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# Reconstruction techniques in supersymmetry searches with the ATLAS experiment

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(on behalf of the ATLAS collaboration)

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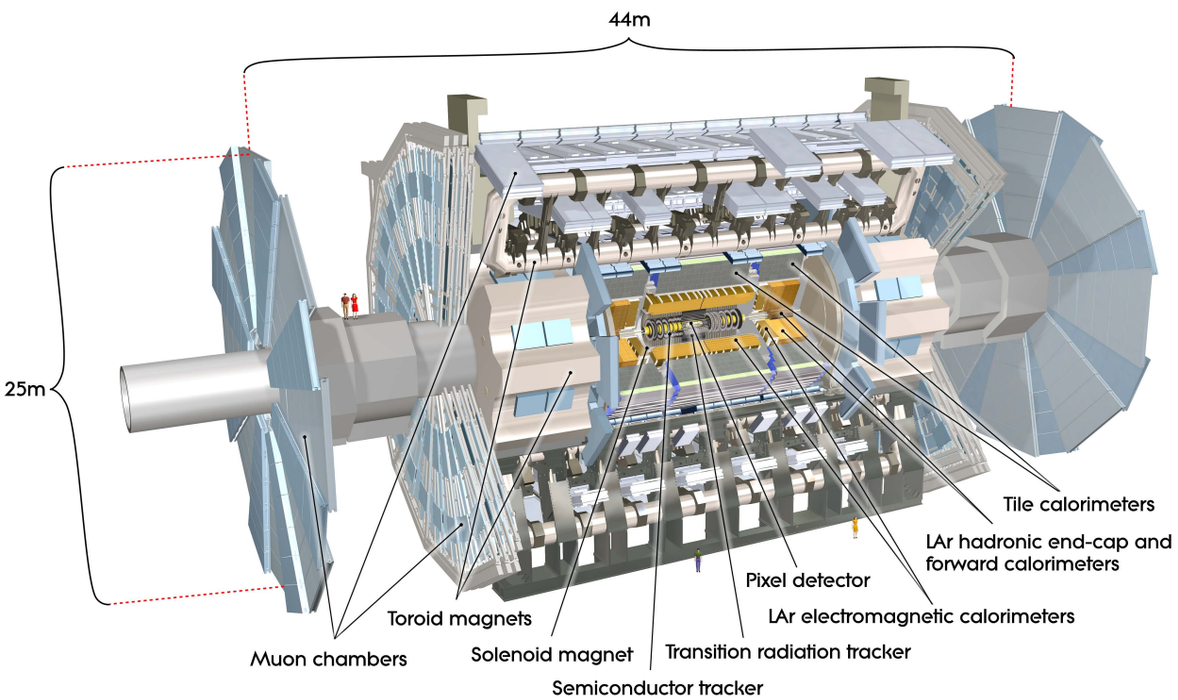
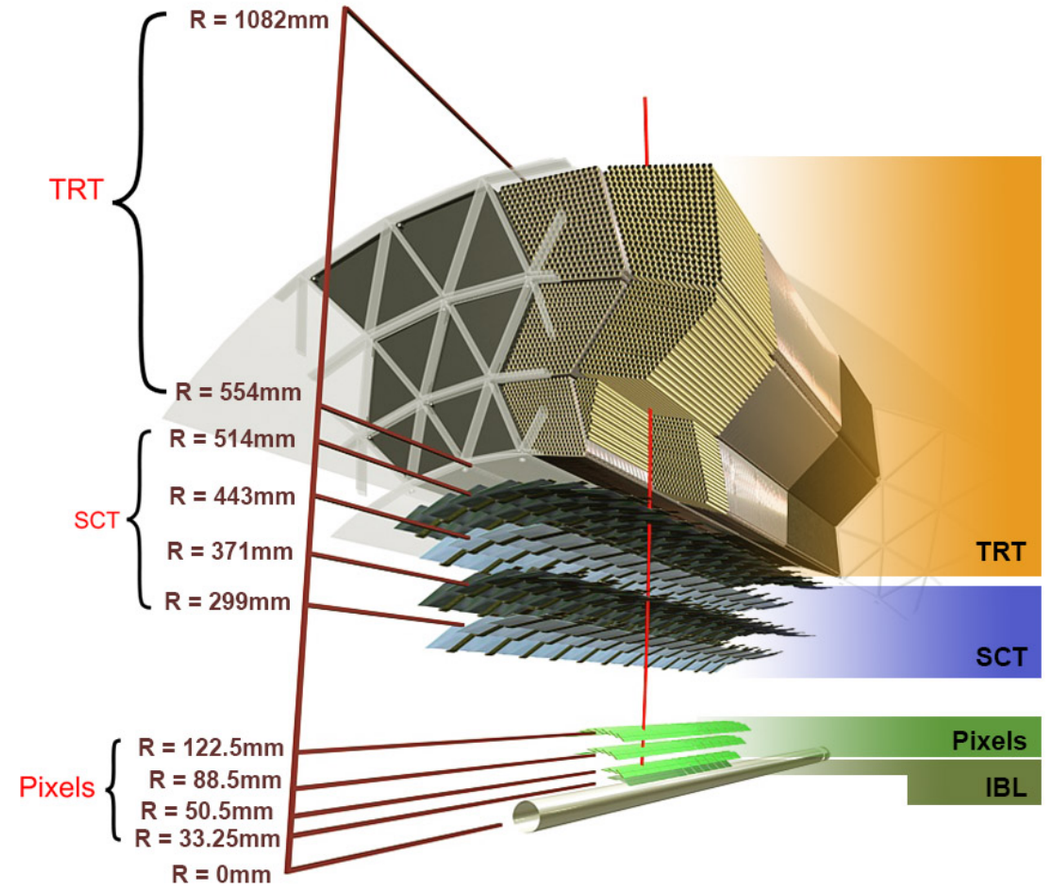
25 years 1992-2017 ATLAS EXPERIMENT

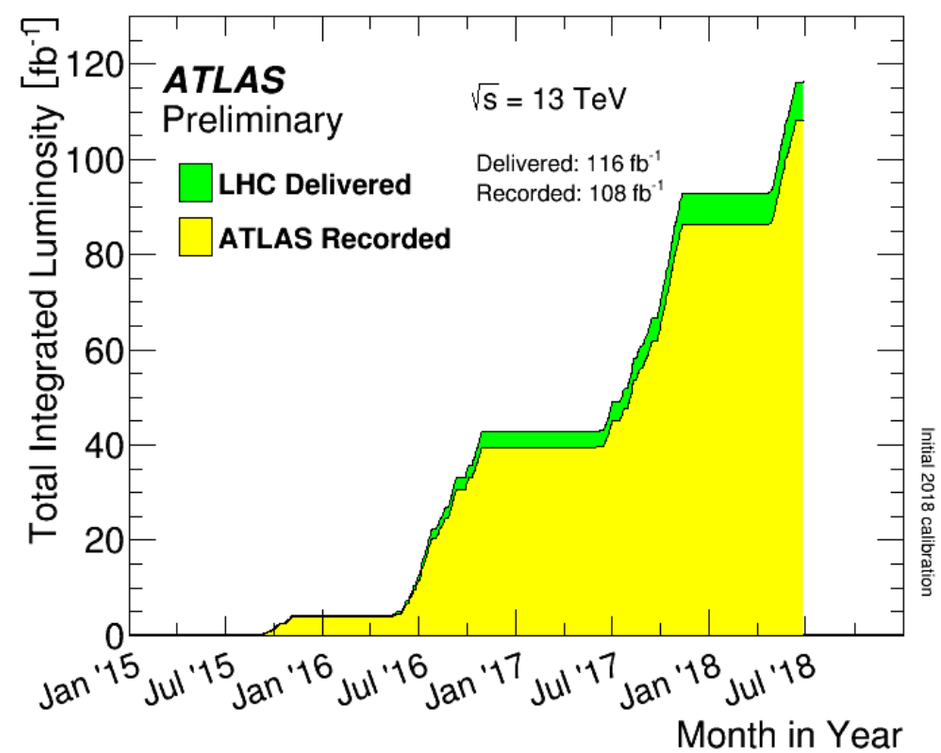
**Sheffield University Learned Society Fund**

# ATLAS Detector



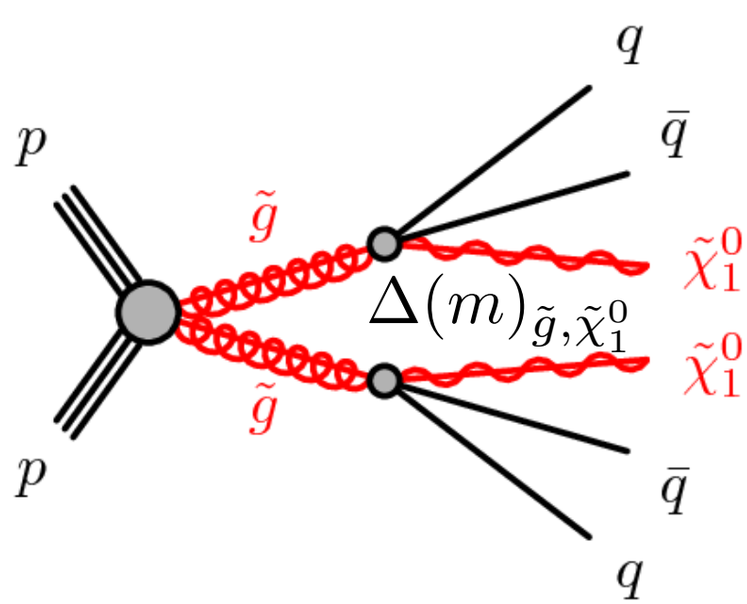

- Main change for run 2 is the Insertable B-Layer (IBL).
- Improved vertexing capabilities.

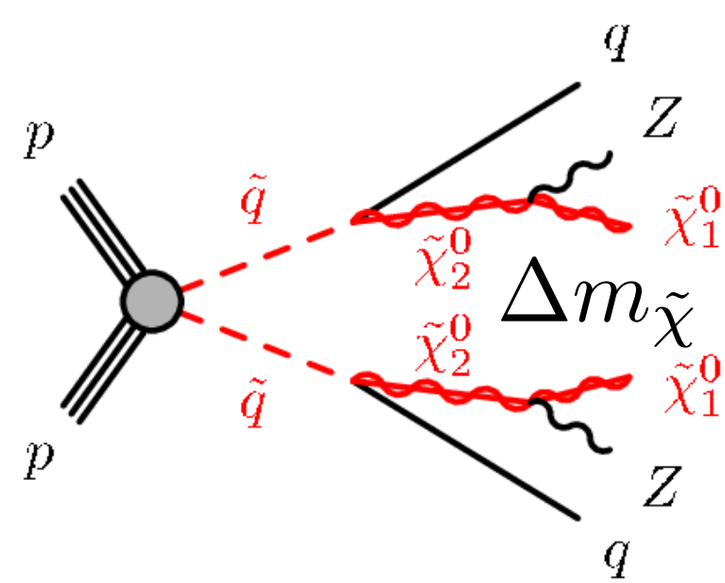


# Supersymmetry Phase-Space

- Complicated decays combined with large mass differences, $\Delta(m)_{\tilde{q},\tilde{\chi}_1^0}$ ,can result in boosted system with multiple quarks - reconstructed with one large-R jet.

- Low mass difference, $\Delta m_{\tilde{\chi}}$ ,can result in low $P_T$ jets or leptons.



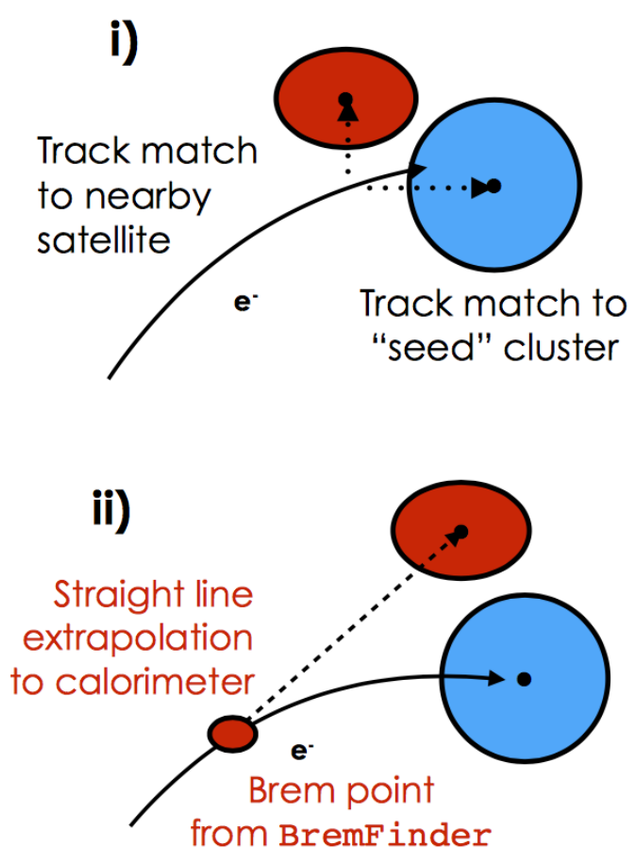



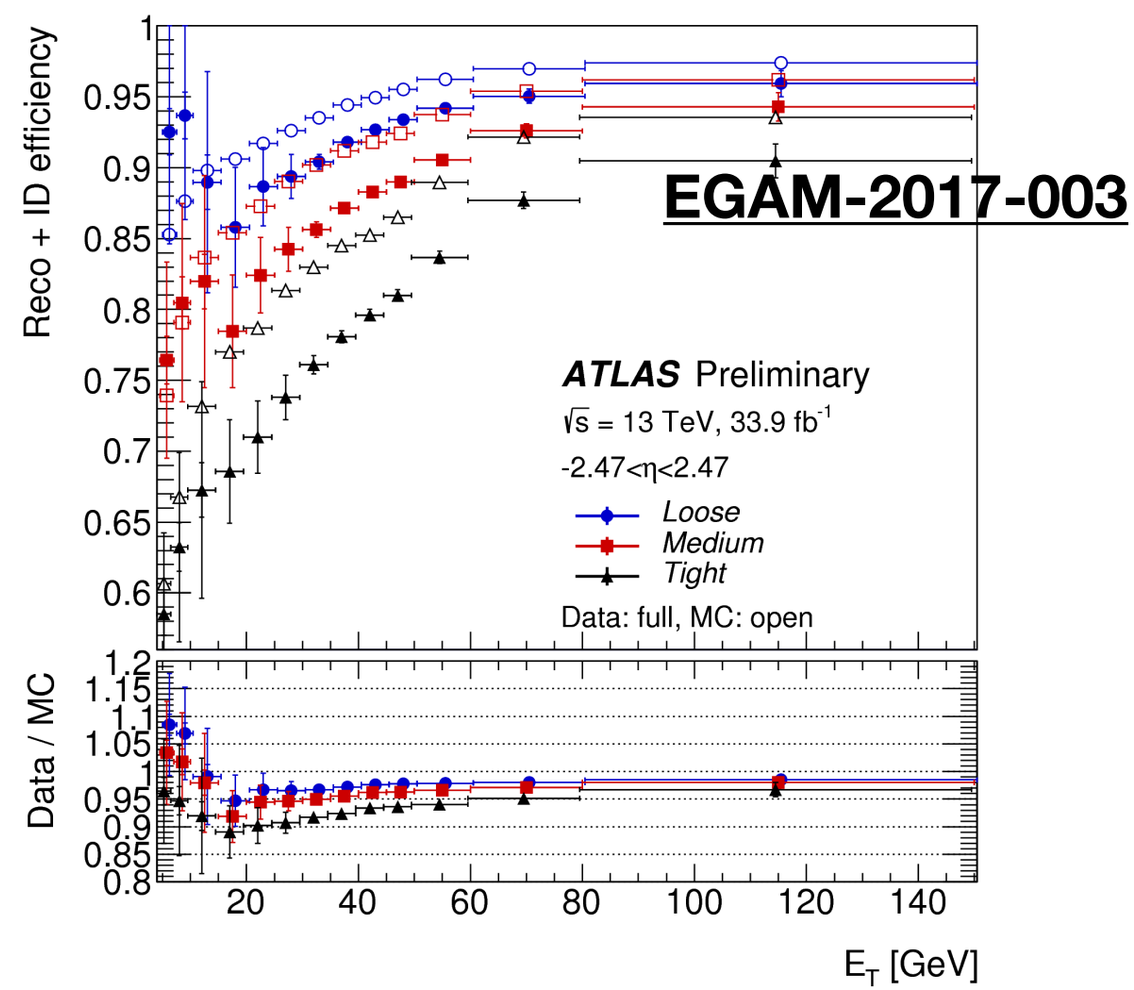
# Soft Electrons

- Electrons currently reconstructed down to 4.5 GeV - was not difficult to implement reconstruction down to these low values, main challenge was tuning selections to evaluate the efficiencies and derive data-MC scale factors.

- Possibility to go to lower electron $P_T$ with topologically formed clusters - formed by dynamically growing cluster based on noise thresholds (previously a fixed size window was scanned across the calorimeter to find clusters above an energy threshold).

- Match track, corrected for Bremsstrahlung, to seed cluster - then add satellite clusters in fixed window. Better electron resolution (than previous sliding window clusters) because this better captures resolution tails caused by Bremsstrahlung photon energy deposits in phi direction.



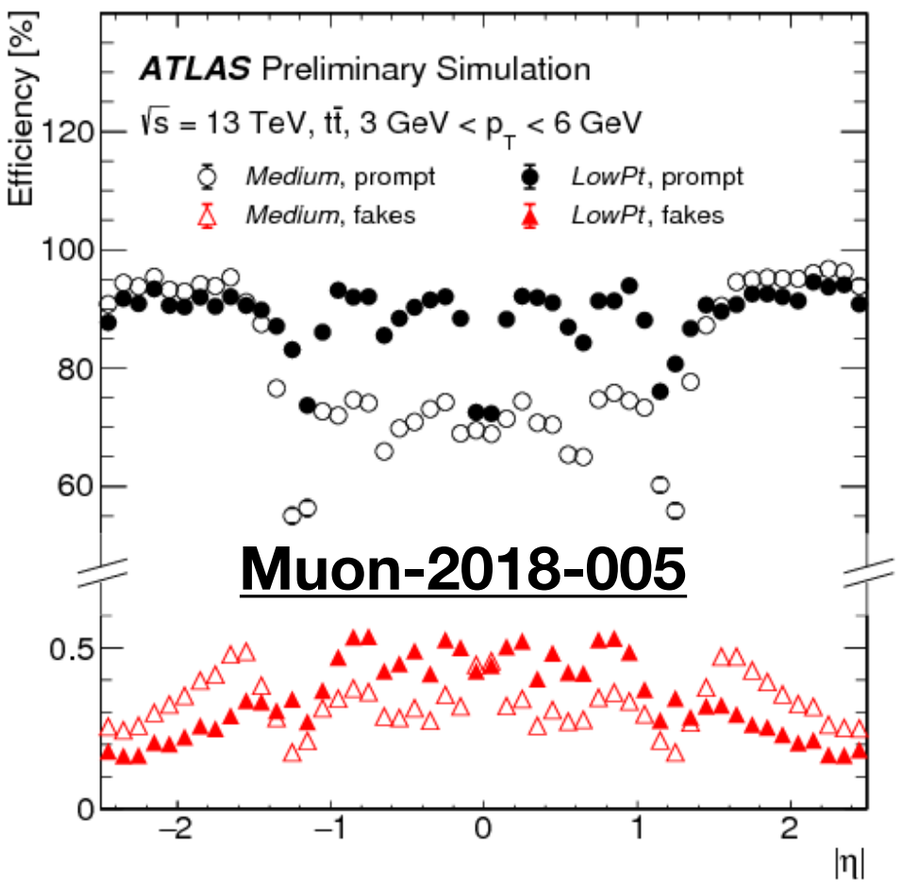



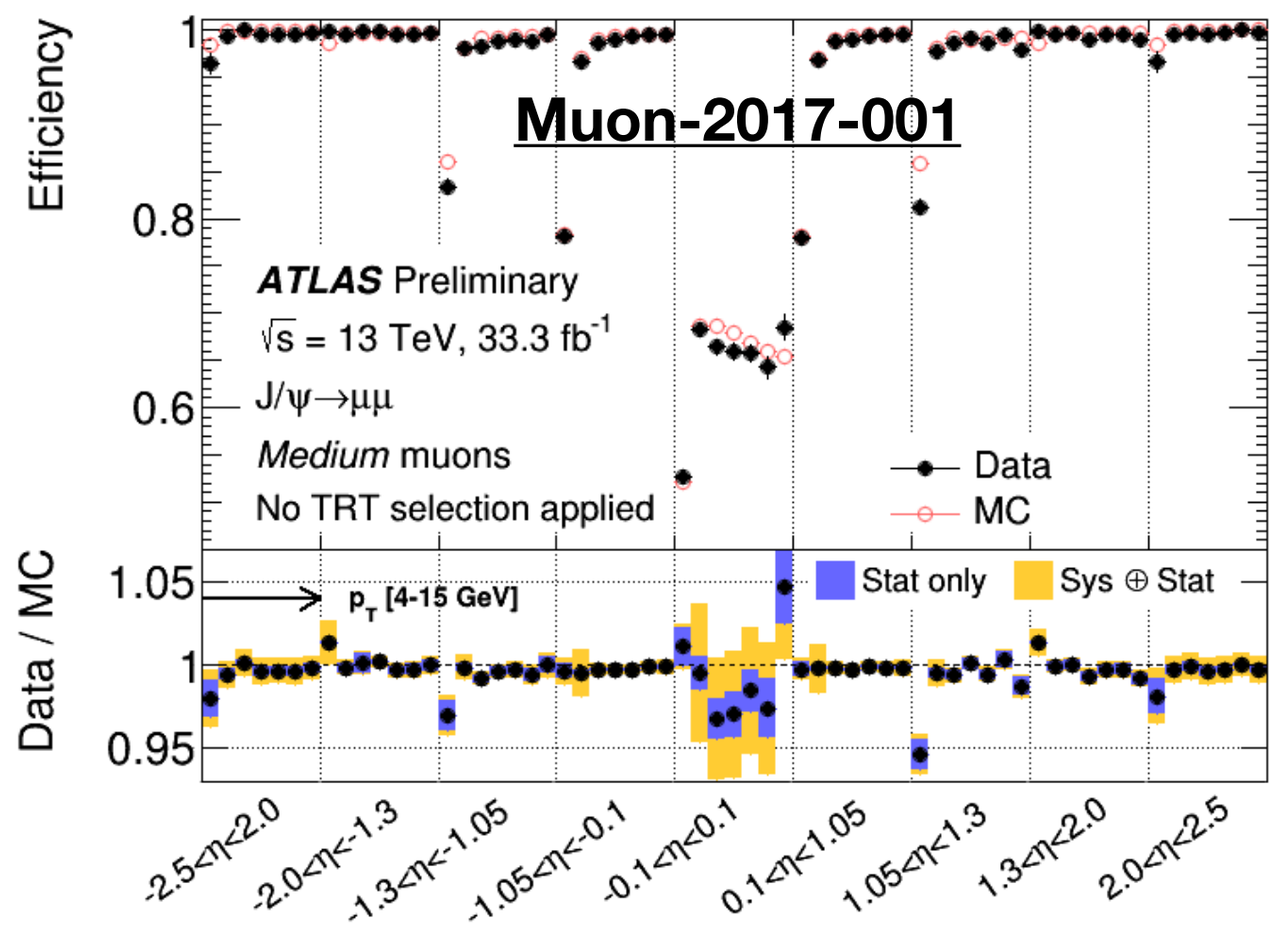
# Soft Muons

- Four categories - Combined (CB) fit of ID and muon track, Segment Tagged if ID track matched to Muon Segment, Calorimeter Tagged if ID track matched to MIP calorimeter deposit, Extrapolated using only MS track with a loose compatability with the IP.

- Reconstruction can currently go down to below 3 GeV (average energy loss in calorimeter is 3 GeV) - challenges to get here included improving reconstruction using only hits in innermost MS station whilst controlling the fake rate and commissioning of new partial-event building triggers to select 1 muon + 1 track signatures.

- Current published SUSY analyses use muons as far down as 4 GeV - future analyses will be able to go down to 3 GeV (see Zhi Zheng's poster and Muon-2018-005)



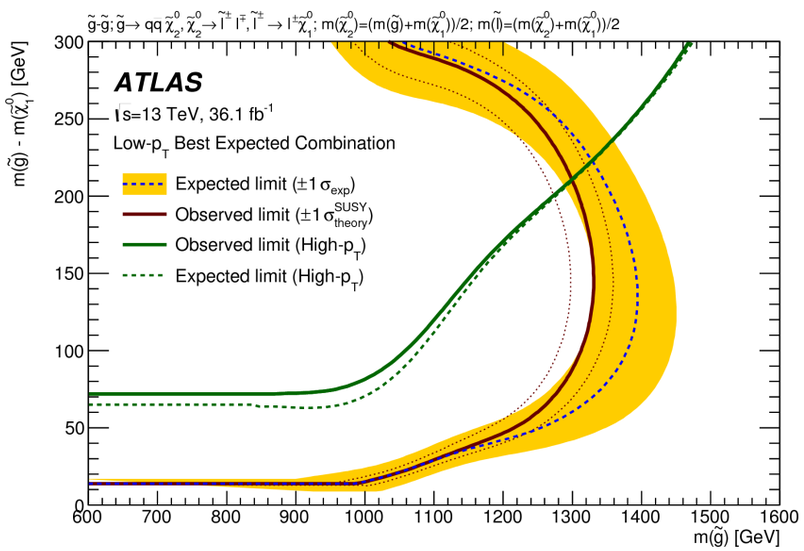



# Soft Leptons

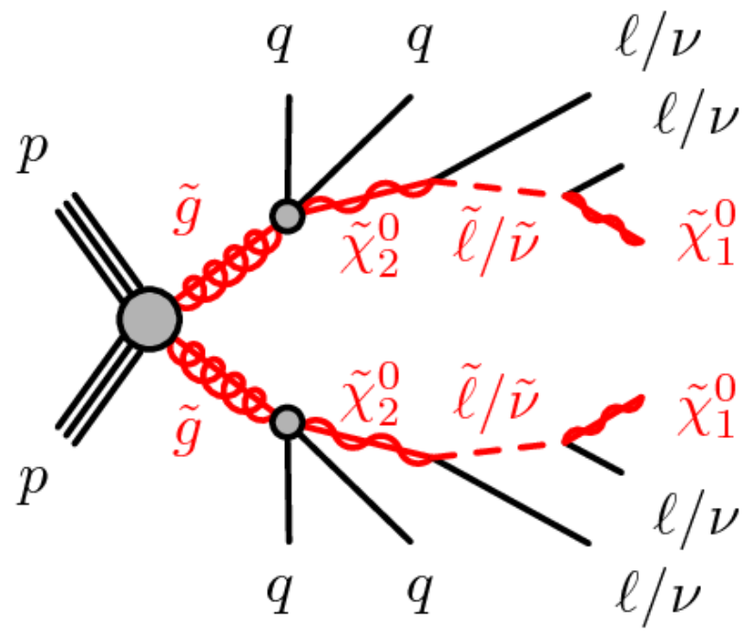
- Analysis targeting gluino decay via sleptons with 7 GeV lepton $P_T$ thresholds shows significant gains in sensitivity (mass splitting of ~15 GeV c.f ~70 GeV without low $P_T$ Signal Region (SR)).

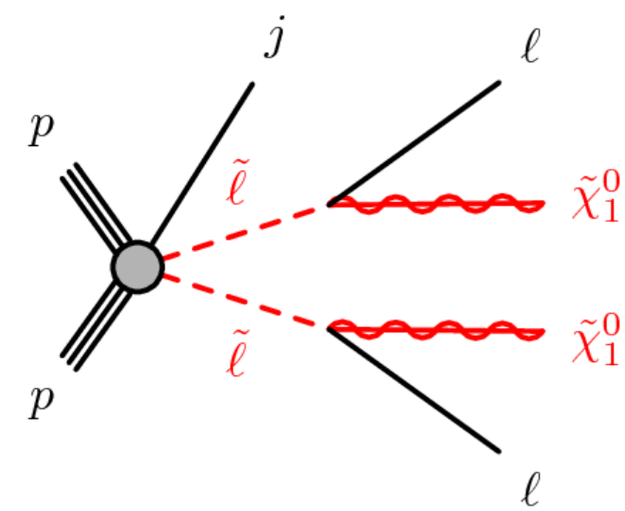
- Further gains possible with new lower thresholds - much of background is fake lepton from heavy flavour decays. Key to improving the performance lies with lepton isolation and impact parameters.

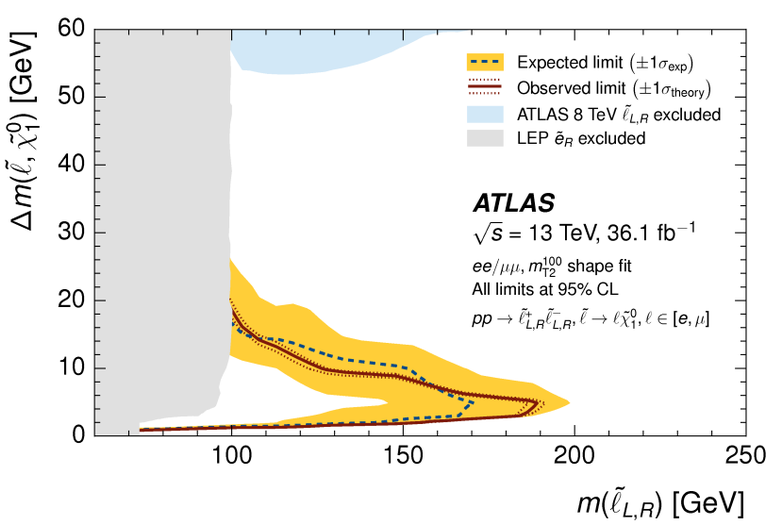
- New ideas being studied include prompt lepton tagger to replace isolation algorithms, which could potentially have better performance for rejection of heavy flavour decays.




**arXiv:1805.11381**

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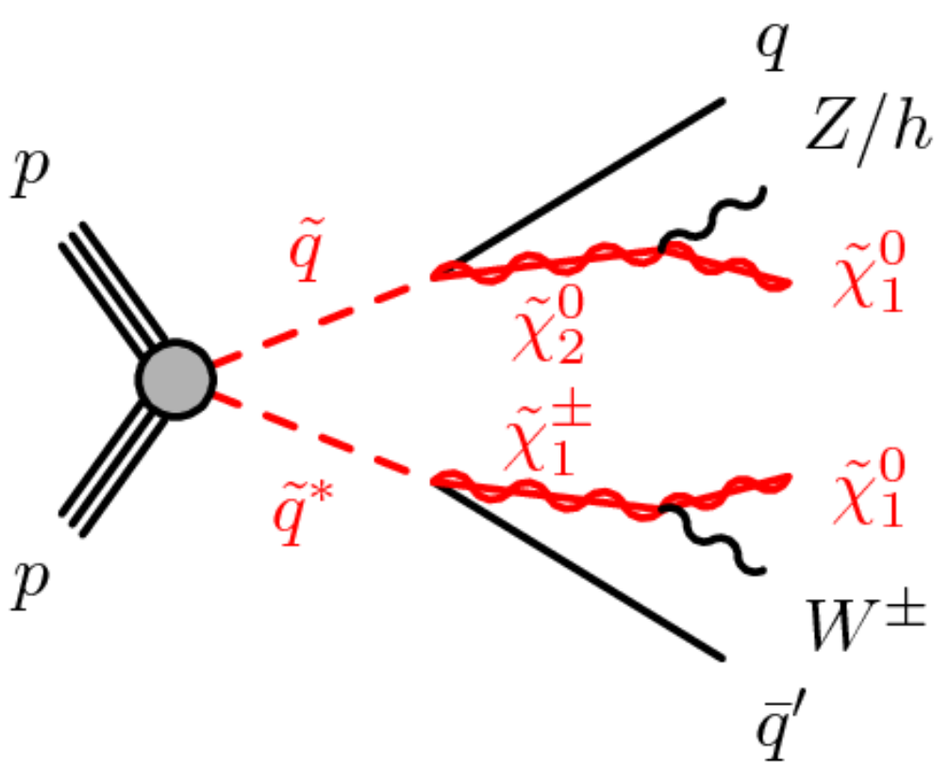
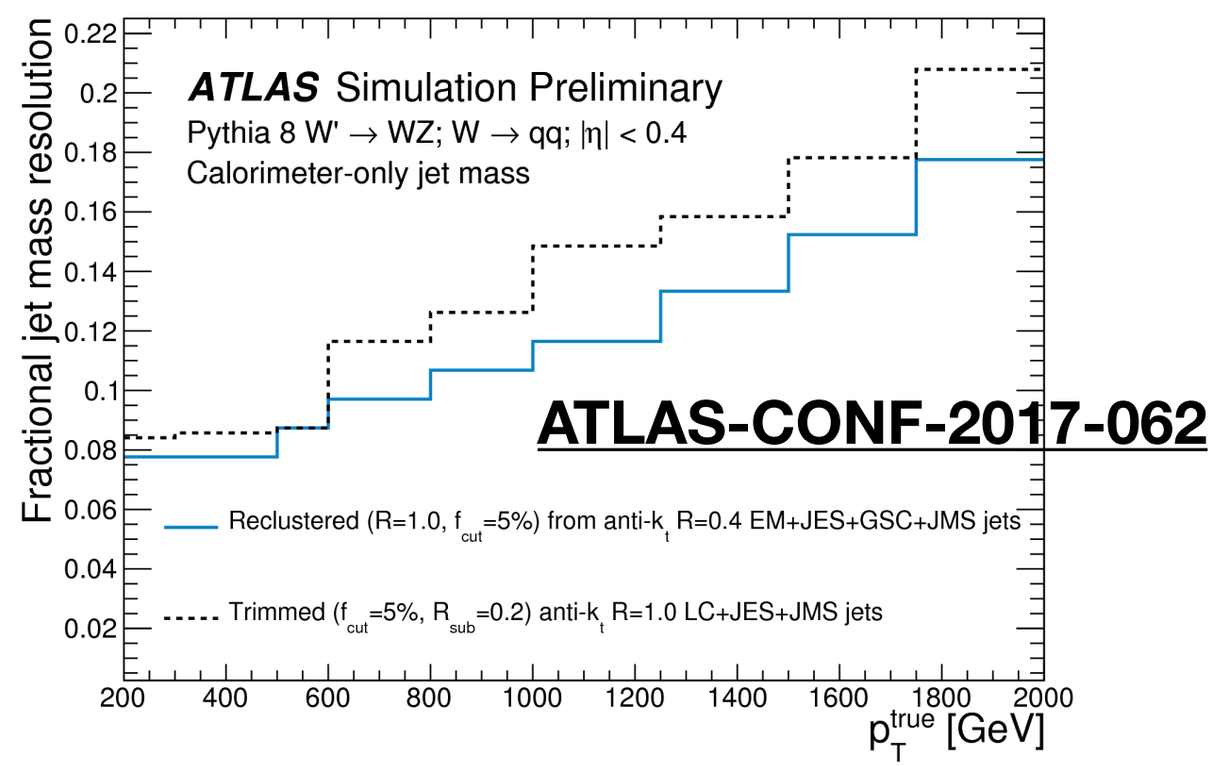
Using lowest supported lepton thresholds for muons (4 GeV) and electrons (4.5 GeV) key to constrain models with slepton-neutralino mass differences down to 1 GeV.

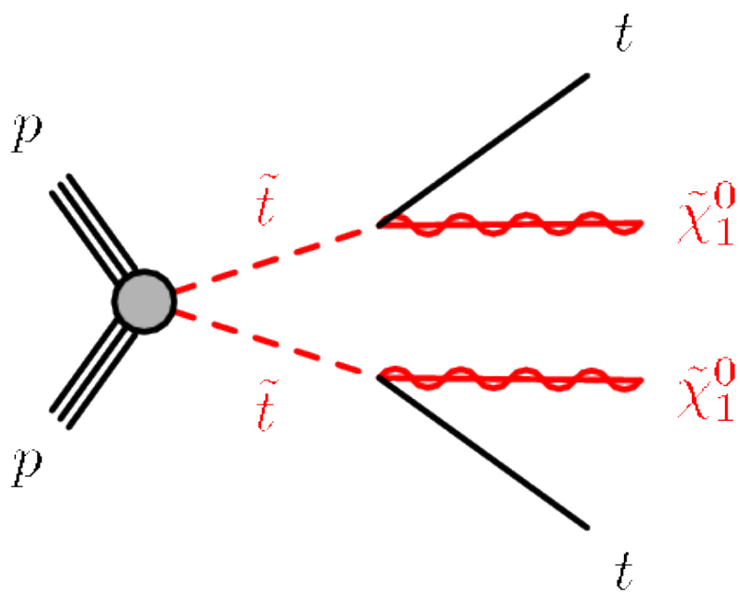
# Reclustered jets

- “Standard” jet finding in ATLAS uses the Anti-Kt algorithm with a radius parameter of 0.4
- In boosted topologies the two jets could be close together - then use larger radius jets.
- Two strategies investigated - run jet finding with large radius parameter (e.g. 1.0) or cluster the existing calibrated 0.4 jets into a larger jet (known as reclustering).
- Reclustering can use the detailed calibrations and uncertainties from the 0.4 jets - allows more flexibility in the parameters of the large R jet because no dedicated calibration is needed.

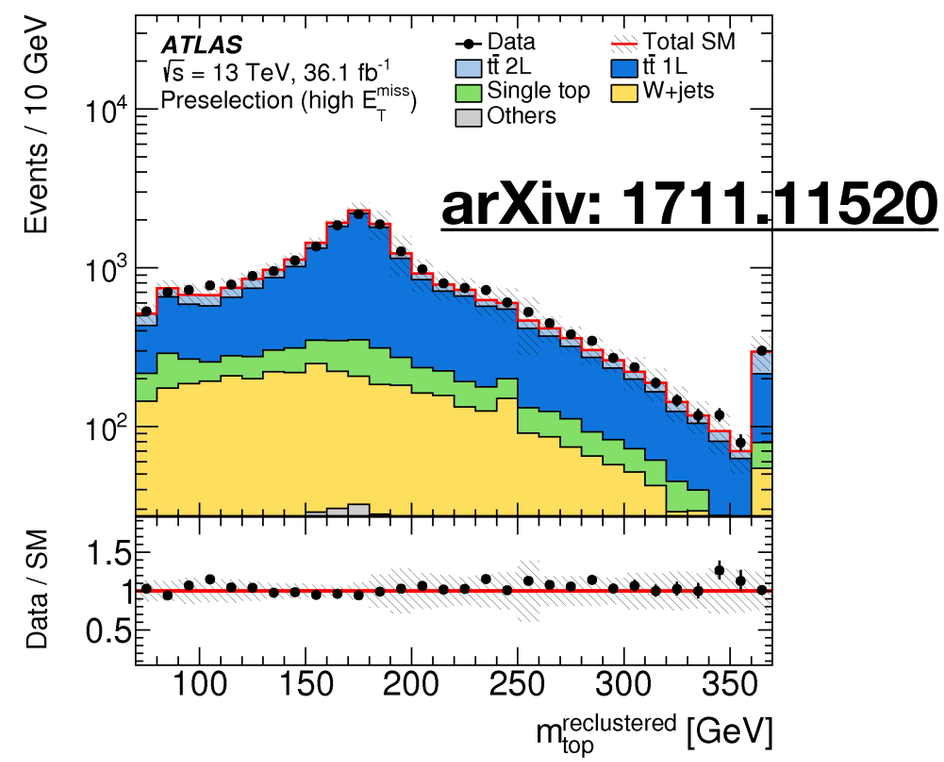


# Top Tagging

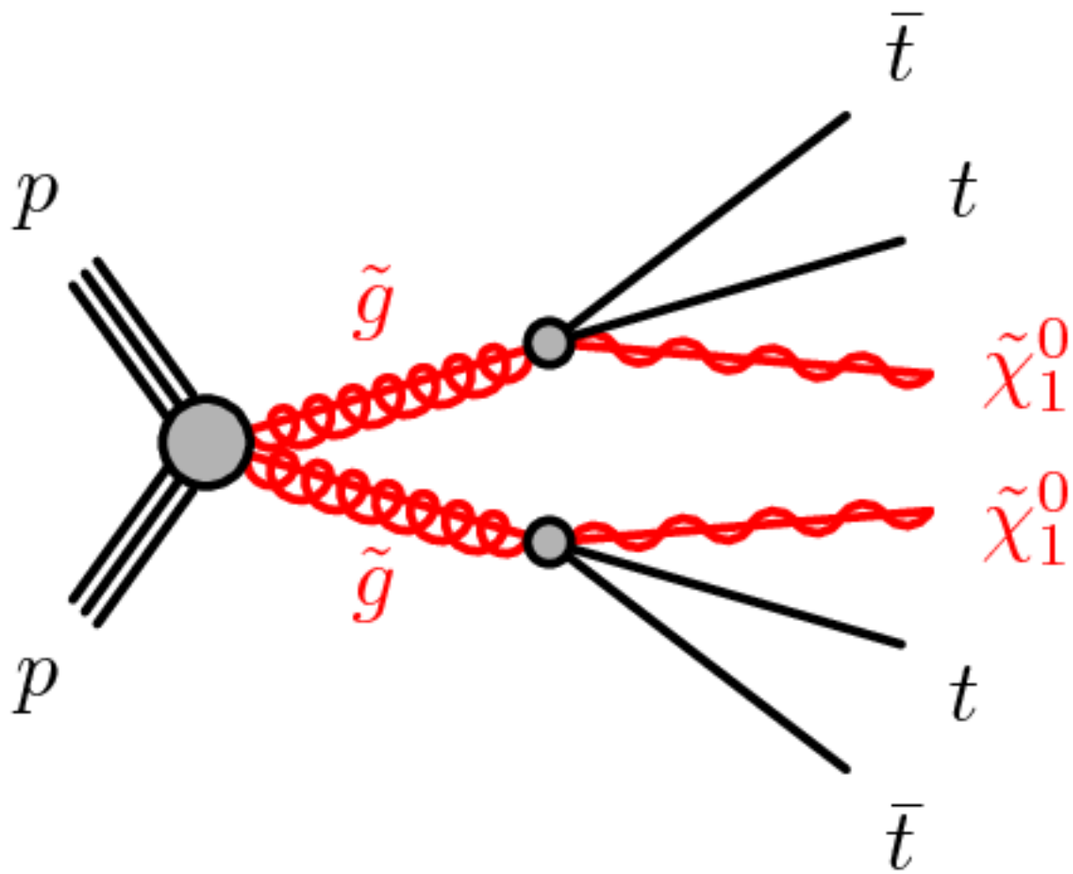


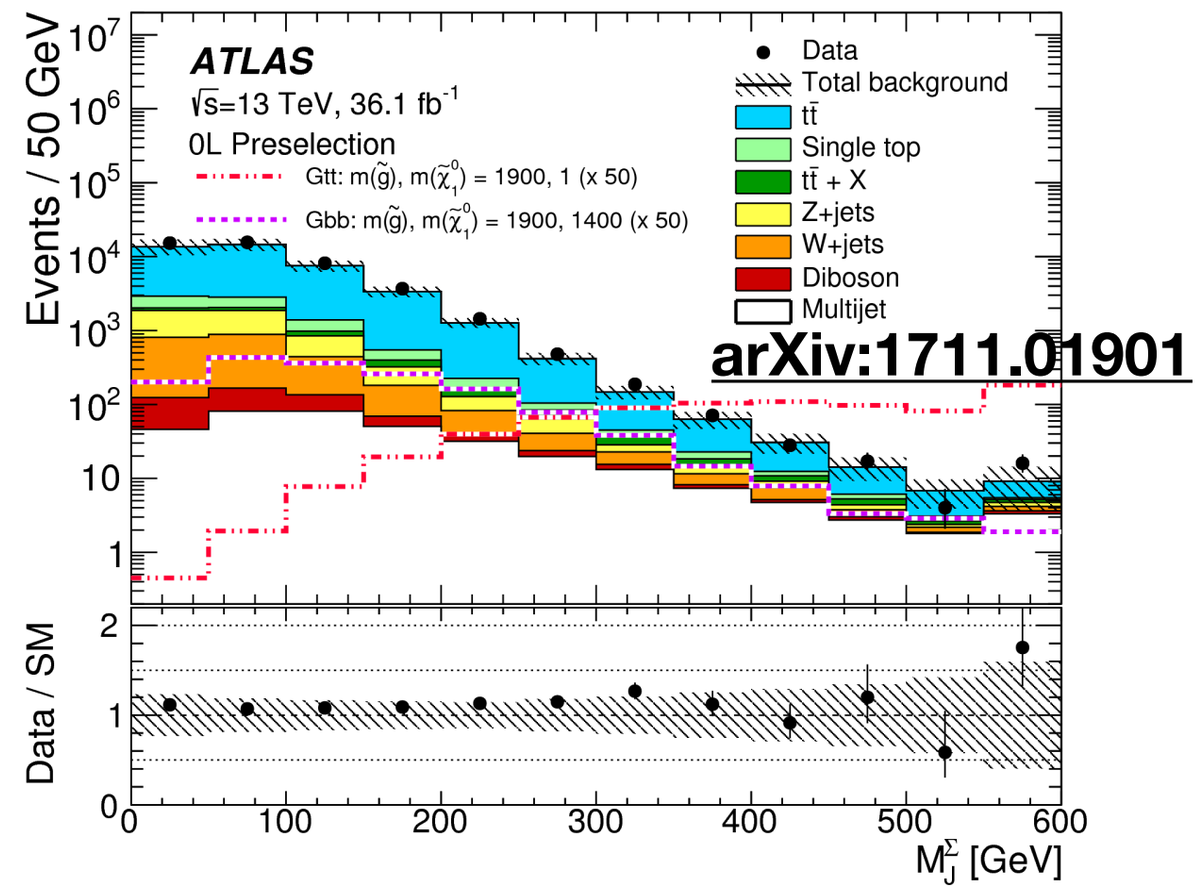

$$R(P_T) = 2\frac{m_{top}}{p_T}$$




- In stop production, with one lepton, we can tag hadronic top decays to suppress di-leptonic top pair backgrounds.
- Recluster 0.4 jets into 3.0 jets and then reduce radius based on the jet $P_T$, with assumption on the mass (top in this case).
- If this results in a large change in jet $P_T$, then the jet is discarded.
- Finally one can place a cut on the reclustered jet mass.

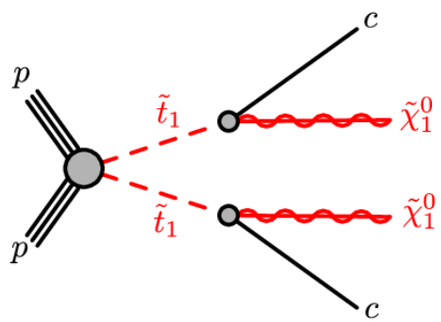
# Total Jet Mass




- Recluster 0.4 jets into 0.8 jets with AntiKt algorithm.
- Sum mass of jets with $P_T$ > 200 GeV and |eta| < 2.0 - typically large in models with four top quarks, whilst largest background has only two top quarks.

# Flavour Tagging

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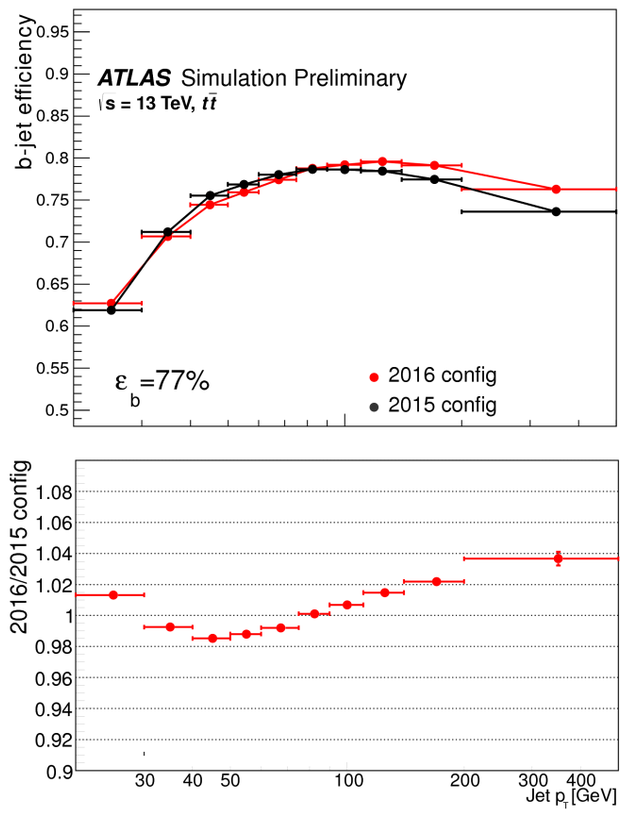
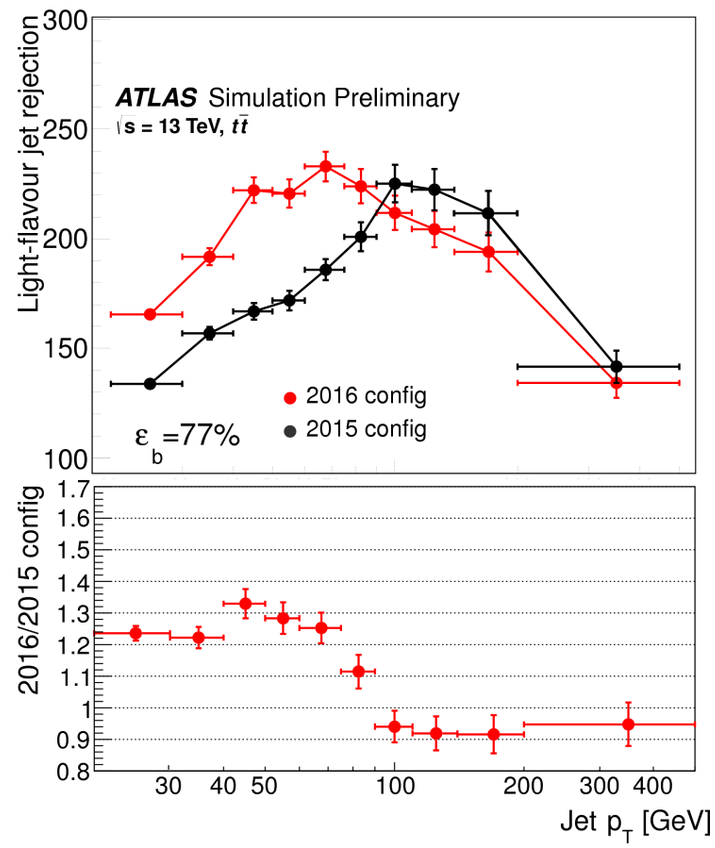
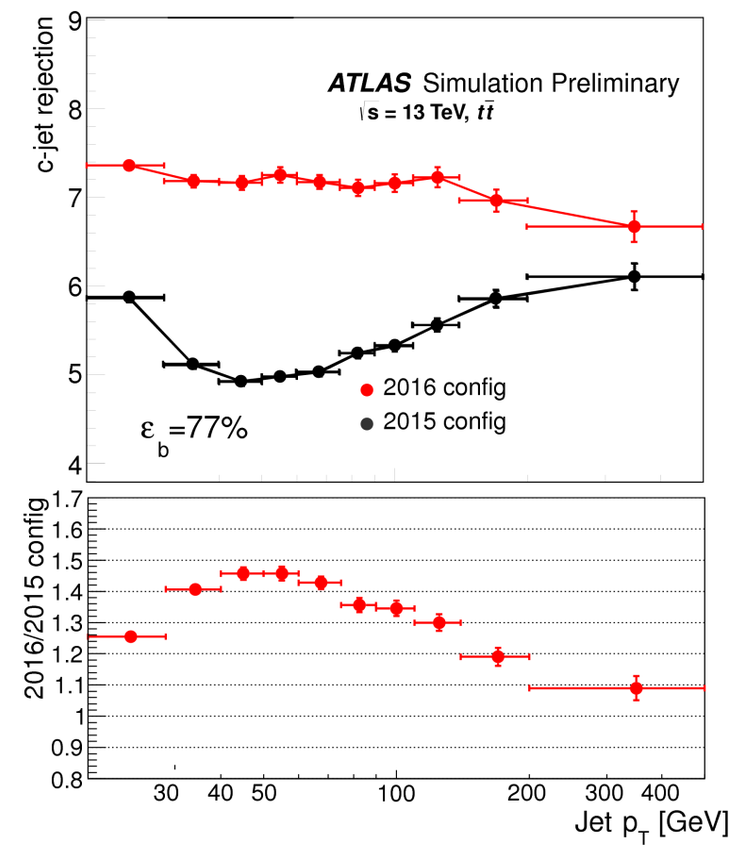
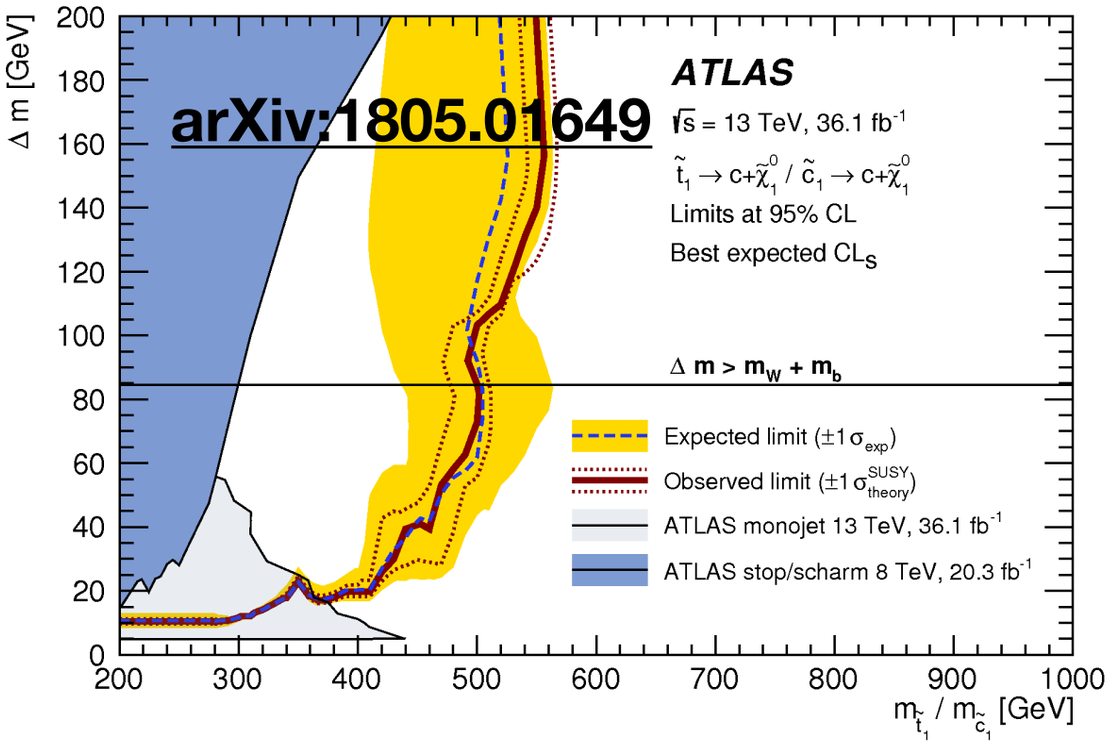


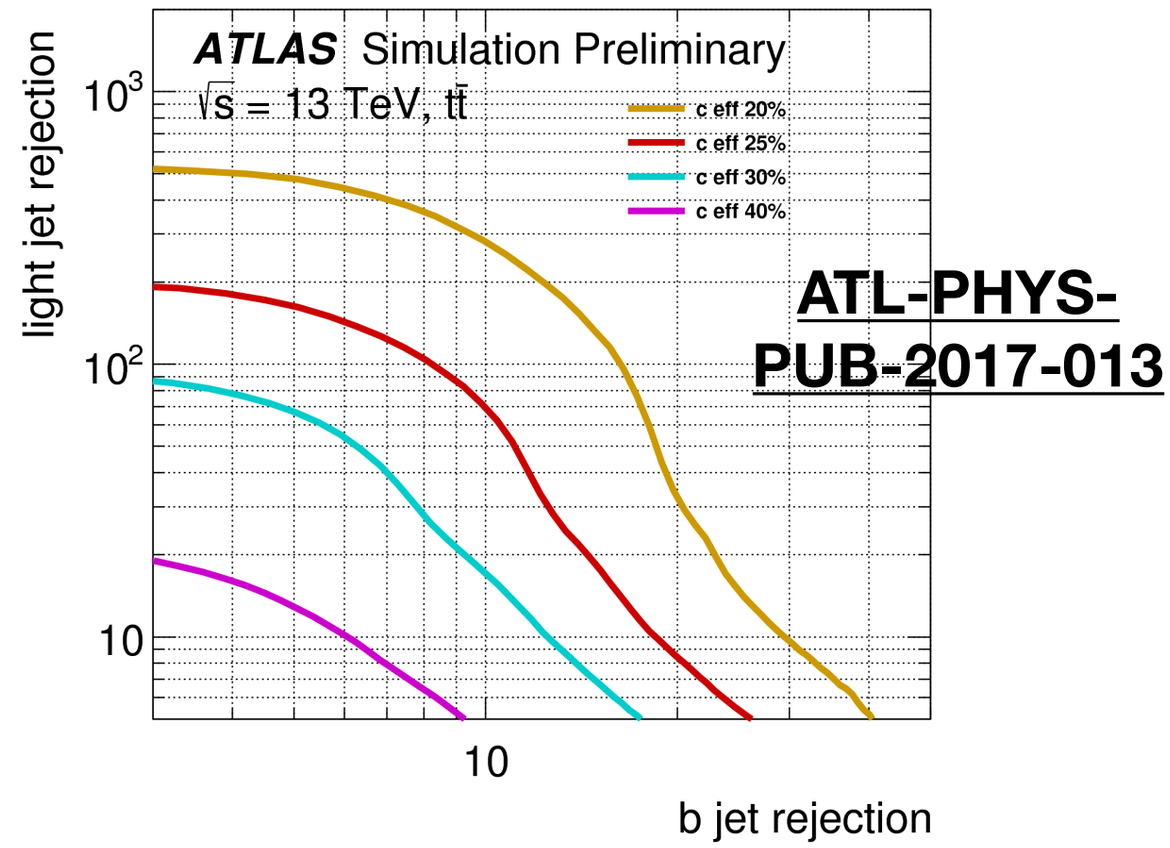




- Production of third generation squarks leads to decay signatures with charm or bottom quarks.
- Boosted Decision Tree analyses output of Impact Parameter, Secondary Vertex Finding and Decay Chain Multi-Vertex algorithms.
- Significant improvements w.r.t Run 1 in performance illustrated with 77% fixed efficiency Working Point.

# Charm Tagging

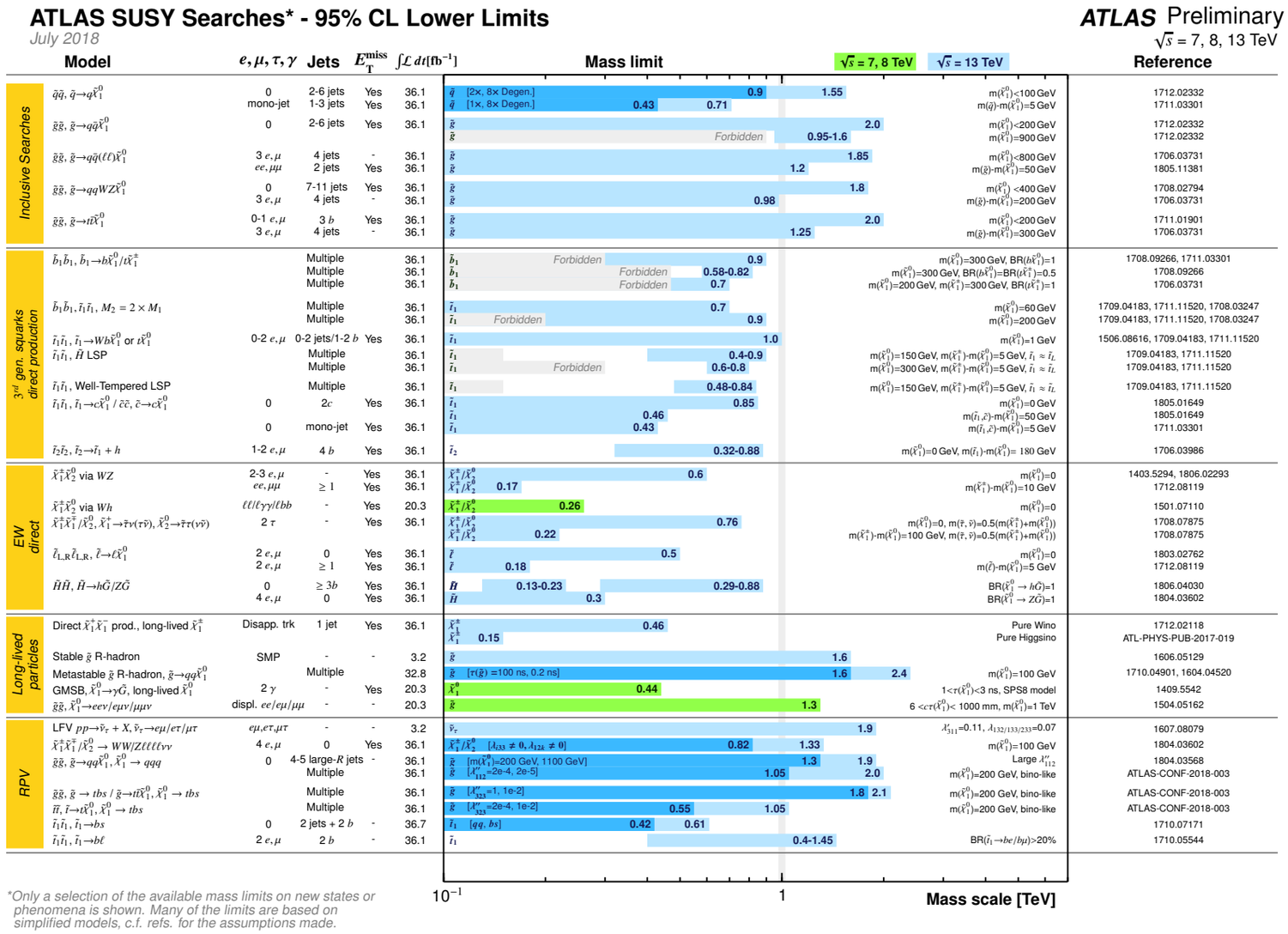



- Charm tagging algorithms use additional variables, related to different kinematics of charm and b-hadron decays (such as invariant mass of secondary tracks, secondary track rapidities, distance from primary to secondary vertex, fraction of jet track energy carried by secondary tracks etc), to discriminate between b and c flavour jets

- New result from Run 2 on stop to charm decays recently released.

# Conclusions




- Reconstruction algorithms being used to push into more extreme parts of SUSY model phase space.

- Many new ideas being investigated in ATLAS - particle flow based jets and MET, low $P_T$ b-tagging with track jets, machine learning for reconstruction (neutral net, BDT, image recognition etc).

- More results to come from ATLAS SUSY searches, some of which will take advantage of the best performing new reconstruction techniques (as well as any improvements in existing algorithms to come)!