qqHqq STXS binning

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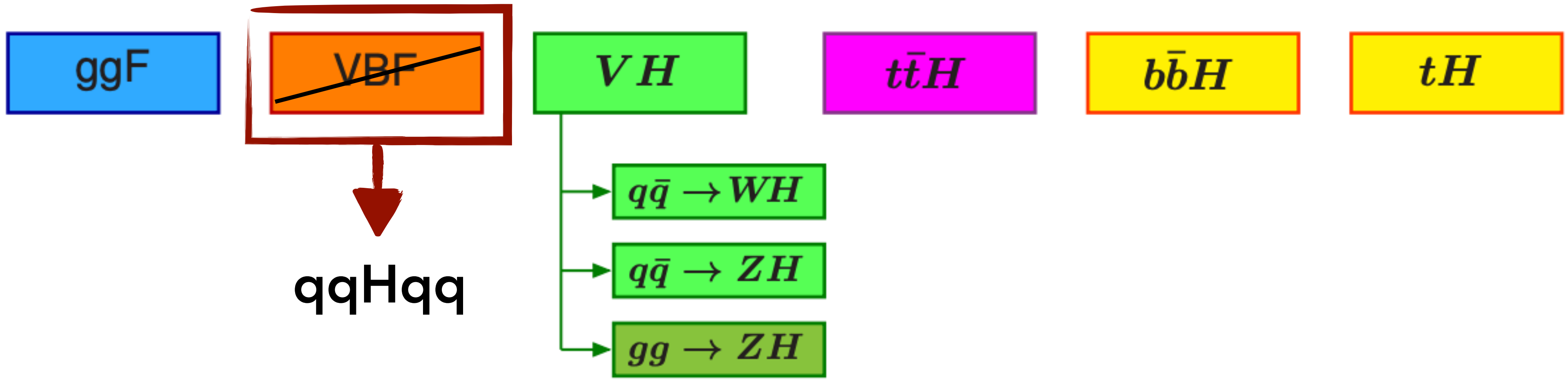
IHEP

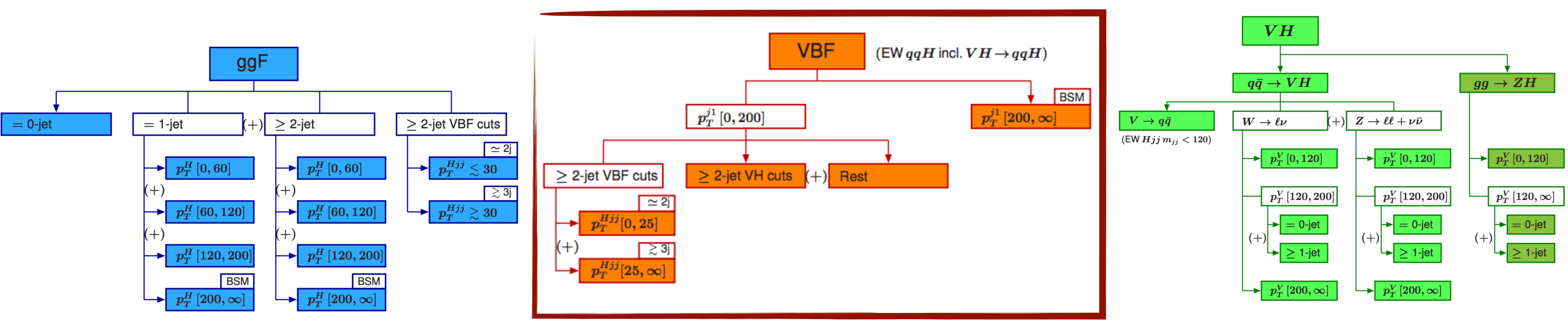
ATLAS EXPERIMENT

Current STXS

- **Stage-0:** split by production mode (for $|y_H| < 2.5$)
  - replace the run1-like μ measurements

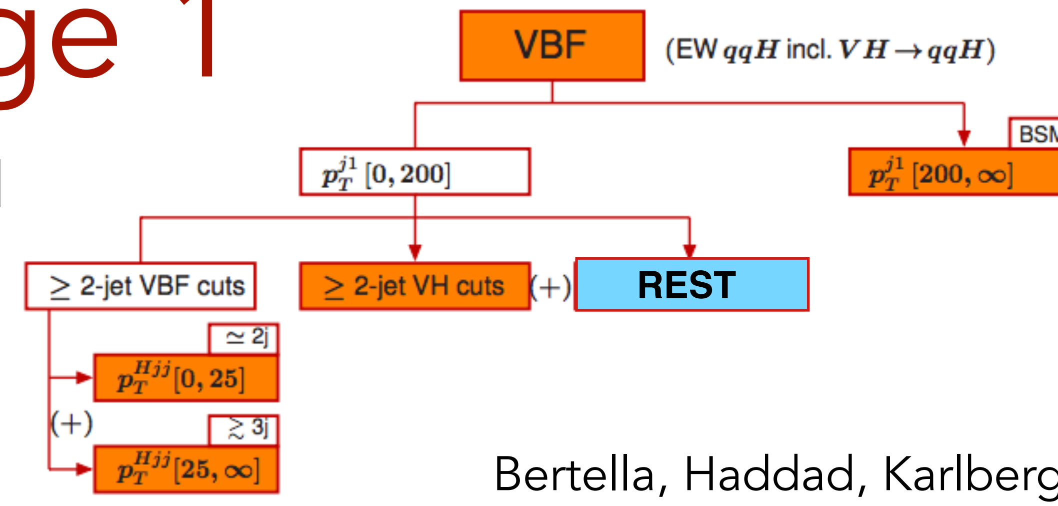


- **Stage-1: Split modes into dominant & most characterising kinematic regions**
  - Most regions accessible with the full Run2 dataset



Currently considering several changes to cope with experimental/theory constraints

Limitation of VBF-stage 1



- **Practical experience has shown that VBF-stage 1 needs substantial revision**
  - Almost 56% of the VBF events lands on < 2 jets region due to the p_T threshold
  - Events with multiple kinematics land in the **REST** bin, making uncertainties estimation more complicated:
    - 0 < mjj < 60 GeV and 120 < mjj < 400 GeV, N_j < 2 jets events and $\Delta\eta_{jj}$ < 2.8 & mjj>400 GeV
- More details, LHC Higgs XS workshop agenda

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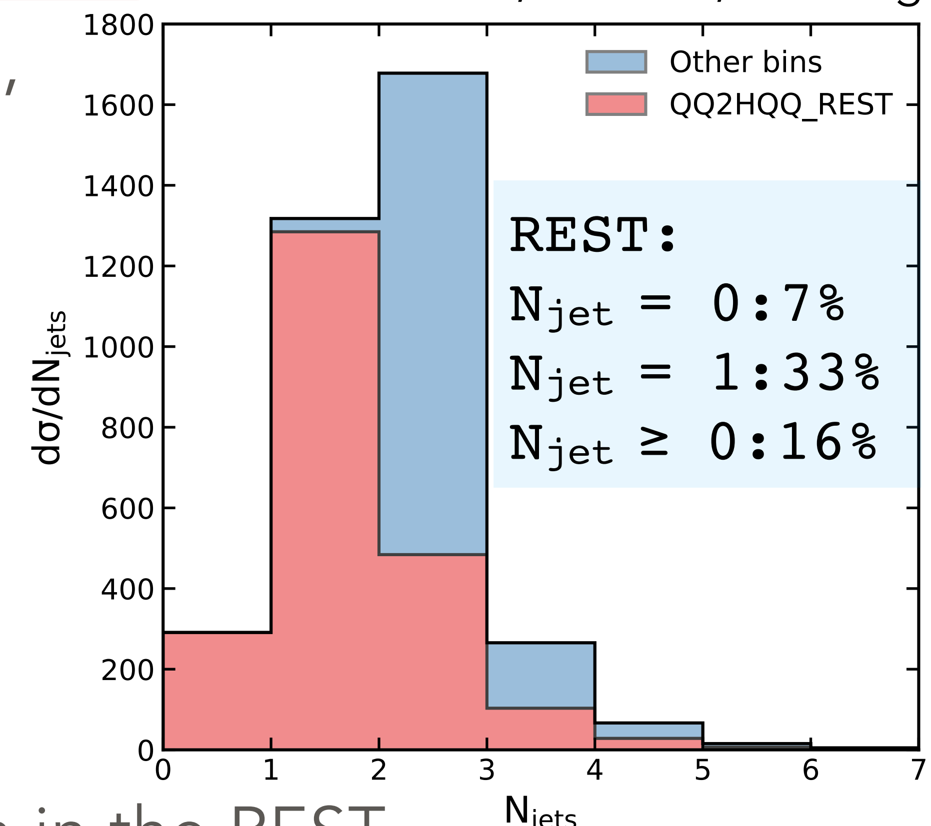

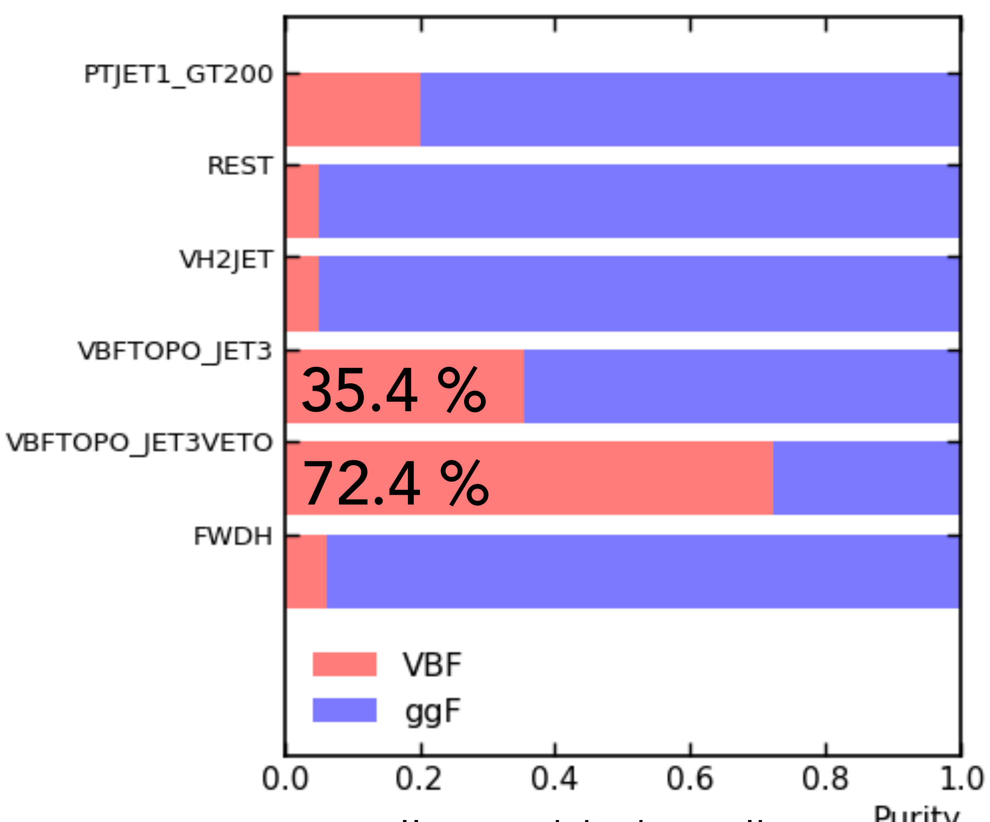

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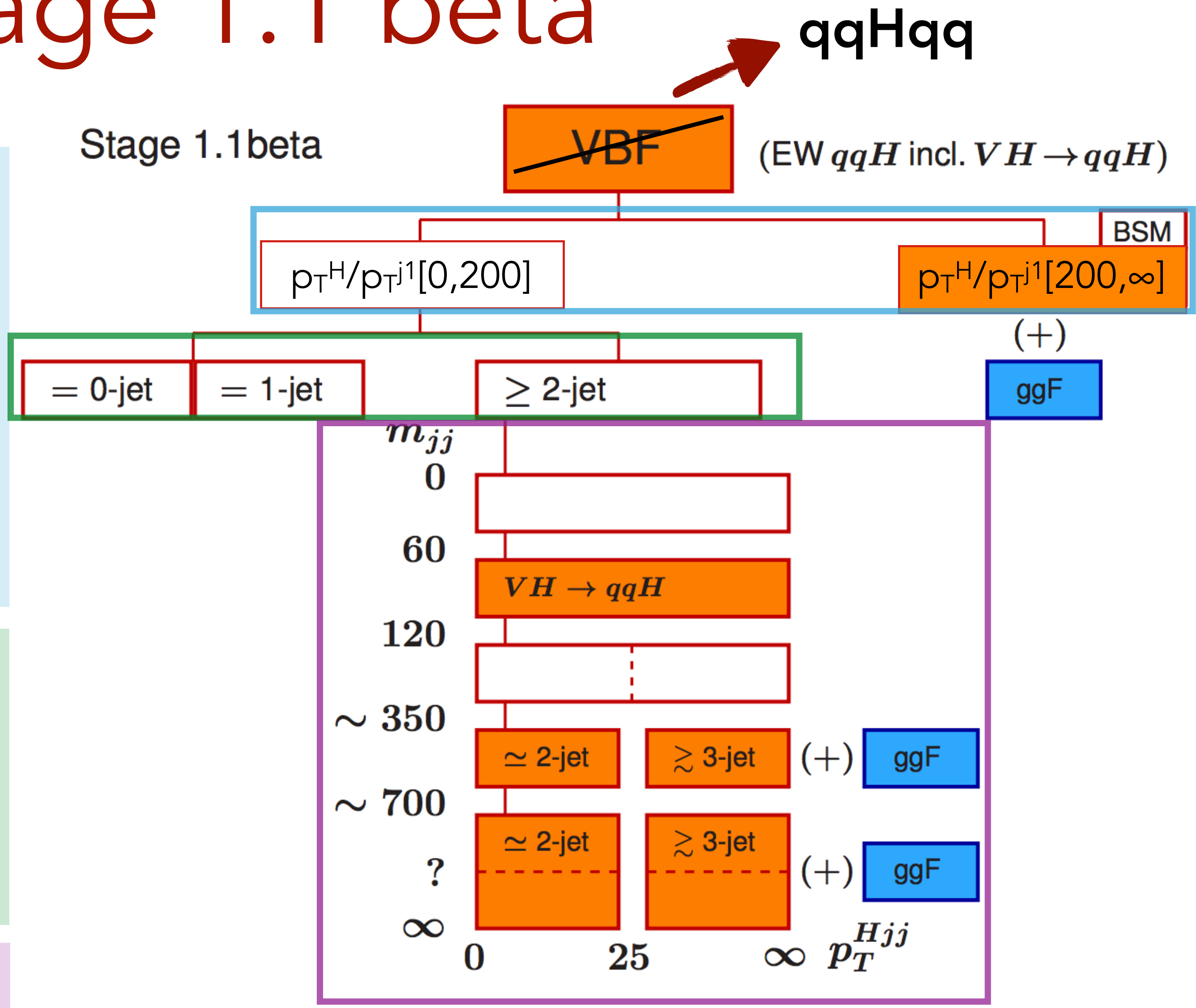
- High VBF contribution in the REST
  - **Add additional bin to put aside the 0-1 jet events**
- More than 20% ggF contamination in the VBF-like bin
  - **More finer binning for VBF-like events**

VBF Stage 1.1 beta

- Change BSM bin from P_T^{j1} to P_T^H
  - Match the ggH stage-1 and allow consistent merging
  - Further split at higher P_T^H possible
- Split 0,1-jet categories
  - Unlikely to be measurable, except maybe 1-jet bin
- Δy_{jj} could be ignored as a simple M_{jj} cut covers VBF phase-space
  - Allow theory uncertainty treatment based on M_{jj} spectrum



- Disclaimer: all the feedback are mainly from analyses targeting the VBF production. Only a side note on VH-had

Feedback: $H \to \gamma\gamma$, $H \to ZZ^*$

$H \to \gamma\gamma$

- Feedback provided also in a past meeting, here
- VBF cuts bin: shown that $|\Delta y_{jj}| > 2.8$ cut is not needed give the high correlation with M_{jj}
- The cut at 400 GeV was largely chosen from the very first $H \to \gamma\gamma$ selection
  - Better to split: 120, 350-400, and 700-800 GeV, corresponding to loose, normal, tight VBF
  - Alternative splitting defined by ~equal fractions of events in each mjj bin: 120, 420, and 850 GeV

$H \to ZZ^*$

- Investigation of the truth-reco m_{jj} migration in view of the differential analysis
- Few configurations tested. [120,450] bin seems to have lower truth-reco m_{jj} migration wrt [120,350] and an higher purity: diagonal term ~70%
- STXS bins in m_{jj} will be adopted in the analysis. Therefore, it will be good to considered migration effect
  - In term of STXS results, high migrations will cause high correlations and extrapolation uncertainties

Feedback: $H\to\tau\tau$ & $H\to WW^*$

$H\to\tau\tau$

Signal Region		Inclusive	$\tau_{lep}\tau_{lep}$	$\tau_{lep}\tau_{had}$	$\tau_{had}\tau_{had}$
VBF	High-$p_T^{\tau\tau}$	$+9ptp_T^{j_2} > 30$ GeV $\lvert\Delta\eta_{jj}\rvert > 3$ $m_{jj} > 400$ GeV $\eta_{j_1}\cdot\eta_{j_2} < 0$ Central leptons	—		$p_T^{\tau\tau} > 140$ GeV $\Delta R_{\tau\tau} < 1.5$
	Tight		$m_{jj} > 800$ GeV	$m_{jj} > 500$ GeV $p_T^{\tau\tau} > 100$ GeV	Not VBF high-$p_T^{\tau\tau}$ $m_{jj} > (1550 - 250\cdot\lvert\Delta\eta_{jj}\rvert)$ GeV
	Loose		Not VBF tight		Not VBF high-$p_T^{\tau\tau}$ and not VBF tight
Boosted	High-$p_T^{\tau\tau}$	+1ptNot VBF $p_T^{\tau\tau} > 100$ GeV	$p_T^{\tau\tau} > 140$ GeV $\Delta R_{\tau\tau} < 1.5$		
	Low-$p_T^{\tau\tau}$		Not boosted high-$p_T^{\tau\tau}$		

Process	Particle-level selection	σ [pb]	σ^{SM} [pb]
ggF	$N_{jets}\geq 1$, $60 < p_T^H < 120$ GeV, $\lvert y_H\rvert < 2.5$	1.79 ± 0.53 (stat.) ±0.74 (syst.)	0.40 ± 0.05
ggF	$N_{jets}\geq 1$, $p_T^H > 120$ GeV, $\lvert y_H\rvert < 2.5$	0.12 ± 0.05 (stat.) ±0.05 (syst.)	0.14 ± 0.03
VBF	$\lvert y_H\rvert < 2.5$	0.25 ± 0.08 (stat.) ±0.08 (syst.)	0.22 ± 0.01

- Majority of VBF sensitivity comes from bins with mjj: requirements tighter than the STXS VBF classification
- Tight regime (~ m_{jj} > 500 GeV) has half the statistical uncertainties of the Loose regime
  - Sensitivity below 500 GeV is hampered by increasing backgrounds

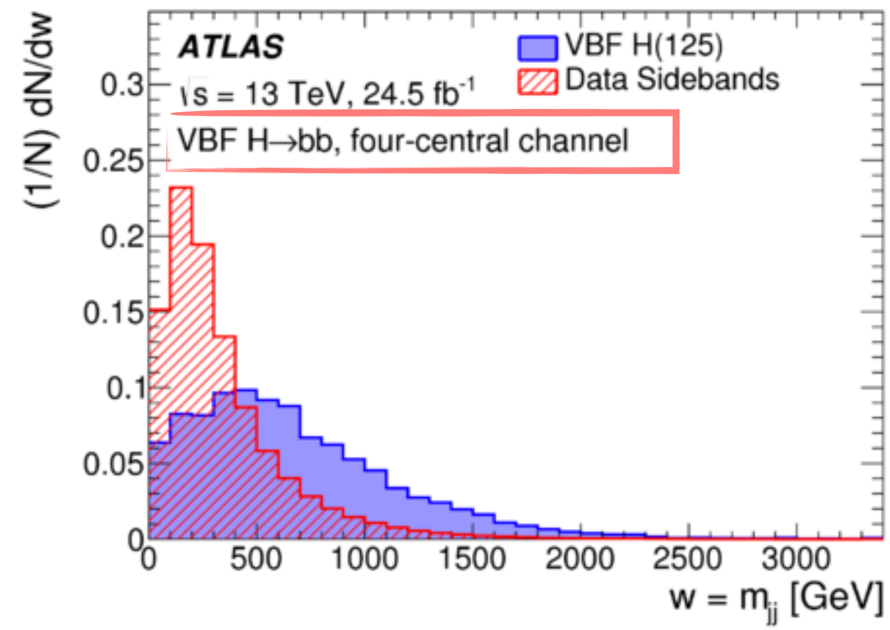
Potential room for improvement from further splitting at high m_{jj}

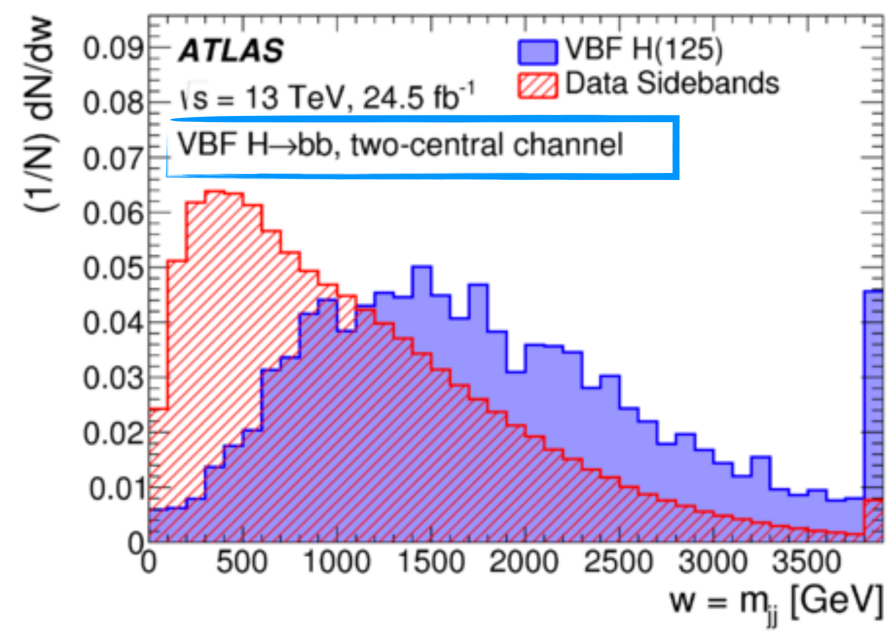
$H\to WW^*$

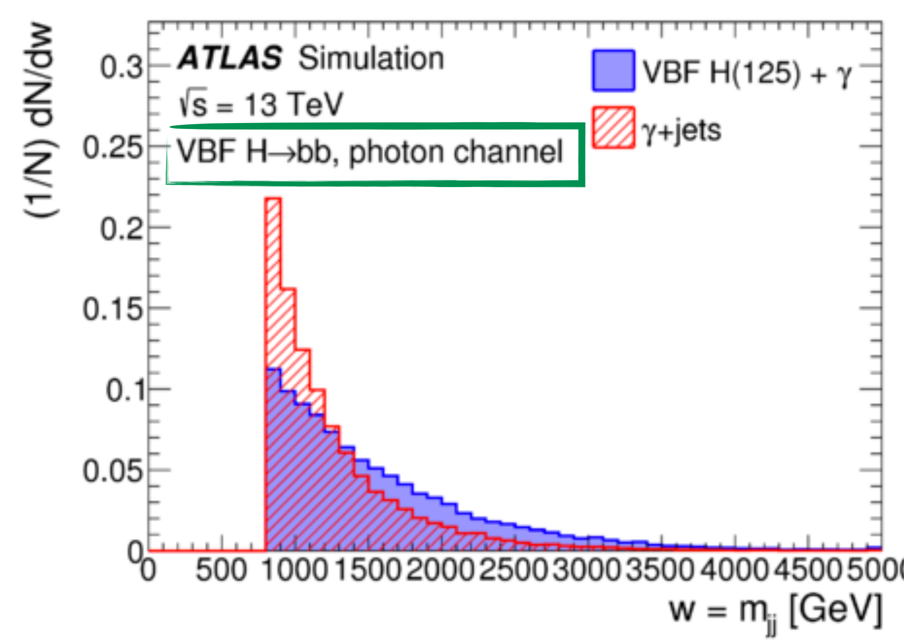
- Most sensitive BDT bin has $m_{jj}\gtrsim$500GeV. S/B higher above 700 GeV. Contributions at high m_{jj} ~ 1.5 TeV
- Second most sensitive BDT bin goes down to ~350 GeV but high background contamination
- In favour of 120, 350, 700, and 1500 GeV

H→bb

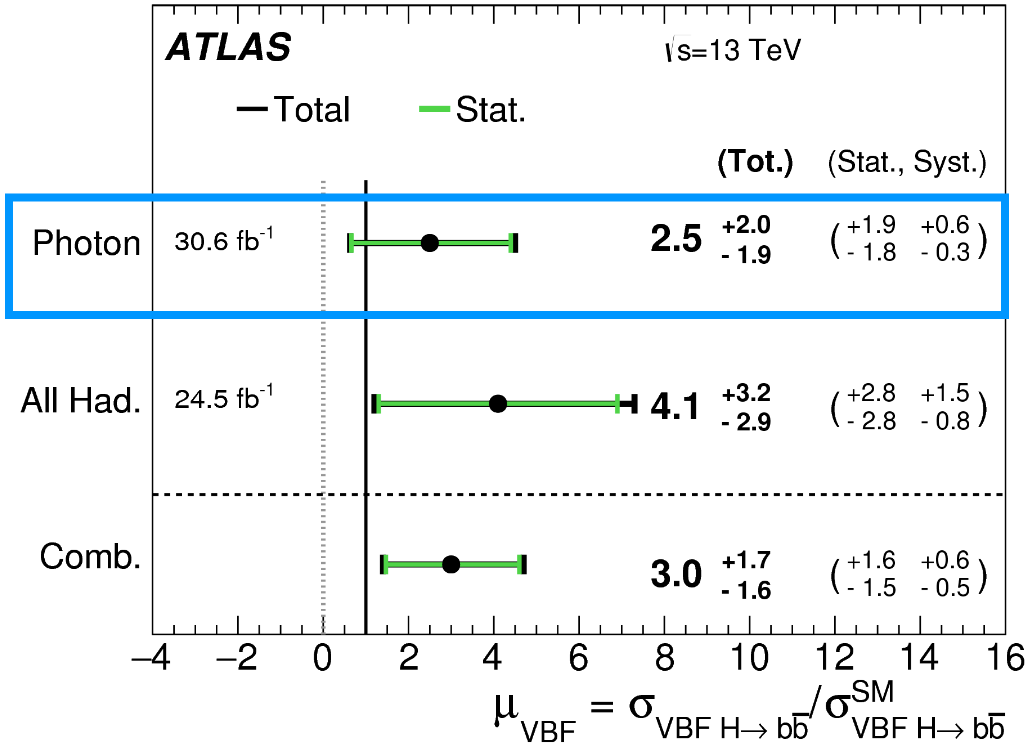
- Reminder: jets pair with the largest invariant mass are used for reco m_{jj} definition
- High jet pT selection up to 95 GeV for the inclusive selection and high $p_T^{bb}[p_T^H]$ 80-160 GeV
- High m_{jj} regions are preferred due to event topology and selections (trigger and offline)
  - VBF inclusive **4-central channel** have highest sensitivity ~700-800 GeV
  - VBF inclusive **2-central channel** have highest sensitivity ~1.5 TeV
  - VBF **photon channel** also have high sensitivity in high m_{jj} region ~1.5 TeV
- For systematic treatment, it is important to have 2j/3j migration in all m_{jj} bins in order to properly handle the extrapolation from truth and reco m_{jj} definition







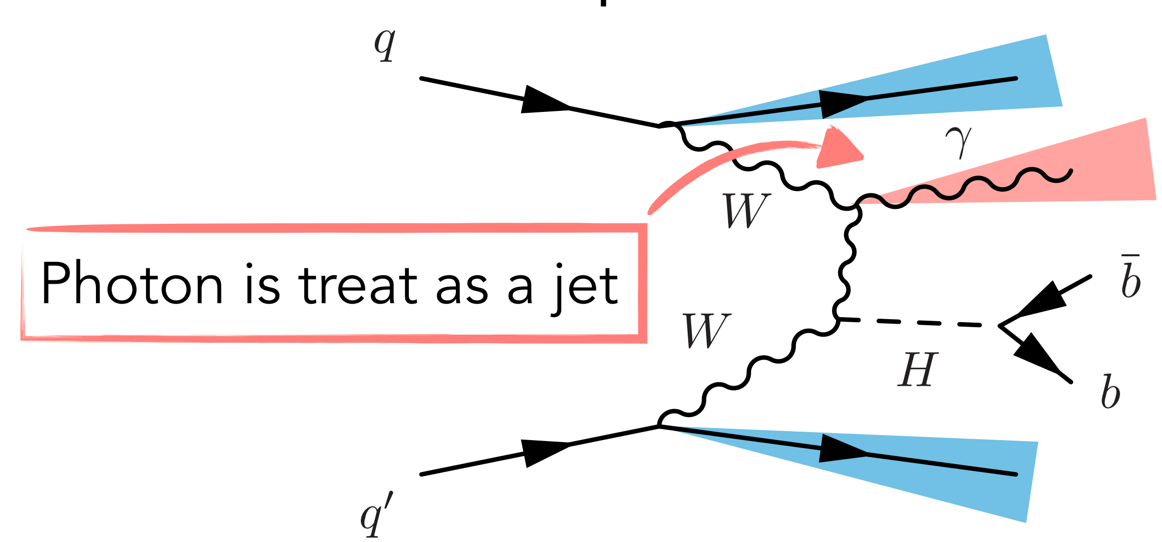
Photon treatment



Channel	*photon*		
Region	SR I	SR II	SR III
VBF	6.2 ± 0.1	5.5 ± 0.1	2.3 ± 0.1
ggF	0.5 ± 0.2	0.3 ± 0.1	0.8 ± 0.3
VH	<0.1	<0.1	<0.1
$t\bar{t}H$	<0.1	<0.1	0.4 ± 0.1

- From 5% to 30% ggF contribution wrt to the VBF inclusive with up to 60%

- Due to **addition photon** present in VBF+γ, STXS selection need to be update to have a proper photon selection
  - **47% of VBF in the 3j bin!**

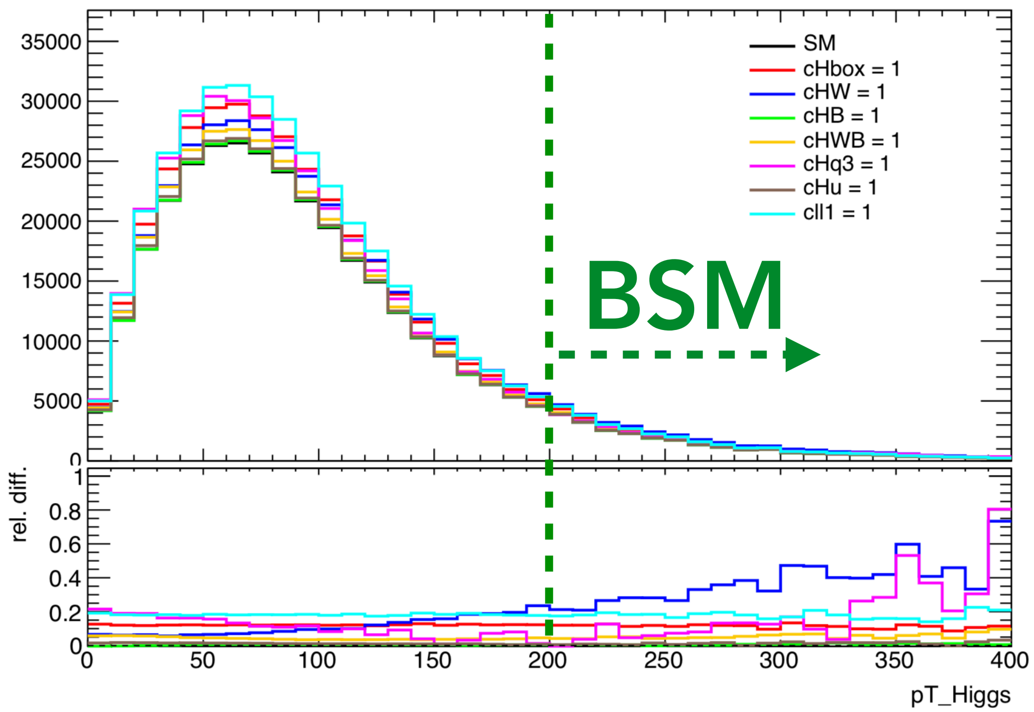


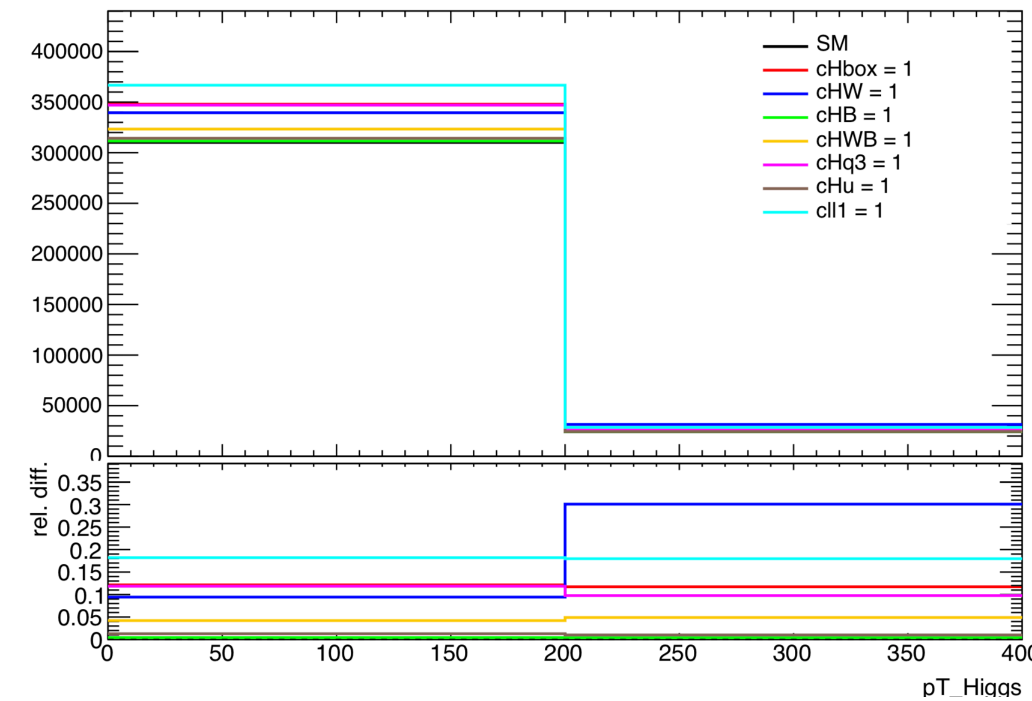
- Can the **VBF+γ** bring useful information in the STXS?
- Is the **VBF+γ** kinematic similar to **VBF?**
- What about bins and **systematic correlation**?
- Technically is feasible to have a **special jet definition**

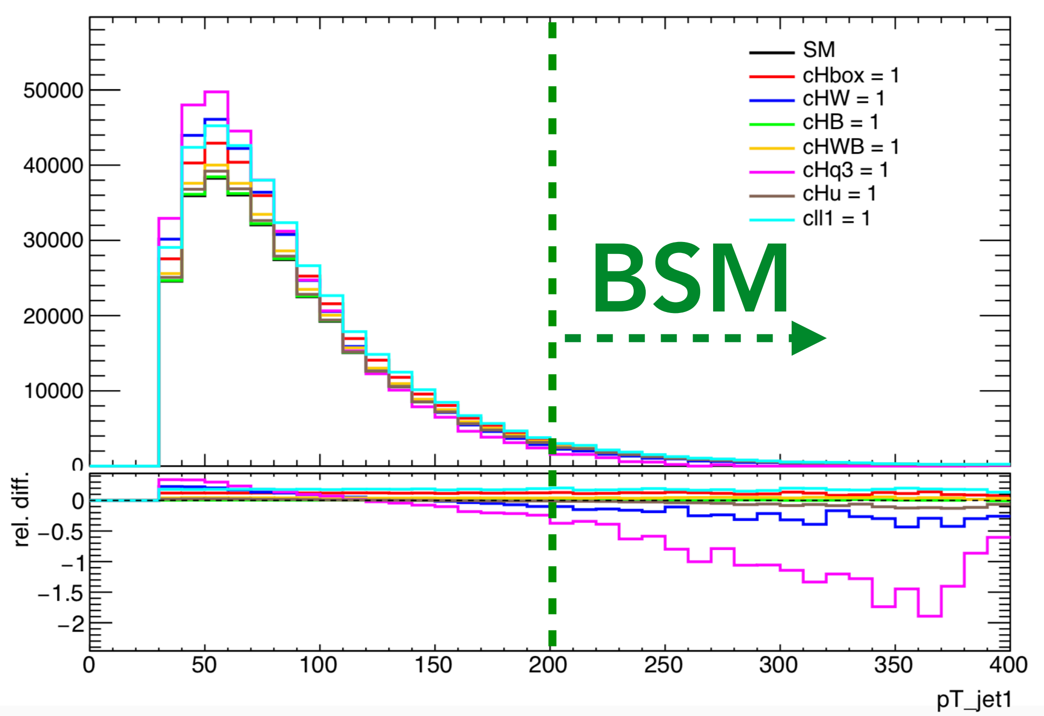
P_T^{j1} vs P_T^H

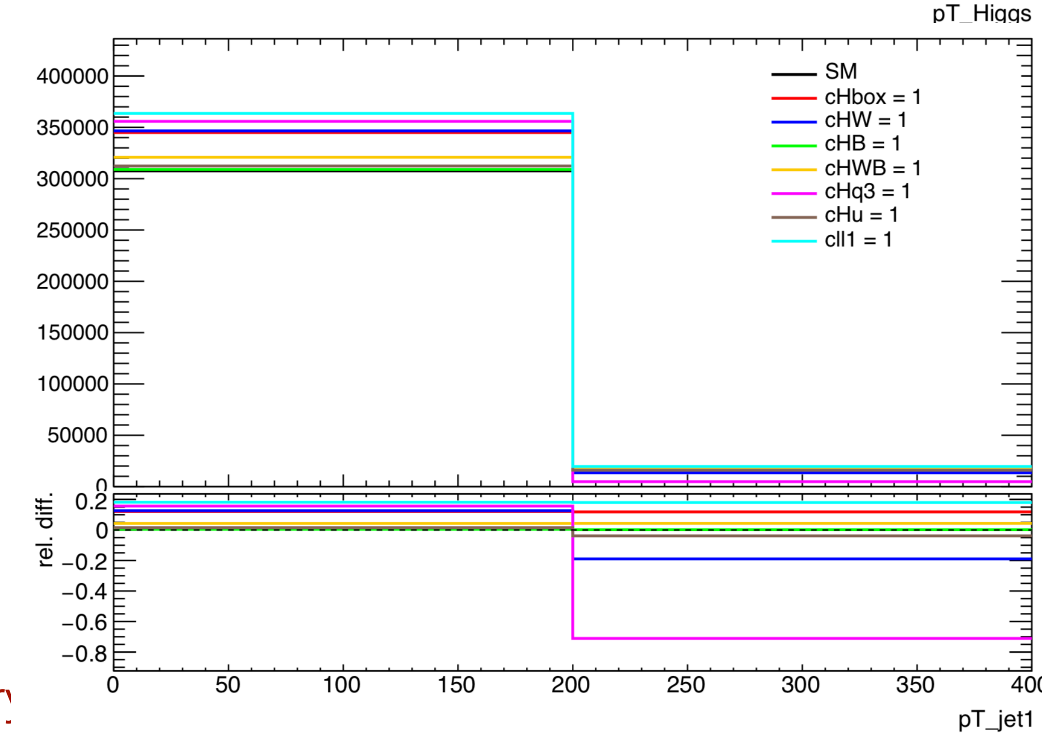
- For the BSM bin we want to know at which scale BSM effects start to kick-off
- It would be nice synchronise of VBF BSM bin with ggH(mainly for merging purpose)
- Generation of the pp->Hqq (VBF+VHhad) process at LO with MG5 with SMEFTsim, either in the SM or with additional EFT operators included

Courtesy of Saskia Falke and Ana Rosario Gomez (LAPP)



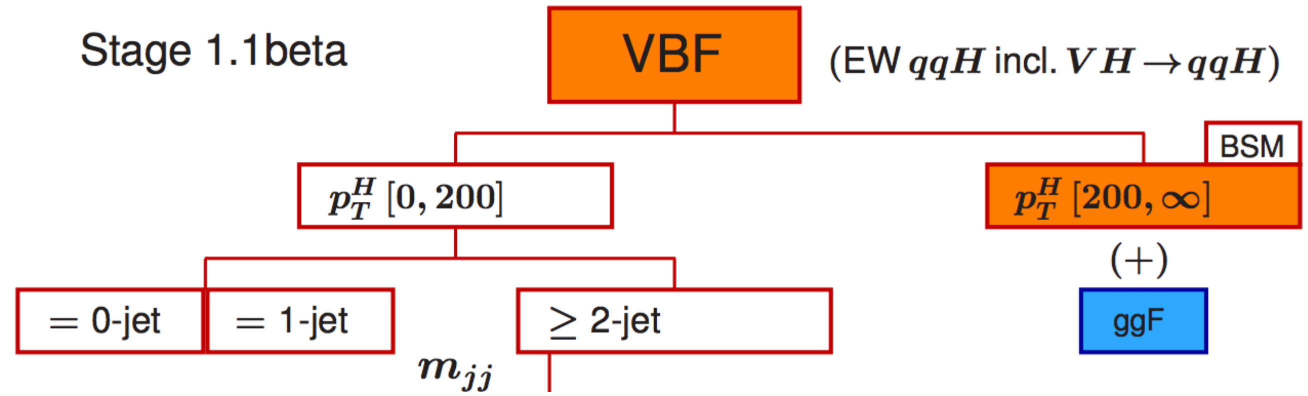


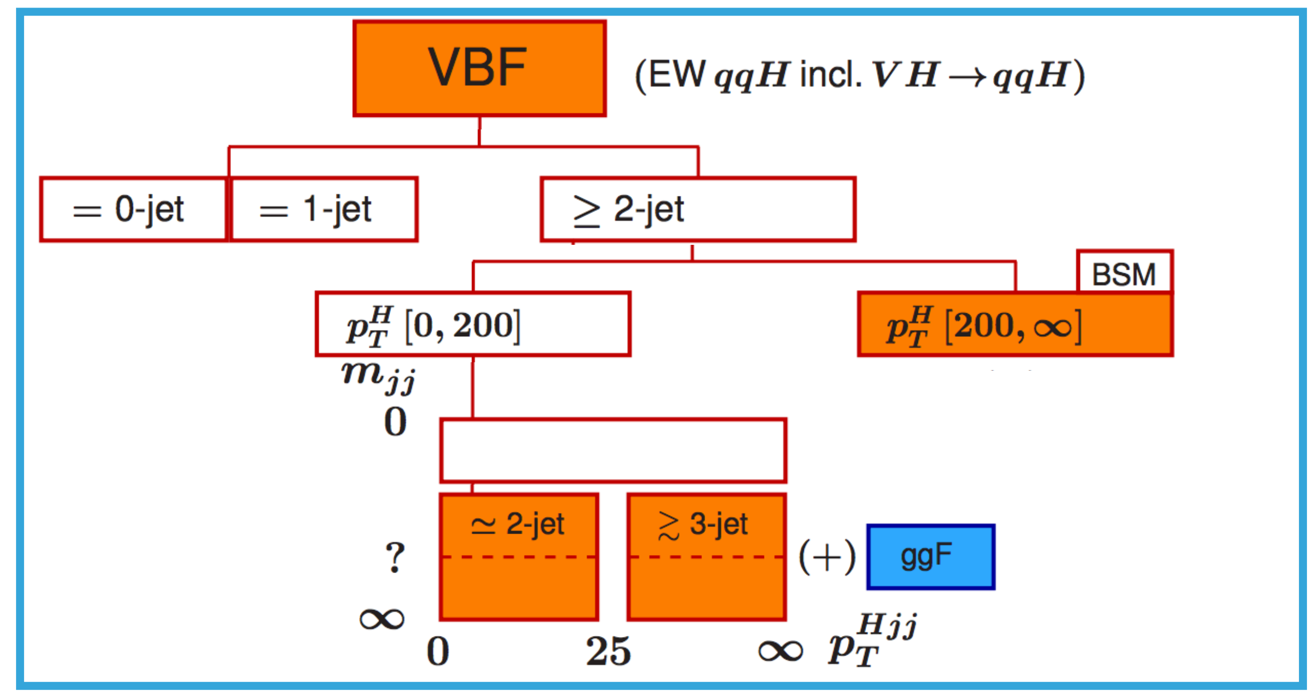


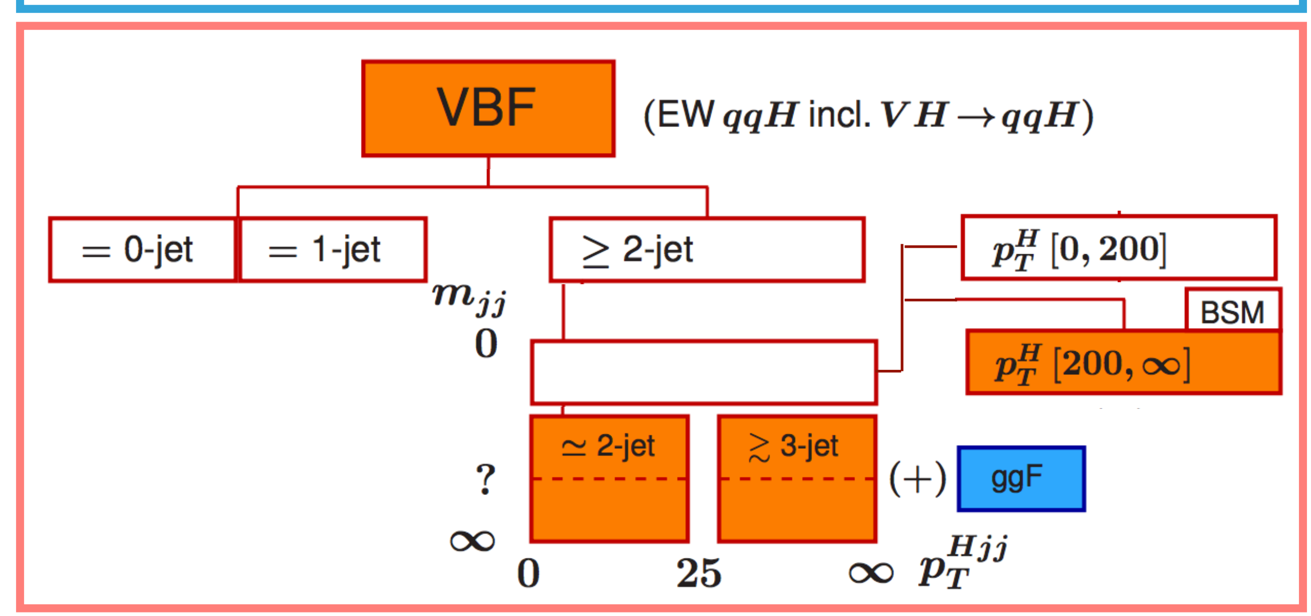


P_T^{j1} vs P_T^H

- No big differences between the two variables
  - Sensitivities depending on the EFT operators
  - Optimal cut could be different for the two variables
- Why we don't move this cut after N_{jets} or even m_{jj} split?
- Points to consider:
  - Some analyses have high p_T^H selection
    - $H \to bb$: $p_T^H >$ 80-160 GeV
    - $H \to \tau\tau$, hh: $p_T^H >$ 140 GeV, see
  - Most of the events will move in BSM bins
  - Possible splits in BSM bin to be considered
    - Allow to properly estimate the uncertainties in the reco SRs

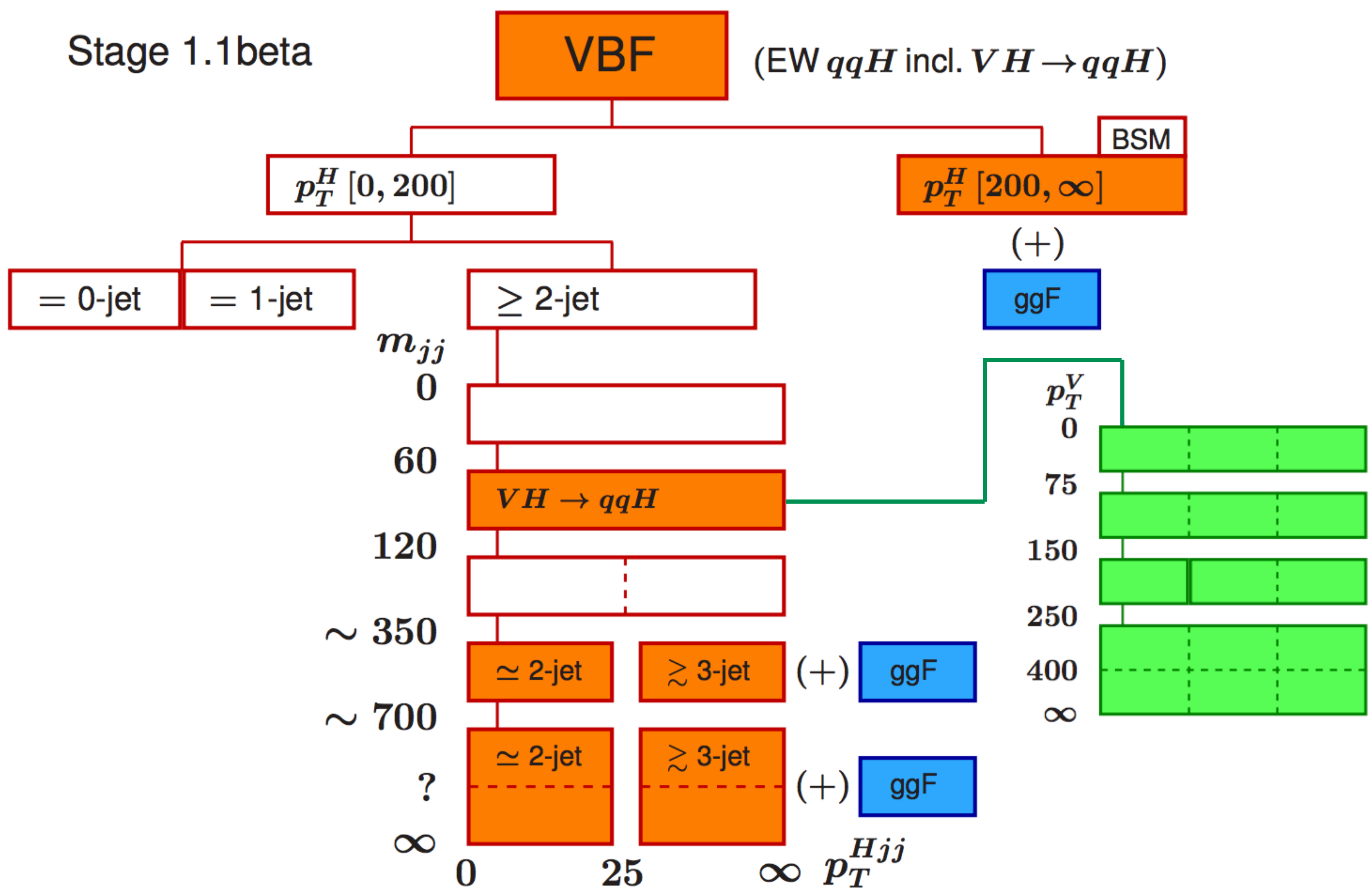






VH-hadronic

- VH(had) and VH(lep) require different measurements. VH(had) is close to VBF in terms of truth-level definition
- VBF/VH(had) separation looses sense at NLO, only qqH→qq defined
- However, we could add p_T^V bins to simplify the merging with VH(lep)



Summary

- All the analyses are happy to have a proper treatment of the REST categories
- More bins in Mjj will accommodate different decay modes
- p_T^{Hjj} bin in all the Mjj bins are encouraged to have a proper estimation of the systematic uncertainties
  - Merging procedure would be then decided based on the analysis sensitivity
- p_T^{j1} vs p_T^{H}: no strictly differences. Options:
  - Keep the current bin
  - Move to p_T^{H} and add p_T^{j1} in the Mjj bins
  - More p_T^{H} after N_{jets} or M_{jj} split
- VBF+γ is a promising channel to access the VBF H→bb.
  - Simple analysis, with very low ggF contamination. Expected around 1-1.5σ
  - An exception should be included in the STXS MC classification tool to allow a proper event categorisation
- VH-had bin could be split in p_T^{V} following VH-lep category

Backup

Jungle in Mjj selection

	Mjj	pTjj cut
$H\to\gamma\gamma$	BDT Loose BDT Tight	2j & 3j
$H\to ZZ^*$	M_{jj}>120 GeV +MVA	2j & 3j
$H\to WW^*$	MVA	2j
$H\to\tau\tau$	Inclusive: 400 GeV hh: (1550-250*$\Delta\eta_{jj}$) GeV ll: 800 GeV lh: 500	—
$H\to bb$	Incl.: MVA* VBF+γ: 800 GeV*	—

* M_{jj} doesn't use the two leading jets, but the combination with high M_{jj}

VBF Stage 1.X beta

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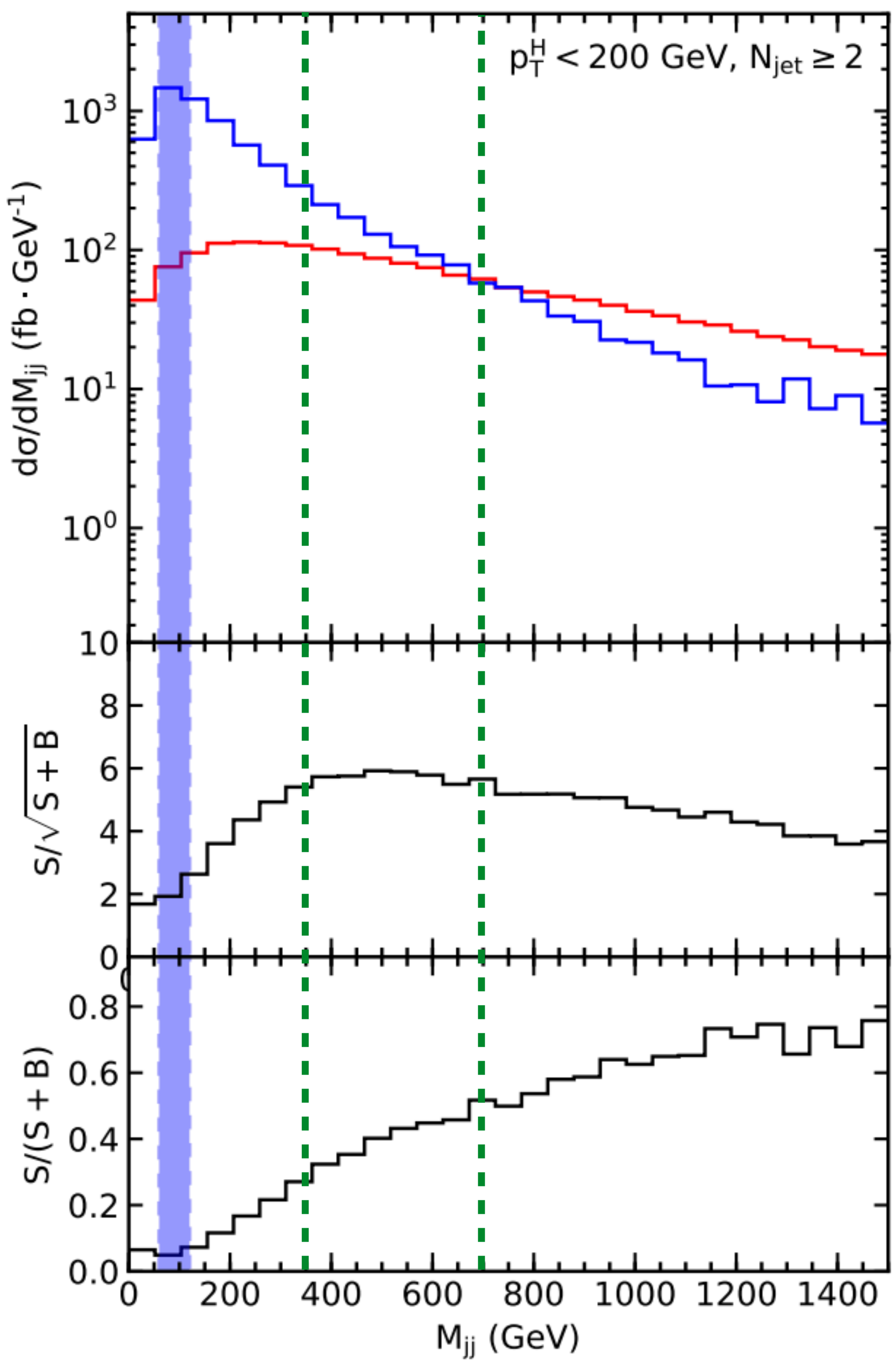
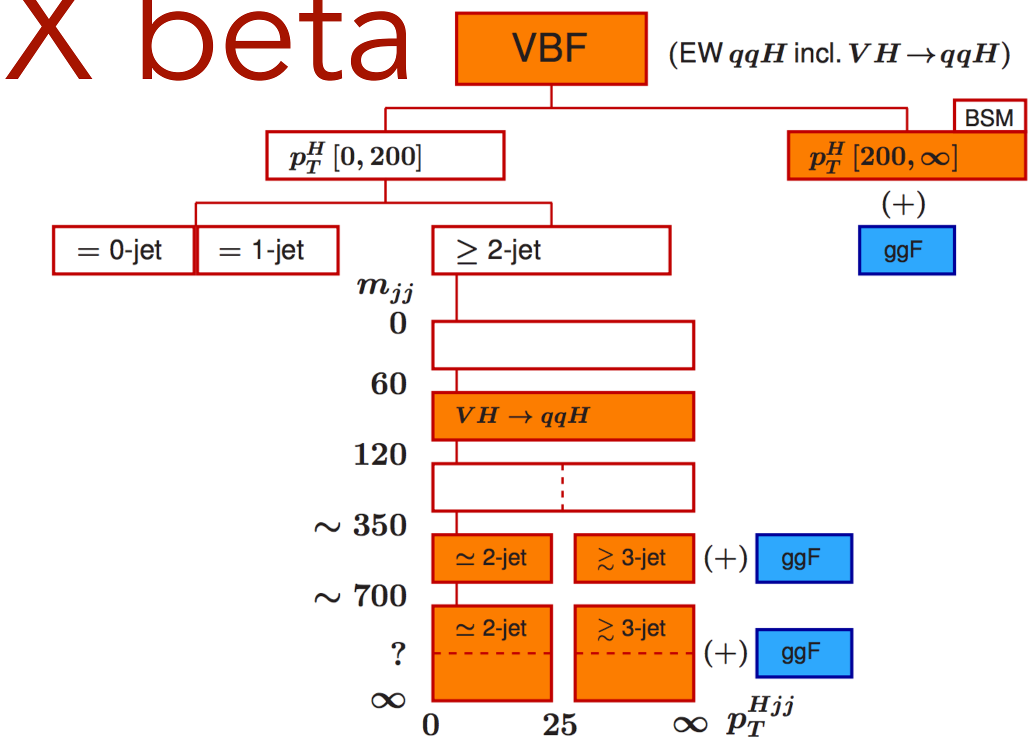
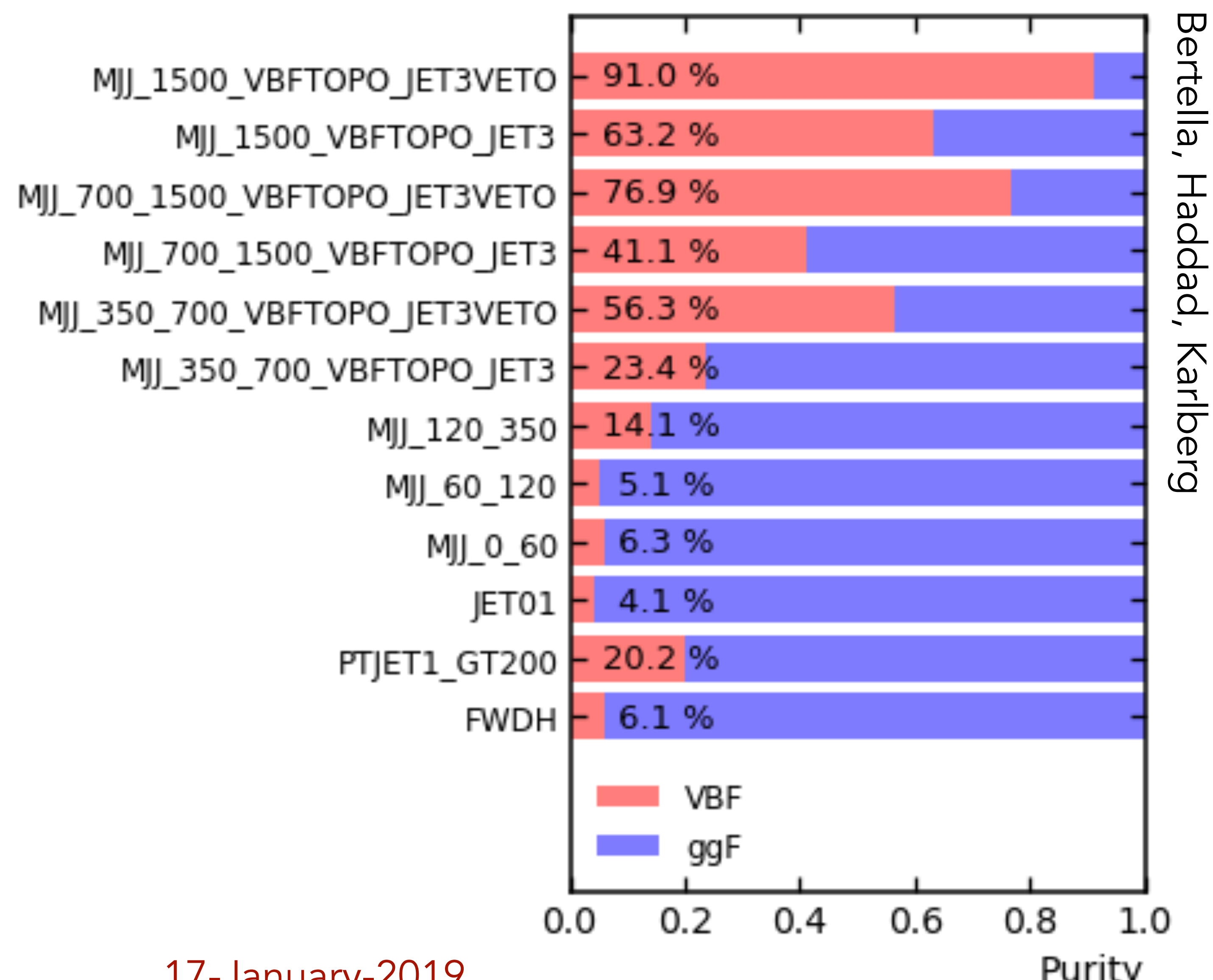
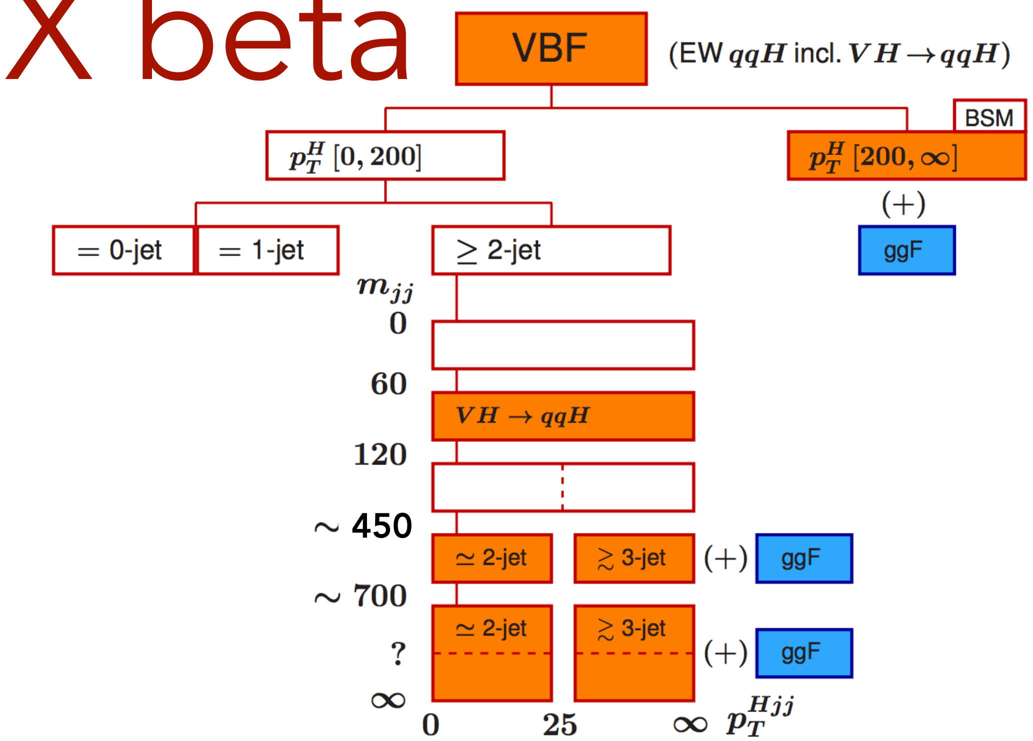






VBF Stage 1.X beta



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