HXSWG-VBF WG

VBF-STSX STAGE-1 UNCERTAINTY SCHEME

C. Bertella, A. Karlberg, Y. Haddad

10/12/2018

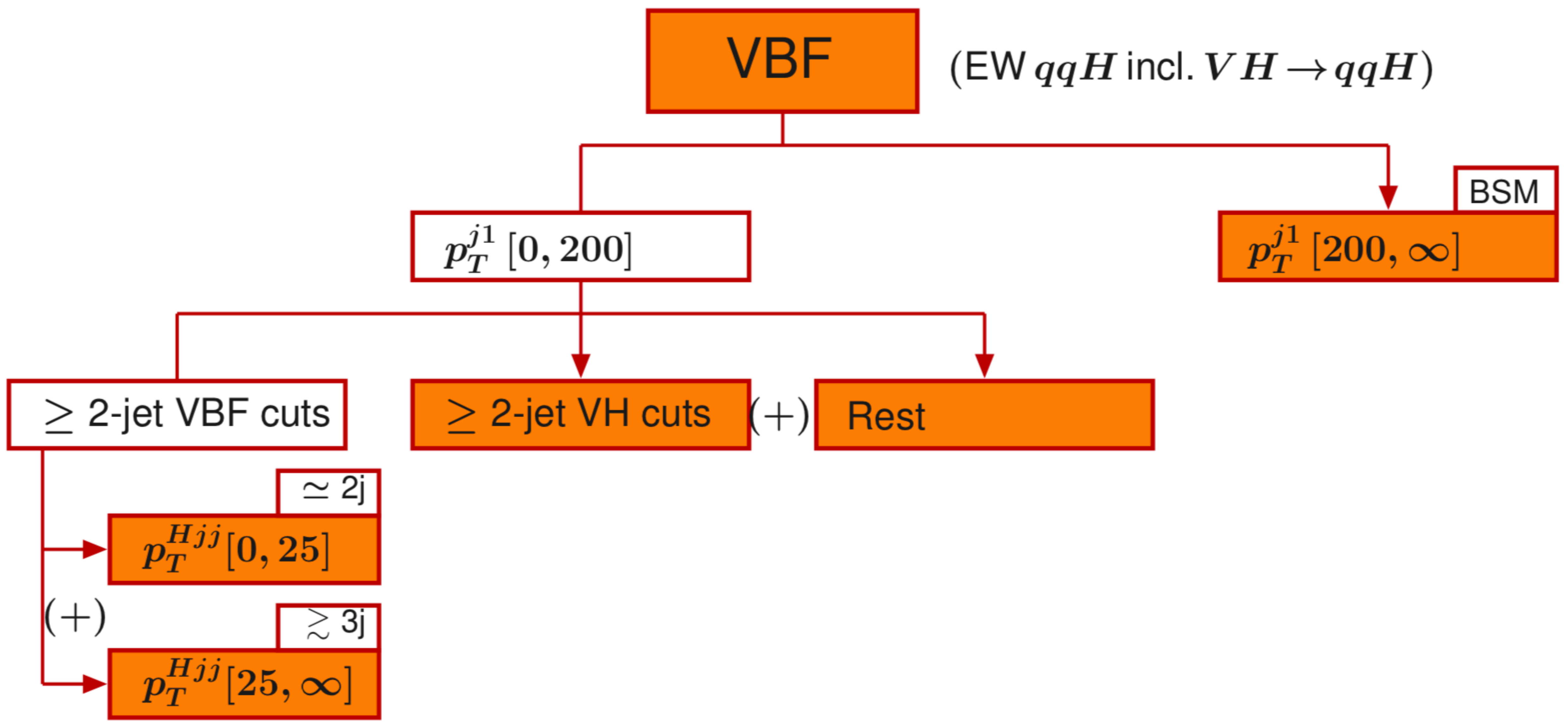
Northeastern University

OUTLOOK

- **Original STSX-VBF Stage 1 and its uncertainty scheme**
  - Limitation and possible improvements
- **A proposed STSX-VBF stage 1.1 and its uncertainty schemes**
  - Advantages and optimisation

INTRODUCTION

- 5 QCD-nuisances accounted:
  - 2 migration uncertainties Δ_{200} and Δ_{25}
    - Extracted using ST method
  - 3 Yield uncertainties for **VBF**, **VH** and **REST** bins
    - Rest includes all the events (including <2 jets events) failing to enter other bins
    - Uncertainties extracted using POWHEG and compared to FO Scale variations on these bins
- We only focus QCD uncertainties
  - EW uncertainties are ignored for the time being until further inputs from experts



	QCD uncertainties					EW uncertainties	
	Δ^{y}_{VBF}	Δ^{y}_{Rest}	Δ^{y}_{VH}	Δ_{200}	Δ_{25}	Δ_{Sud}	Δ_{hard}
p_T^{j1} [0,200]	≈ 1	≈ 1	≈ 1	-1		y	y
≥ 2-jet VBF cuts	≈ 1	≈ 0	≈ 0	$-x_1$	0	$x_1 y$	$x_1 y$
p_T^{Hjj} [0, 25]	$(\approx 1)z$	…	…	$-x_1 z$	+1	…	…
p_T^{Hjj} [25, ∞]	$(\approx 1)(1-z)$	…	…	$-x_1(1-z)$	−1	…	…
≥ 2-jet VH cuts	≈ 0	≈ 0	≈ 1	$-x_2$		$x_2 y$	$x_2 y$
Rest	≈ 0	≈ 1	≈ 0	$-x_3$		$x_3 y$	$x_3 y$
p_T^{j1} [200, ∞]	≈ 0	≈ 0	≈ 0	$+1$		$1-y$	$1-y$

UNCERTAINTY SOURCE PROPAGATION

- Original proposal: the x's are the fraction of the Δ distributed across STSX bins
  - Can lead to over estimated uncertainty
- **Solution**: use acceptances in each STSX bin instead
  - Example : z = $(\Delta_{25}/\Delta_{VBF}) \rightarrow z \approx (\sigma_{25}/\sigma_{VBF})$

Nuisance	Δ^y_{VBF}	Δ^y_{Rest}	Δ^y_{VH}	Δ_{200}	Δ_{25}
$p_T^{j_1}[0,200]$	≈ 1	≈ 1	≈ 1	-1	—
$\geq 2-jetVBFcuts$	≈ 1	≈ 0	≈ 0	$-x_1$	0
$p_T^{Hjj}[0,25]$	$(\approx 1)z$	—	—	$-x_1 z$	$+1$
$p_T^{Hjj}[25,\infty]$	$(\approx 1)(1-z)$	—	—	$-x_1(1-z)$	-1
$\geq 2-jetVHcuts$	≈ 0	≈ 0	≈ 1	$-x_2$	—
$Rest$	≈ 0	≈ 1	≈ 0	$-x_3$	—
$p_T^{j_1}[200,\infty]$	≈ 0	≈ 0	≈ 0	$+1$	—

Need to extract the x's → fraction of the Δ in every STXS bin

→

replace by STSX bin acceptance

$$x_1 = \frac{\Delta_{\text{VBF}}}{\Delta_{200}} \approx \frac{\sigma_{\text{VBF}}}{\sigma_{[0,200]}}$$

$$x_2 = \frac{\Delta_{\text{VH}}}{\Delta_{200}} \approx \frac{\sigma_{\text{VH}}}{\sigma_{[0,200]}}$$

$$x_3 = \frac{\Delta_{\text{Rest}}}{\Delta_{200}} \approx \frac{\sigma_{\text{Rest}}}{\sigma_{[0,200]}}$$

$$z = \frac{\Delta_{[0,25]}}{\Delta_{\text{VBF}}} \approx \frac{\sigma_{[0,25]}}{\sigma_{\text{VBF}}}$$

Example : $$\text{uncert}\left(\sigma_{p_T^{Hjj}\in[0,25]}\right) = z\cdot\Delta^y_{\text{VBF}} \oplus (-x_1 z)\cdot\Delta_{200}\oplus\Delta_{25}$$

$$= \left(\frac{\sigma_{p_T^{Hjj}\in[0,25]}}{\sigma_{VBF}}\right)\cdot\Delta^y_{\text{VBF}} \oplus \left(\frac{\sigma_{VBF}}{\sigma_{[0,200]}}\right)\cdot\left(\frac{\sigma_{p_T^{Hjj}\in[0,25]}}{\sigma_{VBF}}\right)\cdot\Delta_{200}\oplus\Delta_{25}$$

ESTIMATING THE Δ: QCD SCALE VARIATIONS

- **Extracted using QCD variations of the renormalisation and factorisation scales μ_r , μ_f from POWHEG + PYTHIA 8**
  - Dynamic POWHEG scale choice [2]
  - Keeping only variations with $1/2 \leq \mu_r , \mu_f \leq 2$, $1/2 \leq \mu_r/\mu_f \leq 2$
  - Take uncertainty envelope
- **Uncertainty propagation based on Stewart-Tackmann method [1] :**

$$C(\{\sigma_0, \sigma_{\geq 1}\}) = \begin{pmatrix} (\Delta_0^{\mathrm{y}})^2 & \Delta_0^{\mathrm{y}}\,\Delta_{\geq 1}^{\mathrm{y}} \\ \Delta_0^{\mathrm{y}}\,\Delta_{\geq 1}^{\mathrm{y}} & (\Delta_{\geq 1}^{\mathrm{y}})^2 \end{pmatrix} + \begin{pmatrix} \Delta_{\mathrm{cut}}^2 & -\Delta_{\mathrm{cut}}^2 \\ -\Delta_{\mathrm{cut}}^2 & \Delta_{\mathrm{cut}}^2 \end{pmatrix}.$$

- **Jet definition :**
  - Higgs decay products are ignored
  - Jets built using anti-kt R = 0.4 from all stable particles
  - Only jet with pT > 30 GeV and $|\eta| < 4.5$.

[1] - https://arxiv.org/pdf/1107.2117.pdf
[2] - axriv: 1506.02660

SCHEME-0: TREAT Δ_{VH}, Δ_{REST} AND Δ_{VBF} AS UNCORRELATED

- **2 migration uncertainties Δ_{200} and Δ_{25}**
  - Extracted using ST method
- **3 Yield uncertainties for VBF, VH and REST bins**
  - Treated as uncorrelated uncertainties
  - **Subtract the contribution from Δ_{200}**
  - Extracted using QCD Scale variations from POWHEG + Pythia8

	Δ^y_{VBF}	Δ^y_{Rest}	Δ^y_{VH}	Δ_{200}	Δ_{25}
$p_T^{j_1}[0,200]$	≈ 1	≈ 1	≈ 1	-1	—
$\geq 2-jet$ VBF cuts	≈ 1	≈ 0	≈ 0	$-x_1$	0
$p_T^{Hjj}[0,25]$	$(\approx 1)z$	—	—	$-x_1 z$	$+1$
$p_T^{Hjj}[25,\infty]$	$(\approx 1)(1-z)$	—	—	$-x_1(1-z)$	-1
$\geq 2-jet$ VH cuts	≈ 0	≈ 0	≈ 1	$-x_2$	—
Rest	≈ 0	≈ 1	≈ 0	$-x_3$	—
$p_T^{j_1}[200,\infty]$	≈ 0	≈ 0	≈ 0	$+1$	—

$$\Delta_{200} = \sigma_{[200,\infty]} \times \delta_{[200,\infty]}$$

$$\Delta^y_{\mathrm{VBF}} = \sigma_{VBF} \times \left(\delta^2_{VBF} - \delta^2_{[200,\infty]}\right)^{1/2}$$

$$\Delta^y_{\mathrm{VH}} = \sigma_{VH} \times \left(\delta^2_{VH} - \delta^2_{[200,\infty]}\right)^{1/2}$$

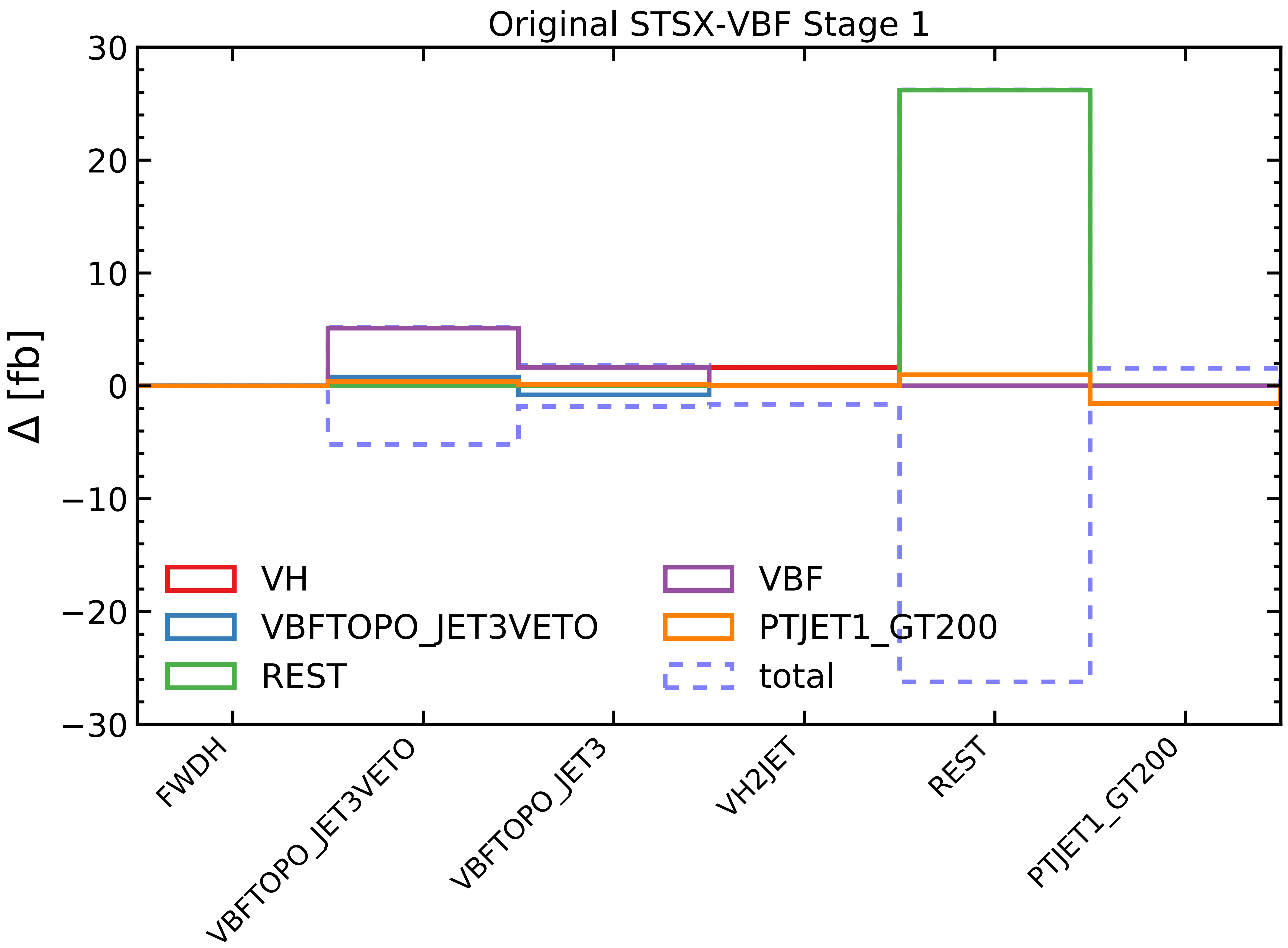
$$\Delta^y_{\mathrm{Rest}} = \sigma_{Rest} \times \left(\delta^2_{Rest} - \delta^2_{[200,\infty]}\right)^{1/2}$$

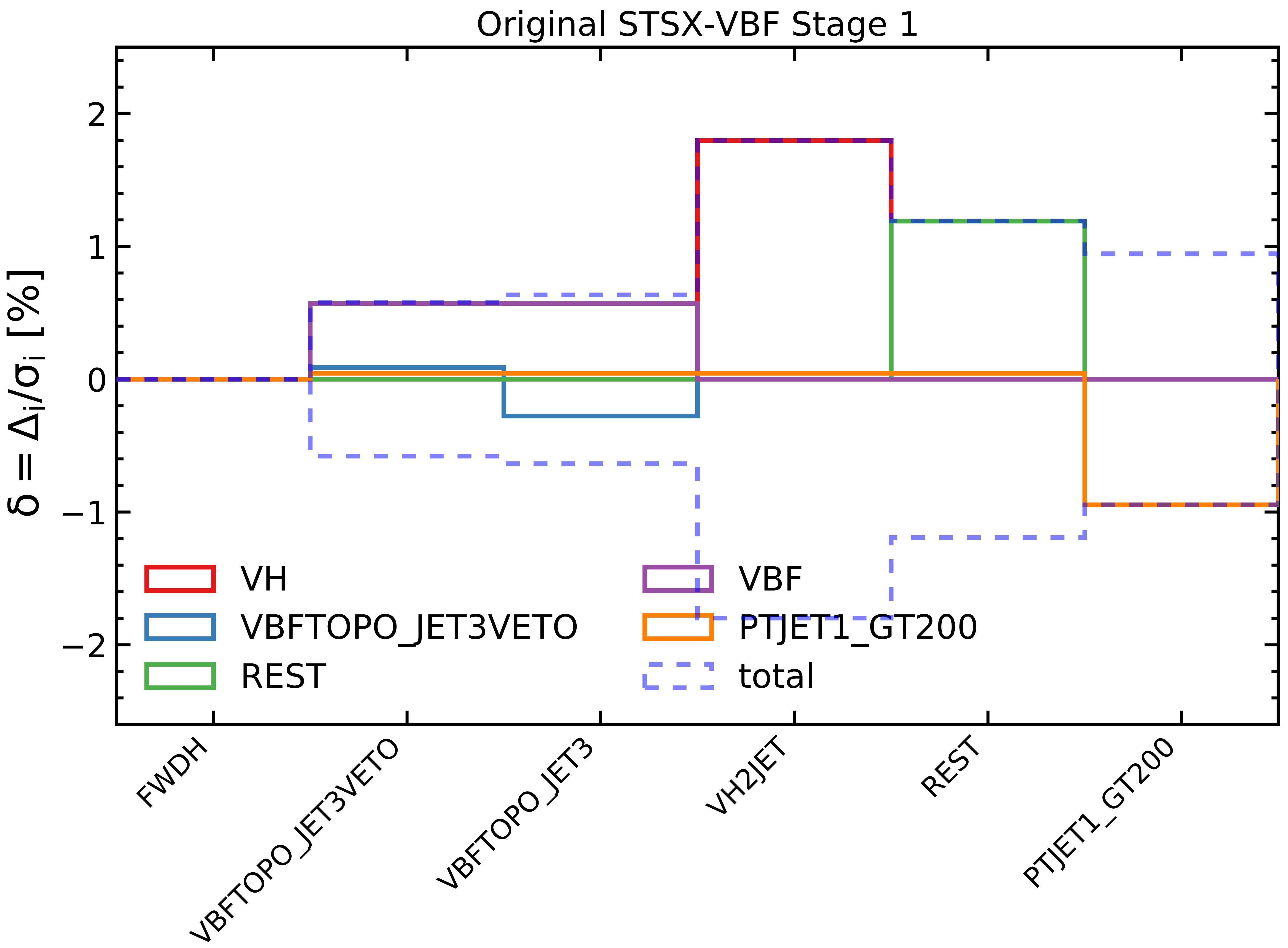
- If undefined uncertainty (aka: $\delta_{VBF} < \delta_{[200,\infty]}$)
  - → Replace with:

$$\Delta^y_{\mathrm{VBF}} = \sigma_{\mathrm{VBF}} \times \rho \cdot \delta_{\mathrm{VBF}}$$

- ρ value of 1/2 is assumed for the remaining talk

THEORY UNCERTAINTY SOURCE





- The overall uncertainty are at a reasonable level, below ~2%
- Δ_{200} and Δ_{25} are anti-correlated for bins above/below as expected
- The contribution of Δ_{25} cancels out if the bins JET3 and JET3VETO are merged

SCHEME-0 UNCERTAINTY: VALUES IN DETAIL

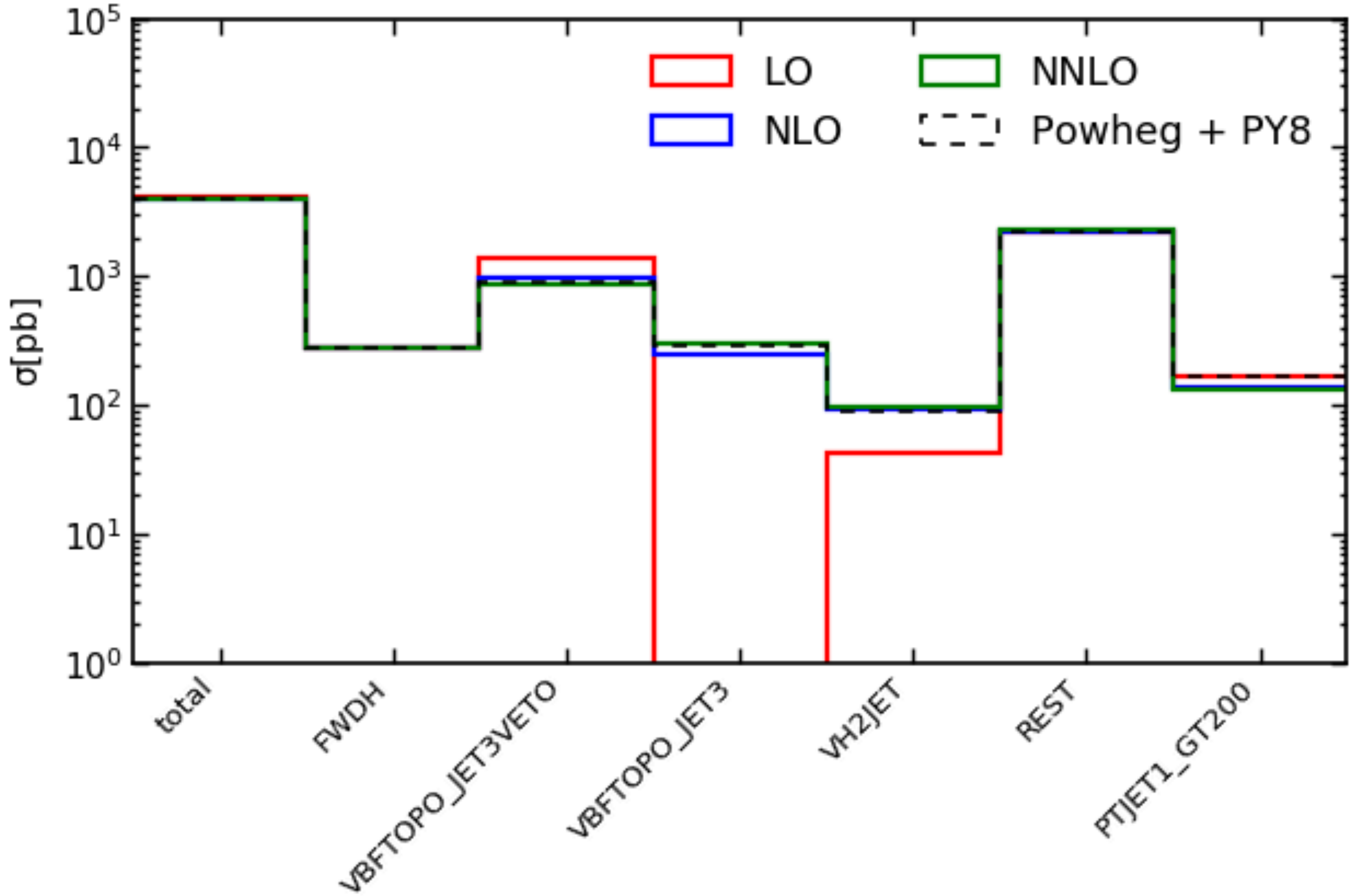
	XS [fb]	VH_Yield[fb]	VBF_Yield[fb]	REST_Yield[fb]	DELTA_25[fb]	PTJET1_GT200[fb]	Total[fb]
FWDH	273.952	0	0	0	0	0	0
VBFTOPO_JET3VETO	896.93	0	5.113	0	0.795	0.403	5.19
VBFTOPO_JET3	286.855	0	1.635	0	−0.795	0.129	1.823
VH2JET	90.542	1.628	0	0	0	0.041	1.628
REST	2200.219	0	0	26.206	0	0.989	26.225
PTJET1_GT200	165.206	0	0	0	0	−1.562	1.562

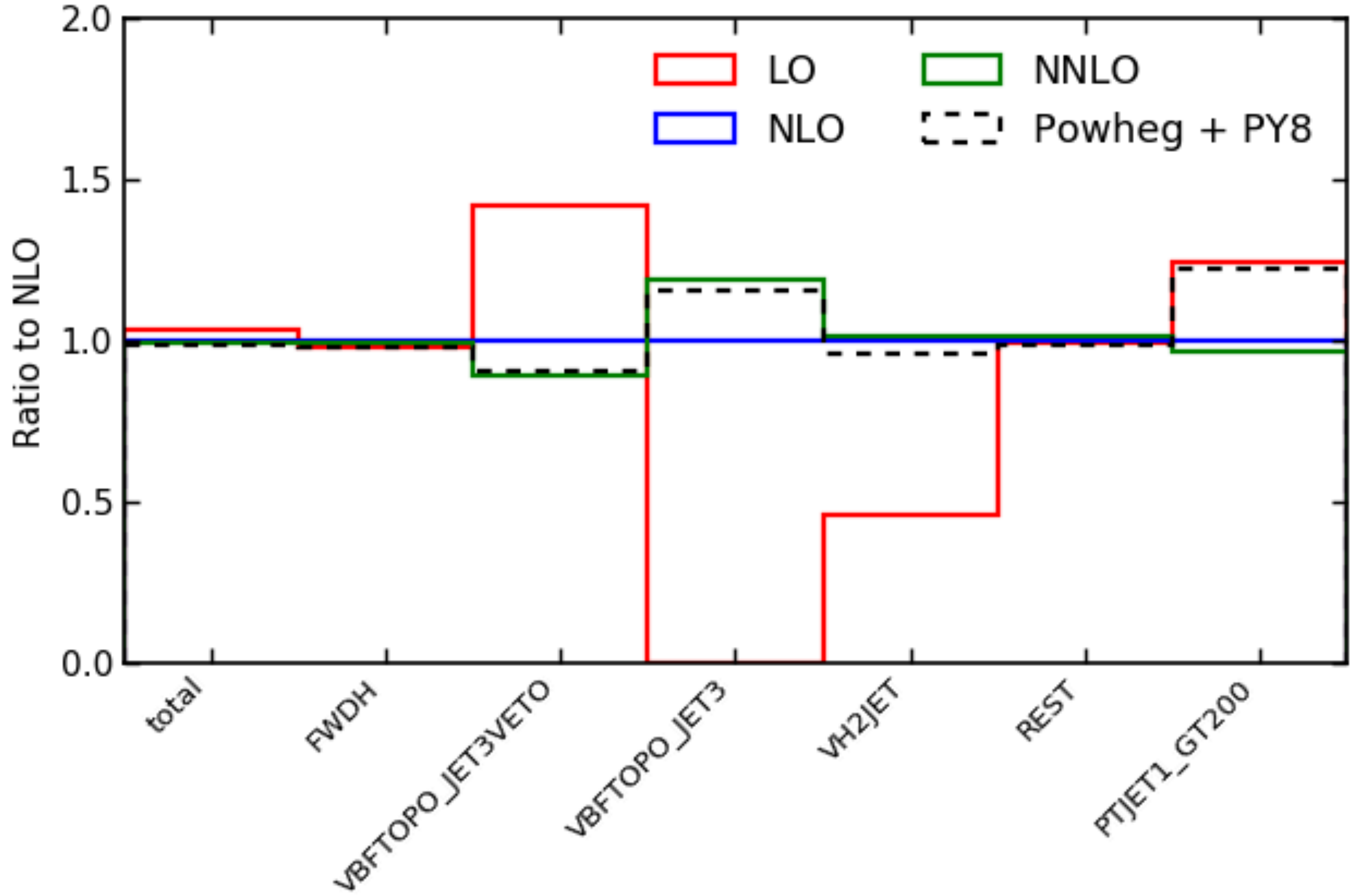
yield uncertainty

anti-correlated migration uncertainty

$\Delta/\sigma_{\text{bin}}$	XS [fb]	VH_Yield[%]	VBF_Yield[%]	REST_Yield[%]	DELTA_25[%]	PTJET1_GT200[%]	Total[%]
FWDH	273.952	0	0	0	0	0	0
VBFTOPO_JET3VETO	896.93	0	0.57	0	0.089	0.045	0.579
VBFTOPO_JET3	286.855	0	0.57	0	−0.277	0.045	0.635
VH2JET	90.542	1.798	0	0	0	0.045	1.798
REST	2200.219	0	0	1.191	0	0.045	1.192
PTJET1_GT200	165.206	0	0	0	0	−0.946	0.946

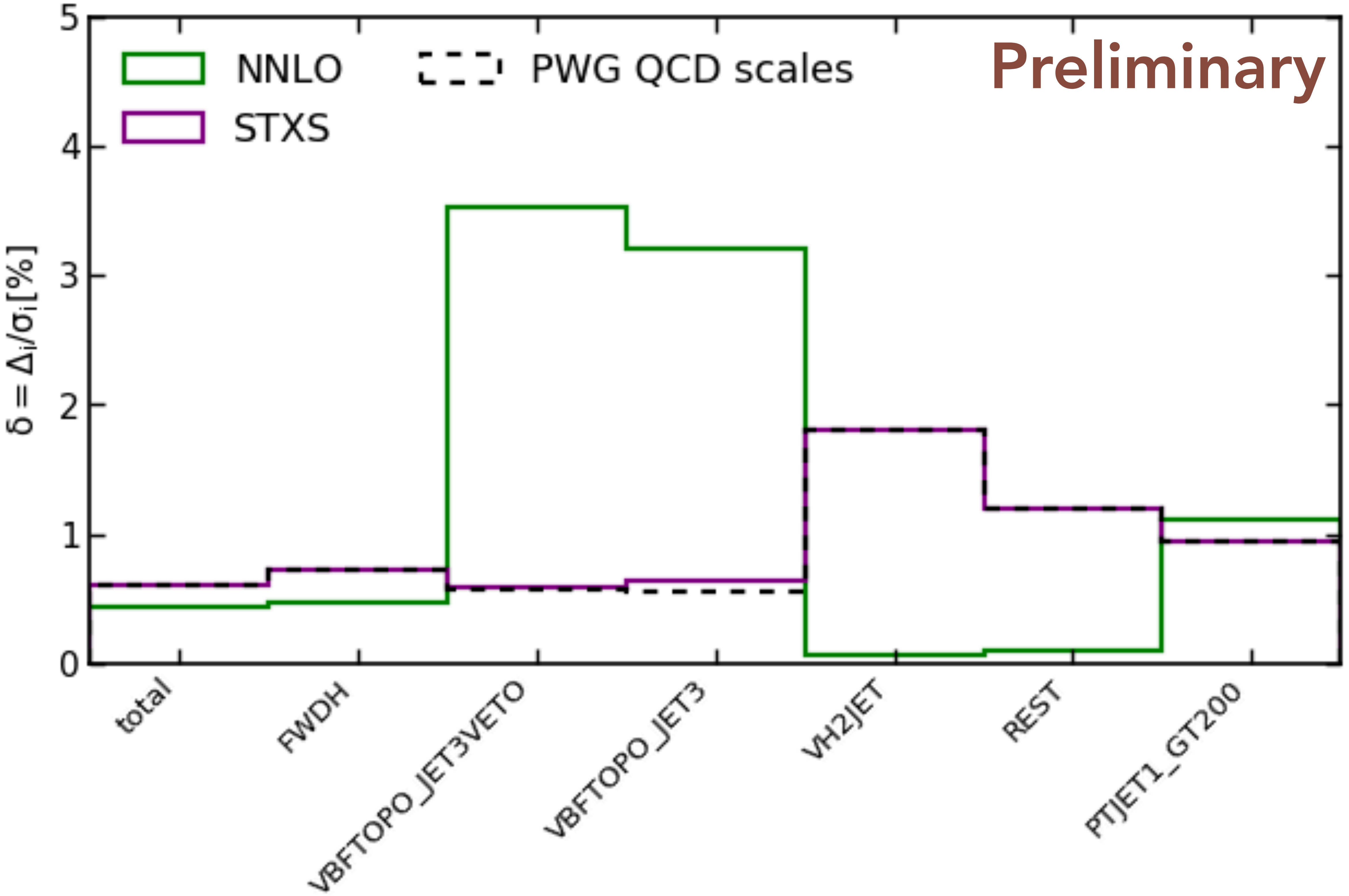
COMPARE WITH FIXED ORDER CALCULATIONS

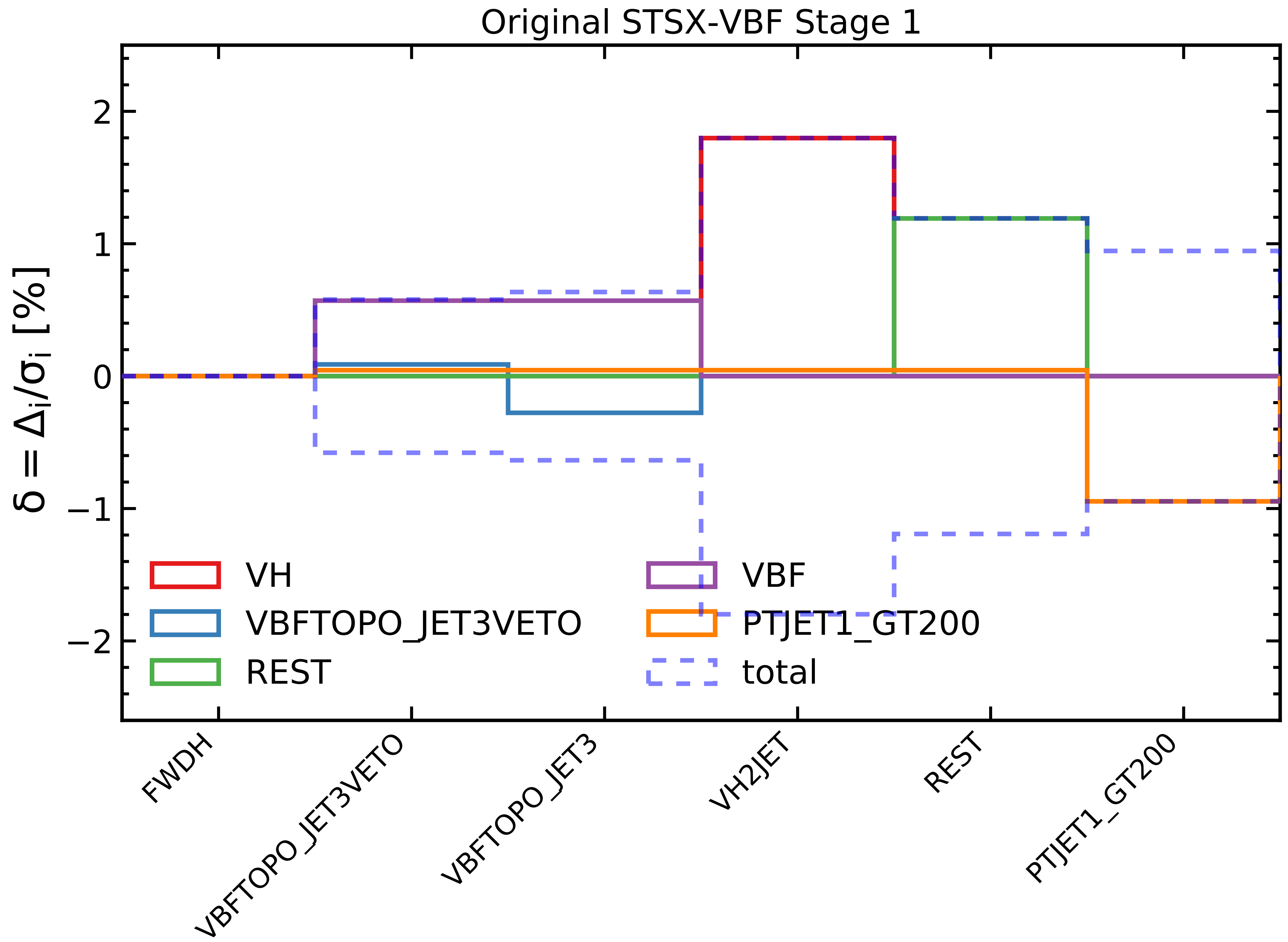




- Fixed order calculation explored using proVBFH (NNLO-QCD)
  - M_W varied by a factor two up and down
  - EW parameters from the PDG with m_h=125
- The XS estimates are consistent with POWHEG predictions

COMPARE WITH FIXED ORDER CALCULATIONS

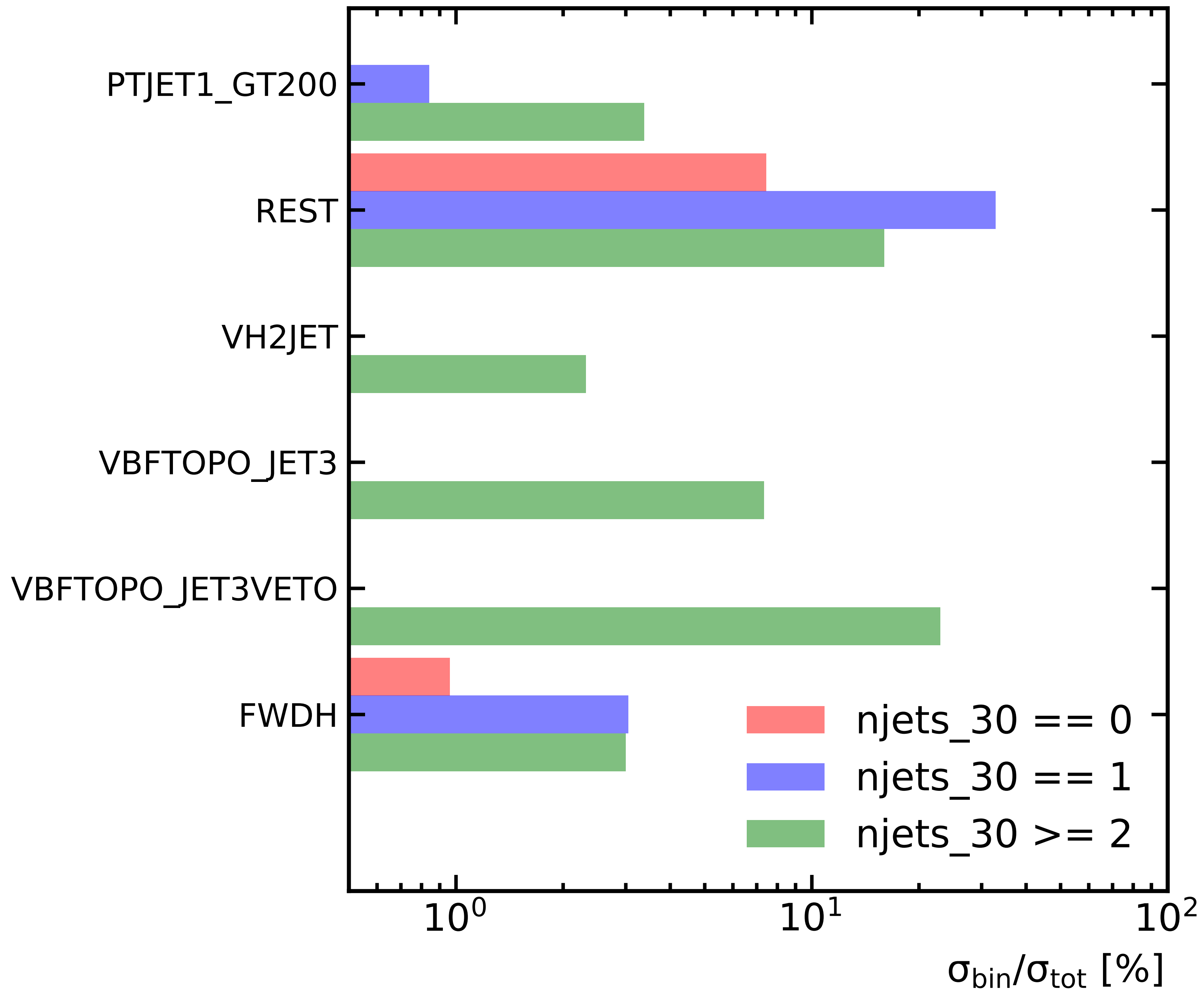


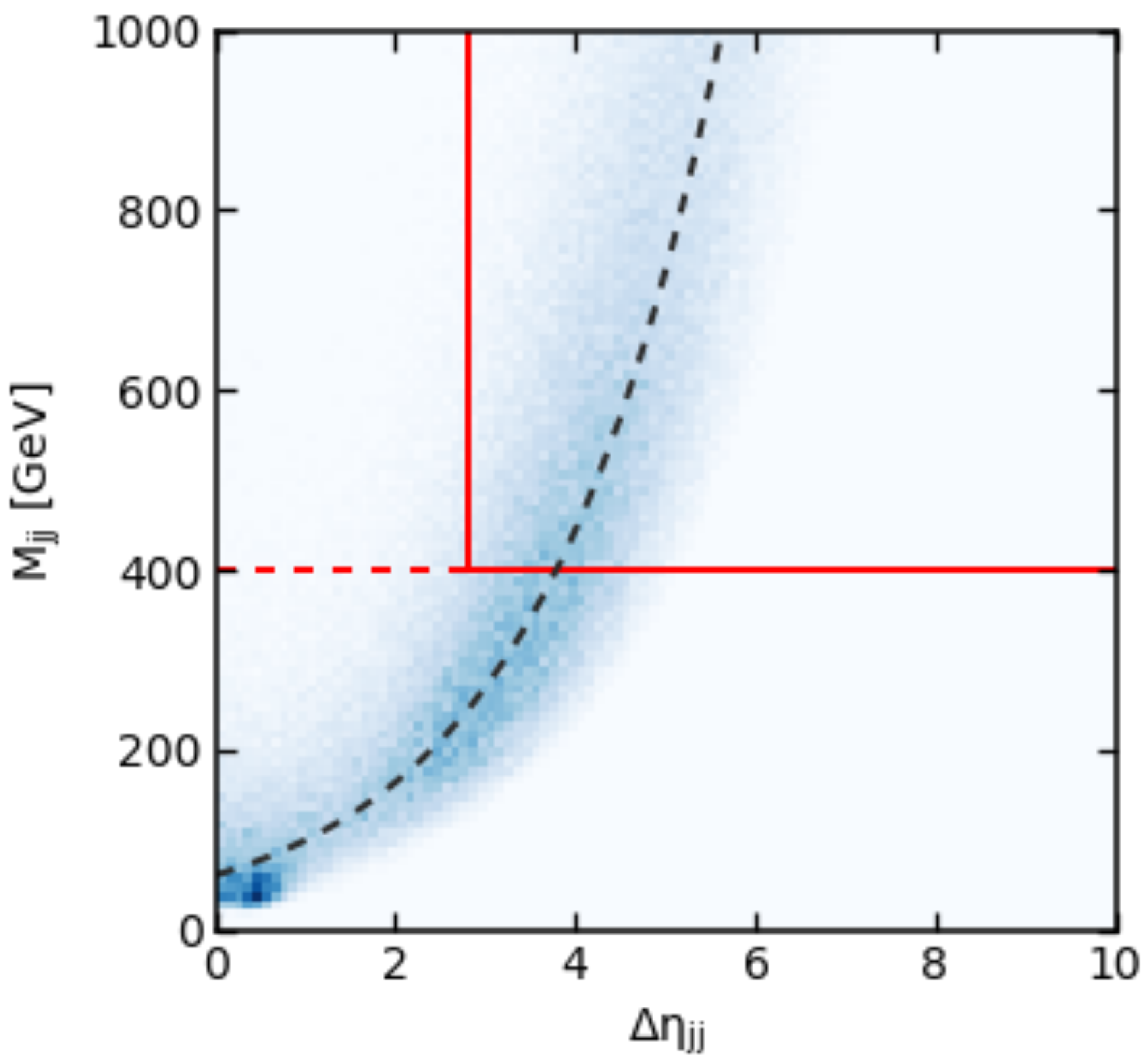


- **Fixed order estimate indicate that POWHEG underestimate the uncertainty in the 2-3 Jet bins**
  - The 3rd jet is generated in POWHEG at LO and from PS
  - Hence the POWHEG QCD scale uncertainties in the VBFTOPO bins are not reliable
  - FO estimation will be used in the future to estimate the uncertainties in the STSX-VBF bins

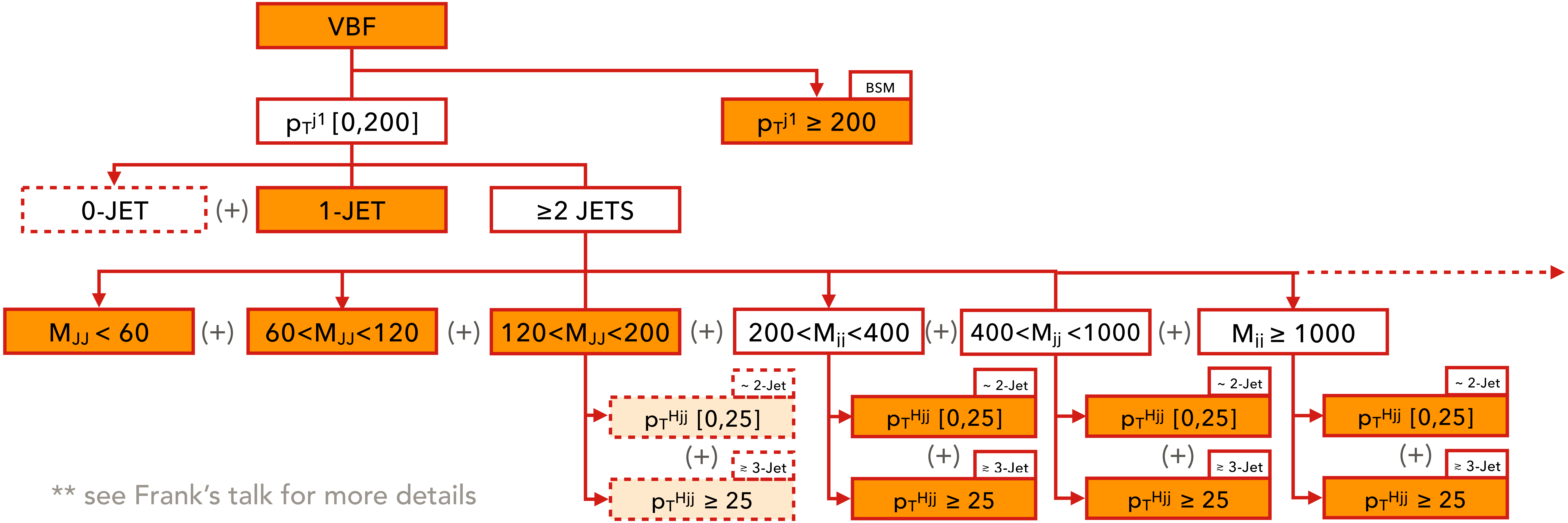
ORIGNAL PROPOSAL LIMITATIONS

- **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 and results hard to interpret**
  - $0 < mjj < 60$ GeV and $120 < mjj < 400$ GeV, $N_j < 2$ jets events and $\Delta\eta_{jj} < 2.8$ & mjj>400 GeV
- We could benefit by adding a 0 and 1-jet category
- Δy_{jj} could be ignored and use only $M_{jj} > 400$ GeV to covers the VBF phase-space
  - Use the same approach as GGF and VH to propagate uncut on the Mjj spectrum
  - This might affect the electroweak corrections on VBF
  - This cut recommend by theory (Terrasse, Rauch and al, 1802.09955)





NEW STSX-VBF STAGE 1



- The event with a jet failing the p_T threshold requirements will be in 0-1 Jet bin
- REST bin will be replaced by Mjj < 60 GeV bin
- **Replace P_T^j by p_T^H to define BSM-sensitive bin** (will be updated in the future)
- More granular binning in M_{jj} is introduced but with merging scheme

NEW STSX-VBF STAGE 1: MIGRATION UNCERTAINTIES

- Total yield uncertainty taken from YR4 the δ_{tot} ~ 0.38 [%]
- Same treatment for Δ_{200} and Δ_{25} as before + remove contribution from Δ_{tot}
- Compute the Δ using yields in the inclusive M_{jj} bins
- The effect of each migration Δ is anti-correlated for bins above/below (same as for VH)

	tot	PTJ1_200	Mjj60	Mjj120	….
PTJET1_GT200	$\sigma_{>200}/\sigma_{tot}$	1	0	0	
JET01	σ_{01}/σ_{tot}	$-\ \sigma_{01}/\sigma_{>200}$	0	0	
MJJ_0_60	$\sigma_{mjj>0}/\sigma_{tot}$	$-\ \sigma_{mjj>0}/\sigma_{>200}$	−1	0	
MJJ_60_120	$\sigma_{mjj>60}/\sigma_{tot}$	$-\ \sigma_{mjj>60}/\sigma_{>200}$	$\sigma_{mjj>120}/\sigma_{mjj>60}$	0	.
MJJ_120_200_VBFTOPO_	$\sigma_{mjj>120\ \&\ ptHjj>25}/\sigma_{tot}$	$\sigma_{mjj>120\ \&\ ptHjj>25}/\sigma_{mjj>200}$	$\sigma_{mjj>120\ \&\ ptHjj>25}/\sigma_{mjj>60}$	$-\sigma_{120>mjj>120\ \&\ ptHjj>25}/\sigma_{120>mjj>120}$	.
MJJ_120_200_VBFTOPO_	$\sigma_{mjj>120\ \&\ ptHjj<25}/\sigma_{tot}$	$\sigma_{mjj>120\ \&\ ptHjj<25}/\sigma_{mjj>200}$	$\sigma_{mjj>120\ \&\ ptHjj<=25}/\sigma_{mjj>60}$	$-\sigma_{120>mjj>120\ \&\ ptHjj<25}/\sigma_{120>mjj>120}$	.
…	.	.	.	.	..

NEW STSX-VBF STAGE 1: MIGRATION UNCERTAINTIES

	tot	PTJ1_200	Mjj60	Mjj120	Mjj200	Mjj400	Mjj1000	Njet	pTHjj
PTJET1_GT200	+	–	0	0					
JET01	+	+	0	0				–	
MJJ_0_60	+	+	–	0				+	
MJJ_60_120	+	+	+	–				+	
MJJ_120_200_VBFTOPO	+	+	+	+	–			+	–
MJJ_120_200_VBFTOPO	+	+	+	+	–			+	+
MJJ_200_400_VBFTOPO	+	+	+	+	+	–		+	–
MJJ_200_400_VBFTOPO	+	+	+	+	+	–		+	+
MJJ_400_1000_VBFTOP	+	+	+	+	+	+	–	+	–
MJJ_400_1000_VBFTOP	+	+	+	+	+	+	–	+	+
MJJ_1000_VBFTOPO_JE	+	+	+	+	+	+	+	+	–
MJJ_1000_VBFTOPO_JE	+	+	+	+	+	+	+	+	+

NEW STSX-VBF STAGE 1: MIGRATION UNCERTAINTIES

- Total yield uncertainty taken from YR4 the δ_{tot} ~ 0.38 [%]
- Same treatment for Δ_{200} and Δ_{25} as before + remove contribution from Δ_{tot}
- Compute the Δ using yields in the inclusive M_{jj} bins
- The effect of each migration Δ is anti-correlated for bins above/below (same as for VH)

$$\Delta_{60} = \sigma_{m_{jj}>60}\left(\delta^2_{m_{jj}>60} - \delta^2_{m_{jj}>0}\right)^{1/2}$$

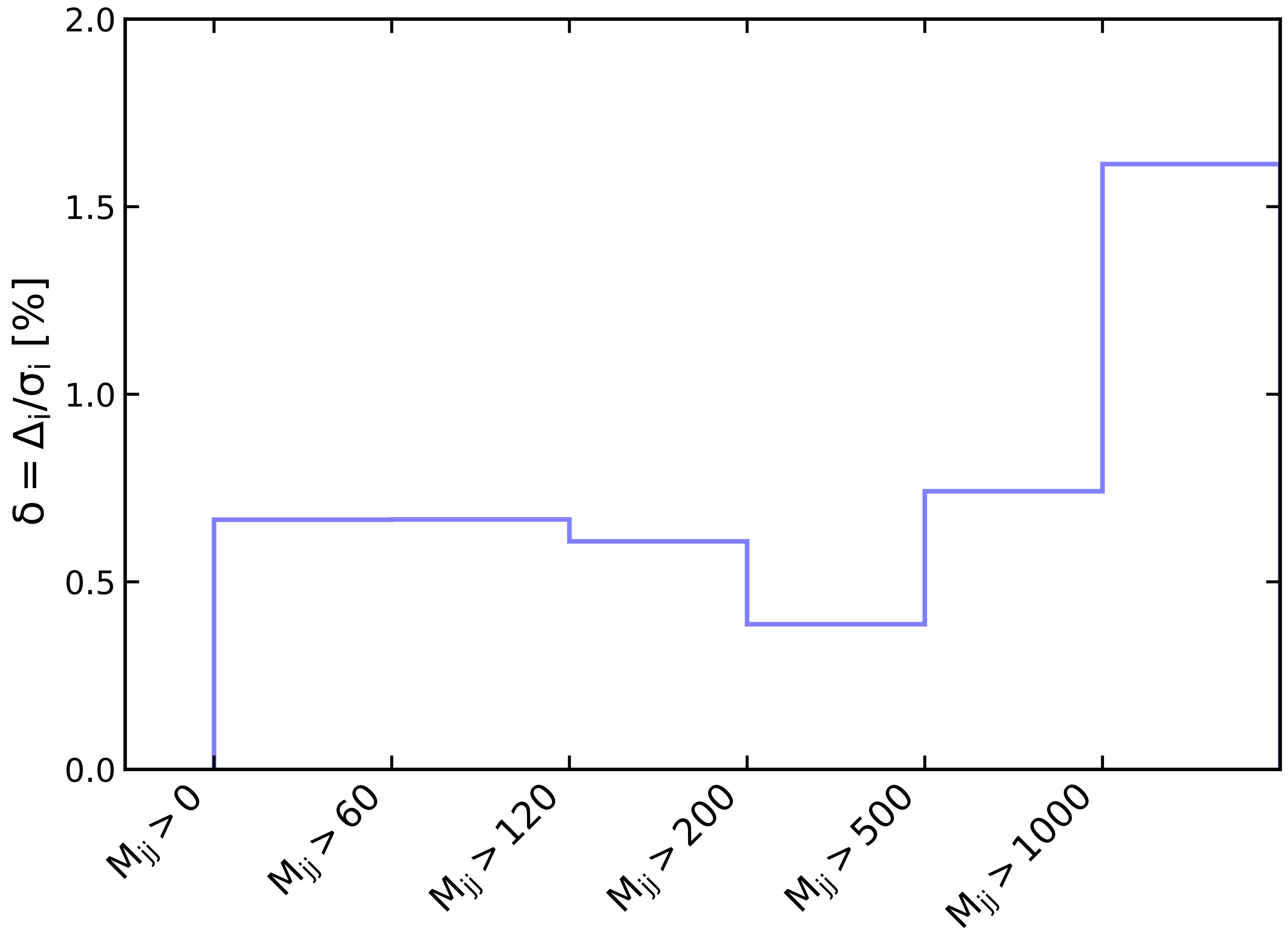
$$\Delta_{120} = \sigma_{m_{jj}>120}\left(\delta^2_{m_{jj}>120} - \delta^2_{m_{jj}>60}\right)^{1/2}$$

$$\Delta_{200} = \sigma_{m_{jj}>200}\left(\delta^2_{m_{jj}>200} - \delta^2_{m_{jj}>120}\right)^{1/2}$$

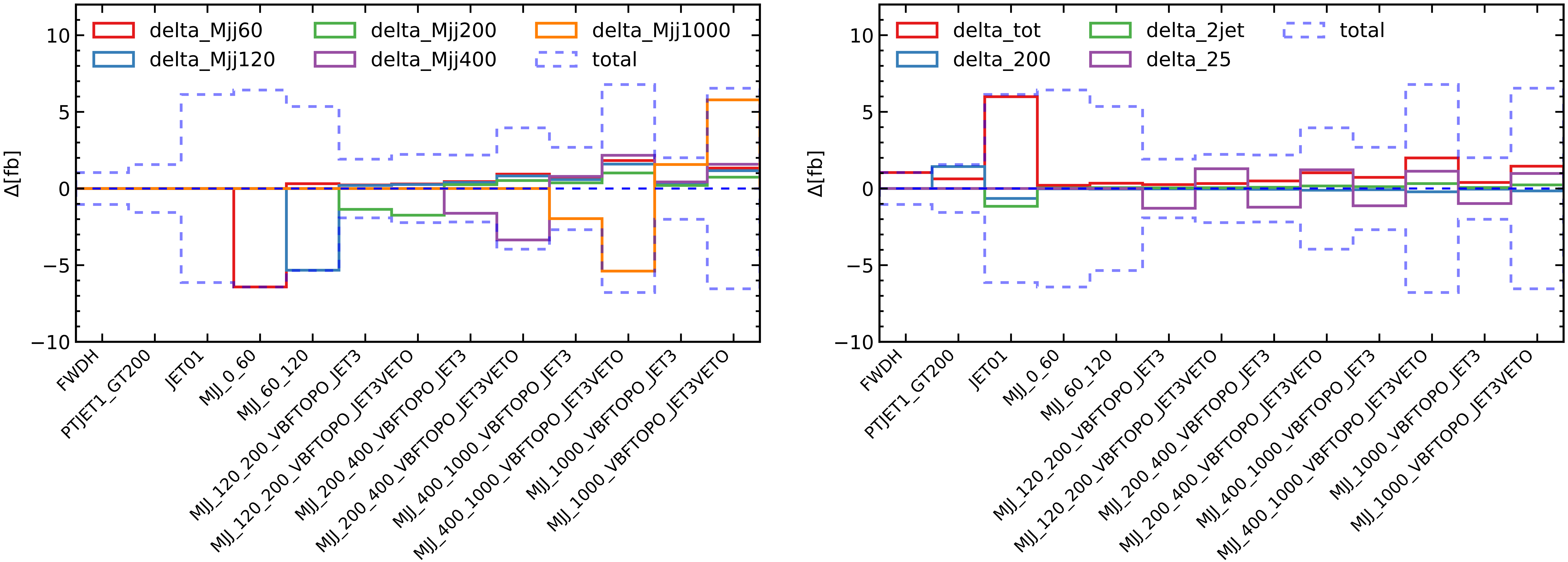
- If undefined uncertainty $\delta_{i+1} < \delta_i$
  - replace with

$$\Delta_{200} = \sigma_{m_{jj}>200} \times \delta_{m_{jj}>200} \times \rho$$

- with $\rho = 0.5$



NEW STSX-VBF STAGE 1 : Δ CONTRIBUTIONS



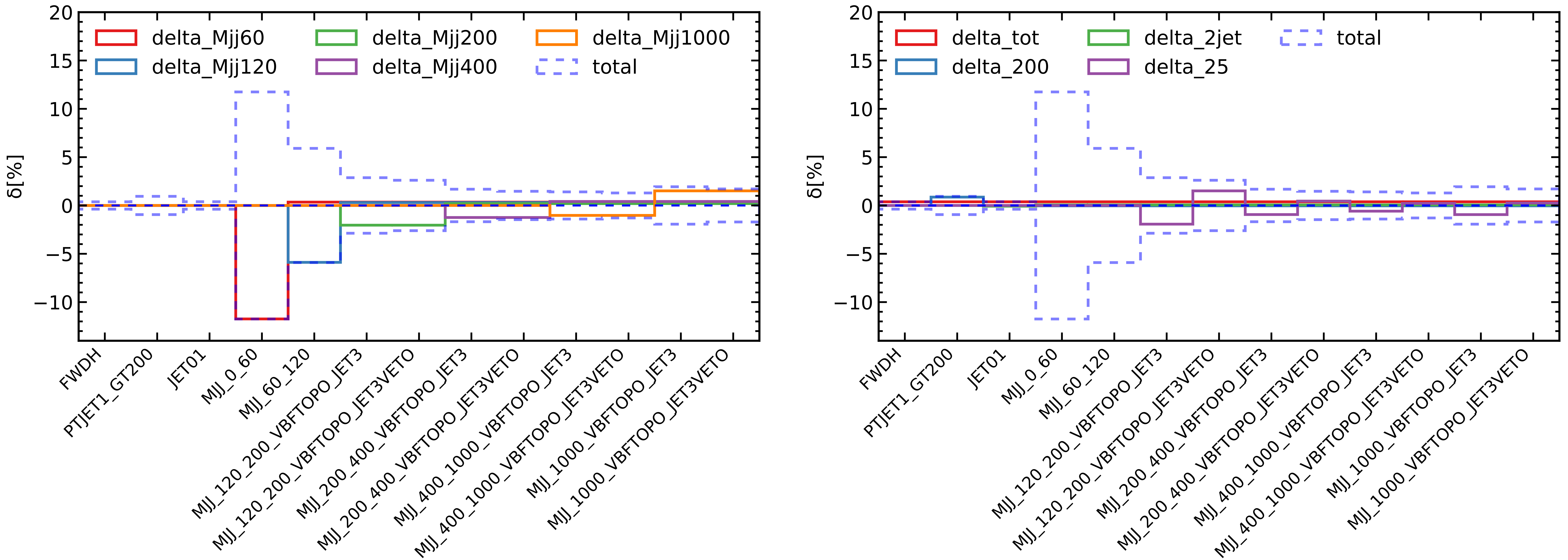
- Same treatment for Δ_{200} and Δ_{25} as before:
  - Anti-correlated for the bins above/below as expected

NEW STSX-VBF STAGE 1: Δ'S IN DETAIL

	XS [fb]	tot	PTJ1_200	Mjj60	Mjj120	Mjj200	Mjj400	Mjj1000	PTHJJ25	JET01/2	Total
FWDH	273.952	1.041	0	0	0	0	0	0	0	0	1.041
PTJET1_GT200	165.206	0.628	1.431	0	0	0	0	0	0	0	1.562
JET01	1575.777	5.987	−0.649	0	0	0	0	0	0	−1.161	6.133
MJJ_0_60	54.689	0.208	−0.022	−6.421	0	0	0	0	0	0.033	6.425
MJJ_60_120	90.542	0.344	−0.037	0.315	−5.329	0	0	0	0	0.055	5.35
MJJ_120_200_VBFTOPO_JET3	66.637	0.253	−0.027	0.232	0.203	−1.359	0	0	−1.288	0.041	1.915
MJJ_120_200_VBFTOPO_JET3VETO	85.324	0.324	−0.035	0.297	0.26	−1.74	0	0	1.288	0.052	2.225
MJJ_200_400_VBFTOPO_JET3	129.734	0.492	−0.053	0.452	0.394	0.251	−1.615	0	−1.219	0.079	2.184
MJJ_200_400_VBFTOPO_JET3VETO	269.617	1.025	−0.111	0.939	0.82	0.522	−3.355	0	1.219	0.165	3.957
MJJ_400_1000_VBFTOPO_JET3	191.272	0.727	−0.079	0.666	0.581	0.37	0.791	−1.964	−1.127	0.117	2.687
MJJ_400_1000_VBFTOPO_JET3VETO	524.441	1.993	−0.216	1.826	1.594	1.015	2.168	−5.386	1.127	0.321	6.783
MJJ_1000_VBFTOPO_JET3	103.695	0.394	−0.043	0.361	0.315	0.2	0.429	1.566	−0.98	0.063	2.007
MJJ_1000_VBFTOPO_JET3VETO	382.816	1.454	−0.158	1.333	1.163	0.741	1.582	5.784	0.98	0.234	6.542

- Same treatment for Δ_{200} and Δ_{25} as before:
  - Anti-correlated for the bins above/below as expected

NEW STSX-VBF STAGE 1: δ CONTRIBUTIONS



- The uncertainties stay at a reasonable levels comparing to the original stage-1 scheme for the region of interest (Mjj > 200 GeV): ~2%
- Relatively large uncertainties found in Mjj ∈ [0, 120] due to very low XS sections
  - Most of the VBF analyses are not sensitive and do not measure the XS in these bins

NEW STSX-VBF STAGE 1: δ's IN DETAILS

	XS [fb]	tot	PTJ1_200	Mjj60	Mjj120	Mjj200	Mjj400	Mjj1000	PTHJJ25	JET01/2	Total
FWDH	273.952	0.38	0	0	0	0	0	0	0	0	0.38
PTJET1_GT200	165.206	0.38	0.866	0	0	0	0	0	0	0	0.946
JET01	1575.777	0.38	-0.041	0	0	0	0	0	0	-0.074	0.389
MJJ_0_60	54.689	0.381	-0.041	-11.742	0	0	0	0	0	0.061	**11.748**
MJJ_60_120	90.542	0.379	-0.041	0.348	-5.886	0	0	0	0	0.061	**5.909**
MJJ_120_200_VBFTOPO_JET3	66.637	0.379	-0.041	0.348	0.304	-2.039	0	0	-1.933	0.061	**2.874**
MJJ_120_200_VBFTOPO_JET3VETO	85.324	0.38	-0.041	0.348	0.304	-2.039	0	0	1.51	0.061	**2.608**
MJJ_200_400_VBFTOPO_JET3	129.734	0.379	-0.041	0.348	0.304	0.193	-1.245	0	-0.94	0.061	1.683
MJJ_200_400_VBFTOPO_JET3VETO	269.617	0.38	-0.041	0.348	0.304	0.193	-1.244	0	0.452	0.061	1.468
MJJ_400_1000_VBFTOPO_JET3	191.272	0.38	-0.041	0.348	0.304	0.193	0.413	-1.027	-0.589	0.061	1.405
MJJ_400_1000_VBFTOPO_JET3VETO	524.441	0.38	-0.041	0.348	0.304	0.194	0.413	-1.027	0.215	0.061	1.293
MJJ_1000_VBFTOPO_JET3	103.695	0.38	-0.041	0.348	0.304	0.193	0.414	1.511	-0.945	0.061	1.936
MJJ_1000_VBFTOPO_JET3VETO	382.816	0.38	-0.041	0.348	0.304	0.193	0.413	1.511	0.256	0.061	1.709

- The uncertainties stay at a reasonable levels comparing to the original stage-1 scheme for the region of interest (Mjj > 200 GeV): ~2%
- Relatively large uncertainties found in Mjj ∈ [0, 120] due to very low XS sections
  - Most of the VBF analyses are not sensitive and do not measure the XS in these bins

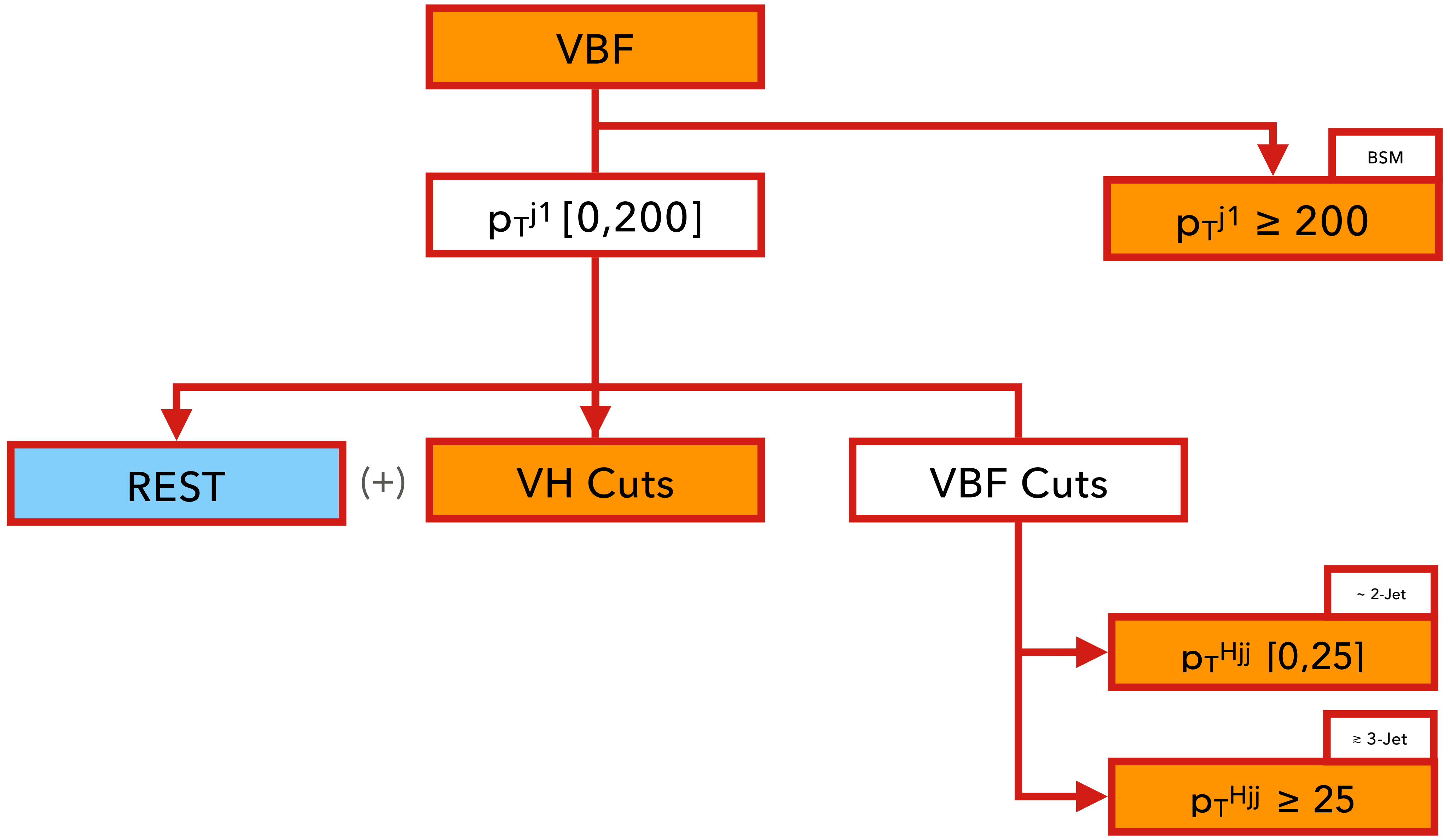
CONCLUSION

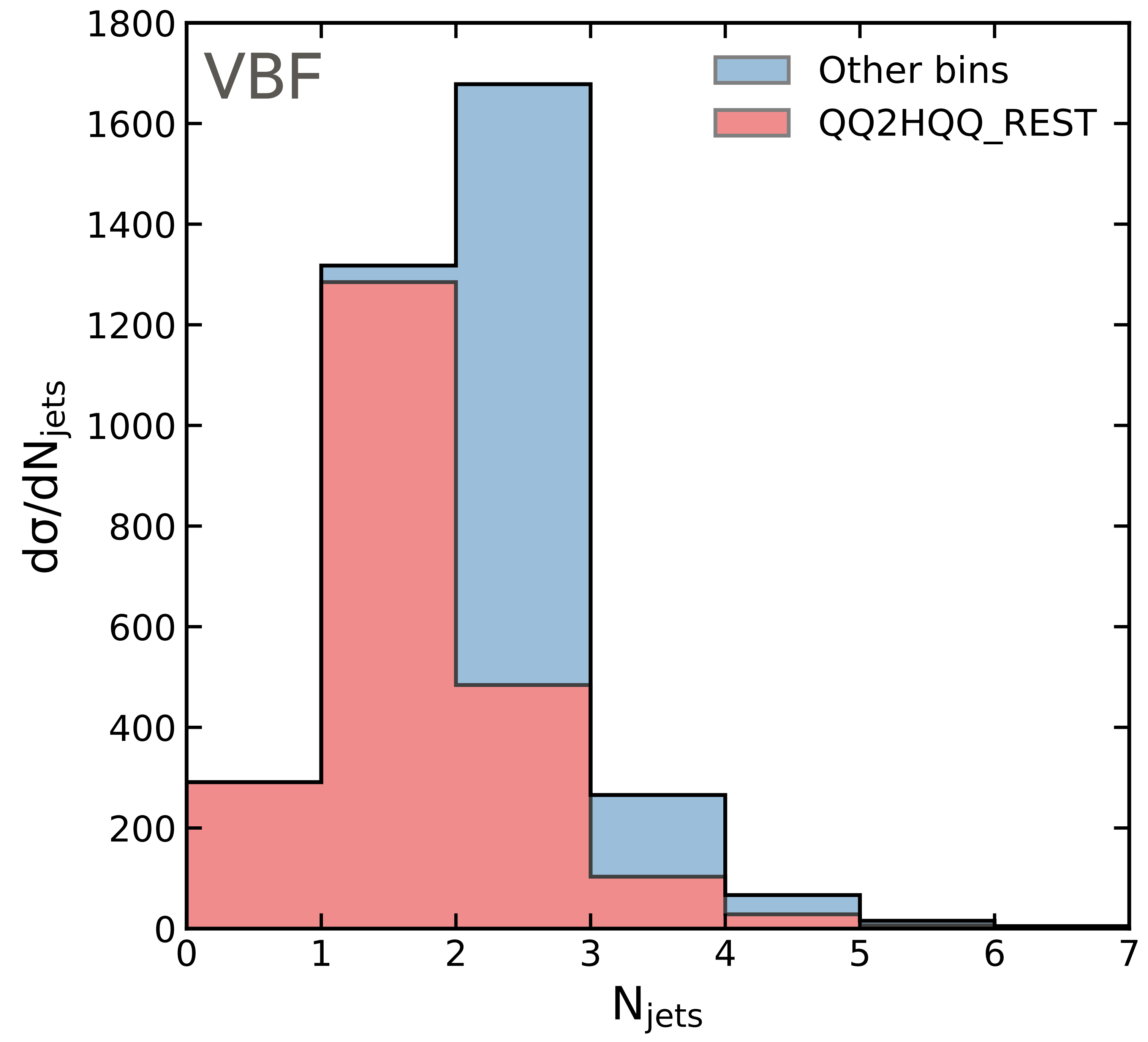
- **Systematic uncertainty prescription for the current VBF STXS stage-1 is proposed**
  - Need to move to FO to have a more robust estimation of the VBFTopo bins
- **Plan to have a new VBF Stage-1 scheme to have a smooth definition of the category using the Mjj spectrum**
  - Discussion on-going with WG2, see Frank' slide
  - Investigation of dropping the low Mjj bins and have a merged bin [0,200] moving the VH hadronic in a separated scheme
- **Moreover, plan to investigate the possibility to have a combined cut in ΔYjj & Mjj**
  - Δy_{jj} cut is important for the VBF- approximation and to reduce the contribution of no VBF-like diagrams

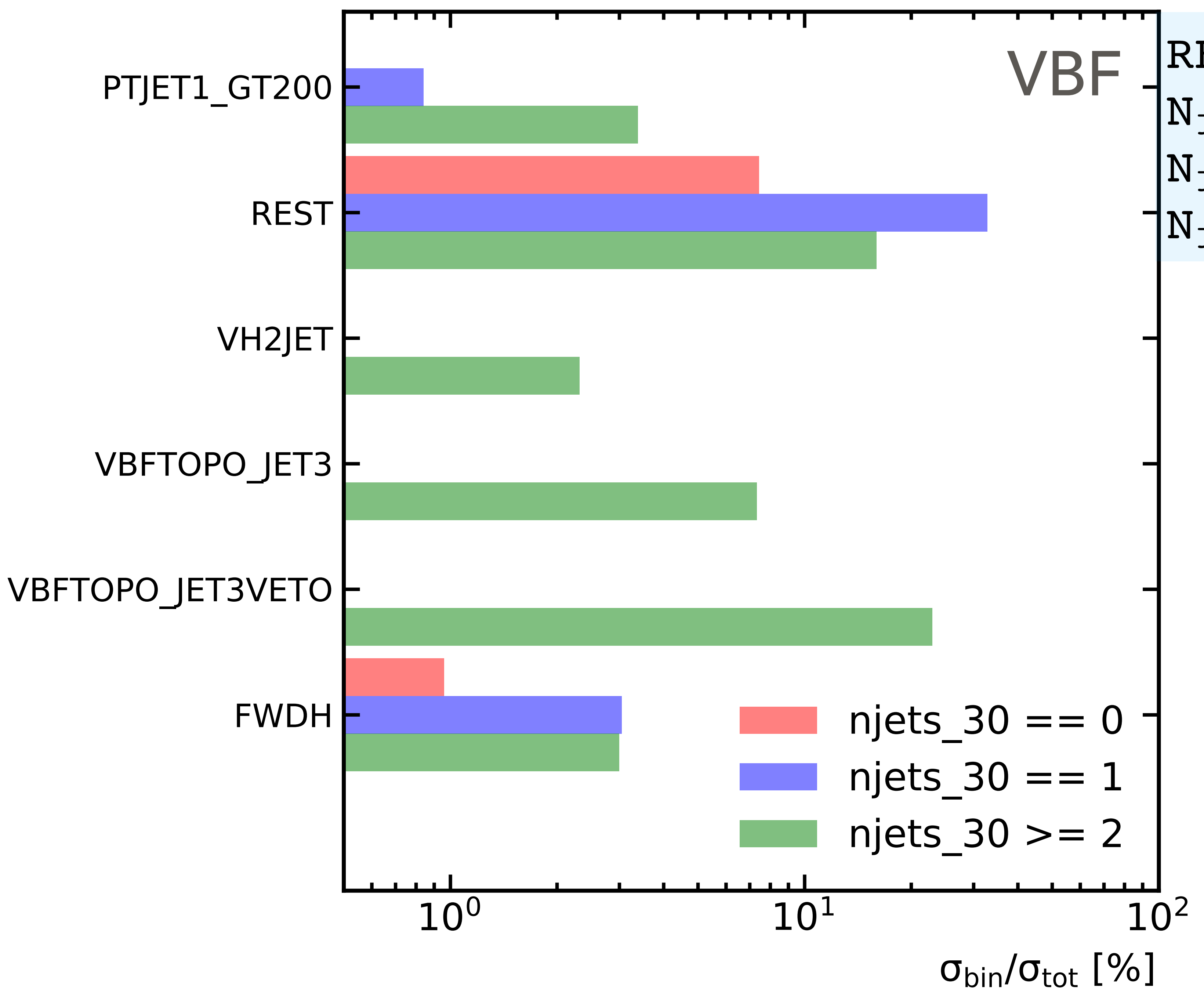
BACKUP

CURRENT STAGE-1 VBF

- **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, < 2 jets events and $\Delta\eta_{jj}$ < 2.8 & mjj>400 GeV
  - **We could benefit by adding a 0 and 1-jet category**



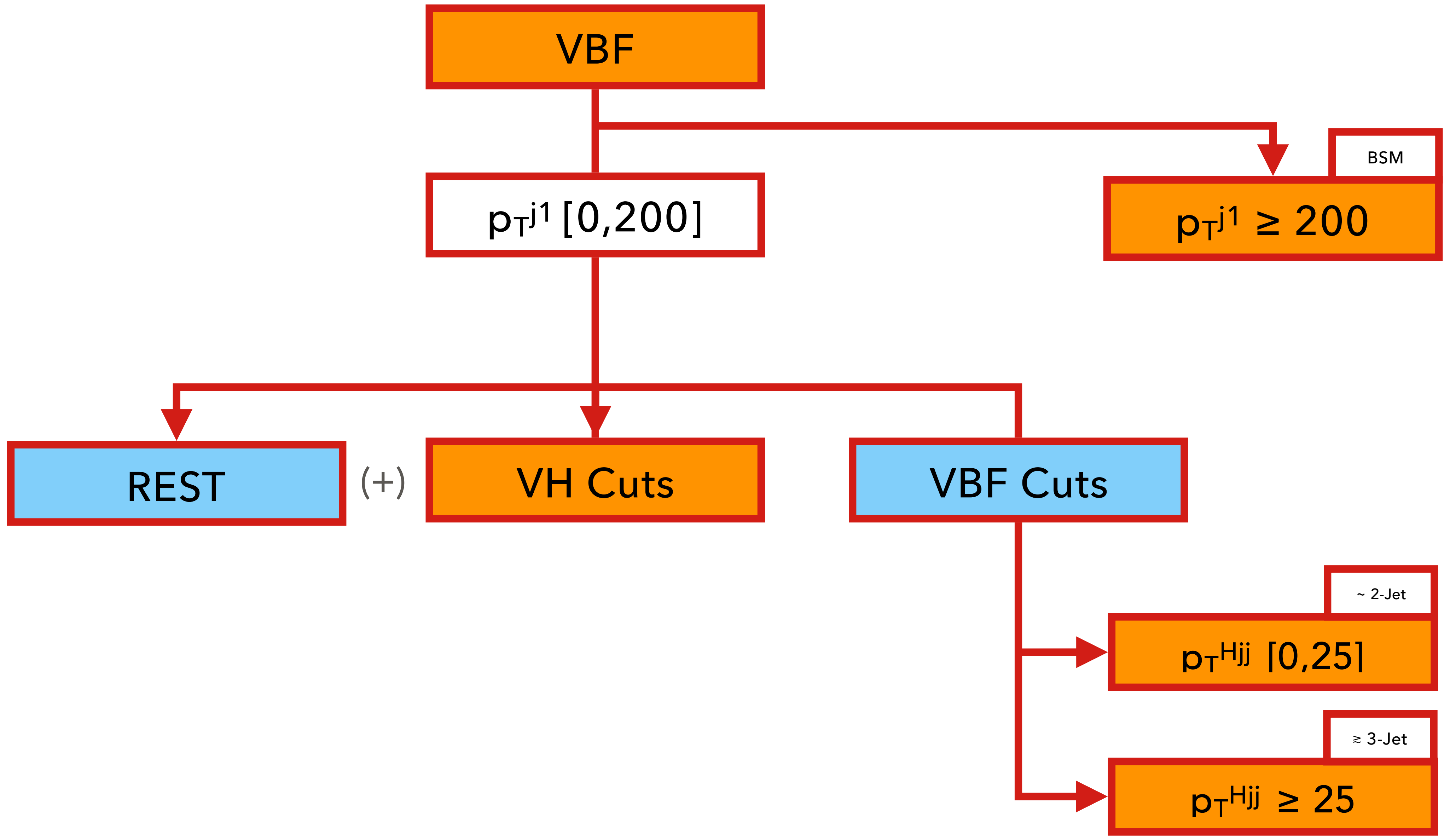




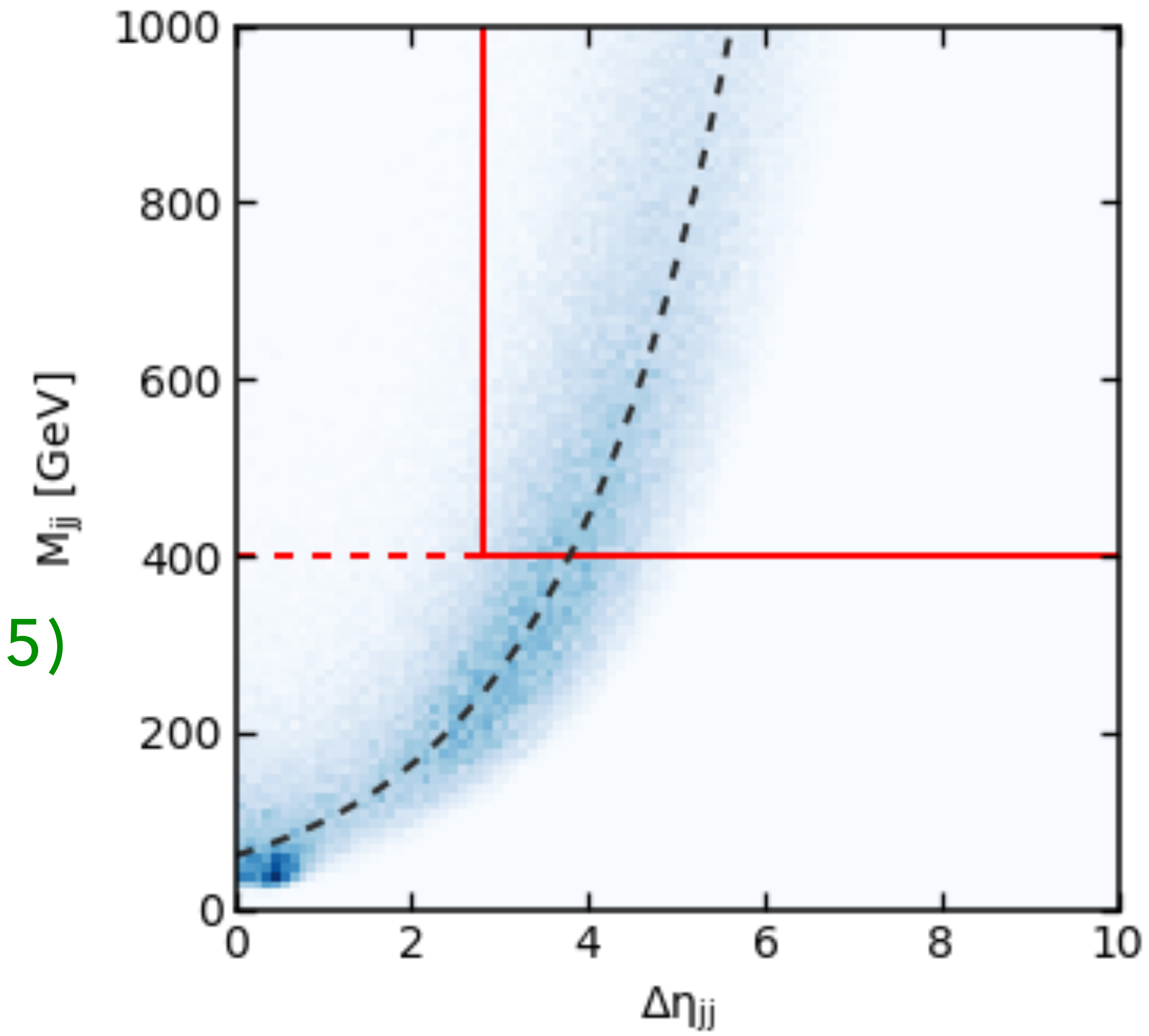
REST:
N_{jet} = 0: 7 %
N_{jet} = 1: 33%
N_{jet} ≥ 0: 16%

CURRENT STAGE-1 VBF

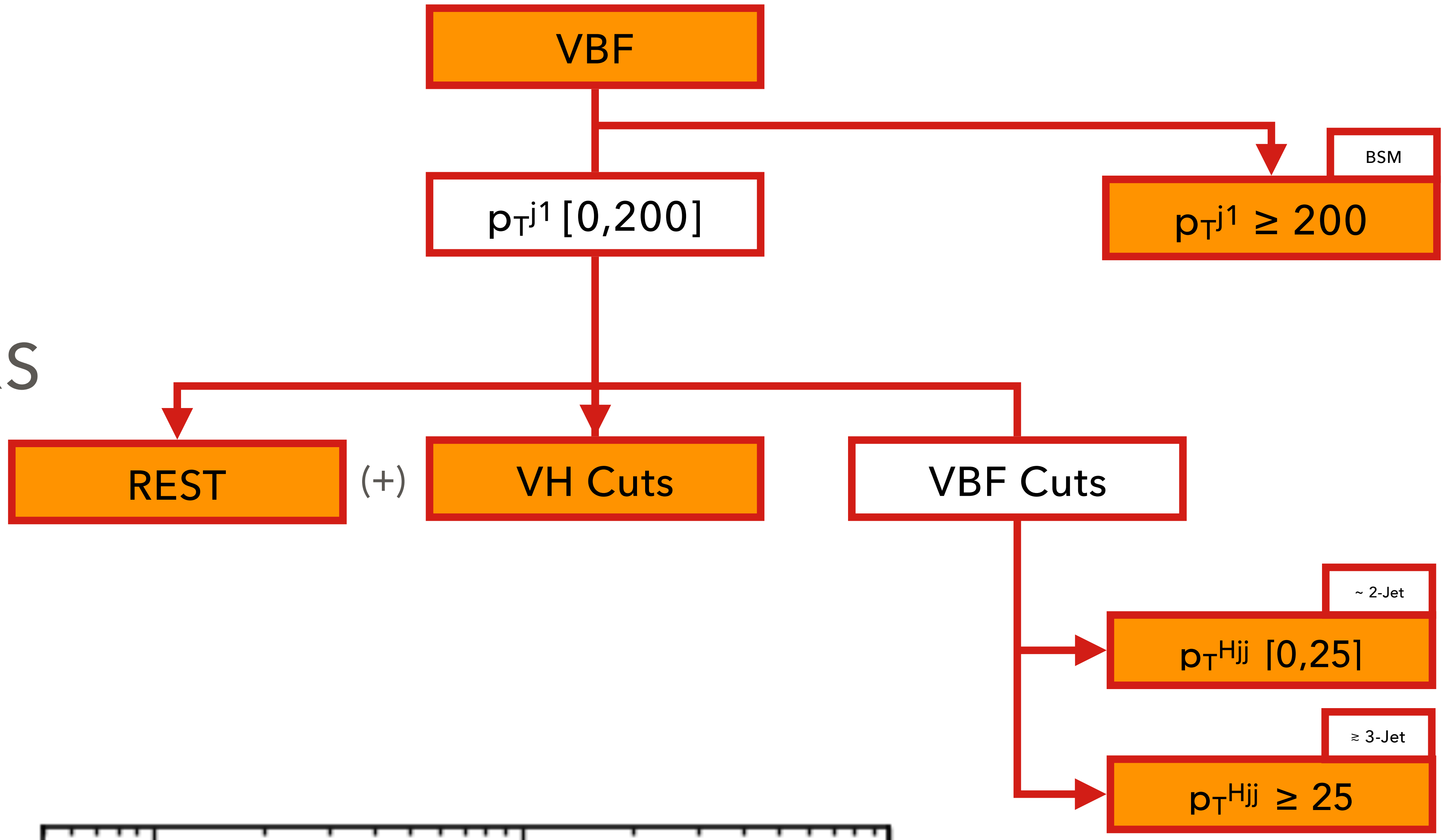
- **Almost 56% of the VBF events lands on < 2 jets region due to the p_T threshold**
- **Events with multiple kinematics land in the REST bin, making uncertainties estimation more complicated:**
  - 0 < mjj < 60 GeV and 120 < mjj < 400 GeV, < 2 jets events and $\Delta\eta_{jj}$ < 2.8 & mjj>400 GeV
  - **We could benefit by adding a 0 and 1-jet category**



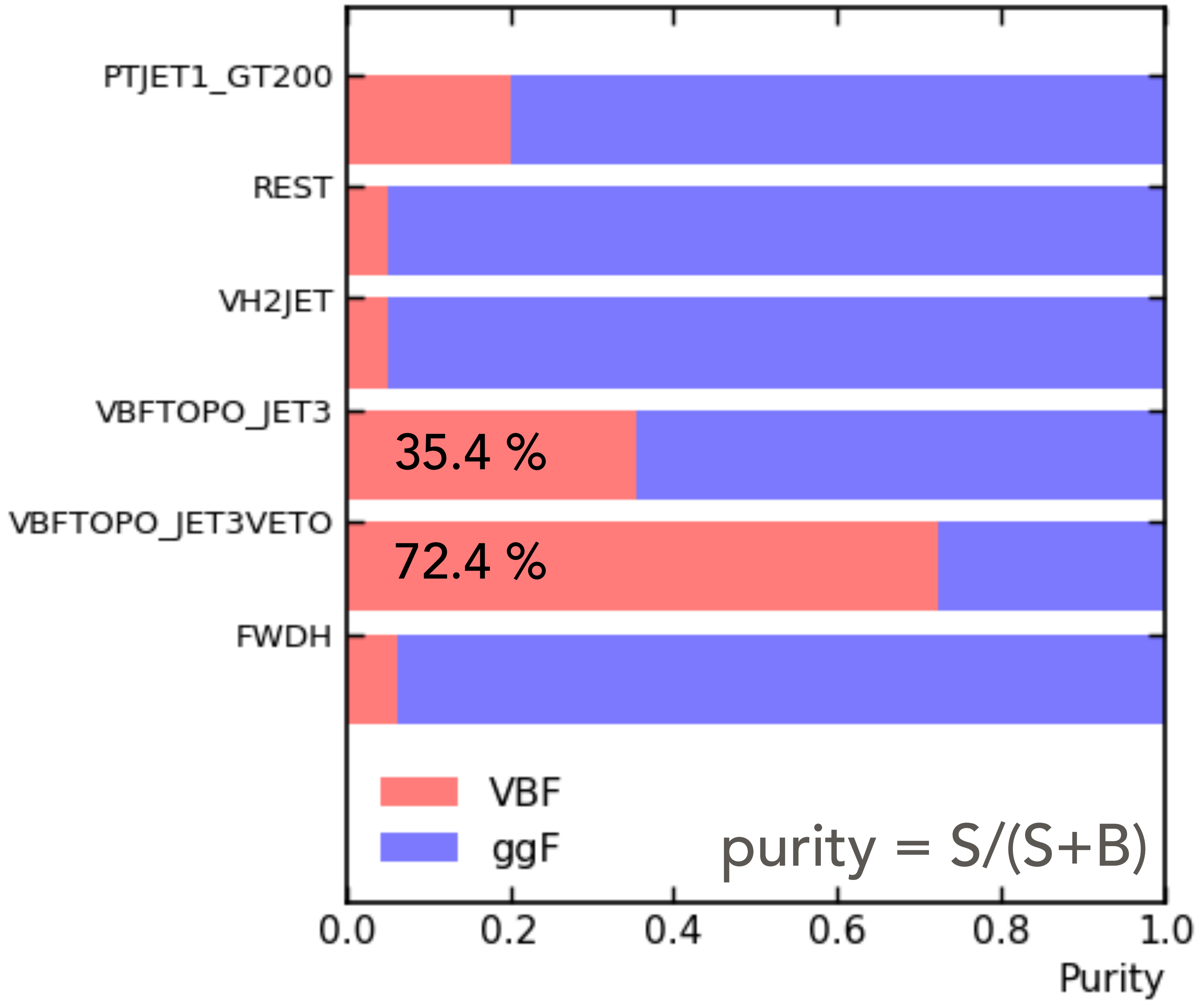
- **VBF bins are defined by Δy_{jj} > 2.8 and Mjj>400**
- **Can cut in Δy_{jj} be ignored, as the cut M_{jj}>400 GeV covers already the VBF phase-space?**
  - This might affect the electroweak corrections on VBF
  - This cut recommend by theory (Terrasse, Rauch and al, 1802.09955)
  - pTj1 or pTH cut might be enough to control EWK corrections?

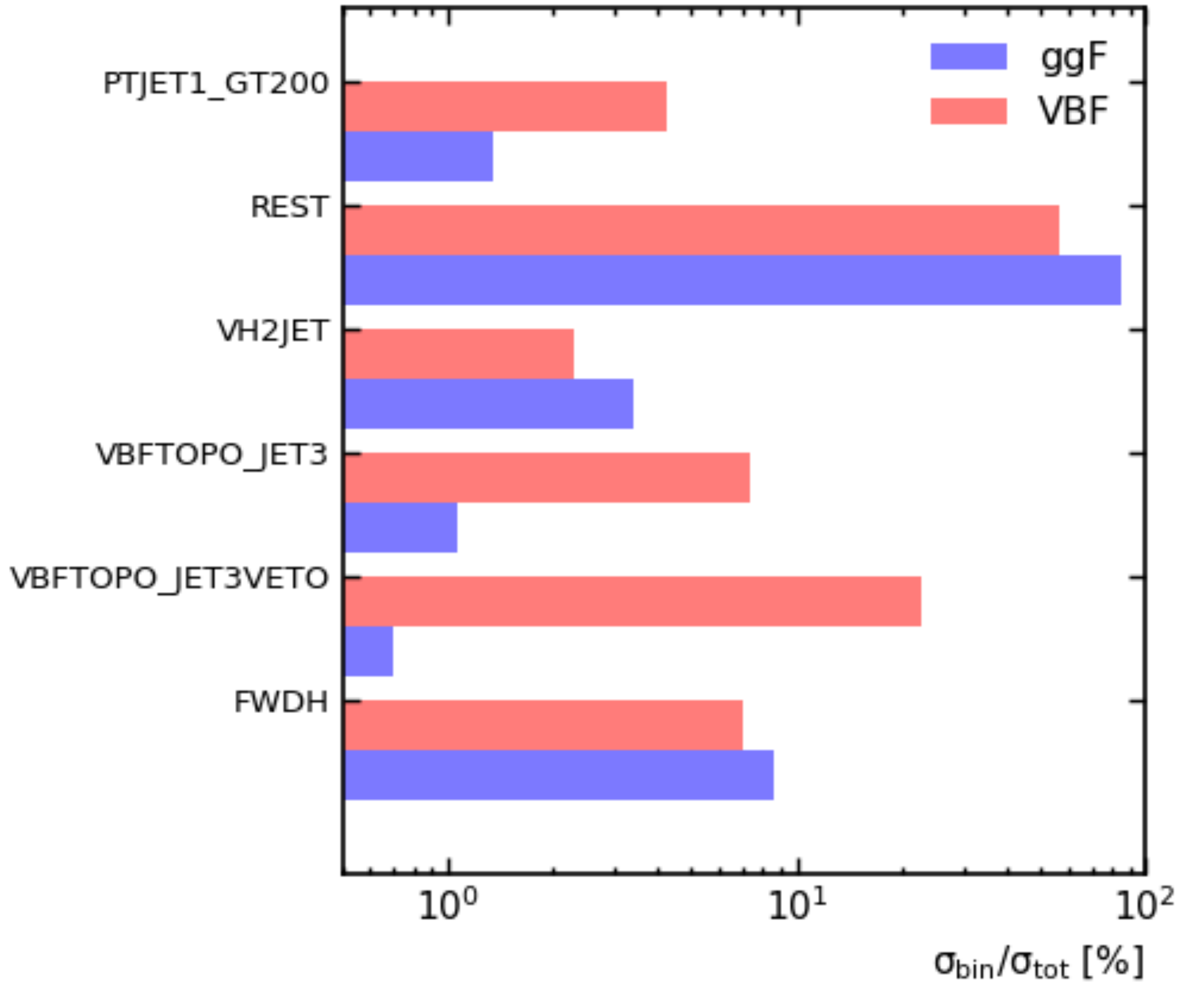


CURRENT STAGE-1 VBF

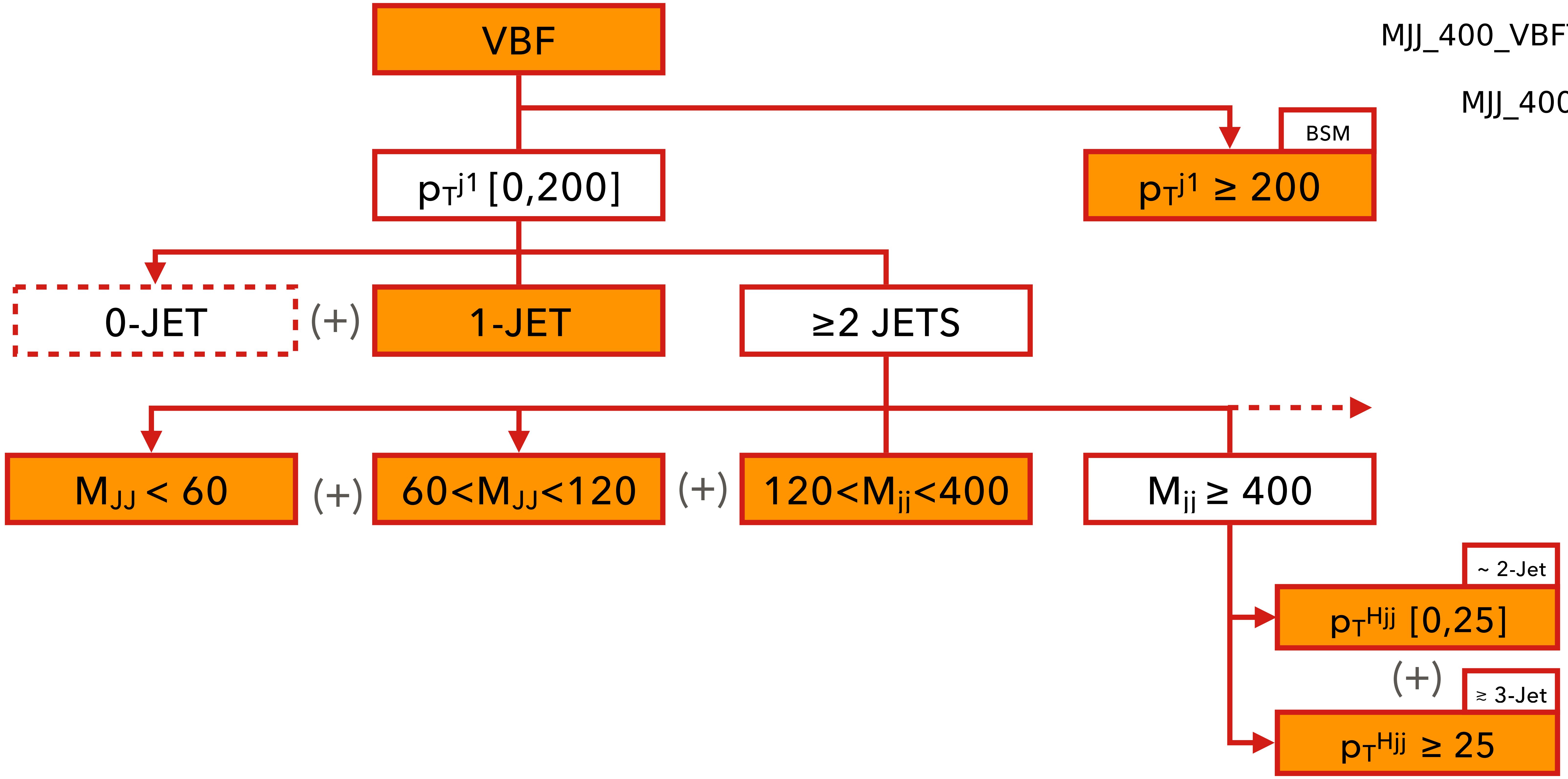


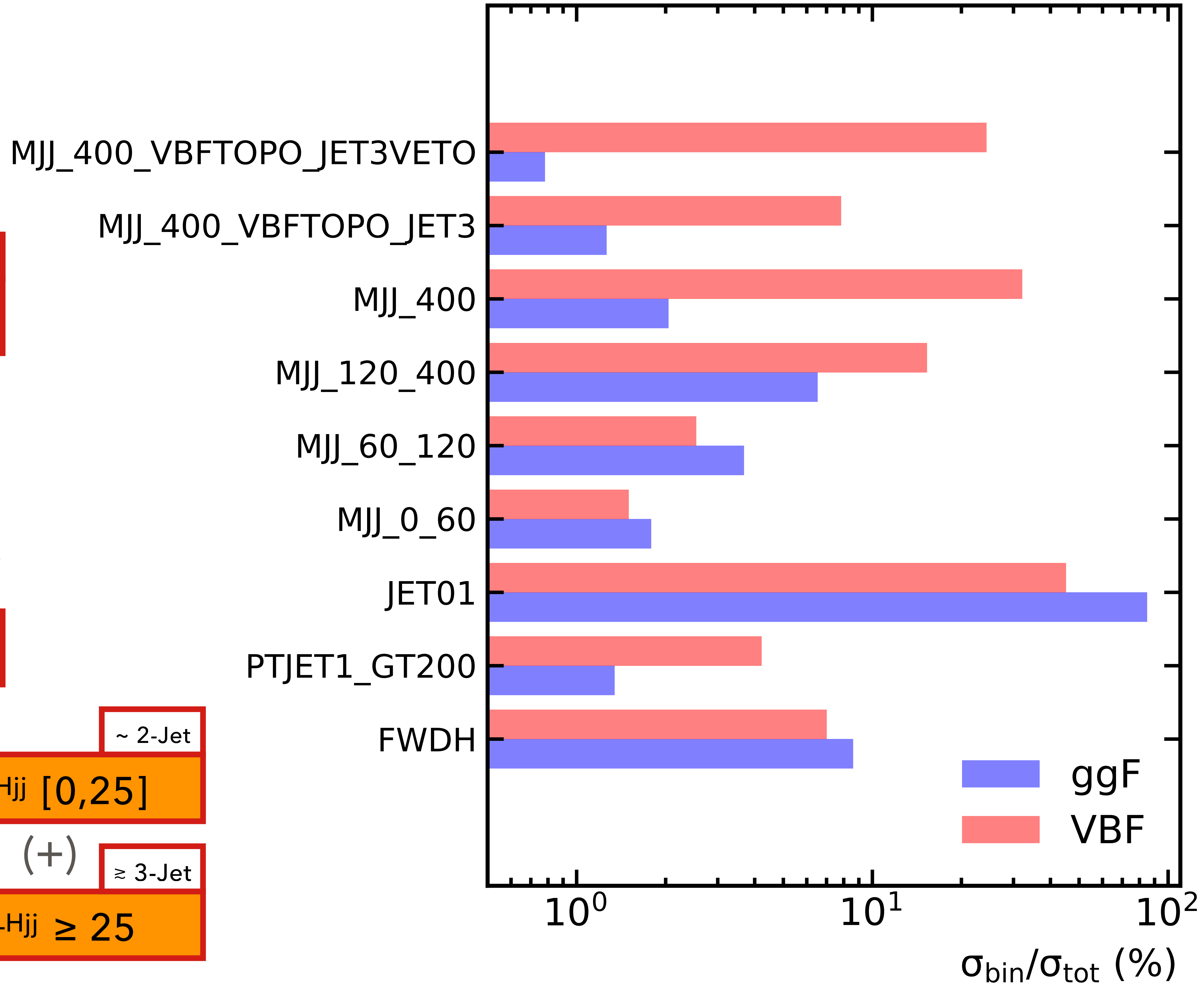
- Looking at the composition of the current STSX-VBF bins
  - Most of the GGF events lands in REST as well as most of the VBF XS
    - **Can we add additional bin to put aside the 0-1 jet events ?**
  - More than 20% ggF contamination in the VBF-like bin
    - **Can we have a more finer binning for VBF-like events?**
    - **Can we increase the purity/significance of the VBF bins?**





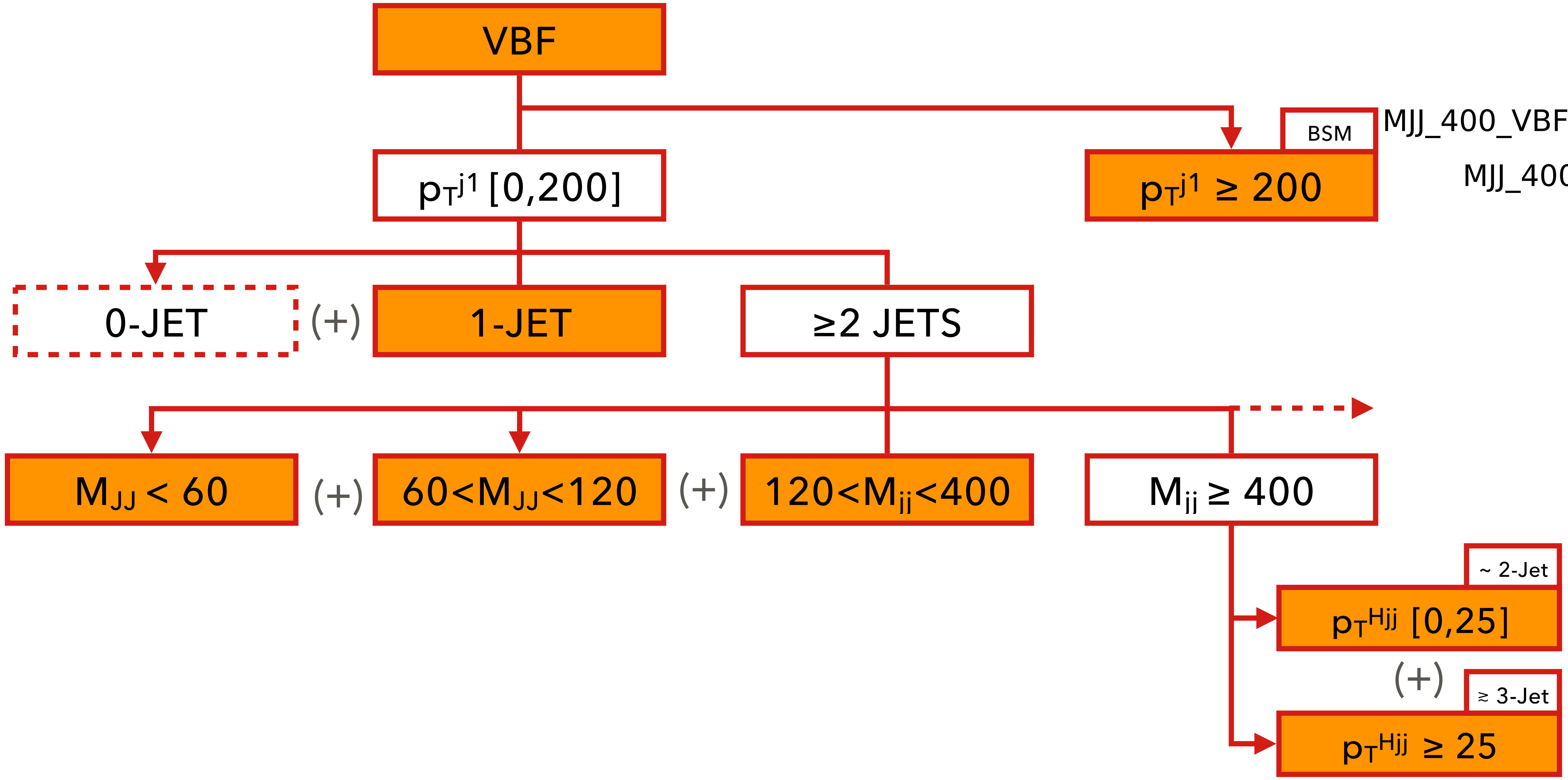
NEW STAGE-1 VBF

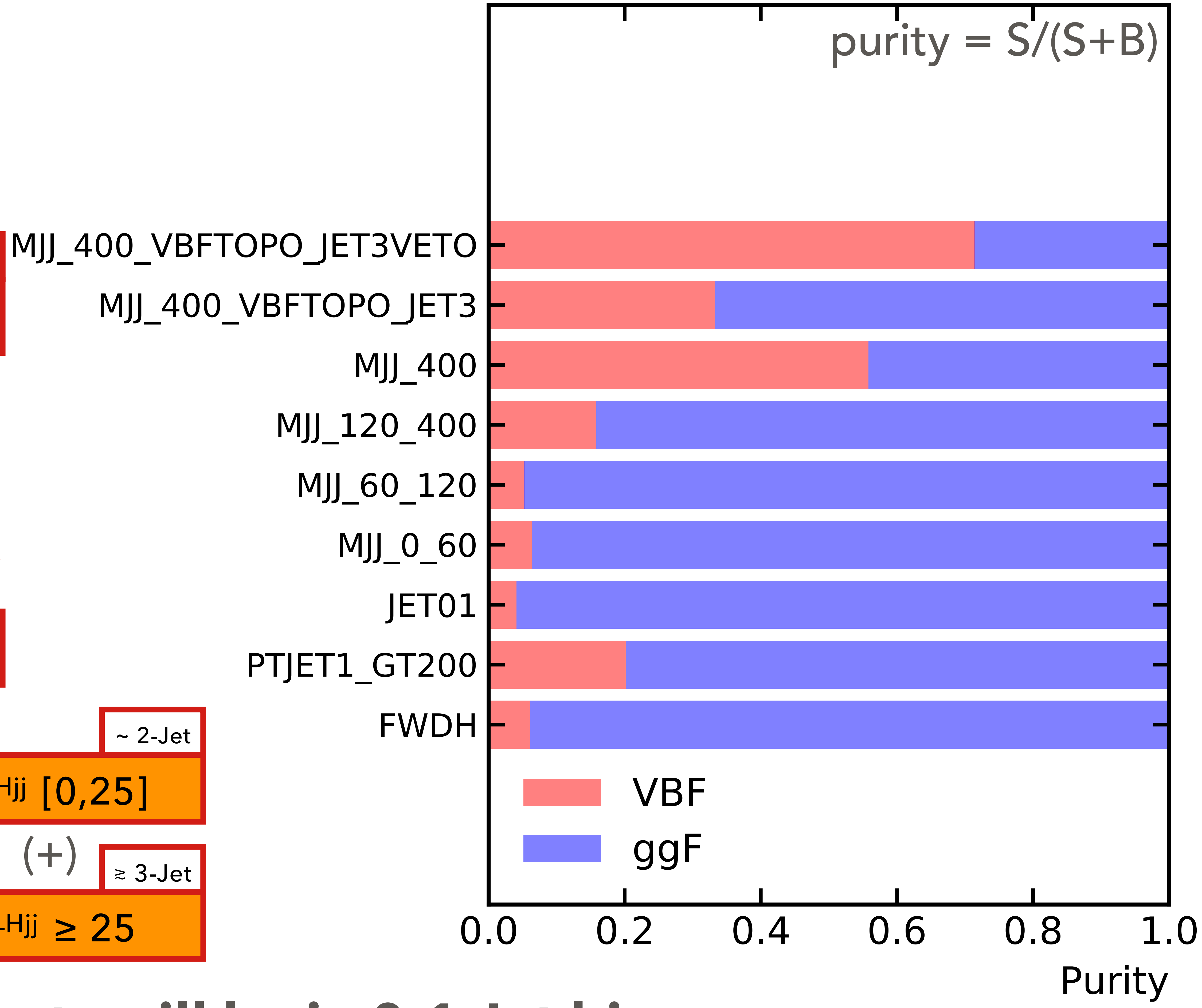




- **The event with a jet failing the p_T threshold requirements will be in 0-1 Jet bin**
- **REST bin will be replaced by Mjj < 60 GeV bin**
- **The systematics uncertainties on M_{jj} estimation becomes straightforward by removing the $\Delta\eta_{jj}$ cut**

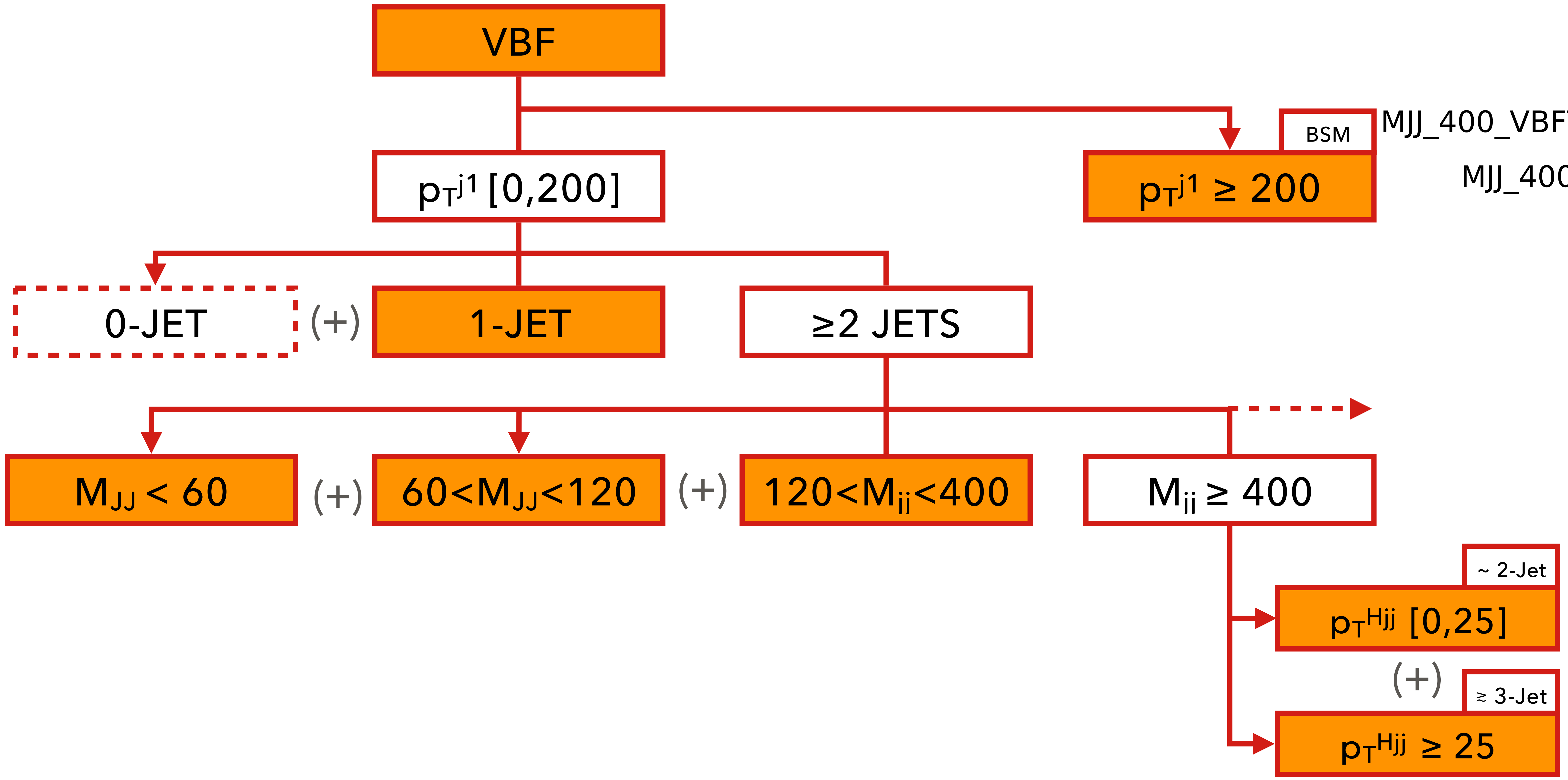
NEW STAGE-1 VBF

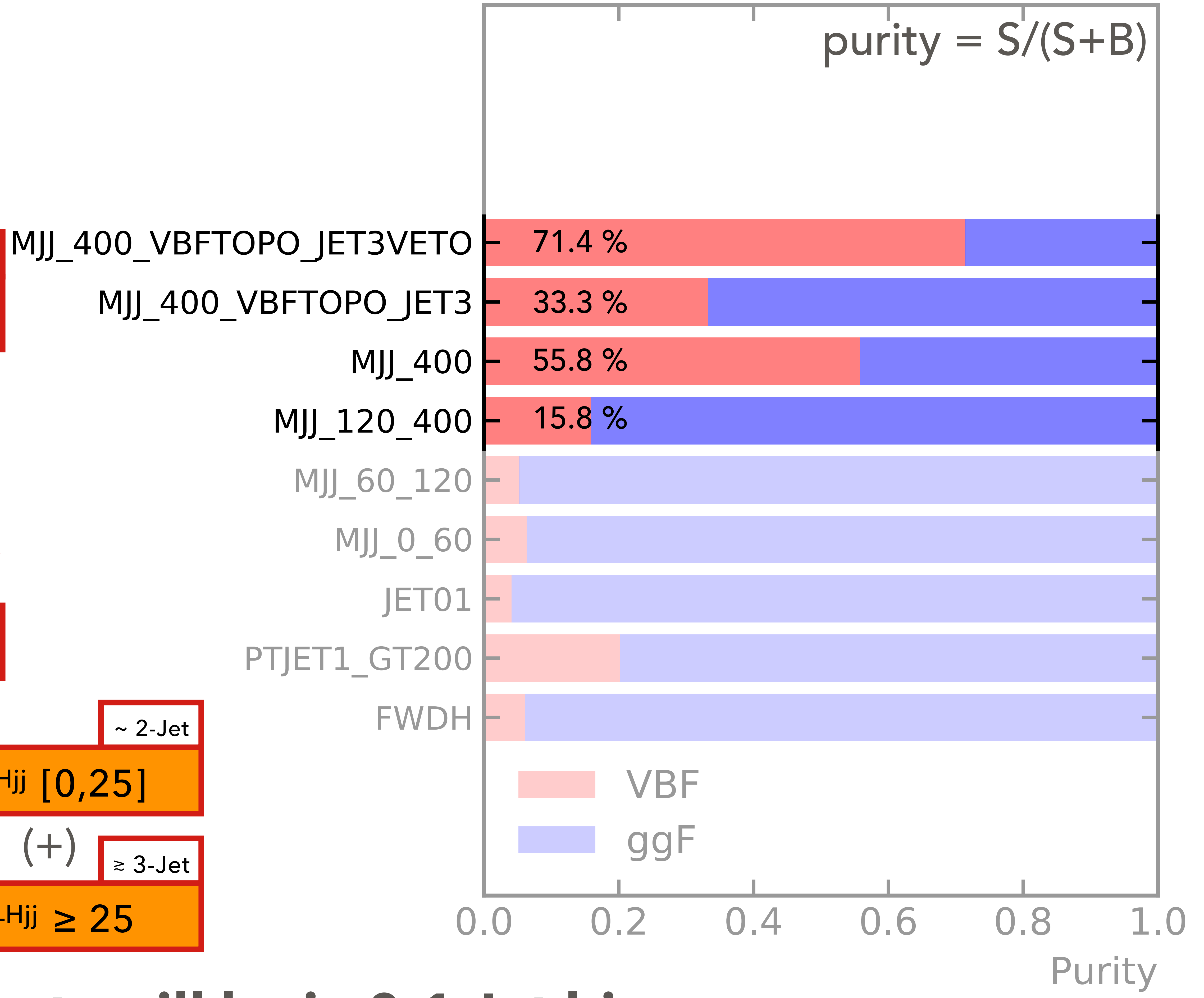




- **The event with a jet failing the p_T threshold requirements will be in 0-1 Jet bin**
- **REST bin will be replaced by Mjj < 60 GeV bin**
- **The systematics uncertainties on M_{jj} estimation becomes straightforward by removing the $\Delta\eta_{jj}$ cut**

NEW STAGE-1 VBF

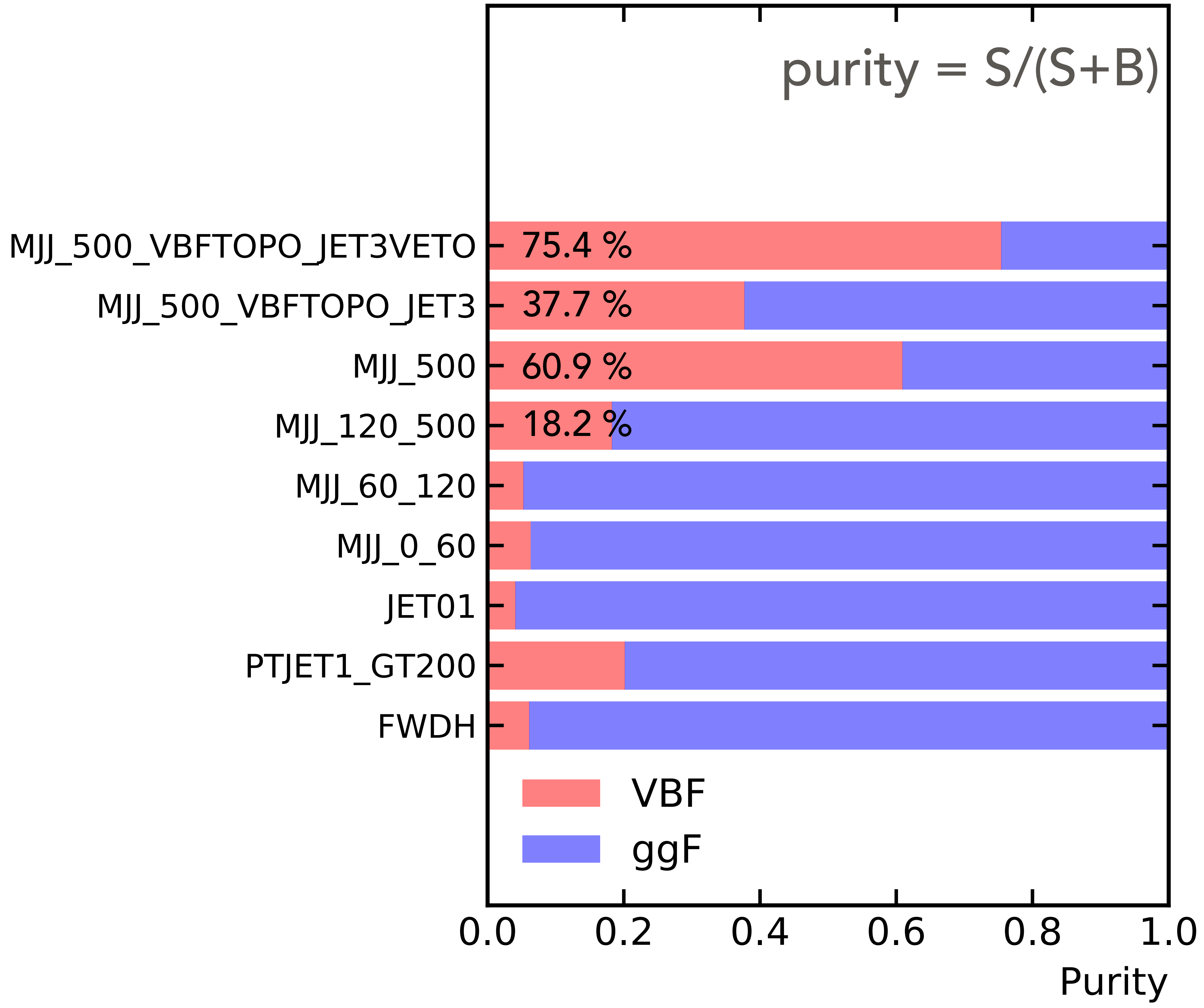


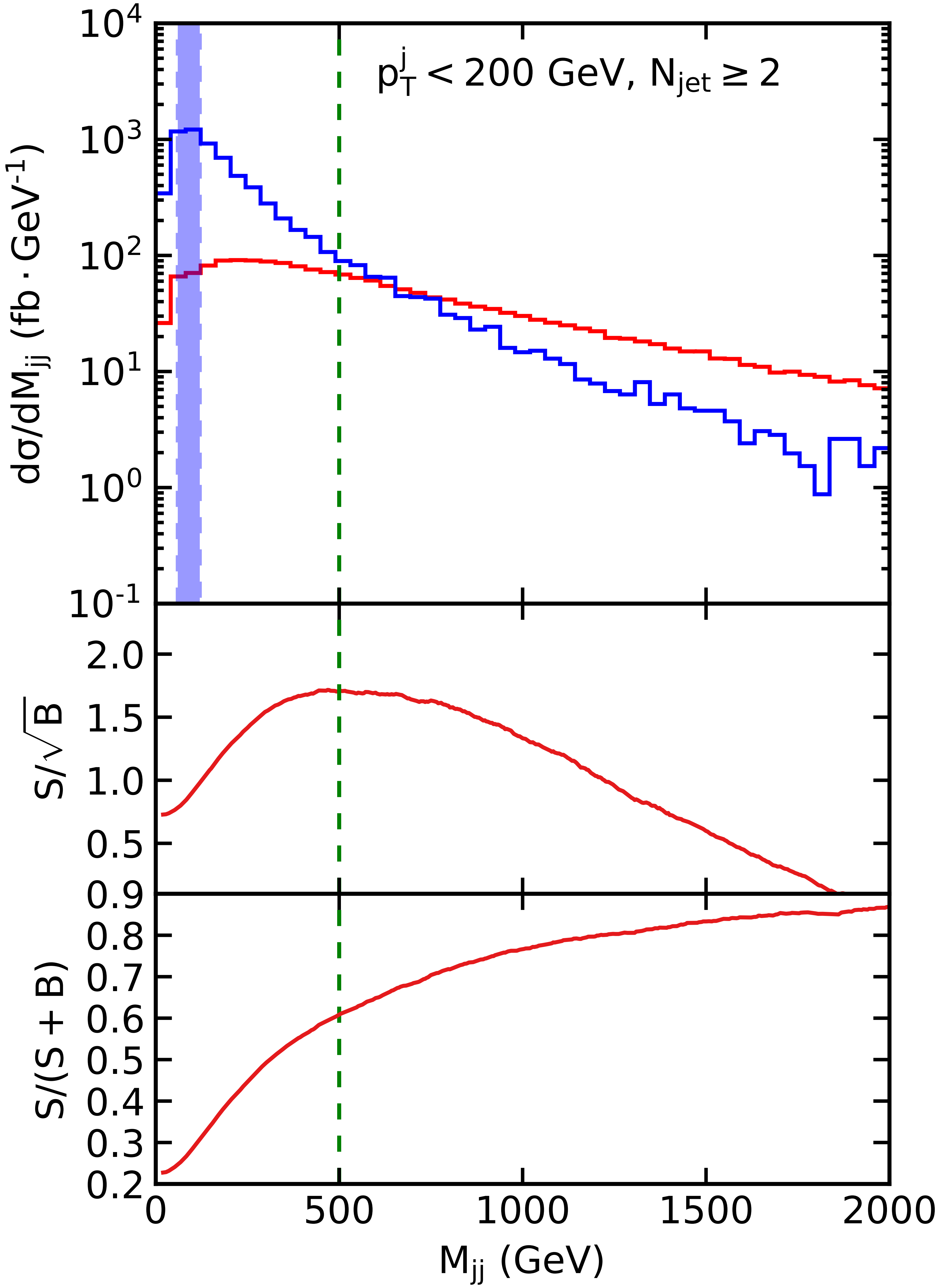


- **The event with a jet failing the p_T threshold requirements will be in 0-1 Jet bin**
- **REST bin will be replaced by Mjj < 60 GeV bin**
- **The systematics uncertainties on M_{jj} estimation becomes straightforward by removing the $\Delta\eta_{jj}$ cut**
- **VBF purity in VBFTOPO_JET3VETO bin reduced by 1% after removing the $\Delta\eta_{jj}$**
  - **Can the Mjj cut be optimised further to enhance significance and VBF purity?**

VBF BIN OPTIMISATION

- **For one cut optimisation we use the simple significance estimator S/√B, with ggH treated as background and boundaries that defines the VH hadronic bin**

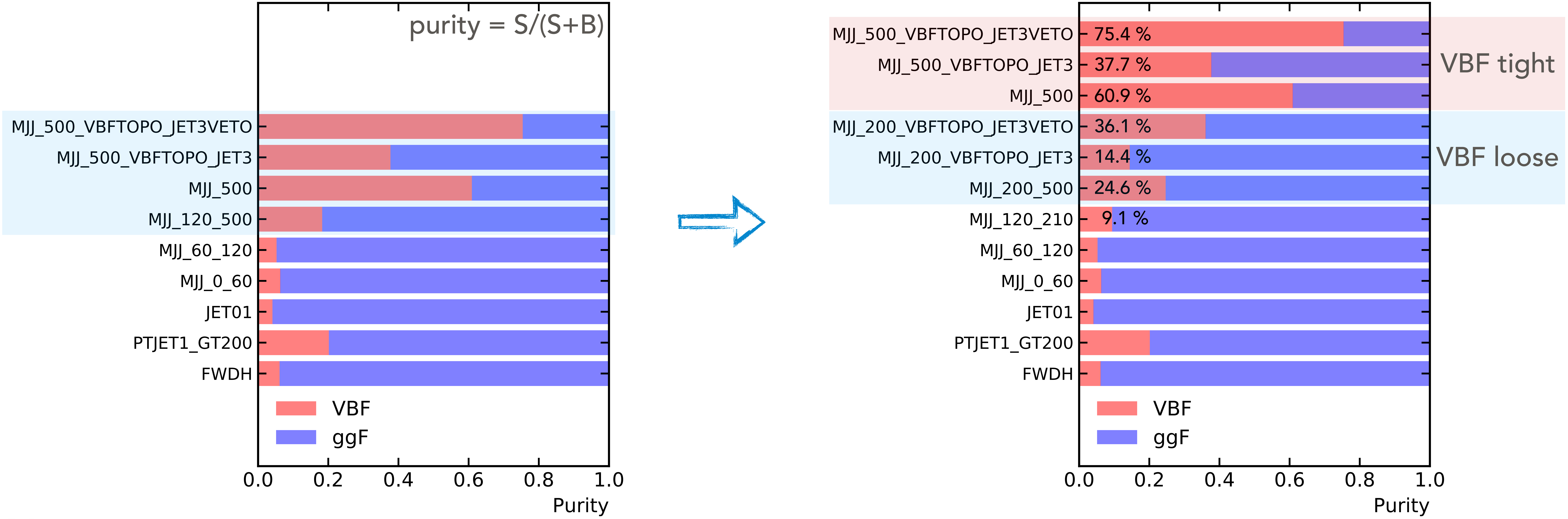




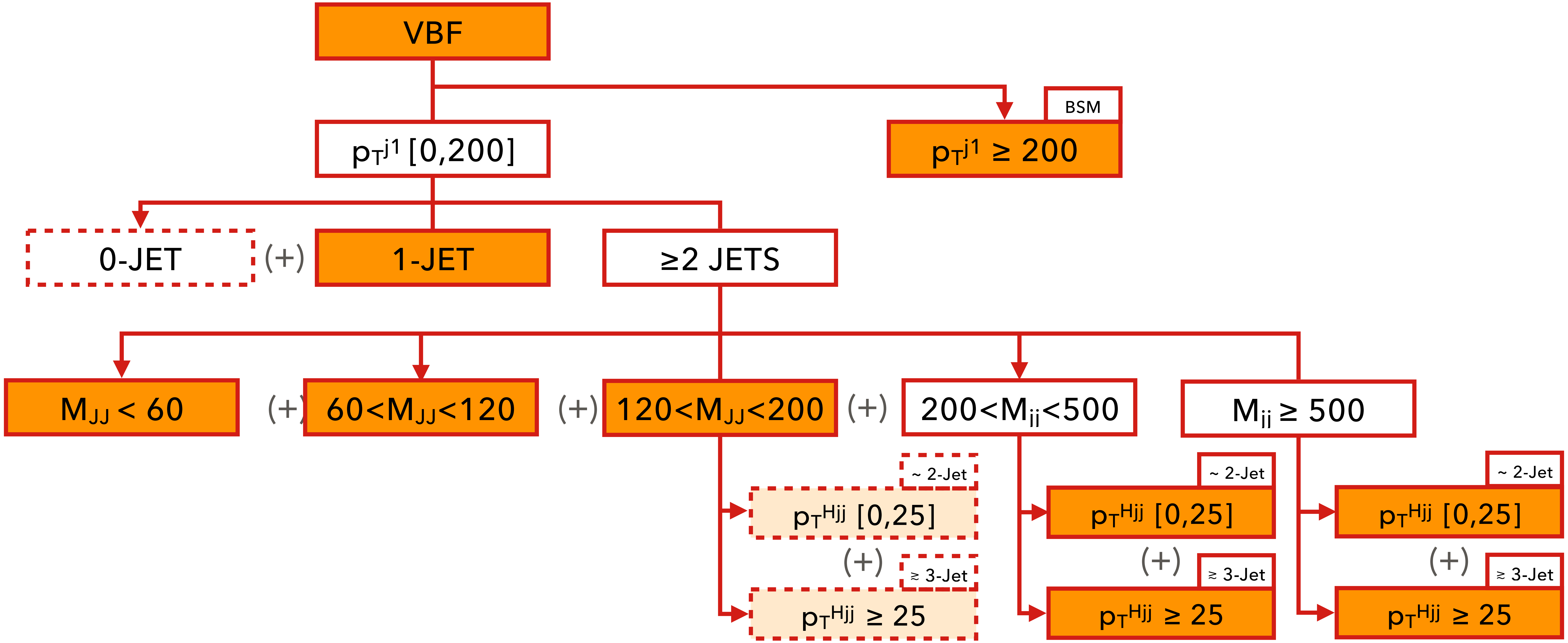
- **Pushing the threshold to M_{jj} > 500 GeV increase the purity of VBF signal in the VBFTOPO_JET3VETO from 71.4% to 75.4%**

VBF BIN OPTIMISATION-2

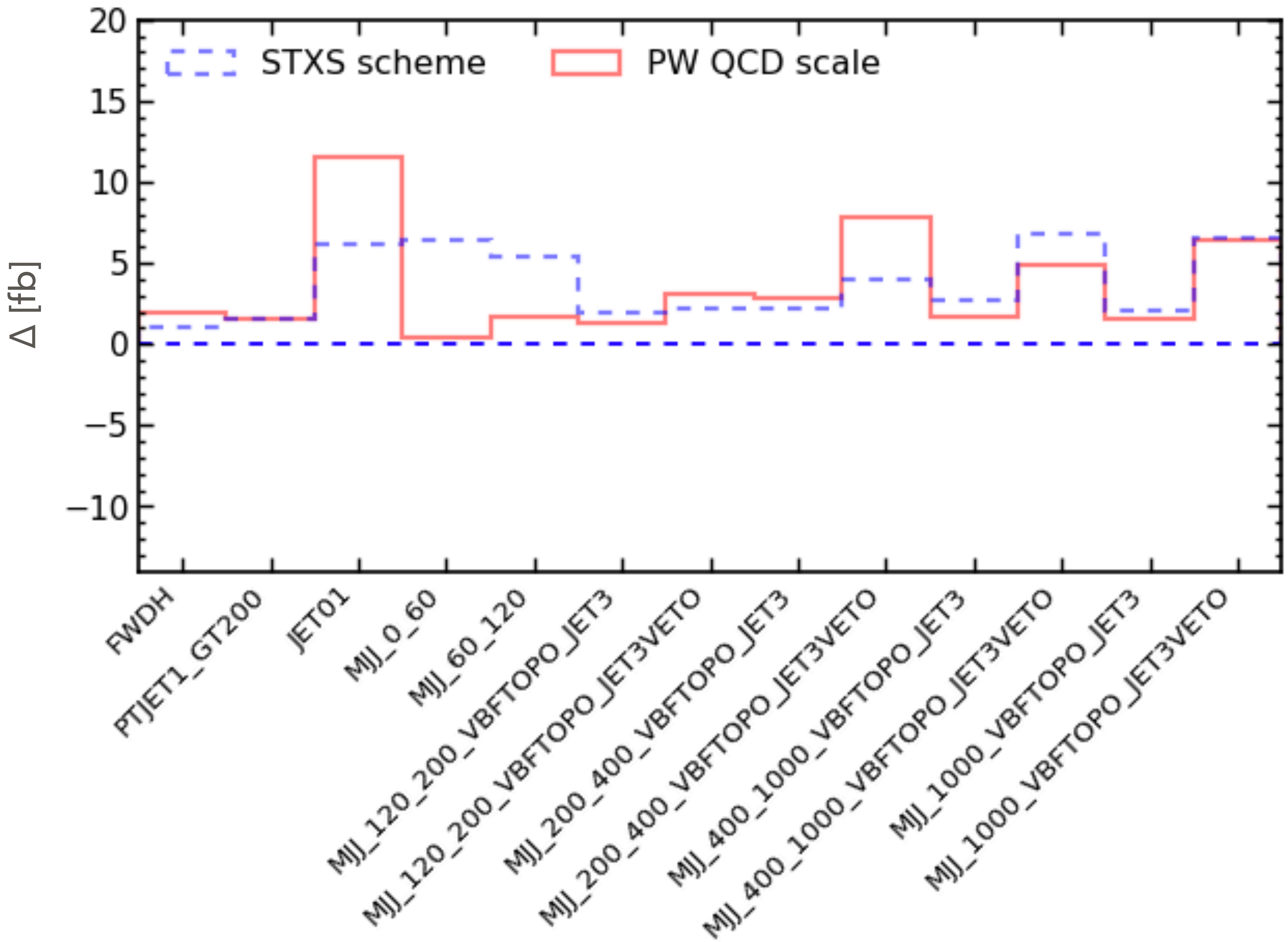
- Ideally we would like to increase as much we can the number of bins, but this is constrained by the experiment and what can be measured with the available statistics at Run2
- For Run2 a loose and tight VBF bins can be defined by splitting the Mjj_120_500 bin following the same procedure as before



STSX-VBF STAGE 1++



NEW STXS BINS: QCD SCALE VS UNCERT SCHEME



DELTA RABIDITY JETS

From arXiv:1802.09955 :

" We can clearly observe that the VBF approximation can be considered valid only for dijet invariant mass cuts above 500 GeV and for rapidity gaps above 2.

….. *Recent experimental analyses do not implement selection criteria for the VBF region as tight as originally envisaged [14–20], and rely on a multitude of multi-variate analysis techniques instead [36]. While for the Higgs plus two jet case the validity of the VBF approximation has been confirmed within a tight selection [21, 22], essentially nothing is known quantitatively for additional radiation as relevant to the veto on central jets (CJV), or virtually any observable exploiting properties of the radiation pattern of the underlying electroweak production process."*

…..

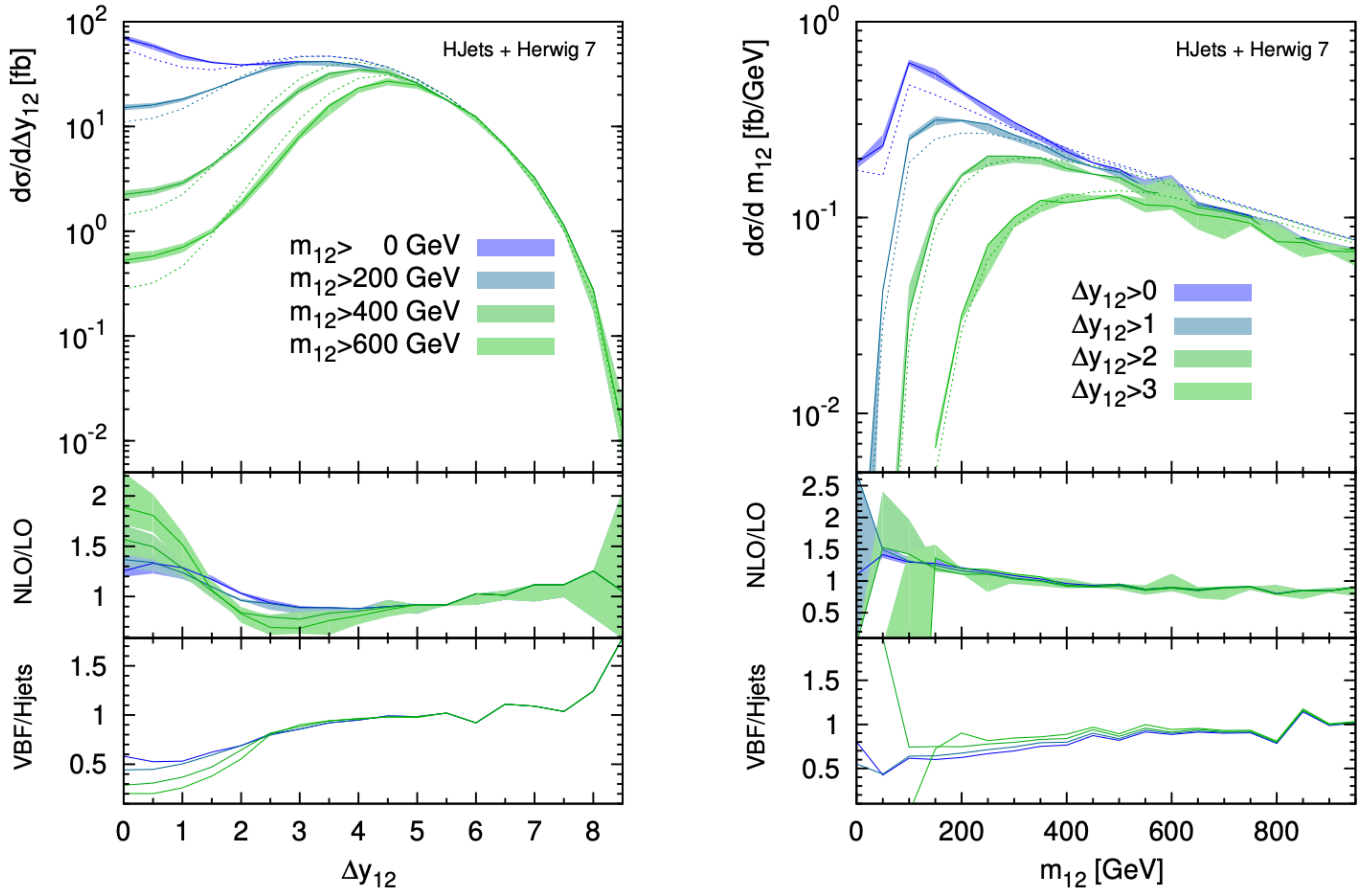


FIG. 4. The rapidity separation Δy_{12} of the leading two jets, for different cuts on their invariant mass (left) and the jet-jet invariant mass m_{12} as a function of the rapidity gap requirement (right). We compare NLO QCD predictions in the full calculation (solid) to the approximate results (dashed).