Pulling Out All the Stops: Jet Substructure and Light Stops Decaying to Multijets

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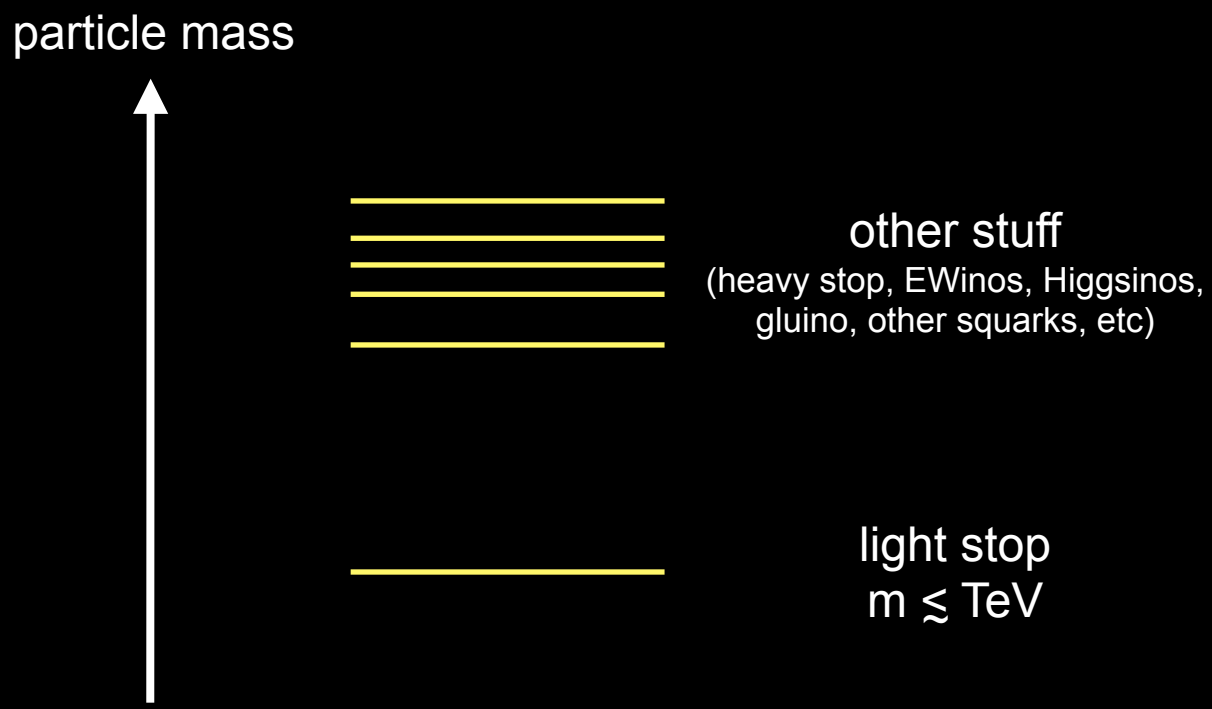
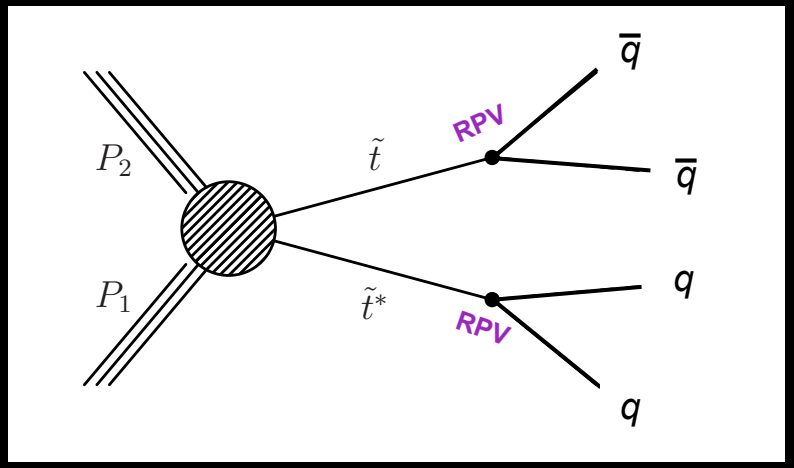
*work in progress with Y. Bai and A. Katz

"Very Natural" SUSY



e.g., Brust, Katz, Lawrence, Sundrum (1111.6670)

Baryon # Violating Decay

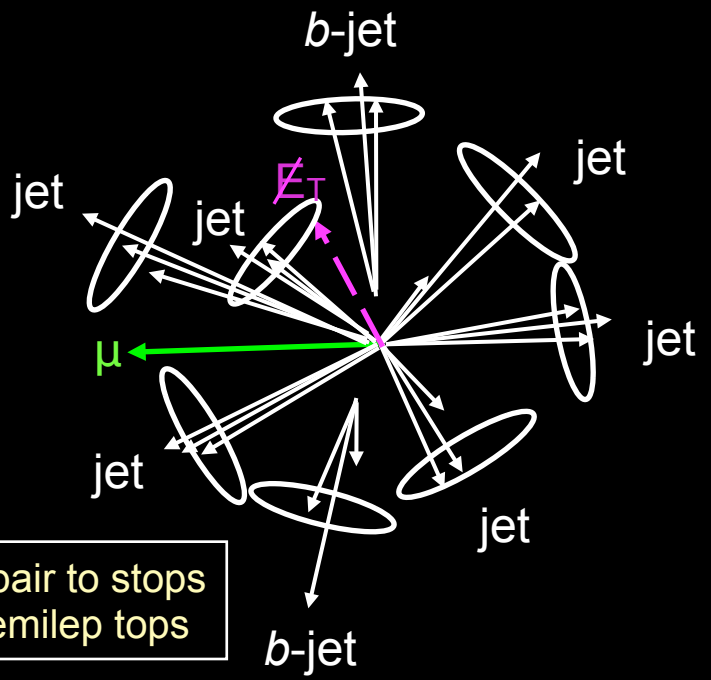


- Baryonic R-parity violation
  - $\lambda''_{3ij}\, \tilde{t}_R\, d_R^i\, d_R^j \quad (i \neq j)$
- 100% decays to 2 down-type quarks
  - prompt if $\lambda'' > 10^{-7}$
  - MFV: 96% contain bottom
- Direct pair production ⇒ fully jetty final-state
  - no handles like leptons or MET

* LNV decays also being explored. See e.g. Evans & Kats (1209.0764)

Alternatives to Direct Production

- Produced in gluino decay (⇒ associated top pair)
  - dileptonic tops (possibly same-sign)
  - semileptonic tops (jet multiplicity, H_T tails, dijet resonance peak)
  - possibly high b-tag multiplicity (3 or 4)
- Produced in sbottom decay
  - extra leptonic handle from $\tilde{b} \rightarrow \tilde{t}\, W$
- Produced in heavier stop decay
  - not yet studied in detail

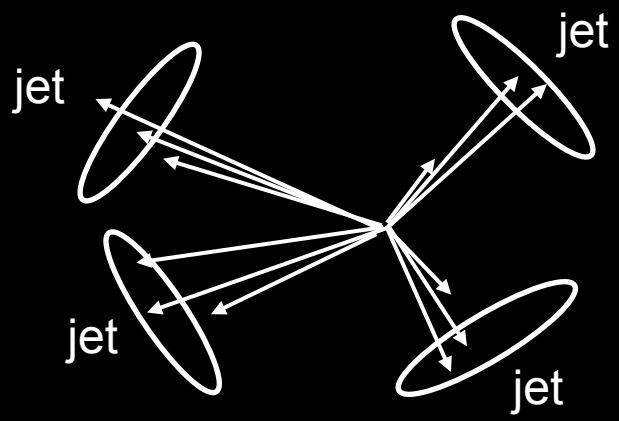


gluino pair to stops and semilep tops

Lisanti, Schuster, Strassler, Toro (1107.5055)
Allanach & Gripaios (1202.6616)
Han, Katz, Son, Tweedie (1211.4025)
Brust, Katz, Sundrum (1206.2353)
ATLAS-CONF-2013-007
ATLAS 1308.1841

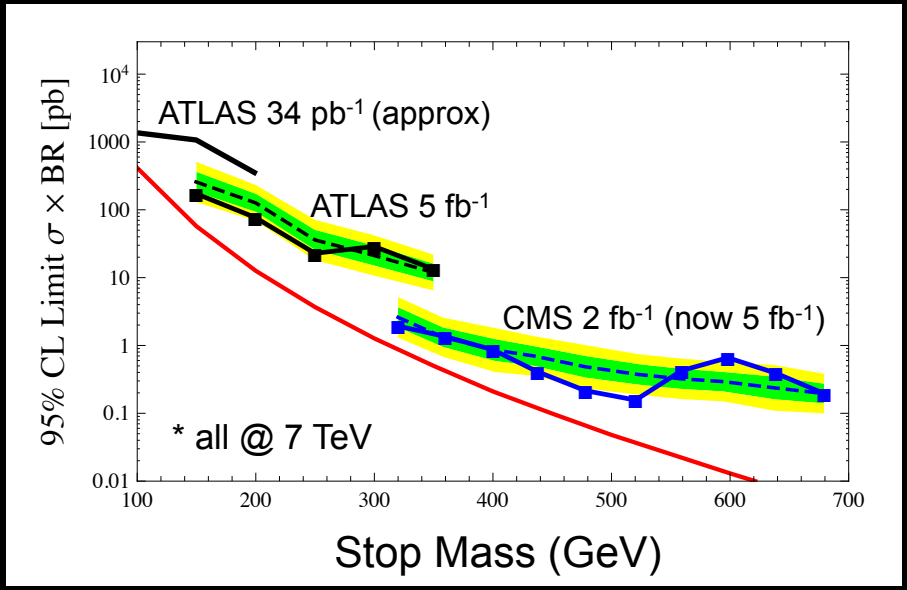
Pursuing Direct Production

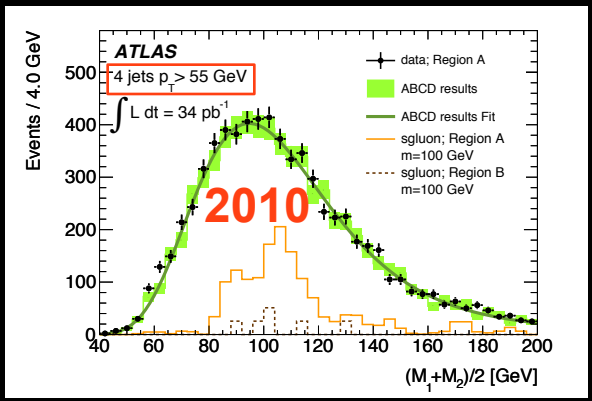
- Much less model-dependent
  - rate and kinematics are only a function of stop mass
  - we will even ignore jet flavor (structure of λ'' coupling)...for now
  - not necessarily SUSY (generic diquark pair search)
- A benchmark for purely jetty searches
- Current limits are very weak
  - LEP: 90 GeV
  - Tevatron: 100 GeV
  - LHC: No limit!!

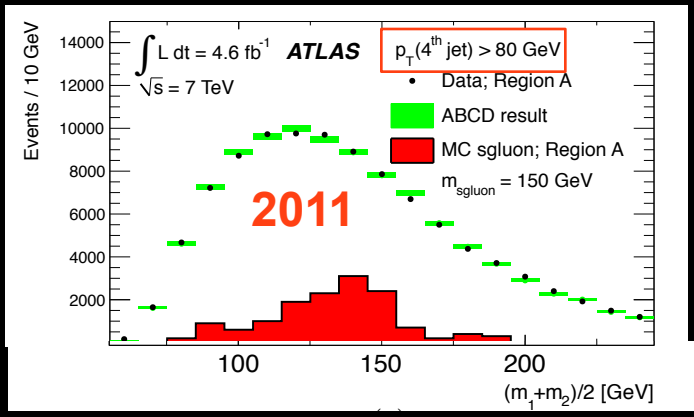


Trigger Creep at the LHC

Our recast stop limits





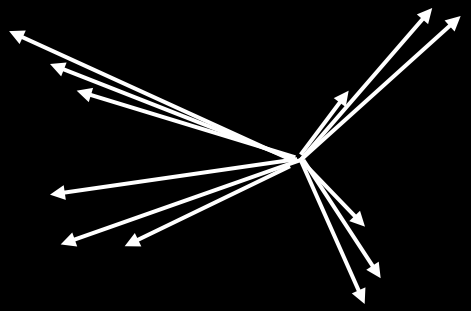


2012 ??

prompt 4j trigger:
$p_T(j_4) > 80$
(uncorrected...maybe 100-110 corrected)

*Alleviated by parked data. See also b-jet-triggered analysis proposed in Franceschini & Torre (1212.3622)


Jet Substructure



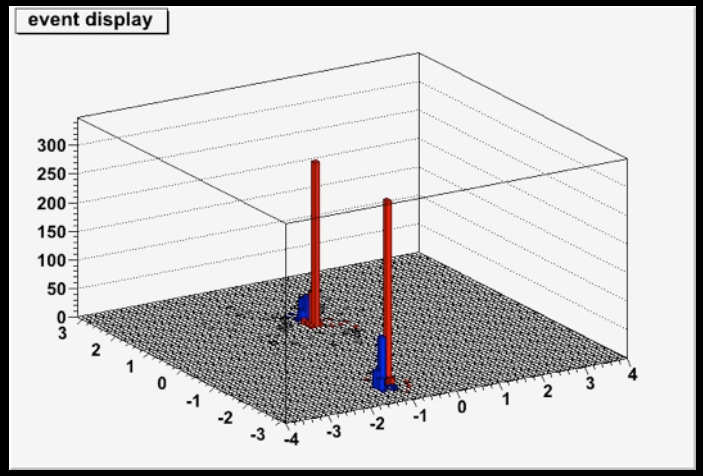
Why Jet Substructure?

- Focus on high-pT “boosted” signal production
  - combinatoric ambiguities automatically resolved by ΔR
  - generally better S/B (e.g., less gg→gggg)
- Flexible partition of decay radiation to individual “quarks”
  - better rejection of uncorrelated radiation (pileup, ISR, UE)
  - better signal mass resolution
- Nearly scale-free procedure
  - bypasses conventional “4-jet” division of highly multibody hadronic phase space, not sensitive to 4-jet trigger thresholds
  - background processed into ~featureless spectrum

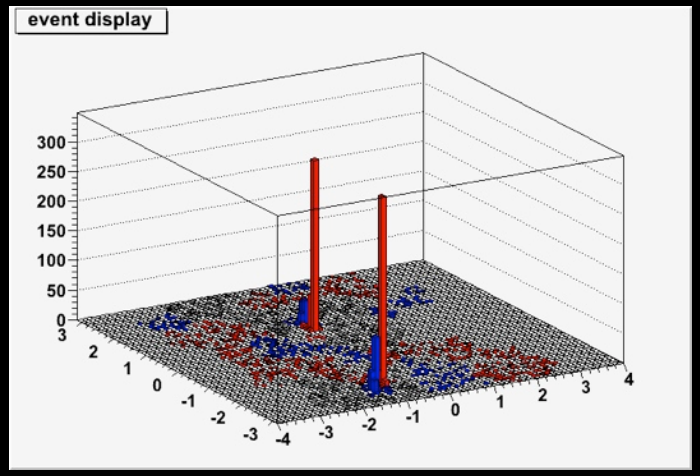
Basic Ingredients

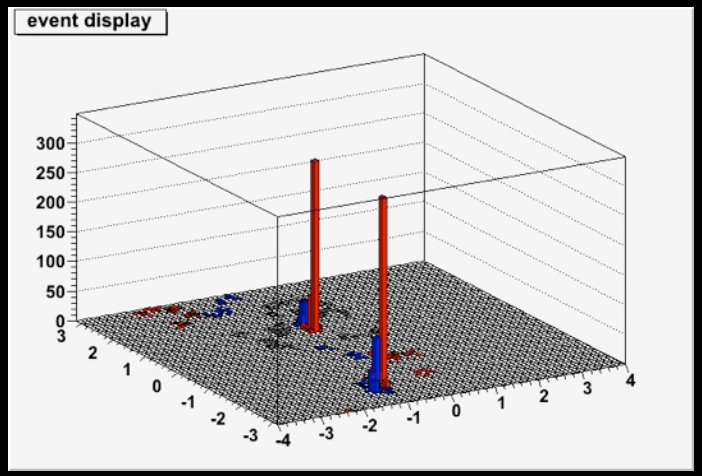
- Select events with jet-H_T trigger: offline $H_T > 900$
  - not very correlated with decay/shower kinematics
  - selects boosted stops for m(stop) < 450
- Pre-trim entire event to remove pileup
  - *Fixed* minijet p_T threshold, tuned to remove $\langle N_{PV} \rangle = 20$ p_T-density
- Capture stop decays in R = 1.5 C/A jets
- Decluster into subjets using BDRS-like prescription
  - halt declustering when subjet p_T's are not too asymmetric *and* neither has large m/p_T
  - original BDRS appears to give a biased QCD spectrum
- Impose kinematic cuts, and run a bump-hunt
  - lots of options for how to estimate the QCD continuum background

Example Event, m(stop) = 100



+ pileup





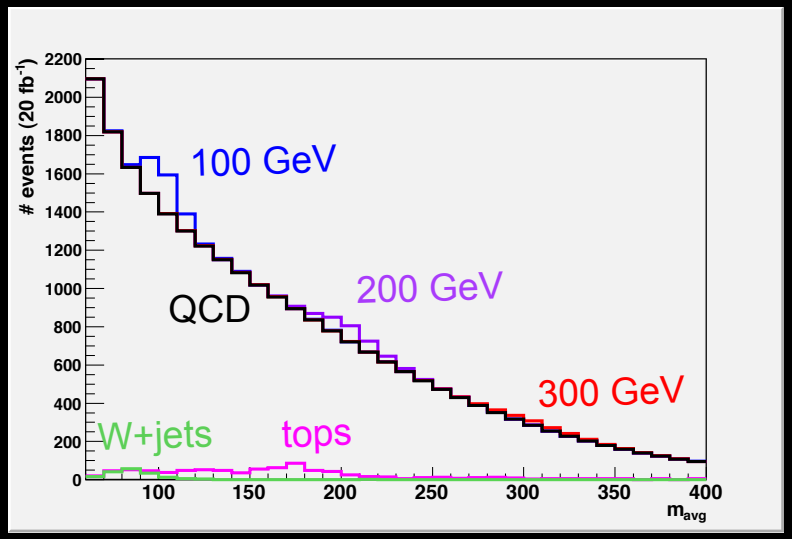
+ trimming

*events gridified to 0.1x0.1

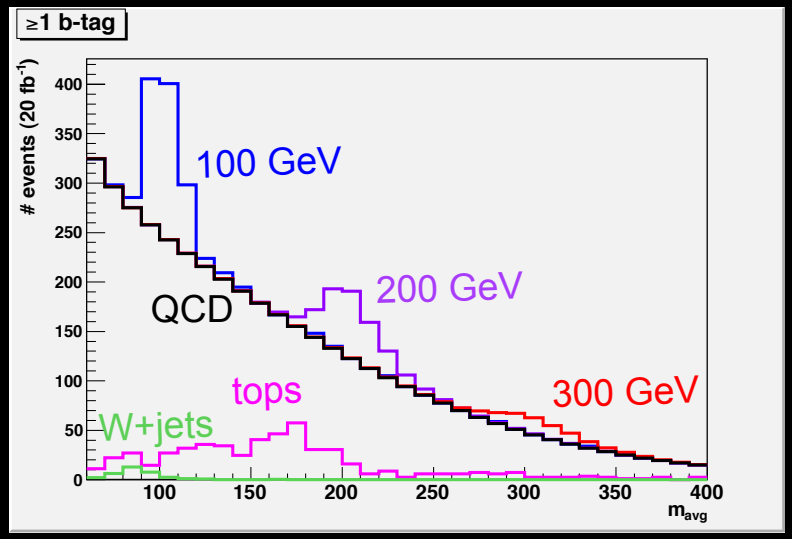
Cuts

- H_T(normal-jets) > 900
- declustered-jet mass asymmetry < 0.1
- CM cos(Θ^*) < 0.3
- p_T(softer-subjet) / p_T(harder-subjet) > 0.3
  - applied to each side independently

Average-Mass Spectra



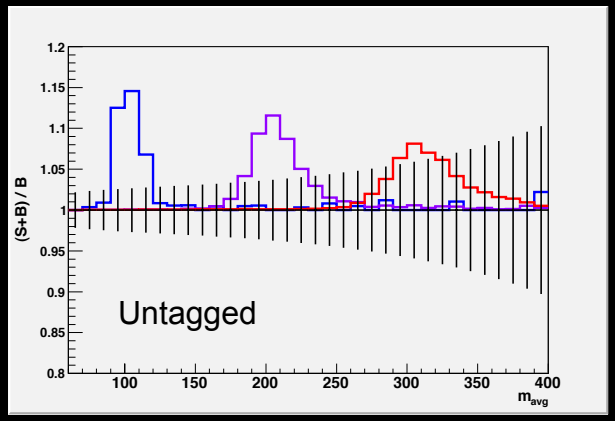
Untagged



At least 1 b-tag
(assuming ~100% BR to bd/bs)

**Be careful of top background!

2012 Sensitivities

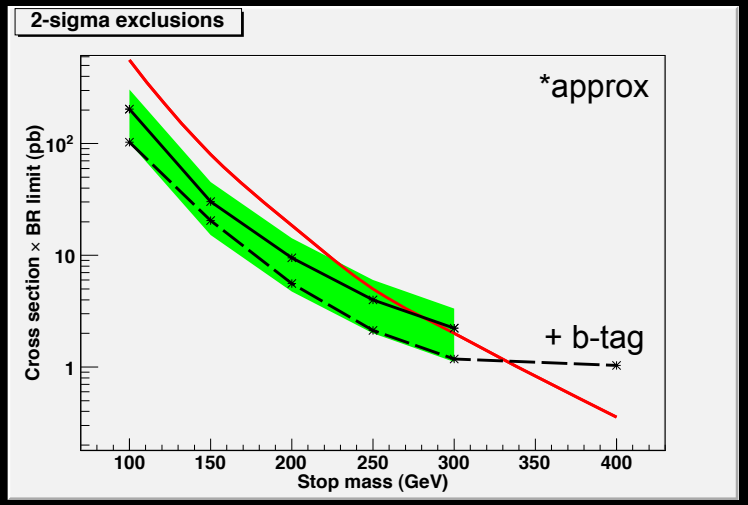


(S+B)/B relative to stat errors

A common strategy is to fit QCD with

$$\frac{d\sigma}{dm_{avg}} = \frac{P_0(1 - m_{avg}/\sqrt{s})^{P_1}}{(m_{avg}/\sqrt{s})^{P_2 + P_3 \ln(m_{avg}/\sqrt{s})}}$$

(but there are other ways...)

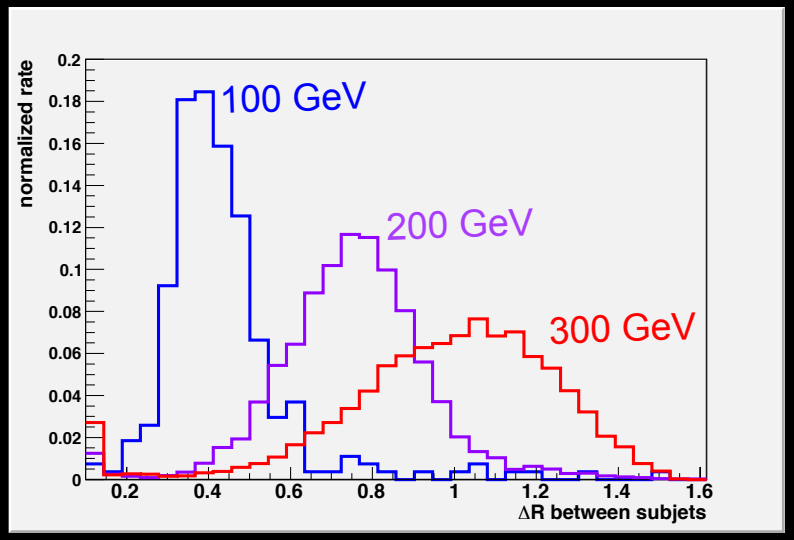


Summary

- SUSY may be hiding in plain sight!
  - O(100 GeV) stop LSP is quite “natural”
  - fully jetty RPV decay is very difficult to spot
- Current LHC searches are not sensitive
  - multijet triggers make life difficult for m(stop) ~ 100 GeV
- Jet substructure approach is extremely promising
  - focus on boosted stop pair production
  - big R ⇒ broad mass range covered
  - > 5σ sensitivity to 100 GeV in 2012
  - untagged exclusion up to almost 300 GeV
  - even better if stop decays to b-quarks
- This is an analysis that can be done *now*

Extras

ΔR Distributions



*Passing all basic cuts