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

Christopher Madrid

Baylor University

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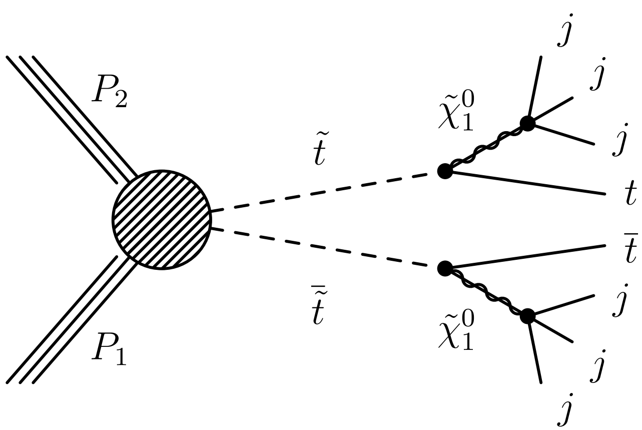
SUS-19-004 Team

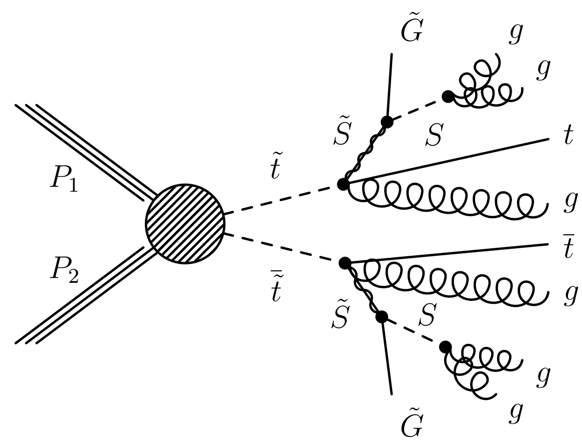
Chris Madrid, Jay Dittmann, Kenichi Hatakeyama (Baylor)
Owen Long (UC Riverside)
Nadja Strobbe, Aron Soha, Jim Hirschauer (FNAL)
Josh Hiltbrand, Jeremy Mans (University of Minnesota)
Kelvin Mei, Christopher Tully (Princeton)

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%)

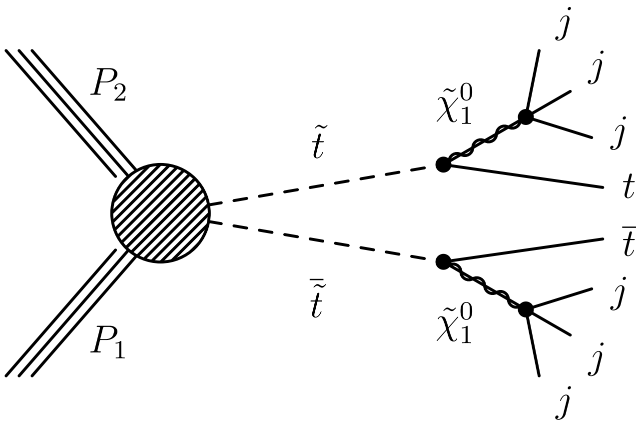


RPV SUSY (UDD)



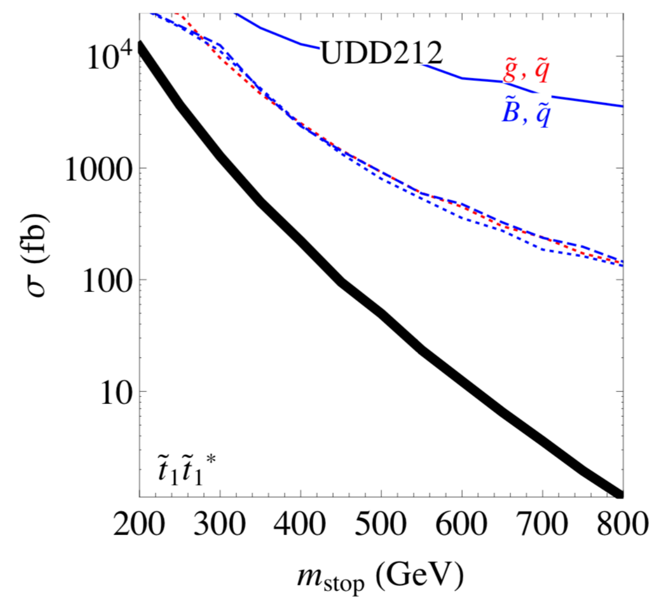
Stealth SUSY (SYY)

Signal Models: RPV SUSY



- Stop production to neutalino 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)

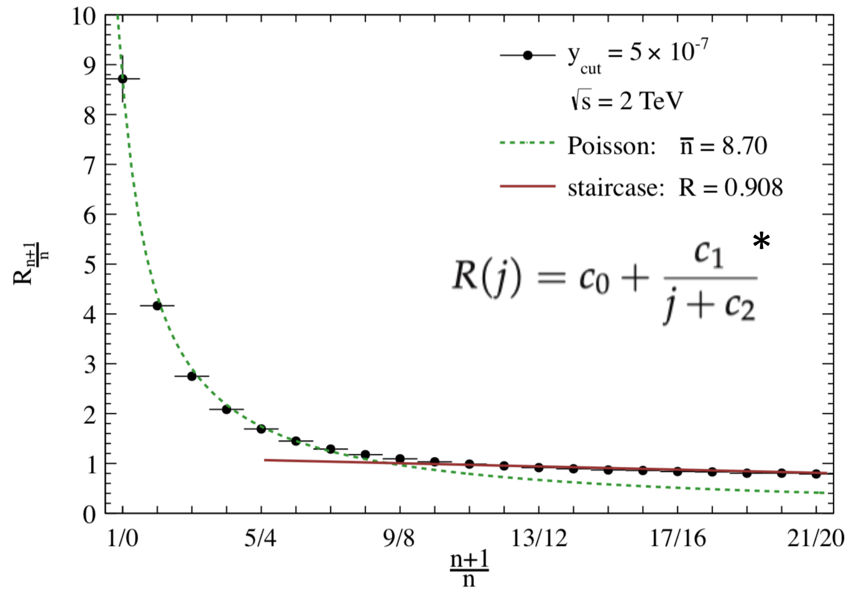


arXiv:1209.0764

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)

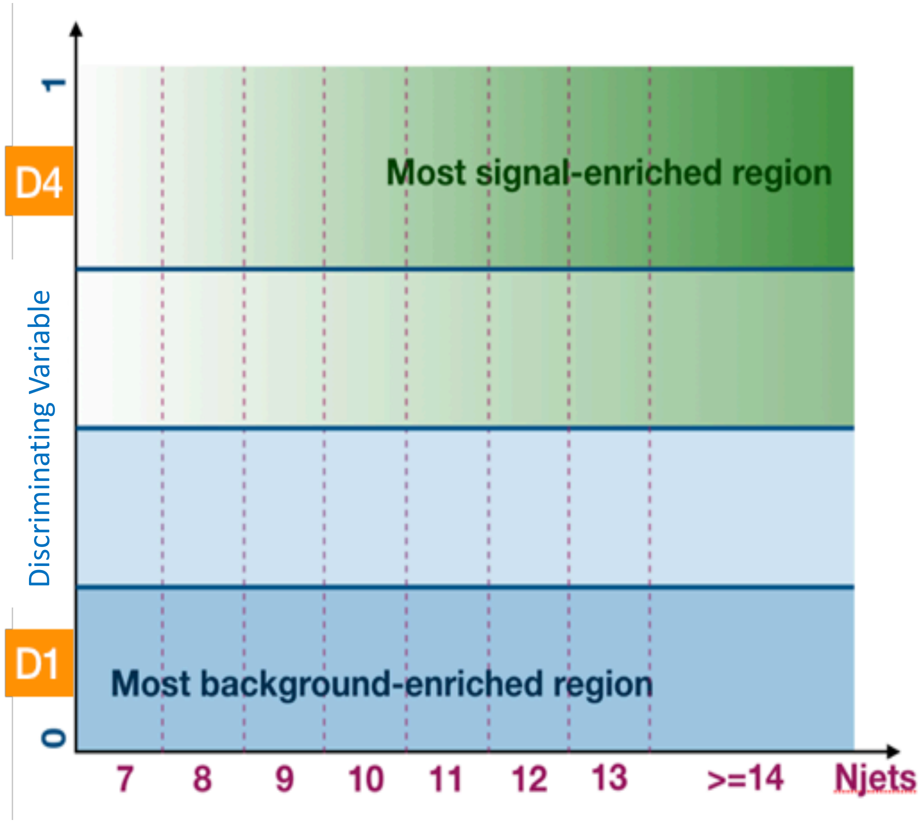


- From theory: ratios of N_{j+1}/N_j can be described by two components
  - a constant at high Njets ("staircase")
  - a falling function at lower Njets ("Poisson")
- Ideally, fit Njets shape in a dedicated control region, and use it as a template in the signal region. Unfortunately, a signal-free control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

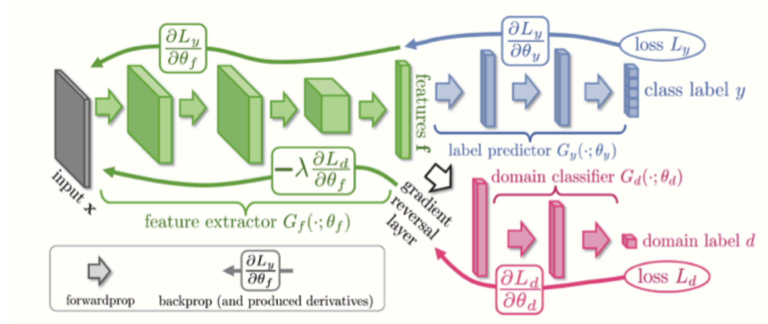
- Use a variable that discriminates signal vs. background that is uncorrelated with Njets
- Divide events into 4 regions for which background events have the same Njets shape
- Do simultaneous fit to all regions with most background-enriched region "D1" acting as the control region for the most signal-enriched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



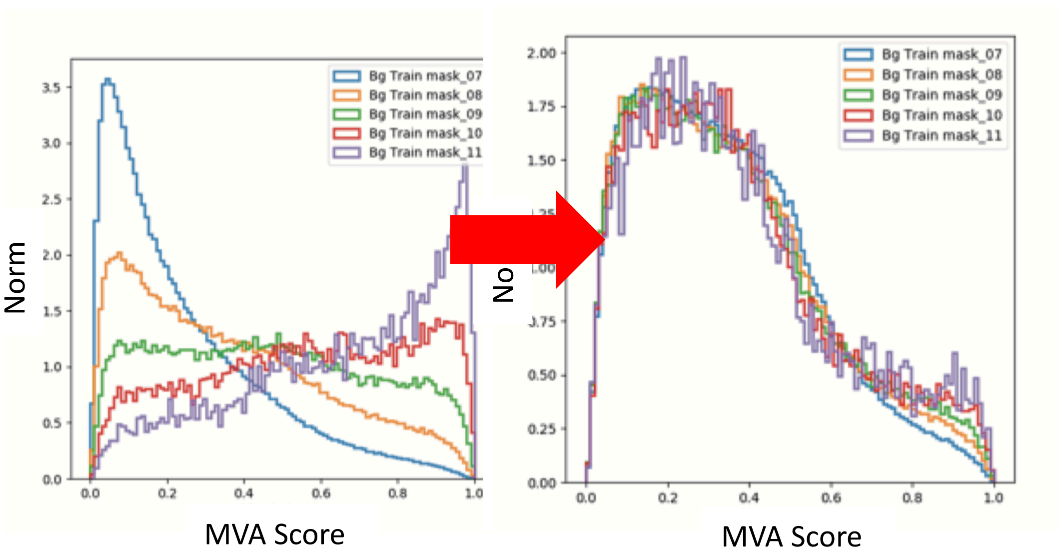
MVA

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

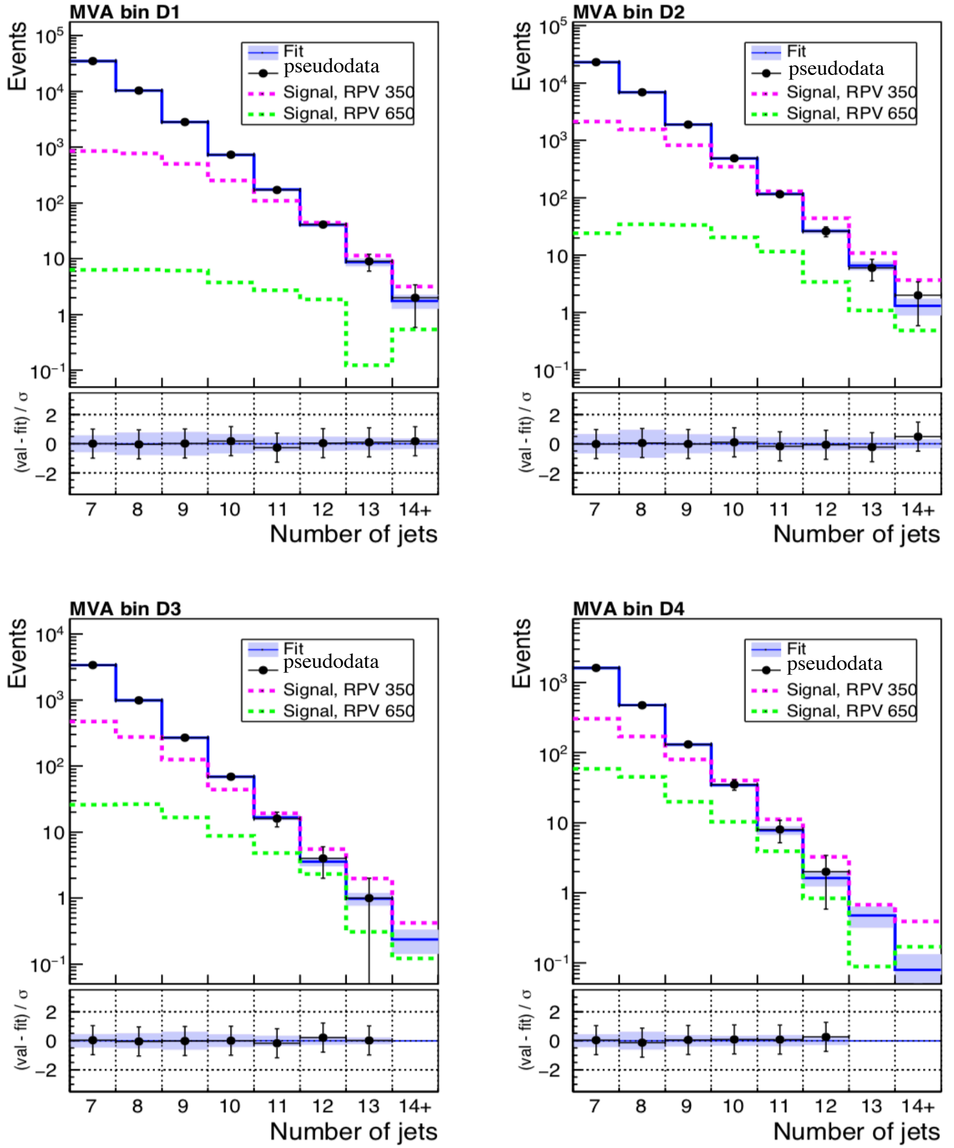
$t\bar{t}$ – With GR

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

Total Fit to MC

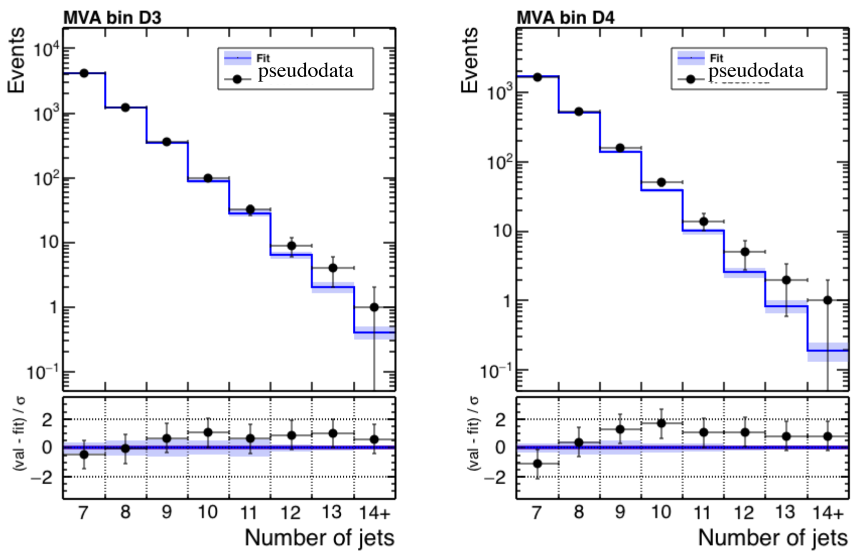
- Now that we have a MVA to bin in we can perform our fits
- Background only fit to pseudodata (made up of MC)
- D1 has the most events and is mostly background (low MVA score)
- D4 has the fewest events, but is mostly signal.

Fit setup works well

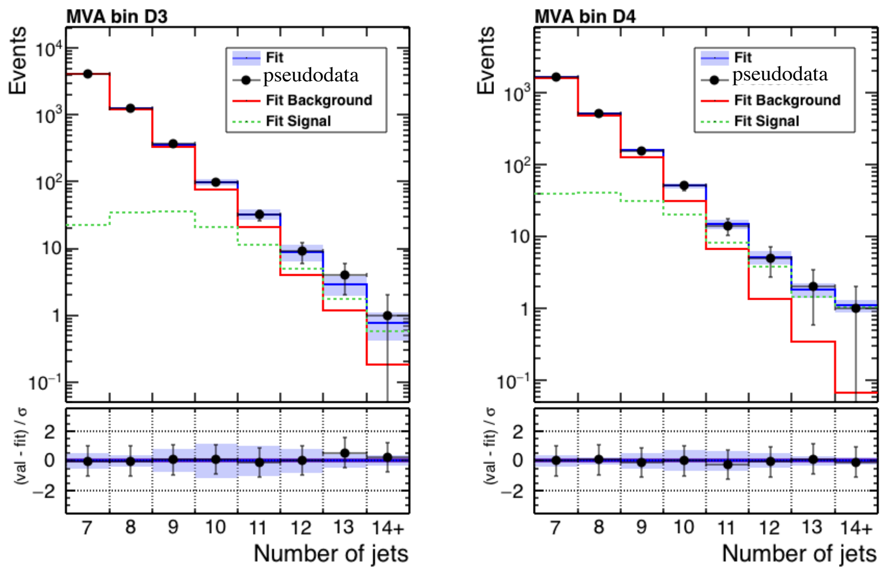


Signal Injection Test

- 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

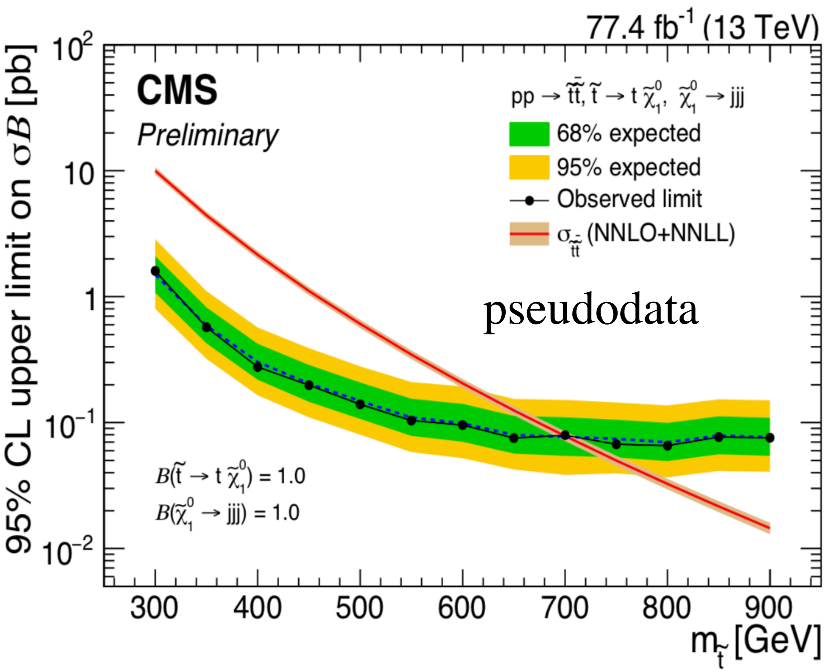


D3 and D4
Signal+Background
Much better pulls
Best fit r: 1.09 +/- 0.32

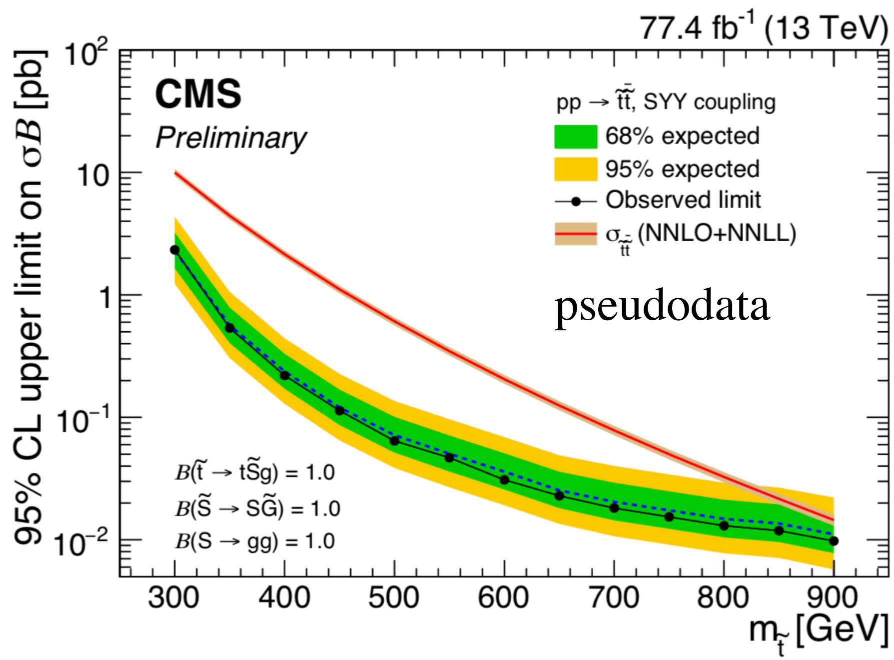
Should be able to see a signal if it is there

Expected Limits (pseudodata)

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



RPV SUSY (UDD)

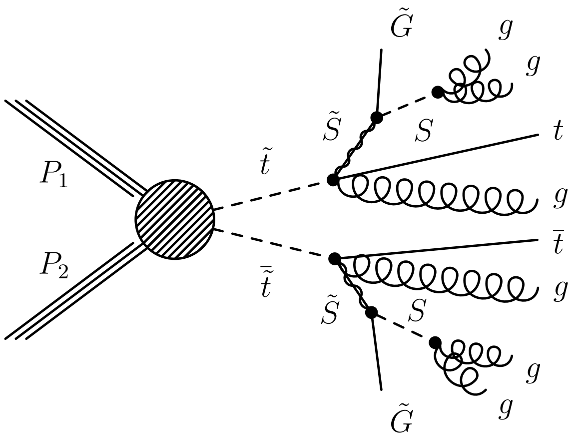


Stealth SUSY (SYY)

Conclusions

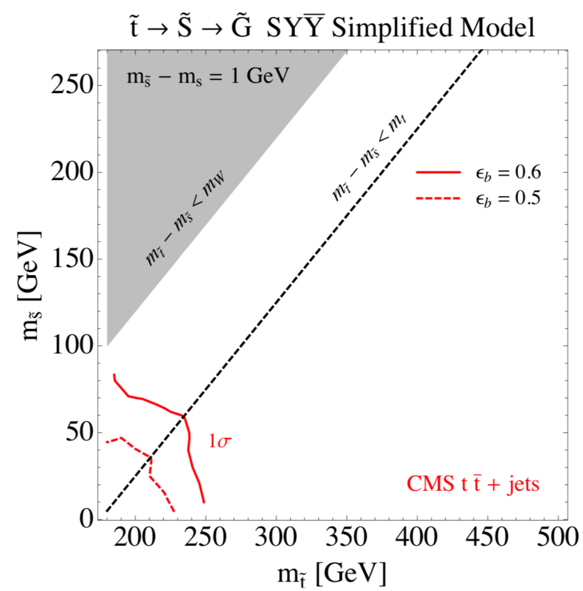
- We are excited to present a new analysis focused on a high jet multiplicity, low missing transverse energy region of phase space.
- There were many challenges to the analysis, but using novel machine learning techniques, like gradient reversal, in combination with existing physics tools, we were able 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 results within the month!

Signal Models: Stealth SUSY



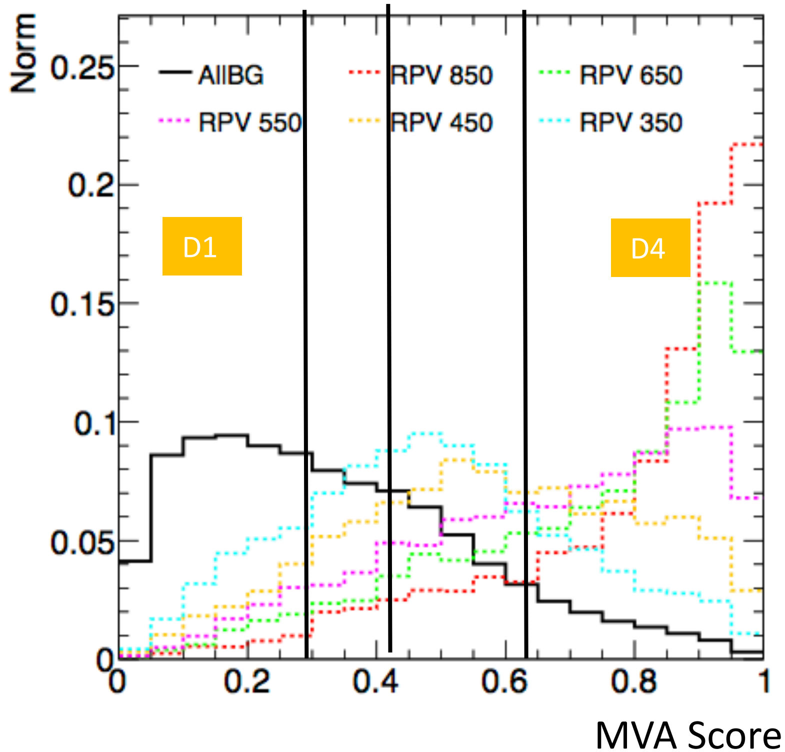
- Stop production to a singlino, gluon, and top
- Introduces a stealth sector: Collection of fields with suppressed coupling to SUSY breaking sector
- Minimal stealth sector: singlet state and singlino superpartner $(S, \tilde{S})$
- Particles/superpartners mass is degenerate in this sector
- Gravitino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

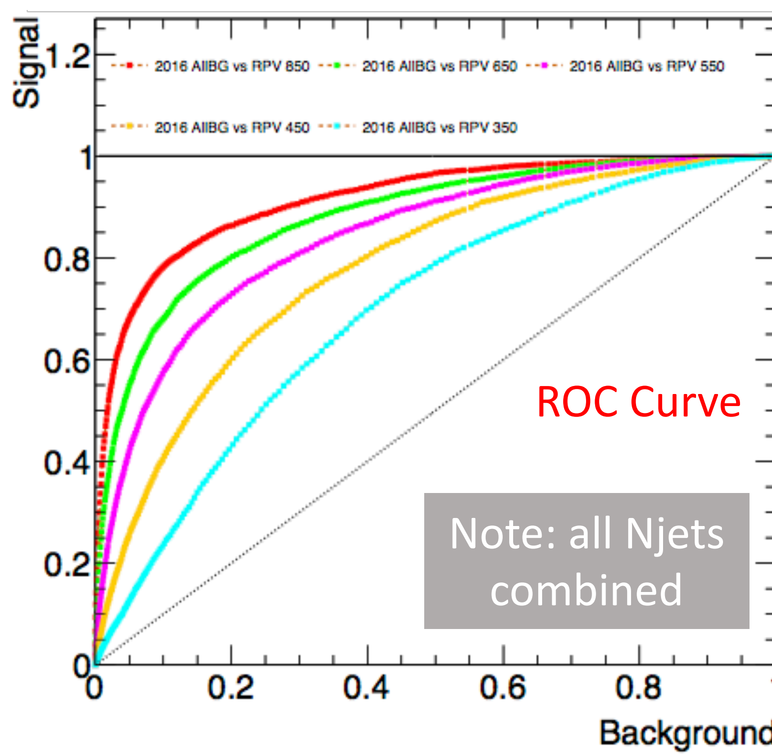
- Our model assumes singlino mass of 100 GeV
- Limits do not extend beyond $m_{\tilde{t}}$ = 200-250 GeV



arXiv:1512.05781

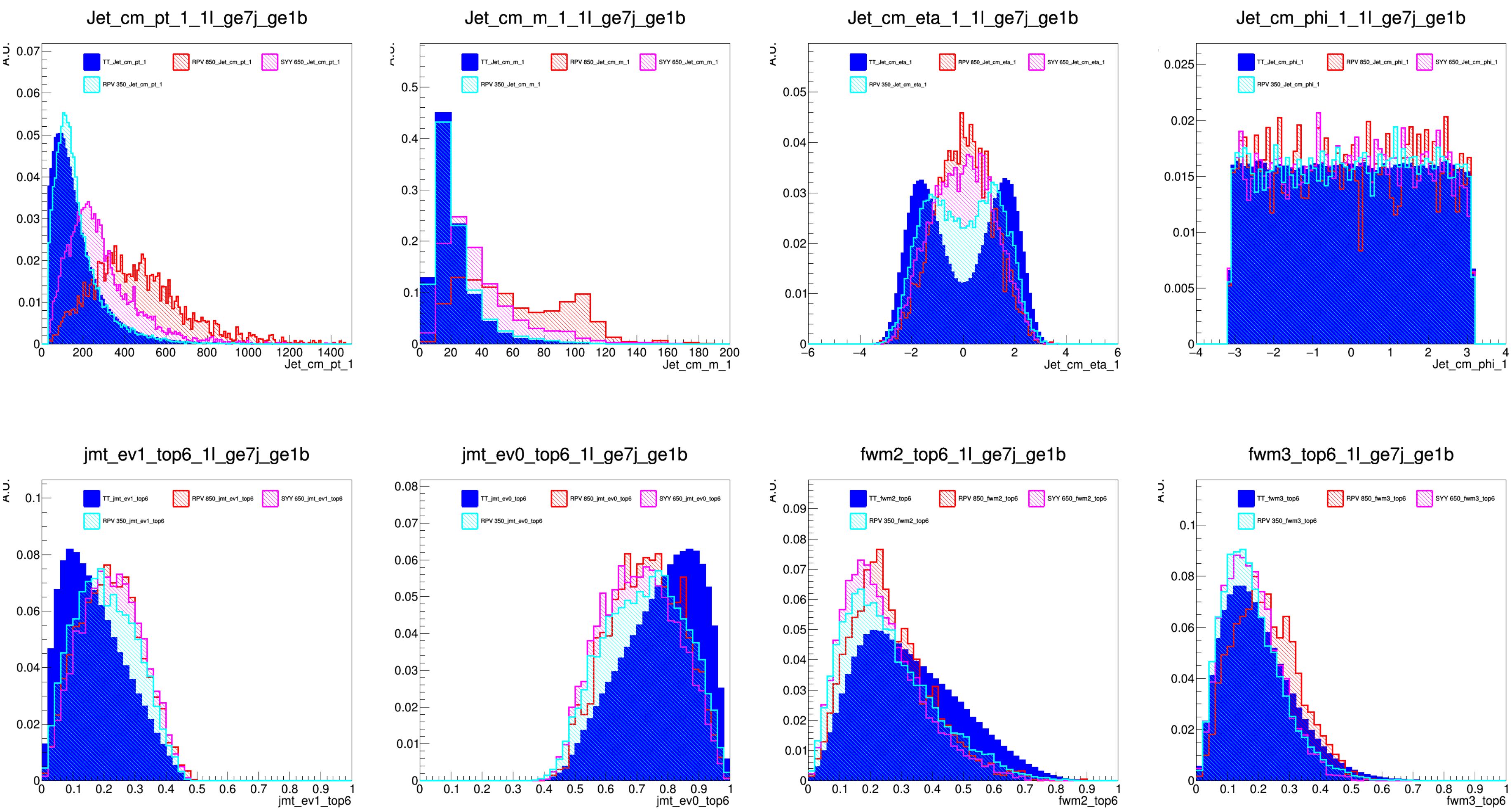
MVA Performance





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

MVA Inputs


Jet_cm_pt_1_1l_ge7j_ge1b
TT_Jet_cm_pt_1
RPV 850_Jet_cm_pt_1
SYY 650_Jet_cm_pt_1
RPV 350_Jet_cm_pt_1
A.U.
Jet_cm_pt_1
Jet_cm_m_1_1l_ge7j_ge1b
TT_Jet_cm_m_1
RPV 850_Jet_cm_m_1
SYY 650_Jet_cm_m_1
RPV 350_Jet_cm_m_1
Jet_cm_m_1
Jet_cm_eta_1_1l_ge7j_ge1b
TT_Jet_cm_eta_1
RPV 850_Jet_cm_eta_1
SYY 650_Jet_cm_eta_1
RPV 350_Jet_cm_eta_1
A.U.
Jet_cm_eta_1
Jet_cm_phi_1_1l_ge7j_ge1b
TT_Jet_cm_phi_1
RPV 850_Jet_cm_phi_1
SYY 650_Jet_cm_phi_1
RPV 350_Jet_cm_phi_1
Jet_cm_phi_1
jmt_ev1_top6_1l_ge7j_ge1b
TT_jmt_ev1_top6
RPV 850_jmt_ev1_top6
SYY 650_jmt_ev1_top6
RPV 350_jmt_ev1_top6
A.U.
jmt_ev1_top6
jmt_ev0_top6_1l_ge7j_ge1b
TT_jmt_ev0_top6
RPV 850_jmt_ev0_top6
SYY 650_jmt_ev0_top6
RPV 350_jmt_ev0_top6
jmt_ev0_top6
fwm2_top6_1l_ge7j_ge1b
TT_fwm2_top6
RPV 850_fwm2_top6
SYY 650_fwm2_top6
RPV 350_fwm2_top6
A.U.
fwm2_top6
fwm3_top6_1l_ge7j_ge1b
TT_fwm3_top6
RPV 850_fwm3_top6
SYY 650_fwm3_top6
RPV 350_fwm3_top6
A.U.
fwm3_top6

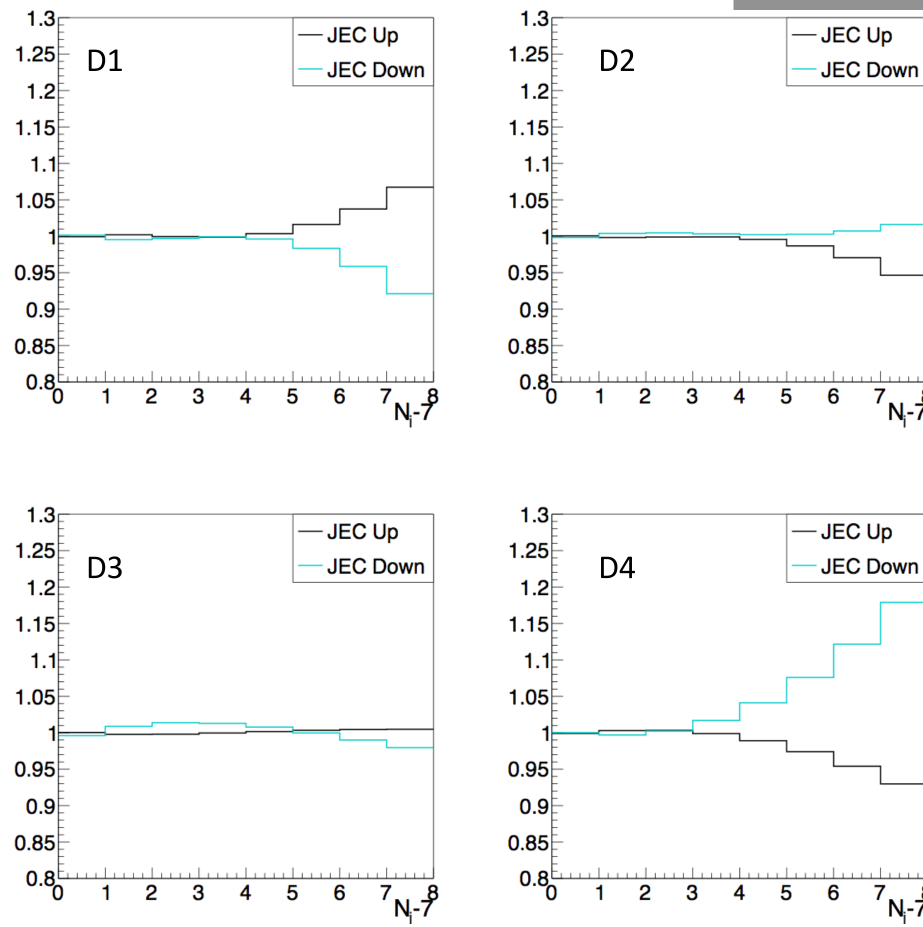
Systematics

- **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