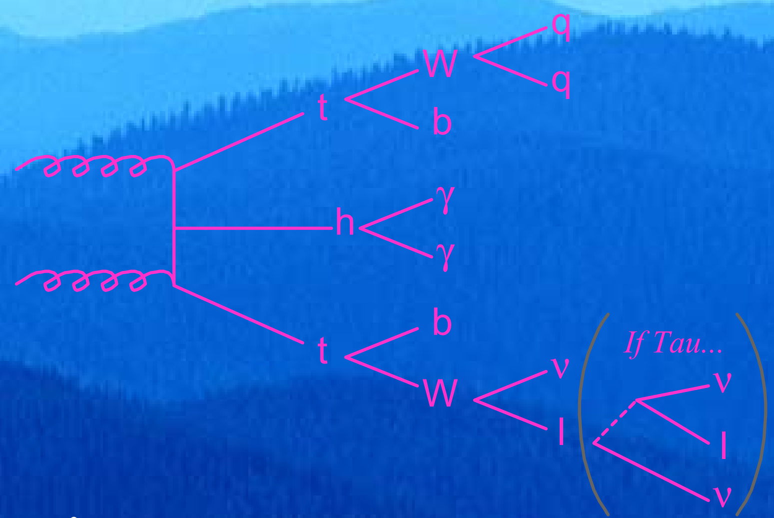
Associated Higgs boson production via $gg/qq \rightarrow ttH(h^0)$, $t \rightarrow l+X$, $H(h^0) \rightarrow \gamma\gamma$



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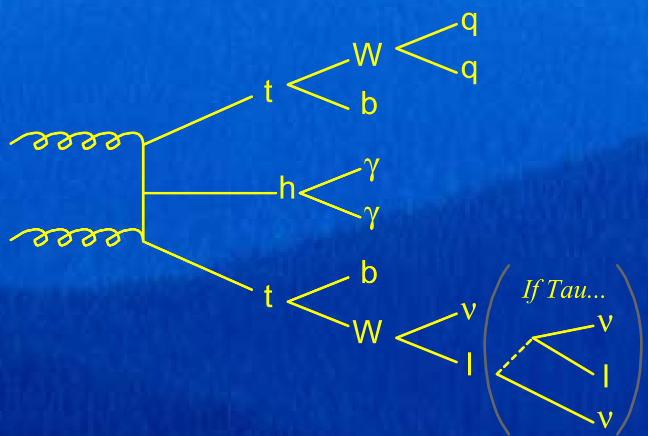
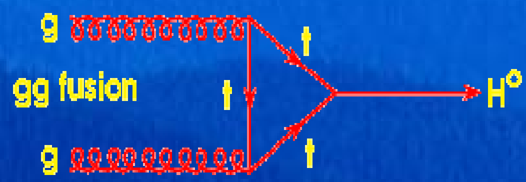
Topology and Motivation-I

- An SM or two-doublet neutral Higgs boson produced in association with a tt pair with $H(h^0) \rightarrow \gamma\gamma$ 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





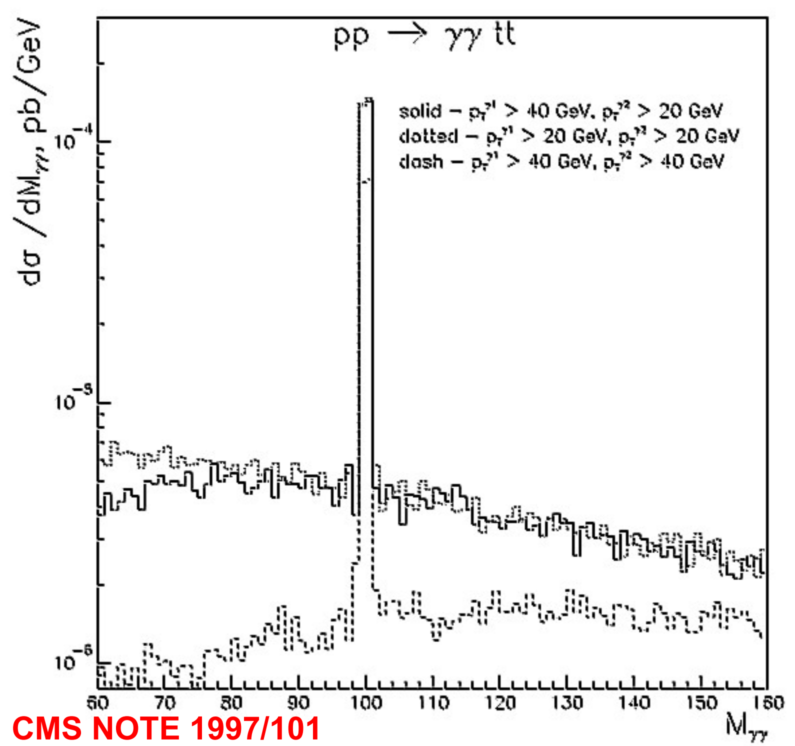
- Particular 2-doublet case of MSSM: gluon fusion production channel subject to suppression given top-stop degeneracy (maximal mixing) , not true for associated production channels.

Topology and Motivation-II

Advantage:

- Presence of tt pair: high-multiplicity events

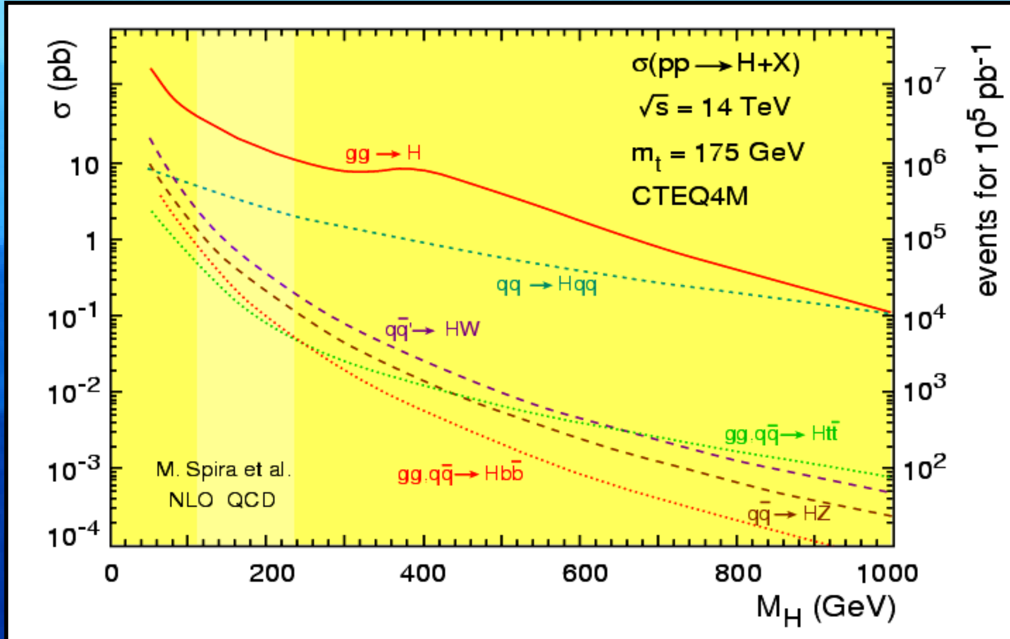
Less vulnerable to QCD background than WH/ZH



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.

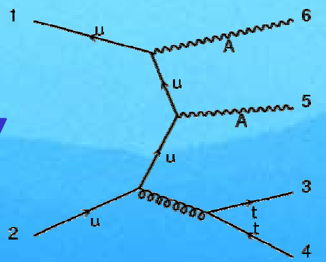
- In ATLAS:Full simulation study in Physics TDR (based on thesis of G. Eymard (LAPP), S/sqrt(B)={4.3-2.8} for mH={100-140} , signal efficiency ~30%. CERN-ATL-COM-PHYS-2004-056 par Beauchemin, P and Azuelos, Georges "Search for the SM Higgs Boson in the gamma gamma + ETmiss channel" For 100fb-1, for ttbarh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

Backgrounds

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

- **Irreducible:**

$l\gamma\gamma$

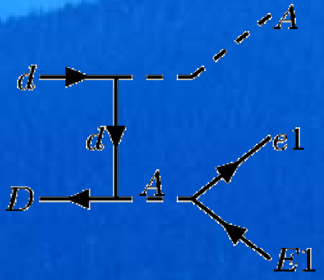


Process	Generators
$tt\gamma\gamma$ (+ njets)*,	ALPGEN, MADGRAPH
$bb\gamma\gamma$ + (njets)	MADGRAPH, COMPHEP
$W\gamma\gamma$ (+ njets)**, $Z\gamma\gamma$ (+ njets)**	MADGRAPH, ALPGEN

- **Reducible:**

$ll\gamma$

ljj, llj



Process	Generators
$ll\gamma(\gamma)$,	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)

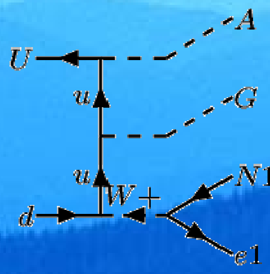
COMPHEP (Boos, Dubinin, Ilyin, Pukhov, Savrin)

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

Backgrounds

- **Reducible:**

lγj



γγj, γjj,

jjj

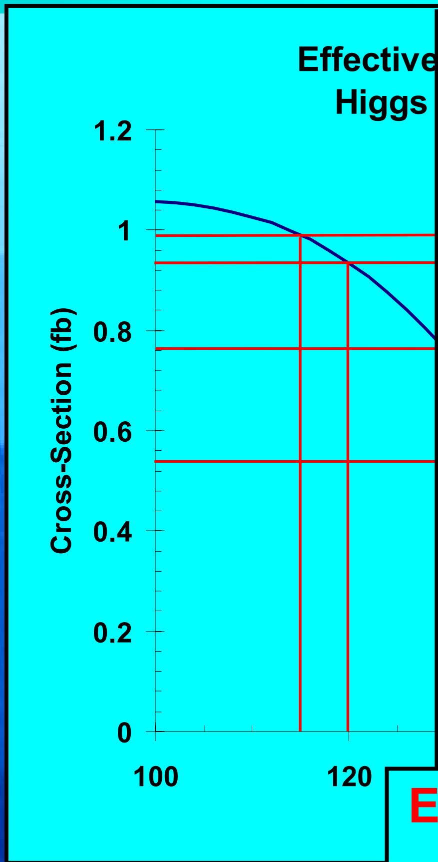
Process:	Generators:
Wγ (+ njets)**, Zγ (+ njets)**	MADGRAPH, ALPGEN
kW+mZ (+njets)	ALPGEN
W(Z)+tt (+njets), W(Z)+bb (+njets)	ALPGEN
bbγ (+njets), ttγ (+njets) **,	MADGRAPH, ALPGEN
bbtt (+njets), bbbb (+njets), tttt (+njets)	ALPGEN
mγ +njets, tbbar (W) + jets, t + jets, Wtbbar + jets	ALPGEN, (PYTHIA)

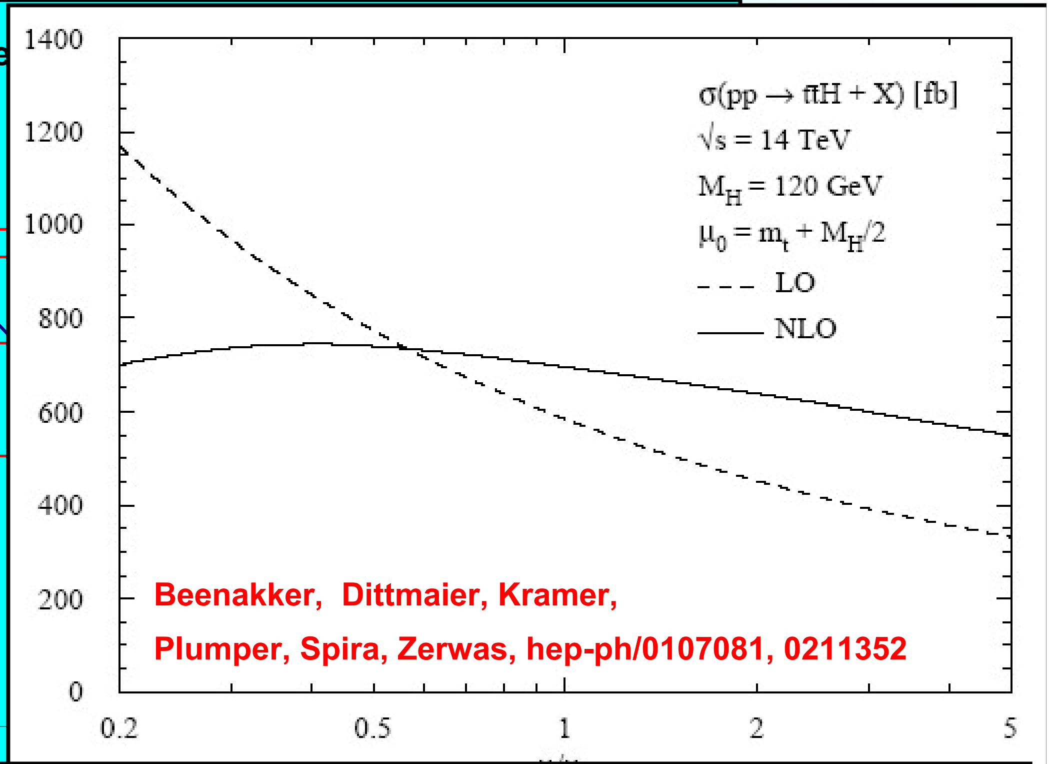
- **Note: Several processes could contribute as both irreducible and reducible background and/or to several reducible ‘signals’. Virtually any high-multiplicity process could be a reducible background.**
- **Must watch out for double-counting of background!**

Signal Cross-sections--SM

Standard Model H

- LO HQQ 1.1 (M. Spira), ALPGEN & MADGRAPH compared
- σ(ttH)x BR ($H \rightarrow \gamma\gamma$) 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





Estimated Number of signal events,

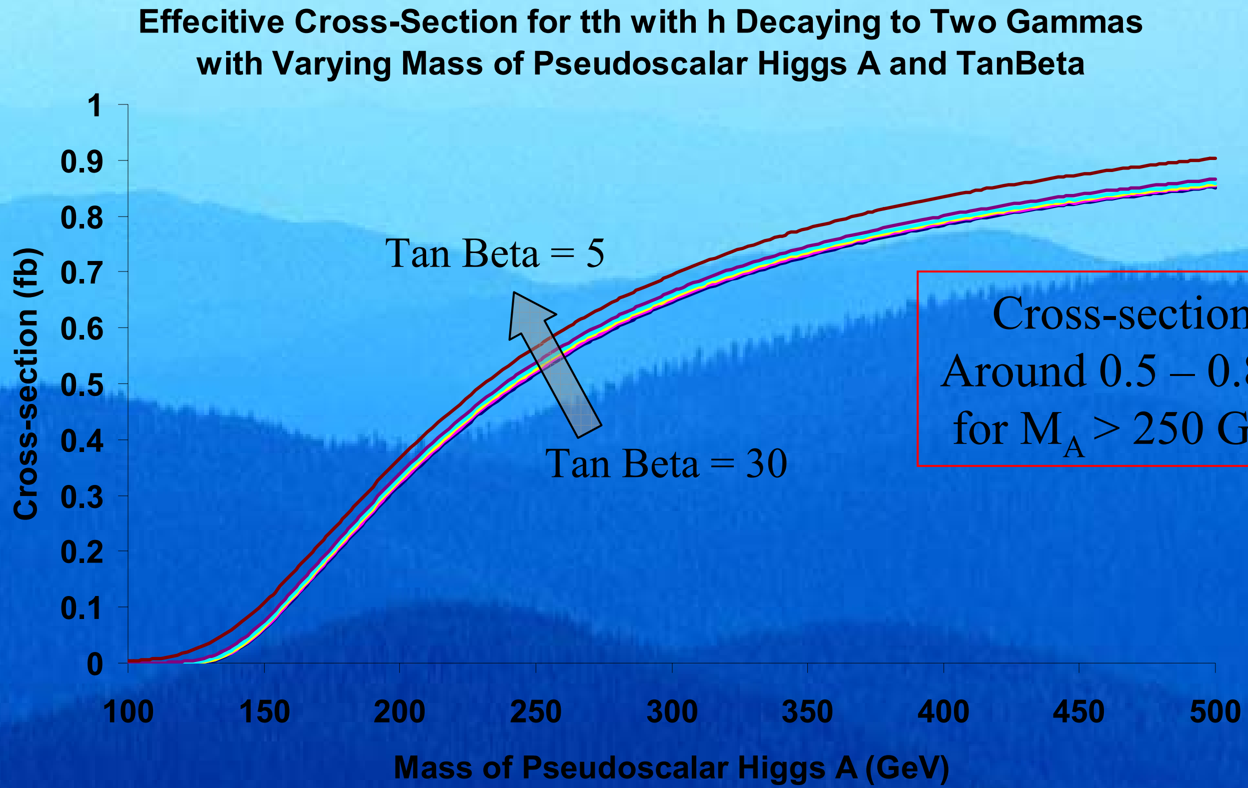
ttH,$H \rightarrow \gamma\gamma$ (HQQ & HDECAY), K-factor~1.4

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

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

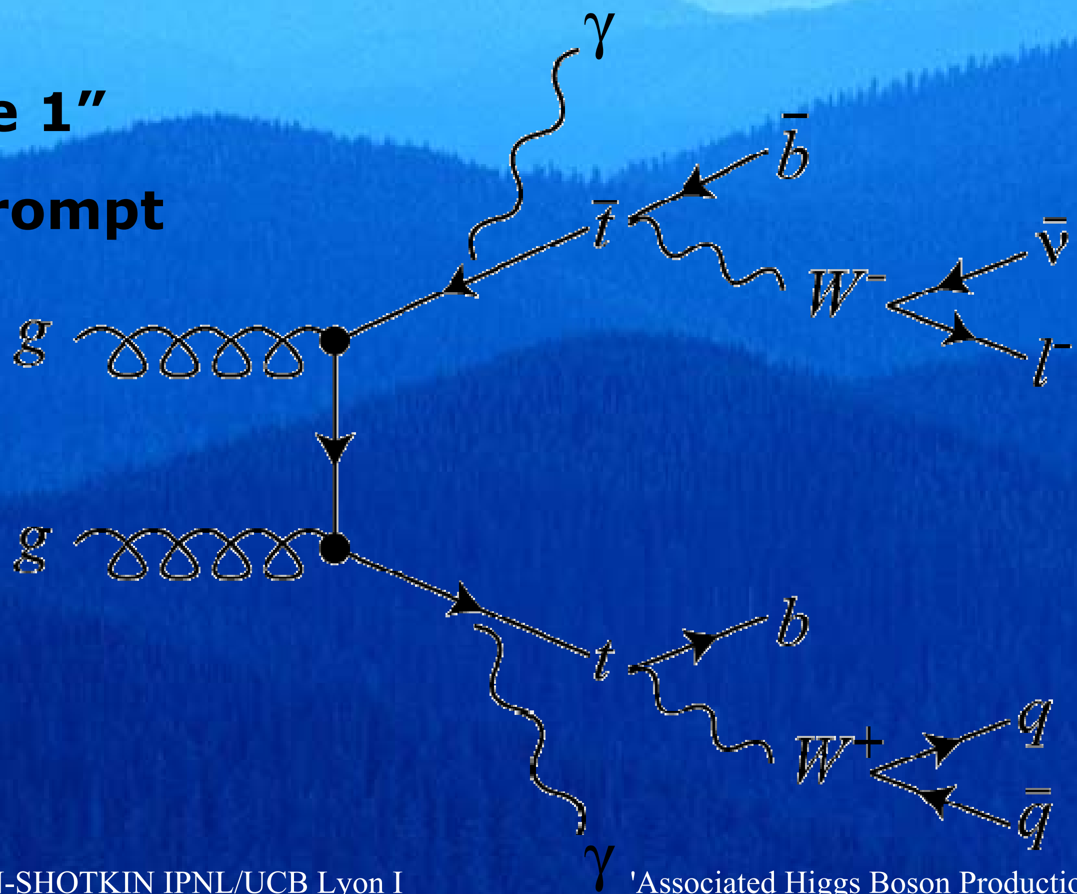
Current Methodology

• **ME generated events (ALPGEN/MG)➔PS & hadronization w/PYTHIA 6.225**

• A priority is proper treatment of ttγγ

"Type 1"

Both Prompt



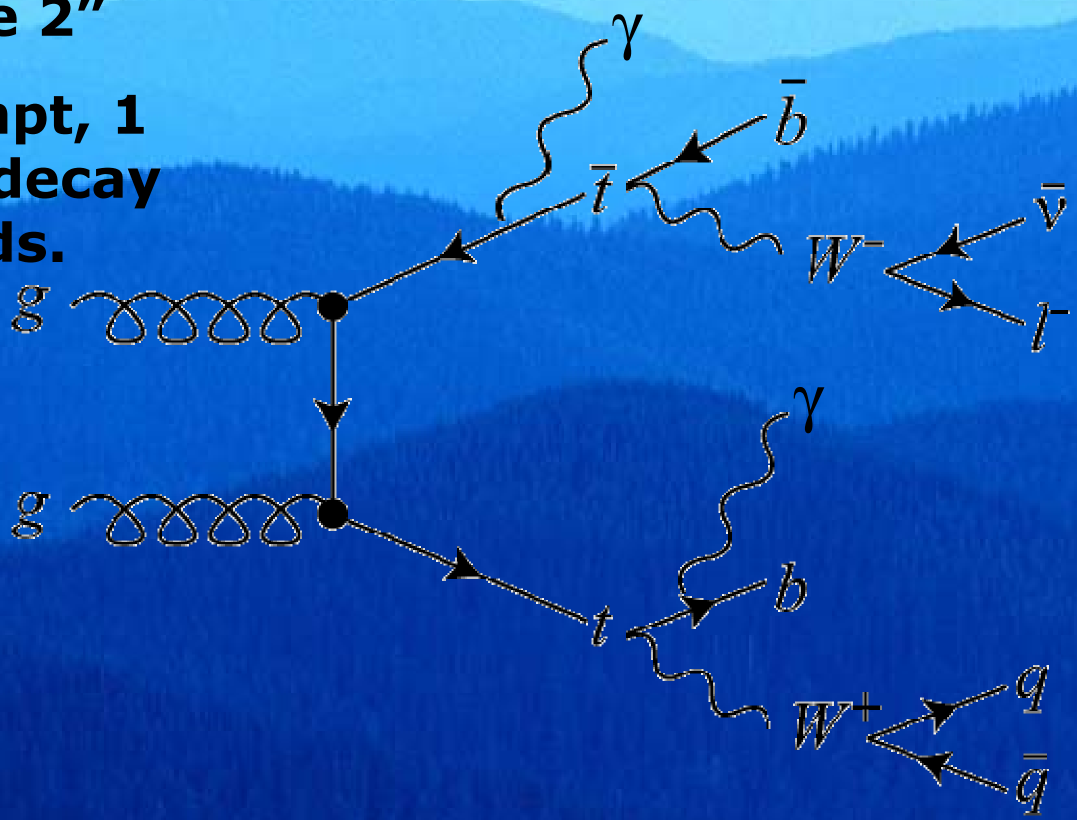
Cross-section
1.6 fb

Current Methodology

- Priority is proper treatment of $t\bar{t}\gamma\gamma$

"Type 2"

1 Prompt, 1 from t decay prods.



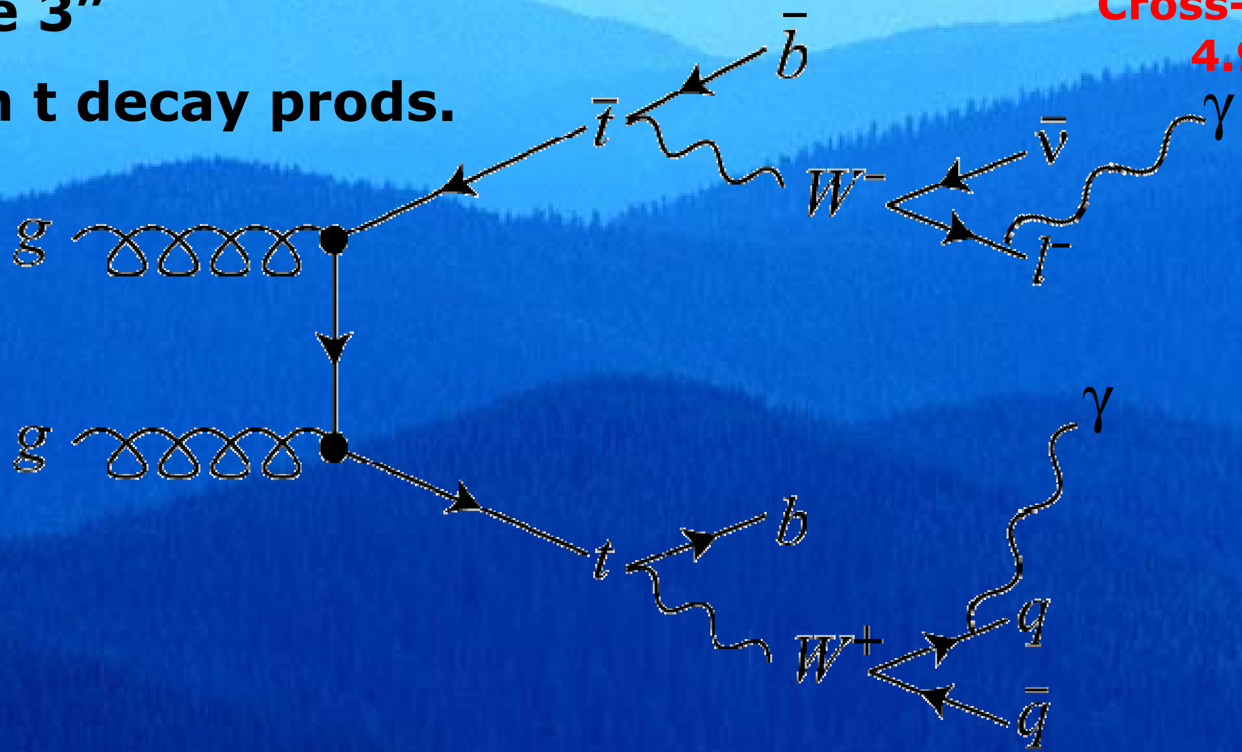
Cross-section 6.1 fb

Current Methodology

- Priority is proper treatment of ttγγ

"Type 3"

Both from t decay prods.

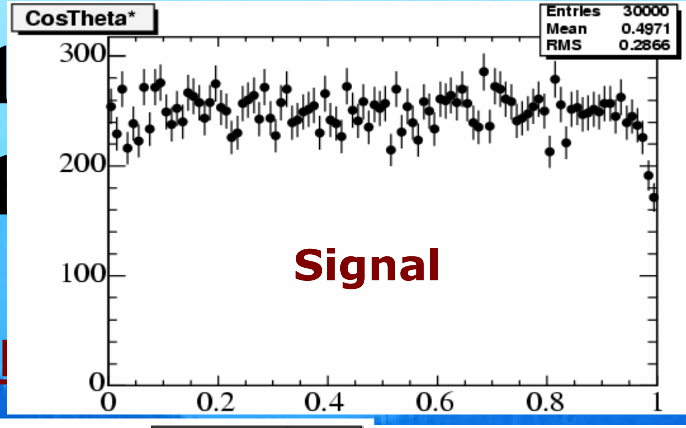


Cross-section 4.9 fb

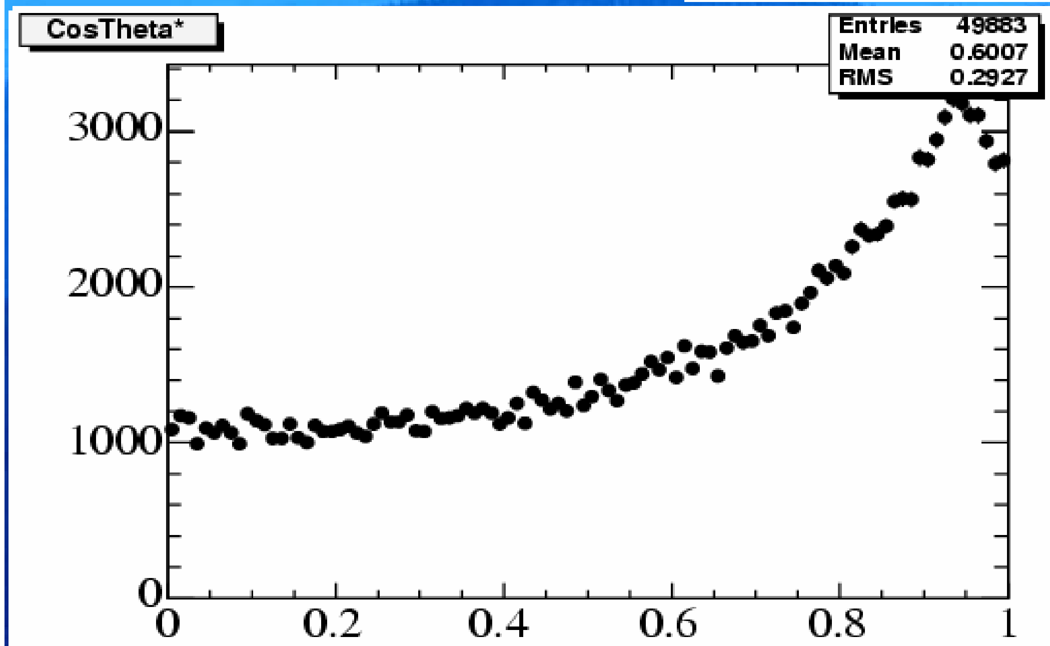
Some particle-level plots...(ttbarH signal and ttγγ backgrounds..

MC Tuning – ttgg Backgrounds

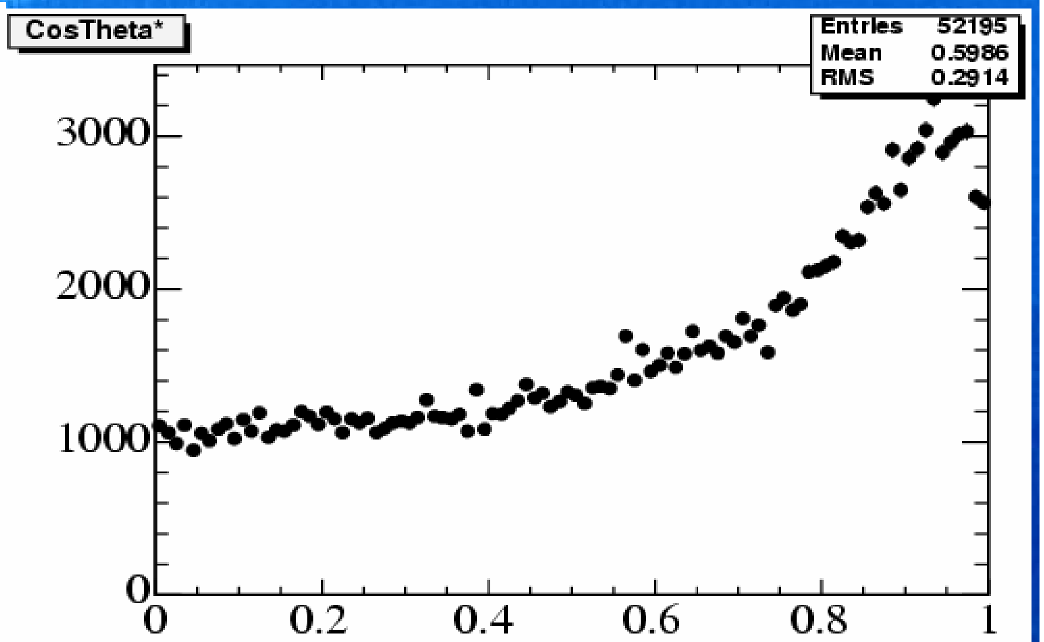
- AlpGen Type 1 … horoughly tested with MadGraph … ement



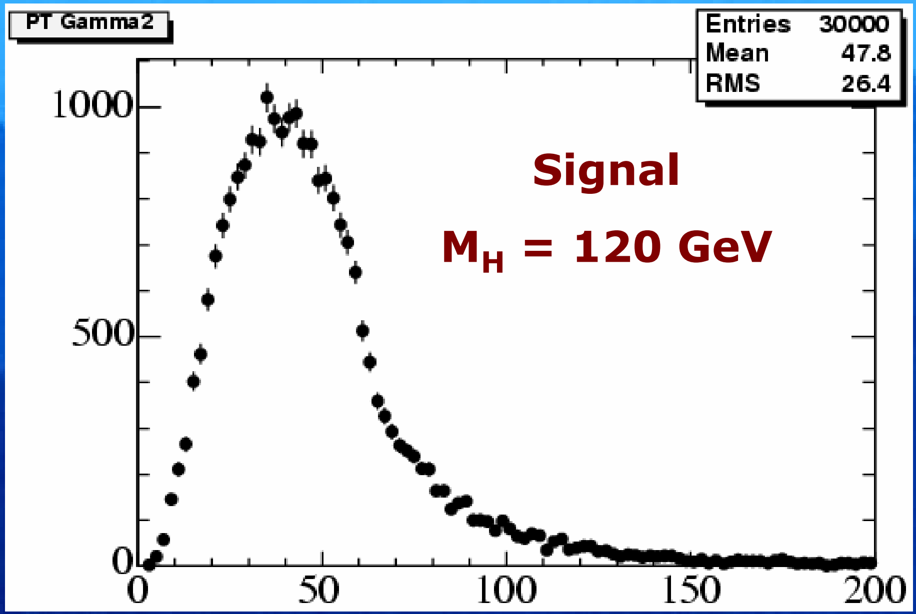
MadGraph

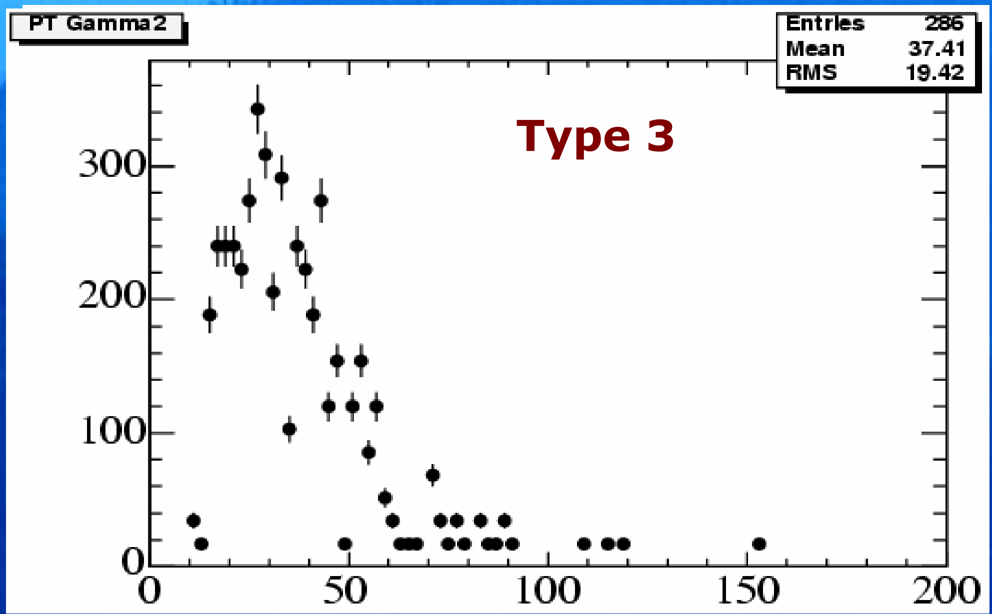


AlpGen



- Plots below generated with AlpGen
- Mean P_t is lower in background by 8-10 GeV





LO Background Cross-sections:Partial List

Irreducible:

Process	σ x BR (1 W->l ν)	Generator
ttγγ (1,2,3)	1.6, 6.1, 4,9 fb	AL,MG(1) (1,2)
bbγγ	221 fb	MG (1)
Wγγ	23.6 fb	MG (2)
Zγγ	27.0 fb	MG (2)

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

(1)➔ $p_{T\gamma}$>20 GeV, η_γ<2.5

(2)➔ $p_{T\gamma}$>15 GeV, η_γ<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
γγ + 1jet	70.0 pb	AL(3)
γγ + 2jets	60.4 pb	AL(3)
γγ + 3jets	33.1 pb	AL(3)
γγ + 4jets	15.3 pb	AL(3)
γ + 2jets	60.3 nb	AL(3)
γ + 3jets	26.8 nb	AL(3)
γ + 4jets	9.1 nb	AL(3)
γ + 5jets	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)

Selection

- Several available variables to cut on
- Typically
  - Higgs mass window (+/- 1.5 GeV, if M_H known)
  - p_t of gammas, p_t of 2-gamma resultant, sum of p_t of gammas
  - Costheta*
  - Lepton p_t
  - Dot product of gamma & lepton 3-momenta
  - Various gamma and lepton isolation cuts
  - Multiplicity cuts on non-tt backgrounds
- Awaiting full sets of irreducible backgrounds before studying cuts in greater detail

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..))
- 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) ? Possible strategy to evaluate possibly very small [order 10**-4] fake rates to avoid prohibitively massive ME generations (suggested by ML Mangano): "recycling" of same smaller ME sample through different PS randomizations
- ....

Institutes and Manpower

- University of Bristol : Robert Frazier, Dave Newbold
- IPN Lyon: Suzanne Gascon-Shotkin, Morgan Lethuillier, Damien Mercier
- Imperial College London: Sasha Nikitenko