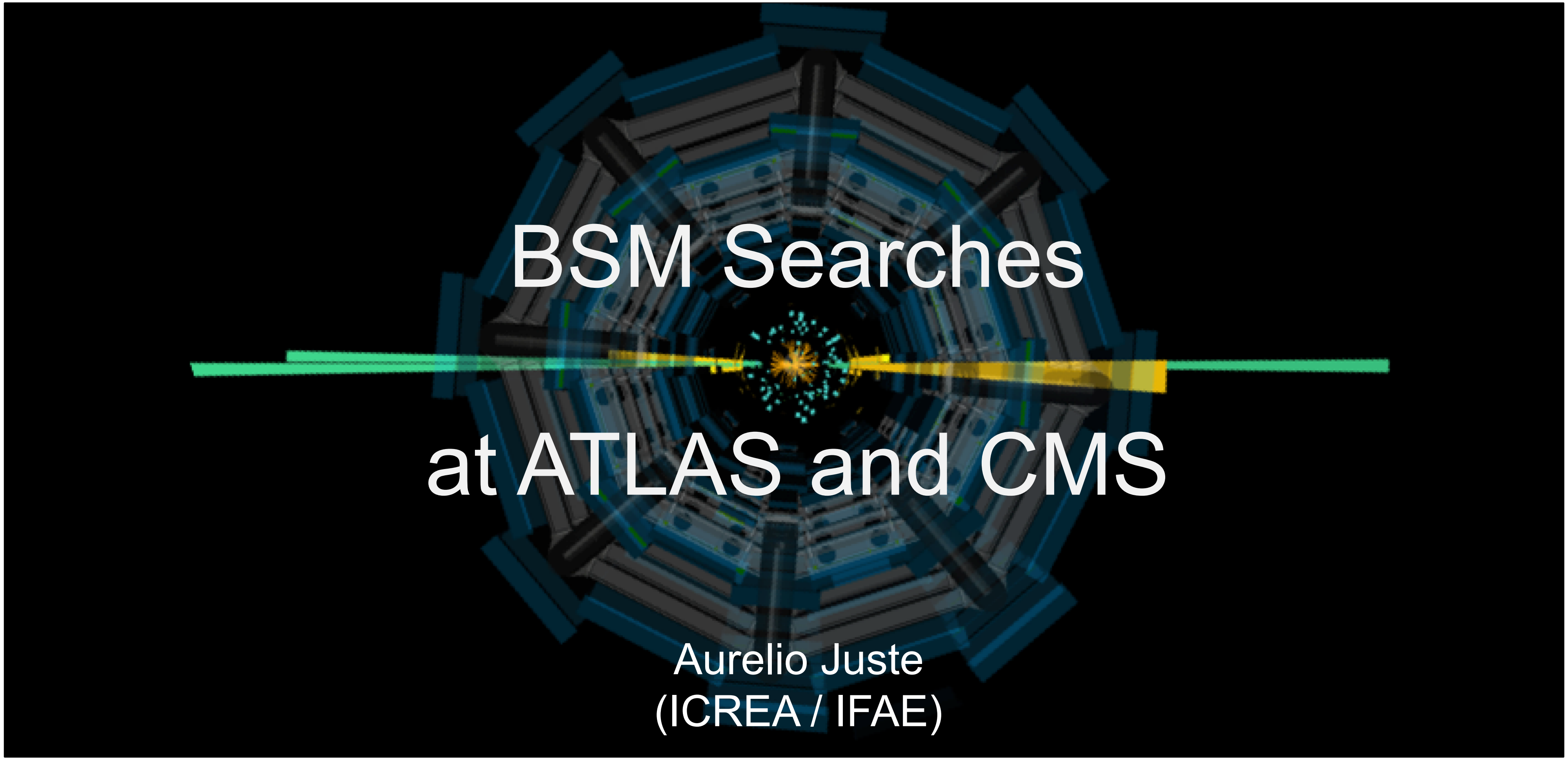
XXIII IFT Christmas Workshop, IFT, Madrid, December 13-15, 2017

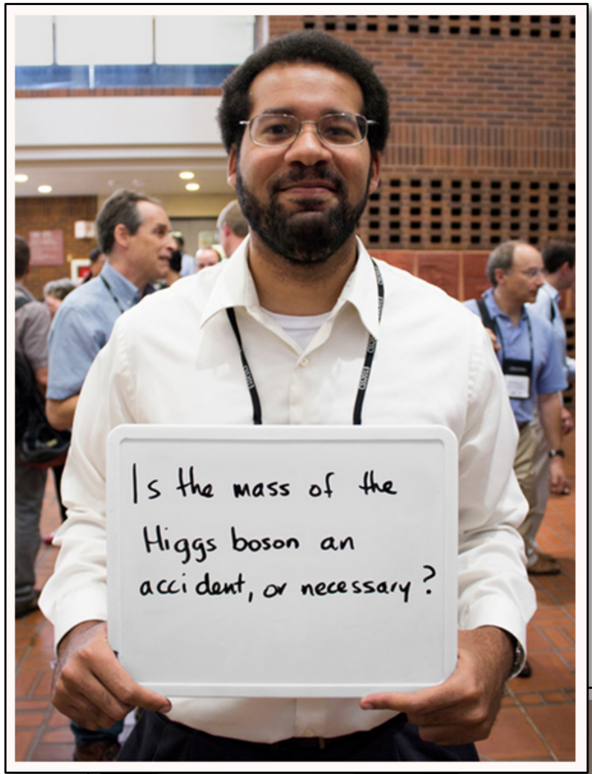


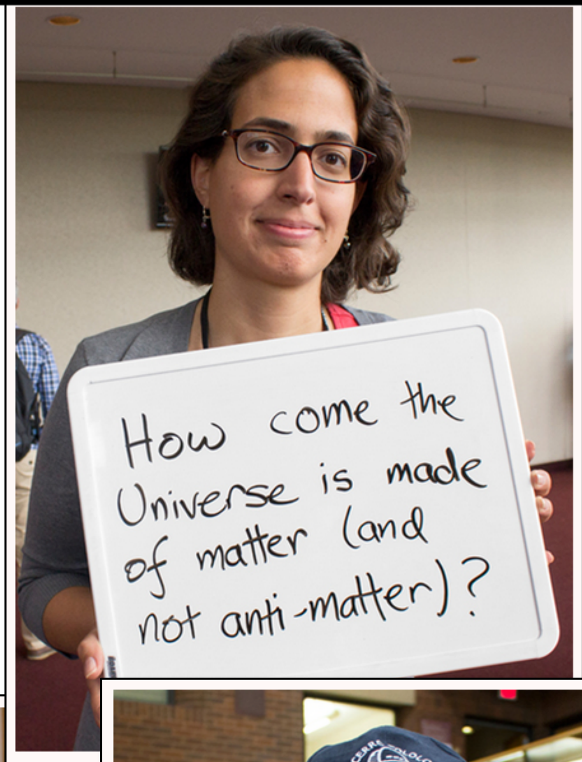
BSM Searches at ATLAS and CMS

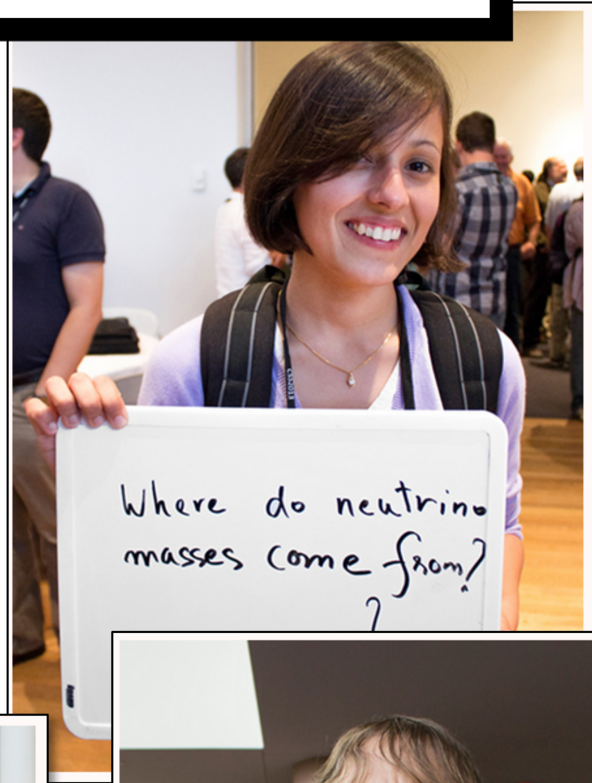
Aurelio Juste
(ICREA / IFAE)

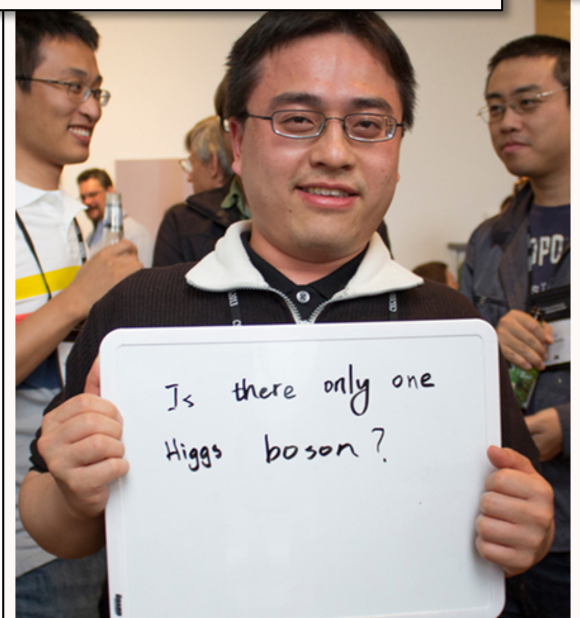
On behalf of the ATLAS and CMS Collaborations

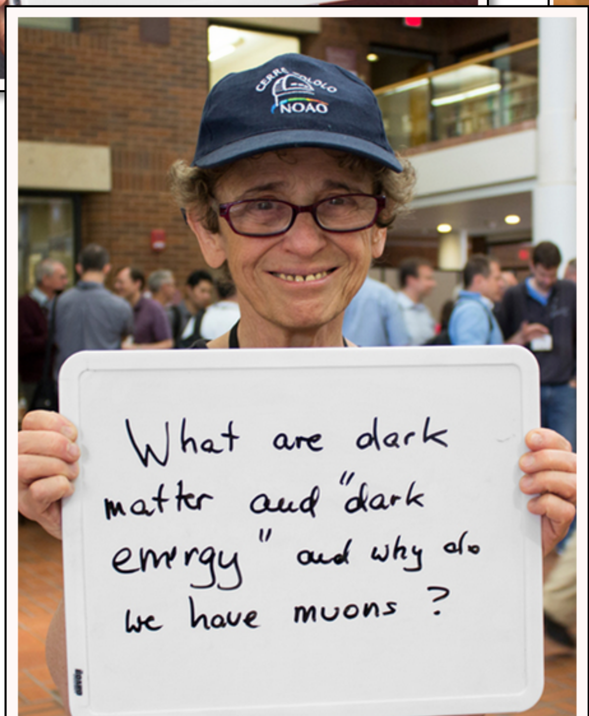
Pursuing big questions

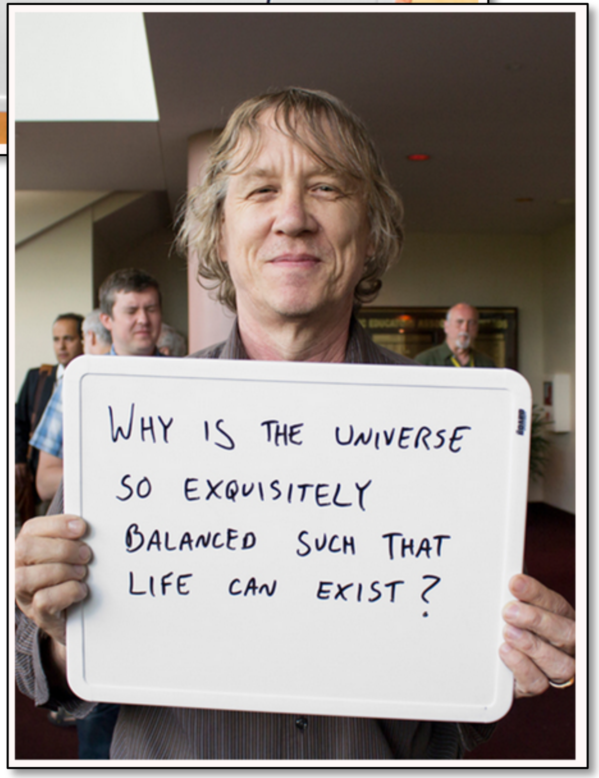




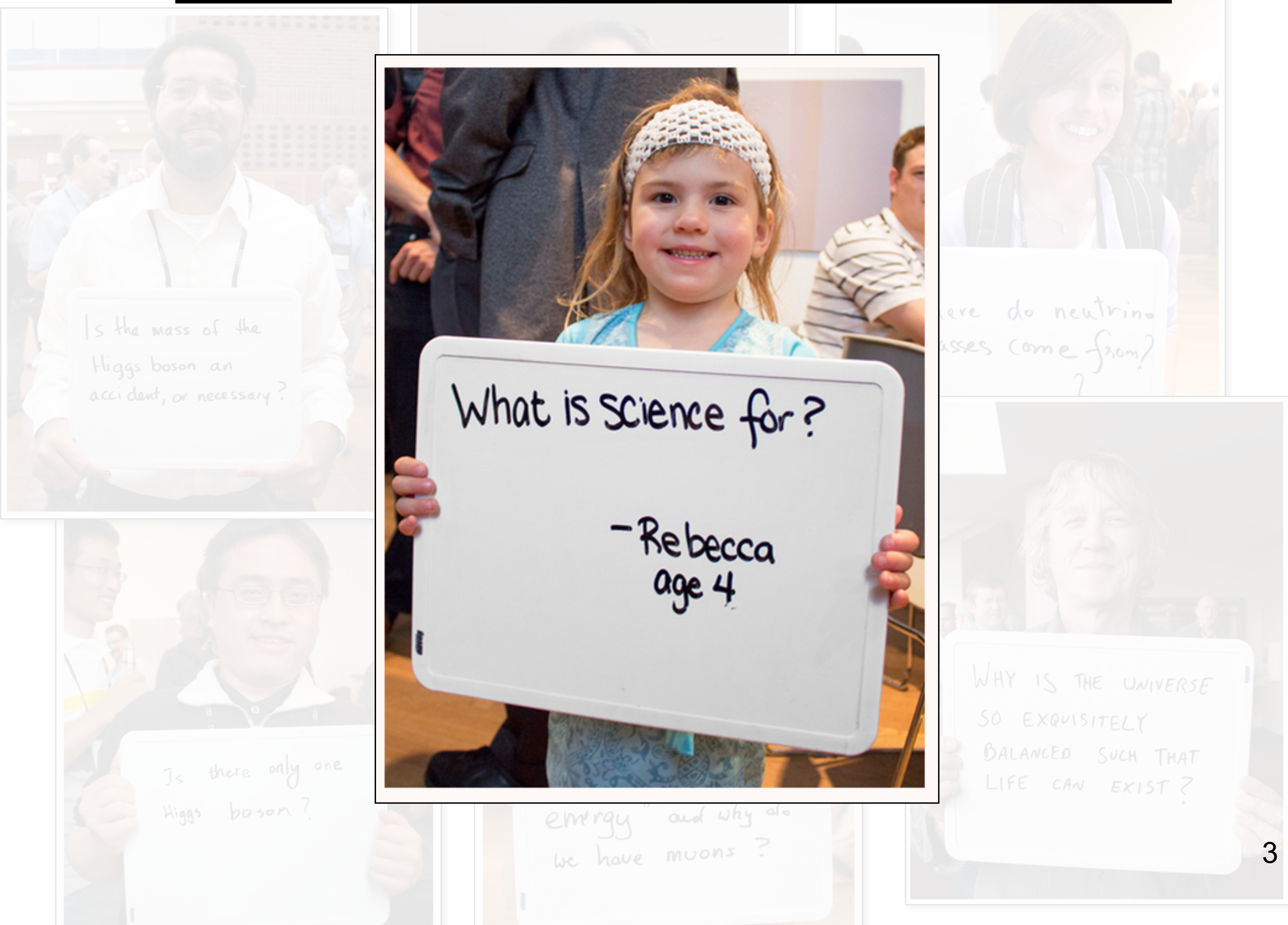




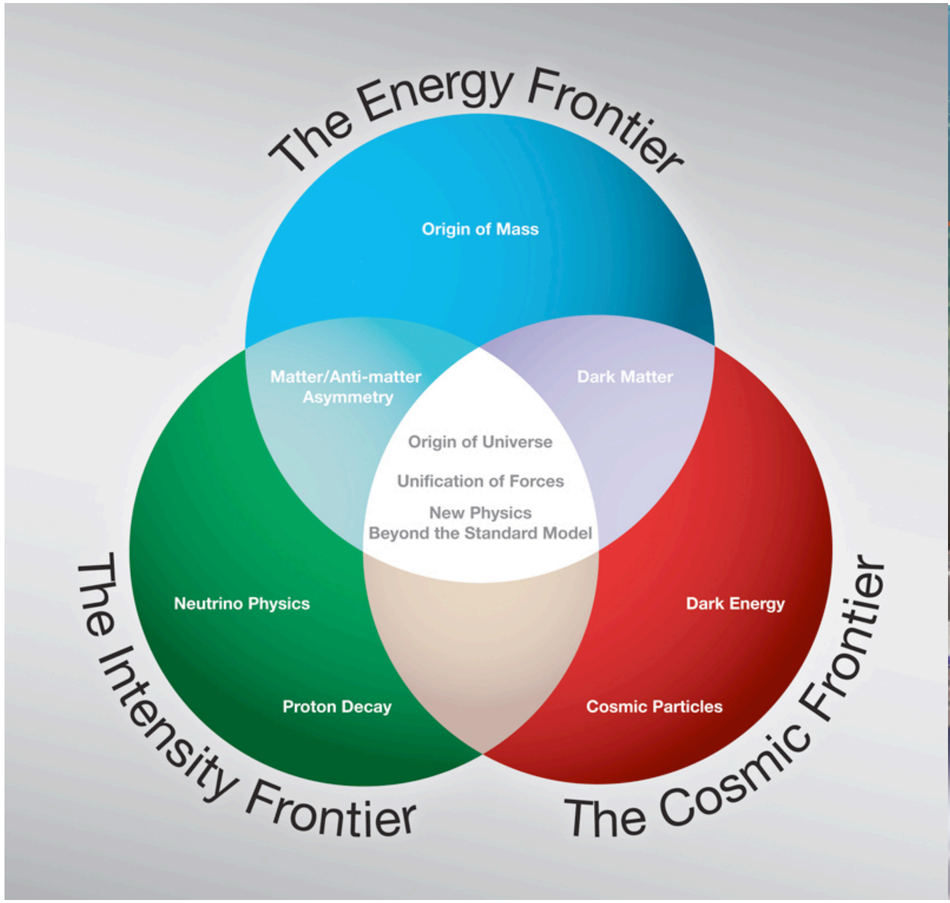


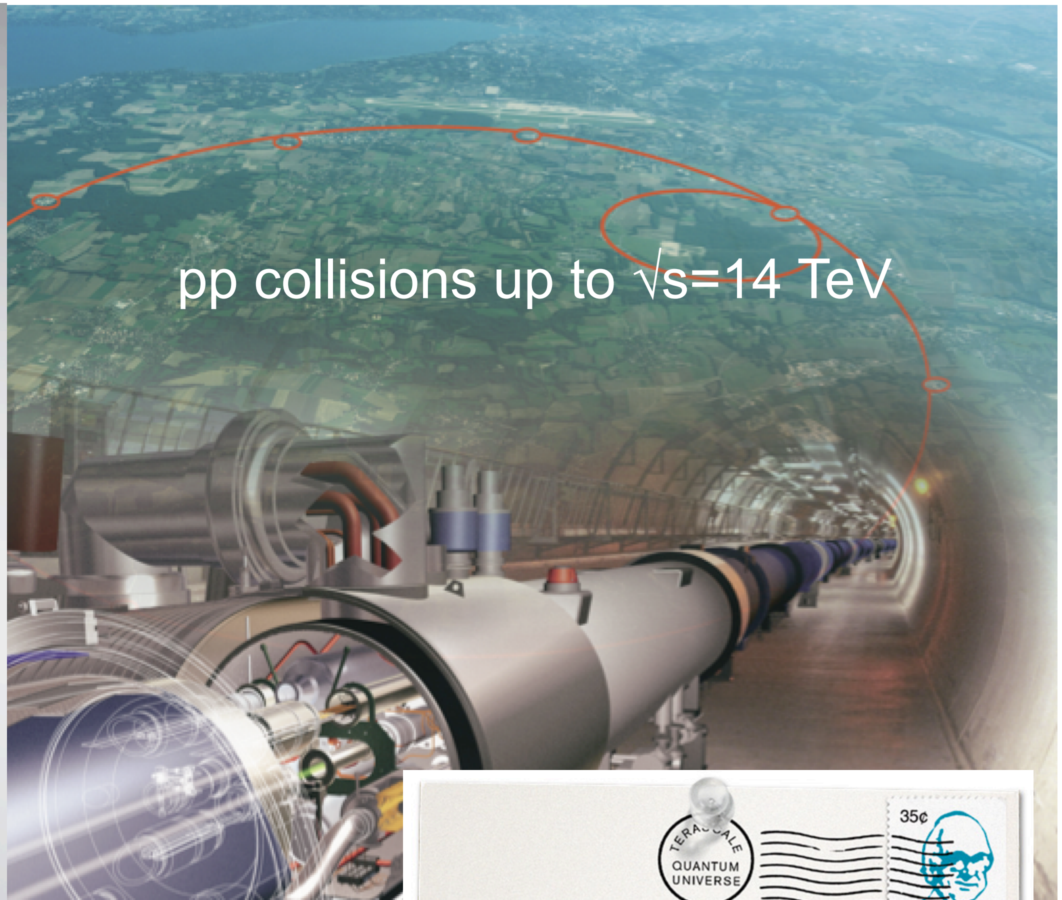


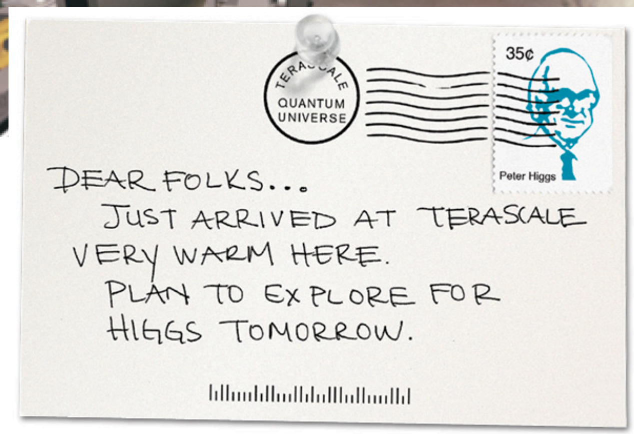
Pursuing big questions



The LHC and the Energy Frontier







The LHC represents an extremely powerful instrument to search for New Physics (NP):

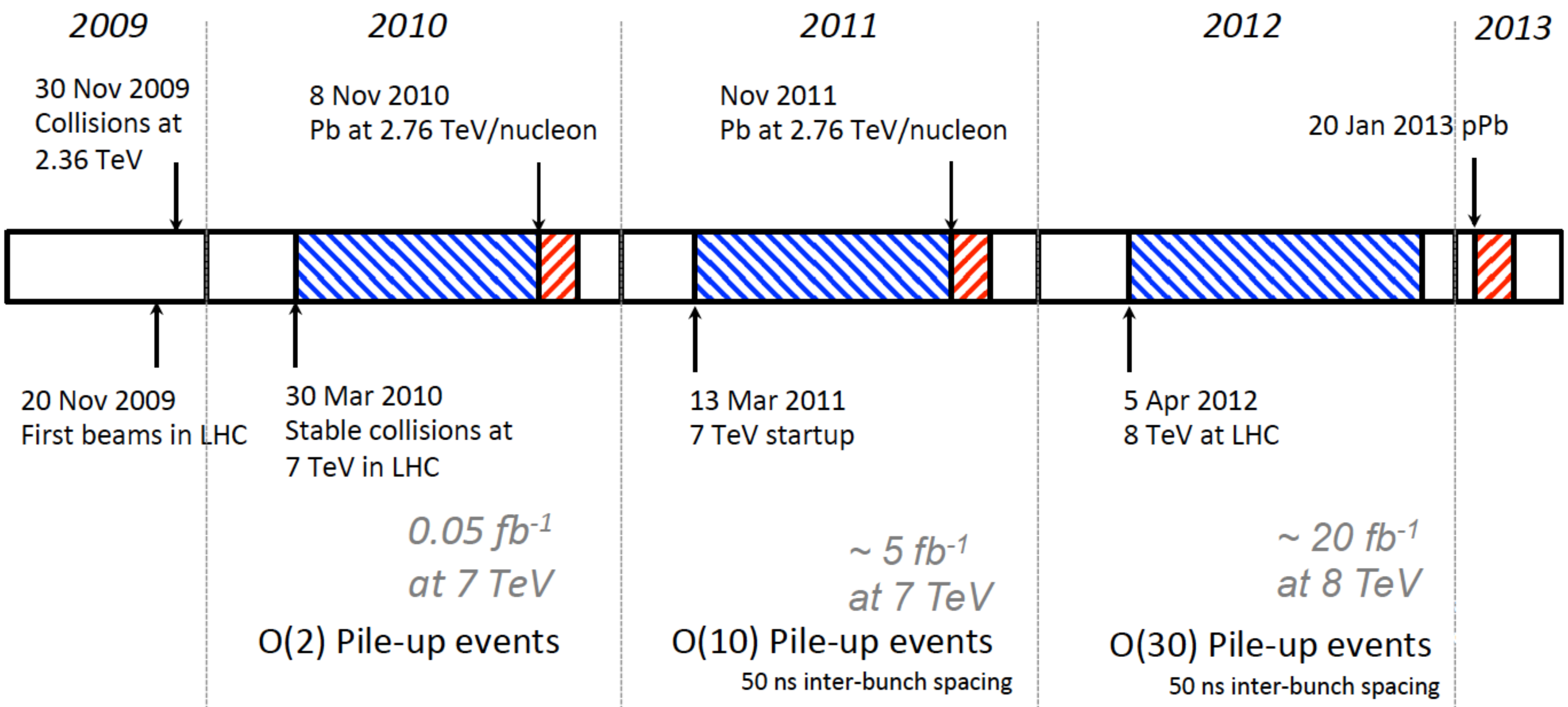
- Direct searches for new particles in a plethora of kinematic regions and final state signatures.
- Broad program of precise measurements of SM processes and parameters.

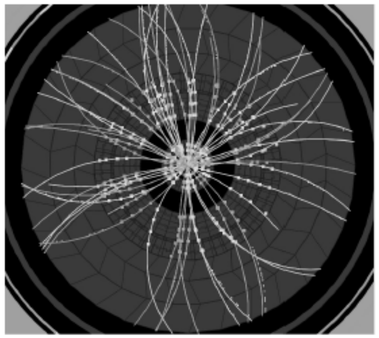
Outline

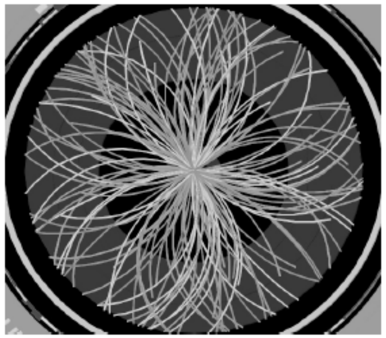
- Introduction
  - LHC Run 1 recap and Run 2 status
  - Indirect searches (precision measurements)
- Overview of direct searches (*)
  - New physics in the Higgs sector
  - Supersymmetry searches
  - Exotics searches (vector-like quarks, dark matter, new heavy resonances, long-lived particles)
- Summary and outlook

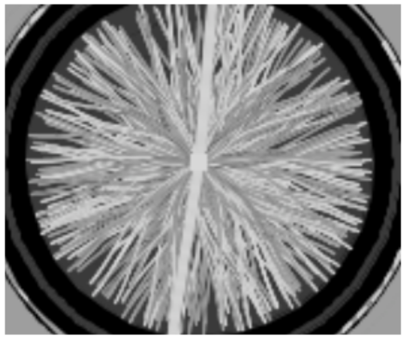
(*) Focused on Run 2. Just a few selected results shown.

LHC Run 1

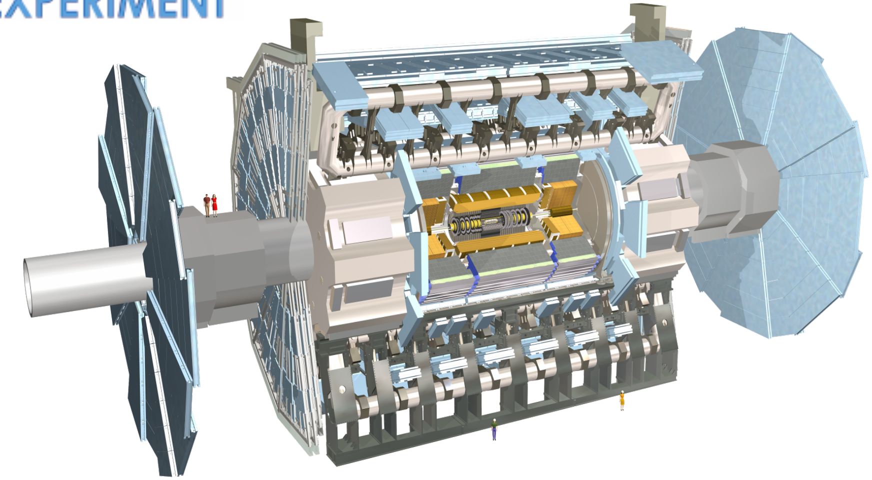

2009
2010
2011
2012
2013
30 Nov 2009
Collisions at
2.36 TeV
8 Nov 2010
Pb at 2.76 TeV/nucleon
Nov 2011
Pb at 2.76 TeV/nucleon
20 Jan 2013 pPb
20 Nov 2009
First beams in LHC
30 Mar 2010
Stable collisions at
7 TeV in LHC
13 Mar 2011
7 TeV startup
5 Apr 2012
8 TeV at LHC
0.05 fb-1
at 7 TeV
~ 5 fb-1
at 7 TeV
~ 20 fb-1
at 8 TeV
O(2) Pile-up events
O(10) Pile-up events
50 ns inter-bunch spacing
O(30) Pile-up events
50 ns inter-bunch spacing

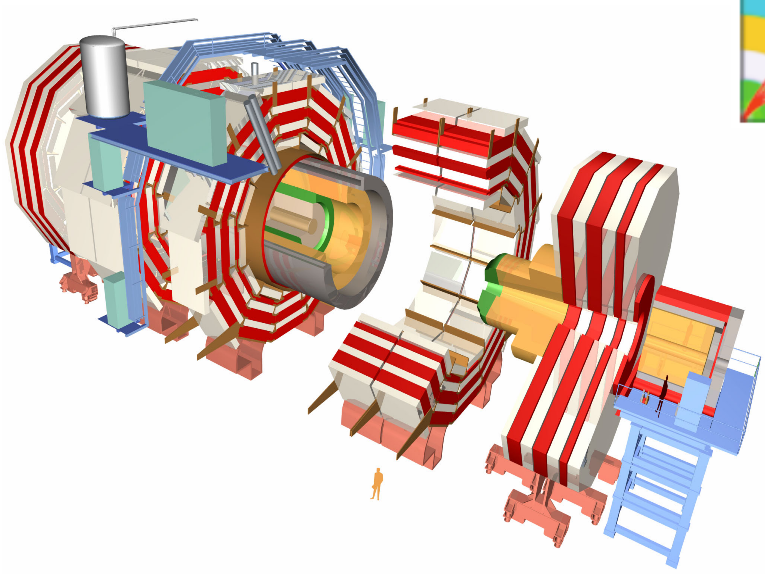




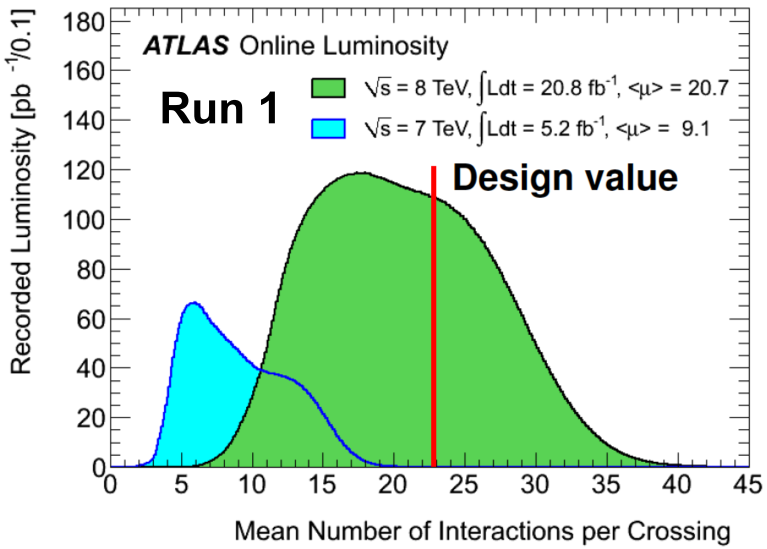


ATLAS and CMS experiments

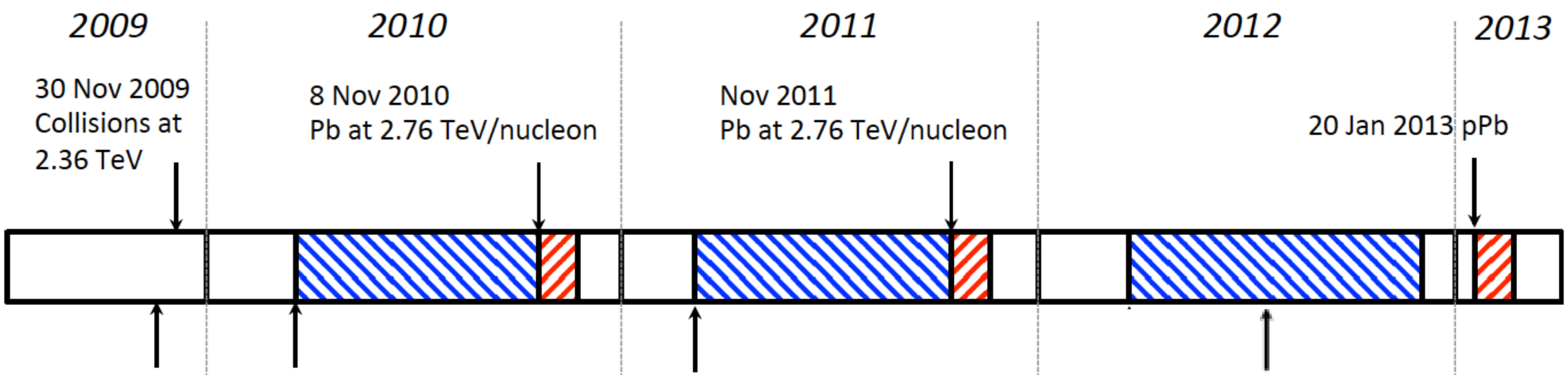




- Multipurpose detectors:
  - Central tracking in solenoidal B field
  - Electromagnetic and hadronic calorimeters
  - Muon detectors
- Excellent performance up to the highest instantaneous luminosities delivered by the LHC. ~93% data-taking efficiency.



LHC Run 1

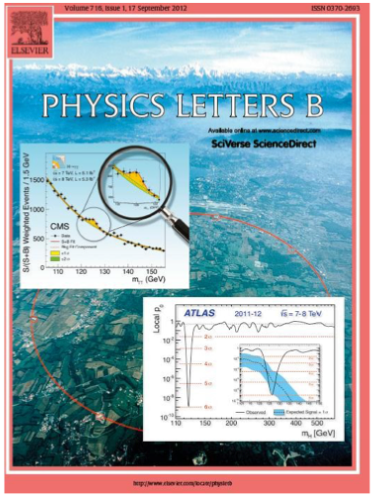


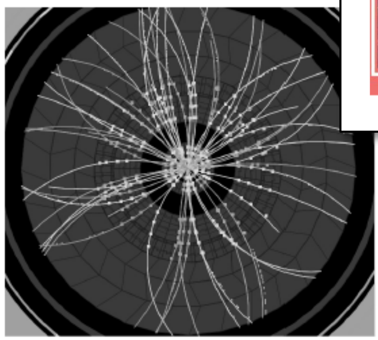
0.05 fb⁻¹

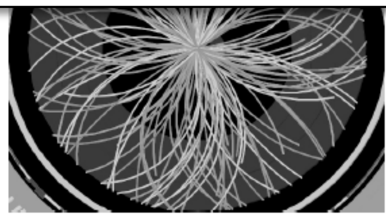
at 7 TeV

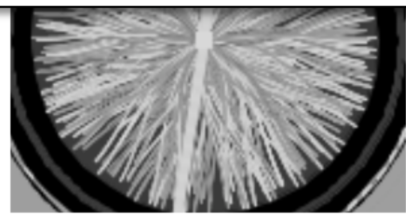
O(2) Pile-up event

4 July 2012: Higgs boson discovery

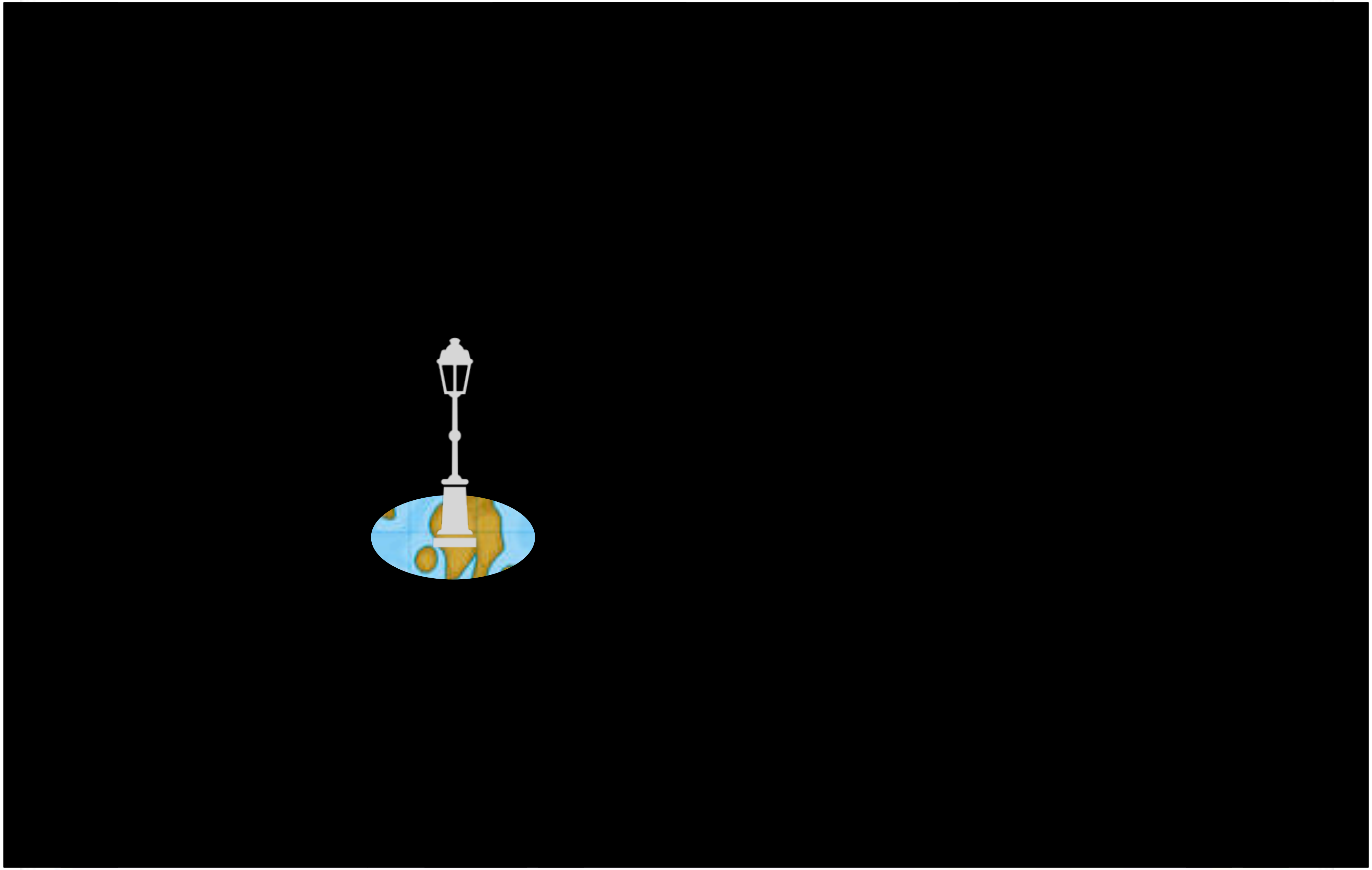








How do we explore the BSM landscape?



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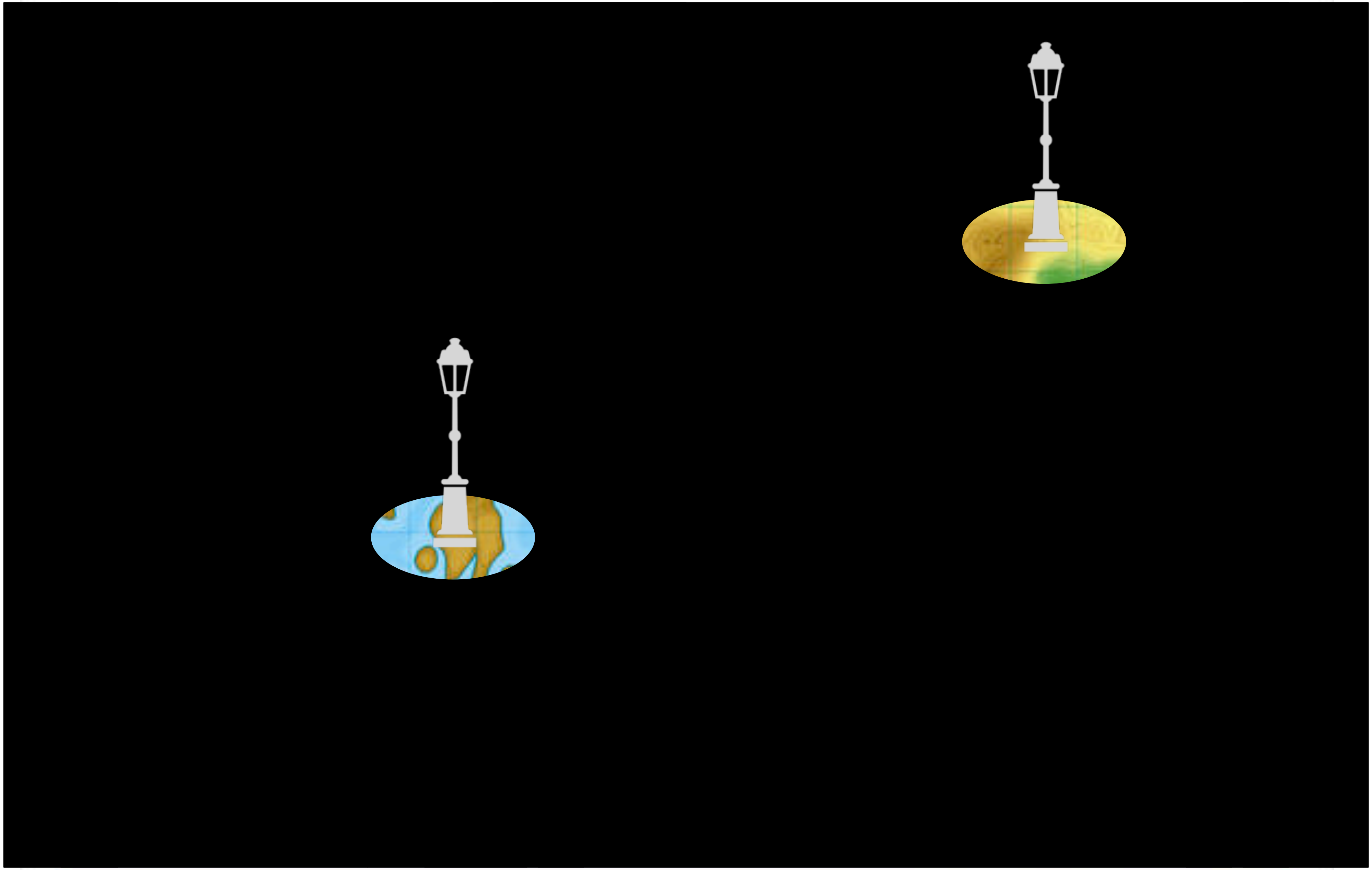

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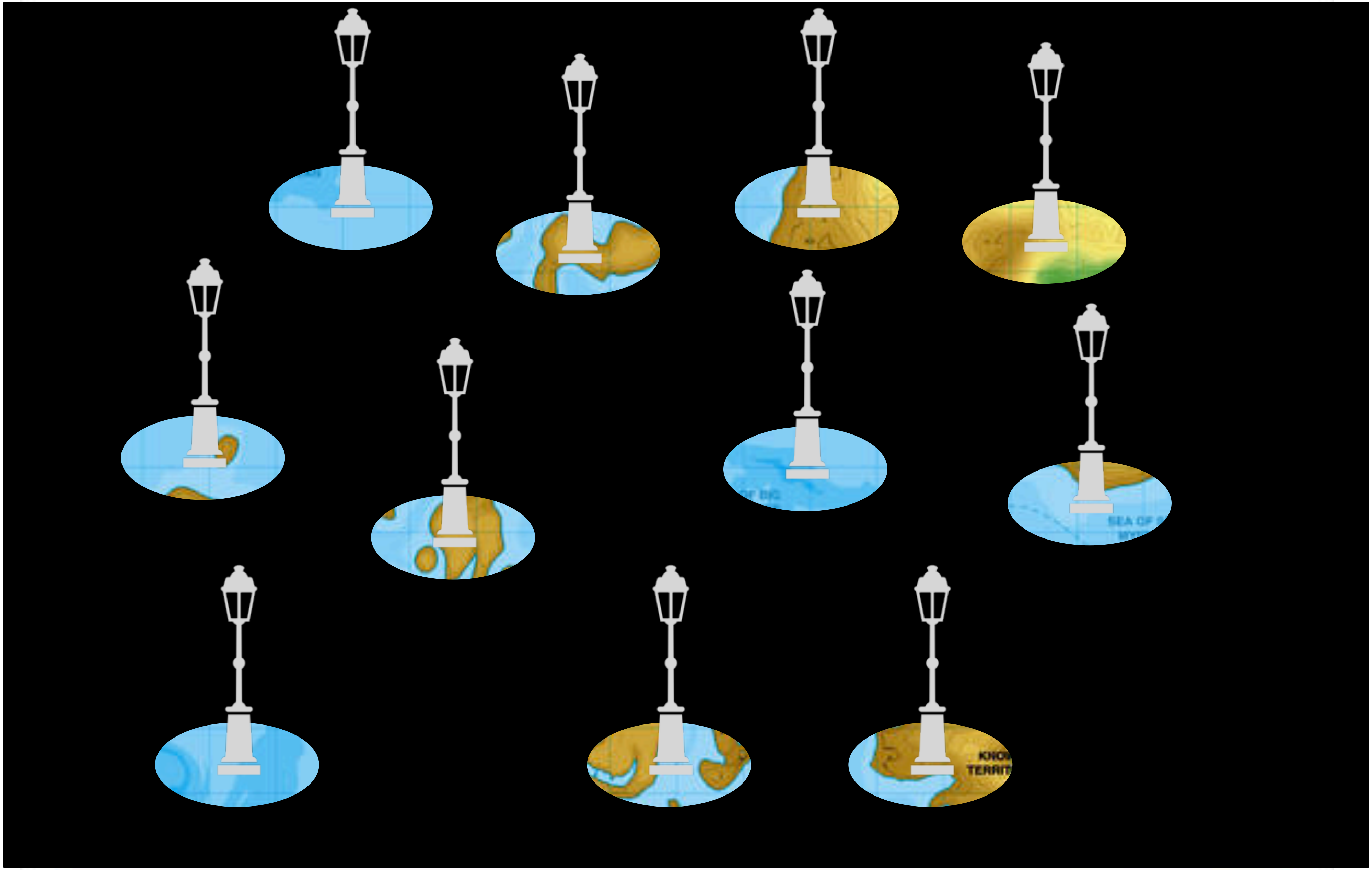
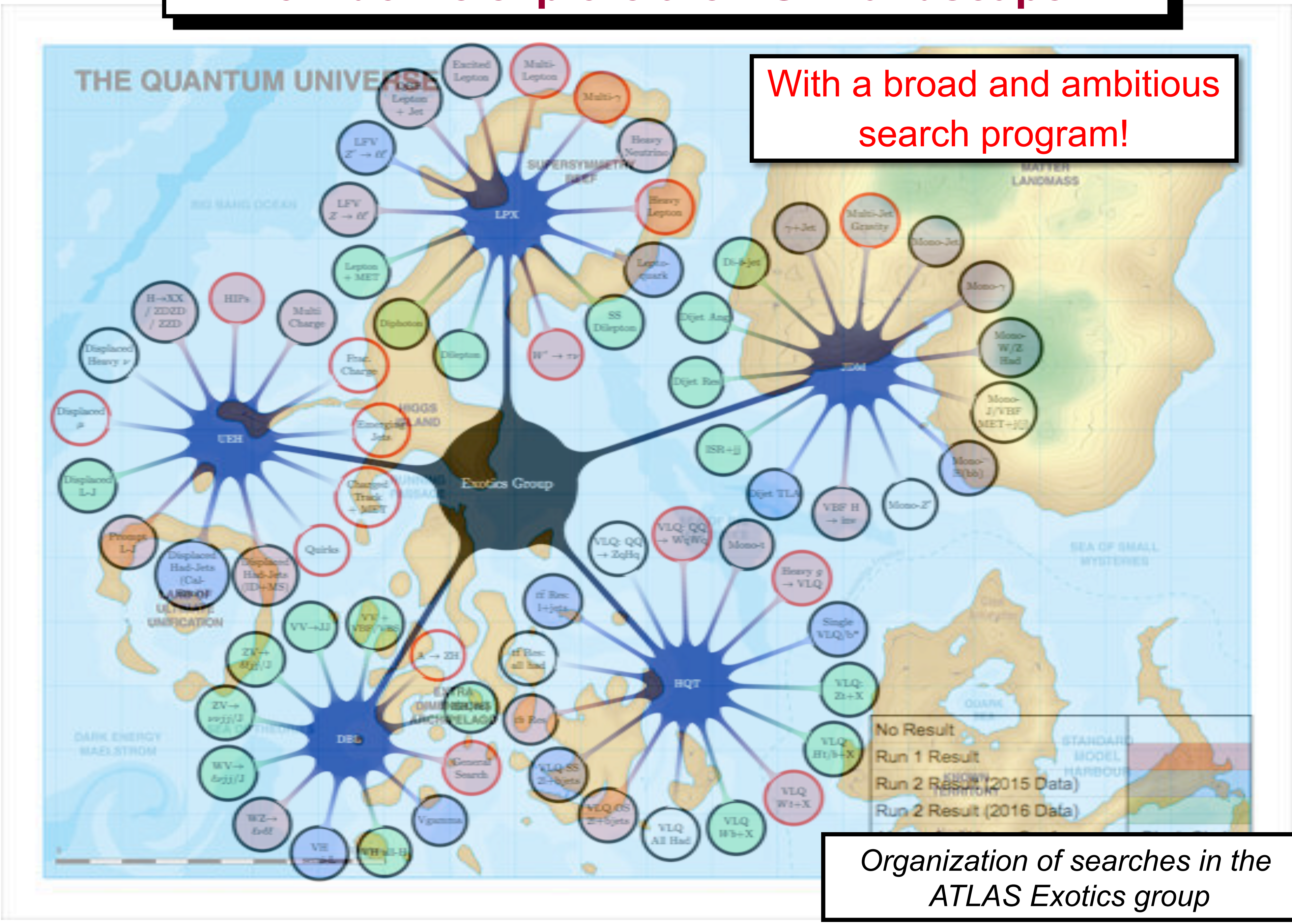


How do we explore the BSM landscape?

How do we explore the BSM landscape?

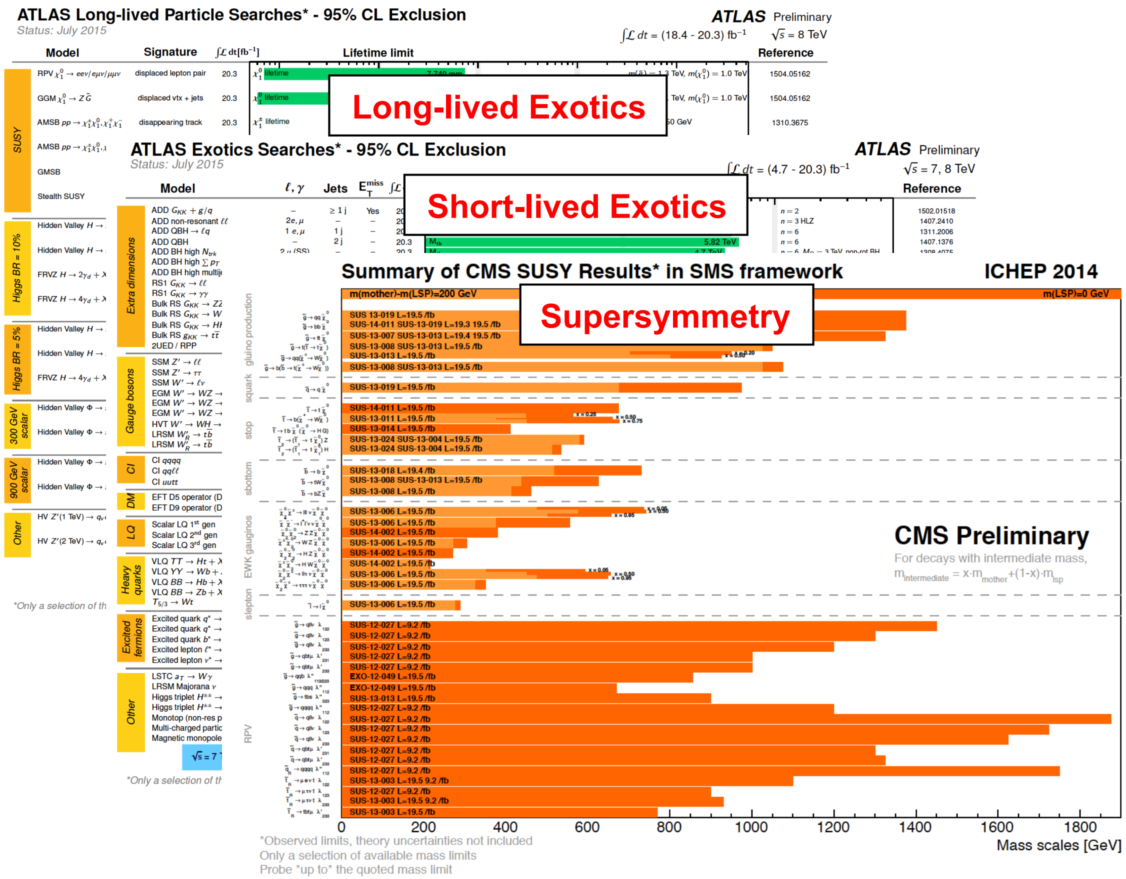
With a broad and ambitious search program!



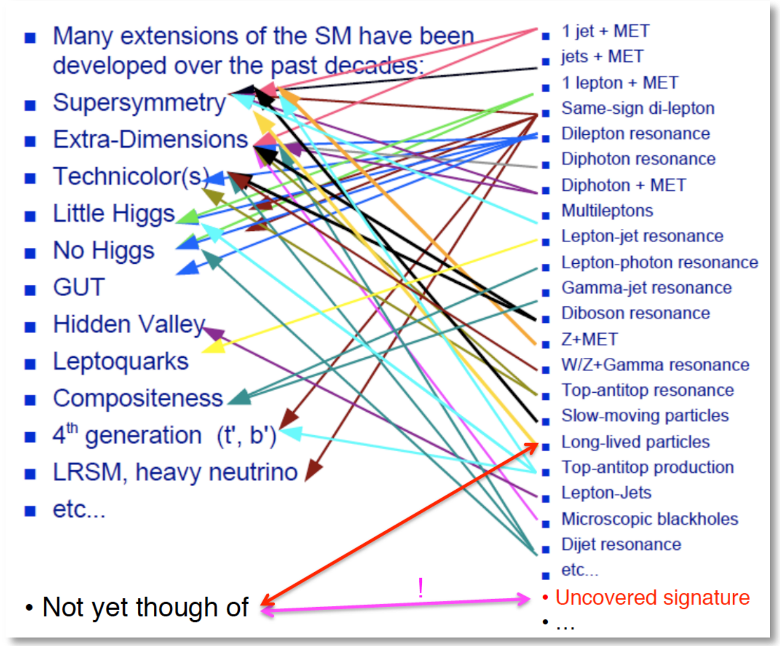
Organization of searches in the ATLAS Exotics group

LHC Run 1 recap

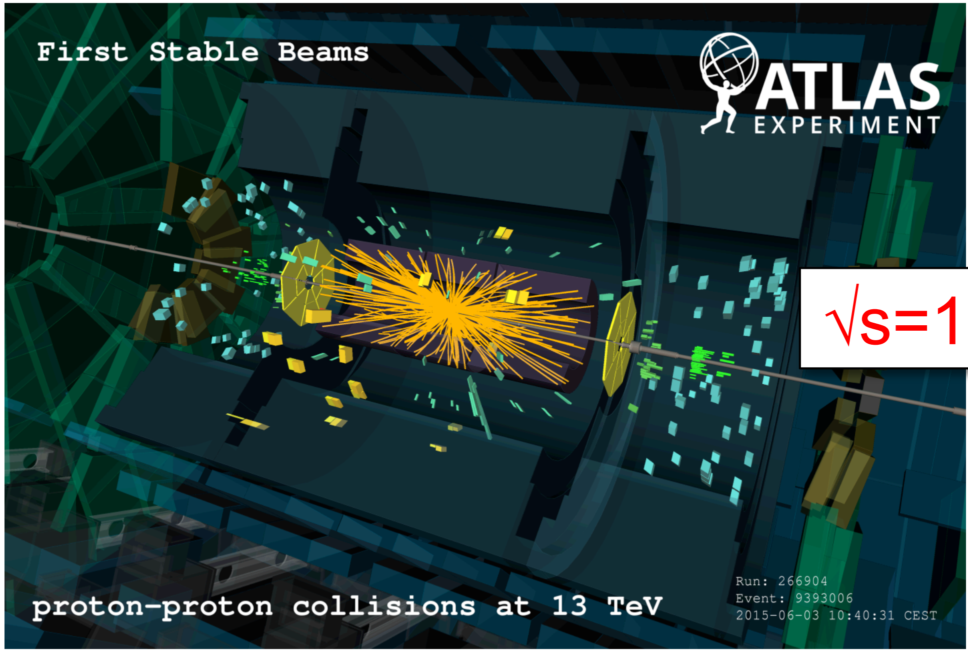
- No clear indications of physics beyond the SM.
  ➔ useful constraints on the parameter space of many NP models.
- Moving forward need to continue to:
  - cast as wide as possible net, even with some theoretical guidance.
  - cover broad phase spaces: many detector signatures, large range of masses, large span in production rates,…



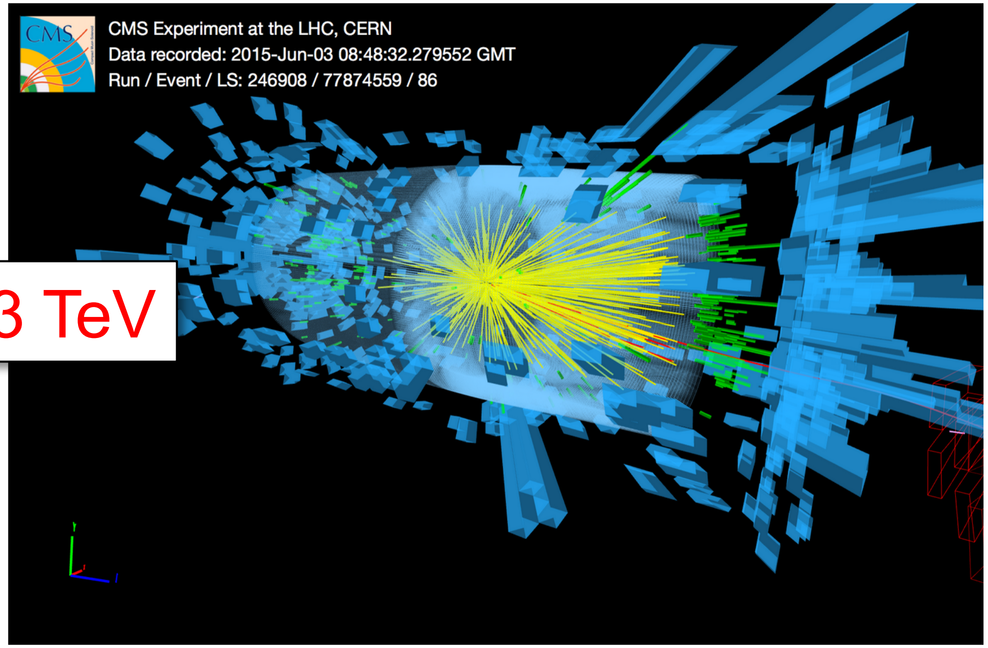
Signature-driven searches



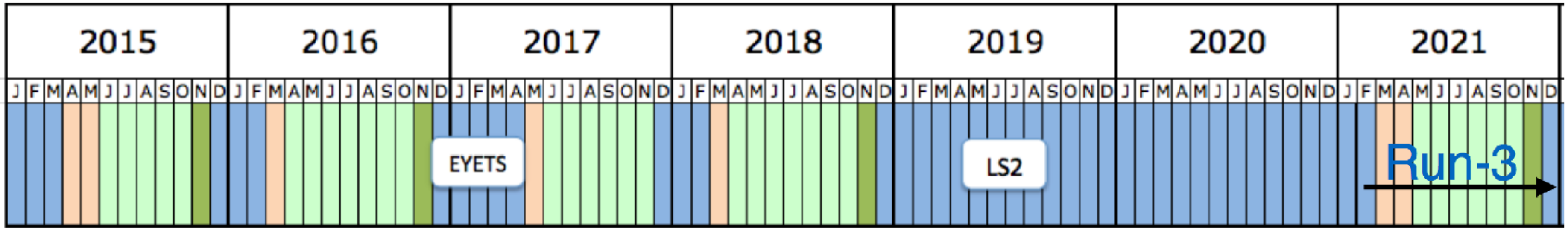
June 3, 2015: Run 2 starts!



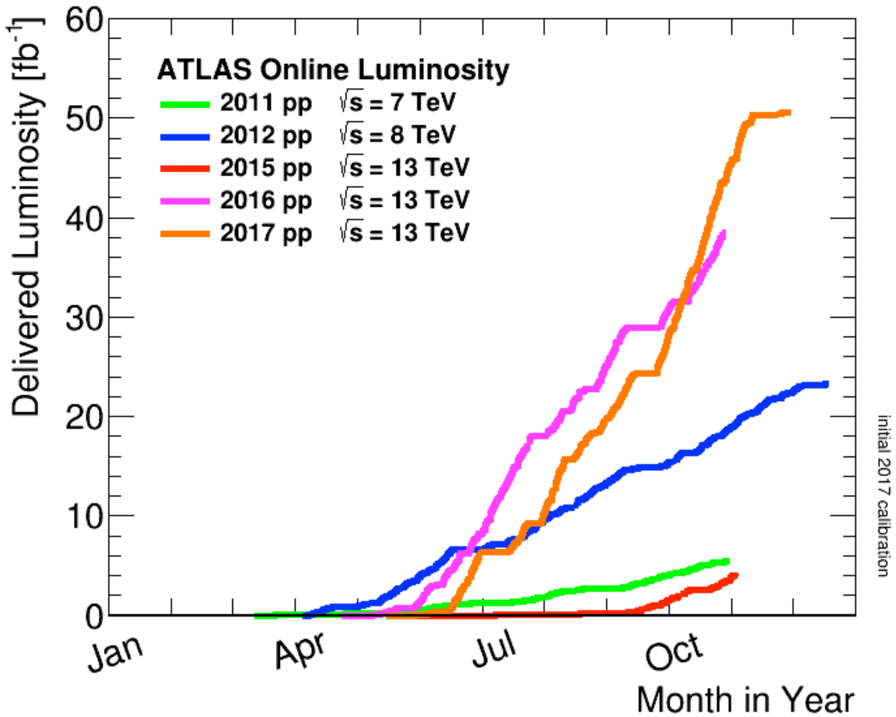
$\sqrt{s}$=13 TeV



Run 2 status/plans



3fb^{-1} 36fb^{-1} Target ~45fb^{-1} x year



Results discussed today

13 TeV pp 2015 dataset (at 25 ns):

- Highest inst. luminosity: 5x10^{33} cm^{-2}s^{-1} (Run 1: 7-8x10^{33} cm^{-2}s^{-1})
- **~3.9 fb^{-1} recorded**

13 TeV pp 2016 dataset:

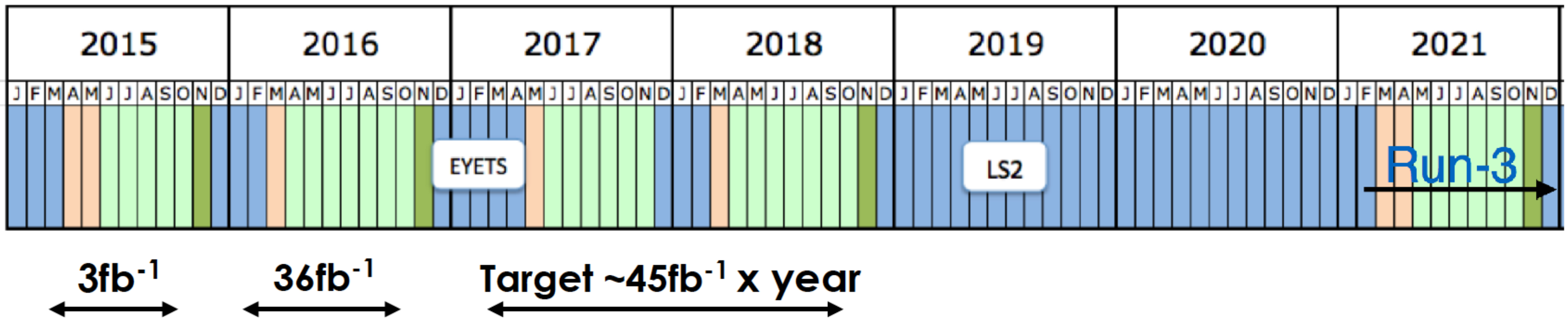
- Record inst luminosity of ~1.4x10^{34} cm^{-2}s^{-1}.
- Record daily delivered luminosity of ~0.6 fb^{-1}.
- **~36 fb^{-1} recorded**

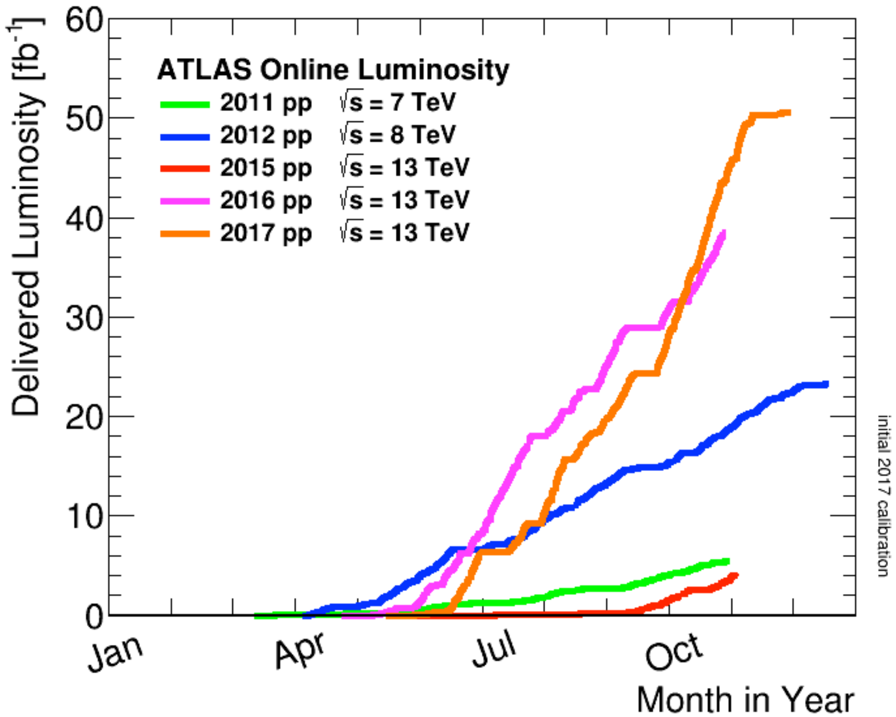
2015+2016: ~36 fb^{-1} analyzed

Full Run 2: expect ~120 fb^{-1}

Outstanding performance!

Run 2 status/plans





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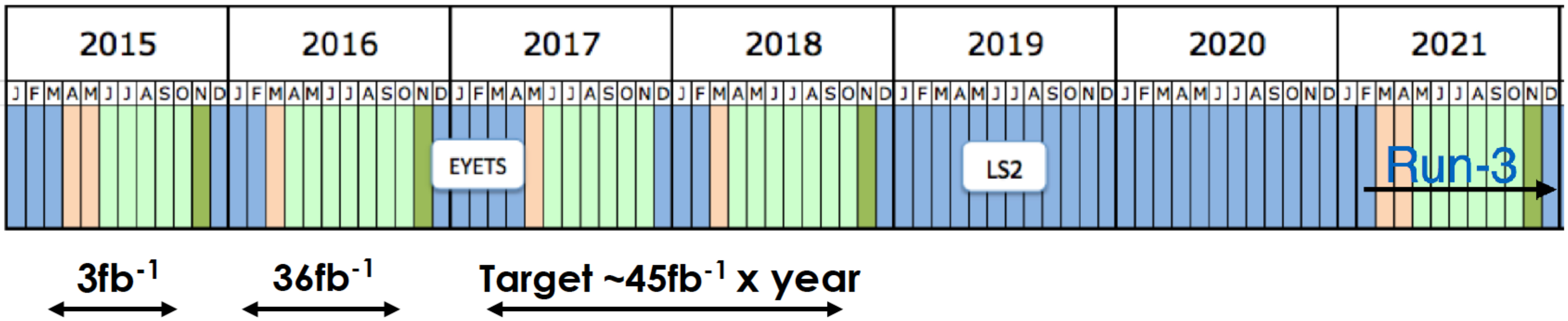
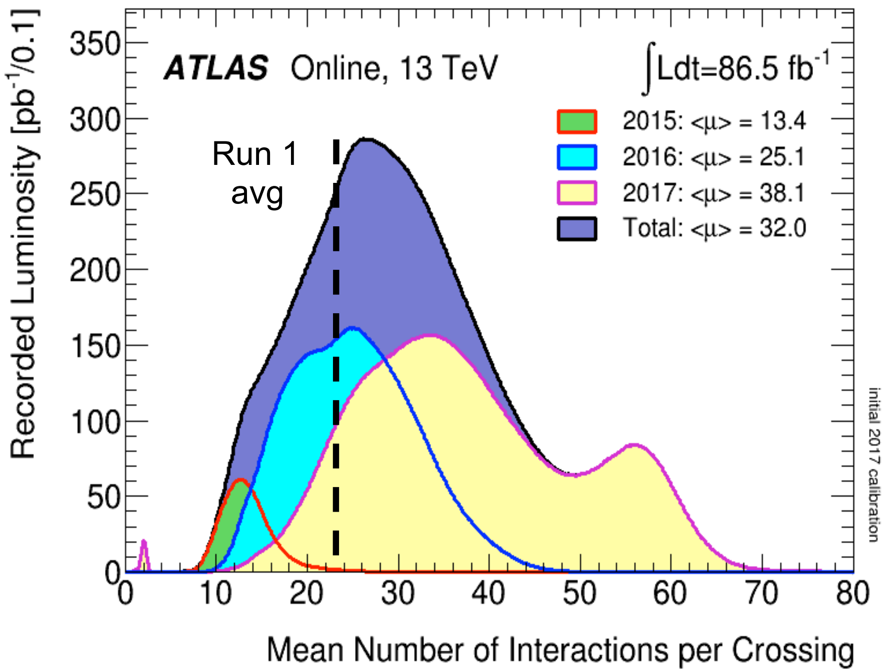
13 TeV pp 2017 dataset:

- Collisions restarted on May 23, 2017.
- Record inst luminosity of ~$2.1x10^{34}$ $cm^{-2}s^{-1}$.
- **~47 fb^{-1} recorded**

Run 2 status/plans





Challenge: average pileup in 2017 of ~38 interactions per bunch crossing

13 TeV pp 2015 dataset (at 25 ns):

- Highest inst. luminosity: 5×10^{33} $cm^{-2}s^{-1}$ (Run 1: 7-8×10^{33} $cm^{-2}s^{-1}$)
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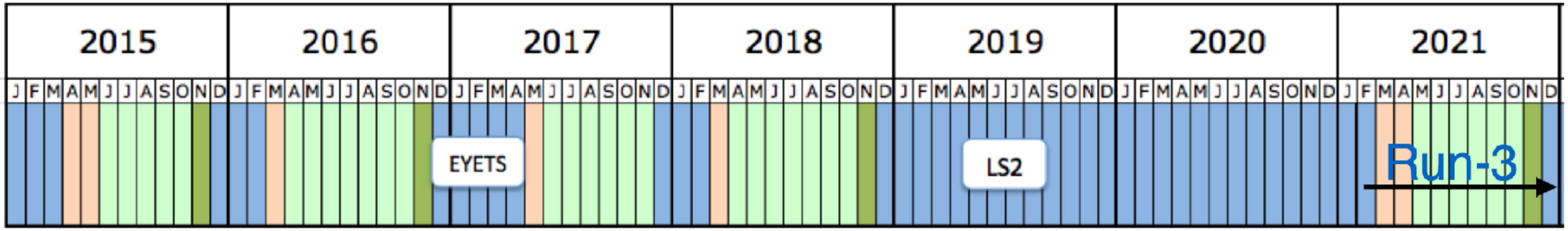
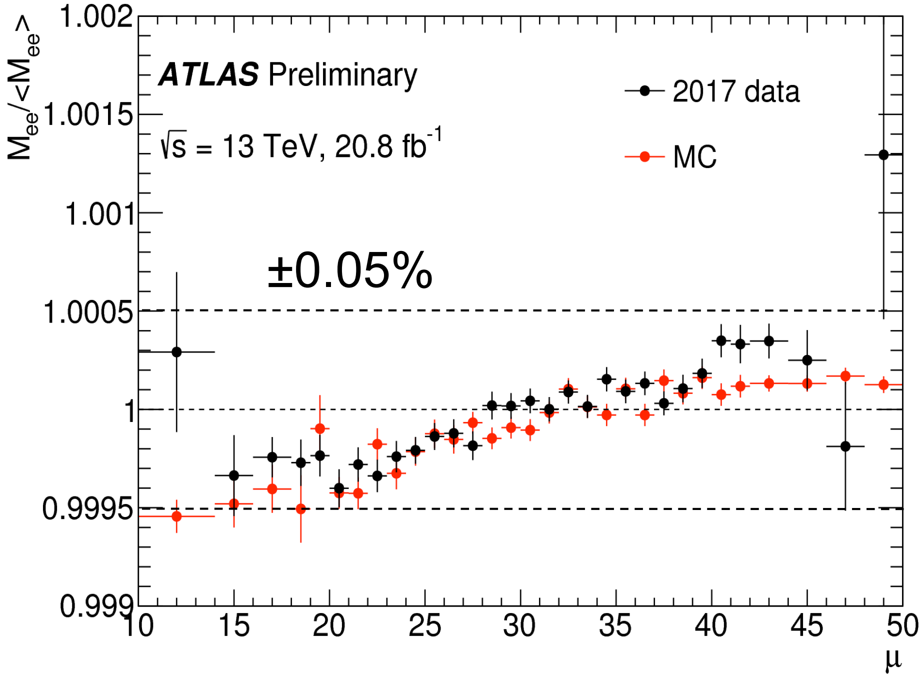
Run 2 status/plans



3fb^{-1} 36fb^{-1} Target ~45fb^{-1} x year



Sophisticated reconstruction/calibration algorithms are **able to handle pileup**

13 TeV pp 2015 dataset (at 25 ns):

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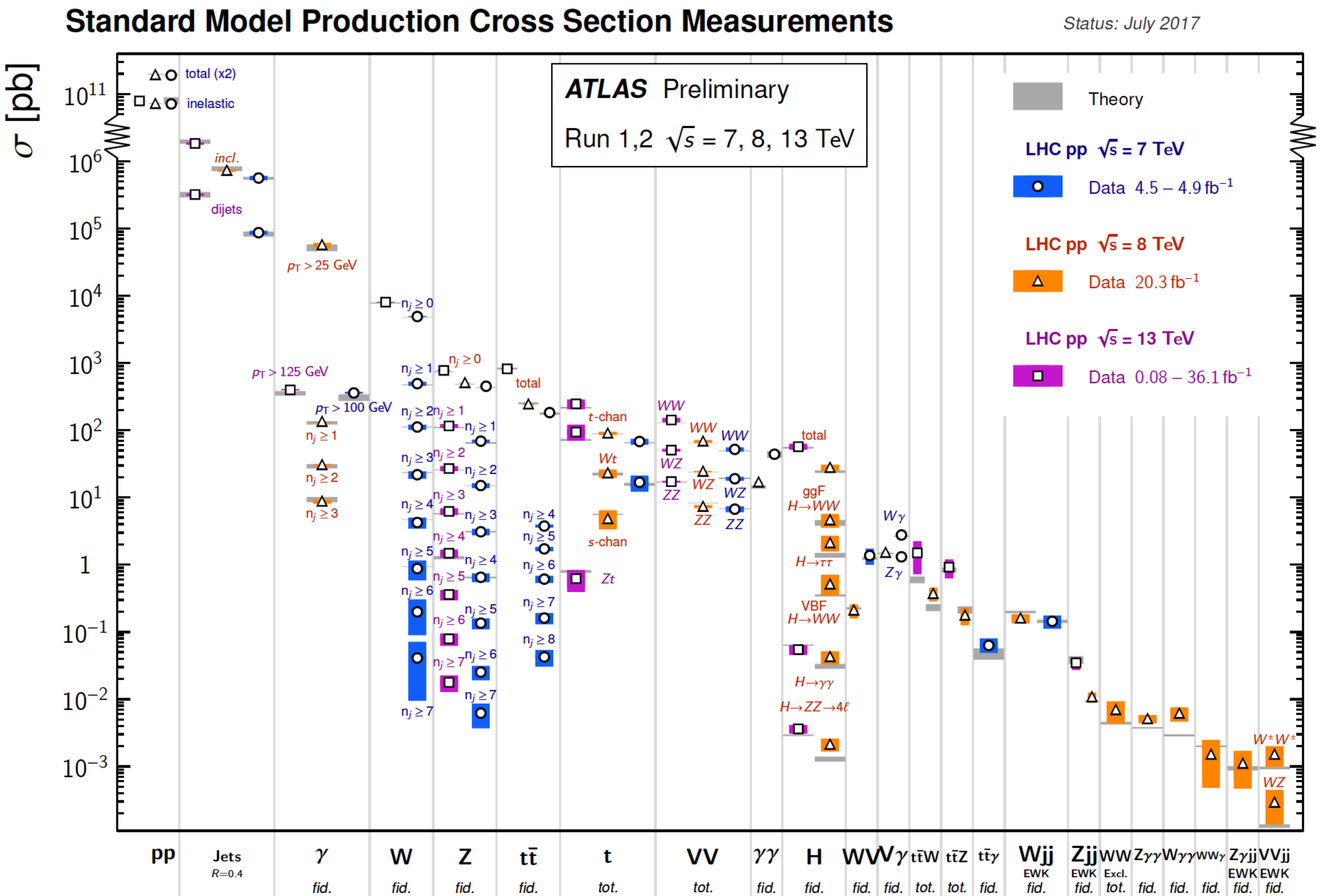
Standard Model measurements



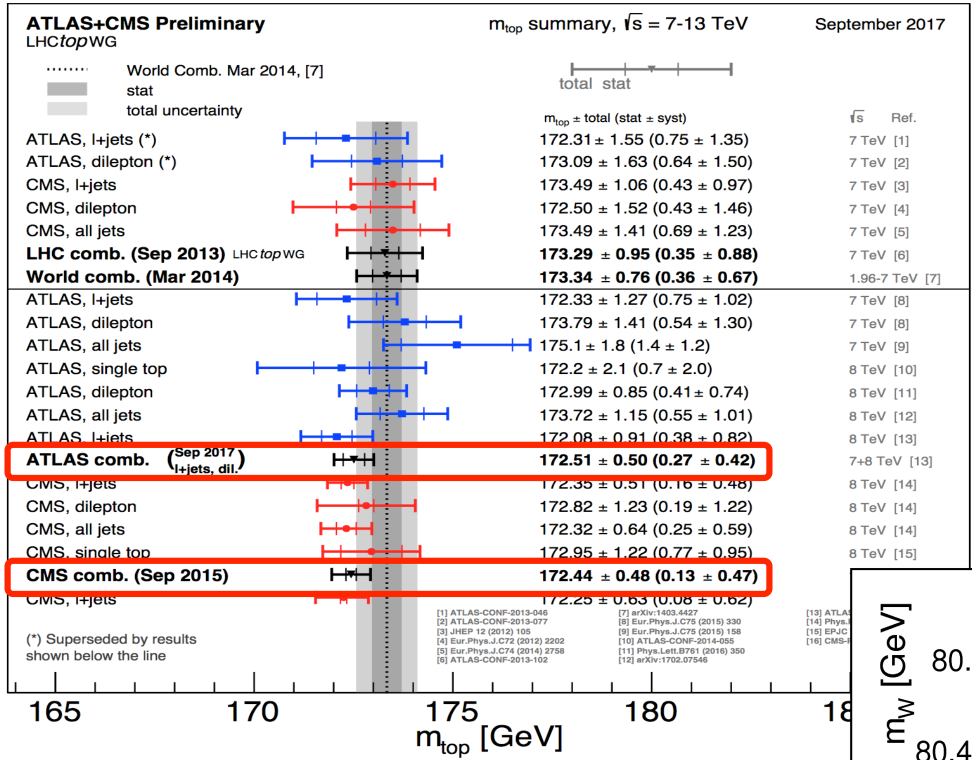
14 orders of magnitude

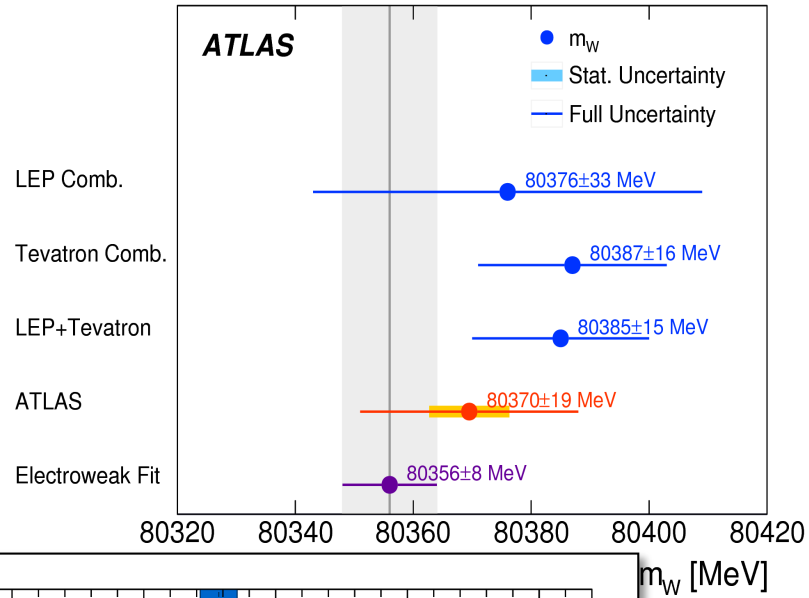
Stunning achievement, both from experiment and theory.

Also a necessary step to confidently search for NP.

Precision electroweak measurements

Play a crucial as SM consistency tests and as indirect probes of NP.





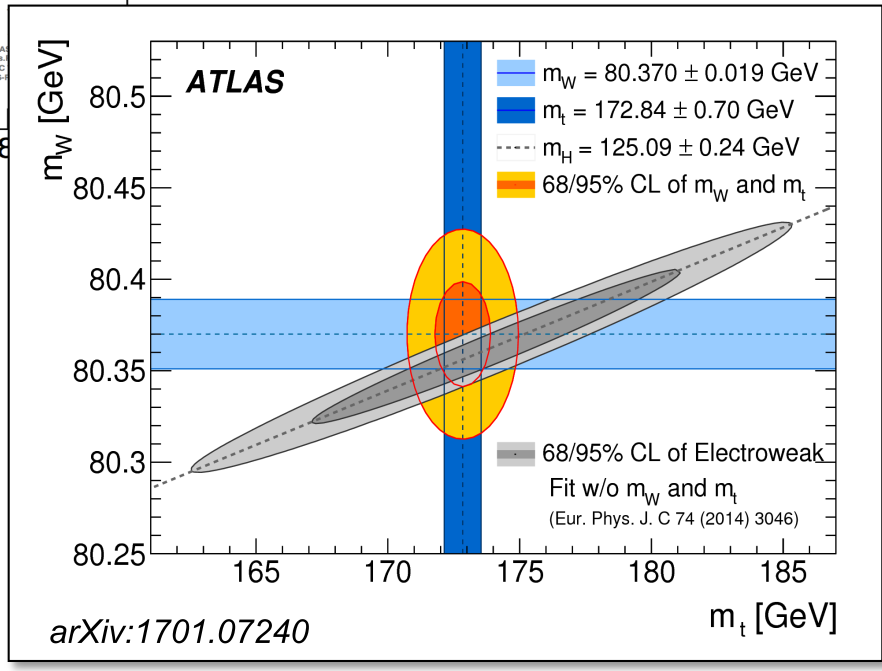
Top mass: 0.5 GeV precision/experiment!

- Caveat: top mass definition.
- Some tension with Tevatron comb:

$$m_t^{\text{Tev}} = 174.30 \pm 0.65 \text{ GeV}$$

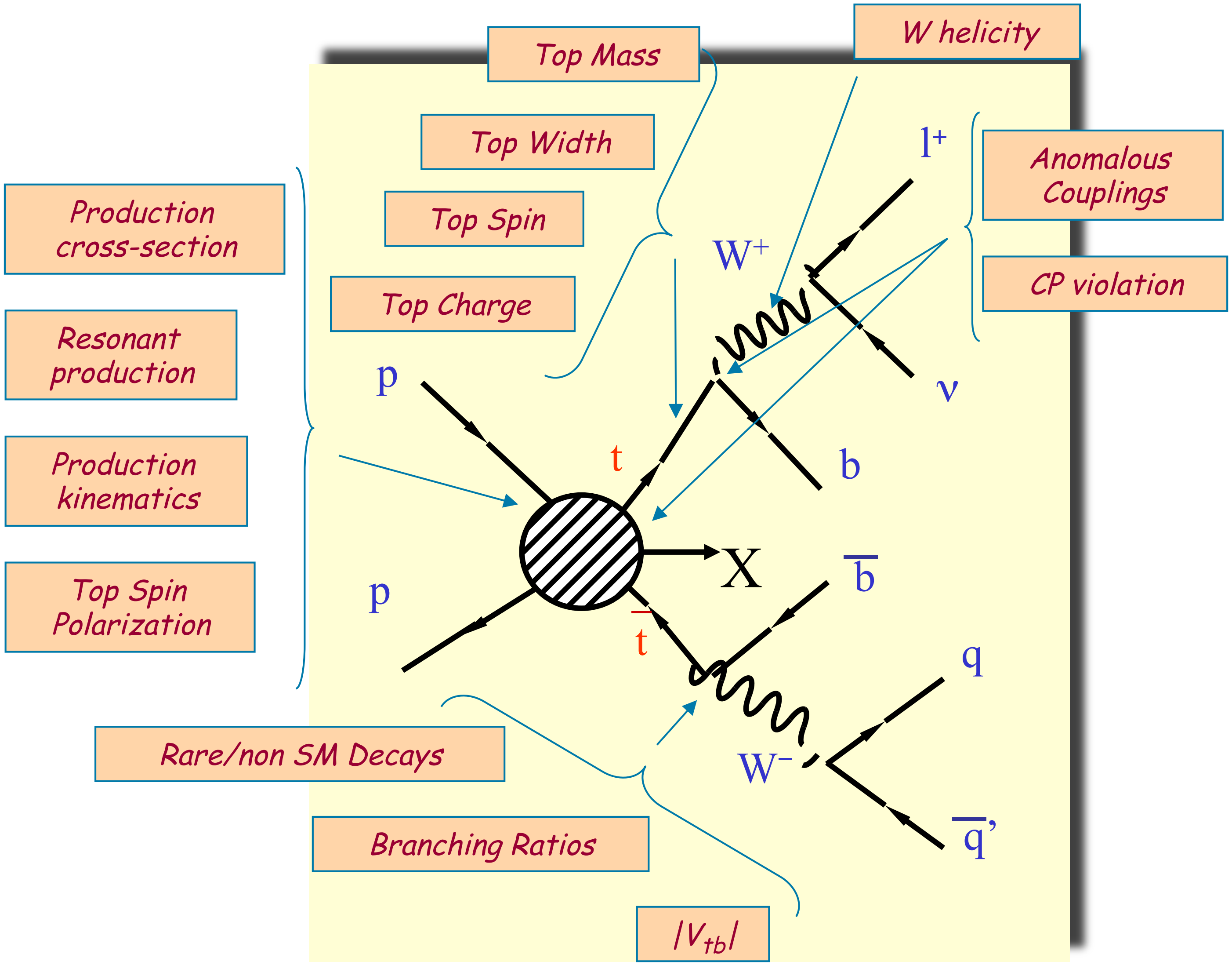
W mass: 19 MeV precision at ATLAS

- Further progress needed to match precision from EW fit.



Top quark properties measurements

Huge statistics in top quark samples allow to sensitively probe NP.



Top quark properties measurements

Huge statistics in top quark samples allow to sensitively probe NP.

Production cross-section

Resonant production

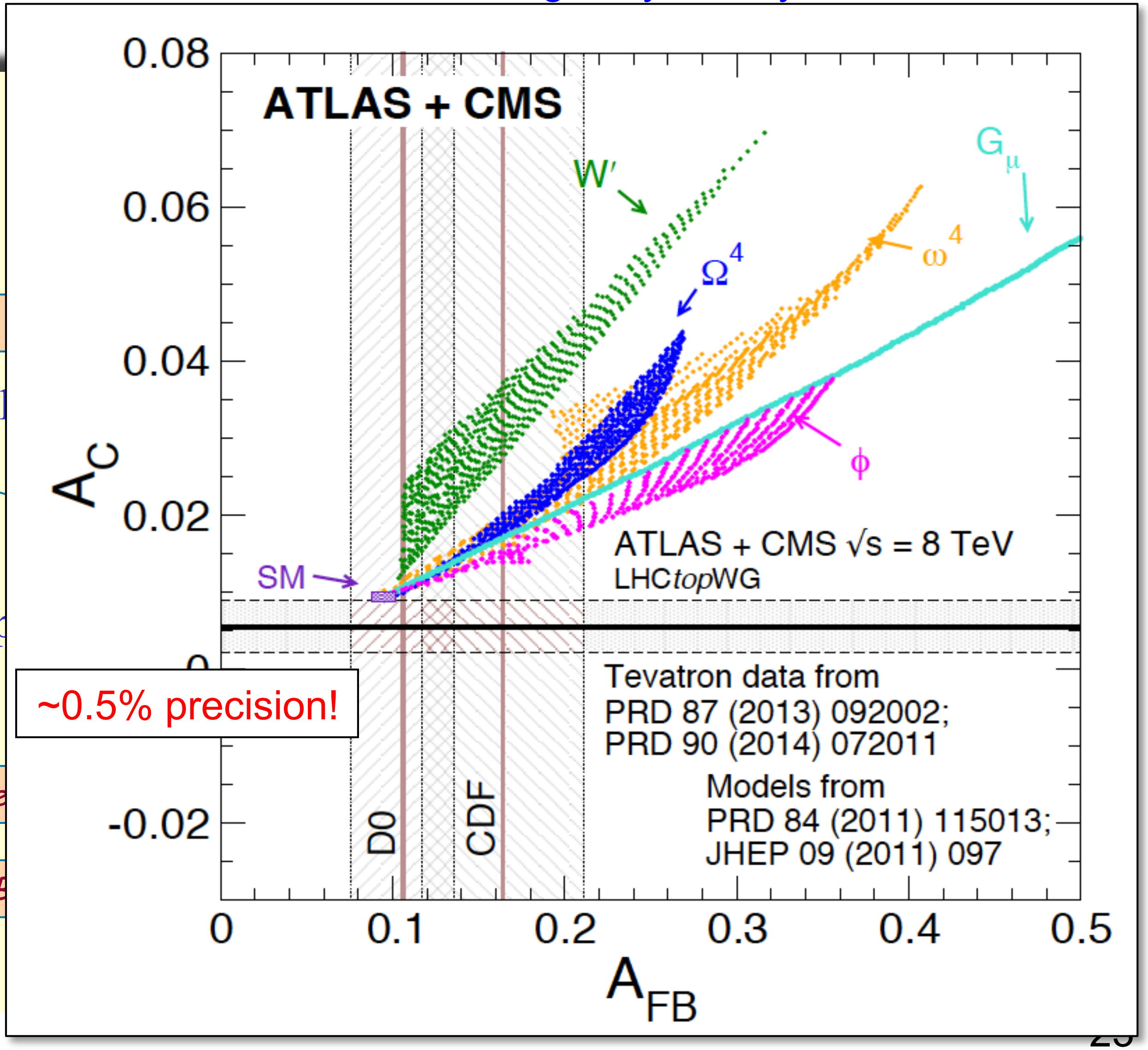
Production kinematics

Top Spin Polarization

Rare/non SM De

$t\bar{t}$ charge asymmetry

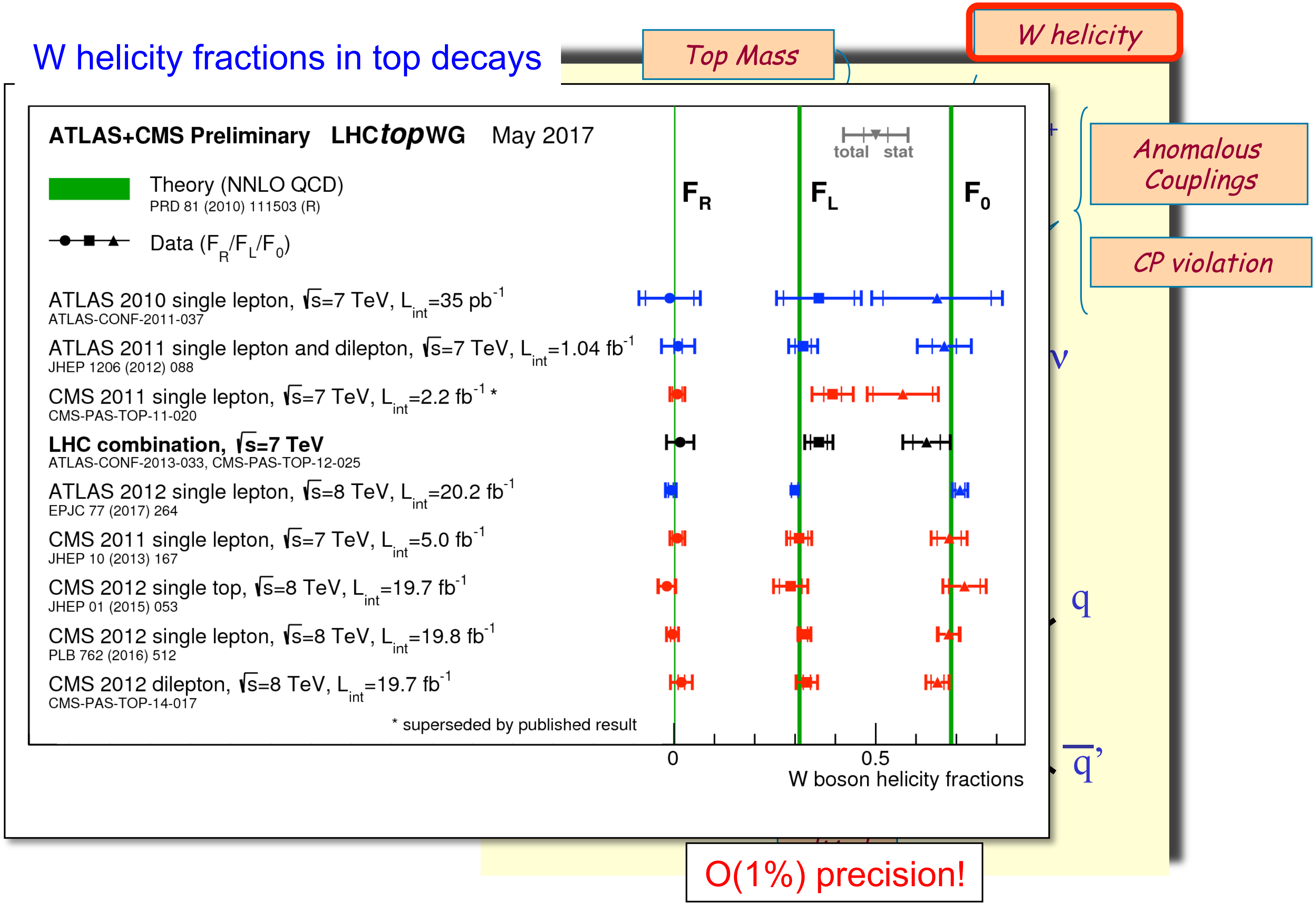
arXiv:1709.05327



Top quark properties measurements

Huge statistics in top quark samples allow to sensitively probe NP.

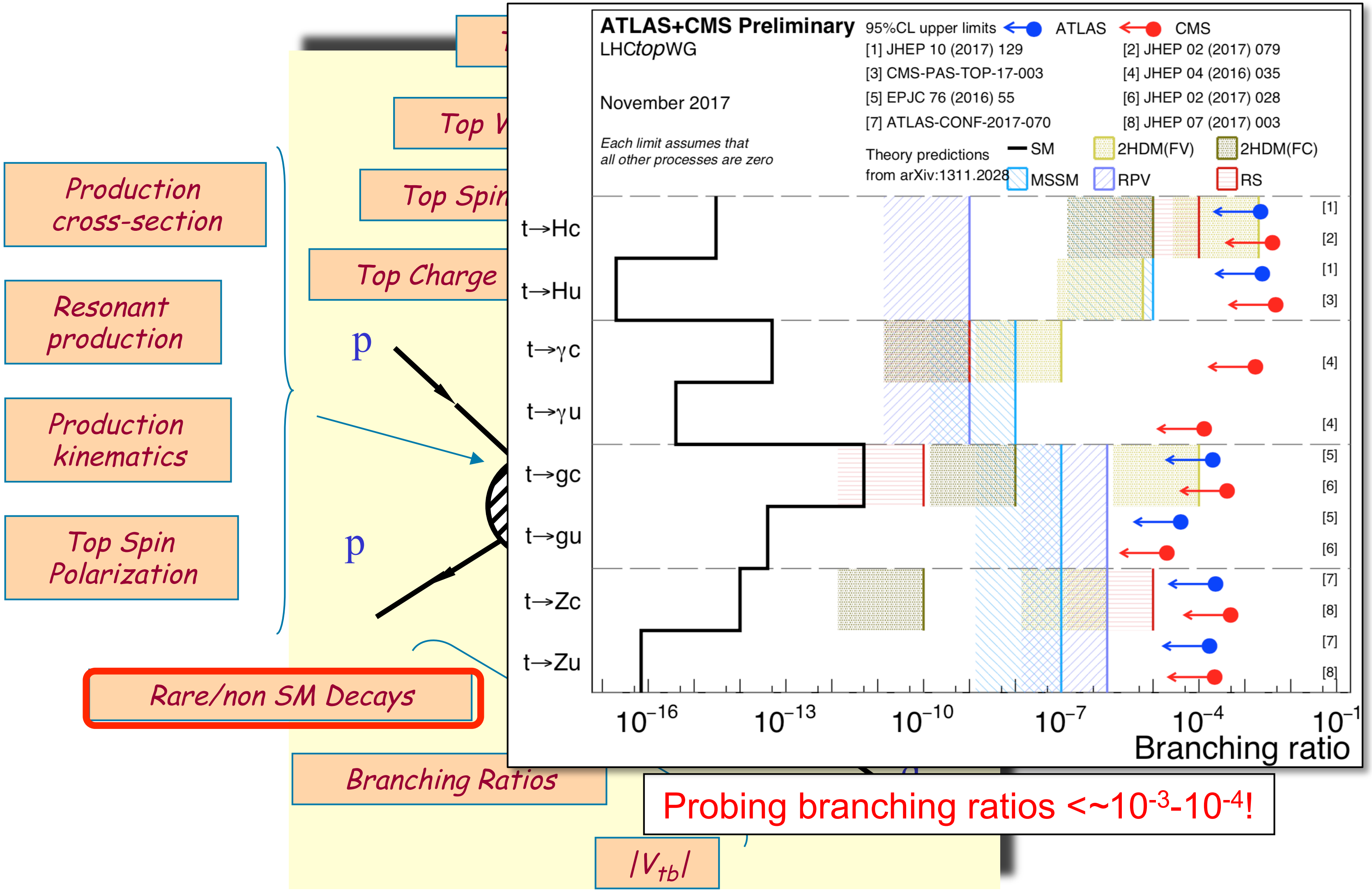
W helicity fractions in top decays



Top quark properties measurements

Huge statistics in top quark samples allow to sensitively probe NP.

Flavor-changing neutral-current top decays

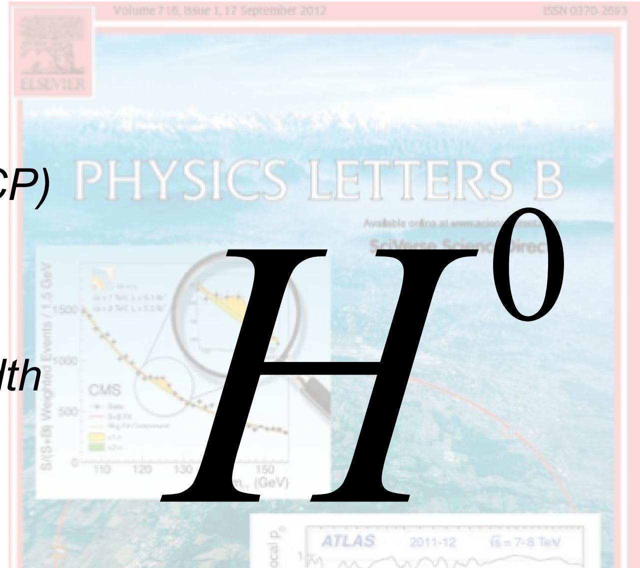


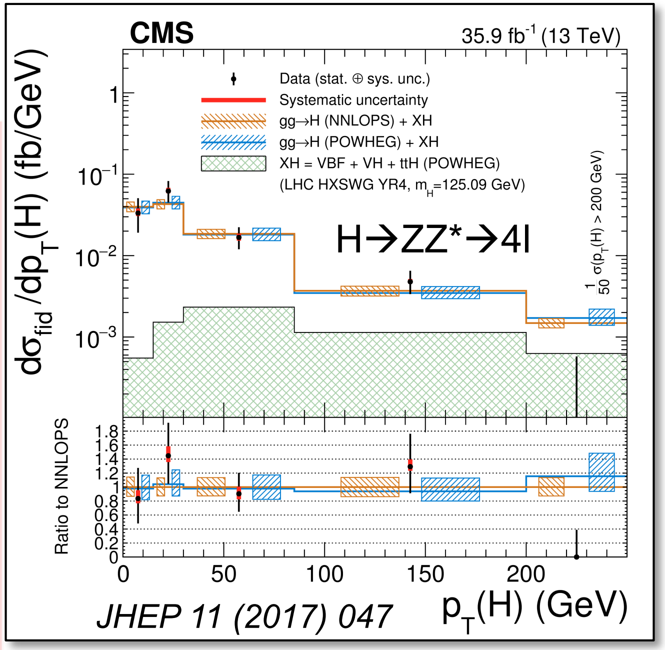
Probing branching ratios <~10^{-3}-10^{-4}!

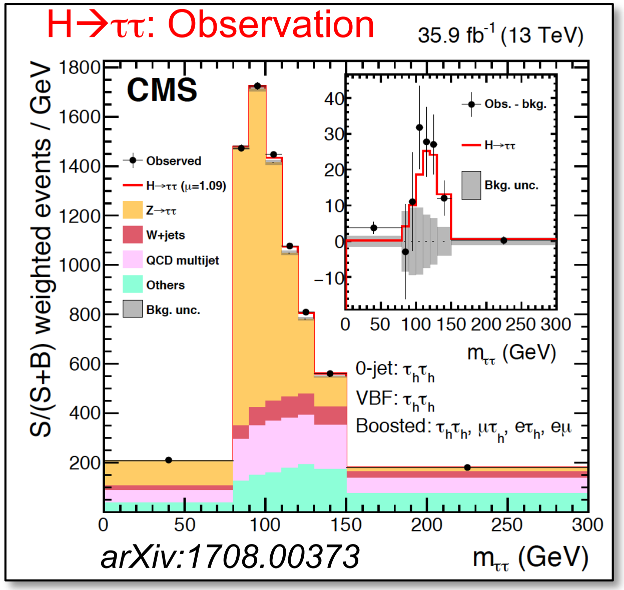
Higgs boson properties measurements

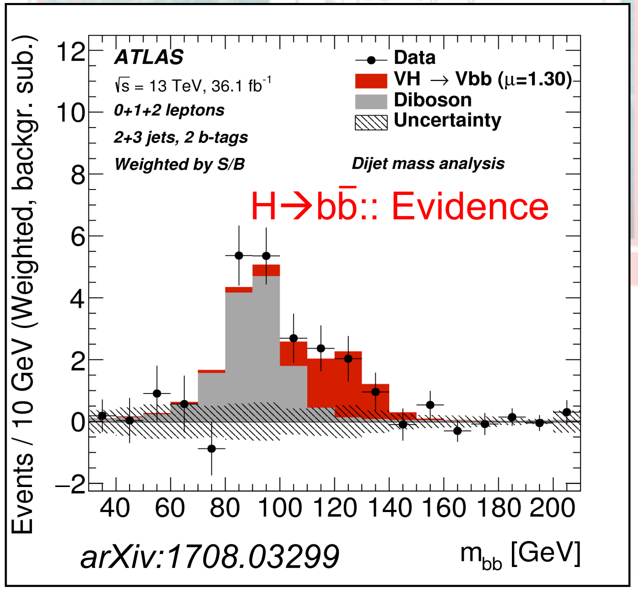
Program of precision Higgs measurements in full swing!

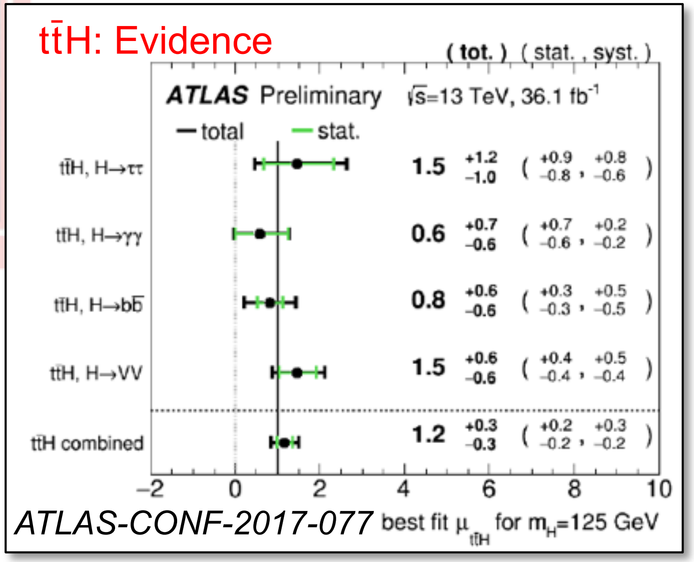
- *Mass*
- *Quantum numbers (spin, CP)*
- *Coupling properties*
- *Differential cross sections*
- *Off-shell couplings and width*
- *Interferometry*



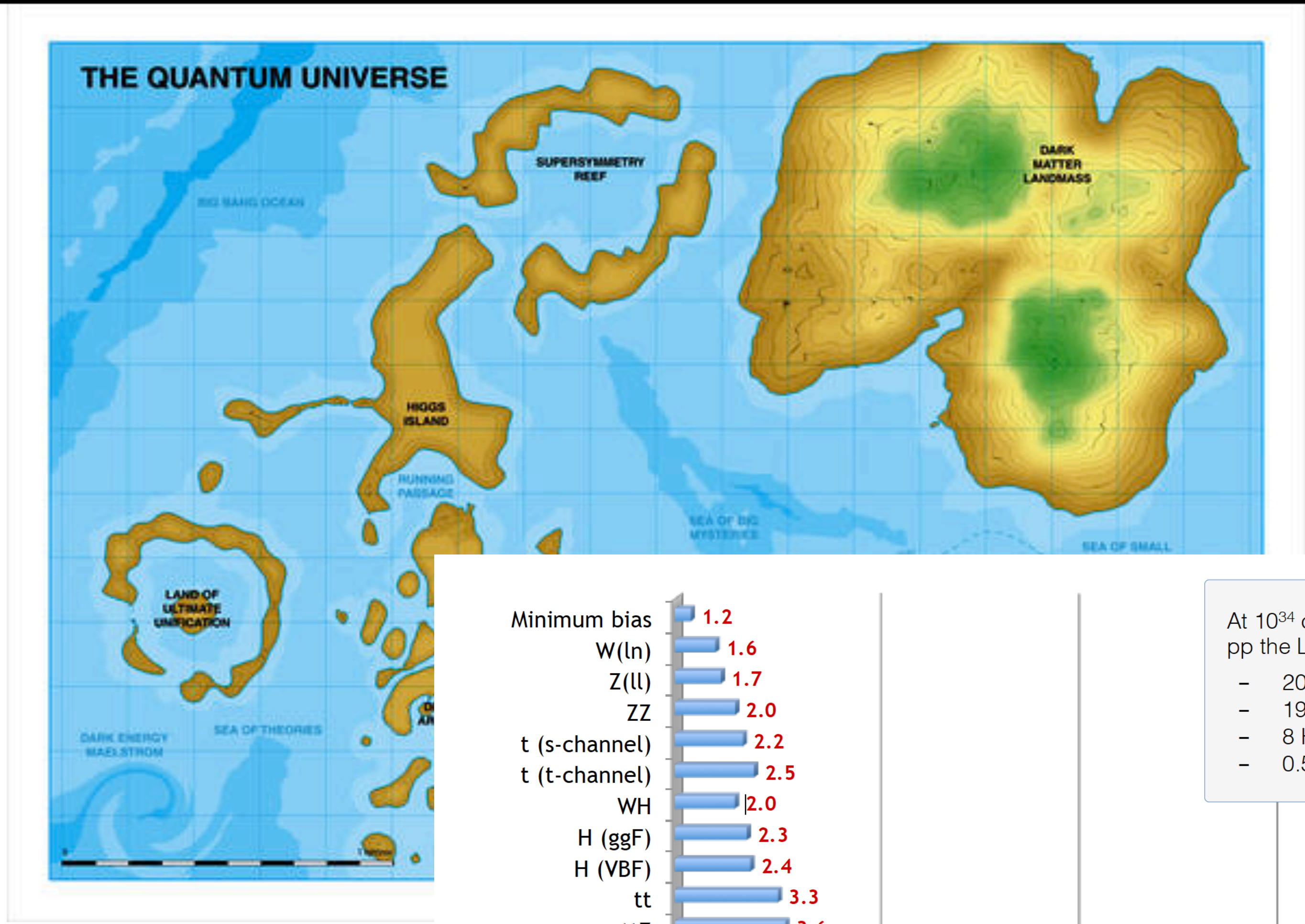


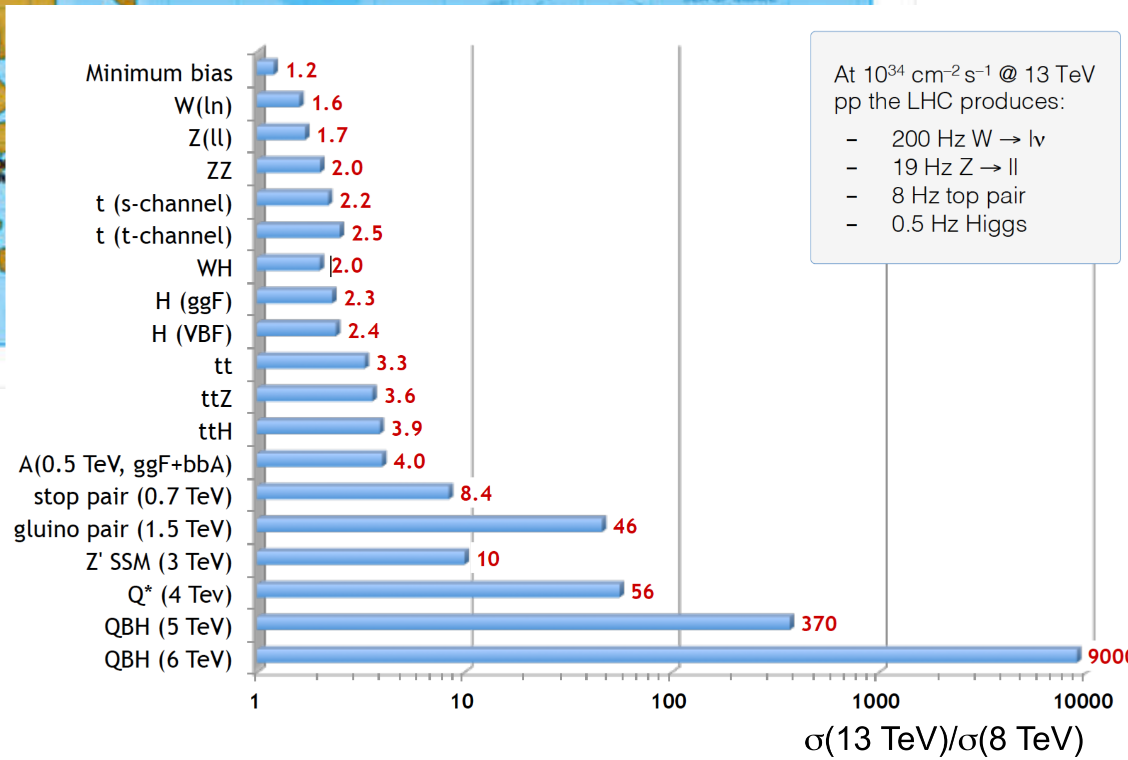






Direct searches for new phenomena





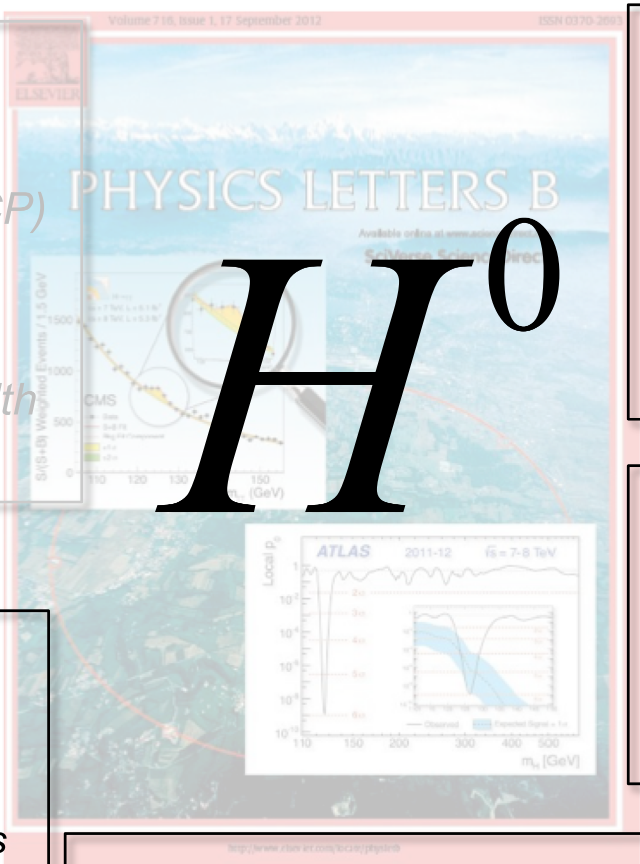
Terra Incognita

With great expectations!

In some cases already exceed Run 1 sensitivity with <2 fb^{-1} at 13 TeV!

Explosion of the Higgs physics landscape!

Since the discovery of the Higgs boson, an entire new field has emerged.



Precision measurements

- *Mass*
- *Quantum numbers (spin, CP)*
- *Coupling properties*
- *Differential cross sections*
- *Off-shell couplings and width*
- *Interferometry*

Rare / BSM decays

- $H^0 \rightarrow \mu\mu$
- $H^0 \rightarrow Z\gamma$
- $H^0 \rightarrow J/\psi\gamma$, $\Upsilon(ns)\gamma$
- LFV $H^0 \rightarrow \mu\tau$, $e\tau$, $e\mu$
- $H^0 \rightarrow aa$

…and more!

- *FCNC $t \rightarrow H^0 q$ decays*
- *Di-Higgs production*
- *Trilinear coupling*
- *… etc*

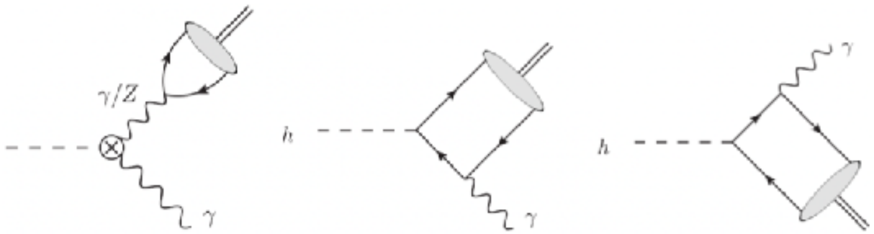
Is the SM minimal?

- *2HDM searches*
- *MSSM, NMSSM searches*
- *Doubly-charged Higgs bosons*

Tool for discovery

- *Portal to DM (invisible Higgs)*
- *Portal to hidden sectors*
- *Portal to BSM physics with H^0 in the final state (VH^0, H^0H^0)*

Rare Higgs boson decays

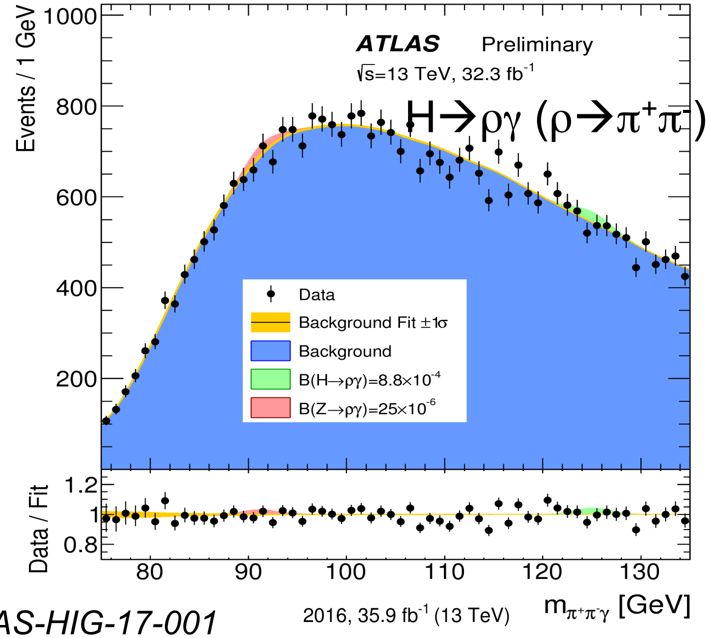


Very rare in SM:

$B(H \to \varphi\gamma) = (2.31 \pm 0.11) \times 10^{-6}$

$B(H \to \rho\gamma) = (1.68 \pm 0.08) \times 10^{-5}$

ATLAS-CONF-2017-057

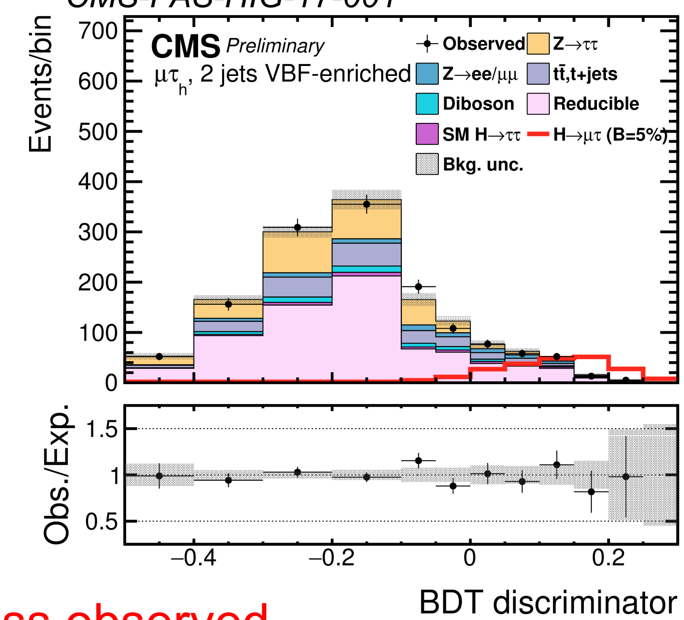


H→ργ & H→φγ

- Sensitive to s-/ud-quark Yukawa couplings.
- Reconstruct $\rho\gamma \to \pi^+\pi^-\gamma$ and $\phi\gamma \to K^+K^-\gamma$. Dedicated triggers, data-driven background.

$B(H \to \varphi\gamma) < 4.8 \times 10^{-4}$
$B(H \to \rho\gamma) < 8.8 \times 10^{-4}$

CMS-PAS-HIG-17-001



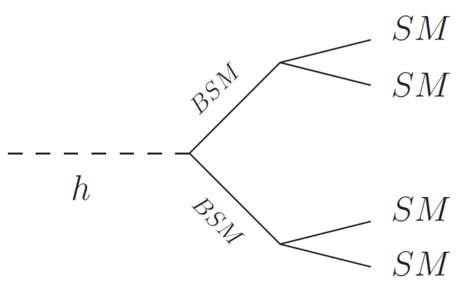
H→μτ, eτ

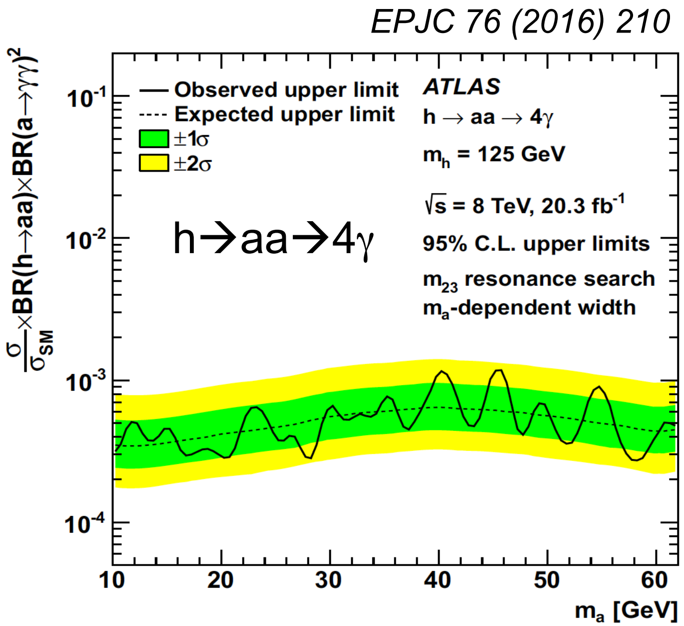
- Lepton-flavour-violating decays also very rare in the SM.
- Use BDT discriminant and multiple event categories.

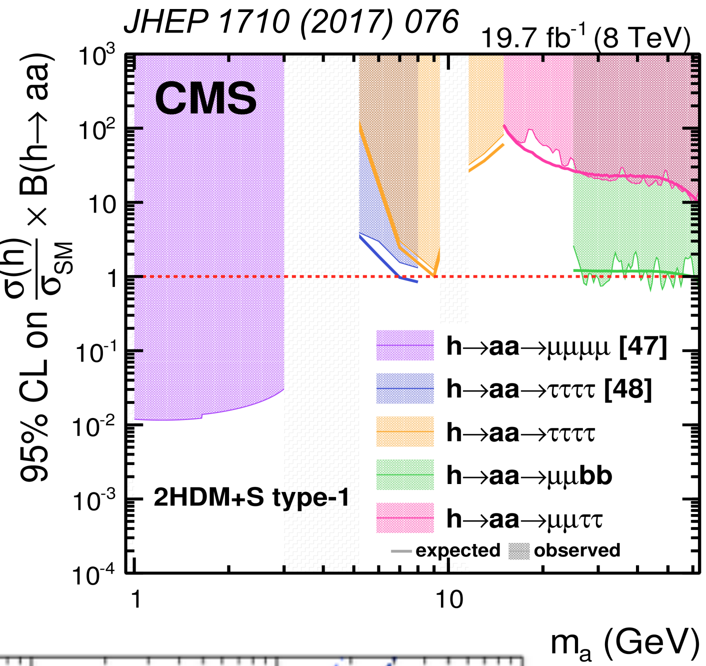
$B(H \to \mu\tau) < 0.25\%$ $B(H \to e\tau) < 0.61\%$

No significant excess observed

Exotic Higgs boson decays





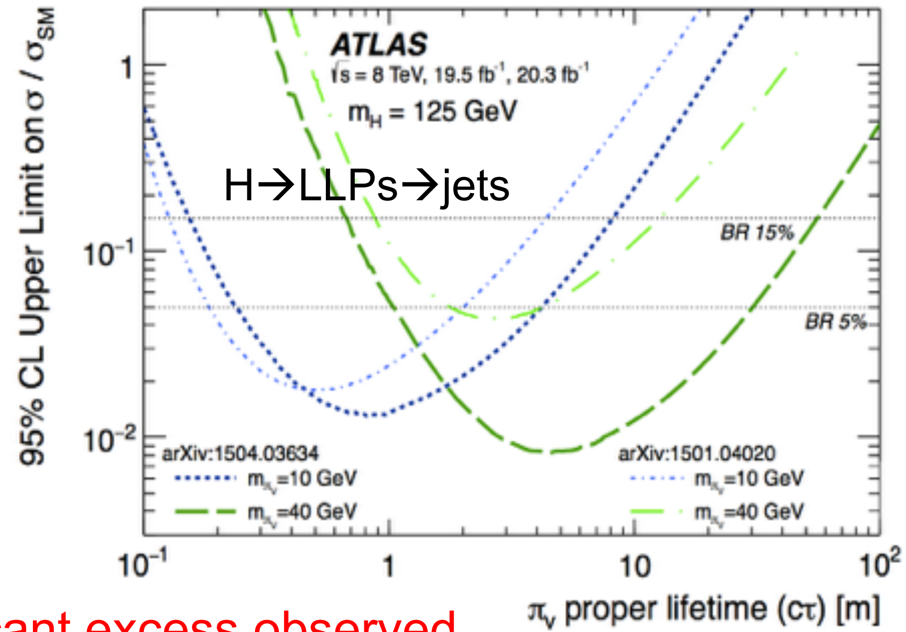


H→aa, a=low-mass pseudo-scalar

- Rich set of resonant decay topologies.
- BR(a→XX) model dependent.

H→LLPs, LLP=long-lived particle

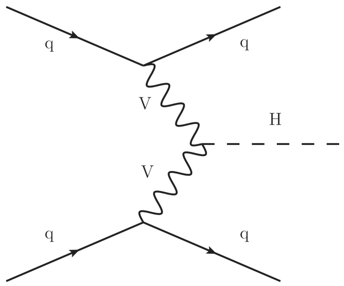
- Rich and challenging set of decay topologies often requiring significantly customized analysis methods.
- Lifetime treated as a free parameter.

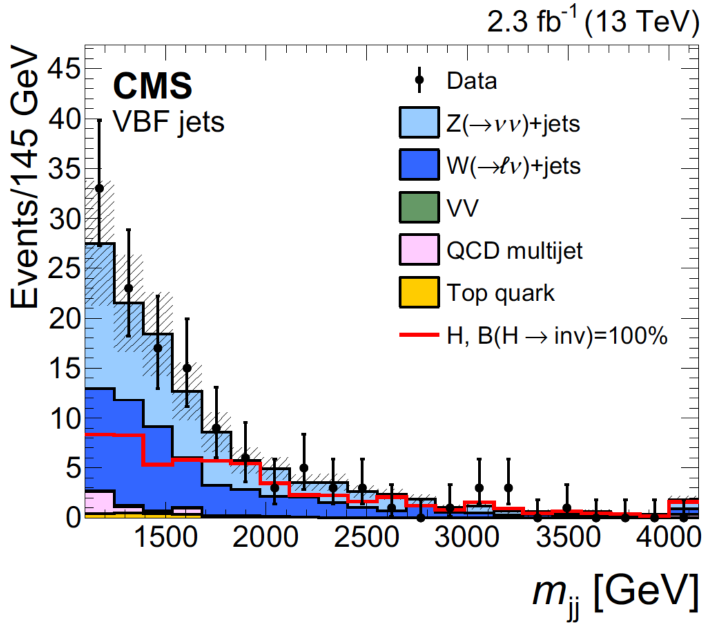


No significant excess observed

Invisible Higgs boson decays

- Most sensitive searches use VBF production:
  - Main selection on m_{jj}, $\Delta\eta_{jj}$, and large E_T^{miss}.
- Derive upper limit on BR(H→inv), under the assumption of SM production cross section.
- Result also interpreted in the context of a Higgs-portal model of dark matter interactions.





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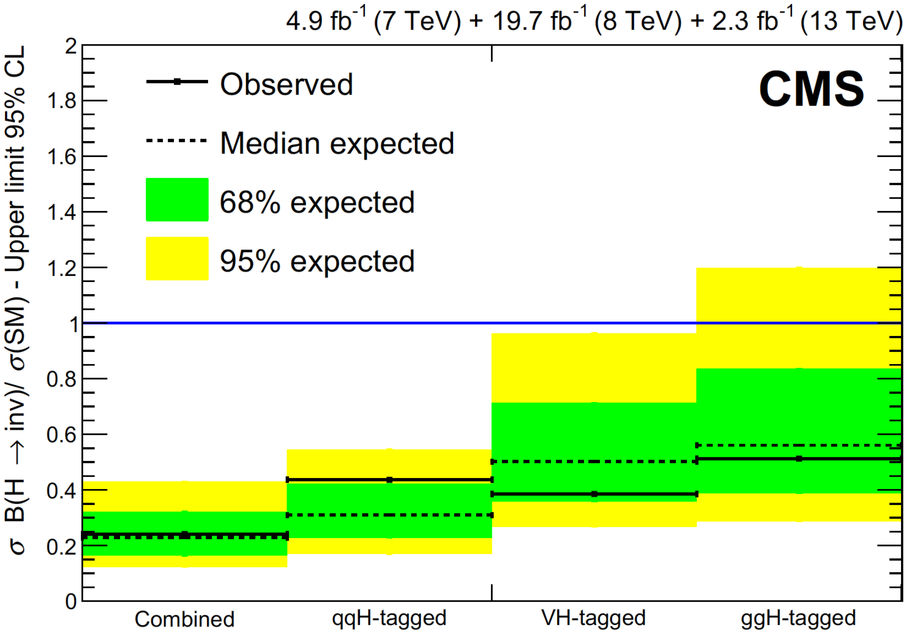
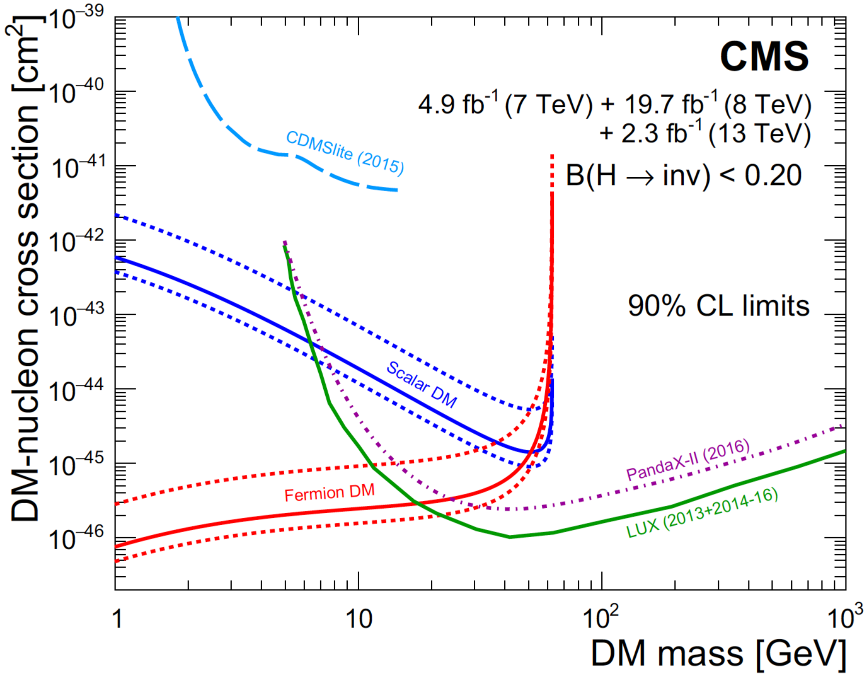
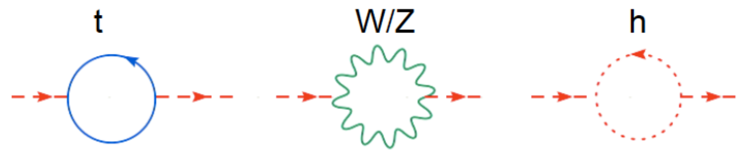


BR(H→inv) < 0.24 (0.23 exp) at 95% CL



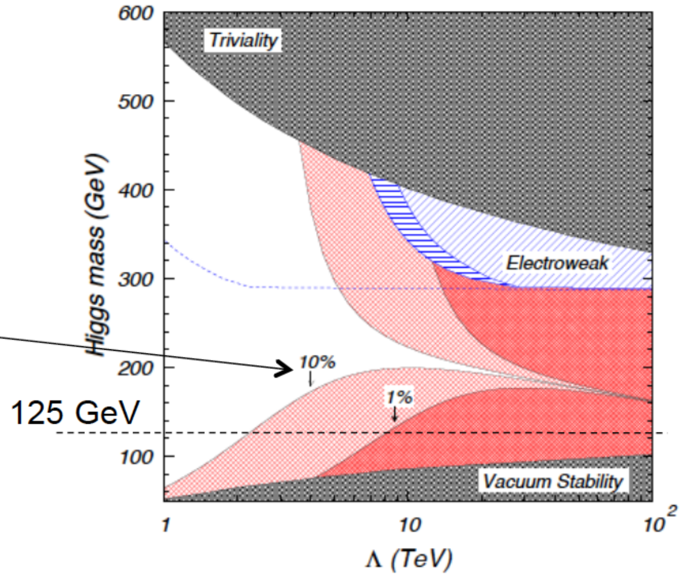
Implications from Higgs boson discovery



$$(125\,\mathrm{GeV})^2 = m_{H0}^2 + \left[-(2\,\mathrm{TeV})^2 + (700\,\mathrm{GeV})^2 + (500\,\mathrm{GeV})^2\right]\left(\frac{\Lambda}{10\mathrm{TeV}}\right)^2$$

Either New Physics appears at a scale Λ or there has to be a very delicate cancellation

Amount of fine tuning

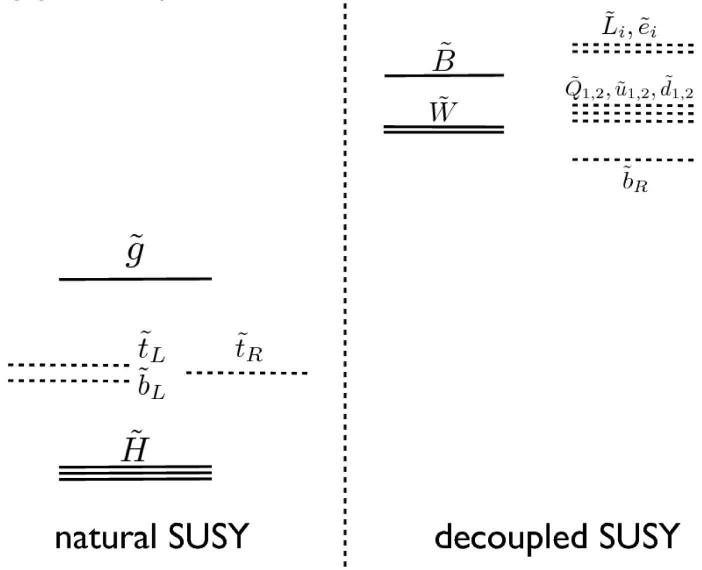


- “Natural” solutions by postulating new states at ~1 TeV curing Higgs boson quantum instabilities (SUSY, new strong dynamics) or that fundamental Planck mass at the electroweak scale (extra dimensions).

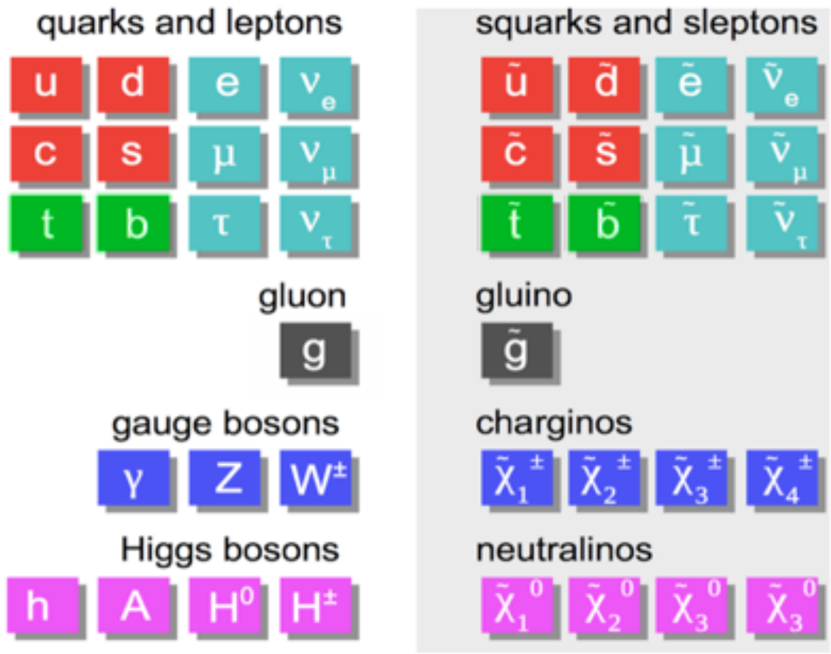
  ➔ Precision Higgs couplings and direct searches for new states are complementary.
- However, no “no loose” theorem anymore. [Cosmological relaxation of the EW scale?]
- Searches relatively agnostic but do often focus on models that address naturalness problem and/or have a dark matter candidate.

Supersymmetry

- Many features make it one of the strongest candidates to extend the SM:
  - Solves the hierarchy problem
  - Can provide a dark-matter candidate: if R-parity is conserved, lightest SUSY particle (LSP, neutralino) is stable
  - Predicts gauge coupling unification
  - …
- In typical "Natural SUSY" scenarios the 3rd generation squarks (stop/sbottom) and the gluino can be relatively light (also the Higgsinos).



Global symmetry between fermions & bosons: all SM particles have SUSY partners



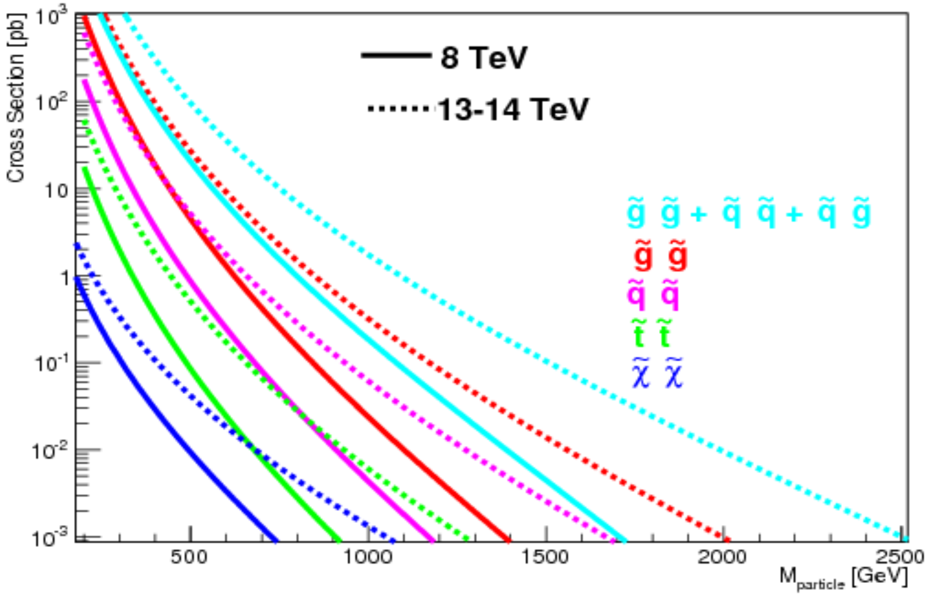
Q|fermion> = |boson>

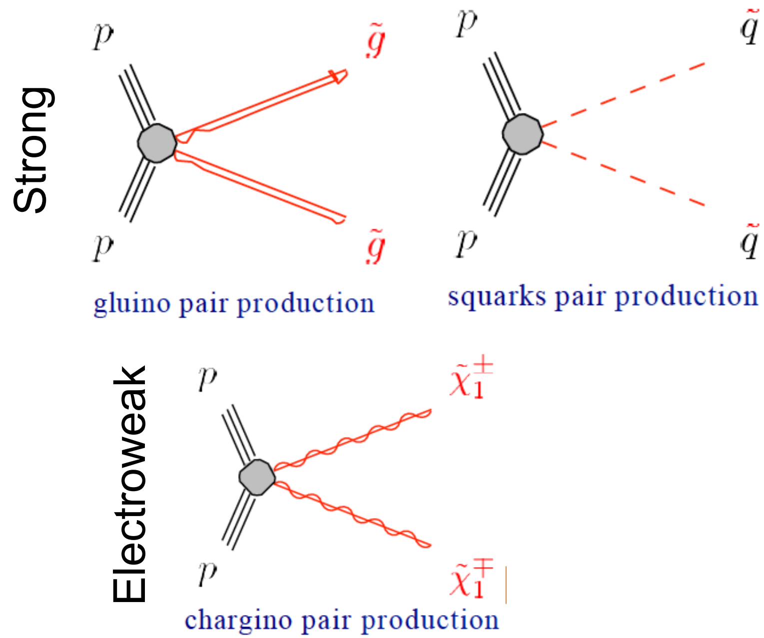
Q|boson> = |fermion>

$s_{SUSY} = s_{SM} - 1/2$

$R = (-1)^{2s}(-1)^{3B}(-1)^{L}$

Classification of SUSY searches





- **Large increase in cross section from 8 to 13 TeV!**
- **Inclusive searches for squarks/gluinos**
  - Large cross sections
  - Rich final states in the case of $\tilde{g}\tilde{g}$
- **Dedicated searches for lightest stop/sbottom**
  - Moderate cross sections
  - Final states closer to SM background

Focus on searches for gluino and 3rd generation squarks with early Run 2 data

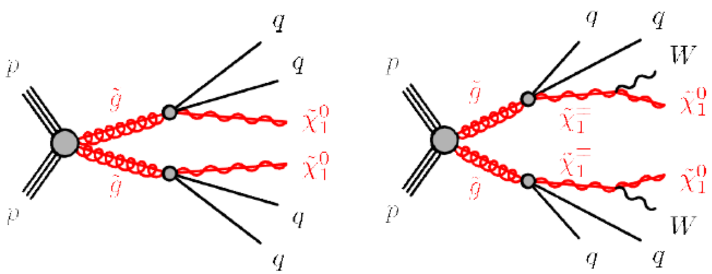
- **Searches for charginos/neutralinos**
  - Low cross sections
  - Multilepton final states with low SM background

Discovery potential of beyond Run-1 limits reached with 2015+2016 data

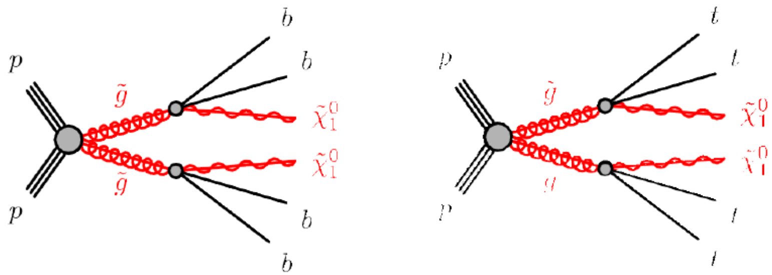
- Searches for long-lived particles and RPV SUSY

Natural SUSY: Gluino

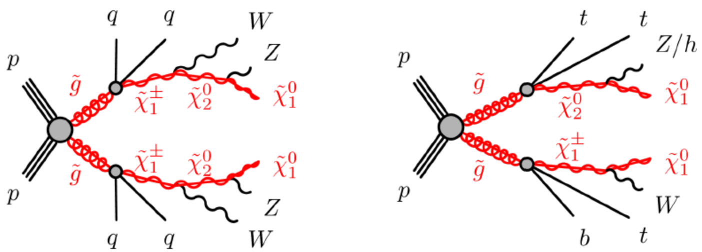
- Strong production of gluino pairs one of the most promising search channels with early Run 2 data: σ(13 TeV)/σ(8 TeV)~46 for gluino mass of 1.5 TeV.
- Gluinos (and 1st/2nd generation squarks) often targeted by so-called "inclusive searches".
  - R-parity conserving (RPC) scenarios ➔ LSP weakly interacting
- Typical signature: jets, E_T^{miss}, w/ or w/o leptons, w/ or w/o b-jets.



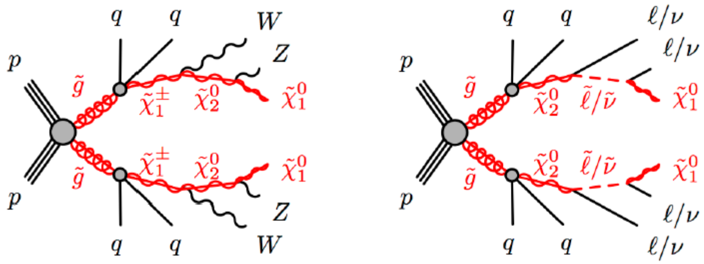
2-6 jets+E_T^{miss}



multi b-jets+E_T^{miss}



7-10 jets+E_T^{miss}



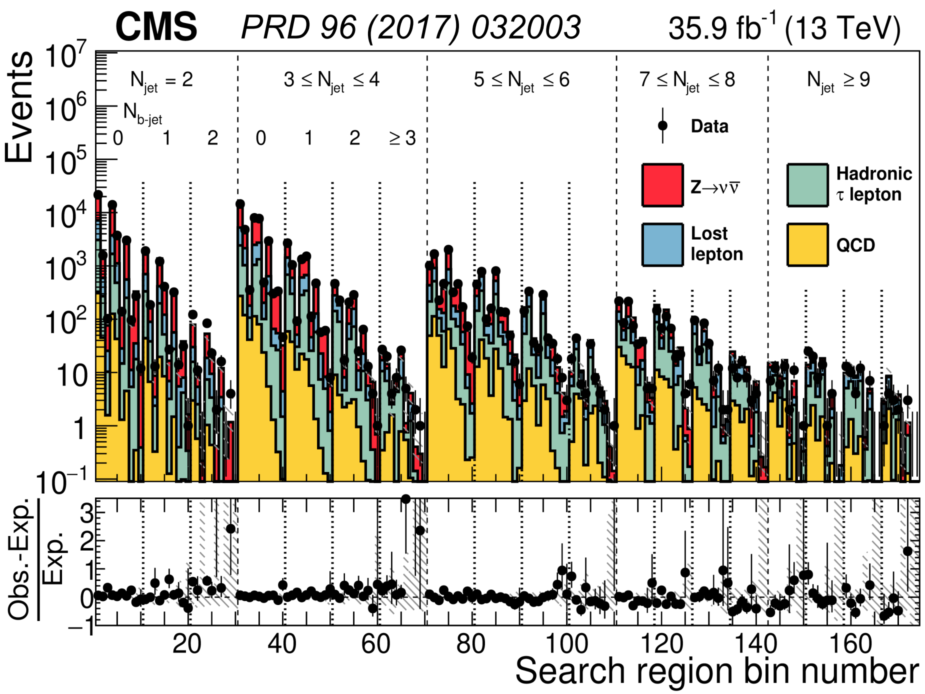
SS dilepton/trileptons+E_T^{miss}

…

Natural SUSY: Gluino

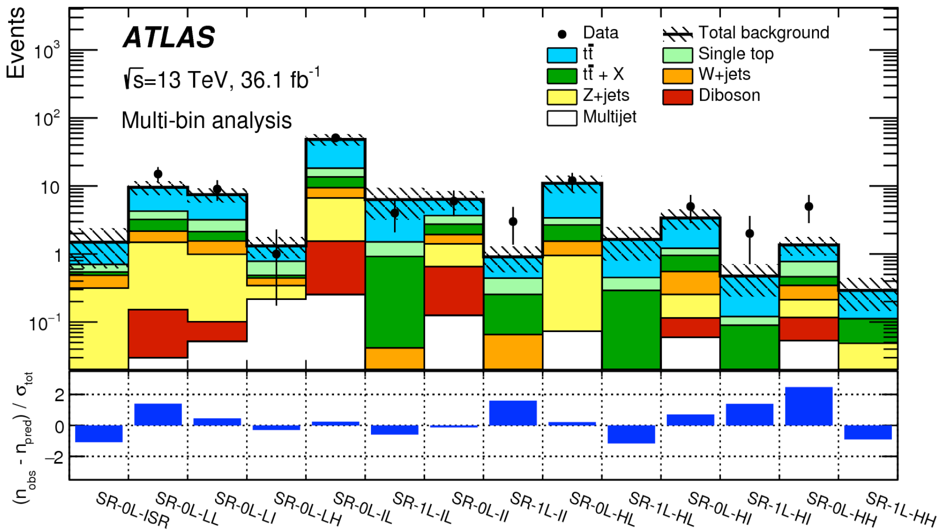
- Many search regions needed to cover a large number of possible decay chains. For example:

0-lepton+jets+E_T^{miss}



multi b-jets+E_T^{miss}

arXiv:1711.01901



SS 2l/3l+jets+E_T^{miss}

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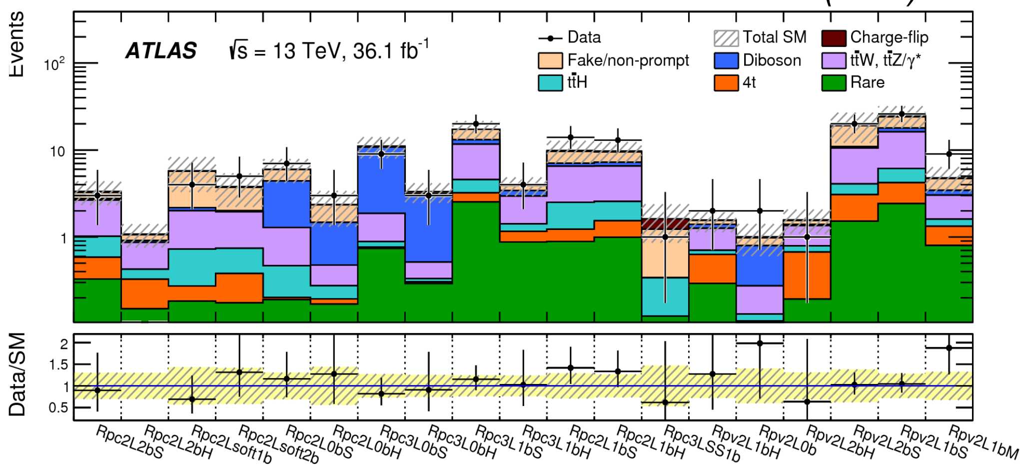
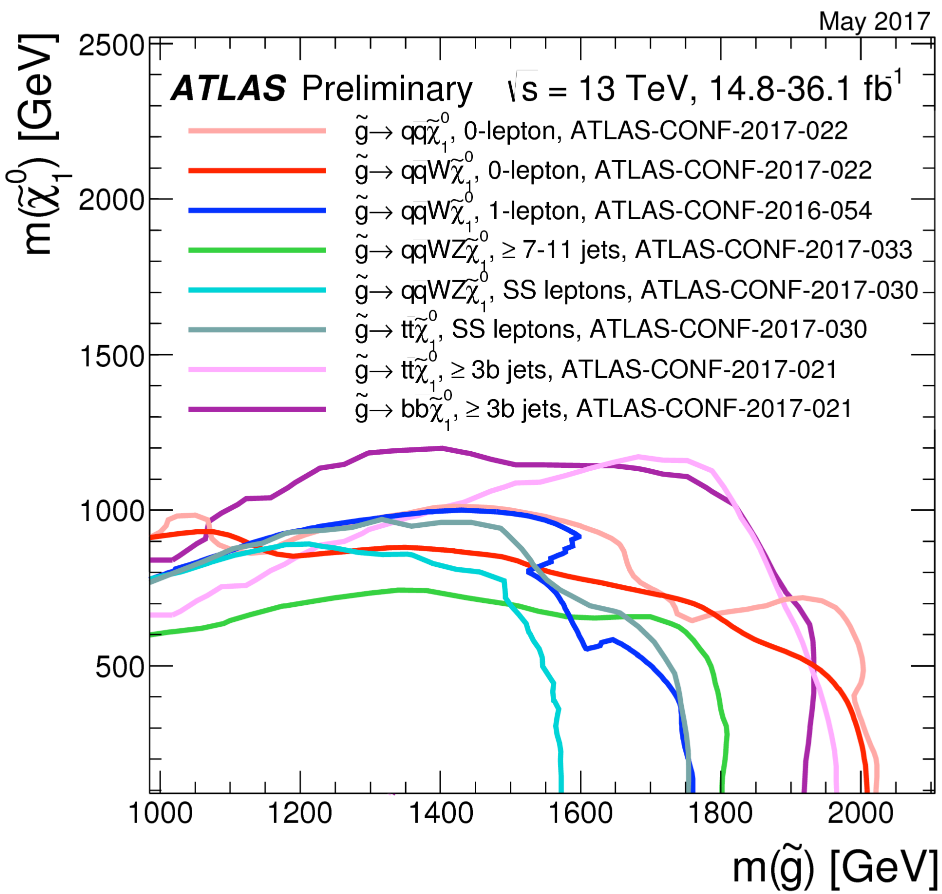
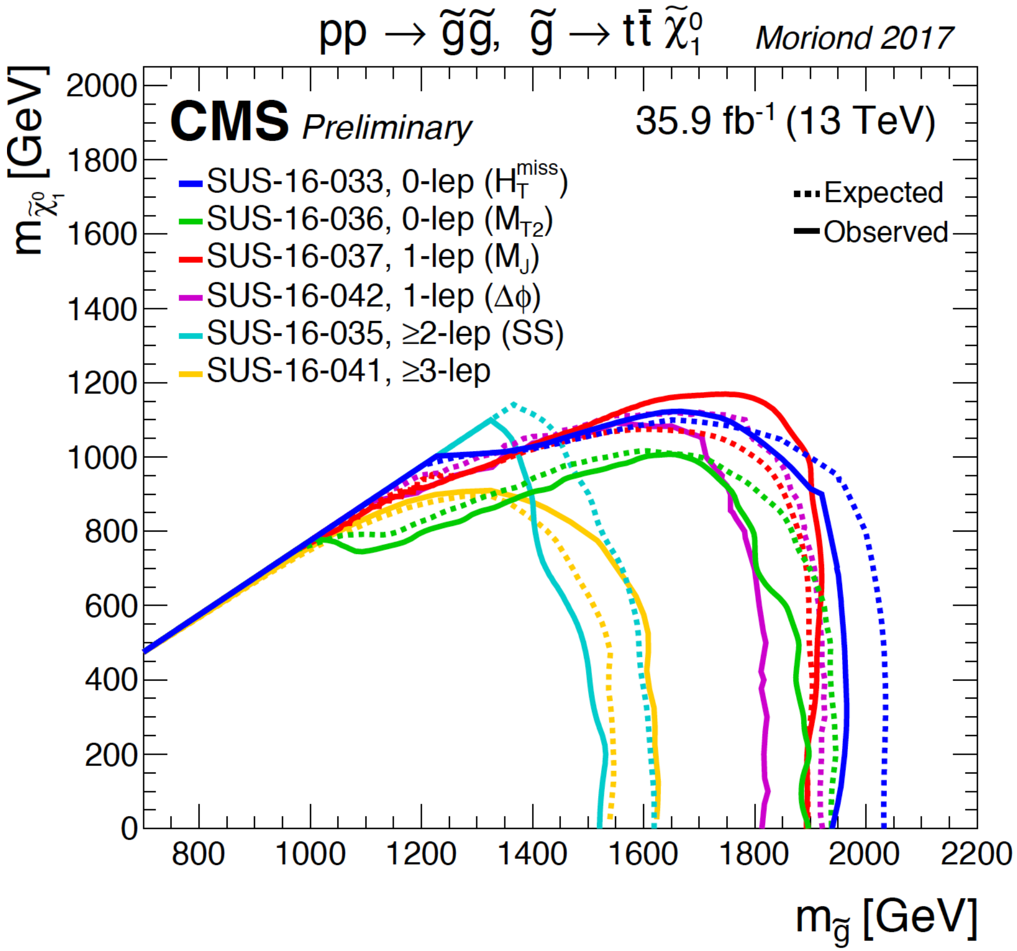


Natural SUSY: Gluino

No significant excess observed

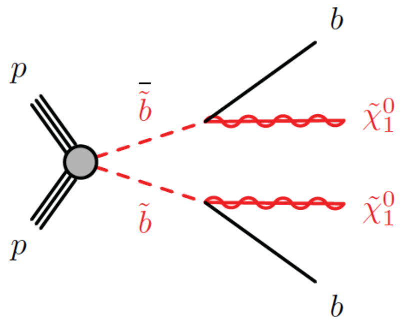


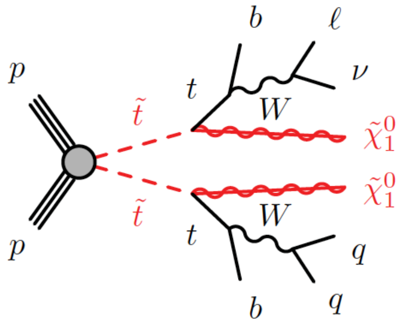


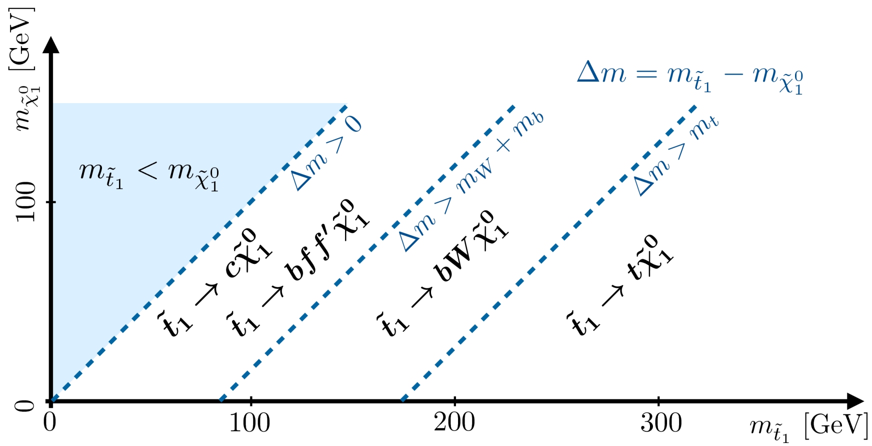
Highest mass limits for gluino reaching ~2 TeV

(compared to ~1.3 TeV in Run 1)

Natural SUSY: 3rd generation squarks







- Many sophisticated analyses targeting bottom and top squarks.
- Experimentally, can be quite challenging:
  - low production rate,
  - several possible decay modes, depending on SUSY mass spectrum.
- Dedicated searches employing a large number of signal regions based on boosted hadronic resonances and other variables.

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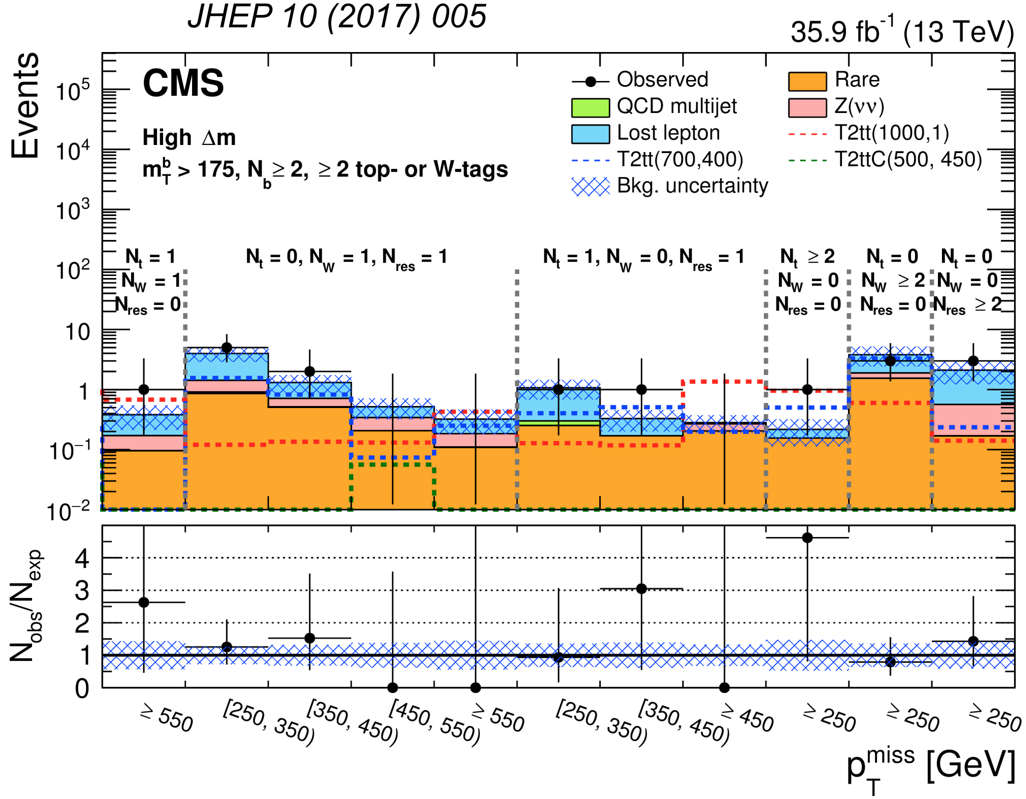
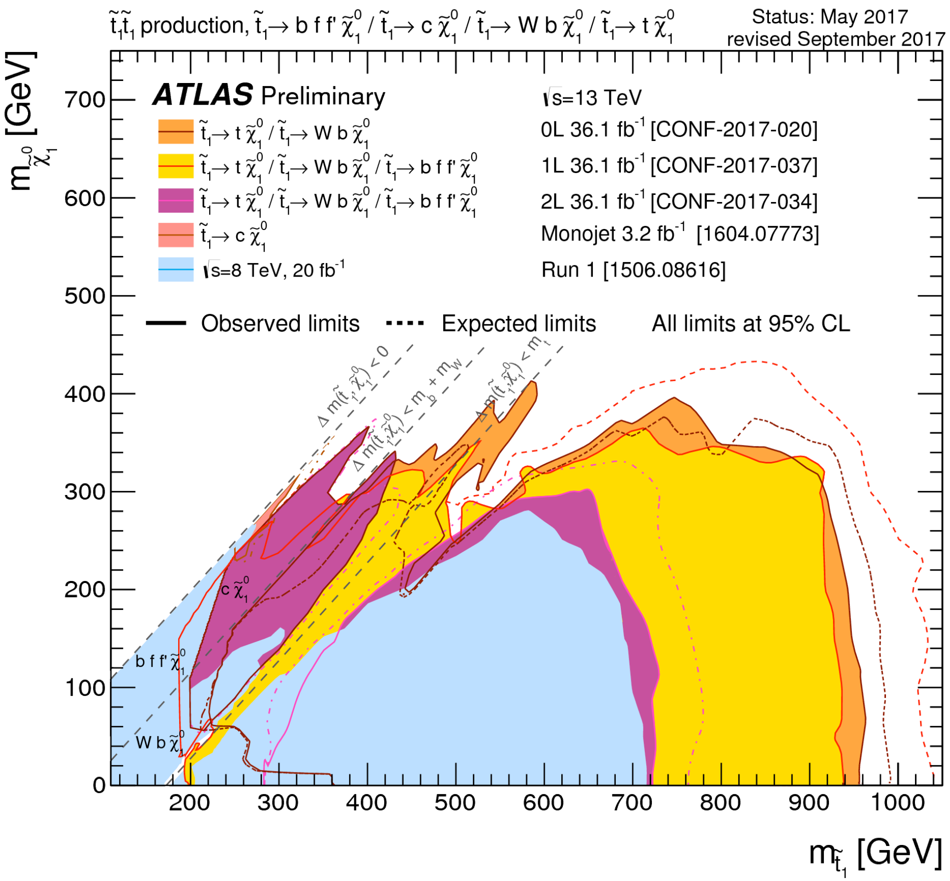
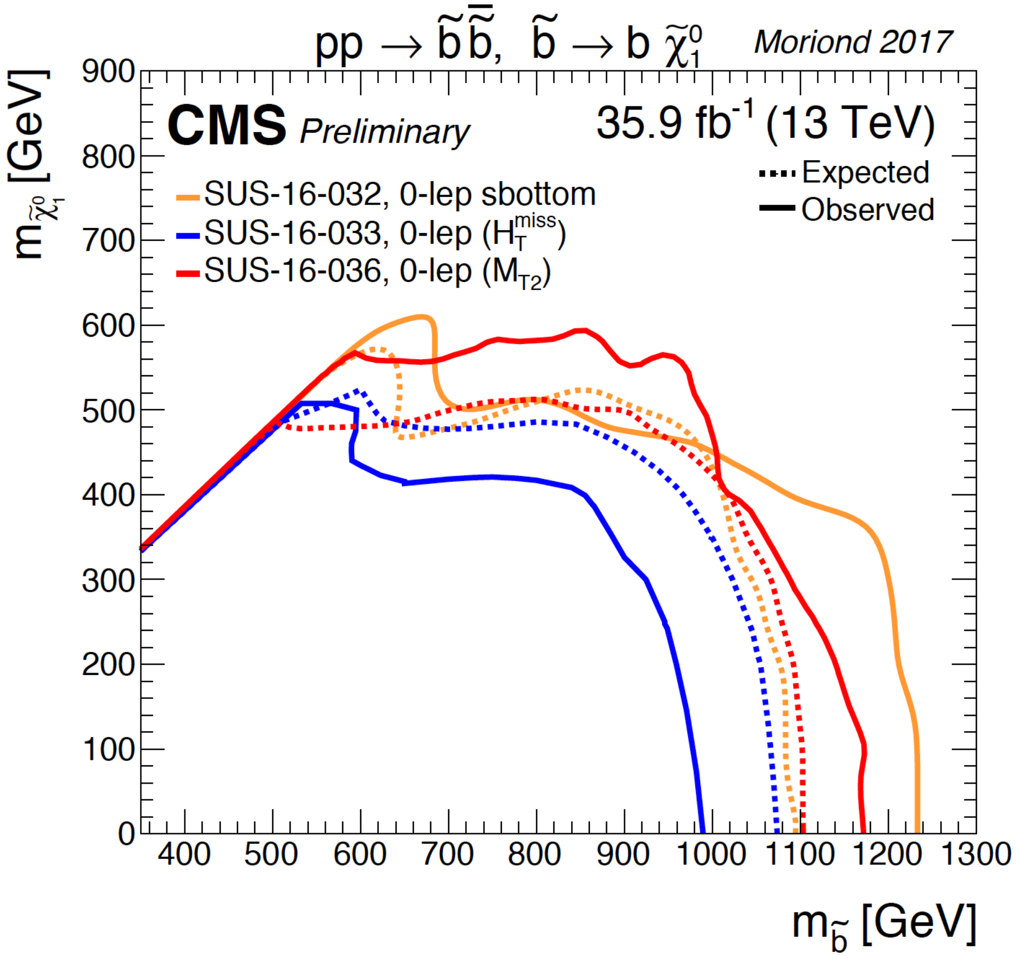


Natural SUSY: 3rd generation squarks

No significant excess observed





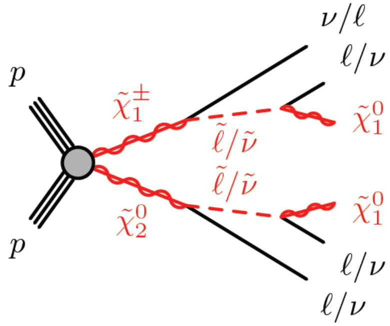
Highest mass limits for top squark ~1.1 TeV (for massless neutralino)

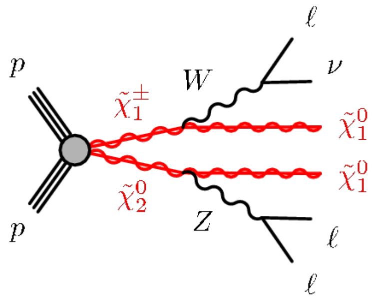
Highest mass limits for bottom squark ~1.2 TeV (for massless neutralino)

BUT beware of **simplistic assumptions** in simplified models!

Natural SUSY: Electroweak production

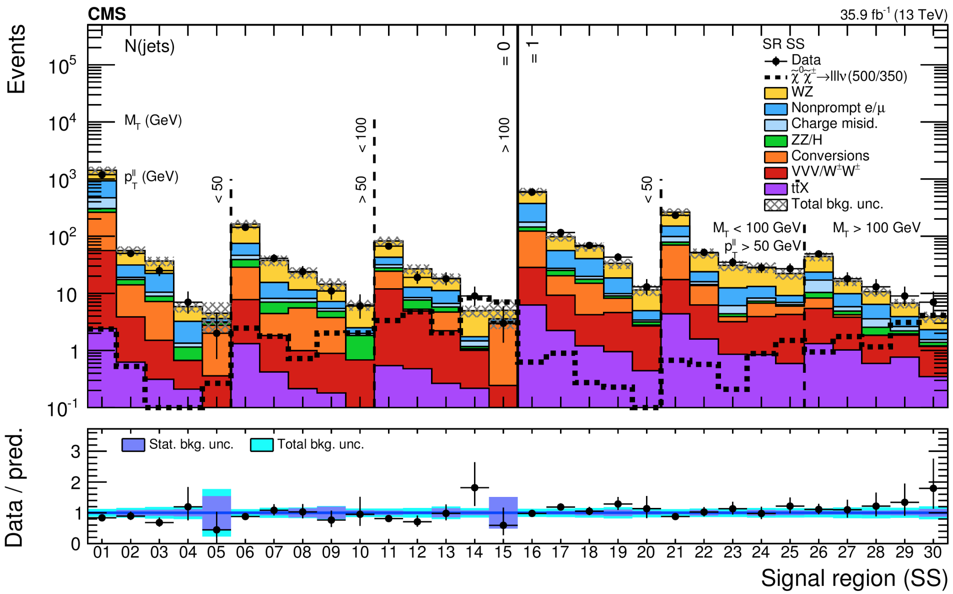
- If colored sparticles have mass above 3-4 TeV scale, the EW sector could be the only one accessible.
  - Very low production rate, large dataset needed.
- Exploit multi-lepton nature of final state events
  - Depends on chargino/slepton/neutralino mass hierarchy.
- Explore a variety of signal regions. For example:



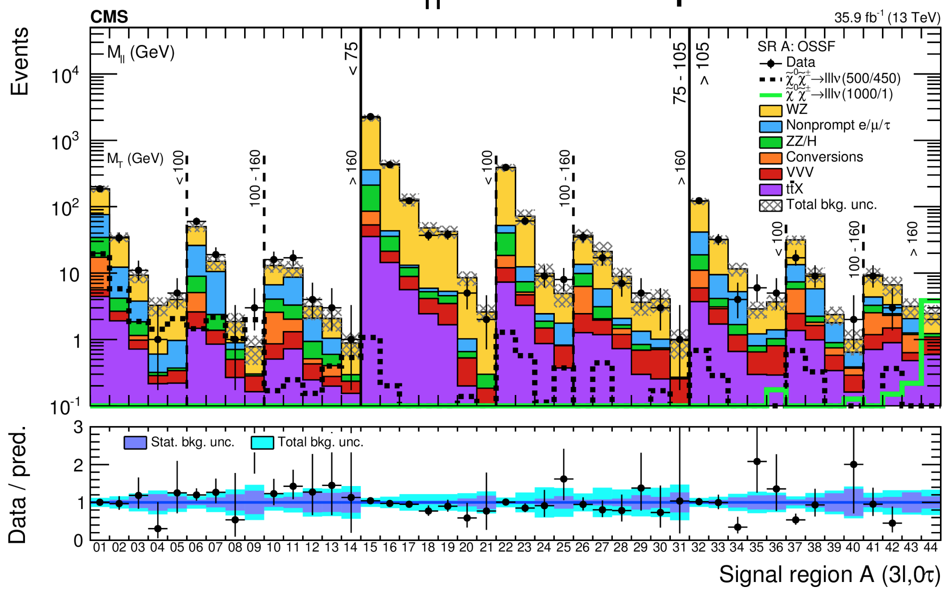


SS 2l

arXiv:1709.05406



3l+0τ_h ≥1 SFOS pair

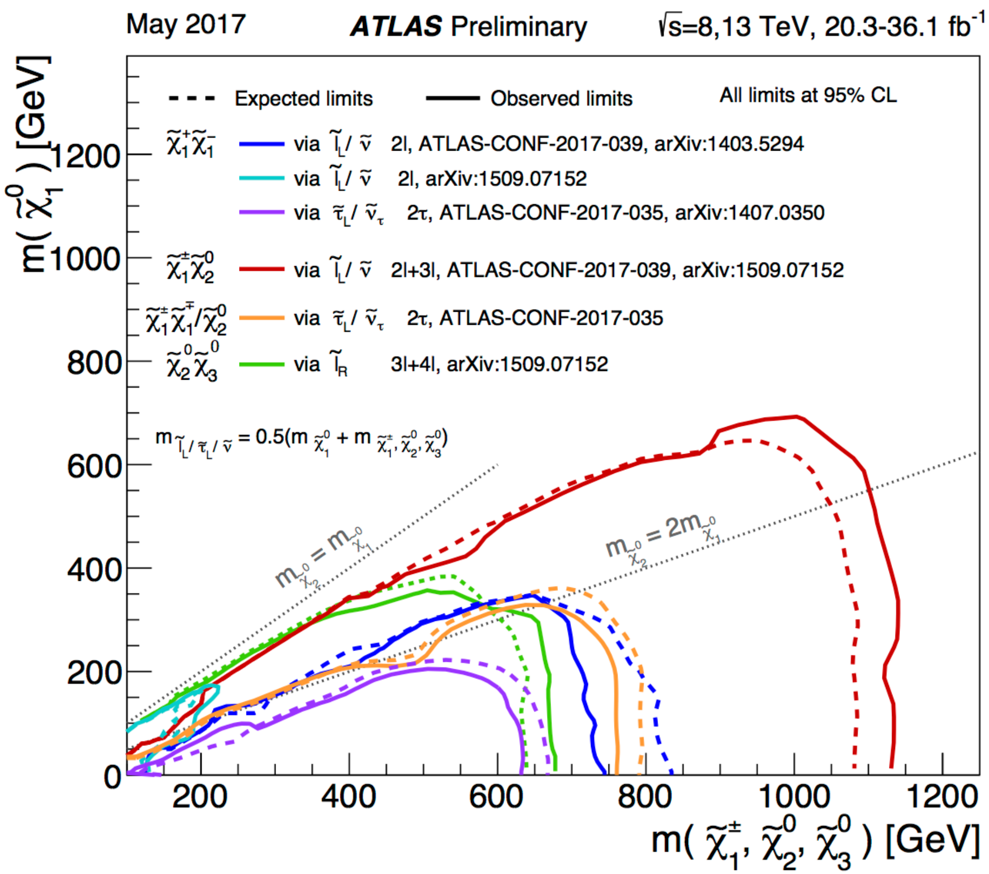


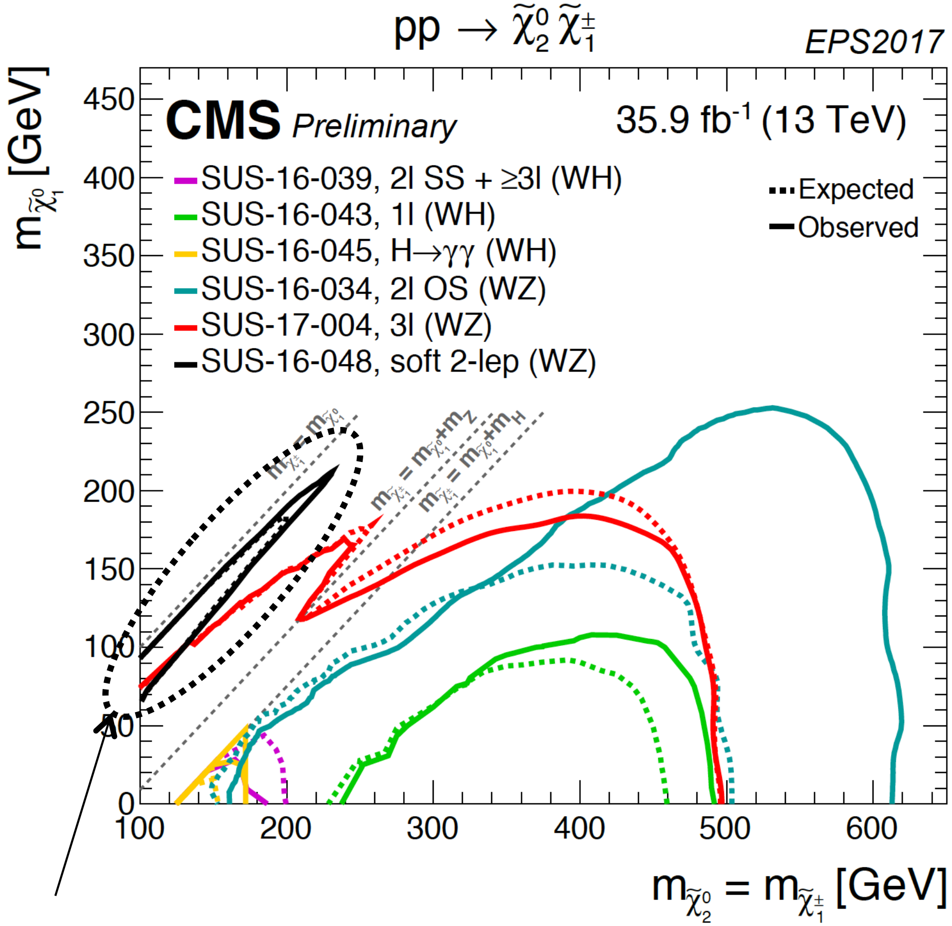
Total of 158 regions (incl 2, 3, 4 leptons, all types)

No significant excess observed

Natural SUSY: Electroweak production

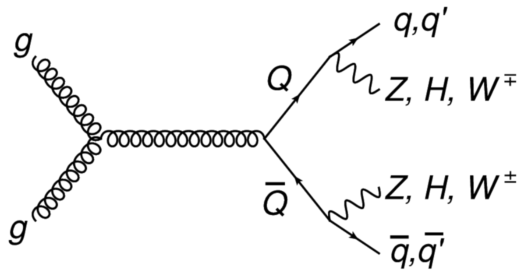
- Powerful exclusions in decays via sleptons
  - Mass limits on selectron/smuon up to 500 GeV – not yet on staus!
- If kinematically forbidden, decays via WZ or WH (on-shell or off-shell in compressed scenarios)



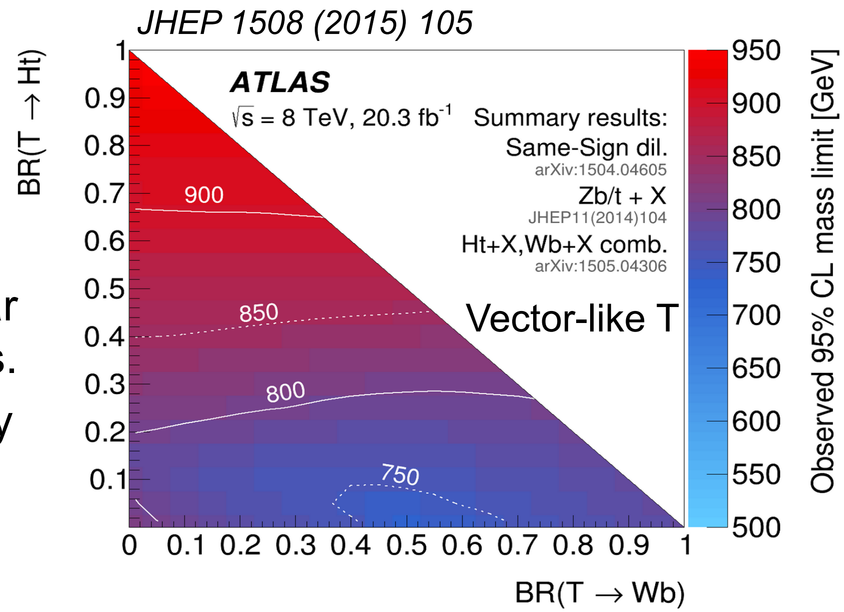


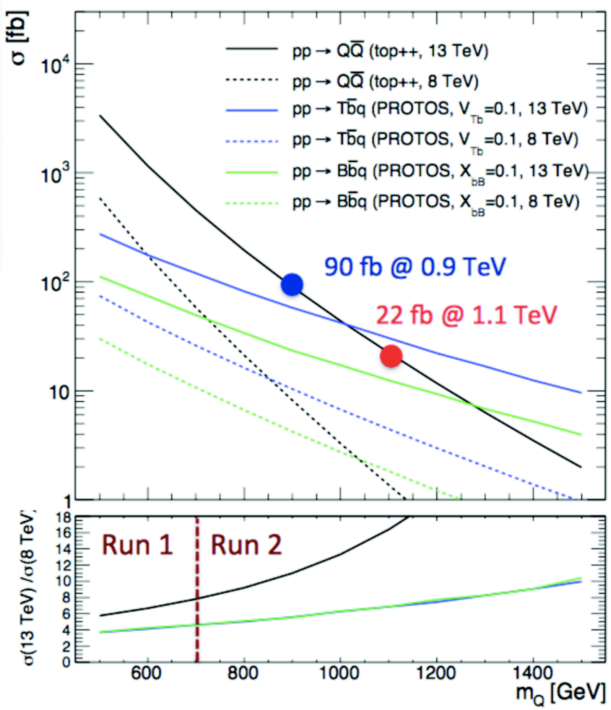
Dedicated analysis on compressed scenarios

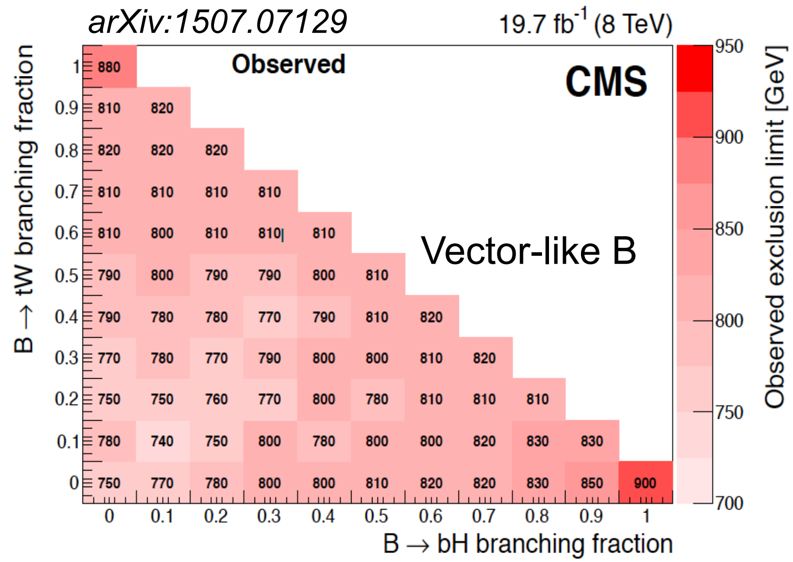
Natural Exotics: Vector-like quarks



- Vector-like top and bottom quarks naturally appear in composite Higgs and extra-dimensional models.
- Very rich phenomenology depending on the heavy quark mass and quantum numbers.
- Run 1 excluded masses below ~750 GeV.



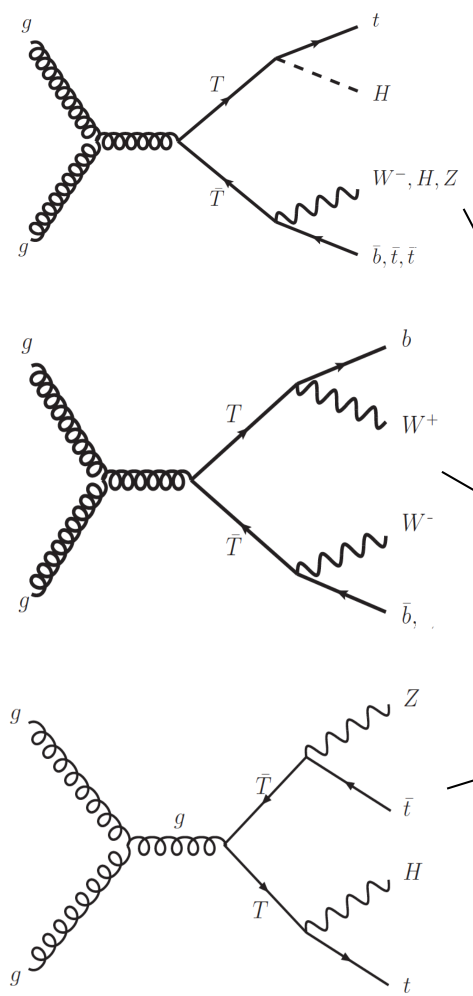


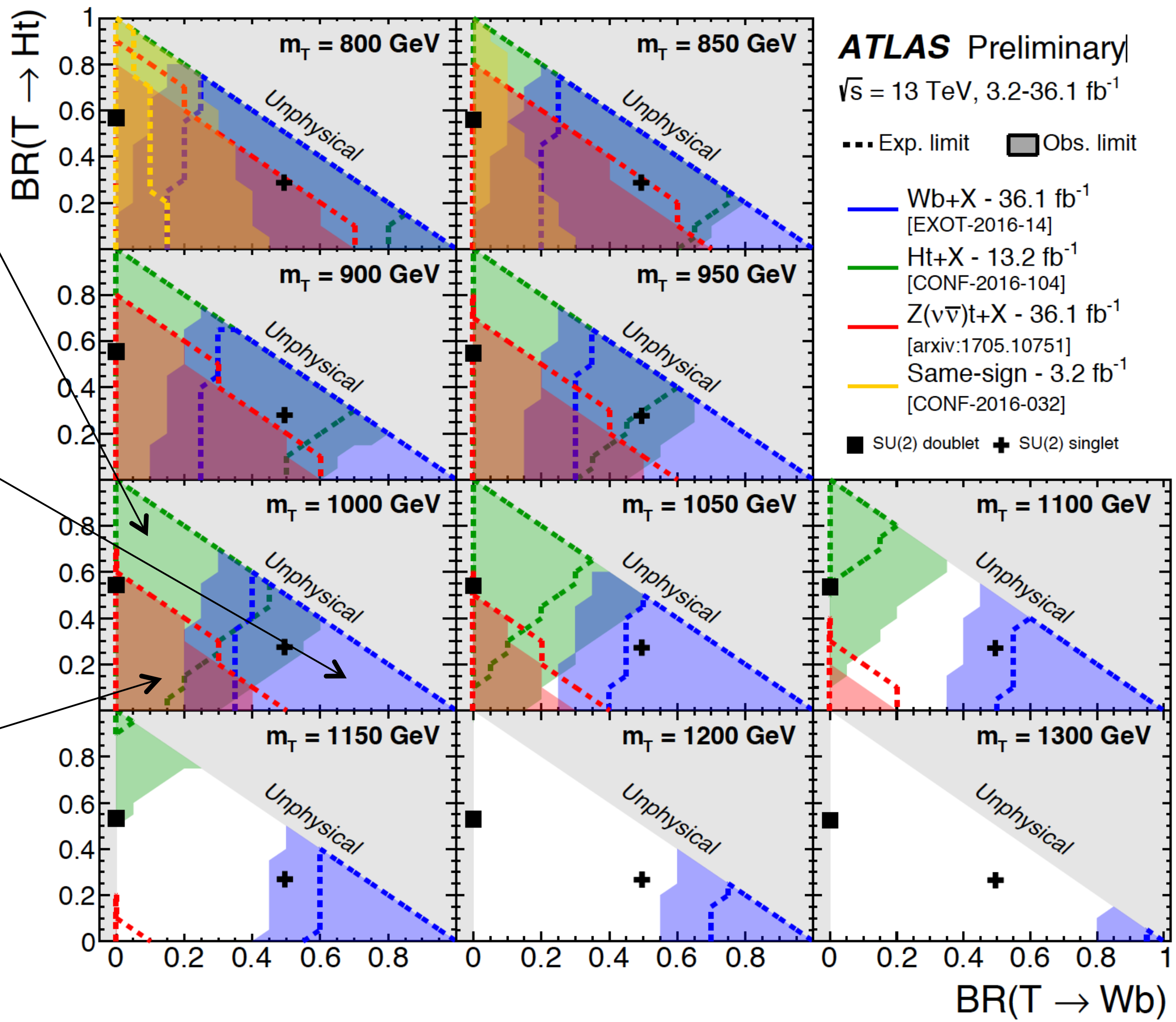


Great potential for discovery in Run 2!

Natural Exotics: Vector-like quarks

- Broad program of searches for pair production excludes masses below ~1 TeV over the whole branching ratio plane (up to 1.3 TeV at BR=100%).



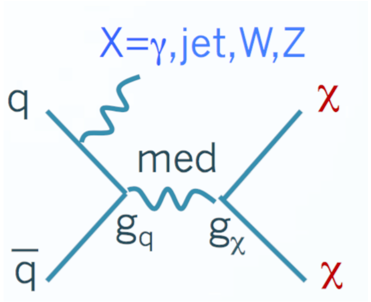


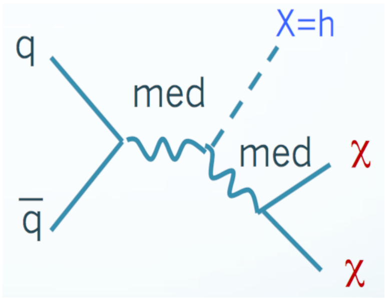
Dark matter

Direct Detection (t-channel) Collider Searches (s-channel)

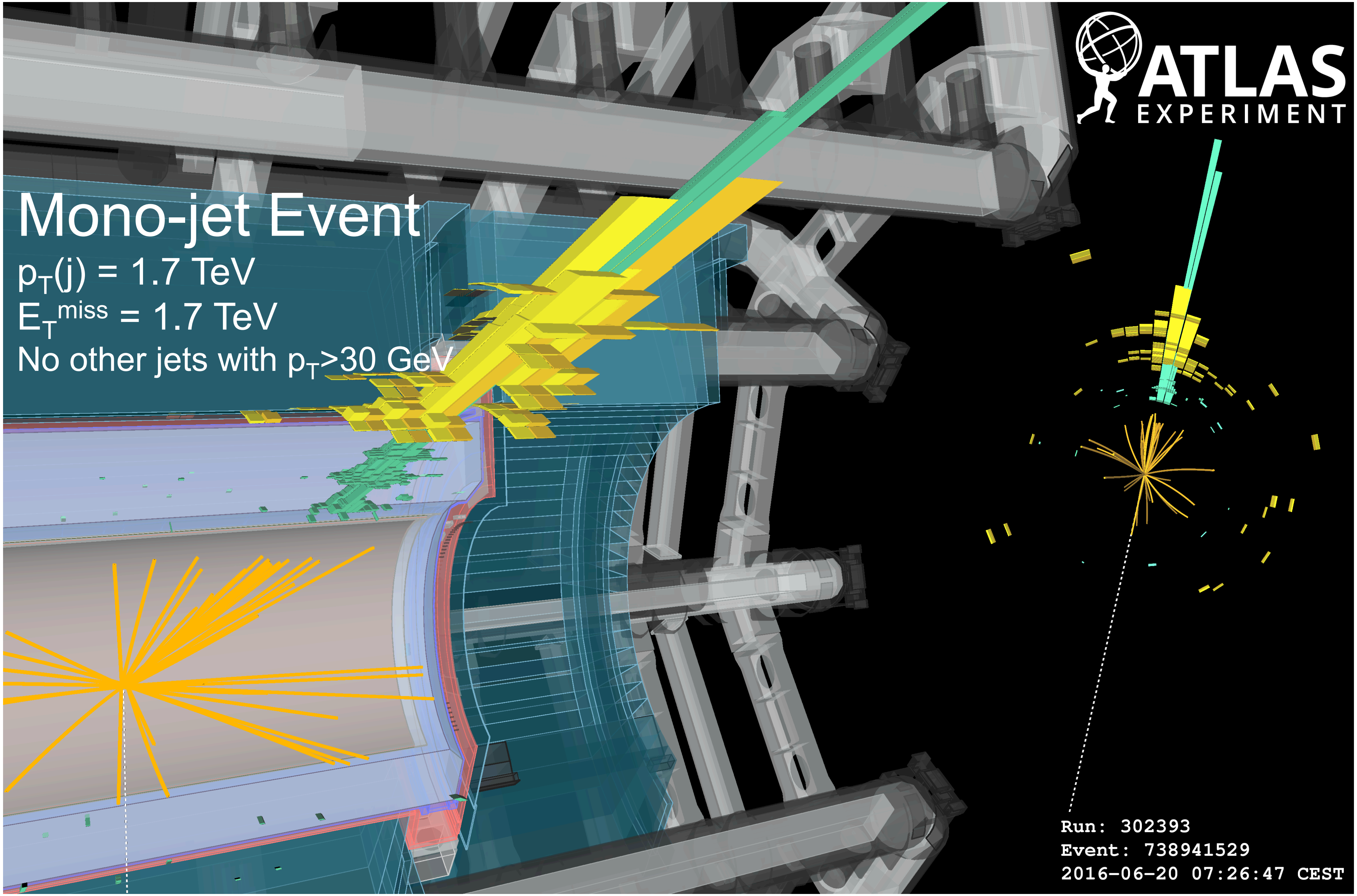
- Dark matter can also be produced at colliders.
- Being searched in association with SM particles, giving signatures of E_T^{miss}+X

(X can be pretty much anything: q, g, V, h, top(s), b(s)) ➔ **"Mono-mania"**

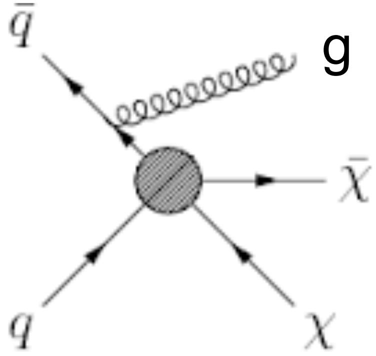




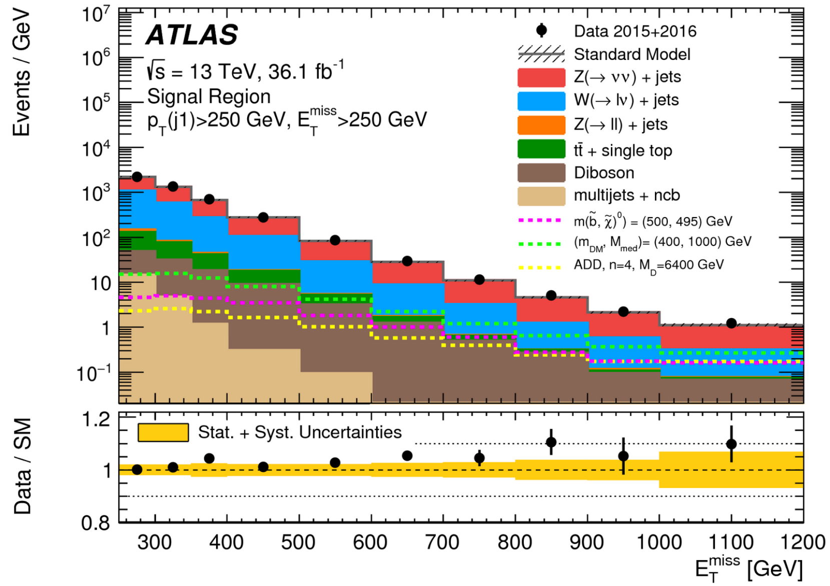
- Common "language" established with simplified models:
  ATLAS-CMS Dark Matter (DM) Forum (*arXiv:1507.00966*)
  - DM particle is a Dirac fermion χ
  - Mediator (med) exchanged in the s-channel
  - 5 parameters: M_{med}, m_χ, g_q, g_χ, Γ_{med}
  - Physics objects (X) produced in ISR (or radiated in case of h)
  - EFT models kept as benchmark (but with clear limitations and validity bounds)


ATLAS
EXPERIMENT
Mono-jet Event
$p_T(j)$ = 1.7 TeV
E_T^{miss} = 1.7 TeV
No other jets with p_T>30 GeV
Run: 302393
Event: 738941529
2016-06-20 07:26:47 CEST

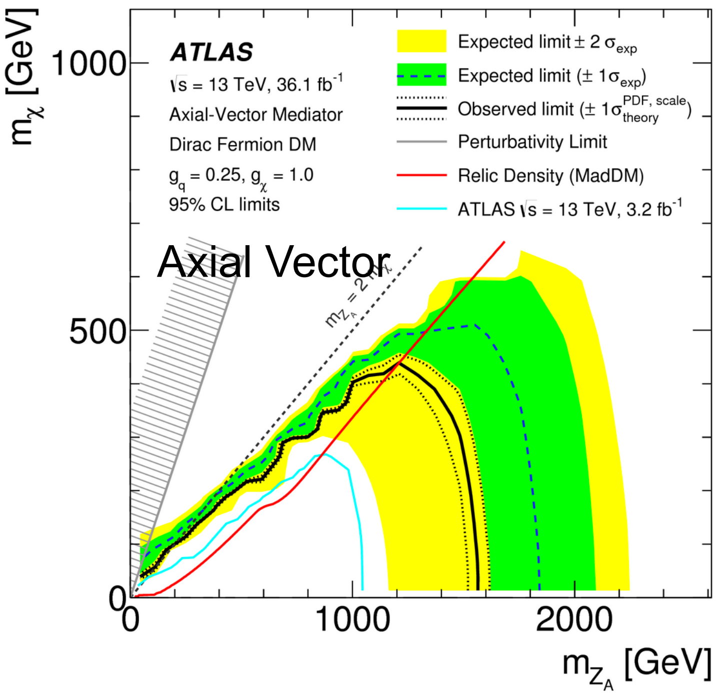
Dark matter: Mono-jet



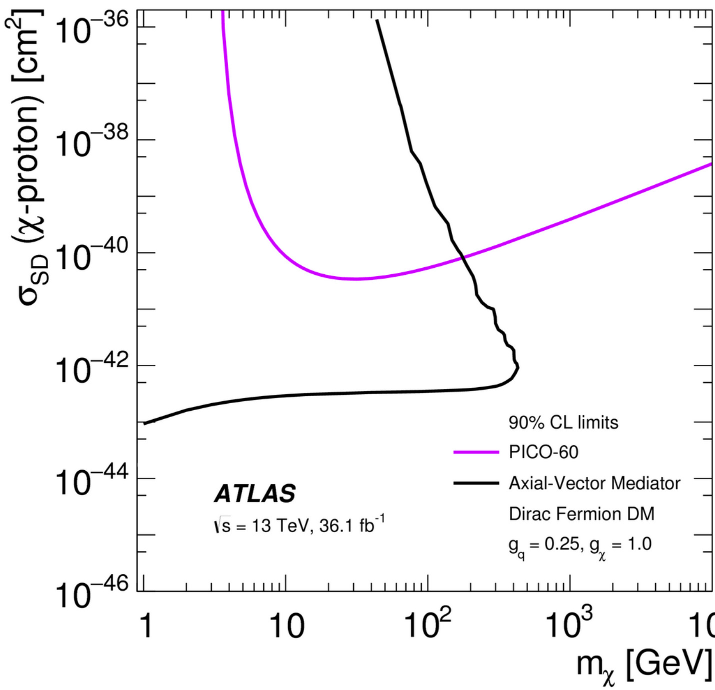
High-p_T jet + large E_{Tmiss}
(low jet multiplicity)



- Main backgrounds: Z(→νν)+jets, W(→lν)+jets
- **Most powerful and generic DM search**



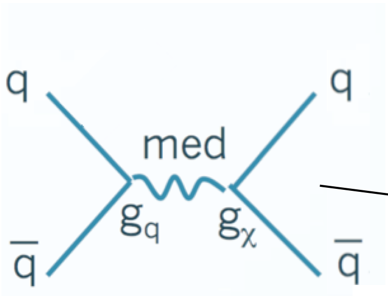
90% CL exclusion limit on the spin-dependent σ(χ-p) (model dependent)



arXiv:1711.03301

Mono-jet – dijet resonances complementarity

- If the mediator is produced by $q\bar{q}$, it will also decay into $q\bar{q}$
  ➔ probed by dijet resonance searches!



Off-shell region:

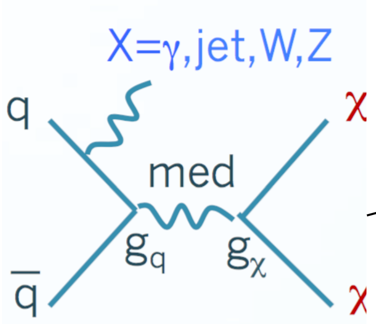
$M_{med} < 2m_\chi$

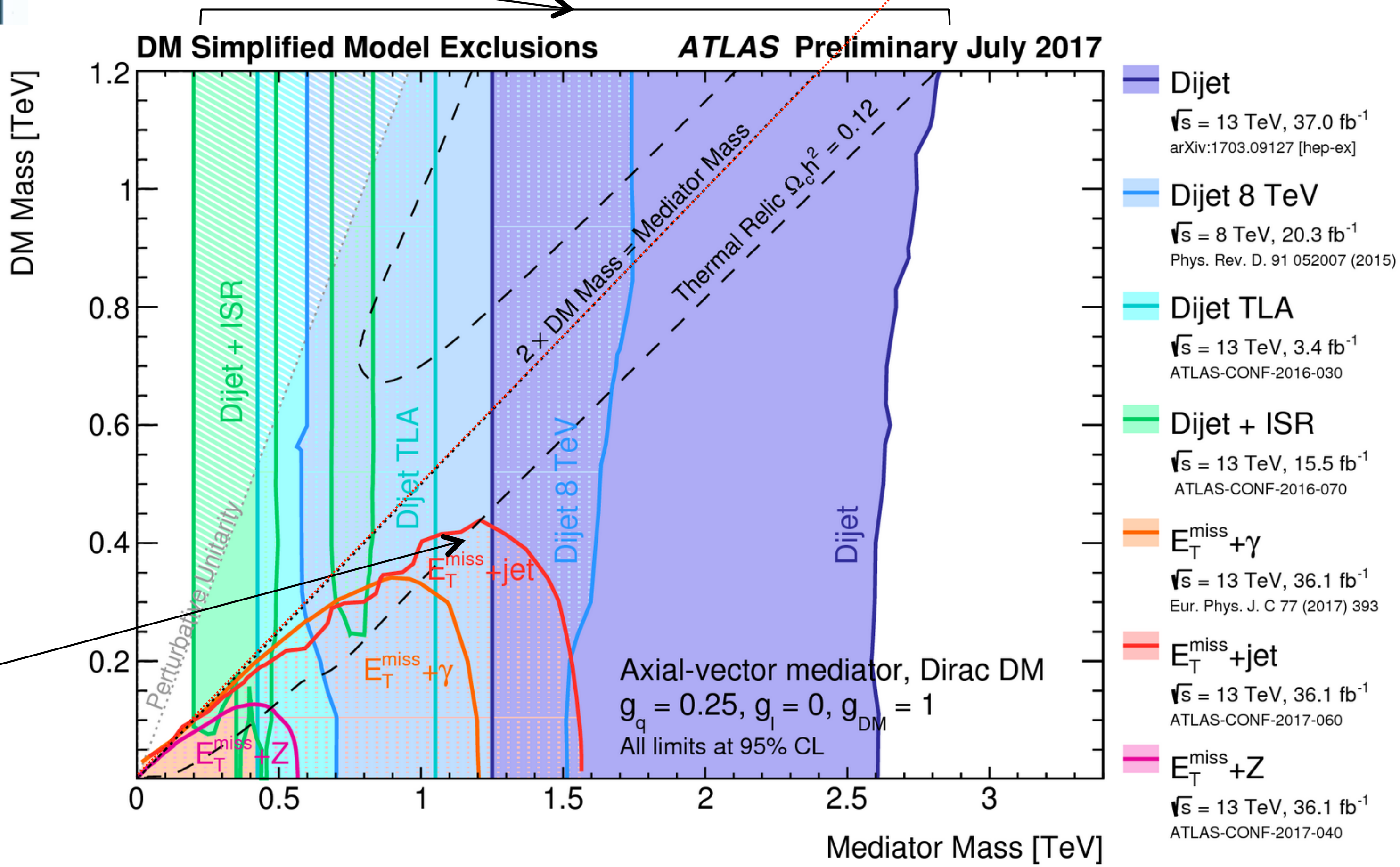
The mediator can decay only to di-jet

On-shell region:

$M_{med} > 2m_\chi$

The mediator can decay also to DM





Dark matter: mono-W/Z and mono-Higgs

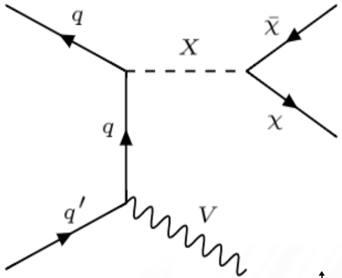
- **Mono-W/Z**: provides information on the couplings to u- and d-quarks, as well as on their relative sign.

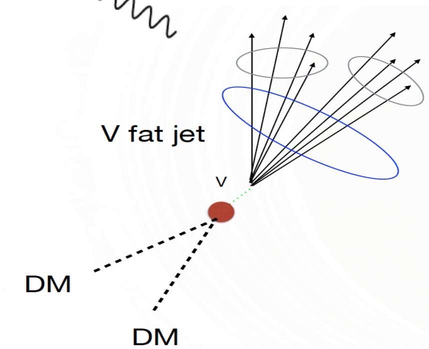
  Most-sensitive search: boosted hadronically-decaying W/Z + E_T^{miss}

- **Mono-Higgs**: searches consider the H→bb, γγ decay modes.

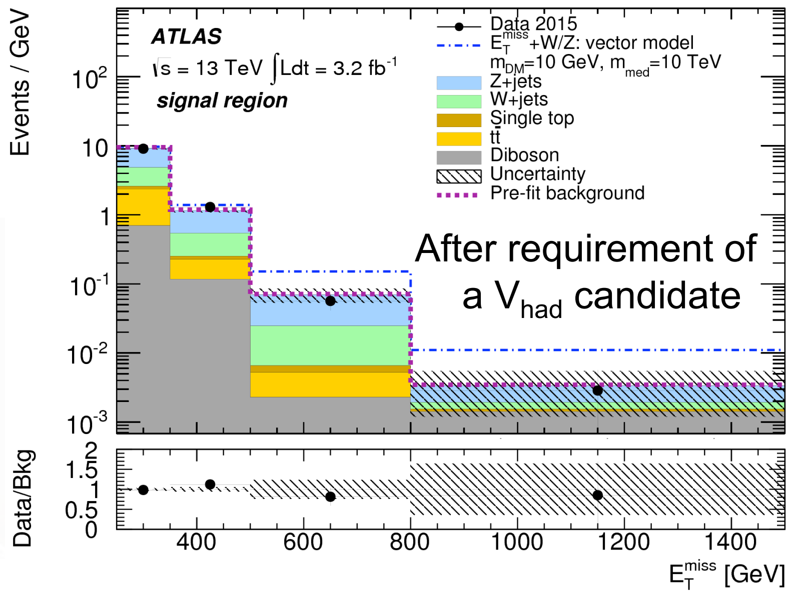
  Several benchmark scenarios considered.

  E.g.: Z'-2HDM

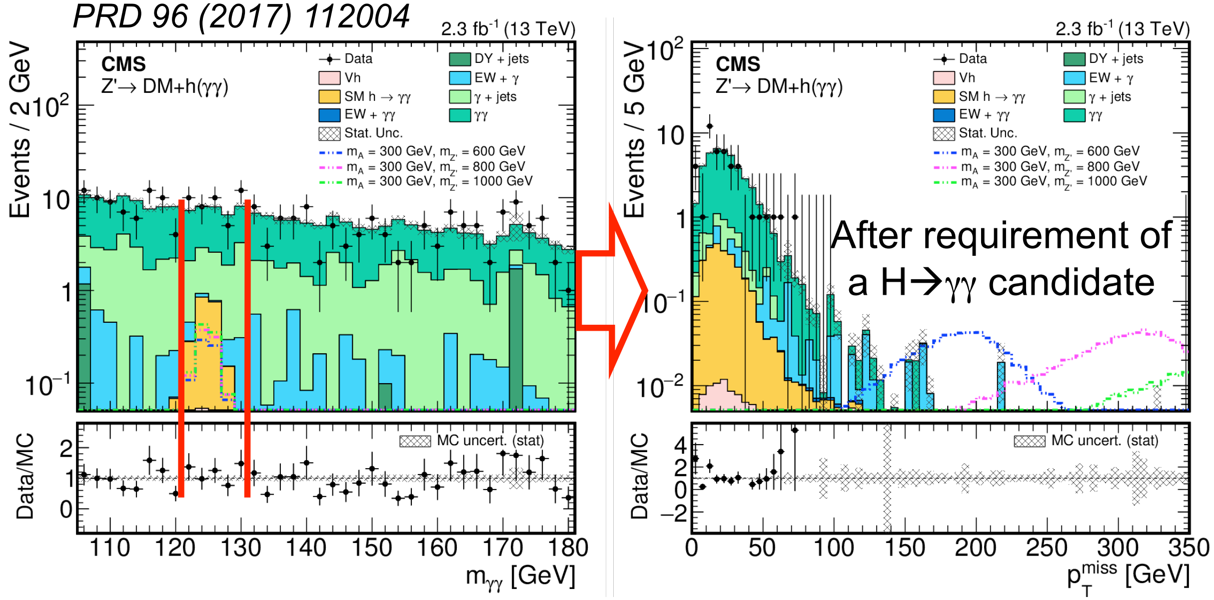


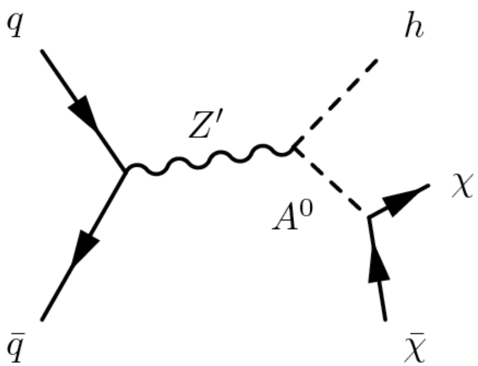


PLB 763 (2016) 251



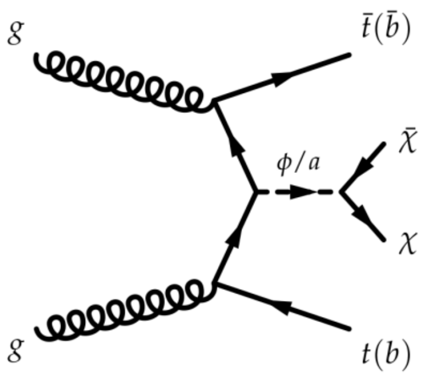
PRD 96 (2017) 112004

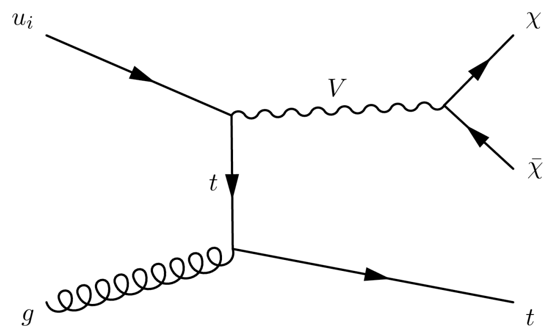


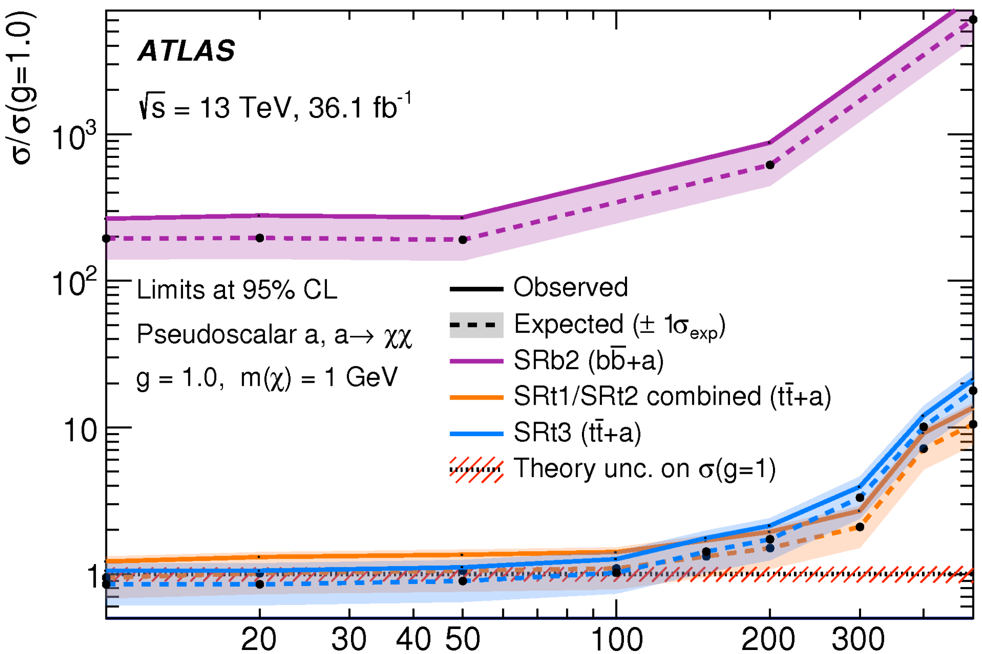


Dark matter: DM+heavy-flavor

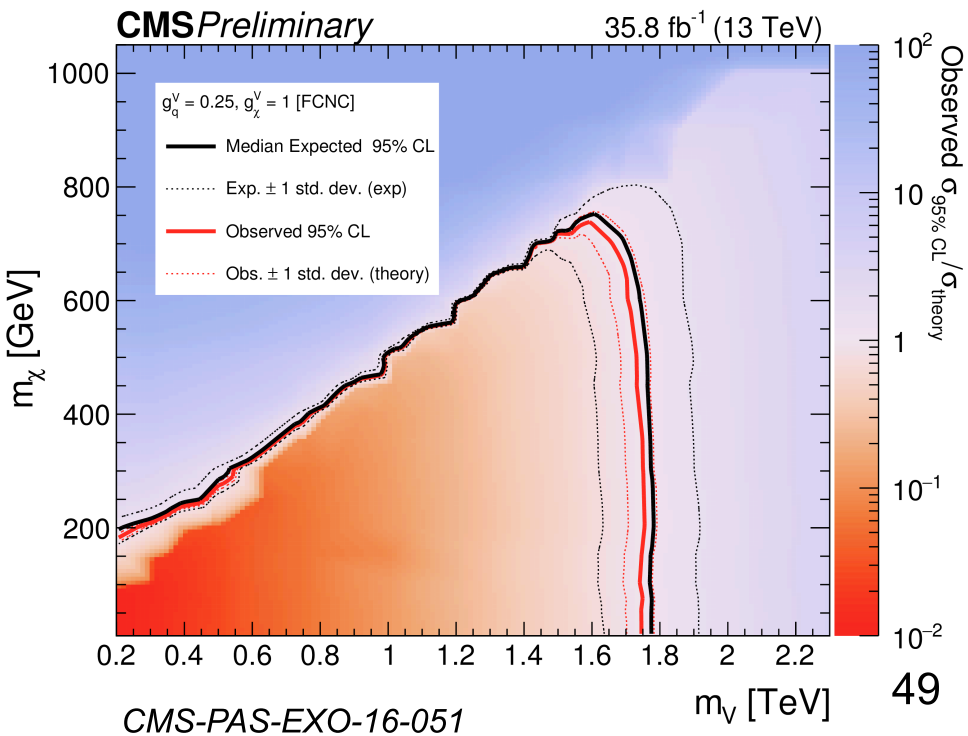
- Dark matter produced in association with bottom/top particularly sensitive to (pseudo-)scalar interactions: $coupling \propto m_q$
- Also searches for a single top-quark+E_T^{miss} (e.g. via FCNC).



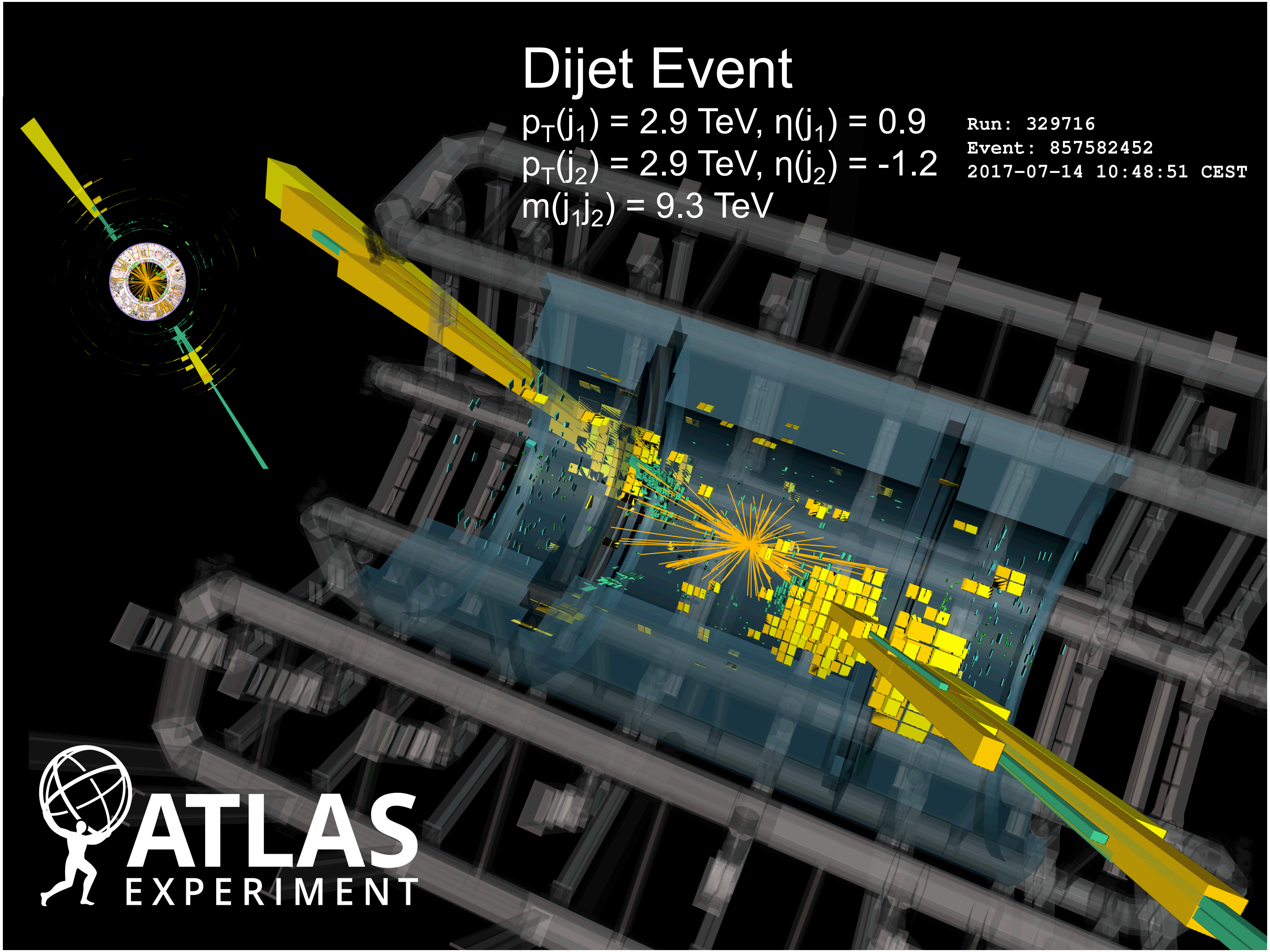




arXiv:1710.11412



CMS-PAS-EXO-16-051


Dijet Event
$p_T(j_1)$ = 2.9 TeV, $\eta(j_1)$ = 0.9
$p_T(j_2)$ = 2.9 TeV, $\eta(j_2)$ = -1.2
$m(j_1 j_2)$ = 9.3 TeV
Run: 329716
Event: 857582452
2017-07-14 10:48:51 CEST
ATLAS
EXPERIMENT

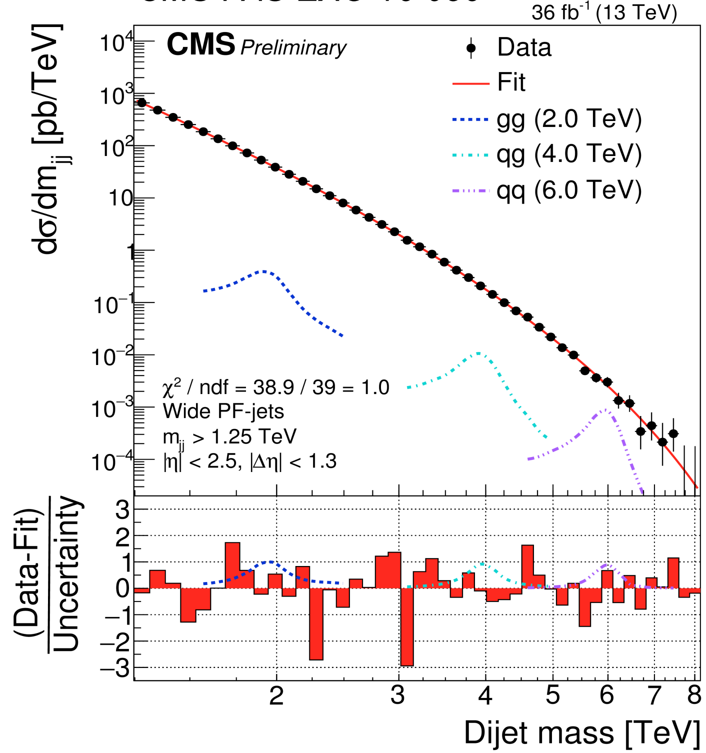
Resonances in high-p_T multijet final states

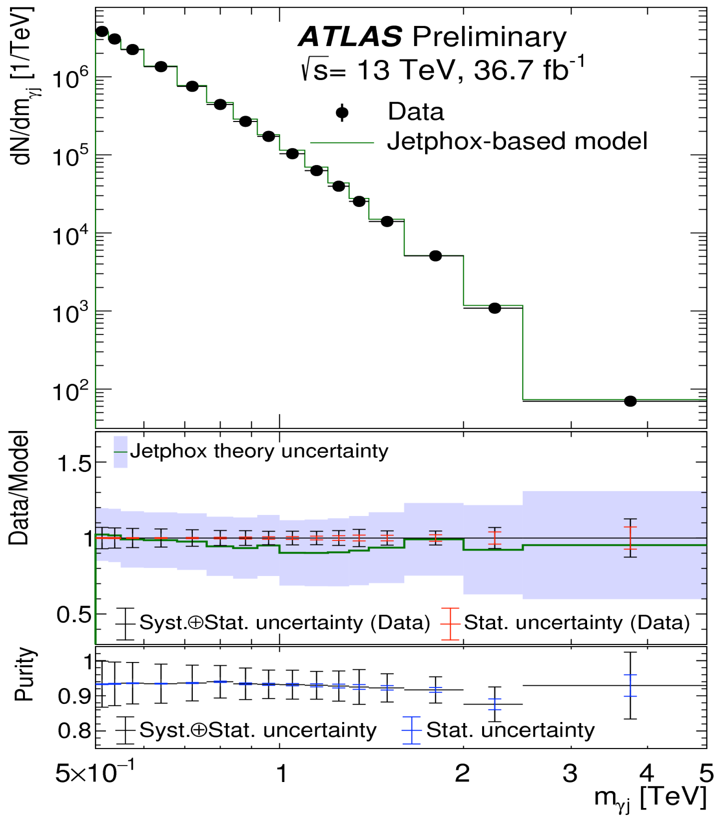
Early Run 2 searches focused on processes with the highest cross sections.

- Dijet resonances and angular distributions
- Photon+jet resonances
- High-p_T multijets and lepton+jets produced e.g. by strong gravity
- …

No excess found

CMS-PAS-EXO-16-056





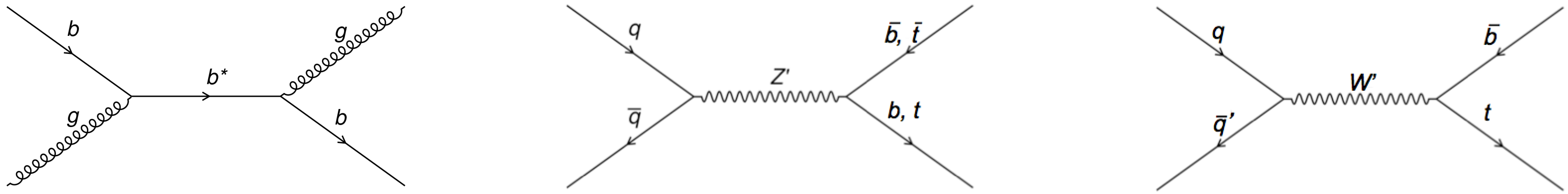
ATLAS

PRD 96 (2017) 052004

Model	95% CL exclusion limit	
	Observed	Expected
Quantum black hole	8.9 TeV	8.9 TeV
W'	3.6 TeV	3.7 TeV
W^*	3.4 TeV 3.77 TeV – 3.85 TeV	3.6 TeV
Excited quark	6.0 TeV	5.8 TeV
Z' $(g_q = 0.1)$	2.1 TeV	2.1 TeV
Z' $(g_q = 0.2)$	2.9 TeV	3.3 TeV
Contact interaction $(\eta_{LL} = -1)$	21.8 TeV	28.3 TeV
Contact interaction $(\eta_{LL} = +1)$	13.1 TeV 17.4 TeV – 29.5 TeV	15.0 TeV

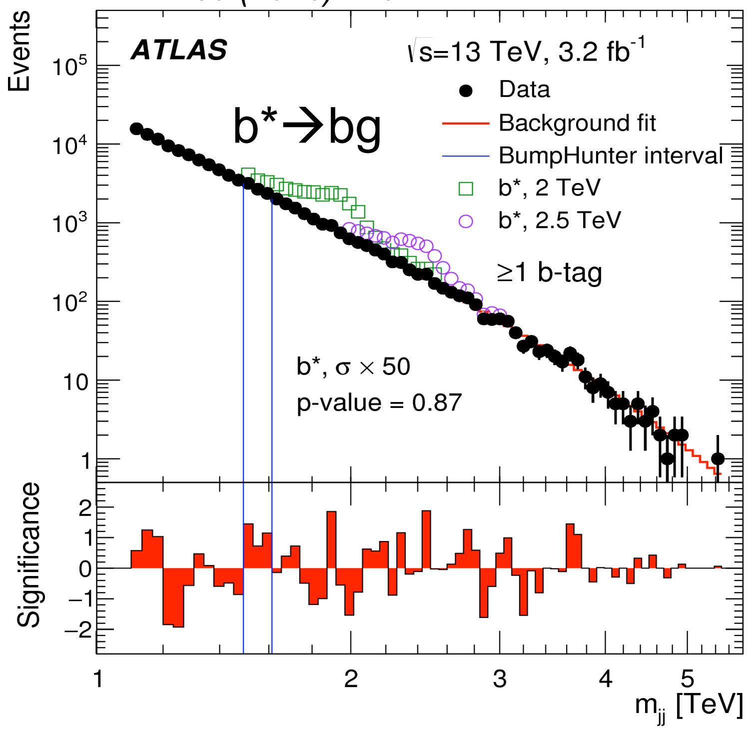
Resonances in high-p_T multijet final states

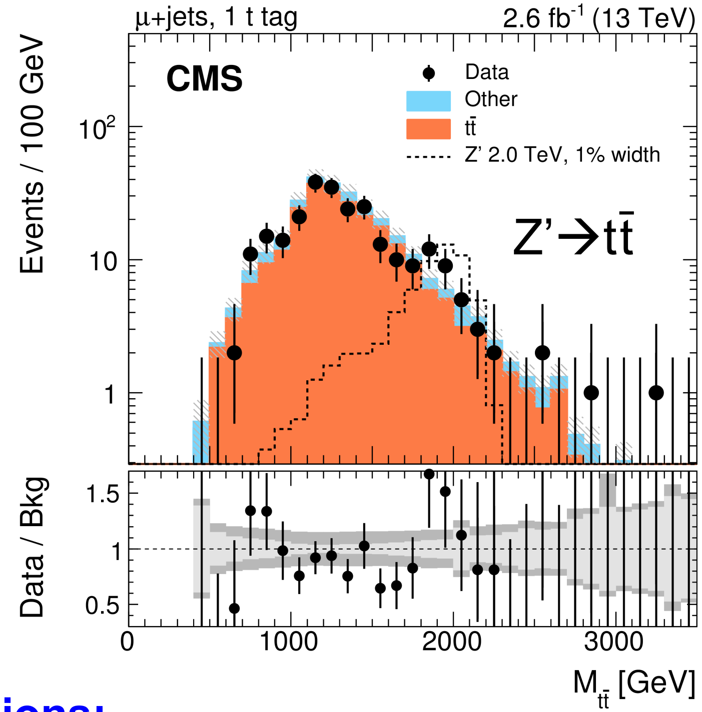
- Also searches for resonances decaying into 3rd generation quarks.



No excess found

PLB 759 (2016) 229





95% CL exclusions:

Excited b quark: $1.1 < m_{q^*} < 2.1$ TeV

SSM Z': $1.1 < m_{Z'} < 1.5$ TeV

95% CL exclusions:

TC2 Z' ($\Gamma/M = 1\%$) : $0.6 < m_{Z'} < 2.5$ TeV

KK gluon: $0.5 < m_{gKK} < 3.3$ TeV

W'_R: $m_{W'} < 3.6$ TeV

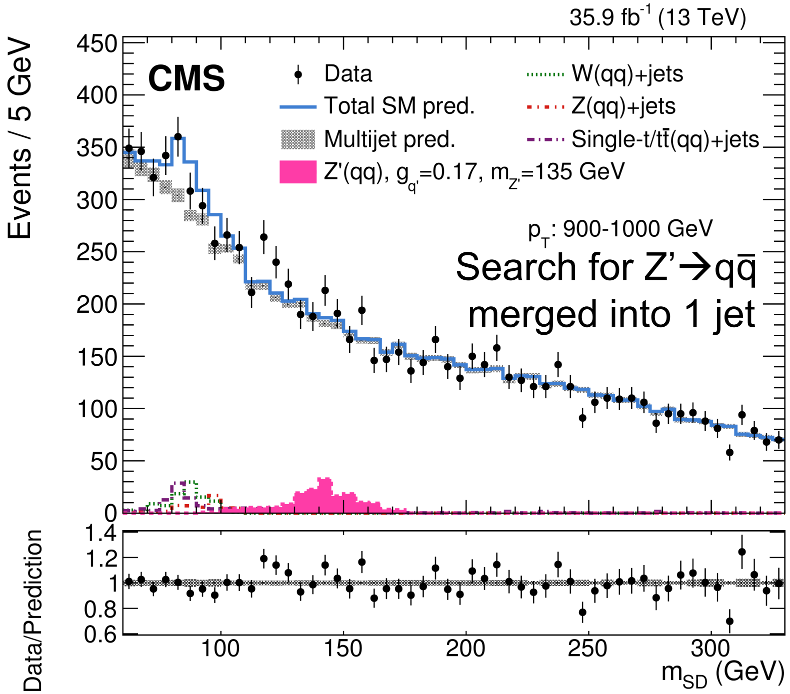
JHEP 07 (2017) 001

arXiv:1708.08539

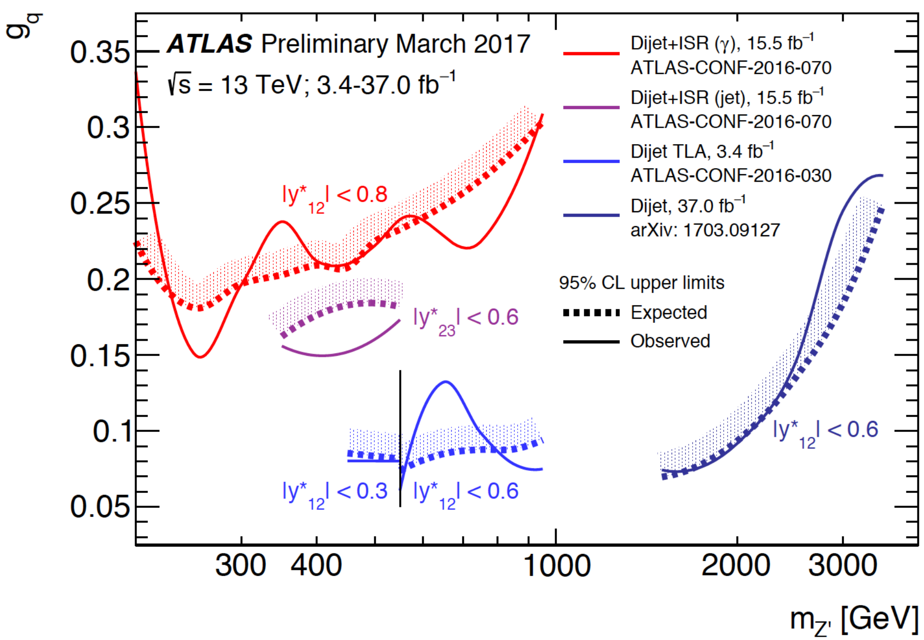
Low-mass dijet resonances

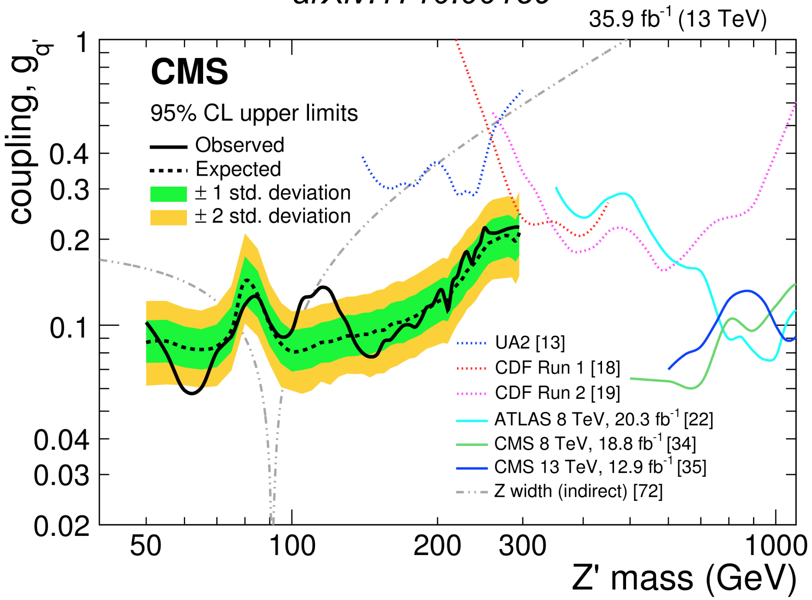
- Sensitivity to light dijet resonances statistically limited due to jet trigger prescales.
- Several strategies developed:
  - Trigger-level analysis: use trigger-level jets and partially-reconstructed events (challenging jet reconstruction and calibration; no inner detector information).
  - Associated production with a high-p_T photon or jet from initial state radiation.

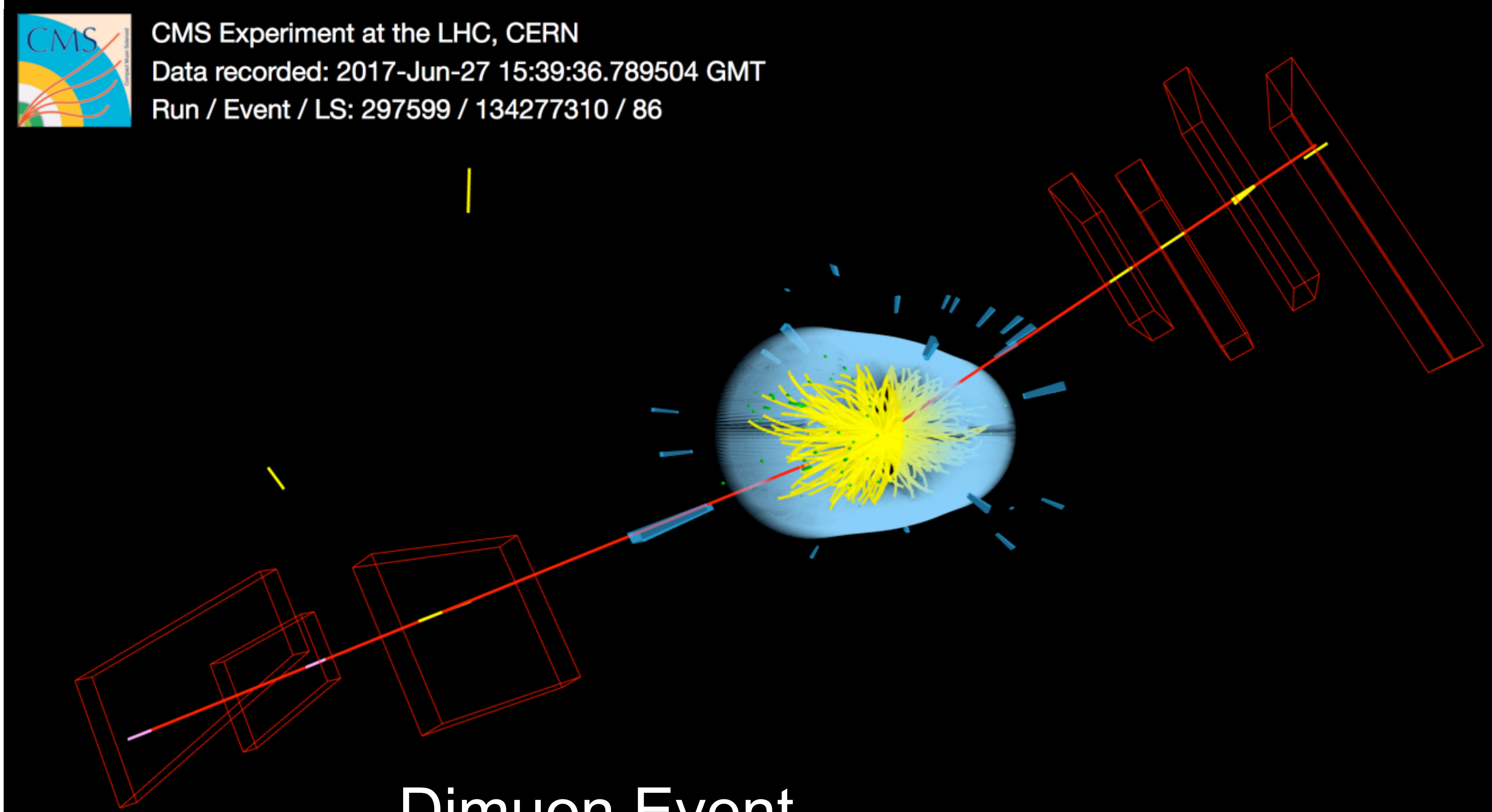
    ➔ Also use jet substructure techniques!



arXiv:1710.00159







Dimuon Event

$m(\mu\mu)$ = 2.4 TeV

Highest-mass Run 1 events:

1.8 TeV (ee), 1.9 TeV ($\mu\mu$)

Resonances in leptonic final states

- Searches for resonant production of Z'→ll, $l\tau_{had}$ (l=e, μ), $\tau_{had}\tau_{had}$ and W'→eν, $\mu\nu$.

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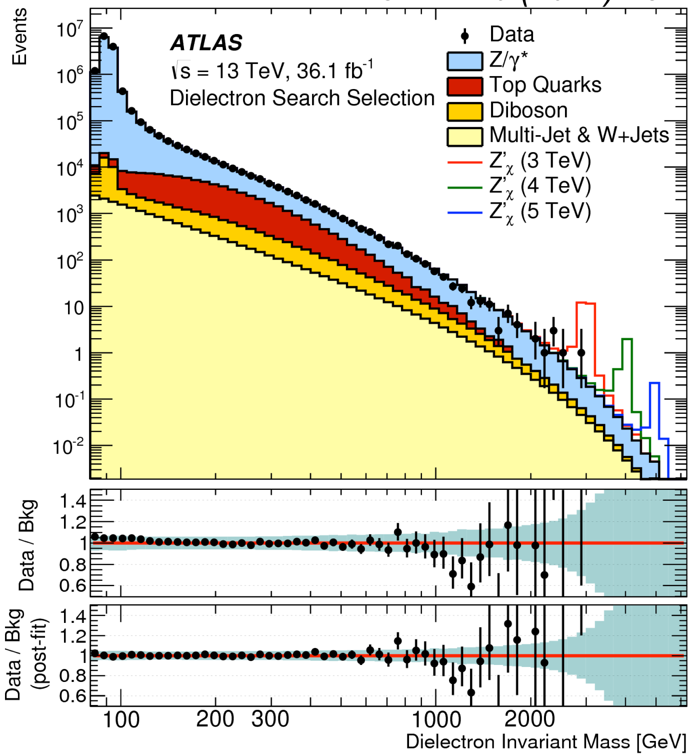
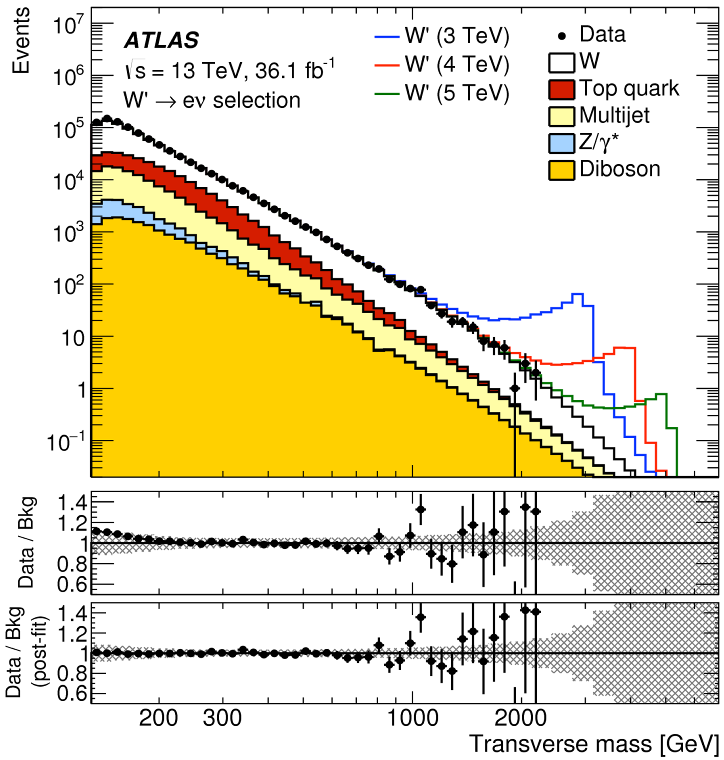


arXiv:1706.04786



95% CL exclusions:

Z'$_{SSM}$→ee/$\mu\mu$: $m_{Z'}$<3.9 TeV (Run 1: 2.5 TeV)

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Z'→eμ: $m_{Z'}$<3.0 TeV

Z'→eτ_{had} ($\mu\tau_{had}$): $m_{Z'}$<2.7(2.6) TeV

EPJC 76 (2016) 541

95% CL exclusions:

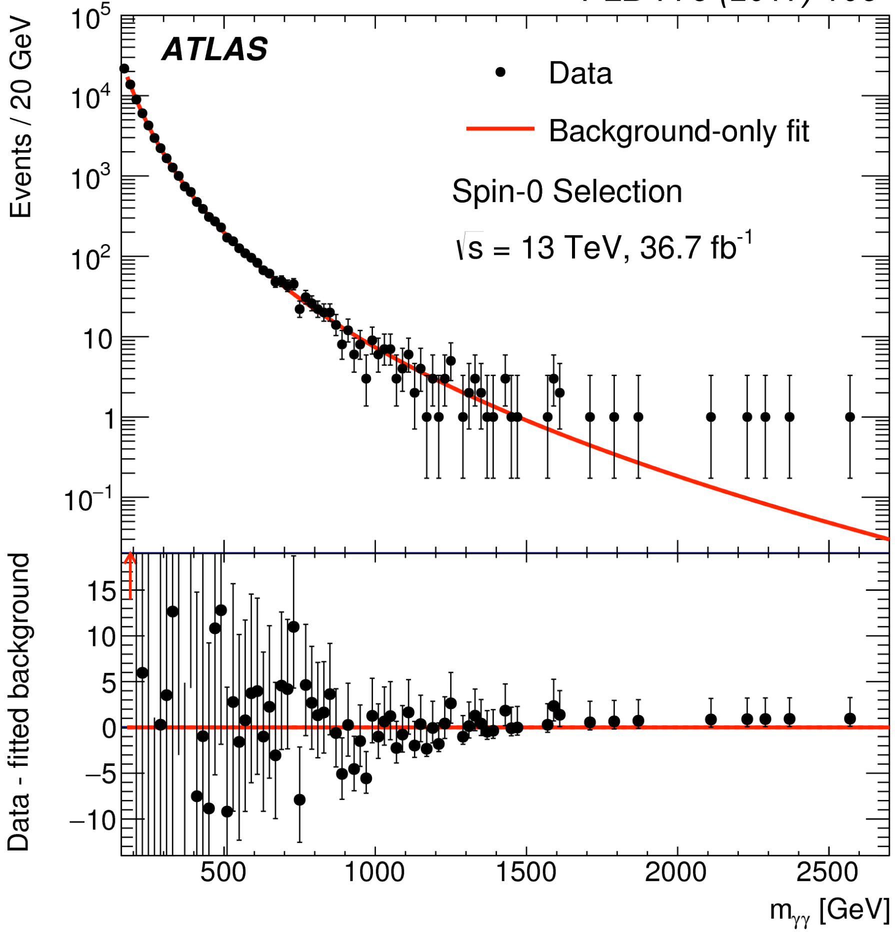
W'$_{SSM}$: $m_{Z'}$<5.1 TeV (Run 1: 3.2 TeV)

No excess found

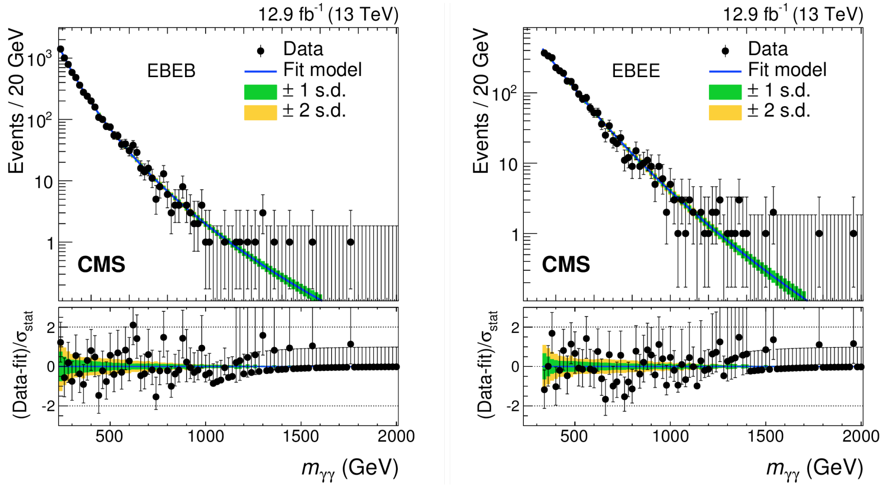
Diboson resonances (γγ)

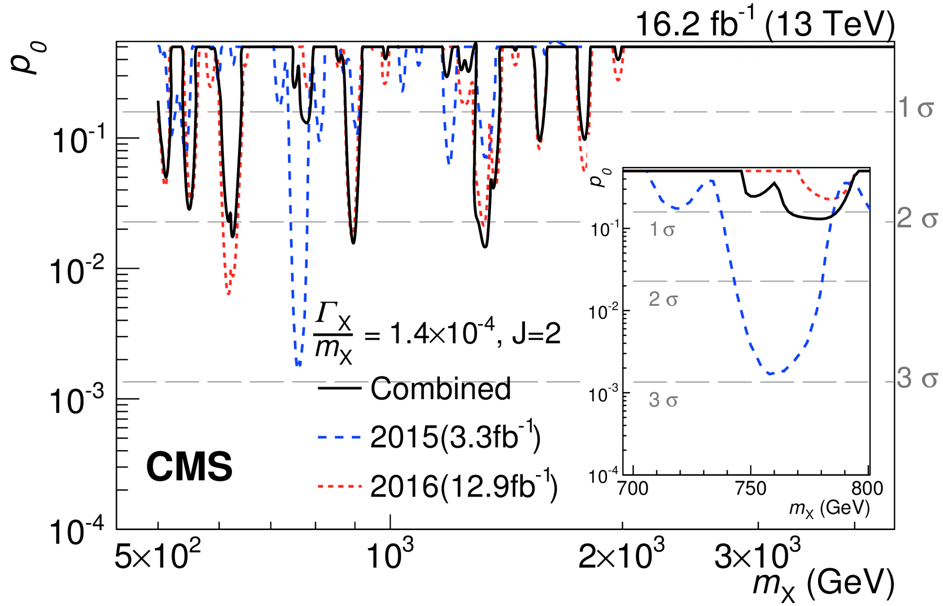
- Resonance searches with interpretations for:
  - Spin 0 (extended Higgs sectors)
  - Spin 2 (extra dimensions)

PLB 775 (2017) 105



PLB 767 (2017) 147





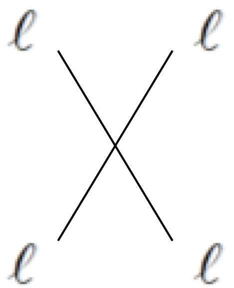
Also X→Zγ resonances

No excess found

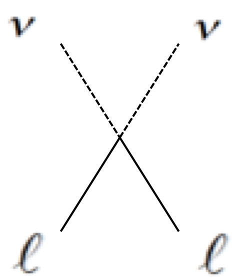
Diboson resonances (WW, WZ, ZZ)

- Many final state signatures explored!

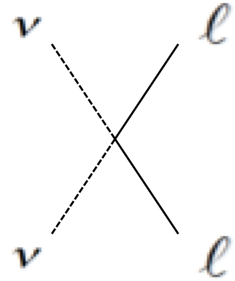
ZZ (Z→ll)



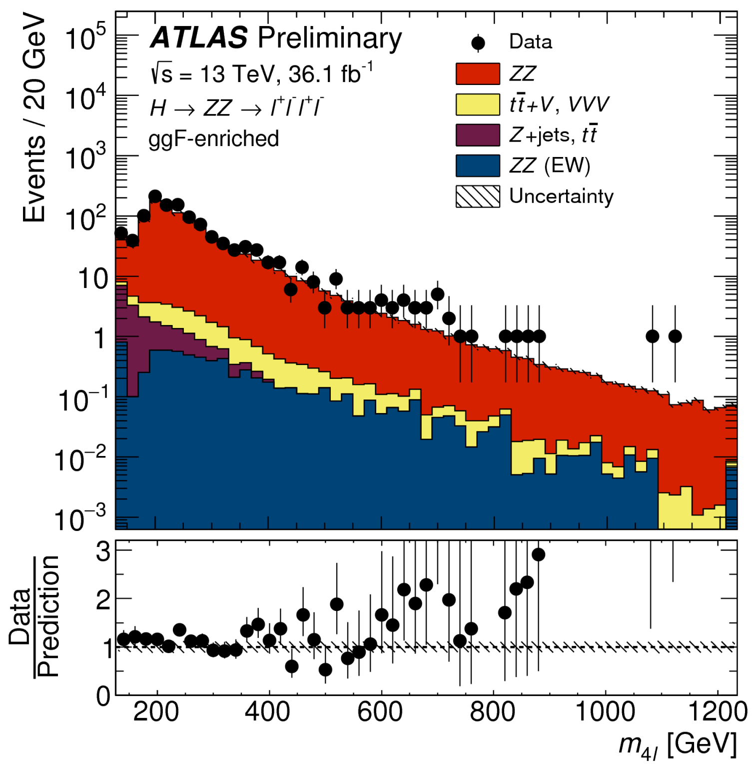
ZZ (Z→ll,νν)



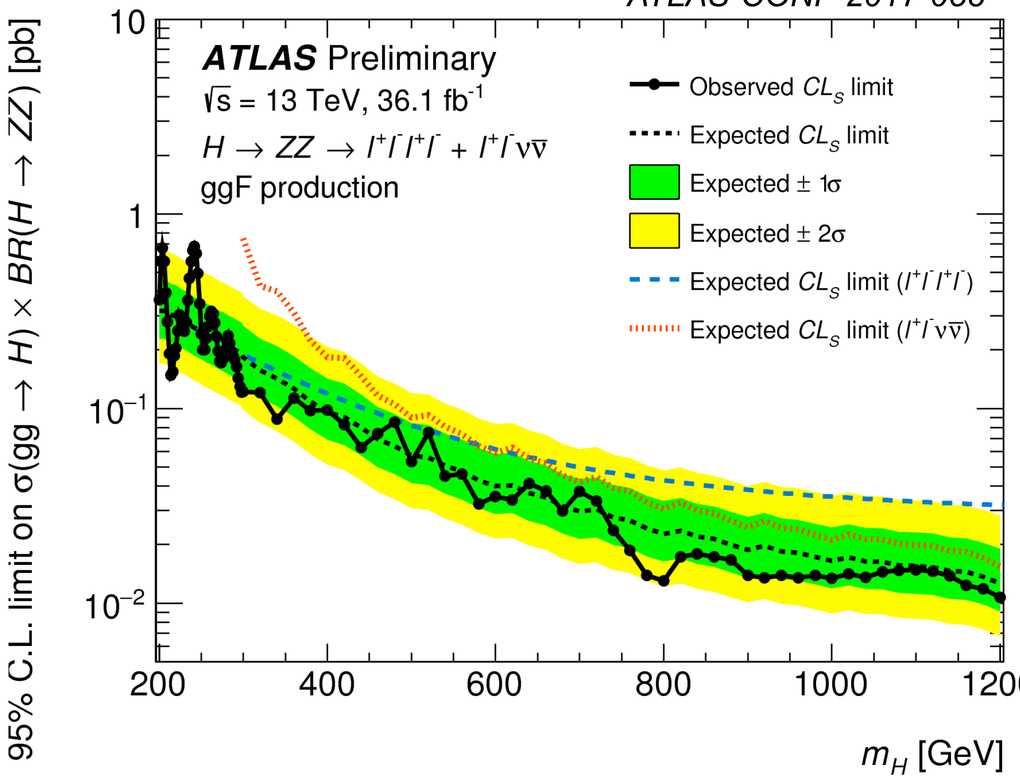
WW (W→lν)



ATLAS-CONF-2017-058



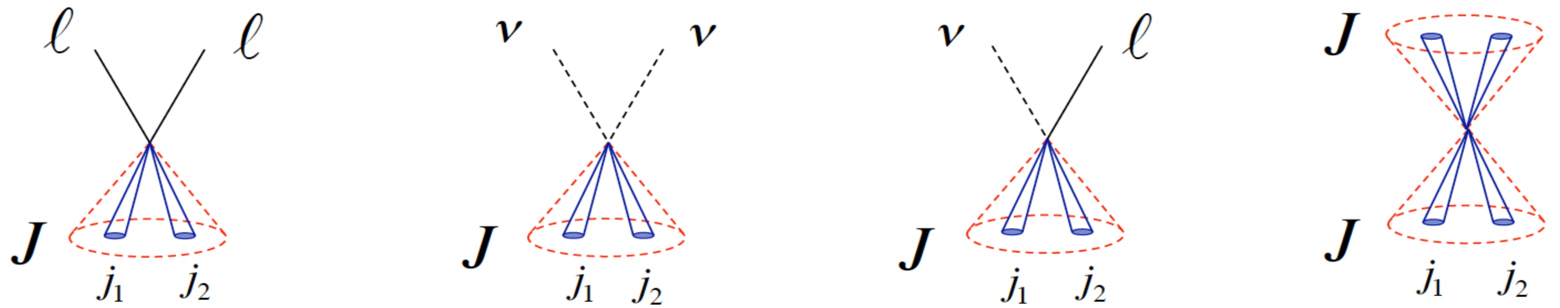
ATLAS-CONF-2017-058

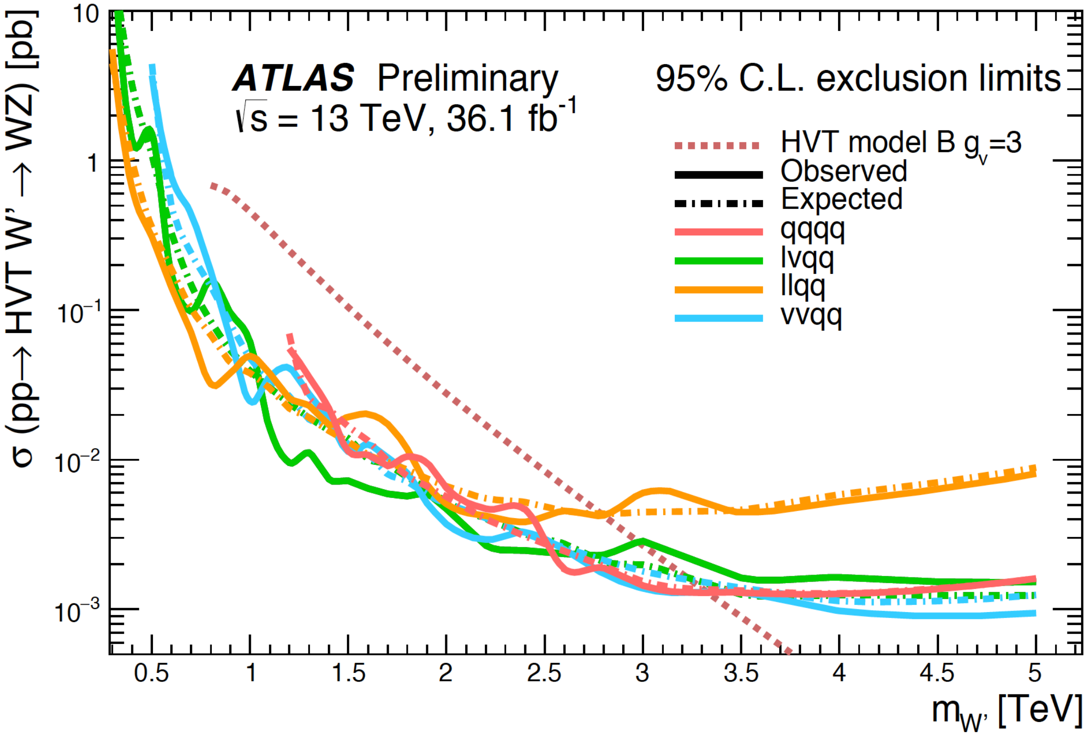


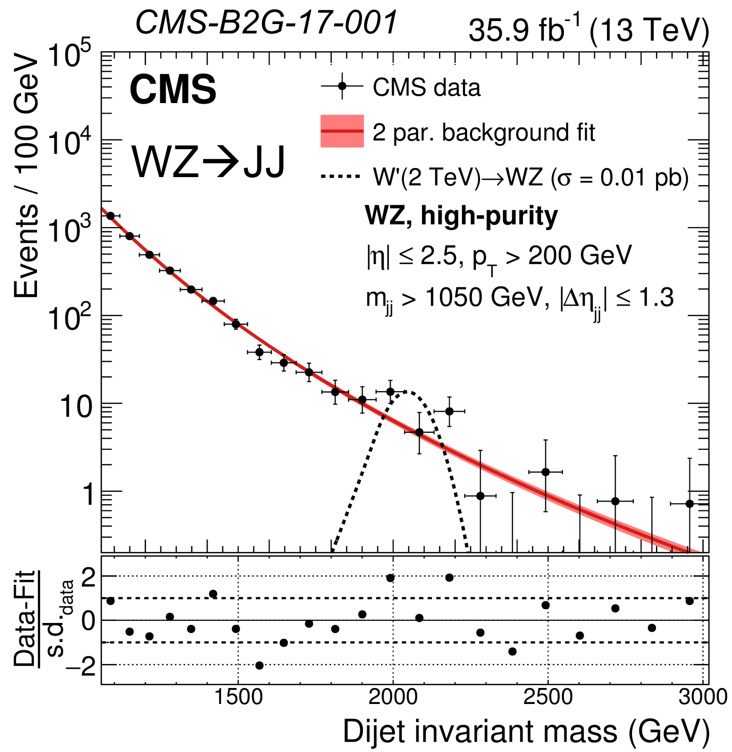
Diboson resonances (WW, WZ, ZZ)

- Many final state signatures explored!

ZV (Z→ll, V→jj) **ZV** (Z→νν, V→jj) **WV** (W→lν, V→jj) **VV** (V→jj)



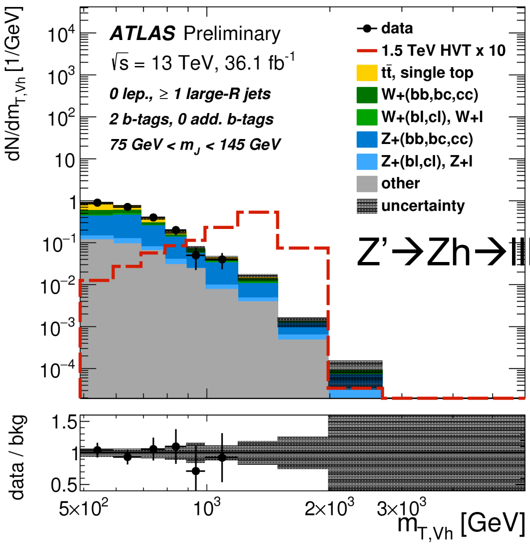


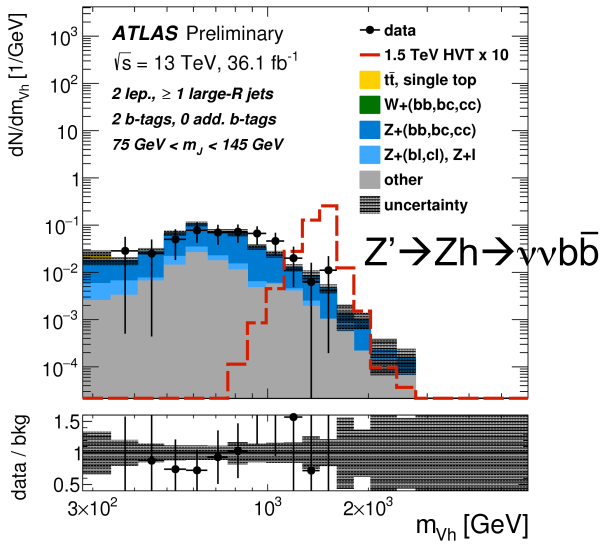


Diboson resonances (Wh, Zh)

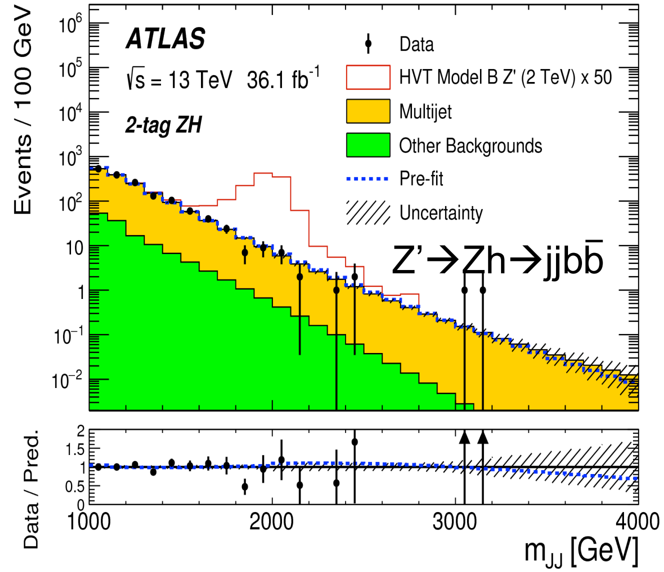
- Several searches for X→Vh (X=A or V') with h→$b\bar{b}$ performed.

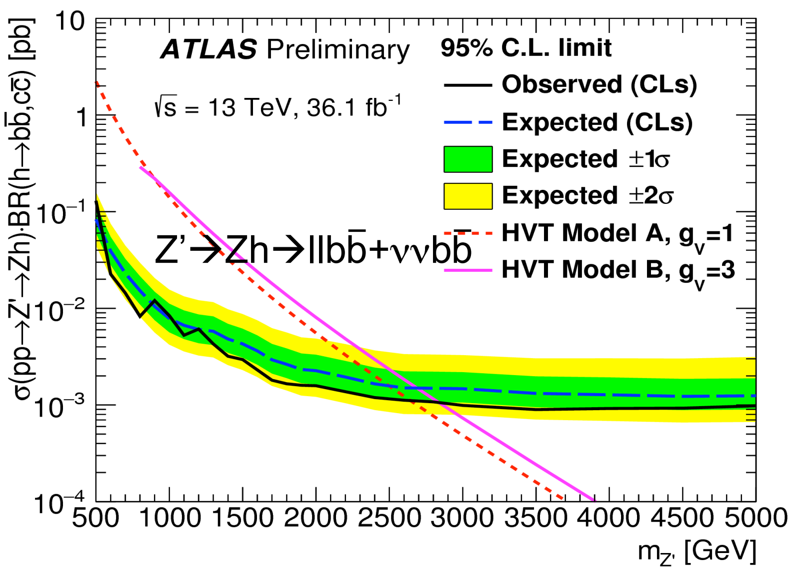
ATLAS-CONF-2017-055

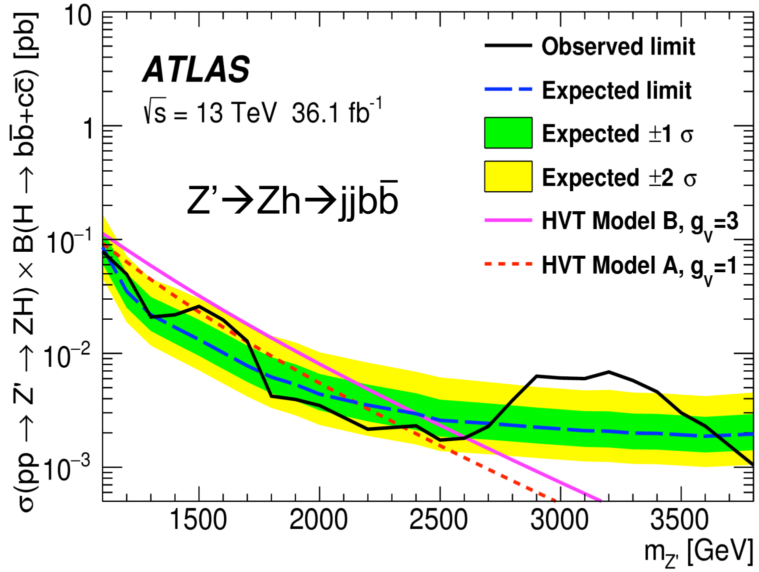




PLB 774 (2017) 494

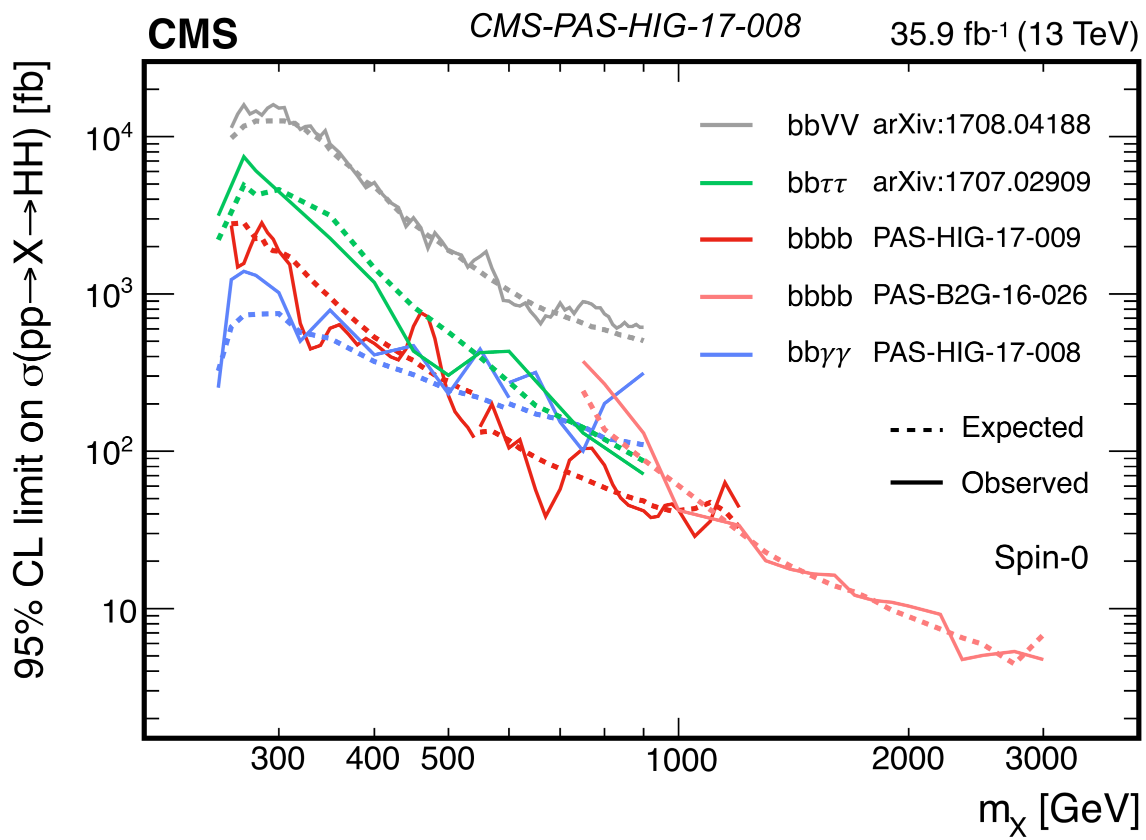


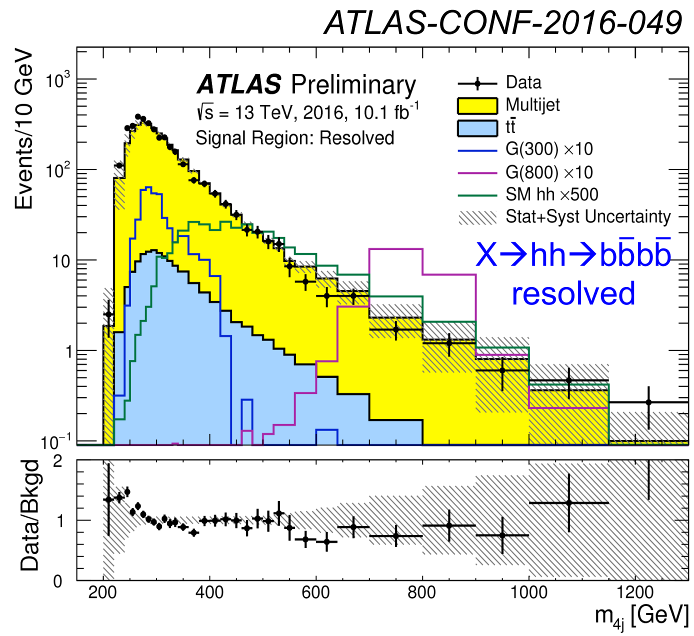


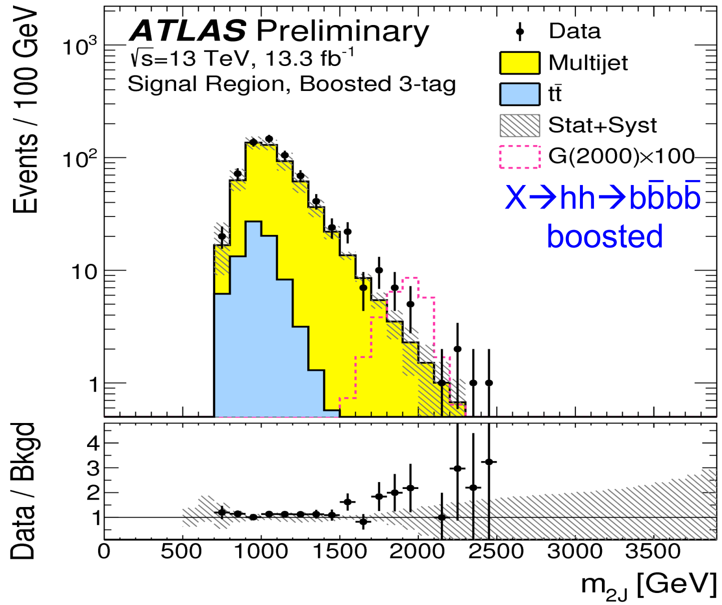


Diboson resonances (hh)

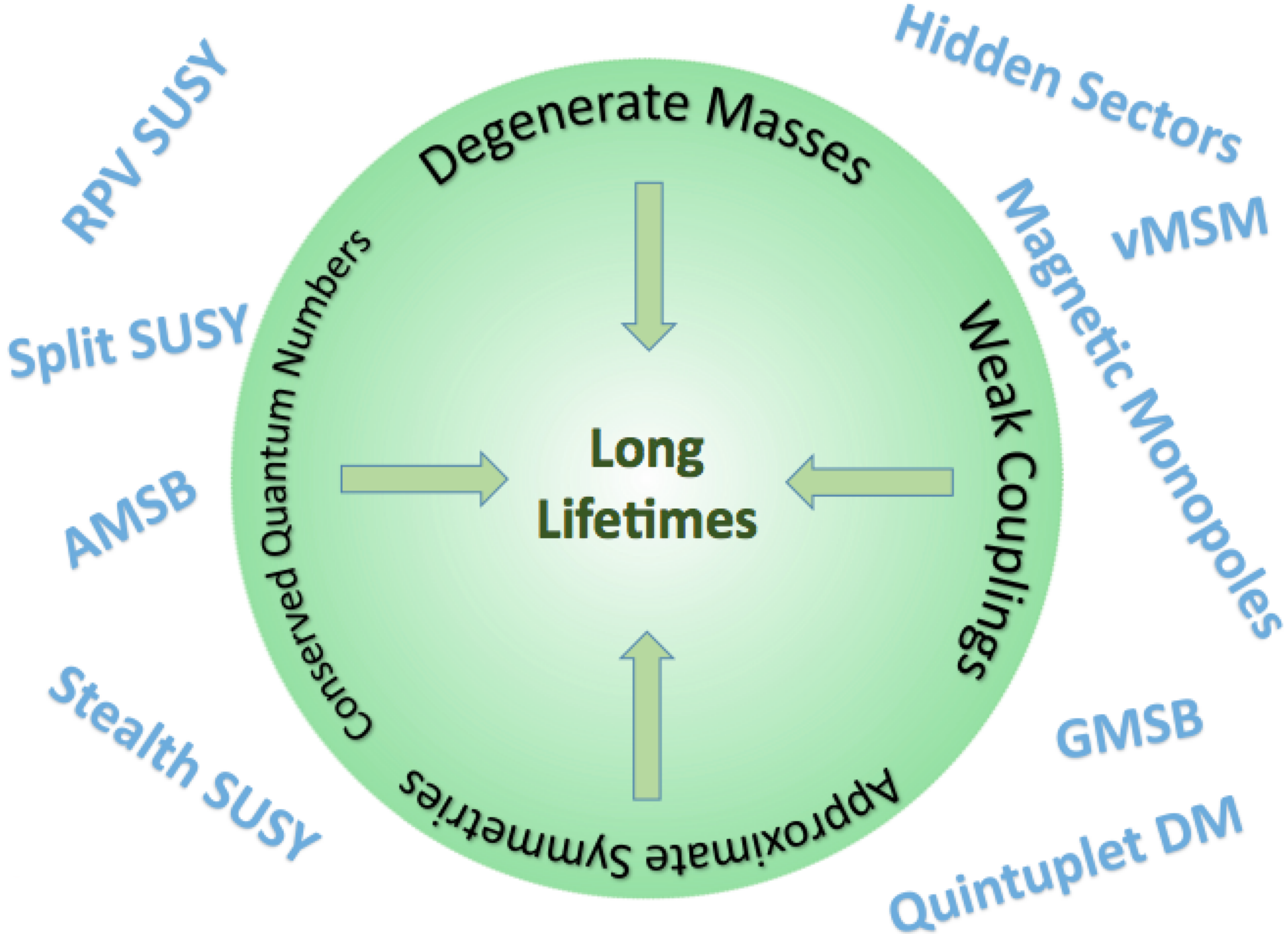
- Broad program of searches for X→hh (X=spin 0 or 2).
- Exploiting $b\bar{b}$+X (X=γγ, ττ, VV and $b\bar{b}$) final states.
  - For X→hh→$b\bar{b}b\bar{b}$ consider resolved and boosted regimes.
- Sensitivity dominated by $b\bar{b}b\bar{b}$ and $b\bar{b}\gamma\gamma$ channels.







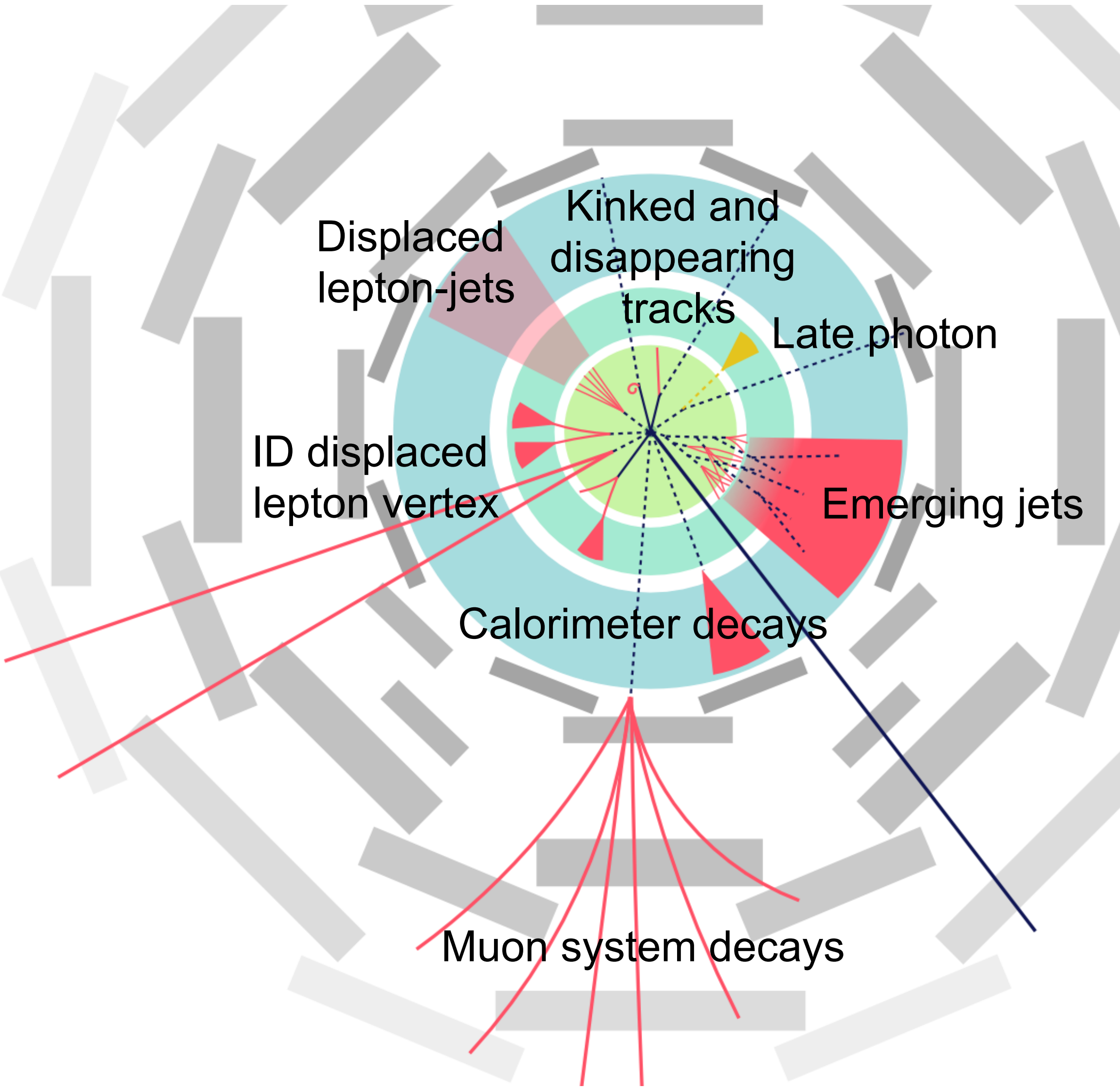
Signature-driven searches



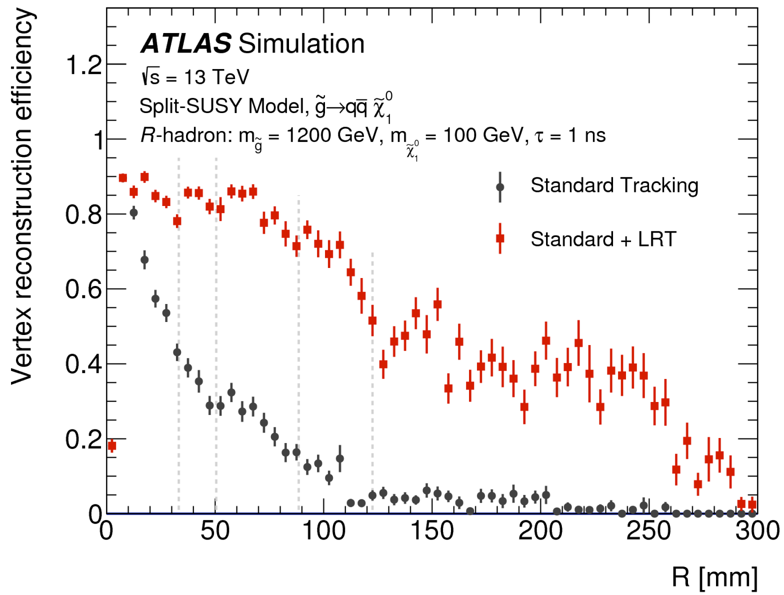
Searches for long-lived particles

- Many BSM scenarios involve long-lived particles (LLP).
  ➔ Multitude of signatures, most requiring dedicated reconstruction strategies and observables.

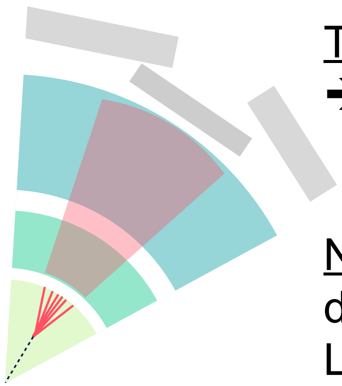
- Large-radius tracking
- Inner-detector tracklets
- Ionisation energy loss
- Time-of-flight
- Dedicated processing and data formats
- …



arXiv:1710.04901



Searches for long-lived particles



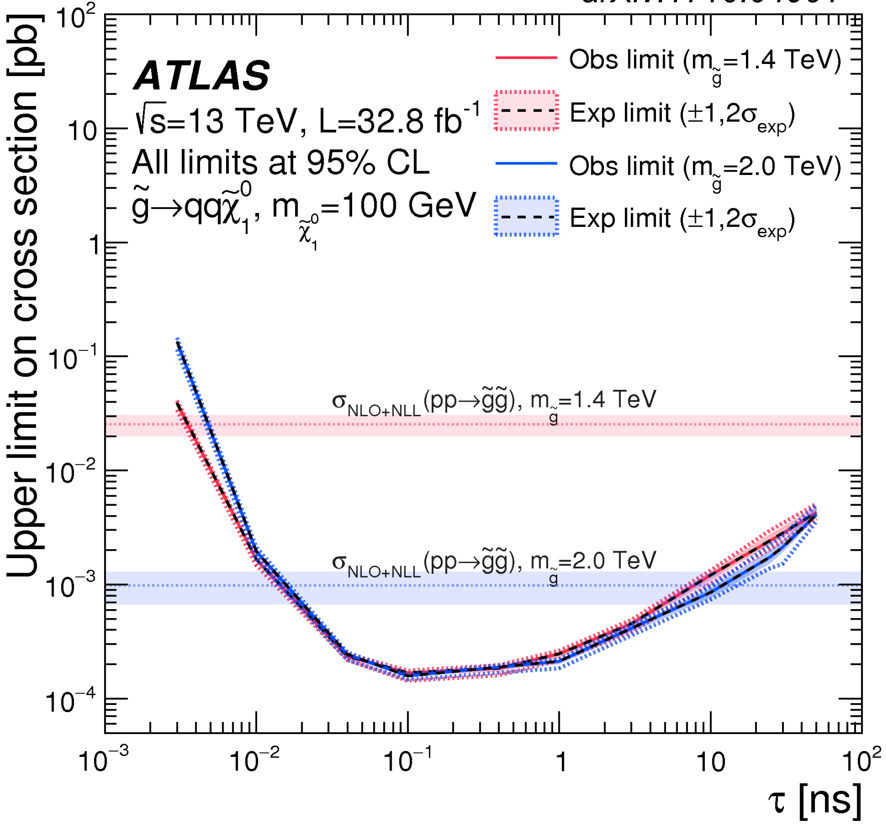
<u>Target</u>: non-prompt gluino
➔Displaced vertices

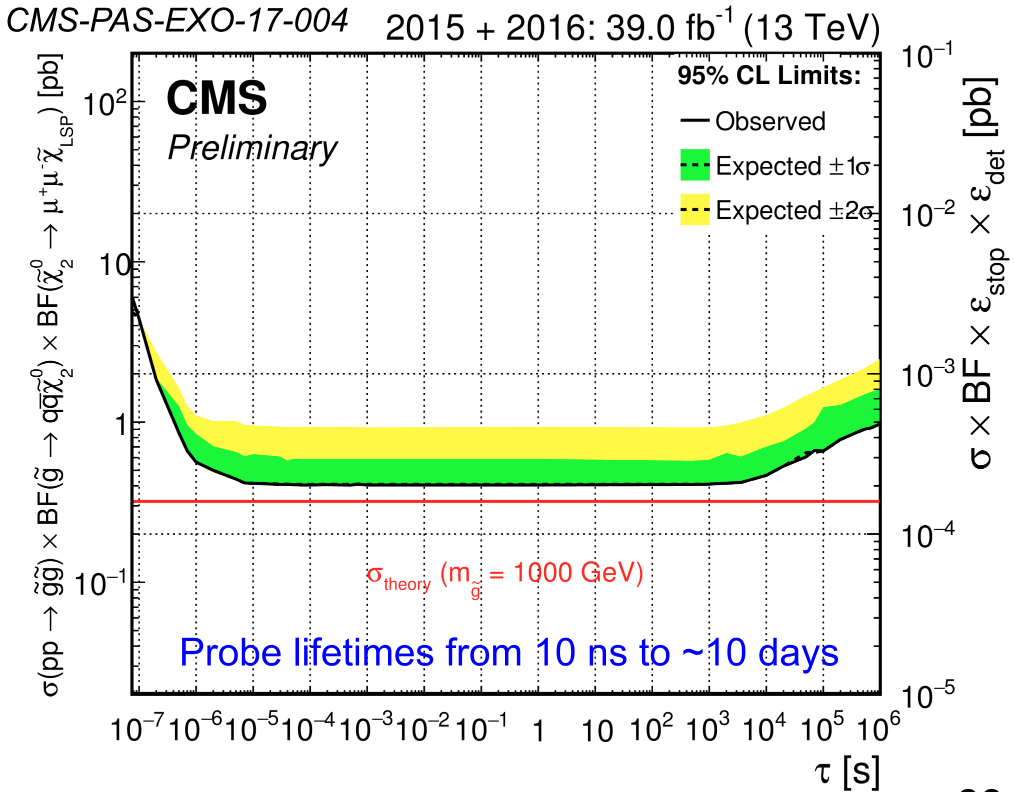
<u>Need</u>: Dedicated re-tracking, decay vertex from massive LLP.

<u>Target</u>: LLP that stops in the detector, decays to muons some time after they are produced (gluinos, multiply-charged massive particles).

<u>Need</u>: Custom trigger to record events out-of-time with collisions. Dedicated algorithm for Delayed StandAlone muon tracks.

arXiv:1710.04901



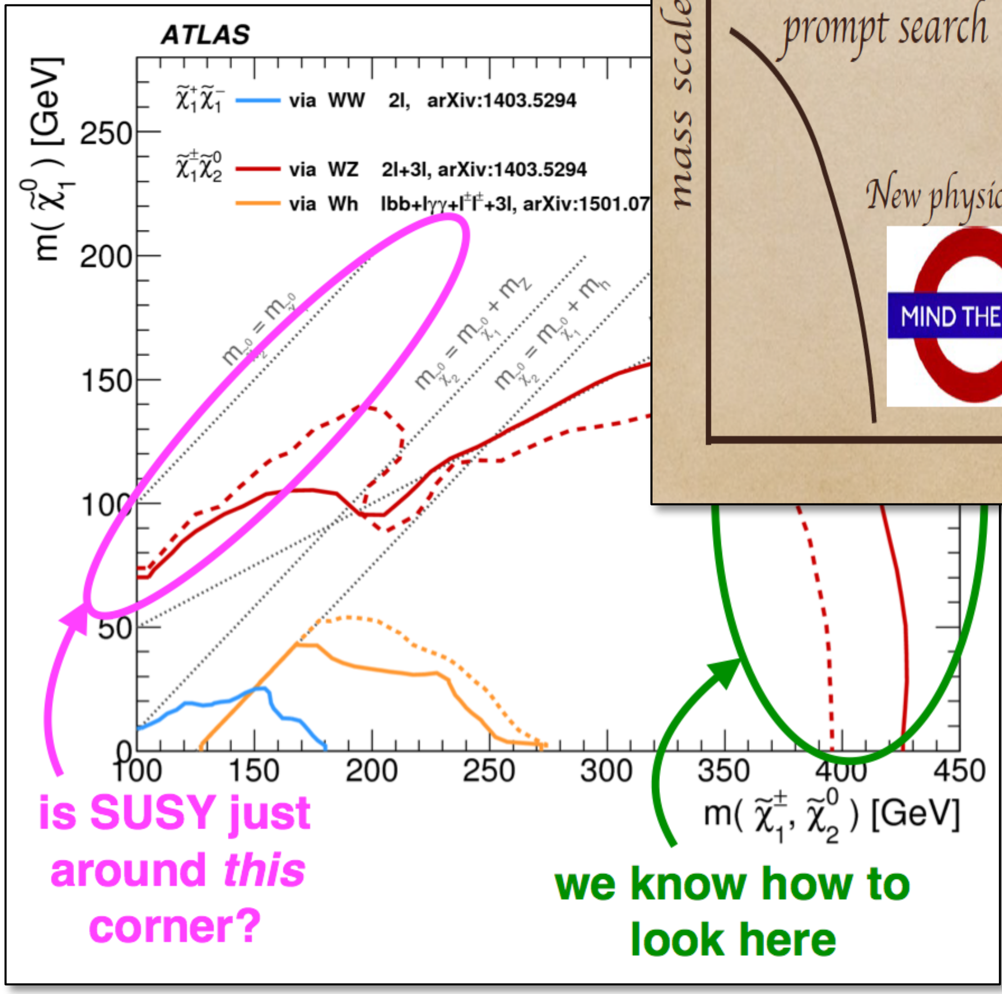


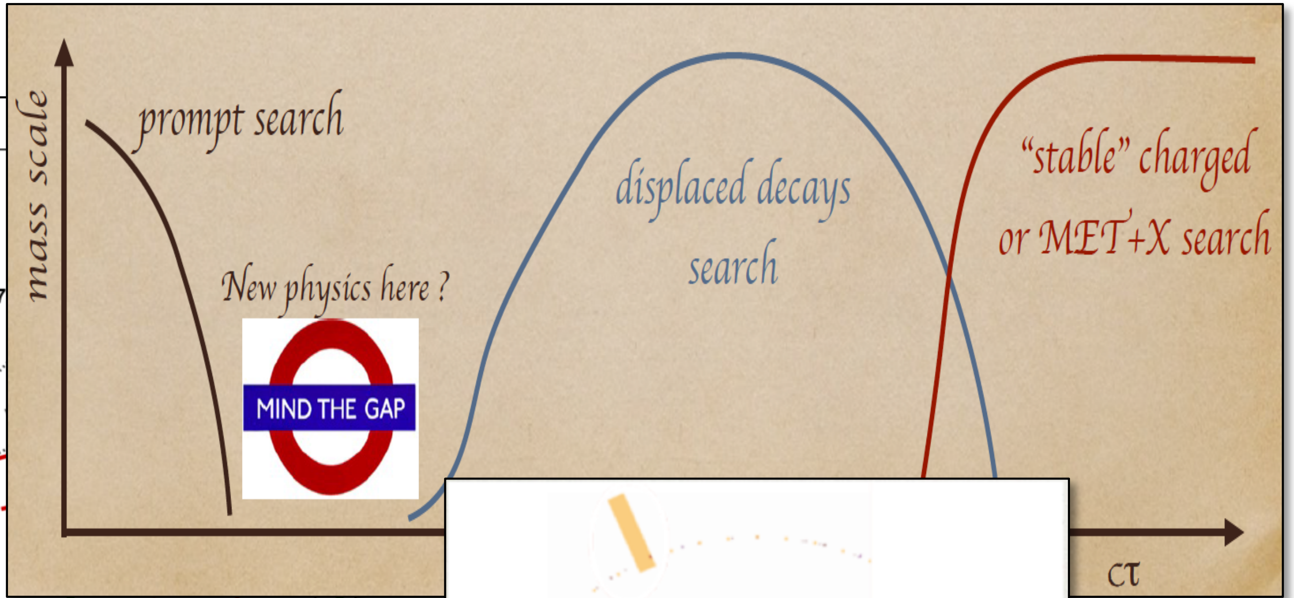
No significant excess found

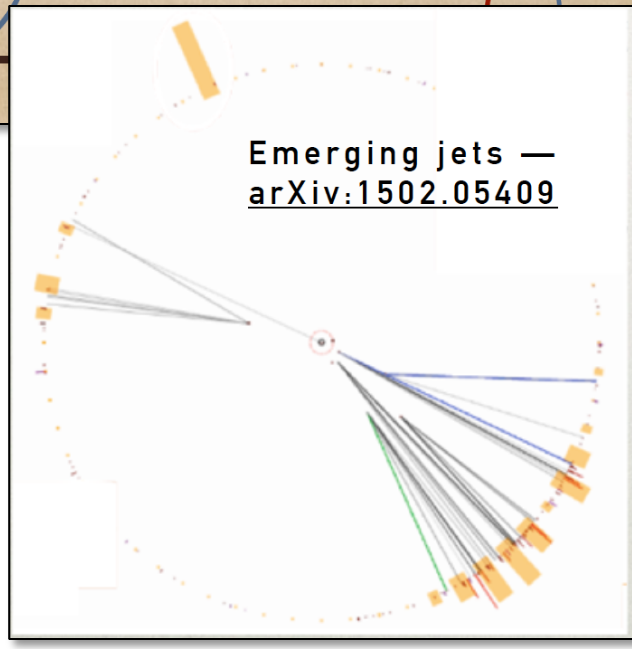
Avoiding holes in sensitivity

- Crucial to continue to develop search strategies to fill holes in sensitivity, including adding new uncovered signatures.

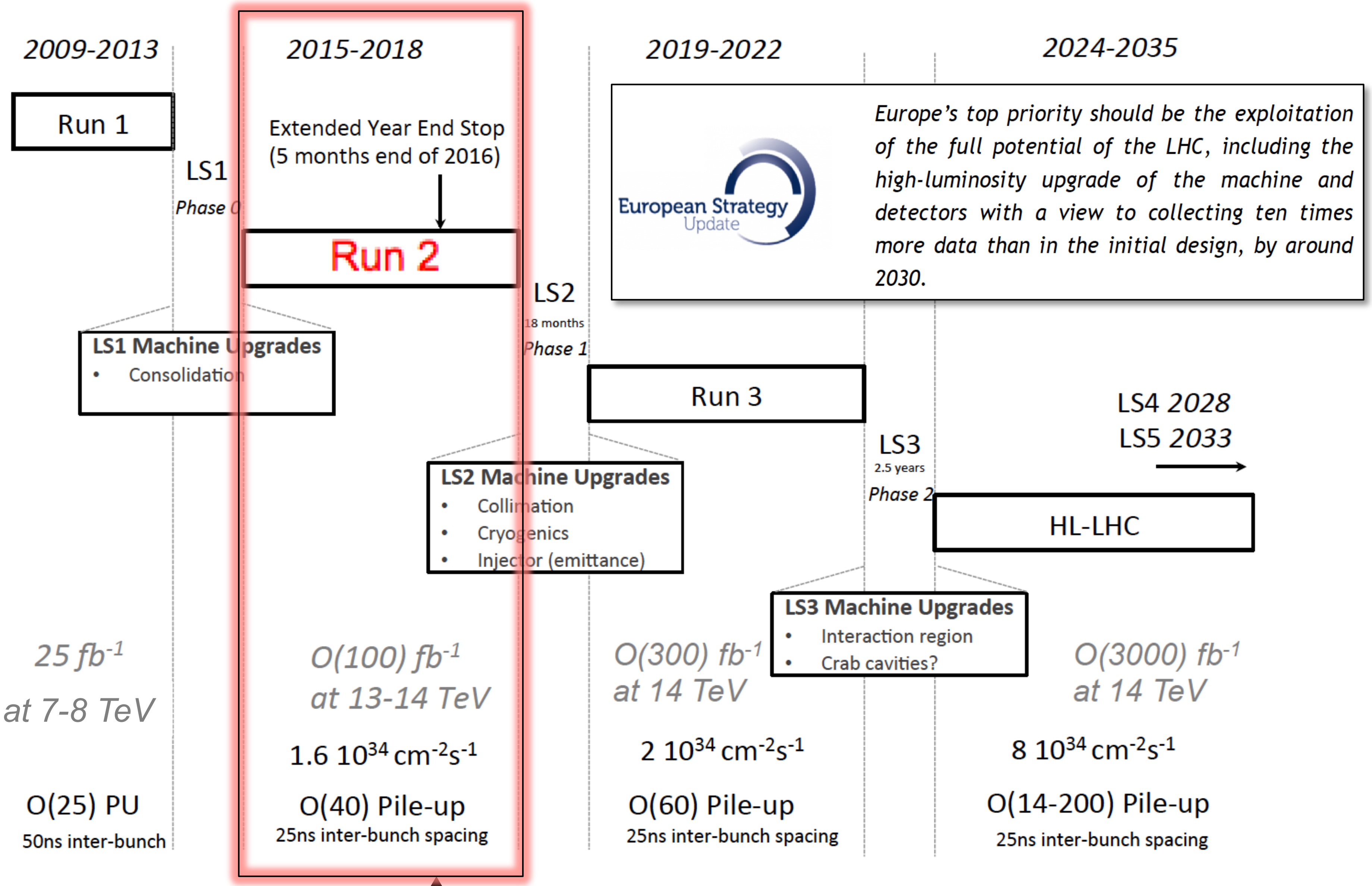
Compressed SUSY spectra







LHC beyond Run 2



We are at the beginning of a ~20 year program!

Wow, what a ride!

Summary and outlook

Status is good!

- **The LHC Run 2 is in full swing.**
- The LHC machine and the ATLAS and CMS detectors continue to show a spectacular performance.
- A host of new NP searches have been released with the full 2015+2016 dataset corresponding to **~36 fb^{-1} at $\sqrt{s}$=13 TeV.**

https://twiki.cern.ch/twiki/bin/view/AtlasPublic

http://cms.web.cern.ch/news/cms-physics-results

- **No significant excess observed yet.**

  Stringent constraints set on a broad range of NP scenarios.

Summary and outlook

Prospects are even better!!

- Some old and new excesses begging for more data.
- **The full Run 2 dataset will not just be a x3 gain in luminosity wrt now:**

  Most analyses are implementing improvements to scale faster than √L.

  Large gain for analyses that have much better triggers in 2017!

  Infinite gain for analyses that didn't exist before!!

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- **Only ~1% of the data the LHC will provide has been analyzed.**
  More data, ever improving analysis strategies and ingenious theoretical guidance may lead to the next revolution in particle physics.

Summary and outlook

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Looking forward to new exciting discoveries!