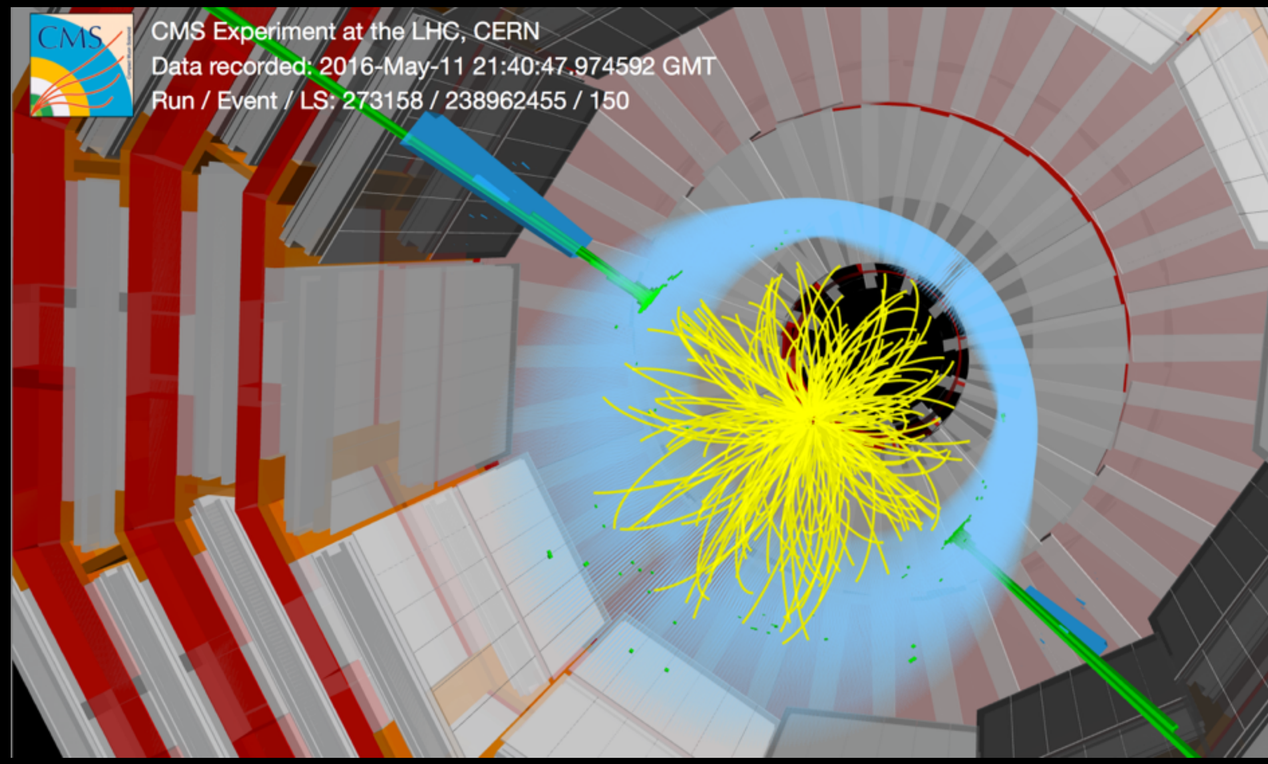
LHC PHYSICS & CONNECTIONS



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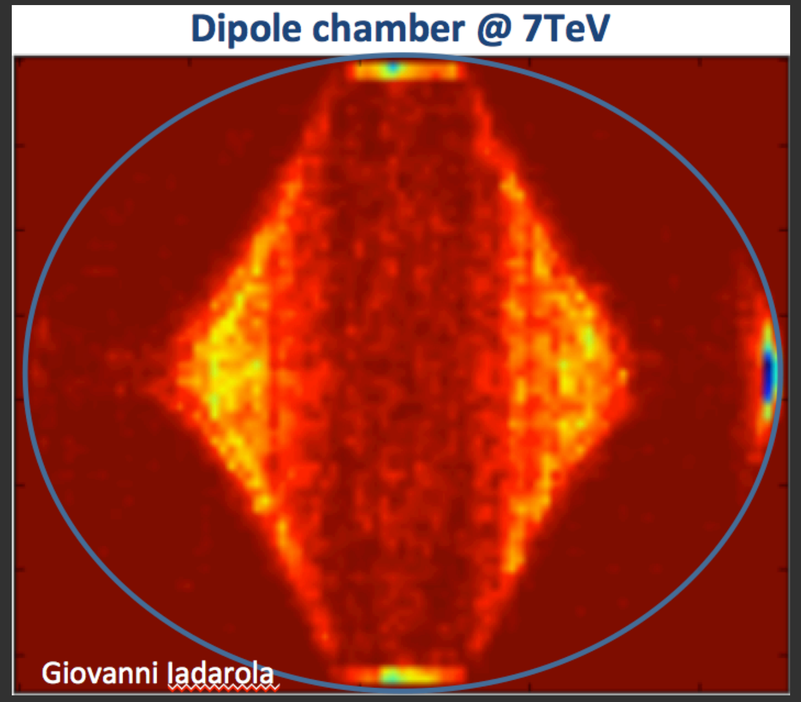
THE LHC

HL-LHC ready

2015 RECOMMISSIONING

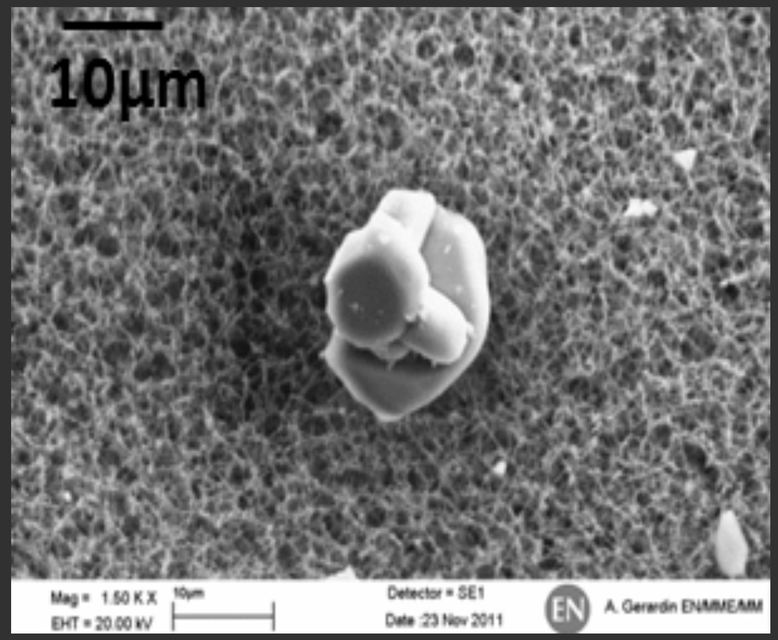
Electron cloud

- Anticipated
- Significant head load to cryogenics



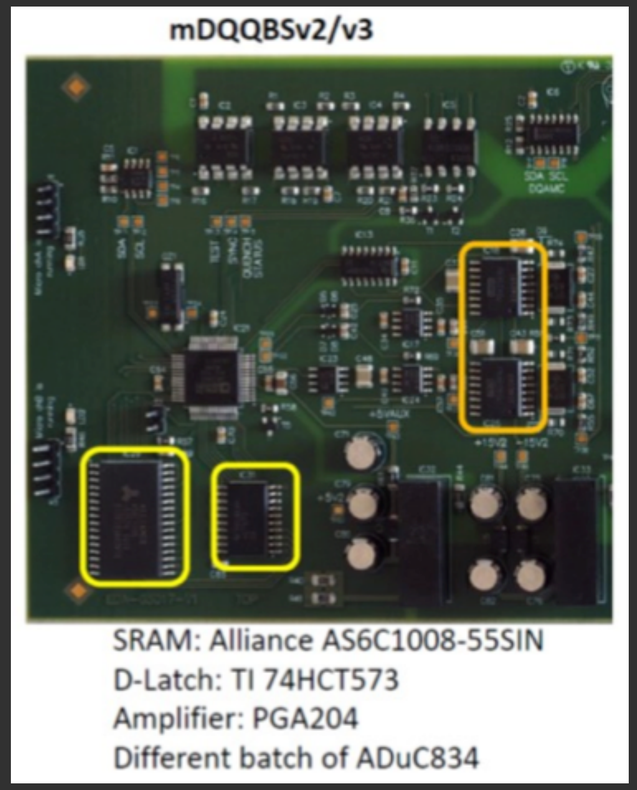
UFOs

- 8 UFO dumps within 2 weeks (Sep 20 to Oct 5)
- Conditioning observed



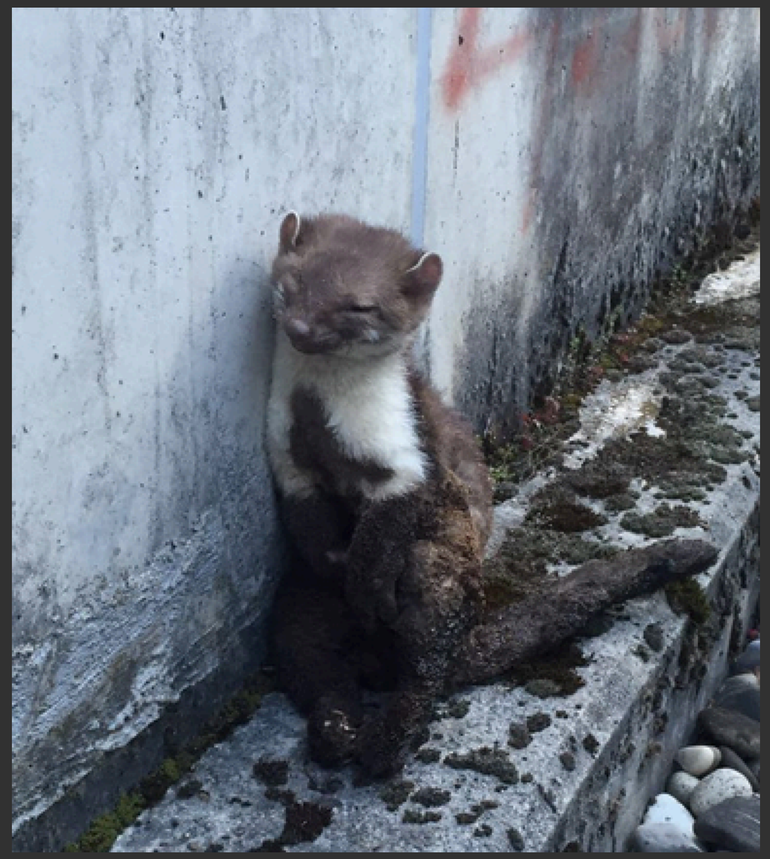
Radiation to electronics

- Mitigation measures (shielding, relocation…)
- Non-rad hard components used in LS1 upgrade



CHALLENGES LHC2016

WEASEL



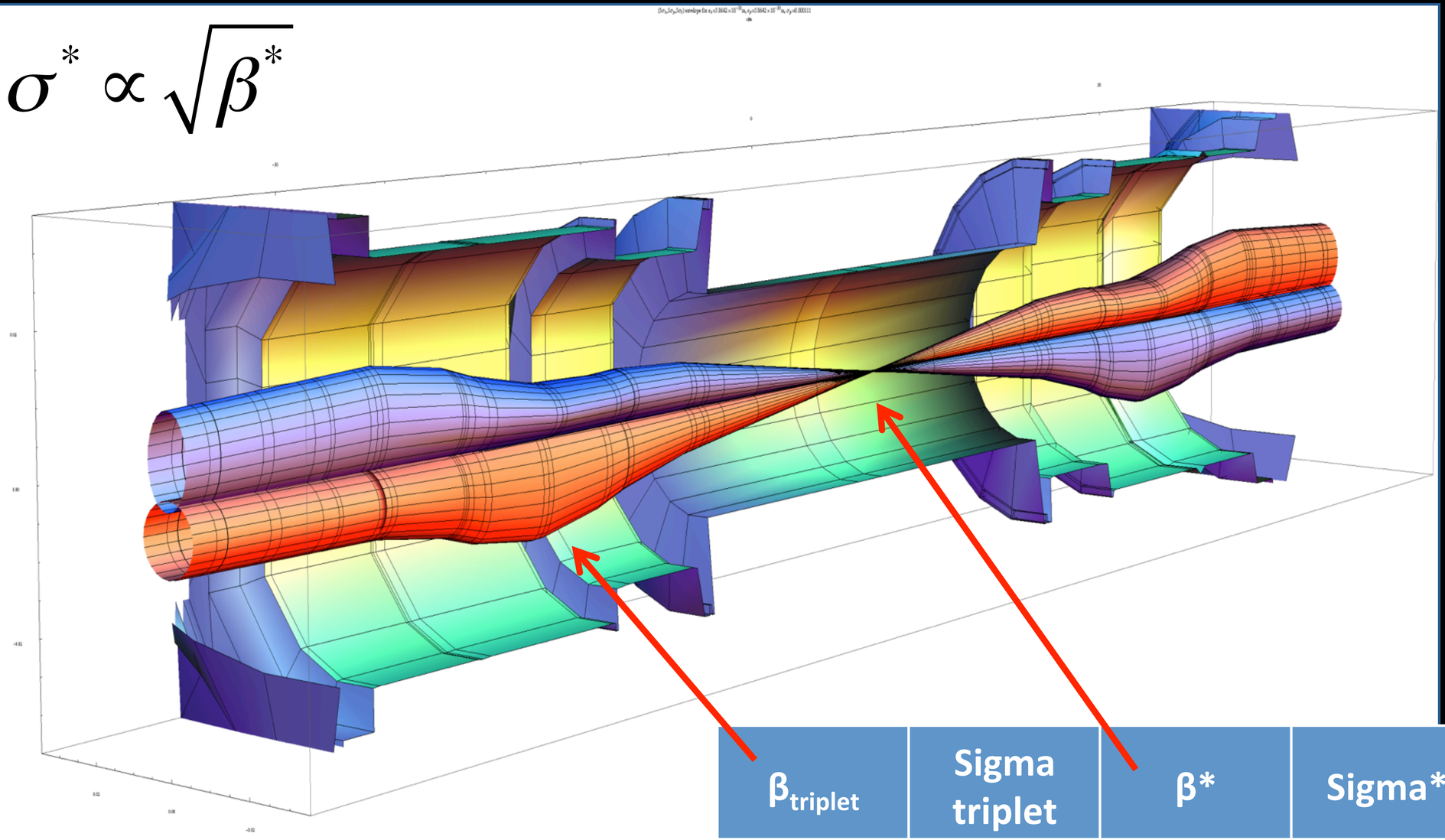
PS MAIN POWER SUPPLY

SPS BEAM DUMP

- Limited to 96 bunches per injection
- 2076 bunches per beam cf. 2750

OPTIMAL SQUEEZE LHC2016

$$\sigma^* \propto \sqrt{\beta^*}$$

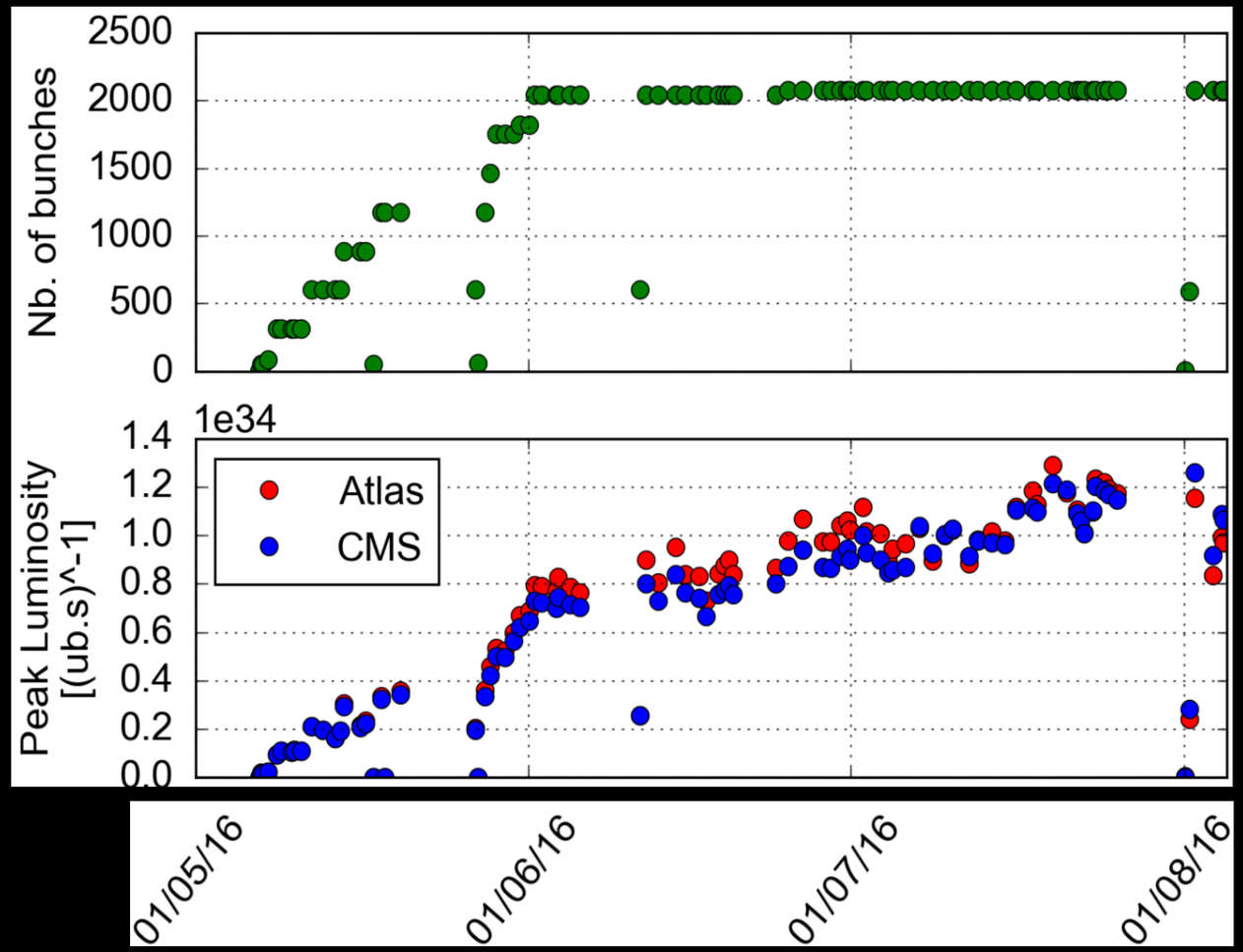


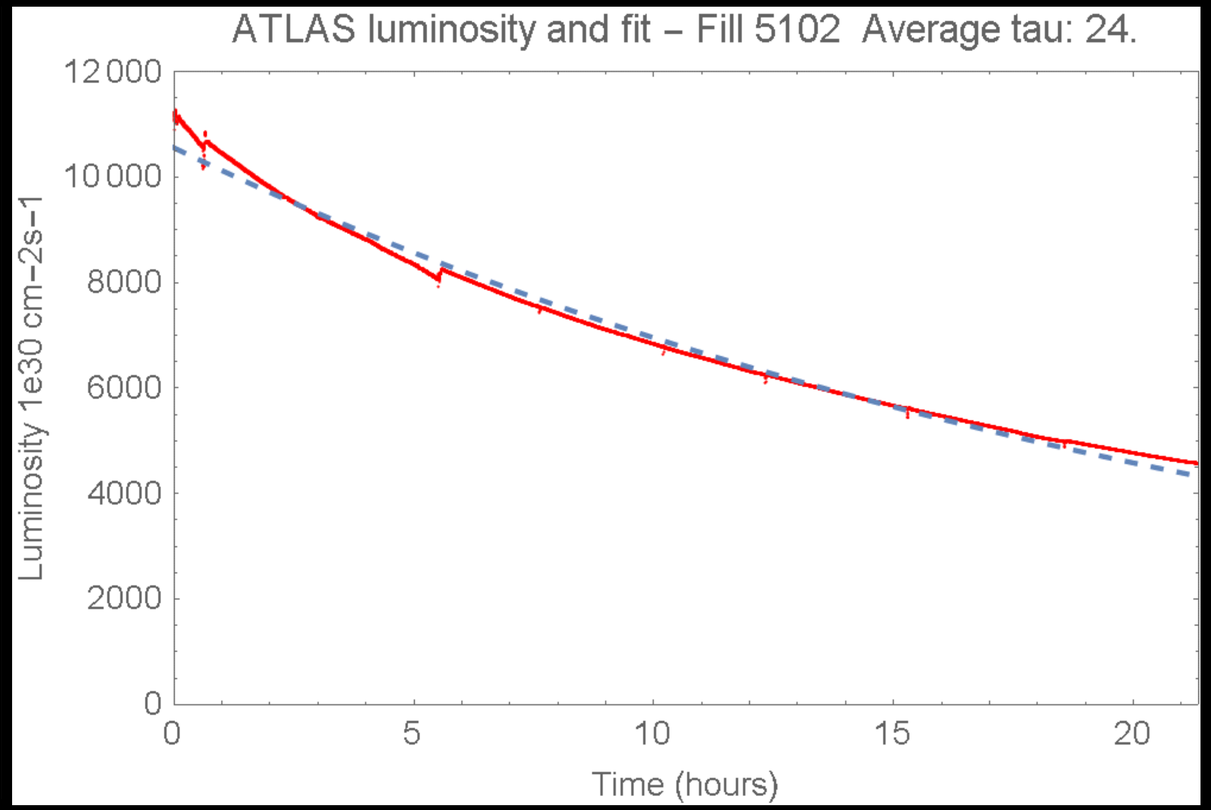
$$\mathcal{L} \propto \frac{1}{\beta^*}$$

$\beta_{triplet}$	Sigma triplet	β*	Sigma*
~4.5 km	1.5 mm	40 cm	13 um

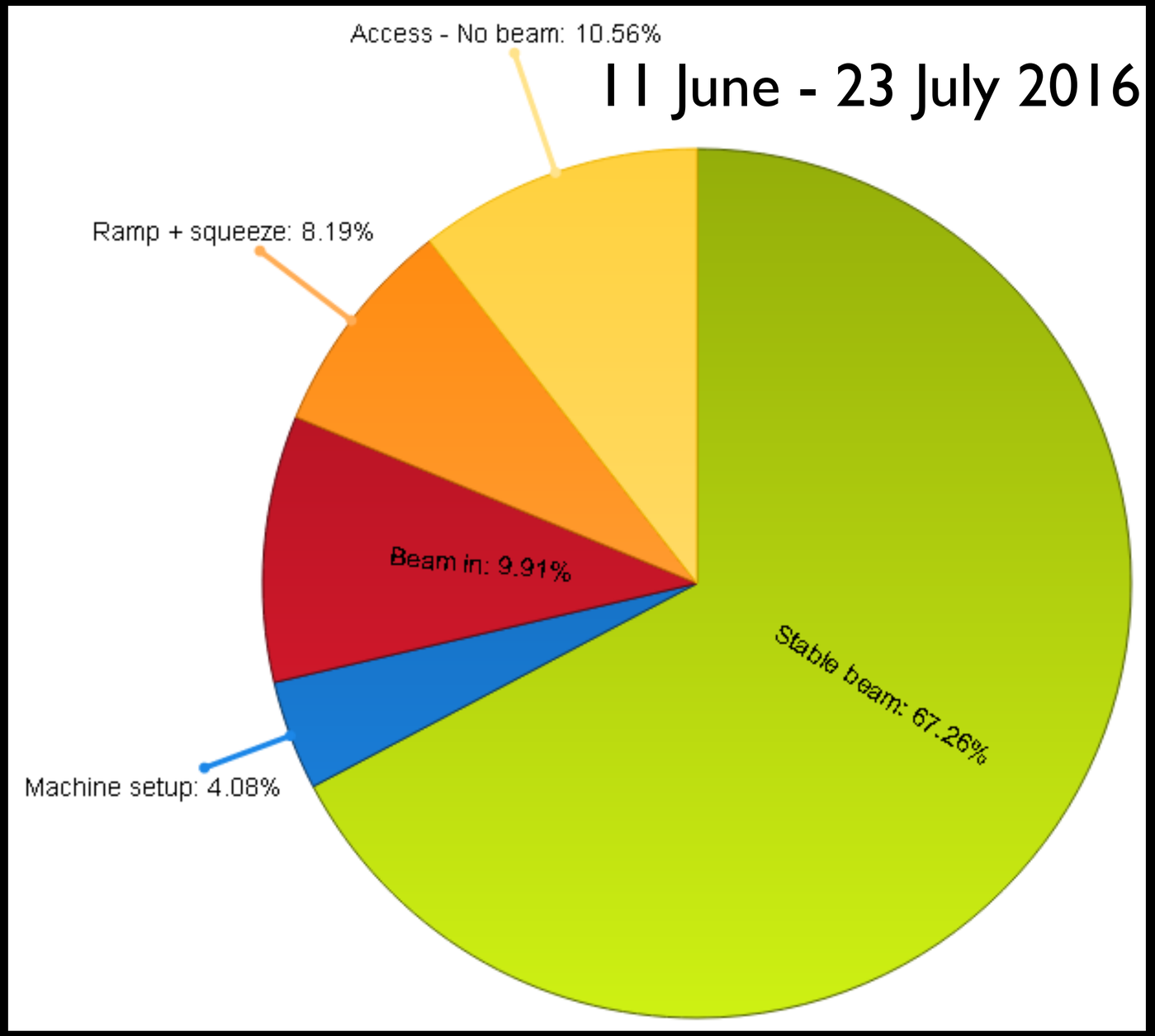
LHC2016

Maximum luminosity limited to ~1.7e34 cm-2s-1 by triplet cooling limitations



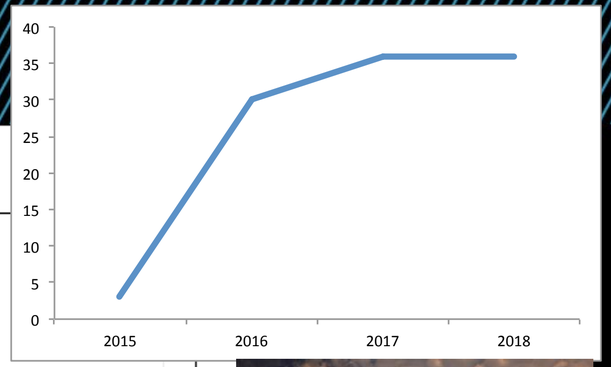


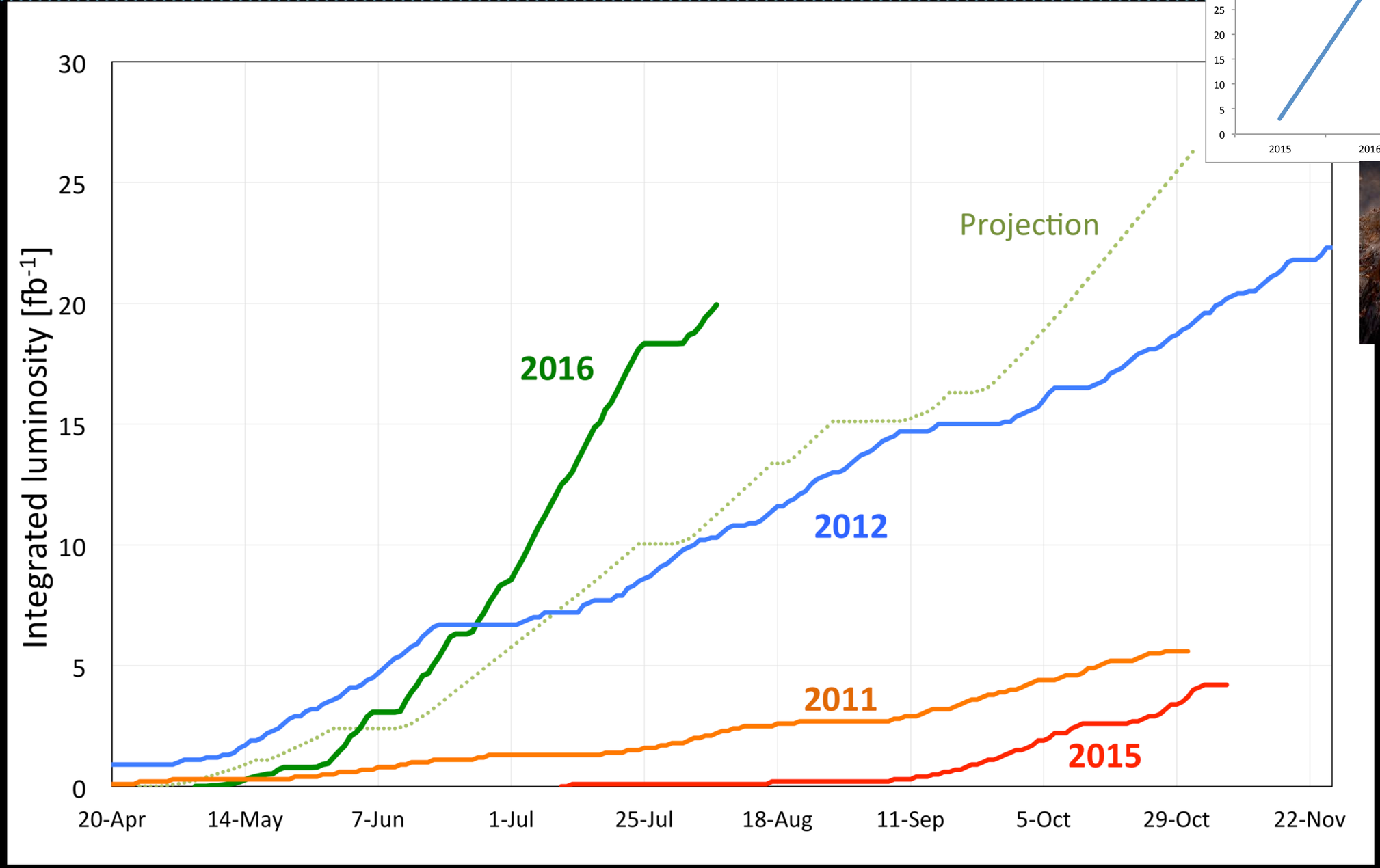
LHC2016



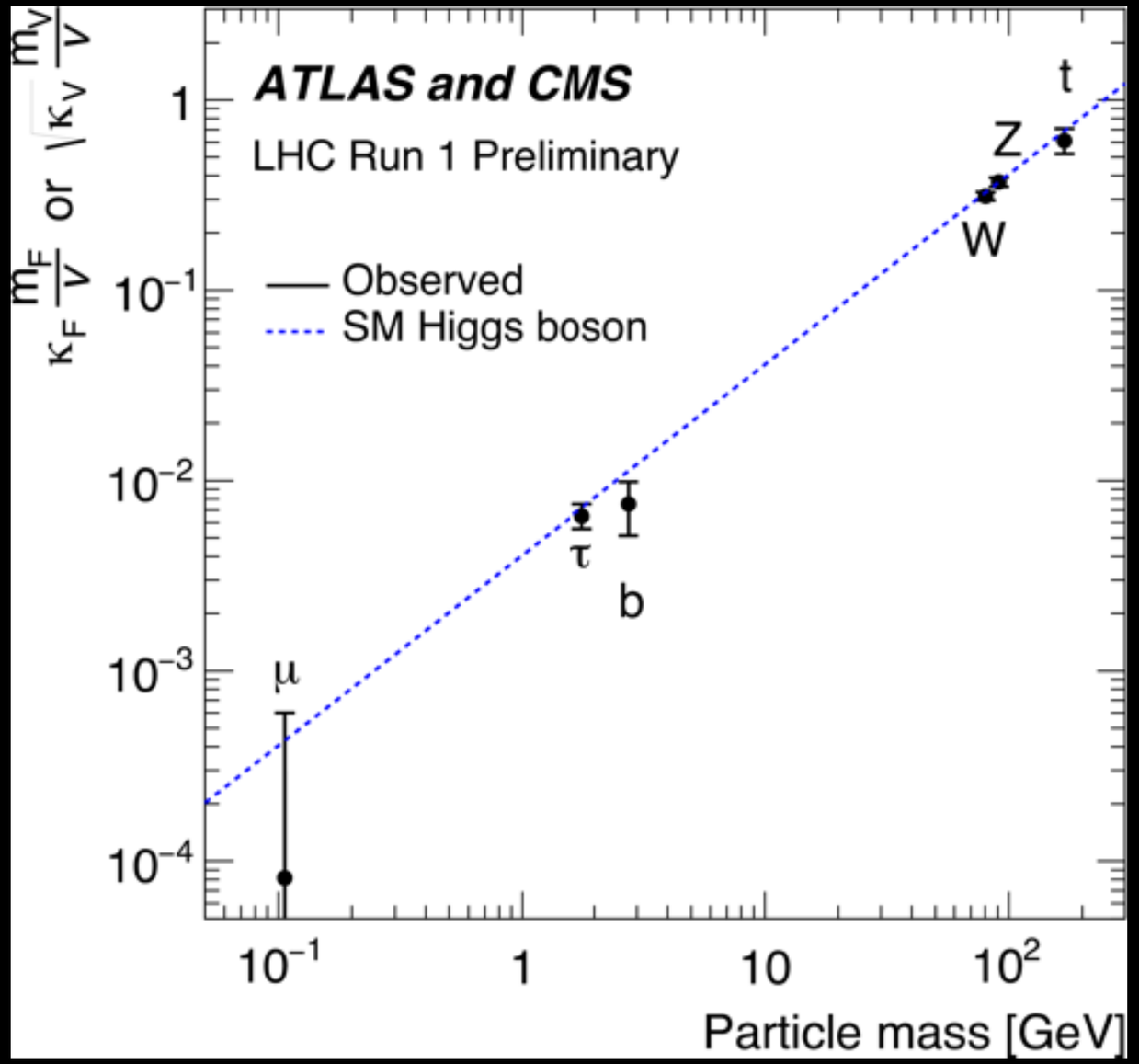
- Astounding availability and few premature dumps, 84% availability combined with very few premature dumps. Up to 22 July - 67% time in Stable Beams (physics efficiency).
- As of 29th July : around 72 days proton physics left (the possibility of dropping a week is to be discussed). The res of the year is somewhat choppy (MD, technical stop, special physics runs) - assuming 60% physics efficiency: another 3.7 million seconds.
- Since 11 June: 15 fb-1 delivered - around 340 pb-1/day.
- Assuming 60% Stable Beams and similarly availability gives ~20/fb additional integrated luminosity between 1st August and 1st November.

INTEGRATED LUMINOSITY

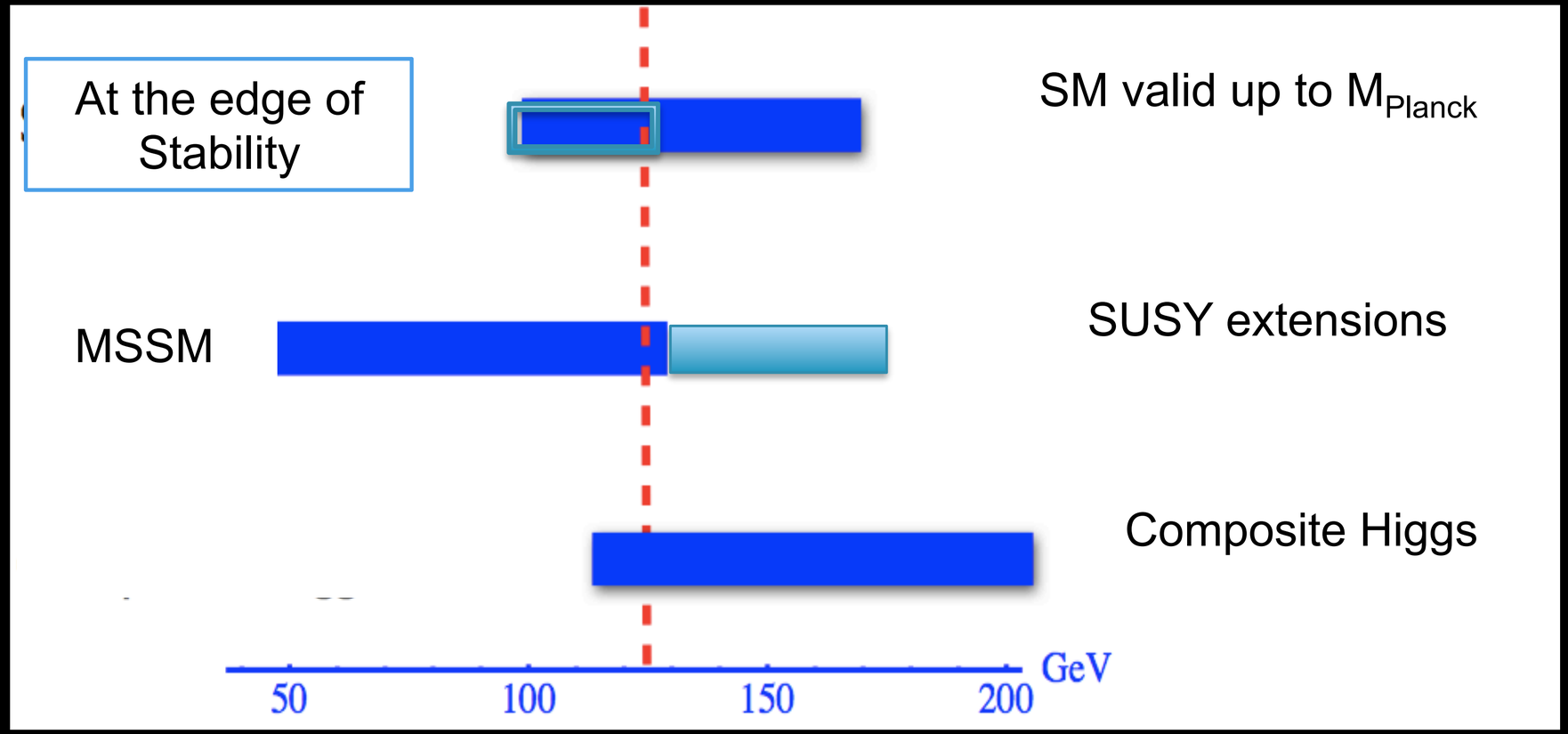




THE HIGGS & BEYOND



HIGGS CURVEBALL (S) REMINDER



125-126 GeV

- suspiciously light for a composite Higgs boson
- suspiciously heavy for minimal SUSY

(or you need to work SUSY extensions with enlarged Higgs sectors)

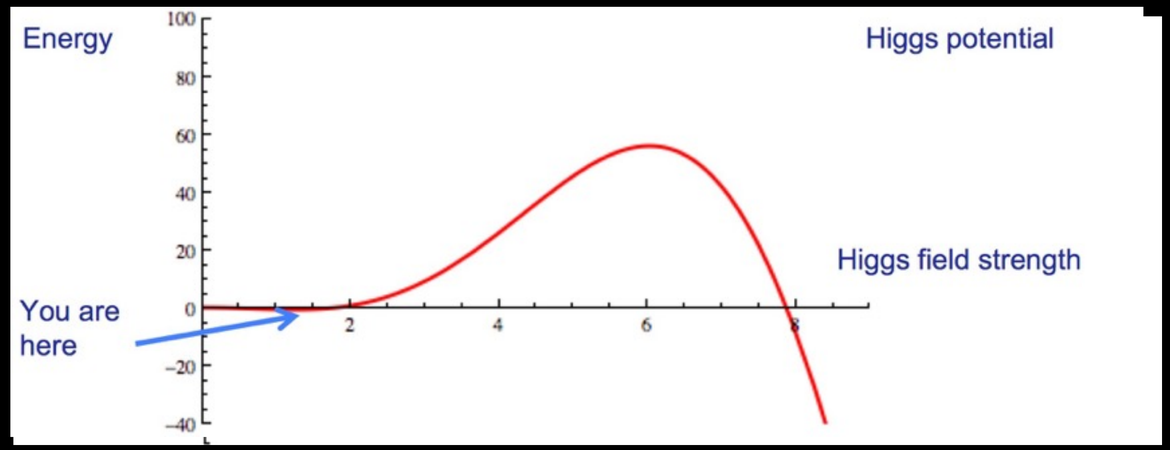
HIGGS CONNECTIONS

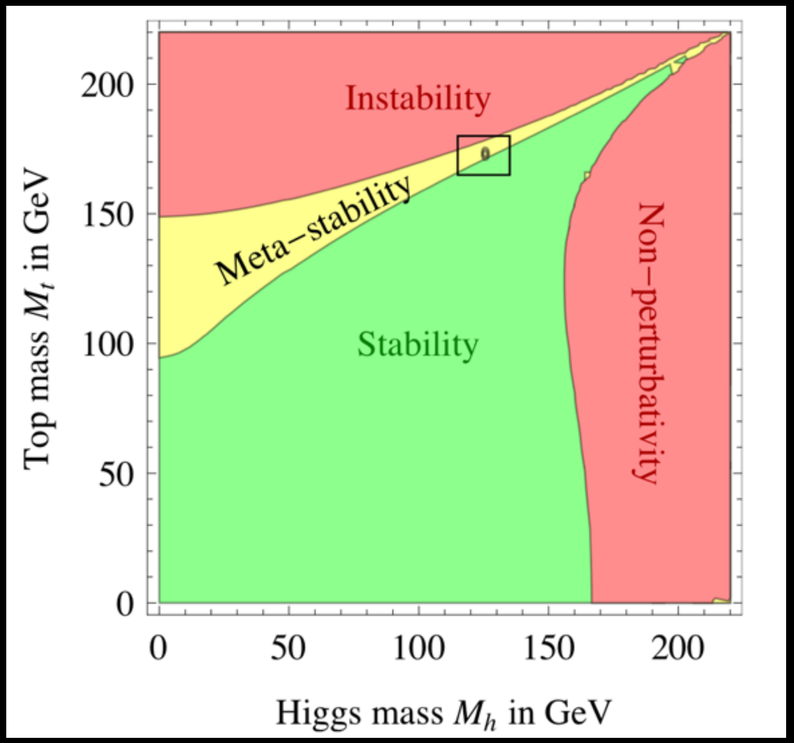
- Does the Higgs destabilize the vacuum
- How does the electroweak scale emerge
- Is there a Higgs portal to dark matter
- Is the Higgs sector responsible for the genesis of matter in the early universe
- How does the Higgs talk to neutrinos
- Is the Higgs related to inflation or dark energy

- motivates: precision program, discovery program (w/ energy push), observation program

VACUUM STABILITY

- The Higgs field is self-sourcing with a quartic self-interaction λ
- The strength of this interaction has distance-dependent quantum corrections from the Higgs coupling to other particles, esp. the top quark
- The Higgs effective potential depends on the Higgs mass and the Higgs self coupling
- The quantum corrections depend on the top mass and an energy scale that is bigger the bigger is the strength of the Higgs field.



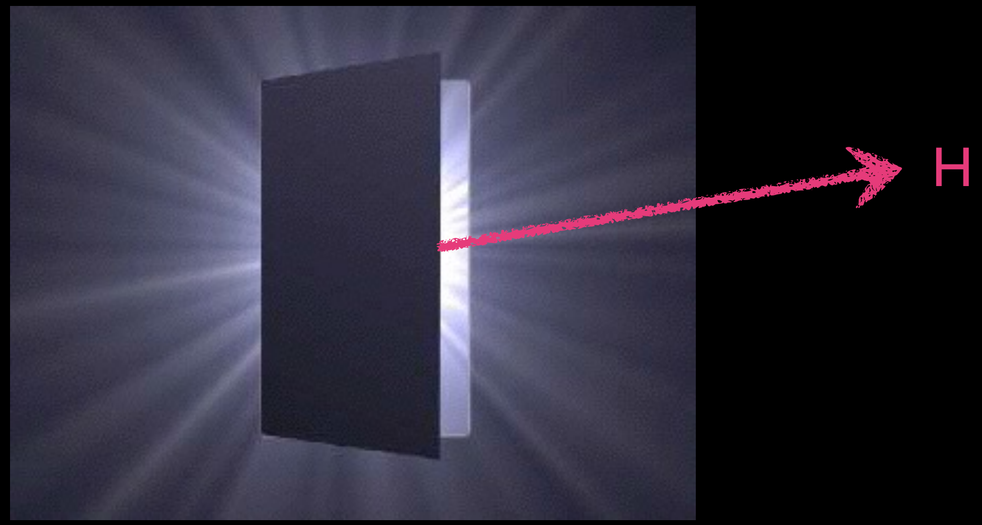


EWK SCALE EMERGENCE

- Going back to Coleman and Weinberg, one possibility is that EWSB is in fact generated by a radiative instability
- Then the electroweak scale may be generated by dimensional transmutation, like the QCD scale, but with weak couplings
- there exist models where all mass scales are generated with dimensional transmutation! (e.g. Bardeen and others, with a singlet additional scalar)
- There is something very appealing about the idea that all mass is quantum phenomenon
- The Planck scale (i.e. Newton's gravitational constant) must be generated as a quantum effect
- Grand unification is wrong, etc
- CAN WE TEST THESE IDEAS EXPERIMENTALLY?

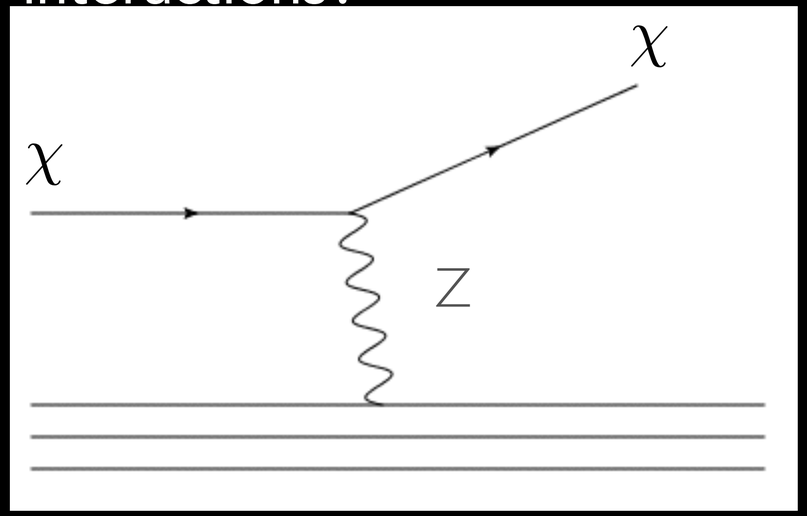
HIGGS PORTAL

- If stable, the extra scalar (dim. transmut.) could be WIMP dark matter, or could couple to lighter “dark” fermions or scalars, or even heavier “dark” gauge bosons, that are WIMP dark matter
- This is the scenario of a dark sector with a Higgs portal...

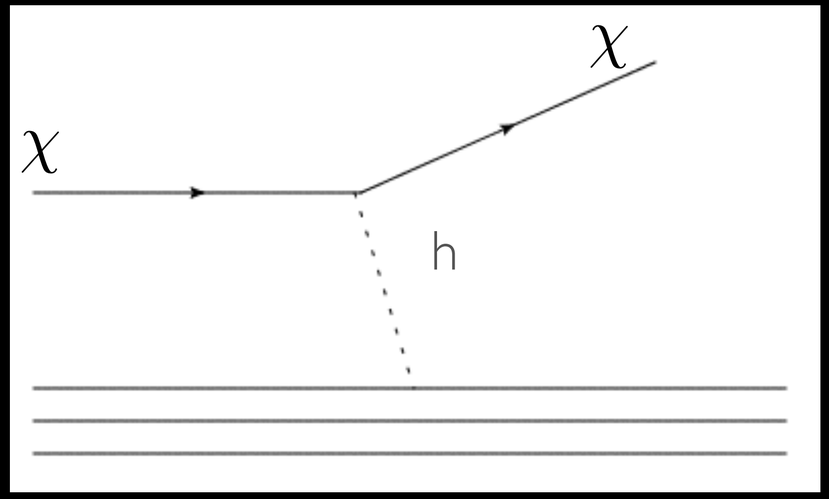


HOW DOES DM INTERACT WITH BARYONIC MATTER?

via the Standard Model weak interactions?



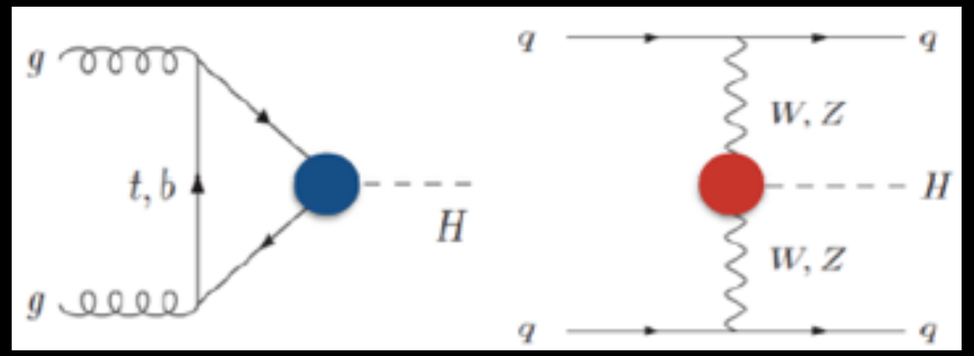
via
gravity
we know

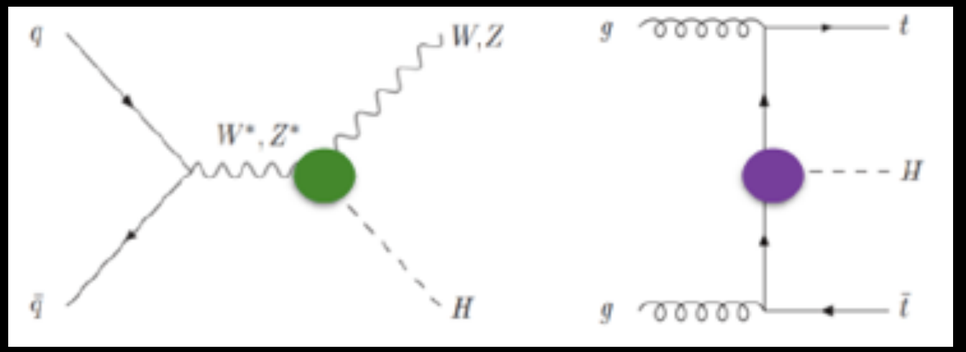


via the Higgs boson?

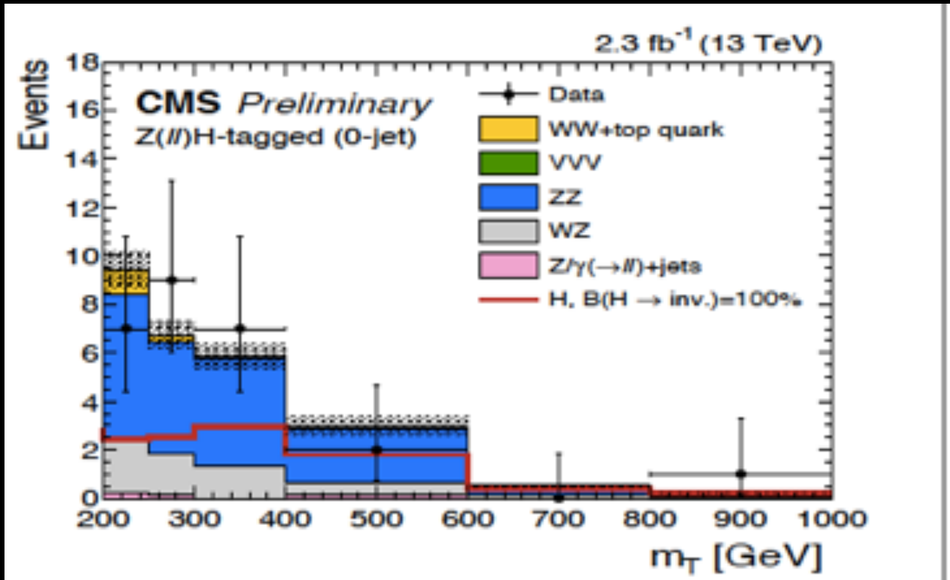
INVISIBLE HIGGS DECAYS (DM)

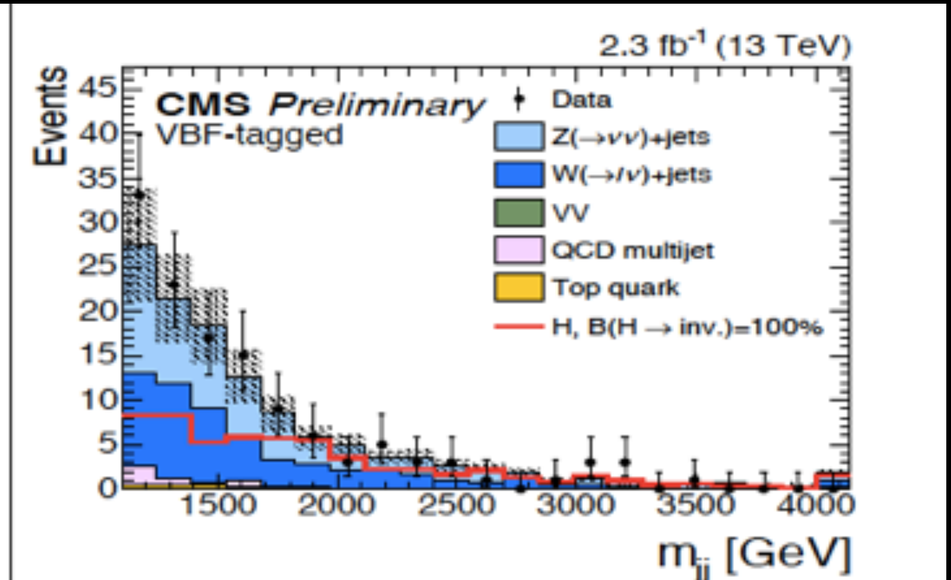
- Higgs-tag+ MET in
  - qqH: VBF signature with two forward jets and rapidity gap and large dijet mass
  - Z(ll/bb)H: two leptons / b-jets compatible with Z boson
  - Z/W(jj)H: two jets compatible with Z or W boson
  - ttH: two top quark candidates
  - gF Higgs: mono-jet search

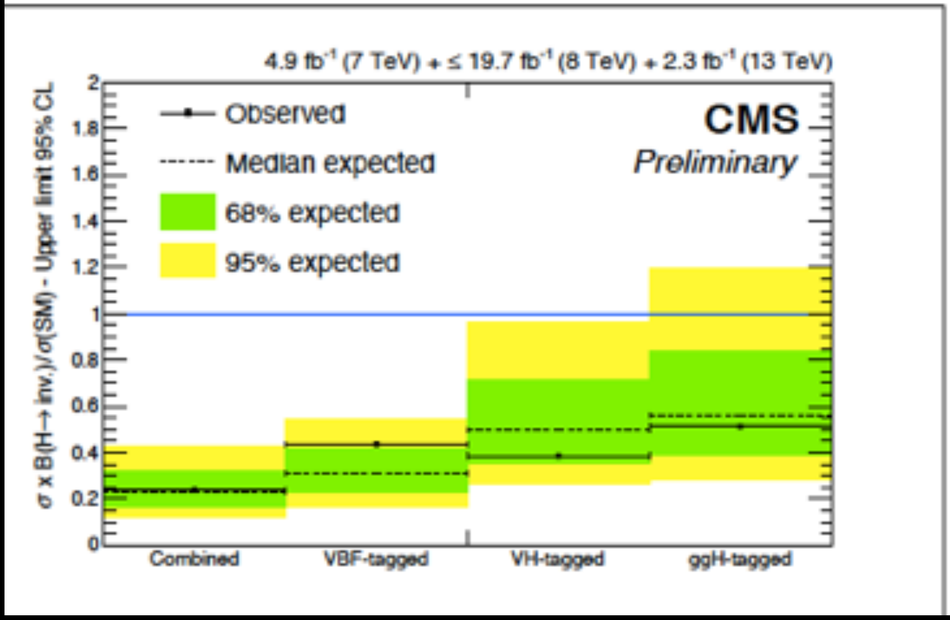


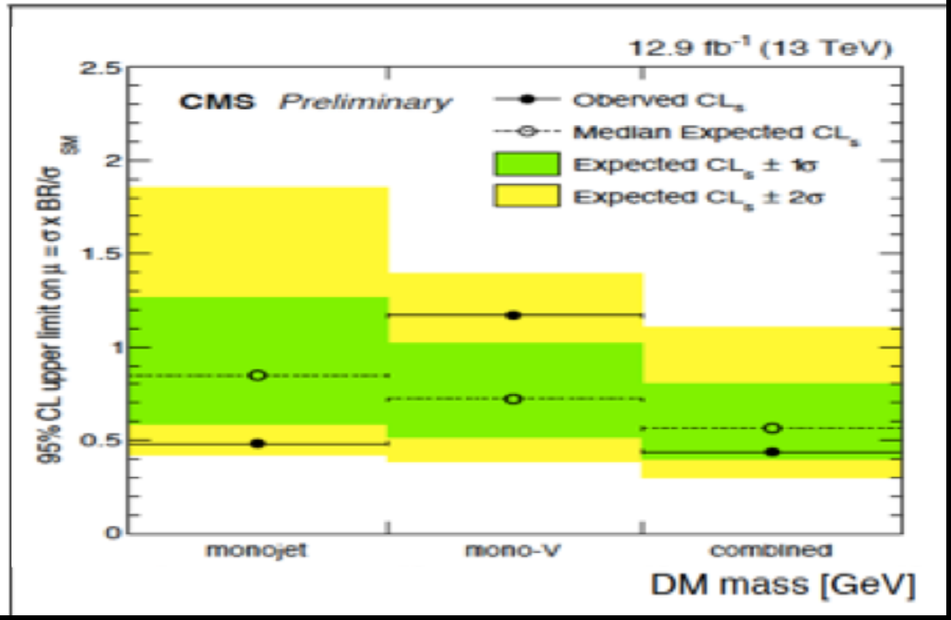


INVISIBLE HIGGS DECAYS (DM)



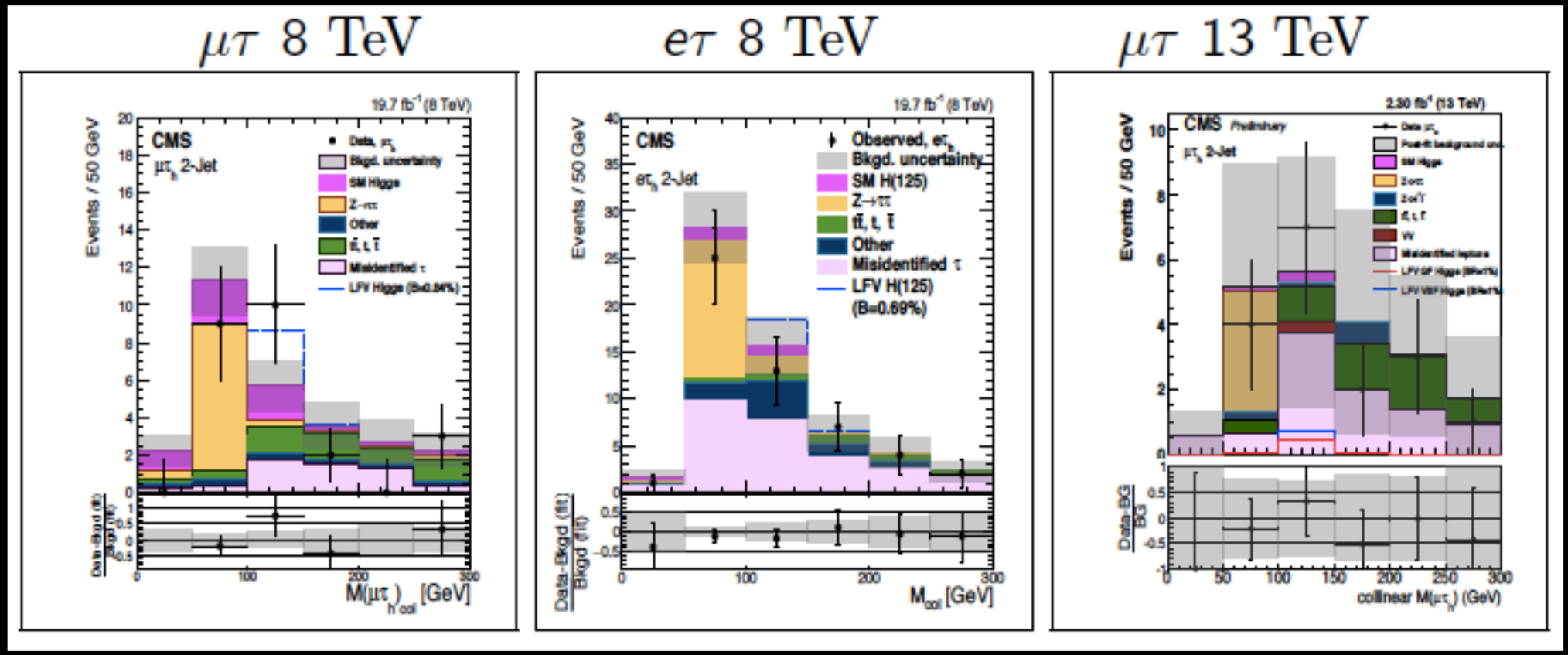






LEPTON FLAVOR VIOLATING HIGGS DECAYS

- Search for mass peak at mH ~ 125 GeV in μτ / eτ / eμ pairs
- Analysis leaning on SM Higgs H→ττ measurements
- Direct limits on BR (H→ μτ / eτ / eμ) established
- Interesting fluctuation in μτ final state at 8 TeV



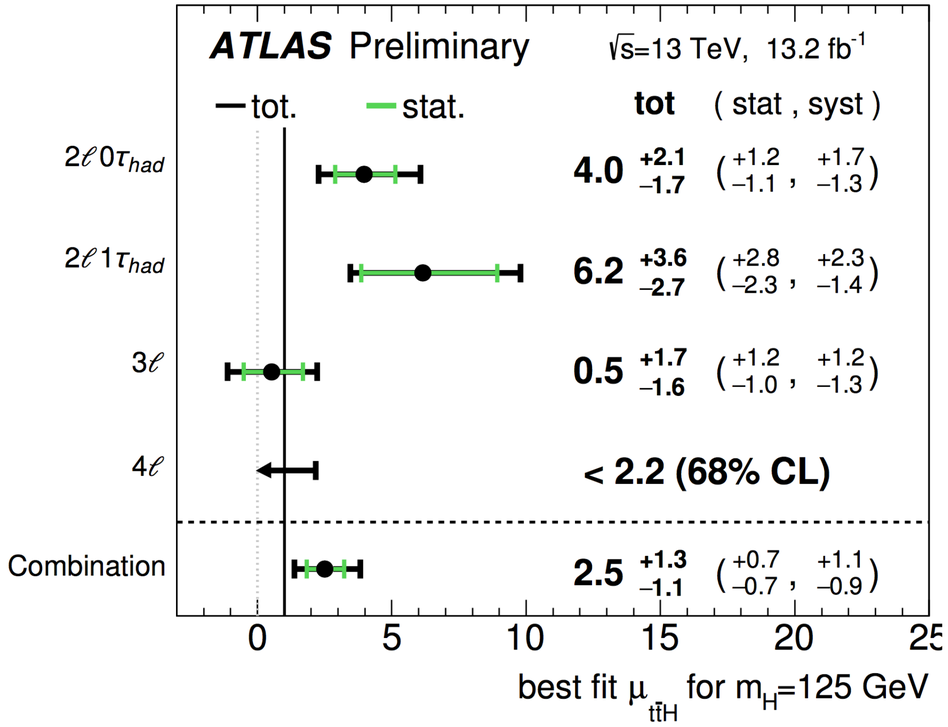
TTH STATUS

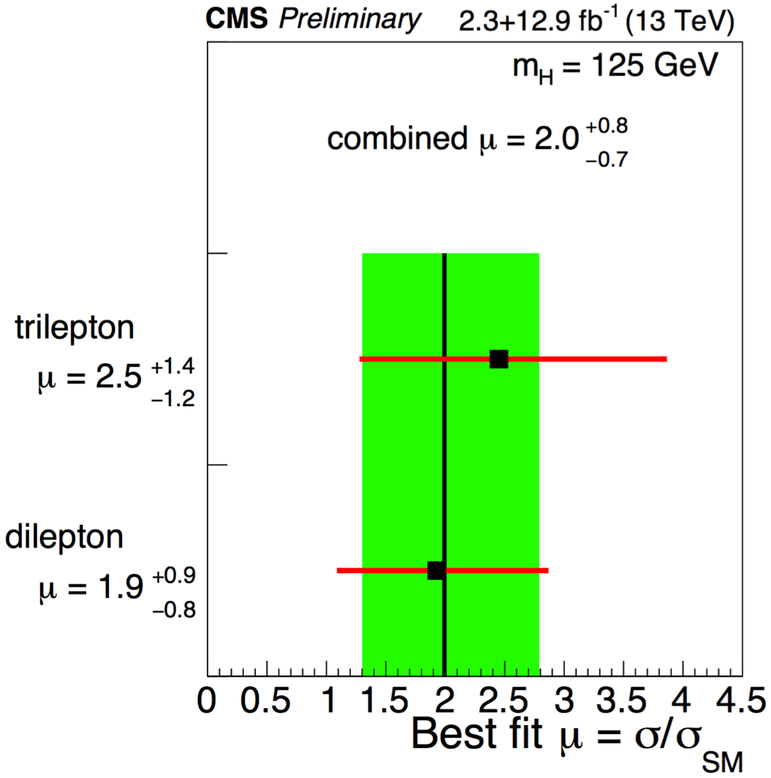
What did Run 2 see in tt+(H → WW) so far?

ATLAS@ICHEP: $\mu = 2.5^{+1.3}_{-1.1}$

CMS@ICHEP: $\mu = 2.0^{+0.8}_{-0.7}$

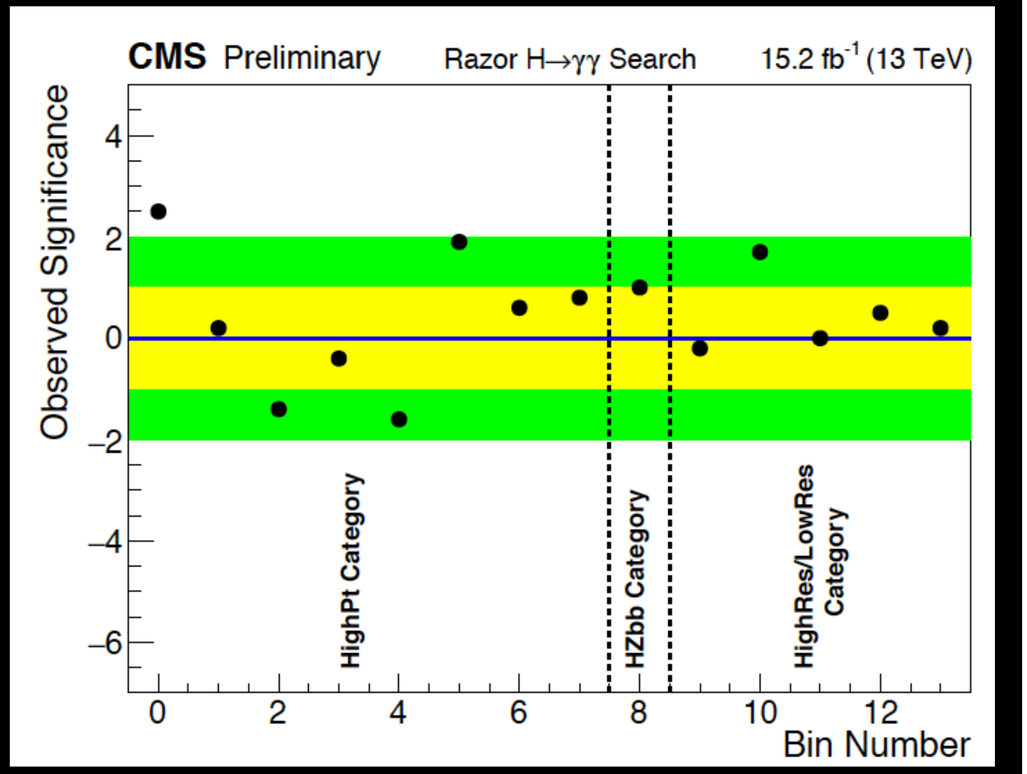
(ATLAS+CMS@Run1: $\mu = 5.0^{+1.8}_{-1.7}$)

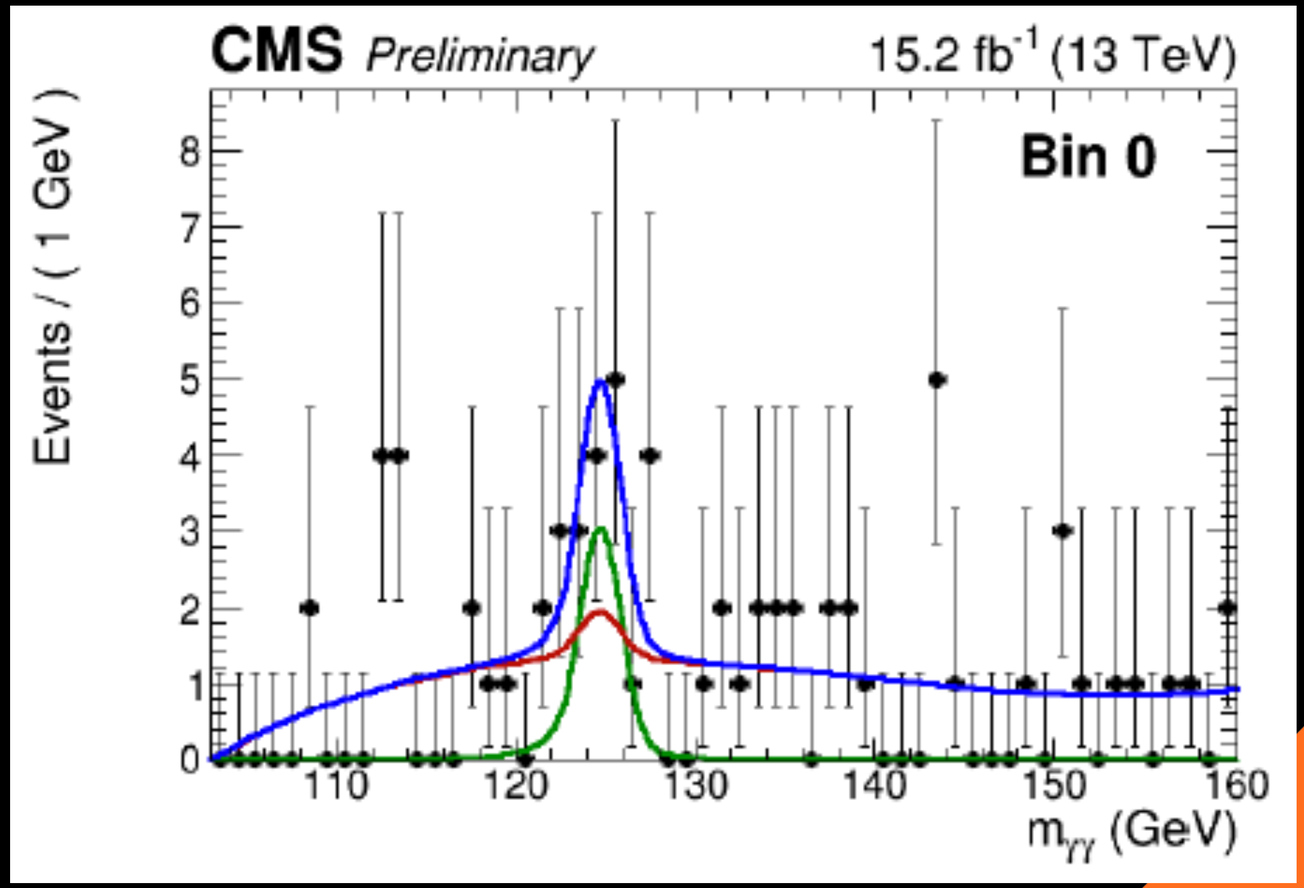




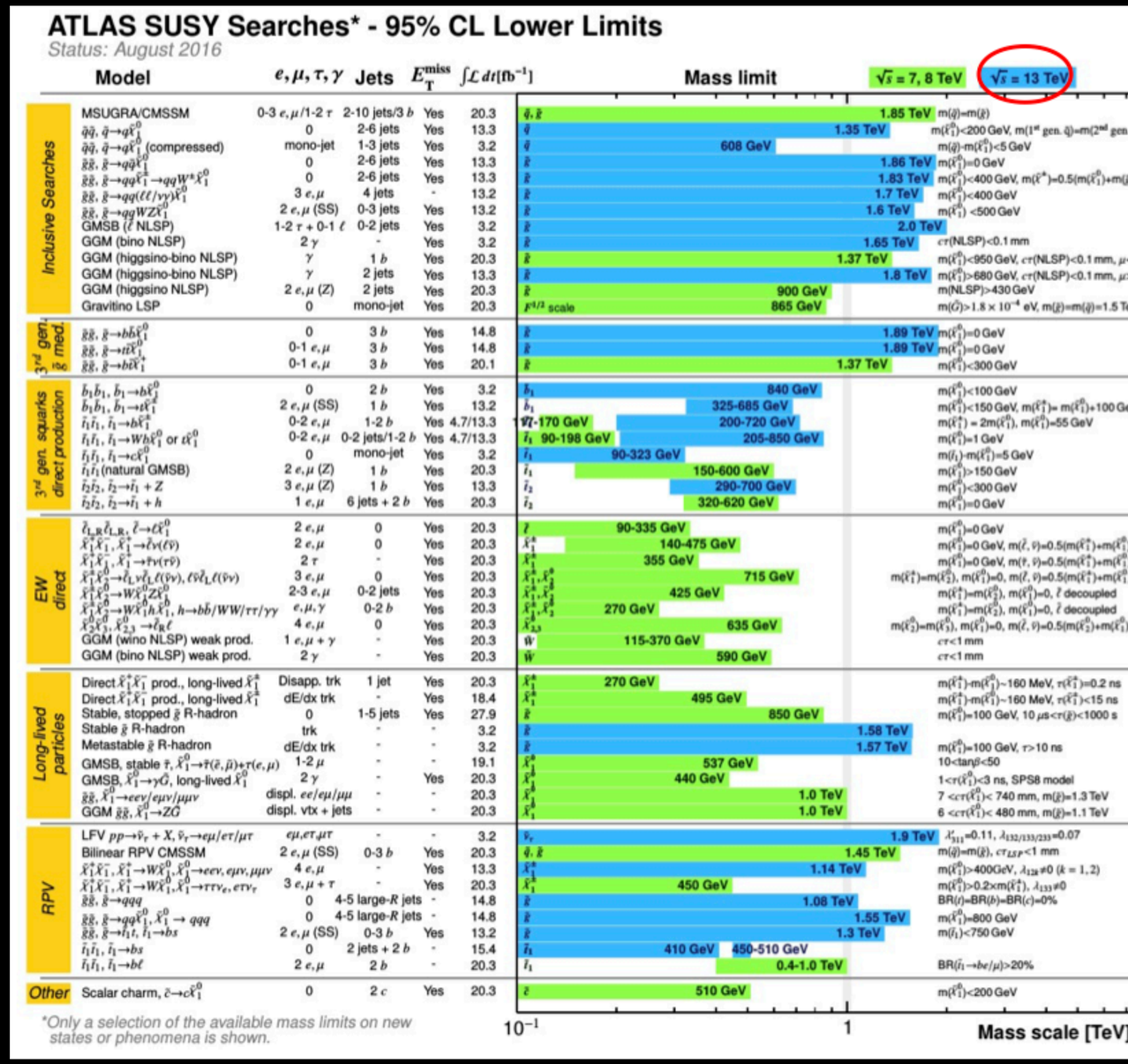
Ian Low SEARCH2016

RAZOR DIPHOTON EXCURSION



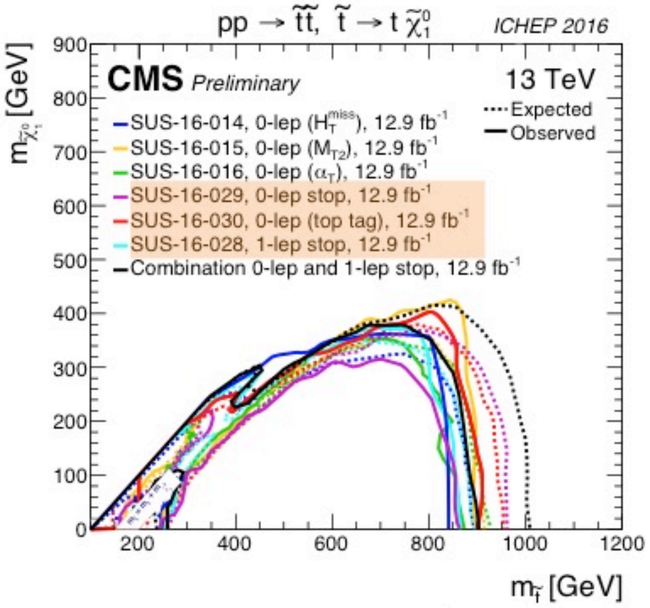


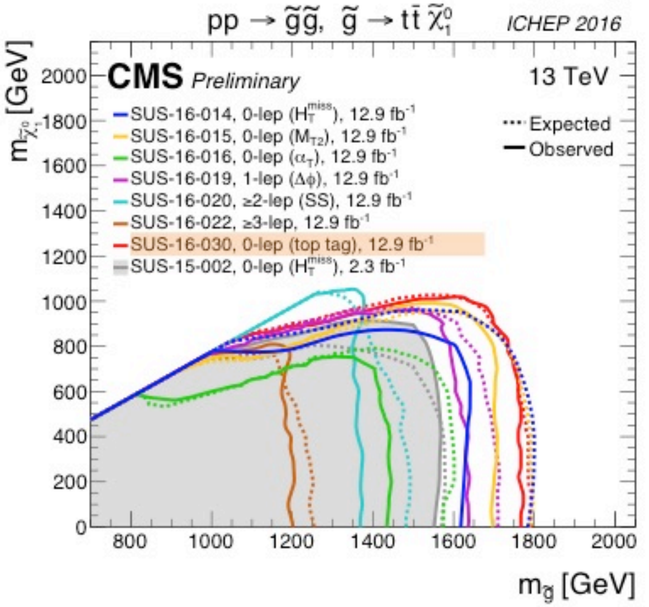
SUSY


ATLAS SUSY Searches* - 95% CL Lower Limits
Status: August 2016
Model
e, μ, τ, γ
Jets
E_T^{miss}
$\int \mathcal{L}\, dt[fb^{-1}]$
Mass limit
$\sqrt{s}$ = 7, 8 TeV
$\sqrt{s}$ = 13 TeV
Inclusive Searches
MSUGRA/CMSSM
$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$
$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$ (compressed)
$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\nu\nu)\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}_1^0$
GMSB ($\tilde{\ell}$ NLSP)
GGM (bino NLSP)
GGM (higgsino-bino NLSP)
GGM (higgsino NLSP)
GGM (higgsino-bino NLSP)
Gravitino LSP
3rd gen. $\tilde{g}$ med.
$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}_1^+$
3rd gen. squarks direct production
$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$
$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^{\pm}$
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}_1^{\pm}$
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$
$\tilde{t}_1\tilde{t}_1$(natural GMSB)
$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$
$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+h$
EW direct
$\tilde{\ell}_{LR}\tilde{\ell}_{LR}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}, \tilde{\chi}_1^{\pm}\to\tilde{\ell}\nu(\ell\tilde{\nu})$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}, \tilde{\chi}_1^{\pm}\to\tilde{\tau}\nu(\tau\tilde{\nu})$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$
$\tilde{\chi}_3^0\tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$
GGM (wino NLSP) weak prod.
GGM (bino NLSP) weak prod.
Long-lived particles
Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$
Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$
Stable, stopped $\tilde{g}$ R-hadron
Stable $\tilde{g}$ R-hadron
Metastable $\tilde{g}$ R-hadron
GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$
GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to eev/e\mu\nu/\mu\mu\nu$
GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to ZG$
RPV
LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$
Bilinear RPV CMSSM
$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to eev, e\mu\nu, \mu\mu\nu$
$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\nu_e, e\tau\nu_\tau$
$\tilde{g}\tilde{g}, \tilde{g}\to qqq$
$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$
$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1t, \tilde{t}_1\to bs$
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$
Other
Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$
1.85 TeV
1.35 TeV
608 GeV
1.86 TeV
1.83 TeV
1.7 TeV
1.6 TeV
2.0 TeV
1.65 TeV
1.37 TeV
1.8 TeV
900 GeV
865 GeV
1.89 TeV
1.89 TeV
1.37 TeV
840 GeV
325-685 GeV
170 GeV
200-720 GeV
90-198 GeV
205-850 GeV
90-323 GeV
150-600 GeV
290-700 GeV
320-620 GeV
90-335 GeV
140-475 GeV
355 GeV
715 GeV
425 GeV
270 GeV
635 GeV
115-370 GeV
590 GeV
270 GeV
495 GeV
850 GeV
1.58 TeV
1.57 TeV
537 GeV
440 GeV
1.0 TeV
1.0 TeV
1.9 TeV
1.45 TeV
1.14 TeV
450 GeV
1.08 TeV
1.55 TeV
1.3 TeV
410 GeV
450-510 GeV
0.4-1.0 TeV
510 GeV
*Only a selection of the available mass limits on new states or phenomena is shown.
10^{-1}
1
Mass scale [TeV]

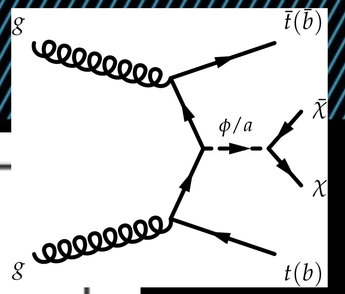
Conclusion

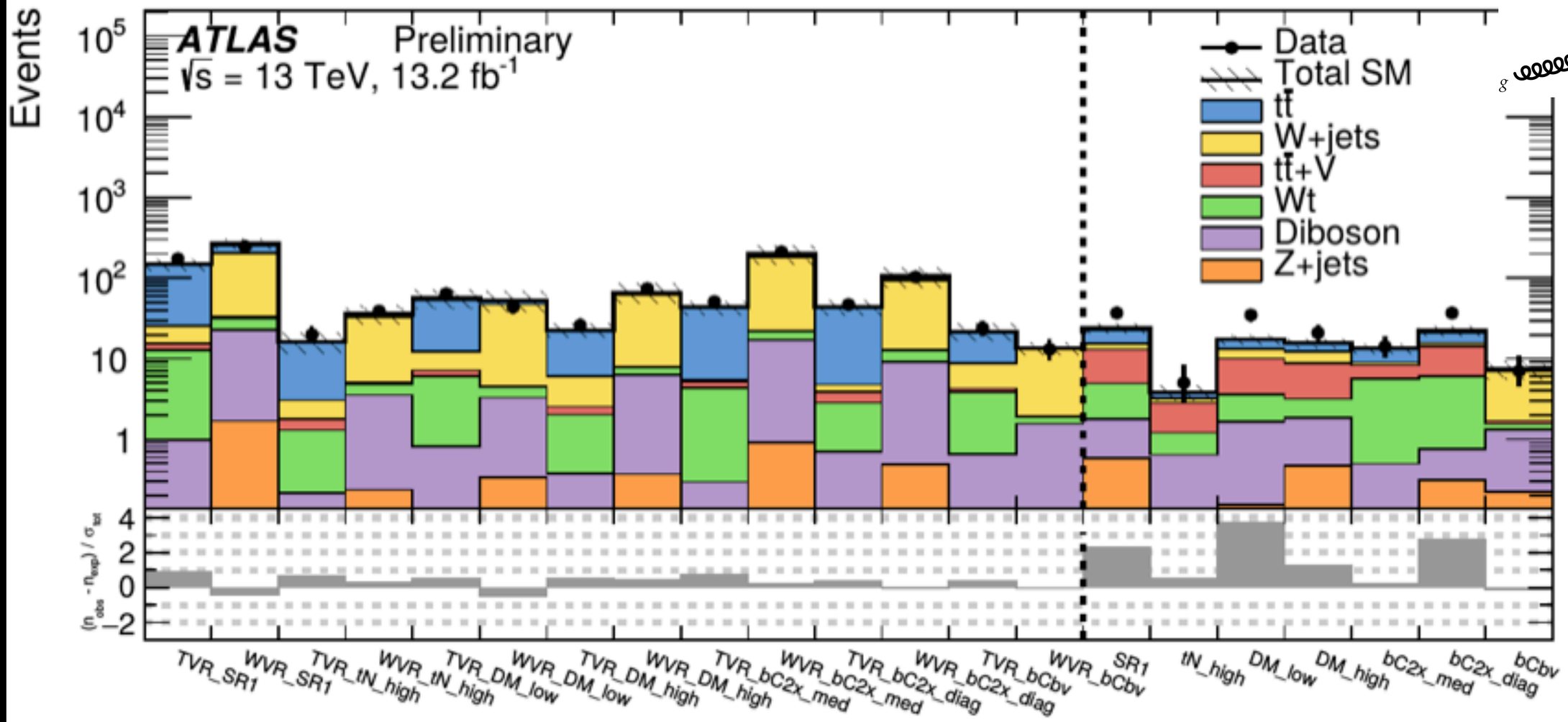
- Presented searches for third generation squarks using 12.9 fb^{-1} of 13 TeV data
- No significant deviation from the standard model is observed
- Extended limits on top squark (up to 910 GeV from 760 GeV in 2015) and gluino (up to 1780 GeV from 1580 GeV in 2015) masses in the context of Simplified Model Spectra
- LHC running very well, expect up to 30–40 fb^{-1} by the end of the year





SUSY/DM WITH TOP IN THE FINAL STATE

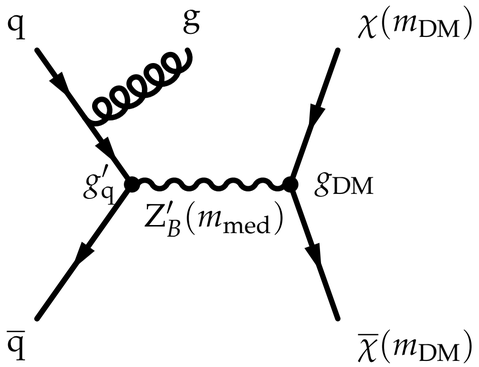




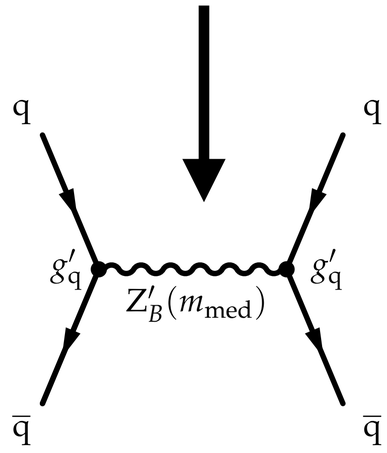
- Excess of 3.3 sigma observed in DM_low

SENSITIVITY TO DM

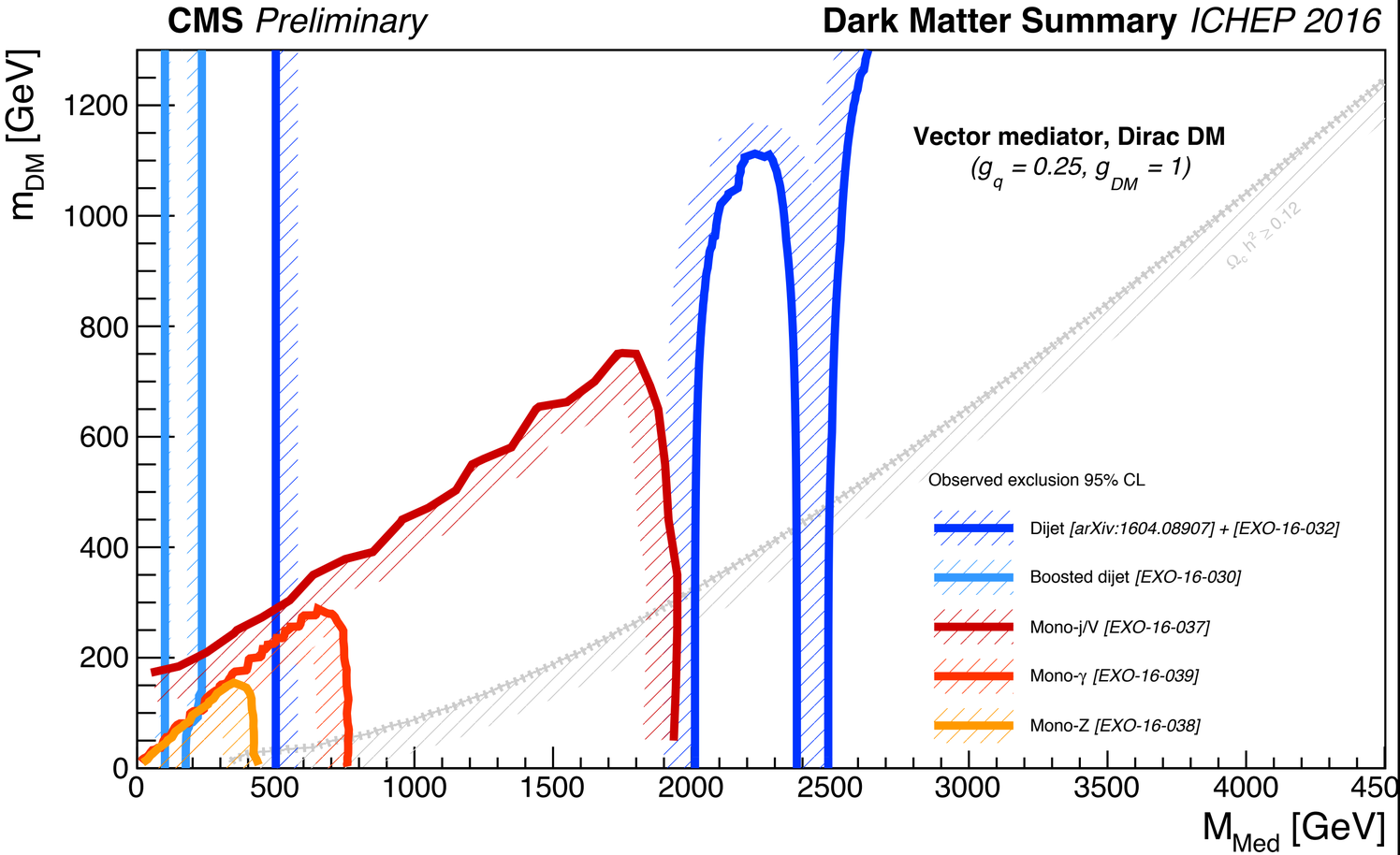
- Sensitive to large range of parameter space by looking directly for resonant production of the mediator



MET+X



DIJET



WHERE IS BSM

WHERE IS BSM

Everywhere:
DM,DE,inflation,
baryogenesis,
neutrinos masses

WHAT ARE WE MISSING

WHAT ARE WE MISSING

clues?
thoughts?
paradigm shifts?
AOTA?

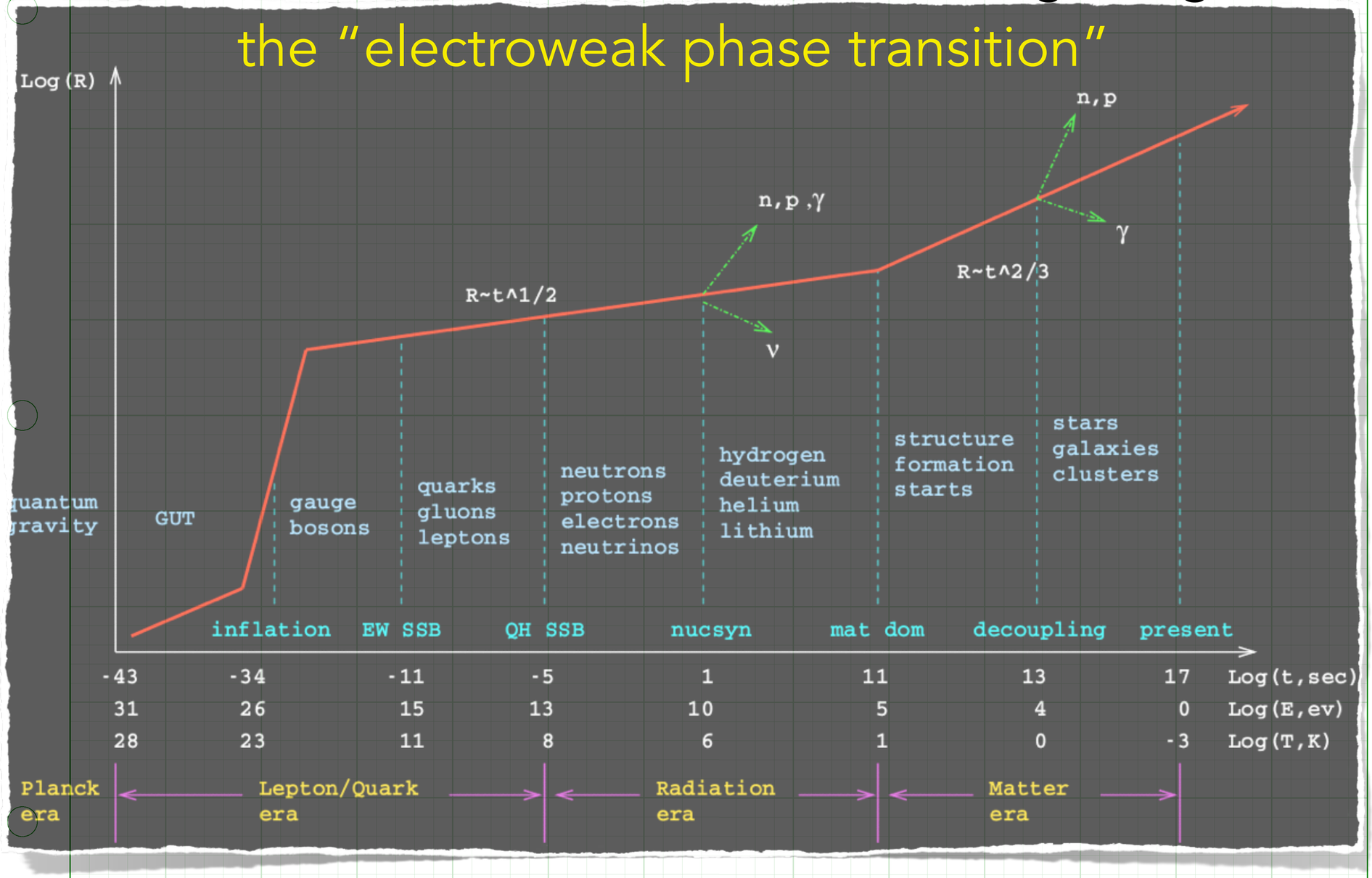
study exhaustively the Higgs &
neutrinos properties
&
search for the DM everywhere
it can be searched for

look for connecting principles

GINO BOLLA 25/09/1968 - 04/09/2016

H: the earliest known event of the Big Bang:

the "electroweak phase transition"



H: the earliest known event of the Big Bang:

the “electroweak phase transition”

- Successful Electroweak Baryogenesis **requires new physics at the LHC energies**
  - New particles that couple strongly to the Higgs
  - **New sources of CP violation appearing in the Higgs sector**
  - Could be a two-stage process involving the dark sector, as in models of asymmetric dark matter

Implies discoveries for the LHC and ILC!

New sources of CP violation also relevant to **EDM searches**

Strong 1st order phase transition -> gravity wave signature

Higgs questions define a twenty year experimental program

- Is there a Higgs portal to dark matter
  - WIMP-nucleon scattering via Higgs → direct dark matter searches
  - Does the Higgs have invisible decays → LHC, HL-LHC
  - Direct WIMP production → LHC, HL-LHC, HE-LHC
- Did the Higgs trigger the (baryo)genesis of matter
  - CP violation in Higgs sector? -> LHC precision measurements, EDMs
  - Phase transition requires richer Higgs sector → LHC, HL-LHC, HE-LHC searches
  - Baryogenesis vs leptogenesis, CP violation in neutrinos -> LBNE

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Higgs questions define a twenty year experimental program

- Is the Higgs vacuum unstable
  - stabilized by SUSY? → LHC
  - more accurate Higgs and top masses → LHC
  - new heavy particles coupled to Higgs? → LHC, HL-LHC, HE-LHC
- How does the Higgs talk to neutrinos?
  - are neutrinos Majorana? -> neutrinoless double beta decay
  - heavy electroweak triplet/singlet particles? → LHC, HL-LHC, HE-LHC searches
  - neutrino mass matrix -> NOvA, T2K, LBNE