Boosting the discovery of $p\,p \to h\,h \to b\,b\,\tau\,\tau$ at the LHC

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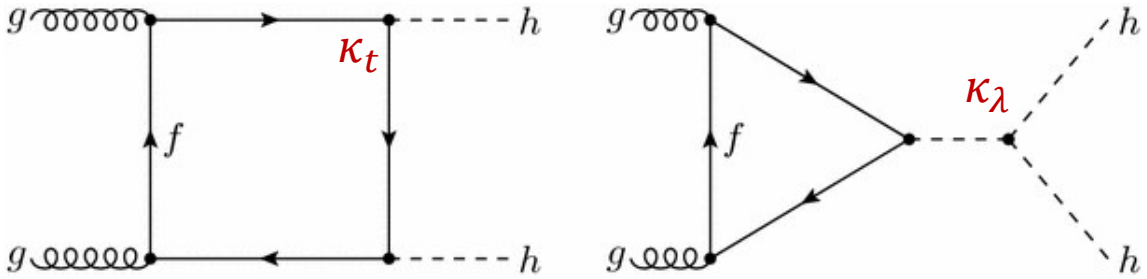
Introduction

- **Higgs pair production**



- **Higgs self-coupling**

$$\mathcal{L}_h = \frac{1}{2}\partial^\mu h \partial_\mu h - \frac{1}{2}m_h^2 h^2 - \kappa_\lambda \lambda_{SM} v h^3 - \frac{m_t}{v}(v + \kappa_t h)(\bar{t}_L t_R + h.c) + \cdots$$

✓ Di-Higgs search has a meaning to measure the Higgs self coupling and to understand the Higgs potential

✓ The topology is determine by each Higgs decay chain

Figure ref : arXiv:1512.08928

Signal vs Background

@ 14TeV, 39.64 fb (HH), 953.6 fb (TT)

Channel	Leptons	X section	Topology $* \ l = e \ or \ \mu$
HH2Tau	0	~1.2	$hh \rightarrow b\ b\ \tau\ \tau \rightarrow b\ b\ \tau_h\ \tau_h + met$
TT2Tau	0	~5097.2	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ \tau_h\ \tau_h + met$
HH2Tau	1	~1.3	$hh \rightarrow b\ b\ \tau\ \tau \rightarrow b\ b\ \tau_h\ l + met$
HH2W*W	1	~0.15	$hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ \tau_h\ l + met$
HH2WW*	1	~0.15	$hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ l\ \tau + met \rightarrow b\ b\ l\ \tau_h + met$
TT2Tau	1	~5546.3	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ \tau_h\ l + met$
TT1Tau	1	~29700.2	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ \tau_h\ l + met$
HH2Tau	2	~0.36	$hh \rightarrow b\ b\ \tau\ \tau \rightarrow b\ b\ l\ l + met$
HH2W*W1Tau	2	~0.08	$hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ l\ l + met$
HH2WW*1Tau	2	~0.08	$hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ l\ \tau + met \rightarrow b\ b\ l\ l + met$
HH2WW0Tau	2	~0.47	$hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ l\ l + met$
TT2Tau	2	~1508.7	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ l\ l + met$
TT1Tau	2	~16158.3	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ l\ l + met$
TT0Tau	2	~43263.9	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ l\ l + met$

Signal vs Background

@ 14TeV, 39.64 fb (HH), 953.6 fb (TT)

Channel	Leptons	X section	Topology $* \; l = e \; or \; \mu$
HH2Tau	0	~1.2	$hh \to b\,b\,\tau\,\tau \to b\,b\,\tau_h\,\tau_h + met$
TT2Tau	0	~5097.2	$\bar{t}t \to b\,w\,b\,w \to b\,b\,\tau\,\tau + met \to b\,b\,\tau_h\,\tau_h + met$
HH2Tau	1	~1.3	$hh \to b\,b\,\tau\,\tau \to b\,b\,\tau_h\,l + met$
HH2W*W	1	~0.15	$hh \to b\,b\,w\,w^* \to b\,b\,\tau\,l + met \to b\,b\,\tau_h\,l + met$
HH2WW*	1	~0.15	$hh \to b\,b\,w\,w^* \to b\,b\,l\,\tau + met \to b\,b\,l\,\tau_h + met$
TT2Tau	1	[illegible]	[illegible] $b\,\tau_h\,l + met$
TT1Tau	[illegible]	[illegible]	[illegible] $b\,\tau_h\,l + met$
HH2Tau	2	[illegible]	[illegible] $b\,b\,l\,l + met$
HH2W*W1Tau	2	~0.08	$hh \to b\,b\,w\,w^* \to b\,b\,\tau\,l + met \to b\,b\,l\,l + met$
HH2WW*1Tau	2	~0.08	$hh \to b\,b\,w\,w^* \to b\,b\,l\,\tau + met \to b\,b\,l\,l + met$
HH2WW0Tau	2	~0.47	$hh \to b\,b\,w\,w^* \to b\,b\,l\,l + met$
TT2Tau	2	~1508.7	$\bar{t}t \to b\,w\,b\,w \to b\,b\,\tau\,\tau + met \to b\,b\,l\,l + met$
TT1Tau	2	~16158.3	$\bar{t}t \to b\,w\,b\,w \to b\,b\,\tau\,l + met \to b\,b\,l\,l + met$
TT0Tau	2	~43263.9	$\bar{t}t \to b\,w\,b\,w \to b\,b\,l\,l + met$

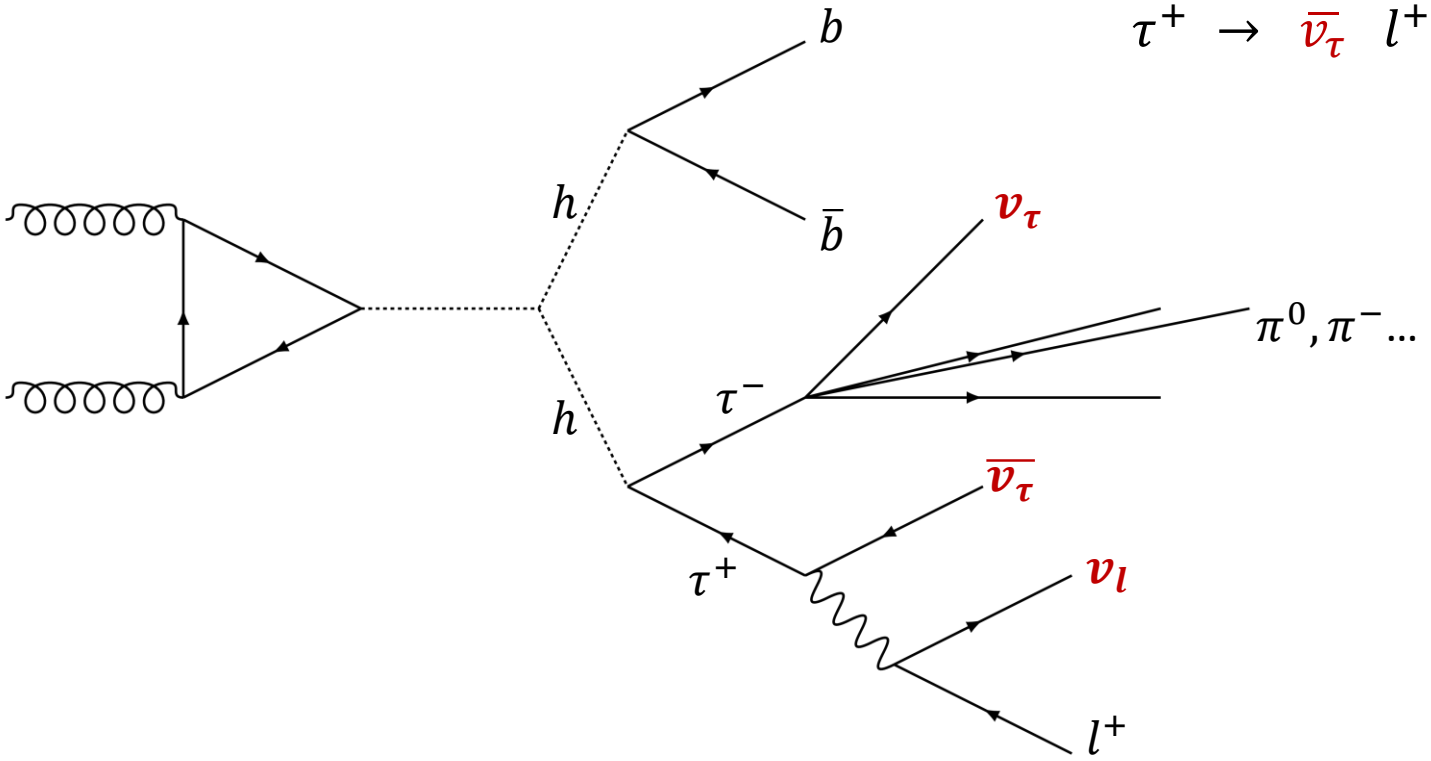
Too Many $t\bar{t}$ Background

How to reconstruct the missing information?

Ex) HH2tau : 1 lepton + 1 tau_h Channel $hh \rightarrow b\,b\,\tau^-\tau^+$

$\tau^- \rightarrow \nu_\tau \;\; \tau_h$

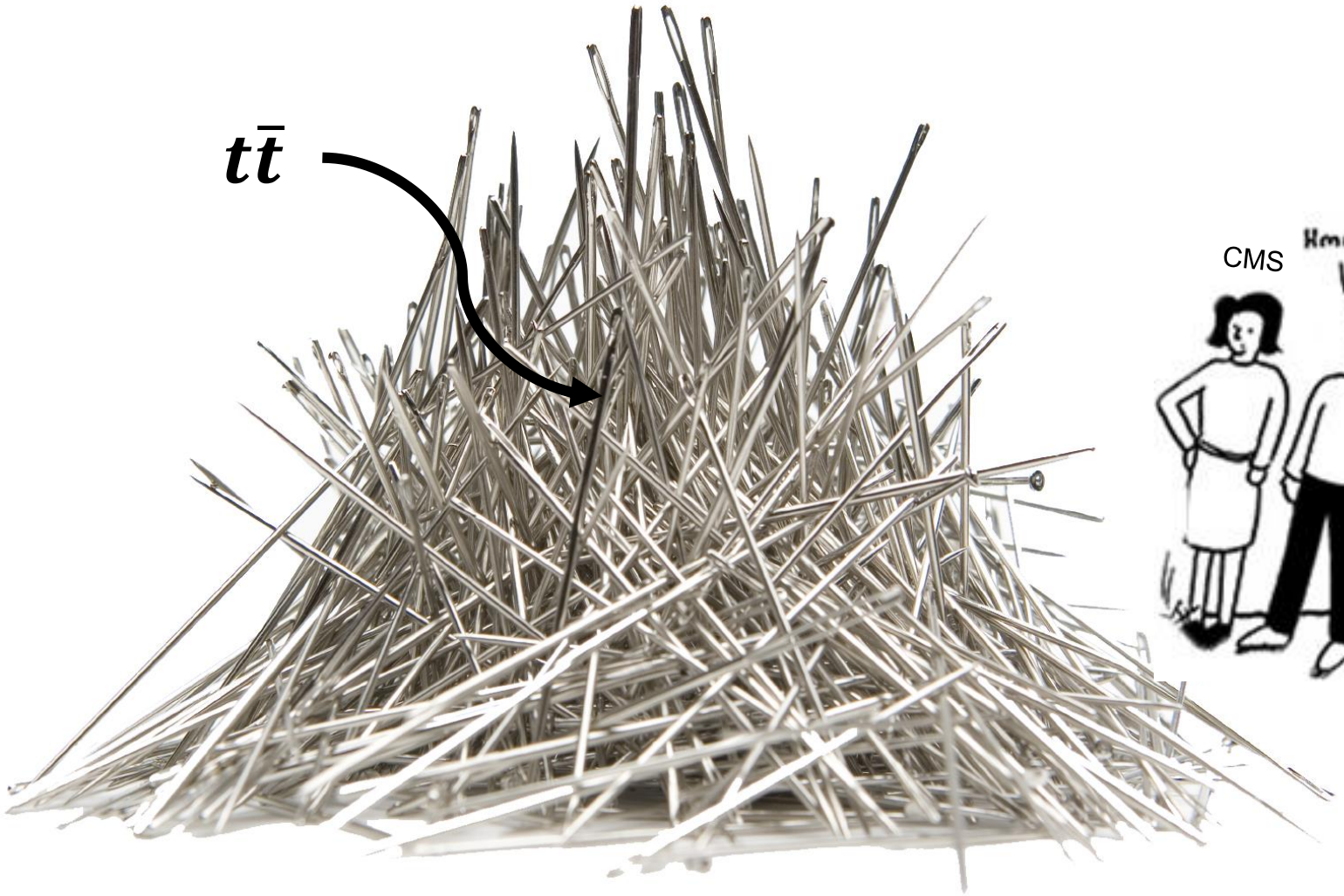
$\tau^+ \rightarrow \bar{\nu}_\tau \;\; l^+ \;\; \tau_l$



$\mathbf{H \rightarrow \tau\tau/WW}$

# of Neutrinos >= 2

A Needle(HH) in a stack of Needles($t\bar{t}$)



HH?

OptiMass introduction

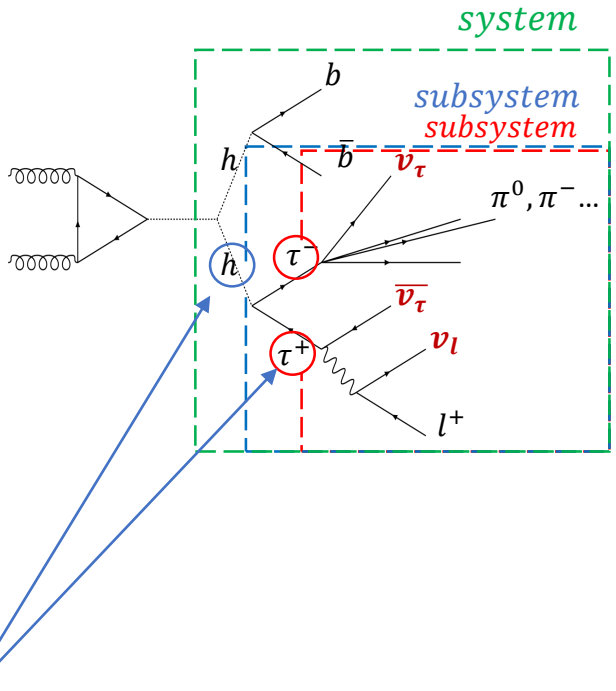
M = *minimized mass variable function*
λ_a = *augmented Lagrange parameter*
μ = *penalty parameter*
$\vec{x}$ = ***missing momentum***
c_a = ***physical constraints***

- Augmented Lagrangian method

$$\mathcal{L}_k(\vec{x} \mid \lambda, \mu) = \boldsymbol{M(\vec{x})} - \sum_{a=1}^{m} \lambda_{ak}\, c_a(\vec{x}) + \frac{1}{2\mu_k} \sum_{a} c_a^2(\vec{x}).$$

$$\lambda_a^{k+1} = \lambda_a^k - \frac{c_a(\vec{x}_k)}{\mu_k}$$

$$\boldsymbol{CD} = ||c(\vec{x}_k)|| < \eta^* \quad with\ ||c(\vec{x}_k)|| = \sqrt{\sum_a |c_a(\vec{x}_k)|^2}$$



✓ **OM (OptiMass)** ~ TARGET MASS

✓ **CD (Compatibility Distance)** ~ **0** for TRUE SYSTEM

OPTIMASS: A Package for the Minimization of Kinematic Mass Functions with Constraints
- Cho, Won Sang *et al.* JHEP 1601 (2016) 026 arXiv:1508.00589

Multi-Variable Classification

- All distinctive decay topology ⇒ Characterized by each constraints, c_a / systems
- Using **OptiMass**, we can reconstruct the mass of systems/subsystems
  ⇒ the classes for MVA classification

For 1 lepton Channel	
OM h2ta S	CD h2ta S
OM h2ta Mh1	CD h2ta Mh1
OM h2ta maxMta12	CD h2ta maxMta12
OM h1tawos S	CD h1tawos S
OM h1tawos Mh1	CD h1tawos Mh1
OM h1tawos maxMw12	CD h1tawos maxMw12
OM h1tawoff maxMw12	CD h1tawoff maxMw12
…	…
OM t2ta S	CD t2ta S
OM t2ta maxMt12	CD t2ta maxMt12
OM t2ta maxMta12	CD t2ta maxMta12
OM t2ta maxMw12	CD t2ta maxMw12
OM t1ta S	CD t1ta S
OM t1ta maxMt12	CD t1ta maxMt12
…	…

For 0 lepton Channel	
OM h2ta S	CD h2ta S
OM h2ta Mh1	CD h2ta Mh1
OM h2ta maxMta12	CD h2ta maxMta12
OM t2ta S	CD t2ta S
OM t2ta maxMt12	CD t2ta maxMt12
OM t2ta maxMta12	CD t2ta maxMta12
OM t2ta maxMw12	CD t2ta maxMw12
OM t2ta maxMt12_c2_etas05	CD t2ta maxMt12_c2_etas05
OM t2ta maxMt12_c1_etas005	CD t2ta maxMt12_c1_etas005
OM t2ta maxMt12 c2_etas01	CD t2ta maxMt12 c2_etas01

- ✓ (0l) # (Visible Features)
  = 12 dim
- ✓ (0l) # (OM Features)
  = 6(hh)+14(ttbar) = 20 dim
- ✓ (1l) # (Visible Features)
  = 12 dim
- ✓ (1l) # (OM Features)
  = 30(hh)+22(ttbar) = 52 dim
- ✓ (2l) # (Visible Features)
- (2l) # (OM Features)
  = (Talk on Thu.
  By Dr. Wonsang Cho)

❖ **Visible : CMS/ATLAS common features ~ $p_T, \Delta R, \Delta\phi$ …**

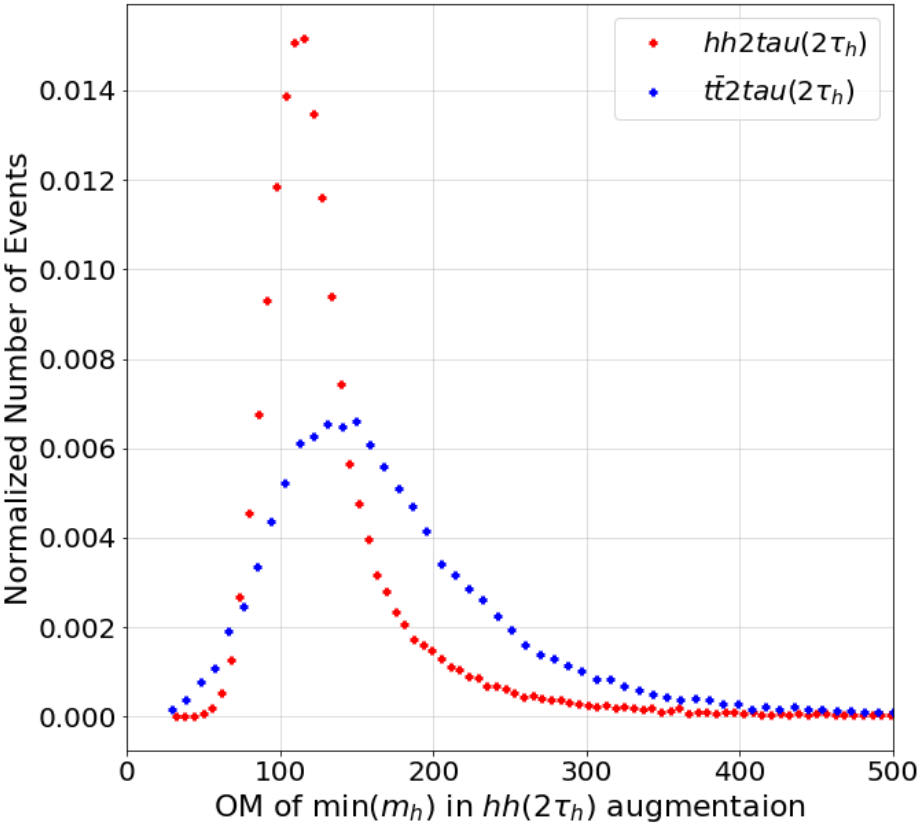
Event Selection

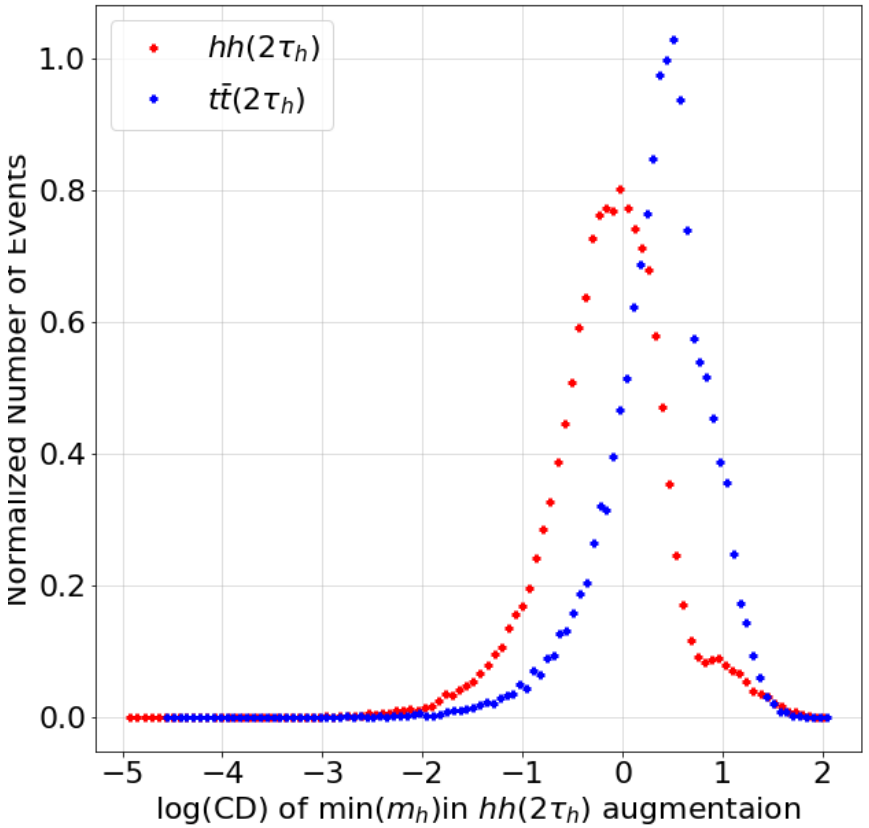
- **Using …**
  - MC : MG5_aMC v2.5.5 + MADSPIN (Decay)
  - Showering : PYTHIA8
  - Detector Simulation : Delphes
  - CT10nlo for all Channel

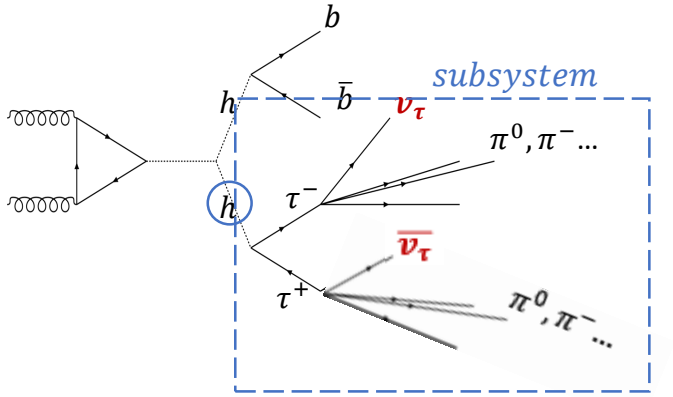
- **Cut …**
  - Delphes : Using delphes_card_ATLAS.dat
  - Tau Tagging : $\Delta R < 0.4$, $\Delta R_{track} < 0.2$, $P_T^{Track} > 1.0$, $P_T^{\tau} > 2.0$, $\eta_{\tau} < 2.5$
    1-prong Eff = 70% , N(>1)-prong eff = 60%
  - Others are same with delphes_card_ATLAS.dat default

- Hadronic Tau decay using ALL N-prongs

0-lepton & 2-hadronic decay tau



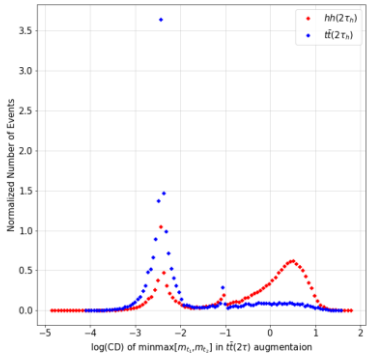


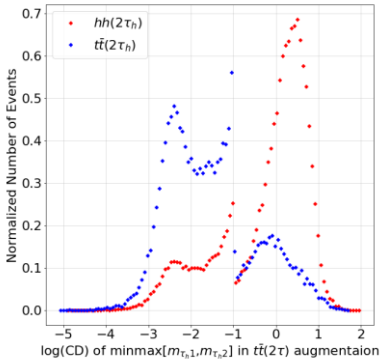


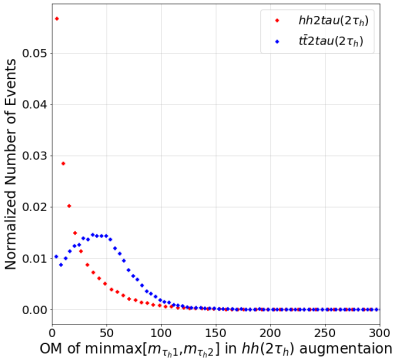
Constraints of Mass

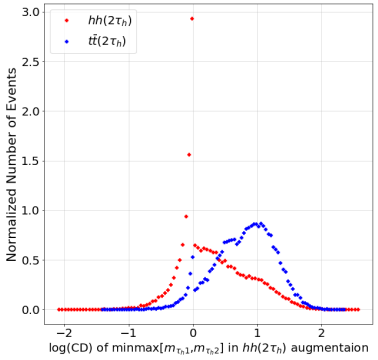
- Tau1 = 1.77
- Tau2 = 1.77
- Tau1 = Tau2

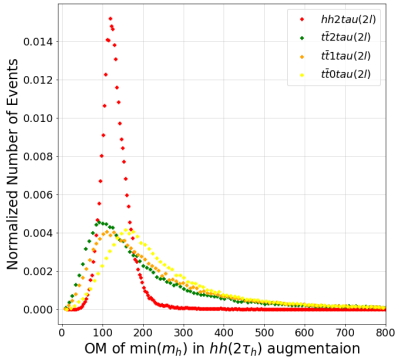
OM/CD of (2l,1l,0l) Channels

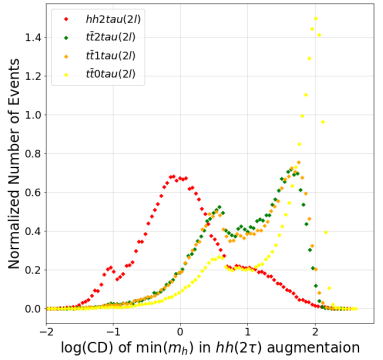


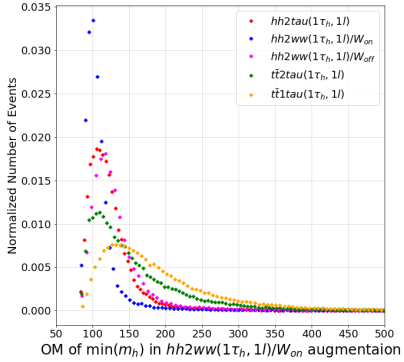


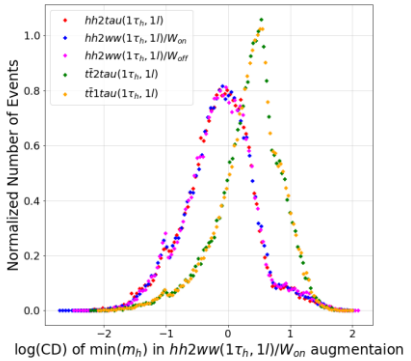


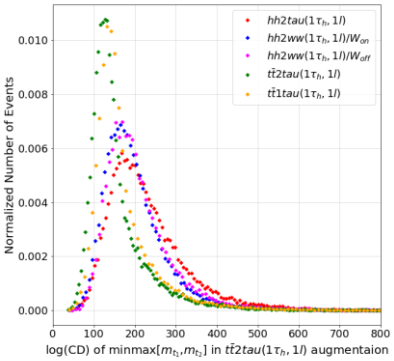


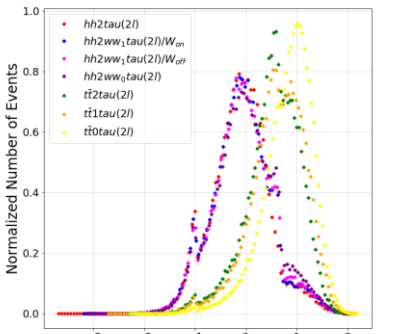


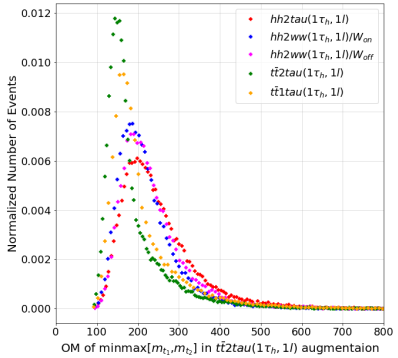


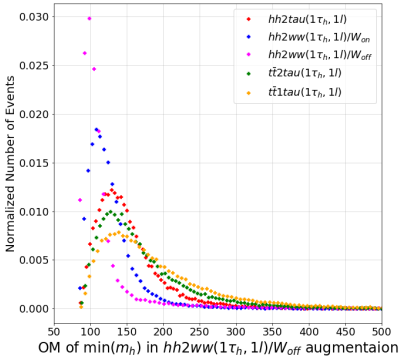










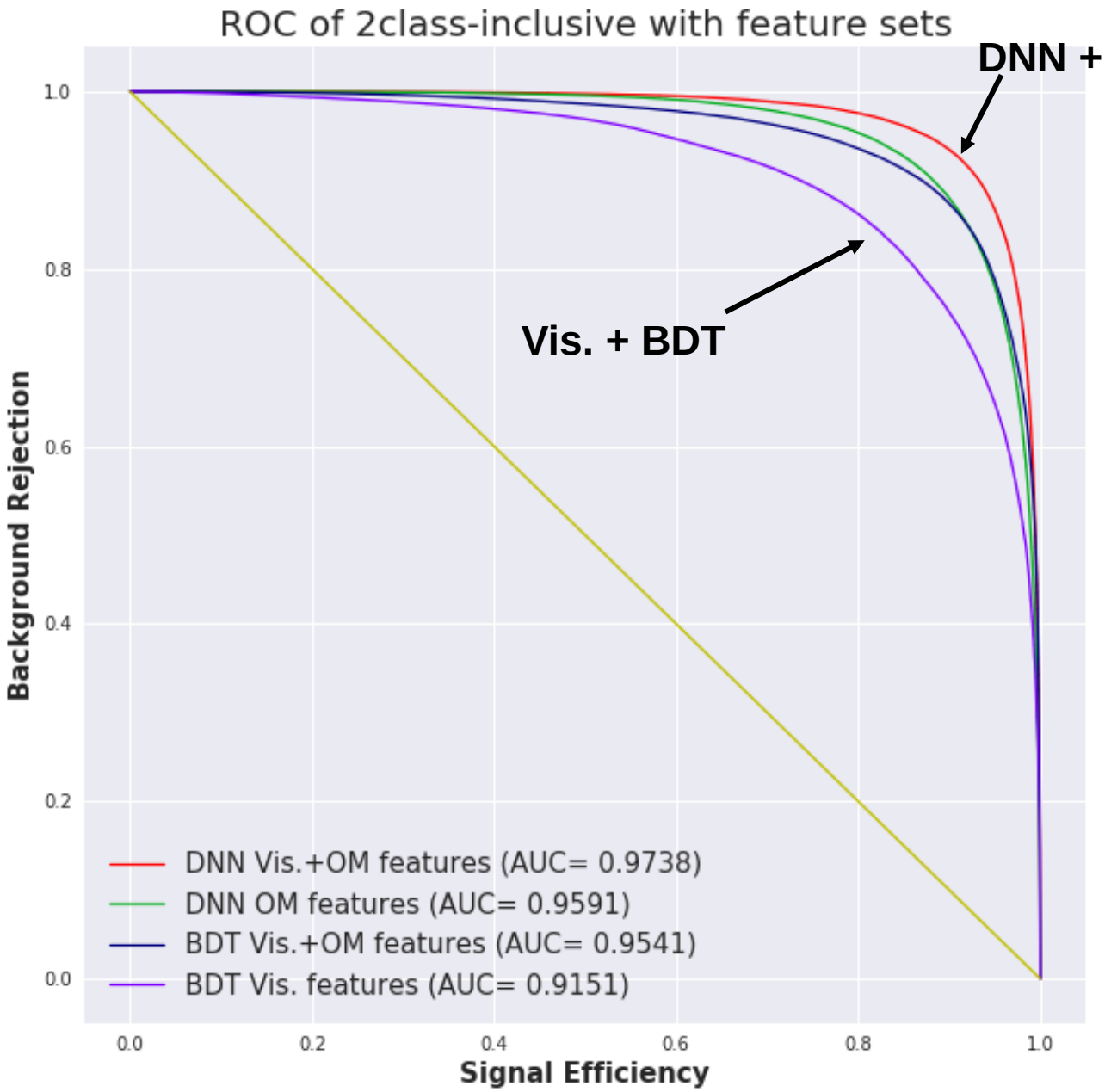


DNN vs BDT

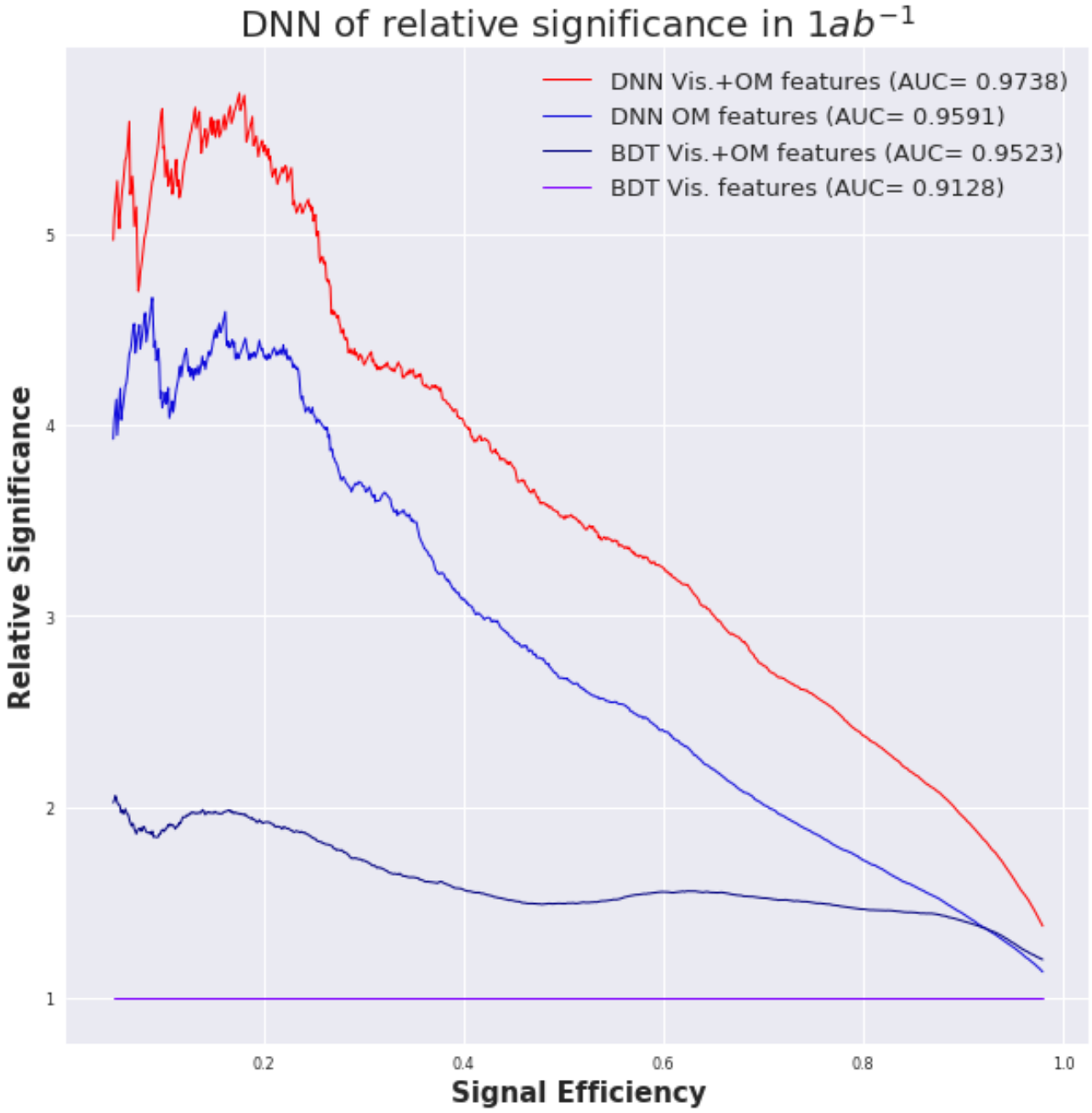
- **Deep Neural Network**
  - ✓ Keras + Tensorflow module
  - ✓ 7~8 hidden layers + 500 nodes per hidden layers
  - ✓ 2 / 5 / 7 nodes output (for each class)
  - ✓ Using 'RELU' Activation function + 'SoftMax' output layer
  - ✓ Dropout = 0.2~3 + Batch Normalization

- **Boost Decision Tree**
  - ✓ Using 'AdaBoostClassification' in sklearn module
  - ✓ Max_depth = 2~3
  - ✓ # of Estimators = 500~1000, learning rate = 0.01
  - ✓ Algorithm = 'SAMME'

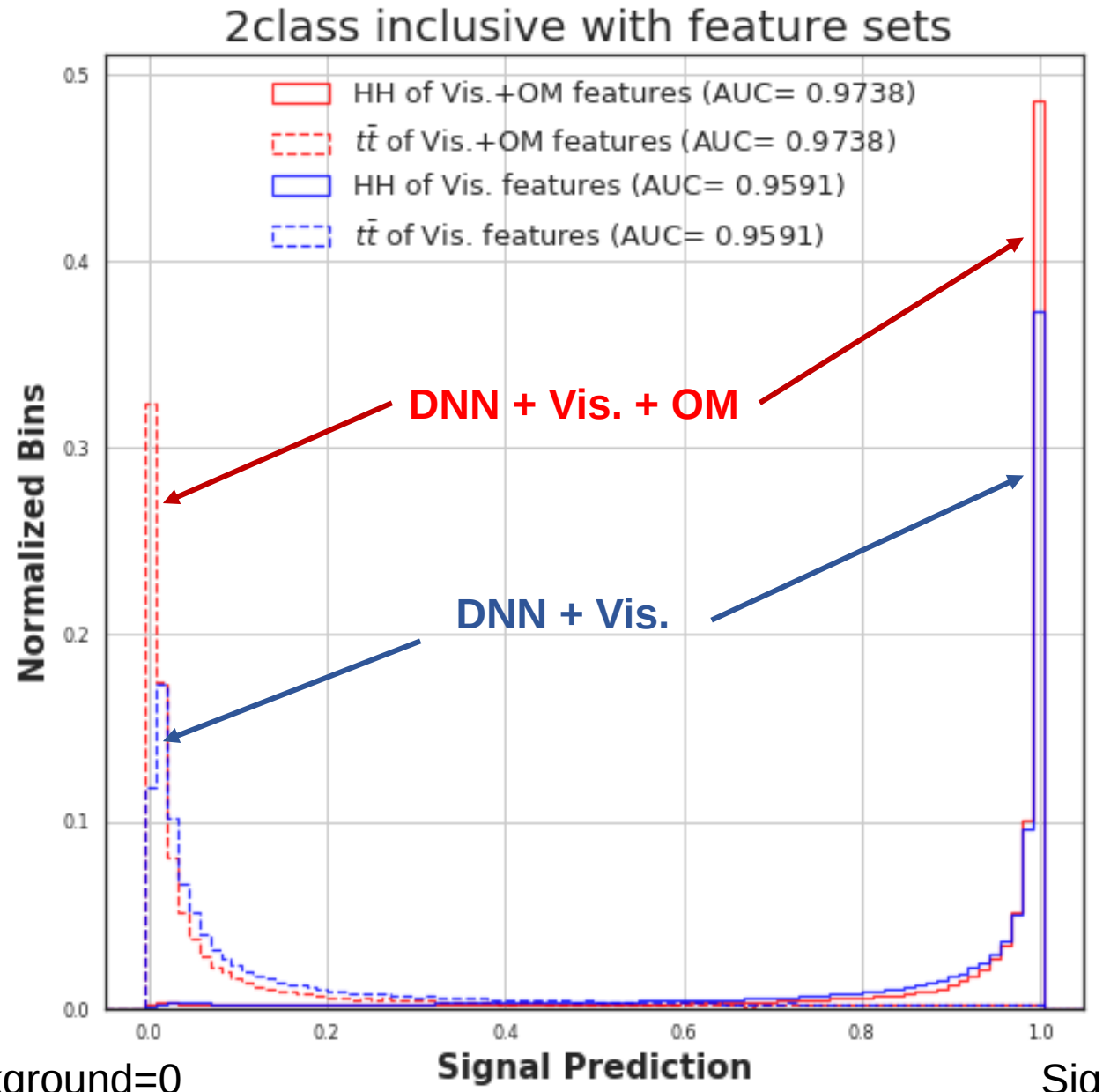
ROC Result for 0 lep (2b+2tau_h)



Significance Result for 0 lep (2b+2tau_h)



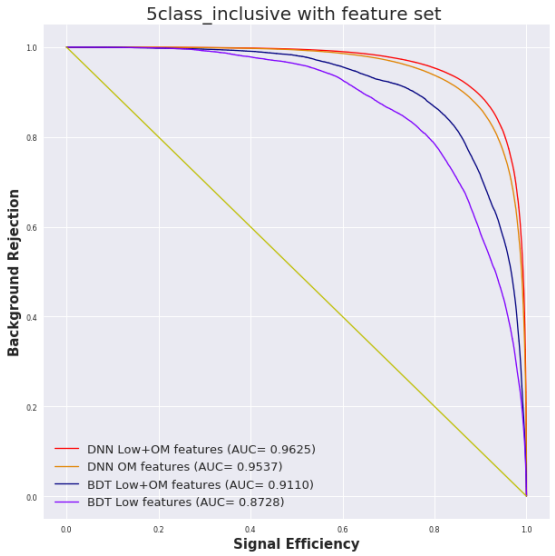
Result for 0 lep (2b+2tau_h)

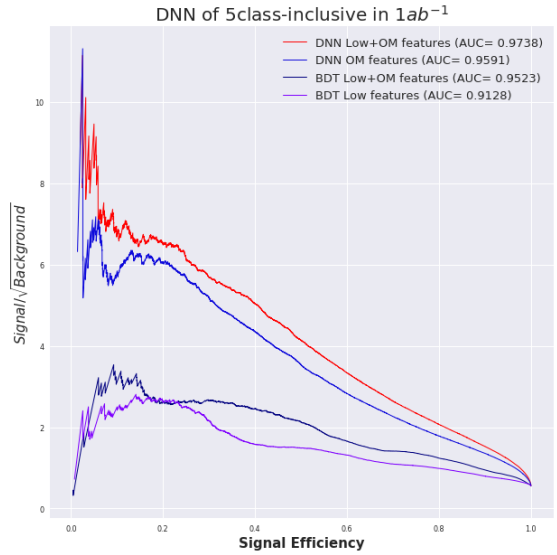


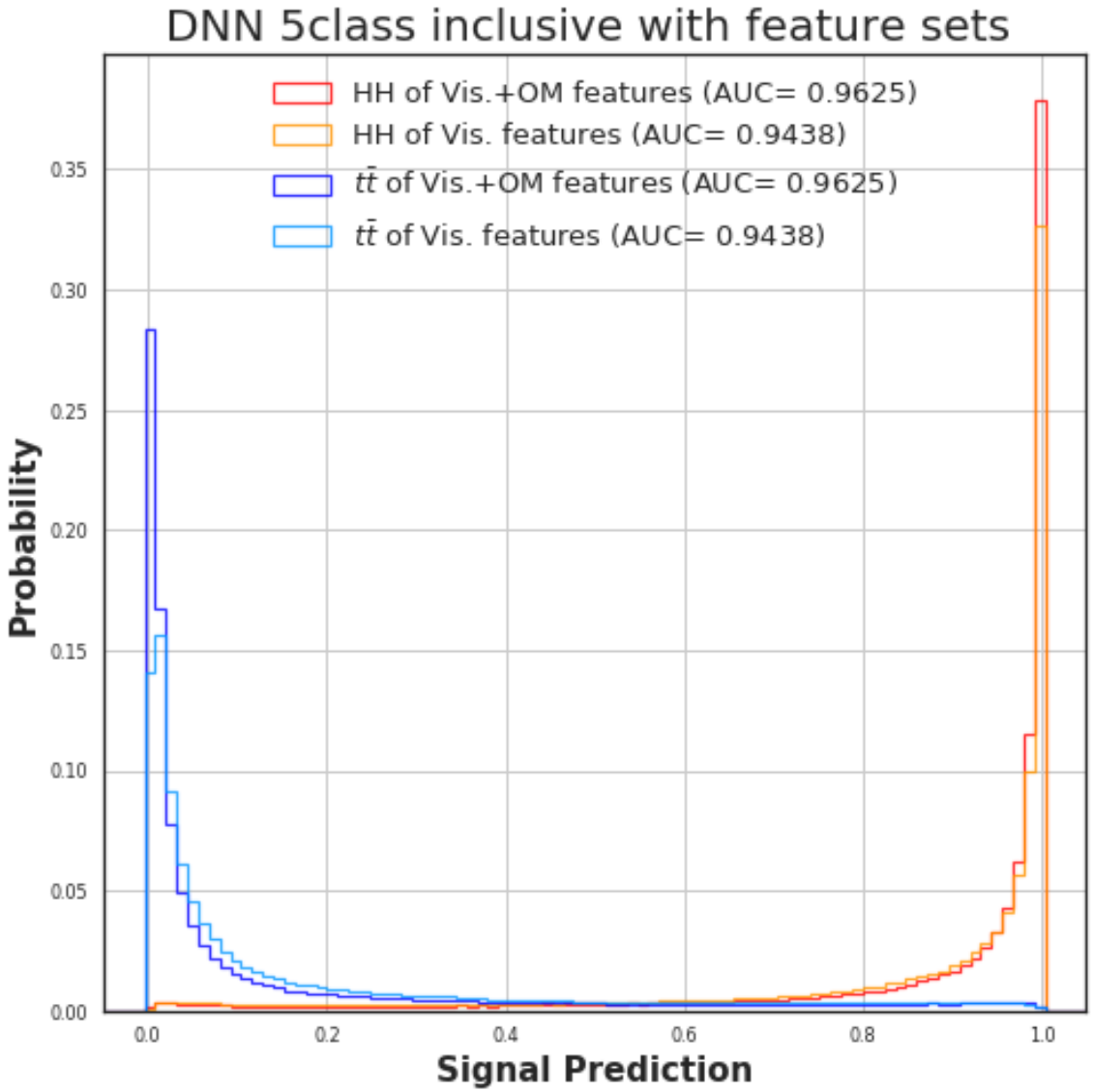
Background=0

Signal=1

Classification Result for (1l) Channels







Variable Importance Score Result for (0/1) lepton

Rank	Feature Variables	Importance
1	**OM h2ta maxMta12**	**11%**
2	dR_bb	10%
3	mt2_bbtata	9%
4	**CD t2ta maxMta12**	**9%**
5	**CD h2ta maxMta12**	**9%**
6	**CD h2ta S**	**8%**
7	pT_tata	8%
8	**CD h2ta Mh1**	**7%**
9	**CD t2ta maxMt12 c2_etas01**	**7%**
10	dR_tata	5%
11	pT_bb	3%
12	**OM t2ta maxMt12 c1_etas1**	**3%**
13	**OM t2ta maxMt12 c2_etas01**	**2%**
14	dphi_bbmet	2%
15	**OM h2ta Mh1**	**2%**
16	**OM t2ta maxMt12**	**2%**

Rank	Feature Variables	Importance
1	**OM h2ta maxMta12**	**21%**
2	**OM h1tawos Mw1**	**15%**
3	dr_lta	10%
4	pt_lta	10%
5	**OM h2ta Mh1**	**9%**
6	dr_bb	5%
7	**CD h2ta S**	**5%**
8	**CD h2ta Mh1**	**5%**
9	mt_ta1	3%
10	**OM h1tawoff Mw2**	**2%**
11	**OM h1tawos maxMw12**	**2%**
12	**OM h1tawos Mh1**	**2%**
13	**OM h1tawoff Mh1 c2_etas100**	**1%**
14	**OM h1tawoff maxMw12**	**1%**
15	**CD h1tawos Mh1**	**1%**
16	**CD t1ta S**	**1%**
17	**CD h1tawos Mh1 c2_etas10**	**1%**

Result of 0/1-lepton

@ 14TeV, 39.64 fb (HH), 953.6 fb (TT)
1000 fb luminosity (1 ab^{-1})

	HH2Tau	TT2Tau	HH2Tau	TT2Tau
Cross Section	~1.2	~5097.2	~1.6	~35246.5
Number of Detected	~1,200	~5,097,200	~1,600	~35,246,500
	↓ # of remained ↓			
BDT + Visible	~240	~65,659	~328	~19,803
BDT + Visible + OM	~240	~17,630	~328	~18,615
DNN + OM	**~240**	**~3,205**	**~328**	**~3,329**
DNN + Visible + OM	**~240**	**~1,995**	**~328**	**~2,831**

Assume the same amount of signal

Conclusion

- ✓ Discovering **HH** is important
- ✓ But we have to distinguish the signal from the **HUGE background (ttbar)**
- ✓ We introduce
  - **New Handles : "OPTIMASS Variables" (~40)**
  - **Improved Classification Method : "DNN"**

AUC(CMS, BDT) = 0.91 -> AUC(Ours) = 0.97

!!! Use DNN + OPTIMASS Variables !!!

Q&A

BACK UP

❖ **Visible : CMS/ATLAS common features**

- **CMS-HIG 17-002**

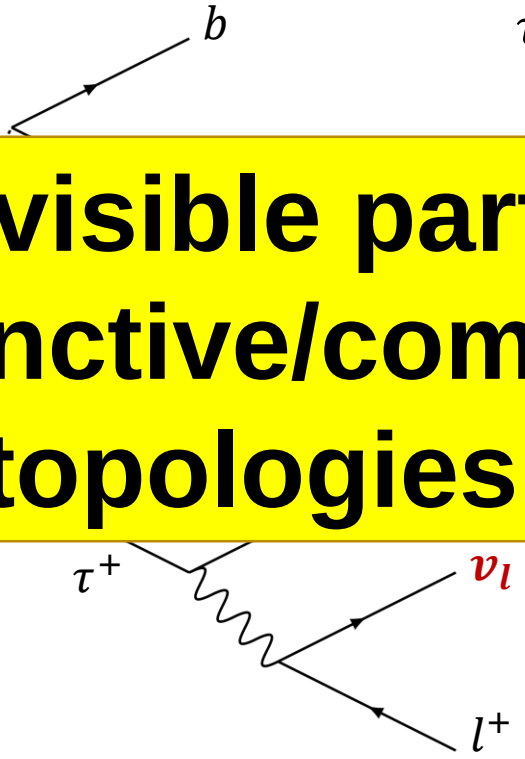
- 'dr_tata', 'dr_bb’
- 'dphi_bbtata’, 'dphi_tatamet'', 'dphi_bbmet', 'dphi_ta1met', 'dphi_ta2met'
- 'pt_tata', 'pt_bb’
- 'mt2_bbtata,'mt_ta1', 'mt_ta2'

How to reconstruct the missing information?

Ex) HH2tau : 1 lepton + 1 tau_h Channel $hh \rightarrow b\,b\,\tau^-\tau^+$

$\tau^- \rightarrow \nu_\tau \;\; \tau_h$

$\tau^+ \rightarrow \bar{\nu}_\tau \;\; l^+ \;\; \tau_l$



Too Many invisible particles from each distinctive/complicated decay topologies

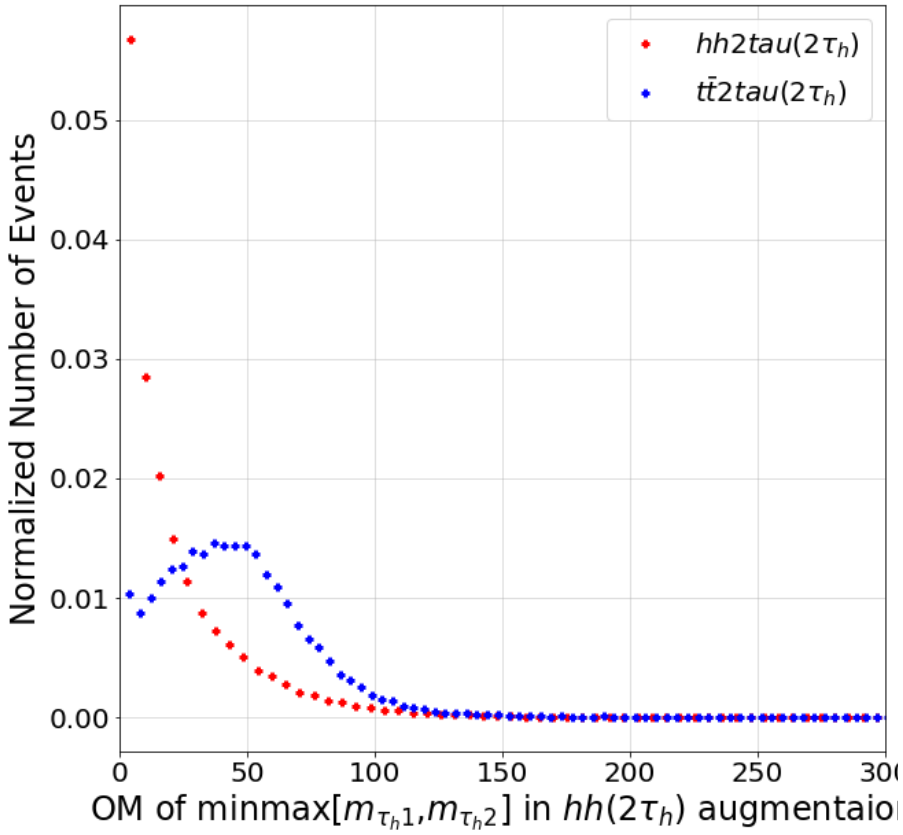
# of Neutrinos >= 2

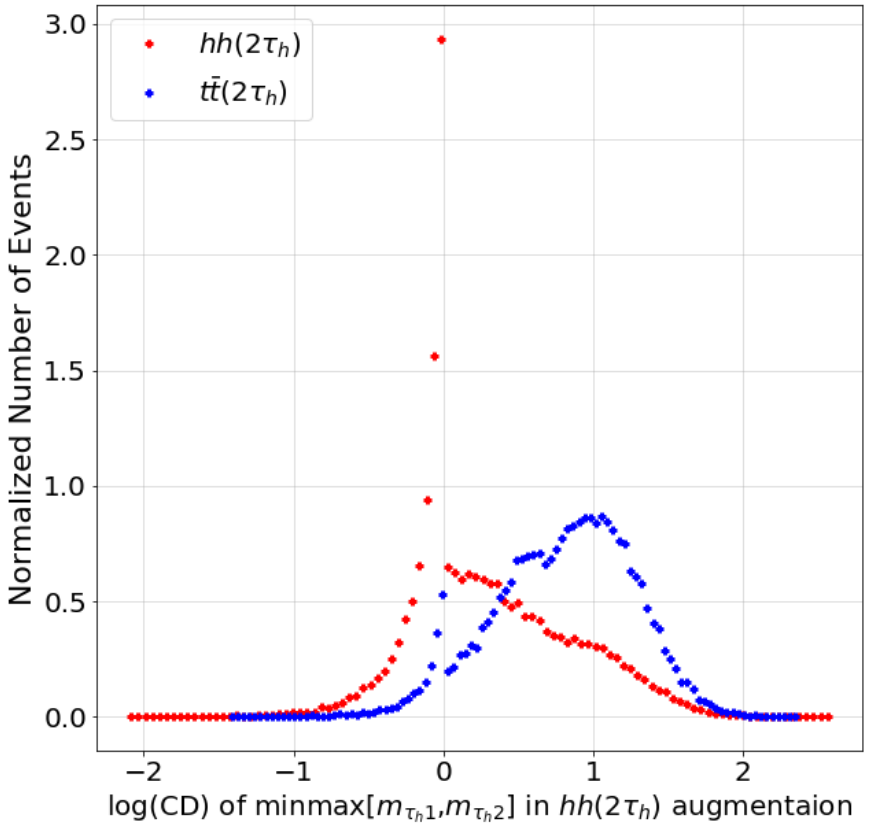
Event Selection

$* \; l = e \; or \; \mu$

- **0-l**eptons + **2-h**adronic decay tau **(2 class)**
  - $(SG) \quad hh \rightarrow b\ b\ \tau\ \tau \qquad\qquad\qquad\qquad \rightarrow b\ b\ \tau_h\ \tau_h + met$
  - $(BG) \quad \bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ \tau_h\ \tau_h + met$
- **1-l**eptons + **1-h**adronic decay tau **(5 class)**
  - $(SG) \quad hh \rightarrow b\ b\ \tau\ \tau \qquad\qquad\qquad\qquad \rightarrow b\ b\ \tau_h\ l\ + met$
  - $(SG) \quad hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ \tau_h\ l\ + met$
  - $(SG) \quad hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ l\ \tau + met \rightarrow b\ b\ l\ \tau_h\ + met$
  - $(BG) \quad \bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ \tau_h\ l\ + met$
  - $(BG) \quad \bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ \tau_h\ l\ + met$
- **2-l**eptons + **0-h**adronic decay tau **(7 class)**
  - $(SG) \quad hh \rightarrow b\ b\ \tau\ \tau \qquad\qquad\qquad\qquad \rightarrow b\ b\ l\ l\ + met$
  - $(SG) \quad hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ l\ l\ + met$
  - $(SG) \quad hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ l\ \tau + met \rightarrow b\ b\ l\ l\ + met$
  - $(SG) \quad hh \rightarrow b\ b\ w\ w^* \qquad\qquad\qquad\qquad \rightarrow b\ b\ l\ l\ + met$
  - $(BG) \quad \bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ l\ l\ + met$
  - $(BG) \quad \bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ l\ l\ + met$
  - $(BG) \quad \bar{t}t \rightarrow b\ w\ b\ w \qquad\qquad\qquad\qquad \rightarrow b\ b\ l\ l\ + met$

0-lepton & 2-hadronic decay tau





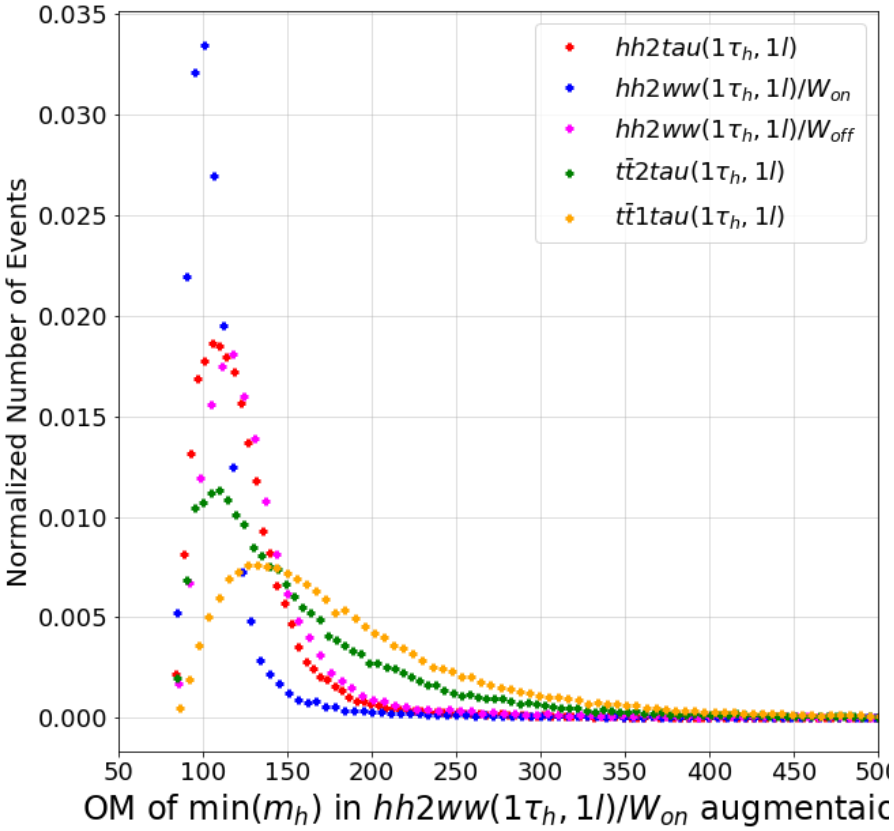
Event Selection

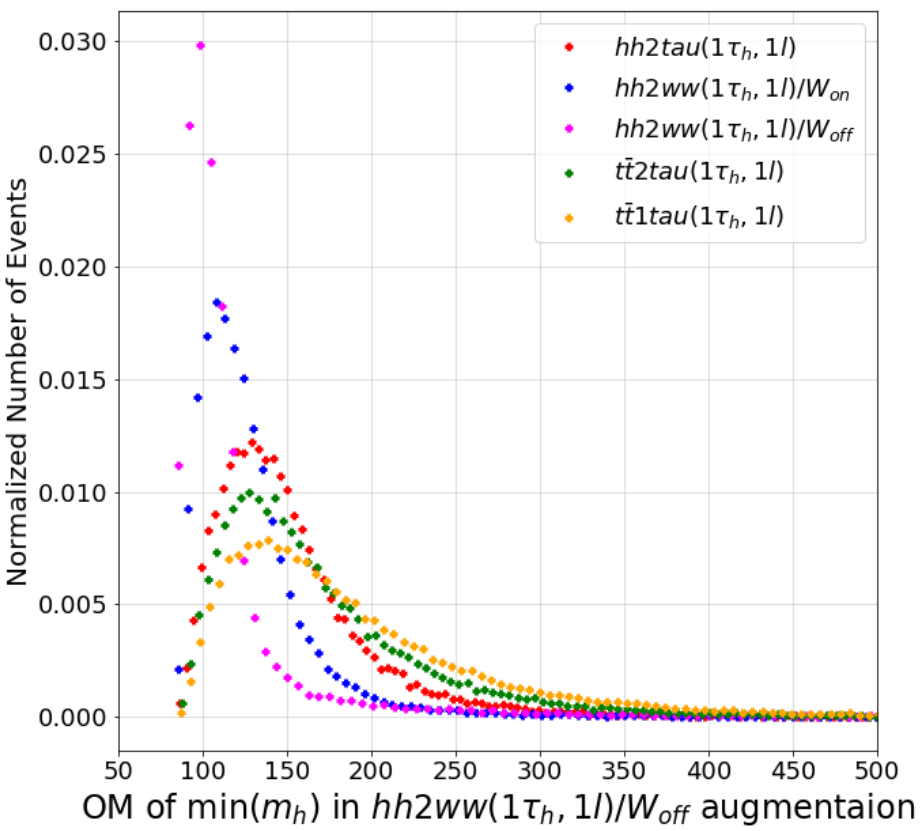
- Using …
  - MG5_aMC v2.5.5 + MADSPIN / Delphes / PYTHIA8
  - CT10nlo

- Cut …
  - Delphes : Using delphes_card_ATLAS.dat
  - Tau Tagging : $\Delta R < 0.4$, $\Delta R_{track} < 0.2$, $P_T^{Track} > 1.0$, $P_T^{\tau} > 2.0$, $\eta_{\tau} < 2.5$
    1-prong Eff = 70% , N(>1)-prong eff = 60%

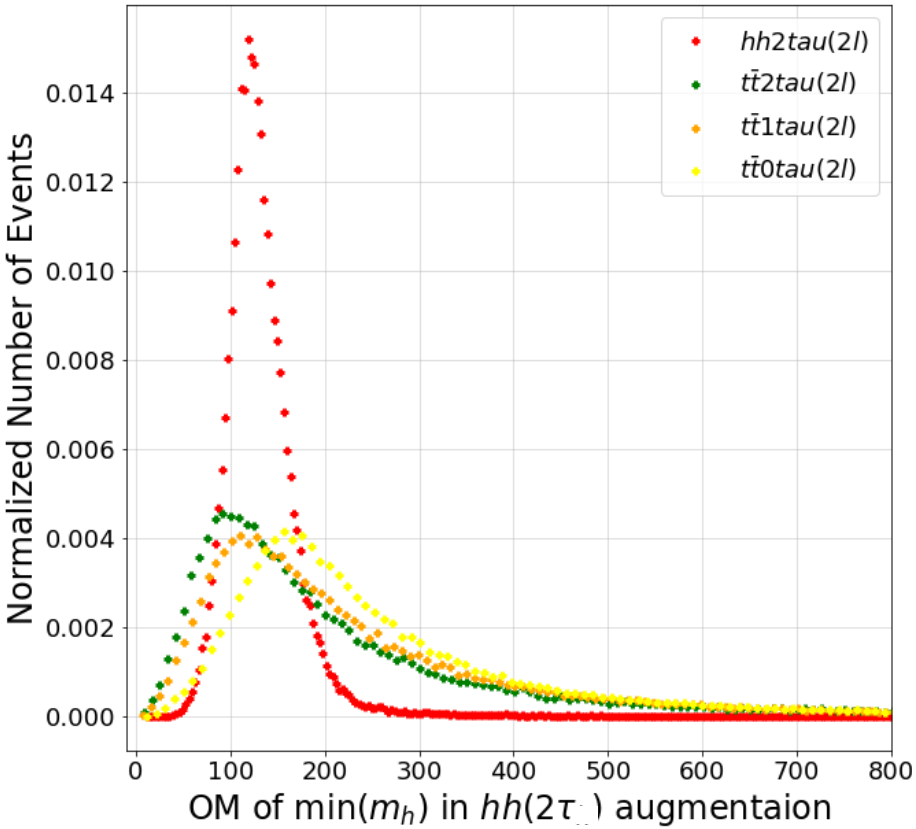
- Hadronical Tau decay using ALL N-prongs

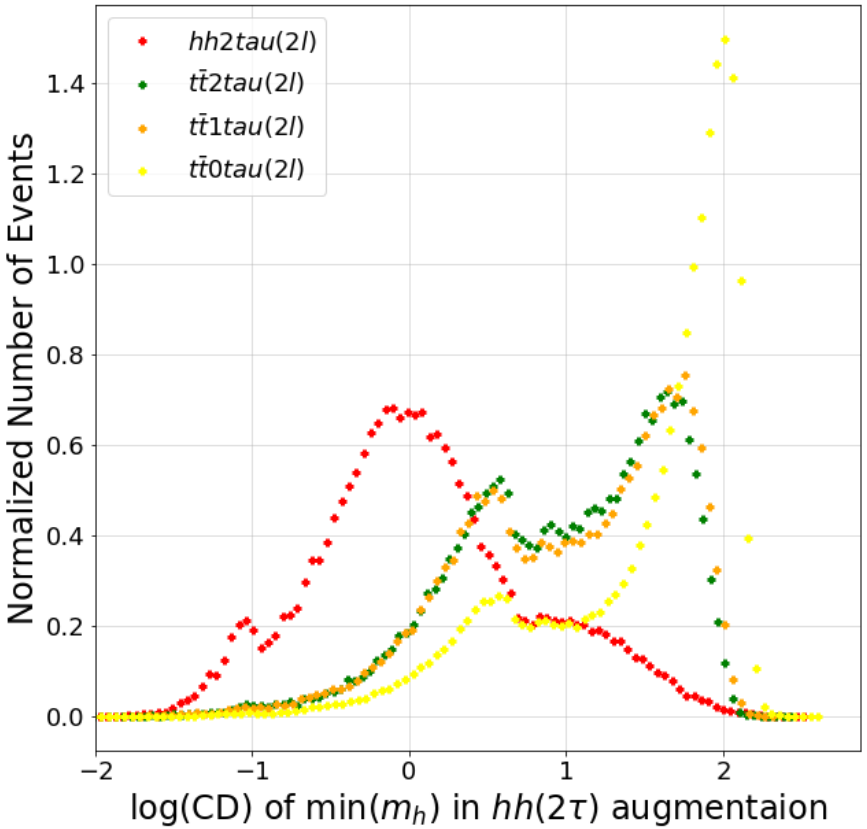
1-lepton & 1-hadronic decay tau





2-lepton & 0-hadronic decay tau

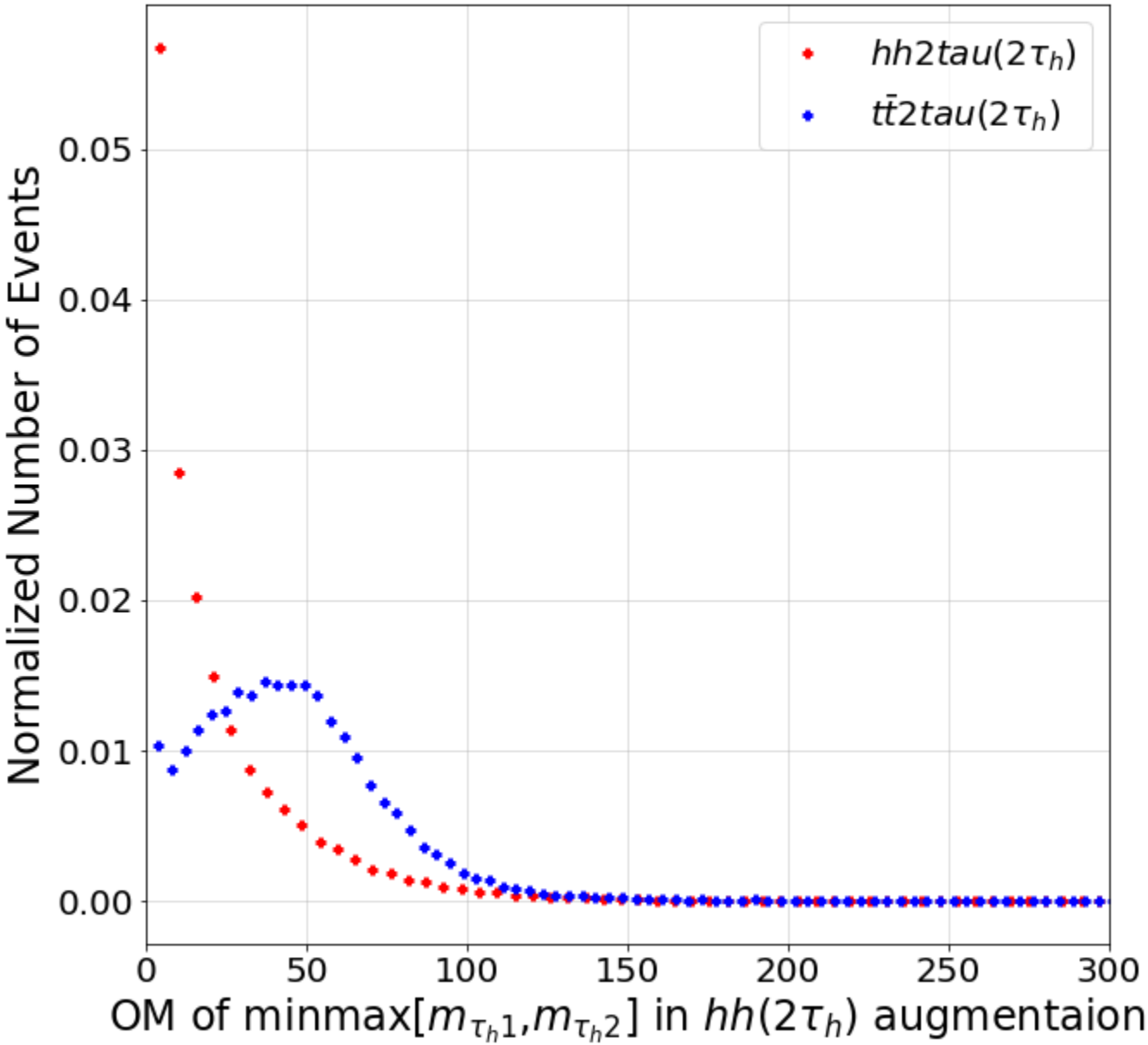




Constraints of Mass

- H1 (tata) = 125.
- H2 (bb) = 125.
- Tau1 = Tau2

0-lepton & 2-hadronic decay tau



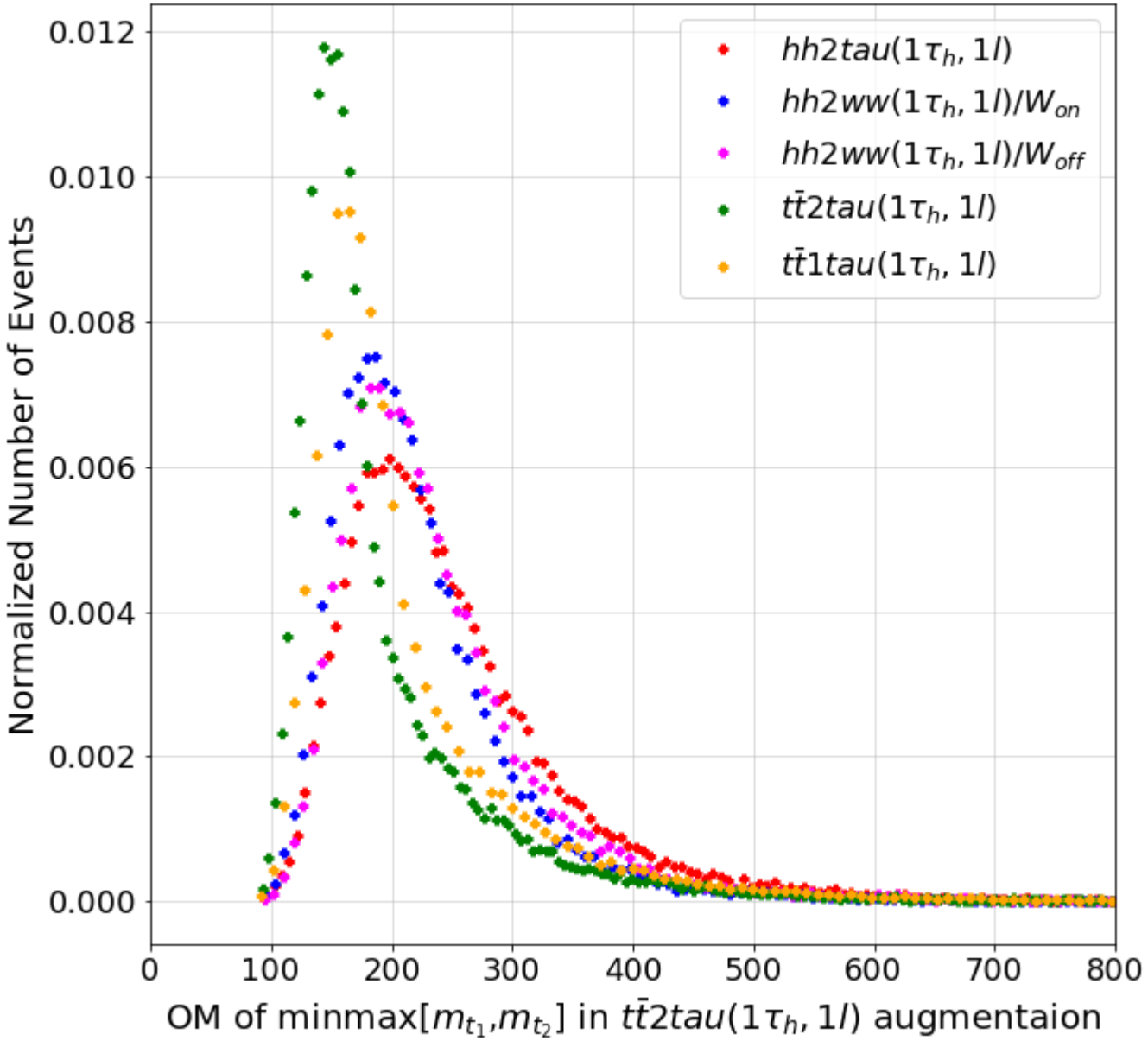
Constraints of Mass

- H1(tautau)= 125
- H2(bb)= 125
- Tau1 = Tau2

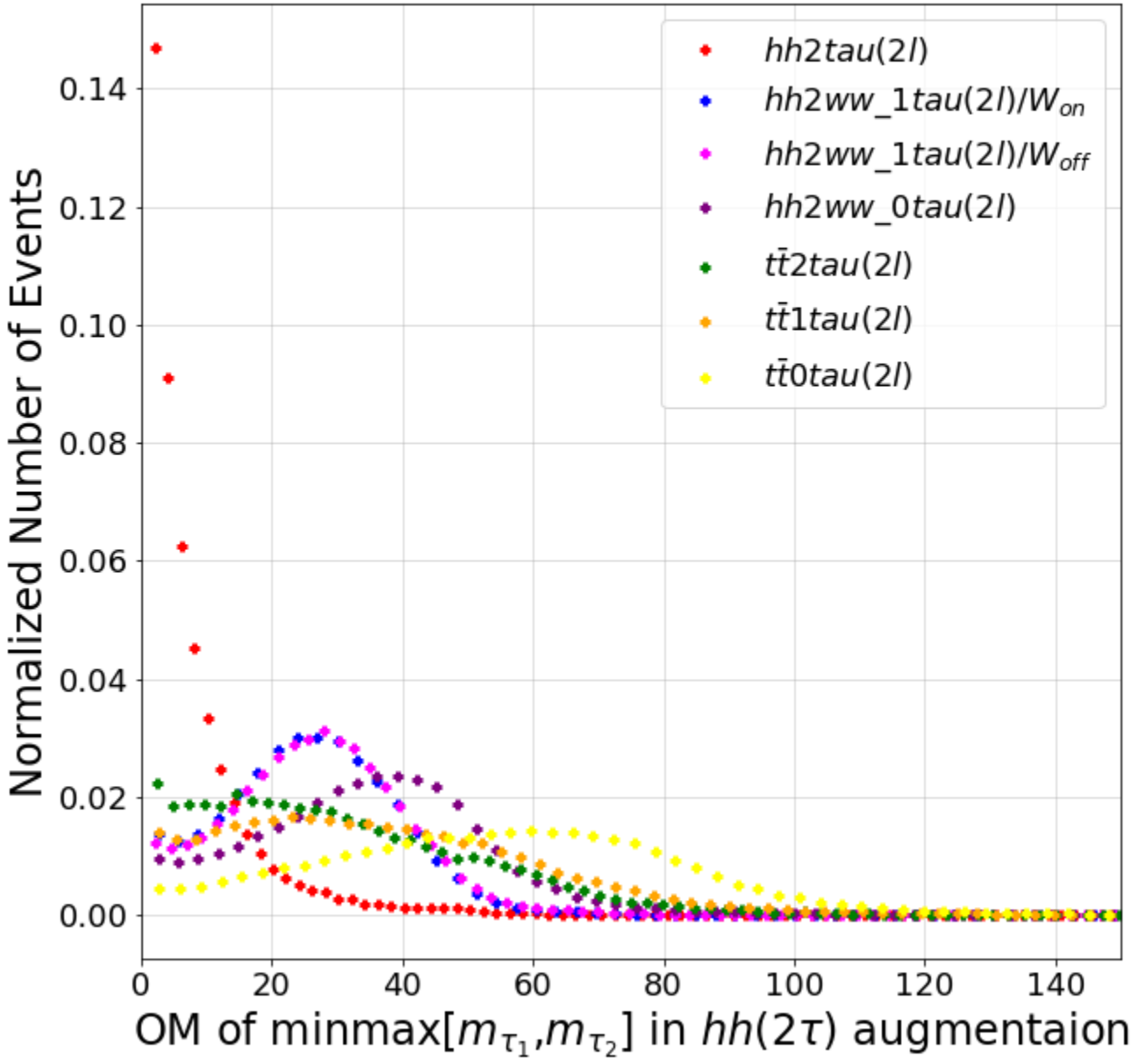
1-lepton & 1-hadronic decay tau

Constraints of Mass

- t1 = t2
- W1 = 80.4
- W2 = 80.4
- tau1 = 1.77
- tau2 = 1.77



2-lepton & 0-hadronic decay tau



Constraints of Mass

- H1 (tautau) = 125.
- H2 (bb) = 125.
- Tau1 = Tau2

Back up slides - OptiMass introduction

- Lagrange multipliers

$$M(\vec{x}^*) \equiv \min_{x \in \mathbb{R}^n} M(\vec{x}) \; s.t \; c_{a=1,\dots,m}(\vec{x}^*) = 0.$$

Minimum value of the function

constraints

$$\mathcal{L}(\vec{x}, \lambda) = M(\vec{x}) - \sum_{a=1}^{m} \lambda_a \, c_a(\vec{x}).$$

-> It does NOT tell us which is the correct minimizer among the N-stationary points!

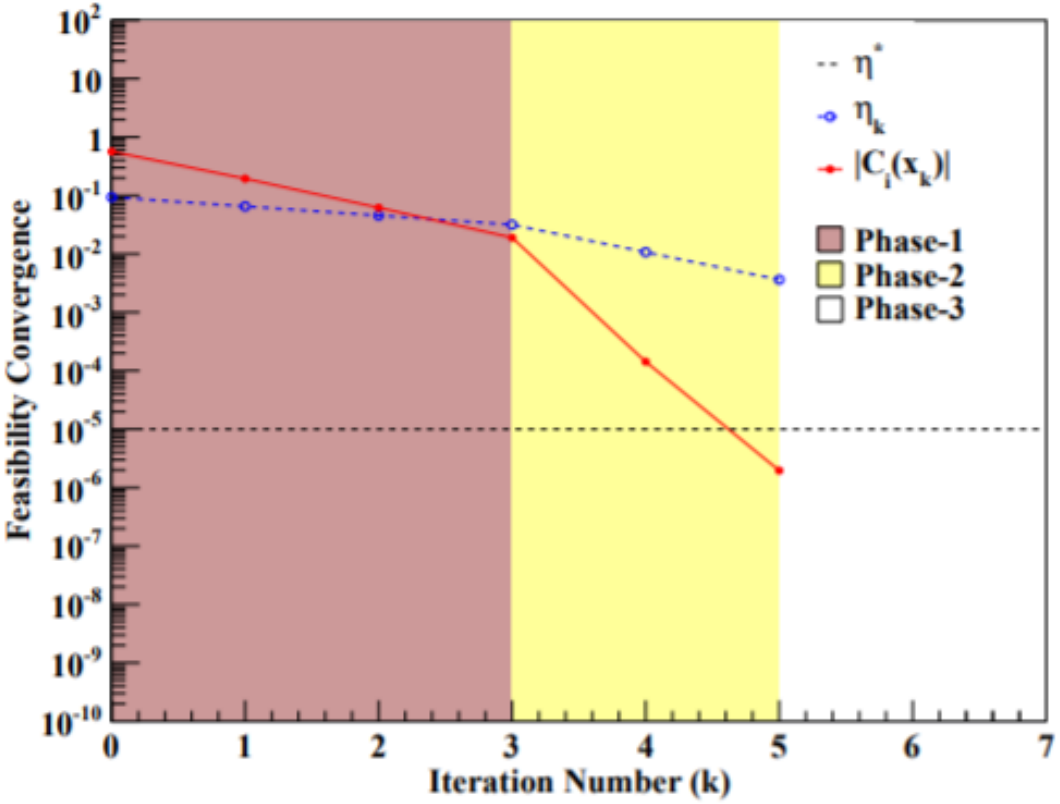
$M = minimized\ mass\ variable\ function$
$\lambda_a = augmented\ Lagrange\ parameter$
$\mu = penalty\ parameter$

- Penalty methods

$$P(\vec{x}, \mu) \equiv M(\vec{x}) + \frac{1}{2\mu} \sum_{a=1} c_a^2(\vec{x}).$$

OPTIMASS: A Package for the Minimization of Kinematic Mass Functions with Constraints
- Cho, Won Sang *et al.* JHEP 1601 (2016) 026 arXiv:1508.00589

Back up slides - OptiMass introduction



- ✓ The evolution of the intermediate feasibility tolerance η^k
- ✓ The real feasibility $||c_i(x_k)||$
- ✓ The scale set by the ultimate feasibility tolerance η^*

Back up slides – OPTIMASS Algorithm Example

OPTIMASS: A Package for the Minimization of Kinematic Mass Functions with Constraints - Cho, Won Sang *et al.* JHEP 1601 (2016) 026 arXiv:1508.00589 (pg 17-18)

3.2.1 Example one

Our first example involves minimizing the objective function

$$f(x, y) = x + y, \tag{3.30}$$

over the usual plane, $\vec{x} \equiv (x, y)$, subject to the constraint

$$x^2 + y^2 - 1 = 0. \tag{3.31}$$

This constraint implies that our solution must lie on a unit circle centered at the origin. Clearly, the function (3.30) is minimized along the circle at the point

$$(x^*, y^*) = \left(-\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2} \right), \tag{3.32}$$

which is the global minimizer in this example.

The objective function, (3.30), is plotted in the left panel of figure 2. The locus of feasible points (i.e., the unit circle about the origin,) is shown in black. With the Lagrange multiplier method, one adds a Lagrange multiplier term to the objective function as in (2.4)

$$\mathcal{L}(x, y, \lambda) = x + y - \lambda (x^2 + y^2 - 1). \tag{3.33}$$

There are two *stationary points* given by

$$(x^*, y^*, \lambda^*) = \pm\left(\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}\right). \tag{3.34}$$

The Hessian corresponding to the function (3.33) is

$$H_{\mathcal{L}} = \begin{pmatrix} -2\lambda & 0 \\ 0 & -2\lambda \end{pmatrix}, \tag{3.35}$$

and the condition for a minimum (i.e., that $H_{\mathcal{L}}$ should be positive definite) requires us to choose $\lambda < 0$, which selects the correct minimizer among the two stationary points (3.34):

$$(x^*, y^*, \lambda^*) = (-\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}), \tag{3.36}$$

confirming the earlier result (3.32).

We now wish to verify that the OPTIMASS algorithm reproduces this solution. After running the code, we obtain

$$(x^*, y^*; \lambda^*) = (-0.707106, -0.707106; -0.707180), \tag{3.37}$$

which is consistent with (3.36) ($\sqrt{2}/2 = 0.707107...$). We note that this convergence only required five steps, suggesting that the minimum was found relatively easily. The right panel of figure 2 shows a contour plot of the augmented Lagrangian,

$$\tilde{\mathcal{L}}(x, y; \mu_5, \lambda_5) = (x + y) - \lambda_5 (x^2 + y^2 - 1) + \frac{1}{2\mu_5}(x^2 + y^2 - 1)^2 \quad \text{with} \tag{3.38}$$

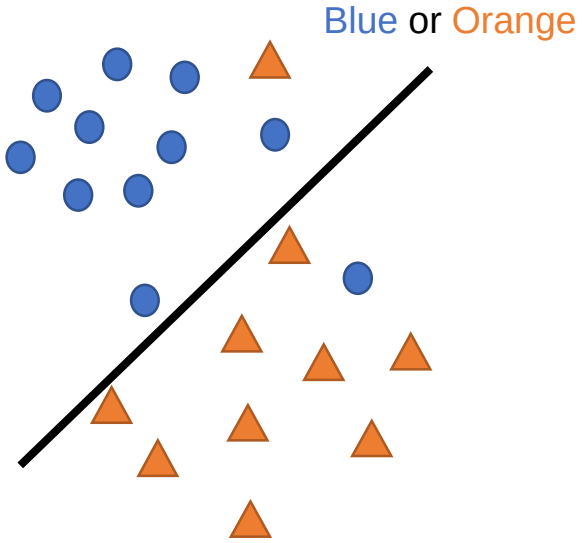
Summary(Backup)

- **Di-Higgs search in …**
  - 2b + 2-lep
  - 2b + 1-lep + 1-tau_h
  - 2b + 2-tau_h
- **High Level Feature variables for each decay channel**
  - Existing (low level) variables (P_T/deltaR/MT2 …)
  - OPTIMASS variables (om/cd)
  - Around 40~70 variables
- **Using Deep Neural Network**
  - Multi-class Classification
  - Better performance than only using low level features

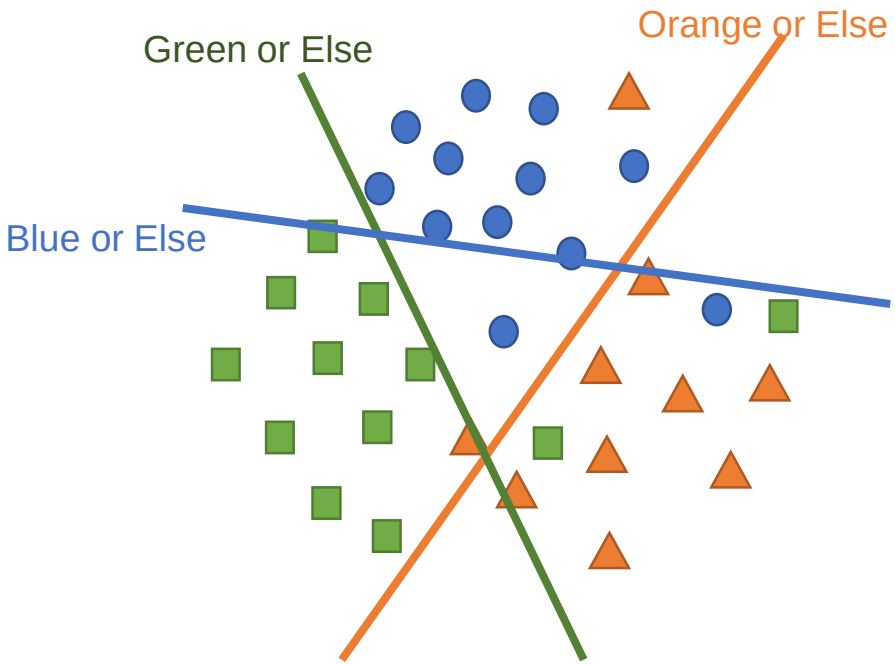
Use DNN + OPTIMASS Variables!!!

Multi-Class Classification

Binary classification



Multi-Class classification



❖ **Visible : CMS/ATLAS common features**



Signal vs Background

@ 14TeV, 39.64 fb (HH), 953.6 fb (TT)

Channel	Leptons	X section	Topology $* \ l = e \ or \ \mu$
HH2Tau	0	~1.2	$hh \rightarrow b\ b\ \tau\ \tau \rightarrow b\ b\ \tau_h\ \tau_h + met$
TT2Tau	0	~5097.2	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ \tau_h\ \tau_h + met$
HH2Tau	1	~1.3	$hh \rightarrow b\ b\ \tau\ \tau \rightarrow b\ b\ \tau_h\ l + met$
HH2WW*W1Tau	2	~0.08	$hh \rightarrow b\ b\ w\ w \rightarrow b\ b\ l\ l + met \rightarrow b\ b\ l\ l + met$
HH2WW*1Tau	2	~0.08	$hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ l\ \tau + met \rightarrow b\ b\ l\ l + met$
HH2WW0Tau	2	~0.47	$hh \rightarrow b\ b\ w\ w^* \rightarrow b\ b\ l\ l + met$
TT2Tau	2	~1508.7	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ \tau + met \rightarrow b\ b\ l\ l + met$
TT1Tau	2	~16158.3	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ \tau\ l + met \rightarrow b\ b\ l\ l + met$
TT0Tau	2	~43263.9	$\bar{t}t \rightarrow b\ w\ b\ w \rightarrow b\ b\ l\ l + met$

Too Many invisible particles from each distinctive/complicated decay topologies