Dissecting Jets plus $\not{E}_T$ Searches

with N-body extended simplified models

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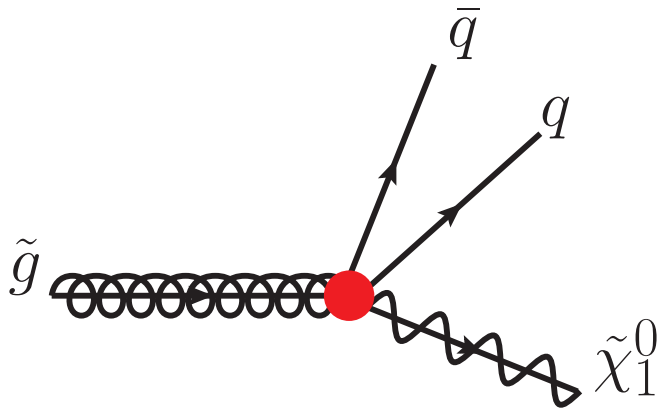
Simplified Models and LHC searches

- Simple and flexible formalism
- Still many possible searches and observables $\Rightarrow$ Why?
- What is each observable suited for?
- How are these observables related?
- Can we compare their performances?



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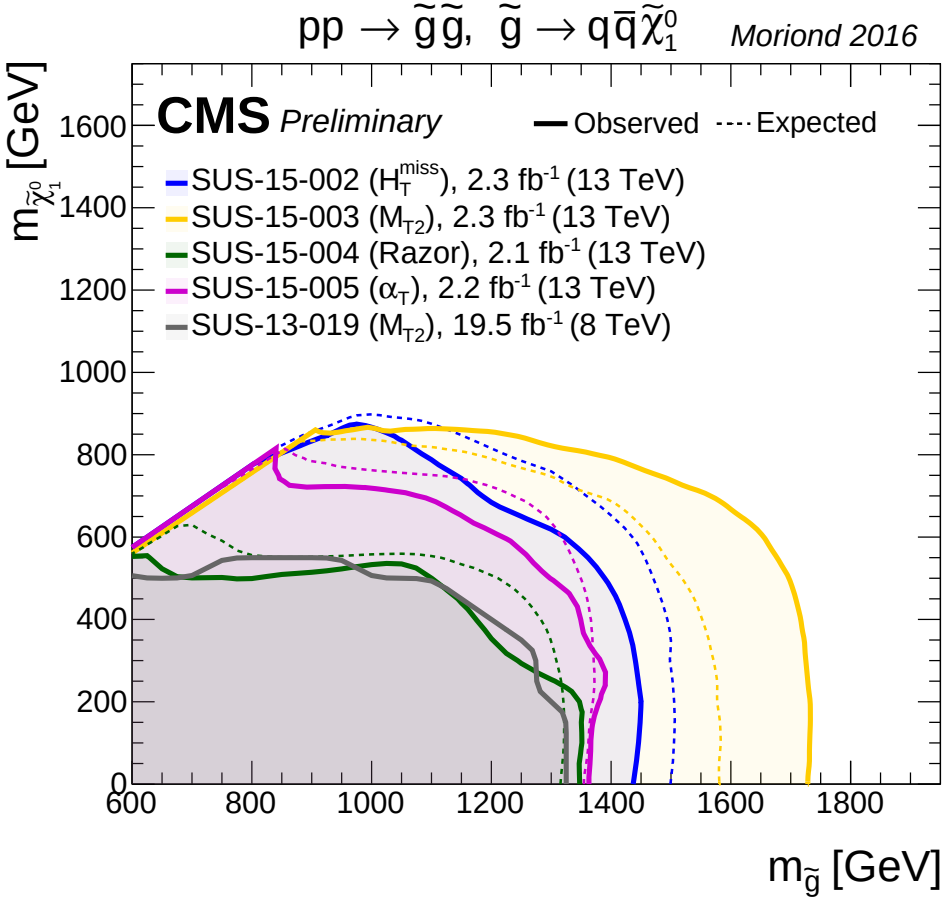


How to get an intuition for an optimal search strategy?

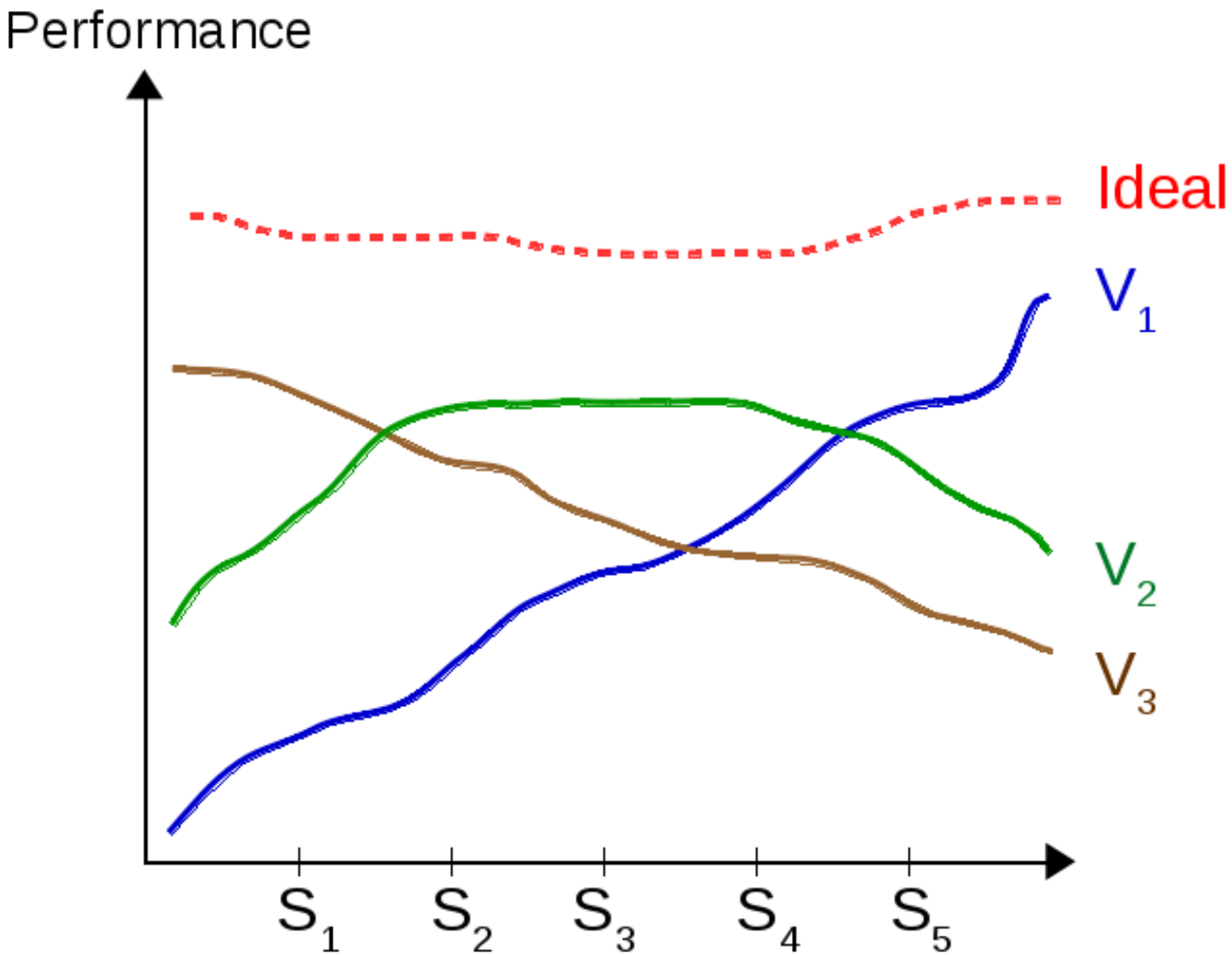
The Dissection Problem

observables

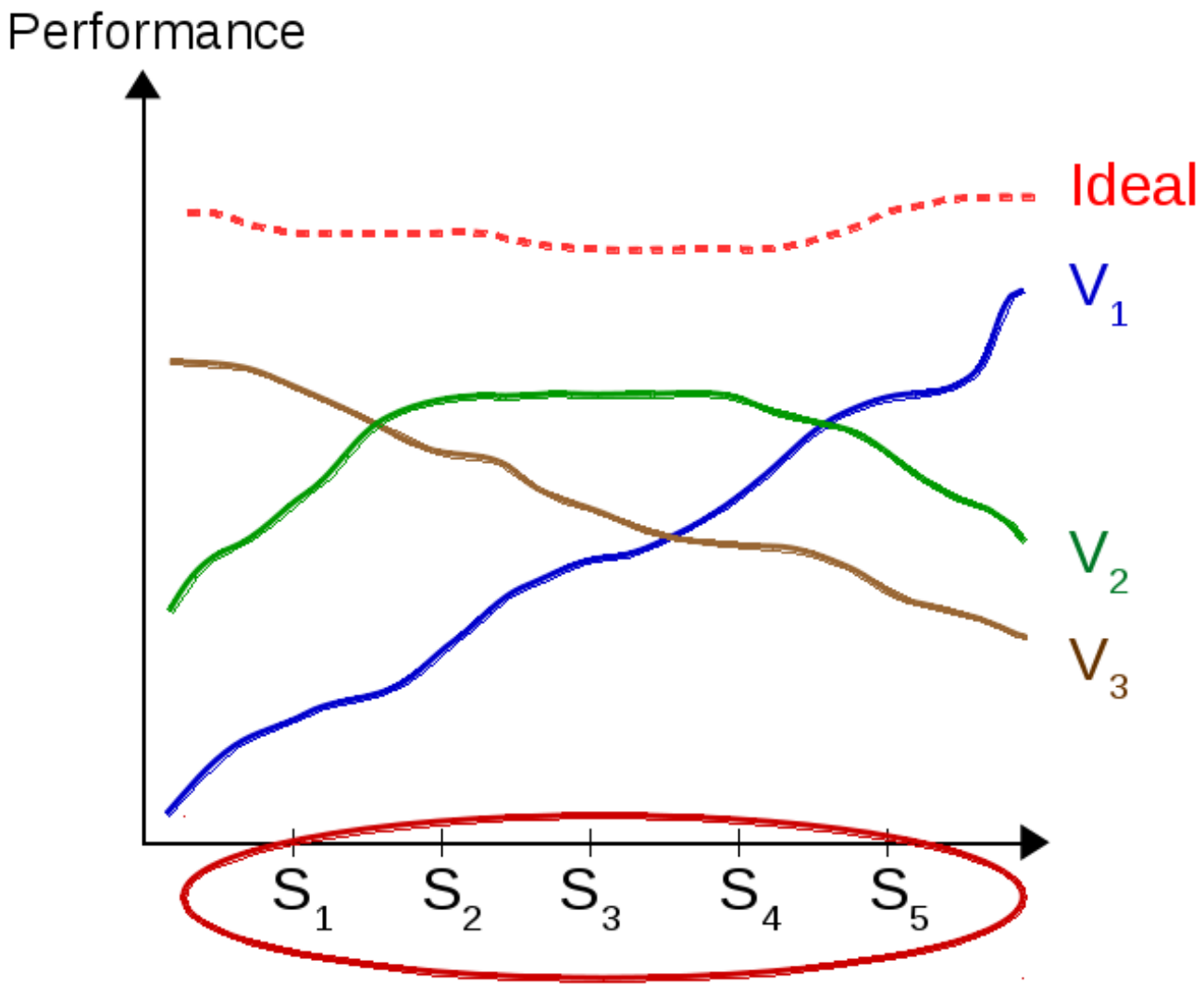
?

simplified model space

The Dissection problem: the ideal result



The Dissection problem: the ideal result

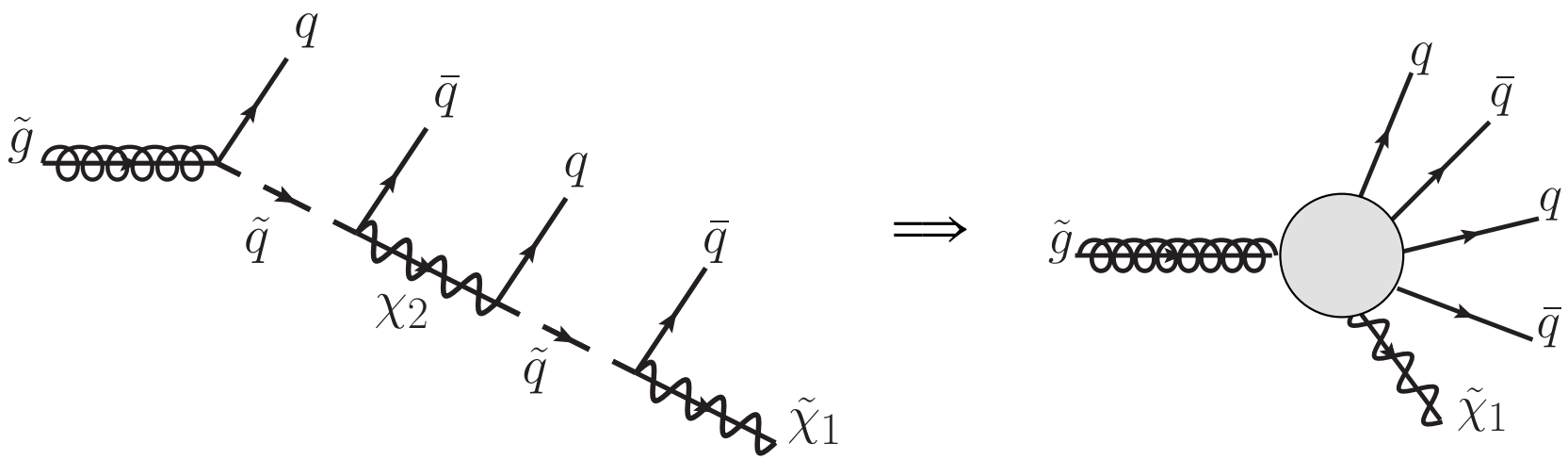


The *n*-body extended simplified models

Many LHC searches do not use kinematic features (edges, etc...)

⇒ Ignore intermediate on-shell states

⇒ Ignore angular correlations



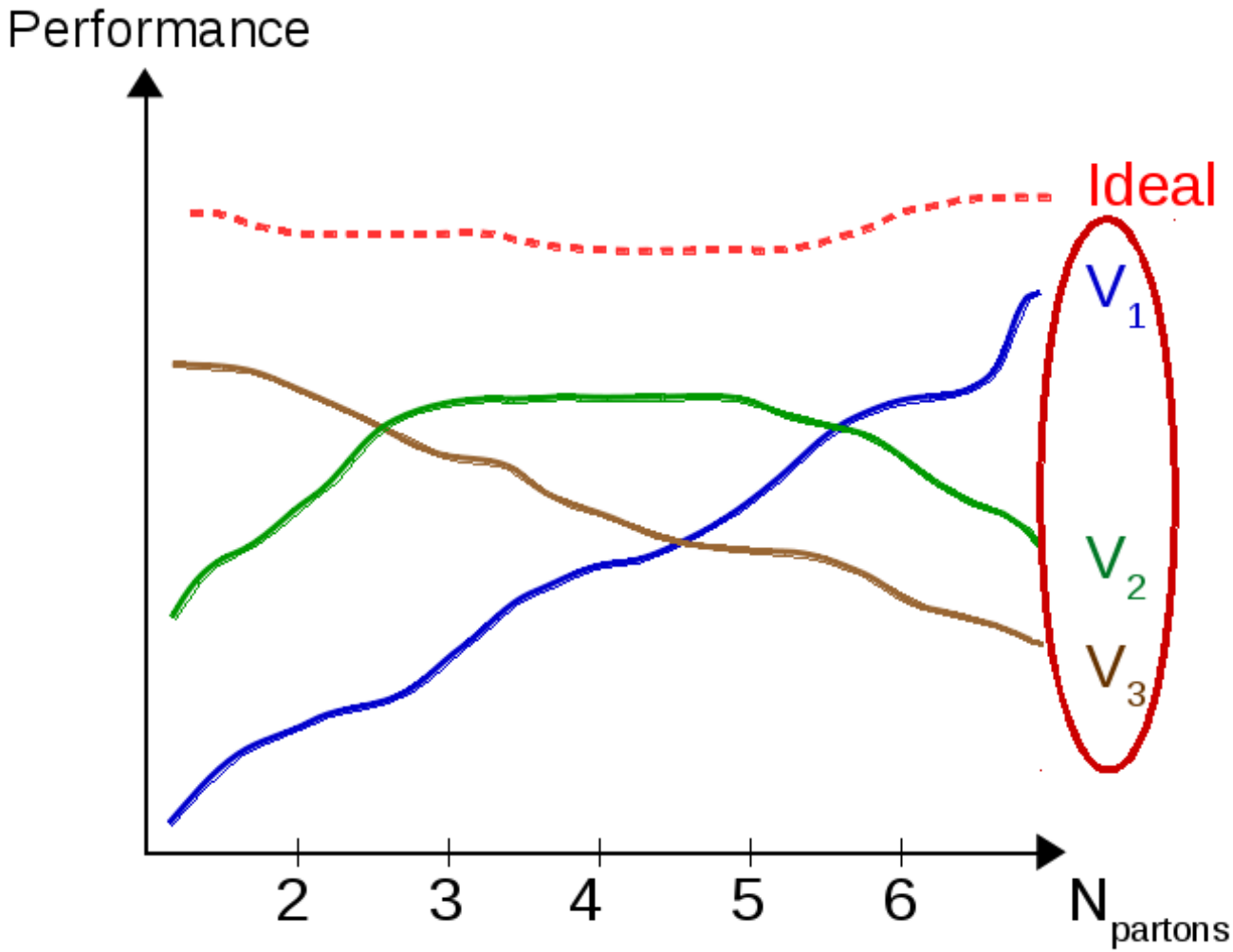
$$\mathscr{L} = \frac{1}{2} m_{\tilde{g}} \bar{\tilde{g}} \tilde{g} + \frac{1}{2} m_{\tilde{\chi}} \bar{\tilde{\chi}} \tilde{\chi} + \frac{y^4}{\Lambda^5} \bar{q} q \bar{q} \tilde{g} q \bar{\tilde{\chi}}$$

n-body vs Simplified Models

- Classify the signals using the number of partons

Production	Decay Channel	Final State
$\widetilde{q}\,\widetilde{q}$	$\widetilde{q} \to q\,\widetilde{\chi}$	2 partons $+ \not{H}_T$
$\widetilde{q}\,\widetilde{g}$	$\widetilde{g} \to q\,\overline{q}\,\widetilde{\chi}$ $\widetilde{q} \to q\,\widetilde{\chi}$	3 partons $+ \not{H}_T$
$\widetilde{g}\,\widetilde{g}$	$\widetilde{g} \to q\,\overline{q}\,\widetilde{\chi}$	4 partons $+ \not{H}_T$
$\widetilde{q}\,\widetilde{g}$	$\widetilde{g} \to q\,\overline{q}\,Z^0\,\widetilde{\chi}$ $\widetilde{q} \to q\,\widetilde{\chi}$	5 partons $+ \not{H}_T$
$\widetilde{t}\,\widetilde{t}$	$\widetilde{t} \to t\,\widetilde{\chi}$	6 partons $+ \not{H}_T$
$\widetilde{q}\,\widetilde{g}$	$\widetilde{g} \to t\,\overline{t}\,\widetilde{\chi}$ $\widetilde{q} \to q\,\widetilde{\chi}$	7 partons $+ \not{H}_T$
$\widetilde{g}\,\widetilde{g}$	$\widetilde{g} \to q\,\overline{q}\,Z^0\,\widetilde{\chi}$	8 partons $+ \not{H}_T$

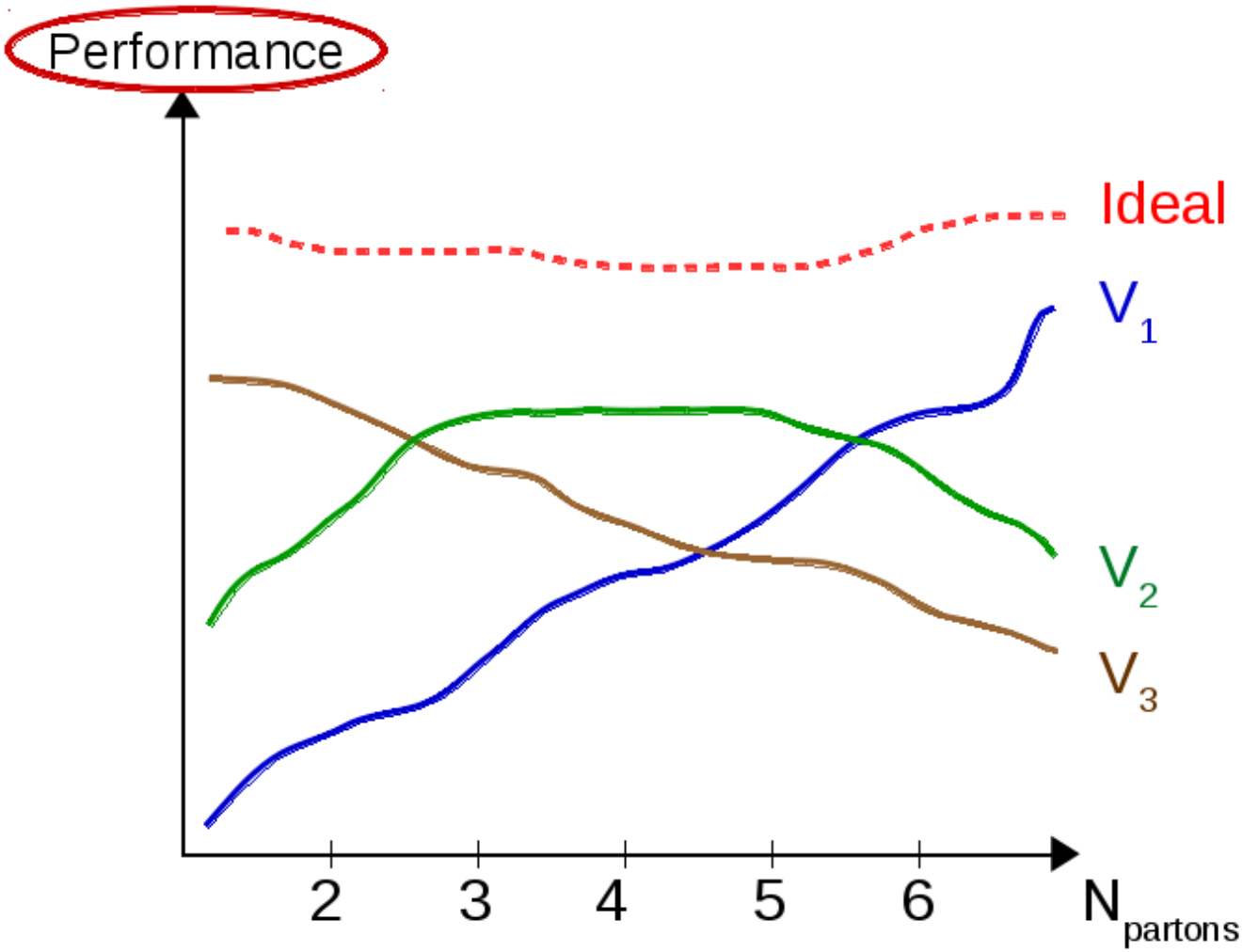
Dissection: the ideal result



Observables

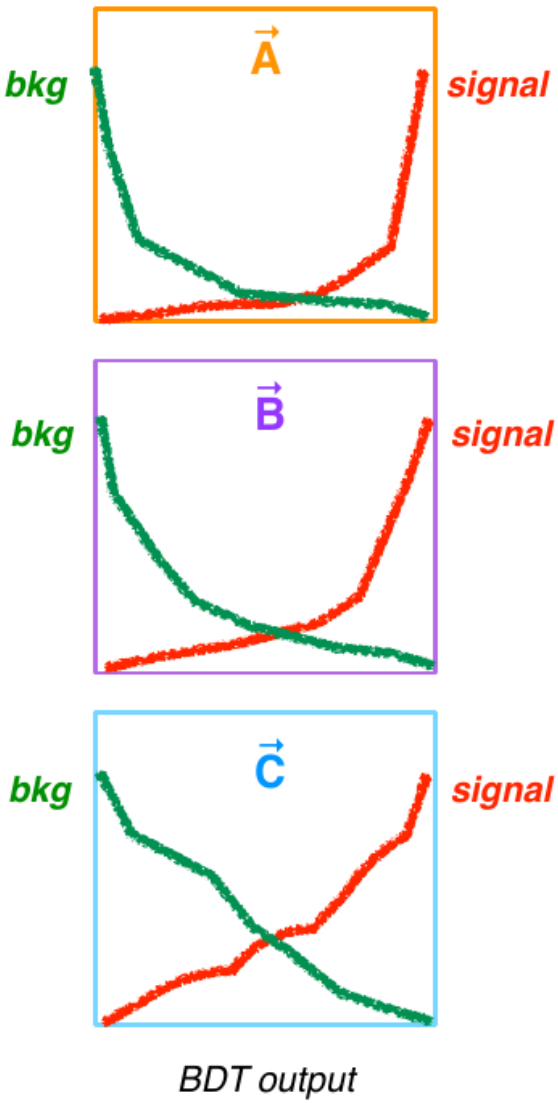
- **"Beginner" observables:**
  - H_T
  - MHT
  - N_{jets}
- **"Intermediate" observables:**
  - $MHT/\sqrt{H_T}$
  - m_{eff}
  - $\sum M_J$
- **"Advanced" observables:**
  - M_{T2}
  - M_{T2}^{CMS}
  - M_R, R
  - α_T

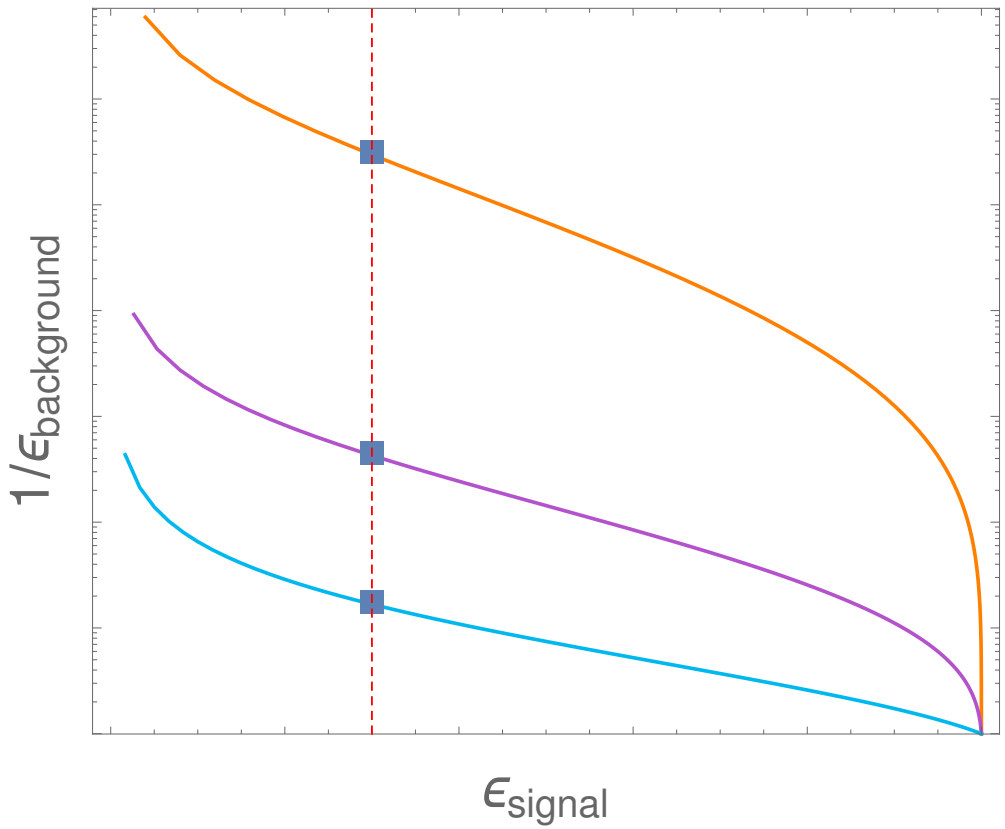
Dissection: the ideal result



Observable performance: ROC curves

- Use Boosted Decision Trees to study correlated variables





Fix ϵ_{signal}, compare background rejection rates

Our procedure

Signals

- Uncompressed study: $m_\chi = 1$ GeV
- Compressed study: $m_\chi = 0.95 m_{\tilde{g}}$

Backgrounds

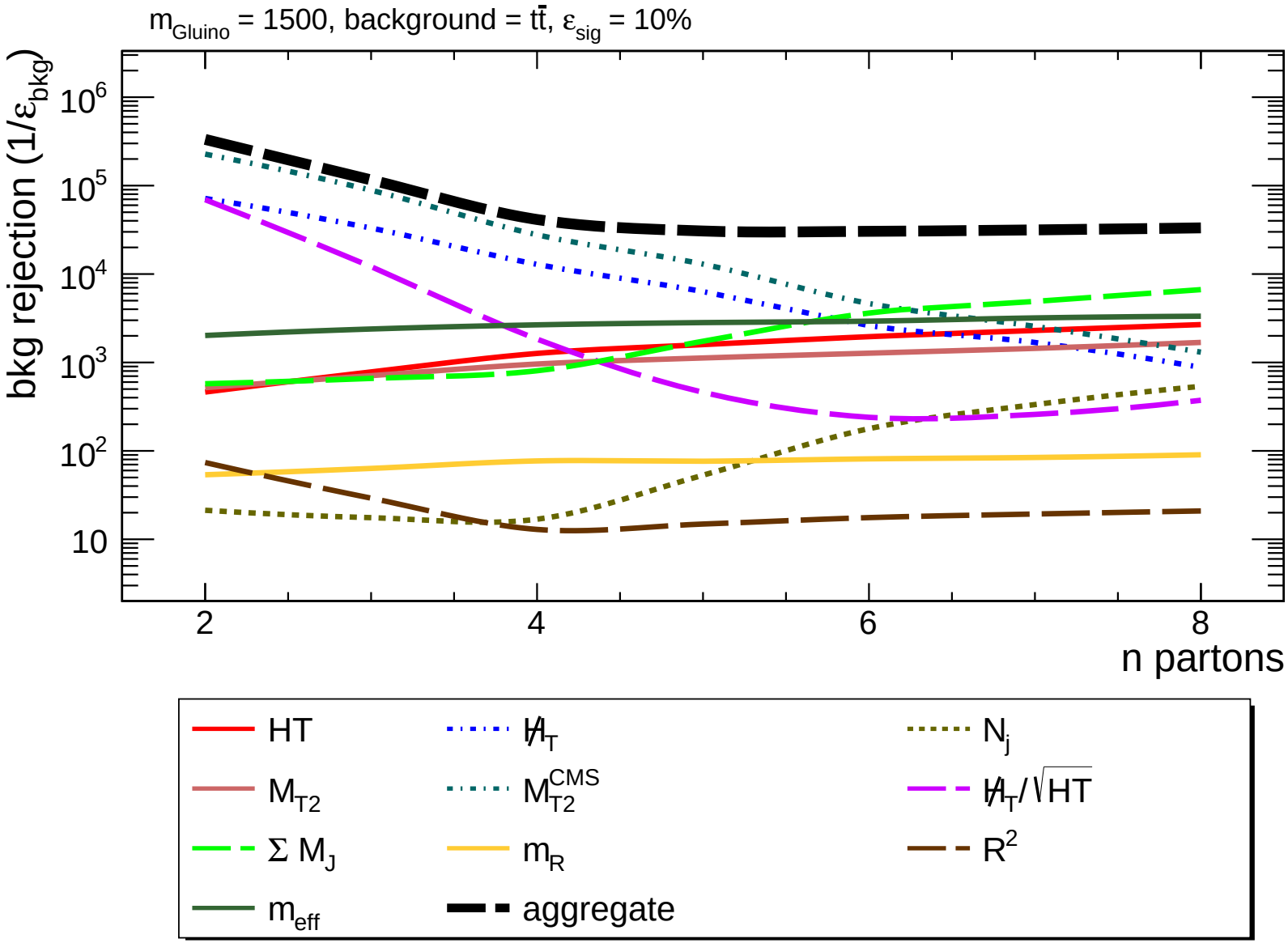
- QCD: 1-4 jets
- W, Z + 1-3 jets
- $t\bar{t}$

Preselection cuts

- MHT $>$ 200 GeV
- $H_T > 500$ GeV
- $\Delta\phi_{j_1 j_2} > 0.4$ ⚠ Weakens the performance of α_T!

Model "ideal" case by throwing all our observables in the BDT

Results: one variable, uncompressed



Individual variable groups

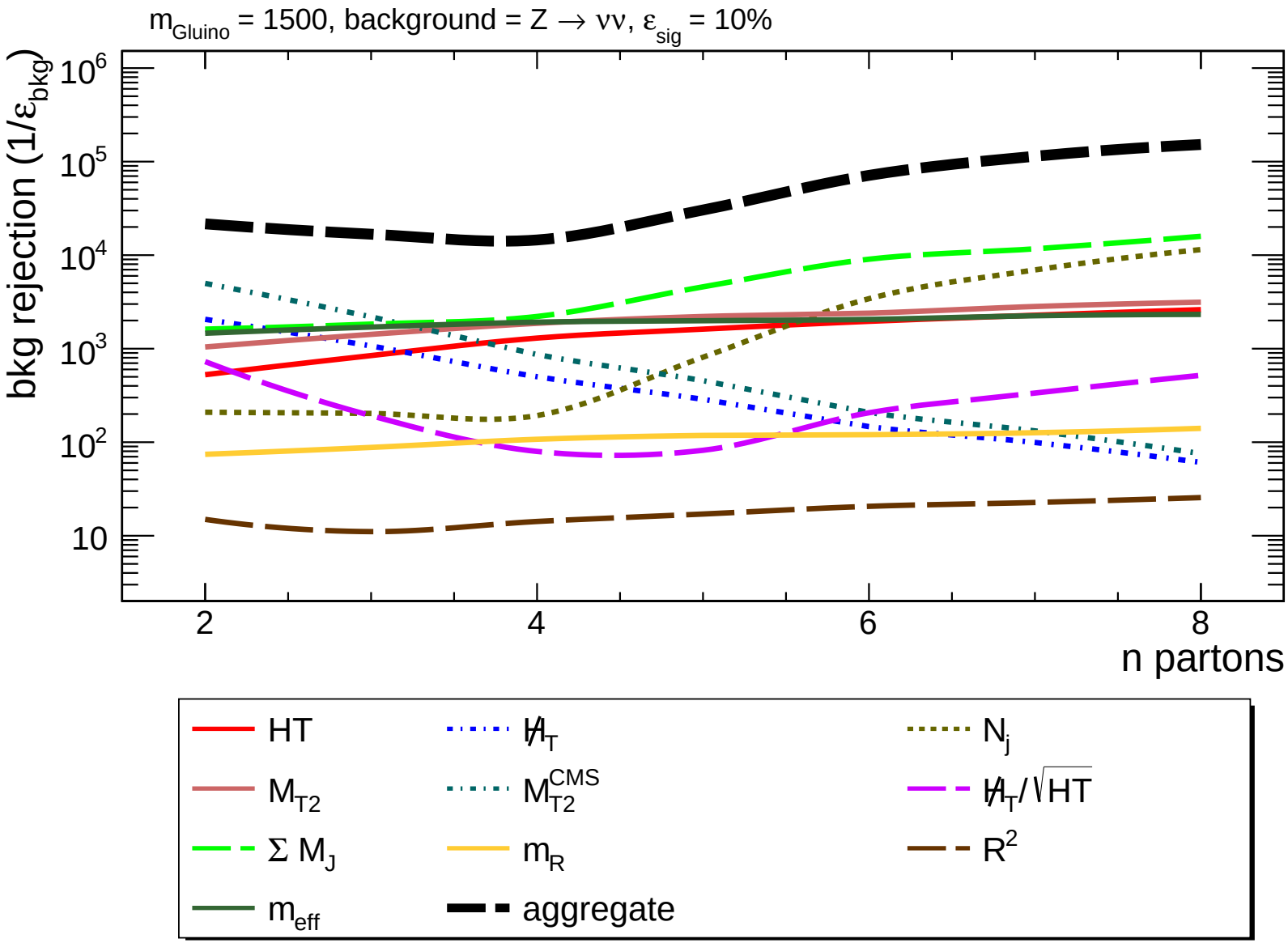
Three main categories of variables

- **Missing energy type**: $\{\text{MHT}, M_{T2}^{\text{CMS}}\}$, sensitive to the invisible "neutralino" states
- **Energy scale type**: $\{H_T, M_{T2}, M_R, m_{\text{eff}}\}$, sensitive to the overall energy scale of the event
- **Energy structure type**: $\{N_{\text{jets}}\}$, sensitive to the structure of the visible energy, here the number of partons

Some "non-beginner" variables probe more than one type $\Rightarrow$ More stable performance over the signal range

- **Hybrid variables:** $\left\{R^2, \text{MHT}/\sqrt{H_T}, M_J\right\}$

Results: one variable, uncompressed



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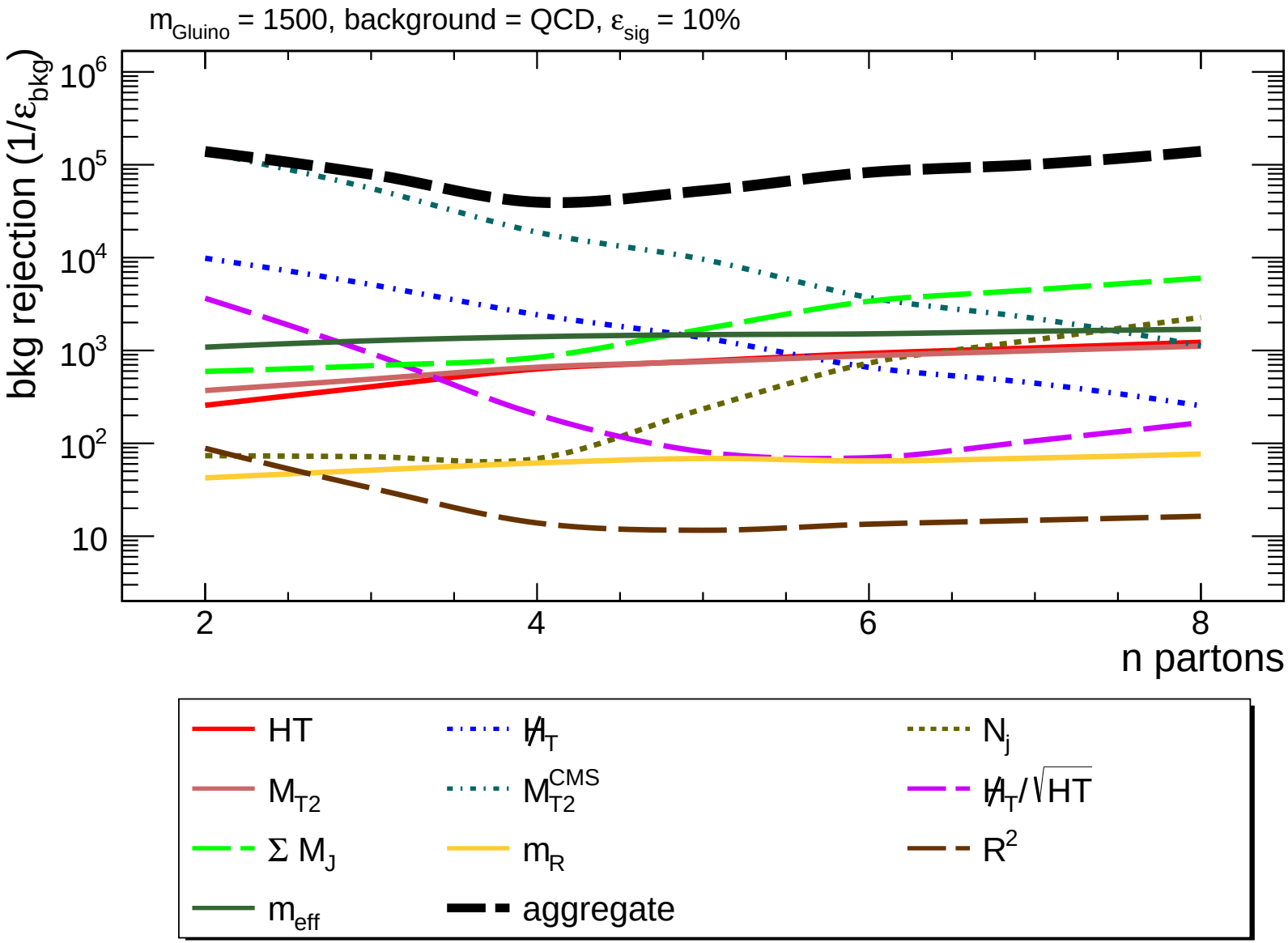
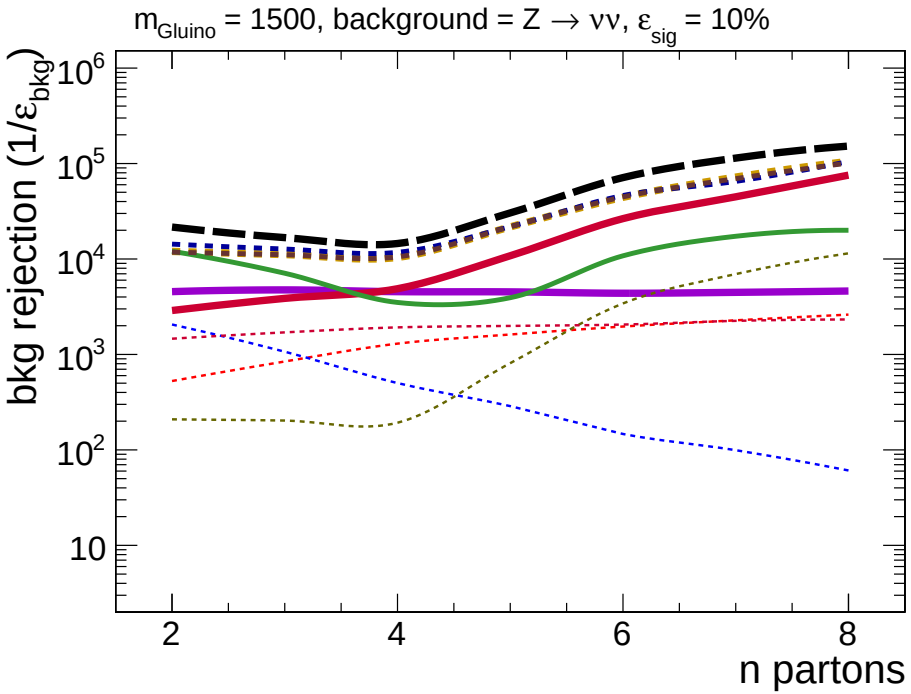
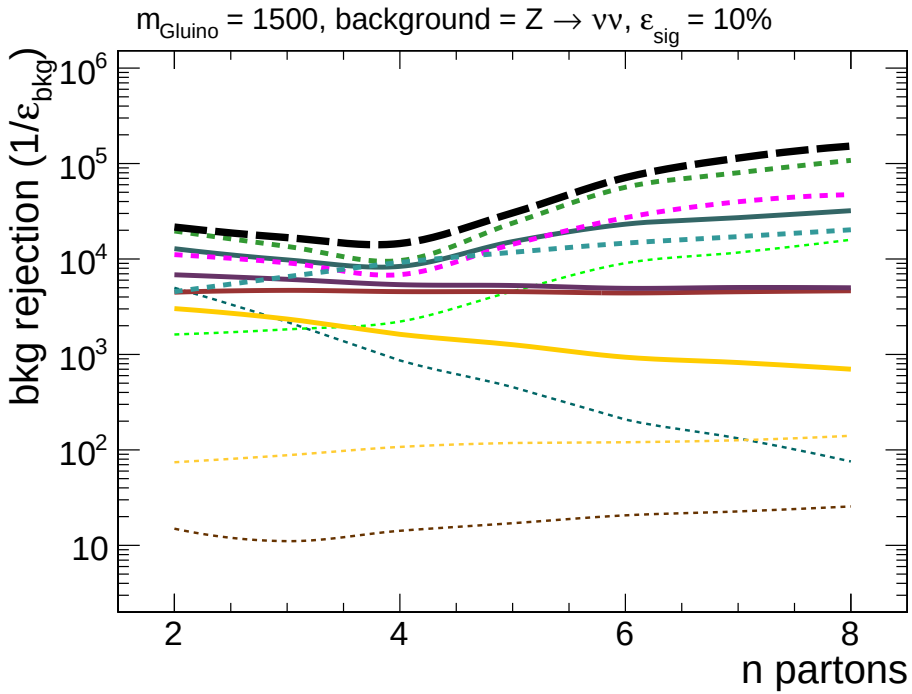
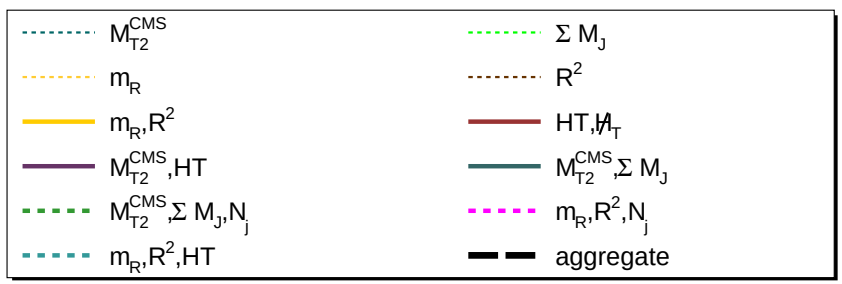


Results: combinations of variables







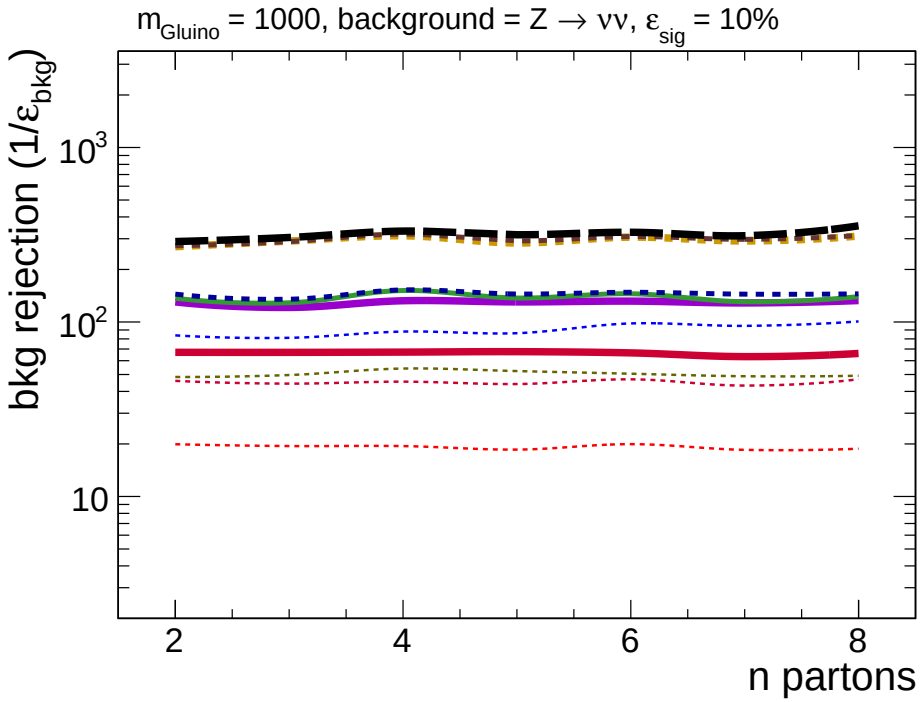
2D: solid lines

3D: thick dashed lines

Uncompressed Signals

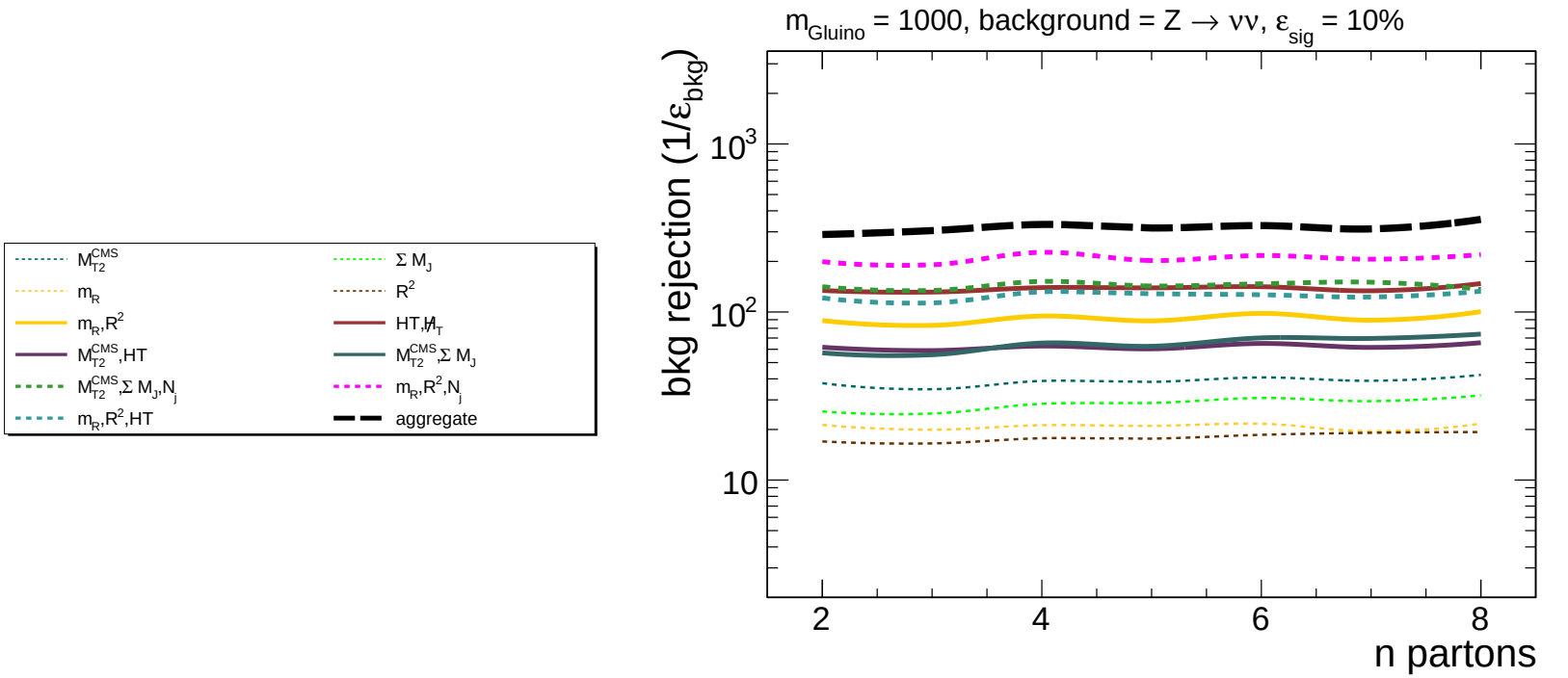
- Combinations of two variables of different types are generally insufficient in one regime
- $\{M_{T2}^{\text{CMS}}, \sum M_J\}$ does best since $\sum M_J$ is a hybrid variable
- Combining one variable of each type can provide "ideal" coverage for all signals and backgrounds
- The "beginner" variables $\{MHT, H_T, N_{\text{jets}}\}$ capture most of the features of the signal
- Slight improvement possible using M_{T2}^{CMS} and/or $\sum M_J$

Compressed spectra



- Jets from the gluino decay escape detection
- As in the uncompressed case $\{MHT, H_T, N_{\text{jets}}\}$ performs best
- Dependence in N_{jets}: ISR from the initial gluons (pair-production of a colored state) ⇒ 2D searches should suffice for "WIMP" states

Compressed spectra



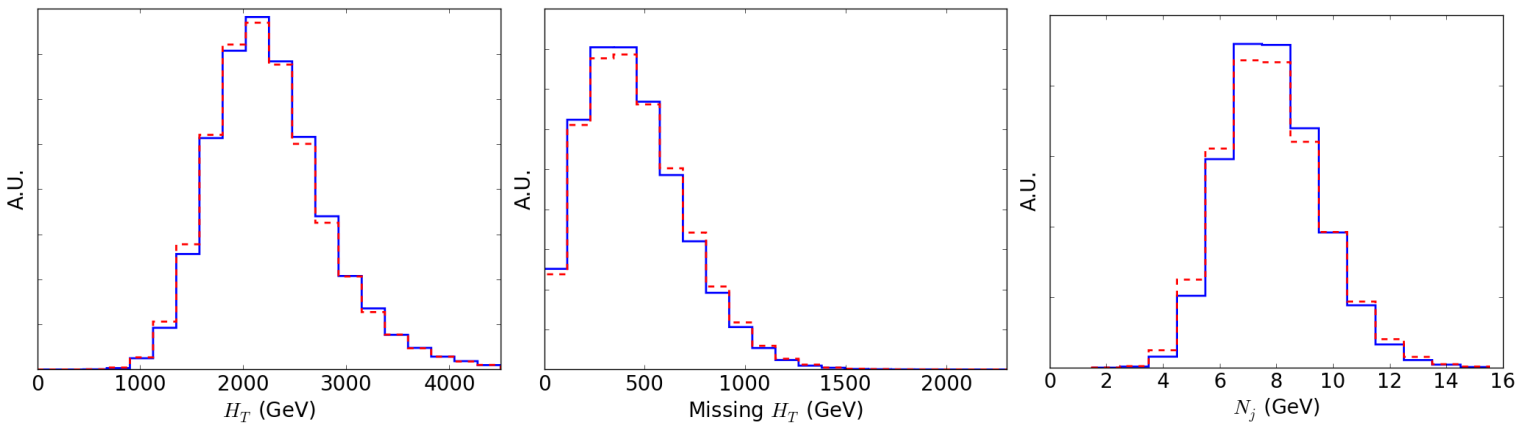
- Jets from the gluino decay escape detection
- As in the uncompressed case $\{MHT, H_T, N_{\text{jets}}\}$ performs best Razor does well here too.
- Dependence in N_{jets}: ISR from the initial gluons (pair-production of a colored state) ⇒ 2D searches should suffice for "WIMP" states

Summary

- The *n*-body extended simplified models allow for a compact representation of the performance of a search in signal space
- Global analysis of the variables used in jets plus MET searches for a wide range of signals
- Combining three variables is enough to cover all the background and signal space
- Consistency of our formalism: need to work on mapping models with cascades to n-body models
- Extend the formalism to more LHC searches: final state vector bosons, leptons, etc...

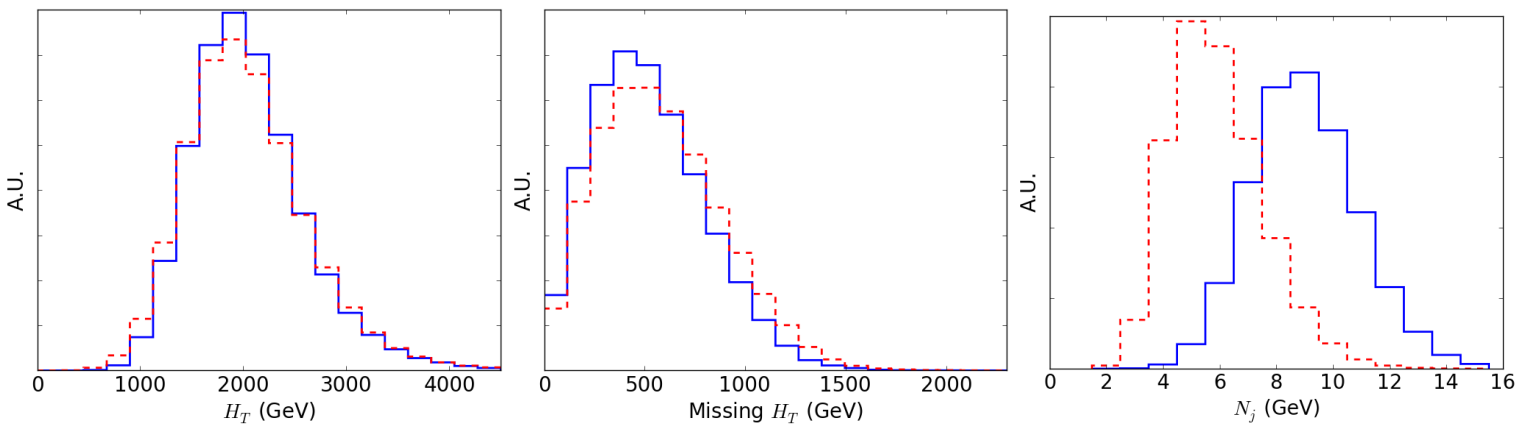
On-shell intermediate particles

$\tilde{g} \to q\bar{q}(Z \to q\bar{q})\tilde{\chi}$ vs 3-parton simplified model



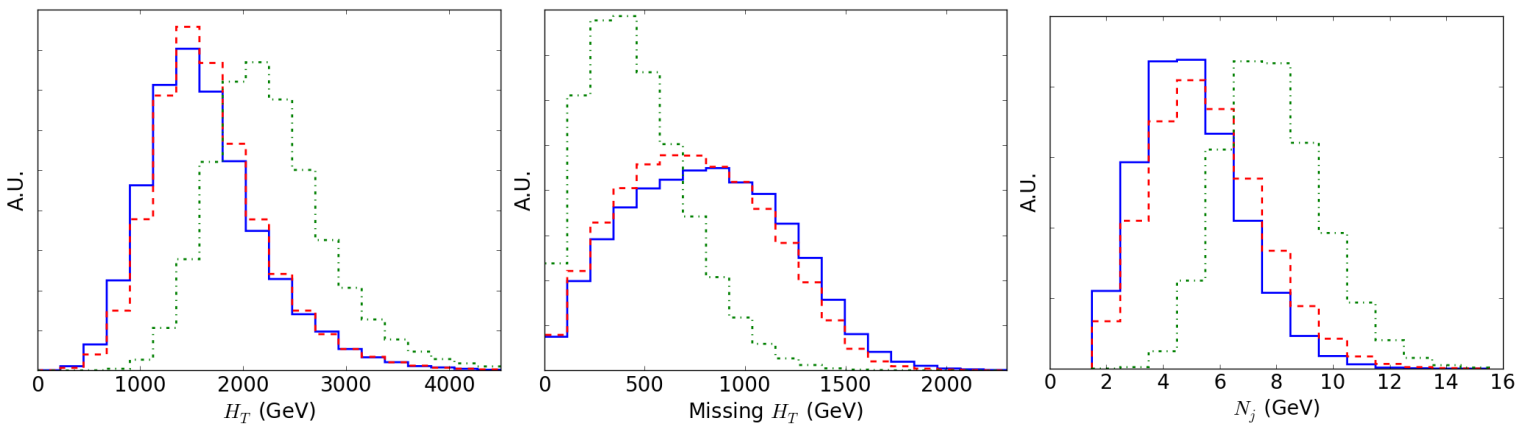
On-shell intermediate particles

$\tilde{g} \to t\bar{t}\tilde{\chi}$ vs 2-parton simplified model

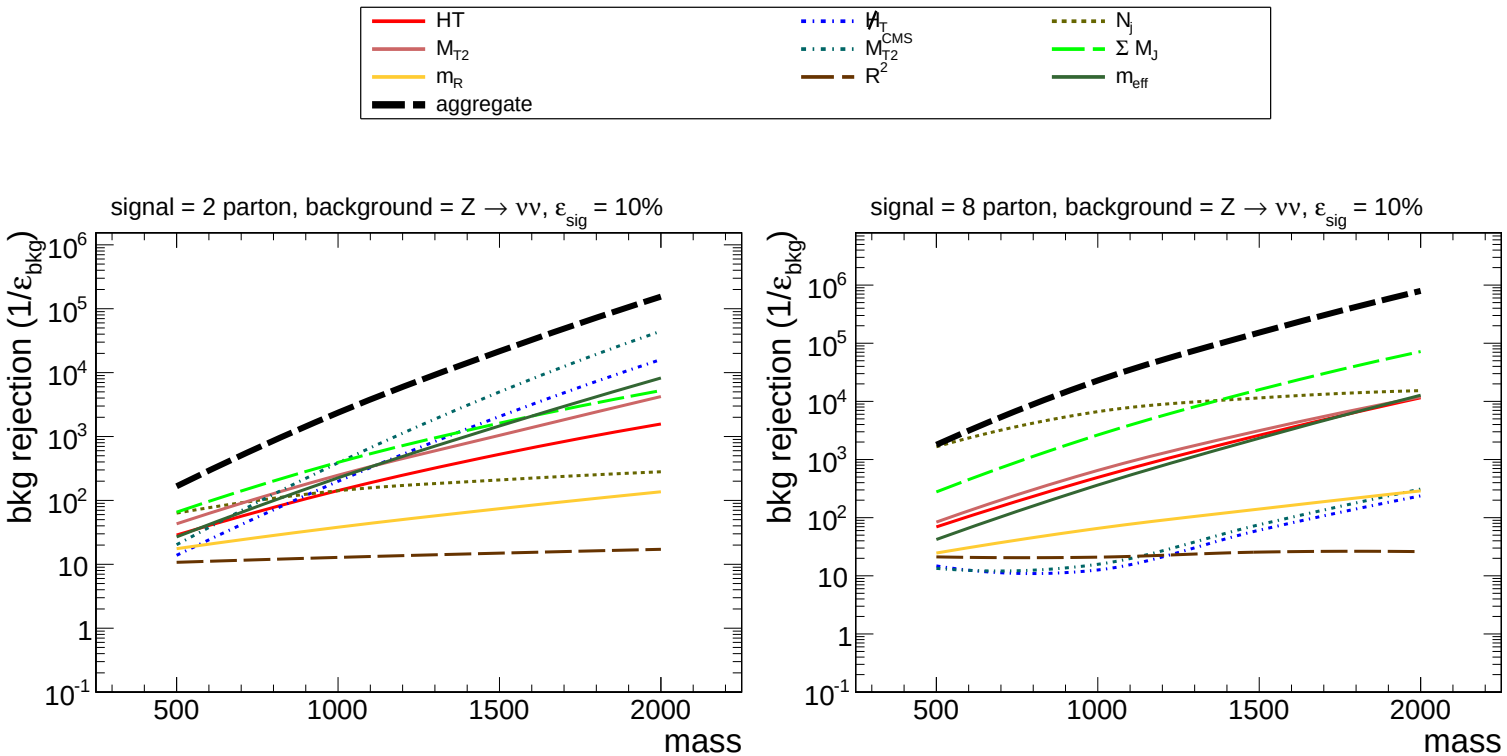


On-shell intermediate particles

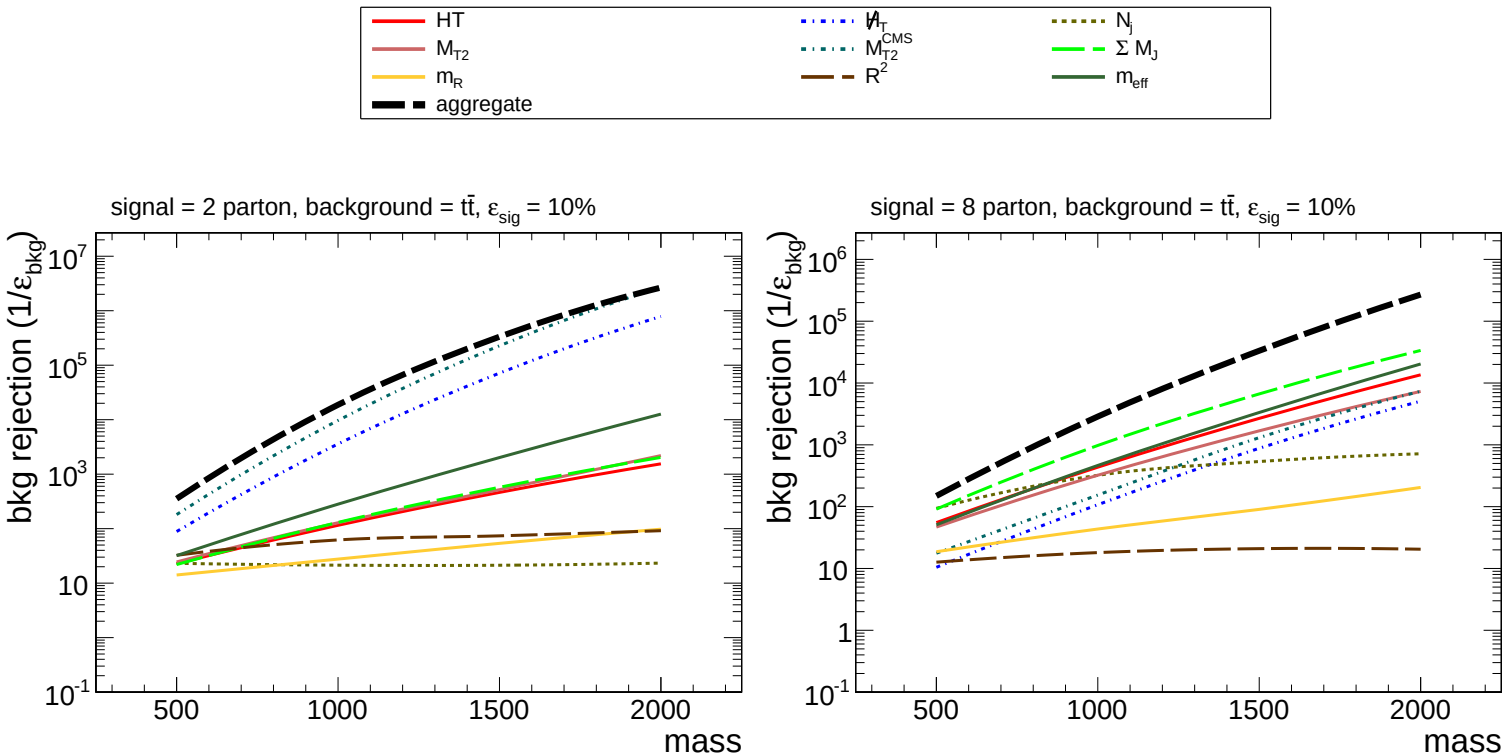
$\tilde{t} \to t\tilde{\chi}$ vs 1-parton simplified model vs 3-body simplified model



Mass dependence: $Z \to \nu\nu$



Mass dependence: $t\bar{t}$



Mass dependence: QCD