Latest results on Exotics Searches

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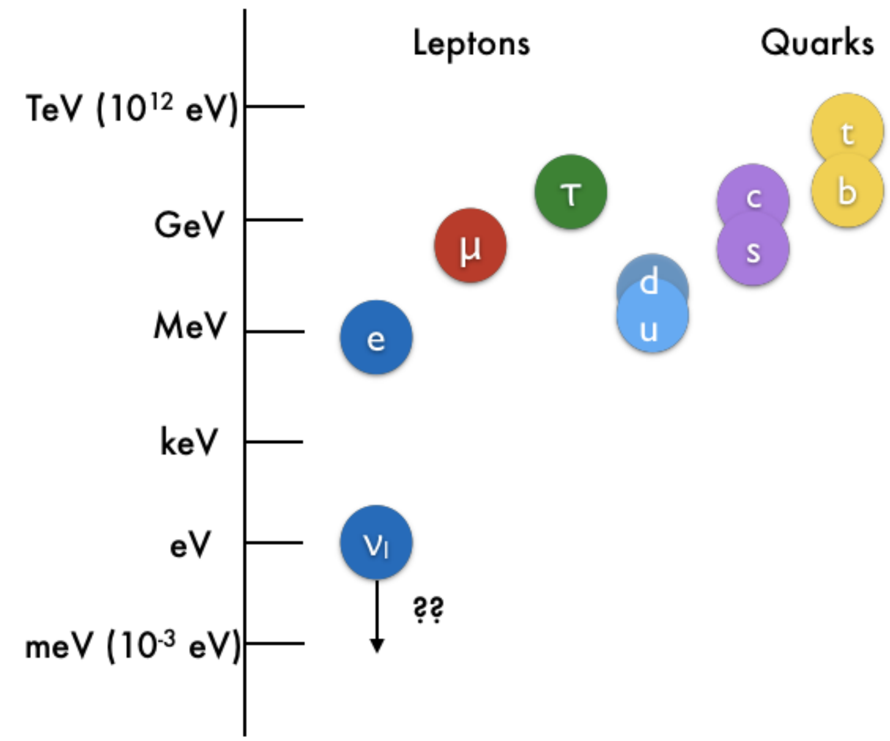
Why look for new physics?

The Standard Model is an extremely successful theory, but it leaves many questions unanswered.

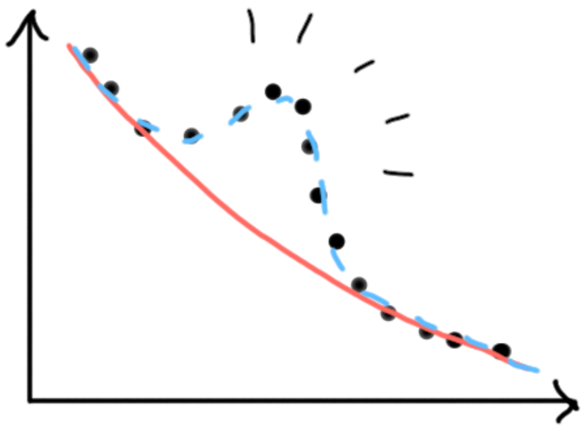
- Why same number of generation for lepton and quarks?
- Why only 5% of matter made of ordinary SM particles?
    - **what is dark matter?**
- Why is the observed M^2_{Higgs} 10^{32} times smaller than predicted? Naturalness problem or hierarchy problem

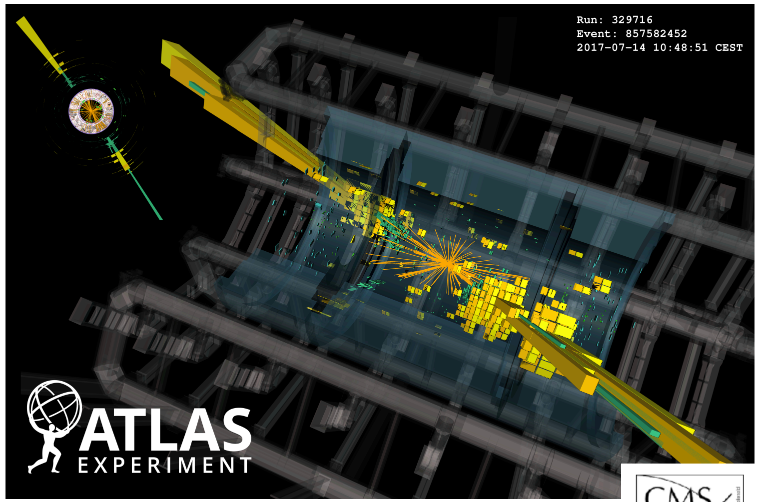


- Is there a more fundamental theory of which the Standard Model is a low energy approximation?
- Many extensions of the SM or alternative theories **try to solve these unanswered questions**

Approach and roadmap for experiments

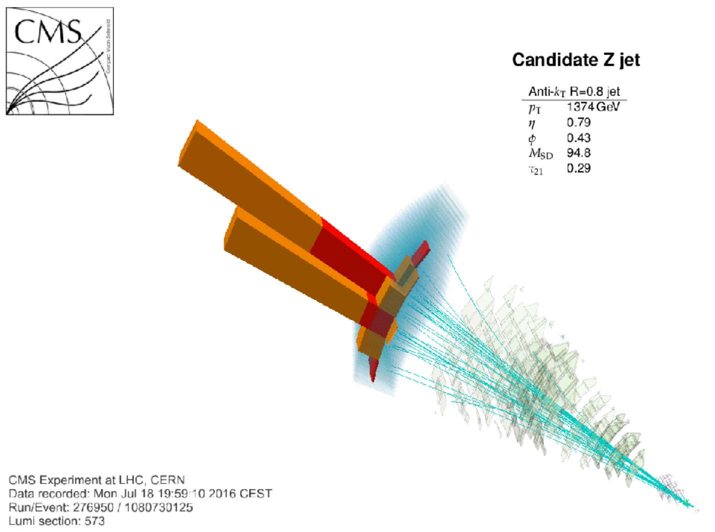
- Cover all possible signatures and be ready for the unexpected
- Be as model-independent as possible
  - Use of benchmark models to test the significance of the searches





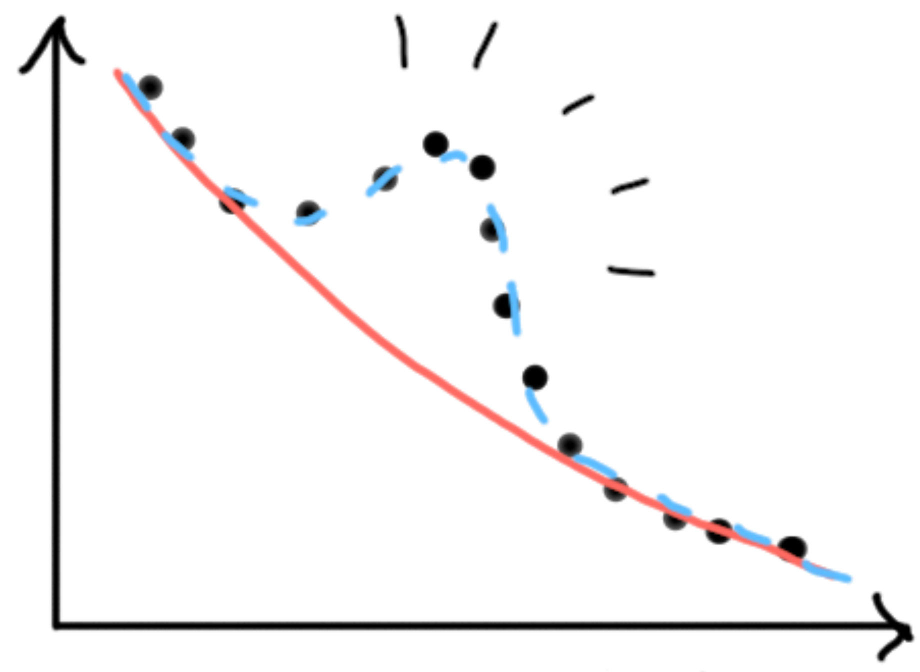
Dijet event with mjj=9.5 TeV

- Experimentally:
  - Search for extremely high masses
  - Go for the really exotic:
    - Models with new interactions, quarks, leptons
    - Unconventional signatures
  - **Explore new analysis techniques to boost discovery potential**



- Several results presented at this conference, impossible to cover them all
- Focus on very recent or brand new results

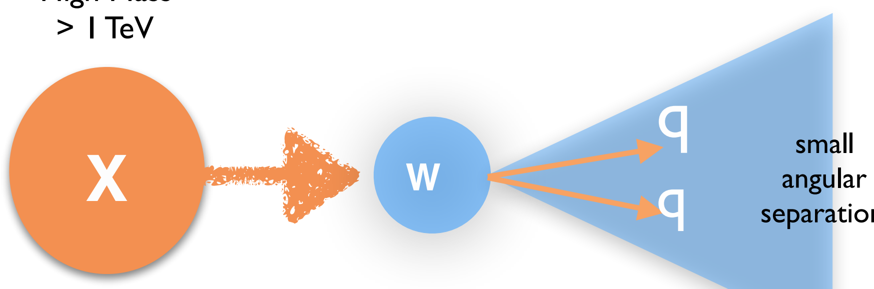
Resonances



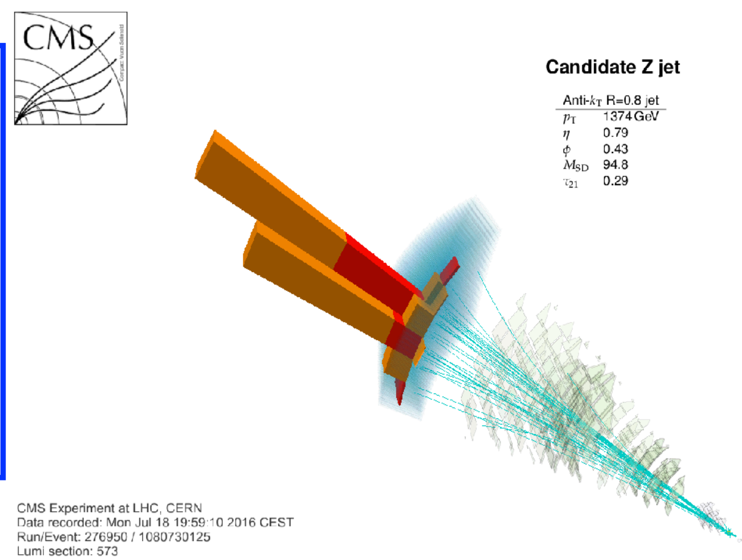
- Parallel talks:
  - Talk by S. Maschek, S. Ghosh, J.Love, S. Schramm, D. Roy, D. Karasavvas, by F. Scutti, J. Lorenz, D. Moran

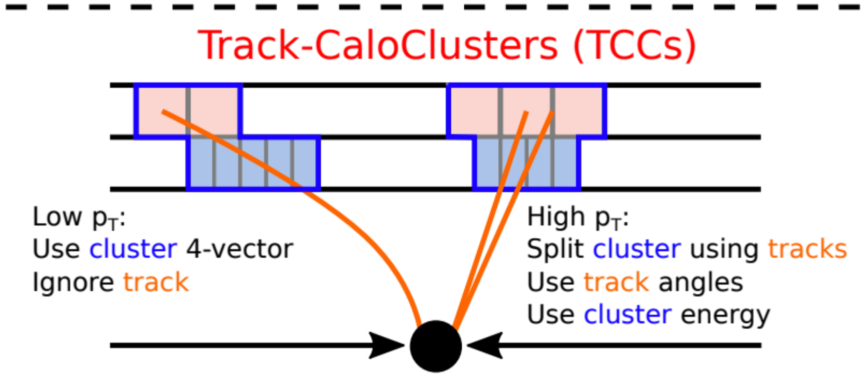
Searches for diboson resonances

- Targeting O(100 GeV) to multi-TeV resonances (radions, gravitons, new vector bosons, extended Higgs sector) in different BSM scenarios:
  - Improved tagging algorithms for high-pT V→qq, H→bb, H→ττ and top decays
  - Dense environment: **object perfomance is critical**



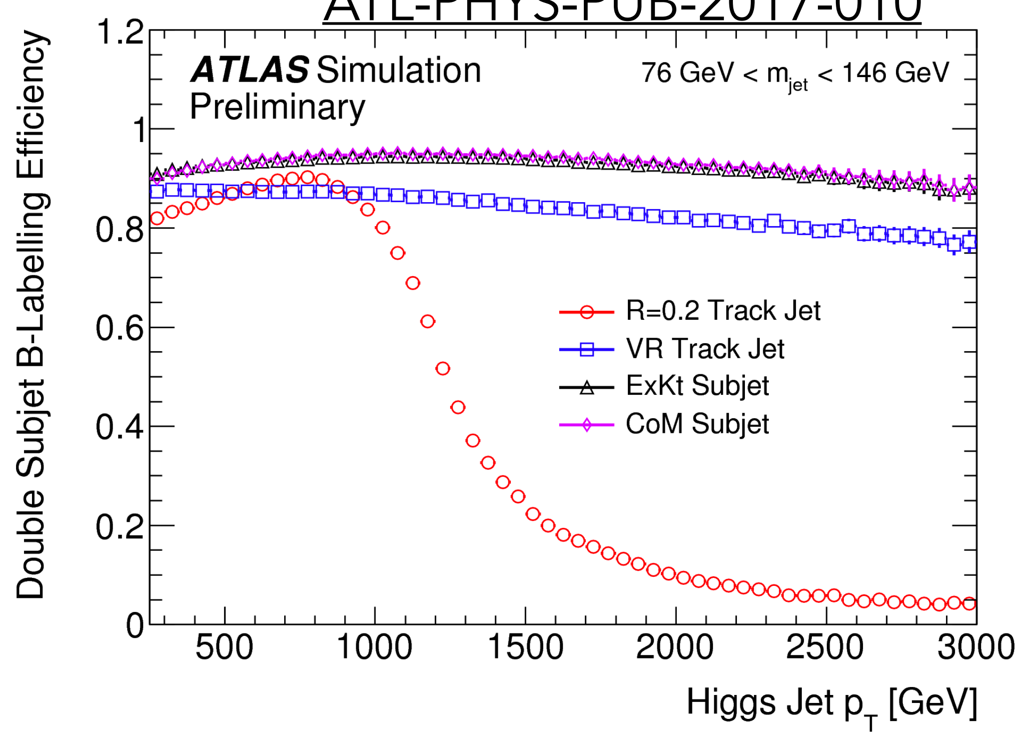
- CMS: Particle Flow jets
- ATLAS: new TCC jets to combine calorimeter info with superior angular resolution of trackers.





- H → bb tagging in ATLAS match b-tagged R = 0.2 track jets to R = 1.0 jets
  - Breaks down at high pT → **switch to variable-radius (VR) jets** or CenterOfMass jets: Boost to Higgs frame to reconstruct two subjets
- **CMS: DeepCSV algorithm** ==> deep NN with information on tracks and secondary vertices associated

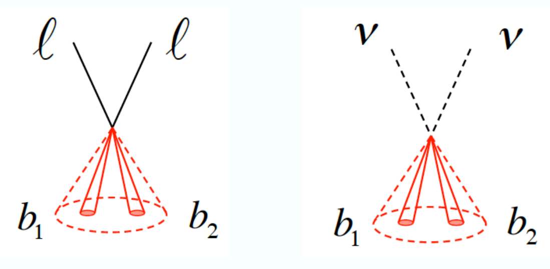
ATL-PHYS-PUB-2017-010



VH resonances B2G-19-006 [ATLAS-CONF-2020-043]

NEW

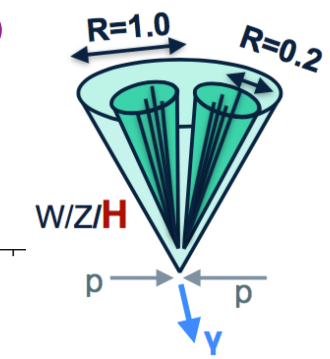
0 and 2 lepton semileptonic final state

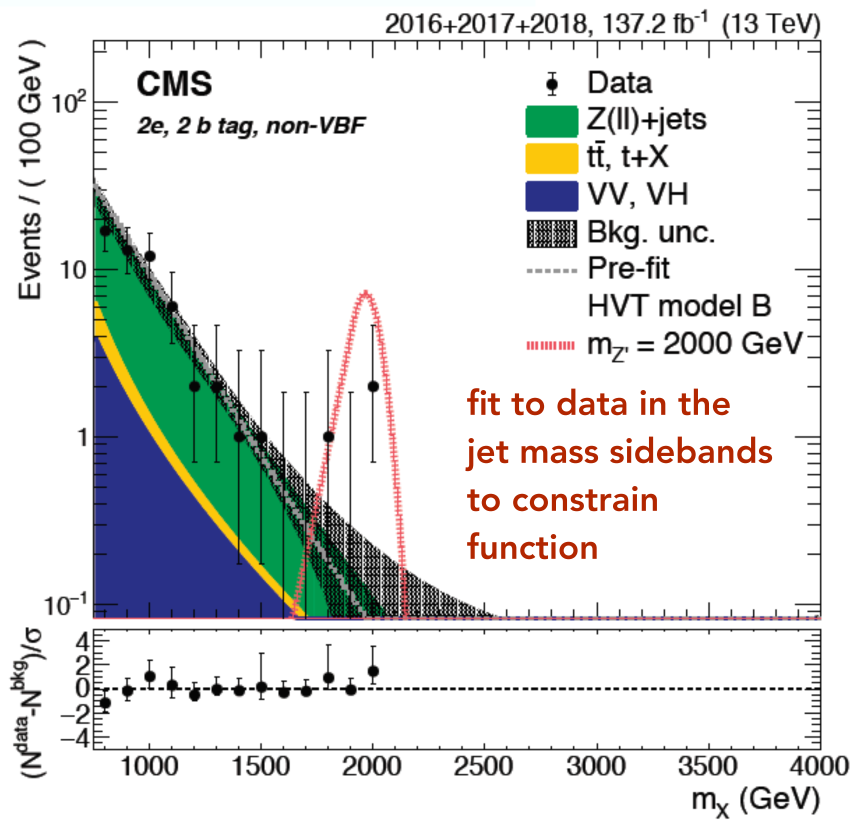


TCC jet
VR track jets for b-jet

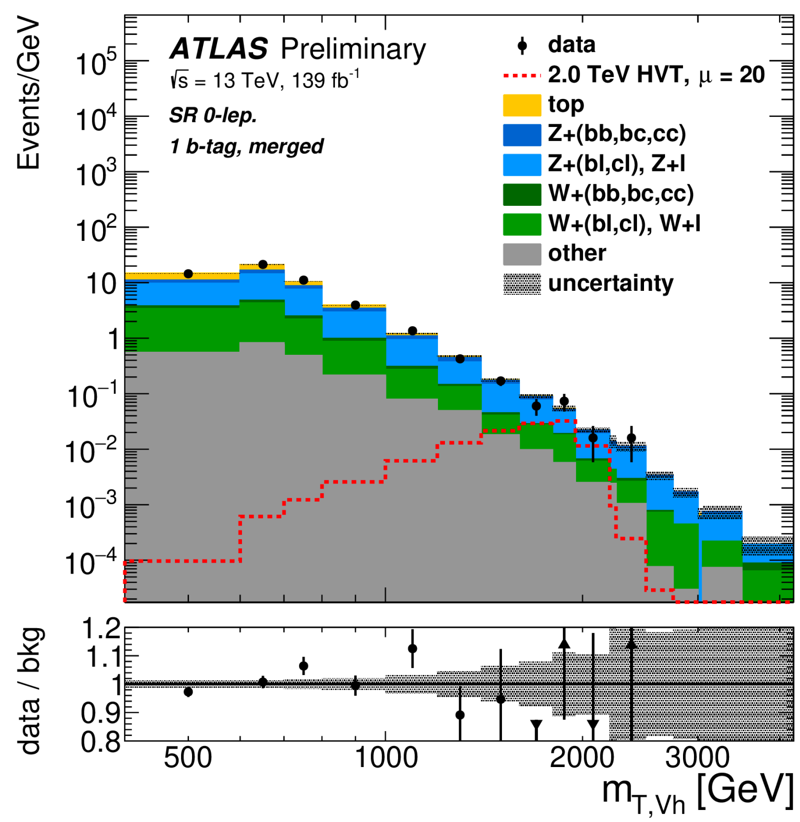
photon+H->bb

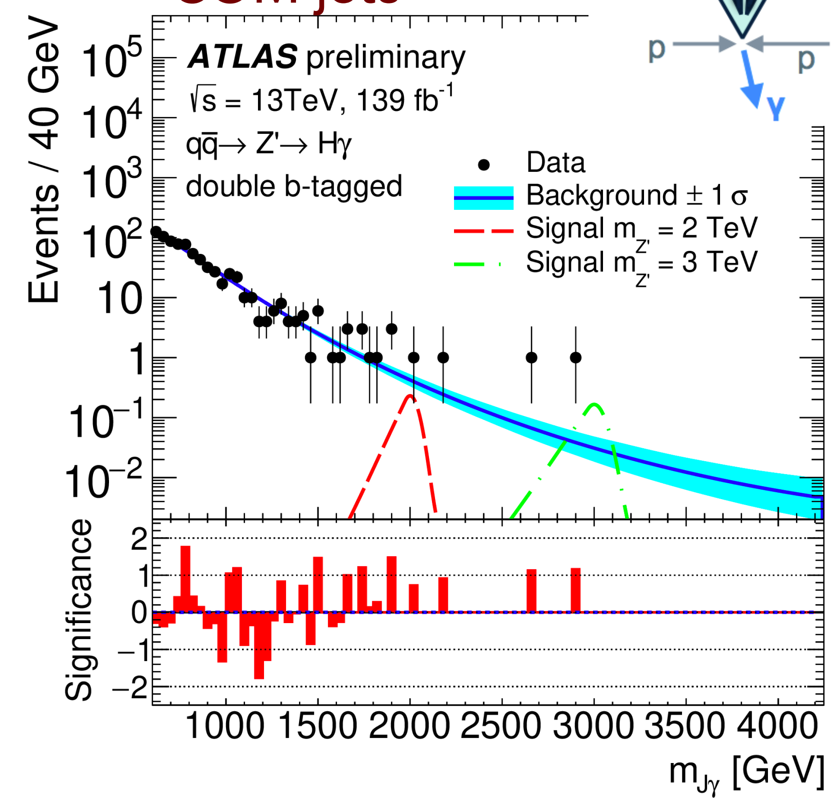
TCC jet
COM jets

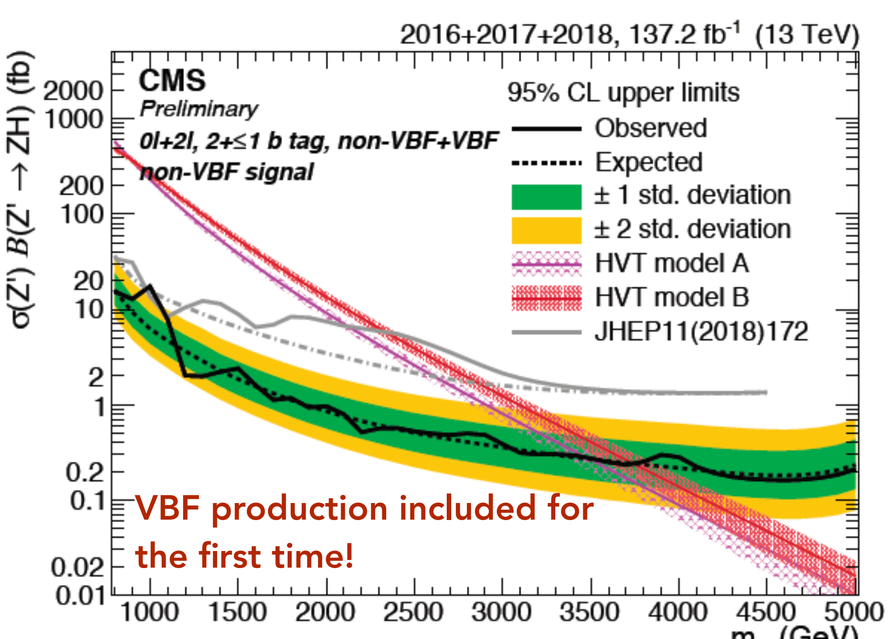




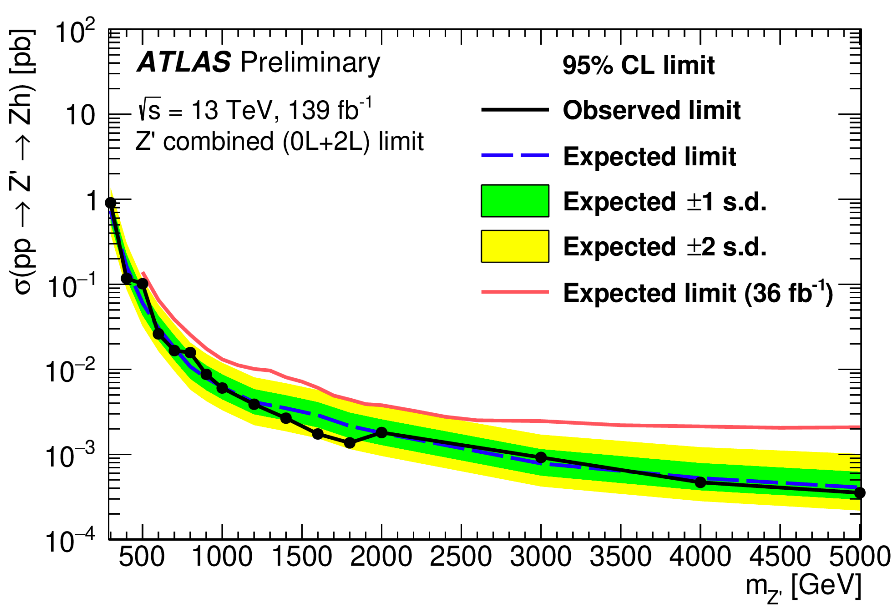
fit to data in the jet mass sidebands to constrain function



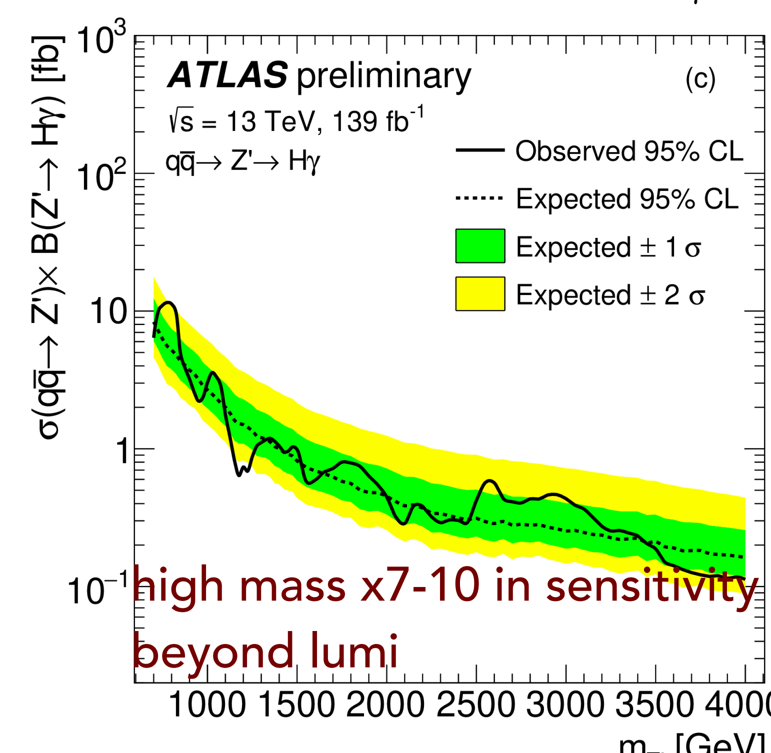




VBF production included for the first time!

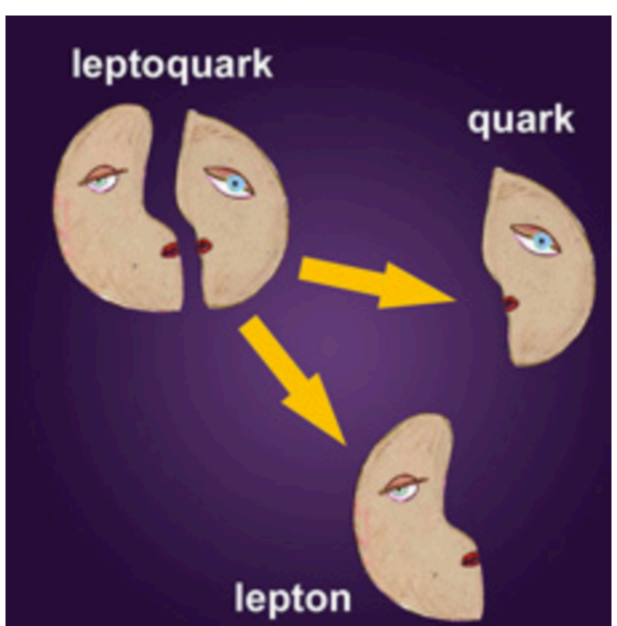


high mass x2 in sensitivity beyond lumi



high mass x7-10 in sensitivity beyond lumi

New quarks and lepton flavor violation

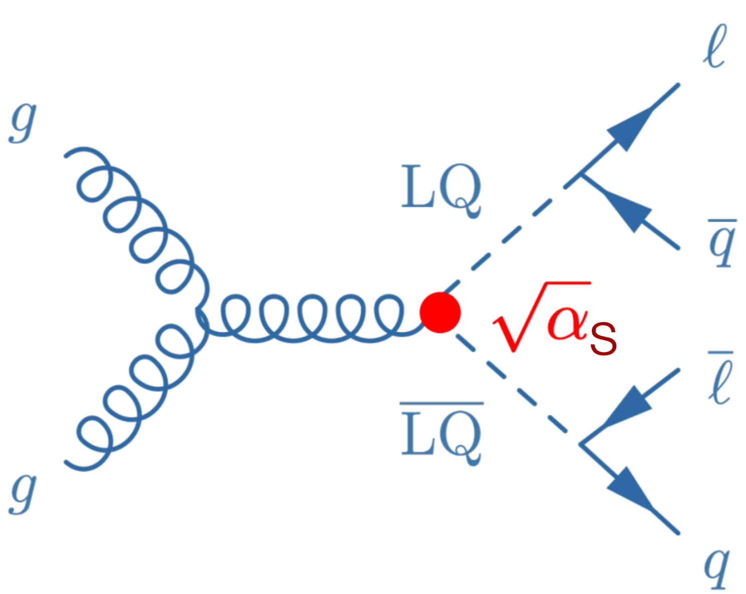


- Parallel talks:
  - Vector like quarks: Talk by J. Hogan, V. Wong, A Froehlich
  - Leptoquarks: Talk by B. Kilminster, Y. Okumura

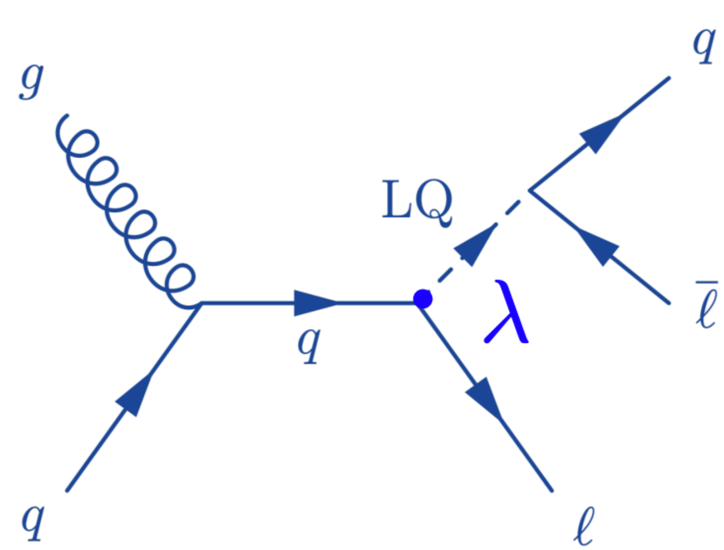
Leptoquarks

- LQ appears in many BSM models to answer the question: **Why same number of generation for leptons and quarks**
- leptoquarks carry both lepton and baryon number
  - decay in lepton-jet
  - Scalar or vector boson
  - Coupling LQ-ℓ-q : λ_q
- Reinitiated interest motivated by b-anomalies : R(D(*)), R(K(*))

pair



single

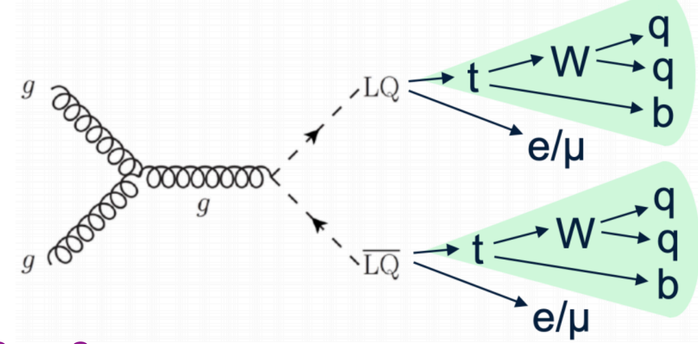


Highlights:

- **emphasis on *cross-generational LQ***

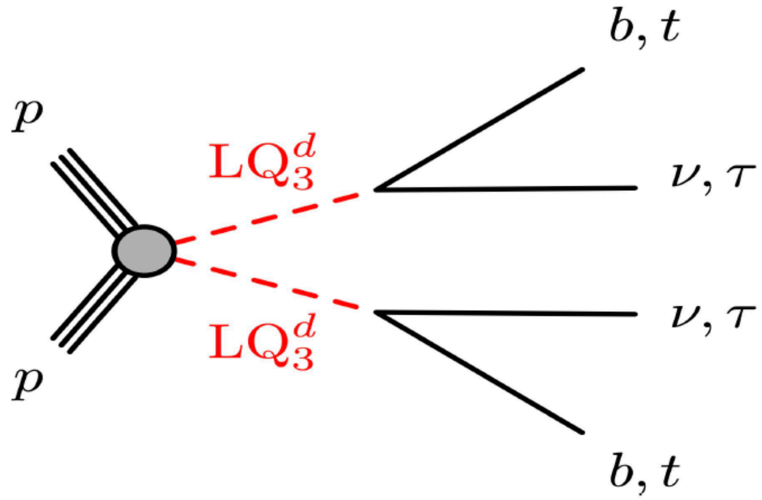
New leptoquarks results (ATLAS)

NEW



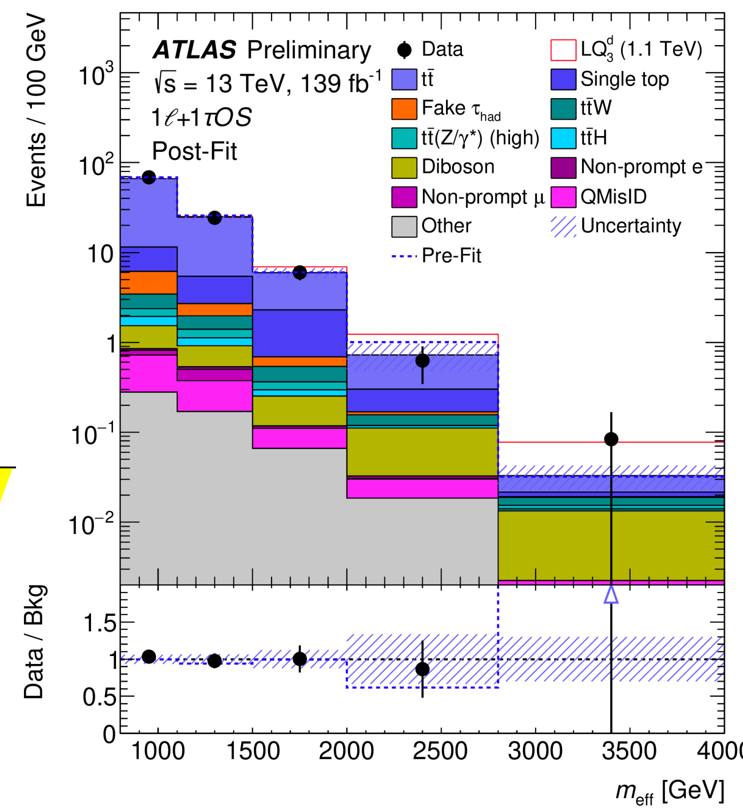
LQLQ ->t τ t τ

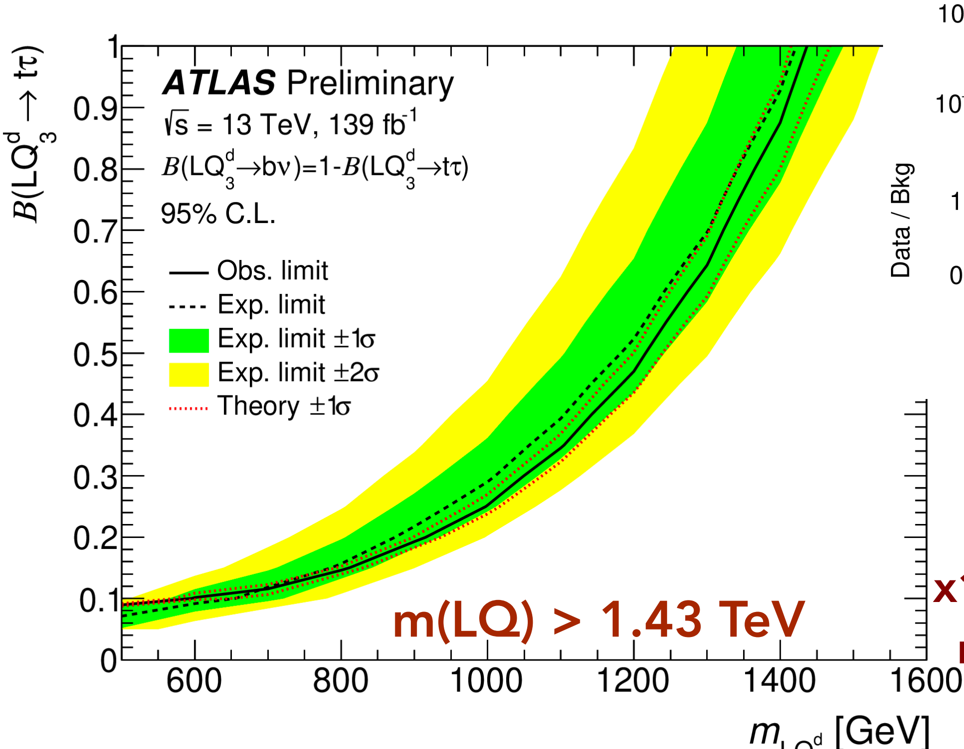
- First dedicated analysis in ATLAS
- ≥ 1 e / μ + ≥ 1 τ had (5 channels)
- RNN tau identification technique deployed (ATL-PHYS-PUB-2019-033)



$$m_{\text{eff}} = \sum_{(\text{jet, e, μ, τ})} p_T + E_T^{\text{miss}}$$

ATLAS-CONF-2020-029





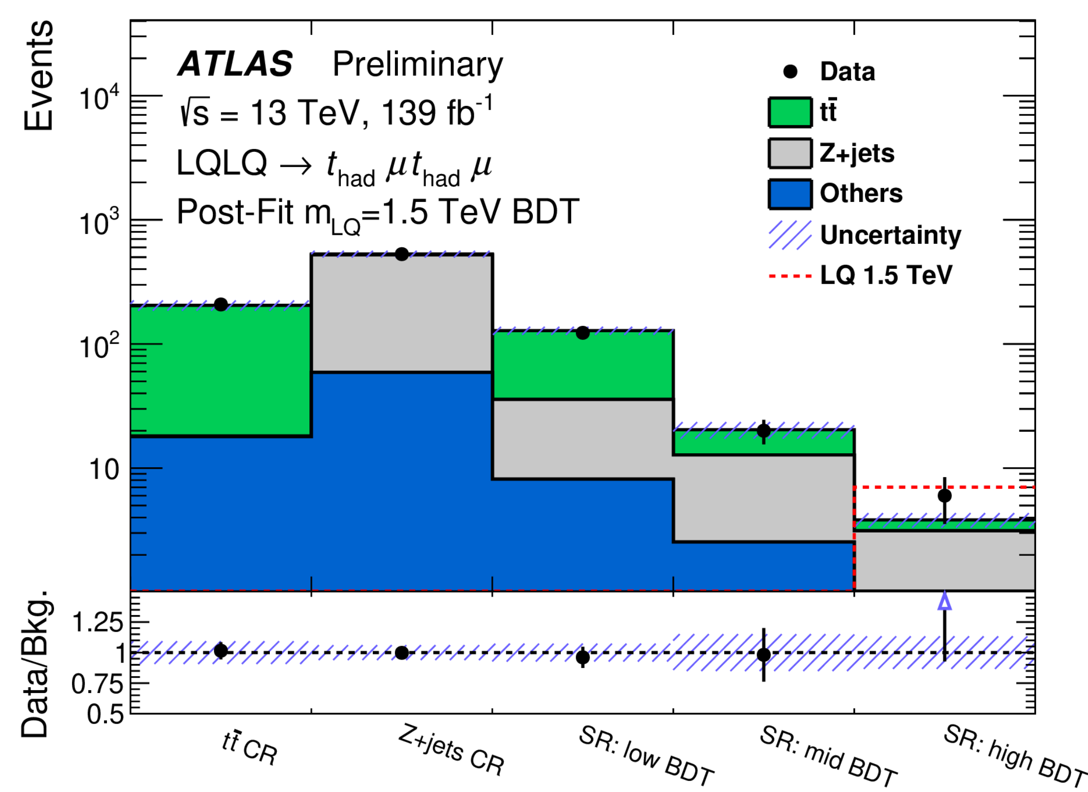
m(LQ) > 1.43 TeV

Improvement of a factor of x10 in sensitivity (~500 GeV in mLQ) with respect to ATLAS and CMS 36 fb-1

LQ to tℓ tℓ

- target the **hadronic** decay channel in the boosted regime
- Signal region: 2 leptons, ≥ 2 R=1.0 jets, ≥ 2 R=0.4 jets and optimized with **BDT**
- ***cross-generational LQ***

ATLAS-CONF-2020-033

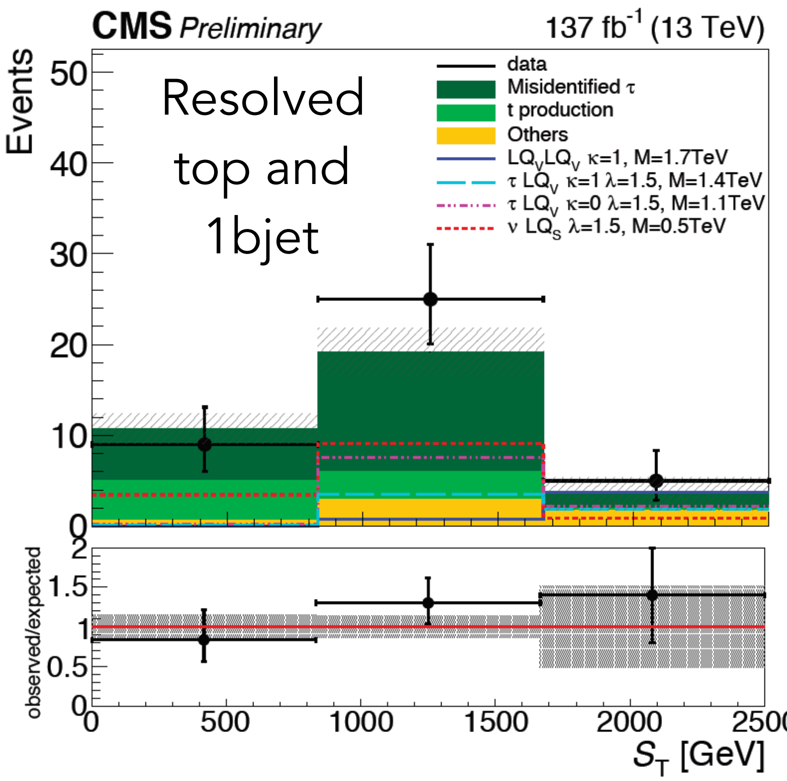


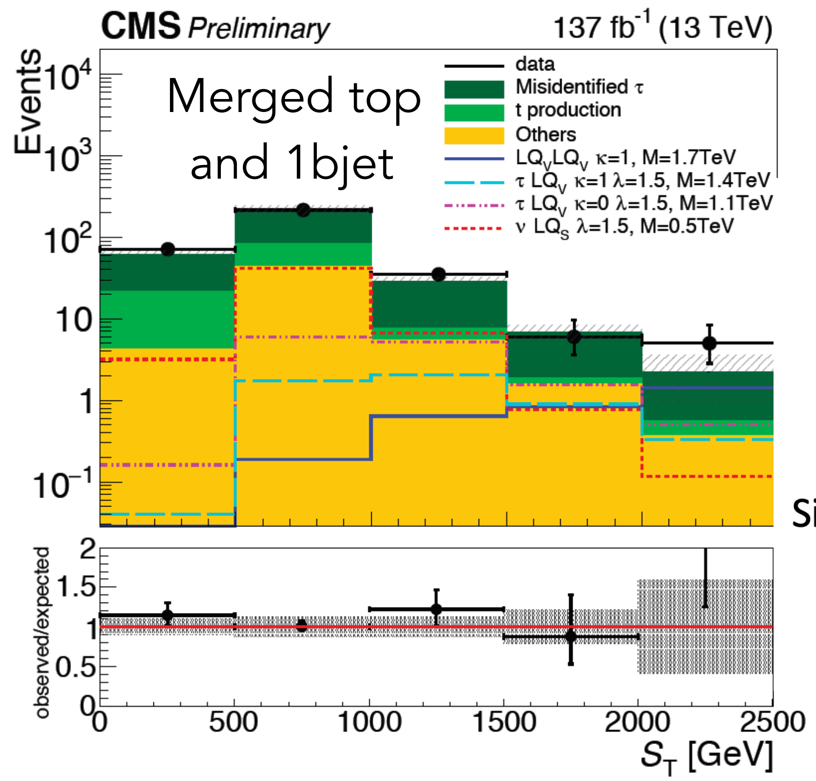
m(LQ) > 1.48 TeV

Search for singly and pair-produced 3rd generation LQs

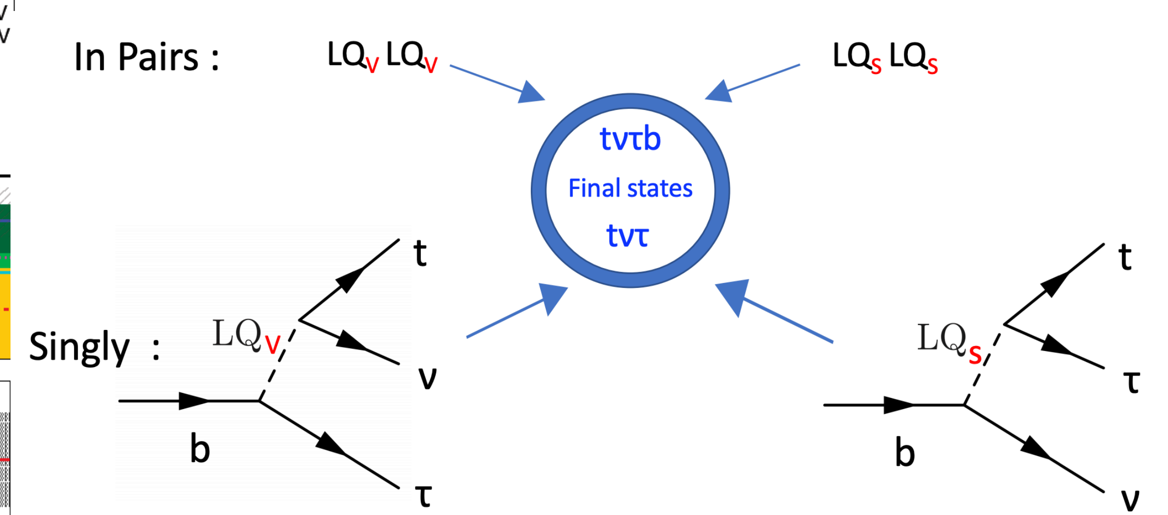
CMS-PAS-EXO-19-015

- First analysis to look for both singly and pair produced LQs
  - high p_T^{miss}, high H_T, one hadronic top candidate and one hadronic τ

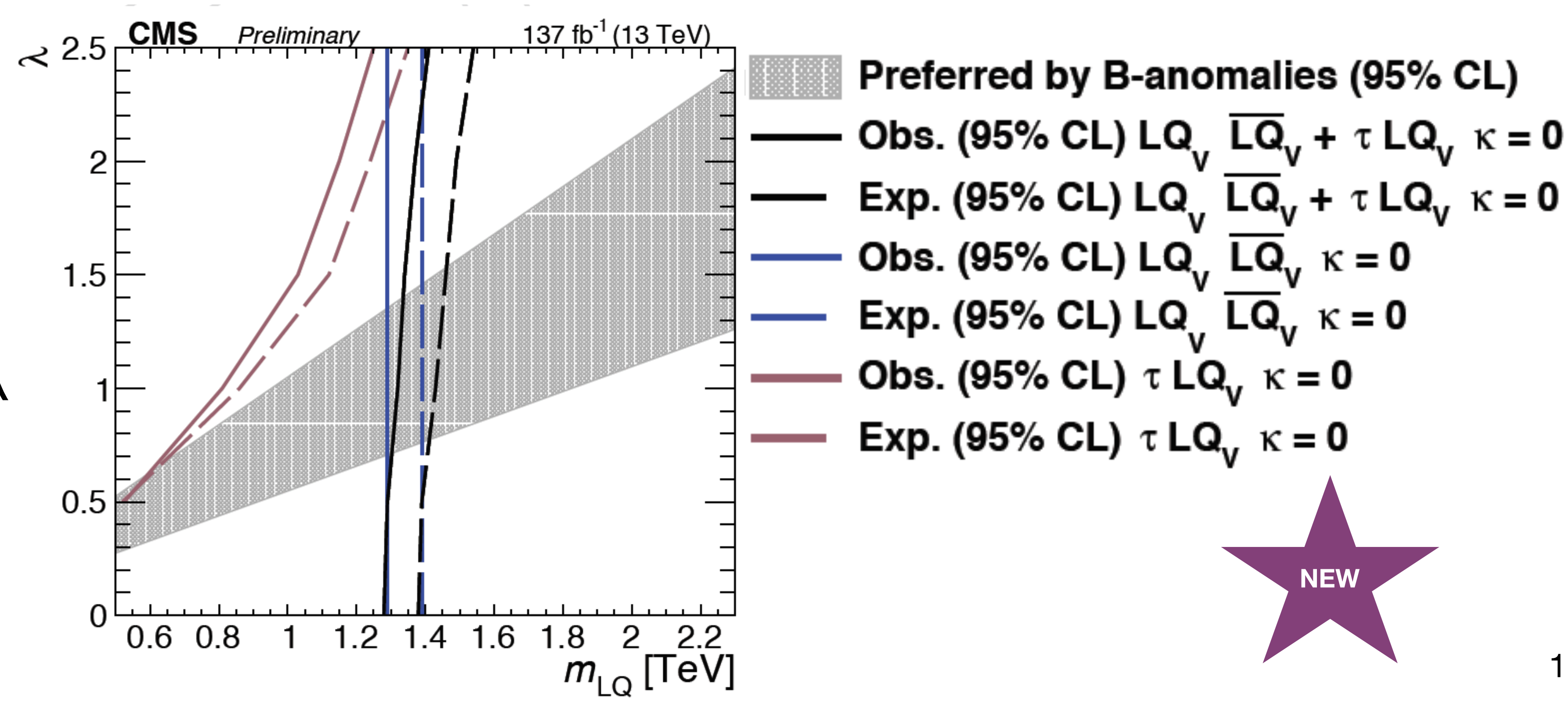




from B. Kilminster talk



The range of lower limits on the LQ mass, at 95% CL, is 0.98-1.73 TeV, depending on λ (LQ coupling to lepton and quark) and the leptoquark spin

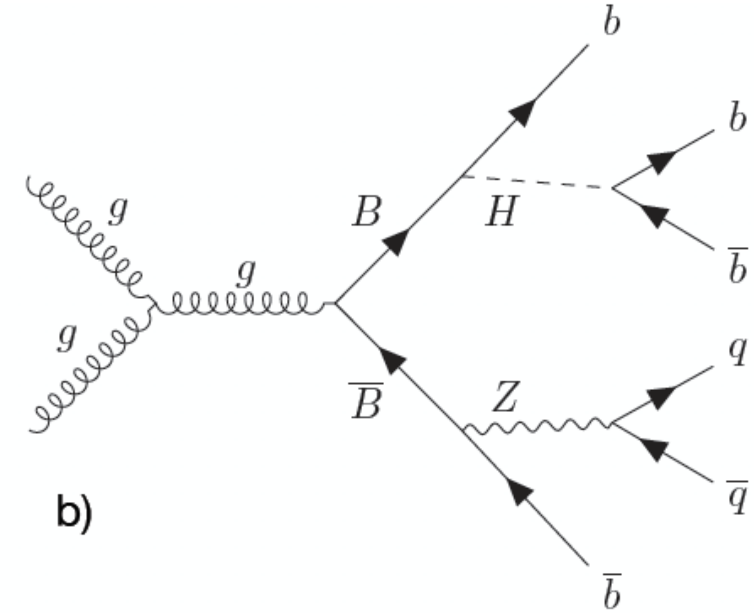


NEW

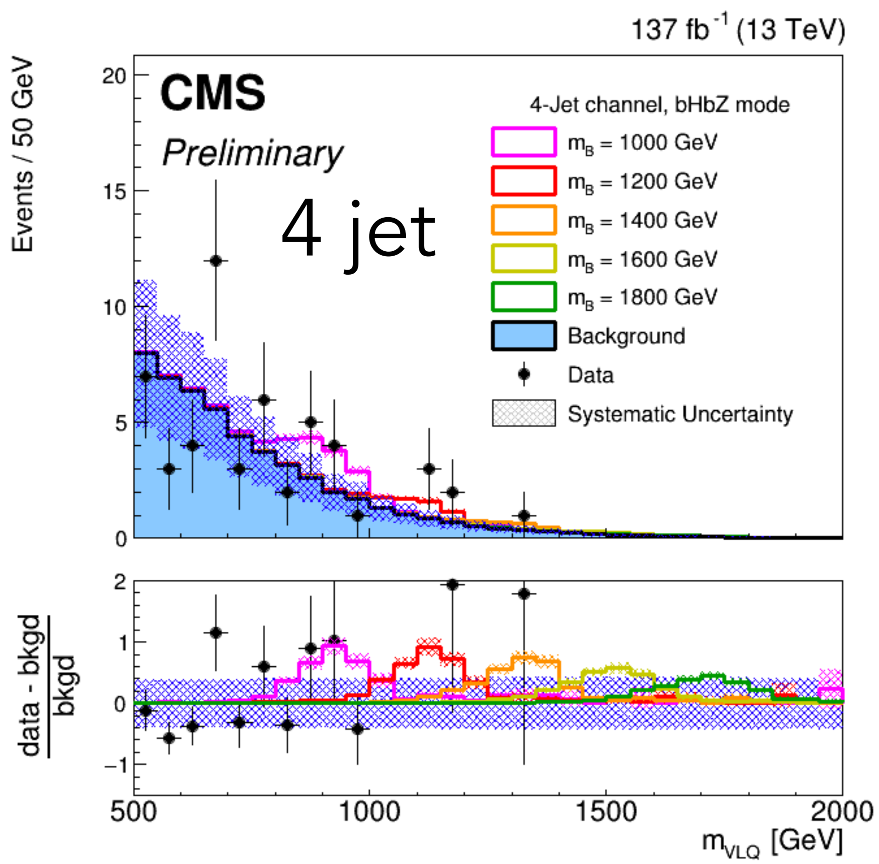
Vector-like quark BB pair production [B2G-19-005]

- Predicted in many theories (extra-dimensions, Higgs compositeness, …) to solve **hierarchy problem**
  - Strong production of pairs, electroweak single production
- Target the fully hadronic B->bH and B->bZ decays by tagging each jet:
- Challenges:
  - Combinatorics
  - Background estimation

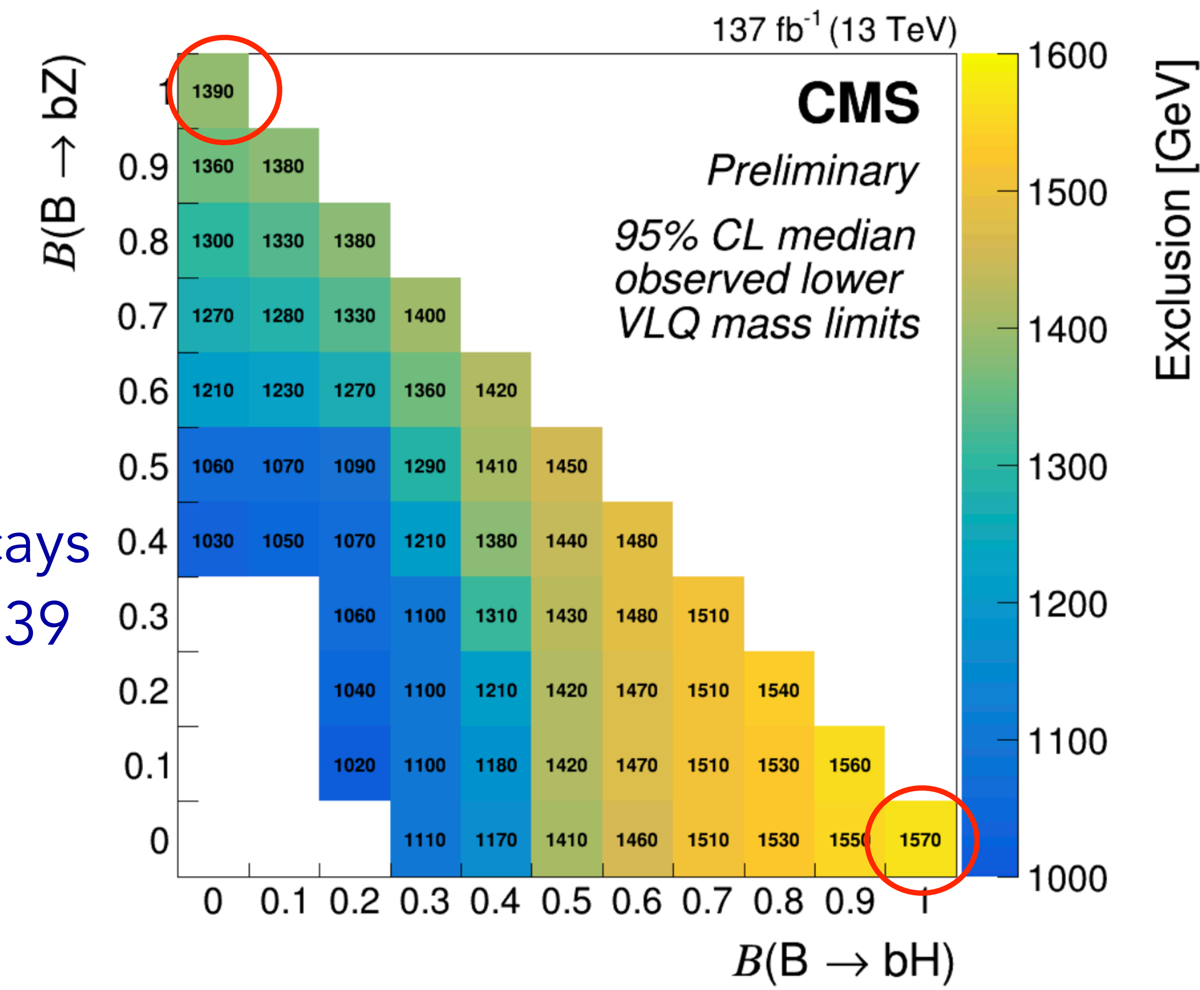
NEW



Strongest CMS sensitivity to date for BB production in bH/bZ dominated decay scenarios – 300 to 500 GeV more powerful!

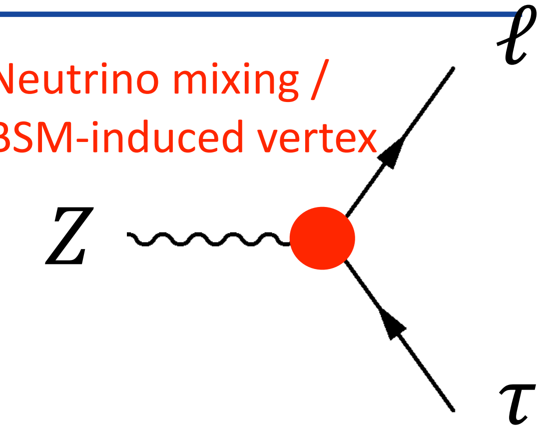


1.57 TeV if the VLQ decays to a b quark and a H. 1.39 TeV if it decays to a b quark and a Z



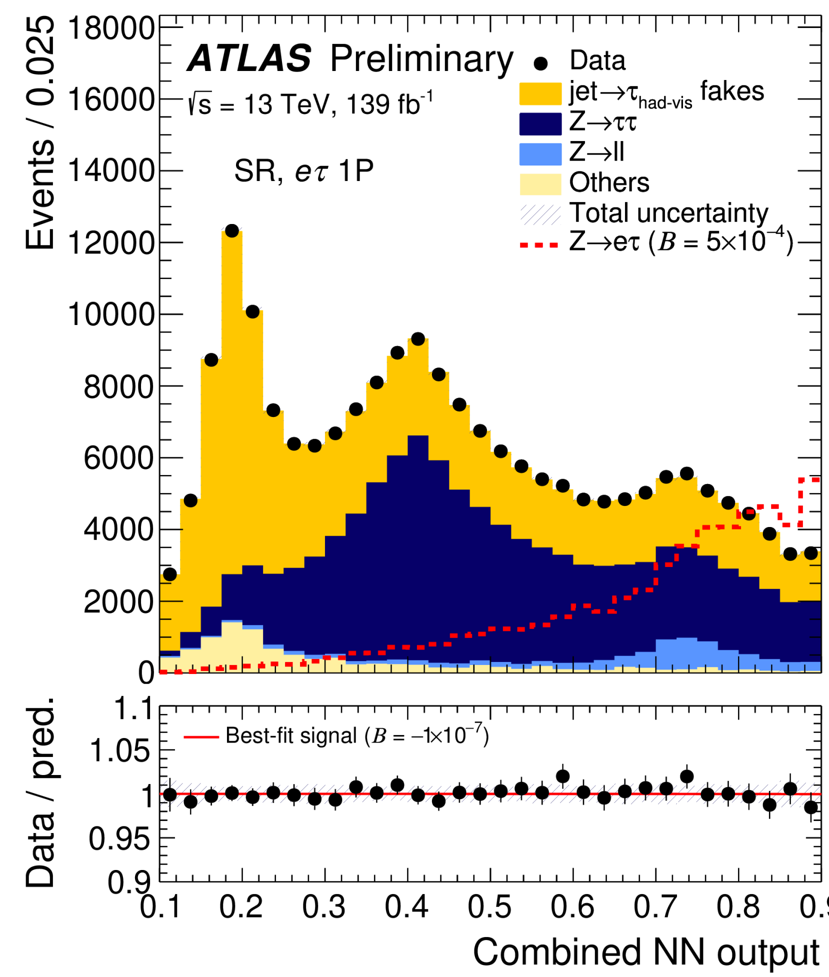
Lepton flavour violation $Z \to e\tau/\mu\tau$ decays [ATLAS-CONF-2020-035]

NEW



- Lepton flavour is an accidental symmetry in the SM
  - Neutrino oscillations show that LFV indeed occurs in nature
  - What about charged leptons (with neutral currents)?

- **Consider $\ell\tau_{had}$ events**
  - Use NN multi-classifiers for different backgrounds
    - jet->tau fakes, $Z\to\tau\tau$ and $Z\to\ell\ell$
  - Fit NN output in SR (→constrain signal) +mass in CR (→constrain Z and τ uncertainties)

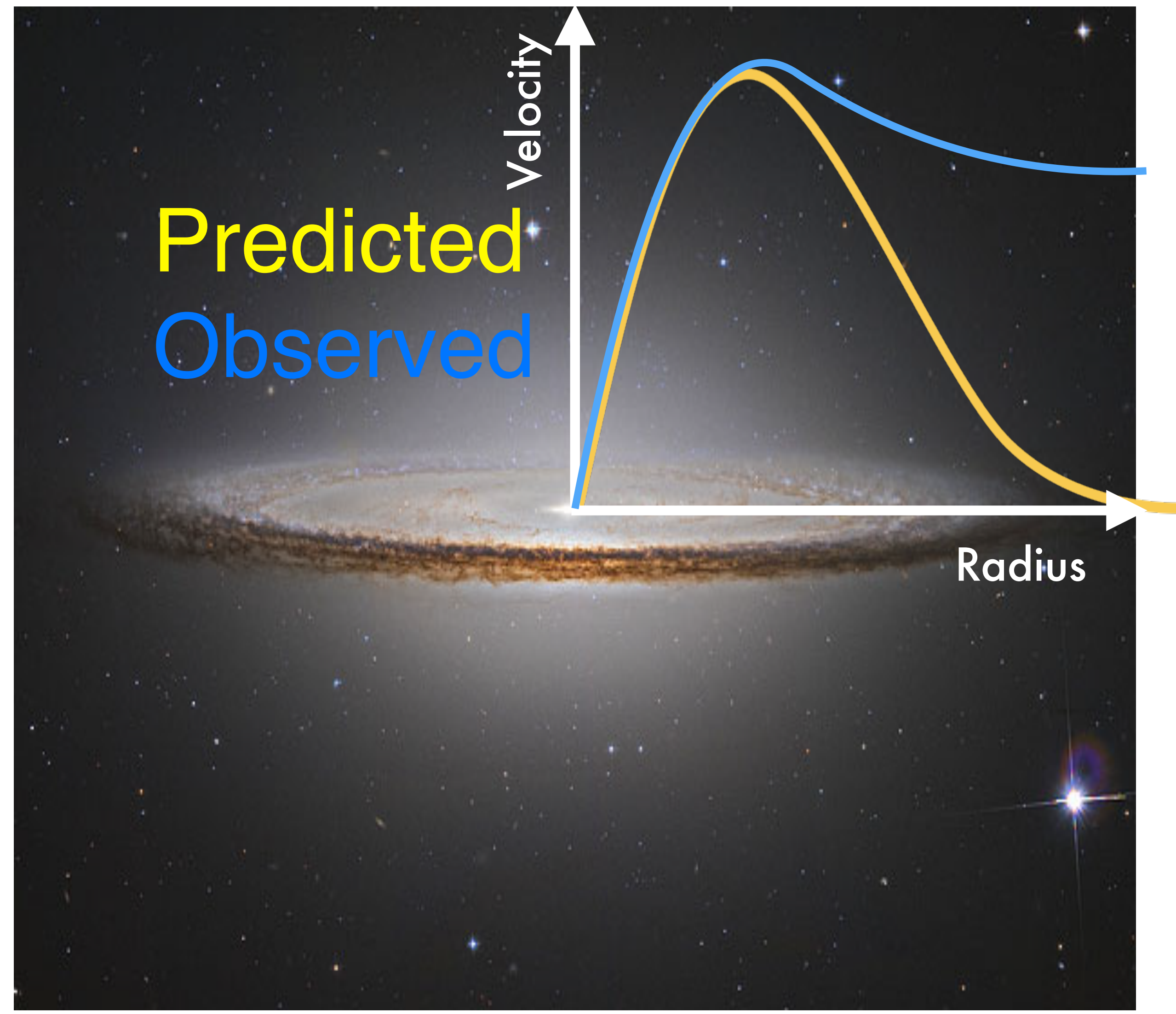


Upper 95% CL limits	ATLAS	LEP
B(Z —> e τ)	8.1×10^{-6}	9.8×10^{-6} [OPAL]
B(Z —> μ τ)	9.5×10^{-6}	12×10^{-6} [DELPHI]

- **Set current most stringent upper limits on BR $Z\to\ell\tau$**, previous limits by **LEP ==> thanks to improved tau ID and lumi**
- **Primarily limited by statistics**

Dark Matter

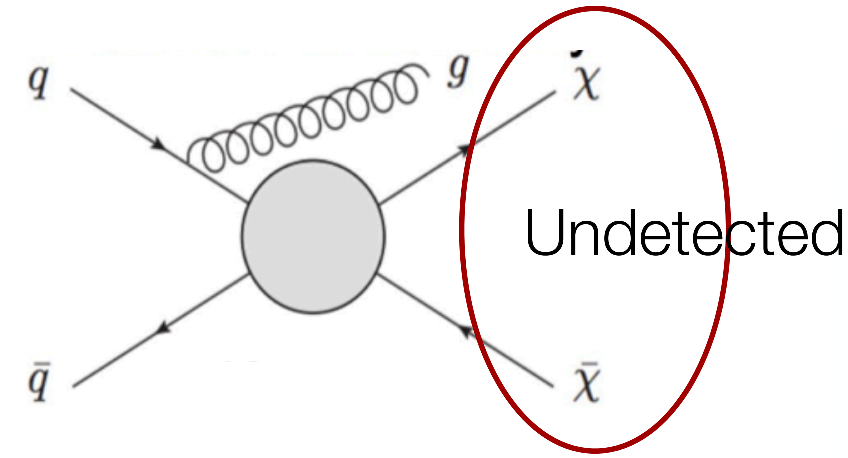
- Why only 5% of matter made of ordinary SM particles?
  - **what is dark matter?**

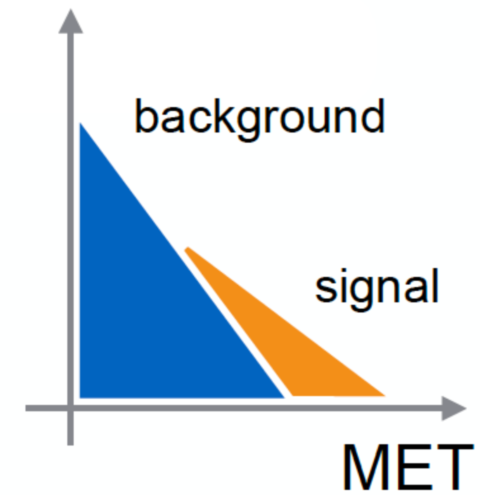


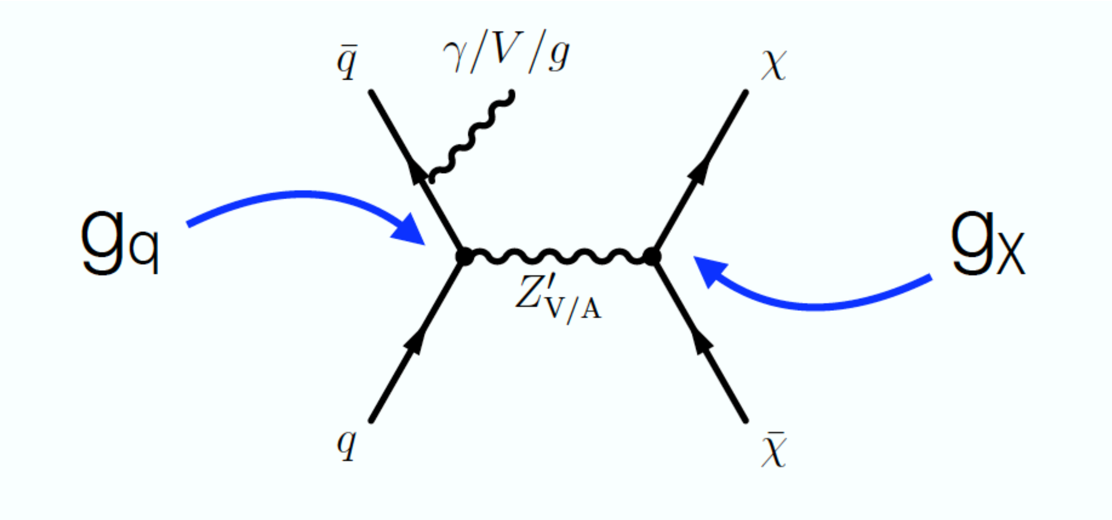
- Parallel talks:
  - ATLAS or CMS: Talk by B. Carlson, R. Khurana, H. De La Torre
  - Dark Sector: Talk by E. Graziani [Belle2], B. Shuve, Y.Li [Babar], X. Vidal [LHCb]

Dark Matter

- Pair production at LHC
  - DM candidates escape the detector (weakly interacting)
- Large Missing energy distribution is the key variable



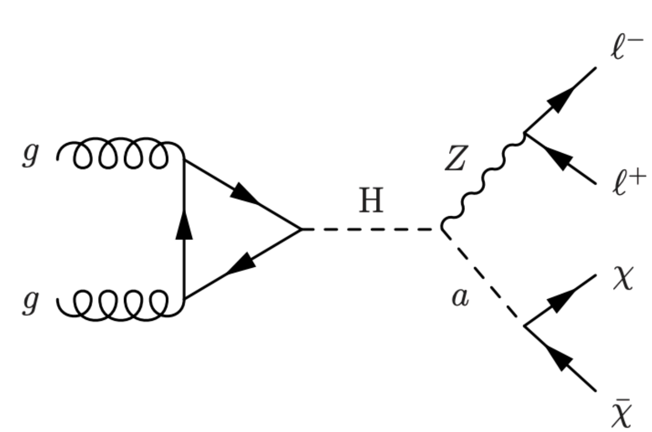


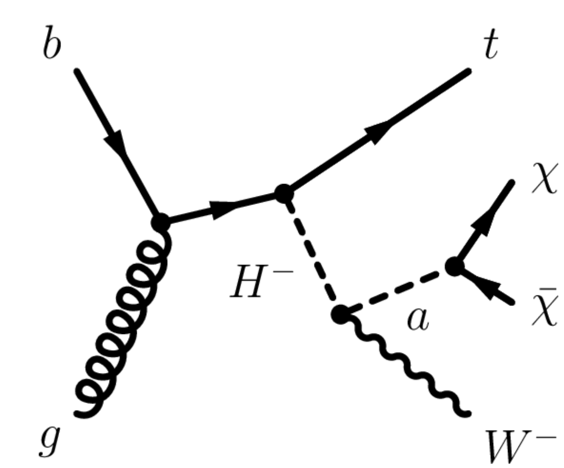


- Simplified S-channel model: **Mediator that couples to SM and to Dark Sector particles**
- **low mass mediator searches:** triggering on an **associated object** or performing analysis at the **"trigger level"**

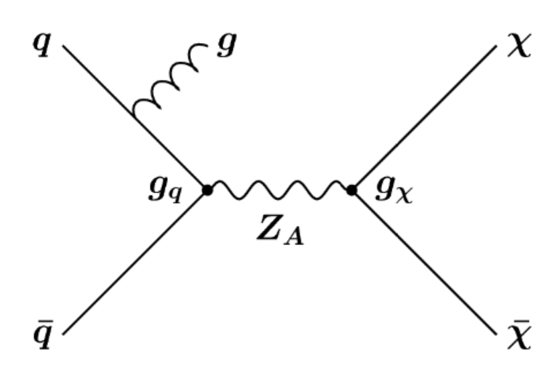
More complete models:

- 2HDM+a:
  - Two Higgs doublet model, with charged heavy Higgs ($H^{\pm}$)
  - Additional pseudoscalar mediator to dark matter (a)



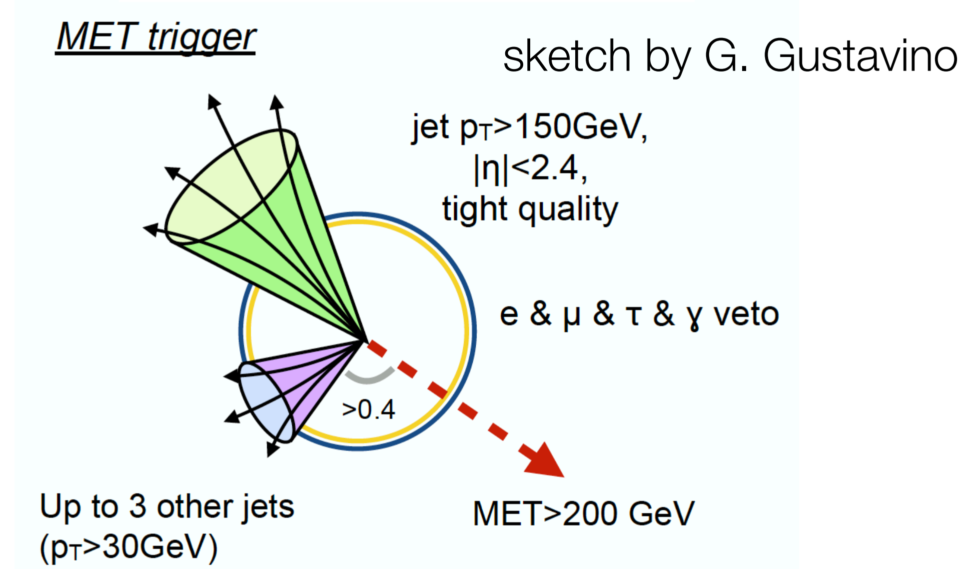


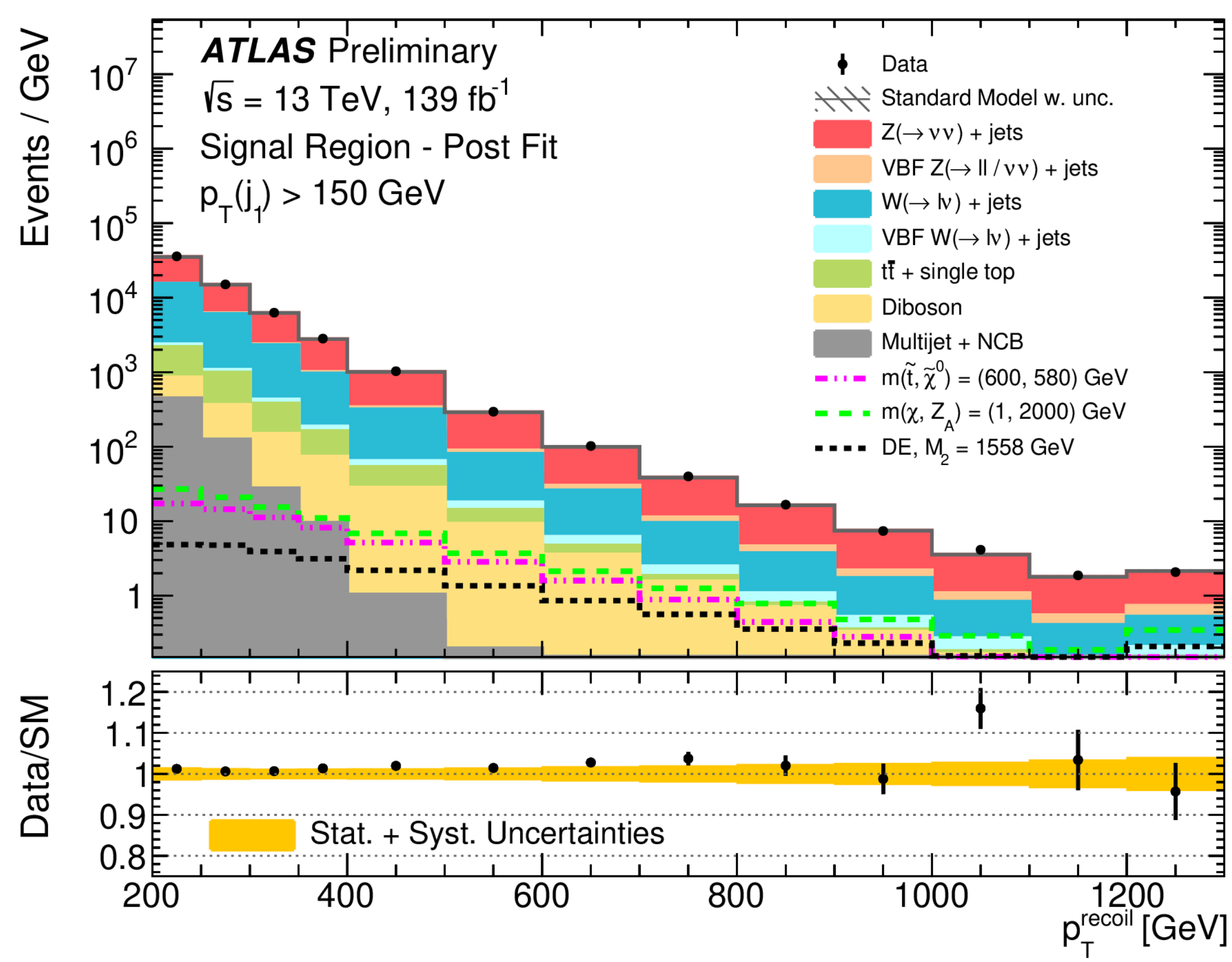
Mono-jet [ATLAS-CONF-2020-048]

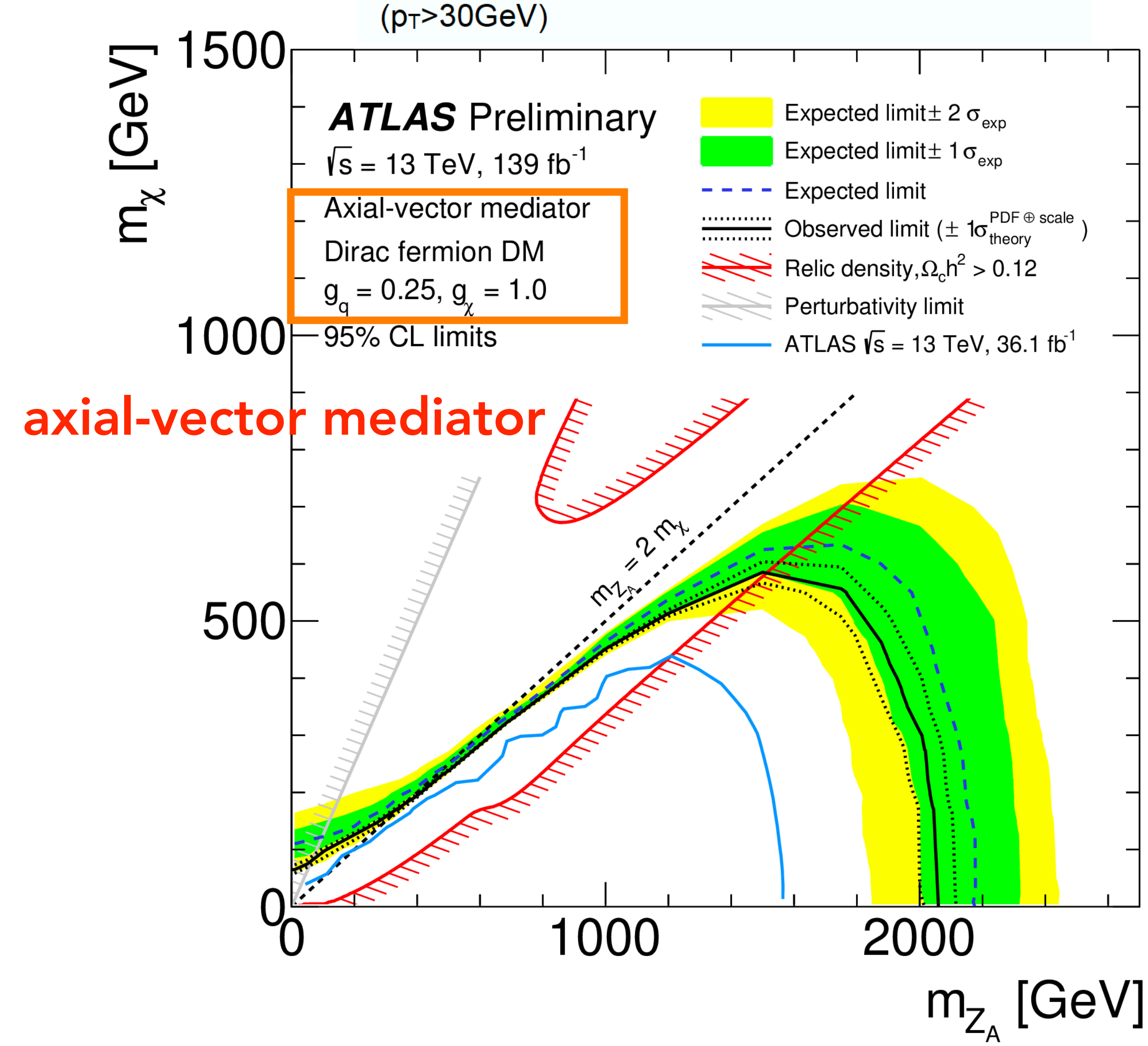


NEW

- Most sensitive mono-X channel for ISR processes
- Search for a MET excess.
  - *Dominant backgrounds given by the **Z(νν)+jets** and **W(lν)+jets** processes constrained in 1 lepton an 2 lepton control regions*
  - *Reduction of V+jets theory uncertainties by factor of ~2 thanks to corrections at NNLO in QCD and NLO in EW*

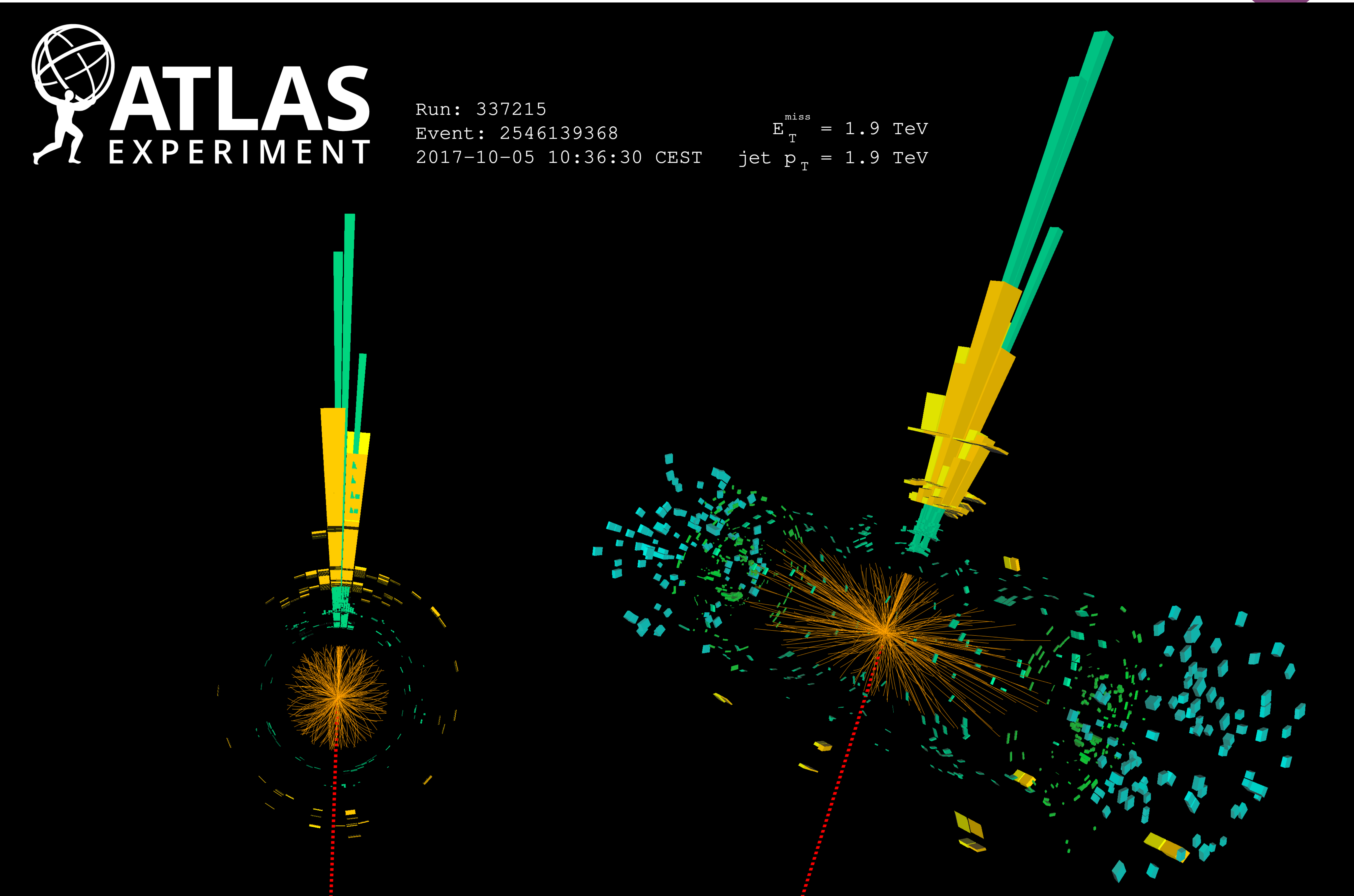






Mono-jet [ATLAS-CONF-2020-048]

NEW

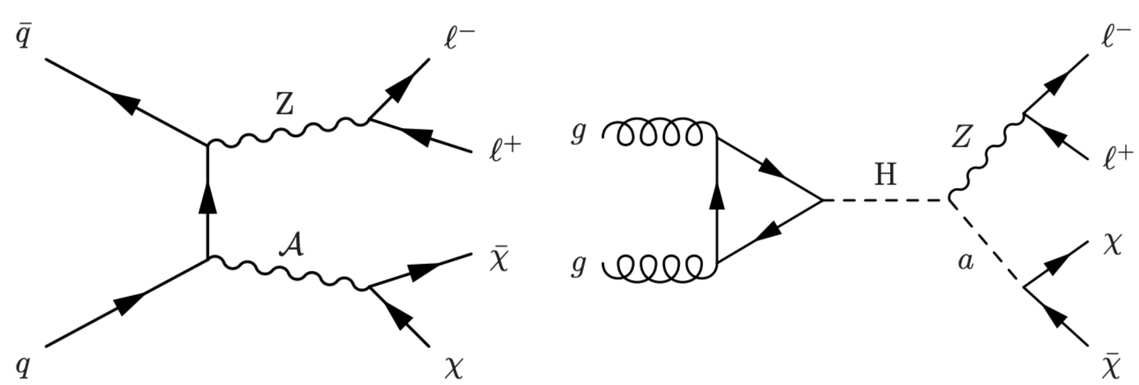


m_χ [GeV]

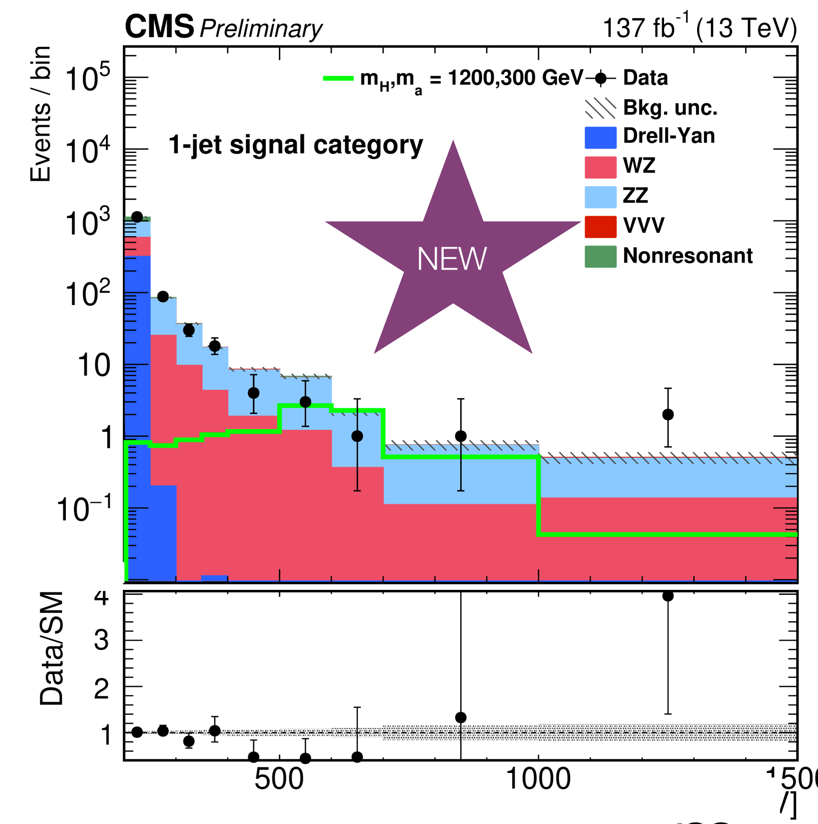
Search for DM particles with a Z boson

CMS-PAS-EXO-19-003

- Use dilepton trigger to go down in mediator masses and require high p_T^{Miss}
- Fit to the m_T or p_T^{Miss} distribution to extract signal

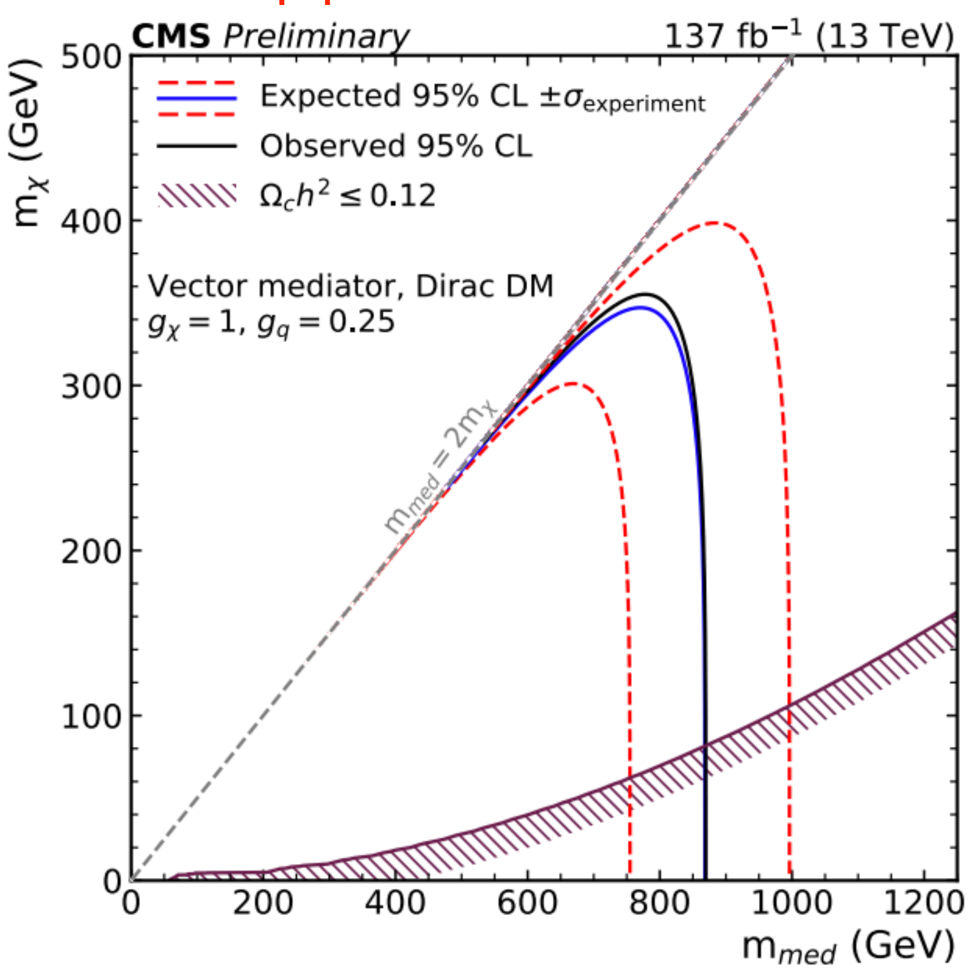


Obs 95% upper limit on B(H→invisible) is 29%

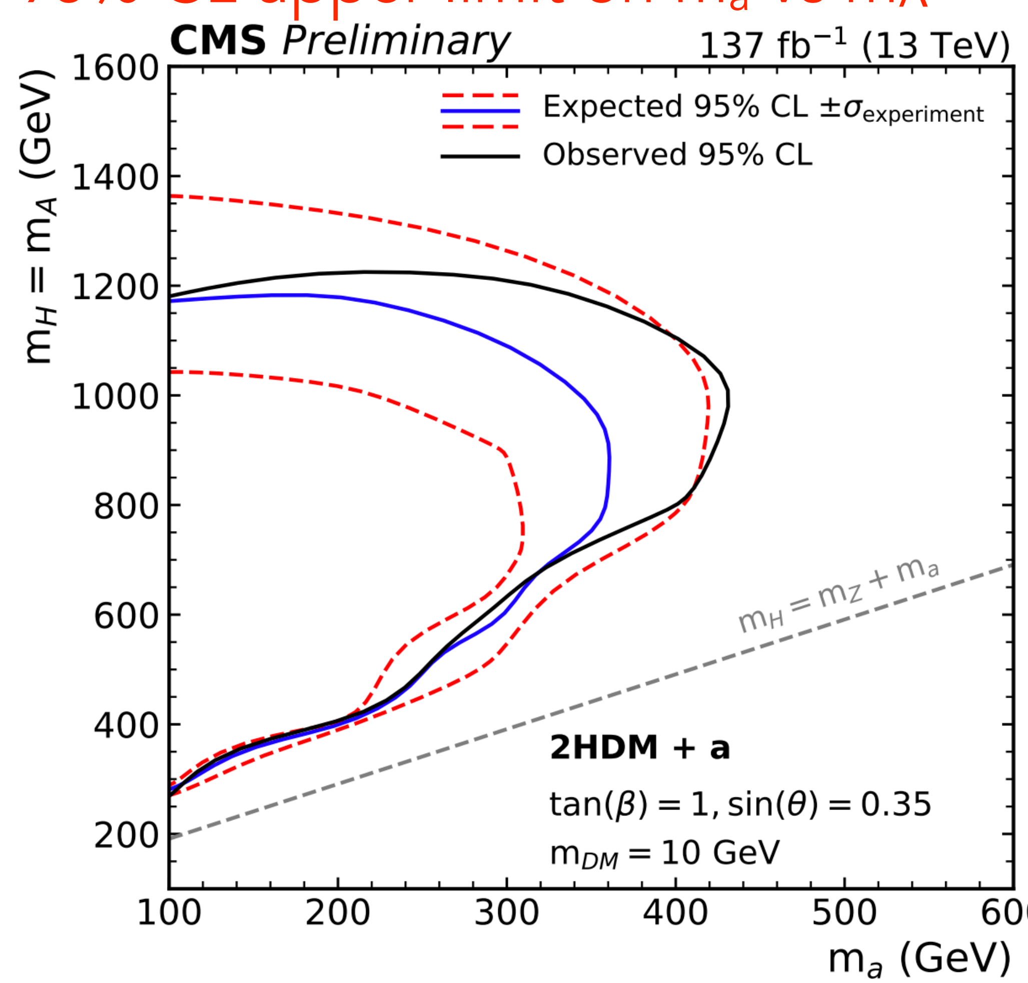


m_T

95% CL upper limit on m_{med} vs m_χ



95% CL upper limit on m_a vs m_A

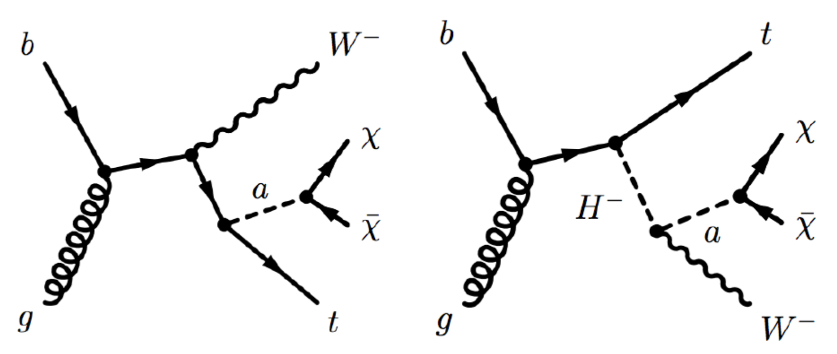


Search for DM+single top [ATLAS-CONF-2020-034]

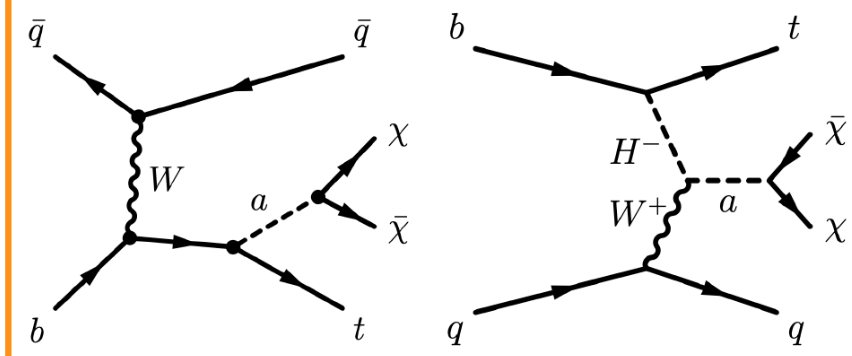
NEW

Targeting 2HDM+a

tW + MET Signature (1L & 2L)



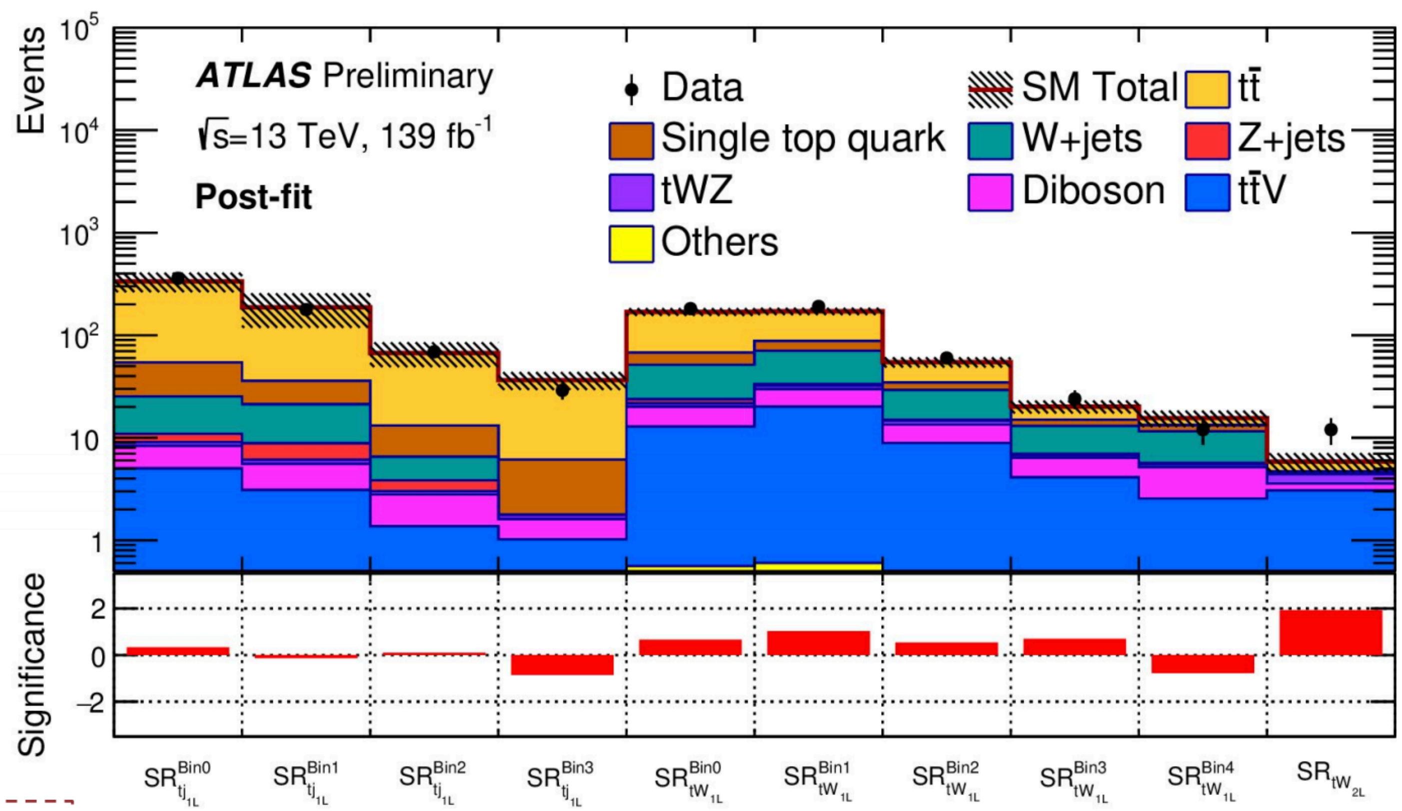
tj + MET Signature (1L)

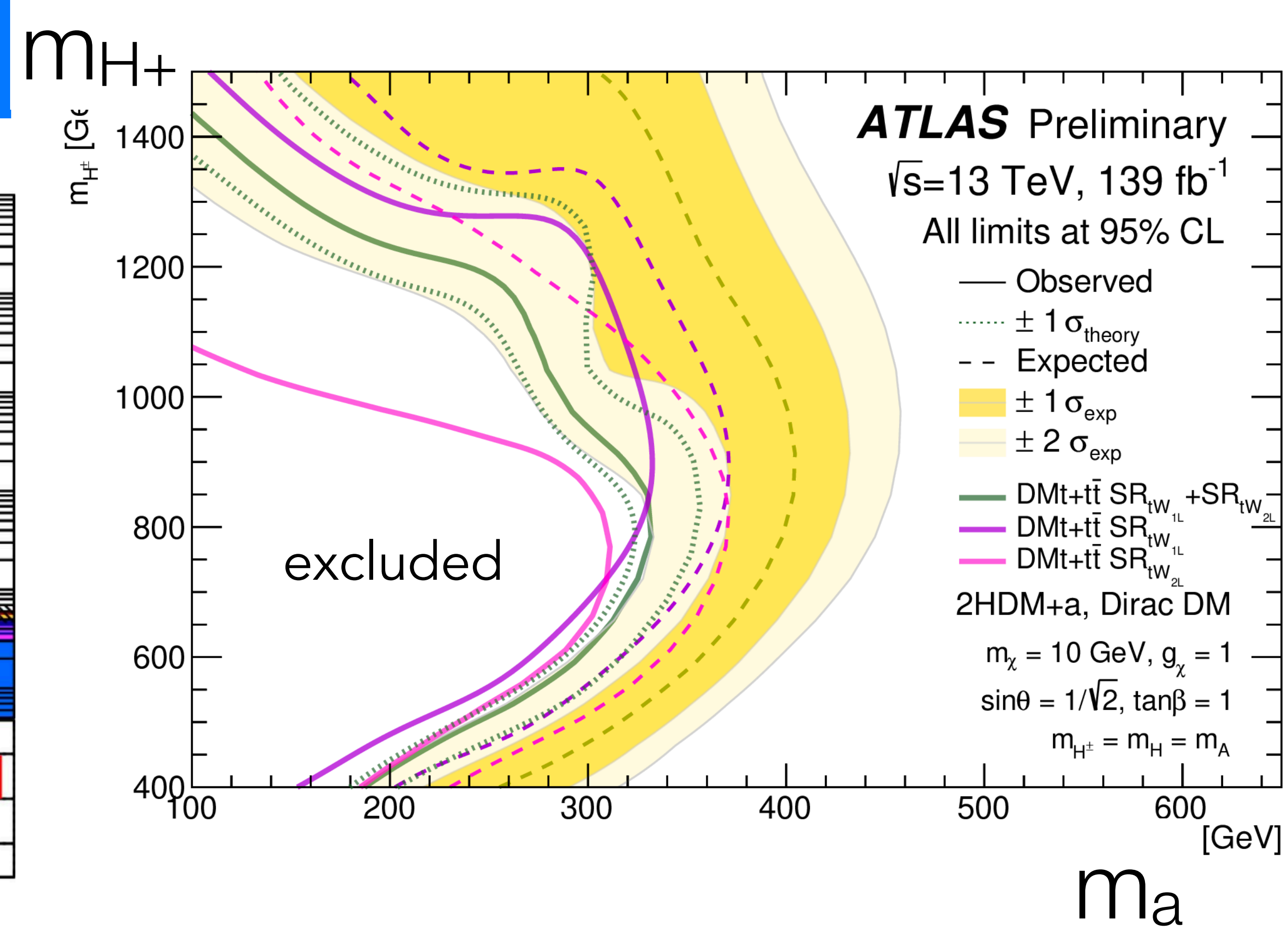


First time analysis is done!

- **tW+MET 1L**: >= three jets >=1 b-jets, high MET. Shape fit on E_T^{miss},
- **tW+MET 2L**: >=1 b-jets, high E_T^{miss}. Single-bin SR

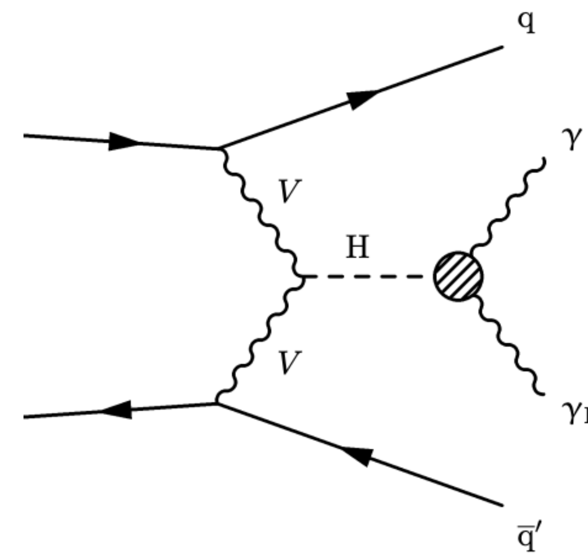
- **tj+MET 1L**: E_T^{miss} trigger and 1 lepton + jets selection. shape fit on BDT score





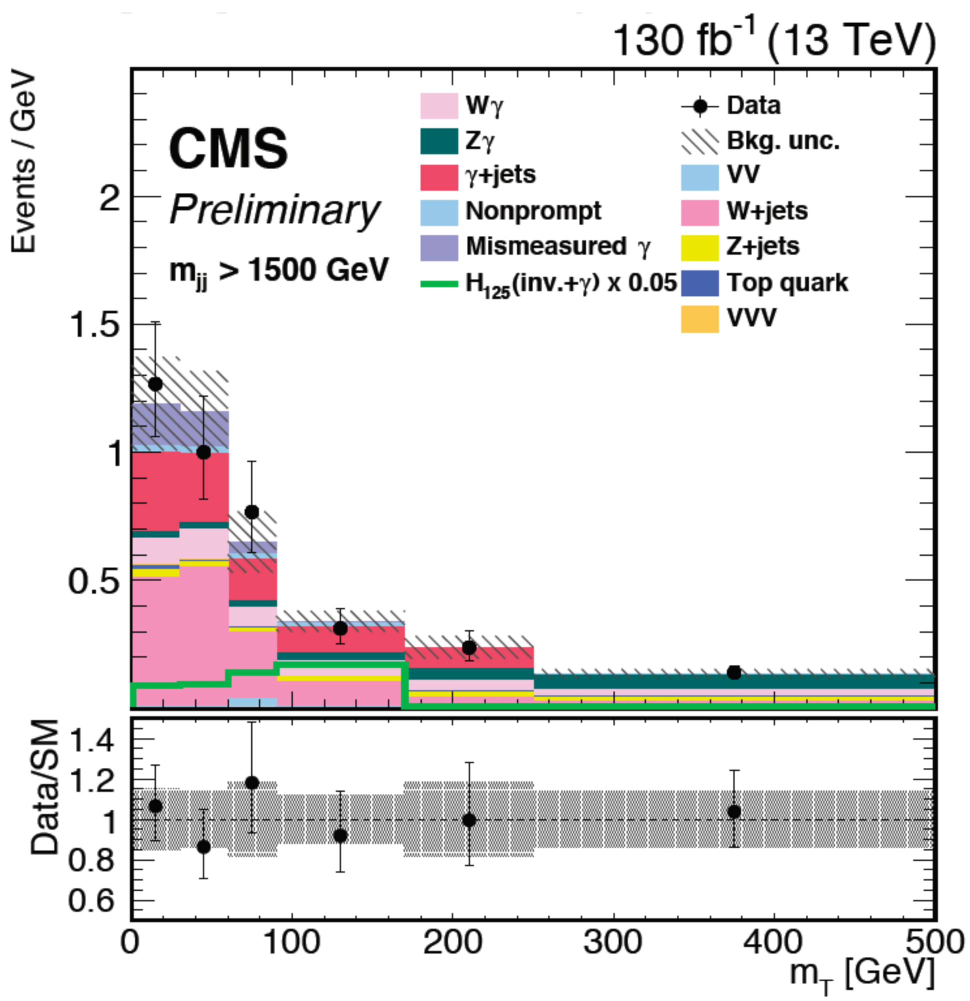
Dark photon in VBF Higgs events [CMS-PAS-EXO-20-005]

- Dark sector: New set of particles typically charged under some dark forces. Weak coupling allows interaction b/w SM and DM via mediator or loop-induced or mixing.
  - Dark photon mixes with standard photon and induces coupling to fermions

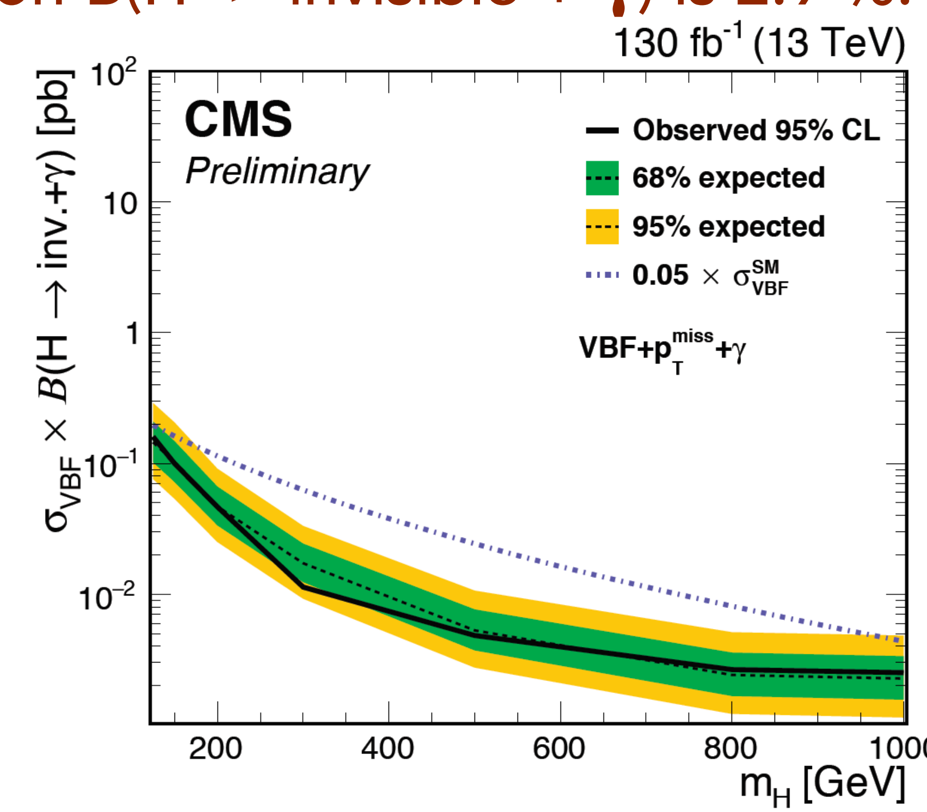


- Two forward high-p_T jets, large p_T^{miss} and an isolated high p_T photon
  - Results for m_H=125 GeV and high mass higgs

Fit to the mT distribution (p_T^{miss} + photon)



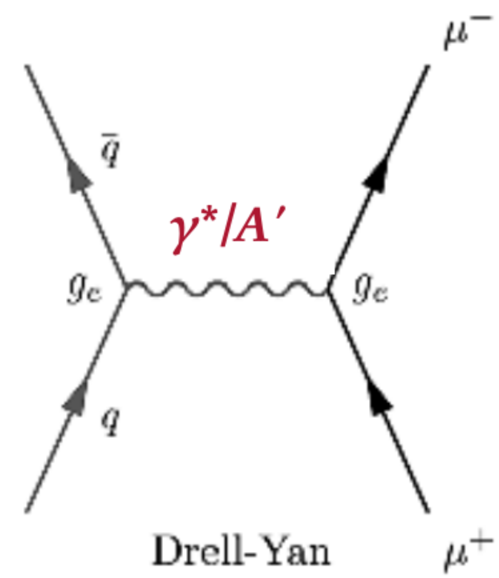
Combining with CMS ZH search the obs UL at 95% CL at m_H = 125GeV **on B(H -> invisible + γ) is 2.9 %.**

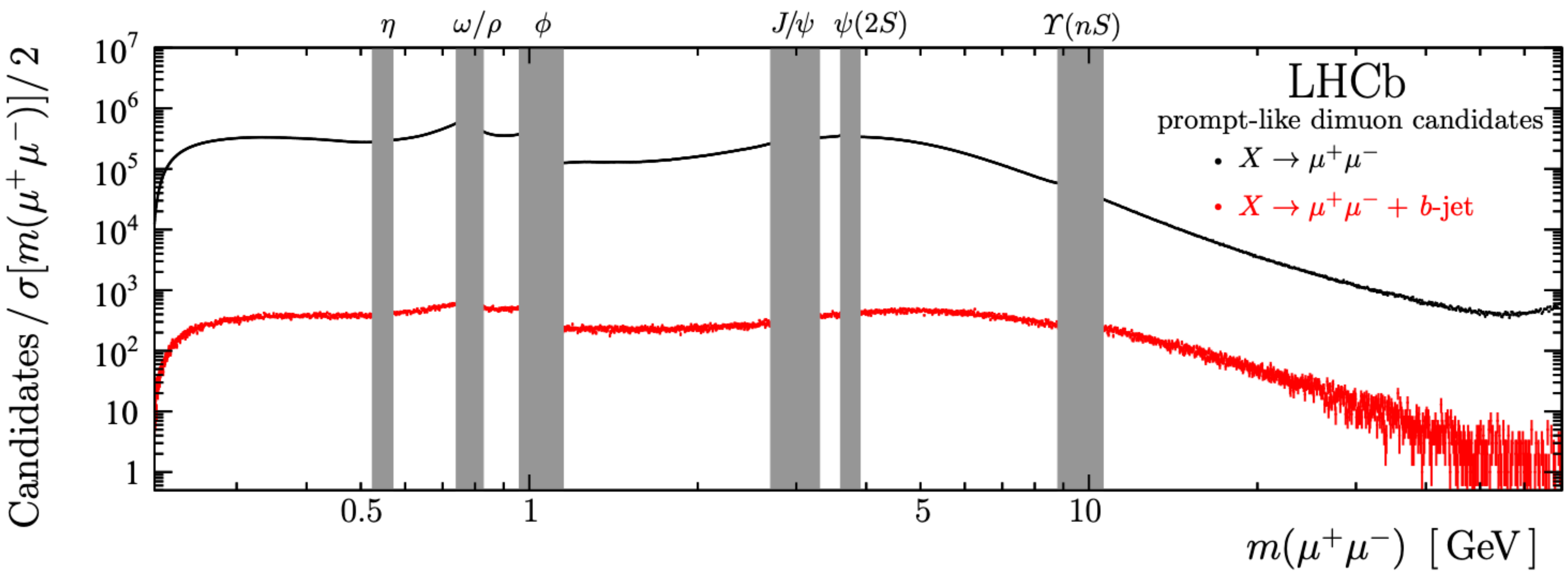


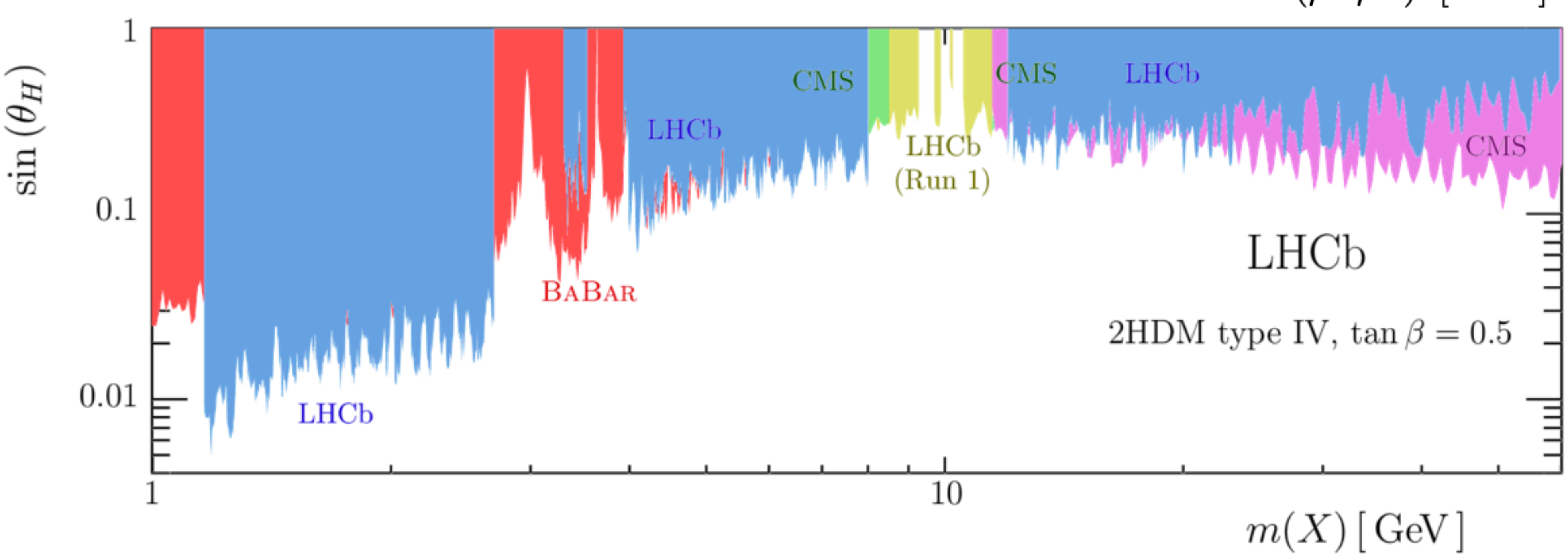
Low mass di-muon resonance at LHCb

LHCB-PAPER-2020-013

- LHCb dedicated flavour experiment in the forward region at the LHC (1.9 < η < 4.9):
  - Excellent μ± ID and reconstruction efficiency.
  - Excellent vertex and mass resolution: typically 7-20 MeV
  - Low pT trigger means low masses accessible. Ex: $p_T^{\mu} > 1.5$ GeV.
- Prompt and displaced dimuon search







90% CL limits for X-Higgs mixing angle for the Two-Higgs-doublet (2HDM) model scenario

Low mass di-muon resonance at LHCb

LHCB-PAPER-2020-013

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    - Excellent $\mu^{\pm}$ ID and reconstruction efficiency.
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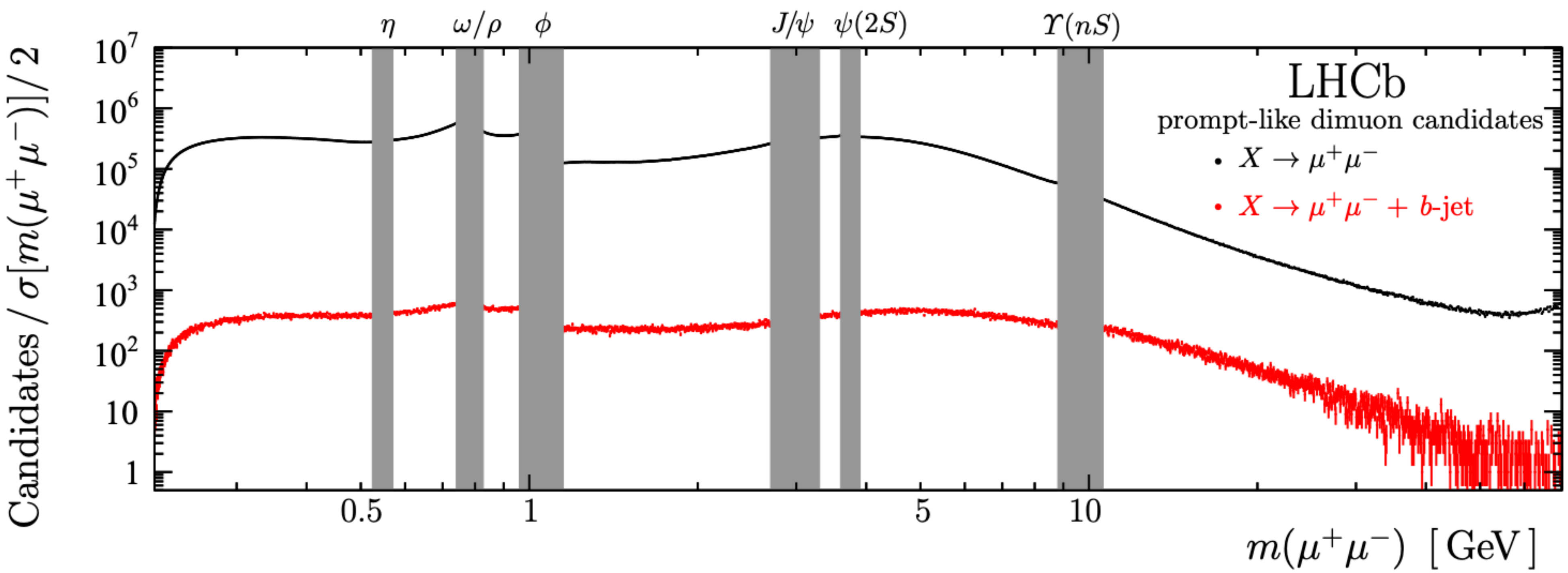
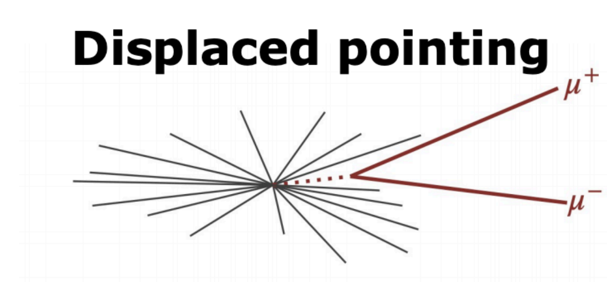
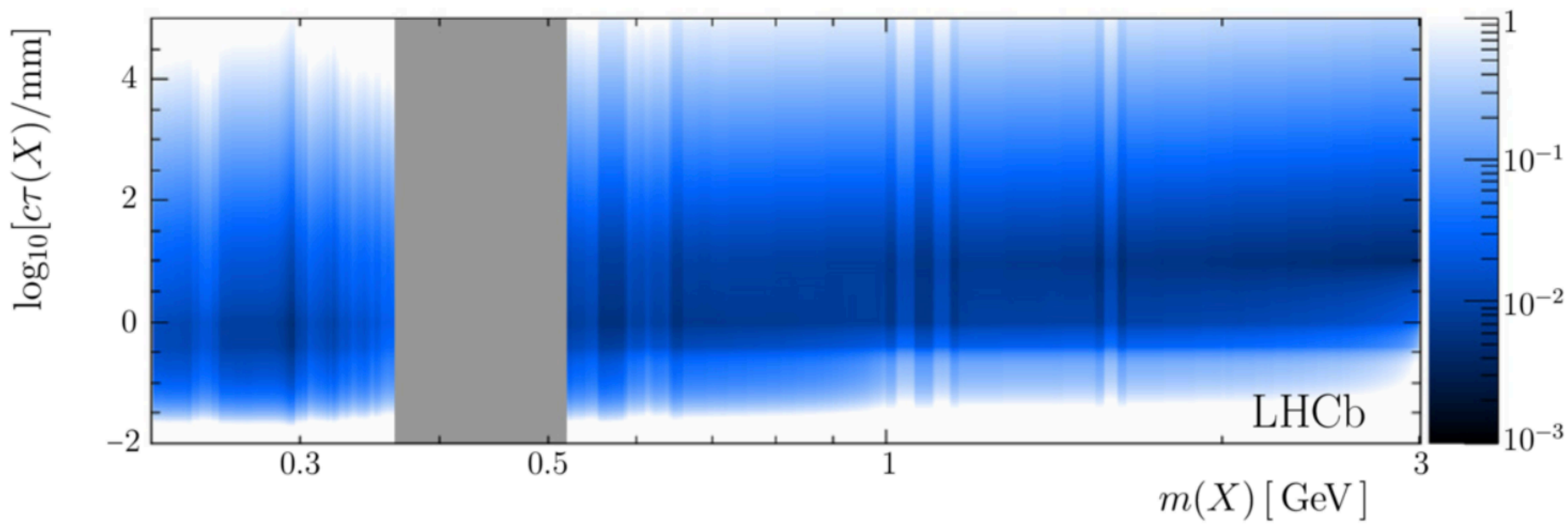
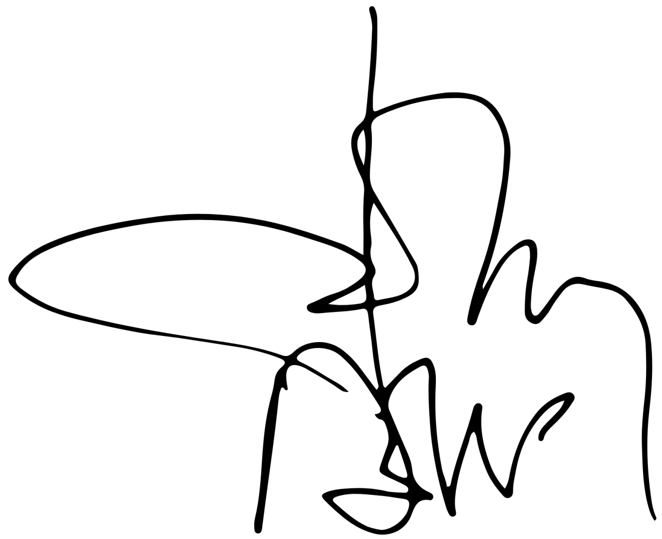






Hidden Valley scenario: consist of a sector with light particles connected to the SM sector only via massive particles.

Upper limits on γ - Z_{HV} kinetic mixing. Results depend on hidden hadron multiplicity



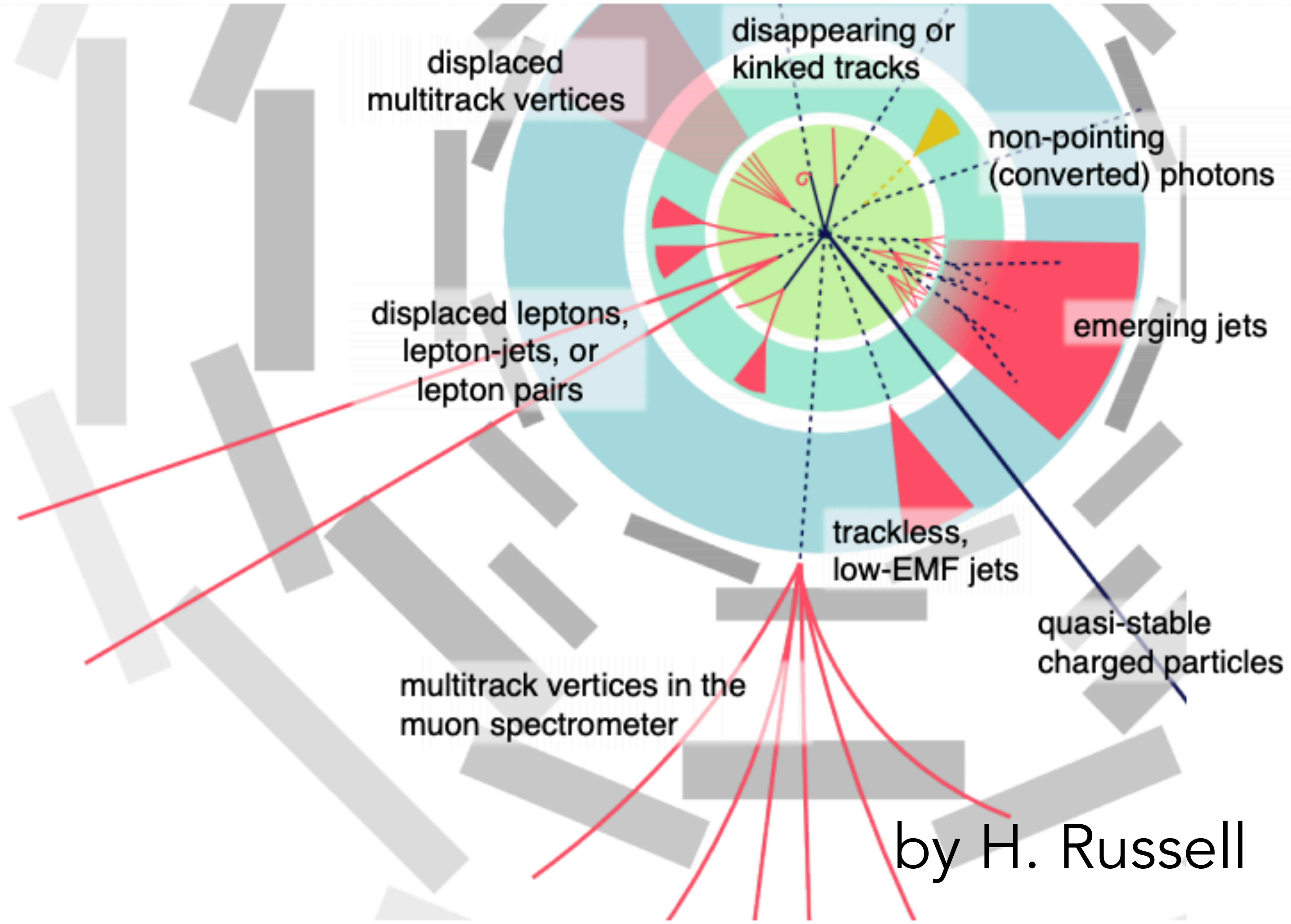
Unconventional signatures

- Parallel talks:
  - Talks by B. Francis, J. Williams, M. Verducci, T. Holmes

Searches for long lived particles

- **Long-lived (LL) and unconventional exotic particles** with striking signatures **predicted by many extensions of the SM**.
- Examples:
  - Heavy, long-lived, charged particles
    - R-hadrons, Sleptons
  - Particles can decay in the detector after few cm
    - neutralinos in GMSB, mass-degenerate gauginos, particles of an Hidden Sector

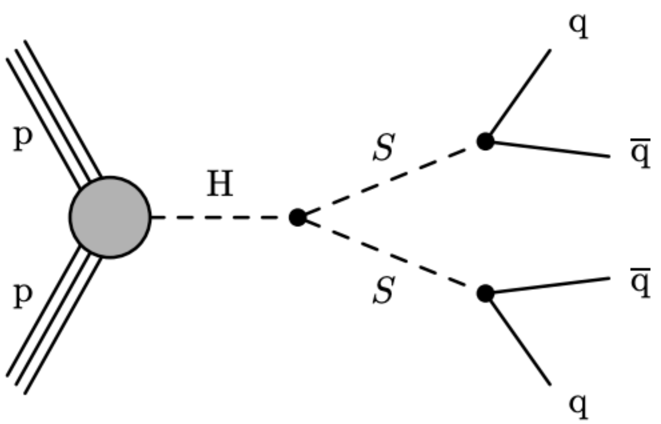
- **Challenging from the experimental point of view**
  - Non-standard reconstruction
  - Displacements, timing and ionization
    - Dedicated triggers
- Non-standard background is a challenge
  - Detector noise, cosmic rays, reconstruction failures
  - Usually estimated from data



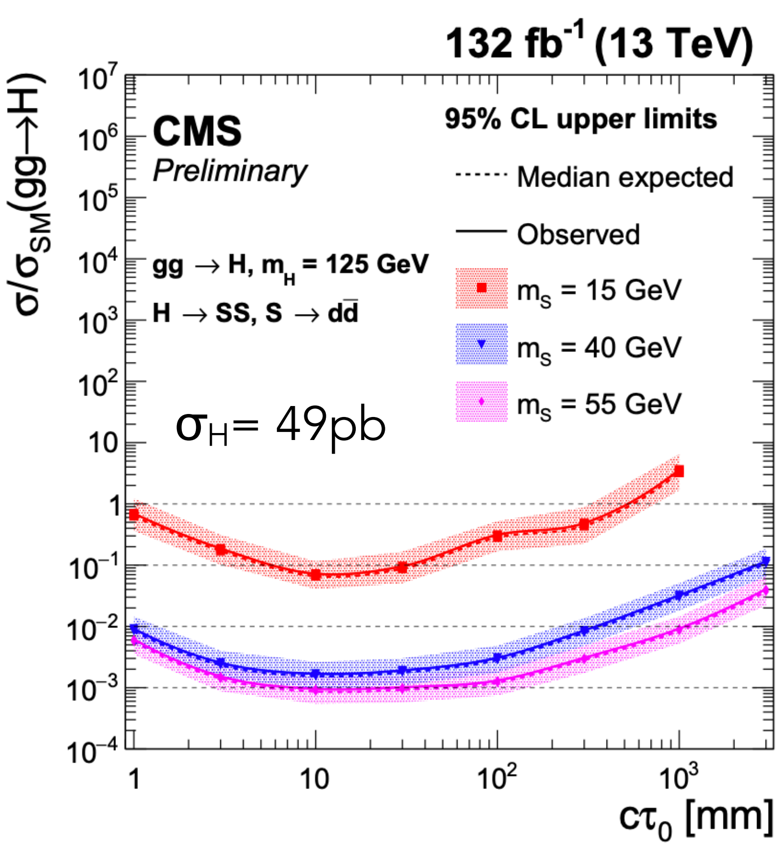
by H. Russell

Displaced jets [EXO-19-021] and Search for Strongly Interacting Massive Particles [CMS-PAS-EXO-17-010]

- Distinctive topology : pair of jets originating at a secondary vertex
- **Different signal models targeted: LLP decaying to q-qbar, Exotic decays of Higgs: gg → H → 2S, S → qq where cτ ~ 1mm to 3m**

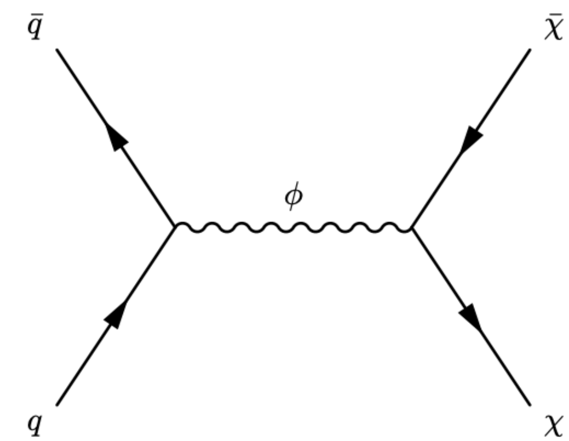


- Highlights:
  - Dedicated displaced triggers
  - Dedicated secondary Vertex reconstruction
  - BDT with variables like vertex track multiplicity

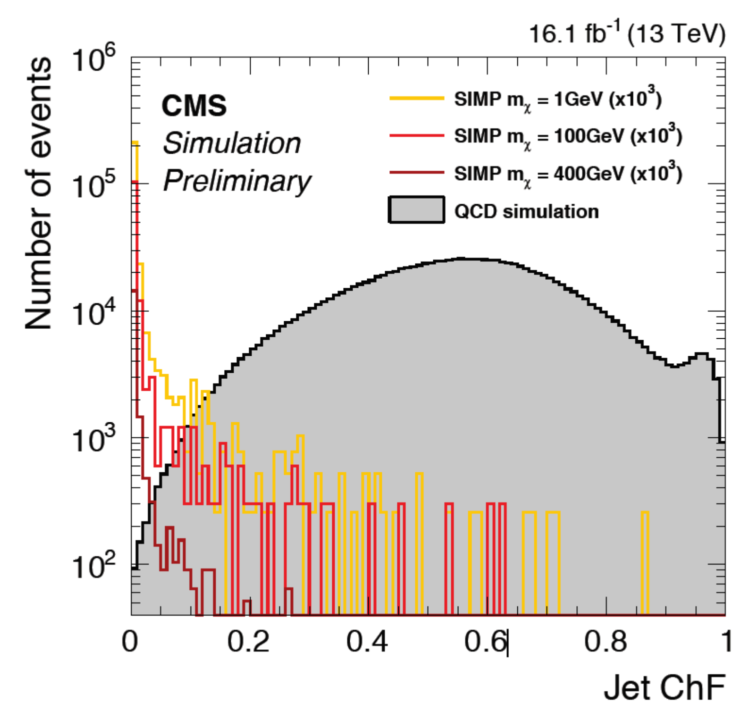


combined with a previous CMS search for displaced jets

Dark matter in the form of SIMP manifesting themselves as a **pair of jets without tracks**



- Two back-to-back jets with low charged energy fraction ChF
- Data-driven estimation of QCD
- **Set first limits on a potential SIMP signal, excluding SIMP masses up to 900GeV at 95% CL.**

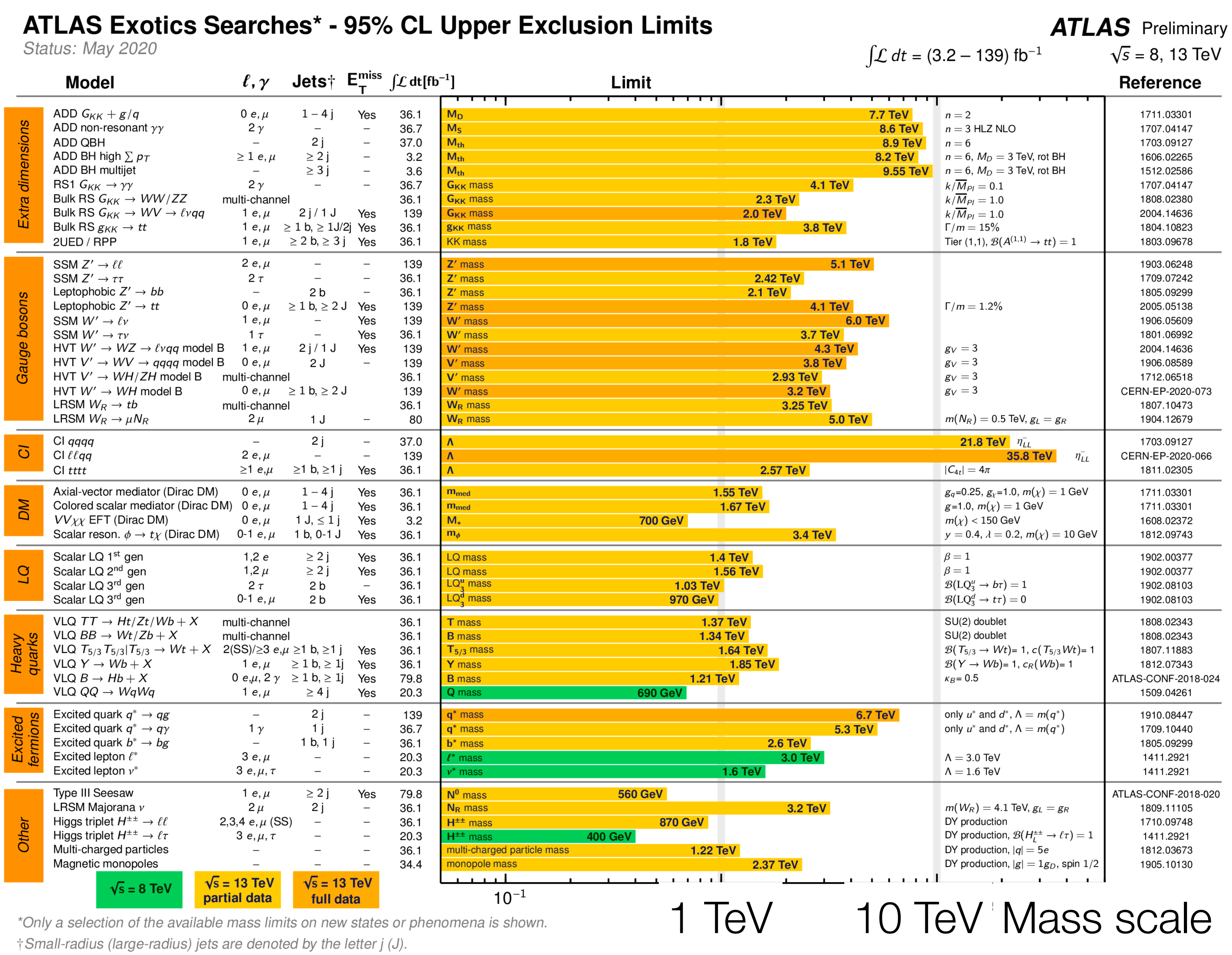


ATLAS result on cal ratio: Eur. Phys. J. C 79 (2019)

Conclusion

- Searching for exotics is a broad program, both in terms of questions asked and of final states!
  - **In many places, able to increase the sensitivity beyond the expectation from the increased dataset owing to important work on analysis techniques, on object performance or unconventional signatures**
- Broadening the scope by minimizing direct theory biases or by adding additional interpretations

- **Many full run-2 results still to come.**
- **Many more details were covered in parallel talks!**



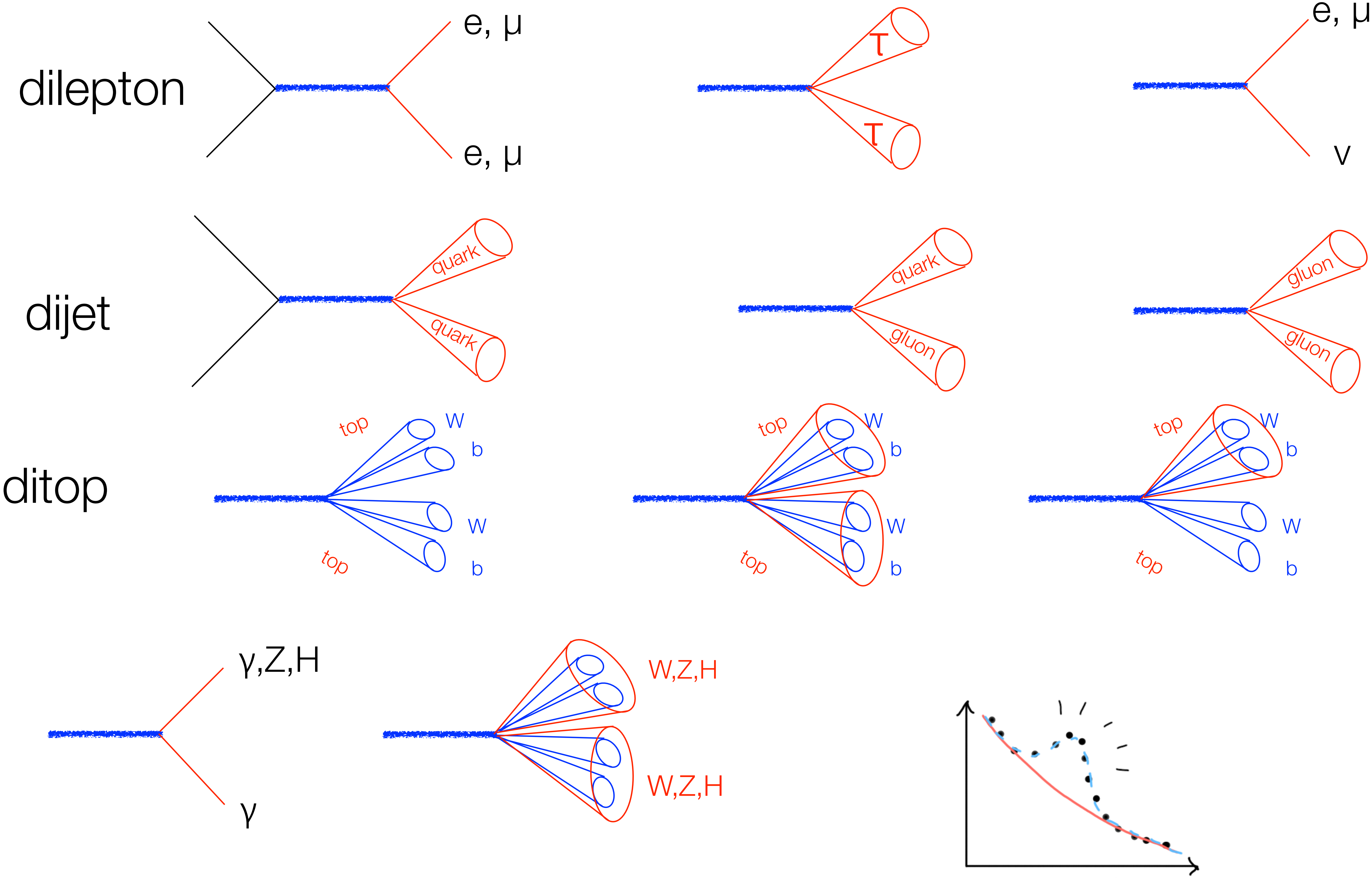
Conclusion

- Searching for exotics is a broad program, both in terms of questions asked and of final states!
  - **In many places, able to increase the sensitivity beyond the expectation from the increased dataset owing to important work on analysis techniques, on object performance or unconventional signatures**
- Broadening the scope by minimizing direct theory biases or by adding additional interp

Thanks for listening!

- **Many full run-2 results still to come.**
- **Many more details were covered in parallel talks!**

Resonances



dilepton
e, μ
e, μ
τ
τ
e, μ
ν
dijet
quark
quark
quark
gluon
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b
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b
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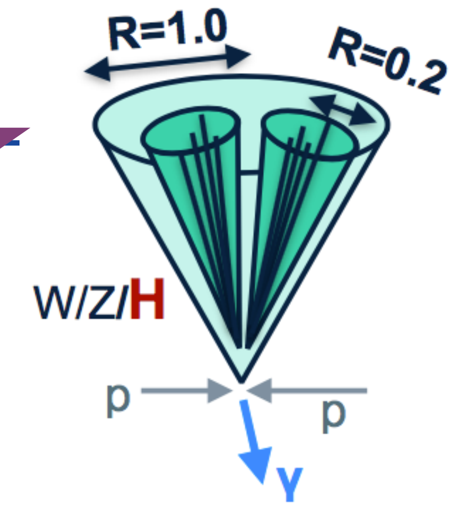
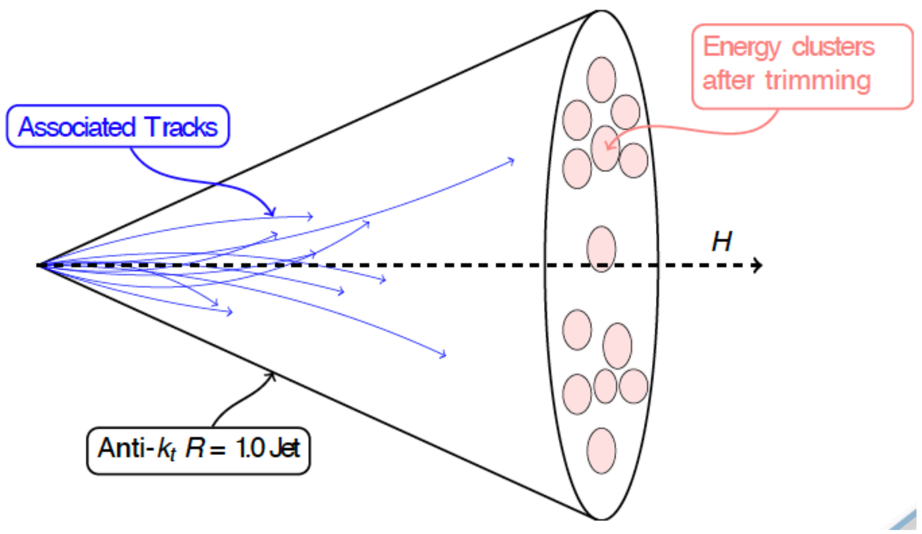
γ,Z,H
γ
W,Z,H
W,Z,H

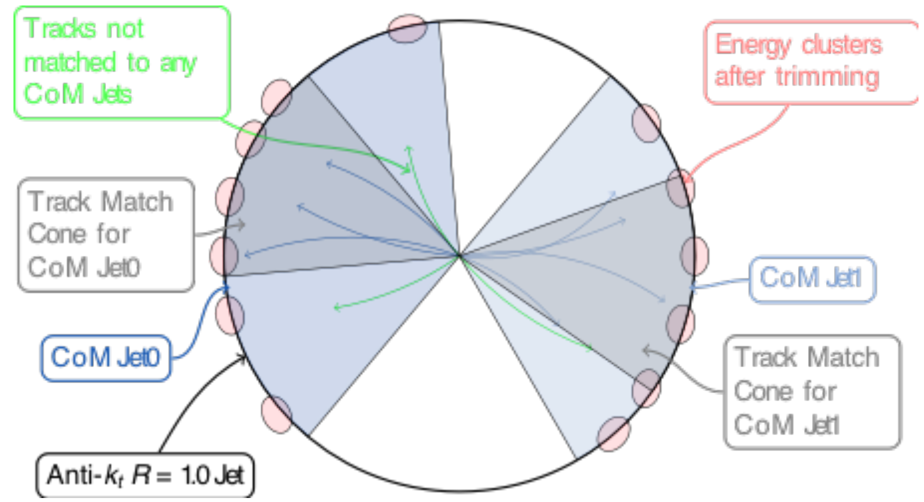
H+γ resonances (HDBS-2018-17)

NEW



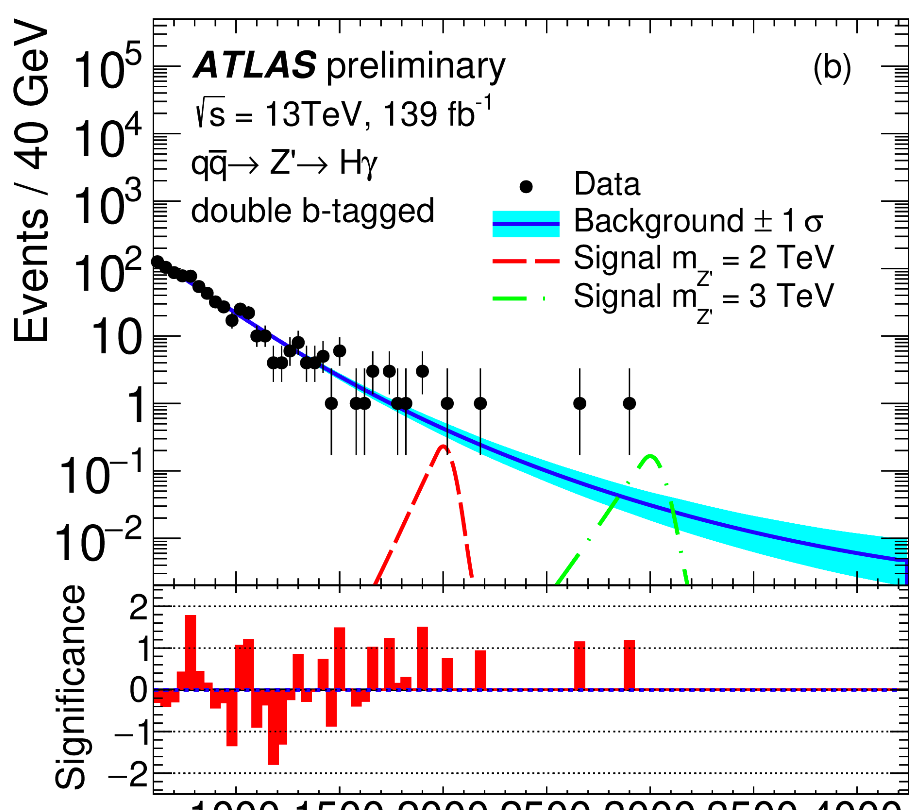
- Require a photon and a large-R jet (Ak10 LCTopo Jet)
- A novel b-tagged algorithm, Center of Mass tagger (CoM), is applied to tag the Higgs

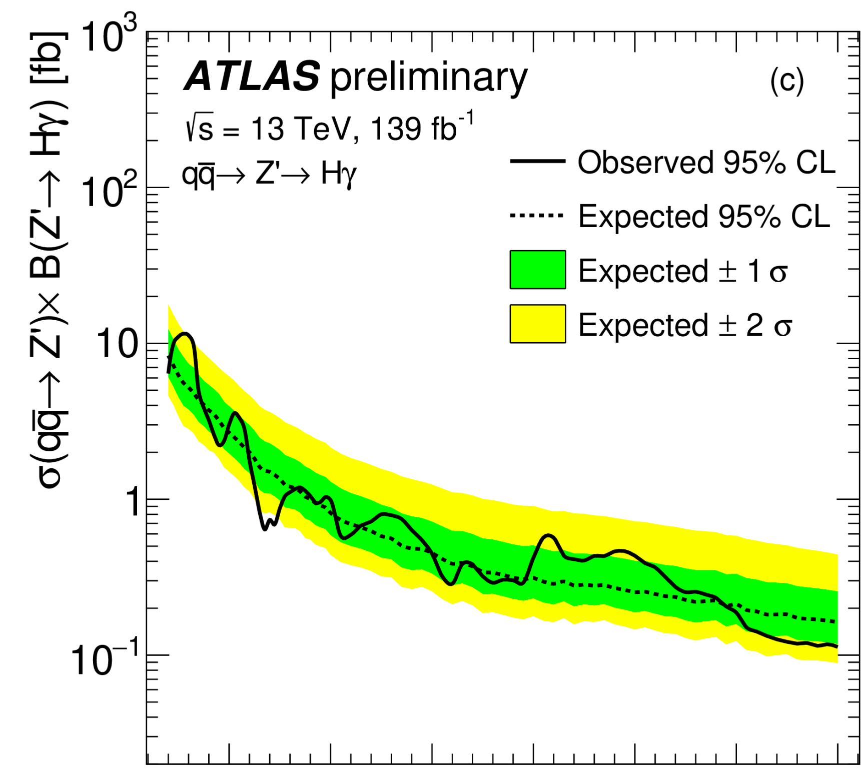




1. Collect Large-R jet information
2. Boost to Higgs (Large-R jet) frame
3. Reconstruct two subjets
4. Associate track to subjet
5. Boost back to lab frame

- Parametric fit to the $m_{J\gamma}$ spectrum to get the background shape ==> checked in control regions
- **Improvement beyond luminosity over the full mass spectrum thanks to new techniques:**
  - **in the high mass x10 in sensitivity**



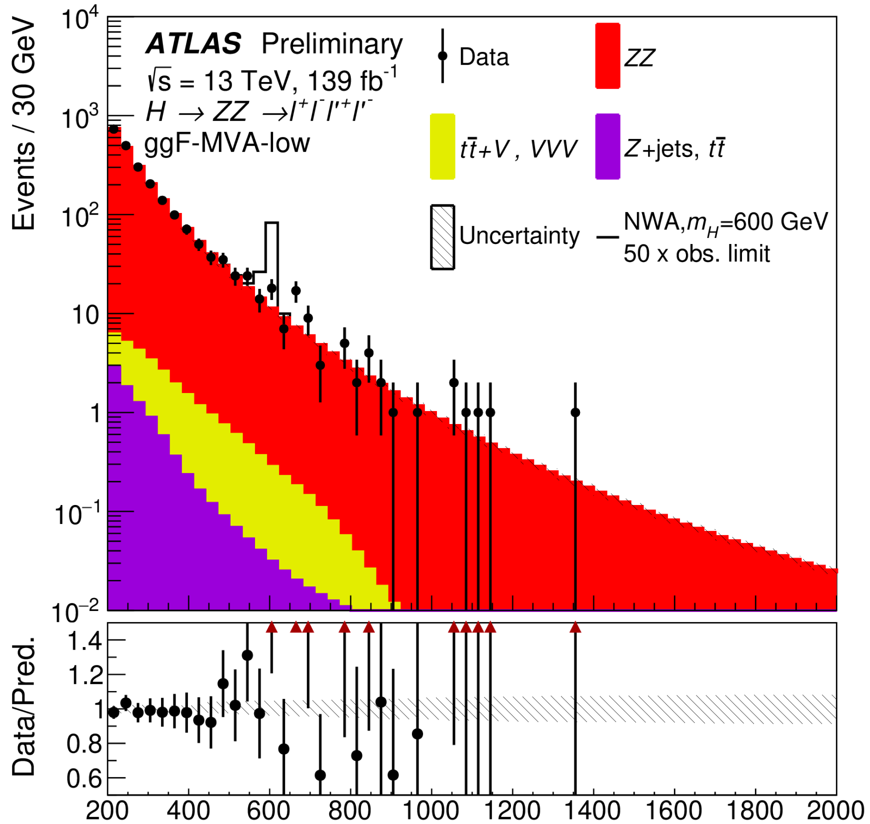


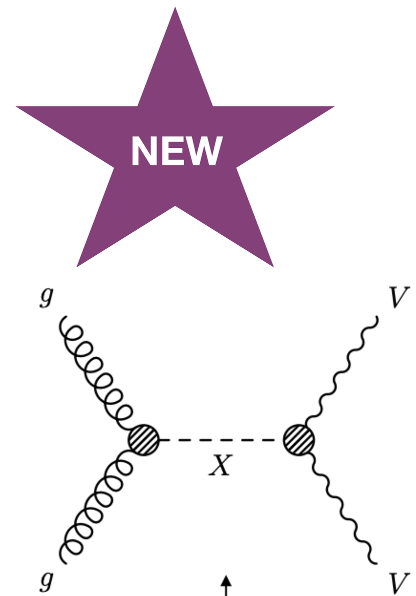
VV resonances

ATLAS-CONF-2020-032 https://arxiv.org/abs/2004.14636

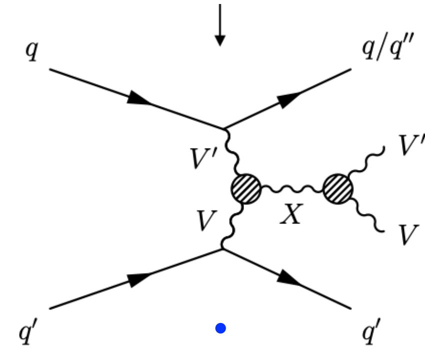
4 lepton: m_{4l}

llvv: 2 lepton and E_T^{miss}

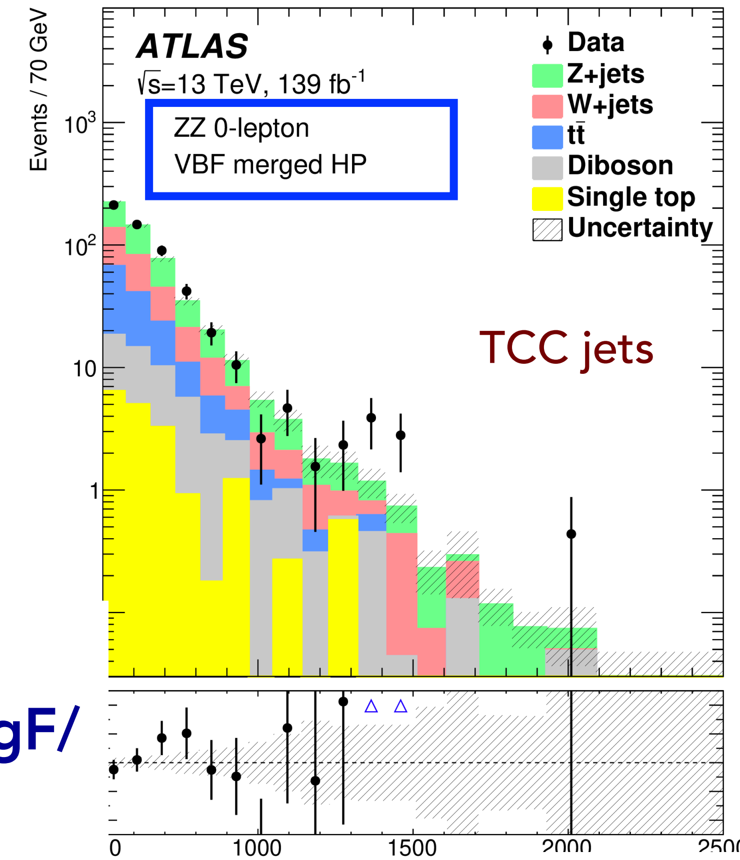




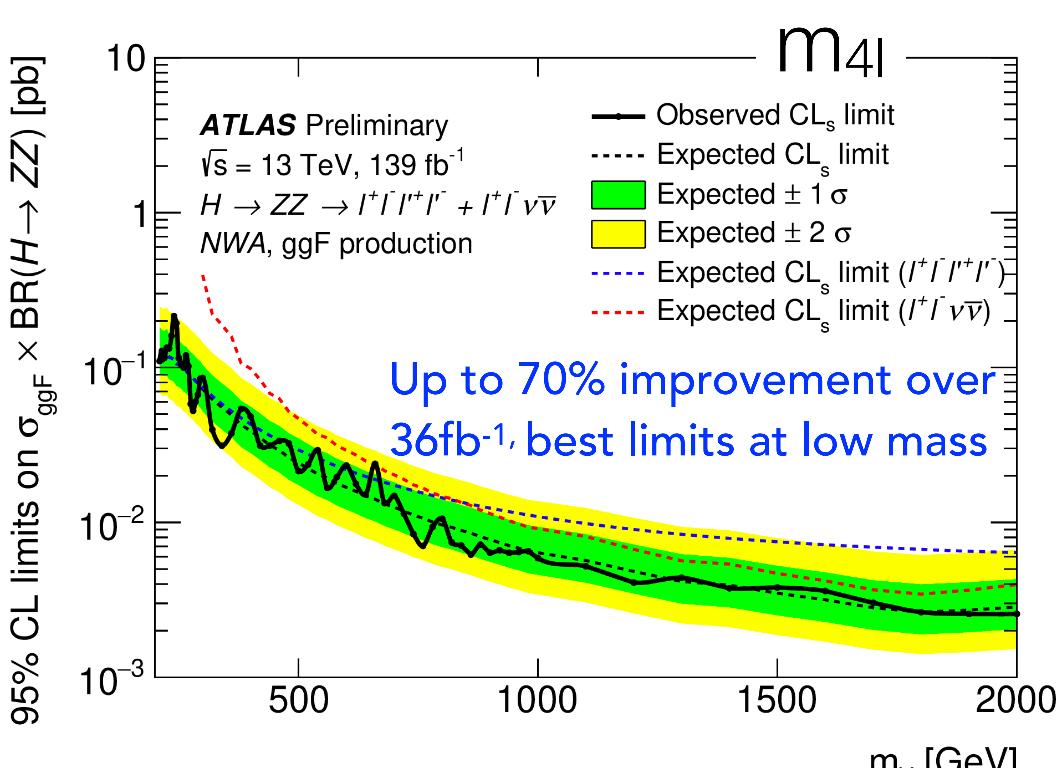
New **NN for categorizing ggF/ DY or VBF**



VV semileptonic: ZV->vvjj, WV->lvjj, ZV->lljj

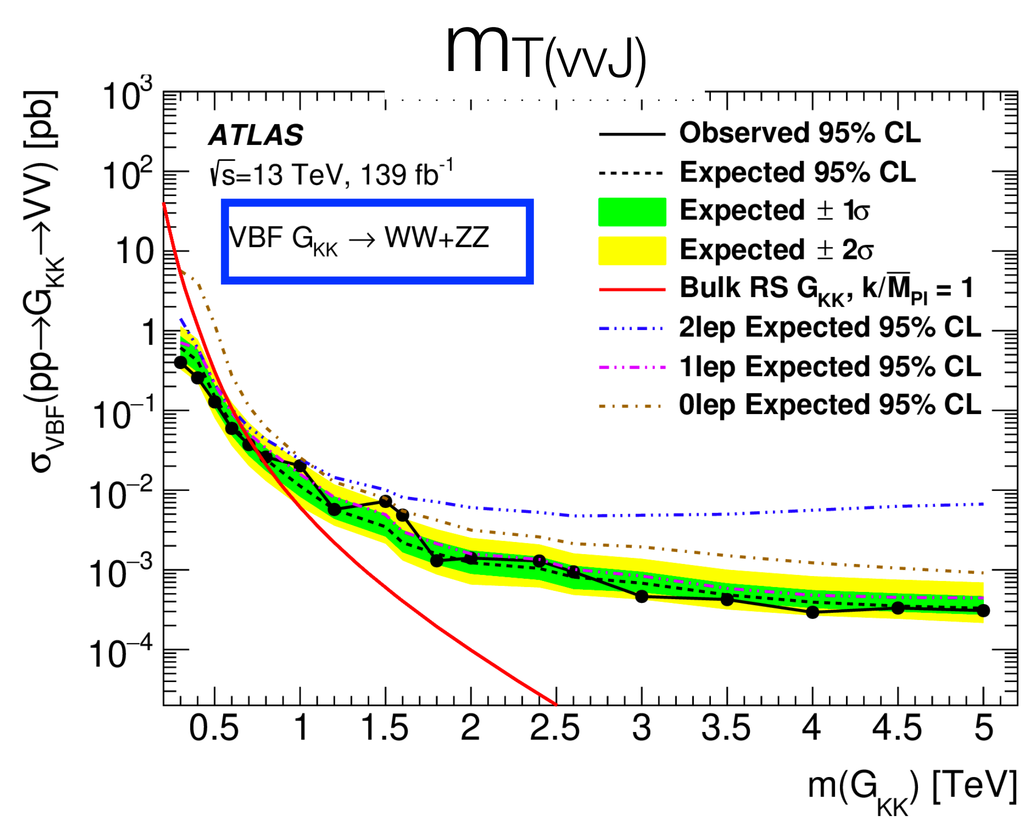


for W′ (Z′) produced in a strong scenario exclude masses below 4.3 (3.9) TeV. Best limits so far



Up to 70% improvement over $36fb^{-1}$, best limits at low mass

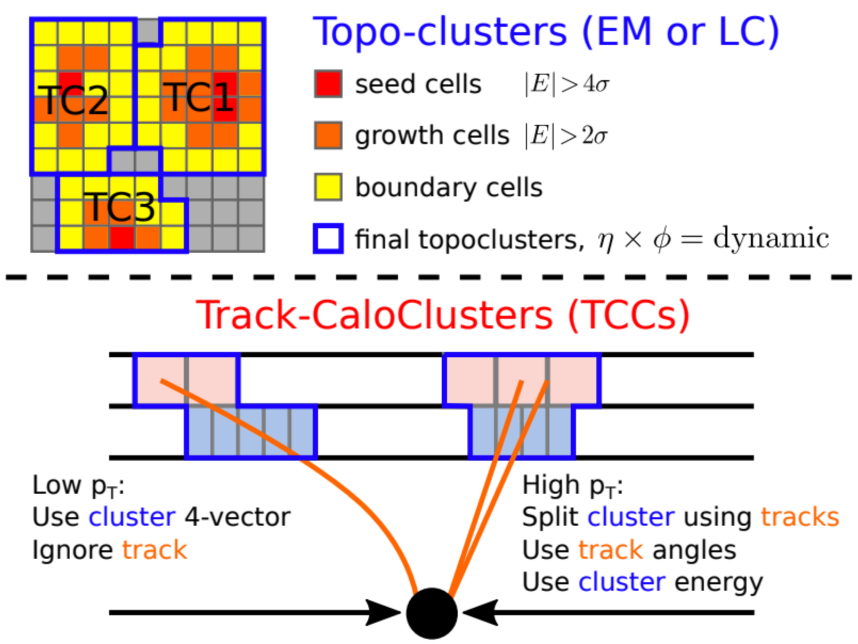
$m_{T(vvJ)}$

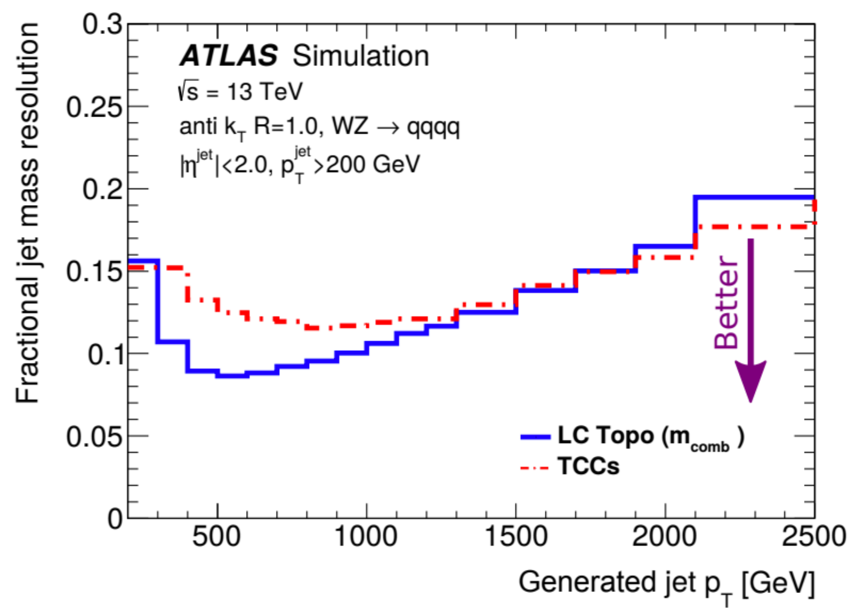


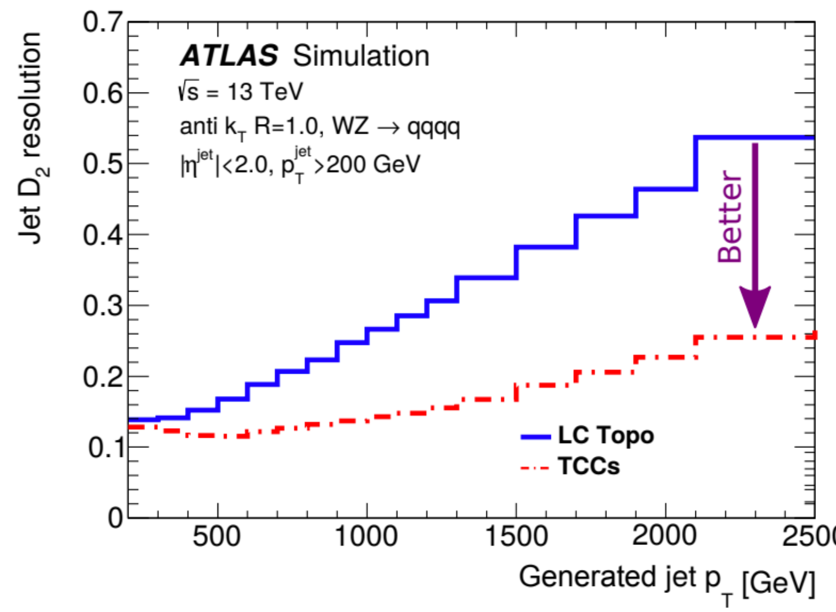
TCC jets

From S. Schramm talk

- Generic diboson search uses jets built from topoclusters: generally best jet mass resolution
- VV and VH searches use jets built from TCCs: best boson tagging performance due to D_2



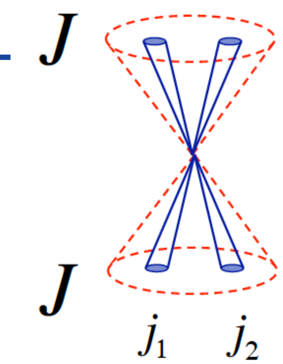




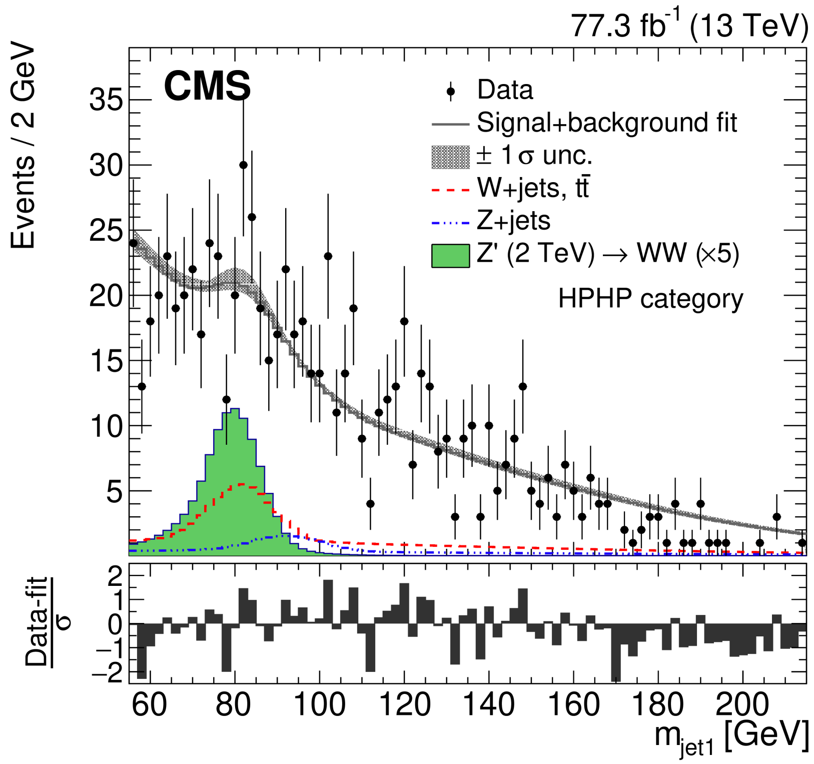
VV→qqqq resonances

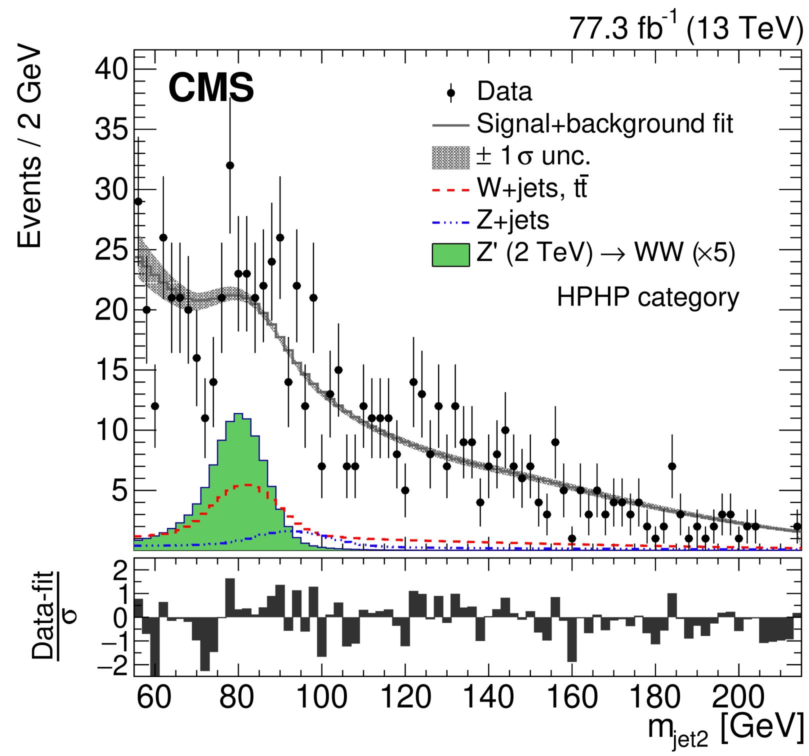
CMS: EurPhysJC80,237(2020)

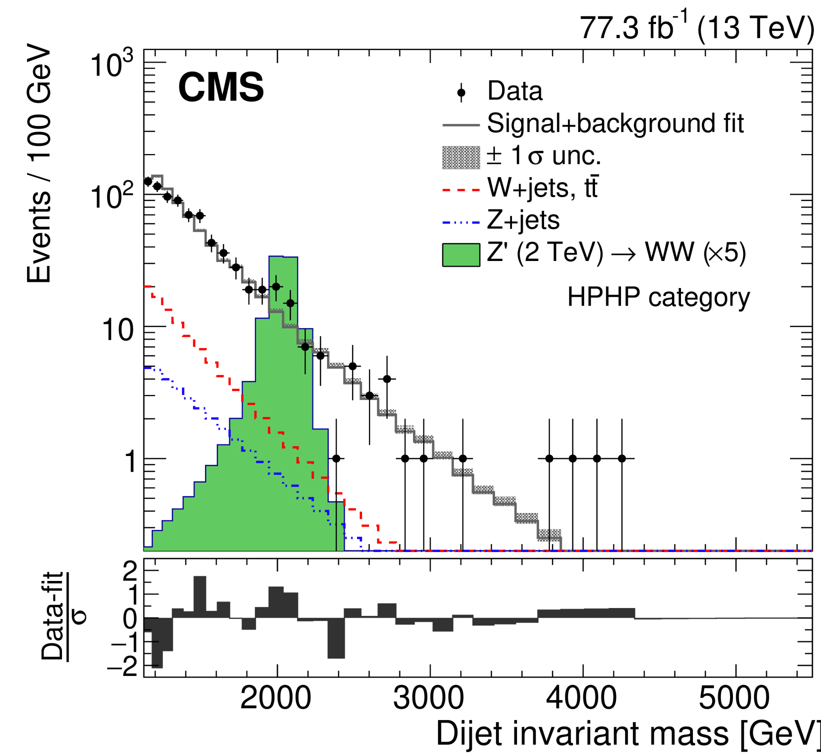
VV(JJ)



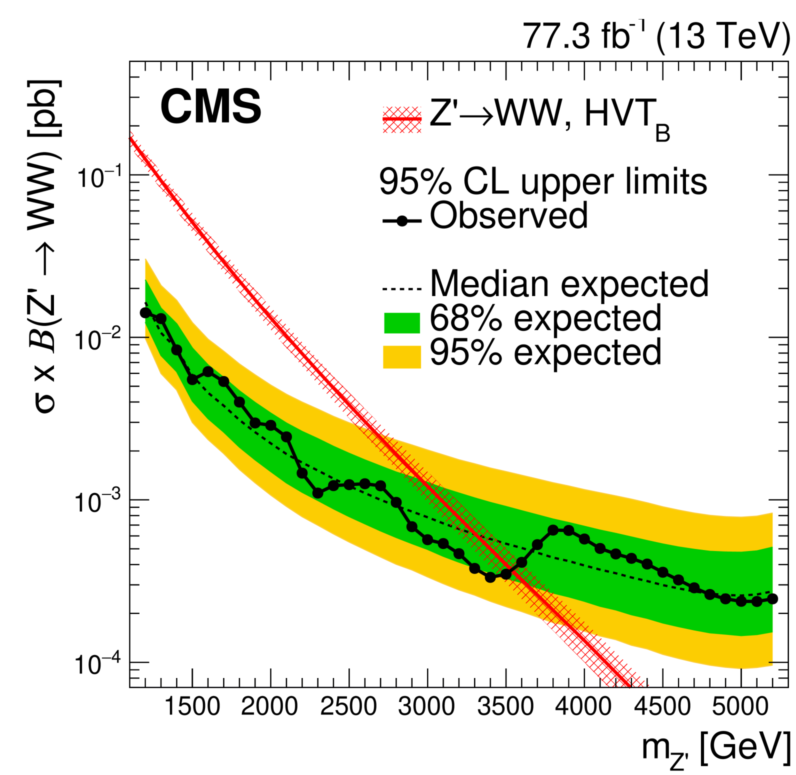
- Search for massive resonances decaying to WW, WZ or ZZ.
  - Boosted W/Z decaying into single large-radius jets







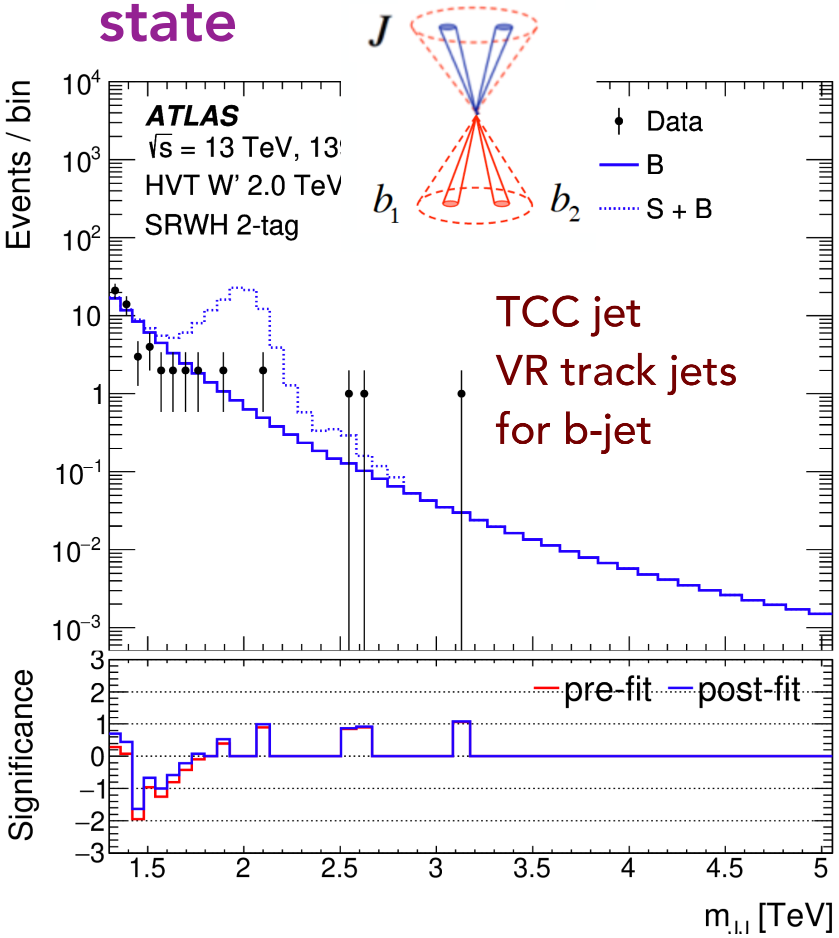
- **New analysis method:** 3D fit to masses of the two jets and dijet invariant mass
  - ⇒ up to 30% improvement in sensitivity.
- **Under strong-like scenario, exclusions for W′ (Z′) resonances with masses below 3.8 (3.5) TeV.**



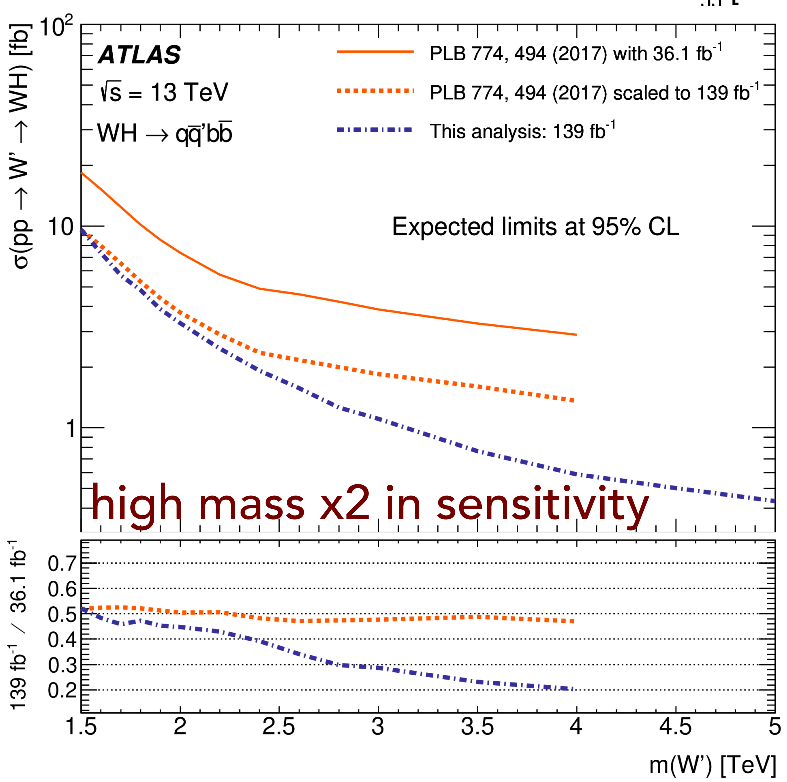
VH resonances [arXiv:2007.05293] [ATLAS-CONF-2020-043]

NEW

Fully-hadronic final state



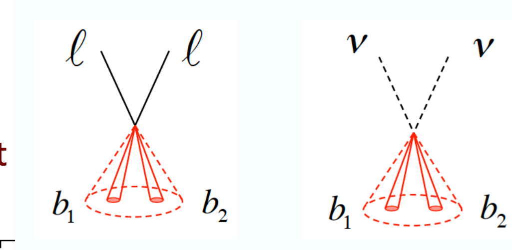
TCC jet
VR track jets
for b-jet

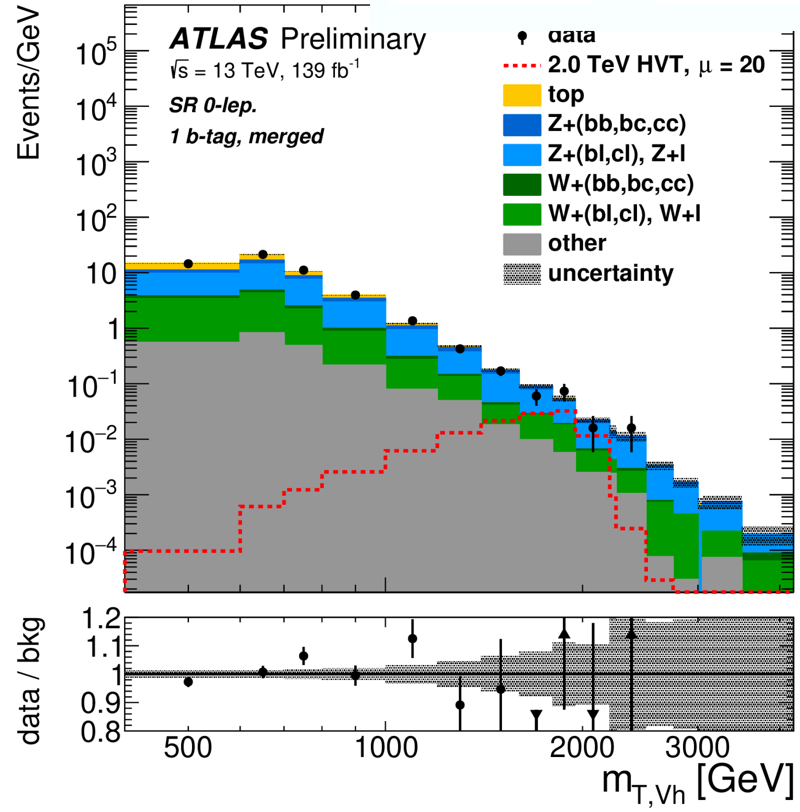


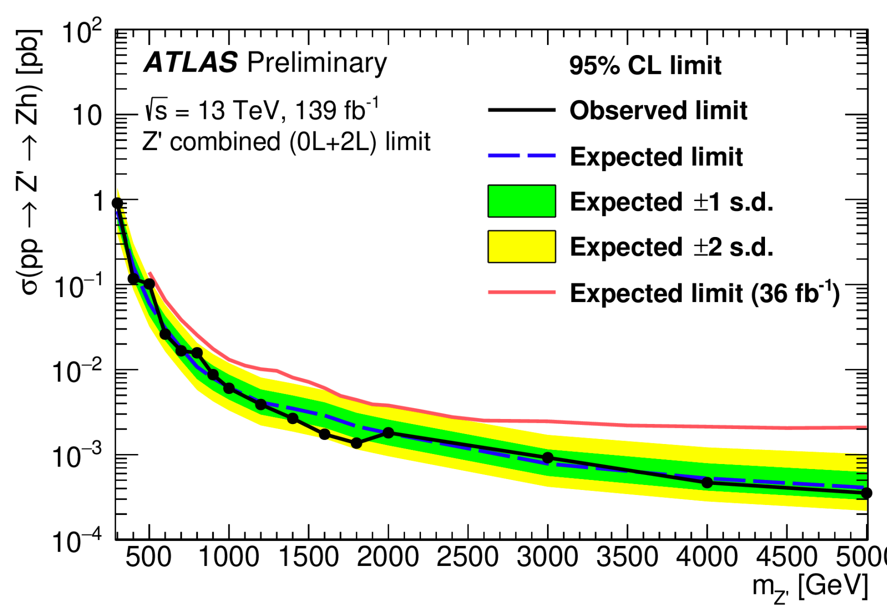
high mass x2 in sensitivity

0 and 2 lepton semileptonic final state

TCC jet
VR track jets for b-jet

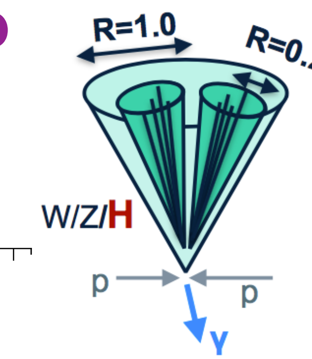




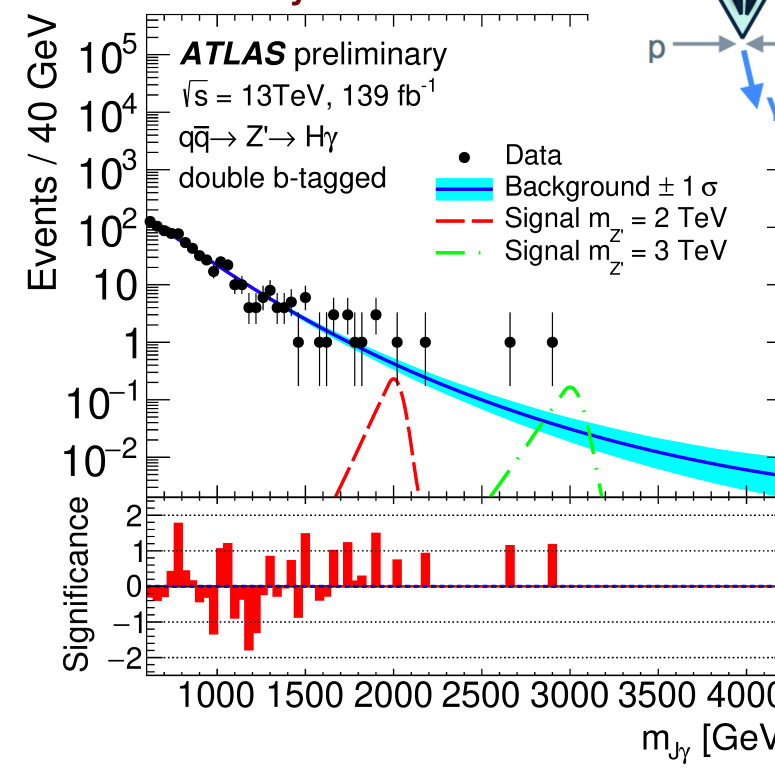


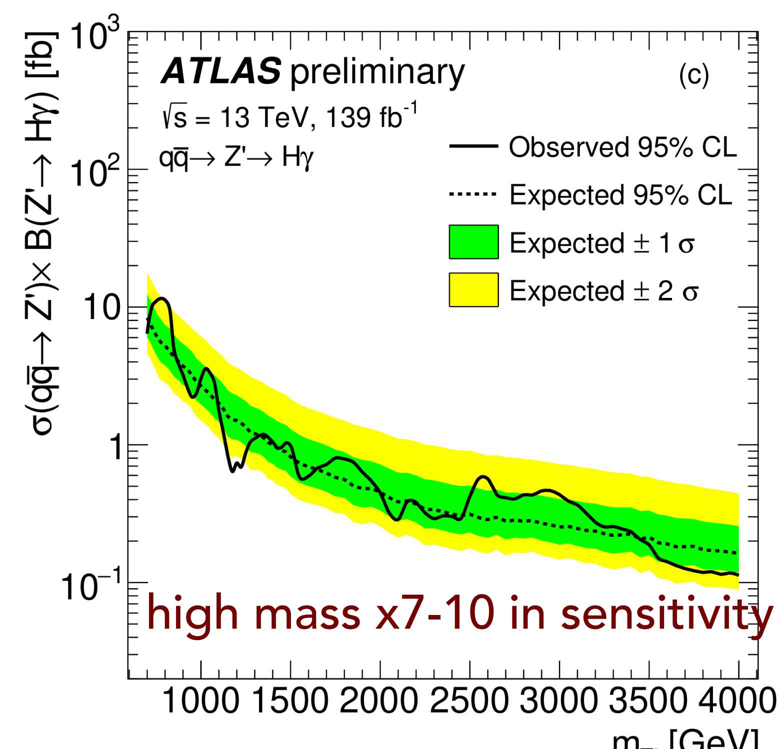
high mass x2 in sensitivity

photon+H->bb



TCC jet
COM jets





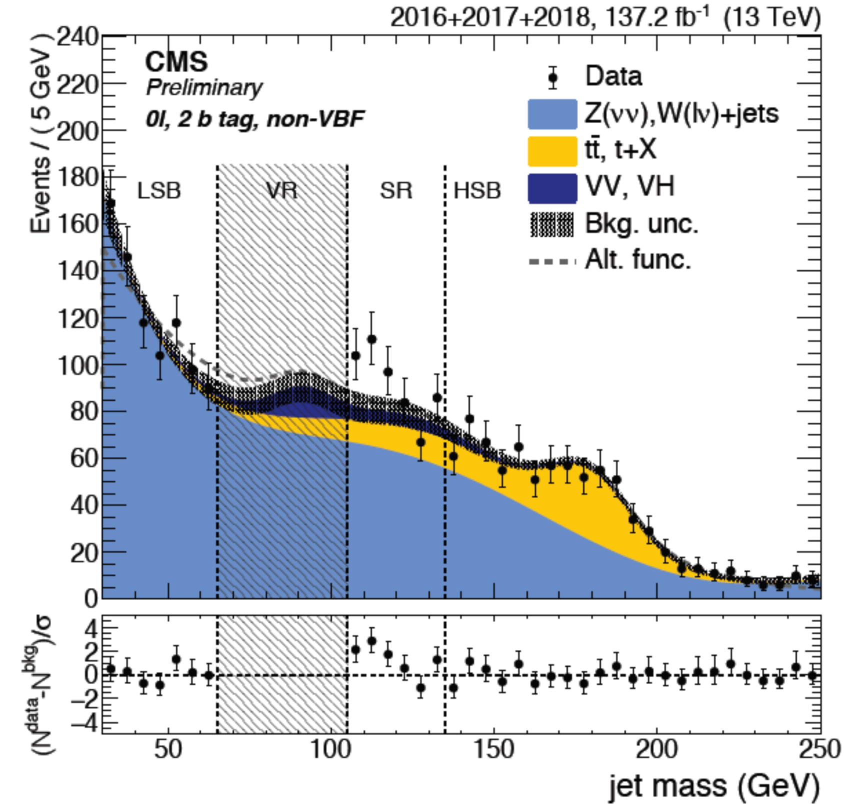
high mass x7-10 in sensitivity

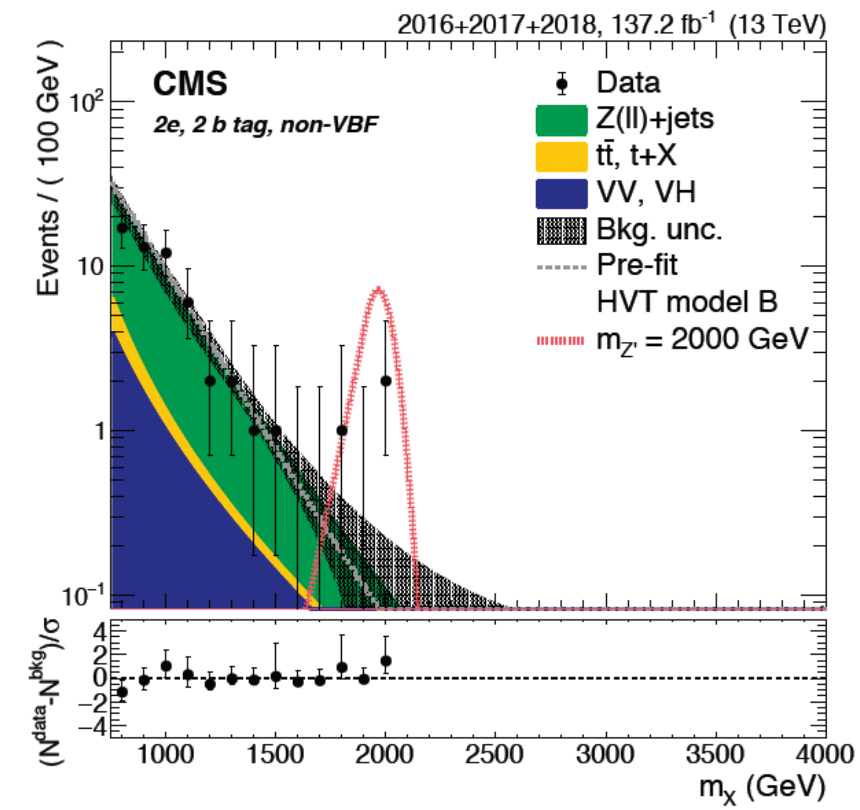
Z(nunu/ll)H(bb) CMS

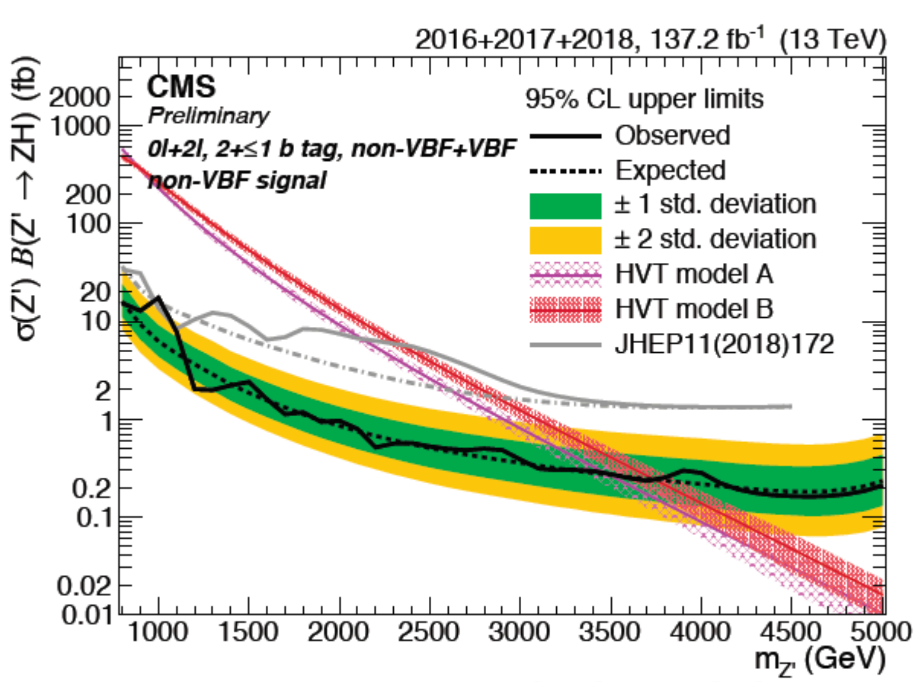
B2G-19-006

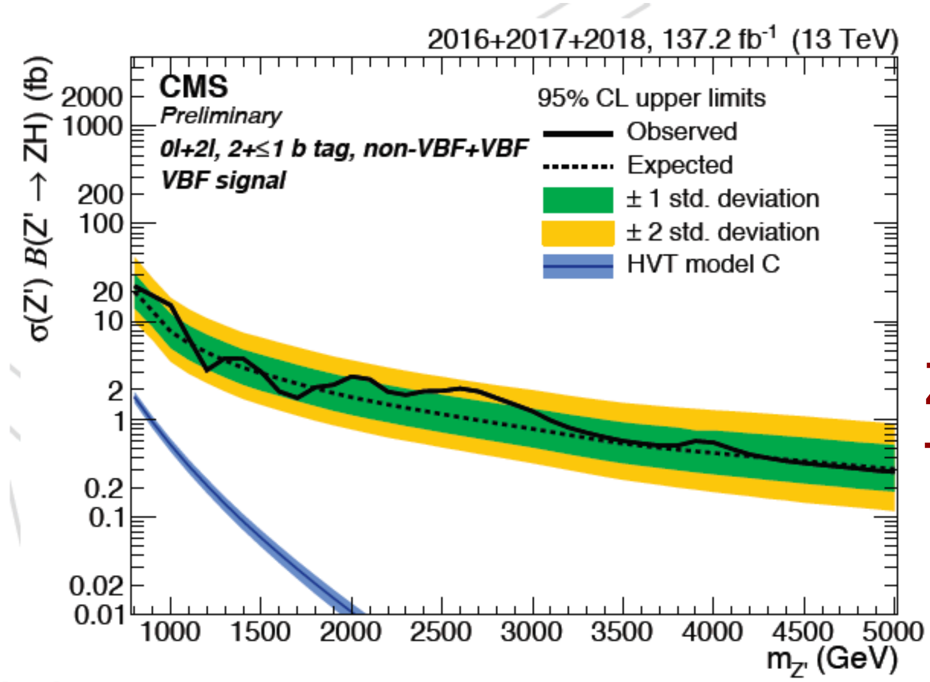
- Search for spin 1 resonances in the boosted regime for m_X> 800 GeV ==>**0 lepton (large ptmiss) and 2 lepton channels considered**
  - **Including VBF production for the first time!**

- Use new NN for tagging b-jets from Higgs
- The m_X (or m_{TX}) distributions are estimated using fit to data in the jet mass sidebands.









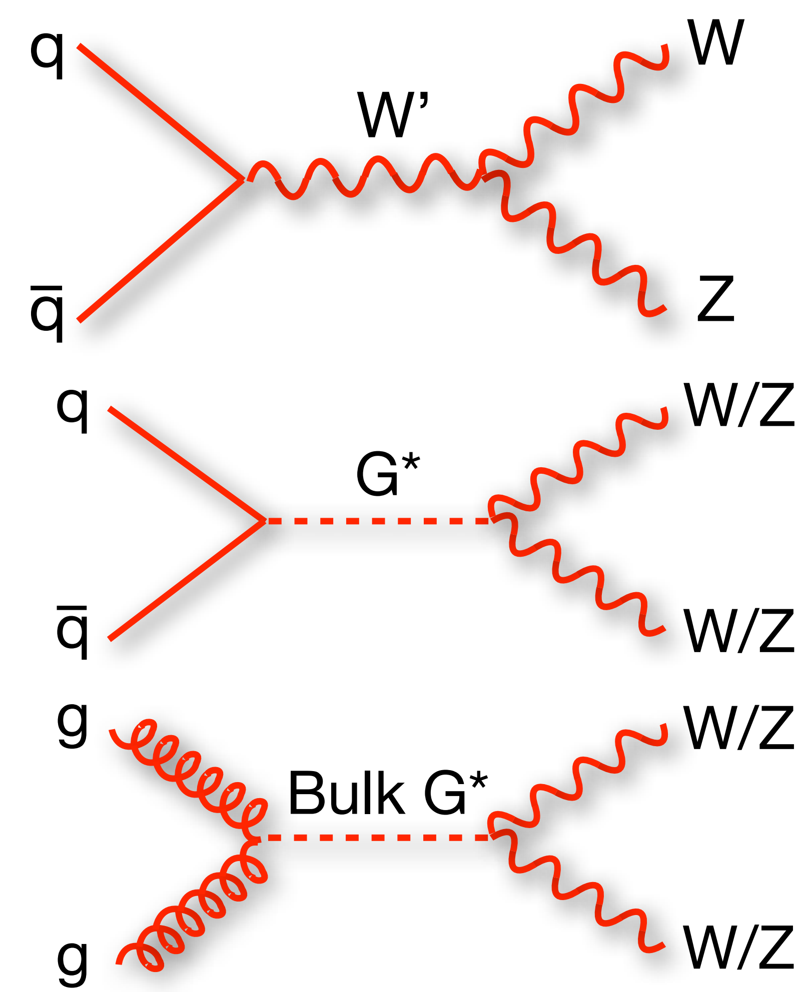
Z′ with mass below 3.5 and 3.7 TeV is excluded

Resonance models

Charged (WZ)

Sequential Standard Model (W', spin-1)

✳ Trilinear W'WZ coupling set by Extended Gauge Model: ~ $(M_W/M_{W'})^2$



Neutral (WW,ZZ,HH)

Randall-Sundrum graviton (RS G*, spin-2)

✳ Traditional benchmark model with extra dimensions

Bulk RS graviton (Bulk G*, spin-2)

✳ Graviton couples more with heavy particles (W, Z, t)

✳ Smaller σ, but larger branching ratio to WW, ZZ

HVT (Simplified Lagrangian)

Model A

✳ weakly coupled vector resonances from extension of the gauge group

Model B

✳ produced in a strong scenario e.g. composite higgs model

Dark Higgs s(VV) hadronic signal

$$\mathcal{L}_\chi = -\frac{1}{2} g_\chi Z'^\mu \bar{\chi}\gamma^5\gamma_\mu\chi - g_\chi \frac{m_\chi}{m_{Z'}} s\bar{\chi}\chi + 2 g_\chi Z'^\mu Z'_\mu (g_\chi s^2 + m_{Z'} s)$$

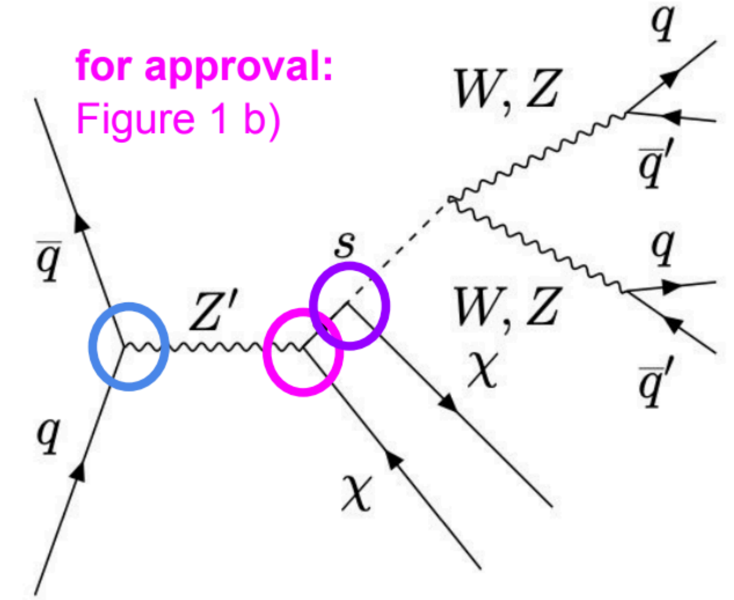
(see diagram on previous slide)

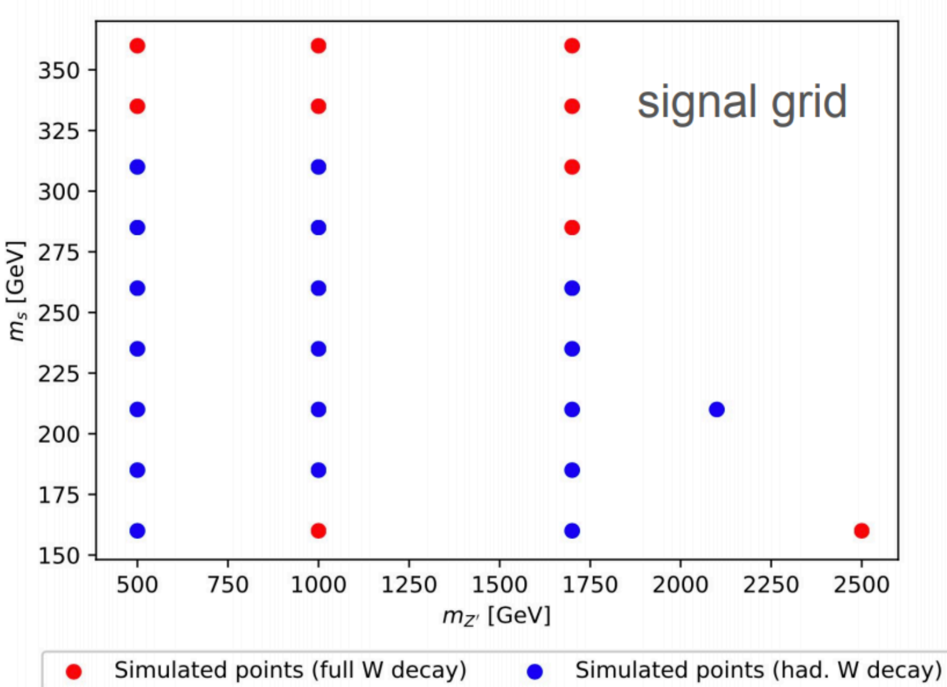
$$\mathcal{L}_q = -g_q Z'^\mu \bar{q}\gamma_\mu q$$

interaction Lagrangians for dark sector (top) and for coupling to quarks (bottom)

- SM particle content extended by **Z' spin-1 mediator**, **dark matter particle** χ, and **dark Higgs boson s**
- model parameter choices: (c.f. LHC DM WG benchmark recommendations)
    - Z' coupling to quarks g_q = 0.25
    - Z' coupling to DM and s: g_χ=1.0
    - dark matter mass m_χ = 200 GeV
    - mixing angle (SM Higgs, dark Higgs) θ = 0.01
    - scan in $m_{Z'}$ and m_s (see signal grid)

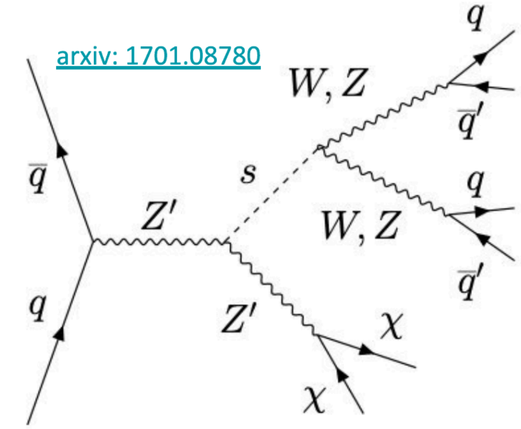
for approval: Figure 1 b)





all points with m_S > 160 GeV also simulated with full Z decay

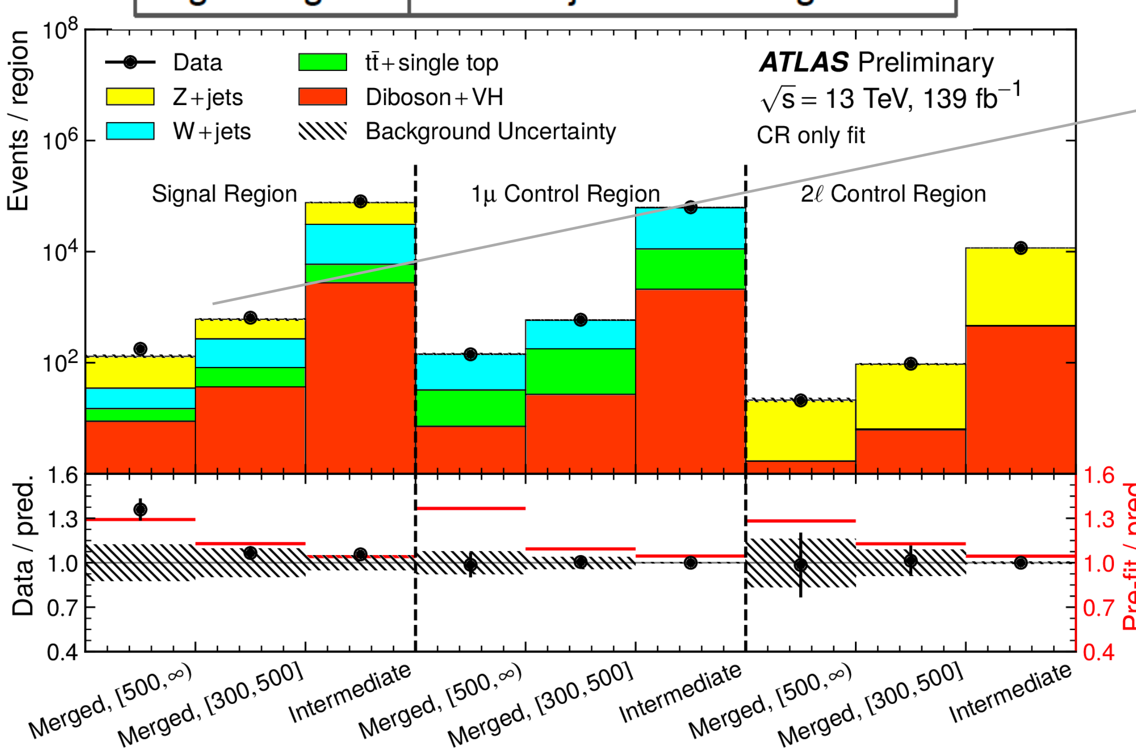
Mono S(VV) ATLAS-CONF-2020-036

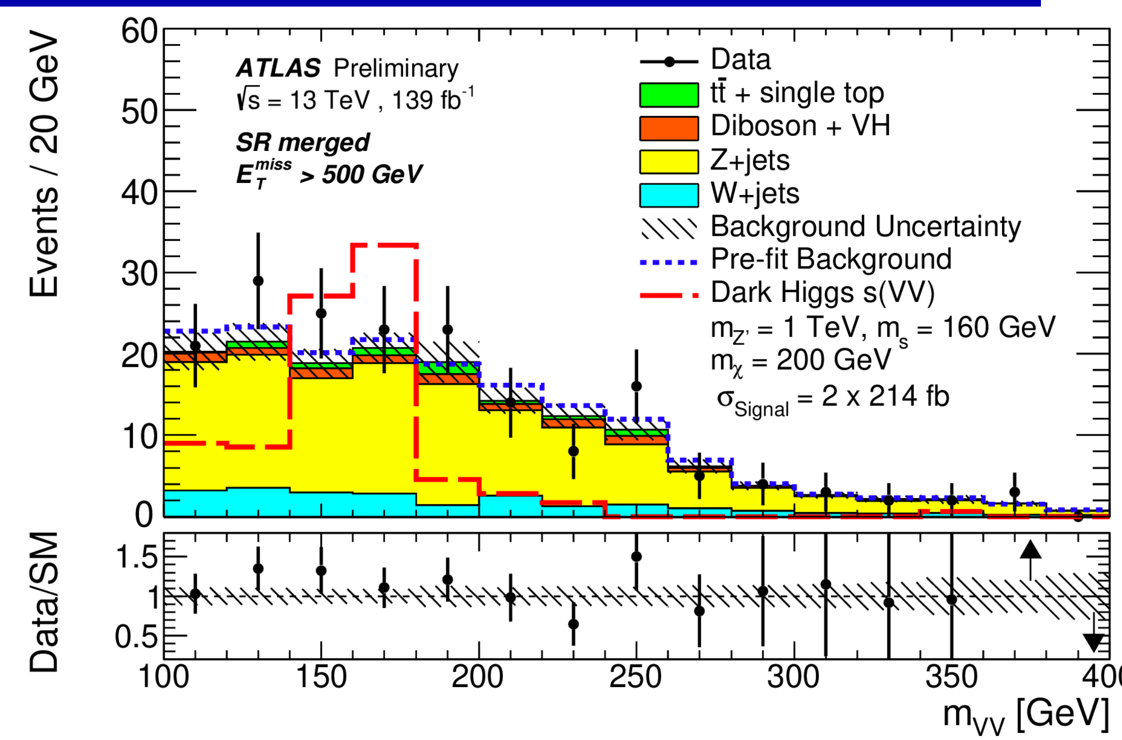


Dark Higgs model: simplified model arxiv:1701.08780 mass range from [160, 360] GeV where s(VV) decay is favored

- Challenging ET miss + V(qq)V(qq) final state ==> use **Track-Assisted-Reclustered (TAR) jets** :
  1. Start from calibrated small-R jets and reclustered to trimmed large-R jets
  2. Match tracks to constituents small R jets
  3. Rescale tracks to the pT of the matched small R jets
  4. jet substructure observables from matched ID tracks

0 lepton	1 lepton	2 lepton
signal region	W/Z+jets control regions	



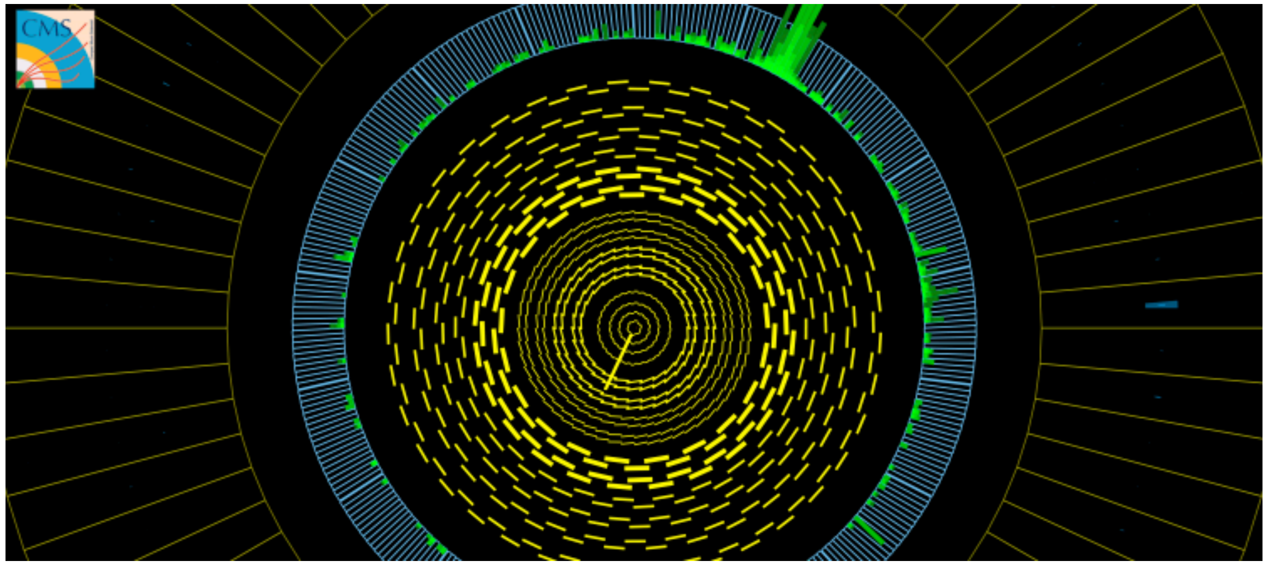


First limits on the dark Higgs parameter space for s(VV) signature

$\sigma(pp \rightarrow s\chi\chi \rightarrow VV\chi\chi) < 0.32 - 0.03$ pb

Disappearing track [arXiv:2004.05153]

- If the decay products of an LLP in the tracker are un-detected, the track "disappears"
  - Neutral, weakly interacting
  - Too low momentum to be reconstructed
- Canonical Benchmark: anomaly-mediated supersymmetry breaking model (AMSB)

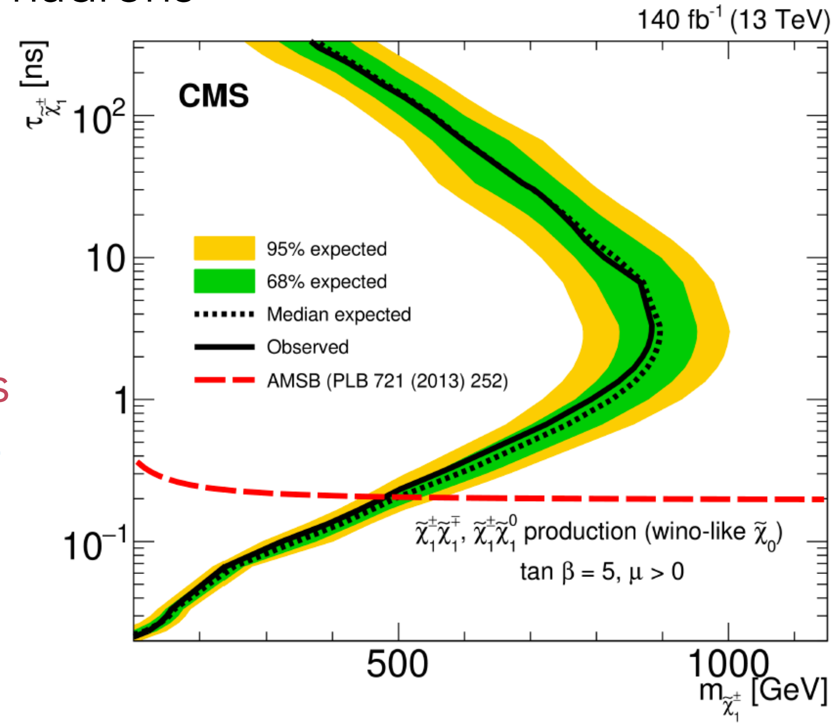


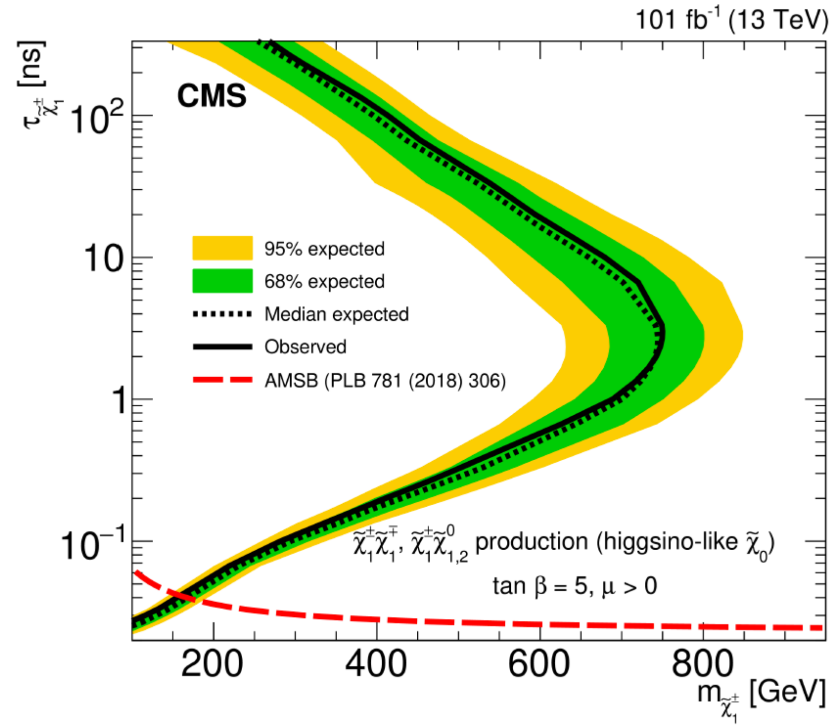
New phase 1 CMS pixel upgrade 3—>4-layer pixel tracker ==> Improves the sensitivity to short particle lifetimes

- **Backgrounds include charged hadrons that interact with detector material, mis-reconstructed leptons and spurious tracks** ==> explore and mitigate possible ways of losing tracker hits, estimate remaining probability to fall into search region
- Track selection: >= 3 missing outer hits ==> rejects most SM tracks, < 10 GeV energy deposited in a cone ==> rejects most electrons and charged hadrons

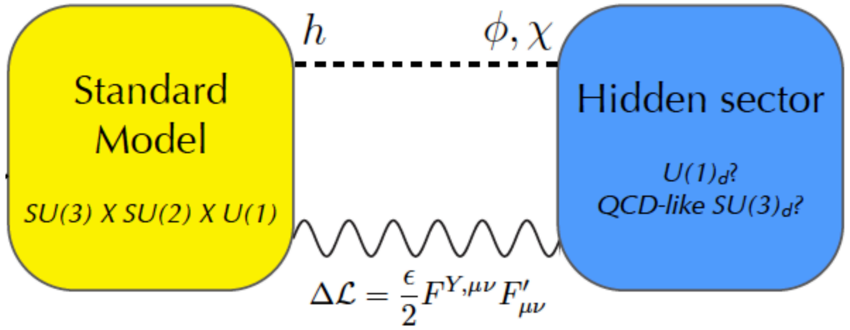
In the context of AMSB, these results exclude charginos below

- Wino-like neutralino case – 884 (474) GeV for a lifetime of 3 (0.2) ns
- Higgsino-like neutralino case – 750 (175) GeV for a lifetime of 3 (0.05) ns



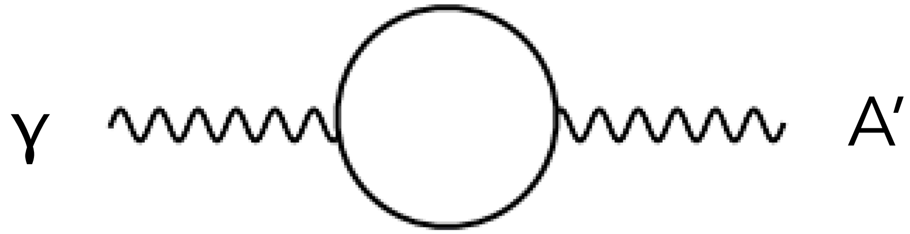


The hidden sector

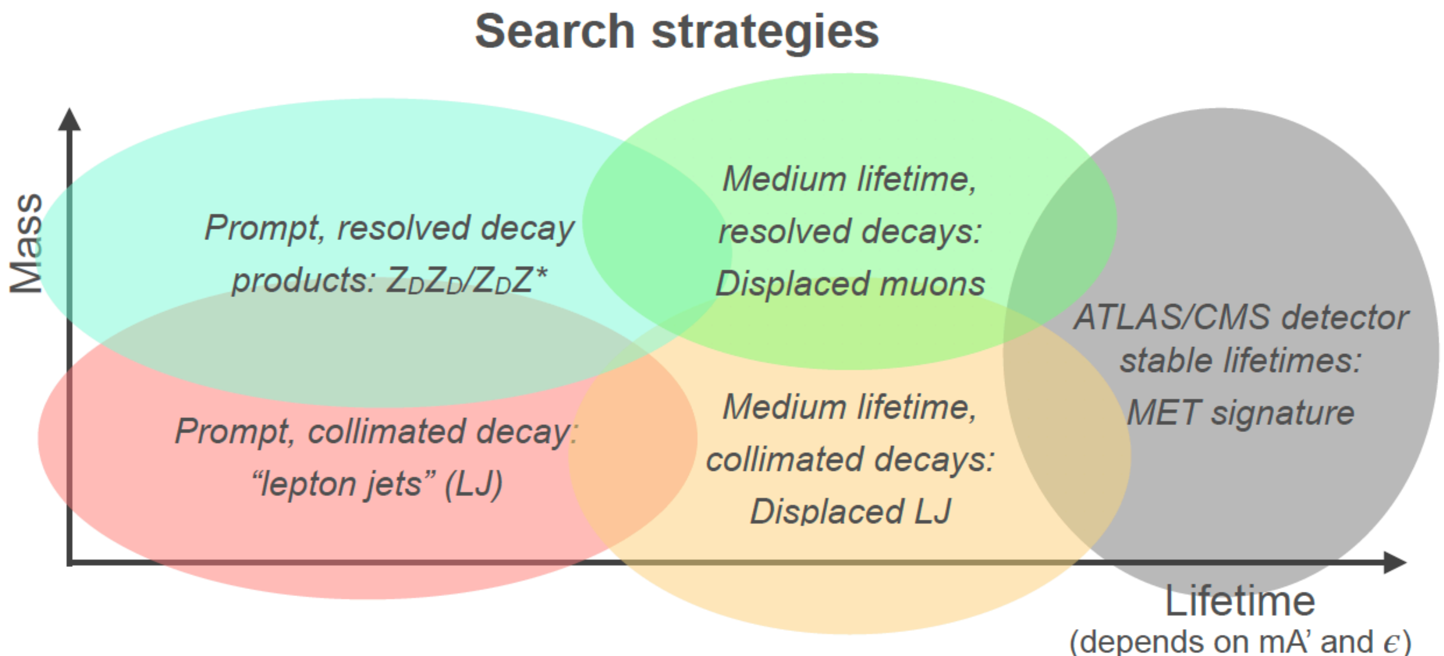


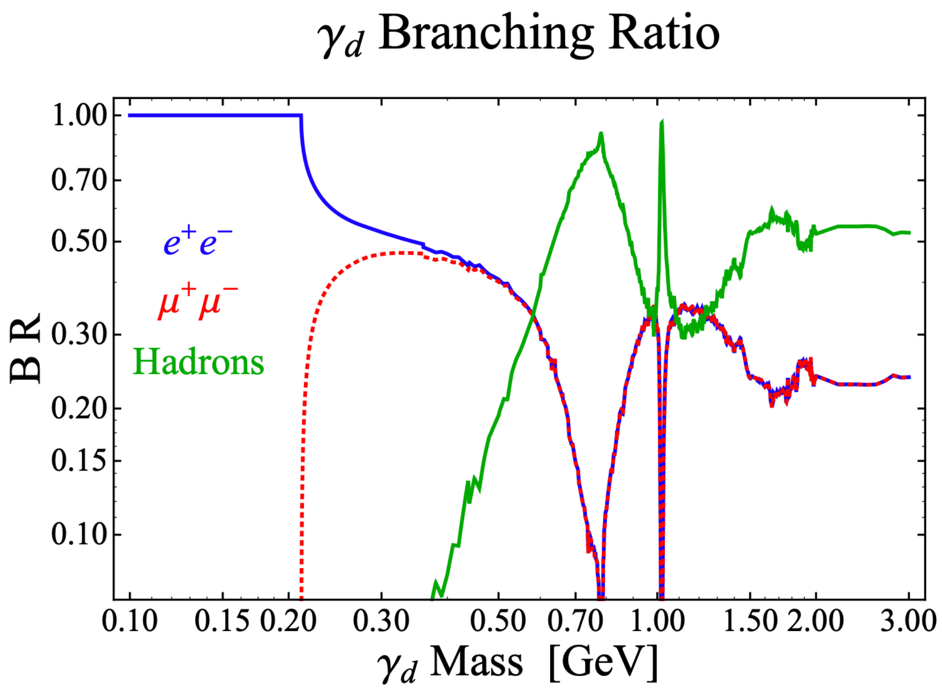
- The "dark sector" consists of particles that do not couple to known SM fields, but interact through a mediator:
  - Dark photons (vector portal), dark scalars (Higgs portal), ALPs (axion), sterile neutrinos…
    - Mediators can provide "portal" to DM candidates or be candidates themselves.

Dark photons, A'

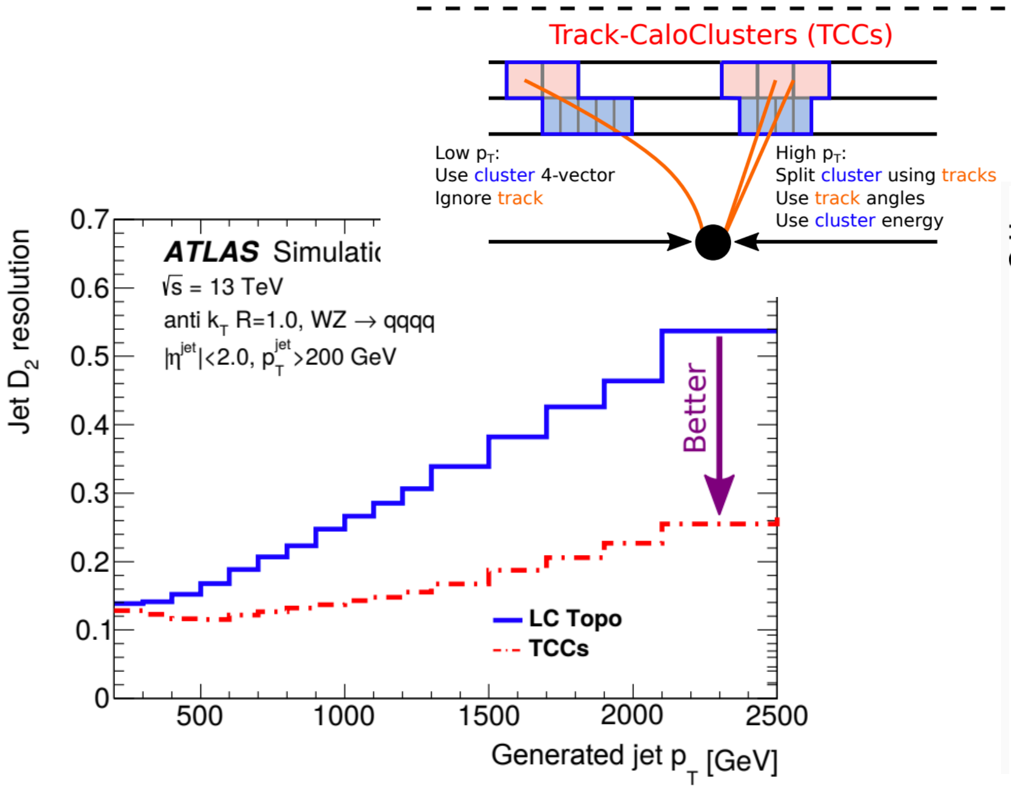


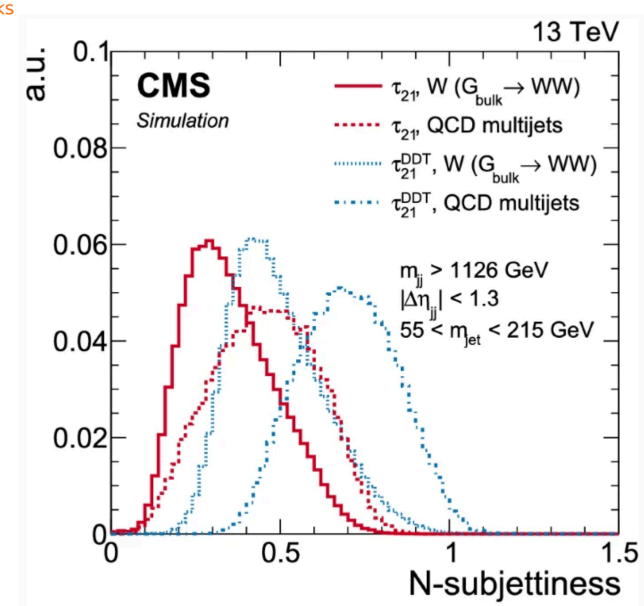
- Add a U(1)D where massive dark gauge boson (A'/Z_D/ γ_D) kinetically mix with SM photon
- Parameters: kinetic mixing term, ε and mA'



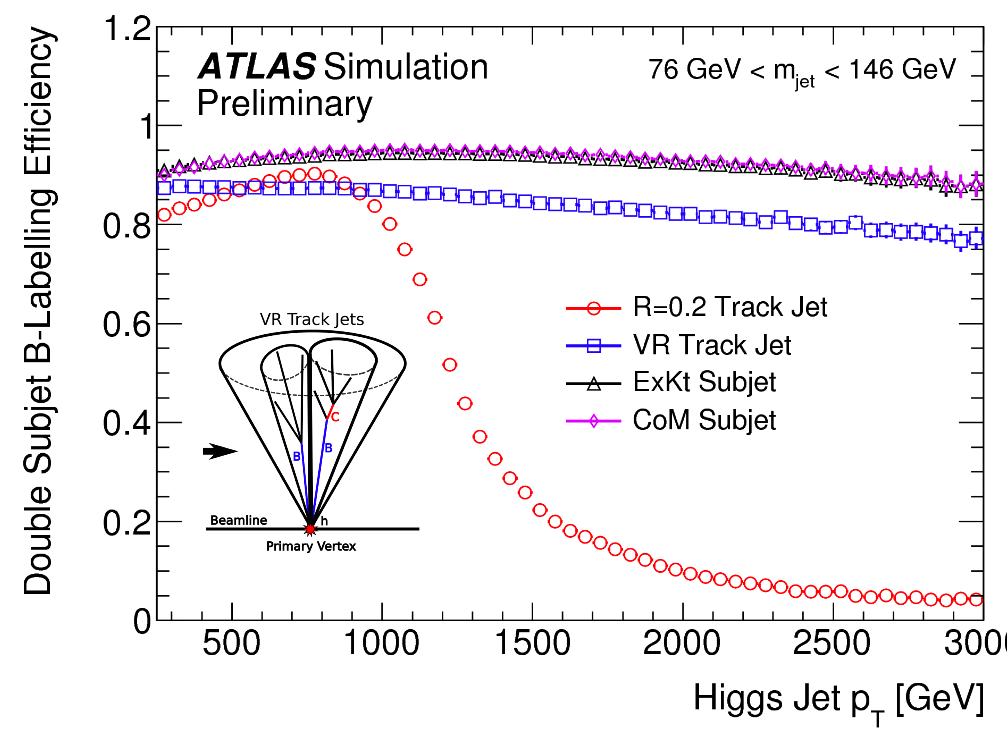


Object performance

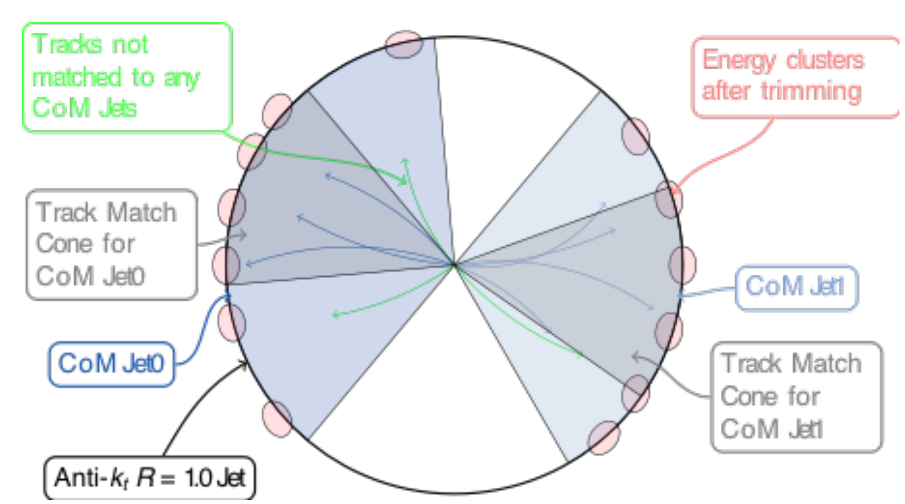




- CMS: PFlow jets with N-subjettiness
- ATLAS: new TCC jets to combine calorimeter info with superior angular resolution of trackers. ATL-PHYS-PUB-2017-010



- H → bb tagging in ATLAS matched pairs of b-tagged R = 0.2 track jets to R = 1.0 jets
  - Breaks down at high pT as b-hadron decays overlap → **switch to variable-radius (VR) jets**
    - or CenterOfMass jets: Boost to Higgs frame to reconstruct two subjets



- **CMS: DeepCSV algorithm** ==> deep neural network applied to small or large R jets by providing information on tracks and secondary vertices associated with the jet input.

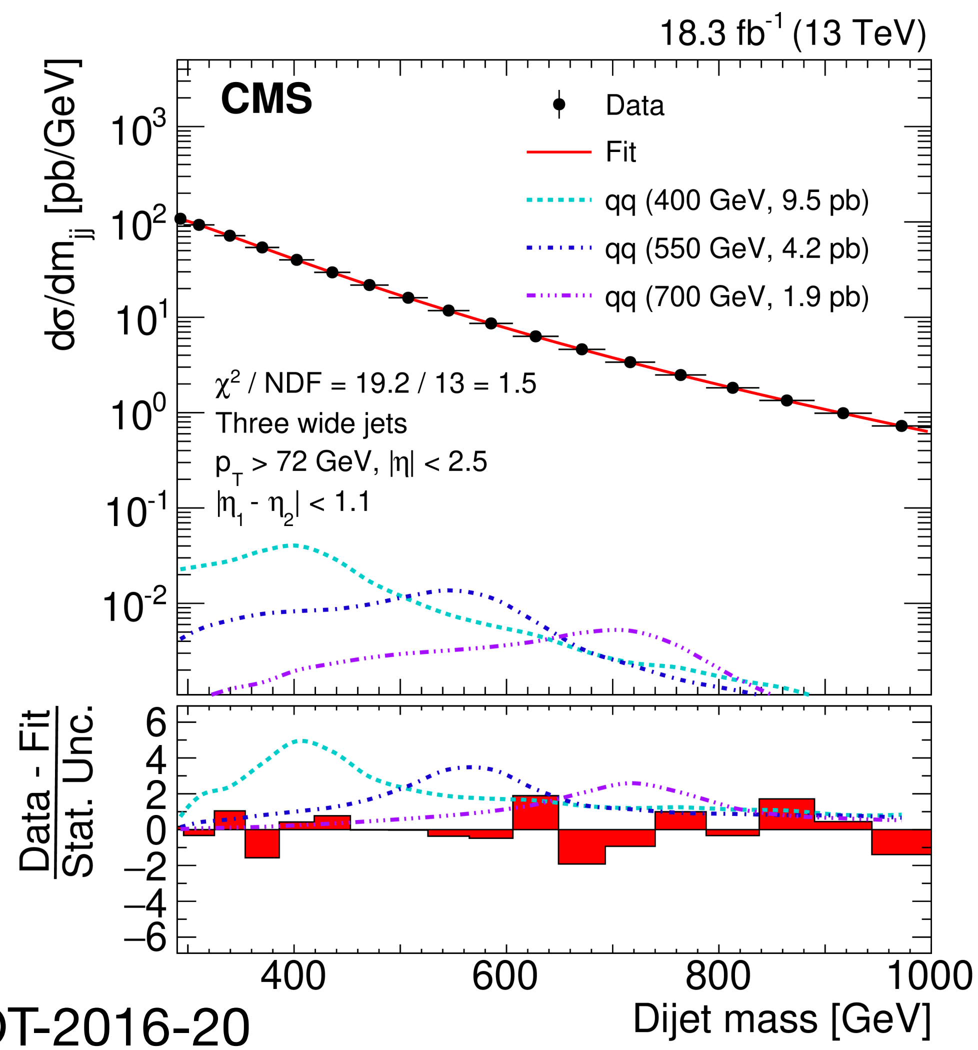
Light mediators at trigger level

- Use selective readout to reduce the event size and therefore allow more events to be recorded, increasing the sensitivity to new physics where rates of SM background processes are very large.

Z'->qq

CMS EXO-19-004

- Use scalar momentum sum for trigger and save calorimeter jet info **only**
- Require three jets to get sufficiently high HT
- Fit invariant mass of two hardest jets and search for excesses

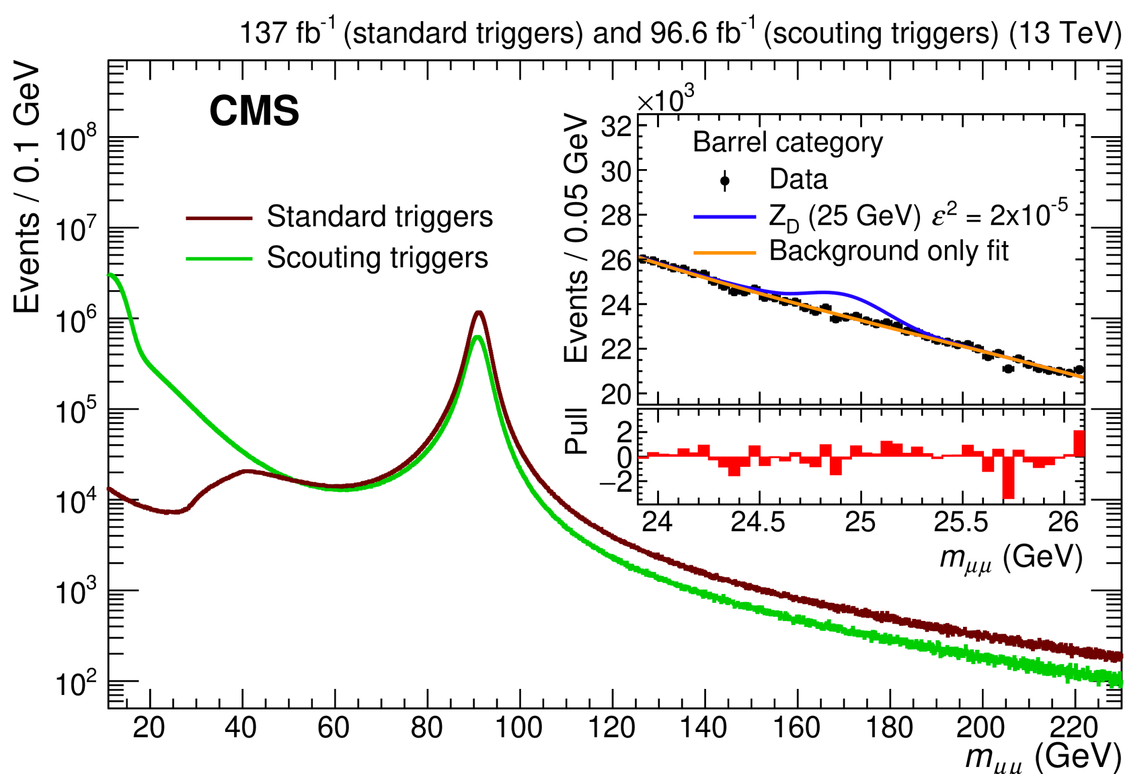


ATLAS EXOT-2016-20

Z'->μμ

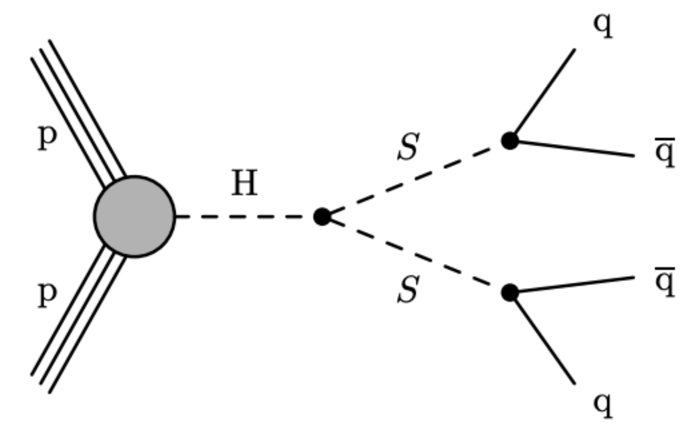
CMS EXO-19-018

- Standard triggers access lower masses for leptons than jets ==> still limiting for very low mass resonances
- **First ever trigger-level muons!**
- Save only 4- momentum, isolation, track quality information at very high rates

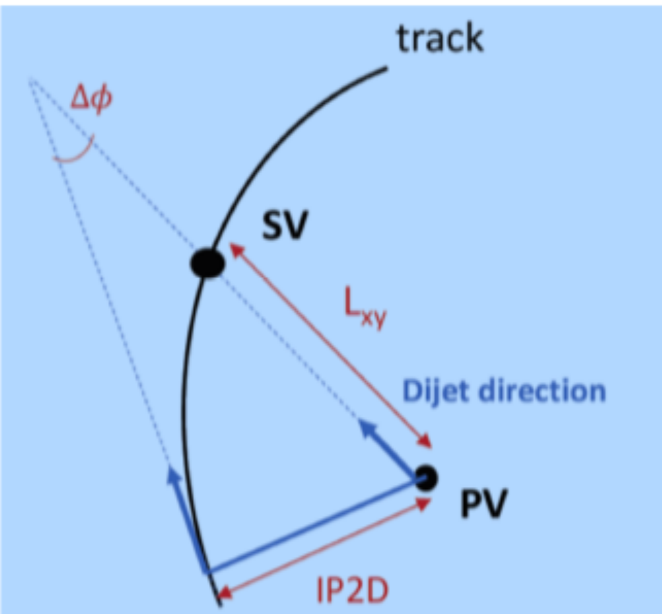


10x - 100x gain below 45 GeV thanks to trigger level analysis

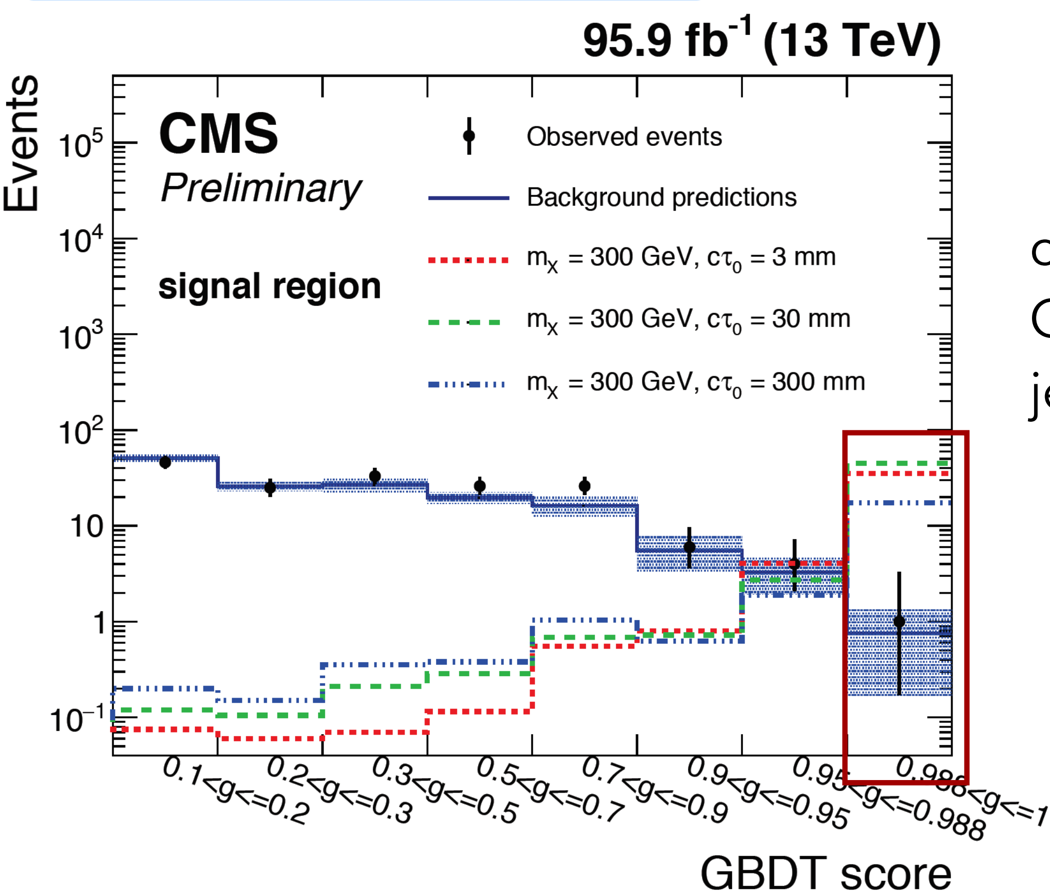
Displaced jets [EXO-19-021]



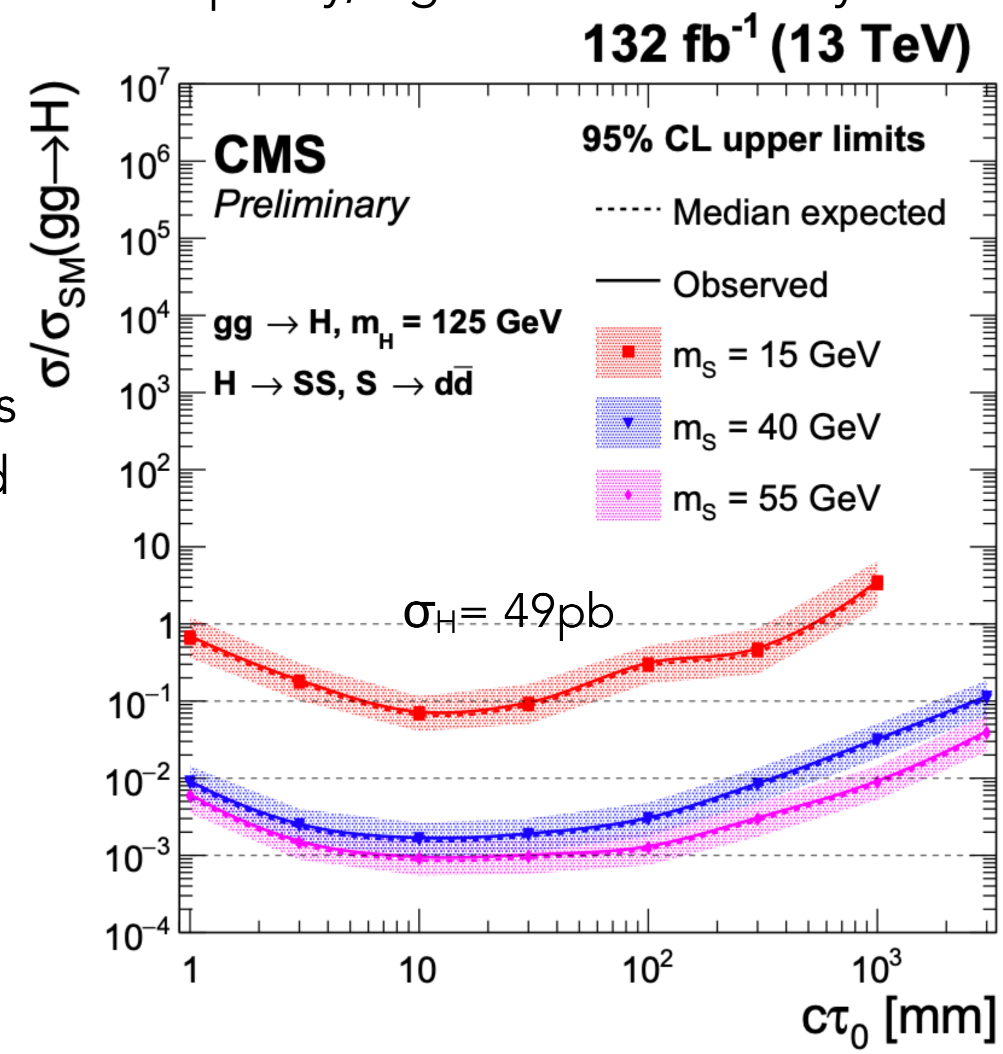
- Distinctive topology : pair of jets originating at a secondary vertex
- **Different signal models targeted: LLP decaying to q-qbar, Exotic decays of Higgs: gg → H → 2S, S → qq where cτ ~ 1mm to 3m**



- Highlights:
  - Dedicated displaced triggers for 2017 and 2018 data
  - Dedicated secondary Vertex reconstruction
  - BDT with variables like vertex track multiplicity, signed IP2D and Lxy



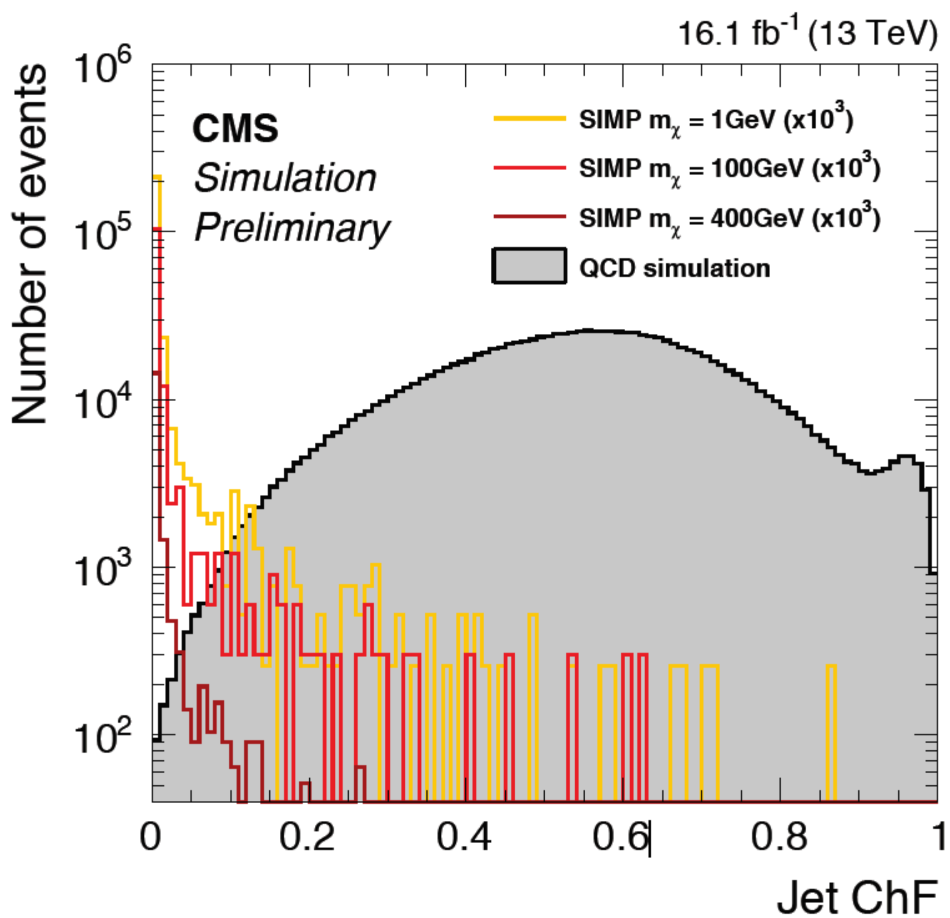
combined with a previous CMS search for displaced jets



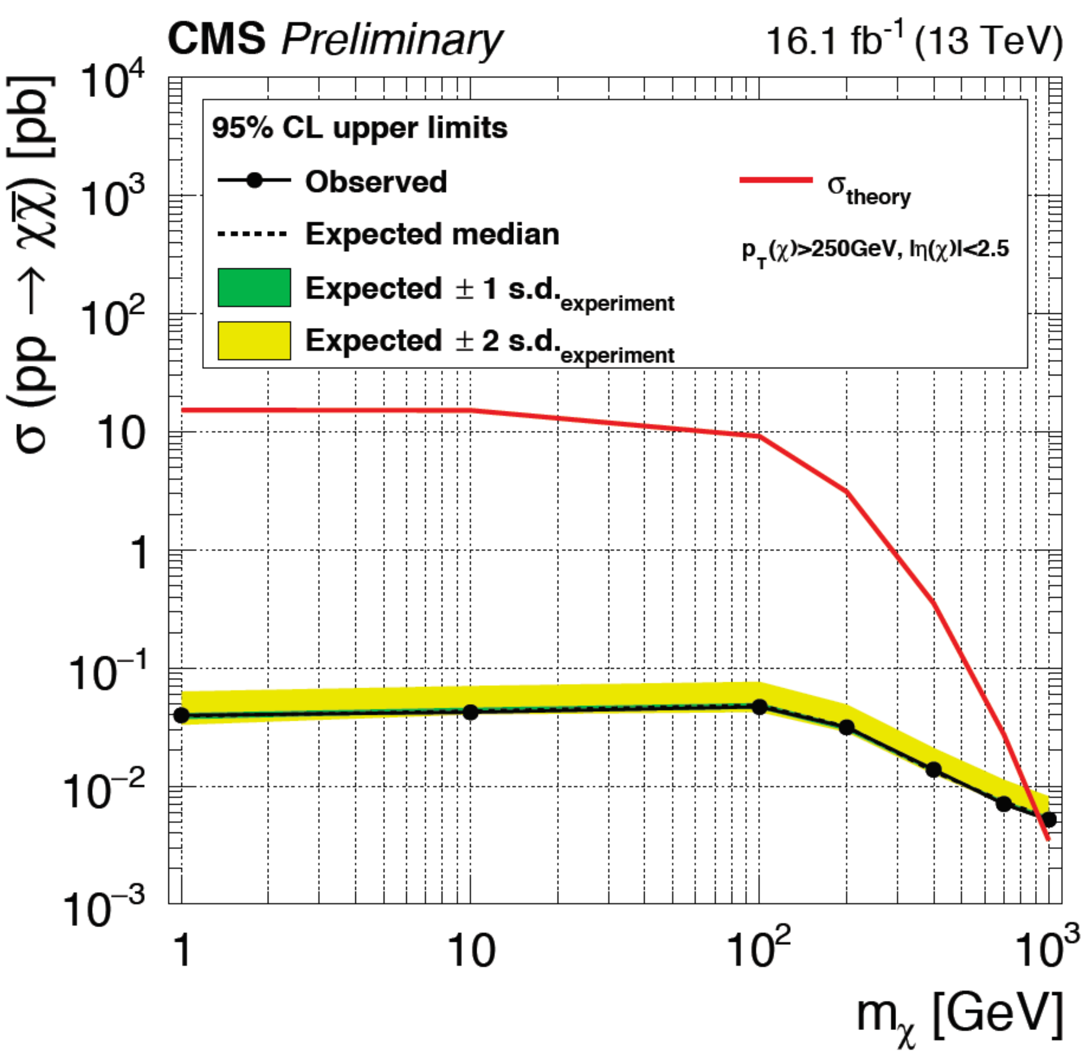
Search for Strongly Interacting Massive Particles [CMS-PAS-EXO-17-010]

NEW

Manifesting themselves as a **pair of jets without tracks**



- Two back-to-back jets with low charged energy fraction ChF with p_T> 550GeV and photon veto to get rid of γ+ jets events
- Modified reconstruction: reconstruct jets using both the first and second vertex



- Signal region:
  - ChF of both jets < 0.05
  - Using both first and second vertices
- Data-driven estimation of QCD
- **Set first limits on a potential SIMP signal, excluding SIMP masses up to 900GeV at 95% CL.**
  - **Model independent: σ (95%) = 0.18 fb**

Dark Matter Summary plots