New physics searches at ATLAS

Zhijun Liang（梁志均）

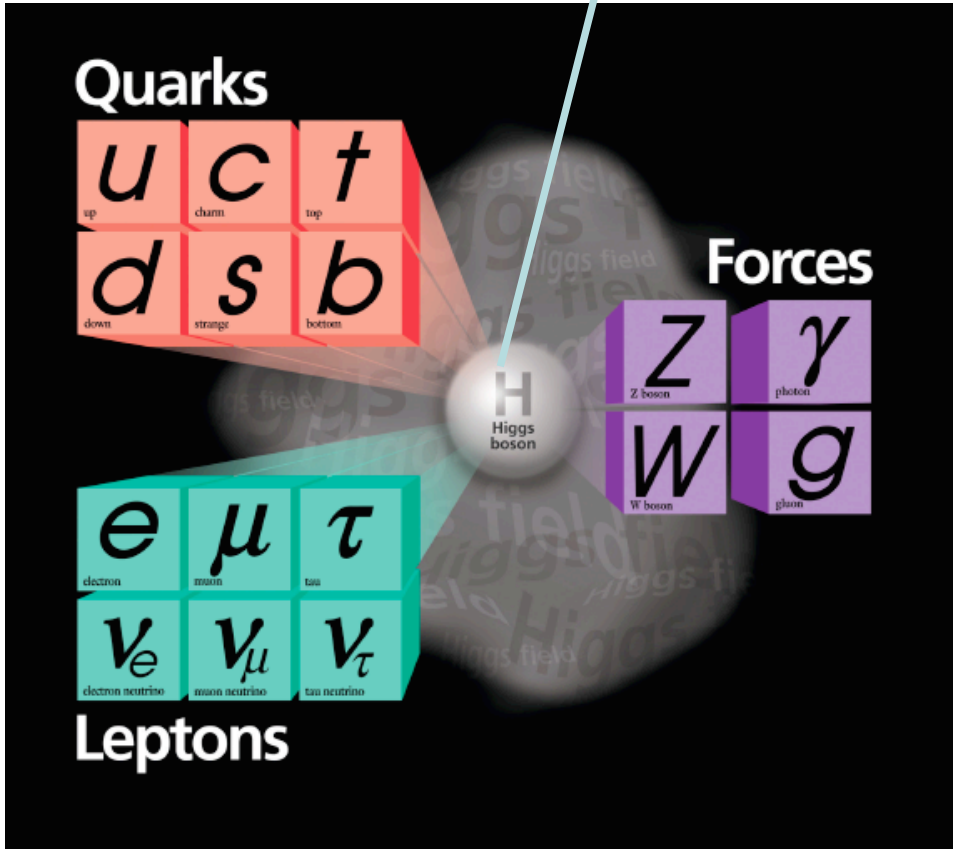
Institute of High Energy Physics ,
Chinese Academy of Science
(中国科学院高能物理研究所)

Composite 2019, GuangZhou, Nov 21-23

Motivation

Portal to dark matter or dark sector?

4th generation? Compositness? Lepton quark?



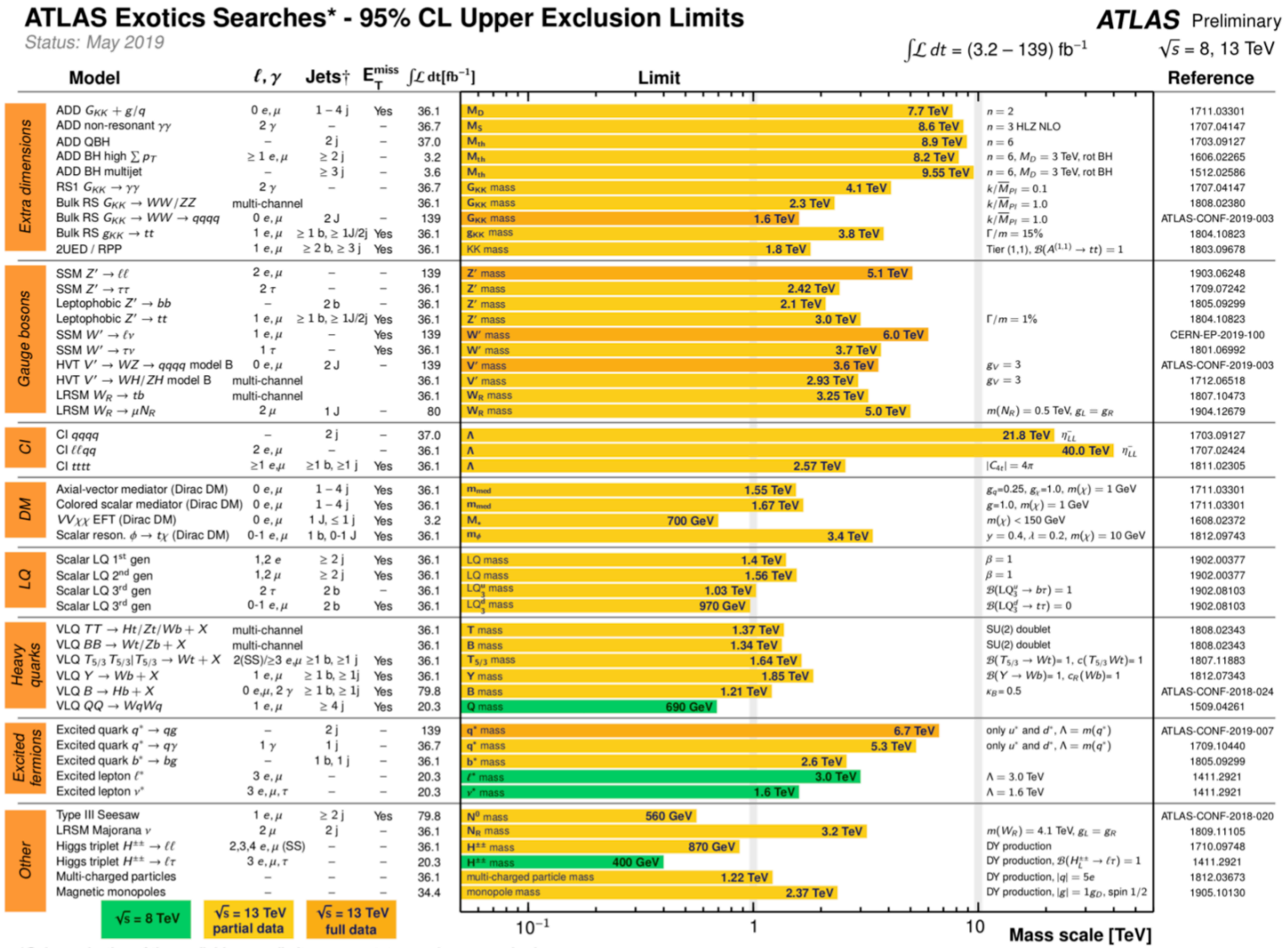
New heavy vector boson (W', Z')?

Dark partners?

Heavy leptons ? neutrino mass?

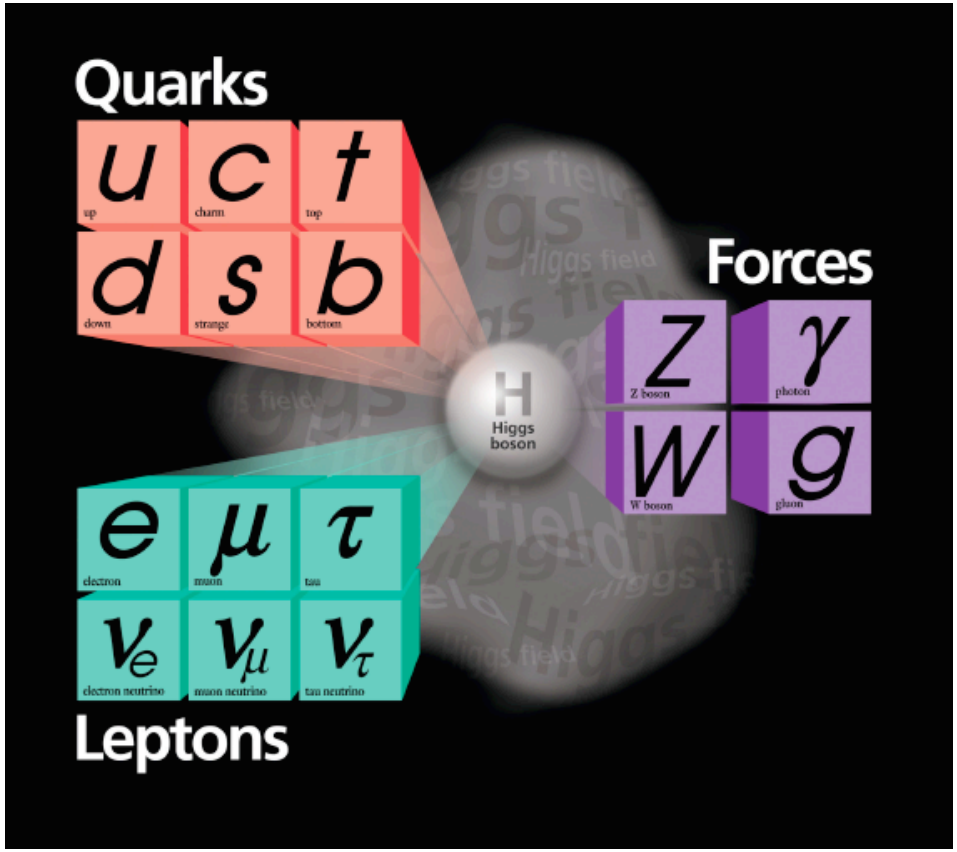
ATLAS Exotics search summary

- A final state often probes multiple theories



Di-jet resonance

Compositness?
$q^* \rightarrow qq$

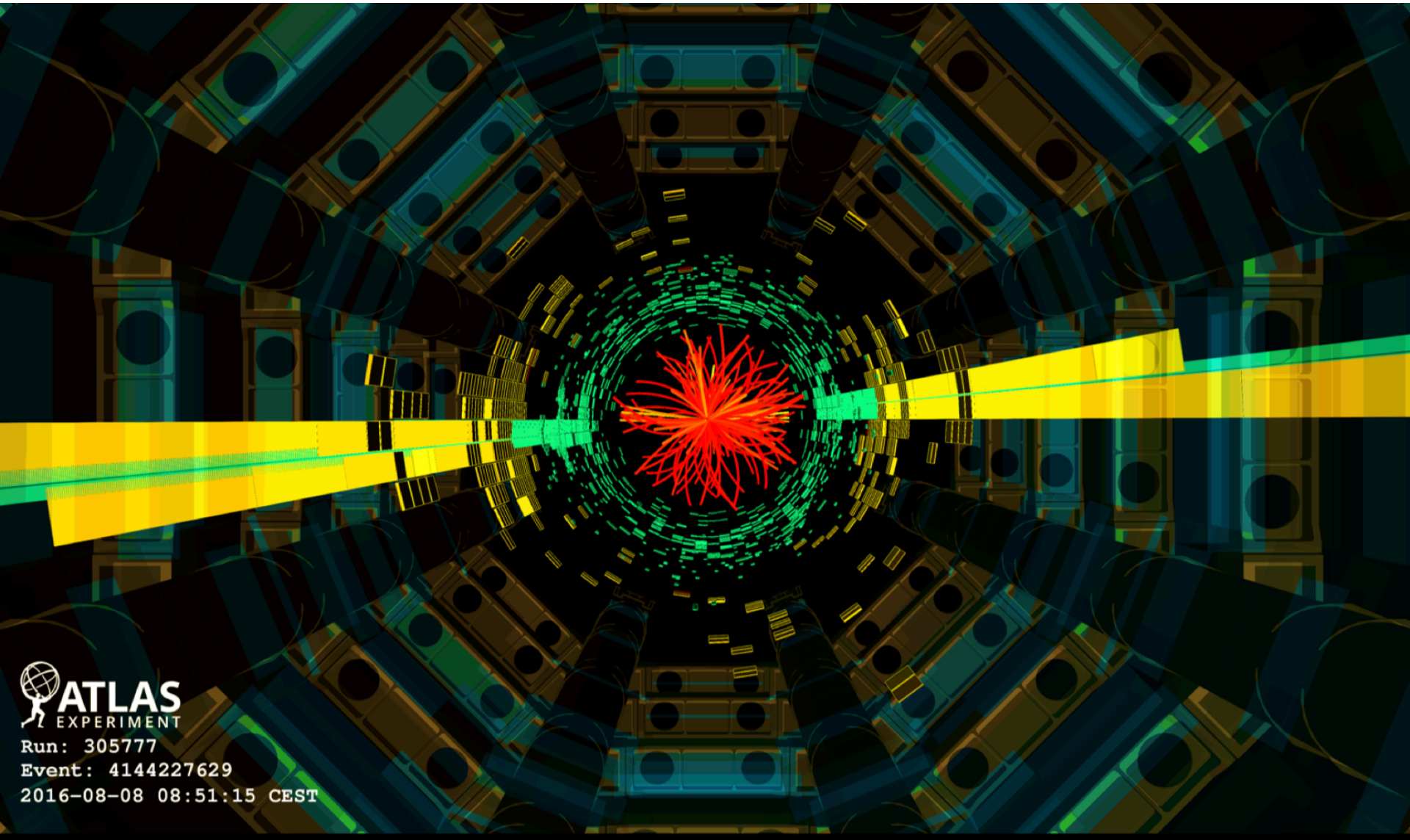


New heavy vector boson (W', Z')?

$W' \rightarrow qq$
$qq \rightarrow Z' \rightarrow qq$

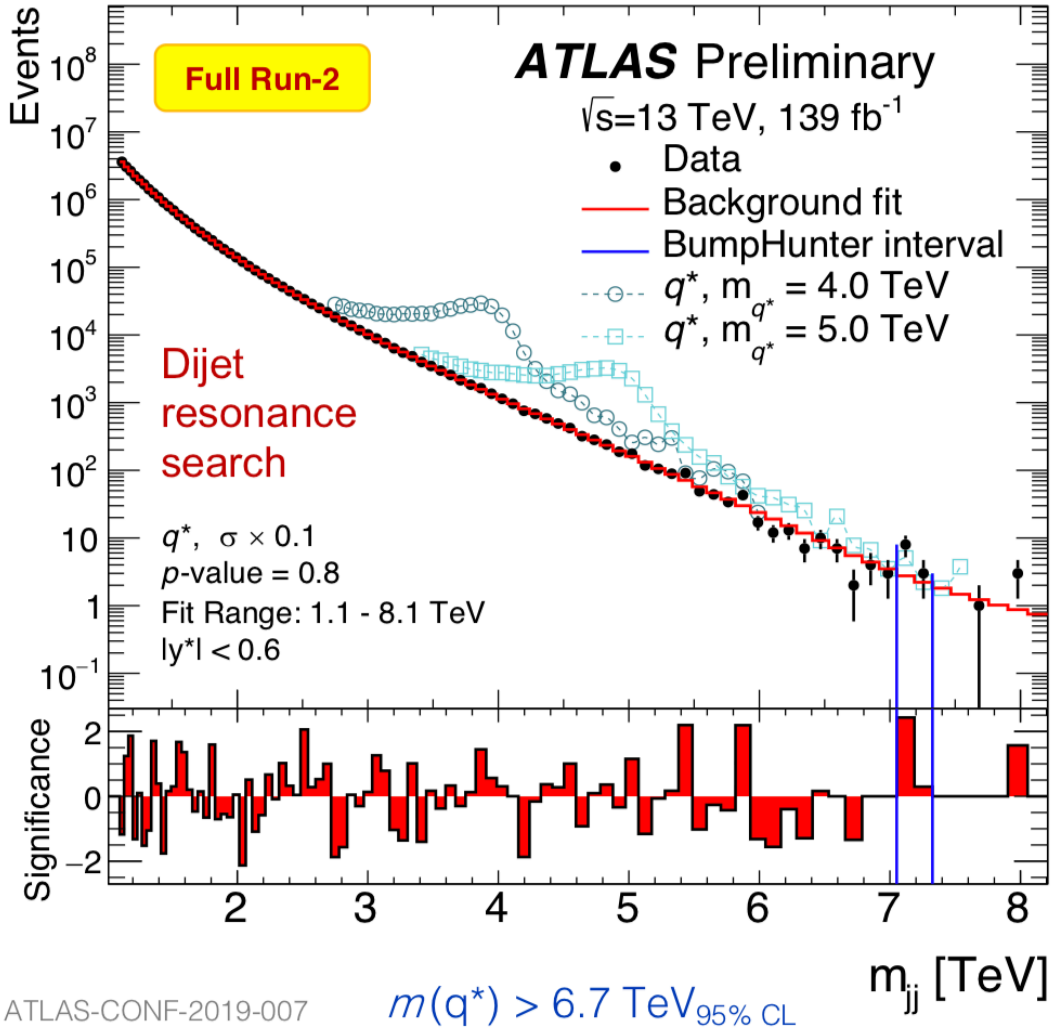
Di-jet resonance searches

Highest-mass central dijet event of 8.0 TeV selected in resonance search



Di-jet resonance searches

- Smoothly-falling background: fit to the data - no
- Mass limit at set at 6.7 TeV on a benchmark q* →gq.

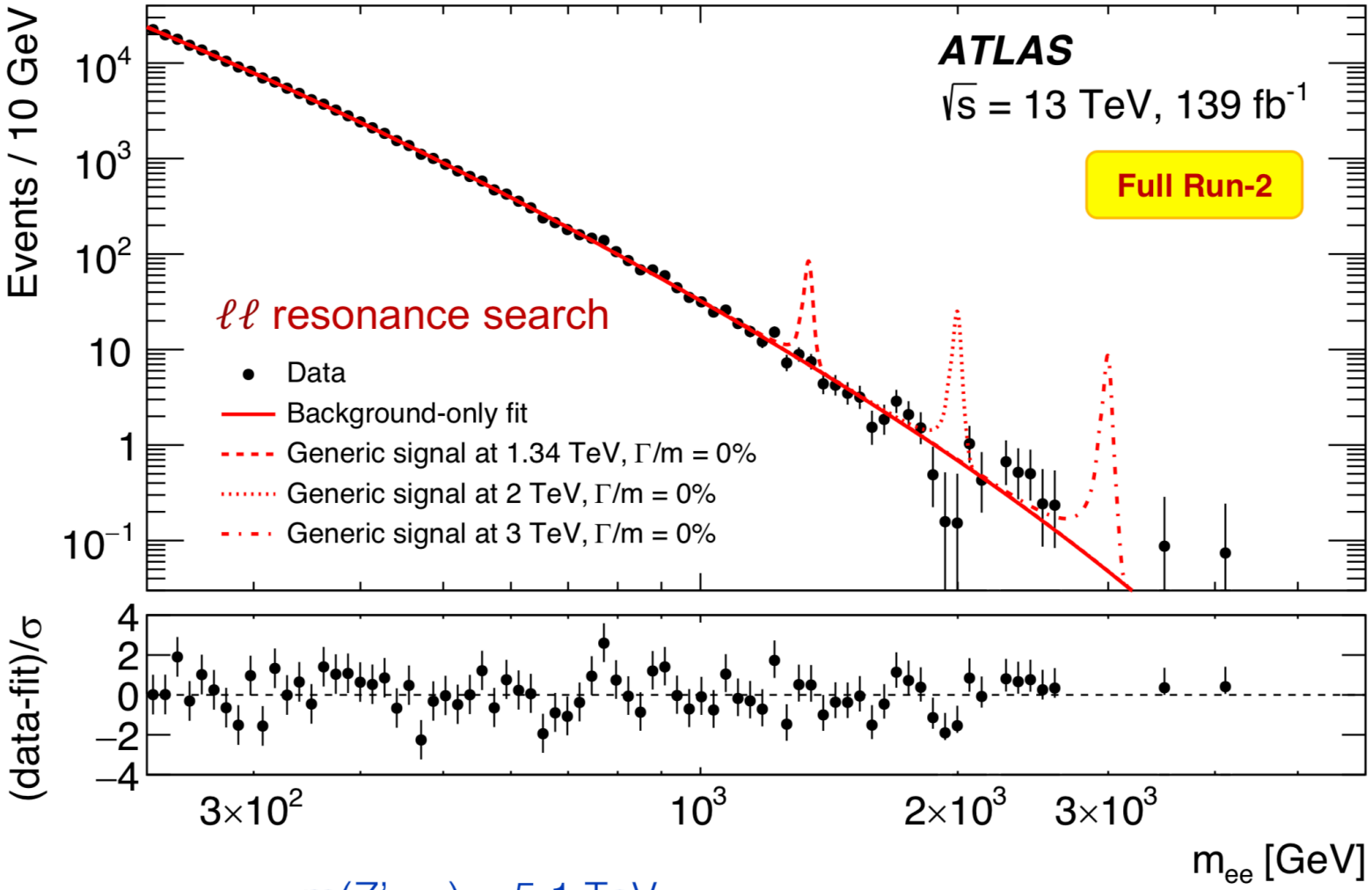


ATLAS-CONF-2019-007

$m(q^*) > 6.7\ \text{TeV}_{95\%\ CL}$

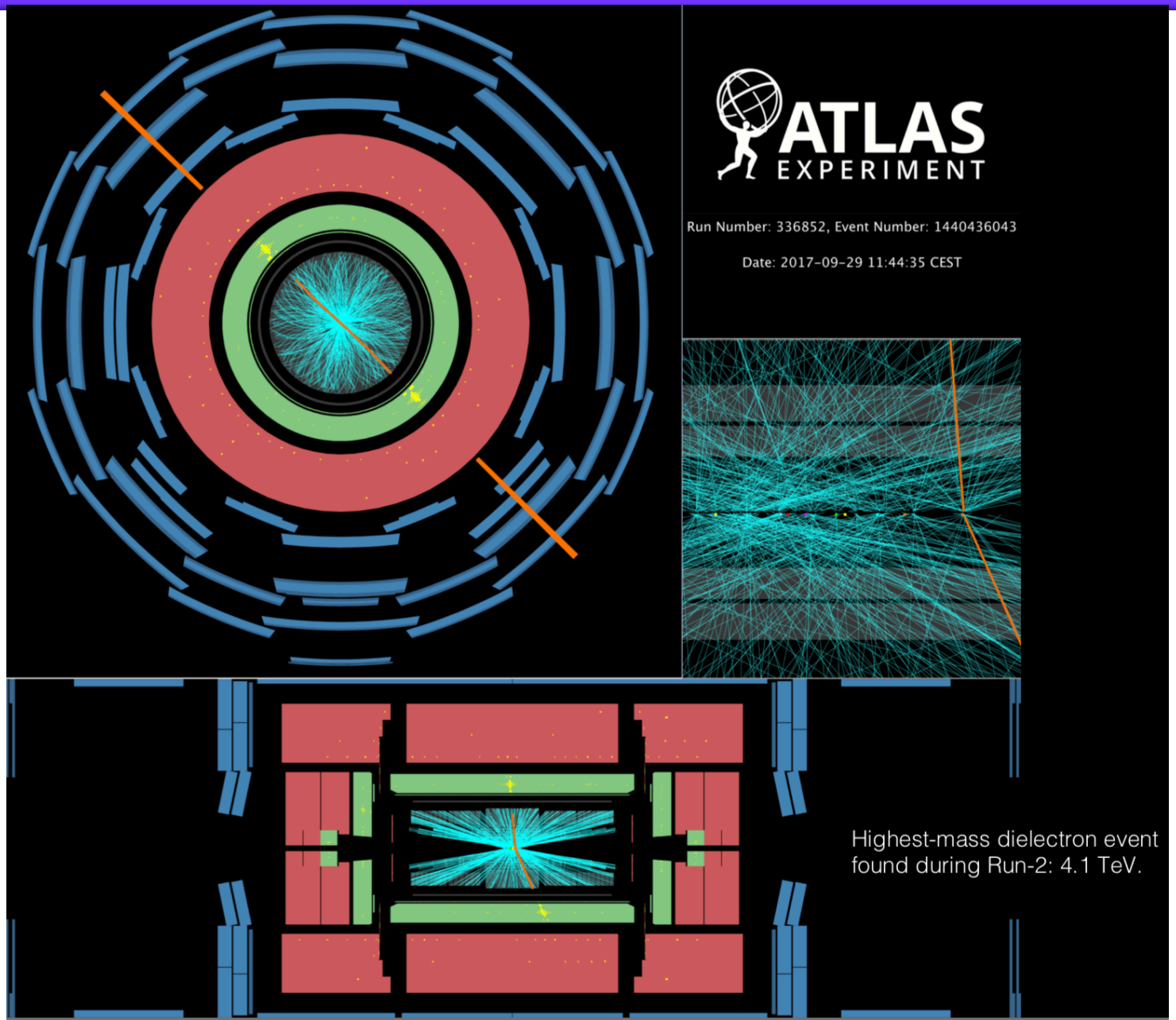
Di-lepton search

- Limits set on benchmarks Z' (for ex. Z'SSM excluded up to 5.1 TeV)
- Dedicated high-pT lepton ID to improve sensitivity



arXiv:1903.06248 $m(Z'_{SSM}) > 5.1\ \text{TeV}_{95\%\ CL}$

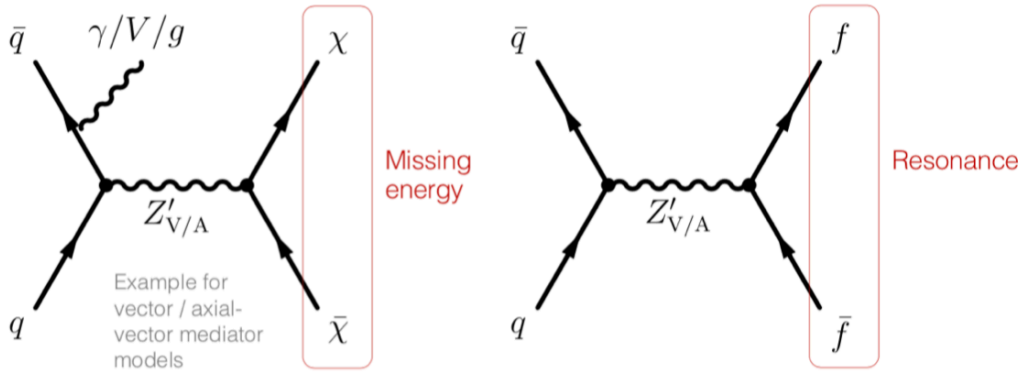
Di-lepton search

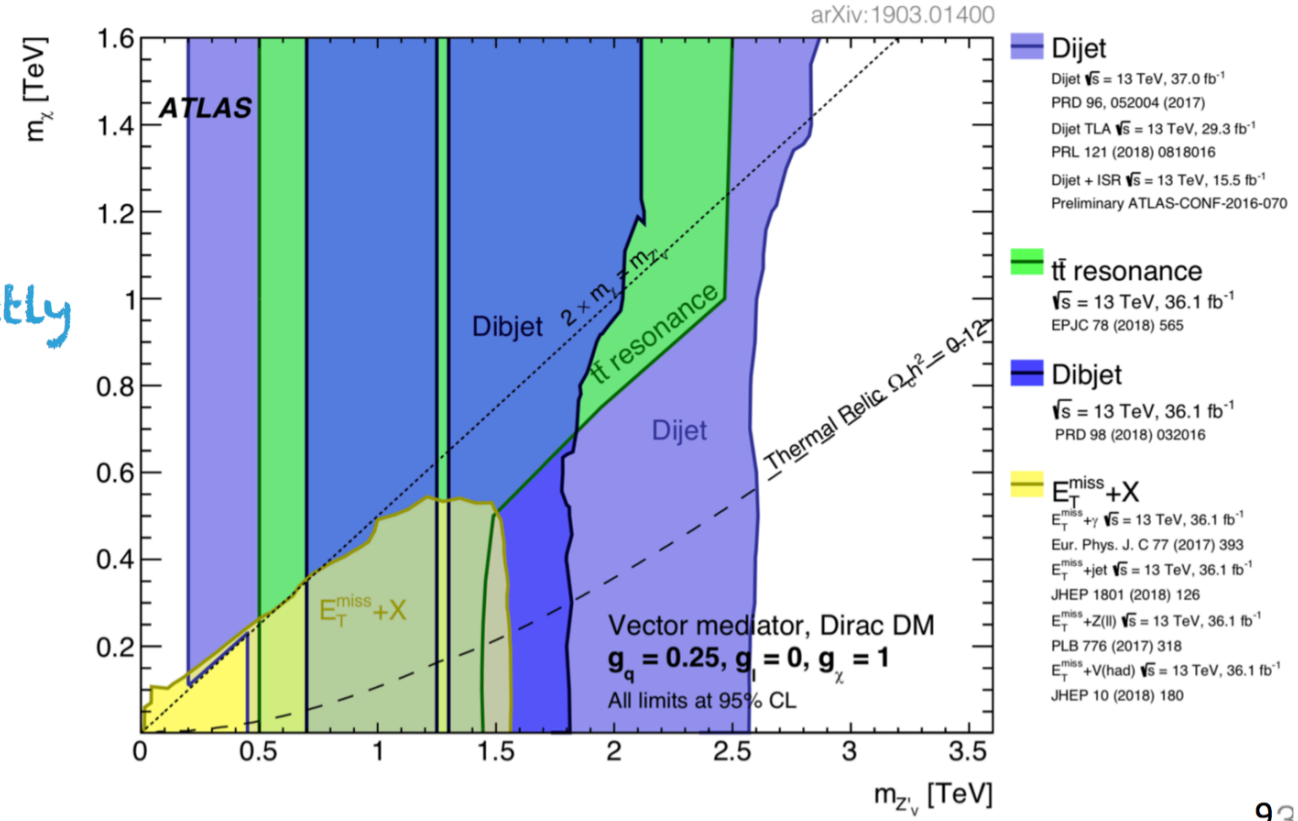


Dark matter search

Portal to dark matter or dark sector?
H→XX

If produced at LHC, DM will be Mediated by particle can directly search for.

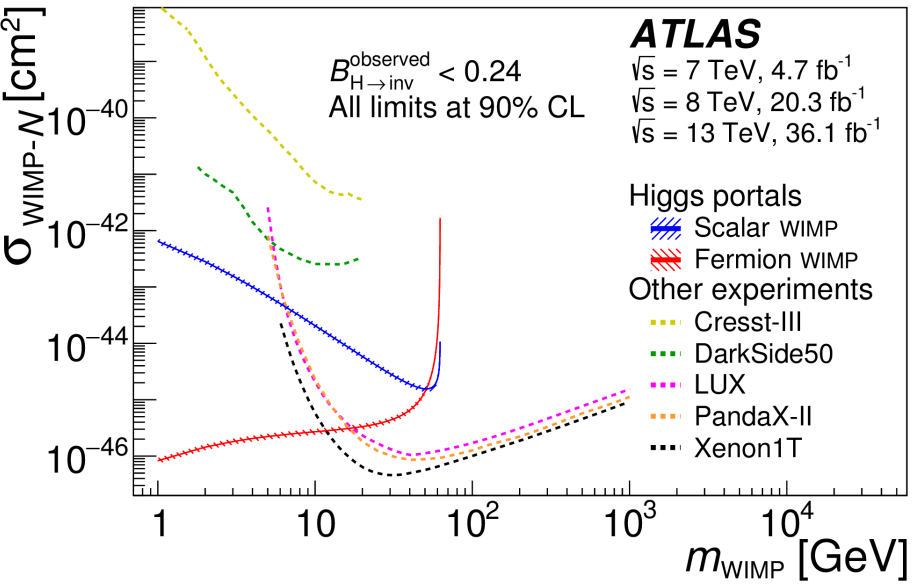


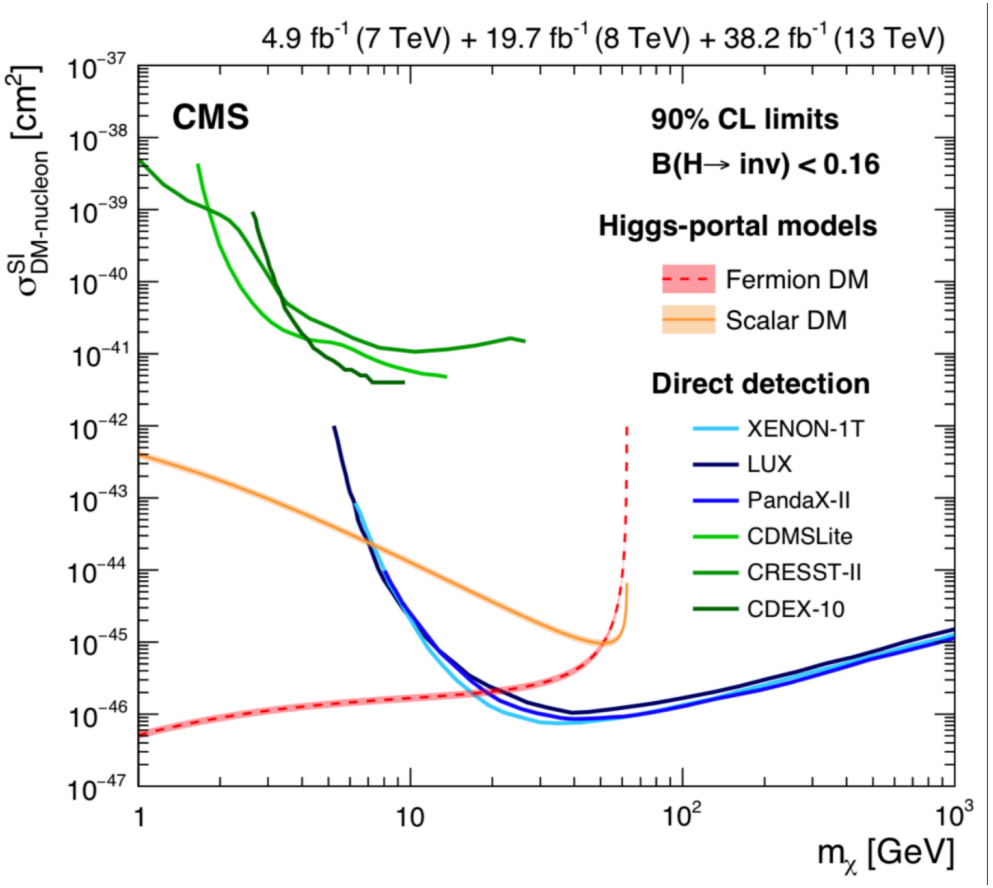


Dark matter searches

ATLAS: arXiv:1904.05105
CMS: arXiv:1809.05937

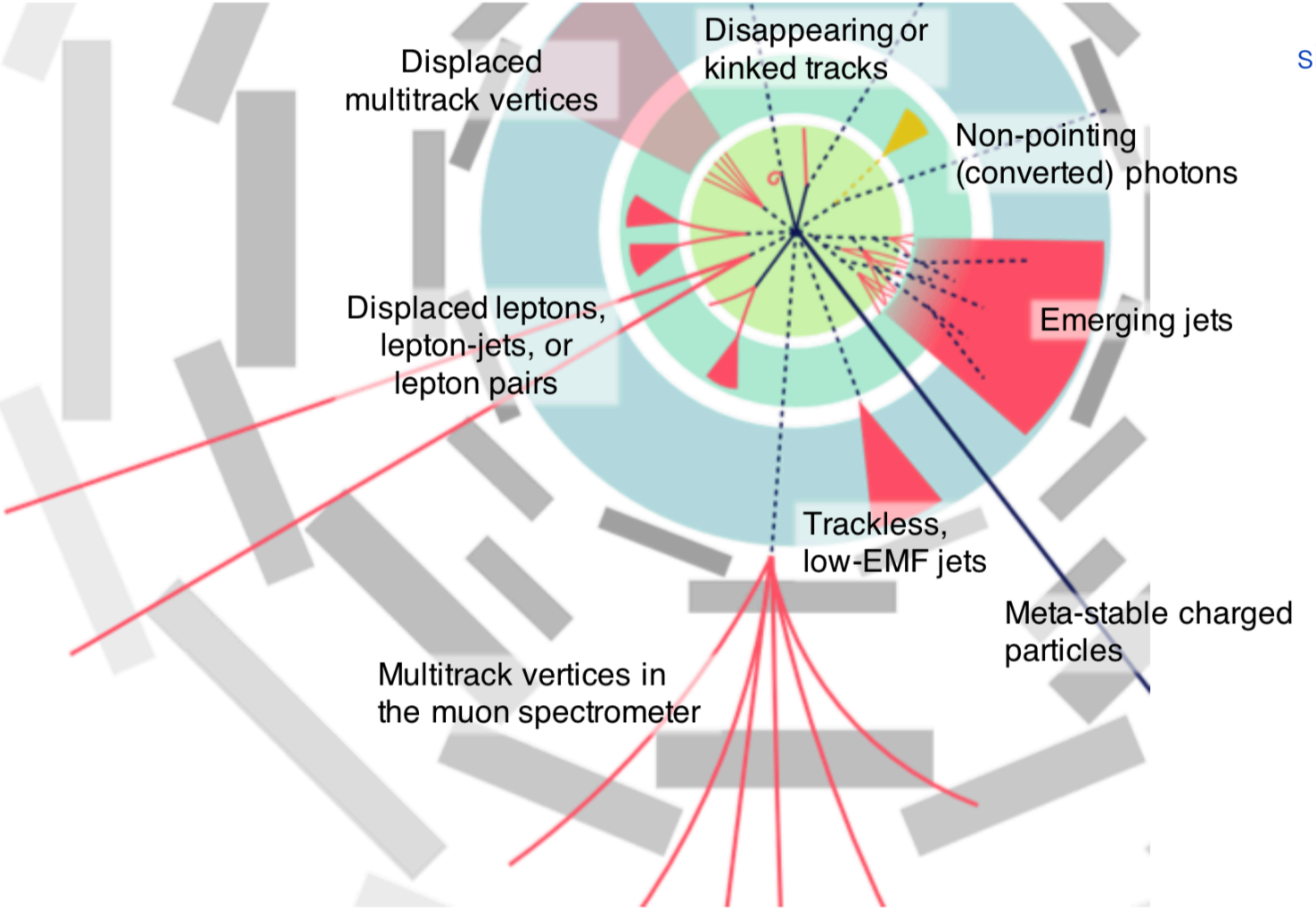
- If light enough, Higgs boson can decay to DM (H → invisible)
  - BR(H→inv) < 26% (17% expected) for ATLAS
  - BR(H→inv) <19% (15% expected) for CMS





Long-lived particle search

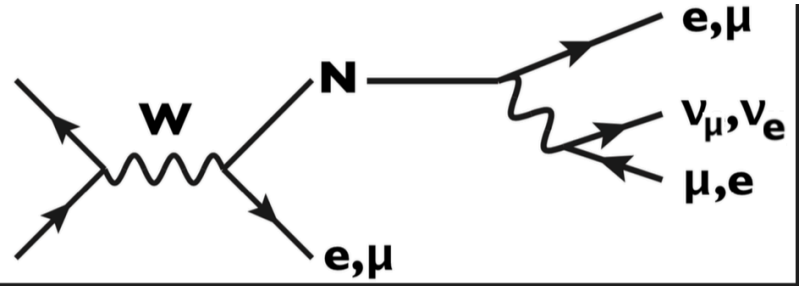
Long-lived particles can occur in case of weak couplings, small phase space (mass degeneracy), high virtuality (scale suppression)

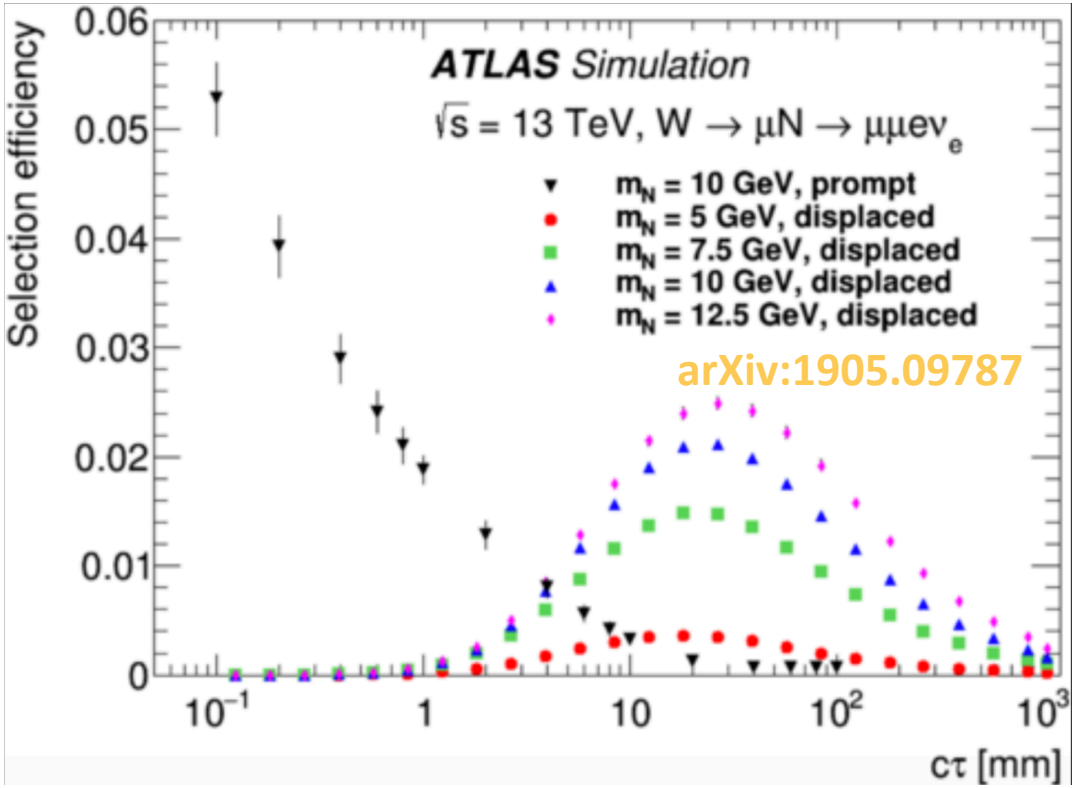


Diverse set of signatures that need to be pursued by dedicated, usually non-standard analyses, some requiring special triggers

Long-lived particle search: Type-I heavy neutrino

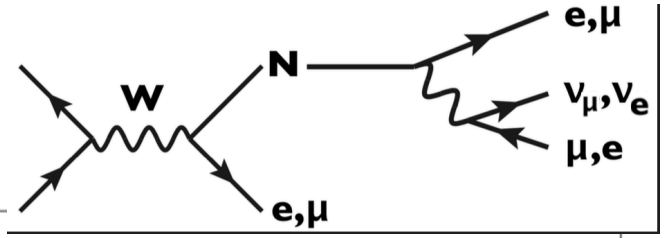
- Displaced analysis Selection:
  - Displaced vertex of two opposite-sign tracks μμ or μe (4-300 mm)
  - One prompt μ
- Mjaor Background : single top and multi-fake displaced tracks

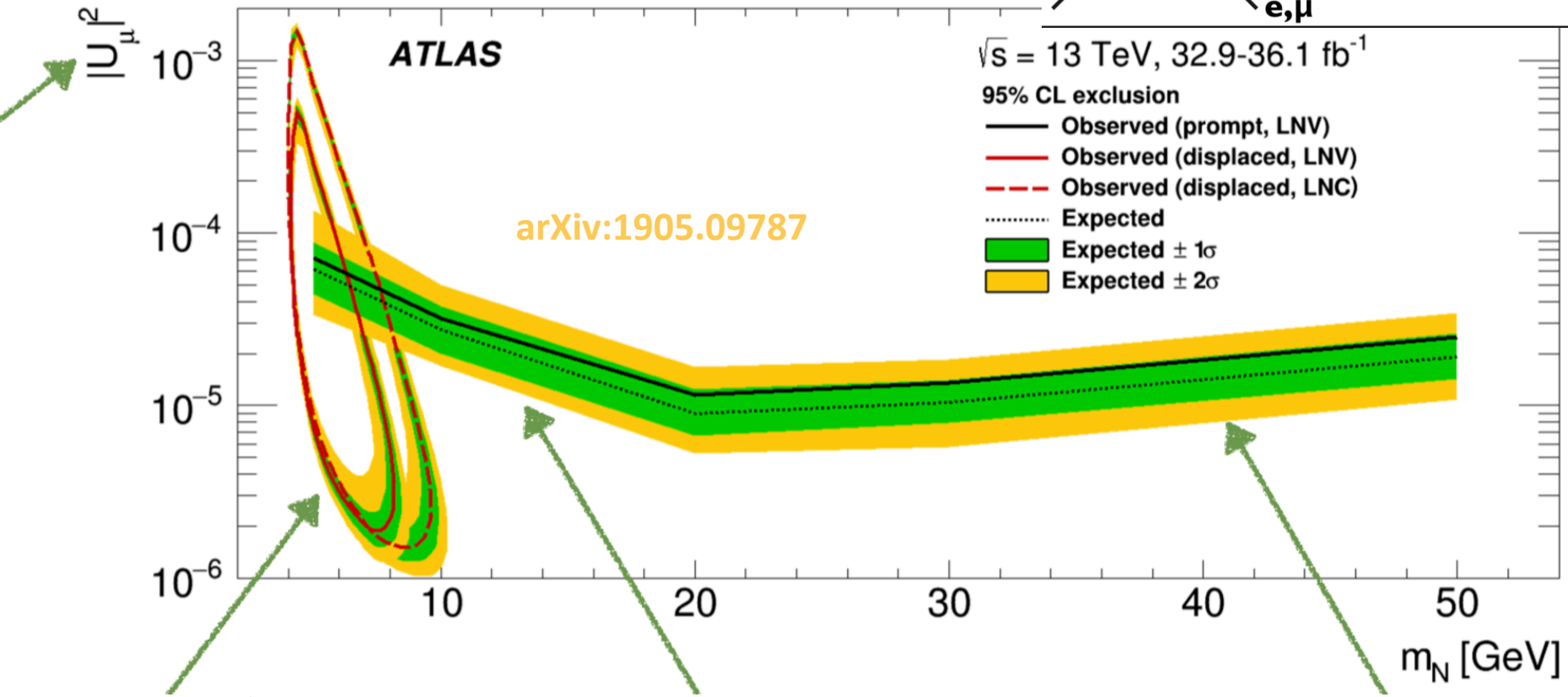




Long live particle search: Type-I heavy neutrino

- Both prompt analysis and displaced used.
- Display analysis improve sensitivity in low mass.





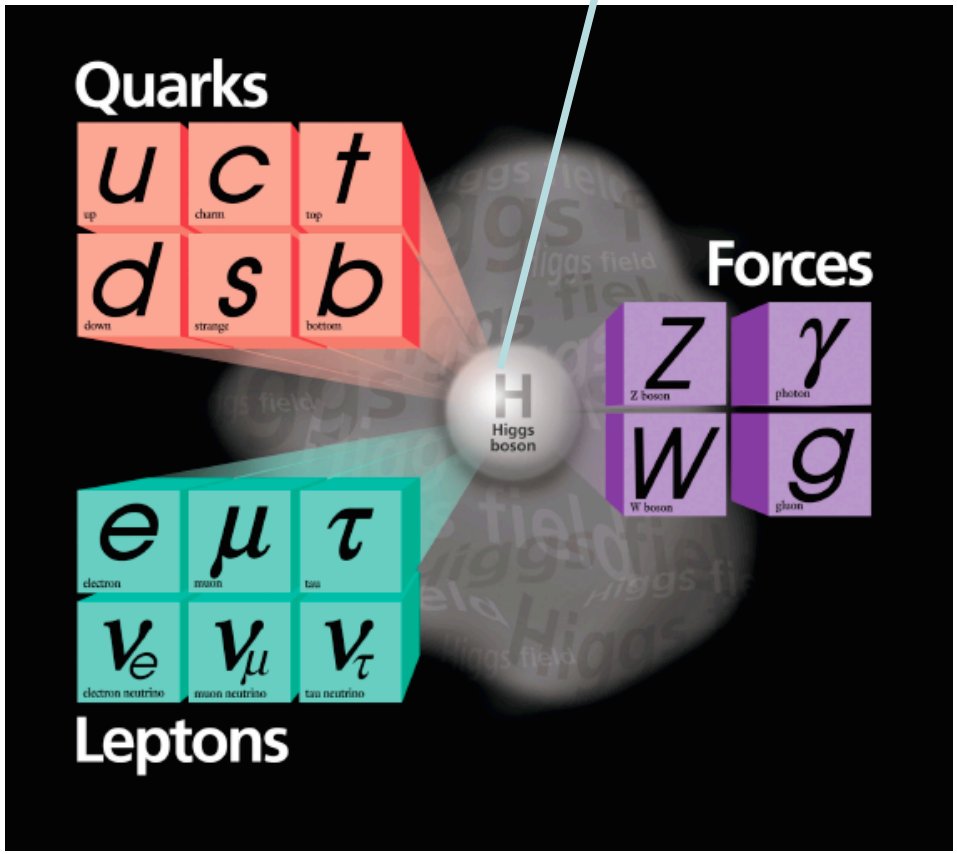
Displaced analysis improving sensitivity

Lower prompt sensitivity due to longer lifetime

Di-boson and Di-Higgs search

Extra-dimensions scenarios with radion/G→WW/ZZ/

Extended sector?
h→HH



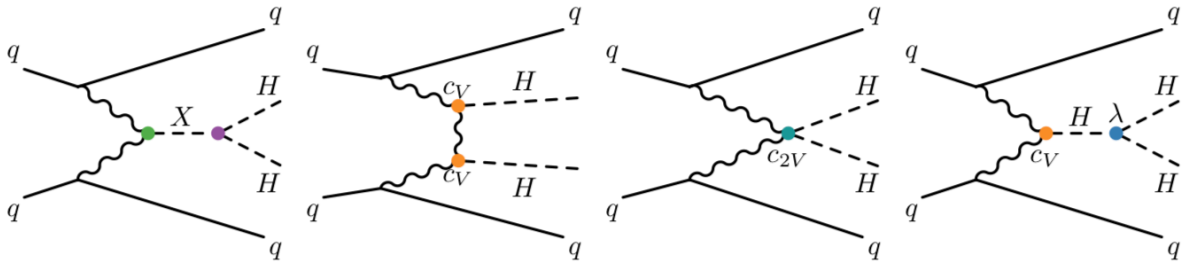
New heavy vector boson (W', Z')?

W'→WZ, Z'→WW

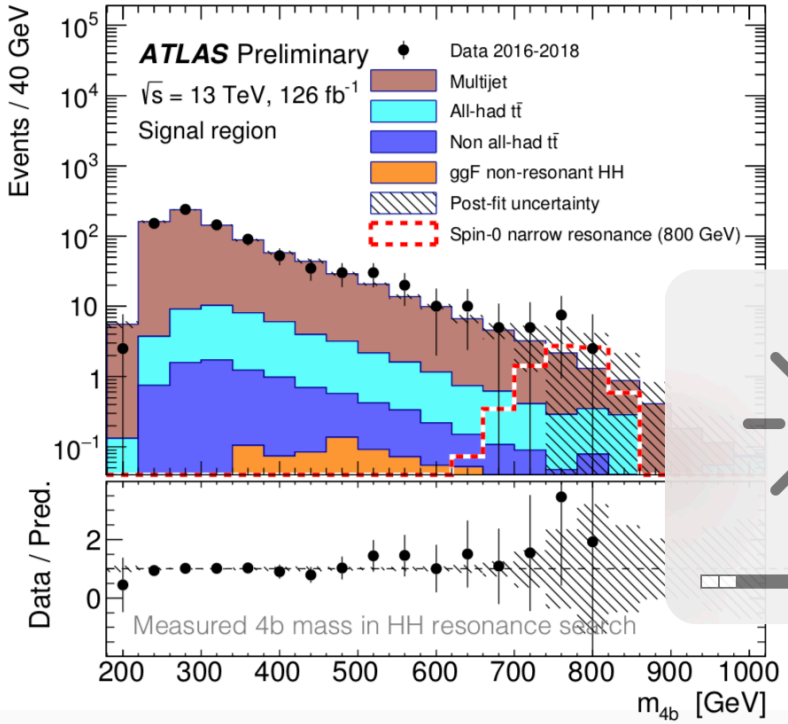
Di-Higgs: Double the Higgs for double the difficulty

Search for HH production in 4b channel through VBF

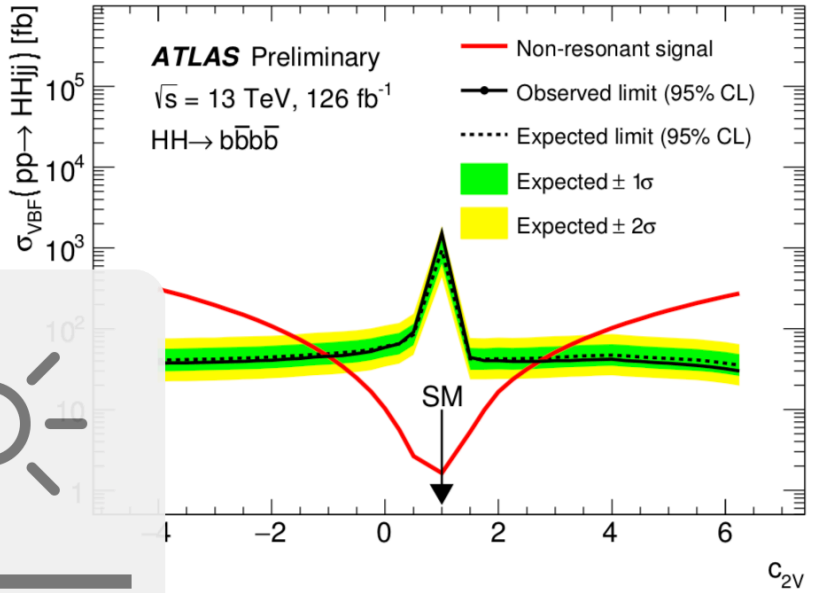
Backgrounds from data using m_{bb} sidebands



ATLAS-CONF-2019-030



SM: $\lambda = c_V = c_{2V} = 1$

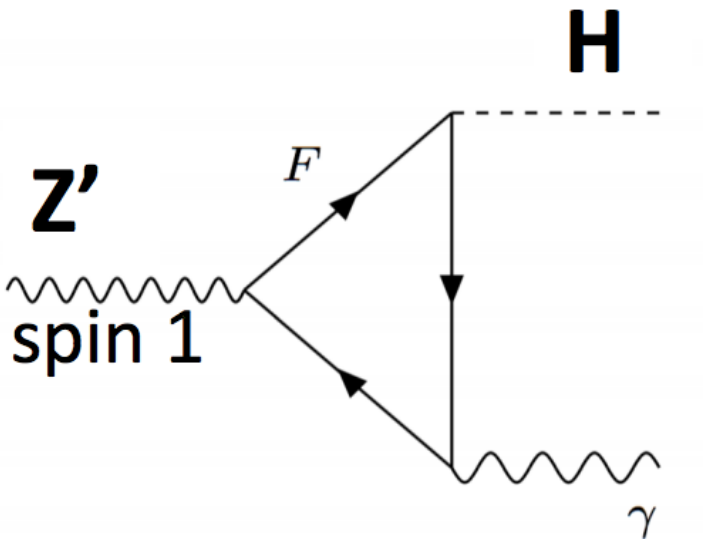


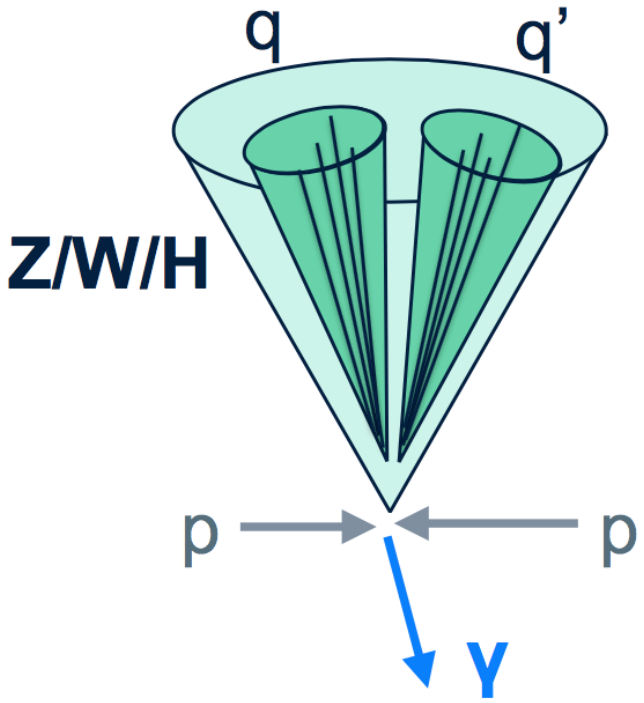
95% CL limits $-1.0 < c_{2V} < 2.7$ (non-resonant search)

Limit on non-resonant search of 2.0 pb (SM: 1.7 fb)

Diboson search : X-> Hγ

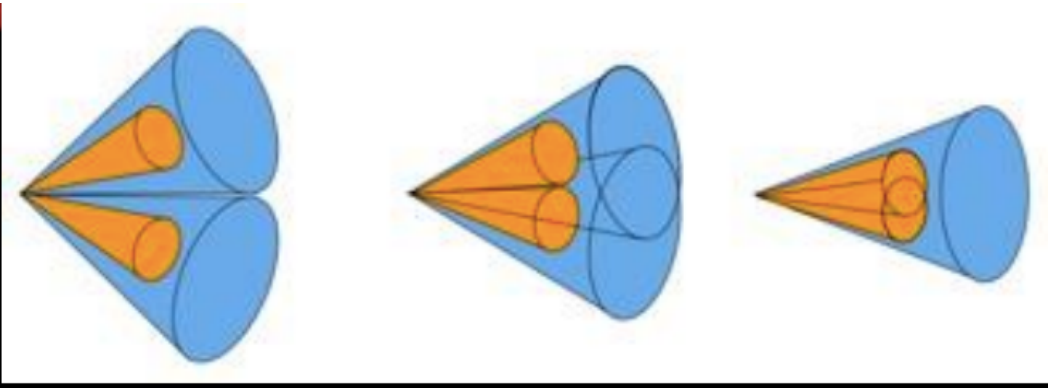
- Motivation
  - Search for anomalous magnetic moments of H (or W/Z)
    - More W/Z anomalous coupling will be covered Dr. Shu Li tomorrow
  - Several models predict a new massive scalar decaying into Hγ
- Event selection :
  - boosted jet (b tagging) -- from H, W or Z decay
  - high pT γ (pT>250GeV)
- The main background
  - γ +jets
  - Hγ
  - Hγ

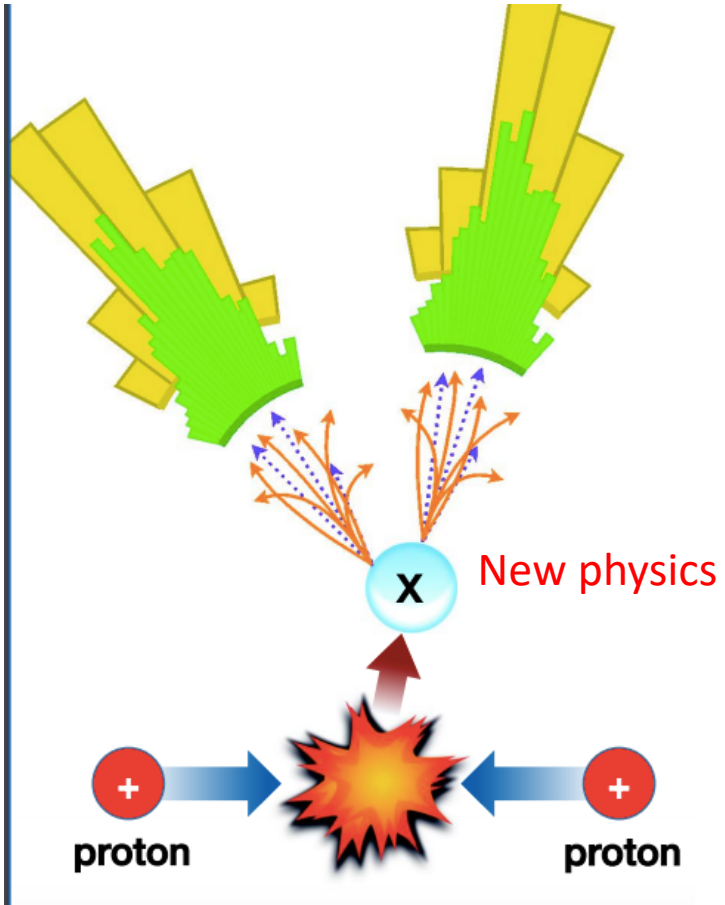




Key issue in search for TeV new physics

- Two b jets from boosted Higgs decay merge into one
- Difficult to reconstruct Higgs boson in jet final state
- Two new analysis technique used in this analysis
  - **B tagging on track jets**
  - **Jet substructure**

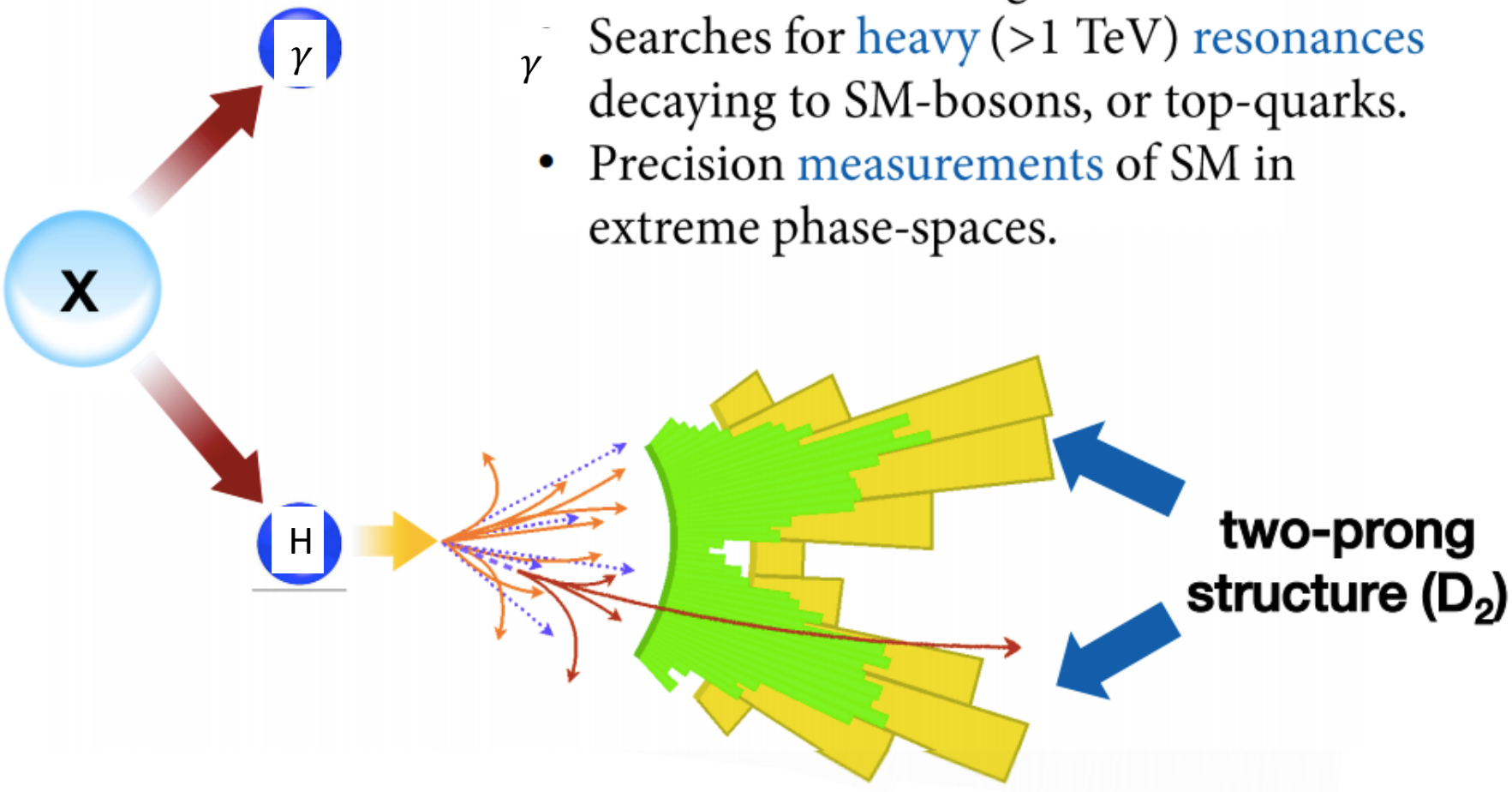




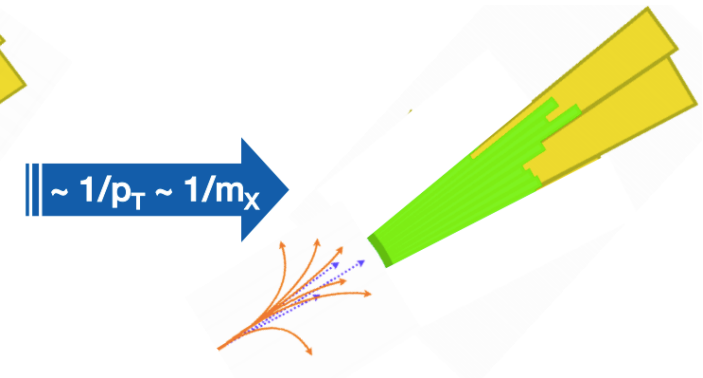
Jet Substruture

Jet substructure crucial tool for:

- Inclusive search for and measurement of H→bb in boosted regime.
- Searches for heavy (>1 TeV) resonances decaying to SM-bosons, or top-quarks.
- Precision measurements of SM in extreme phase-spaces.



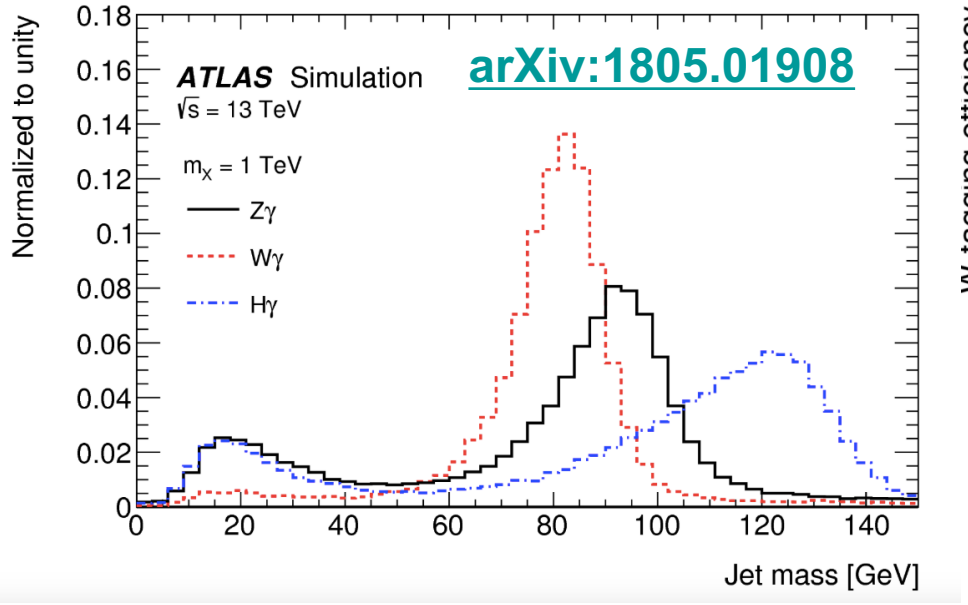
Jet mass

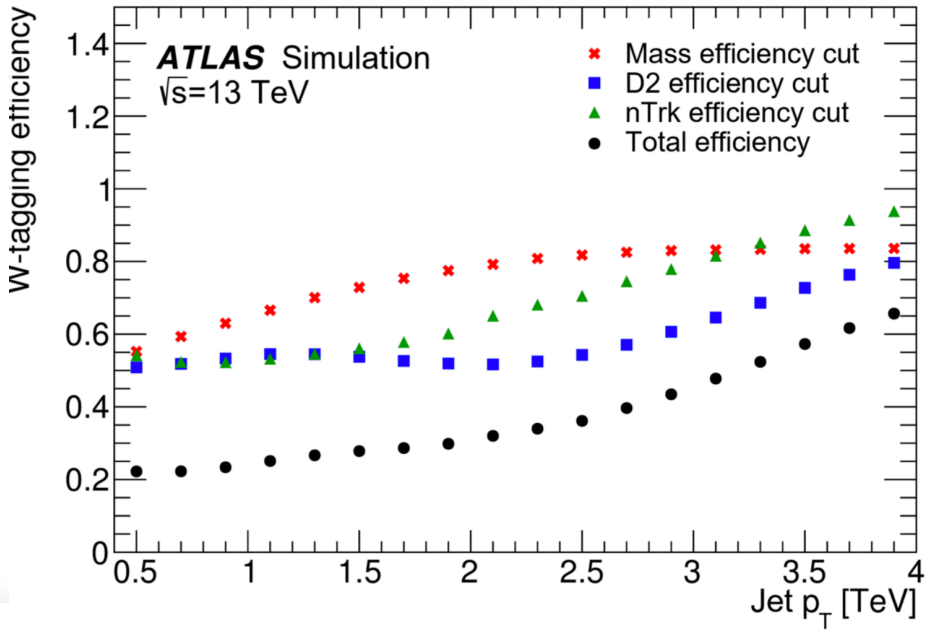


jet mass:

$$m^{\text{calo}} = \sqrt{\left(\sum_{i \in J} E_i\right)^2 - \left(\sum_{i \in J} \vec{p}_i\right)^2}$$

Reconstructed boosted H, Z and W boson

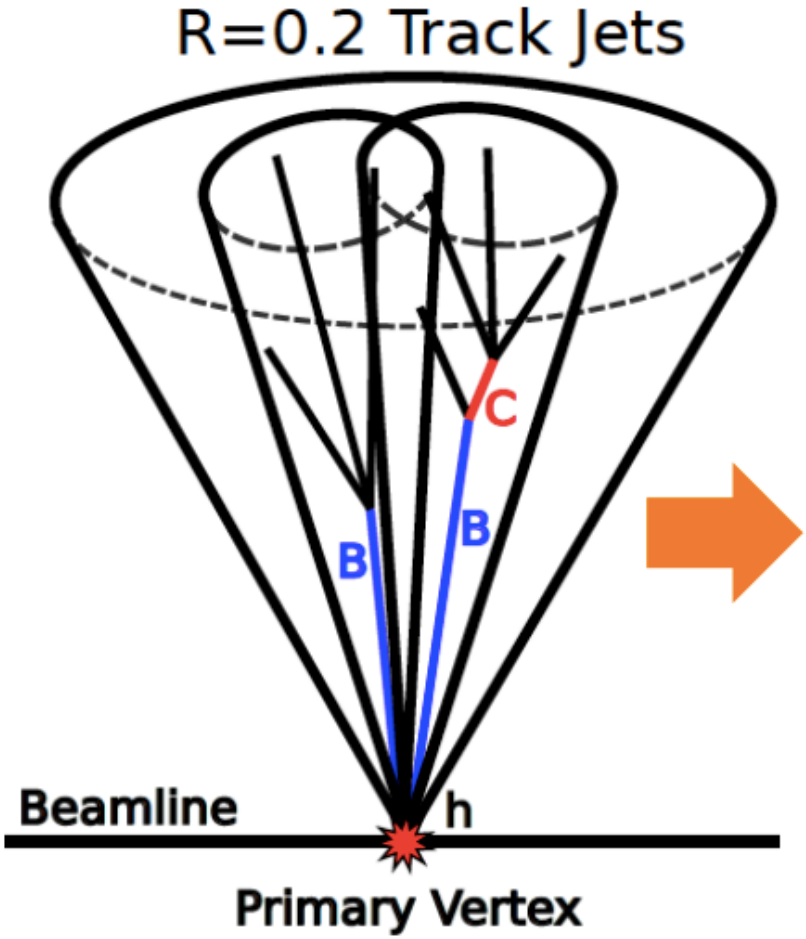




B tagging on track jet

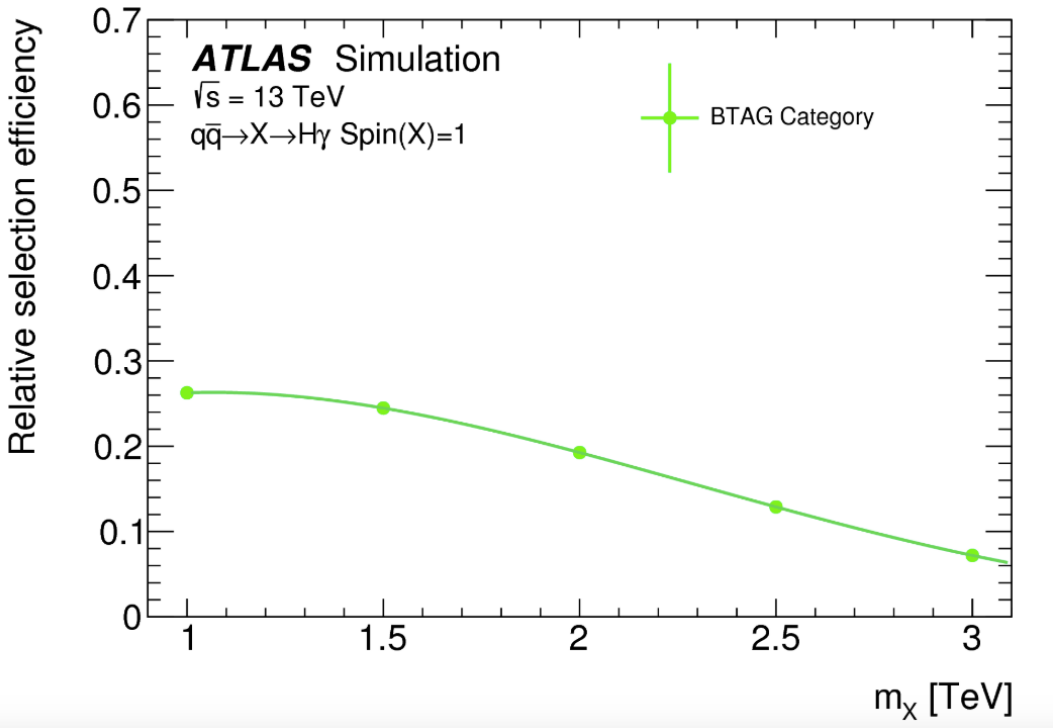
- B tagging based on track jet

Track jets overlapping for Higgs with very high momentum



Significant efficiency loss for resonance with higher mass

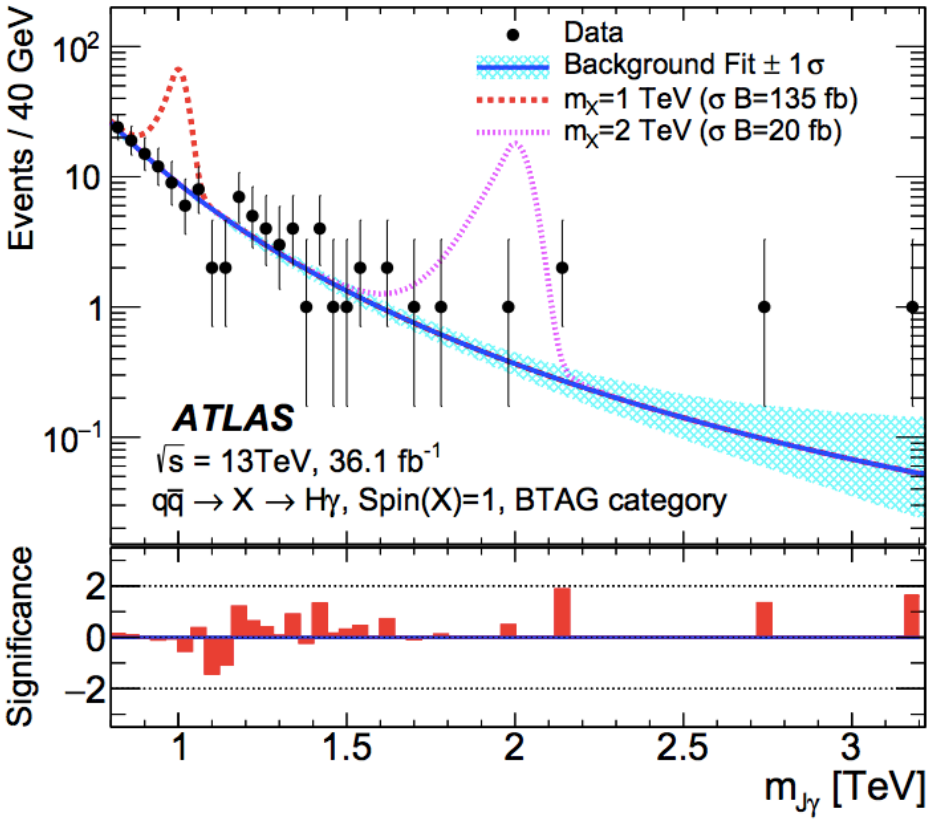
arXiv:1805.01908

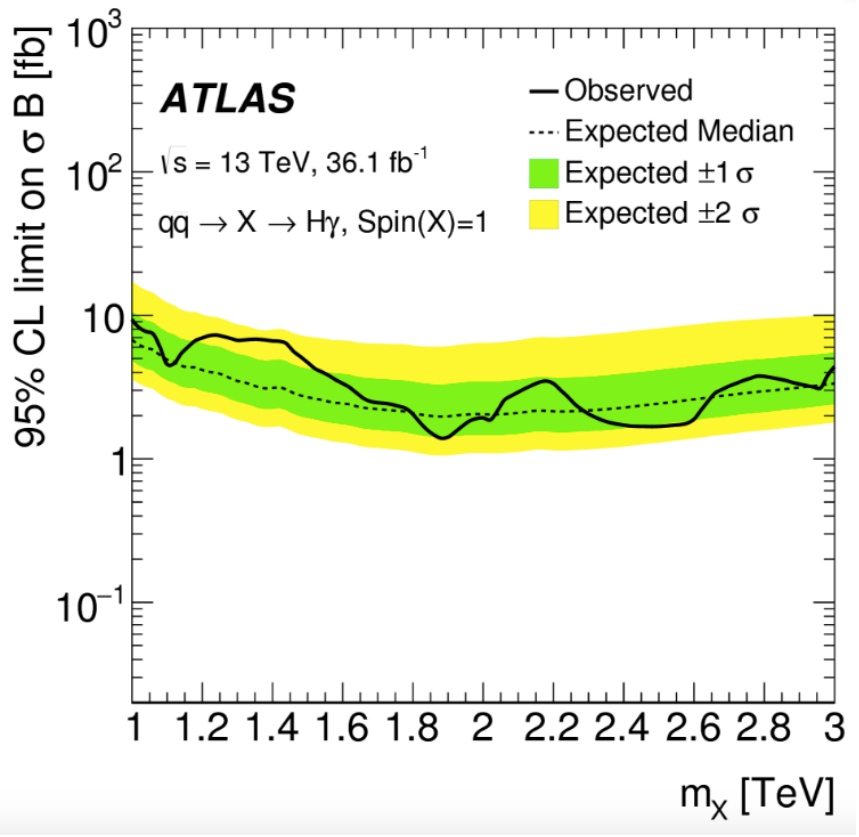


Limit setting of X-> Hγ search

- Use analytic function to fit fast falling background from
  - γjets, Zγ, SM VBF Hγ
- The first X-> Hγ limits (from 1TeV to 3TeV)

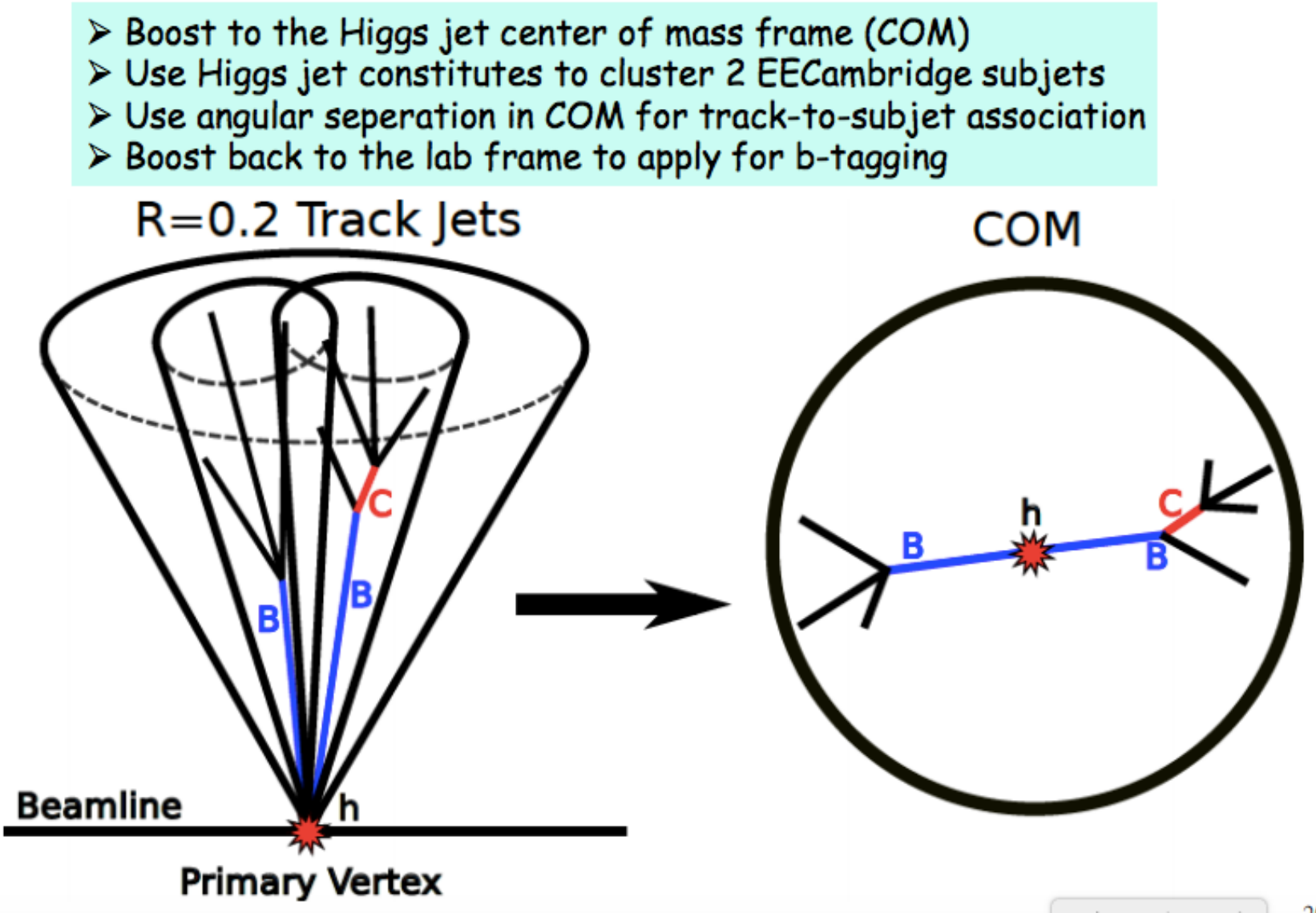
arXiv:1805.01908





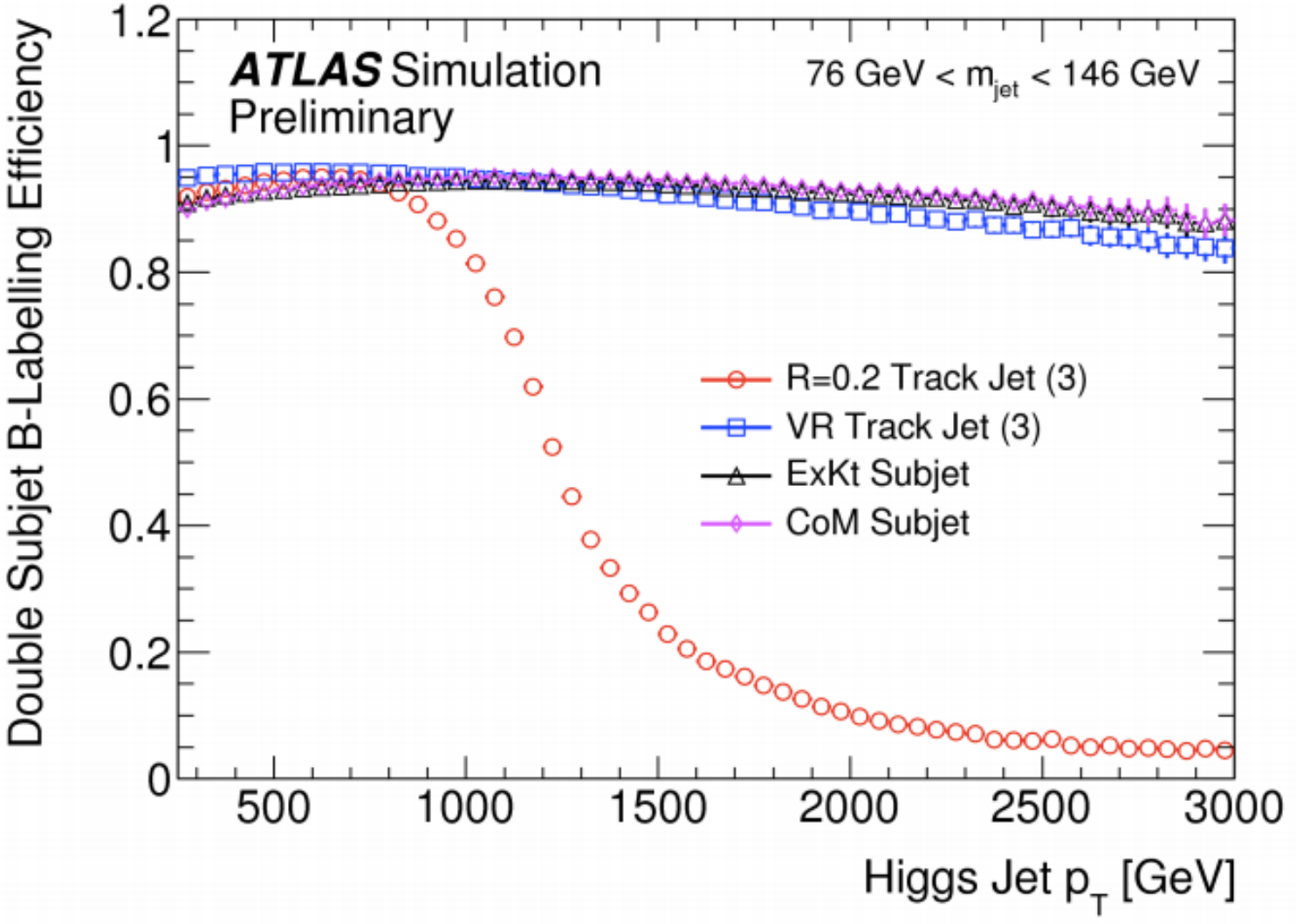
Prospect of X->H+γ and di-higgs search

- Development in advanced double b jet tagger



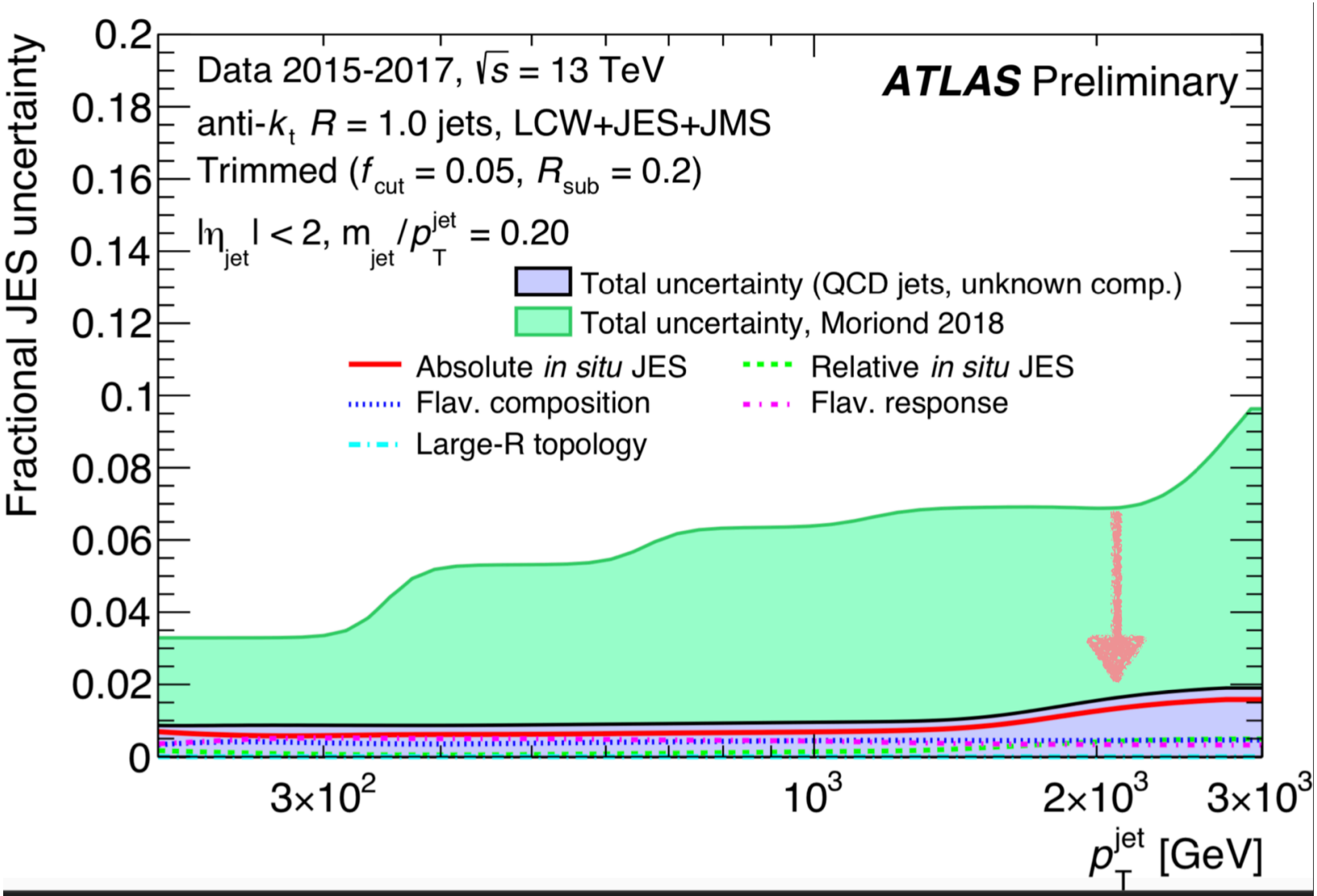
Prospect of future X->H+γ search

Expect significant improvement in full run-2 dataset
In double b tagging efficiency



Prospect of X->H+γ and di-higgs search

Very recent large improvement on large-R jet energy scale uncertainty, which will benefit future searches!



Summary

- **Short review (incomplete) review of ATLAS Exotics search**
- **Good progress in Di-Higgs and Di-boson search**
  - **Better Large-R jets jet energy calibration**
  - **More Advanced double b taggers**
- **Long-lived/challenging signatures to become a more important focus**

B jet energy corrections

- Using ATLAS default jet energy calibrations
  - Higgs mass resolution is not great
  - Asymmetry in mass, long tail in low mass region
- Dedicated B jet calibration
  - Muon-in-jets corrections
  - Kinematic likelihood