Hunting coloured scalars with machine learning

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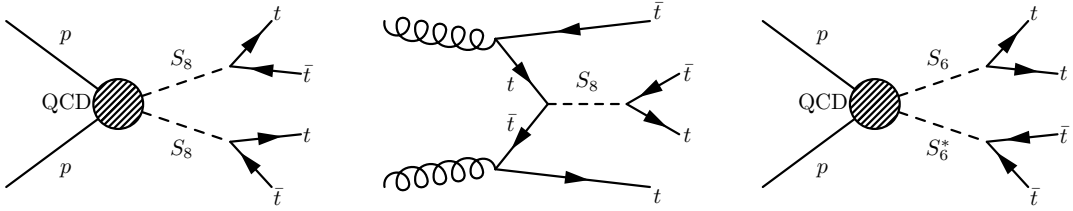
Model

Simplified model: Extend the SM by S_8 or S_6 with couplings to top quarks:



(motivated by Composite Higgs models)

Preselection cuts

Design a NN-based search for

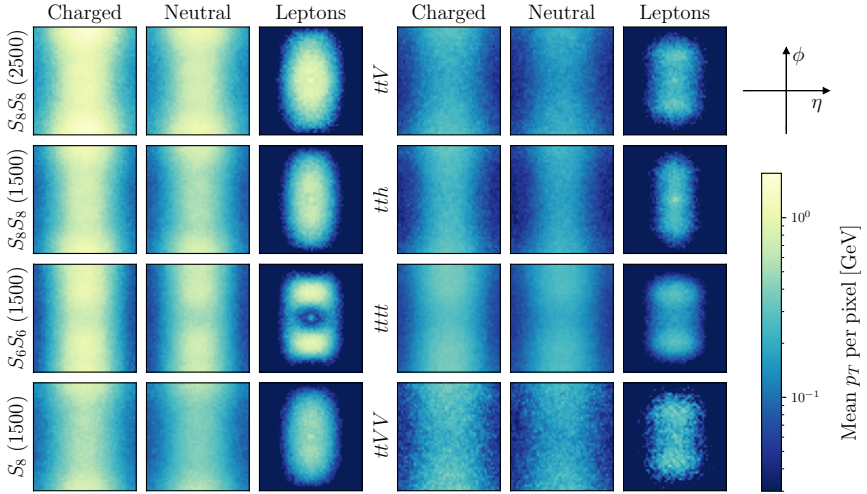
$$t\bar{t}t\bar{t} \to (W^+b)(W^-\bar{b})(W^+b)(W^-\bar{b}) \to \ell^\pm\ell^\pm + 4b + 4j + \not{p}_T,$$

Preselection:

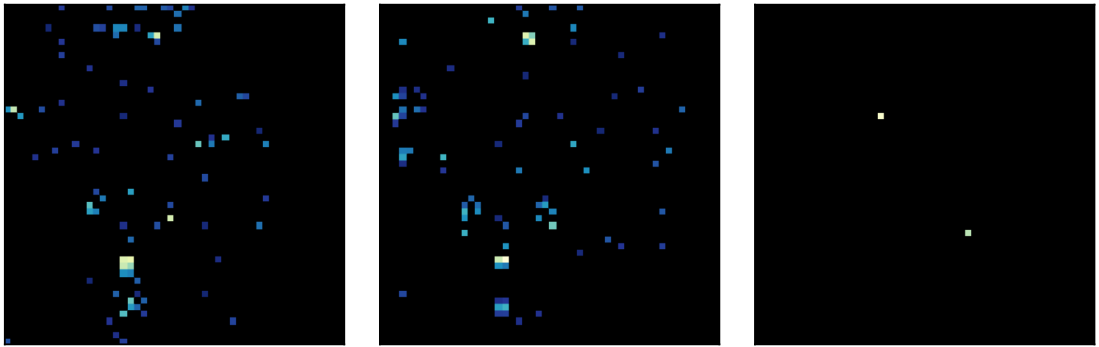
- 2 same-sign leptons
- ≥ 3 light jets
- ≥ 3 b-tagged jets
- and some kinematic cuts

$\Rightarrow$ Backgrounds: $tttt$, ttV, $ttVV$, tth

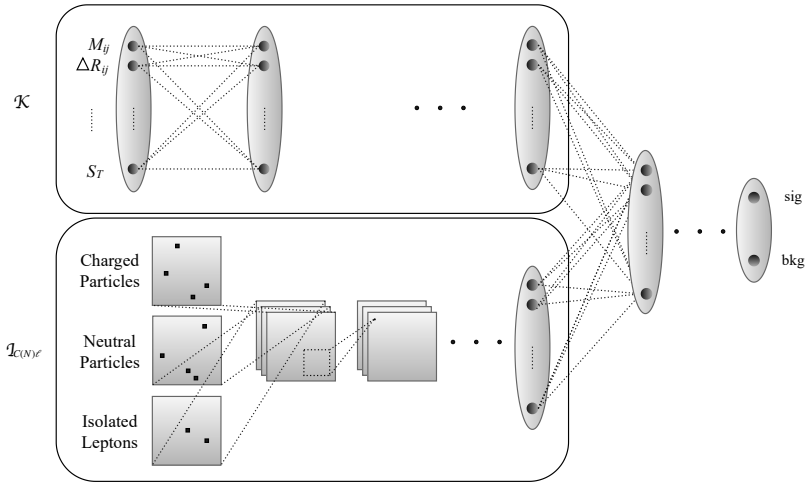
Jet images


Charged
Neutral
Leptons
Charged
Neutral
Leptons
S_8S_8 (2500)
S_8S_8 (1500)
S_6S_6 (1500)
S_8 (1500)
$t\bar{t}V$
$t\bar{t}h$
$t\bar{t}t\bar{t}$
$t\bar{t}VV$
ϕ
η
10^0
10^{-1}
Mean p_T per pixel [GeV]

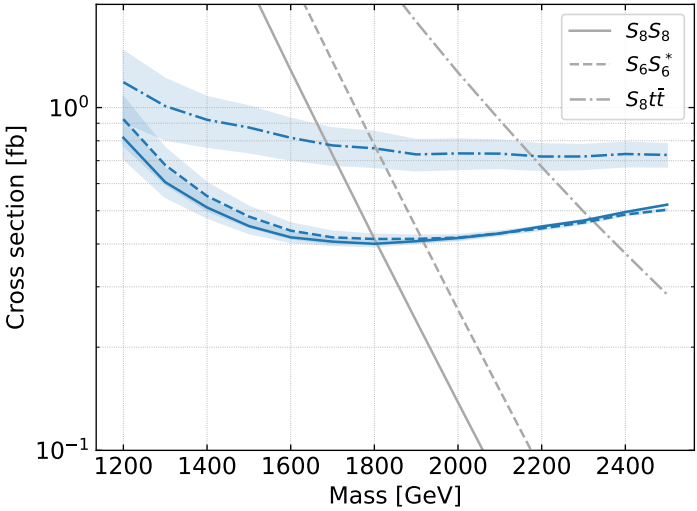
Jet images



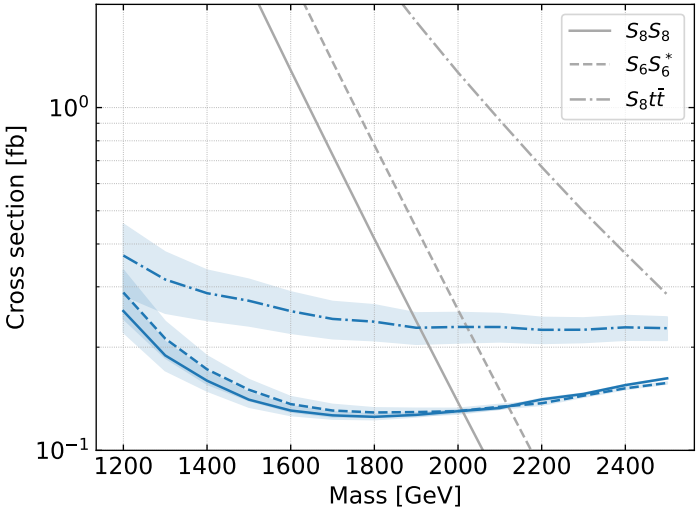
Neural network architecture



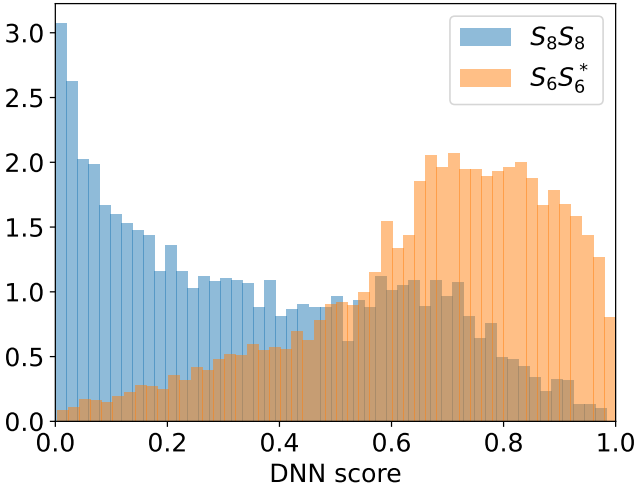
Expected discovery reach at 3 ab^{-1}



Expected exclusion limit at 3 ab^{-1}

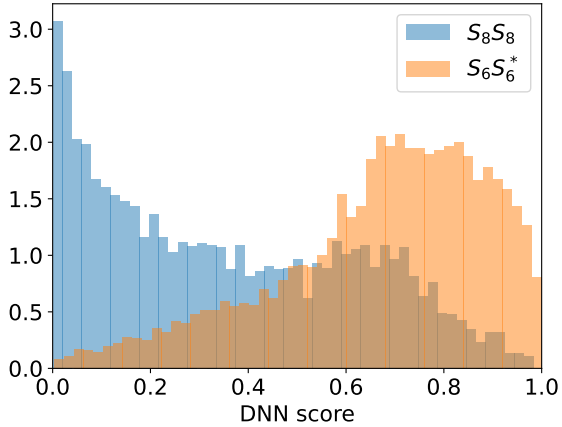


Identifying the signal process: octet or sextet?



Identifying the signal process: octet or sextet?

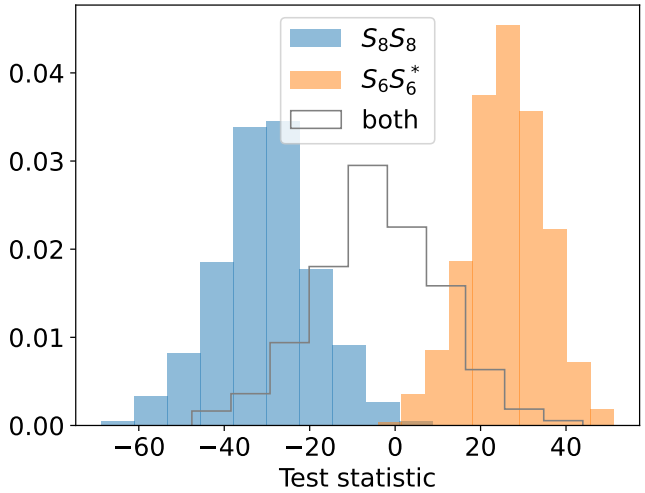
Given DNN scores $\{x_i\}$, which distribution did they come from?



$$\mathcal{L}_j(\{x_i\}) = \prod_{i=1}^{N} f_j(x_i)$$

$$t = -2 \ln \frac{\mathcal{L}_1(\{x_i\})}{\mathcal{L}_2(\{x_i\})}$$

Identifying the signal process: octet or sextet?



Summary

With computer vision tools we can

- search for processes with busy final states,
- discover coloured scalars in four top quark events,
- identify the underlying resonance.
- More details: `arXiv:2506.04318`

Backup

Technical details

- Simplified models implemented in FeynRules
- Generate events with MadGraph5 at LO or NLO
- PDF set NNPDF 3.0
- Showering with Pythia8
- Detector simulation with Delphes
- Machine learning with PyTorch

Pile-up (different signal: 2304.09195)