LES HOUCHES

centre de physique

Higgs with tops working subgroup

People and topics:

M. Spira, M. Kraemer: NLO ttbarh_0, ttbarA calculations at TeVatron and LHC

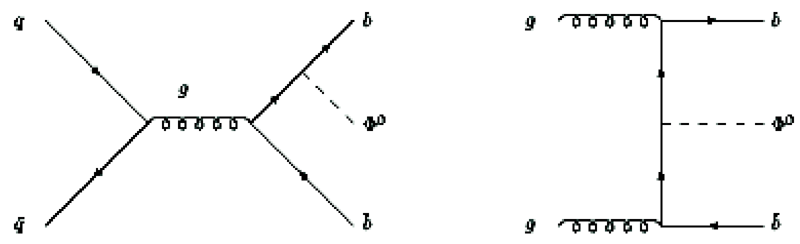
P. Skands (w/ PYTHIA team): ttbar + jets, hard jet rates in PYTHIA 6.3, possible impact on ttbarH at LHC

R. Frazier, S. Gascon, A. Nikitenko (with M. Spira, F. Maltoni, F.Piccinini and ALPGEN team): ttbarH(h_0), H(h)➔2gamma in CMS

F. Maltoni (w/K.Paul, T.Stelzer, S.Willenbrock): t+H+q at LHC

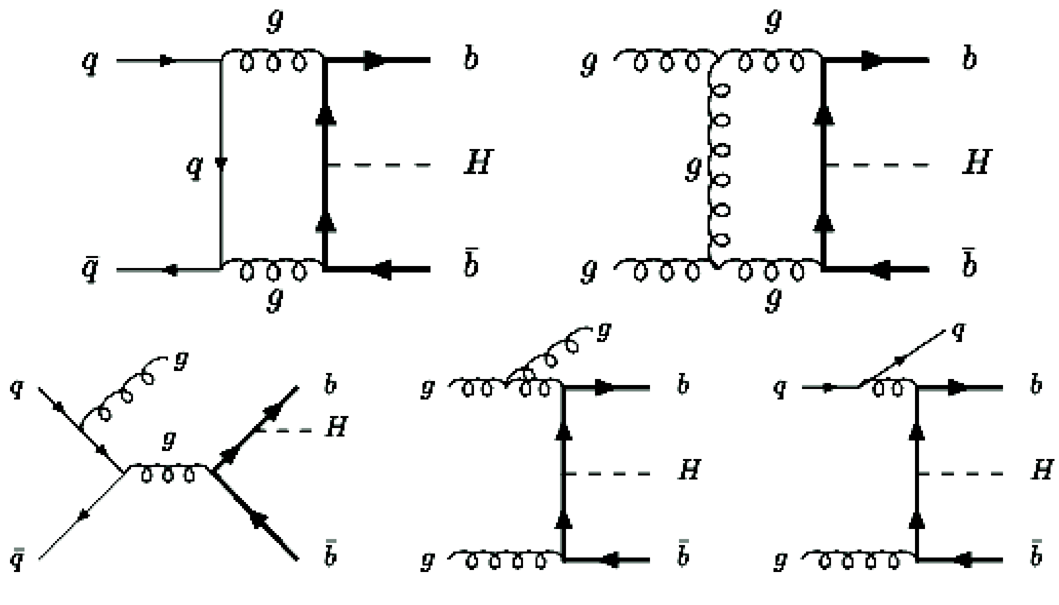
M. Spira, M. Kraemer: NLO ttbarh_0, ttbarA calculations

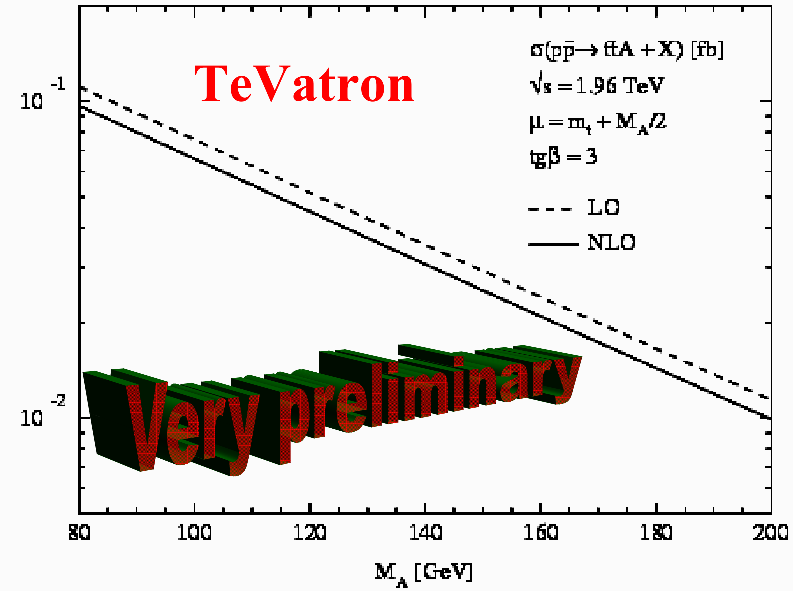
BREMSSTRAHLUNG: $pp \to t\bar{t} + A$

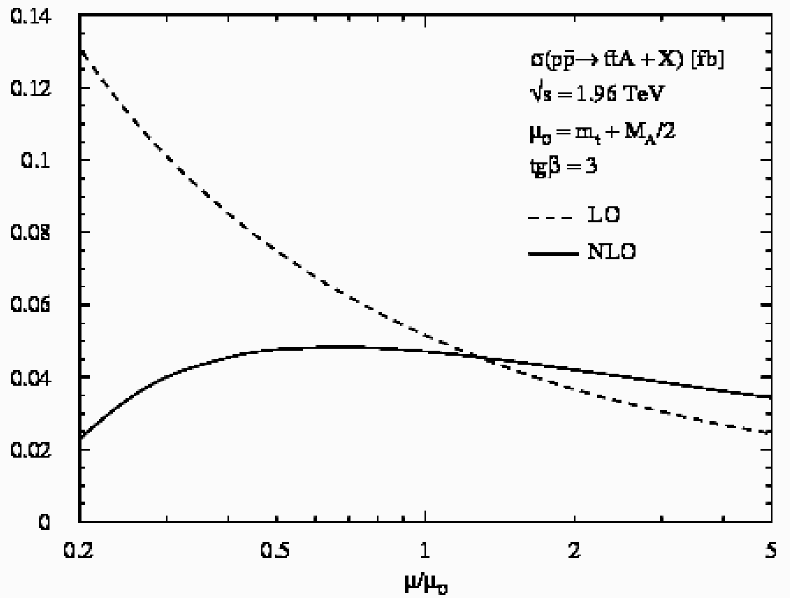


dominant

- QCD corrections:







Dittmaier, Krämer, S.

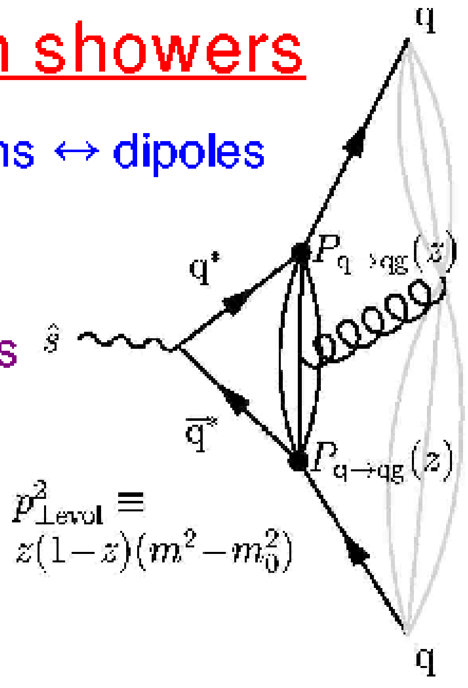
Calculations for LHC, ttbarA/ttbarh_0 ratios to follow for proceedings

P. Skands, C.Oleari, S. Schumann, J. Campbell and S. Gascon): ttbar + jets, hard jet rates in PYTHIA 6.3, possible impact on ttbarH at LHC

Sjostrand, Mrenna, PS

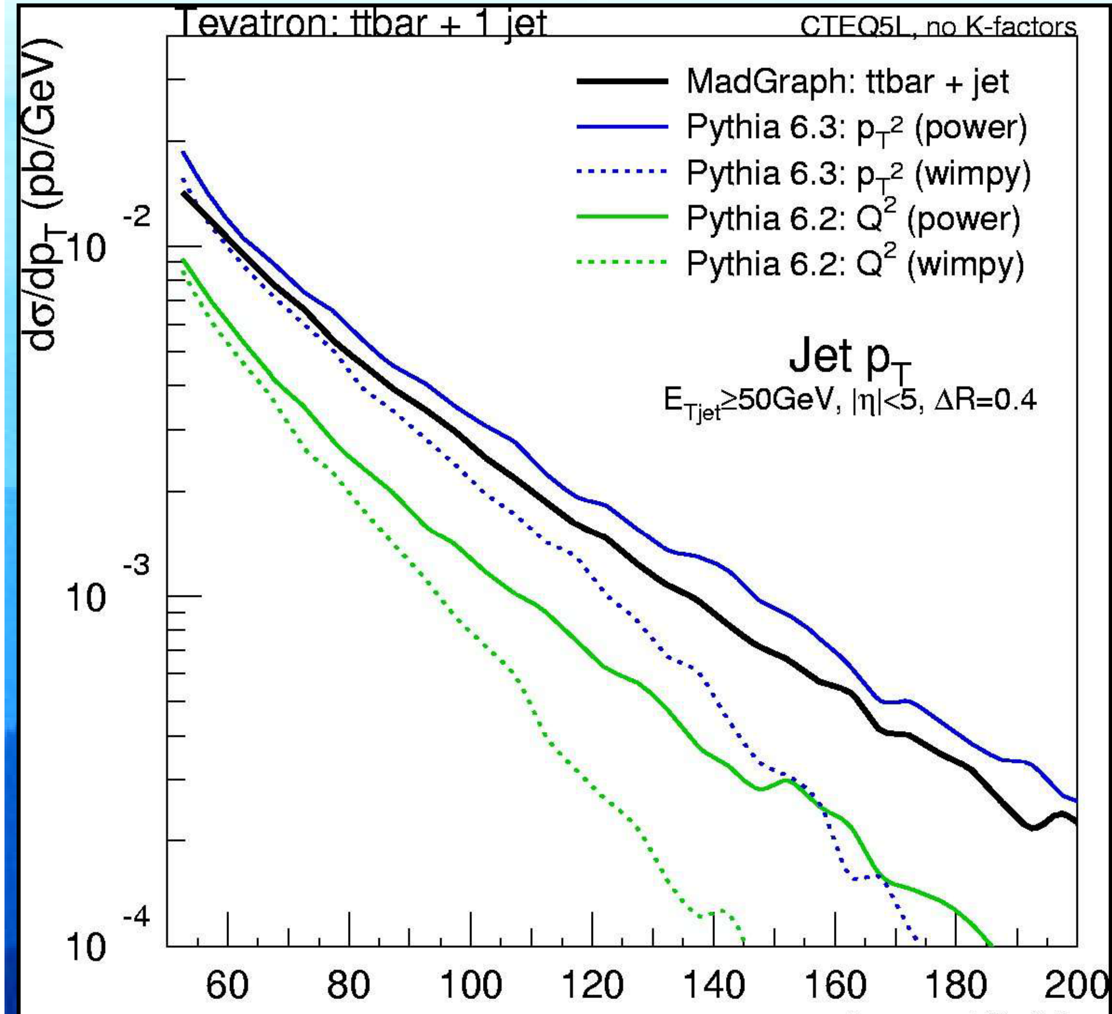
PYTHIA 6.3

- "0'th" approach to matching: improve parton shower algorithm itself
  (if doable, gives fast results for "all" processes)
- ⇨ <u>Completely rewritten parton showers</u>
  - Based on dual description of QCD: partons ↔ dipoles
  - Ordered in (lightcone) <u>pT</u> of branchings
    Sudakovs ⇨ Priority to high-pT branchings
  - ISR + FSR, QCD + QED



(old Q2-ordered showers also still kept as option)

P. Skands, presentation at DIS05



P. Skands, presentation at DIS05

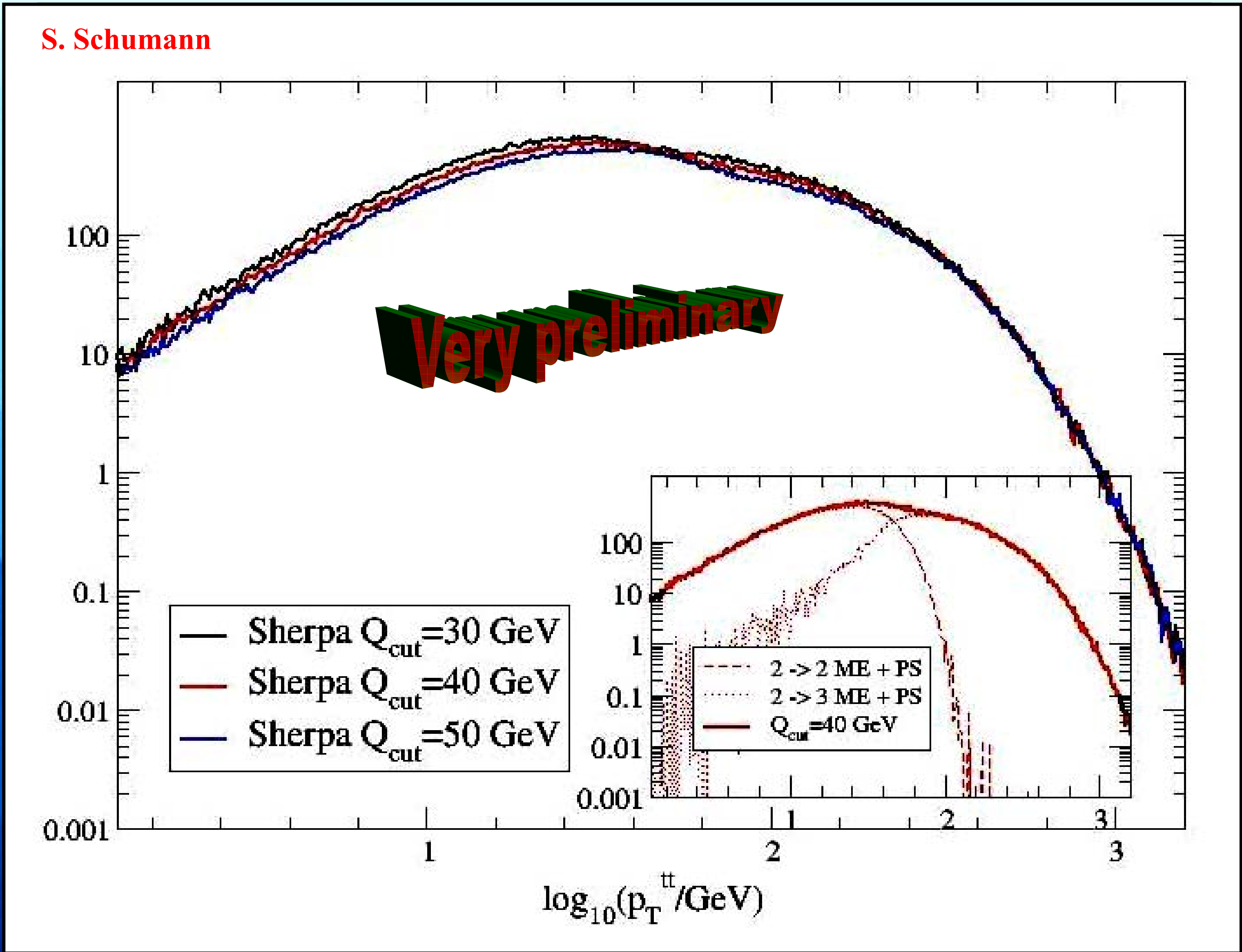
- Compare 6.2/6.3 with other ME codes (NLO, MC@NLO and SHERPA) and on other observables. Use pt of the ttbar pair in inclusive ttbar + X as a first benchmark (first preliminary plots from the 2nd workshop session→…..)

- Questions raised by P. Skands study of ttbar + jets events comparing pt of jets generated with new PYTHIA 6.3 PS algorithm (pt**2 rather than Q**2 ordering) vs. 6.2:

- Results indicate that new PS algorithm may more closely approximate ME code predictions (here, MadGraph) for jet Pt and hard jet rates at the TeVatron

- Issue for the workshop: Is the effect general to other observables, other processes and to the LHC?

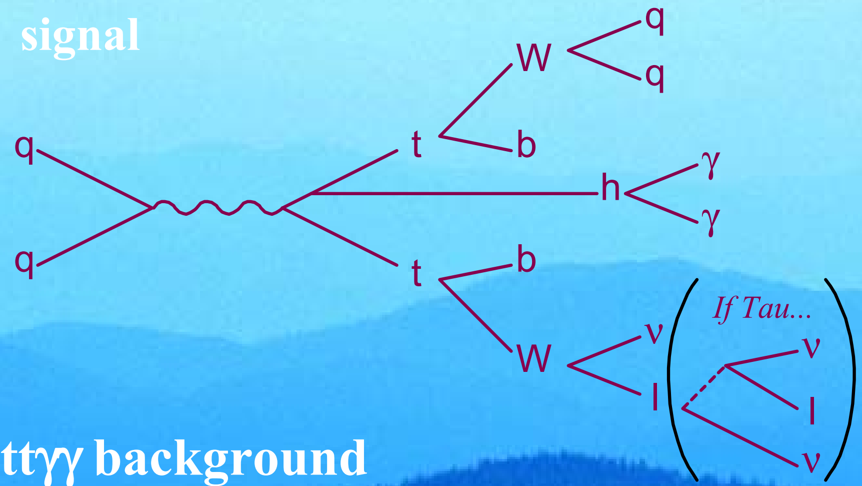
- Possible effect on ttbar_H visibility at the LHC: Comparison underway of 6.2 vs 6.3 on top of ME (ALPGEN) within official CMS framework (comparable implementation of UE nontrivial between two versions)

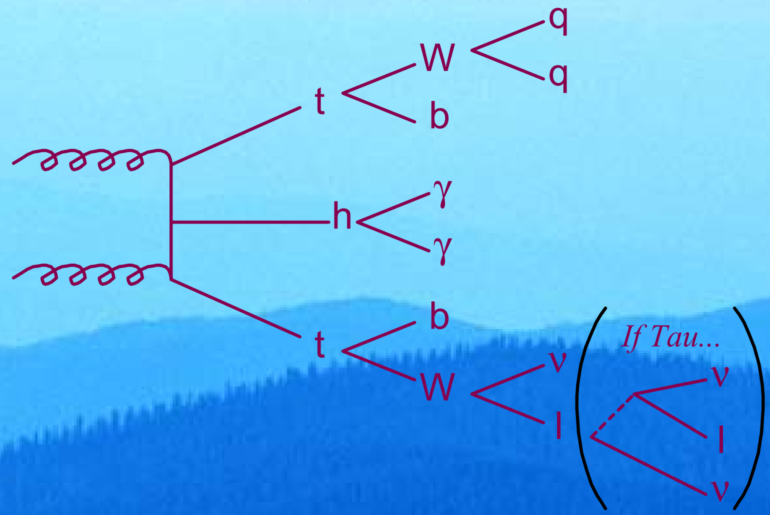


- PT of ttbar pair: good agreement between SHERPA, MC@NLO and NLO particularly at large values
- Relative insensivity to Q_{cut} value

R. Frazier, S. Gascon, A. Nikitenko with LOTS of help from theorists (M. Spira, ALPGEN and MADGRAPH authors…): qq, gg➔ttbarH(h_0), H(h)➔2γ in CMS

signal

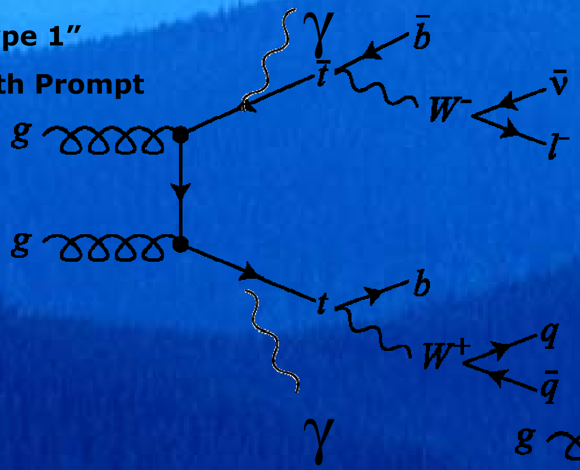




ttγγ background

"Type 1"

Both Prompt

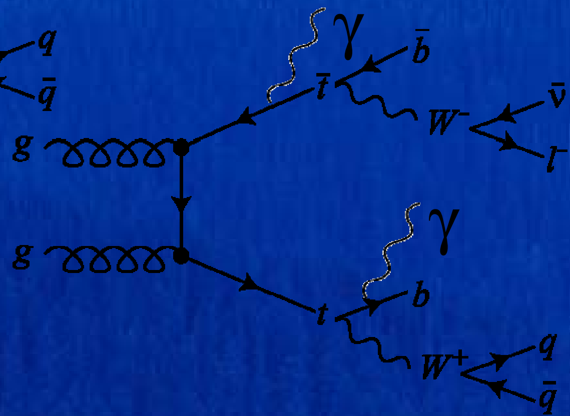


Cross-section 1.6 fb

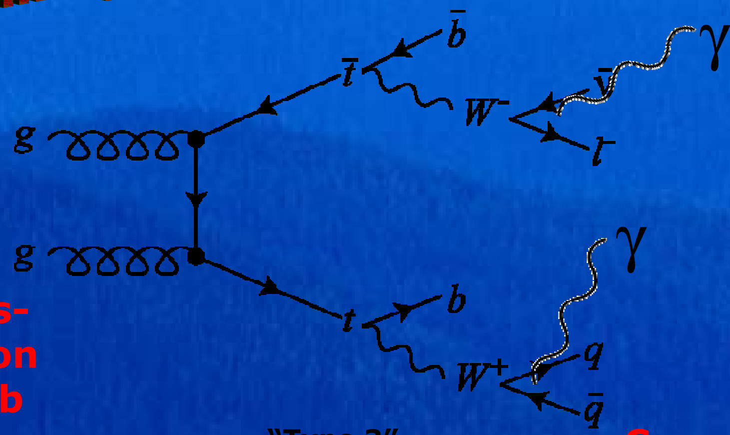
Very preliminary

"Type 2"

1 Prompt, 1 from t decay prods.



Cross-section 6.1 fb



"Type 3"

Both from t decay prods.

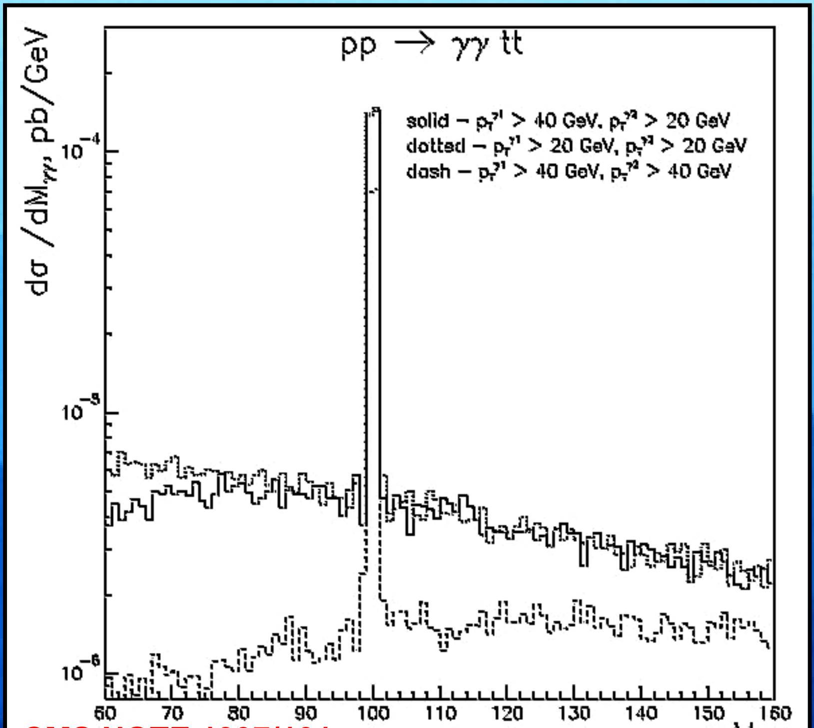
Cross-section 4.9 fb

ALPGEN V1.3 (LO)(Mangano, M.Moretti, Piccinini, Pittau, Polosa)

Advantage:

- Presence of tt pair: high-multiplicity events

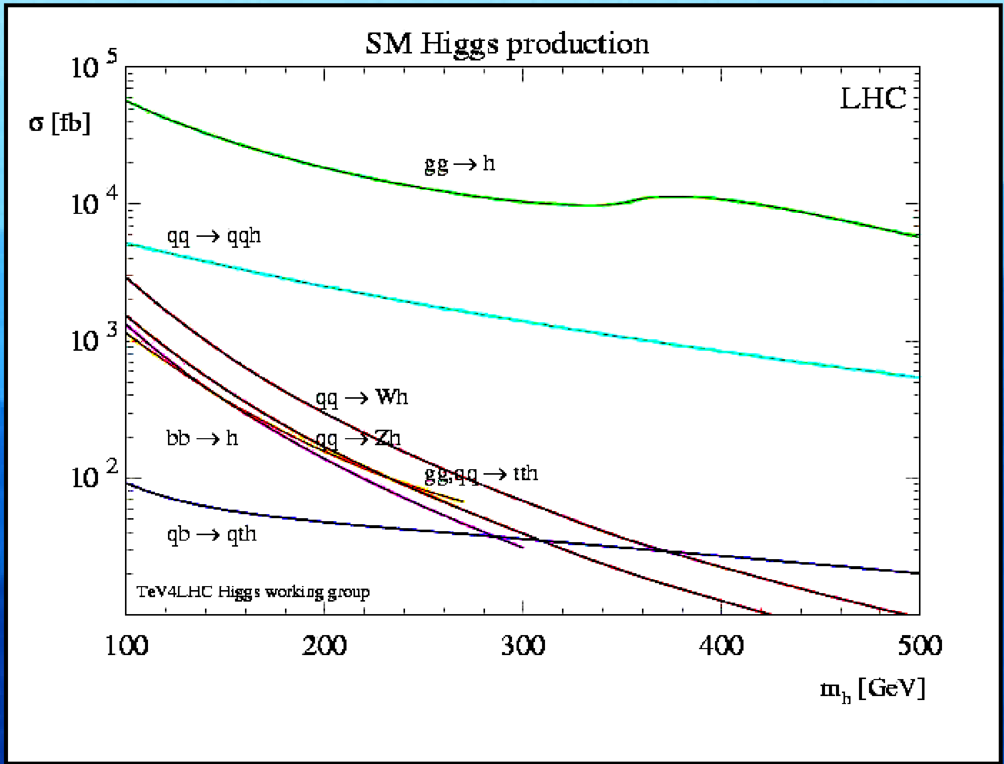
Less vulnerable to QCD background than WH/ZH



CMS NOTE 1997/101

Disadvantage:

- Relatively low cross-section even compared to WH/ZH



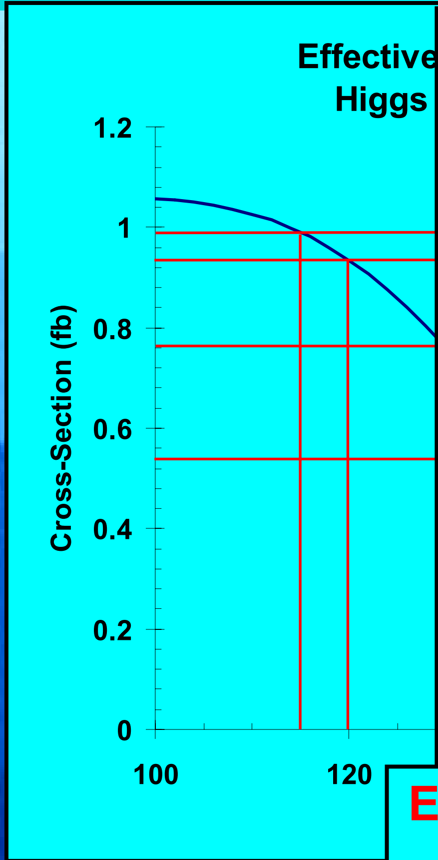
- Prior work in CMS: Generator-level studies of the SM (Ilyin et al, CMS NOTE 1997/101), and MSSM (R. Kinnunen & D, Denegri, CMS NOTE 1997/057) cases demonstrated S/B~1.

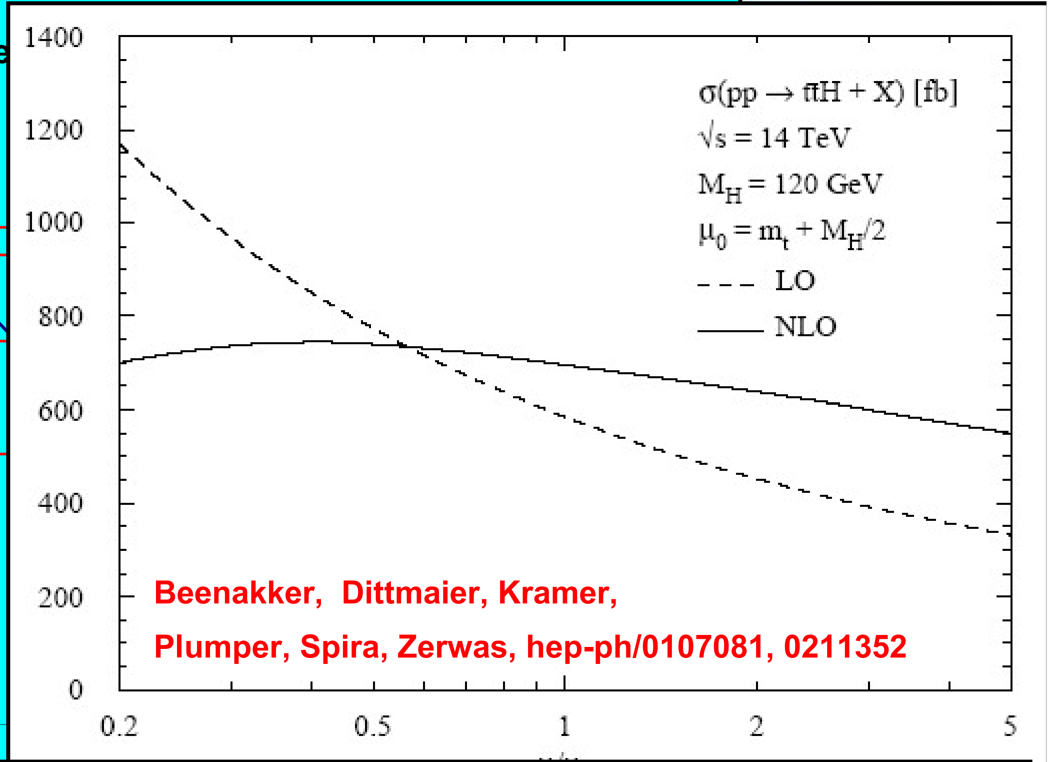
- In ATLAS:Full simulation study in Physics TDR (based on thesis of G. Eymard (LAPP), S/sqrt(B)={4.3-2.8} for mH={100-140} , signal efficiency ~30%. CERN-ATL-COM-PHYS-2004-056 par Beauchemin, P and Azuelos, Georges "Search for the SM Higgs Boson in the gamma gamma + ETmiss channel" For 100fb-1, for ttbarh channel, for mH=120 GeV, S/B of ~2 (10.2 signal events for 5.4 background events).

Signal Cross-sections--SM

Standard Model H

- LO HQQ 1.1 (M. Spira), ALPGEN & MADGRAPH compared
- σ(ttH)x BR (H→γγ) from HDECAY 3.101 (Djouadi, Kalinowski, Spira)
- NLO corrections (Beenakker, Dittmaier, Kramer, Plumper, Spira, Zerwas, hep-ph/0107081, 0211352) stabilize σ against renormalization scale, K-factor~{1.2-1.4}
- Use ALPGEN/MG for event generation since exact ME treatment ,conserves spin correlations in t decays
- Strategy: Low-luminosity:γγl signature to add events to WH/ZH and other channels for discovery . High-luminosity: reconstruct t masses for positive id: measure top Yukawa coupling





Estimated Number of signal events, ttH,H→γγ (HQQ & HDECAY), K-factor~1.4

Higgs Mass (GeV)	After 30 (1/fb)	After 100 (1/fb)
115	41.6	138.6
120	39.3	130.9
130	32.0	106.8
140	22.6	75.2

LO Background Cross-sections:Partial List

Irreducible:

Process	σ x BR (1 W->l ν)	Generator
$tt\gamma\gamma$ (1,2,3)	1.6, 6.1, 4,9 fb	AL,MG(1) (1,2)
$bb\gamma\gamma$	221 fb	MG (1)
$W\gamma\gamma$	23.6 fb	MG (2)
$Z\gamma\gamma$	27.0 fb	MG (2)

CTEQ5L, $m_{\gamma\gamma}$>80 GeV +

(1)➔ $p_{T\gamma}>20$ GeV, $\eta_\gamma<2.5$

(2)➔ $p_{T\gamma}>15$ GeV, $\eta_\gamma<2.7$

(3)➔ $p_{Tj,l,\gamma}>15$ GeV, $\eta_{\gamma,j,l}<2.7$, ΔR(l,j or j,j)>0.3

(4)➔ $p_{Tj,l,b}>$ 15 GeV, $\eta_{,b,l}<2.7$, ΔR(Q,Q or l,j)>0.3

- Strong dependence on renormalization scale
- Very preliminary, do not yet include K-Factors
- As in WH/ZH, may have a need for generator-level preselections for some backgrounds

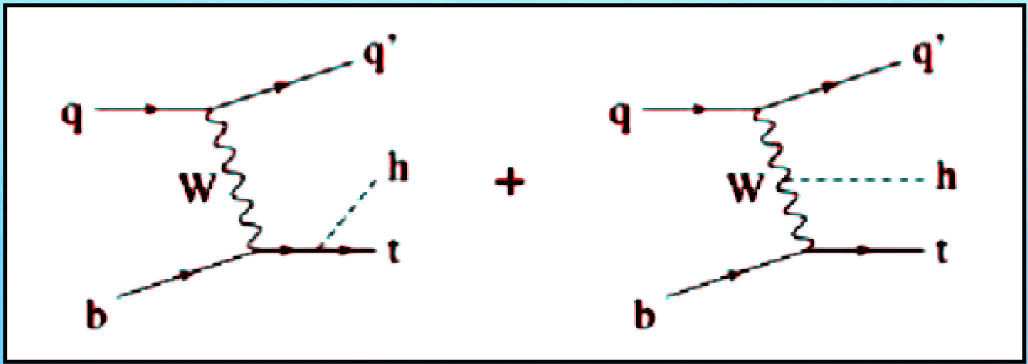
Reducible:

Process	σ	Generator
$\gamma\gamma + 1$jet	70.0 pb	AL(3)
$\gamma\gamma + 2$jets	60.4 pb	AL(3)
$\gamma\gamma + 3$jets	33.1 pb	AL(3)
$\gamma\gamma + 4$jets	15.3 pb	AL(3)
$\gamma + 2$jets	60.3 nb	AL(3)
$\gamma + 3$jets	26.8 nb	AL(3)
$\gamma + 4$jets	9.1 nb	AL(3)
$\gamma + 5$jets	2.5 nb	AL(3)
tttt	2.9 fb	AL (4)
tttt + 1 jet	3.4 fb	AL (4)
ttbb	1.1 pb	AL (4)
ttbb + 1 jet	1.2 pb	AL (4)
bbbb	3.5 nb	AL (4)
bbbb + 1 jet	2.9 nb	AL (4)

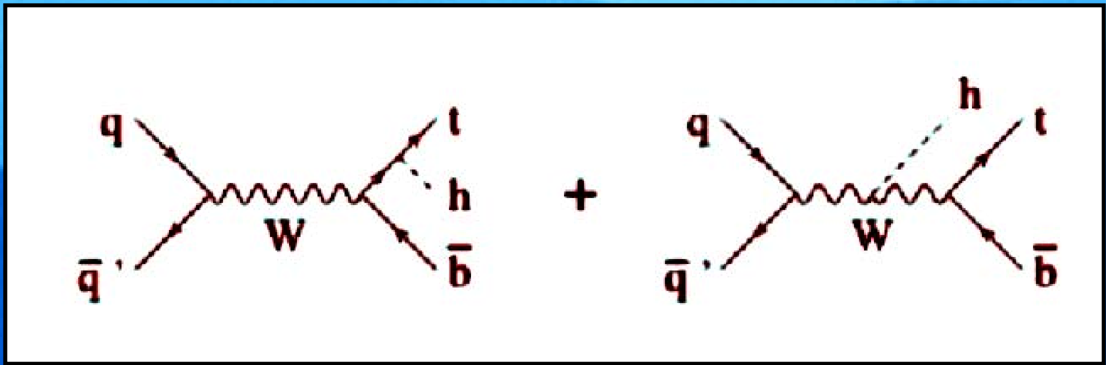
Issues (Th/Exp) + Wish List

- Incorporation of 'delicate' SM background processes in ME generators: $tt\gamma\gamma$ (+ njets), $W\gamma\gamma$ (+ njets) [in test]; $tt\gamma$ (+njets), $bb\gamma\gamma$ + (njets), Wbbar$\gamma\gamma$ (+ njets).. [to come soon]
- NLO cross-sections for myriad SM background processes
- NLO generators for myriad SM background processes (evaluate possible differences in distributions of discriminating variables wrt LO)
- ME/PS/Hadronization issues: (ME/PS matching, correct hard jet rates and effect on signal visibility (PYT 6.2 vs 6.3.., currently 6.2))
- Evaluation of irreducible component of all reducible backgrounds at particle level for
  - First handle on 'dangerosity'
  - Finalize size and strategy (preselection?) for samples for full simulation
- Detector Simulation, Reconstruction, Pileup Issues:
  - Rates of fake photons/leptons from leptons/jets (instrumental /pileup background): what are single and double fake rates in our context? Can we afford to neglect some double-fake reducible background processes (e.g. ljj, llj, γjj) ?
- Detailed simulation study for CMS physics Technical Design Report, complete particle-level study (at least) for proceedings.......

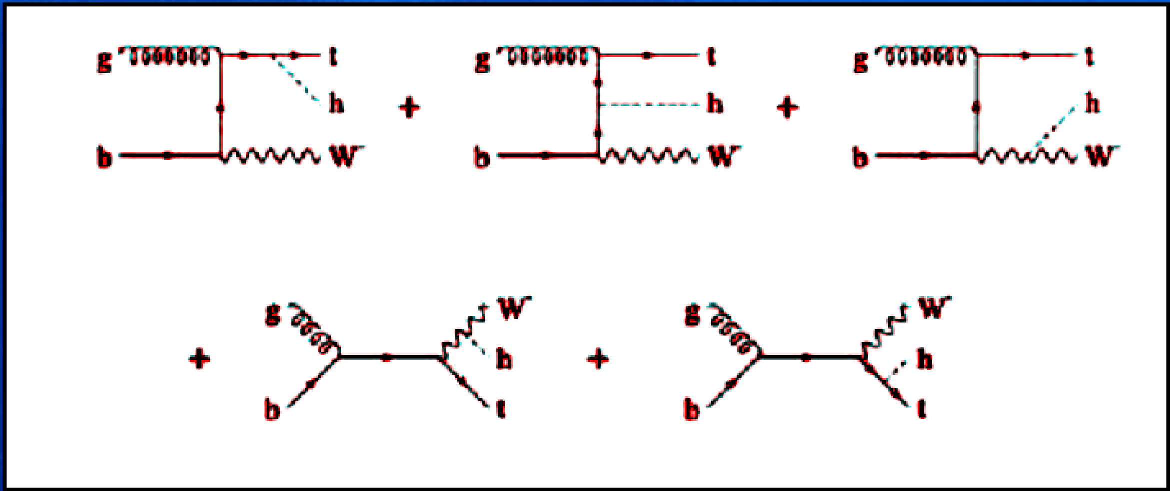
F. Maltoni (w/K.Paul, T.Stelzer, S.Willenbrock): t+H+q at LHC



t-channel (first studied in 90's by Diaz-Cruz & Sampayo, Stirling & Summers, Ballestrero & Maina, Bordes and Van Eijk)



s-channel

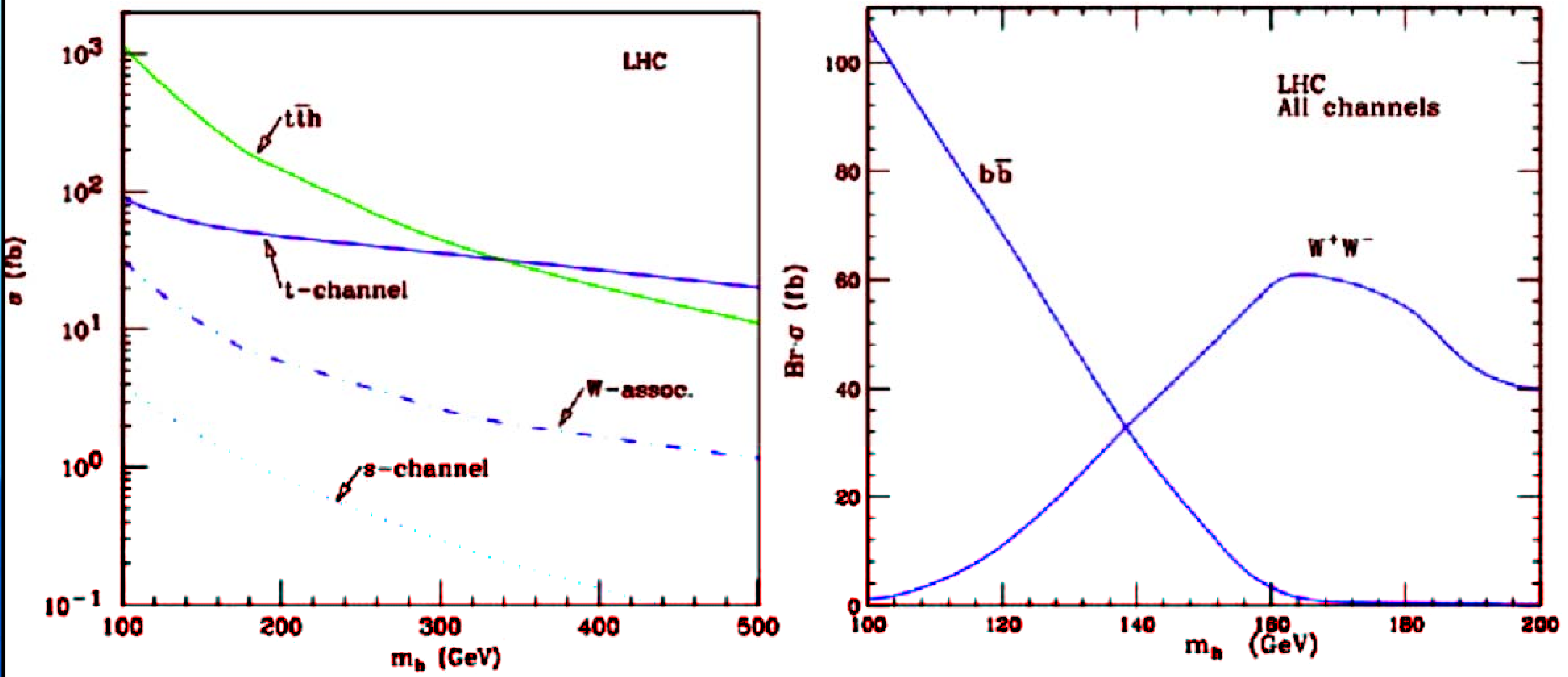


W-associated channel

Signature: 3 b-jets, 1 lepton + 1 forward jet

Single top + Higgs production at the LHC

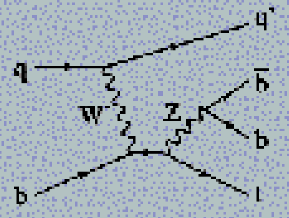
F. Maltoni



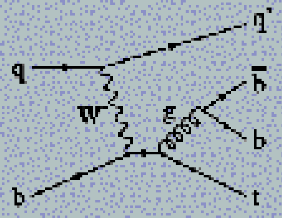
- pp @ $\sqrt{s} = 14$ TeV
- the t-channel gives the largest contribution, about one order of magnitude smaller than $t\bar{t}h$ (note the different fall off, though)
- for $m_h < 120$ GeV we expect a cross section of about 100 femtobarns
  $\Rightarrow$ no hope for $h \to \gamma\gamma$, but what about $h \to b\bar{b}$?

3 b's

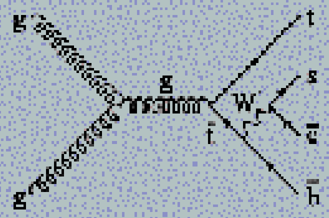
F. Maltoni



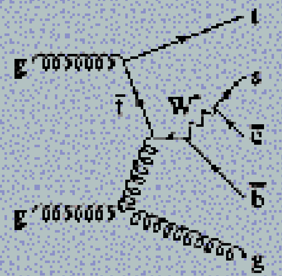
tZ : irreducible bkg



$tb\bar{b}$: irreducible bkg



$t\bar{t}$: reducible bkg



$t\bar{t}j$: reducible bkg

	3b-tag (low luminosity)				
	Signal	tZ	$tb\bar{b}$	$t\bar{t}$	$t\bar{t}j$
Detector cuts	0.80	2.1	4.1	810	100
$\lvert m_{b\bar{b}} - m_h \rvert < 22$ GeV	0.75	0.83	0.54	450	38
$\lvert\eta_j\rvert > 2, p_j^T > 50$ GeV	0.30	0.44	0.26	13	8.0
$m_{b\bar{b}j} > 250$ GeV	0.35	0.35	0.25	-	7.4
Events with 30 fb^{-1}	10	10	7	-	220

Experimental ideas for improvement welcome!

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Higgs with tops working subgroup: Future Plans (Proceedings)

- NLO ttbarh_0, ttbarA cross-section calculations at LHC and ratio of ttbarA/ttbarh_0 NLO cross-sections
- Cross-check on comparison of hard jet rates between ME/new PS algorithm (PYTHIA 6.3) with SHERPA, MC@NLO and MCFM with ttbar + jets benchmark at LHC, extension to other observables
- Evaluation of impact on ttbarH visibility at LHC (CMS case)
- Completion of ttbarH(h_0), H(h)→2γ at particle level with CMS including complete ME treatment of irreducible and most reducible backgrounds
- t+H+q at LHC : Actively searching experimental ideas to improve visibility!

Triggering

- Probably triggering on the ‘OR’ of the following triggers is sufficient:

  – Di-photon trigger: P_t > 40, 25 GeV

  – Inclusive photon: P_t > 80 GeV

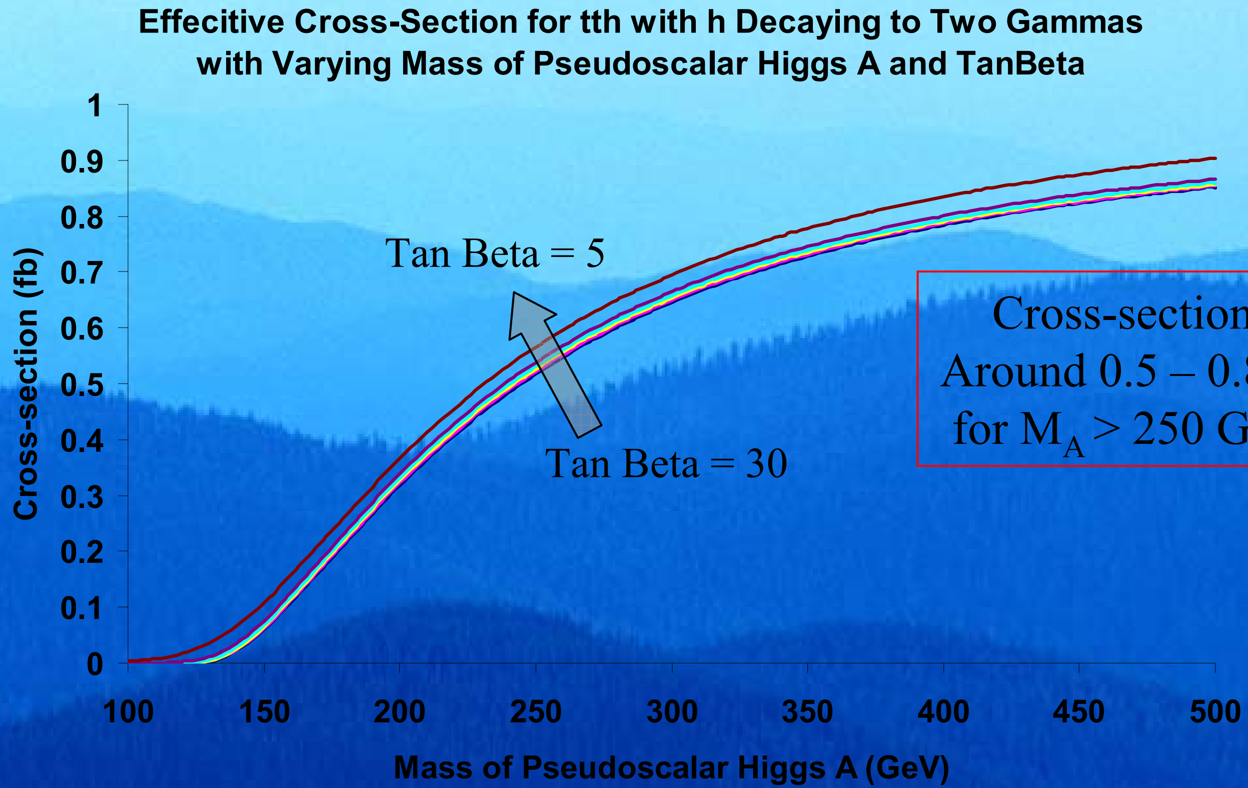
  – Inclusive electron: P_t > 29 GeV

  – Inclusive muon: P_t > 19 GeV

Signal Cross-sections--MSSM

2-doublet h^0 (MSSM)

- HQQ + HDECAY
- Would be wonderful to have NLO cross-sections!
- Possibility to eventually use FAMOS for simulation of intermediate points in MSSM parameter space…



Cross-section:
Around 0.5 – 0.8 fb
for $M_A > 250$ GeV

Parameters used for maximal mixing scenario:

$\mu = -200$, $M2 = 200$, $M_{SUSY} = 1$TeV

$M_{Gluino} = 800$GeV, $A_t = 2450$ GeV

Results to be provided

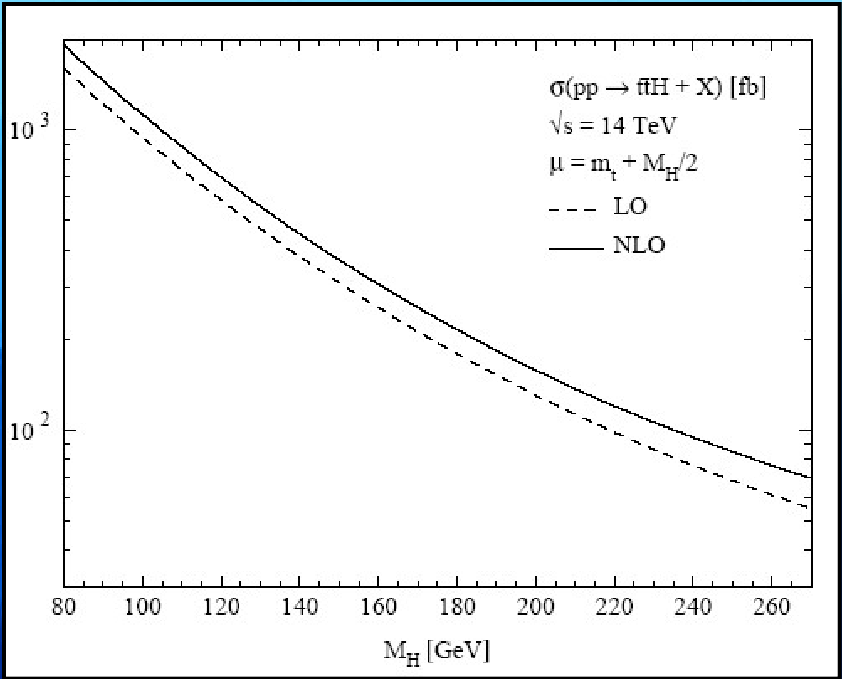
SM Higgs

- Signal efficiencies and significances for a range of interesting masses
- Reconstructed 2-photon mass peak
- Insight into instrumental and misidentification backgrounds (for example electron faking photon) which only can only come from a full simulation study.

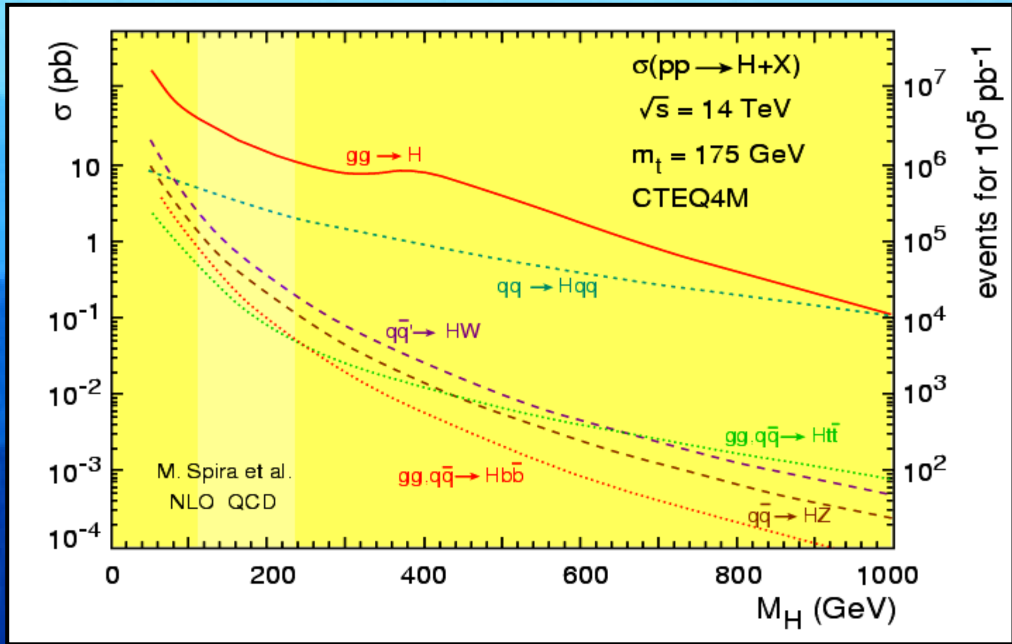
2D/MSSM h^0

- Signal efficiencies and significances for a grid of interesting or benchmark points in parameter space
- Reconstructed 2-photon mass peaks
- Contribution/update to exclusion plot in $\tan\beta$ vs. m_A phase space
- Possible extension to models beyond the MSSM

Backup

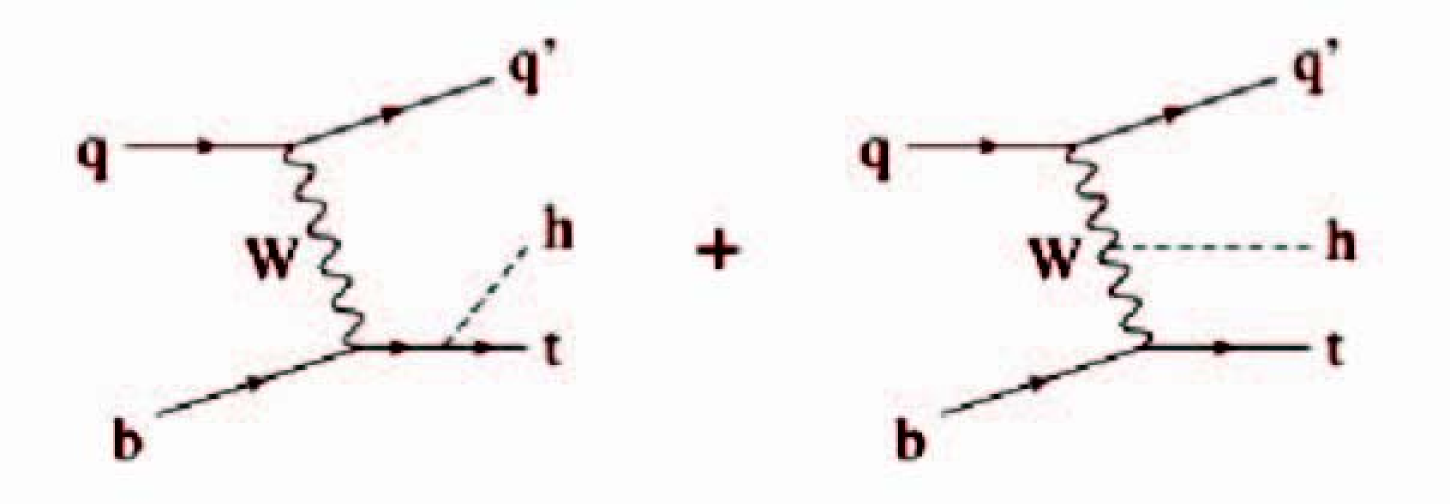


σ(pp → tt̄H + X) [fb]
√s = 14 TeV
μ = m_t + M_H/2
LO
NLO
10^3
10^2
80
100
120
140
160
180
200
220
240
260
M_H [GeV]

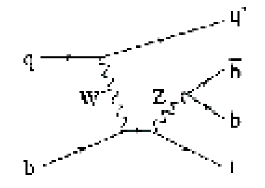


σ(pp → H+X)
√s = 14 TeV
m_t = 175 GeV
CTEQ4M
σ (pb)
events for 10^5 pb-1
gg → H
qq → Hqq
qq̄' → HW
gg,qq̄ → Htt̄
gg,qq̄ → Hbb̄
qq̄ → HZ
M. Spira et al.
NLO QCD
M_H (GeV)

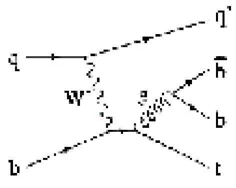
Backup



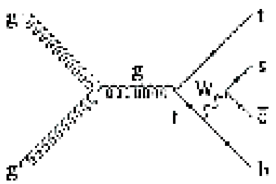
3 b's



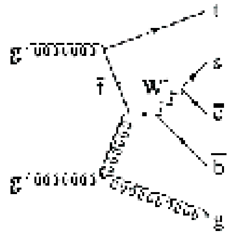
tZ : irreducible bkg



$tb\bar{b}$: irreducible bkg



$t\bar{t}$: reducible bkg



$t\bar{t}j$: reducible bkg

	3b-tag (low luminosity)				
	Signal	tZ	$tb\bar{b}$	$t\bar{t}$	$t\bar{t}j$
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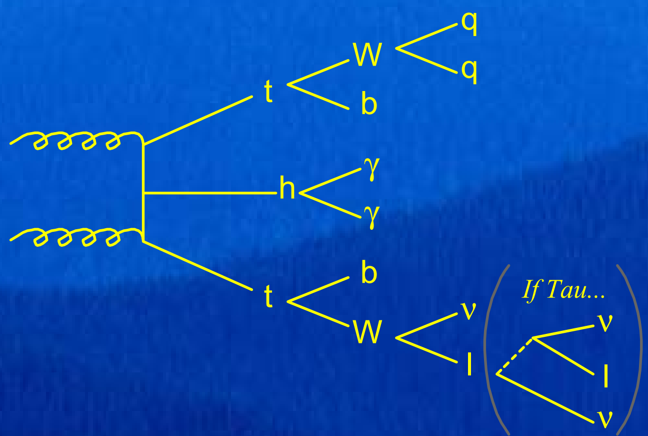
$m_{b\bar{b}j} > 250$ GeV	0.35	0.35	0.25	-	7.4
Events with 30 fb^{-1}	10	10	7	-	220

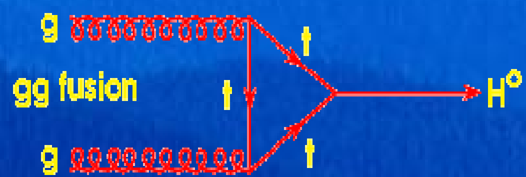
Topology and Motivation-I

- An SM or two-doublet neutral Higgs boson produced in association with a tt pair with $H(h^0) \to \gamma\gamma$ shares the following minimal signature with the WH and ZH channels just discussed (O.Ravat, M. Lethuillier [IPNL]):

  2 isolated high-pt photons with $m_{\gamma\gamma}=m_H$: fully reconstructible mass peak

  1 isolated high-pt tagging lepton from a t decay product (usually a W): Handle to beat down QCD background, and reconstruct primary vertex. Less dependence on photon energy resolution than gluon fustion channel





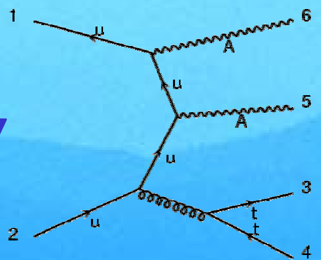
- Particular 2-doublet case of MSSM: gluon fusion production channel subject to suppression given top-stop degeneracy (maximal mixing) , not true for associated production channels.

Backgrounds

Process: | **Generators (All LO):**

- **Irreducible:**

$l\gamma\gamma$

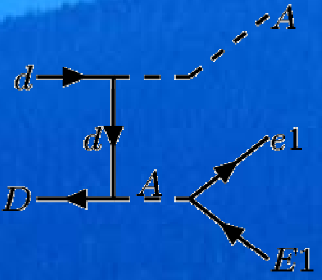


Process	Generators (All LO)
$tt\gamma\gamma$ (+ njets)*,	ALPGEN, MADGRAPH
$bb\gamma\gamma$ + (njets)	MADGRAPH, COMPHEP
$W\gamma\gamma$ (+ njets)**, $Z\gamma\gamma$ (+ njets)**	MADGRAPH, ALPGEN

- **Reducible:**

$ll\gamma$

ljj, llj



Process	Generators (All LO)
$ll\gamma(\gamma)$,	PYTHIA, COMPHEP
W(Z)+tt (+njets), W(Z)+bb (+njets)	ALPGEN
kW+mZ (+njets) ,tbbar (W) + j, t + jets, Wtbbar + jets	ALPGEN

ALPGEN (Mangano,Moretti, Piccinini, Pittau, Polosa) '*'→processes specially added for this analysis '**'→ processes to be added for this analysis

MADGRAPH (Maltoni, Stelzer)

COMPHEP (Boos, Dubinin, Ilyin, Pukhov, Savrin)

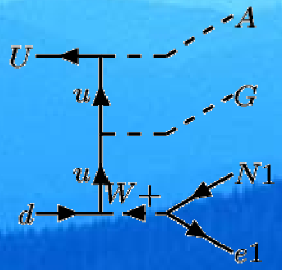
PYTHIA (Lonnblad, Mrenna, Sjostrand, Skands) PHOTOS (Barberio, Was) used to generate radiation photons where not provided

Backgrounds

Process: | **Generators:**

- **Reducible:**

$l\gamma j$



$\gamma\gamma j$, γjj,

jjj

Process	Generators
$W\gamma$ (+ njets)**, $Z\gamma$ (+ njets)**	MADGRAPH, ALPGEN
kW+mZ (+njets)	ALPGEN
W(Z)+tt (+njets), W(Z)+bb (+njets)	ALPGEN
$bb\gamma$ (+njets), $tt\gamma$ (+njets) **	MADGRAPH, ALPGEN
bbtt (+njets), bbbb (+njets), tttt (+njets)	ALPGEN
$m\gamma$ +njets, tbbar (W) + jets, t + jets, Wtbbar + jets	ALPGEN, (PYTHIA)

- Note: Several processes could contribute as both irreducible and reducible background and/or to several reducible 'signals'. Virtually any high-multiplicity process could be a reducible background.
- Must watch out for double-counting of background!