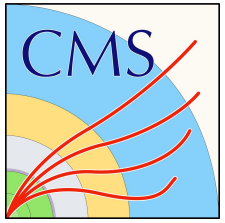
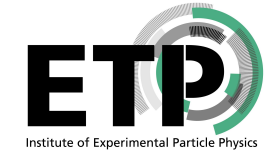




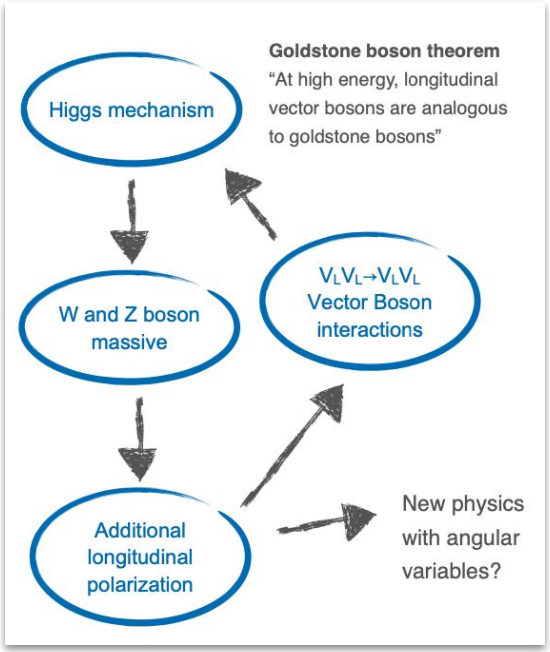
Summary and plans for WG3 activities

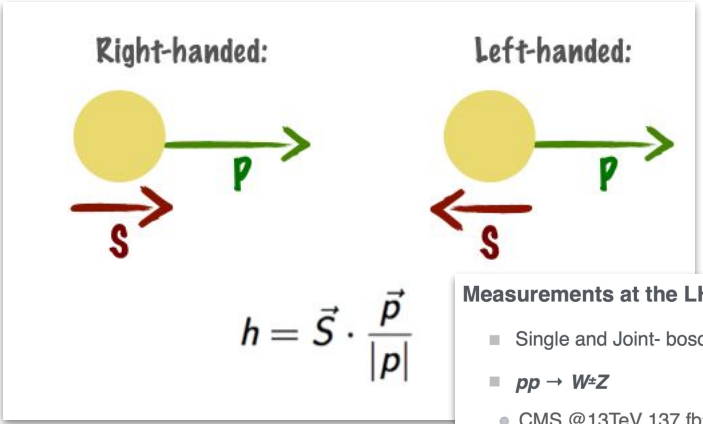
Valentina Cairo (CERN),
Matteo Presilla (KIT)

1st COMETA General Meeting, Izmir

Huge THANK YOU to all the speakers for their wonderful talks!

Polarizations measurements





Measurements at the LHC:

- Single and Joint- boson polarization measurements
- ***pp → W±Z***
  - CMS @13TeV 137 fb^{-1} (inclusive phase space) CMS-SMP-20-014
  - ATLAS @13TeV 139 fb^{-1} (inclusive phase space) Phys. Lett. B 843 (2023) 137895
  - ATLAS @13TeV 139 fb^{-1} (high p_T (Z) phase space) Submitted to PRL New!
- ***pp → ZZ***
  - ATLAS @13TeV 140 fb-1 (inclusive phase space) JHEP 12 (2023) 107
- ***pp → W±W±jj***
  - CMS @13TeV 137 fb^{-1} (VBS phase space) Phys. Lett. B 812 (2020) 136018

From Q/A: interesting to compare outcomes of **different generators.**

- With our current data we are already able to probe the polarization fractions in VV production.
  - Results include the first evidence or observation of double longitudinally polarized gauge bosons in VV production
  - Big limiting factor for our measurements is the modelling of the polarization templates! → theory community is actively working on the topic!
  - VBS production still severely limited by data statistics, but already showing promise in same-sign WW production. A lot can be expected as we gather more data!

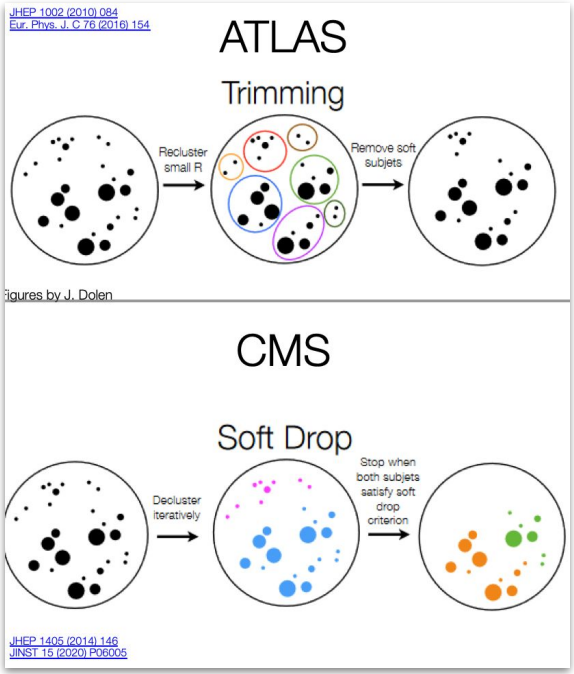
Jet substructures in VBS/VBF

Key elements among various techniques

- Grooming →
- Mass
- Substructure moments
- Pile-up mitigation
- Quark-gluon tagging

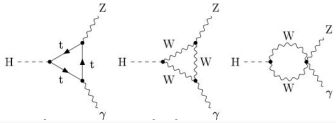
Usage in LHC Run 2 analyses:

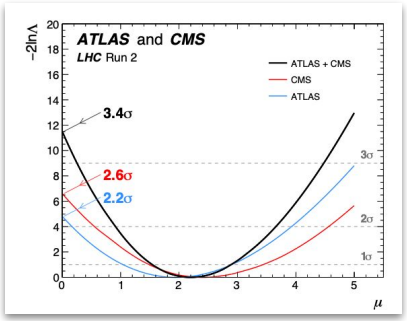
CMS WW, WZ and ATLAS VV

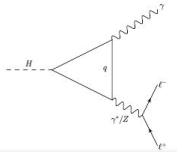


From Q/A: **One of the issues in the future might be theory uncertainties, how to address it? Experiments typically look at comparison between generators for instance to check stability => to expand and elaborate during WG3 activities (see also session 3 panel discussion)**

Exotic Higgs (and rare Higgs decays)

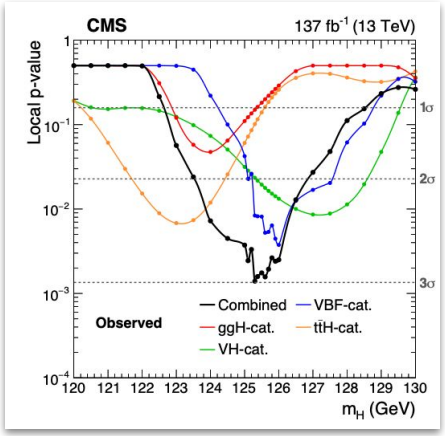




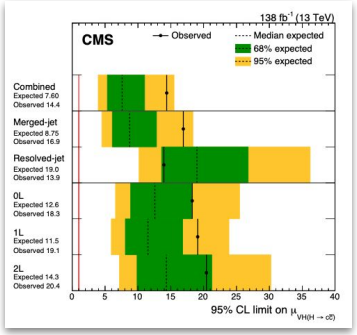


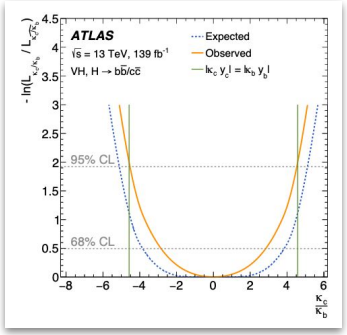
- ATLAS observed (expected) significance: 3.2σ (2.1 σ)
- $\mu = 1.5 \pm 0.5$

H->μμ

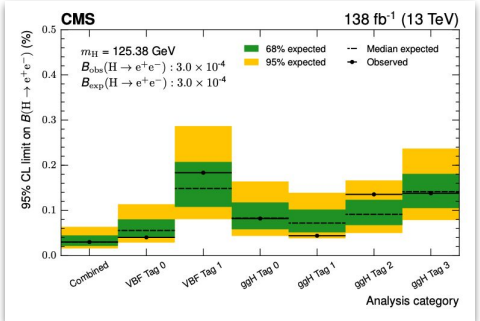


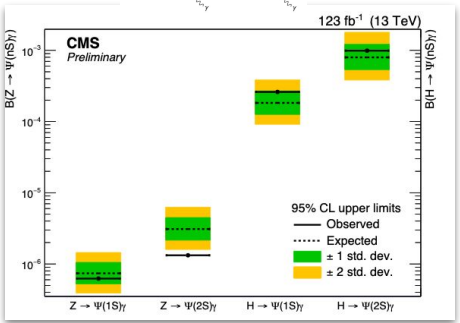
H->cc



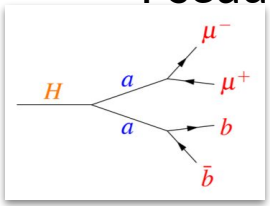


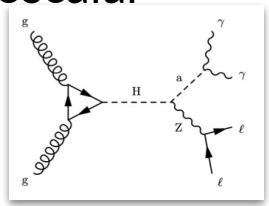
H->ee





Pseudoscalar

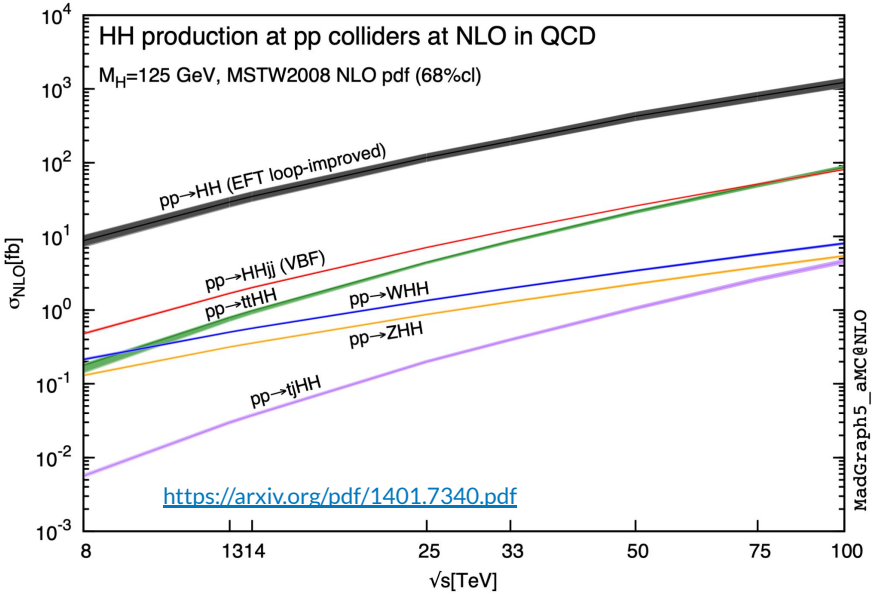




LFV

- Some BSM theories allow LFV processes
- H→eμ, H→eτ, H→$\mu\tau$ become possible

hh production modes

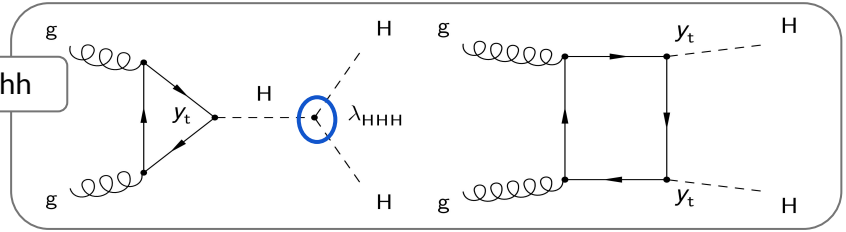


With full Run 2, possible to target also **subdominant** production modes

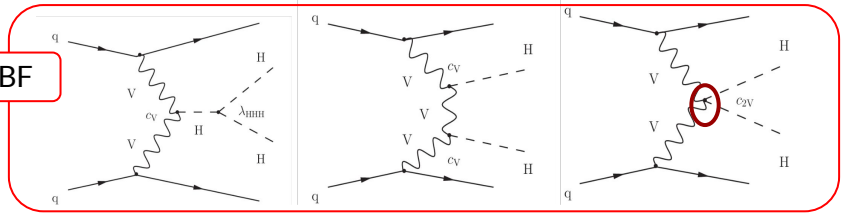
→ Diagrams also involve a different couplings

Exp. **observation very hard**, but small **modifications** to **VVhh** would lead to **big changes** in σ

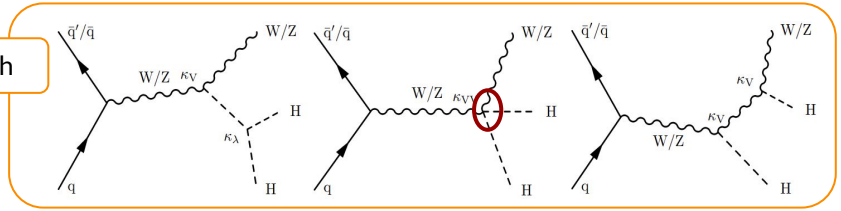
gghh



VBF

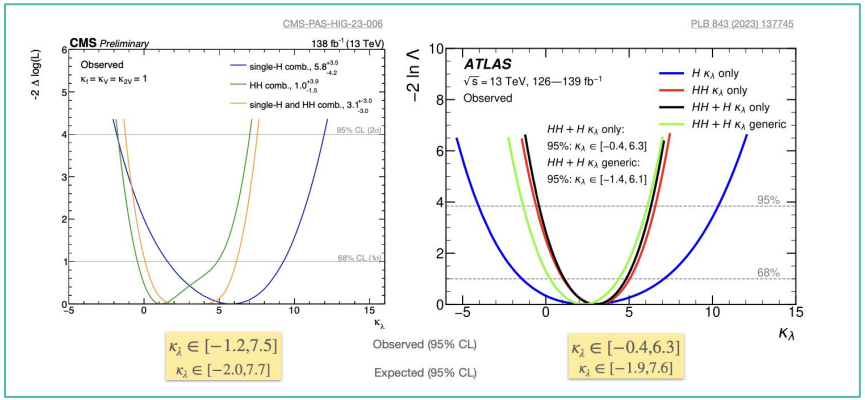


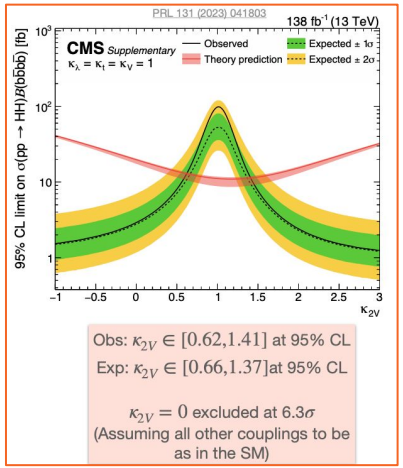
Vhh

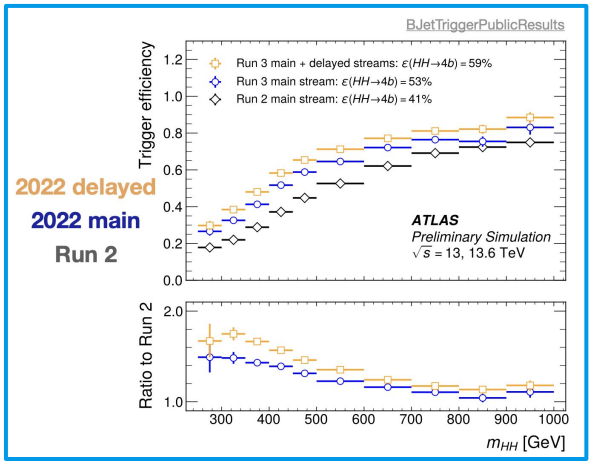


smaller xsec

multi-Higgs



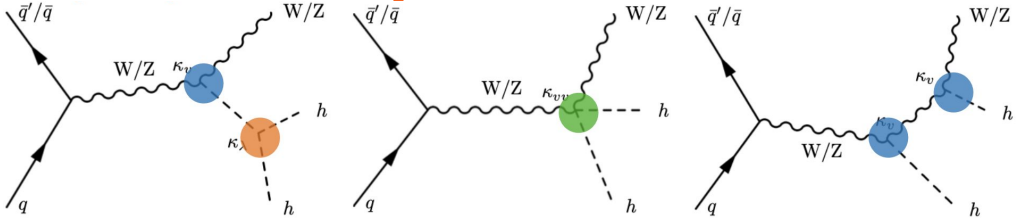


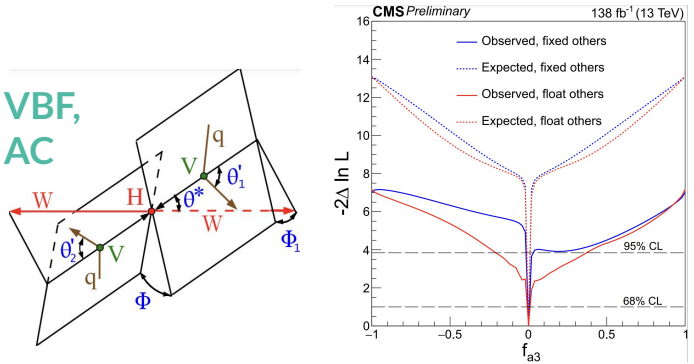


- Combined results: HH signal strength limit & Constraints on self-coupling
- highlights from ATLAS (HH → bb̄ττ, HH → bb̄γγ) and CMS (HH → 4b)
- Trigger challenges and recent related developments in Run 3 (GN2 b-tagging - ATLAS, ParticleNet b-tagging - CMS)

VVh, Vhh, and rarest multiboson processes

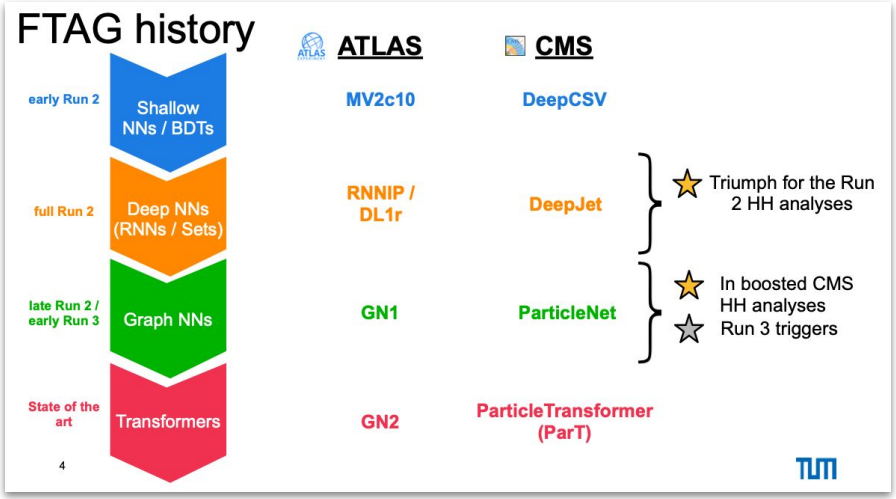
- Rare Vhh production
  - non-resonant => SM and k-framework
    resonant => sensitivity to specific BSM scenarios
- Search for anomalous effects, in the tensor structure of the H interactions with electroweak bosons (HVV):
  - matrix element likelihood approach &/or a neural network to optimize the measurement of anomalous couplings, as well as interpretation in terms of EFT scenarios
- Novel approach to aQGC from VVhh
  - competitive to traditional VBS probes
  - new possibile signatures to explore

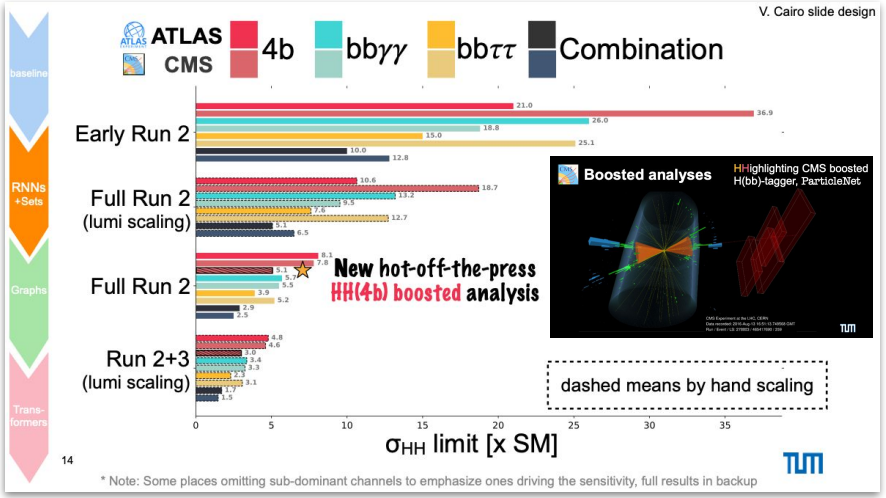


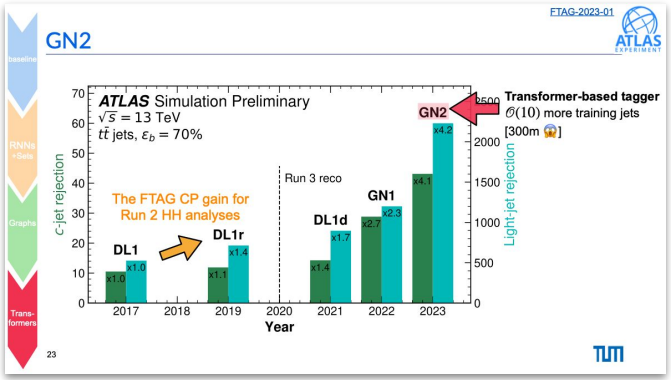


	VBS W$^{\pm}$V semileptonic		VBF HH→ bb̄bb̄	
Coeff.	no unitarity	w/ unitarity	no unitarity	w/ unitarity
f_{M0}/Λ^4	[-0.47,0.47]	[-0.96,1.02]	[-0.43,0.43]	[-0.90,0.87]
f_{M1}/Λ^4	[-1.5,1.5]	[-2.3,2.4]	[-1.7,1.7]	[-3.5,3.5]
f_{M2}/Λ^4	[-0.69,0.68]	[-2.1,2.1]	[-0.62,0.61]	[-1.7,1.7]
f_{M3}/Λ^4	[-2.5,2.4]	[-6.8,6.3]	[-2.4,2.4]	[-6.5,6.6]
f_{M4}/Λ^4	[-1.4,1.4]	[-2.4,2.5]	[-1.8,1.8]	[-3.9,4.0]
f_{M5}/Λ^4	[-2.0,2.0]	[-3.0,3.1]	[-3.2,3.2]	[-6.9,7.0]
f_{M7}/Λ^4	[-2.4,2.4]	[-3.5,3.5]	[-3.5,3.5]	[-7.1,7.1]
f_{S0}/Λ^4	[-1.8,2.0]	[-2.6,3.3]	[-14,13]	/
f_{S1}/Λ^4	[-2.4,2.4]	[-5.8,6.1]	[-5.1,4.5]	/
f_{S2}/Λ^4	[-2.3,2.4]	[-4.8,5.2]	[-8.1,7.1]	/

Flavor tagging performances







- Favour tagging: crucial ingredient for HH searches and active area of innovation
  - Any improvements in flavour tagging take us a step closer to HH evidence
- Large platform for Physics+ML interplay
- Boosted techniques unlocking searches in previously unexplored regimes

inputs from other sessions

- Theory session
- Short-talks session

How do we make our predictions useful for the experiment?

- Dominant $\mathcal{O}(\alpha^7)$ corrections expensive, can't be done with MCs like Madgraph5_aMC@NLO
- MoCaNLO produces histograms for arbitrary observables $\mathcal{O}$ into n bins:

$$\left\{ \mathcal{O}_{\mathrm{L}}^i,\ \mathcal{O}_{\mathrm{R}}^i,\ \frac{1}{\mathcal{O}_{\mathrm{R}}^i - \mathcal{O}_{\mathrm{L}}^i} \int_{\mathcal{O}_{\mathrm{L}}^i}^{\mathcal{O}_{\mathrm{R}}^i} \mathrm{d}\mathcal{O} \frac{\mathrm{d}\sigma}{\mathrm{d}\mathcal{O}} \right\}_{i=1}^{n}$$

- time-consuming, but straightforward: rerun for other cuts and bin limits
- MoCaNLO can't produce unweighted events: technical limitation

Possible avenues with Madgraph5_aMC@NLO/SHERPA:

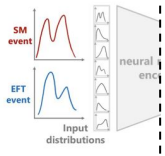
- run it with Sudakov logs [E. Bothmann, D. Napoletano] [D. Pagani, M. Zaro] [D. Pagani, T. Vitos, M. Zaro]
- compare against exact results
- if agreement is found, use it and reweight

Christopher Schwan

Variational AutoEncoders for Anomaly Detection

Generative model: it **learns to decode samples drawn from the same probability distribution of the**

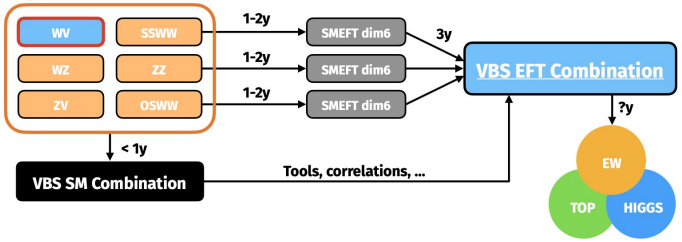
→ **robust** and **varia**



Giulia Lavizzari - 1st COMETA

This work lays the foundation for a global dim-6 interpretation of VBS processes in CMS

- The **first dim-6** interpretations of a VBS process with **semileptonic final state**
- The VBS SM combination: **starting point for a global EFT interpretation of VBS**



G. Boldrini, 29/02/2024, 1st COMETA General Meeting 15

- ✓ **first implementation of polarized cross sections in Sherpa**
- ✓ **higher order QCD corrections @nLO + PS & via multijet-merging**
- → **first fully-realistic VB polarization samples including higher order QCD effects for VBS processes**

Mareen Hoppe

What comes next ...

- ❑ Extension to NLO QCD and approximate NLO EW
- ❑ Applications in phenomenological analyses: BSM studies (UFO), full NLO effects for VBS processes

Thank

WG3 activities

- Plans for next meeting:
  - kick-off of our activities on March 27th (±days), focusing on jet substructure developments.
    Target is to gather the experimental COMETA community first, including a report from this GM by one of us group leaders.
    Hybrid format with CERN room.
- Big overlap by definition with other working groups (but apparent smaller room for original exp. R&D outside collaborations) => our activity should focus in improving discussion and clarify various ambiguities and open issues, with an eye on possibile new developments to push

  highlight a criticality => stimulate discussion => promote R&D (also opening STSMs calls with pre-defined "titles")

- Practically speaking:
  - **joint-hackathons with ML community**
    - prepare inputs from HEP open data or available simulations > "simplify" one of our topic of interest (e.g. optimization of a rare multiboson coupling measurement with delphes-based samples
  - **Theory/Exp talks** (also ML/Exp talks) focused on the major aspects of the (similar to collider-cross-talks format)
    - sectors in which we already have expertise in COMETA (from this gm experience)
      - VHH resonant searches, new models, new sectors and more investigation on EFT/ACs/couplings modifiers interpretation (despite being something already covered by LHC Higgs WG)
      - New theory developments in the VBS physics/
      - Di-boson polarized from theory community
  - **Pheno studies on unexplored production HH/VV production and decay modes towards HL-LHC**
    - Would be an interesting **input to the European Strategy update**

thank you!