Impact of sFCal Upgrades to the HL-LHC Upgrade Analysis VBF H->WW->lvlv

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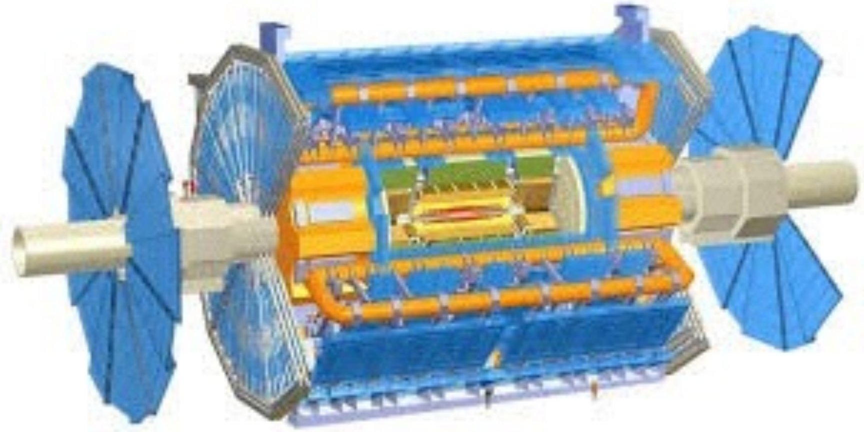
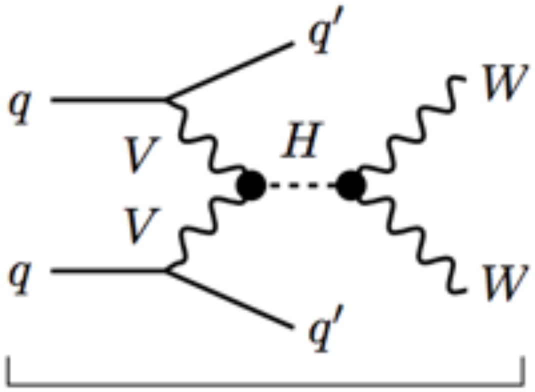
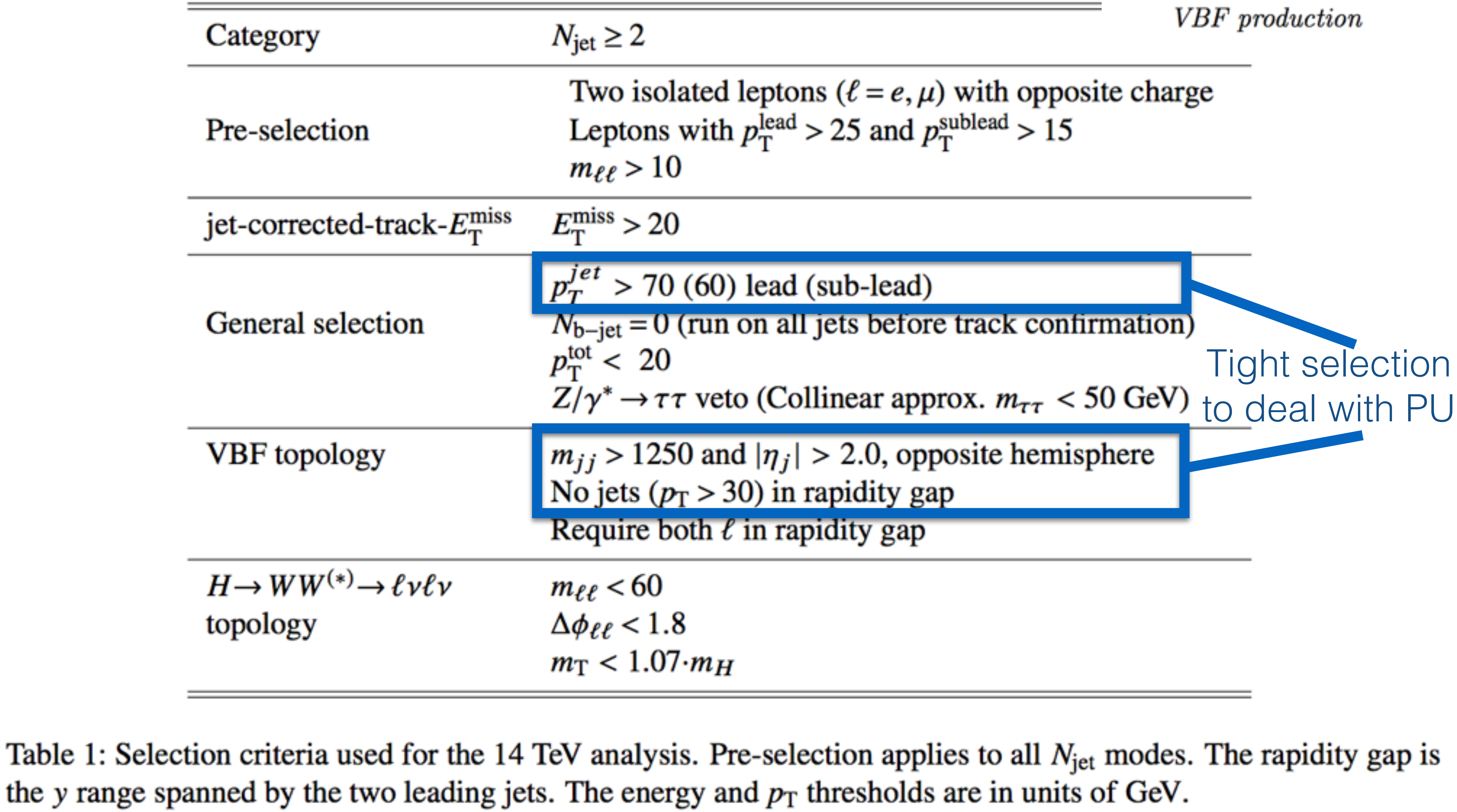
PUB Note Link in CDS
https://cds.cern.ch/record/2140057
Higgs Group Approval Presentation
http://cern.ch/ProspectsHWWVBF



Event Selection



VBF production



Category	$N_{\text{jet}} \geq 2$
Pre-selection	Two isolated leptons ($\ell = e, \mu$) with opposite charge Leptons with $p_T^{\text{lead}} > 25$ and $p_T^{\text{sublead}} > 15$ $m_{\ell\ell} > 10$
jet-corrected-track-E_T^{miss}	$E_T^{\text{miss}} > 20$
General selection	$p_T^{jet} > 70$ (60) lead (sub-lead) $N_{\text{b-jet}} = 0$ (run on all jets before track confirmation) $p_T^{\text{tot}} < 20$ $Z/\gamma^* \rightarrow \tau\tau$ veto (Collinear approx. $m_{\tau\tau} < 50$ GeV)
VBF topology	$m_{jj} > 1250$ and $\lvert\eta_j\rvert > 2.0$, opposite hemisphere No jets ($p_T > 30$) in rapidity gap Require both ℓ in rapidity gap
$H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ topology	$m_{\ell\ell} < 60$ $\Delta\phi_{\ell\ell} < 1.8$ $m_T < 1.07 \cdot m_H$

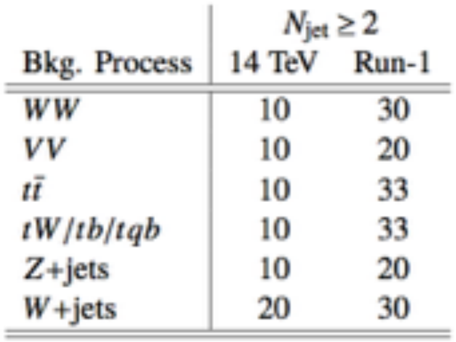
Tight selection to deal with PU

Table 1: Selection criteria used for the 14 TeV analysis. Pre-selection applies to all N_{jet} modes. The rapidity gap is the y range spanned by the two leading jets. The energy and p_T thresholds are in units of GeV.

Systematic Uncertainties

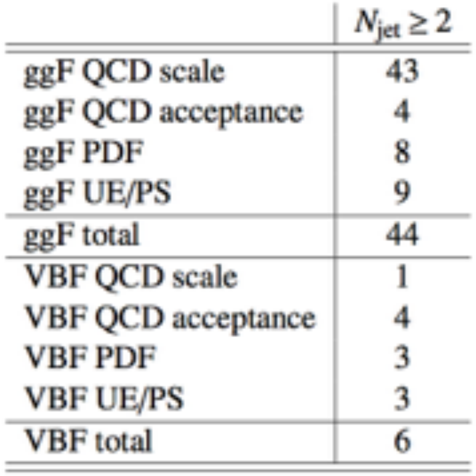
$$\mu = \frac{N_{\rm exp} - N_{\rm bkg}}{N_{\rm sig}}.$$

$$\text{Significance} = \frac{N_{\rm sig}}{\sqrt{N_{\rm bkg} + \sum_{i=0}^{\rm bkg} \sigma_{i,\rm bkg}^2}}.$$



Bkg. Process	$N_{\rm jet} \geq 2$ 14 TeV	 Run-1
WW	10	30
VV	10	20
$t\bar{t}$	10	33
$tW/tb/tqb$	10	33
Z+jets	10	20
W+jets	20	30

Table 5: The total systematic uncertainty (in %) for the background processes. The uncertainties used in the Run-1 analysis [6] results are quoted.



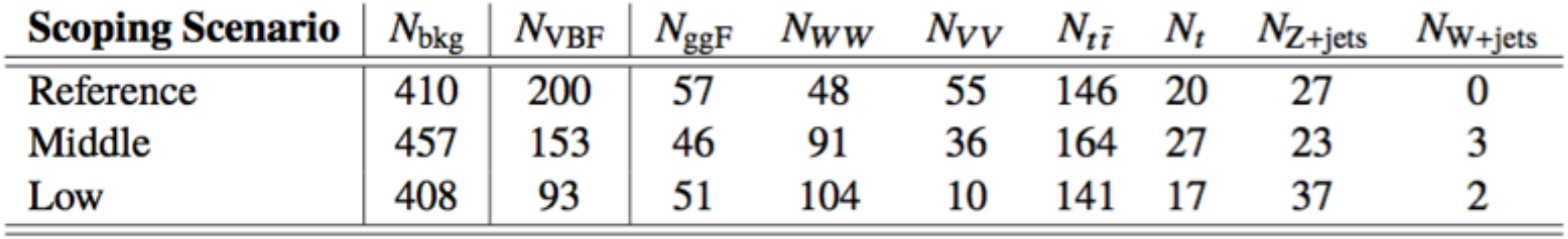
	$N_{\rm jet} \geq 2$
ggF QCD scale	43
ggF QCD acceptance	4
ggF PDF	8
ggF UE/PS	9
ggF total	44
VBF QCD scale	1
VBF QCD acceptance	4
VBF PDF	3
VBF UE/PS	3
VBF total	6

Table 11: Current theoretical uncertainties (in %) for the 8 TeV analysis. The uncertainties are split into the QCD scale and acceptance uncertainties, PDF and UE/PS uncertainties.

Results are shown with following signal (VBF & ggF) uncertainties:

1) *No signal unc.*
2) *1/2 of the Run-1 unc.*
3) *Run-1 unc.*

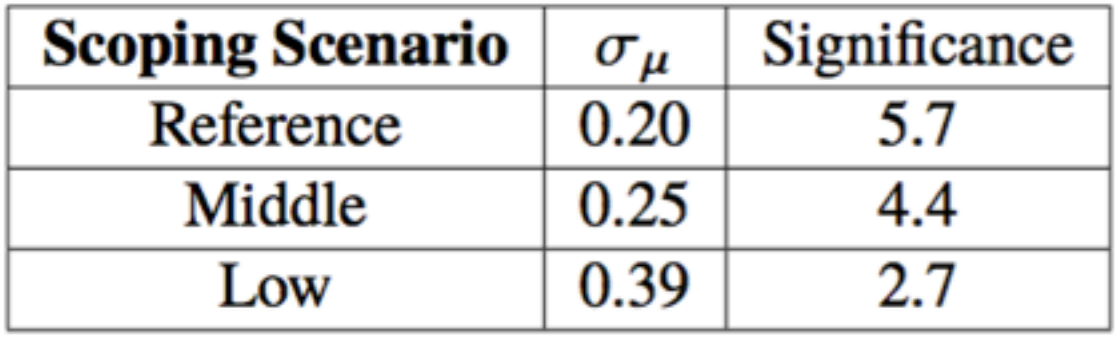
Results



Scoping Scenario	N_{bkg}	N_{VBF}	N_{ggF}	N_{WW}	N_{VV}	$N_{t\bar{t}}$	N_t	$N_{\text{Z+jets}}$	$N_{\text{W+jets}}$
Reference	410	200	57	48	55	146	20	27	0
Middle	457	153	46	91	36	164	27	23	3
Low	408	93	51	104	10	141	17	37	2

Table 6: The signal and background event yields as expected at 14 TeV, with pile-up of 200 inelastic collisions per bunch crossing and 3 ab^{-1} of data after all selection requirements in Table 3 for each of the three scoping scenarios.

S/B~0.49 (gold)



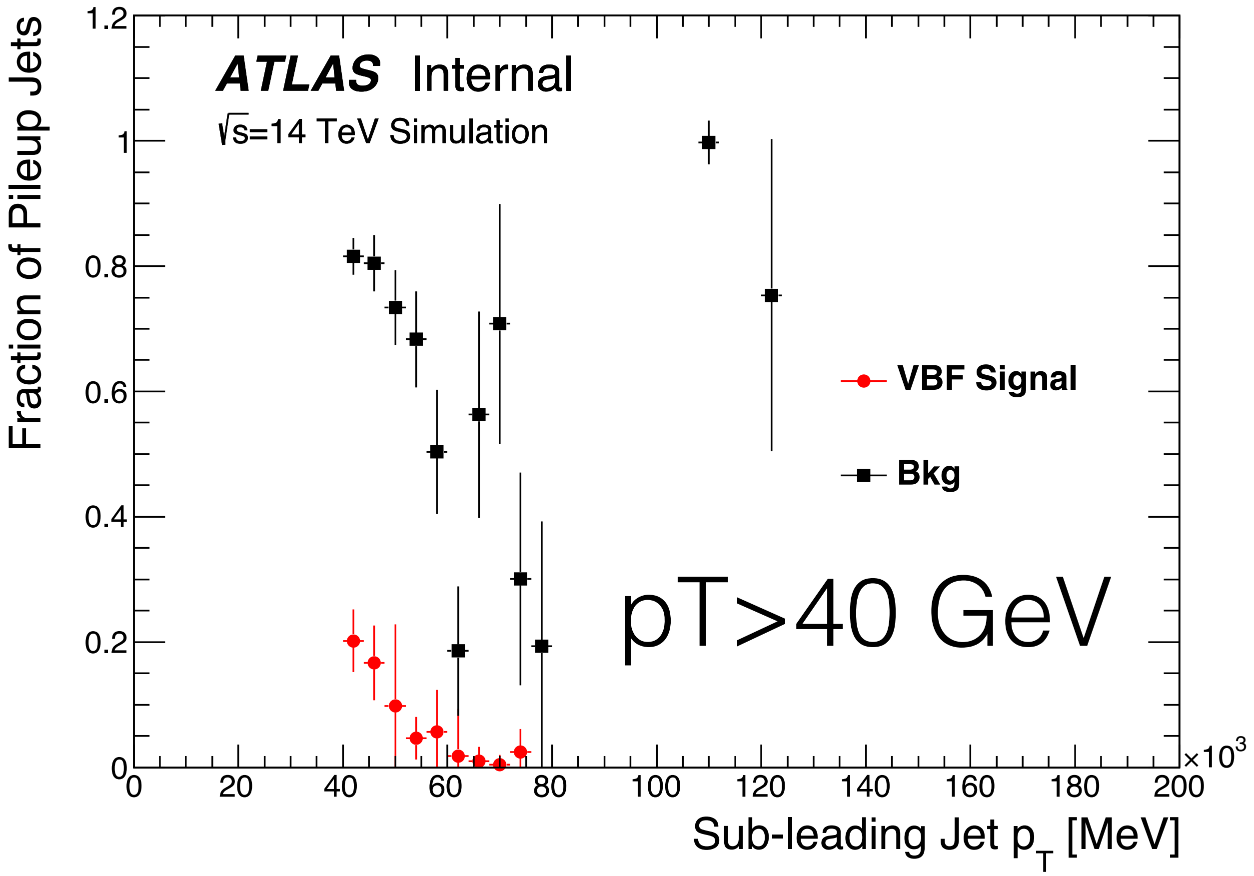
Scoping Scenario	σ_μ	Significance
Reference	0.20	5.7
Middle	0.25	4.4
Low	0.39	2.7

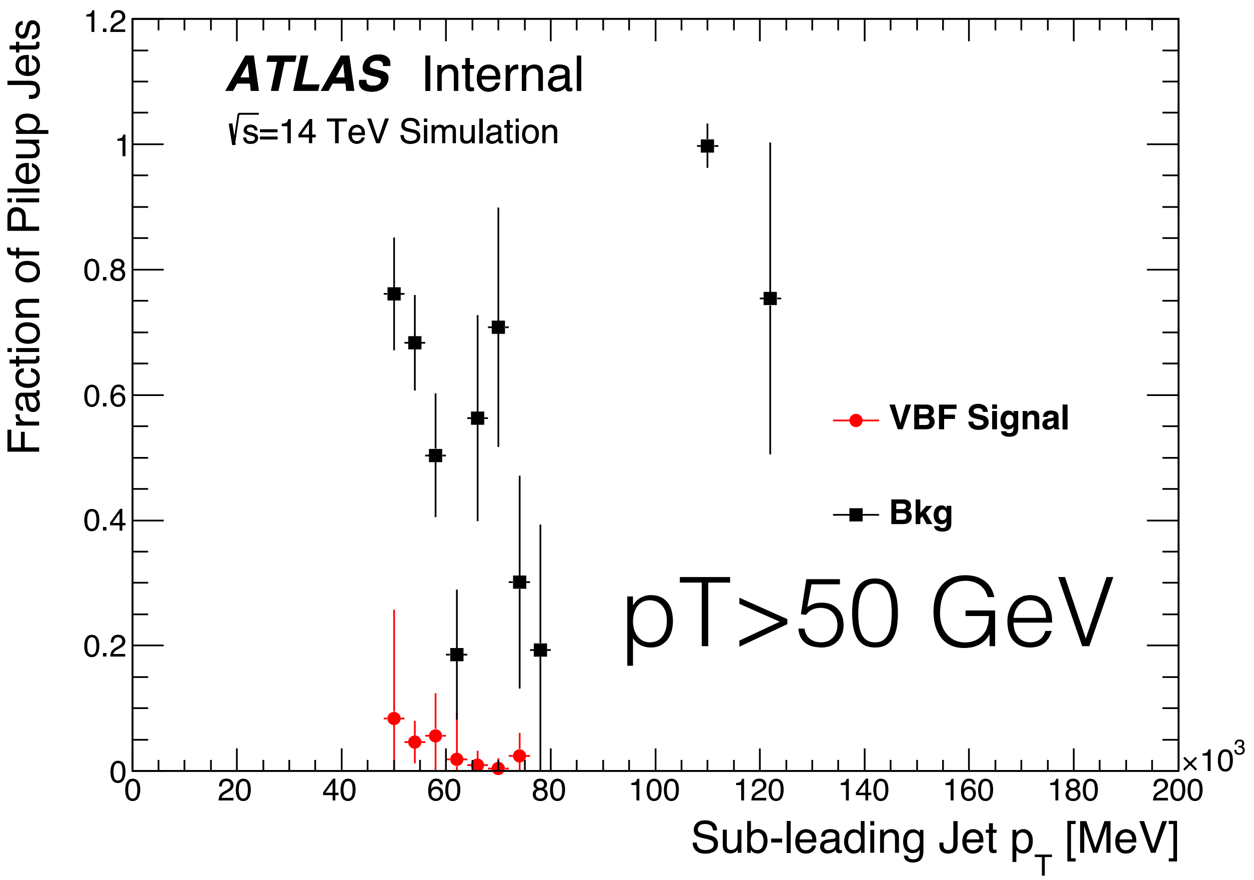
Table 7: The expected σ_μ and significance are shown for the three scoping scenarios considering the same level of theoretical systematic uncertainties on the VBF and ggF Higgs production taken from Table 4.

- Gains of 36 (49)% for the Middle (Reference) relative to the Low in signal strength uncertainty
- Analysis was optimized on signal strength NOT on significance.

Loosen Selections

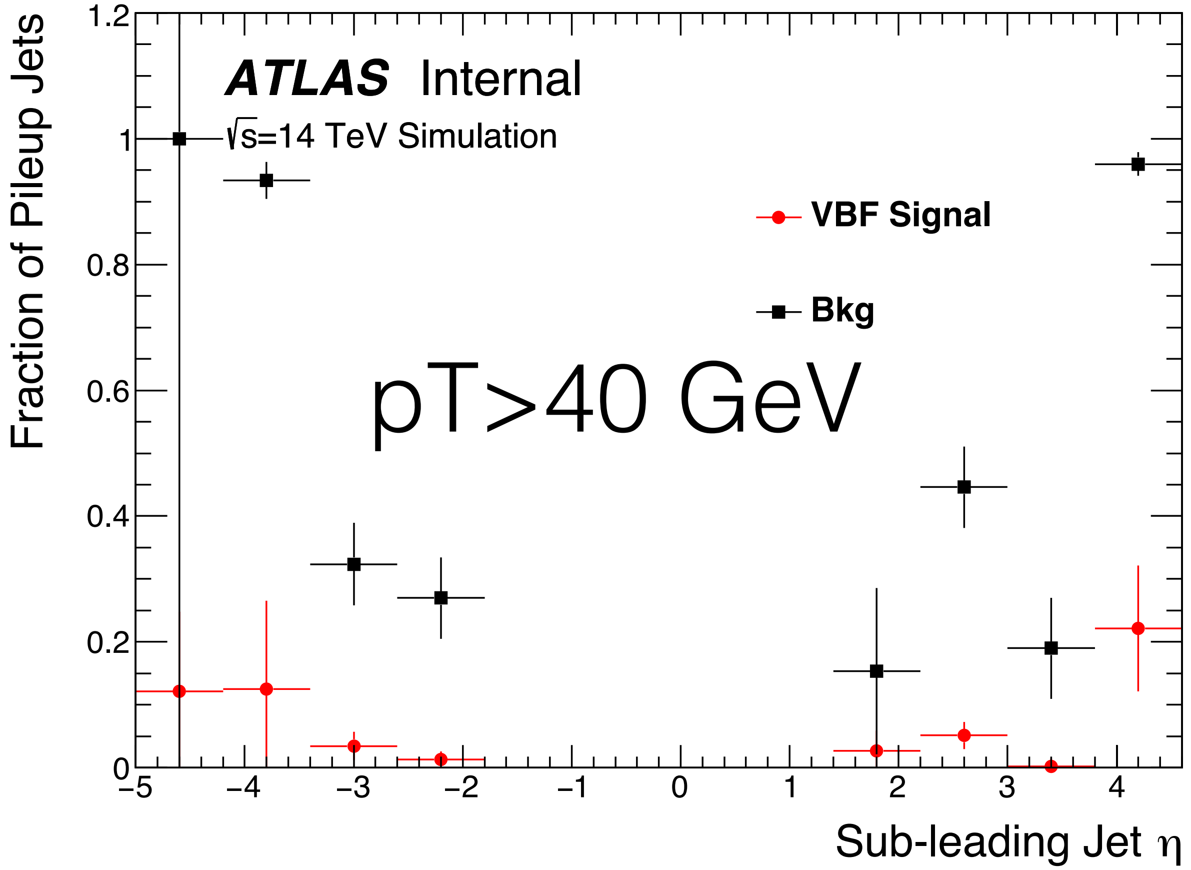
- Mjj selection is removed and jet pT selection is lowered to 40 or 50 GeV
- The fraction of HS and PU jets is shown for the signal and backgrounds
- Fraction of pileup jets is reduced with the higher jet threshold

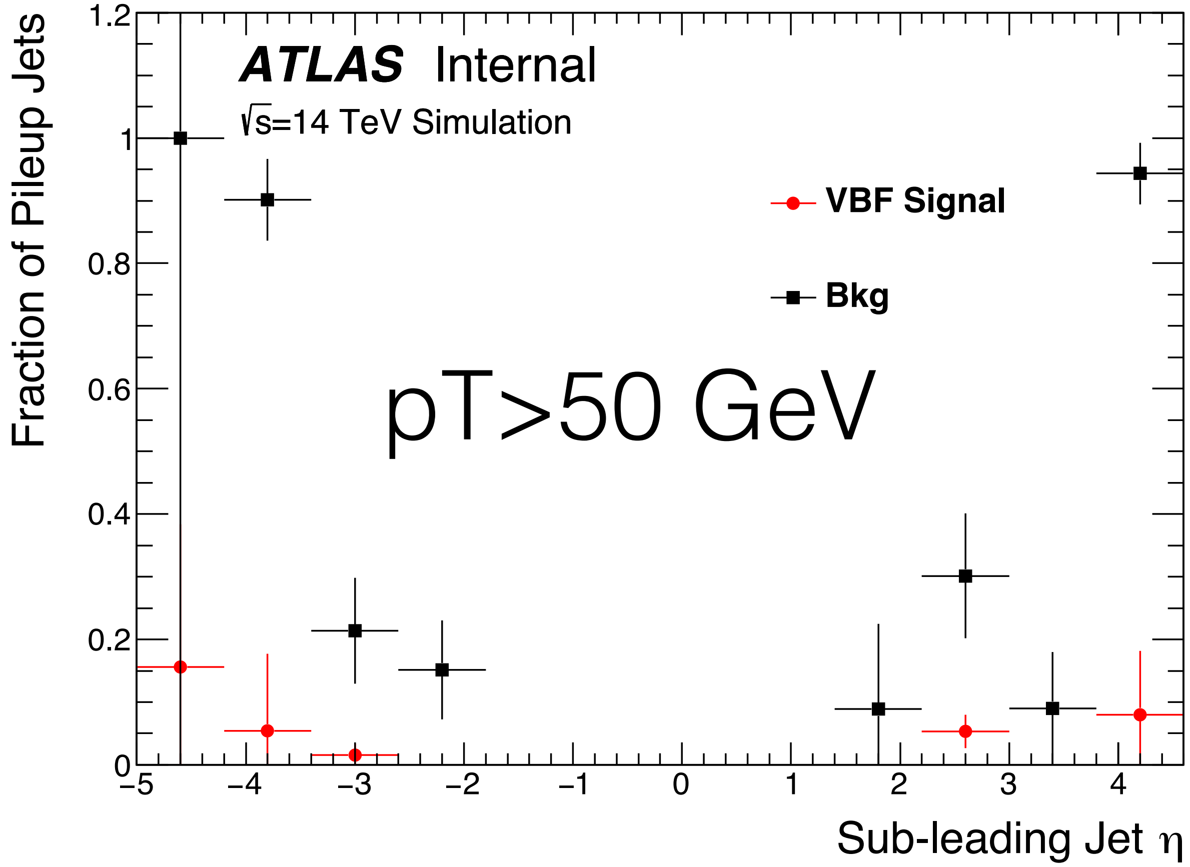




Loosen Selections

- Mjj selection is removed and jet pT selection is lowered to 40 or 50 GeV
- Fraction of pileup jets is reduced with the higher jet threshold
- Fraction of PU jets increases beyond |eta|>3.8





sFCal Plans

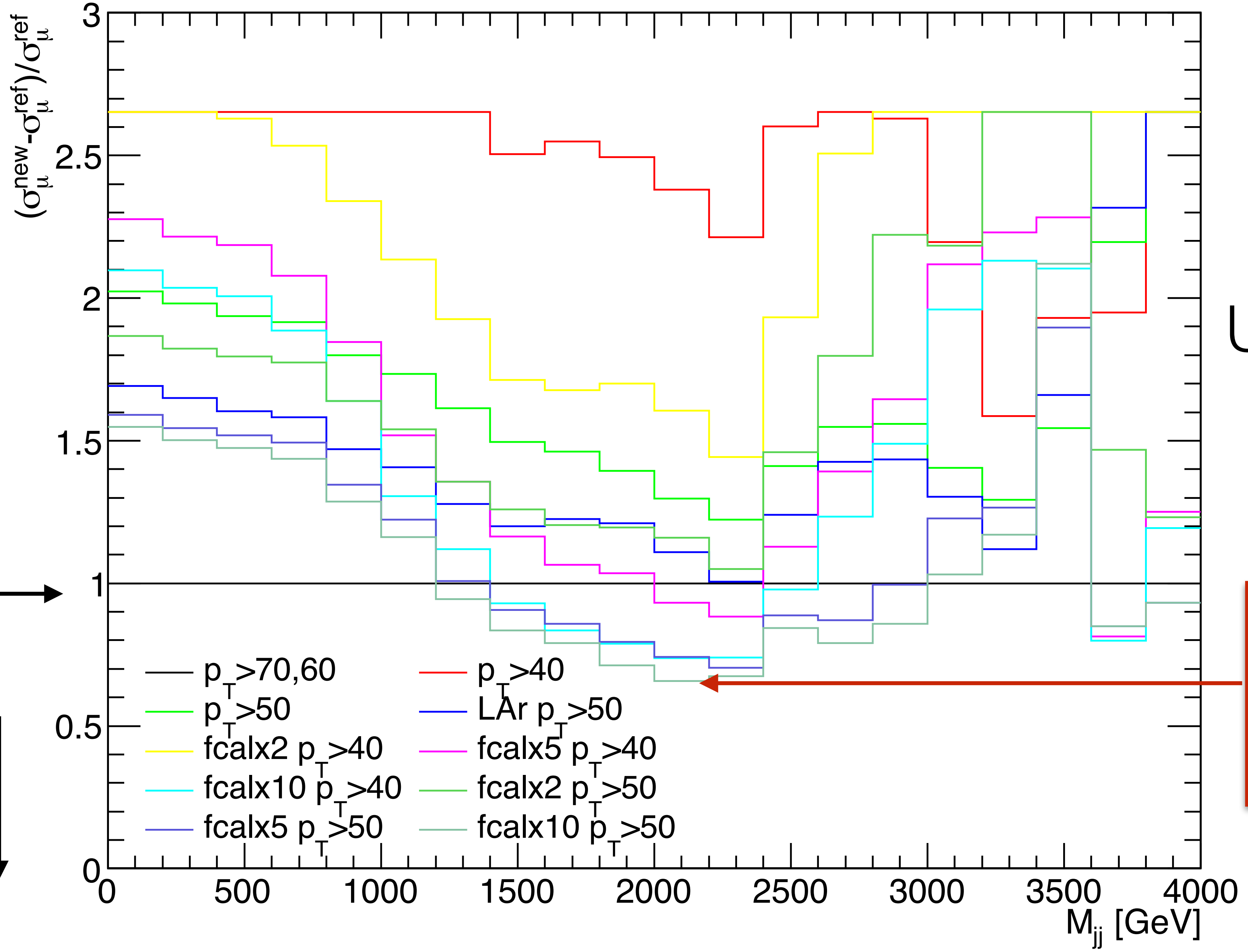
- Plan to optimize the selection cuts for the best mu-error with the following improvements on the “Reference” scenario
  - Reduction in PU jets of 50%, 80%, and 90% with 100% HS jet efficiency in the region of 3.2<|η|<4.5
  - **Results on next slide**

sFCal Changes

Worse mu-error

Reference Analysis

Better mu-error



No Signal Uncertainties included

Best Improvement fcalx10

- Loosen the jet pT requirements to 40, 50 GeV & optimize on Mjj
- sFCal with 5xPU jet rejection improves on the current analysis by ~28%. 10x with jet pT>50 GeV has up to 35% improvement in mu-error. **Need to reach ~factor of 5 PU jet rejection to have a large impact**

Conclusions

- **Need to reach ~factor of 5 PU jet rejection to have a large impact**

- sFCal having a factor of 5 rejection gives ~28% improvement in mu-error

- Factor of 10 rejection of PU jets increases improvement to 35%.

- Little concerned that removing |eta|>3.8 jets would also improve the reference analysis. Then the sFCal improvements would be smaller.

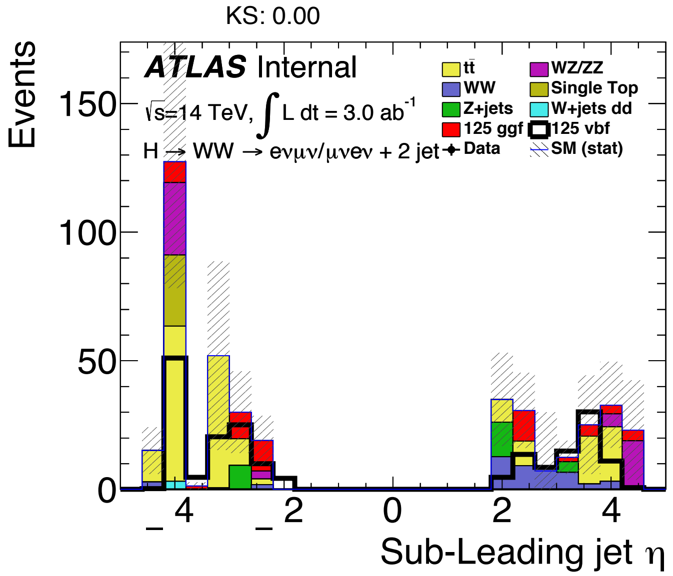
Backup

Preliminary sFCal Upgrade Impact

- Explored the potential improvements in PU jet rejection of a factor of 2, 5, and 10 for jets with 3.2<|eta|<3.8. So PU jet acceptance of 2%, 1%, 0.4%, and 0.2%.
- Caveats:
  - Statistics are low
  - After the tight Mjj selection, most of the “tagging”-jets in the forward region are HS jets. Improvement may be possible with looser selections
  - The (Central jet veto) veto on jets between the tagging jets are mostly more central |eta|<3.2
- QCD WW background, which comes often from 1HS and 1PU jet, is reduced by 30% in the x10 scenario. It is 6% of the total bkg.

Reference Scenario
Full Signal uncertainties

sFCal	Sign.	mu_err	%
Nominal	5.7	0.20	N/A
x2	5.73	0.199	0.5
x5	5.81	0.196	2.0
x10	5.90	0.193	3.6



Preliminary sFCal Upgrade Impact

Reference Scenario uncertainties

mu_err	%
0.20	N/A
0.199	0.5
0.196	2.0
0.193	3.6

- Explored the potentia rejection of a factor c eta|<3.8. So PU jet ac 0.2%.
- Caveats:
  - Statistics are low
  - After the tight Mjj jets in the forwarc Improvement may selections
  - The (Central jet v tagging jets are r
- QCD WW background, which comes often from 1 HS and 1PU jet, is reduced by 30% in the x10 scenario. It is 6% of the total bkg.

1. Study does not optimize the analysis for the sFCal changes
2. Only considers the region up to 3.8 in eta.