A generic anti-QCD tagger

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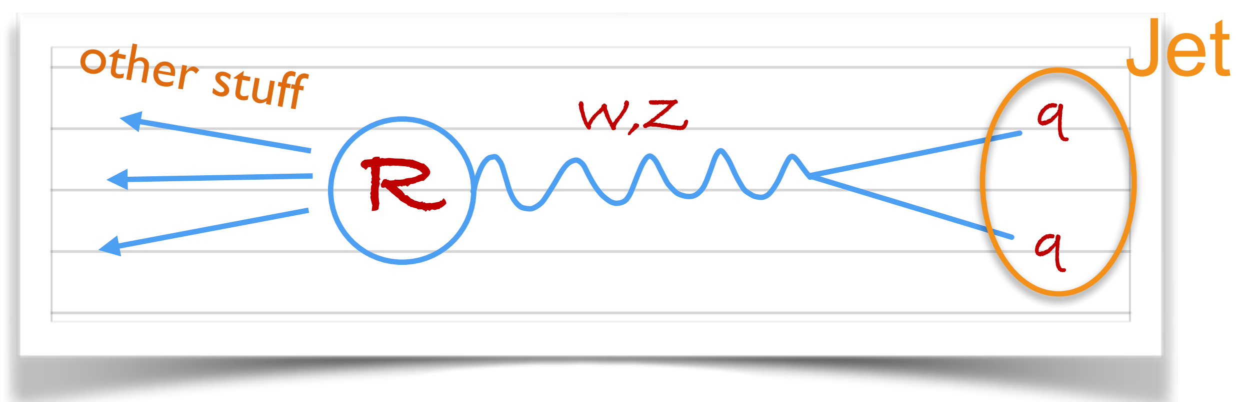
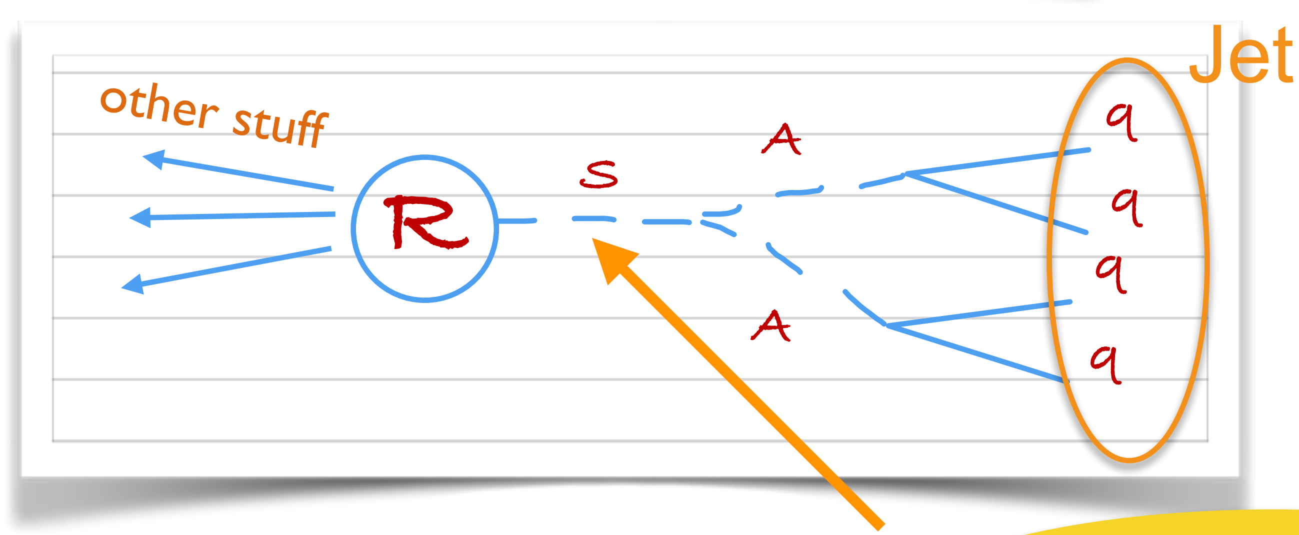
Motivation in brief

- New physics may not give nice leptonic signals
  - Example of model given at the end
- Cascade decays of heavy resonances often give jets as final state object
  - single cascade



searched for by ATLAS & CMS

  - multiple cascade



uncovered

\`stealth boson´
JAAS 1705.07885

It turns out that standard dedicated tools that are used to `tag´ 2-pronged decays [from W/Z bosons] are not able to detect multi-pronged decays [stealth bosons]

It is compulsory to develop generic tools that are sensitive to various types of new physics signals

Main idea: instead of focusing on the signal, which we don't know how it is, we focus on background, which we know well.

Proof of concept: first generic anti-QCD tagger described here. Further possibilities can be developed…

JAAS, Collins, Mishra, 1709.01087

Generic anti-QCD tagger

Machine learning techniques allow to build generic anti-QCD taggers that efficiently discriminate multipronged jets [considered as signals] against jets from quarks and gluons [considered as background].

These taggers use as input a generalised set of variables measuring the jet *N*-subjettiness [i.e. how it looks *N*-pronged] Datta, Larkoski, 1704.08249

$$\tau_N^{(\beta)} = \frac{1}{p_{T\,J}} \sum_i p_{Ti} \min\left\{\Delta R_{1i}^{\beta}, \Delta R_{2i}^{\beta}, \ldots, \Delta R_{Ni}^{\beta}\right\}$$

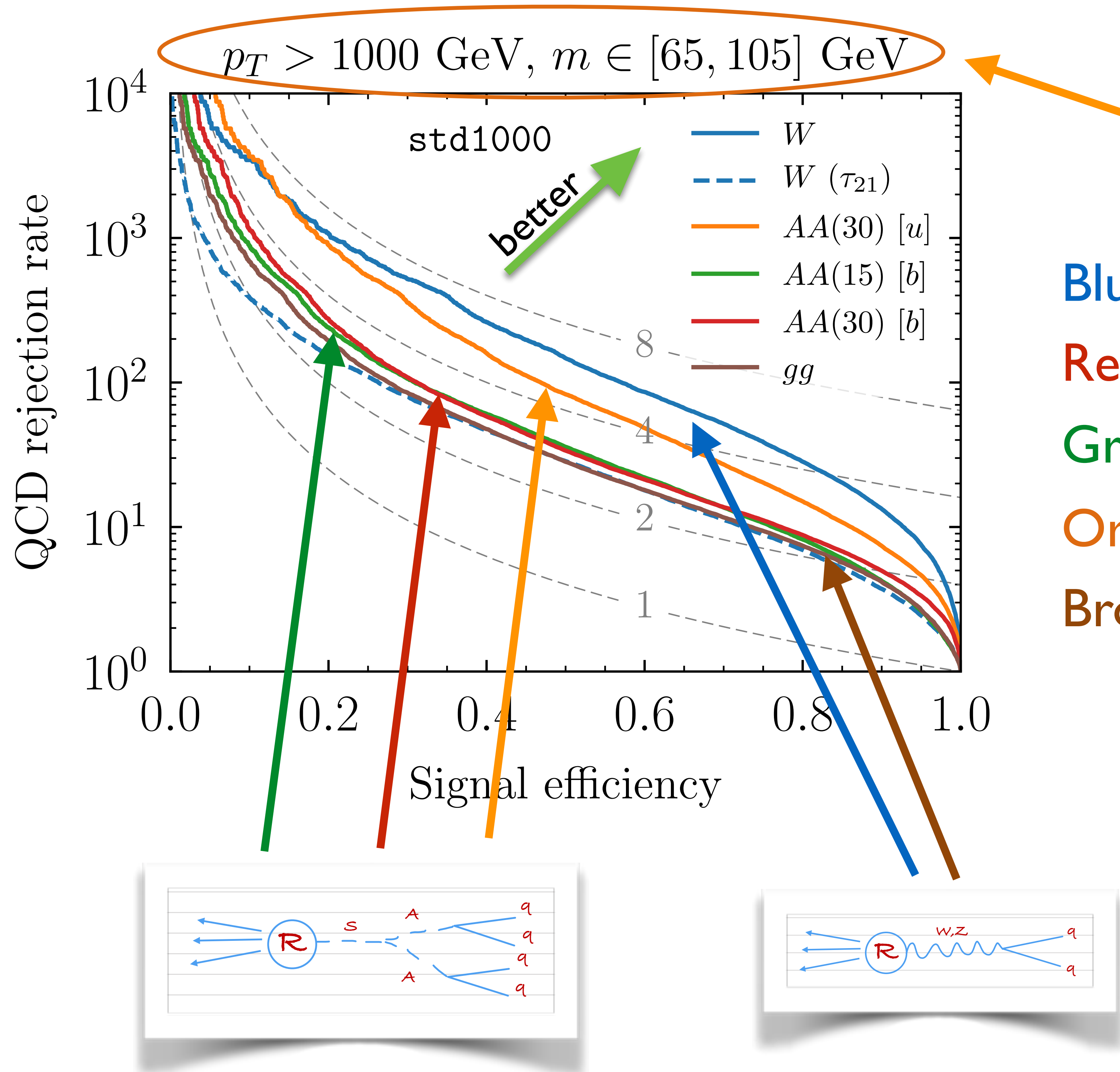
of which the commonly used τ_{21} corresponds to τ_2^1/τ_1^1.

These variables are the input to a neural network that is trained using

- signals: jets with 2, 3 and 4-pronged decays, model-agnostic.
- background: jets from quarks and gluons.

And the tagger even learns to identify signals for which it is not trained.

Example: tagger performance for particles with M = 80 GeV



training intervals

Blue: *W* bosons

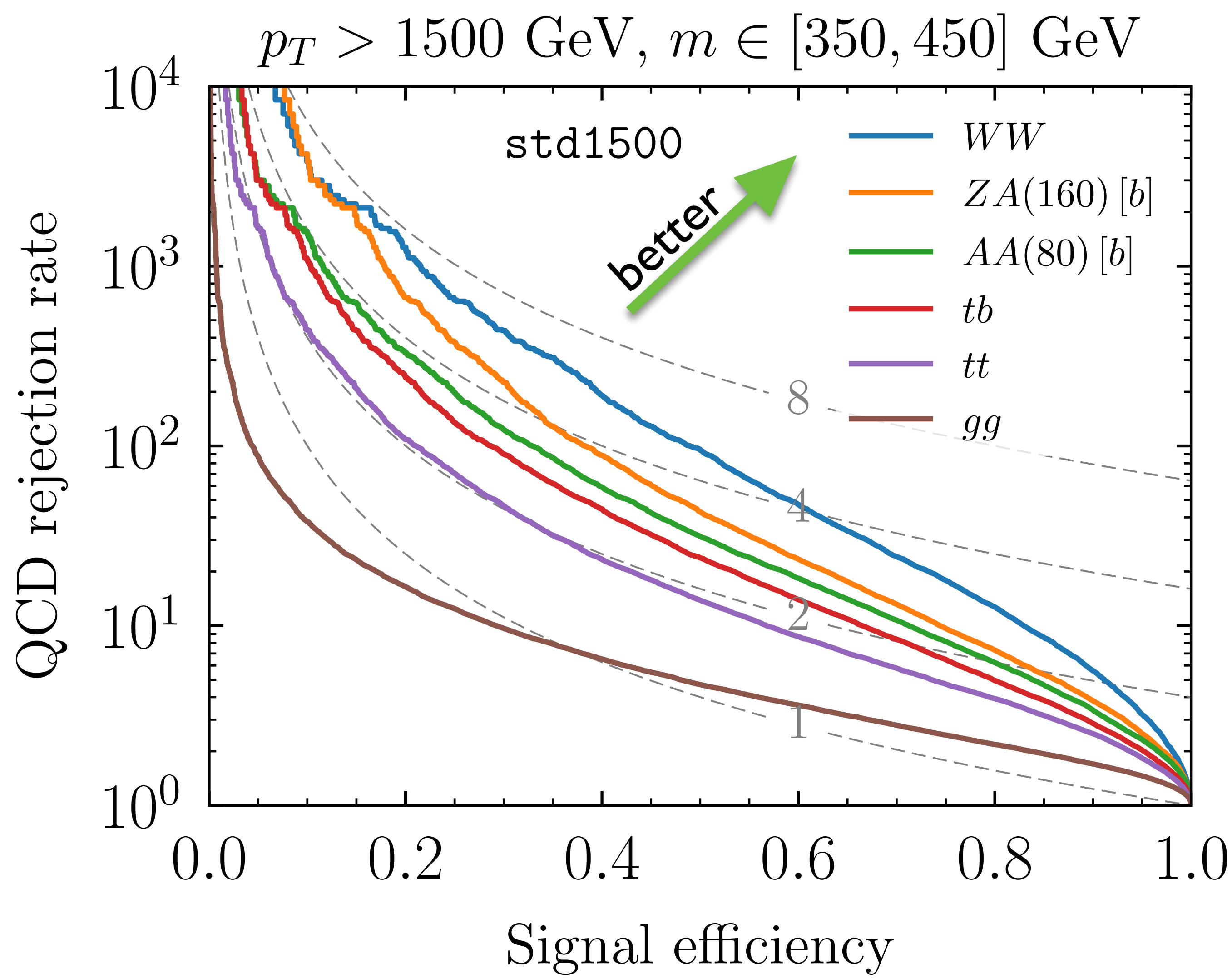
Red: stealth bosons M_A = 30 GeV

Green: stealth bosons M_A = 15 GeV

Orange: $H_1{}^0 \to uuuu$ M_A = 30 GeV

Brown: $H_1{}^0 \to gg$

Example: tagger performance for particles with M = 400 GeV



Blue: $H_l^0 \to WW$

Red: $H^\pm \to tb$

Green: $H_l^0 \to bbbb$ M_A = 80 GeV

Orange: $H_l^0 \to ZA$ M_A = 160 GeV

Purple: $H_l^0 \to tt$ six-pronged jet!

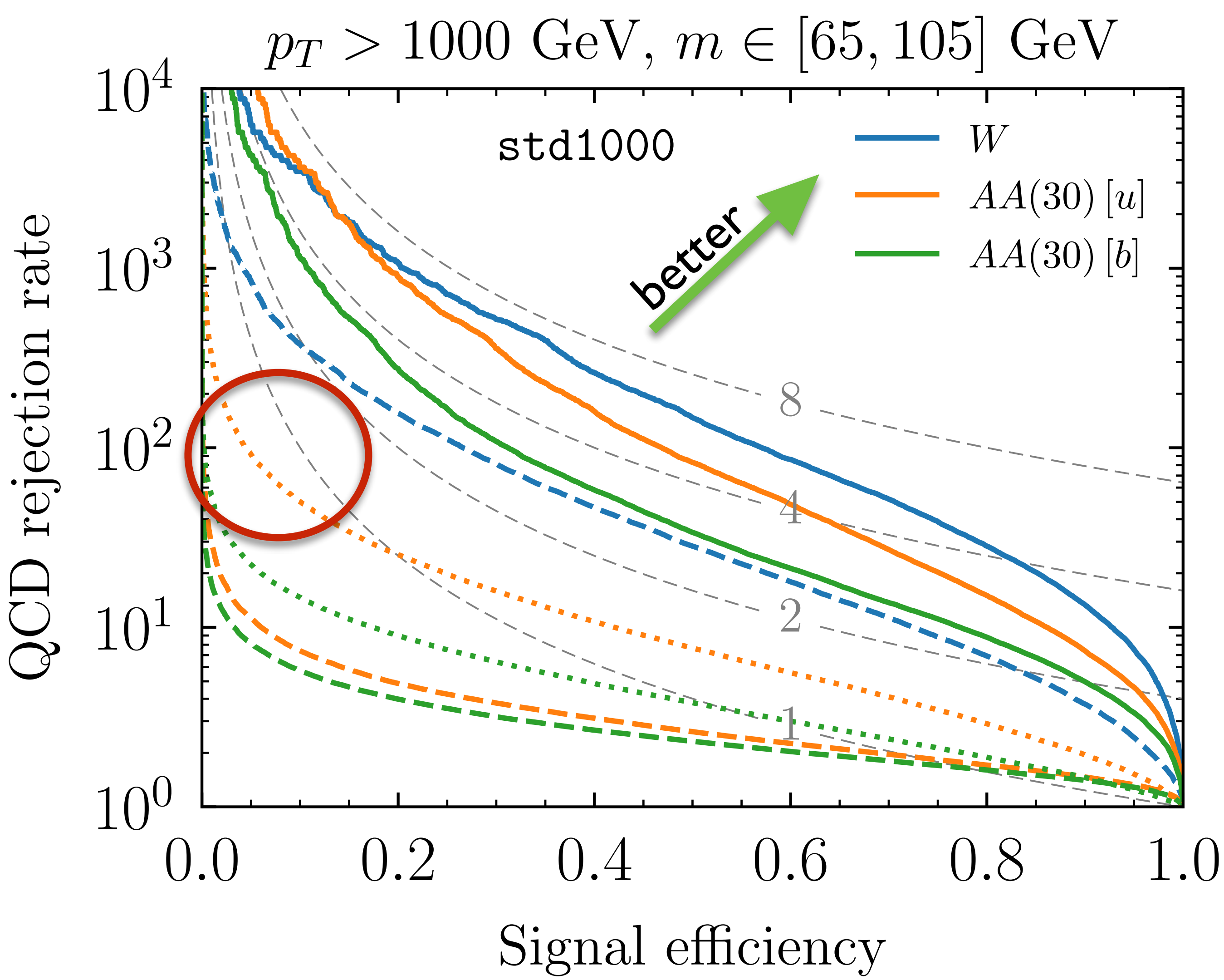
Brown: $H_l^0 \to gg$

> The tagger works well for various topologies, even for $H_l^0 \to gg$ *and* a six-pronged jet not trained for.

FAQ #1

Q: Can't you use τ ratios for multi-pronged jets?

A: Not really. They are not very efficient and, in addition, you don't know a priori which τ ratio you should use.



Blue: W bosons

Green: stealth bosons M_A = 30 GeV

Orange: $H_1{}^0 \rightarrow uuuu$ M_A = 30 GeV

Dashed: τ_{21}

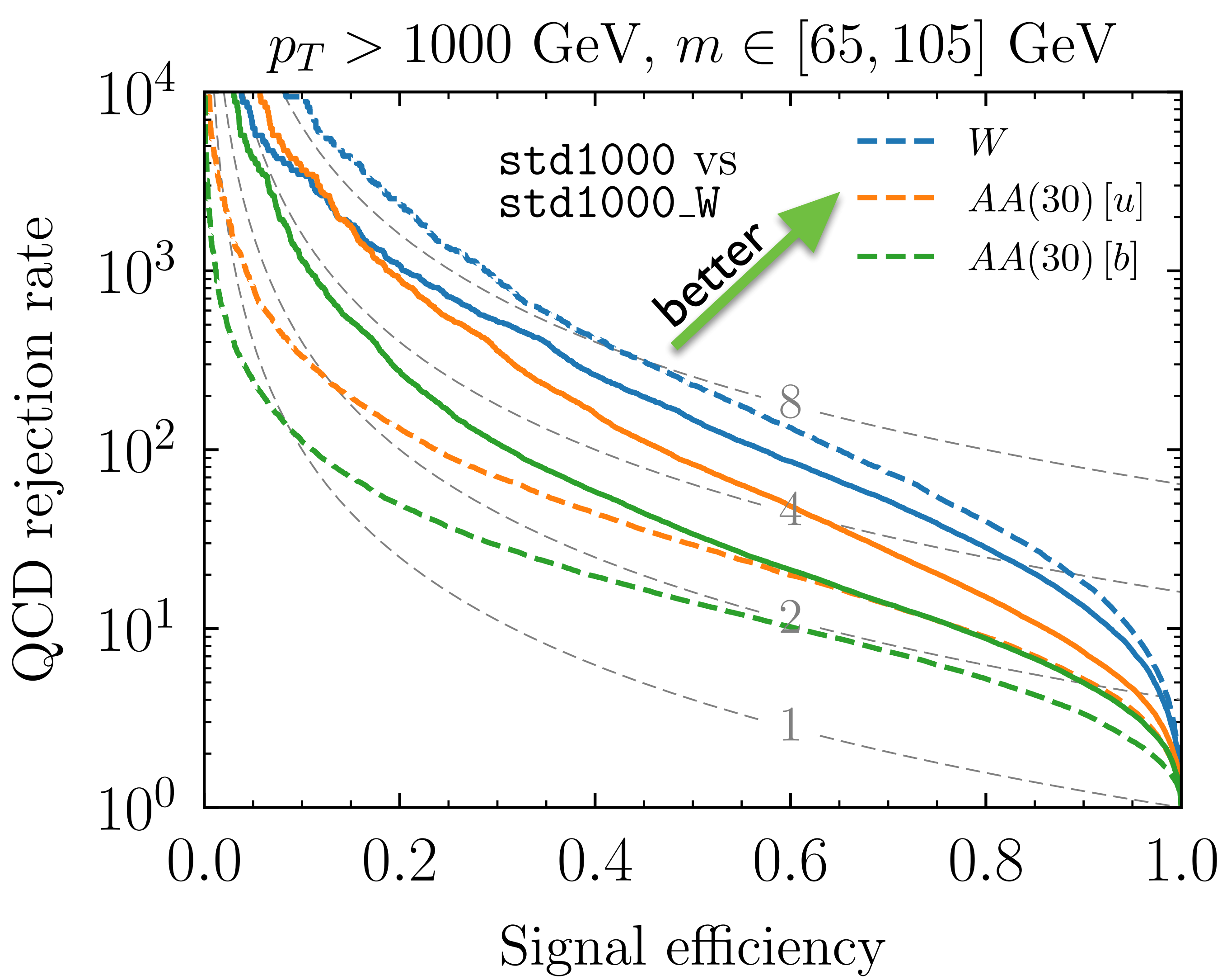
Dotted: τ_{42}

Note that τ ratios actually reduce the signal significance

FAQ #2

Q: But a dedicated tagger performs better…

A: Certainly, but the generic tagger performs better for other [generic] signals different from the one trained on



Blue: *W* bosons

Green: stealth bosons M_A = 30 GeV

Orange: $H_l{}^0 \rightarrow uuuu$ M_A = 30 GeV

Solid: generic tagger

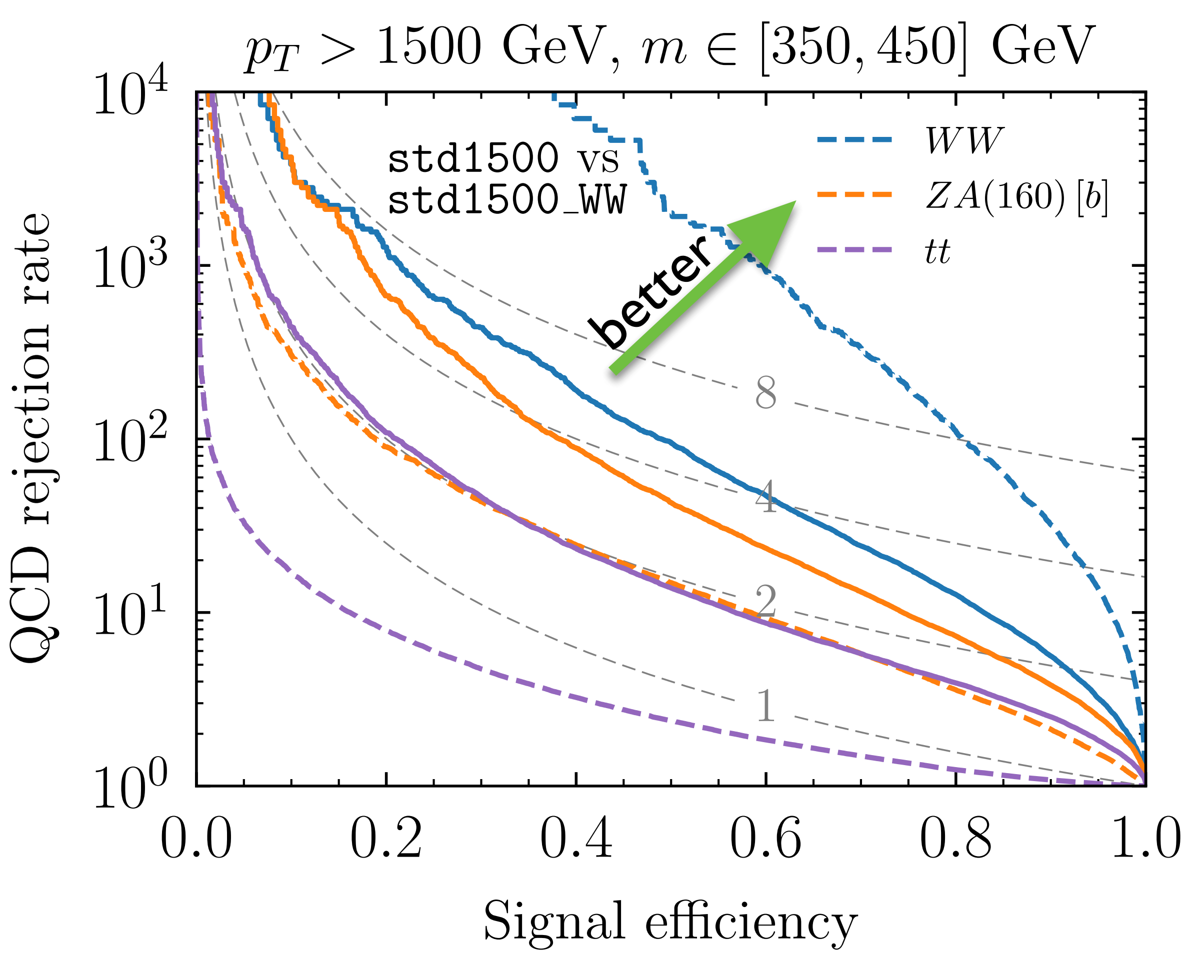
Dotted: dedicated *W* tagger

FAQ #3

Q: Can't I just use a 4-pronged dedicated tagger?

A: (sigh) It performs worse even for 4-pronged signals not trained for…

[NNs are trained on signal jets corresponding to decays with flat phase space]



Comparison with dedicated *WW* tagger for particles with *M* = 400 GeV

Blue: $H_l^0 \to WW$

Orange: $H_l^0 \to ZA$ M_A = 160 GeV

Purple: $H_l^0 \to tt$

Solid: generic tagger

Dashed: dedicated tagger

The dedicated *WW* tagger completely fails for *tt*

FAQ #4

Q: This is nice, but how can I do it? You show one tagger for M = 80, one tagger for M = 400…

A: There are several ways to achieve mass decorrelation:

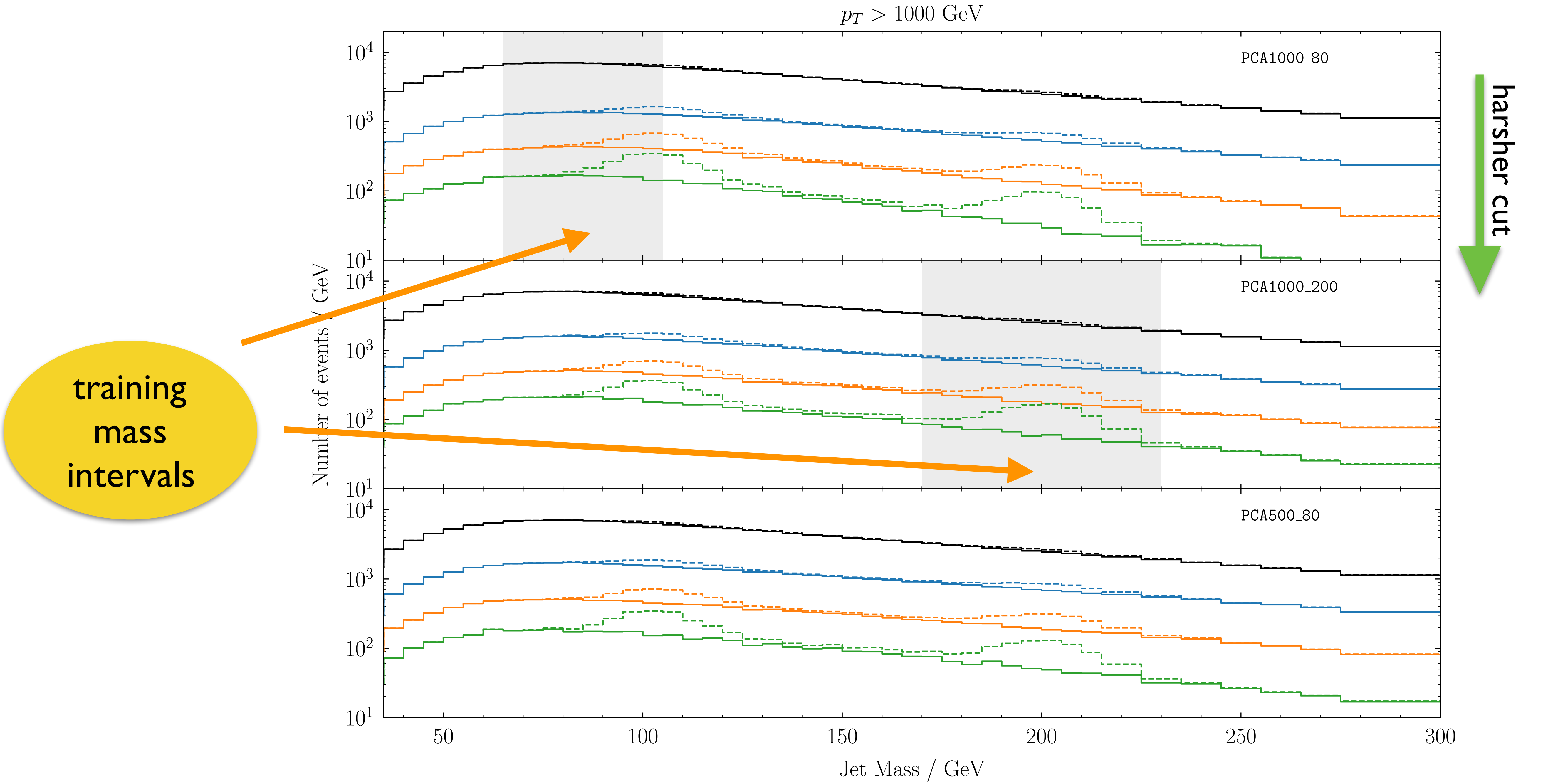
- Preprocessing
- Adversarial networks
- … [illustrate me, please]

Decorrelation with preprocessing

Mass-decorrelated taggers that do not shape background can spot signals with masses different from those used for training

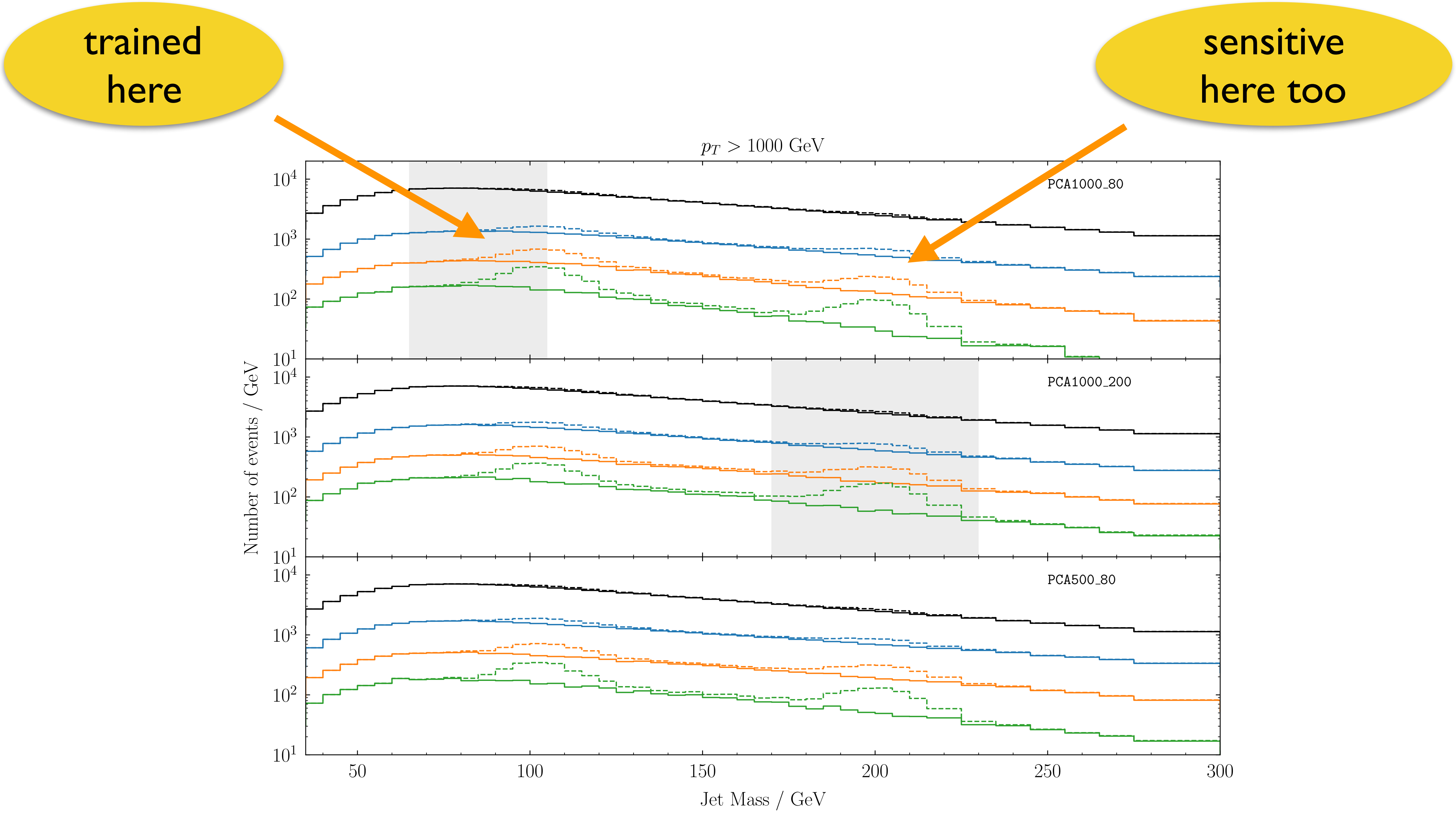
Three taggers, same pseudo-data

Background + injected signals



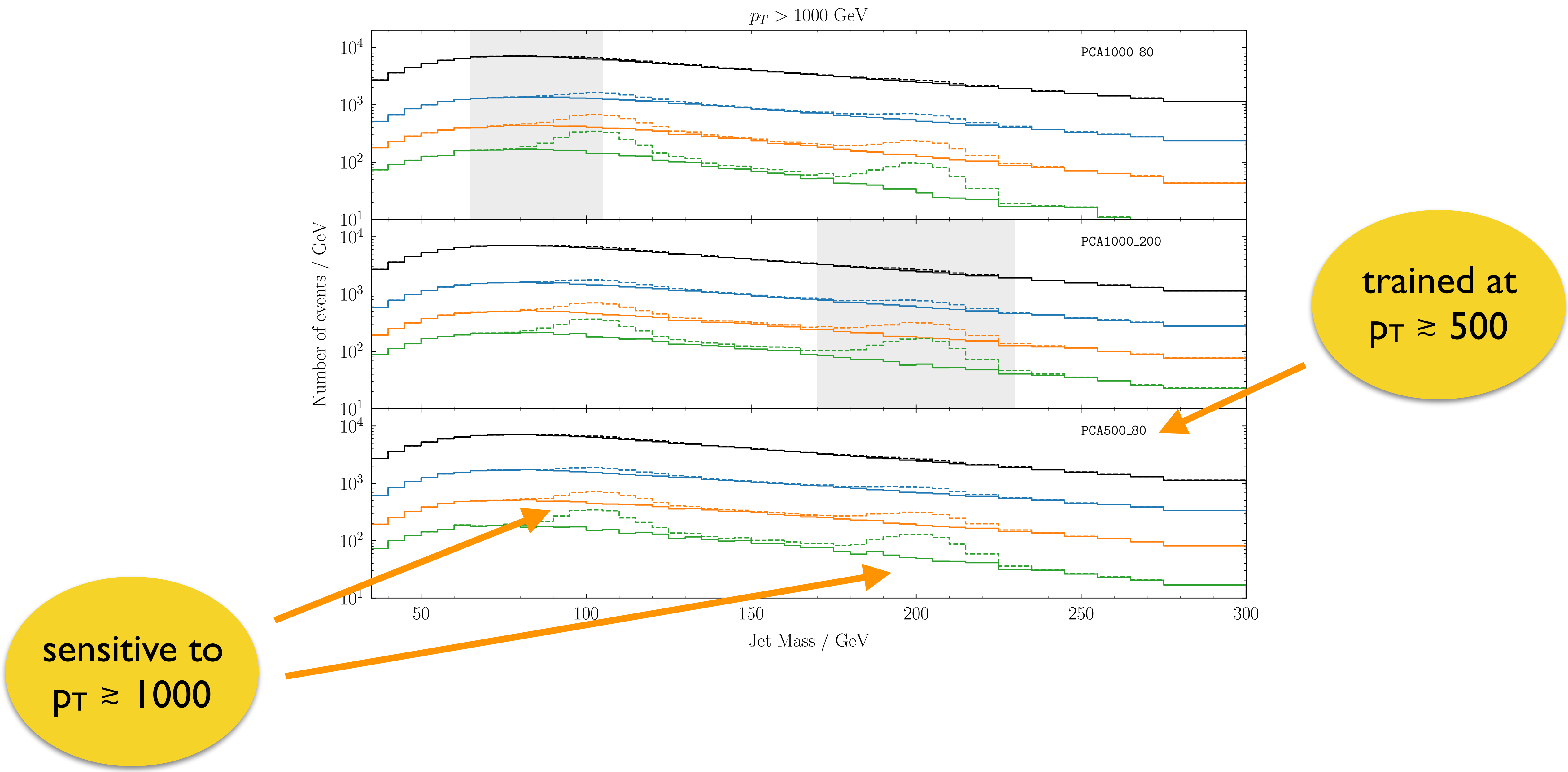
In detail:

- You need to <u>select some jet mass interval</u> for training but the preprocessing of the input makes the tagger insensitive to that



In detail:

- You need to select some jet p_T interval for training but the preprocessing of the input makes the tagger insensitive to that



Application

JAAS, Joaquim, coming soon!

Model: leptophobic Z' boson [if not, forget about it]

- Extra matter required for anomaly cancellation

→ simplest possiblities: extra quarks [model 1] or leptons [model 2]

Possibility of dark matter
Caron et al. 1807.07921

- Z' needs new scalar to get mass

→ simplest and less troublesome: singlet χ

- New fermions need mass too…

→ singlet χ can do it, and this fixes the U(1)′ hypercharge

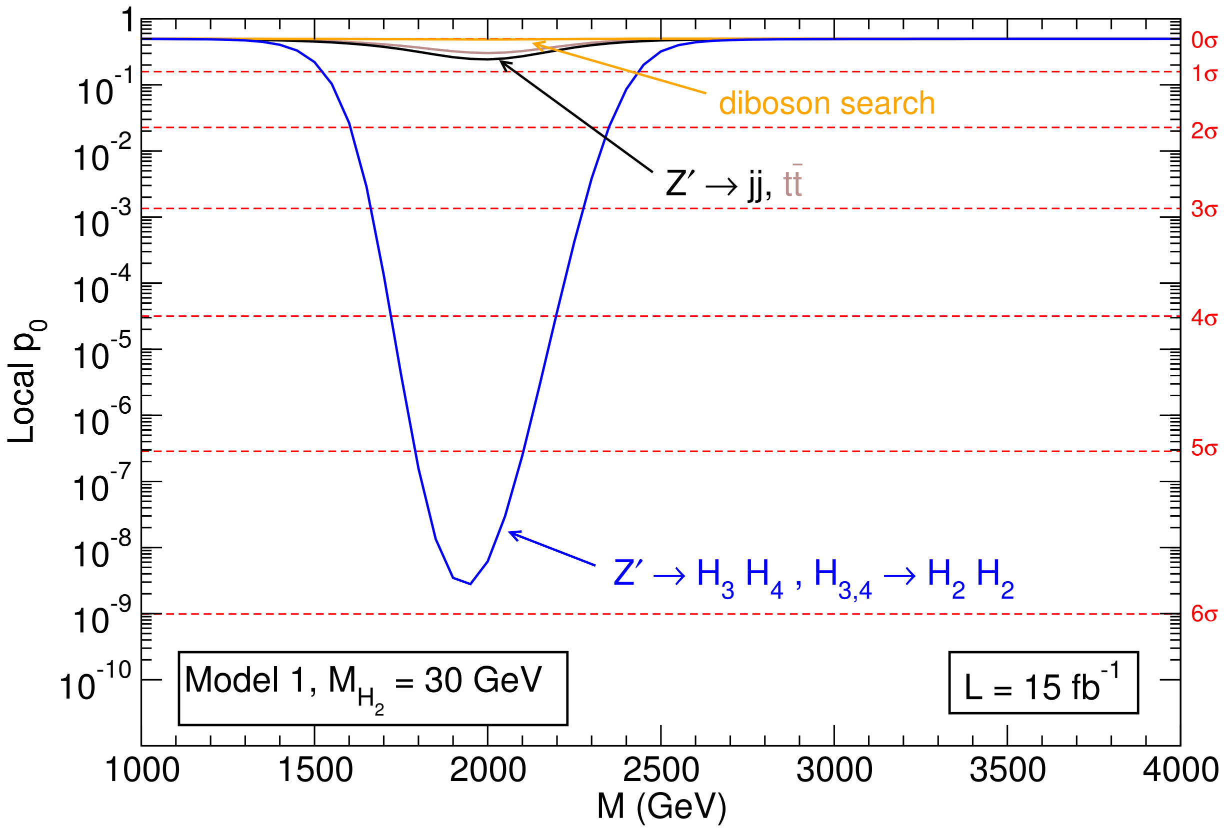
- And you can have two singlets χ_1 and χ_2

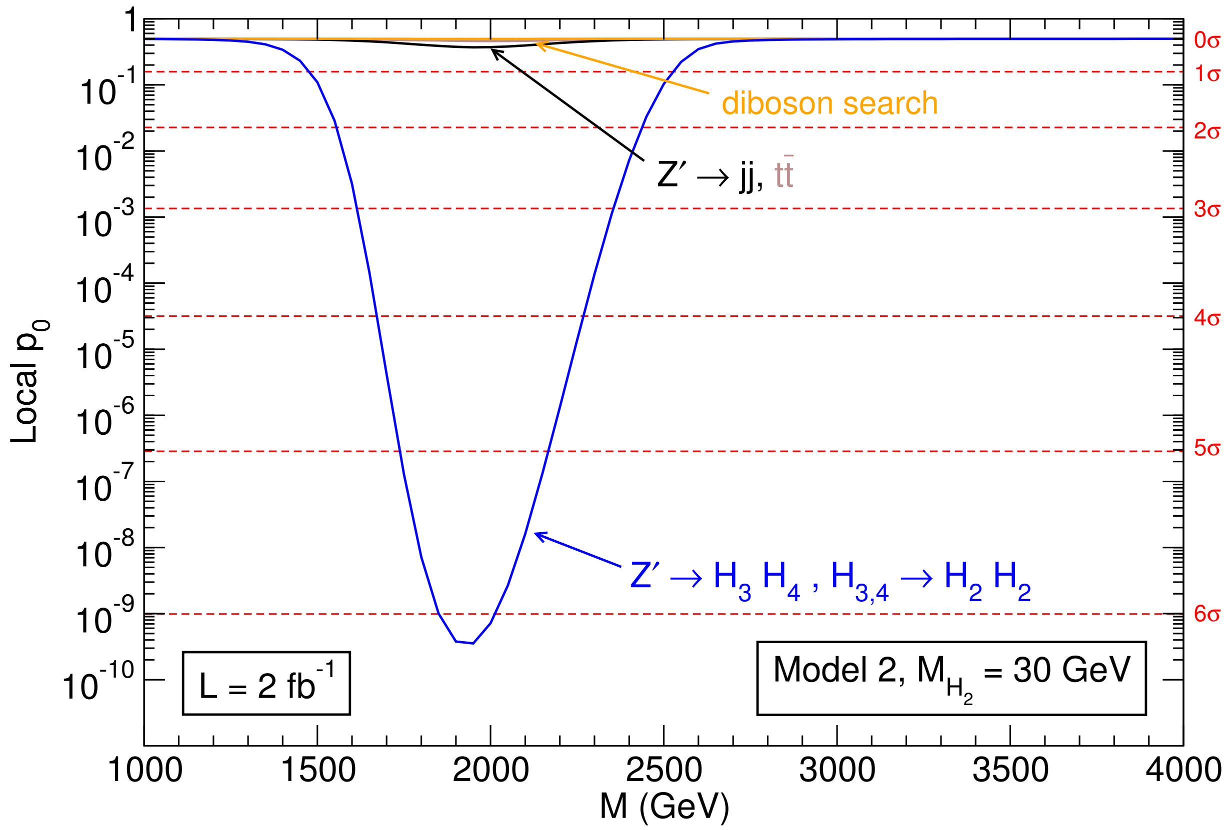
→ in which case you have cascade decays!

Generic* search. Tagger fixed to have 10^2 background rejection.

$Z' \to jj, Z' \to tt, Z' \to H_3\, H_4$ [stealth bosons] with M = 80 GeV

comparison of sensitivity vs standard channels





Generic* search. Tagger fixed to have 10^2 background rejection.

$Z' \rightarrow jj$, $Z' \rightarrow tt$, $Z' \rightarrow H_3\ H_4$ [stealth bosons] with M = 400 GeV

comparison of sensitivity vs standard channels