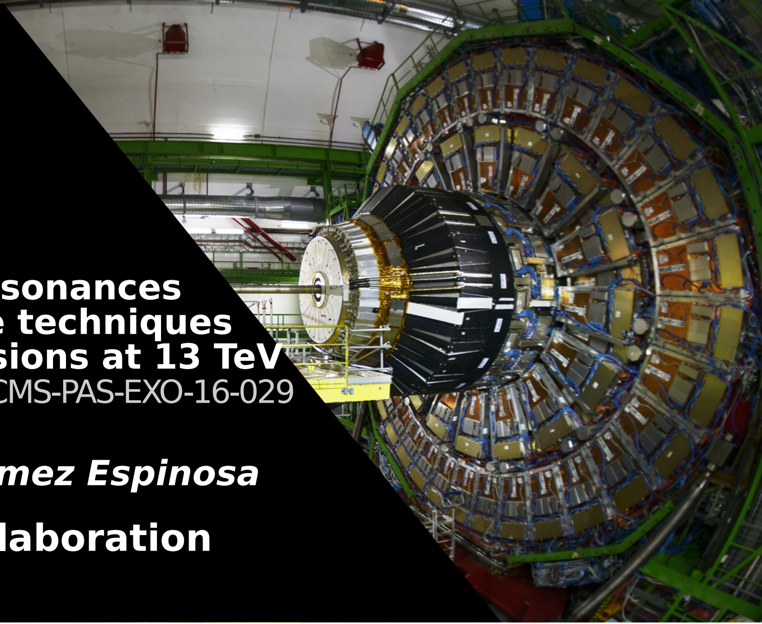
Search for low-mass pair-produced dijet resonances using jet substructure techniques in proton-proton collisions at 13 TeV

CMS-PAS-EXO-16-029

Alejandro Gomez Espinosa

on behalf of the

CMS Collaboration



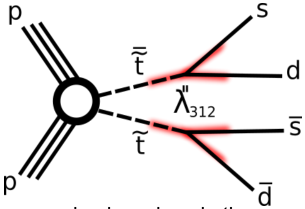
APS DPF 2017 **August 1, 2017**

CMS RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

What are we searching for?

Theory Model

Hadronic RPV SUSY



Direct pair production of top squarks decaying via the λ''_{312} RPV coupling into two light quarks

Why is it important?

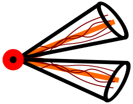
Because there is an open window in the search for RPV stops at low masses from previous searches!

- CDF: from 50 to 100 GeV at 1.96 TeV (Phys. Rev. Lett. 111, 031802)
- CMS Run I: from 200 to 350 GeV at 8 TeV (Phys. Lett. B 747 (2015) 98)
- Atlas Run II: from 250-405 GeV and 445-510 GeV at 13 TeV (ATLAS-CONF-2016-084)

How do we reach low masses?

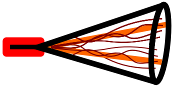
By exploiting current LHC energy to study boosted signatures and probe lower masses.

From resolved jets....

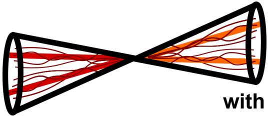


particles created at rest

... to boosted jets!



particles created with momentum



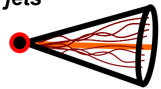
Search for 2 AK8 jets with high pt and substructure

The average jet mass distribution of the two leading jets using anti-kt jets with cone size R=0.8 is investigated for evidence of a signal consistent with localized deviations from the estimated SM backgrounds.

Why is it challenging?

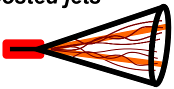
QCD jets or boosted jets?

QCD jets



coming from a quark or gluon

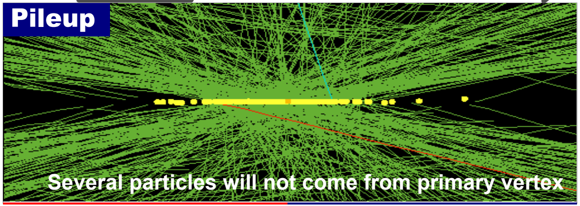
boosted jets



coming from a massive particle

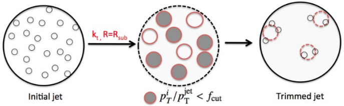
How do we differenciate these processes?

Pileup



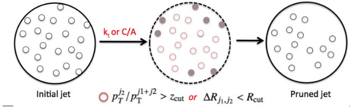
Substructure Techniques

- **"Trimming"** http://arxiv.org/abs/0912.1342 (D. Krohn, J. Thaler, L. Wang)
  - uses k_t algorithm to create subjets of size R_{sub} from the constituents of the large-R jet: any subjets failing $p_T i$ / p_T < f_{cut} are removed



Tuned parameters: f_{cut} and R_{sub}

- **"Pruning"** http://arxiv.org/abs/0912.0033 (S. Ellis, C. Vermilion, J. Walsh)
  - Recombine jet constituents with C/A or kt while vetoing wide angle (R_{cut}) and softer (z_{cut}) constituents. Does not recreate subjets but prunes at each point in jet reconstruction



Tuned parameters: R_{cut} and z_{cut}

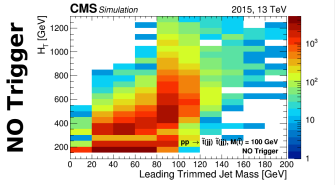
"N-subjetiness" http://arxiv.org/abs/1108.2701 (J. Thaler, K. Van Tilburg)

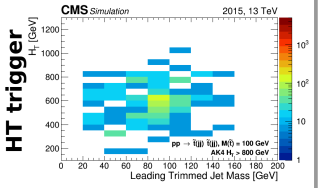
Creates N subjet axes within a jet and sums angular distances of jet consituents to their nearest subjet axis. This variable is a jet shape designed to identify boosted hadronic objects.

How do we trigger on these events?

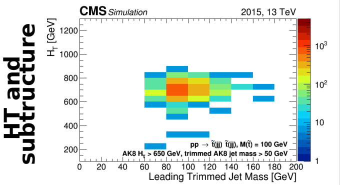
For a signal at 100 GeV:

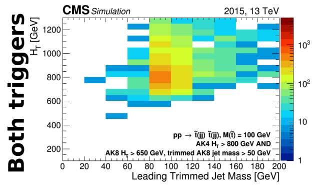
2D space: sum pt of AK8 jets(HT) vs mass



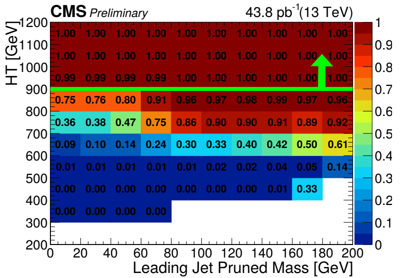


The nominal HT based trigger was not sufficient for the signature, therefore we **developed a new trigger** based on HT and subtructure techniques:





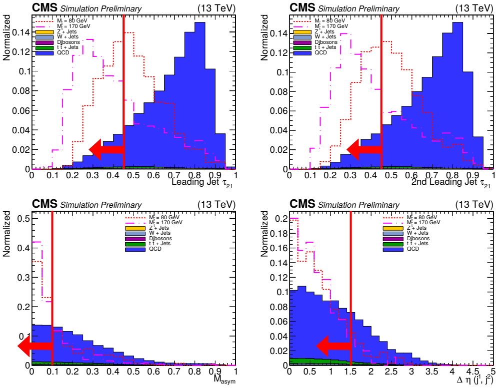
Trigger efficiencies



Here we show the trigger efficiency in HT vs Leading jet pruned mass for a logical OR between the substructure trigger and the nominal HT hadronic trigger.

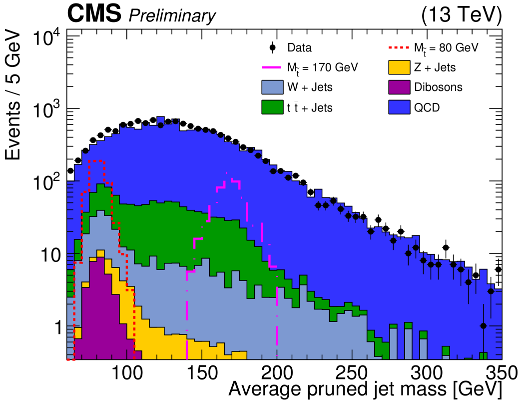
Which events are selected?

Event Selection



Each variable is plotted with all selection criteria apart from that on the variable being shown. Distributions normalized to unit area. Red arrows and lines represent where the selection is applied.

Background Composition



Each color represents a different SM MC sample. Dashed lines are selected signal samples. Points are data.

CMS RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

How do we model the SM processes?

Non-resonant backgrounds

QCD MC sample does not describe properly the background. Therefore, we use a data-driven techniques to model the QCD contribution called "*ABCD method*".

ABCD method:

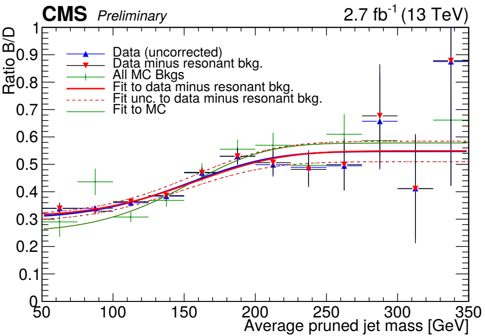
* Use two uncorrelated variables. Divide the 2D space into a signal enriched region (*A*) and three QCD enriched regions (*B*,*C*,*D;* with small signal contamination).

* Because the two variables are uncorrelated, then:

$$A/B = C/D \Rightarrow \mathbf{A = B*C/D}$$

We define regions as:

	$M_{asym} < 0.1$	$M_{asym} > 0.1$
$\|\eta_{j1} - \eta_{j2}\| > 1.5$	Region B	Region D
$\|\eta_{j1} - \eta_{j2}\| < 1.5$	Region A	Region C

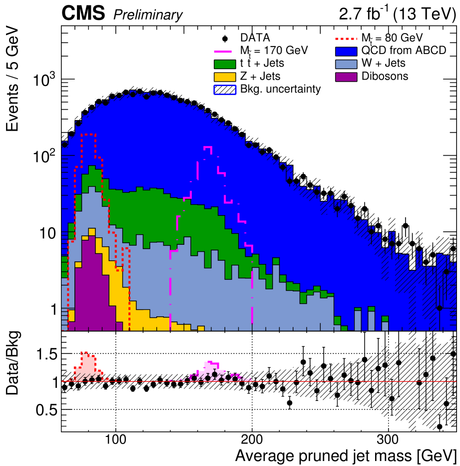


Resonant backgrounds

5% of total background: ttbar, Wjets, Zjets, dibosons. Use MC samples, properly validated.

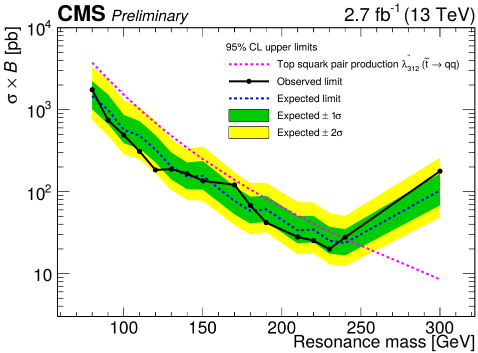
What do we find?

Results



Exclusion Limits

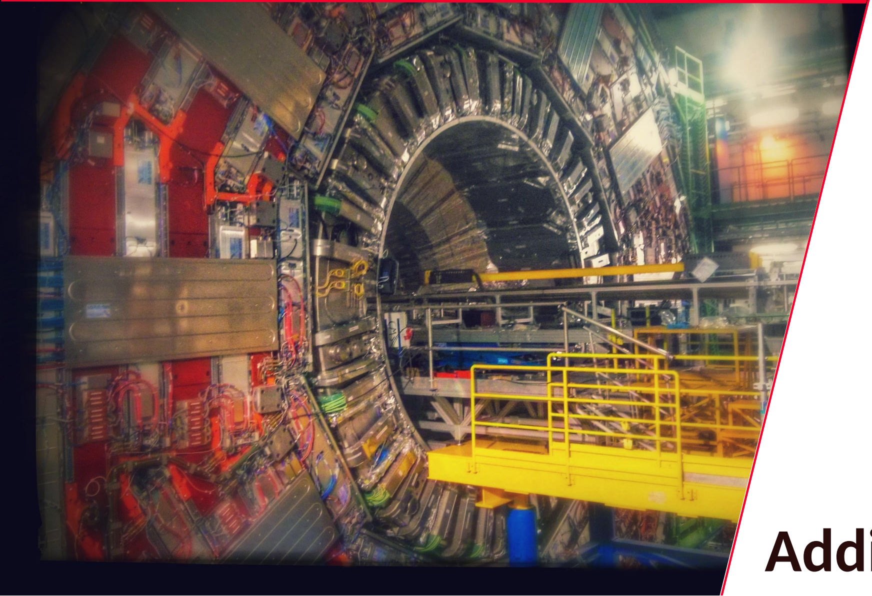
Since no excess is observed in data, we set limits on the production cross section (σ) x branching ratio (B) of stops with the RPV coupling UDD312.
We assume 100% branching ratio of stops to light quarks.



We exclude masses below 240 GeV.

Conclusions

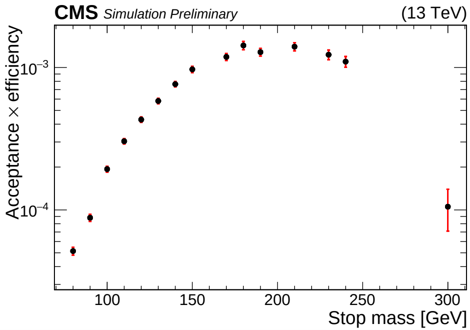
- A search has been performed for pair production of boosted resonances decaying to quarks giving a dijet signature from proton-proton collisions from the LHC at $\sqrt{s} = 13$ TeV with the CMS detector.
- The distribution in the average pruned jet mass has been used to search for an excess compatible with a resonant signal above the SM background.
- No significant deviation is found. Therefore we proceed to set limits on the pair production of stops decaying to jets via the RPV coupling λ''_{312}.
- Exclusion limits are set on the stop pair production cross section with decays through the RPV SUSY coupling λ'''_{312} to light-flavor jets at 95% confidence level. **We exclude stop masses between 80 GeV and 240 GeV**.
- We are updating the search with more data and improving the background estimation. New results soon.. stay tuned!



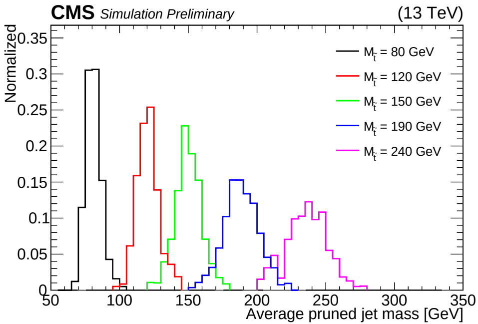
Additional Slides

Signal acceptance

Acceptance times efficiency



Signal mass distributions



Systematic uncertainties

Signal uncertainties

Source of Systematic	Effect	Value
Luminosity	Yield	2.7%
Trigger	Yield	2%
Pileup	Yield	1.5%
PDF	Yield	12%
Two-prong Tagger Scale Factor	Yield	17%
Jet Energy Scale	Yield	0.8%-5%
Jet Energy Resolution	Yield	0.6%-3%
MC Statistics	-	bin-by-bin
Jet Mass Scale	Resonance Shape	2%
Jet Mass Resolution	Resonance Shape	11%

Background uncertainties

Background	Source of Systematic	Effect	Value
QCD ABCD method:	Closure	Yield	10%
	Transfer Factor Fit Uncertainty	Shape	0.8%-8%
	Statistics in Sideband Region (C)	Shape	bin-by-bin
Resonant backgrounds:	Systematic in MC Backgrounds	Yield	50%
	MC Statistics	Shape	bin-by-bin