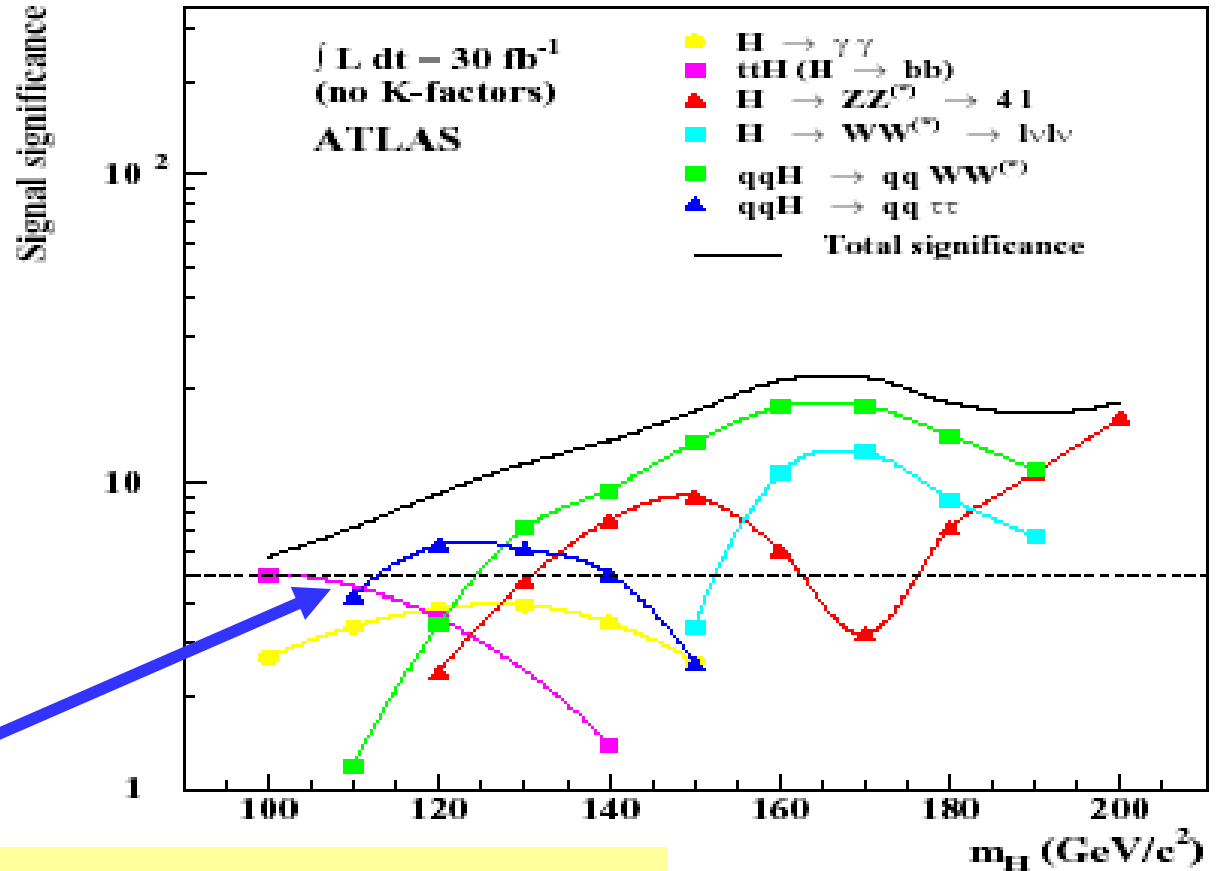


**VBF H- $\rightarrow$   $\tau\tau$  - $\rightarrow$  hh**  
**ANALYSIS**  
**UPDATE**

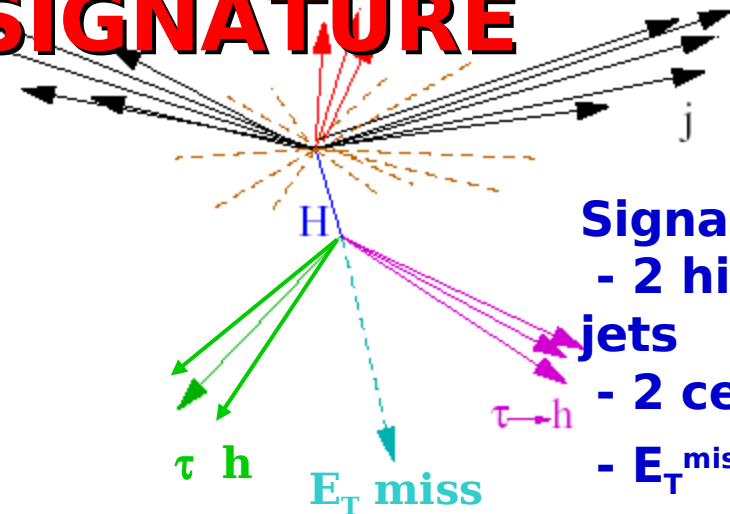
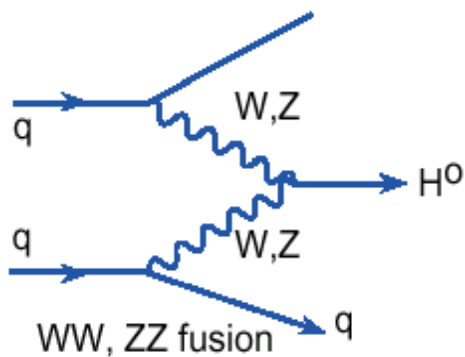
**F.Sarri,Z.Zenonos,V.Cavasinni**

# TAU CHANNEL FOR LOW HIGGS MASS



Previous study (hep-ph/0402254) :  
 $\tau \rightarrow l\nu l\nu$  ,  $\tau \rightarrow l\nu h\nu$  .  
 In  $30 \text{ fb}^{-1}$  about 32 signal events and  
 22 background events for H mass at

# PECULIAR VBF SIGNATURE

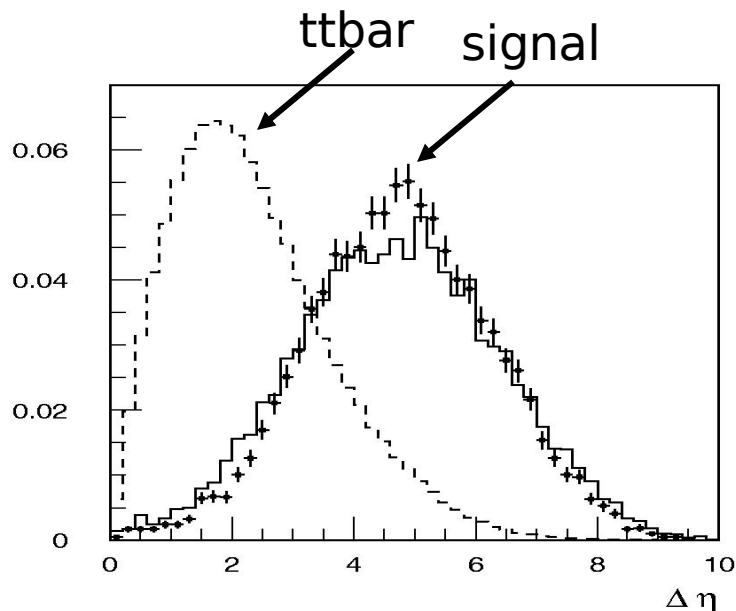
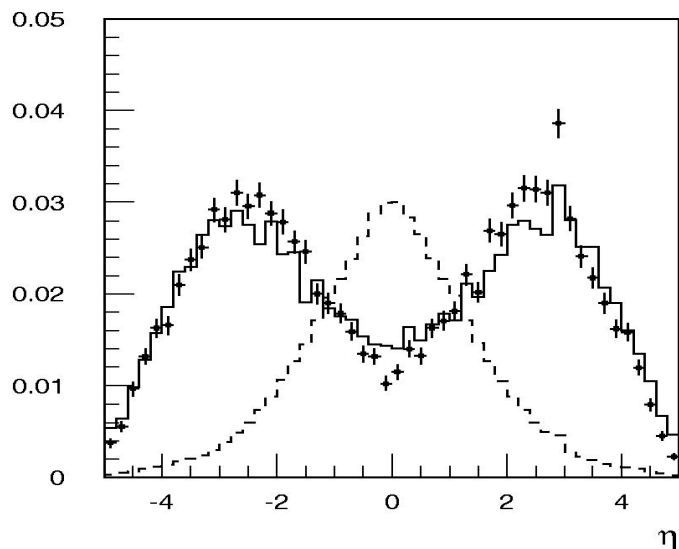


- Signal signature :**
- 2 high  $p_T$  forward jets
  - 2 central tau jet
  - $E_T^{\text{miss}}$

**VBF characteristic:**

- 2 high  $p_T$  forward jets
- depleted jet activity in the central region

**Rapidity distribution for the tagged forward jets for signal and for  $t\bar{t}$  background**



# MASS RECONSTRUCTION IN COLLINEAR APPROXIMATION

## Mass Reconstruction:

Observe  
missing transverse momentum  
and visible Tau-decay products

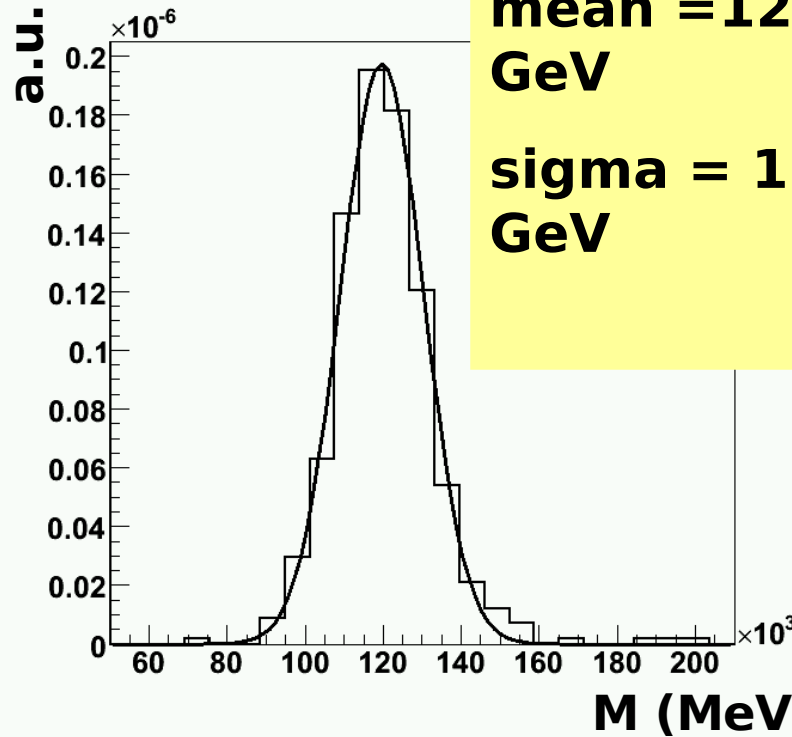
Assume  
collinearity

Solve 2  
for

Taus c

Higgs c

For  $\tau\tau \rightarrow \text{had had}$ , if  $x_{1,2}$   
visible energy  
the two



# CROSS SECTIONS FOR SIGNAL AND BACKGROUNDS

$$\sigma_{\text{VBF } H(120) \rightarrow \tau\tau} \approx 300 \text{ fb}$$

BR (tau had) : 65% ; BR( $\tau\tau \rightarrow hh$ ) : 42.25 %

$$\sigma_{\text{sig}} \approx \sigma_{\text{VBF } H(120) \rightarrow \tau\tau} \cdot BR(\tau\tau \rightarrow hh) \approx 125 \text{ fb}$$

$$\frac{\text{QCD events : } \sigma_{\text{QCD}} = 9.45 \text{ mb}}{(\text{msel}=1, Q_T > 10 \text{ GeV})} \quad \frac{\sigma_{\text{sig}}}{\sigma_{\text{QCD}}} = 1.3 \cdot 10^{-11}$$

$$\frac{\text{ttbar} \rightarrow \text{bbWW:}}{(\text{inclusive})} \quad \sigma_{\text{ttbar}} = 548 \text{ pb} \quad \frac{\sigma_{\text{sig}}}{\sigma_{\text{ttbar}}} = 2.28 \cdot 10^{-4}$$

$$\frac{\gamma^*/Z + \text{jets :}}{(p_T > 10 \text{ GeV})}$$

$$(\gamma^*/Z \rightarrow \tau\tau) + \text{jets} : \sigma = 1742 \text{ pb}$$

~ 700 pb with 2 hadronic taus

Huge background: analysis relies on rejection factors ( $10^{-5} - 10^{-6}$ ) for  $\tau$

# FULL SIMULATED SAMPLES

❖ Analysis with ATLFAST  
(Athena9.0.4)  
gave promising results : in  $30 \text{ fb}^{-1}$  5.7  
signal events, 3.8 background events  
(Z, ttbar and QCD).

❖ Now full simulated data available  
(Athena12.0.6) Alpgen/Herwig, Pythia.

❖ Trigger information included. Filters  
❖ Some background samples still applied  
missing.

Dijet samples:

$P_T$  : 8-17 GeV

$P_T$  : 17-35 GeV

$P_T$  : 35-70 GeV

$P_T$  : 70-140 GeV

$P_T$  : 140-280 GeV

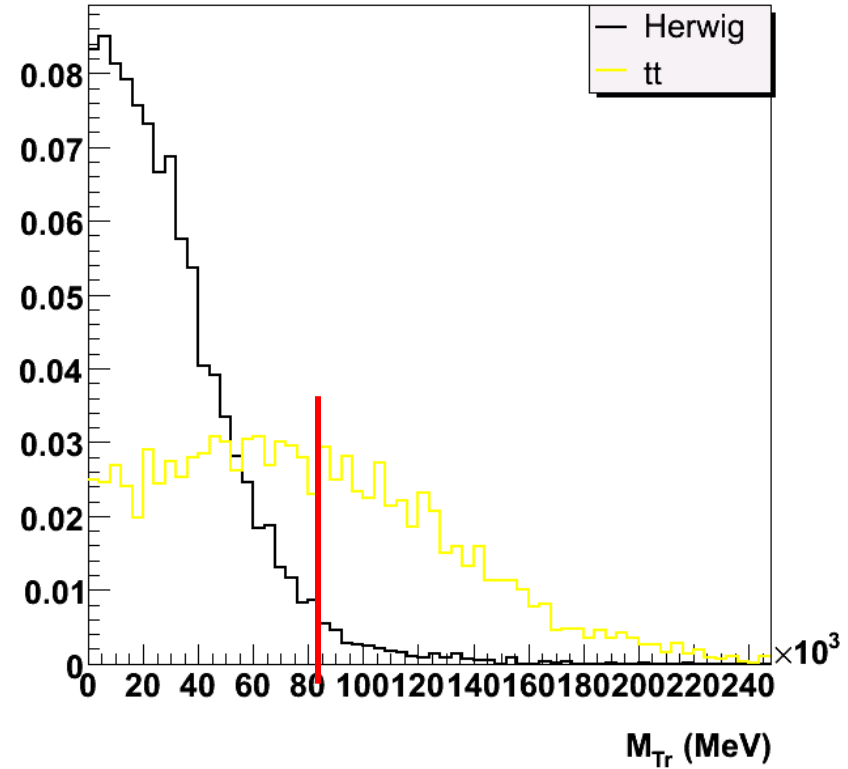
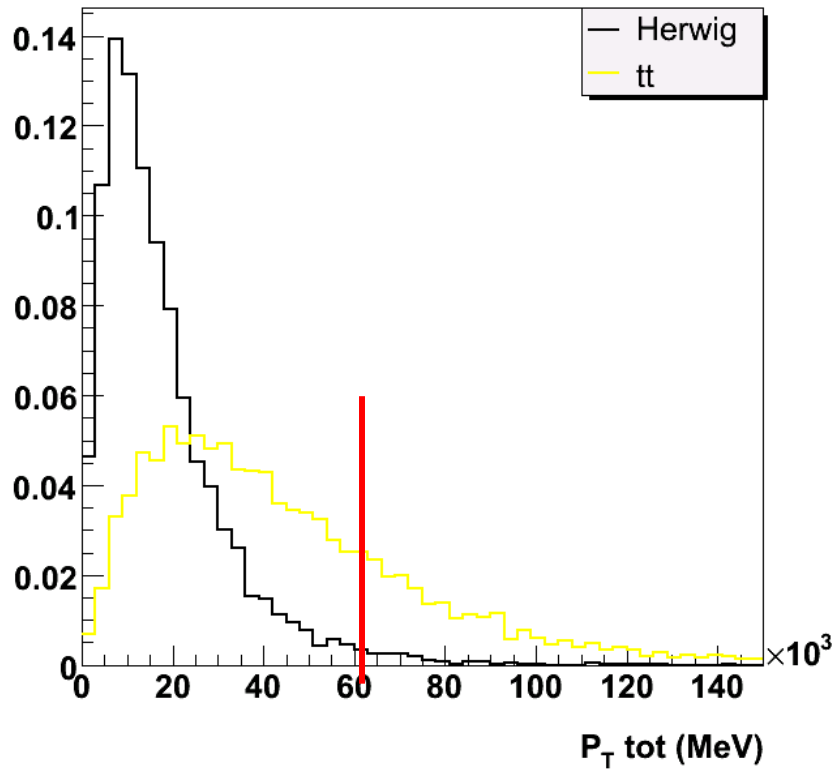
Sample	Events	X section
Signal	49200	$(\text{fb})^{-1}$ 70.5
Z+Np0	5000	1200
Z+Np1	5000	13900
Z+Np2	15254	8490
Z+Np3	8950	3590
Z+Np4	3250	1140
W+Np3	45500	130000
W+Np4	4250	37800
W+Np5	7950	13900
ttbar	415178	461000
J0	140000	17.6E+12
J1	185000	1.38E+12
J2	155000	9.33E+10
J3	230000	5.88E+9
J4	375400	3.08E+8

# CUTS FOR THE ANALYSIS

- **trigger** tau35i+ L1 MET40
- **two tau jets**,  $p_T > 35, 30$  GeV  
 good tau candidate (tauRec) :  
 $|charge|=1$ ,  $nTracks=1$  or  $3$ ,  $lh > 4$ ,  $PT > 30$  GeV  
 electron veto (for all electron object in AOD within  $\Delta R=0.1$ ) :  
 1) if  $|\eta|$  of tau  $< 1.7$ ,  $TRT\_HT\_Hits/TRT\_Hits < 0.2$  for the leading track.  
 2)  $ethad1/et > 0.002$  for all  $|\eta|$  range (electron with  $author=1$  or  $3$ )
- **two forward jets** (cone 0.4),  $p_T > 40$  GeV,  $20$  GeV, no overlap with taus.
- **MET energy** (RefFinal)  $> 40$  GeV
- **collinear approximation**:  $0.2 < x_{\tau_{1}}, x_{\tau_{2}} < 1$ ,  $|\phi_{\tau_{1}} - \phi_{\tau_{2}}| < 2.9$
- **$p_T$  tot  $< 60$  GeV** ( $PT_{tot} = PT_{\tau_{1}} + PT_{\tau_{2}} + PT_{miss} + PT_{j1} + PT_{j2}$ )
- **Transverse mass**  $< 80$  GeV  $M_T = \sqrt{2P_T(\tau_{1}\tau_{2})P_T^{miss}(1 - \cos \Delta\phi)}$
- **$\eta_{1} * \eta_{2} < 0$ .**
- **tau1 and tau2 central**: should be between jet1 and jet2 in eta
- **$|\eta_{1} - \eta_{2}| > 4$ .**
- **$M_{j1j2} > 700$  GeV**
- **Central jet veto**: no jet with  $p_T > 20$  GeV in central region, except taus
- **Mass window** :  $105 < M_{\tau\tau} < 140$  GeV

Cut sequence and thresholds have been changed to be more uniform with other HG3 analysis.

# NEW VARIABLES FOR THE ANALYSIS



$P_{T\text{tot}} =$

$$P_{T\text{tau}1} + P_{T\text{tau}2} + P_{T\text{miss}} + P_{Tj1} + P_{Tj2}$$

$P_{T\text{tot}} > 60 \text{ GeV}$

$$M_T = \sqrt{2P_T(\text{tautau})P_T^{\text{miss}}(1 - \cos \Delta\phi)}$$

$$M_T(\tau\nu\nu) < 80 \text{ GeV}$$

Effective also on Z+Np4 and Z+Np5



# CUT FLOW INCLUDING TRIGGER

Cut	Signal	Z+jets (*)	ttbar	W+jets(*)	QCD(*)
Init. Xsec (fb)	70,5	28320	461000	181700	19.1E+
Trigger	11,0	1411,0	72157	13372	5.1 E <sup>17</sup>
	4	9			
2tau (el. veto)	1,92	146,4	474	104	0
N>=2jets	1,55	97,93	431	72,9	0
ETmiss	1,22	65,44	373	66,5	0
Coll.approx.	0,88	40,98	71,1	24,9	0
PTtot	0,85	37,97	50,0	24,9	0
Tran. Mass	0,85	37,22	44,4	24,9	0
Forw. Jets	0,73	14,62	14,4	7,5	0
Centrality	0,68	7,81	5,55	0	0
Jet separat.	0,49	1,71	2,22	0	0
Dijet Mass	0,45	1,71	1,11	0	0
Jet Veto	0,42	0,91	1,11	0	0
Mass Window	0,36	0	0	0	0

(\*) statistics insufficient

# CUT FACTORIZATION FOR Z,W,ttbar

Cut	ttbar	Z+0	Z+1	Z+2	Z+3	Z+4	W+3	W+4	W+5
Total	415178	5000	5000	15254	8950	3250	45500	4250	7950
At least 4jets	387810	2032	2174	13425	8765	3237	38299	4129	7915
2jets, $ \Delta\eta  < 2.5$	384177	2018	2166	13354	8730	3214	37916	4086	7841
2 jets, $p_T > 40, 20$ GeV	232880	116	92	2549	3338	1731	7170	1512	4816
Forw. Jets	89010	34	28	772	1230	722	2688	636	2187
Jet separat.	13241	18	6	74	148	113	476	116	500
Dijet Mass	8027	7	2	33	68	55	270	68	337
Jet Veto	1894	4	1	29	33	9	226	34	49

Forw  
Jet  
cuts

2jets, $ \Delta\eta  < 2.5$	384177	2018	2166	13354	8730	3214	37916	4086	7841
2taus, $p_T$ $> 35, 30$ GeV	956	60	218	685	451	172	127	14	28
$E_{T\text{miss}}$	647	0	27	145	133	59	55	9	16
Coll.Approx	111	0	17	90	80	36	13	3	5
Transv.Mass	102	0	17	90	79	35	12	3	5
Mass Windows	8	0	0	8	5	6	2	0	1

tau  
and  
 $E_{T\text{miss}}$   
cuts

Cross Section (fb)	4,38E-2	4,8E-4	1,3E-3	9,7E-3	7,6E-3	5,9E-3	3,41E-2	7,4E-2	1,09E-2
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No trigger cut, no  $P_{T\text{tot}}$  cut (effective on ttbar, Z+4, Z+5) on background  $\approx 0.19\text{fb}$

Signal with all cuts but trigger has a cross section **0.54 fb**

(\*) not all  
samples

# UT FACTORIZATION FOR QCD on progress

Cut	J0	J1	J2	J3	J4
Total	140000	185000	155000	230000	375400
At least 4jets	928	8492	31438	102665	224442
2jets, $ \Delta\eta  < 2.5$	920	8375	30808	100259	221985
2 jets, $p_T > 40, 20$	18	144	1715	22896	109915
GeV Forw. Jets	6	62	509	8516	45654
Jet separat.	5	32	350	3153	9693
Dijet Mass	1	17	240	2300	6793
Jet Veto	1	13	186	1596	3458

Only Forward jets cuts



Mass window cent. jets	44	268	1361	2459	1323
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Only M W cut (norm. to central)

2taus, $p_T > 35, 30 \text{ GeV}$	0	0.43	1.6	5.2	11
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Only tau cut (norm to central)

ETmiss	11	48	189	1135	12863
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Only  $E_T^{\text{miss}}$  cut

≈ 0,64 fb

Cross Section (fb)	0.025	0.04	0.31	0.25	0.02
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(\*)

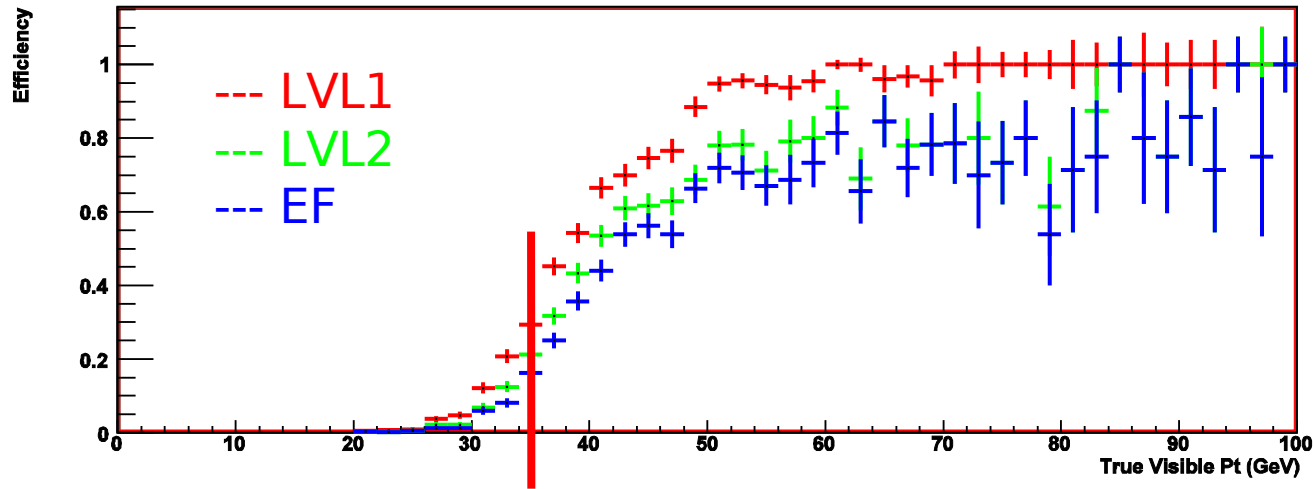
no trigger cut, no further tau cuts.

Signal with all cuts but trigger has a cross section **0.54 fb**

(\*) not all samples

-understand background shape : rough estimate of event number in the mass

# TRIGGER OPTIMIZATION



Tau35i for 12.0.6

Tau trigger still need to be optimized.  
Better performance in new Athena release  
13.0.30

# CONCLUSION AND FUTURE WORK

Changes on cut flow have been done to be similar to other HG3 analysis.

Analysis in full simulation still need more data to optimize cuts:  
50 K of Z+2p ready in Toronto but not yet on GRID.  
500 K of ttbar are going to be produced.  
Z+jets (Pythia) will be also used.

Signal with pileup will available to make accurate comparisons.

In Athena13.0.3 **new trigger menus for two hadronic taus** implemented.

ATLFAST production just started in NBI, we will start use these data.

QCD issue: important background that will never have enough MC statistics.

A first approach with factorization seems to show that it can be take at the level of the signal.

Need to understand background shape.

Use of parameterization for tau efficiency/rejection?

Use of ATLFAST + parameterization?