Search for an invisibly decaying Higgs Boson with ATLAS

- impact on Level 1 trigger -

- **Summary of Higgs searches using the Vector Boson Fusion (VBF) mode**
- **Invisible Higgs in VBF**
- **Tag jets ® Impact on Level 1 trigger**

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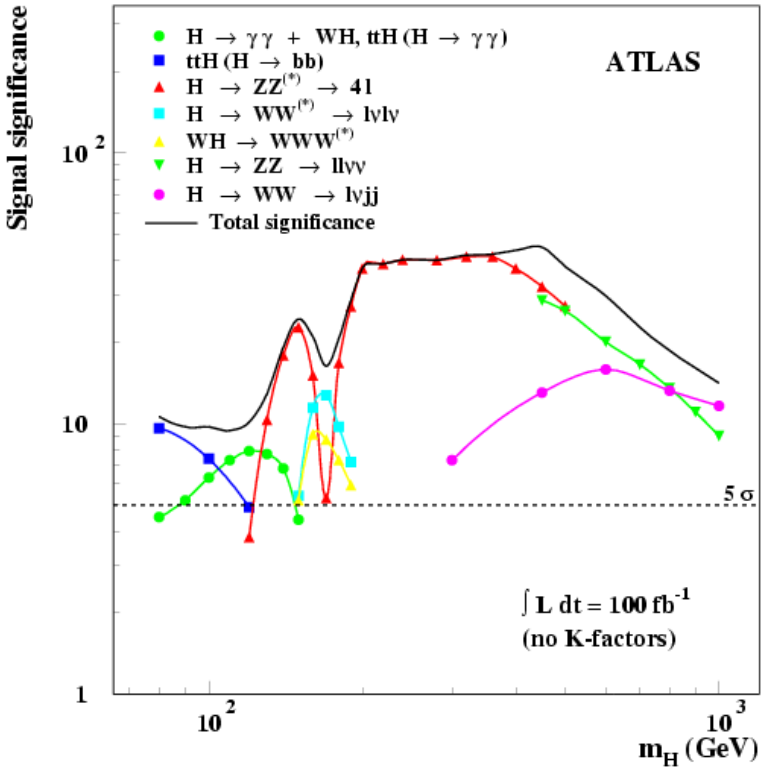
Main search channels at the LHC

$$\frac{S}{\sqrt{B}}$$



$m_H < 2\, m_Z$: $t\bar{t}H \to \ell b\bar{b} + X$, $H \to gg$,

$H \to ZZ^* \to 4\ell$, $H \to WW^{(*)} \to \ell\nu\ell\nu$

$m_H > 2\, m_Z$: $H \to ZZ \to 4\ell$

$qqH \to ZZ \to \ell\ell\,\nu\nu$

$qqH \to ZZ \to \ell\ell\,jj$

$qqH \to WW \to \ell\nu jj$

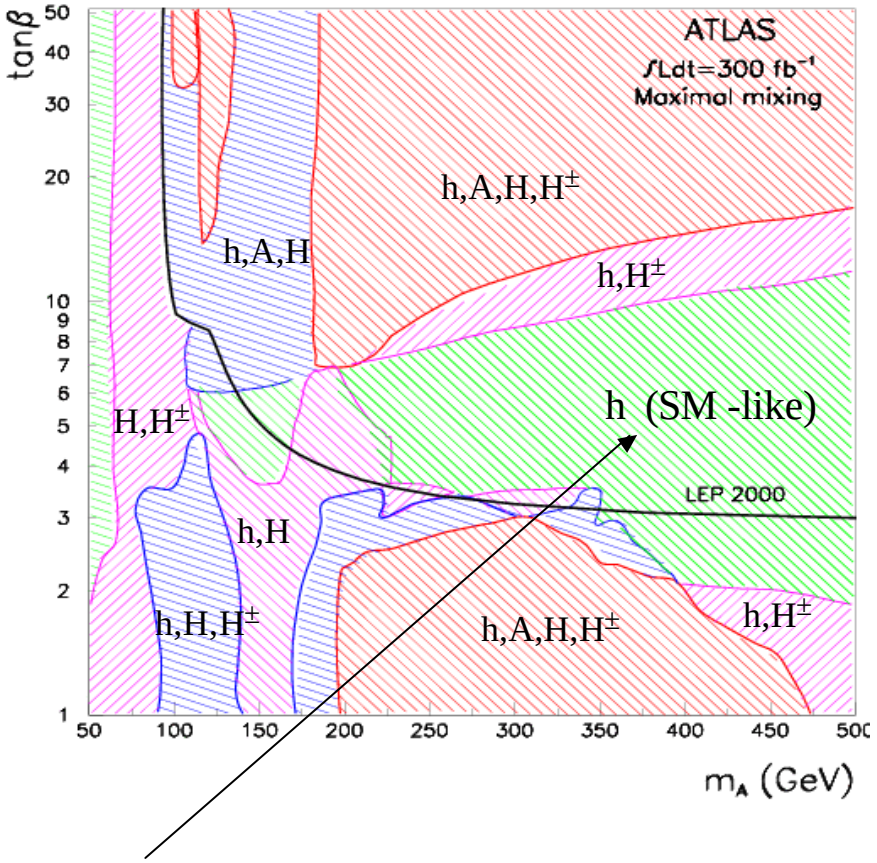
} $m_H > 300$ GeV forward jet tag

10 fb^{-1}: Discovery possible over the full mass range, however, needs combination of ATLAS + CMS

M_H = 115 GeV: **S/ ÖB = 4.7**

- **All standard search channels are triggered by em objects or muons !!**
- **Search relies mainly on the gg-fusion channels !!**

LHC discovery potential for MSSM Higgs bosons



4 Higgs observable
3 Higgs observable
2 Higgs observable
1 Higgs observable

5σ contours

Assuming decays to SM particles only

Here only SM-like h observable if SUSY particles neglected.

- Plane fully covered (no holes) at low L (30 fb^{-1})
- Main channels : $h \to gg$, $b\bar{b}$, A/H $\to \mu\mu$, tt , $H^{\pm} \to t\nu$

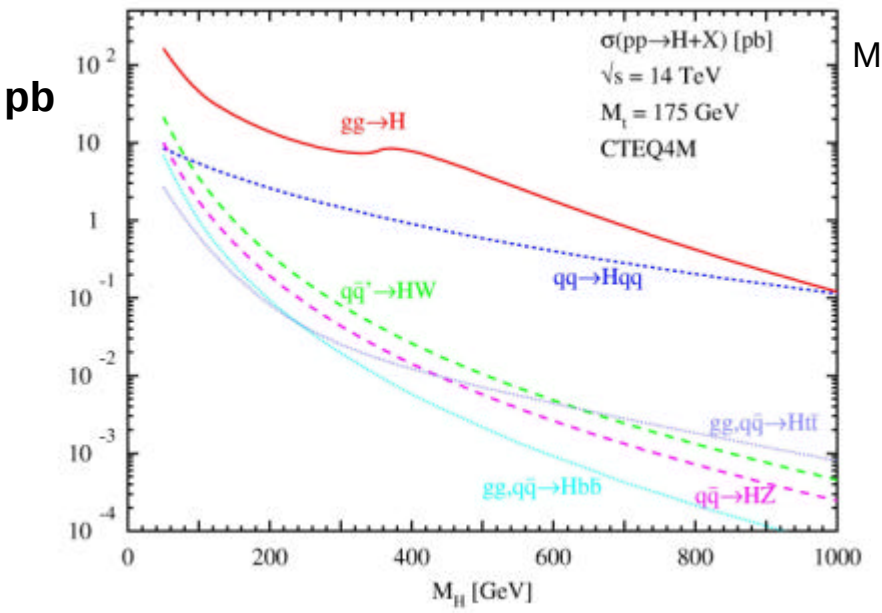
The same in the MSSM plane:
- additional important channel A/H ® t t

default channel: t t ® ℓ n n **had** n
add. channel: t t ® **had** n **had** n (t + P_T^{miss})

(Jürgen Thomas)

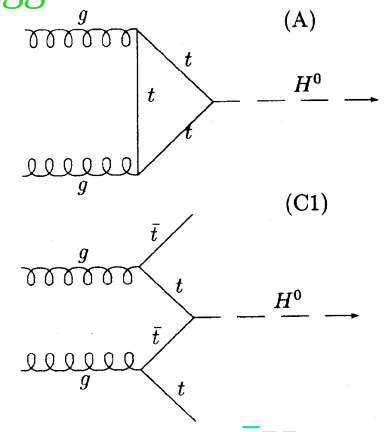
Leading order production cross sections

LHC



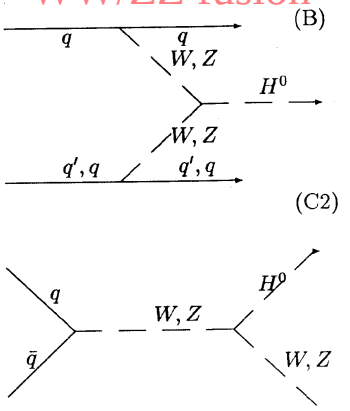
M.Spira et al.

gg fusion



associated $t\bar{t}H$

WW/ZZ fusion



associated WH, ZH

Higgs production via Vector Boson Fusion

Motivation:

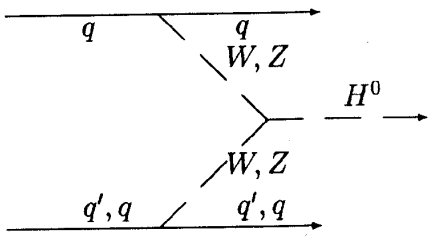
- Increase discovery potential at low mass

- Improve measurement of Higgs boson parameters (couplings to bosons, fermions (taus))

proposed by D.Rainwater and D.Zeppenfeld et al.:
(hep-ph/9712271, hep-ph/9808468 and hep-ph/9906218)

Destinctive Signature of:

- **two high P_T forward jets**
- **little jet activity in the central region**
  - Þ **Jet Veto**



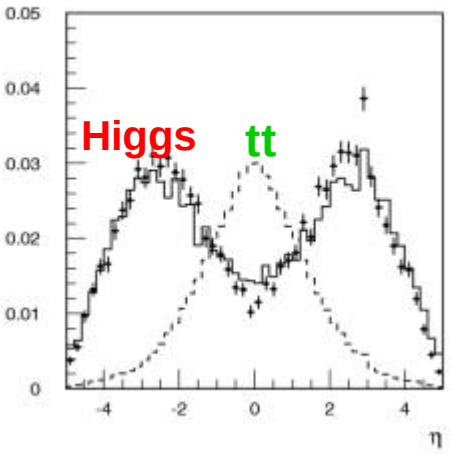
Þ **Experimental Issues:**

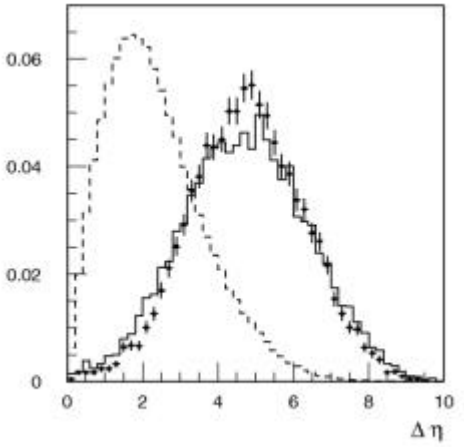
- **Forward jet reconstruction**
- **Jets from pile-up in the central/forward region**

Channels studied: **qqH ® qqWW* ® qq** ℓ n ℓ n
qqH ® qq t t **® qq** ℓ n n ℓ n n
® qq ℓ n n **had** n

Forward tag Jets

Rapidity distribution of tag jets Rapidity separation
VBF Higgs events vs. tt-background

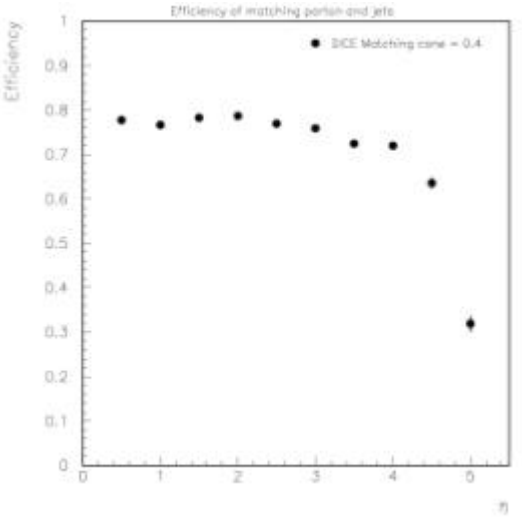




Forward tag jet reconstruction has been studied in full simulation in ATLAS

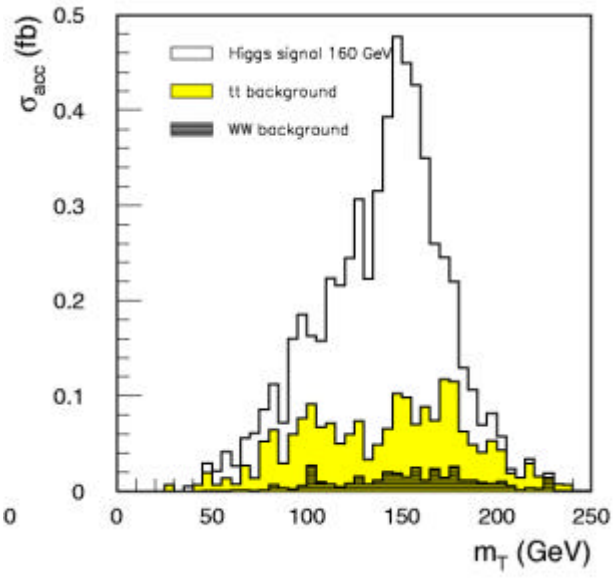
kin. eff. for tag jets = 51.9%
(P_T > 40/20 GeV, , Δ η > 3.6)

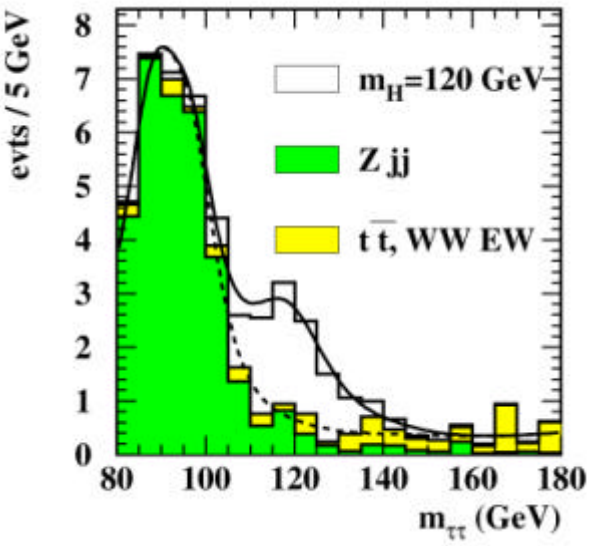
tag eff. per jet: around 75%



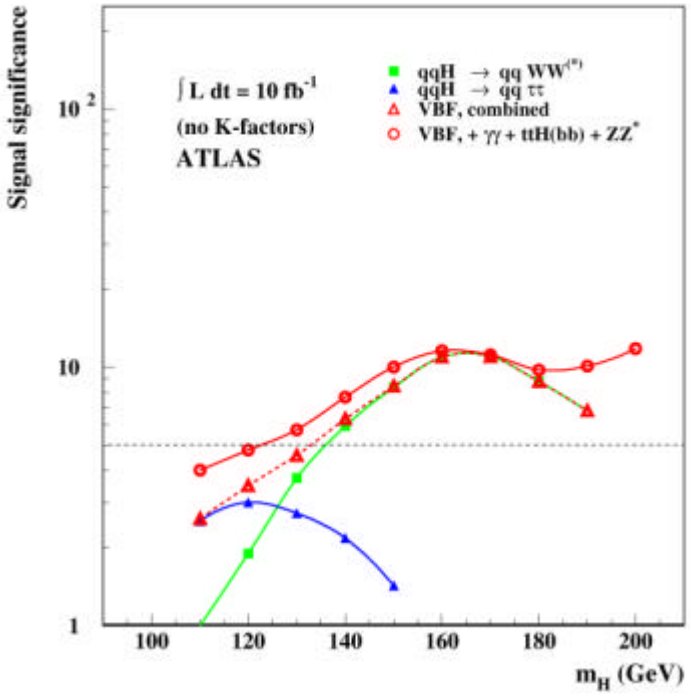
qq H ® qq WW*
® qq l n l n

qq H ® qq t t
® qq l n n l n n
® qq l n n h n





Combined significance of VBF channels for 10 fb^{-1}



- VBF channels (in particular WW*) are discovery channels at low luminosity

- **For 10 fb^{-1} in ATLAS:**

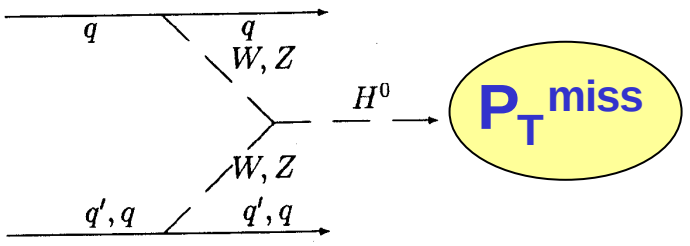
5 s significance for 120 £ m_H £ 190 GeV

Invisible Higgs decays ?

Possible searches: tt H $\rightarrow$ $\ell\nu$b qqb + P_T^{miss}

W/Z H $\rightarrow$ $\ell\nu$ ($\ell\ell$) + P_T^{miss}

qq H $\rightarrow$ qq + P_T^{miss}



Preliminary ATLAS study: (Lionel Neukermans, Annecy)

search for invisibly decaying Higgs boson in VBF mode
(based on study by O.Eboli and D.Zeppenfeld, Phys.Lett.B495 (2000))

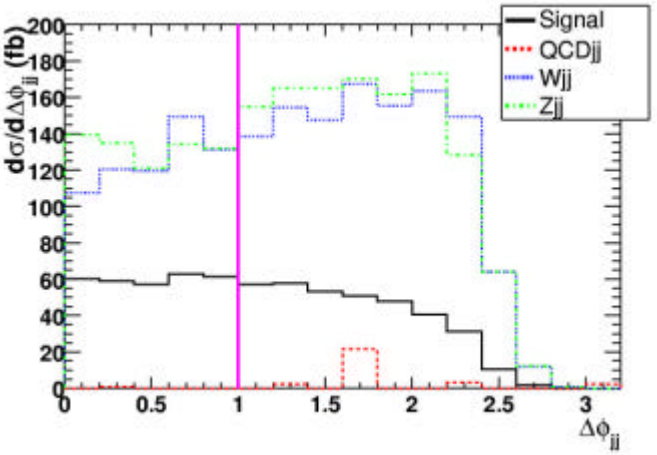
Event selection: 2 tag jets, (P_T, $\Delta\eta$, M_{jj}>1200 GeV)
P_T^{miss} > 100 GeV
Lepton and Jet veto
(no jets with P_T> 20 GeV)

Main backgrounds: W jj production (W $\rightarrow$ $\ell\nu$)
Z jj production (Z $\rightarrow$ $\nu\nu$)
QCD jet production, fake P_T^{miss}

Current belief: requires special forward jet + P_T^{miss} trigger

Discriminating variable: $\Delta\phi_{jj}$ (separation between tag jets)

expect differences due to HIggs coupling structure:

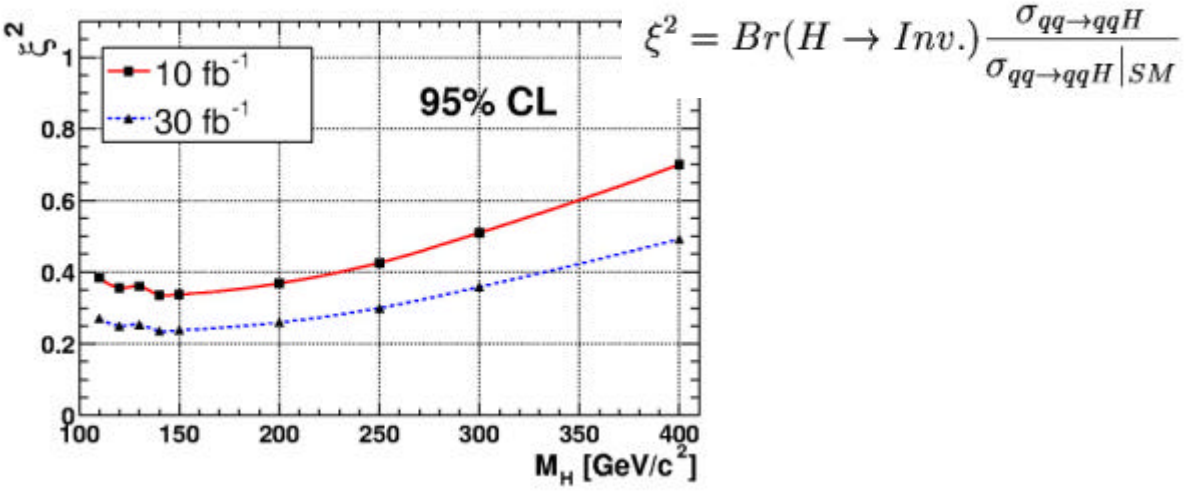


Expected rates
for 10 fb^{-1}:

Signal:	590 events
W-backgr:	1215 events
Z -backgr:	1230 events

background normalization via W $\rightarrow \ell\nu$ and Z$\rightarrow \ell\ell$
in region $\Delta\phi$ >1 needed, to constrain the background
(estimated background uncertainty: 4-5%)

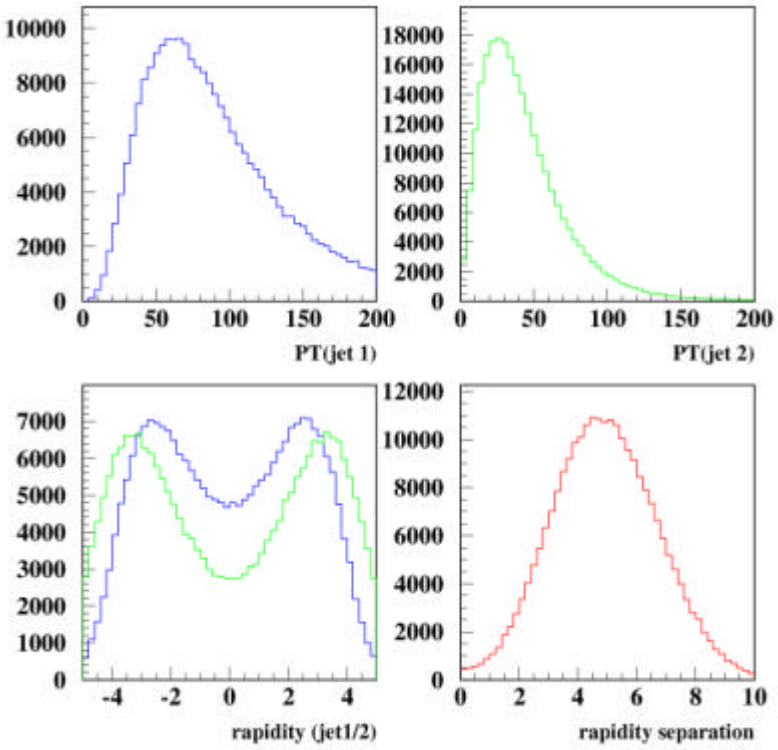
Sensitivity:

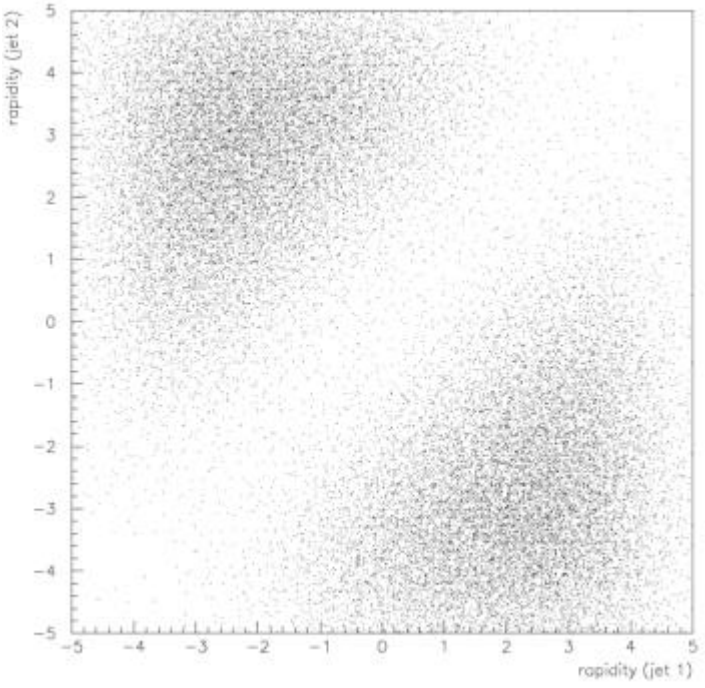


$$\xi^2 = Br(H \rightarrow Inv.)\frac{\sigma_{qq\rightarrow qqH}}{\sigma_{qq\rightarrow qqH}|_{SM}}$$

- Needs confirmation from more detailed simulation (trigger)
- Non-Standard Model background ??
- Needs confirmation in ttH and/or WH channel to demonstrate presence of a Higgs boson

Closer look at tag jets in VBF Higgs events



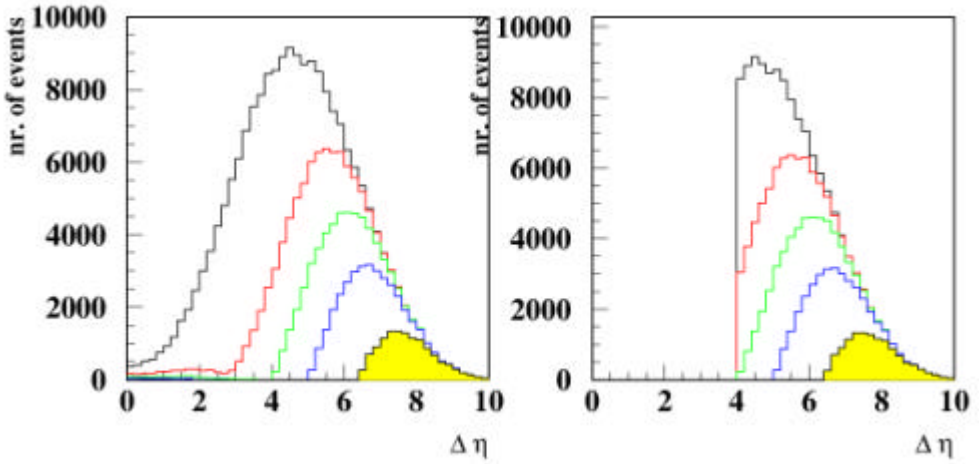


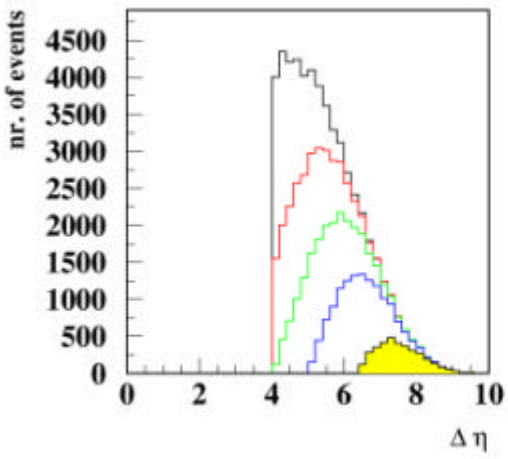
Signal acceptance (offline cuts):

	P_T(jets)	D h > 4.0	P_T^{miss} > 100 GeV
20/ 20	0.79	0.51	0.22
40 / 20	0.74	0.47	0.21
40/ 40	0.45	0.27	0.15

Acceptance of a forward jet trigger:

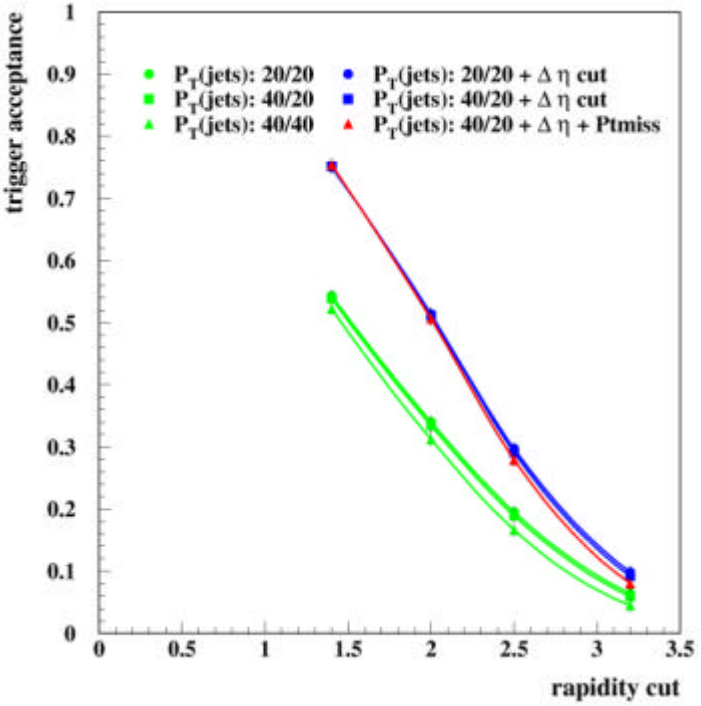
require tag jet intervals: > 1.4, 2.0, 2.5, 3.2



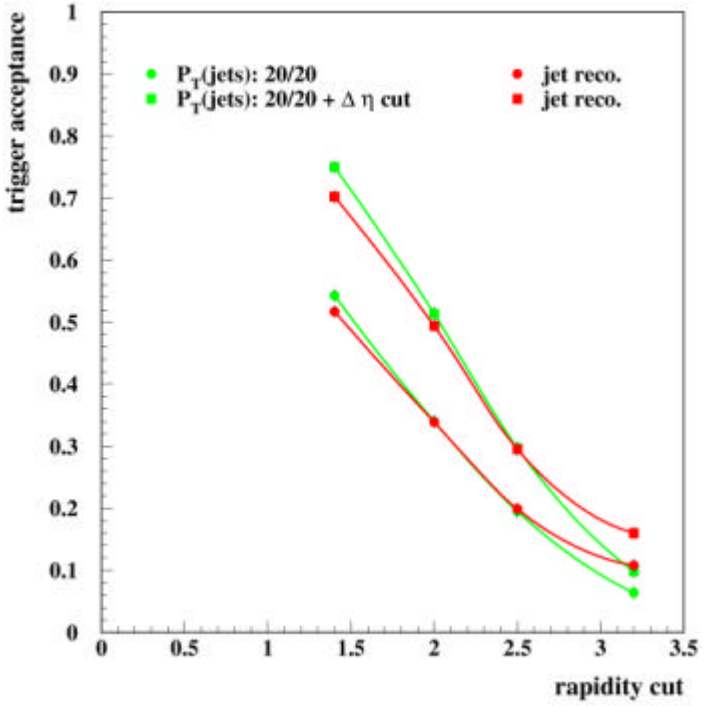


L1-Trigger acceptance

a) Parton level information (tag jets):



b) incl. ATLFAST jet reconstruction, PYTHIA ISR/FSR:



Conclusions

- Vector boson fusion offers a possibility to search for an invisibly decaying Higgs boson

  ATLAS should not miss this opportunity !!
  We need to trigger on those events

- Forward FCAL trigger seems not very useful (may be useful for other types of physics, diffractive production..... ??)

  need at least to be extended in endcap calorimeters

- Maybe these topologies could be better covered by a 2-jet + P_T^{miss} trigger
  (low P_T thresholds !! , but large P_T^{miss})

  other goodies: large $\Delta\eta$
  no jet activity in central region ??

- Discussion between L1-Trigger and Physics groups must continue