第十四届TeV物理工作组学术研讨会

Polarization fraction measurement in same sign WW scattering using deep learning

arXiv:1812.07591

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Outline

- 1. Higgs and vector boson
- 2. Vector boson scattering (VBS)
- 3. VBS same-sign WW
- 4. Polarization fraction measurement in VBS same-sign WW
- 5. Polarization fraction measurement in VBS ZZ (on-going)
- 6. Conclusion

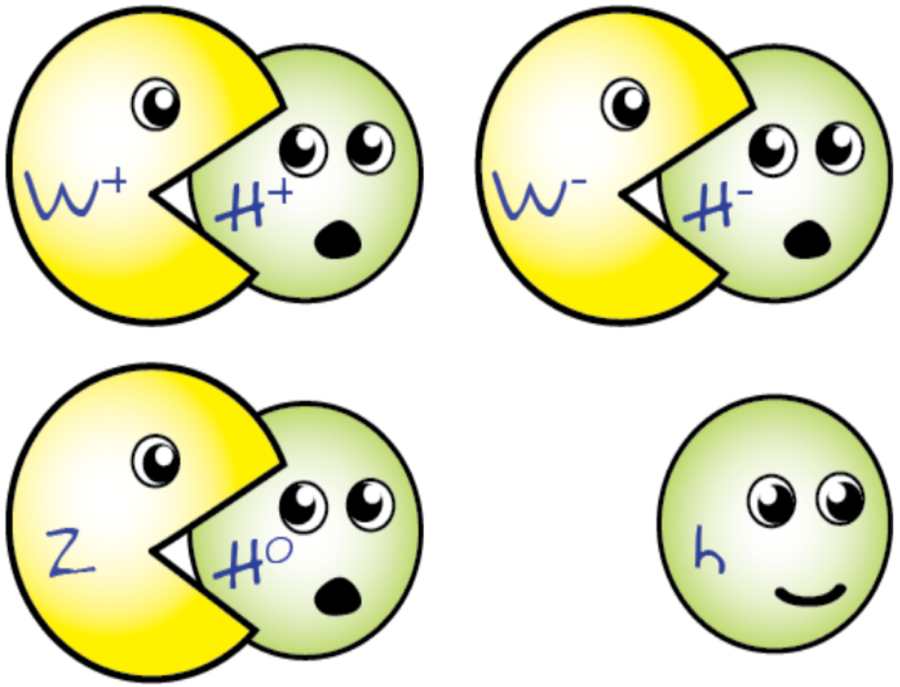
Higgs and longitudinal fraction of vector boson

- Without Higgs, gauge bosons are massless in Standard Model (SM) with gauge symmetry.

- Higgs mechanism put forwarded
  - Breaking gauge symmetry, attaining mass of gauge bosons.

  - For Electroweak sector, Electroweak symmetry breaking
    - Massive vector bosons (W^+, W^-, and Z boson)
    - Transverse and longitudinal polarization fraction

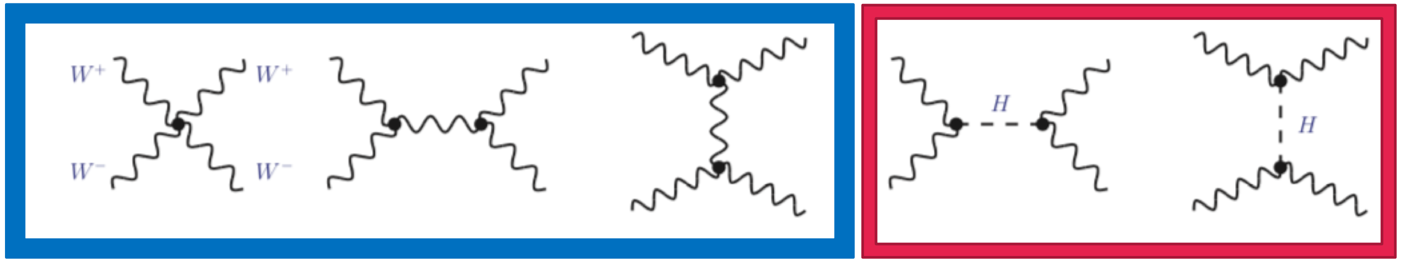
    - Additional massive scalar boson : Higgs boson.



VBS and Unitarity violation

- If there is no Higgs boson

  → Cross-section of vector boson scattering diverges.

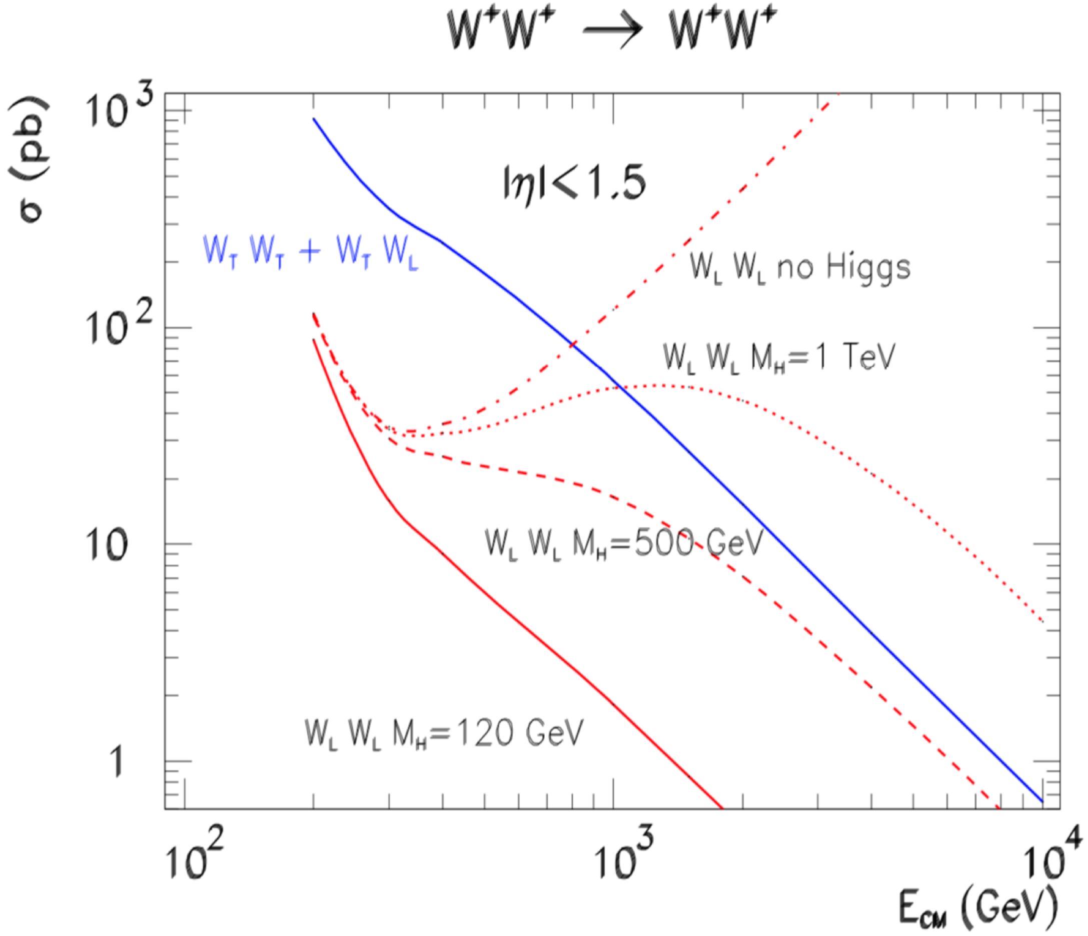


- If Higgs boson is too heavy (> 1 TeV)

  →Diverge

→ Unitarity violation

- $V_L V_L$ -> $V_L V_L$ scattering is crucial.

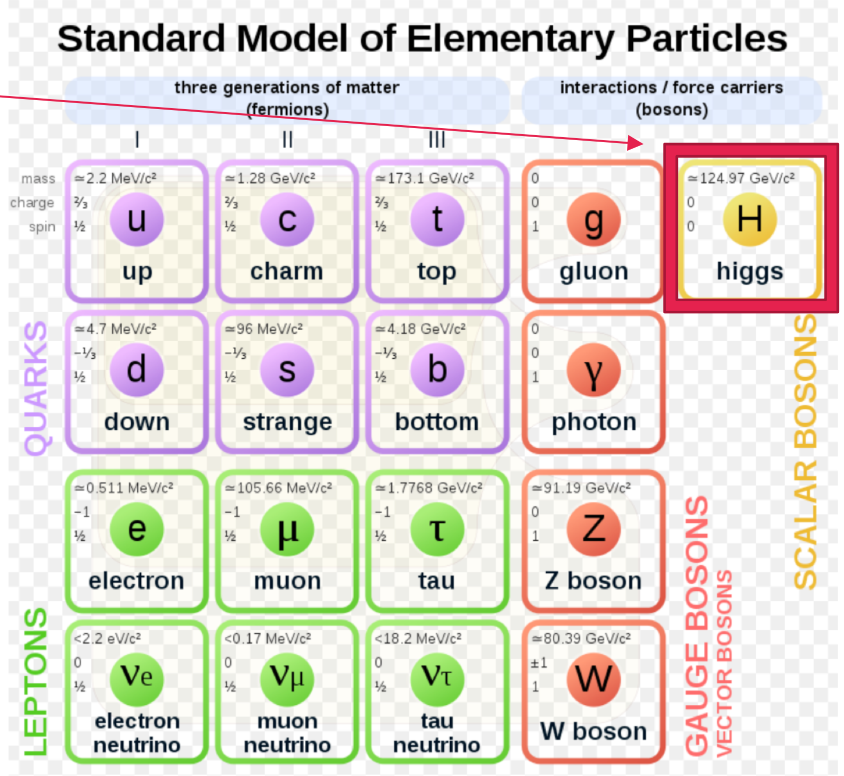


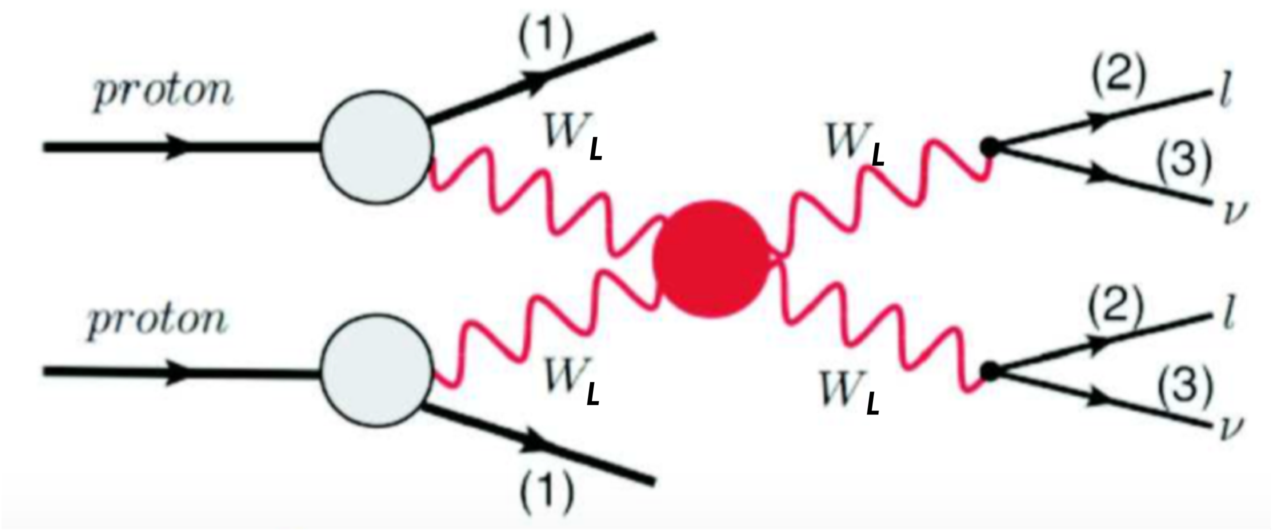
arXiv:1412.8367

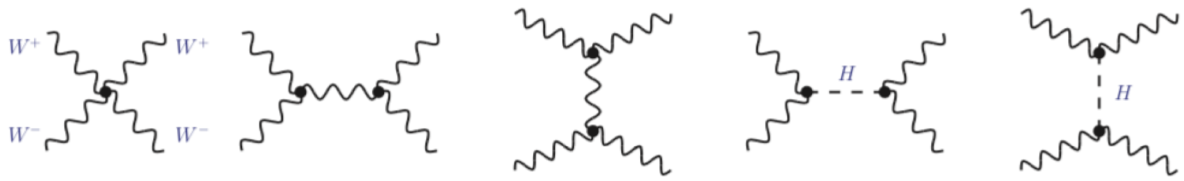
Higgs boson and vector boson scattering (VBS)

- SM Higgs boson found around mass of ~125GeV.

- Higgs boson unitarization can be tested by VBS process ($V_L V_L$ -> $V_L V_L$)
  - VBS same-sign WW scattering is one of the most promising channel

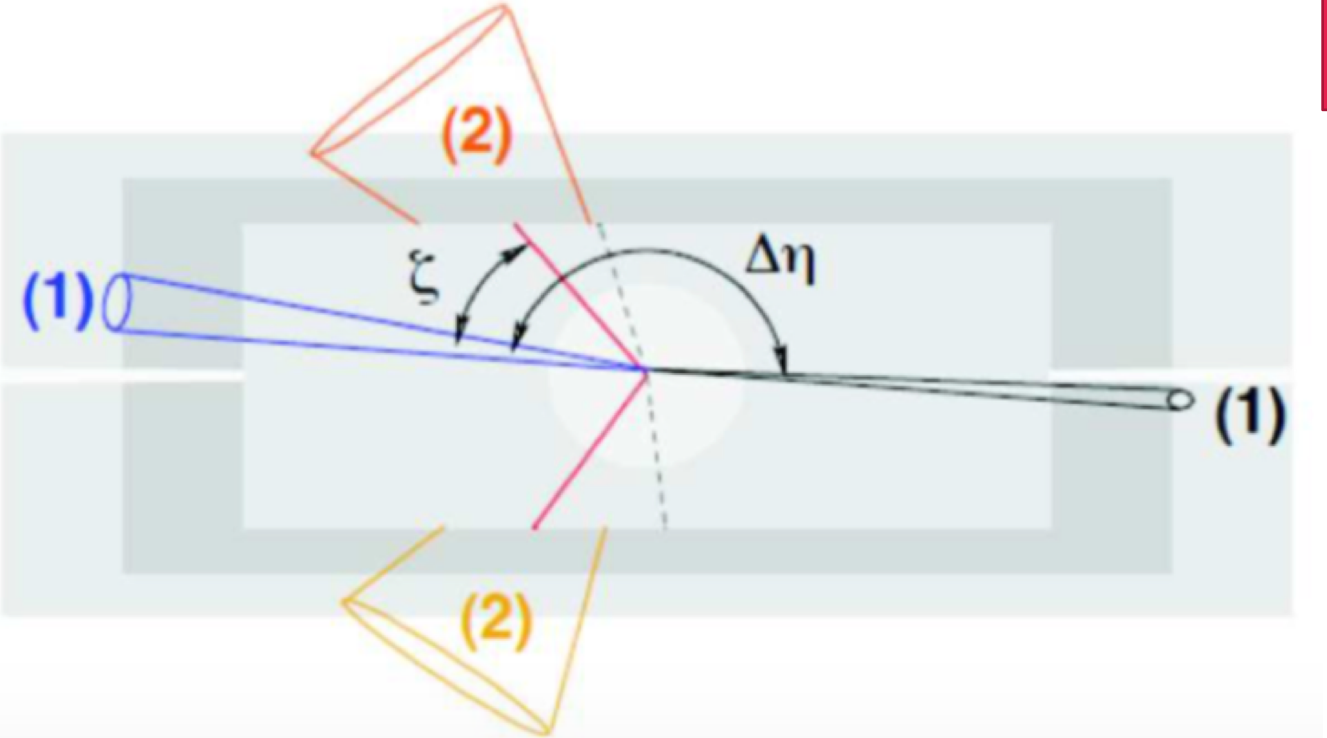


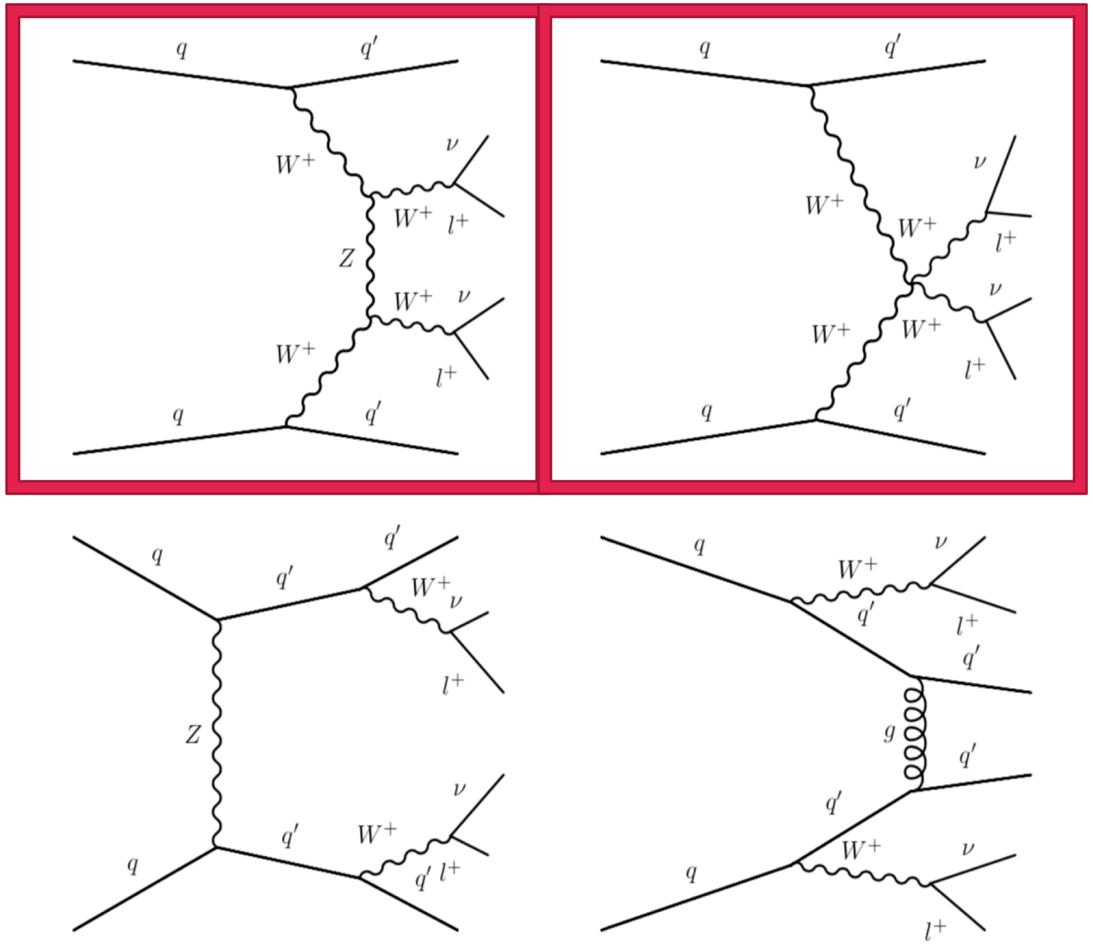




Vector boson scattering

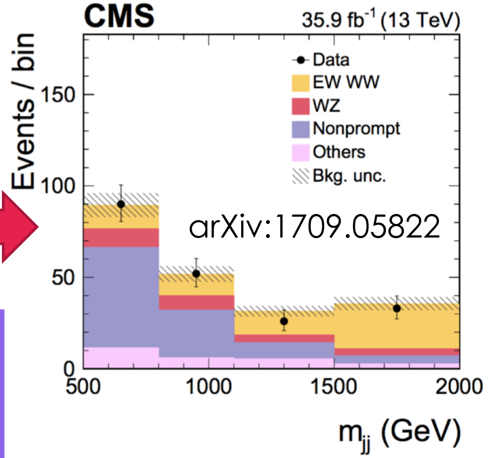
- Two energetic jets in forwarded region
- Relatively pure EWK region in between the two jets
  - Profits from low background



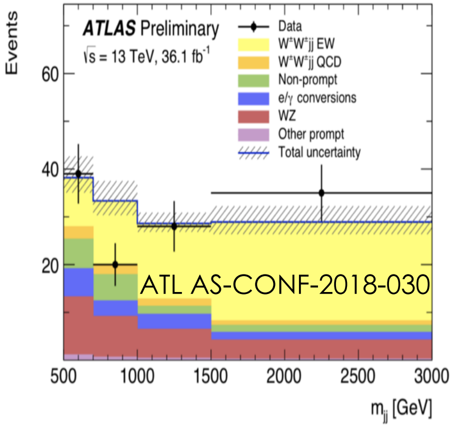


VBS Same-sign WW scattering

- The process (WW -> WW) has been observed by both ATLAS and CMS with luminosity of ~$36fb^{-1}$, at $\sqrt{s} = 13\ TeV$.



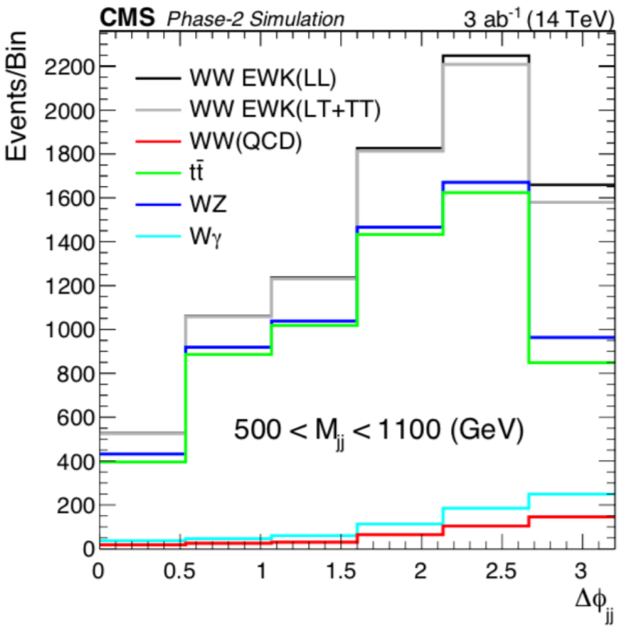
arXiv:1709.05822

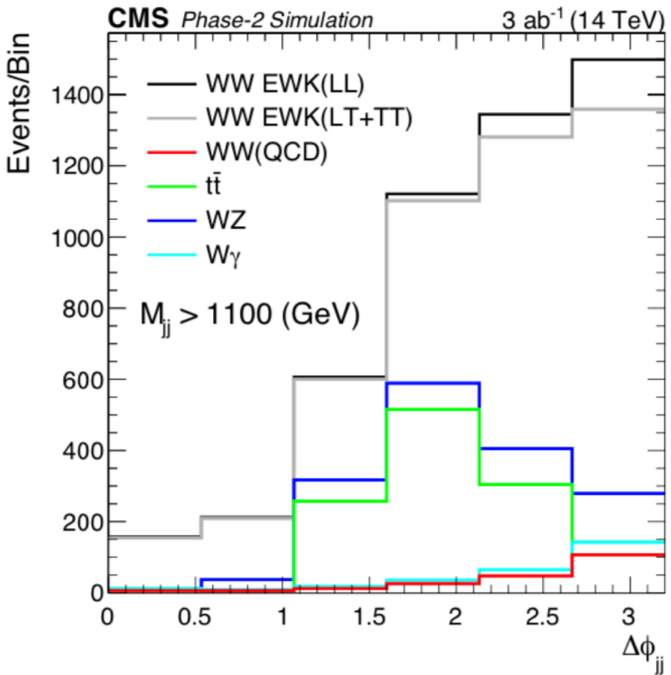


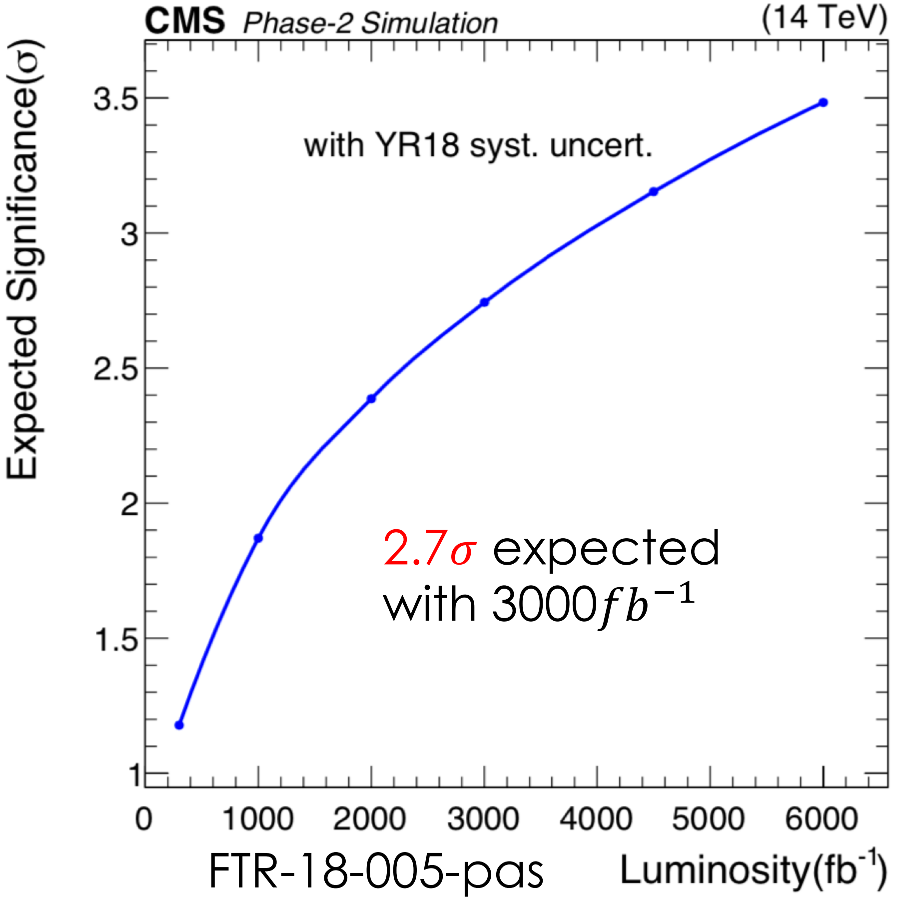
ATL AS-CONF-2018-030

- Longitudinal fraction of vector boson only takes ~6%
  - →Not enough data for measuring $W_L W_L$ -> $W_L W_L$ with current Data.
  - →High Luminosity LHC, prediction on $W_L W_L$ -> $W_L W_L$
    - $\sqrt{s} = 14\ TeV$
    - Lumi = $3000fb^{-1}$

Multivariate analysis?







2.7σ expected with $3000fb^{-1}$

FTR-18-005-pas

VBS Same-sign WW private event production

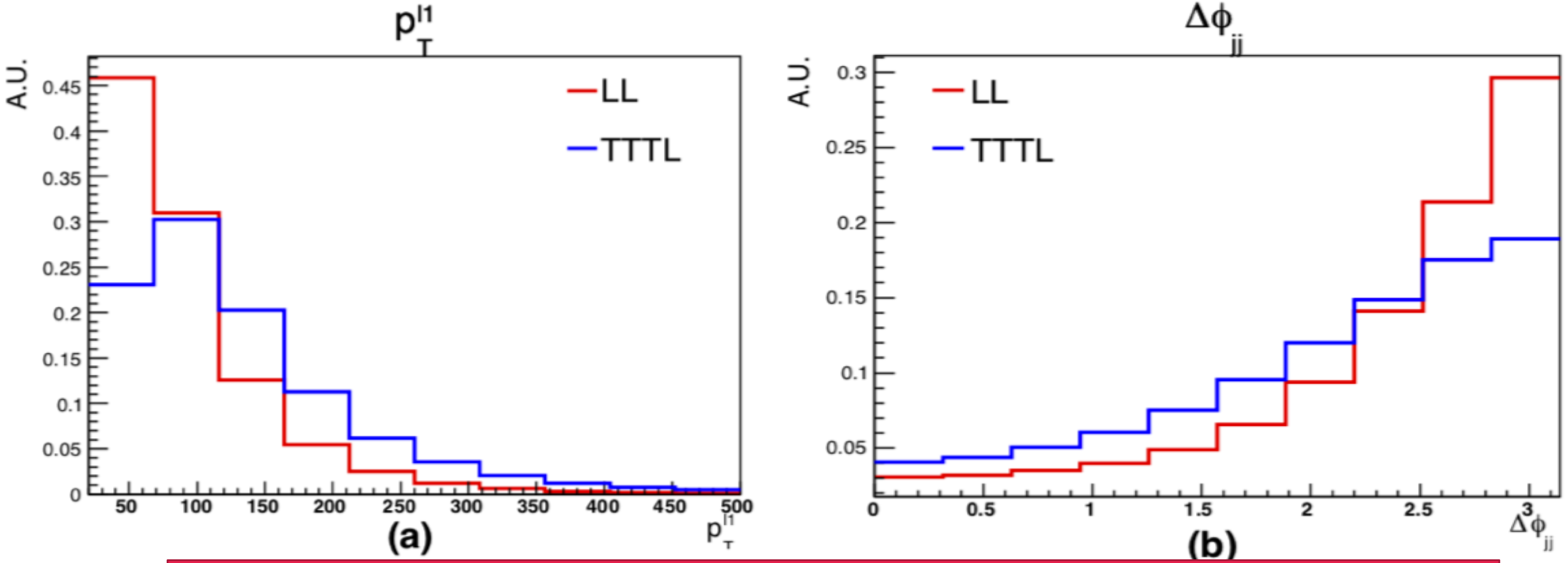
MC production pipe line

MadGraph5_ aMC@NLO → **DECAY** → **Pythia & Delphes** → **Event selection**

- Charged lepton
  - Charged lepton number ≥ 2
  - Same electrical charge
  - P_T > 20 GeV
  - $|\eta|$ < 2.4
  - Z veto (40 < M_{ll} < 70, or M_{ll} > 110)
  - $\Delta\eta_{ll}$ < 2.0
- Missing transverse momentum
  - P_T > 40 GeV
- Jet
  - Jet number ≥ 2
  - P_T > 30 GeV
  - $|\eta|$ < 4.7
  - M_{jj} > 850 GeV
  - $\Delta\eta_{jj}$ > 2.5
- Other
  - B jet veto

Typical kinematic distribution : P_T^{l1} , $\Delta\phi_{jj}$

- $V_L V_L$ -> $V_L V_L$ → ***LL***
- "$V_T V_T$ -> $V_T V_T$" & "$V_T V_L$ -> $V_T V_L$" → ***TTTL***



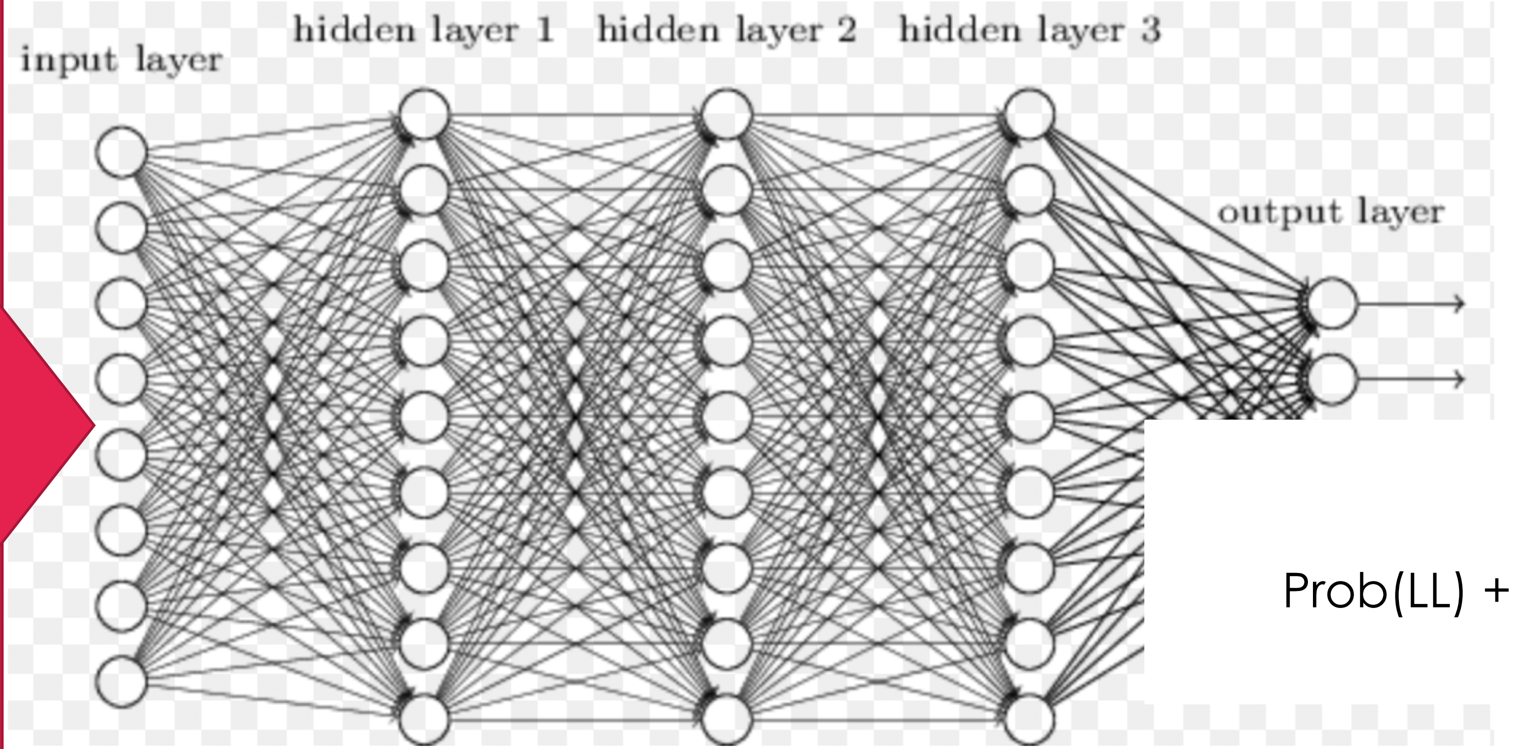
Not enough discriminating power → Idea :: Go for ***multivariated classification***

DNN dense model

Dataset
- Train Dataset → Obtain Trained DNN model → LL and TTTL classifier
- Test Dataset → Test performance of the model

Low level:
lep1pt,
lep1eta,
lep1phi,
lep2pt,
lep2eta,
lep2phi,
jet1pt,
jet1eta,
jet1phi.,
jet1M
jet2pt,
jet2eta,
Jet2phi,
jet2M,
MET,
METphi

High level:
dr_ll_jj,
dphijj,
detajj,
Zeppen_lep1,
Zeppen_lep2



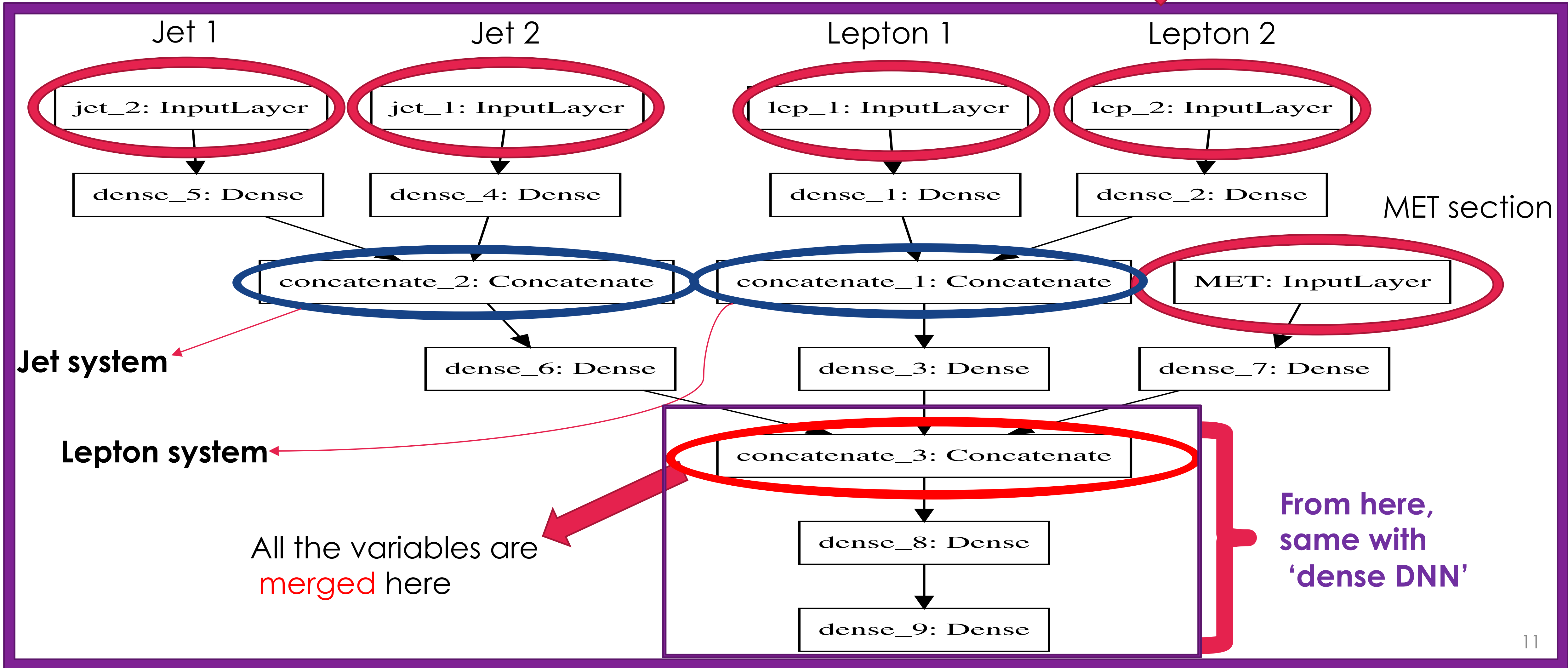
Prob(LL)
Prob(TTTL)

Prob(LL) + Prob(TTTL) = 1

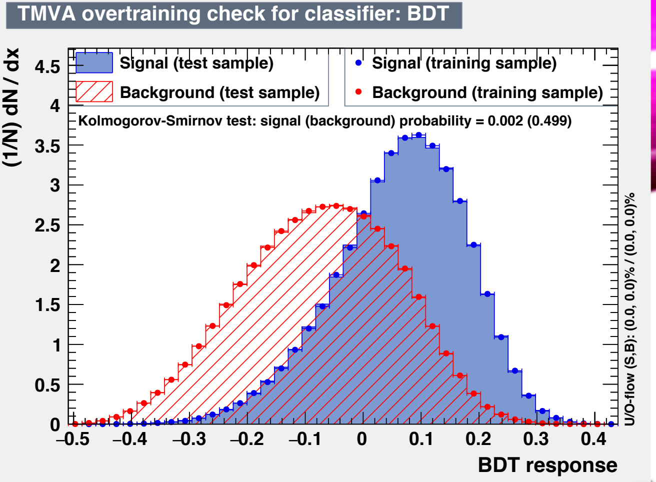
DNN particle-based model

Polarization might be highly correlated with angular variable of **each particle**

Separate each particle and train!



DNN performance



BDT

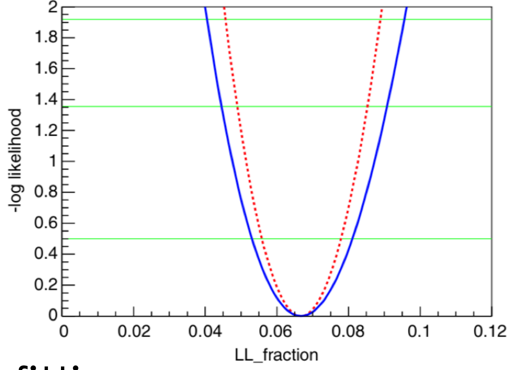
One event *in,* ***one discriminant value*** *out*

↓

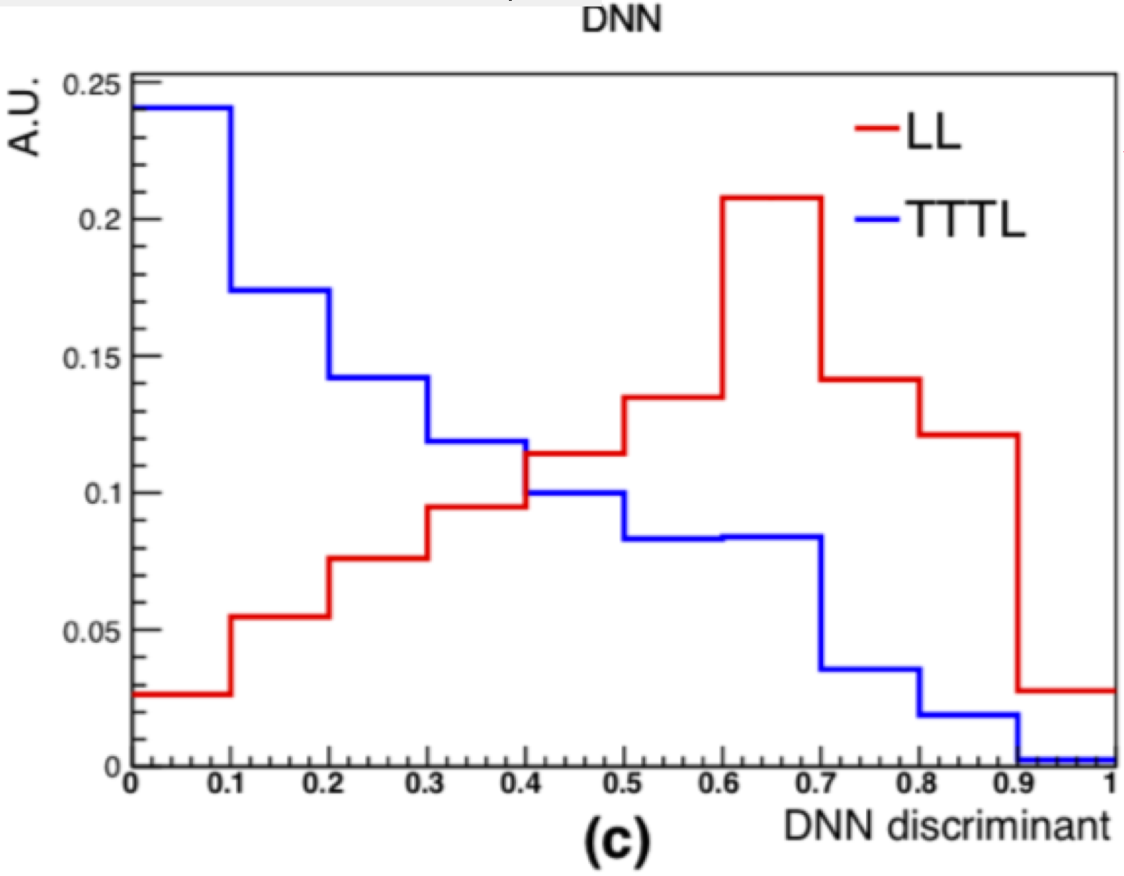
Multiple events *in,* ***multiple discriminant values*** *out*

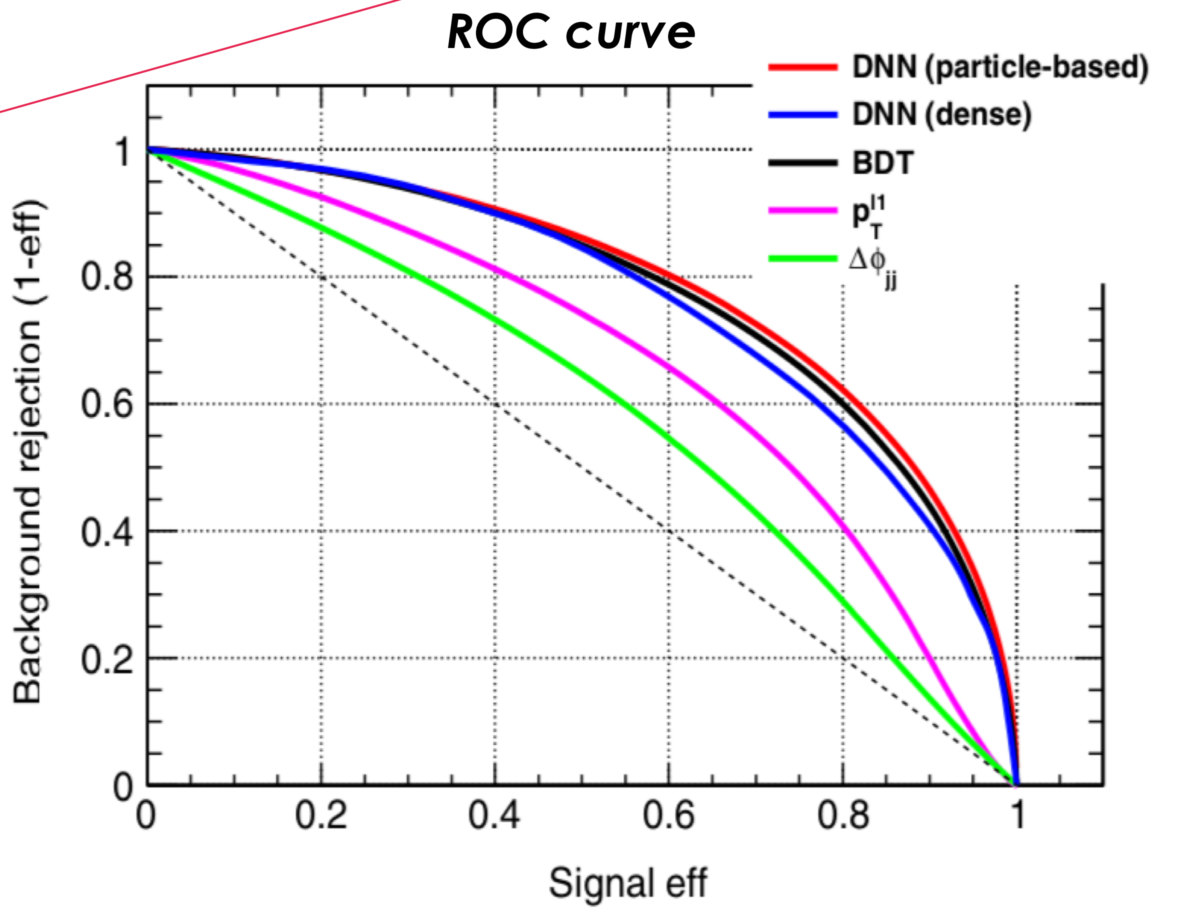
↓

Discriminant distribution

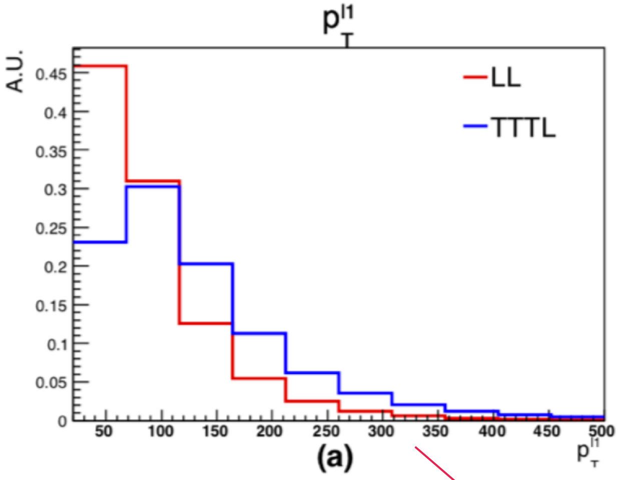


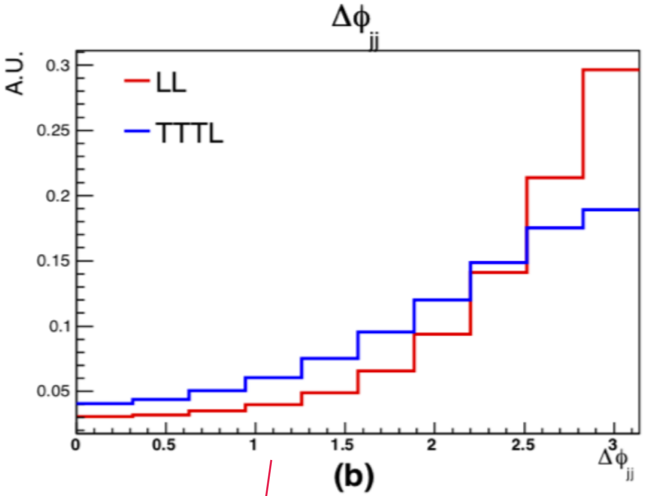
fitting $(M_{jj} > 1.5\ GeV)$

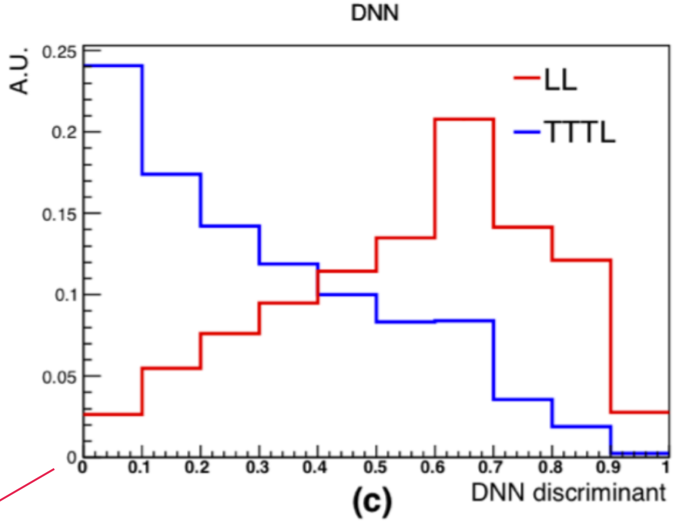




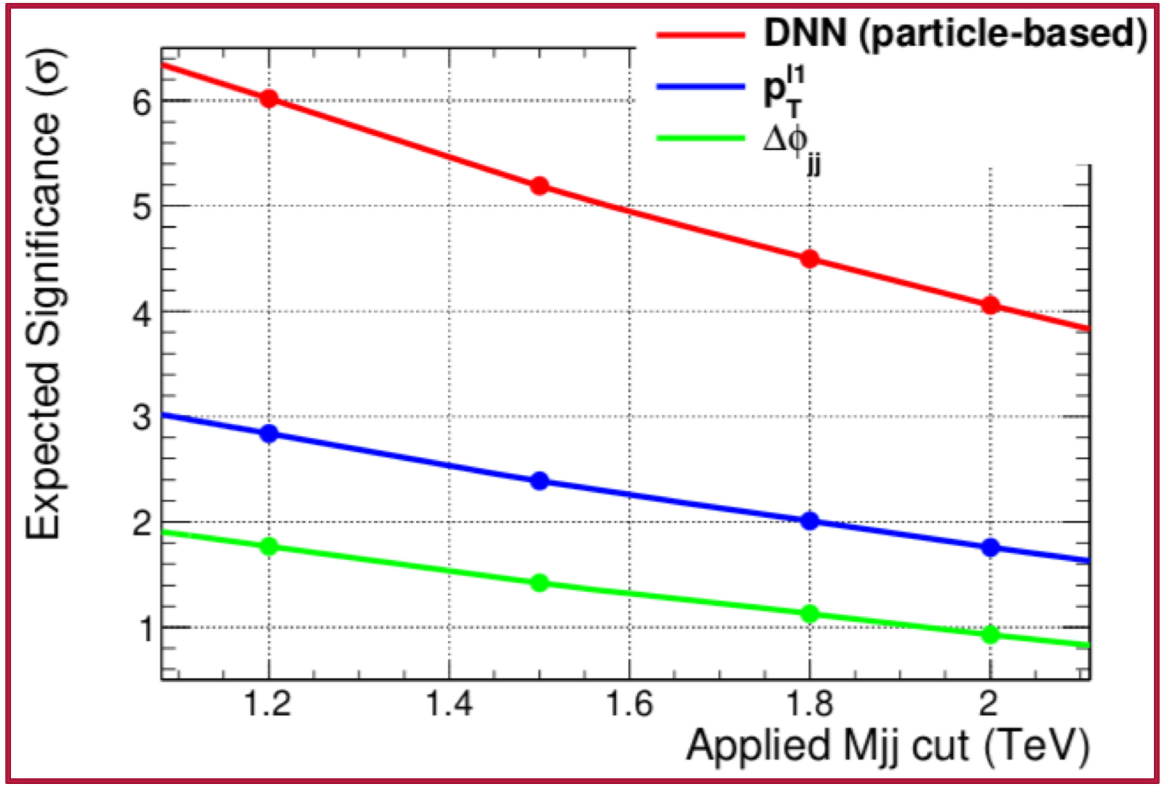
VBS-SSWW Results





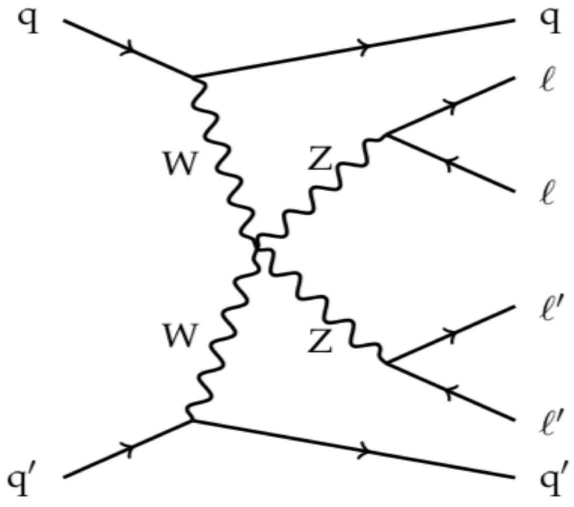


m_{jj} cut	True Fraction	$p_T^{l_1}$	$\Delta\phi_{jj}$	DNN
> 850 GeV	6.66%	$6.67\%^{+1.95\%}_{-1.90\%}$	$6.67\%^{+2.80\%}_{-2.76\%}$	$6.66\%^{+1.11\%}_{-1.04\%}$
> 1200 GeV	6.68%	$6.70\%^{+2.26\%}_{-2.22\%}$	$6.70\%^{+3.29\%}_{-3.25\%}$	$6.68\%^{+1.26\%}_{-1.20\%}$
> 1500 GeV	6.67%	$6.71\%^{+2.62\%}_{-2.57\%}$	$6.68\%^{+3.85\%}_{-3.80\%}$	$6.67\%^{+1.44\%}_{-1.37\%}$
> 1800 GeV	6.69%	$6.70\%^{+3.02\%}_{-2.96\%}$	$6.68\%^{+4.48\%}_{-4.42\%}$	$6.69\%^{+1.63\%}_{-1.56\%}$
> 2000 GeV	6.66%	$6.67\%^{+3.34\%}_{-3.27\%}$	$6.66\%^{+4.98\%}_{-4.93\%}$	$6.66\%^{+1.79\%}_{-1.71\%}$



Higher significance achievable!

Polarization Fraction Measurement in VBS ZZ (on-going)



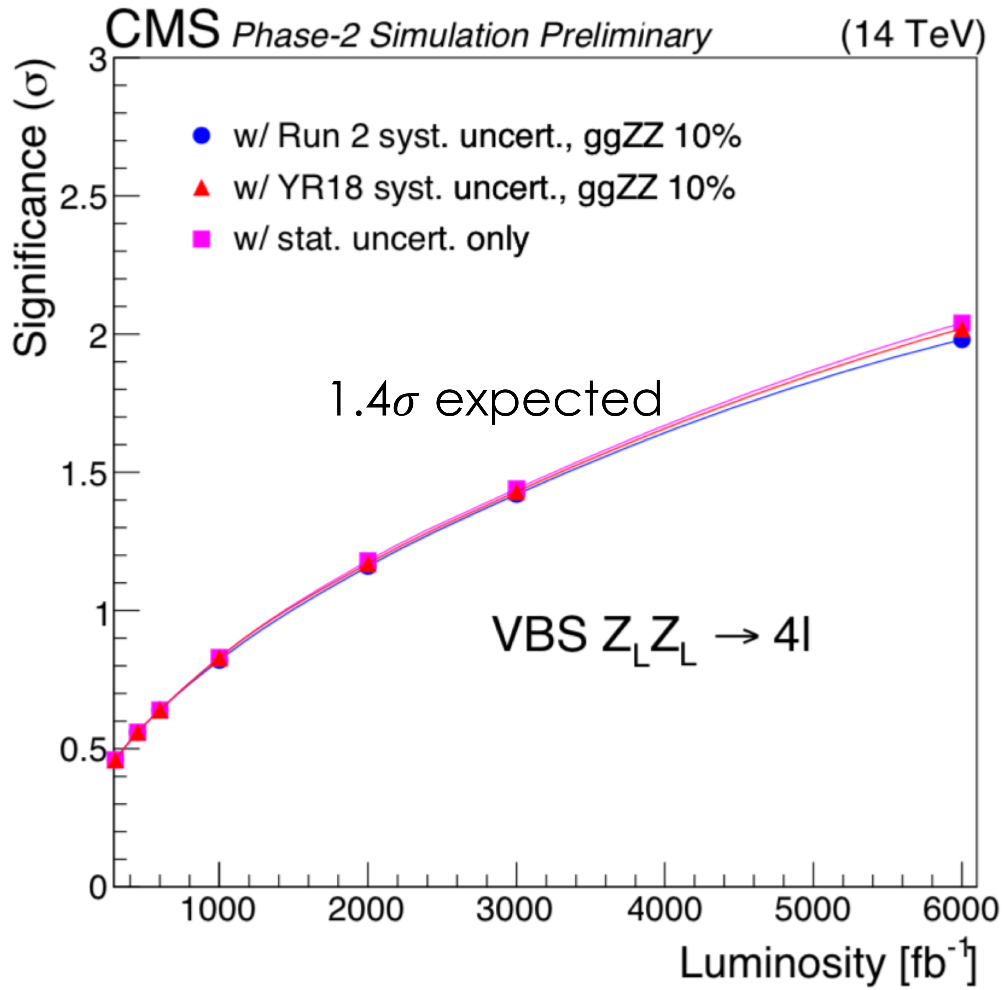
Advantages comparing with VBS Same-sign WW:

- No missing transverse momenta
  → Particle-based DNN

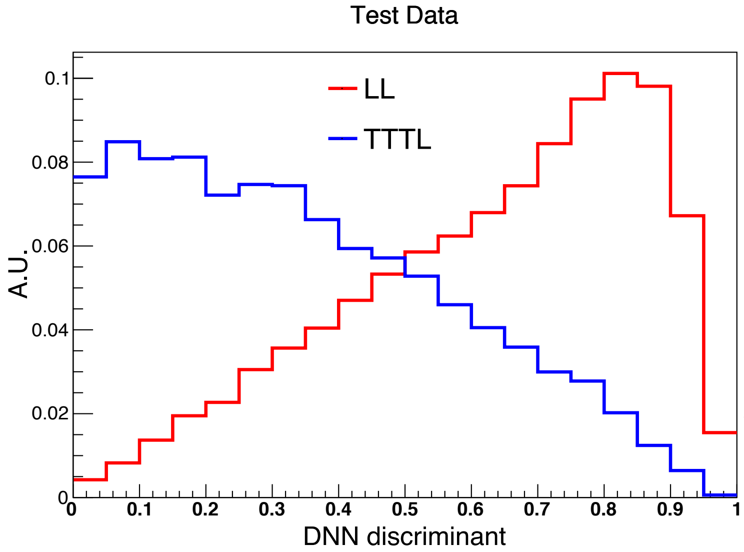
- Easy to modeling background from other process

Disadvantage :

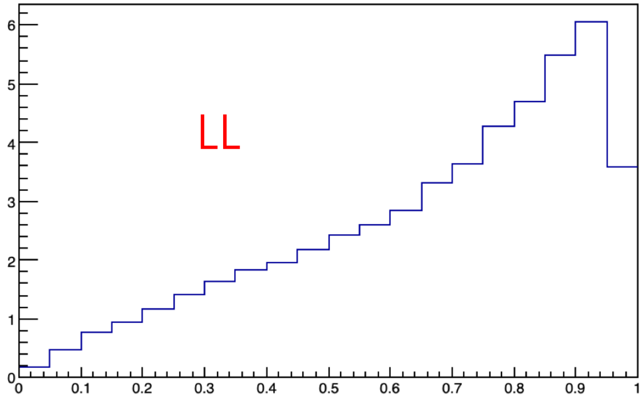
- Low cross-section
  → Lower yield for signal MC

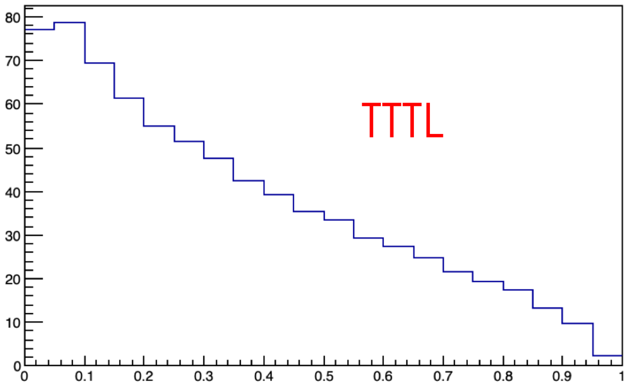


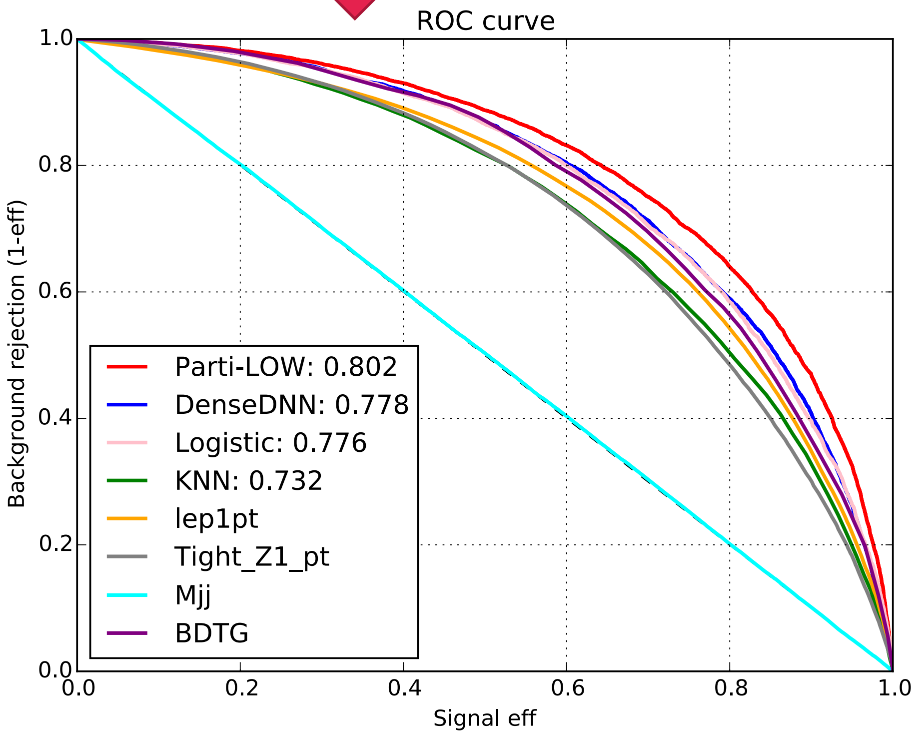
ROC curve & Asimov Data

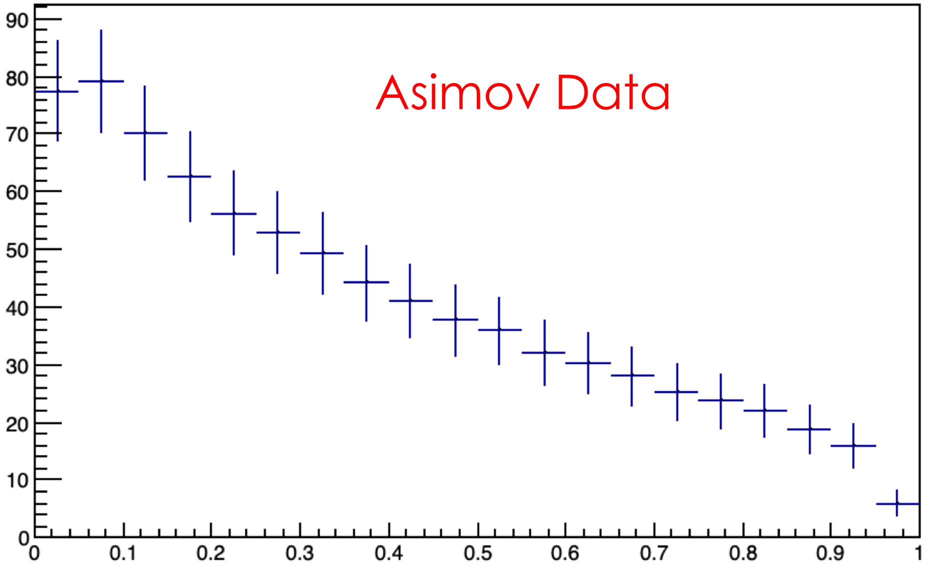


Trained Model









Summary

- Longitudinally polarized vector boson scattering ($V_L V_L$ -> $V_L V_L$) is crucial for testing Higgs unitarization.

- Within VBS same-sign WW channel, which is one of the most promising VBS channel, we need further more data or advanced technique for observing $V_L V_L$ -> $V_L V_L$.

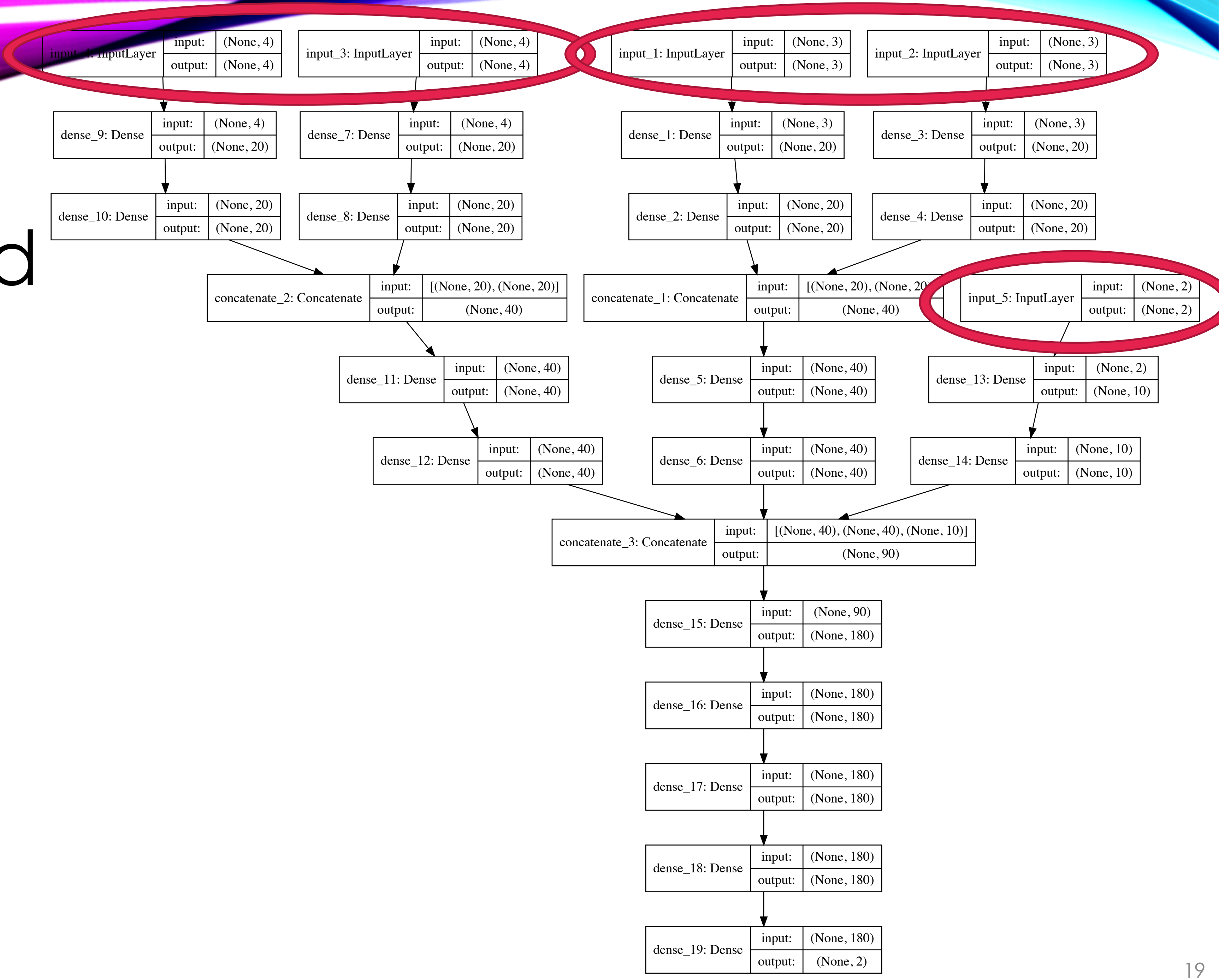
- DNN can be applied to improve sensitivity.
  - Particle-based DNN could be tried for further improvement.

- Particle-based DNN model might be able to apply on other similar analysis.

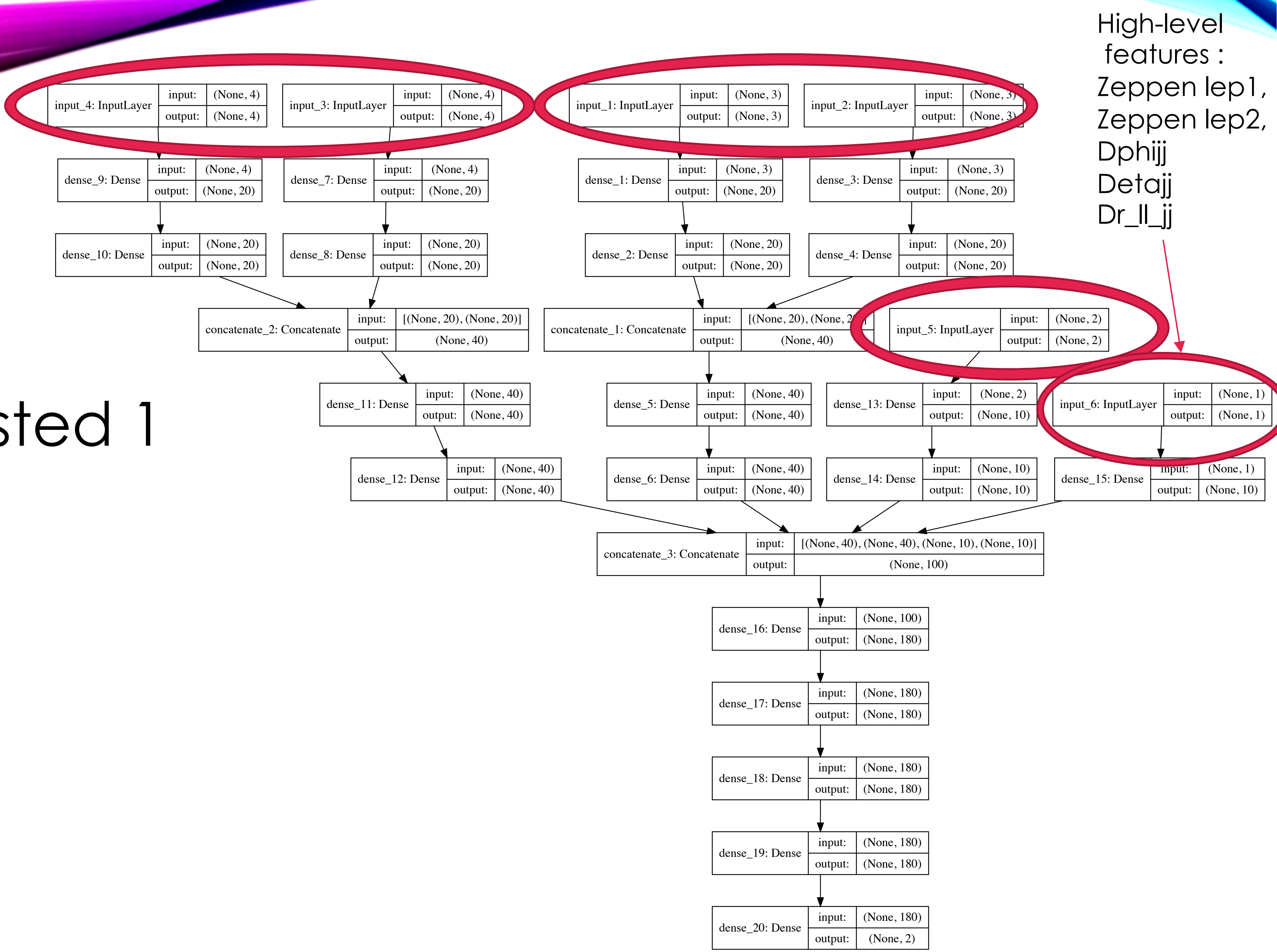
Thank you!

Back-up

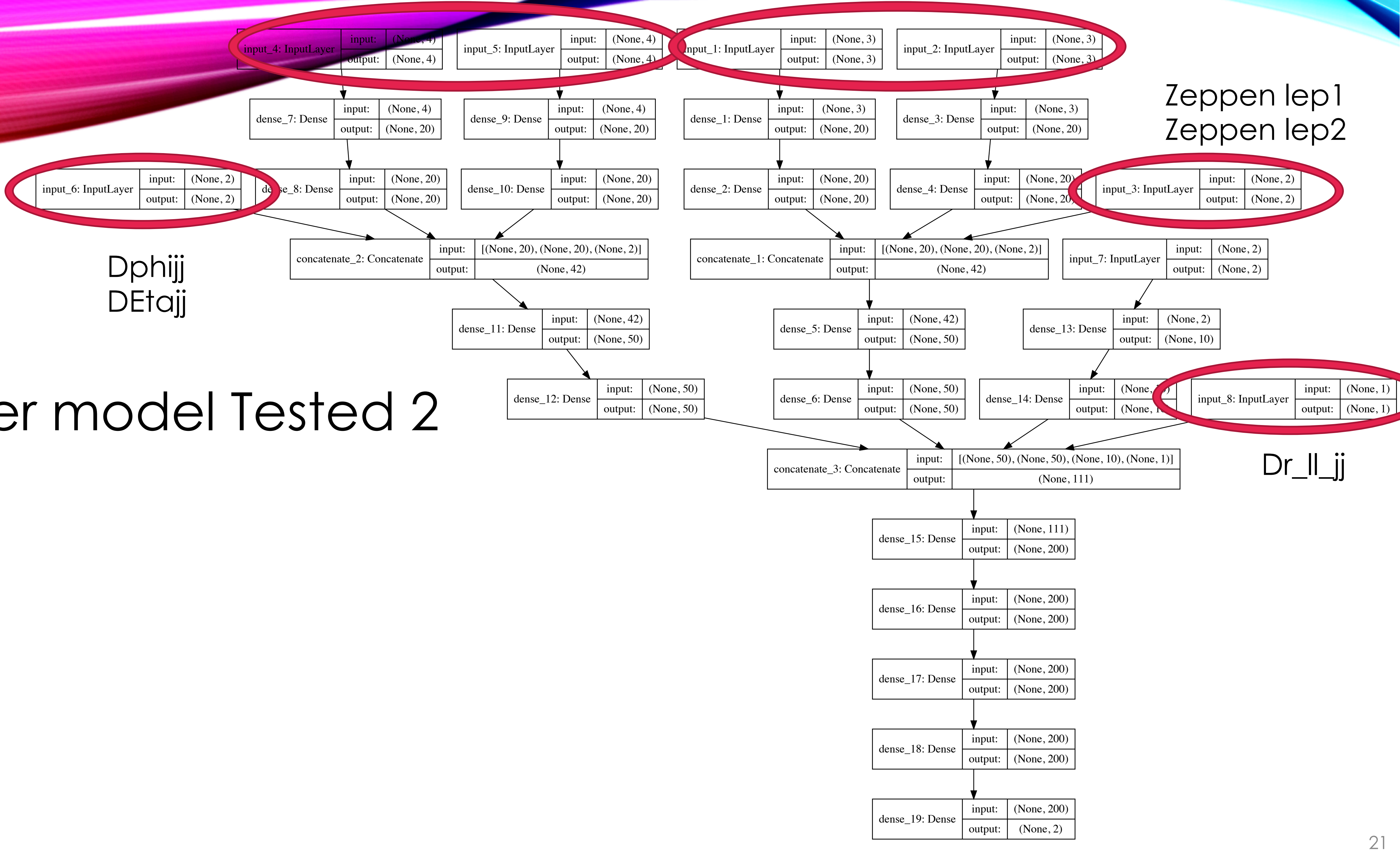
Real model used : default model



Another model Tested 1

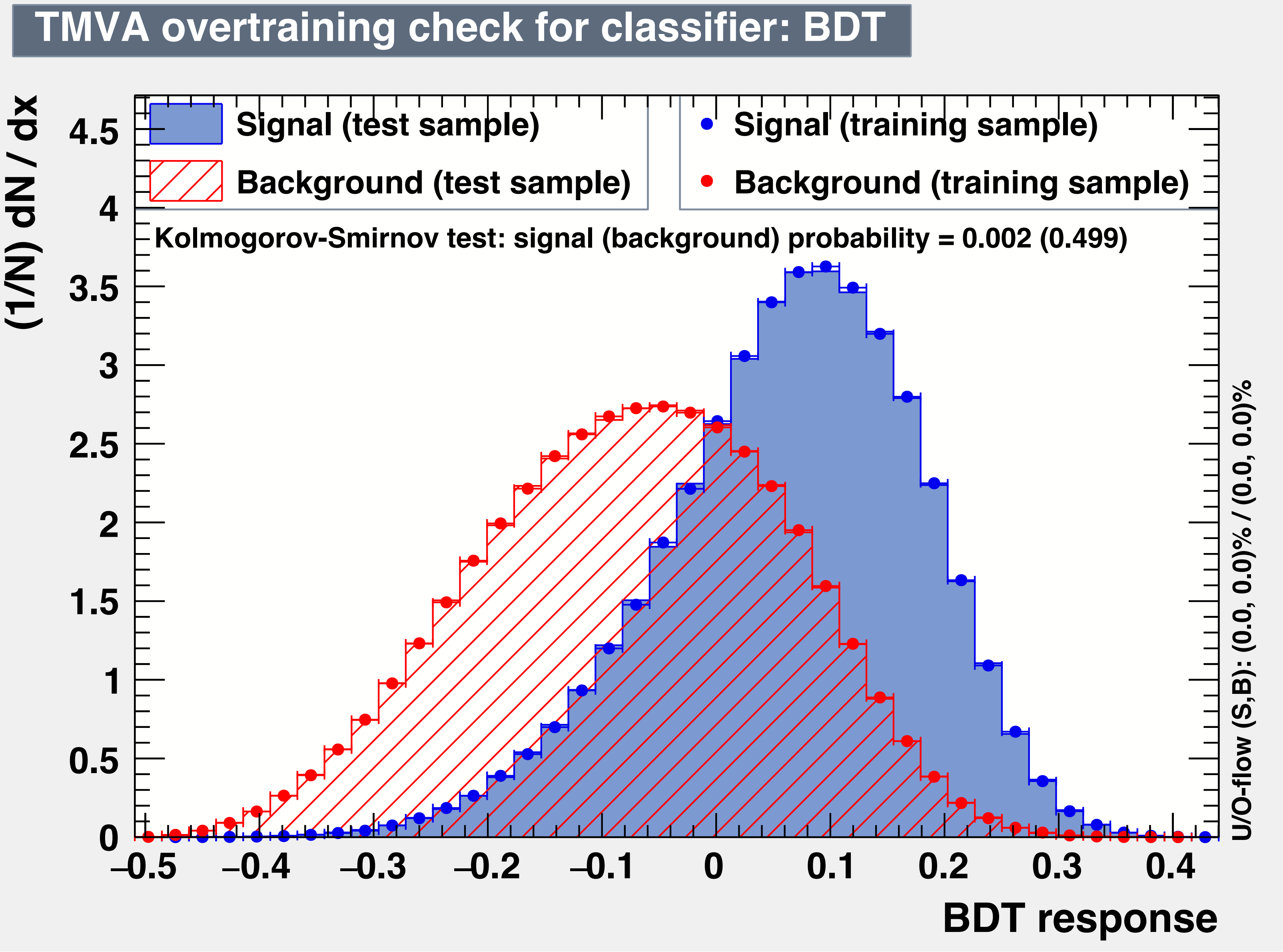


Another model Tested 2

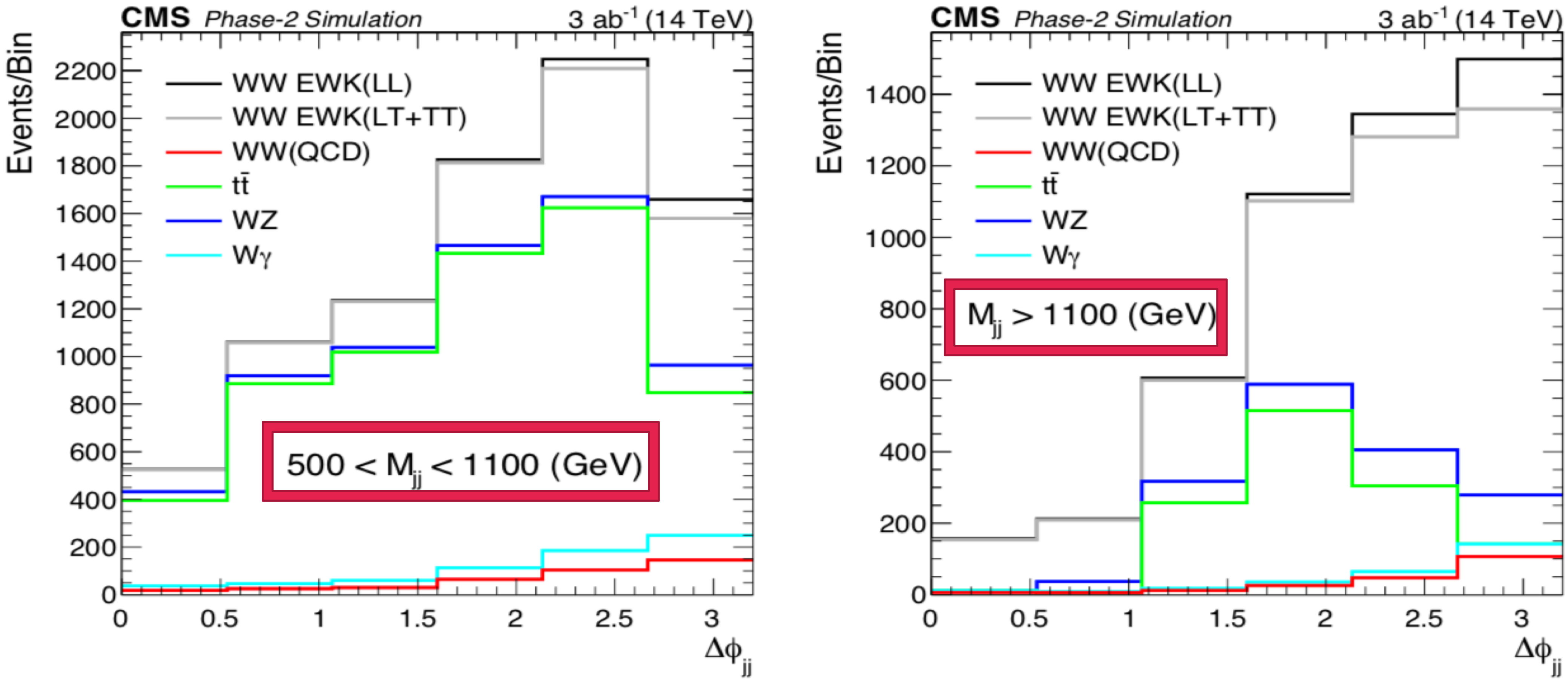


SSWW BDT

1000 trees of 5 maximum depth, 'Adaptive Boost' used for boosting (Gradient optimizer tested as well)



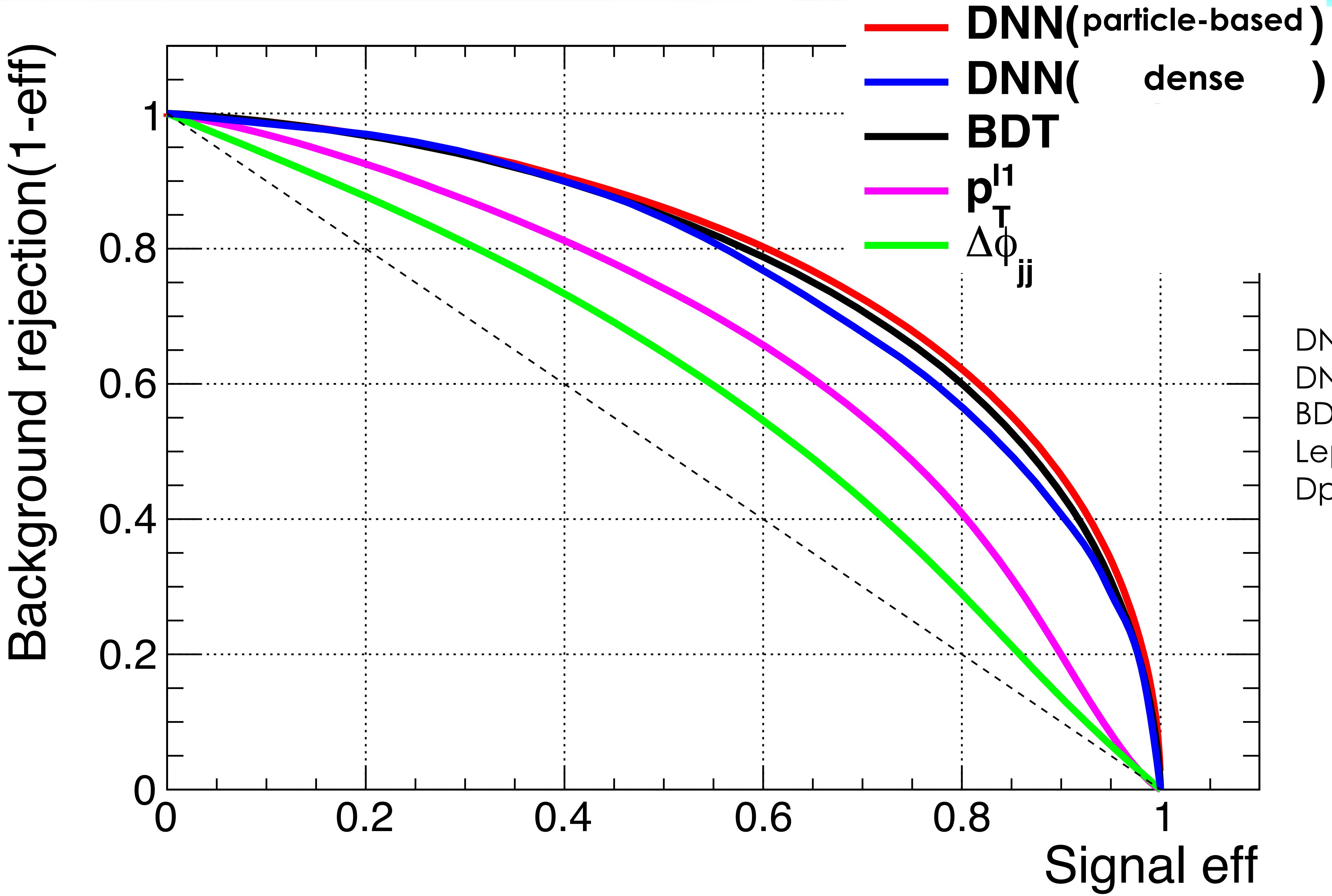
SSWW Background samples



Plots are from FTR 18-005 : Clearly showing dominant backgrounds (ttbas & WZ) are being suppressed in high Mjj region

→ Mjj>1.5TeV, 2.0TeV -> background would be negligible

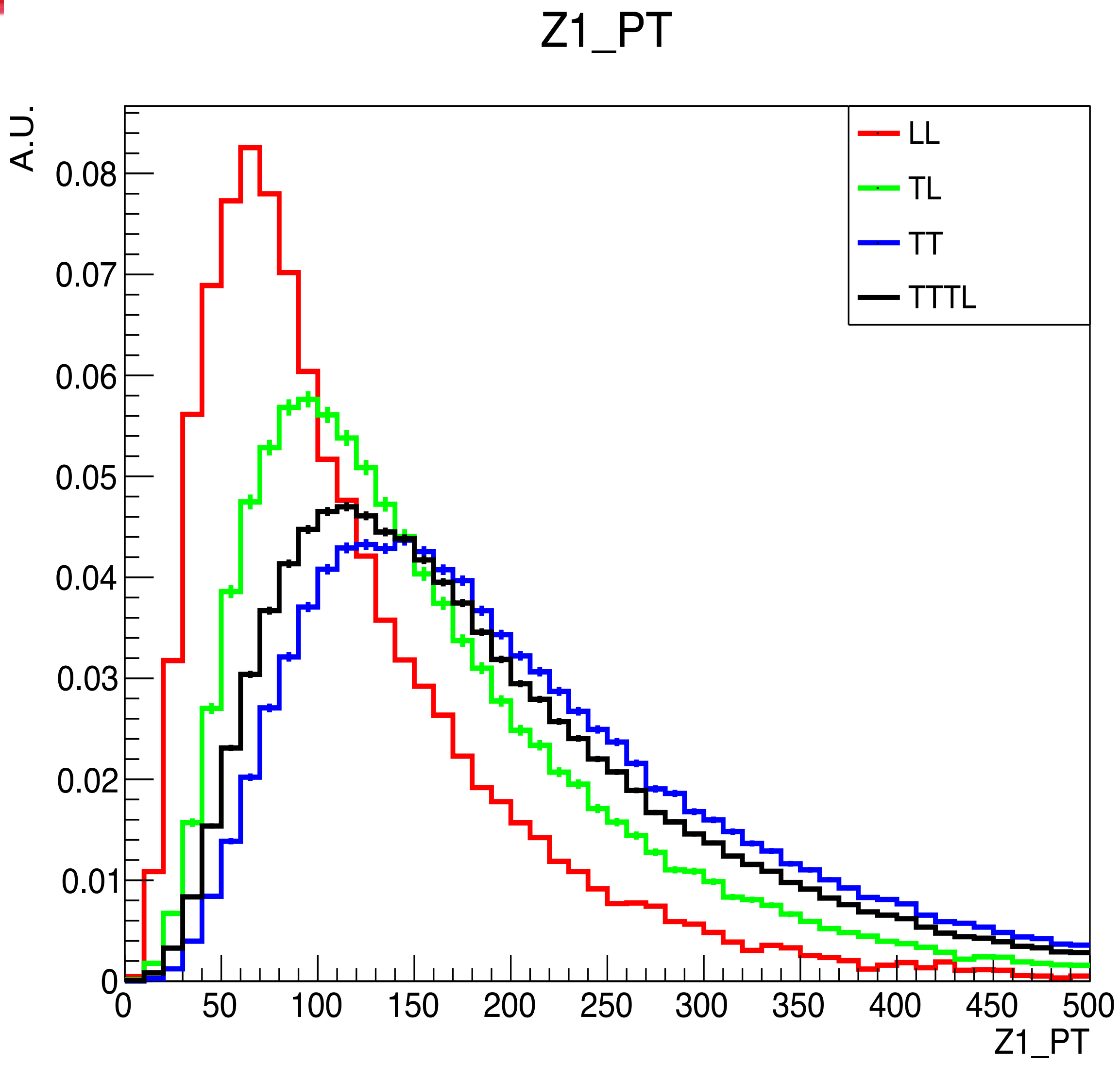
SSWW ROC

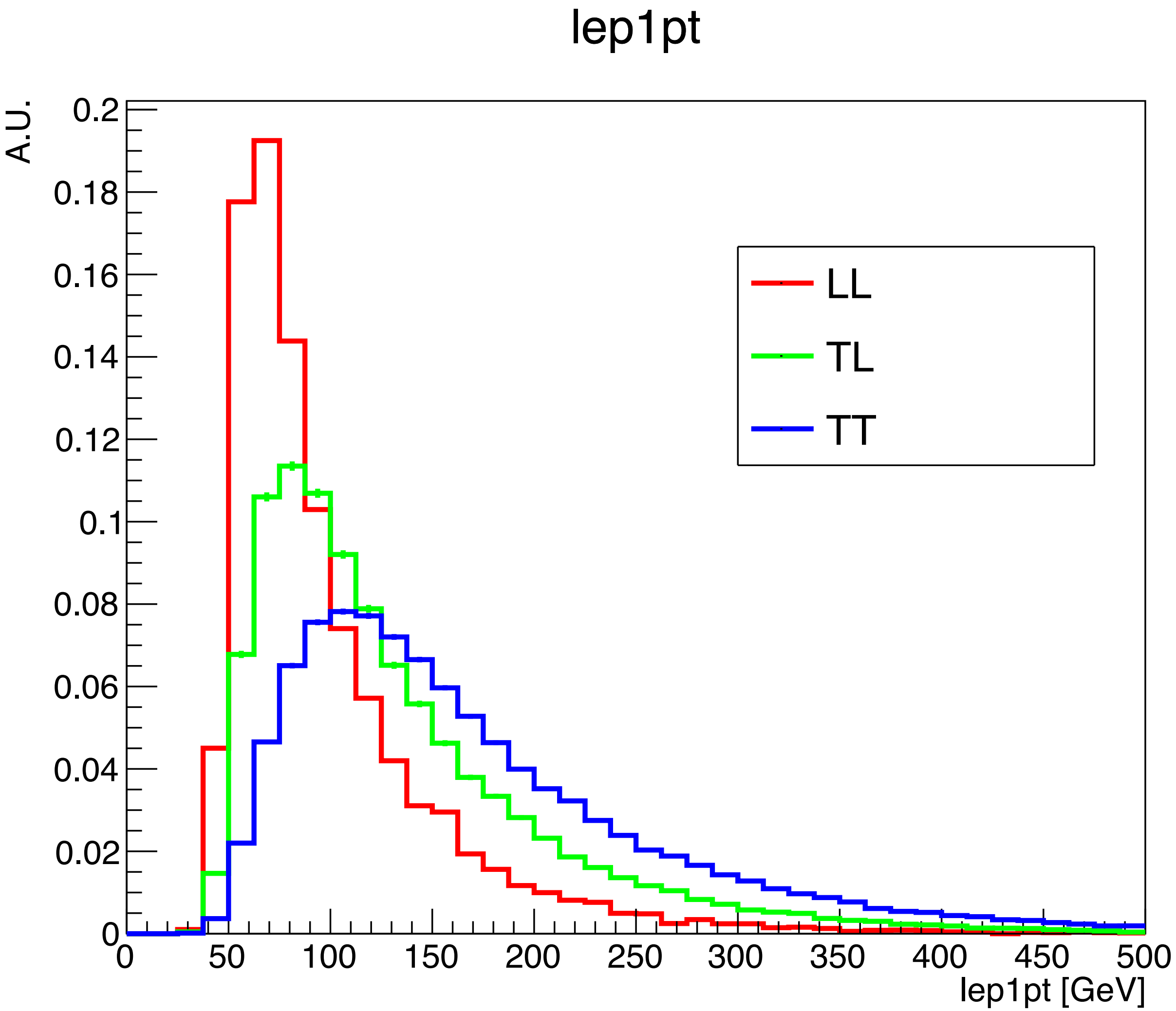


AUC

DNN Gradual :	0.788
DNN Sequential :	0.762
BDT :	0.776
Lep1pt :	0.666
Dphijj :	0.591

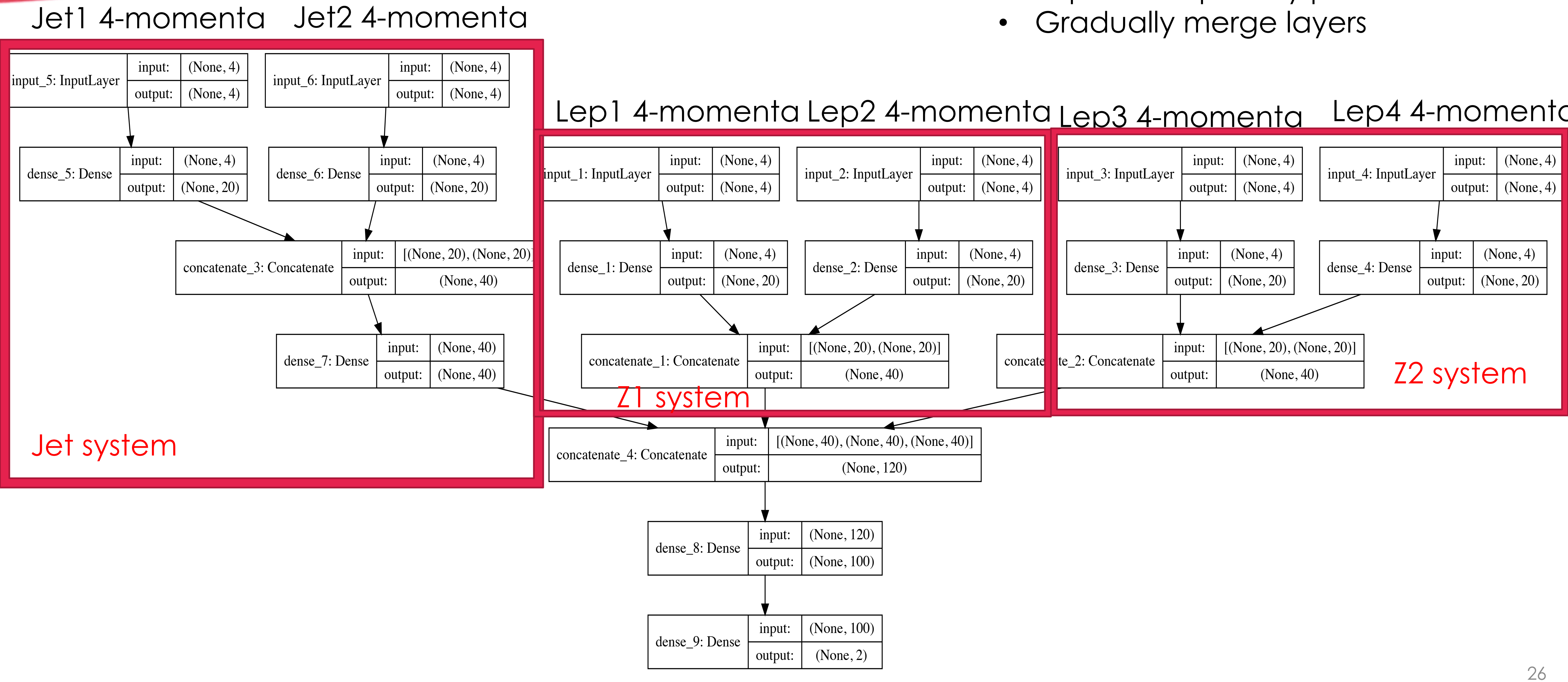
VBS ZZKinematic distribution : Z1_PT, lep1pt





Particle-based DNN

- Separate inputs by particle
- Gradually merge layers



Particle-based DNN

arxiv: 1812.07591

VBS Same-sign WW study