Sleptons without hadrons

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Based on 1901.0XXXX

Builds on work in 1805.09335, 1812.08750 (Pascoli, Ruiz, Weiland)

Brief outline

- Jet vetoes in (B)SM studies at the LHC
- Motivating a dynamic veto for BSM studies
- Right-handed smuons at the LHC

Jet vetoes in (B)SM studies at the LHC

In studies of uncolored physics at hadron colliders it is often very useful to veto hadronic activity from the primary IP in order to distinguish the process of interest from e.g. a huge QCD background.

While straightforward at the analysis-level, there are several subtleties involved which make this a rich field to study on the theory side.

Jet vetoes in (B)SM studies at the LHC

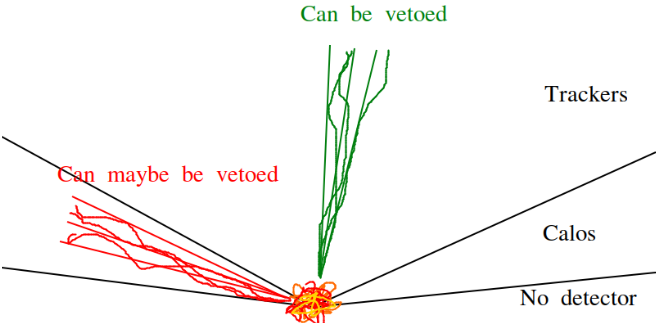
Cross sections which are exclusive in additional QCD radiation above a scale p_T^{veto} at hadron colliders are sensitive to Sudakov corrections of the form:

$$\alpha_S^n \log^m \left(\frac{p_T^{\text{veto}}}{Q} \right) \tag{1}$$

where $m \leq 2n$ and Q is the hard scale of the process.

$\Rightarrow$ If $Q \gg p_T^{\text{veto}}$, these terms can be significant and need to be resummed for accurate predictions and to avoid large scale uncertainties.

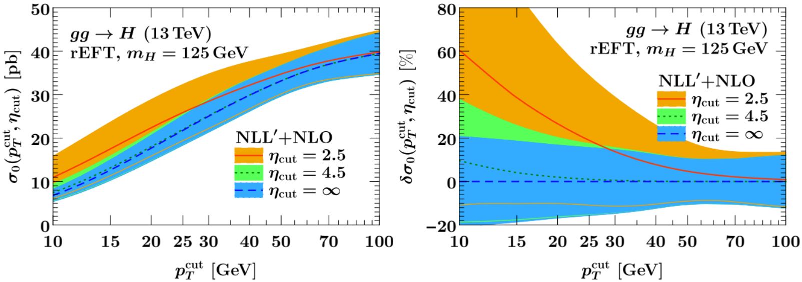
Jet vetoes in (B)SM studies at the LHC



Experimentally it is difficult to distinguish jets from the primary IP from pileup outside of the trackers $\Rightarrow$ jet veto often only applied within $|\eta| \lesssim 2.5$

Jet vetoes in (B)SM studies at the LHC

This leads to additional corrections $\mathcal{O}(Qe^{-\eta_{\rm cut}}/p_T^{\rm veto})$ which again can spoil the perturbative expansion:



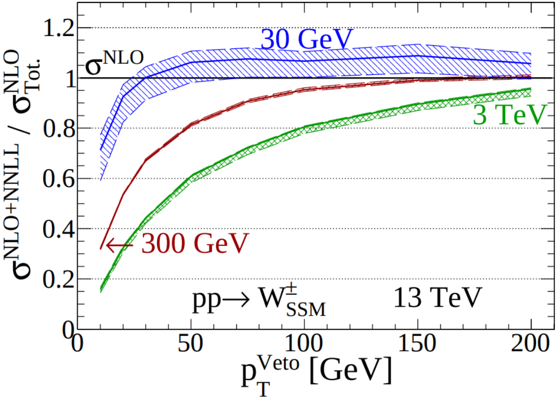
Taken from Michel, Pietrulewicz, Tackmann (1810.12911).

Jet vetoes in (B)SM studies at the LHC

The fundamental problem here is the appearance of a large hierarchy of scales $Q \gg p_T^{\mathrm{veto}}$ between the hard process and the relatively soft jets which need to be vetoed in order to control background processes.

The problem gets particularly bad for searches for heavy new physics where Q can reach the TeV-range: not only is it necessary to resum in order to control the perturbative uncertainty, but the size of the correction is numerically significant and reduces the signal efficiency ("heavier particles generate more radiation").

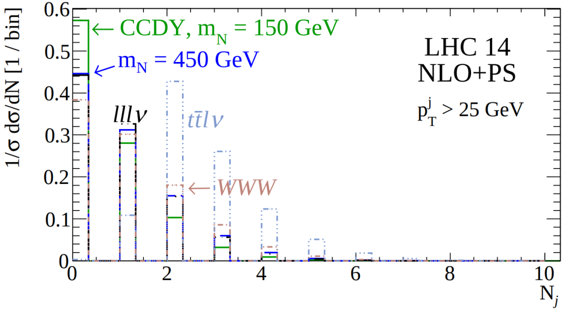
Jet vetoes in (B)SM studies at the LHC



Taken from Fuks, Ruiz (1701.05263).

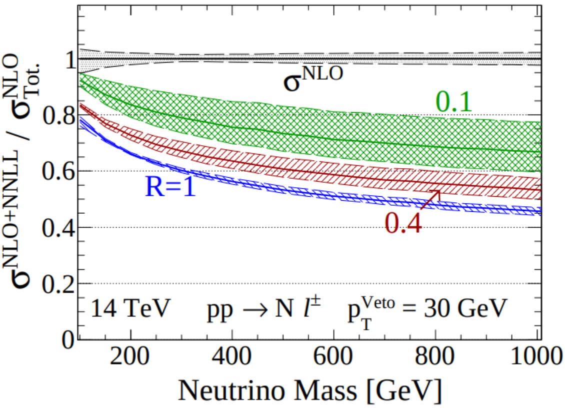
Jet vetoes in (B)SM studies at the LHC

Taking a search for heavy neutrinos as a benchmark:



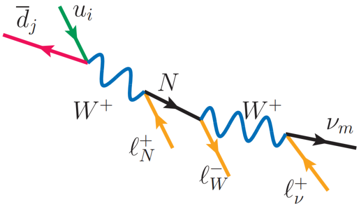
Jet vetoes in (B)SM studies at the LHC

Taking a search for heavy neutrinos as a benchmark:



Motivating a dynamic veto for BSM studies

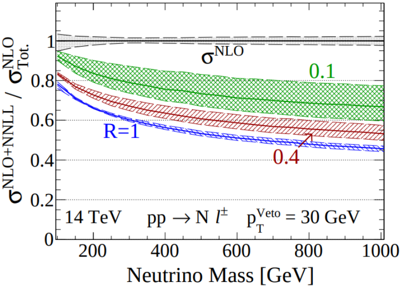
An elegant and simple way to alleviate these problems is to promote p_T^{veto} to a dynamic variable which is chosen such that $Q \sim p_T^{\mathrm{veto}}$ in order to make $\log\left(\frac{p_T^{\mathrm{veto}}}{Q}\right) \ll 1$:

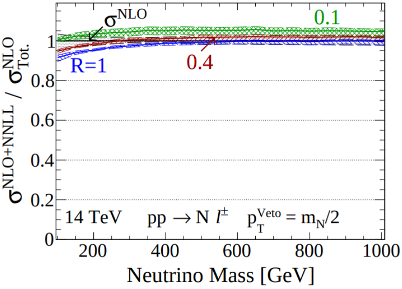


- $p_T^{\ell_N} \sim \frac{m_N}{3}$
- $p_T^{\ell_W} \sim \frac{m_N}{2}$
- $p_T^{\ell_\nu} \sim \frac{m_N}{4}$

Motivating a dynamic veto for BSM studies

Setting $p_T^{\text{veto}} = m_N/2$ drastically improves the situation (it is a "safe jet veto"):





Motivating a dynamic veto for BSM studies

Motivating a dynamic veto for BSM studies

In terms of backgrounds, the most important one to control is often $t\bar{t} + X$ production. Looking at the characteristic p_T in a leptonic top decay at rest,

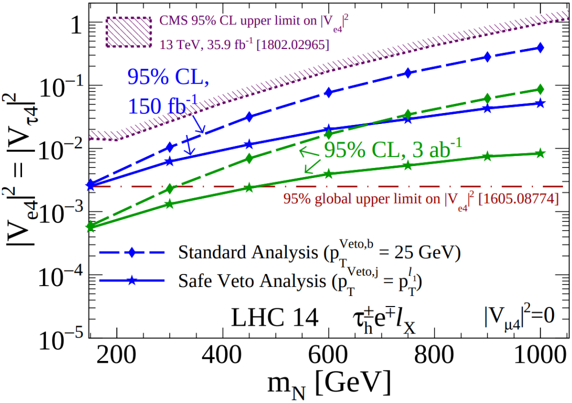
- $p_T^{\ell} \sim m_t(1 + m_W^2/m_t^2)/4 \approx 50 - 55$ GeV
- $p_T^{b} \sim m_t(1 - m_W^2/m_t^2)/2 \approx 65 - 70$ GeV

$\Rightarrow$ Tying the jet veto scale to a lepton p_T will still kill most of the top pair backgrounds.

For even better results, could apply veto on $H_T \sim 2p_T^b$ rather than the leading jet p_T?

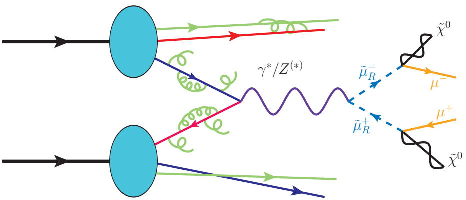
Motivating a dynamic veto for BSM studies

Using $p_T^{\text{veto}} = p_T^{\ell_1}$ in a realistic study shows a significant improvement at large m_N thanks to higher signal efficiency while retaining control of the backgrounds (from 1805.09335):



Right-handed smuons at the LHC

Restricting the measures of hadronic and leptonic transverse activity to exclusive observables is not necessary. We will study Drell-Yan production of right-handed smuons as a benchmark scenario with several permutations of dynamic veto:



Hadronic activity:

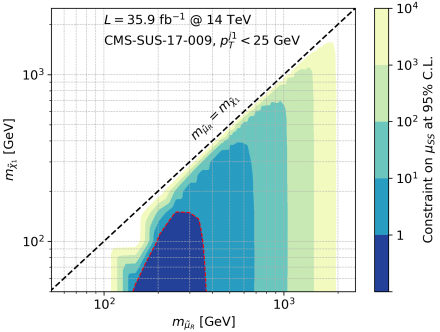
- $p_T^{j_1}$
- H_T

Leptonic activity:

- $p_T^{\ell_1}$
- $p_T^{\ell_2}$
- S_T

Right-handed smuons at the LHC

We reproduce the recent CMS search CMS-SUS-17-009 with our own background predictions, validated against the results of CMS, as a benchmark analysis using a fixed jet veto:



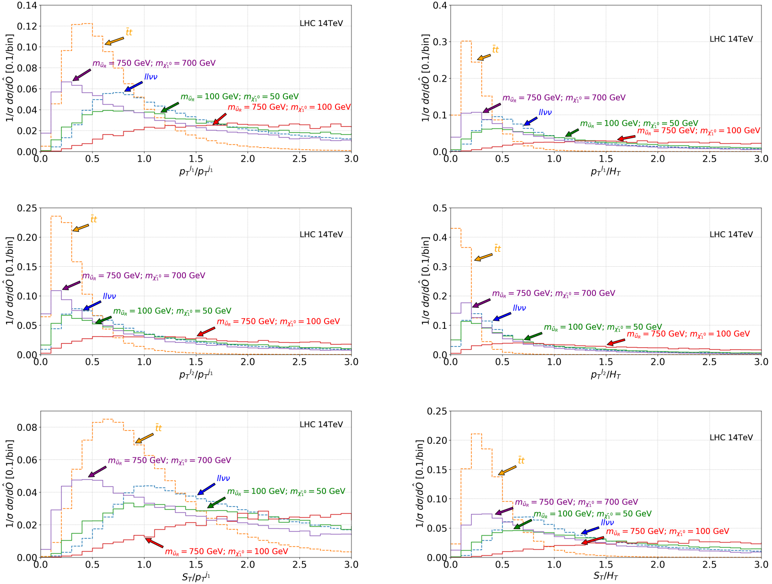
Analysis Object Criteria at $\sqrt{s} = 14$ TeV:
$p_T^{e\ (\mu)\ [\tau_h]\ \{j\}} > 10\ (10)\ [20]\ \{25\}$ GeV,
$|\eta^{e\ (\mu)\ [\tau_h]\ \{j\}}| < 2.4$, anti-$k_T$ w./ $R = 1$
$\Delta R_{\ell_m,\ell_n} > 0.4$, $\Delta R_{\ell j} > 0.4$

Common Analysis Requirements:
$N(\mu^+) = 1$, $N(\mu^-) = 1$, $N(\ell) = 2$,
$m_{\mu\mu} > 20$ GeV, $|m_{\mu\mu} - M_Z| > 15$ GeV,
$M_{T2} > 90$ GeV, MET > 100 GeV,
Binned signal region: MET $\in$ $(a)[100, 150)$, $(b)[150, 225)$, $(c)[225, 300)$, $(d)[300, \infty)$ GeV

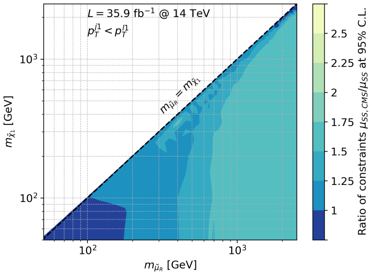
Benchmark (Static) Jet Veto Analysis Requirements:
$p_T^{\mu_1\ (\mu_2)} > 50\ (20)$ GeV, $p_T^{\text{Veto}} = 25$ GeV

Dynamic Jet Veto Analysis Requirements:
Overlapping Signal Categories:
(a) $p_T^{\text{Veto}} = p_T^{\ell_1}$ (b) $H_T^{\text{Veto}} = p_T^{\ell_1}$
(c) $p_T^{\text{Veto}} = S_T$ (d) $H_T^{\text{Veto}} = S_T$
(e) $p_T^{\text{Veto}} = p_T^{\ell_2}$ (f) $H_T^{\text{Veto}} = p_T^{\ell_2}$

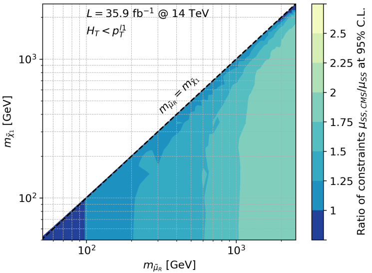
Right-handed smuons at the LHC



Right-handed smuons at the LHC

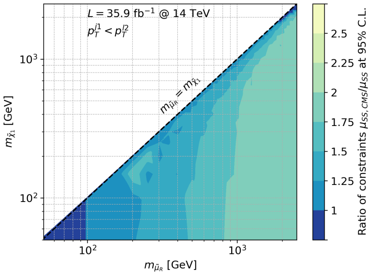


$$p_T^{j_1} < p_T^{\ell_1}$$

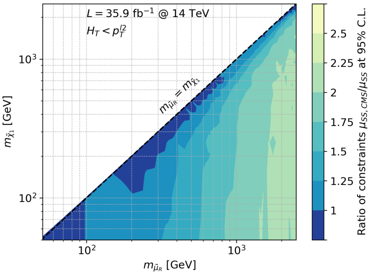


$$H_T < p_T^{\ell_1}$$

Right-handed smuons at the LHC

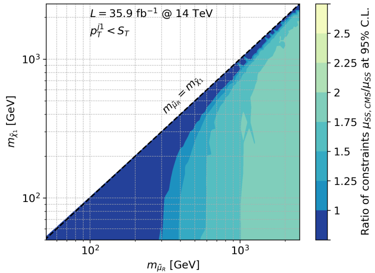


$$p_T^{j_1} < p_T^{\ell_2}$$

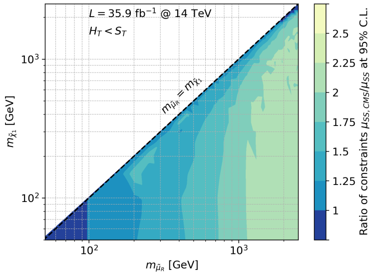


$$H_T < p_T^{\ell_2}$$

Right-handed smuons at the LHC



$p_T^{j_1} < S_T$



$H_T < S_T$

Conclusions

- Jet vetoes are highly useful but require resummed calculations for accurate predictions
- Dynamically relating the veto scale to the hard process is a promising avenue to reduce the theoretical complexity of the veto
- Backgrounds are under good control for reasonable choices of dynamic veto
- Using inclusive observables when designing the dynamic veto is possible
- Significant improvements in sensitivity can be achieved for realistic slepton searches