

Lobhudelei

Tilman Plehn

Boosted tops

Analyses

Local tools

Progress

750 GeV

Lobhudelei for the Local Tagging Group

Tilman Plehn

Universität Heidelberg

Neuenheimer Feld, April 2016

Boosted tops

10+x years of top tagging

1994 $W \rightarrow 2$ jets from heavy Higgs [Seymour]

1994 $t \rightarrow 3$ jets [Seymour]

2006 $t \rightarrow 3$ jets from resonances [Agashe, Belyaev, Krupovnickas, Perez, Virzi]

2008 $H \rightarrow b\bar{b}$ [BDRS Higgs tagger: Butterworth, Davison, Rubin, Salam]

2008 $t \rightarrow 3$ jets from resonances [JH/CMS tagger: Kaplan, Rehermann, Schwartz, Tweedie]

2009 $t \rightarrow 3$ jets in Higgs production [HEPTopTagger: TP, Salam, Spannowsky]

...

2010 first meta analysis [BOOST proceedings]

2011 N-subjettiness [Thaler, van Tilburg]

2011 shower-desconstructed tops [Spannowsky, Soper]

2011 pedagogical review [TP, Spannowsky]

...

2013 track-based Tagger [Schäfzel, Spannowsky]

2013 better HEPTopTagger [Anders, Bernaciak, Kasieczka, TP, Schell]

2015 even better HEPTopTagger2 [Kasieczka, TP, Strebler, Schell, Salam]

...



Gavin's boosted landscape

Boosted tops

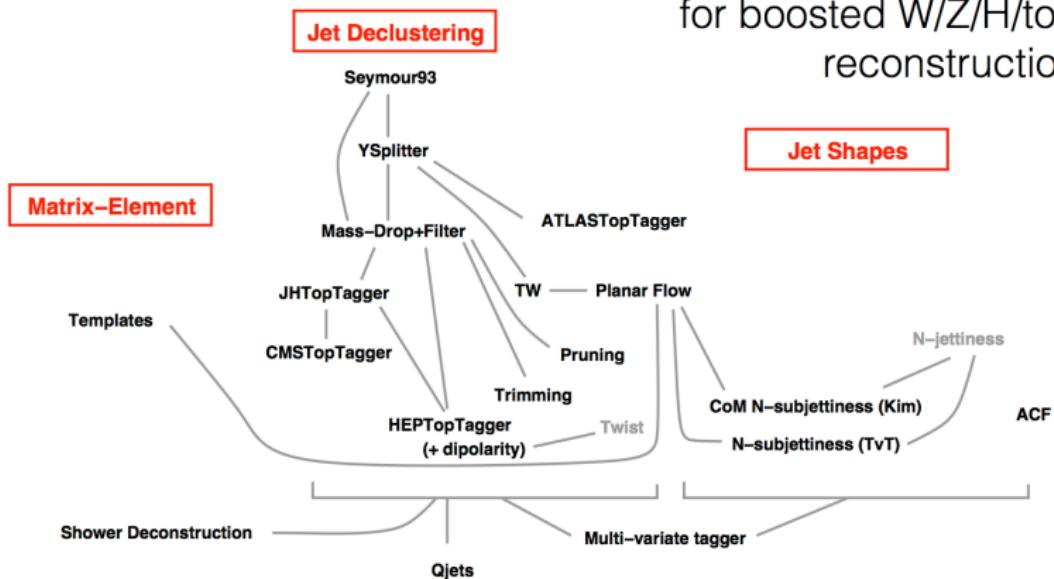
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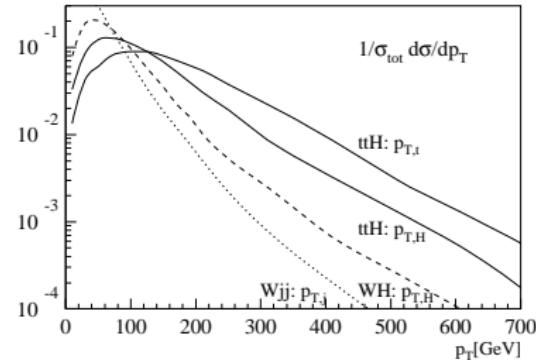
Some of the tools developed
for boosted W/Z/H/top
reconstruction



BDRS Higgs tagger

New strategy for $H \rightarrow bb$ [Butterworth, Davison, Rubin, Salam]

- S: large m_{bb} , boost-dependent R_{bb}
- B: large m_{bb} only for large R_{bb}
- S/B: target large m_{bb} and small R_{bb} , i.e. boosted Higgs
- fat Higgs jet $R_{bb} \sim 2m_H/p_T \sim 0.8$
- $q\bar{q} \rightarrow V_\ell H_b$ sizeable in boosted regime $[p_T \gtrsim 300 \text{ GeV, few \% of total rate}]$
- first real look inside jets [subjets]



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 - first real look inside jets [subjets]
- ⇒ non-trivial challenge to jet algorithms

jet definition	σ_S/fb	σ_B/fb	S/\sqrt{B}_{30}
C/A, $R = 1.2$, MD-F	0.57	0.51	4.4
k_\perp , $R = 1.0$, y_{cut}	0.19	0.74	1.2
SISCone, $R = 0.8$	0.49	1.33	2.3

BDRS Higgs tagger

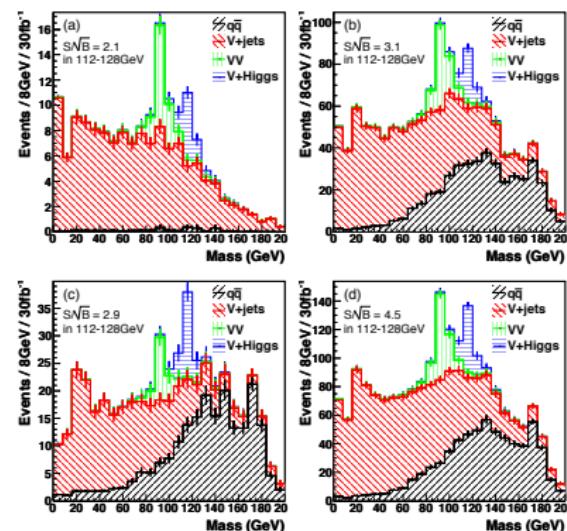
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Results and checks

- combined $V \rightarrow \ell\ell, \nu\nu, \ell\nu$
- Z peak as sanity check
- subjet b tag crucial [70%/1%]
charm rejection an issue

⇒ not sure about current status



Top resonance search

Z' or KK gluon searches with $m \gtrsim 1.3$ TeV

- purely leptonic rate limited
- semi-leptonic with approximate neutrino reconstruction
- purely hadronic considered hard [so let's solve a real problem!]

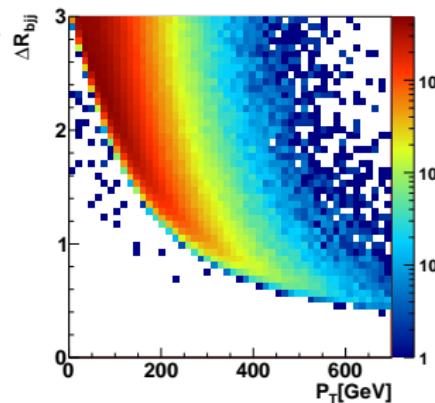
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- tagging easier for higher boost, $p_{T,t} > 600$ GeV
 - Standard Model events at lower $p_{T,t} < 400$ GeV
- ⇒ p_T range main challenge



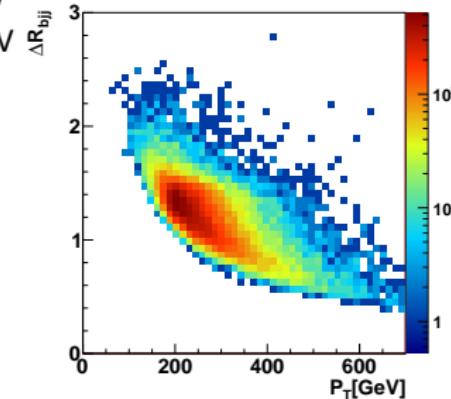
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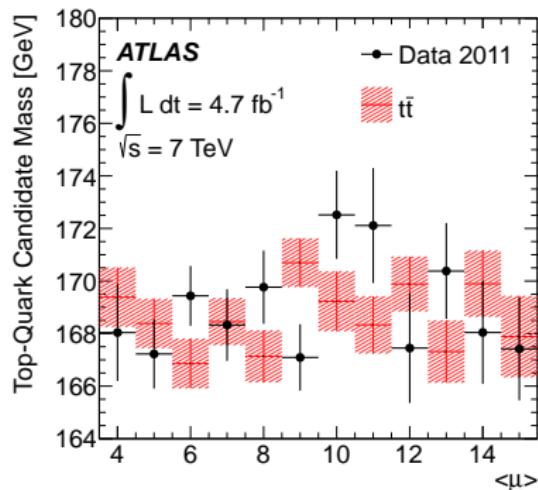
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- pile-up does not kill us



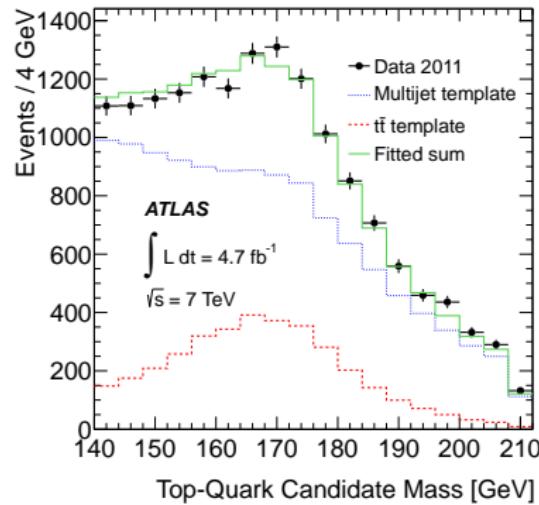
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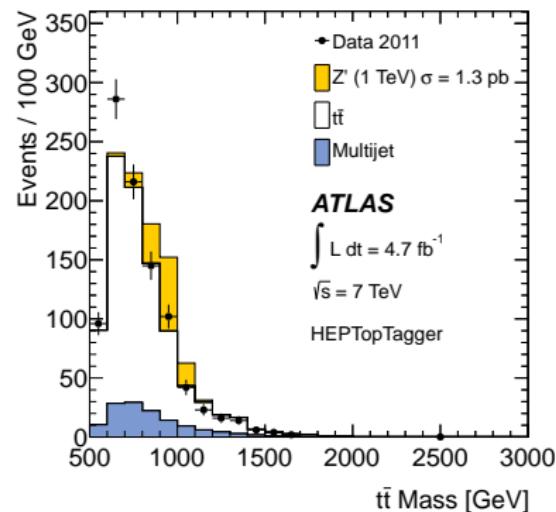
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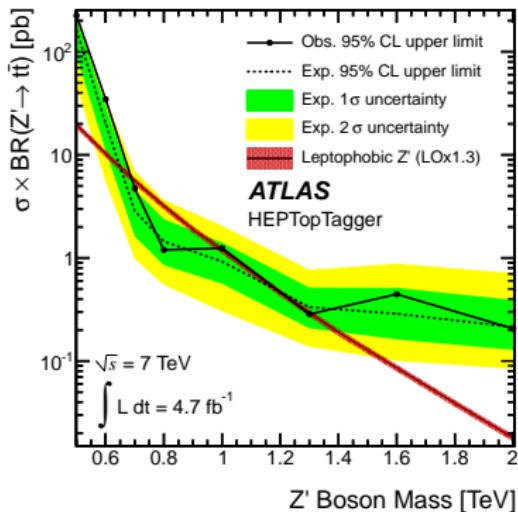
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- pile-up does not kill us
 - top mass comes out right
 - resonance search works
 - QCD can beat multivariate
- ⇒ **wow!**

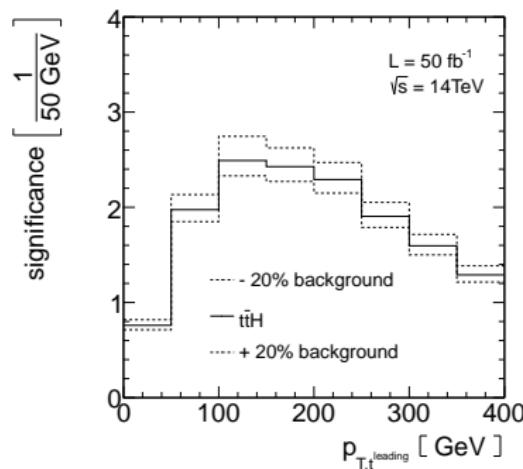


Being a (boring) German

Precision Higgs physics: $t\bar{t}H, H \rightarrow b\bar{b}$

- signal vs background kinematics [MadMax]
- no combinatoric background
- fun: fat Higgs + fat top

[similarly $HH \rightarrow b\bar{b}b\bar{b}$: Lima et al]



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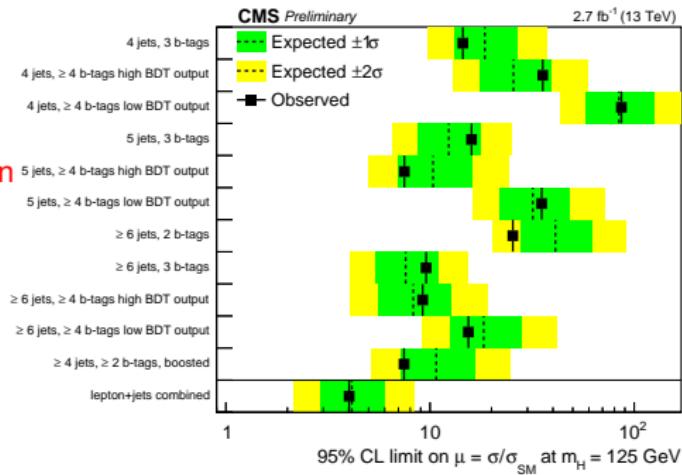
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Finally an analysis! [Kasieczka]

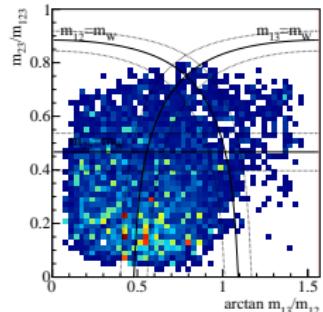
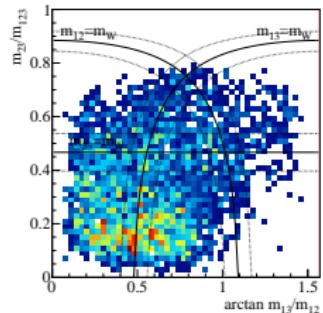
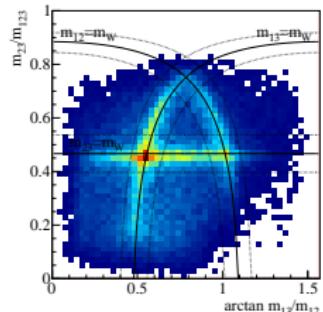
- targeting low- p_T range
 - usual mess of $t\bar{t}H$ analyses
 - boosted search leading limits
- ⇒ now a proud & boring German



1 — HEPTopTagger

Mass drop algorithm [TP, Salam, Spannowsky, Takeuchi]

- 1– C/A fat jet, $R = 1.5$ and $p_T > 200 \text{ GeV}$ [FastJet limitation]
- 2– mass drop, cutoff $m_{\text{sub}} > 30 \text{ GeV}$
- 3– filtering leading to hard substructure triple
- 4– top mass window $m_{123} = [150, 200] \text{ GeV}$
- 5– A-shaped mass plane cuts as function of m_W/m_t
- 6– consistency condition $p_T^{(\text{tag})} > 200 \text{ GeV}$



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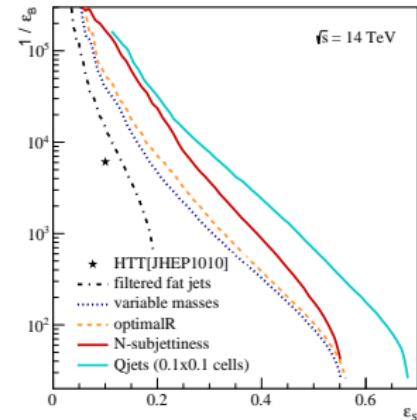
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HEPTopTagger2 [Kasieczka, TP, Salam, Schell, Strebler]

- fat jet to include FSR
 - optimal R_{\min}
 - large to include all decay jets
 - small to avoid combinatorics, ISR, pile-up
 - combined with N-subjettiness and Qjets
 - multi-variate

$$\{m_{tt}, p_{T,t}, m_{jj}^{(\text{filt})}, p_{T,j}^{(\text{filt})}, m_{123}^{(\min, R_{\min})}, m_{123}^{(\max, R_{\min})}, f_W^{(R_{\min})}, R_{\min} - R_{\min}^{(\text{calc})}\}$$
- ⇒ lots of variables: feature or curse?



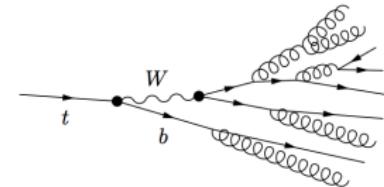
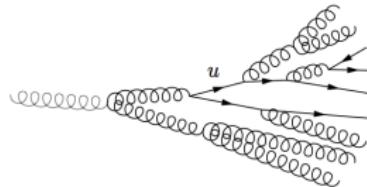
2 — Shower deconstruction

Remember matrix element method [Tevatron]

- measured fully exclusive cross section: $d\sigma$
computed matrix element squared: $|\mathcal{M}|^2(m_t)$
- direct comparison to determine m_t
- log likelihood ratio best test statistic
- combinatorics by adding likelihoods [problem for taggers w/o QJets]

Same for subjets [Soper, Spannowsky]

- background from QCD splittings [parton shower]
signal from hard decays
Sudakovs for non-splitting
- compute LLR for signal and background assumption as ‘top-ness’ measure



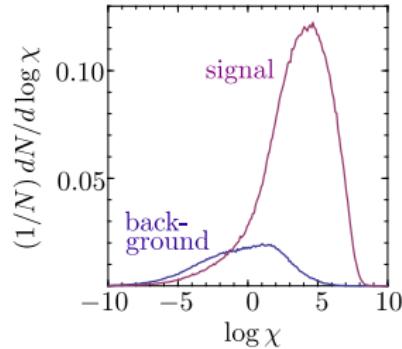
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Implementation [1211.3140]

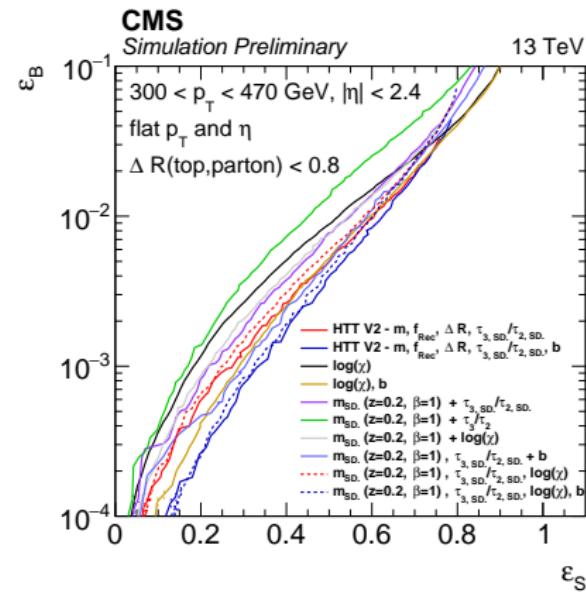
- look at microjets inside fat jet [$R_{k_T} = 0.2, p_T < 5 - 10 \text{ GeV}, N = 9$]
 - approximate parton shower as description [shower time, analytic computation]
 - compute χ for signal/background hypothesis
 - one-paramer tagger χ_{\min} [extended to event deconstruction]
- ⇒ same problem: calculability beyond Pythia?



Recent progress

CMS state of art [Kasieczka]

- 13 TeV study validated with 8 TeV data
 - can we finally beat the CMS tagger? — yes!!
- ⇒ **HEPTopTagger2 and shower deco leading head-to-head**



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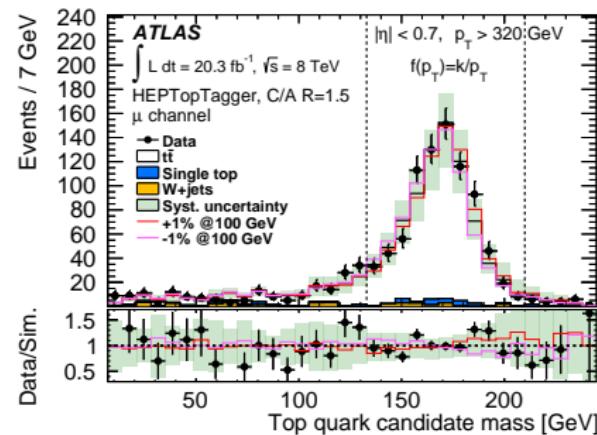
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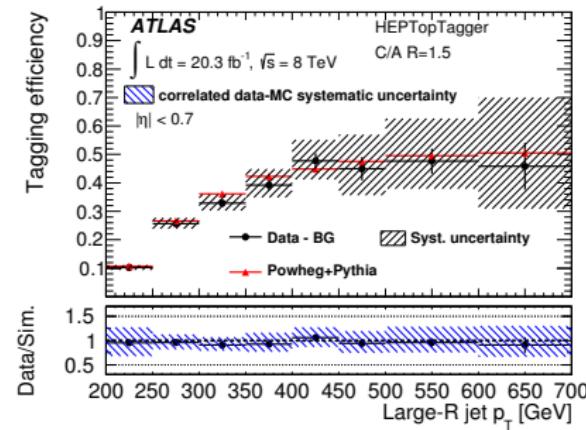
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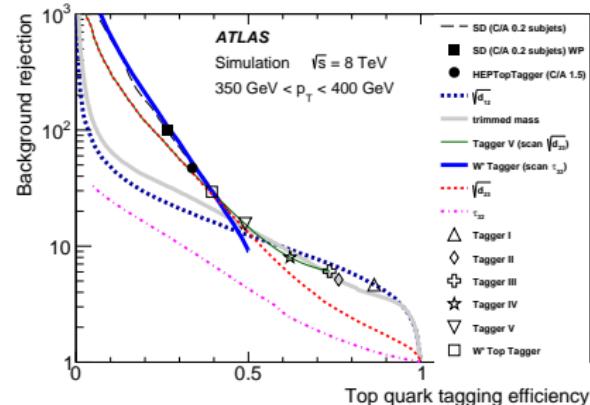
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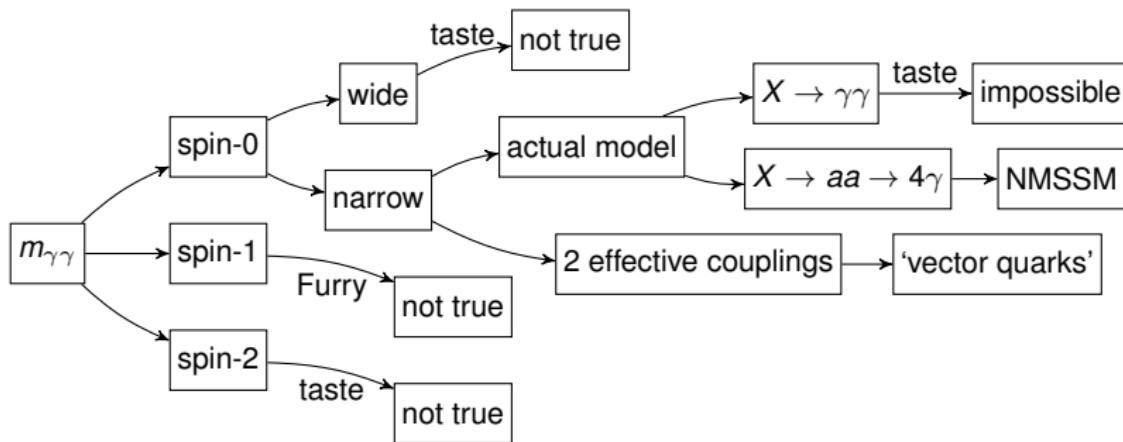
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The finger to particle theory



Since Christoph asked: my take on 750 GeV theory papers

- open questions due to limited significance
 - general problem: signal rate large
 - largely EFT exercise
 - dimension-5 operators $XG^{\mu\nu}G_{\mu\nu}$ and $XA^{\mu\nu}A_{\mu\nu}$ → **avoid di-jet constraints**
 - gauge invariant $XB^{\mu\nu}B_{\mu\nu}$ and $XW^{\mu\nu}W_{\mu\nu}$ → **avoid VV constraints**
 - no clear link to other data
- ⇒ **great to play with, but only for fun, please**

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Outlook

Enjoy the Kulturbrauerei

- QCD can be fun
- theory–experiment link can work great
- visit us again in Heidelberg
- if you did not see the Philosophenweg you missed something
- please, find some interesting physics in Run II

