Search for Supersymmetry at CMS in Events with Large Jet Multiplicity and Low Missing Transverse Momentum at $\sqrt{s} = 13$ TeV

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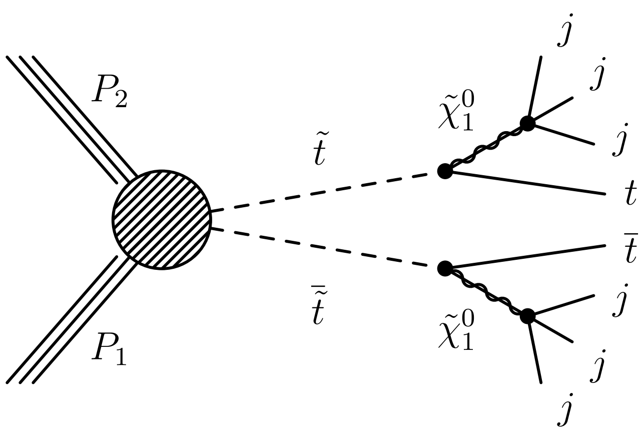
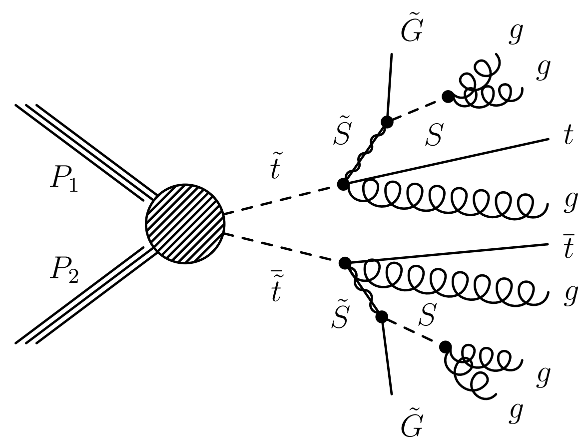
Motivation

- Inspired by lack of evidence of new physics in searches that require missing transverse momentum (MET)
- Two possible models that satisfy this: RPV and Stealth SUSY
- Both model's signature contains two top quarks, 6 additional jets, and low additional missing transverse momentum
- Largest irreducible background is $t\bar{t}$ + jets (~85%)

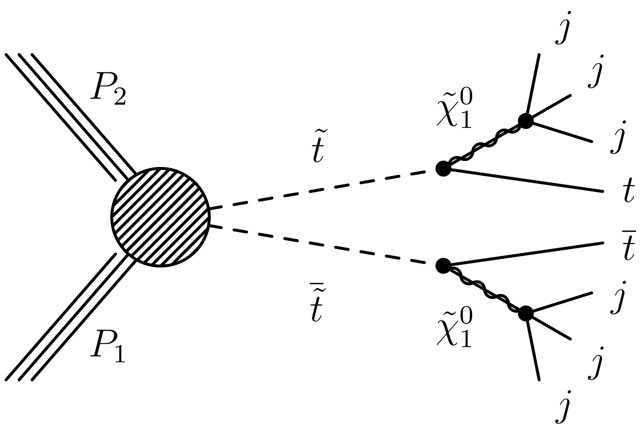


RPV SUSY (UDD)



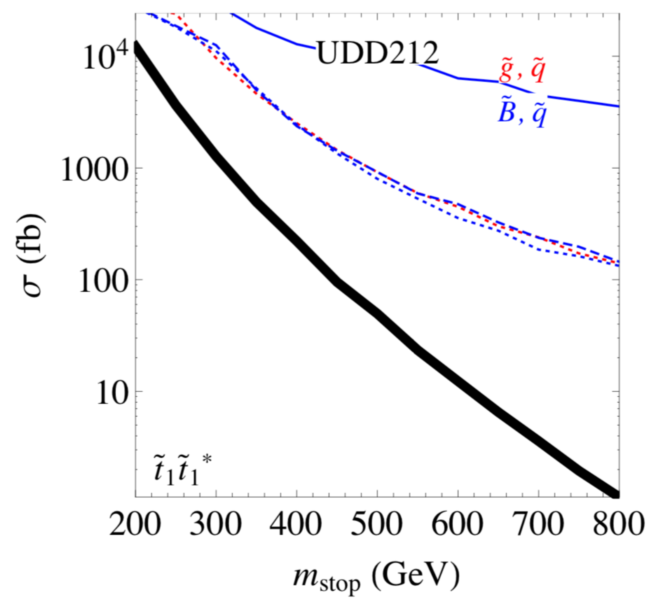
Stealth SUSY (SYY)

Signal Models: RPV SUSY



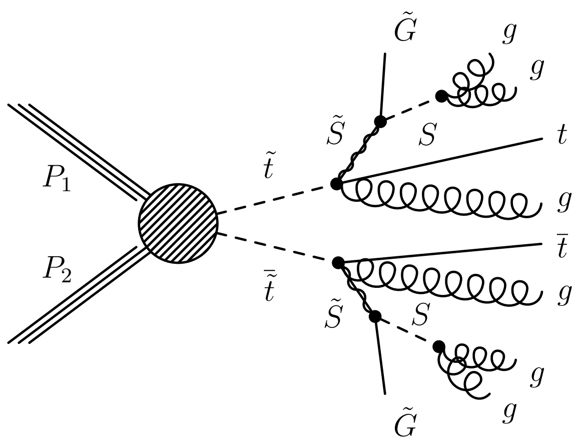
- Stop production to neutralino and a top
- R-parity violation allows the neutralino to decay to light jets through the UDD coupling

- Largely unexplored in the regime of low mass stops (thin solid line shows $m_{\tilde{t}} - m_{\tilde{\chi}^0} = 100$ GeV)



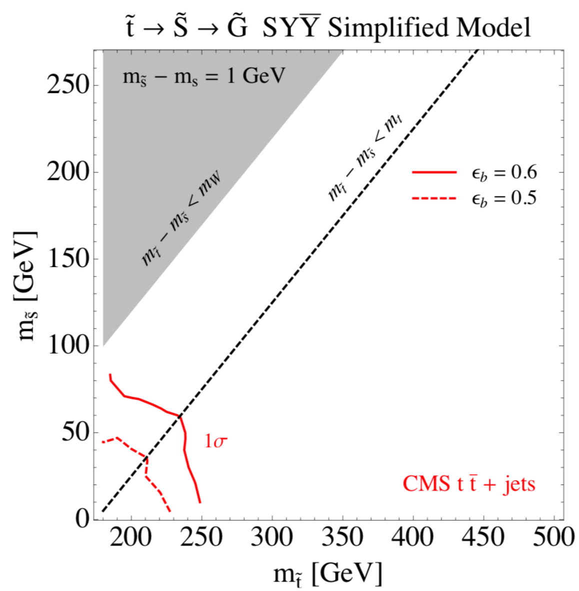
arXiv:1209.0764

Signal Models: Stealth SUSY



- Stop production to a singlino, gluon, and top
- Introduces a stealth sector: collection of fields with suppressed coupling to SUSY breaking sector
- Minimal stealth sector: singlet state and singlino superpartner $(S, \tilde{S})$
- Particles/superpartners mass is degenerate in this sector
- Gravitino has low p_T and mass of 1 GeV in this search

- Our model assumes singlino mass of 100 GeV
- Limits do not extend beyond $m_{\tilde{t}}$ = 200-250 GeV

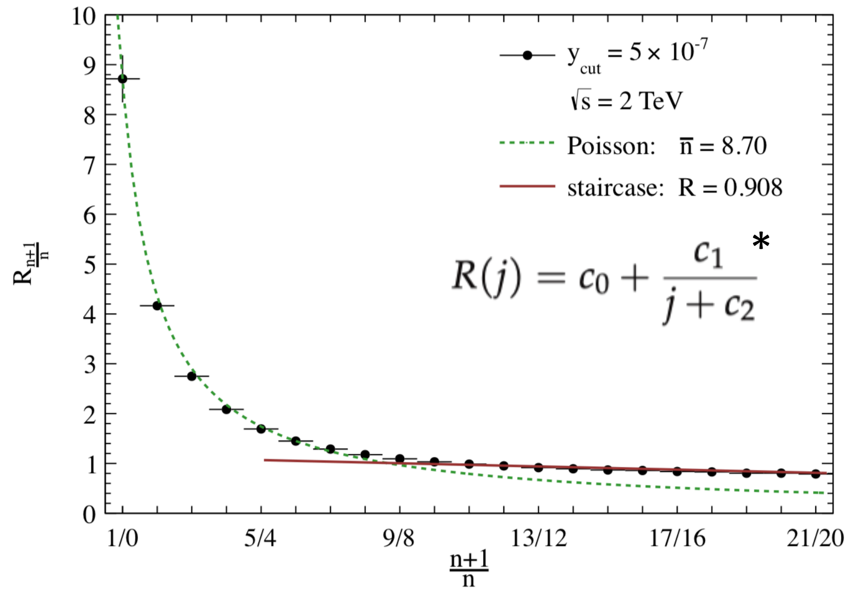


arXiv:1512.05781

Analysis Strategy

arXiv:1208.3676

- Main distinguishing feature of the signal is **high jet multiplicity**
- High jet multiplicity is hard to model, so we want to **rely on data** for background prediction
- Decided to do a fit of the Njet spectrum for $t\bar{t}$ + jets (other backgrounds taken from MC)

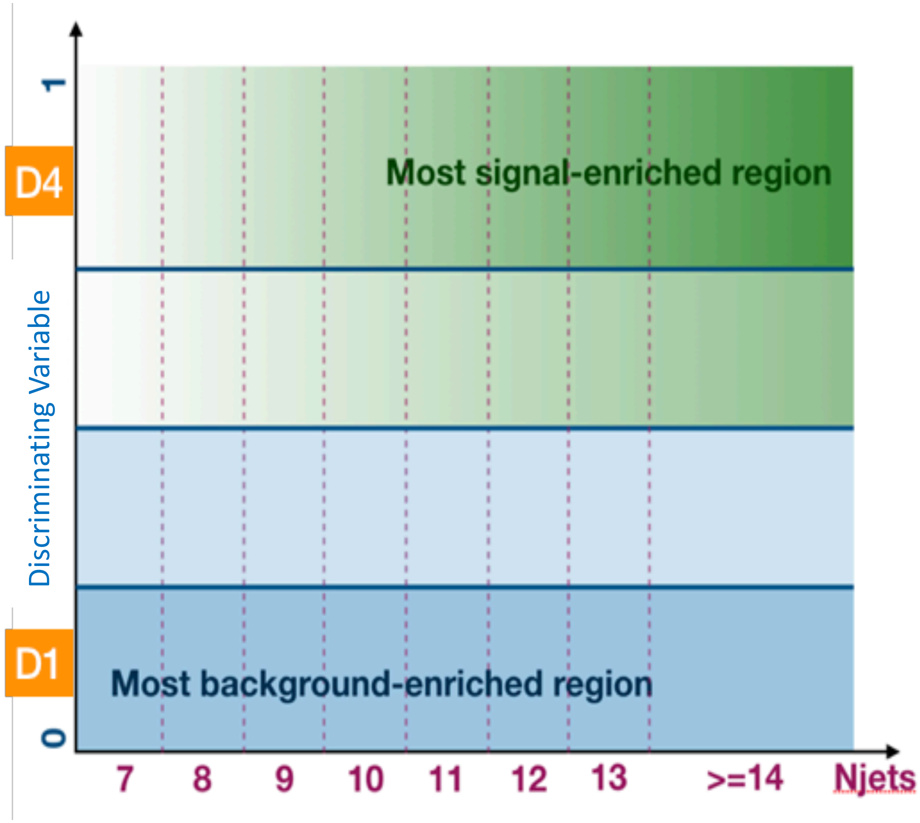


- From theory: ratios of N_{j+1}/N_j can be described by two components
  - a constant at high Njets ("staircase")
  - a falling function at lower Njets ("Poisson")
- Ideally, fit Njets shape in a dedicated control region, and use it as a template in the signal region. Unfortunately, a signal-free control region is hard to construct

* A different fit function analogous to this one is used in the analysis because the parameters were highly correlated

No Control Region

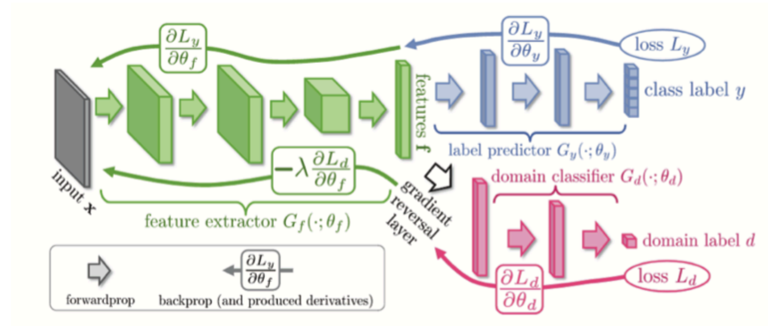
- Use a variable that discriminates signal vs. background that is uncorrelated with Njets
- Divide events into 4 regions for which background events have the same Njets shape
- Do simultaneous fit to all regions with most background-enriched region "D1" acting as the control region for the most signal-enriched region "D4"
- The first reasonable variable attempts gave poor performance or were too correlated with Njets



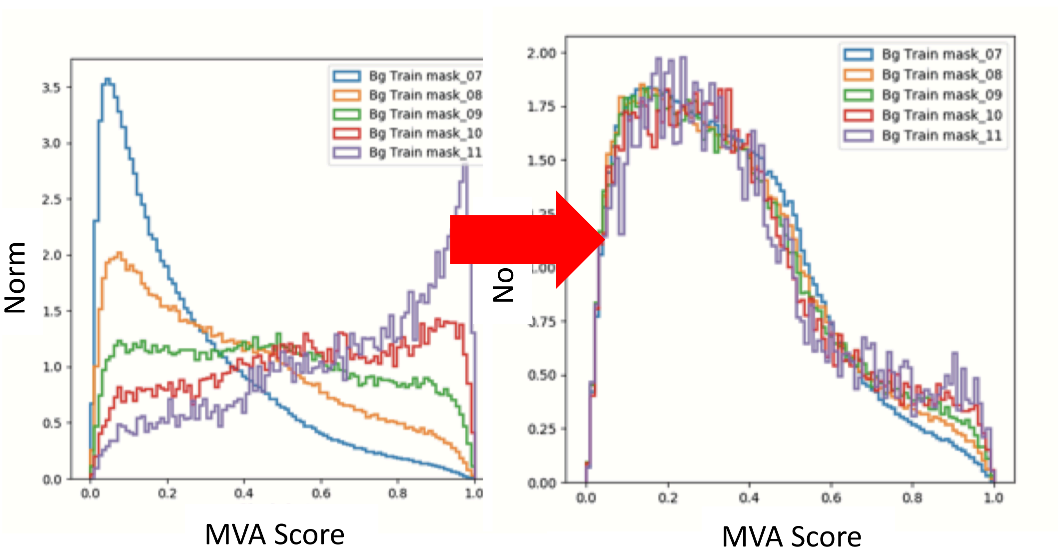
MVA

arXiv:1409.7495

- Used a **Neural Network(classifier)** with **Gradient Reversal (GR)** to create a discriminating variable
- **GR** adds an extra term to the loss function of the training such that it penalizes the NN if it utilizes any information from that classification layer



$$L_{tot} = L_{class.} - \lambda L_{GR}$$

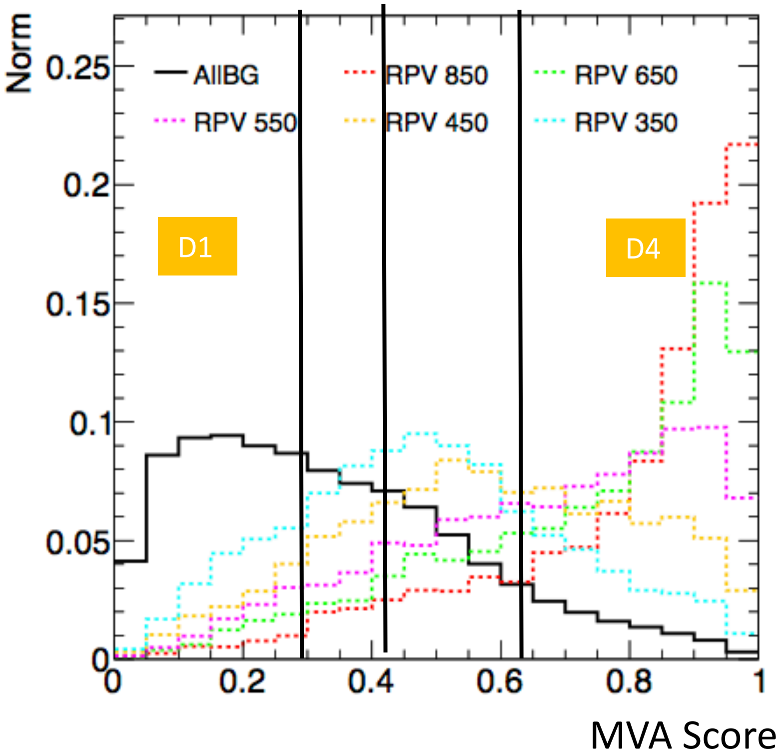


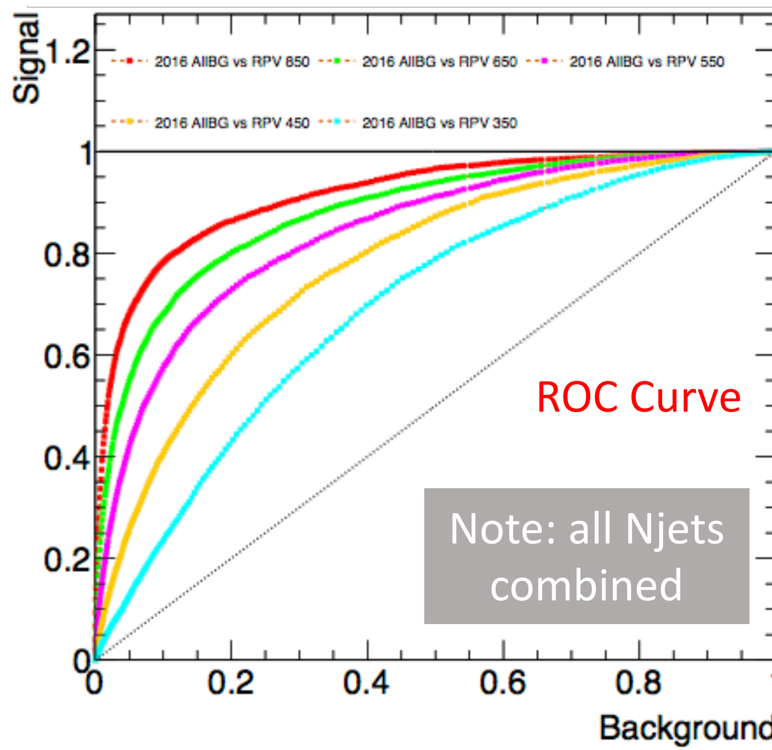
$t\bar{t}$ – No GR

$t\bar{t}$ – With GR

- This allowed us to remove Njet correlation while training at the cost of some performance

MVA Performance

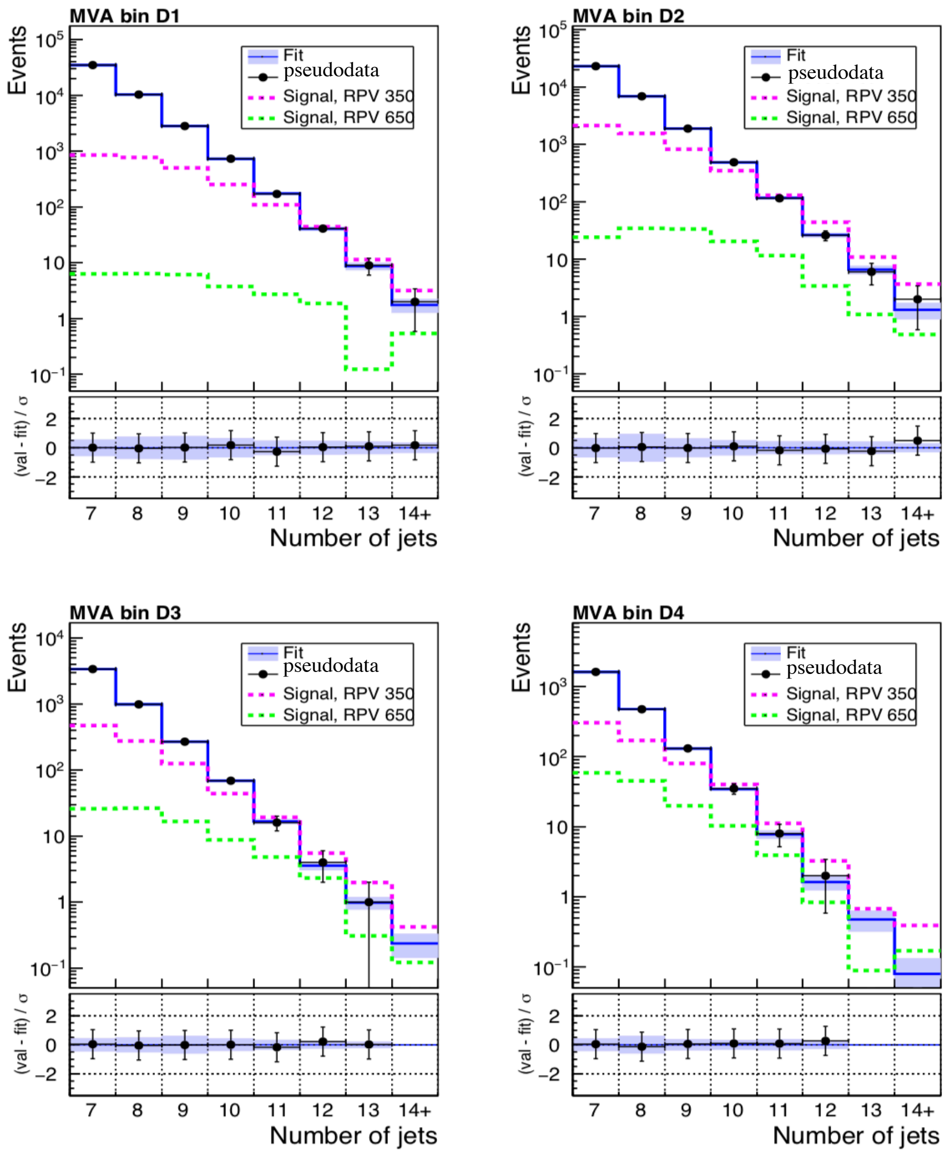




- Good overall discrimination; best for highest mass model
- Bin edges defined to give best sensitivity

Total Fit to MC

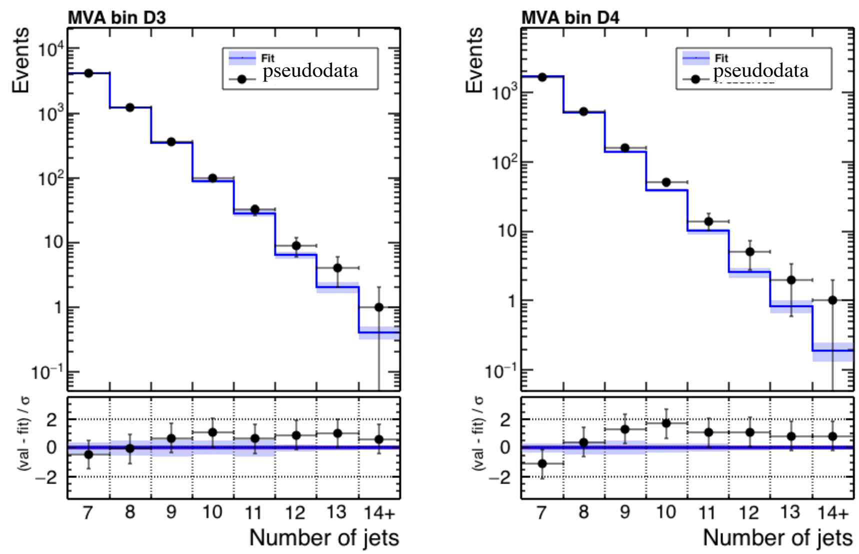
- Now that we have a discriminating variable uncorrelated with Njets to bin in, we can perform the fit.
- Background only fit to pseudodata (made up of MC)
- D1 has the most events and is mostly background (low MVA score)
- D4 has the fewest events, but is mostly signal.



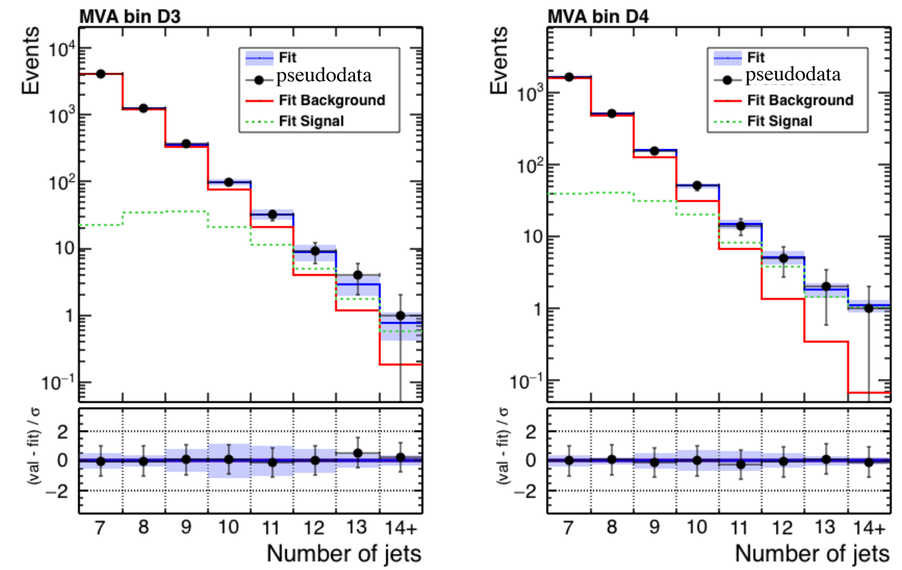
Fit setup works well

Signal Injection Test

- Inject signal (Stealth model with stop mass 650 GeV) with 1x nominal cross section into the pseudodata



D3 and D4
background-only
Clear pulls visible

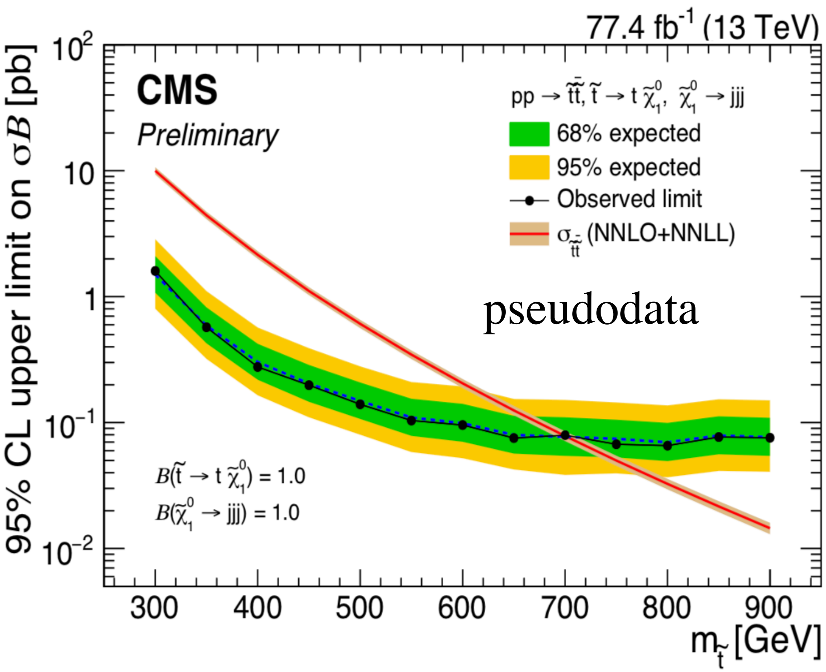


D3 and D4
Signal+Background
Much better pulls
Best fit r: 1.09 +/- 0.32

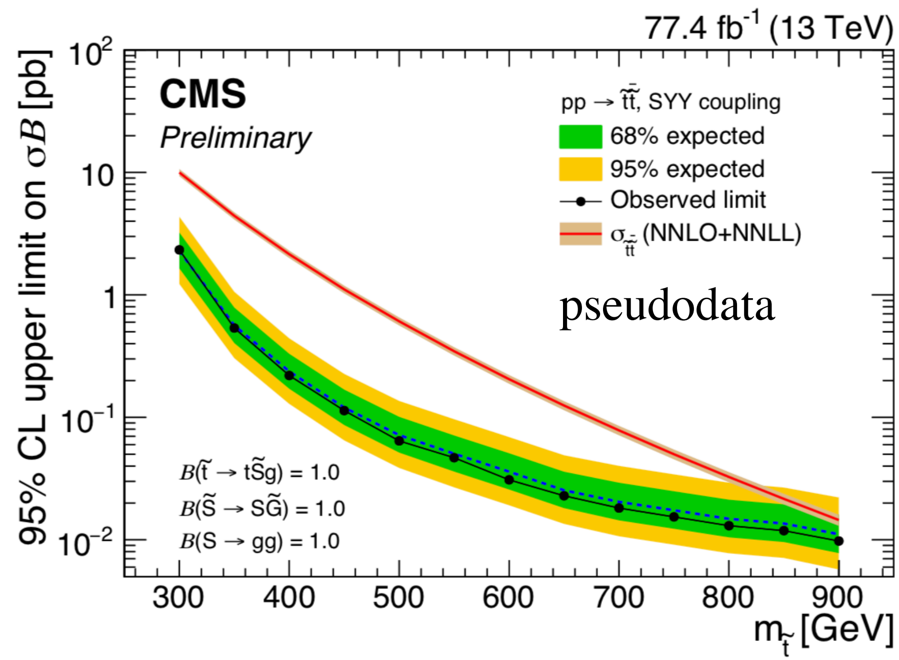
Should be able to see a signal if it is there

Expected Limits (pseudodata)

- Our expected limits for the RPV model is around $m_{\tilde{t}}$ = 700 GeV, whereas for the SYY mode, it is around $m_{\tilde{t}}$ = 900 GeV.



RPV SUSY (UDD)

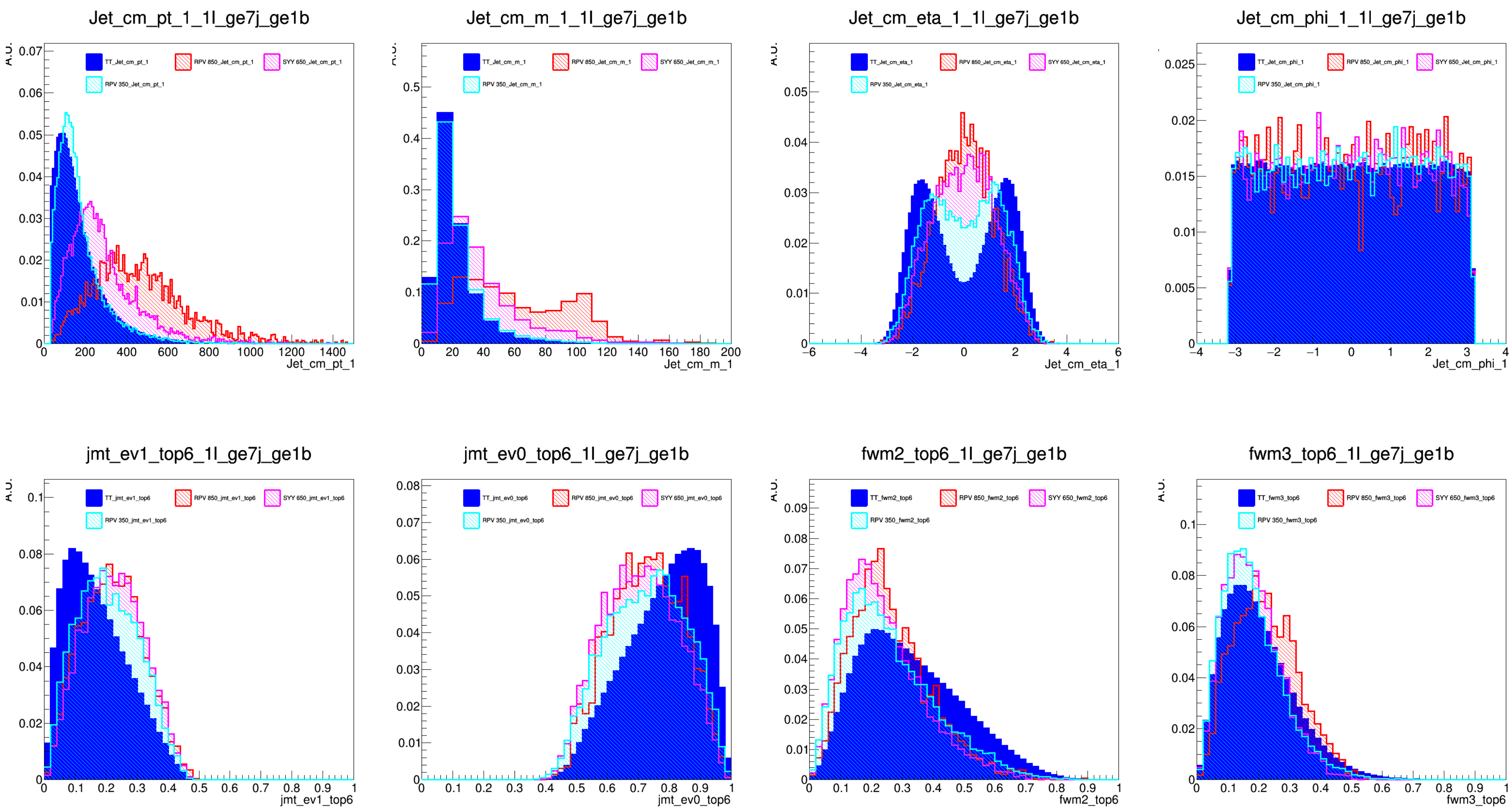


Stealth SUSY (SYY)

Conclusions

- We are excited to present a new analysis focused on a high jet multiplicity, low missing transverse energy region of phase space.
- There were many challenges to the analysis, but using novel machine learning techniques, like gradient reversal, in combination with existing physics tools, we were able to improve on signal sensitivity.
- Signal injection test gives us confidence that if there is a signal we can find it
- Please look forward to hearing about our full Run 2 results

MVA Inputs


Jet_cm_pt_1_1l_ge7j_ge1b
Jet_cm_pt_1
Jet_cm_m_1_1l_ge7j_ge1b
Jet_cm_m_1
Jet_cm_eta_1_1l_ge7j_ge1b
Jet_cm_eta_1
Jet_cm_phi_1_1l_ge7j_ge1b
Jet_cm_phi_1
jmt_ev1_top6_1l_ge7j_ge1b
jmt_ev1_top6
jmt_ev0_top6_1l_ge7j_ge1b
jmt_ev0_top6
fwm2_top6_1l_ge7j_ge1b
fwm2_top6
fwm3_top6_1l_ge7j_ge1b
fwm3_top6

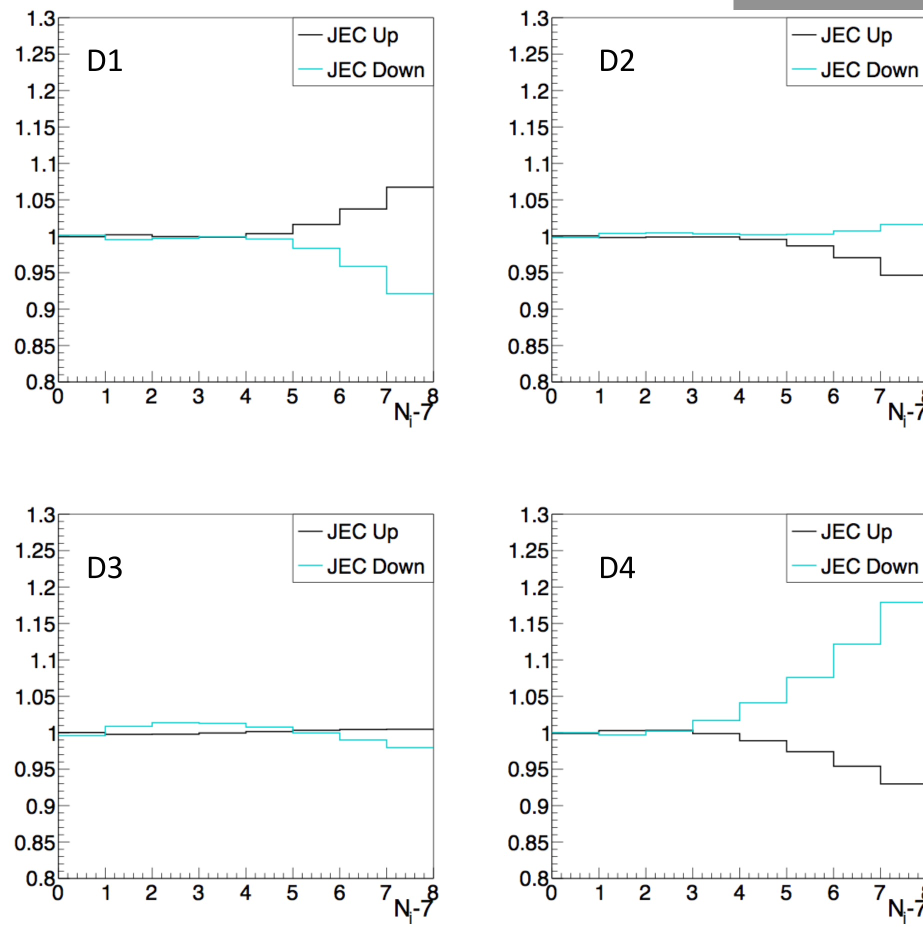
Systematics

- **For ttbar, the only effects that matter are those affecting the relative Njets shape between MVA bins**
- An **overall shape difference will be absorbed by the fit**, as long as the Njet ratios are smoothly falling or constant
- No good control region is available to do these checks, so derive them from MC variations
- Derive systematic uncertainty as double ratio:
  (Njets in MVA bin Di / Average Njets shape)_systematic /
  (Njets in MVA bin Di / Average Njets shape)_no-systematic
  to avoid double counting the shape differences present in the nominal case
- Nominal shape differences taken into account separately
- For event weight based systematics, derive the size of the uncertainty directly from Njets distributions

JEC/JER Systematics

- JEC/JER can cause bin migrations, both between Njets bins and between MVA bins
- To avoid large impact from statistical fluctuations in the tail, do a **background-only fit** to derive the overall and per-MVA bin Njets shape, before computing the double ratio

2016 values



Take largest of Up/Down as symmetric uncertainty