Colorful Top Tagging and Shower Deconstruction

Michael Spannowsky

University of Durham

Motivation

- High-pT tops present in many BSM extensions
  e.g. SUSY, Extra Dimensions, GUTs

- Boosted tops where first identified as important final states where subjet methods are indispensable

  [Agashe, et al PRD 77 (2008); Baur, Orr PRD 76 (2007); Gerbush et al PRD 77 (2008); Lillie et al JHEP 0709]

- Ongoing measurements at LHC - already at 7/8 TeV

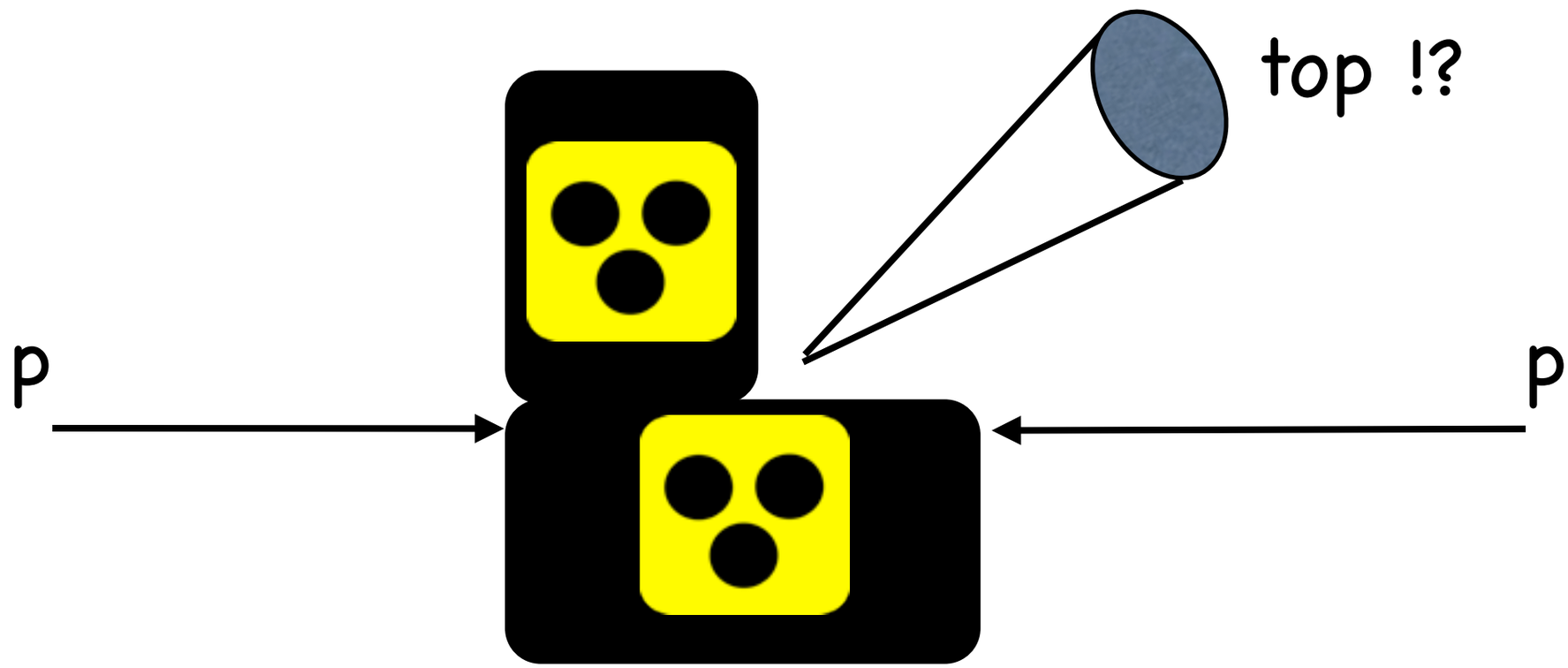
  [CMS-PAS-TOP-11-009; CMS-PAS-EXO-11-006; ATLASXXX

- Many different tagging methods developed and are being tested on data

Generic idea of top taggers:

- Collect top decay products in one fat jet
- Reject uncorrelated noise, i.e. pileup, UE, ISR
  (less important if high-pT and cones are "small")
- Find measure to discriminate between signal and background (i.e. QCD jets)

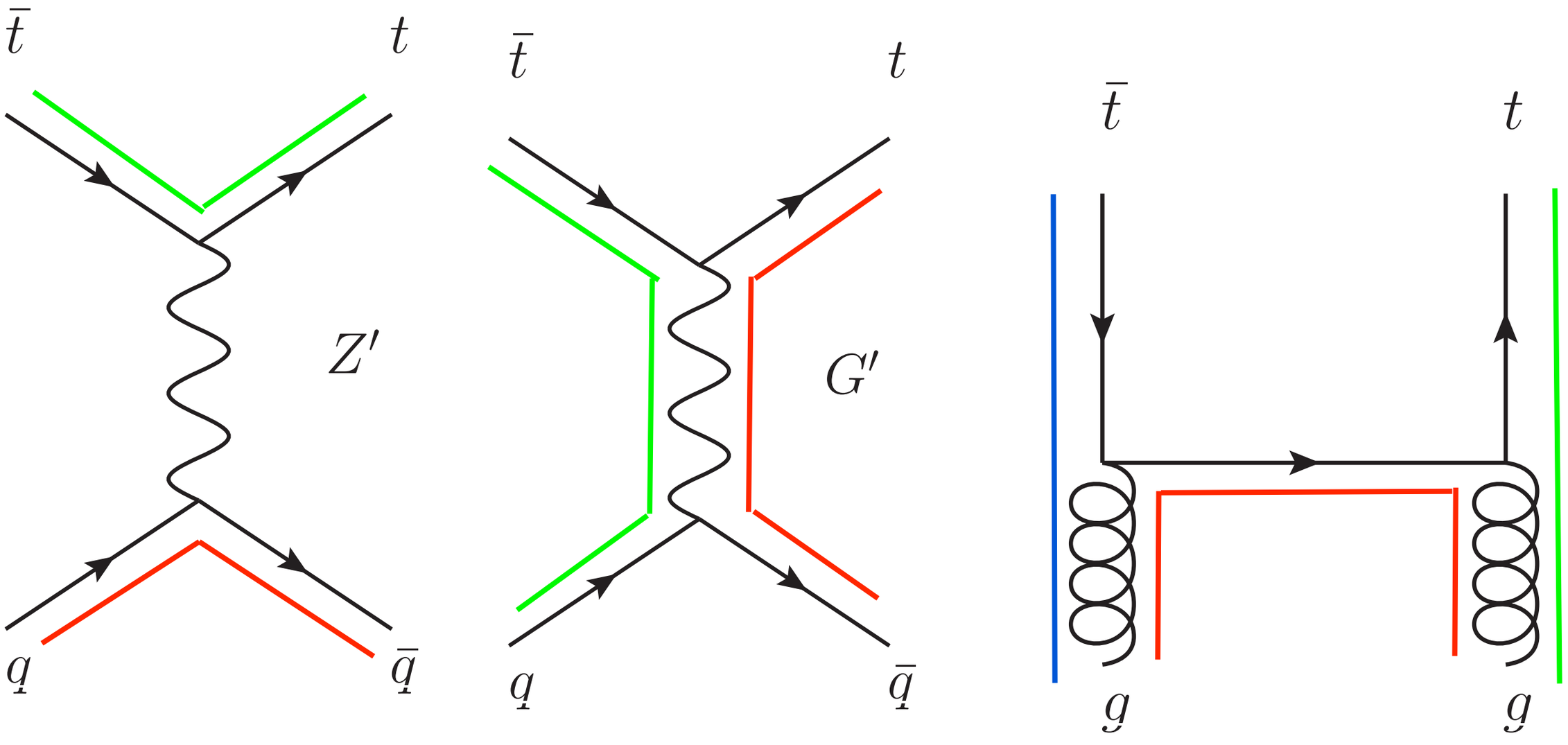
→ Implicitly ignoring rest of event, i.e. production mechanism



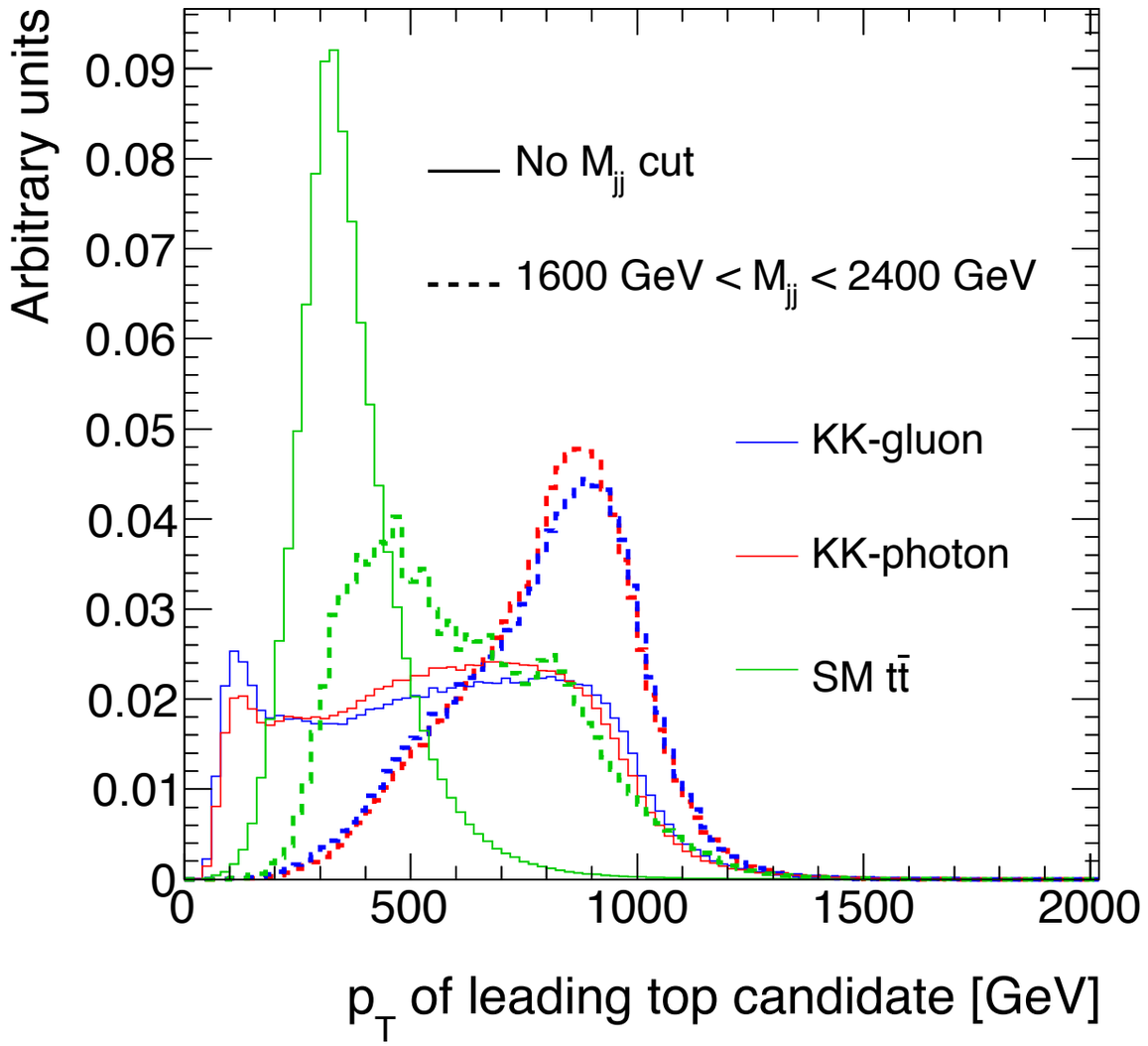
I. Color-flow effects in top reconstruction

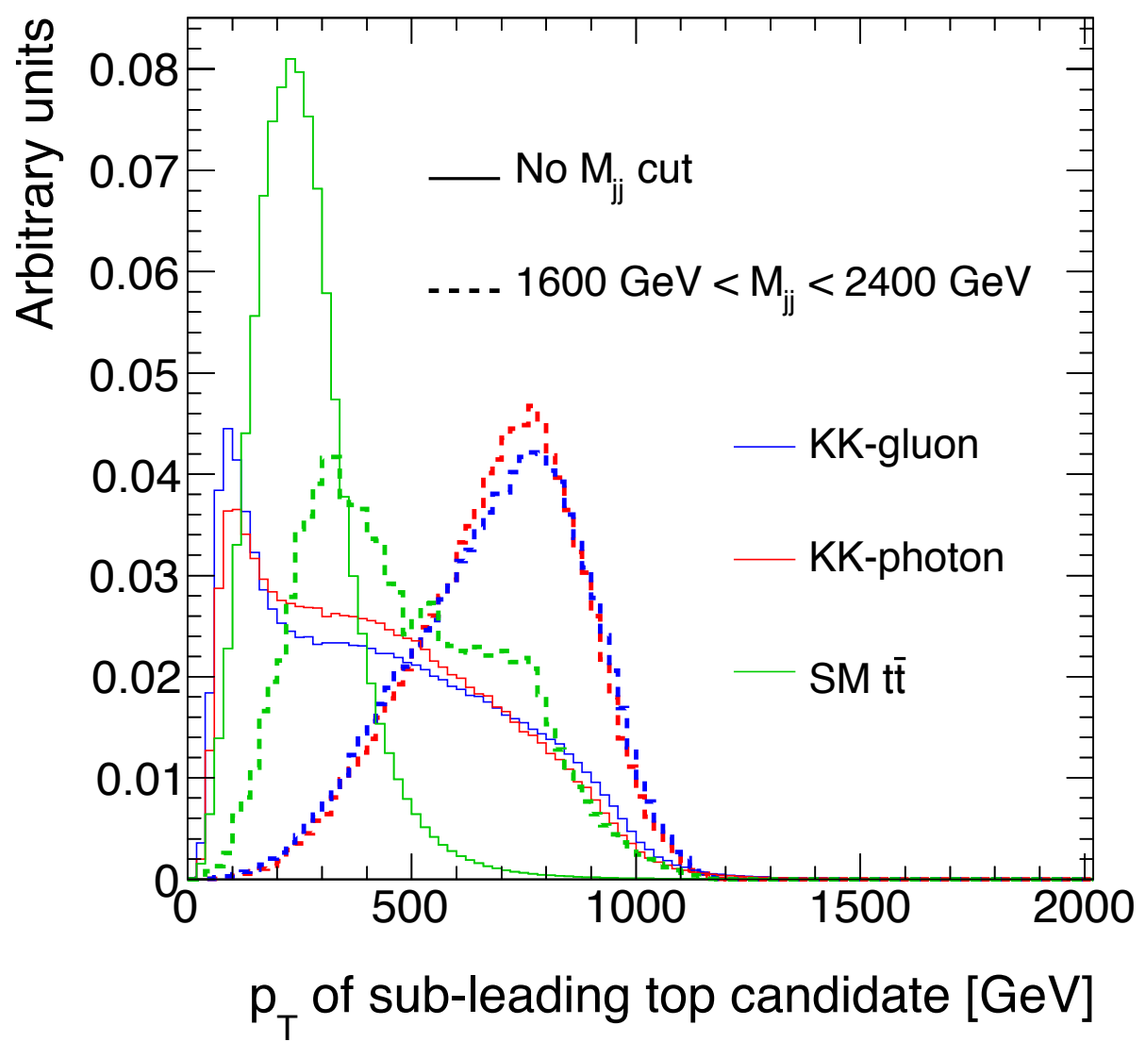
(in collaboration with Kiran Joshi and Andrew Pilkington)

Consider simplest case:
color-octet resonance vs color-singlet resonance



Different color flow for signals and backgrounds





Simulated KK-gluon and KK-photon with $\Gamma/M = 0.2$ both

Event selection cuts:

Two CA jets with pT>500 GeV, R=0.8, |y|<2.5

and $1.6 \leq M_{\mathrm{jj}} < 2.4$ TeV

For evaluation choose publicly available taggers:

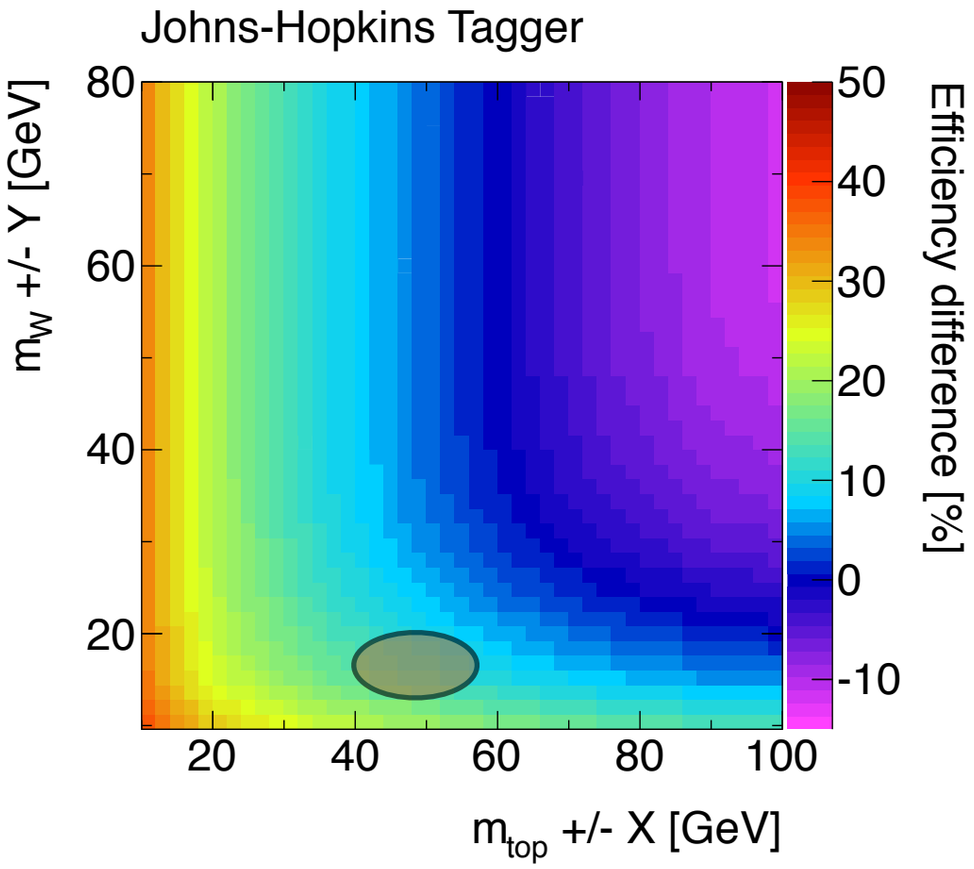
Johns Hopkins Tagger: double mass drop -> 3 or 4 jets
[Kaplan et al PRL 101 (2008)] tag according to top mass, mW, hel. angle

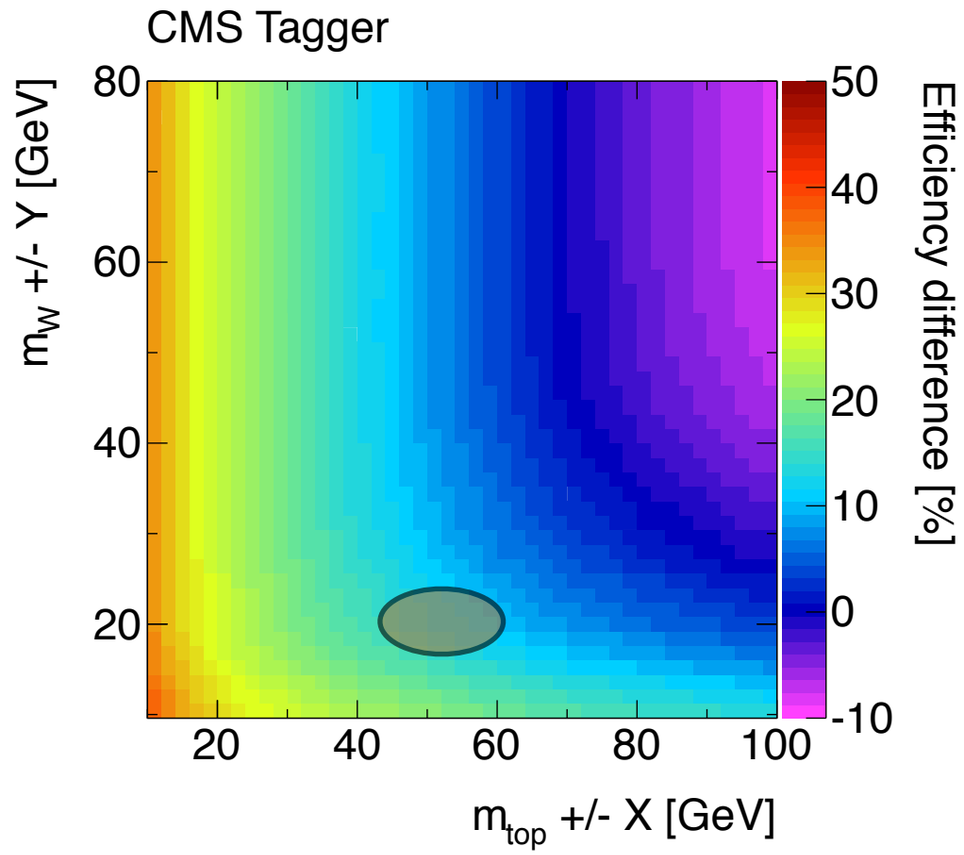
CMS Tagger: like Johns Hopkins but momentum
[CMS-PAS-JME-09-001] dependent angular cond. in mass drop:

$$\Delta R_{j_1,j_2} > \delta_r - A \cdot p_{T,jet}$$

HEP Top Tagger: Infinite mass drop, filtered subjets, tag according to top mass and mass ratio conditions
[Plehn et al, JHEP 1010]

N-subjettiness Tagger: Jet shape observable, counts number of hard energy deposits inside jet. Tag according to τ_3/τ_2 and jet mass
[Thaler, Van Tilburg JHEP 1103]


Johns-Hopkins Tagger
m_W +/- Y [GeV]
m_{top} +/- X [GeV]
Efficiency difference [%]


CMS Tagger
m_W +/- Y [GeV]
m_{top} +/- X [GeV]
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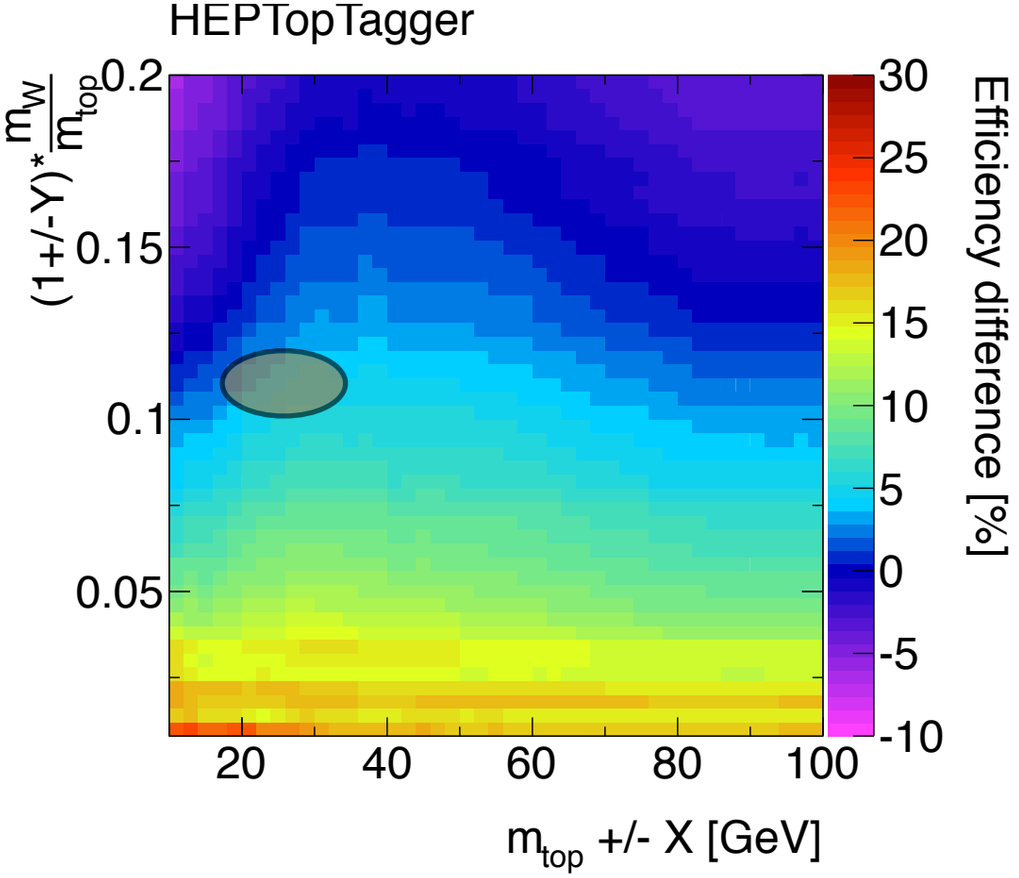
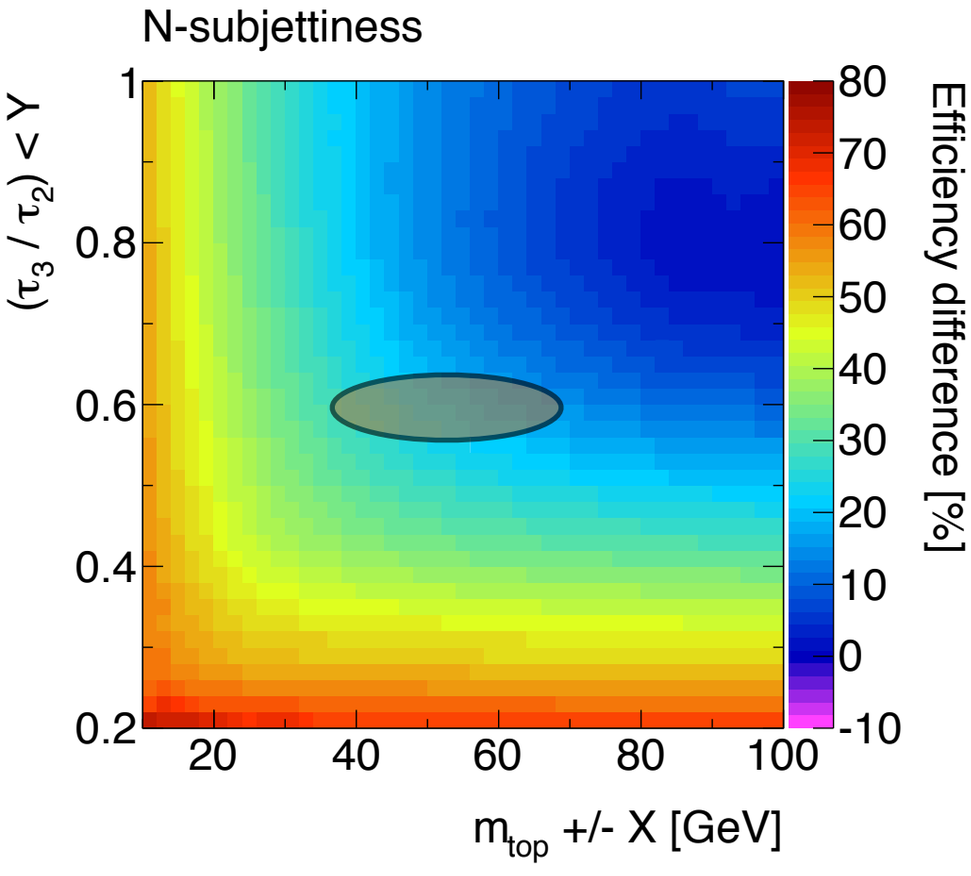
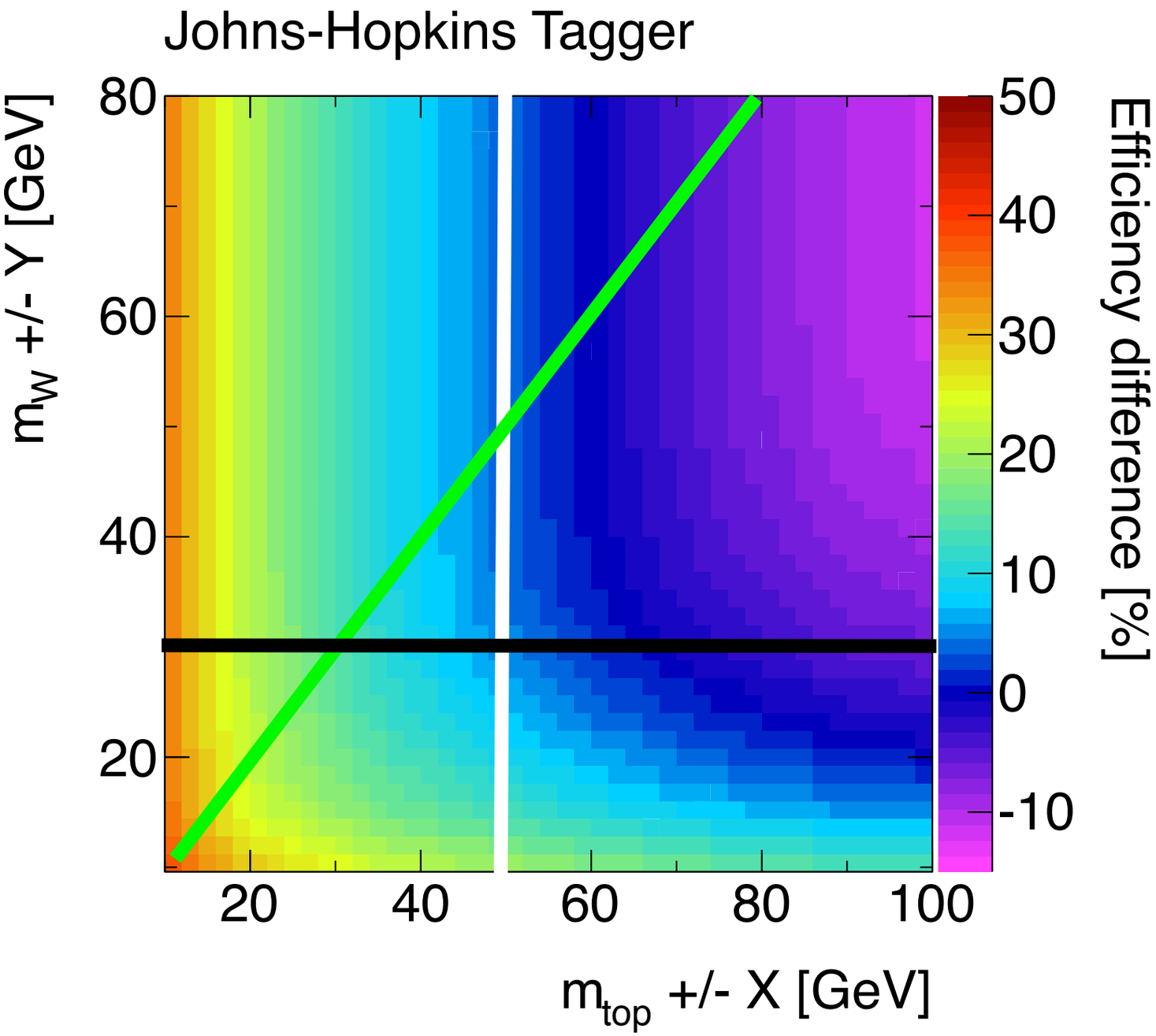
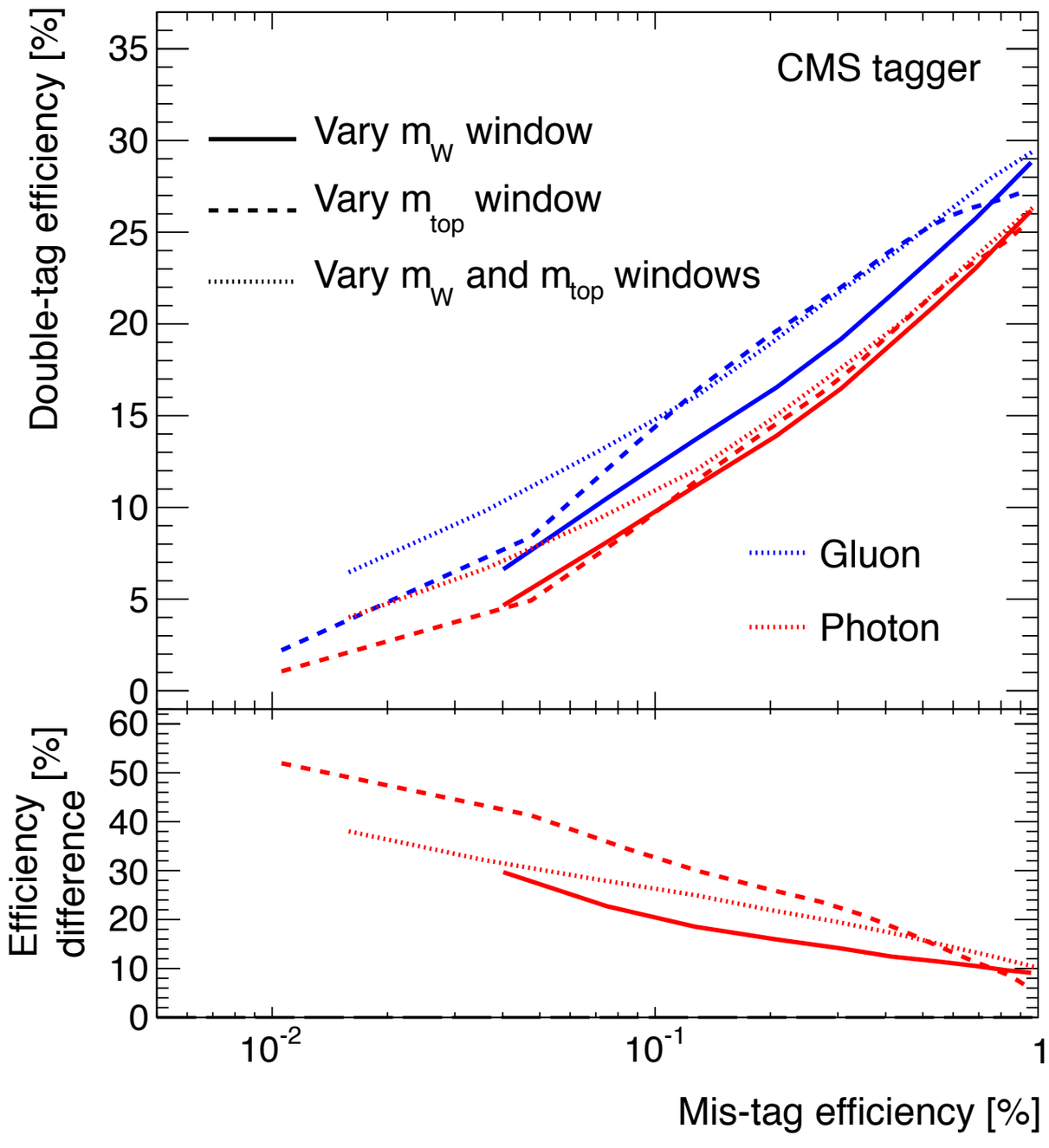

HEPTopTagger
$(1+/-Y)*\frac{m_W}{m_{top}}$
m_{top} +/- X [GeV]
Efficiency difference [%]

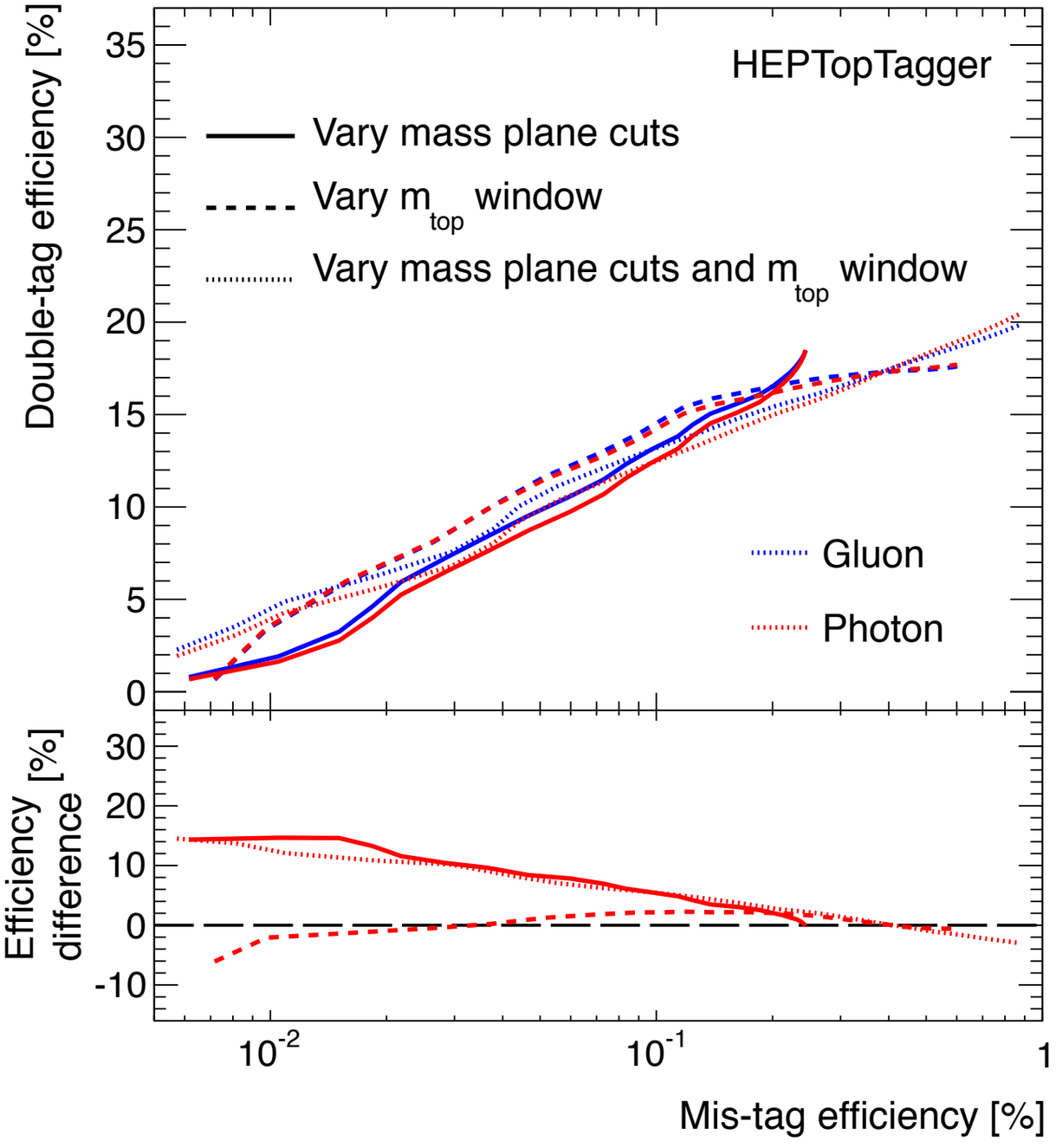

N-subjettiness
$(\tau_3 / \tau_2) < Y$
m_{top} +/- X [GeV]
Efficiency difference [%]



Choose three slices for more quantitative picture

Slices of 2 dim plot





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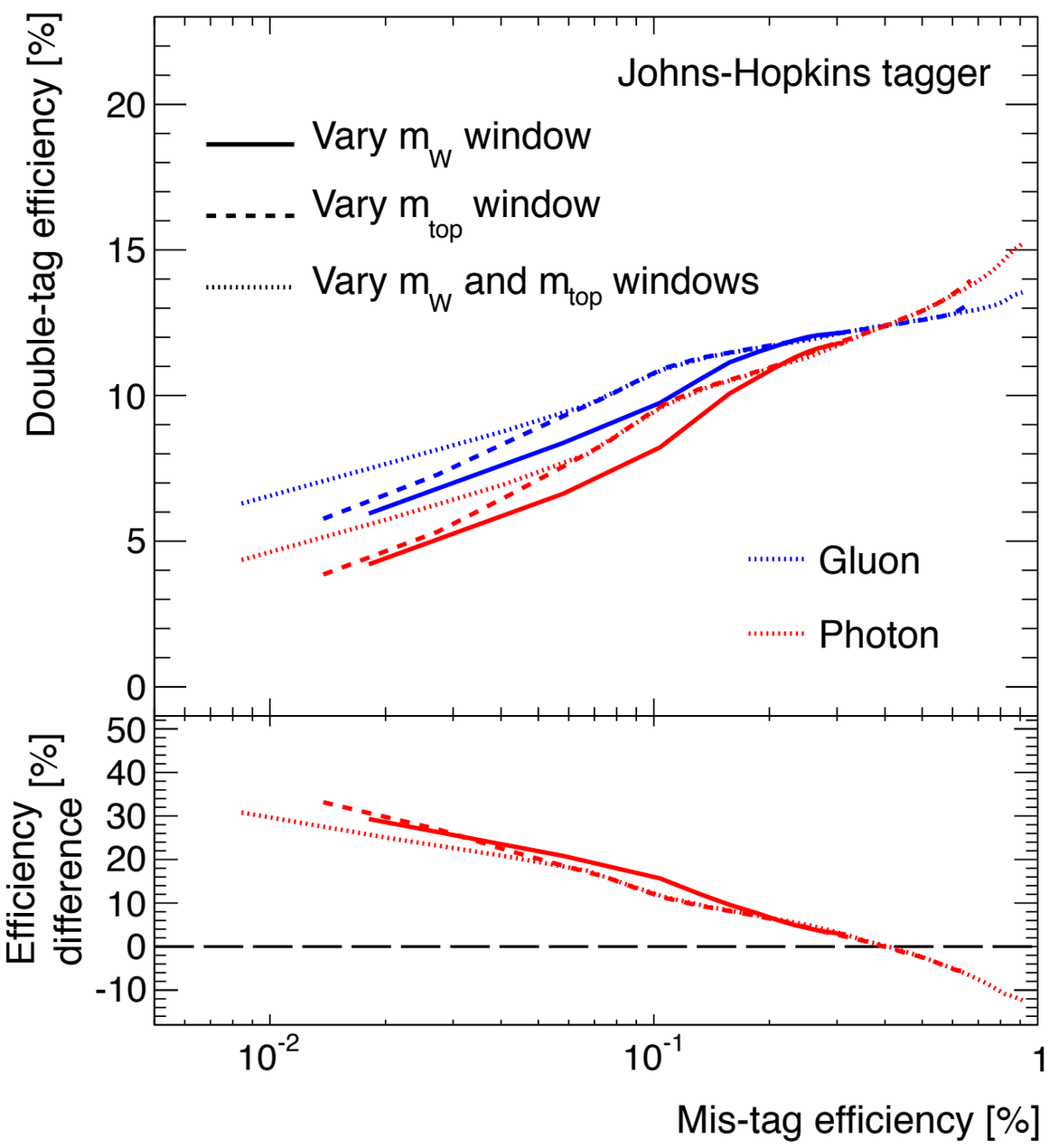
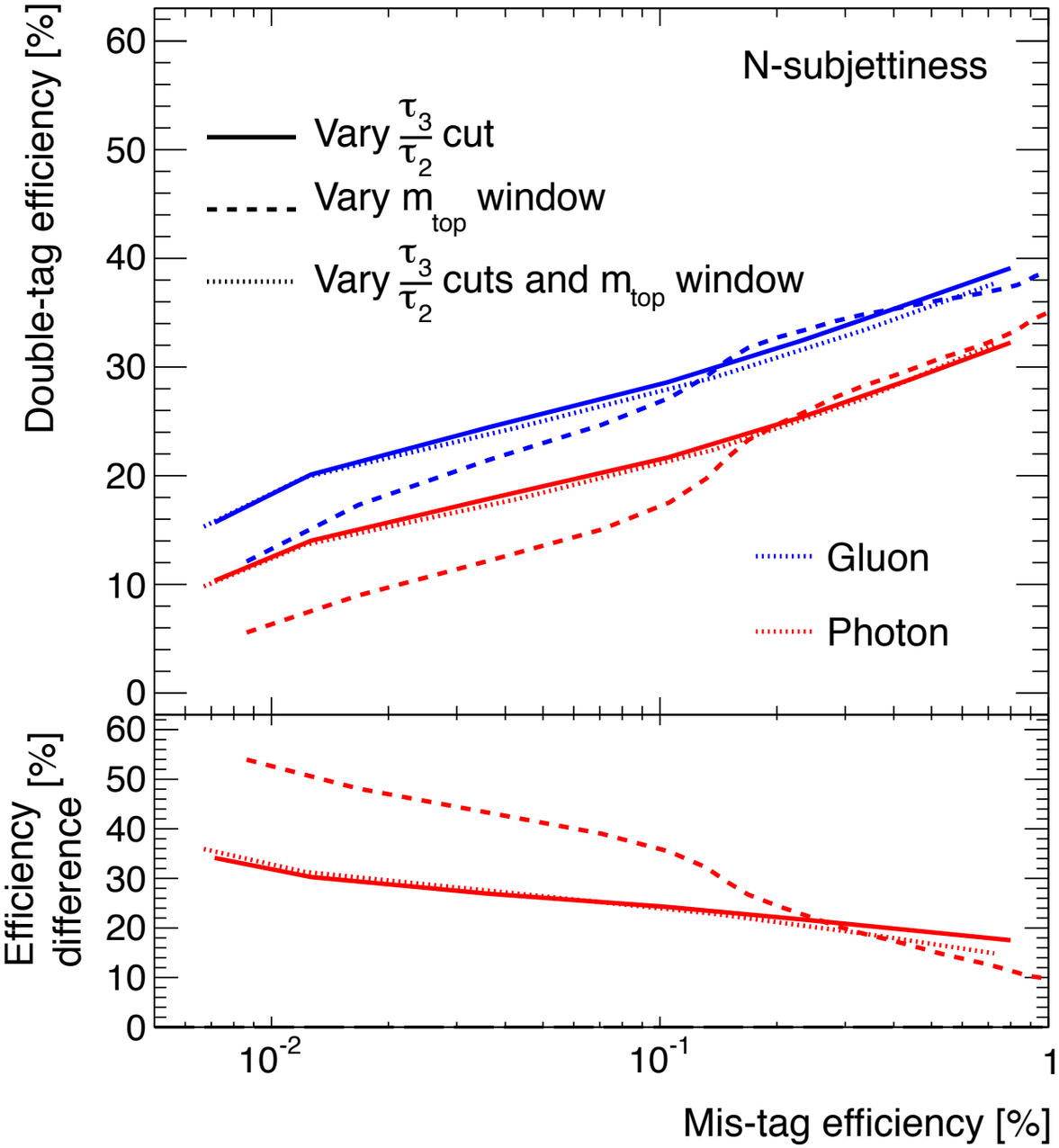
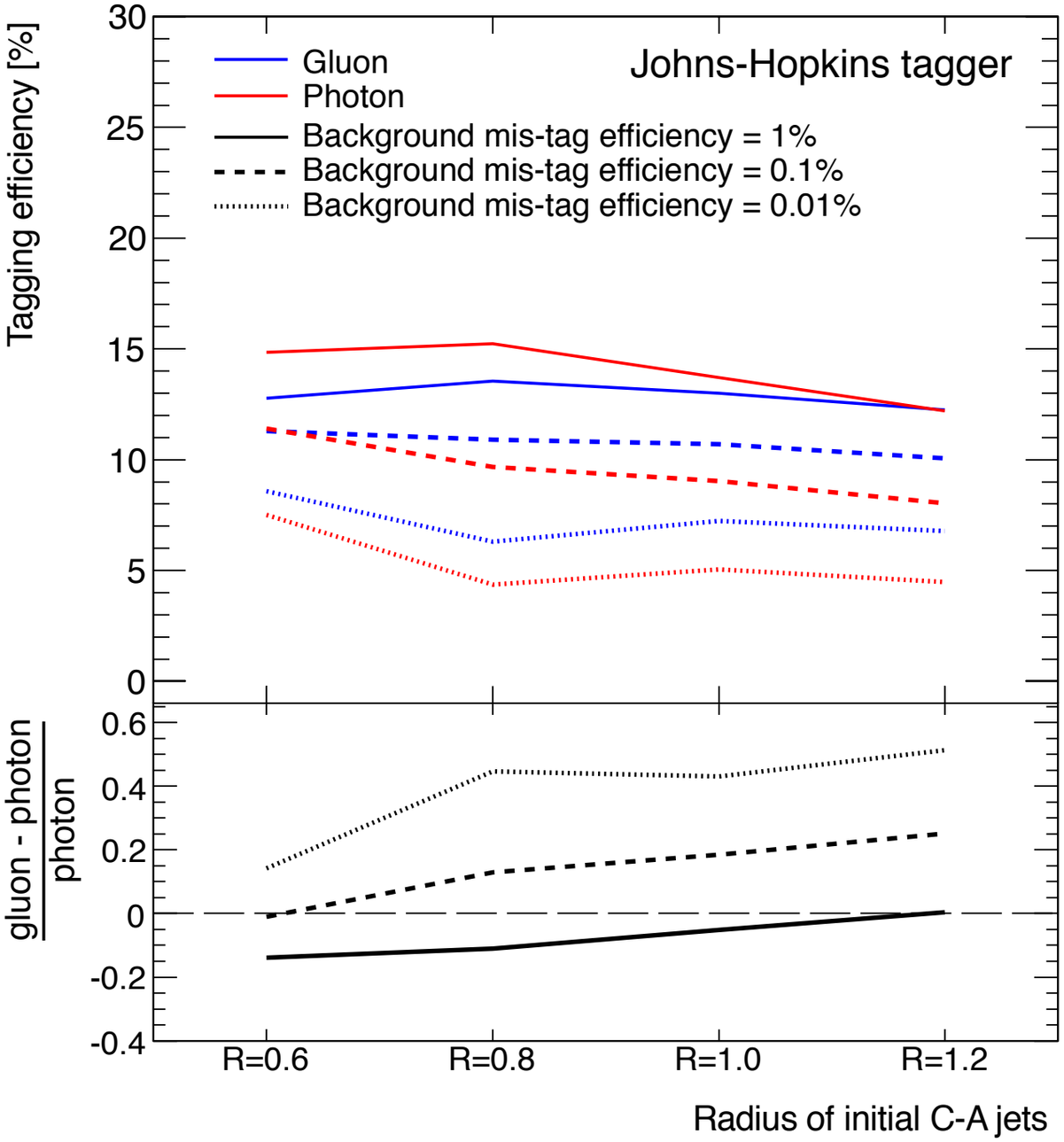
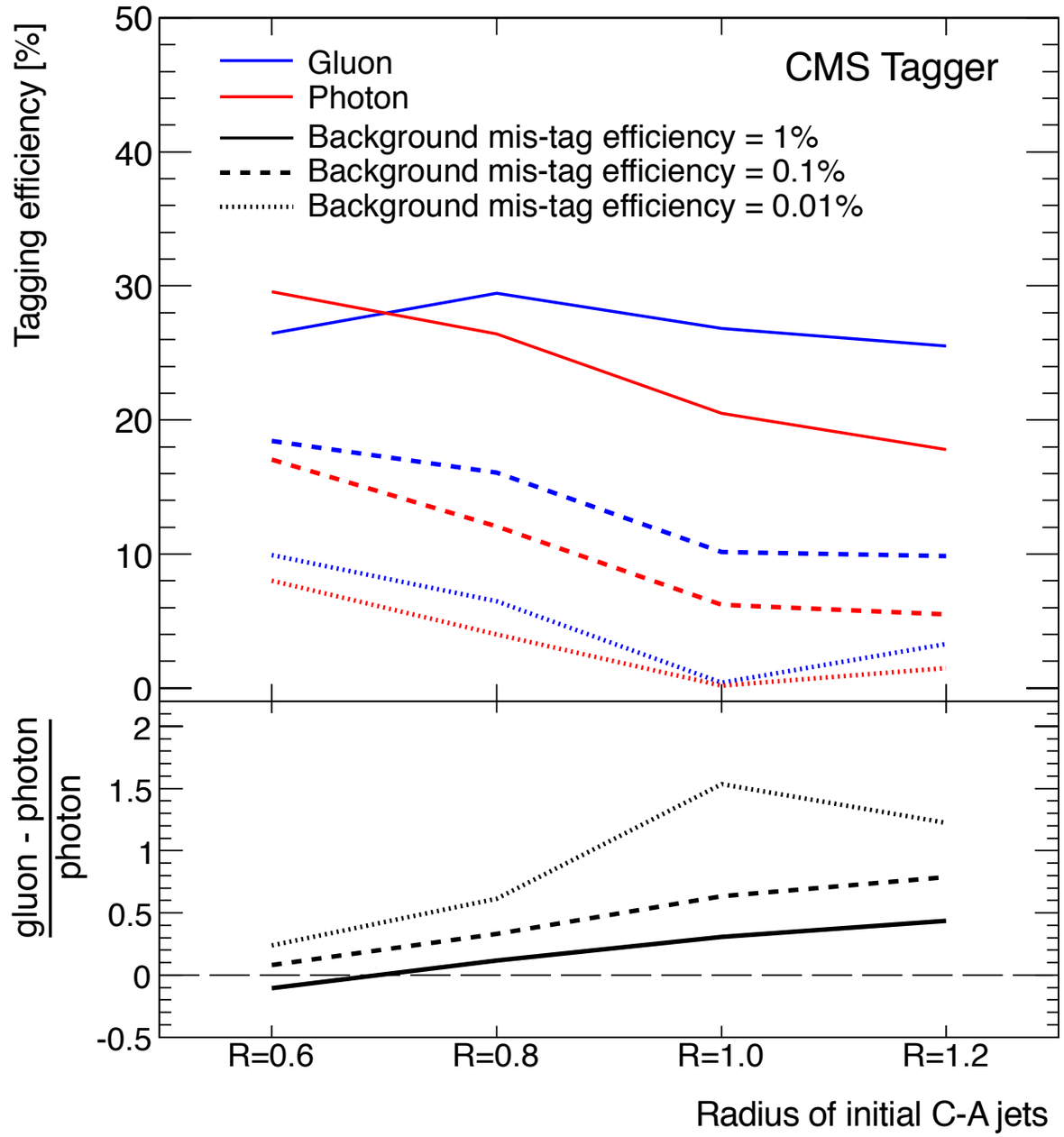




Cone size sensitivity





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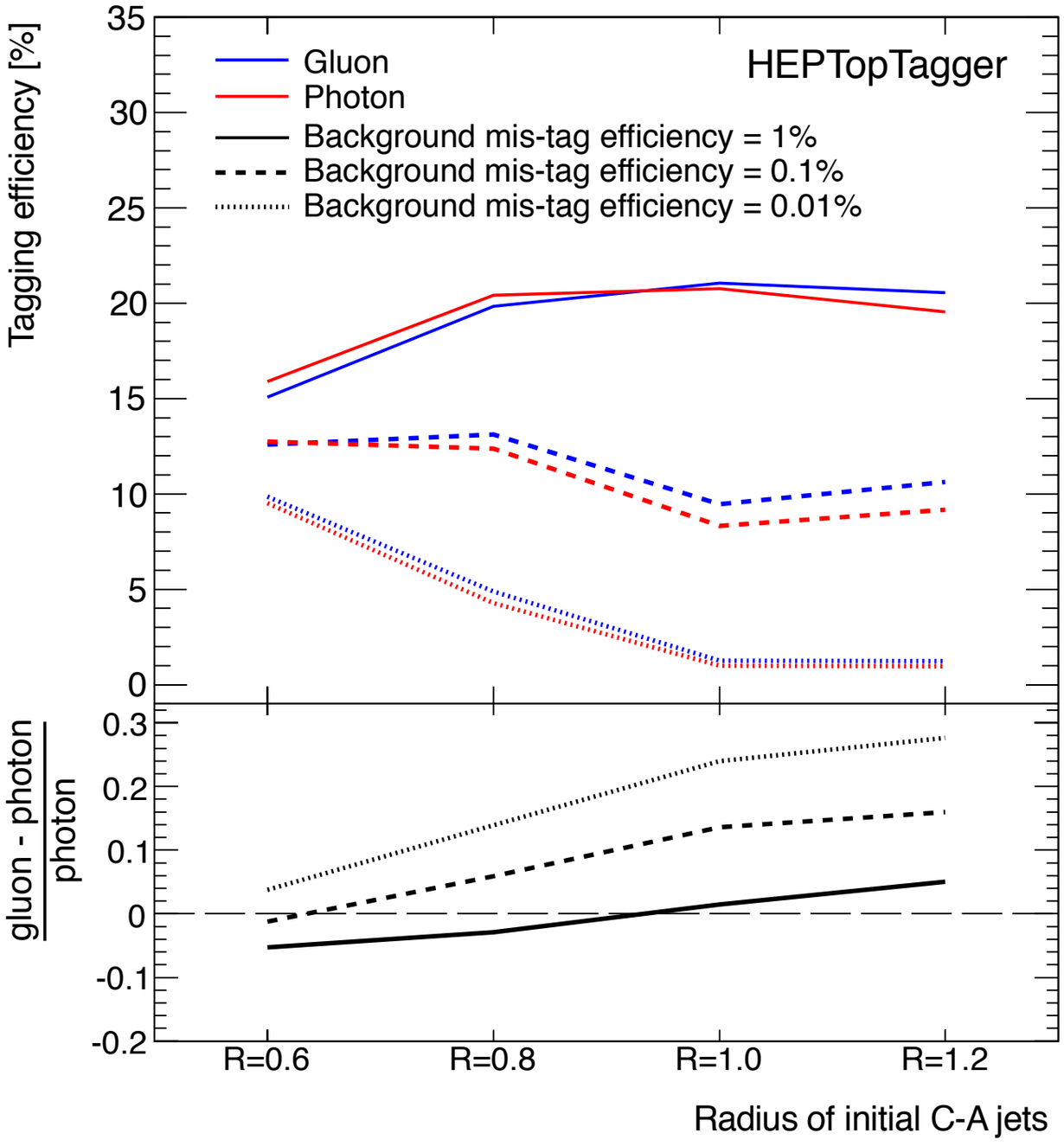
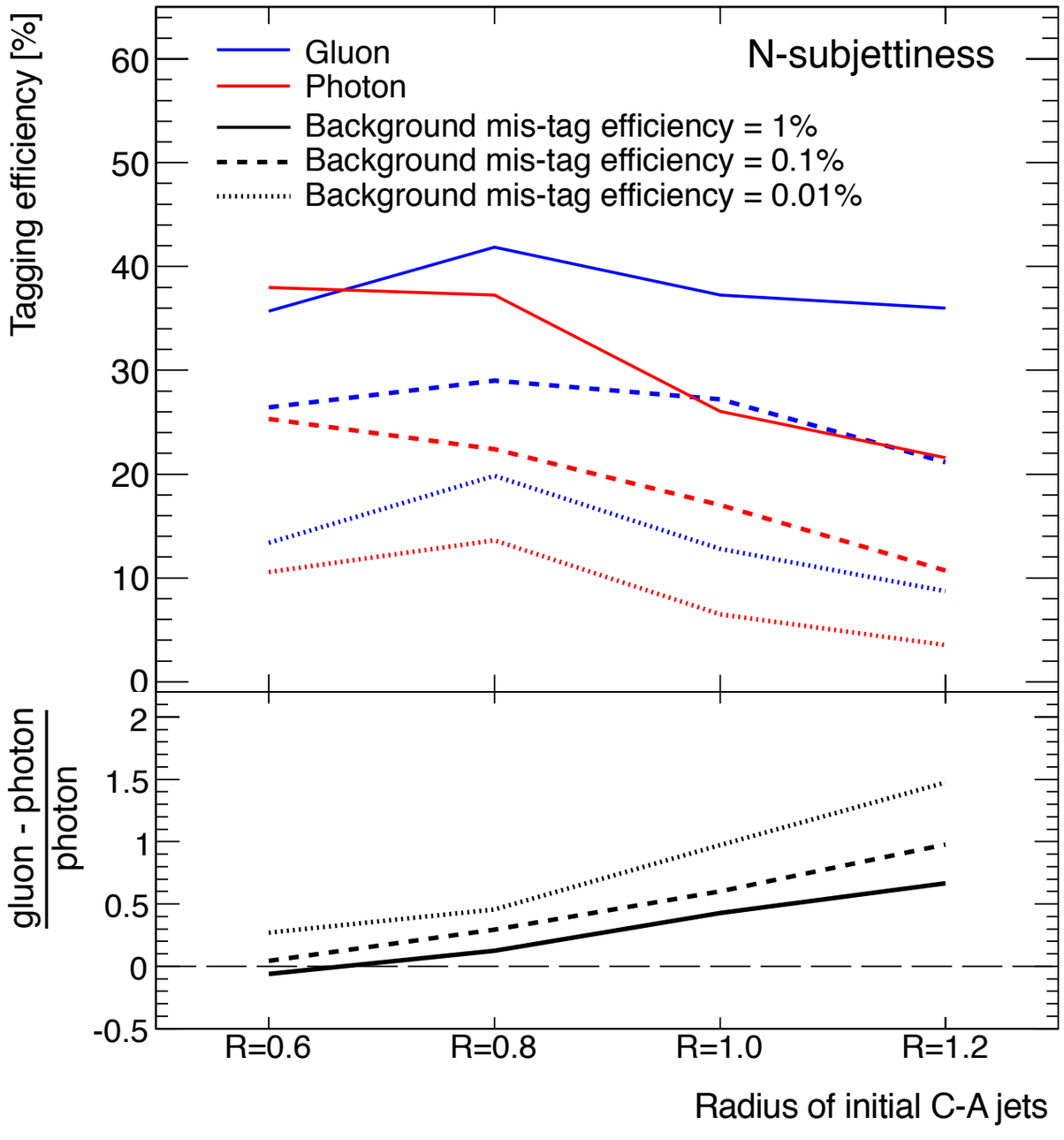
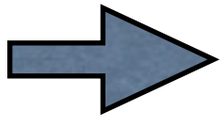
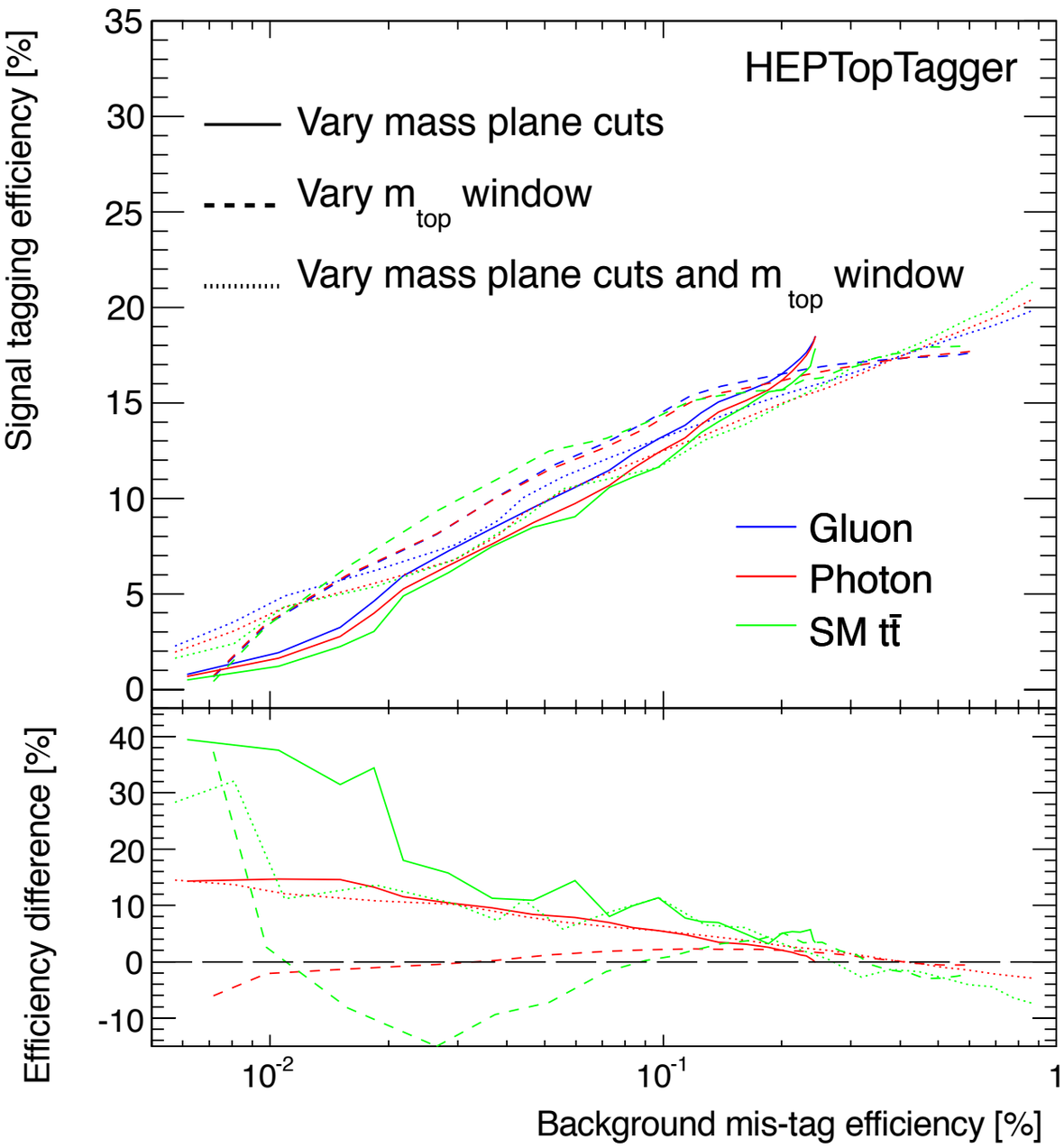


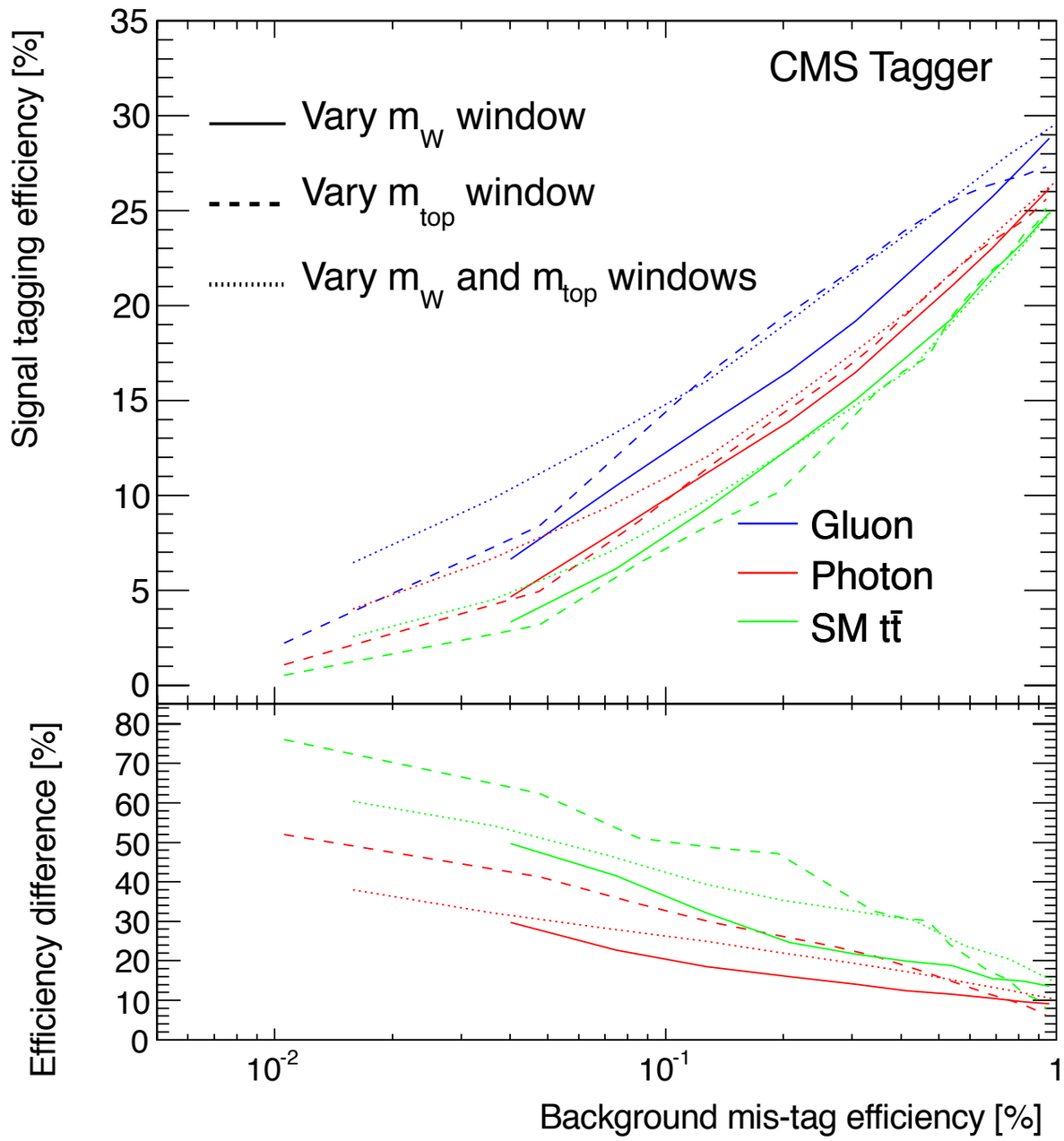




Smart choice of cone size crucial

Absence of control region





Big difference between SM ttbar and BSM scenarios

Impact on experimental searches

from (1204.2488: CMS-EXO-11-006, CERN-PH-EP-2012-77):

The systematic uncertainty in the tagging efficiency was estimated to be 3% (6%) for a single (double) tag, by comparing the W-tagging efficiency in data to MC using a sample of moderately boosted SM $t\bar{t}$ events.

The same methodology also yielded a scale (normalisation) factor of 0.97 for MC events, to recover the central tagging efficiencies observed in the data
-> used for signal and backg.

(Quite pushy, but well...)

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quote from (ATLAS-CONF-2012-102):

"There is no additional uncertainty added for the modelling of variables in the HEPTopTagger as all uncertainties on the input objects (such as the JES) are fully propagated and additionally the substructure variables shown in ... agree very well between data and prediction." (Not correct, but 'Lucky Devils')

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quote from top tagger review (Plehn, Spannowsky, 1112.4441):

"Because the tagging efficiency of the tops does not depend on the spin or the color charge of the heavy resonance, the only parameters which determine if the resonance search is feasible are the resonance's mass and the production cross section" (wrong!)

Some results

All taggers are sensitive to color charge of resonance,
i.e. color flow in event

HEPTagger least sensitive due to built-in (sub)jet grooming

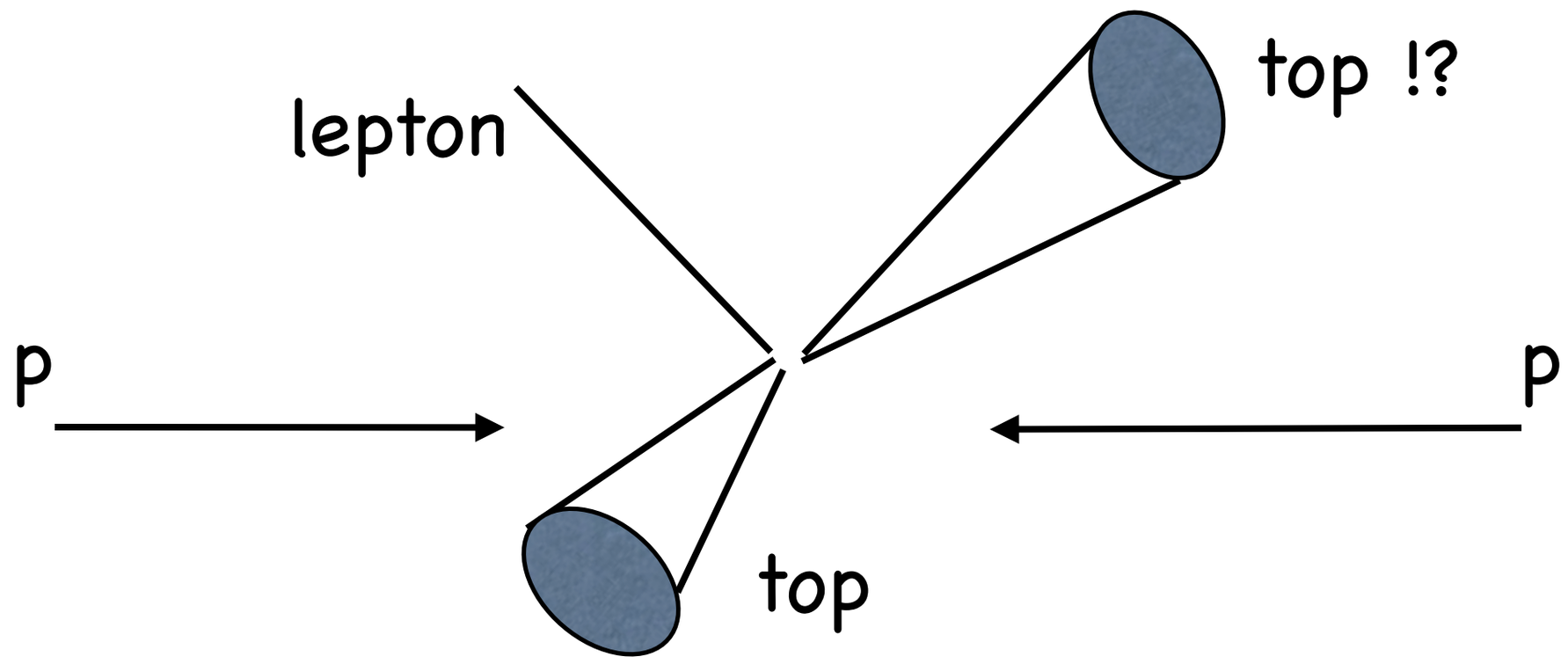
Necessity for high-pT jet grooming underestimated in past

Absence of control region for BSM searches
-> particularly bad if no peak (e.g. stops) or broad resonance
-> completely rely on MC simulation

Present analyses seem to underestimate this effect

If taggers do heavily depend on the sought after resonance why not build directly a hypothesis test (tagger) for the resonance/process?

Idea for Shower Deconstruction



II. Top tagging from shower destruction

(in collaboration with Dave Soper and Zoltan Nagy)

The method:

- Maximal information approach to discriminate signal from backgrounds
  -> UE, ISR, FSR, hard process
- We want one discriminating analytic function

Work closely with ATLAS Glasgow
(James Ferrando, Nicolas Gutierrez, Deepak Kar)

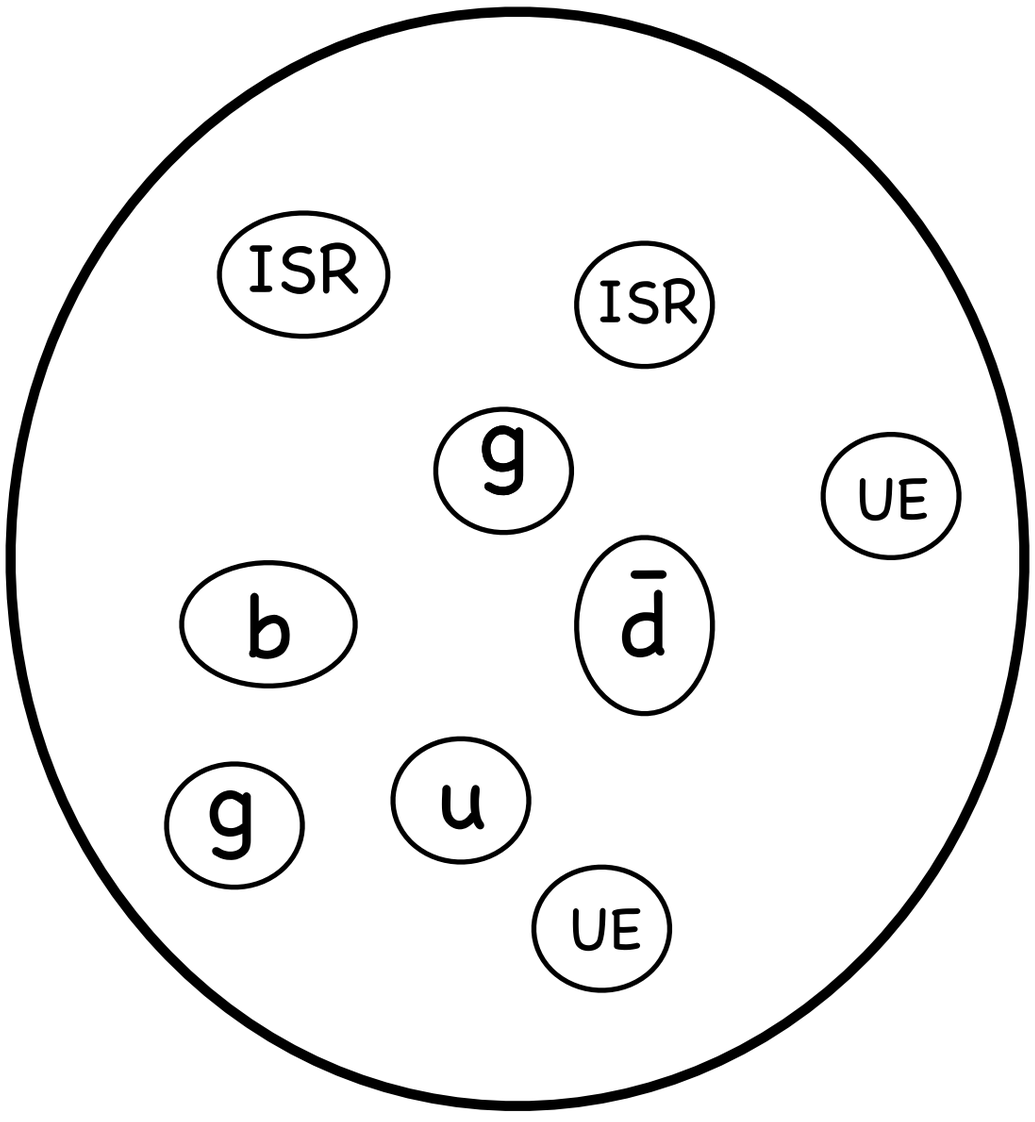
[Soper, MS PRD 84 (2011)]

Final and distant goal:

Shower deconstruction is related to **Matrix Element Method**
like
Full Event Generators to **Parton Level simulation**

For now study boosted tops

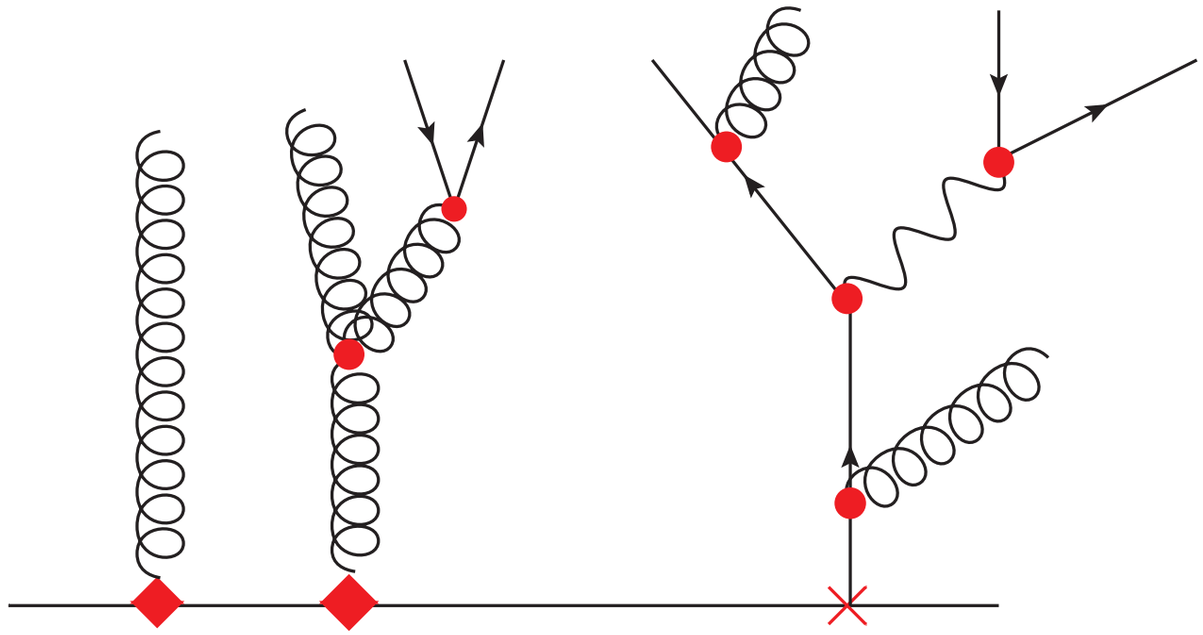
Fat jet: R=1.0, anti-kT



microjets
R=0.15, kT
pT>3.0 GeV

ISR/UE

hard interaction

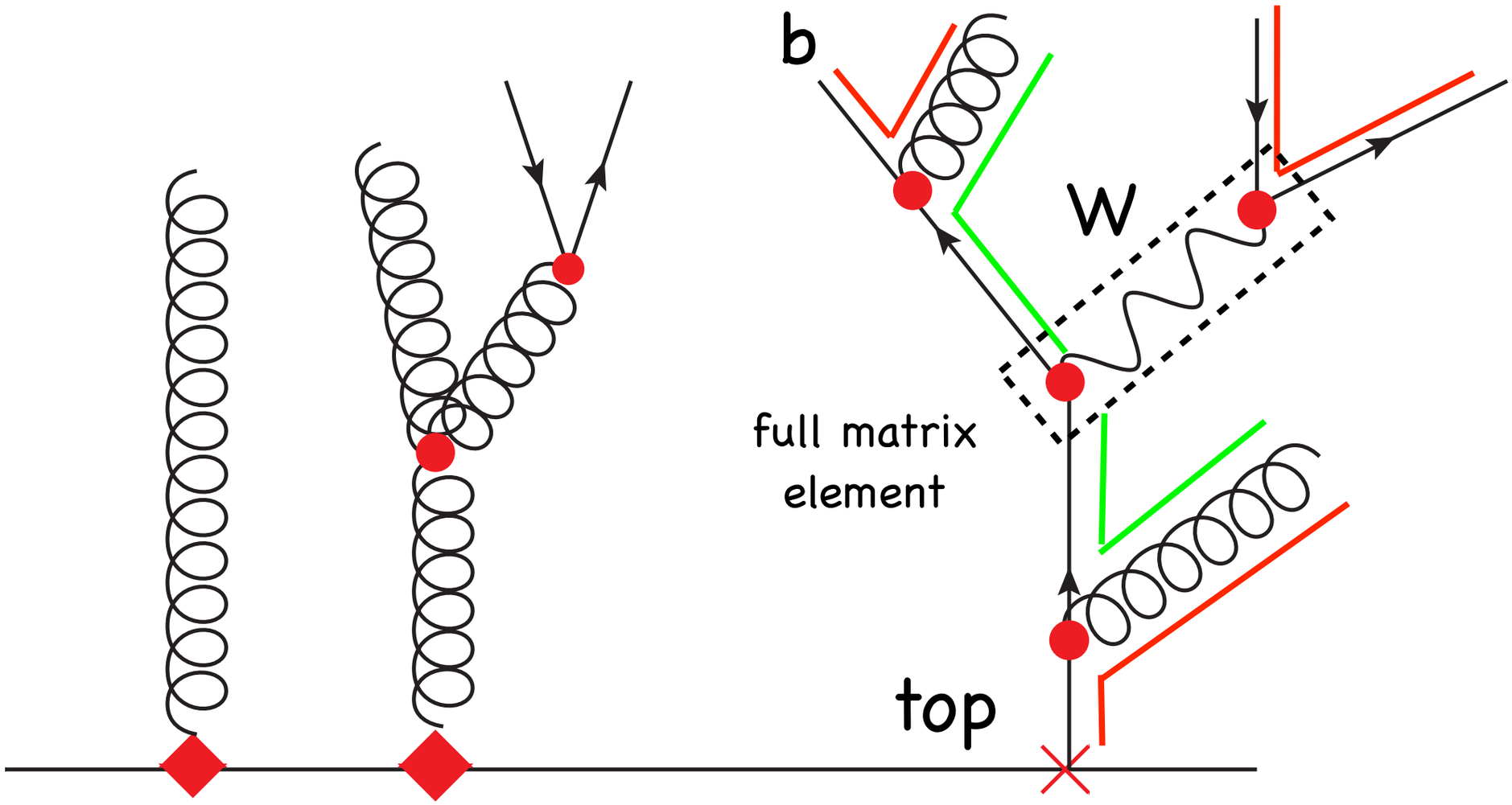


Build all possible shower histories

signal vs background hypothesis based on:

- Emission probabilities
- Color connection
- Kinematic requirements
- b-tag information

Need to convert the shower history into analytic expression



Conceptional difference compared to Higgs from last year:

- Splitting functions for massive emitter and spectator
- Full matrix element for top decay

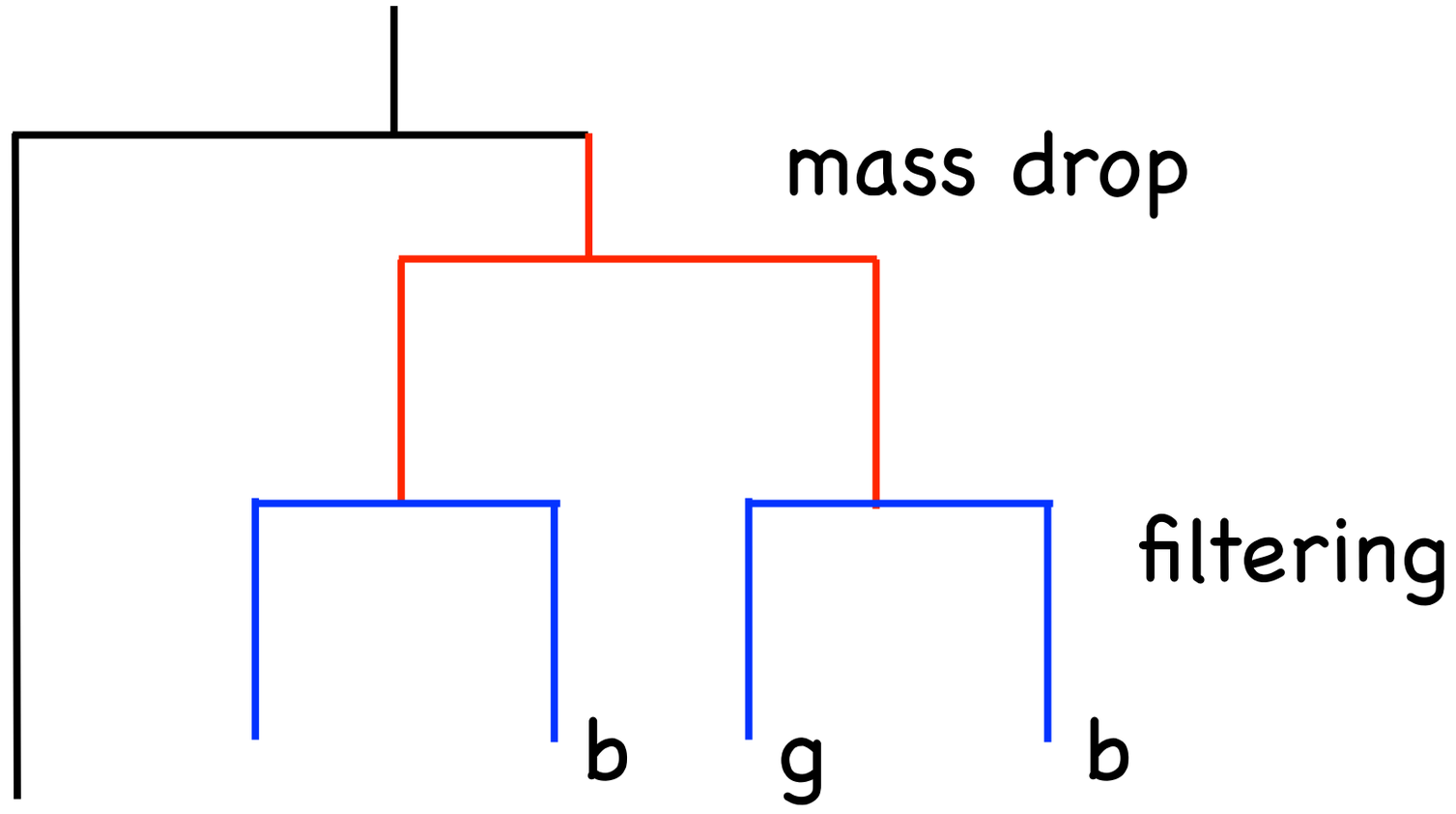
$$\chi(\{p,t\}_N) = \frac{P(\{p,t\}_N|\mathrm{S})}{P(\{p,t\}_N|\mathrm{B})} = \frac{\sum_{\mathrm{histories}} H_{ISR} \cdots \sum_{\mathrm{histories}} |\mathcal{M}|^2 H_{\mathrm{top}} e^{-S_{t_1}} H^s_{tg} e^{-S_g} \cdots}{\sum_{\mathrm{histories}} H_{ISR} \cdots \sum_{\mathrm{histories}} H^b_g e^{S_g} H_{ggg} \cdots}$$

Input to algorithm not recombination history of fat jet but microjets

Jet recombination history is NOT shower history, i.e. for large R

How is SD related to other algorithms?

BDRS:



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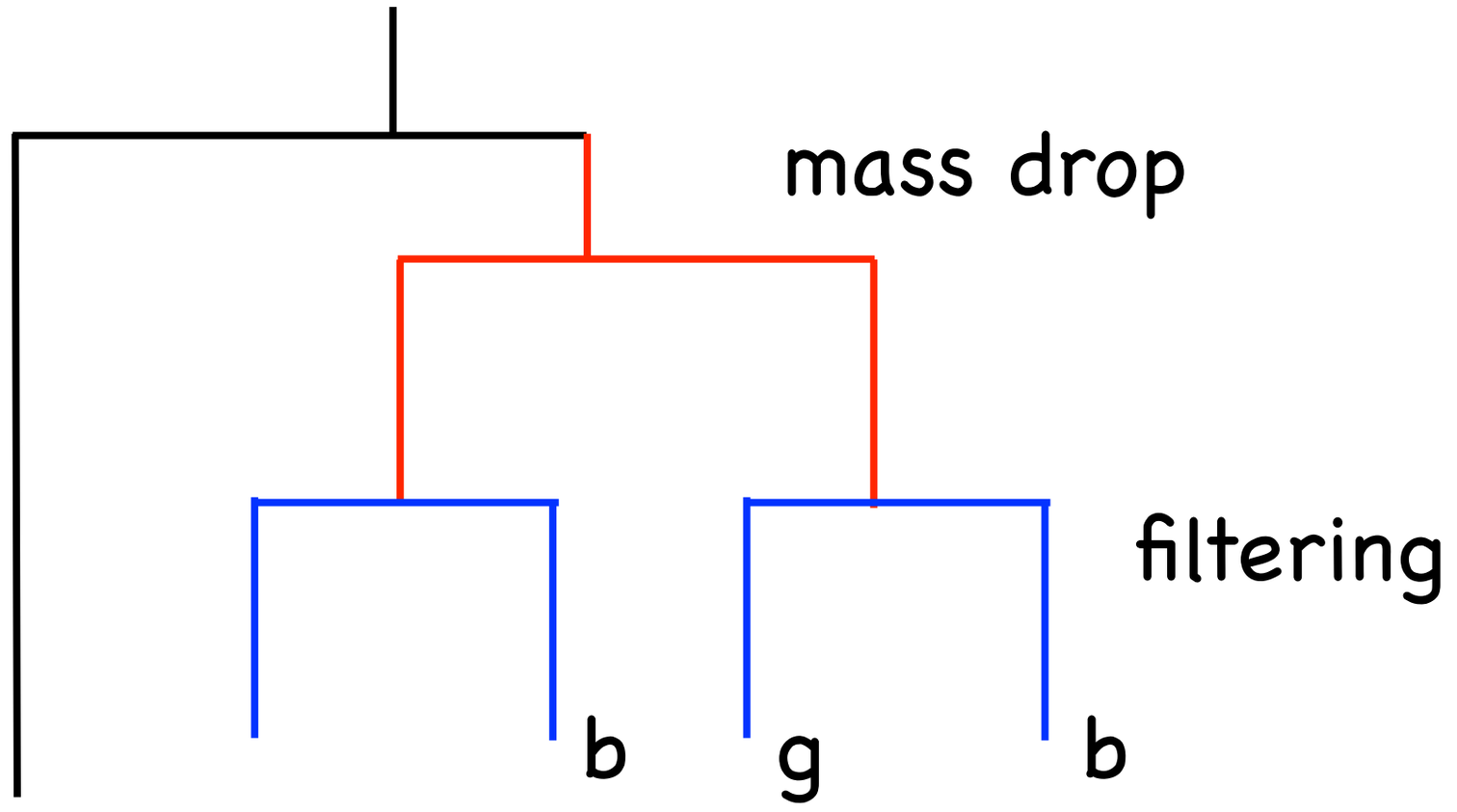

If microjets are basic building blocks of event and all physics is considered SD automatically contains other tagging algorithms

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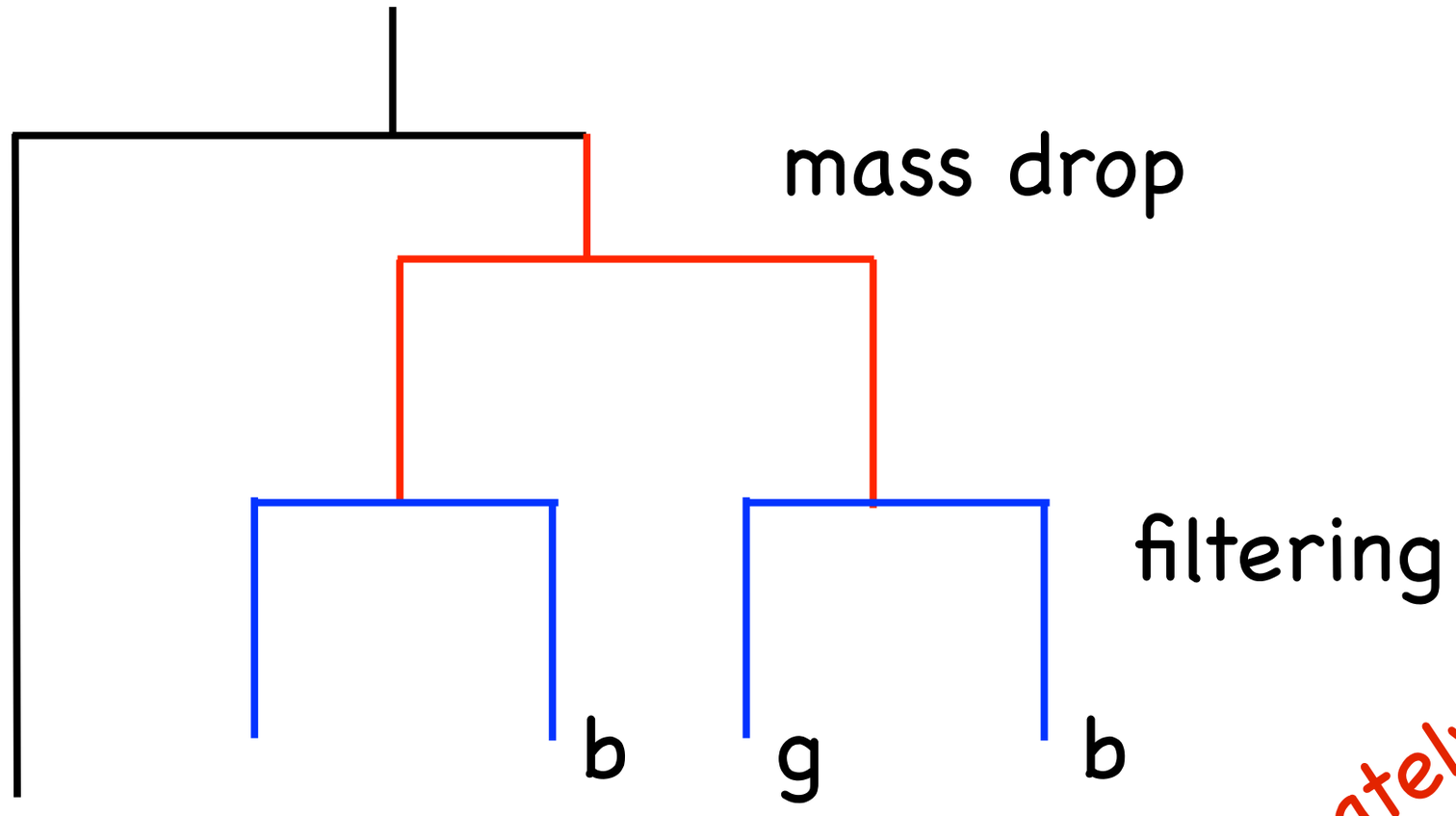

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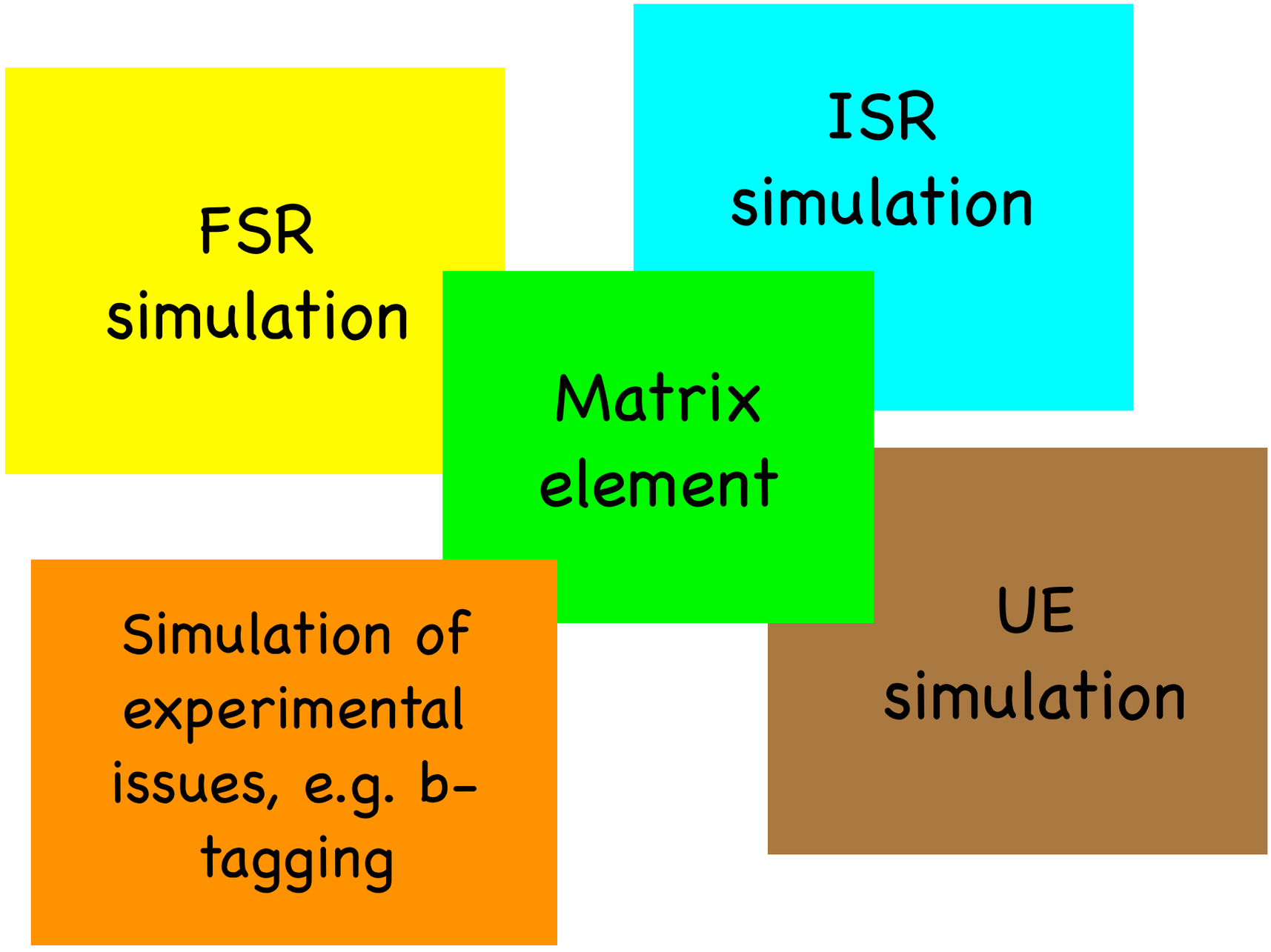
Unfortunately, never possible...

Lots of room for improvement:



Modular built -> improvements are additive

Event selection:

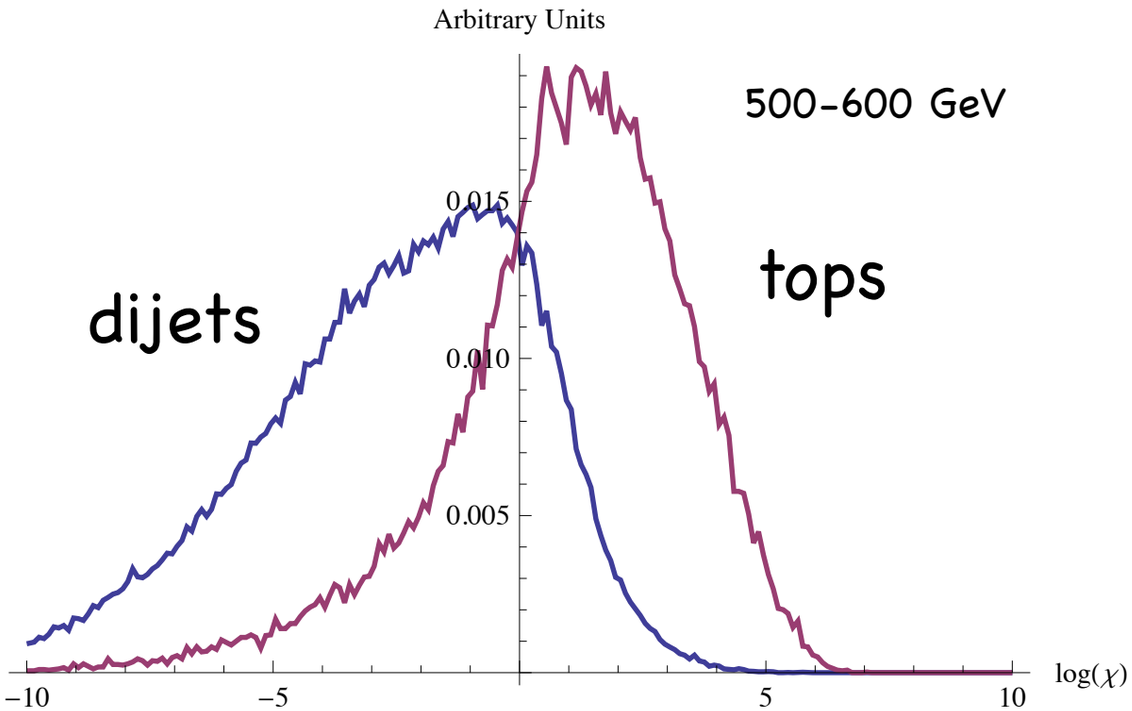
Signal is Z′ with 1.5 TeV simulated with Pythia 8

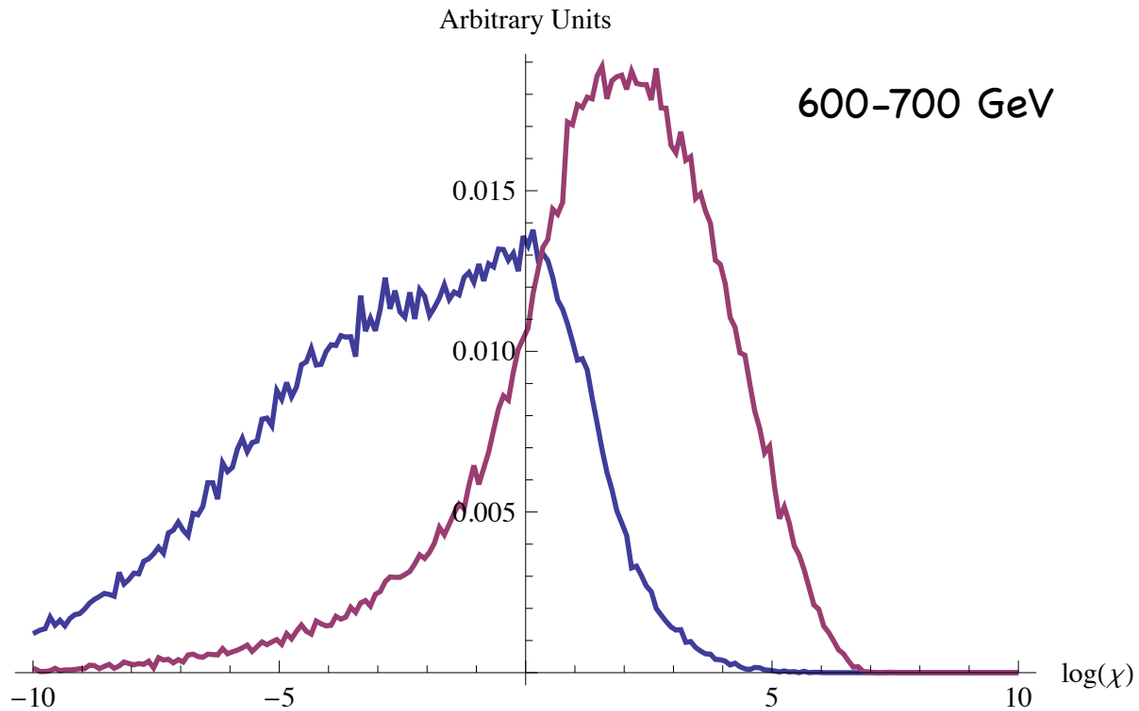
Background is dijets simulated with Pythia 8

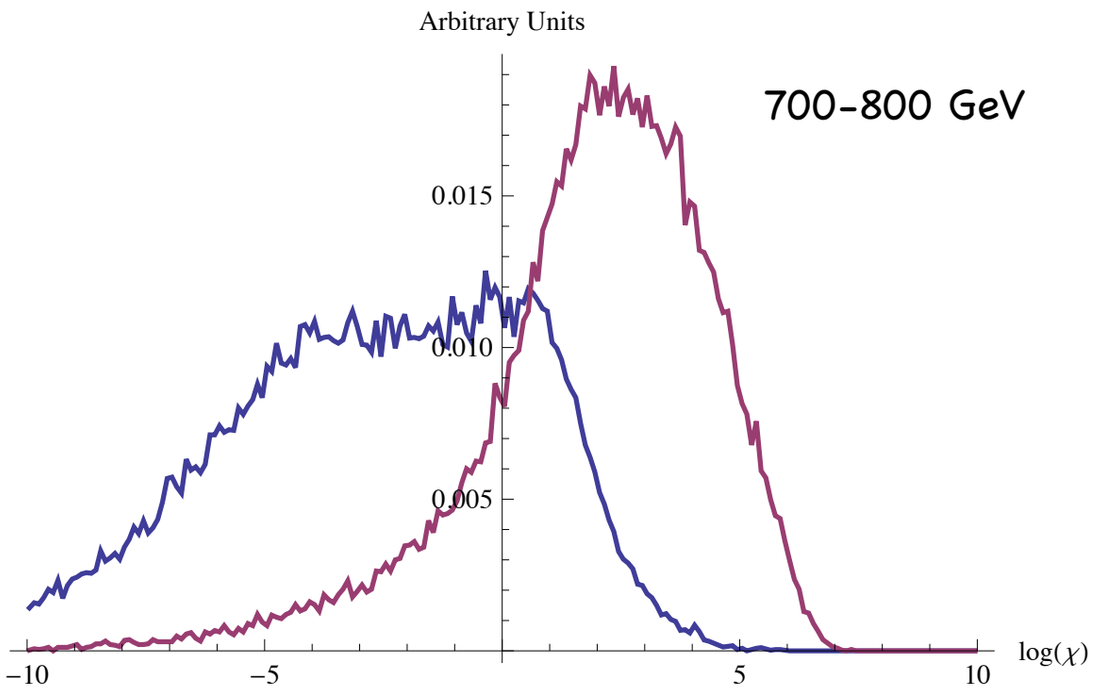
Require:

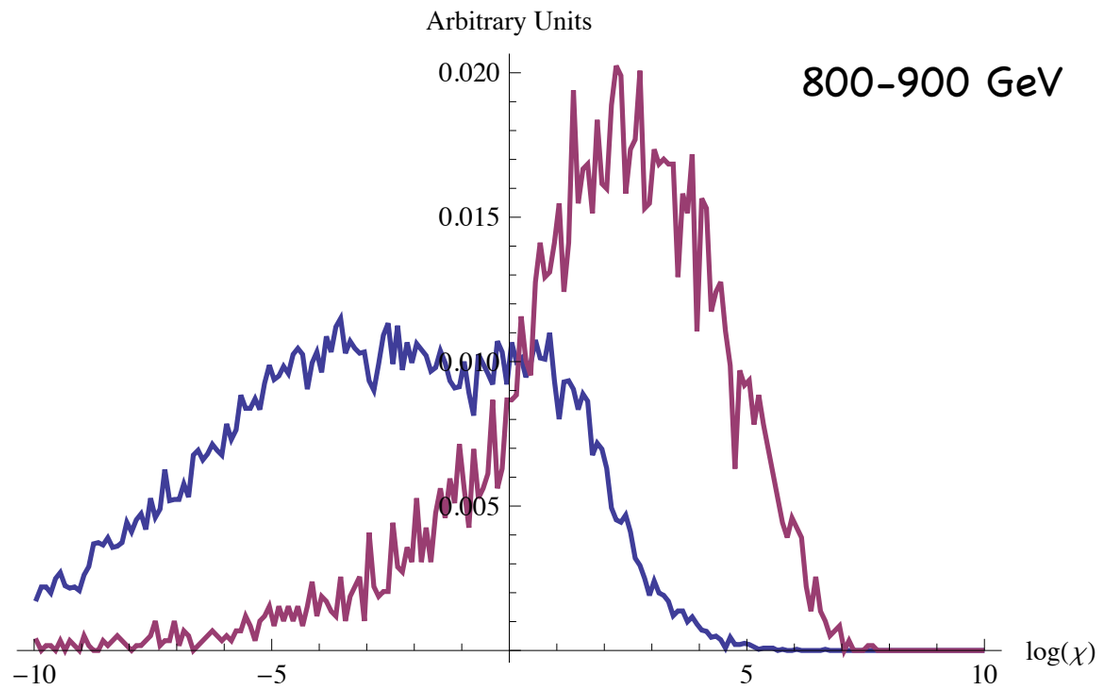
- 2 fat jets CA, R=1.0, pT>500 GeV
- Check for signal using MC truth that top is in fat jet
- For microjets use kT R=0.15, pT>3 GeV
- If more than 9 microjets present discard softest

Chi distributions for signal and background

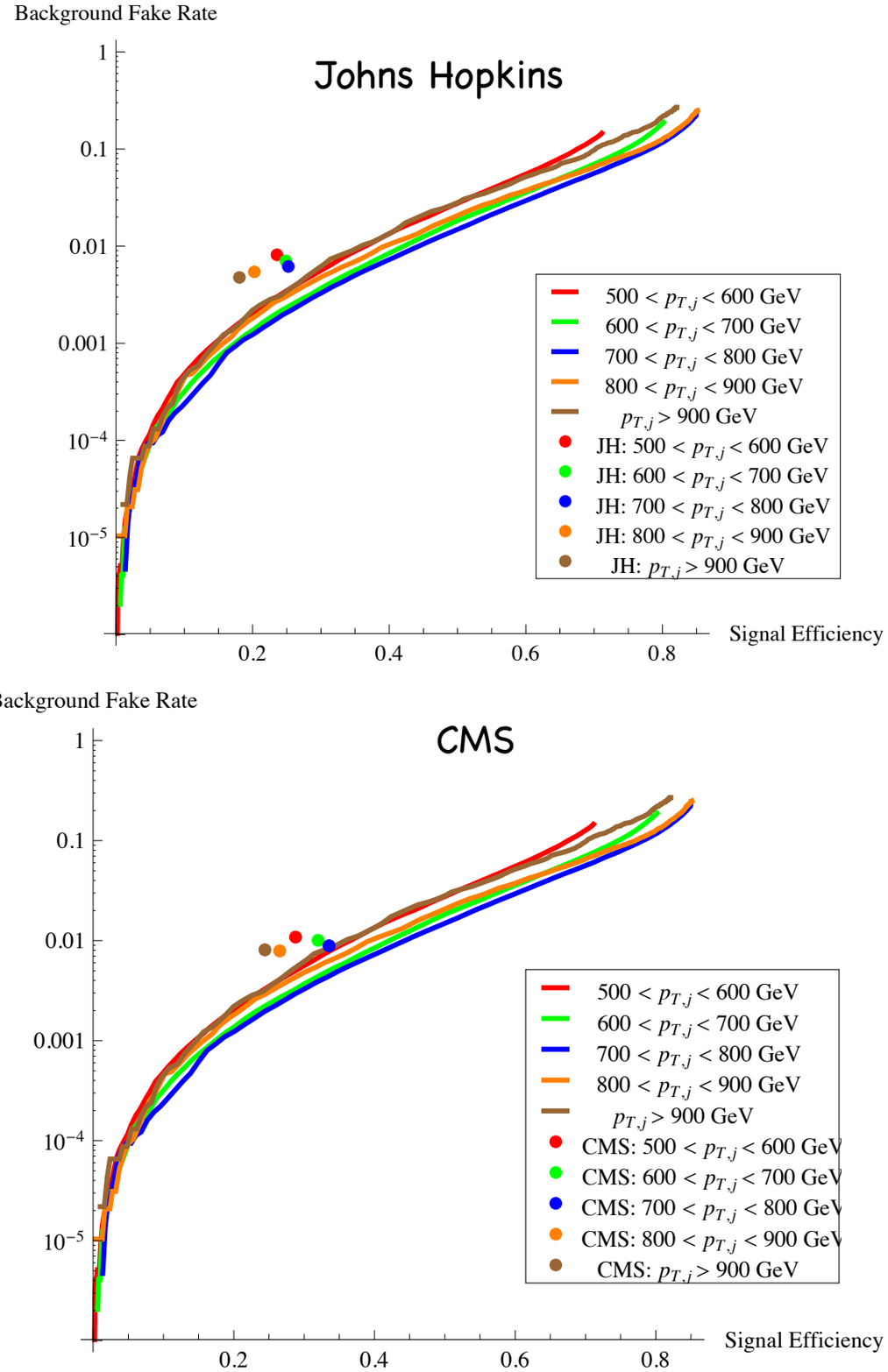


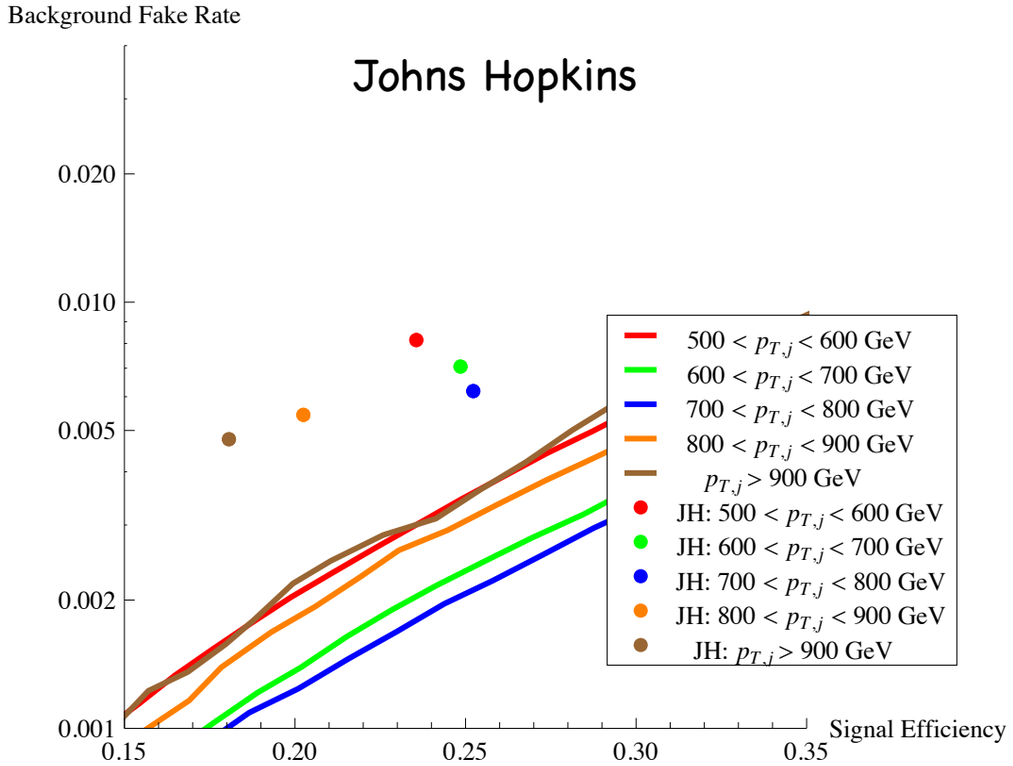


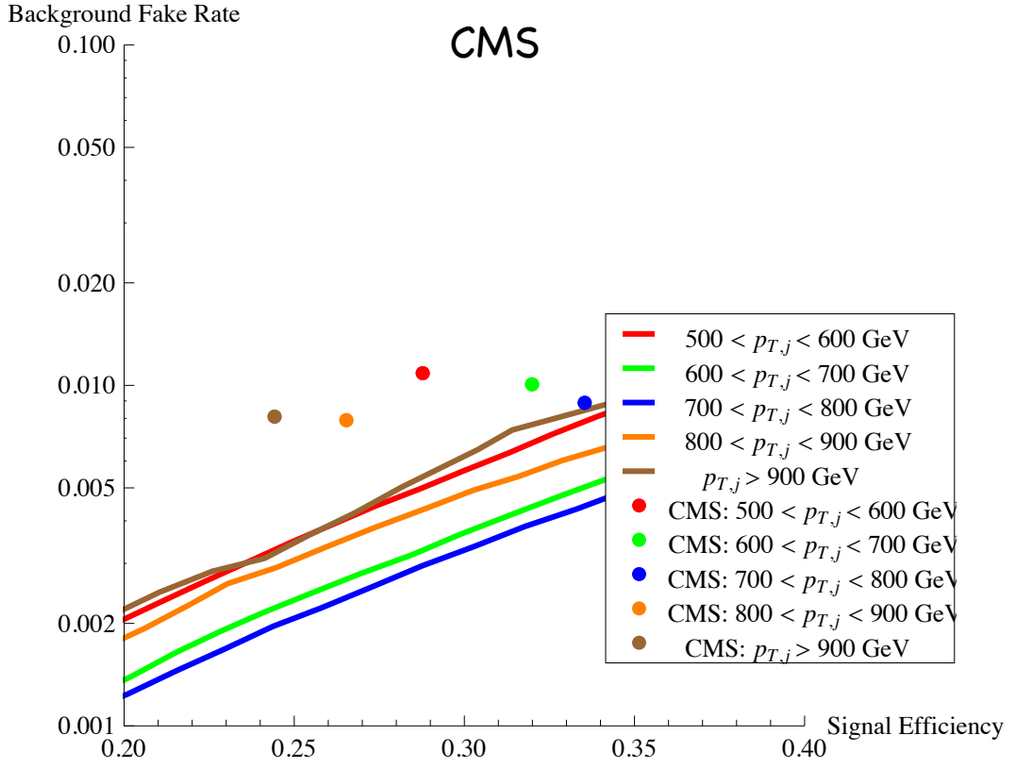




Tagging performance in Z'







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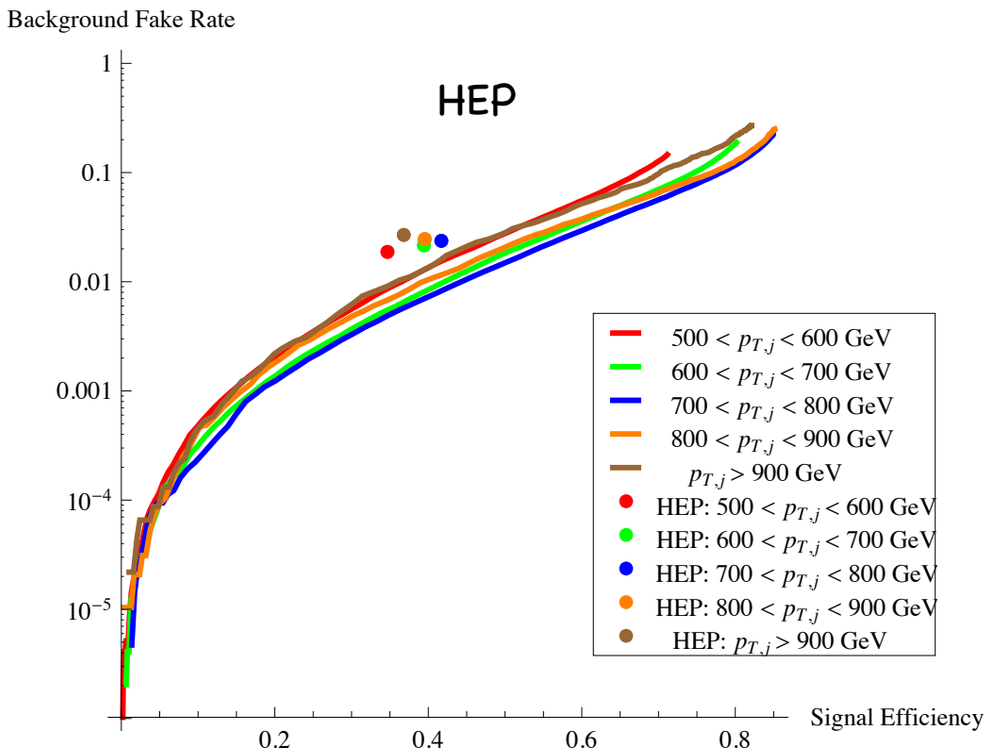
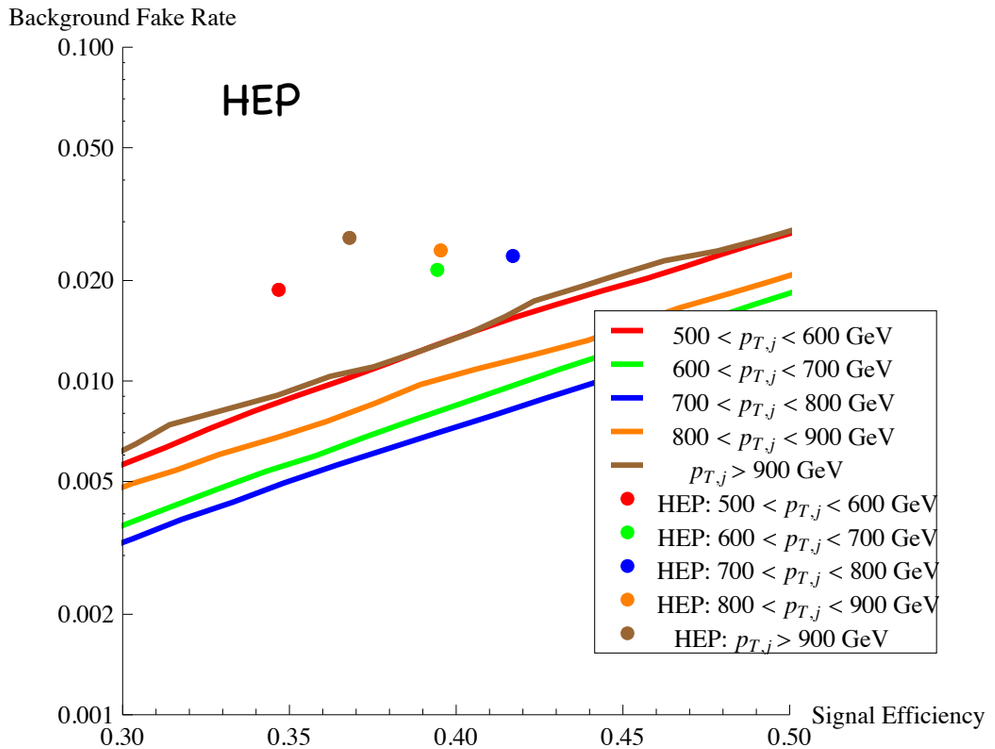
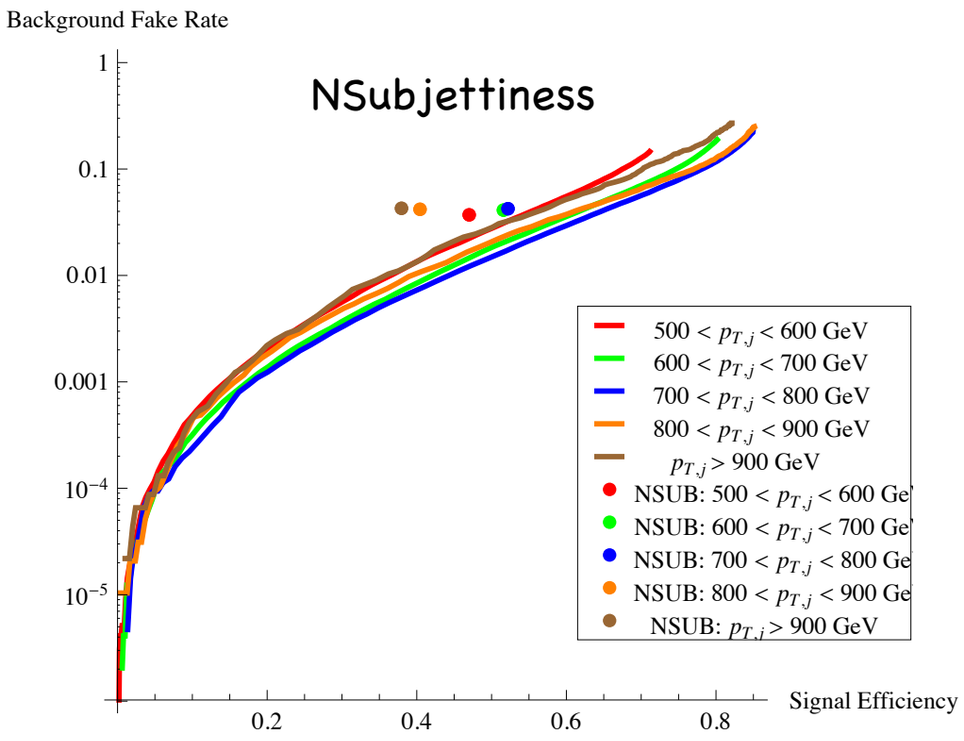
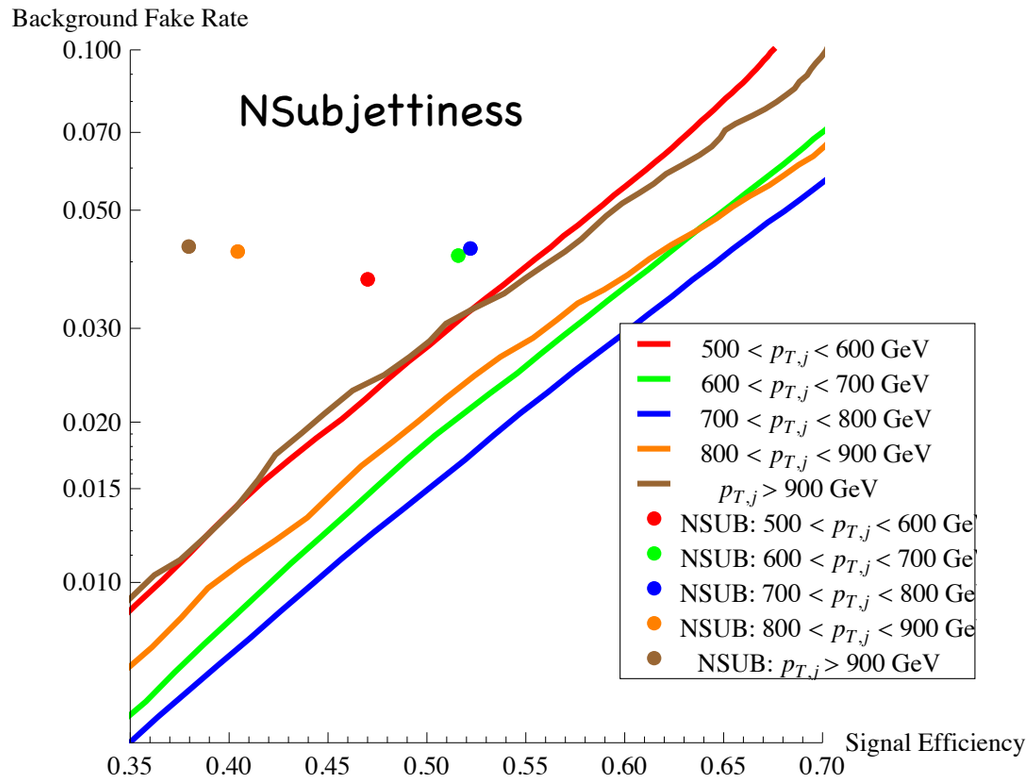
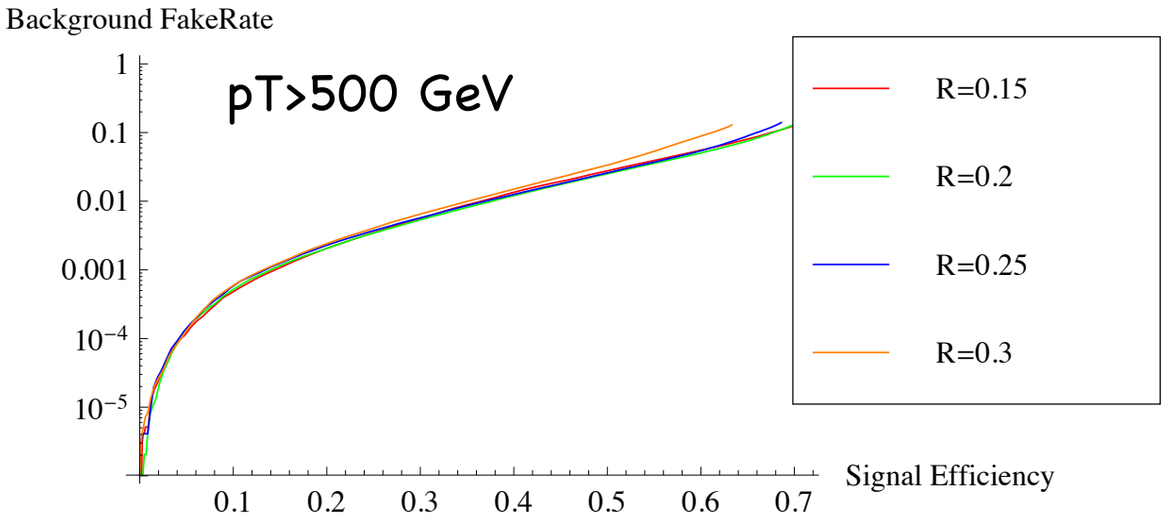


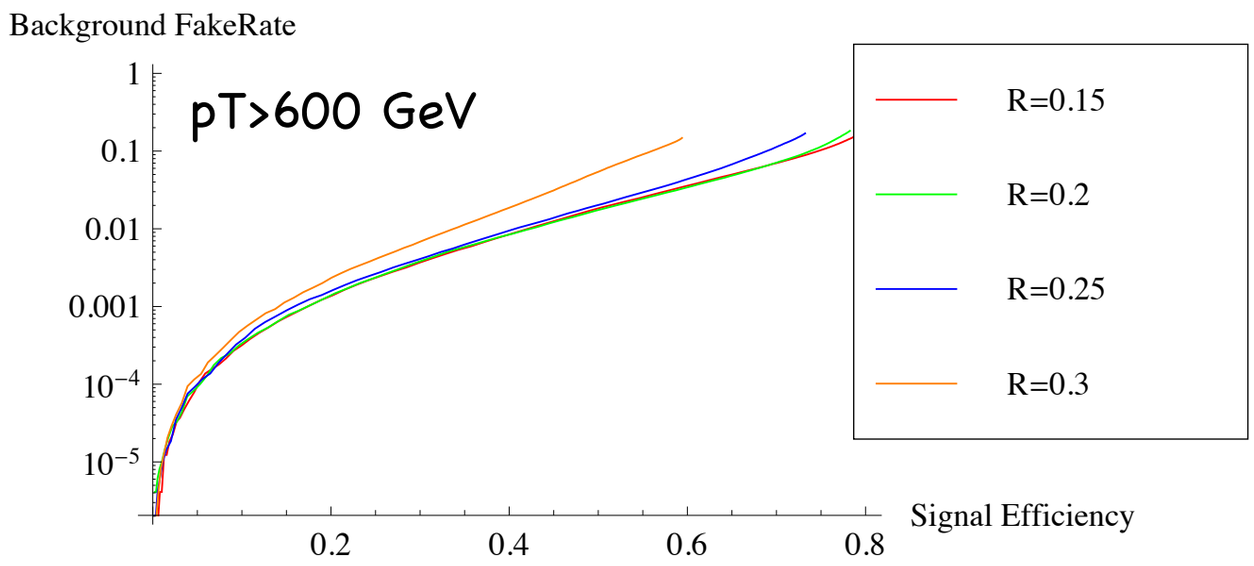


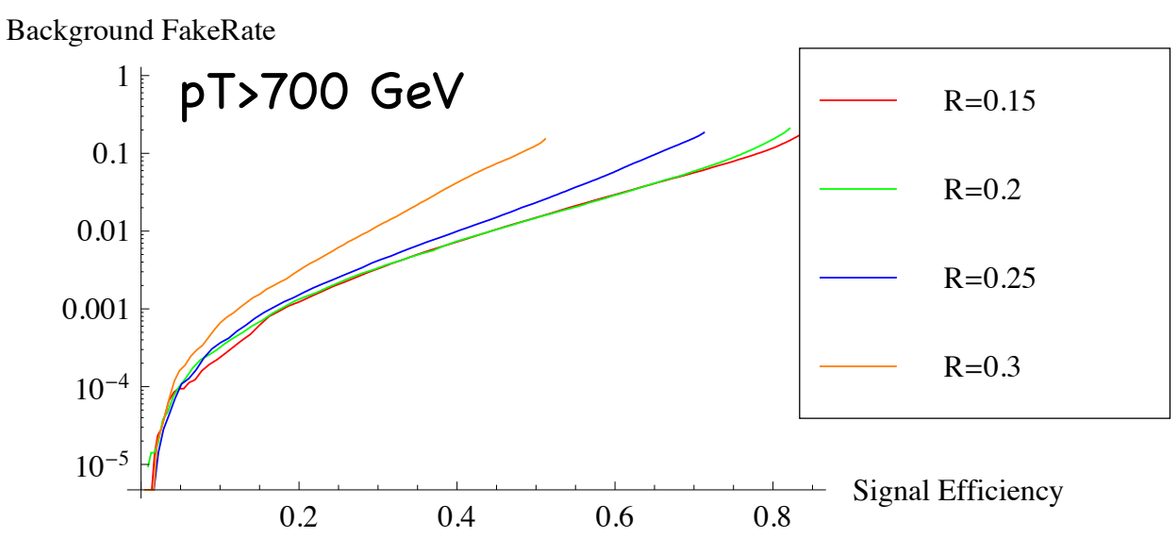


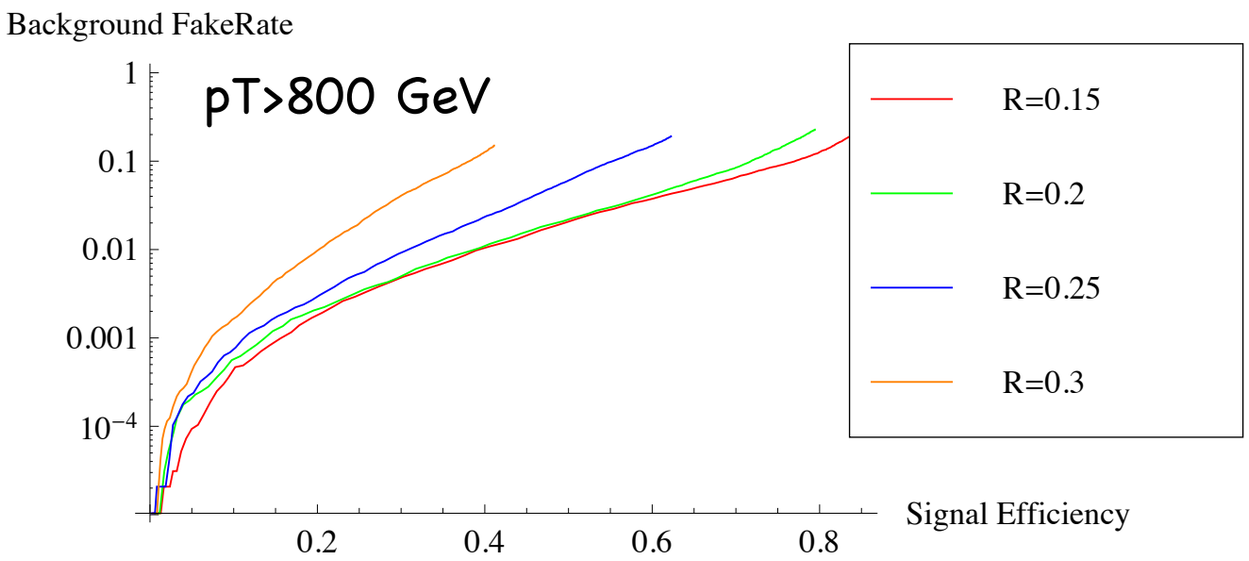


Changing microjet cone size









Summary

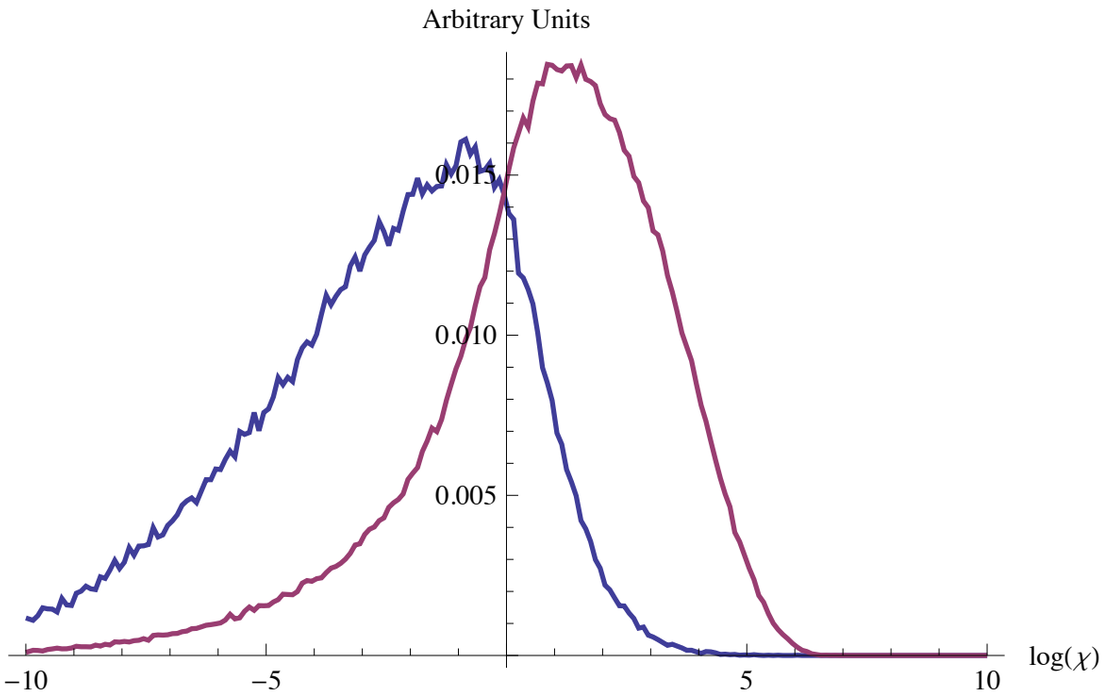
- Shower deconstruction maximum information approach to find new physics at the LHC

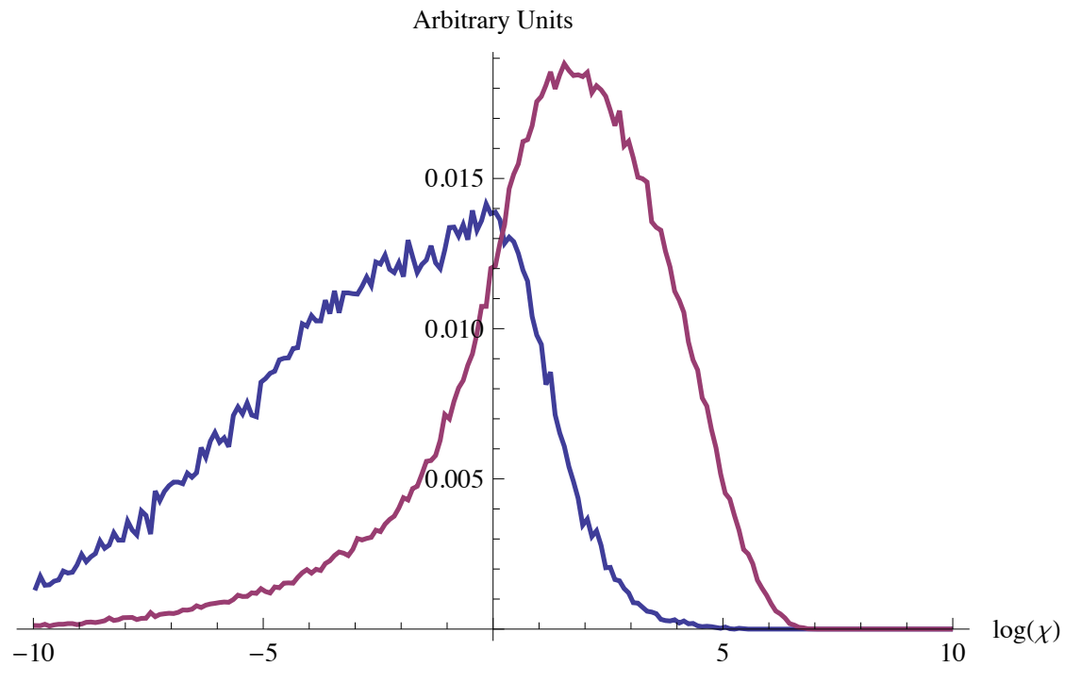
- Potentially strong exp. limitations but large potential

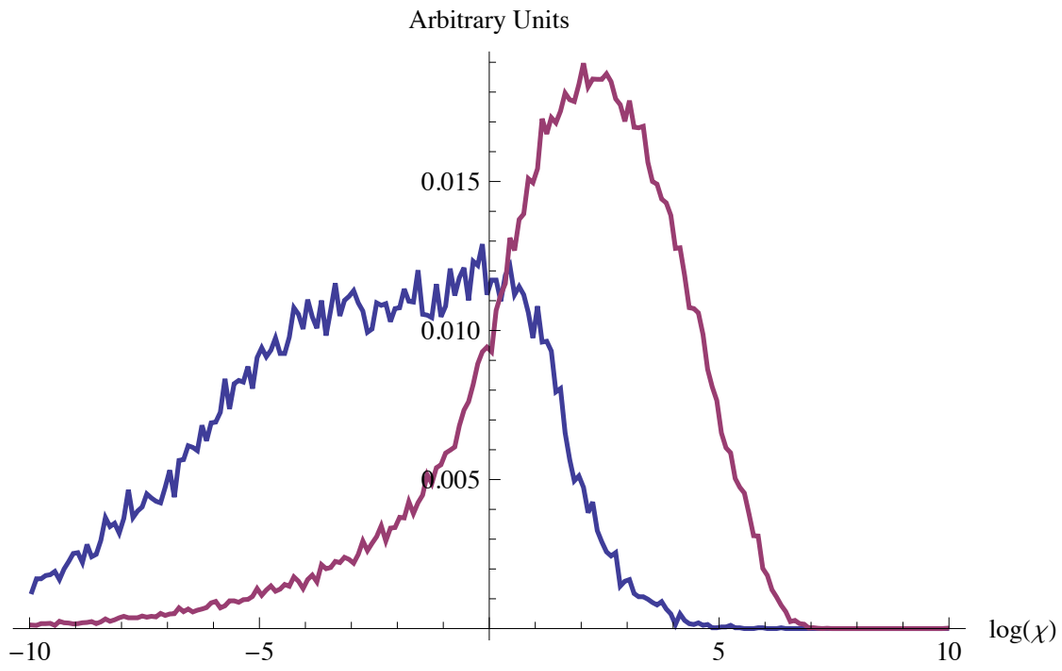
- For studied scenarios SD top tagger improves on existing ones

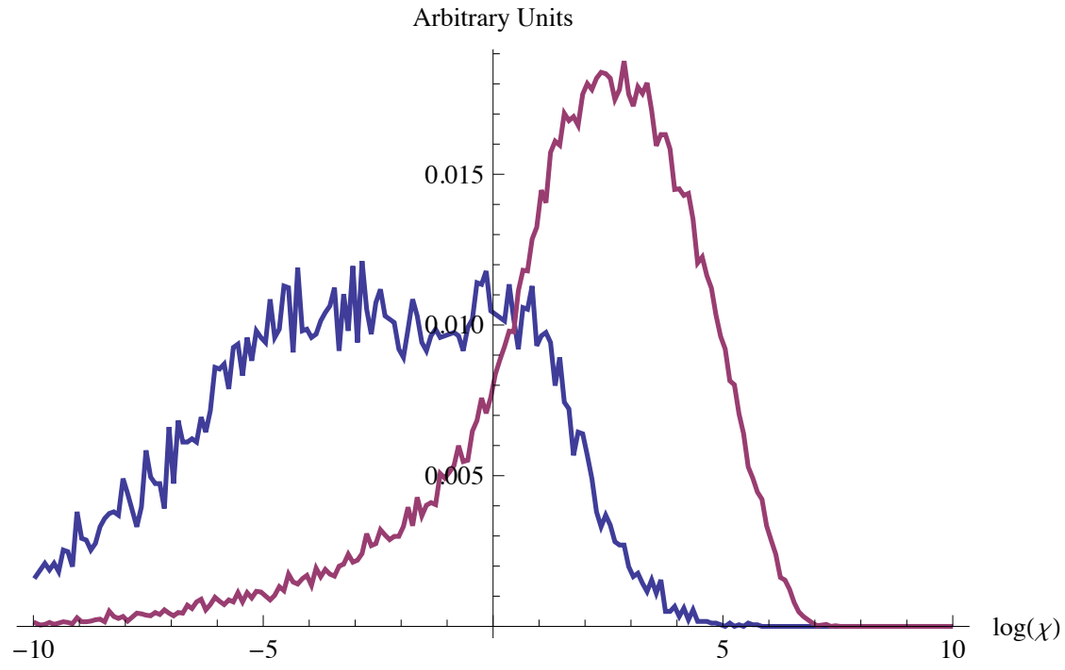
- Close collaboration with experimentalists is important. Thanks to ATLAS Glasgow!

chi distribution in Herwig++ ttbar vs dijets









Herwig++ ttbar vs dijets