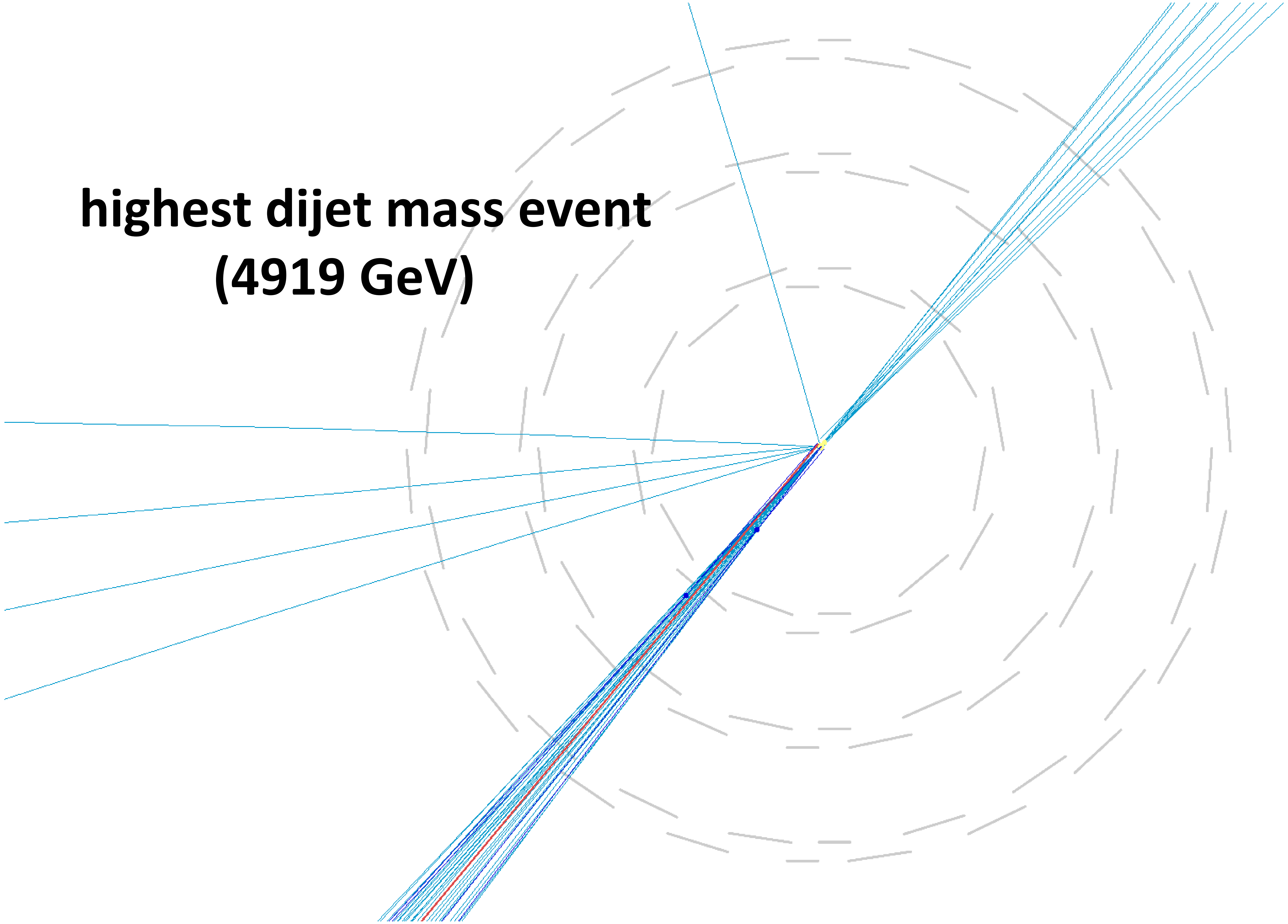


Search for new resonances decaying into boosted W, Z and H bosons at CMS

Caterina Vernieri (Fermilab), presented by Michael Krohn (University of Colorado)

2017 Meeting of the Division of Particles and Fields of the American Physical Society , 31 Jul-4 Aug 2017, Fermilab

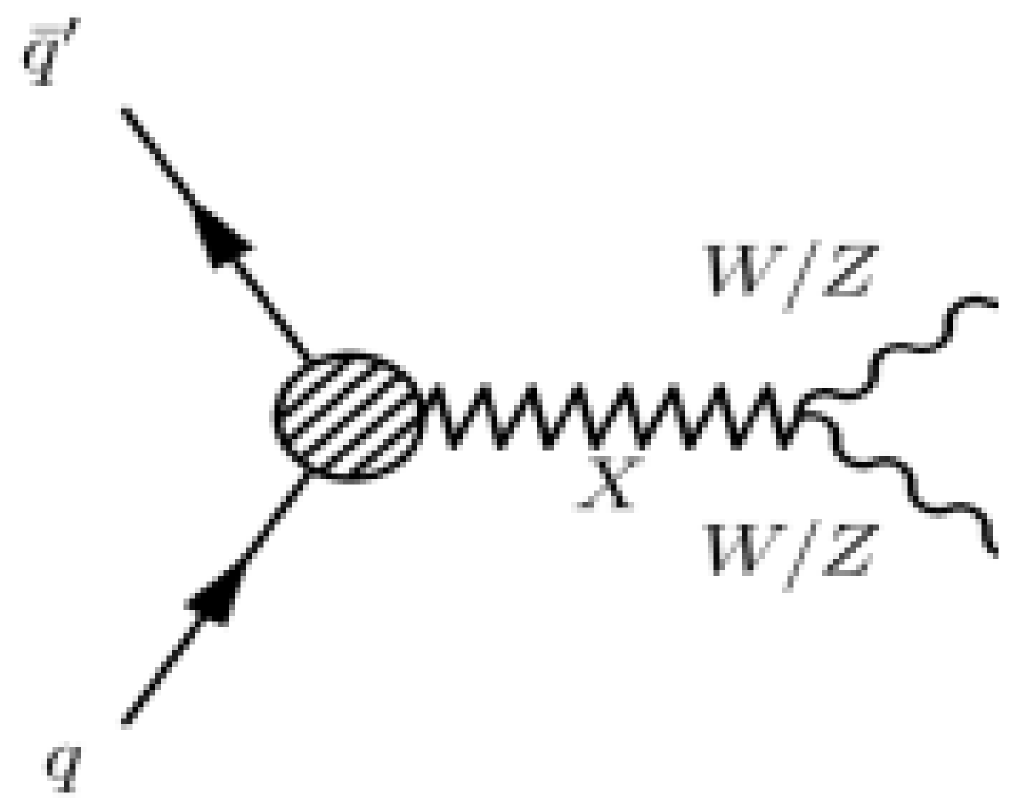
Why look for Diboson resonances?

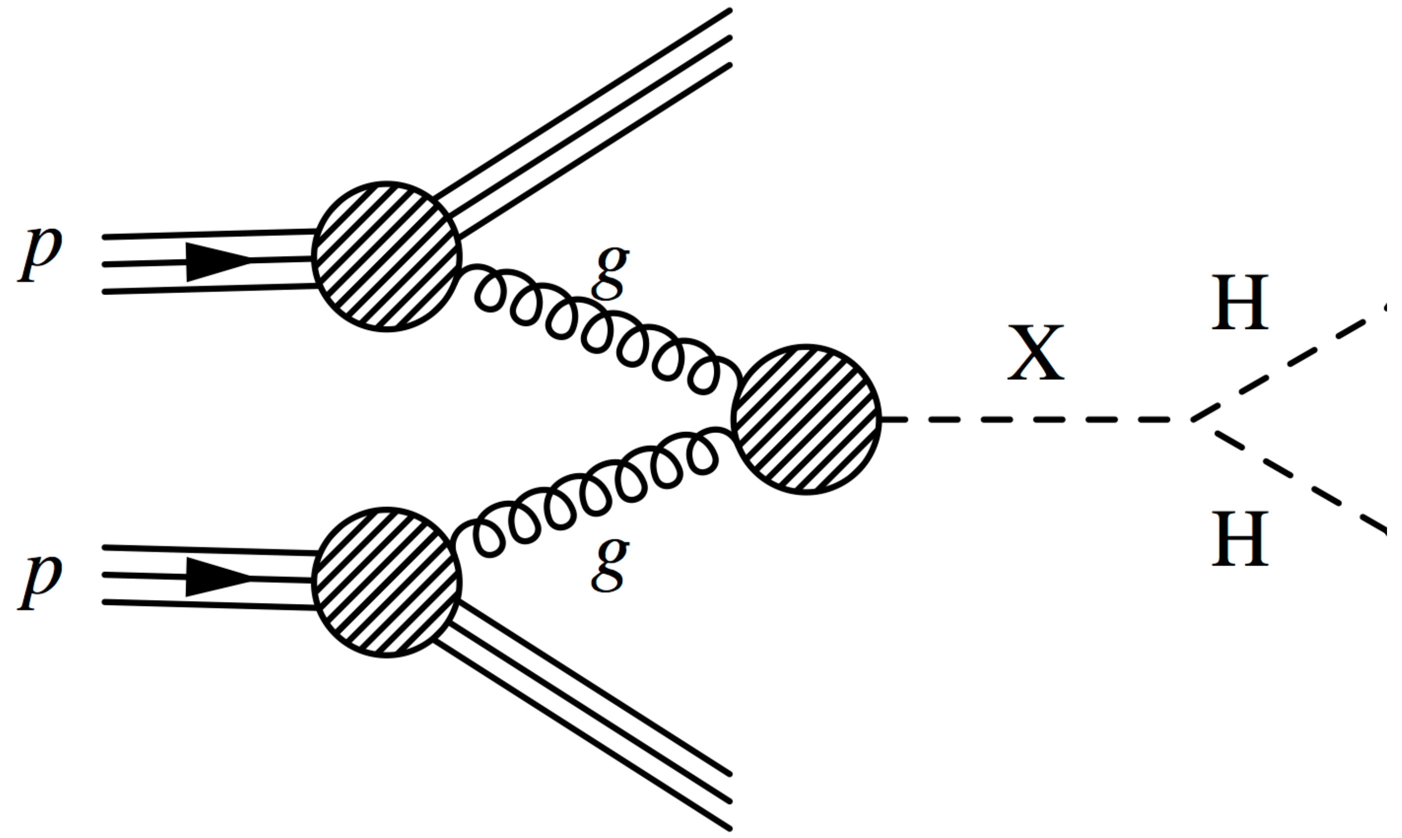
General searches for new physics connected to the gauge sector:

- coupled to W, Z and H bosons

Model independent analyses interpreted according to benchmark models:

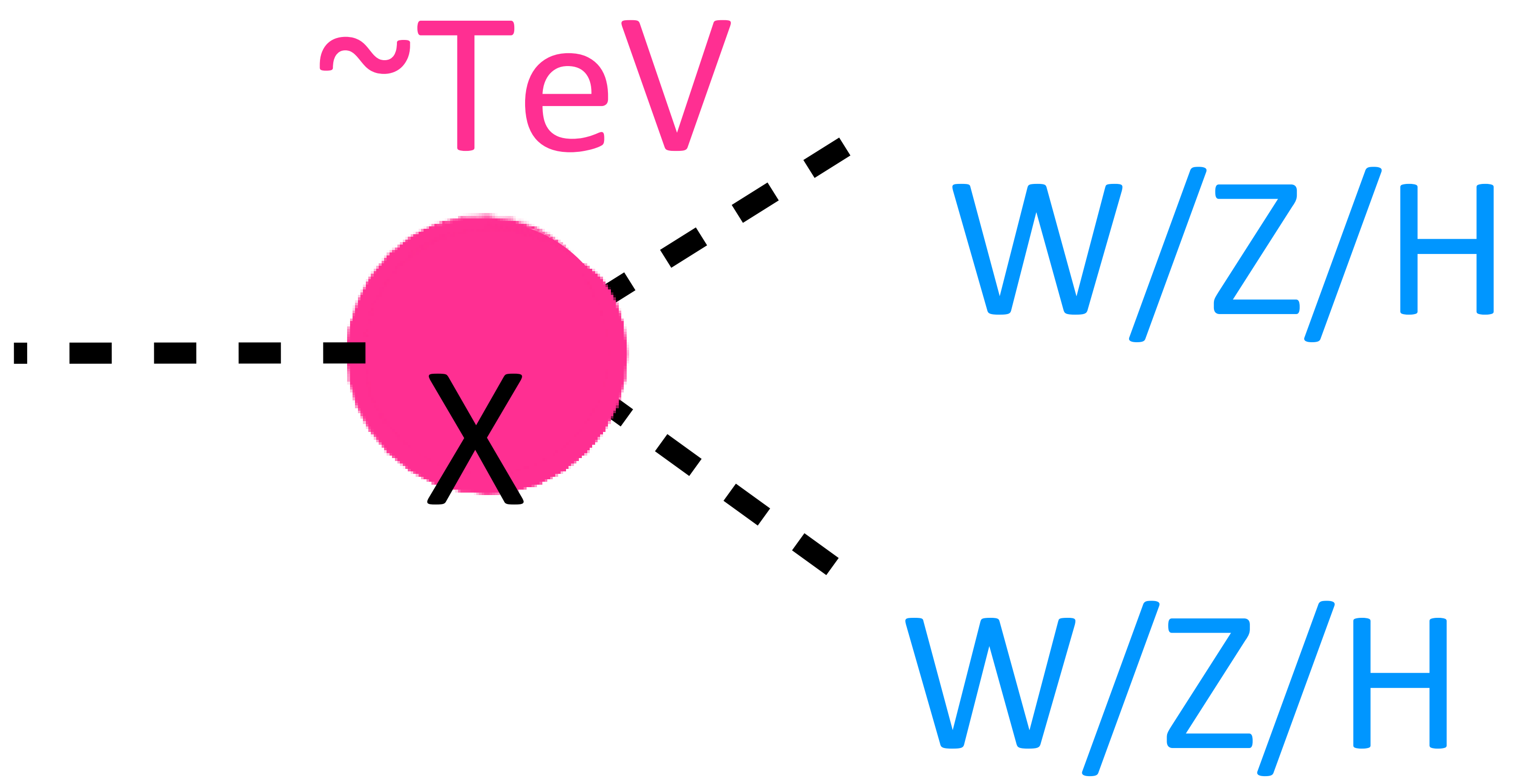
- **Warped Extra Dimension:**
  Integration of gravity in SM and solution to hierarchy problem
    - Prediction of a **spin-2** graviton or **spin-0** radion
- **Heavy Vector Triplet model:**
  Hierarchy of the Higgs boson mass:
    - Introduction of **spin-1** massive bosons (X^0,X^+,X^-)





Heavy resonances decaying to bosons

- Heavy new particles produce boosted SM bosons



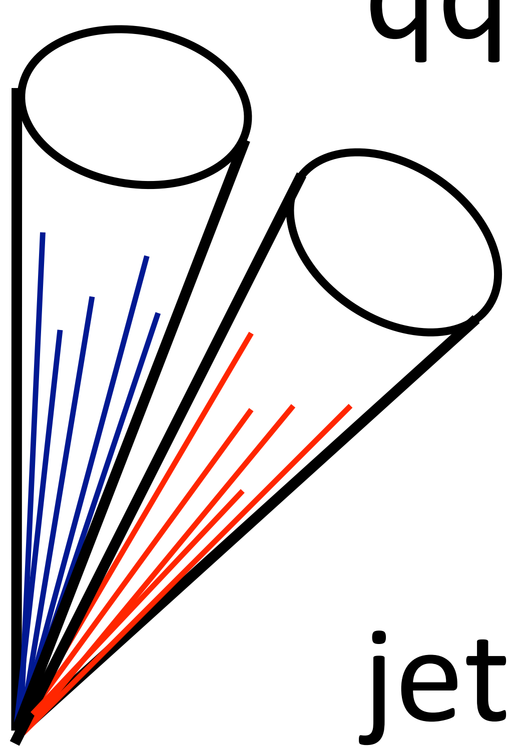
with p_T ~ few hundred GeV

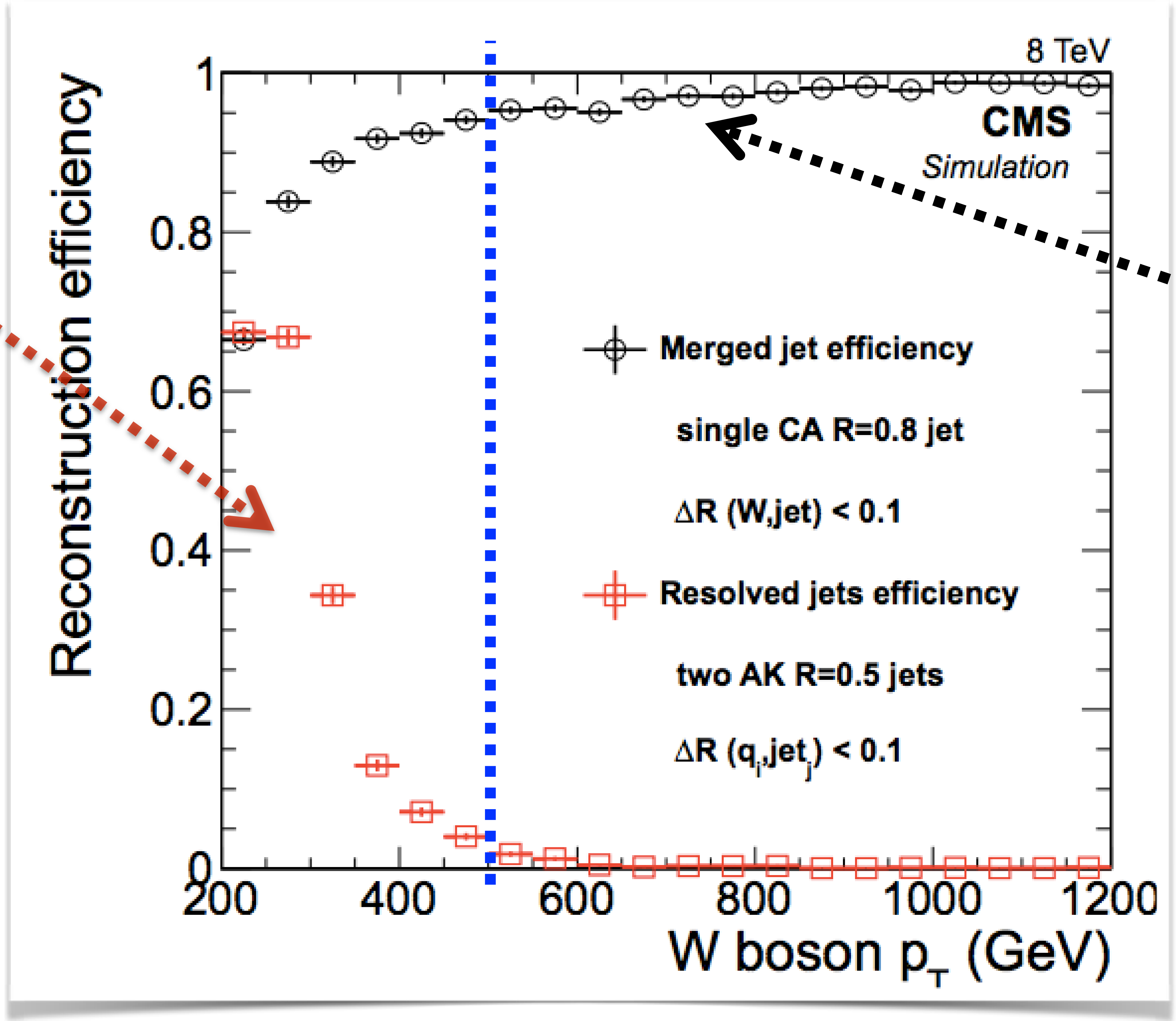
- Highest BR is from hadronic final states (W/Z/H→qq)
- Decay products from SM bosons are highly collimated

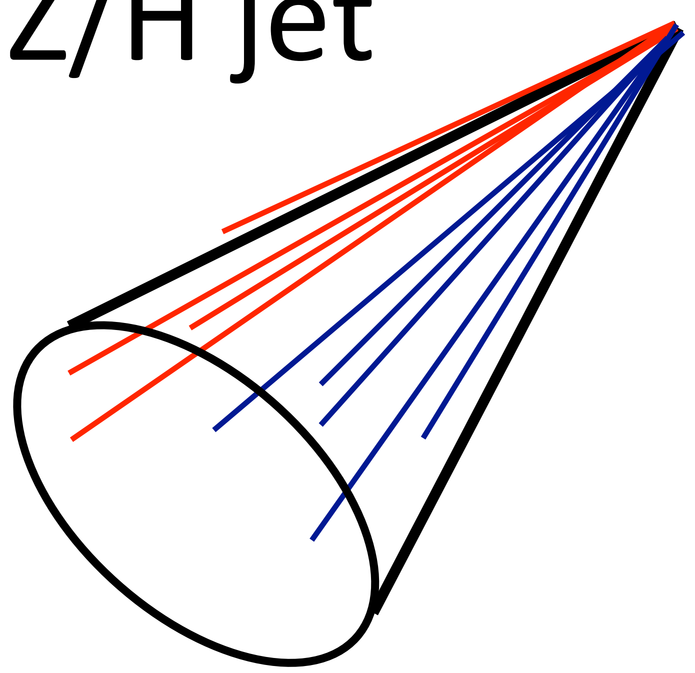
dR(qq) ~ 2m/p_T

Boosted bosons

Bosons produced with high p_T merge into single large-R jet (0.8 CMS)



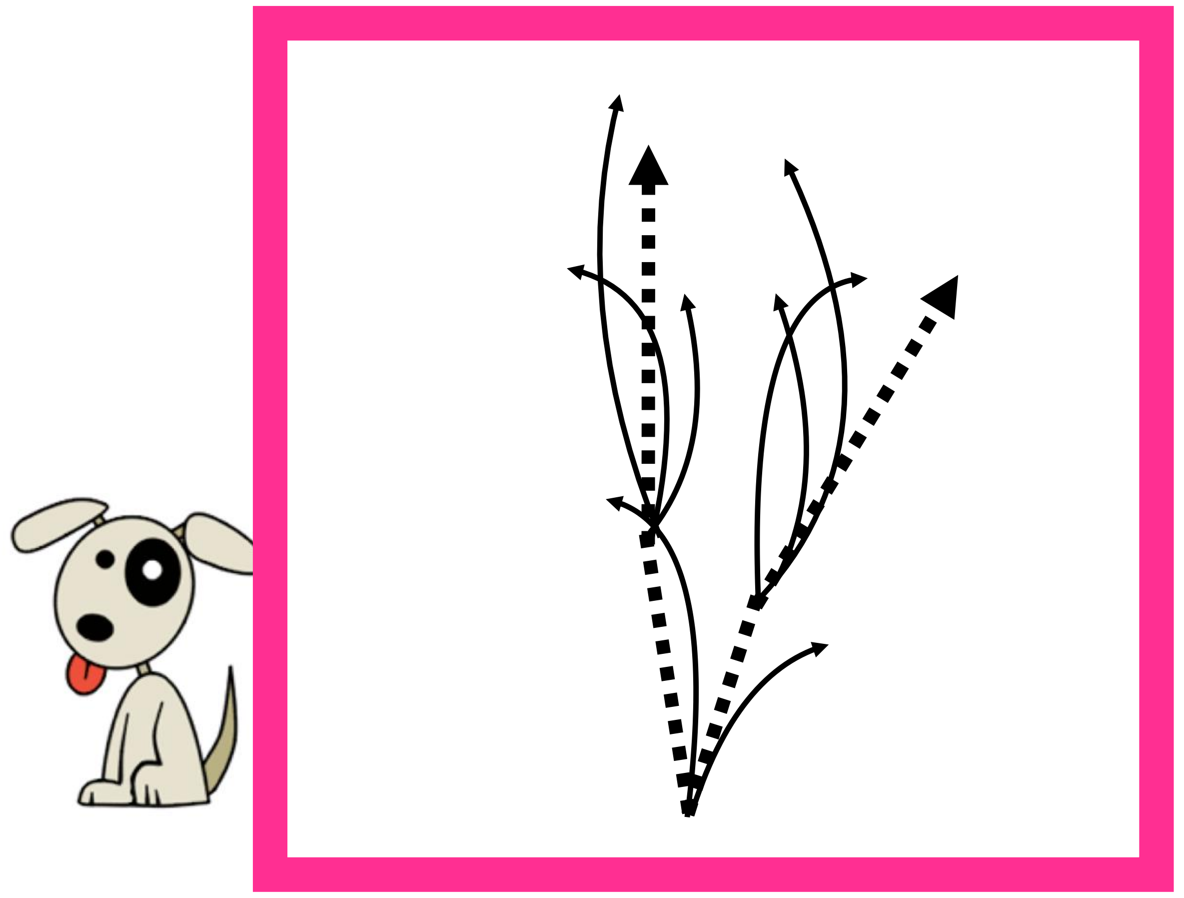




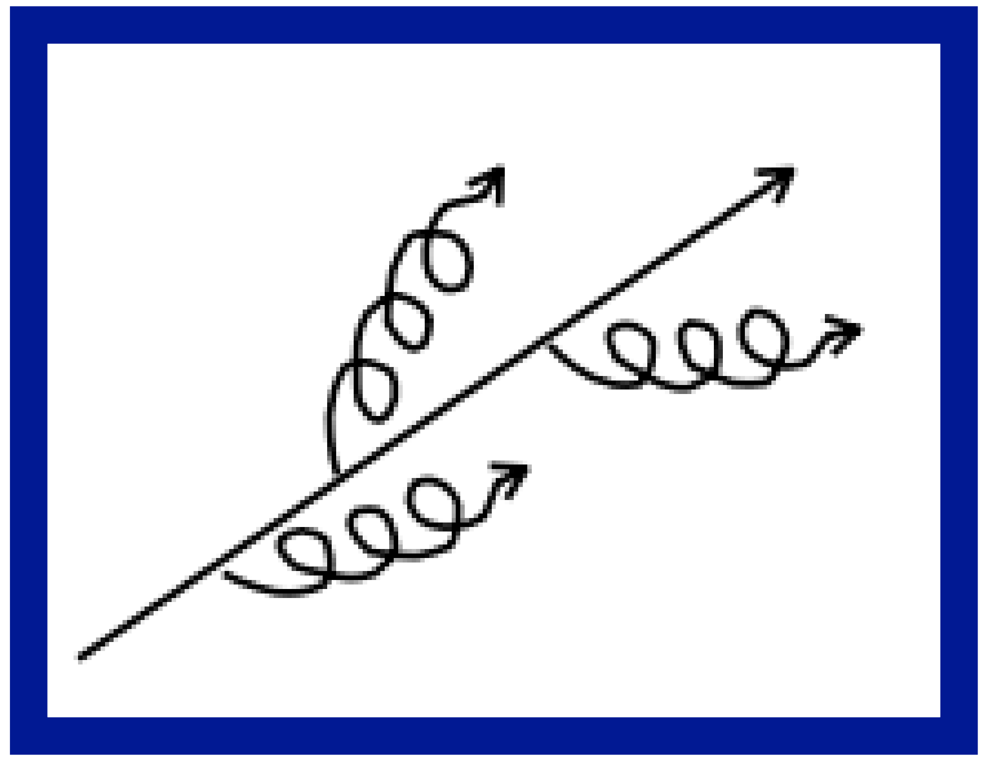
Boson tagging

The boosted W/Z/H($b\bar{b}$) signal is identified as large cone size jets:

- R=0.8
- **PUPPI** (PileUp Per Particle Id) is used to mitigate **pile up effects**



H/Z($b\bar{b}$)

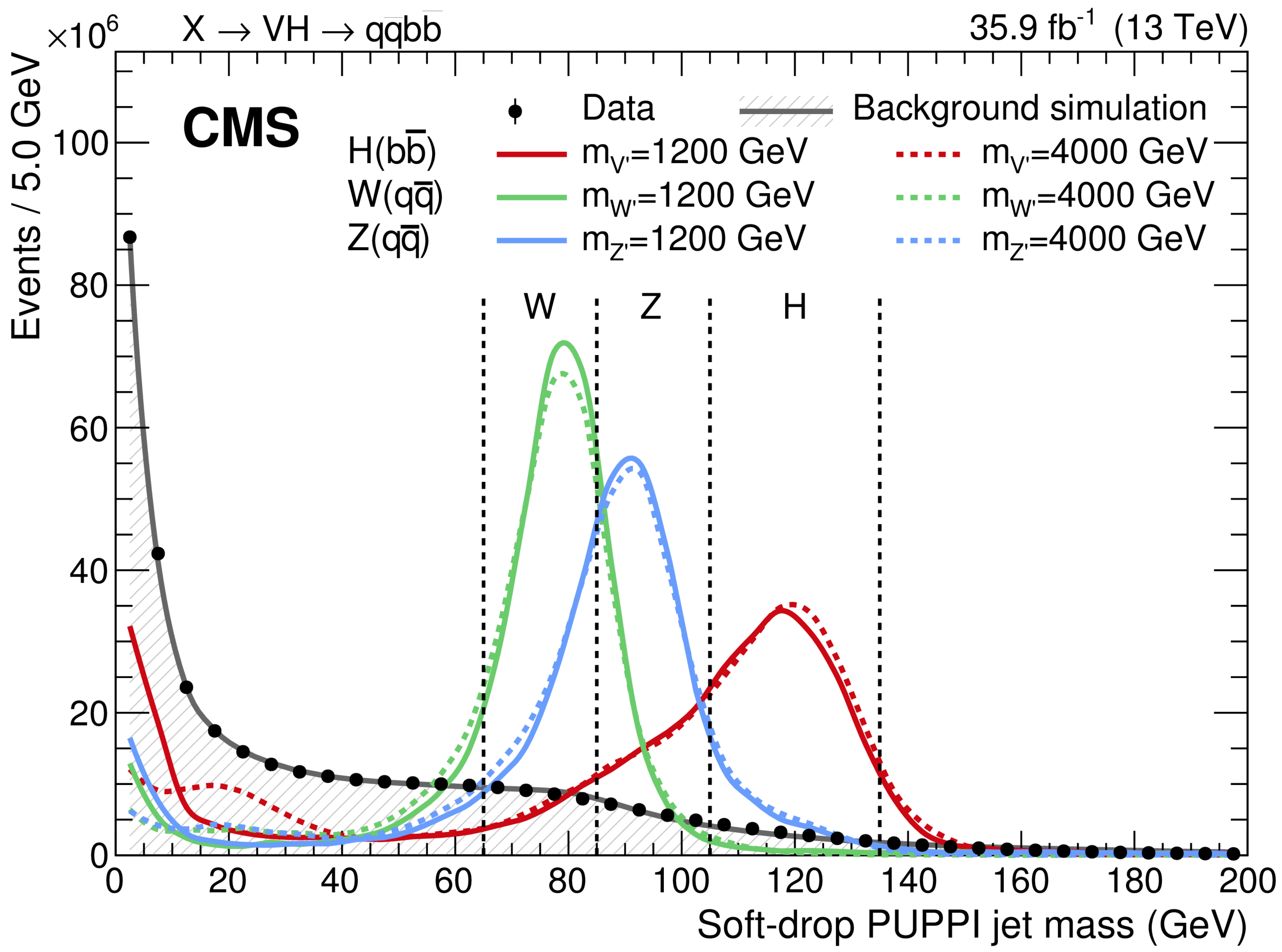


background q/g

Our tools:

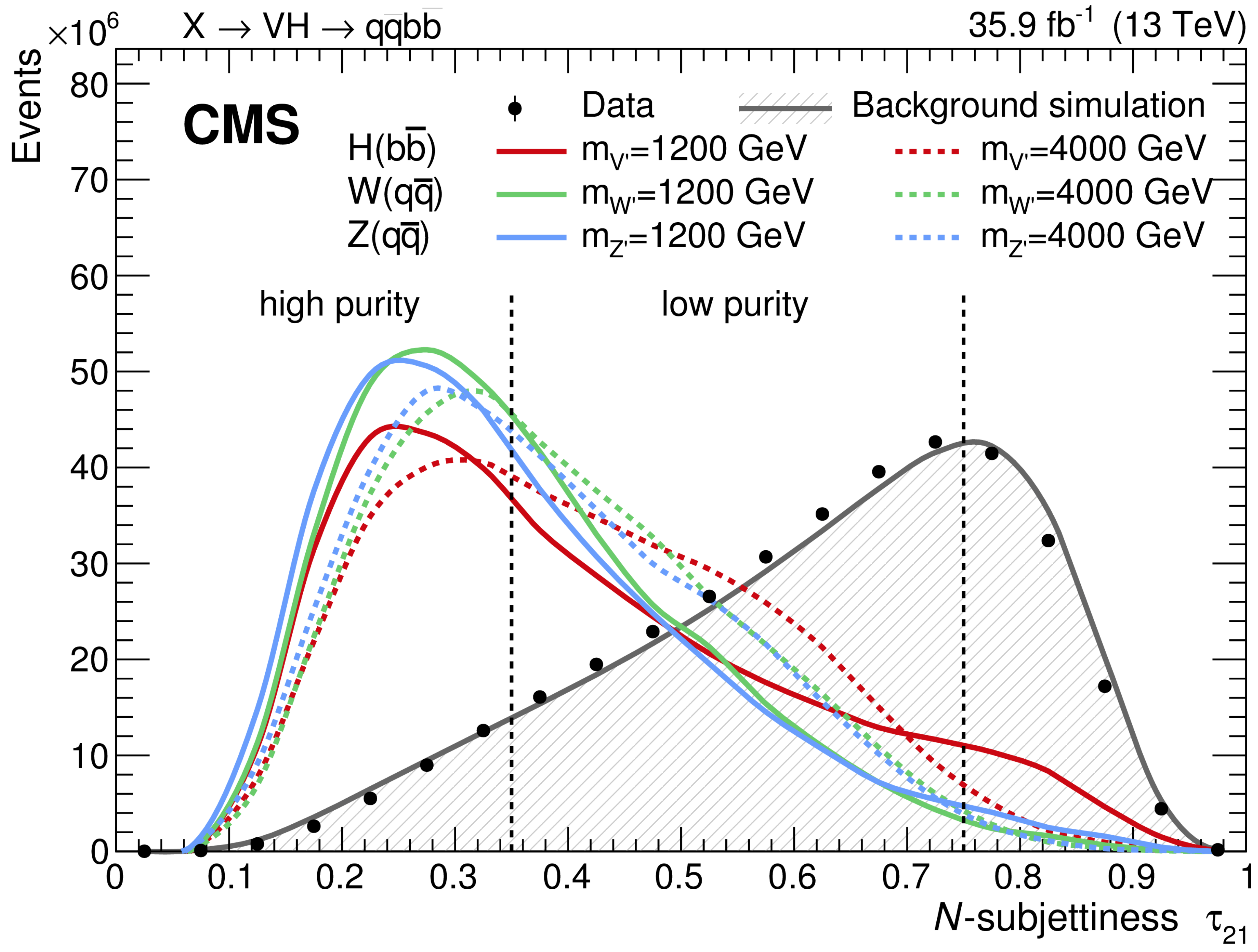
- jet **mass**
- the composite nature of the jet using **substructure**
- **b-tagging** to reconstruct the two B hadrons from the b and $\bar{b}$ within the same fat jet
  - Measurable lifetime: $c\tau \sim 500\ \mu m \rightarrow \beta\gamma c\tau \sim 5mm$ @ 50 GeV
    - displaced secondary vertex

Boson Tagging observables



JET MASS AFTER GROOMING

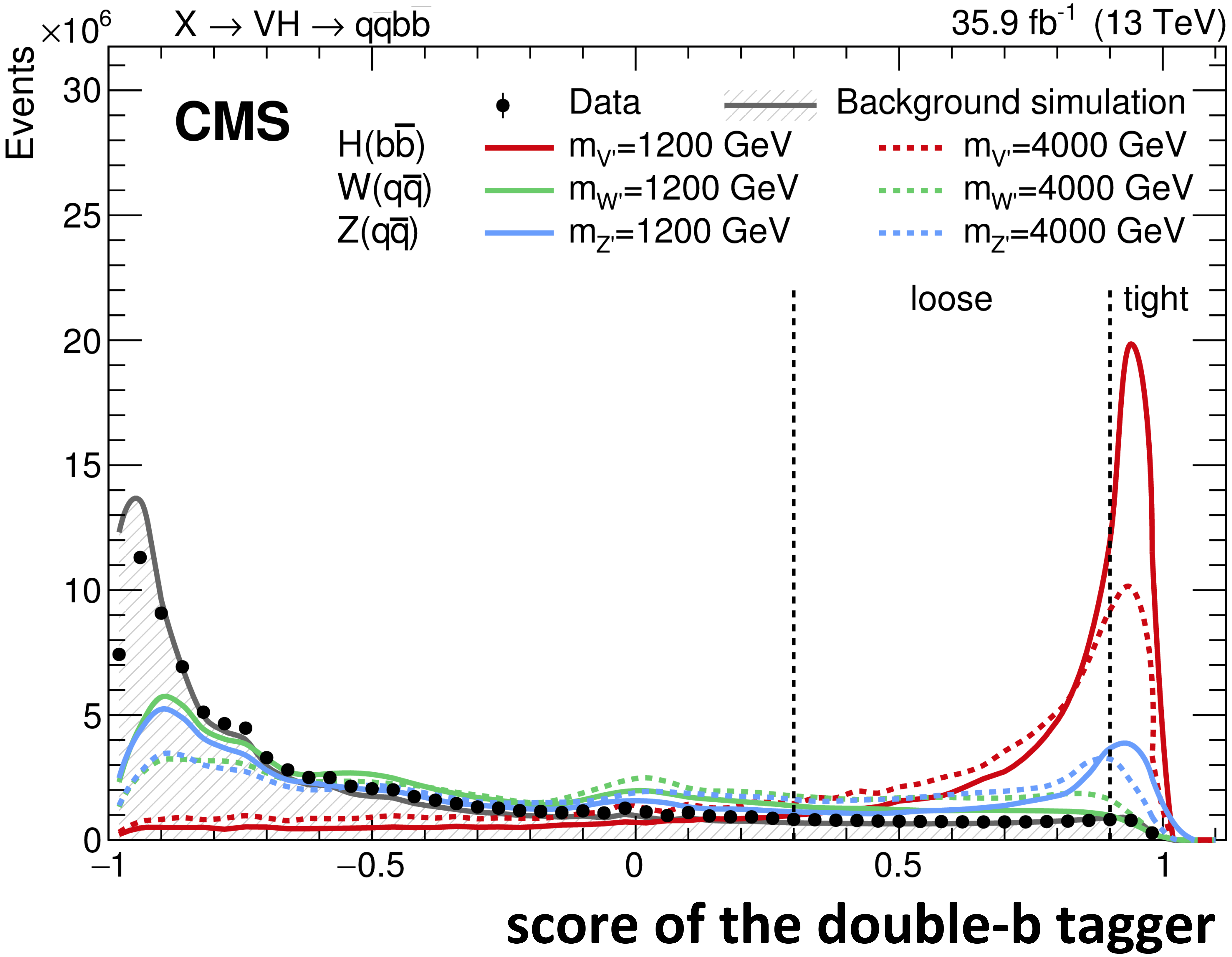
- remove soft and wide-angle radiation (soft drop)
- Primarily aimed to separate W/Z/H-jets from q/g

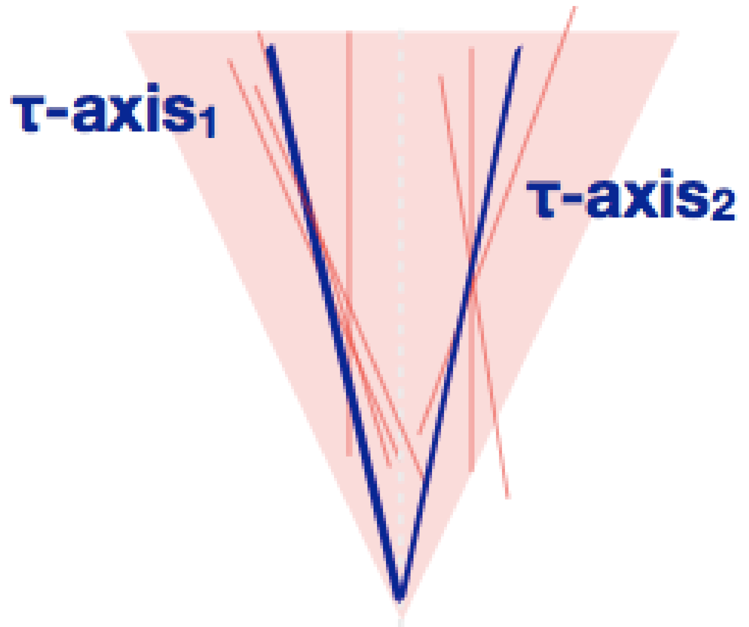


JET SUBSTRUCTURE

measures the degree to which a jet can be considered as composed of N prongs

Tagging observables



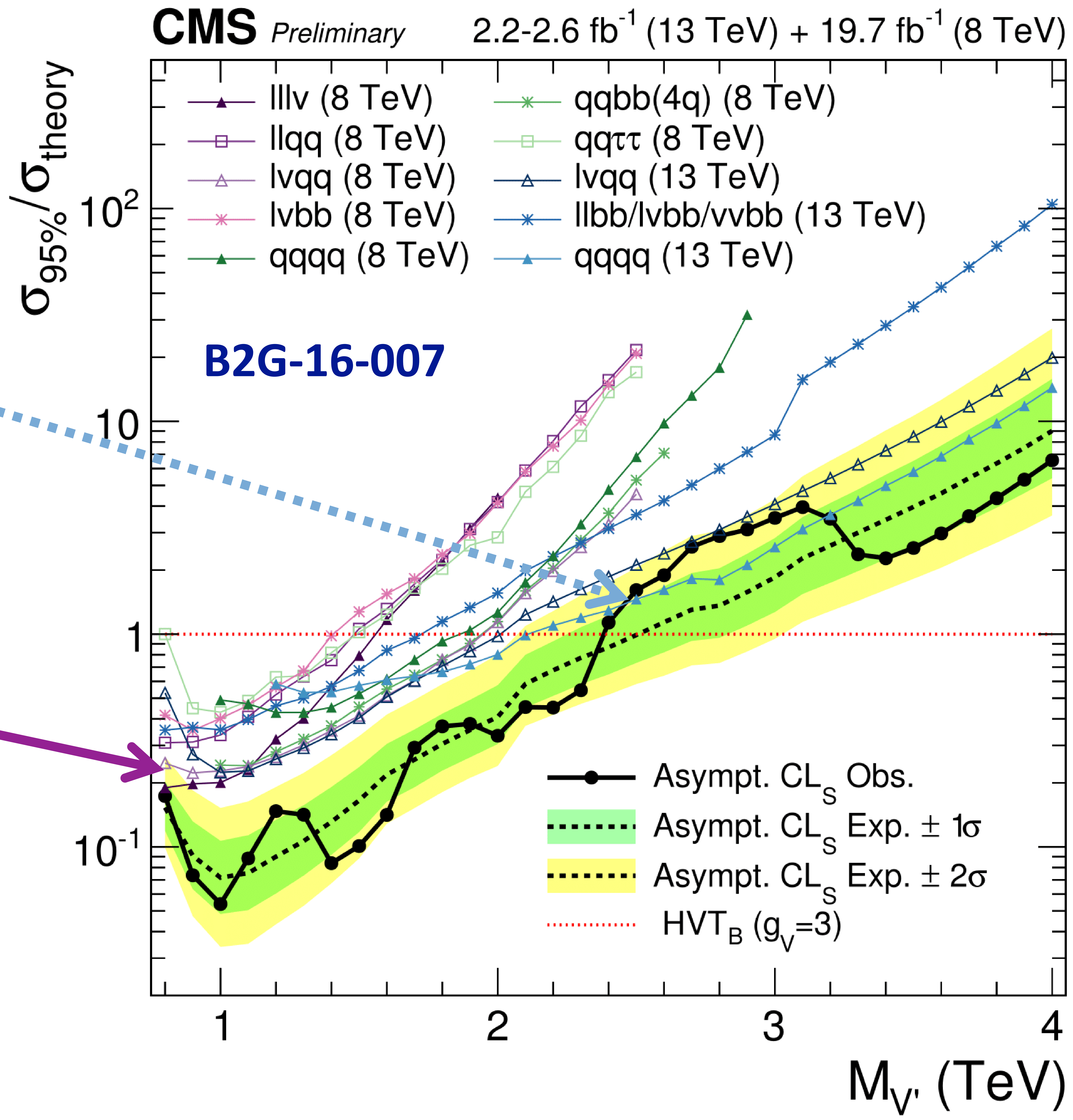


double-b tagger

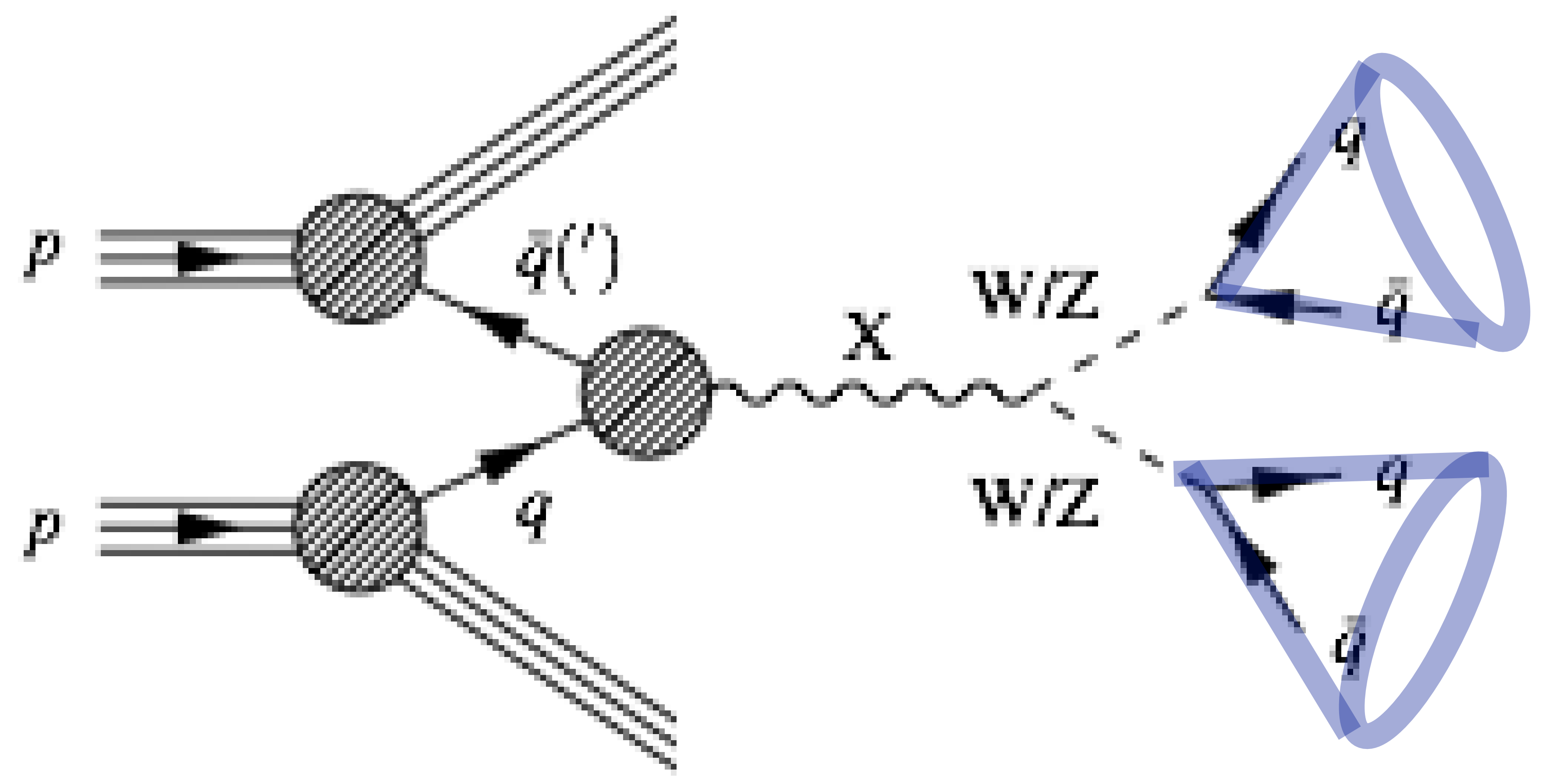
- Identifies the two B hadron decay chains from b and b̄ within the same fat jet.

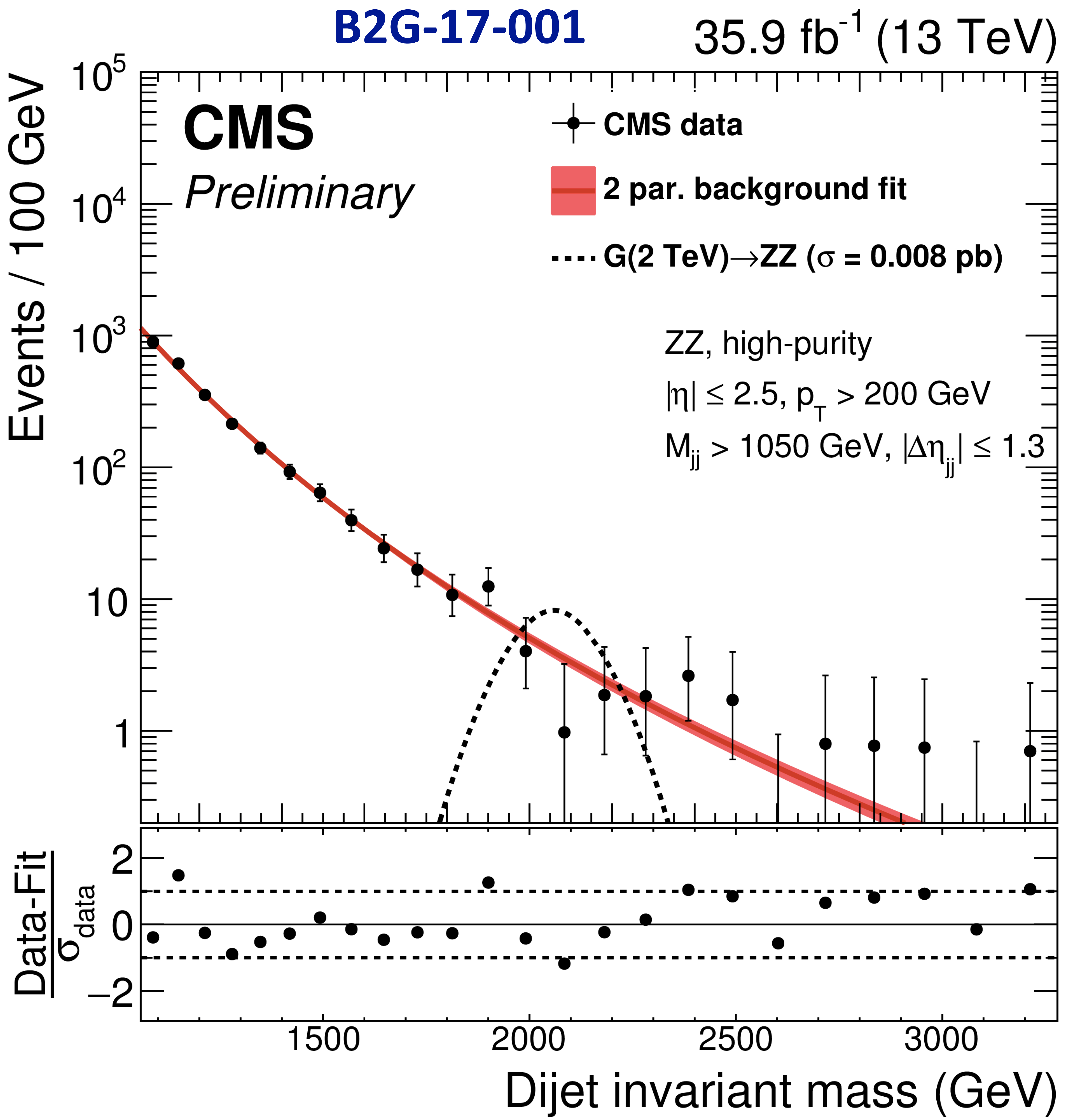
X→VV/VH (V=W/Z)

- **Hadronic** final state benefit from the highest BR
  - most sensitive at high mass
- **Leptonic** states give more sensitivity at lower masses to beat down backgrounds



X→VV→JJ

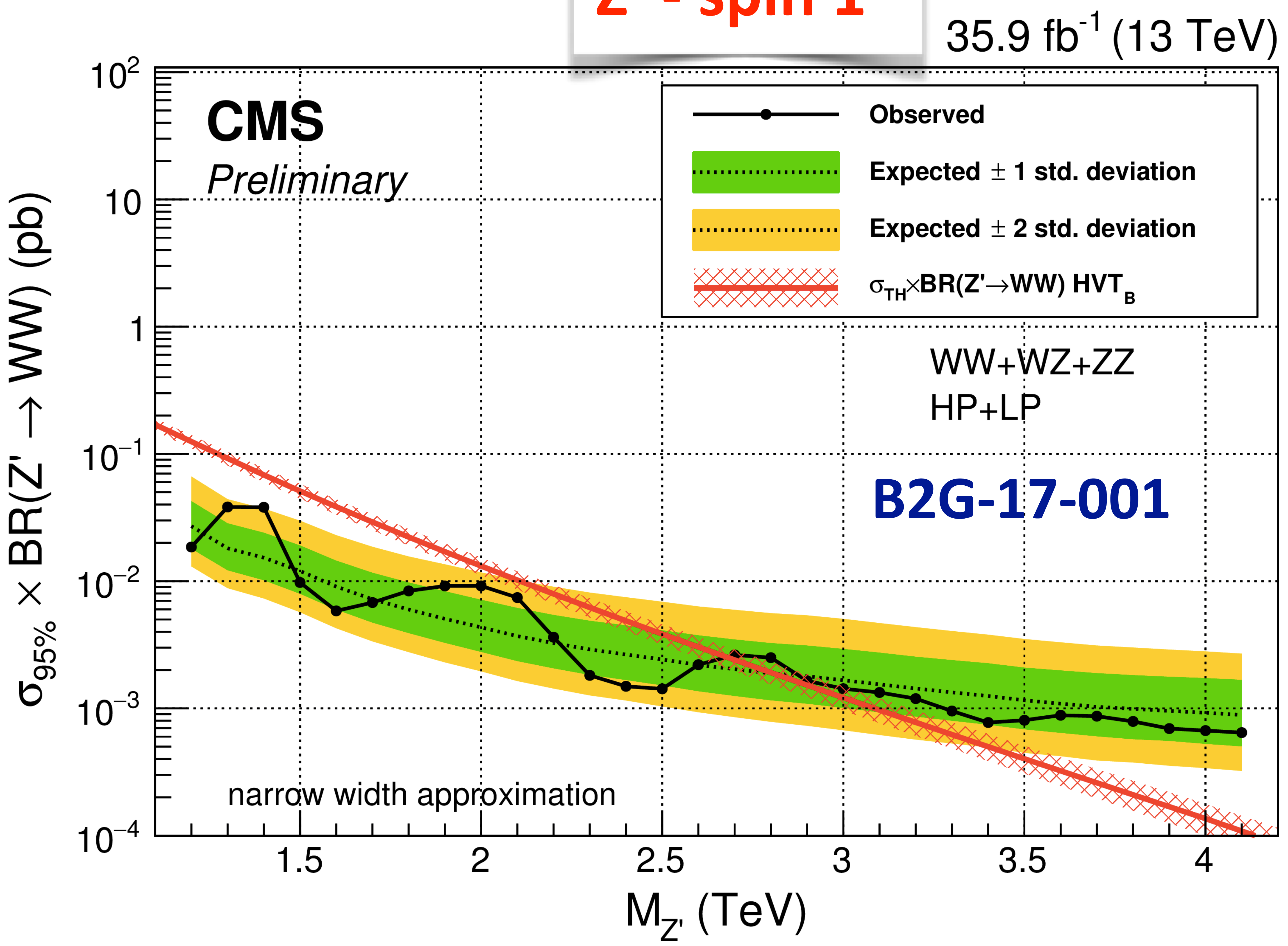




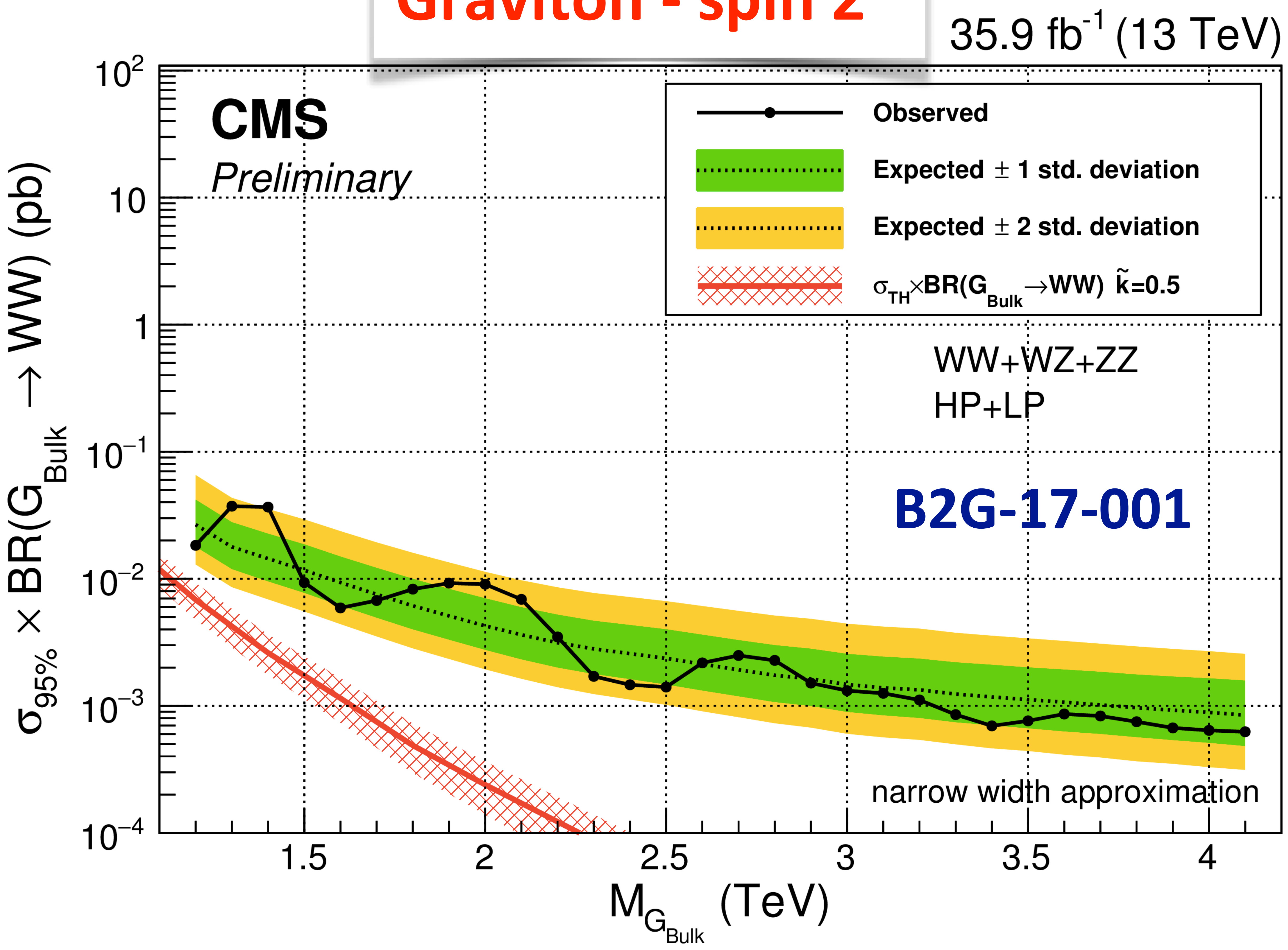
- Online selection full efficient for resonance mass >1 TeV
- Two large cone size jets, each compatible with V hypothesis
- Dijet mass is used to extract the signal

X→VV→JJ

Z' - spin 1

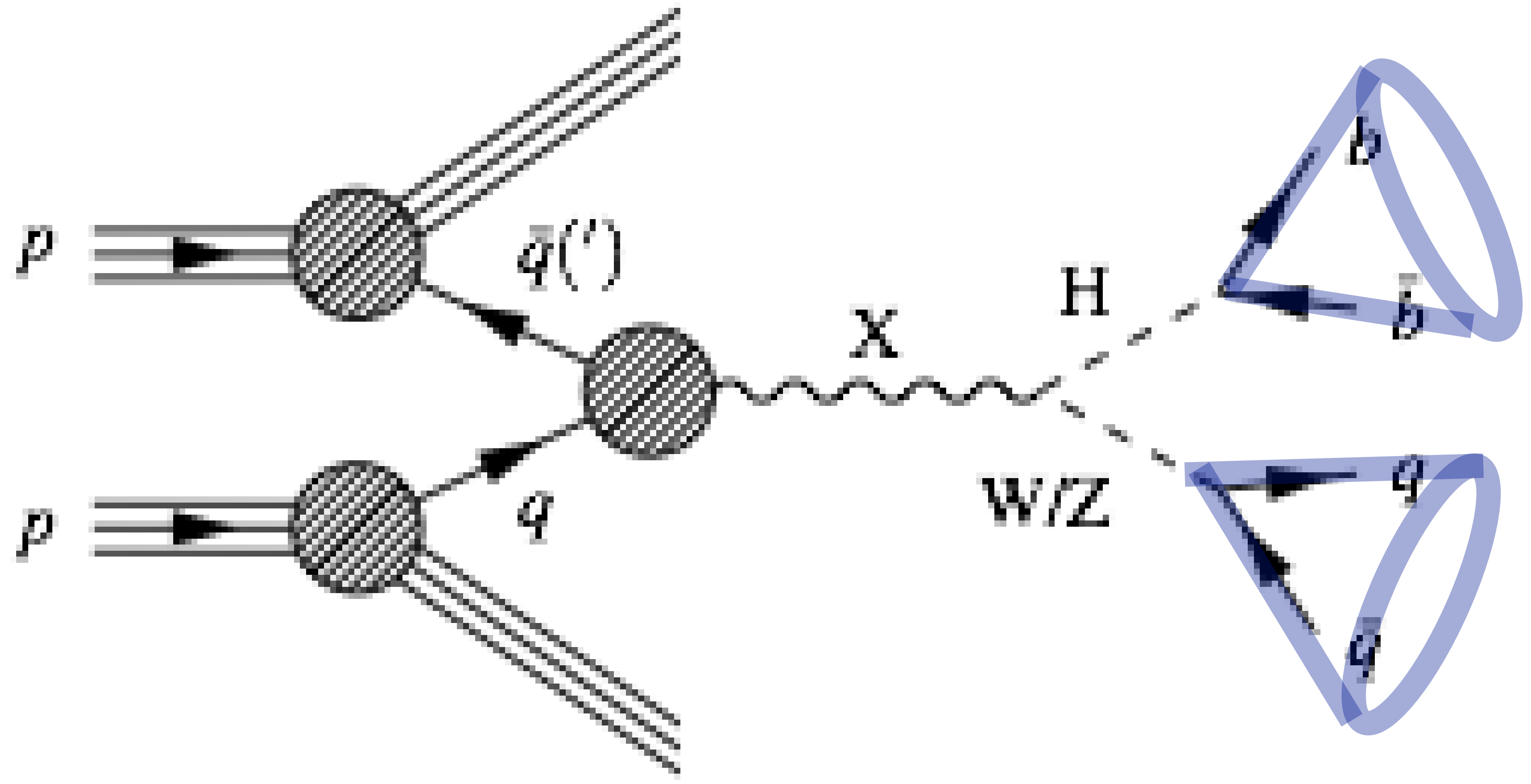


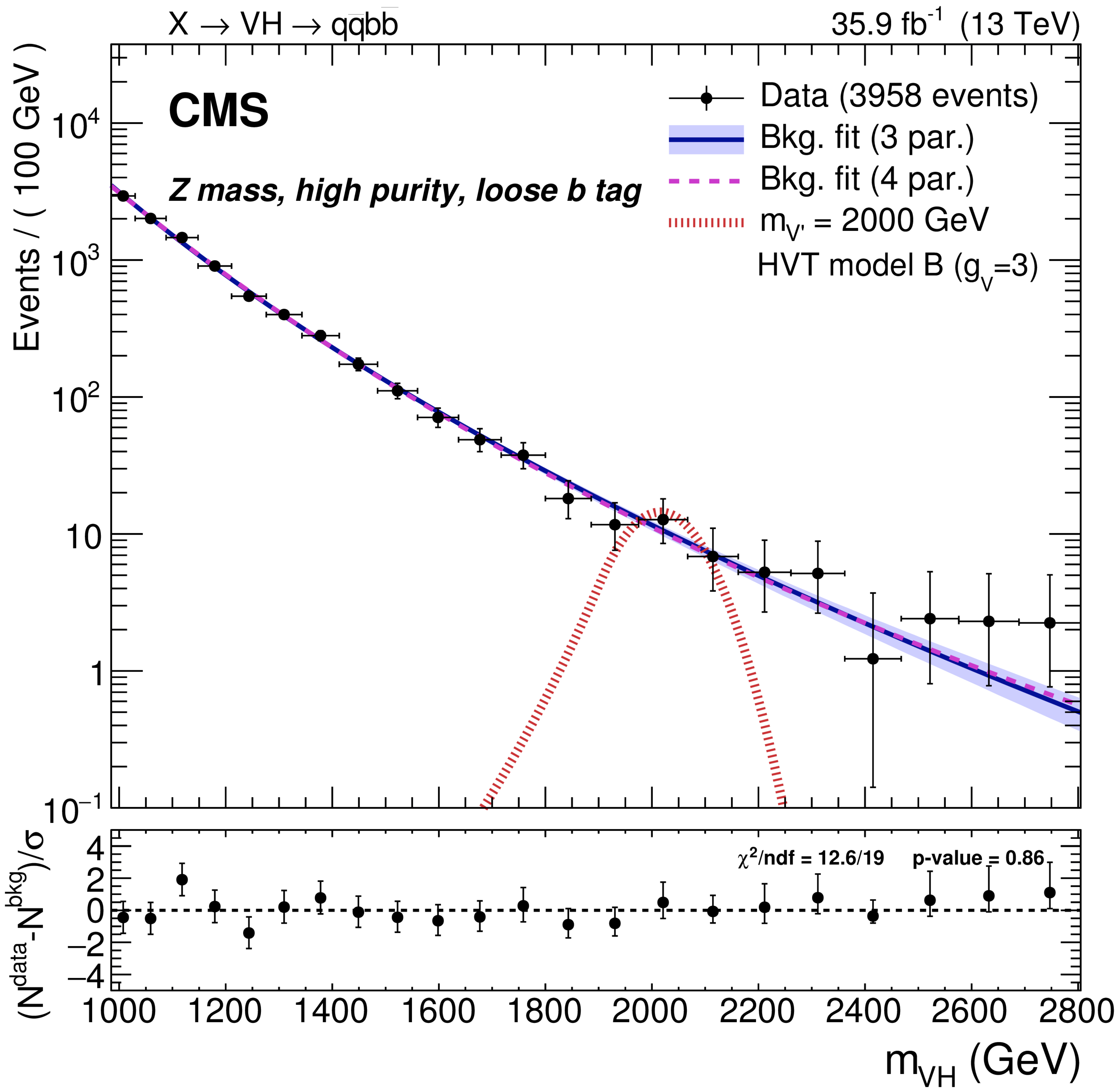
Graviton - spin 2



Sensitivity to BSM resonances decaying into WW, WZ and ZZ of cross section ~ 1-50 fb in the 1.2-4.1 TeV mass range

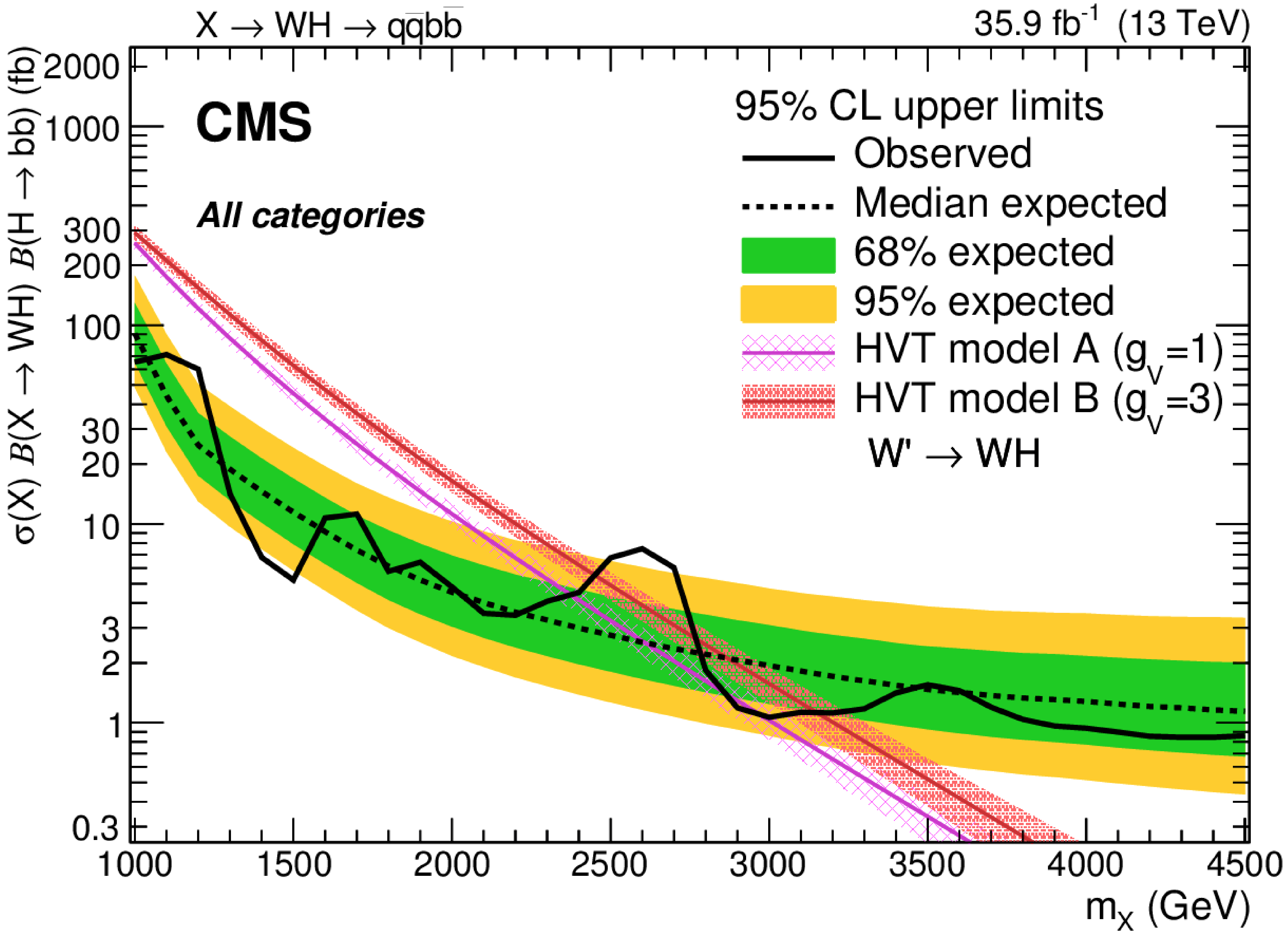
$X \rightarrow VH \rightarrow J_{b\bar{b}}$

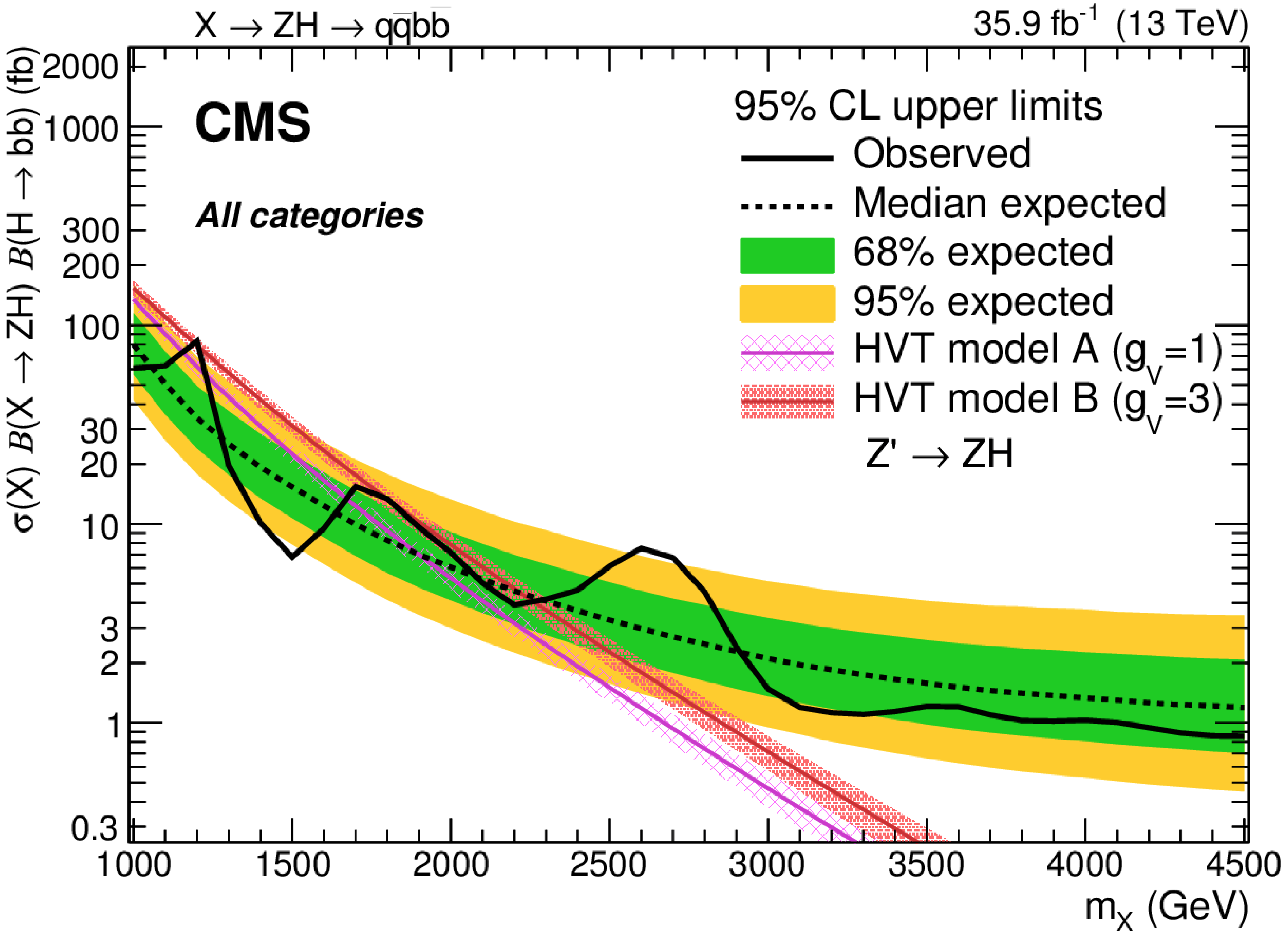




- Similar approach as for VV→ JJ, and double-b tagging to identify the $H(b\bar{b})$ candidates

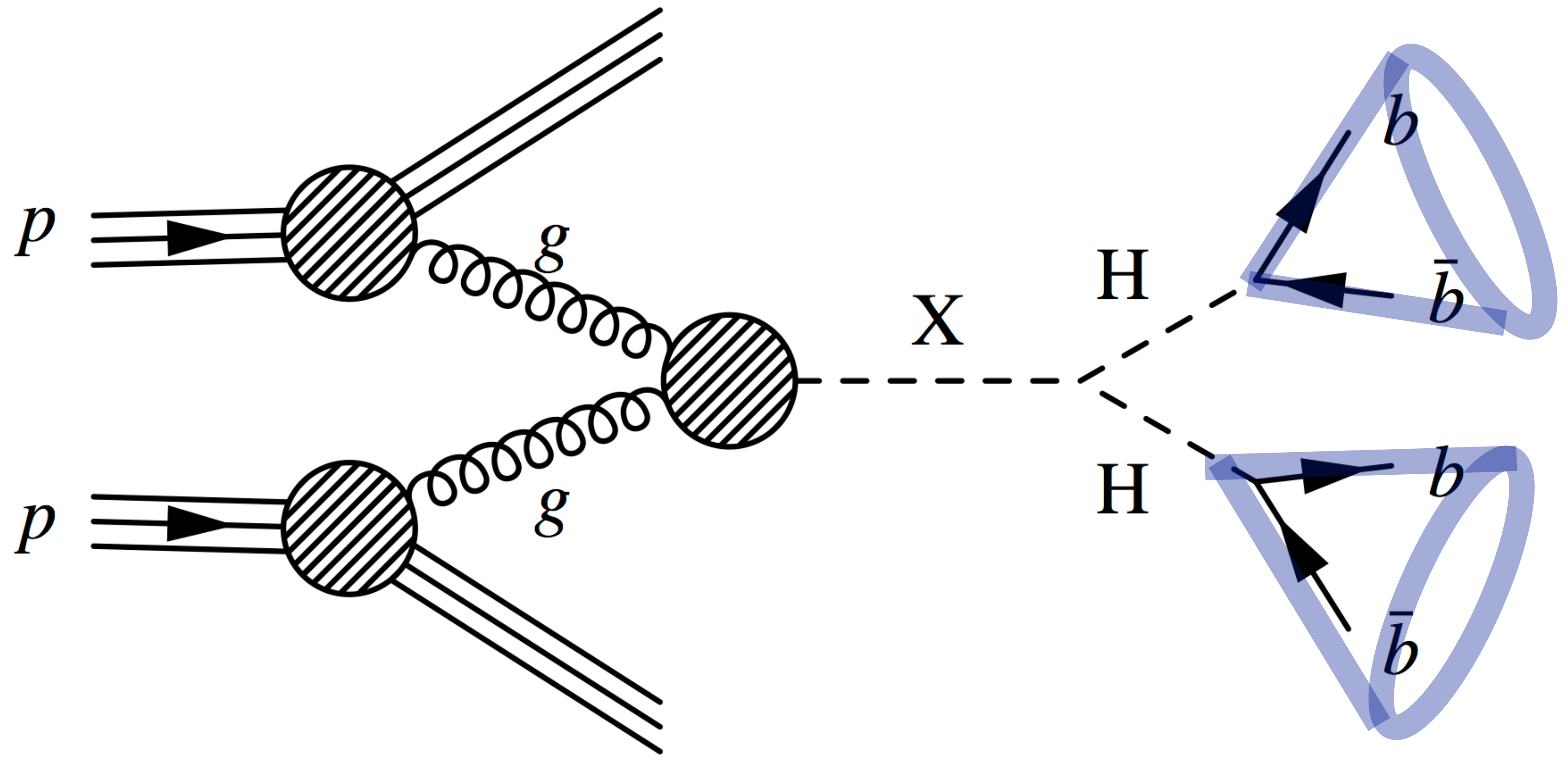
X→VH→Jbb̄

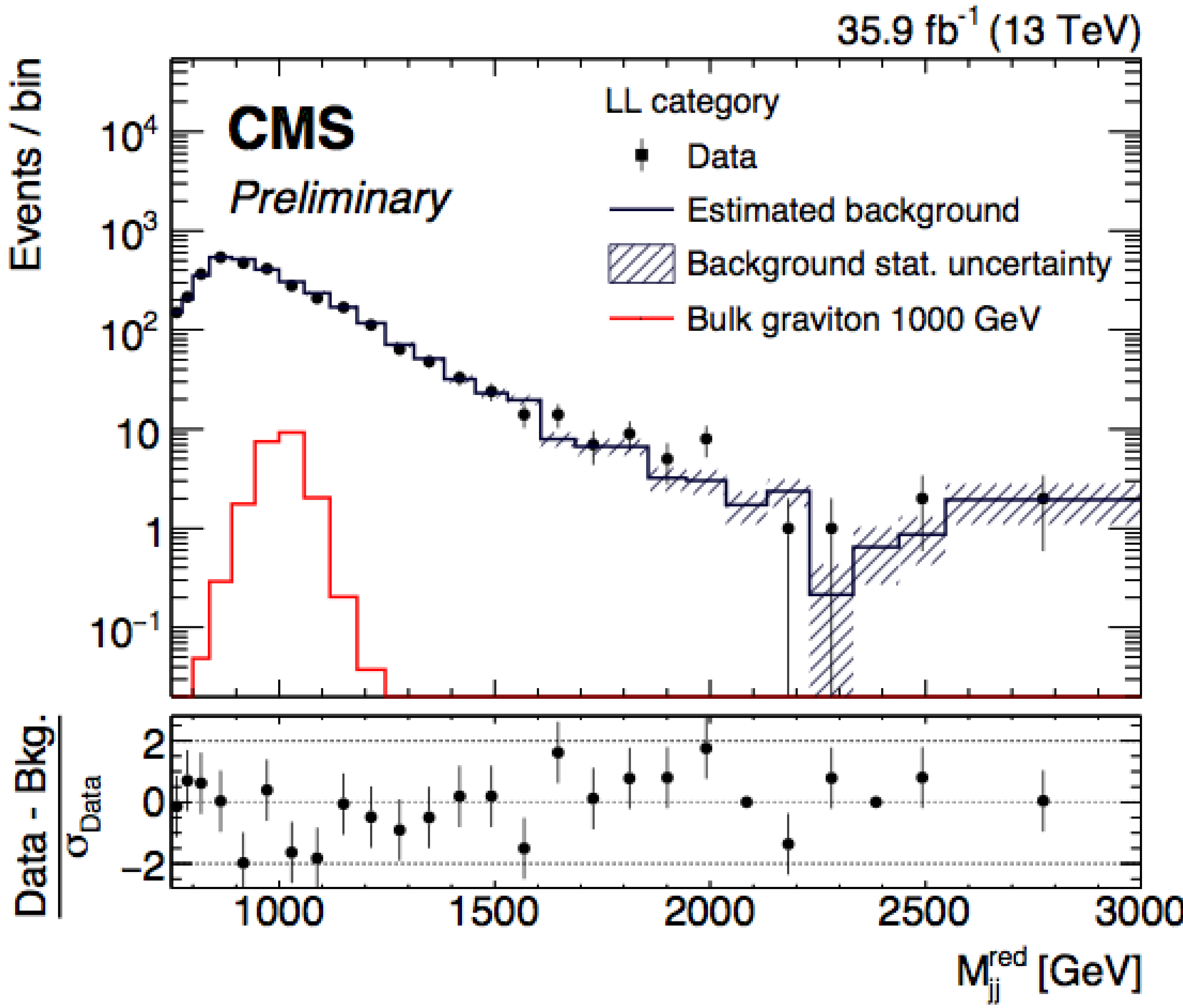




Sensitivity to BSM resonances decaying into WH and ZHZ of cross section ~ 1-100 fb in the 1-4.5 TeV mass range

X→HH(4b)





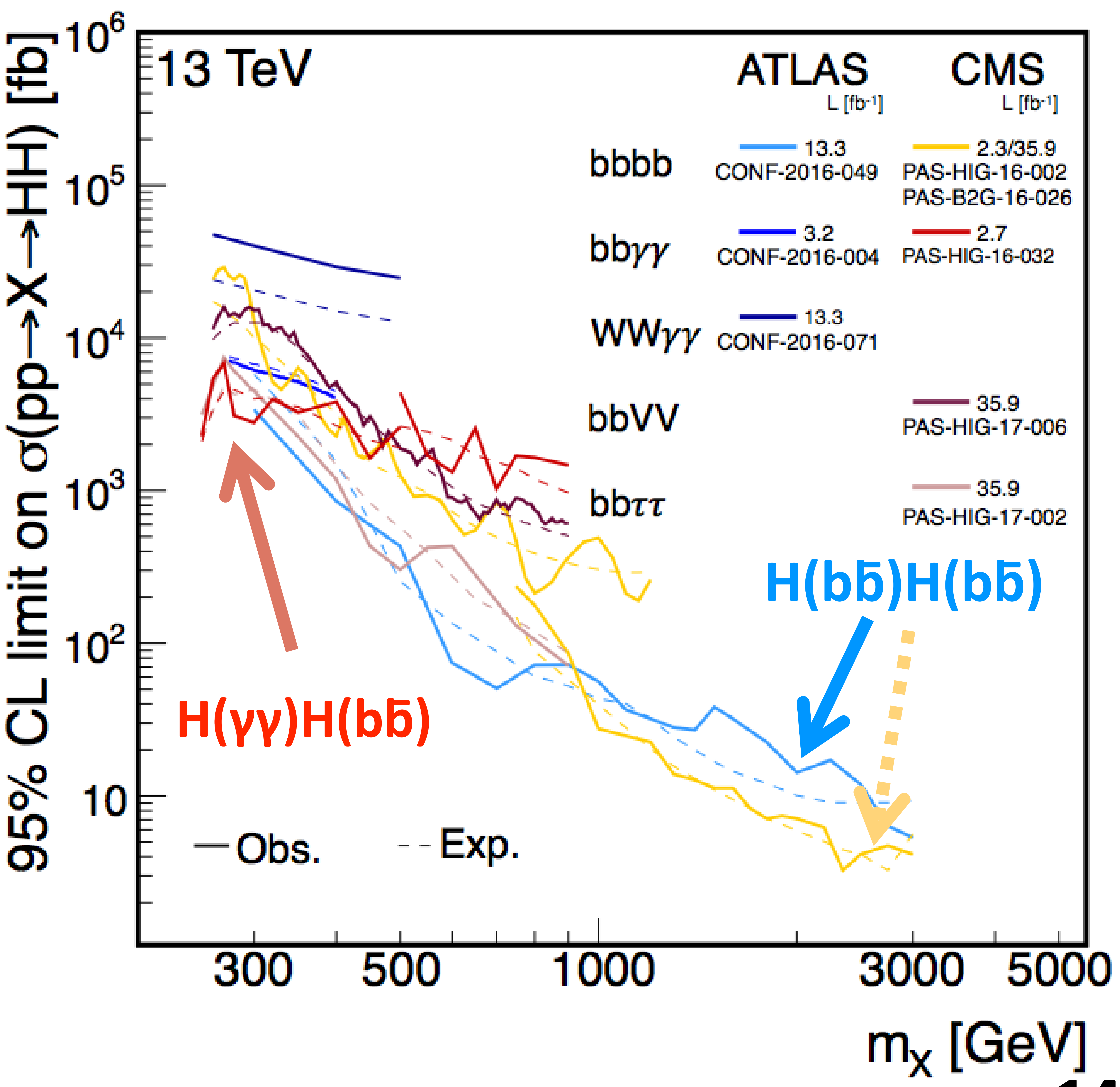
- Similar approach as VH/VV→ JJ and double-b tagging to identify the H(bb̄) candidates
- Multijet background predicted from mass sidebands obtained by inverting the b-tagging requirement on the p_T leading jet

$$M_{jj}^{red} = M_{jj} - (M_{j1} - M_H) - (M_{j2} - M_H)$$

X→HH

H(bb̄)H(bb̄) most sensitive channel for m_X > 400/500 GeV

H(γγ)H(bb̄) complement in the low mass



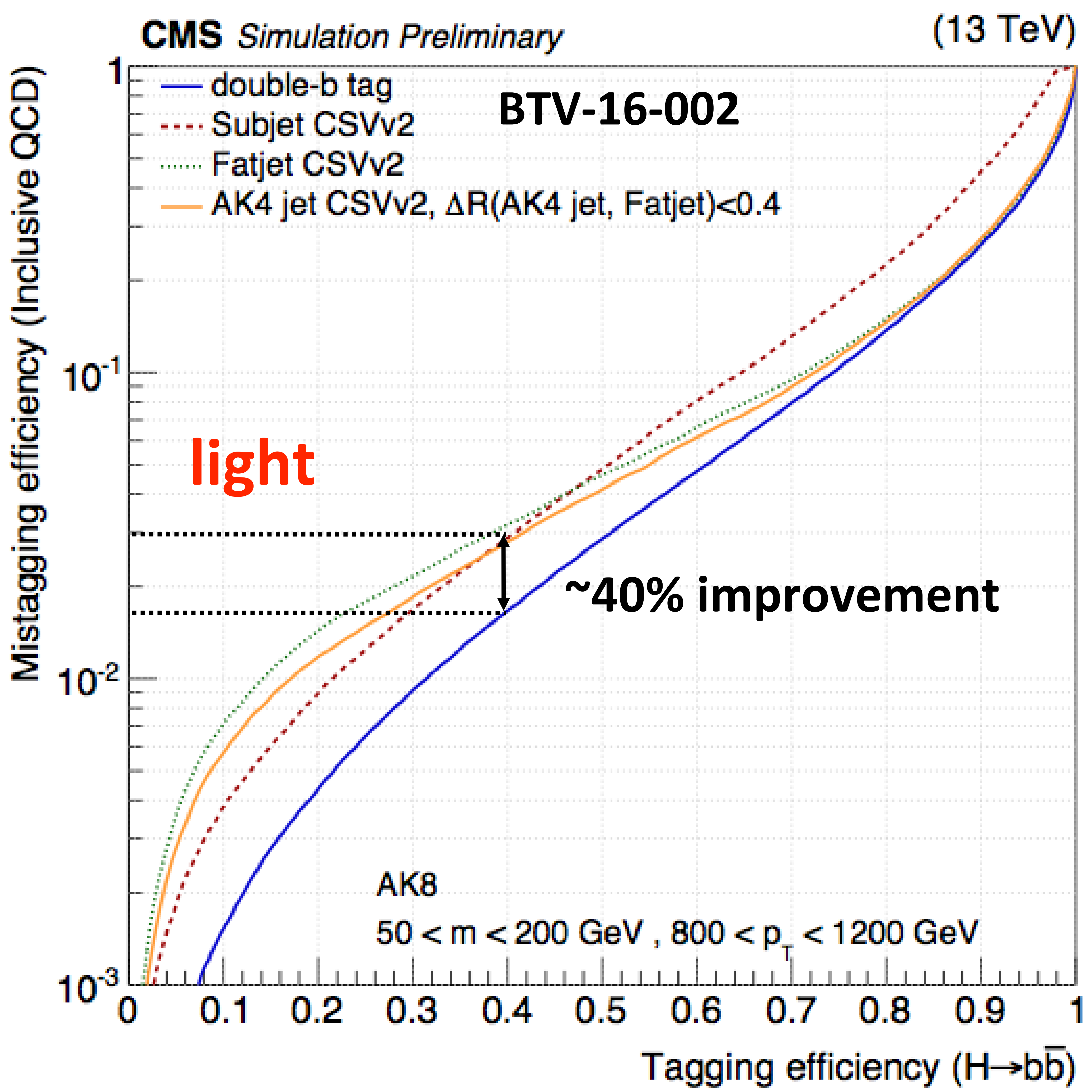
Conclusions & Perspectives

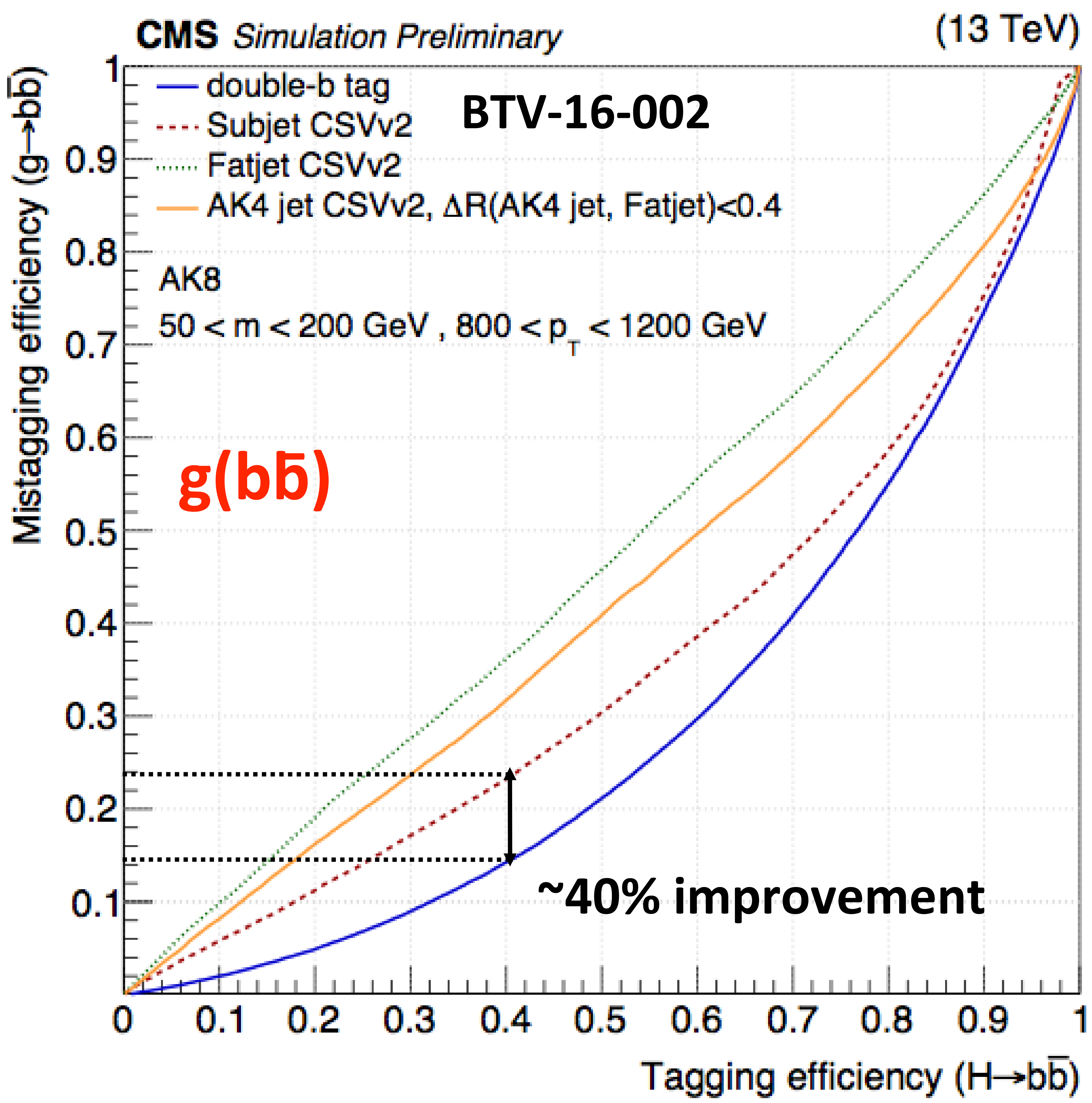
- The 13 TeV dataset should increase by a factor 3 by the end of Run 2 in 2018
  - LHC will probe ***smaller couplings with more data***
- Improvements are also possible from :
  - optimized events selection and improved object reconstruction
  - include ***theory improvements*** on SM predictions

Stay Tuned

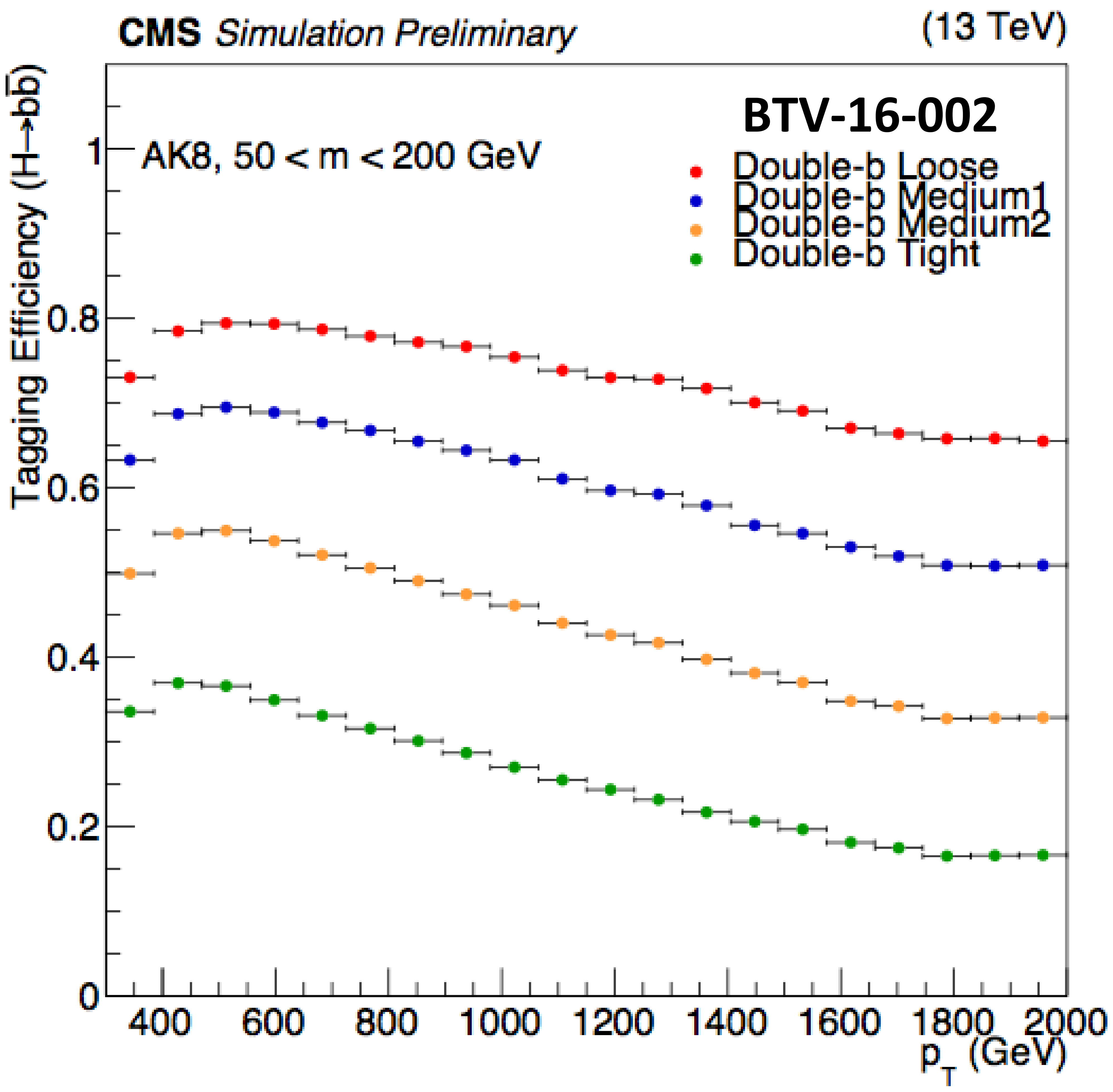
-Additional Material-

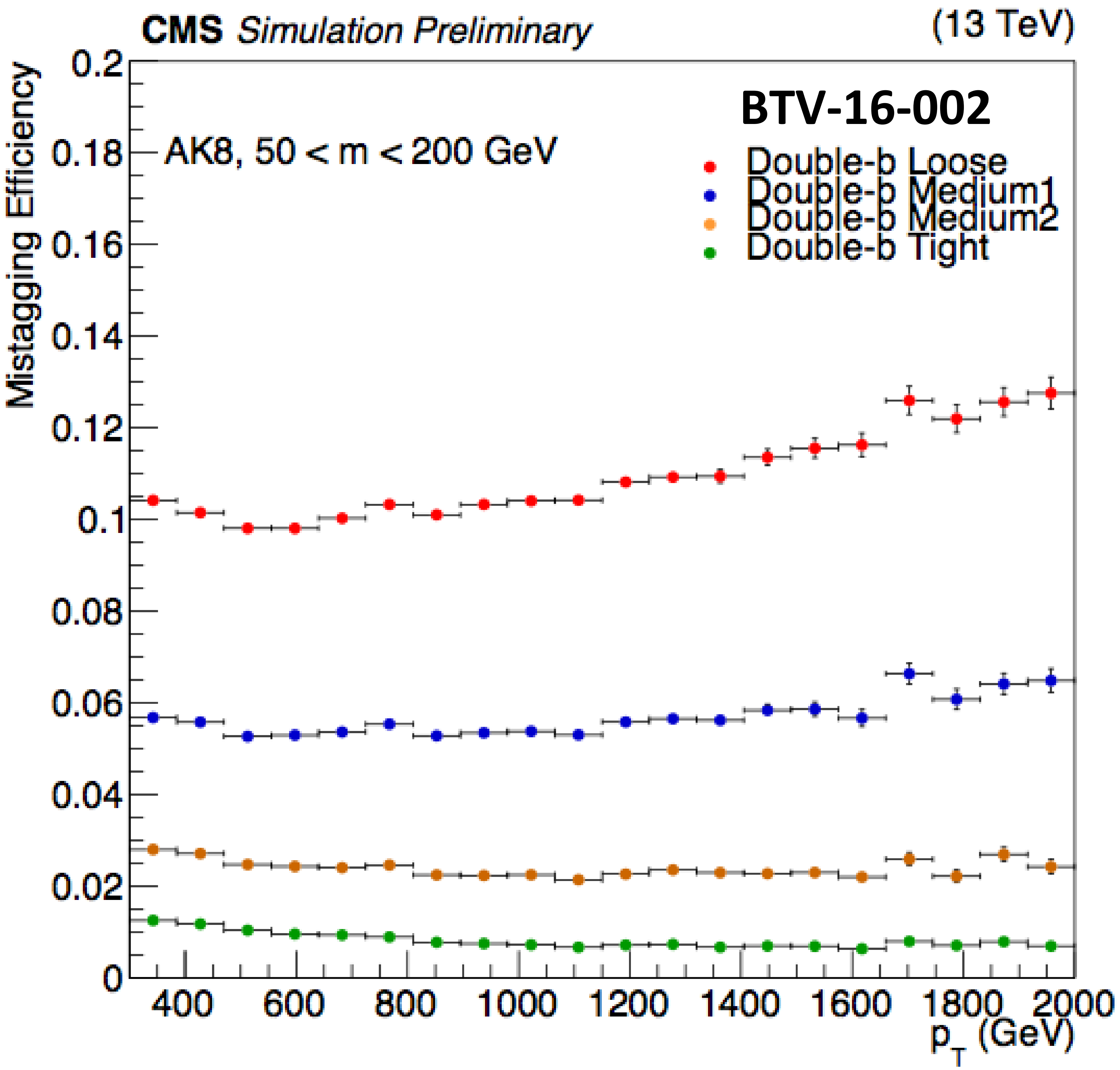
Performance





Performance



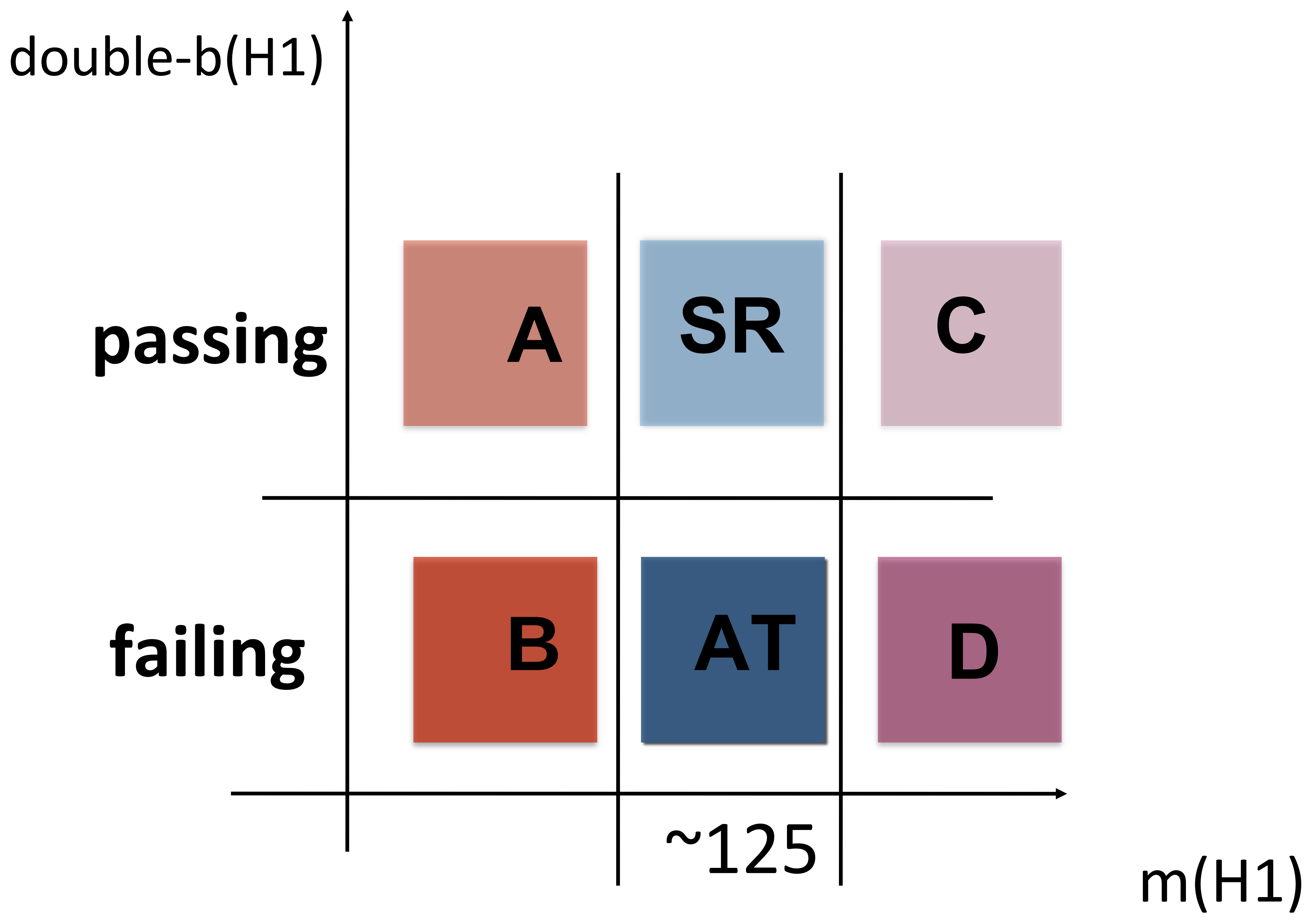


The mistag rate is approximately flat across the p_T range by design

Critical point for searches

Kind of ABCD

* Get absolute normalization for the SR by interpolating between left and right jet mass sidebands
* using failed double-b tag events to predict those that would have passed
* If we require double-b tag on the other jet there is no overlap with VH



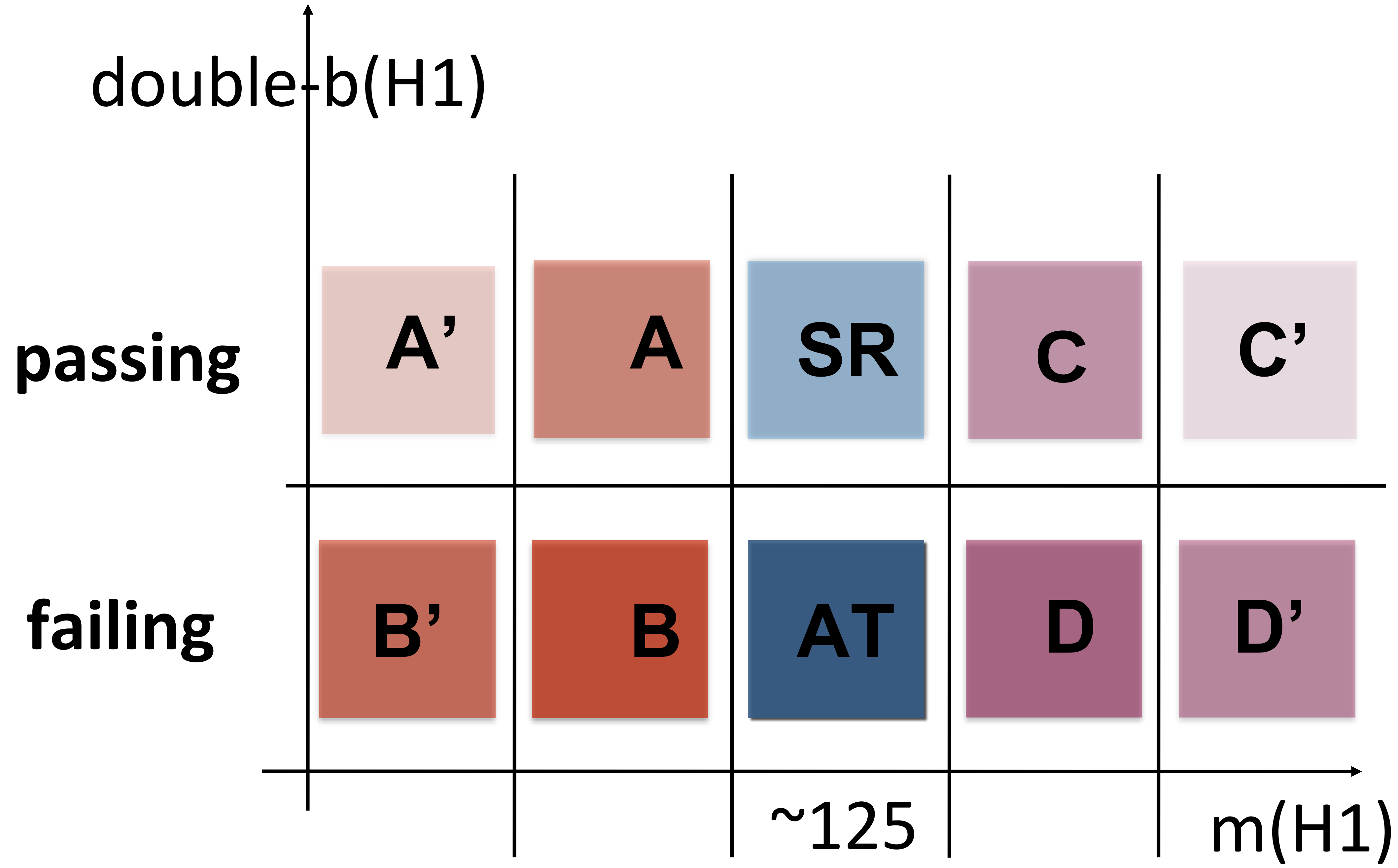
AT * R = SR

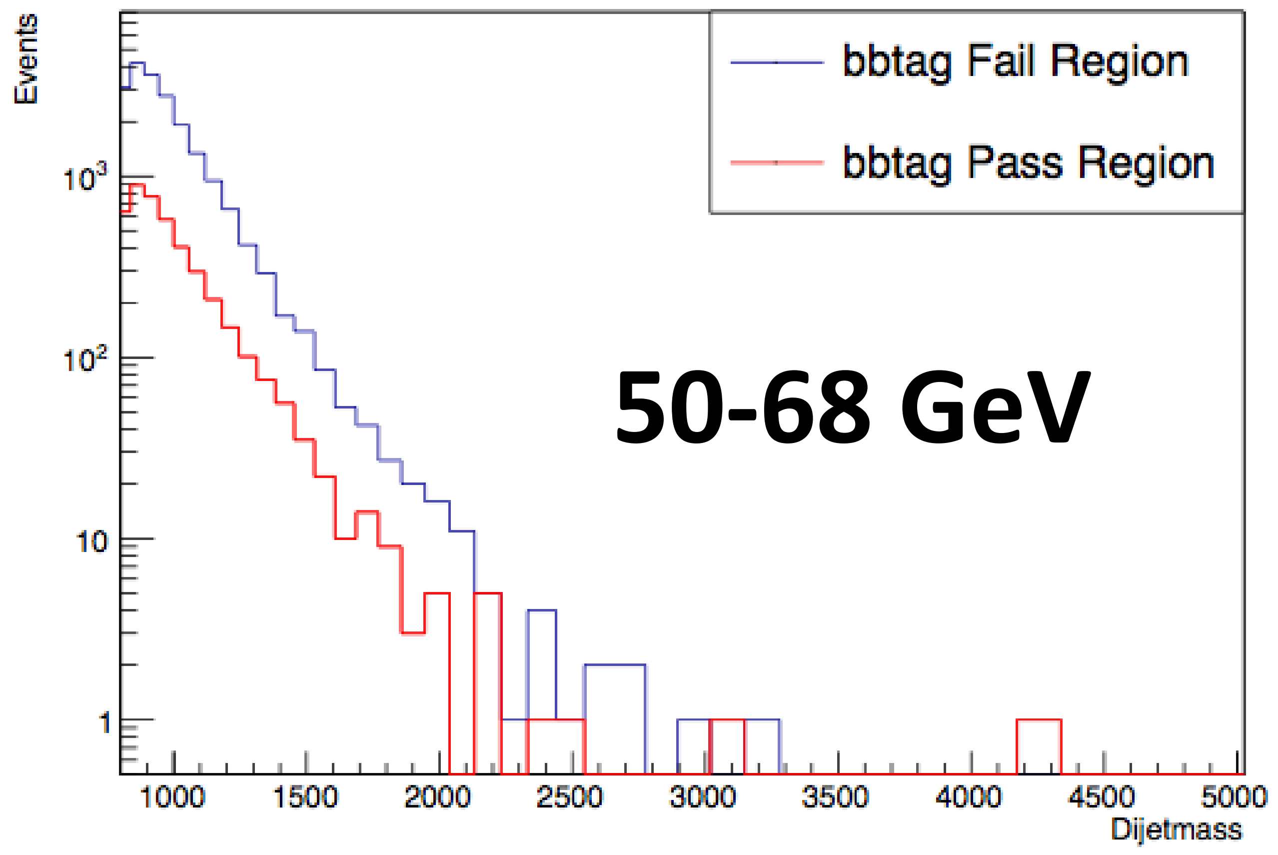
Using A/B and C/D to predict N(AT)/N(SR) as function of jet mass

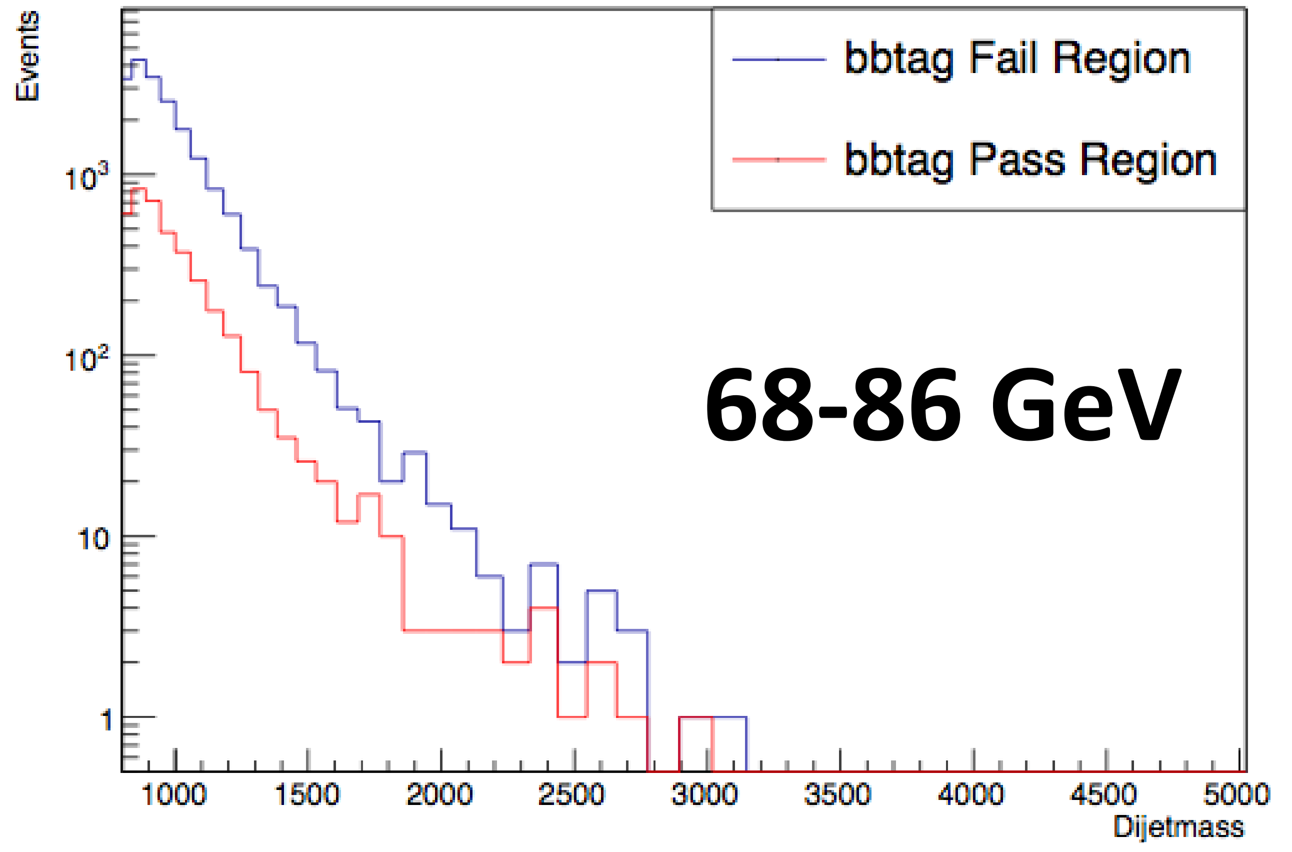
* but to take into account the correlations between double-b-tag and jet mass
  * more slices in jet mass

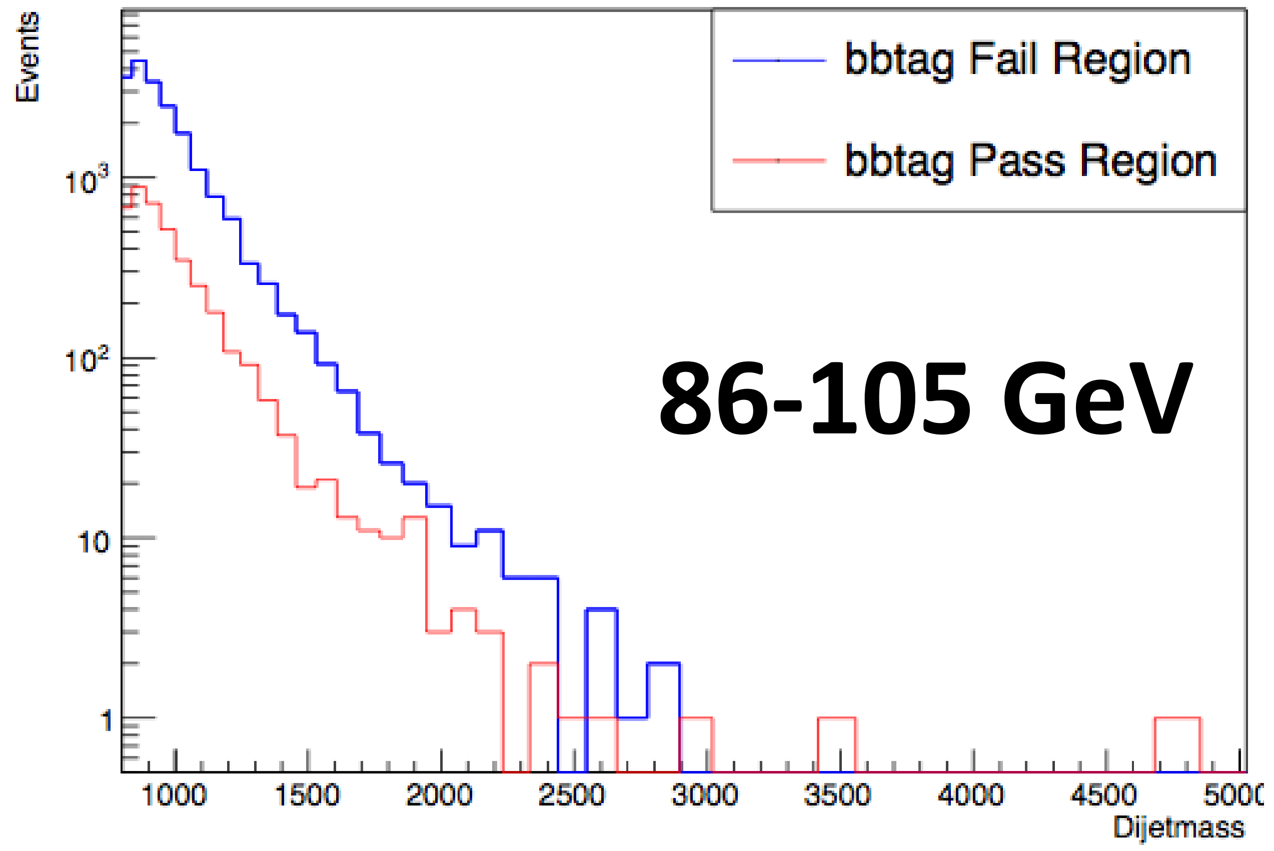
* from a fit we determine the pass/fail ratio for the signal region

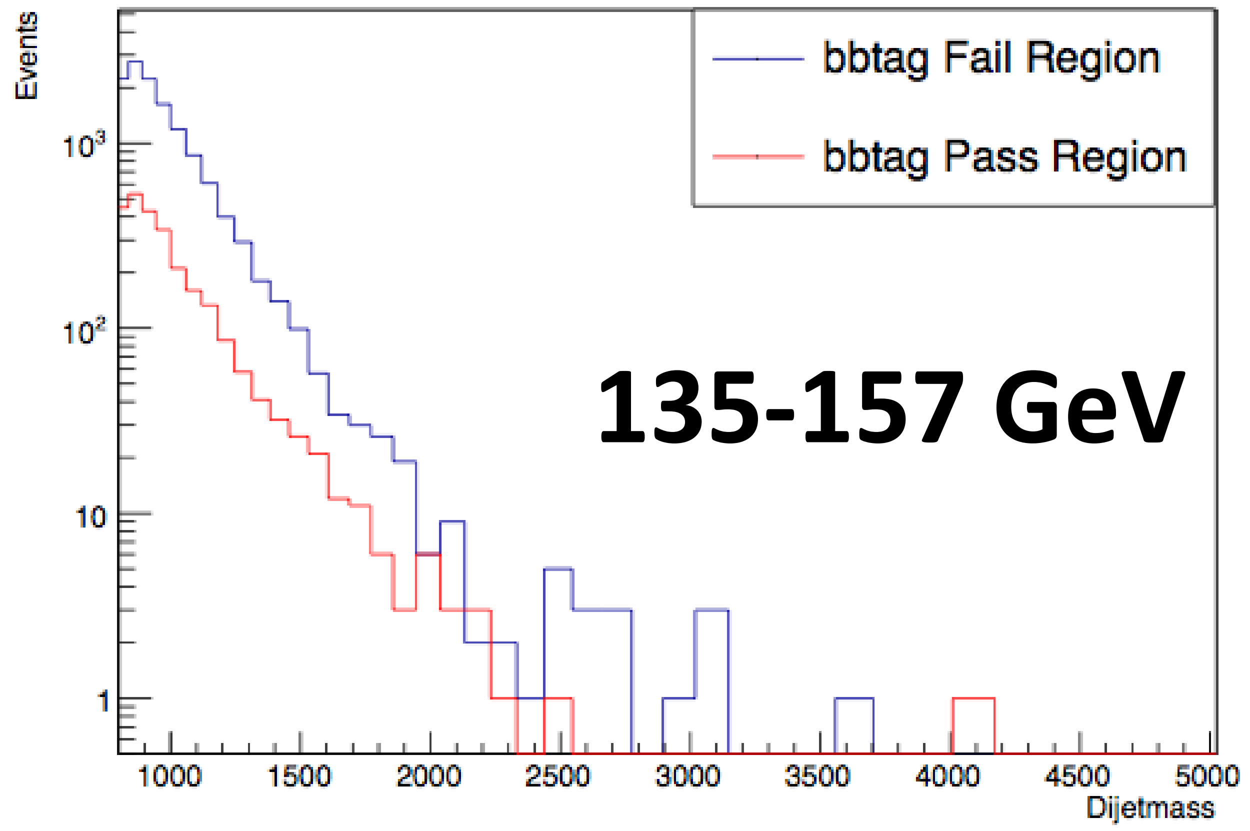
going further …









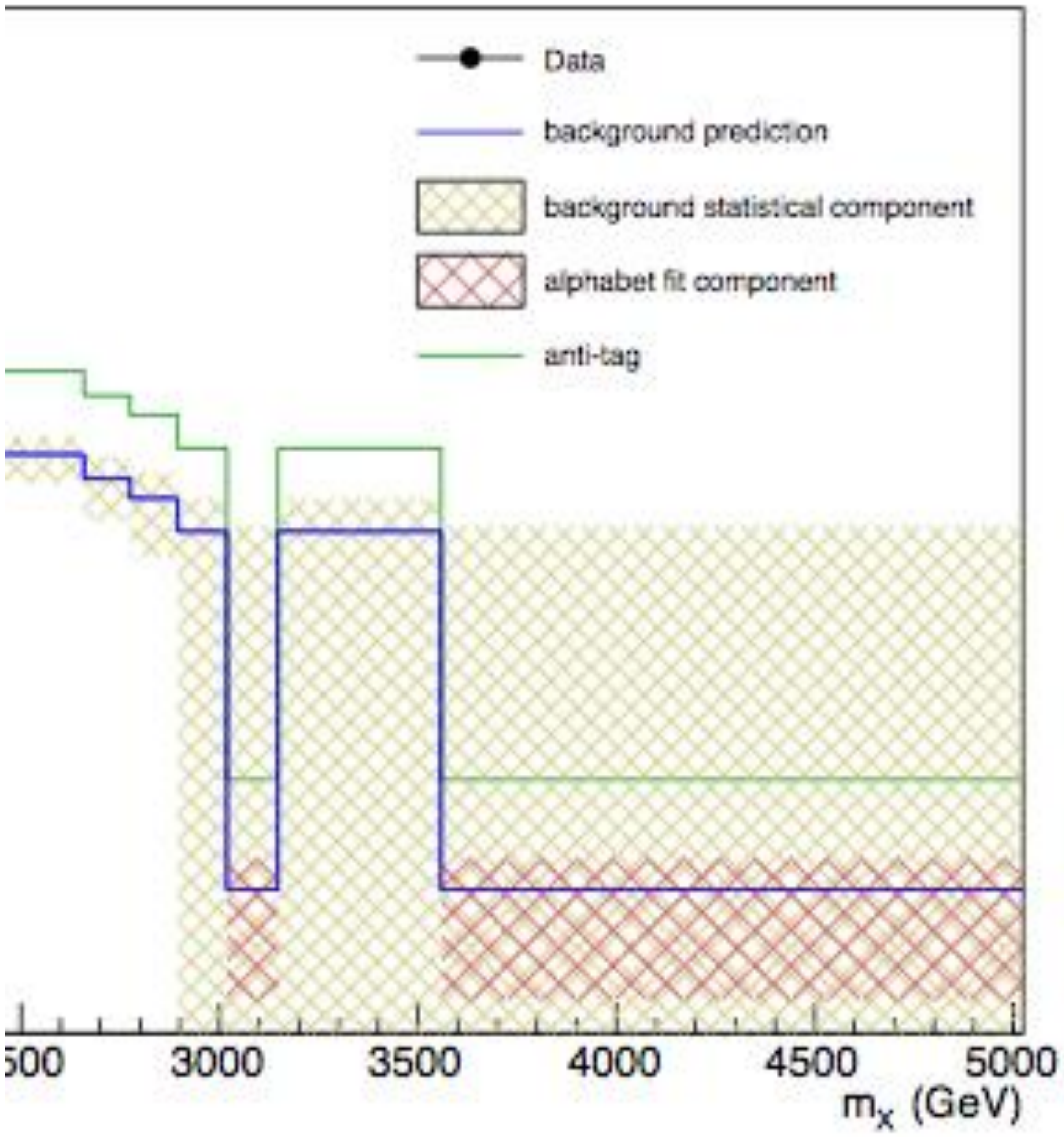


So we measure the Rp/f as function of jet mass

AT * R(m_J-125) = SR

… more in the backup

Uncertainty on the prediction



* We associate two different errors to the prediction:
  * **uncertainty on transfer factor as correlated among bins**
    * 2-15% impact on exp sensitivity
  * **bin-by-bin statistical uncertainty from the anti-tag region statistics**
    * 1-4% impact on exp sensitivity