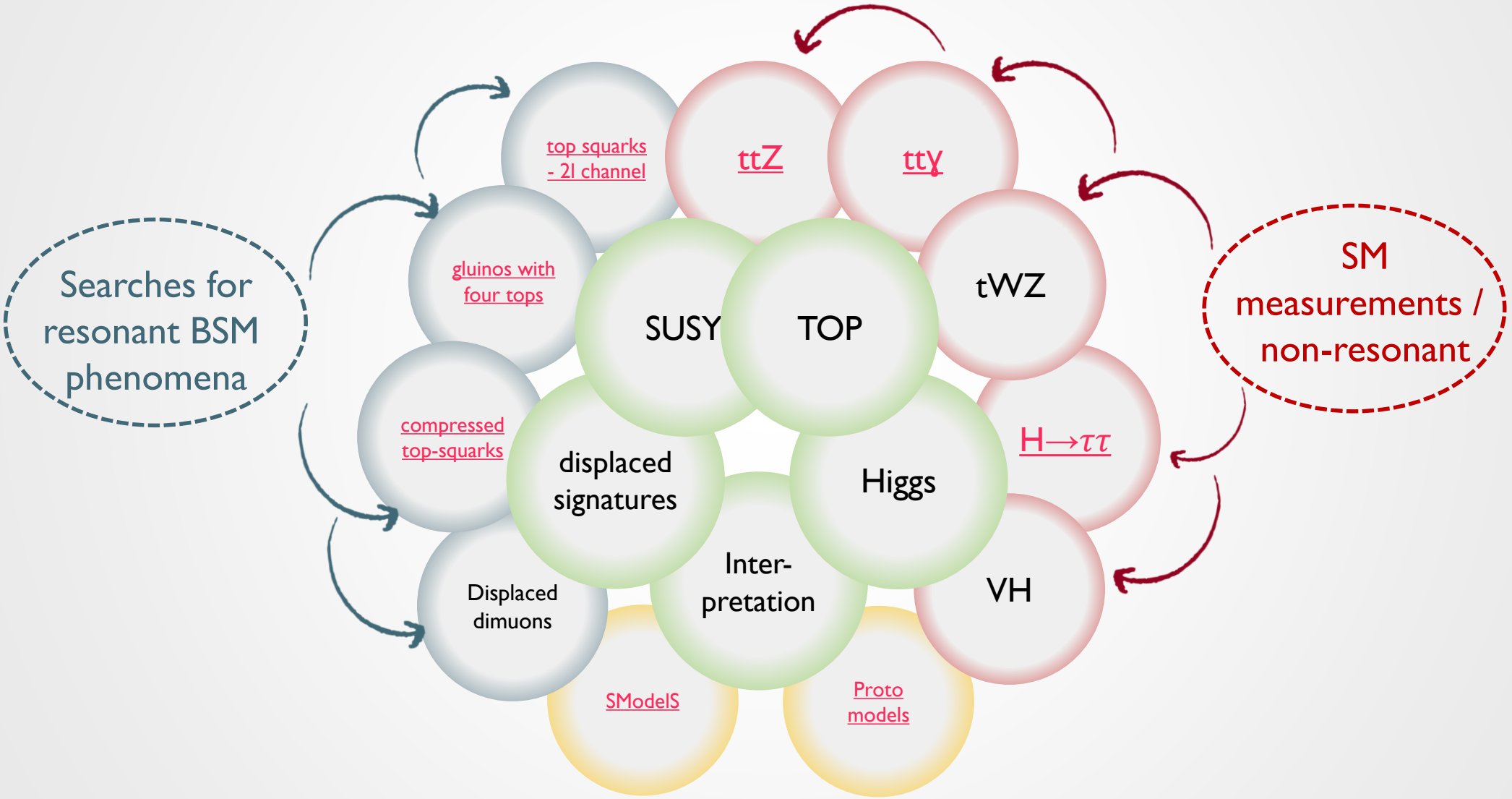
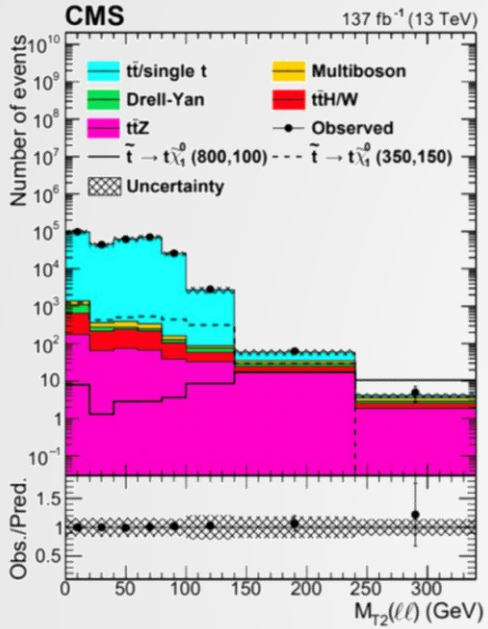
CMS Analysis (opportunities) at HL-LHC

R. Schöfbeck (HEPHY)

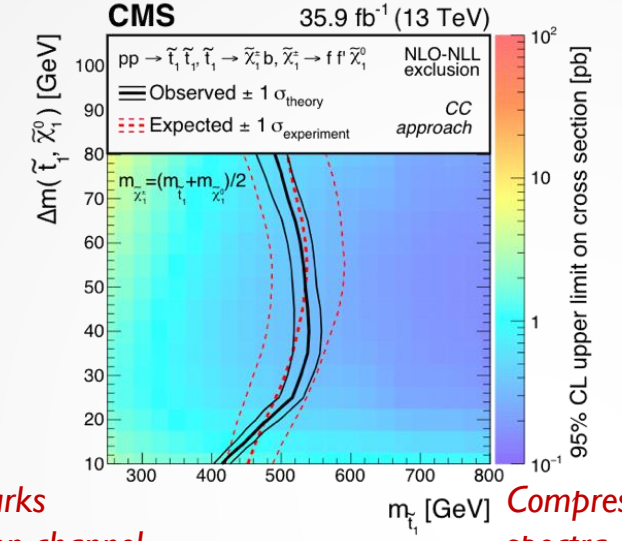
ACTIVITIES @ HEPHY (CMS DATA ANALYSIS)



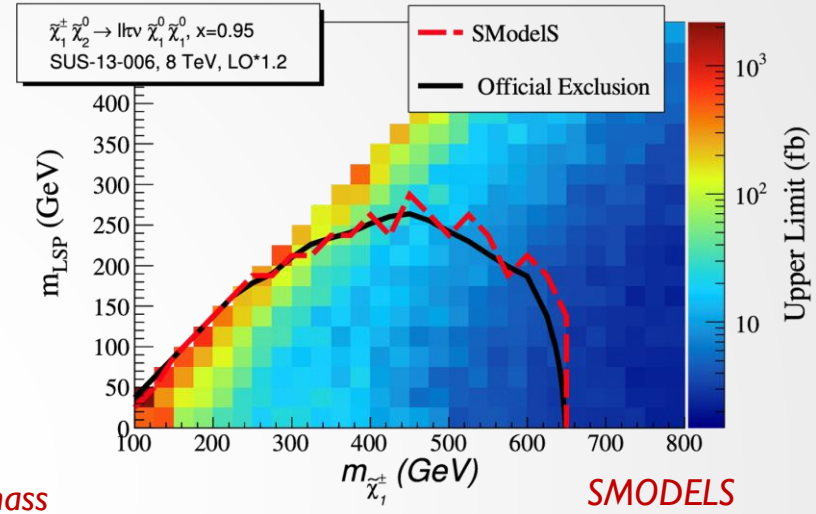
RUN 2 LEGACY (HEPHY EDITION)



Top squarks in dilepton channel

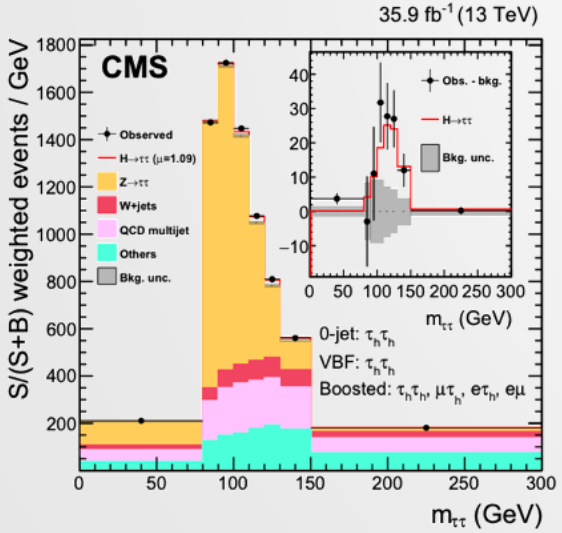


Compressed mass spectra (top squarks)

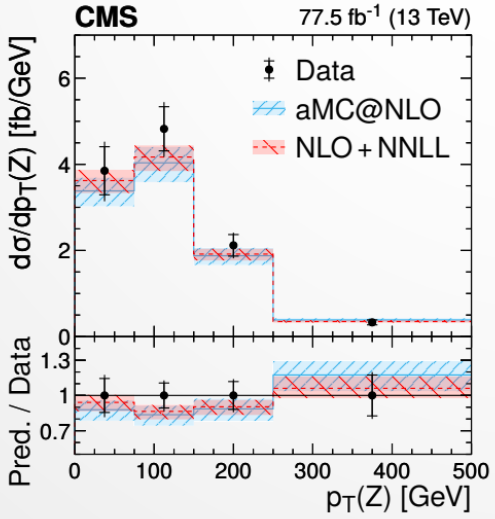


SMODELS reinterpretation

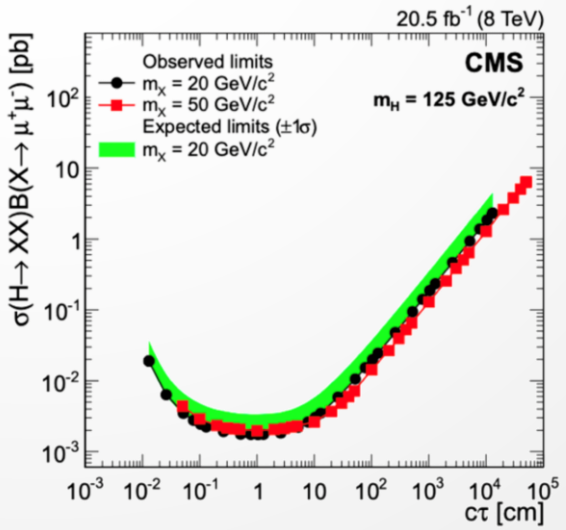
H→ττ observation



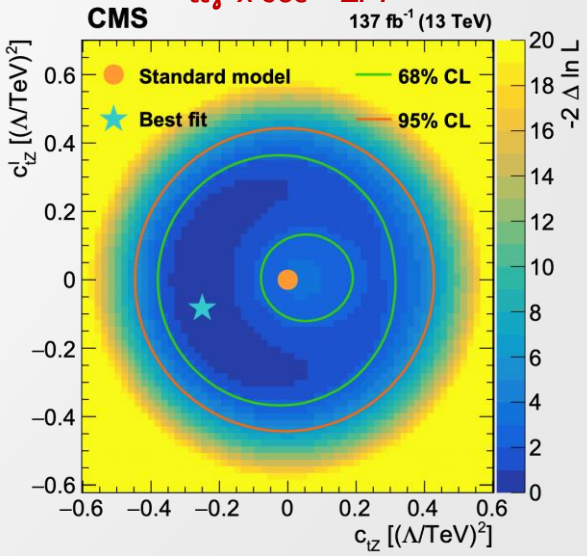
ttZ x-sec +EFT



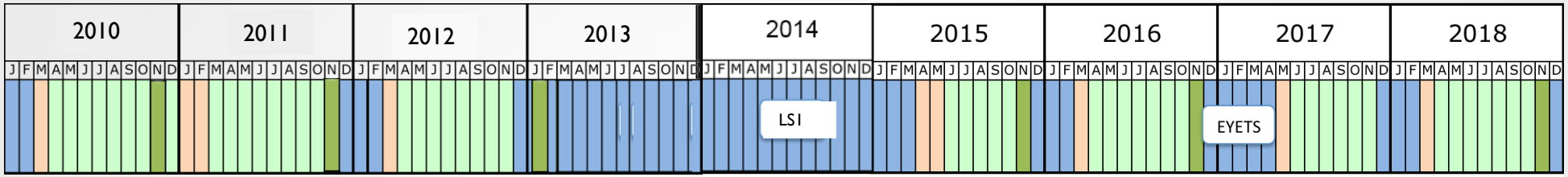
Displaced dimuons (teaser)



ttγ x-sec +EFT



LHC LONG TERM SCHEDULE

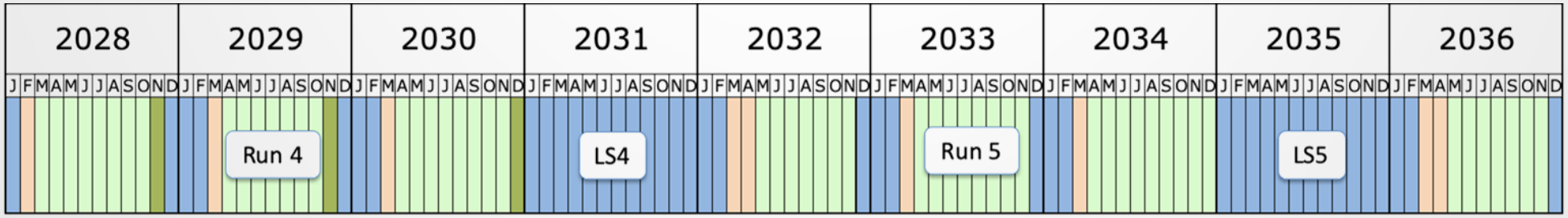


LHC Run I ~20 fb^{-1}

Run2: 137 fb^{-1},
(1.5-2x10^{34} $cm^{-2}s^{-1}$), PU 20-40

Run (2+)3: 300 fb^{-1}
(~2x10^{34} $cm^{-2}s^{-1}$), PU 40-60, "last low PU run"

⟶ HL-LHC

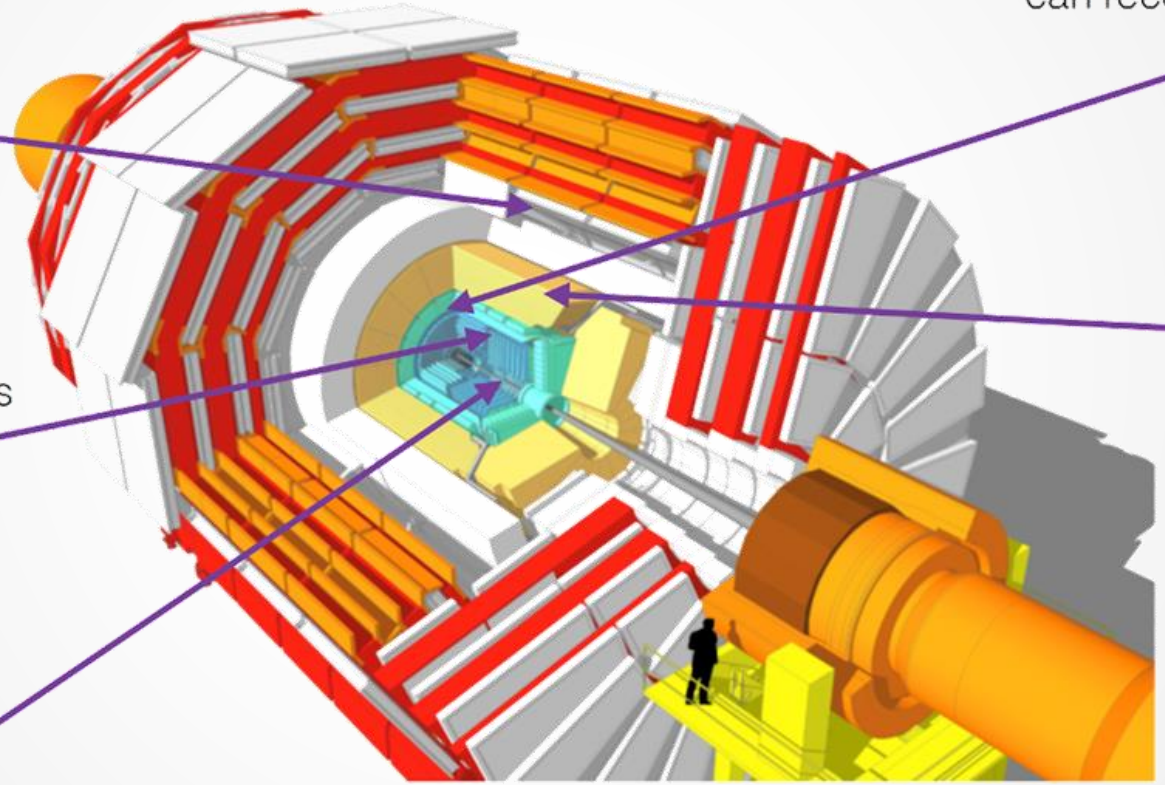


(~5 10^{34} $cm^{-2}s^{-1}$), 3-4 ab^{-1}, PU 140-200 ⟶ CMS Phase II upgrades

CMS PHASE 2 UPGRADES

Improved muon coverage and trigger
increased RPC coverage ($1.5 < |\eta| < 2.4$)
new electronics
CMS-TDR-016

New endcap calorimeters
high granularity
can reconstruct showers in 3D
CMS-TDR-019
HGCal



Updates to calorimeter and trigger
higher granularity
electronics for trigger

New precision timing detector
Timing resolution of 30-40 ps for MIPs
full coverage of $|\eta| < 3.0$
CMS-TDR-020
MTD

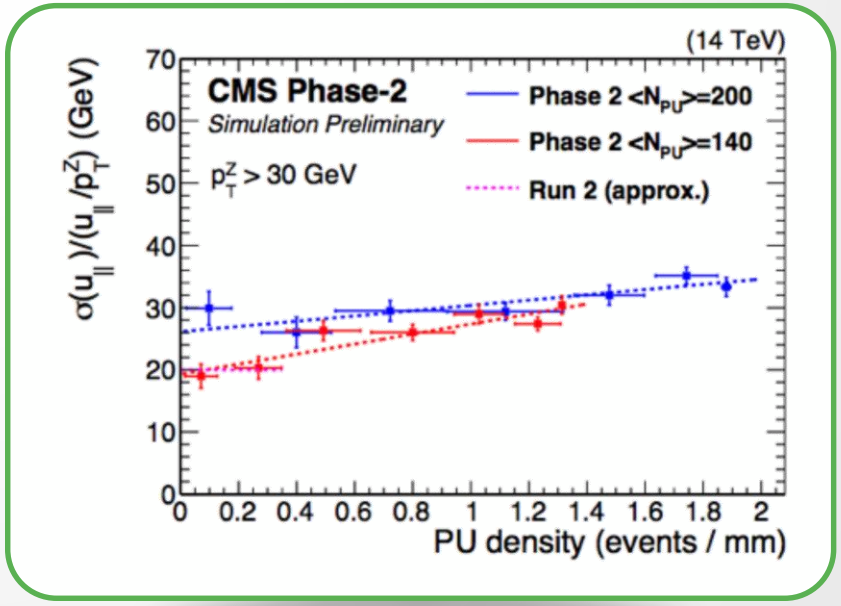
New inner tracker
all silicon tracker
4 layers of pixels
5 layers of strips
coverage to $|\eta| < 4$ CMS-TDR-014

Upgrade to trigger and DAQ
L1 rate increased to 750 kHz
High Level trigger rate to 7.5 kHz
Track information at L1
L1: CMS-TDR-021
DAQ/HLT: CMS-TDR-022

OPPORTUNITIES & CHALLENGES

- Opportunities
  - More data! ⟶ statistical uncertainty scales with luminosity
  - New detector features / improved coverage
    - uncertainties in object performance: machine upgrades (PU≈200) and detector upgrades (HGCal) approximately compensate
  - theoretical uncertainties (reduce by factor 2)
    - PDF, better PS tunes, ME corrections, etc.
  - Lower uncertainties on background prediction
- Challenges
  - High pile up
  - High beam-induced background
  - High radiation leading to challenges in:
    - Triggering, object reconstruction, object performance, analysis

- Increased demands on computing / new dataformats
- Many ingredients for capitalizing on HL-LHC / Phase II
  1. state of the art theoretical tools/calculations
     - estimate of 10+ years of future development
  2. low-level understanding of sub-detector performance
  3. object performance (realistic projections)
  4. novel analysis ideas that incorporate 1-3

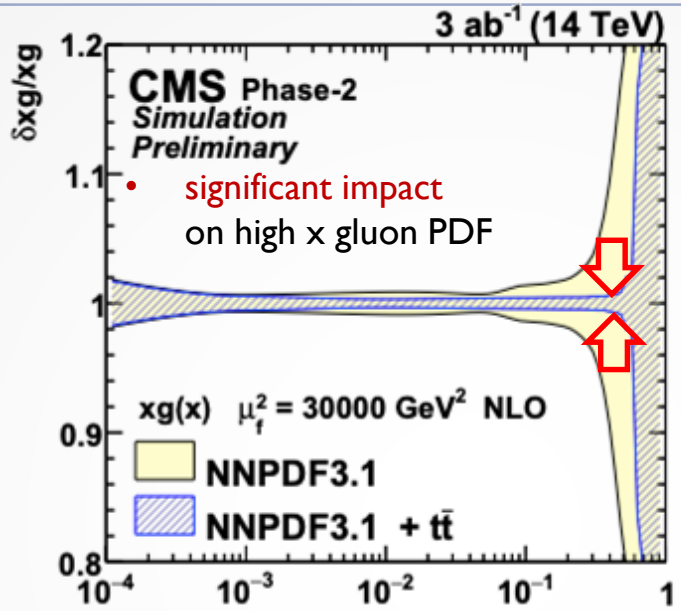


Puppi E_T^{miss} resolution for $p_T(Z) > 30$ GeV

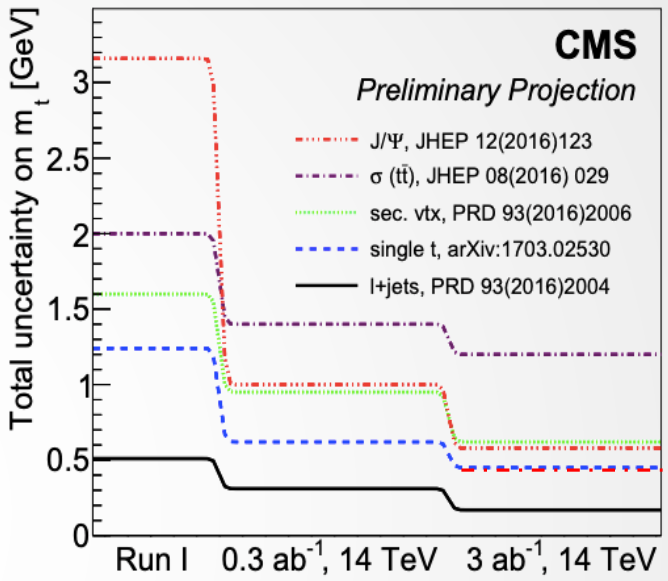
PRECISON IN/FROM TAILS (TOP QUARK)

Phys. Rev. Lett. 116 (2016) 8, 082003

- Greatly extended kinematic reach for heavy resonances
- very high statistical precision in bulk
- boost in precision possible & required on all fronts
- Run II performance achieved or surpassed for most analysis

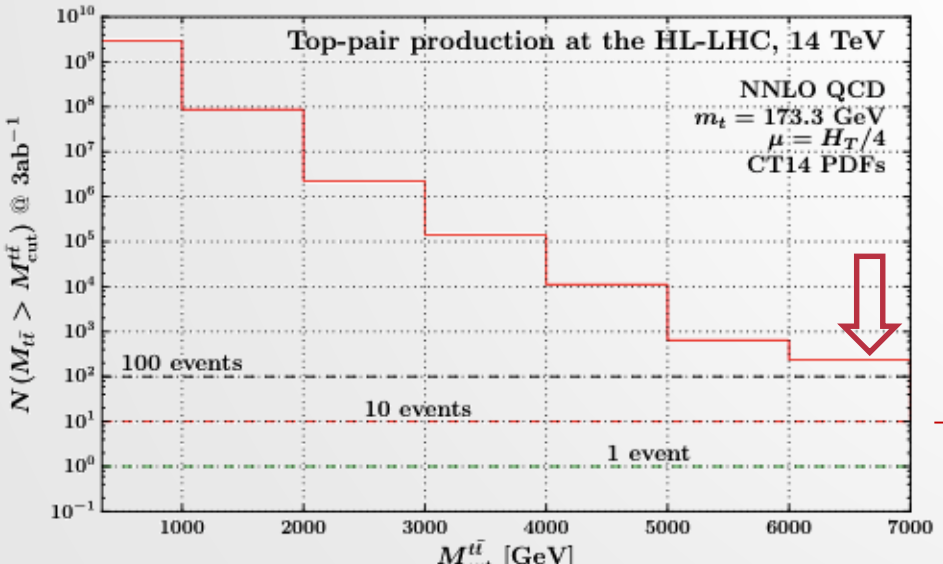


- significant impact on high x gluon PDF



ATLAS J/Ψ projection
± 0.14 (stat) ± 0.48 (sys)

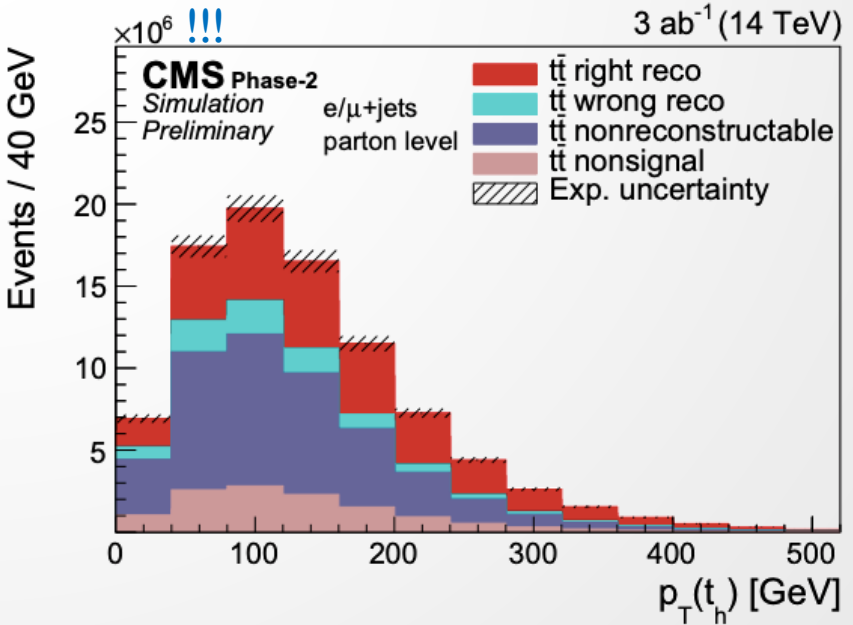
0.17 GeV ⟶
0.1 % (mostly JES)



equivalent count currently at $M^{tt} \gtrsim 3$ TeV

⇩ ≈10 events $M^{tt} > 7$ TeV

Cumulative M^{tt} distribution



- profit from tracking coverage to $|\eta|<4$
- unfolding performance similar to Run-II, despite the higher PU

HIGGS COUPLING AND X-SEC MEASUREMENTS

ATL-PHYS-PUB-2018-054

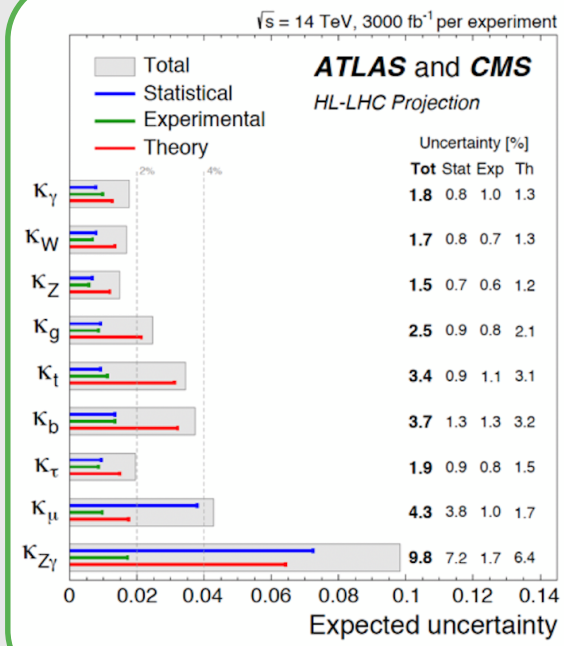
CMS-PAS-FTR-18-011

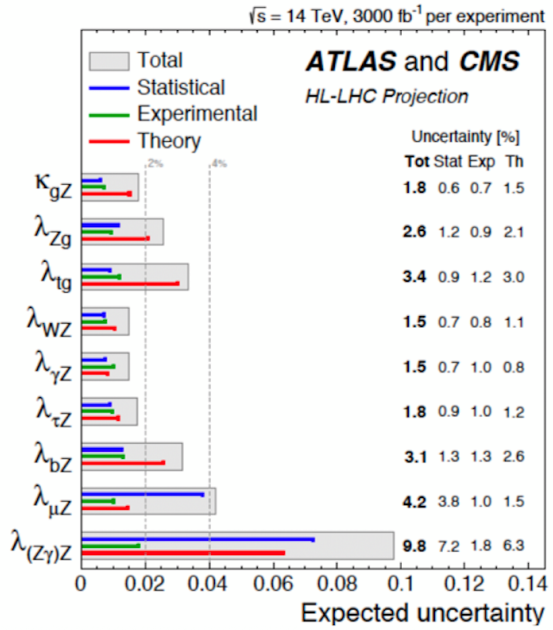
- Precision measurements of the Higgs coupling (modifiers and modifier ratios)
- Parametrize in SM deviations in the κ- framework

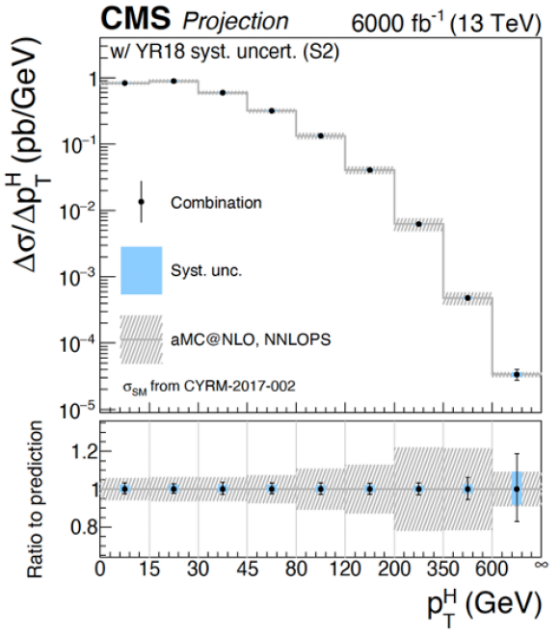
Production modifier: $\kappa_j^2 = \sigma_j / \sigma_j^{\mathrm{SM}}$

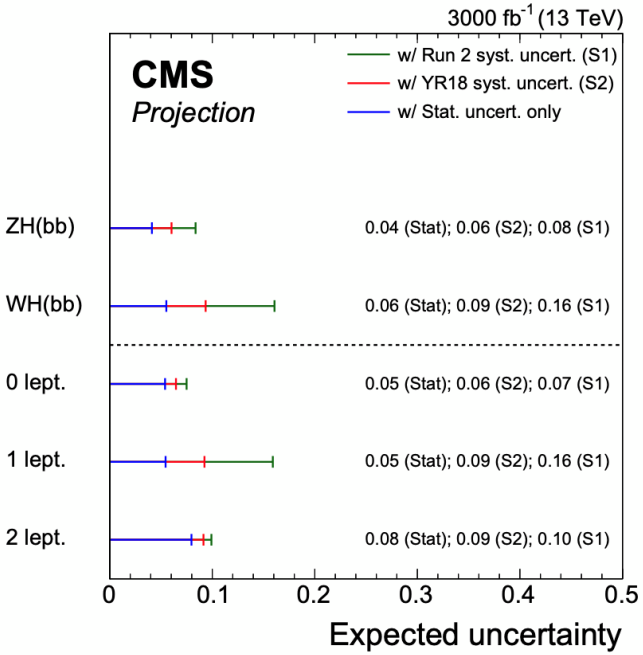
Decay modifier: $\kappa_j^2 = \Gamma^j / \Gamma_{\mathrm{SM}}^j$

Modifier ratio: $\lambda_{ij} = \kappa_i / \kappa_j$







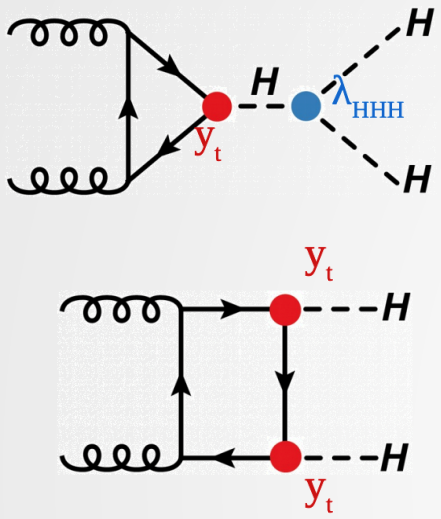


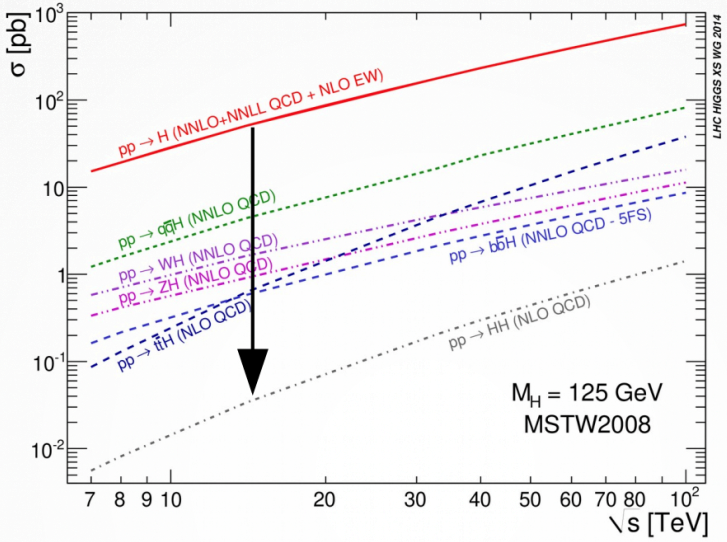
- Measure coupling modifier ratios to partially cancel systematics
- HL-LHC statistical precision poses a dual challenge for systematic and theory uncertainties
- Differential x-sec measurements theory-limited
- Inclusive VH xsec uncertainties at the 10% level (~ factor 4 improvement wrt. Run 2)

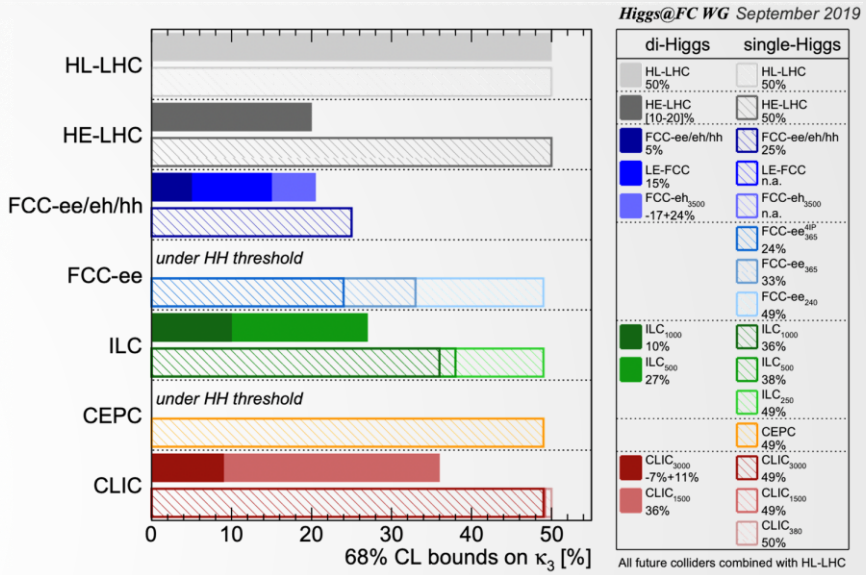
HIGGS SELF COUPLING

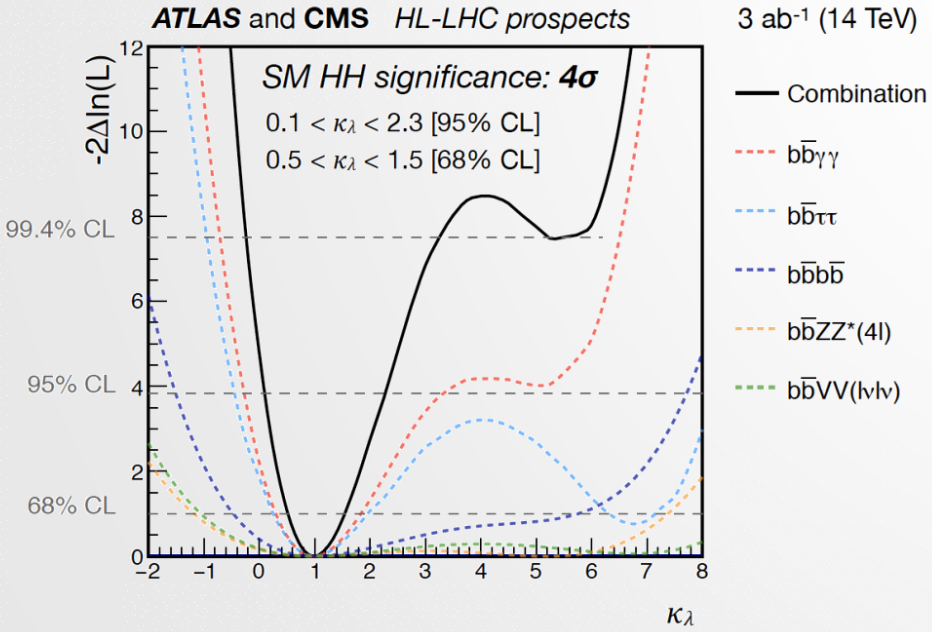
ATL-PHYS-PUB-2018-053

CMS-PAS-FTR-18-019







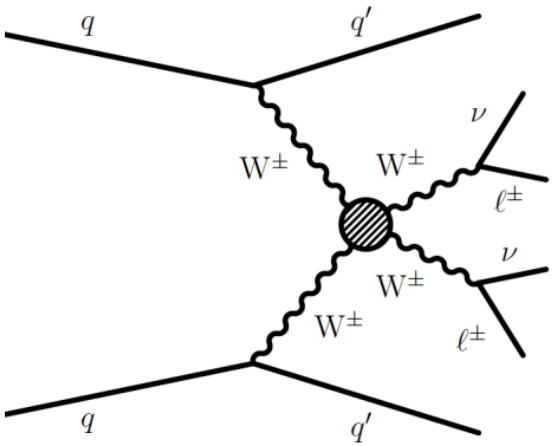


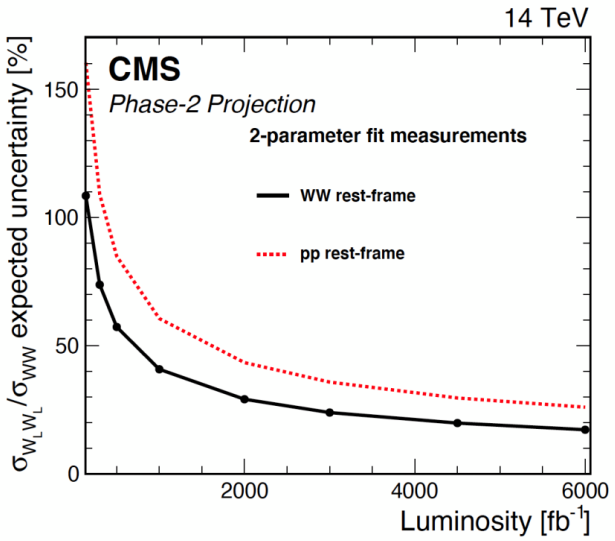
- The shape of the Higgs potential is (arguably) the least experimentally and theoretically constrained part of the SM
- First access to h^3 coupling at HL-LHC
  - Destructive interference in production & low x-sec
  - Many & complicated final states
- 68% CL on κ_λ projectd at 50%.

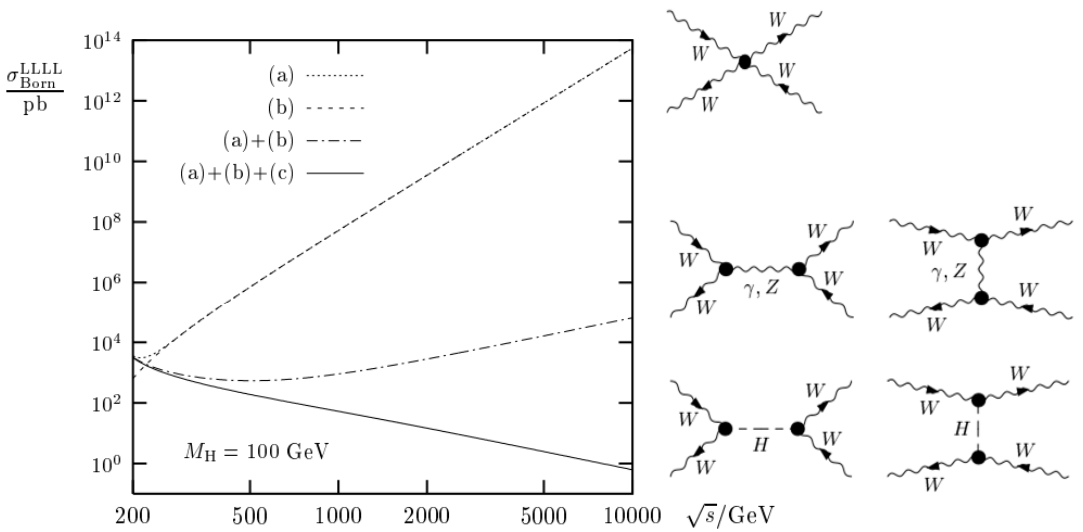
VBS AND RARE PROCESSES

[Denner, Hahn '97]

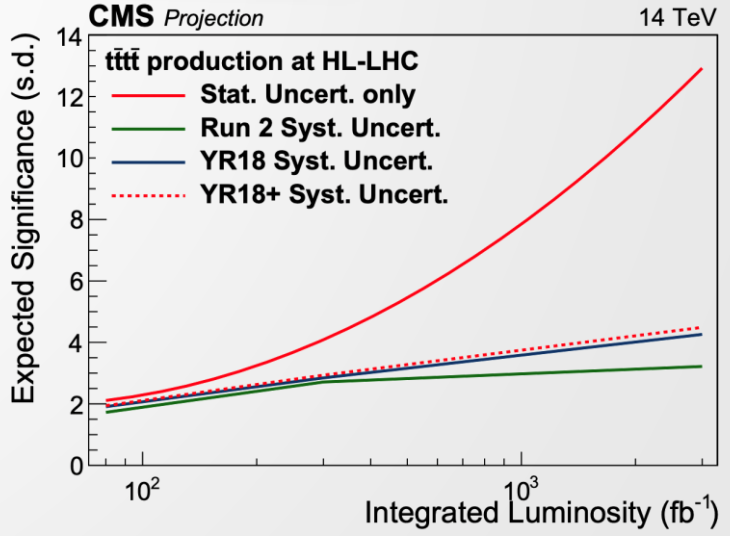
[FTR-18-031]



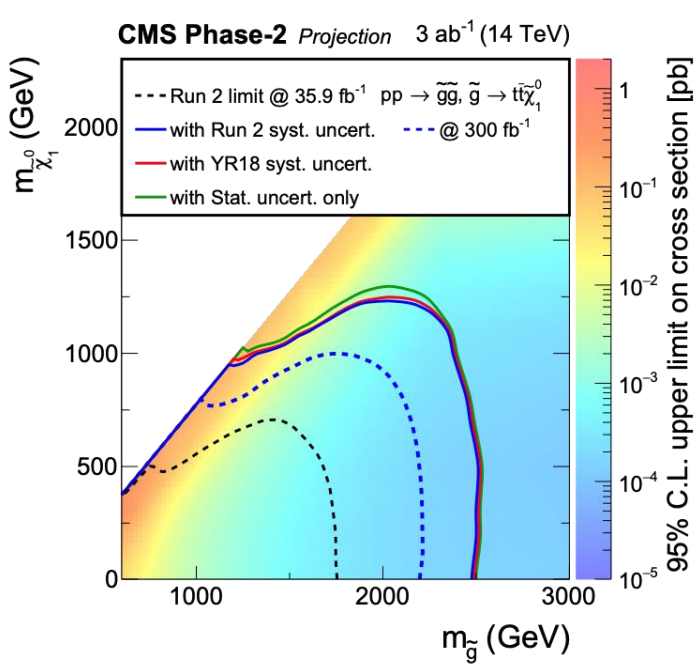


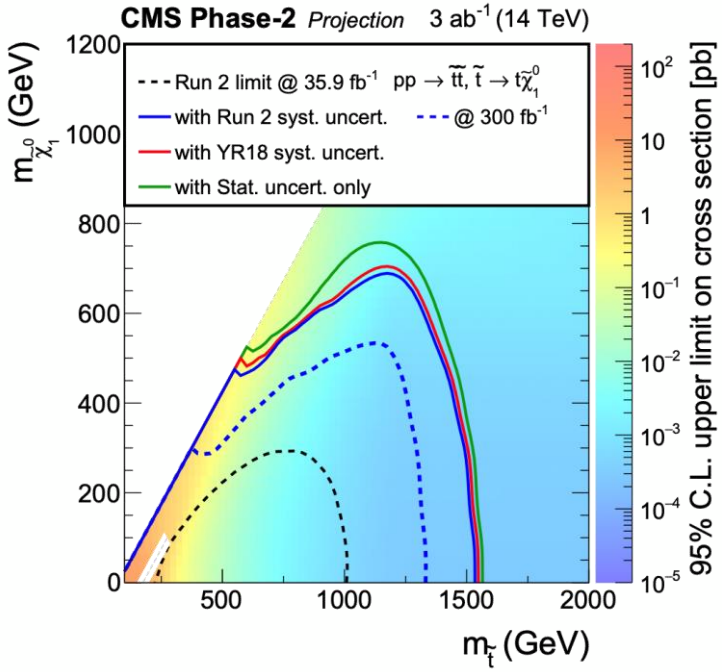


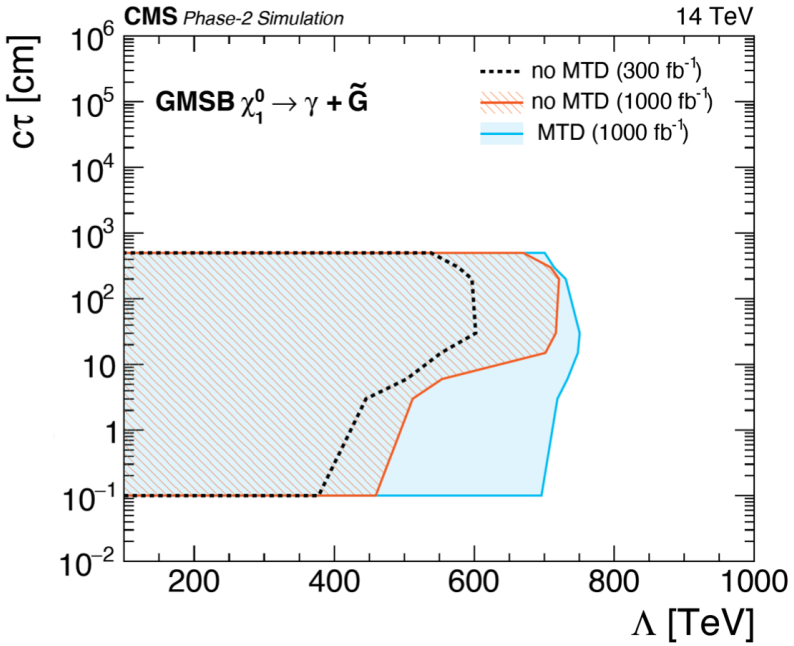
- The weak interaction at high energy under intense scrutiny at HL-LHC
  - 20-30% for VBS (weak) production of W_LW_L
  - tightly linked to Higgs sector via Goldstone Boson Equivalence
    - Subtle cancellations in the SM Gauge-Higgs sector pose sensitive tests
- Most massive processes: 18-20% uncertainty for tttt
  - expect significant improvement on analysis



BSM – OLD AND NEW IDEAS







- SUSY: Gluino/stop search with 3rd generation fermions
  - Add boosted W/top categories + E_T^{miss} + jets.
  - Gluino exclusion (discovery) up to ~2.6 (2.35) TeV
  - Stop exclusion (discovery) reach ~1.5 (1.4) TeV
- BSM searches with compressed/displaced signals benefit from L1 track trigger

- CMS MIP Timing Detector: MTD with @3ops
  - Acceptance of $|\eta| < 3$ for p_T, $p < 0.7$ GeV
- Example: $\chi_1^0 \rightarrow \gamma + \tilde{G}$
  - Measure arrival time in MTD (neutralino TOF)

SUMMARY

- With 3ab^{-1} HL-LHC will be the workhorse for many years to come
- We're now convinced that PU140-200 is a challenge we can meet
- Detector upgrades enlarge the physics scope
- Highly energetic tails and low-xsec processes pose many sensitive tests of the SM – many of them new
- Improvements on theoretical and modelling uncertainties crucial!
- The best is yet to come!