$e^+e^- \rightarrow HA \rightarrow bbbb$ at 1 TeV ILC

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Motivation

- In addition of precision measurements of discovered 126 GeV Higgs boson, ILC also has potential for direct searches of additional states of extended Higgs sector.

- Sensitivity of heavy Higgs pair production is expected to be close to kinematic limit of 1/2 $\sqrt{s}$.

- The ILC with $\sqrt{s}$ = 1 TeV can directly study extra Higgs bosons with masses less than 500 GeV in relatively low tanβ regions, which can't be detected easily in LHC.

- Also decoupling limit approaches relatively faster if Higgs masses are greater than 200 GeV, in which case additional Higgs bosons almost degenerates in mass and have similar decay properties.

Introduction

- Aim is cross-section and mass measurement for the process
  $e^+e^- \to HA \to bbbb$ at $\sqrt{s} = 1$ TeV.

- Integrated luminosity of 1000 fb^{-1} is assumed.

- Generated sample of HA→bbbb signal using Whizard, Pythia used for decay, with following specifications:

  same mass for both particles, 400 GeV
  $tan\beta = 10$
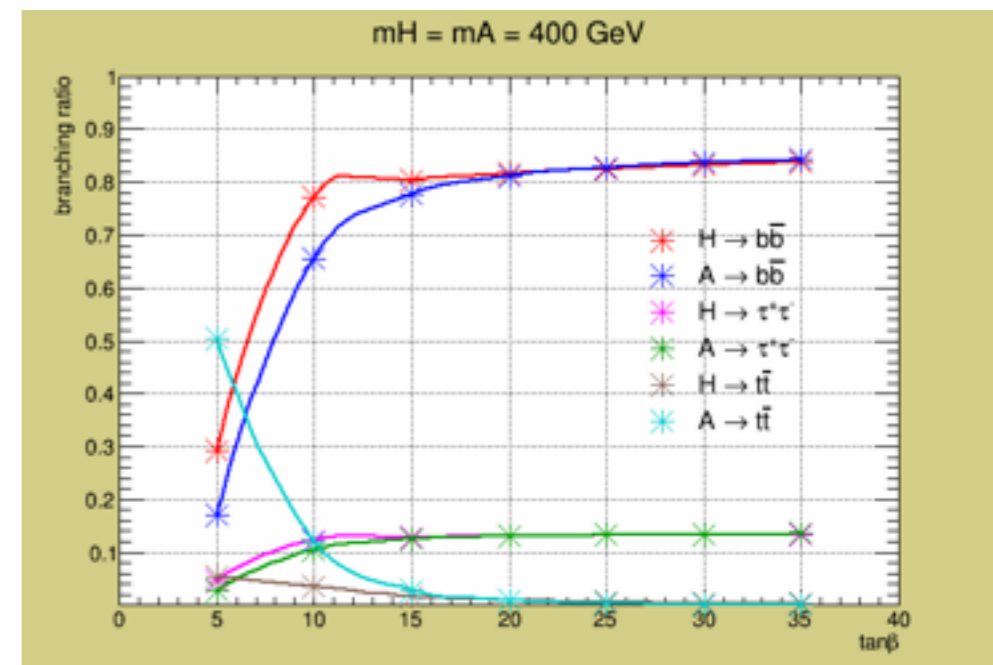 x-section: $\sqrt{s} = 1$ TeV 2.38 fb
  prominent decay into bb(bar)
  Branching fraction for H → bb 77%
  A → bb 65%

- HA production is usually independent of tanβ but branching fraction depends on the tanβ.

4 jet events are selected using mass reconstruction.

- Reconstruction using ChiSquare minimization

  -- same mass is assumed for both particles

$$\chi^2 = \sum (M_{ij} - M_{kl})^2$$

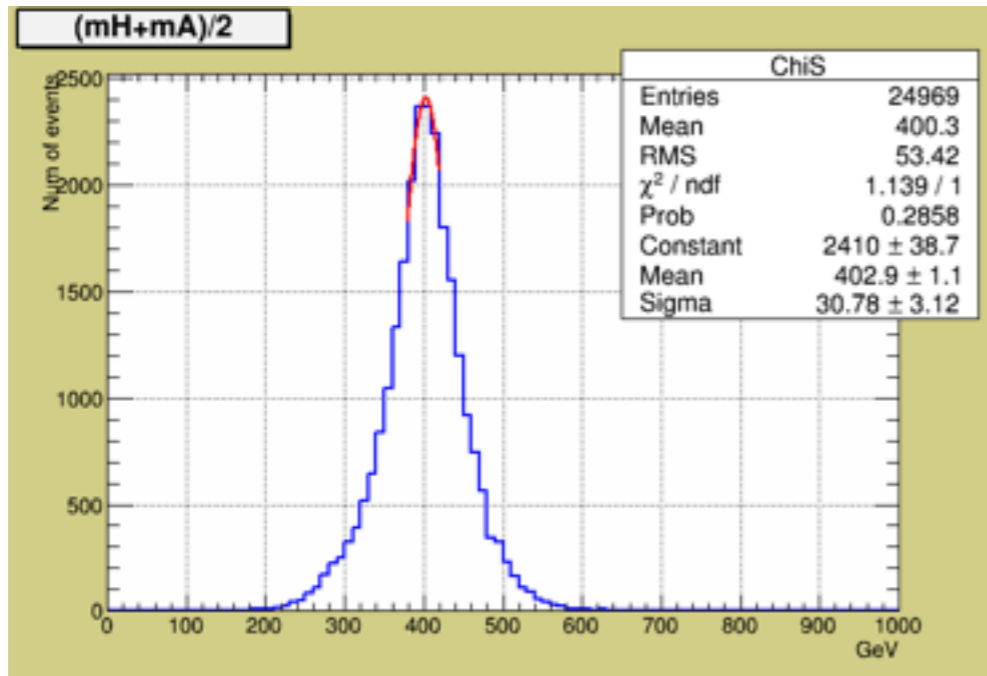 -- three set of jet pairs possible
  -- set of jet pairs with minimum ChiSquare are selected

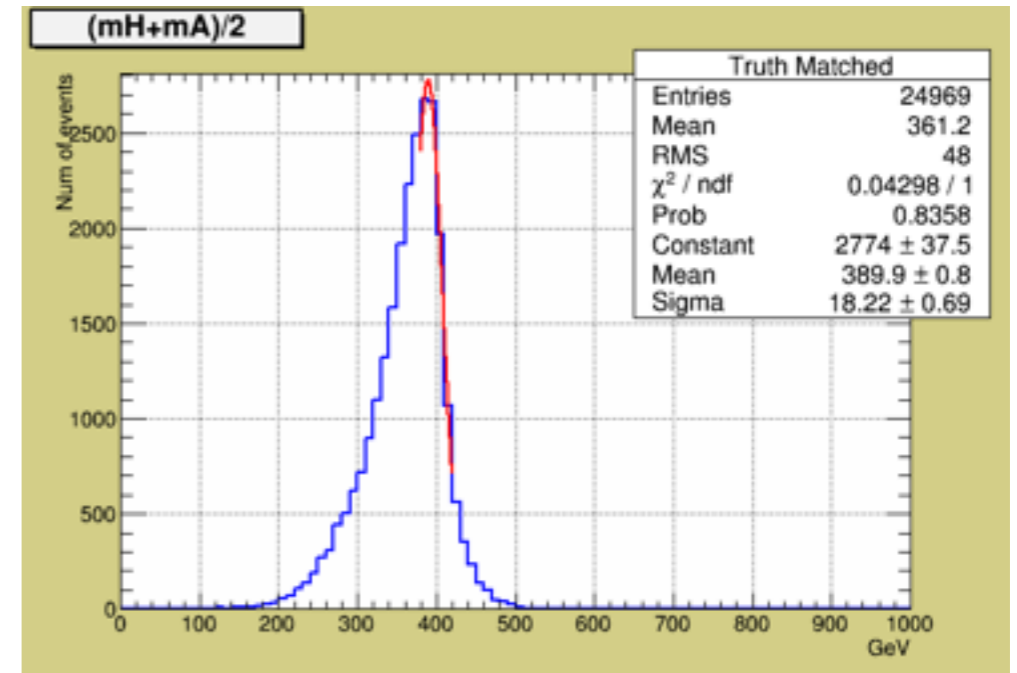- Reconstruction using truth-matching

  -- associate the reconstructed jets to generated b-quarks from
     H/A decays using minimum ΔR between the jet and parton.
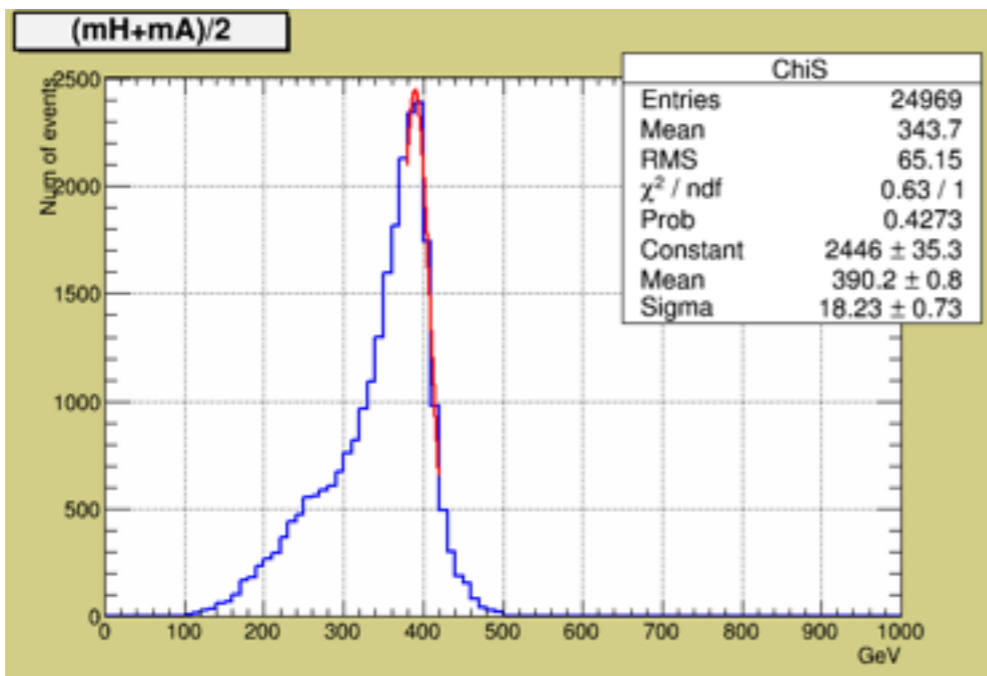 -- in case of duplication, next minimum ΔR is selected.

Truth match jets : Durham

ChiSquare selected jets : kT

kT algorithm with R=1.1

kT algorithm removes some of beam backgrounds resulting in better resolution.

Chi square selected kT jets used for analysis.

SM Backgrounds

Main backgrounds giving same final states are

bosons related:

    Z hadronic

    ZZ hadronic

    WW hadronic

    ZZWWMix hadronic

top pair related

    ttbb : all decay states

    tth : consists of decay states

        tth-2l2nbb-hbb, tth-2l2nbb-hnonbb

        tth-ln4q-hbb, tth-ln4q-hnonbb
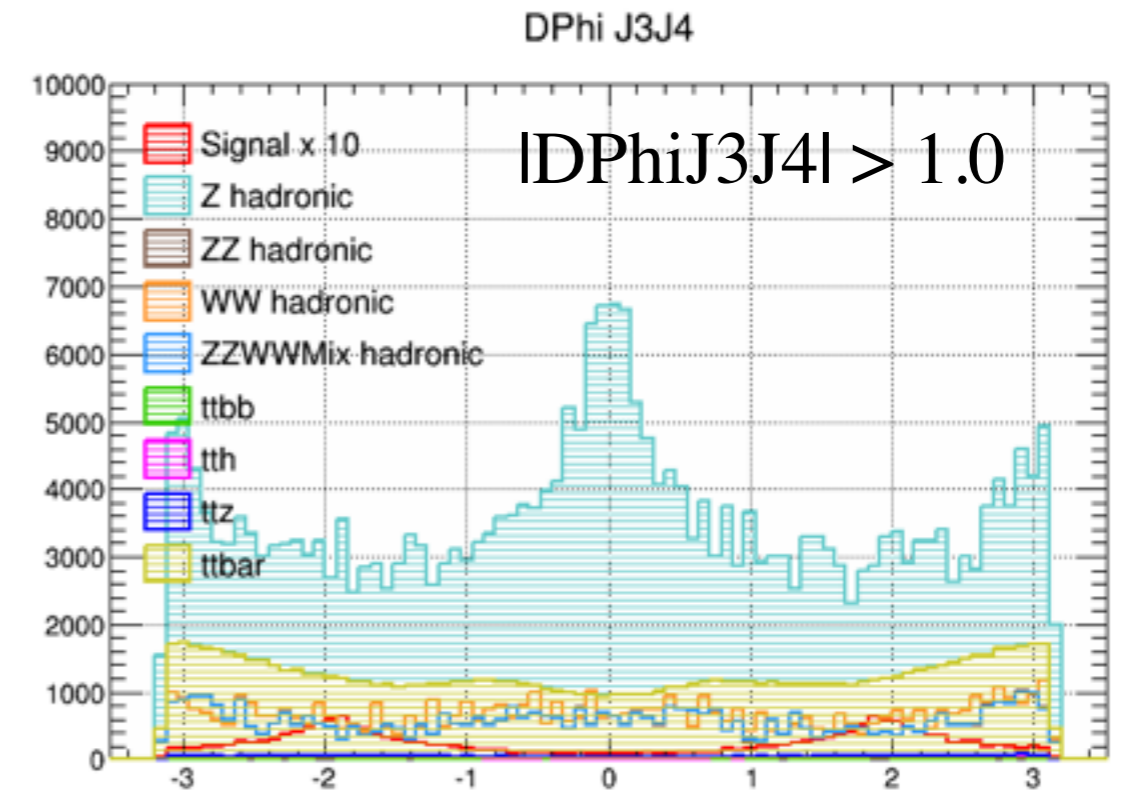
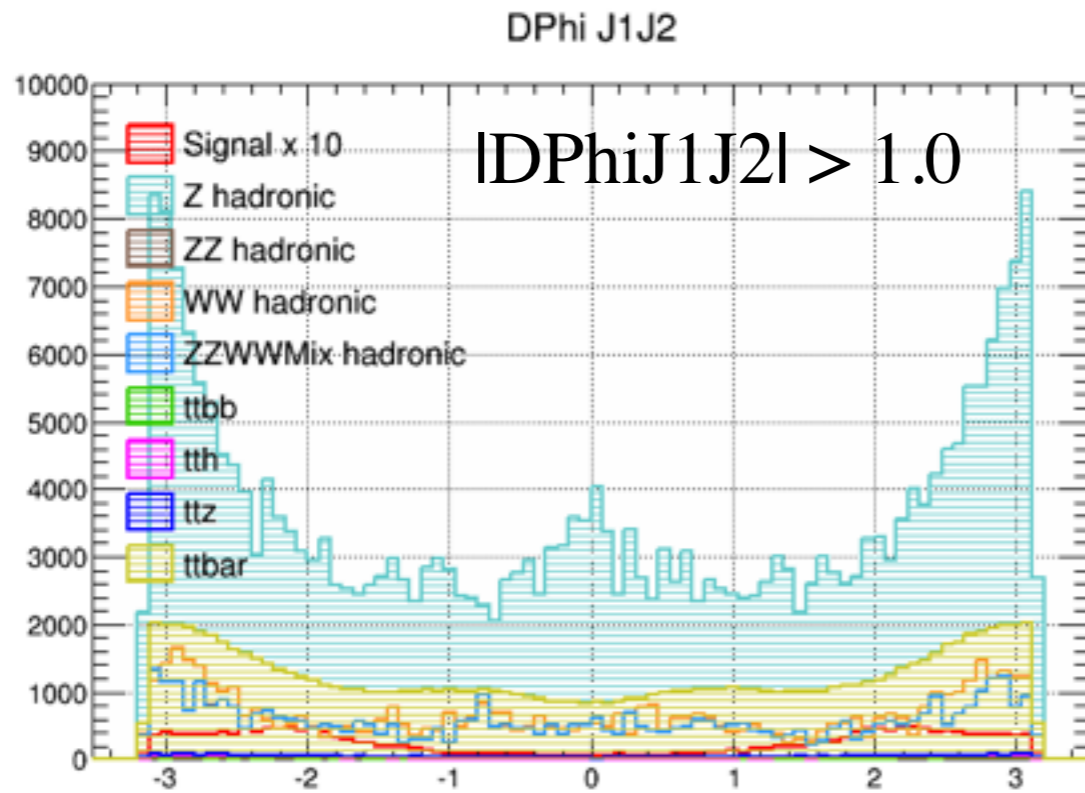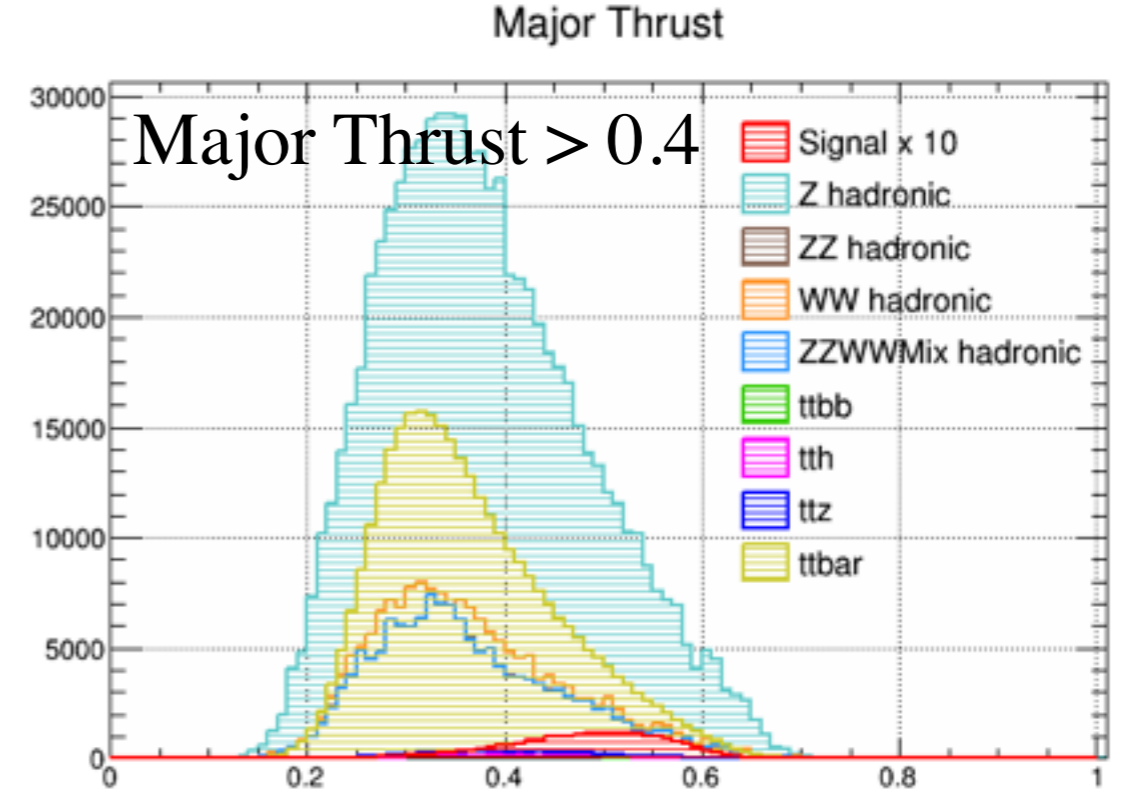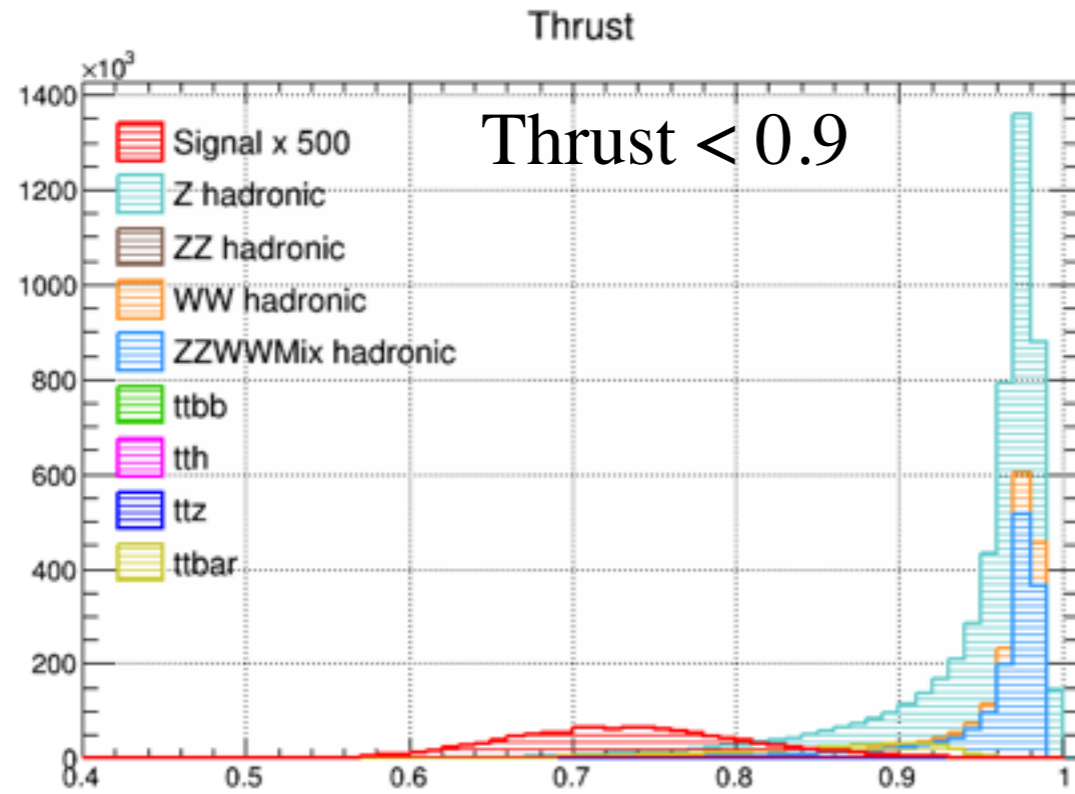   tth-6q-hbb, tth-ln4q-hnonbb

    ttz : all decay states.

    ttbar : ttbar decaying to 6 fermions.

Cross-sections at (-0.8, +0.2) polarity

Cross-sections (fb)	eL.pR	eR.pL
Signal	2.27833	0.108
Z had	5062.662	208.134
ZZ had	162.806	4.61696
WW had	1811.6784	0.3517804
ZZWWMix had	1509.4836	1.1612
ttbb	3.184	0.106
tth	3.184	0.106
ttz	3.81691	0.174685
ttbar	436.488	10.0134

All samples generated using Whizard and Pythia.

Selection

b-tag sum > 3.6

(mH+mA)/2

Legend: Signal x 5, Z hadronic, ZZ hadronic, WW hadronic, ZZWWMix hadronic, ttbb, tth, ttz, ttbar
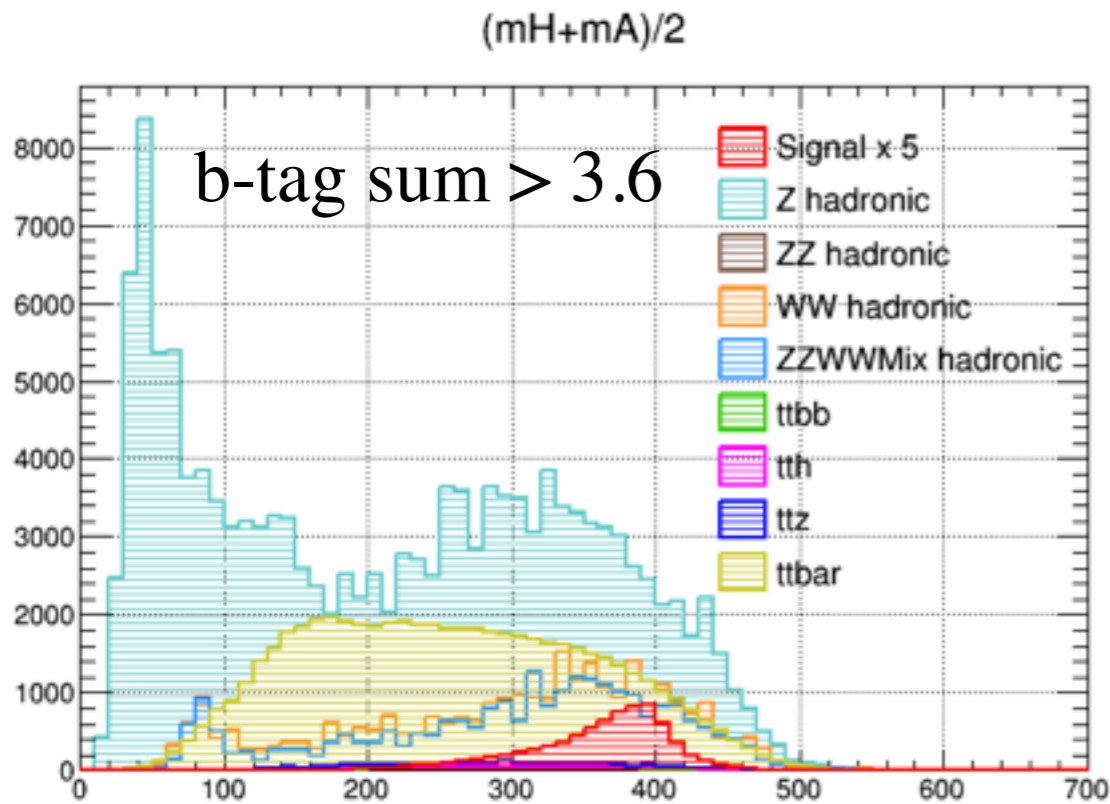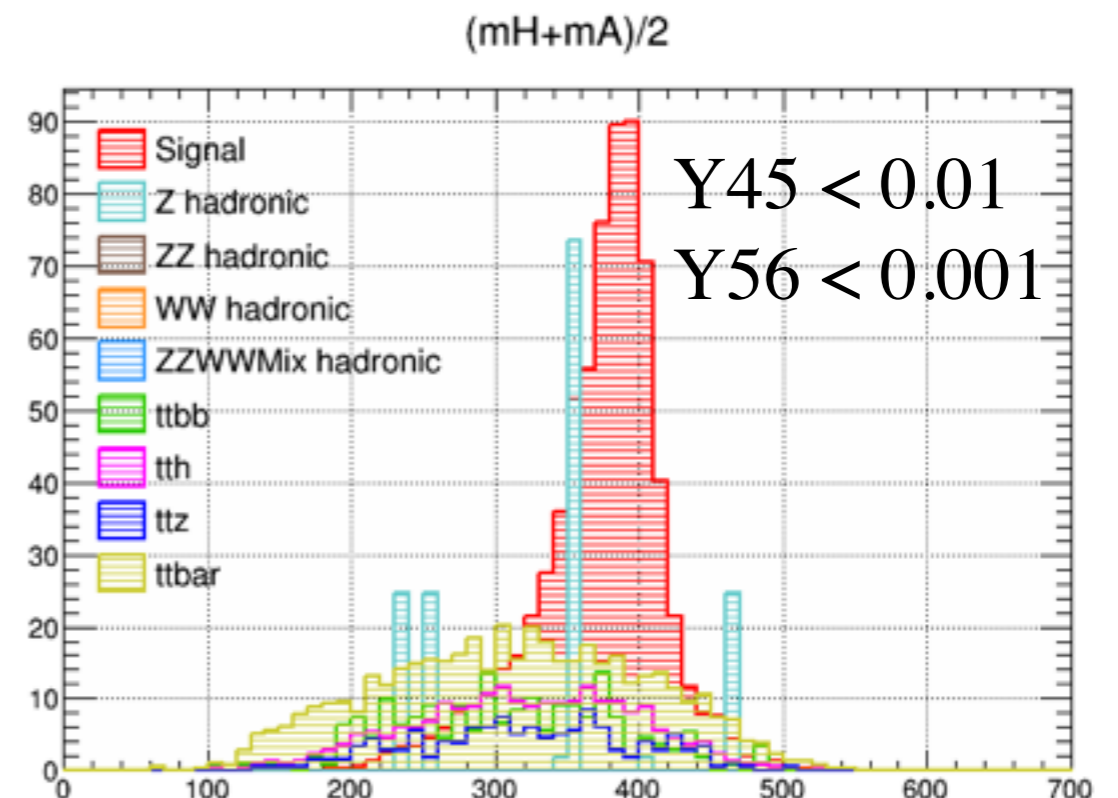
Selection Cuts:
- Cut 1 : Principal Thrust < 0.9
- Cut 2 : Major Thrust > 0.4
- Cut 3 : DPhi jet pairs > 1.0
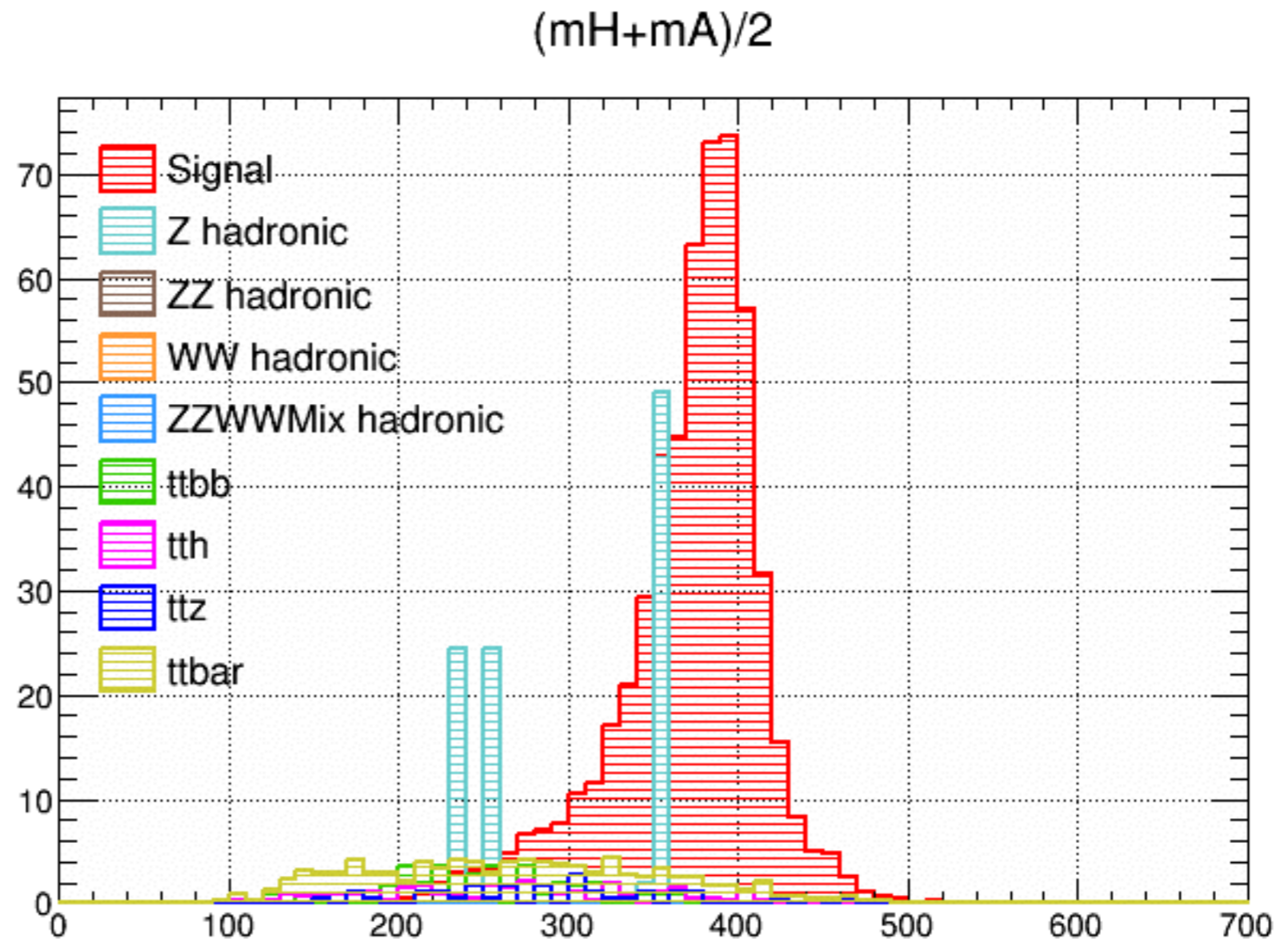- Cut 4 : Sum of b-tag > 3.6
- Cut 5 : Y45 < 0.01, Y56 < 0.001

After applying b-tagging still lots of top backgrounds left.

To remove rest of the top background we apply cut on Y45 and Y56.

Y45 < 0.01
Y56 < 0.001

(mH+mA)/2

Legend: Signal, Z hadronic, ZZ hadronic, WW hadronic, ZZWWMix hadronic, ttbb, tth, ttz, ttbar

Cut-flow table

Sample Cuts	Signal	Z hadronic	ZZ hadronic	WW hadronic	ZZWW hadronic	ttbb	tth	ttz	ttbar	S/√S+B
Total	2386.33	5270800	167423	1812030	1510644.8	3290.41	3290.38	7745.81	446502	
Cut1	2350.28	750468	29191.3	170671	145347	3105.68	3273.38	7601.05	313995	
Eff %	98.49	14.24	17.44	9.42	9.62	94.38	99.48	98.13	70.32	1.97
Cut 2	1993.37	283567	10311.5	53921.2	45997.6	1260.25	1886.81	3902.77	97774.4	
Eff %	83.53	5.38	6.16	2.97	3.04	38.30	57.34	50.38	21.89	2.81
Cut 3	1547.04	141117	5641.3	29338.1	24717.6	781.53	1233.49	2473.94	57627.3	
Eff %	64.83	2.68	3.37	1.62	1.63	23.75	37.49	31.94	12.68	3.01
Cut 4	695.84	150.93	0	0	0	193.38	215.47	121.96	449.59	
Eff %	29.16	- -	- -	- -	- -	5.88	6.55	1.58	0.10	16.28
Cut 5	553.42	99.99	0	0	0	33.57	28.15	20.63	95.26	
Eff %	23.19	- -	- -	- -	- -	1.02	0.85	0.27	0.02	19.20

Final selection:

(mH+mA)/2

Legend:
- Signal
- Z hadronic
- ZZ hadronic
- WW hadronic
- ZZWWMix hadronic
- ttbb
- tth
- ttz
- ttbar

After applying these cuts :

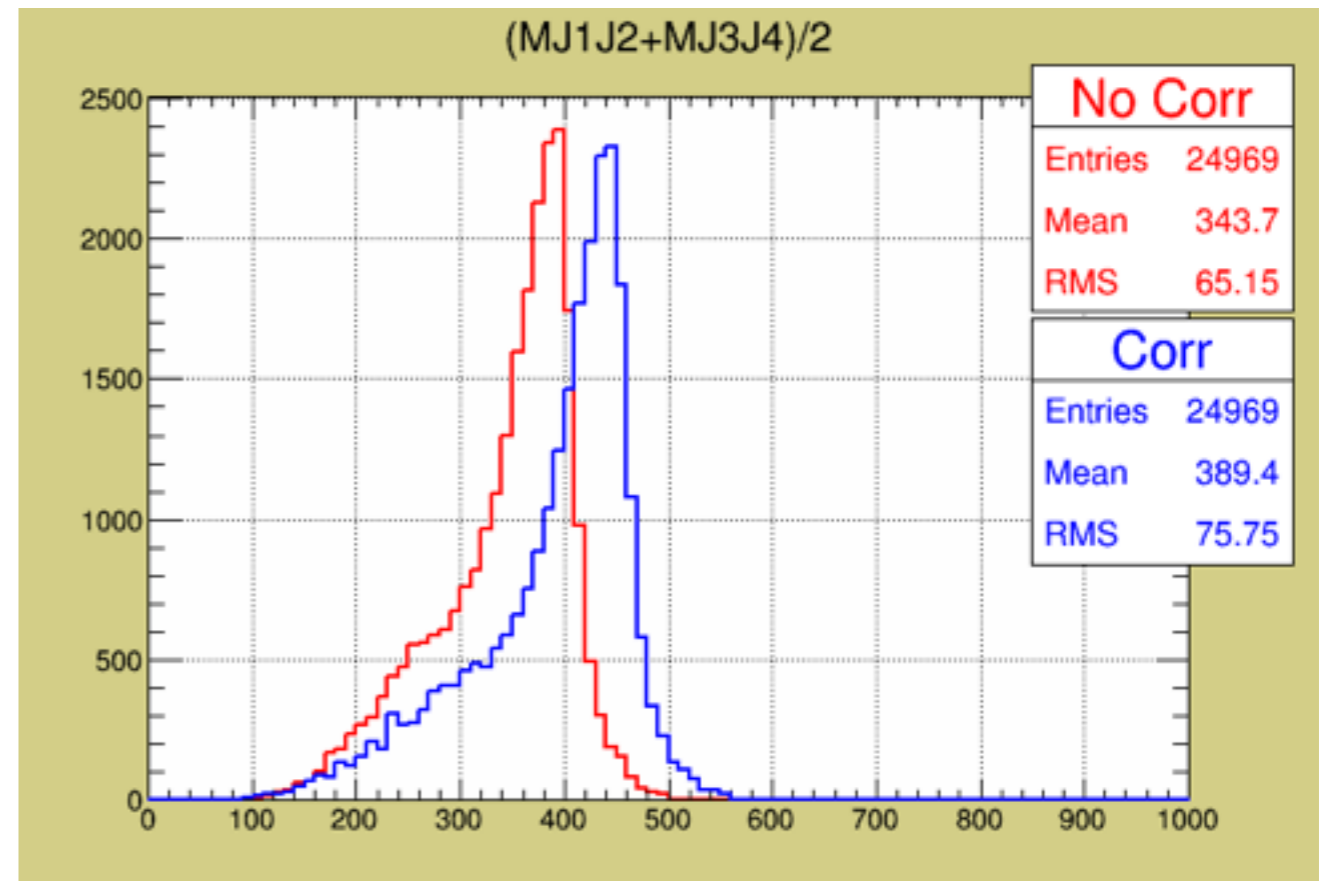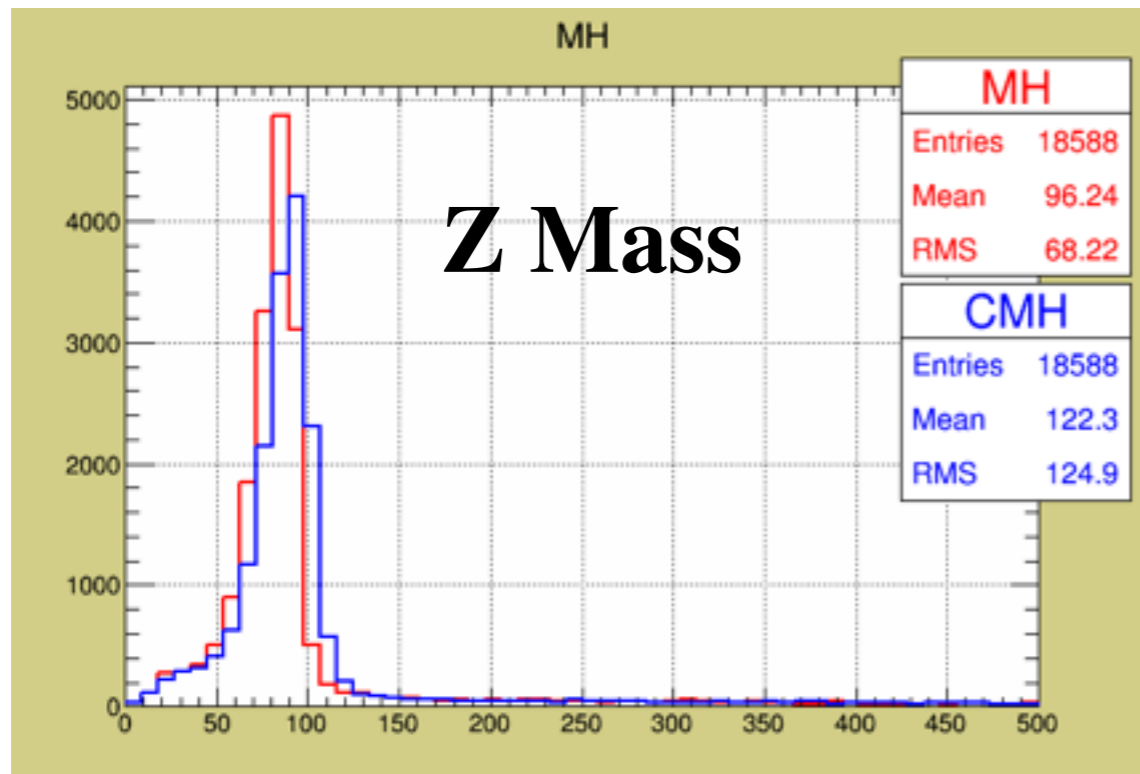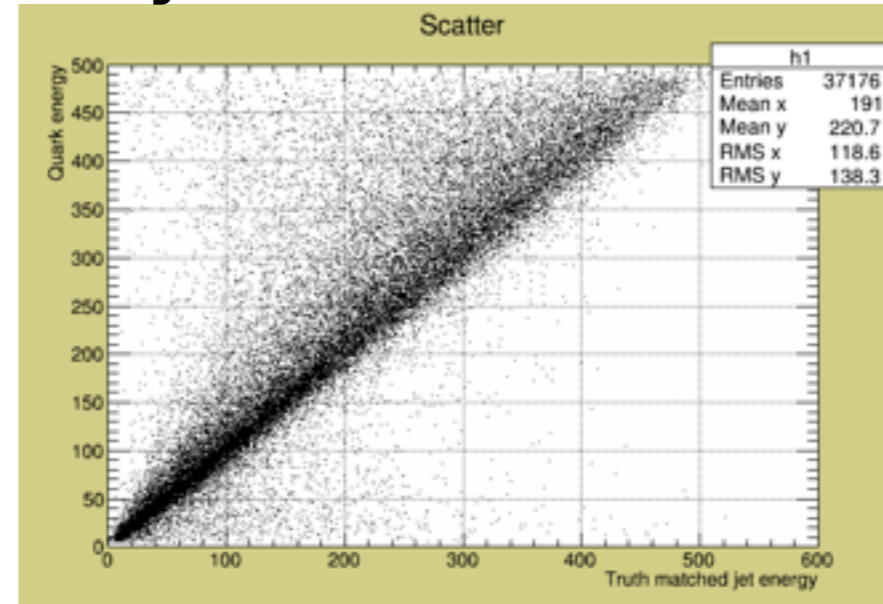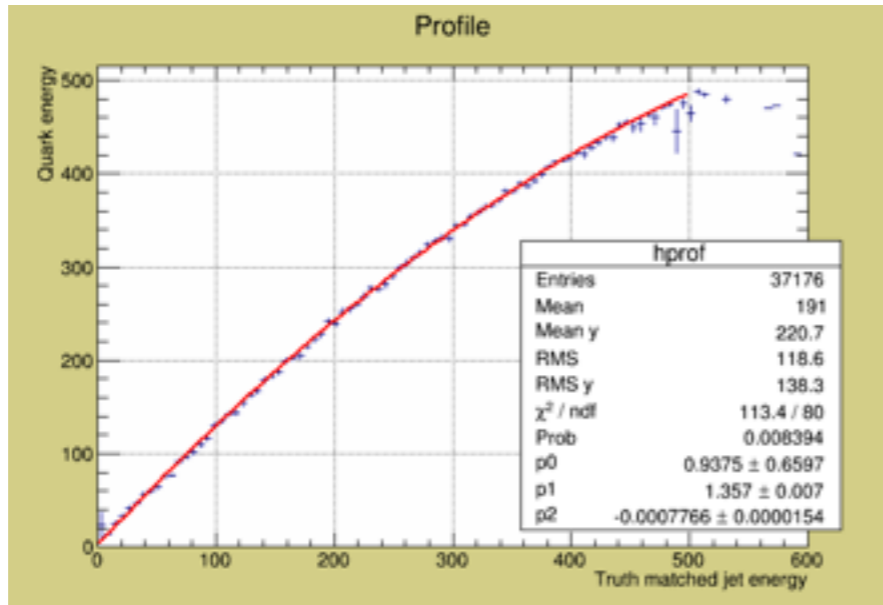Signal events : 553
Background events : 278
S/√S+B = 19.20

ZZ –> 4f hadronic sample.
Selected two truth matched jets from a Z.

$f(x) = p0 + p1*x + p2*x*x$

Z Mass

- Presented status of the heavy Higgs search at 1 TeV ILC.

- Clear separation of signal from background is achieved.

- Studying beam backgrounds to get b-jet energy correction but no success yet.

- Will complete mass and cross-section measurements at $\tan\beta$ and also evaluate systematics asap.

- Next plan is to set a limit independent of mass and $\tan\beta$.

BACKUP

mH/mA
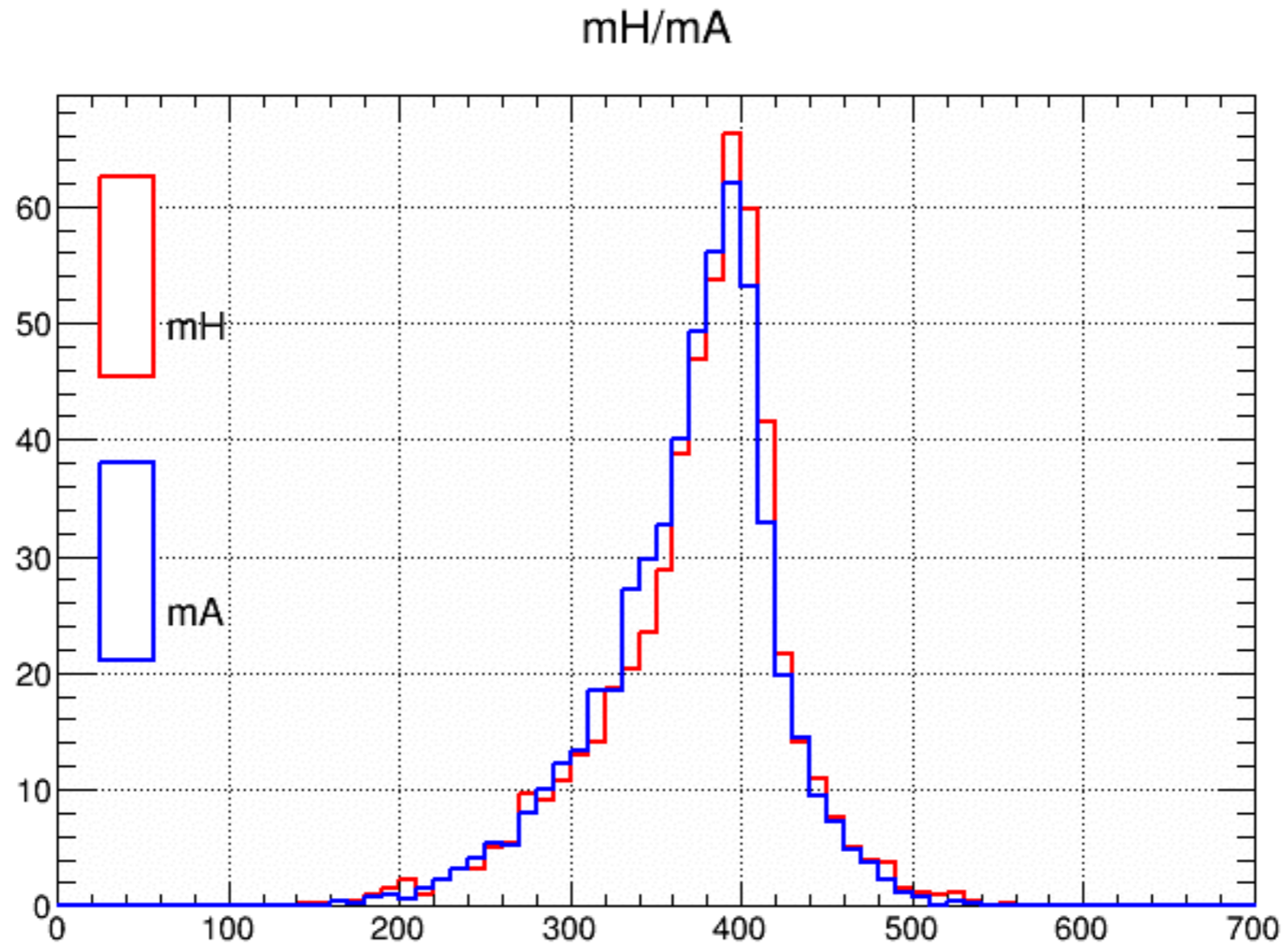
Sample	Signal	Z hadronic	ZZ hadronic	WW hadronic	ZZWW hadronic	ttbb	tth	ttz	ttbar	S/√S+B
Cuts										
Total	2386.33	5270800	167423	1812030	1510644.8	3290.41	3290.38	7745.81	446502	
All Cuts	487.04	180.73	48.28	0	0	18.77	12.47	10.58	104.44	
Eff %	20.41	- -	0.03	- -	- -	0.57	0.38	0.14	0.02	16.58

After applying these cuts :
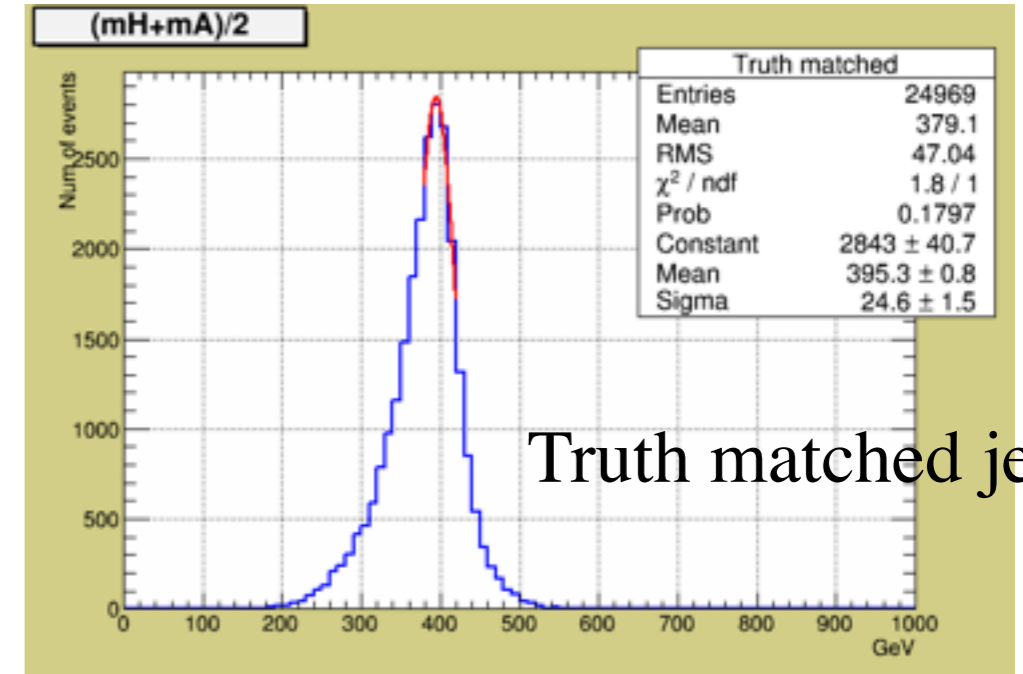   Signal events : 487
   Background events : 375
   S/√S+B = 16.58

(mH+mA)/2

$H \to b\bar{b} \; A \to b\bar{b}$

$H \to \tau^+\tau^- \; A \to \tau^+\tau^-$
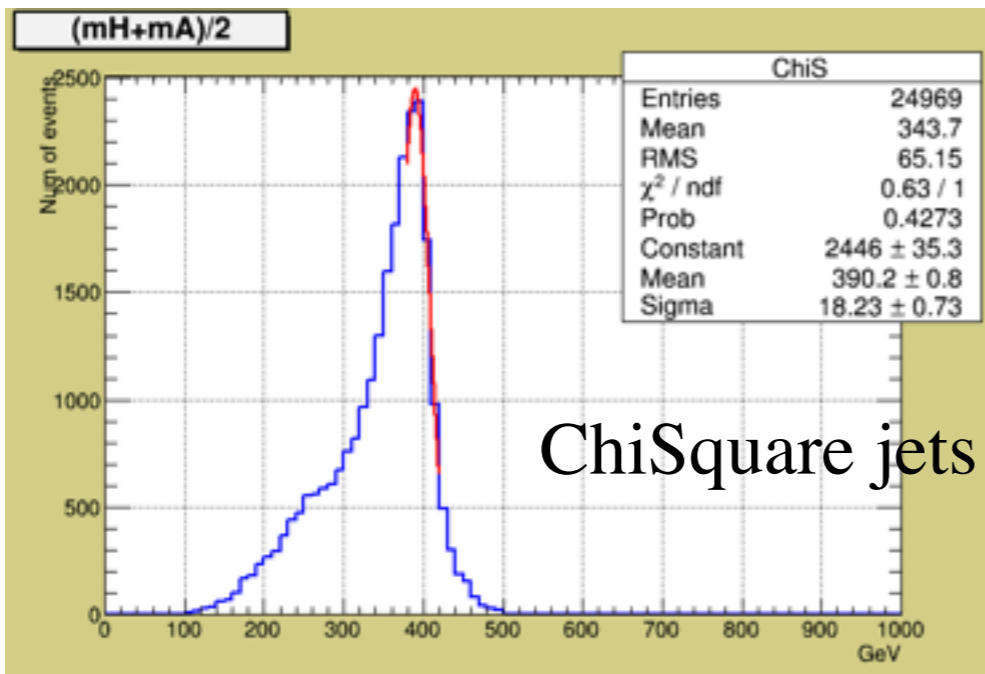
kT : R value
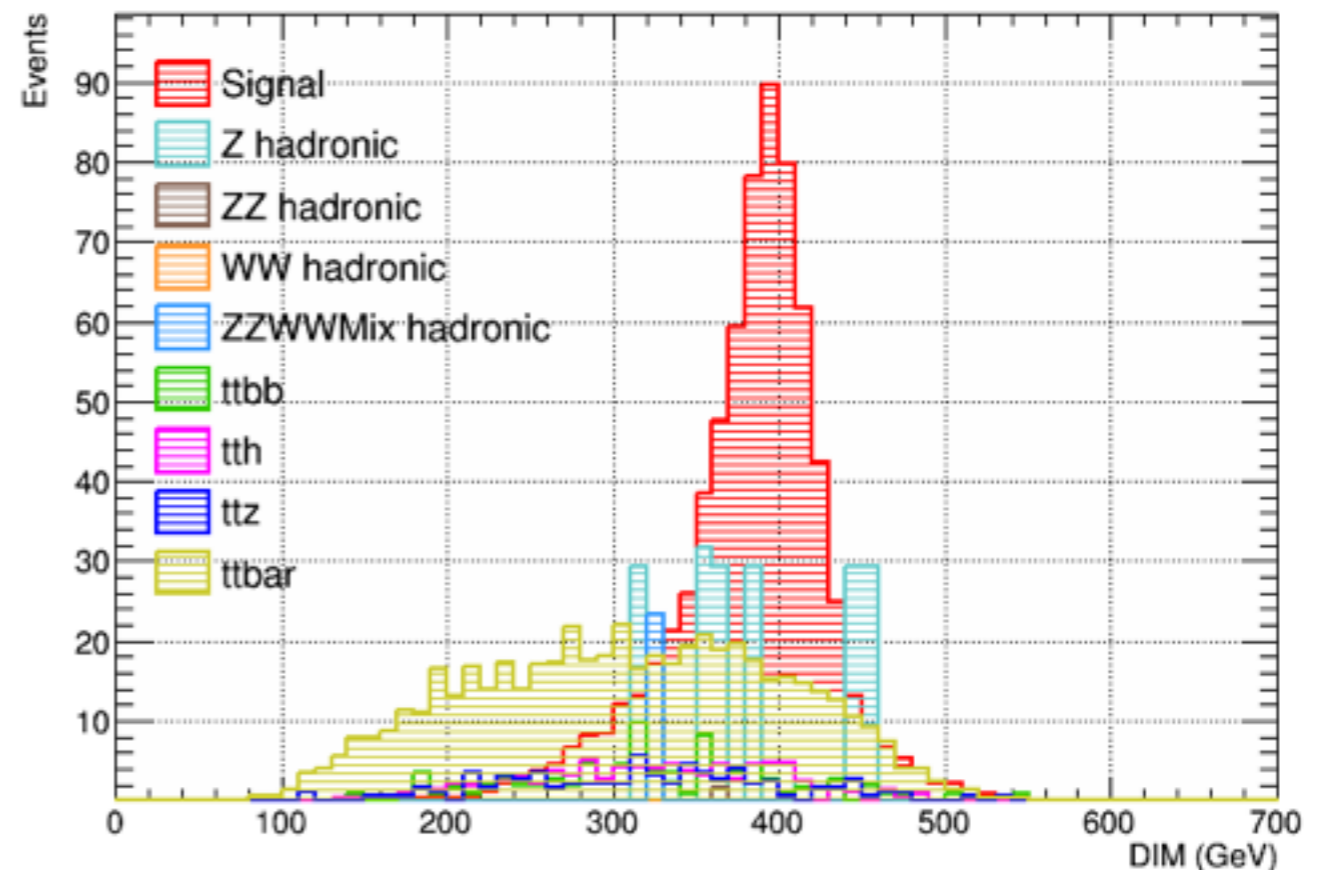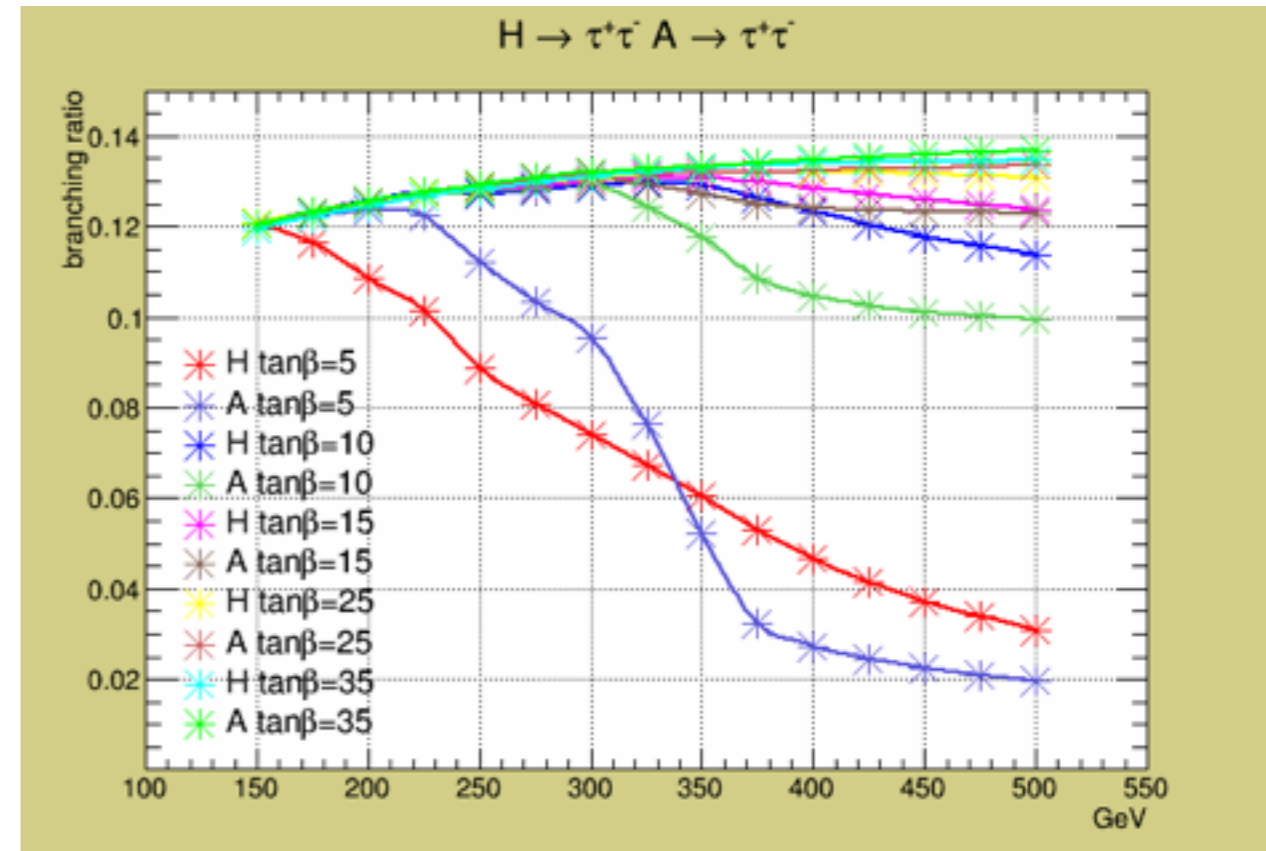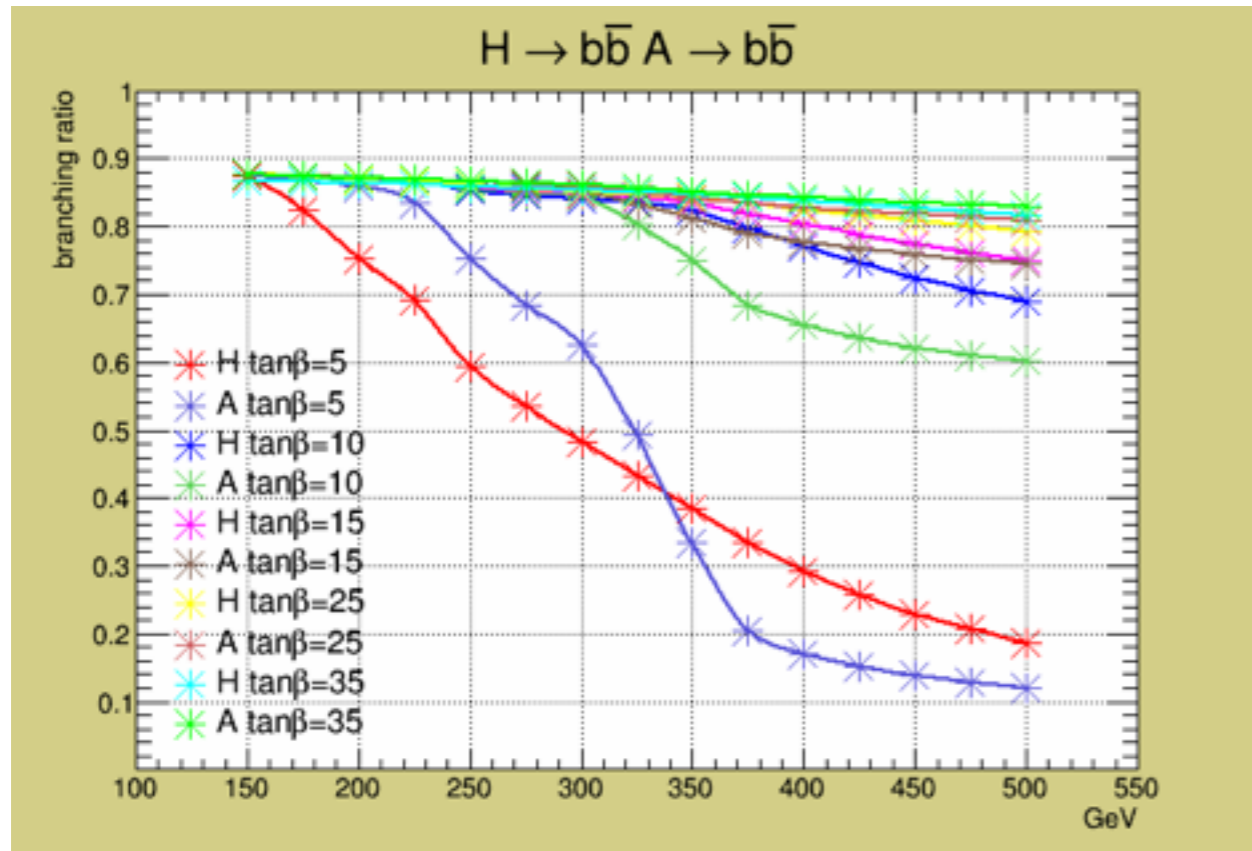
kT algorithm with R=1.1
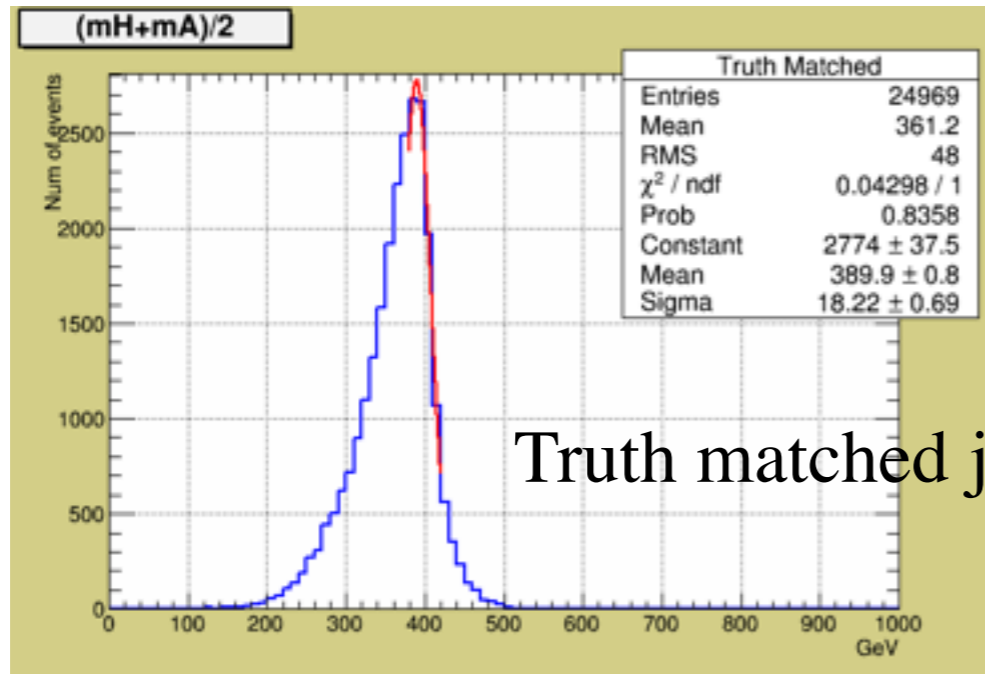
Truth matched jets
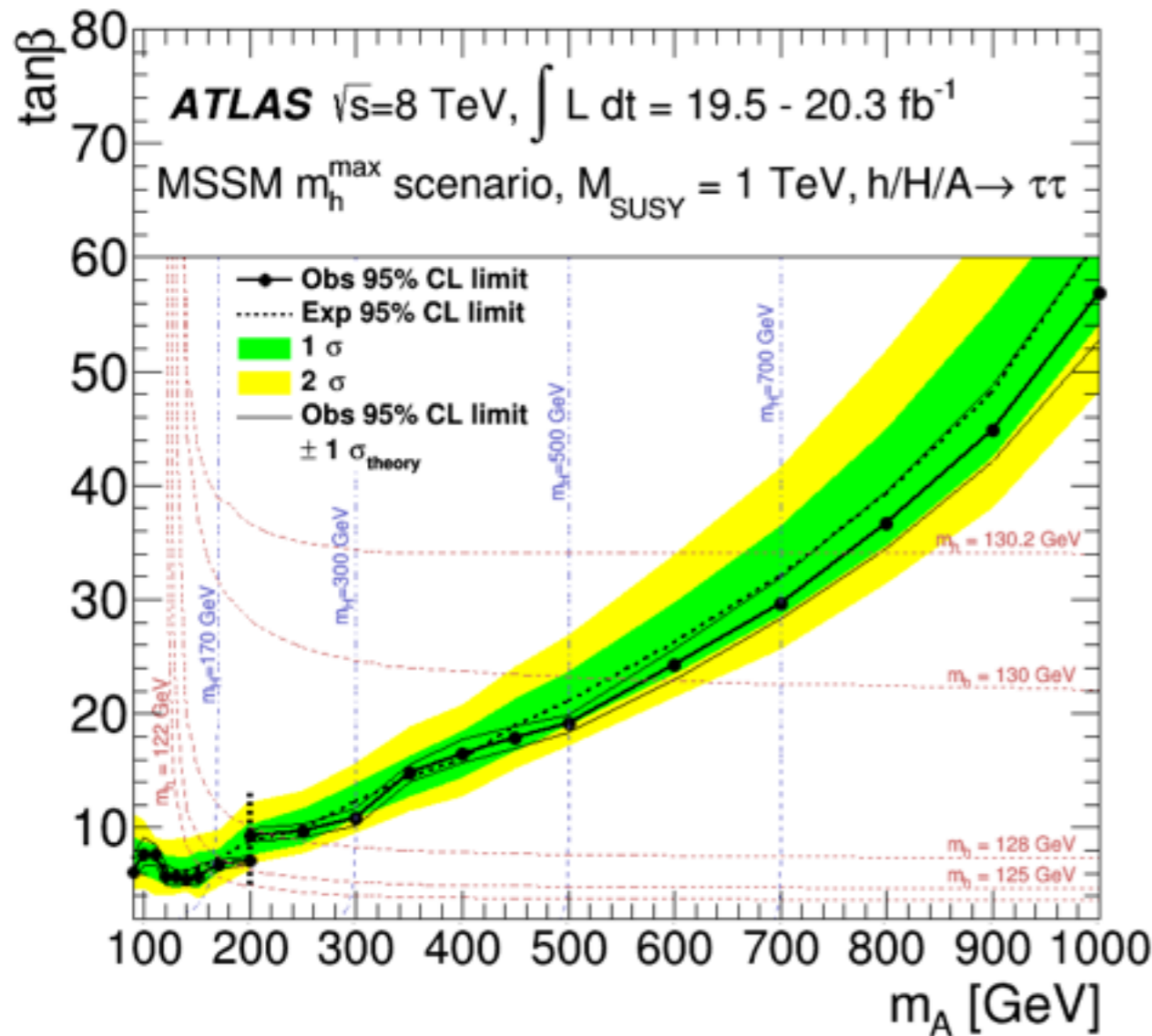

ChiSquare jets

kT algorithm with R=1.5

Truth matched jets
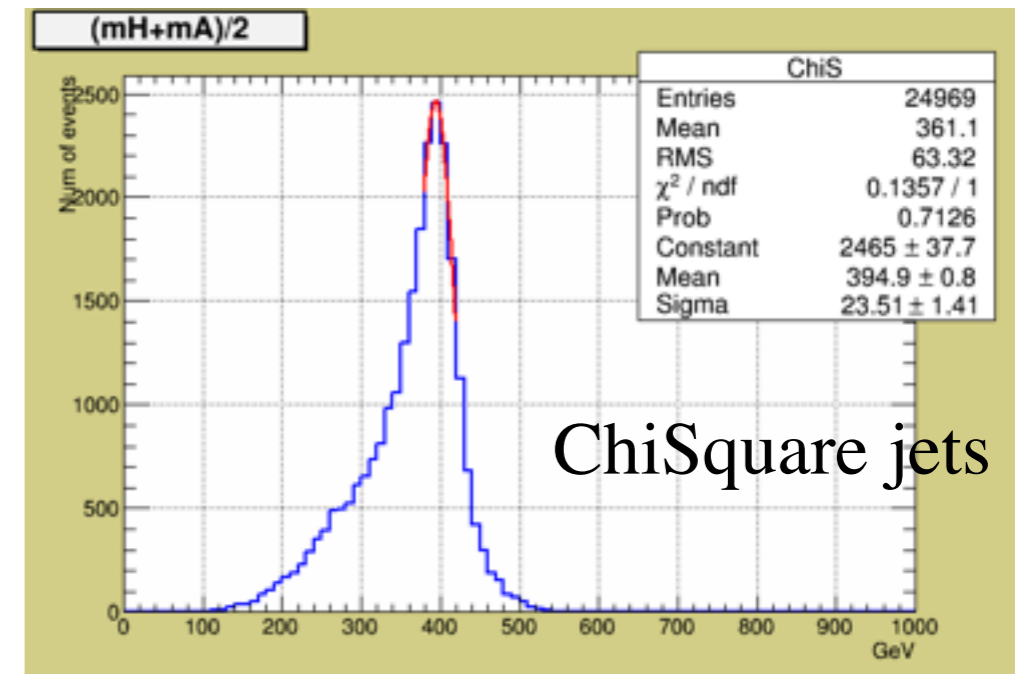
ChiSquare jets

H → **ττ** decay.
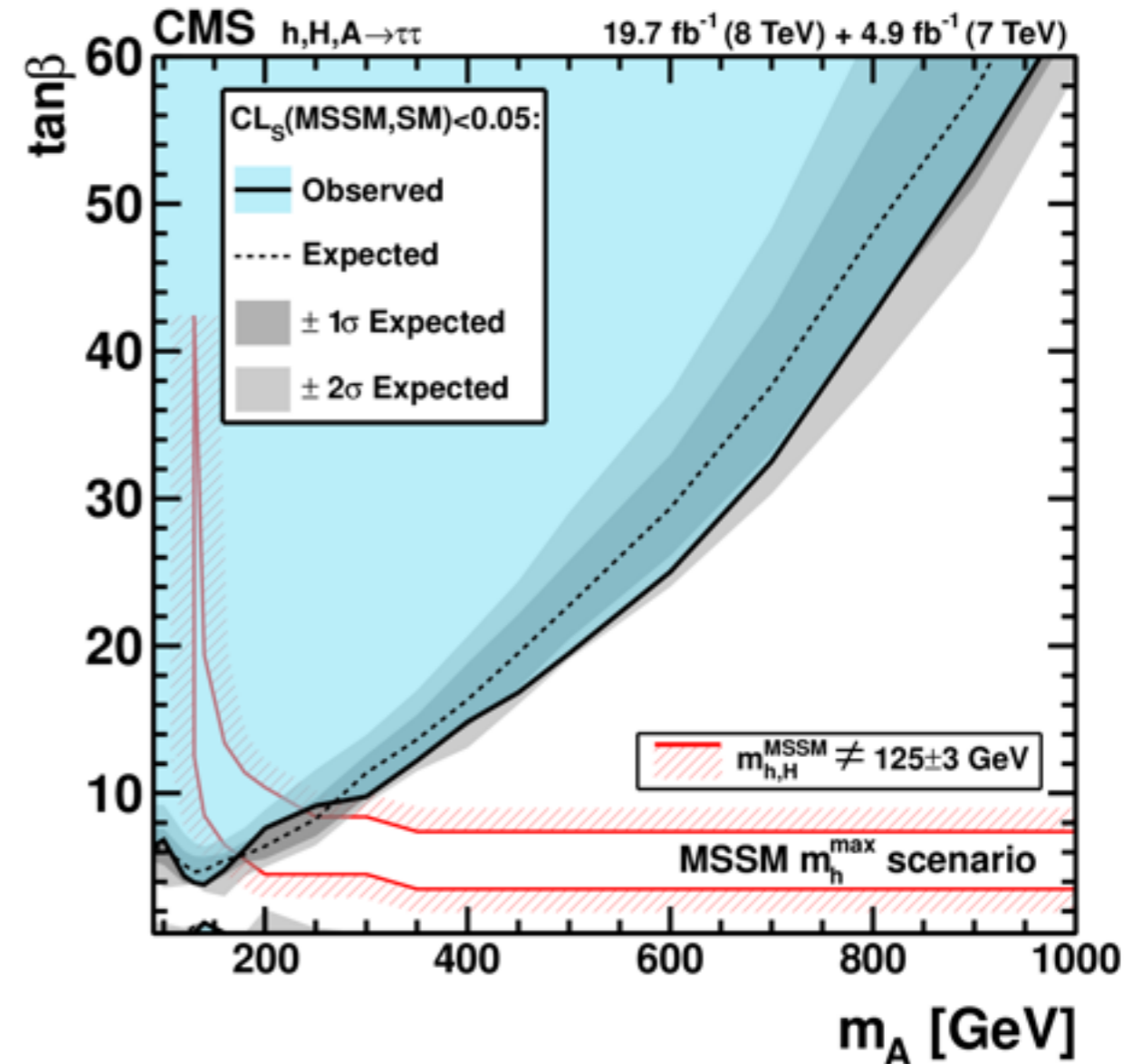
Most of the low mass and low *tanβ* region has been excluded in various MSSM scenarios.