Probing new physics through exotic Higgs decays to a pair of light bosons

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USLUA Lightning Round Talks
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ATLAS EXPERIMENT

Stony Brook University

Exciting Times: Higgs Discovery

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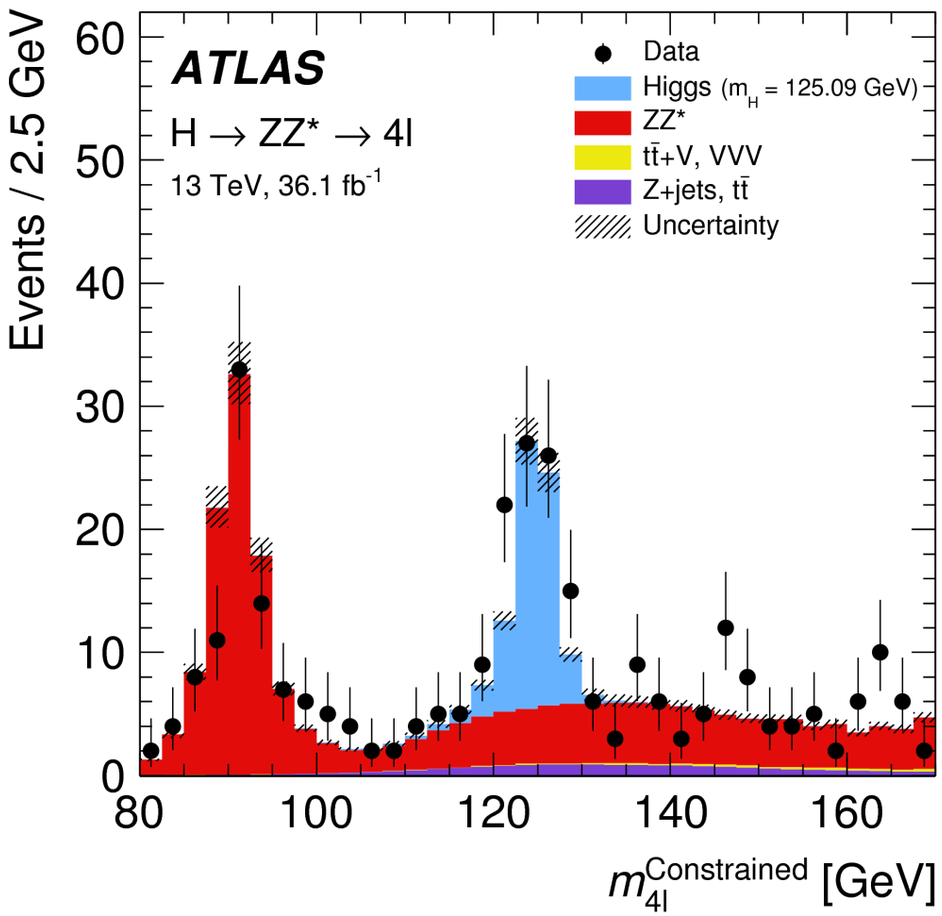
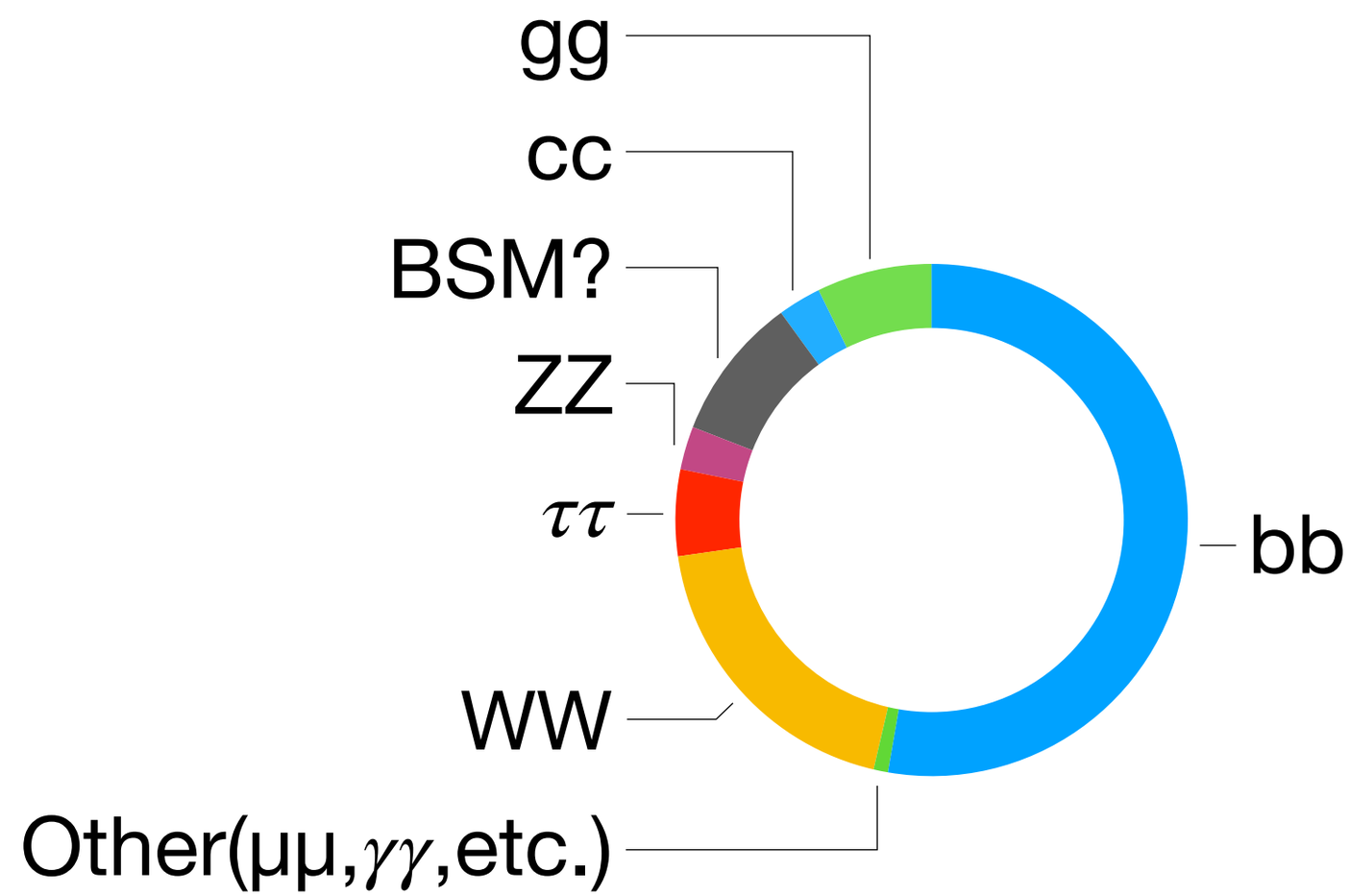
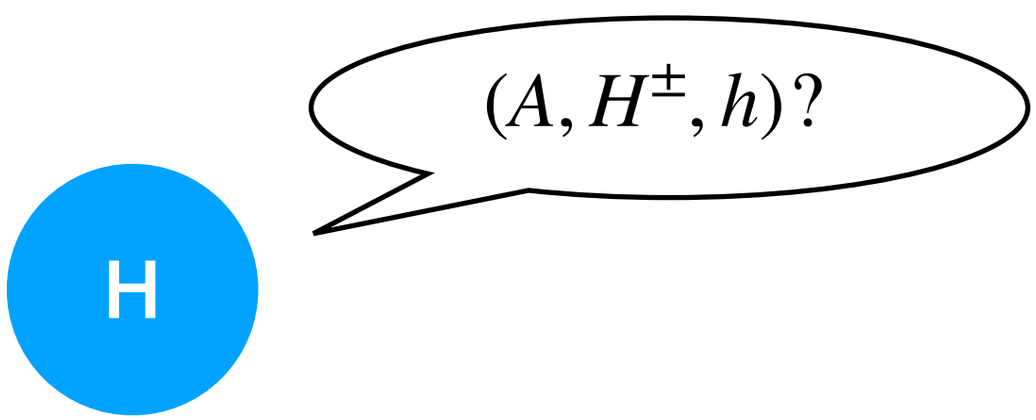
JHEP 03 (2018) 095





- **Open Questions: Why this Higgs mass? Where is SUSY? Dark Matter?**
- **Is this Higgs at 125 GeV completely SM-like?**



Motivation: Exotic Higgs Decays

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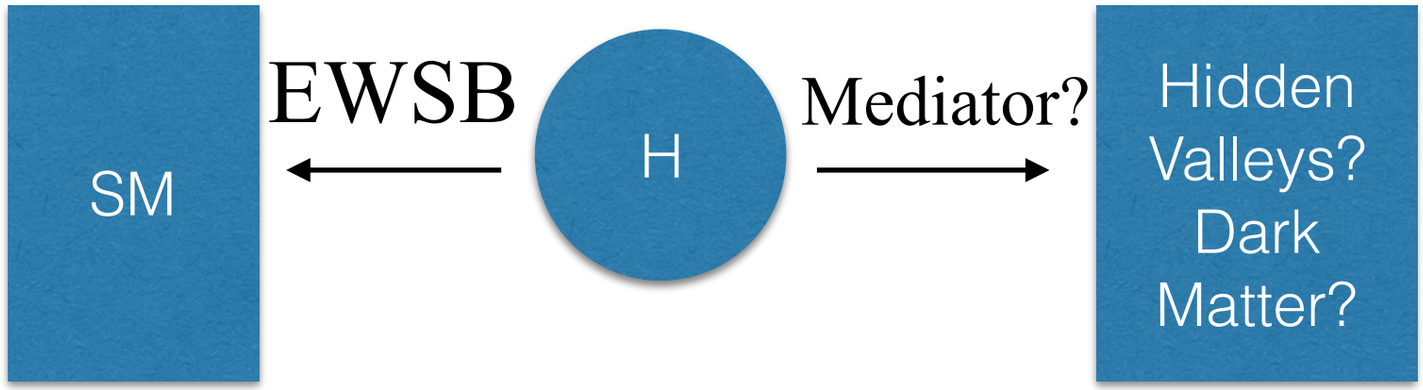
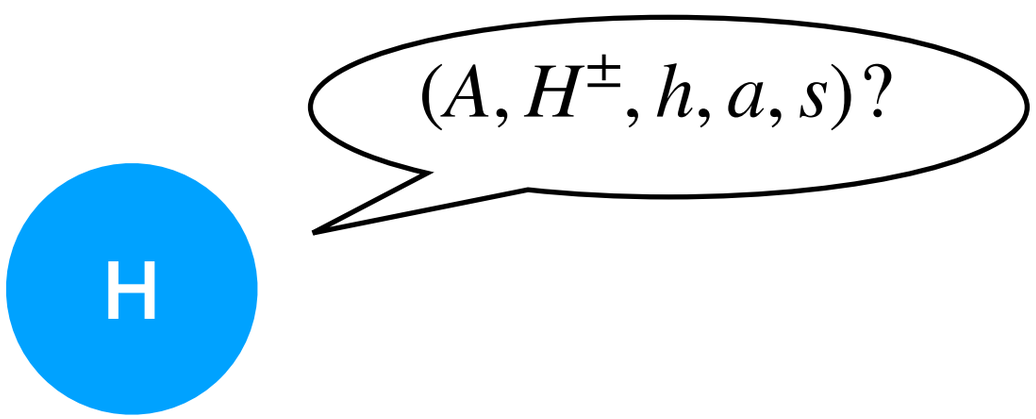
- Discovery of the Higgs: new opportunities to discover new physics!
- New physics may couple to SM only through Yukawa couplings



- Extend Higgs sector to include an extra doublet + additional light singlet: 2HDM+S



Additional singlet → two new states **s, a** which take couplings from the Higgs.

These types of models appear in SUSY extensions, axion models, GUTs…

Is such an extension viable?

Motivation: Exotic Higgs Decays

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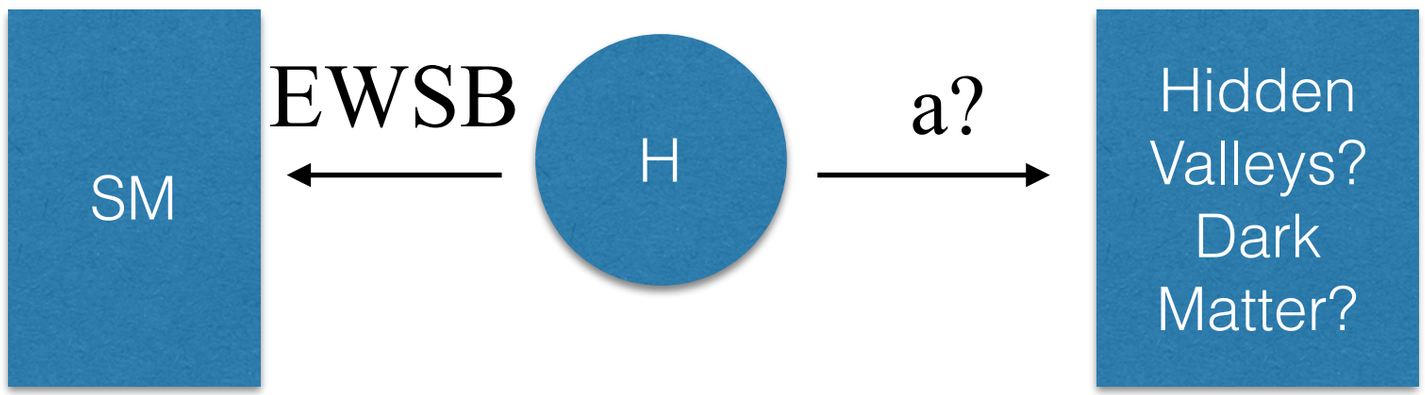

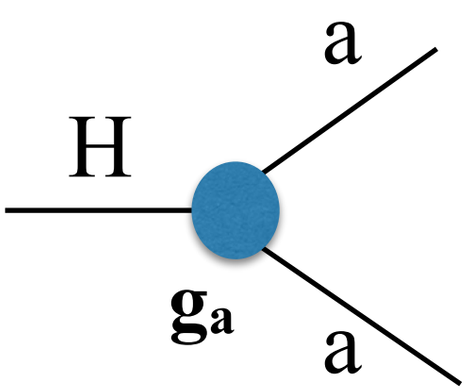

- Extend Higgs sector to include an extra doublet + additional light singlet: 2HDM+S

$\Gamma_H \sim 4.1$ MeV ⟶ **$g_a \sim 10^{-2} \rightarrow$ Br(H→BSM) ~ 10%**

Small width leads to small couplings taking a large BR!

Current constraints from SM Higgs decays: **Br(H→BSM) < 26%** (ATLAS-CONF-2018-031)

Quite a lot of parameter space left!

Dominant Decays

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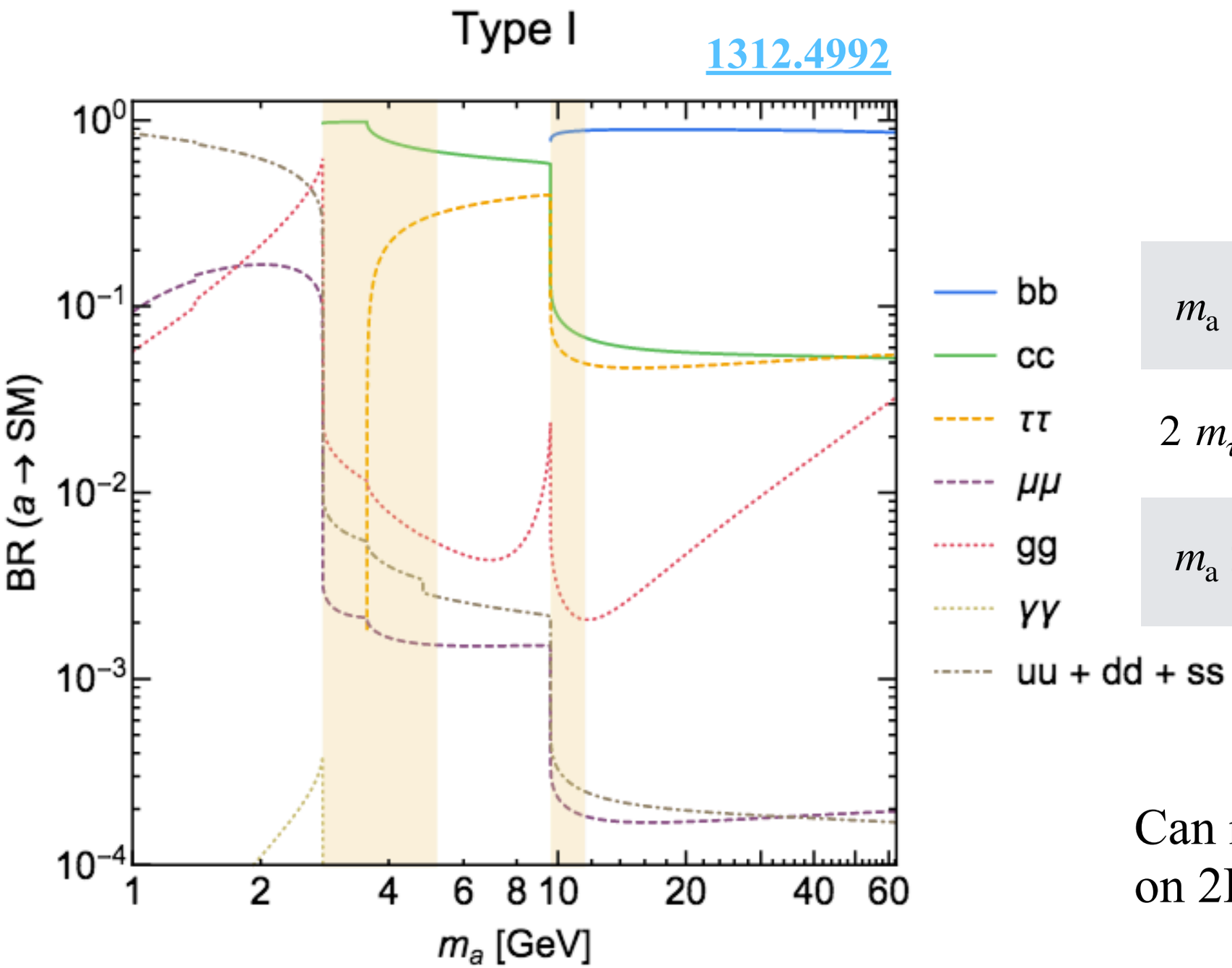
Large parameter space for the decays: $m_a = [0, m_H / 2]$



Mass	Dominant
$m_a < 2\ m_\tau$	uu+dd+ss μμ
$2\ m_\tau < m_a < 2\ m_b$	cc ττ
$m_a > 2\ m_b$	bb

Can move around depending on 2HDM+S type and tan β

Dominant Decays

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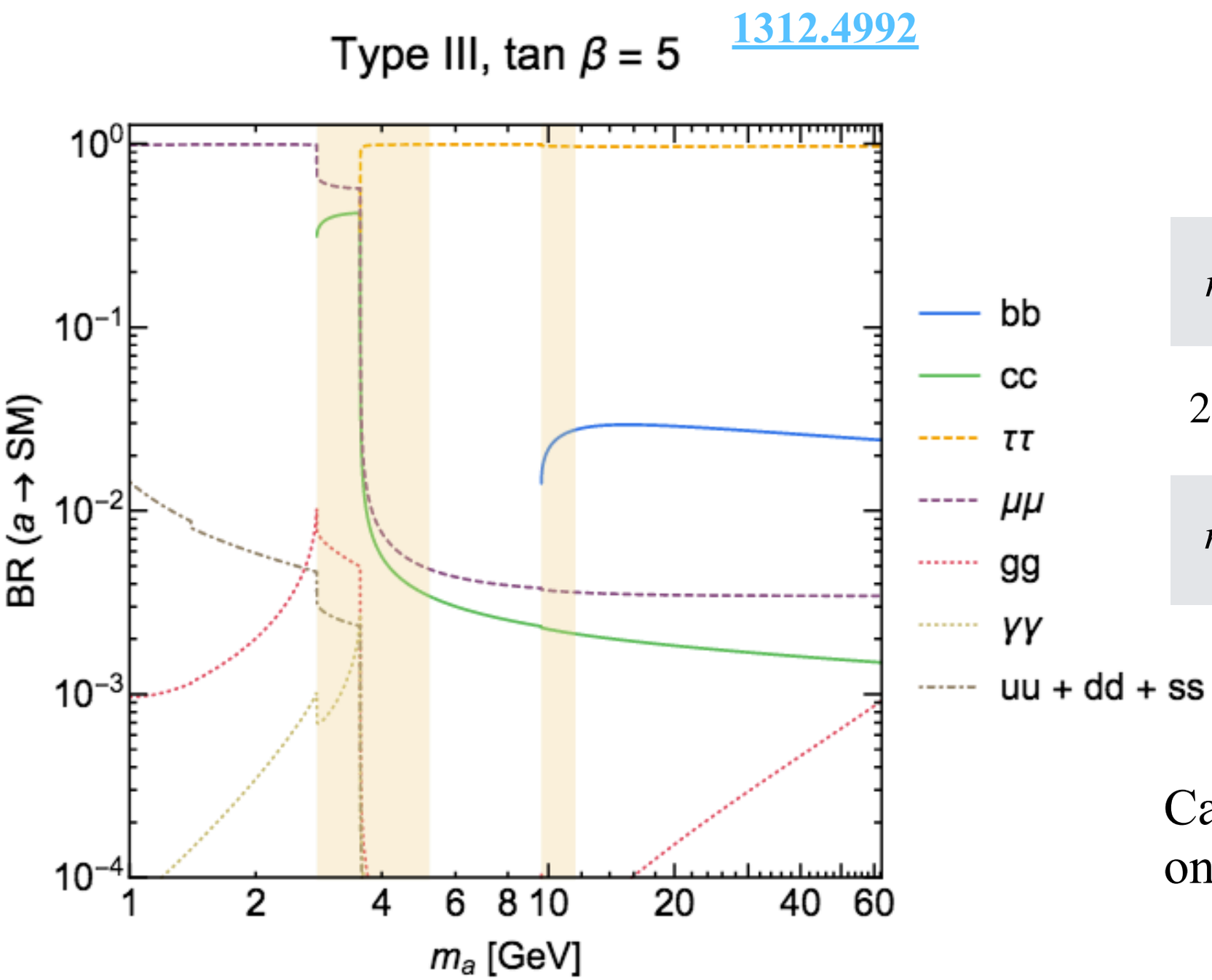

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Experimental Challenges: Trigger

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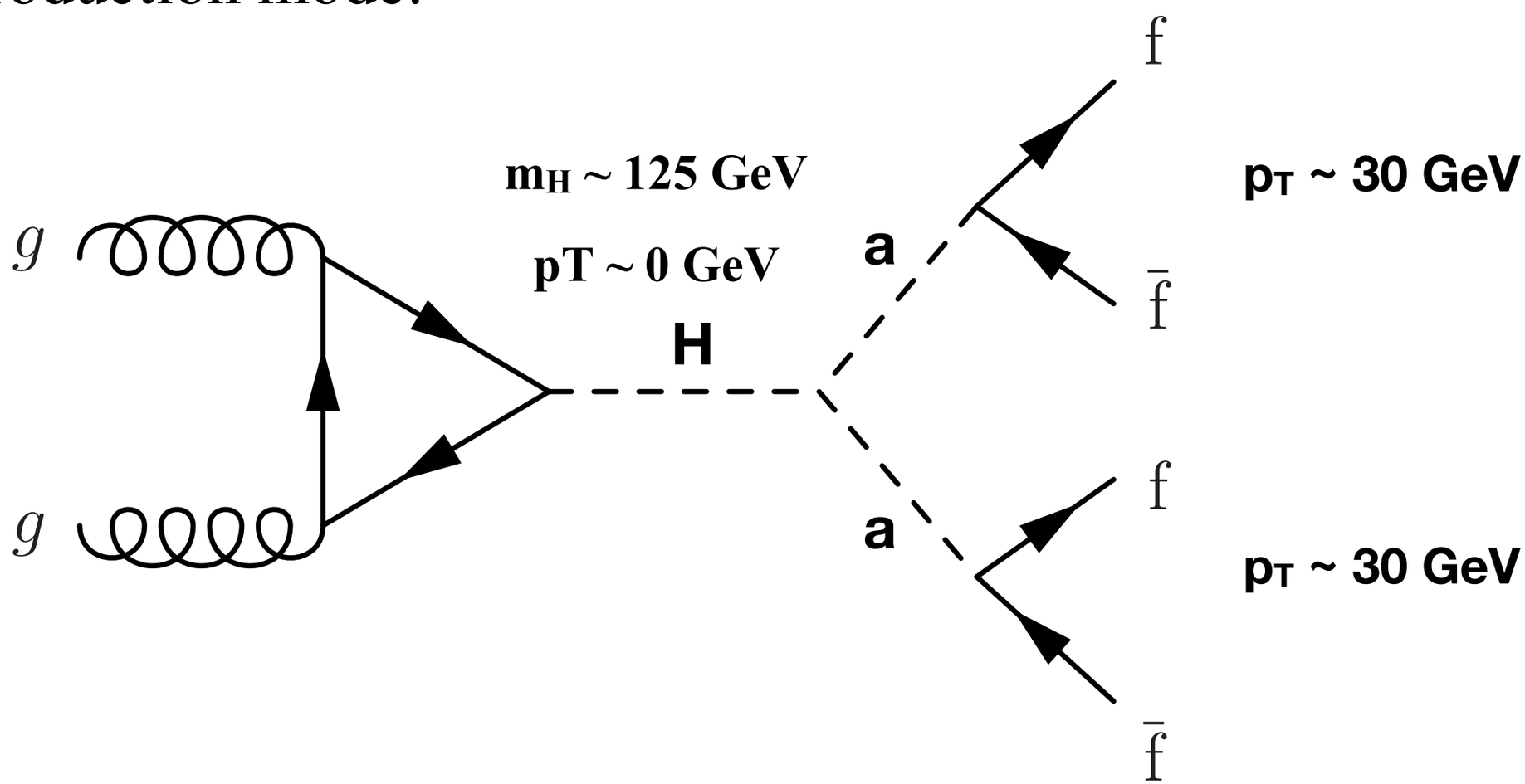
In largest production mode:



If decays are leptons (e,μ): **lowest p_T trigger threshold ~ 27 GeV**

If decays are jets: **lowest p_T trigger threshold >> 30 GeV**

Difficult to trigger on all hadronic final states!

Experimental Challenges: Trigger

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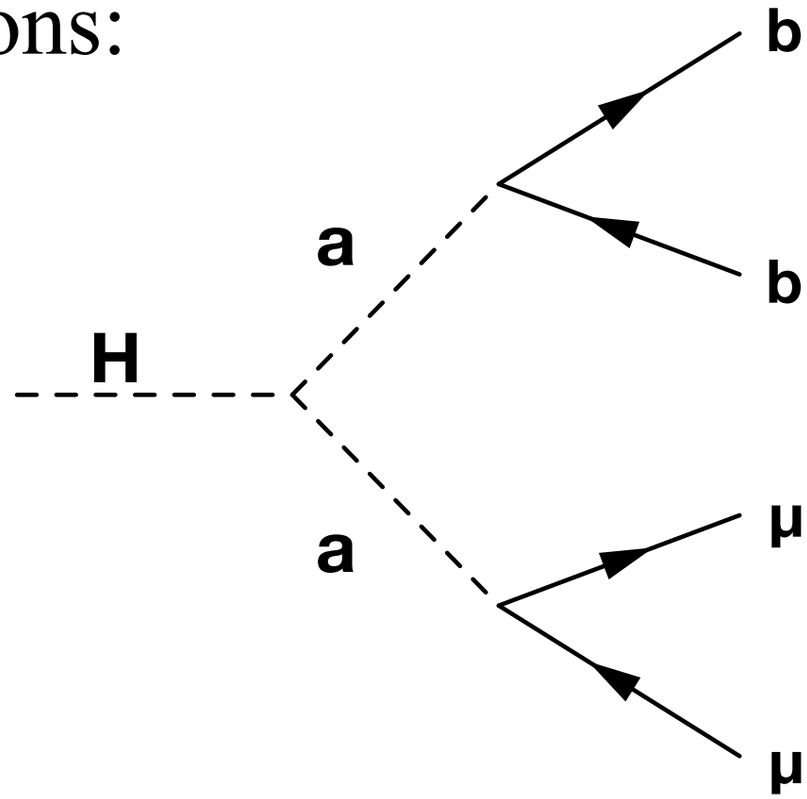
Some Solutions:

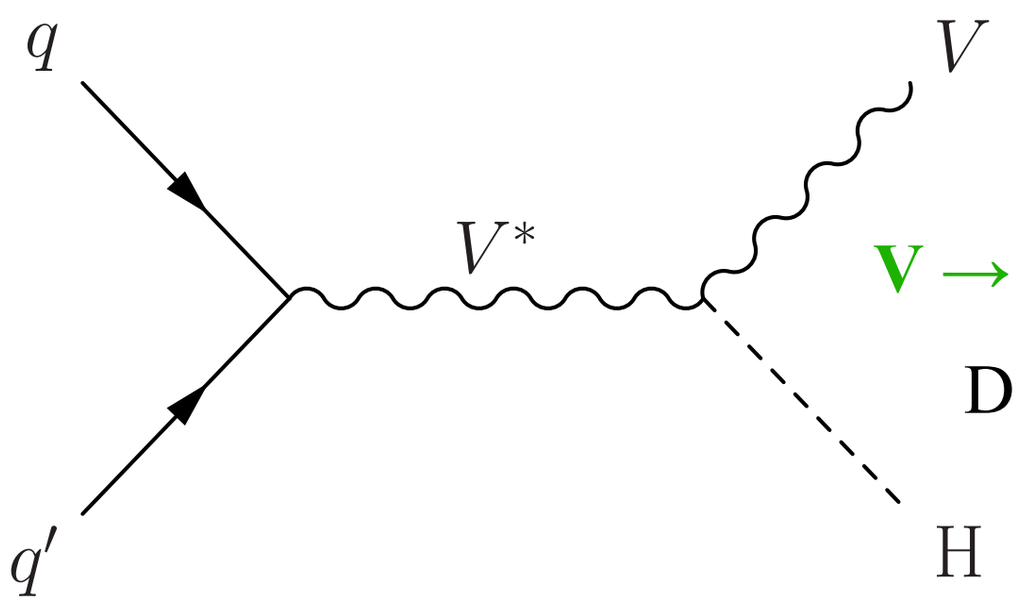


Target mixed final state:

bb → Large BR

μμ → Clean Trigger, good reso.

Downside: **10^2 - 10^4 smaller BR**



Change production mode:

H → 4b, Large BR

V → leptons for trigger + clean up events

Downside: **100x smaller production**

Experimental Challenges: Trigger

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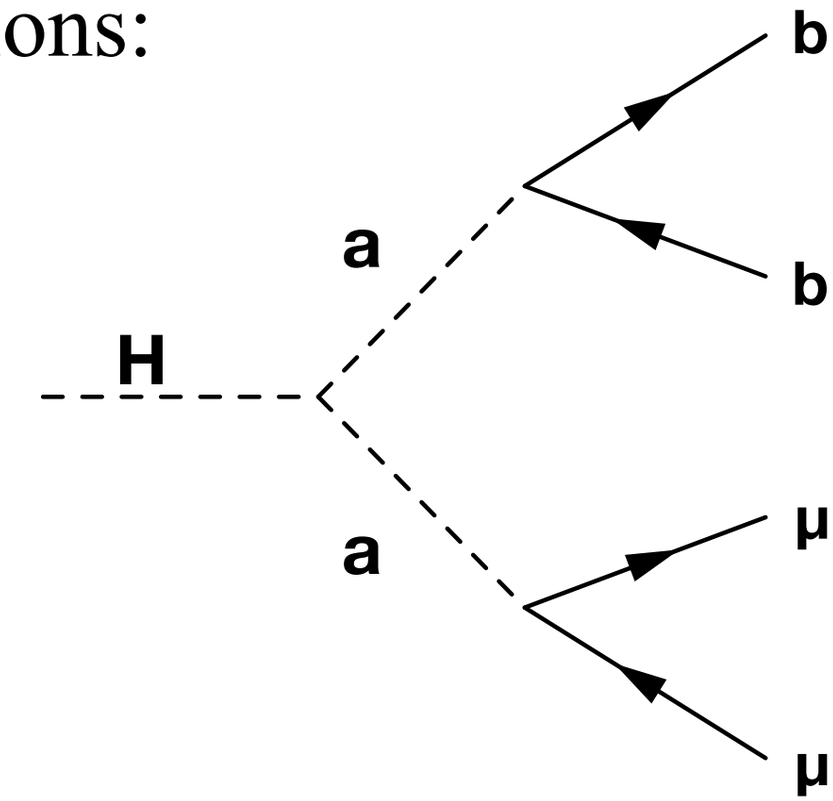

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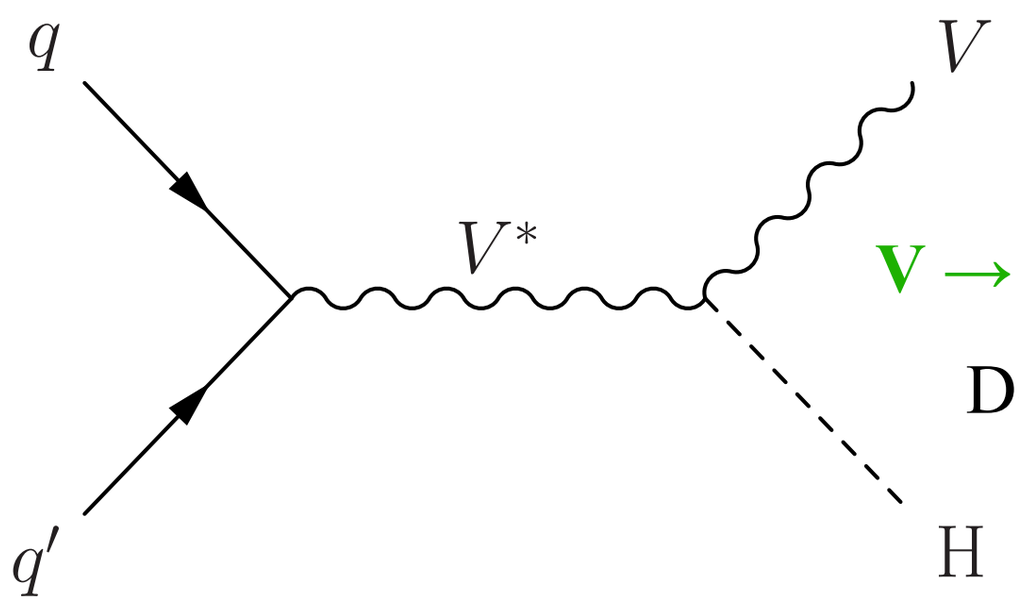
Very Complementary Analyses!



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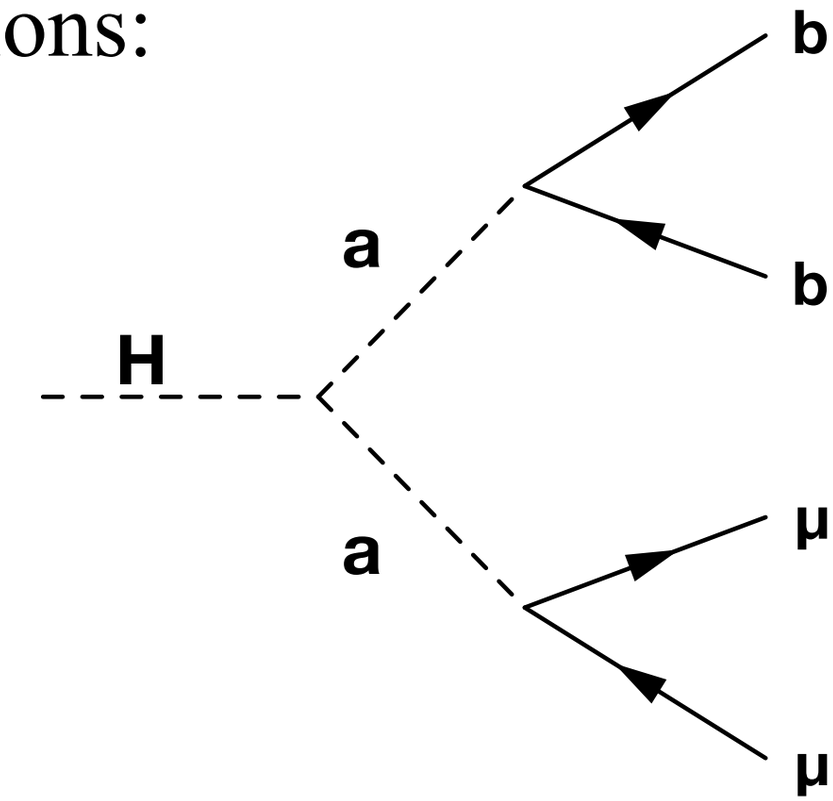

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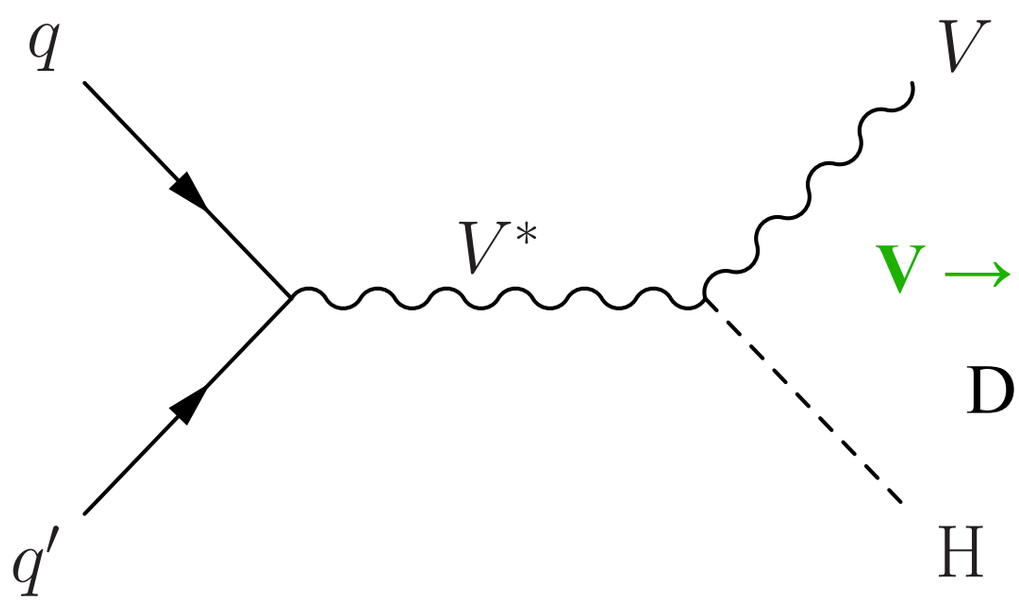

Change production mode:

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Experimental Challenges: Scales

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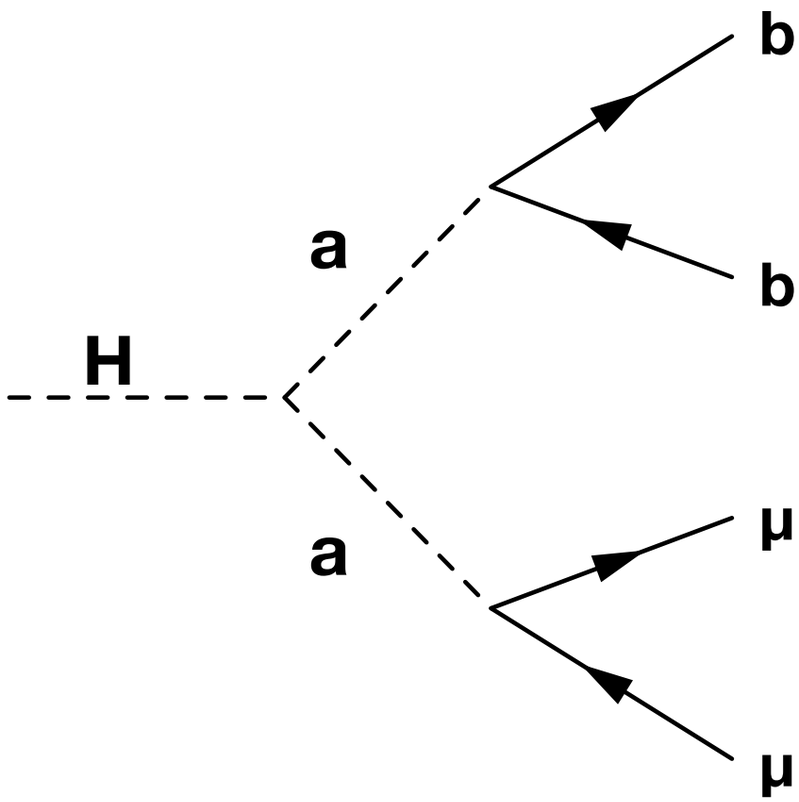
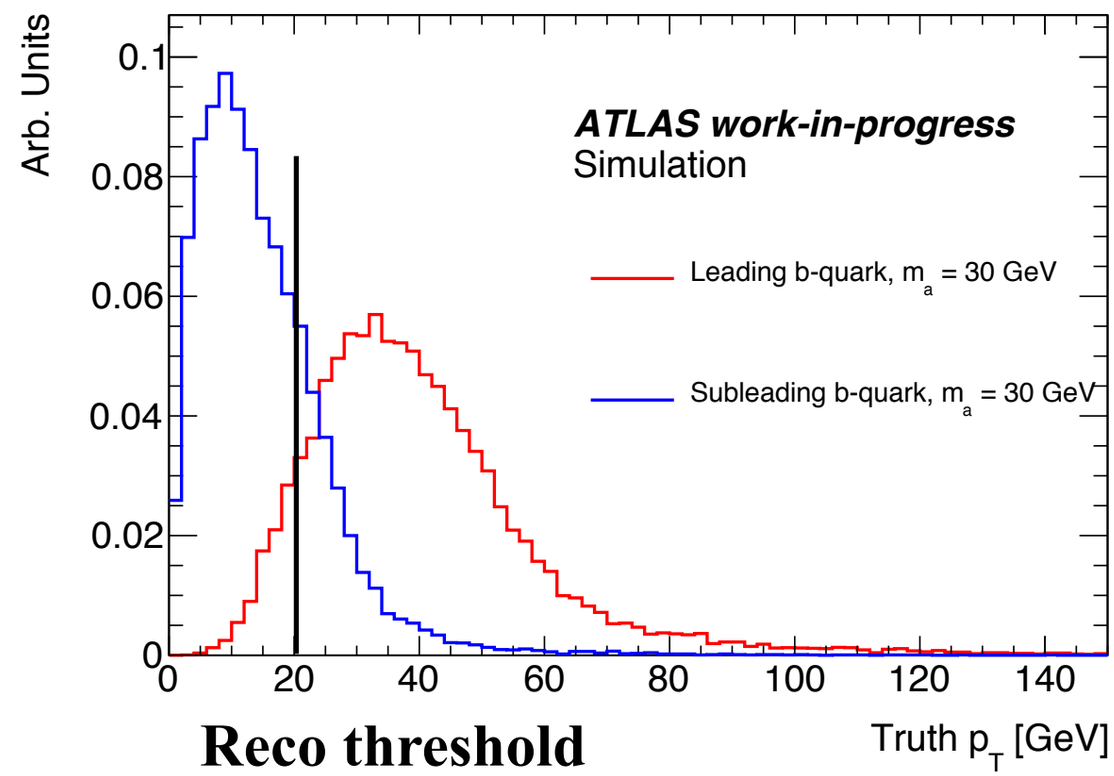
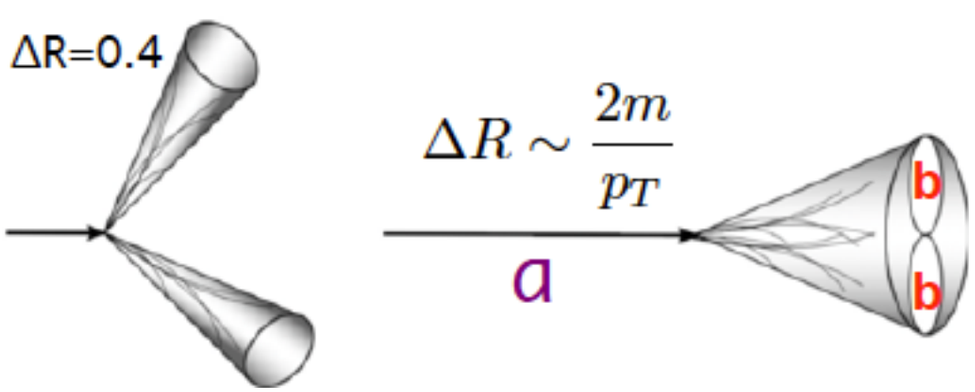
After solving the triggering issue, no other worries…Right?

As m_a becomes lighter… more asymmetric decays



Naive ~ 50% for double b-tag.
Actual ~ 10%! Reco/b-tag ineff.





$\Delta R < 0.8 \rightarrow$ jets start to merge!

$m_a = 15$, $p_T = 40$ GeV

Searching in 2b2μ: Kinematics

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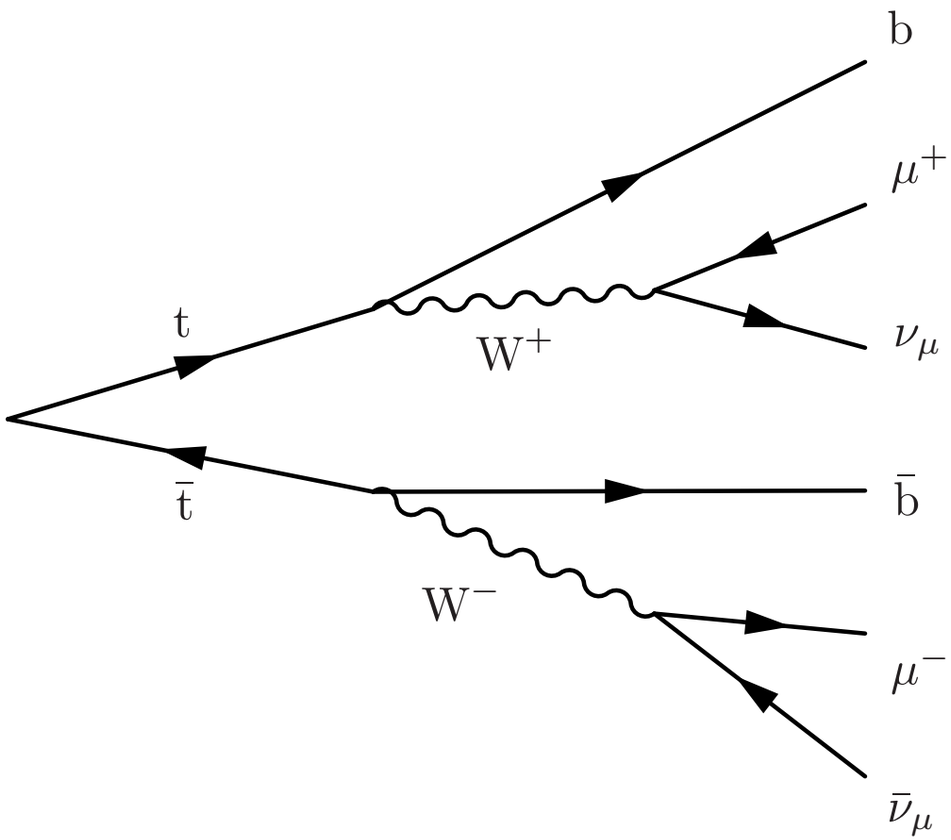
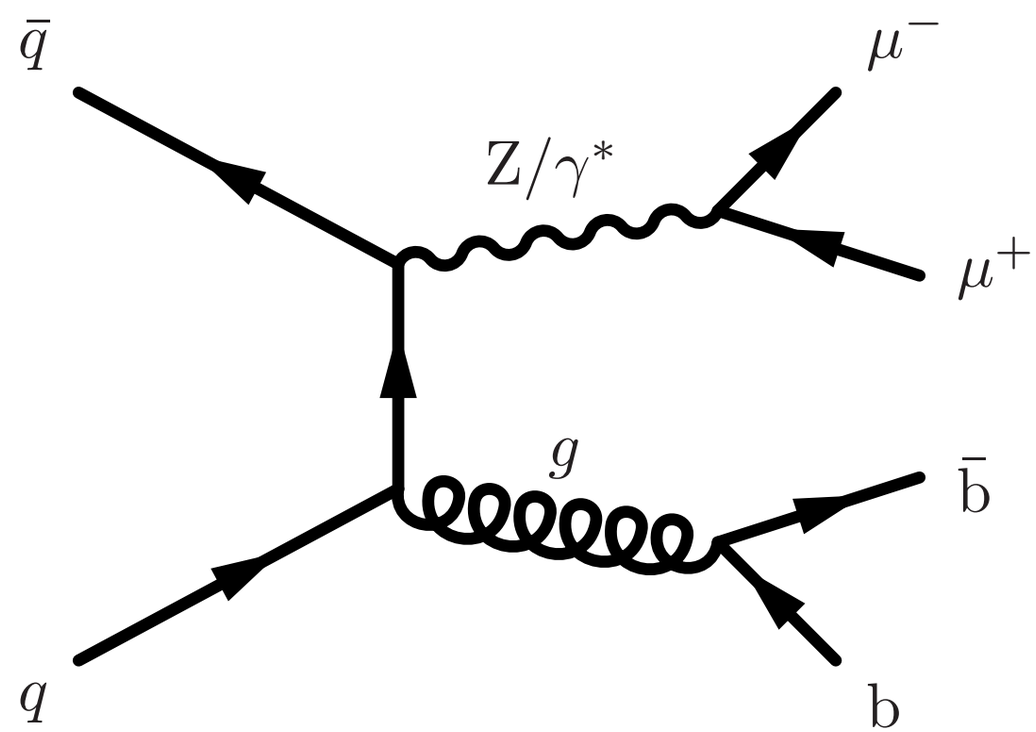
Major backgrounds:





Searching in 2b2μ: Kinematics

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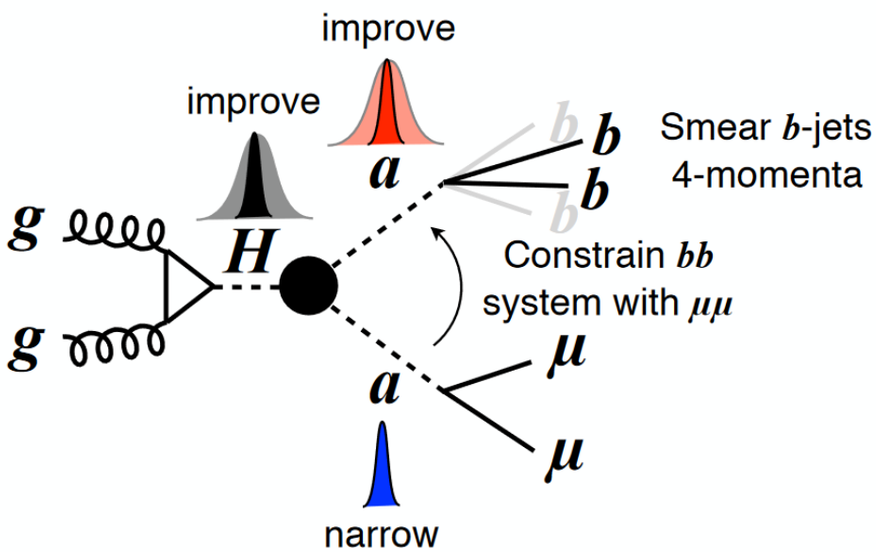
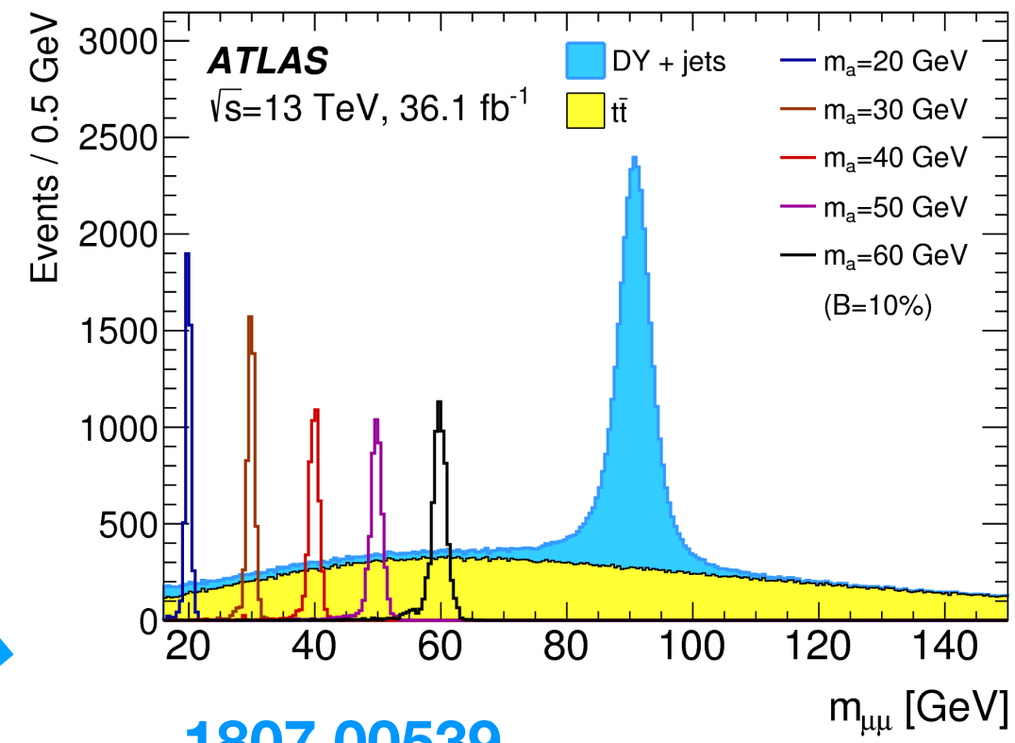
- Major backgrounds are non-resonant in bb!





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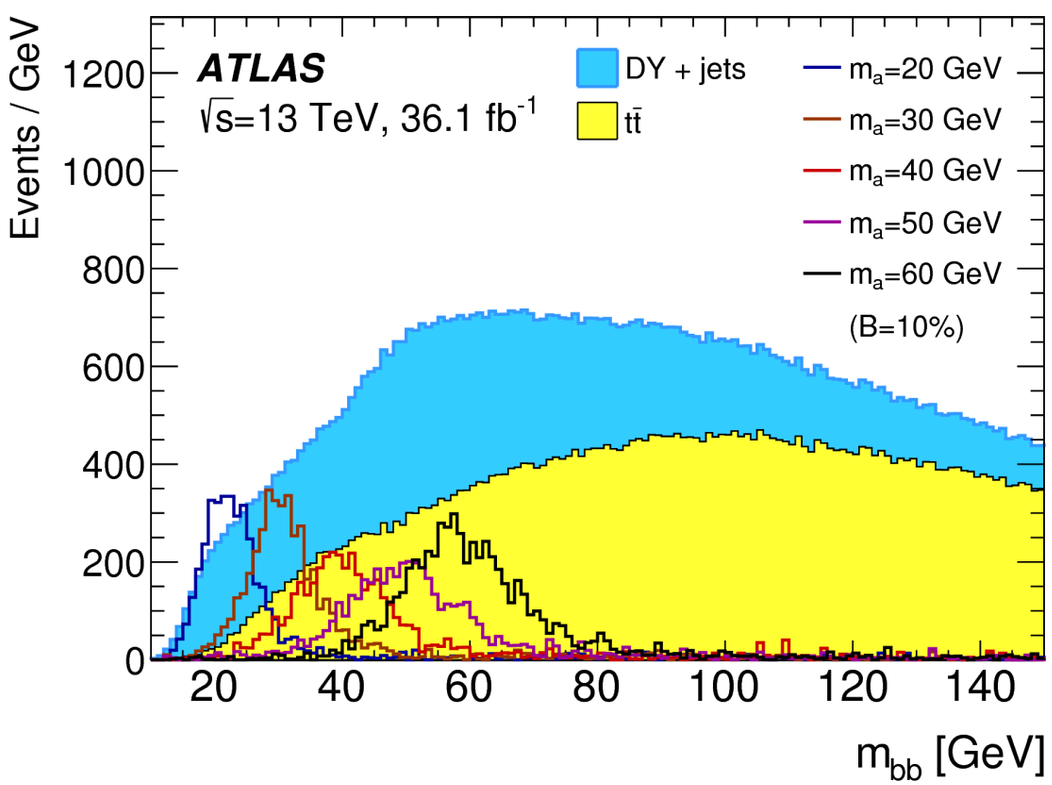

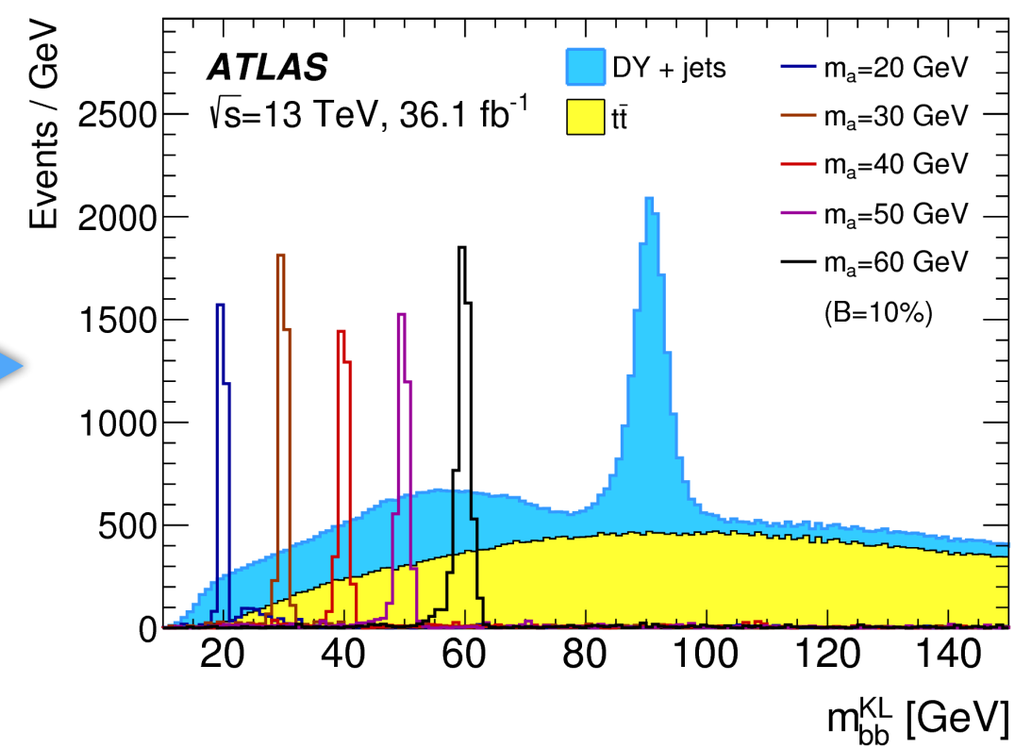

Results

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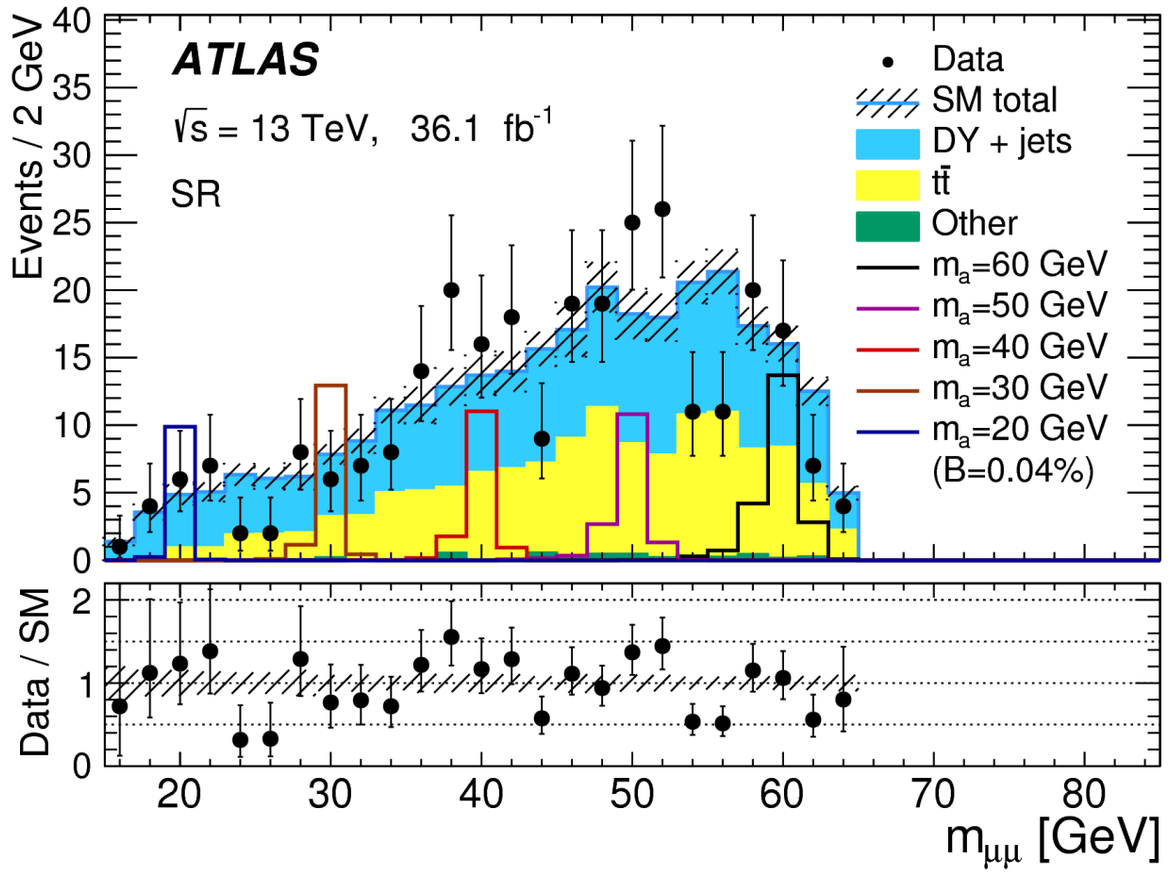
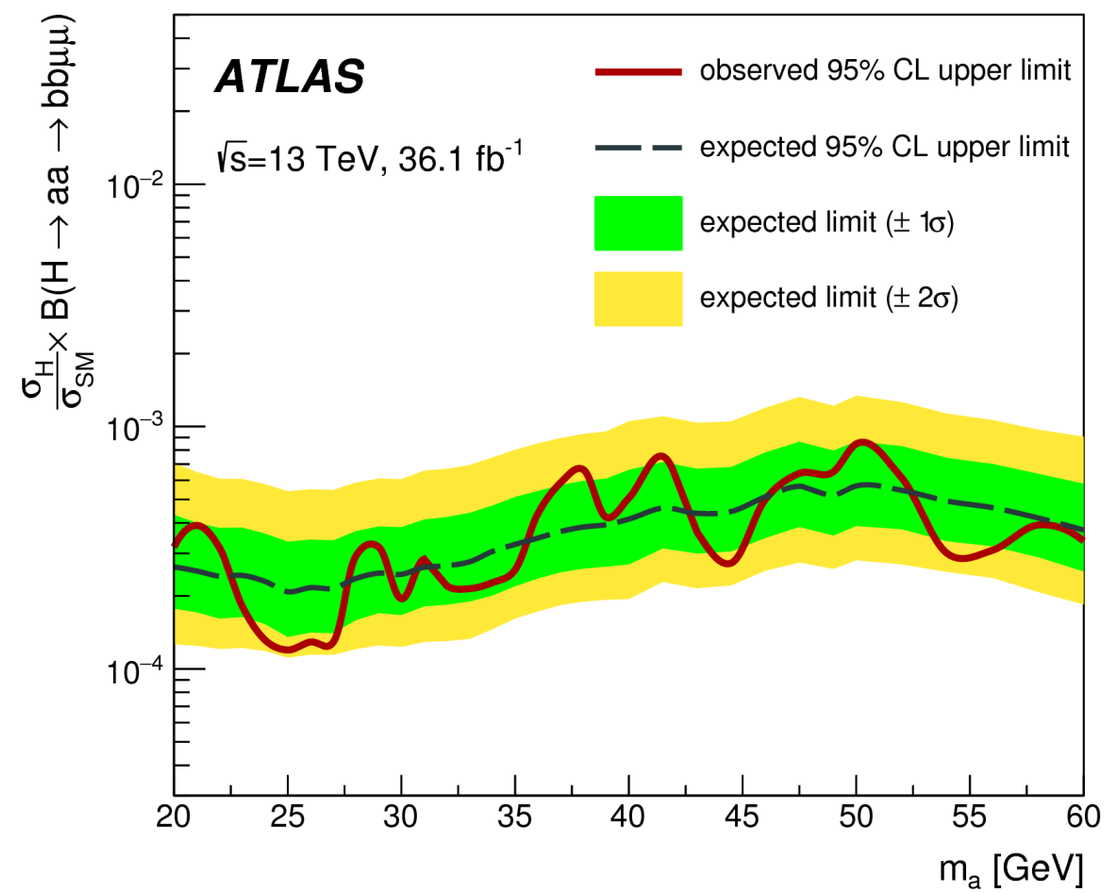
- We're able to provide a limit based on the smallest dimuon mass bins allowed by detector resolution.





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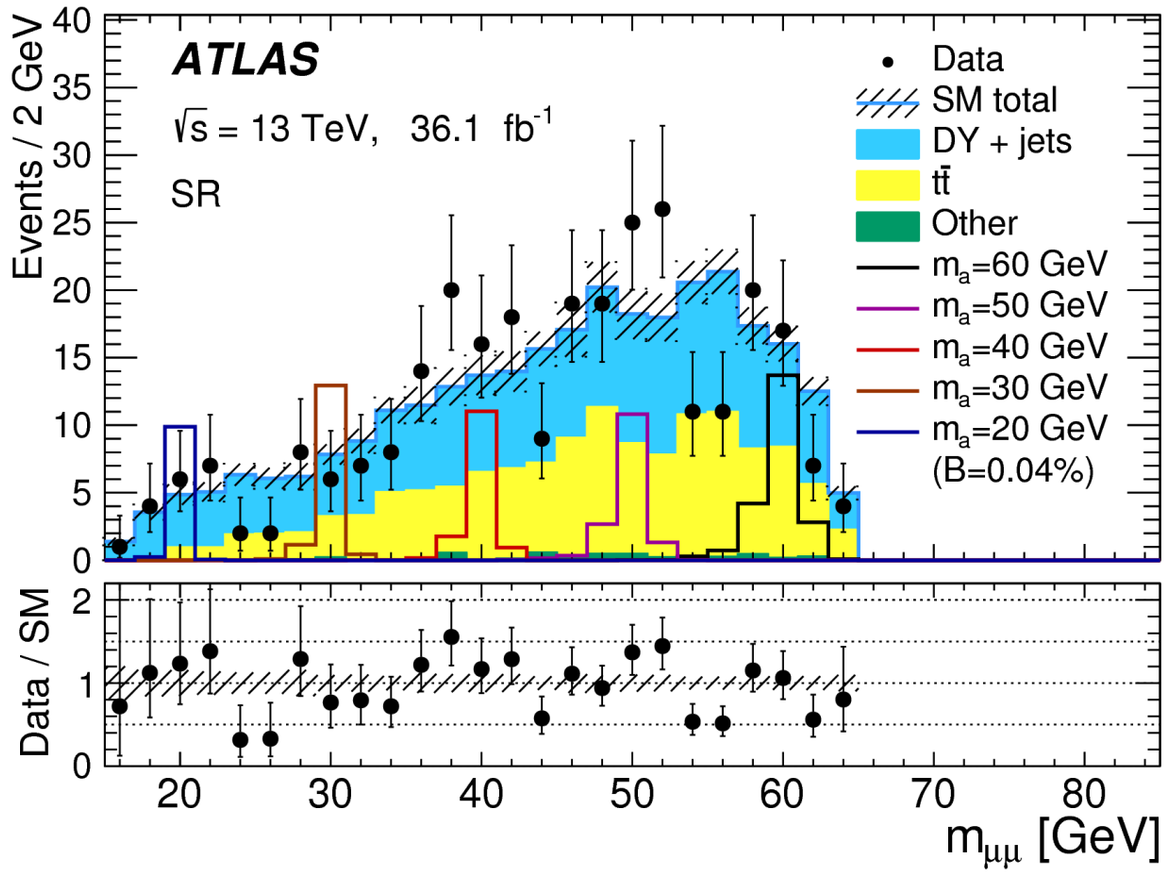

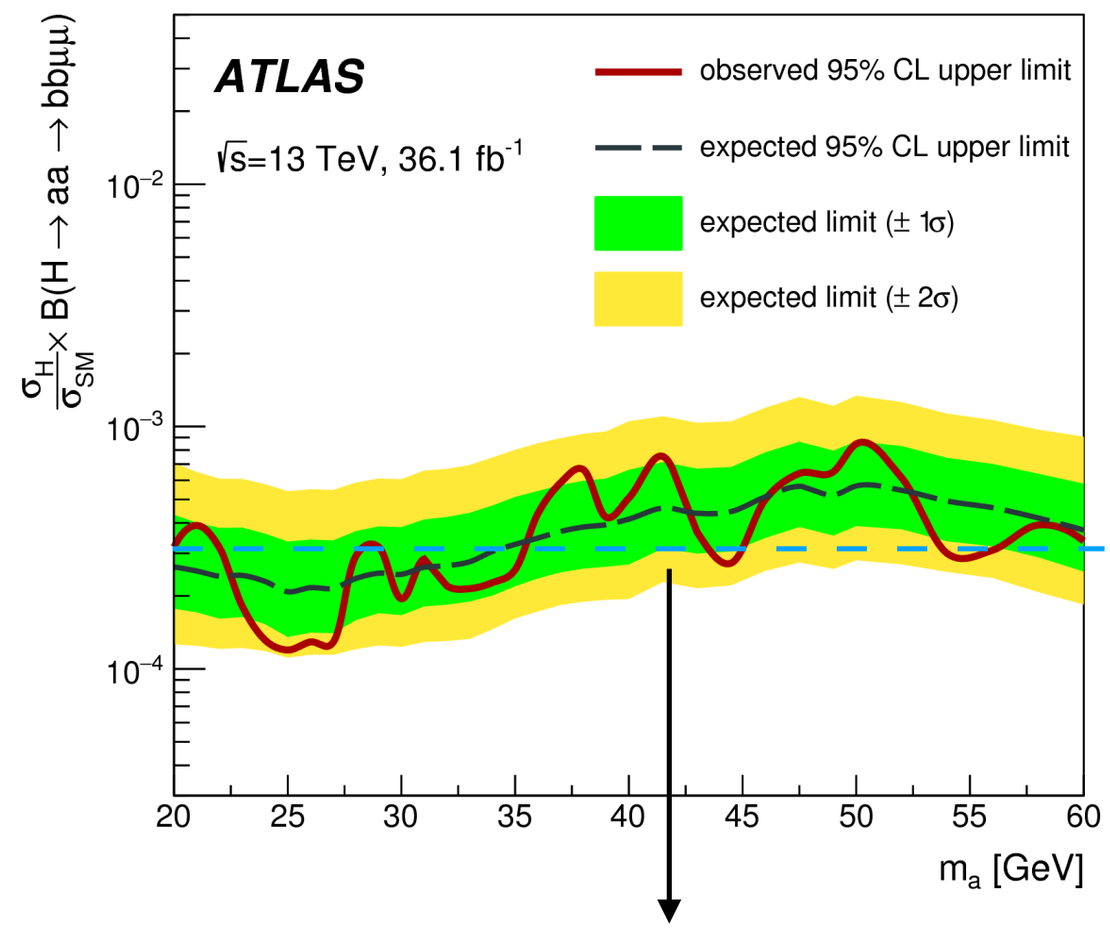

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Limit for Br(H->aa) = 20% in optimistic models!

Increasing Discovery Potential

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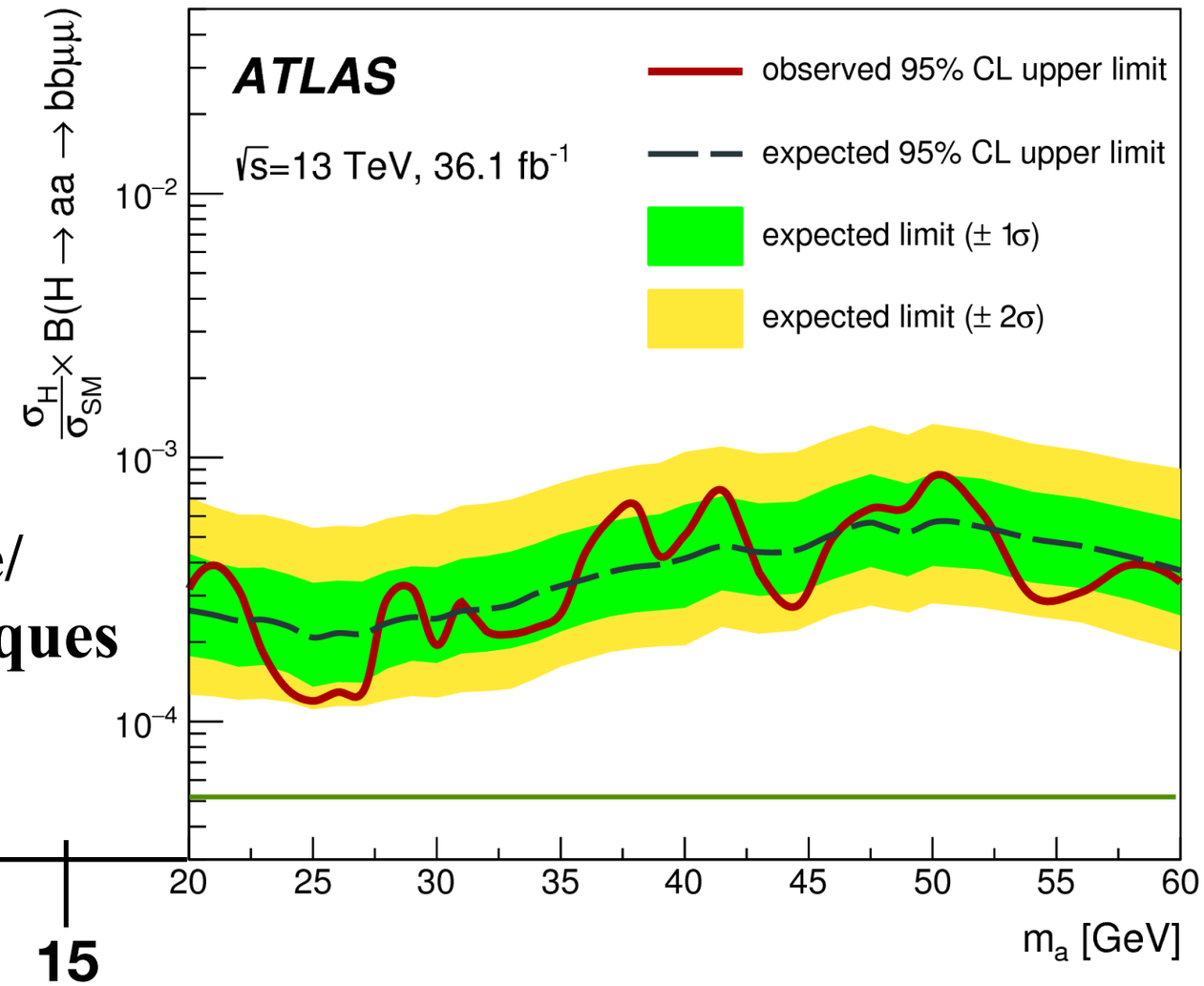

Jet Substructure/
Jet Merging Techniques

Full Run-2
4x more Lumi!
2x better sensitivity!

$p_T(\mu_1,\mu_2) > \{27,7\} \rightarrow \{27,3\}$ GeV: more acceptance!

Adding dimuon trigger channel {15,15}: more acceptance!

Improving b-tagging at low jet p_T? Track jets?

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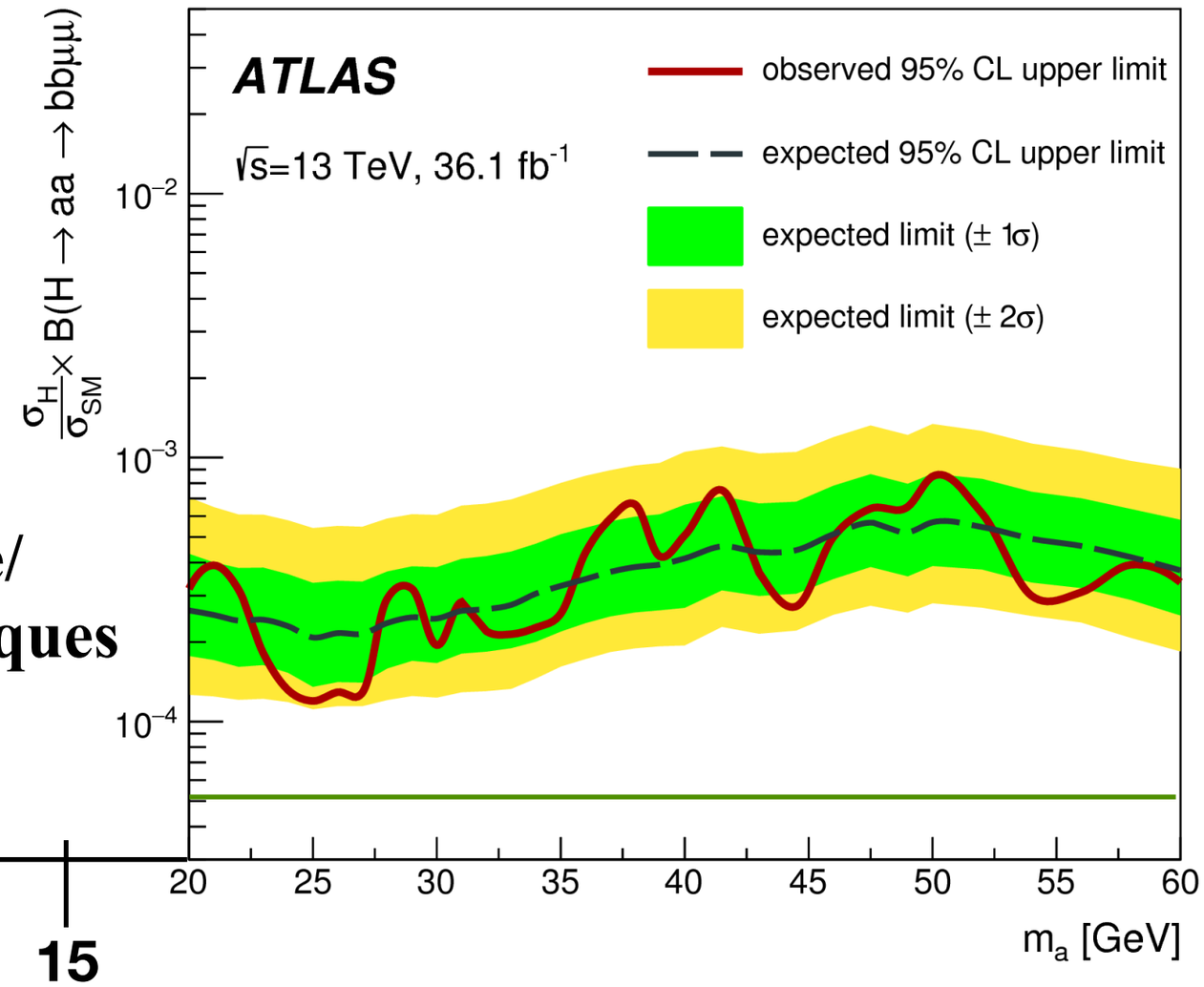

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Many new and exciting ideas await for the future Run-2 analyses!

Backup

The Future?

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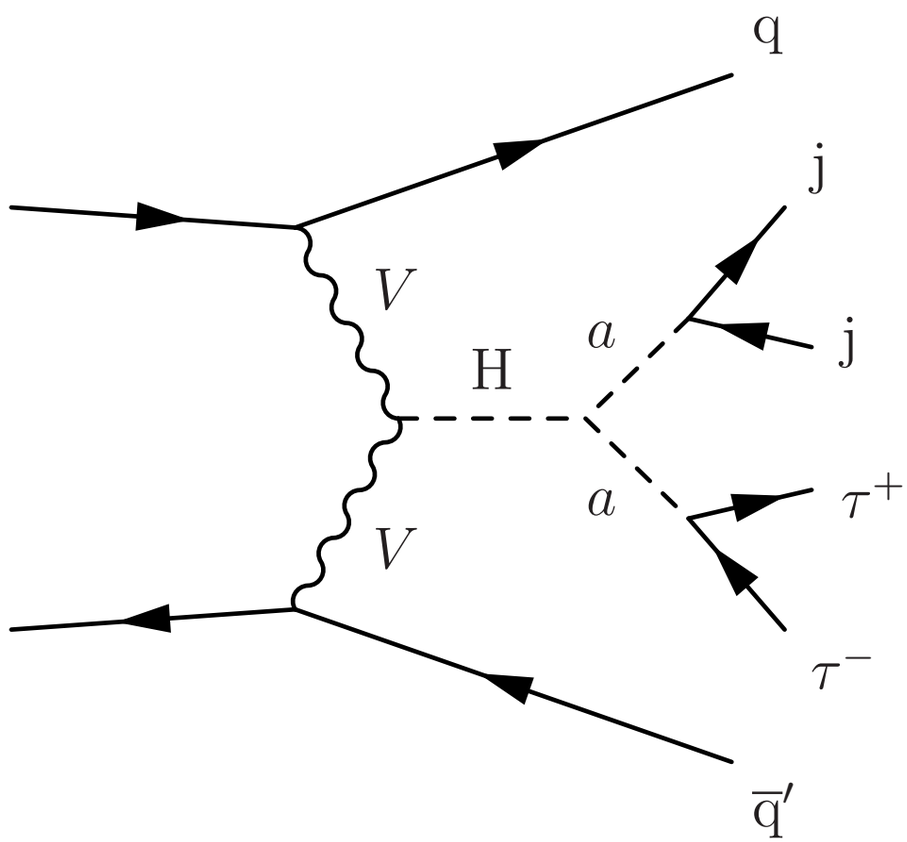

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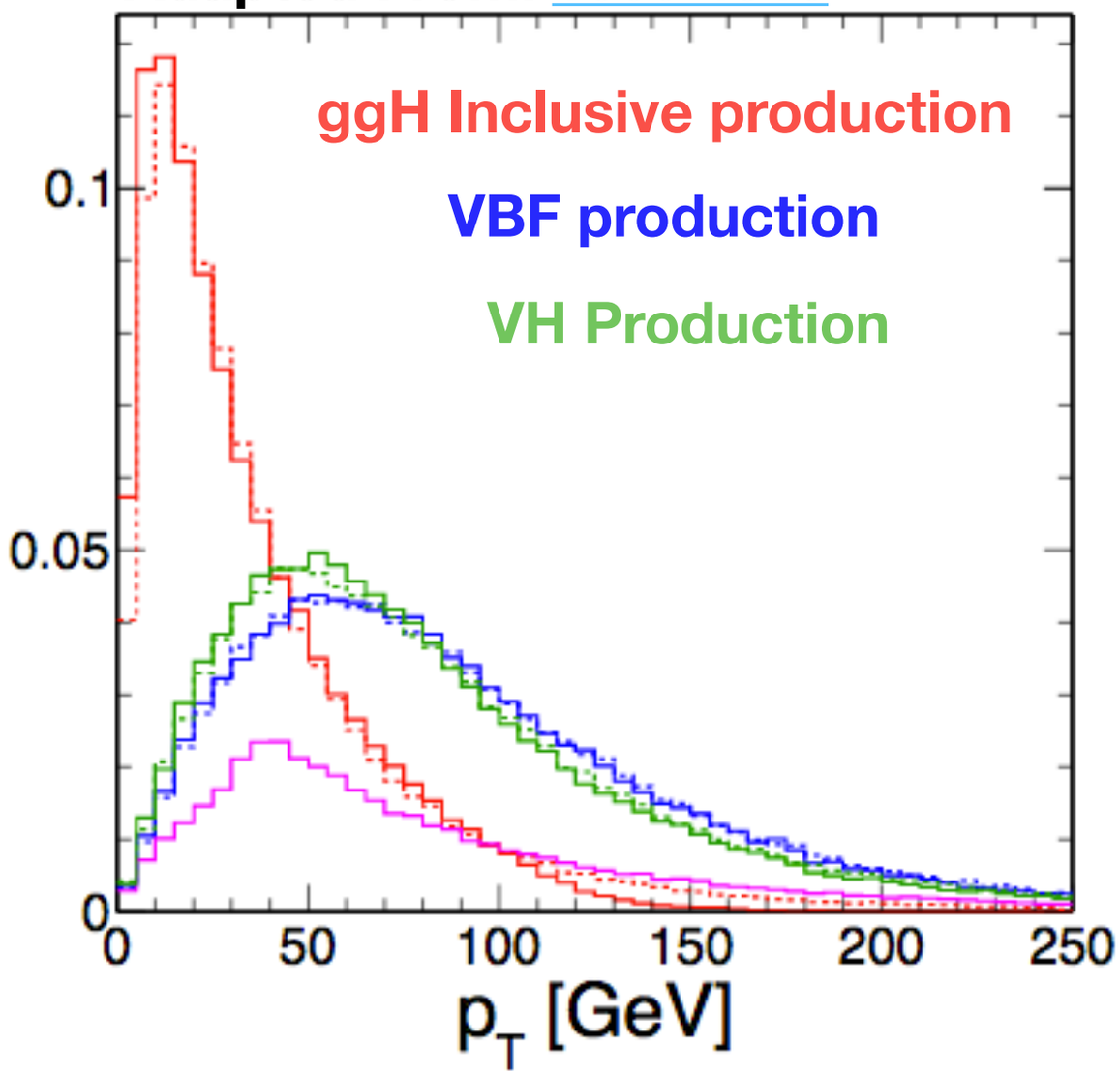

Vector Boson Fusion process: similar Higgs kinematics to VH

Characterized by large $\Delta\eta$,m_{jj} between 2 intermediate pT (50-100 GeV) jets.

Target these two jets and large $\Delta\eta$ using ATLAS L1Topo: trigger running during 2018!