Non standard objects for/from Higgs

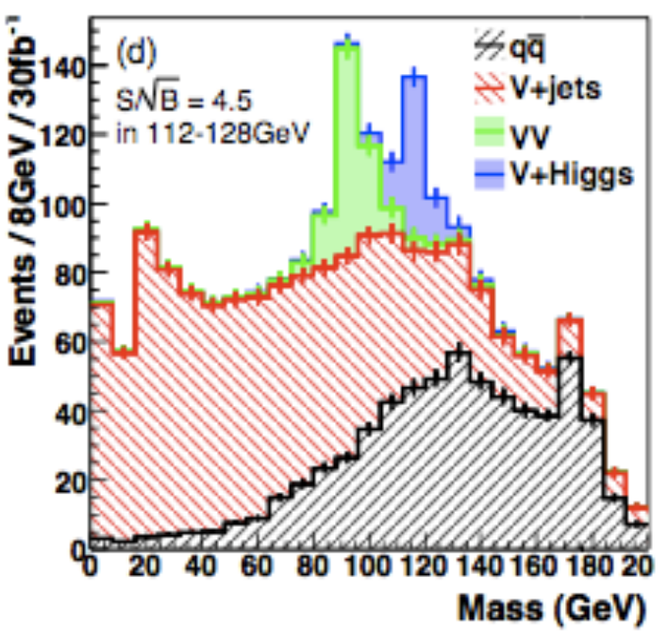
Tuhin S. Roy
University of Washington

Hidden agenda

Jet substructure techniques
in Higgs physics can be really useful!
(even for early LHC)

$$pp \rightarrow V\ h$$

$$\mathcal{L} = 30\ \mathrm{fb}^{-1}$$



Butterworth, Davison, Rubin, Salam

0802.2470

Hidden agenda

Jet substructure techniques
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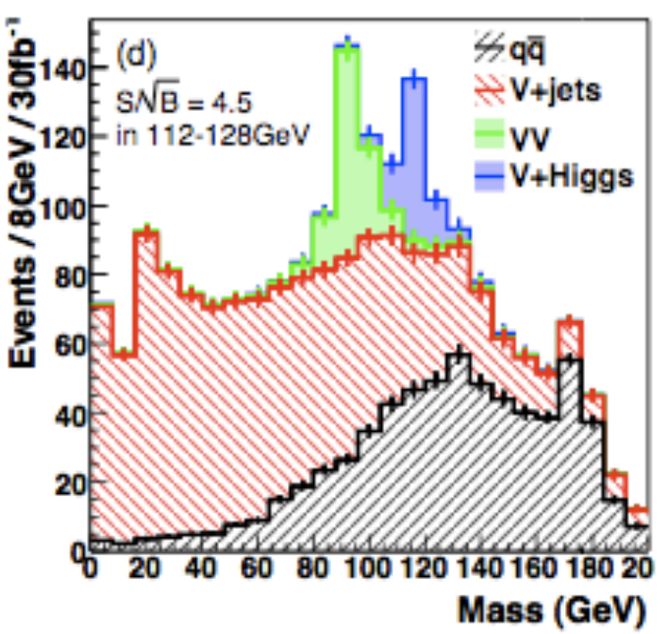
$$pp \to V\ h$$



Butterworth, Davison, Rubin, Salam

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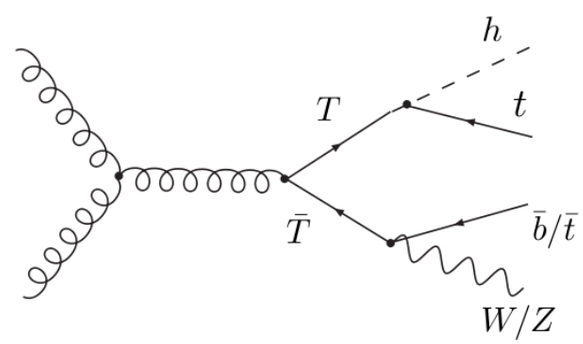
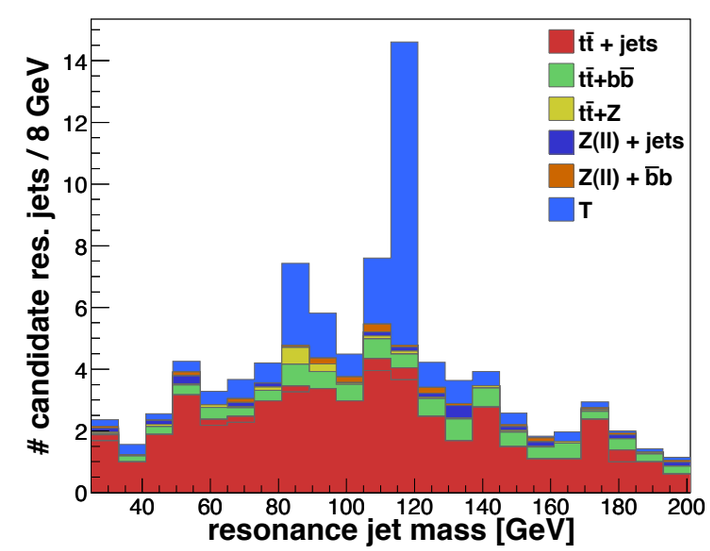


$$\sqrt{s} = 14\ \text{TeV}, \mathcal{L} = 10\ \text{fb}^{-1}$$



$$M_T = 800\ \text{GeV}$$

Kribs, Martin, TSR

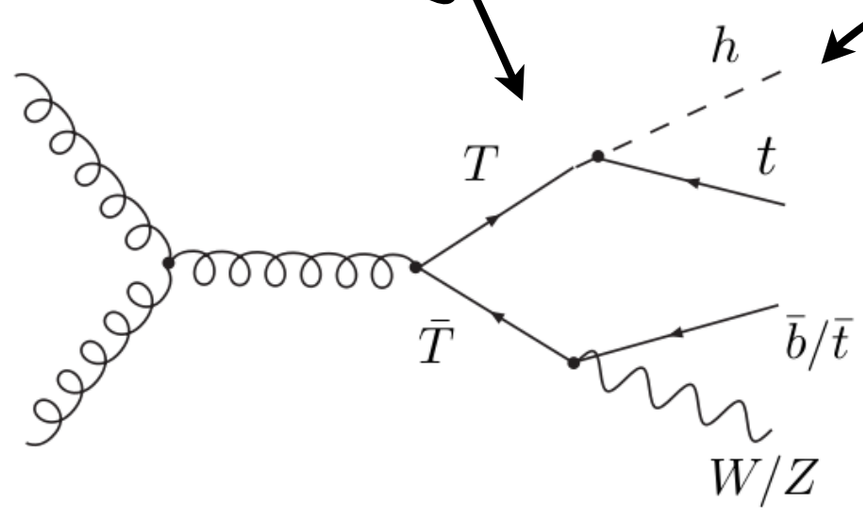
1012.2866

Hidden agenda

Jet substructure techniques
in Higgs physics can be really useful!
(even for early LHC)

production is
non standard

h -> bb
decay is standard



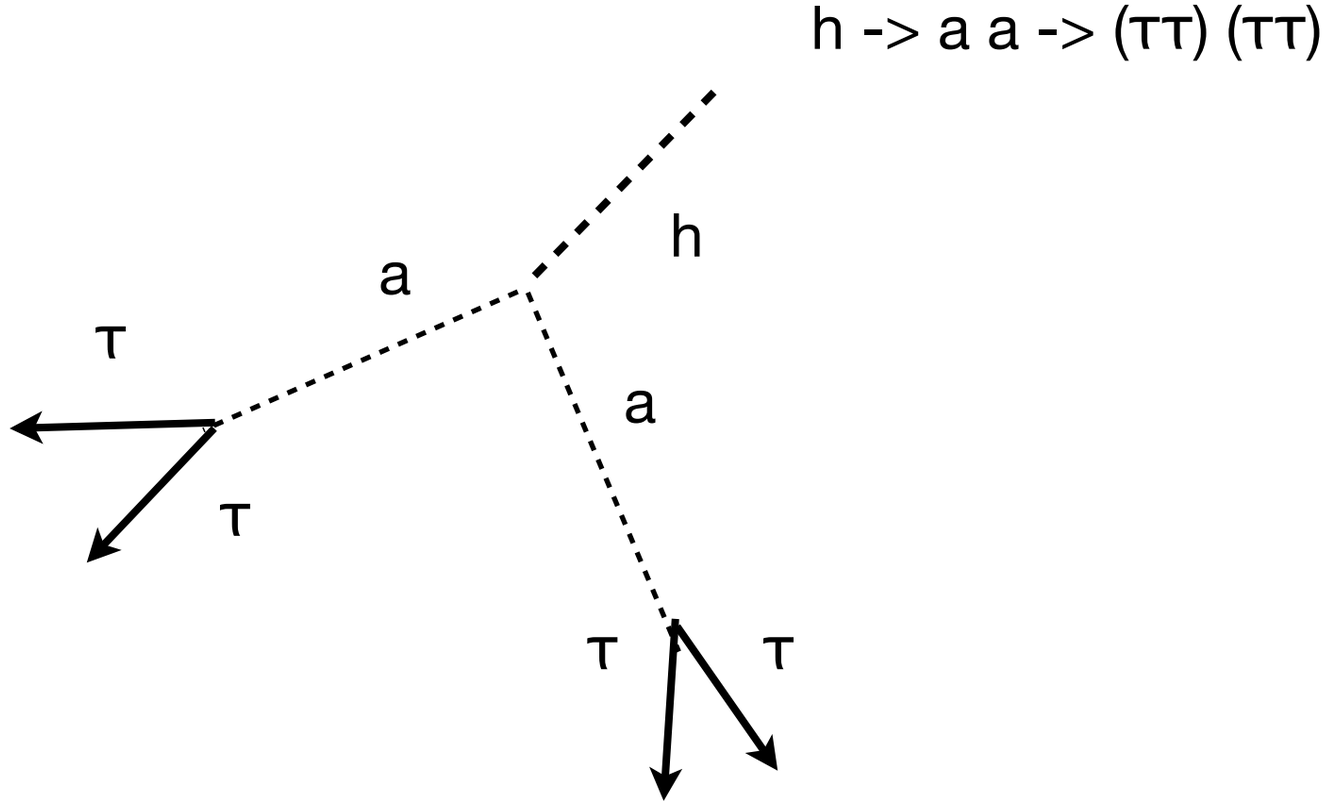
Today's menu

Jet substructure techniques
in Higgs physics can be really useful!
(even for early LHC)

- production of Higgs is standard
- decay is non-standard

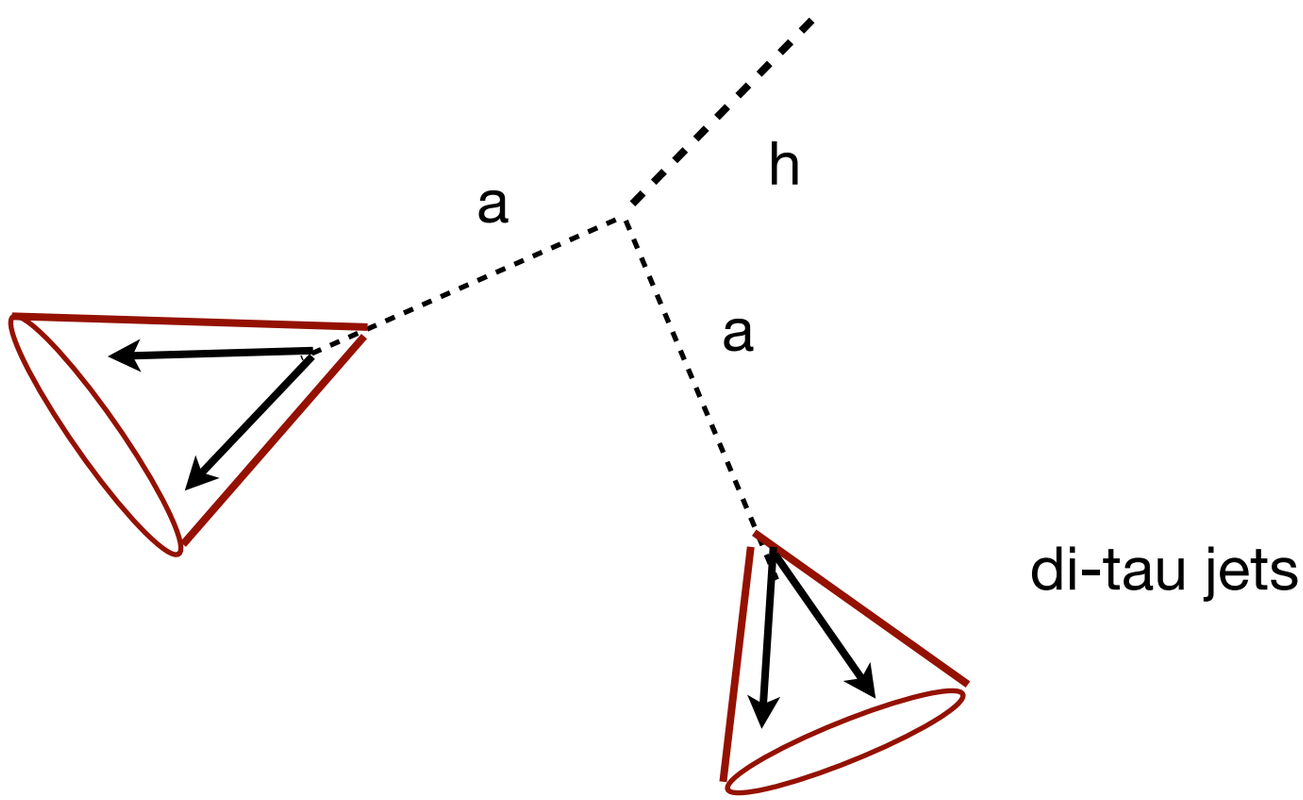
Non-standard objects from Higgs

$$m_h = 120 \text{ GeV} \qquad \text{and} \qquad m_{\mathcal{A}} = 10 \text{ GeV}\,.$$

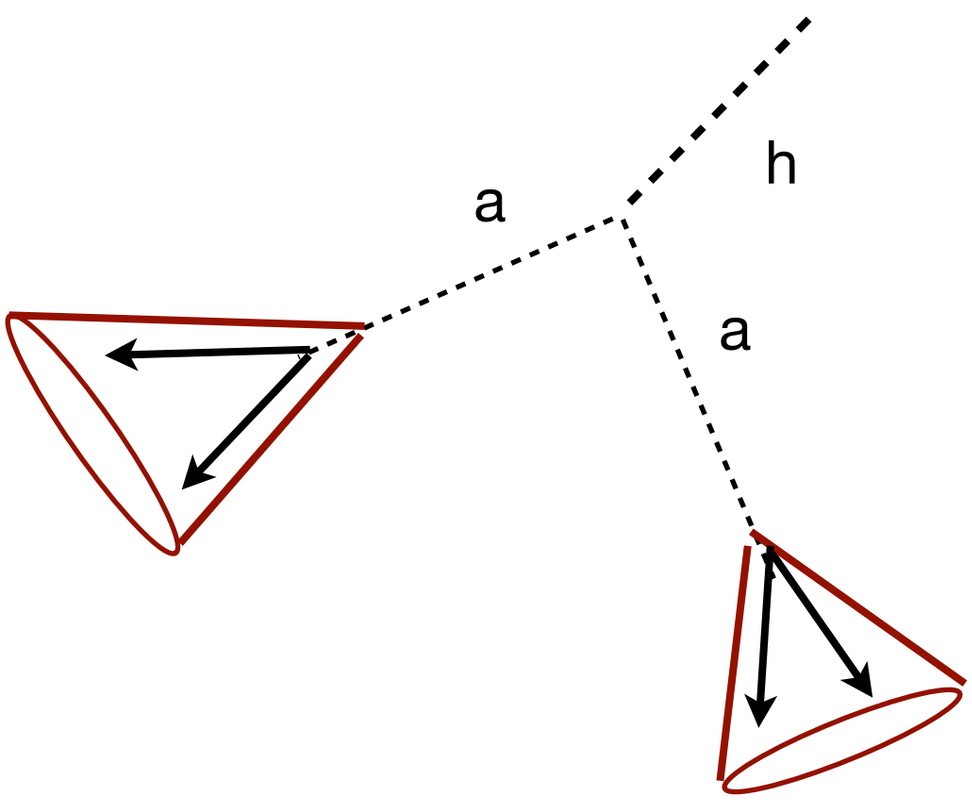


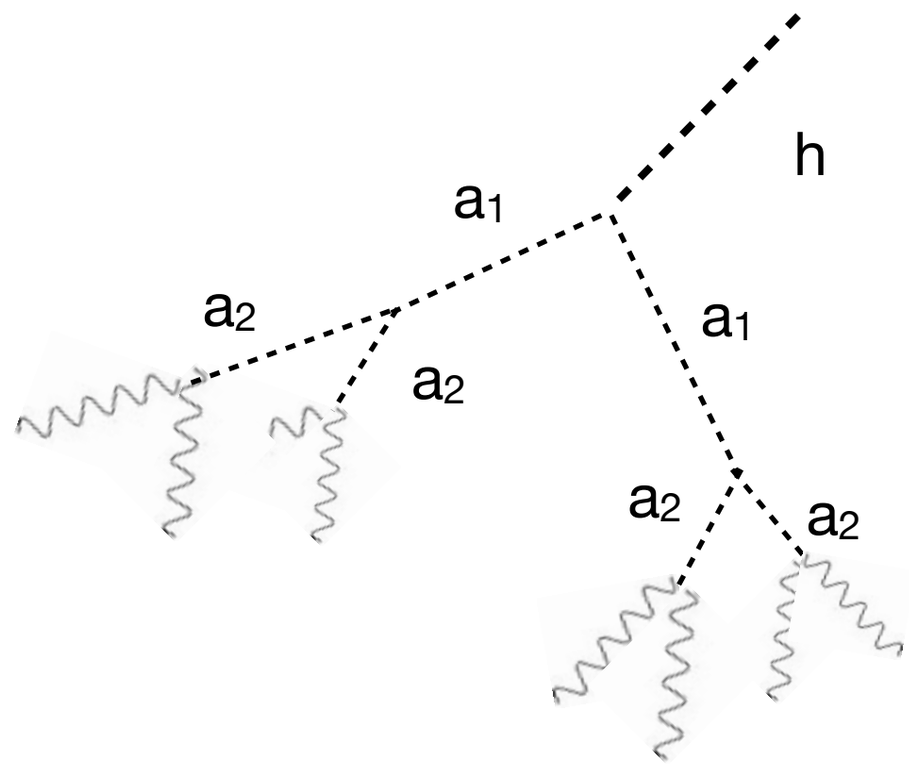
Non-standard objects from Higgs

$m_h = 120$ GeV and $m_{\mathcal{A}} = 10$ GeV .

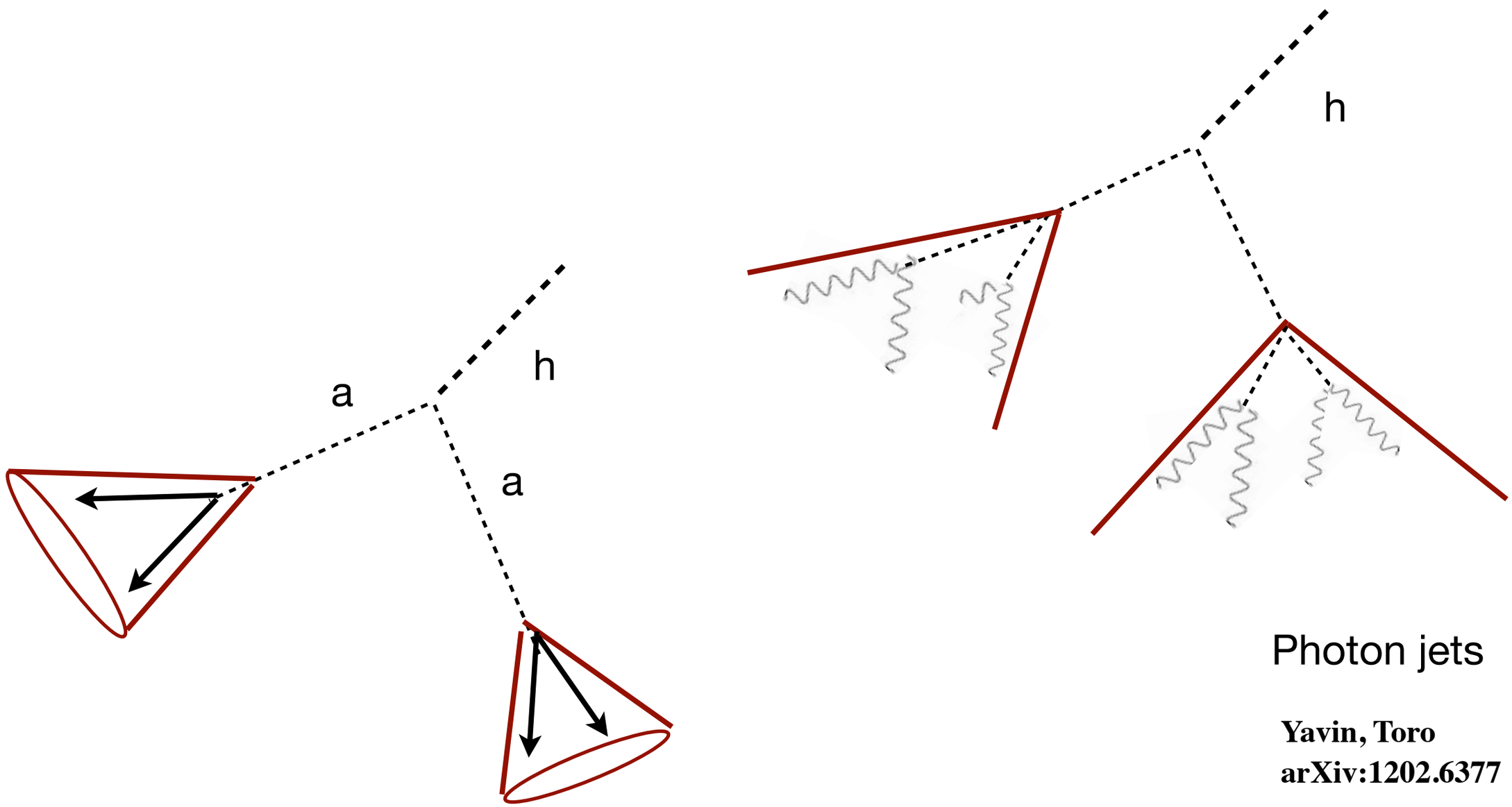


Non-standard objects from Higgs





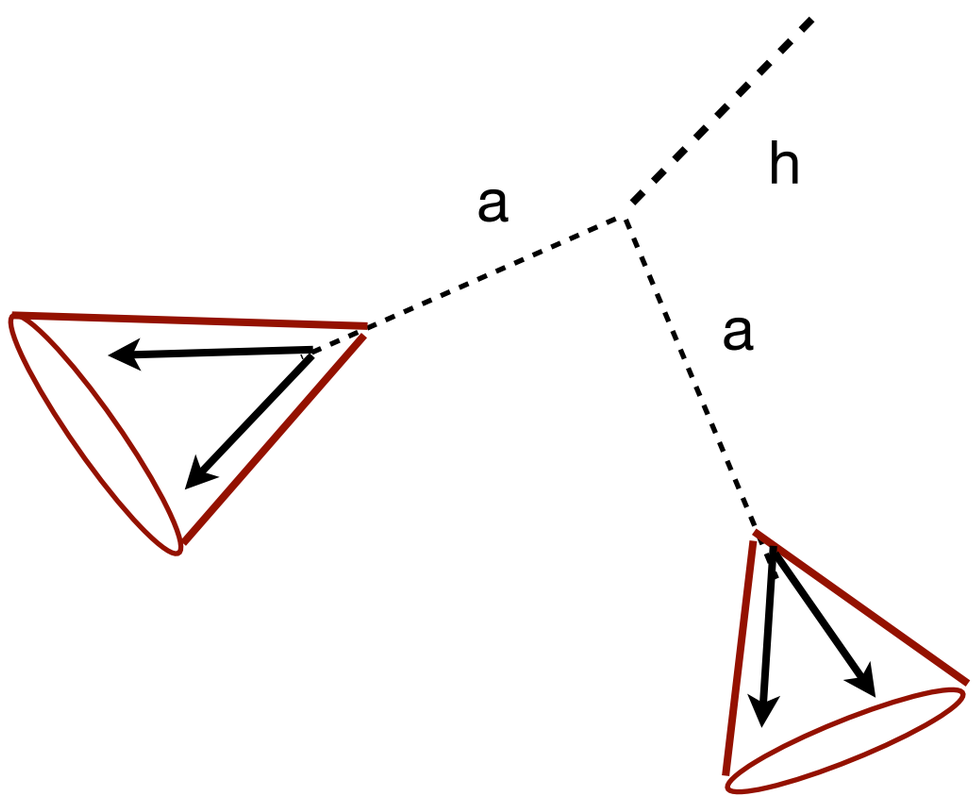
Non-standard objects from Higgs



Photon jets

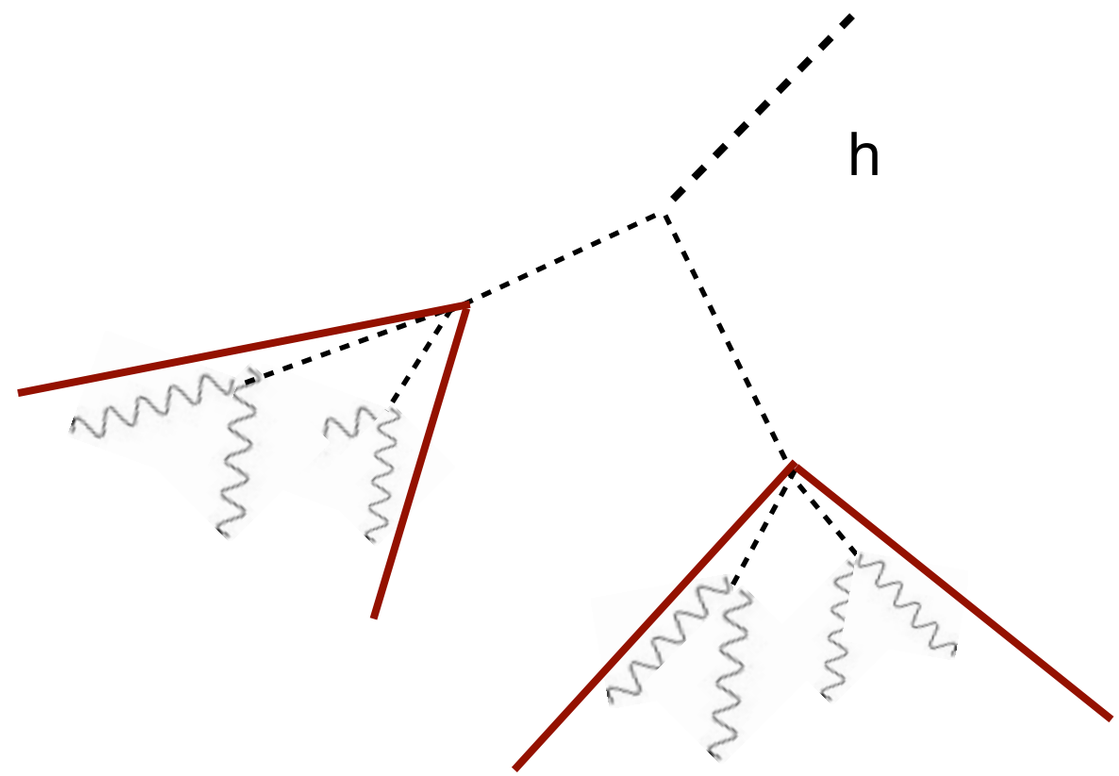
Yavin, Toro
arXiv:1202.6377

Non-standard objects from Higgs



di-tau jets

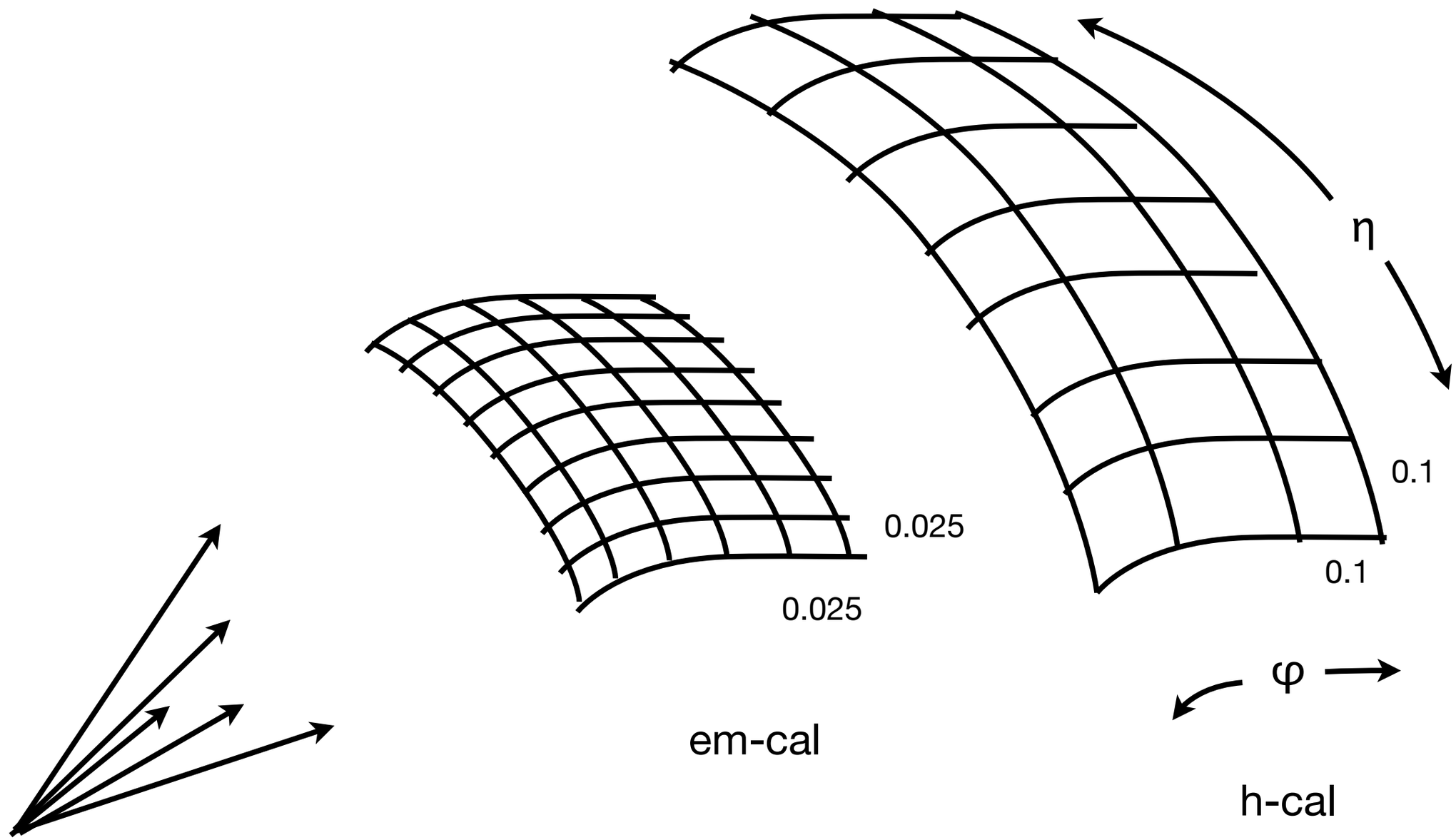
Englert, TSR, Spannowsky
arXiv:1106.4545



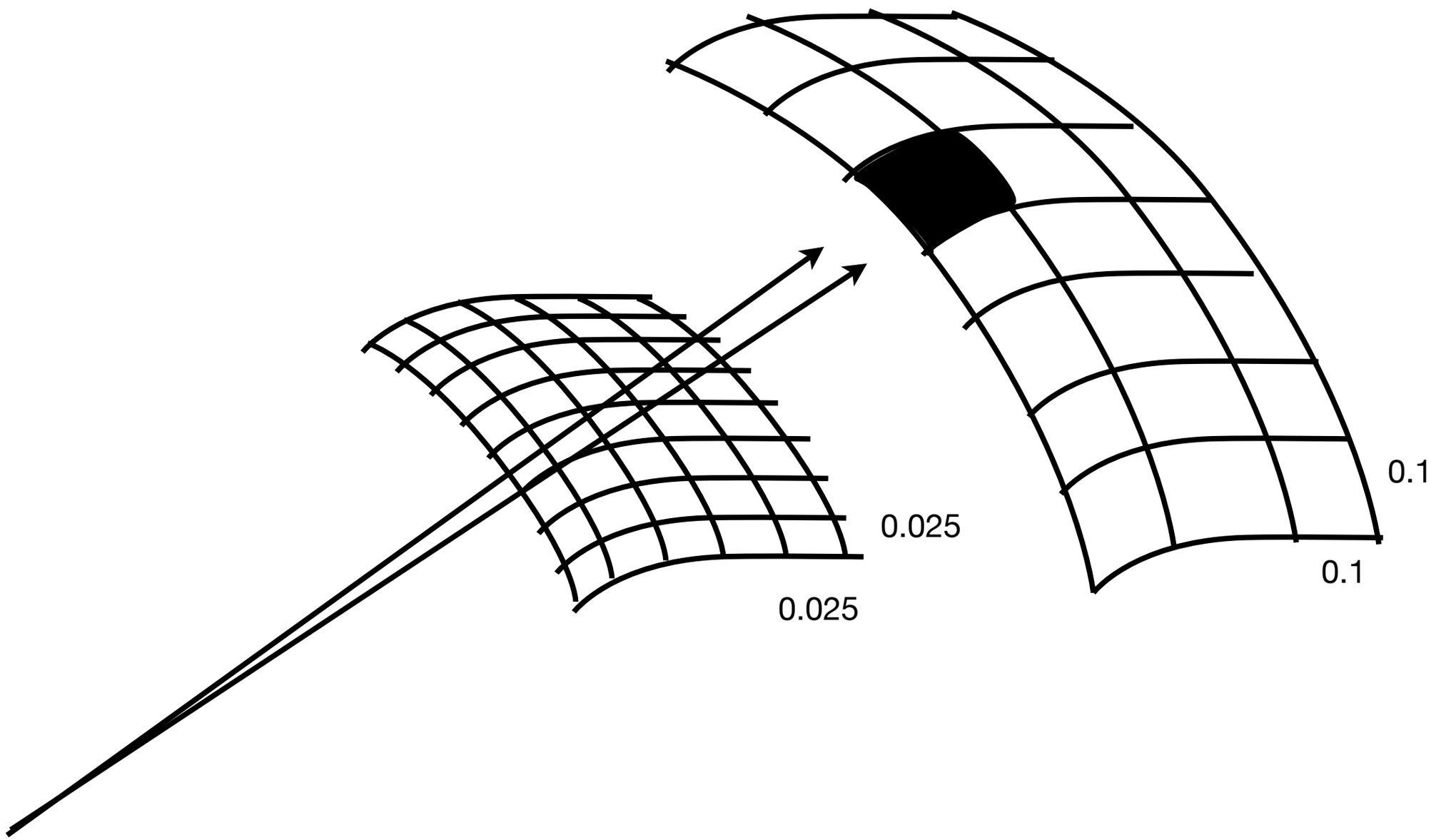
Photon jets

Scholtz, TSR
preliminary studies

this is how my detector looks like!

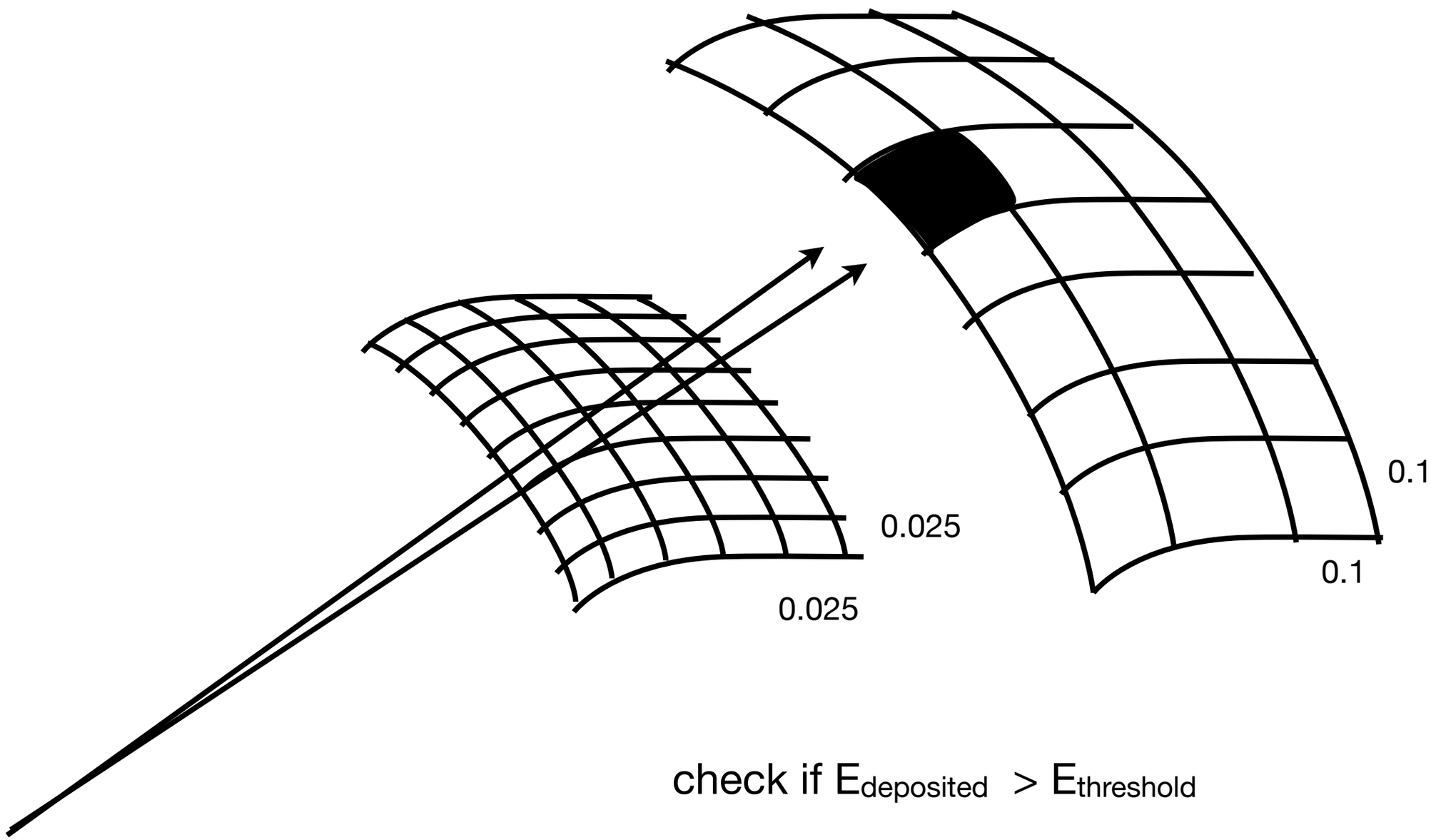


particles -› calorimeter cells -› 4vectors



find the total energy
deposited by
the particles with same (η, φ) cell

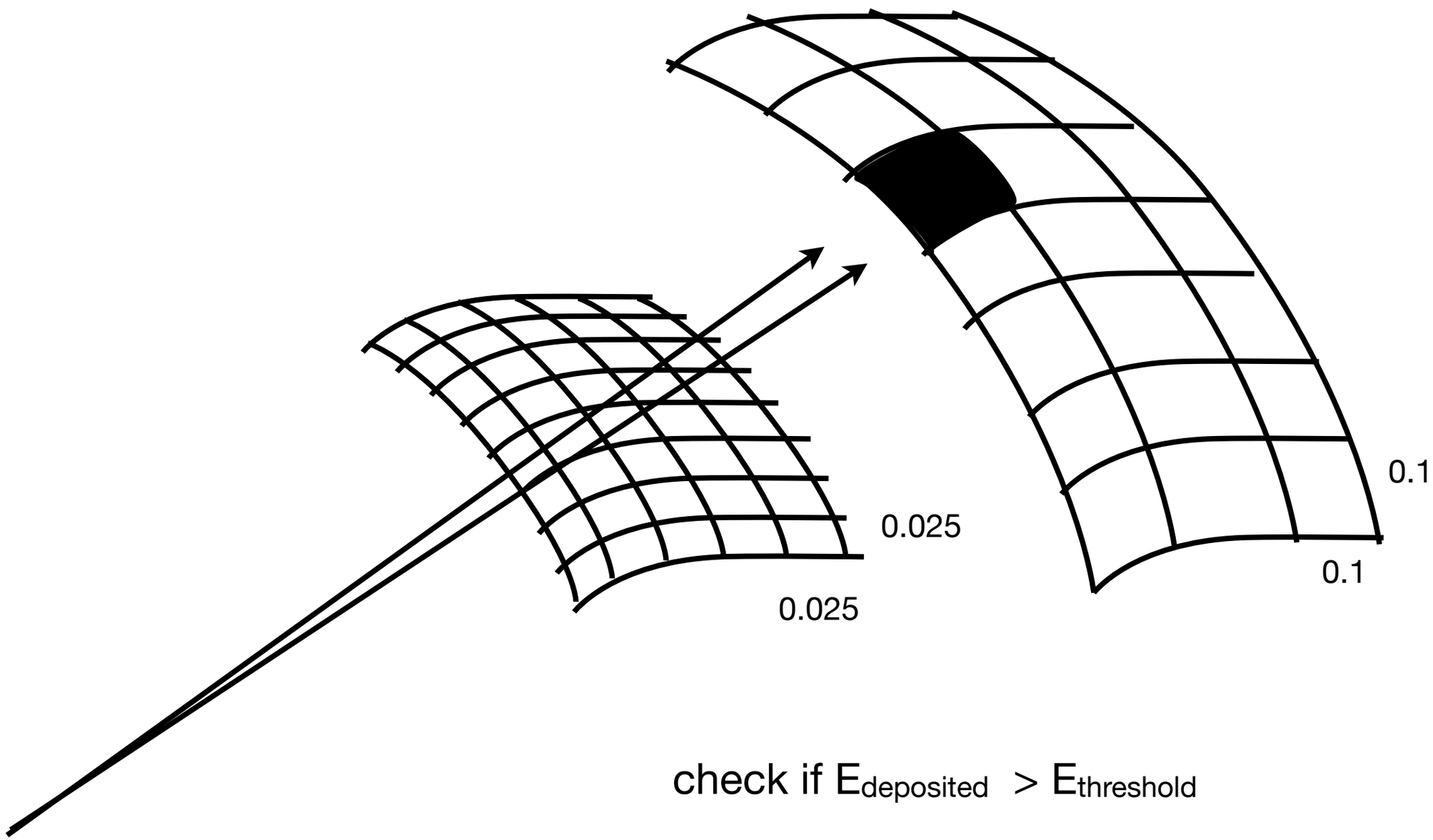
particles -> calorimeter cells -> 4vectors



check if $E_{deposited} > E_{threshold}$

find the total energy
deposited by
the particles with same (η, φ) cell

particles -> calorimeter cells -> 4vectors

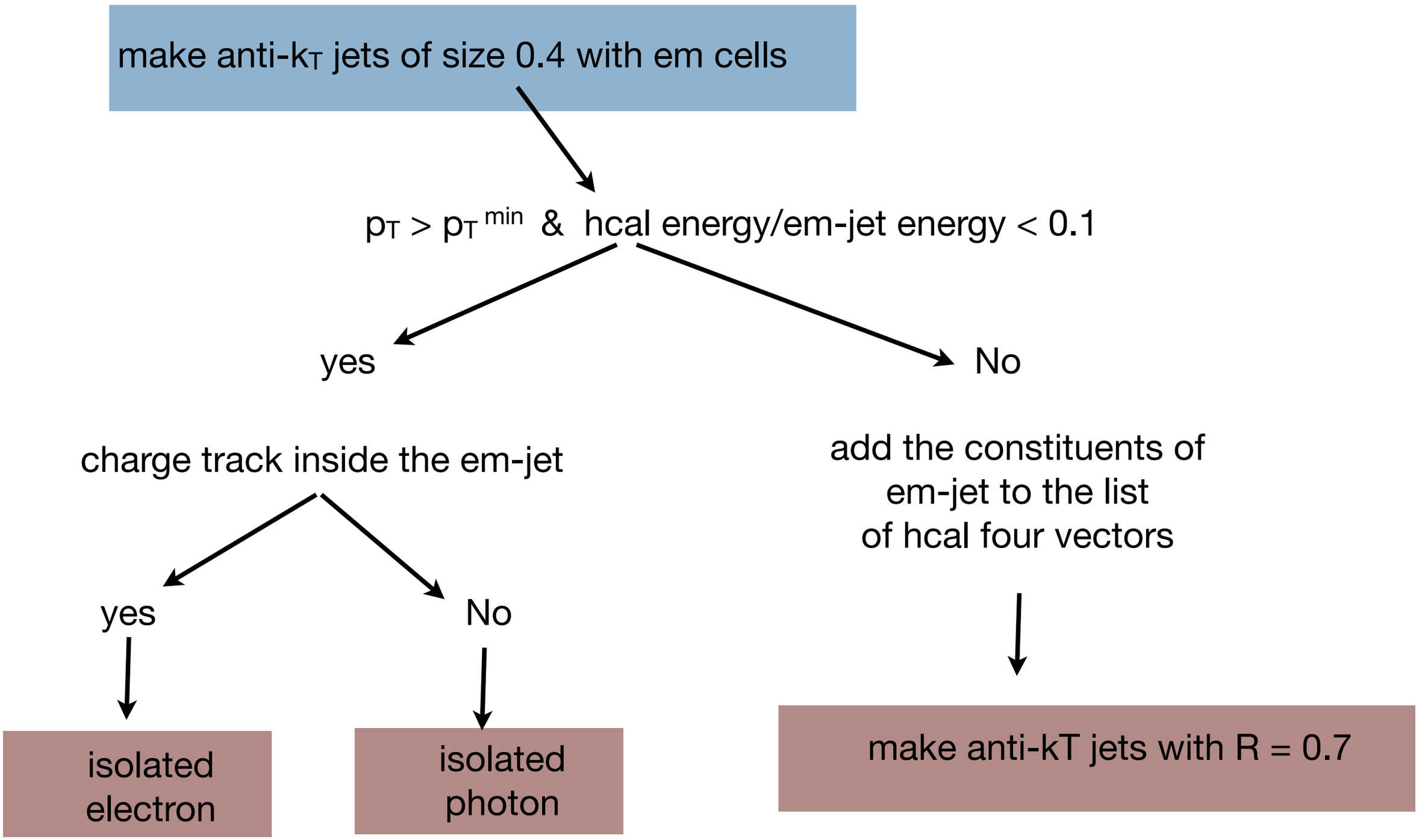


check if $E_{deposited} > E_{threshold}$

find the total energy
deposited by
the particles with same (η, φ) cell

construct massless four-vectors with
($E_{deposited}$, η, φ)

4vectors -> objects



di-tau jets vs. qcd jets

di-tau jets — jets from gg -> h -> a a -> (ττ) (ττ) events

qcd jets — jets from dijet events

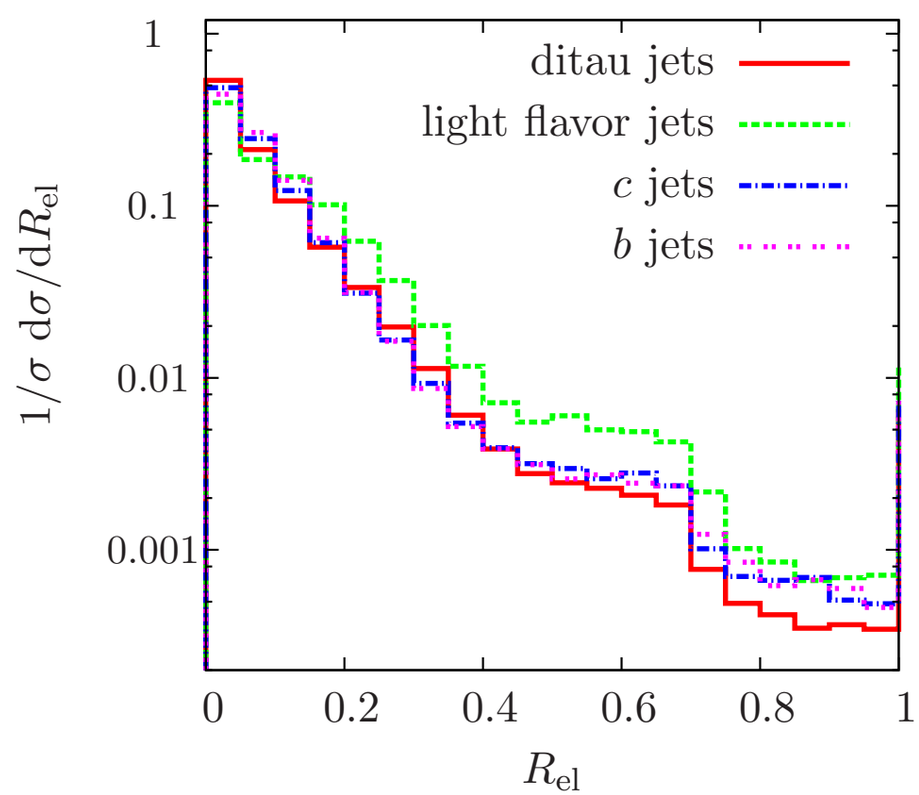
jets were made with $p_T^{min} > 30, 50, 100$ GeV

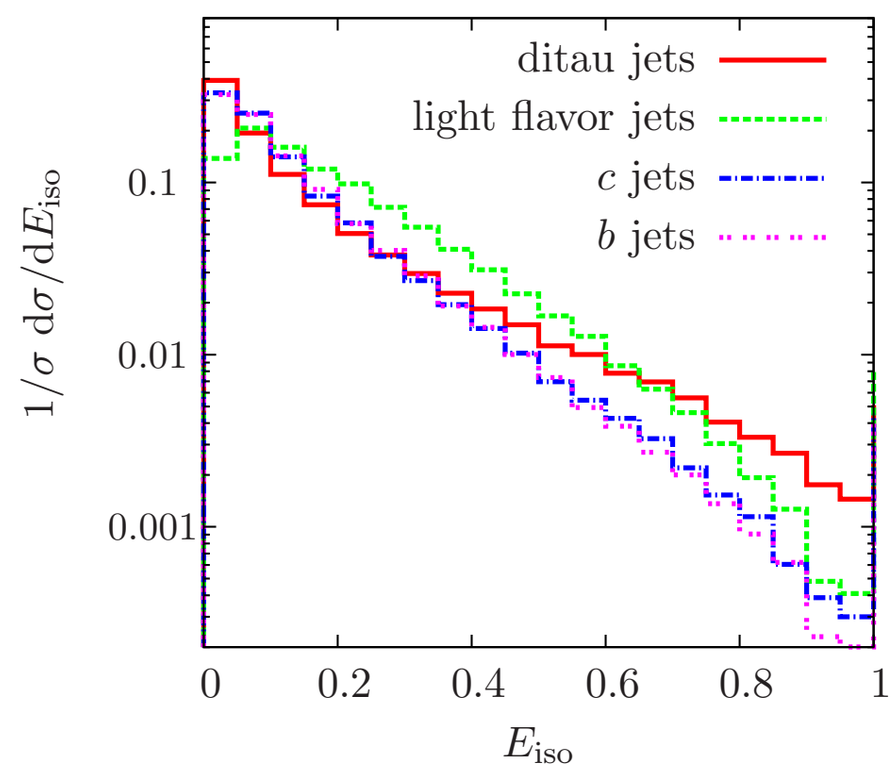
di-tau jets vs. qcd jets

conventional calorimeter based tau-taggers are not that useful in tagging di-tau jets

$$R^j_{\rm em} = \sum_\alpha p_{T,\alpha}\,\Delta R(\alpha, j) \Big/ \sum_\alpha p_{T,\alpha}$$

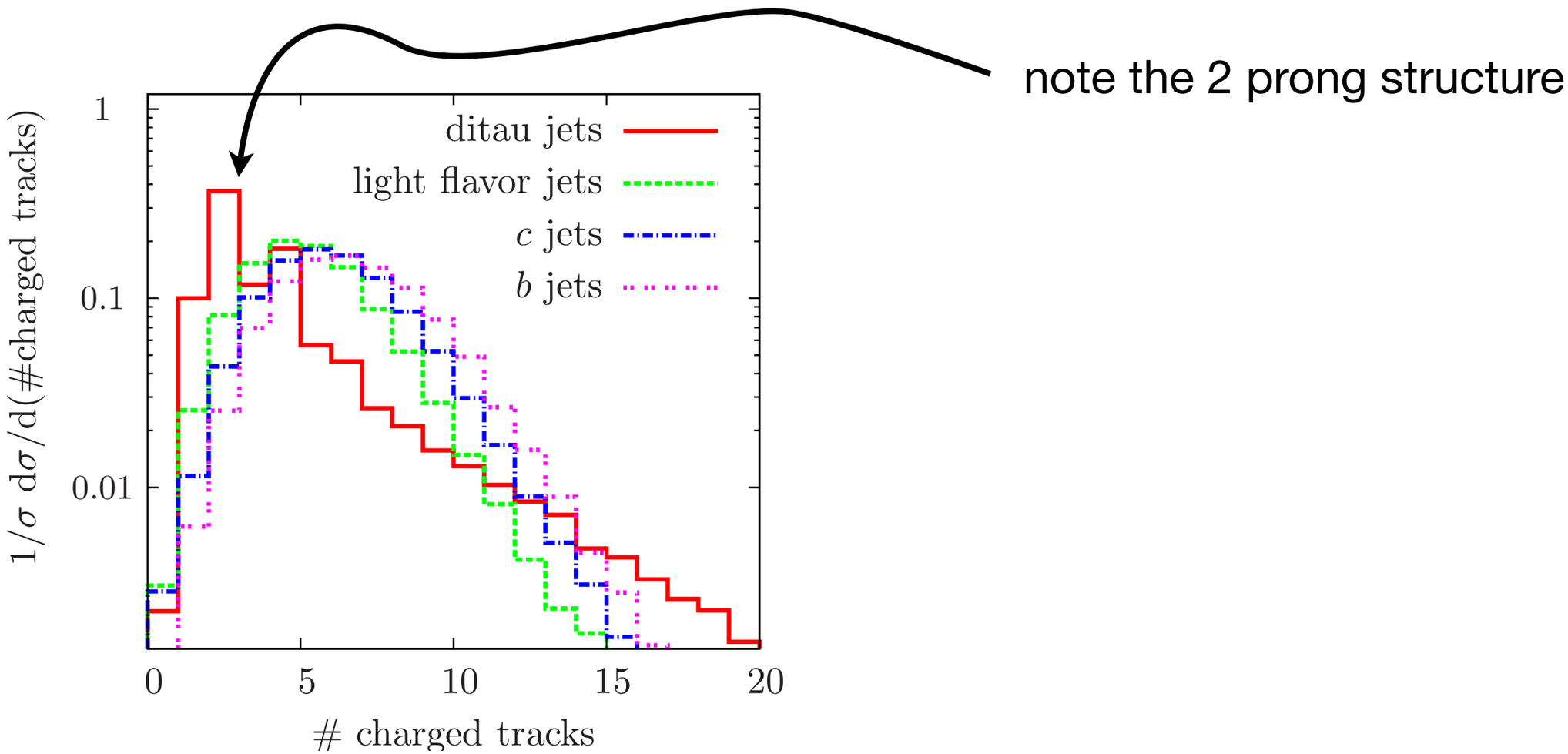
$$E^j_{\rm iso} = \sum_{r_1 \le \Delta R(\alpha,j) \le r_2} p_{T,\alpha} \Big/ \sum_\alpha p_{T,\alpha}$$





di-tau jets vs. qcd jets

information from tracker still helps

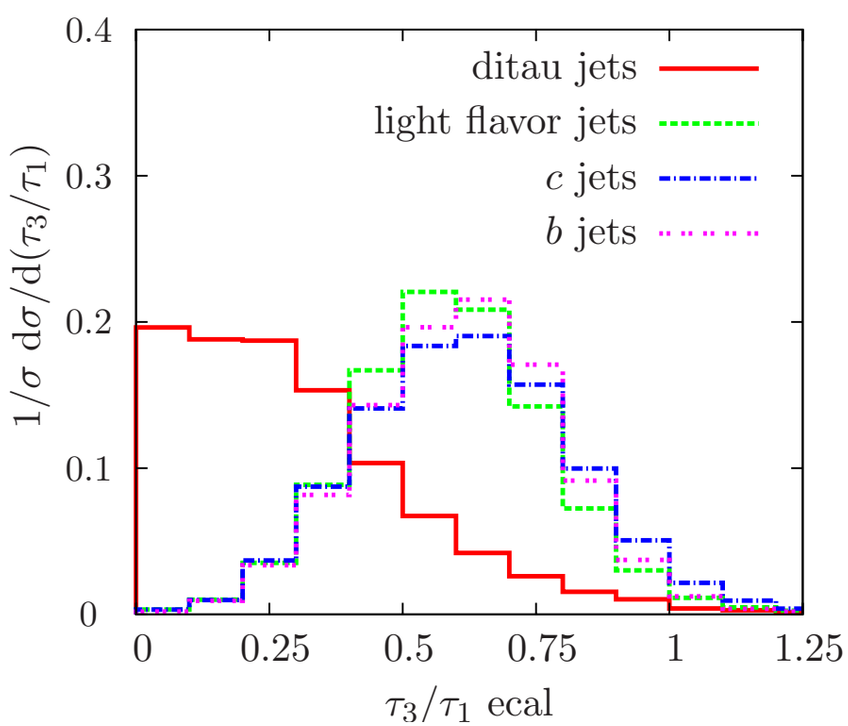


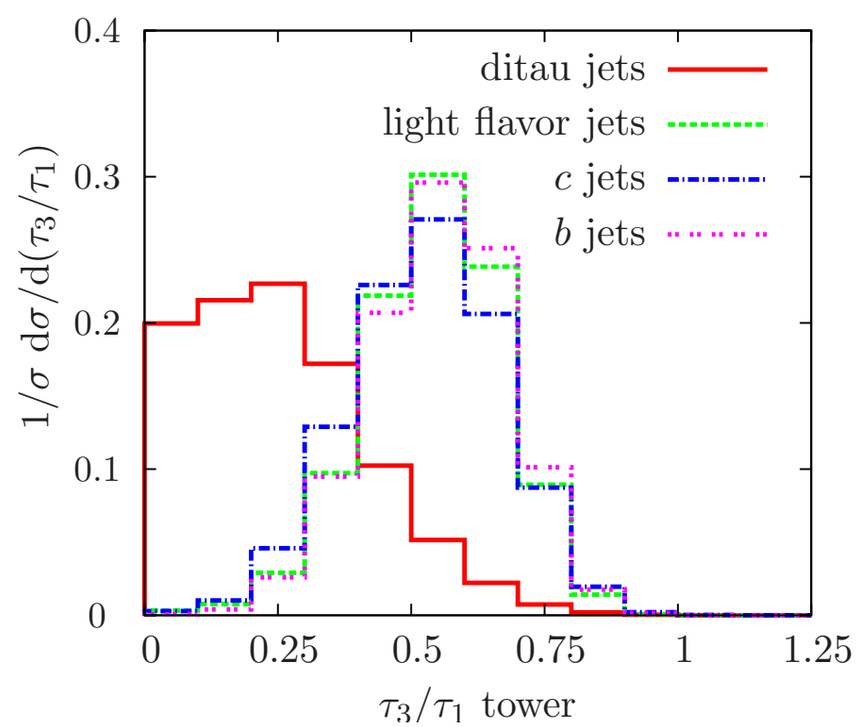
di-tau jets vs. qcd jets

NSubjettiness can be useful

$$\tau_N = \frac{\sum_k p_{T,k} \min\left(\Delta R(1,k), \ldots, \Delta R(N,k)\right)}{\sum_j p_{T,j}\, R}$$

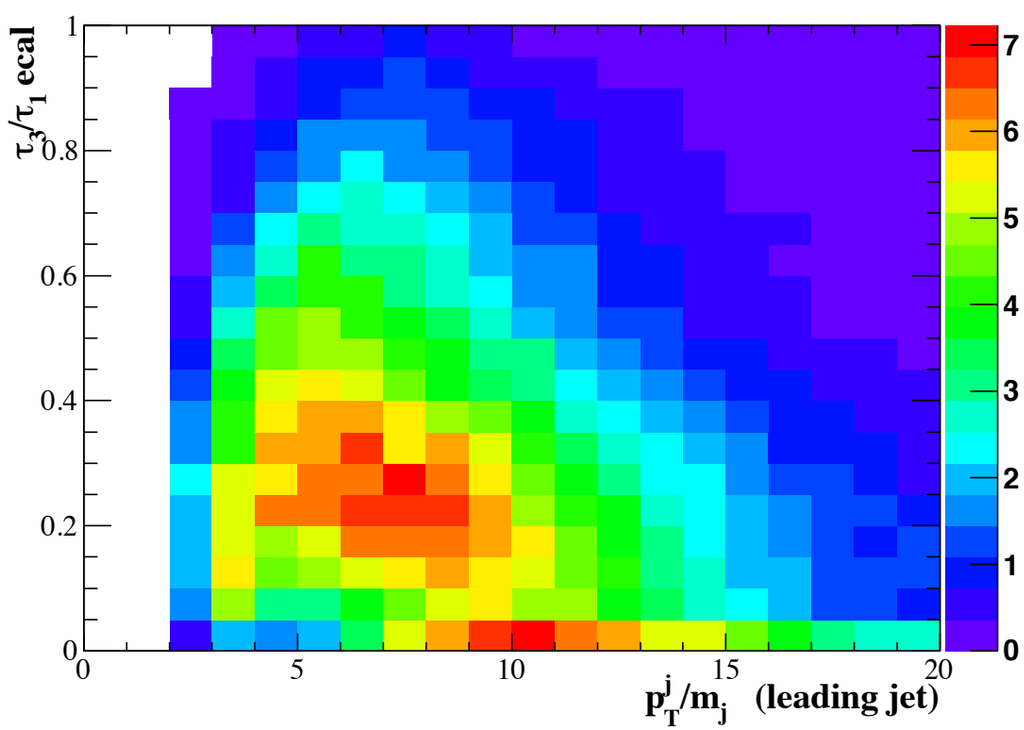
J. Thaler and K. Van Tilburg, JHEP **1103** (2011) 015.

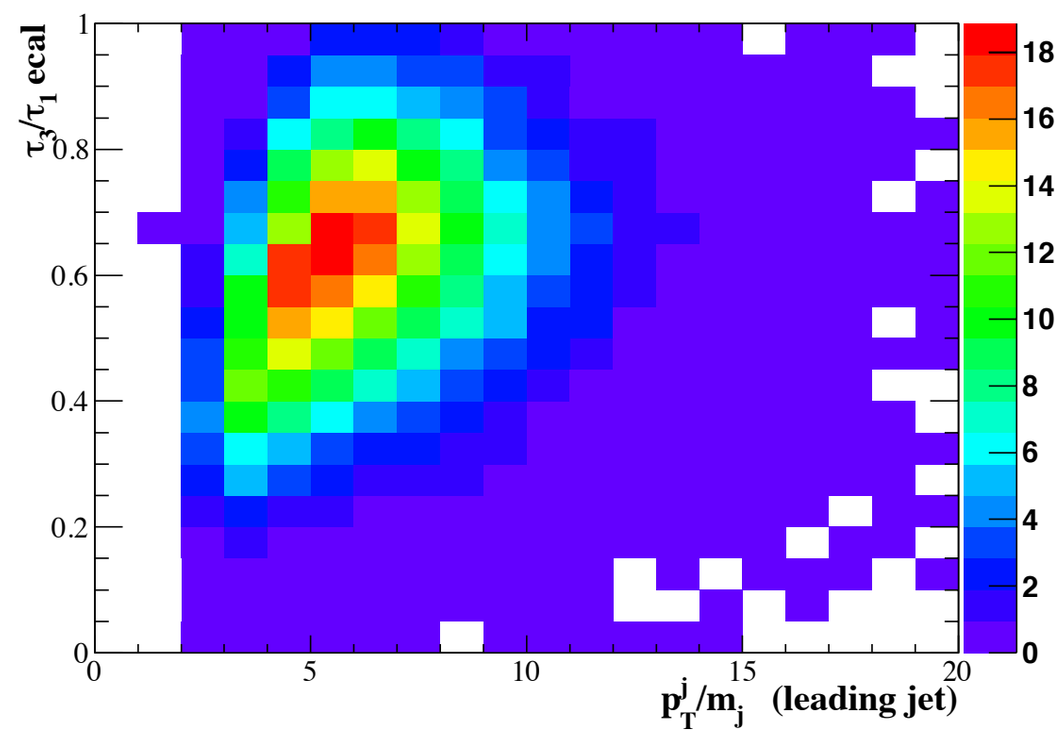




di-tau jets vs. qcd jets

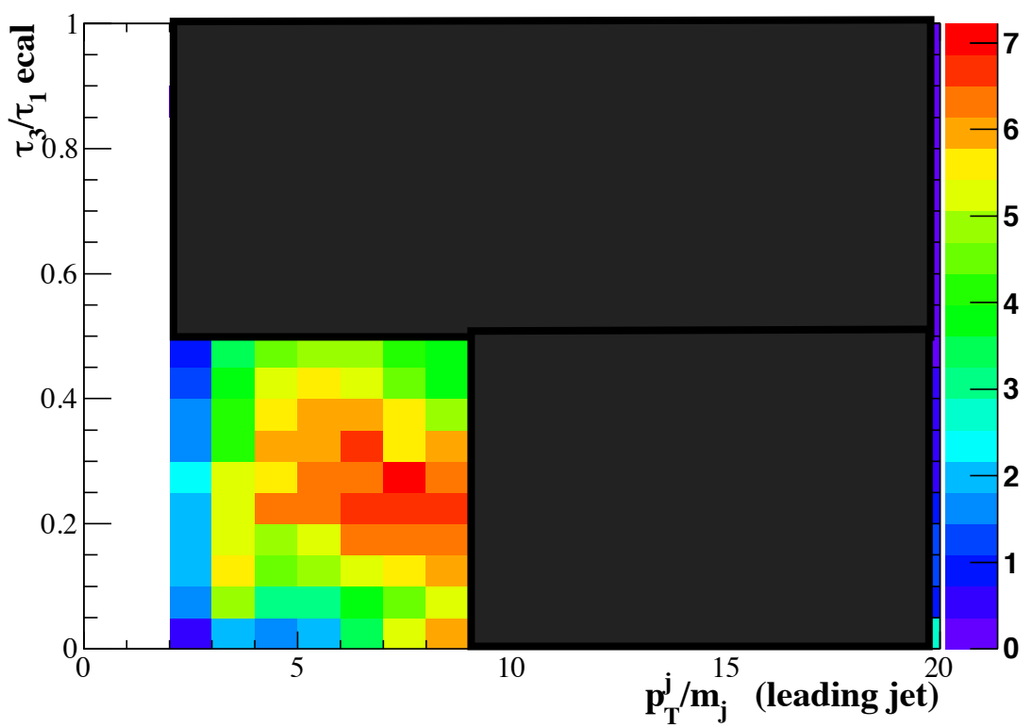
NSubjettiness can be useful

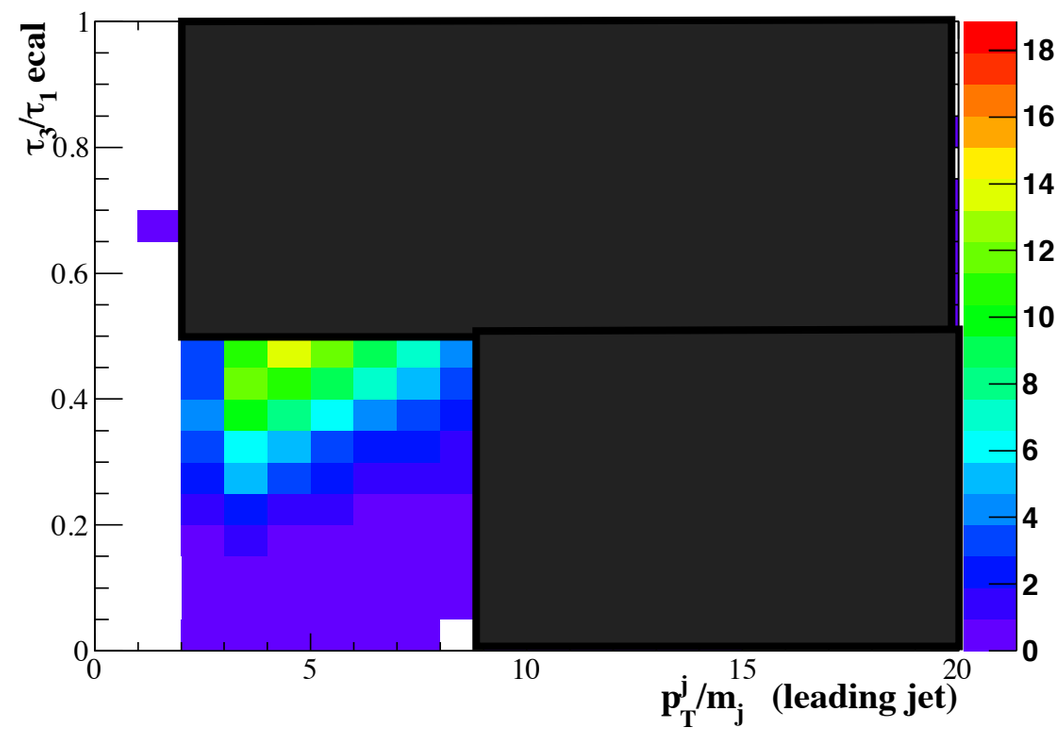




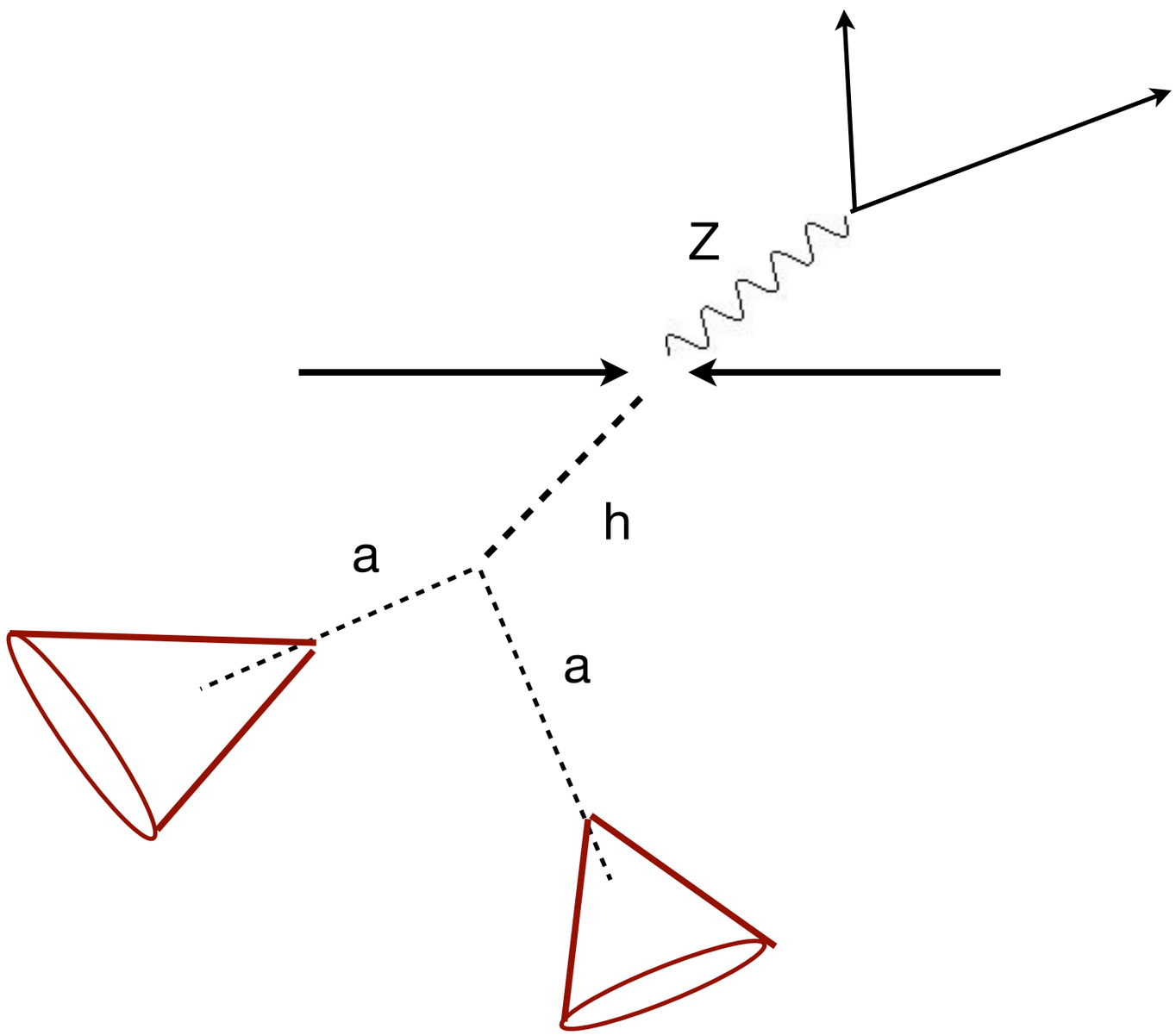
di-tau jets vs. qcd jets

Simple cut helps a lot

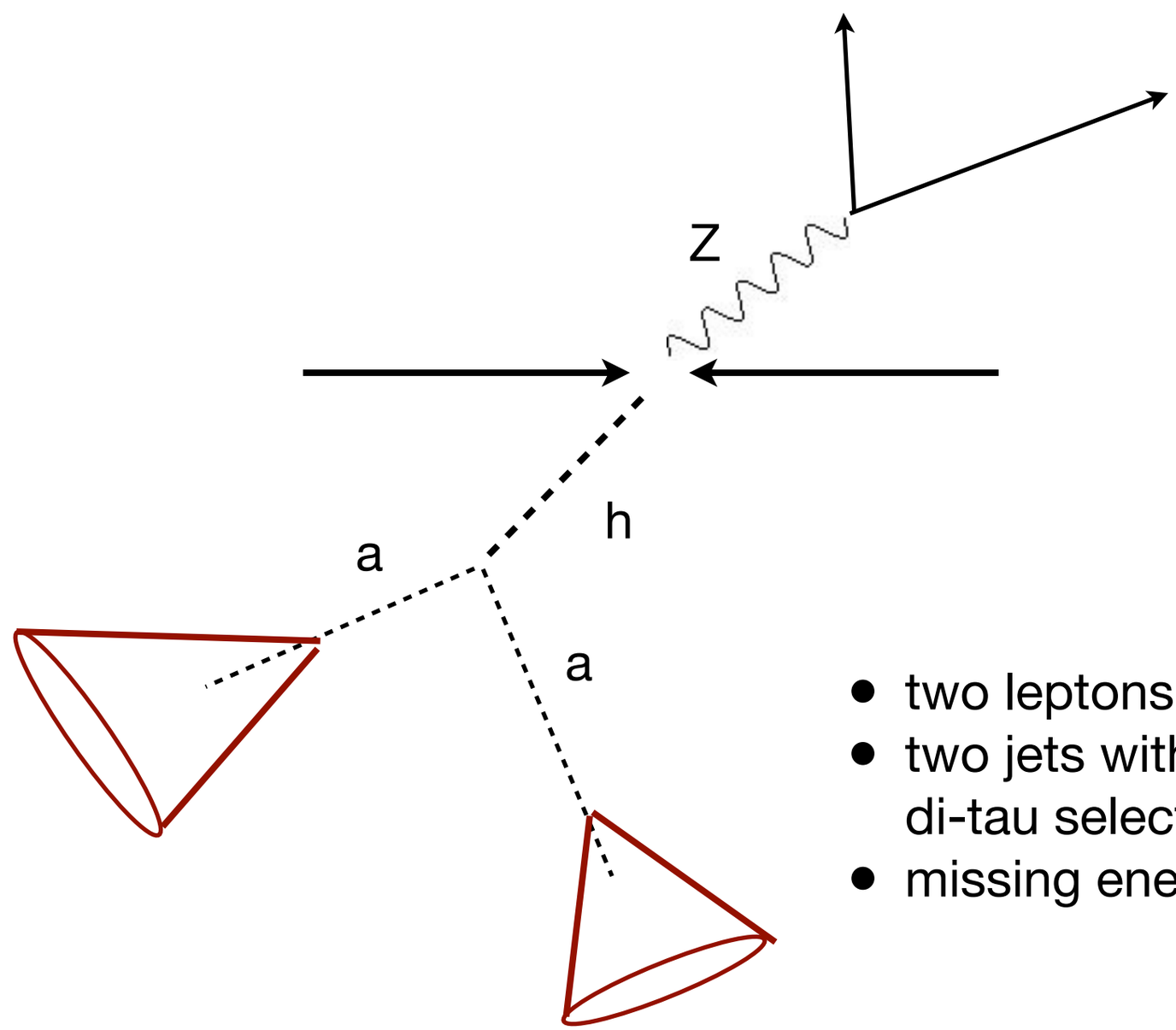




Higgs with di-tau jets



Higgs with di-tau jets



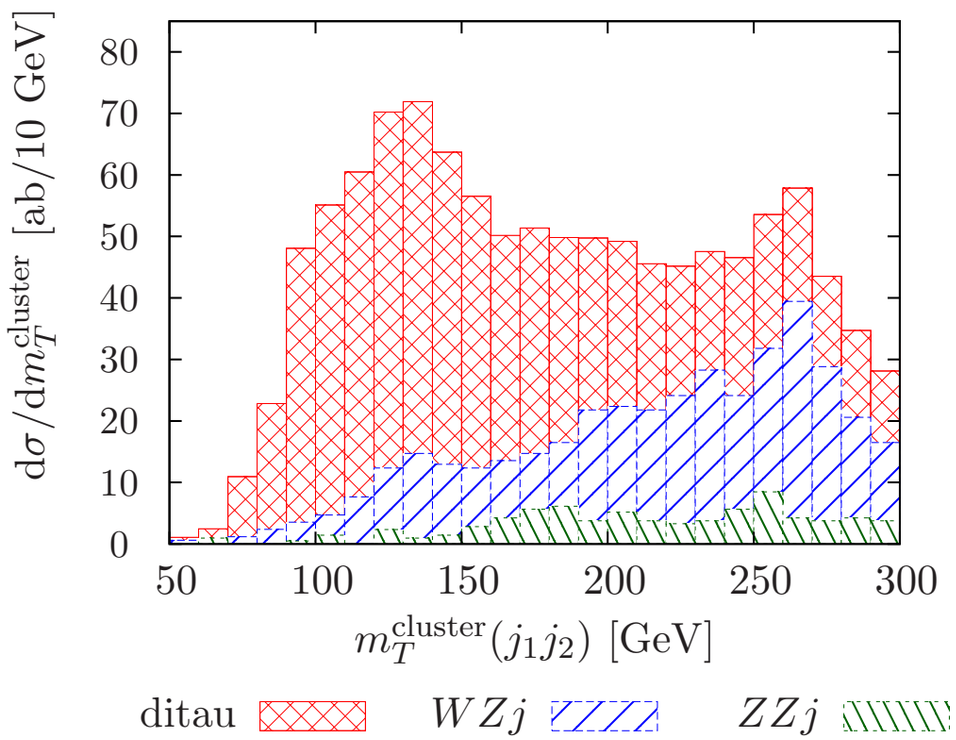
- two leptons that reconstruct a Z
- two jets with at least one passing di-tau selection cut.
- missing energy

Higgs with di-tau jets

Cuts and efficiencies

	ditaus	ZZj	WZj	WWj	$t\bar{t}$
	1.00	1.00	1.00	1.00	1.00
$n_\ell = 2$, Z mass reconstruction with e^+e^- or $\mu^+\mu^-$	0.416	0.217	0.130	0.011	0.026
$\max(p_T^\ell, p_T^{\ell'}) \geq 80$ GeV, $p_T^Z \geq 150$ GeV	0.216	0.048	0.035	0.00019	$3.9\ 10^{-4}$
$n_j \geq 2$ with $p_T^j \geq 30$ GeV, no $\Delta R(j_{50}, Z) \leq 1.5$	0.199	0.0402	0.029	0.00019	$3.0\ 10^{-4}$
$\not{p}_T \geq 50$ GeV, $\lvert\Delta\phi(\not{\mathbf{p}}, Z)\rvert \geq 2$	0.172	0.033	0.021	0.00015	$4.6\ 10^{-5}$
$\tau_3/\tau_1\lvert_{\rm ecal} \leq 0.5$ (leading jet)	0.125	0.011	0.0084	$5.4\ 10^{-5}$	$2.1\ 10^{-5}$
$p_T^j/m_j \geq 7$ (leading jet)	0.083	0.0018	0.0020	$3.0\ 10^{-6}$	$7.2\ 10^{-6}$
cross section [fb]	1.32	0.45	1.83	0.18	0.29

Higgs with di-tau jets



$$m_T^{\rm cluster}(j_1 j_2) < 160 \text{ GeV}$$

$$\sigma(\text{signal}) = 0.50 \text{ fb}$$

$$\sigma(\text{background}) = 0.12 \text{ fb}$$

$$S/\sqrt{B} \gtrsim 5$$

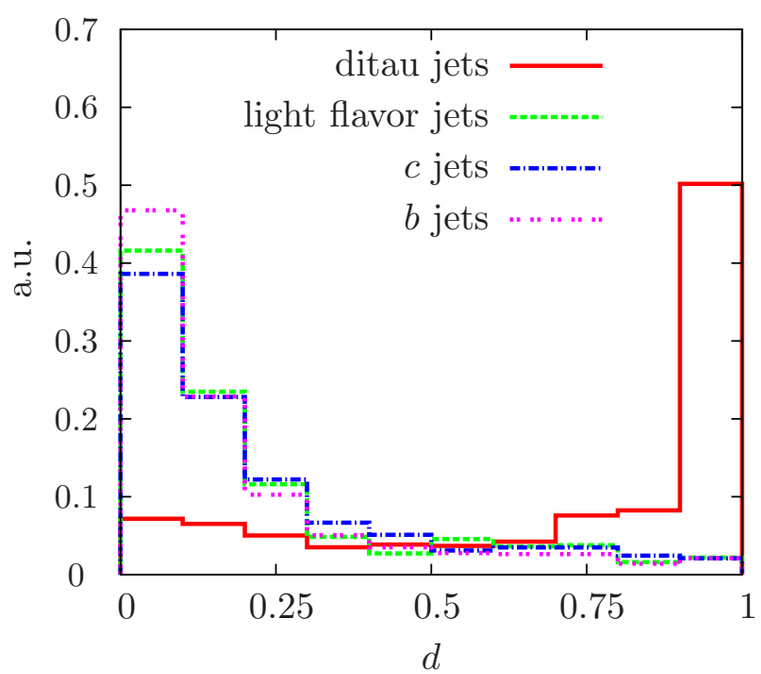
$$\mathcal{L} = 12 \text{ fb}^{-1}$$

$$[m_T^{\rm cluster}(j_1 j_2)]^2 = \left(\sqrt{m^2(j_1 j_2) + p_T^2(j_1 j_2)} + |\not{p}_T|\right)^2 - \left(\mathbf{p}_T(j_1 j_2) + \not{\mathbf{p}}_T\right)^2 .$$

di-tau tagger

combine observables to a likelihood

$$L = f\left(\tau_3/\tau_1|_{\mathrm{ecal}}\right) \times f(p_T^j/m_j) \times f(\text{charged tracks})$$

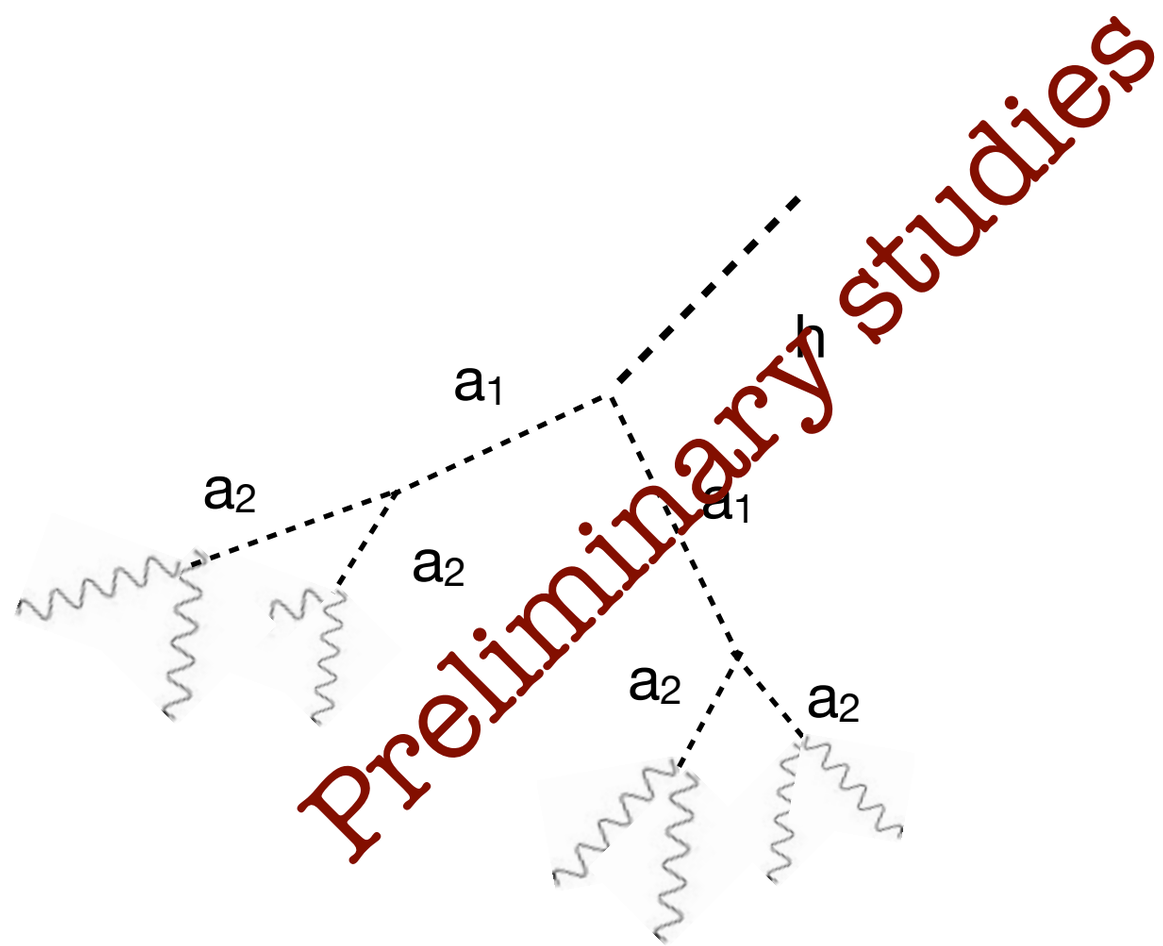


d > 0.7 gives

tagging efficiency of 66%(58%) for

mistagging probability of 7%(6%)

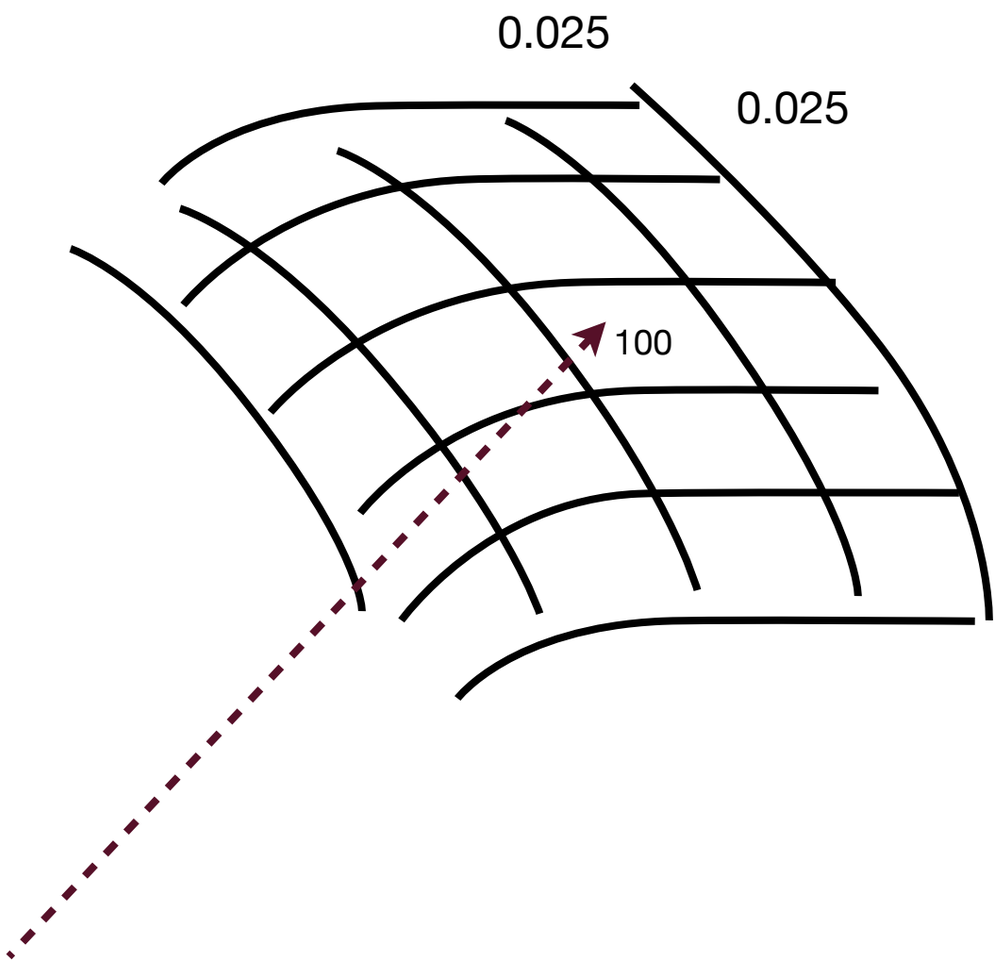
photon jet tagger



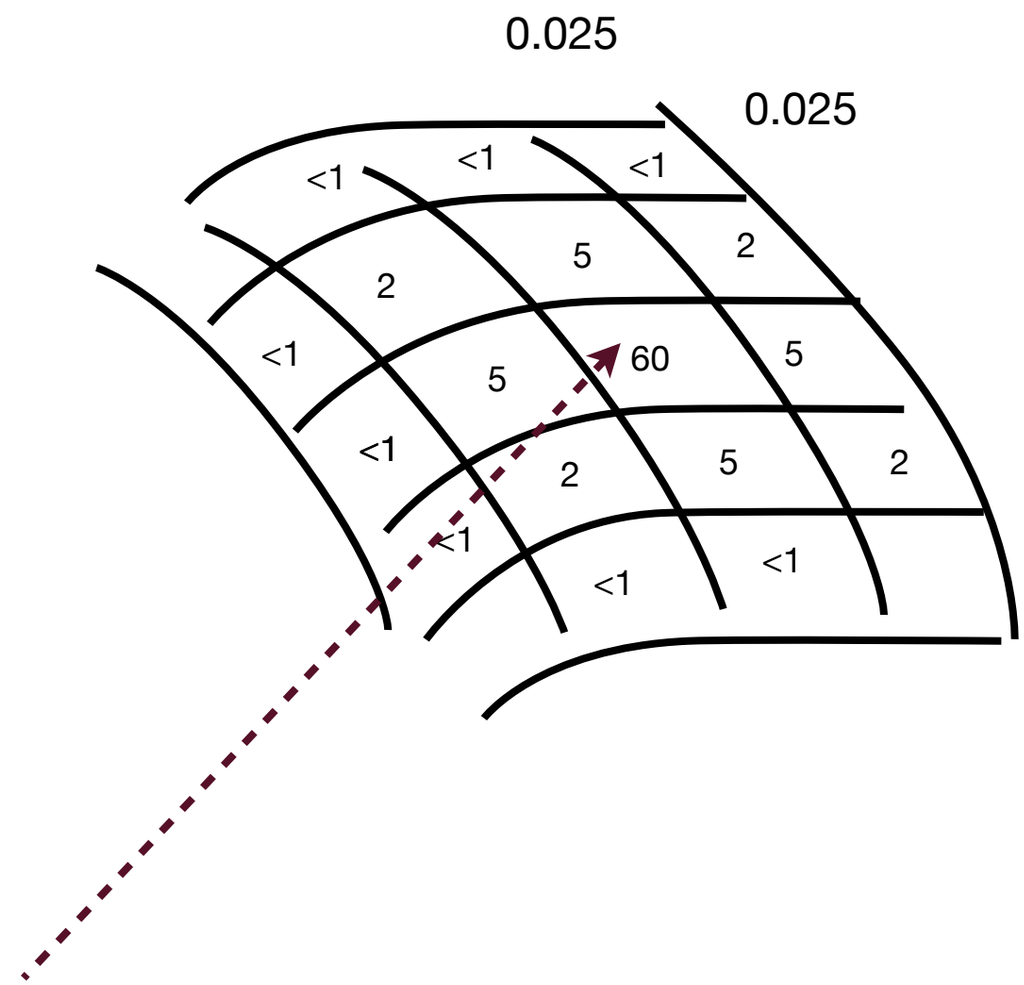
photon jet tagger

but before anything else - one slide about how
Jakub destroyed my detector

photon jet tagger



my nice em-cal



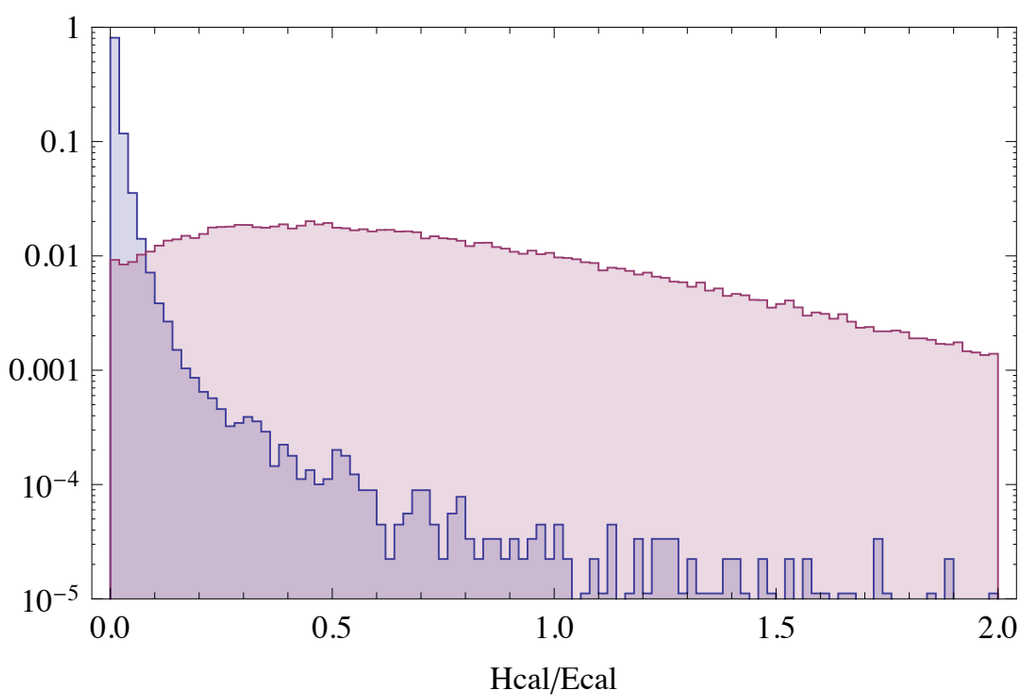
Jakub's crazy em-cal

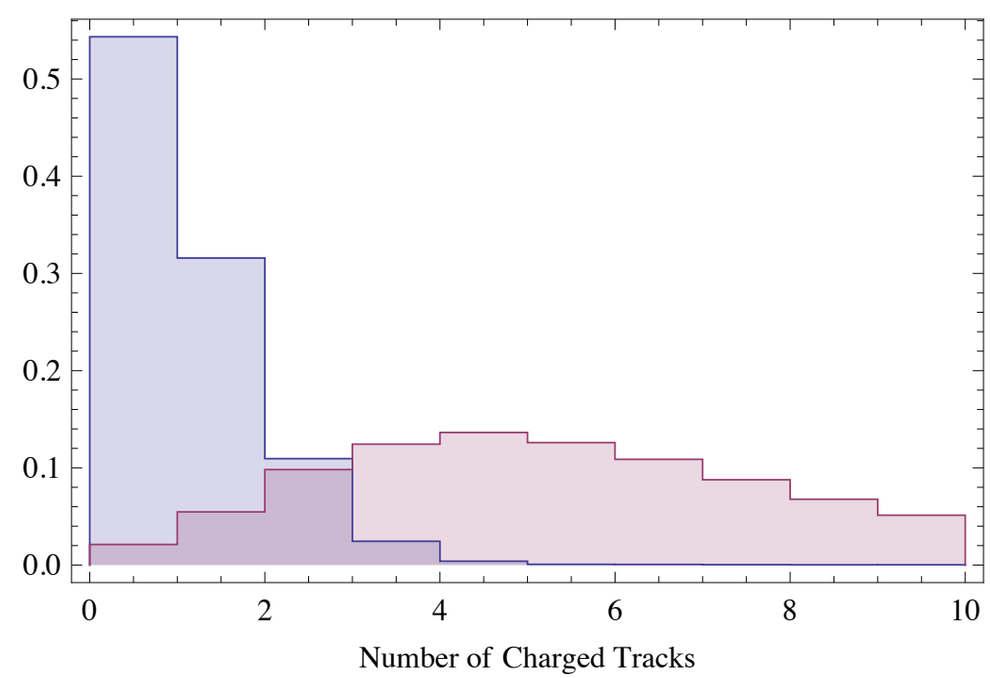
photon jet tagger

the usual suspects

photon jets

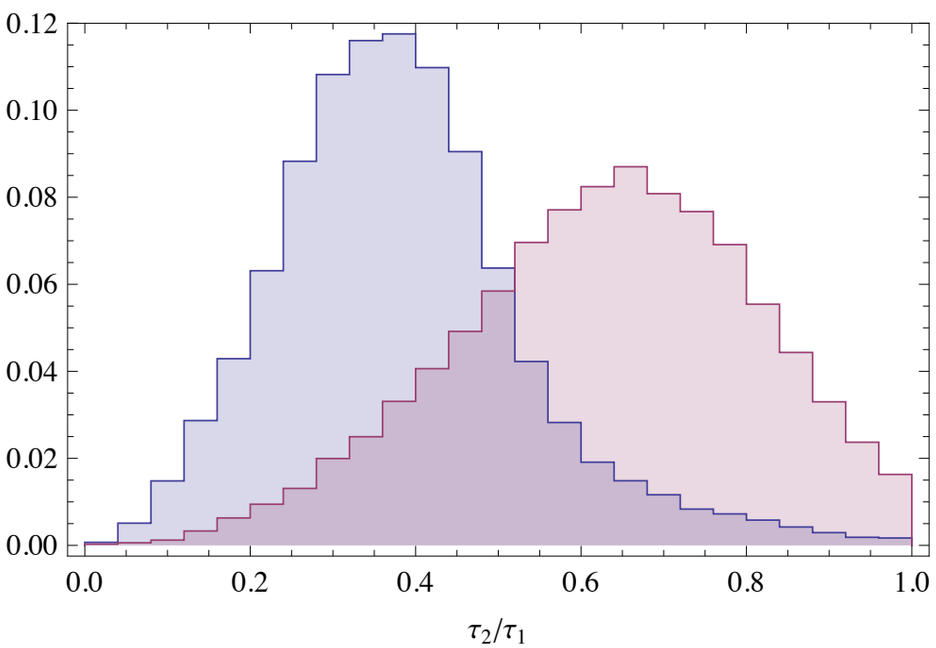
qcd jets

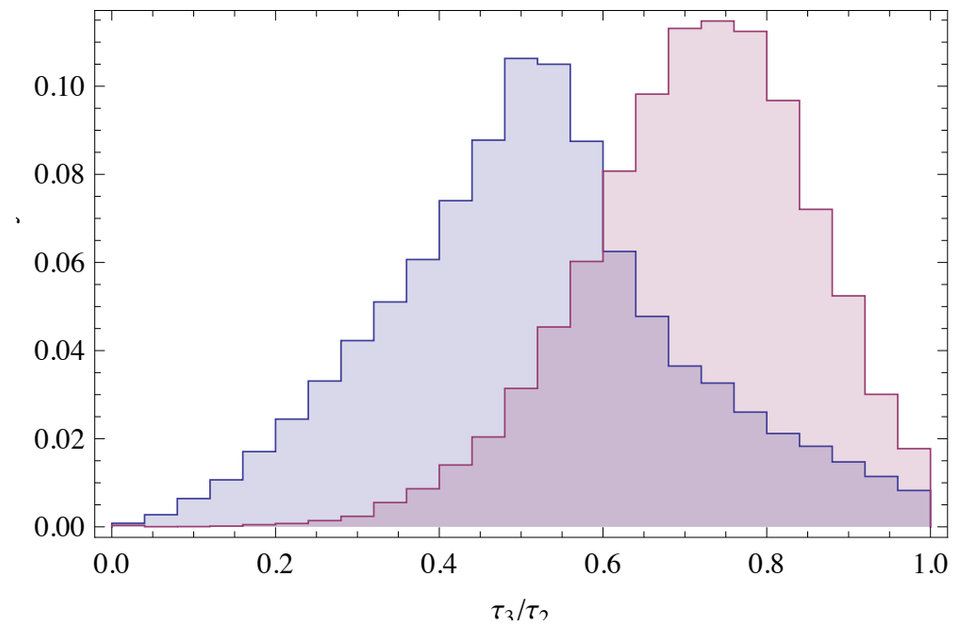


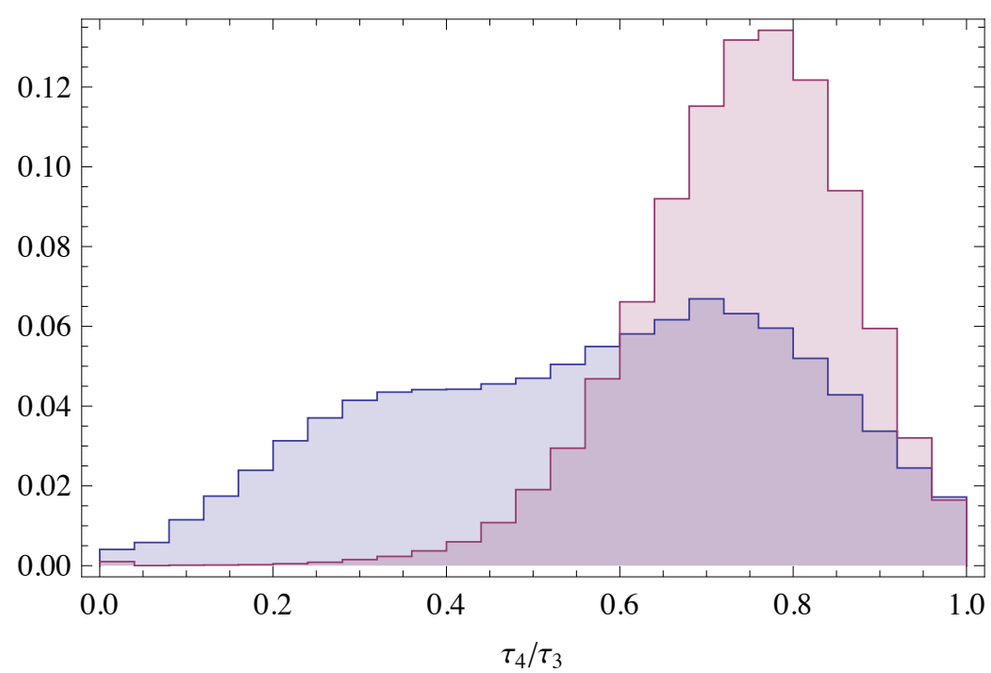


photon jet tagger

NSubjettiness



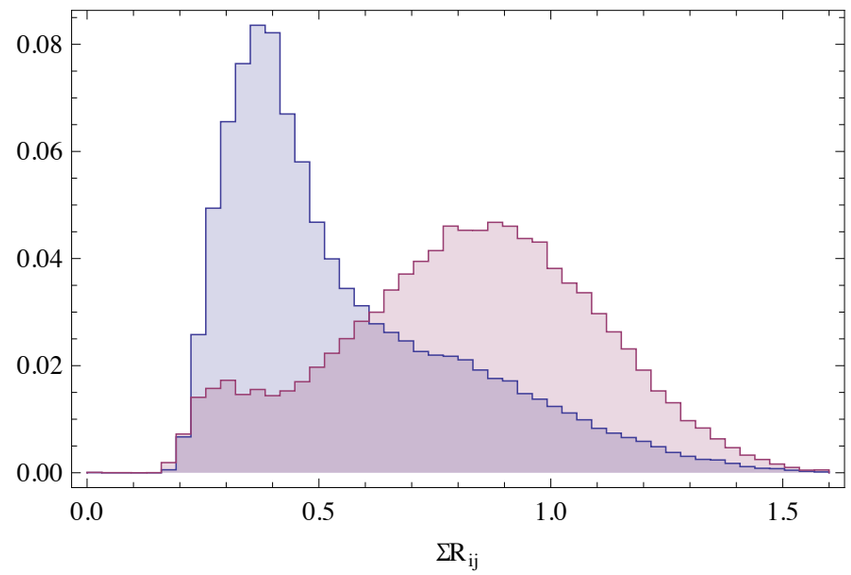




photon jets

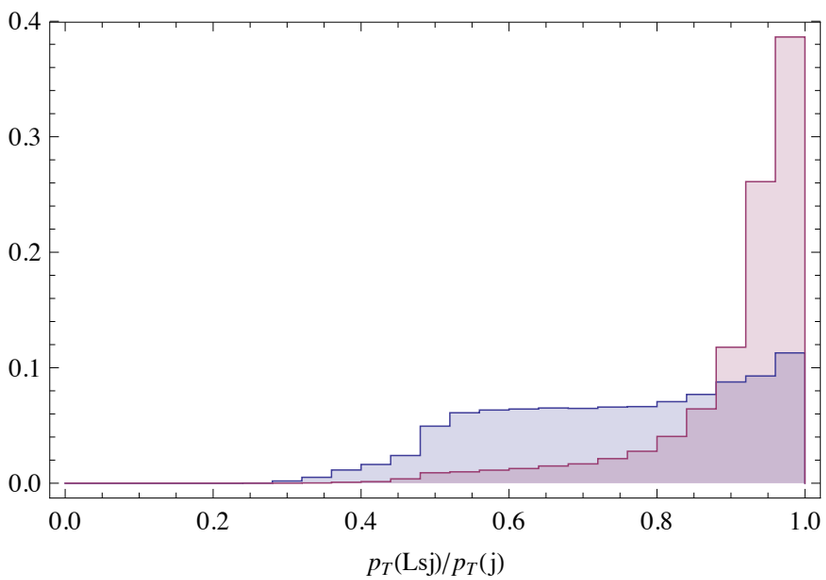
qcd jets

photon jet tagger

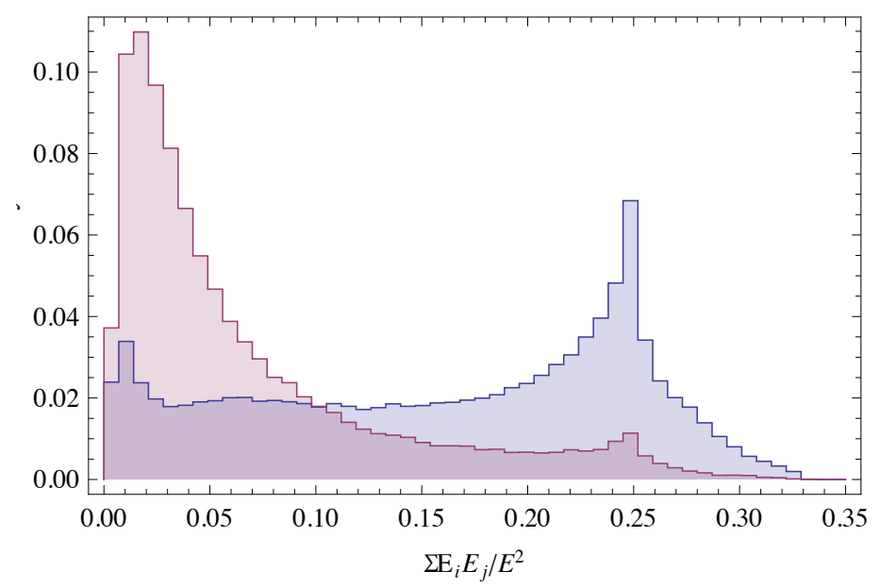


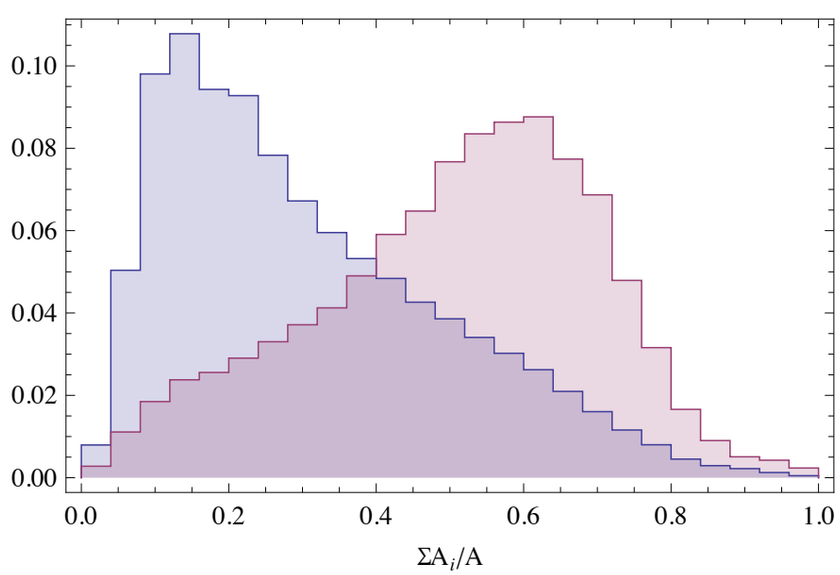
photon jets

qcd jets

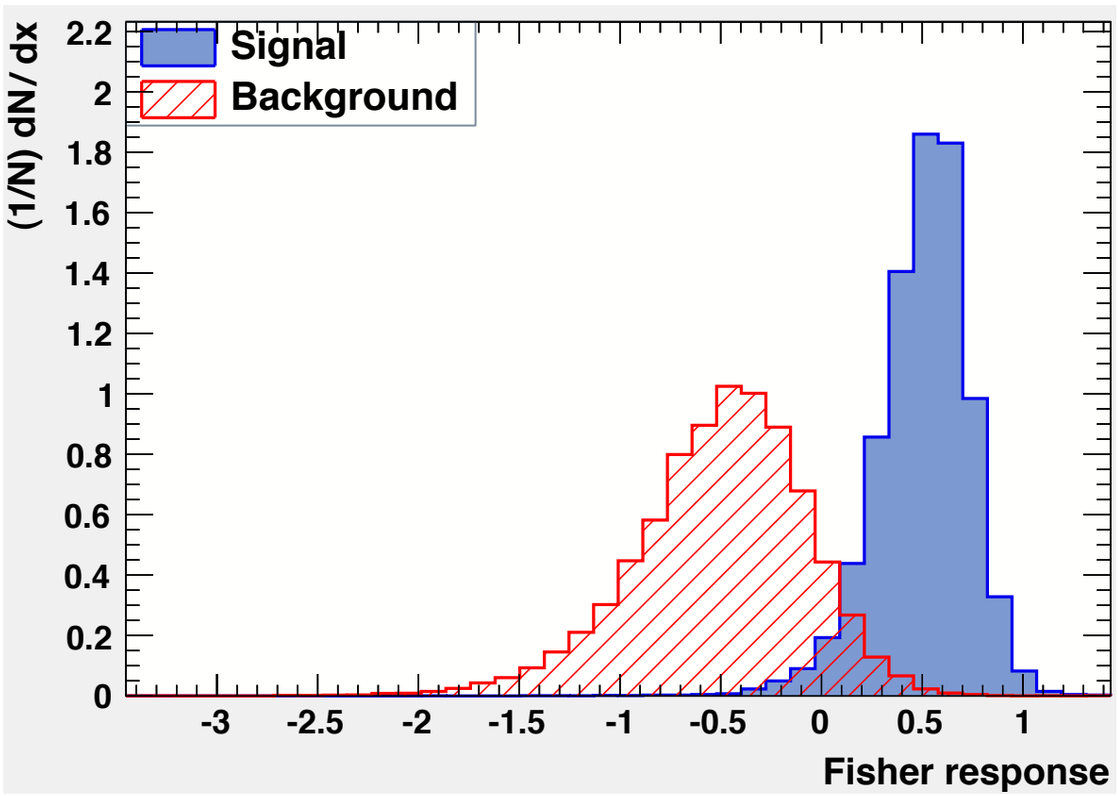


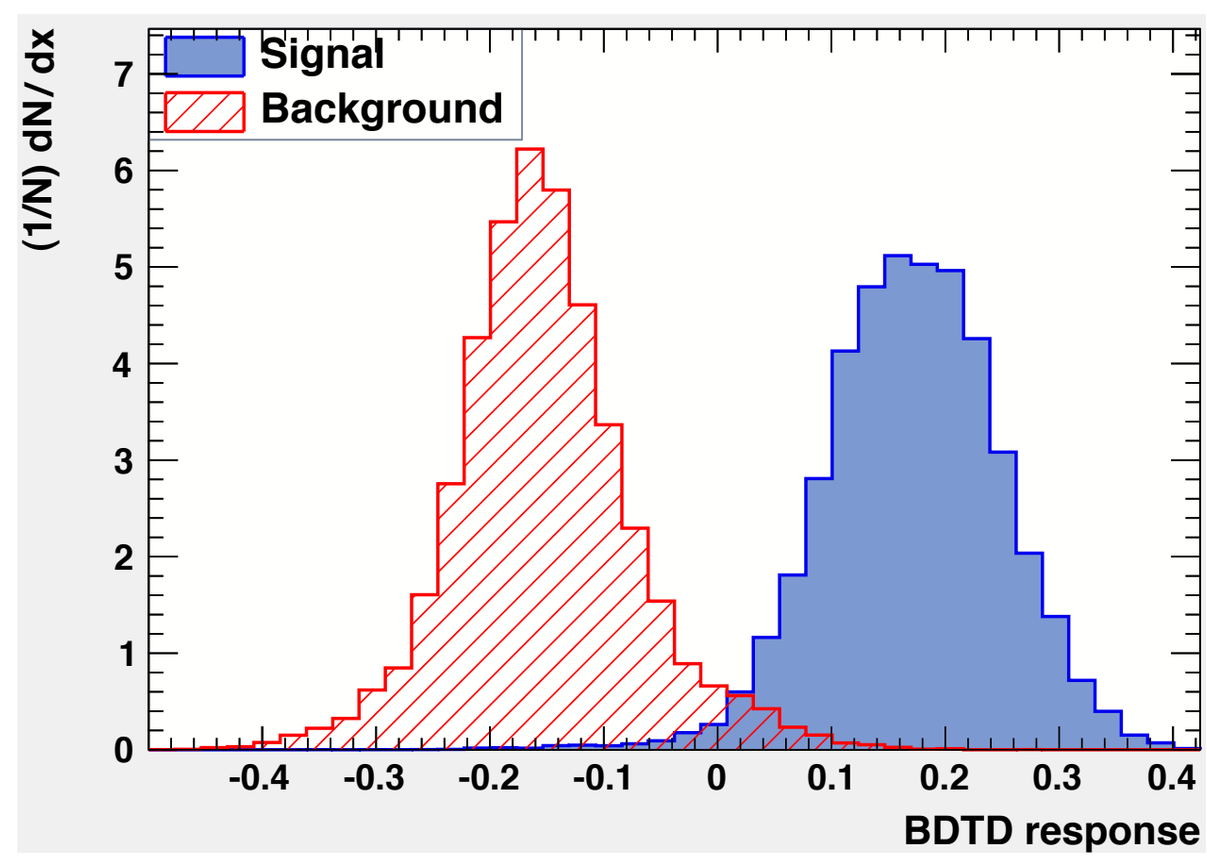
Analysis with 3/5 exclusive subjets



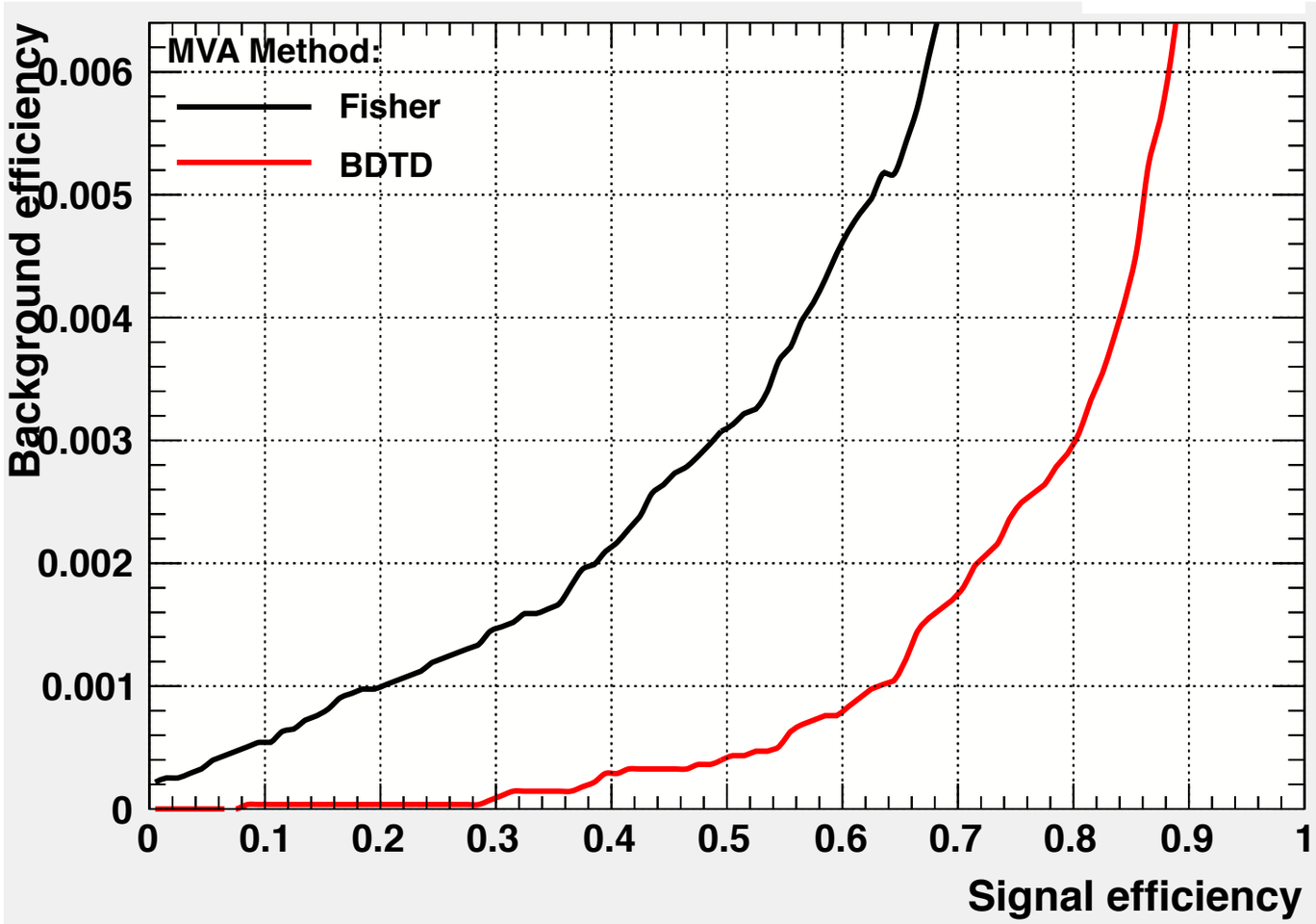


photon jet tagger

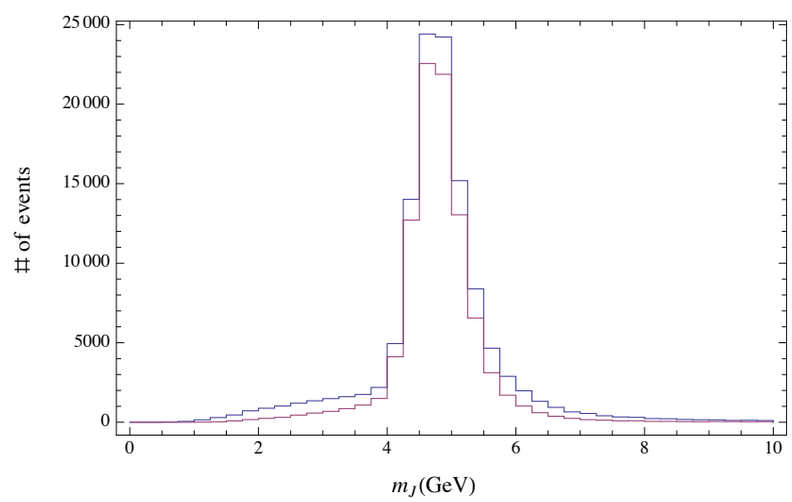


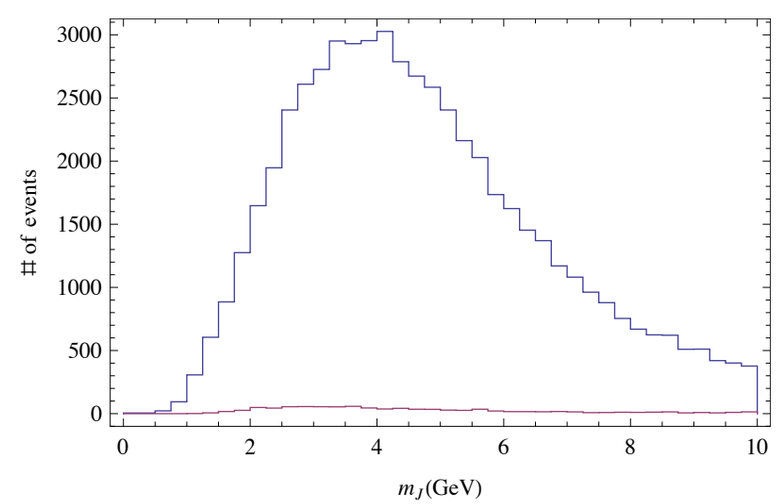


photon jet tagger



photon jet tagger





Higgs as a di-diphoton-jet resonance