

Recent searches for new phenomena with the ATLAS detector



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On behalf of the ATLAS collaboration

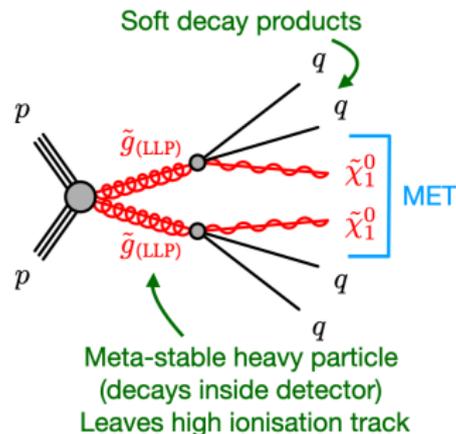
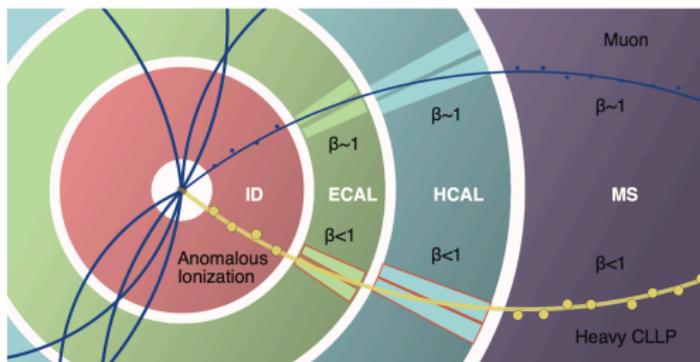
DIS, 4th May 2022

Three unusual searches

- The pixel dE/dx analysis
- The emu asymmetry search
- The non-pointing photon analysis

Pixel dE/dx analysis

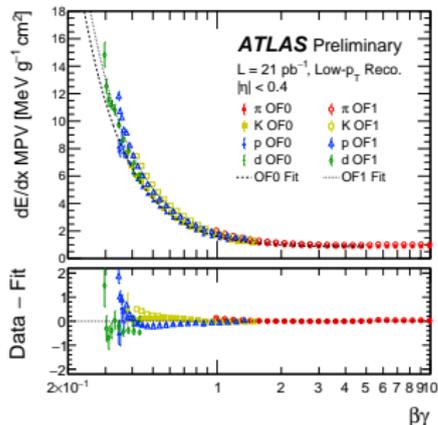
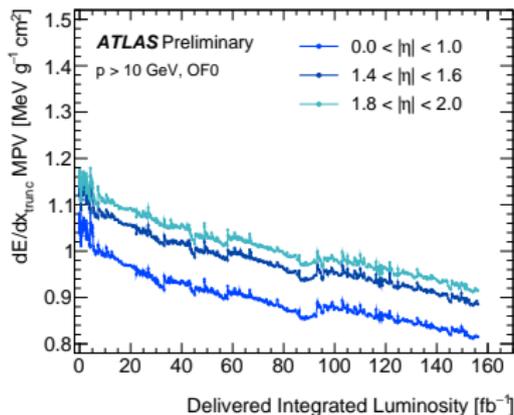
SUSY-2018-42



- **Signature:** anomalously high ionisation (dE/dx) tracks due to a heavy non-relativistic particle
- **Strategy:** parameterise Bethe-Bloch to turn dE/dx into a mass measurement
- **Search** for excess of heavy ionising tracks over data-driven background

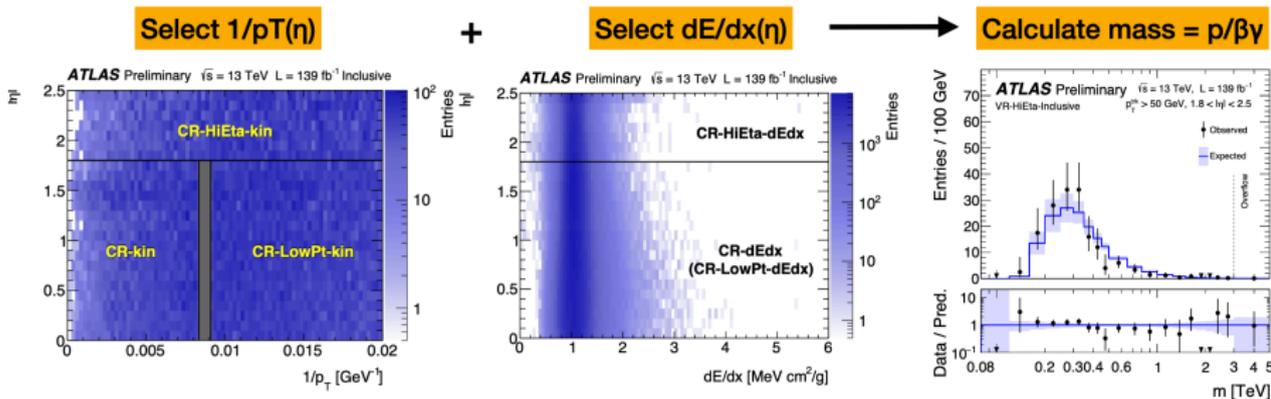
Analysis strategy

- Event selection: E_T^{miss} trigger and $E_T^{\text{miss}} > 170$ GeV
- Track selection:
 - $|\eta| < 1.8$ (pixel barrel), $p_T > 120$ GeV
 - Isolated tracks with large ionisation ($dE/dx > 1.8$)
- Reconstruct the track mass from p_T and $\beta\gamma$ (from dE/dx)
 - dE/dx of a track is an average of all clusters on a track
 - Correct for changes in pixel performance during Run-2
 - Use Bethe-Bloch parameterization to extract $\beta\gamma$ of track



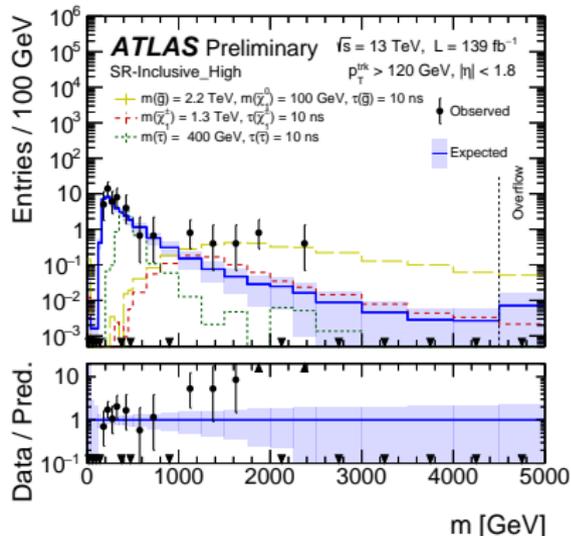
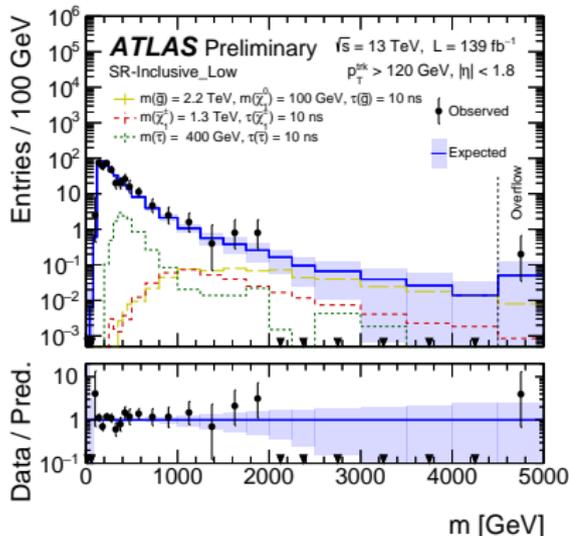
Background estimation

- Fully data-driven technique
 - Invert signal selection to create two CRs per SR: CR-kin and CR-dEdx
 - Generate background tracks from measured $1/p_T$ and dE/dx distributions in CR (binned in η)
 - Validate in dedicated Validation regions: low track p_T ([50, 100] GeV) and high η ([1.8, 2.5])



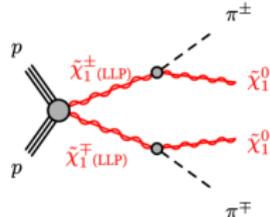
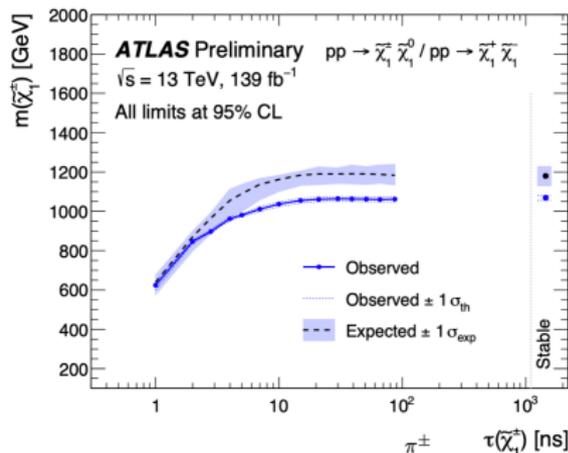
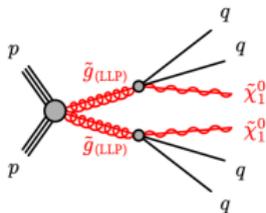
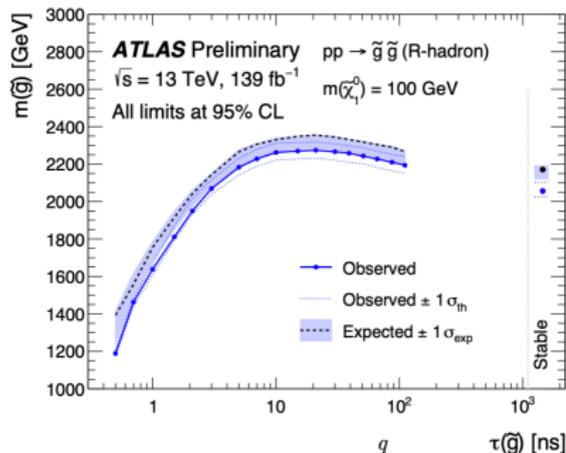
Pixel dE/dx results

- Excess (3.6σ local, 3.3σ global) in high dE/dx SR (> 2.4) with for target mass hypothesis of 1.4 TeV
- A cross-check with timing variables show that candidate tracks have $\beta \approx 1$, which does not support a heavy LLP signal-like interpretation of the excess



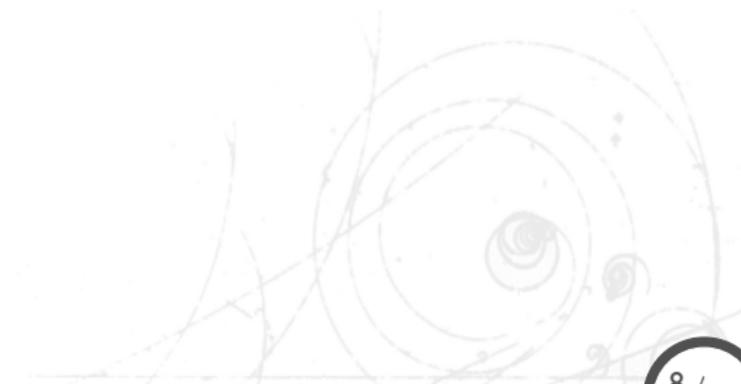
Pixel dE/dx limits

- No signal like excess: can set limits on gluino, chargino and stau hypotheses



Emu asymmetry search

arXiv:2112.08090



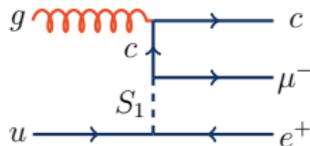
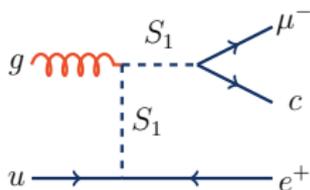
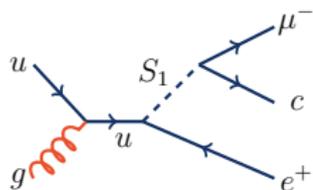
The LHC charge-flavour conspiracy

$$\rho = \frac{\sigma(pp \rightarrow e^+ \mu^- + X)}{\sigma(pp \rightarrow e^- \mu^+ + X)}$$

- **SM:** $\rho = 1$ (assuming lepton flavour universality).
- **SM+LHC+ATLAS:** $\rho \leq 1$,
e.g. from extra $W^+ (\rightarrow \mu^+ \nu_\mu) + \text{jets}$, where the jet is misidentified as an e^- . This is dominant over the charge-conjugate process since we start with a $(pp)^{2+}$ state.
- **BSM,** $\rho > 1$, e.g. from RPV SUSY or leptoquarks.

Signal example: Leptoquarks

Introduce a scalar leptoquark S_1 permitting $S_1 \rightarrow ue^-$ and $S_1 \rightarrow c\mu^-$, the below diagrams will generate $e^+\mu^-$ events:



- The charge-conjugate process produces $e^-\mu^+$, but since there is more u than \bar{u} in the proton, this can result in $\rho > 1$.
- **Signature:** $e + \mu + \text{jet}$, could target with $m_T(\text{jet}, e) + m_T(\text{jet}, \mu)$

Signal example: RPV SUSY

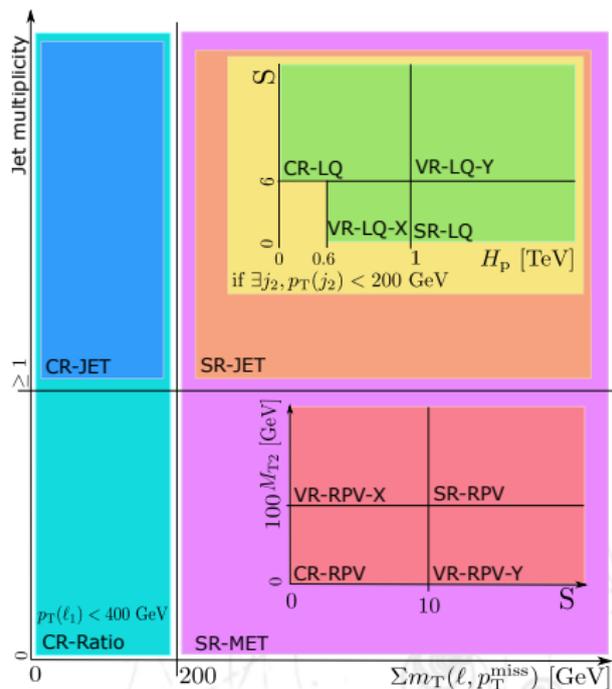
Switch on only λ'_{231} , couples down quark, top quark and muon (where one is exchanged for superpartner), then



due to more d in the proton than \bar{d} (and if $\tilde{\chi}_1^0$ is LSP). This can result in $\rho > 1$. We can exploit MET in final state to target such a model by using variable $m_T(E_T^{\text{miss}}, e) + m_T(E_T^{\text{miss}}, \mu)$.

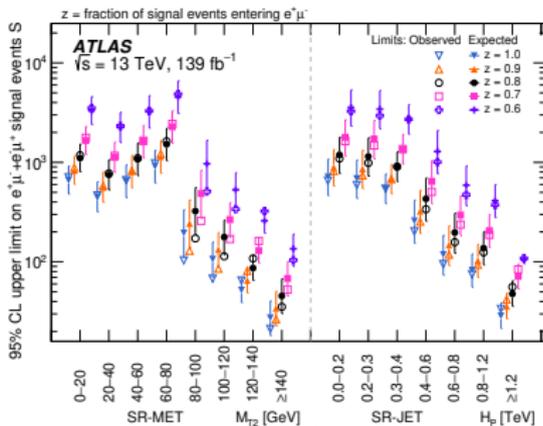
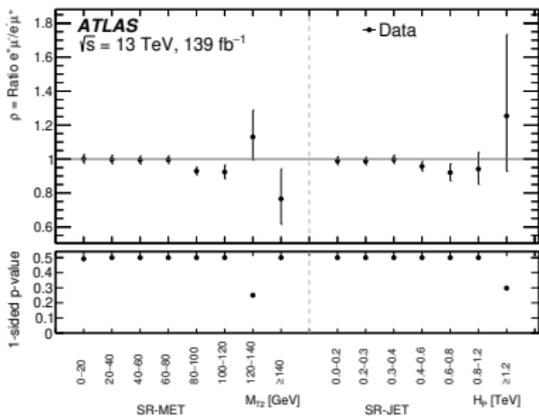
Analysis Strategy

- Measure ρ in data, test if it is significantly larger than 1.
- No background estimate needed for data self-consistency test
- Two sets of signal regions: generic and model-dependent
- Dedicated data-driven fake lepton estimate to account for bias



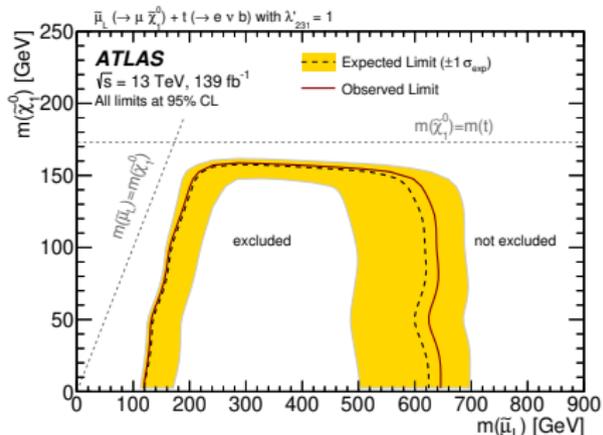
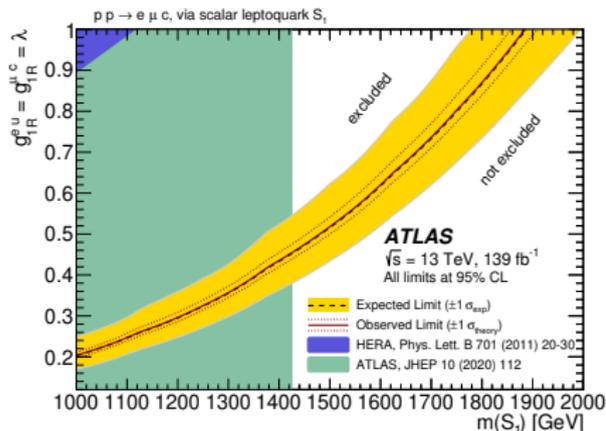
Results

- ρ measured in data, consistent with the SM of $\rho = 1$
- Able to set model independent limits on the number of $e\mu$ events that could be in the signal regions



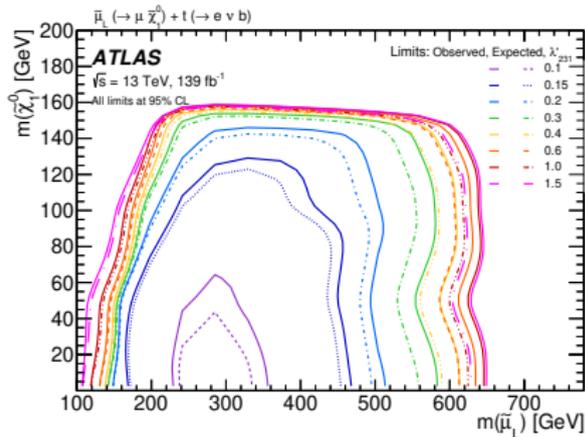
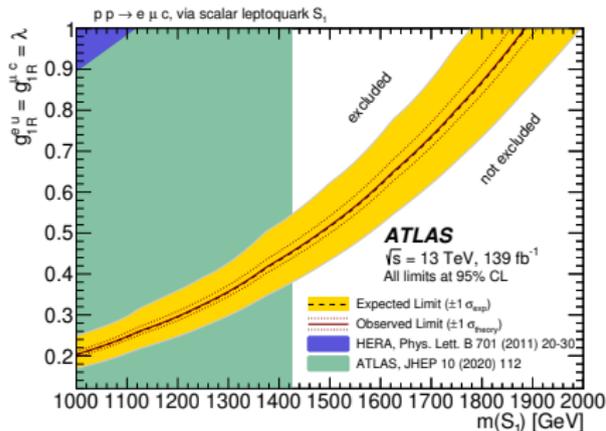
Results

- Model dependent limits also possible with fits in dedicated signal regions.
- Left leptoquarks, right RPV SUSY.



Results

- Model dependent limits also possible with fits in dedicated signal regions.
- Left leptoquarks, right RPV SUSY with different RPV couplings.

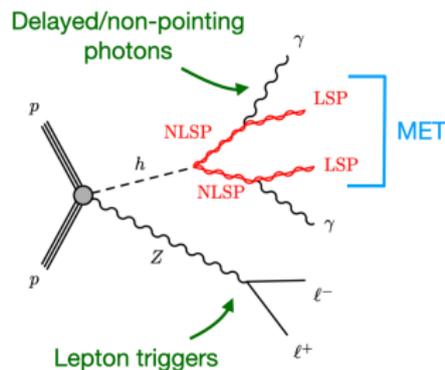


Non-Pointing/Delayed Photons

ATLAS-CONF-2022-017

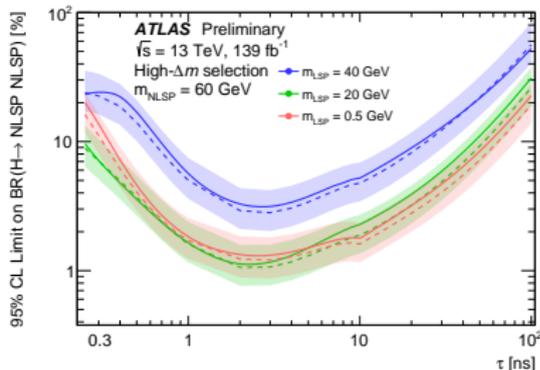
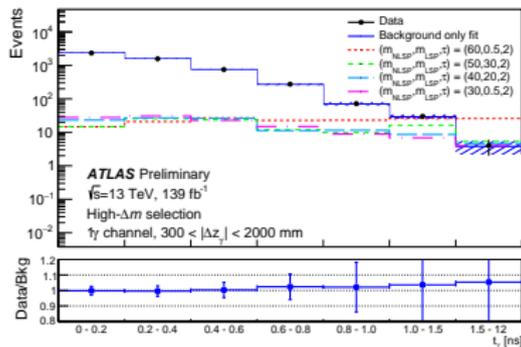
Non-Pointing/Delayed Photons Analysis

- Photons from the decays of a heavy LLP that is late w.r.t bunch crossing and don't point to PV
 - Interpret as Higgs to BSM signal with GMSB decay
- Use precise LAr calorimeter pointing and timing (unique to ATLAS)
 - Signal region = high E_T^{miss} , high timing, high pointing, optimised separately for low- and high- LSP/NLSP splitting
 - Fully data-driven background estimate used



Non-pointing/Delayed photons results

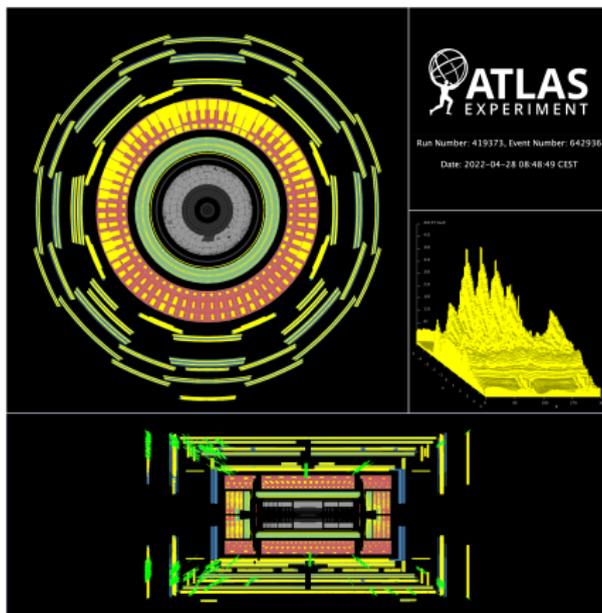
- Simultaneously fit photon timing data templates across 5 categories of photon pointing, separately for low- and high-mass splitting regions
- Result: no excess beyond the SM expectation, set limits on $BR(h \rightarrow 2 \times \text{NLSLP})$
 - As low as 1% for $\tau \sim 1$ ns and high LSP/NLSLP mass splitting of ~ 40 GeV
 - First Run-2 sensitivity to this signature



Summary

- Three new searches with many novel, data-driven techniques, including the first data-only self-consistency search with emu analysis.
- These types of searches can have unique sensitivity to previously unexplored areas, e.g. certain types of single leptoquark production.
- Many searches I didn't get to cover!
- Stay tuned for many more innovative searches from ATLAS Run 2

Thank you!



Pixel dE/dx : [SUSY-2018-42](#)

Emu asymmetry: [arXiv:2112.08090](#), [ATLAS briefing](#)

Non-pointing photons: [ATLAS-CONF-2022-017](#), [ATLAS briefing](#)

New: 2 leptons + jets
[arXiv:2204.13072](https://arxiv.org/abs/2204.13072)

2 leptons + jets

Three searches targeting SUSY models with e^+e^- or $\mu^+\mu^-$, jets and E_T^{miss} .

- **Recursive Jigsaw Reconstruction**

- Model independent follow up to excesses in 2/3L from 36/fb result
- Two discovery regions

- **Electroweak production**

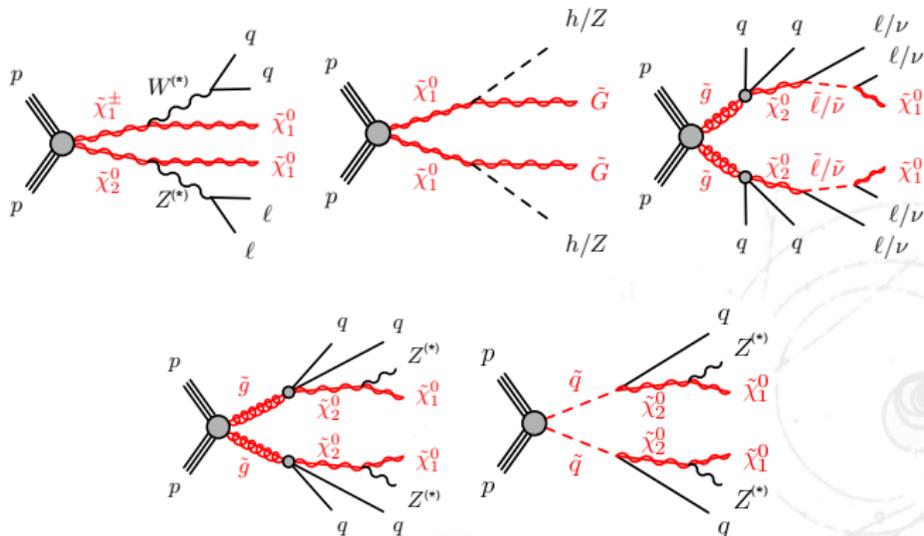
- 13 orthogonal SRs, multi bin fit
- GMSB: $Z (\rightarrow jj)$ $Z (\rightarrow \ell\ell)$ and $Z/h (\rightarrow bb)$ $Z (\rightarrow \ell\ell)$

- **Strong production**

- Bin SRs in $m(\ell\ell)$
- kinematic edge depends on SUSY mass splitting
- 7 overlapping SRs (best expected used for exclusion)

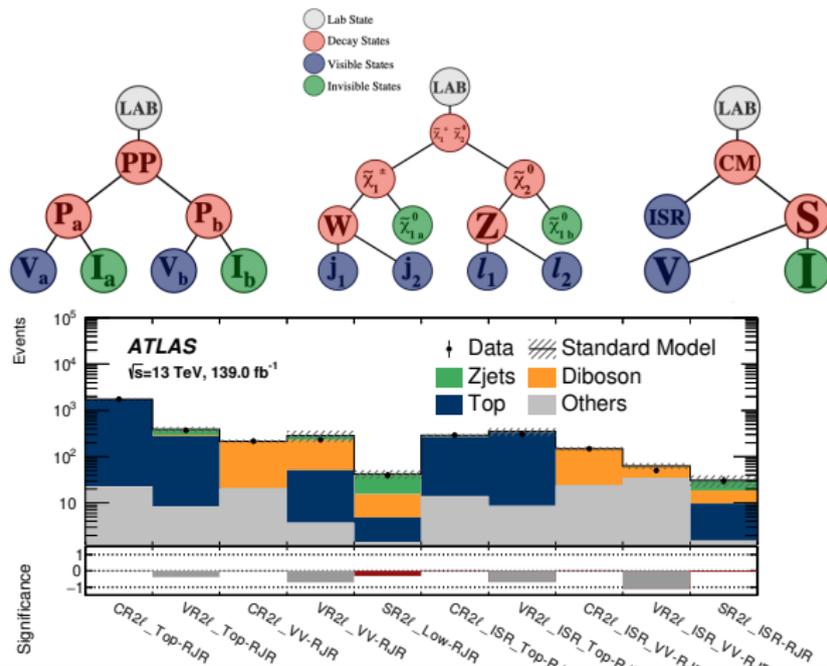
2 leptons + jets: common selection + signals

- Exactly 2 leptons (e^+e^- XOR $\mu^+\mu^-$) each with $p_T > 25$ GeV
- $\times 2$ jets with $p_T > 30$ GeV
- m_{T2} formed from the two leptons and met used to reject $t\bar{t}$ background
- E_T^{miss} -significance used to select events with E_T^{miss} from invisible particles



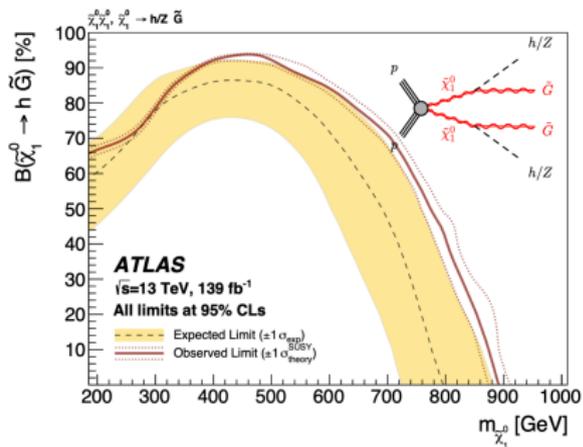
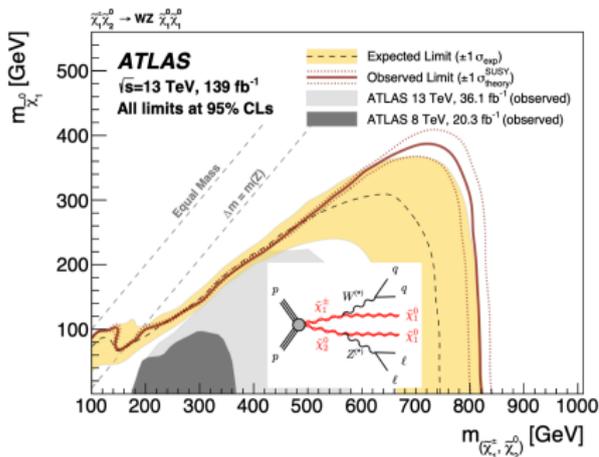
2 leptons + jets: Recursive Jigsaw

- Recursive jigsaw algorithm ([1705.10733](#)) used to assign particles to a given decay tree
- Makes event variables relative to the respective rest frames
- 3σ excess seen in 36/fb [result](#) no longer present.



2 leptons + jets: Electroweak

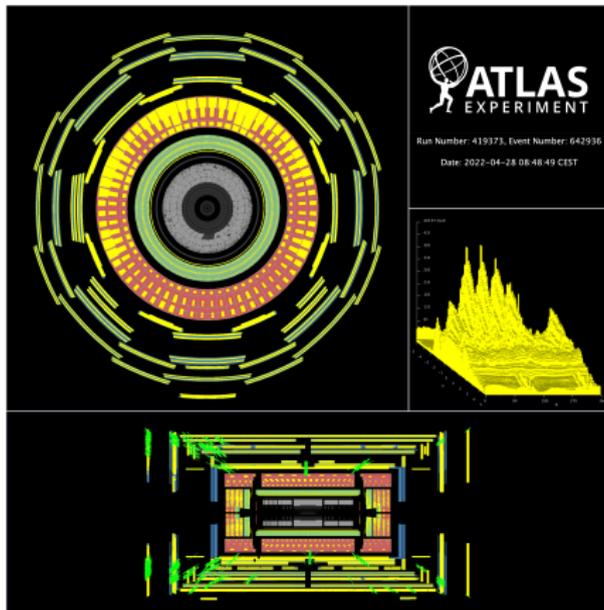
- Split signal regions along E_T^{miss} significance spectrum
- Off-shell looks for $m(\ell\ell) < 70$ GeV
- Signal regions with deficits increase exclusion



Summary

- Three new searches with many novel, data-driven techniques, including the first data-only self-consistency search with emu analysis.
- Plus a bonus brand new search with 2 leptons and jets!
- These types of searches can have unique sensitivity to previously unexplored areas
- Many searches I didn't get to cover!
- Stay tuned for many more innovative searches from ATLAS Run 2

Thank you!



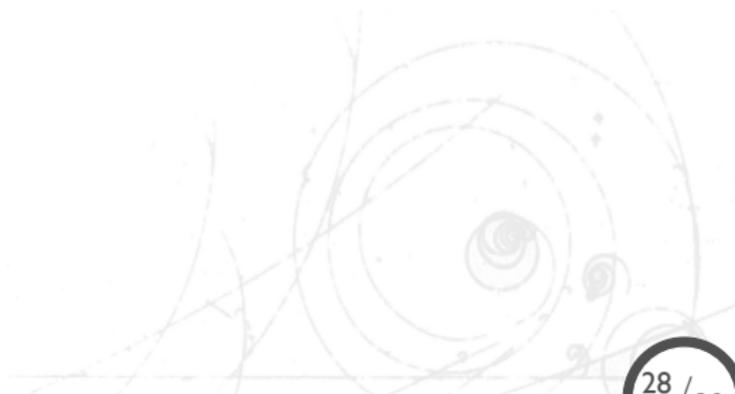
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Non-pointing photons: [ATLAS-CONF-2022-017](#), [ATLAS briefing 2](#)

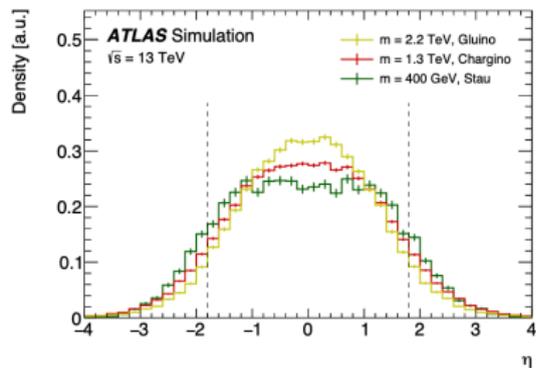
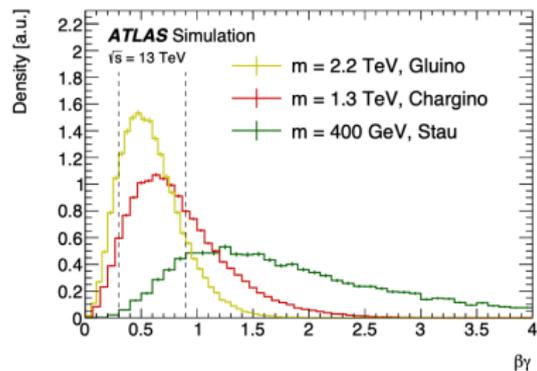
leptons + jets: [arXiv:2204.13072](#)

Backup



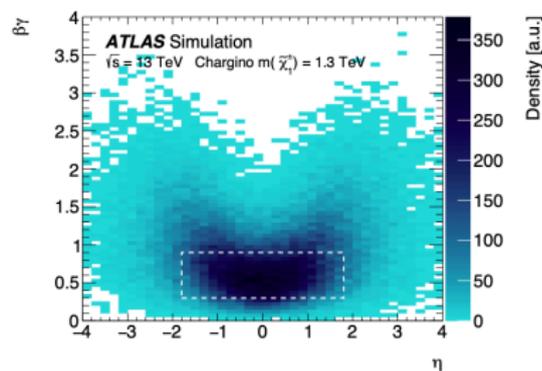
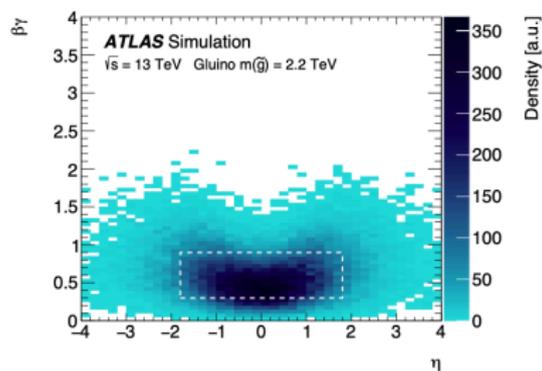
dE/dx analysis: signal distributions

SUSY-2018-42



dE/dx analysis: signal distributions

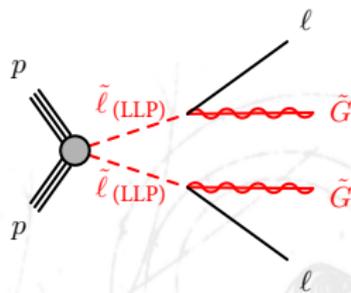
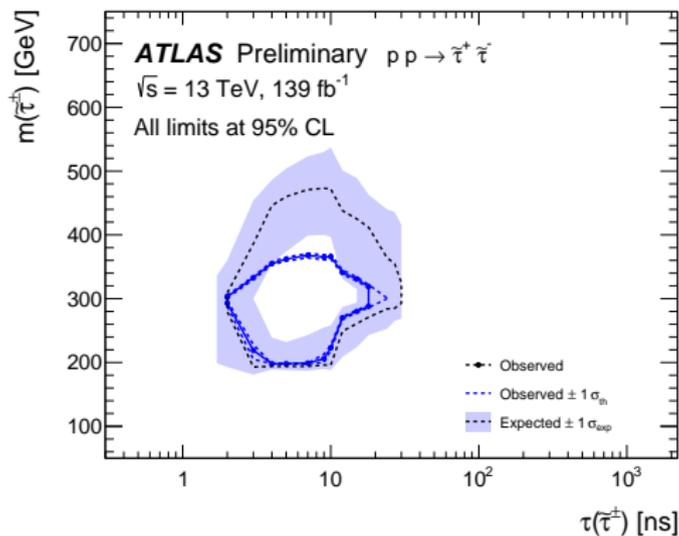
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dE/dx analysis: stau limits

SUSY-2018-42

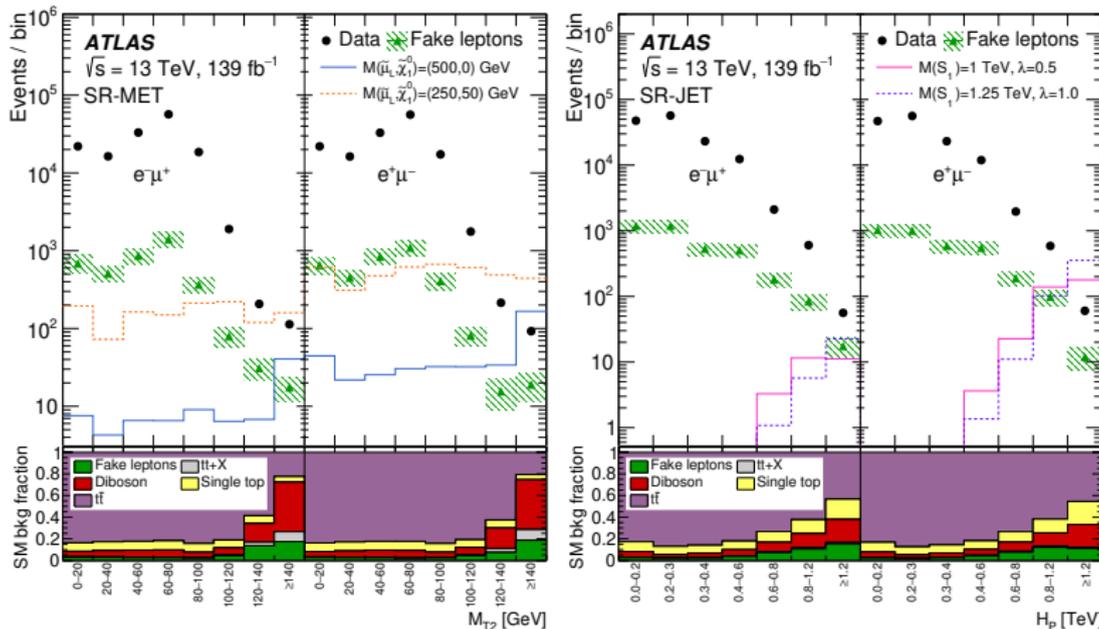
Limits on the stau interpretation.



Emu analysis: data distributions

arXiv:2112.08090

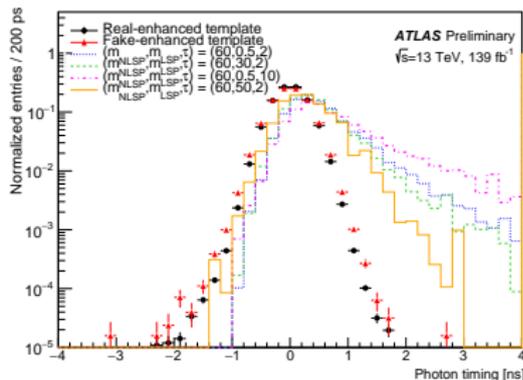
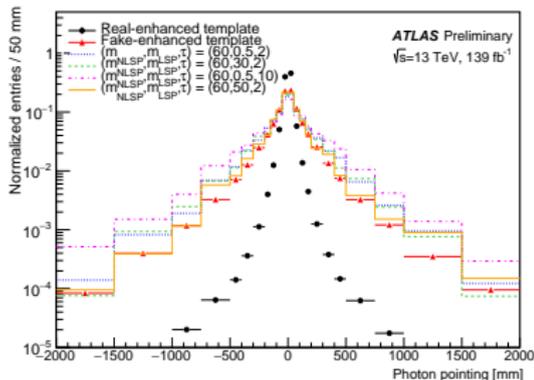
Binned numerator and denominator data distributions for the two general signal regions:



Non-pointing/delayed photons: background

ATLAS-CONF-2022-017

- Real and fake photon distributions for pointing and timing variables
- Very similar for timing, very different for pointing.



Non-pointing/delayed photons: signal regions

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| Parameter | Low- Δm selection ($\Delta m = 10$ GeV) | | | | High- Δm selection ($\Delta m > 10$ GeV) | | | |
|-------------------------------|---|---------------------------|-----------|------|--|---------------------------|-----------|------|
| | CR | VR(E_T^{miss}) | VR(t) | SR | CR | VR(E_T^{miss}) | VR(t) | SR |
| E_{cell} [GeV] | > 7 | | | | > 10 | | | |
| E_T^{miss} [GeV] | < 30 | 30–50 | > 80 | > 80 | < 30 | 30–50 | > 50 | > 50 |
| t_γ [ns] | > 0 | > 0 | < 0 | > 0 | > 0 | > 0 | < 0 | > 0 |
| $ \Delta z_\gamma $ bins [mm] | [0, 50, 100, 200, 300, 2000] | | | | | | | |
| $ t_\gamma $ bins [ns] | [0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 12.0] | | | | | | | |
| 1 γ channel | | | | | | | | |
| $\geq 2\gamma$ channel | [0, 0.2, 0.4, 0.6, 0.8, 1.0, 12.0] | | | | | | | |

2 leptons + jets: Strong

- Weight emu data for flavour symmetric backgrounds (tt, WW)
- Zjets estimate: flip $\Delta\phi(j_{1,2}, E_T^{\text{miss}})$ cuts to define CRs

