Beyond the standard model physics at the HL-LHC

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On behalf of the ATLAS collaboration

Outline

- HL-LHC outlook
- Summary of BSM physics reach at HL-LHC
- Analysis highlights
  - High mass resonances
  - Dark matter searches
- Conclusions

HL-LHC outlook

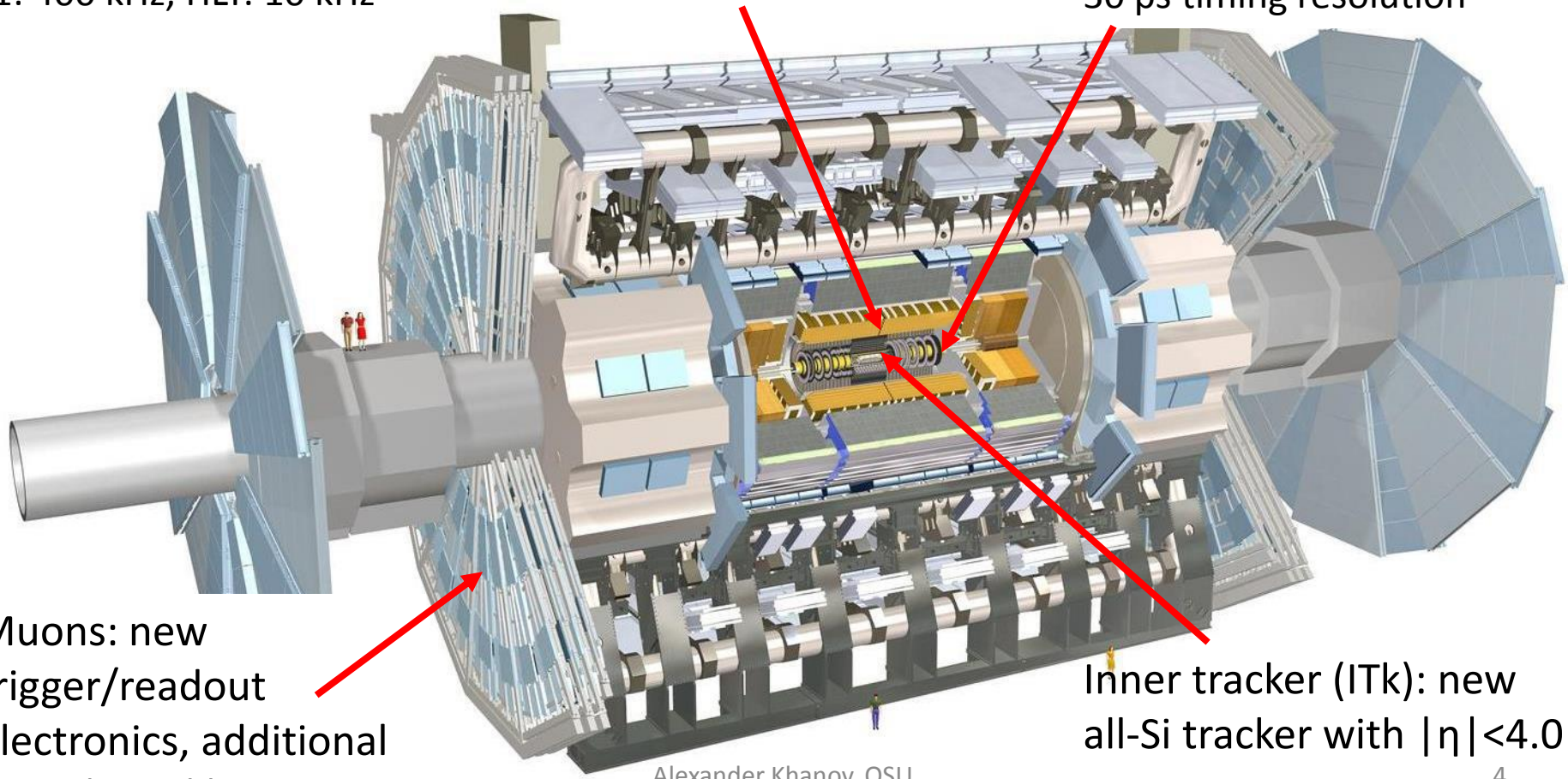
- Integrated luminosity goal: 3000/fb at √s=14 TeV
- Rich physics program:
  - detailed studies of Higgs boson
  - precision measurements of QCD, EW, Higgs, b-physics
  - probing BSM physics in both precise measurements and rare processes

ATLAS detector upgrades for HL-LHC

Triggers:
L0 (Calo+Muon+ITk): 1 MHz,
L1: 400 kHz, HLT: 10 kHz

Calorimeters: new readout electronics

High Granularity Timing Detector: 2.7<|η|<4.2, 30 ps timing resolution



Muons: new trigger/readout electronics, additional inner barrel layer

Inner tracker (ITk): new all-Si tracker with |η|<4.0

Physics potential of HL-LHC

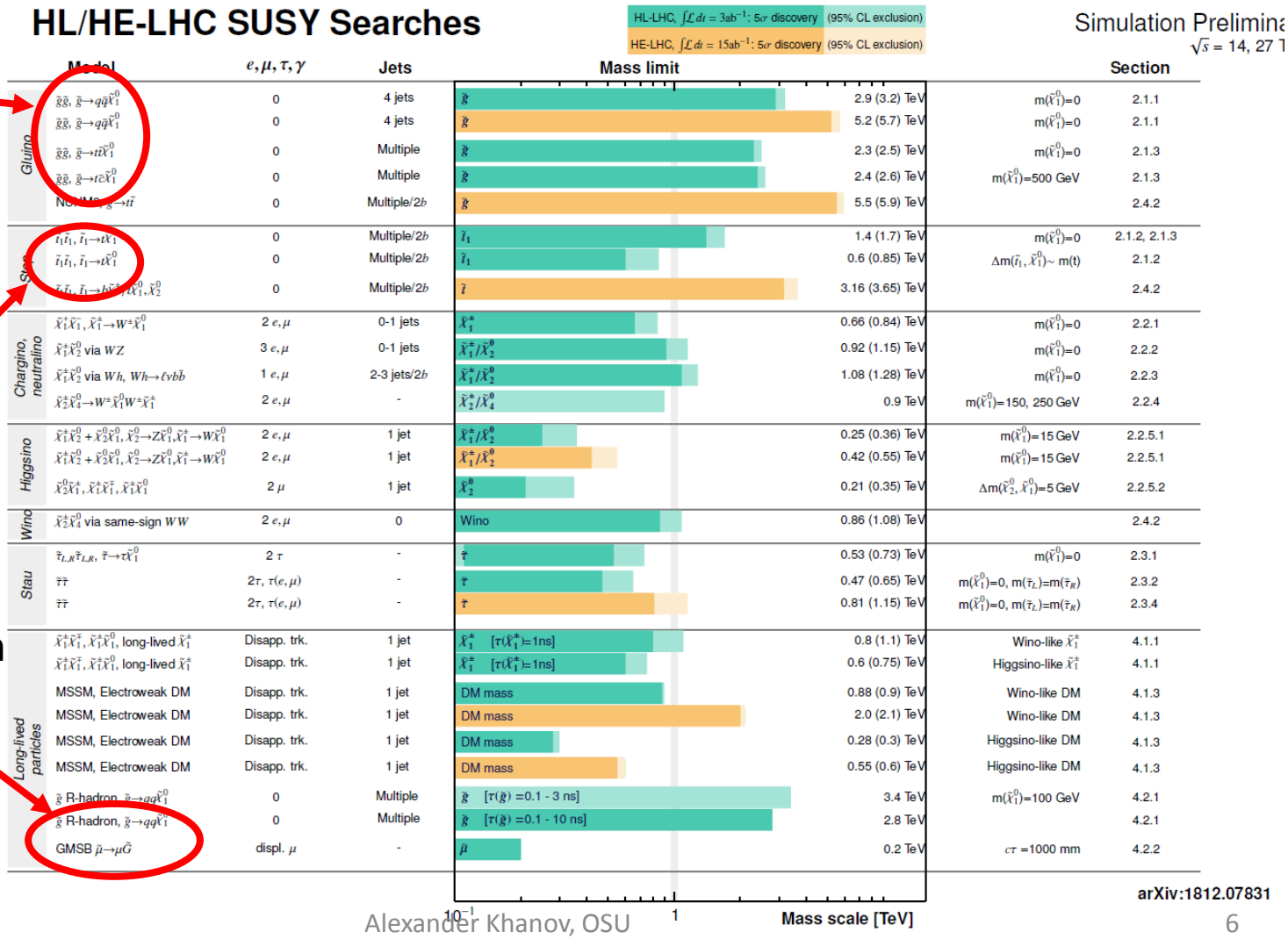
- It has been recently summarized in reports from HL-HE Physics Workshop
  - final jamboree: https://indico.cern.ch/event/783141/
  - Yellow Report: http://cdsweb.cern.ch/record/2664870
- Highlights of BSM physics from the report on the physics potential of HL-HE LHC:
  - supersymmetry (covered in Alberto's talk)
  - dark matter and dark sectors
  - high mass resonances
  - long-lived particles

Expected mass reach: SUSY

gluino mass reach (pair production): 2-3 TeV

stop mass reach: ~1 TeV

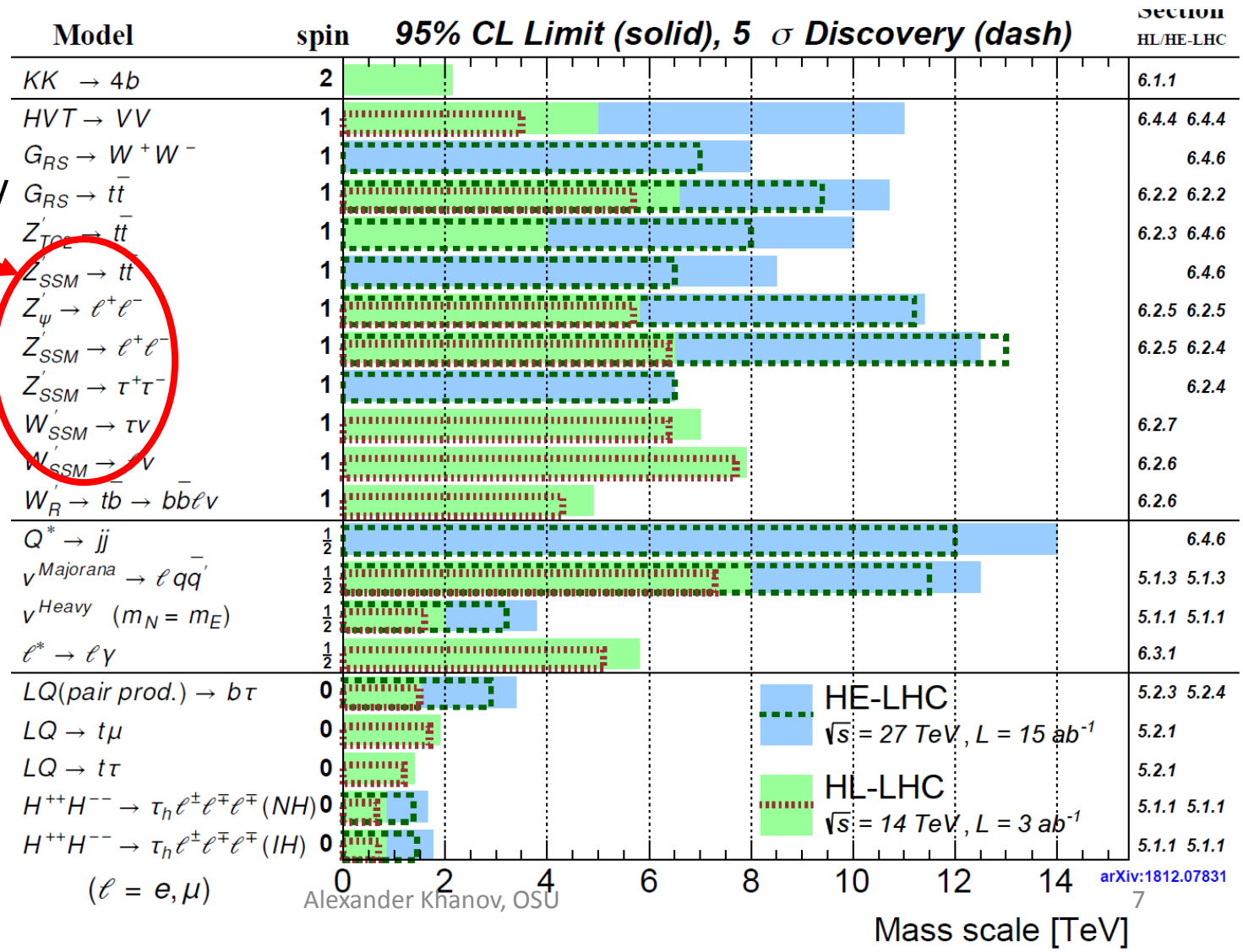
gluino mass reach (LLP→DV_MET): ~3 TeV



arXiv 1812.07831

Expected mass reach: other BSM

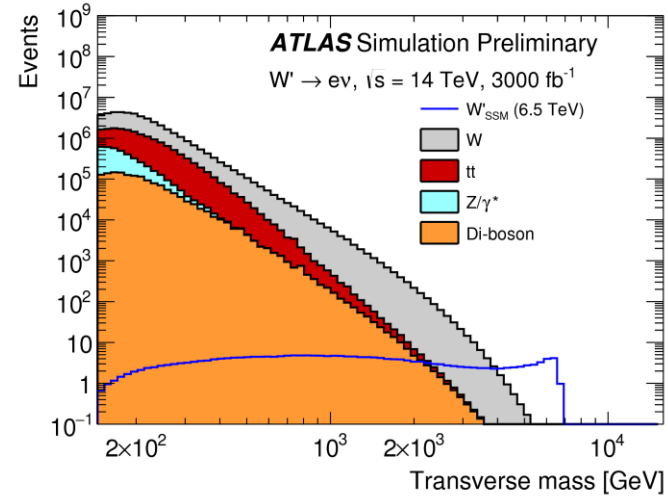
W',Z' to leptons:
mass reach 6-8 TeV

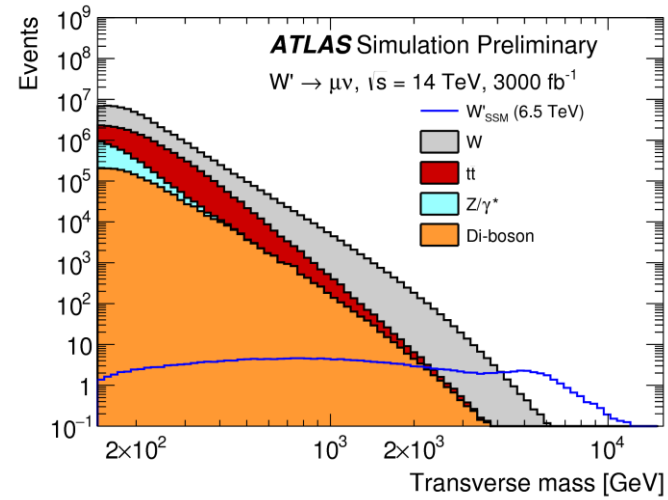


arXiv 1812.07831

Search for W' and Z' resonances

- Scenarios:
  - Sequential Standard Model (SM-like fermion couplings)
  - E_6-motivated models (Z_ψ', 0.5% width vs 3% width for SM-like Z')
- W'→eν (μν) selection: $p_T^{e(\mu)}$>65(55) GeV, MET>55(65) GeV, dominant background: SM W DY production
- Z'→ee (μμ) selection: $p_T^{e(\mu)}$ >25 GeV, same flavor, dominant background: Z*/γ DY production
- These searches are statistics limited, systematics is 7%×m_T (W'), 6.5%×m_{ll} (Z')





ATLAS-PHYS-PUB-2018-044

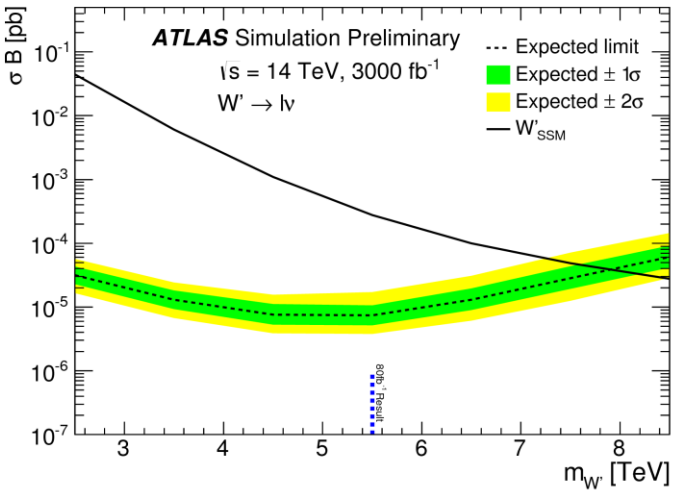
Search for W’ and Z’: results

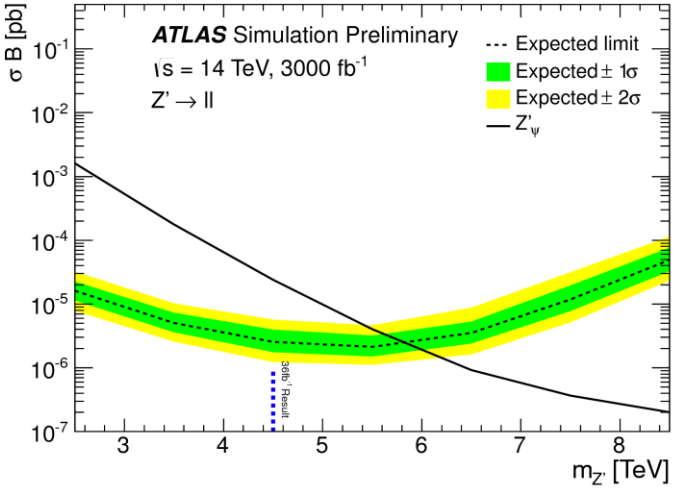
- W’/Z’ can be discovered / excluded up to 6—7 TeV

	W'_{SSM}	Z'_{SSM}	Z'_{ψ}
Discovery	7.7 TeV	6.4 TeV	5.7 TeV
Exclusion	7.9 TeV	6.5 TeV	5.8 TeV

improved from current 5.6 TeV

- Other important W’/Z’ discovery channels: $W'_R \rightarrow tb \rightarrow l\nu bb$, $Z'_{TC} \rightarrow tt \rightarrow l\nu bbjj$





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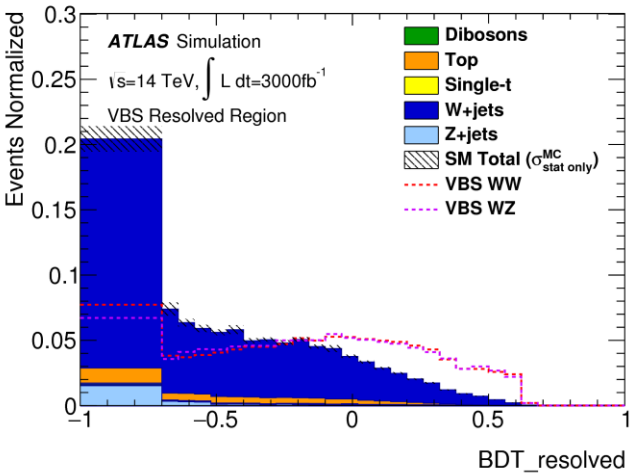
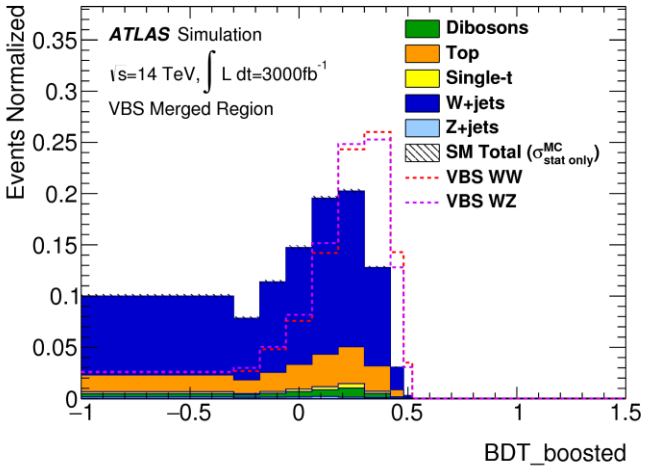
Diboson resonances

- Scenarios:
  - weakly coupled heavy vector triplet (HVT) models like extended gauge symmetry
  - strongly coupled HVT models like composite Higgs
  - Randall-Sundrum model with KK excitations of the graviton
  - (empirical) narrow heavy scalar
- Strategies: resonance search and VBS search (+2 forward non-tagged jets)
- Signal: VV→lvjj (e/μ with pT>27 GeV, W→jj or W→J candidate, MET>60 GeV)
- Background: VV, V+jets





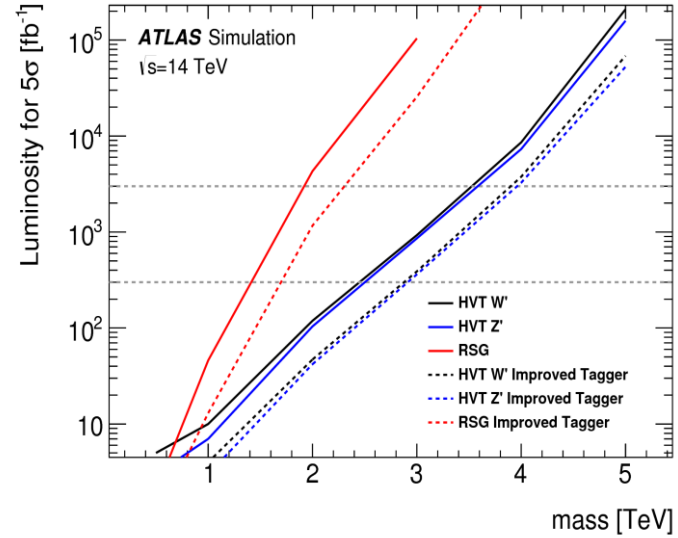
ATLAS-PHYS-PUB-2018-022

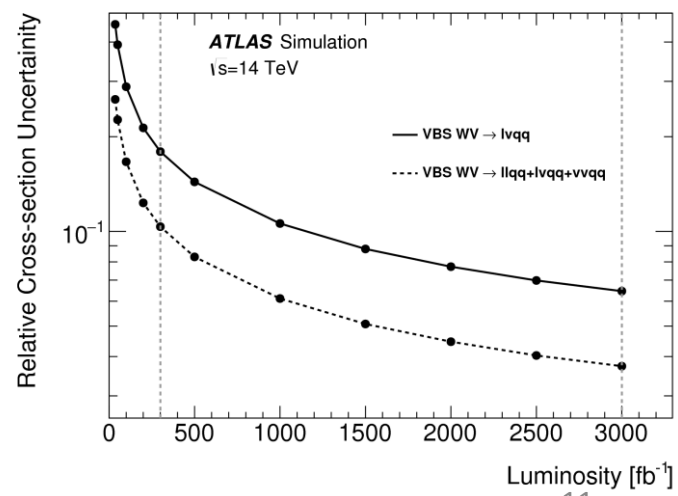
Diboson resonances: results

- VBS VV production is expected to be observed at 5σ at 300/fb, and measured at 6.5% uncertainty at 3000/fb
- Reach/limits for VV resonances (heavy gauge bosons / Randall-Sundrum resonances):

	HGB	RS
Discovery	3.3 TeV	1.7 TeV
Exclusion	4.9 TeV	3.3 TeV

~1 TeV improvement compared to existing limits

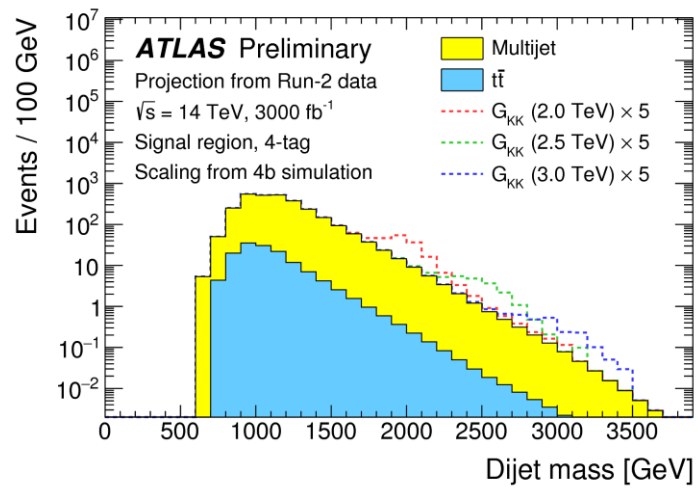


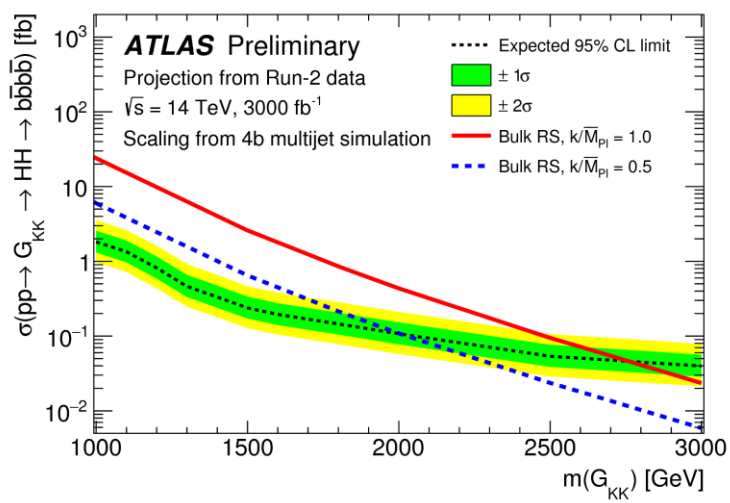


ATLAS-PHYS-PUB-2018-022

Search for resonant HH production

- Scenario: high mass KK gravitons decaying into HH pairs
- Signal: two back-to-back boosted H→bb objects
- Selection: two large-R jets (p_T>450, 250 GeV) – Higgs candidates
- Like the original HH→4b analysis, the extrapolation of Run2 results is complicated since the dominant background is multijets, can only be reliably estimated with data
- The results would benefit from improvement in large-R jet reconstruction and b-tagging

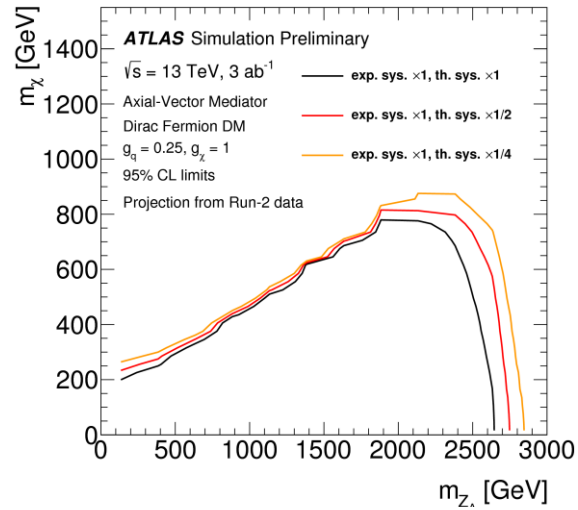


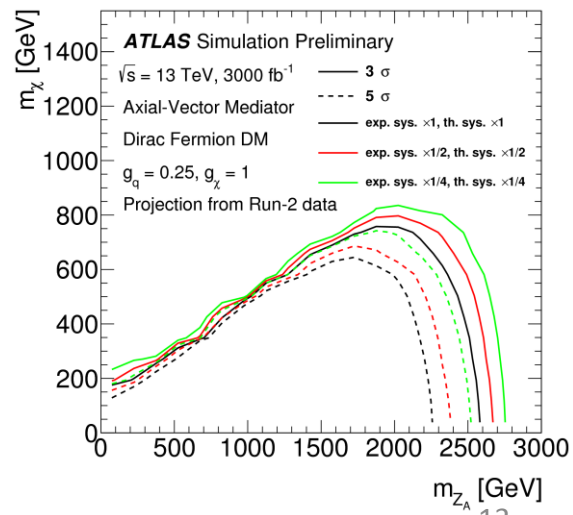


ATLAS-PHYS-PUB-2018-028

DM searches with monojets

- Scenario: pair production of Dirac fermion WIMPs from the s-channel exchange of a spin-1 mediator + associated jet(s) from ISR
- Signal selection: ≥1 jet with p_T>250 GeV + MET>250 GeV
- This analysis is very sensitive to systematics (ISR / FSR, renormalization / factorization scales, JES)
- With 3000/fb, the discovery potential and the exclusion limits on the mediator mass are 2.2—2.5 TeV depending on uncertainties

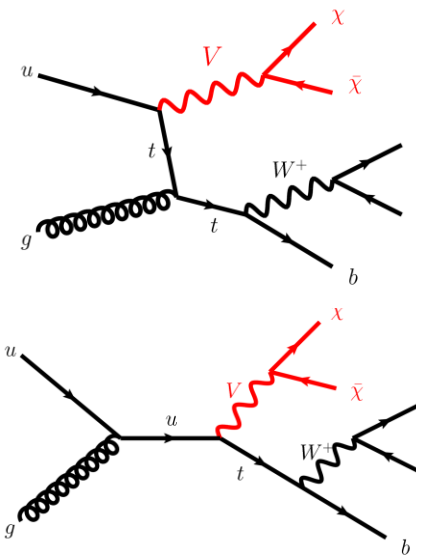


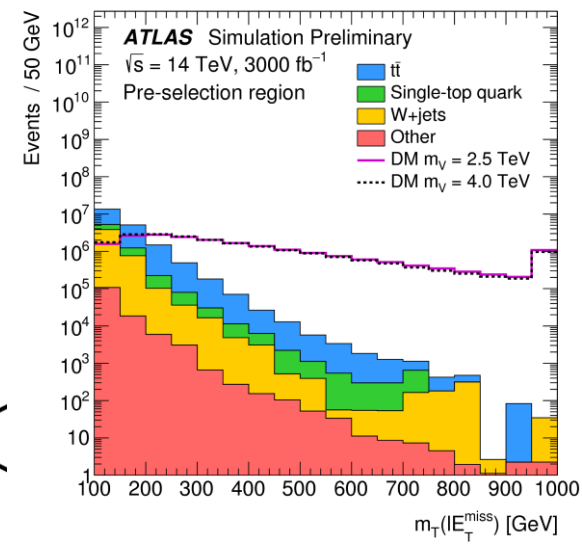


ATLAS-PHYS-PUB-2018-043

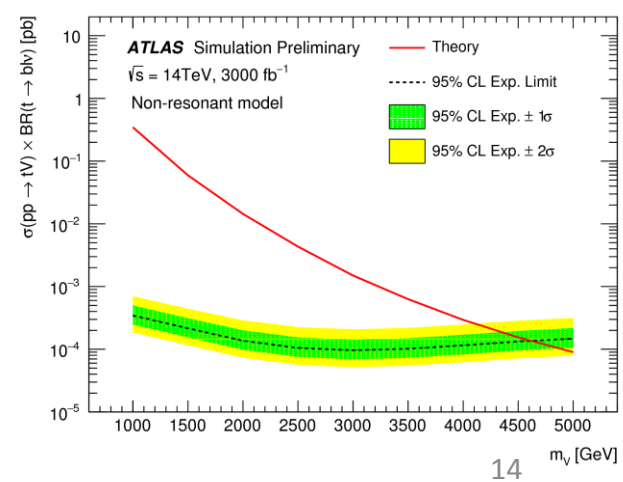
DM searches with monotops

- Scenario: non-resonant production of an exotic massive vector-like particle decaying into DM candidates, and a right-handed top quark
- Signal selection: one e/μ + one b-jet (from t→ Wb→lνb) + MET>100 GeV





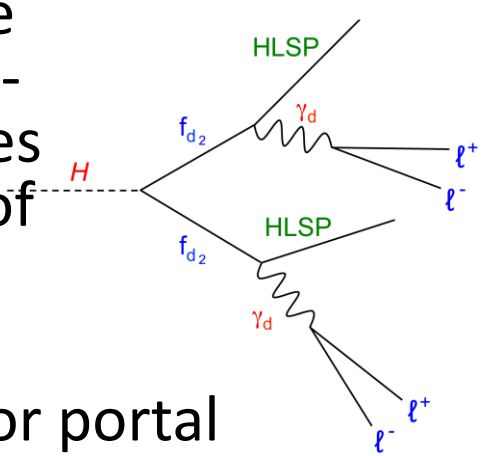
- Exclusion limits on m_V (BDT-based analysis): 4.6 TeV, discovery reach: 4.0 TeV

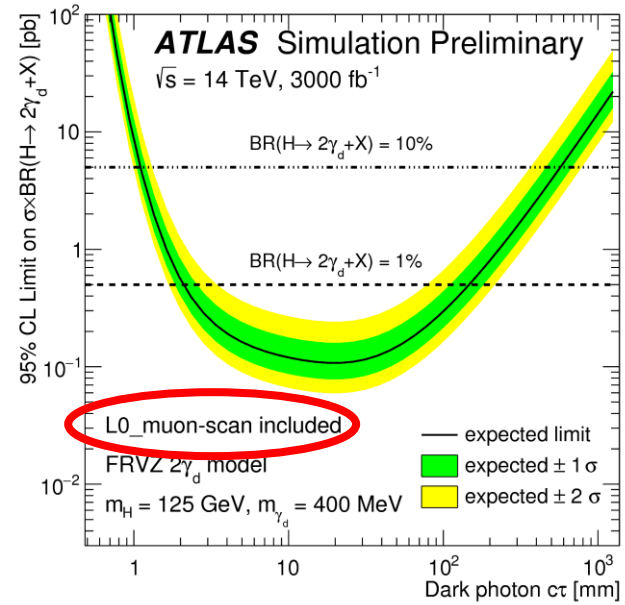


ATLAS-PHYS-PUB-2018-024

Dark photon searches in LLP→μμ

- Dark photons can be searched for as long-lived neutral particles decaying into pairs of muons in the muon system
- Scenario: FRVZ vector portal
- Signal: two calo/ITk isolated muonic lepton-jets (|η|<2.4) back-to-back
- The search would benefit from a dedicated L0 multi-muon scan trigger





ATLAS-PHYS-PUB-2019-002

Excluded $c\tau$ [mm] muonic-muonic	Run-2	Run-3	HL-LHC	HL-LHC w/ L0 muon-scan
BR(H → $2\gamma_d + X$)=10 %	$2.2 \leq c\tau \leq 111$	$1.15 \leq c\tau \leq 435$	$0.97 \leq c\tau \leq 553$	$0.97 \leq c\tau \leq 597$
BR(H → $2\gamma_d + X$)=1 %	-	$2.76 \leq c\tau \leq 102$	$2.18 \leq c\tau \leq 142$	$2.13 \leq c\tau \leq 148$

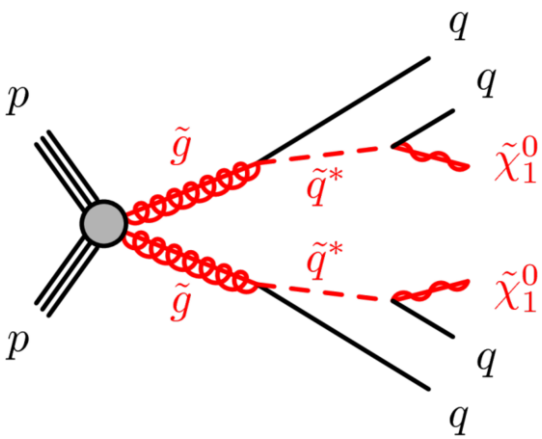
Summary

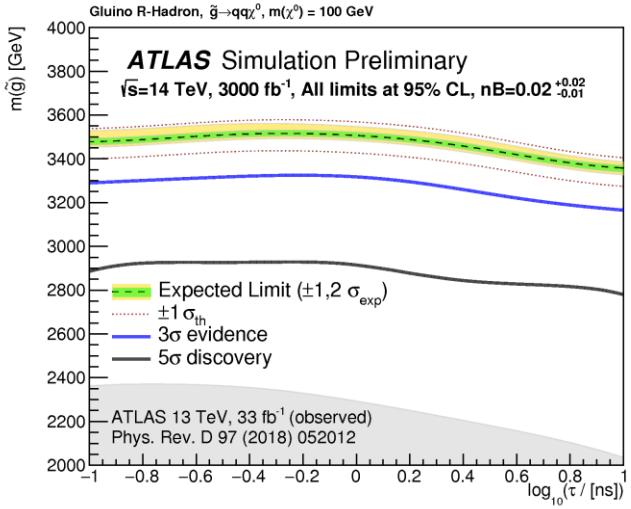
- The LHC will be upgraded to HL-LHC with a goal to achieve 3000/fb at √s=14 TeV in 10 years
  - the ATLAS detector will receive upgrades to its calorimeter, muon, and trigger systems, as well as an new all-Si inner tracker
  - it will open broad perspectives for searches for new particles, both in precision measurements and rare processes
- The upgrade will allow for a wide range of searches for BSM physics, including supersymmetry, dark matter and dark sectors, high mass resonances, and long-lived particles
  - while some of the channels will get a straightforward boost from increased luminosity and improved detector, others will need more creative effort
- The latest estimations of the HL-LHC physics potential summarized in Yellow report are promising
  - with increased amount of effort dedicated to HL-LHC physics, we can hopefully do even better!

Backup

Displaced vertex signatures

- Search for 0.1-10 ns life time LLPs decaying in the inner tracker
- Requires a dedicated version of ATLAS tracking ("displaced tracking")
  - Assume that the new ATLAS ITk will match the Run 2 performance (>90% efficiency for tracks with at least 7 silicon hits)
- Scenario: pair production of gluinos hadronizing into R-hadrons
- Signal selection: ≥1 displaced vertex (m_{DV}>10 GeV) + MET>250 GeV
- Results: can discover gluino R-hadrons up to 2.8 TeV or exclude up to 3.4 TeV





ATLAS-PHYS-PUB-2018-033