CP Sensitivity for STXS 1.3

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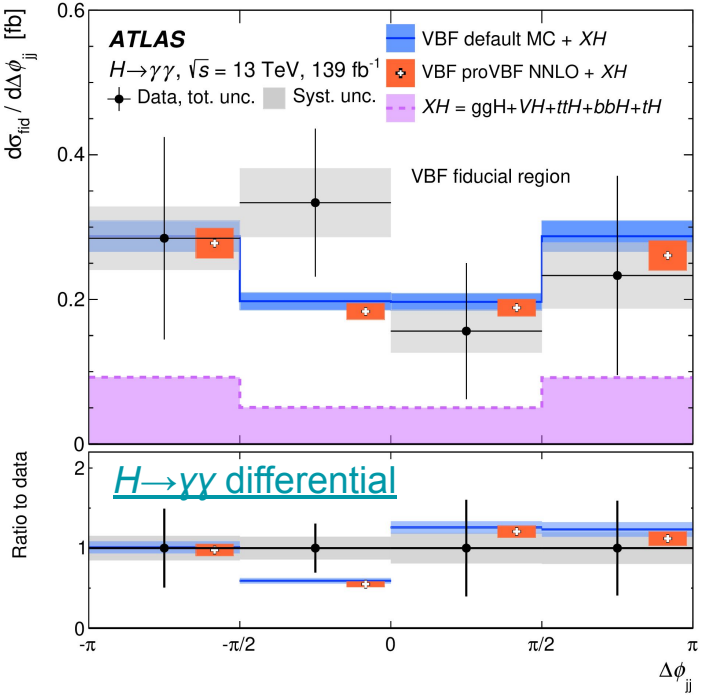
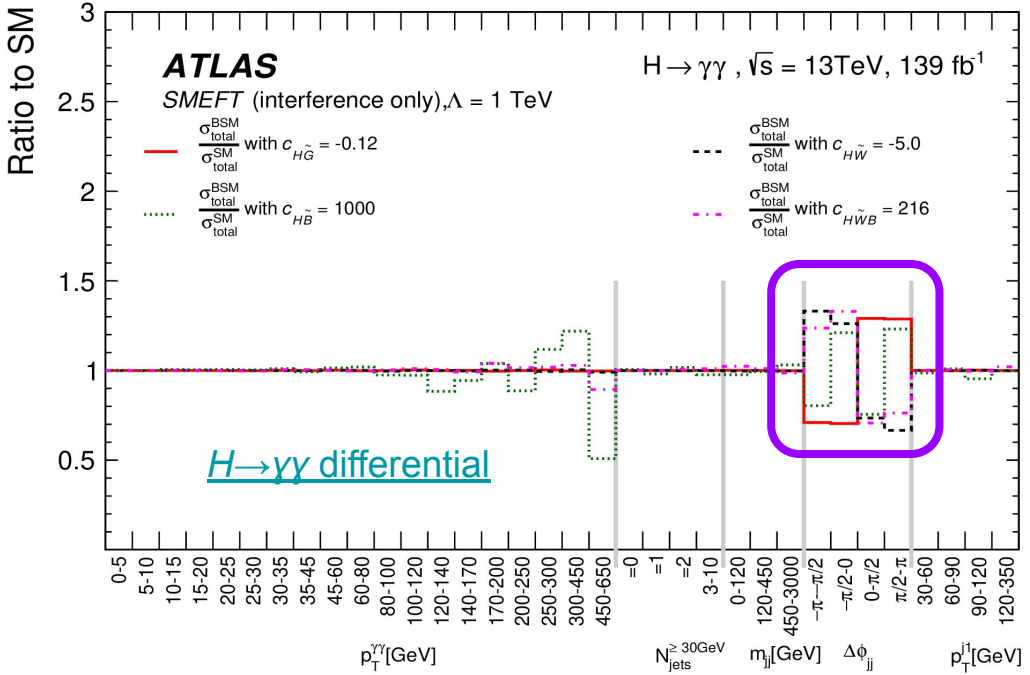
ATLAS EXPERIMENT

CERN

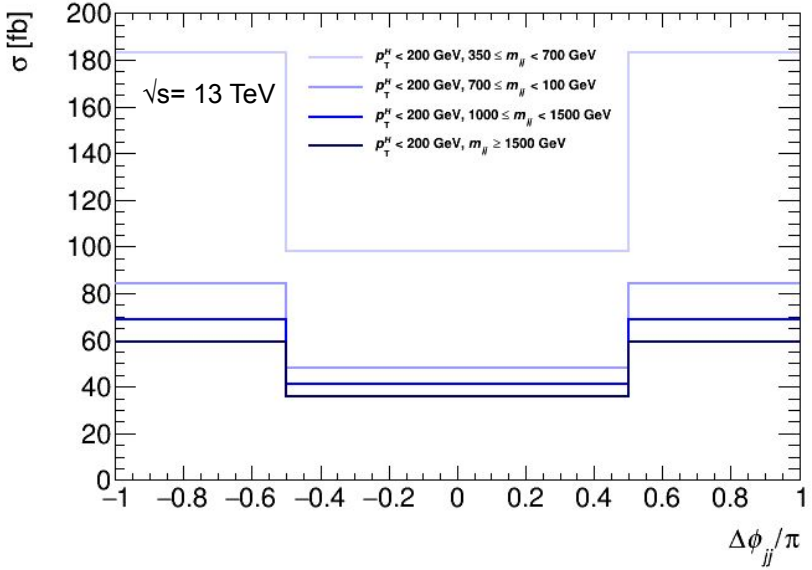
Sensitivity to *CP* Violation

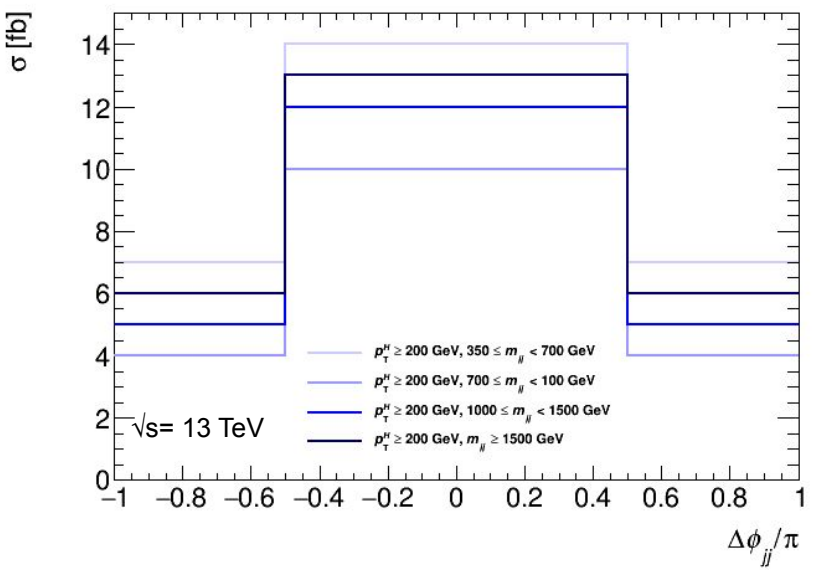




- Currently no sensitivity, all STXS observables are *CP* even. Plan to add $\Delta\phi_{jj}$. Need to find compromise with m_{jj} and p_T^H splitting
- Also possible for ggF 2-jet but challenging in terms of sensitivity

STXS 1.2 with 4 $\Delta\phi_{jj}$ bins. SM prediction



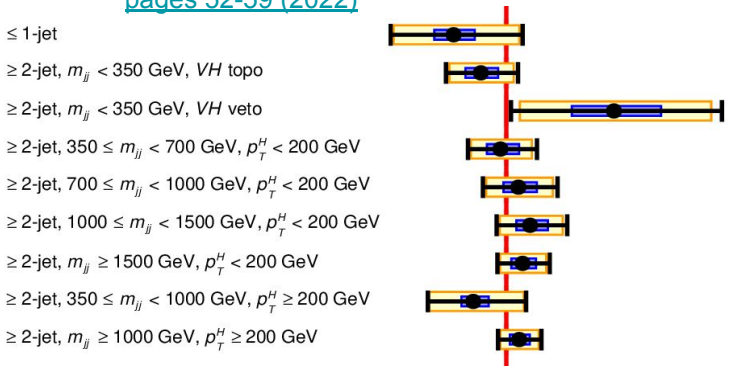


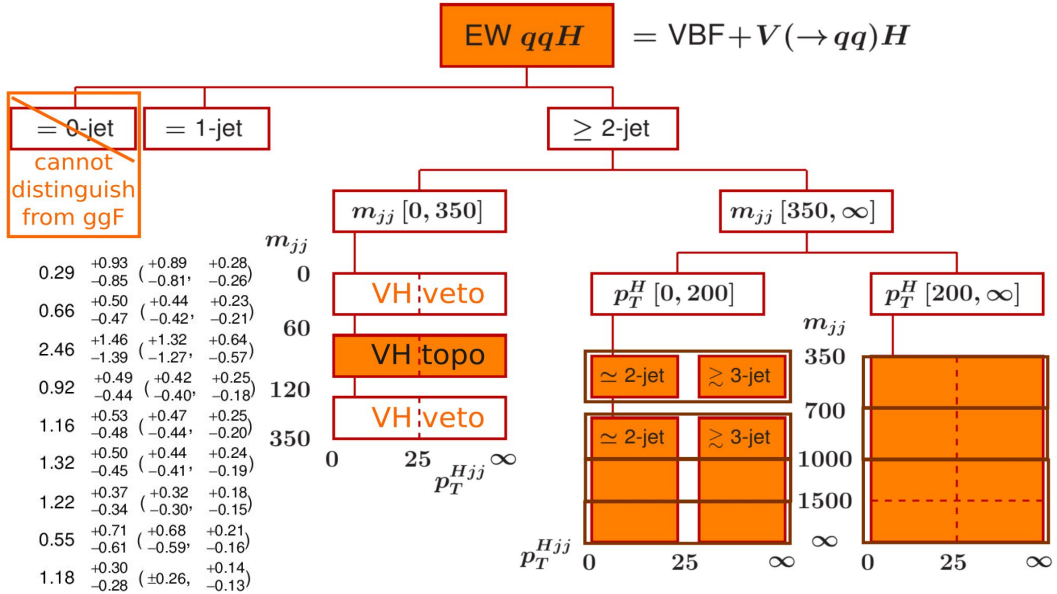
SM prediction derived with MadGraph5 by Matthew Basso. Numbers in backup

- Standard Model is symmetric (CP even)
- [-π/2; π/2] includes 35% of events for p_T^H < 200 GeV but 70% for high p_T^H
  ⇒ the less populated $\Delta\phi_{jj}$ bins include ~15% of the $\Delta\phi_{jj}$ inclusive yield

Possible binning

Nature 607, pages 52-59 (2022)





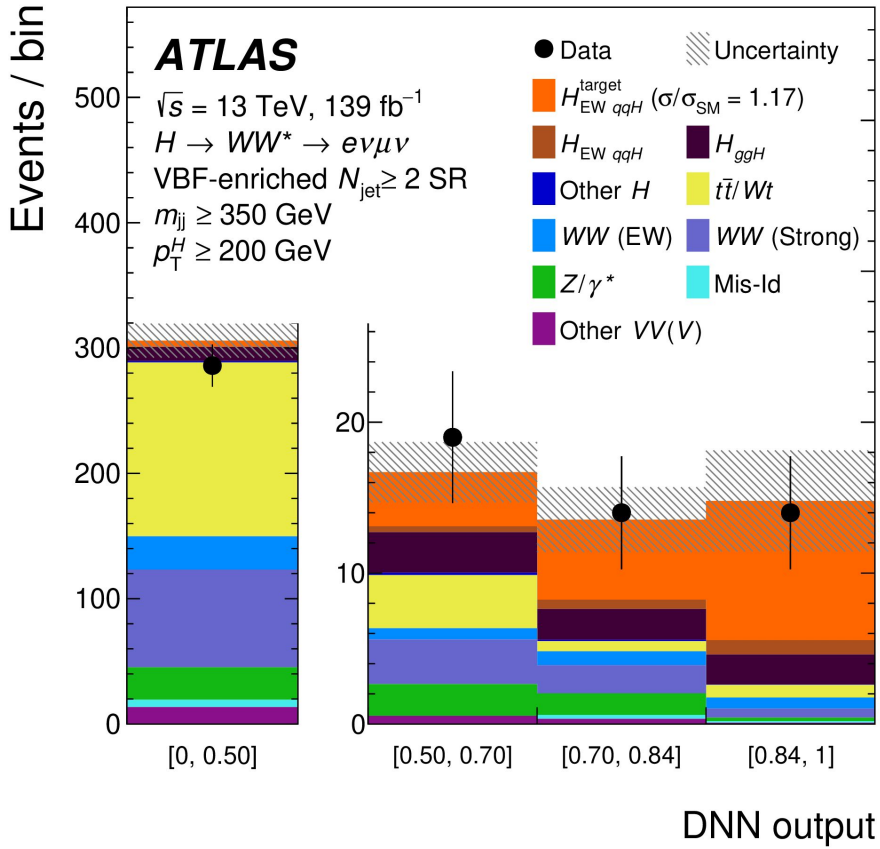
- 30–50% uncertainty when measuring nearly all STXS 1.2 bins
- powerful $H\to\tau\tau$ and $H\to WW$ channels merged the bins >200 GeV for Run 2 → can improve for Run 3
- splitting each bin for m_{jj}>350 GeV into 4 $\Delta\phi_{jj}$ bins seems reasonable (next slide). Analyses could merge m_{jj} bins when needed

Can we measure all these bins?

Short answer: ***yes***. Longer answer

- Critical region is p_T^H>200 GeV, where ATLAS $H\to WW^*\to e\nu\mu\nu$ has 20 events with high purity (next slide). **For Run 3 this will be O(100) events**
  - x factor 2 from luminosity (assuming 300 ifb per experiment)
  - x factor 2 by adding $eve\nu$ and $\mu\nu\mu\nu$ channels (Drell-Yan is not too bad for this phase space)
  - x factor 1.X from cross-section for 13.6 vs 13 TeV (X increasing with p_T^H and m_{jj})
- Splitting into the 16 categories
  - around 4 events are expected for categories in first and last $\Delta\phi_{jj}$ bin$\to\Delta\mu\cong1$
  - around 8 events are expected for categories in 2nd and 3rd $\Delta\phi_{jj}$ bin$\to\Delta\mu<1$
- $H\to\tau\tau$ is about as good as $H\to WW^*\to e\nu\mu\nu$ for VBF overall. For high p_T^H/m_{jj} it does better thanks to the branching ratio and diminishing backgrounds
- Results will be stat dominated. **Could expect $\Delta\mu\cong0.5$** per bin for Run 3 after combining channels and ATLAS+CMS

Can we measure all these bins? link to paper



DNN output for VBF $H \to WW^* \to e\nu\mu\nu$ analysis, p_T^H>200 GeV

Do we need all these bins?

Do we need 4 $\Delta\phi_{jj}$ bins? → **yes**

- splitting at $\Delta\phi_{jj}$=0 is sufficient to search for *CP* violation
- amount of CPV encoded in size of shift. Interesting structure even in SM
- all measurements of $\Delta\phi_{jj}$ (that I know of) use the same 4 bins…

Do we need the split at p_T^H = 200 GeV? → **yes**

- large change in Higgs/non-Higgs, VBF/ggF, …
- BSM may be enhanced for large p_T
- interesting structure for $\Delta\phi_{jj}$

Do we need the m_{jj} splits? → **maybe not all**

- split at 700 or 1000 GeV very useful to separate background enriched region
- p_T^H > 200: splits at 700 or 1000 and 1500 GeV could be removed as far as I know – if we are OK to remove splits that existed in STXS 1.2
- p_T^H < 200 GeV: less stat limited. m_{jj} splits suppress backgrounds incl. ggF

Backup: STXS 1.2 with 4 $\Delta\phi_{jj}$ bins. SM prediction

Cross-sections for 13 TeV **in pb**

		$\Delta\phi_{jj}$			
p_T^H [GeV]	m_{jj} [GeV]	[-π; -π/2]	[-π/2; 0]	[0; π/2]	[π/2; π]
<200	350 – 700	0.183	0.098	0.098	0.183
<200	700 – 1000	0.084	0.048	0.048	0.084
<200	1000 – 1500	0.069	0.041	0.041	0.069
<200	>1500	0.059	0.036	0.036	0.059
>200	350 – 700	0.007	0.014	0.014	0.007
>200	700 – 1000	0.004	0.010	0.010	0.004
>200	1000 – 1500	0.005	0.012	0.012	0.005
>200	>1500	0.006	0.013	0.013	0.006