Università degli Studi di Trieste
INFN Sezione di Trieste

LOW MASS STANDARD MODEL HIGGS $\longrightarrow \tau\tau$ SEARCH

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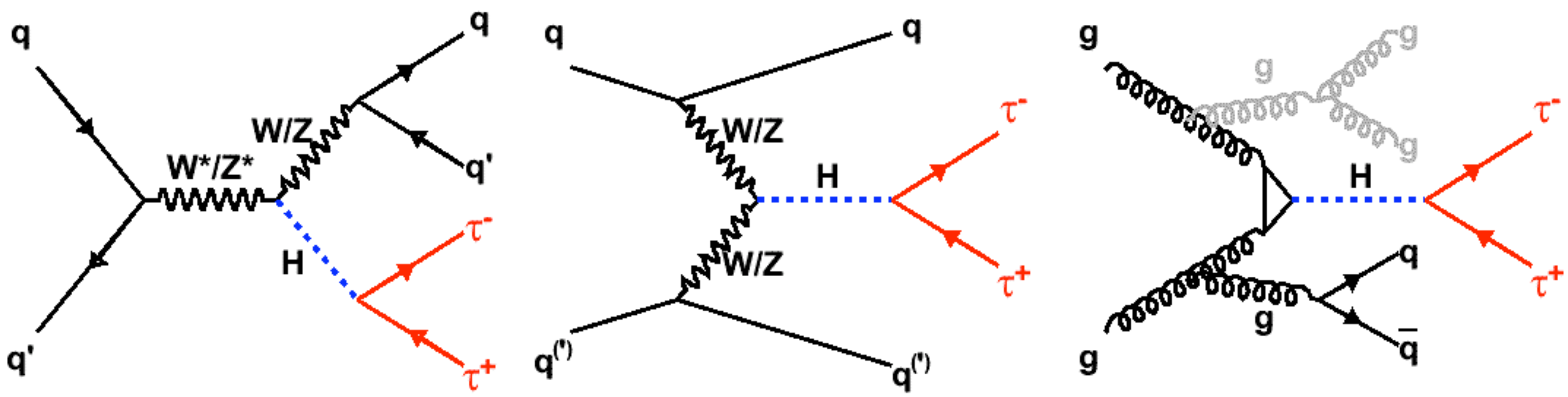
Summary

- Motivations
- Analysis strategy
- Tau identification based on Boosted Decision Trees: some details
- Status of the analysis
- Next steps

Motivations

- Improve low mass Higgs search sensitivity.
- $H \rightarrow \tau\tau$ is a decay mode complementary to $H \rightarrow bb$:
- Simultaneous search of four signal processes. Total σ x B.R. is comparable to other Higgs analyses
- Dominant background is expected to be Z->tautau+jets which is well understood

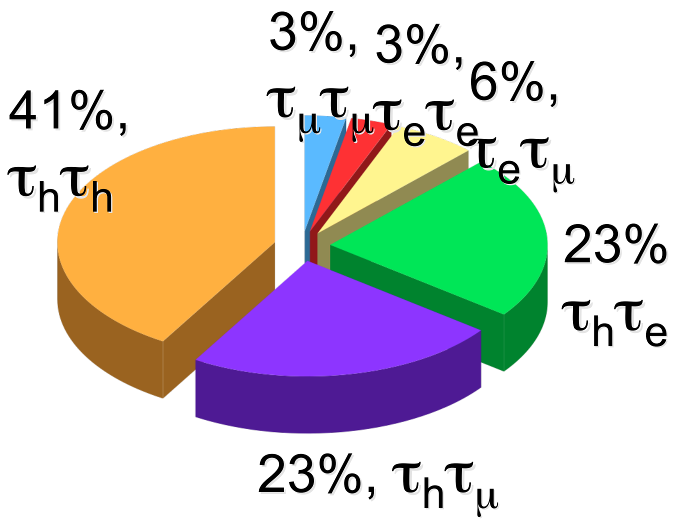


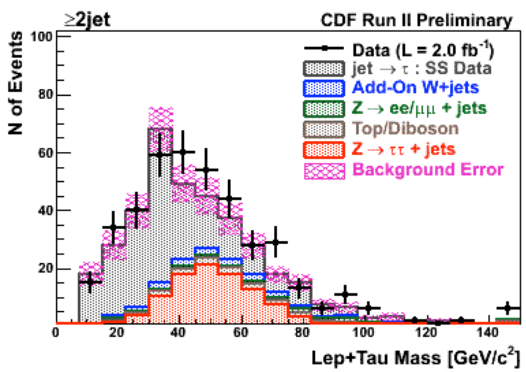
$W(\rightarrow qq') H(\rightarrow \tau\tau)$
$Z(\rightarrow qq')H(\rightarrow \tau\tau)$
VBF $qHq' \rightarrow q'\tau\tau q$
$gg \rightarrow H \rightarrow \tau\tau$

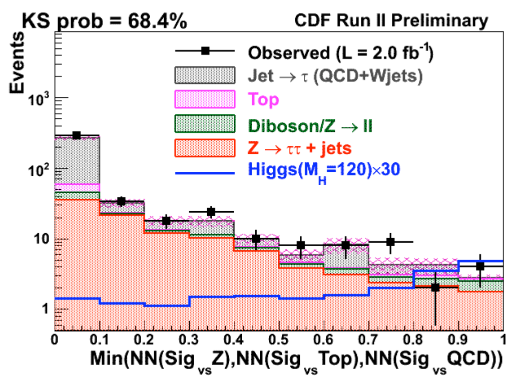
$\tau^+\tau^-$ + 2jets in the final state

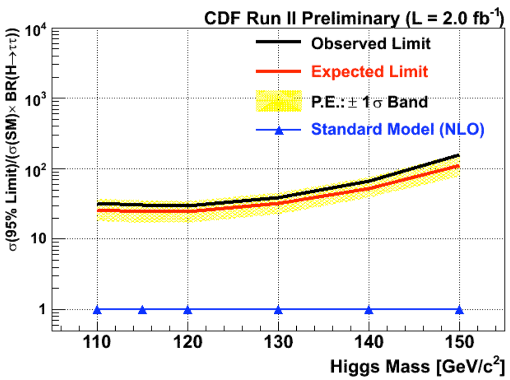
Current blessed result (K.Yorita & Y-K. Kim, note 9179)

Data: 2.0 fb^{-1} (up to period 12)
Signature: one leptonic + one hadronic tau (46% B.R.) + 2 jets
Analysis tecnique: a set of 3 artificial Neural Networks to discriminate signal from principal backgrounds (Z, tt and QCD)
obs.(exp.) limit/SM σ: 30.5 (24.8) at m_H = 115 GeV/c^2.
~10% contribution to low mass limit combination

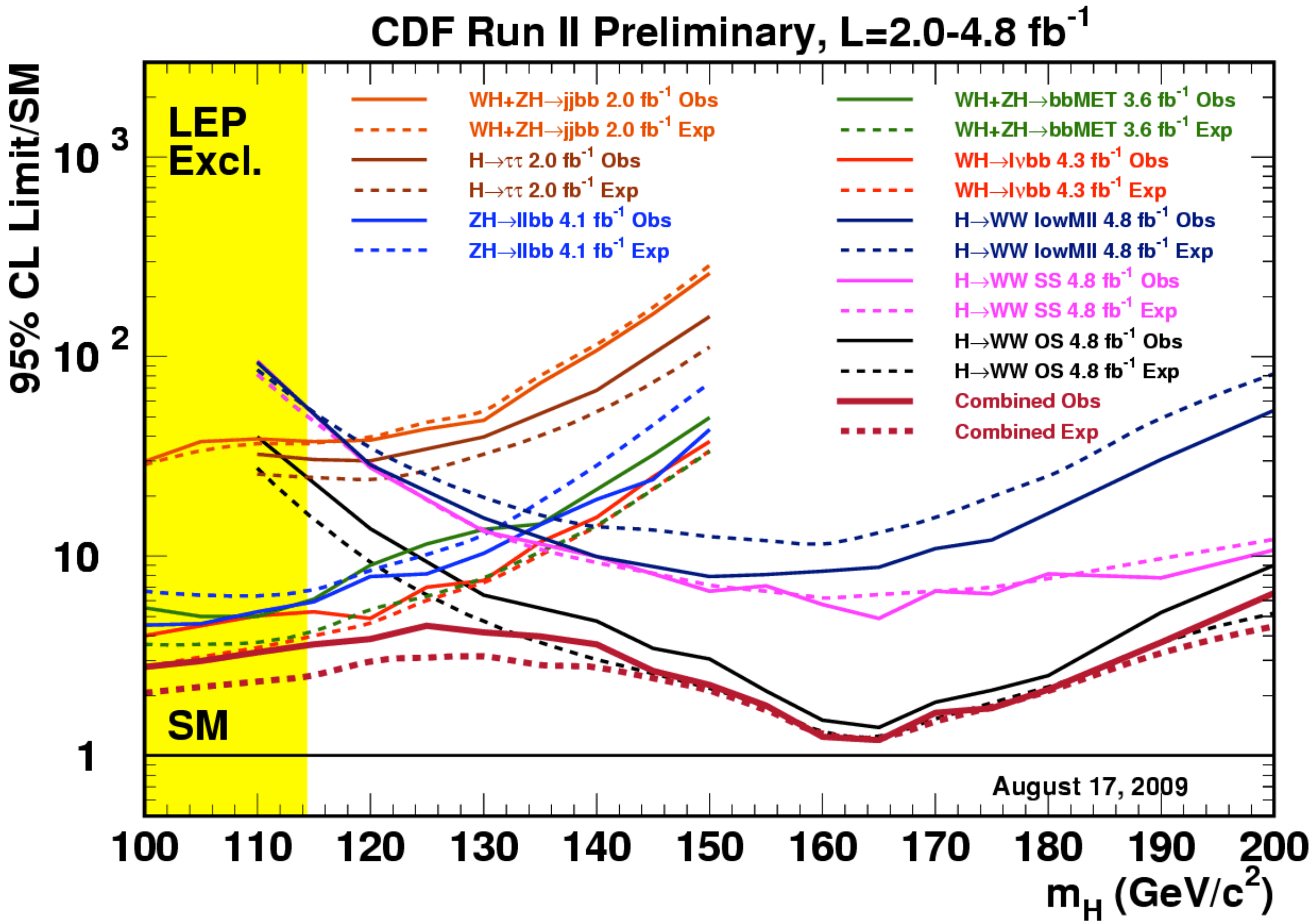








Current blessed result
(K.Yorita & Y-K. Kim, note 9179)



How can we increase sensitivity in the $H \longrightarrow \tau\tau$ channel?

Many possibilities for improvements in the analysis.

- **adding more data**

- **Improve sensitivity by implementing a new hadronic tau identification algorithm**

- **adding 0jet and 1jet channels**

- **looking at other decay modes**

How can we increase sensitivity in the $H \rightarrow \tau\tau$ channel?

Many possibilities for improvements in the analysis.

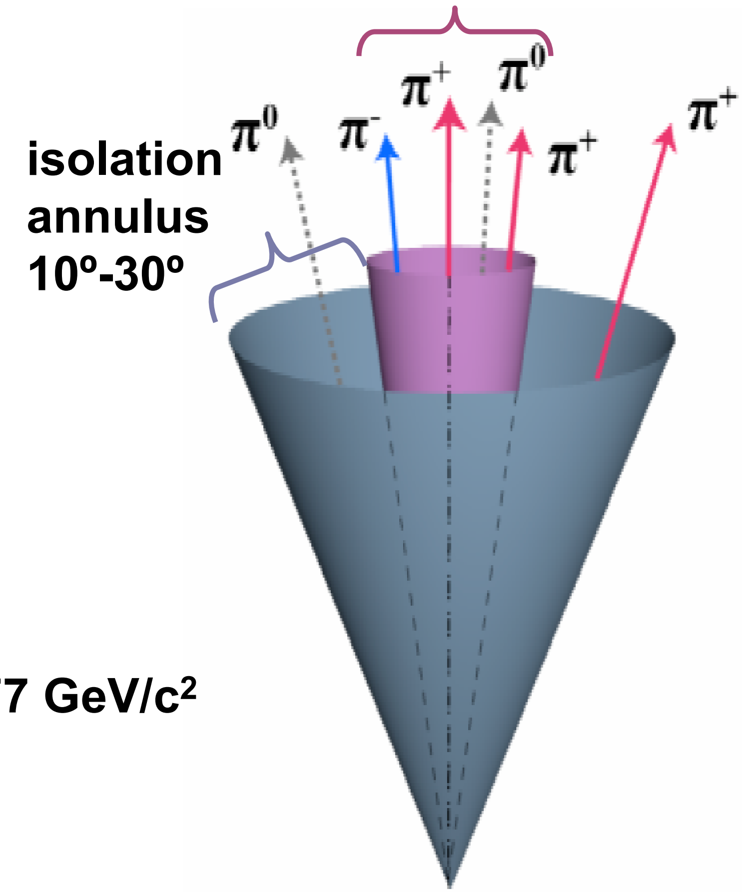
- **adding more data** → It is in our plans to double the data analyzed (4 fb^{-1}) by the end of 2009
- **Improve sensitivity by implementing a new hadronic tau identification algorithm** → I dedicated the second year of my Ph.D. to this work (see note 9667) and I will give more details in the next slides
- **adding 0jet and 1jet channels** → Acceptance can increase x4, but backgrounds become overwhelming
- **looking at other decay modes** → $\tau_e + \tau_\mu$ channel should be straightforward:very clean signature (no DY bkg); +6% acceptance almost for free

CDF tau identification

TAUS decay modes:

$\tau \longrightarrow e\nu_\tau\nu_e$
$\tau \longrightarrow \mu\nu_\tau\nu_\mu$ } leptonic decay B.R. 35%

$\tau \longrightarrow X_h\nu_\tau$ hadronic decay
B.R. 65%
(X_h mainly $\pi^{\pm 0}$,small frac. o kaons)



HADRONIC TAUS

- **a narrow calorimeter jet;**
- **charged tracks with low multiplicity (1 or 3)**
- **reconstructed neutral pions**
- **Invariant mass of hadron system $M_h < M_\tau = 1.777$ GeV/c^2**

STANDARD TAU IDENTIFICATION

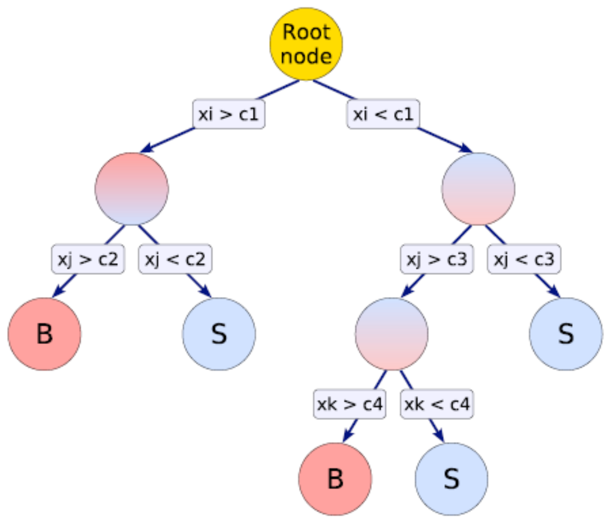
- **two-cone based algorithm**
- **a set of rectangular cuts on tracks and neutral pions**
- **objects in isolation region are used to veto tau-like QCD-jets**

Can we improve tau identification?

CUT-BASED identification ⟶ MULTIVARIATE approach

- All information available in each event is used
- Correlations between different variables are taken into account
- Discrimination between different objects (in our case taus and tau-looking jets) can be more powerful

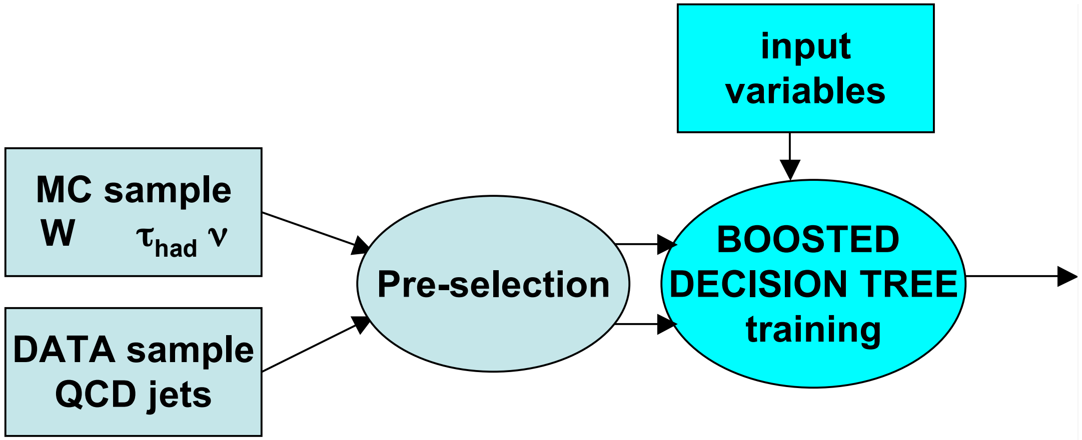
We tested a classifier method based on the BOOSTED DECISION TREES

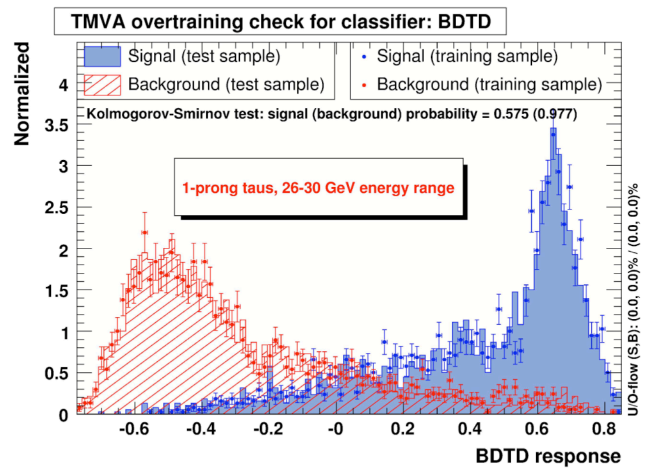


A DECISION TREE: a sequence of rooted binary splits
Ingredients :1) a <u>training sample</u> for signal and background
2) a set of <u>discriminating variables</u>
At the end of a splitting, an event is classified as "signal"(+1) or "background"(-1)

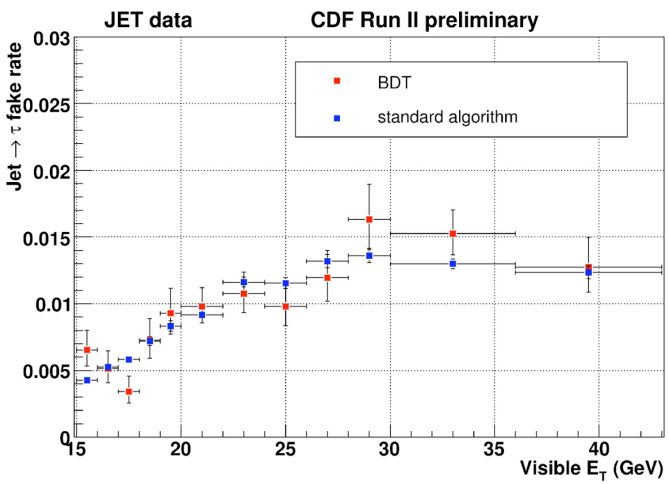
BOOSTING: N trees are created. Events misclassified in the N-th tree, are given an <u>increased weight</u> in the (N+1)th tree.
An event final score is given by the weighted average of different tree outputs

New algorithm based on BDTs trained to discriminate hadronic taus from QCD jets

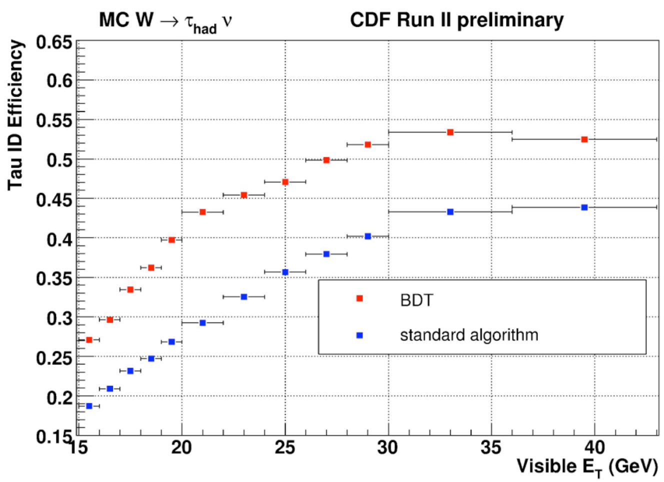




jet → τ fake rate



MC τ_{had} efficiency



With a similar jet → τ fake rate, corresponding efficiency is increased of about 15%.

Scale factor: more detail in next slides

Analysis overview

-We use **"Lepton+Track" trigger**: CEM/CMUP/CMX + an isolated track

-Final state:

1) one tight lepton (e or μ) with Pt > 10 GeV
2) one hadronic tau with visible Pt>15 GeV:
   first step: std ID for code validation by comparing with Kohei's results
   second step: BDT-ID implementation; output lower cuts are chosen in order to keep the same signal acceptance as std ID(and then maximize fake rejection)
3) two jets 0.4cone (0-jet and 1-jet events used as control regions)

-Minimal event selection:

- Primary vertex Z_0 < 60 cm and class>=12
- Leptons are required to have opposite sign (OS)
- Leptons are required to be separated DR>0.4, close in Z (ΔZ<5 cm) and close to primary vertex (ΔZ_0 < 5 cm)
- Z veto (ee/$\mu\mu$)
- Cosmics and conversions rejection
- MET corrected for muon and jets
- leading jet with E_T > 20 GeV

Background estimation

-**Physics background**: Z → ττ, Z → ee, Z → μμ

ZZ/WW/WZ/tt

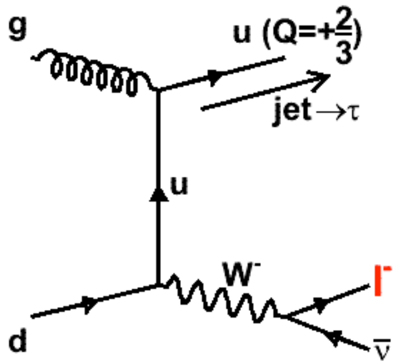
estimated from MC (Pythia) and normalized to the theoretical cross section

-**Fake background**: jet → τ

based on SS DATA

1) QCD/γ+jets

symmetric in charge (OS ≈ SS)



2)W+jets OS vs SS asymmetry: additional W+jets (N_{OS}-N_{SS}) estimated from Alpgen MC
(followed the procedure described in 9179)

3)Small correction to avoid double counting of jet → τ in Z → ee and Z → μμ MC.

TAU ID SF evaluation

- We scale the number of the events to the $Z \rightarrow \tau\tau$ cross section

$$\sigma(Z \rightarrow \tau\tau) = \frac{N_{obs} - SF_{IDtau} N_{bkg}^{MC} - N_{bkg}^{SSdata}}{A \times \varepsilon_{trig} \times SF_{IDlep} \times SF_{IDtau} \times \int Ldt}$$

where
N_{obs} = number of observed events
N_{bkg} = background expectation without $Z \rightarrow \tau\tau$ in the mass range
66 GeV/c^2 < $M_{\tau\tau}$<116 GeV/c^2
A = acceptance
ε_{trig} = trigger efficiencies (electron+track and muon+track)
SF_{IDlep} = ID scale factors for electron and muons
σ = 251.3 pb theoretical value for cross section

$$SF_{IDtau} = \frac{N_{obs} - N_{bkg}^{SSdata}}{\sigma \times A \times \varepsilon_{trig} \times SF_{IDlep} \times \int Ldt + N_{bkg}^{MC}} = 0.99 \pm 0.07$$

Results: background summary 2.3 fb^{-1}

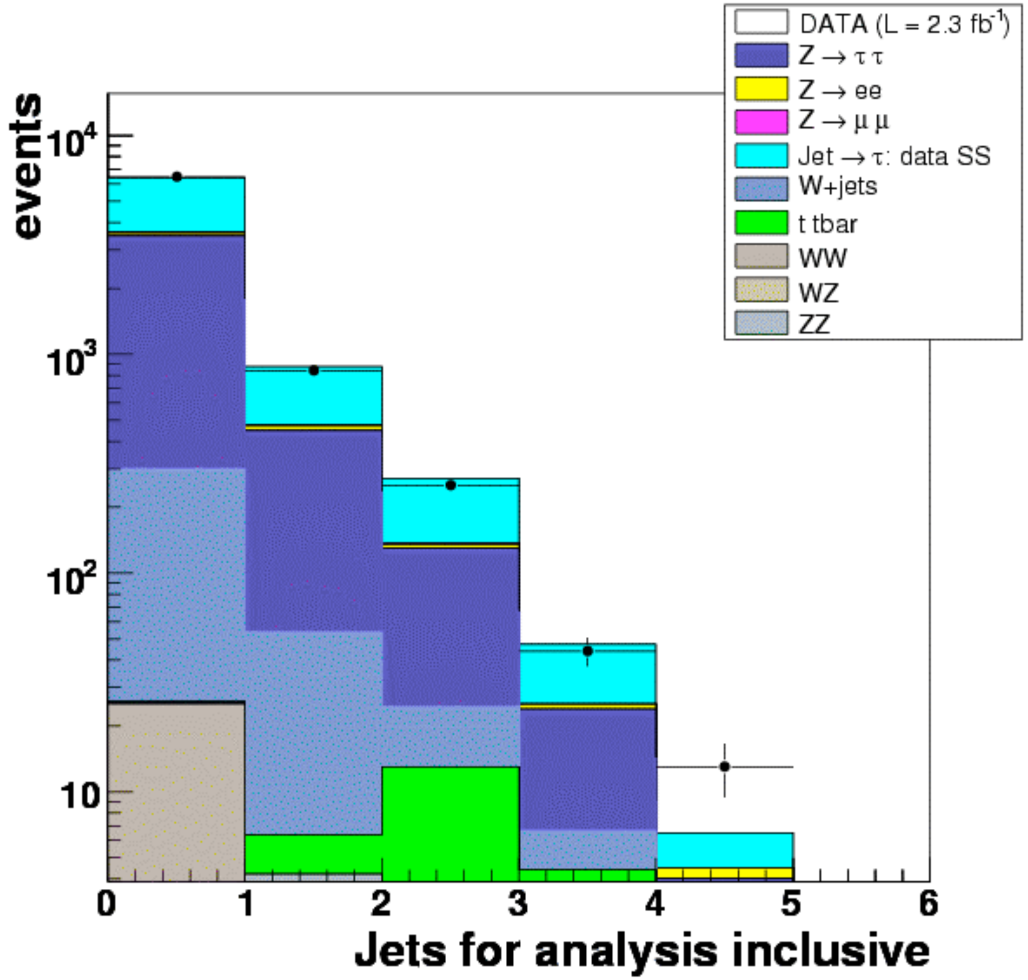
Number of expected events	standard ID first stage	BDT ID second stage	diff(%)
Z/γ^* $\tau\tau$	3583	3702.5	+3
Z/γ^* ee	150.1	133.1	-11
Z/γ^* $\mu\mu$	102	26.5	-74
WW/WZ/ZZ	32.6	31.9	-2
t tbar	19.1	18.8	-2
jet τ (SS data)	4809	3361	-30
add-on W-jets	582.4	350.6	-40
TOTAL BKG	9278	7624	-18
DATA	9509	7634	-20

Results: background summary 2.3 fb^{-1}

Number of expected events	0 – jet	1 – jet	>=2 jets
Z/γ^* $\tau\tau$	3182.7	393.9	125.9
Z/γ^* ee	103.5	22.8	6.8
Z/γ^* $\mu\mu$	22.7	2.8	1.0
WW/WZ/ZZ	25.4	4.2	2.2
t tbar	0.2	2.1	16.5
jet τ (SS data)	2798	405	158
add-on W-jets	272.5	47.6	14.2
TOTAL BKG	**6405**	**878.4**	**324.6**
DATA	**6481**	**841**	**312**

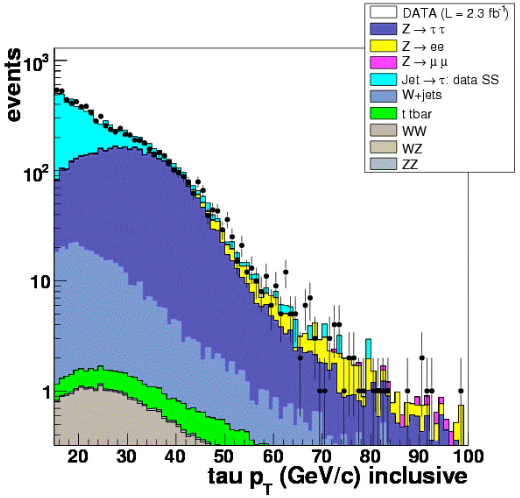
EXPECTED SIGNAL IN 2.3 fb^{-1}(2-JET channel) ~ 0.7 Higgs

Results: some plots

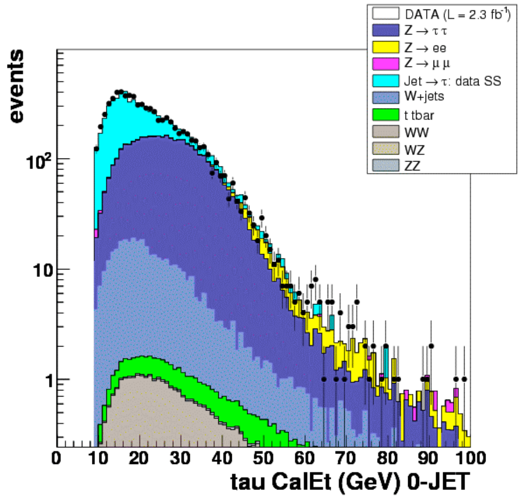


Results: some plots

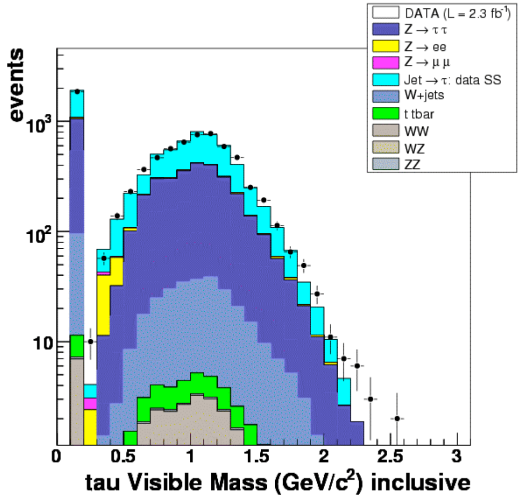
Tau Visible Pt



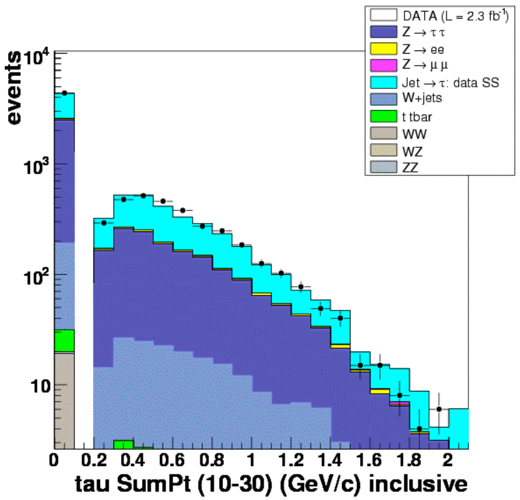
Calorimeter Et



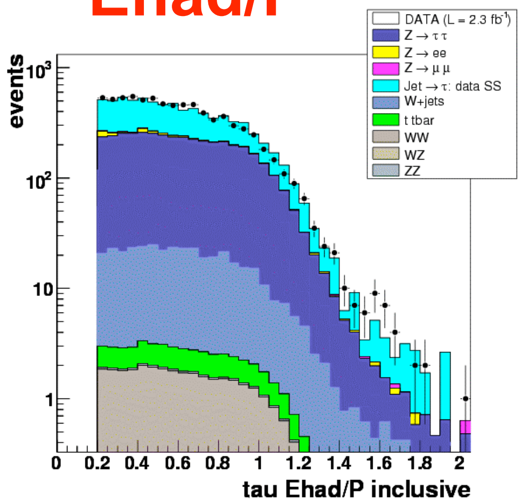
Visible Mass



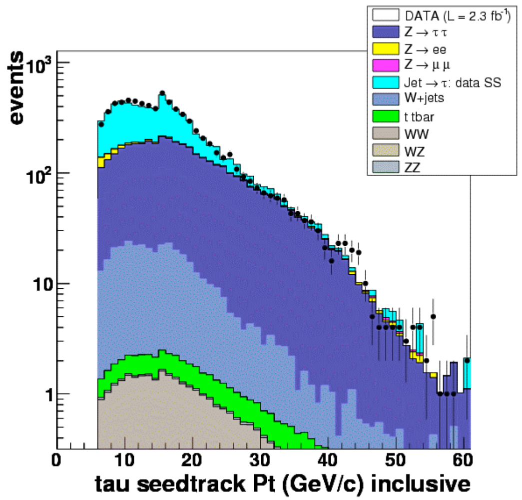
SumTrackPtIso



Ehad/P

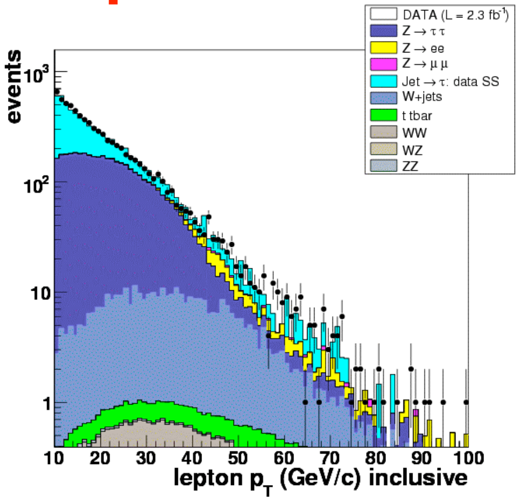


SeedTrackPt

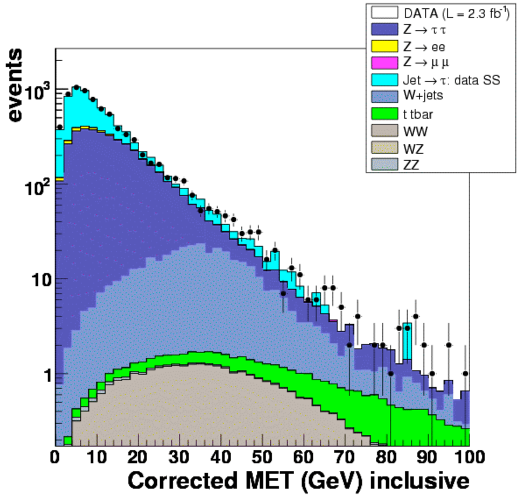


Results: some plots

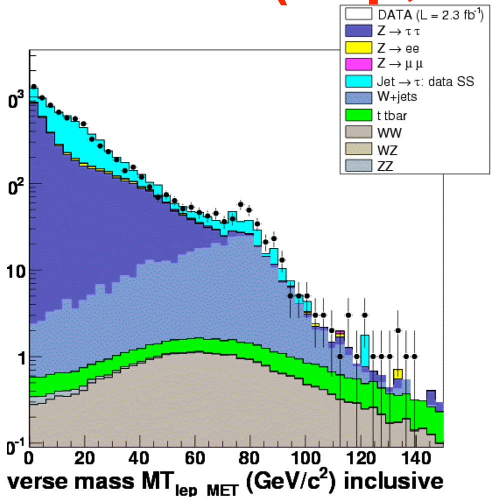
Lepton Pt



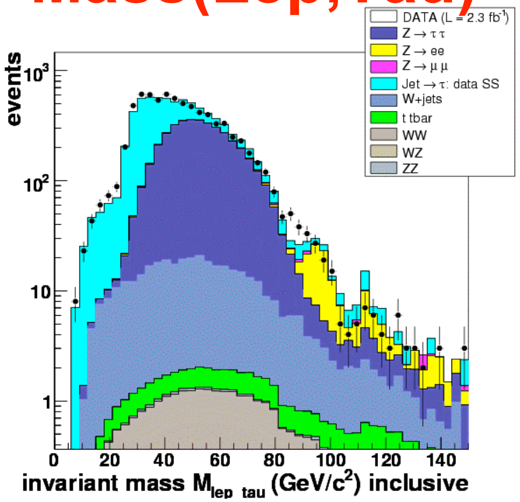
Met



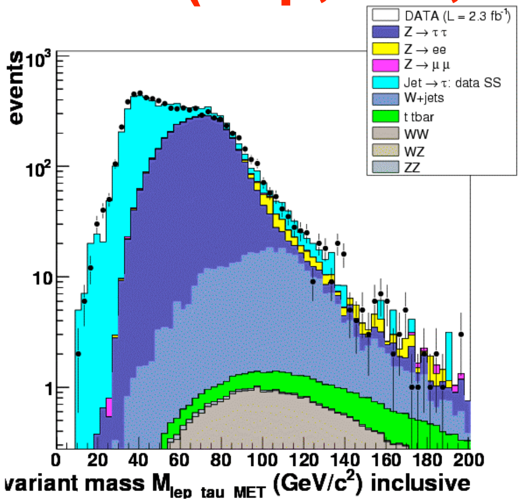
TMass(Lep,Met)



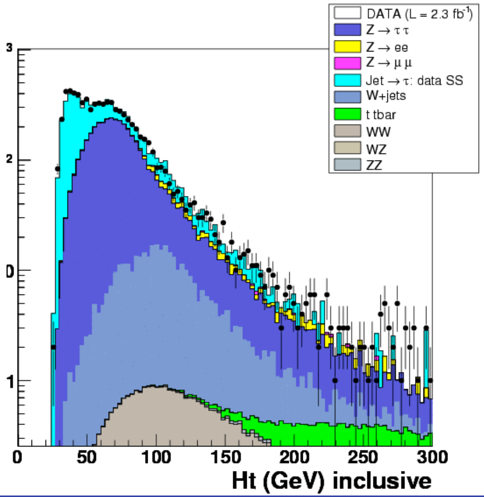
Mass(Lep,Tau)



Mass(Lep,Tau,Met)



SumEt



Conclusions and future steps

• **BDT performances are really good and promising;**

• **Background is pretty well modeled: some small discrepancies are unde investigation;**

IN PROGESS:

• **Systematics evaluation;**

• **BDT training for final event signal vs. background discrimination;**

• **Extension to 4 fb^{-1}: waiting for the trigger efficiencies for the last period (end of September).**