CMS input/status to the WG2 "BSM Higgs" section

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for the CMS collaboration

HL/HE-LHC WG2, 2018/10/23

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CERN

CMS

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MDCCCXLVII

FWF
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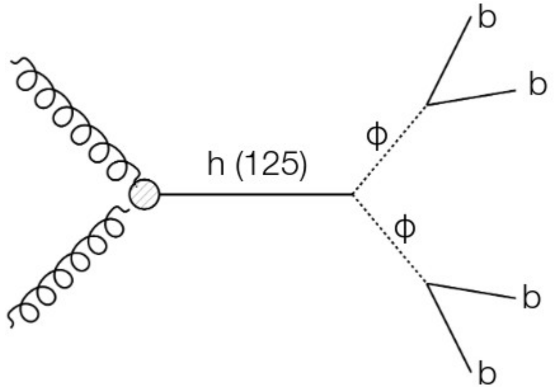
Outline

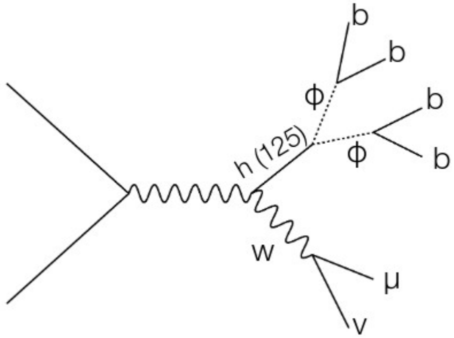
- Status
  - Two CMS contributions pre-approved
    - i.e. can be shown in WG2 meetings and in the overleaf document
  - Still on track: two additional contributions
    - Projection of $h \rightarrow aa$ decays ($\rightarrow 2\mu 2\tau$ / $2b2\tau$ / 4μ)
    - Heavy Higgs searches in $ZZ \rightarrow llqq$

- Details on pre-approved analyses
  - L1 Track jets to trigger on BSM Higgs signatures with displaced jets
  - MSSM $H \rightarrow \tau\tau$ projection

L1 Track jets to trigger on BSM Higgs

- Many BSM searches have multi-jet signatures
  - stop decays to top, RPV SUSY, scalar decays (e.g. Φ→bb)
  - How much can we gain with L1 track jets (new @Phase-2)?
    - In particular in the low-HT region not covered by current triggers
    - Long-lived scalar Φ: Currently, focus on associated production (e.g. VH)
      - Huge rate reduction, typically O(100)

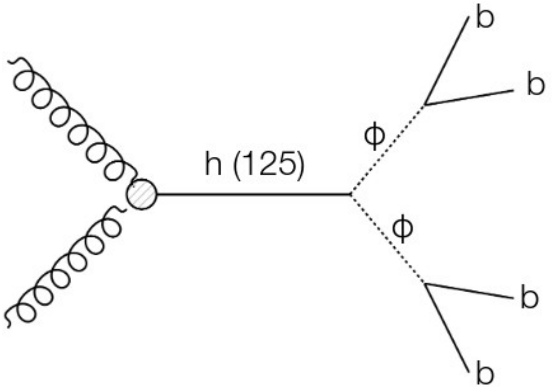




- L1 track jets: handle to lower trigger rates via
  - including displaced track information (→“long“-lived particles)
  - fake jet rejection with track multiplicity requirements

Signal

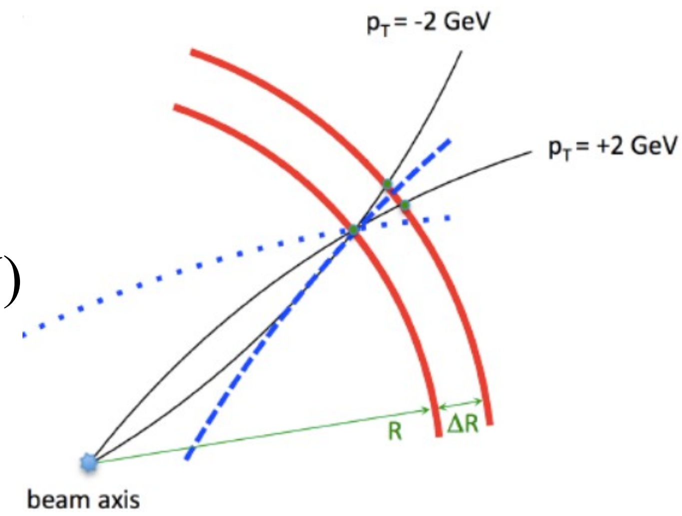
- Signal
  $H(125) \to \phi\phi \to b\bar{b}b\bar{b}$, with masses of 15, 30, and 60 GeV, and $c\tau$ of 0, 1, and 5 cm
  $H(250)$ -“-



- Displaced particle decays → displaced tracks (high d_0)
  - Low reconstruction efficiency for usual prompt tracking algorithms
  - L1: reconstruct displaced tracks with IP up to about 5 cm
    - Then, cluster these tracks into displaced „track jets“

Displaced track jet: L1 reconstruction

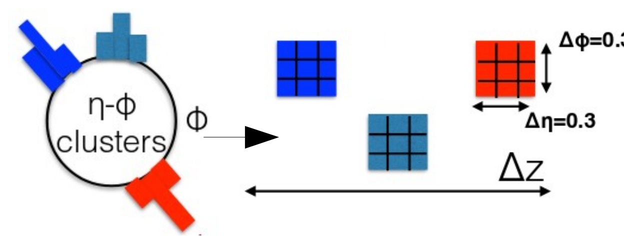
- HL-LHC: can reconstruct displaced tracks at the first trigger level (L1)
- Algorithm
  - Seeded by stubs (pair of hits in two sensors, separated by a few mm, consistent with a prompt track w. pT>2 GeV)



  - Loose criteria on #stubs & track fit quality

track p_T	4 stubs	5 stubs	6stubs
2 – 10 GeV	$\chi^2 < 15$	$\chi^2 < 15$	accept
10 – 50 GeV	reject	$\chi^2 < 10$	accept
> 50 GeV	reject	$\chi^2 < 5$	$\chi^2 < 5$

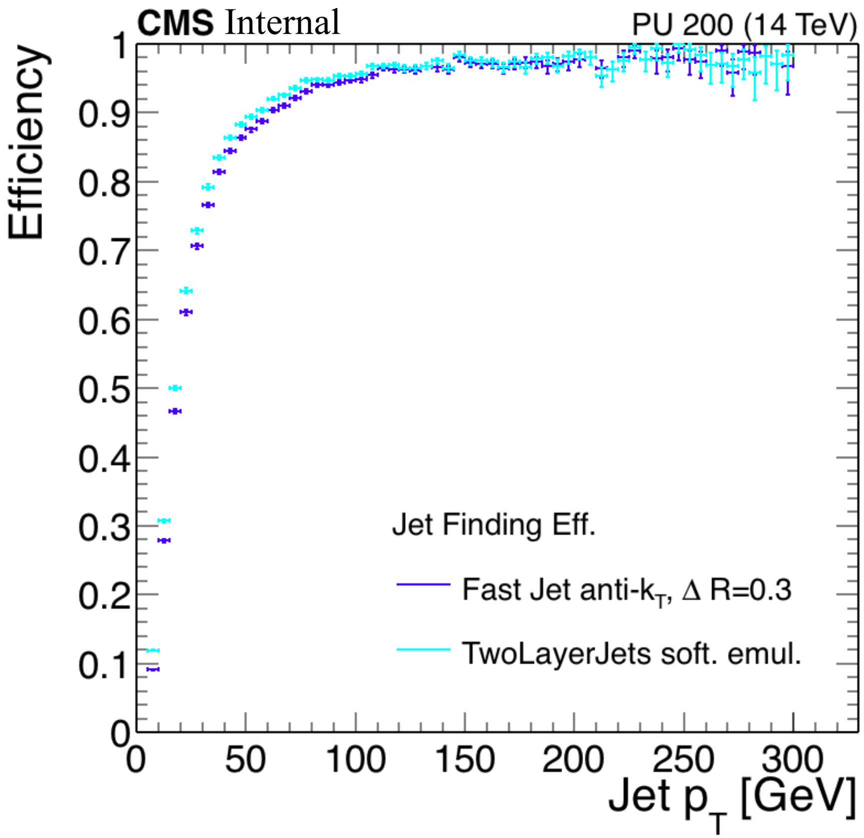
  - Clustering:
    - Sum track pT in bins of size η x φ = 0.2 x 0.23
    - Nearest-neighbour clustering of these bins
    - Sum pT of clusters in each z_0 bin (z_0...distance of track to z axis, bin size=6cm)
    - Select z_0 bin with highest sum-pT



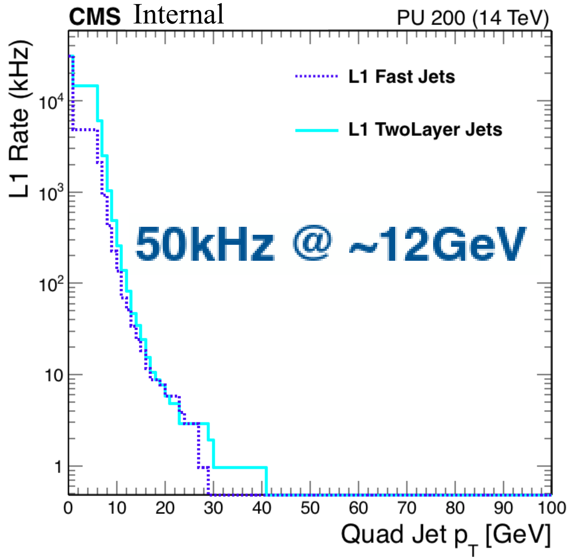
- Coded in Verilog & tested on CTP7 Demo Proj; full firmware integration to be done

Performance

- Simplified trigger algorithm gives performance comparable to anti-kT algorithm with (FASTJET, ΔR=0.3)
  - Track jet reco efficiency vs hadron-level jet pT

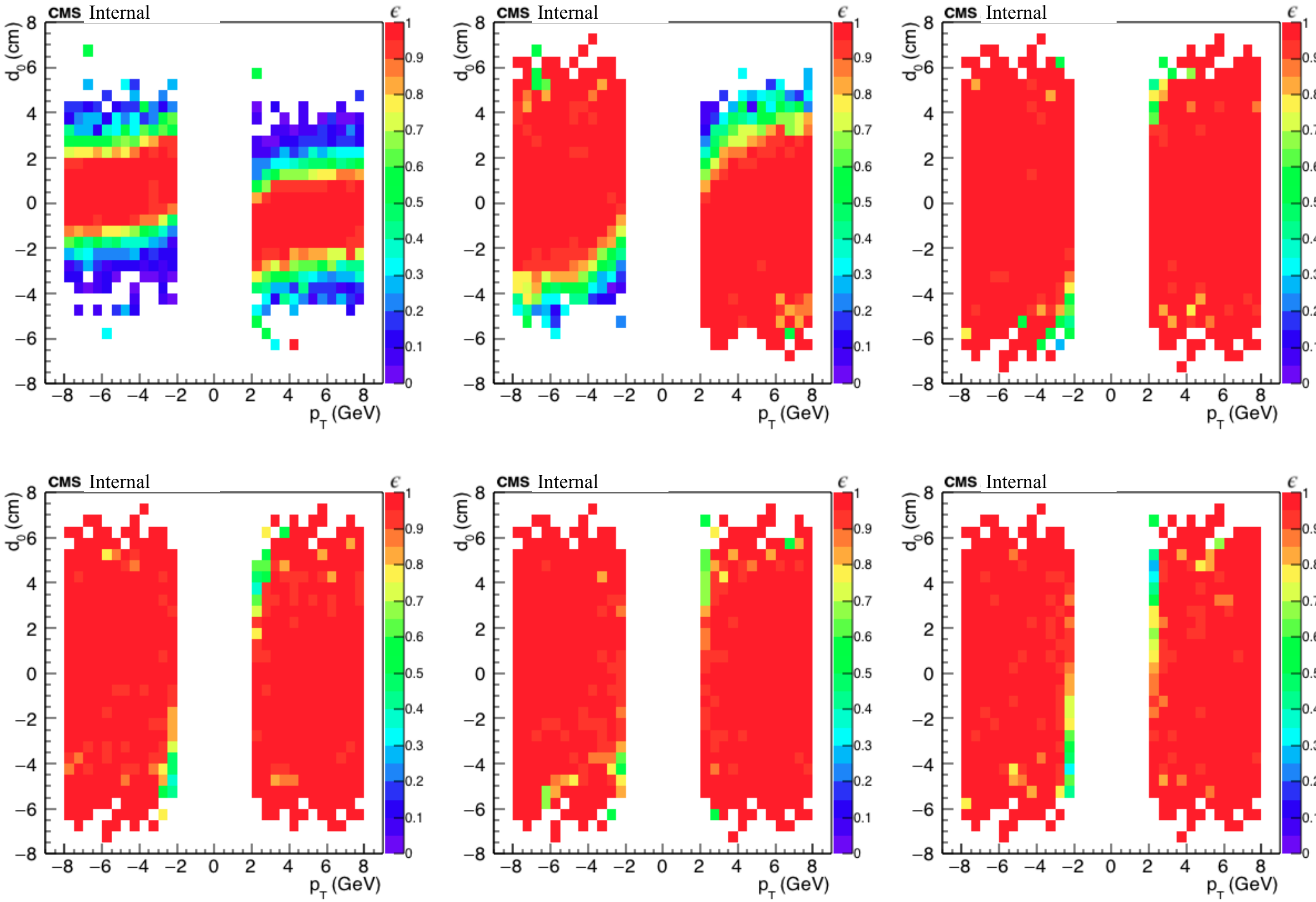


- Rate (4 jets with pT>X)



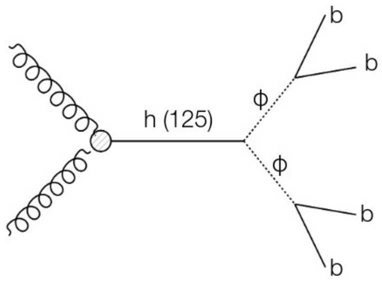
Efficiency for a displaced muon stub

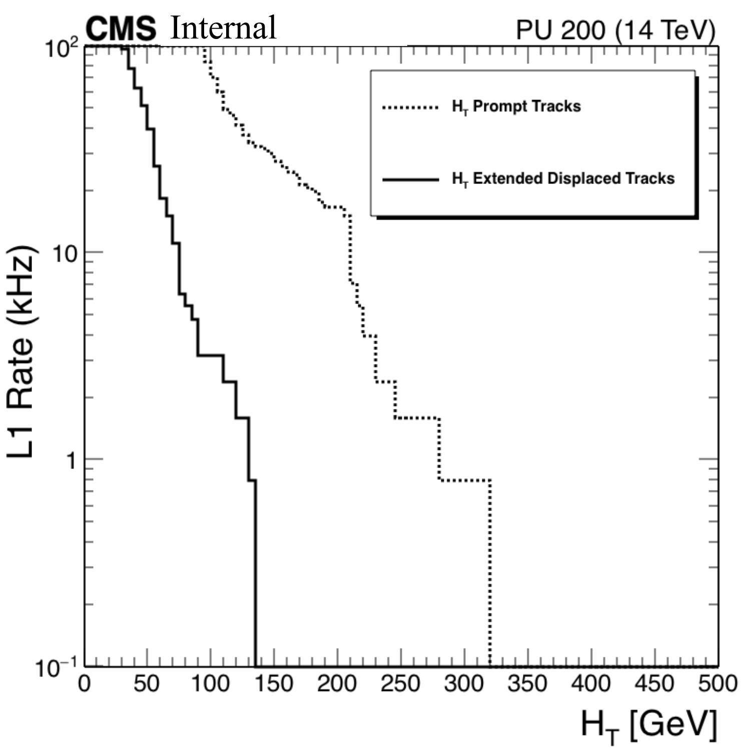
- In the six layers of the L1 tracker barrel, pT(muon)=2-8 GeV
  - Efficiency close to 1 for the outer layers

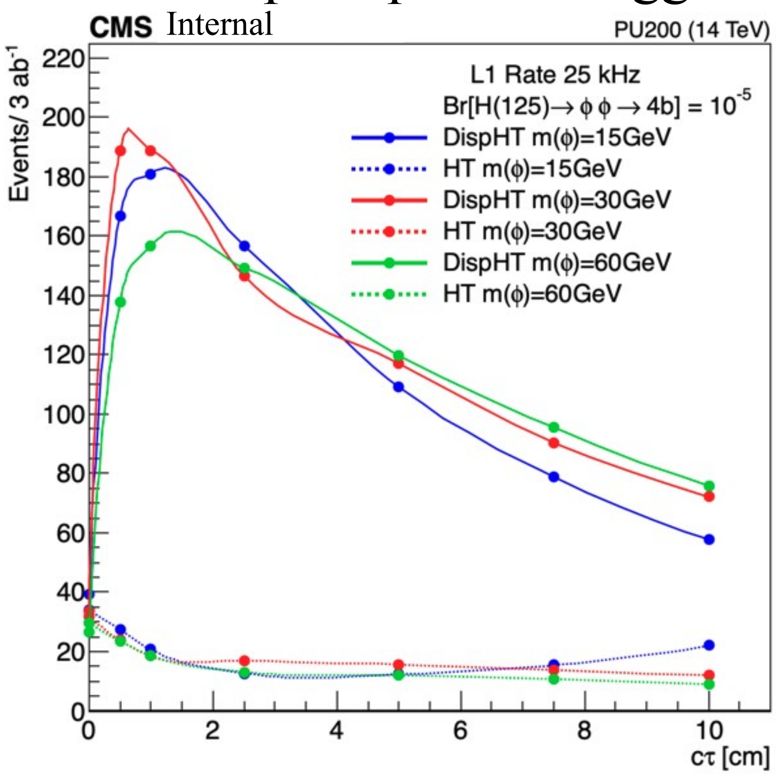


Trigger rates for displaced tracks

- Requiring at least one displaced jet for HT trigger:
  - Can reduce online HT cut from 110 to 50 GeV (const. rate 25 kHz)
  - Feasible to trigger on exotic H(125) decays
  - Can collect up to O(10) more Higgs events wrt a prompt track trigger

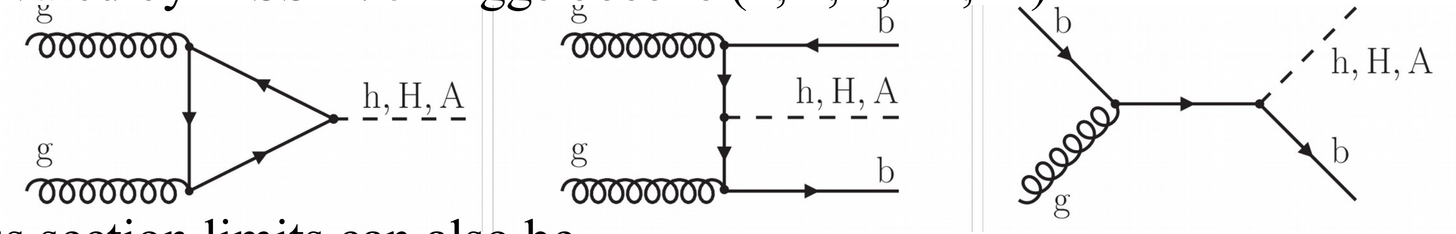




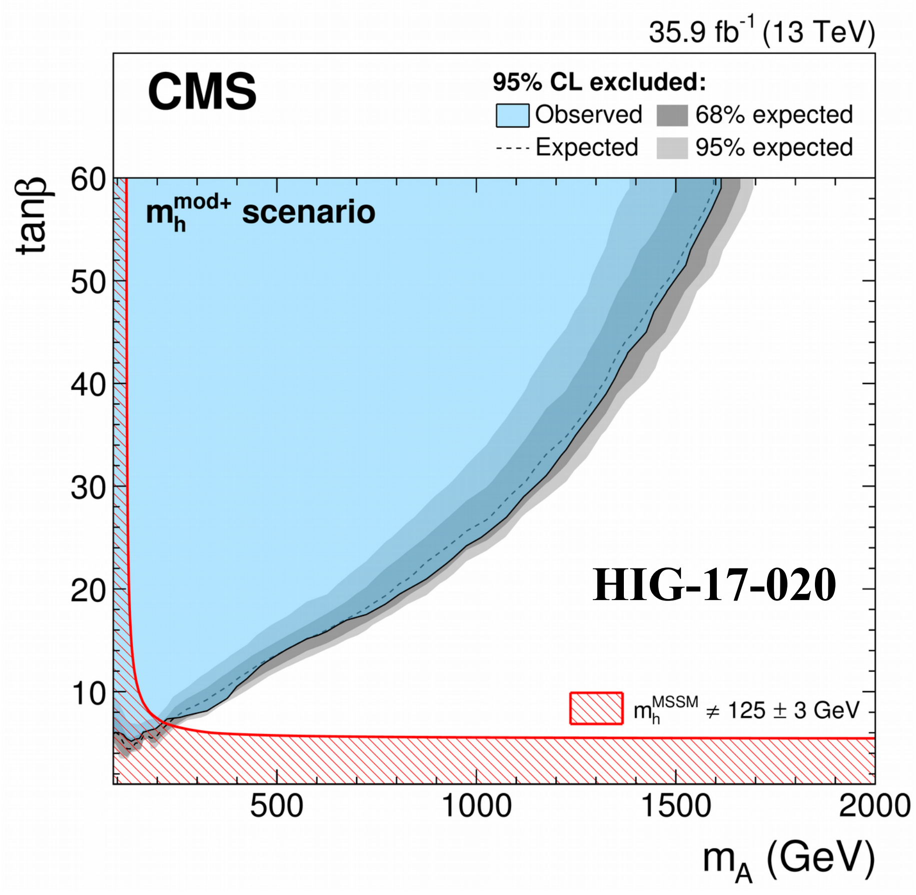


Heavy H→ττ: projections

- Motivated by MSSM: 5 Higgs bosons (h,H,A,H+,H-)

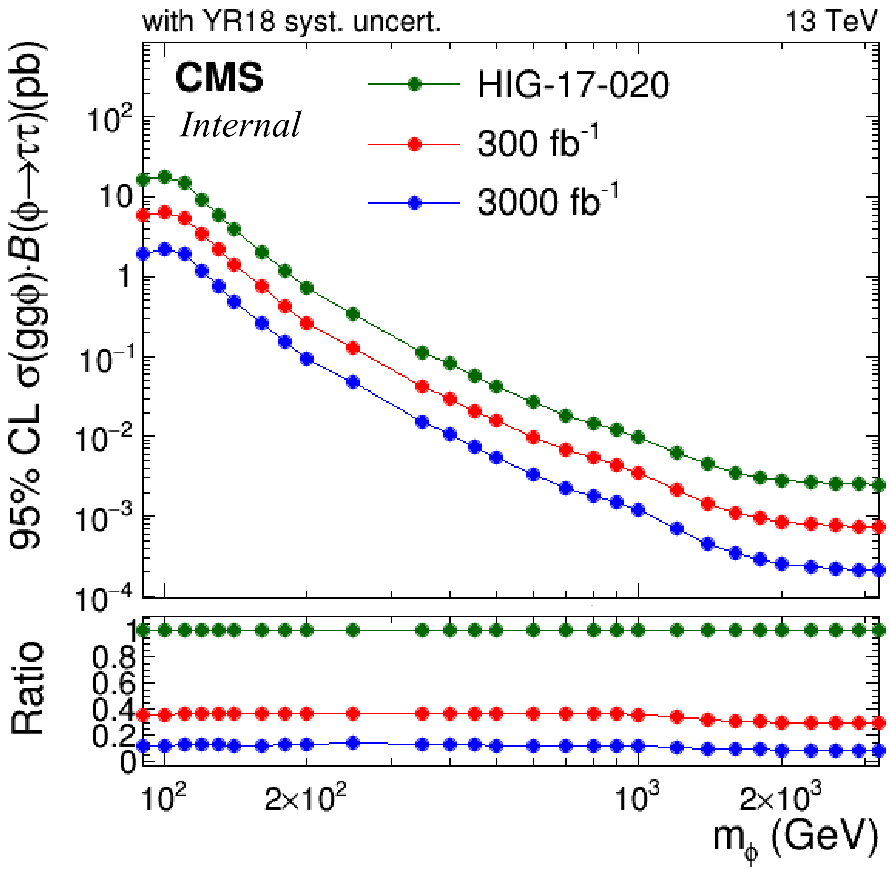


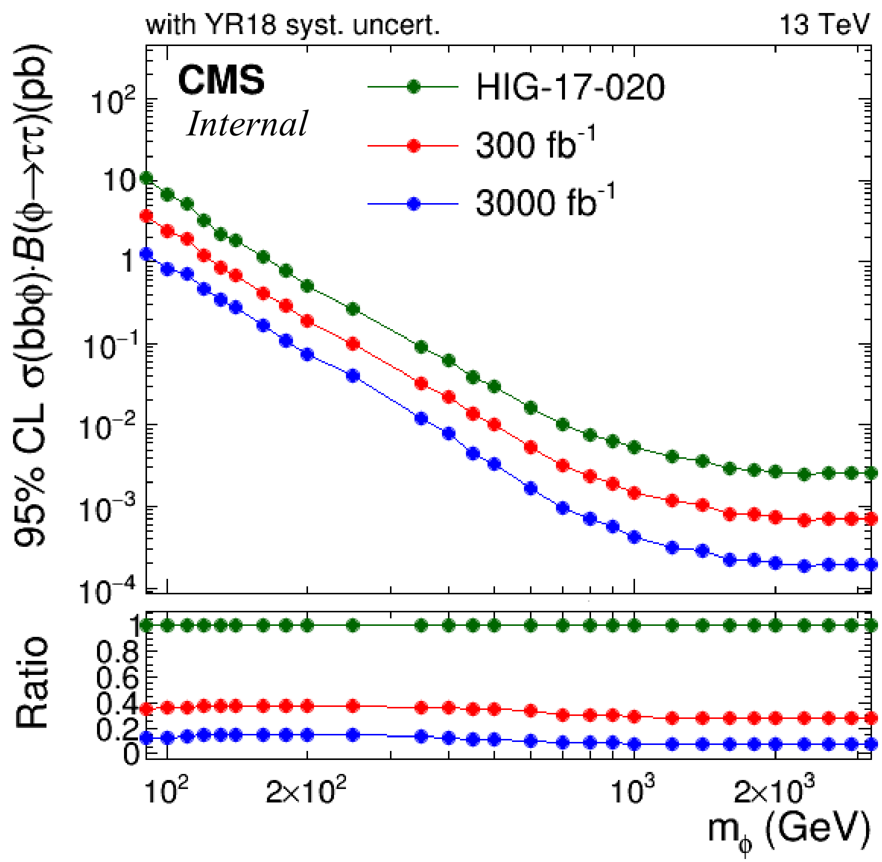
- Cross section limits can also be interpreted in other models, though
- Starting point:
  CMS MSSM HTT search with 2016 data
  - Search for gg→A/H→ττ / gg→A/H→ττ+b[b]
- Extrapolation to 3000 fb^{-1}
  (plus intermediate 300 fb^{-1})
  => Extrapolation by 1 and 2 orders of magnitude



Model-independent limits: lumi

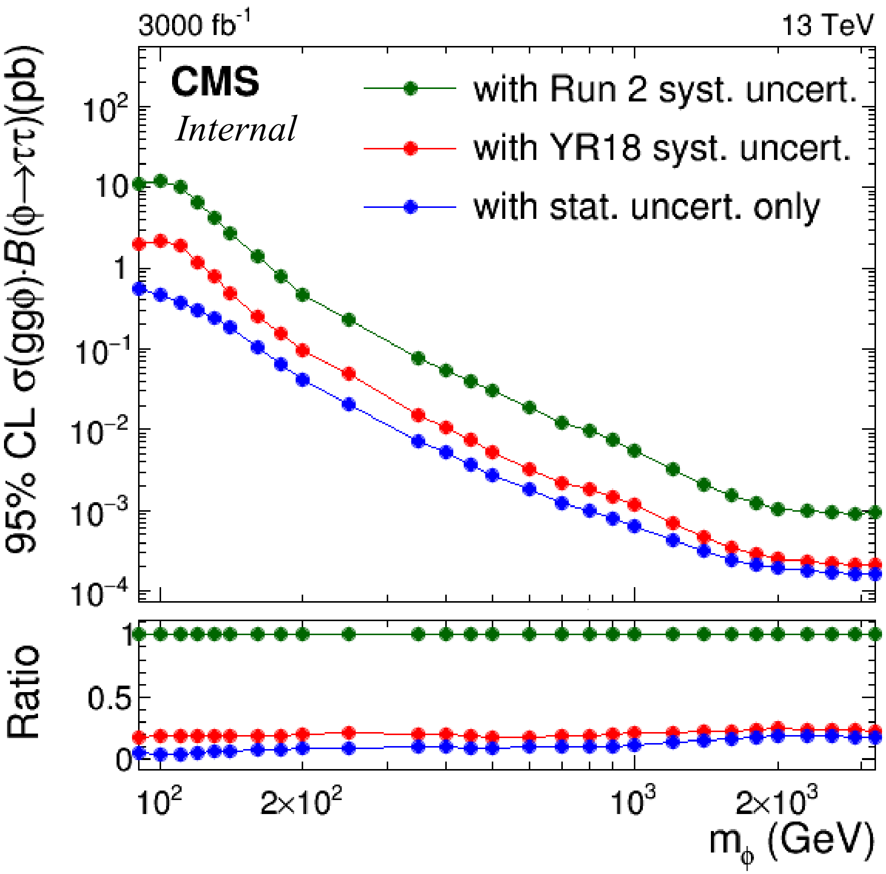
- Sensitivity gain almost directly proportional to sqrt(L)
  - In particular at high mass

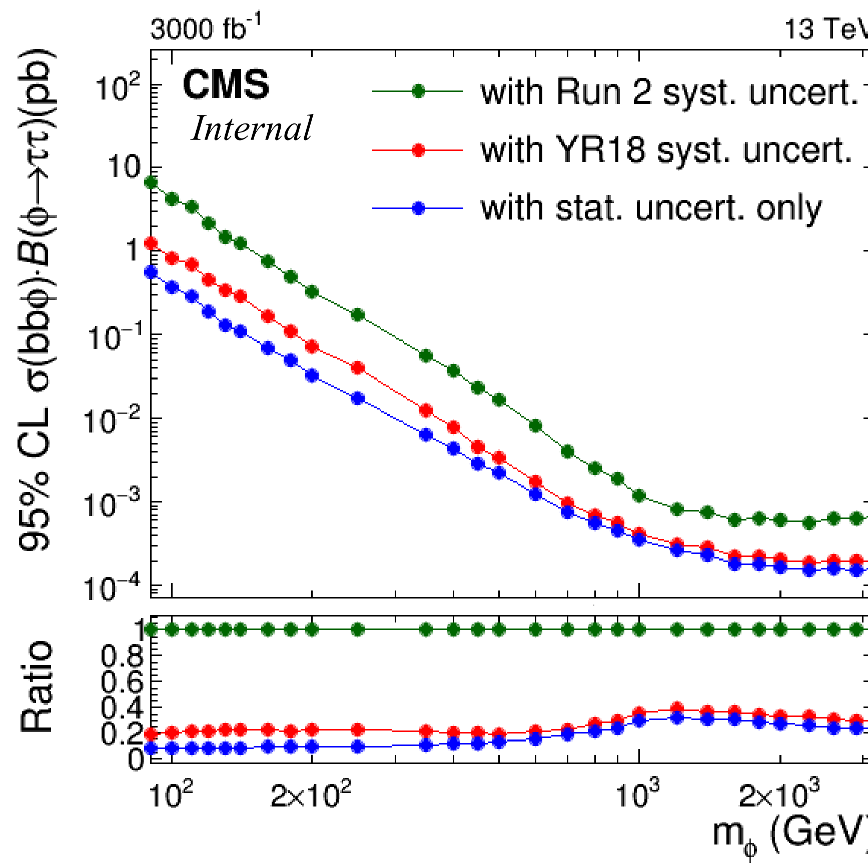




Model-independent limits: uncertainties

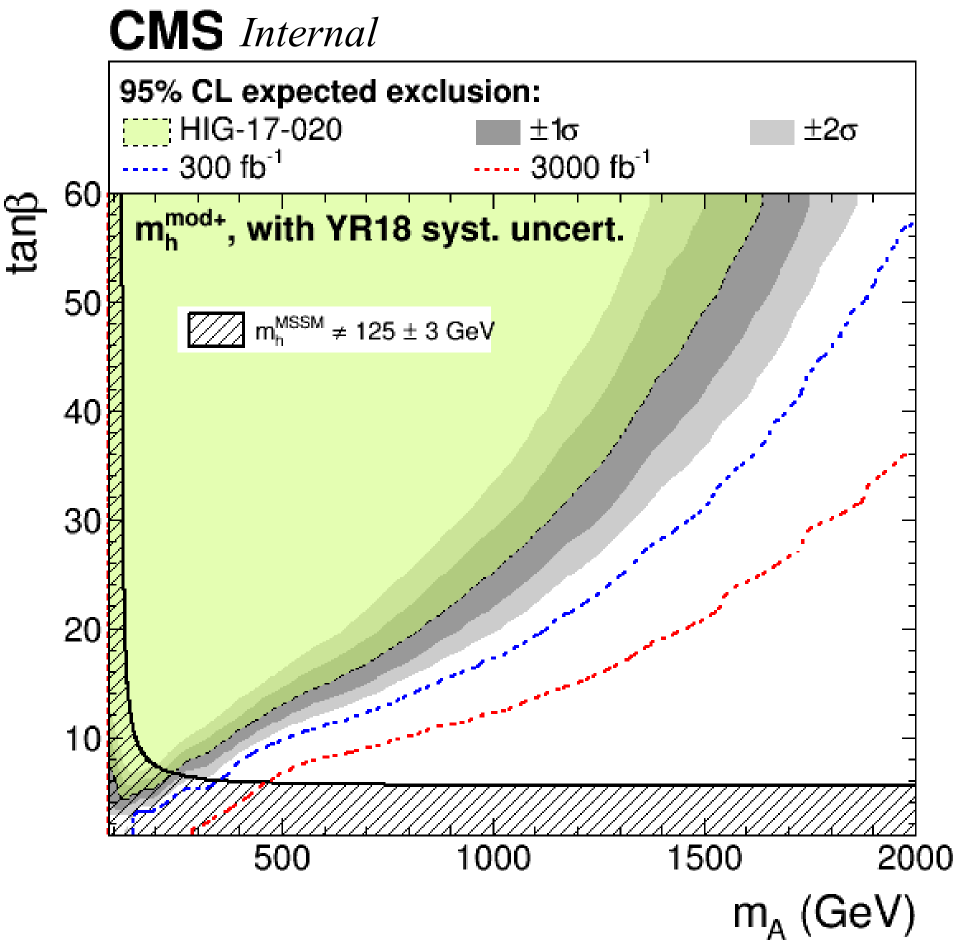
- Sensitivity driven by statistics
  - At high mass, YR18 scenario approaches stat-only limit

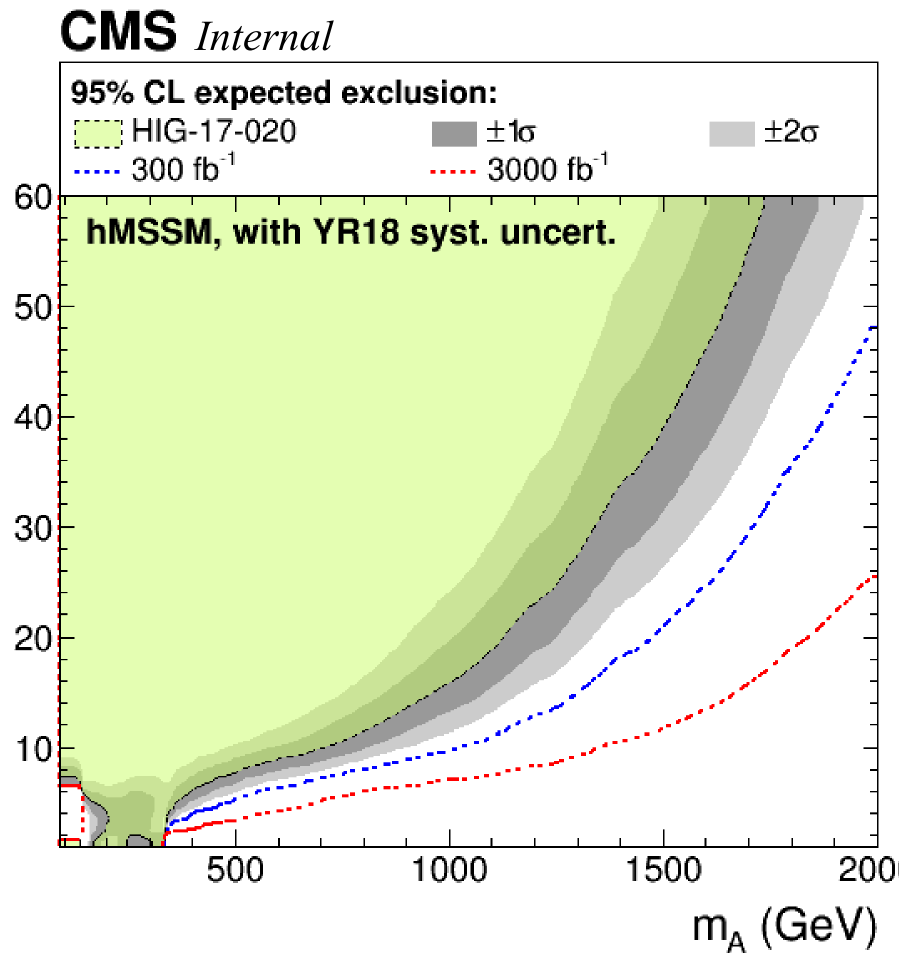




MSSM limits

- At tan β=36, reach extended from 1.25 TeV to 2 TeV





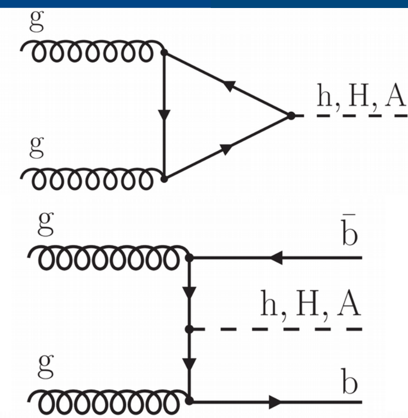
Conclusions

- Four contributions from CMS side:
  - Ready to be added/already added to the overleaf document:
    - L1 track jets for BSM Higgs
    - MSSM HTT projection
  - Almost there:
    - $h \to aa$ decays ($\to 2\mu 2\tau$ / $2b2\tau$ / 4μ)
    - Heavy Higgs searches in $ZZ \to llqq$

Backup slides

HIG-17-020

- Search for gg→A/H→ττ / gg→A/H→ττ+b[b]
- Channels: by tau decay modes: eμ $e\tau_h$ $\mu\tau_h$ $\tau_h\tau_h$
- Categories: with / without b-tag (plus subcategories)
- Background estimates
  - fake factor for $j\to\tau_h$ misID backgrounds
  - CRs to normalized true-tau backgrounds
- Limits on ggH/A and bbH/A
- => translated into MSSM (benchmark) limits



	No b-tag			b-tag		
$H\to\tau\tau\to e\mu$	Low-D_ζ	Medium-D_ζ	High-D_ζ	Low-D_ζ	Medium-D_ζ	High-D_ζ
$H\to\tau\tau\to e\tau_h$	Loose-m_T	Tight-m_T		Loose-m_T	Tight-m_T	
$H\to\tau\tau\to \mu\tau_h$	Loose-m_T	Tight-m_T		Loose-m_T	Tight-m_T	
$H\to\tau\tau\to \tau_h\tau_h$	(SR)			(SR)		
$Z\to\mu\mu$	(CR)			(CR)		
$t\bar{t}(e\mu)$	(CR, both)					

Signal region (SR)

Control region