Summary: Weak Interactions (Experiment)

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June 23, 2017

Agenda Links

Tuesday

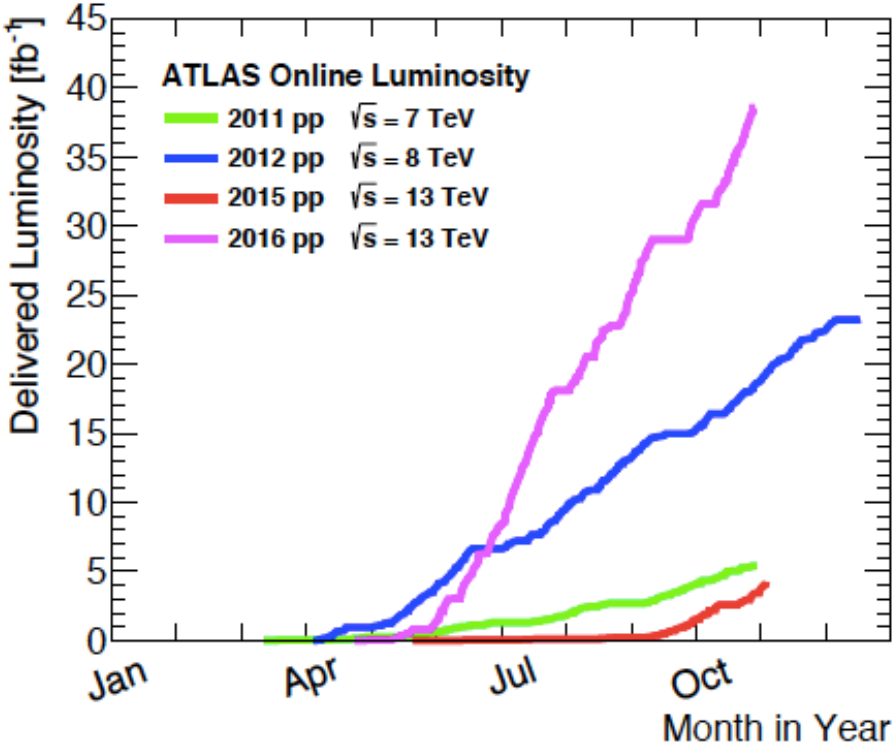
- "Probing for anomalous Higgs-VV couplings in production and decay H→4l at CMS", Jeffrey Roskes
- "Multi-Boson production cross sections at CMS", Daneng Yang
- "Cross section and coupling measurements with the ATLAS detector for the 125 GeV Higgs Boson", Hannah Herde
- "CMS Overview regarding Higgs Production Results", Francesco Fabozzi
- "Measurements of the Higgs boson mass and its spin and CP properties with the ATLAS Detector", Stephen Sekula (given by Tulin Varol)
- "Higgs Properties with the CMS detector", Roberto Rossin

Wednesday

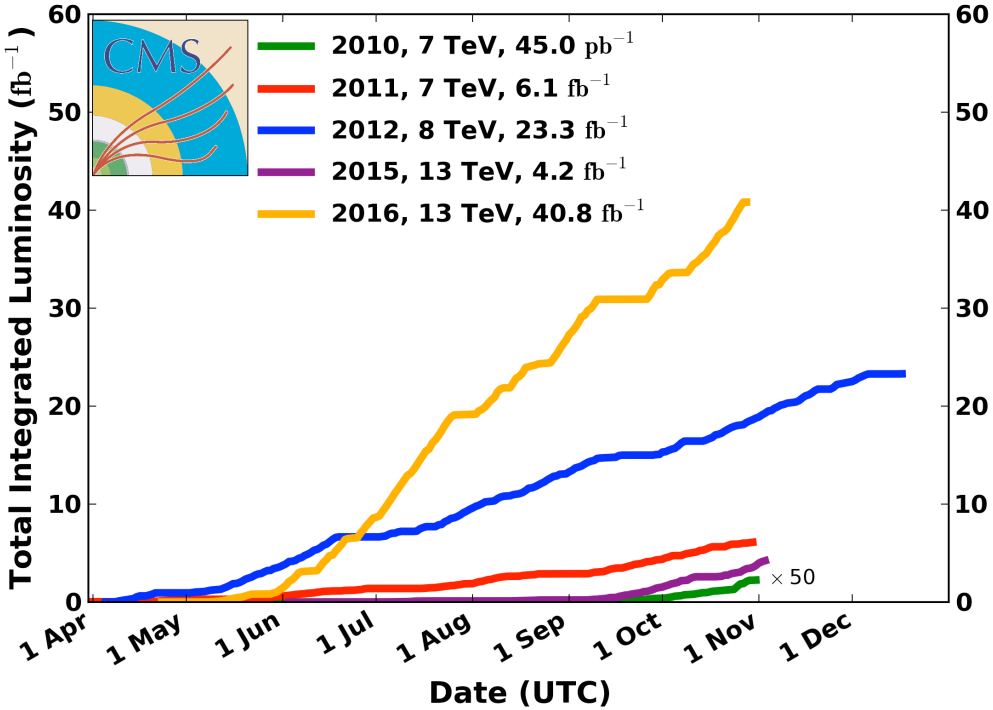
- "CMS Higgs and New Physics", Pierluigi Bortignon
- "Search for rare or non-standard production and decay modes of the Higgs boson with the ATLAS detector", Dhiman Chakraborty
- "CMS Double Higgs Searches", Michael Krohn
- "ATLAS Higgs physics prospects at the high luminosity LHC", Tulin Varol
- "CMS Upgrade (Phase-I and Phase-II) with future prospects in terms of Higgs/ electroweak measurements", Petar Maksimovic
- "Searches for electroweak production of supersymmetric gauginos and sleptons and R-parity violating and long-lived signatures with the ATLAS detector", Ruo yu Shang
- "Searches for squarks and gluinos with the ATLAS detector", Vakhtang Tsiskaridze

LHC Performance

ATLAS Online Luminosity



CMS Online Luminosity



ROADMAP

Multi-bosons

Higgs properties

Higgs and new physics

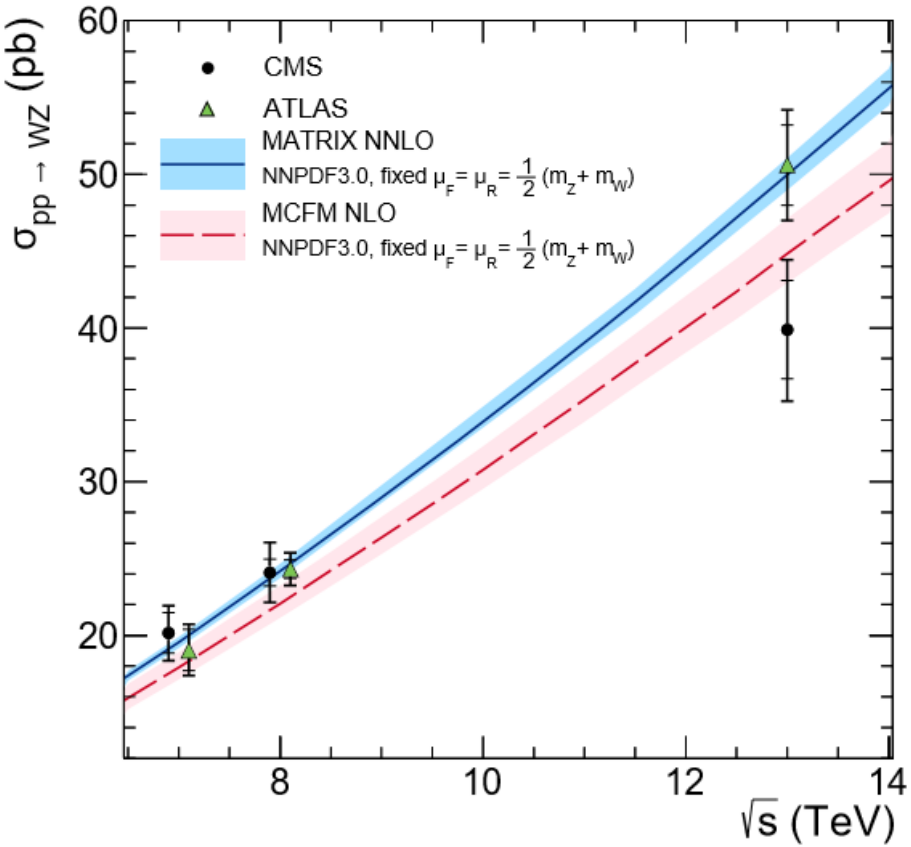
SUSY

HL-LHC

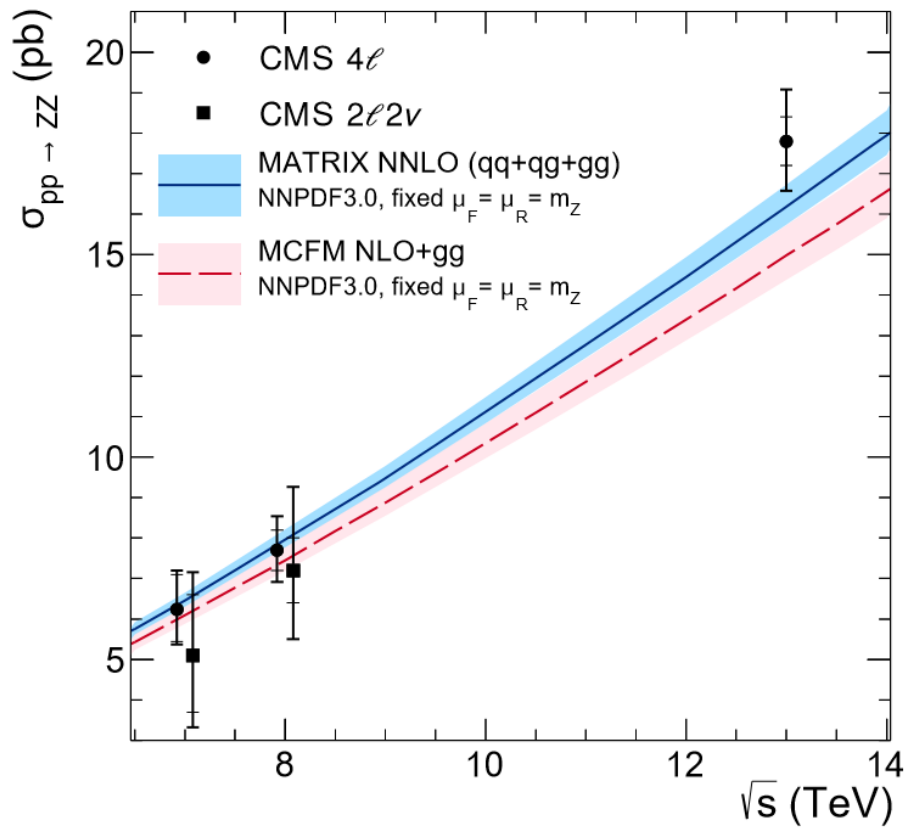
CMS: Daneng Yang

Dibosons: NLO -> NNLO just in time!

WZ

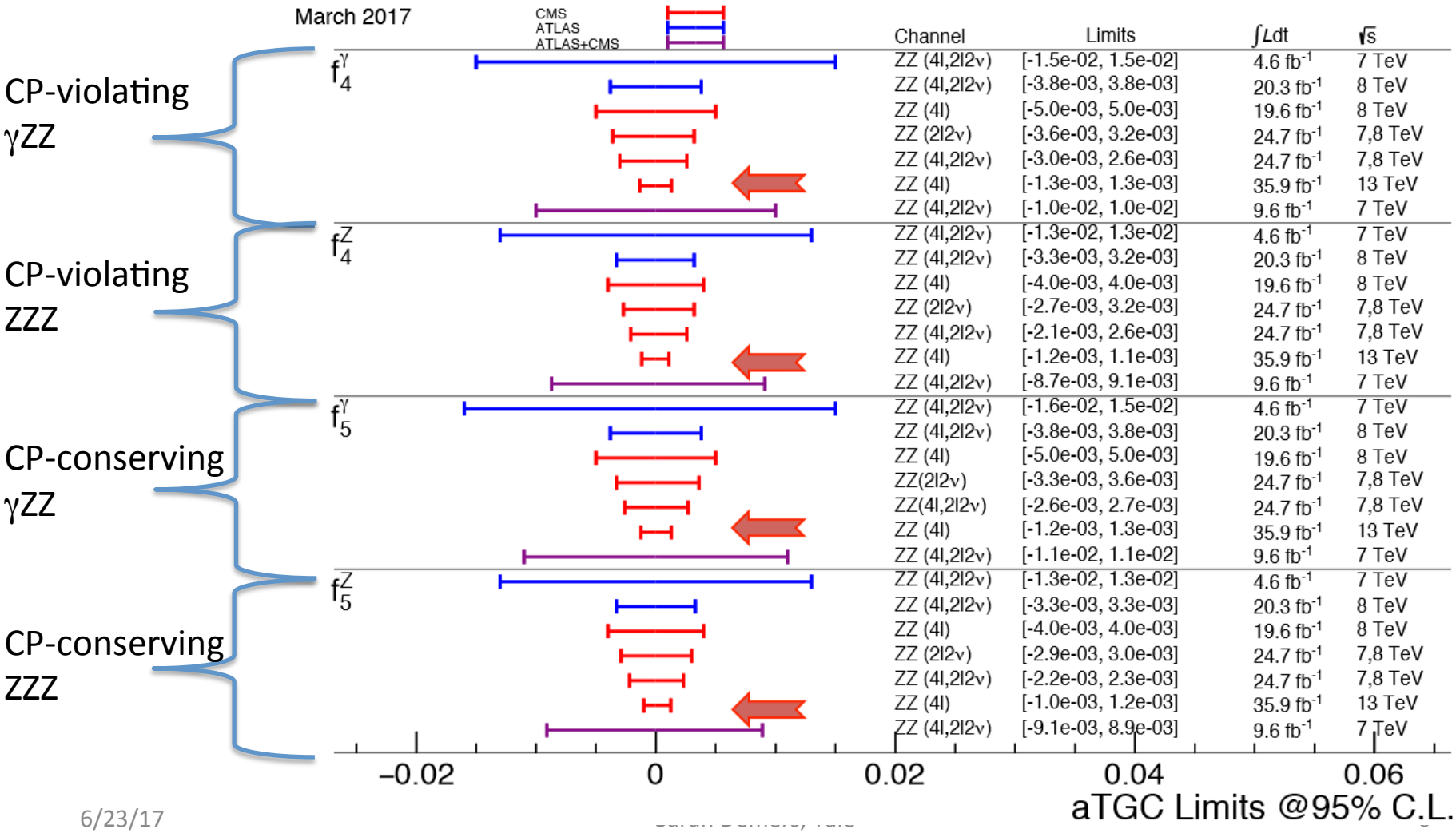


ZZ



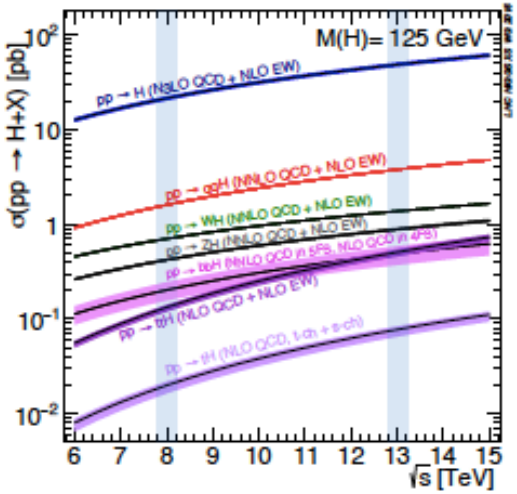
CMS: Daneng Yang

Run 2 Improvements to anomalous triple gauge couplings

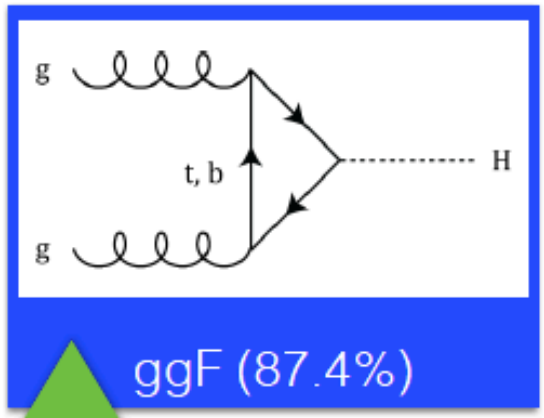


ATLAS: Hannah Herde

125 GeV Higgs boson

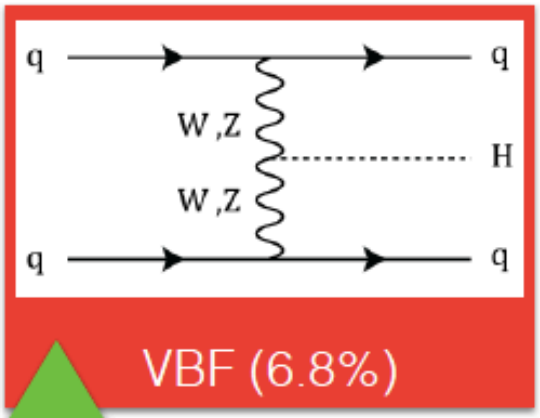


Run I ⟶ Run II



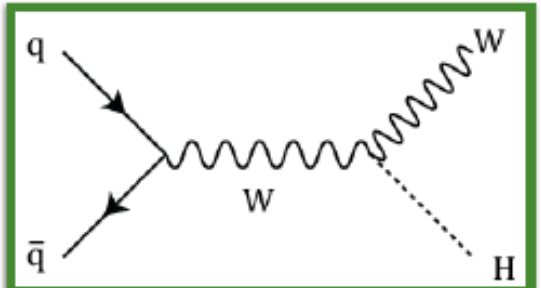
ggF (87.4%)

2.3x



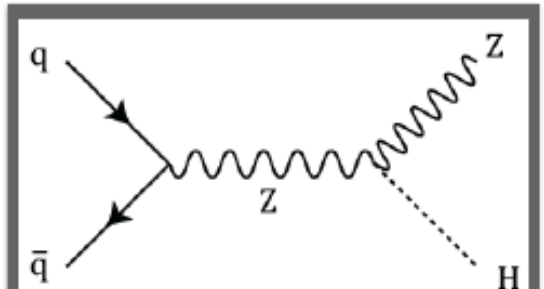
VBF (6.8%)

2.4x



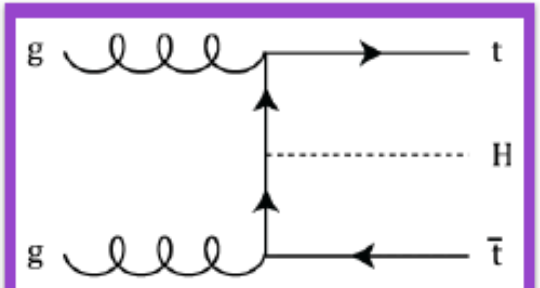
WH (2.5%)

2.0x



ZH (1.6%)

2.1x

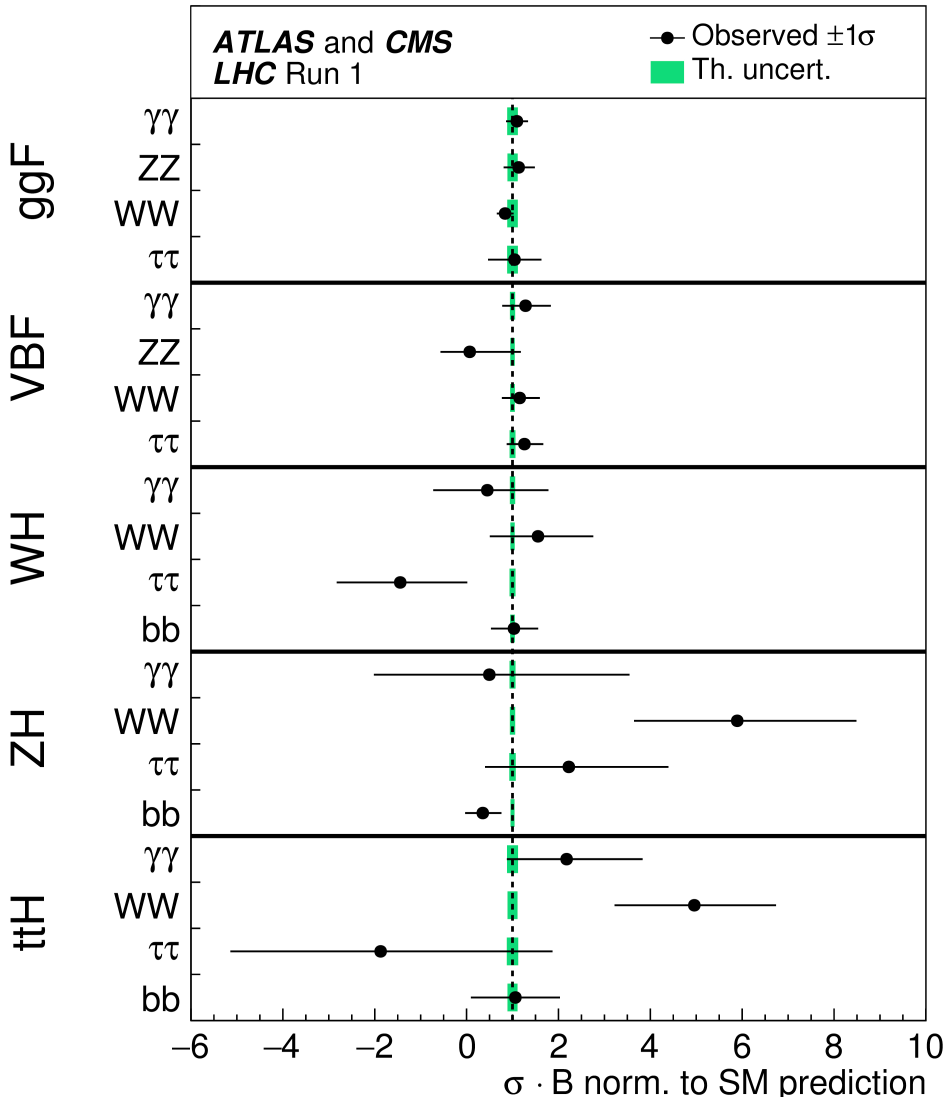


$t\bar{t}H$ (0.9%)

3.9x

ATLAS: Hannah Herde CMS: Francesco Fabozzi, Roberto Rossin

Higgs boson Production & Decay



We continue to improve in both production and decay measurements.

So far no surprises, with the particle acting just like the SM Higgs Boson.

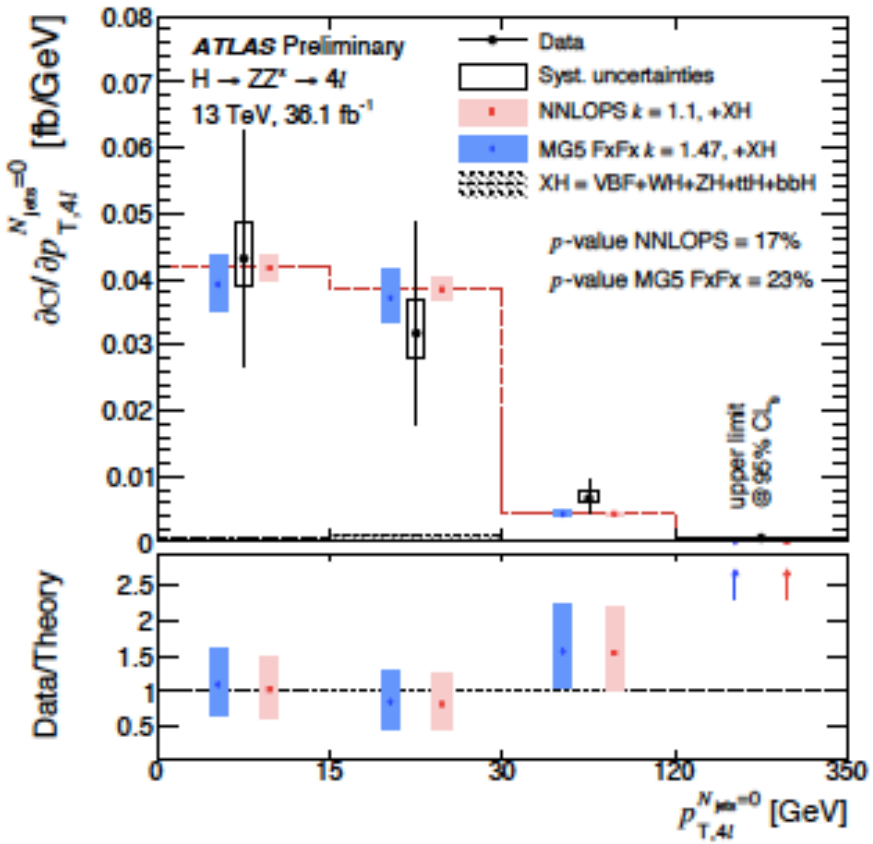
I'll highlight a few measurements released in May, 2017 using the full Run 2 dataset

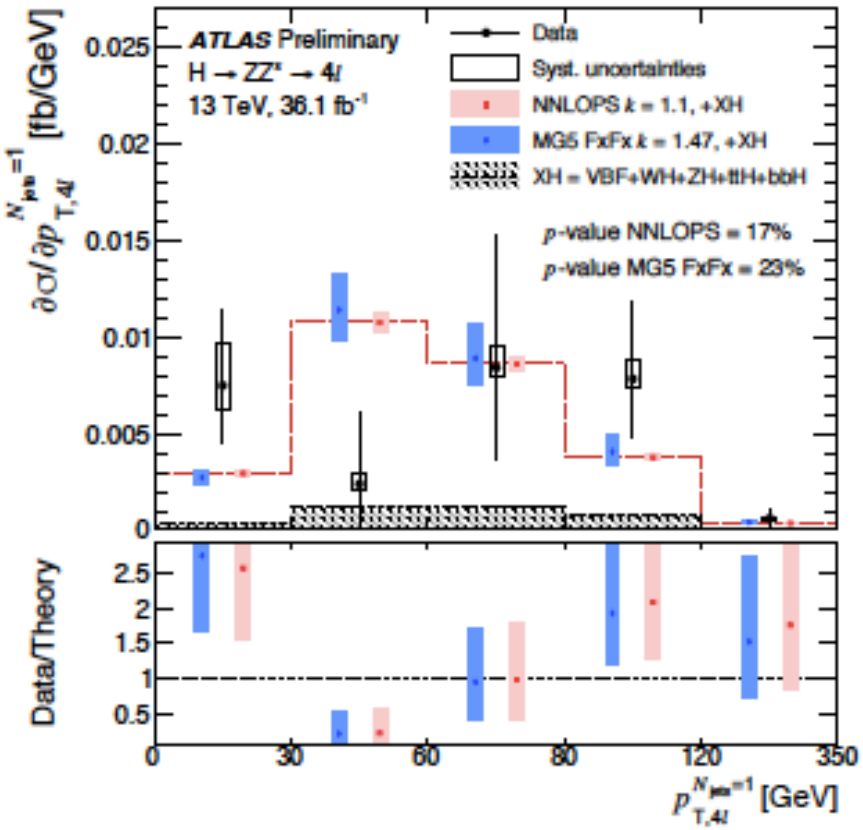
H->ZZ (4l) Double Differential Cross Sections

$N_{jets}=0$

ATLAS

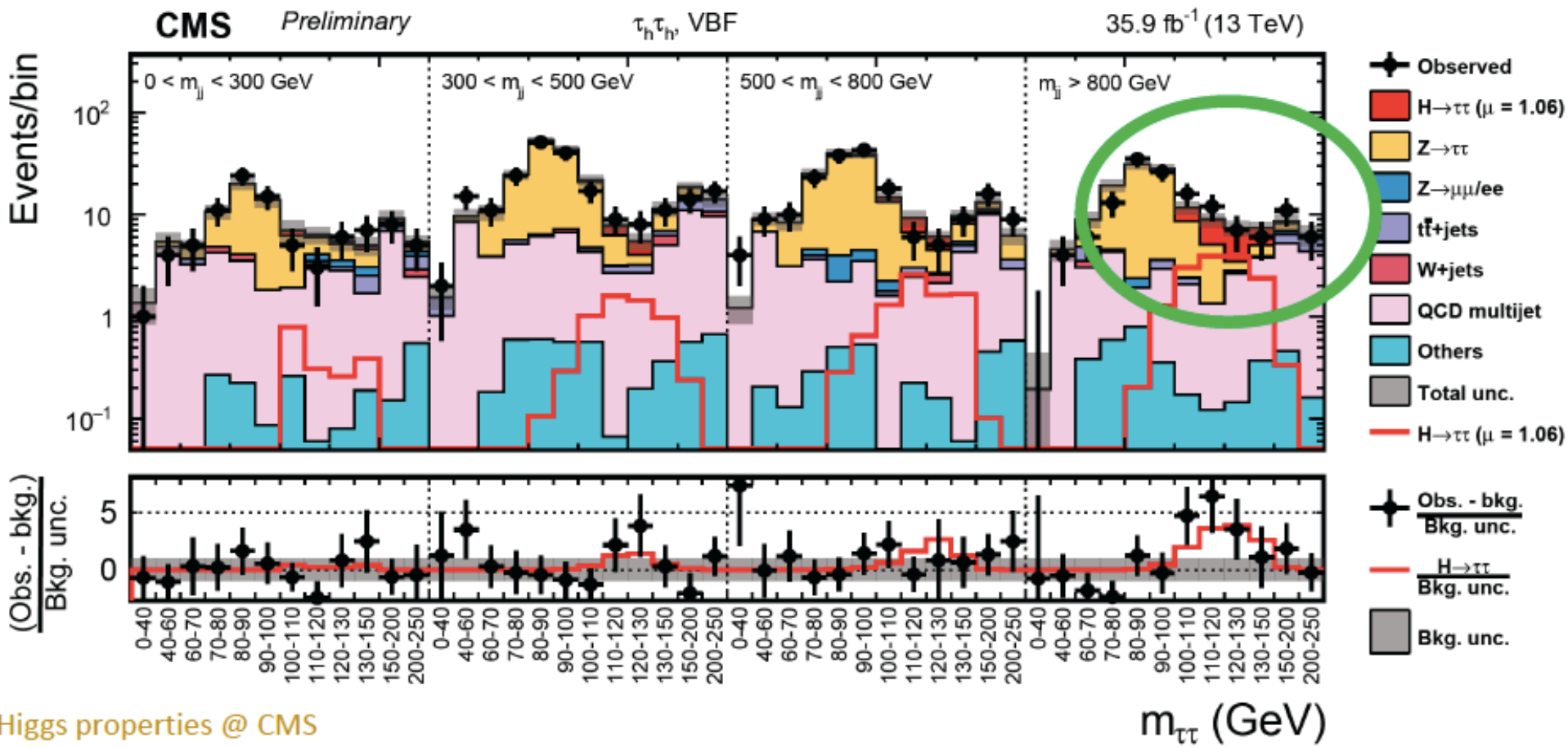
$N_{jets}=1$





CMS: Francesco Fabozzi

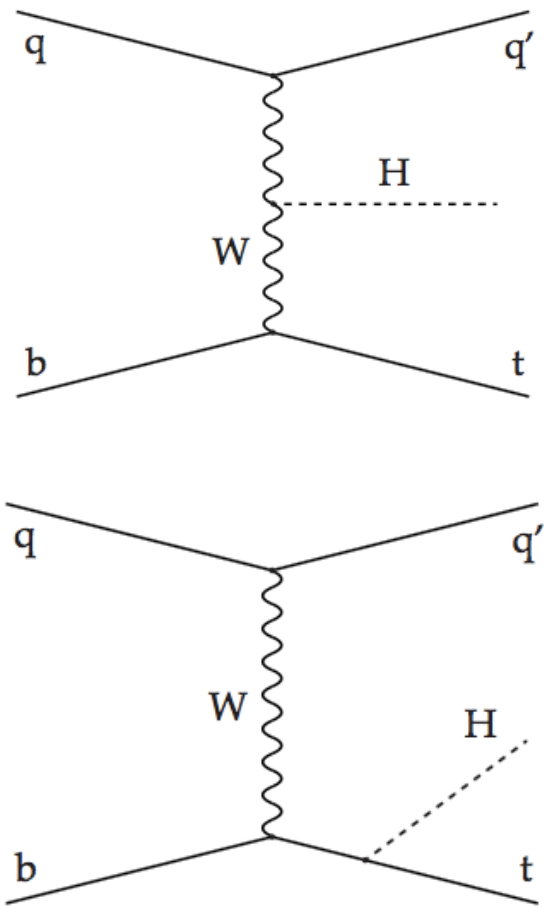
VBF H->ττ, in bins of the jj mass

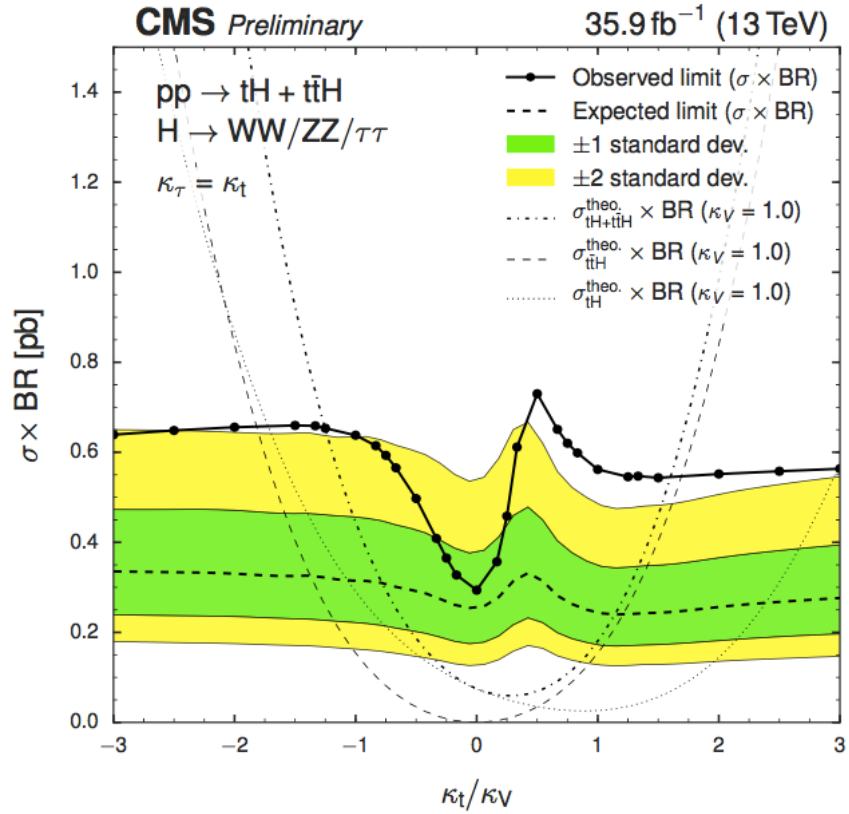


Higgs properties @ CMS

CMS: Francesco Fabozzi

tHq production at CMS

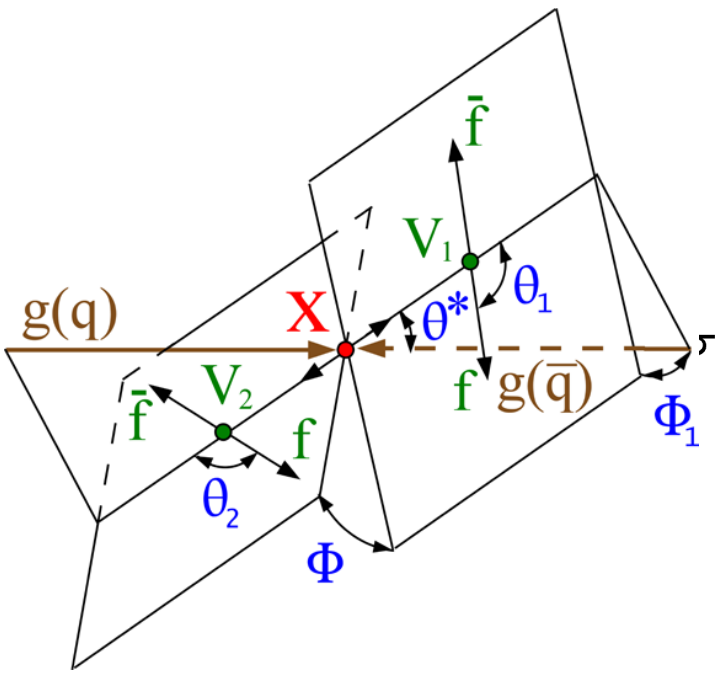


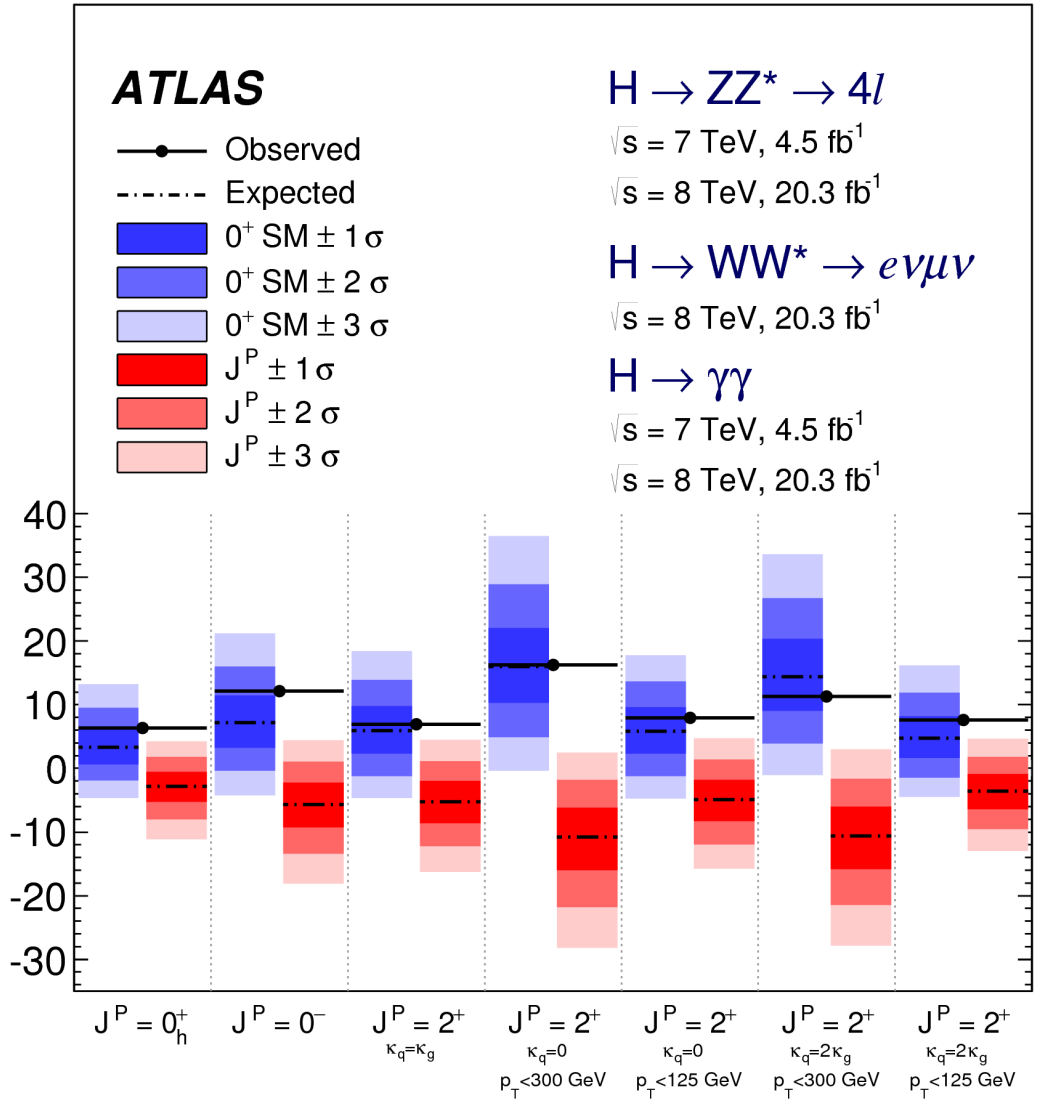


$(\sigma/\sigma_{SM})_{tH+ttH} = 1.8 \pm 0.3\ (stat.) \pm 0.6\ (syst.)$

κ_t values (κ_V=1) outside [-1.25, 1.60] range excluded @95% C.L.

Higgs spin and parity: consistent with SM





ATLAS: Stephen Sekula (Tulin Varol) CMS: Roberto Rossin

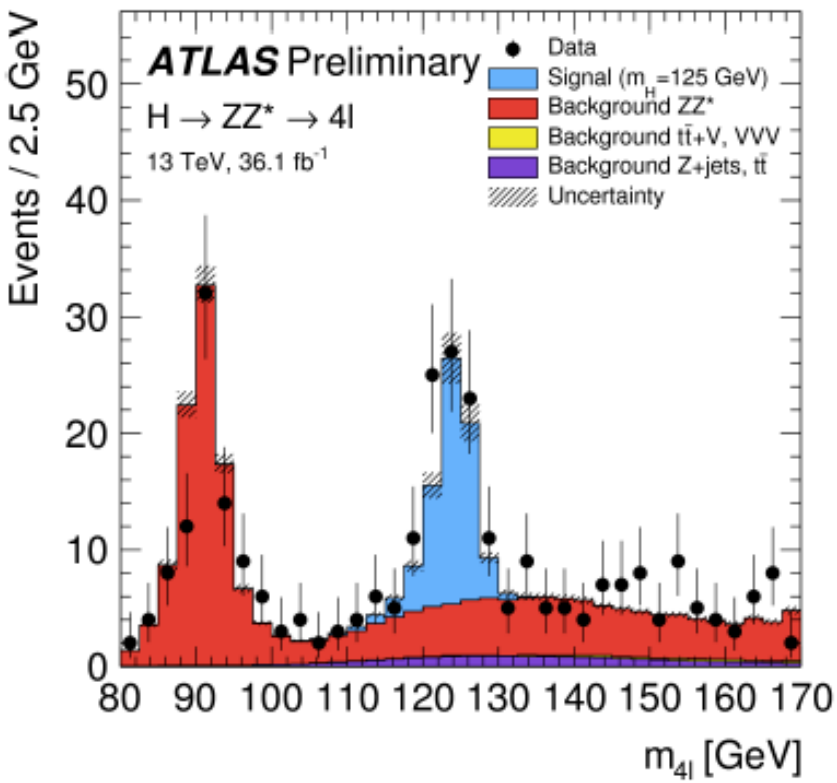
Higgs Mass

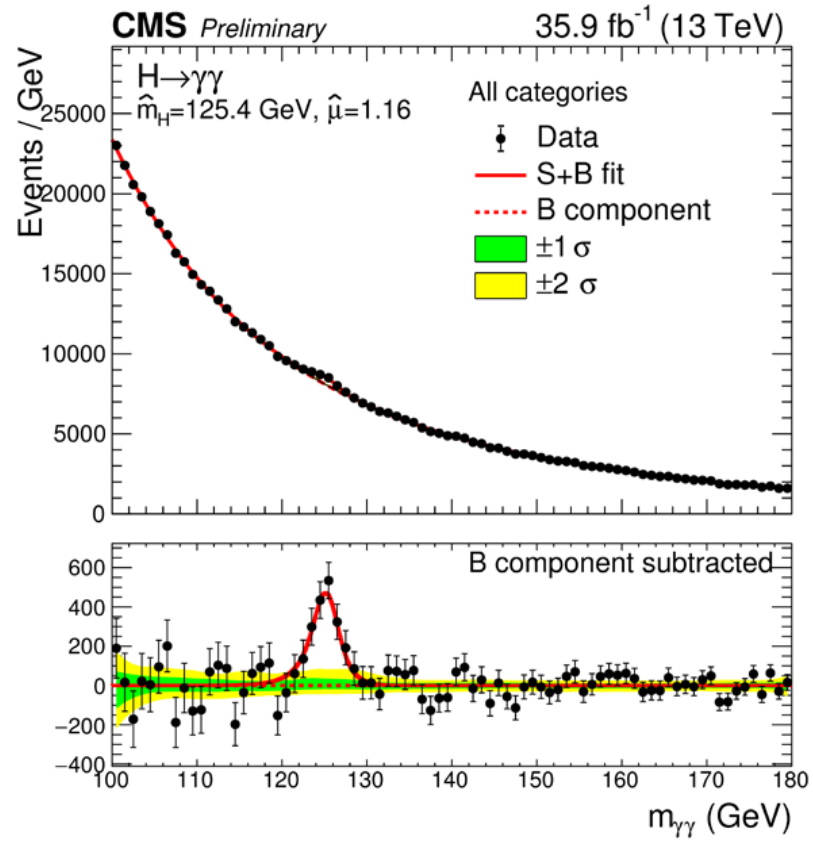
Run 1 combination

ATLAS+CMS: $(125.09 \pm 0.21_{\text{stat.}} \pm 0.11_{\text{syst.}})$ GeV

Phys. Rev. Lett. 114 (2015) 191803

Both ATLAS and CMS have results in the "golden channels" with the full Run 2 dataset

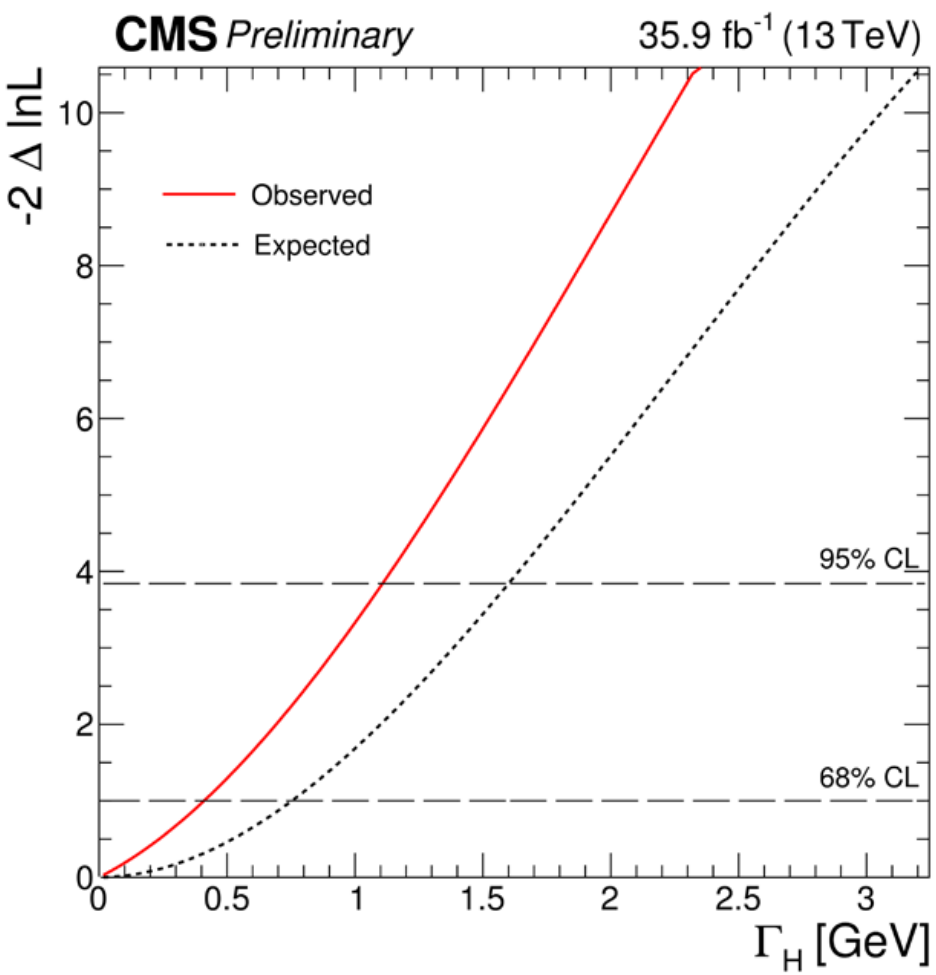




CMS: Roberto Rossin

Higgs Width

Direct Measurement, H -> ZZ -> 4l
SM prediction: 4 MeV
Exp resolution: ~1 GeV



Better sensitivity with indirect measurement, at cost of assumptions

- no BSM particles contributing
- no anomalous couplings

Use simultaneous on-shell & off-shell measurements

$$\sigma^{on-peak}_{gg\to H\to VV} \propto \frac{g^2_{ggH} g^2_{HVV}}{\Gamma_H}$$

$$\sigma^{off-peak}_{gg\to H\to VV} \propto g^2_{ggH} g^2_{HVV}$$

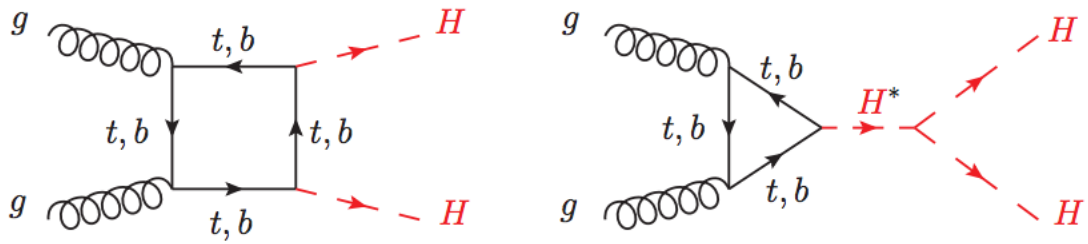
$$\Gamma_H \leq 13\ (26)\ MeV$$

observed (expected) @ 95% C.L.

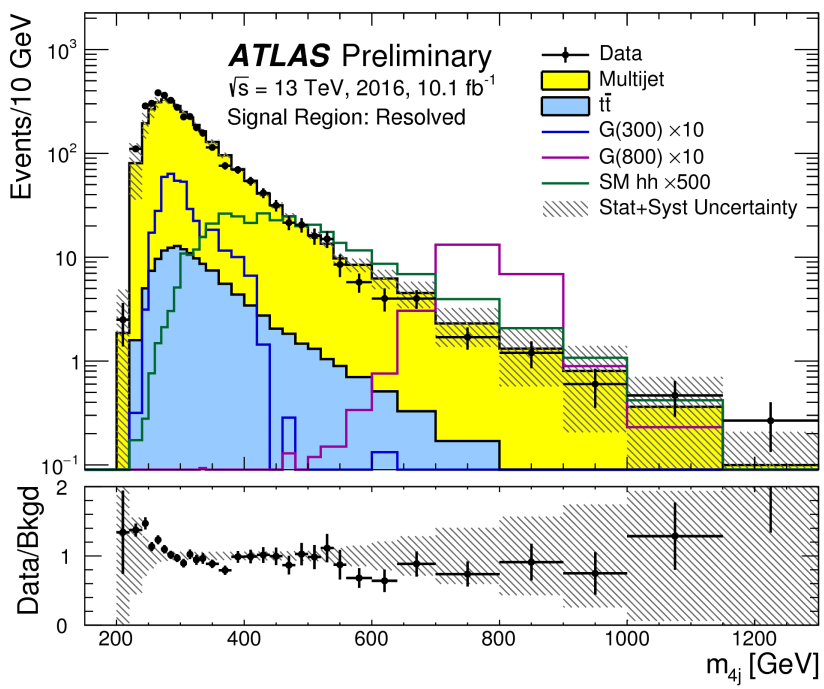
ATLAS: Dhiman Chakraborty CMS: Michael Krohn

Search for Higgs Pair Production

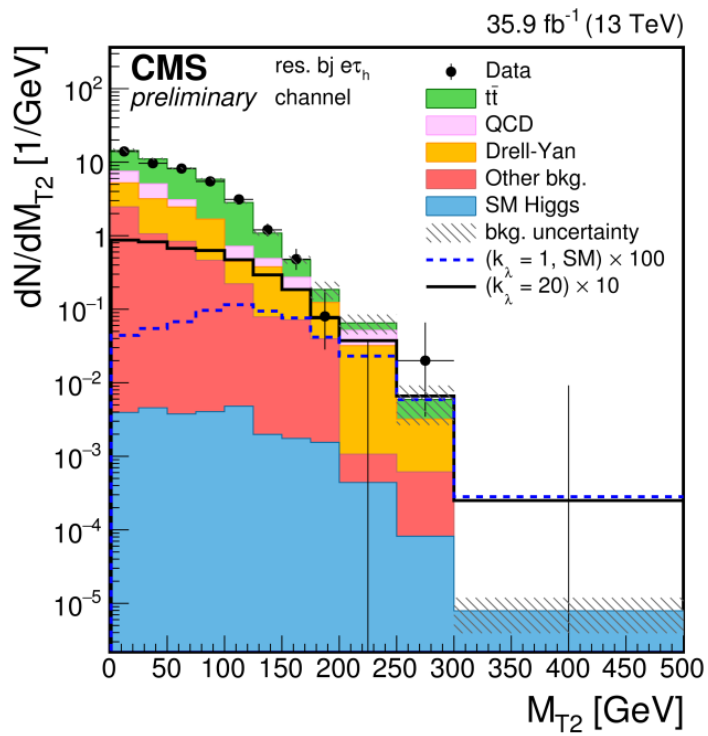
Destructive interference between diagrams -> low cross section (33.4 fb @ √s = 13 TeV



ATLAS HH->bbbb



CMS HH->bbtτ



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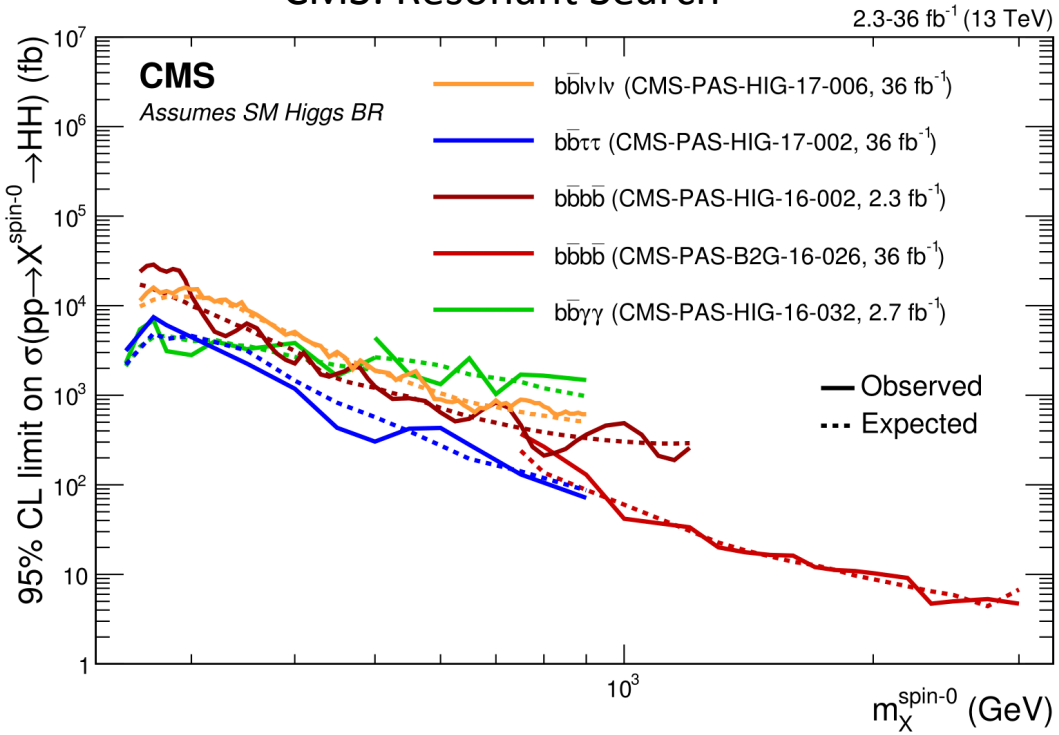
ATLAS: Dhiman Chakraborty CMS: Michael Krohn

Results

ATLAS

Channel	$\int \mathcal{L}\, dt$ (fb^{-1})	Obs. (exp.) 95% C.L. limit on σ/σ_{SM}	
$bbbb$	13.3	29 (38)	ATLAS-CONF-2016-049
$bb\gamma\gamma$	3.2	117 (161)	ATLAS-CONF-2016-004
$\gamma\gamma WW$	13.3	747 (386)	ATLAS-CONF-2016-071

CMS: Resonant Search



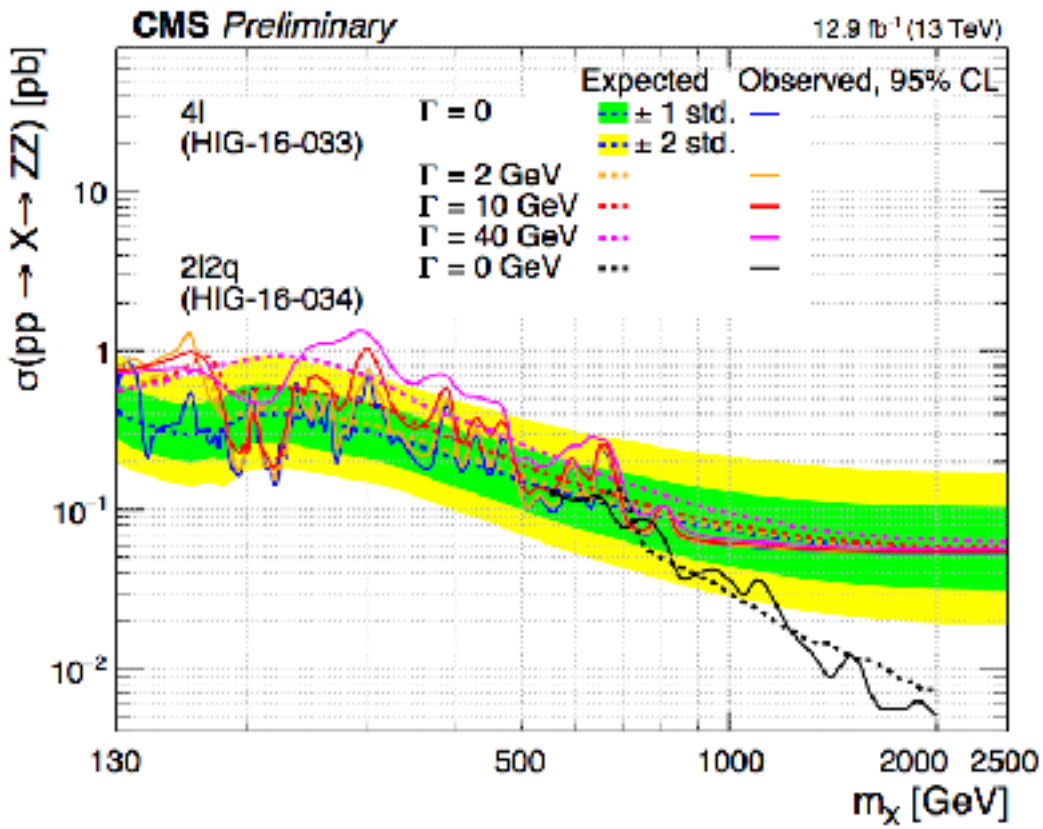
CMS

13 TeV non-resonant observed(expected) 95% CL limits		
bbbb	342(308)	2.3-2.7fb^{-1}
bbVV	79(89)	35.9fb^{-1}
bbττ	28(25)	35.9fb^{-1}
bbγγ	91(90)	2.7fb^{-1}

Search for a Heavy Higgs

X→ZZ (4l)

- 2 categories: gg and VBF (includes VH)
- m4l as observable
- parametrised signal shape in m_X and Γ_X

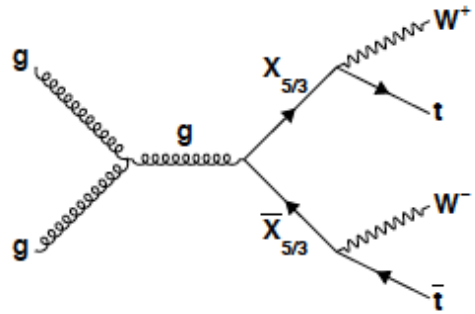


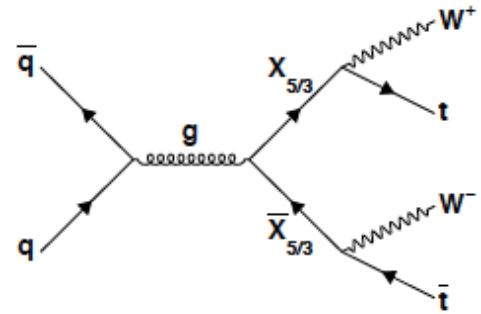
No excess observed.

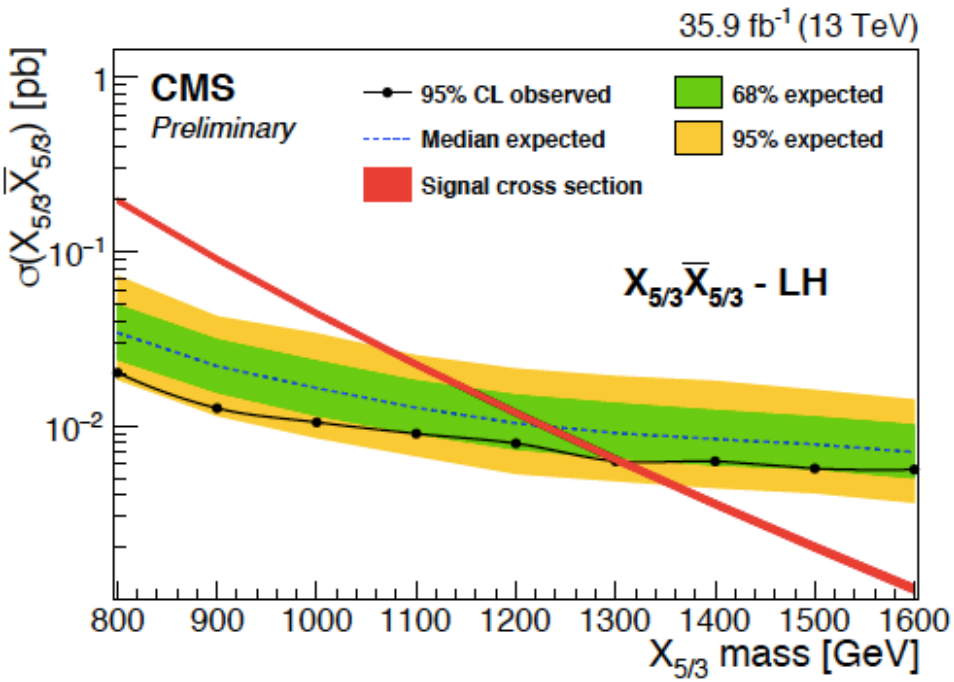
CMS: Periluigi Bortignon

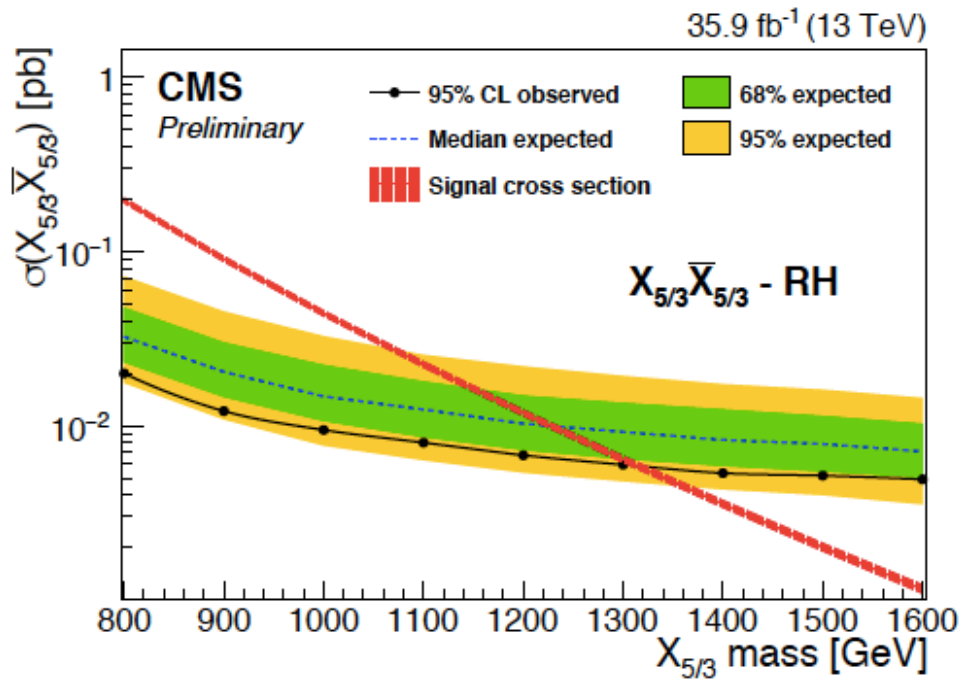
Search for a Composite Higgs or Little Higgs

Composite Higgs (CHM), little Higgs, Randall-Sundrum, and other models predict Vector-Like Quarks

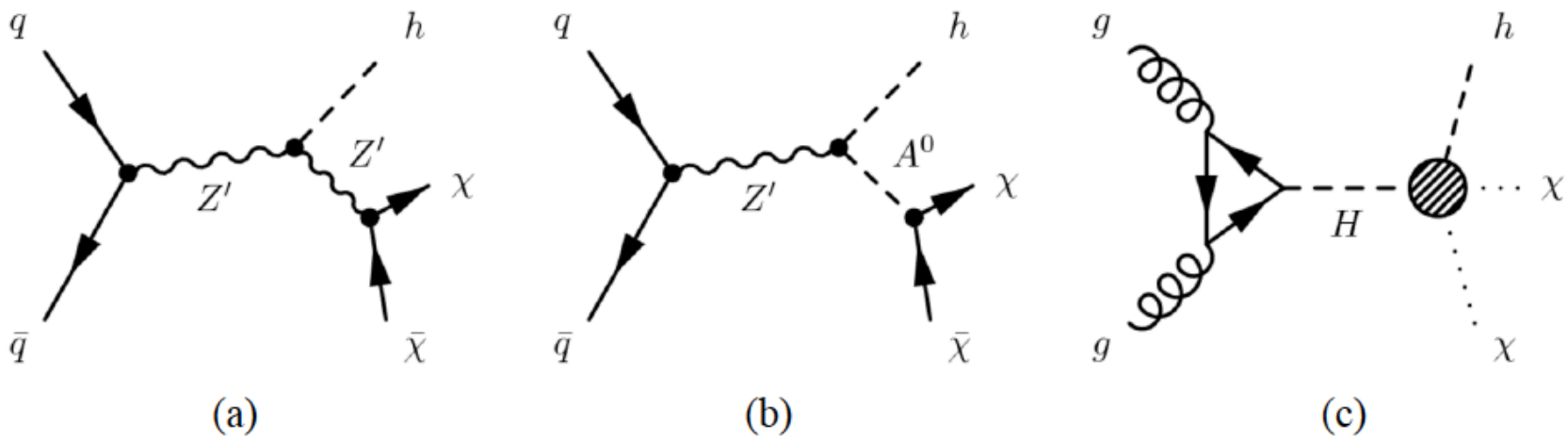








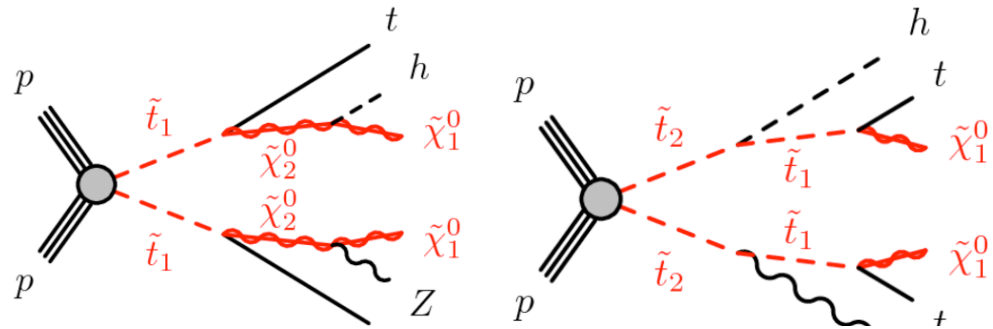
The Higgs and Dark Matter?



- (a): Z'_B model, the $U'(1)_B$ baryon symmetry ensures stability of χ.
- (b): Z'-2HDM, A^0 is the pseudoscalar Higgs state.
- (c): Heavy scalar model: $2m_h < m_H < 2m_t$, $m_\chi \approx \frac{m_h}{2}$ ensures validity of assumption $B(H \to h\chi\chi) = 1$.
- The DM candidate is a Dirac fermion in (a) and (b), scalar in (c).

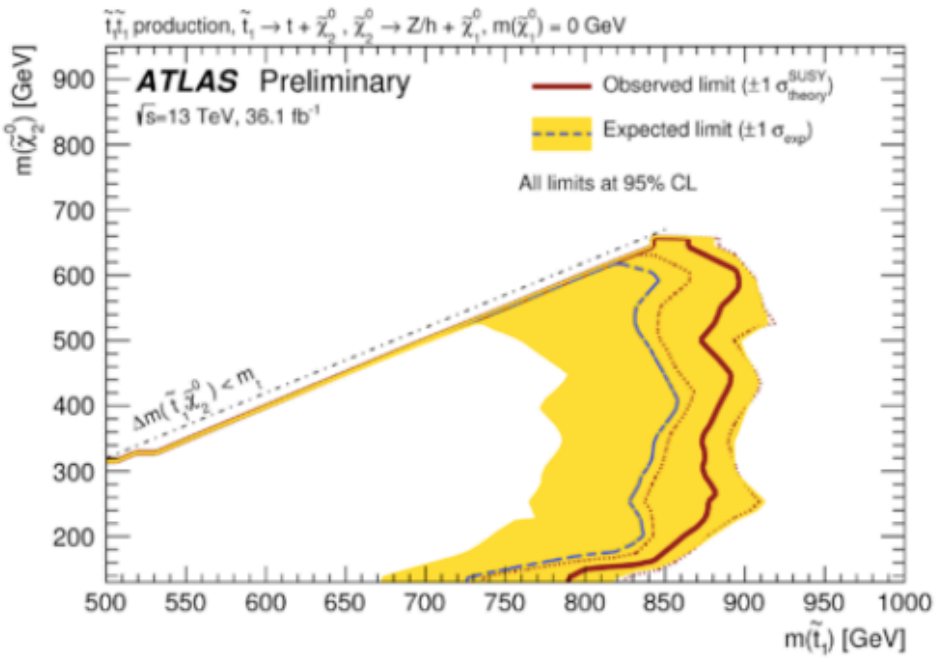
ATLAS: Dhiman Chakraborty

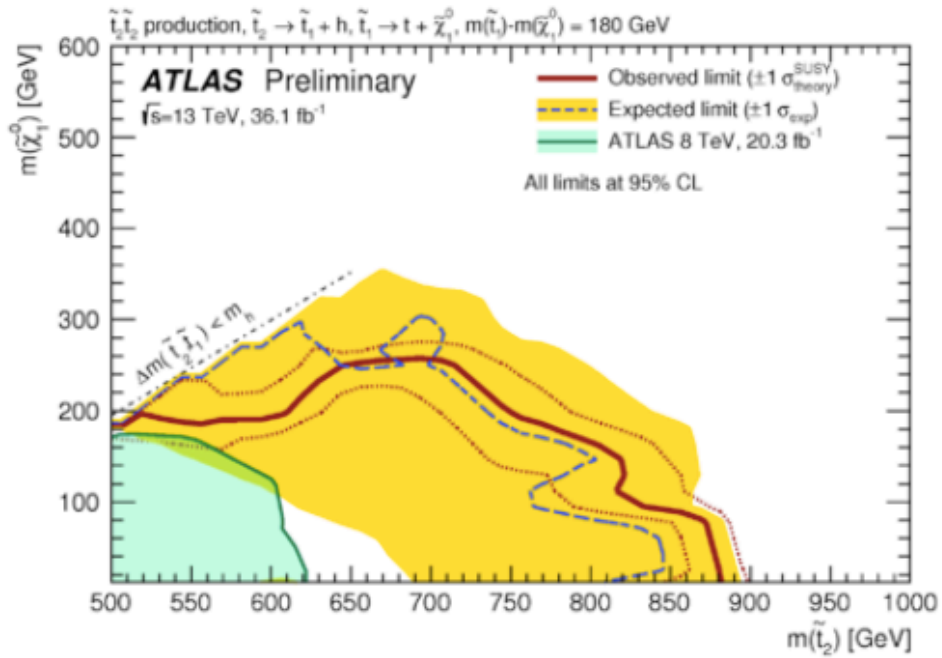
The Higgs in stop quark decays?



assuming $\mathrm{BR}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0) = \mathrm{BR}(\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0) = 0.5$.

assuming $\mathrm{BR}(\tilde{t}_2 \to h\tilde{t}_1) = 1$.





Anomalous Couplings in HVV with H->4l

	VBF-jets	VH-jets	untagged	2015
VBF signal	2.4 (1.6)	0.1 (0.1)	2.2 (0.3)	0.4 (0.2)
ZH signal	0.1 (0.2)	0.3 (0.5)	0.7 (1.0)	0.1 (0.1)
WH signal	0.1 (0.3)	0.3 (1.0)	0.8 (2.2)	0.1 (0.3)
$gg \to H$ signal	3.2 (3.3)	1.9 (2.0)	49.6 (49.4)	4.4 (4.4)
$t\bar{t}H$ signal	0.1 (0.1)	0.0 (0.0)	0.5 (0.6)	0.0 (0.1)
$q\bar{q} \to 4\ell$ bkg	0.9	1.1	56.3	5.2
$gg \to 4\ell$ bkg	0.1	0.1	5.5	0.5
VBF/VVV bkg	0.1	0.0	0.4	0.0
Z+X bkg	3.6	2.0	29.1	1.7
Total expected	10.7	5.8	145.2	12.9
Total observed	11	2	145	11

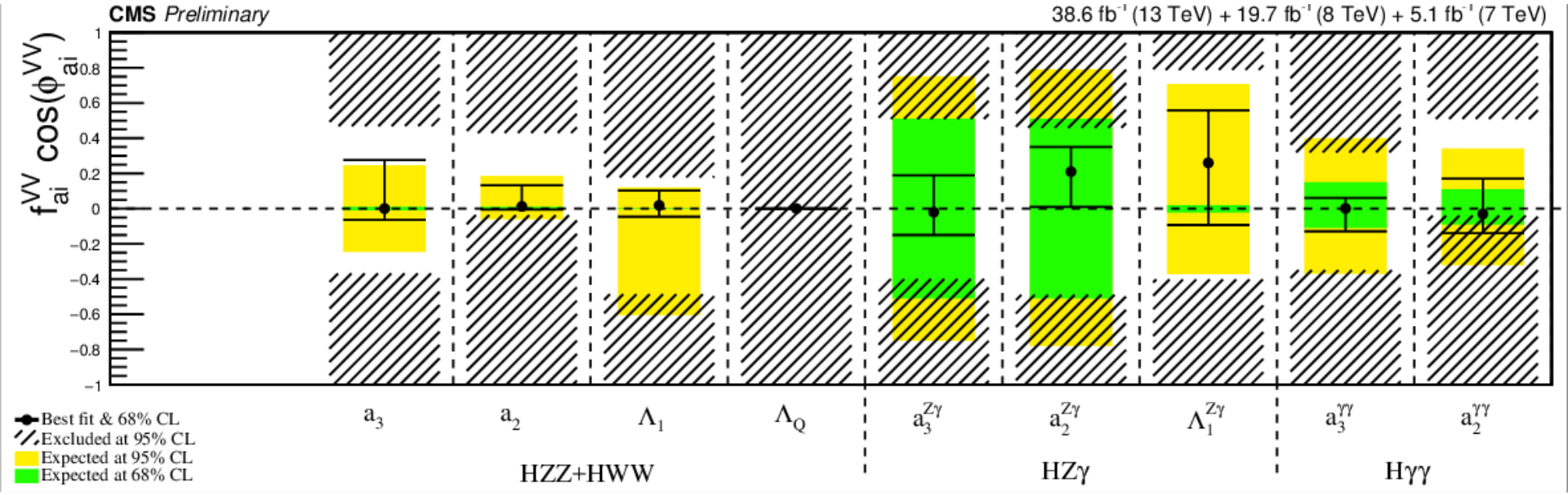
Use matrix element (MELA) discriminants

- optimally select VBF and VH events
- optimally separate different contributions to the amplitude

CMS: Heshy Roskes

Results

38.6 fb^{-1} (13 TeV) + 19.7 fb^{-1} (8 TeV) + 5.1 fb^{-1} (7 TeV)

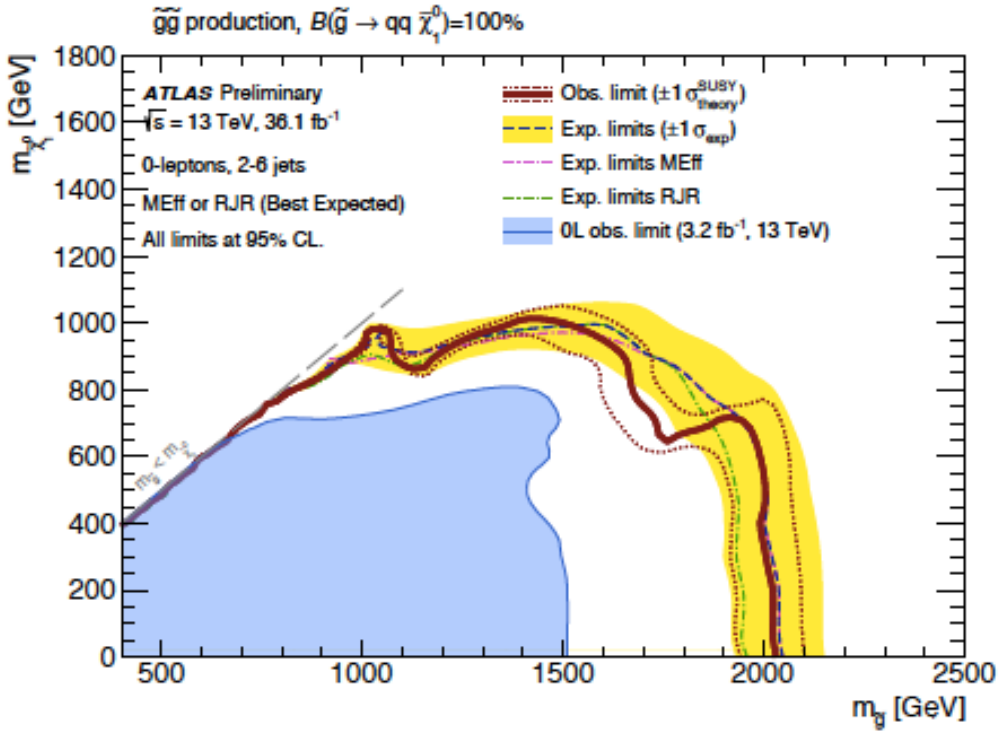


They expect narrow 2σ limits by the end of Run2

ATLAS: Ruo yu Shang, Vakhtang Tsiskaridze

Wherefore Art Thou, SUSY?

Searching for squarks and gluinos from strong production of SUSY



ATLAS: Ruo yu Shang, Vakhtang Tsiskaridze

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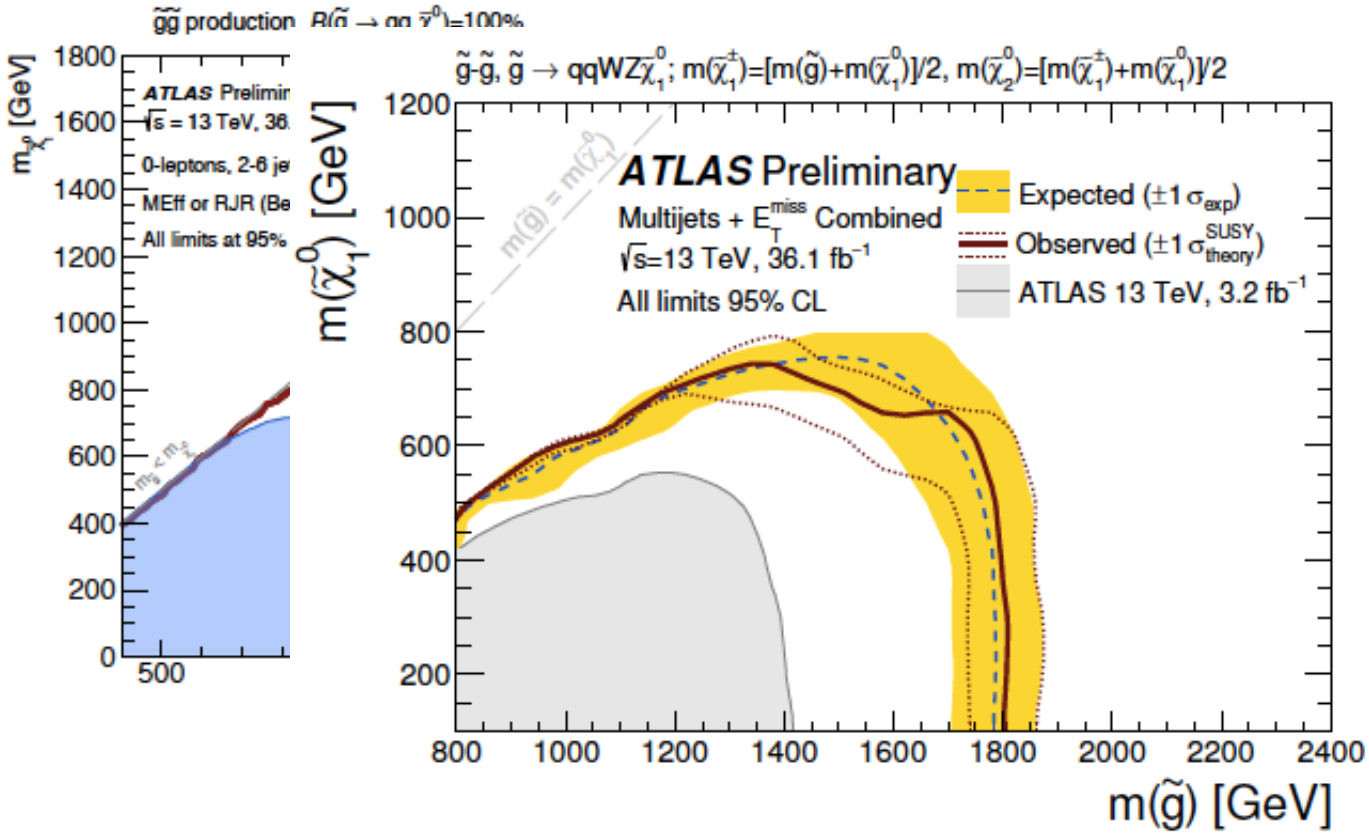

ATLAS: Ruo yu Shang, Vakhtang Tsiskaridze

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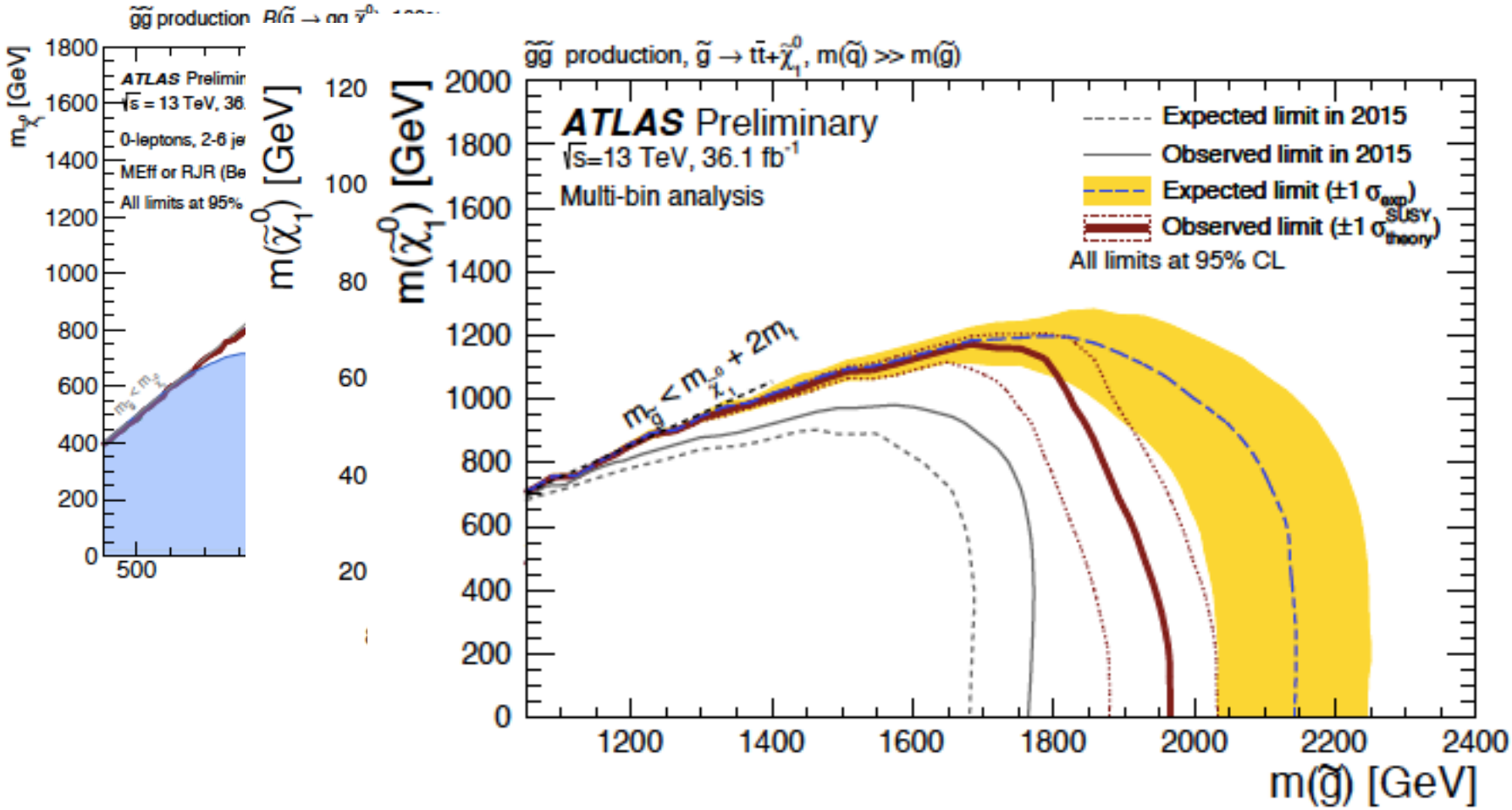
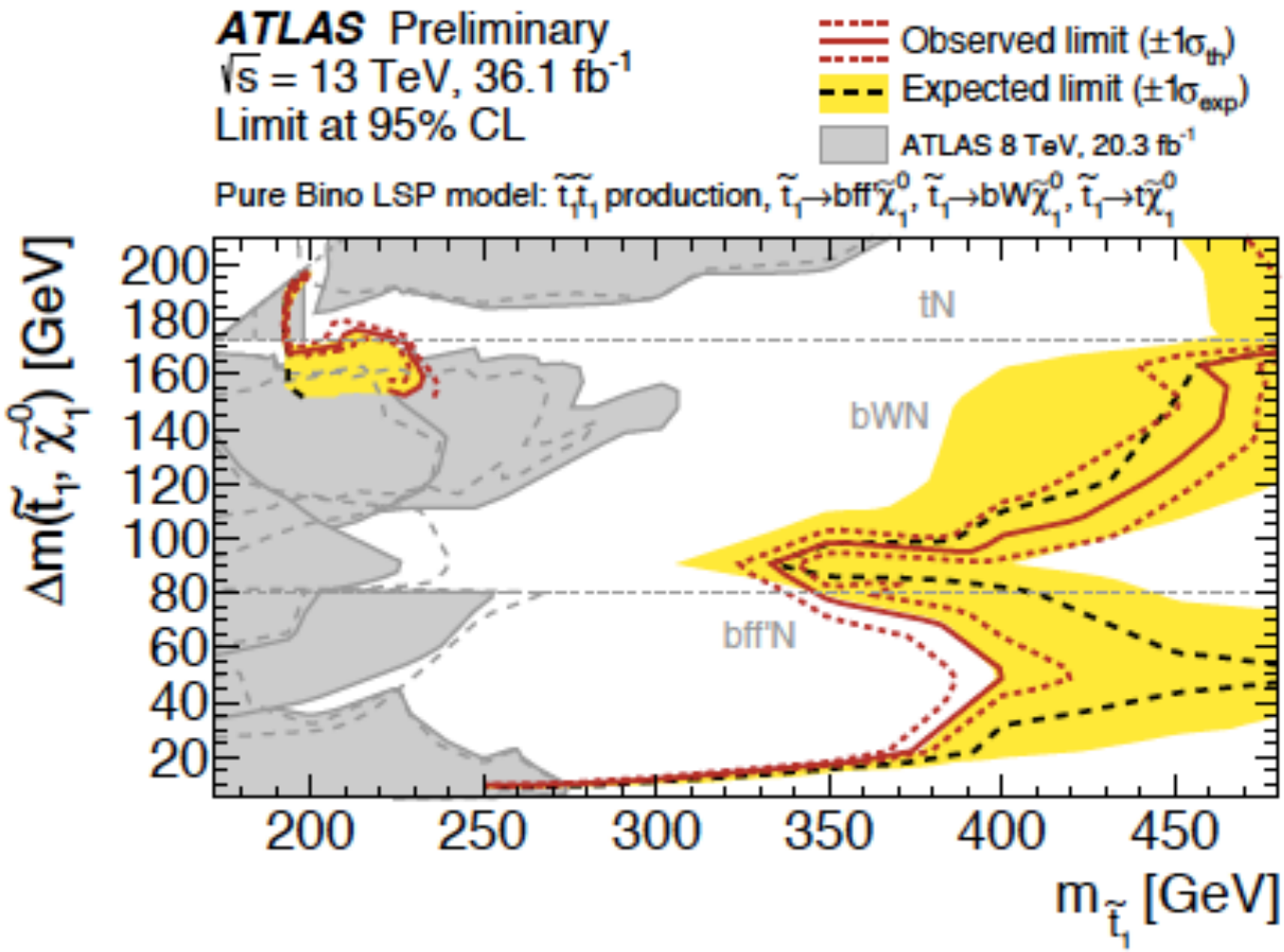


ATLAS: Ruo yu Shang, Vakhtang Tsiskaridze

Enticing Gap: Compressed Scenario, Stop quark mass at ~230 GeV



ATLAS: Ruo yu Shang, Vakhtang Tsiskaridze

Wherefore Art Thou, SUSY?

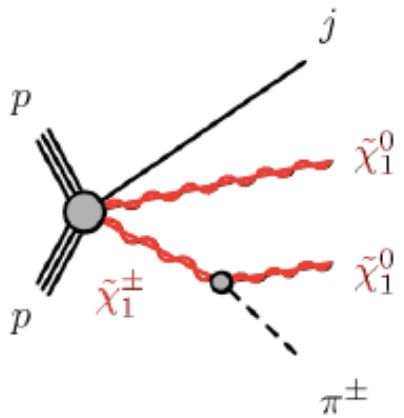
Conventional approach to search for gluino with multi-jets & $\not{E}_T$ excludes m[gluino] up to 2 TeV. No sign of SUSY.

We explore different approaches to look for EW gaugino, R-parity violating SUSY, and long-lived particles:

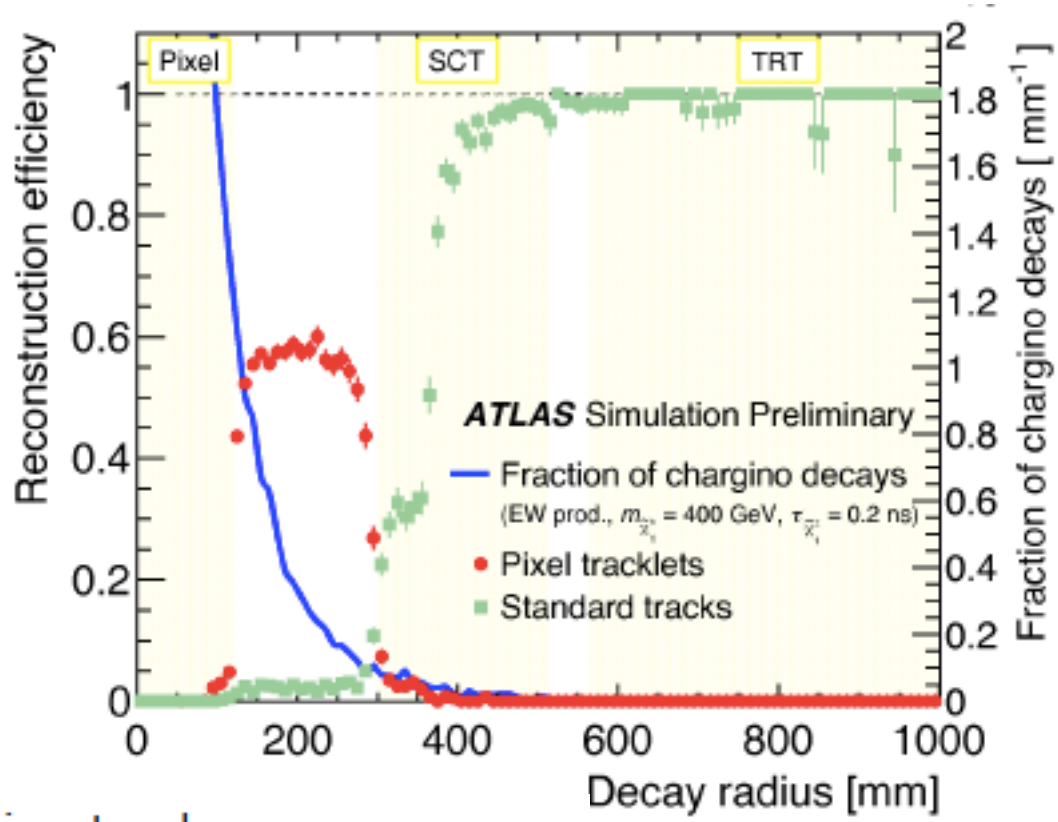
- (multi-ℓ & $\not{E}_T$) probes **gaugino** mass up to 1 TeV.
- (paired resonance) probes **stop** mass up to 2 TeV.
- (displaced vtx & disappearing trk) probes **gluino** mass up to 2 TeV.

The Disappearing Track

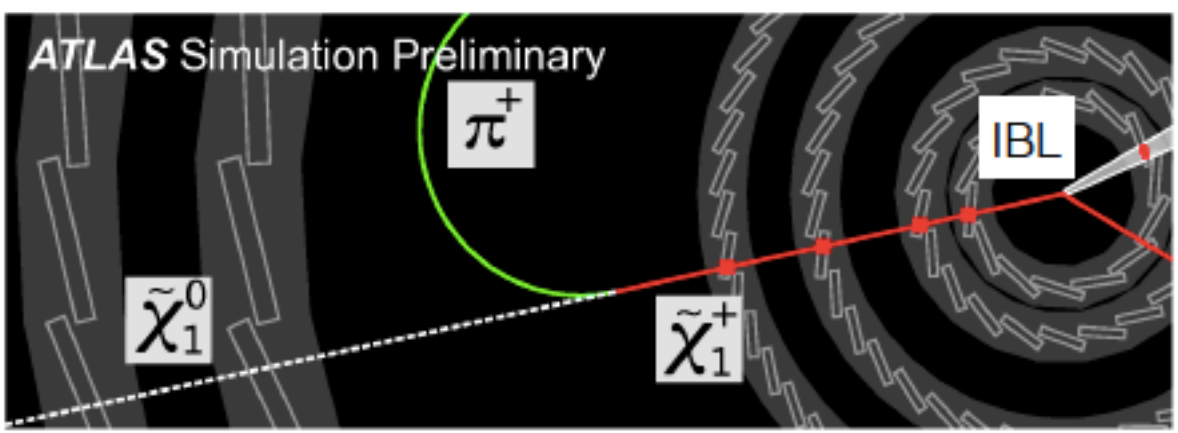
ATLAS: Ruo yu Shang, Vakhtang Tsiskaridze



small Δm, $\chi^\pm \rightarrow$LSP+very soft $\pi^\pm$



disappearing track



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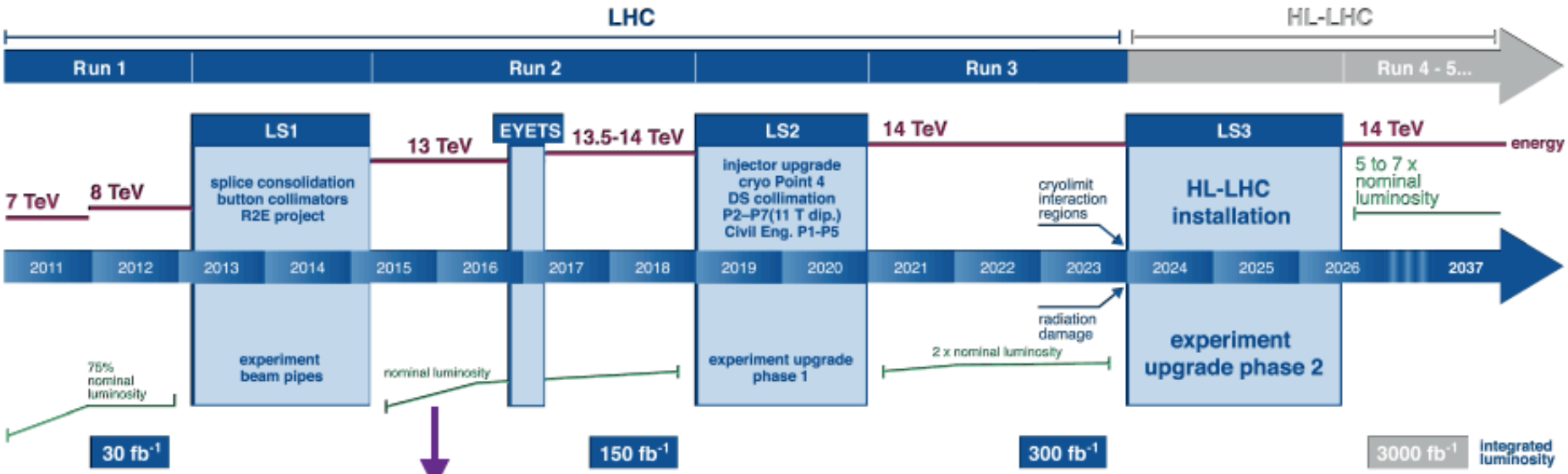
HL-LHC



$\mathcal{L}_{peak}$ = 1.4 x 10^{34} cm^{-2} s^{-1}
<μ> = 25

$\mathcal{L}_{peak}$ = 2-3 x 10^{34} cm^{-2} s^{-1}
<μ> = 50-60

$\mathcal{L}_{peak}$ = 5 x 10^{34} cm^{-2} s^{-1}
<μ> = 140

$\mathcal{L}_{peak}$: Peak luminosity
<μ>: Average number of pp interactions per bunch crossing

ULTIMATE VALUES
$\mathcal{L}_{peak}$ = 7.5 x 10^{34} cm^{-2} s^{-1}
<μ> = 200

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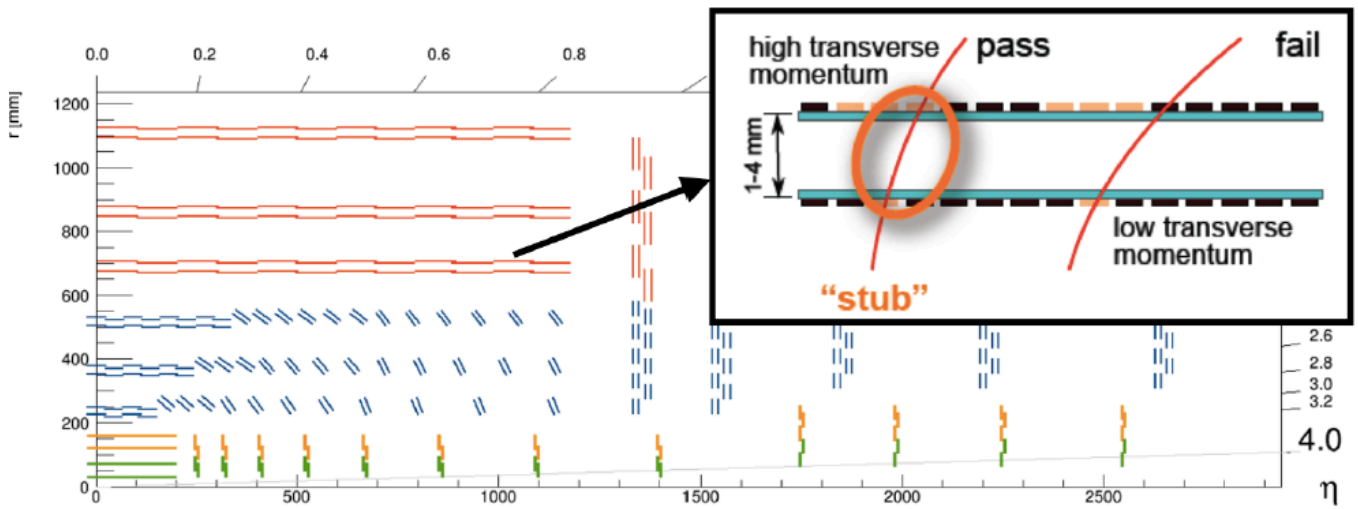
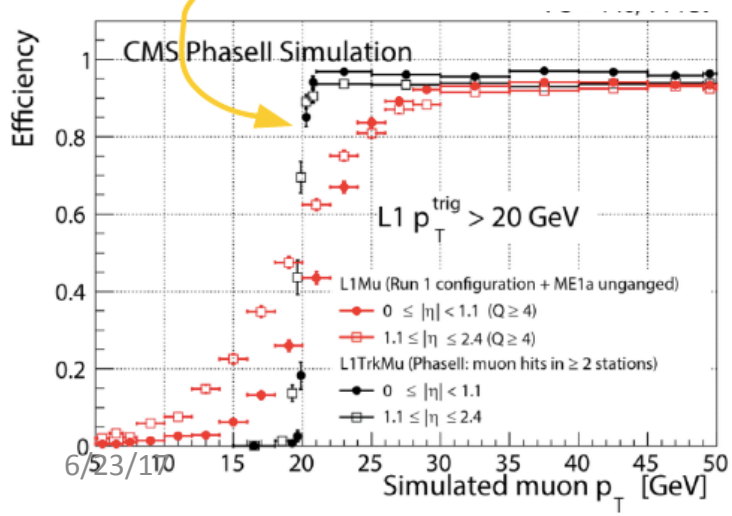
How to cope with HL-LHC conditions?

CMS Detector Upgrades

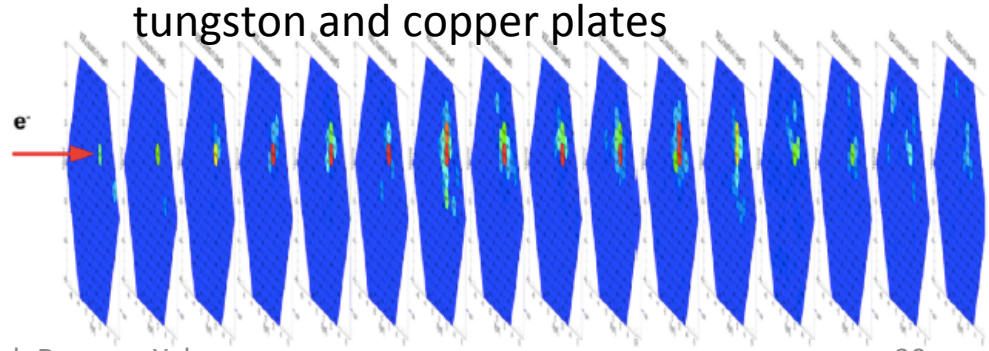
CMS self-seeded track trigger



Sharper turn on



endcap calorimeter, 6 million channels
tungston and copper plates



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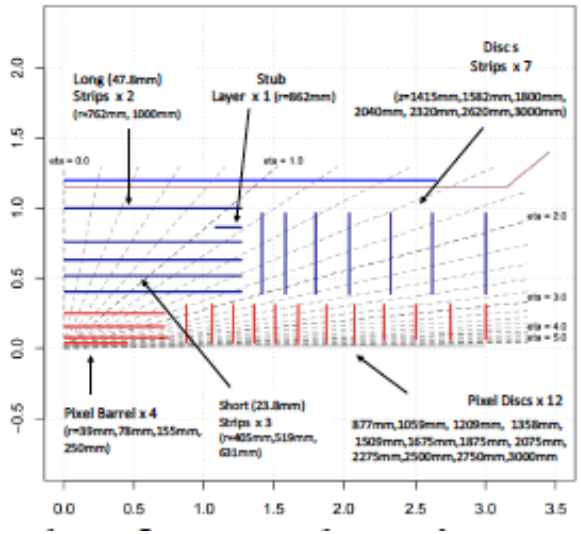
How to cope with HL-LHC conditions?

ATLAS Detector Upgrades



fully silicon tracking detector & upgraded trigger and data acquisition

Now

Level-1 Hardware processors — 100 kHz

↓

High Level Trigger Computer Farm — 1 kHz

↓

Data Recording

HL-LHC Upgrade

Level-0 Hardware processors — 1 MHz

↓

Level-1 Hardware processors — 400 kHz ← Track info

↓

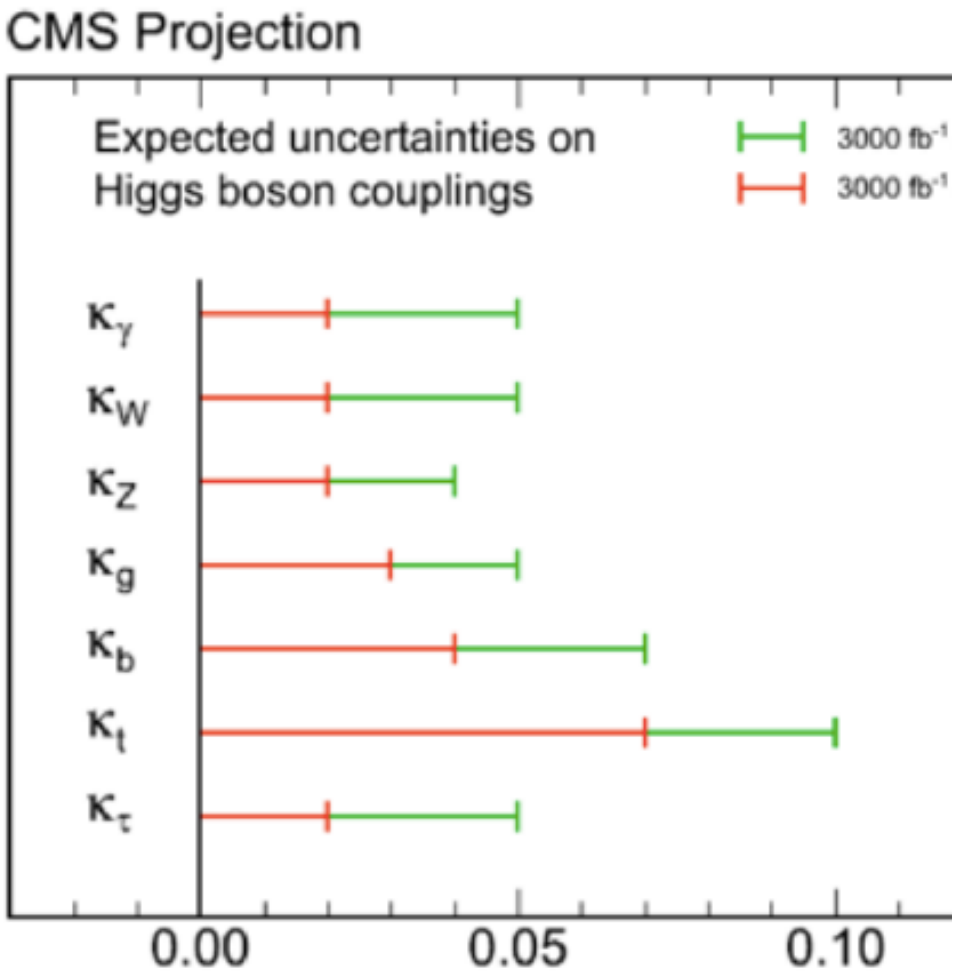
FTK+Event Filter Computer Farm — 10 kHz

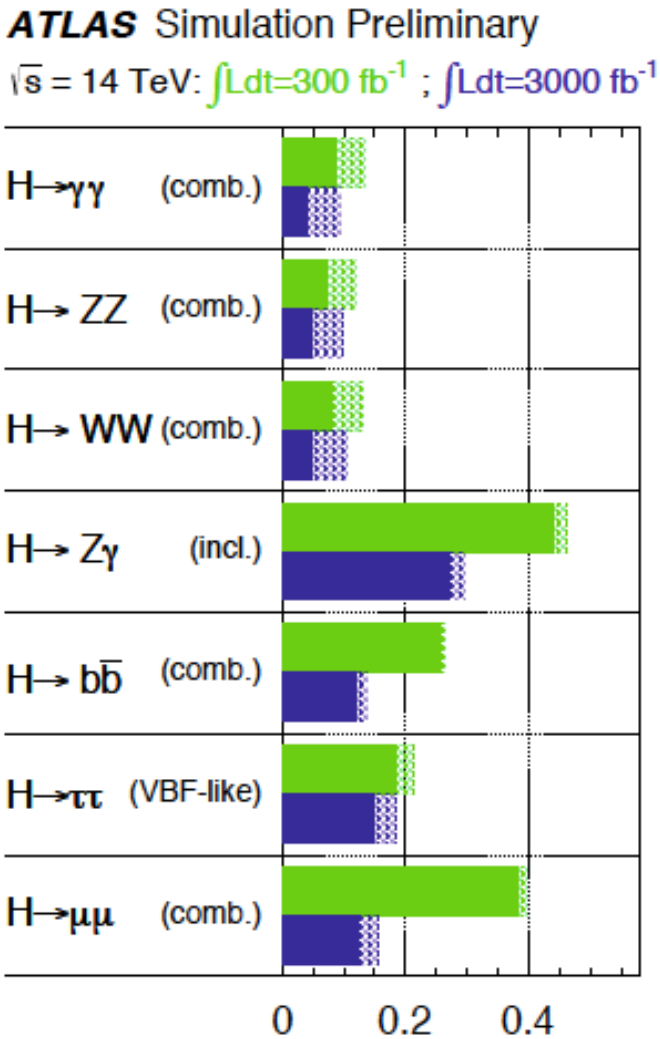
FTK: Fast TracKer Trigger

HL-LHC Physics Prospects

ATLAS: Tulin Varol CMS: Petar Maksimovic

A 125 GeV SM Higgs Boson





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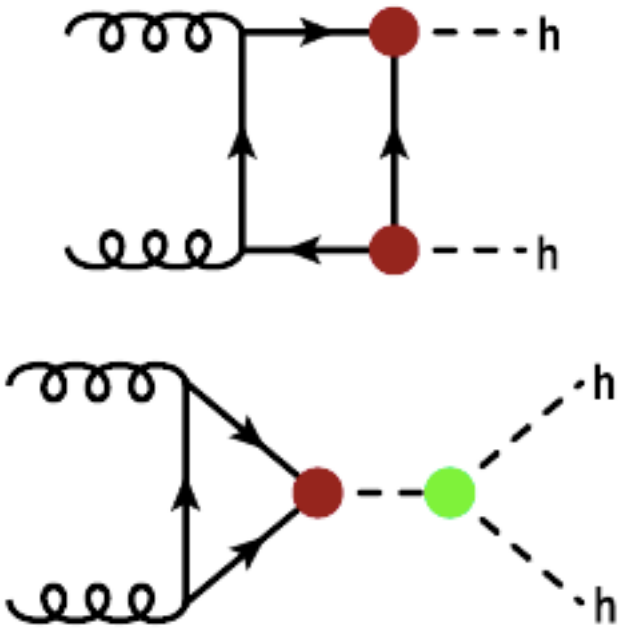
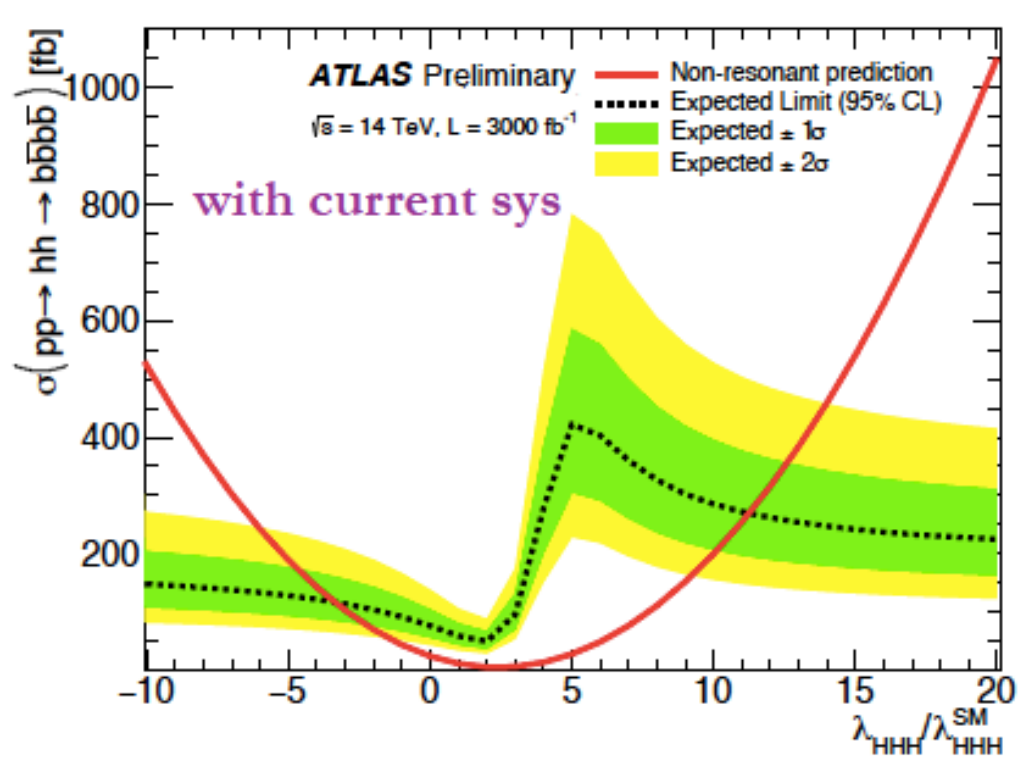
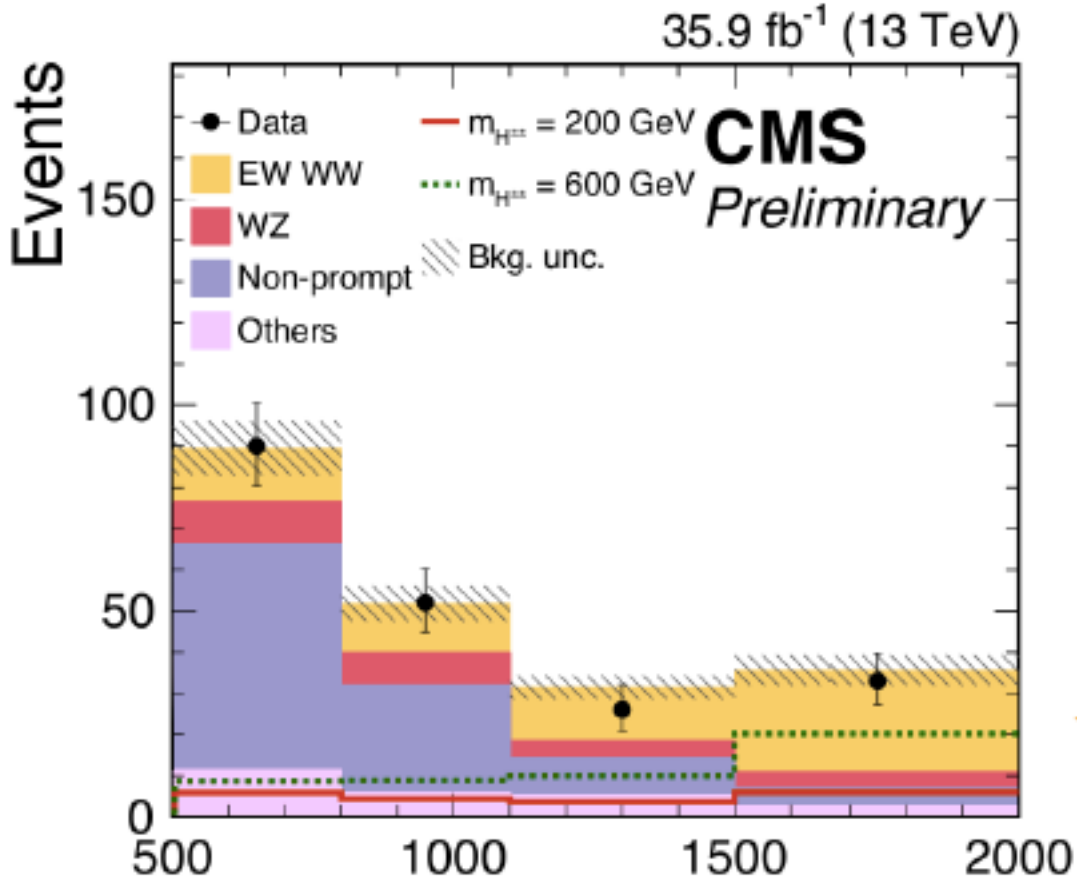
Higgs Self-Coupling

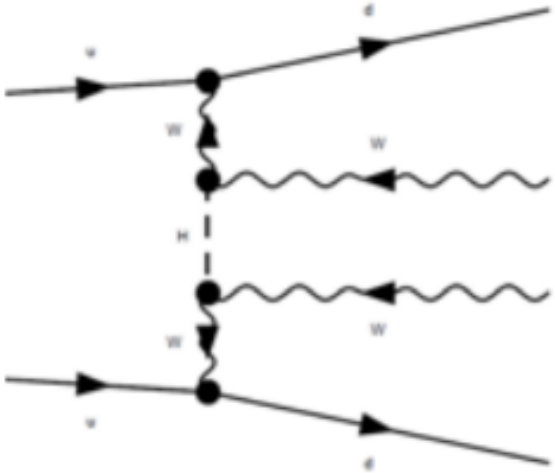


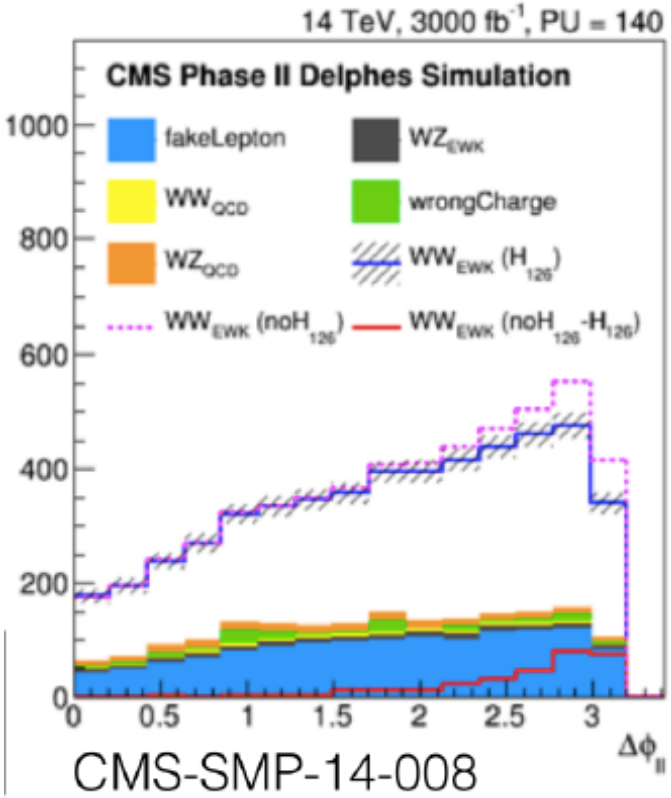


Jet Threshold [GeV]	Background Systematics	σ/σ_{SM} 95% Exclusion	$\lambda_{HHH}/\lambda_{HHH}^{SM}$ Lower Limit	$\lambda_{HHH}/\lambda_{HHH}^{SM}$ Upper Limit
30 GeV	Negligible	1.5	0.2	7
30 GeV	Current	5.2	-3.5	11
75 GeV	Negligible	2.0	-3.4	12
75 GeV	Current	11.5	-7.4	14

WW Scattering







CMS-SMP-14-008

- For now, the BSM landscape looks very much like this

Roberto Rossin

- For now, the BSM landscape looks very much like this

Roberto Rossin

I would have been much happier with this

• For now, the BSM landscape looks very much like this

Roberto Rossin

I would have be

The LHC has only delivered approximately 5% of the expected data, and is not yet at full design luminosity.

While the situation is sobering, depression on account of no new physics is premature.

It's time for all hands on deck!