Searches for Exotic Signatures at the LHC

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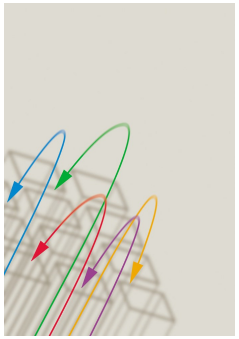
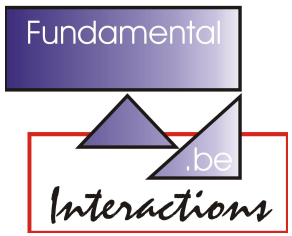




21 December 2017
Final Meeting IAP
“Fundamental Interactions”

Searches for exotic signatures at the LHC

- from energy…

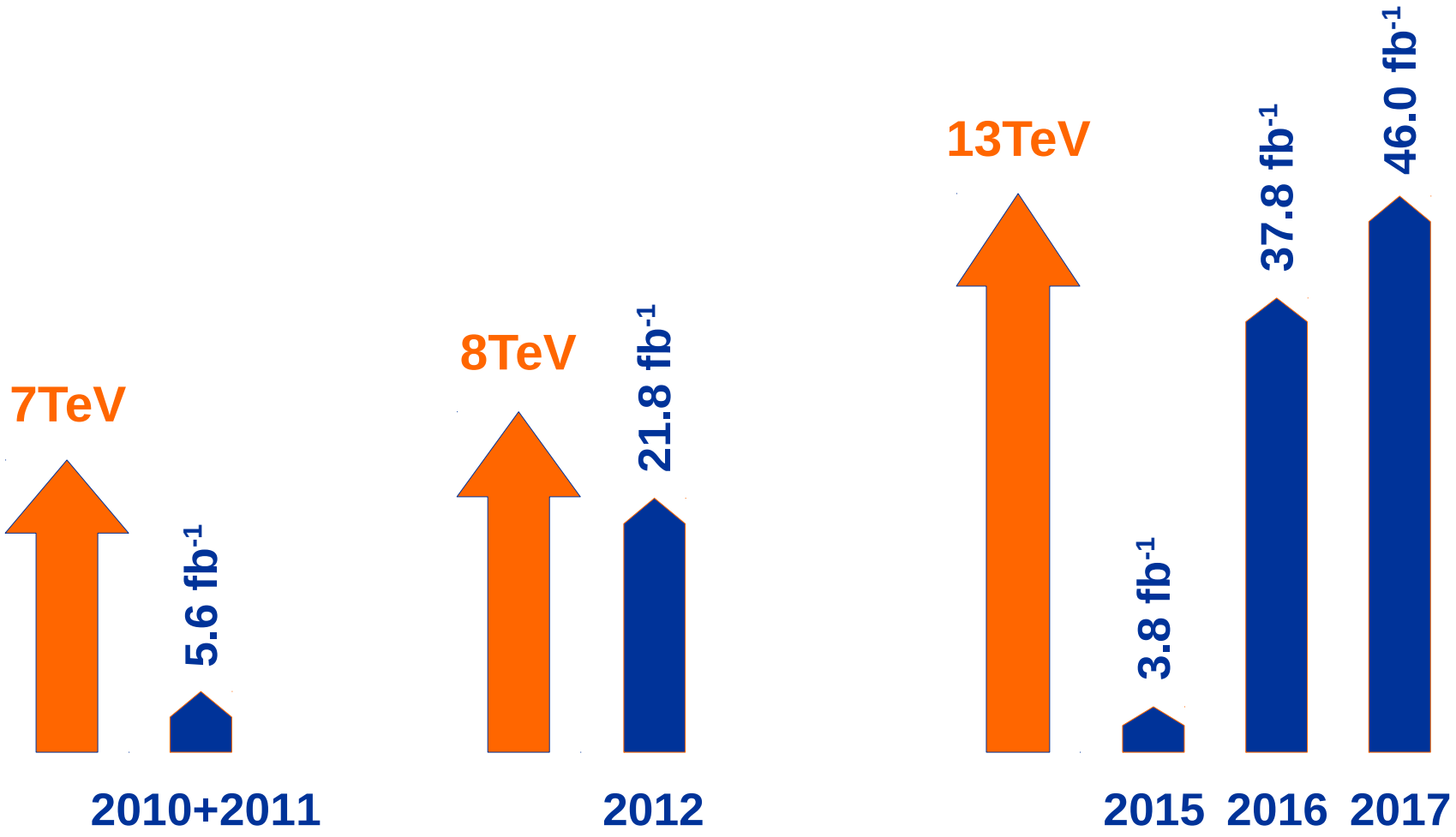
  …to luminosity

- what now?

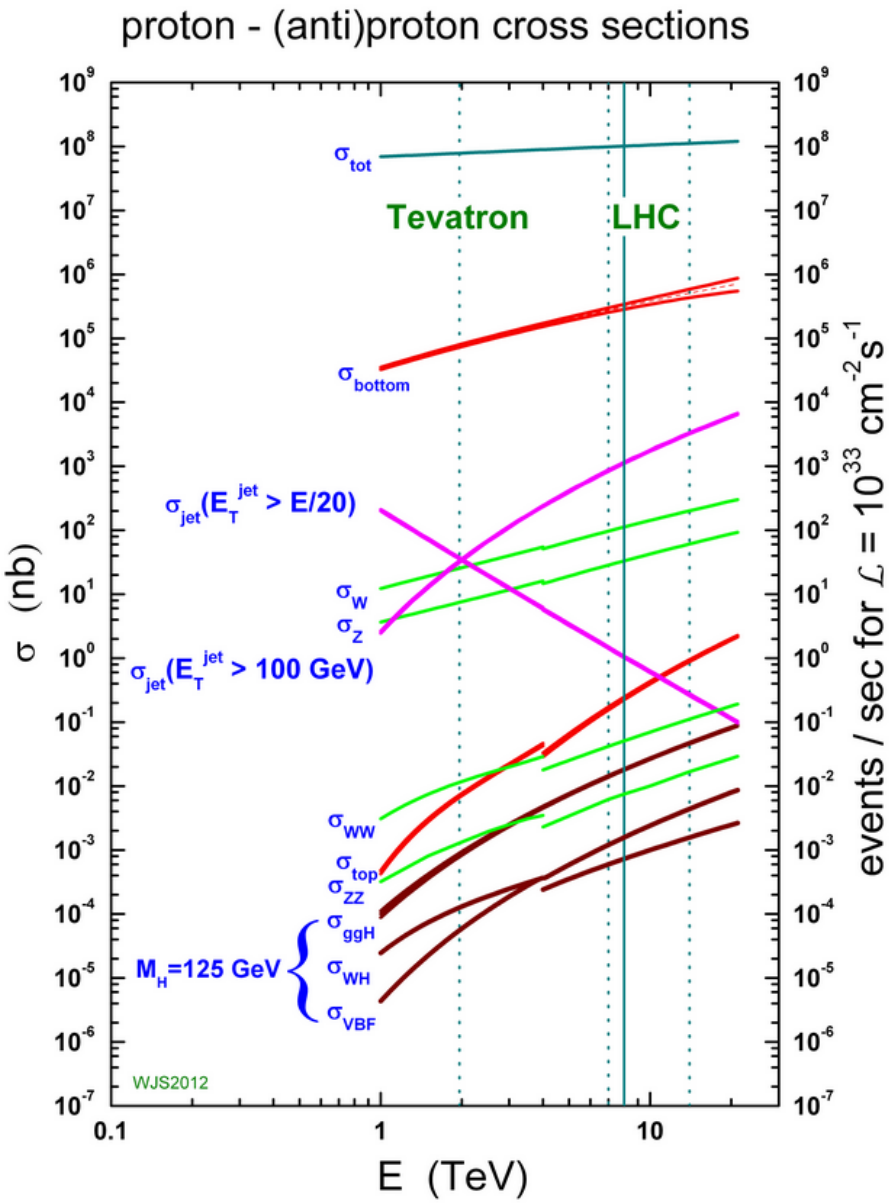
- new opportunities
  - dark matter
  - long-lived particles
  - experimental anomalies

The LHC revolution

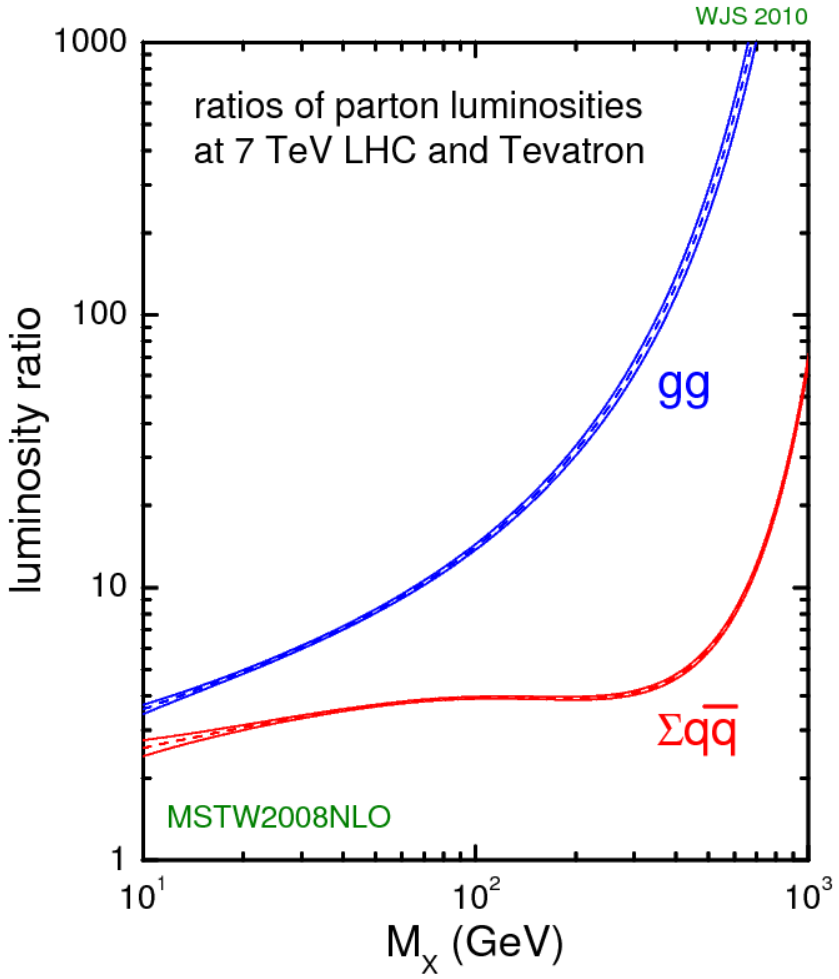
- world-record energies, luminosities beyond expectation

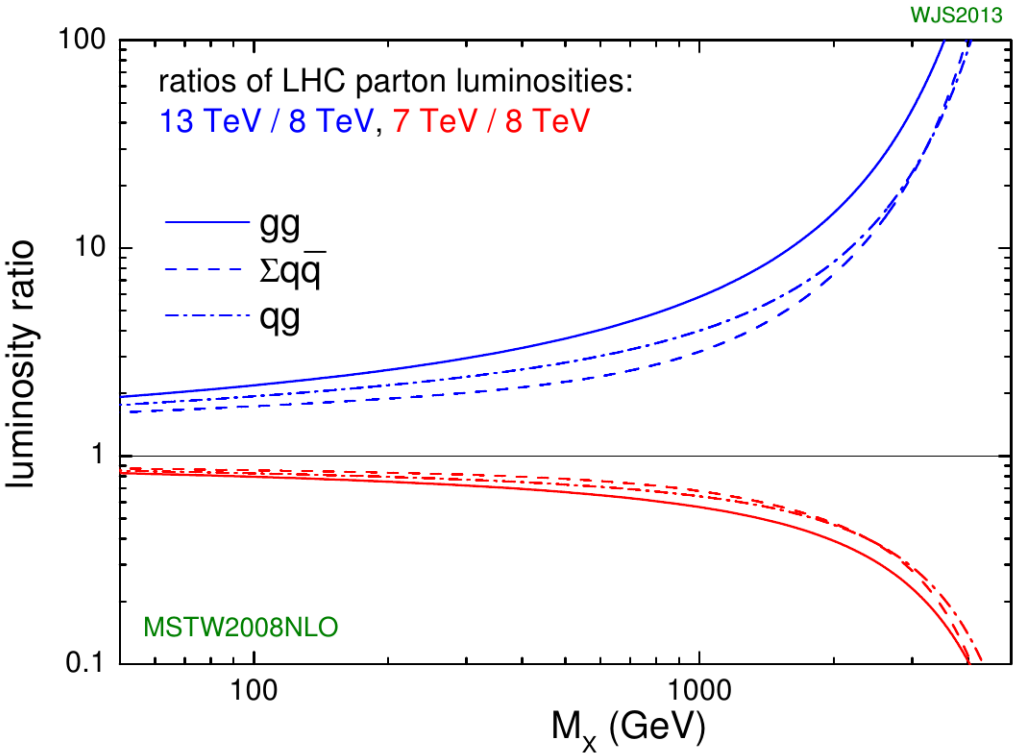


The energy frontier



The energy frontier



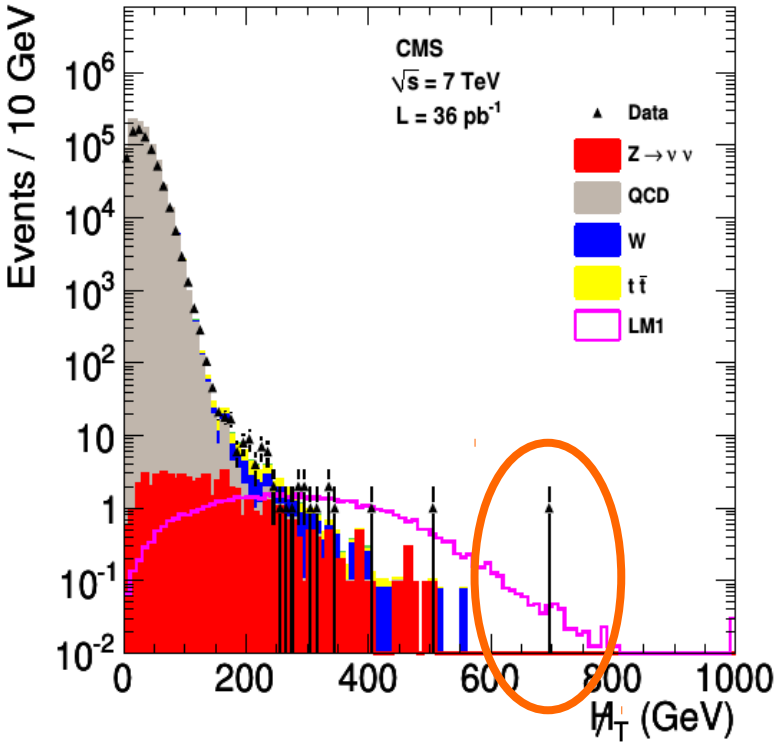


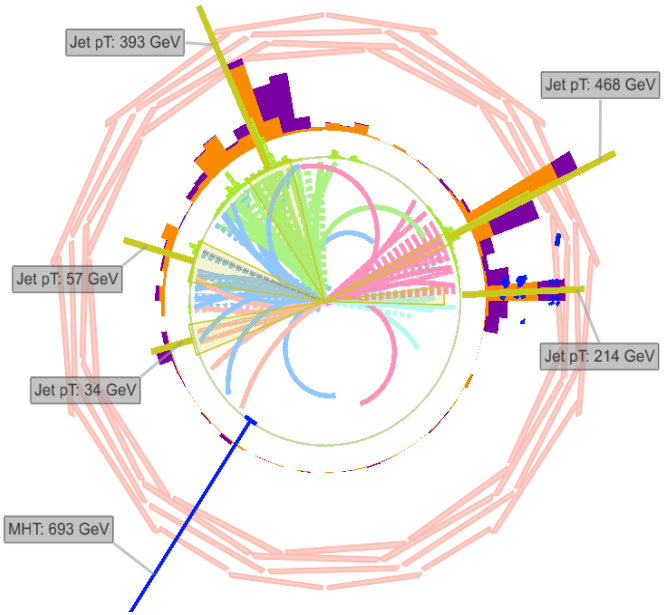
The energy frontier

Excitement in 2010 and 2015

- first data at world-record centre-of-mass energy collisions
  - "new physics around the corner"

JHEP 08 (2011) 155





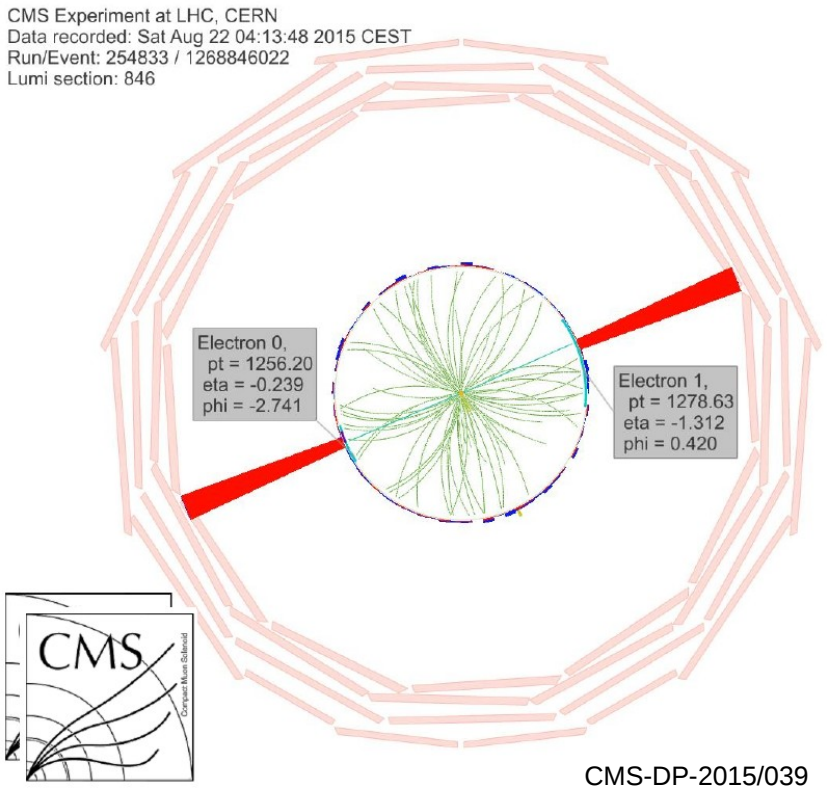
MET = 693 GeV

The energy frontier

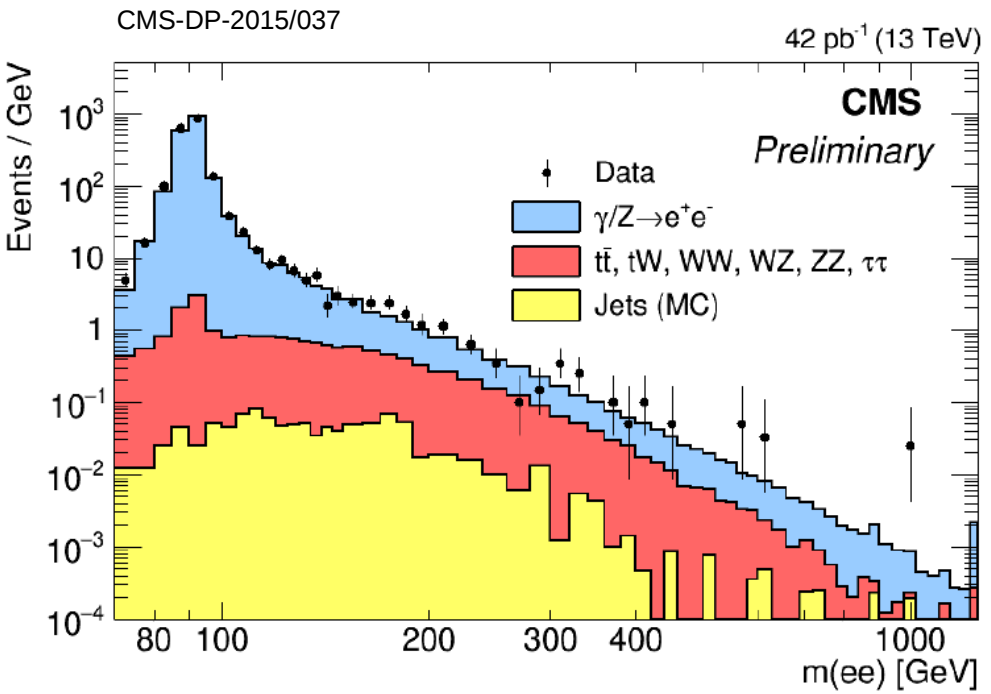
Excitement in 2010 and 2015

- first data at world-record centre-of-mass energy collisions
  - "new physics around the corner"

$m(e^+e^-) = 2.91$ TeV
$B < 0.002$ ev. ($64 pb^{-1}$)



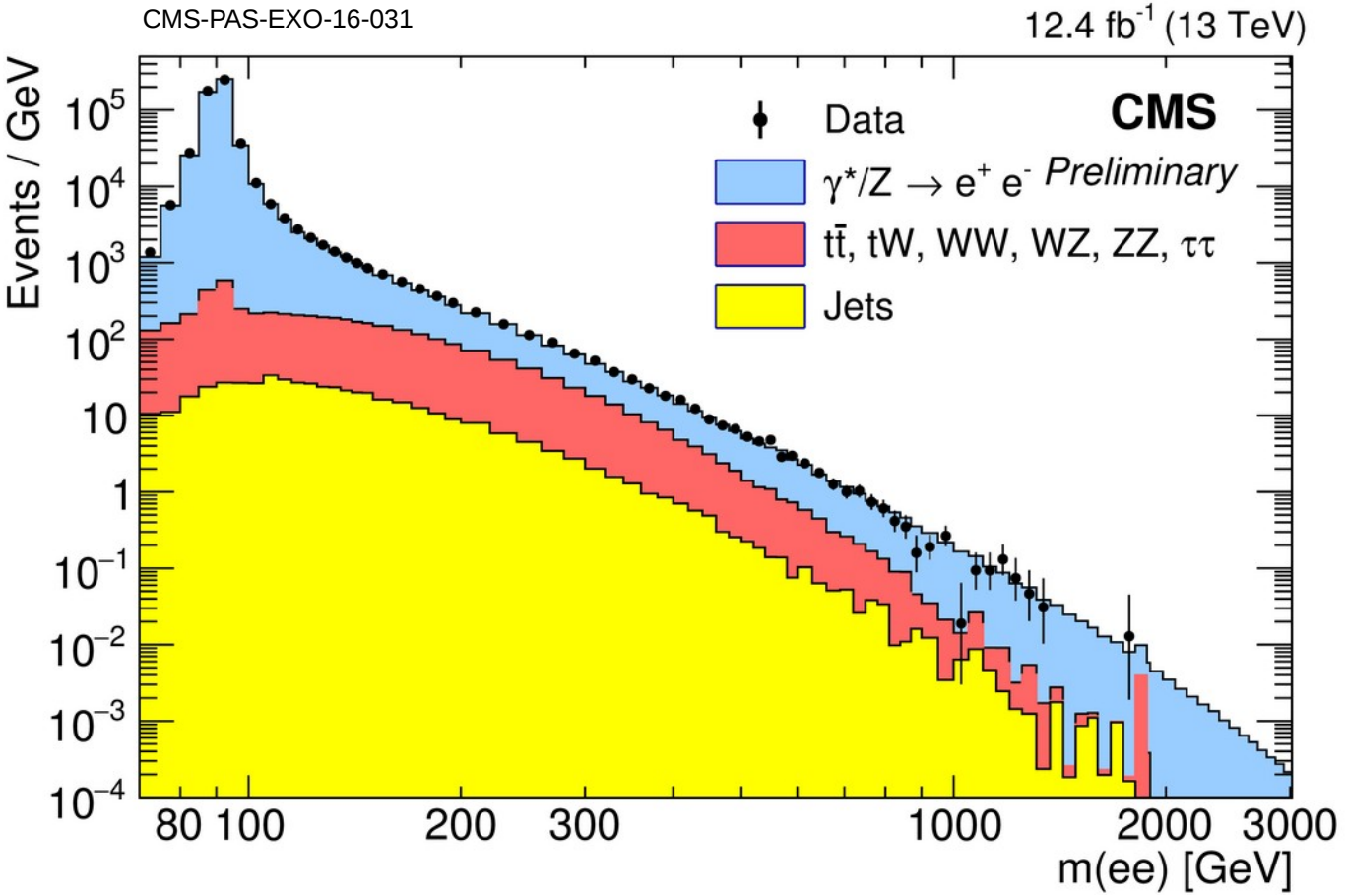
CMS-DP-2015/039



On the kinematic tails

Current state of the art

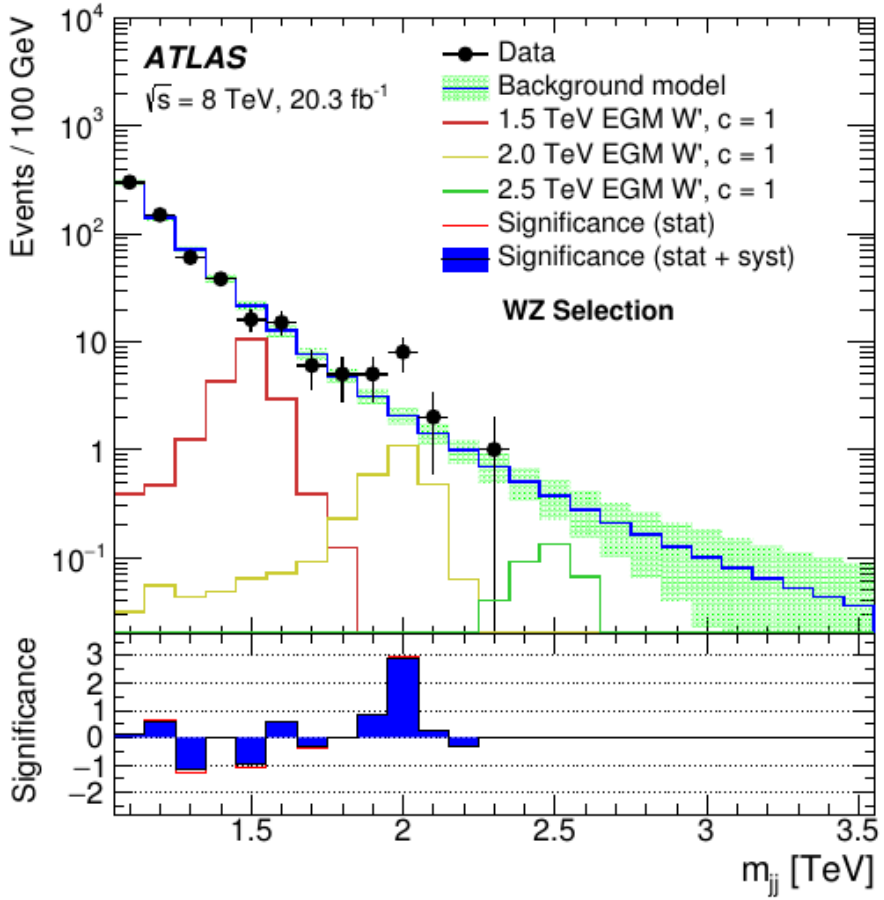
- smooth spectra including tails incredibly well predicted



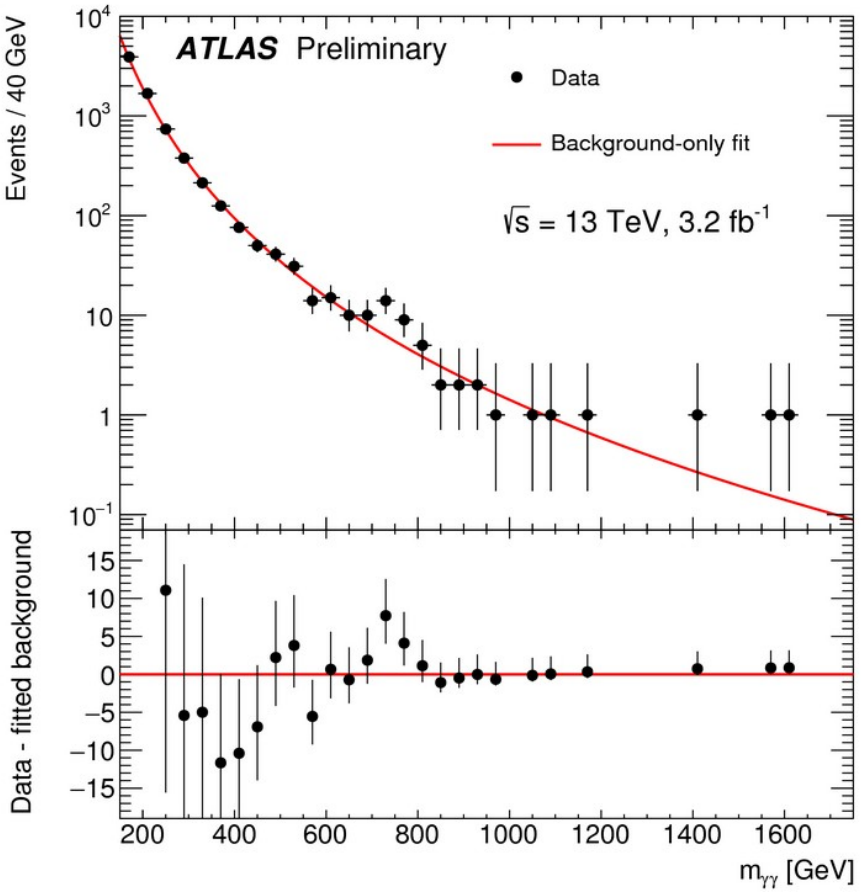
On the kinematic tails

We still had some surprises...

JHEP 12 (2015) 055



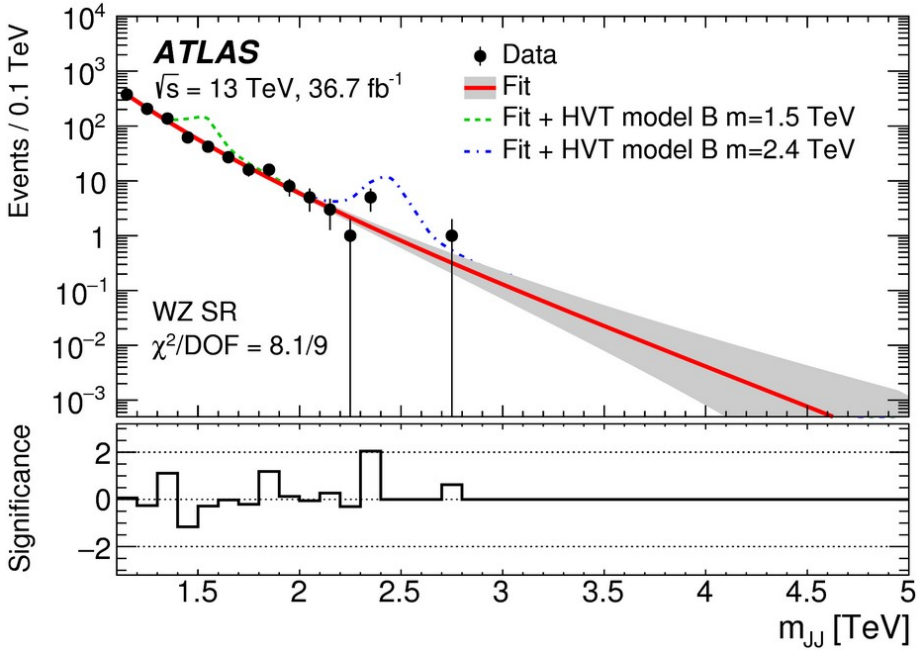
ATLAS-CONF-2015-081 and JHEP 09 (2016) 001



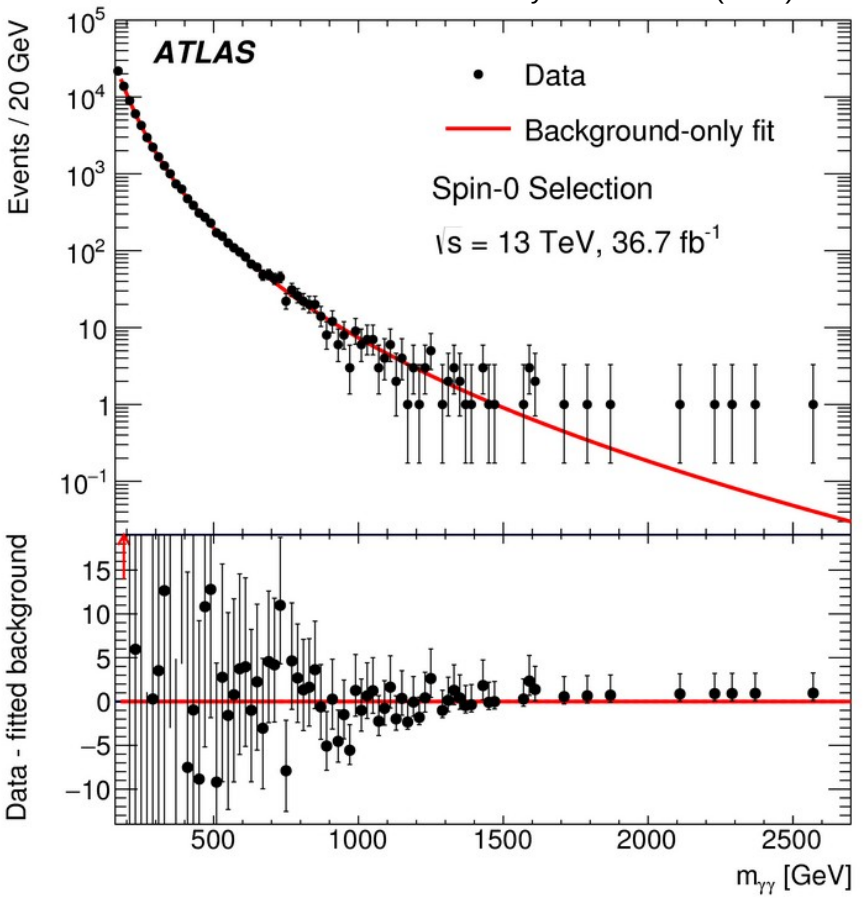
On the kinematic tails

We still had some surprises…

Phys. Lett. B 777 (2017) 91



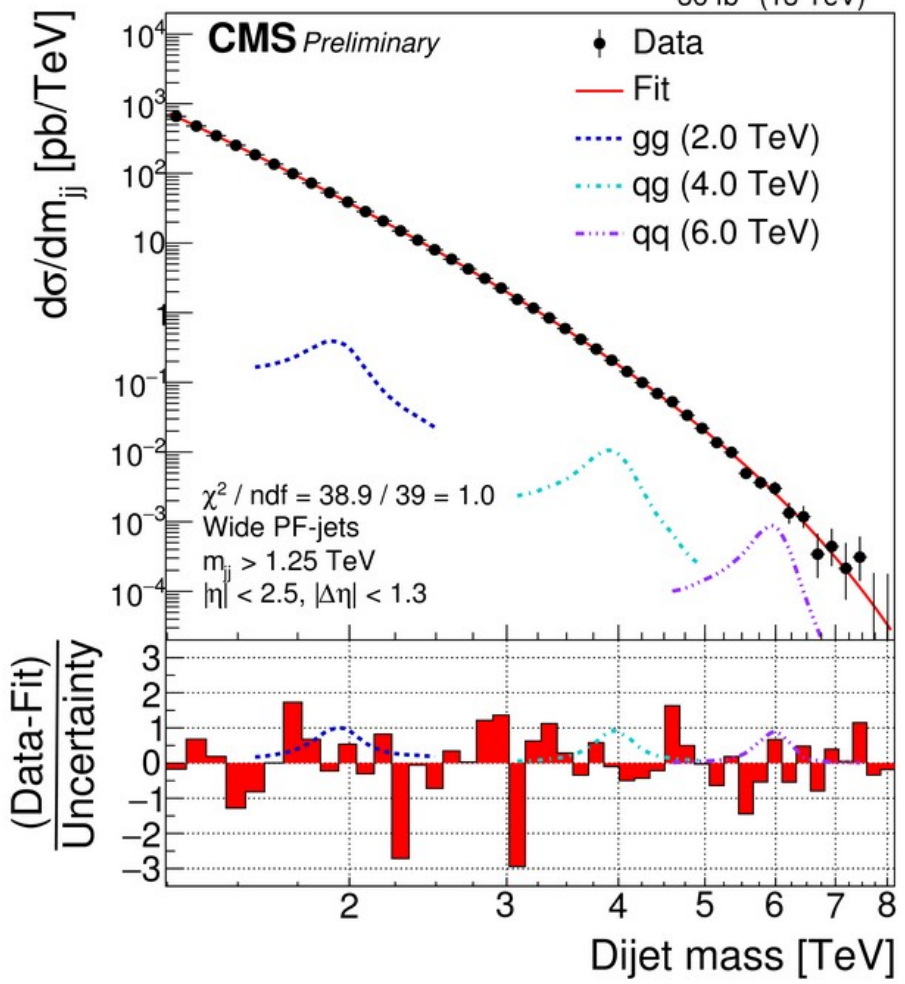
Phys. Lett. B 775 (2017) 105



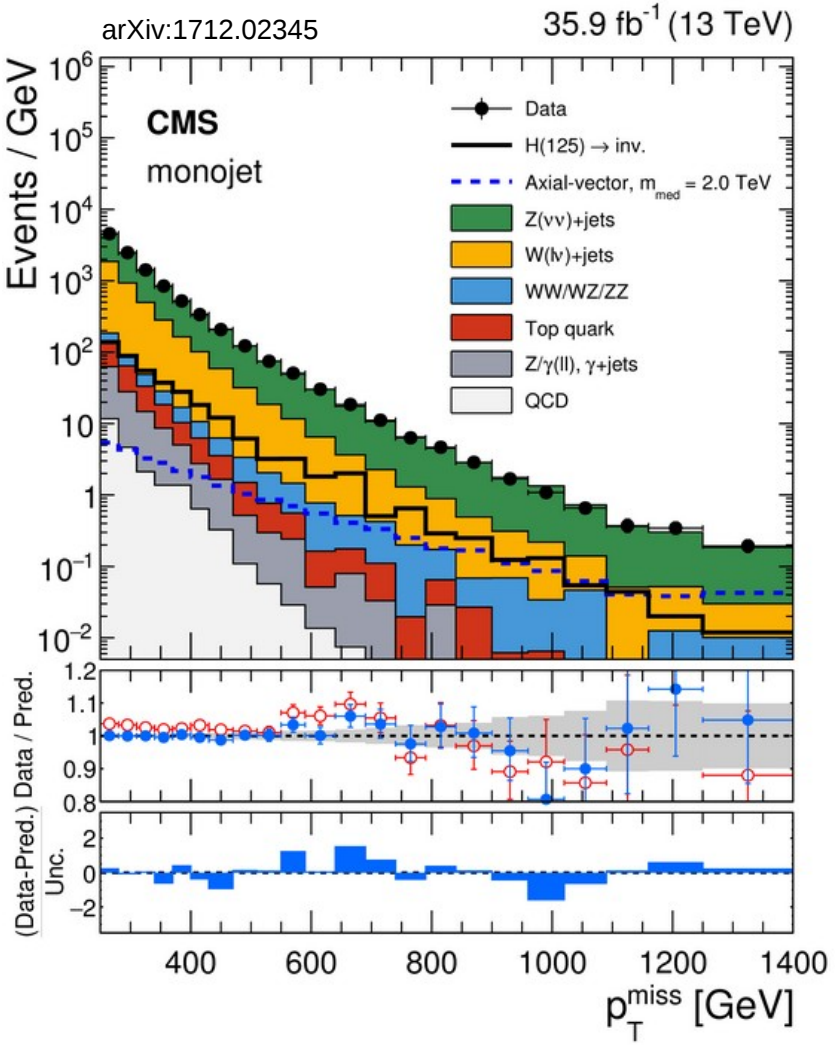
On the kinematic tails

Also excellent hadronic control

CMS-PAS-EXO-16-056



arXiv:1712.02345



see also Eur.Phys.J. C77 (2017) 829

From energy to luminosity

So what now?

- data volume now grows ~ linearly
  - while statistical uncertainties on tails scale with ~ sqrt (data volume)
  - 100fb^{-1} now
  - 150fb^{-1} by end of 2018
  - 500fb^{-1} by end of 2023

    jump in luminosity from 2026 onwards (HL-LHC): towards 3000fb^{-1}

- “classic” analyses now often systematically limited
  - DMWG meeting 18/12: “Monojet: from now on, systematically-limited search”
  - and not easy to further improve

From energy to luminosity

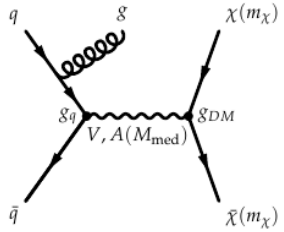
So what now?

- new era – change of mindset
  - precision measurements
    - global interpretations
  - evolution of the search program
- create new search opportunities
  - follow up experimental anomalies
  - new final states or topologies
  - new approaches in our data taking and use of it
  - new analysis techniques improving sensitivity
  - new territory in model parameter space
  - new interpretations or combinations
  - analyses that were previously at the limit of sensitivity

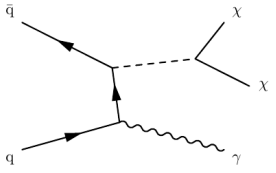
New opportunities: DM

Dark Matter searches with simplified models

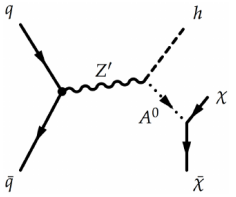
- explore “all” final states



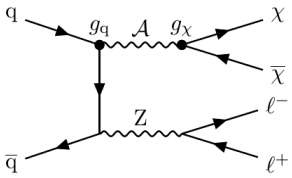
MonoJet

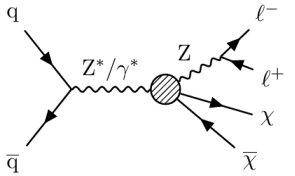


MonoPhoton

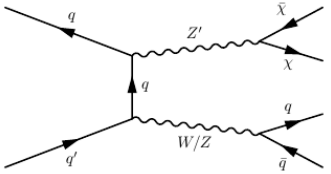


MonoHiggs

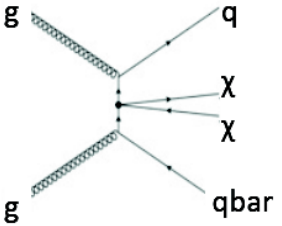




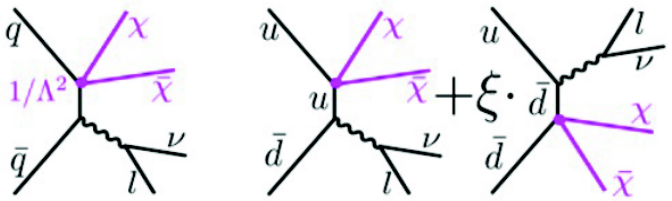
MonoZ (leptonic)



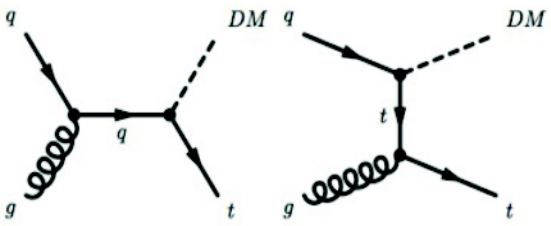
MonoW/Z (Hadronic)



BBbar /TTbar



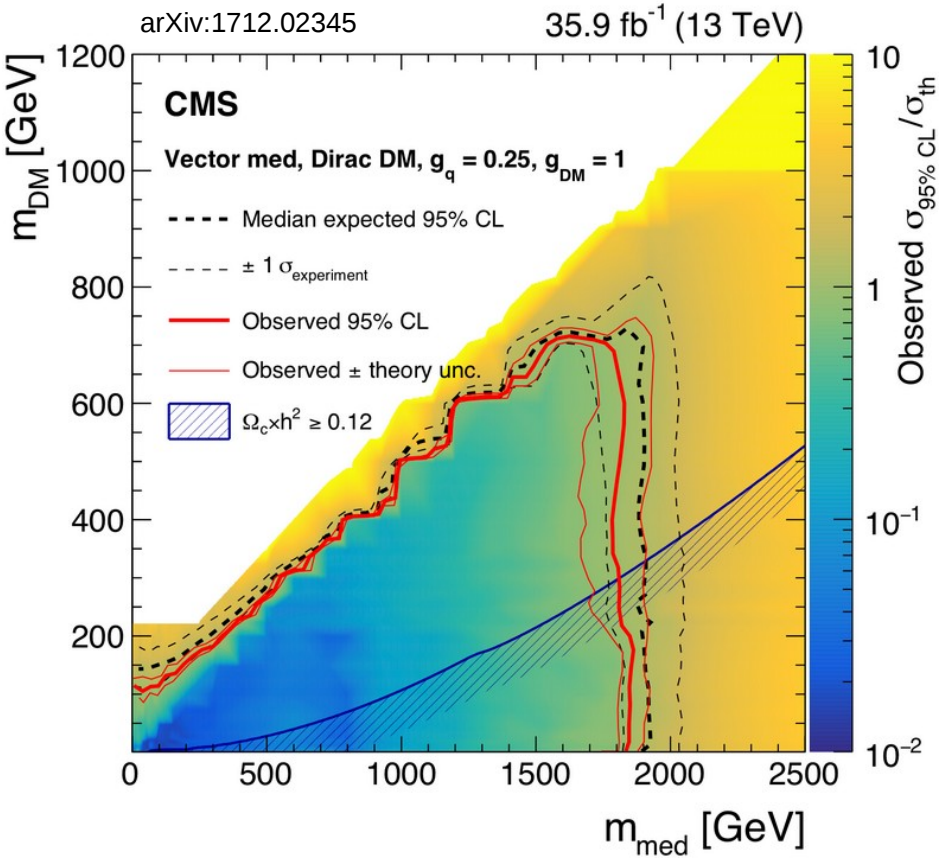
MonoW (monoLepton)

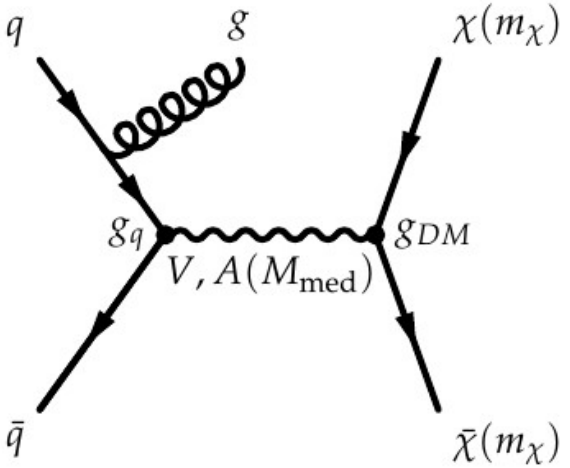


MonoTop

New opportunities: DM

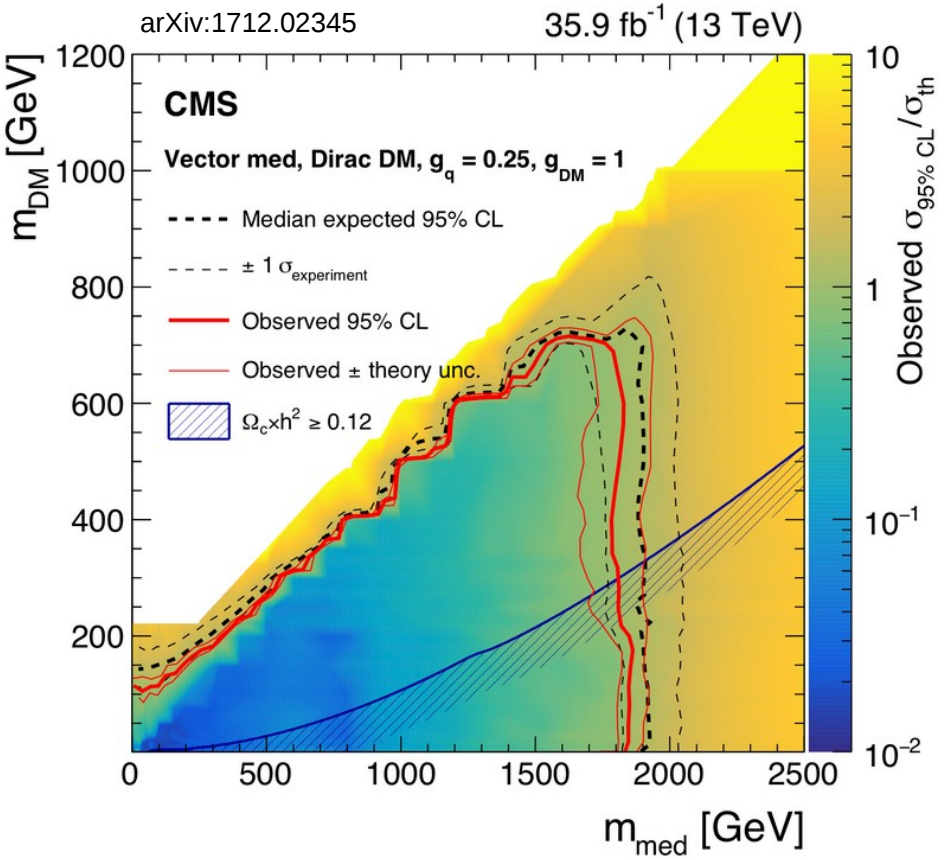
“Invisible mediator” searches

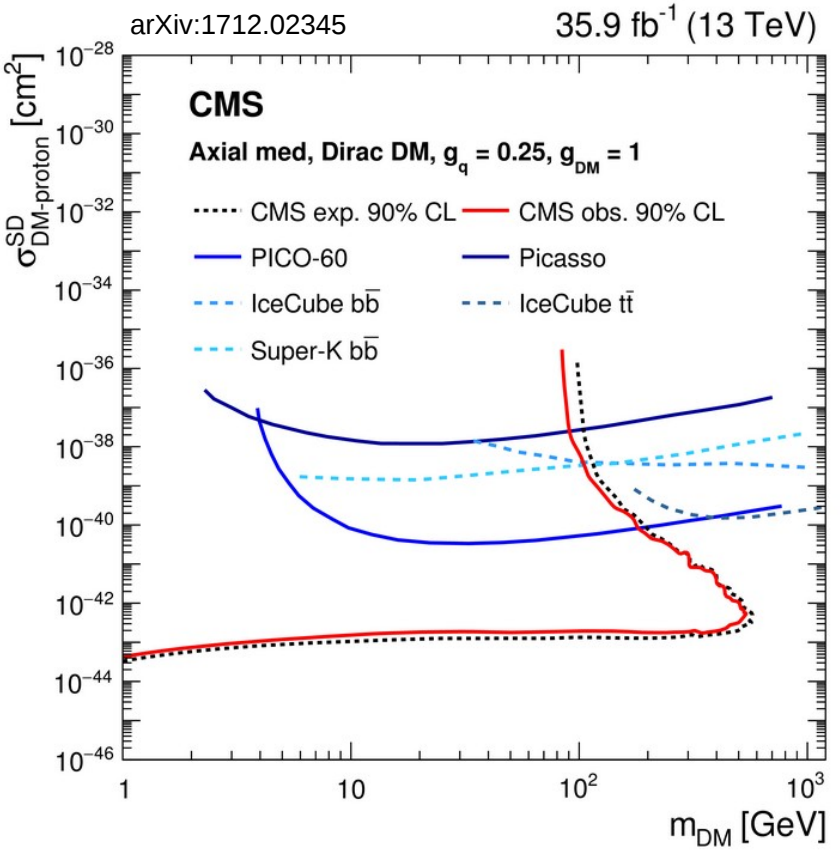




New opportunities: DM

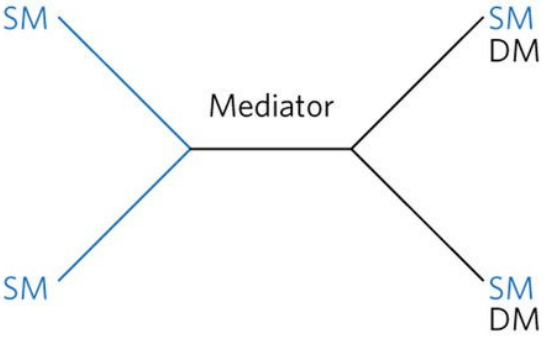
Link beyond LHC



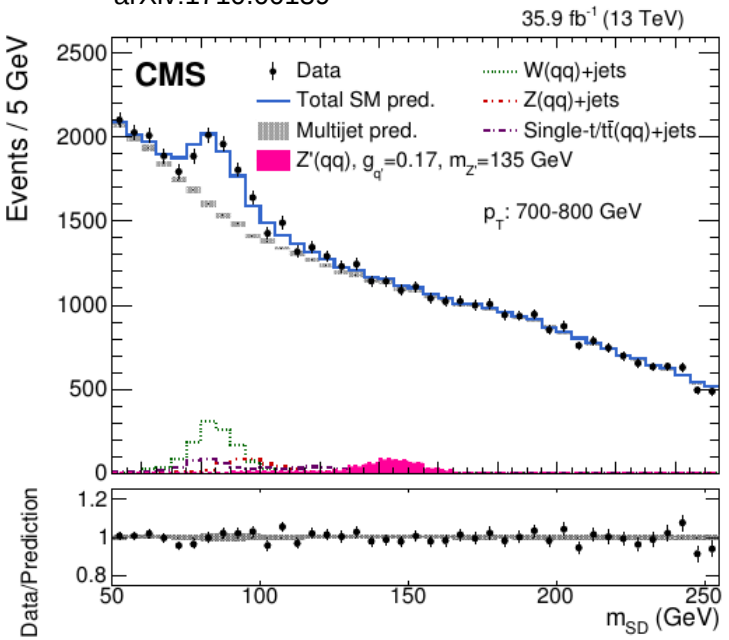


New opportunities: DM

Link “visible mediator” searches



arXiv:1710.00159



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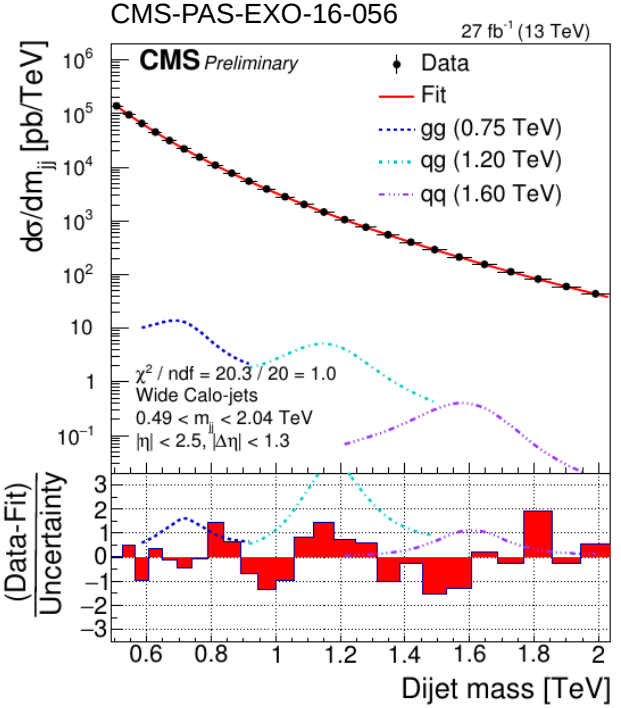

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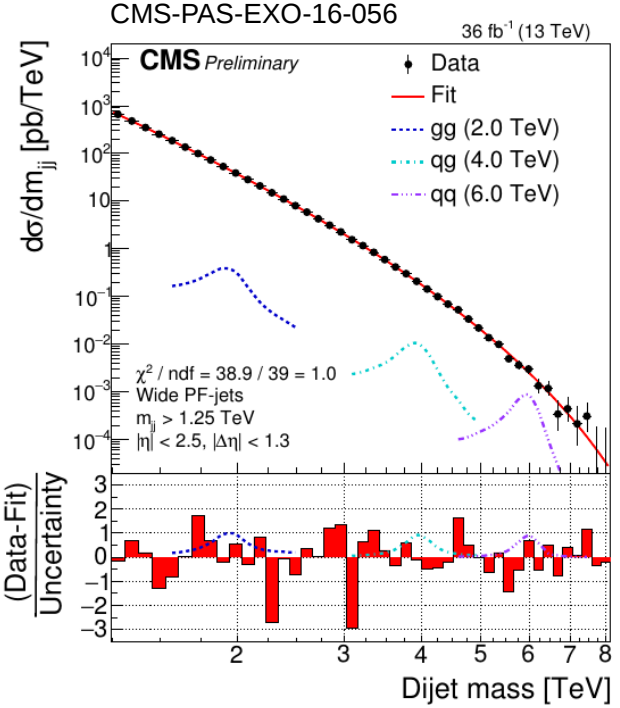
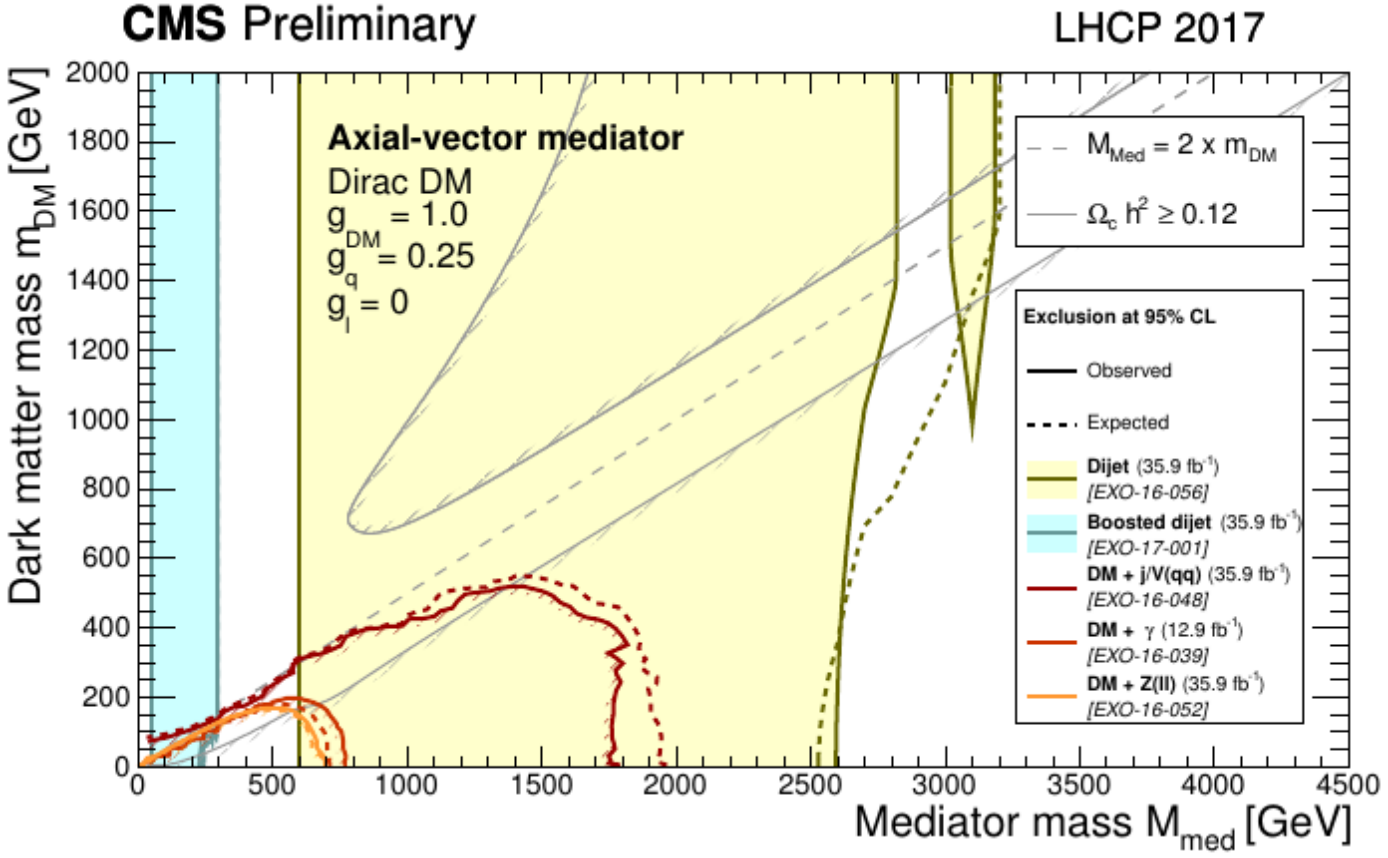


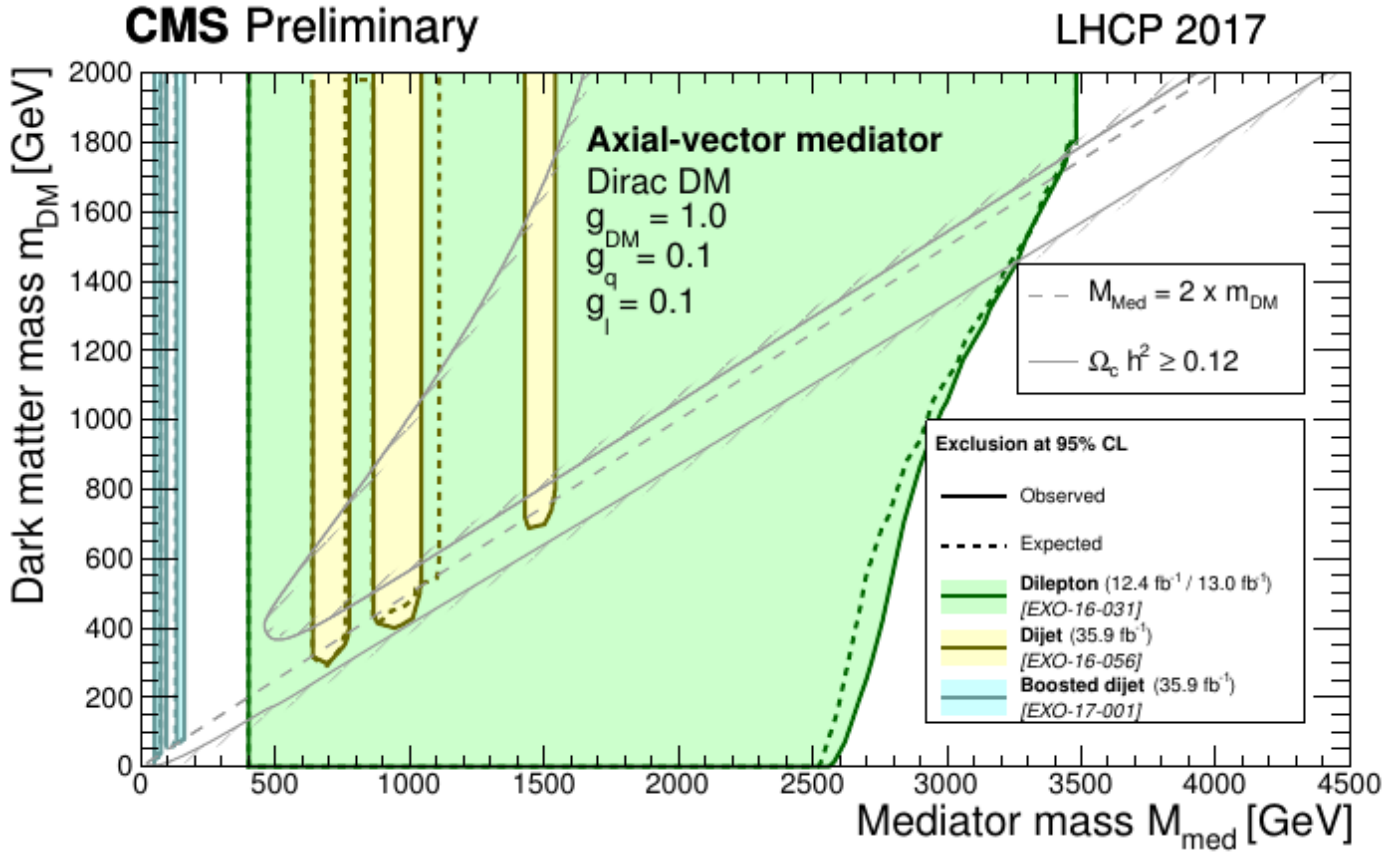
New opportunities: DM

Status Dark Matter searches



New opportunities: DM

Status Dark Matter searches

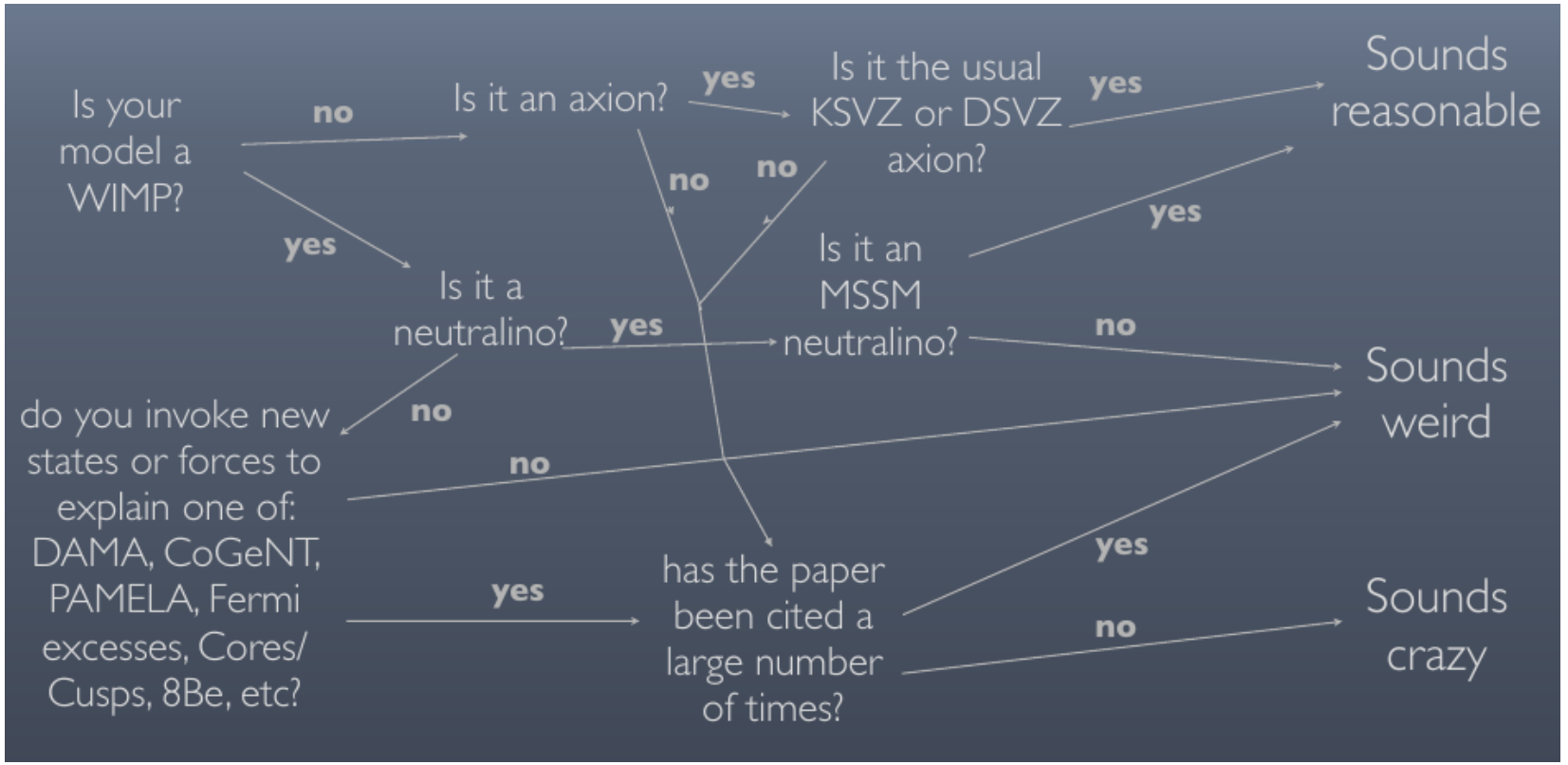


- careful! very sensitive to considered couplings!

New opportunities: exotics

Off the beaten track

- what is exotic is time-dependent



Neil Weiner's DM bingo card

- like fashion: the creative of today is tomorrow mainstream (or forgotten...)

New opportunities: long-lived

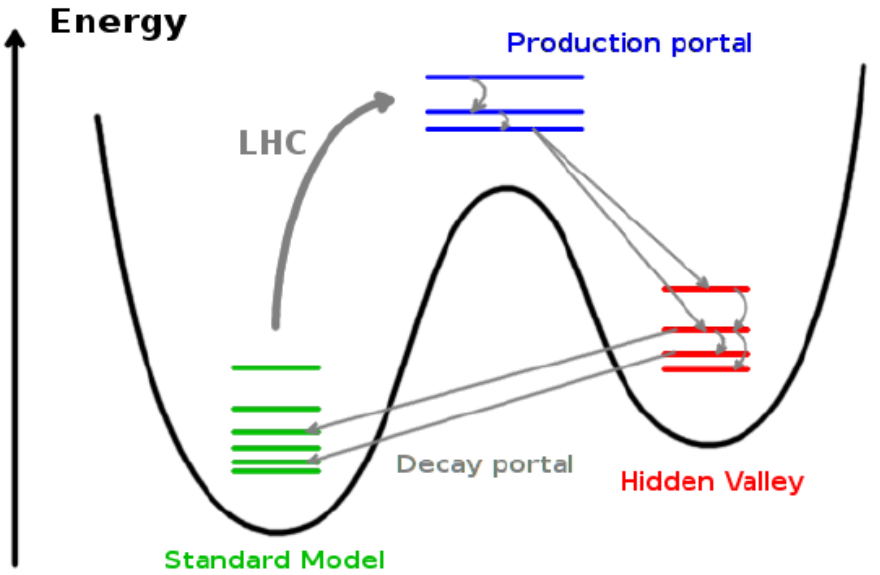
Long-lived particles at the LHC

- no BSM so far → move away from under the lamppost
- long-lived particles are theoretically motivated
  - small mass splittings

    eg. SUSY
  - high-mass barrier

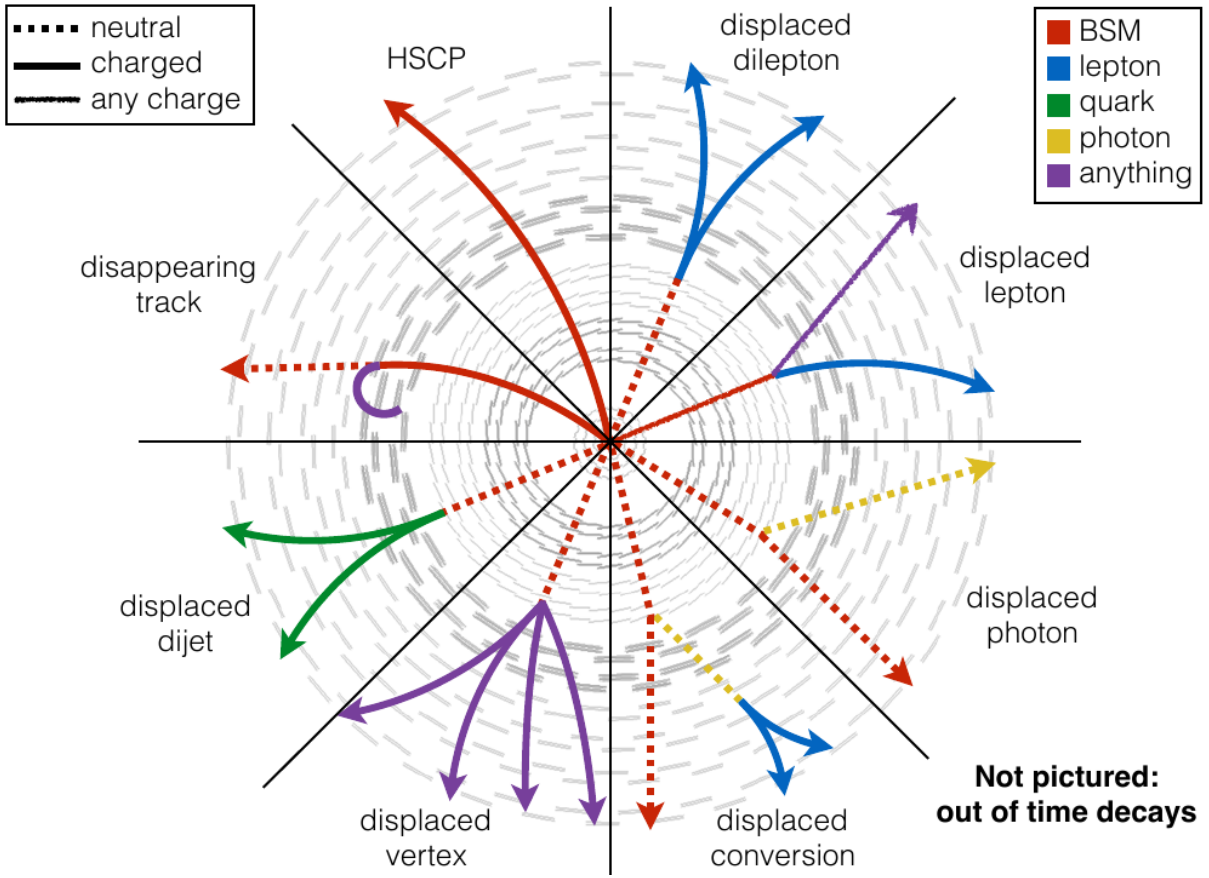
    eg. Hidden Valleys
  - small couplings

    eg. dark photons
- theoretical landscape is vast!
- “exotic new physics could be around the corner”



New opportunities: long-lived

- also experimental landscape is vast
- maximize experimental coverage of unusual signatures
  - using pheno motivation



Courtesy J. Antonelli

New opportunities: long-lived

- experimental exotics
  - non-standard simulation

    eg. R hadrons, SIMPs, quirks,...
  - non-standard reconstruction

    non-standard timing

    dE/dx

    secondary vertices & displaced jets

    veto on material interactions

    Soft Unclustered Energy Patterns

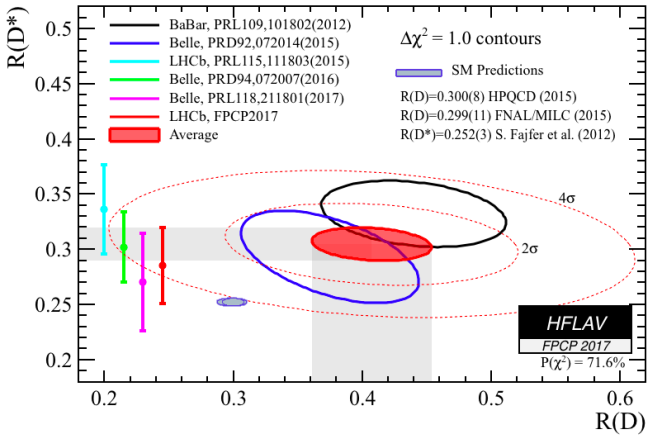
    ...
  - non-standard triggers

    displacement at trigger, trigger-level analysis, new L1 ideas,...
- our detector was often not designed for this
  - use flexibility and versatileness to get the most out of it
- rich program of searches for the next few years!

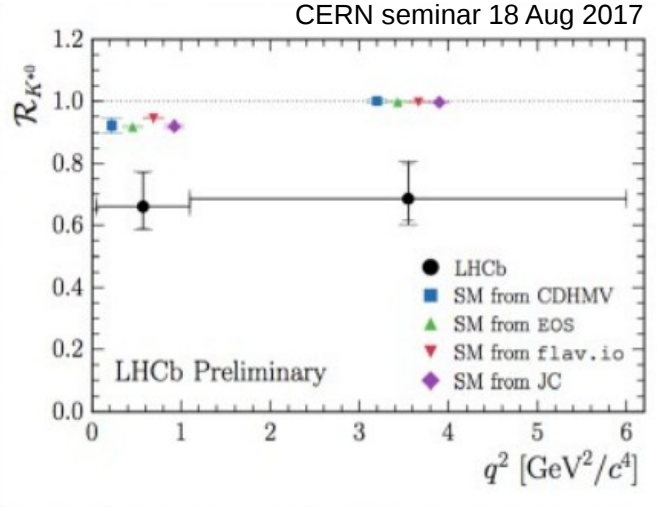
New opportunities: anomalies

Flavour anomalies

- several few-sigma deviations in $R_{D^{(*)}}$, $R_{K^{(*)}}$, P'_5 ,...



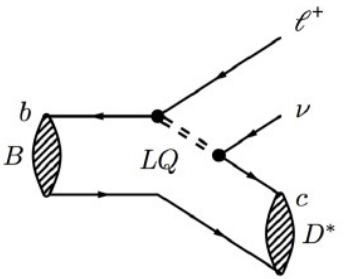
CERN seminar 18 Aug 2017

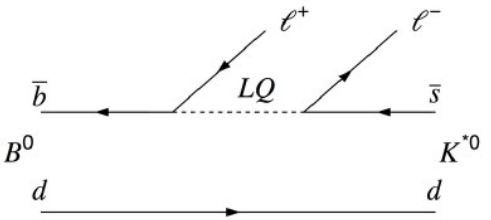


- anomalies come and go, but attractive here is that they could be explained together with minimal extra new physics

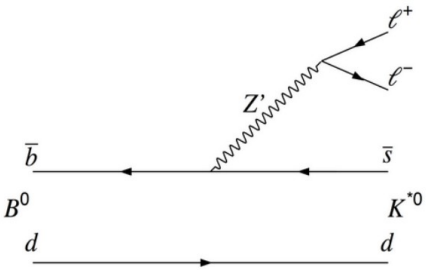
New opportunities: anomalies

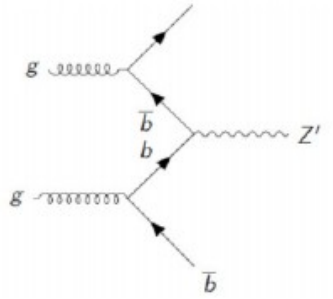
- leptoquarks (LQ)
  - TeV scale, 3rd generation favoured
  - reinforcing searches for LQ's
    - single- and pair-produced
    - different generations

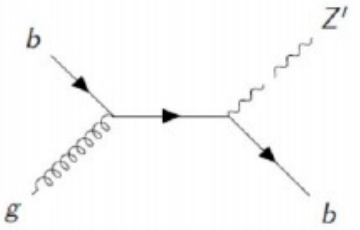




- Z's
  - di-tau search
    - links to e-mu final state
  - coupling to b?
    - associated Z' – b production to explore







Conclusions

- rich set of exotics searches in CMS
  - more than 130 exotics papers so far
- the LHC has entered the luminosity era
  - the CMS search program is evolving
  - usual exotic searches to follow slow pace of luminosity growth
  - new exotic opportunities being actively pursued

    dark matter intensely explored with 13TeV data

    long-lived particles in intense development

    on guard for experimental anomalies
- the IAP provided fertile grounds and a scientific community that allowed for a visible Belgian role in CMS and pheno exotics over the years

Thank you!