

R-parity violating stop decays in events with a lepton and many jets



[results not CMS
approved]

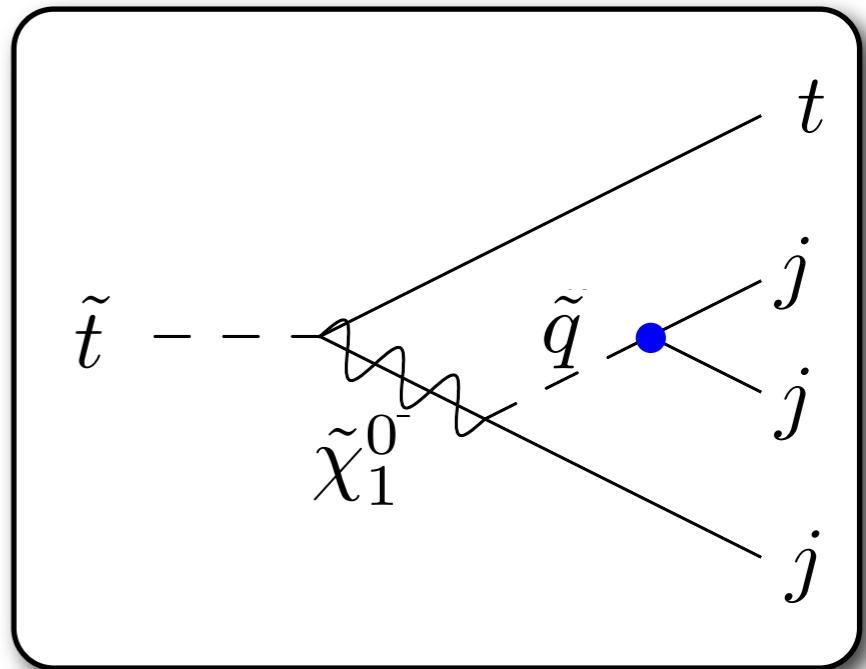
James Hirschauer
(Fermilab)



30 June 2013
Snowmass Energy Frontier Workshop
Seattle, WA

Motivation

- A major goal of the EF is to discover or rule out **natural SUSY (with light stop)** as solution to the hierarchy problem.
- **Basic searches assume R-parity conservation** and large missing transverse energy (MET).



We must be sure we **do not miss a natural stop in case of R-parity violation (RPV)!!**

- RPV = **challenging event topology**
- MET → extra jets (**looks just like tt+jets+pileup**)
- Need **harsh kinematic cuts** to suppress background → **low efficiency**.
- Low efficiency →

sensitivity requires large integrated luminosity

Overview of study

- Scenarios: **14 TeV, 300** and **3000/fb**, with **50** and **140 pileup** (PU).
- At 8TeV/25PU, these searches rely on **jet multiplicity** and **S_T** (scalar sum of object p_T).
- At high PU, use **kinematic variables** in MVA.

Backgrounds

- Centrally produced Delphes 3.0.9 samples [1,2].
- Z/W/H/g+jets (both on- and off-shell bosons)
- tt+jets

Signal : stop → top+bino, bino → jjj (via UDD212)

- From **Jared Evans** (Rutgers) [3].
- Stop mass 400–1100 in 100 GeV steps
- bino mass = 1/2 * (stop mass)
- tt-like final state : ttbar + 6 jets

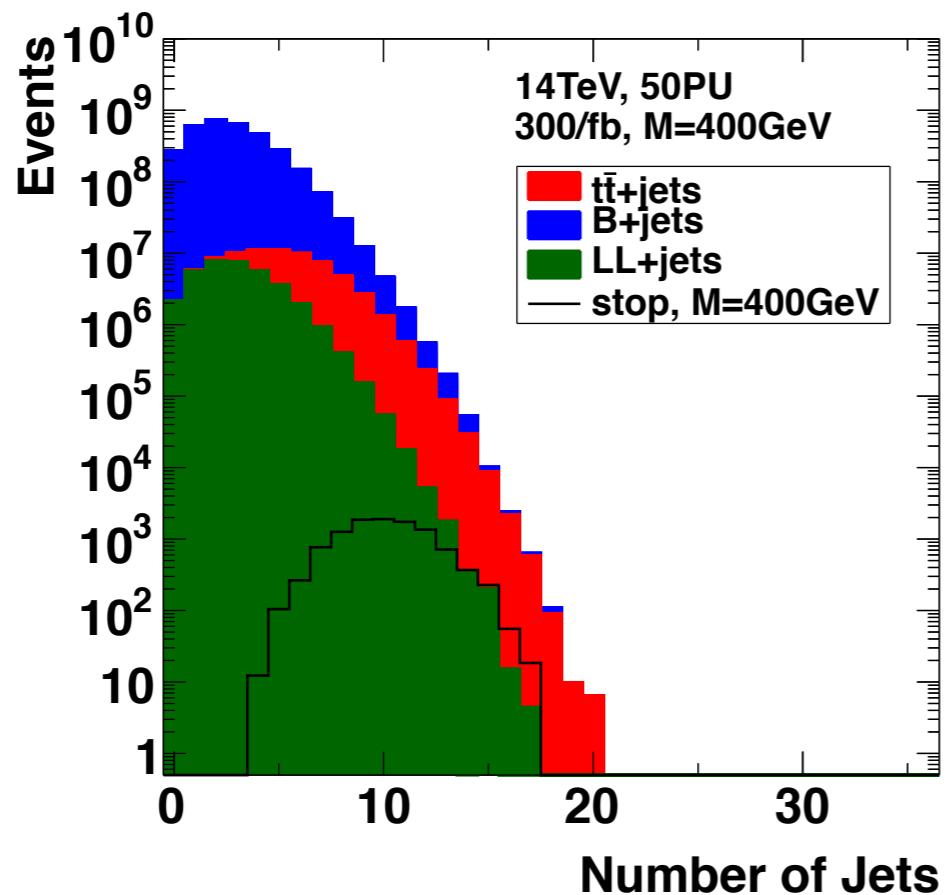
[1] "Snowmass Energy Frontier Simulations for Hadron Colliders", A. Avetisyan, JH, et. al. arXiv:1307.XXX, July 2013

[2] "Standard Model Background Generation for Snowmass using Madgraph", A. Avetisyan, JH, et. al. arXiv:1307.XXX, July 2013

[3] Talk from BNL meeting : <https://indico.bnl.gov/getFile.py/access?contribId=127&sessionId=12&resId=0&materialId=slides&confId=571>

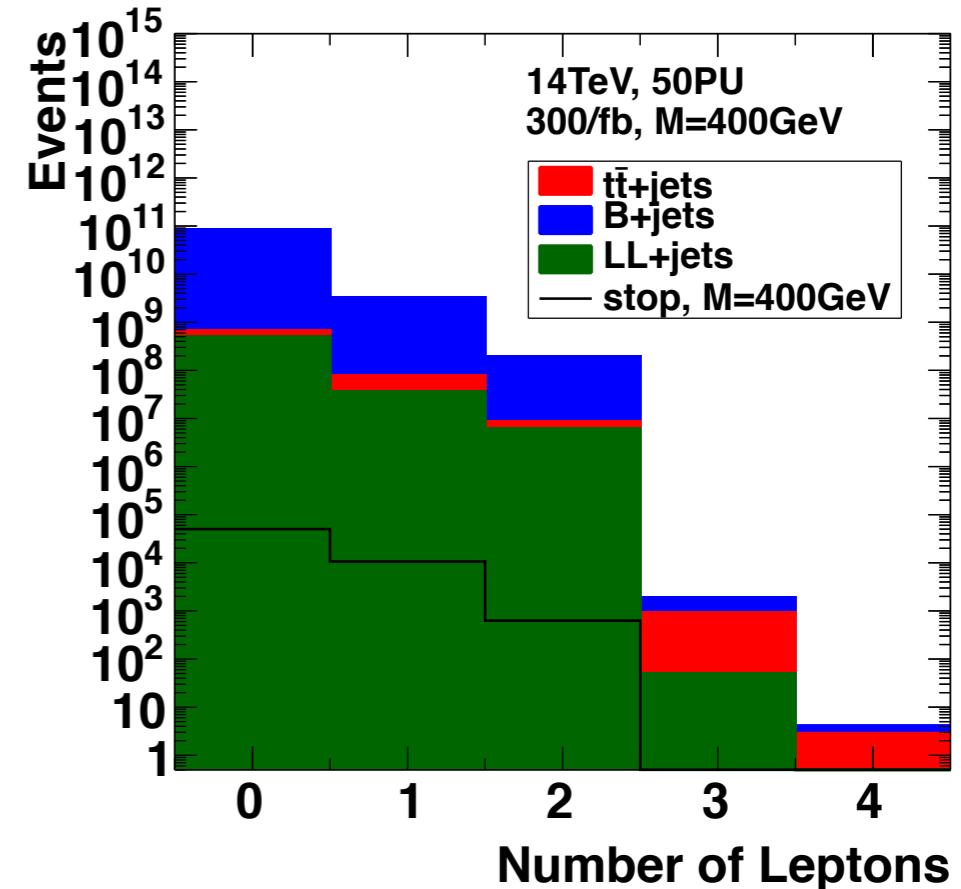
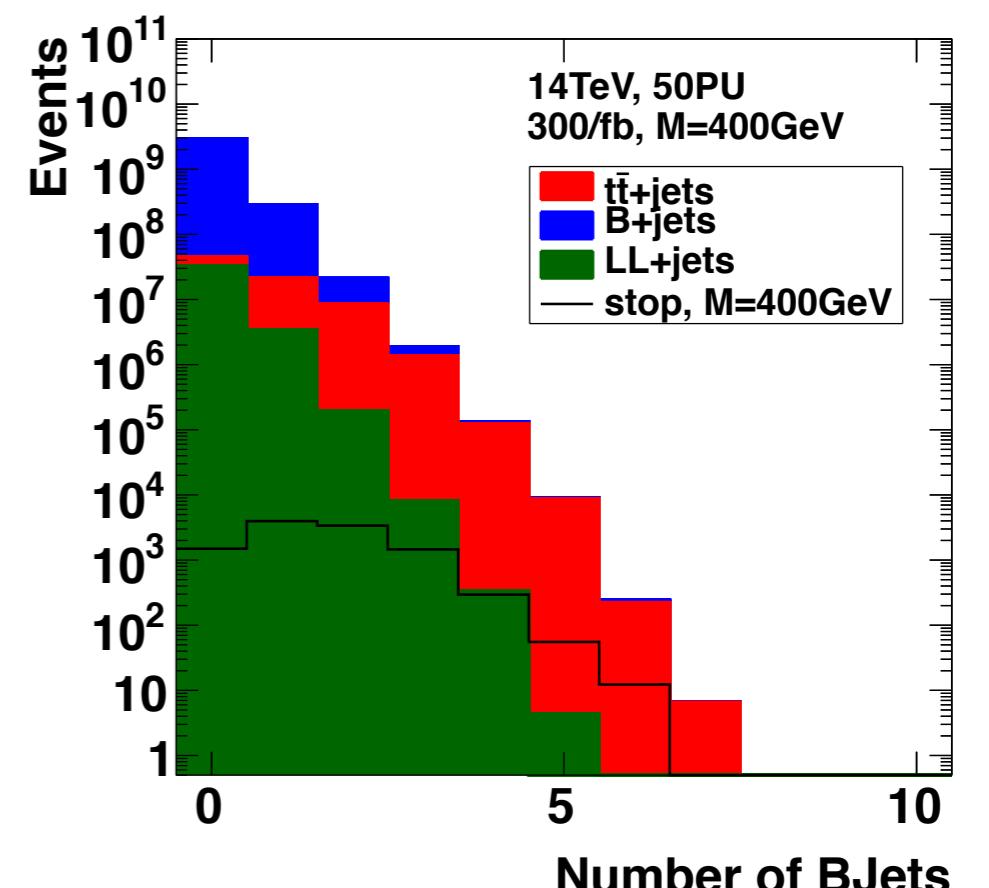
Object multiplicity

- **tt+jets dominates** at high N_{jets} .
- 82/17/1% of signal has 0/1/2 leptons.
- Signal is charm rich → many b-tagged jets.
- S/B is 10^{-3} – 10^{-4} at high N_{jets} .



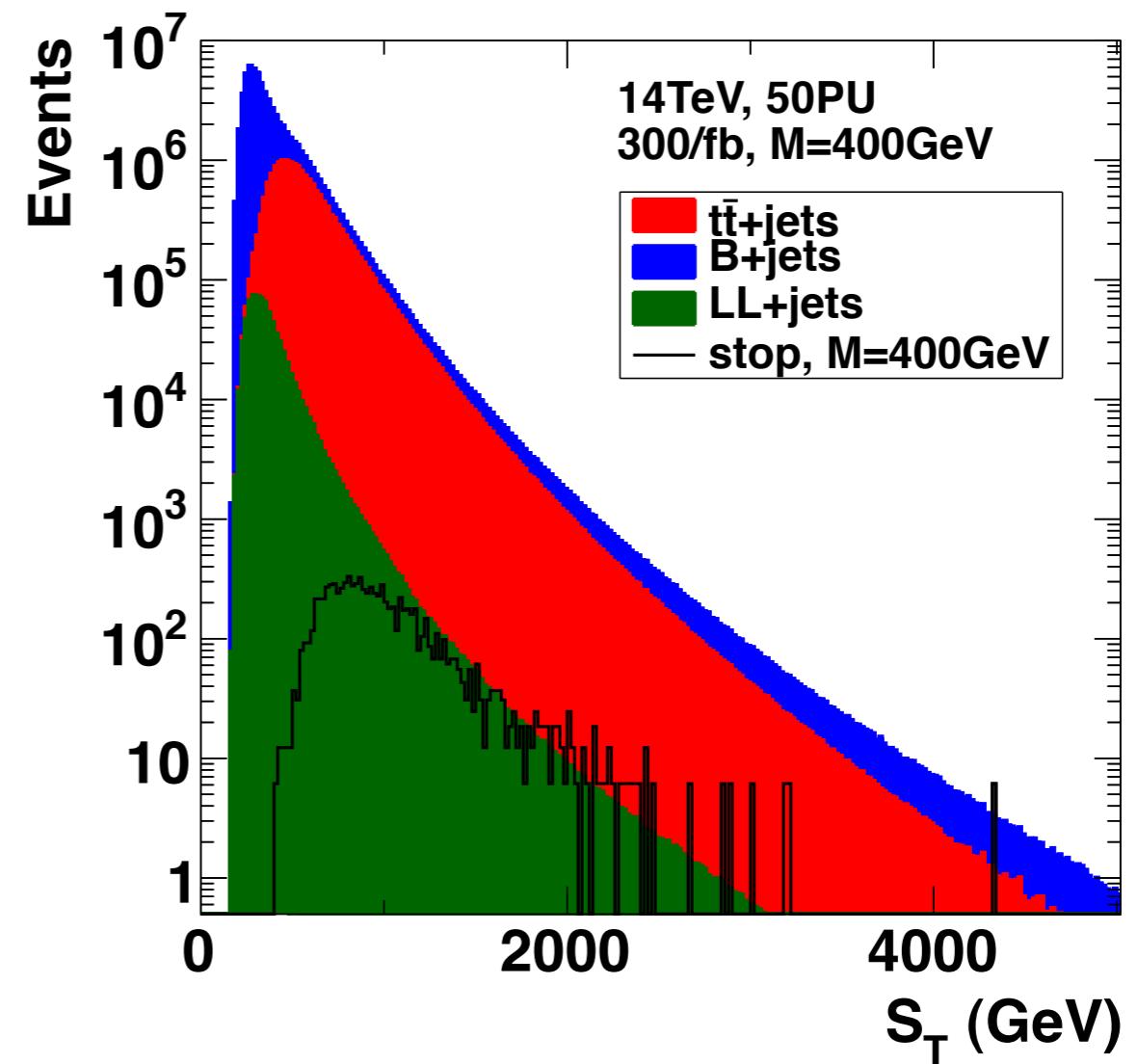
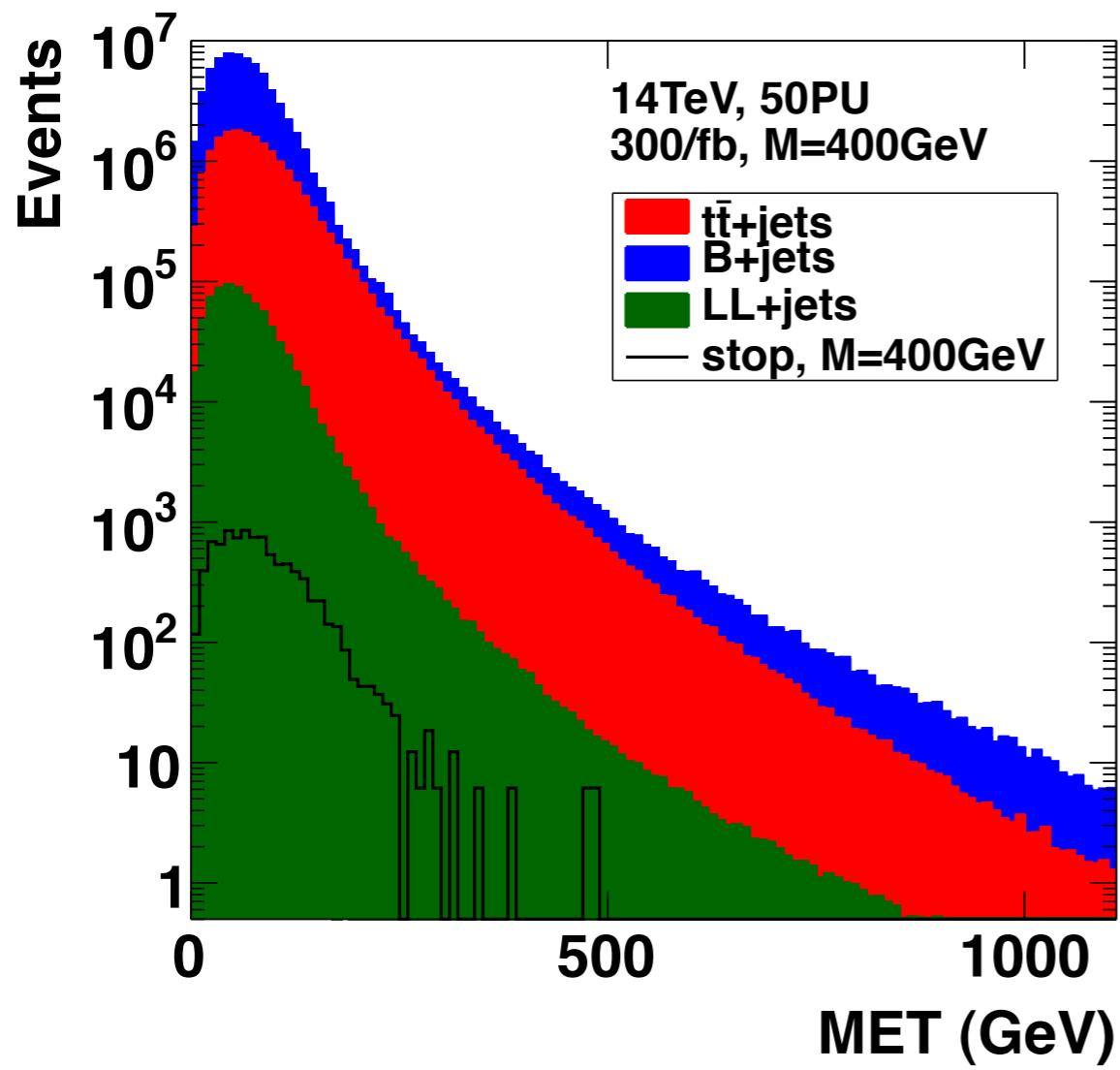
Object selection

p_T of e/ μ /jet > 30/30/40 GeV
 $|\eta|$ of e/ μ /jet < 1.5/2.1/2.4
jet $|\eta| < 2$ at 140 PU



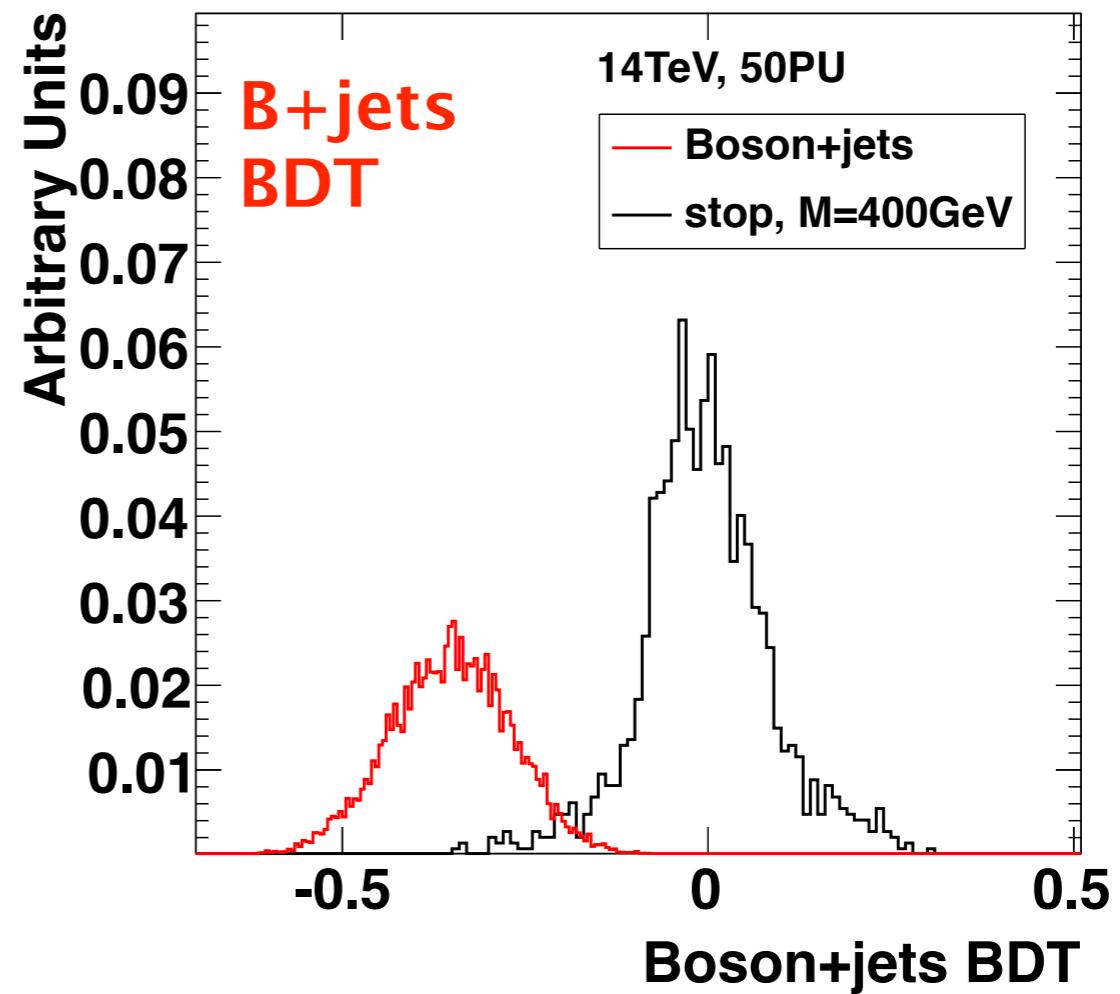
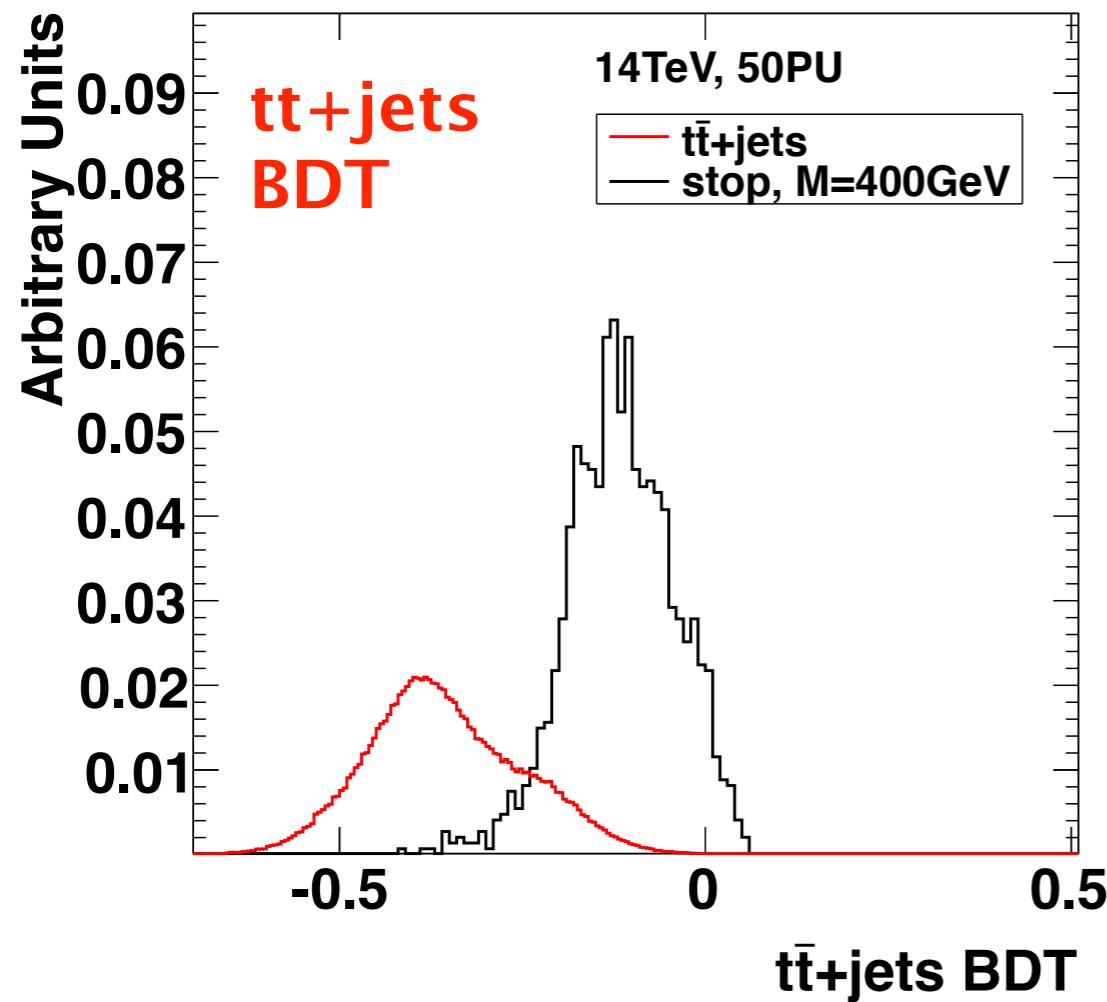
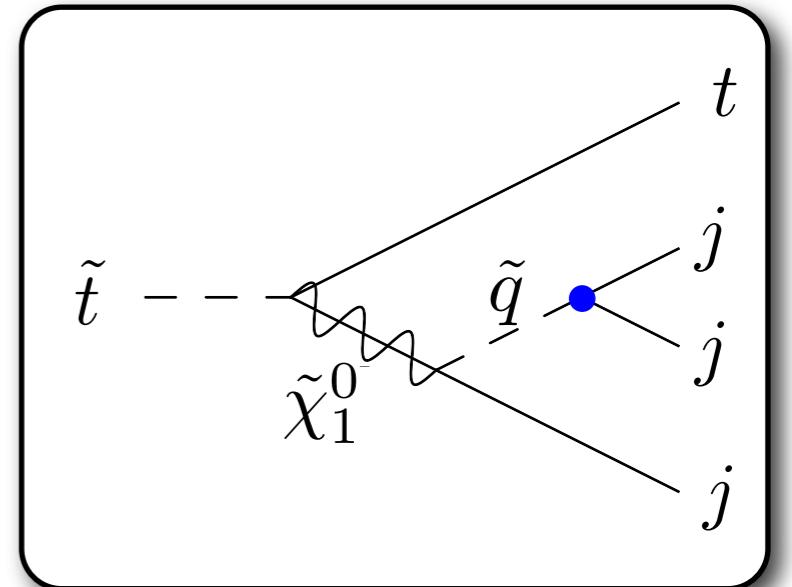
S_T and MET

- MET is not helpful, as expected.
- S/B is still 10^{-3} - 10^{-4} at high S_T .
- Need to take advantage of **event kinematics** ...



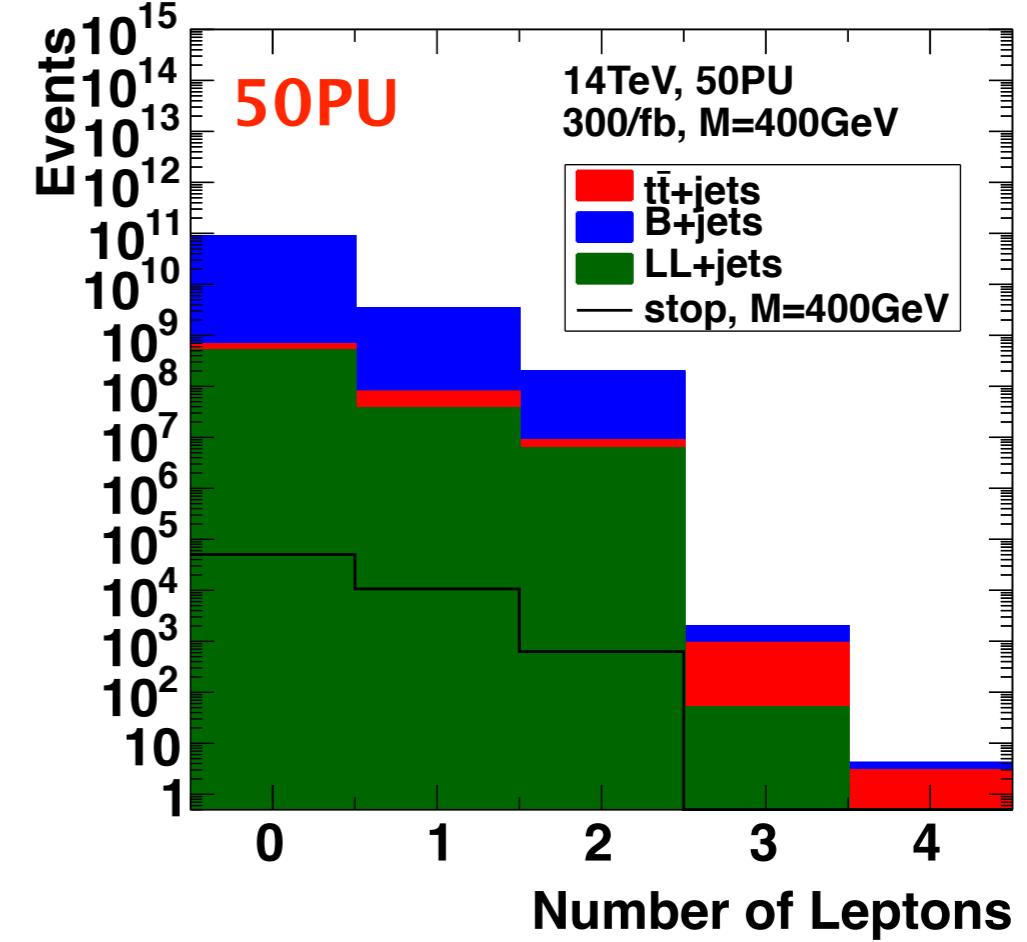
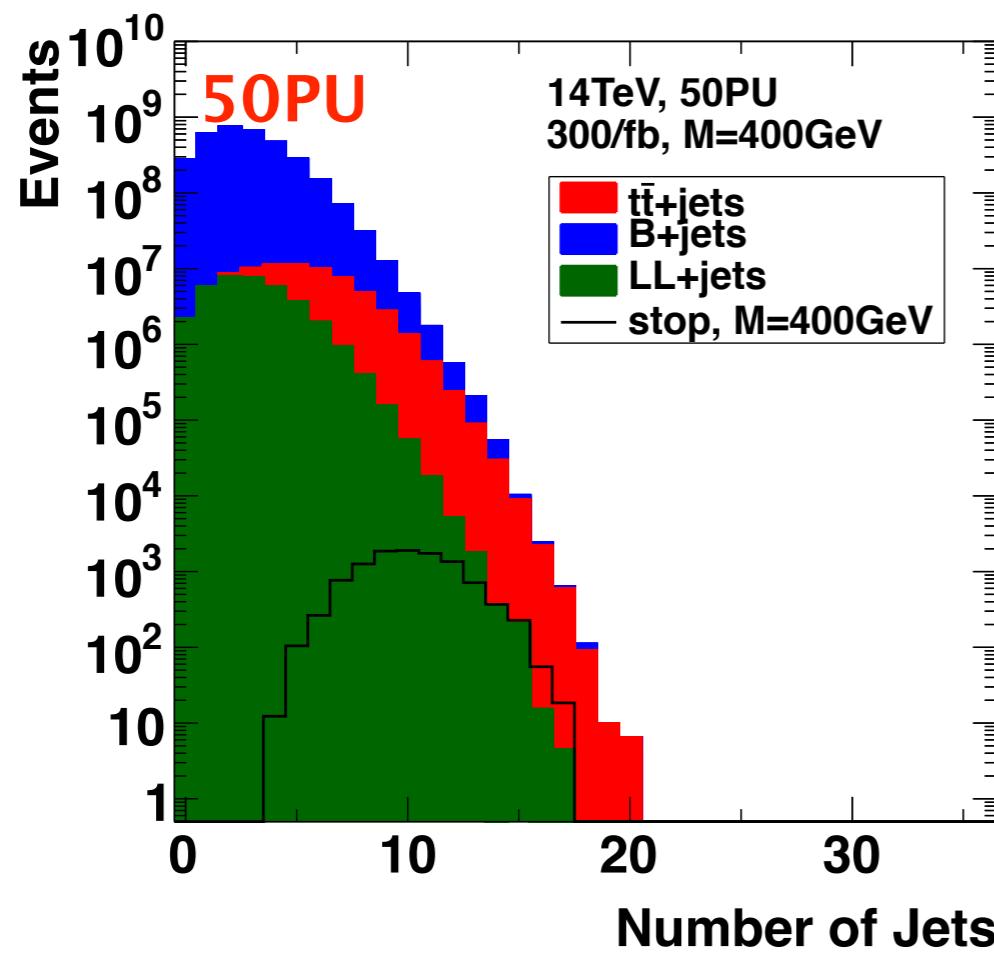
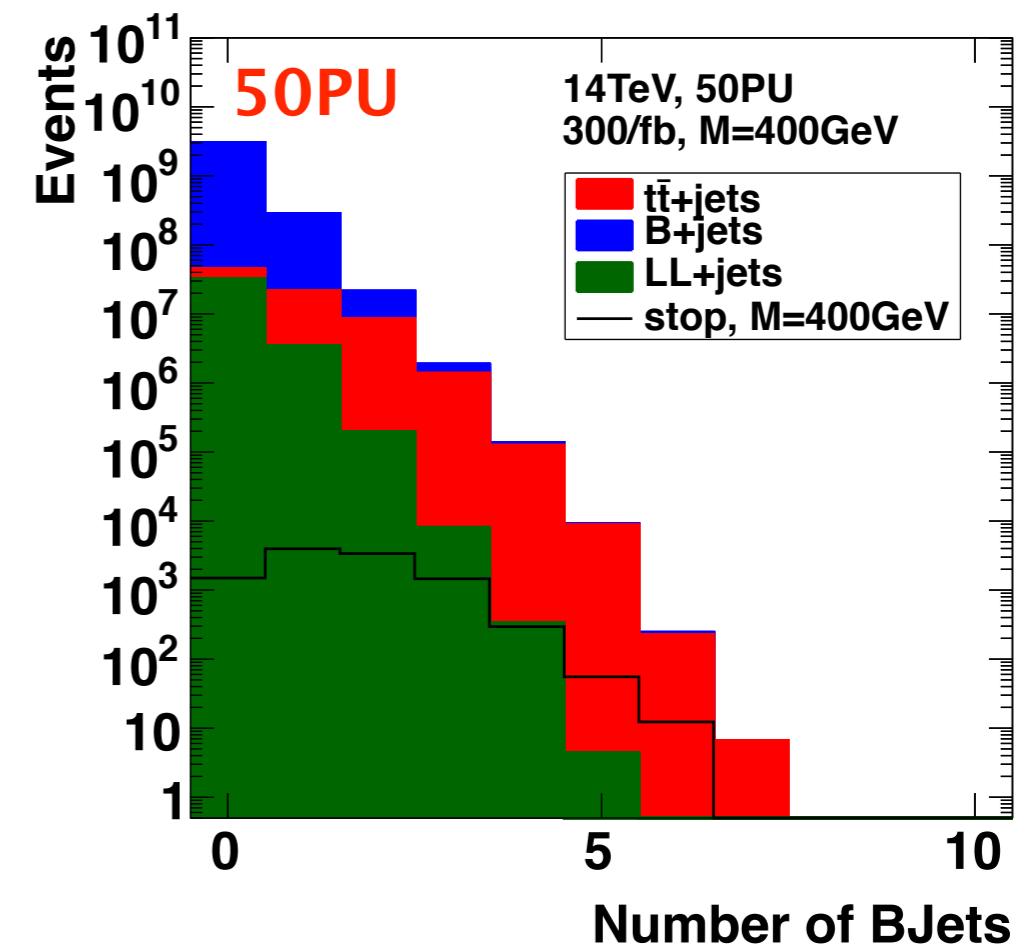
Kinematics : Boosted Decision Trees

- **2 tops and 2 resonances** (each decay to 3 jets).
- Many combinations → **use BDT**.
- **26 variables**:
 - N_{jets} , N_{bjets} , S_T ,
 - p_T/S_T , η , φ for lepton and 6 leading jets.



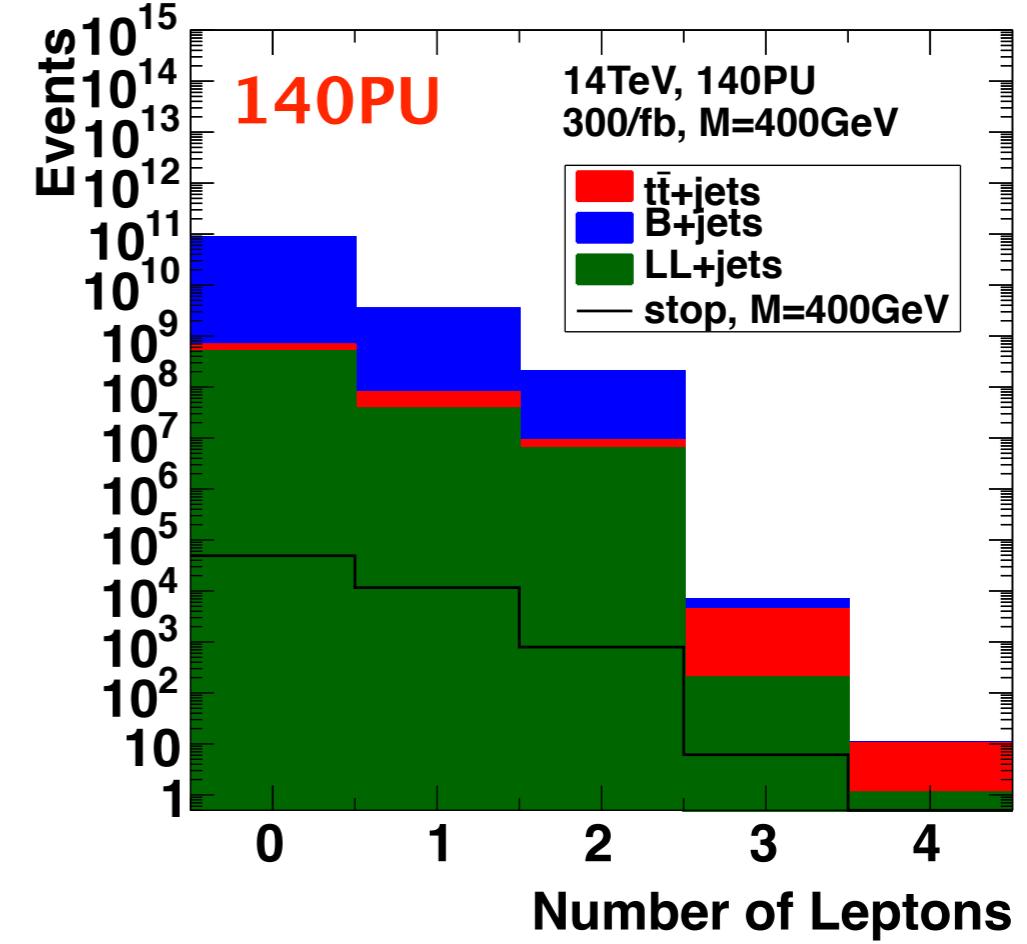
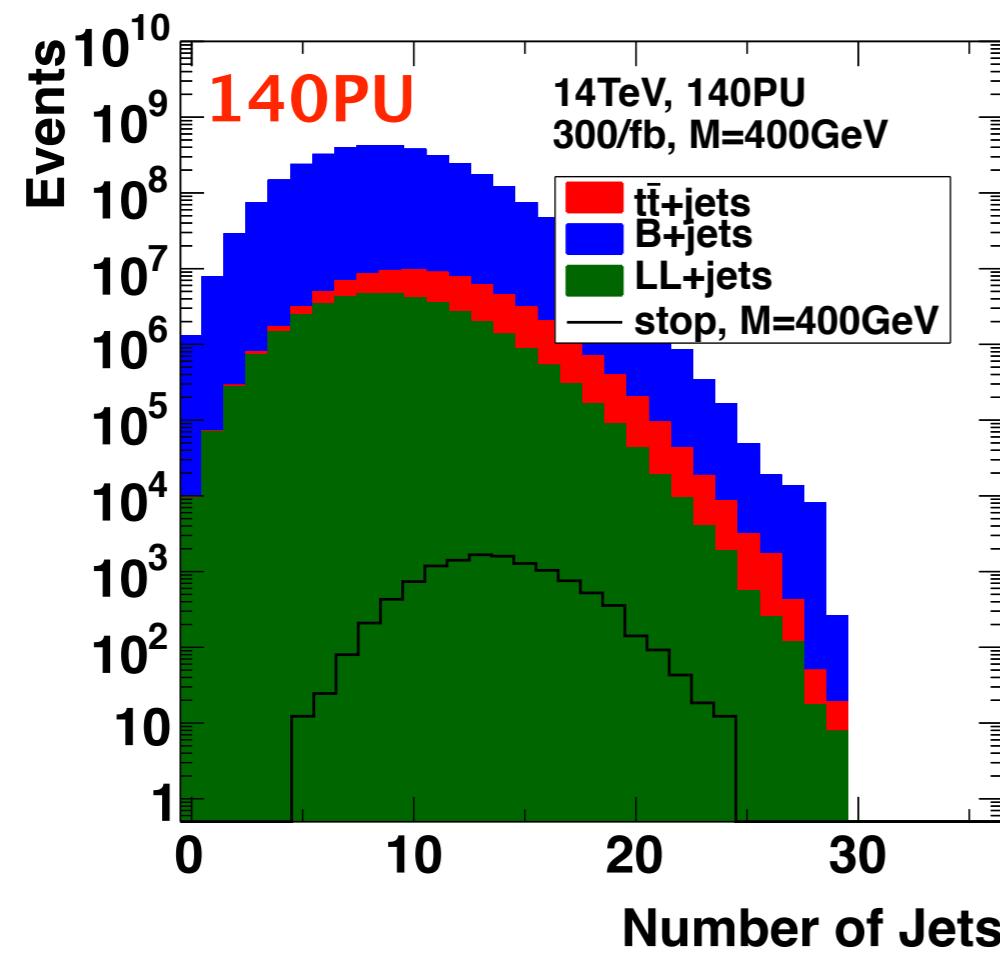
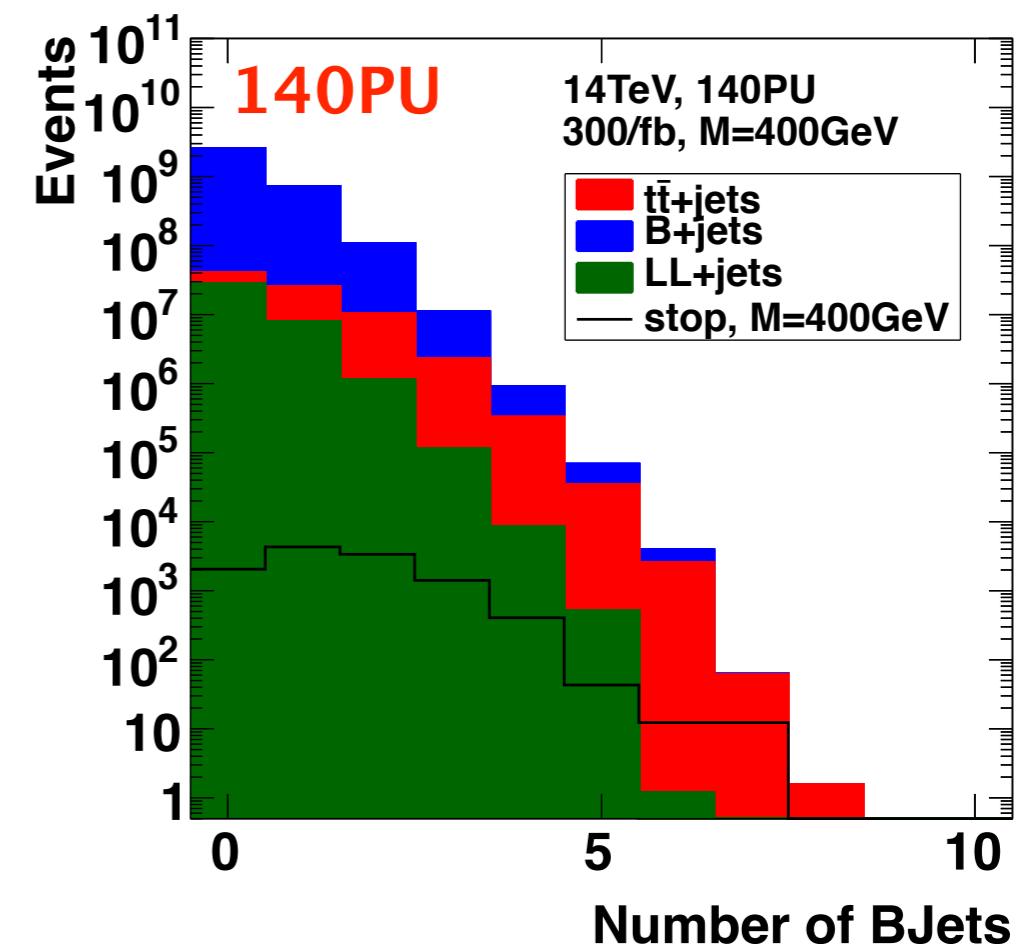
$\langle \text{Pileup} \rangle = 50$

- Primary effect is more jets.
- Low level PU rejection will most likely improve in next 5–10 yrs.



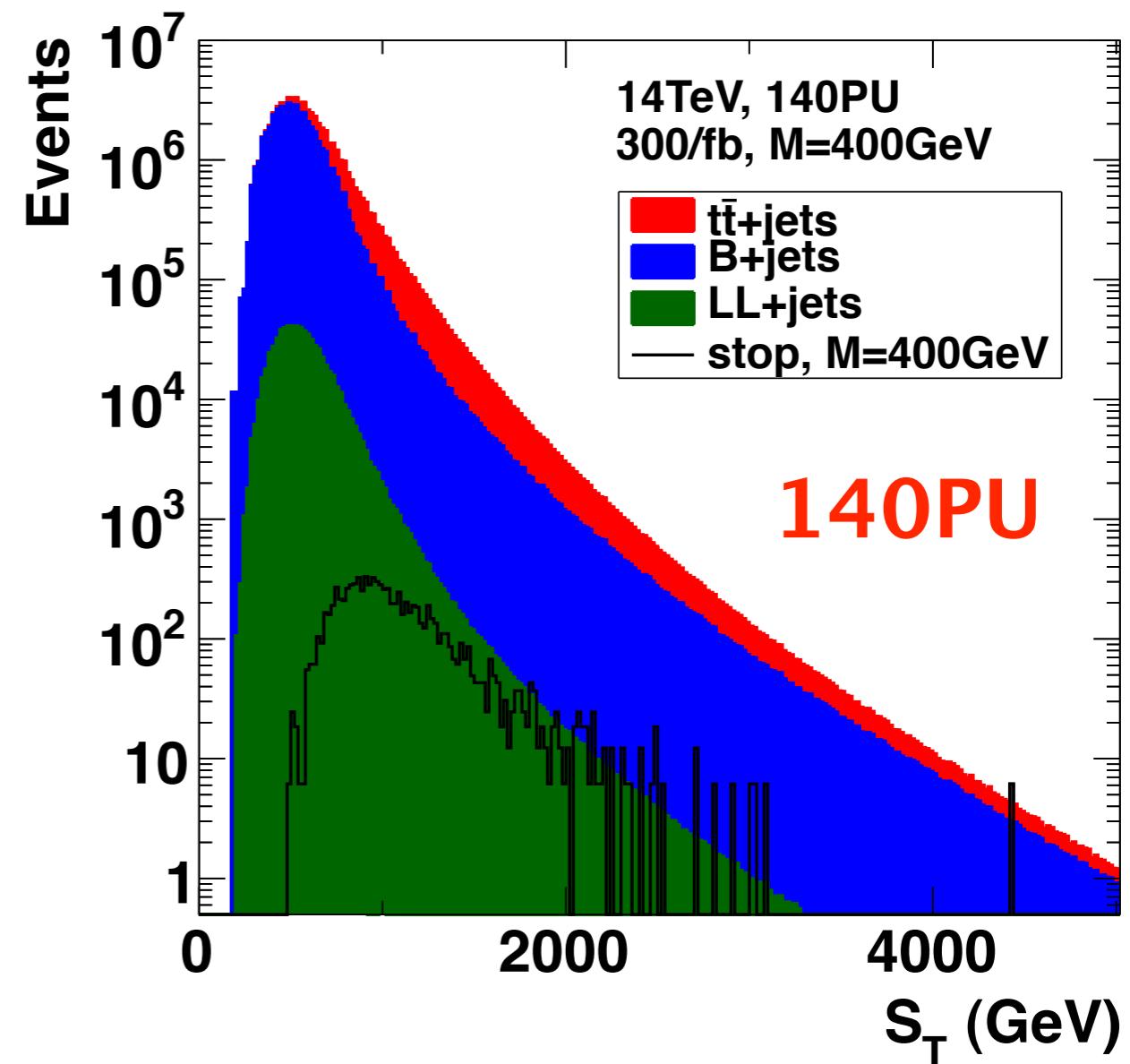
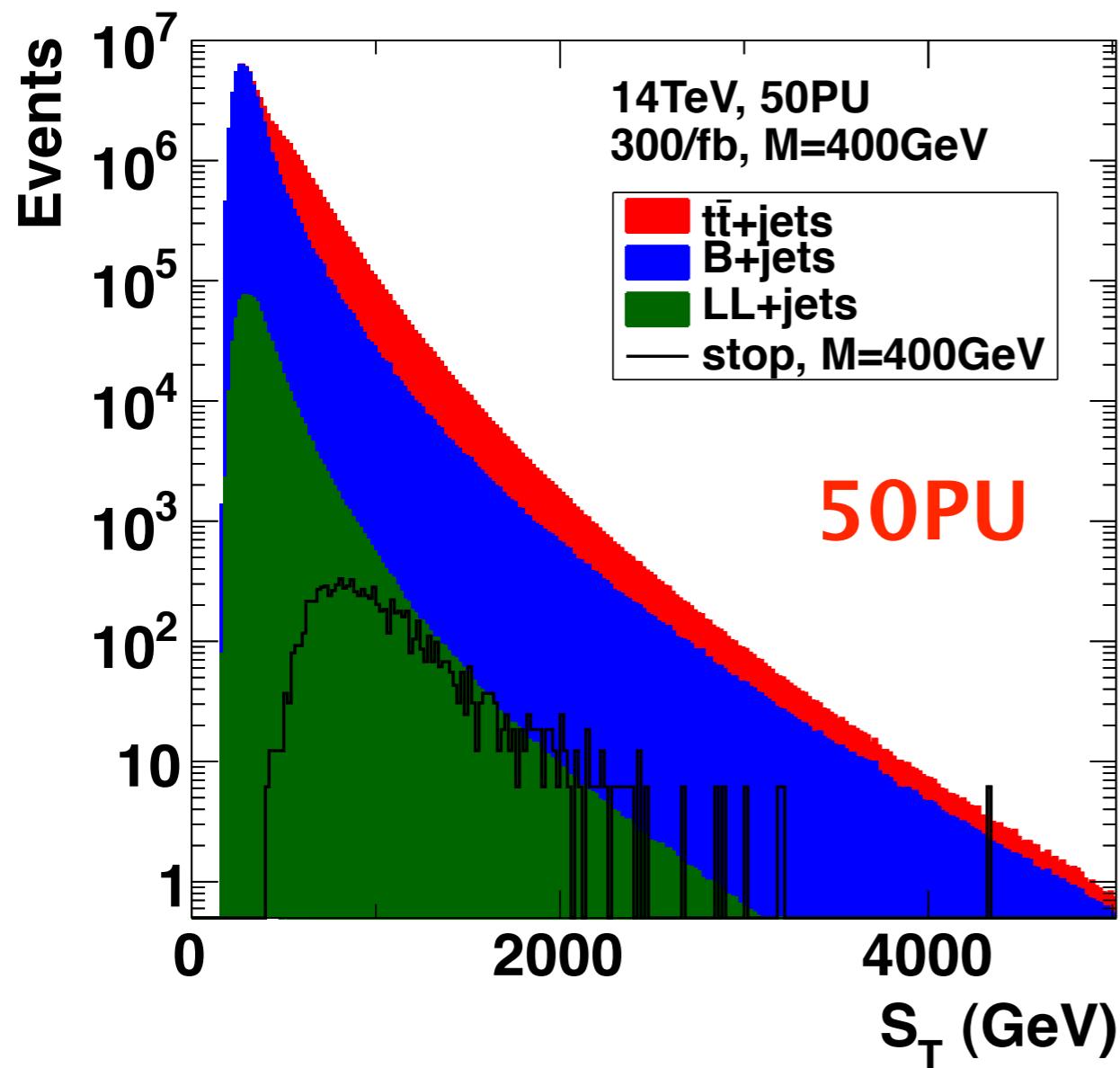
$\langle \text{Pileup} \rangle = 140$

- Primary effect is more jets.
- For 140PU require 5 jets with $|\eta| < 2$.



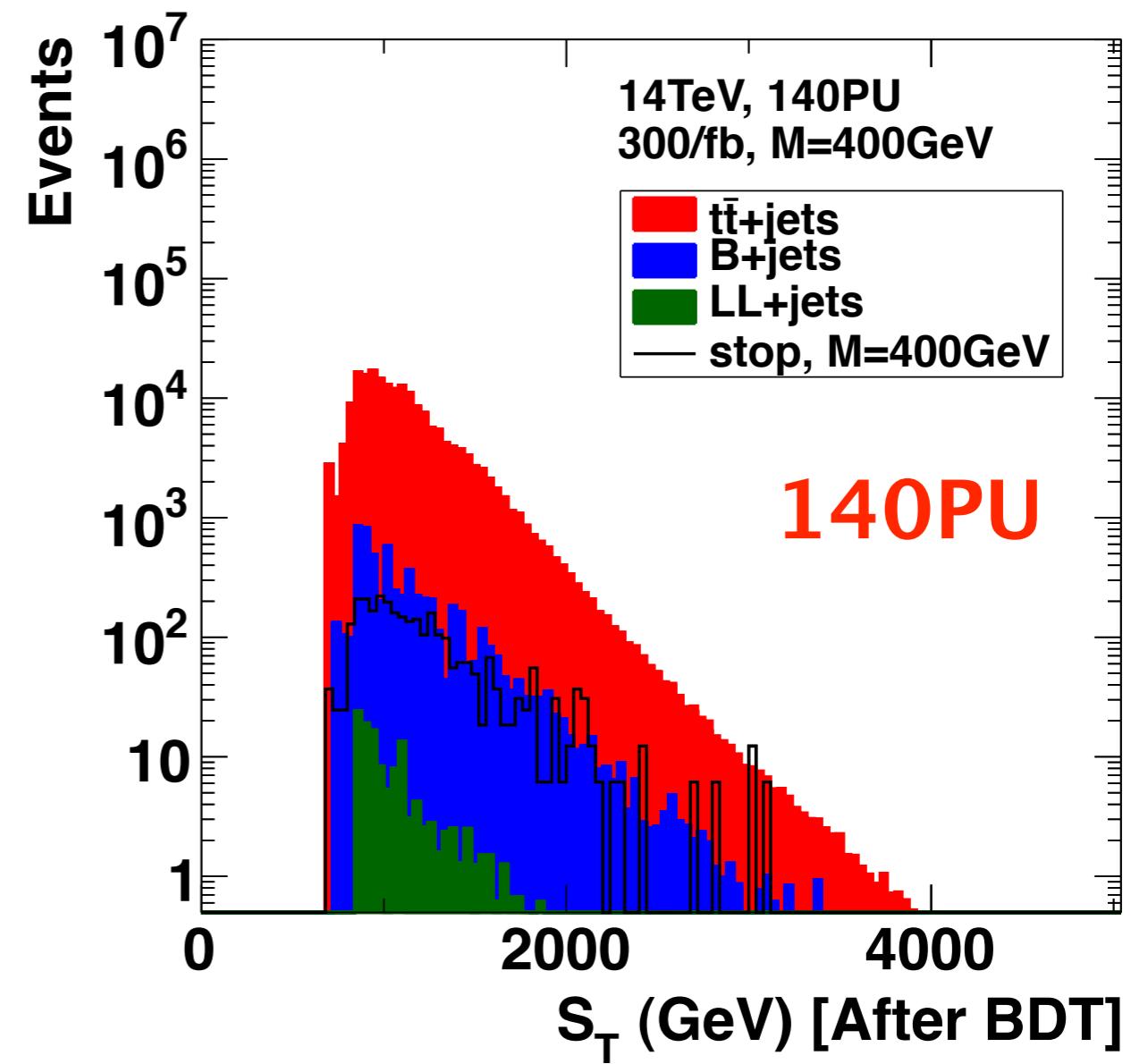
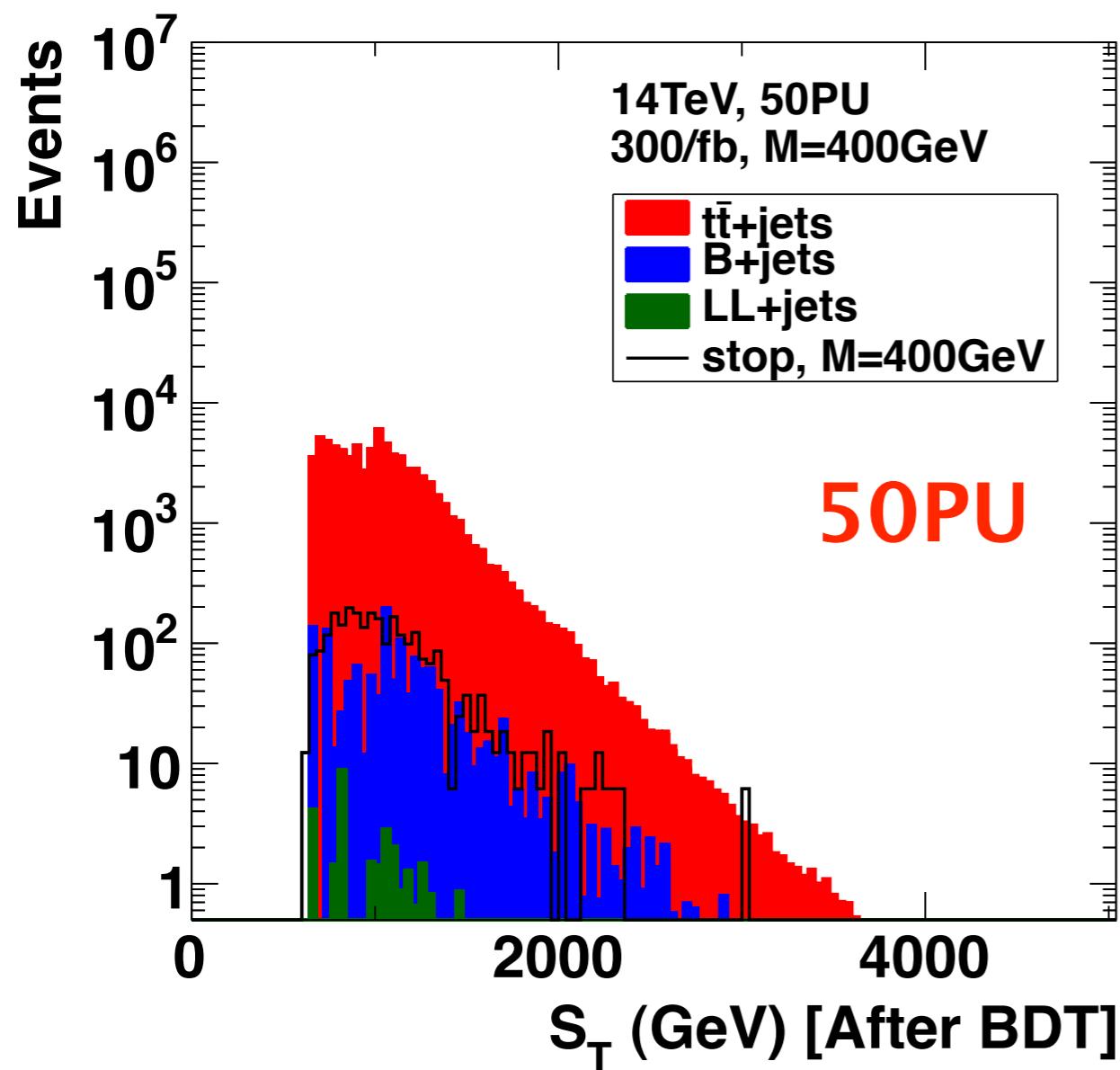
Results : Pre-selection

- Require **1 lepton**, **≥ 6 jets**, and **≥ 5 jets** with $|\eta| < 2$ for 140PU.



Results : BDT Selection

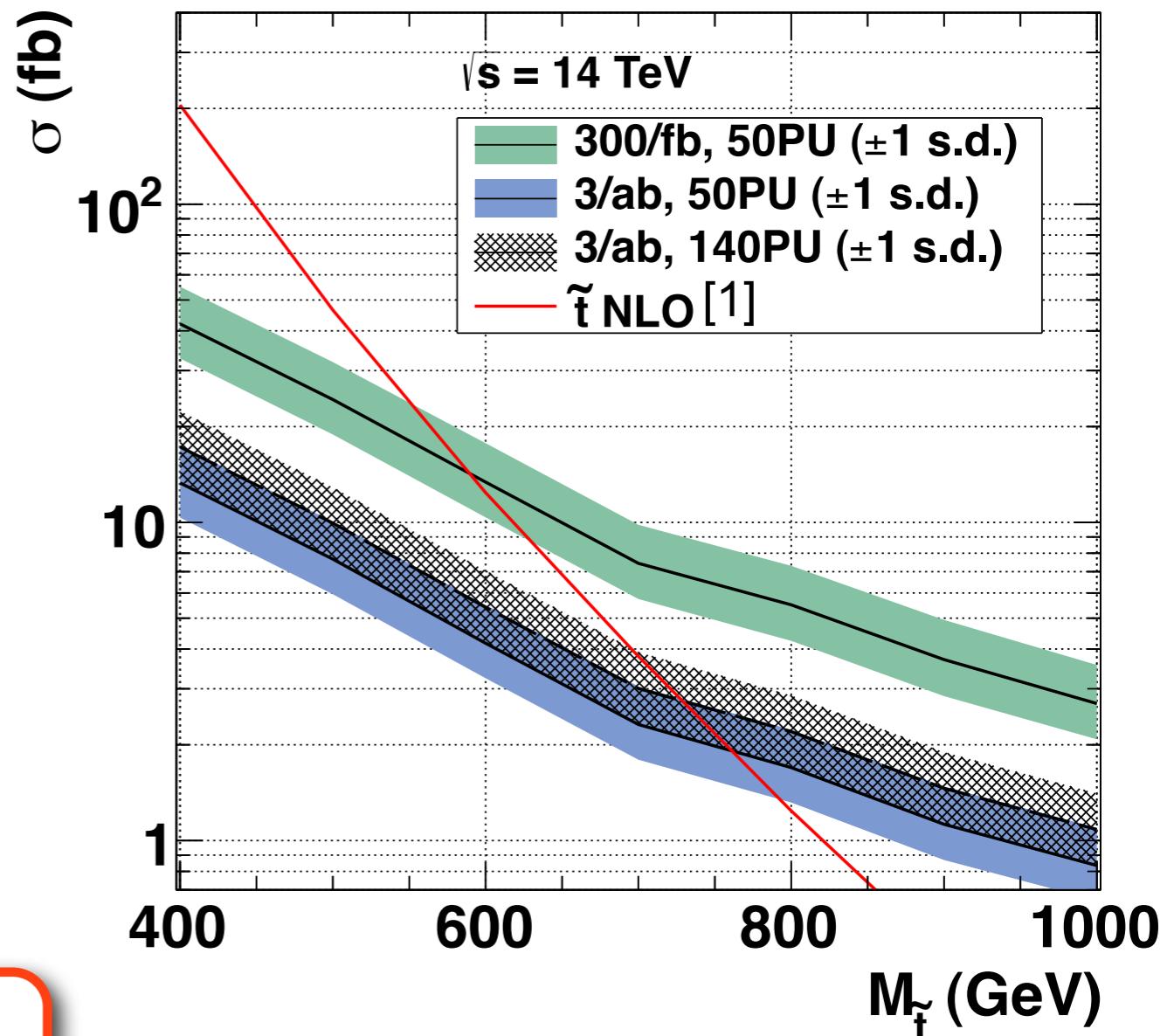
- Require **1 lepton**, **≥ 6 jets**, and **≥ 5 jets** with $|\eta| < 2$ for 140PU.
- Apply thresholds on both tt and B+jets **BDTs**, **trained and optimized** at each **mass point** and PU scenario.



95% CL sensitivity

- **10x luminosity improves** cross section sensitivity by $\sqrt{10}$ (of course).
- **140PU reduces** cross section sensitivity by 30%.

$\int \mathcal{L}$	Pileup	Mass reach
300/fb	50PU	595 GeV
3/ab	50PU	775 GeV
3/ab	140PU	740 GeV



Testing naturalness

$m_{\text{stop}} = 500 \text{ GeV} \rightarrow \sim 20\%$ fine tuning

$m_{\text{stop}} = 700 \text{ GeV} \rightarrow \sim 10\%$ fine tuning

[1] cross section:
 Kramer et al, arXiv:1206.2892
 Evans, Howe with Prospino (for Snowmass)

Systematic Uncertainty

- So far, no systematic uncertainty on background prediction (σ_{bkg}) included.
- Sensitivity lost when $\sigma_{\text{bkg}} \sim S/B$.
- In current formulation $S/B \sim 3\%$ → this is **precision search!!**

300/fb, 50 PU

Mass (GeV)	N_{sig}	N_{bkg}	ϵ_{sig} (%)	ϵ_{bkg} (1e-4)	S/B
400	2644.5	76195	4.3	11.39	0.035
500	415.7	12144	3.0	1.82	0.034
600	54.7	870	1.5	0.13	0.063
700	26.7	682	2.4	0.10	0.039
800	7.6	276	2.1	0.04	0.028
900	2.6	114	2.0	0.02	0.023
1000	2.8	544	5.8	0.08	0.005

Similar to search for RPC decay $\tilde{t} \rightarrow m_t + \text{LSP}$ with $m_{\tilde{t}} \simeq m_t$, except for S_T differences and $\sigma_{\tilde{t}\tilde{t}^*}(m_t) \sim 10 \times \sigma_{t\bar{t}}(400 \text{ GeV})$.

To do:

- Continue trying to improve S/B.
- Reoptimize accounting for σ_{bkg} .

Steps in next 1-2 weeks

- Add sub-dominant backgrounds:
 - single-top + tB (10-20% tt)
 - BB (<1% B)
- Investigate S/B improvements.
- Extend to **stop → top+chargino, chargino → τ/ν jj** study.

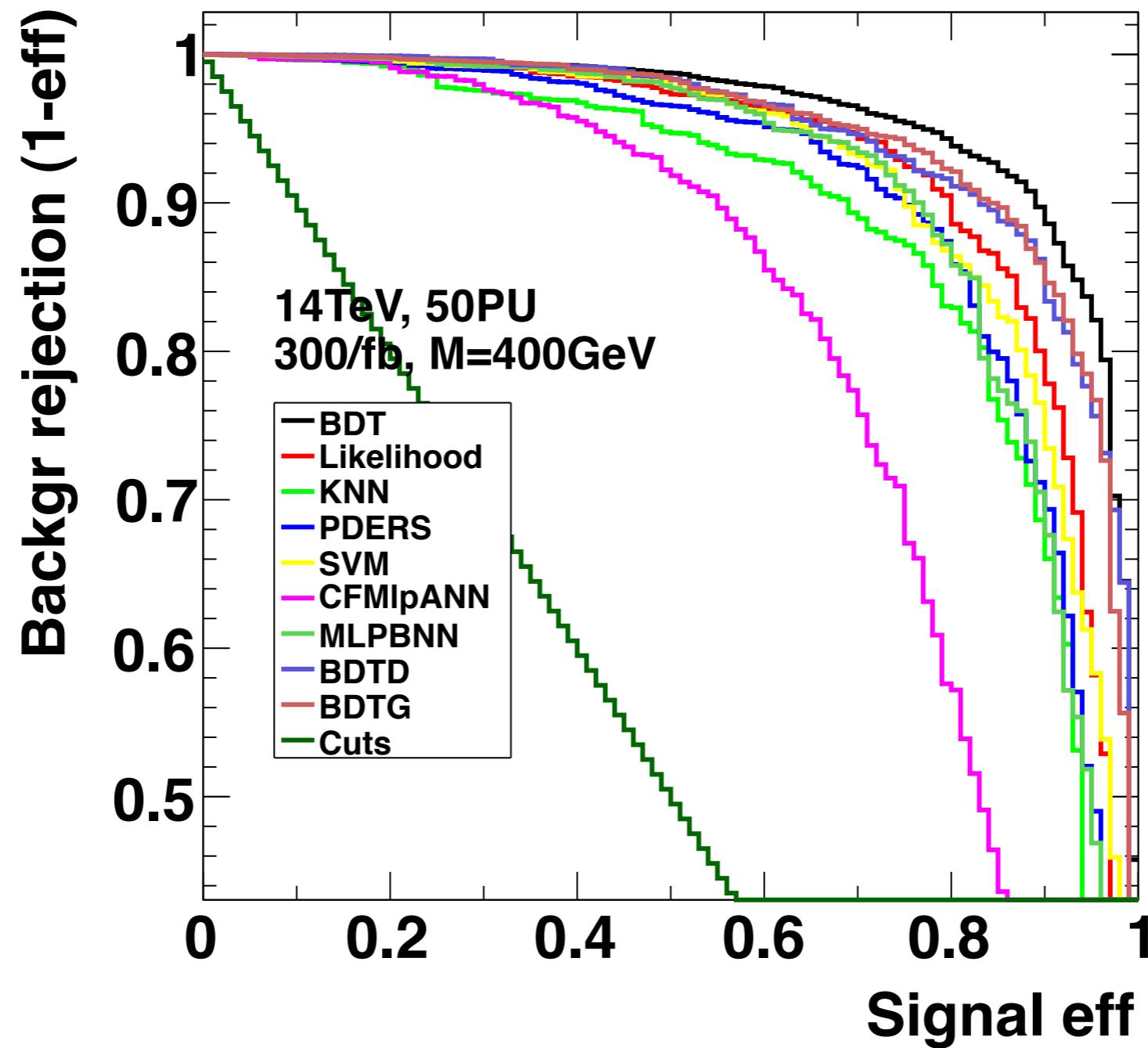
Conclusion

- RPV decays of $\tilde{t}\tilde{t} \rightarrow tt + jets$ is challenging to separate from **SM tt+jets**.
- **Large SM tt+jets background and small signal (S/B~3%)** requires **precision measurement**.
- Assuming precise result or improved S/B:

3000 fb at 14 TeV is **crucial for testing naturalness at <10%** (stop mass >700 GeV).

Additional Material

Multivariate Analyzers



BDTs

