Produzione anomale di VV e VH
ANA-HDBS-2020-05

Lecce (unico gruppo INFN coinvolto)
M. Centonze,
G, Chiodini,
A. Palazzo,
E.J. Schioppa,
S. Spagnolo

PREMESSA

- La presentazione piu' recente che riassume lo stato generale dell'analisi e' qui
  - https://indico.cern.ch/event/1155003/contributions/4849582/attachments/2446423/4192328/VVVHSemilepStatusReport.pdf (Yassine El Ghazali) al meeting generale del w.g. DBL (DBL Subgroup Meeting) del 18 maggio
    - https://indico.cern.ch/event/1155003/

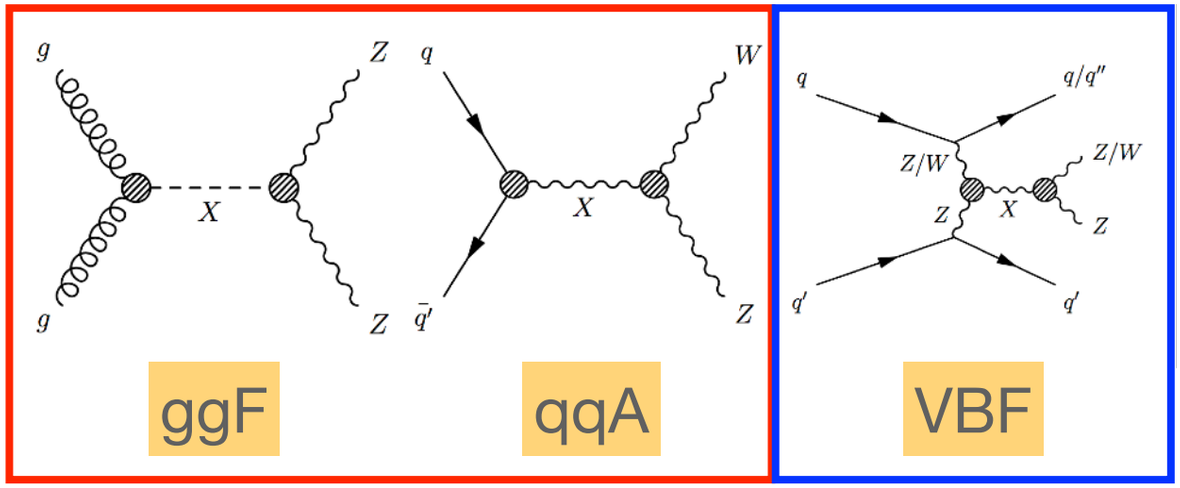
- Da Glance: ANA-HDBS-2020-05
  - ***Second iteration of the search for VV and VH resonances in semileptonic final states***, exploiting the synergy between the two decay modes, using improved analysis techniques (qg-tagging, boosted Z->ee tagging, more sophisticated MVAs), inclusion of VBF mode, and additional interpretations (ALP, non-resonant)
    - Pubblicazioni del 1st round:
      - HDBS-2018-10 DBL - VV semileptonic pubblicato su Eur. Phys. J. C 80 (2020) 1165
        - Search for heavy diboson resonances (WW, ZZ, WZ) in semileptonic final states in pp collisions at $\sqrt{s}=13$ TeV with the ATLAS detector [intera stat del run2]
        - Lecce + Napoli; *tesi di PhD di A. Giannini e M. Lavrogna (NA)*
      - HDBS-2020-19, DBL - VH semileptonic [intera stat del run2] draft ATL-COM-PHYS-2021-362
        - 2nd circulation appena conclusa (7 Giugno) - *no gruppi INFN coinvolti*

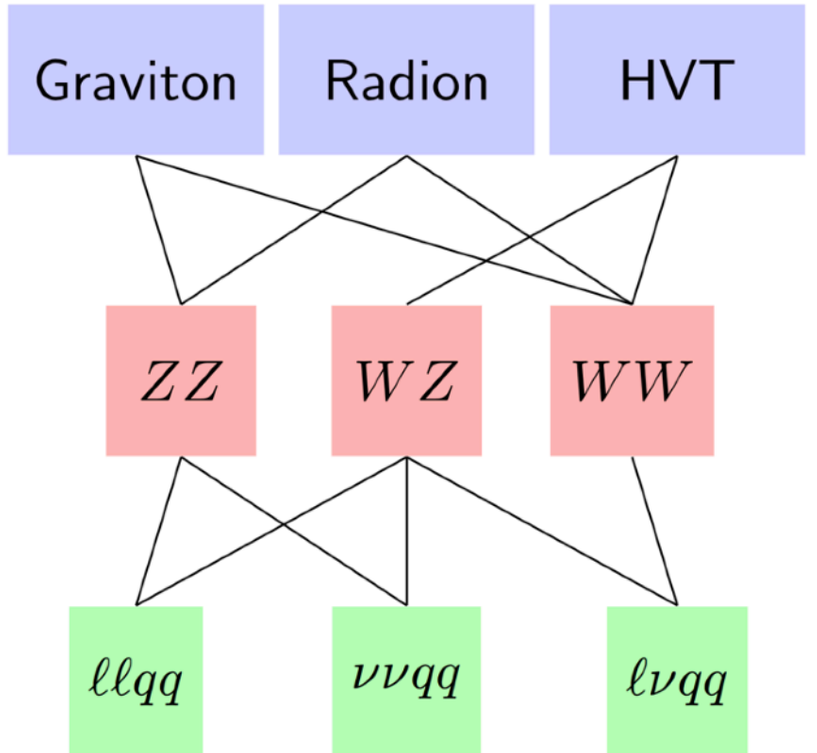
ANA-HDBS-2018-10

1st round resonant VV

L= e,μ

- Search for X -> VV-> 0L, 1L, 2L
  - + 1 large-R jet (***merged regime***, powerful at high X mass) OR
  - + 2 jets (***resolved regime***, except for the 0L channel)
- ***Two topologies*** for X production mechanisms investigated separately
  - quark-antiquark annihilation or gluon-gluon fusion and vector boson fusion
    - ***event classification with a RNN developed for this analysis***
- ***Three model classes*** for interpretation:
  - spin 0 (RS Radion), spin 1 (W', Z' in HVT), spin 2 (RS graviton)
- Selection (in addition to leptonic V):
  - (p_T dependent) mass cuts on hadronic V [+ jet substructure in the merged regime] define low-purity and high purity SRs, in some cases separated further based on the hadronic V being reconstructed from b-tagged jets or not
- Z+jets, W+jets and top control regions to define the normalisation of the main backgrounds depending on the leptonic channel





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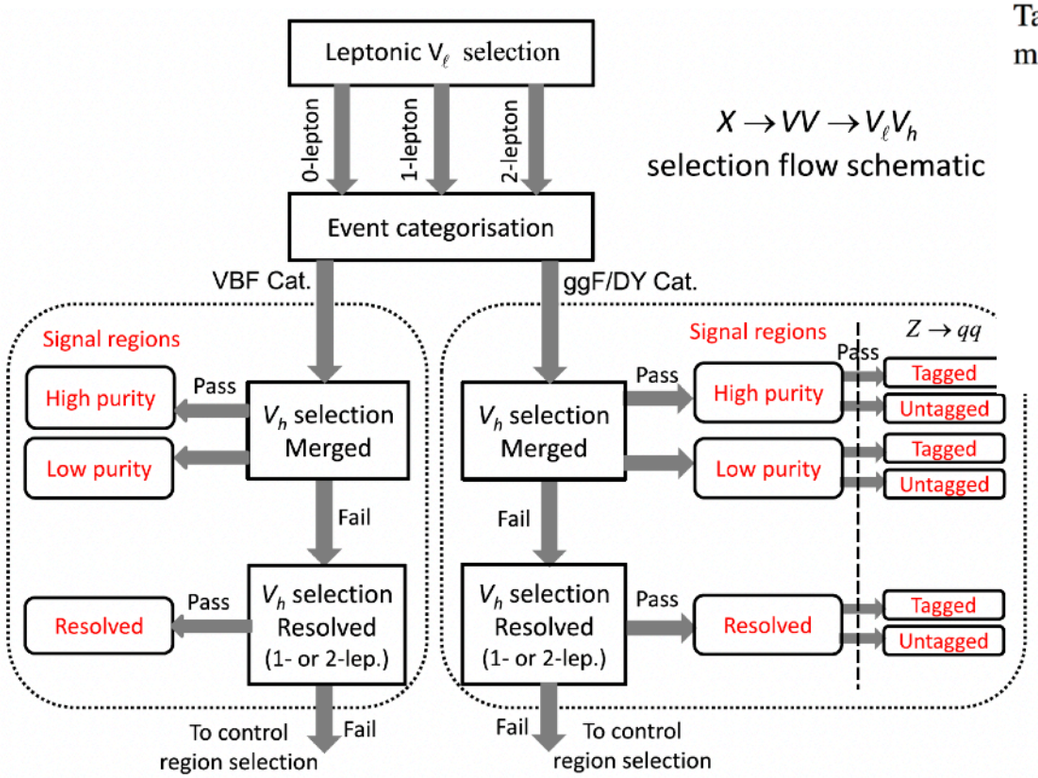


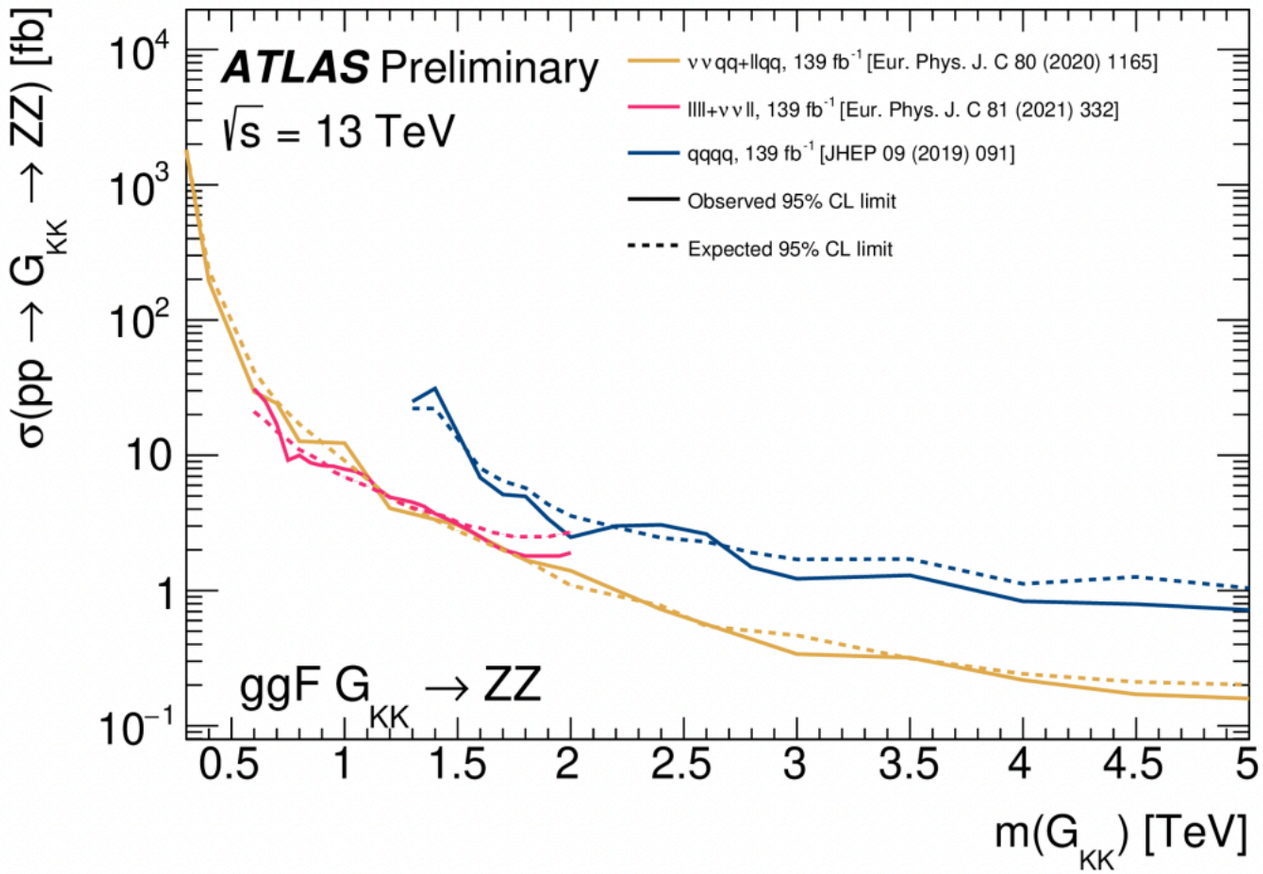
$X \to VV \to V_\ell V_h$ selection flow schematic

- A complex flow: for example, 9 SR for ZZ interpretation on the 2L channel (!)
- m_{llJ} or m_{lljj} as signal / background discriminant
- Jets: TCC large-R jets, EMTopo, VR track-jets for b-tagging of large R jets; MVC2c10 b-tagging
  - Standard CP recommendations for 1st round full stat Run2 analyses

Table 5: Observed (expected) 95% CL lower limits on the mass, in TeV, of different resonances in the benchmark models studied. The symbol "–" means no limit is set.

Production process	RS radion	HVT			RS graviton
			W'	Z'	
ggF/DY	3.2 (2.9)	Model A	3.9 (3.8)	3.5 (3.4)	2.0 (2.2)
		Model B	4.3 (4.0)	3.9 (3.7)	
VBF	–	Model C	–	–	0.76 (0.77)

ATL-PHYS-PUB-2021-018 June 2021

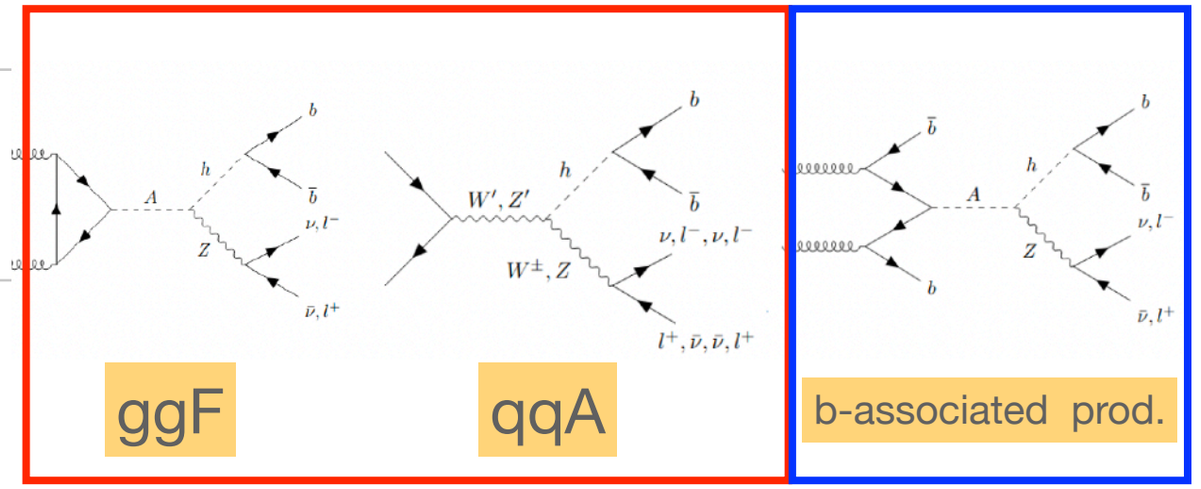


The power of the semileptonic channel

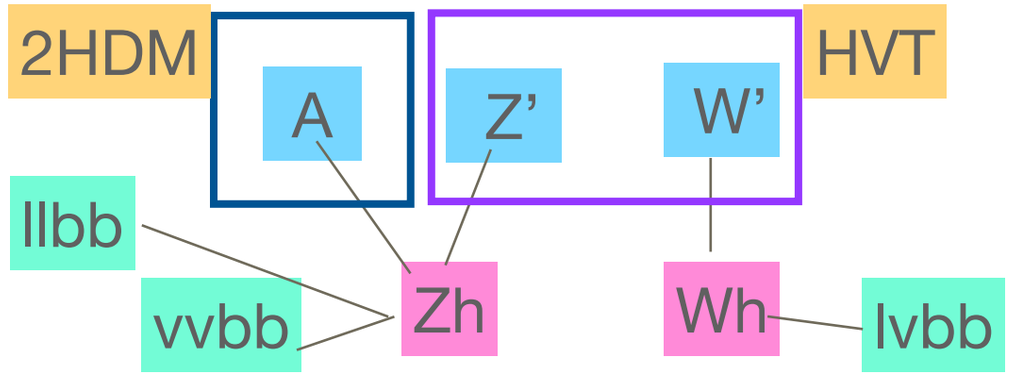
ANA-HDBS-2020-19

1st round resonant VH

L= e,μ



- Search for X -> VH-> 0L, 1L, 2L + bb
  - ***merged regime*** OR ***resolved regime***
- ***Two classes of production modes***
  - quark-antiquark annihilation or gluon-gluon fusion and b-associated production
- ***Two model classes*** for interpretation:
  - spin 1 (W', Z' in HVT)
  - CP-odd spin 0 A->Zh in 2HDM (type I-IV)
- Selection (in addition to leptonic V):
  - mass cuts on hadronic V + 1b, 2b, >=3b
- Control regions with mass sidebands (W/Z+jets) or eμ leptonic selection (top-CR)
- Jets and b-tagging like ANA-HDBS-2018-10



Gain in 2nd round

Very similar structure of the VV and VH analyses
Common weakness points (for example low selection eff. of e-channel at high p_T)
Shared strategies, solutions, improvements, new jets (flow and UFO) and b-tagging (DL1R)
ML for large-R jet classification (h->bb, W/Z,, top, background), improved efficiency for Z->ee ,
Parametric DNN for mass interpretation

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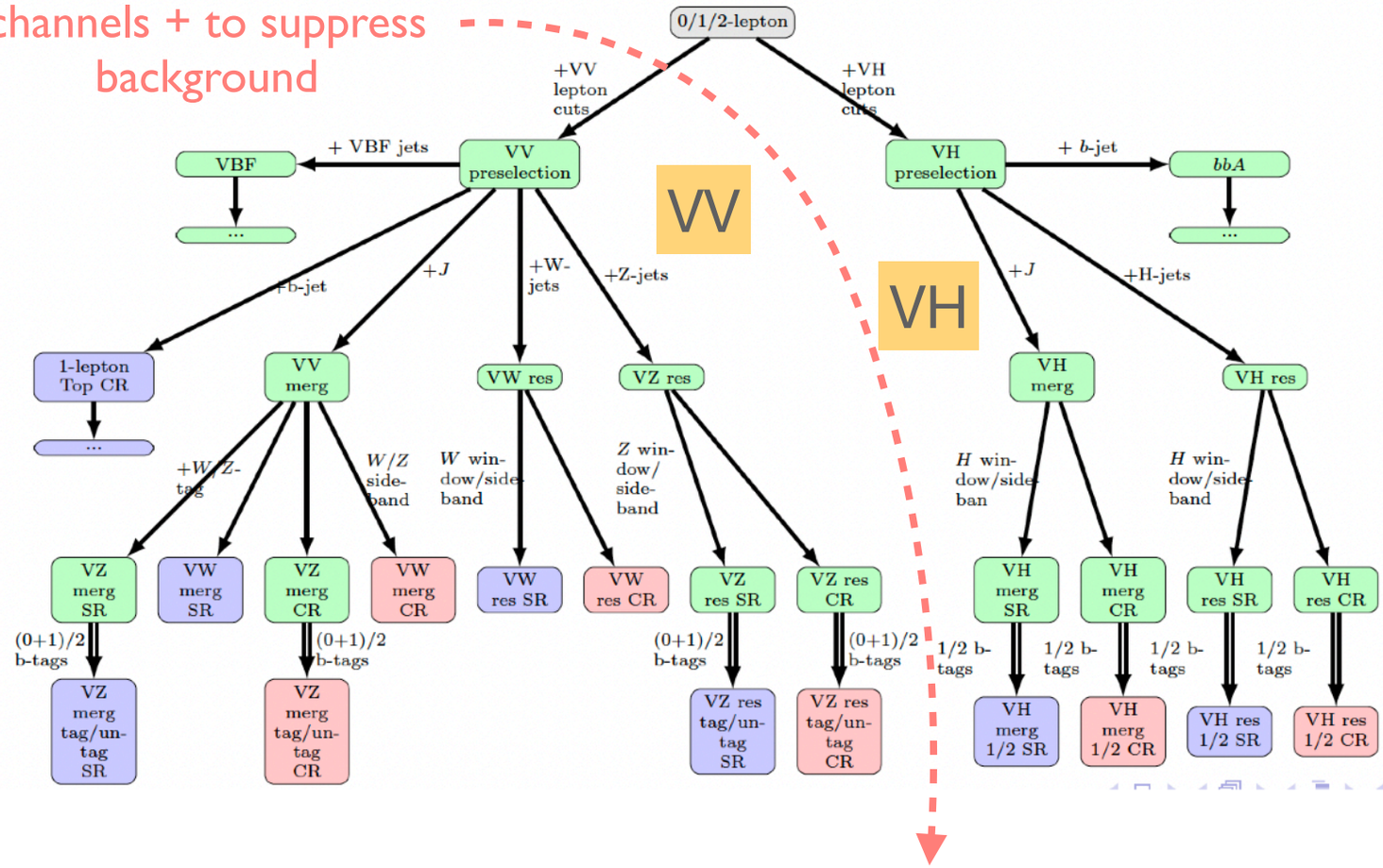
2nd round resonant (and non resonant) VV and VH

L= e,μ

- Very similar structure of the VV and VH analyses
  - Common weakness points (for ex. low selection eff. of e-channel at high p_T)
  - Shared strategies, solutions, improvements, new jets (particle flow and UFO) and new b-tagging (DL1R)
  - Extended use of ML:
    - *for large-R jet classification (h->bb, W, Z, top, QCD)*
    - improved efficiency for Z->ee
    - Parametric networks with parameter = X mass
    - Use RNN in VH
- EFT interpretation
  - Several operators affecting VV *and V+jets*
  - *Strategy discussed with theoreticians and ATLAS wide EFT* interpretation fora

To be used to make orthogonal VV and VH channels + to suppress background

Analysis flow



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- Willing to cure the decrease in efficiency at large p_T in the 2L channel due to merging e.m. showers in the calorimeters

- Z -> ee tagger
  - Reconstruct overlapping electrons as small-R jets
  - NN trained on jet kinematics and other properties; the output probabilities of ee, e/γ, QCD, tau are combined in a discriminant

Very good separation

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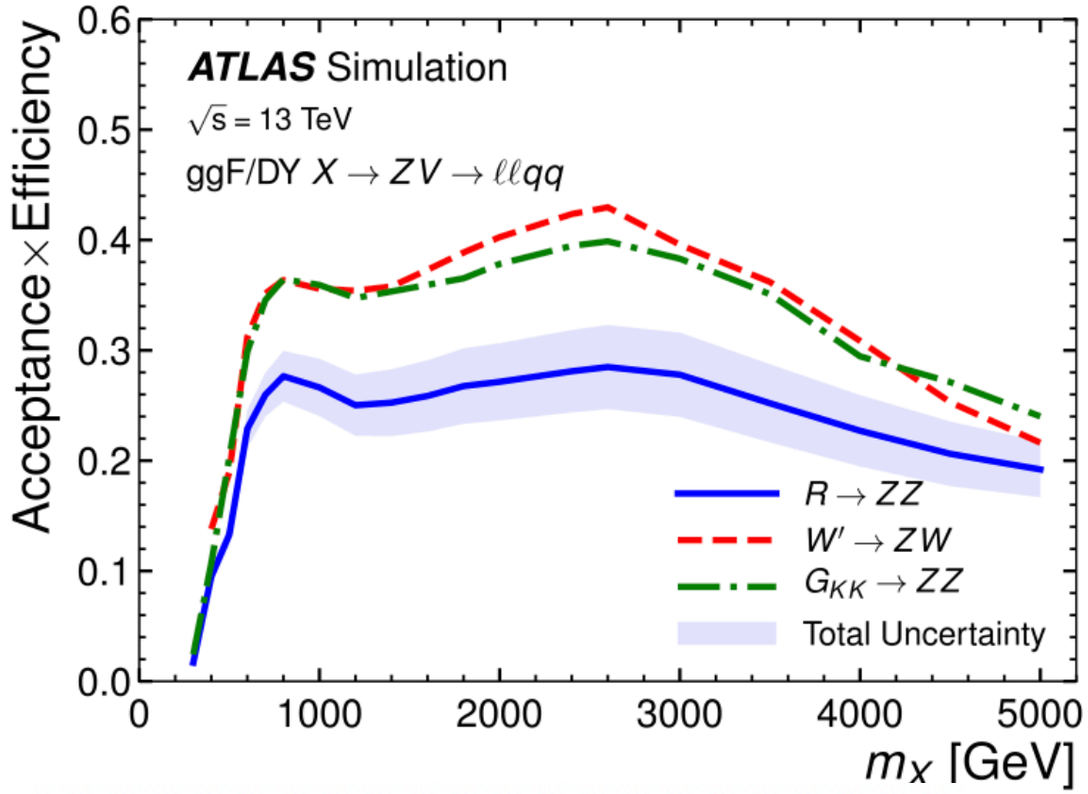

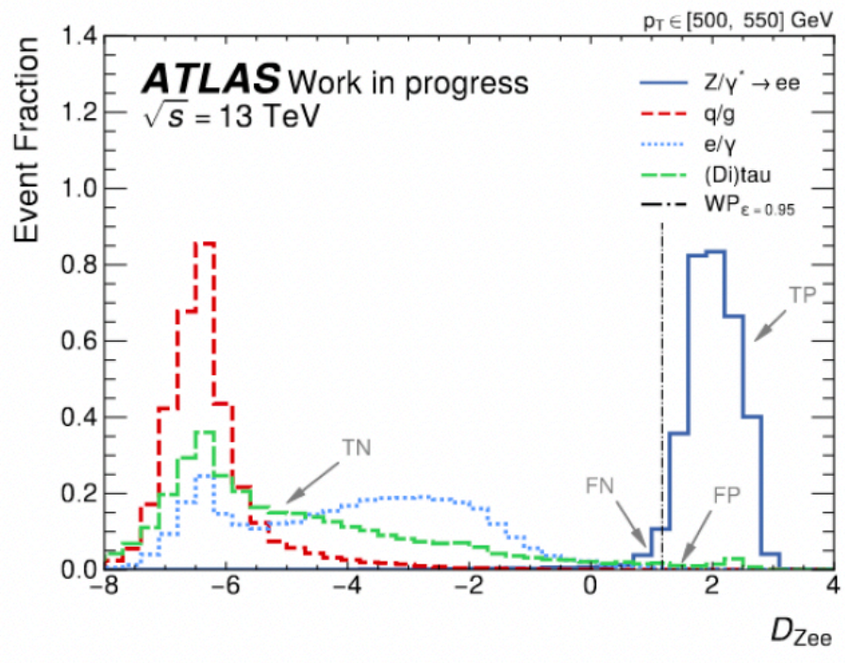

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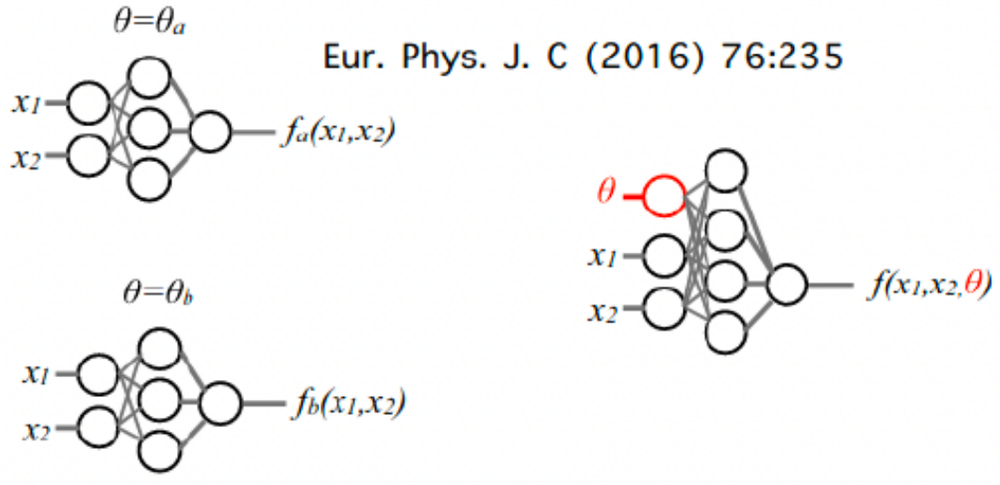
ANA-HDBS-2018-10 supporting note

- Improve signal / background separation going beyond $m_{ll+hadronic\ V}$

- Parametric DNN (Lecce and Tong)
  - Explored already for ANA-HDBS-2018-10 (D. Backas [Lecce] & al)
  - Discriminant from NN replaces $m_{ll+hadronic\ V}$ in signal fit



Eur. Phys. J. C (2016) 76:235

Approach used in several analyses by now:
For example HH->bbττ

- **Merged input variables**
  - Lepton: p_T, η, ϕ and E
  - FatJet: p_T, η, ϕ and E
  - $Z(ll)$: m, p_T, Njets
- **Resolved input variables**
  - Lepton: p_T, η, ϕ and E
  - leading/subleading jet: p_T, η, ϕ and m, nTracks
  - $Z(ll)$: m, p_T, Njets

Input

Parameter: m_X

Gain: improved sensitivity, no need to train N networks for N mass points

ML cost: background shape depends on m_X hypothesis under test

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- Improve signal / background separation going beyond $m_{ll+\text{hadronic V}}$

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General timeline

New production of CxAOD just ready with new variables, allowing for combined VV+ HV studies, harmonization, optimization

6,8 months to EB request foreseen

Ongoing studies:

- Optimize selection of training set vs statistics;
- Optimize set of input variables (low level, mix of low level + high level)
- Extend set of input variables
  - using extended tagger output/input variables
  - extra event objects
- Optimize DNN architecture (how deep ?)
- Establish gain in expected limits