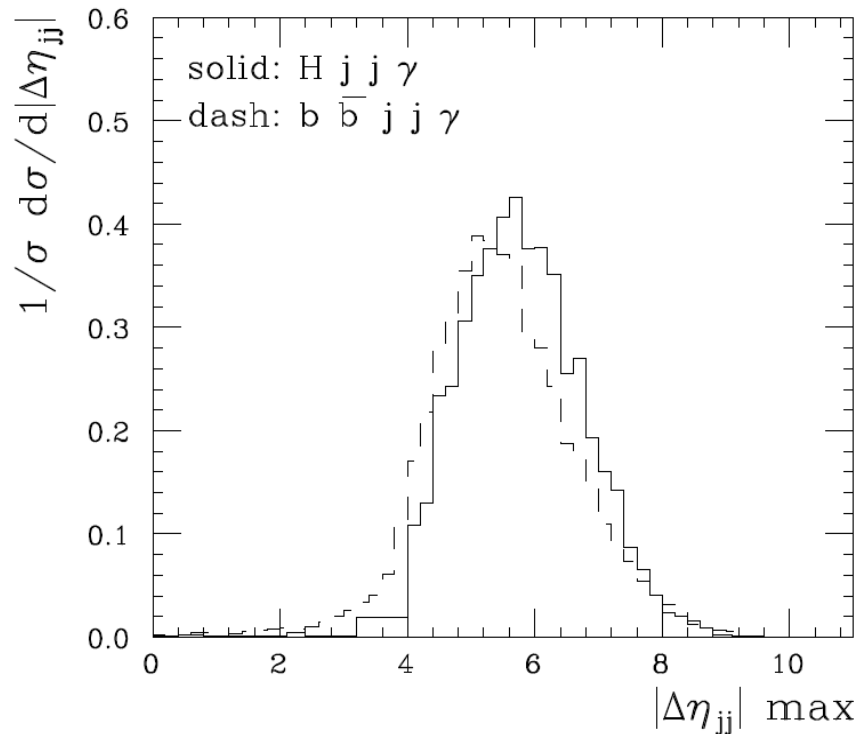
$\Delta\eta(j1,j2)$

j1=highest pT

j2=second highest pT

$pT(j1) > 60 \text{ GeV}$

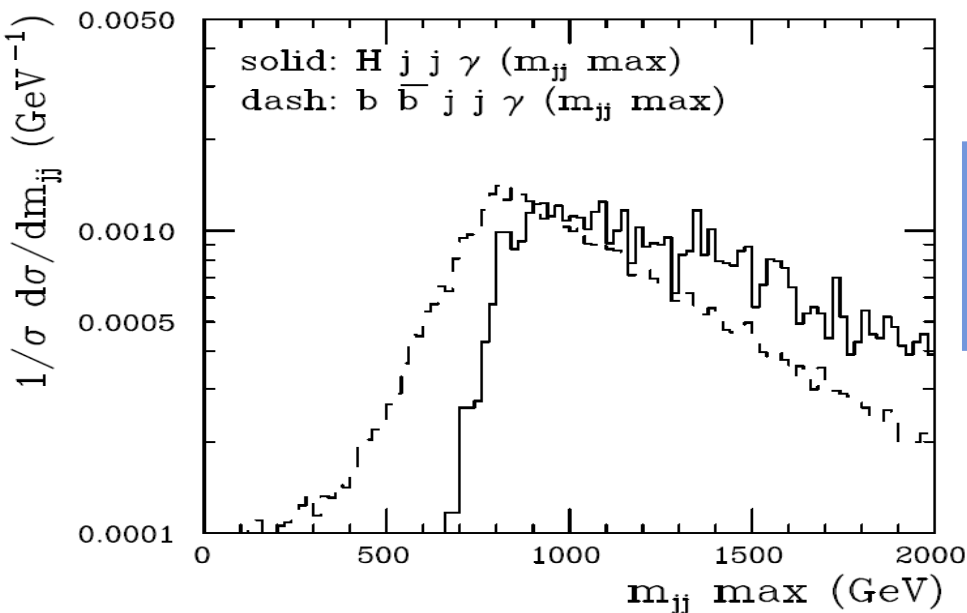
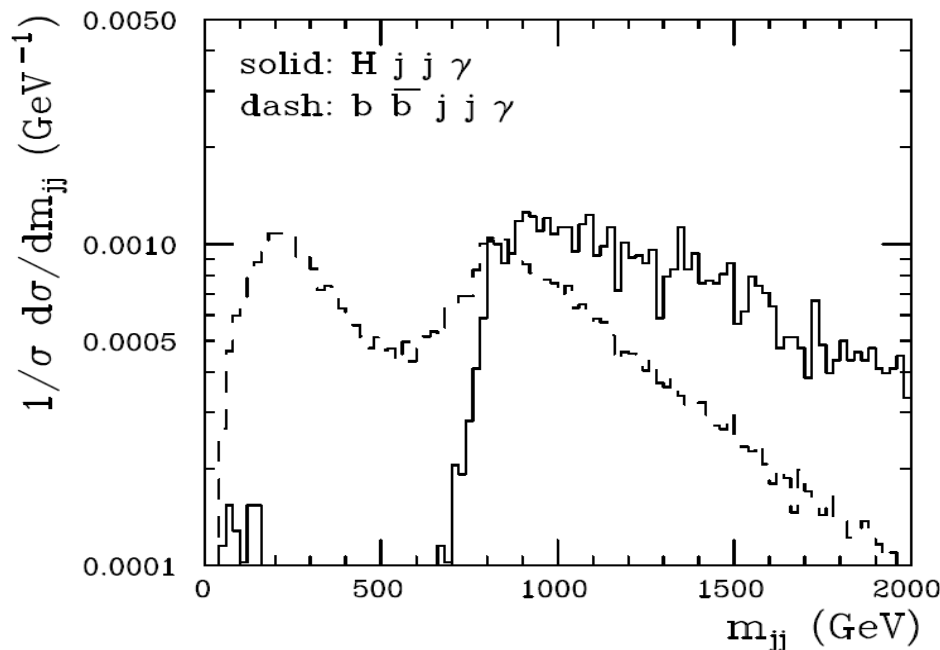
$pT(j2) > 30 \text{ GeV}$



Algorithm2:

$\max[\Delta\eta(j1,j2)]$ among
all jets

Parton shower effects



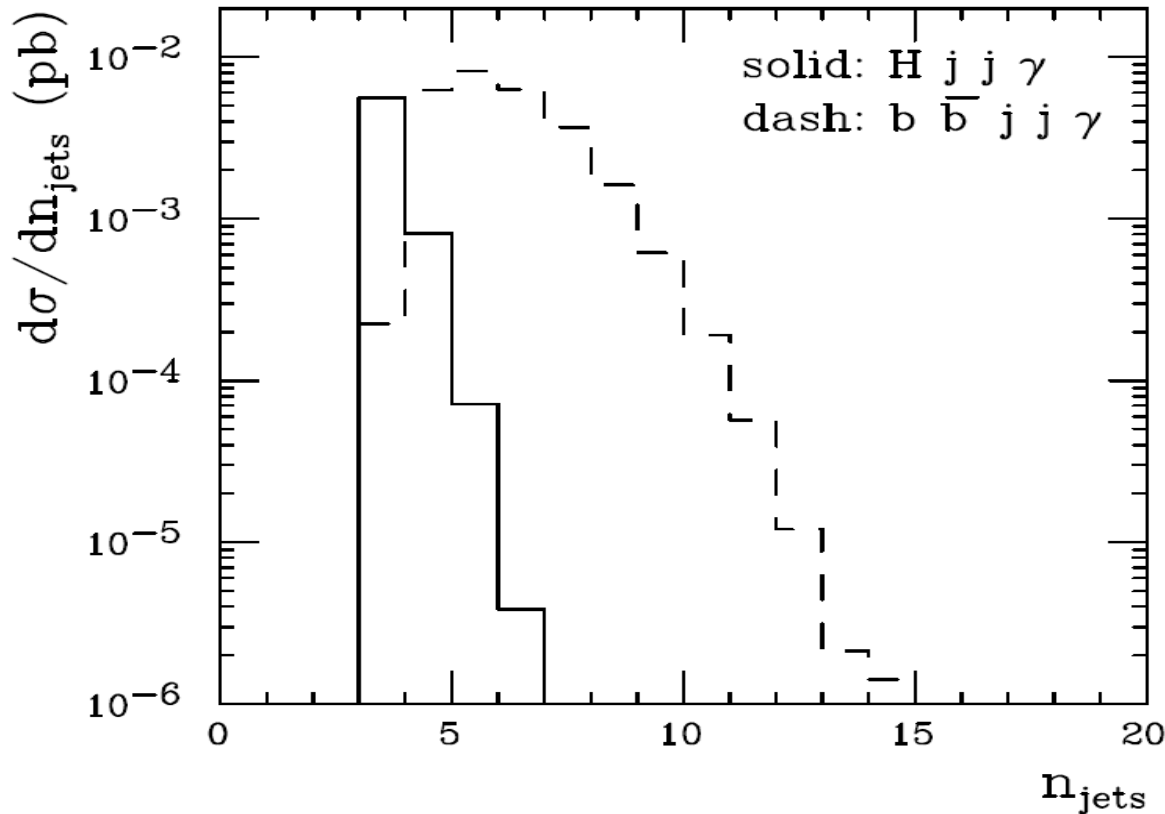
Algorithm1:
 $m(j1,j2)$
j1=highest pT
j2=second highest pT

$pT(j1) > 60 \text{ GeV}$

$pT(j2) > 30 \text{ GeV}$

Algorithm2:
 $\max[m(j1,j2)]$ among
all jets

jet multiplicity distribution



■ we expected a factor 4 improvement for S/B when parton shower effects are included

■ however a very recent analysis shows a more modest enhancement of S/B when complete parton shower effects are included

D.M. Asner et. al. arxiv:1004.0535

Conclusions

- Requiring an associated central photon in the Higgs production via VBF offers great advantages:
 - **trigger efficiency**
 - **strong suppression of QCD bckg**
 - **$S/B \sim 1/10$**
 - **sensitivity to Hbb & HWW couplings**
- complete parton shower effects recently included:

Herwig	➡	49% increase in signf
Phytia	➡	16% increase in signf

Higgs sector in the MSSM

Two complex Higgs boson doublets **HU** and **HD**
(giving masses to Up and Down quarks)

■ Spectrum:

- two CP-even (**h,H**)
- one CP-odd (**A**) neutral
- one pair of **charged Higgs bosons**

■ At tree-level, Higgs sector fully specified by two parameters:

$$\tan\beta = \langle \text{HU} \rangle / \langle \text{HD} \rangle$$

mA = mass of pseudoscalar A.

(radiative corrections depend on other SUSY parameters)

■ Light-Higgs boson mass scenario, **naturally predicted in the MSSM** with $m_H < 134 \text{ GeV}$

■ Large $\tan\beta$ scenarios are favored:

- ▶ viable dark matter candidate
- ▶ large radiative corrections to lightest Higgs boson mass
- ▶ large SUSY contributions to $(g-2)_\mu$: needed to accomodate the present 3.4σ deviation
- ▶ H/A Yukawa to b-quarks enhanced by $\tan\beta$

■ CDF and D0 collaborations have recently analyzed $pp \rightarrow (H,A,h) \rightarrow \tau \tau$

- ▶ no evidence of signal observed;
- ▶ only an excess of events in the region $m_H=140-160$ and $\tan\beta>45$ observed;
- ▶ limits on m_A and $\tan\beta$ out to be weaker than expected

b-quark fusion process $bb \rightarrow H/A$

- **main mechanism for H/A production at large $\tan\beta$**
- **$bb \rightarrow H/A$ rates comparable with $gg \rightarrow H/A$ rates:**
in SM is two order of magnitude smaller than gluon fusion
- **particularly sensitive to the composition of proton in terms of b-quarks**
- **no direct measurement of b-quark parton density derived perturbatively from gluon parton density**
- **no hope in the SM to separate $bb \rightarrow h$ from $gg \rightarrow h$**
- **in MSSM this is possible for large $\tan\beta$, although a contamination of $gg \rightarrow h$ is unavoidable**

$$pp \longrightarrow H/A + \gamma$$

EG, Mele, Rathsmann, PR D77 (2008) 055020 (Tree level)

EG, Mele, Piccinini (in preparation) (NLO QCD correct.s)

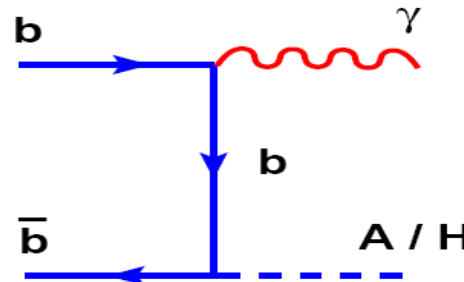
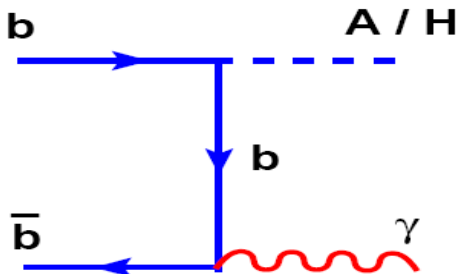
- if a high- p_T photon is required then no contamination from gg fusion
- a photon in the final states selects the initial partonic process
- large $\tan\beta$ compensates for EM suppression

Vanishes

$$gg \rightarrow H/A + \gamma$$

forbidden by C-parity

stable under radiative corrections



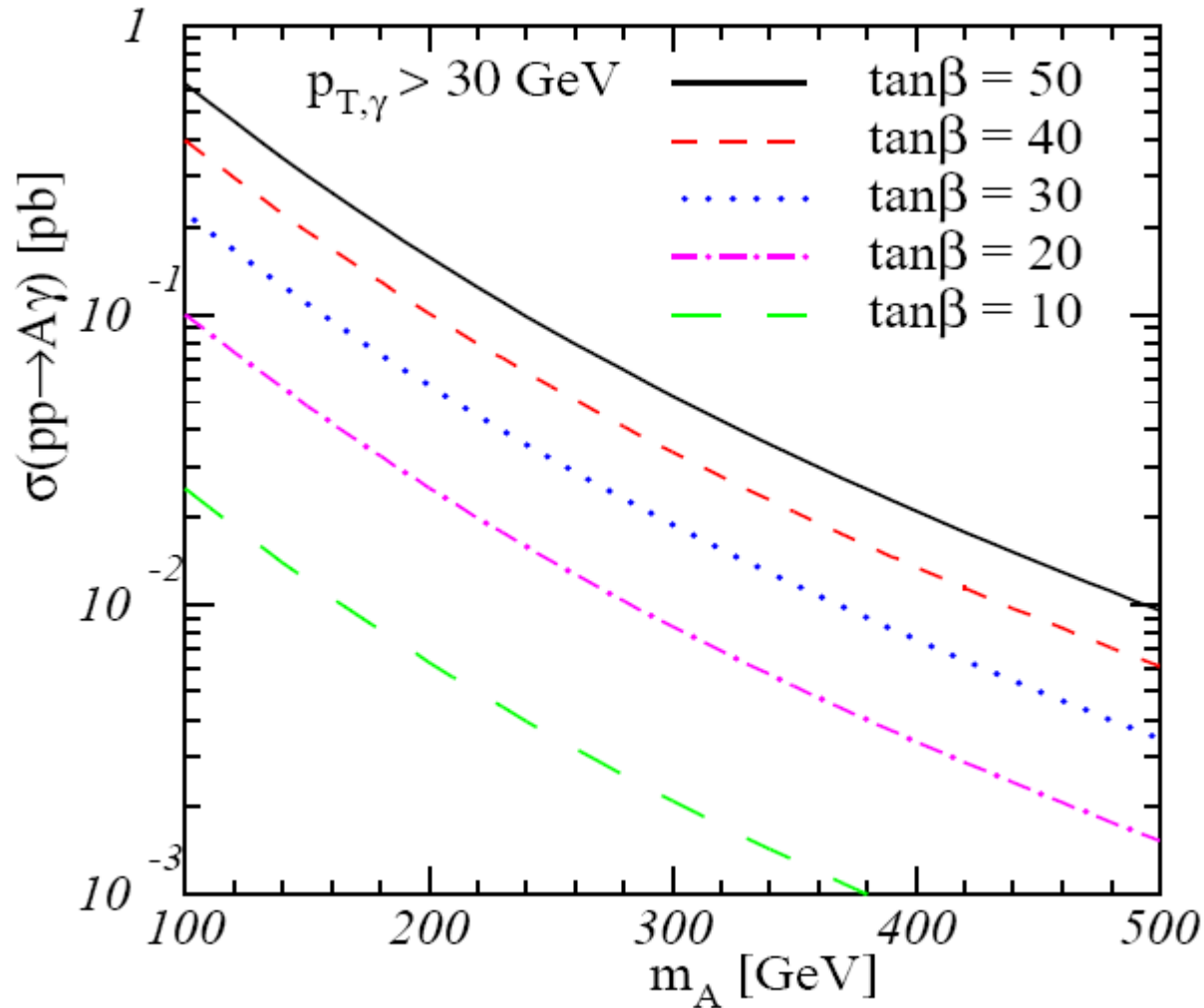
most promising signature is $H/A \rightarrow \tau \tau$

- **BR~10% for large $\tan\beta$ almost insensitive to m_H**
- **BCKG for $\tau\tau+\gamma$ final states has an EW origin and is well under control**
- **tagging tau leptons allows drastic reduction of the BCKG**
- **tau-tau signature well studied in SM and MSSM. Very promising for Higgs discovery**

Note: the complete tau-tau invariant mass can be fully reconstructed, provided the two taus are not neither back-to-back nor collinear in lab frame (due to undetected neutrinos)

Condition satisfied by requiring a large p_T of the photon

signal cross section in pb versus m_A



◆ Structure functions used : CTEQ6L1 with factorization scale = $M_A/2$

◆ Tevatron x-section = 2.5 fb, for $p_T > 20$ GeV, $m_A = 150$, $\tan\beta = 50$

analysis of tau-tau signature

$$pp \rightarrow H/A \gamma \rightarrow \tau\tau \gamma$$

- **main irreducible BCKG** is due to tau-pair production via gamma or Z off-shell

also: $pp \rightarrow WW \gamma$ with $W \rightarrow \tau\nu$

negligible: x-sec $\sim 14\text{fb}$ for $p_T > 30\text{ GeV}$

- **only the resonant $H/A \rightarrow \tau\tau$ production associated to a high p_T photon can disentangle the initial bb partonic state**

- **the spurious signal coming from channel**

$$bb \rightarrow H/A \rightarrow \tau^* \tau \rightarrow \tau\tau \gamma,$$

with photon radiated by a tau, must be also kept under control

■ Large SUSY radiative corrections on b-Yukawa factorizes. Small residual dependence

■ in MSSM, $m_A \sim m_H$ (at large $\tan\beta$)
gives a factor 2 of enhancement in the cross-section

■ assumed tau-pair efficiency = 0.2

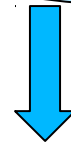
it comes from

$\tau \rightarrow \ell \nu_\tau \nu_\ell$ (35%)	ID efficiency = 90%
$\tau \rightarrow h \nu$ (50%)	ID efficiency = 25%

double hadronic decays contribute with 0.016 to 0.2

optimized set of cuts to avoid non-resonant production

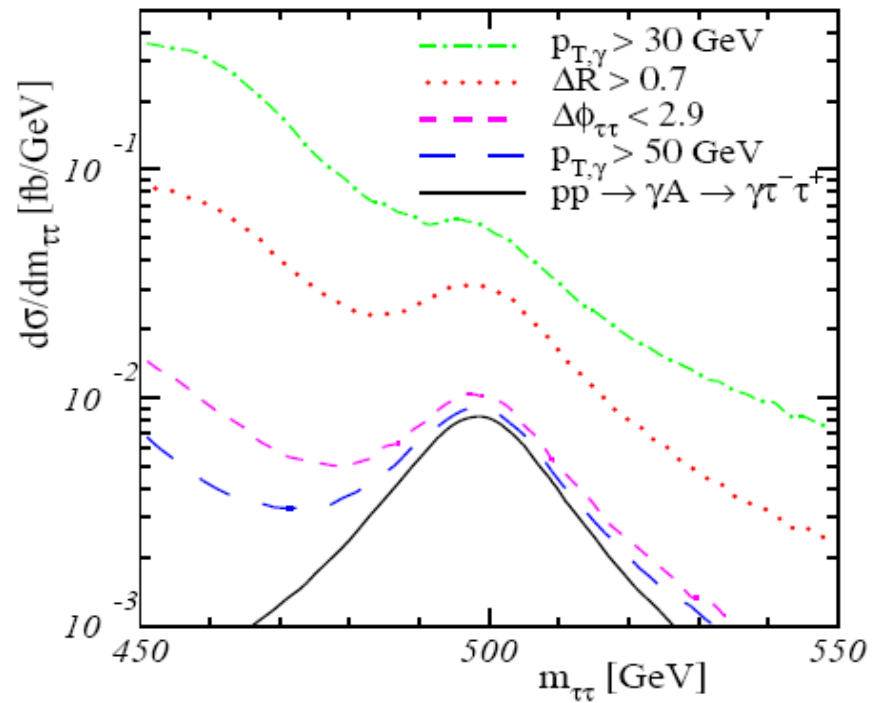
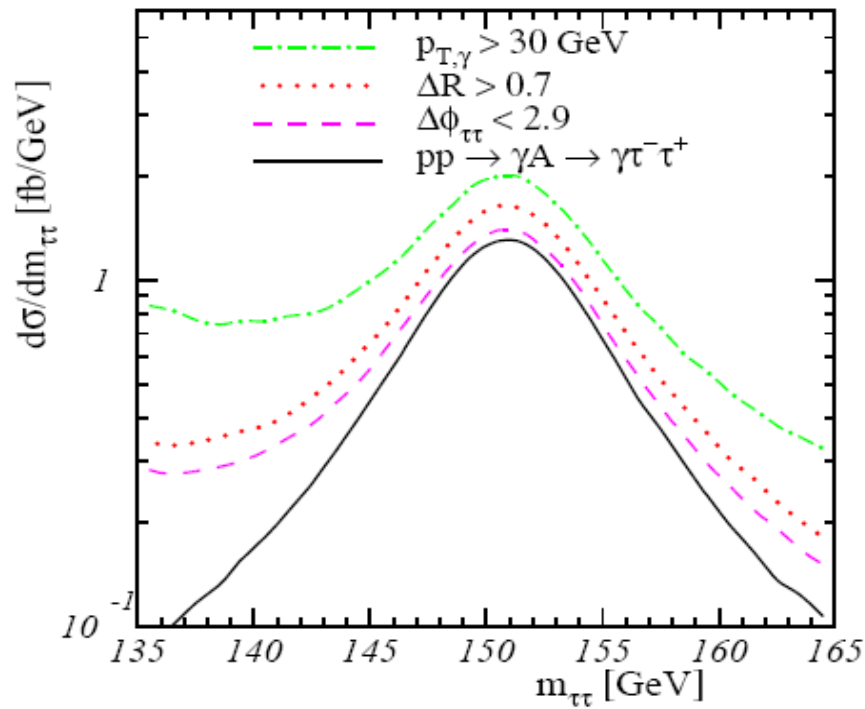
- $p_T^\gamma > 30, 30, 40, 50$ GeV, for $m_A = 150, 200, 300, 500$ GeV,
- $0.9 m_A < m_{\tau\tau} < 1.1 m_A$ on the $\tau\tau$ invariant mass ;
- $p_T^{\tau^\pm} > 20\text{GeV}$, $|\eta_\gamma| < 2.5$, $|\eta_{\tau^\pm}| < 2.5$
- $\Delta R_{\gamma\tau^\pm} > 0.7$, $\Delta R_{\tau\tau} > 0.7$, $\Delta\phi_{\tau\tau} < 2.9$.



**suppress the kin. configurations where
photon is collinear to one of taus: allows
tau-tau mass reconstruction**



$\Delta\phi_{\tau\tau} < 2.9$ **quite effective at larger masses**



■ after applying all cuts one gets substantial purity of the signal $bb \rightarrow H/A \gamma$

■ γ -radiation off b's : 83% (66%) of observed rate for $m_A=150$ (500) GeV at $\tan\beta=50$

Signal cross-section and corresponding significance S

$\tan \beta$	20		30		40		50	
m_A	σ_S (fb)	S	σ_S (fb)	S	σ_S (fb)	S	σ_S (fb)	S
150	5.58	7.3	12.5	13	22.1	19	34.5	24
200	3.00	5.3	6.81	9.5	12.3	14	19.9	18
300	0.727	2.4	1.67	4.5	3.08	6.7	5.03	9.1
500	0.0981	0.72	0.238	1.5	0.456	2.4	0.768	3.4

$$S = n(S) / \sqrt{n(S) + n(B)}$$

➡ sensitivity to
PDF $\sim O(20\%)$

➡ $L=100/\text{fb}$, $\varepsilon(\tau\tau)=0.2$

➡ only irreducible bckg

- Important to check if these conclusions remain stable under QCD corrections. EG, Mele, Piccinini (in preparation)
- At the $O(\alpha_S)$ order one has to include the
 - one-loop virtual corrections to the basic process
 - real gluon emission → necessary in order to cancel the infrared divergencies
 - $g b \rightarrow b H \gamma$ must be included
- At NLO in QCD: $gg \rightarrow H g \gamma$ induced by a loop of top
 - could spoil the sensitivity of the x-section to the b-parton density. Important to check its magnitude
(EG, Mele, Piccinini, future work)
- QCD corrections included are crucial for a precise determination of the cross section at LHC

Conclusions

- the request of an associated high-pT photon in the Higgs boson production offers great advantages (trigger efficiency improved)

- **SM** $pp \rightarrow H \gamma + j j$

with a **light Higgs boson** decaying in $H \rightarrow b\bar{b}$, can help in constraining both Hbb and HWW couplings ($L=100$ /fb)

- **MSSM** $pp \rightarrow H/A + \gamma$

- with $H/A \rightarrow \tau \tau$, can provide a clean probe of the b-quark density in the proton at large $\tan\beta$ ($L=100$ /fb up to $m_A=500$)
- **one-loop QCD corrections** has been included (work in preparation)

what if $\gamma \rightarrow W$: **HW jj** Rainwater (2001)



- it could help in constraining bbH coupling
- however, accurate studies of background and parton shower effects are missing
- relevant cross section is smaller than $H \gamma jj$

with same optimized event selection criteria
(with constraints on photon applied to
charged lepton)

for $m_H=120$ GeV and $p_T(\gamma) > 20$ GeV we get

$$\sigma(H \gamma jj) \sim 4.4 \times \sigma(HWjj)$$

$\nu \quad l=e,\mu$