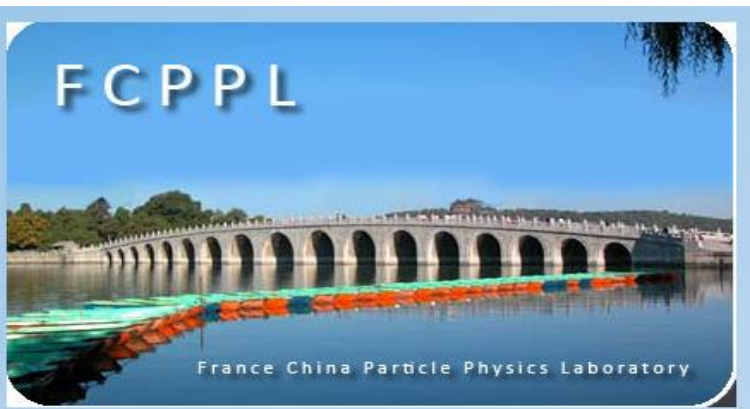


Collaborations between IPHC and PKU: ttH multileptonic channel etc.

Qiang Li

HEP Group, *Peking University, Beijing, China*

FCPPL2017, Tsinghua Univ, 2017. 03. 27



Milestone of our collaborations

IPHC, Strasbourg, France

Daniel Bloch

Nicolas Chanon

(this week@Moriond QCD)

Catherine Le Bihan

Xavier Coubez

PKU, Beijing, China

Yajun Mao

Qiang Li

Jing Li

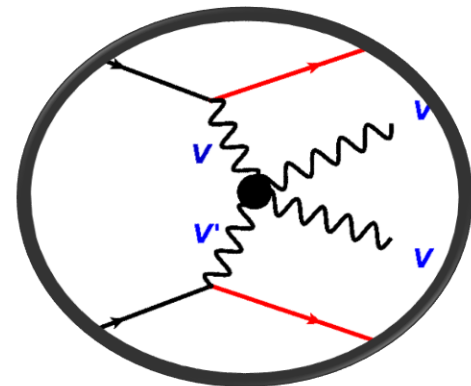
(@ Strasbourg)

Zhenwei Cui

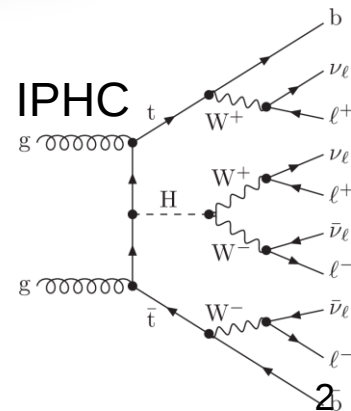
- Start Collaborating on Vector Boson Scattering measurement from 2014 while **Nicolas served as co-convenor of CMS Standard model Diboson group**

1612.09256 JHEP VBS WGamma

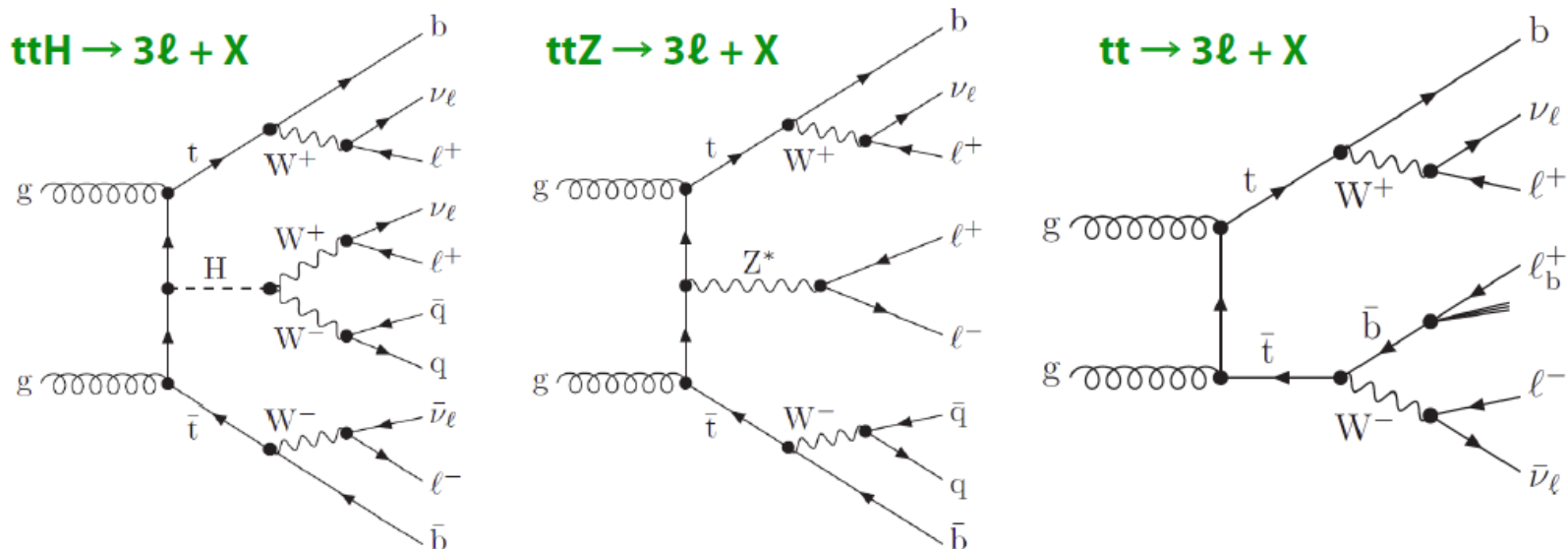
1702.03025 PLB VBS ZGamma



- Then Ms. Jing Li visited Strasbourg 3 months twice,
- April - June 2016*
- Mid Feb - May 2017*
- supported jointly by FCPPL, IPHC and PKU,
- working on Matrix Element Method application to $t\bar{t}H$ search in CMS



ttH Searches in multilepton channels



- Targeting $H \rightarrow WW^*/\tau\tau/ZZ^*$ (relative contributions $\sim 70/20/10\%$)
 - 2 lepton same-sign (2lss) and ≥ 3 leptons (3l)
- Complementary to $H \rightarrow b\bar{b}/\gamma\gamma$ searches

- Background:
 - Backgrounds: tt+W/Z, tt+jets (same-sign required to reduce Drell-Yan and ttZ)
 - Background normalization from control region: loosened identification (fakes), Z to ll (mis-charge)

- ATLAS-CONF-2016-058 (Aug 2016, $L = 13.2 \text{ fb}^{-1}$)
- CMS-PAS-HIG-2016-022 (Aug 2016, $L = 12.9 \text{ fb}^{-1}$) ICHEP2016
- CMS PAS HIG-17-004 (Mar 2017, **$L = 35.9 \text{ fb}^{-1}$**) Moriond2017



ttH Searches: Strategy

- $\ell^\pm \ell^\pm + 0 \tau_h + \geq 4 \text{ jets}$ ($\geq 1 \text{ b}$)
 - split in ee, eμ, μμ, -- vs ++
 - eμ, μμ split in loose/tight b-tagging (tight is $\geq 2 \text{ b}$)
- $3\ell + 0 \tau_h + \geq 2 \text{ jets}$ ($\geq 1 \text{ b}$)
 - split in tight vs loose b-tag, split total charge +1 vs -1
- $4\ell + 0 \tau_h + \geq 2 \text{ jets}$ ($\geq 1 \text{ b}$)
 - veto $H \rightarrow 4\ell$
- $\geq 1 \tau_h$ states to be done in dedicated $H \rightarrow \tau\tau$ analysis

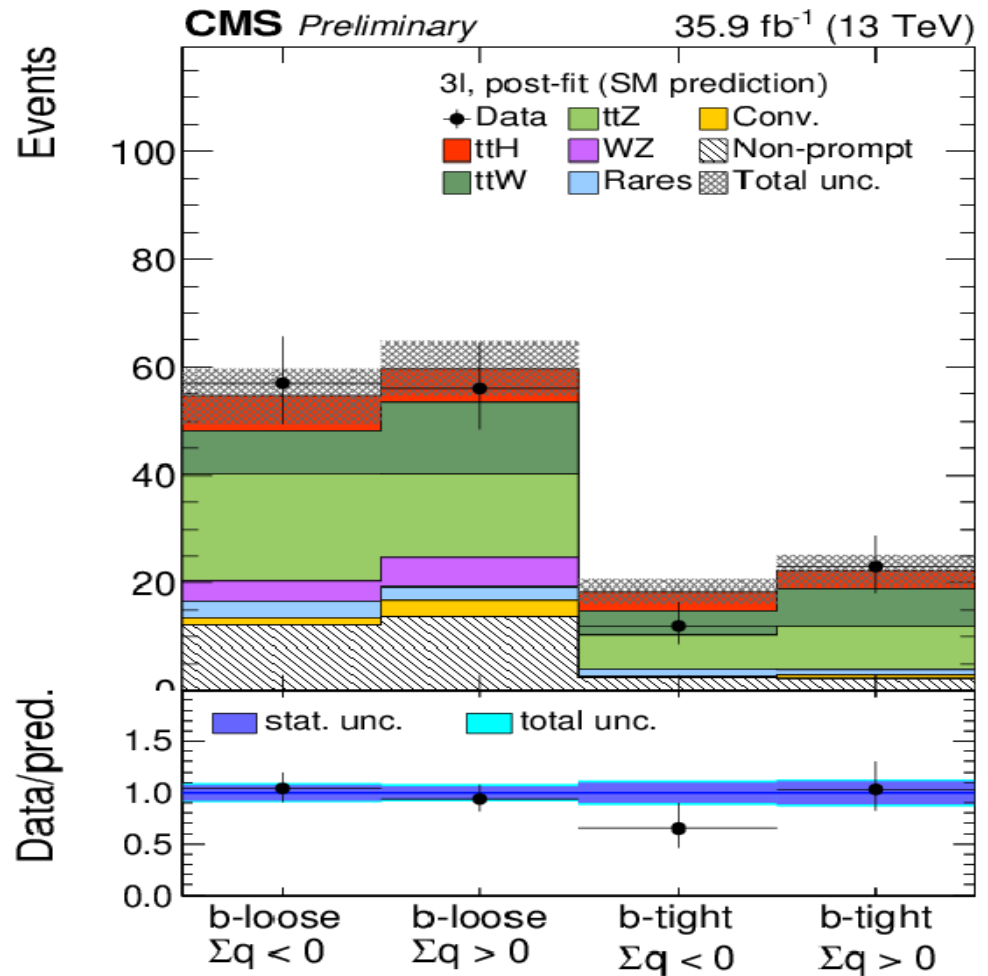
2l, 3l:

Two BDTs to discriminate ttH vs tt/ttV

3l:

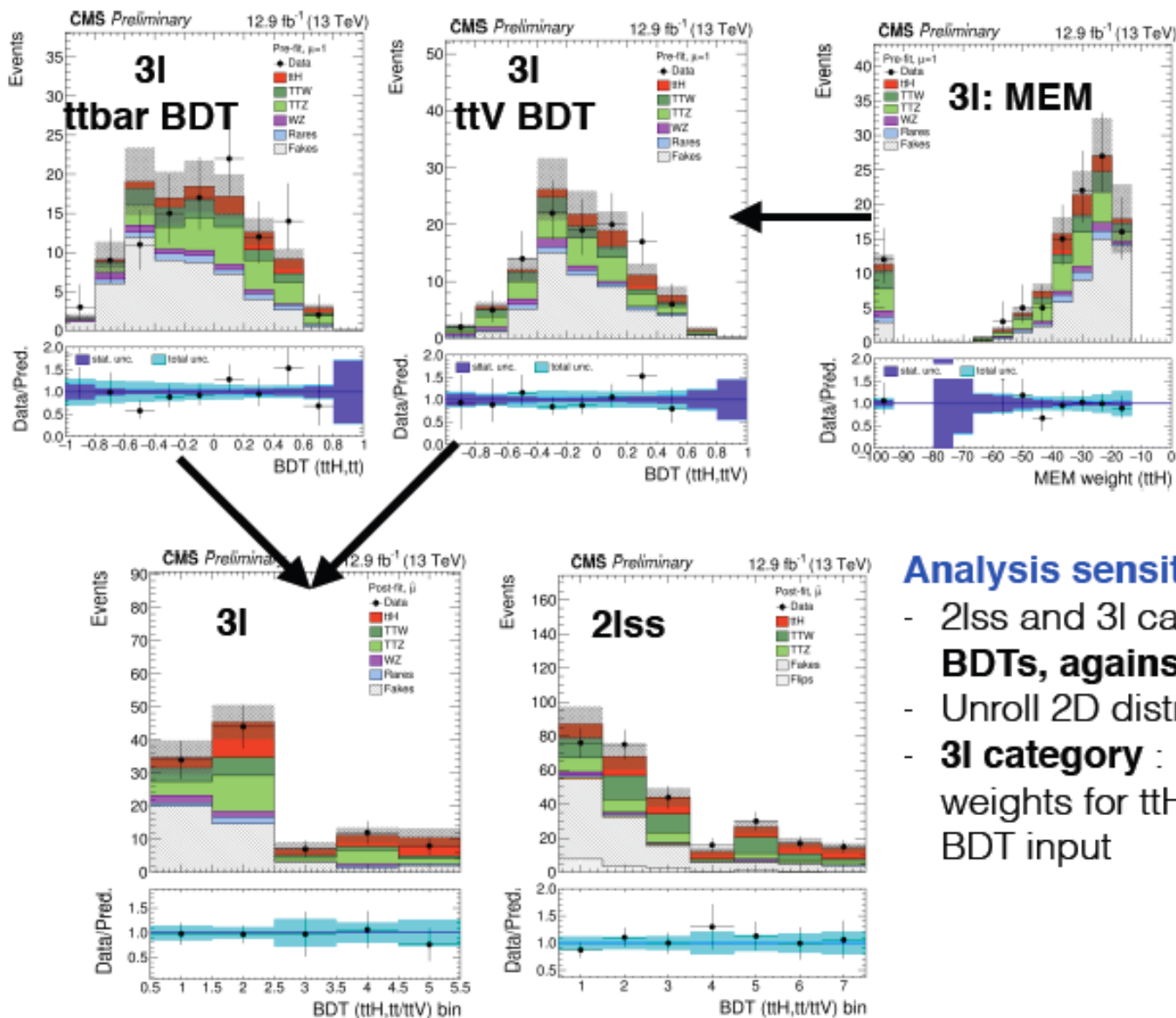
BDT vs ttV uses likelihood ratio from

Matrix Element computation



ttH Searches: Strategy

HIG-16-022



Analysis sensitivity:

- 2lss and 3l categories: Train **2 BDTs, against ttbar and ttW/Z**
- Unroll 2D distributions
- **3l category** : include log of **MEM** weights for ttH, ttW and ttZ as ttV BDT input

Matrix Element Method

Integration:
VEGAS in ROOT

Matrix element:
Madgraph C++ standalone

MEM weight

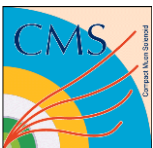
$$w_{i,\alpha}(\Phi') = \frac{1}{\sigma_\alpha} \int d\Phi_\alpha \cdot \delta^4\left(p_1^\mu + p_2^\mu - \sum_{k \geq 2} p_k^\mu\right) \cdot \frac{f(x_1, \mu_F) f(x_2, \mu_F)}{x_1 x_2 s} \cdot \left| \mathcal{M}_\alpha(p_k^\mu) \right|^2 \cdot W(\Phi' | \Phi_\alpha)$$

Phase-space enforcing 4-momentum conservation:
analytic (same as in Madweight)

PDF:
LHAPDF interface
NNPDF

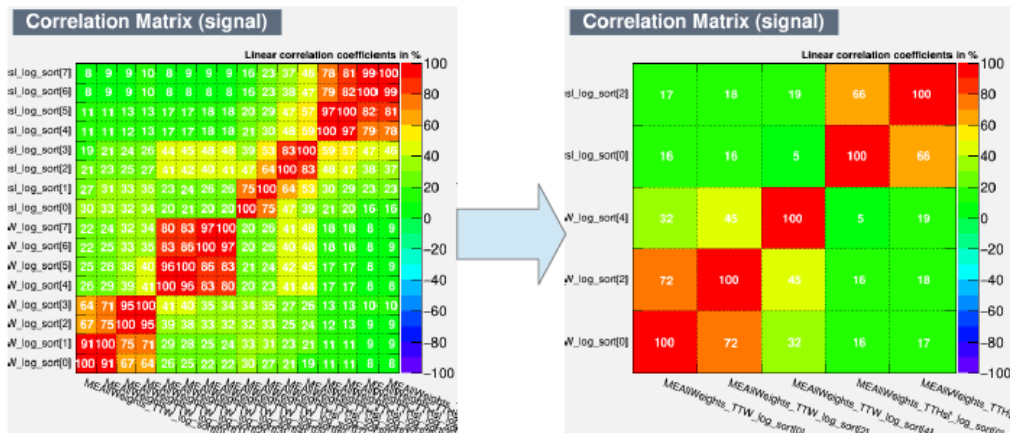
Transfert functions:
Evaluated in MCrn2 samples

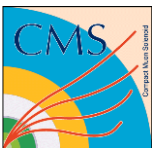
- ttH MET Framework setup in IPHC with C++, includes 2lss, 3l (and 4l) categories
- Categories where 1 or 2 jets are not reconstructed are included (integrate over jet momenta)



Jing's Contribution under supervision of Nicolas

- She was the **first to try out** the newly-completed MEM software.
- Dedicated studies to summarize **permutation** over reconstructed leptons and jets assignment to the parton level matrix element
- Proposed several ideas to **reduce** permutations which were implemented.
- Include the weights from permutations into a **BDT**. Presented her work in the CMS ttH multilepton group and was well received. The results were improving the performance by a few %.
- The BDT training code she has been setting up was also used as a basis for the later results at IPHC.





ttH Moriond 2017



Category	Observed μ fit $\pm 1\sigma$	Expected μ fit $\pm 1\sigma$
Same-sign di-lepton	1.7 (−0.5) (+0.6)	1.0 (−0.5) (+0.5)
Three lepton	1.0 (−0.7) (+0.8)	1.0 (−0.7) (+0.8)
Four lepton	0.9 (−1.6) (+2.3)	1.0 (−1.6) (+2.4)
Combined (2016 data)	1.5 (−0.5) (+0.5)	1.0 (−0.4) (+0.5)
Combined (2015 data) [42]	0.6 (−1.1) (+1.4)	1.0 (−1.1) (+1.3)
Combined (2015+2016 data)	1.5 (−0.5) (+0.5)	1.0 (−0.4) (+0.5)

Significance wrt $\mu(\text{ttH}) = 0$ hypothesis:

– CMS: 3.3 σ (expected for SM ttH: 2.5 σ)

**Rencontres de Moriond
QCD and High Energy Interactions**

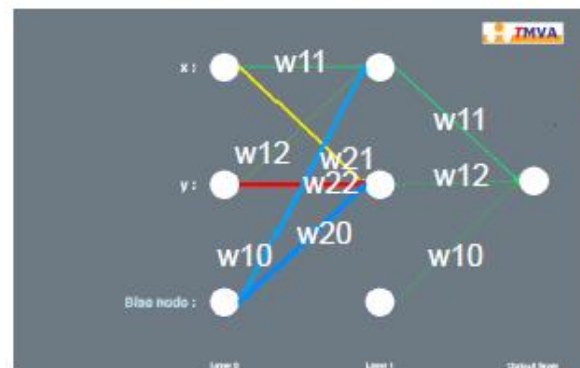
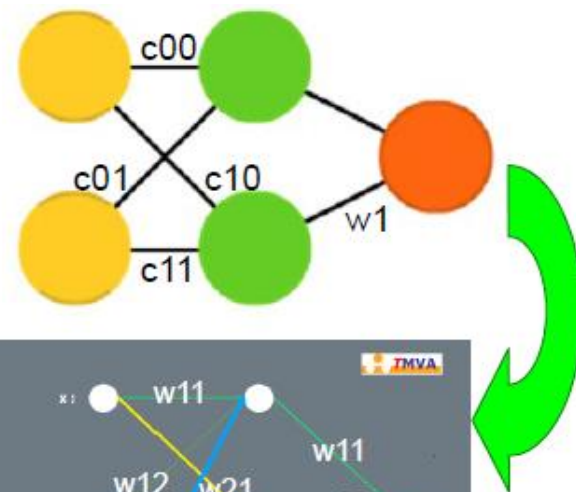
LA THUILE, MARCH 25 - APRIL 1, 2017

More from
Nicolas's Plenary
@MoriondQCD 2017

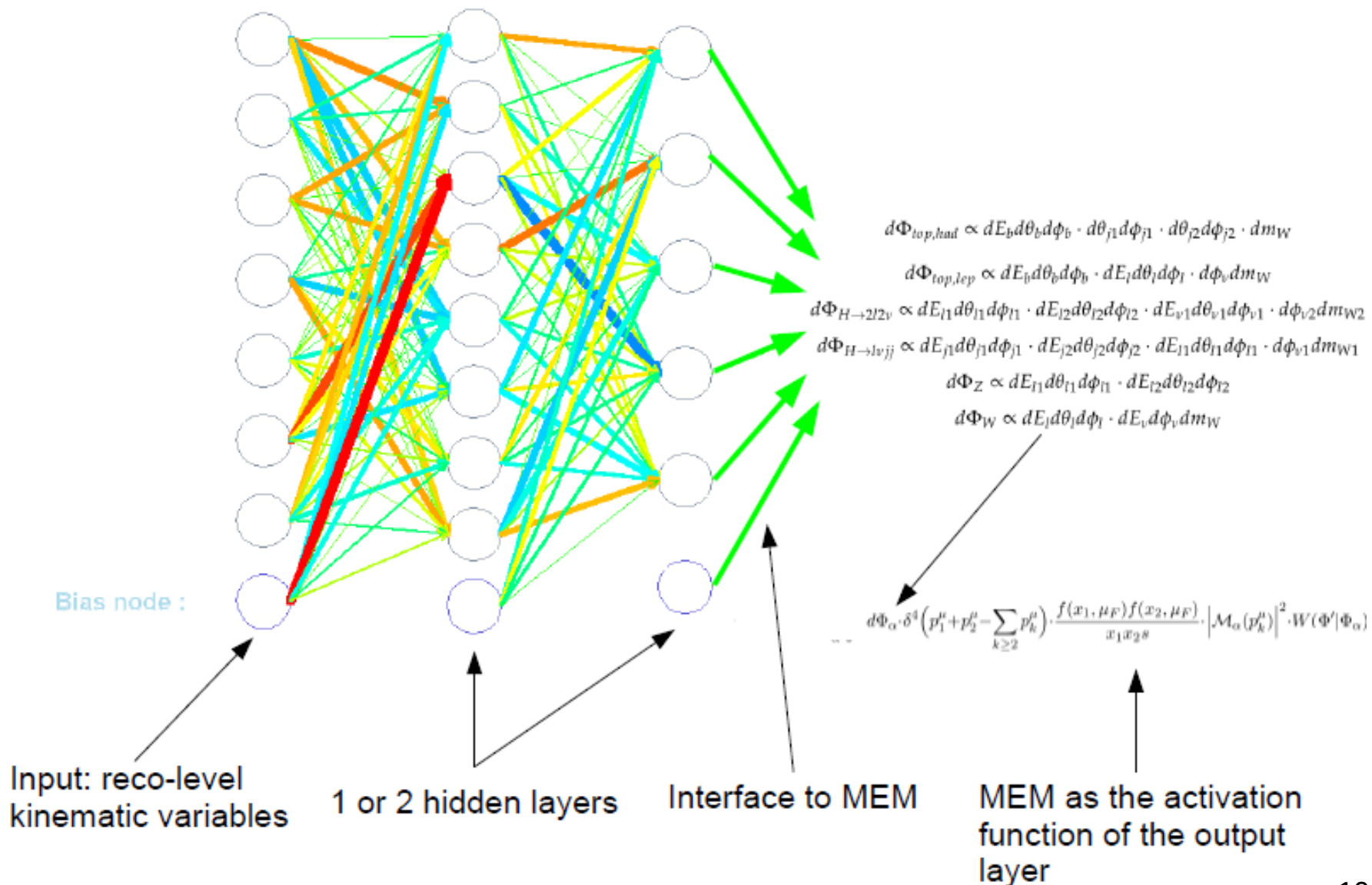
Jing's Poster
@LHCP2017

- Try other, and new, hybridization of the **MEM and MVA** method, and profit from latest MVA developments.
- Combine the use of MEM as a kinematic fit with a Neural Network to select maximum signal/background discrimination.
- Utilize new developments on **deep learning** to improve over training of traditional methods

Currently, Jing has gone through the details of simple NN method and cross-checked with TMVA implementation successfully, either with toy samples or CMS ttH inputs



2017 plans: NN $\rightarrow$ MEM



- To benefit from recent fast development in machine learning, based on our rich experiences on MEM and MVA in CMS analysis
- One of the potential deliverables would be a phenomenology paper.
HH, Jet tagging, CEPC $H \rightarrow \mu\mu$
- Aiming also at a contribution to the CMS ttH multilepton analysis of 2017 data and related publications.
- PKU and IPHC are grateful to the support from FCPPL and both sides, and would like to strengthen our collaborations.
- Nicolas will move to IPNL by mid-2017. Jing may visit France again in Fall 2017.
- We are also considering for application CSC and Eiffel Scholarship for a joint Ph.D. program in 2018

Merci