Search for Top FCNC with H → $\gamma\gamma$ at CMS

2021 Taiwan HEP Meeting

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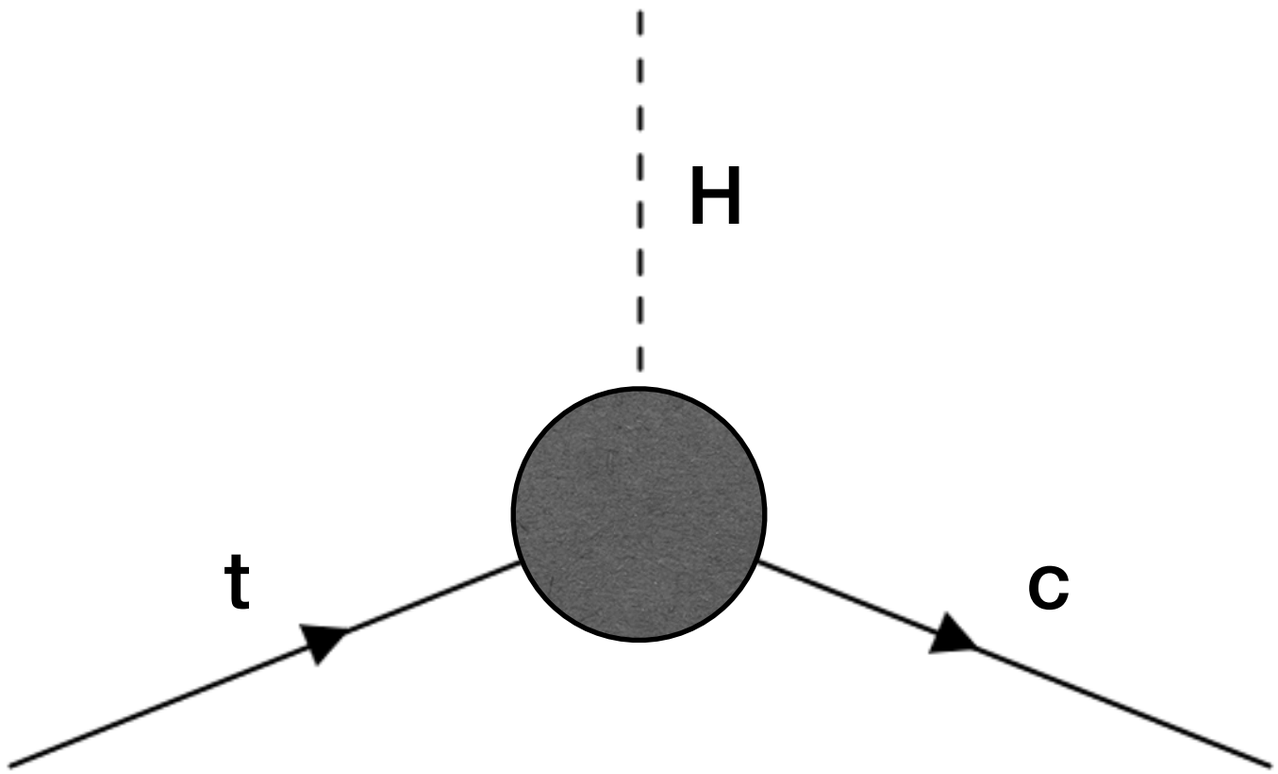
22 January, 2021

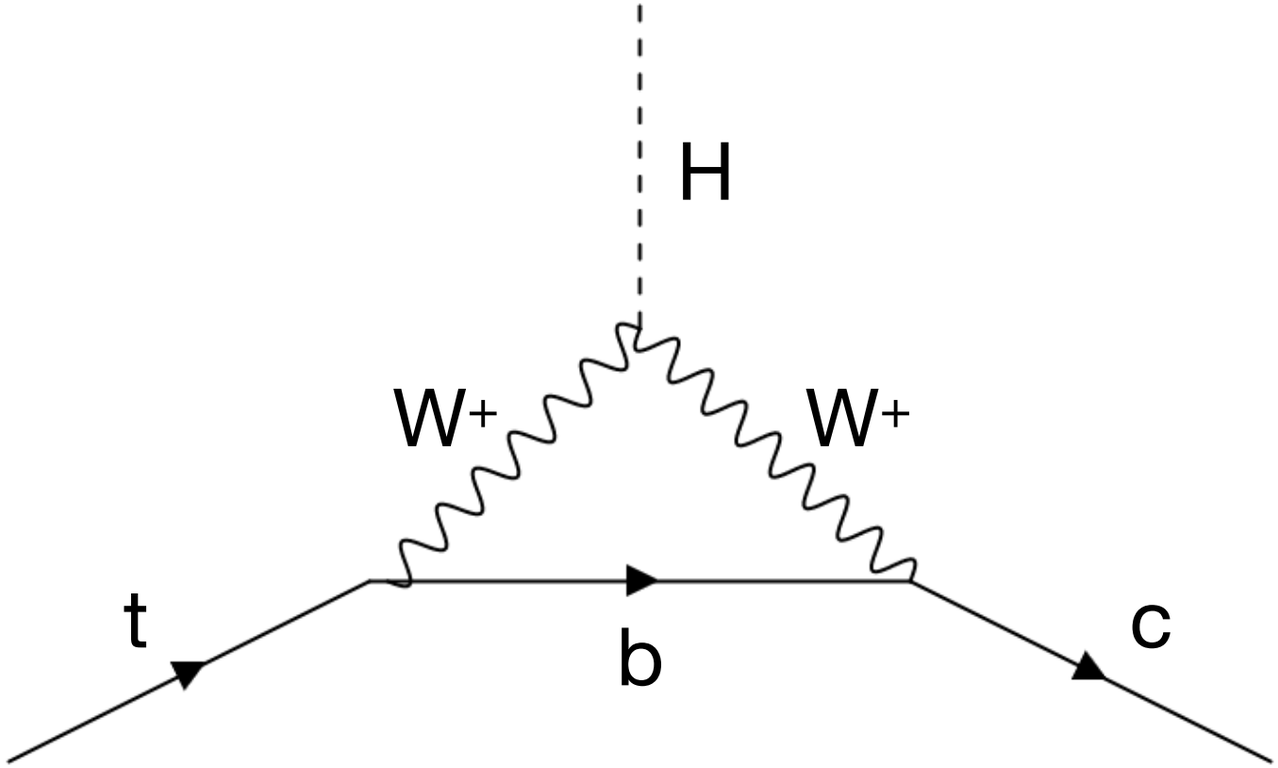
Flavor-Changing Neutral Current

- What is it?
  - “A hypothetical interaction that changes the flavor of a fermion without altering its electric charge”



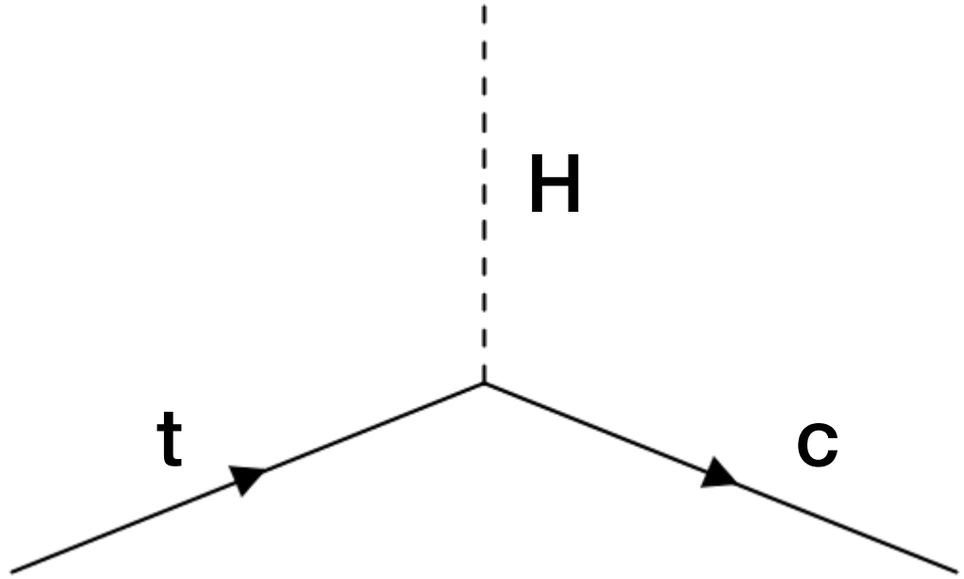
Flavor-Changing Neutral Current

- FCNC in the Standard Model (SM)
  - Forbidden at tree level
  - Loop level highly suppressed by the GIM mechanism
  - Branching fractions are predicted to be extremely small (10^{-14})



Flavor-Changing Neutral Current

- t→qH FCNC in the physics beyond the SM (BSM)
  - Well-motivated by various BSM theories
    - Warped extra dimensions
    - Composite Higgs scenarios
    - Flavor violating 2HDM models
    - Quark-singlet models
    - R-parity violating SUSY



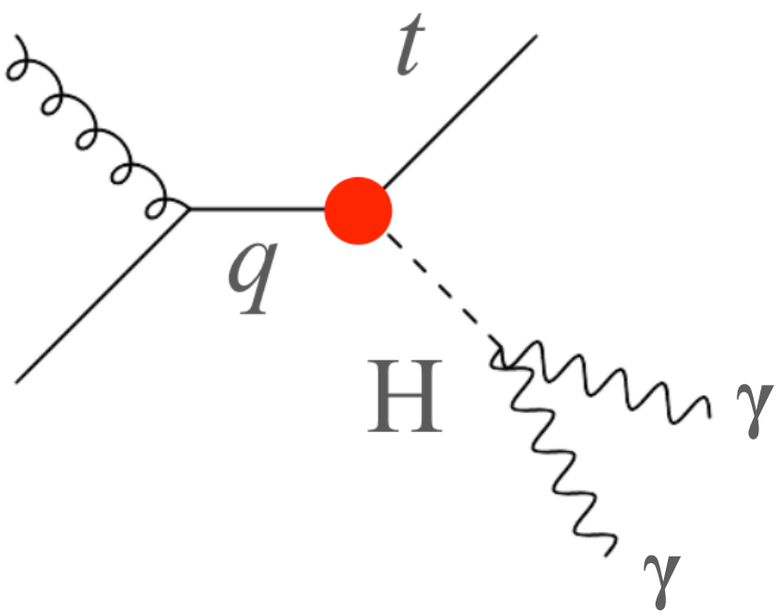
- Branching fraction for t→Hc could be on the order of 10^{-4}
- A possible “Discovery Story” within LHC data

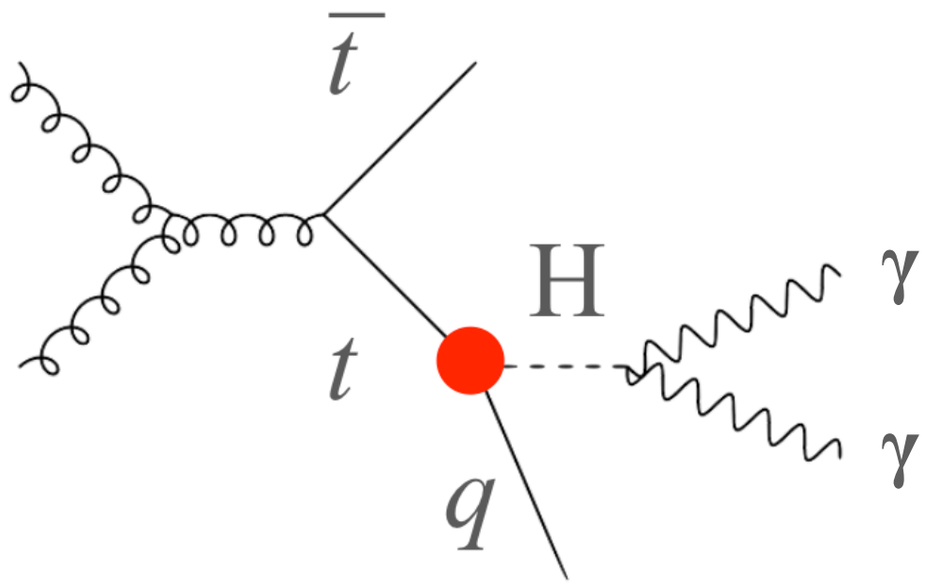
Analysis Overview

- Search for the Higgs boson as an FCNC in the $\gamma\gamma$ decay channel
- Consider both single top (ST) and tt (TT) FCNC production

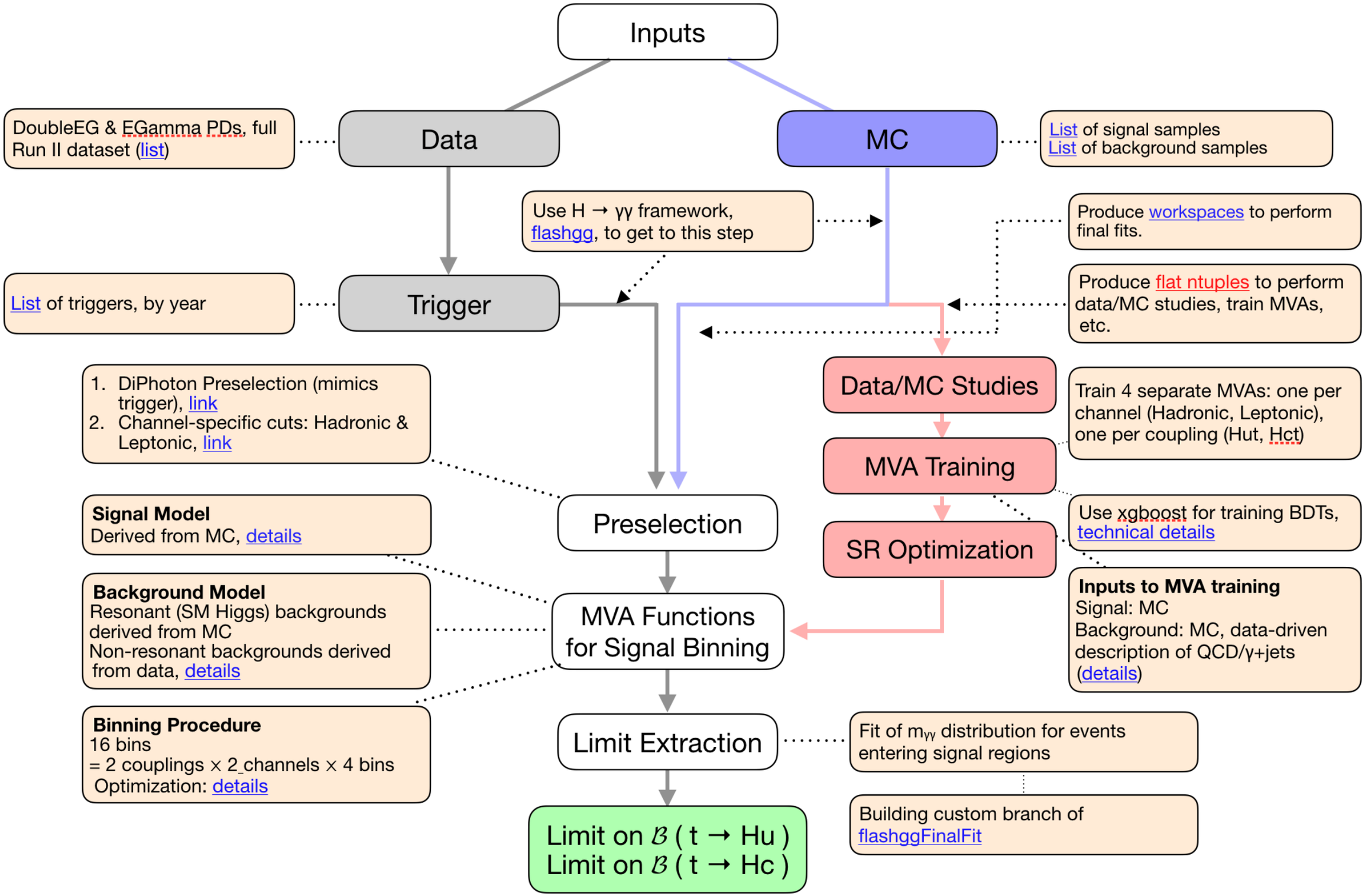
  to set limits on branching fractions, $\mathfrak{B}(t\to Hu)$ and $\mathfrak{B}(t\to Hc)$

- Use full Run-II dataset (2016-2018) for result



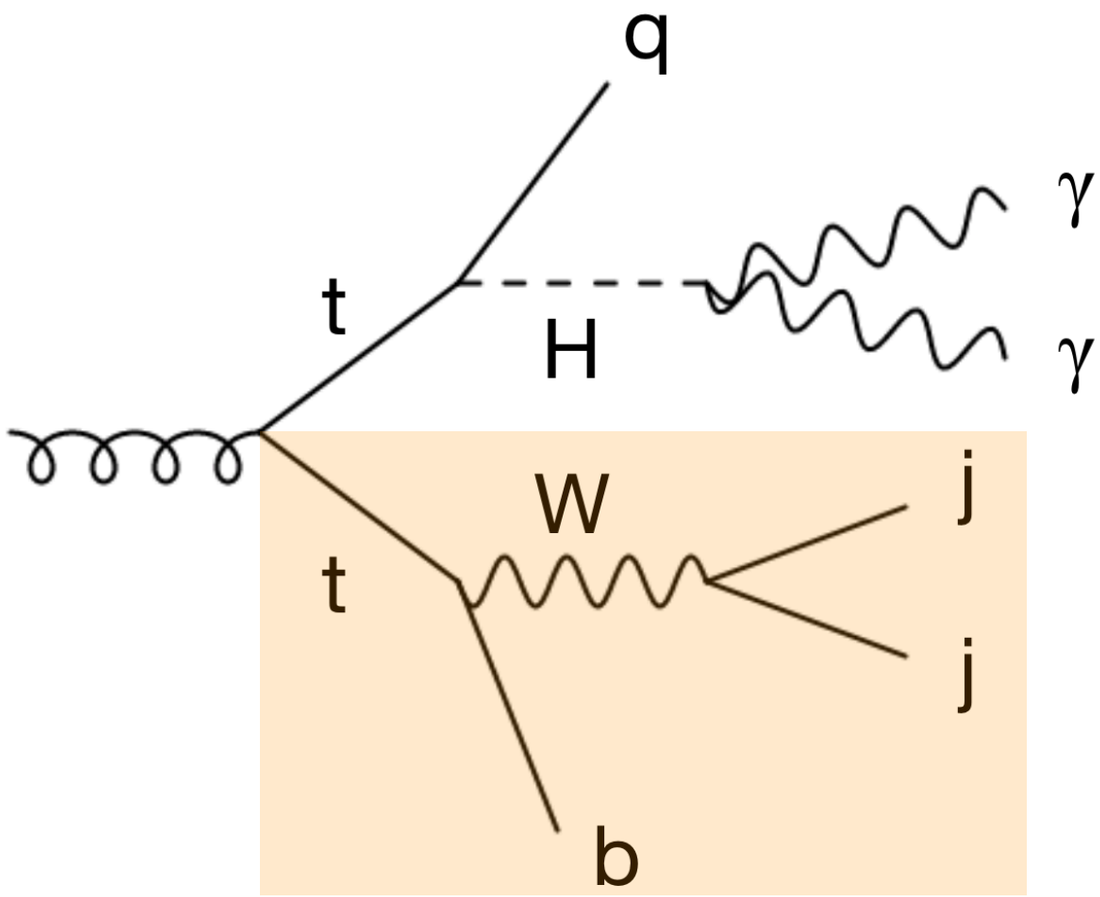


Workflow


Inputs
Data
MC
DoubleEG & EGamma PDs, full Run II dataset (list)
List of signal samples
List of background samples
Use H → γγ framework, flashgg, to get to this step
Produce workspaces to perform final fits.
List of triggers, by year
Trigger
Produce flat ntuples to perform data/MC studies, train MVAs, etc.
Data/MC Studies
1. DiPhoton Preselection (mimics trigger), link
2. Channel-specific cuts: Hadronic & Leptonic, link
Train 4 separate MVAs: one per channel (Hadronic, Leptonic), one per coupling (Hut, Hct)
MVA Training
Signal Model
Derived from MC, details
Use xgboost for training BDTs, technical details
SR Optimization
Preselection
Inputs to MVA training
Signal: MC
Background: MC, data-driven description of QCD/γ+jets (details)
Background Model
Resonant (SM Higgs) backgrounds derived from MC
Non-resonant backgrounds derived from data, details
MVA Functions for Signal Binning
Binning Procedure
16 bins
= 2 couplings × 2_channels × 4 bins
Optimization: details
Limit Extraction
Fit of $m_{\gamma\gamma}$ distribution for events entering signal regions
Building custom branch of flashggFinalFit
Limit on $\mathcal{B}$ (t → Hu)
Limit on $\mathcal{B}$ (t → Hc)

Top Reconstruction Methods

- Motivation
  - QCD, γ+jets, $\gamma\gamma$+jets backgrounds are significant in analysis channels
- Methods
  - Mass constraints variables
  - Top Tagger BDT
  - Minimum χ2 method
  - Quadratic equation method
  - FCNC reconstruction neural network



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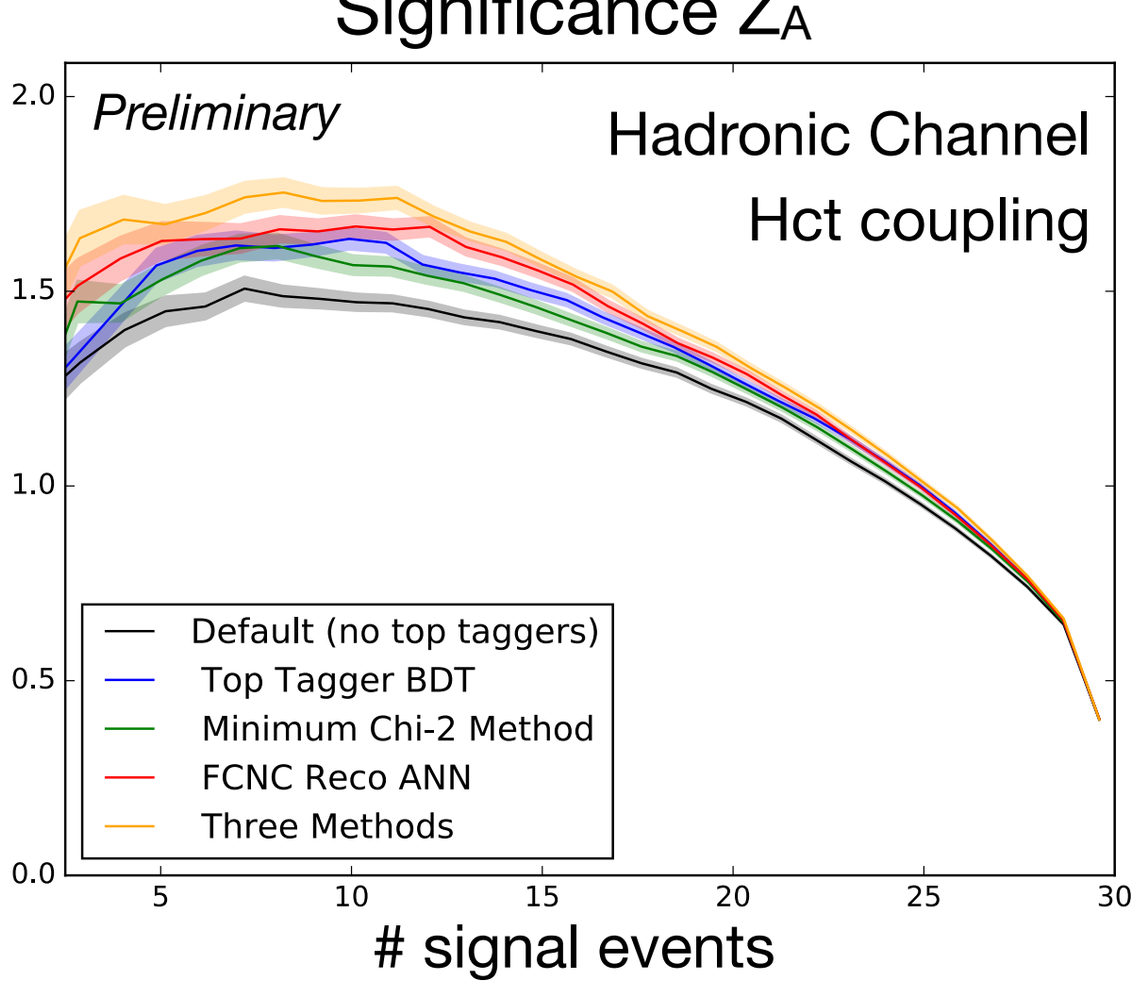
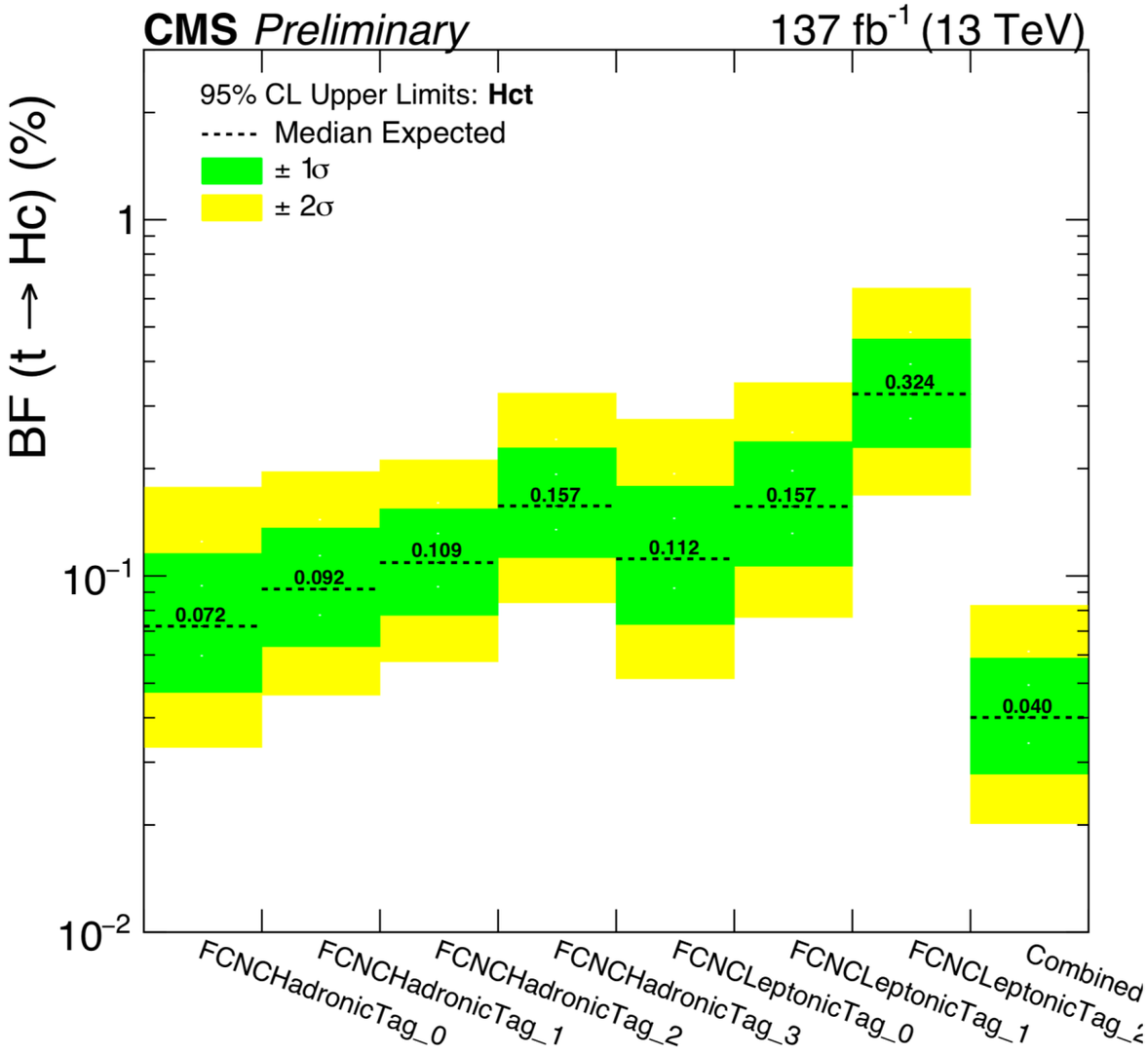
- Performance
  - Result in 20-30 % improvement in expected limits!

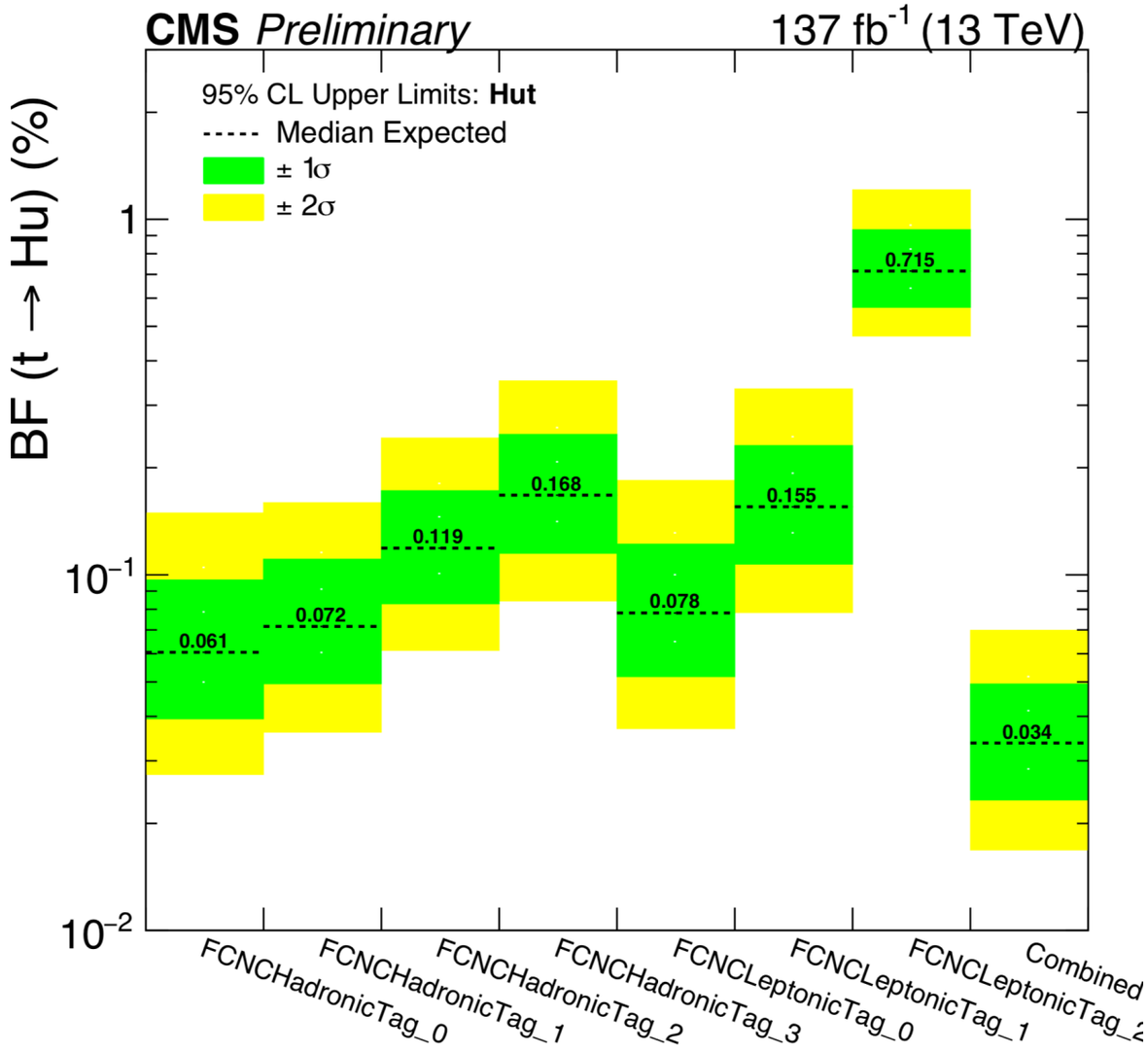


Expected Result

- Expected limits are a factor of ~3 better than the current best results

Analysis	$B(t \to Hu)$	$B(t \to Hc)$	Channels	$L(fb^{-1})$	Limit Type	Reference
ATLAS 2016	1.2×10^{-3}	1.1×10^{-3}	$b\bar{b}, \tau^+\tau^-, \gamma\gamma$, multilepton	36.1	Observed	JHEP 05 (2019) 123
TOP-20-007	3.4×10^{-4}	4.0×10^{-4}	$\gamma\gamma$	137	Expected	This Analysis





Summary

- Keep pushing the limits and updating new result!