Improvements of the τ jet measurement applied to the low mass Higgs search in ττ

1. Particle Energy Flow (PEF) for τ-jet measurement
2. Multivariate Analysis (MVA) for the Higgs search

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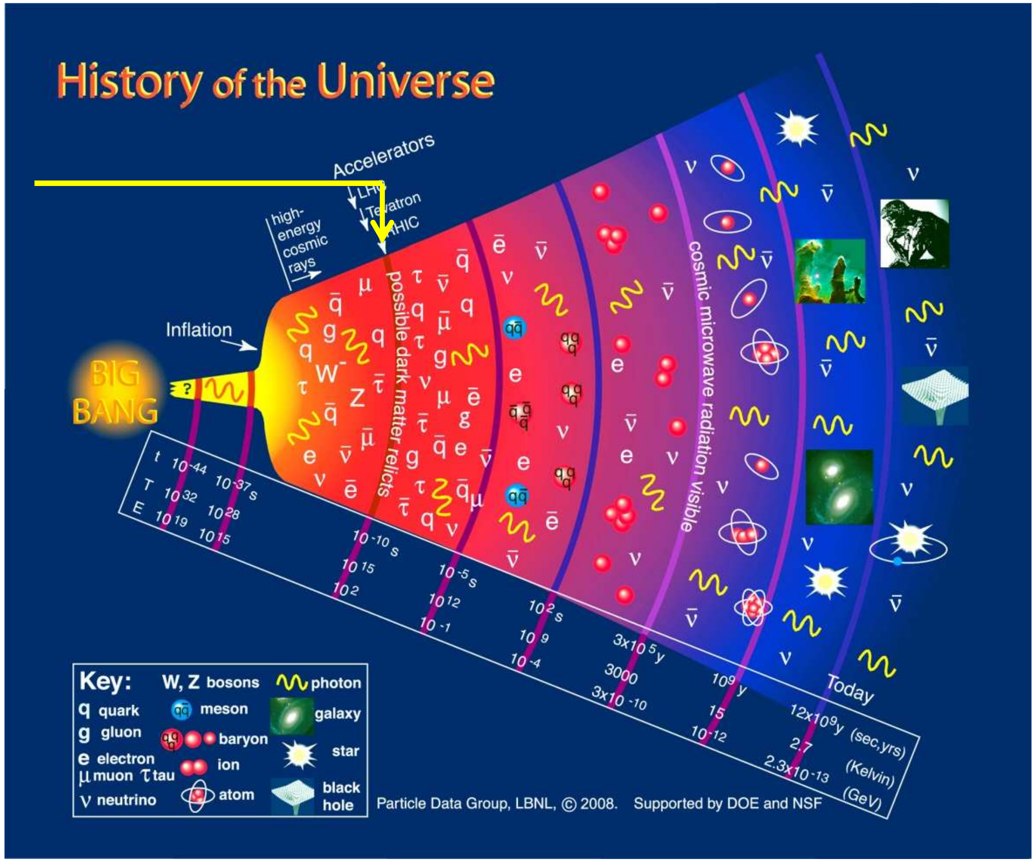
High Energy and Hadronic session

Higgs Boson

The "God" particle
The origin of mass

The only (elementary) particle predicted by the Standard Model that has not yet been observed experimentally.

10^{-10}s after the Big-Bang, the vacuum is filled with a condensate of Higgs particles. The elementary particles W/Z bosons, quarks and leptons, collide with them as they travel through the vacuum, hence acquiring the masses.



The prime objective of LHC experiments is the Higgs boson discovery and study

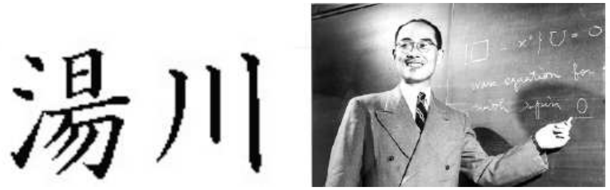
Multivariate Analysis (MVA)

MVA are powerful statistical techniques for analyzing data with many variables simultaneously.
Make use of all possible discriminating features between signal and background samples including complex non-linear correlations
Many multivariate analysis in Toolkit for Multivariate Data Analysis, (TMVA) running with ROOT package:
Boosted Decision Trees (BDT), Artificial Neural Networks (ANN), Bayesian likelihood, Fisher discriminant ….

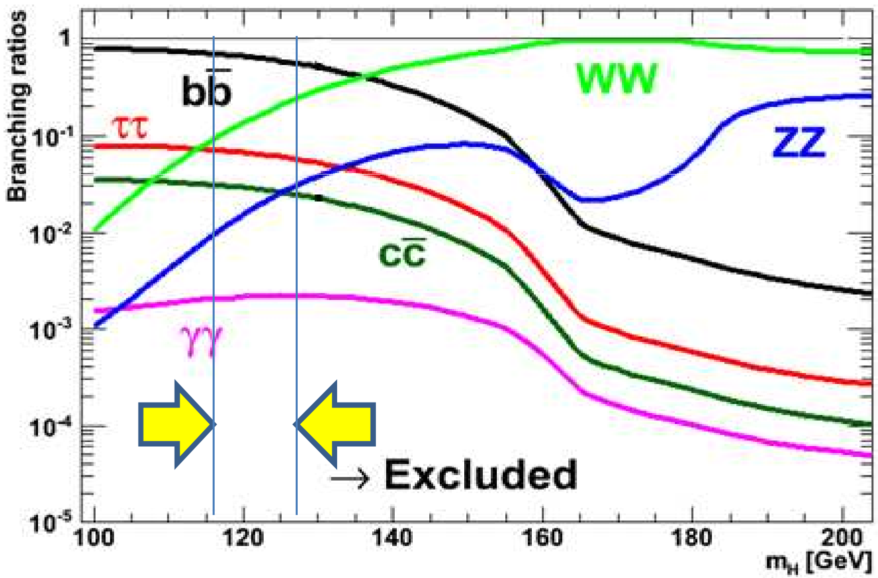
should choose a set of variables plugged in the MVA to separate signal from background…

Higgs search in ττ decay

- ττ : important channel for Higgs discovery
- Once Higgs is discovered, it is crucial to measure Higgs coupling to fermions (Yukawa coupling)
- τ decays to hadrons or lepton (e,μ) associating with missing energy (νs)



Branching ratio of the SM Higgs boson

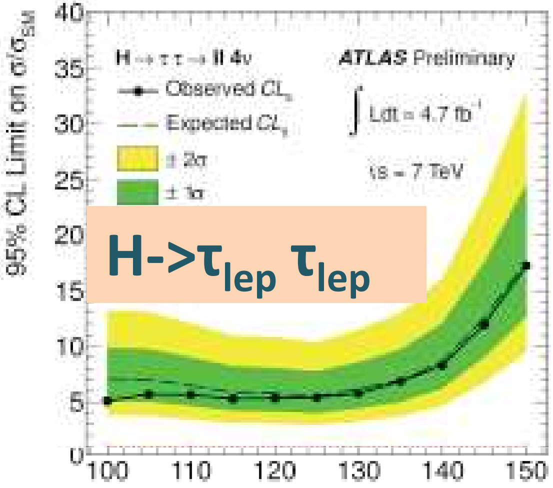


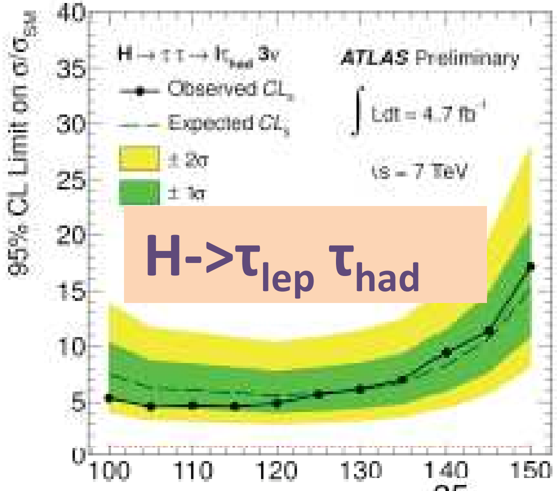
Search strategy depends on τ's decay modes

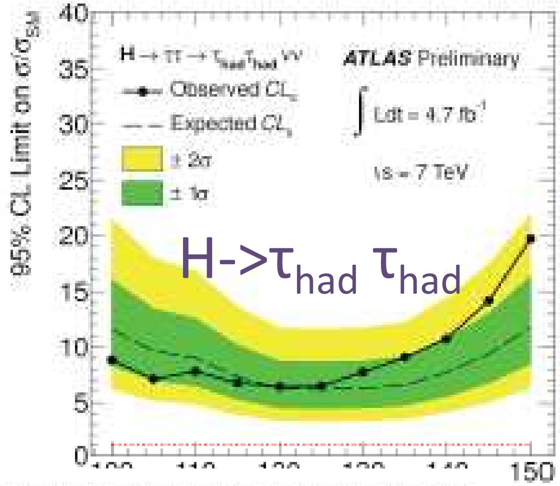
ττ decay	BR	note
hh	4/9	High stat,QCD bkg
lh	4/9	High stat, less QCD bkg than hh
ll	1/9	Low stat, most clean

ATLAS/CMS 112.9-115.5 and 127-600 GeV excluded with 5 fb^{-1}

Status of Higgs to ττ search in ATLAS







Moriond 2012

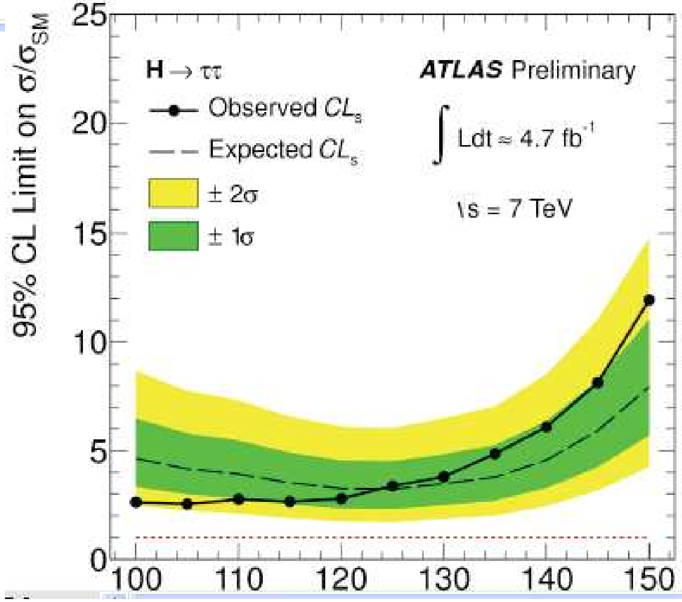
combined 95%CL limit(120 GeV) :

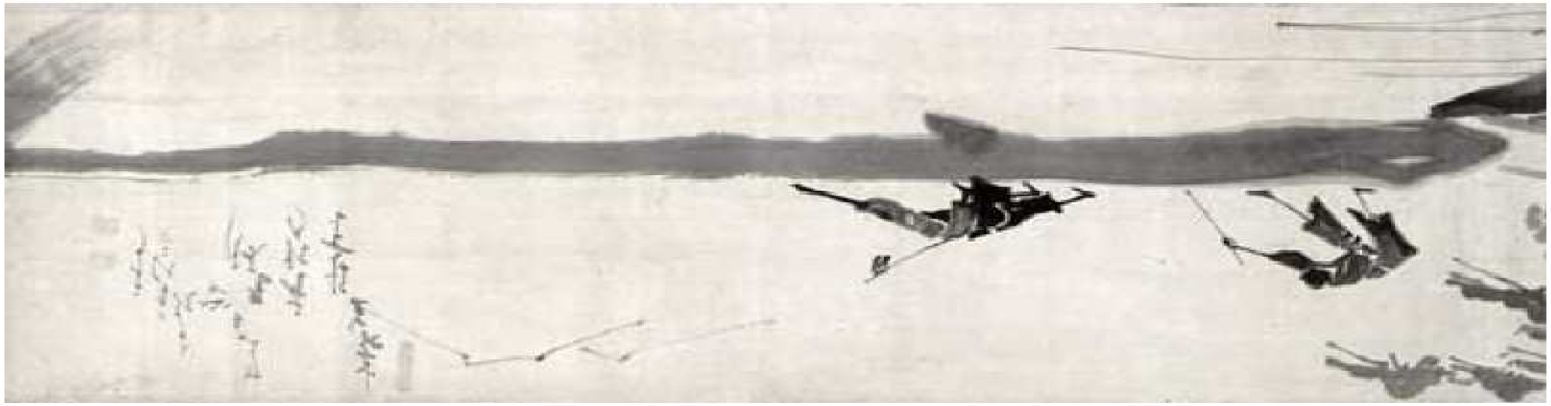
expected 3.4 x SM

observed 2.8 x SM

Purpose:

discovery channel -> ~15fb^{-1}





Ekaku Hakuin
1686-1769

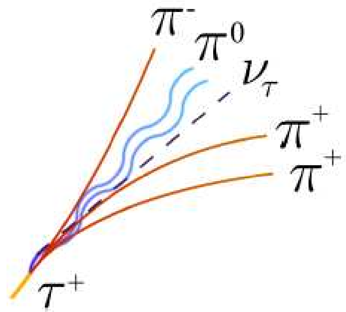
Proposal

1. Z->ττ is the irreducible main background. Separate Higgs from Z by good mass reconstruction
   -> employ a particle energy flow techniques : combining tracker and calorimeter information.
2. Since τ decay involves many kinematic variables, we propose to develop a multivariate analysis (MVA) method to reduce backgrounds while retaining maximum signal events

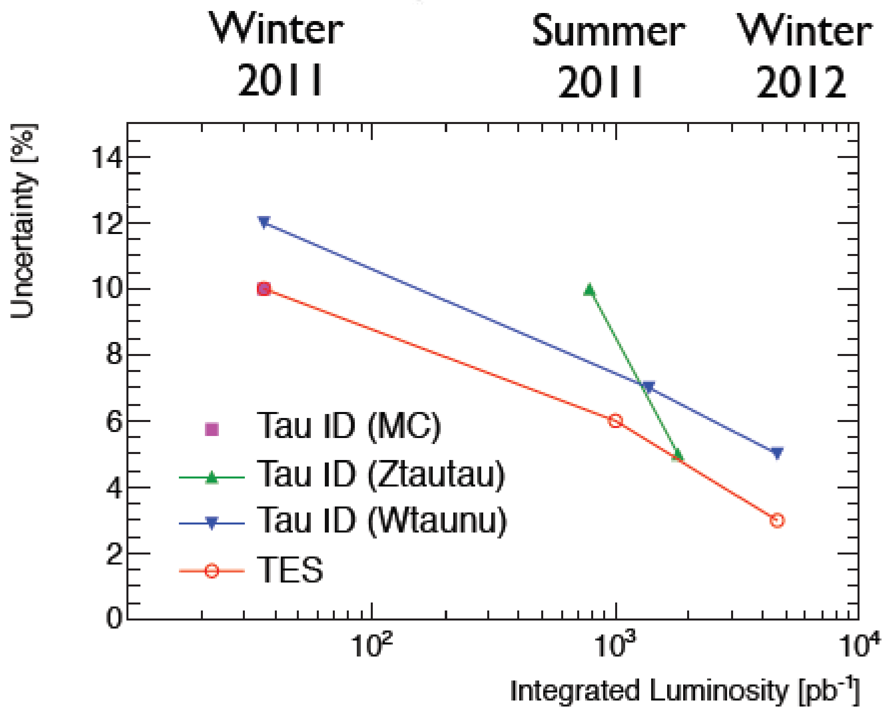
τ Energy Scale (TES)

decay mode	branching fraction
main hadronic modes	
$\tau^\pm \to \pi^\pm \nu_\tau$	10.9%
$\tau^\pm \to \pi^\pm \pi^0 \nu_\tau$	25.5%
$\tau^\pm \to \pi^\pm \pi^0 \pi^0 \nu_\tau$	9.3%
$\tau^\pm \to \pi^\pm \pi^\pm \pi^\mp \nu_\tau$	9.3%
$\tau^\pm \to \pi^\pm \pi^\pm \pi^\mp \pi^0 \nu_\tau$	4.6%

66% of hadronic τ decays have π^0 ‘s



energy scale current uncertainty:
3-6% **(largest contribution is from hadronic shower energy measurement)**

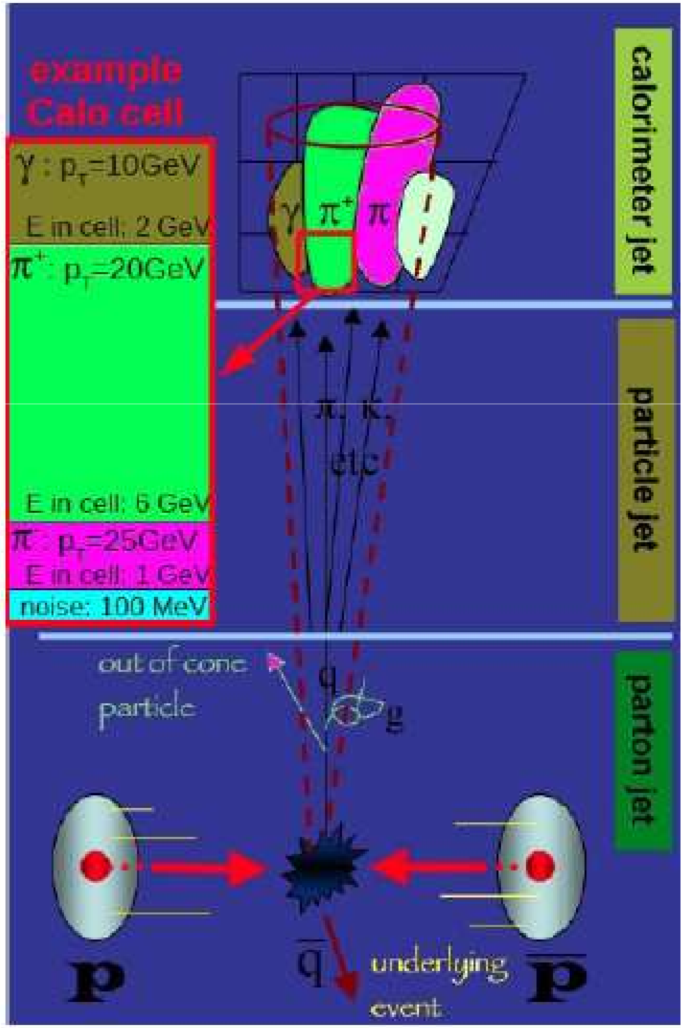


our proposal : reduce TES uncertainty using particle energy flow analysis (PEF)

Particle Energy flow

The τ energy can be decomposed into the energy of its constituent particles
(1-3 prongs + $n\pi^0$)
each particle is measured with the most appropriate detector:
tracker for $\pi^\pm$'s
(more accurate than calorimeter)
calorimeter for π^0's

- select the π^o cluster(s)
- π^o in cluster ? (π^o counting)
- reconstruct 4-vectors of the π^o s (π^o finding)
- apply corrections if necessary

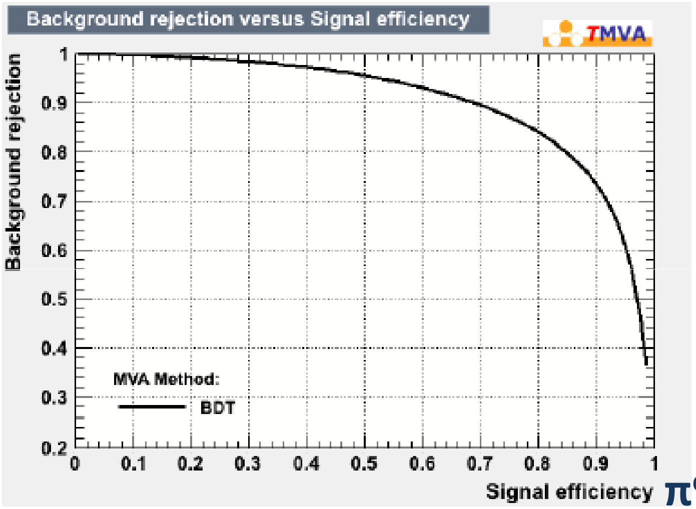


New Strategy –BDT

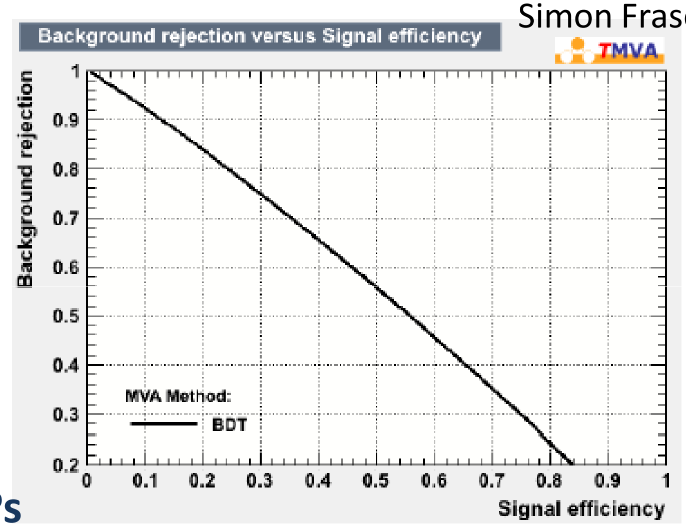
Using boosted decision tree methods (BDT) for π^o reconstruction
(variables: em fraction, em radius, energy fraction in layers of calo, …)

M. Trottier-McDonald
Simon Fraser University

no π^os



π^os



Separating with π^0s from no π^0s

Separating 1 π^0 from 2 π^0s

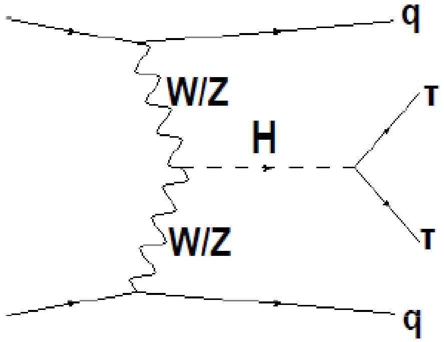
Establishing the presence of π^0s is easy, while counting how many is hard.

aim at better τ id efficiency and better energy scale (1-3%).
pileup is a challenge. TES performed as a function of #vertices

Status of the Higgs Search

$H \rightarrow \tau\tau \rightarrow lh$

Vector-boson fusion process (VBF)



2 very forward jets

- Looking for Higgs with emphasis on VBF process where two high energy jets are associated with a Higgs. The analysis is based on cut-base.
- Preliminary investigation using MVA has started.
- Plan is to implement MVA and PEF.

$H \rightarrow \tau\tau \rightarrow ll$

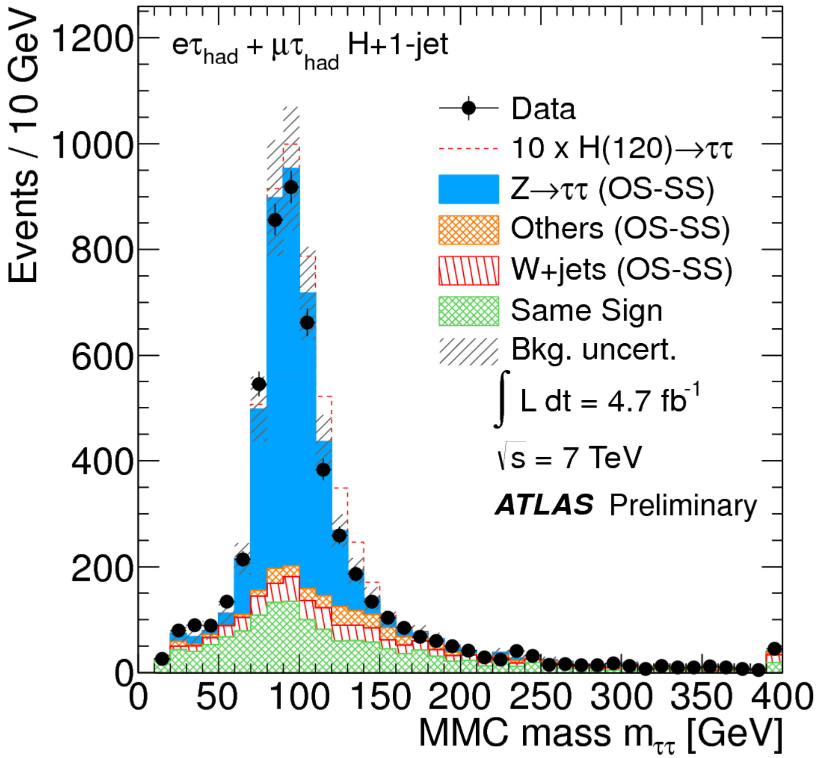
- Examine $Z \rightarrow \tau\tau \rightarrow e\mu$ events to develop MVA that is adoptable for Higgs search.
- This experience will be transferred to other channels.

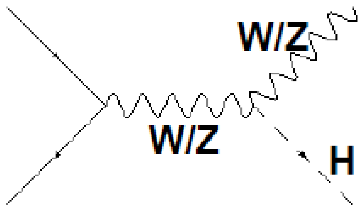
K. Hanawa (U Tsukuba)

$H \rightarrow \tau\tau \rightarrow lh$

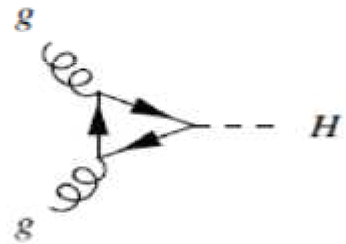
cut-base

Selection is optimized depending on the number of associated jets





w/ jets no in VBF category



w/ no jet

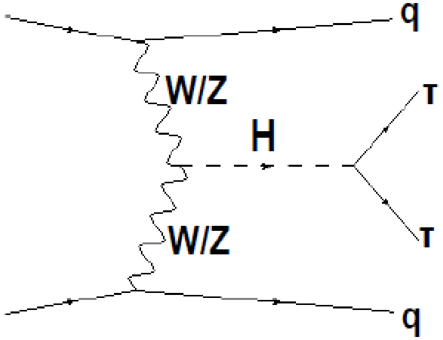
Irreducible Z background
Signal expectation for H(120)

optimal reconstruction of the τ mass despite 2,3 or 4 neutrino (ν) with MMC (Missing Mass Calculator) :
calculates ττ invariant mass, solving ν "statistically"

P. Pétroff
(Lal Orsay)

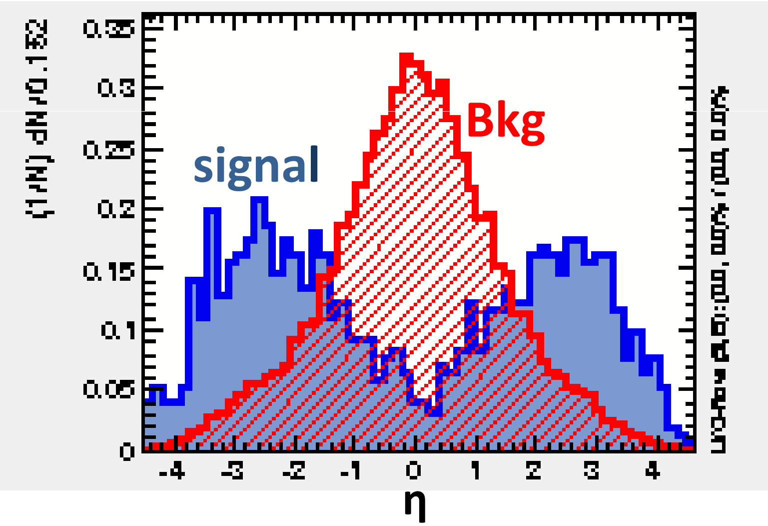
MVA lepton-hadron

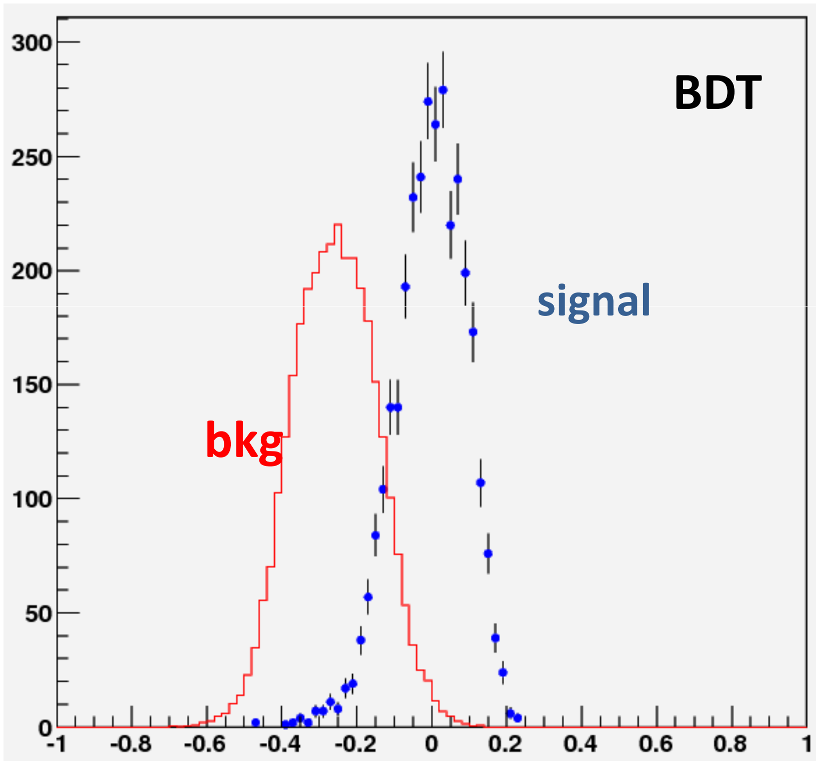
background
W+jets
Z+jets
ttbar
diboson
QCD



VBF

Very preliminary study





18 variables: most poweful use the very forward jets kinematics

Higgs 120 GeV

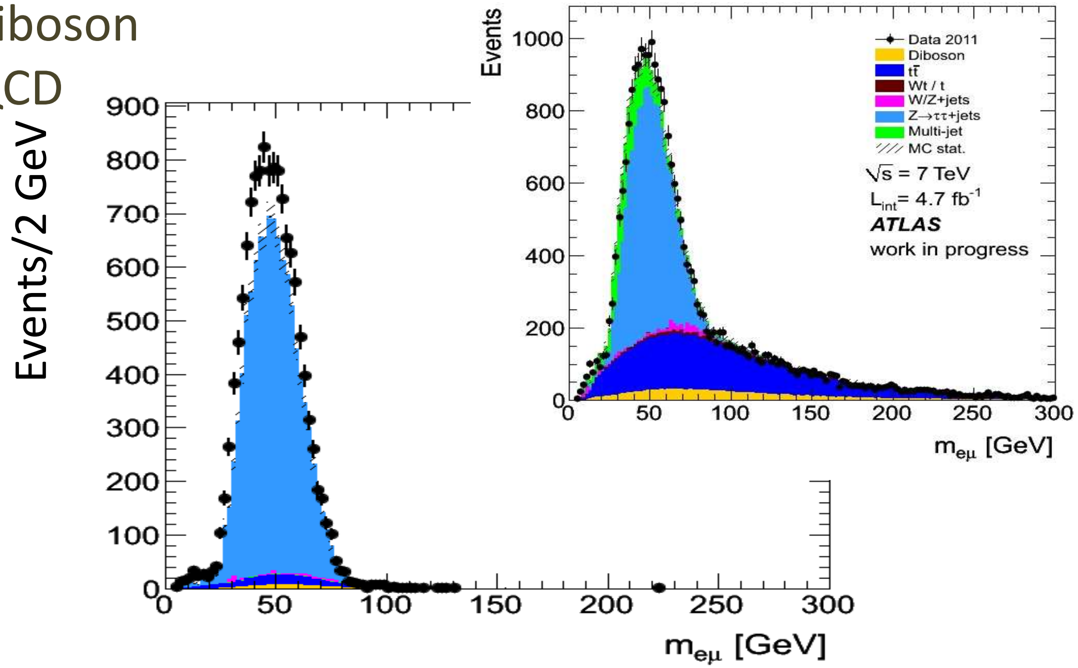
K. Mochizuki
U. Tsukuba

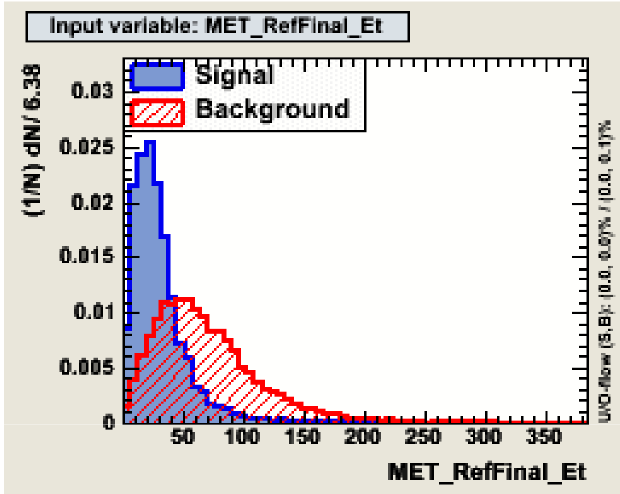
MVA Lepton Lepton using Z->ττ

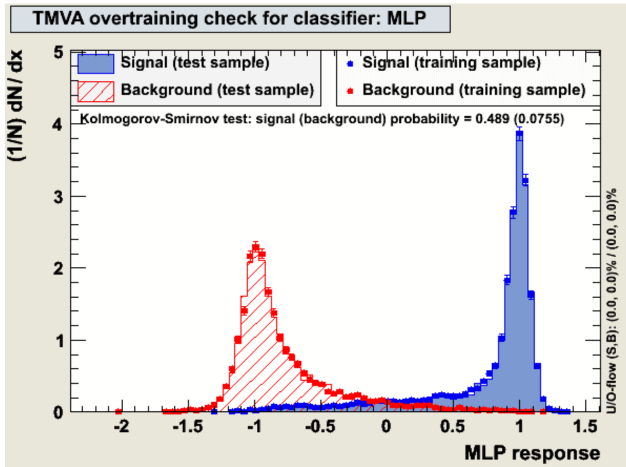
__background__
W+jets
Z+jets
ttbar
diboson
QCD

11 input variables
Neural Net (NN)

Distribution before applying this NN selection

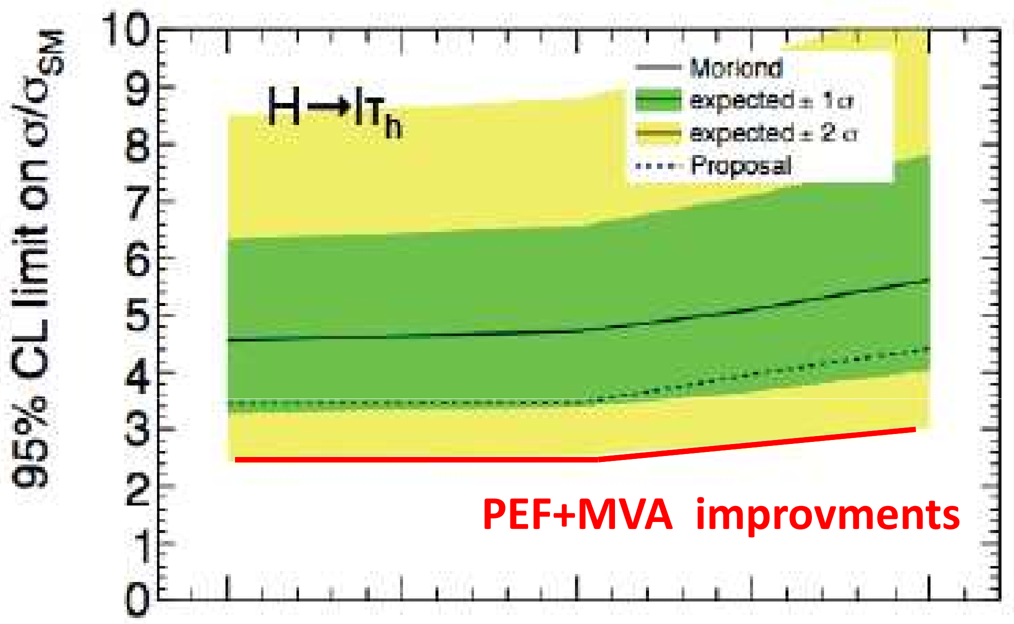






Distribution after this NN selection:
Z-boson is reconstructed with small background and affordable loss in number of events

Improvement lh



5 fb^{-1}

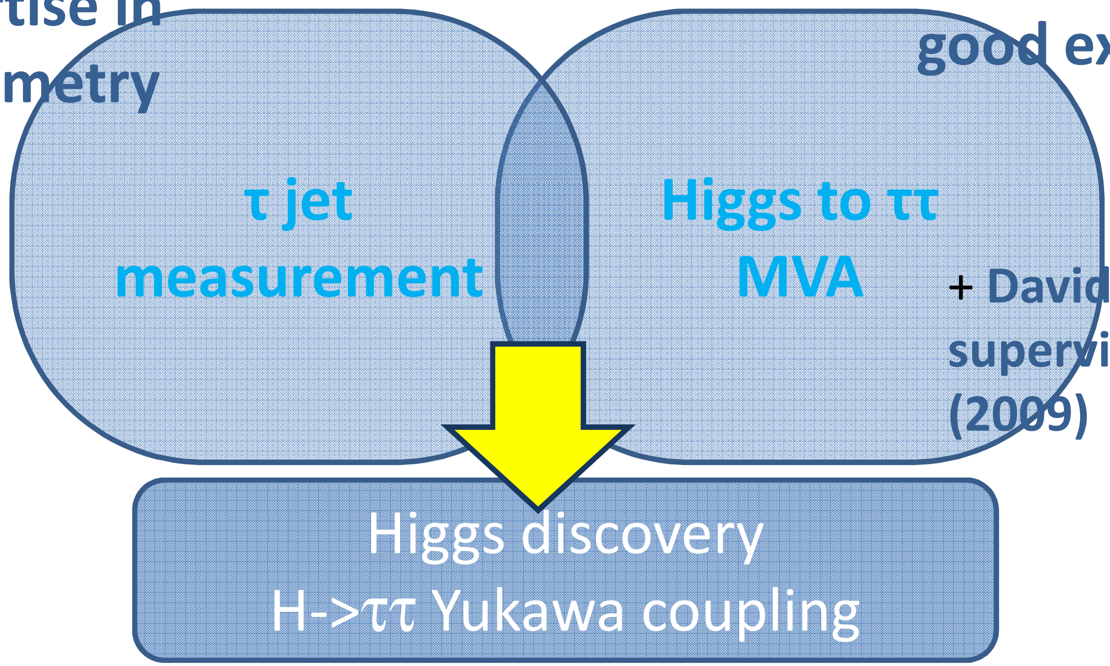
Expected improvement in the lh channel (red line)
similar improvements for ll (hh) should lead ττ to be a very important discovery channel at ~15 fb^{-1}

Sharing of the tasks

KEK: former τ-id convener (Soshi Tsuno)

LAL Orsay: good expertise in calorimetry

Tsukuba University: good expertise



+ David Rousseau (LAL) supervisor of H->ττ thesis (2009)

Keita Hanawa (H->ττ -> lepton – hadron ->thesis)
Kazuya Mochizuki (H->ττ -> lepton – lepton ->thesis)

Budget

IN2P3 **euros: 8000 (800K yen) :**
3 month stay of a student at LAL, meeting + travel

KEK **yen : 340K (3400 euros) :**
meeting + travel

Tsukuba **yen : 640 K (6400 euros) :**
short stays in France + travel

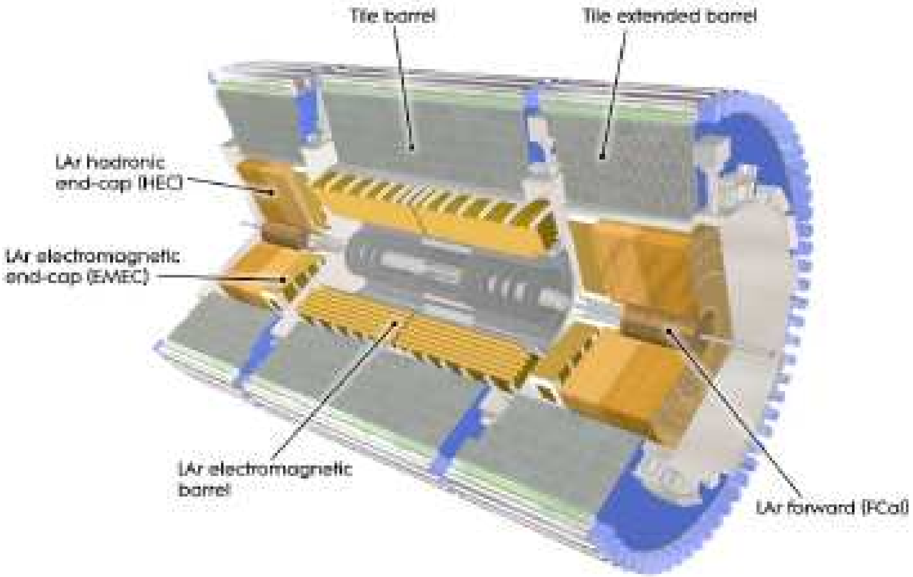
for more details, report to the LH06 written proposal

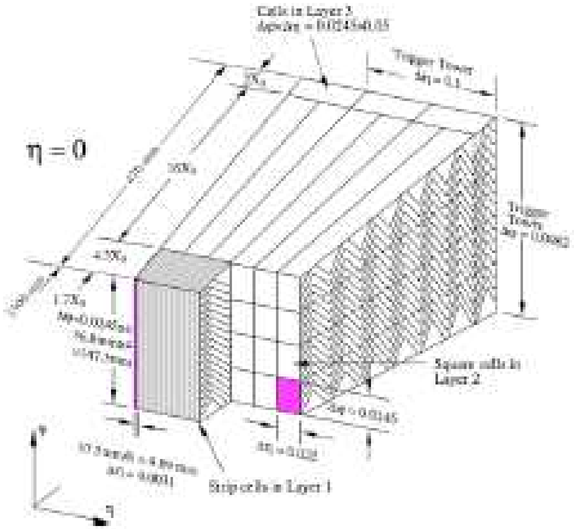
Conclusion

- The KEK, LAL and Tsukuba groups have been working on Higgs search in $\tau\tau$ decay mode and have accumulated expertise in analysis.
- To enhance the sensitivity of this decay mode, which is required for Yukawa coupling measurement, improvement in τ energy measurement and adoption of MVA are crucial.
- This can be achieved by a close collaboration of LAL (for calorimetry expertise) and KEK/Tsukuba (for analysis expertise), who are very complementary to fulfill the searching program presented here.

Backup slides

ATLAS Calorimeters





LAr EM barrel module

- Complete azimuthal symmetry,
  Coverage $|\eta|<4.9$

Electromagnetic Calorimeter

- Pb-LAr accordion geometry
- 3 longitudinal samples $|\eta|<2.5$
- Presampler detector $|\eta|<1.8$
- 173k channels

$$\sigma(E)/E = 10\%/\sqrt{E} \oplus 0.7\%$$

Hadronic Calorimeter

- Barrel : iron - scintillator tiles (3 longitudinal samples)
  EndCap/Forward: Cu/W-LAr (4/3 longitudinal samples)
- 20k channels
- 3 longitudinal samples $|\eta|<2.5$

$$\sigma(E)/E = 50\%/\sqrt{E} \oplus 3\% \quad , |\eta| < 3.2$$

$$\sigma(E)/E = 100\%/\sqrt{E} \oplus 10\% \quad , |\eta| > 3.1$$

Cosmics/single beam data taking

- September/October 2008
- Several smooth runs with most of ATLAS detector partitions ON
- Data reprocessed at Christmas 2008
  - Bad channel status: 1.0% problematic , 0.1% masked

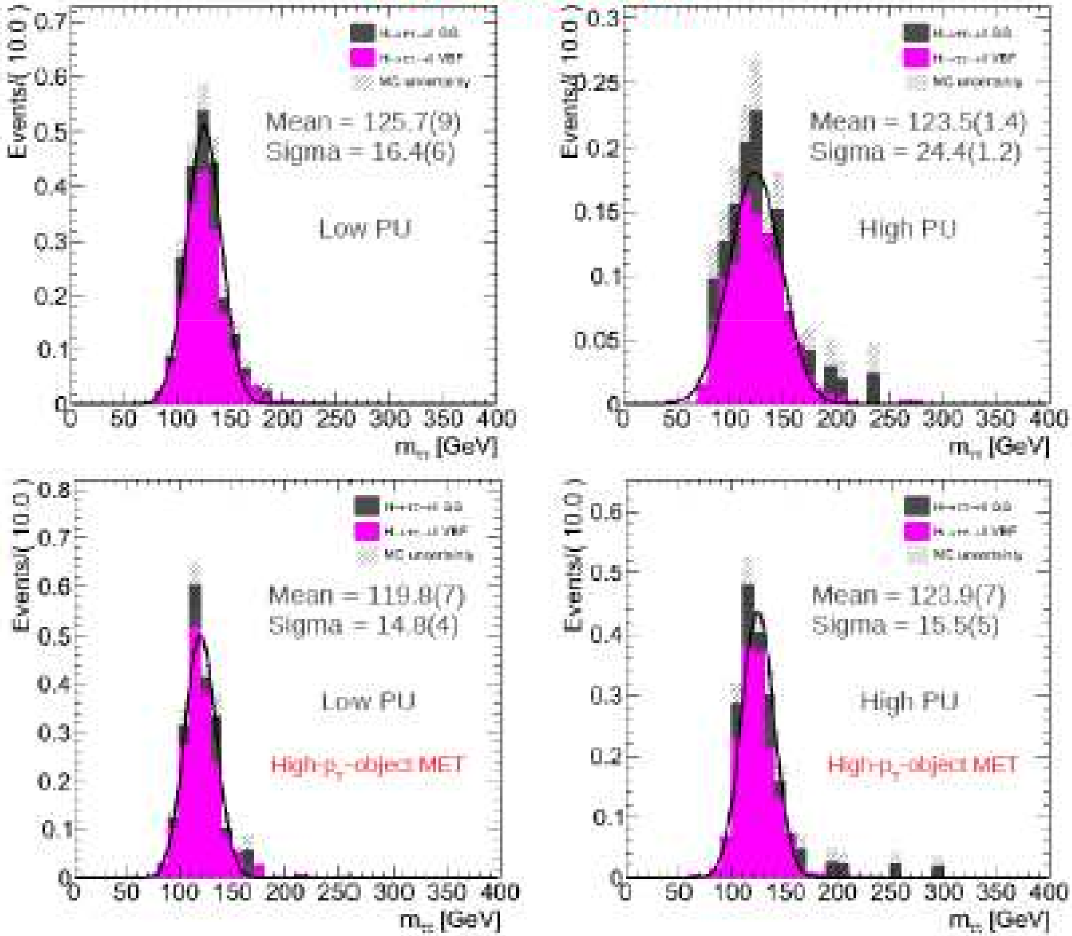
Process	Cross-section (pb) [× BR]
$W \to \ell$+jets ($\ell = e, \mu, \tau$)	10.46×10^3
$Z/\gamma^* \to \ell\ell$+jets (mass$_{\ell\ell}$ >40 GeV)	1.07×10^3
$Z/\gamma^* \to \ell\ell$+jets (10<mass$_{\ell\ell}$ <40 GeV)	3.89×10^3
$t\bar{t}$	164.6
Single top t-, s- and Wt-channels	58.7, 3.9, 15.6
Di-boson WW, WZ and ZZ	46.2, 18.0, 5.6
$gg \to H \to \tau\tau \to \ell\tau_h$	0.54
VBF $H \to \tau\tau \to \ell\tau_h$	0.041
WH $H \to \tau\tau \to \ell\tau_h$	0.0015
ZH $H \to \tau\tau \to \ell\tau_h$	0.00083

• In 2012 the high level of pileup will be one of the most challenging experimental issue.

• We have evaluated possible alternatives to the MET RefFinal

• In particular we evaluated the performance of the MET built from high p_T (analysis level) objects. **+ calo clusters validated by tracker**

VBF selection



• Mass resolution decreasing ~50% in high PU (<m>=30) samples with RefFinal, while it increases by only ~5% with high-pT objects MET