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CHICAGO



SUSY with a twist



Giordon Stark
July 18th, 2016

indico.cern.ch/event/439039



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SUSY with a ~~twice~~ BOOST

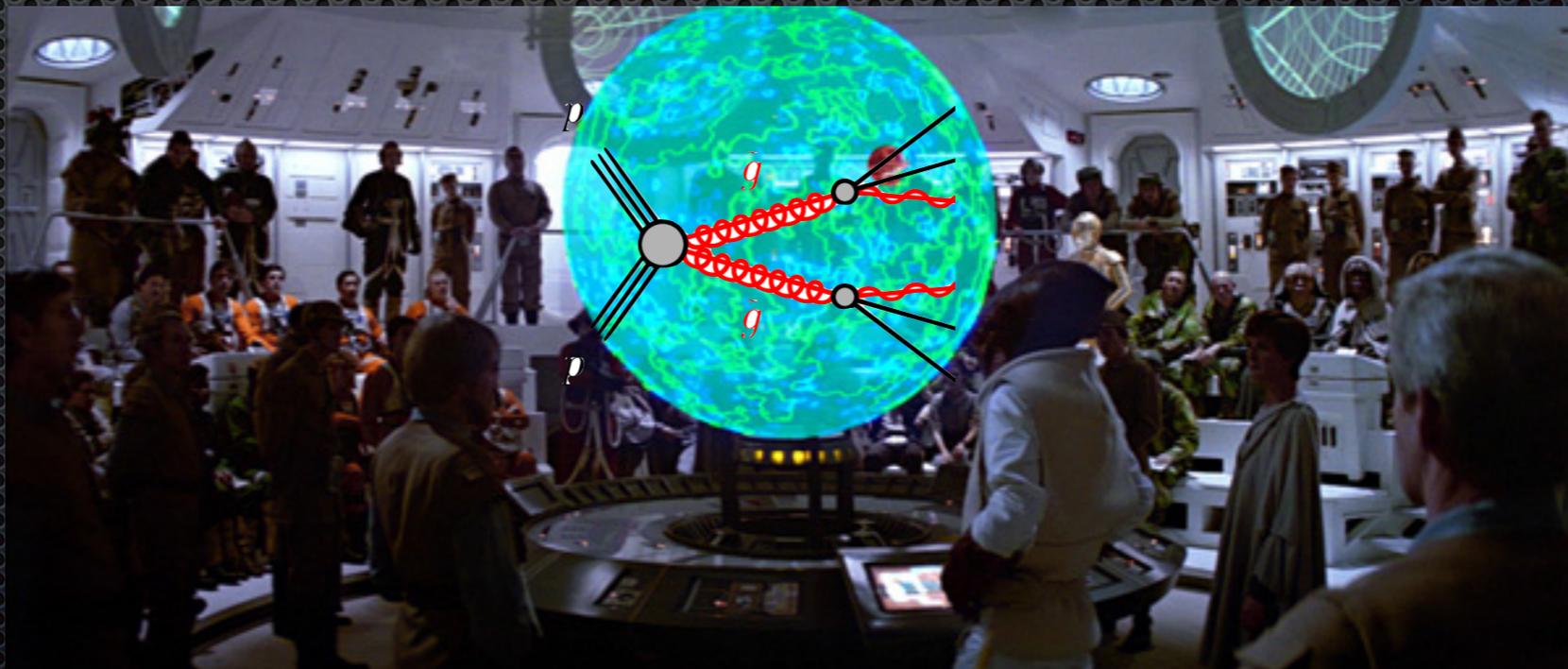


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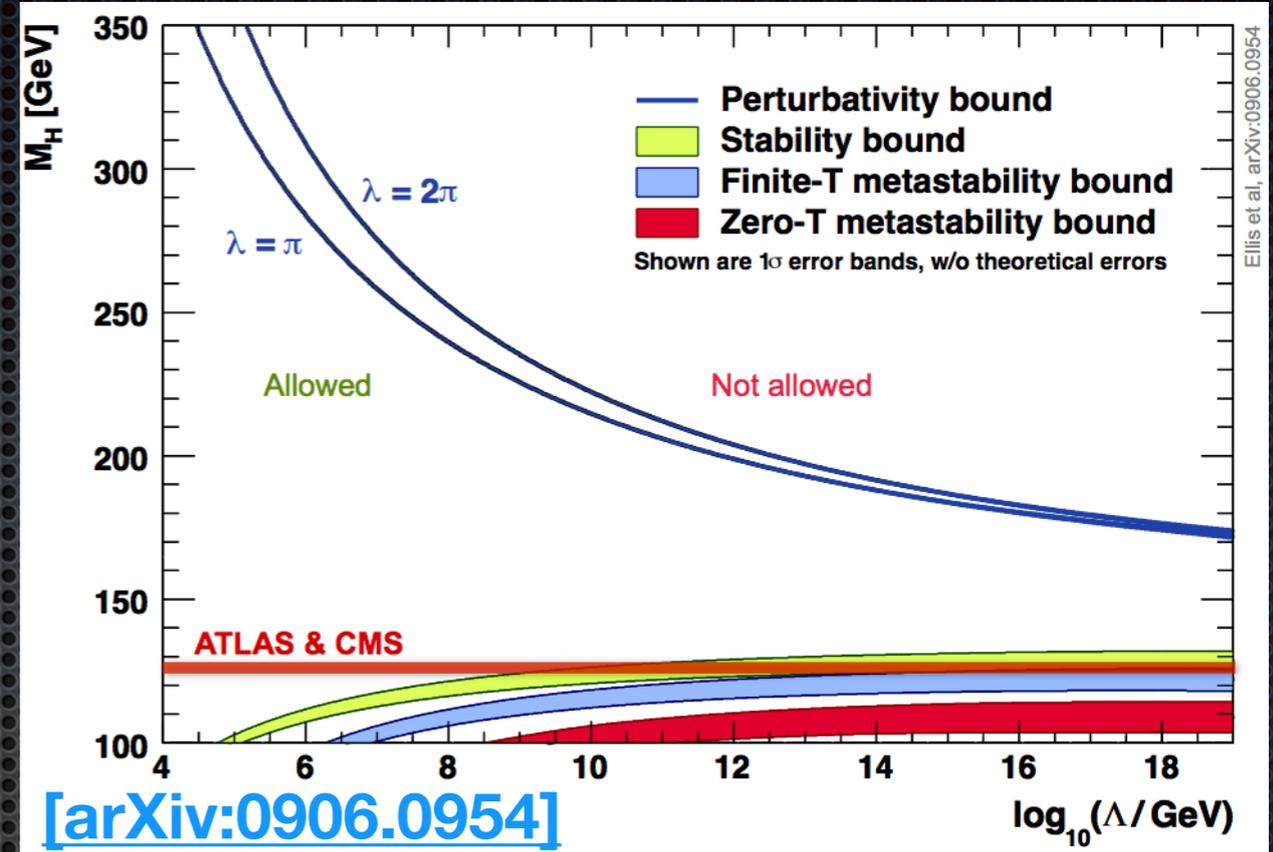
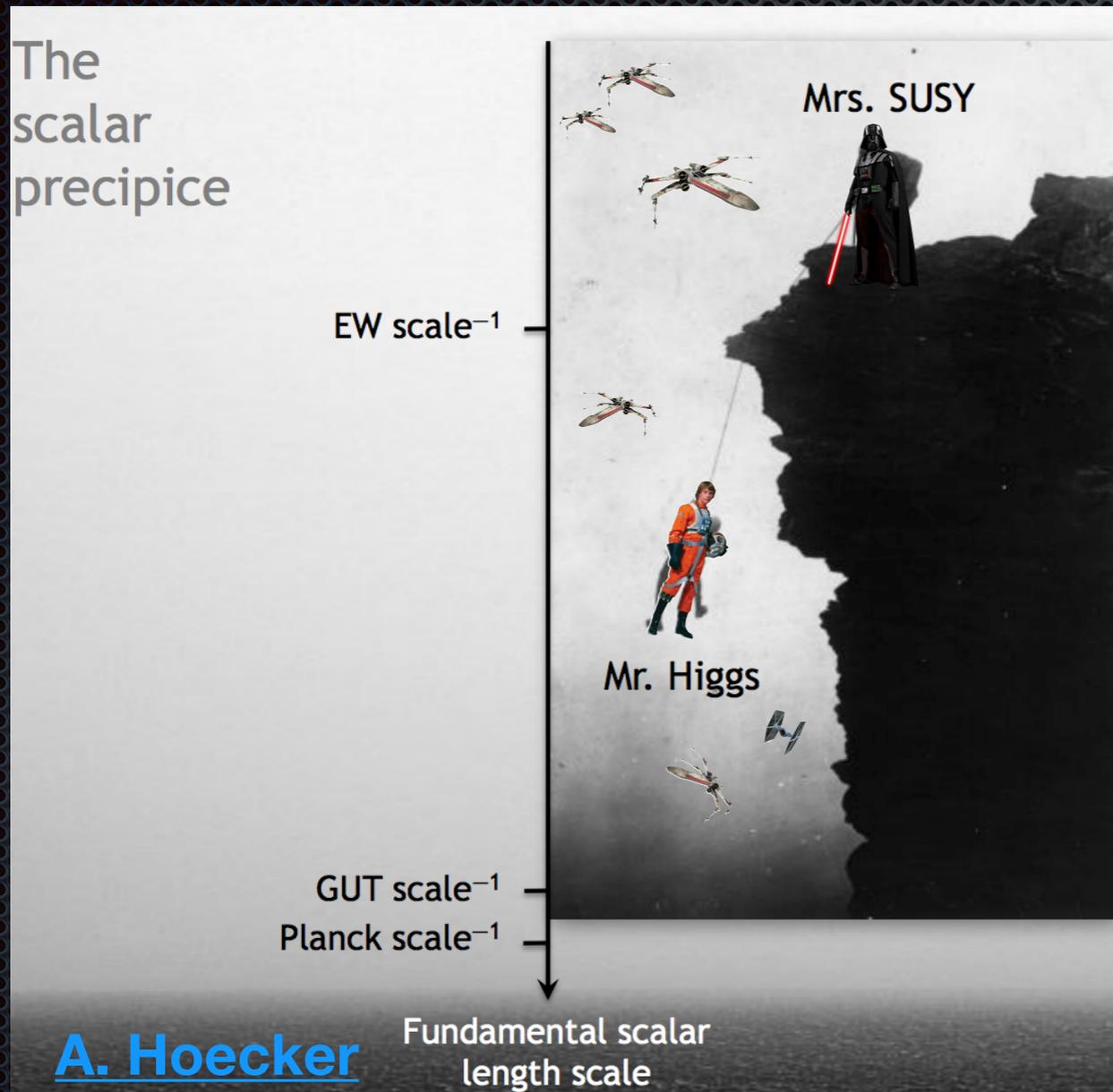
indico.cern.ch/event/439039

SUPER THE SEARCH FOR MORE PARTICLES SYMMETRY

- We found the Higgs Boson — how do we motivate SUSY?
- *Run 1 Search: RPV Gluino* — total jet mass
- *Run 2 Search: Stop 1-Lepton* — reclustered jets
- *Run 2 Search: Gtt* — substructure top-tagging, reclustered jets

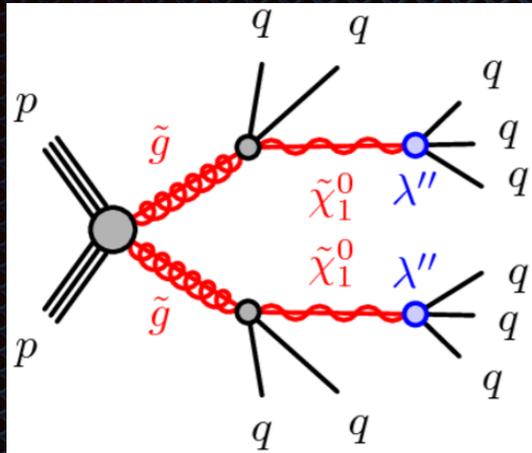


Higgs Boson

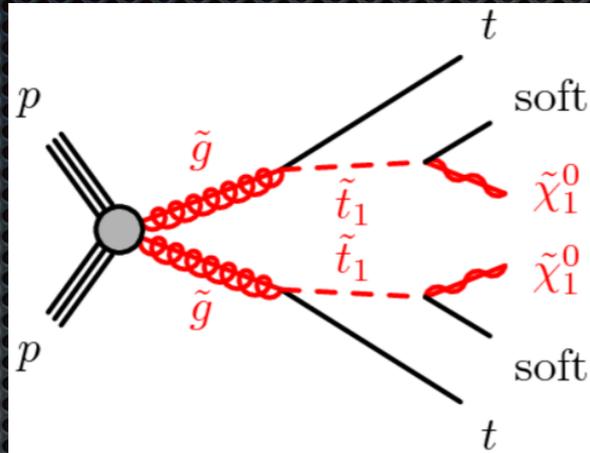


- ✦ mass at 125 GeV is light
 - ✦ argue for naturalness
- ✦ Supersymmetric particles restore balance to the **FORCE**
 - ✦ Leading theories predict a light stop and gluino
 - ✦ Stop production via gluinos can produce **4 tops in final state!**

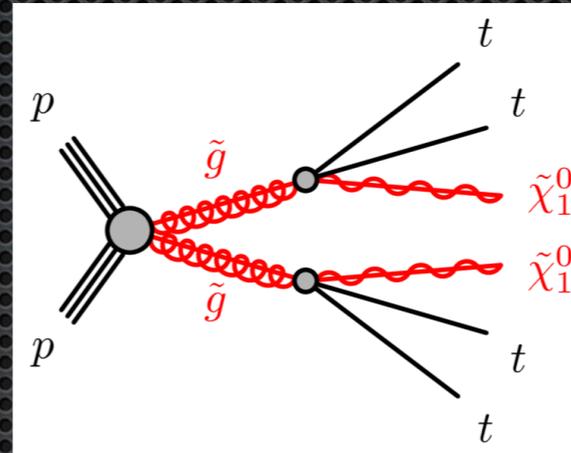
Supersymmetry Models



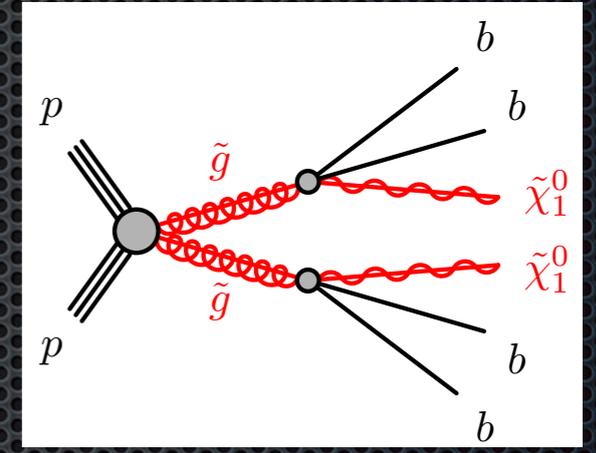
RPV Gluino



Stop 1L

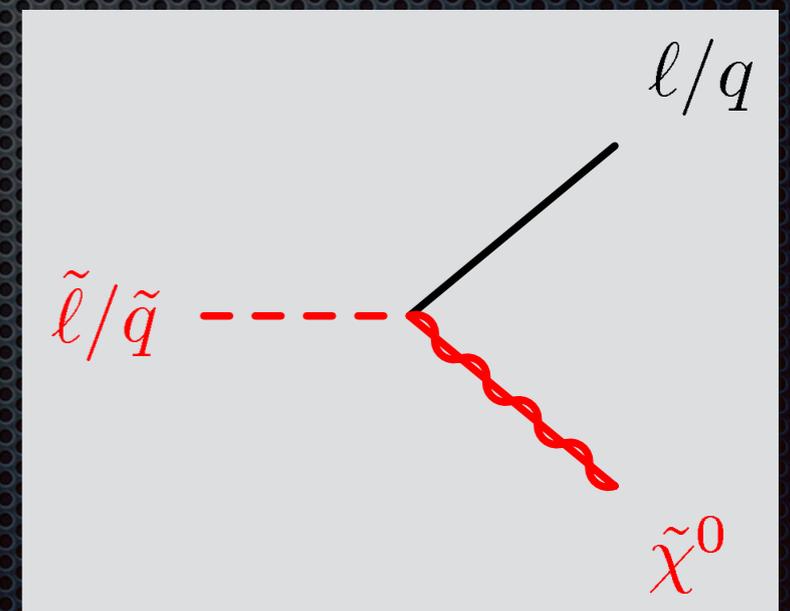


Gtt



Gbb

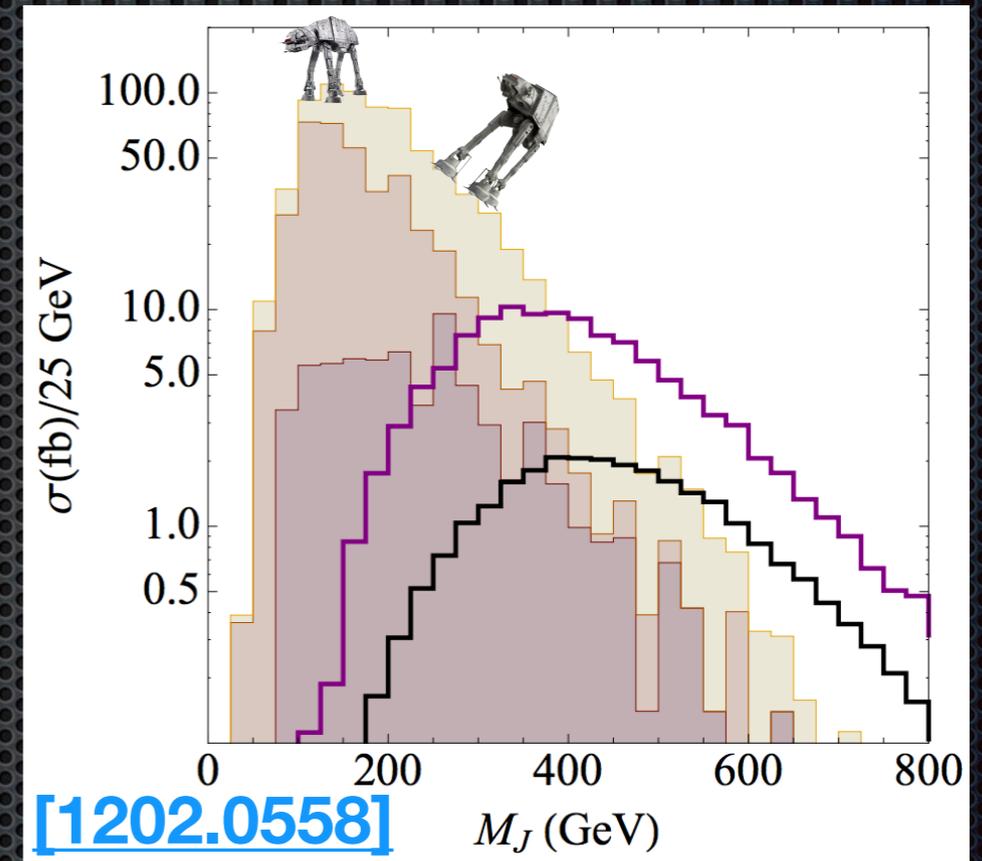
- Gluino searches are well-motivated
 - Decays to squark and quark
 - Squark decays to quark + LSP
- The signature of a classic SUSY search
 - **lots of jets + lots of MET**



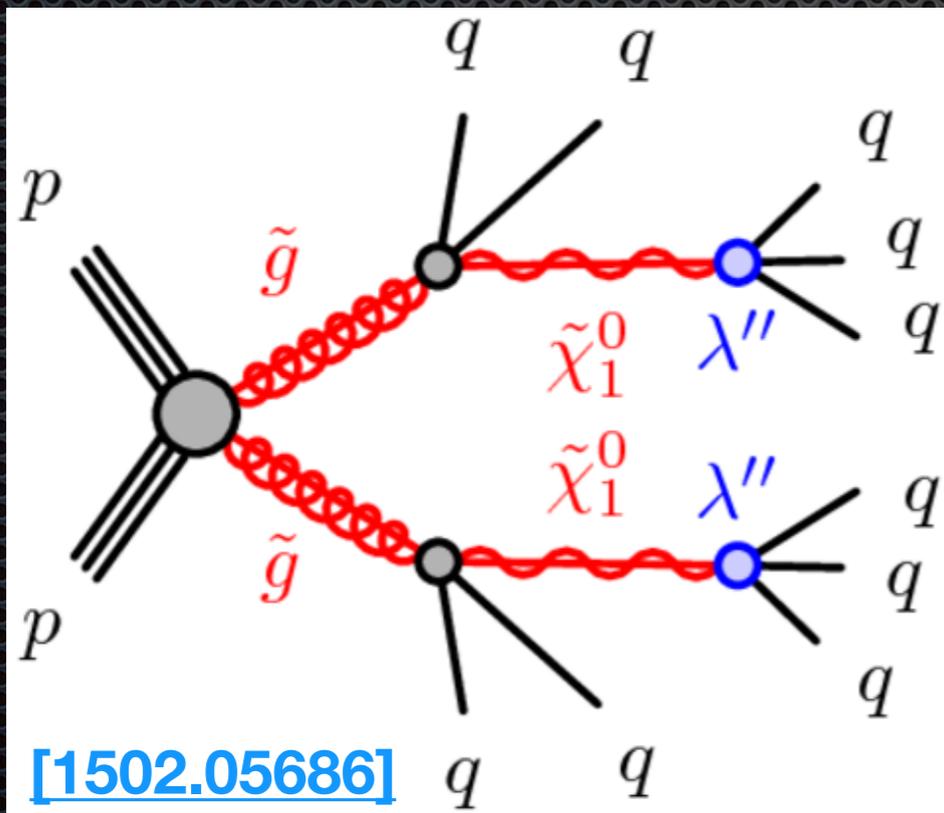
RUN 1

8 TeV RPV Gluino

- Decays to fully hadronic final states
- Search regions defined using
 - **total jet mass** of standard large-R trimmed jets
 - high jet multiplicity



[1202.0558]



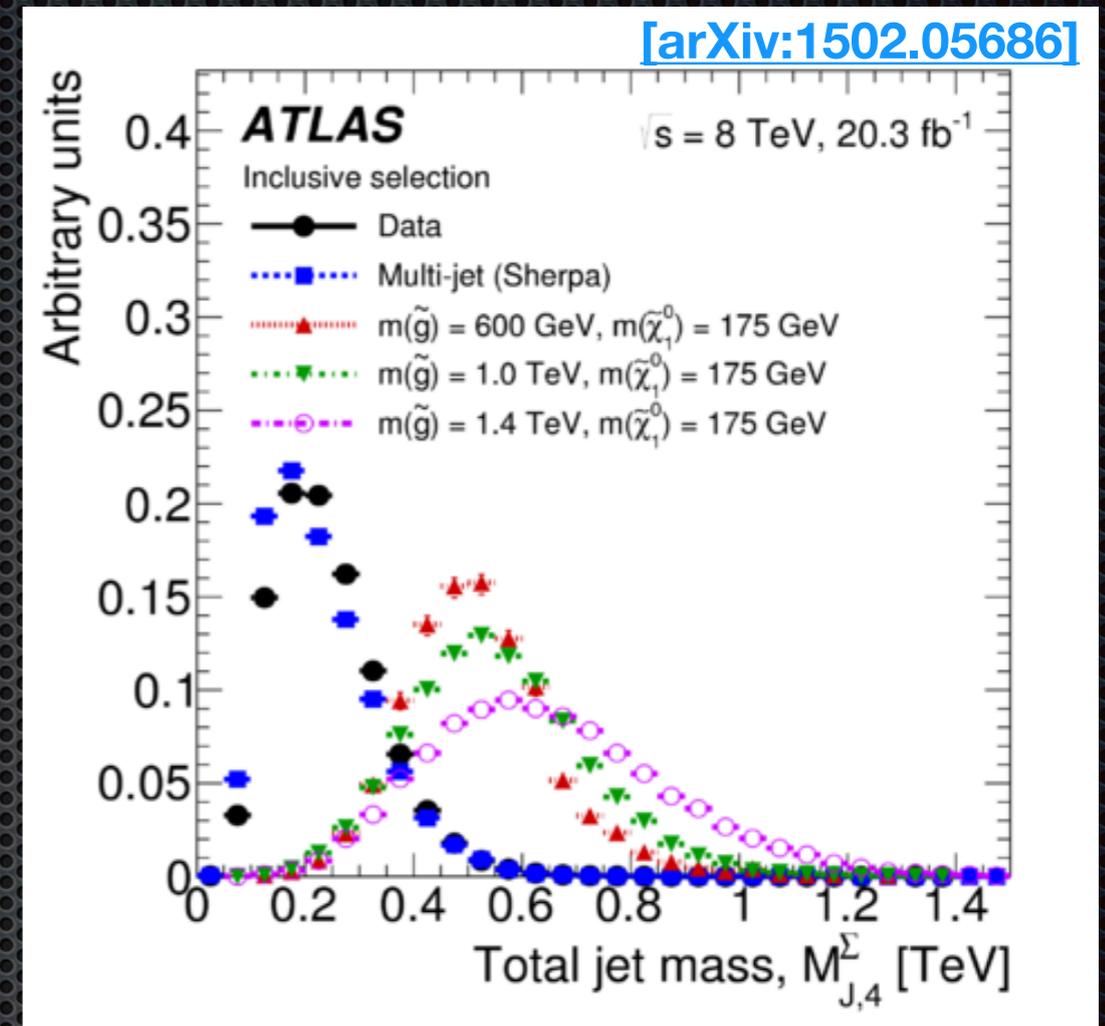
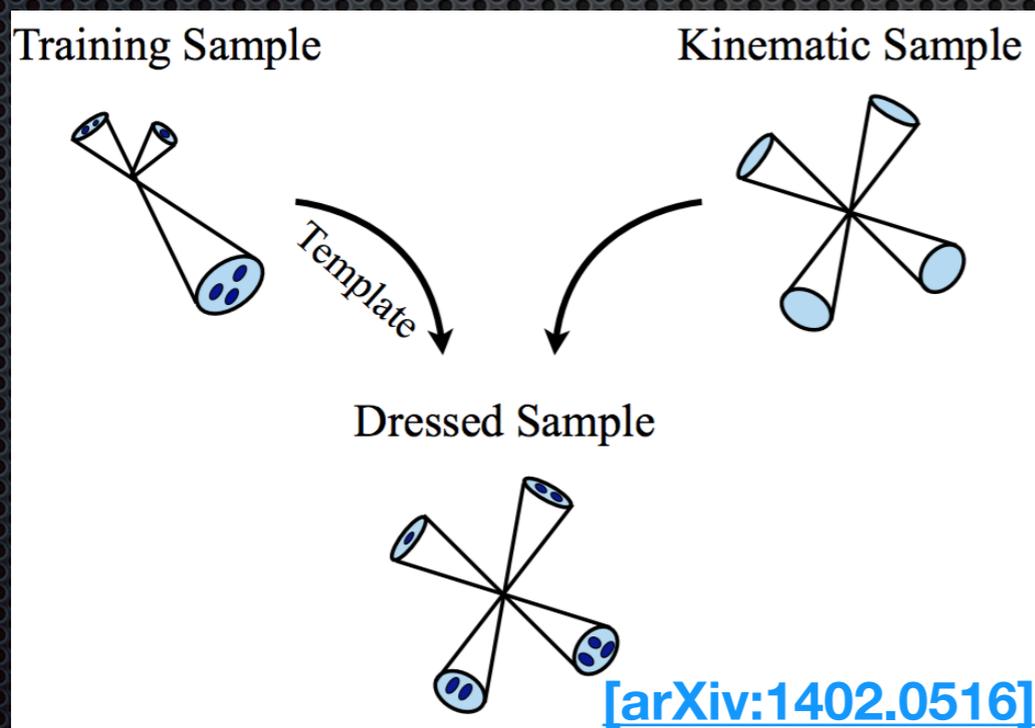
[1502.05686]

Accidental Substructure

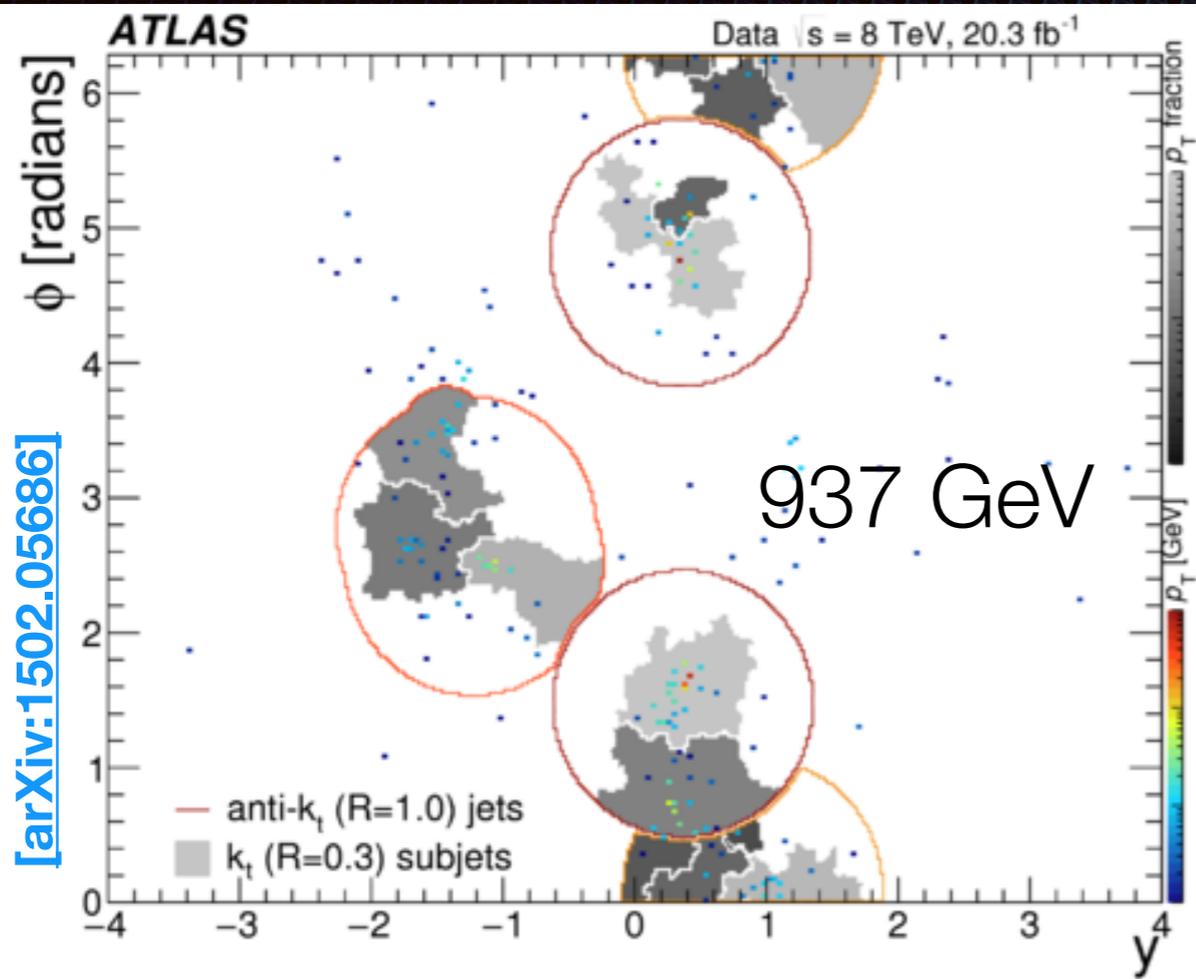
- 10-quark model produces a lot of jets
- Do not need BOOST to see overlaps!

Total Jet Mass

- A **template method** is used to predict total jet mass constructed from individual jet mass templates
- Training sample maps jet kinematic variable p_T to total jet mass variable

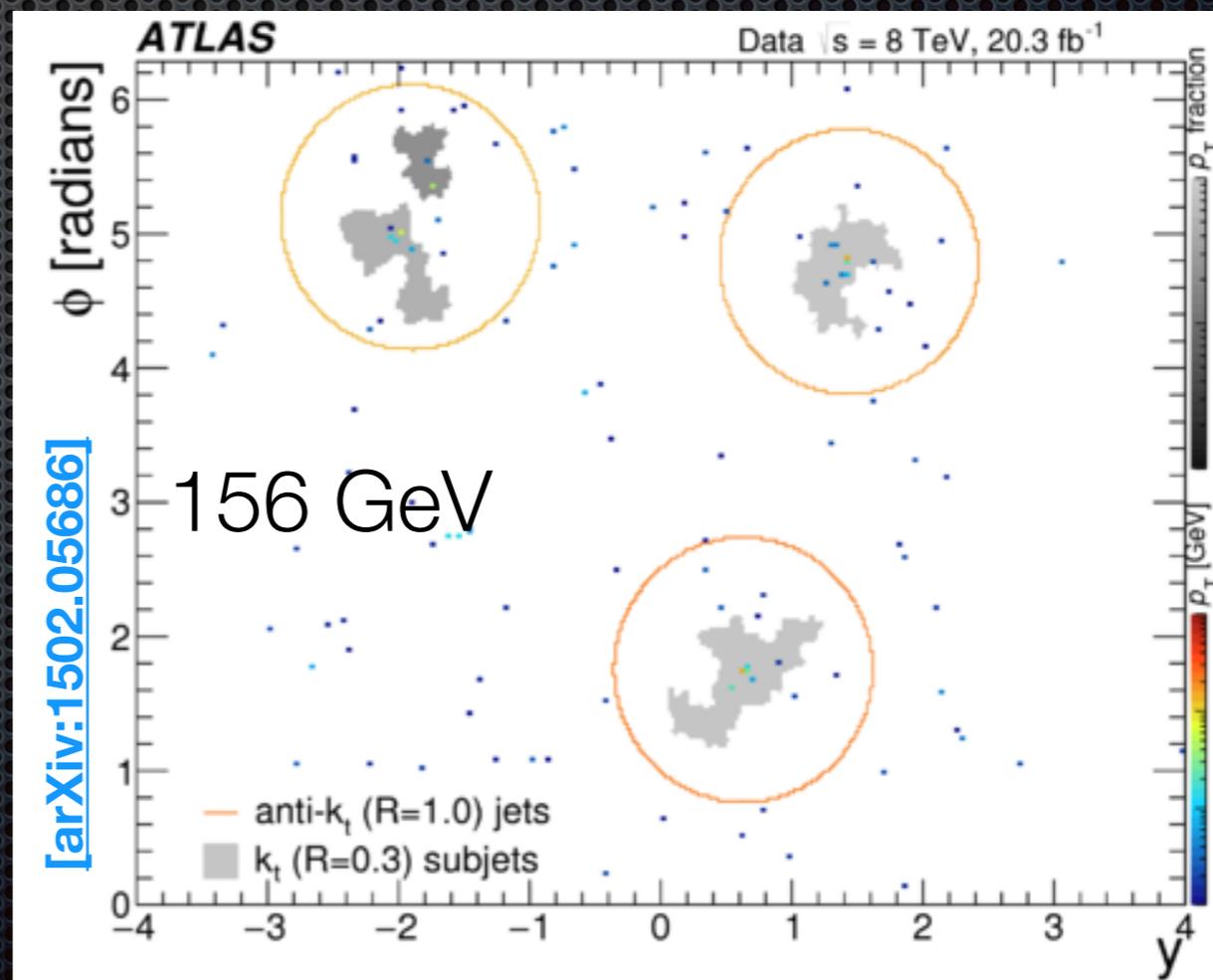
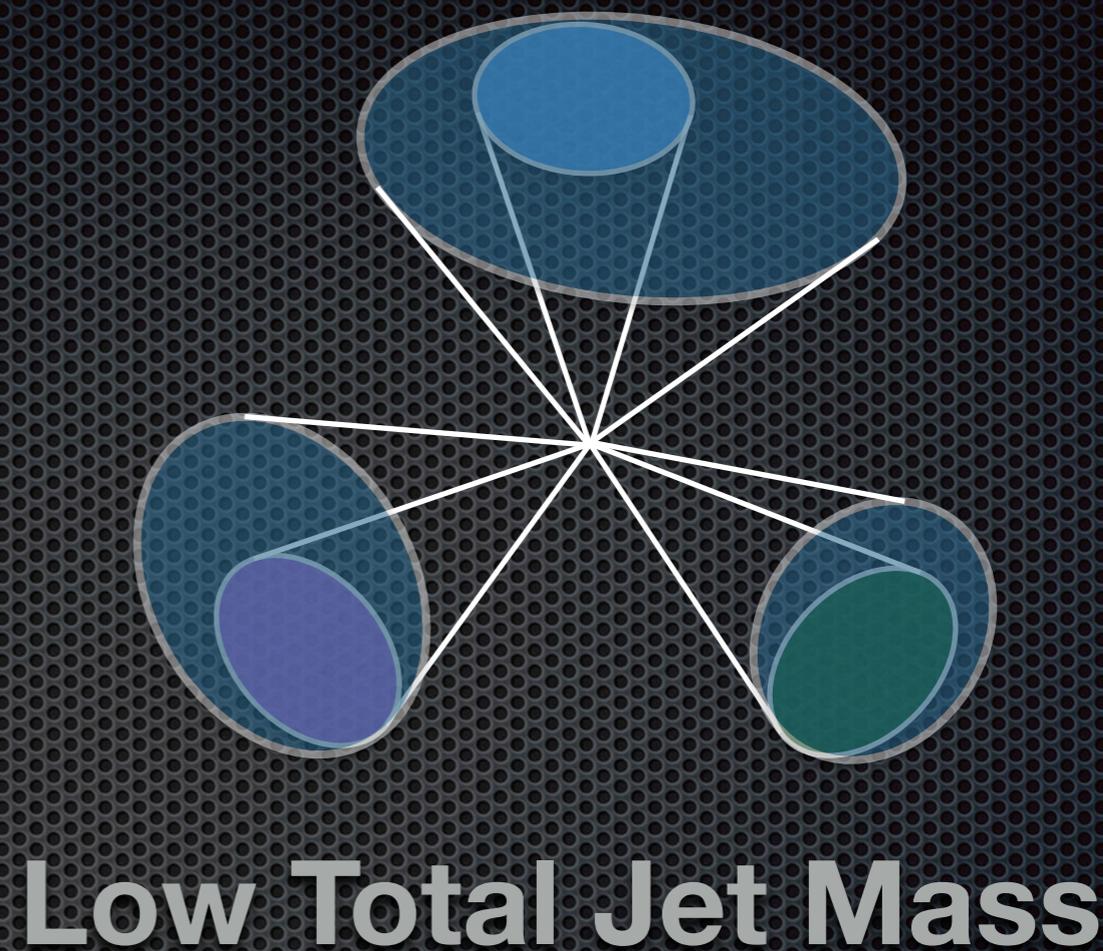
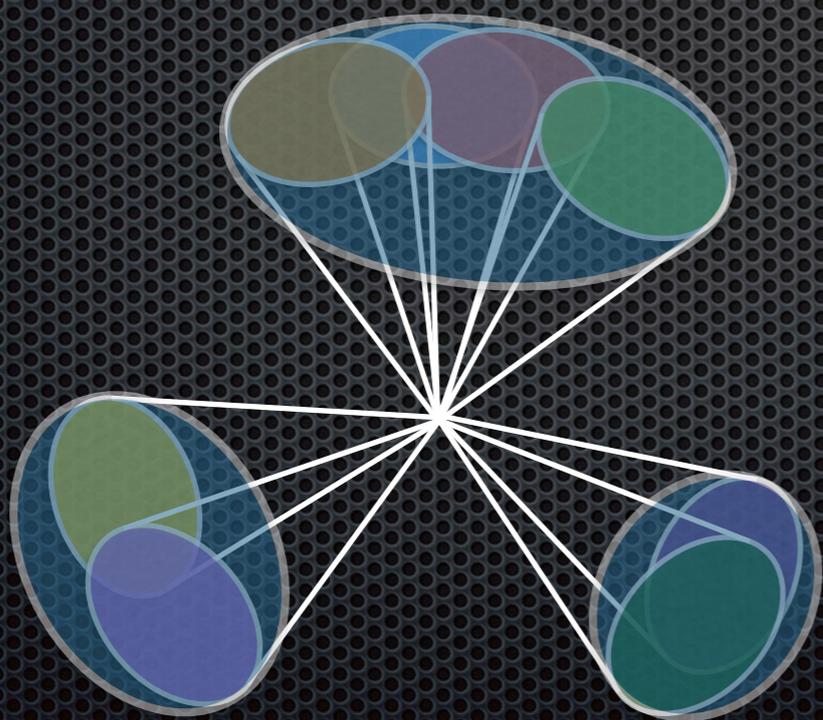


Jets with substructure have high mass!



[\[arXiv:1502.05686\]](https://arxiv.org/abs/1502.05686)

High Total Jet Mass

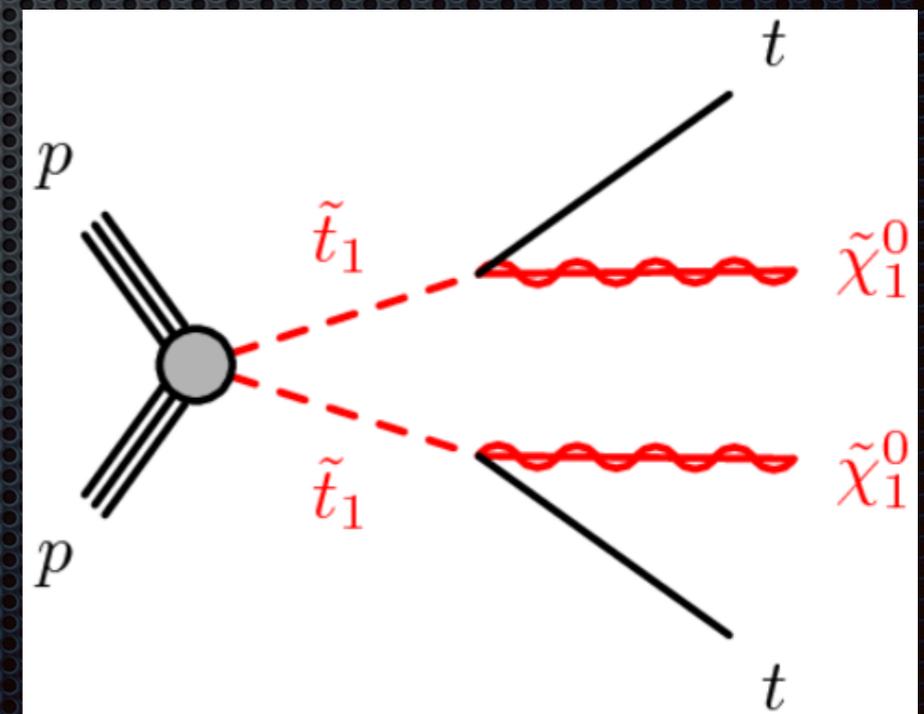
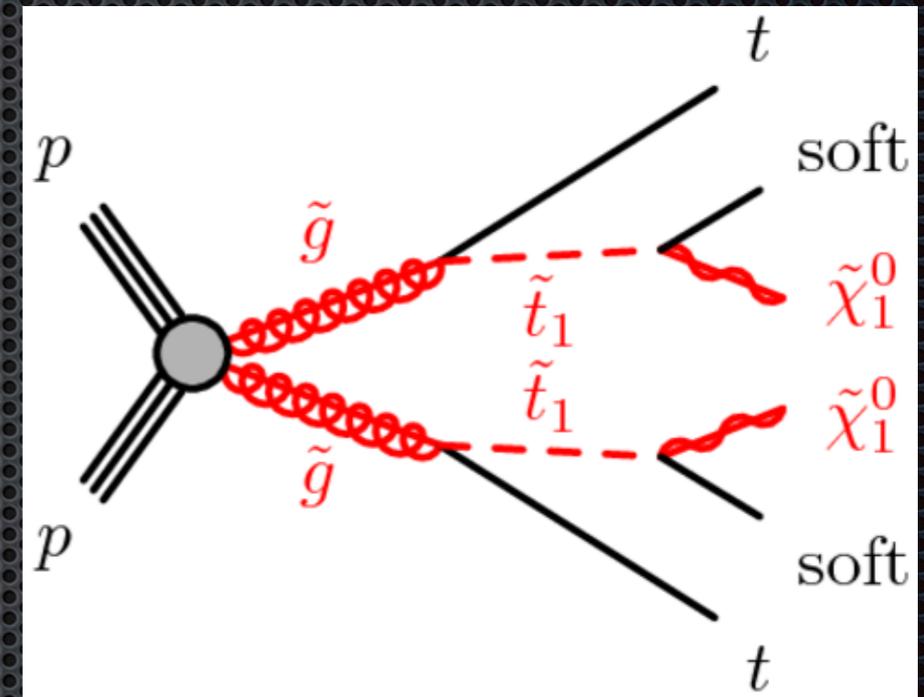
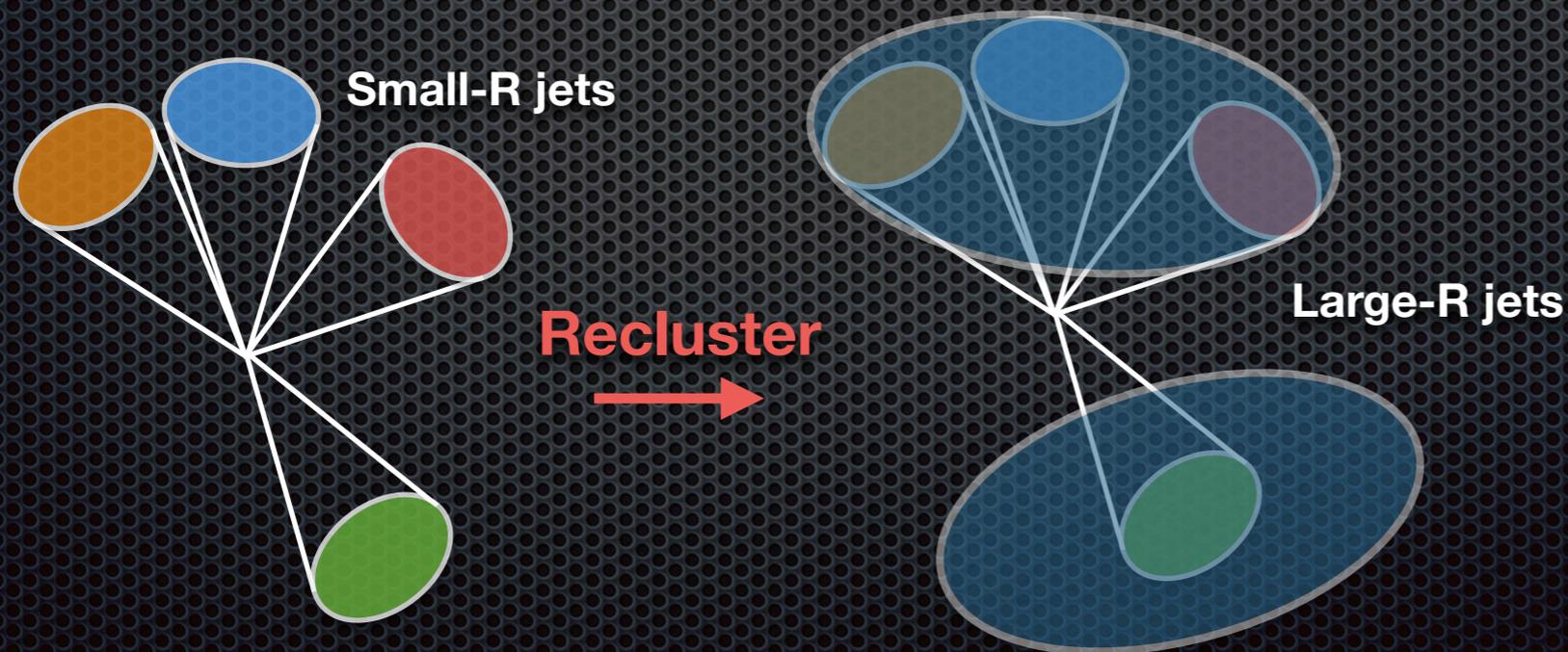


[\[arXiv:1502.05686\]](https://arxiv.org/abs/1502.05686)

RUN 2

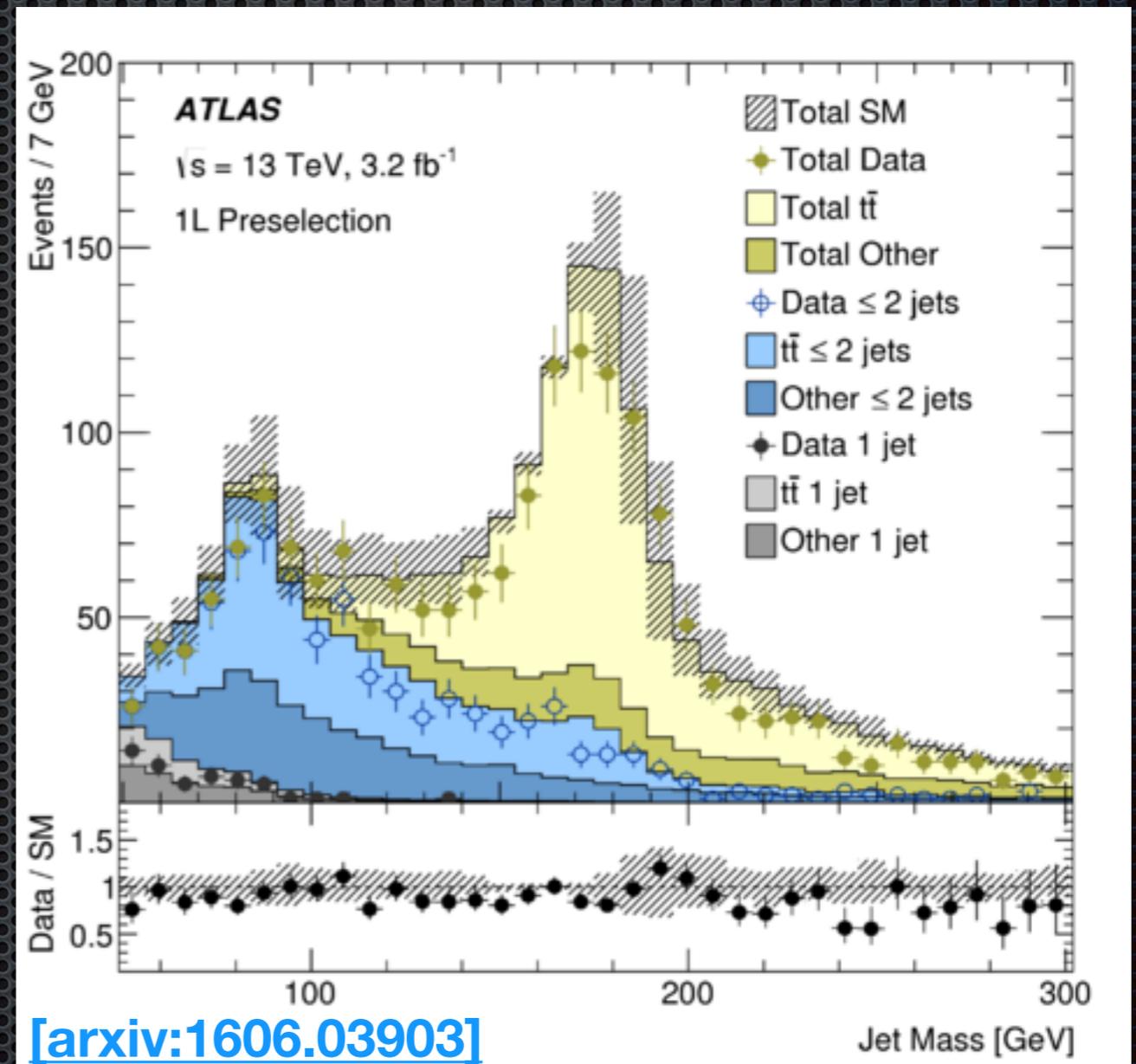
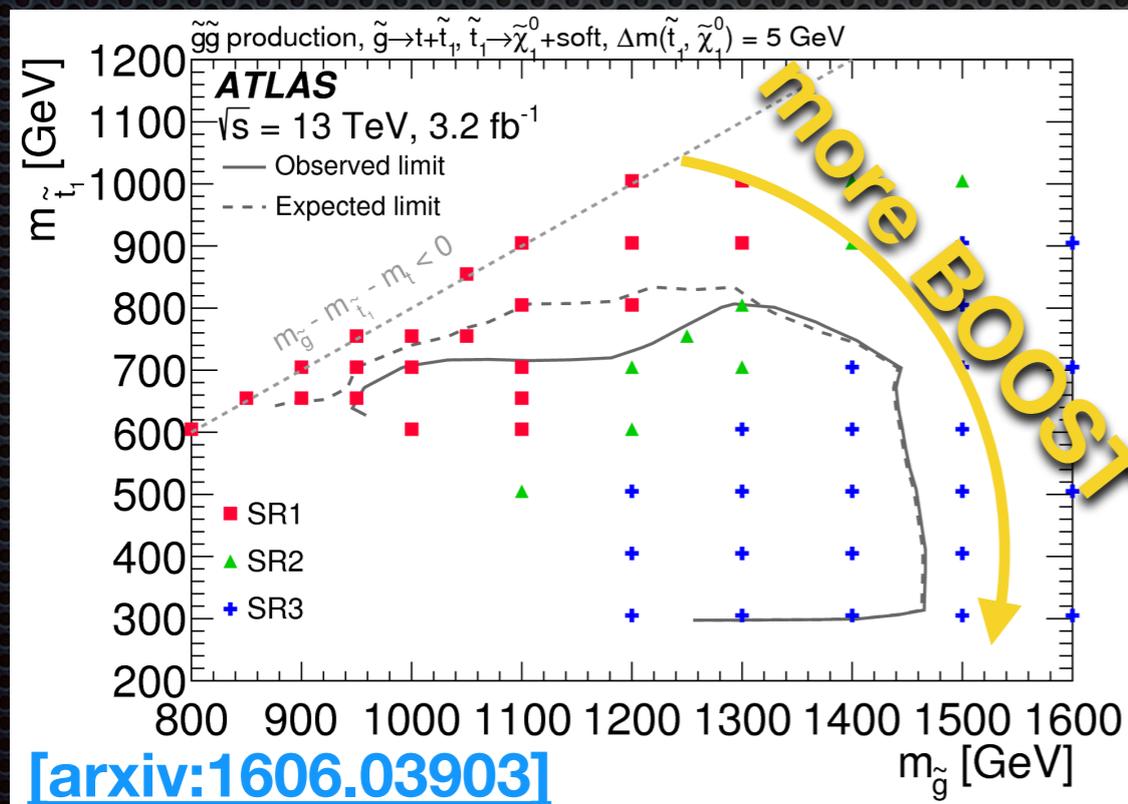
Stop 1-Lepton

- SUSY search focusing on one isolated lepton (electron or muon)
- Uses large radius, trimmed jets reclustered from small radius ($R=0.4$) jets
 - Two different radii: $R=1.0$, $R=1.2$
 - does not include leptons in the **reclustering**
- Final state is identified by two tops + MET (**tt+MET**)
 - a “high” stop mass leads to **BOOSTed tops**



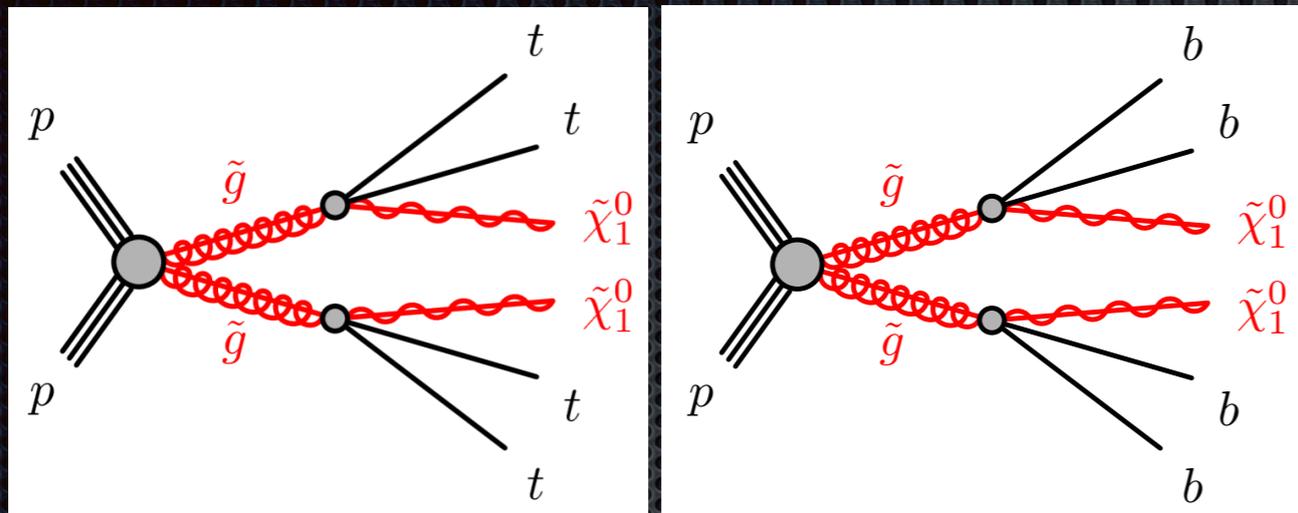
Stop 1-Lepton Reclustering

- Reclustering performs very well and is not significantly mismodeled in data — substructure is very well-motivated
- SR1** does not use reclustered jet mass — computes a mass variable by summing invariant mass of three small-R jets
- SR2** uses $R=1.2$, **SR3** uses $R=1.0$

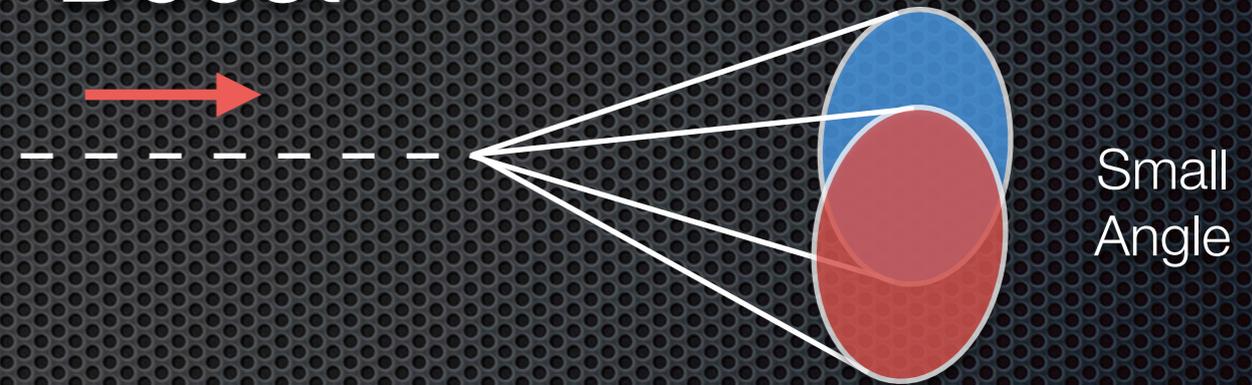
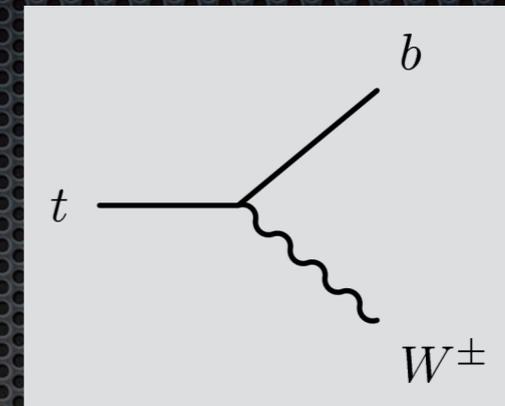


BOOSTed regions use smaller reclustered jets

Gtt (2015)

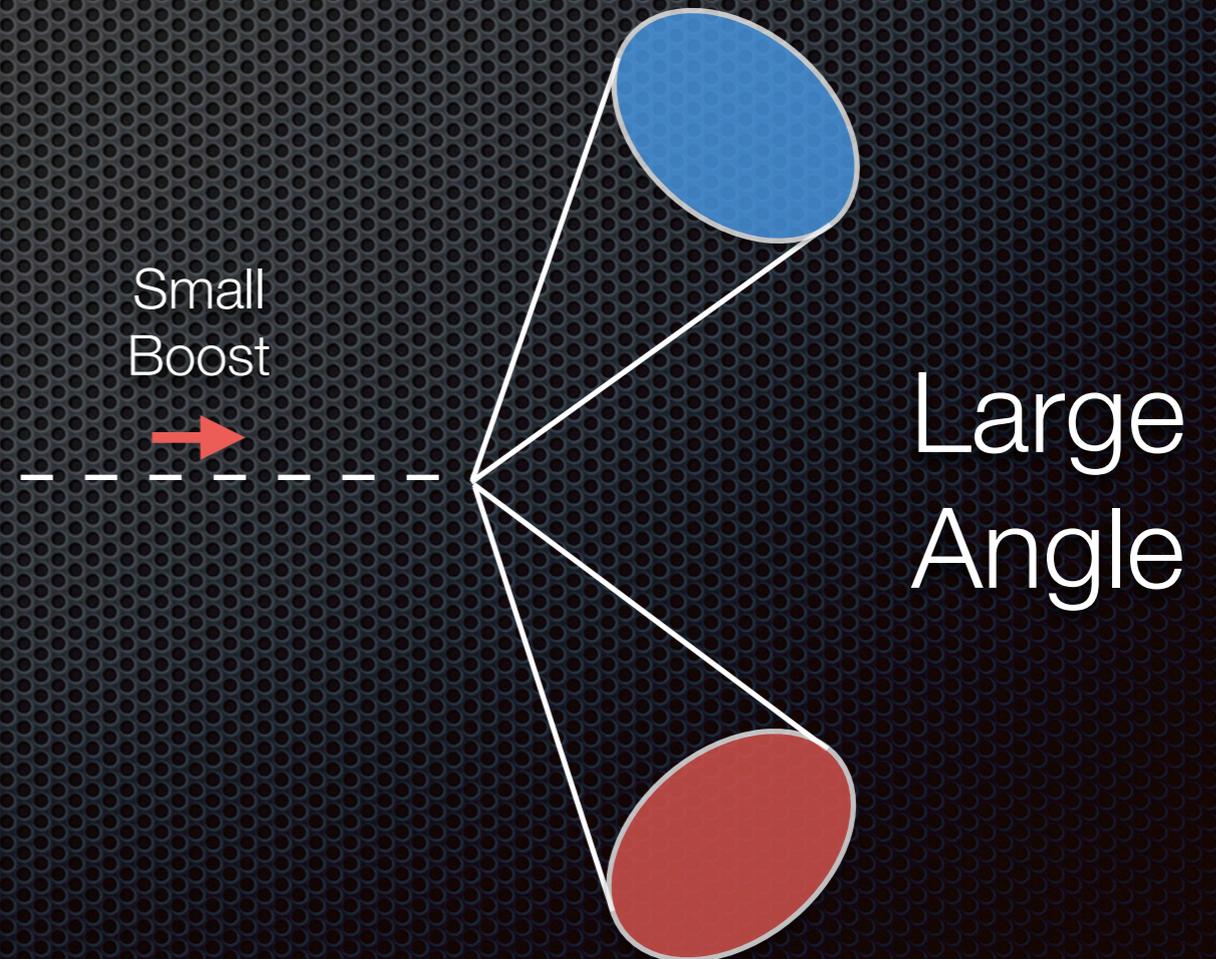


Large Boost



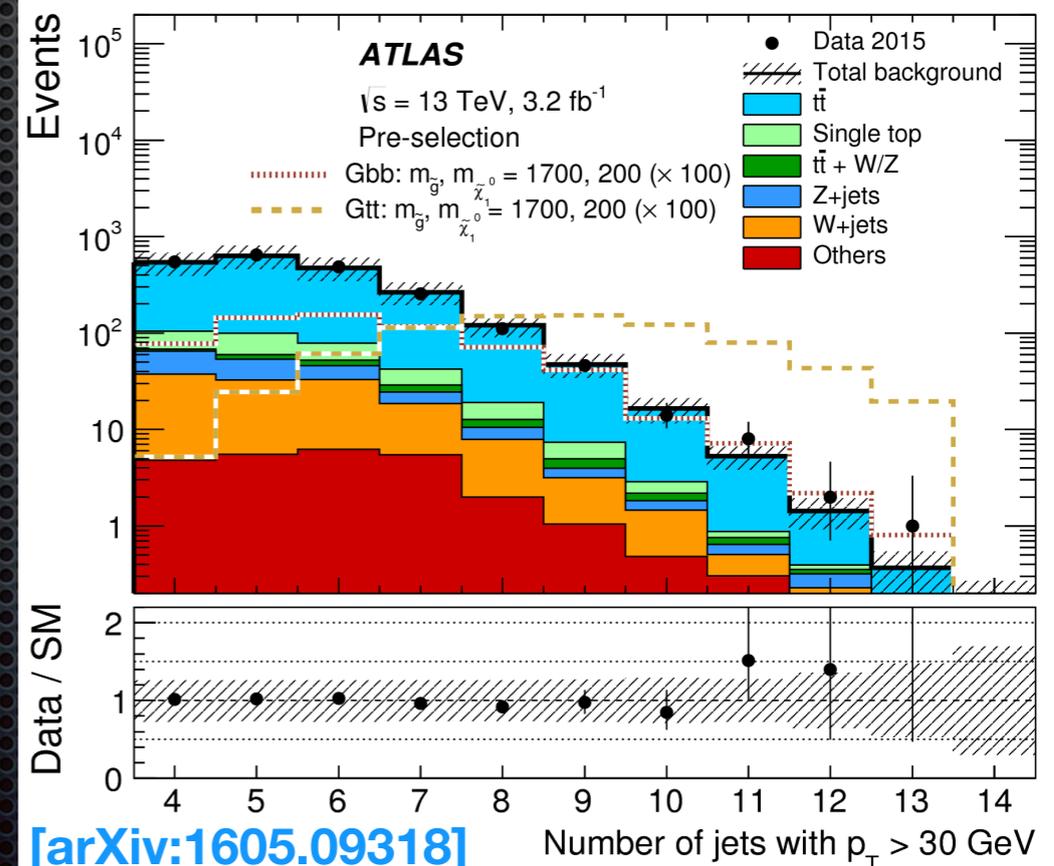
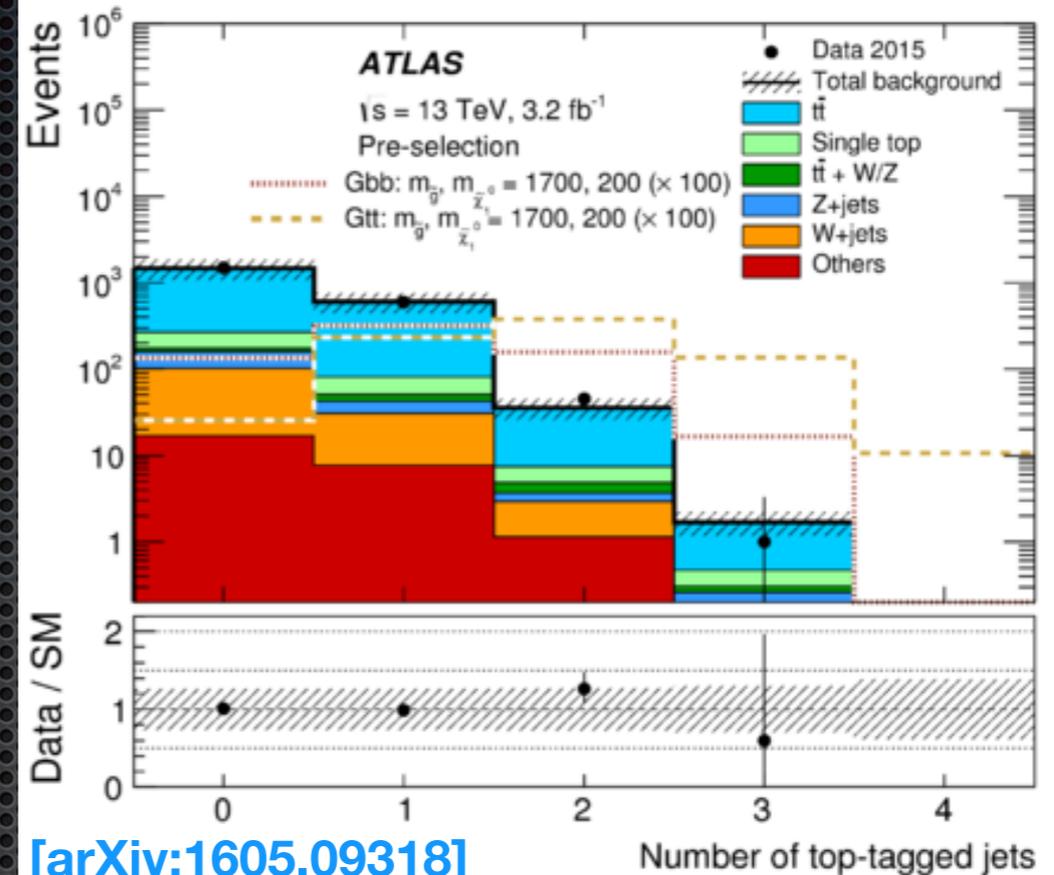
- SUSY search focusing on zero and one-lepton channels for stop and sbottom
 - large radius, trimmed jets reclustered from small radius ($R=0.4$) jets
 - tops, ≥ 3 b -jets, ≥ 4 jets, large MET
 - potentially isolated electrons or muons
- Define signal regions based on mass splitting between gluino and neutralino

Small Boost



Gtt (2015)

- ✦ Gtt model has **lots of handles**
 - ✦ **need high efficiency** because we have so many other handles already
- ✦ Uses reclustered jets as large-R jets
- ✦ Top-tagging — [substructure tagger II](#) [[BOOST2015](#)]
 - ✦ **high efficiency** (80%) for **BOOST**ed tops!
 - ✦ **reclustered jets** with **mass > 100 GeV** are considered top candidates
- ✦ We have lots of potential (**accidental?**) overlaps with 4 tops in the final state
 - ✦ **simple** mass tagging **will be efficient**
 - ✦ more **complex** taggers based on nsubjettiness or shower deconstruction **would reject signal**



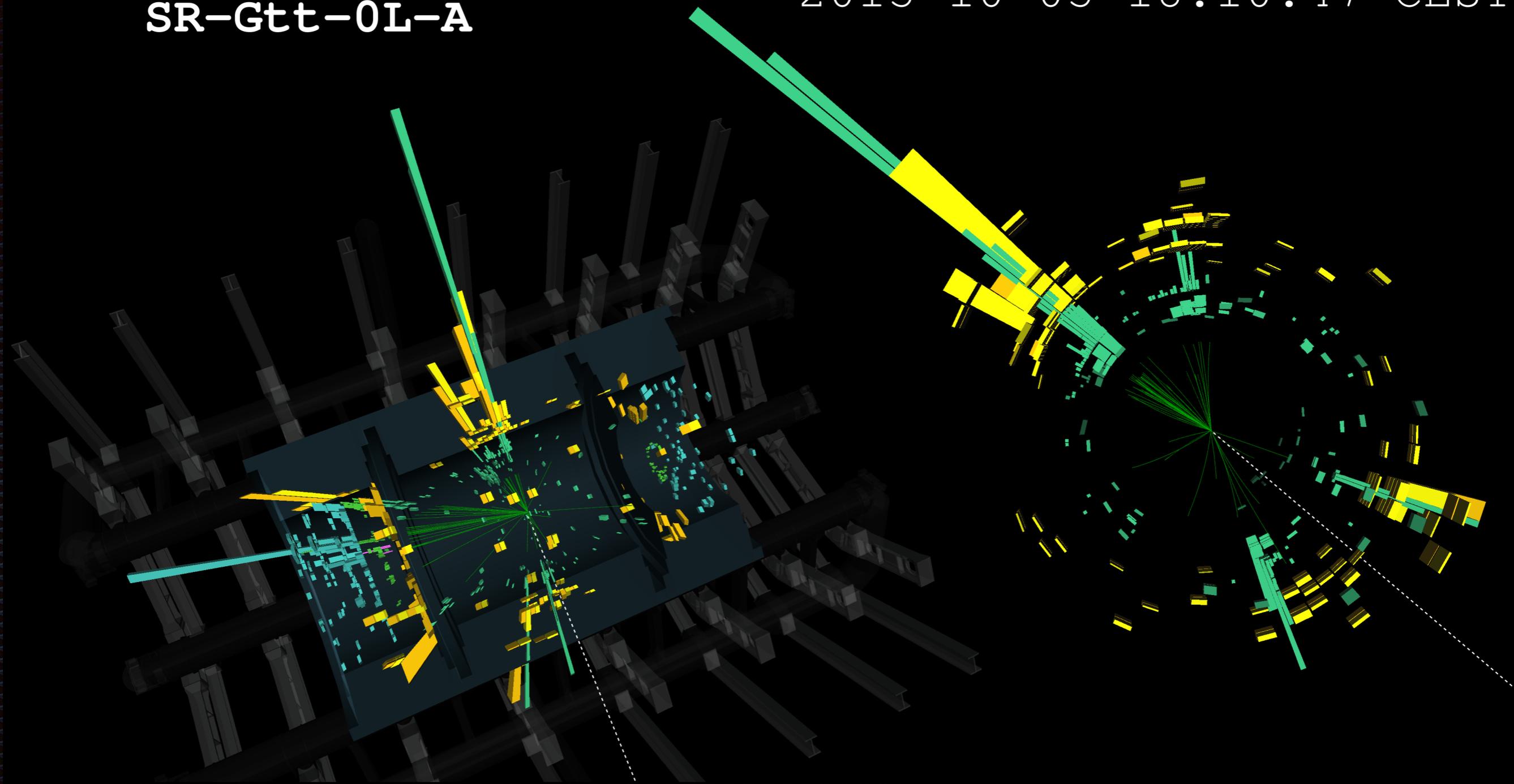
Contains a boosted top candidate!



Run: 281074

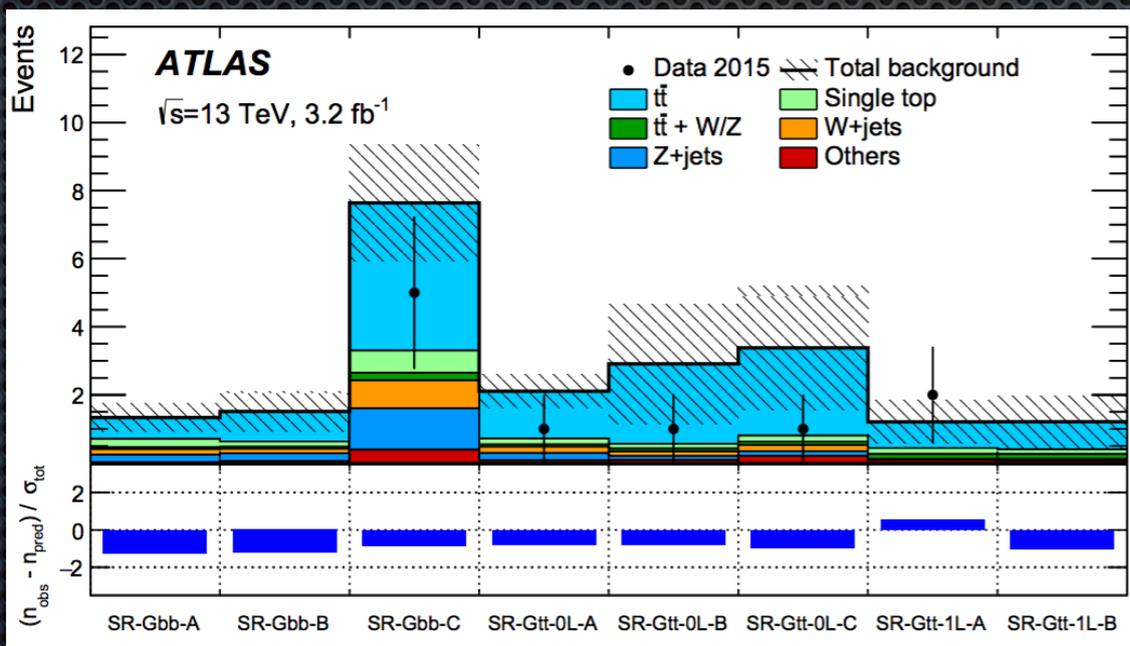
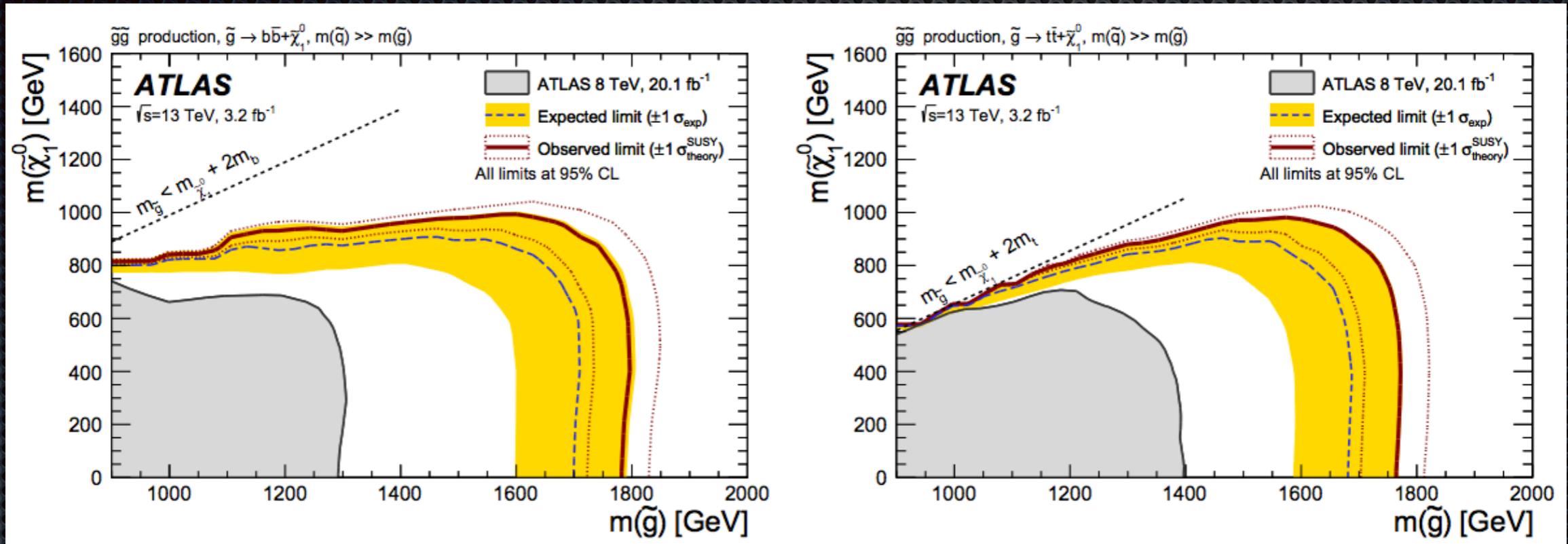
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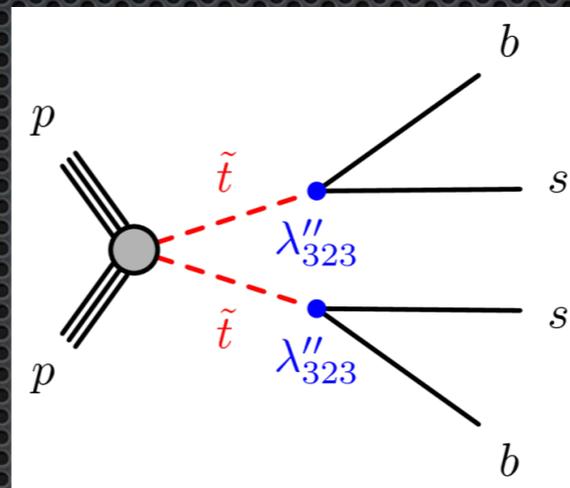
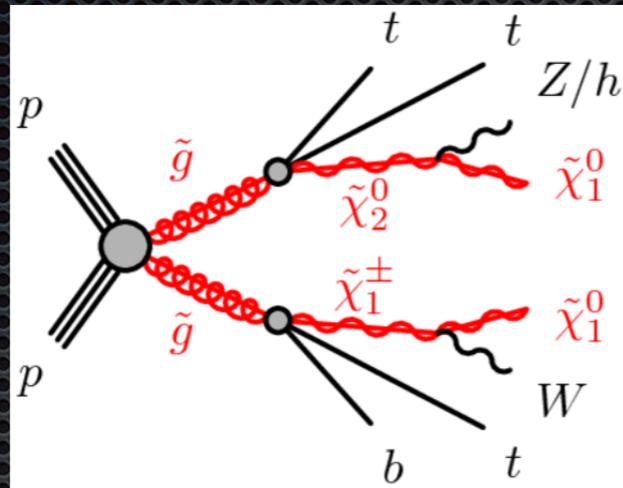
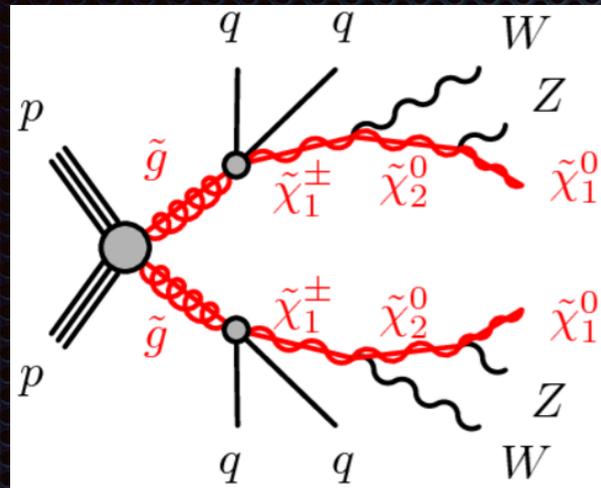
[\[arxiv:1605.09318\]](https://arxiv.org/abs/1605.09318)

Gtt 2015 Results



- 8 signal regions 0/1L, covering full phase space
- Optimized for 3fb discovery
- No excess observed (though a few correlated deficits)

Where else can we look?

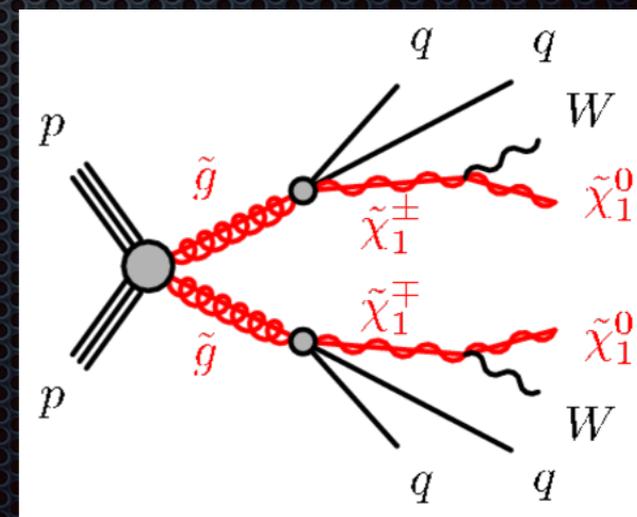
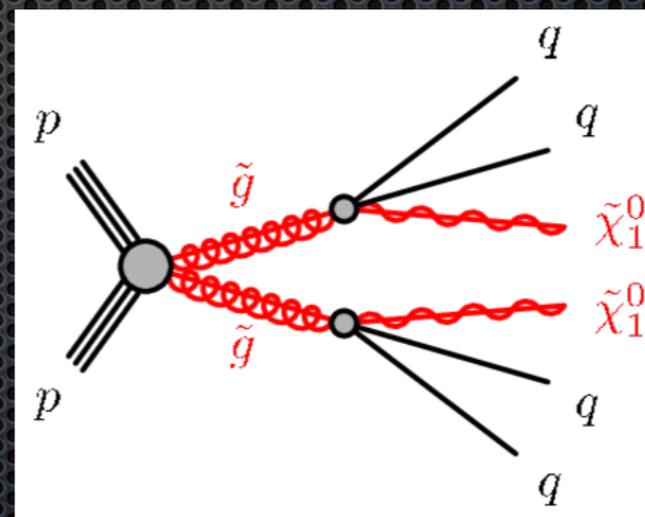
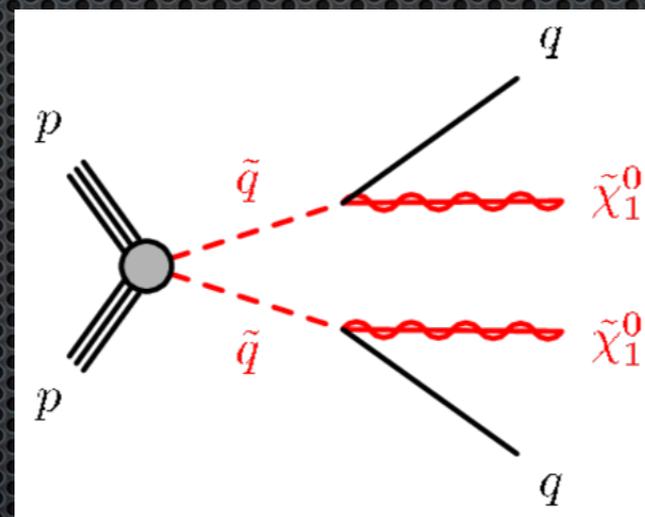
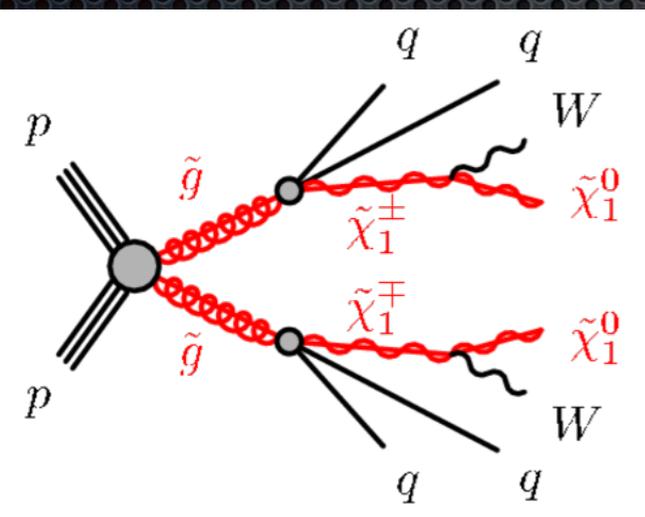


PRODUCTION	DECAY CHANNEL	FINAL STATE
$\tilde{q}\tilde{q}$	$\tilde{q} \rightarrow q\tilde{\chi}$	2 partons + \mathcal{H}_T
$\tilde{q}\tilde{g}$	$\tilde{g} \rightarrow q\tilde{q}\tilde{\chi}$ $\tilde{q} \rightarrow q\tilde{\chi}$	3 partons + \mathcal{H}_T
$\tilde{g}\tilde{g}$	$\tilde{g} \rightarrow q\tilde{q}\tilde{\chi}$	4 partons + \mathcal{H}_T
$\tilde{q}\tilde{g}$	$\tilde{g} \rightarrow q\tilde{q}Z^0\tilde{\chi}$ $\tilde{q} \rightarrow q\tilde{\chi}$	5 partons + \mathcal{H}_T
$\tilde{t}\tilde{t}$	$\tilde{t} \rightarrow t\tilde{\chi}$	6 partons + \mathcal{H}_T
$\tilde{q}\tilde{g}$	$\tilde{g} \rightarrow t\tilde{t}\tilde{\chi}$ $\tilde{q} \rightarrow q\tilde{\chi}$	7 partons + \mathcal{H}_T
$\tilde{g}\tilde{g}$	$\tilde{g} \rightarrow q\tilde{q}Z^0\tilde{\chi}$	8 partons + \mathcal{H}_T

[0L 7-10 jet \[1602.06194\]](#)

[RPV 2x2 Stop \[1601.07453\]](#)

[\[1605.01416\]](#)



[1L 2-6 jet \[1605.04285\]](#)

[0L 2-6 jet \[1605.03814\]](#)

Conclusion

- ✦ Run 2 is **just** getting started
- ✦ Higher energy, more particles in final states, more **BOOST**
- ✦ Apply **substructure techniques** to more and more analyses
 - ✦ very loose top-tagging, jet reclustering, total jet mass, and other **energy structure [1605.01416]** variables

BOOST
THE SUSY AWAKENS
2016

Run 2

A NEW HOPE

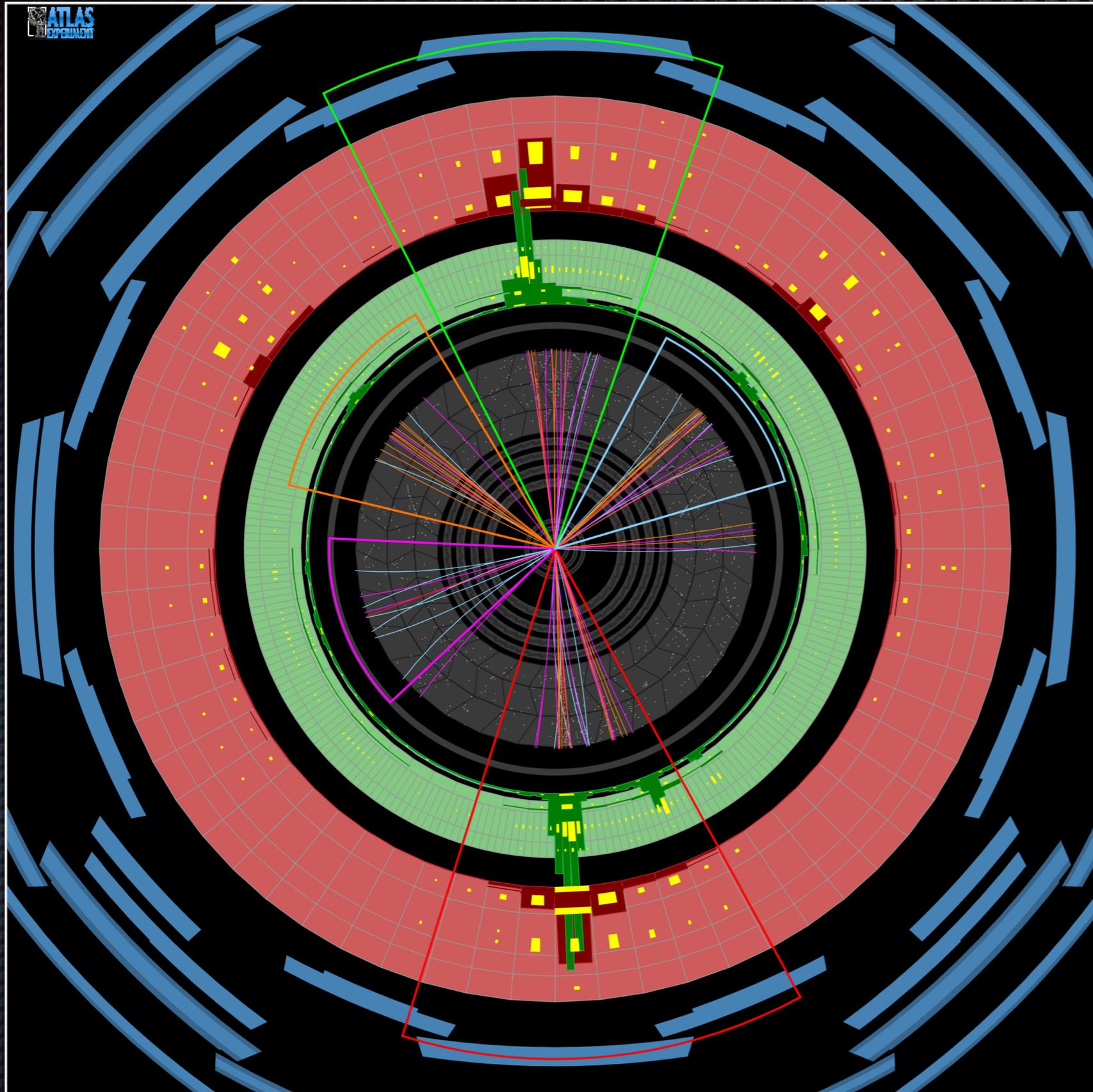
It is a period of civil searches. Rebel supersymmetry, striking from a hidden dimension, have won their first victory against the Standard Model.

During the decay, Rebel gluinos managed to split into BOOSTed quarks and LSPs in the Empire's ultimate weapon, the ATLAS Experiment, an armored particle detector with enough power to destroy an entire weasel.

Pursued by the Empire's sleepless graduate students, Director-General Gianotti races to CERN aboard her 18 tram, to restore balance to the galaxy....

Backup

Total Jet Mass = 937 GeV and $|\Delta \eta|=0.04$

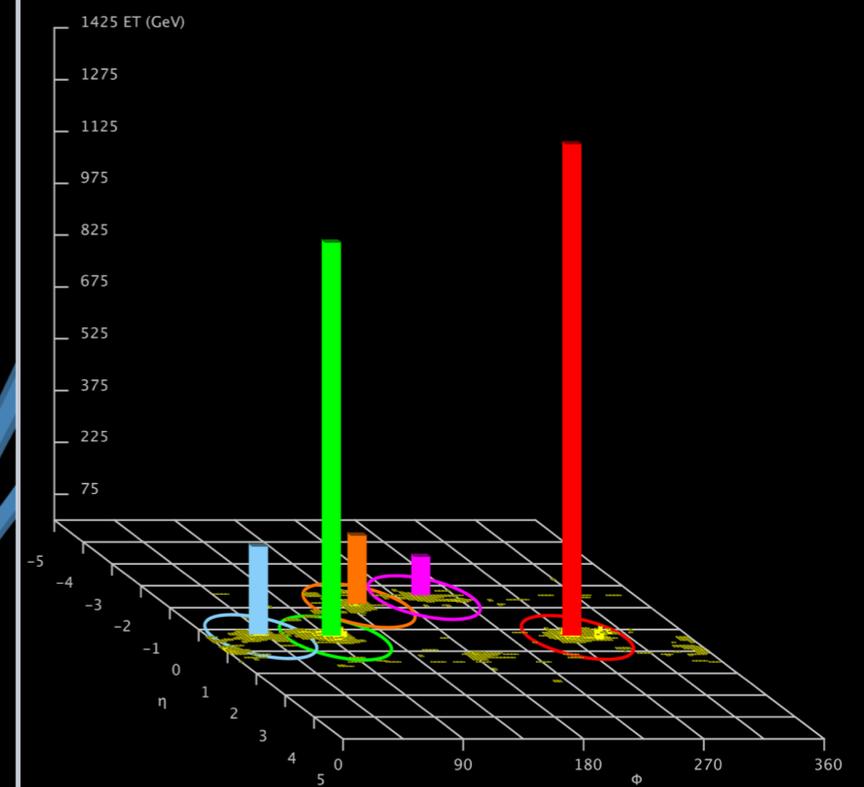


ATLAS
EXPERIMENT

Run Number: 214553, Event Number: 215620967

Date: 2012-11-15 16:32:56 UTC

[\[arXiv:1502.05686\]](https://arxiv.org/abs/1502.05686)



Jets shown are Anti-Kt R=0.4 jets