

Invisible Higgs decays

- ✿ Theoretical motivation
- ✿ Status in 3 production modes:
 1. vector boson fusion mode
 2. associated vector boson mode: WH and ZH
 3. associated $t\bar{t}H$ production mode
- ✿ Prospects

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Invisible Higgs

Invisible Higgs decays:

decays into any stable, neutral weakly interacting particles

- ☛ neutralinos
- ☛ gravitinos
- ☛ gravitons
- ☛ majorons

Models such as:

☛ **MSSM with R-parity conservation:**

$H^0 \rightarrow \chi^0 \chi^0$ dominate

☛ **with R-parity violation:**

$H^0 \rightarrow$ majorons

☛ **Extra dimensions:**

$H^0 \rightarrow$ invisible

+ generate ν masses

LEP limit: $m_H > 114.4 \text{ GeV}$

Cross-sections and trigger

	Production σ $m_H = 120 \text{ GeV}$	trigger
gluon fusion $gg \rightarrow H$	$\sim 30 \text{ pb}^{-1}$	nothing
VBF $qq \rightarrow qqH$	$\sim 4 \text{ pb}^{-1}$	2 jets + p_T^{miss} (not resolved)
$qq \rightarrow WH$	$\sim 3 \text{ pb}^{-1}$	single lepton
$qq \rightarrow ZH$	$\sim 1 \text{ pb}^{-1}$	1 or 2 leptons
ttH $gg \rightarrow ttH$	$\sim 0.5 \text{ pb}^{-1}$	single lepton

Vector boson fusion

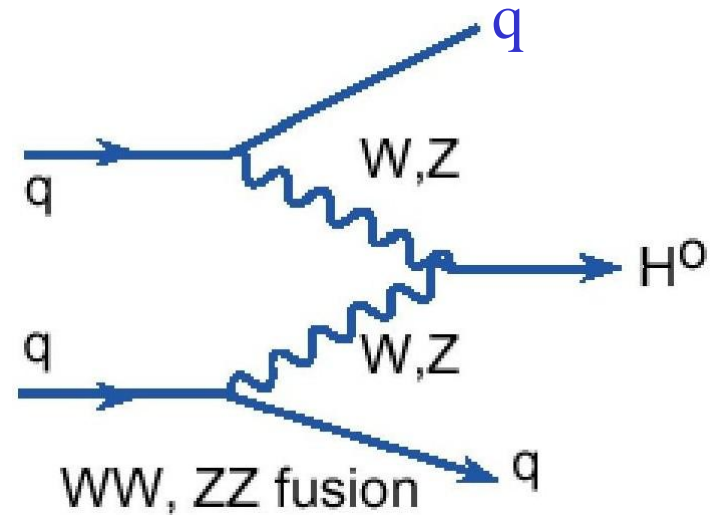
Decay characteristics:

- two forward jets
- no jets in central region
- large p_T^{miss} in central region

Main backgrounds:

- $Z + 2$ jets, $Z \rightarrow \nu\nu$
- $W + 2$ jets, $W \rightarrow l\nu$
- QCD + 2 jets

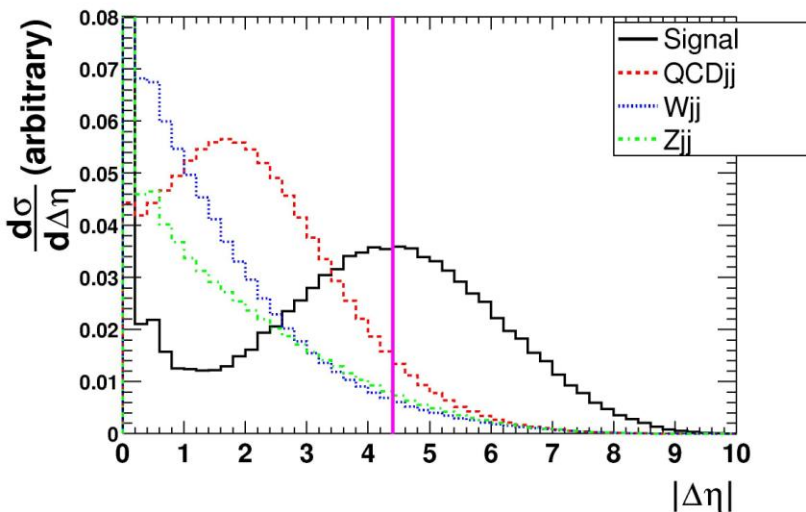
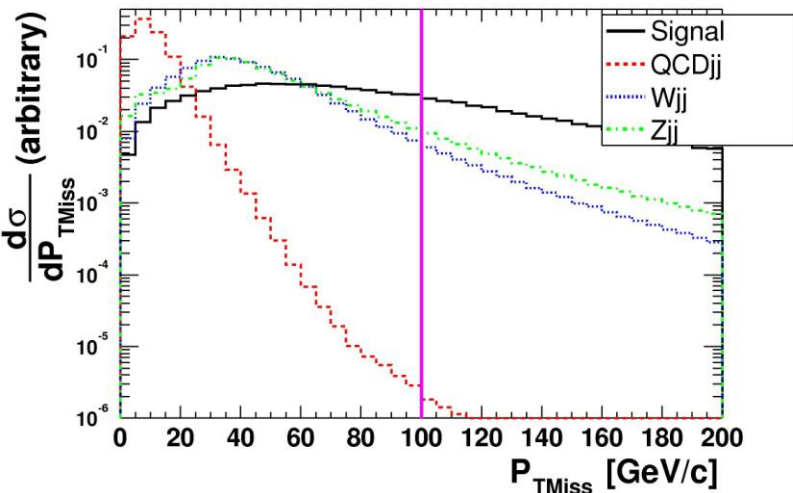
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process	σ (pb ⁻¹)
qqH	~ 4
QCDjj	2×10^7
Zjj	2731
Wjj	6700



Main selection cuts efficiency

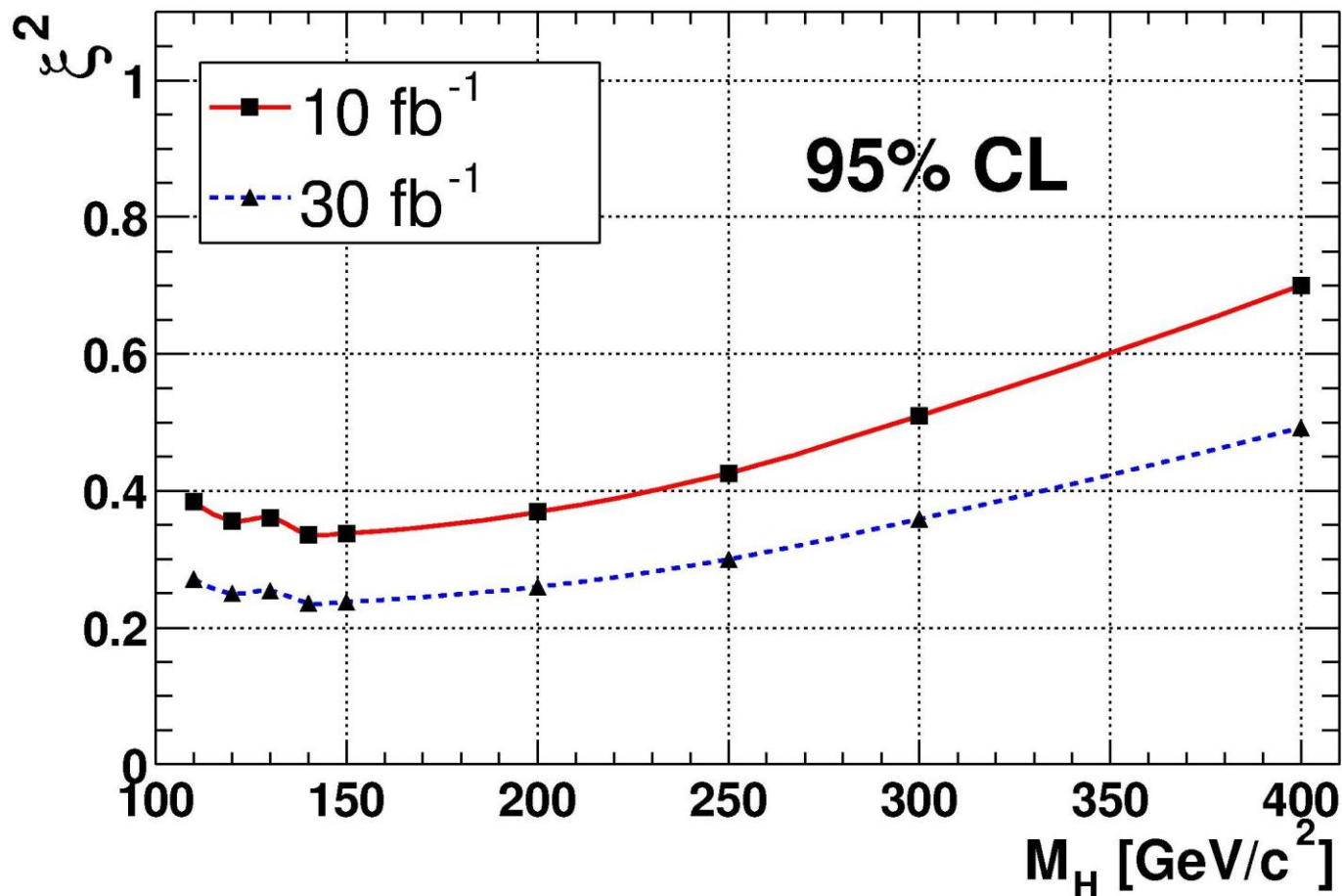


σ in pb^{-1}

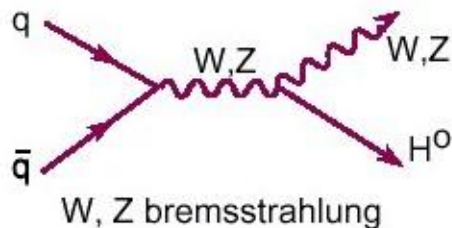
cut	qqH (130 GeV)	Wjj	Zjj
none	3.6	6700	2700
p_T^{miss}	1.8	520	270
jets	0.4	7.6	4.2
M_{jj}	0.2	2.5	1.2

VBF discovery potential

$$\xi^2 = \sigma \times \text{BR}(H \rightarrow \text{inv}) / \sigma_{\text{SM}}$$



Associated vector boson: WH



$$m_T = \sqrt{2p_T^\ell \cancel{p}_T (1 - \cos \phi)}$$

WH selection:

1 lepton + $p_T^{\text{miss}} > 100 \text{ GeV}$
 + large transverse mass m_T

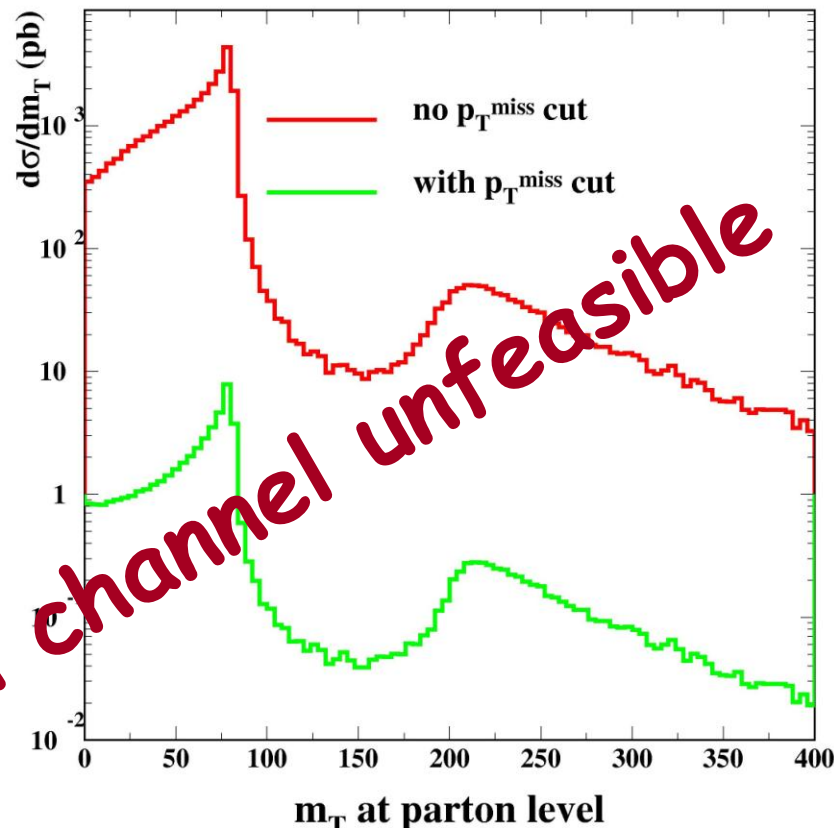
main backgrounds:

WZ: $W \rightarrow lv, Z \rightarrow \nu\nu$

W inclusive

$t\bar{t}, t \rightarrow bl\nu$

WH channel unfeasible



large $p_T^{\text{miss}} \Rightarrow$ off-shell $W_{\text{incl.}}$

Associated production: ZH

ZH selection:

2 leptons + $p_T^{\text{miss}} > 95 \text{ GeV}$
+ likelihood selection

backgrounds:

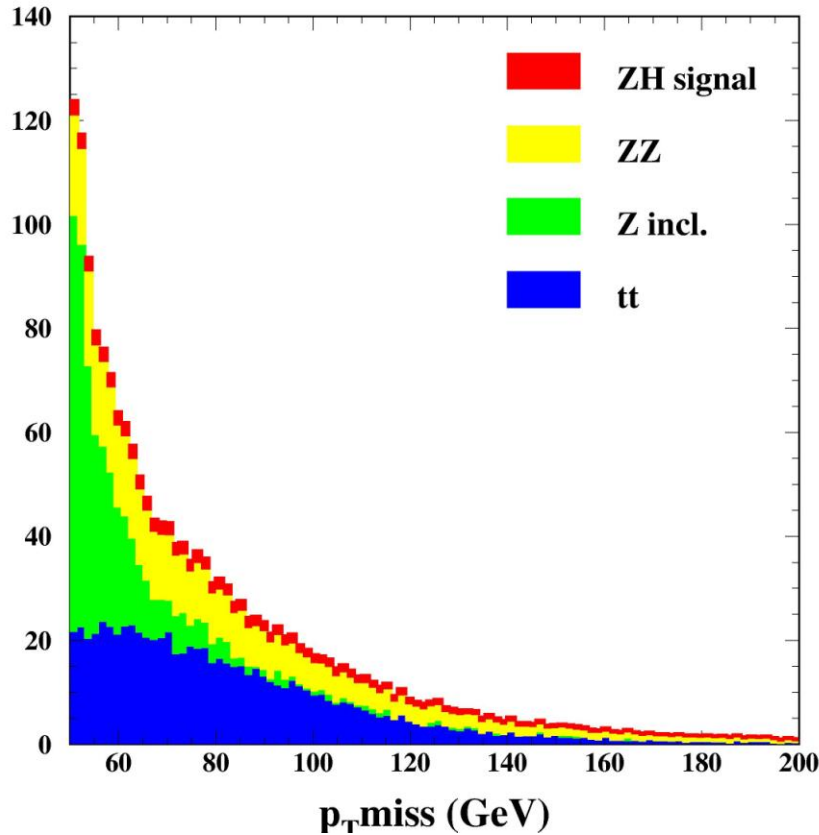
- 🚫 $ZZ \rightarrow \ell\ell \nu\nu$ (irreducible)
- 🚫 $WW \rightarrow \ell\nu \ell\nu$
- 🚫 $ZW \rightarrow \ell\ell \mu\nu$
- 🚫 $t\bar{t}, t \rightarrow b\ell\nu$
- 🚫 Z inclusive
- 🚫 $ZZ \rightarrow \ell\ell \tau\tau$



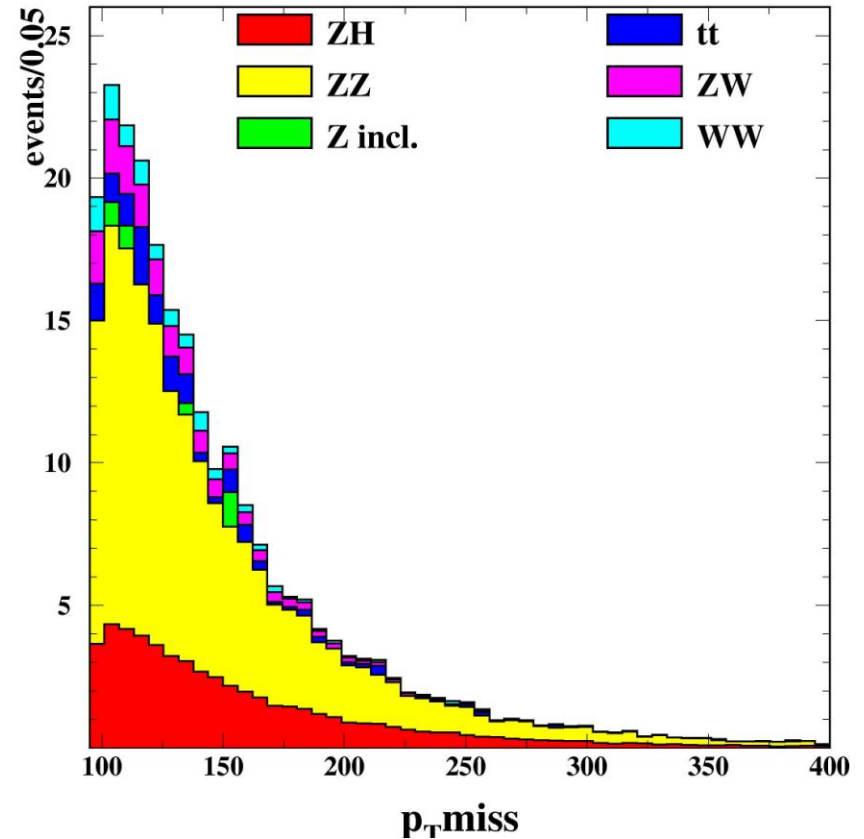
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$p_{T,miss}$ distribution

before likelihood cut

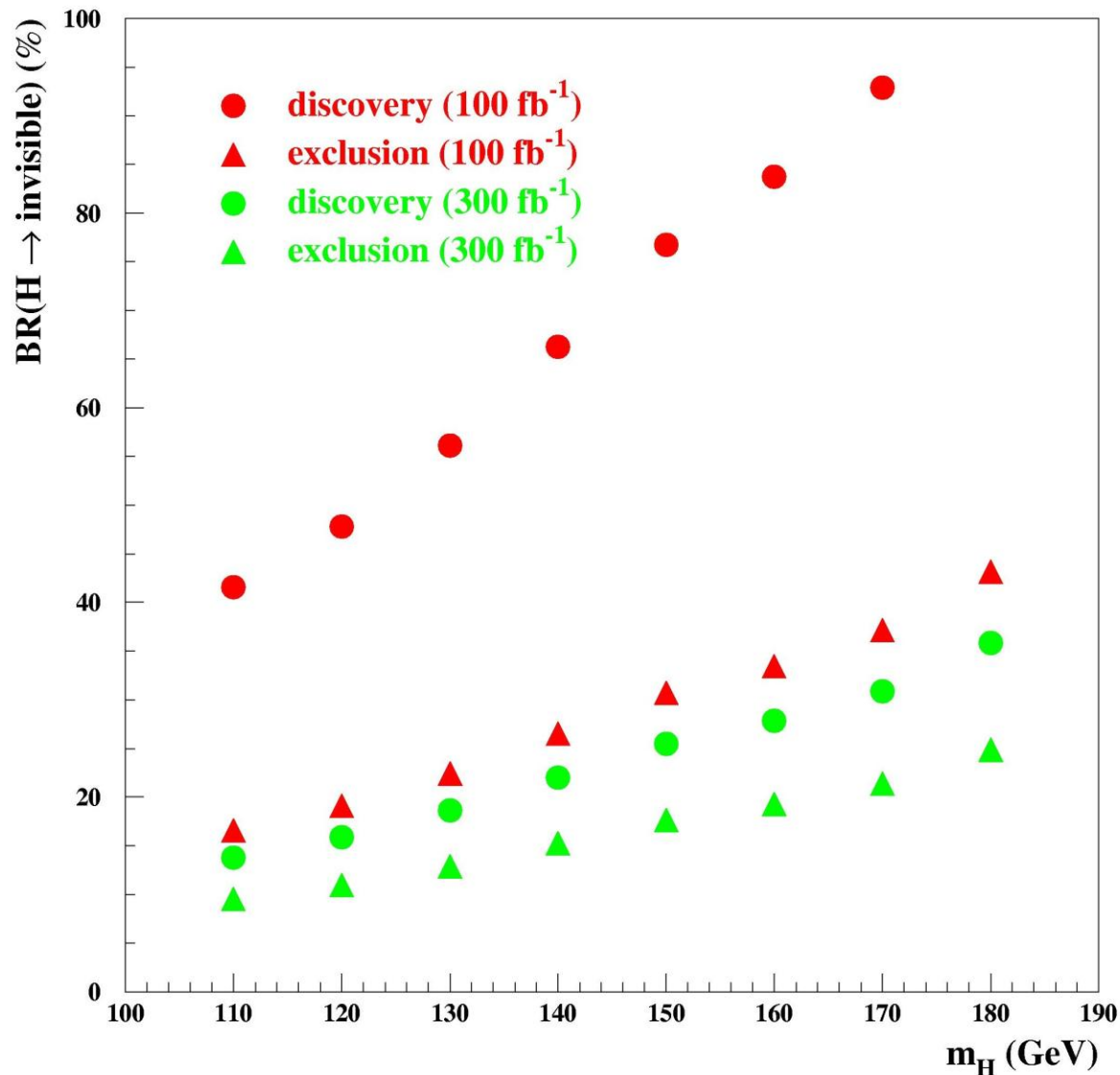


after likelihood cut

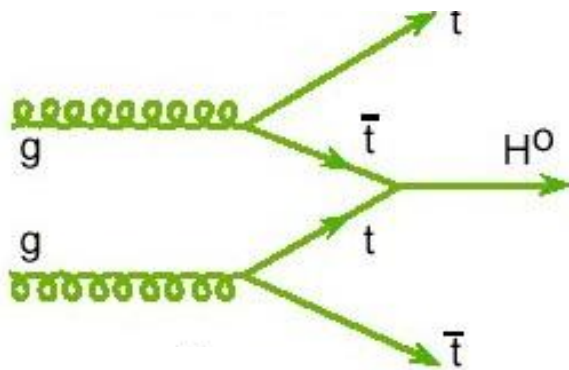


of events expected with 10 fb^{-1}

BR($H \rightarrow \text{inv}$) limits from ZH



ttH channel



selection: (rejection)

- 1 lepton (bb Z/γ^{*})
- 2 b-jets (incl. Z and W)
- t → jjb, $m_{jj} = m_W, m_{jjb} = m_t$
- large m_T and E_T^{miss} (tt)

main backgrounds

gg or qq → tt

gg or qq → ttZ, Z → νν

gg or qq → ttW, W → lv

gg or qq → bb Z/γ^{*}
with Z/γ^{*} → ll

qq → bbW, W → lv

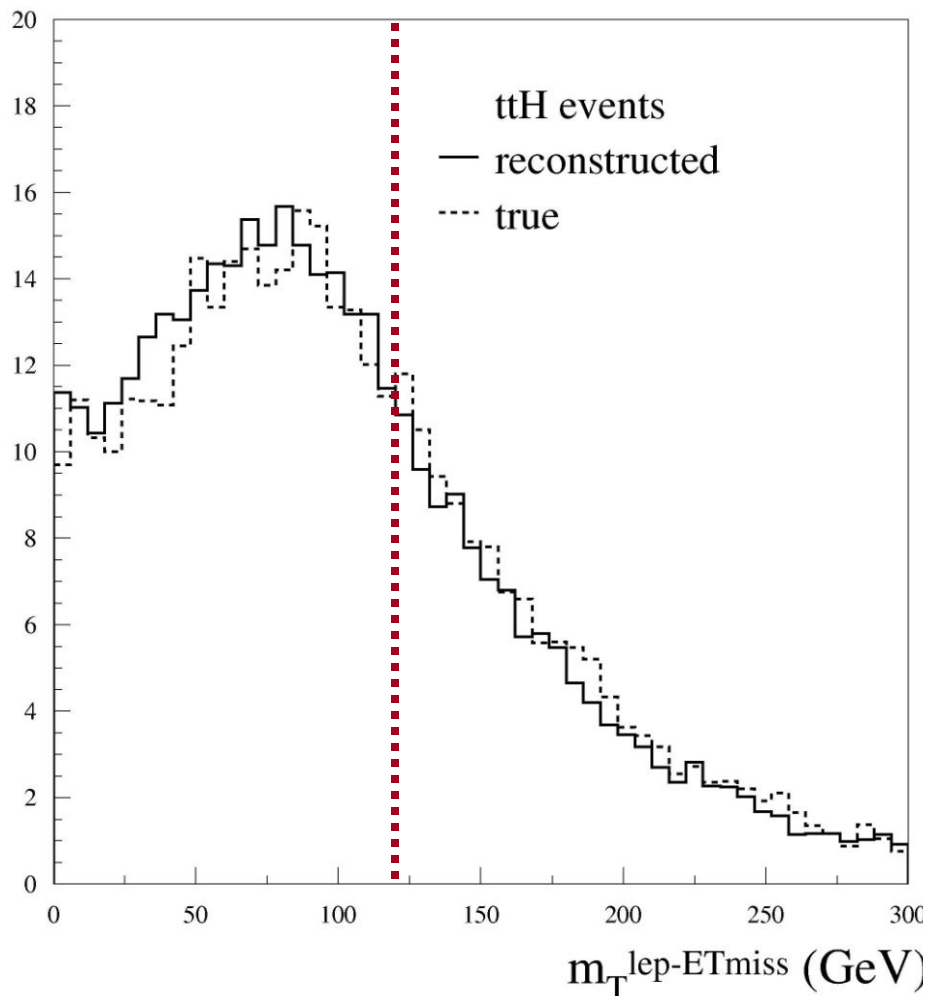
QCD: Z incl., W incl.

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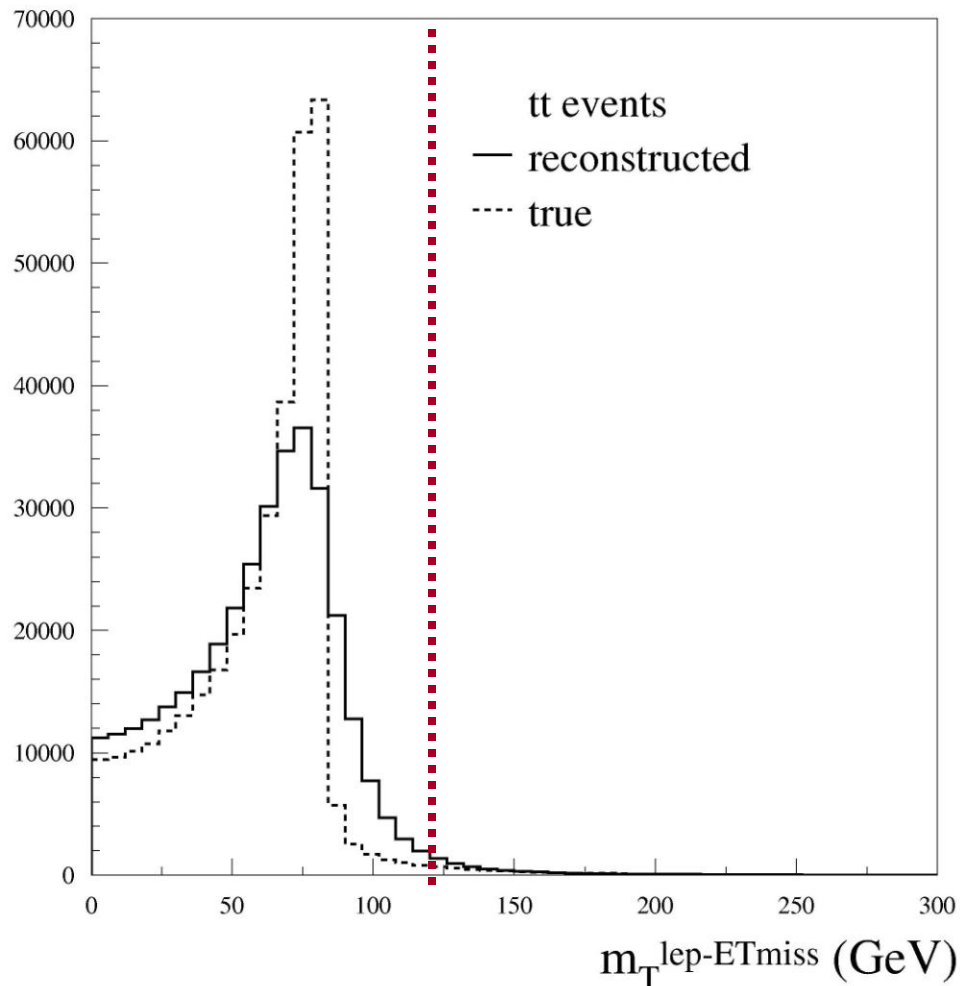


Effect of m_T cut on tt bgnd

ttH signal: $\sigma=0.5 \text{ pb}^{-1}$



tt bgnd: $\sigma=490 \text{ pb}^{-1}$



tt background composition

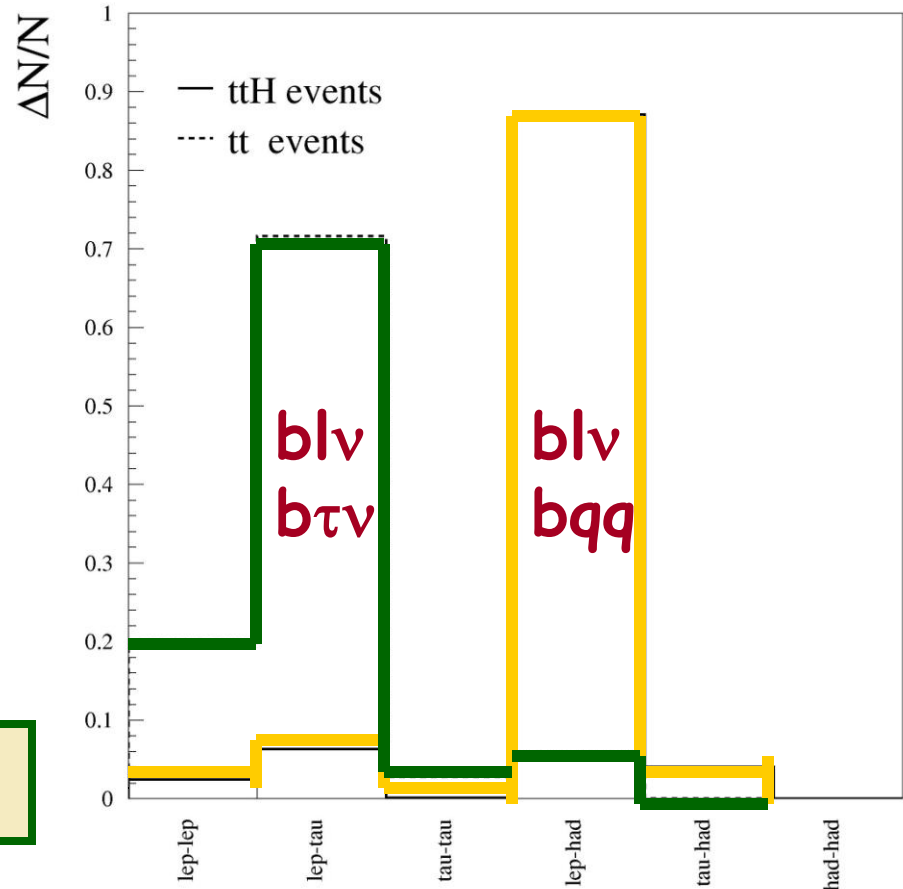
bgnd tt events:

70% $tt \rightarrow b\bar{\nu} b\tau\nu$

signal ttH :

88% $ttH \rightarrow b\bar{\nu} bqq H$

must remove $b\tau\nu$ events



ttH: not proven feasible yet

Process	# events
ttH ($m_H=120$ GeV)	45
tt	115 (Pythia) 190 (Herwig)

1. It is crucial to find an efficient way to reject the tt \rightarrow blv b τ v events
2. One must also understand the differences at generator level

Conclusion

- ✨ **Invisible Higgs decays detectable at ATLAS:**
 - VBF channel most promising: discovery with $\sim 30 \text{ fb}^{-1}$
 - ZH channel: same sensitivity with $\geq 200 \text{ fb}^{-1}$
 - ttH channel requires further studies
- ✨ **An excess of events above SM backgrounds in several channels necessary for a discovery**
- ✨ **All analyses described in ATL-COM or PHYS notes; combined paper planned later this year.**
- ✨ **Full simulation required.**