Higgs discussions summary experimental perspective

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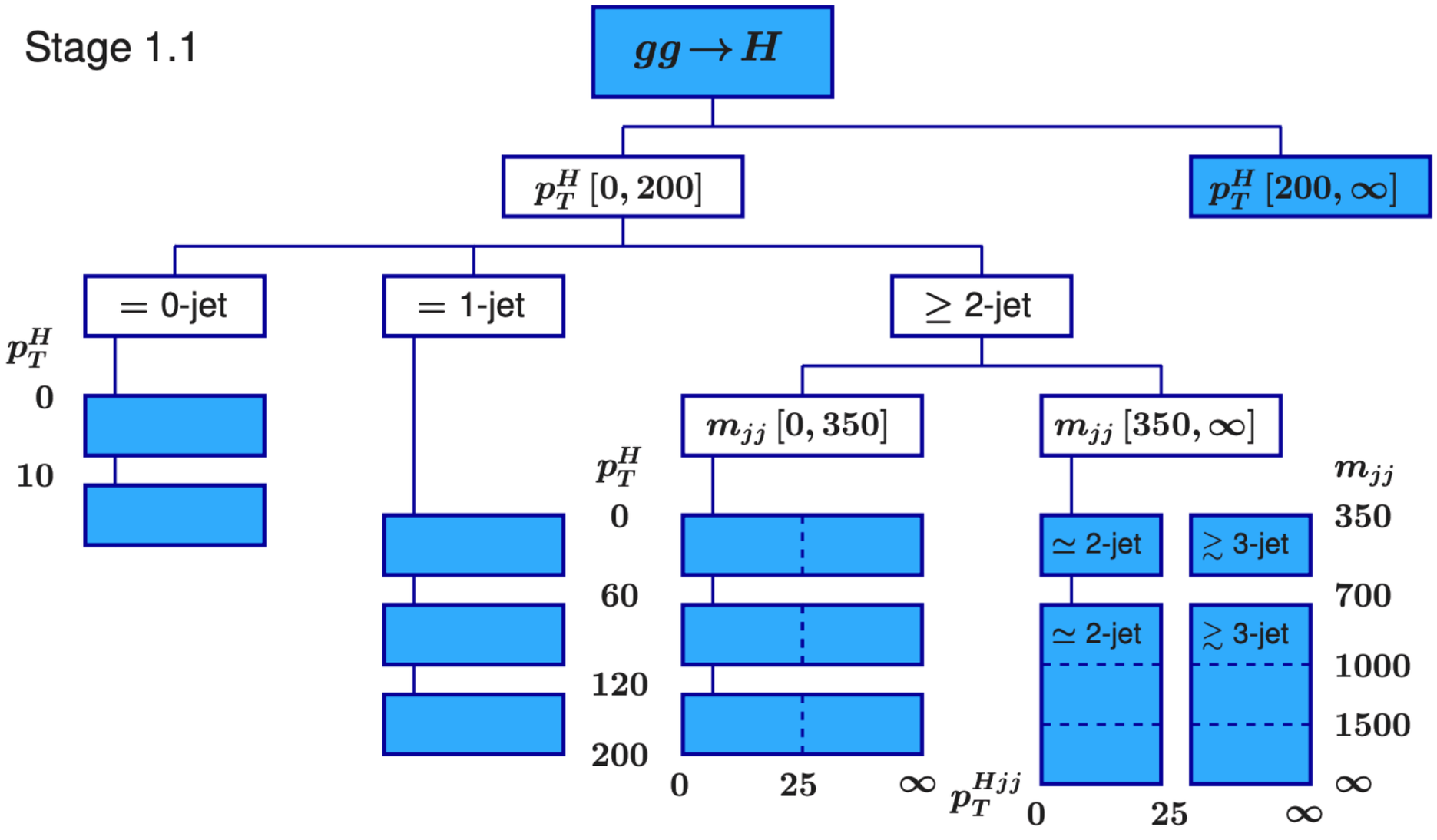
Topics discussed

- STXS in Higgs production
  - define/test binning for boosted ggH (pT > 200GeV)
  - define/test binning for ttH(tH)
  - CP sensitive binning for VBF
- “STXS something” for Higgs decays
- EW corrections in VBF

Other discussions overlapped with other groups and are summarised in other sessions (e.g EFT H interpretation, EFT for HH @ NLO, ttbb backgrounds, quark/gluon tagging, parton showers/MC variations, …)

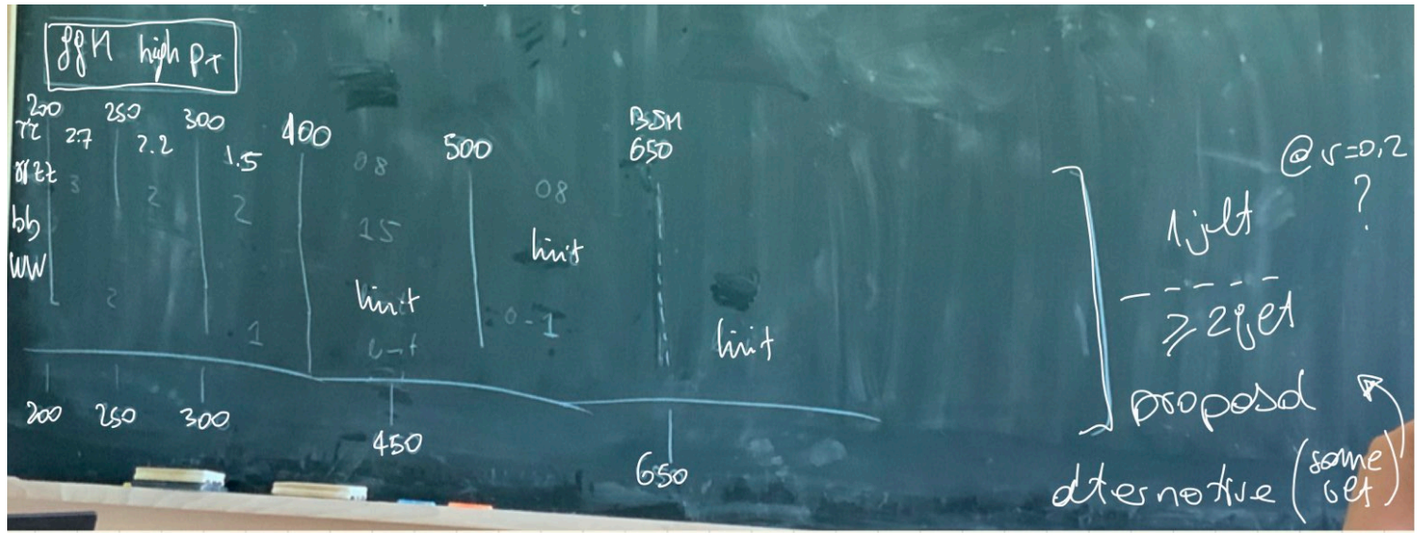
STXS binning ggH



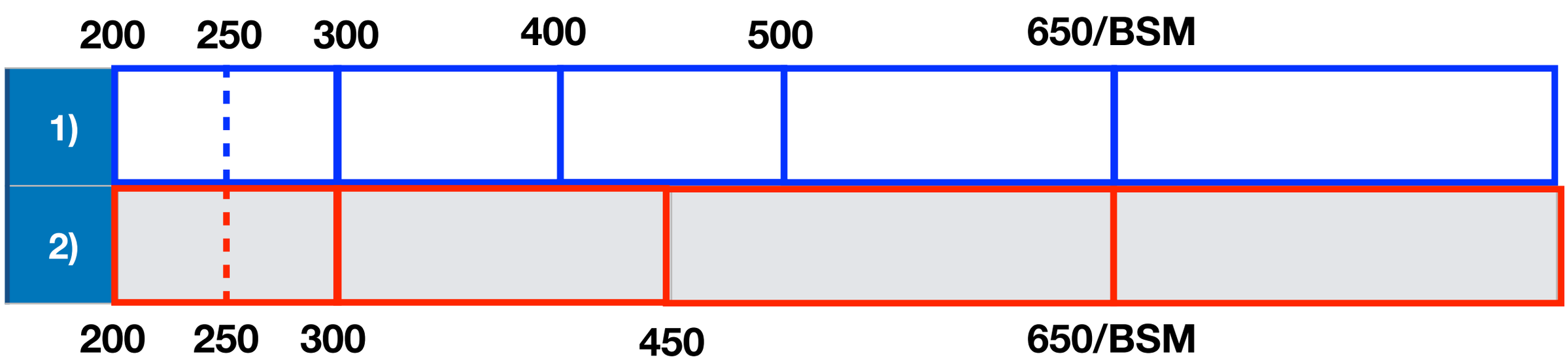
Questions

- Where do $H \to b\bar{b}$, $H \to \tau\tau$, $H \to \gamma\gamma/ZZ^*$ sensitivities stop? What can $H \to WW^*$ do?

STXS binning ggH



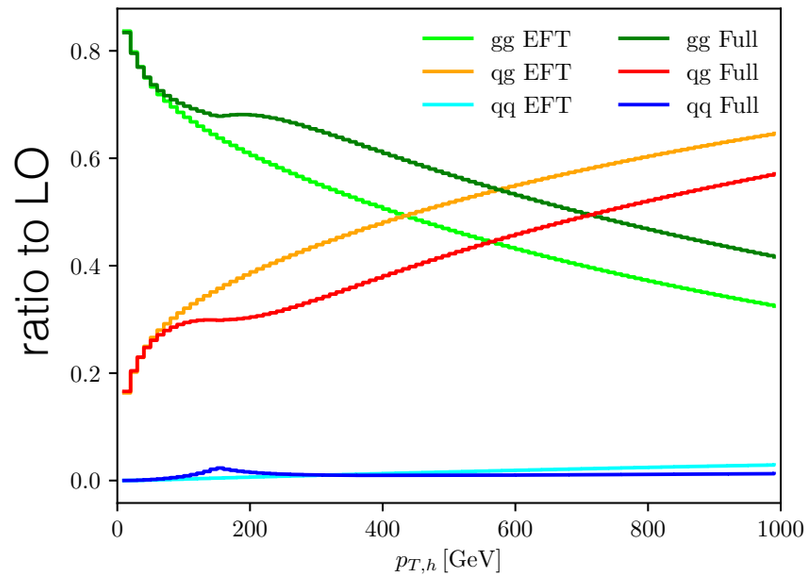
- **Proposed 2 sets of binning to be tested:**
  - mainly based on extrapolating down HL-LHC ATLAS-CMS projections [γγ, ZZ, bb]



- **Waiting for more precise feedback from analyses:**
  - some numbers shown from ATLAS H->ττ, might be refined
  - CMS H->WW started some studies (important for the decision on the splitting around 400/450
  - H->bb might lead the discussion on the location of the upper pT bins (some more refined numbers from ATLAS should arrive soon)

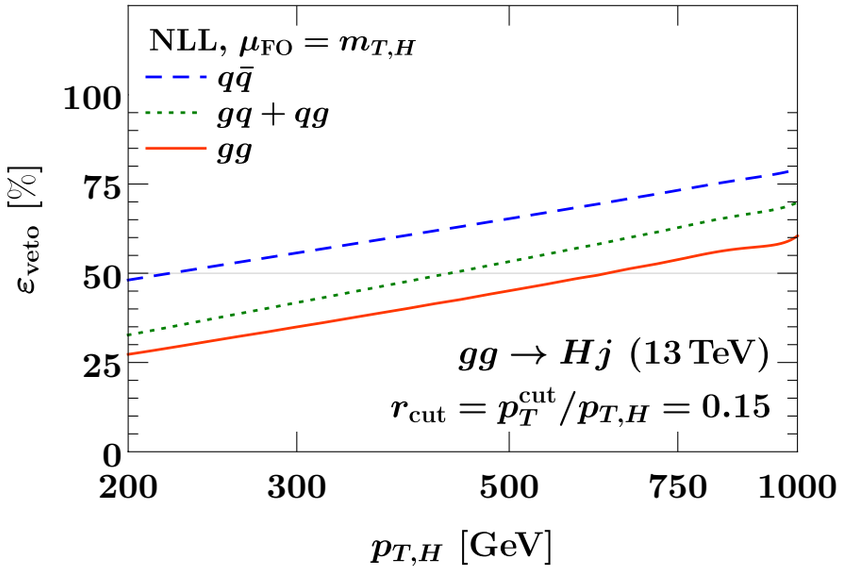
Binning: work in progress

S. Jones



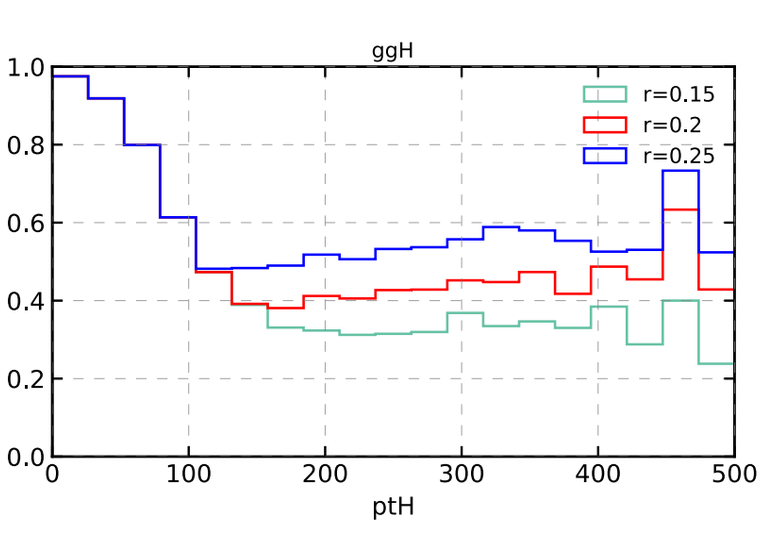
- **additional binning for extra jet activity?**
  - treatment of top loop affects initial partonic fractions
  - q/g could help separating them
- **can a veto on 2nd leading jet differentiate the production diagrams (gg / gq / qq)?**

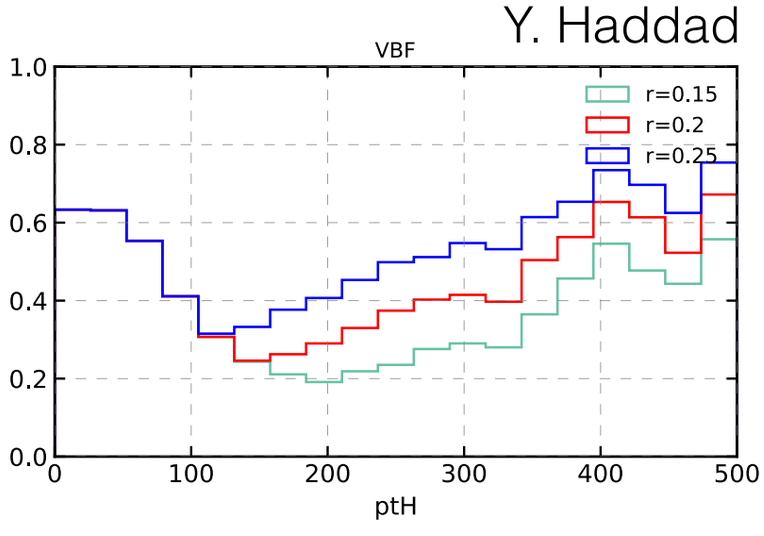
J. Michel



- ratio variable: r = pt_j2/pt_H
- r<0.15 = 30 GeV jet for pt_H=200 GeV
- cut is quite aggressive (only ~30% of ggH events retained and little discrimination power for initial state)

Y. Haddad





fraction of events surviving r<xx cut

- **can the cut help to separate ggF from VBF?**
  - very little separation power (picture worsen as a function of jet pt)
  - use it as dashed bin?

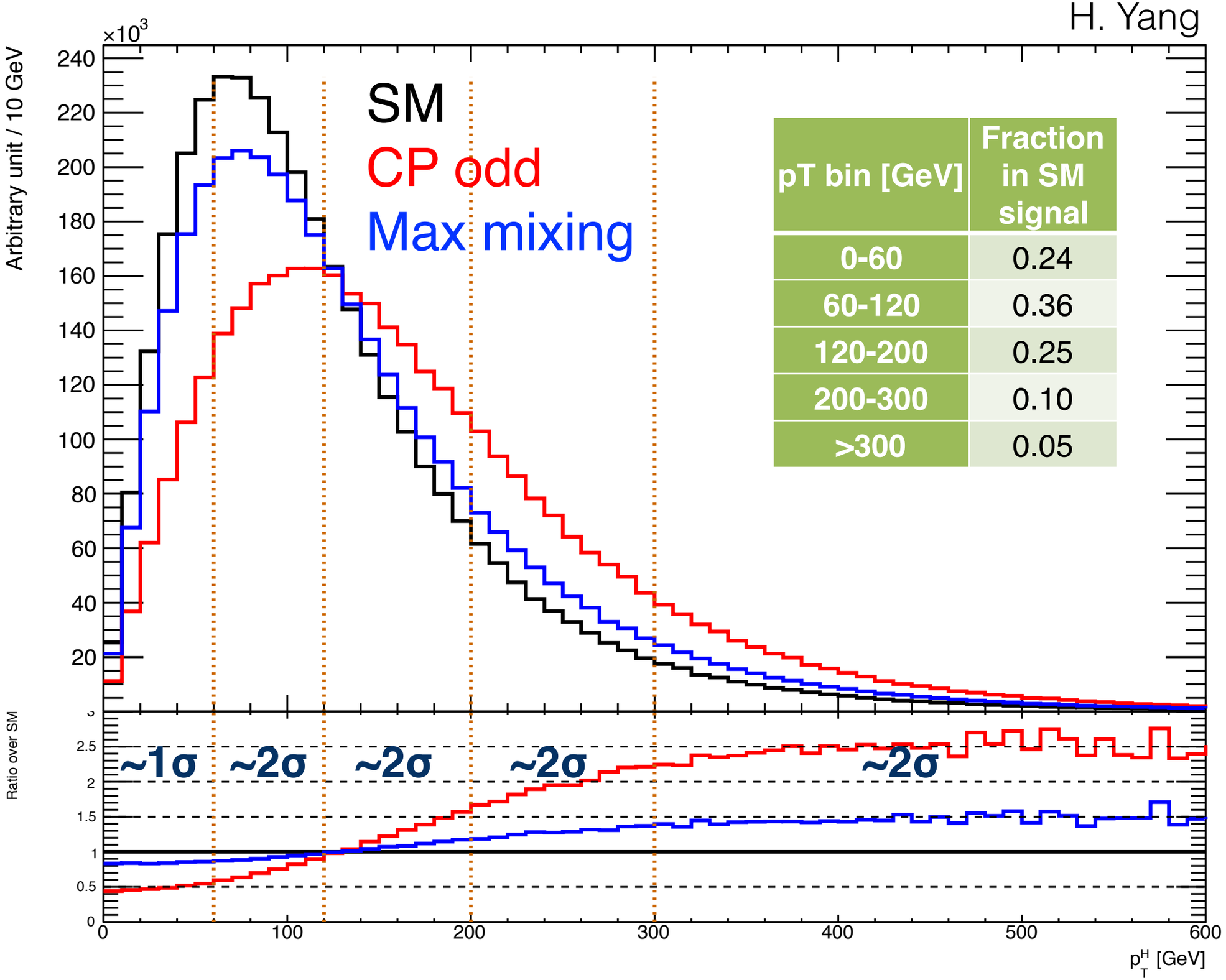
ttH binning

- ttH cross-section: 0.5065 pb @ 13 TeV
- Proposal: introduce bins in p_T^H at **60 GeV, 120 GeV, 200 GeV, and 300 GeV** (mirroring bins in ggH)
  - Rough sensitivity estimation from diphoton channel @139 fb^{-1}

Lumi		Total	γγ	WW+ZZ+ττ	bb
140 fb^{-1}	Produced	70910	161	21569	41192
	Selected	6596	43	1583	4970
300 fb^{-1}	Produced	151950	345	46219	88268
	Selected	14136	93	3393	10650

Efficiencies derived from ATLAS 139 fb^{-1} analysis for ttH(γγ), and ATLAS 36 fb^{-1} analyses for bb/multi-lepton

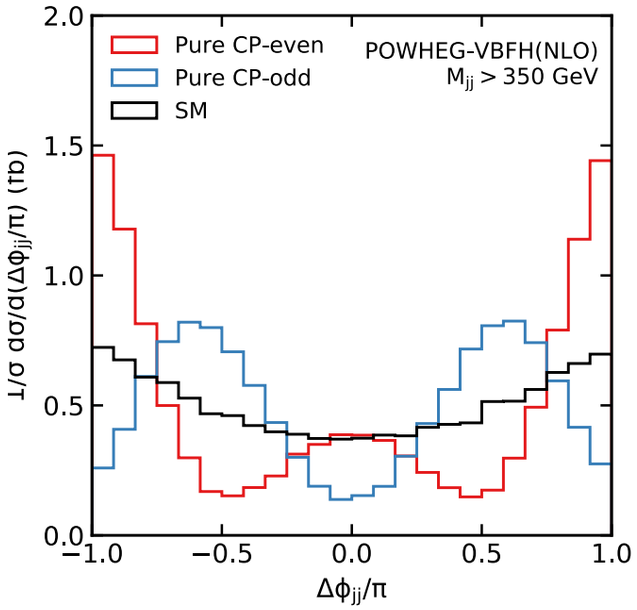
Truth p_T spectrum



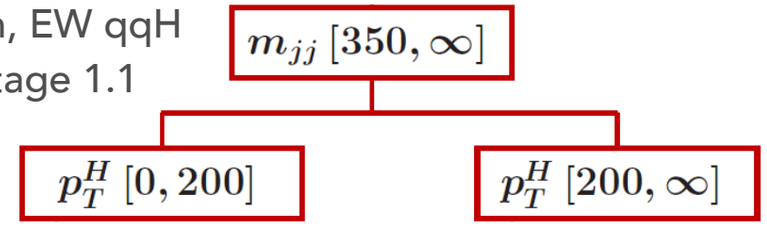
pT bin [GeV]	Fraction in SM signal
0-60	0.24
60-120	0.36
120-200	0.25
200-300	0.10
>300	0.05

VBF CP-SENSITIVE BINS

- Azimuthal angle difference of the two tagging jets probes the tensor structure of HVV vertex
  - flat distribution for SM = a1-Term, follows a cos(2$\Delta\varphi_{jj}$) for a2 and a3 terms
  - Signed $\Delta\varphi_{jj}$: where sign is from [1] $\varepsilon_{\mu\nu\rho\sigma} b_+^\mu p_+^\nu b_-^\rho p_-^\sigma = 2p_{T,+}p_{T,-}\sin(\phi_+ - \phi_-) = 2p_{T,+}p_{T,-}\sin\Delta\Phi_{jj}$
  - For VH hadronic: similar definition as for VH leptonic can be used (mjj < 350 GeV) [2]
- We took a mixture of SM and CP-odd/even and measured deviation from SM
  - 3 values of f_{mix} are used (0.1%, 1%, 10%)

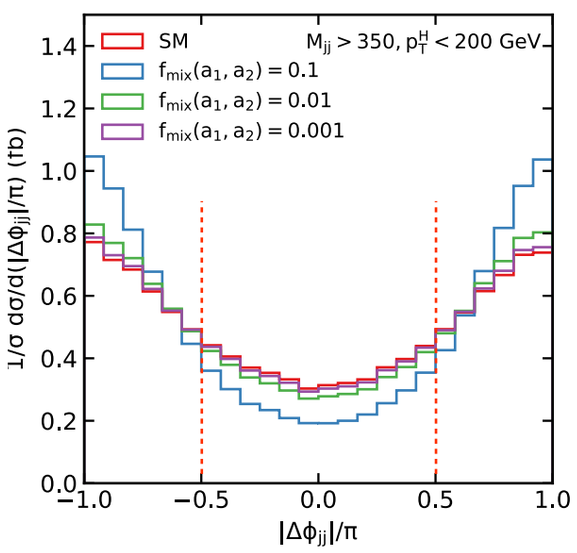


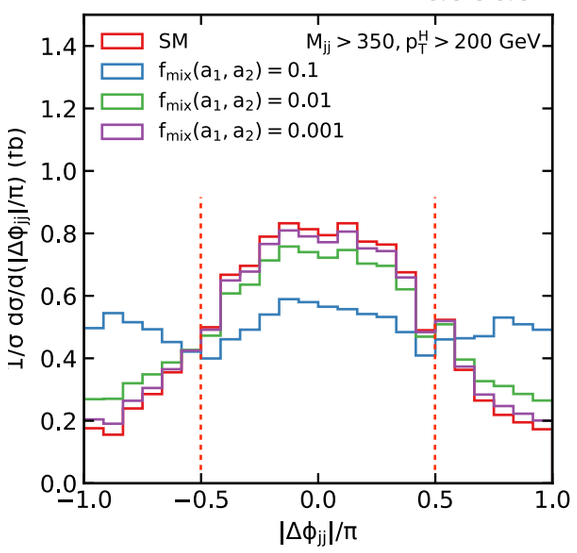
from, EW qqH Stage 1.1



- a_2 : CP-even interaction

Y. Haddad





- Higher pTH is more sensitive to deviations
  - but unlikely to measured with enough stat with Run2 data
- More sensitive to CP-even
  - No amplitude deviation at low PTH bins for (a_1,a_3) mixing

[1] - https://arxiv.org/abs/hep-ph/0703202 (eq 18)
[2] - https://arxiv.org/pdf/1712.02350.pdf

VBF CP-SENSITIVE BINS

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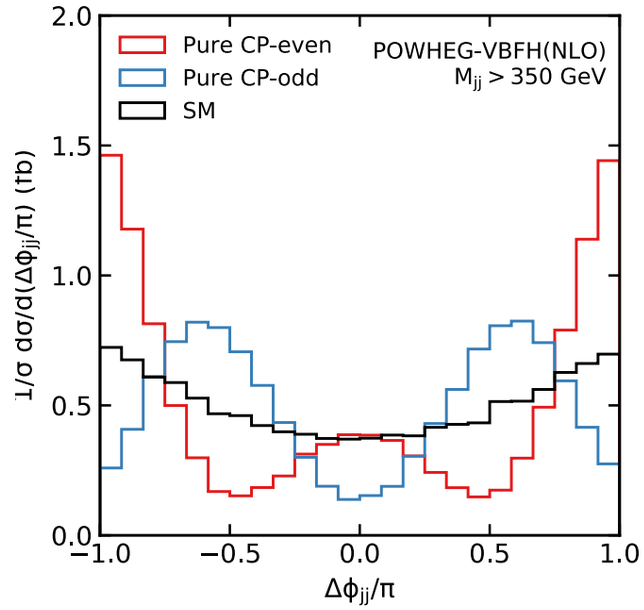

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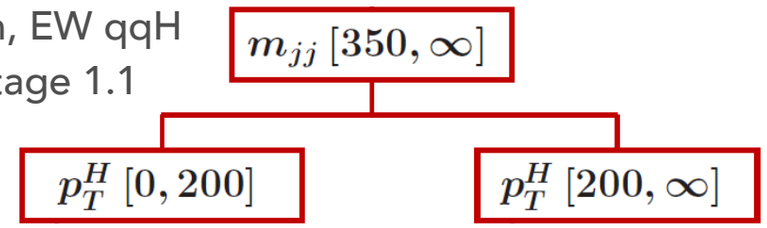
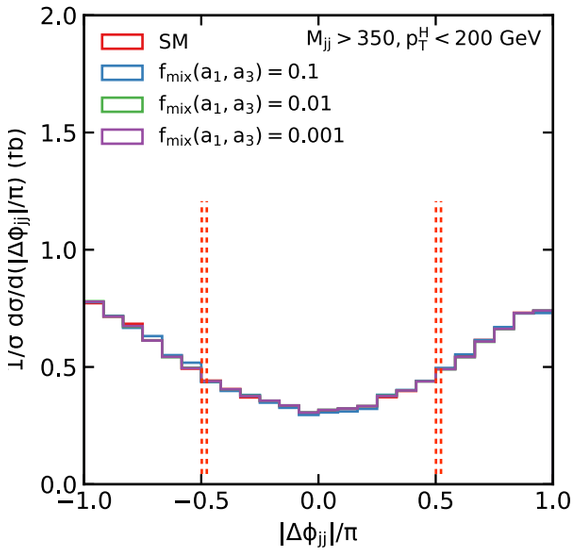
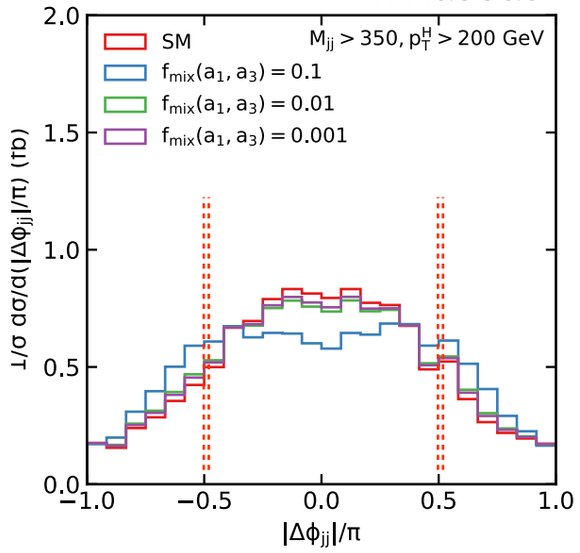


- a_3 : CP-odd interaction

Y. Haddad





- Higher pTH is more sensitive to deviations
  - but unlikely to measured with enough stat with Run2 data
- More sensitive to CP-even
  - No amplitude deviation at low PTH bins for (a_1,a_3) mixing
- Since larger amplitudes at 0 and $\pm\pi$
  - Possible binning [0,-π/2,π/2,π] in both High and low P_T^H
- Need further studies to conclude

[1] - https://arxiv.org/abs/hep-ph/0703202 (eq 18)
[2] - https://arxiv.org/pdf/1712.02350.pdf

“STXS something” for Higgs decays

- Try to define measurement bins for H→4l and H→lvlv as in STXS
- The goal is to have an “agnostic binning” avoiding EFT parameter “bias” on how to split

- Ansatz: split according to “sensitivity” to decay phase space
- Generate SMEFTsim H→4l, relevant operators:
  cHB, cHW, cHWB, cHBtil, cHWtil, cHWBtil, cHe, cHl1, cHl3, cHDD
- Use Matrix element observable ME(cHB, …, cHDD)/ME(SM) as discriminator and fit to a sample of SM H→4l events (only interested in the covariance matrix)
- Eigenvectors of covariance = directions of sensitivity
- For each eigenvector j build dedicated observable ME(EV_j)/ME(SM)
  (EV_j = direction of sensitivity for a combination of operators)

Done

- Can define bins that “split SM sample in half” along each ME(EV_j)/ME(SM)
- Tricky: The size of the eigenvalues depends on the definition of the cXX
  → a priori no order what is “best” measured and in which order to split!

First results

- Large hierarchy of eigenvalues for H→4l

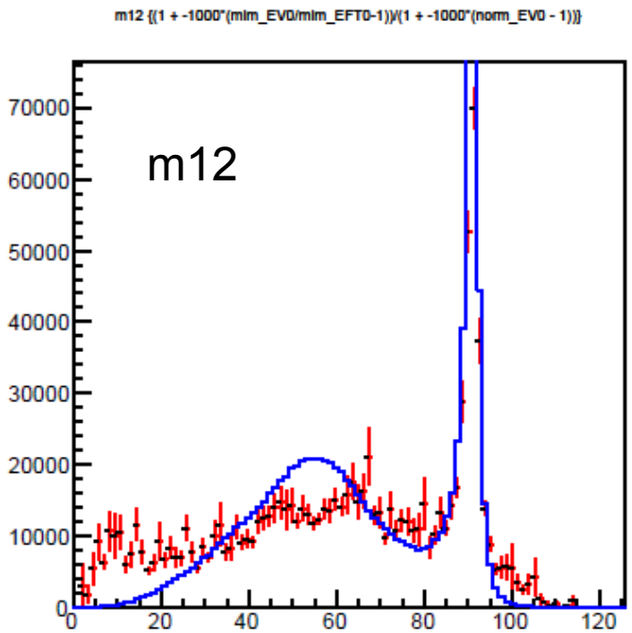
```
549544.0925 : EV = -0.53 cHB -0.04 cHW -0.15 cHWB -0.76 cHBtil -0.25 cHWtil -0.25 cHWBtil

135045.3148 : EV = -0.67 cHB -0.06 cHW -0.19 cHWB +0.25 cHBtil +0.64 cHWtil +0.18 cHWBtil

17802.7597  : EV = -0.42 cHB -0.04 cHW -0.11 cHWB +0.55 cHBtil -0.71 cHWtil +0.01 cHWBtil

314.5775    : EV = -0.01 cHB -0.00 cHW +0.00 cHWB -0.25 cHBtil -0.18 cHWtil +0.95 cHWBtil

160.1771    : EV = -0.24 cHB -0.26 cHW +0.94 cHWB -0.01 cHBtil +0.01 cHWtil -0.01 cHl1 +0.01 cHDD

.....
```

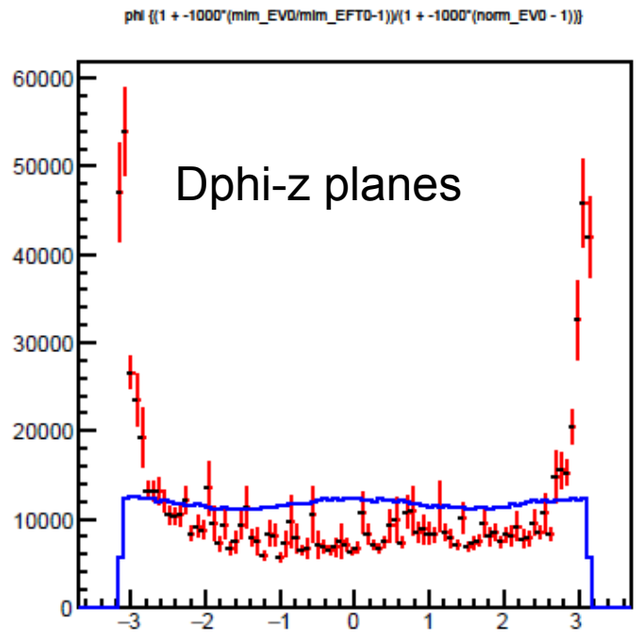
- It seems only the first 2 or 3 independent directions can be measured. The observable effect for the rest seems too small
- Open issues:
  - Order of eigenvectors and in which order to split into bins? How to choose bins?
  - Add acceptance cuts and add ZZ/WW background, as ME ratio diverges in some points! Current results and eigenvalues+vectors are likely very unreliable/biased!
  - Does it work for HWW?
- To be shown: one gets ~ the same final bin definition when using a different formalism, e.g. POs, to start defining bins. The method should be independent from the initial “base” (EFT, POs, etc…)
- Bonus: redefine ME-based observable into something closely related, but human readable. But bins will likely NOT be intuitive

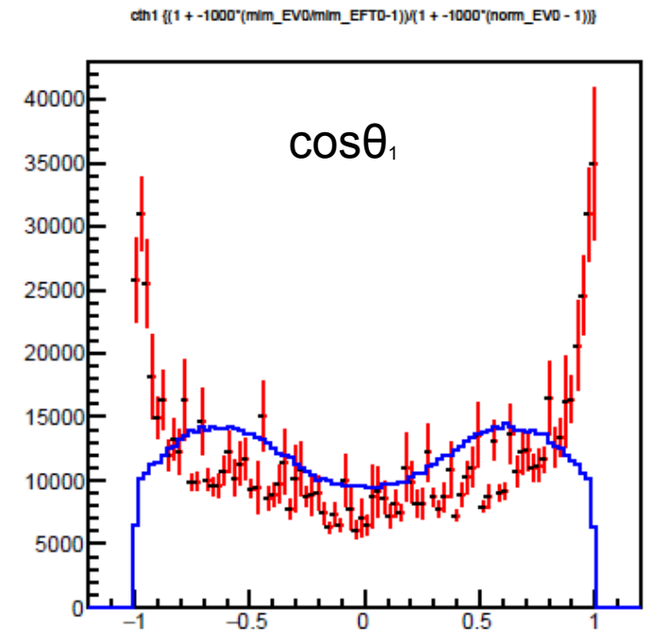
First results

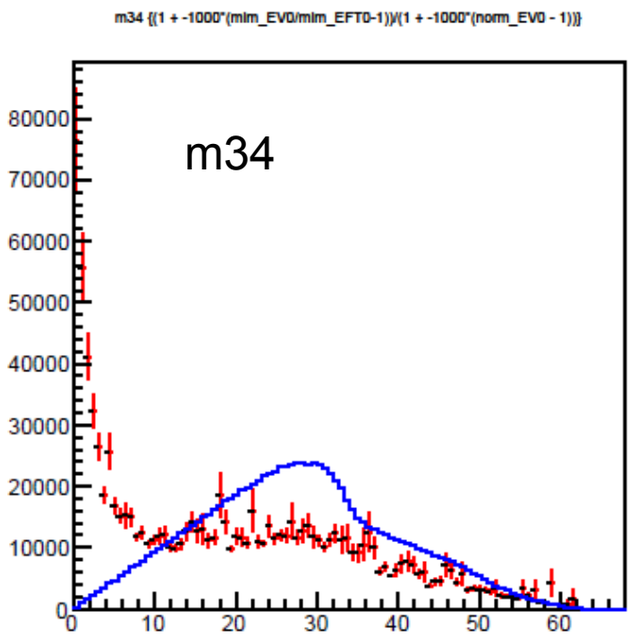
Illustration of the EV_0 direction on the standard angular basis.
EV_0 maximises the shape deviations from the SM

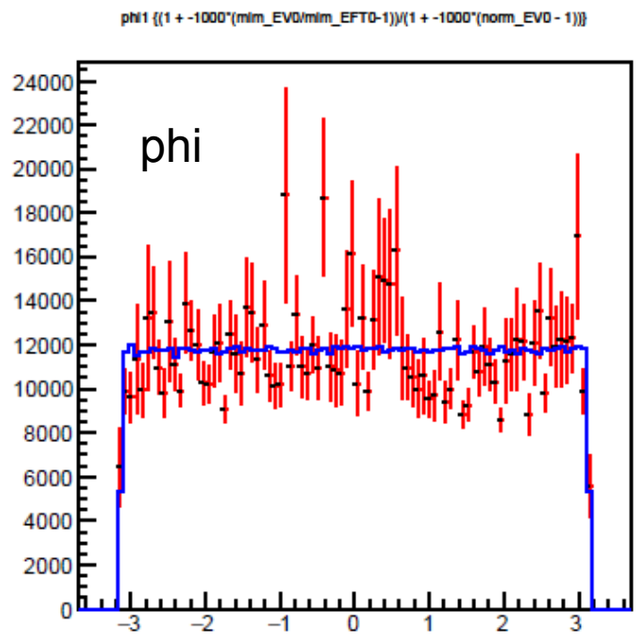
SM
EFT

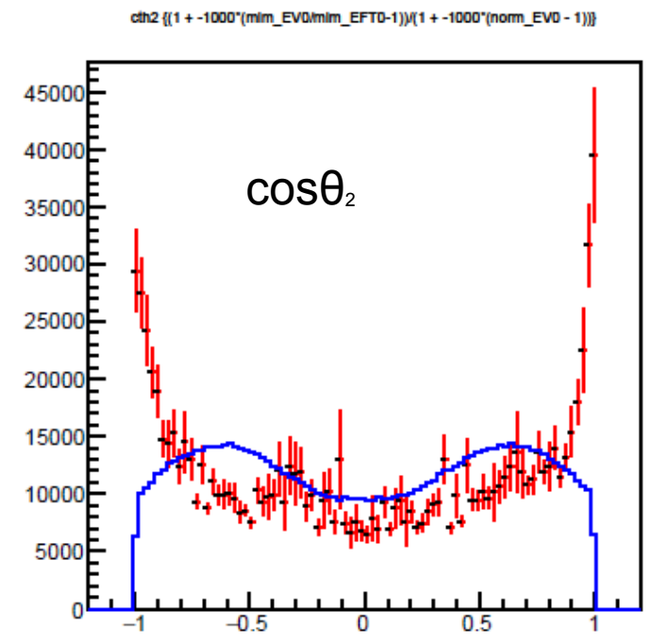










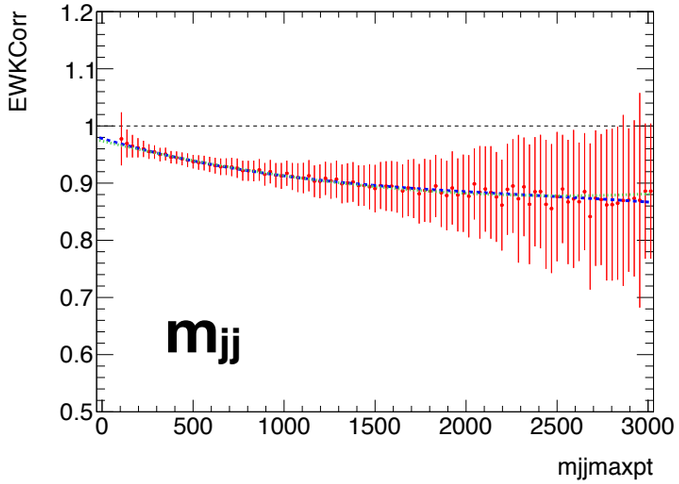


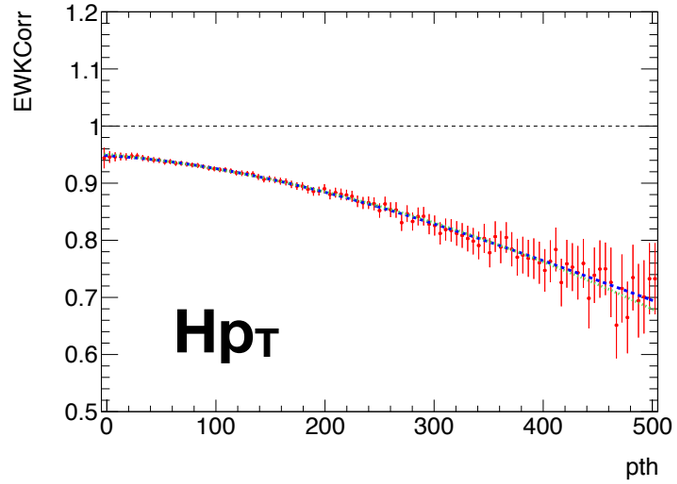
N. Berger

EWK corrections in VBF STXS bins

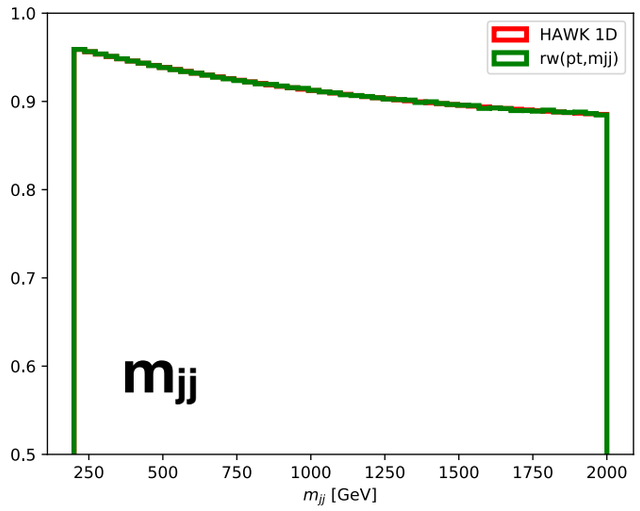
V. Dao

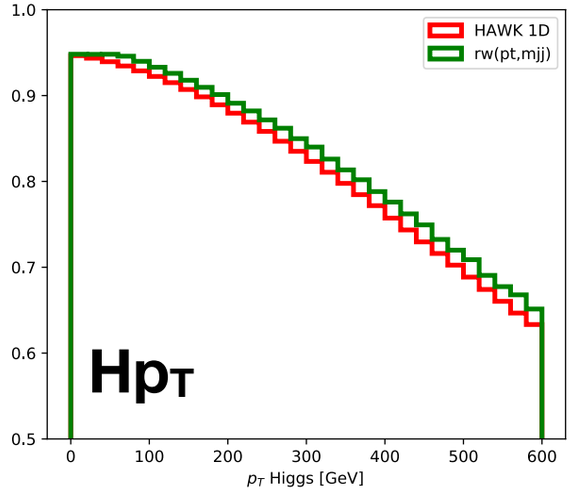
- **Took some 1D distributions from HAWK made by the LHCHIGGSXS WG (link).** Some caveats:
  - plots made for a 2j, $|dY_{jj}|>3$ selection
  - needs to be re-done but used as starting point



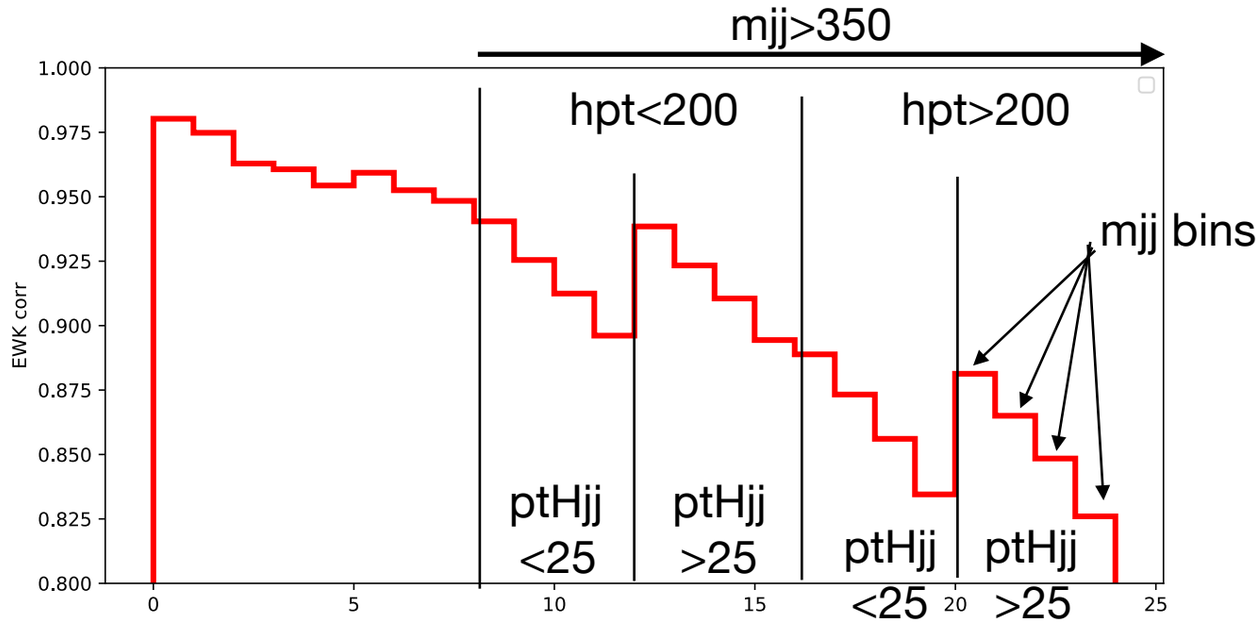


- **Trying to describe the correction with a single function of 2 variables f(m_{jj},hp_T):**
  - mjj and hpT are mildly correlated
  - apply sequential approach: reasonable closure but could certainly be improved





- **calculated EWK corr in VBF bins:**
  - first pass
  - clearly corrections above are not reliable in nJet<2 and low dY



- Ultimate goal: "full multidimensional correction (or STXS bins) directly from HAWK"