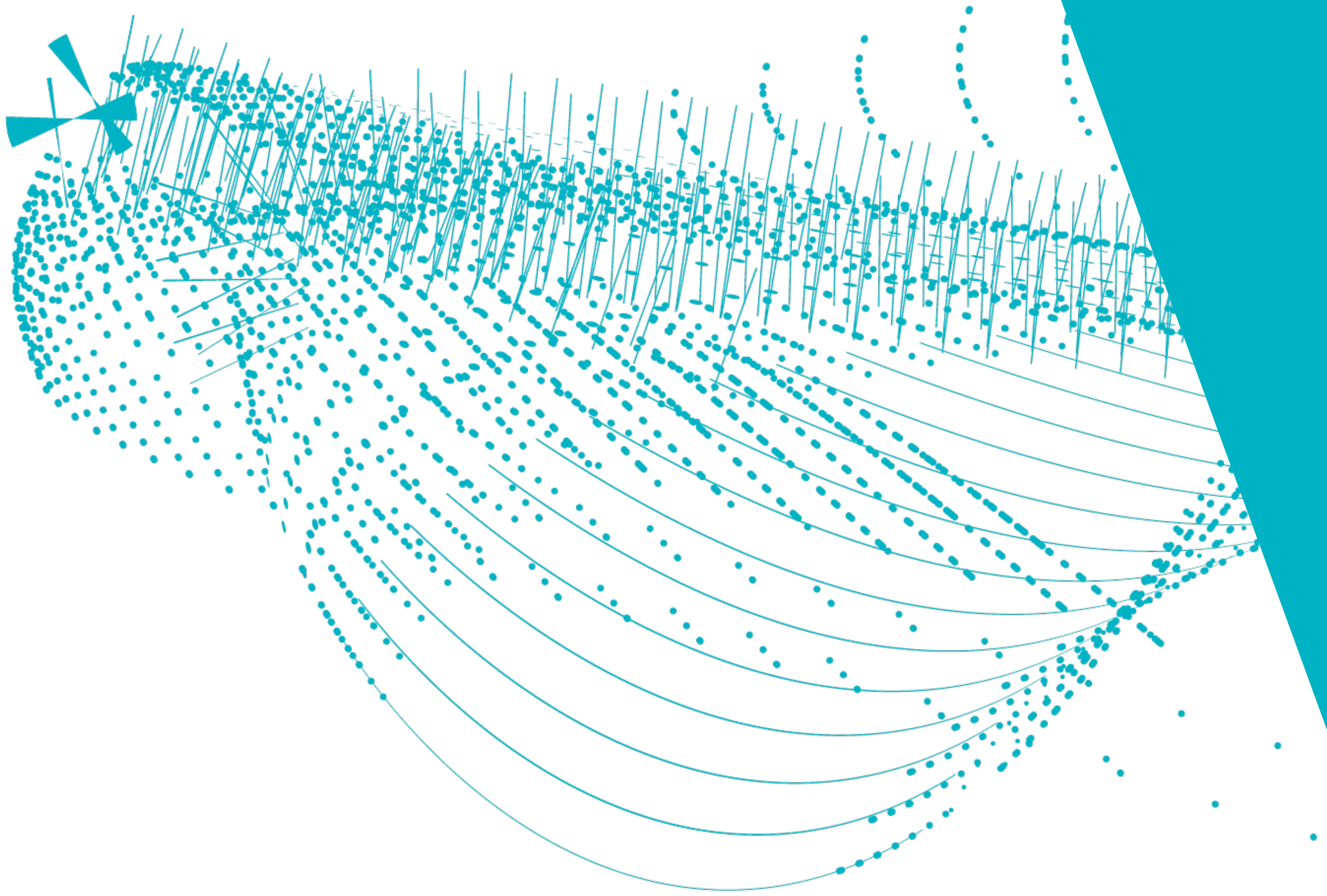
SEARCHES WITH THE ATLAS EXPERIMENT

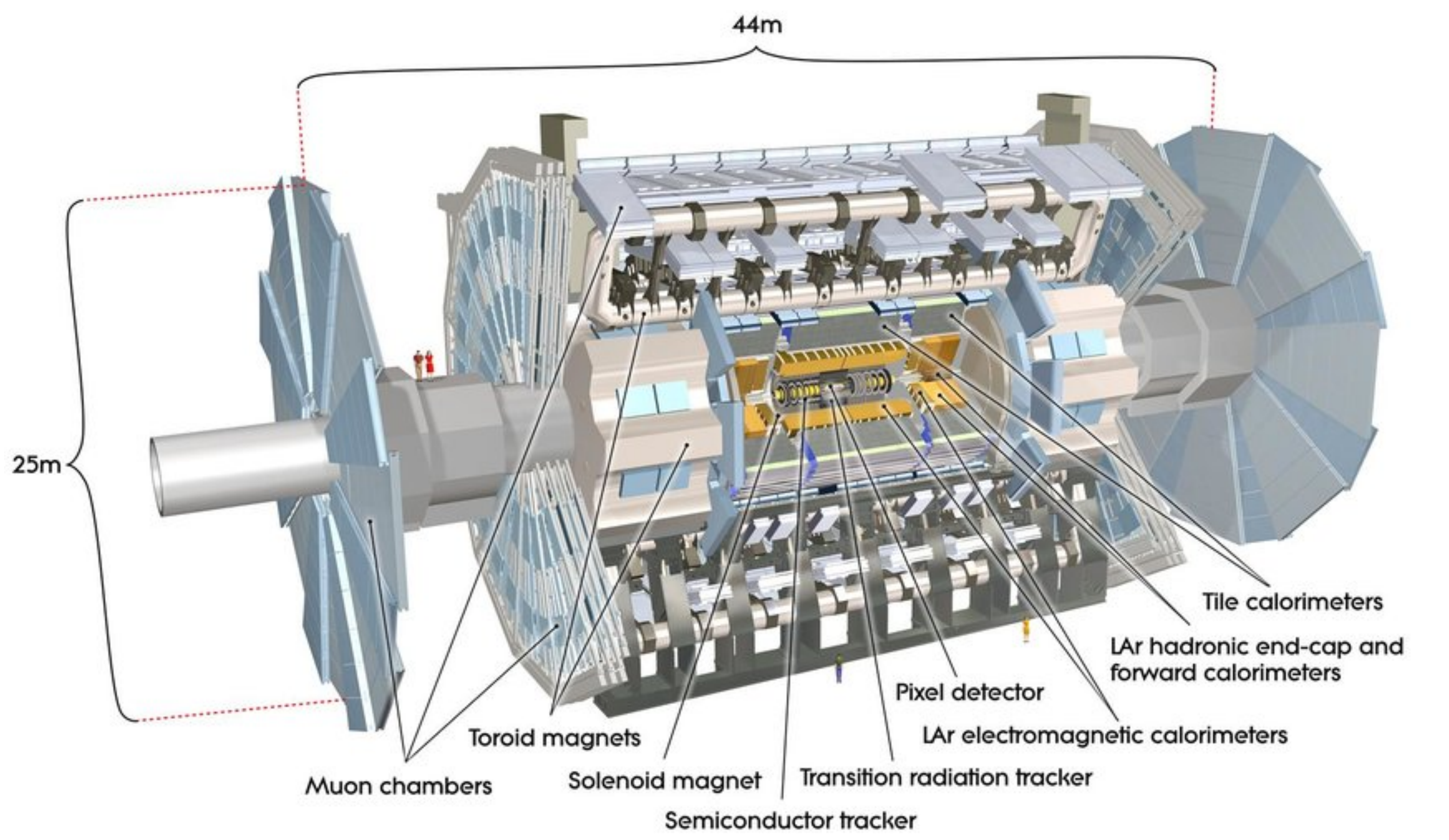


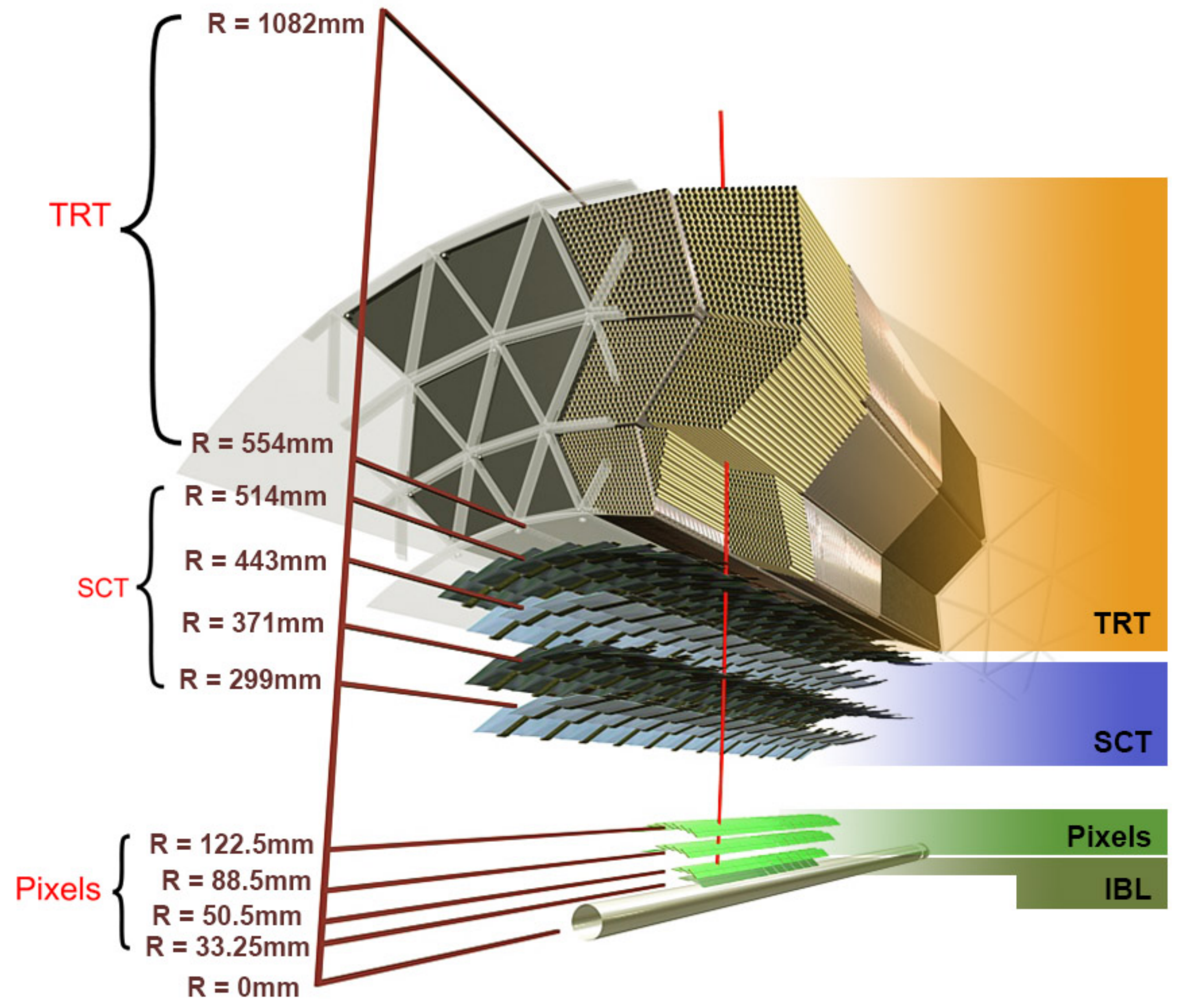
RECONSTRUCTION TECHNIQUES IN SUPERSYMMETRY

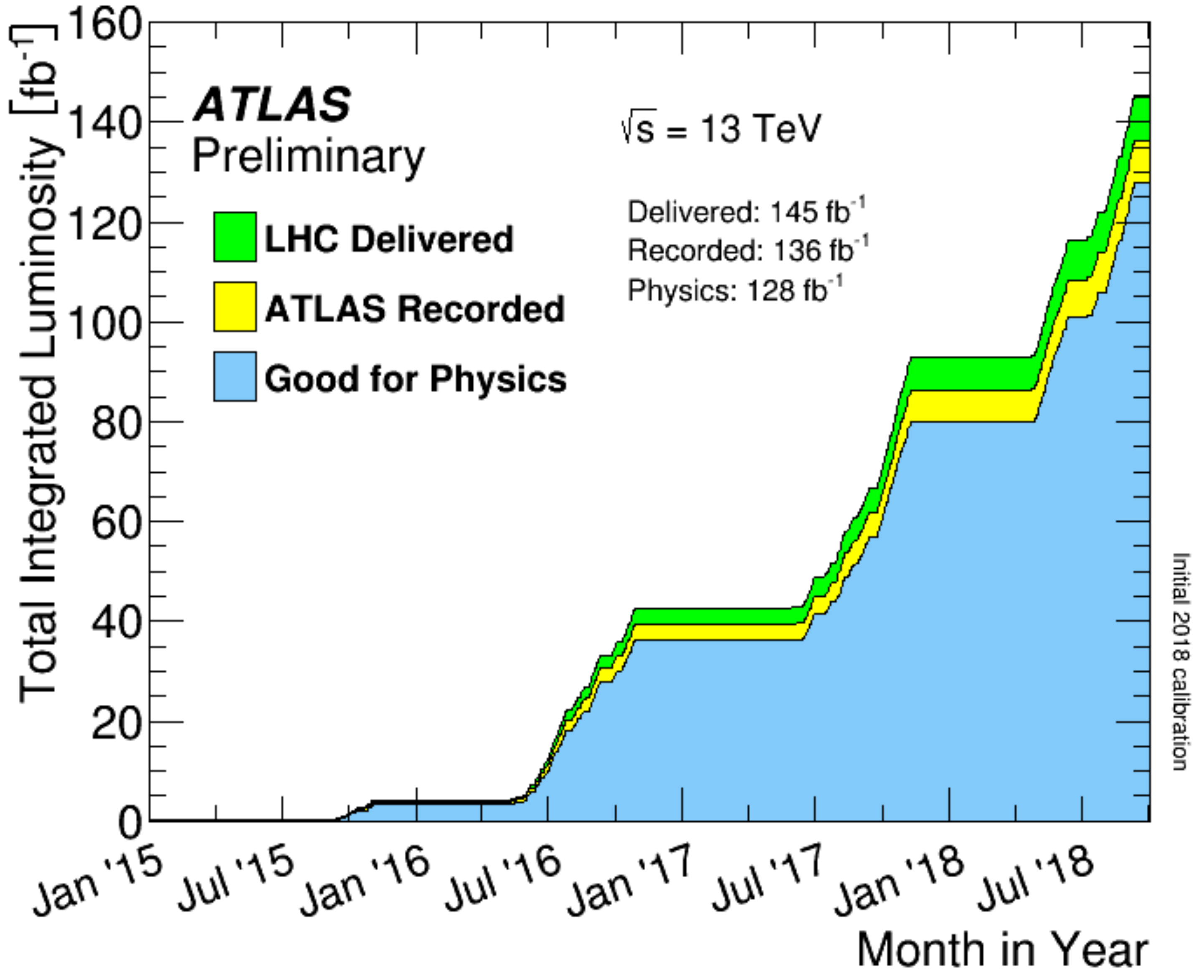
Ambrosius Vermeulen
(on behalf of the ATLAS collaboration)

THE ATLAS DETECTOR

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







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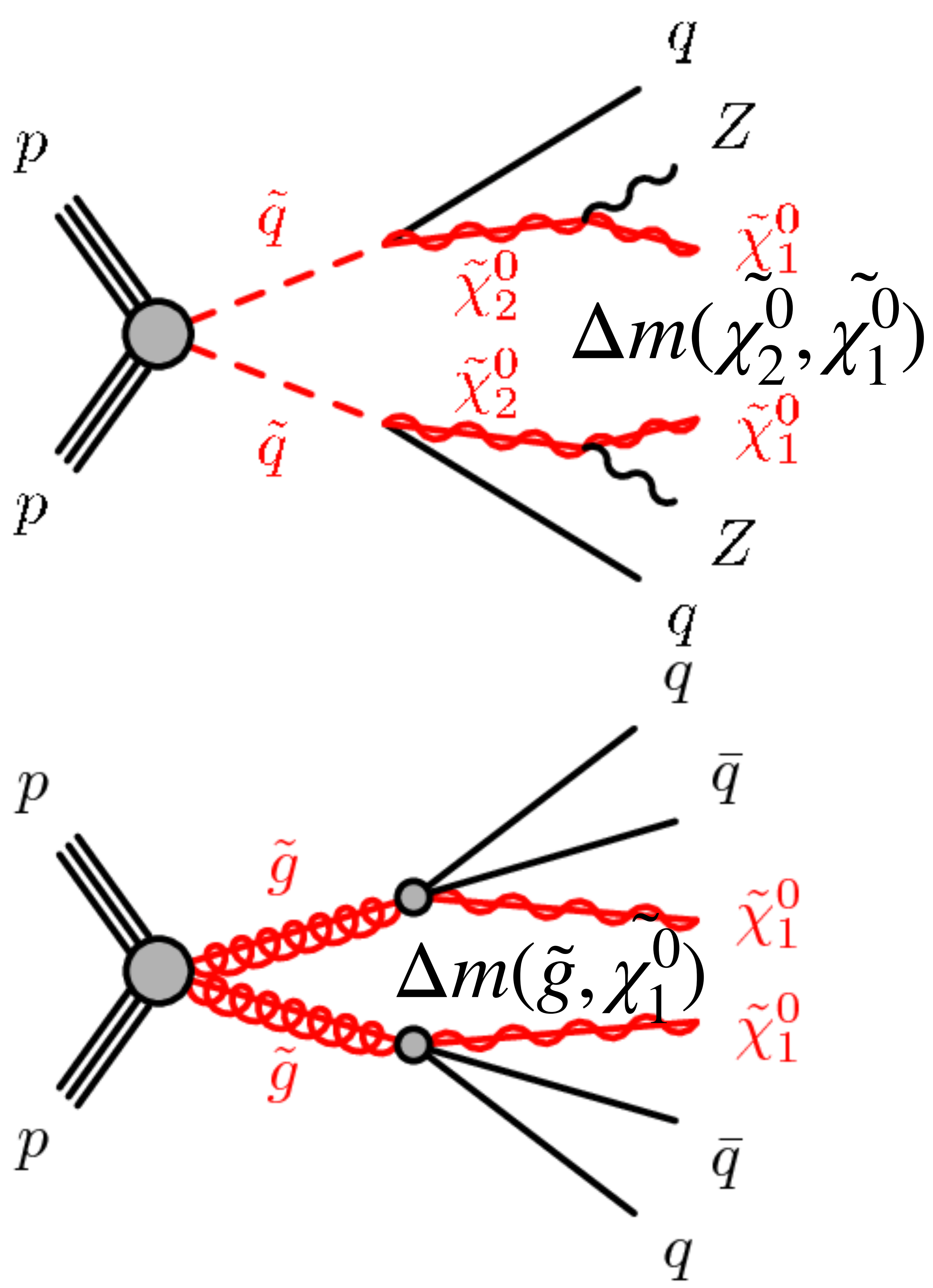
WHAT DO WE TARGET?

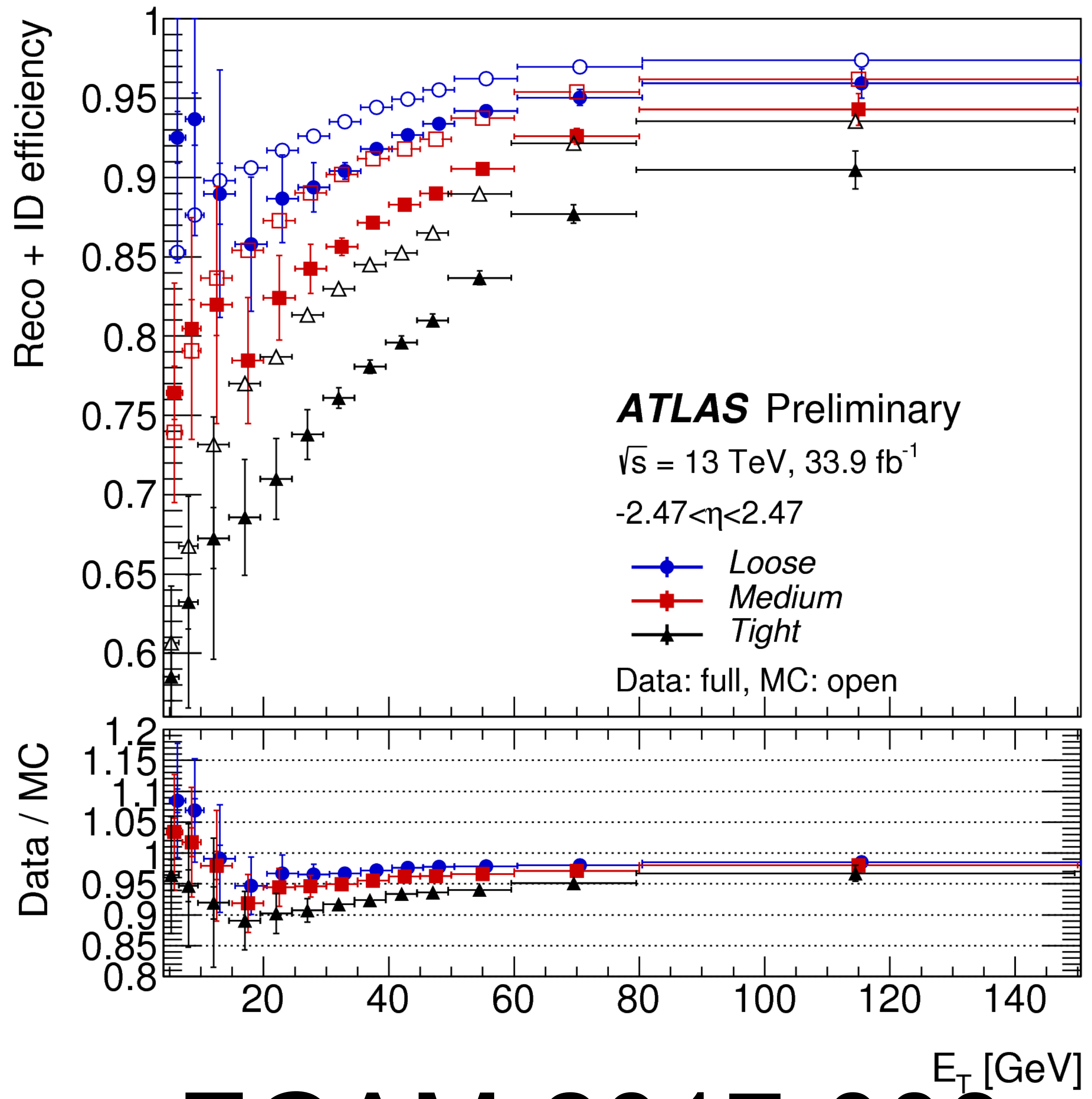


- Low mass differences, $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$ can result in low P_T jets or leptons
- Large mass differences, $\Delta m(\tilde{g}, \tilde{\chi}_1^0)$ can result in a boosted system with multiple quarks, reconstructed with a large-R jet
- Neutralinos will cause E_T^{miss}

LOW MASS RECONSTRUCTION

GOING LOWER IN LEPTON PT

- Electrons currently reconstructed down to 4.5 GeV, using topologically formed clusters and dedicated Bremstrahlung correction
- Muons are reconstructed down to 3 GeV (average energy loss in the calorimeter is 3 GeV)
- Current published SUSY analyses use muons as far down as 4 GeV



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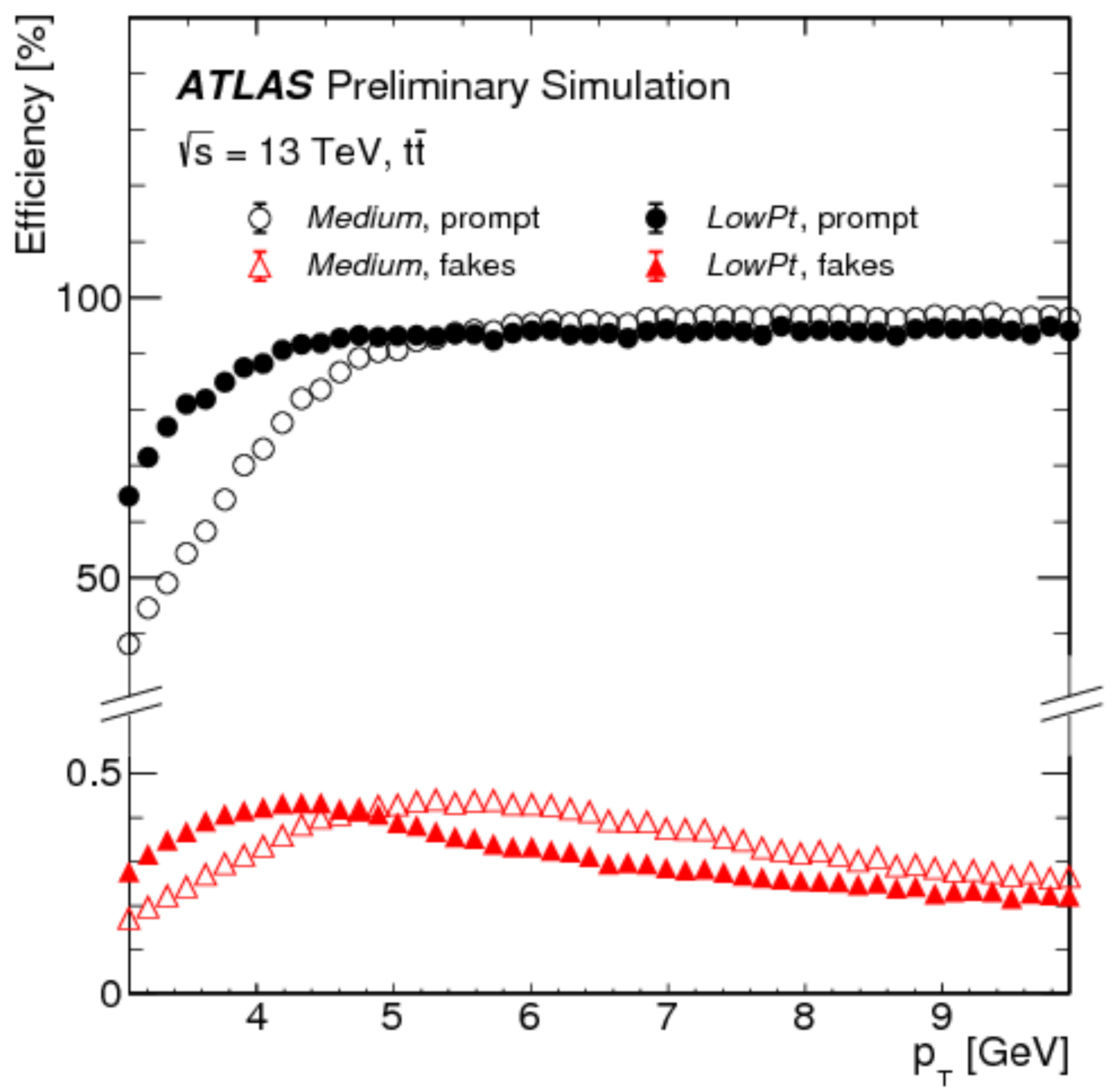

MUON-2018-005

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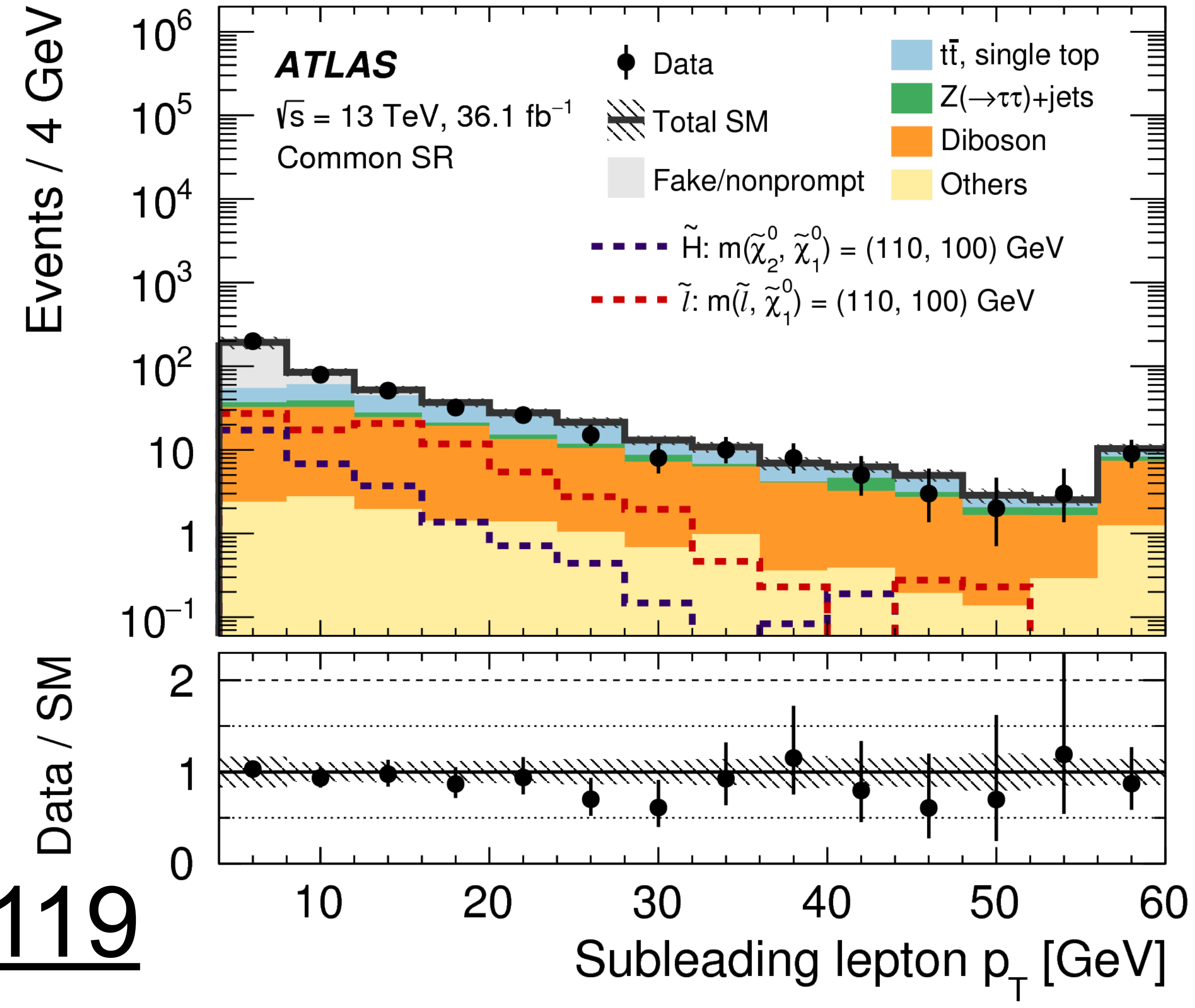
HOWEVER.. CONSEQUENCES OF SOFT LEPTONS

- Further gains are possible with new lower P_T thresholds
- However, lots of extra background is fake lepton from heavy flavour decays
- Key to improving the performance lies with lepton isolation and impact parameters

- New ideas could replace isolation algorithms, such as a BDTs



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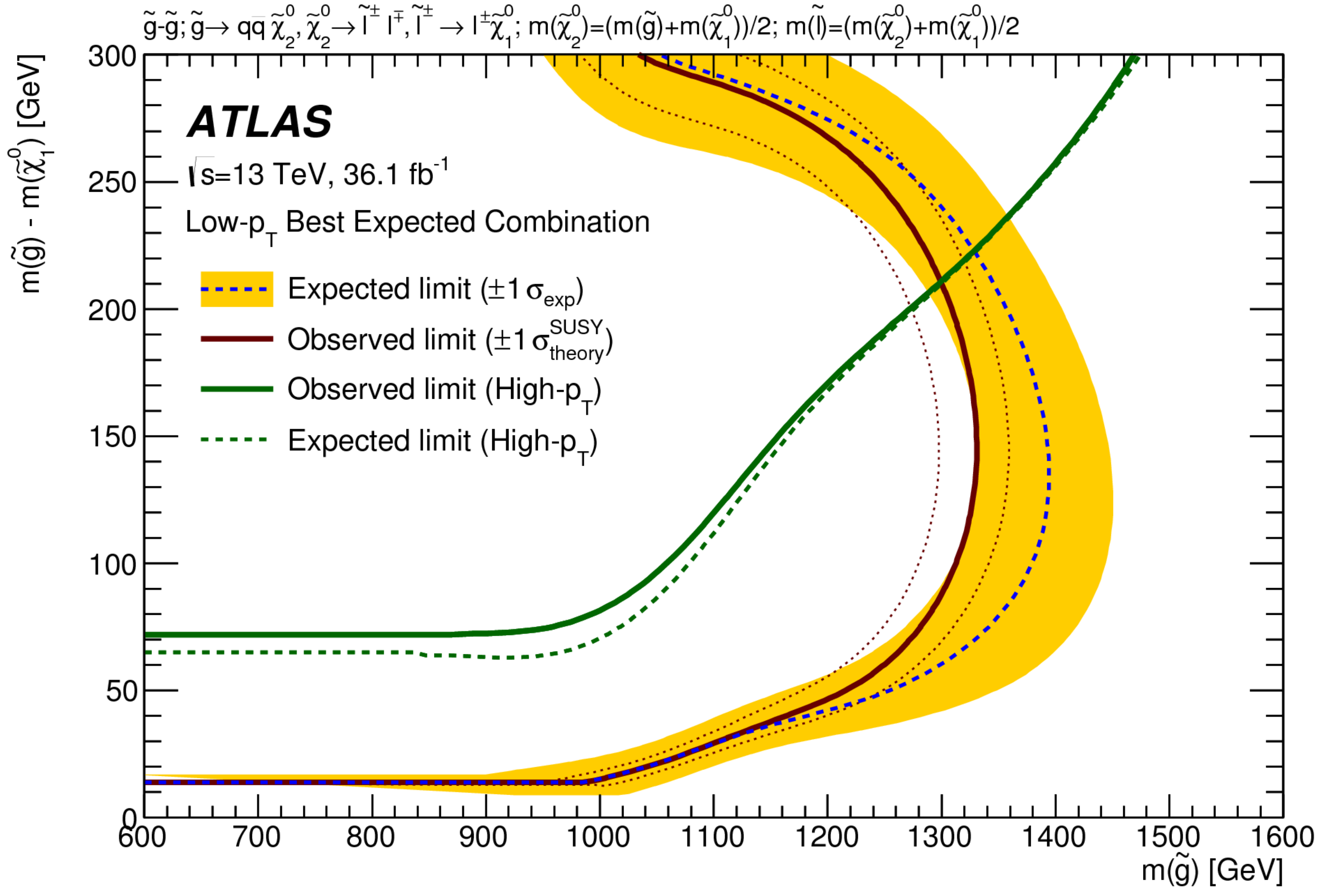

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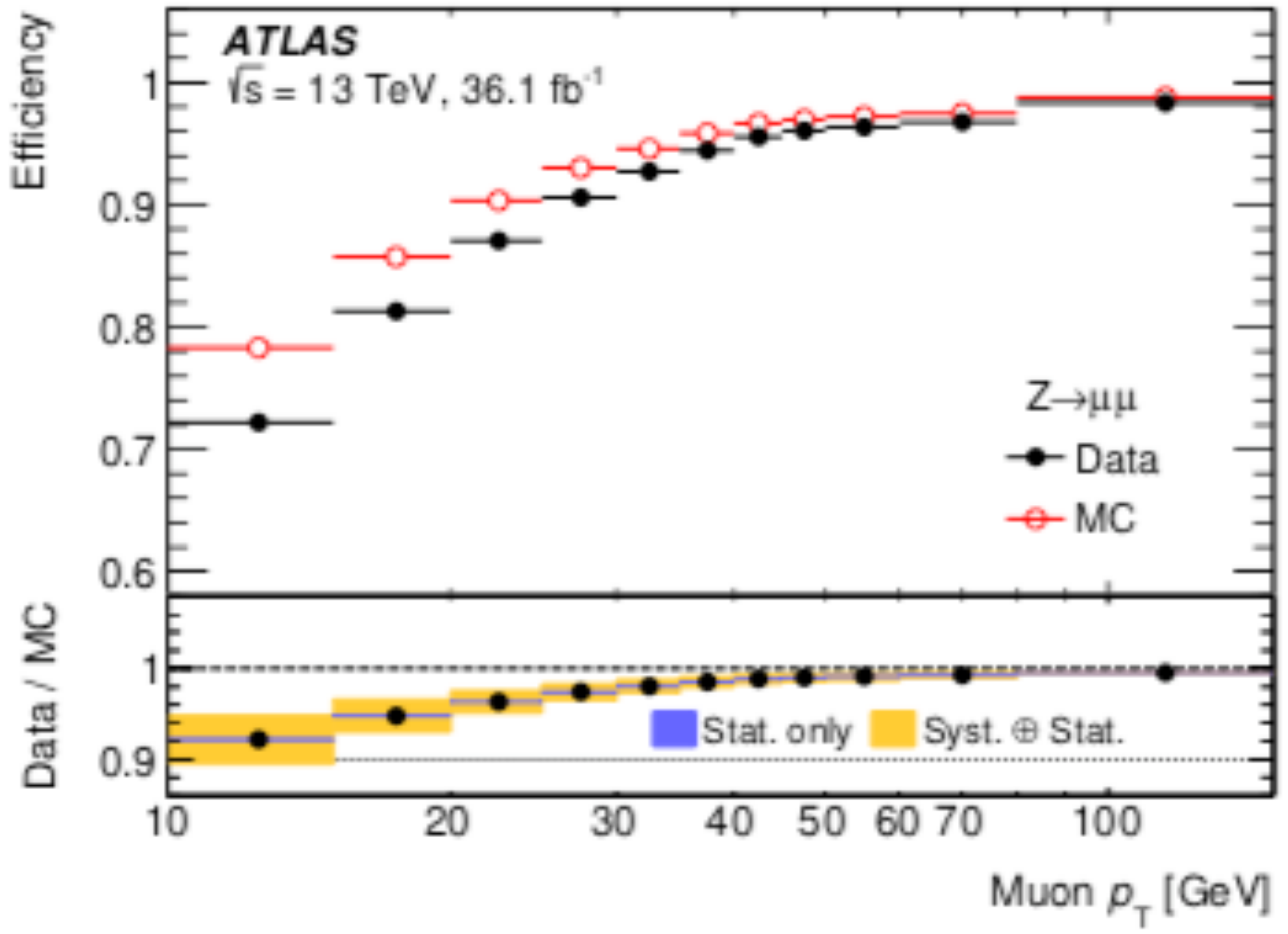
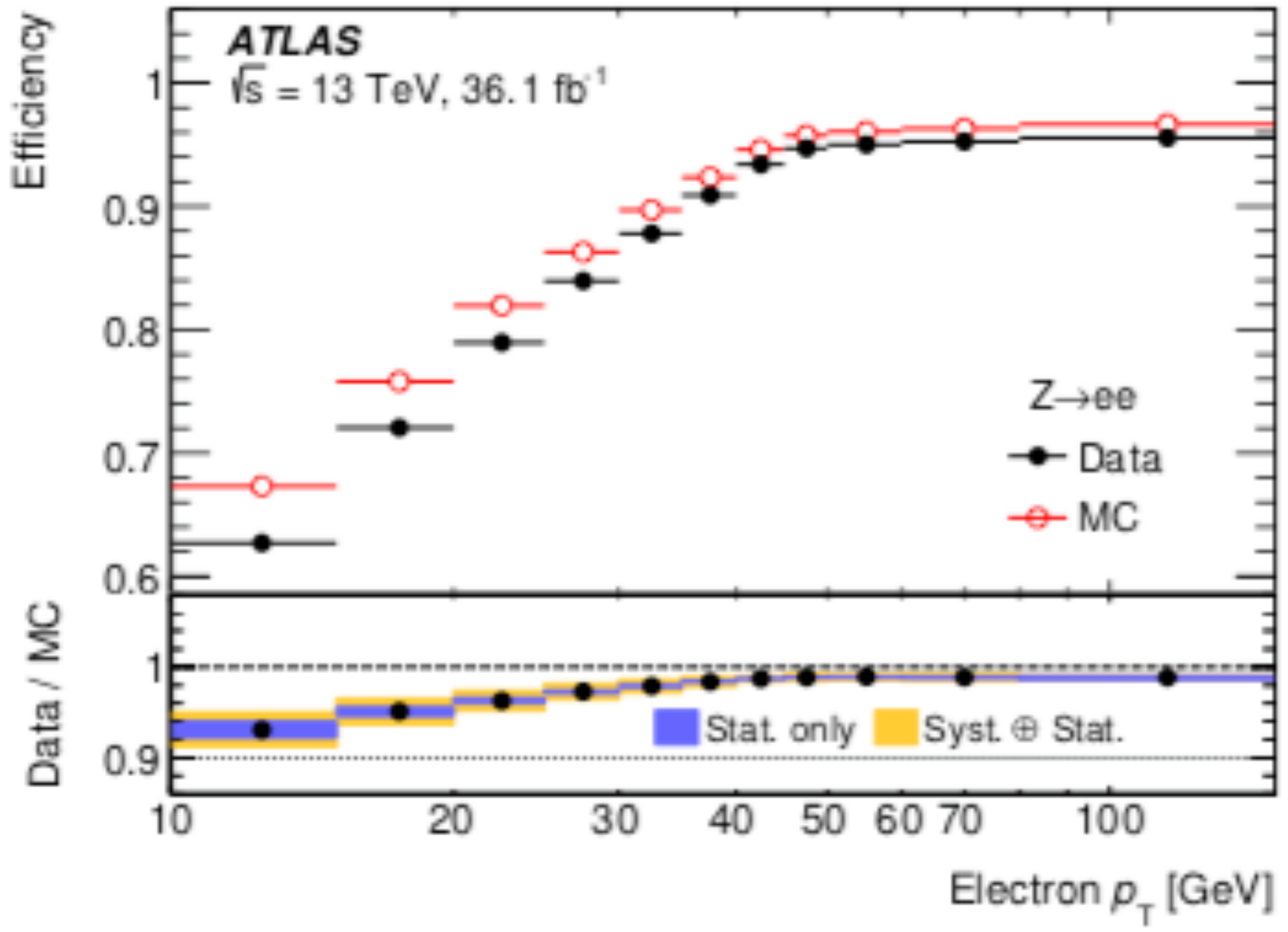
A PROMPT LEPTON TAGGER

- To replace isolation algorithms. A BDT could be trained which could potentially have better performance for rejection of heavy flavour decays
- Taking as input the energy deposits and charged-particle tracks in a cone around the lepton direction
- Example by the ttH group. Large SF's at low P_T, this could be improved with choosing a different working point





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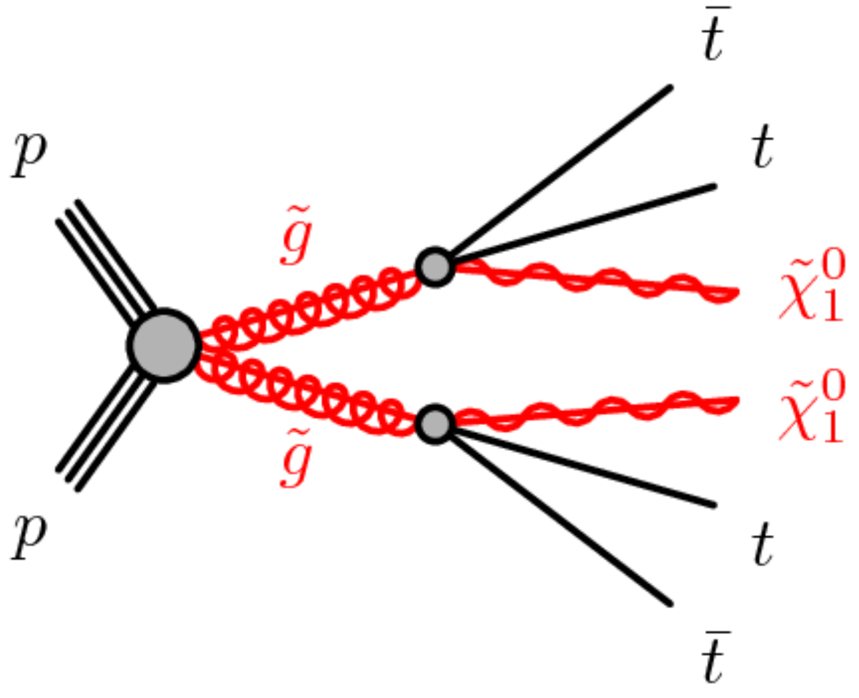
HIGH MASS RECONSTRUCTION

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
- Two strategies:
  - Use a larger radius parameter
  - Cluster existing calibrated 0.4 radius jets into a larger jet (reclustering)
- Reclustering can use the detailed calibrations and uncertainties from 0.4 jets - allows more flexibility in the parameters of large R jets because no dedicated calibration is needed



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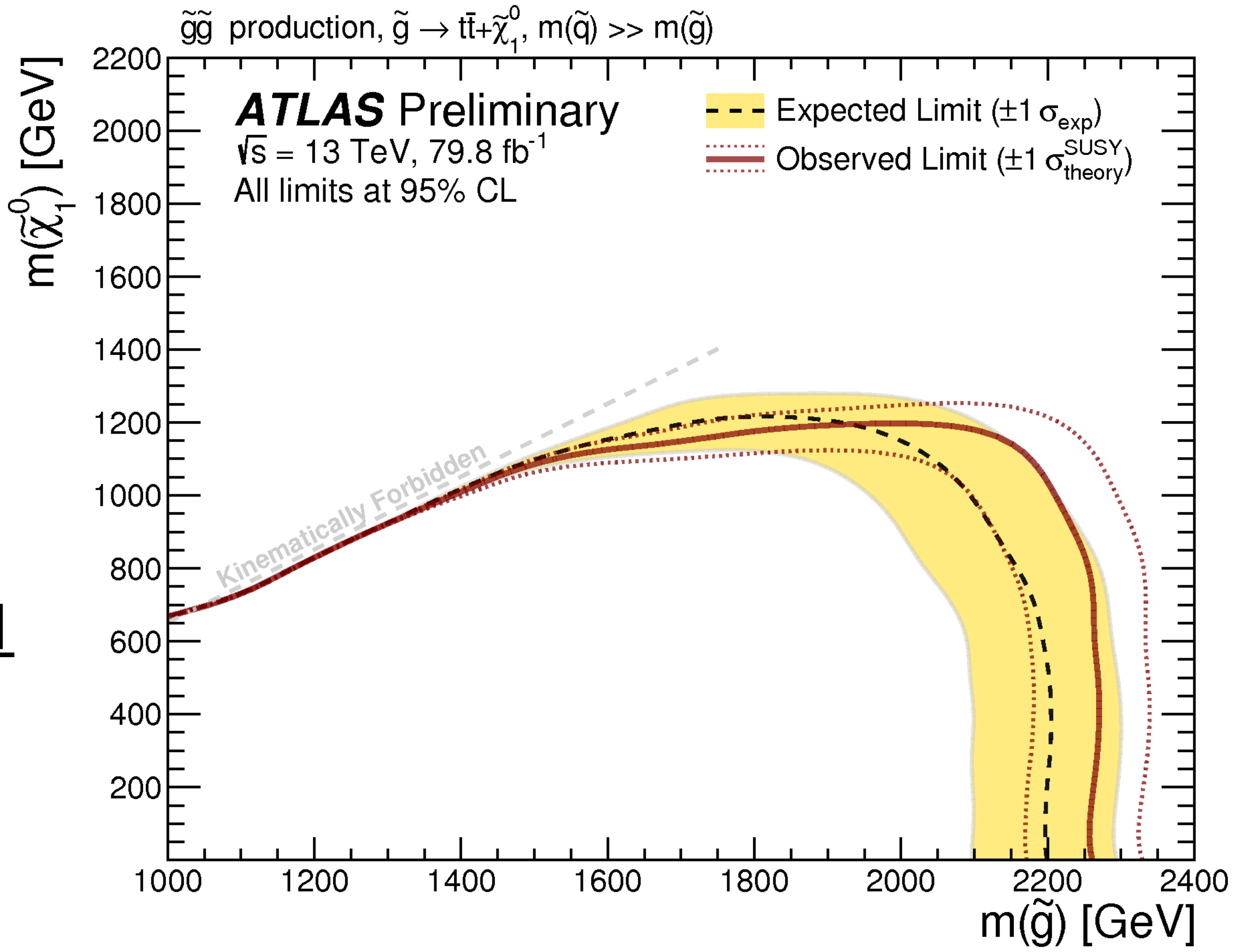

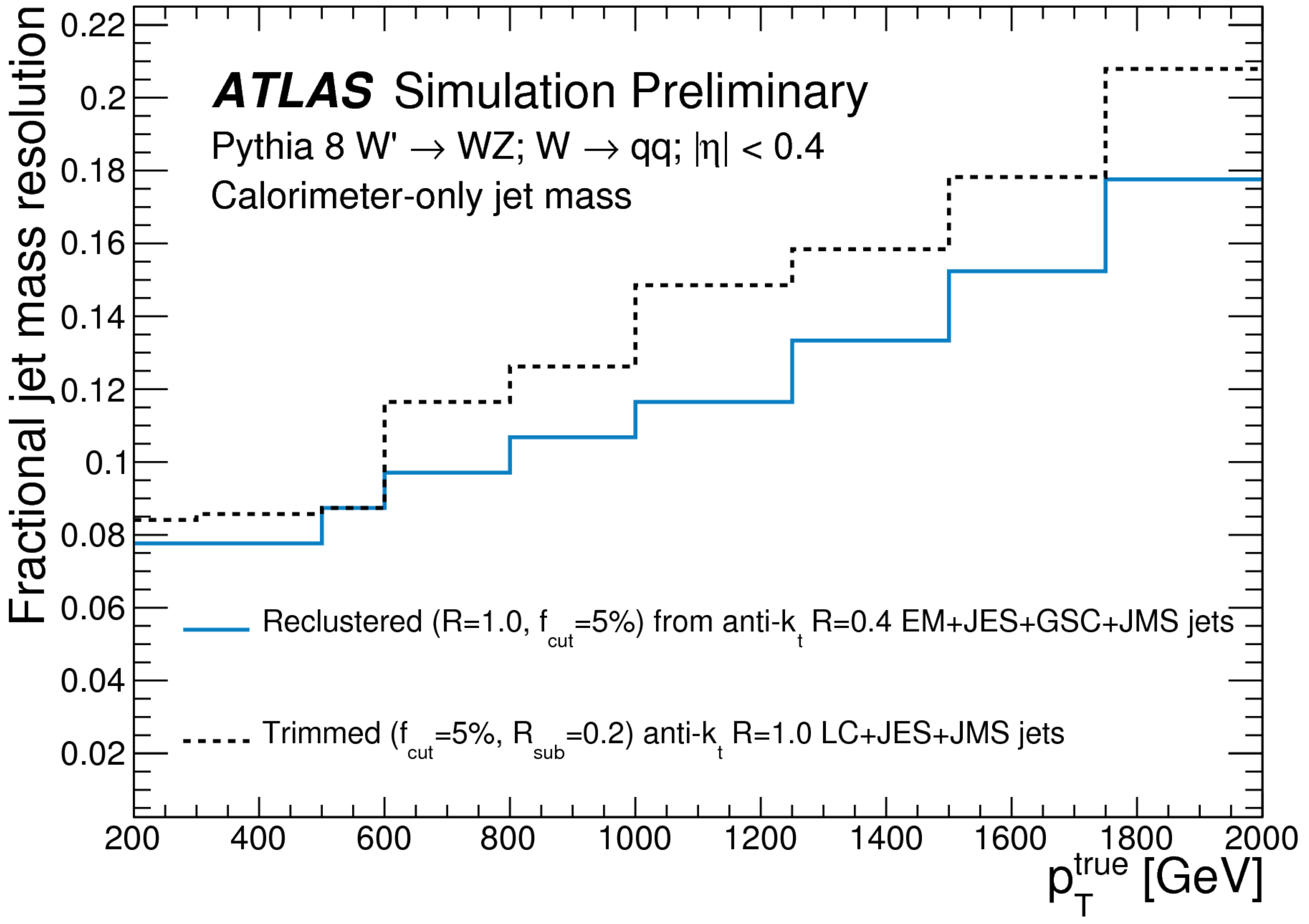

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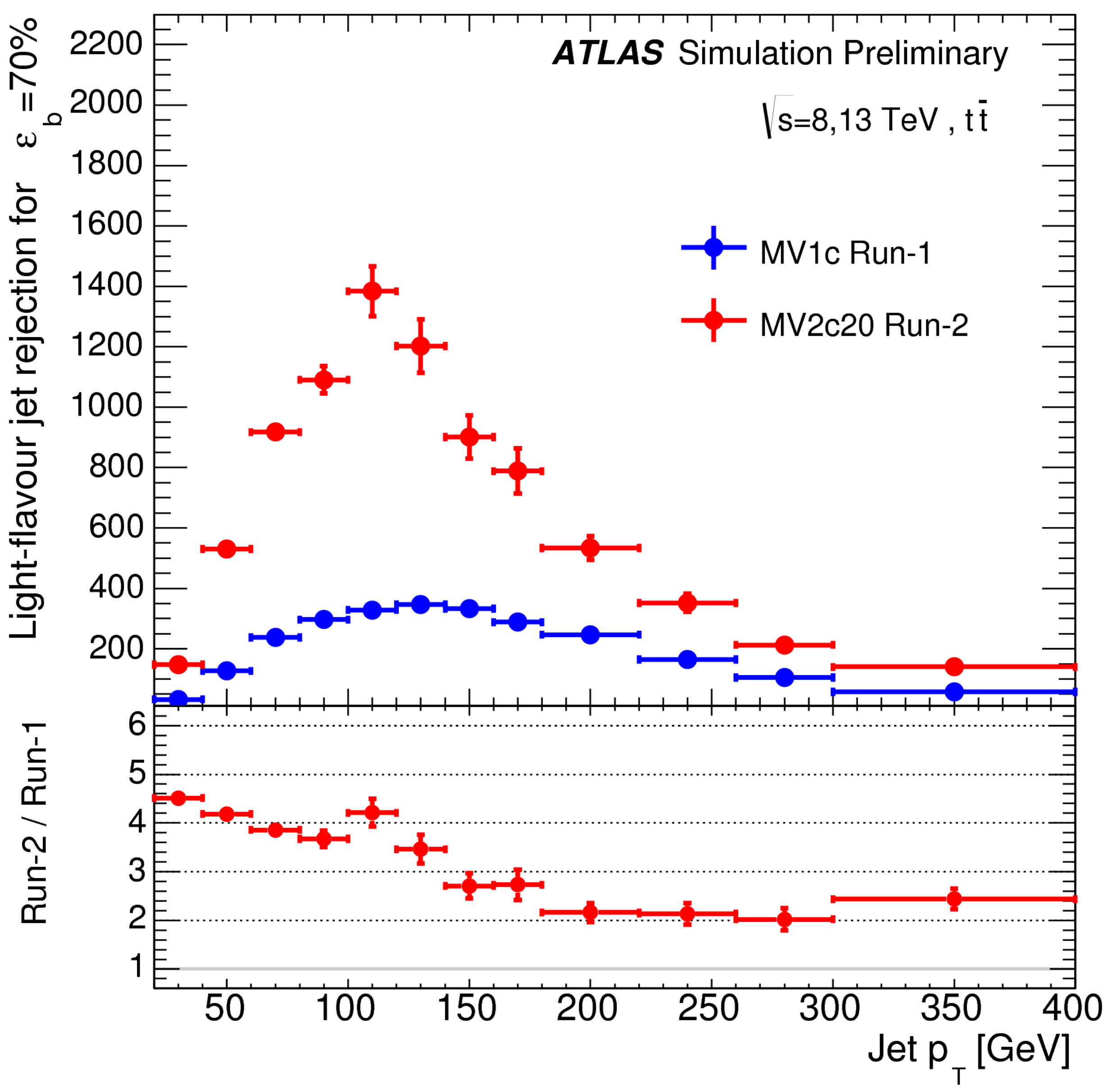
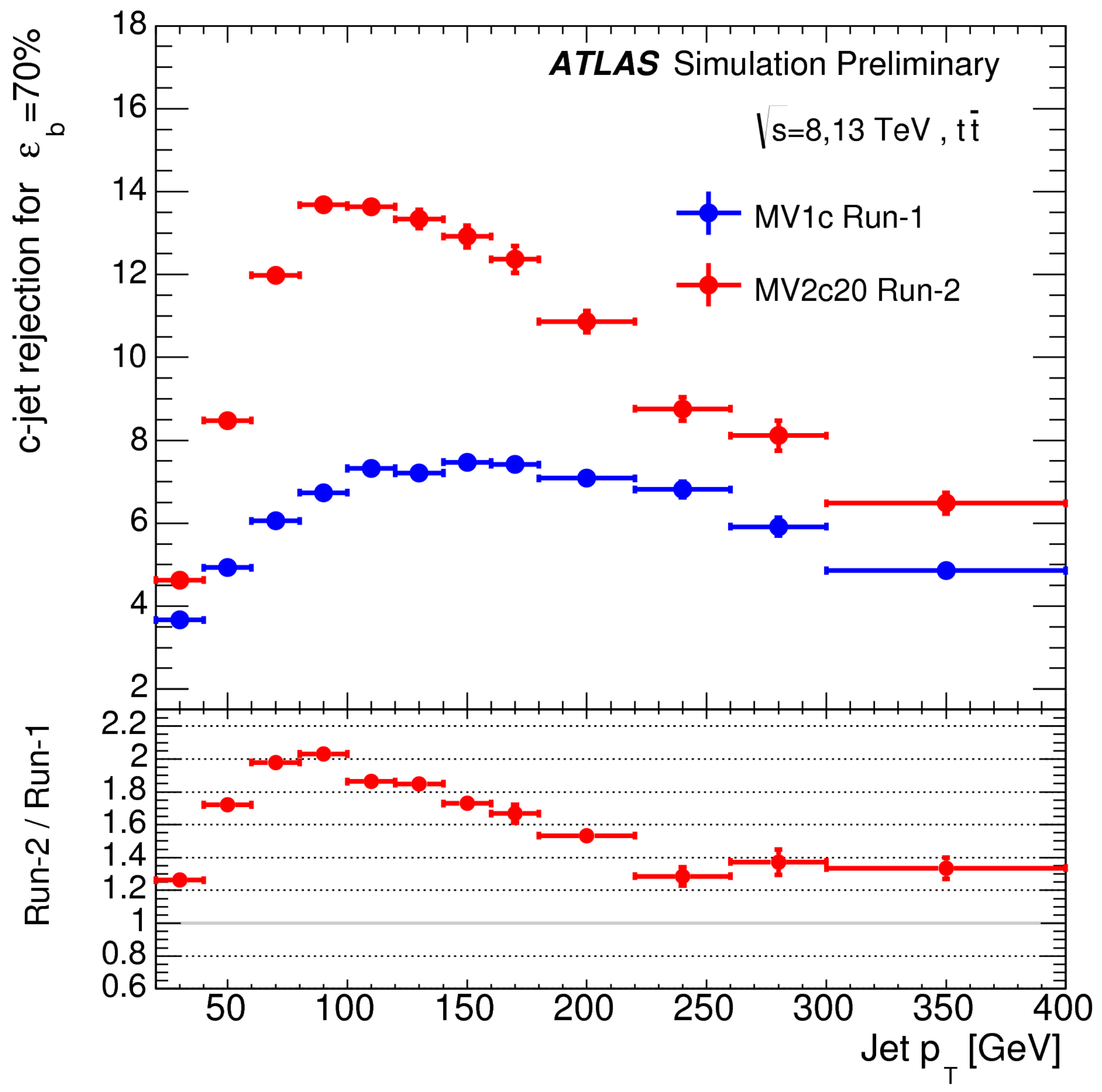
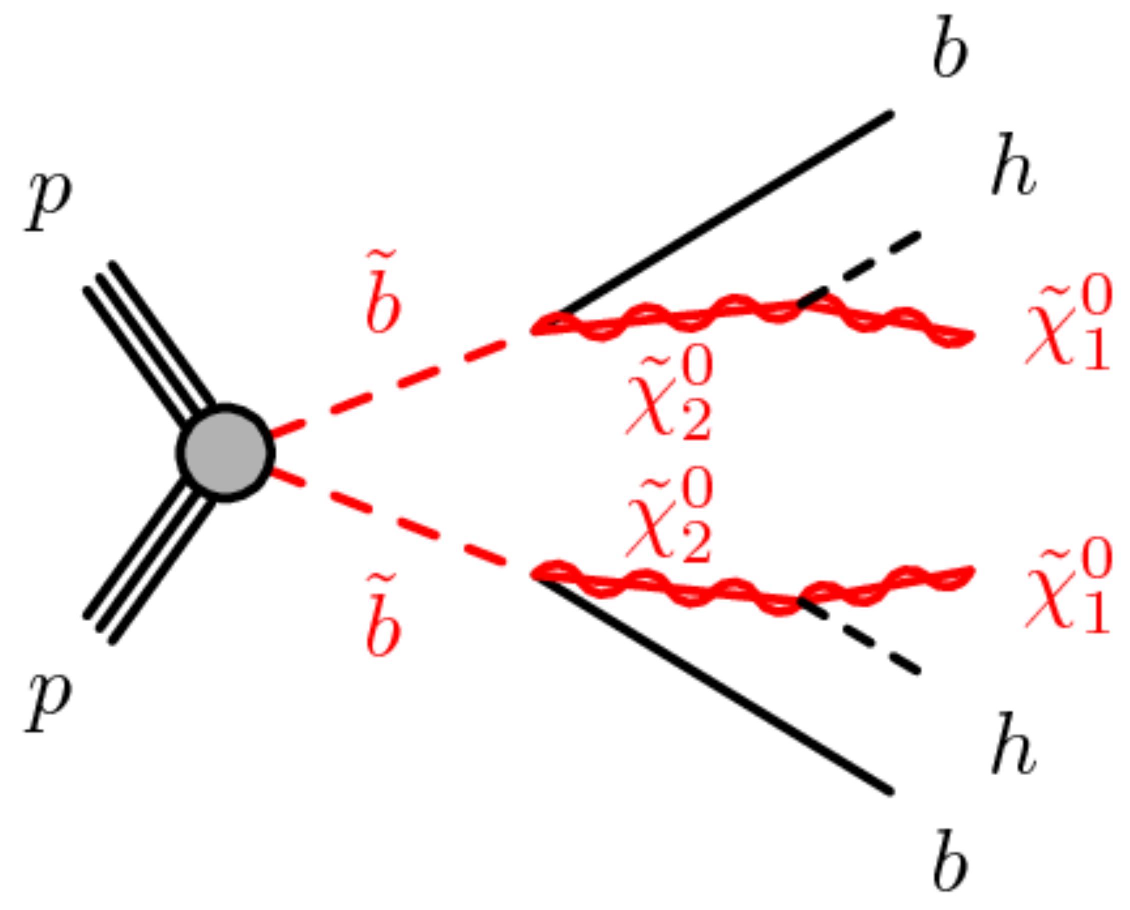
FLAVOUR TAGGING

- 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 b-tagging improvements can be seen with respect to run 1 (including IBL)



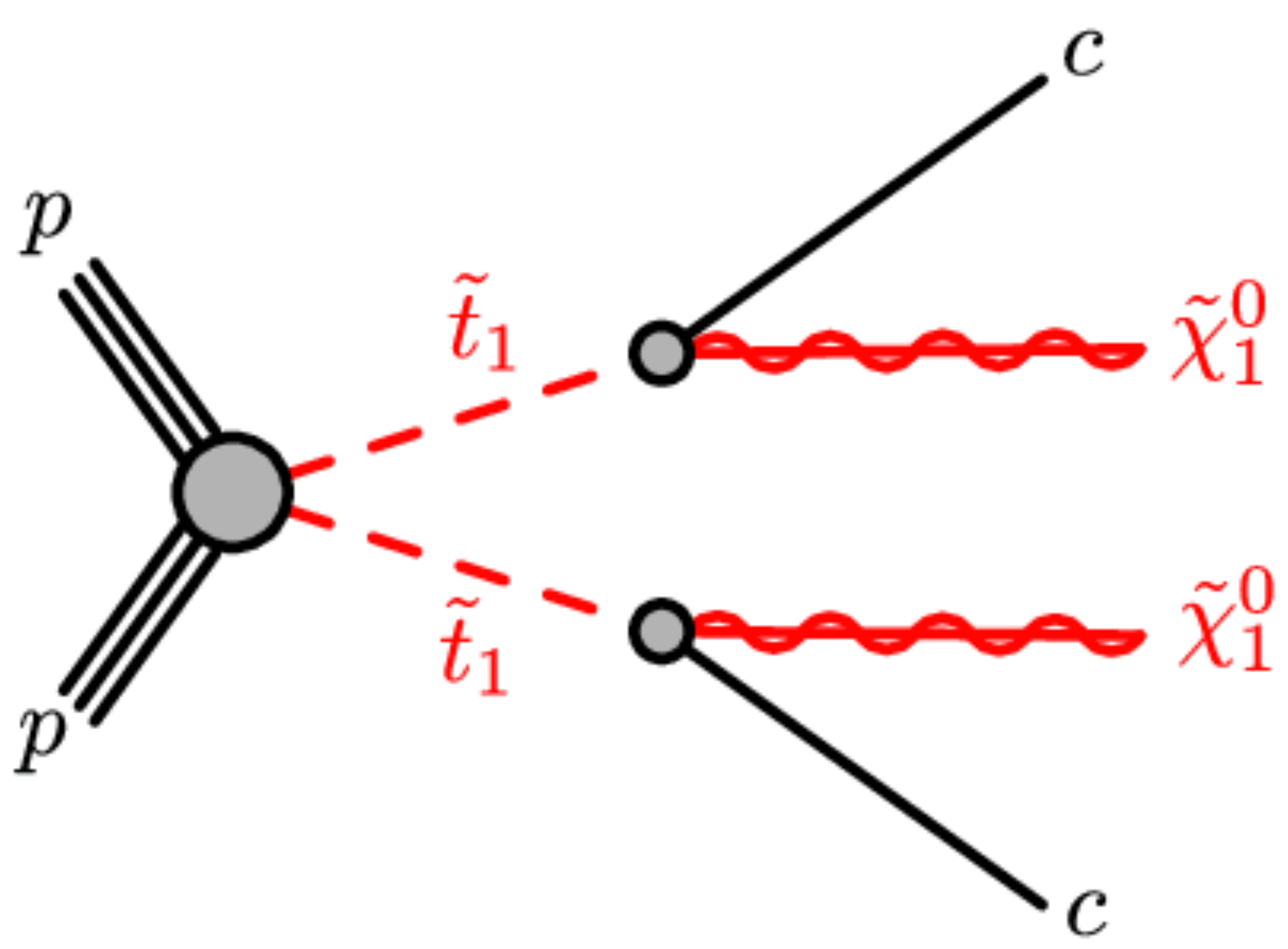


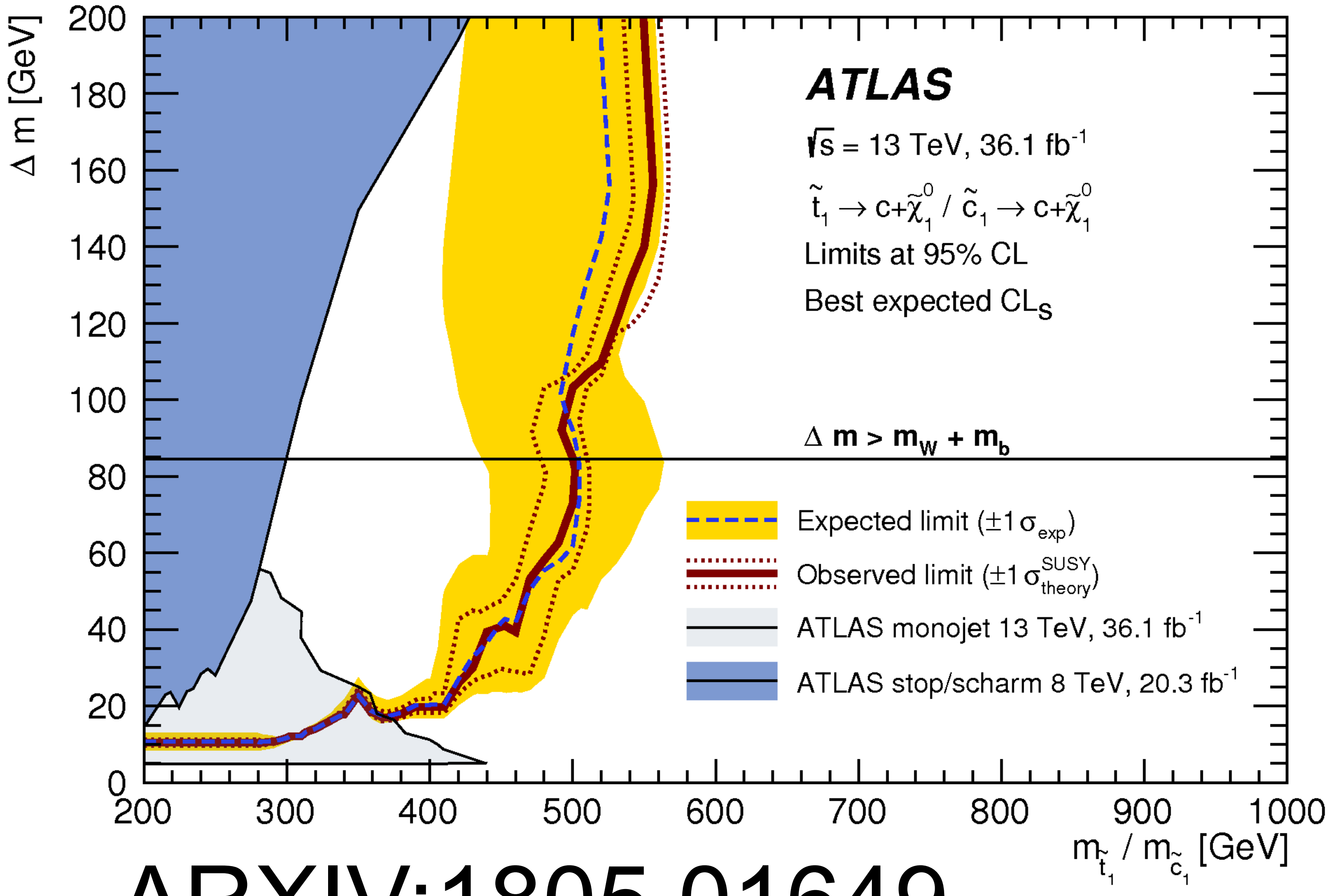


ATL-PHYS-PUB-2015-022

CHARM TAGGING

- Charm tagging algorithms use additional variables
- 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
- New result from run 2 on stop to charm decays recently released





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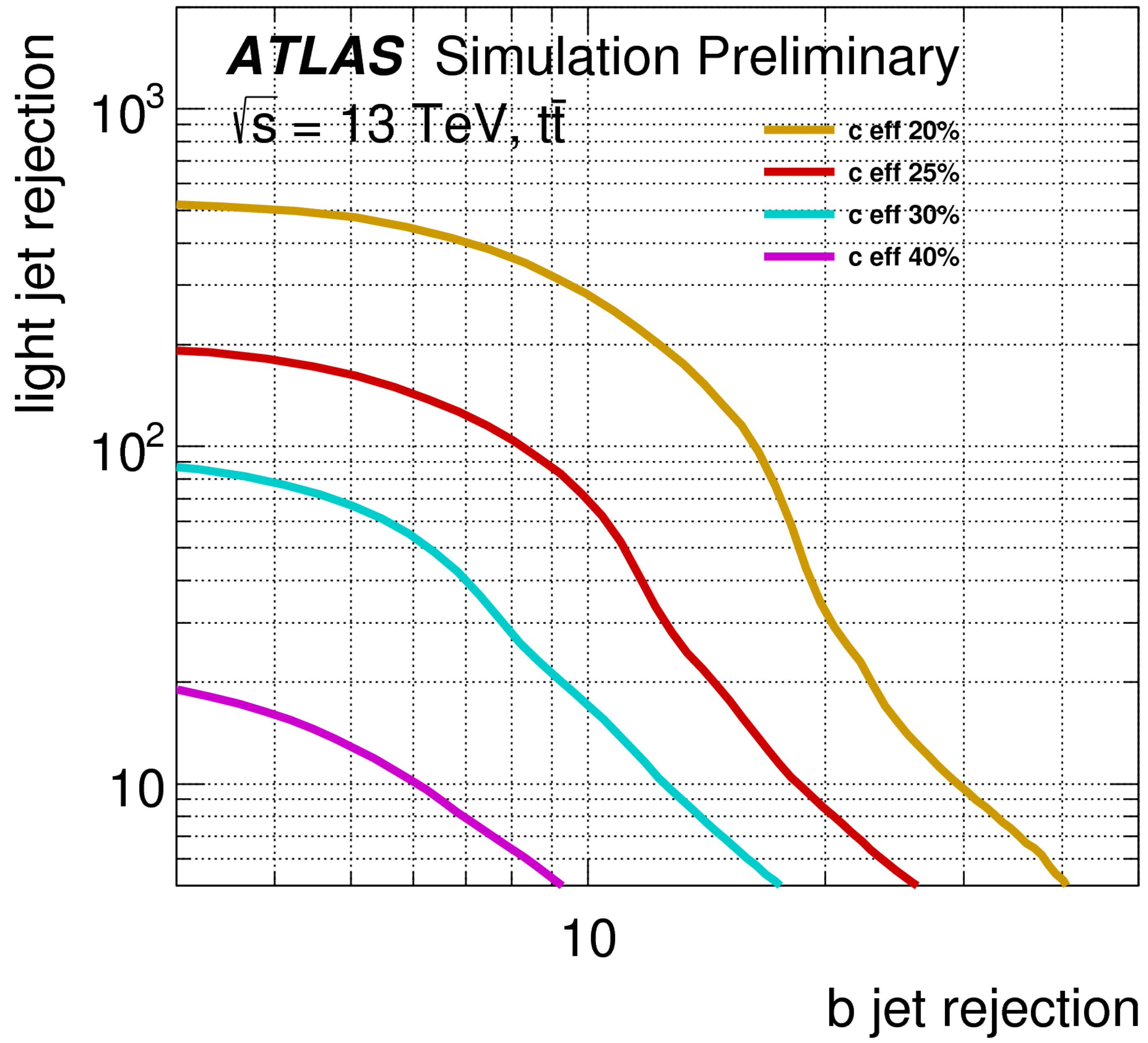


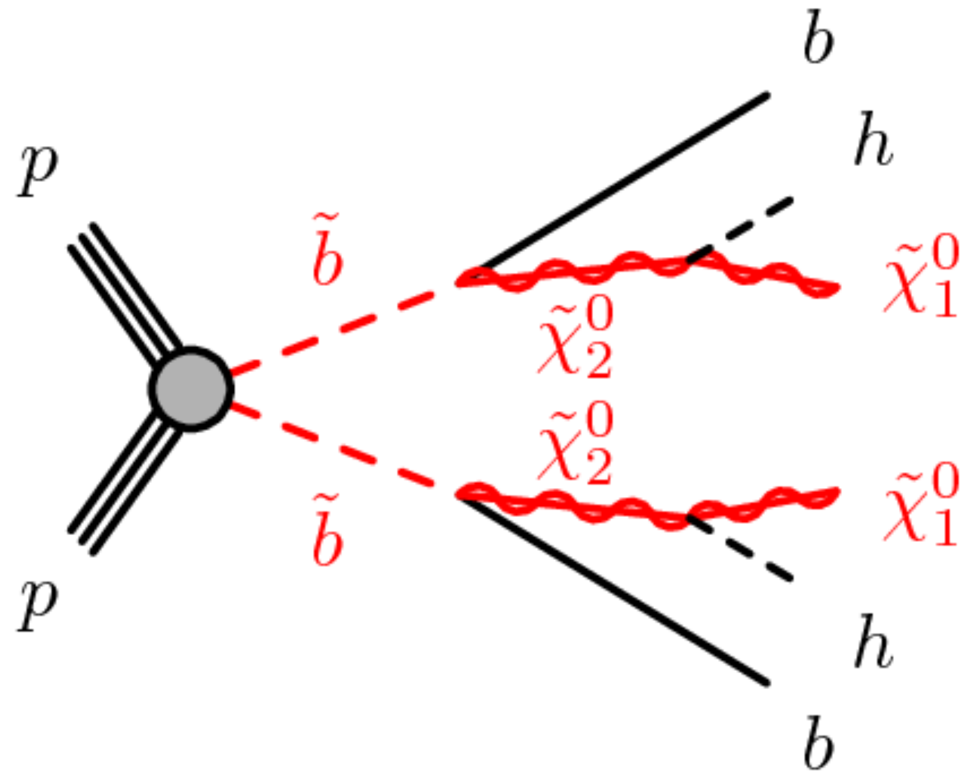
ATL-PHYS-PUB-2017-013

E_T^{miss} RECONSTRUCTION

E_T^{miss} WHICH IS FAKE

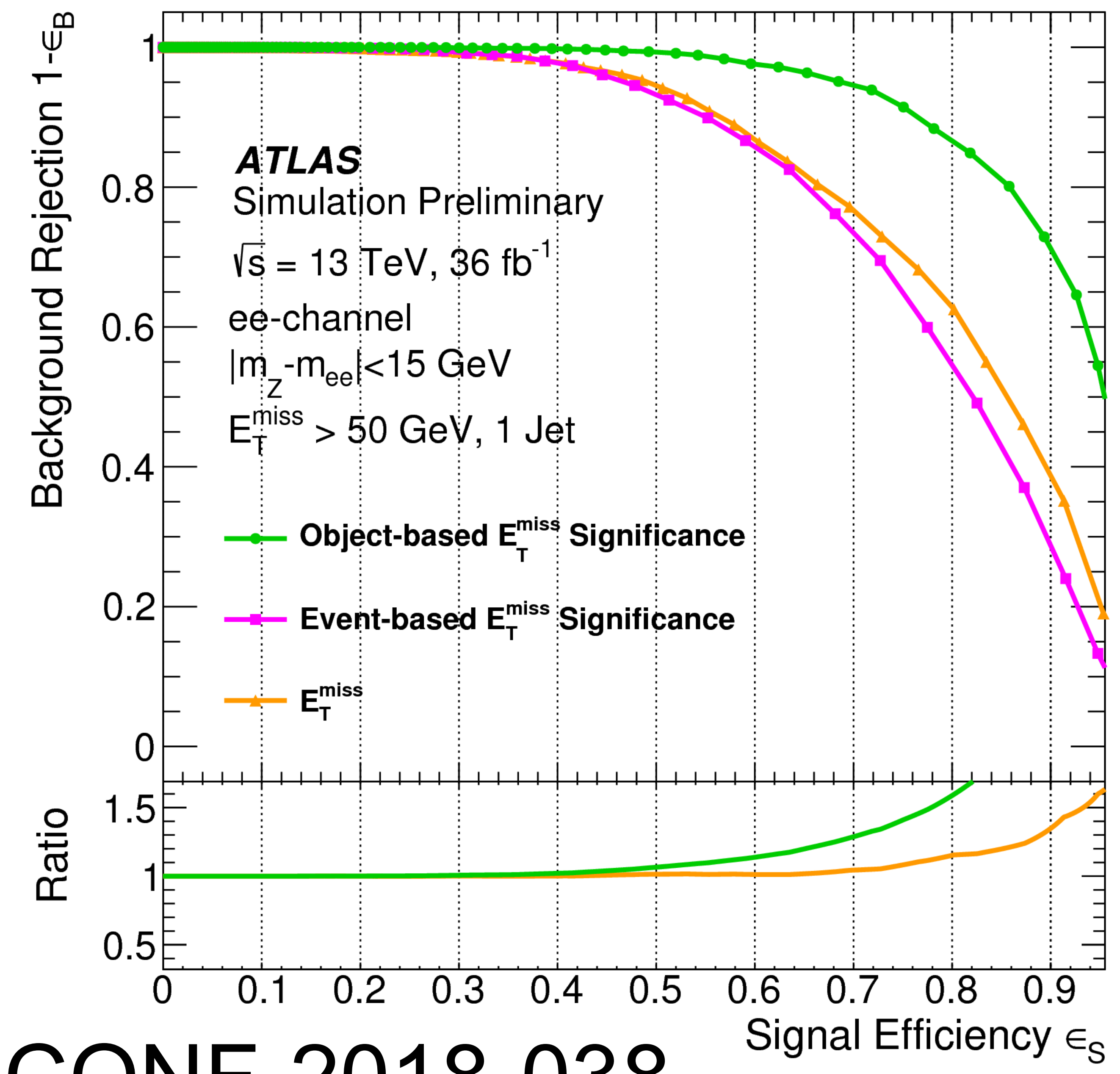
- E_T^{miss} is an important variable in searches as it is indicative of neutralinos
- Fake E_T^{miss} can arise from interacting particles which escape the acceptance of the detector, are inaccurately (resolution) reconstructed, or fail to be reconstructed all together

FOR EXAMPLE



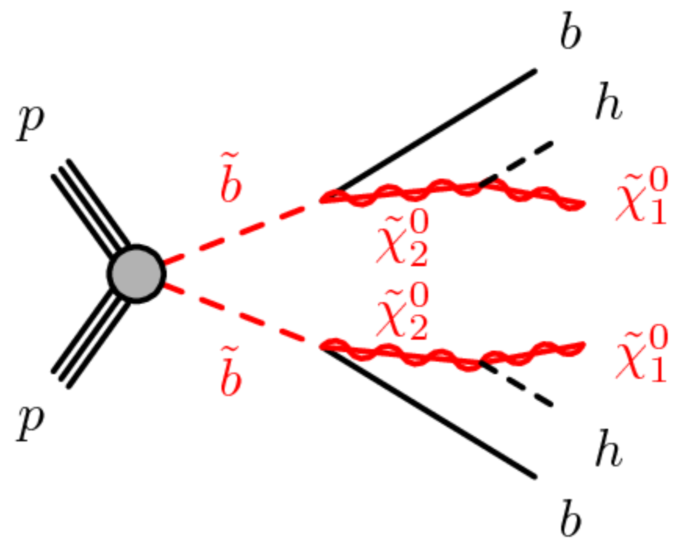
- 0L suffer from QCD background, a process where real $E_T^{miss} = 0$
- Bad MC modelling, large cross-sections, and resolution effects result into large fake E_T^{miss}

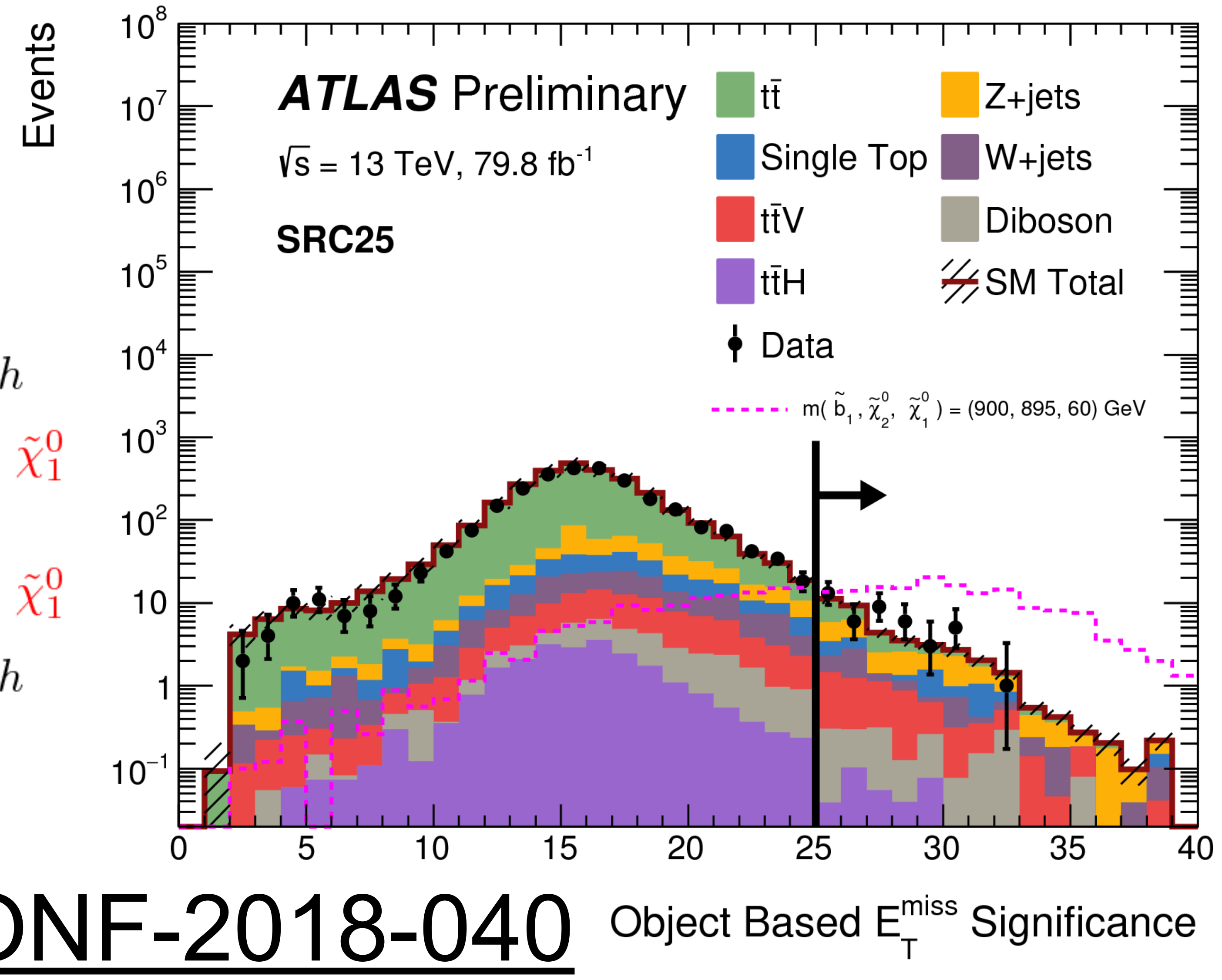
E_T^{miss} SIGNIFICANCE



ATLAS-CONF-2018-038

- Indicates the degree to which the reconstructed E_T^{miss} is consistent with momentum resolution and particle identification efficiencies
- Event-based significance: $\mathcal{S} = \frac{E_T^{miss}}{\sqrt{H_T}}$ or $\mathcal{S} = \frac{E_T^{miss}}{\sqrt{\sum E_T}}$
- Object-based definition: log-likelihood ratio that the reconstructed E_T^{miss} is consistent with the hypothesis of 0 real E_T^{miss}, based on full event composition





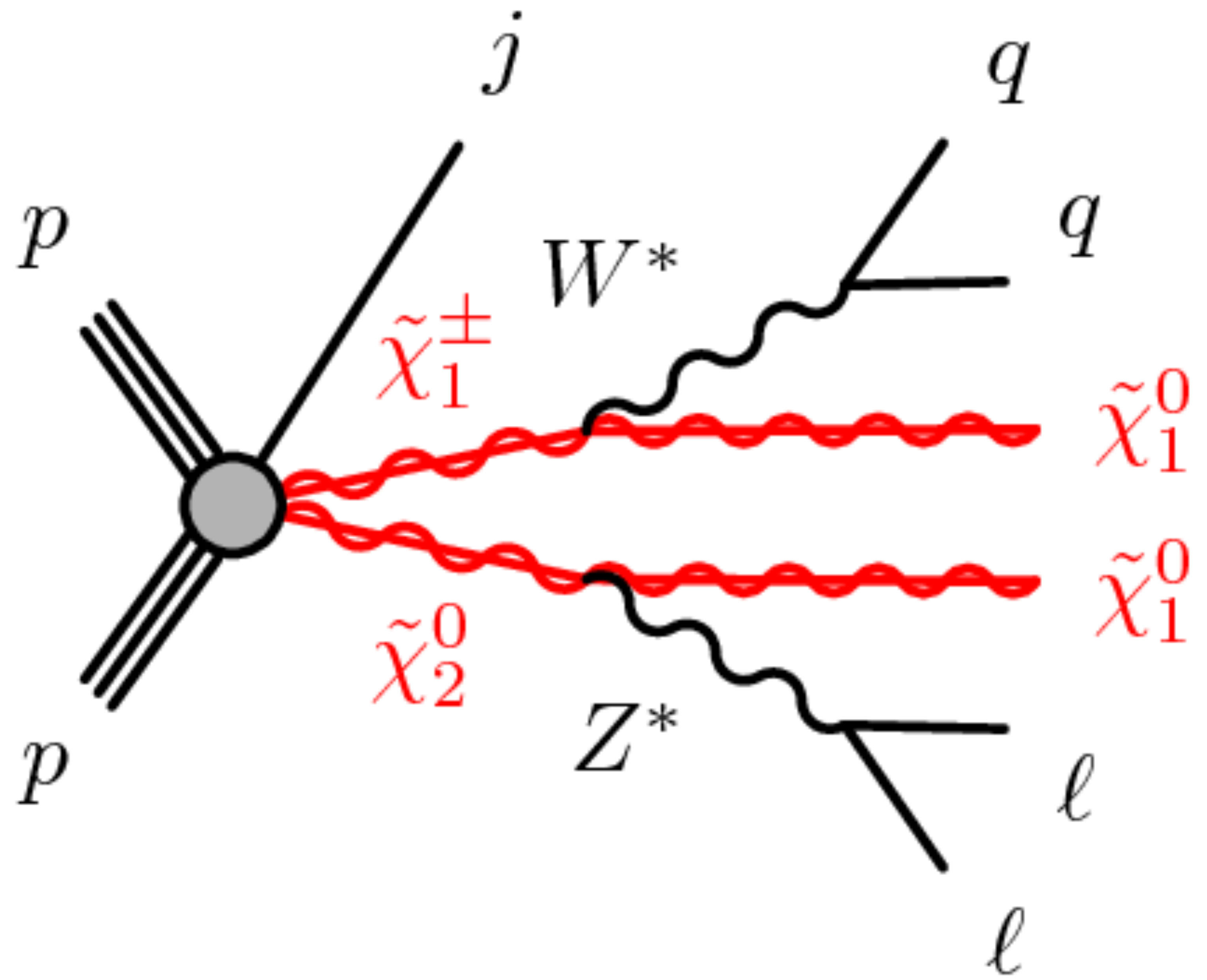
ATLAS-CONF-2018-040

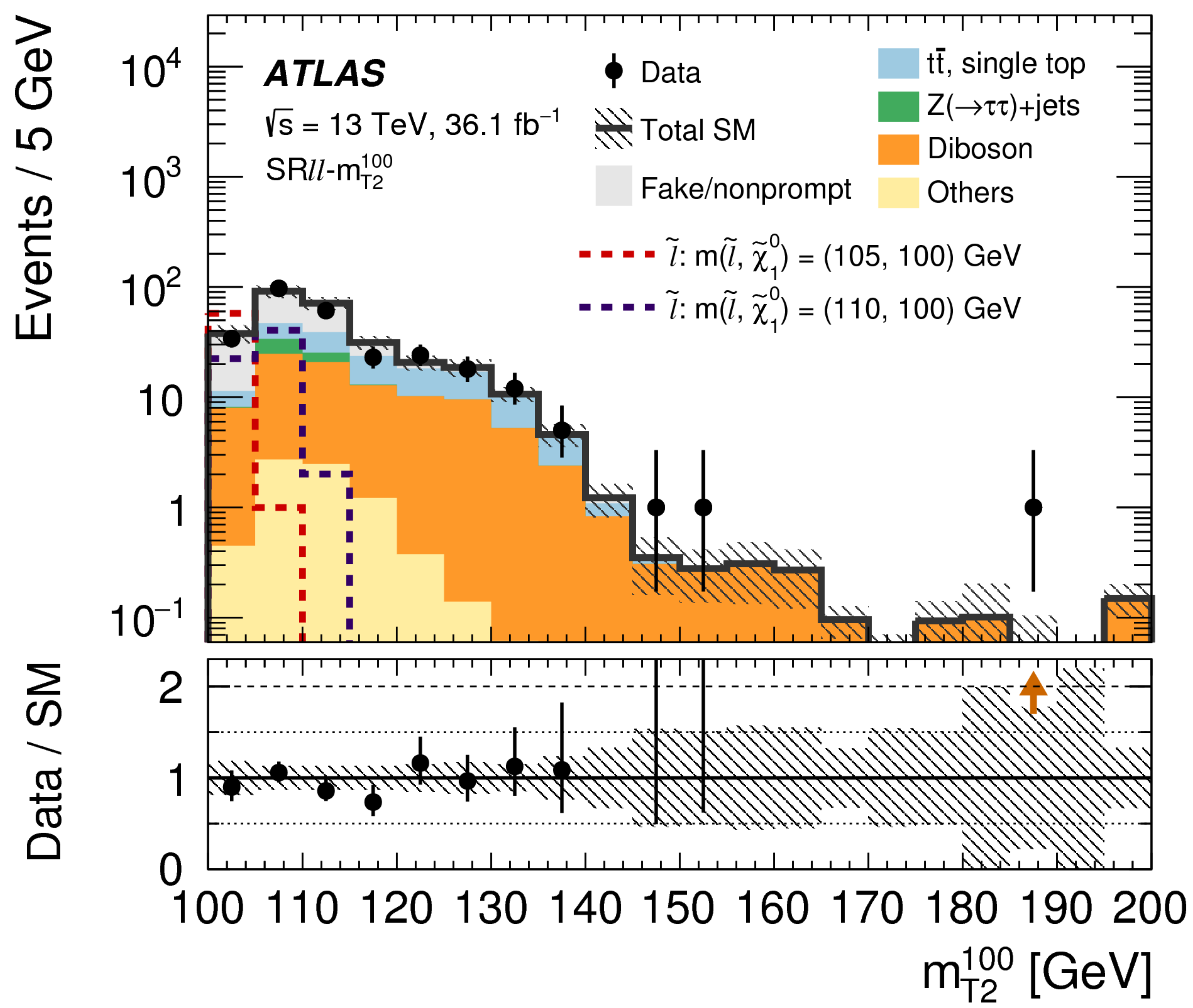
<u>UNKNOWNS</u> IN SUSY RECONSTRUCTION

M_{T2}

We measure **one** variable E_T^{miss}, but this is actually **two** particles:

- Two massive particles have escaped undetected
- The masses of these particles are unknown
- The masses of their parent particles are unknown
- The center-of-mass energy of the collision is not known
- The boost along the beam axis is not known





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$$m_{T2}^2(\chi) = \min_{E_{T1}^{miss(1)}+E_T^{miss(2)}=E_T^{miss}} [max\{m_t^2(p_T^{(1)}, E_T^{miss(1)}; \tilde{\chi}_1^0), m_t^2(p_T^{(2)}, E_T^{miss(2)}; \tilde{\chi}_1^0)\}]$$

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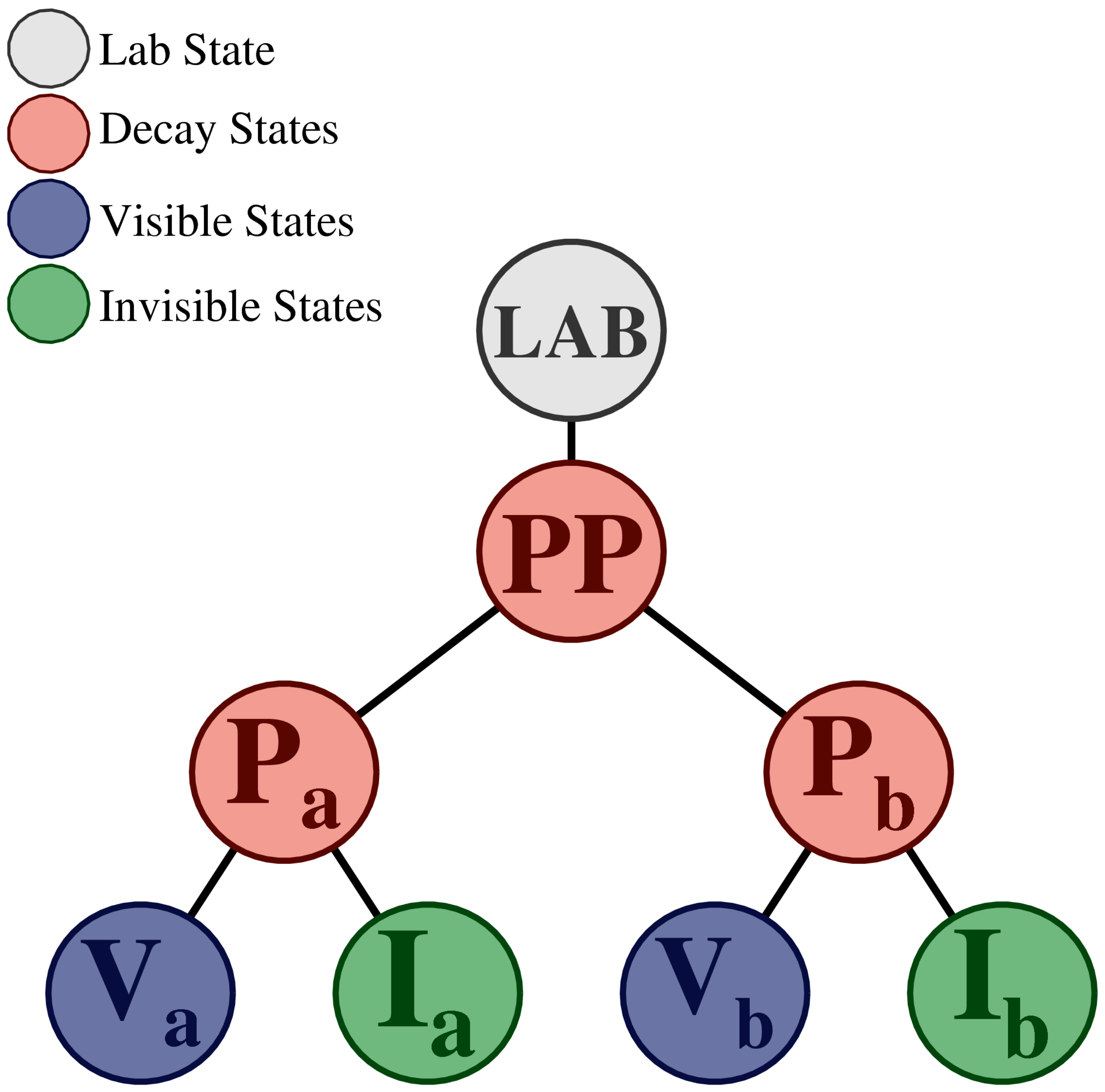
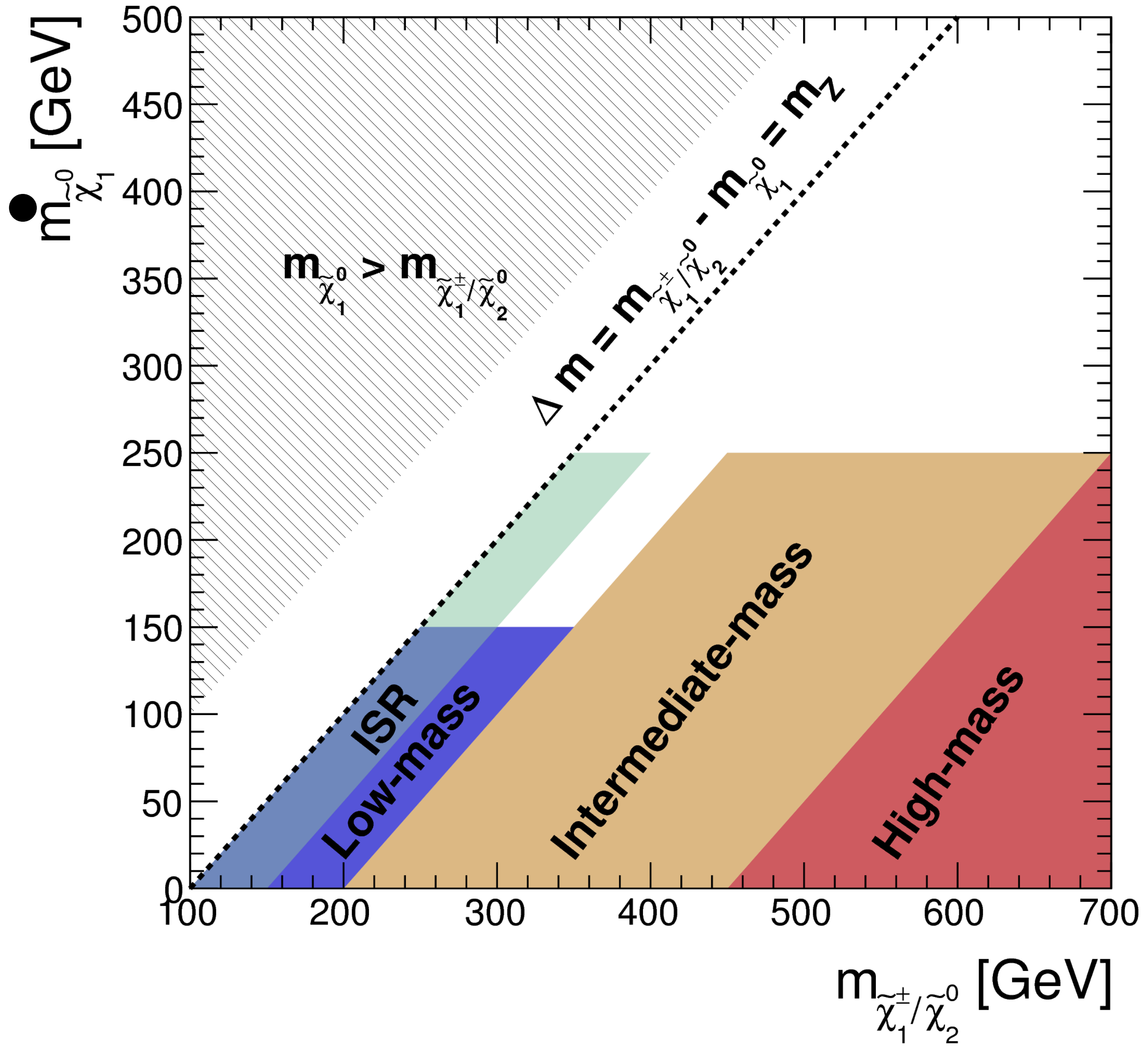
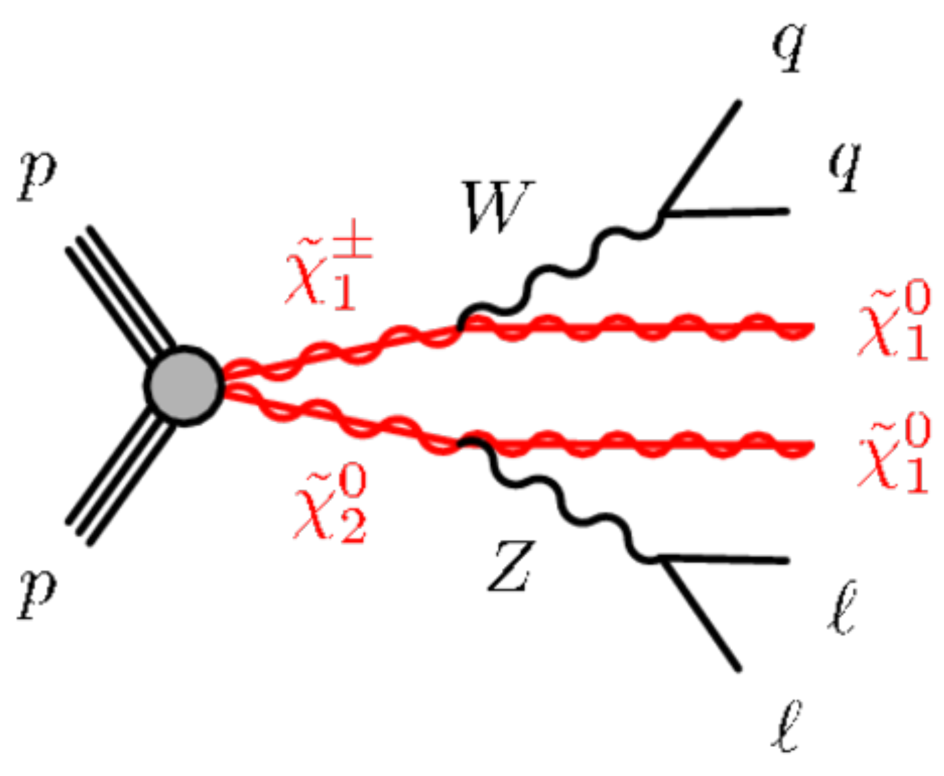
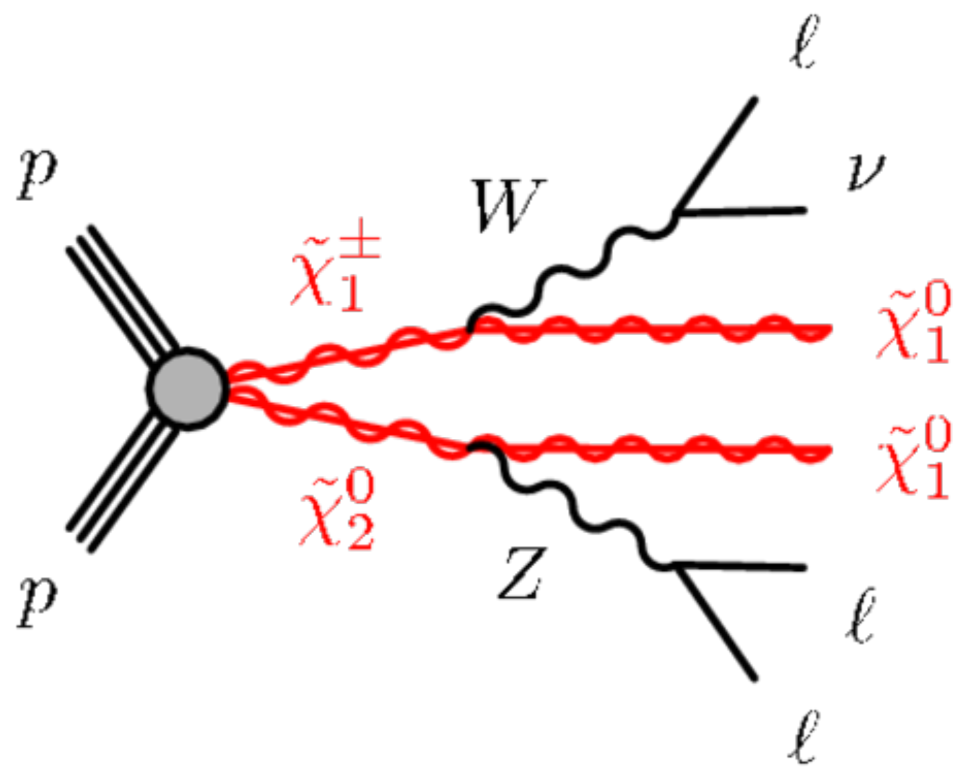
RECURSIVE JIGSAW

- A collection of approaches expressing masses as a function of unknowns, and then maximizing or minimizing, like M_{T2}
- Use measured event properties to approximate rest frames of intermediate particles in a “decay tree”
- RJR gives a new basis of observables based on energies and momenta of objects in these frames









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CONCLUSIONS

- Reconstruction algorithms being used to push into more extreme parts of SUSY phase space
- Many new ideas - lower P_T leptons, BDT for isolation, object based E_T^{miss} significance, recursive jigsaw reconstruction
- Full run 2 results to come from ATLAS SUSY searches on challenging signatures