RECENT HIGHLIGHTS OF ATLAS AND CMS

AND SOME NOTES ON PHYSICS PROSPECTS AT THE HL/HE-LHC

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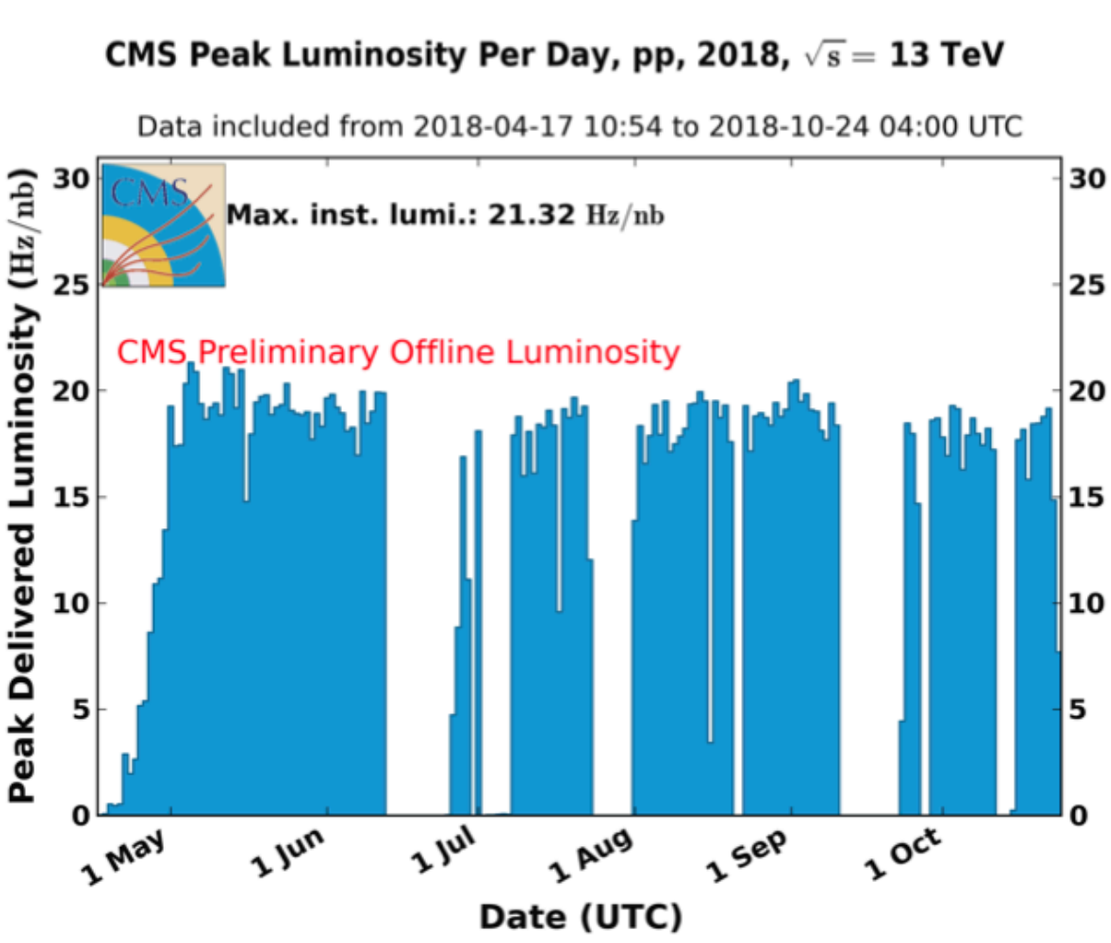
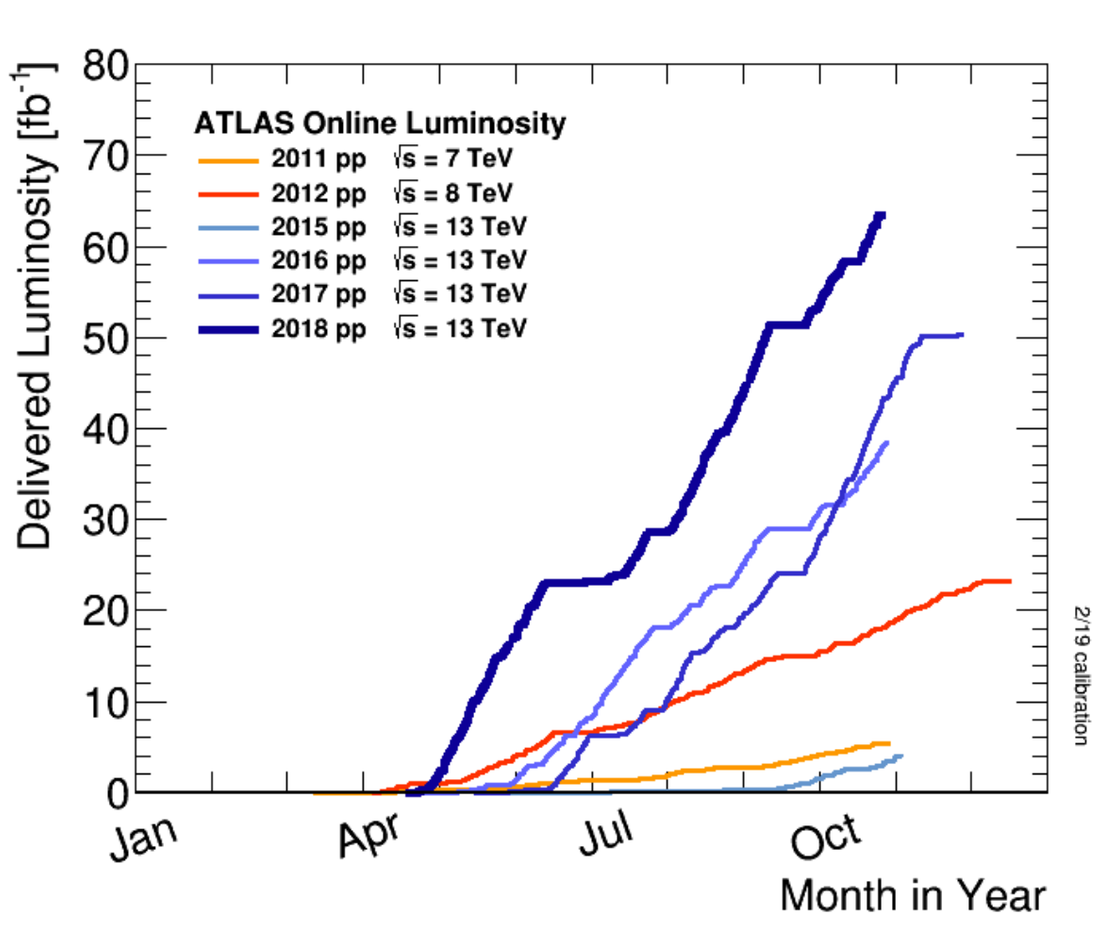
CMS
ATLAS EXPERIMENT

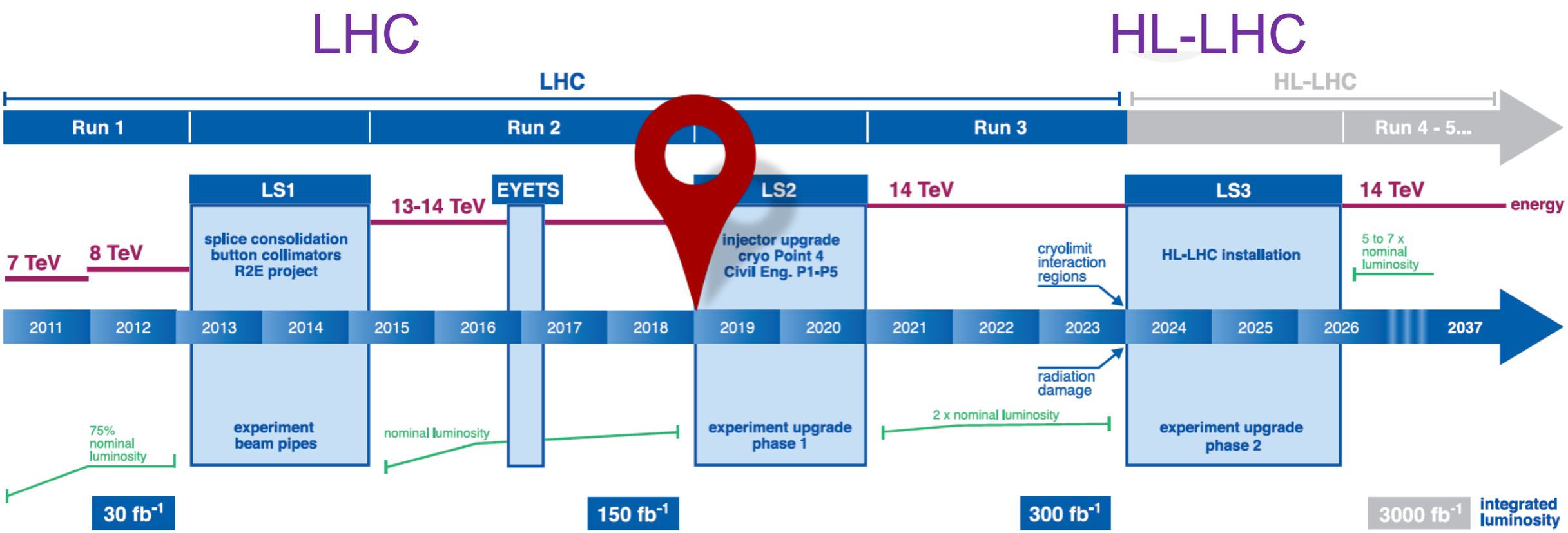
So long Run2…

- The 2nd run of the LHC has just ended marking the conclusion of an extremely successful data taking period
  - Excellent performance of the accelerator and of the CMS and ATLAS experiments
  - Peak luminosity close to 2 10^{34} Hz/cm^2 (x2 the original design)
  - **~150 fb^{-1} of 13TeV pp collisions recorded for analysis in each experiment**
  - This dataset is unprecedentedly large, but also only 5% or less of the total planned integrated luminosity for the full LHC program!





What are the collaborations up to today ?



- Currently in the LHC LS2 (technical stop), which data-taking wise gives us a small reprieve to analyse the wealth of data the experiments have collected during Run2, before restarting with another pp run at 14 TeV in 2021 where the dataset collected should at least double
- On the detector end, as busy as ever, or even more - preparing both for Run3 and for the HL-LHC upgrades
  - In 2016 after LS3 (a shutdown for major upgrades) the LHC will become the high-luminosity run (HL-LHC) where the luminosity will increase x10

ATLAS&CMS Recent Results

Preface: Impossible to cover all the CMS&ATLAS results in 30' - not even all the ones presented in the 2019 winter conferences (over 60 brand new papers and notes in February/March)

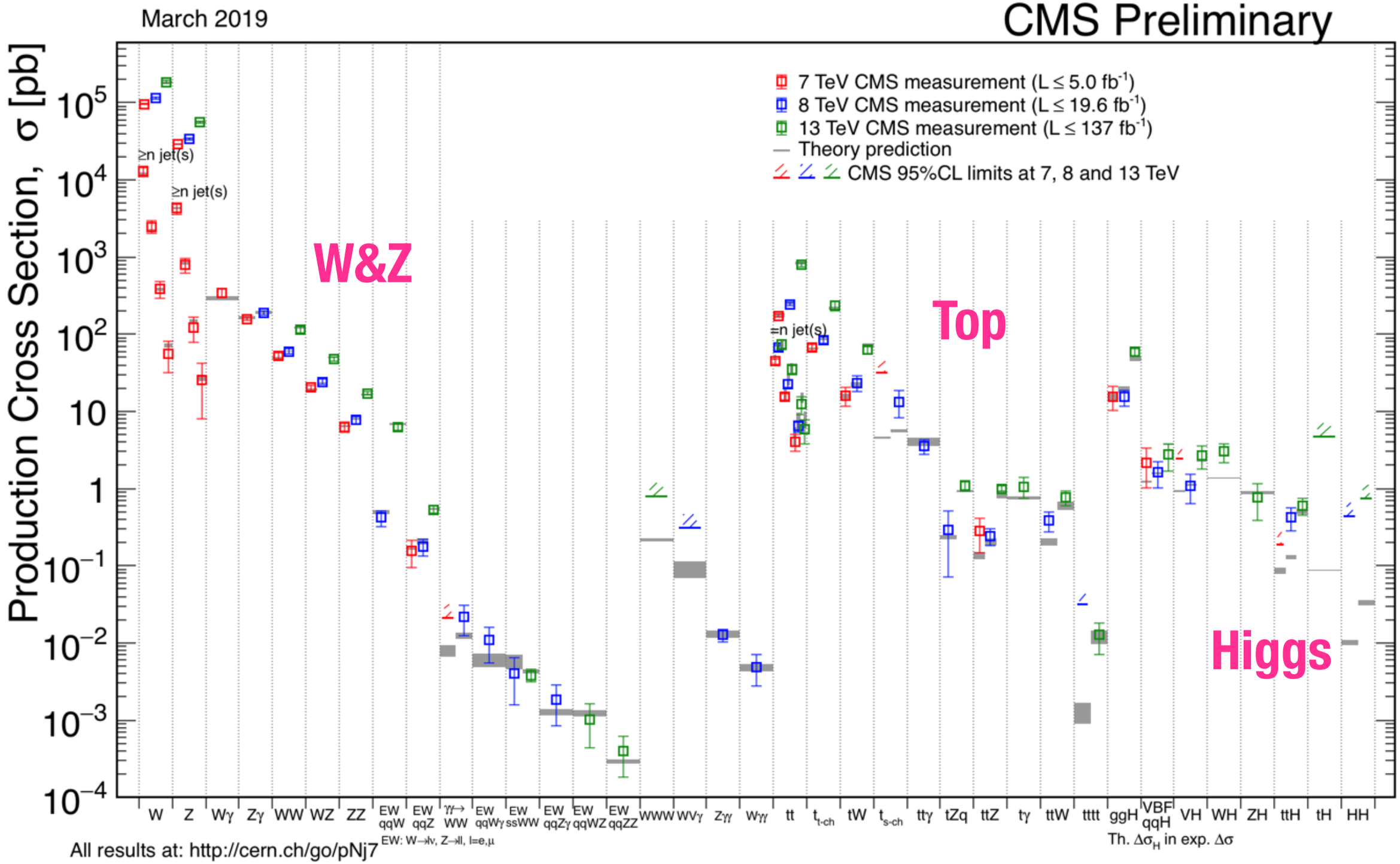
This presentation will necessarily be a incomplete snapshot of the current status, framed by the photographer's lens

Not intended as a comprehensive overview!

Find the full list of papers and preliminary notes in the experiment publication webpages

Triumph of the Standard Model

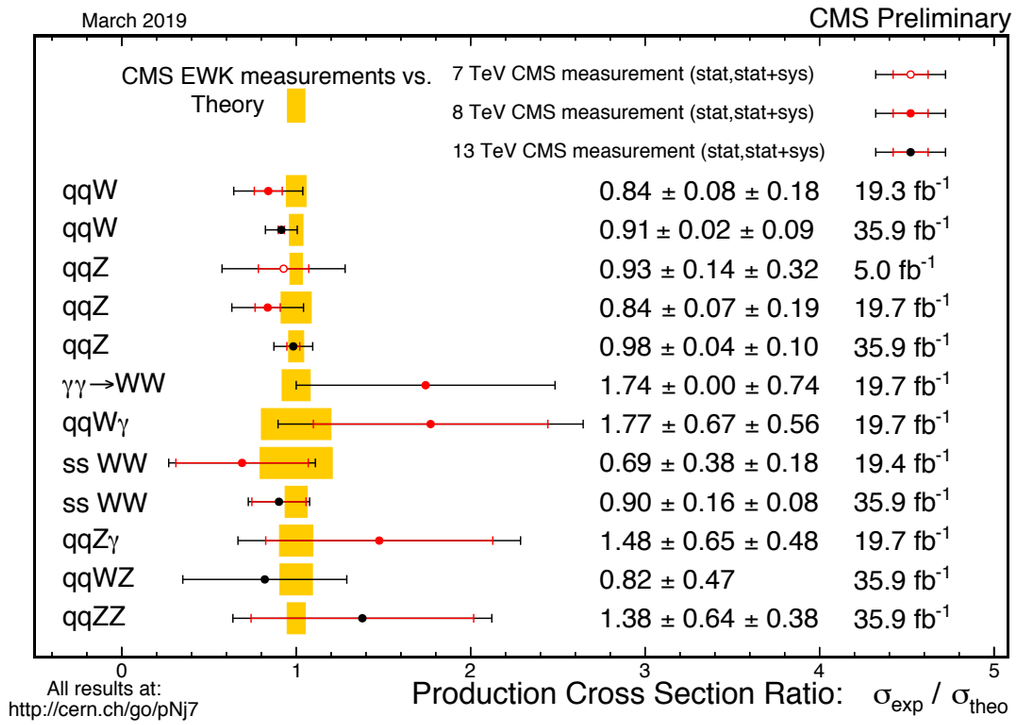
As a starting point: ATLAS and CMS are today measuring
the SM at 7/8/13 TeV over 9 orders of magnitude

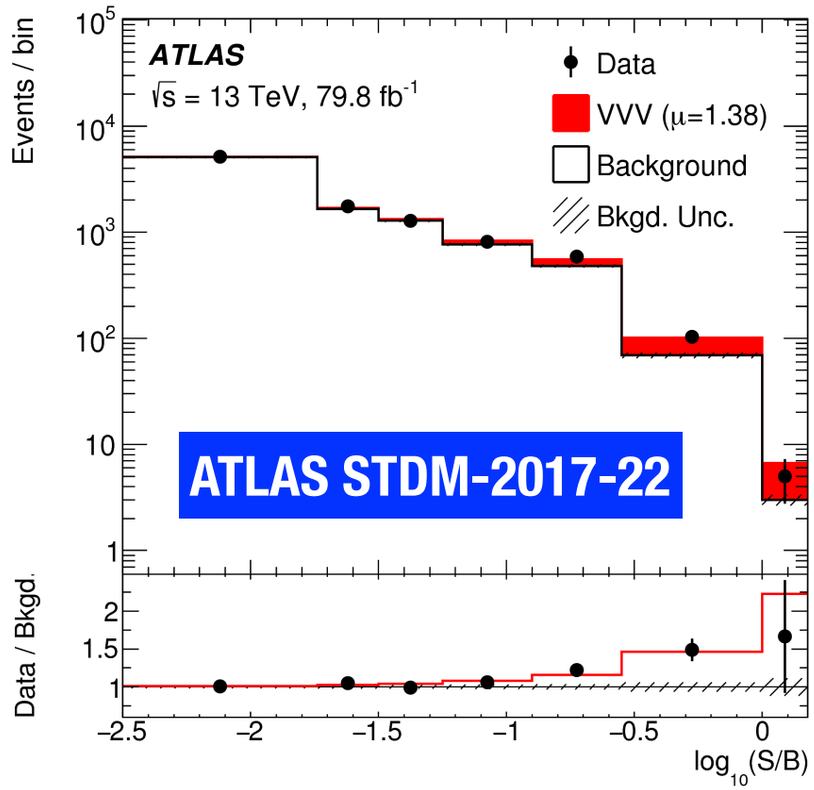


Precision Standard Model Measurements

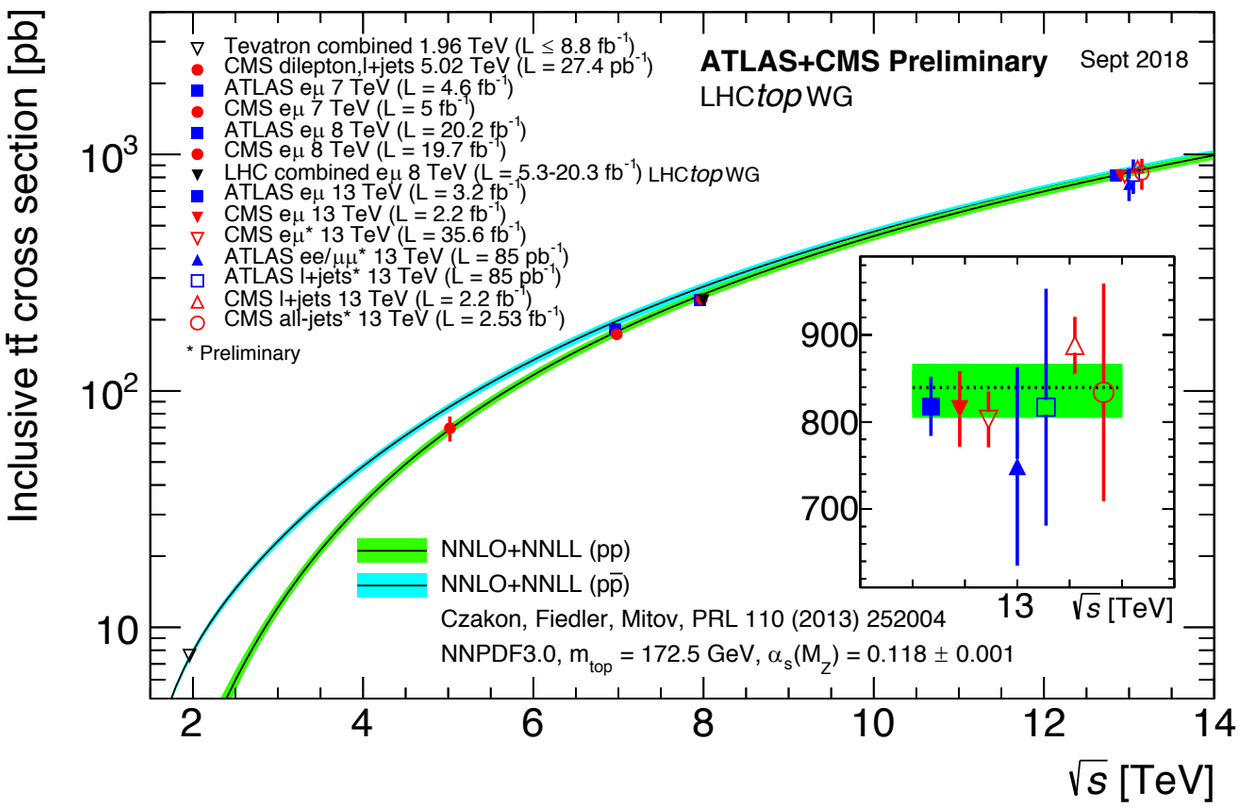
- Expanding catalogue of precise SM measurements at 7,8 at 13 TeV (cross sections - including EWK production, asymmetries, weak mixing angle…)

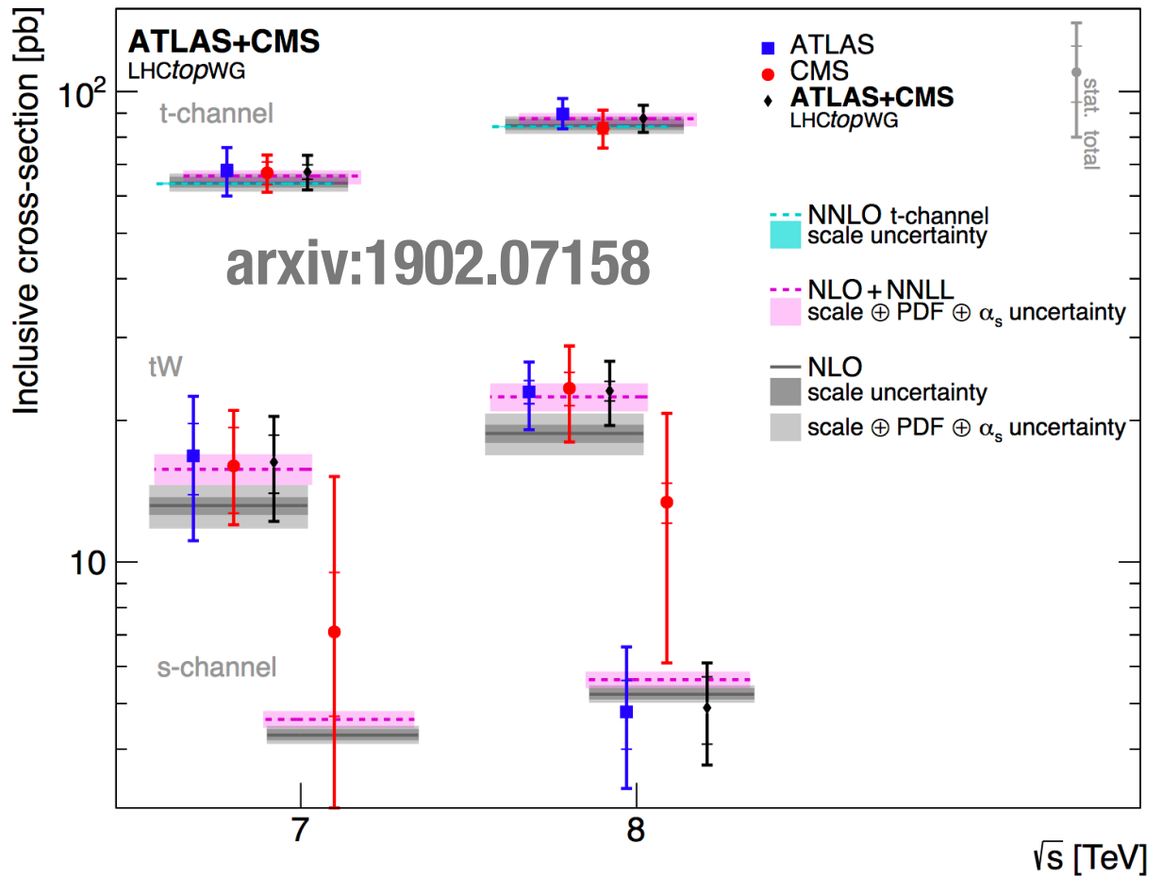
- Rare processes becoming accessible.
  - Example: multi-bosons, with the **first evidence of VVV production with 80 fb^{-1} of the collected data**, in good agreement with the theoretical predictions





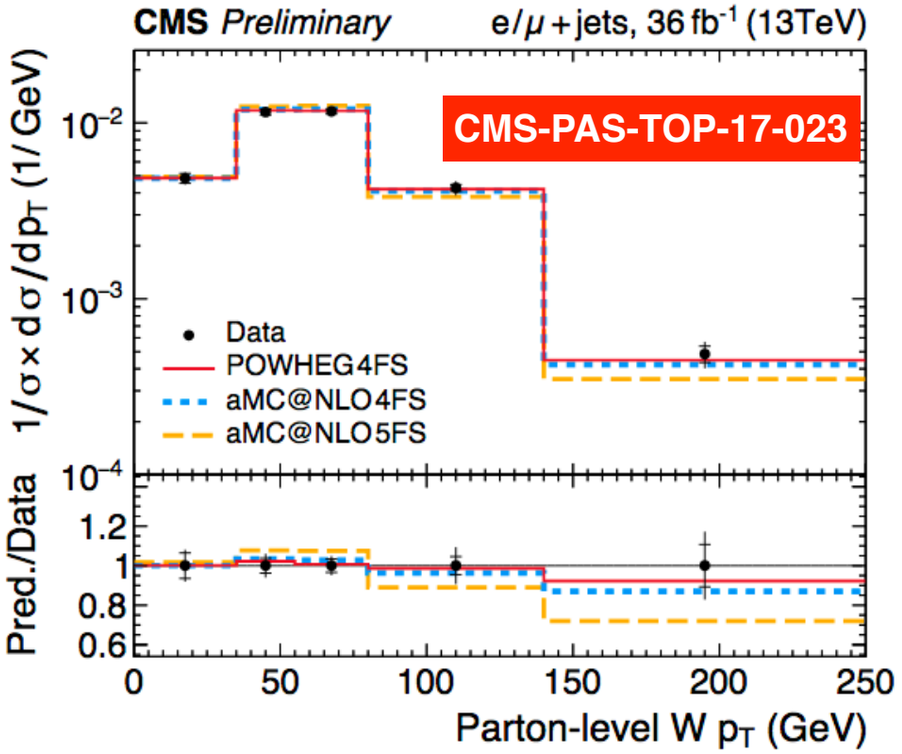
Exploiting the Top Factory



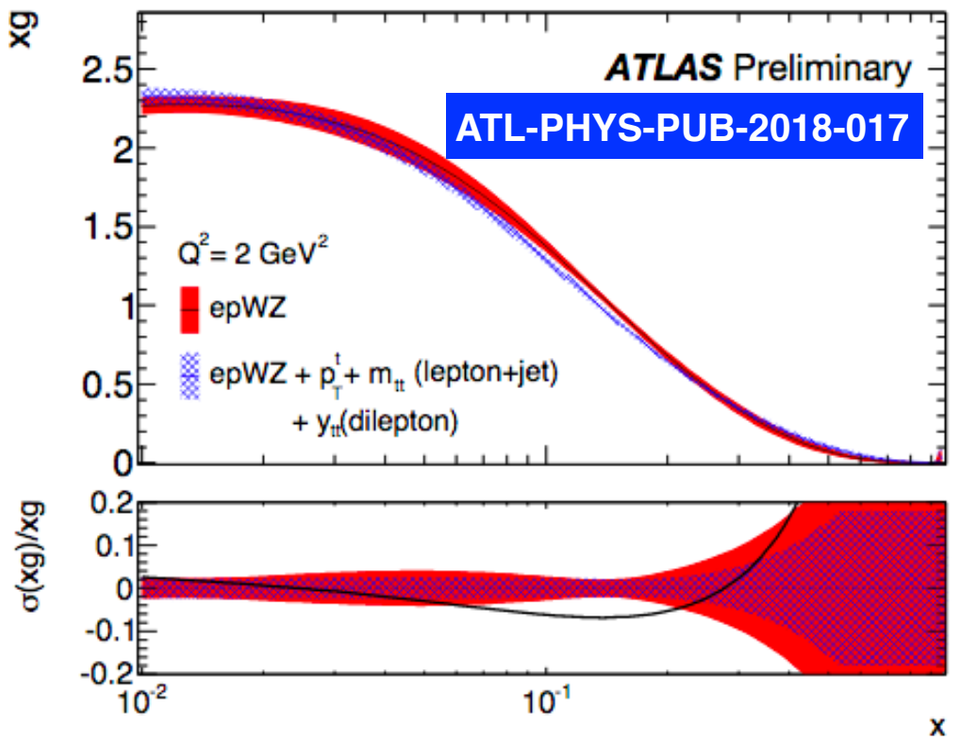


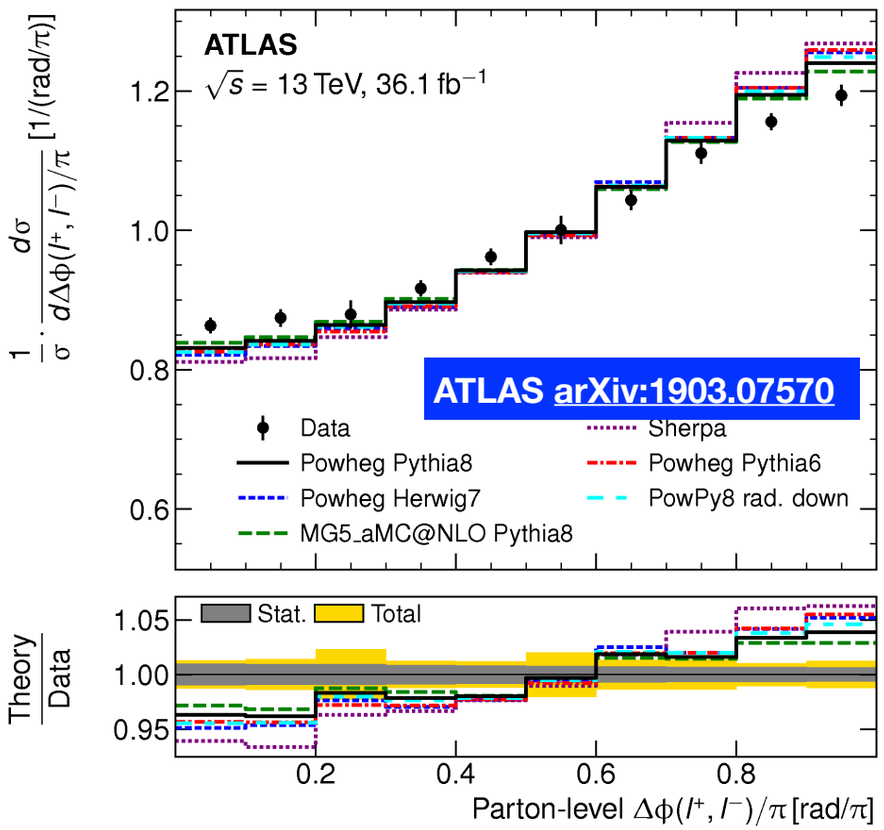
ttbar and single top production under scrutiny

Exploring Top Quark Production



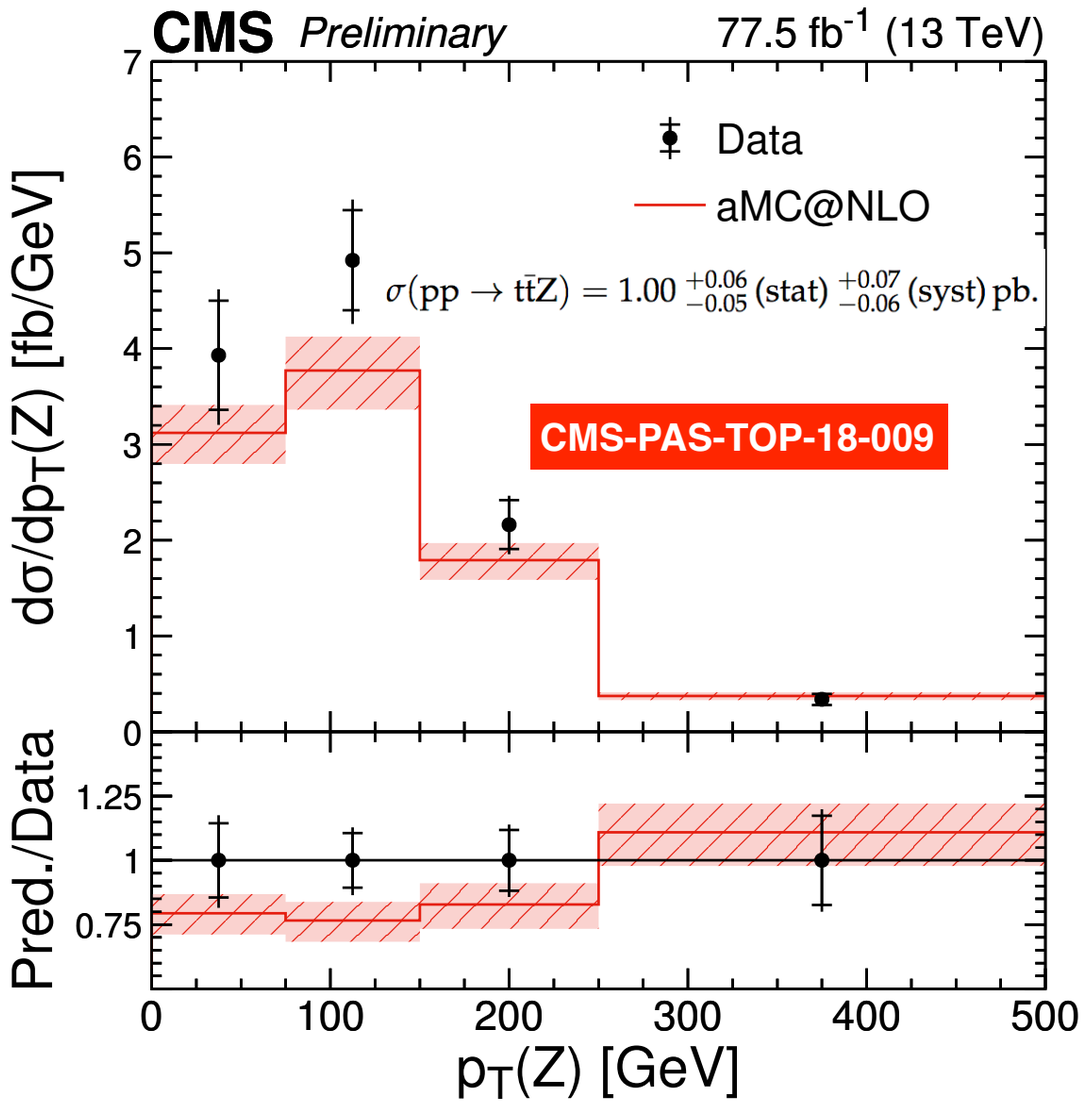
- Increasingly more precise (multi-) **differential distributions** becoming accessible, not only in ttbar: differential single top production cross section
- ttbar production at LHC provides the only direct **constraint on high x gluon PDF**
- Pt spectrum still presenting mysteries: pt somewhat softer in data than predicted even at NNLO
- **Tensions in top-spin correlations** (missing higher order corrections to top kinematics?)

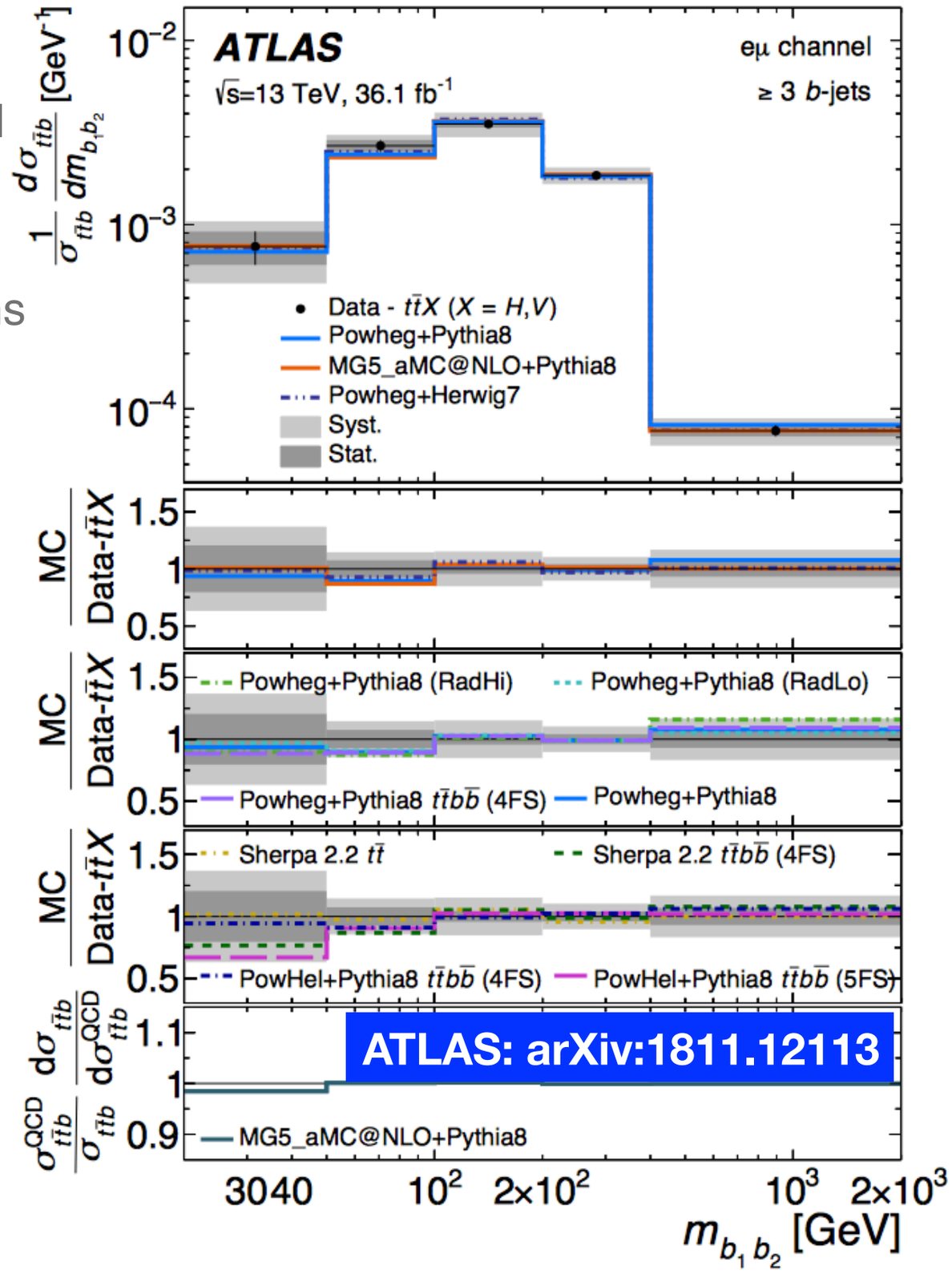




Beyond t and tt: tt+X

- **ttV** : probing the EWK couplings of the top : 10% precision (better than NLO), moving to differential distributions
- **tt+bb :** large theoretical uncertainties, experimental precision now better than predictions



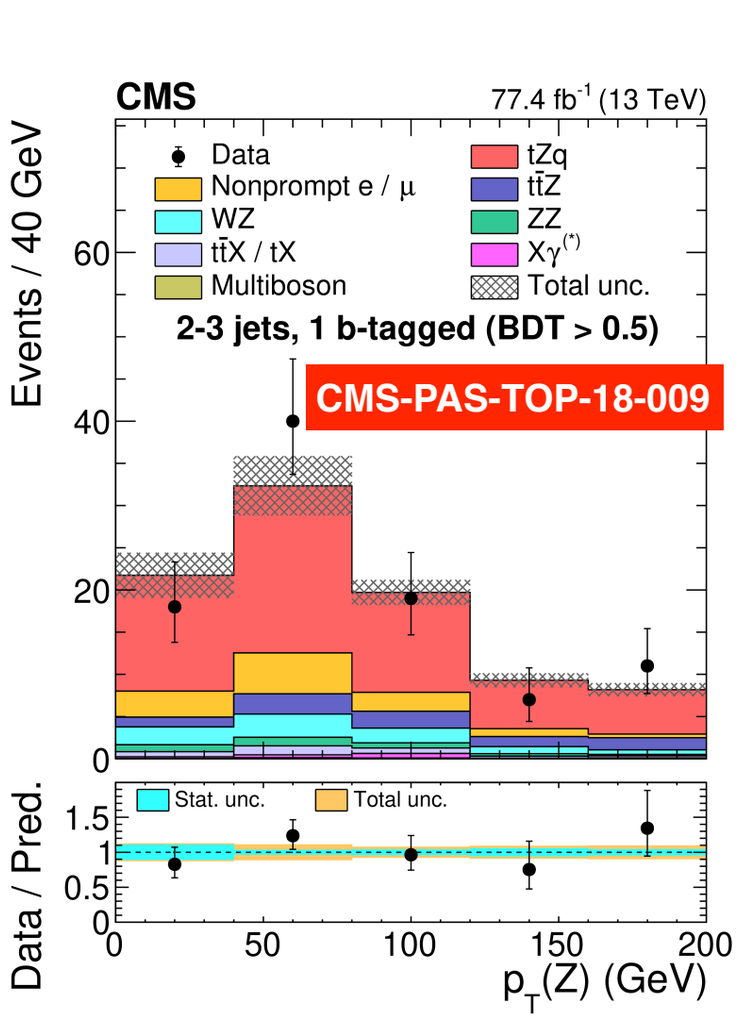


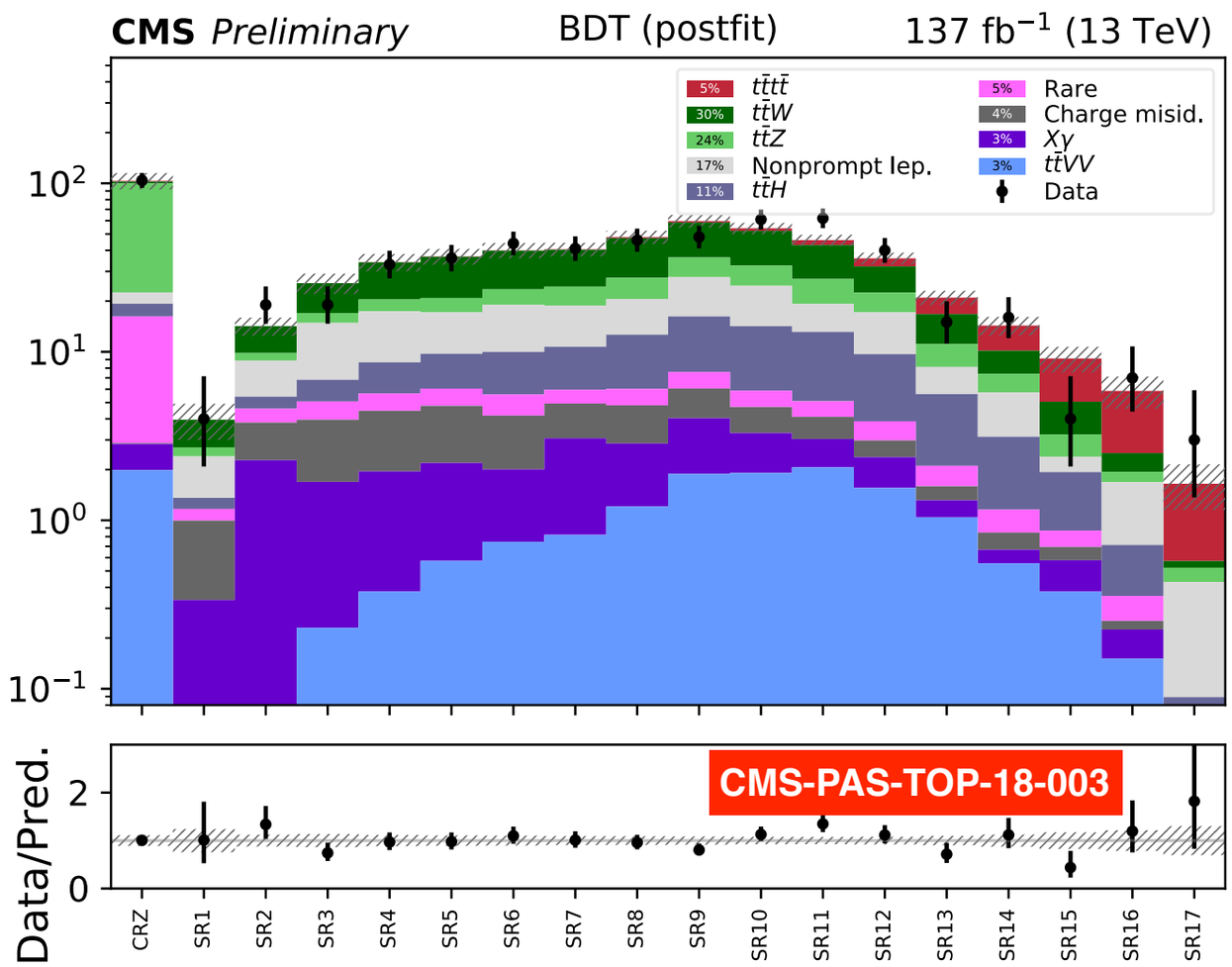
Rare Top Production

- **Observation of tZq** - rare SM process (1pb) , Sensitive to t-Z coupling, FCNCs, triple WWZ coupling

$$\sigma(\mathrm{pp} \to \mathrm{tZq} \to \mathrm{t}\ell^{+}\ell^{-}\mathrm{q}) = 111 \pm 13\,(\mathrm{stat})\,^{+11}_{-9}\,(\mathrm{syst})\,\mathrm{fb}$$

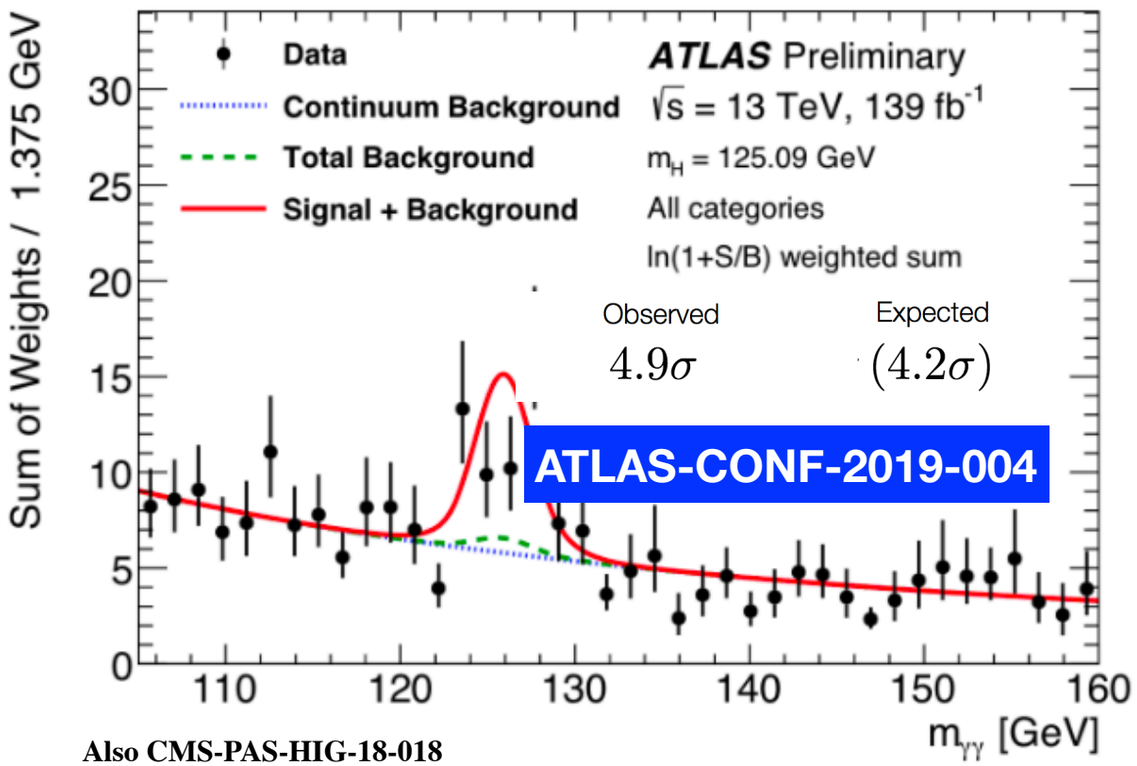
- **Search for 4top production:** very rare, 0.01pb, sensitive to top yukawa coupling.
  - CMS (TOP-18-003): obs. (exp.): 2.6 (2.7) ; ly/ySMl < 1.7 @ 95% CL

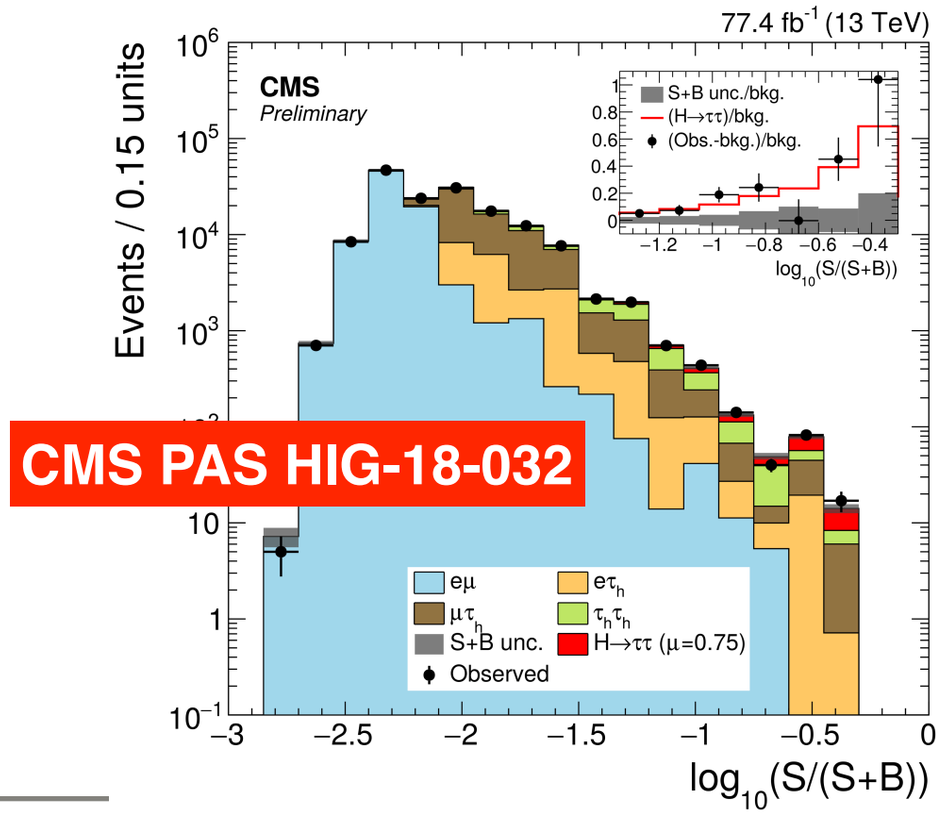




2018: a good year for Higgs&Fermions

- Higgs coupling to bosons already well established.
- **Highlight of 2018: Observation of Higgs coupling to third generation fermions**
  - Winter19 updates to **Hbb** and **Hττ** (both with STXS, CP in ττ) and **ttH** (updated ttH Hgg)
- Coupling to second generation? **μμ**: currently ~2 the SM reach in each experiment with partial Run2 data -> next in line!

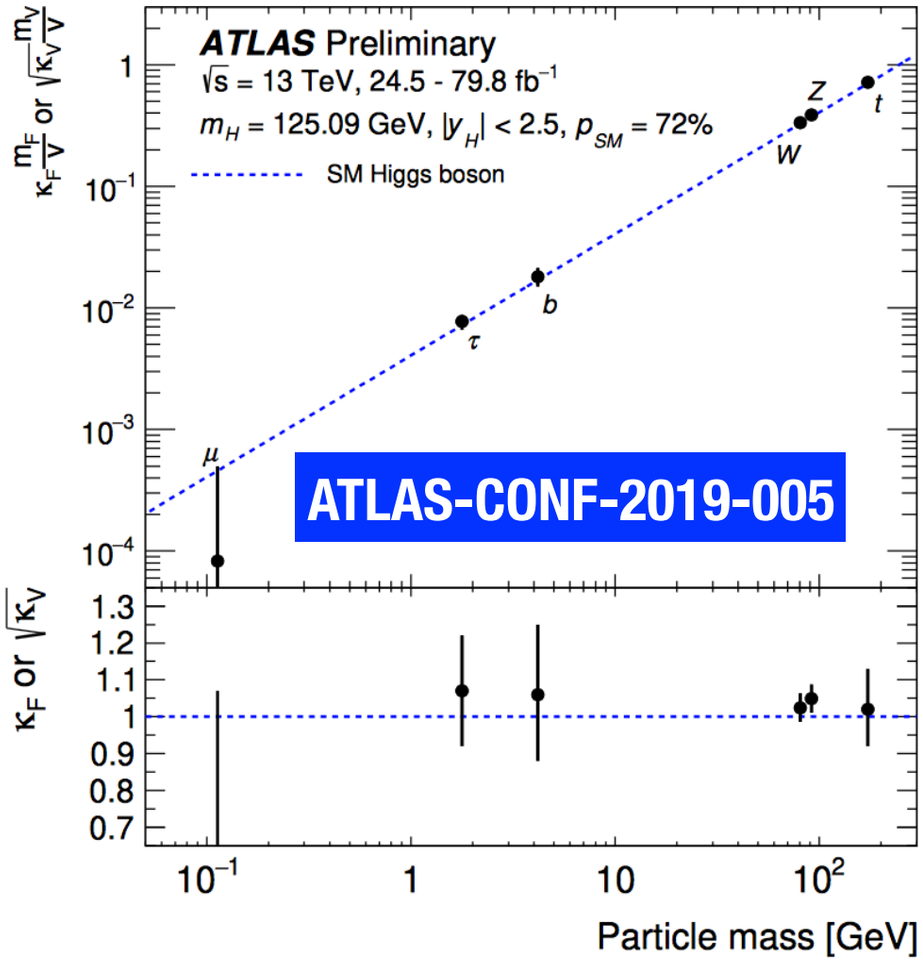


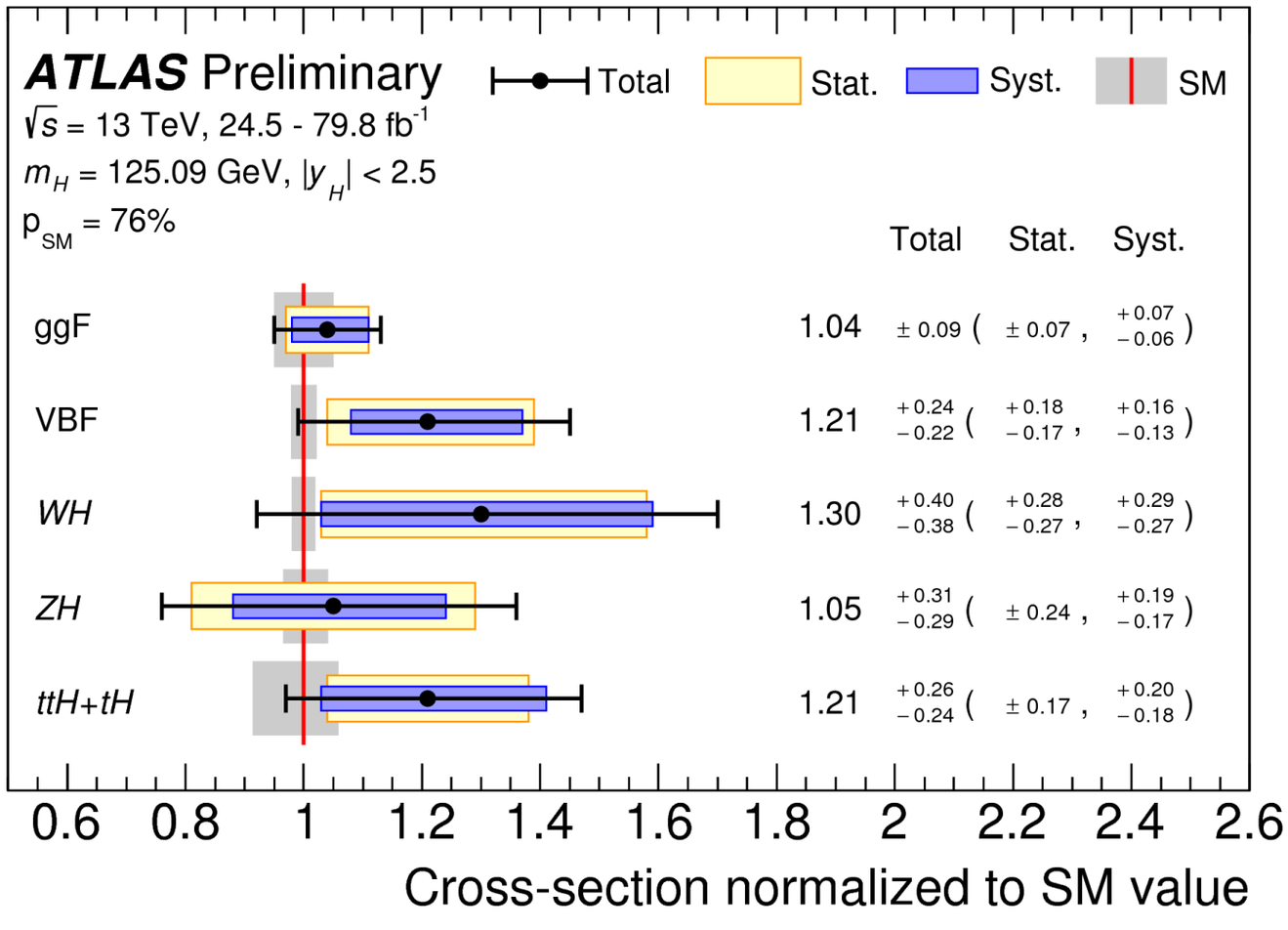


Higgs Production & Decay

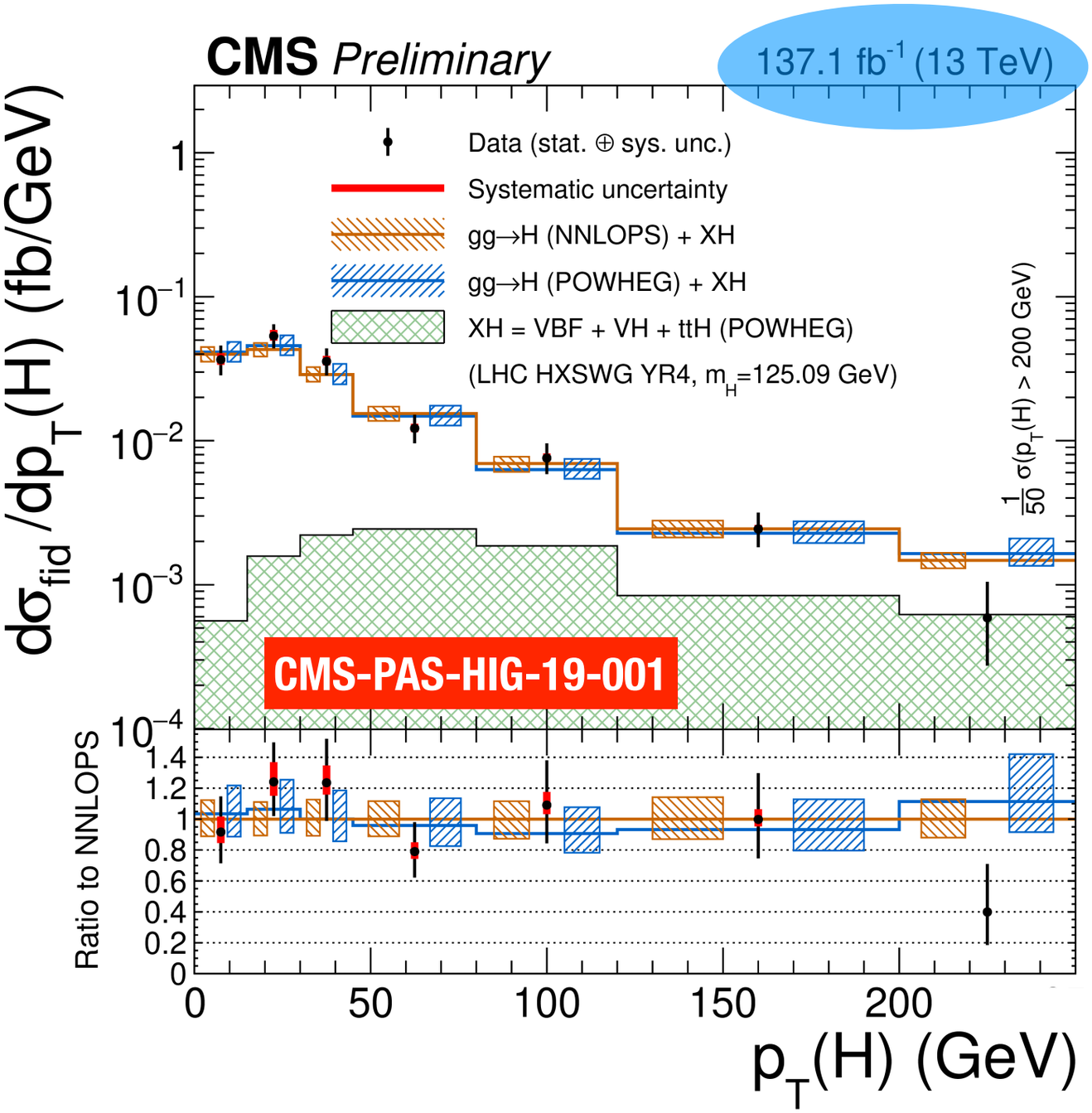
- **Main higgs production & decay modes observed now. Kappas to 10-20%.**
- Firmly in the **precision / measurement era**, with similar performance in CMS and ATLAS: Single experiment partial Run2 results more precise already than the Run1 ATLAS+CMS combination!

$$\mu = 1.11^{+0.09}_{-0.08} = 1.11 \pm 0.05\,(\text{stat.})\,^{+0.05}_{-0.04}\,(\text{exp.})\,^{+0.05}_{-0.04}\,(\text{sig. th.})\,^{+0.03}_{-0.03}\,(\text{bkg. th.})$$



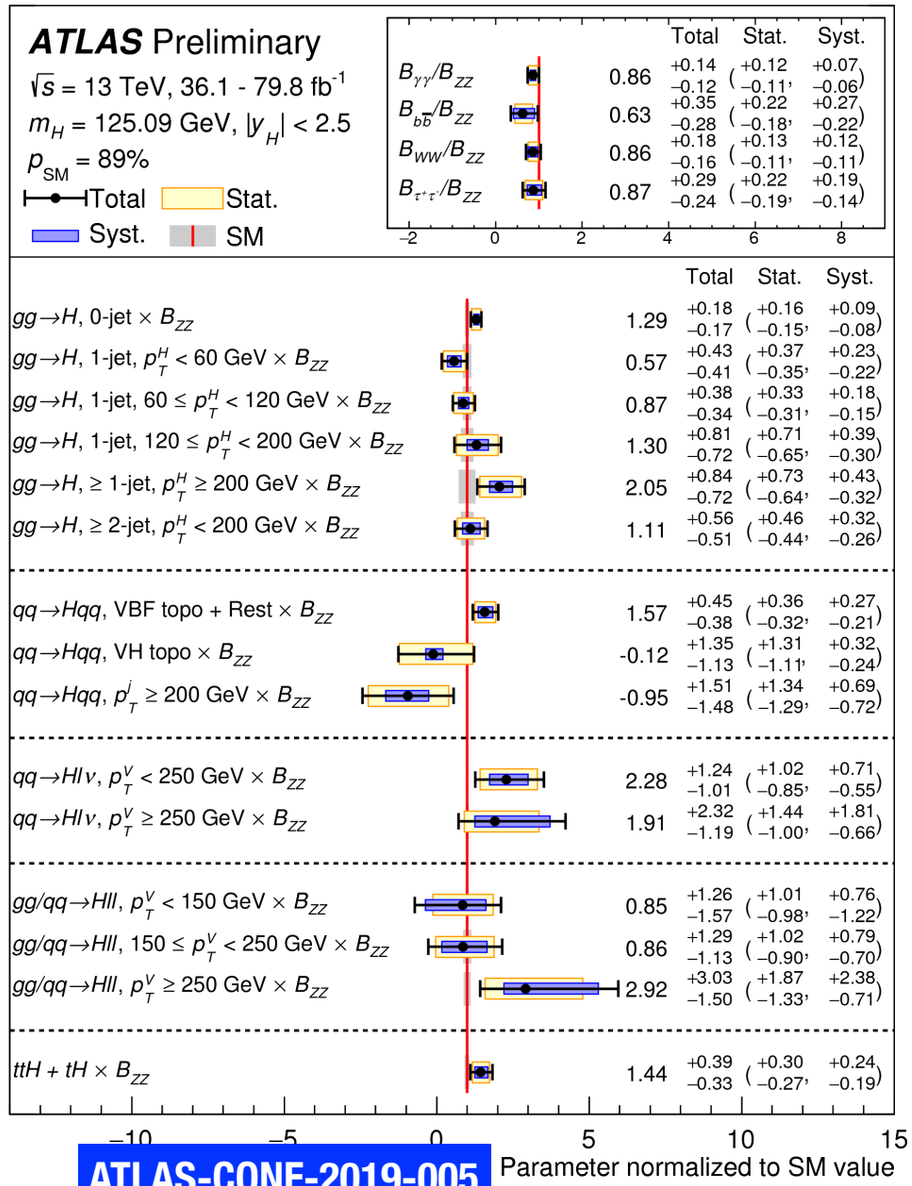


Differential & Fiducial Higgs CrossSections



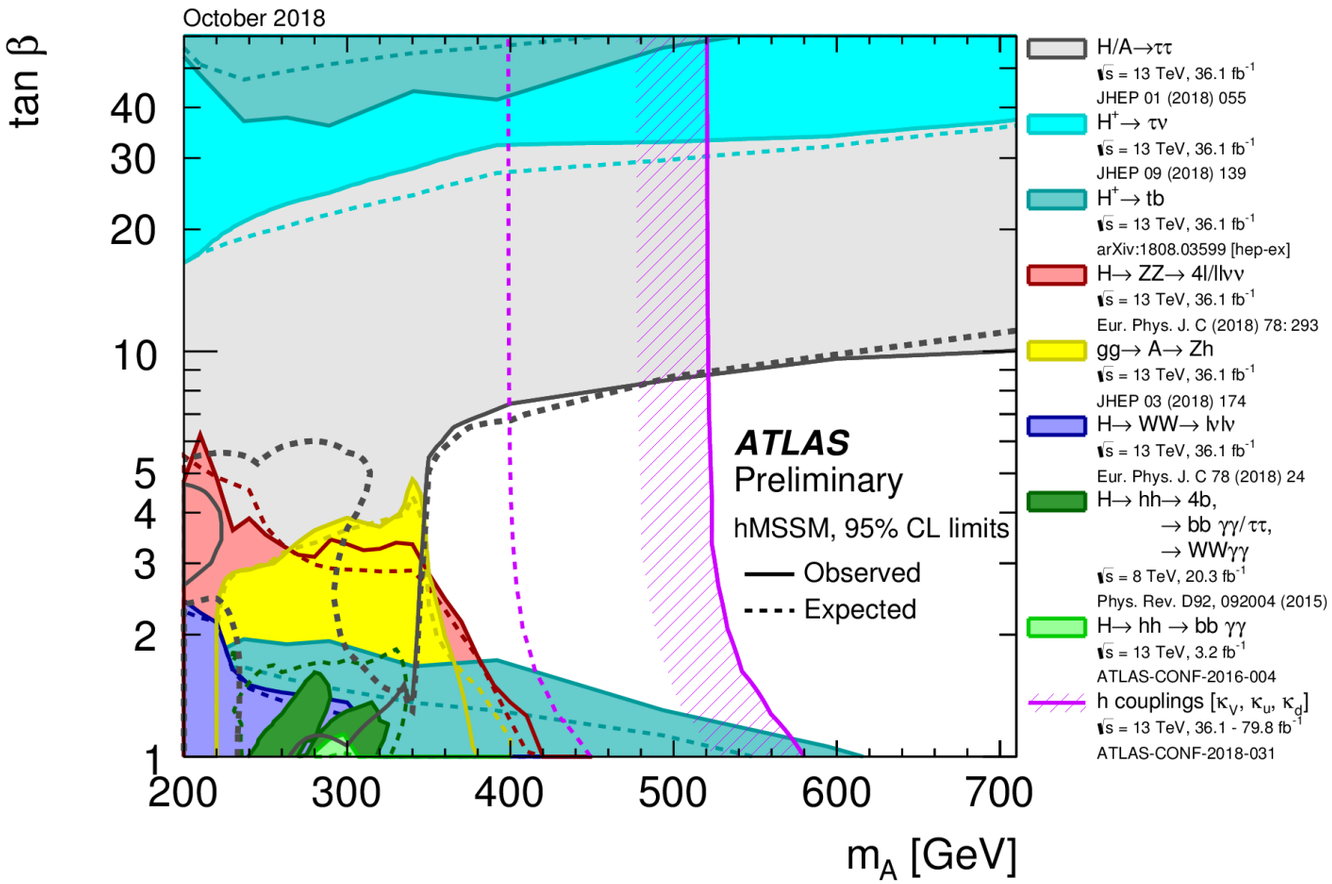
- Simplified template cross-sections available for most channels: minimise dependence on the theoretical model

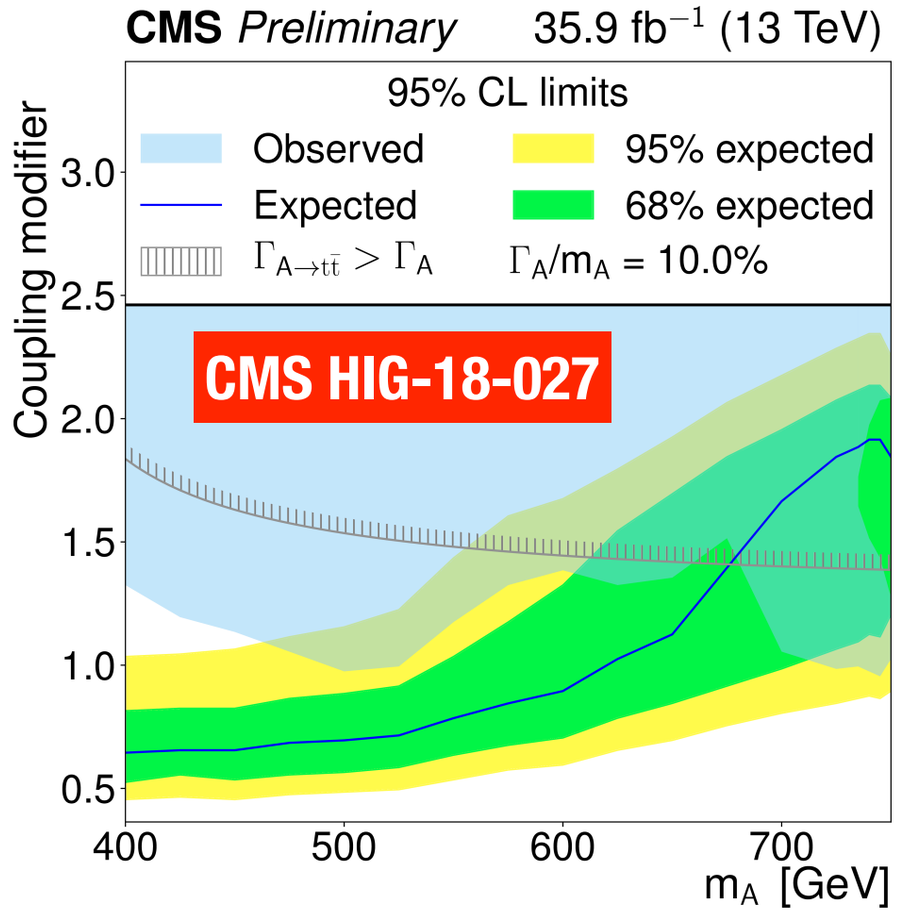
- Beyond quoting cross section agreement with the SM: measure the cross section as a function of Higgs kinematic variables (pt, eta of the products or of the Higgs, number of jets in the event,…)



Exploring the Higgs Sector

- Additional scalars are a common feature of BSM models (MSSM and 2HDM, NMSSM, …). Large landscape of searches for BSM Higgs with unprecedented sensitivity and new techniques.

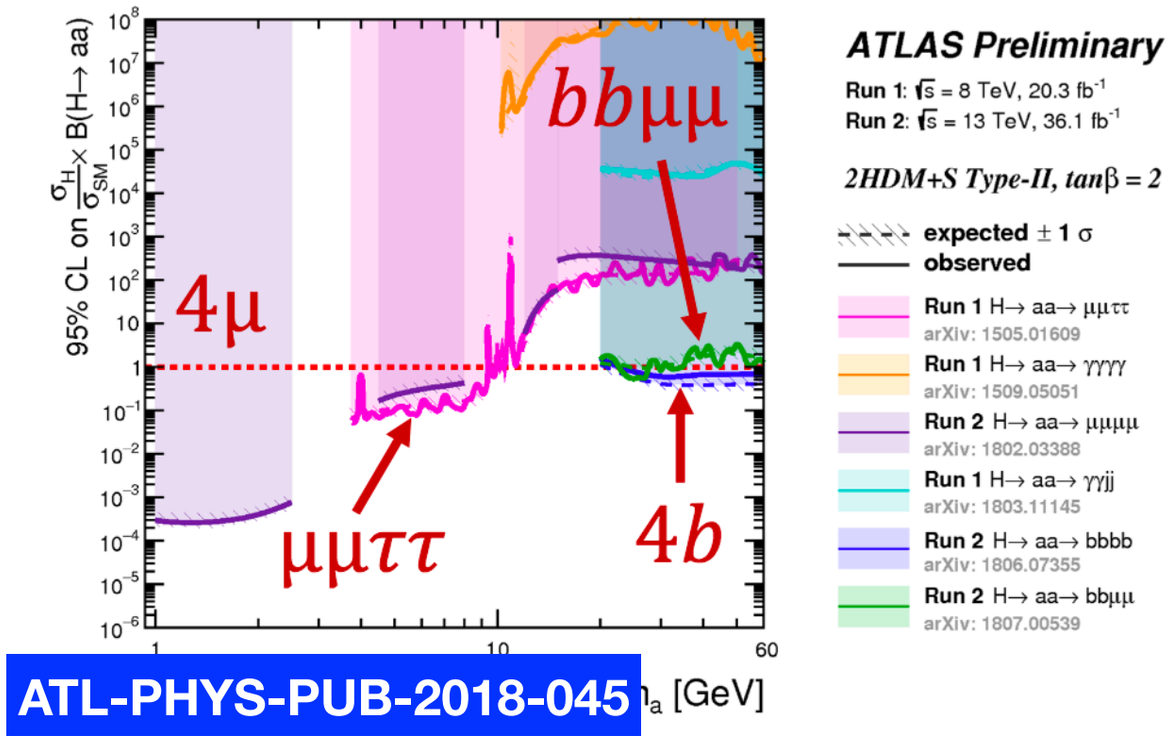


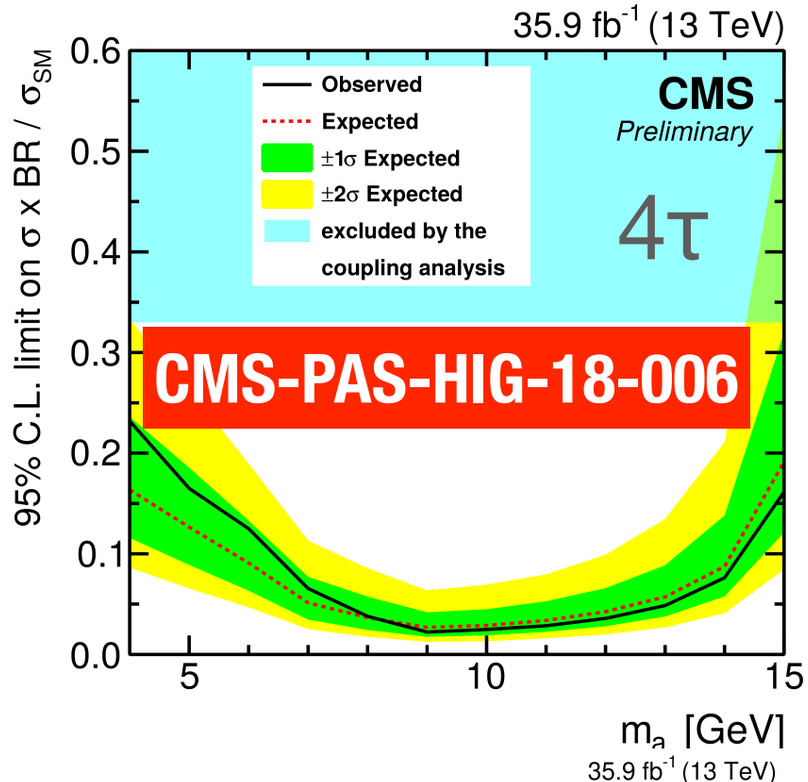


Constraints on BSM Higgs from the measured H(125) couplings, but also from direct searches targeting a large variety of final states, in “model independent” ways and also for different concrete benchmarks, old and new. No surprises yet.

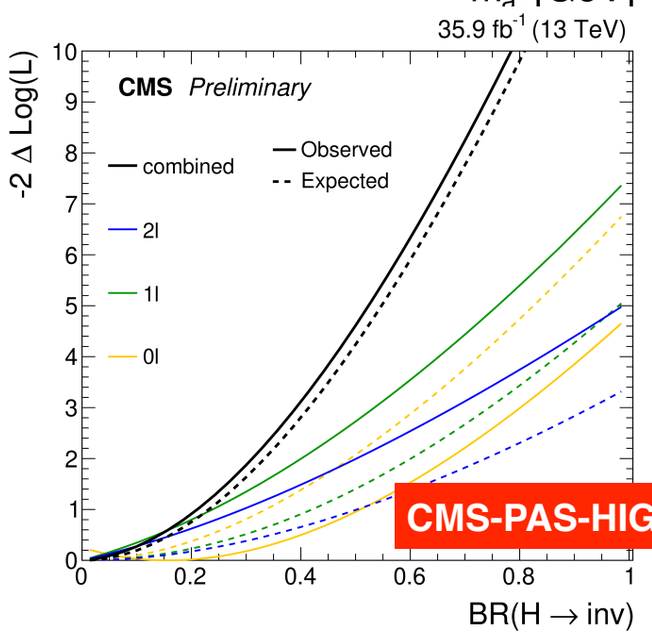
Exotic Higgs Decays

- B(BSM) limits from Higgs couplings (~20%) leave large phase space for BSM decays of H(125): expanding list of Higgs Exotic searches, for instance h->aa (2HDM+S)





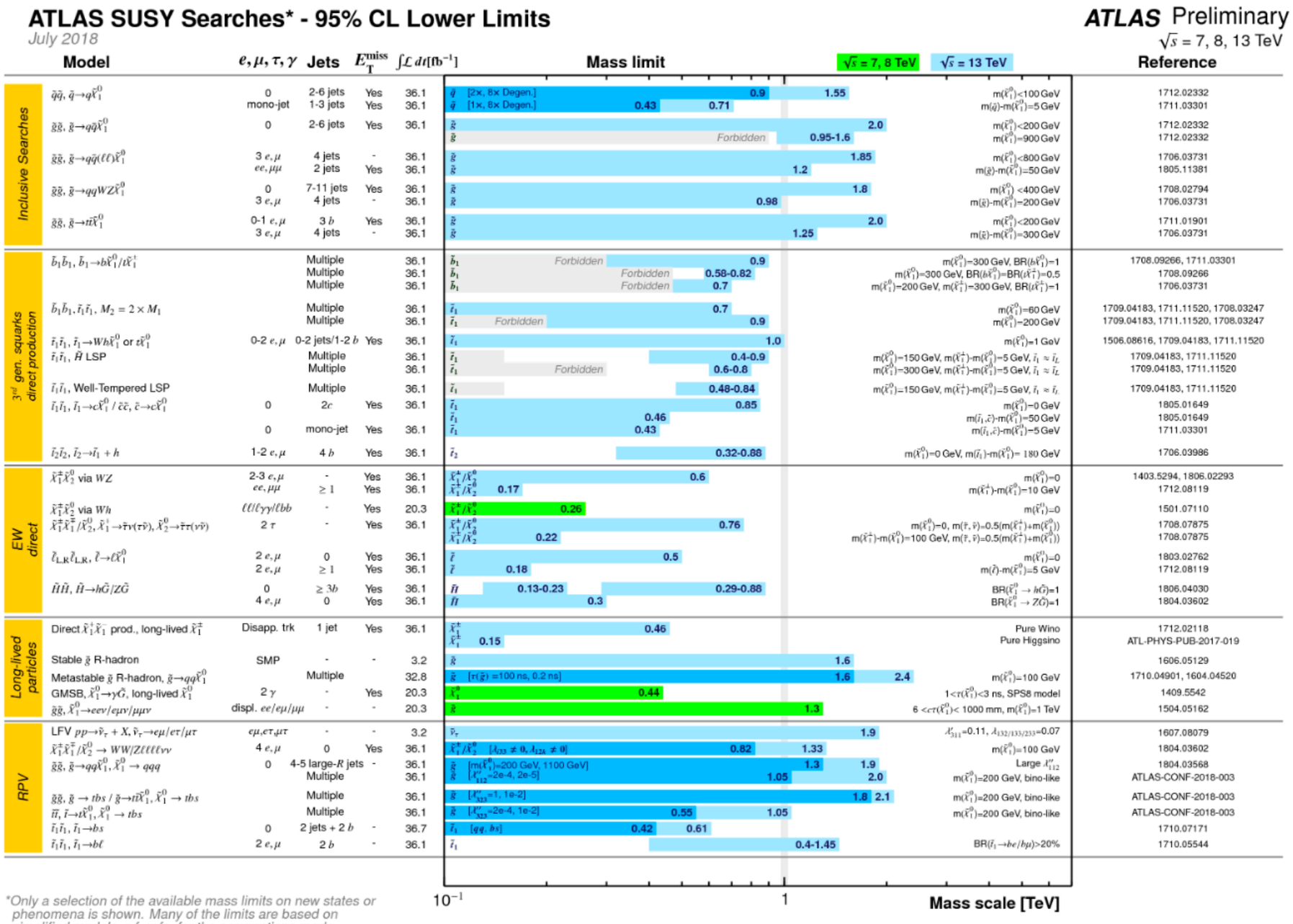
- Special mention to Higgs invisible (connection between Higgs and dark matter searches): **B(H->inv) < 0.19 (0.15) @ 95%CL in CMS, B(H->inv)<0.26 (0.17) in ATLAS…**



Now also ttH, H->inv!:
CMS-PAS-HIG-18-008: B(H→inv)< 0.46(0.48)

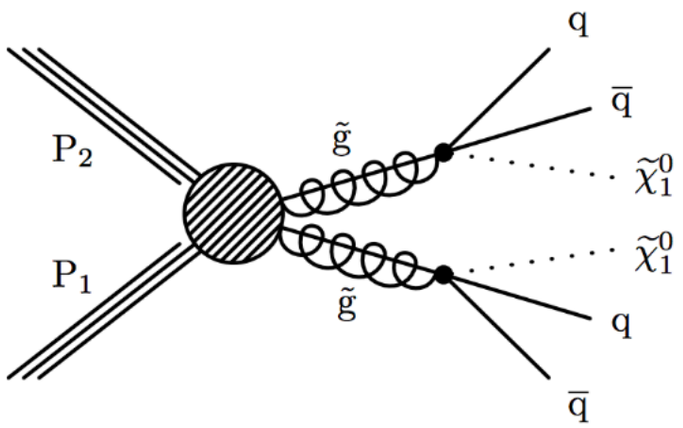
Looking for New Physics?

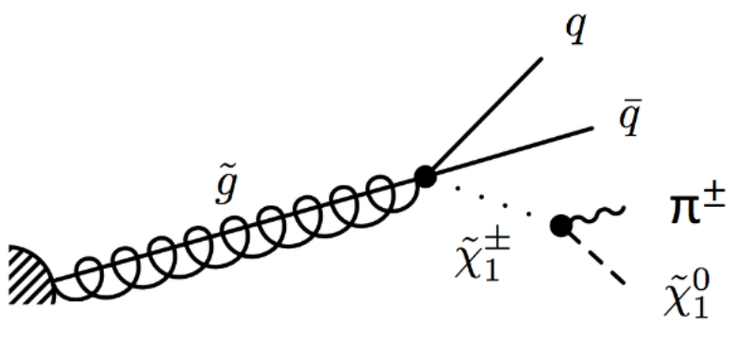
- Leaving no stone unturned in the search. Going from traditional searches to exploiting new techniques: is BSM hiding in difficult corners of the phase-space?

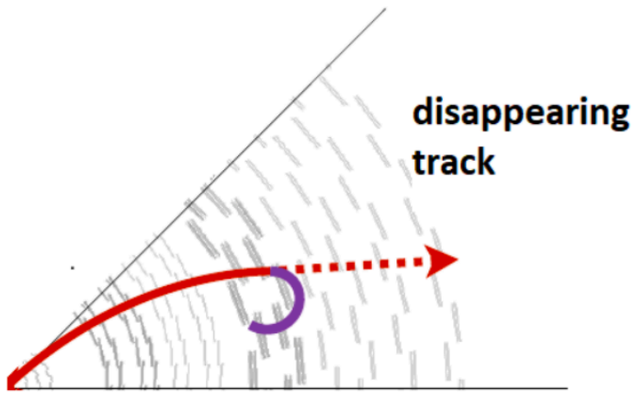


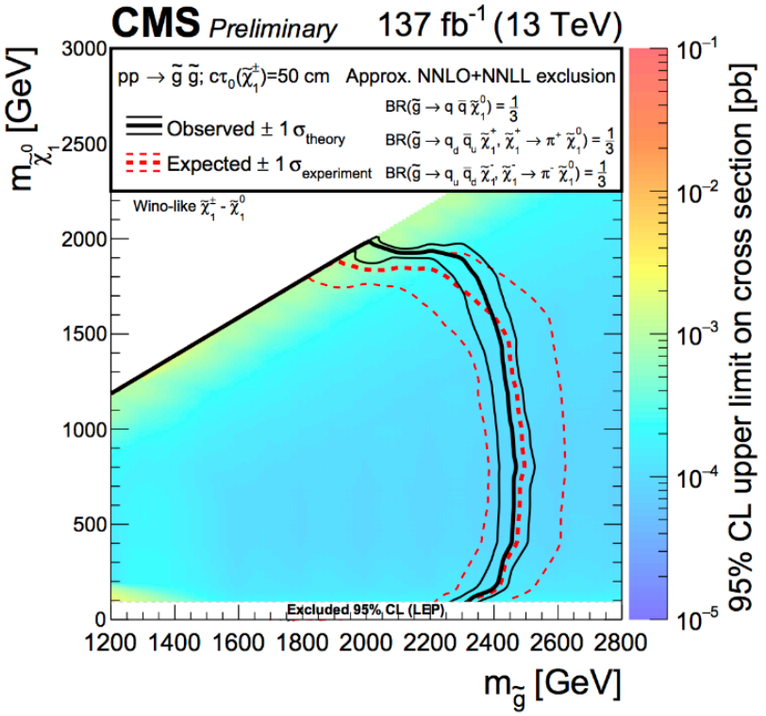
Looking for New Physics?

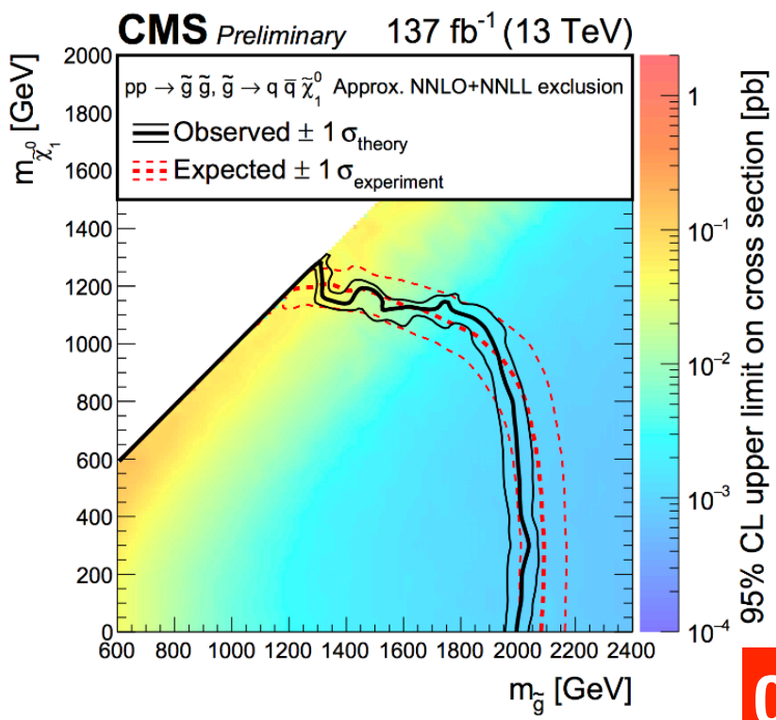
- Example: disappearing track searches: well reconstructed track in the inner layers of the tracker that “goes missing” (at least two outer tracker layers missing hits). Categorize by length of observed track to catch a range of lifetimes.







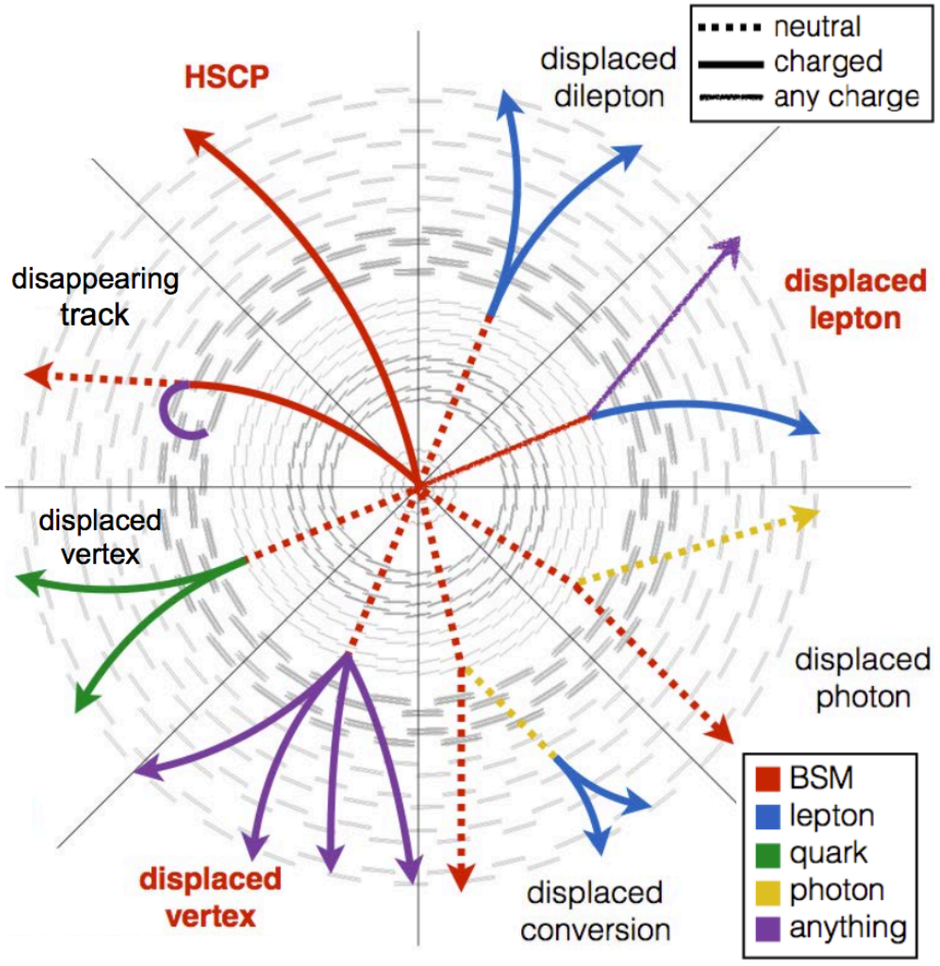




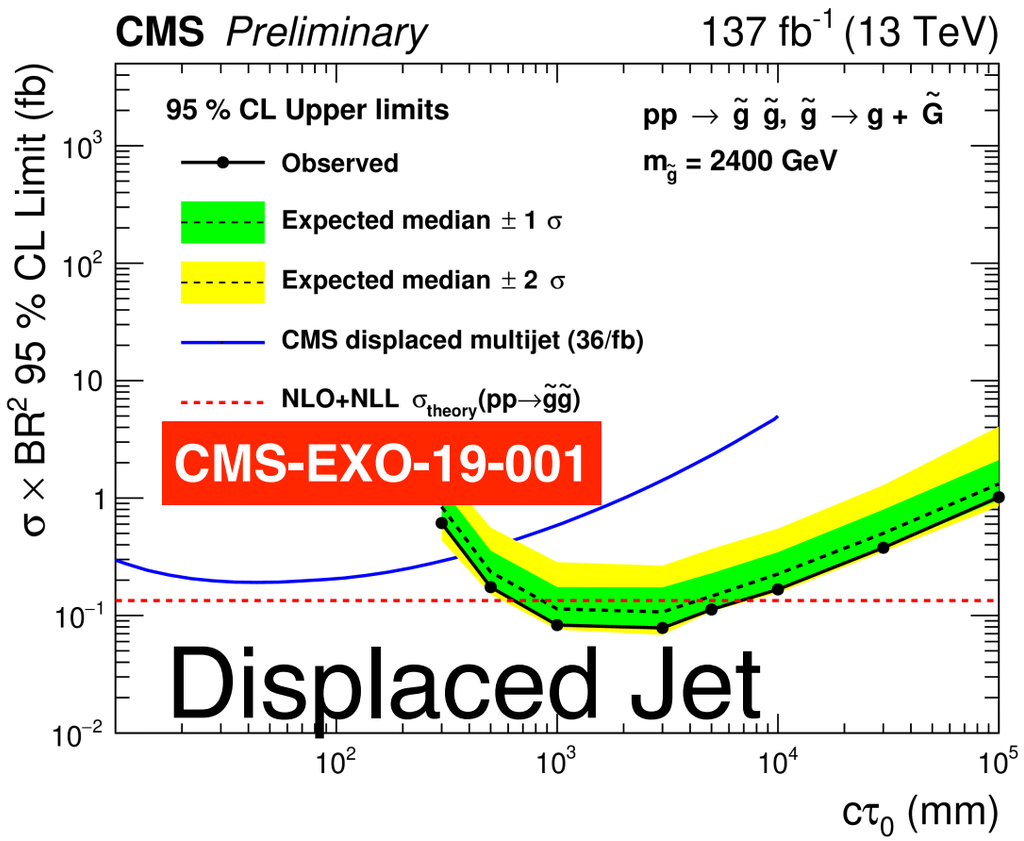
CMS SUS-19-005

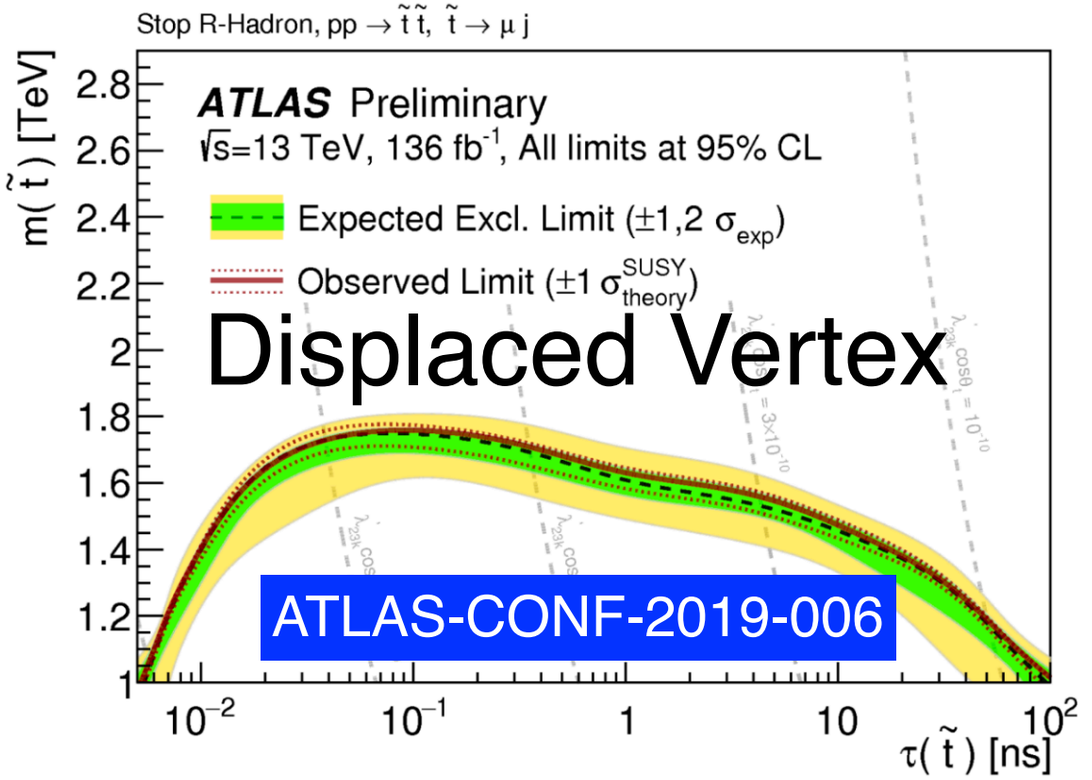
Long Lived?

- Disappearing tracks was one example. The searches for long lived particles are a promising, expanding field
- Challenging experimentally, with innovative techniques in fast development
- Multiple signatures and topologies for charged and neutral LLP



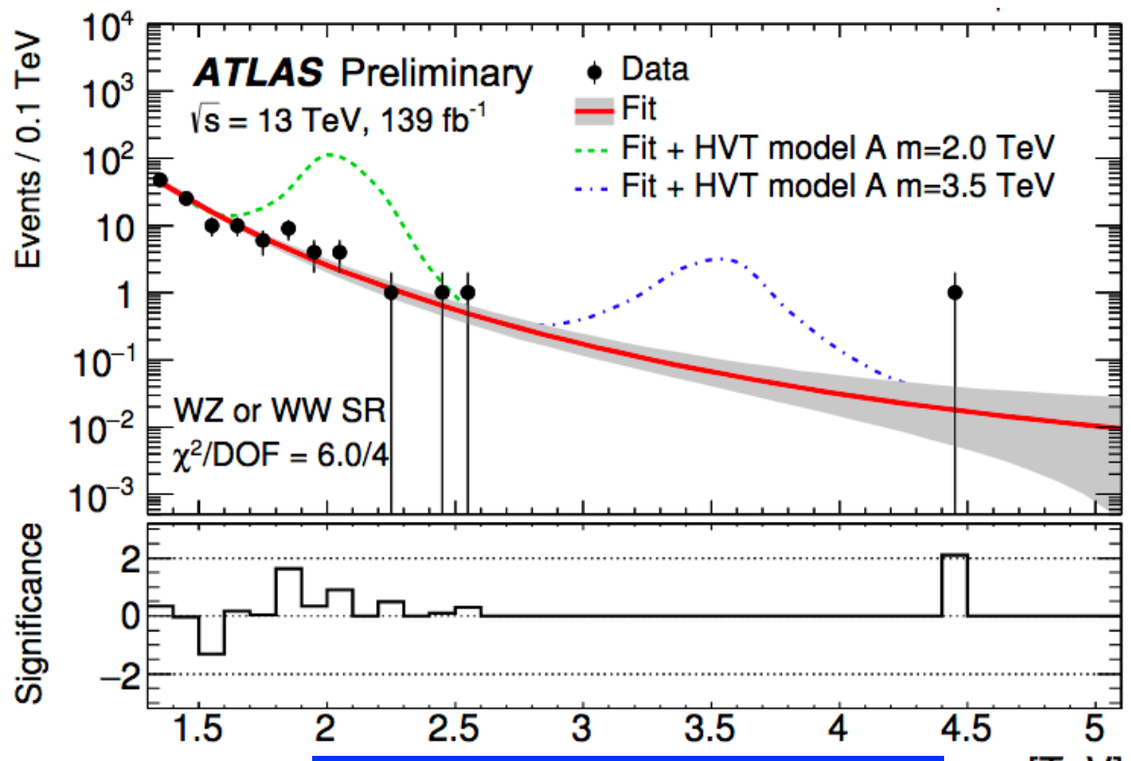
Credits: J. Antonelli



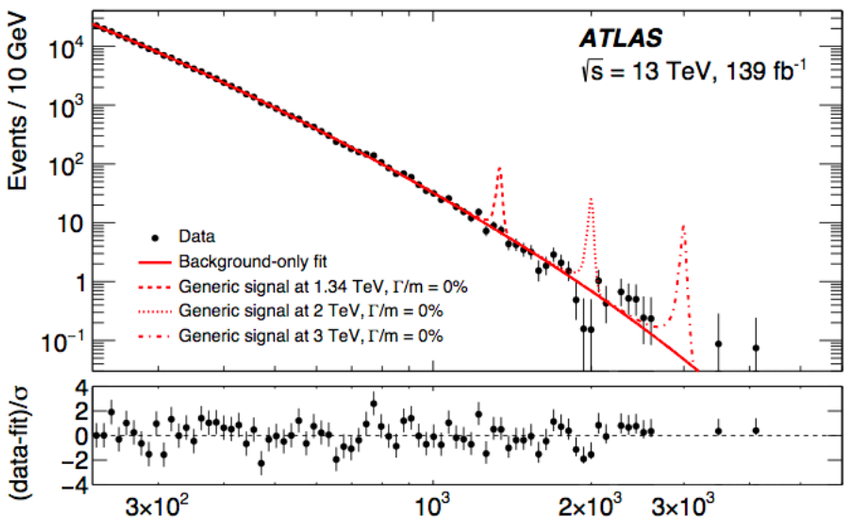


Resonances

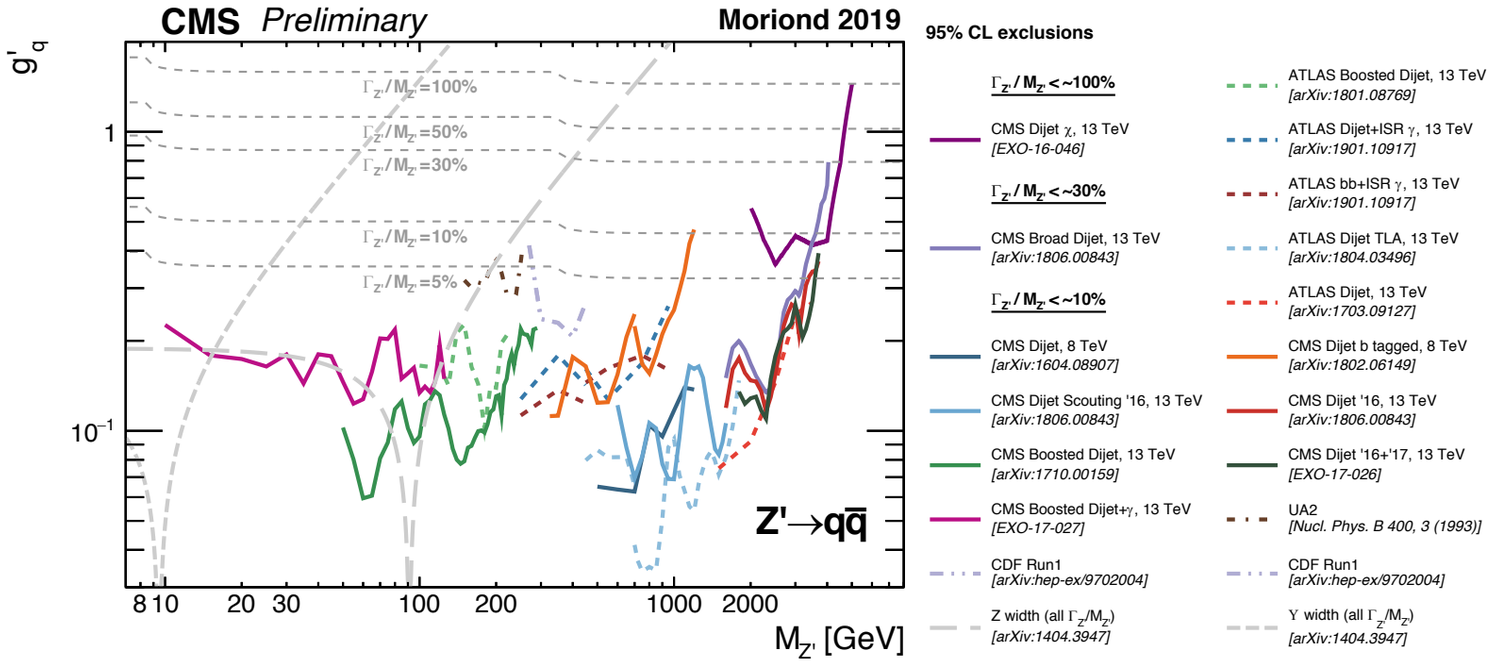
- Diboson, dilepton, dijet…
- Jet substructure well established as a key analysis technique
- Lower mass reach through innovative trigger strategies - scouting (CMS) and trigger-level analysis (ATLAS)



ATLAS-CONF-019-003

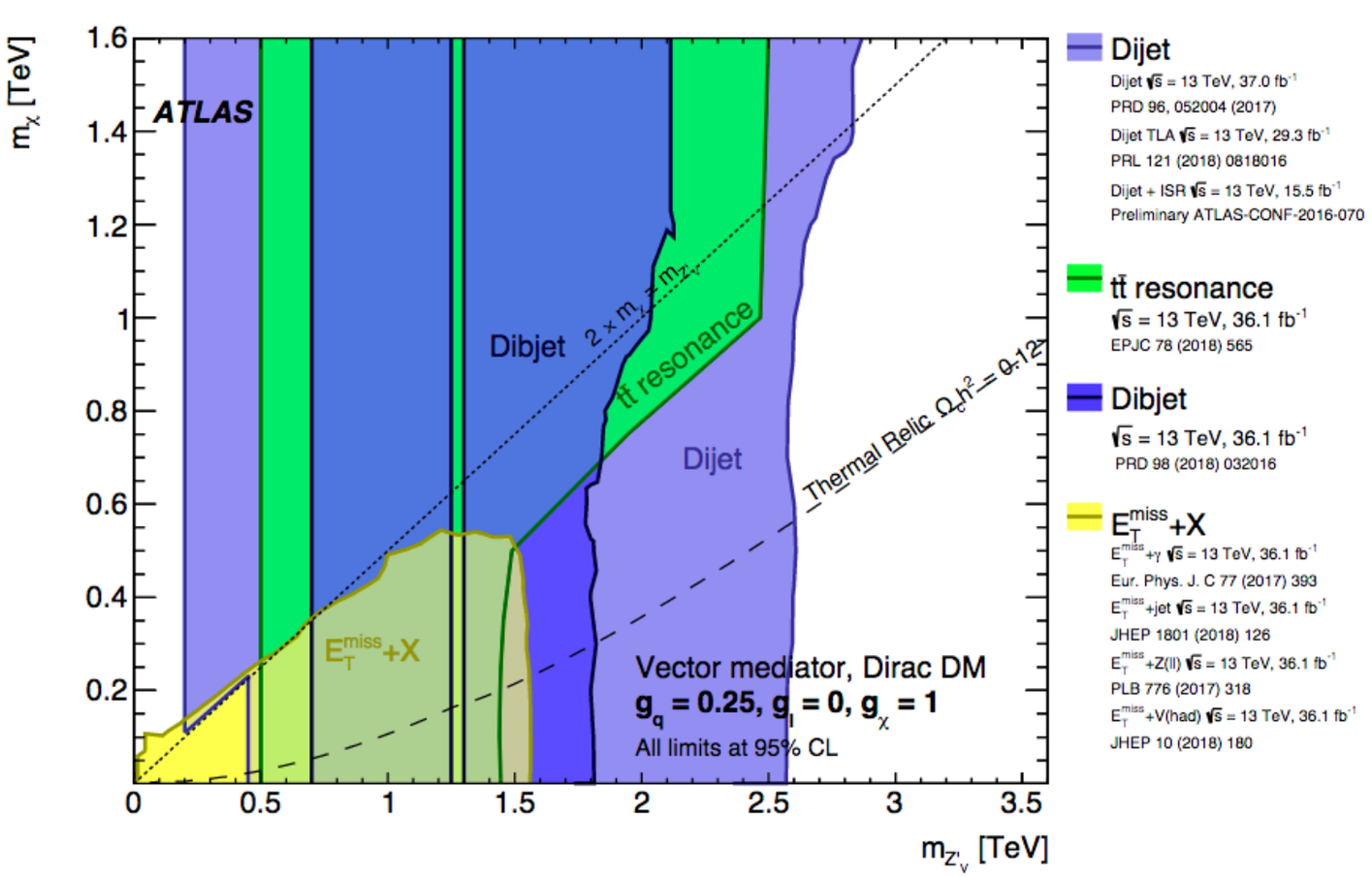


ATLAS:1903.06248

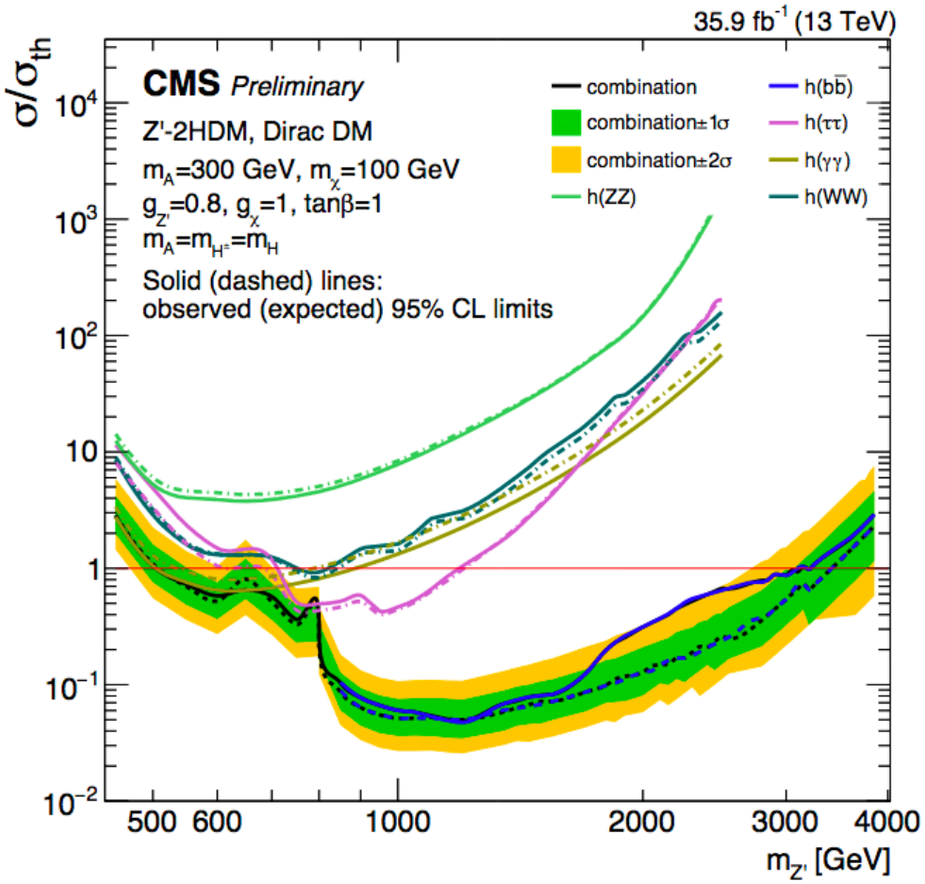


Dark Matter Searches

- Large coverage of topologies: no surprises yet, but expanding phase-space covered
- Complementary to direct searches, improved sensitivity at low masses



ATLAS: arxiv:1903.01400

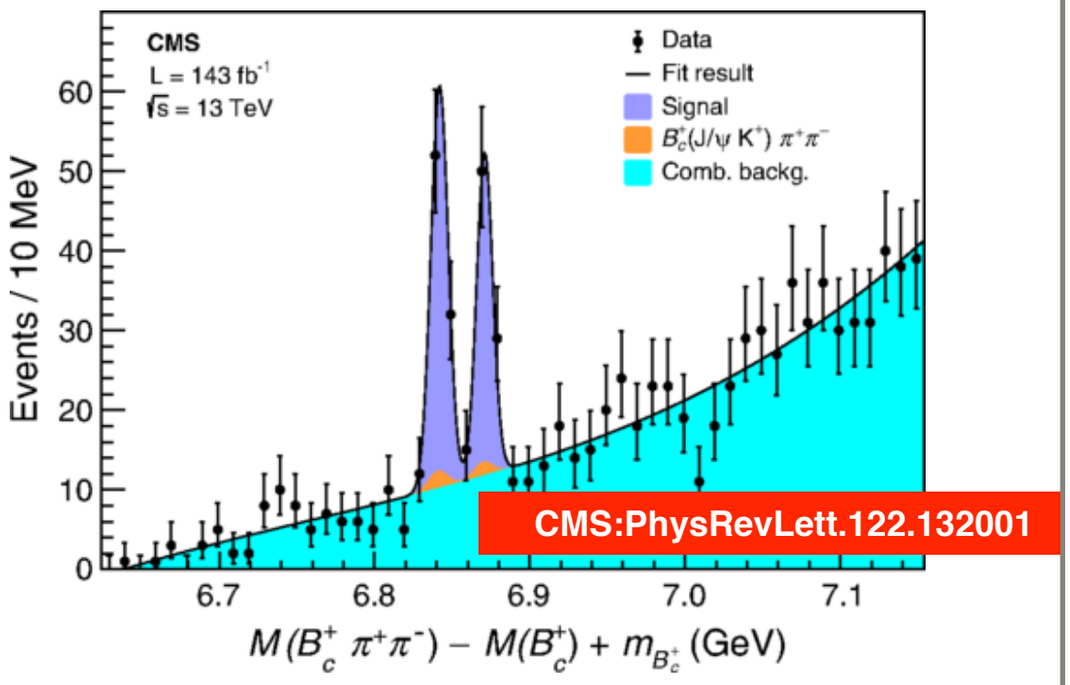


CMS EXO-18-011

Recent B-Physics results

- Observation of Two Excited B^+_c States and Measurement of the $B^+_c(2S)$ Mass in pp Collisions at 13 TeV

  - The observation of two peaks, rather than one, is established with a significance exceeding five standard deviations.

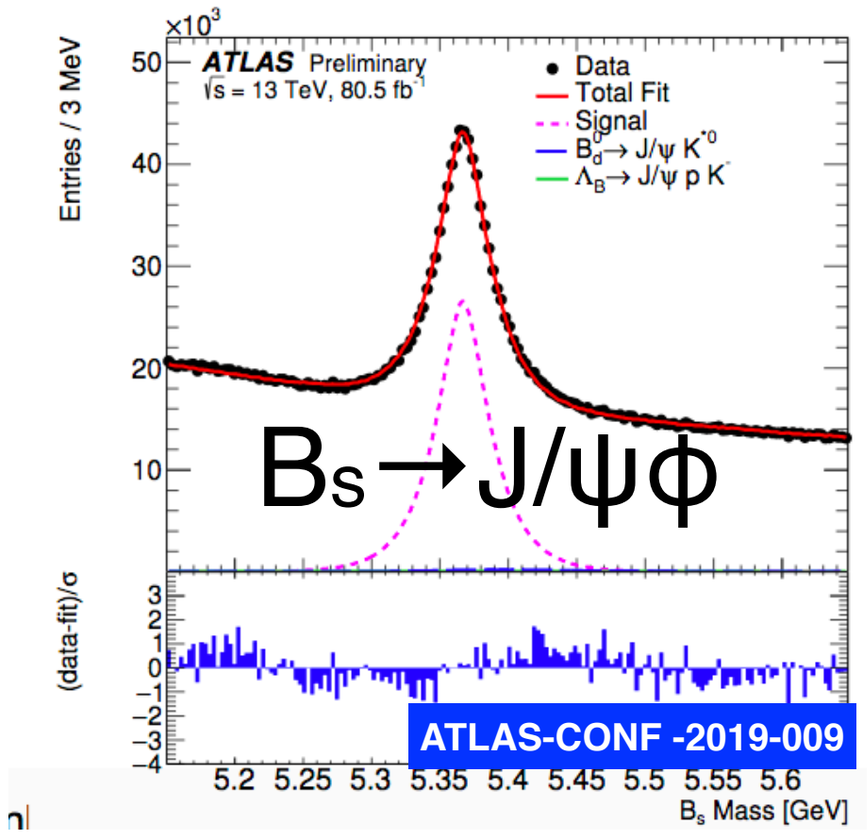


- $\tau \rightarrow \mu\mu\mu$ updated limits in CMS:

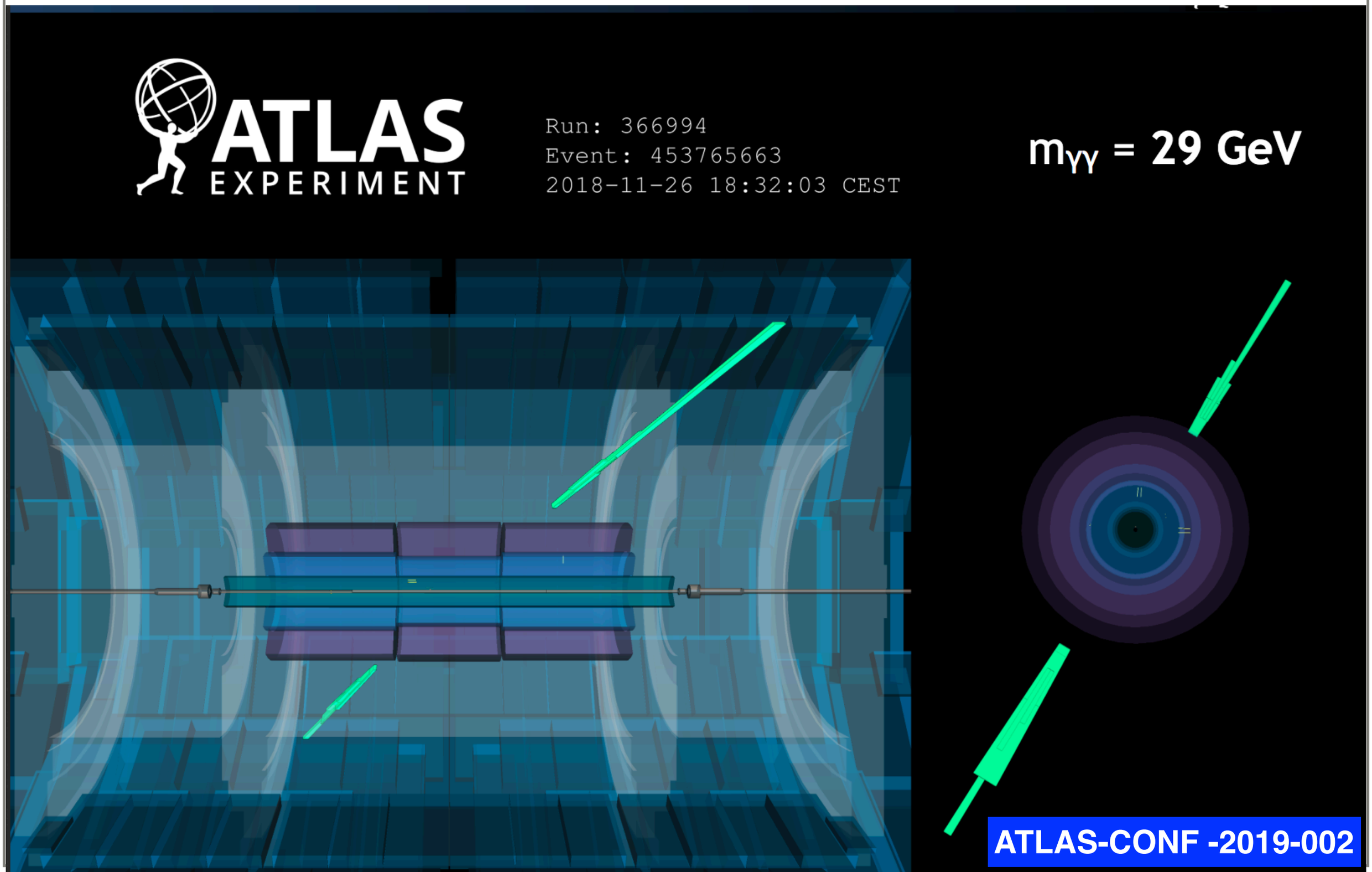
  - BF<8.8(9.9)e-8 at 90%CL (CMS-PAS-BPH-17-004)

- Time-dependent angular analysis of $B_s \rightarrow J/\psi\phi$

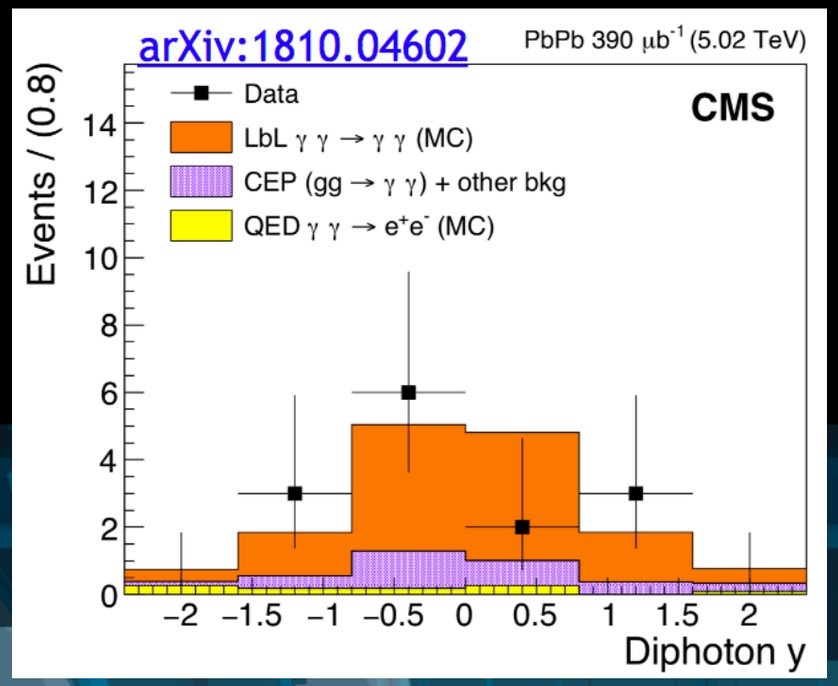
$$\begin{aligned} \phi_s &= -0.076 \pm 0.034\,(\text{stat.}) \pm 0.019\,(\text{syst.})\ \text{rad} \\ \Delta\Gamma_s &= 0.068 \pm 0.004\,(\text{stat.}) \pm 0.003\,(\text{syst.})\ \text{ps}^{-1} \\ \Gamma_s &= 0.669 \pm 0.001\,(\text{stat.}) \pm 0.001\,(\text{syst.})\ \text{ps}^{-1} \end{aligned}$$

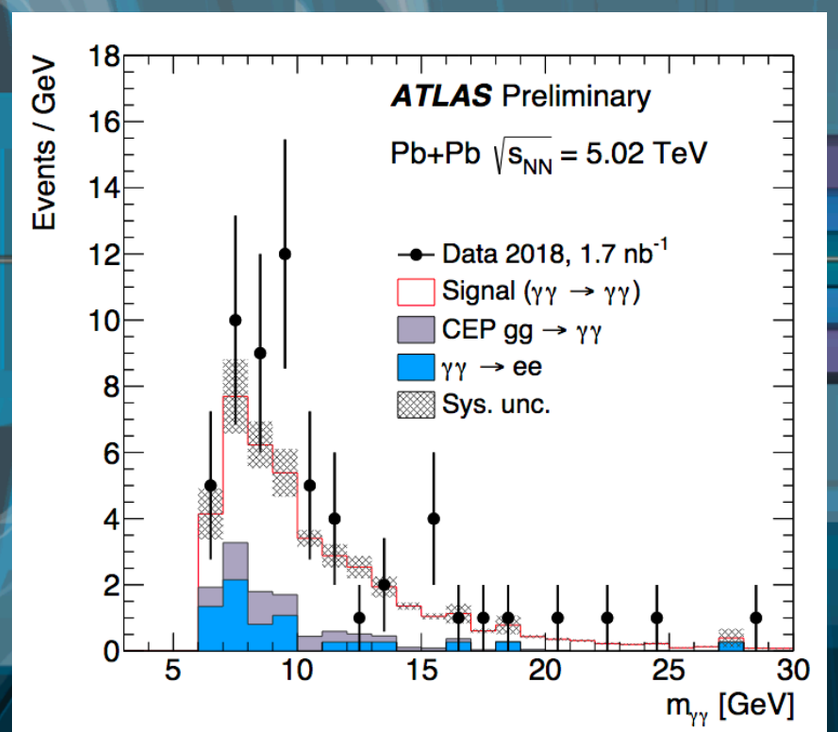


Light by light scattering



Light by light scattering





Run: 366994
Event: 453765663
2018-11-26 18:32:03 CEST

$m_{\gamma\gamma}$ = 29 GeV

First high-energy evidence light by light scattering by ATLAS & CMS (2015 Pb+Pb dataset @ 5.02 TeV)

NEW: Observation (ATLAS, Pb+Pb LHC November 2018 @ 5.02 TeV): 8.2σ(6.2σ) observed (expected)

Fiducial cross-section measured with 20% precision

ATLAS-CONF -2019-002

HINTS OF THE FAR FUTURE…

WARNING: JUST SOME NOTES ON HL/HE-LHC (TIME)

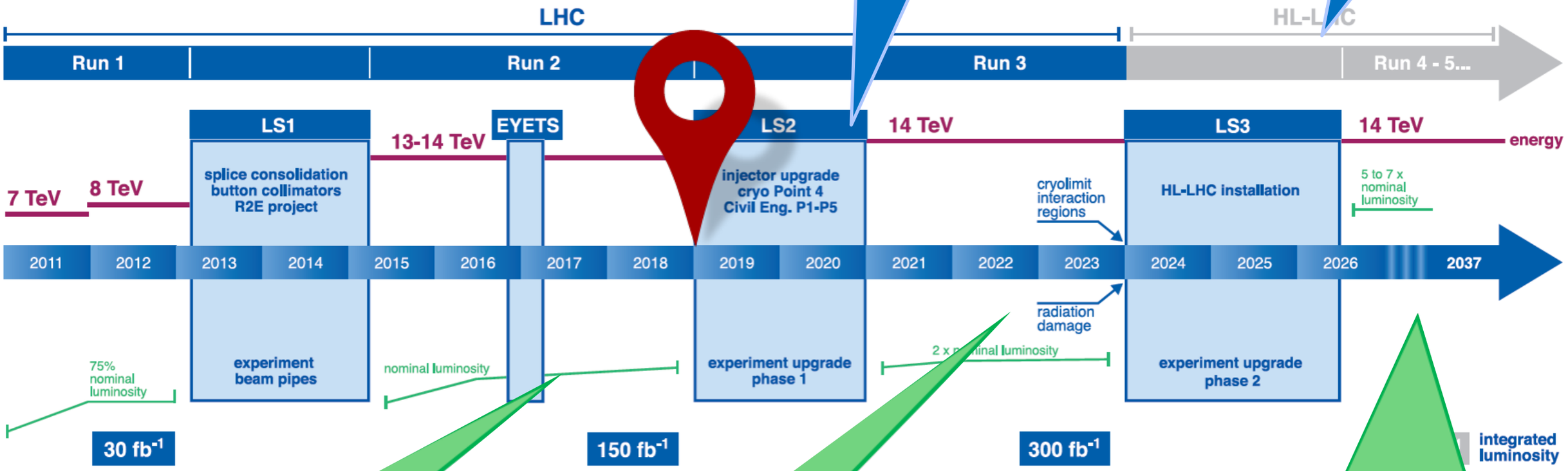
So what next?

upgrade of injector chain to deliver brighter bunches

new interaction region layout and crab cavity

LHC

HL-LHC



Run 2:
Design $\mathcal{L} = 10^{34}/\mathrm{cm}^2/s$

Run 3:
$\mathcal{L} = 2\times10^{34}/\mathrm{cm}^2/s$
for 300/fb

HL-LHC: Peak $\mathcal{L} = 2\times10^{35}/\mathrm{cm}^2/s$
level luminosity to
Nominal scenario: $\mathcal{L} = 5\times10^{34}/\mathrm{cm}^2/s$
for 3000/fb; Pile-up $<\mu>$ = 140
Ultimate Scenario: $\mathcal{L} = 7.5\times10^{34}/\mathrm{cm}^2/s$
for 4000/fb; Pile-up $<\mu>$ = 200
⇒25% increase in integrated lum.

- And HE-LHC?: LHC tunnel, 16T magnets
  ➨ 27 TeV collisions (15 ab-1, ~800PU)

(* slide taken from P. Azzi)

Precision physics at the HL-LHC?

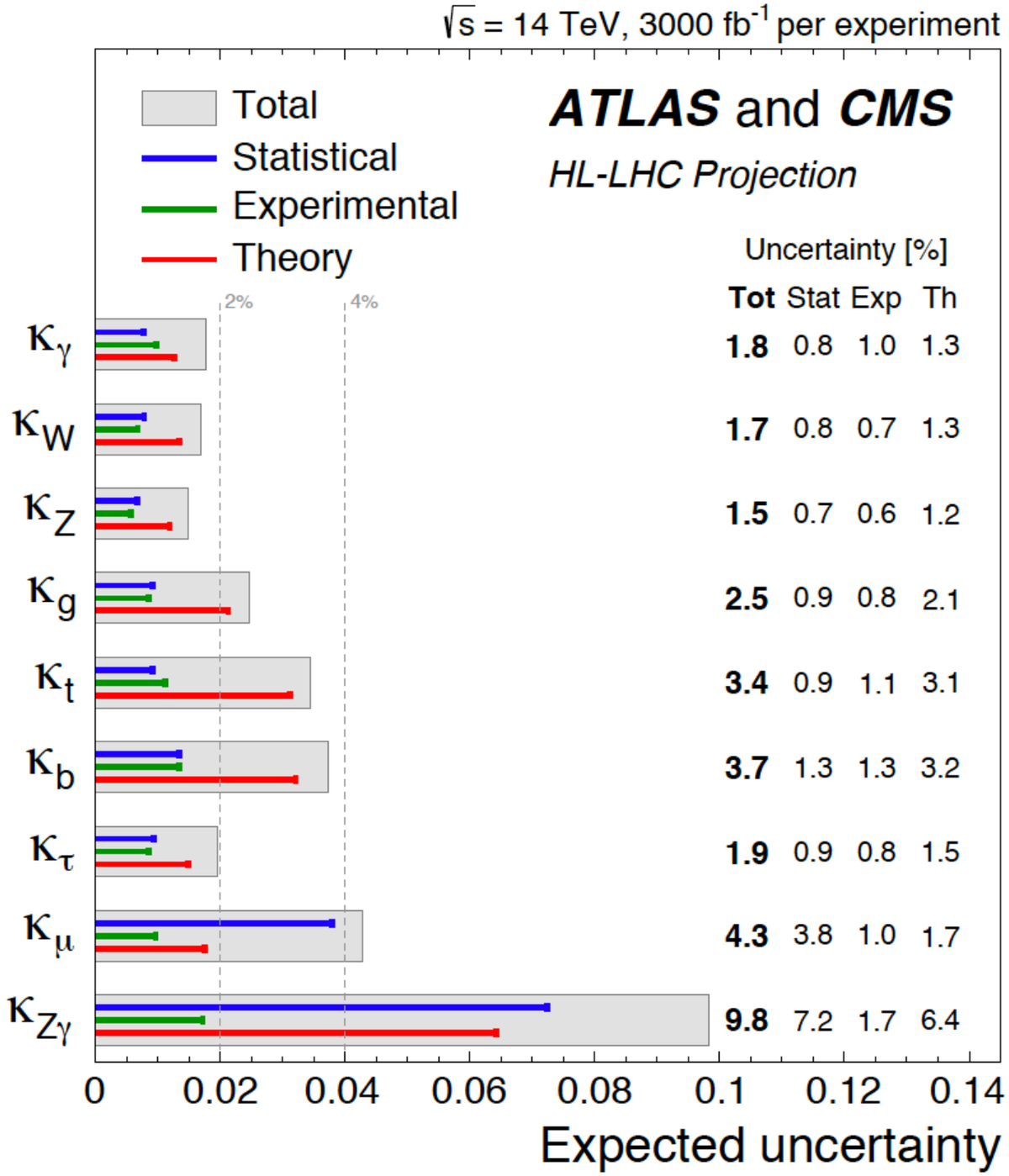
- **High statistics does not come for free: extremely challenging conditions**
  - High luminosity ➔ up to 200 pileup interactions per crossing
  - Detector elements and electronics are exposed to high radiation dose

- **Extensive upgrade program by ATLAS and CMS underway, with the goal of improving or at least maintaining the current performance despite the hard conditions**
  - Effective pileup mitigation & extended capabilities with new algorithms
  - Increased detector acceptance
  - Increased spatial granularity to resolve signals from individual particles
  - Precise timing measurements to provide an additional dimension for discrimination

- Performance of the future detectors documented in Technical Design Reports

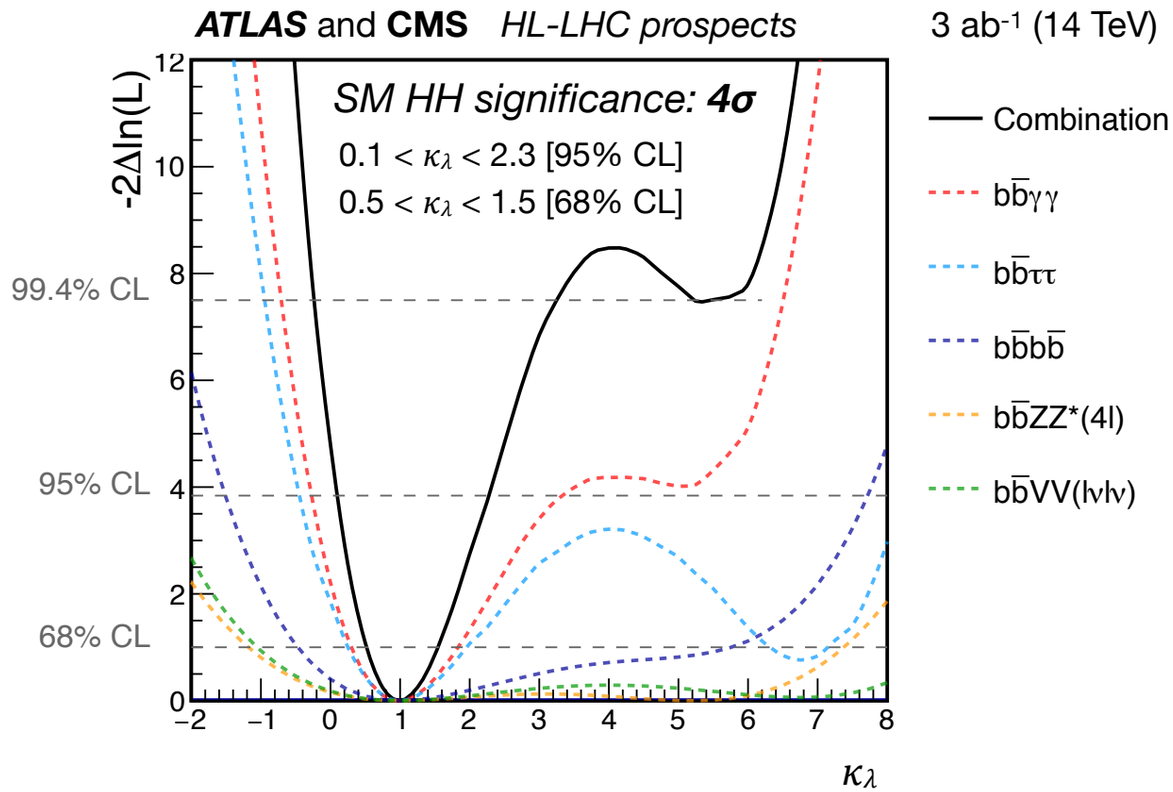
- **Physics Reach discussed in the 2018 Yellow Reports (SM, Higgs, BSM, Flavour, Heavy Ions), submitted to the European Strategy**
  - **I'll be showing some examples of the Higgs and BSM reach ahead, not aiming to discuss the full report**

Higgs @ HL-LHC



arxiv:1902.00134

- Precision on kappas of 2-4% can be reached for the non-statistically dominated modes
- Exploitation of the full dataset: differential cross sections as a key tool; rarer modes can be measured

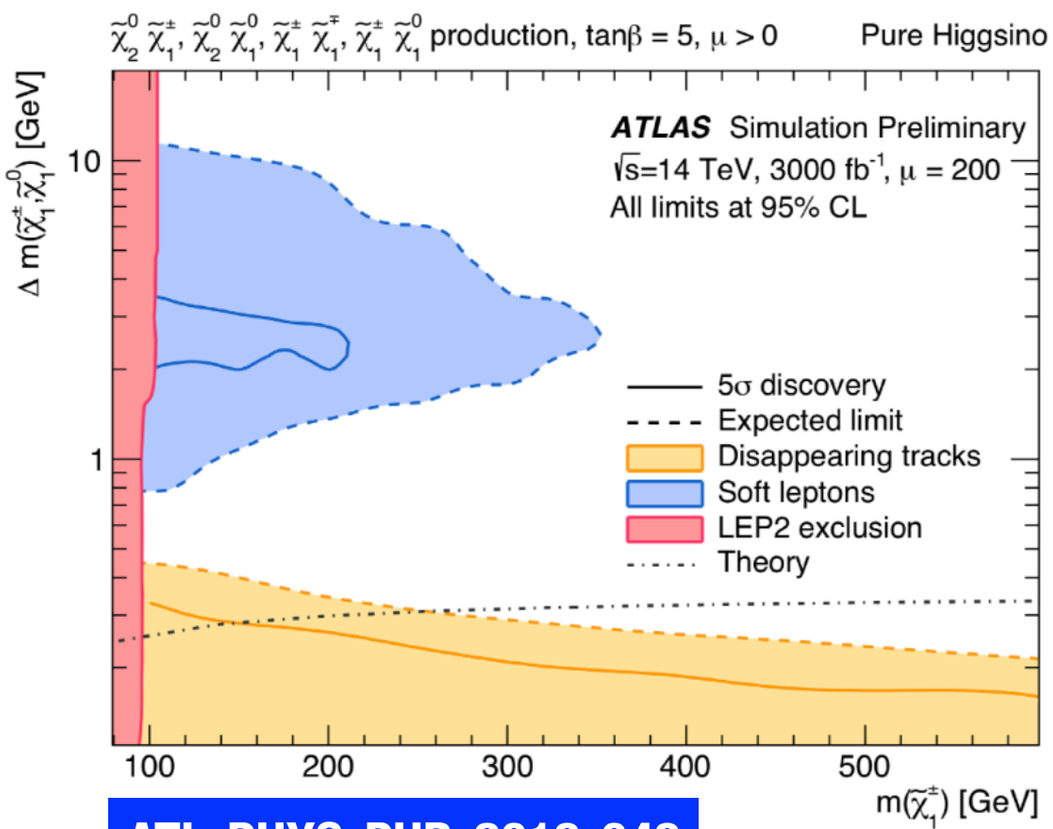


- 4 sigma on HH production, second minimum of the negative self-coupling log-likelihood excluded at 99.4% CL.

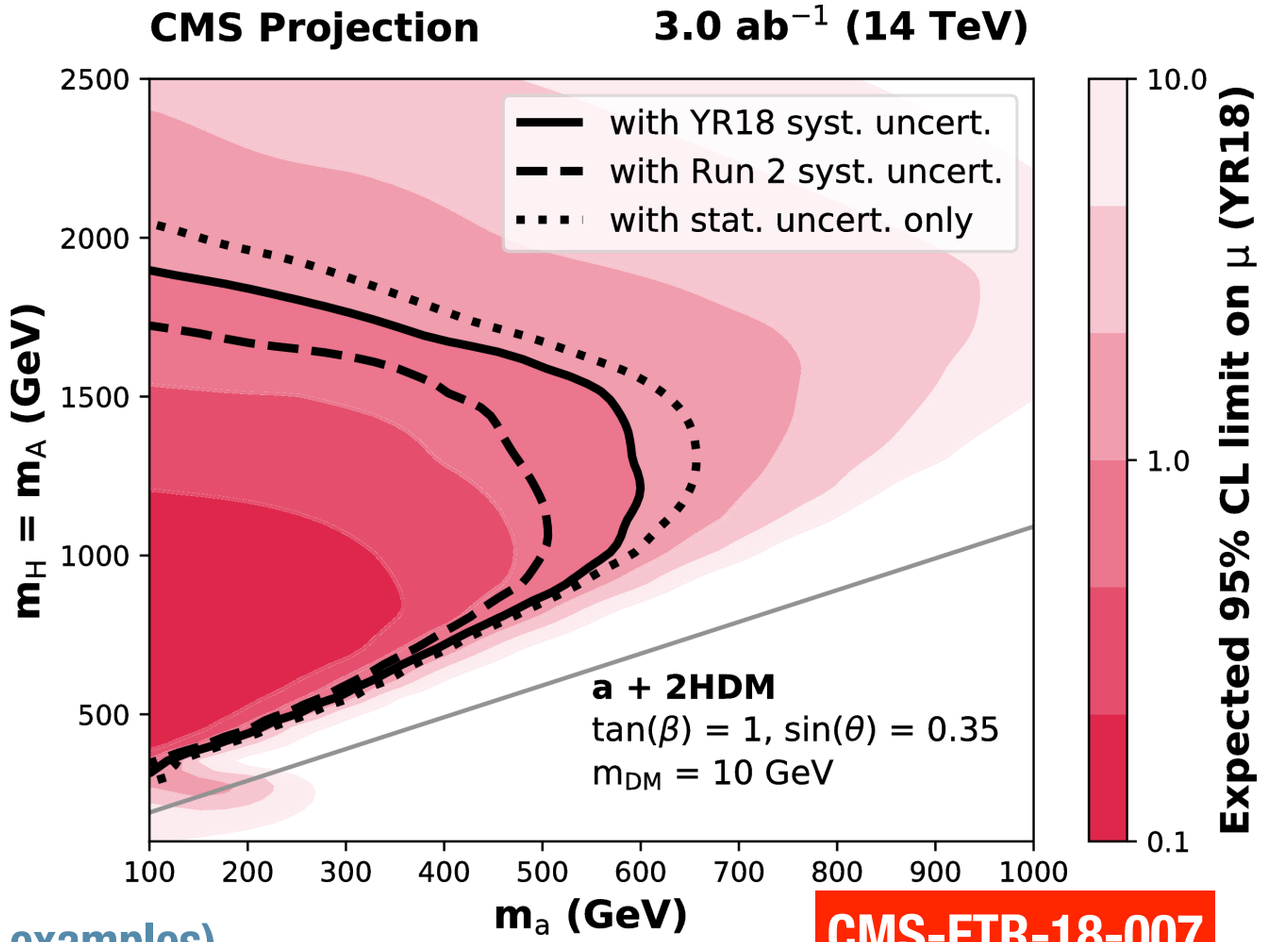
BSM @ HL/HE-LHC

Broaden the scope: looking for rare processes, weaker couplings, as model independently as possible. Exploit the detector upgrades to gain access to new corners of phase space.

Sensitivity to new physics with masses from 200 GeV to 8 TeV. For some channels, automatic gain (higher energy, lumi, better detector) - in some other channels developments and new techniques will be critical.



ATL-PHYS-PUB-2018-048



CMS-FTR-18-007

(Just two examples)

BSM @ HL/HE-LHC

HL/HE-LHC SUSY Searches

HL-LHC, $\int \mathcal{L}\,dt = 3\text{ab}^{-1}$: 5σ discovery (95% CL exclusion)
HE-LHC, $\int \mathcal{L}\,dt = 15\text{ab}^{-1}$: 5σ discovery (95% CL exclusion)

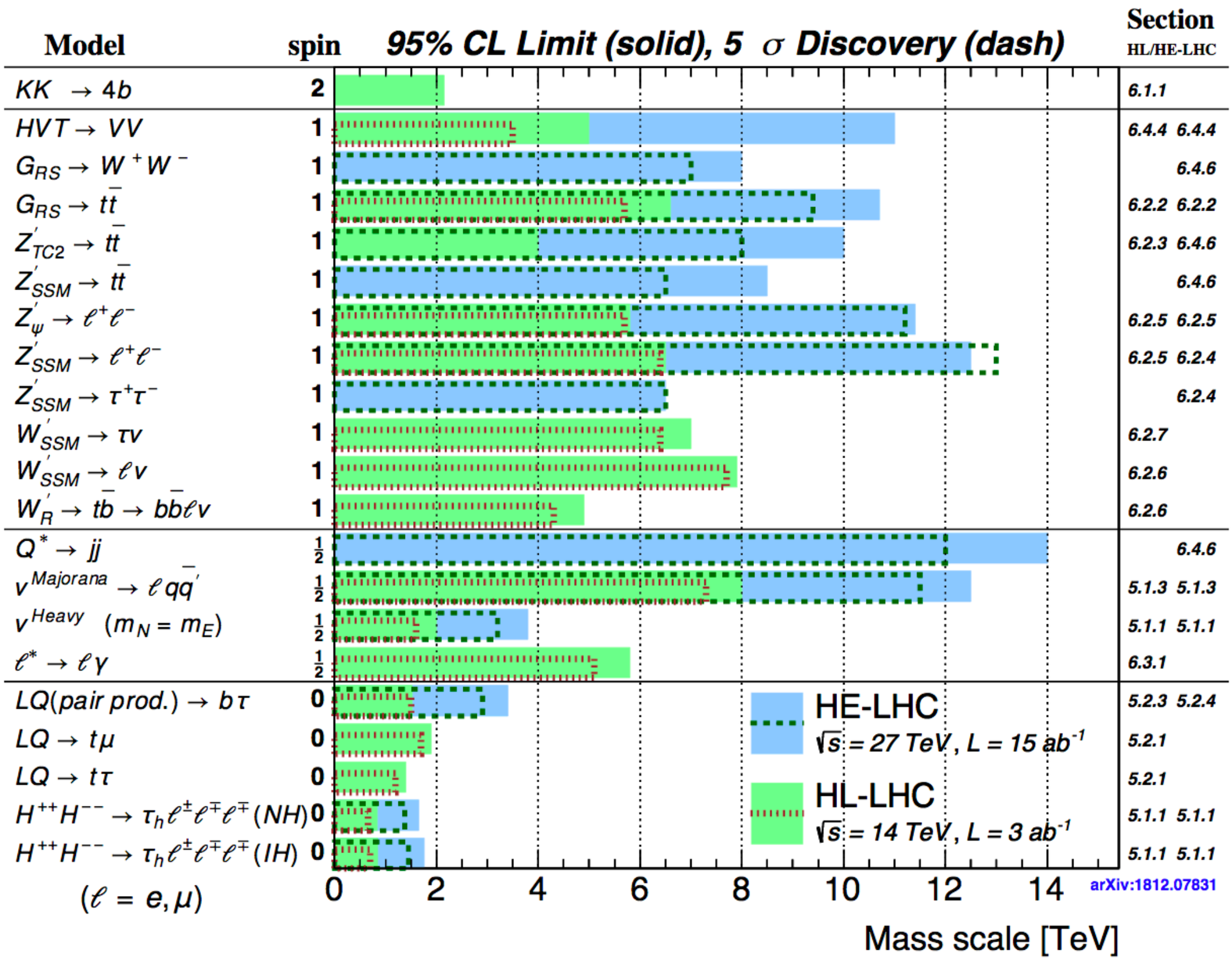
Simulation Preliminary
$\sqrt{s}$ = 14, 27 TeV

	Model	e, μ, τ, γ	Jets	Mass limit		Section
Gluino	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	4 jets	2.9 (3.2) TeV	$m(\tilde{\chi}_1^0)$=0	2.1.1
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	4 jets	5.2 (5.7) TeV	$m(\tilde{\chi}_1^0)$=0	2.1.1
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	Multiple	2.3 (2.5) TeV	$m(\tilde{\chi}_1^0)$=0	2.1.3
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{c}\tilde{\chi}_1^0$	0	Multiple	2.4 (2.6) TeV	$m(\tilde{\chi}_1^0)$=500 GeV	2.1.3
	NUHM2, $\tilde{g}\to t\bar{t}$	0	Multiple/2b	5.5 (5.9) TeV		2.4.2
Stop	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to t\tilde{\chi}_1^0$	0	Multiple/2b	1.4 (1.7) TeV	$m(\tilde{\chi}_1^0)$=0	2.1.2, 2.1.3
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to t\tilde{\chi}_1^0$	0	Multiple/2b	0.6 (0.85) TeV	$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0)\sim m(t)$	2.1.2
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}^{\pm}/t\tilde{\chi}_1^0, \tilde{\chi}_2^0$	0	Multiple/2b	3.16 (3.65) TeV		2.4.2
Chargino, neutralino	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^\pm\to W^\pm\tilde{\chi}_1^0$	2 e, μ	0-1 jets	0.66 (0.84) TeV	$m(\tilde{\chi}_1^0)$=0	2.2.1
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via WZ	3 e, μ	0-1 jets	0.92 (1.15) TeV	$m(\tilde{\chi}_1^0)$=0	2.2.2
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via Wh, $Wh\to\ell\nu b\bar{b}$	1 e, μ	2-3 jets/2b	1.08 (1.28) TeV	$m(\tilde{\chi}_1^0)$=0	2.2.3
	$\tilde{\chi}_2^\pm\tilde{\chi}_4^0\to W^\pm\tilde{\chi}_1^0 W^\pm\tilde{\chi}_1^\pm$	2 e, μ	-	0.9 TeV	$m(\tilde{\chi}_1^0)$=150, 250 GeV	2.2.4
Higgsino	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0 + \tilde{\chi}_2^0\tilde{\chi}_1^0, \tilde{\chi}_2^0\to Z\tilde{\chi}_1^0, \tilde{\chi}_1^\pm\to W\tilde{\chi}_1^0$	2 e, μ	1 jet	0.25 (0.36) TeV	$m(\tilde{\chi}_1^0)$=15 GeV	2.2.5.1
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0 + \tilde{\chi}_2^0\tilde{\chi}_1^0, \tilde{\chi}_2^0\to Z\tilde{\chi}_1^0, \tilde{\chi}_1^\pm\to W\tilde{\chi}_1^0$	2 e, μ	1 jet	0.42 (0.55) TeV	$m(\tilde{\chi}_1^0)$=15 GeV	2.2.5.1
	$\tilde{\chi}_2^0\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm\tilde{\chi}_1^\mp, \tilde{\chi}_1^\pm\tilde{\chi}_1^0$	2 μ	1 jet	0.21 (0.35) TeV	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$=5 GeV	2.2.5.2
Wino	$\tilde{\chi}_2^\pm\tilde{\chi}_4^0$ via same-sign WW	2 e, μ	0	0.86 (1.08) TeV		2.4.2
Stau	$\tilde{\tau}_{L,R}\tilde{\tau}_{L,R}, \tilde{\tau}\to\tau\tilde{\chi}_1^0$	2 τ	-	0.53 (0.73) TeV	$m(\tilde{\chi}_1^0)$=0	2.3.1
	$\tilde{\tau}\tilde{\tau}$	2τ, $\tau(e, \mu)$	-	0.47 (0.65) TeV	$m(\tilde{\chi}_1^0)$=0, $m(\tilde{\tau}_L)$=$m(\tilde{\tau}_R)$	2.3.2
	$\tilde{\tau}\tilde{\tau}$	2τ, $\tau(e, \mu)$	-	0.81 (1.15) TeV	$m(\tilde{\chi}_1^0)$=0, $m(\tilde{\tau}_L)$=$m(\tilde{\tau}_R)$	2.3.4
Long-lived particles	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp, \tilde{\chi}_1^\pm\tilde{\chi}_1^0$, long-lived $\tilde{\chi}_1^\pm$	Disapp. trk.	1 jet	0.8 (1.1) TeV	Wino-like $\tilde{\chi}_1^\pm$	4.1.1
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp, \tilde{\chi}_1^\pm\tilde{\chi}_1^0$, long-lived $\tilde{\chi}_1^\pm$	Disapp. trk.	1 jet	0.6 (0.75) TeV	Higgsino-like $\tilde{\chi}_1^\pm$	4.1.1
	MSSM, Electroweak DM	Disapp. trk.	1 jet	0.88 (0.9) TeV	Wino-like DM	4.1.3
	MSSM, Electroweak DM	Disapp. trk.	1 jet	2.0 (2.1) TeV	Wino-like DM	4.1.3
	MSSM, Electroweak DM	Disapp. trk.	1 jet	0.28 (0.3) TeV	Higgsino-like DM	4.1.3
	MSSM, Electroweak DM	Disapp. trk.	1 jet	0.55 (0.6) TeV	Higgsino-like DM	4.1.3
	$\tilde{g}$ R-hadron, $\tilde{g}\to qq\tilde{\chi}_1^0$	0	Multiple	3.4 TeV	$m(\tilde{\chi}_1^0)$=100 GeV	4.2.1
	$\tilde{g}$ R-hadron, $\tilde{g}\to qq\tilde{\chi}_1^0$	0	Multiple	2.8 TeV		4.2.1
	GMSB $\tilde{\mu}\to\mu\tilde{G}$	displ. μ	-	0.2 TeV	$c\tau$ =1000 mm	4.2.2

10^{-1} 1 **Mass scale [TeV]**

arXiv:1812.07831

BSM @ HL/HE-LHC


Model
spin
95% CL Limit (solid), 5 σ Discovery (dash)
Section HL/HE-LHC
KK → 4b 2 6.1.1
HVT → VV 1 6.4.4 6.4.4
G_RS → W+W− 1 6.4.6
G_RS → tt̄ 1 6.2.2 6.2.2
Z'_TC2 → tt̄ 1 6.2.3 6.4.6
Z'_SSM → tt̄ 1 6.4.6
Z'_ψ → ℓ+ℓ− 1 6.2.5 6.2.5
Z'_SSM → ℓ+ℓ− 1 6.2.5 6.2.4
Z'_SSM → τ+τ− 1 6.2.4
W'_SSM → τν 1 6.2.7
W'_SSM → ℓν 1 6.2.6
W'_R → tb̄ → bb̄ℓν 1 6.2.6
Q* → jj 1/2 6.4.6
ν Majorana → ℓqq̄' 1/2 5.1.3 5.1.3
ν Heavy (m_N = m_E) 1/2 5.1.1 5.1.1
ℓ* → ℓγ 1/2 6.3.1
LQ(pair prod.) → bτ 0 5.2.3 5.2.4
LQ → tμ 0 5.2.1
LQ → tτ 0 5.2.1
H++H−− → τhℓ±ℓ∓ℓ∓(NH) 0 5.1.1 5.1.1
H++H−− → τhℓ±ℓ∓ℓ∓(IH) 0 5.1.1 5.1.1
(ℓ = e, μ)
HE-LHC
√s = 27 TeV, L = 15 ab-1
HL-LHC
√s = 14 TeV, L = 3 ab-1
0 2 4 6 8 10 12 14
Mass scale [TeV]
arXiv:1812.07831

Conclusions

- The very successful LHC Run2 has just ended - leaving CMS and ATLAS with ~150fb^{-1} of data to exploit

- The collaborations are working hard to broaden their already wide physics programs: from SM measurements, including studying the properties and kinematics of top quarks and Higgs bosons, to hunting down new physics in every possible manifestation in a collider

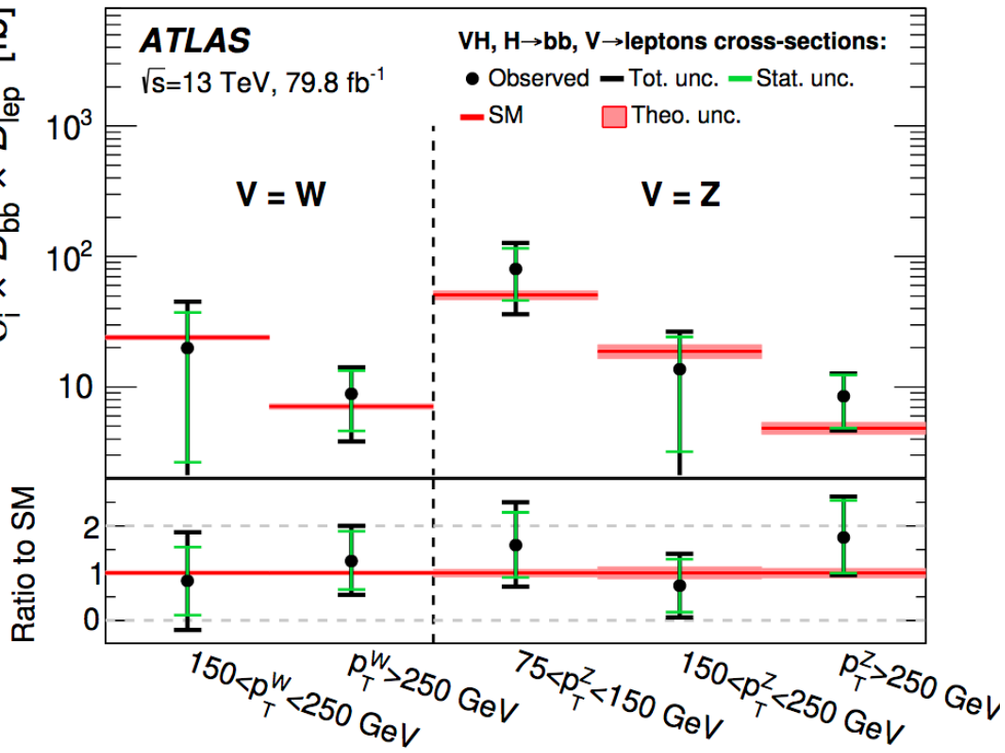
- At the same time, getting ready for the challenges ahead: Run3 and the HL-LHC

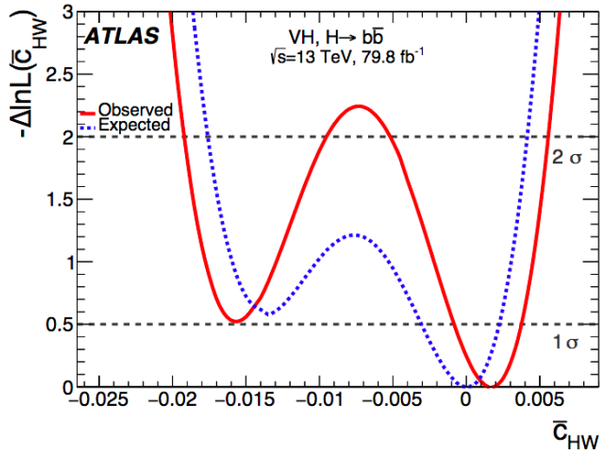
- YellowReport 2018: five documents exploring the physics potential of the HL/HE-LHC- exciting path ahead!

BACKUP

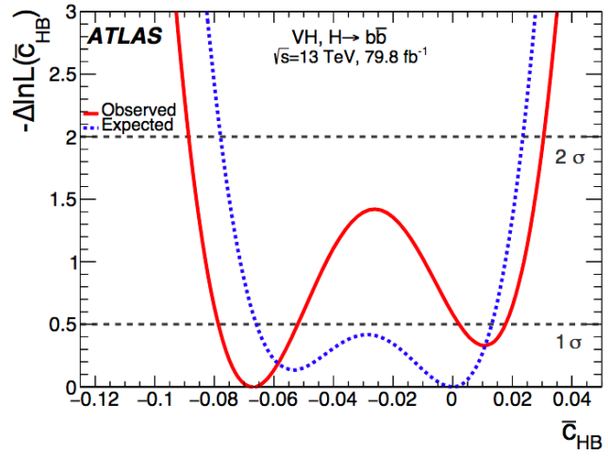
STXS Indirect Constraints

arxiv:1903.04618

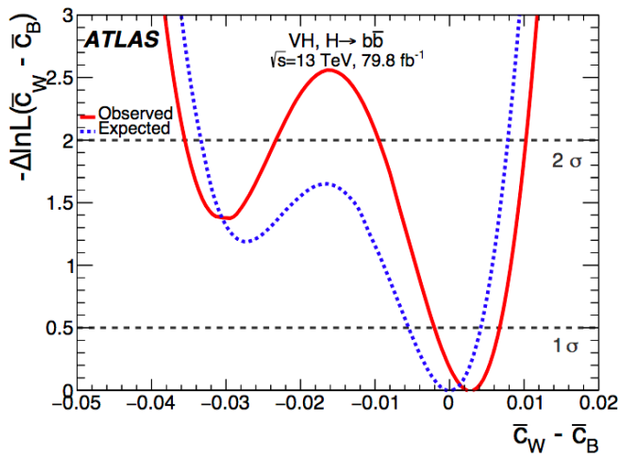




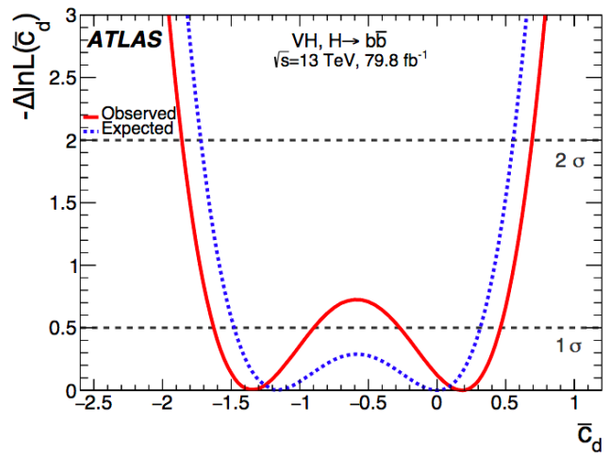
(a)



(b)



(c)

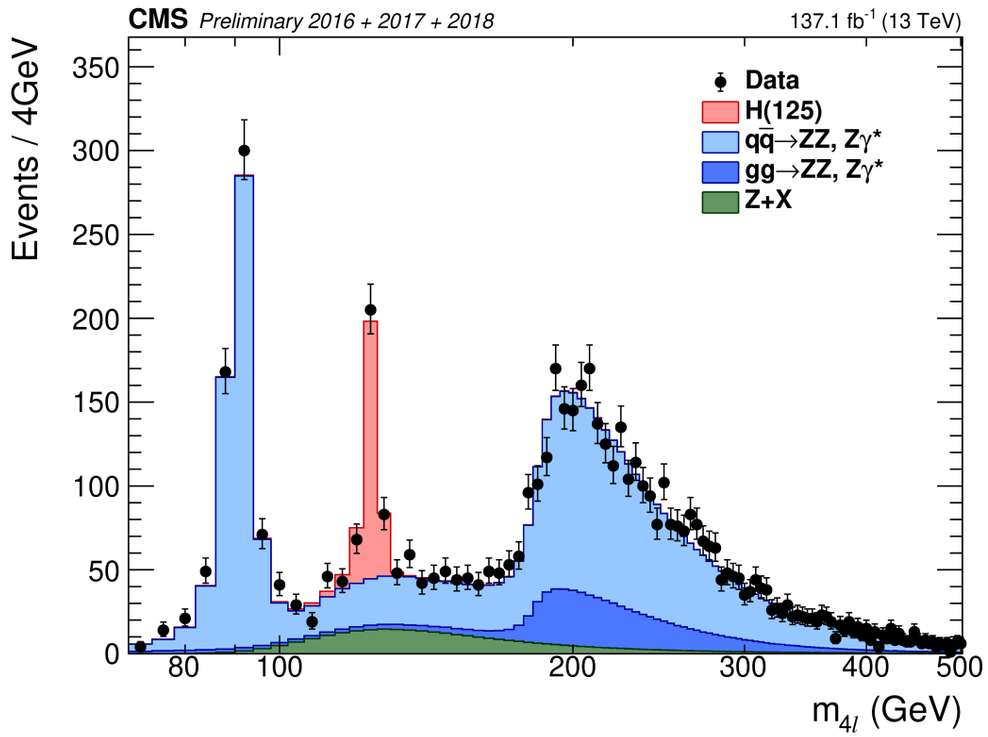


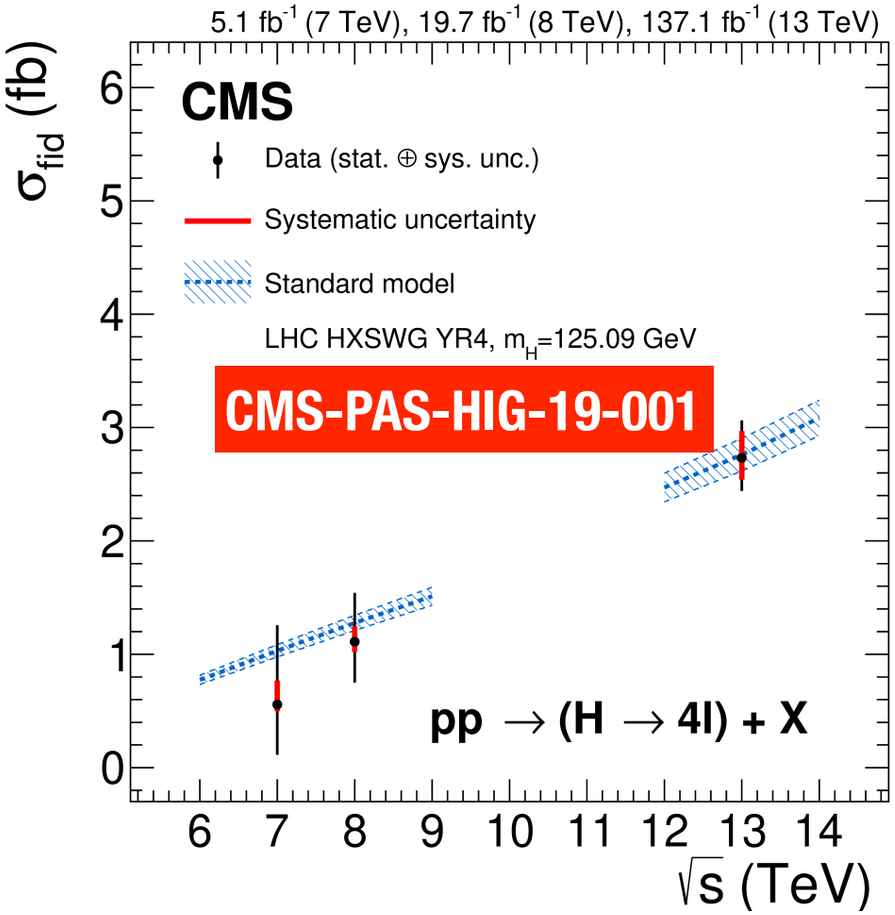
(d)

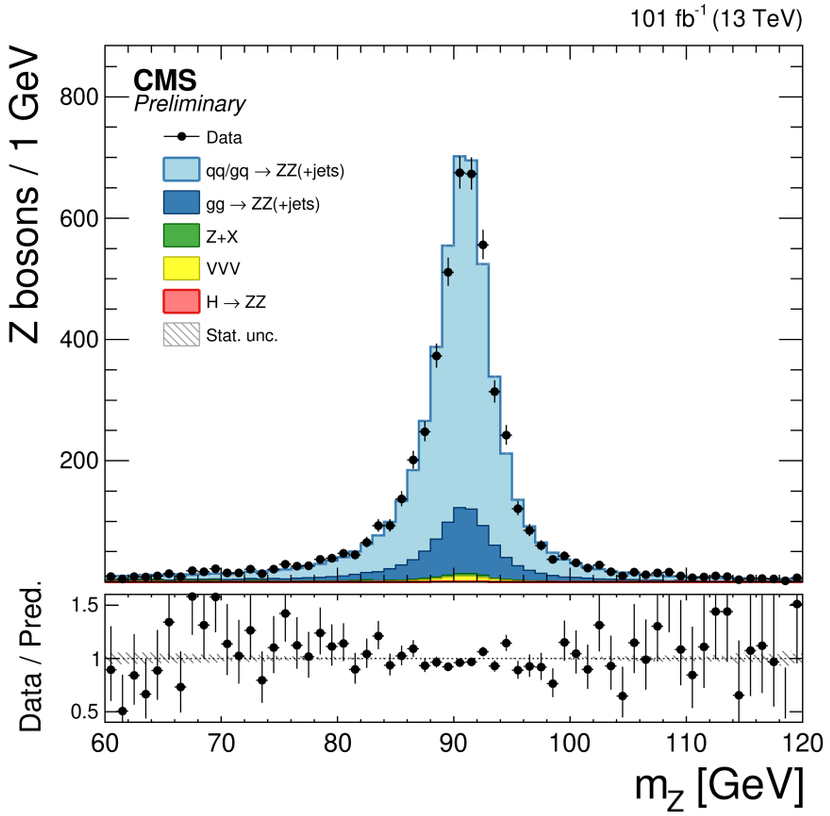
$$\bar{c}_{HW} = \frac{m_W^2}{g}\frac{c_{HW}}{\Lambda^2}, \quad \bar{c}_{HB} = \frac{m_W^2}{g'}\frac{c_{HB}}{\Lambda^2},$$

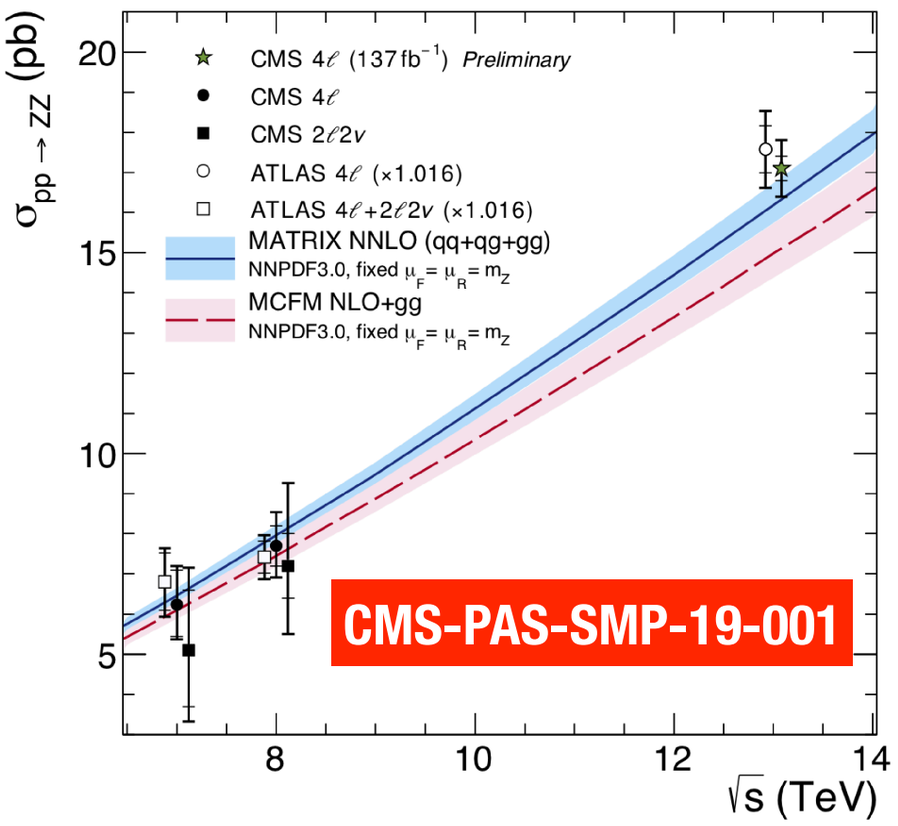
$$\bar{c}_W = \frac{m_W^2}{g}\frac{c_W}{\Lambda^2}, \quad \bar{c}_B = \frac{m_W^2}{g'}\frac{c_B}{\Lambda^2}, \quad \bar{c}_d = v^2\frac{c_d}{\Lambda^2},$$

HZZ and ZZ


CMS Preliminary 2016 + 2017 + 2018
137.1 fb-1 (13 TeV)
Data
H(125)
qq̄→ZZ, Zγ*
gg→ZZ, Zγ*
Z+X
Events / 4GeV
m4l (GeV)

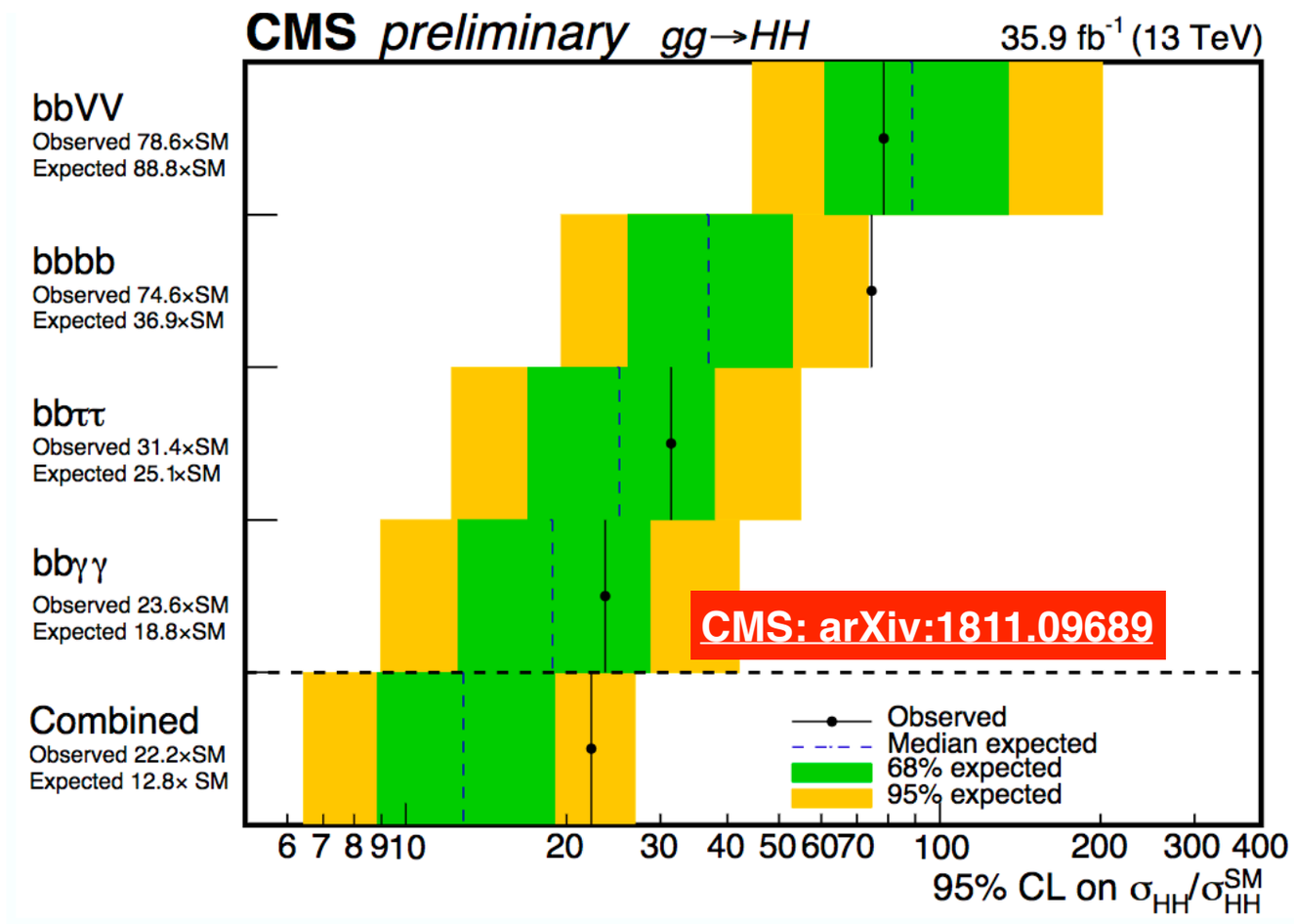

5.1 fb-1 (7 TeV), 19.7 fb-1 (8 TeV), 137.1 fb-1 (13 TeV)
CMS
Data (stat. ⊕ sys. unc.)
Systematic uncertainty
Standard model
LHC HXSWG YR4, mH=125.09 GeV
CMS-PAS-HIG-19-001
pp → (H → 4l) + X
σfid (fb)
√s (TeV)

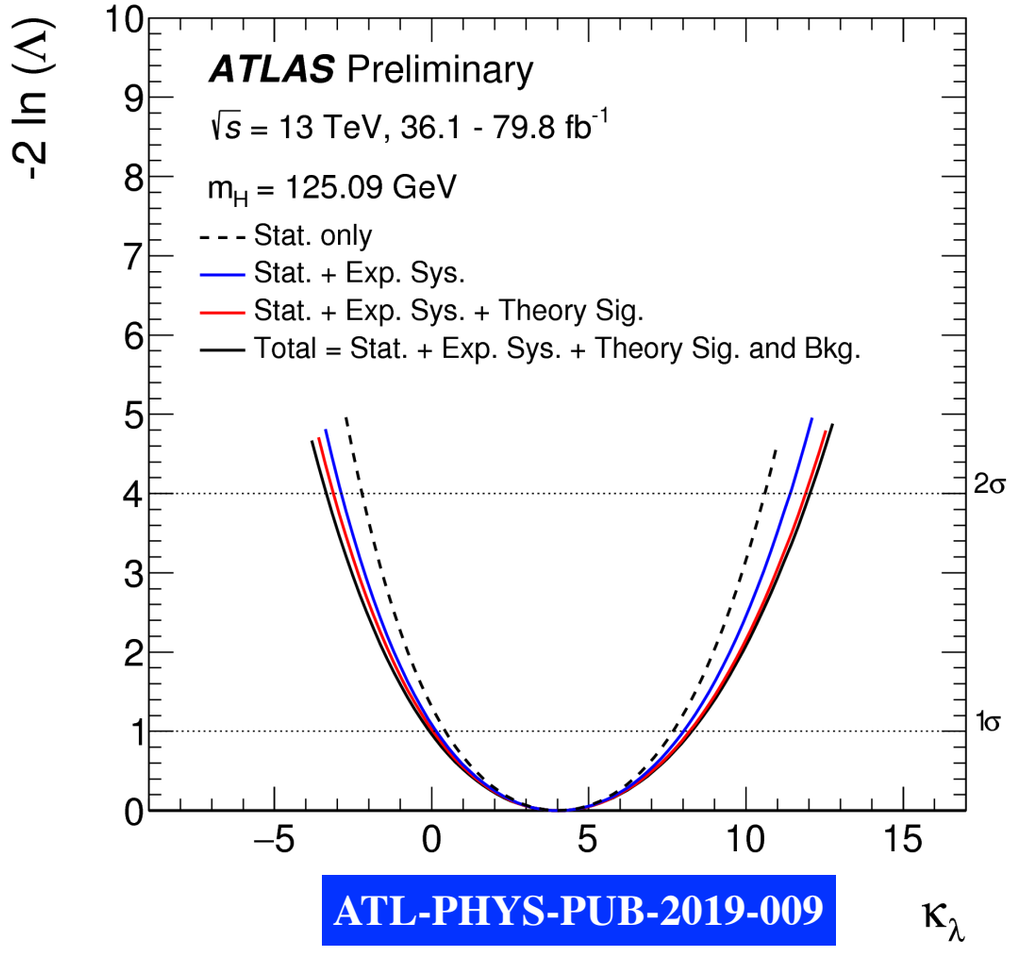

101 fb-1 (13 TeV)
CMS
Preliminary
Data
qq/gq → ZZ(+jets)
gg → ZZ(+jets)
Z+X
VVV
H → ZZ
Stat. unc.
Z bosons / 1 GeV
Data / Pred.
mZ [GeV]


CMS 4ℓ (137 fb-1) Preliminary
CMS 4ℓ
CMS 2ℓ2ν
ATLAS 4ℓ (×1.016)
ATLAS 4ℓ+2ℓ2ν (×1.016)
MATRIX NNLO (qq+qg+gg)
NNPDF3.0, fixed μF = μR = mZ
MCFM NLO+gg
NNPDF3.0, fixed μF = μR = mZ
CMS-PAS-SMP-19-001
σpp → ZZ (pb)
√s (TeV)

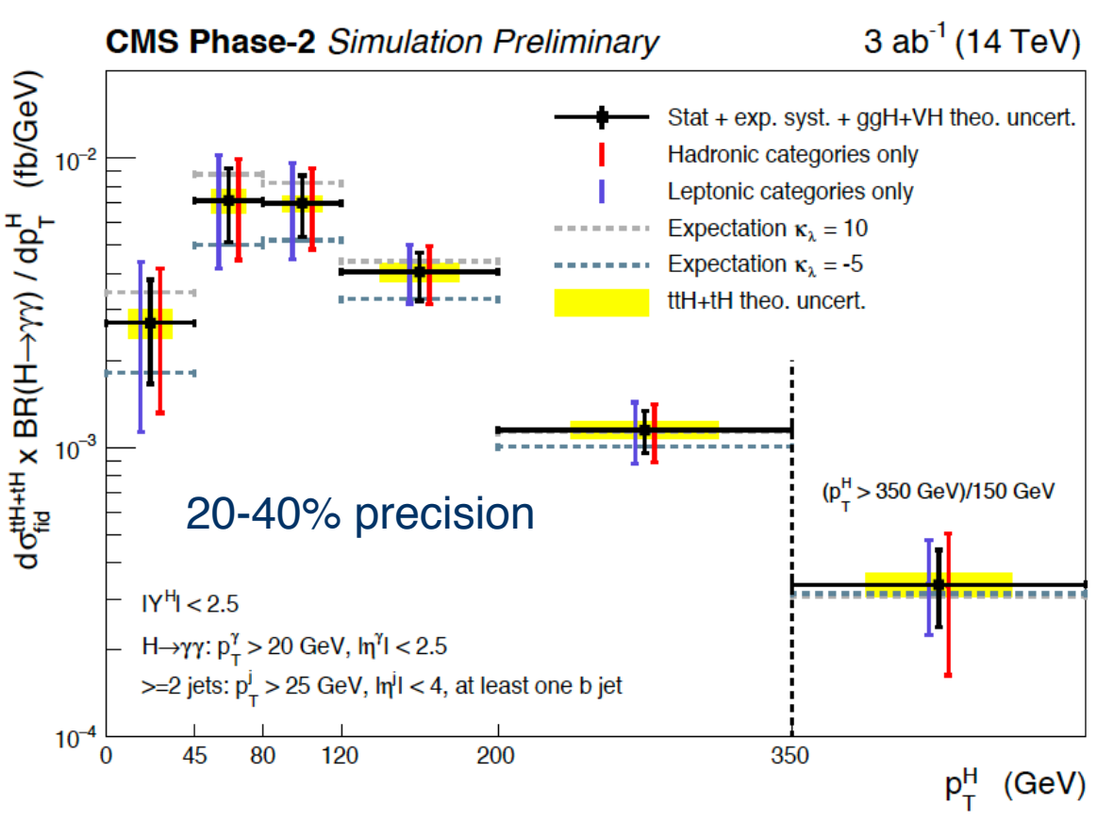
Sensitivity to the Higgs Self Coupling

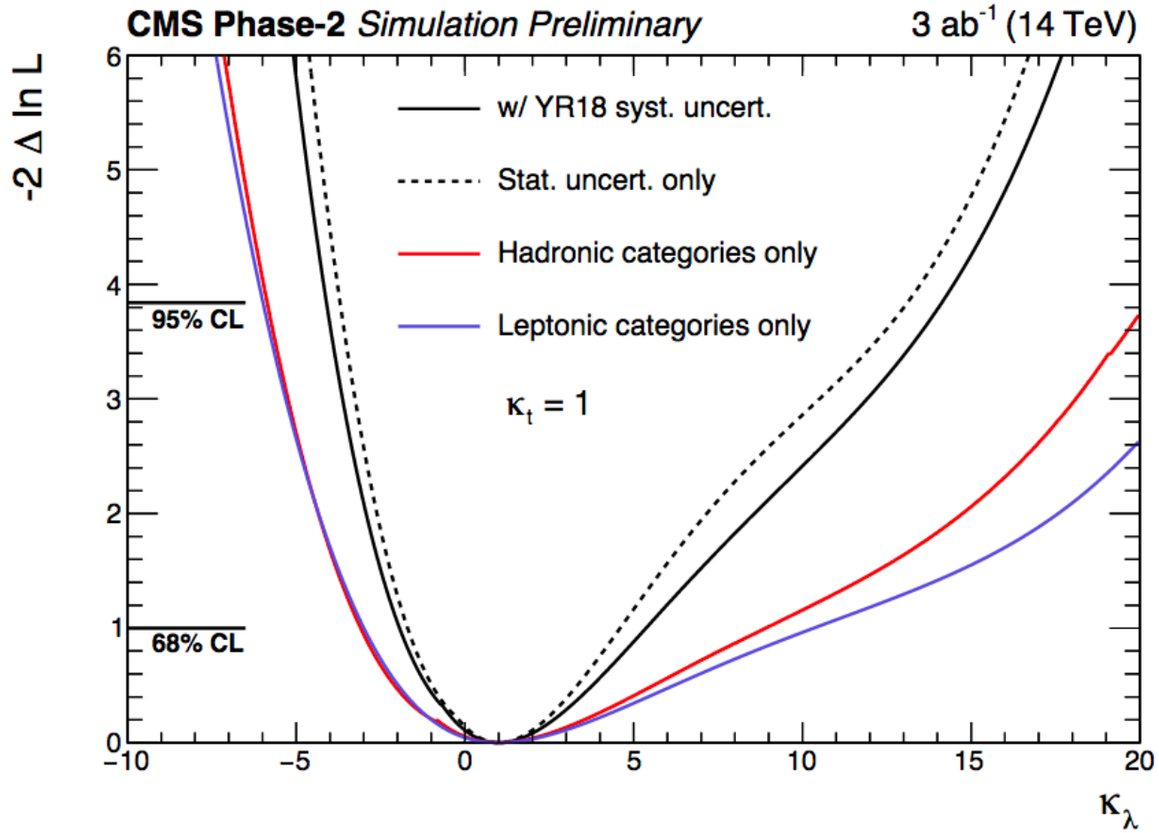
- **HH production: σ~ 31 fb@13TeV**
  - Very low cross section: destructive interference between triangle and box
  - Sensitive to BSM physics : Small changes of the couplings can lead to large changes in production
  - Driven by bbgammagamma and bbtautau : Currently ~10 times the SM cross section (2016 data)
- Alternative approach: Indirect constraints on Higgs self coupling from single Higgs





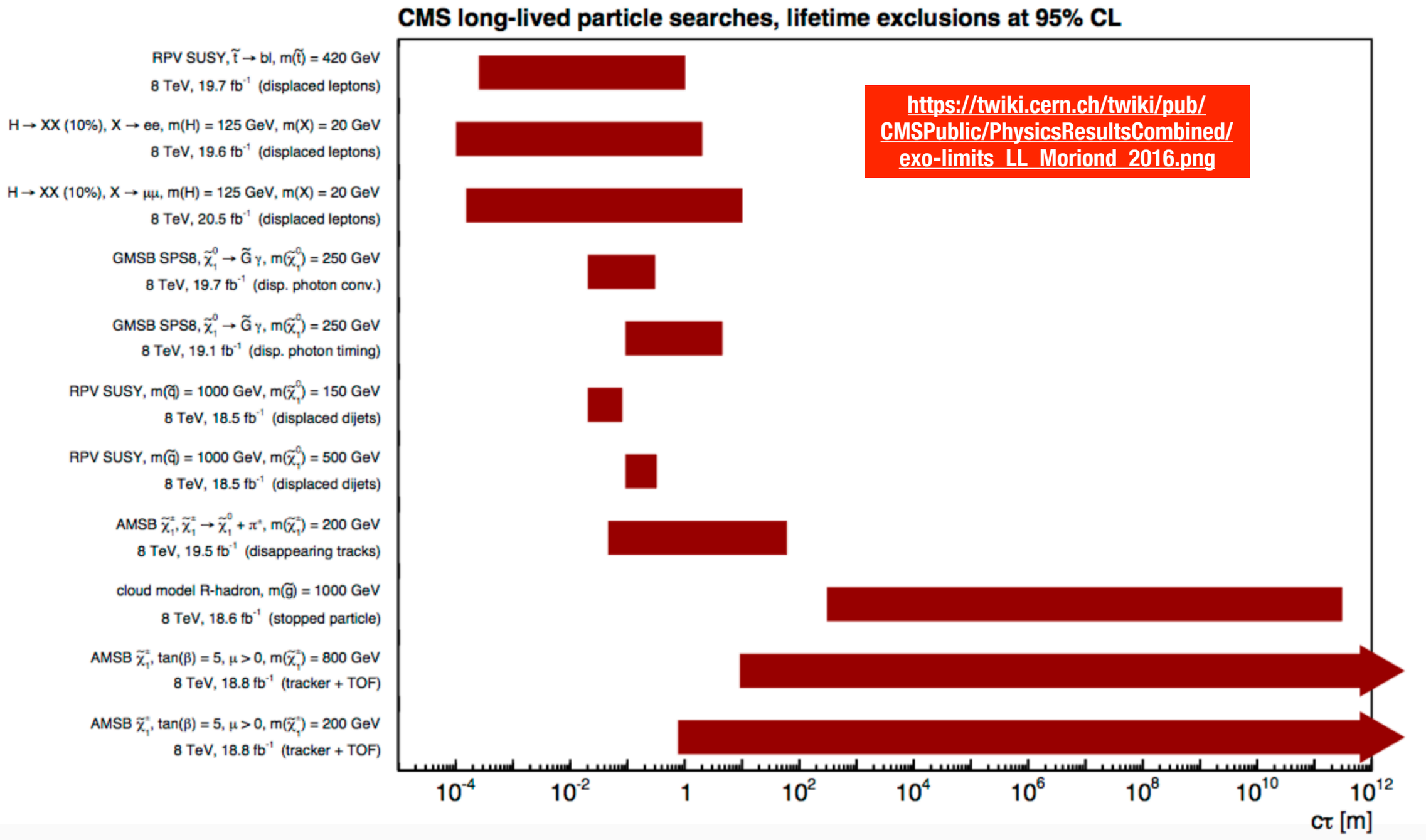
HL-LHC: SelfCoupling constraint from ttH Hgg





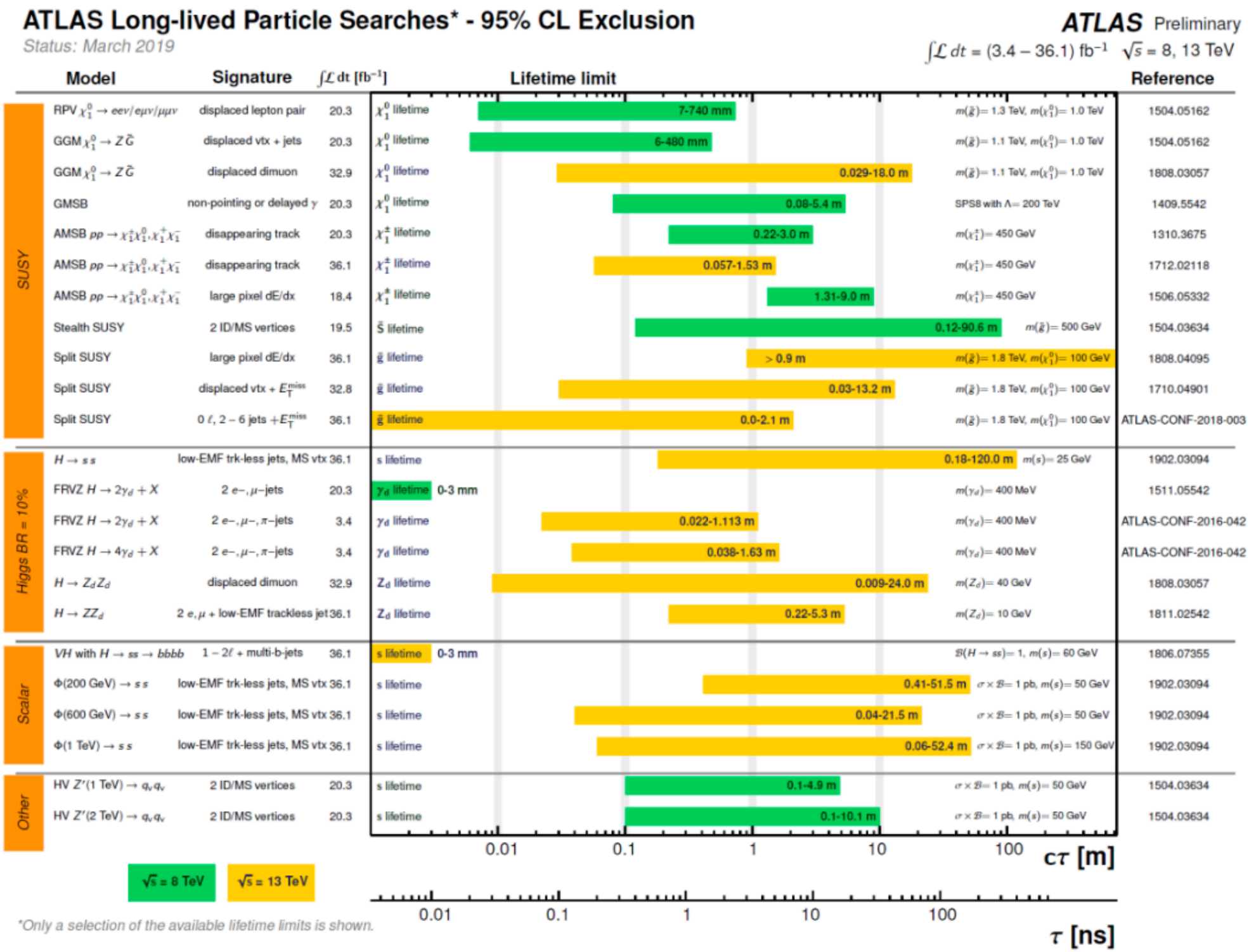
CMS: FTR-18-020

Long Lived Summaries

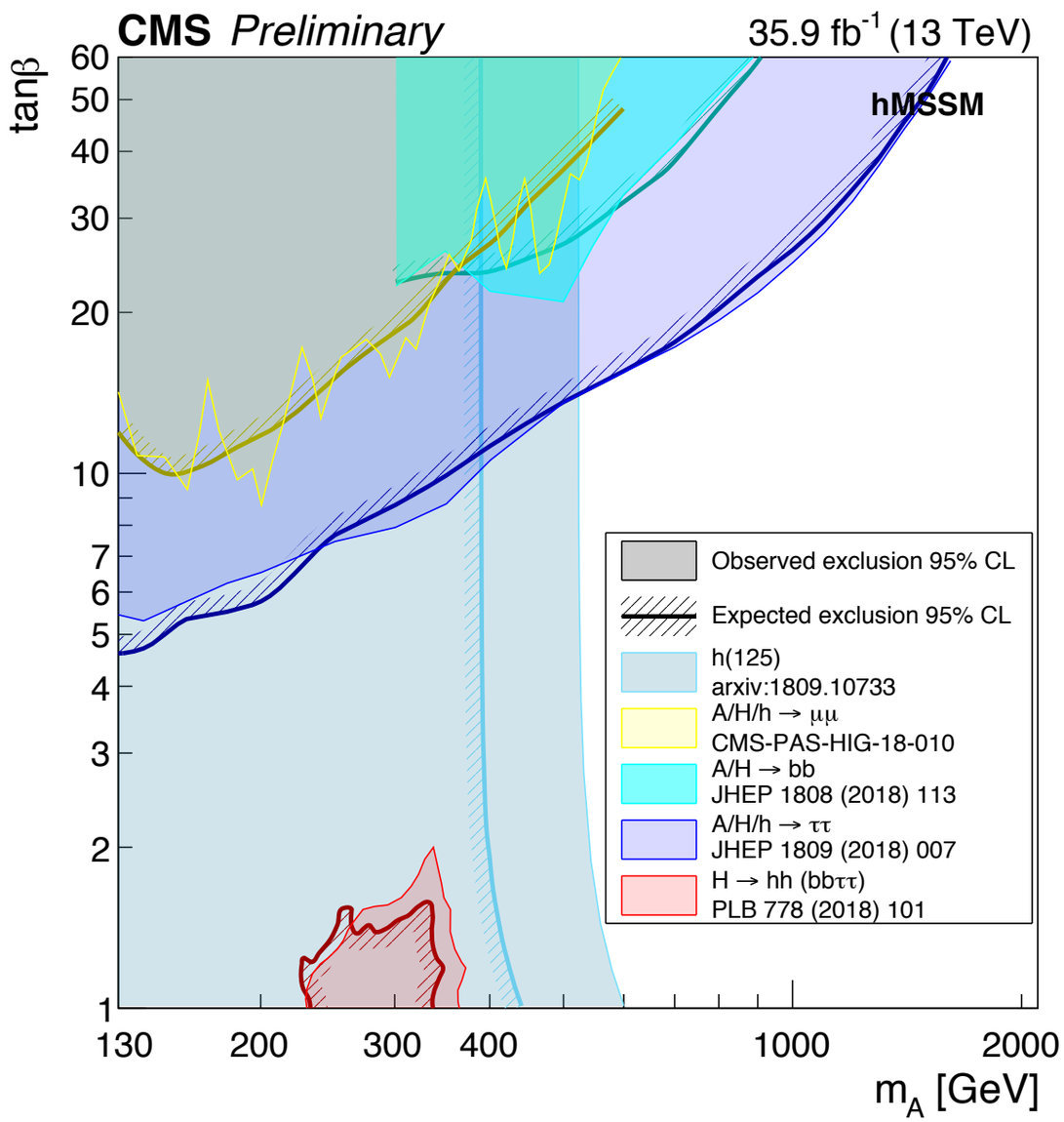


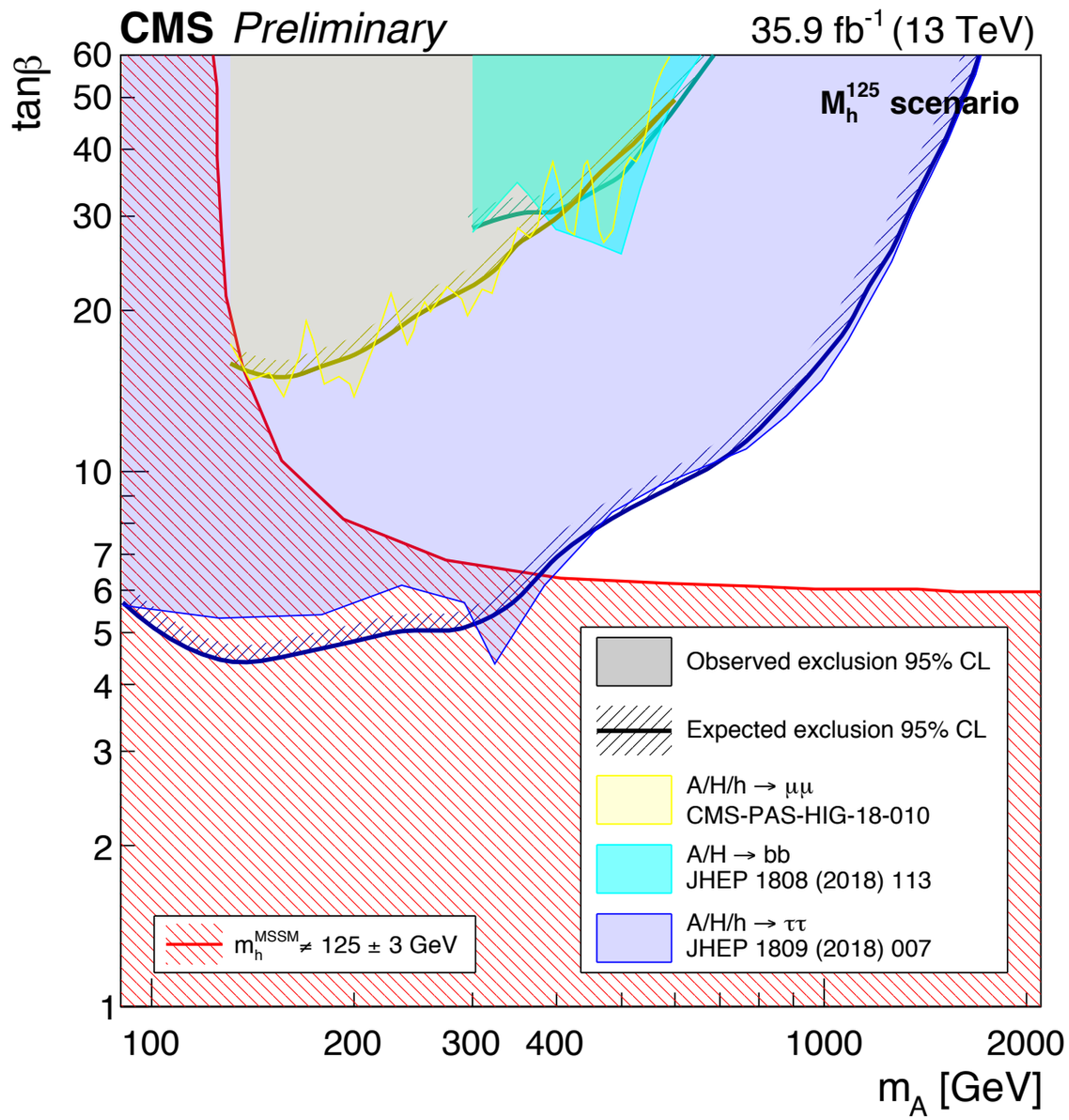
https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsCombined/exo-limits_LL_Moriond_2016.png

Long Lived Summaries



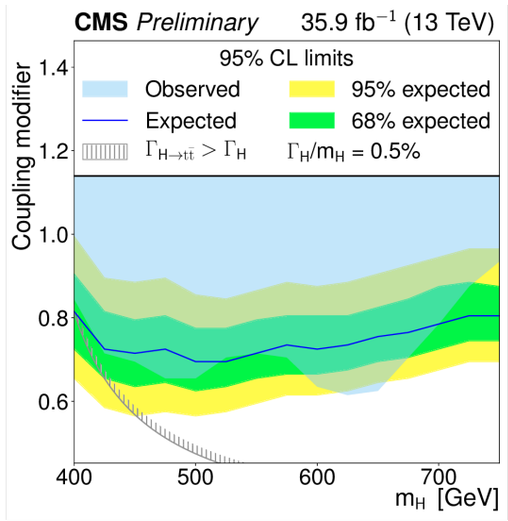
Exploring the Higgs Sector

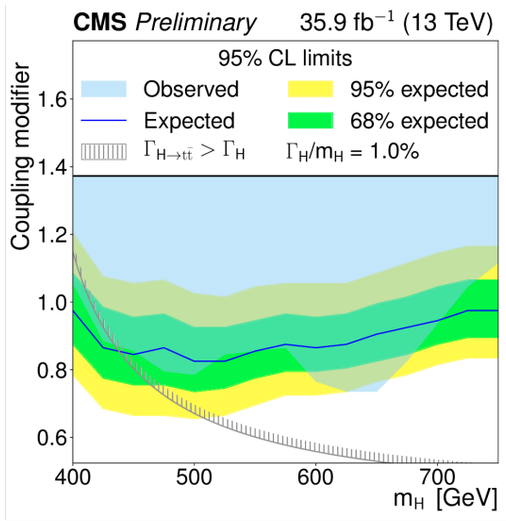


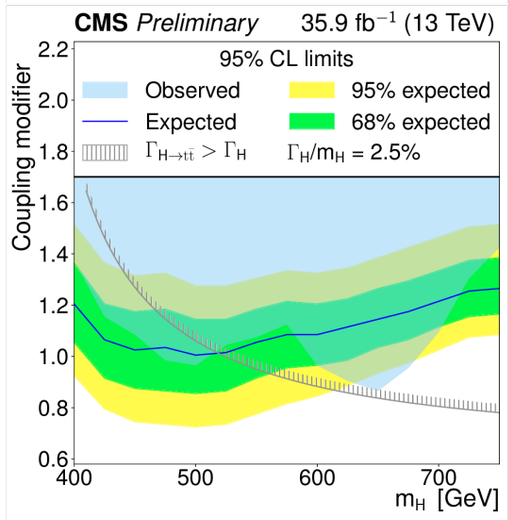


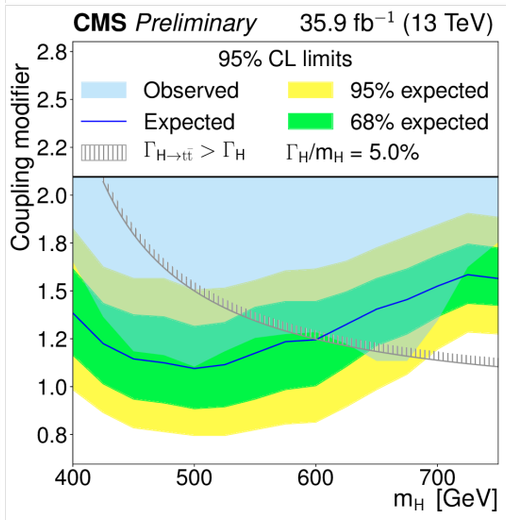
CMS Summary plots

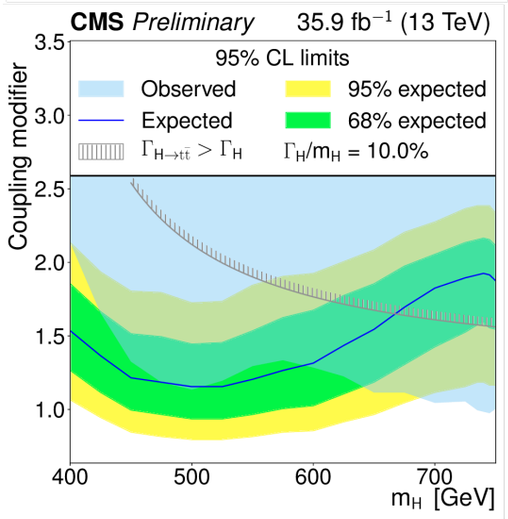
Heavy H/A->ttbar

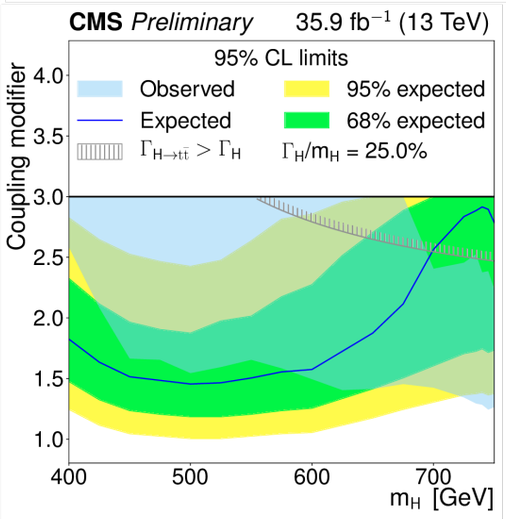


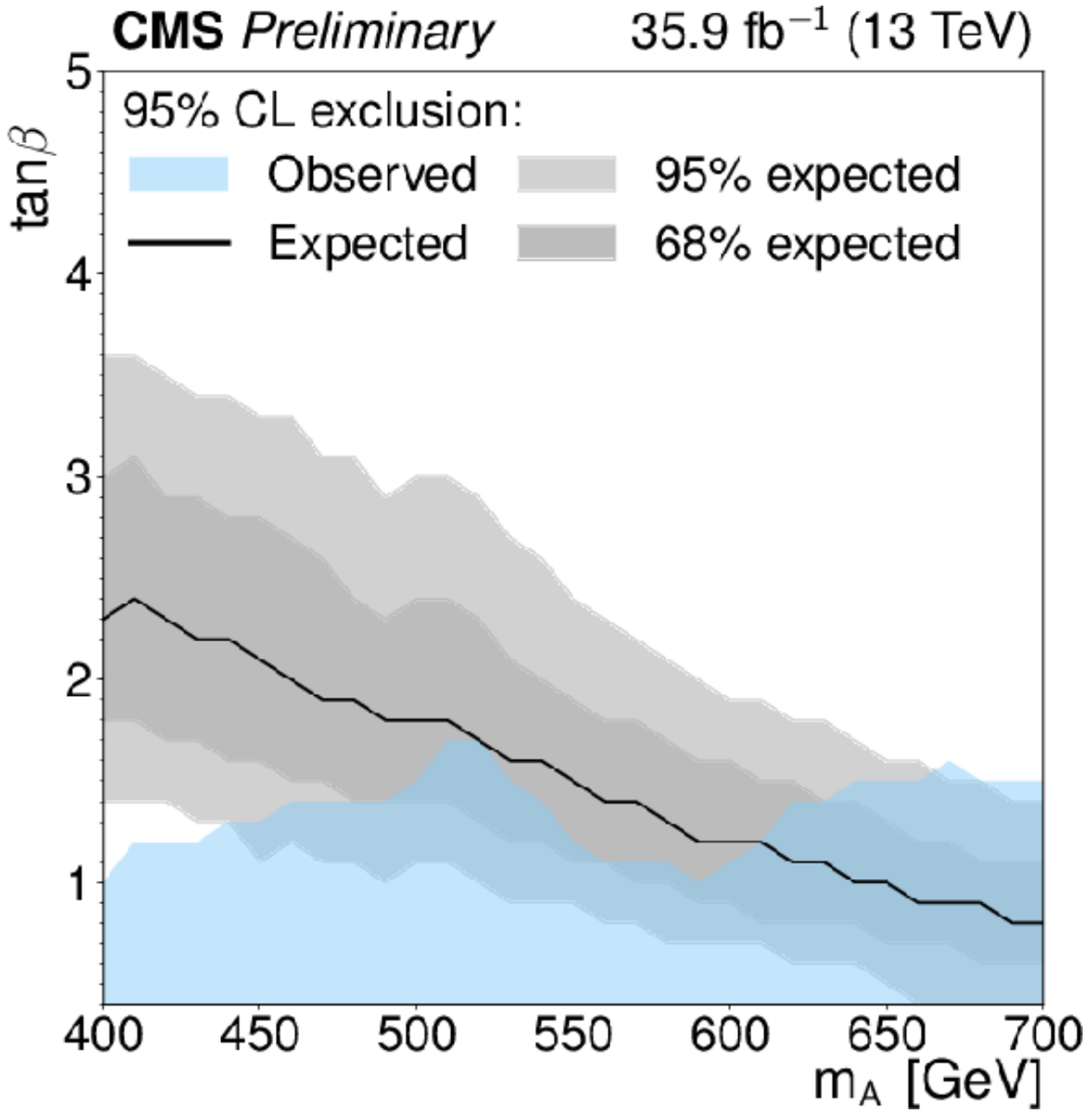








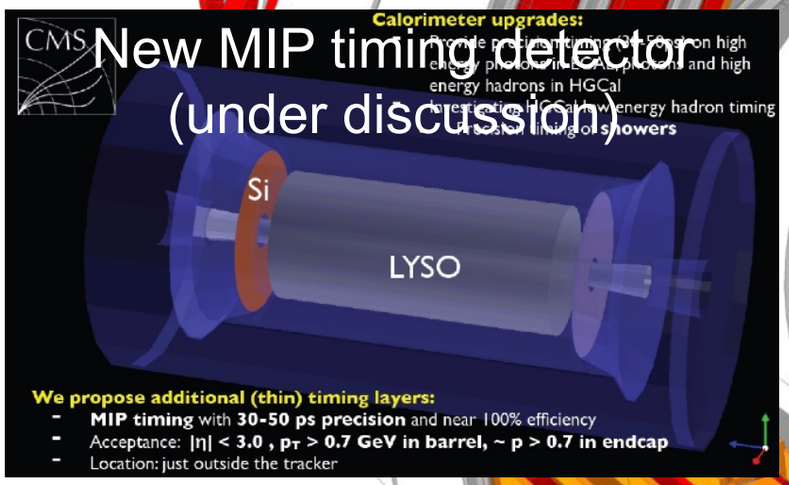




MUON SYSTEMS
- New DT/CSC BE/FE electronics
- GEM/RPC coverage in 1.5<|η|<2.4
- Muon-tagging in 2.4|η|<3.0

BARREL CALORIMETERS
- New BE/FE electronics
- ECAL: lower temperature
- HCAL: partially new scintillator

ENDCAP CALORIMETERS
- high granularity calorimeter
- Radiation tolerant scintillator
- 3D capability and timing



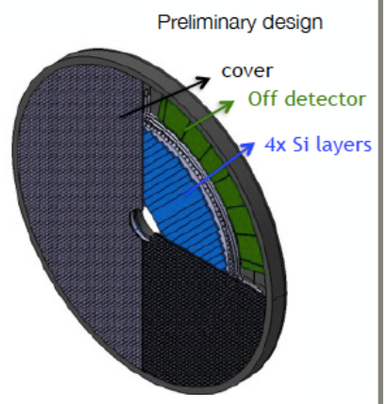
TRACKER
- radiation tolerant, high granularity, low material budget
- coverage up to |η|=3.8
- track trigger at l1

TRIGGER & DAQ
- Track-trigger @L1
- L1 rate ~750kHz
- HLT output ~7.5kHz

(* slide stolen from P. Azzi)

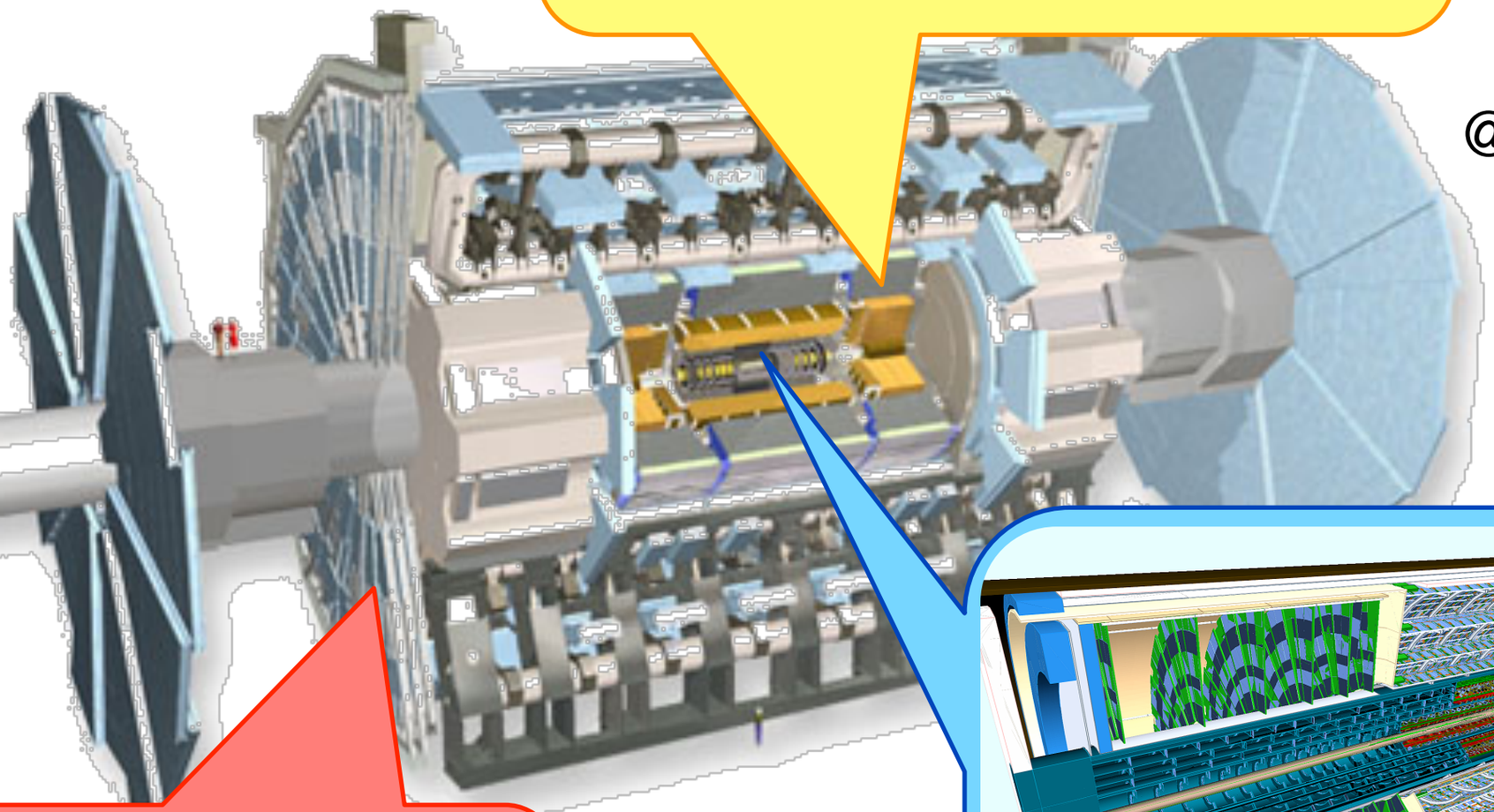
Trigger and DAQ
- L0 (Calo+μ): 1 MHz
- L1 (Calo+μ+Itk): 400 kHz
- HLT: 10 kHz

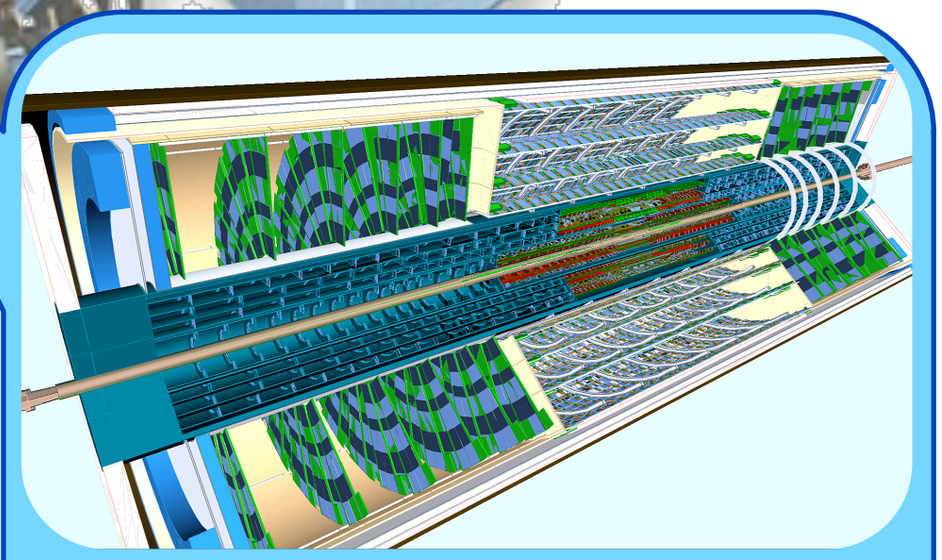
Calorimeters
- New readout electronics compatible with L0 1 MHz rate
- High granularity timing detector (under discussion)



HGTD

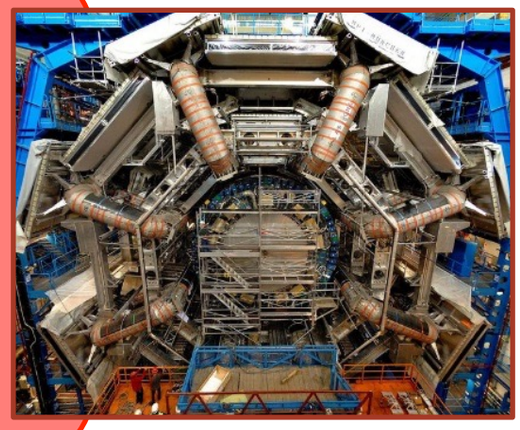
@z~3500mm





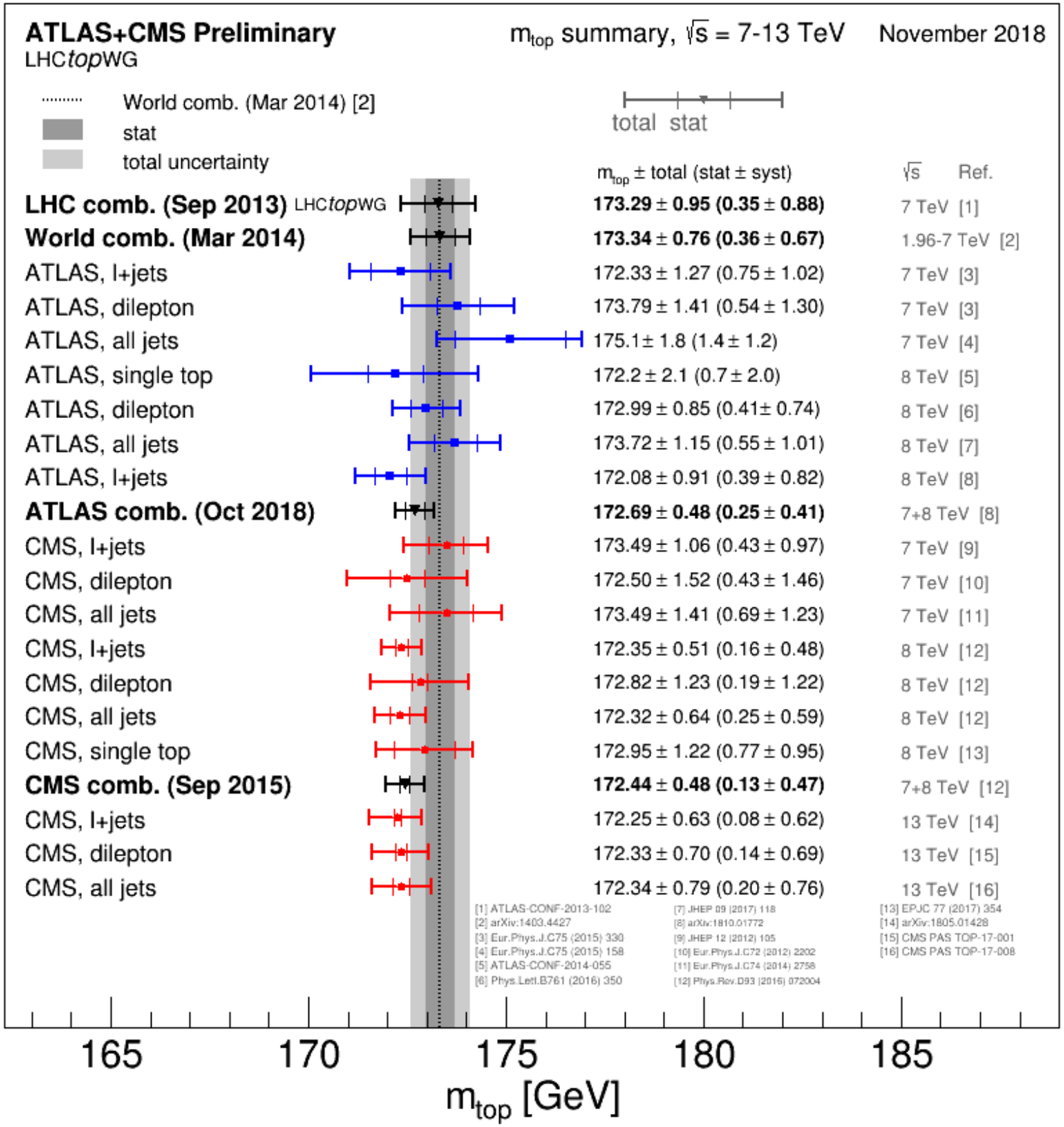
All-silicon tracking detector
5 pixel+4 strip layers to |η|<4

Muon systems
- New readout and trigger electronics
- Additional chambers for inner barrel layer improves acceptance
- Muon tagger for 2.7<|η|<4.0



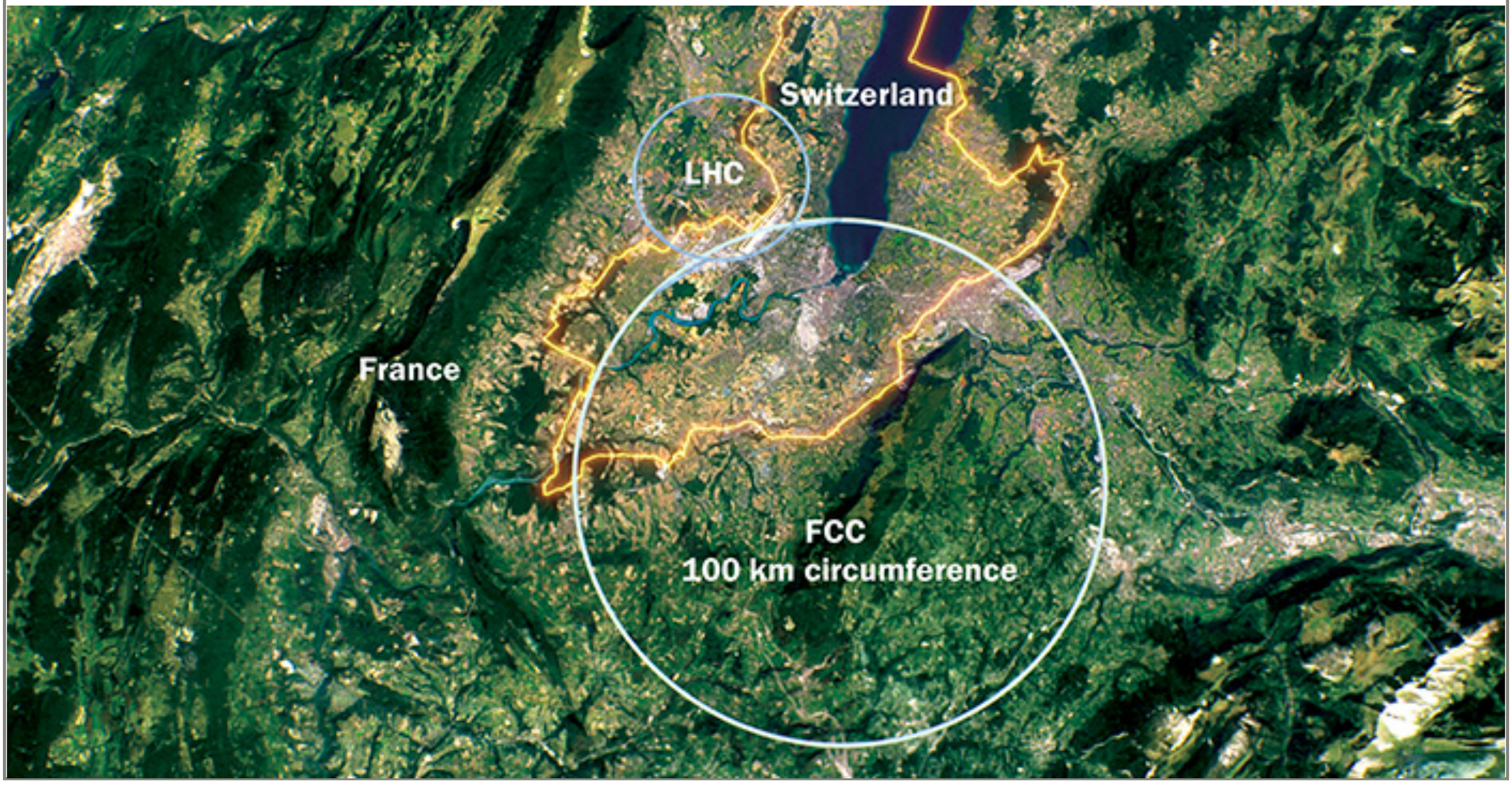
(* slide stolen from P. Azzi)

Exploiting the Top Factory



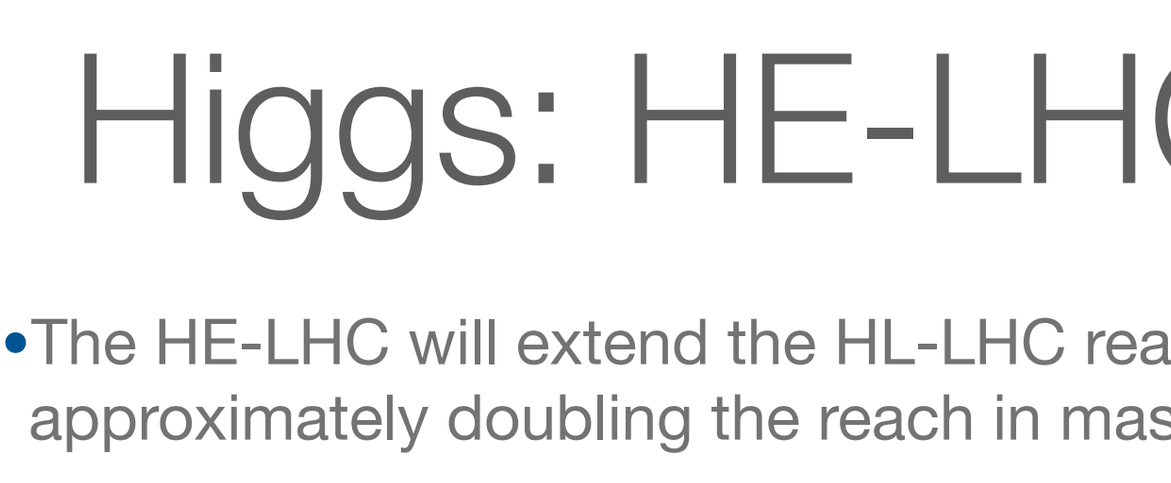
FCC

https://fcc-cdr.web.cern.ch/

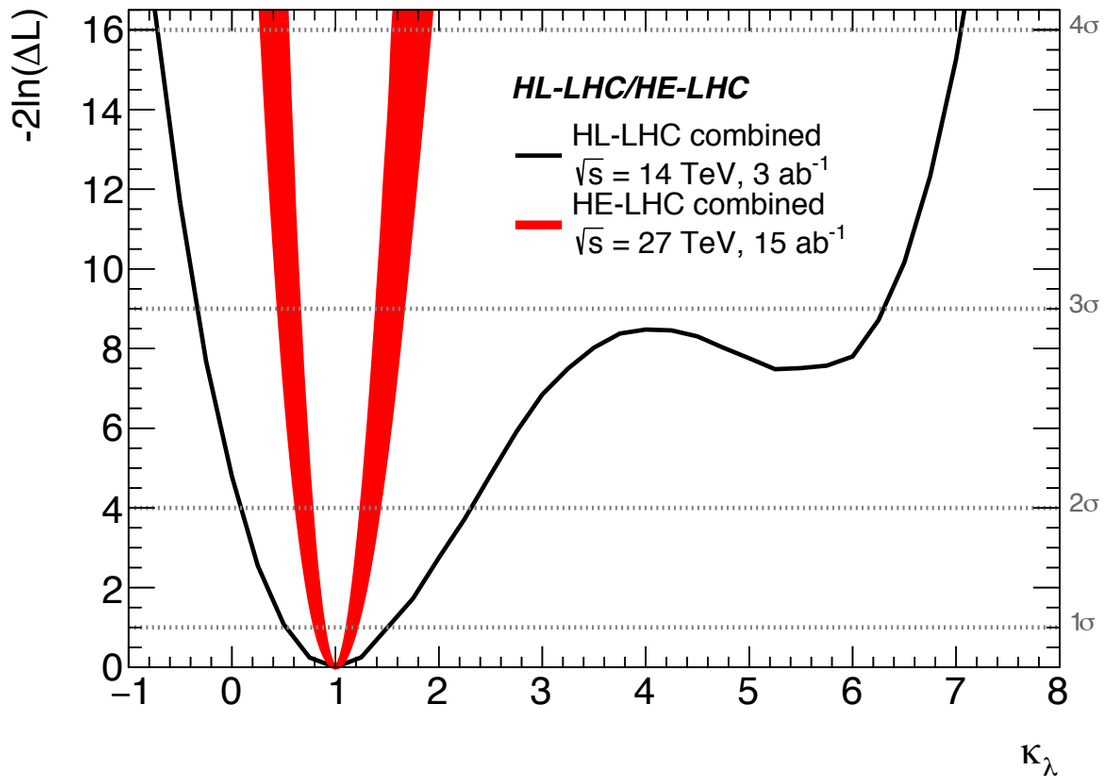


Higgs: HE-LHC?

- The HE-LHC will extend the HL-LHC reach in direct searches for new particles, approximately doubling the reach in mass —> high impact on BSM Higgs studies
- In terms of SM Higgs, it will enhance statistically limited processes and enable the access to very large transverse momenta.



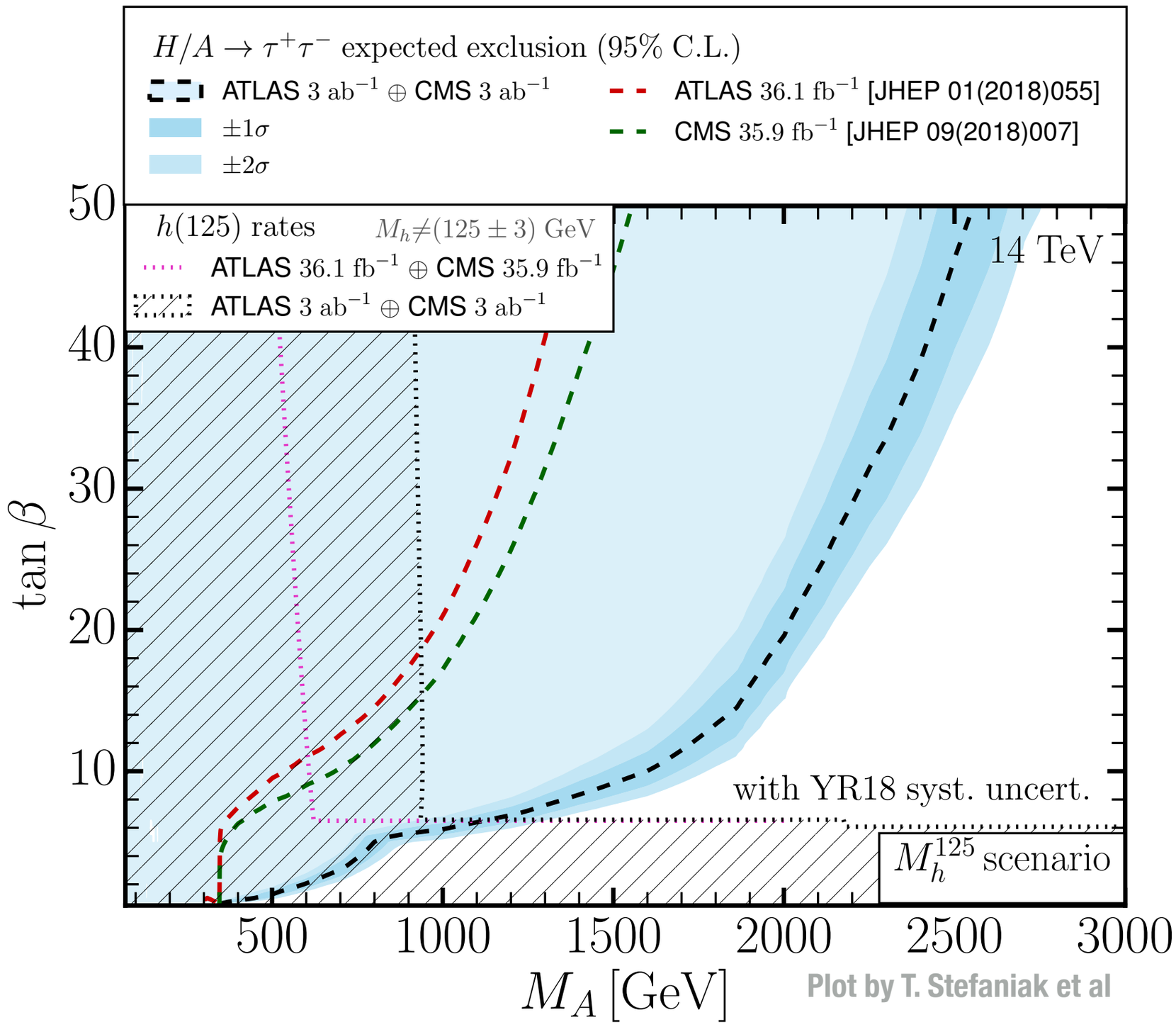
Fit by J. De Blas et al using CMS/ATLAS projections



- As an hyphotesis, assuming an additional factor of 1/2 reduction of theoretical uncertainties plus the increase in cross section yields clear improvements in the global fit results
- Once again, special focus on HH reach: precision of 10% to 20% on κ_λ could be achieved from just the combination of the two main decay modes (bbtautau and bbgammagamma)

MSSM Higgs @ HL

Update of the traditional MSSM scenarios: comparison of direct Htautau limits and indirect constraints from the couplings extrapolations



Plot by T. Stefaniak et al