Jets for everyone

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In collaboration with Gavin Salam, Matteo Cacciari and Juan Rojo

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Why QCD? Why jets?

QCD is everywhere at the LHC:

- QCD *per se*: multijets, PDF constraints, backgrounds, top, . . .
- Standard Model: Higgs ($H \to b\bar{b}$), W + jets, backgrounds, . . .
- Beyond SM: SUSY often has QCD decay products

QCD surely present, interesting and complementary to lepton channels

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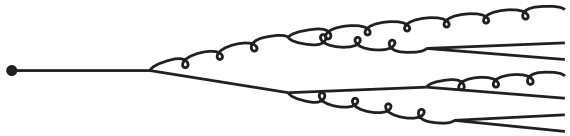

QCD generates collinear showers

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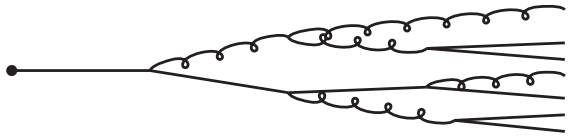

QCD generates collinear showers

parton $\longrightarrow$ collimated shower $\approx$ jet

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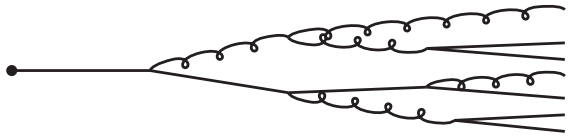

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QCD everywhere $\Rightarrow$ jets everywhere

Recent progress, part 1: defining jets

parton $\longrightarrow$ collimated shower $\approx$ jet

Not a true equality, no unique definition

a jet definition is a recipe: $\{\text{particles}\} \longrightarrow \{\text{jets}\}$

Example: Cambridge/Aachen algorithm

Successively recombine the closest particles

until they are all more than R apart

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Timeline:

19xy	introduction of k_t, Cambridge/Aachen (C/A), cone algorithms
1990	SNOWMASS Accords, set of rules to satisfy
$\approx$ 2000	k_t, C/A too slow; fundamental problems with the cone
2005-08	k_t, C/A made fast enough,
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Notes:

- The proper basic set of tools is only available since recently
- Having the choice is good: each alg. has its pros and cons

Recent progress, part 2: towards the future

Generic interest in using the tools properly/better

- Correctly choosing the jet definition
  $\rightarrow$ significant $S/\sqrt{B}$ improvements
- jet areas: subtraction of the background (UE, pileup, heavy-ions)
- jet substructure:
  - filtering: many applications
  - subjets: boosted taggers

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New generation of algorithms

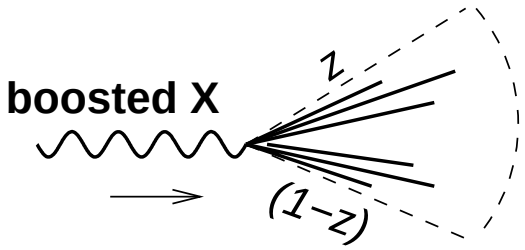
Analytic computations available/under progress

benefit for everyone!

Example: boosted Higgs

[J.Butterworth, A.Davison, M.Rubin, G.Salam,08]

- $H \to b\bar{b}$: dominant decay for small M_H but large backgrounds
- boosted H (WH, HZ): many advantages (*e.g.* no $t\bar{t}$ background), main problem: small cross-section
- boosted particle: decay products in the same jet

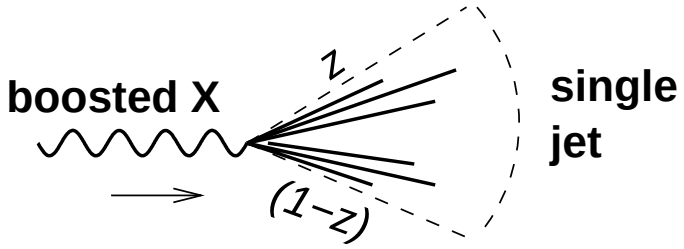


$$R \gtrsim \frac{m}{p_t} \frac{1}{\sqrt{z(1-z)}}$$

Note: also valid for top (with similar methods)

Example: boosted Higgs

[J.Butterworth, A.Davison, M.Rubin, G.Salam,08]



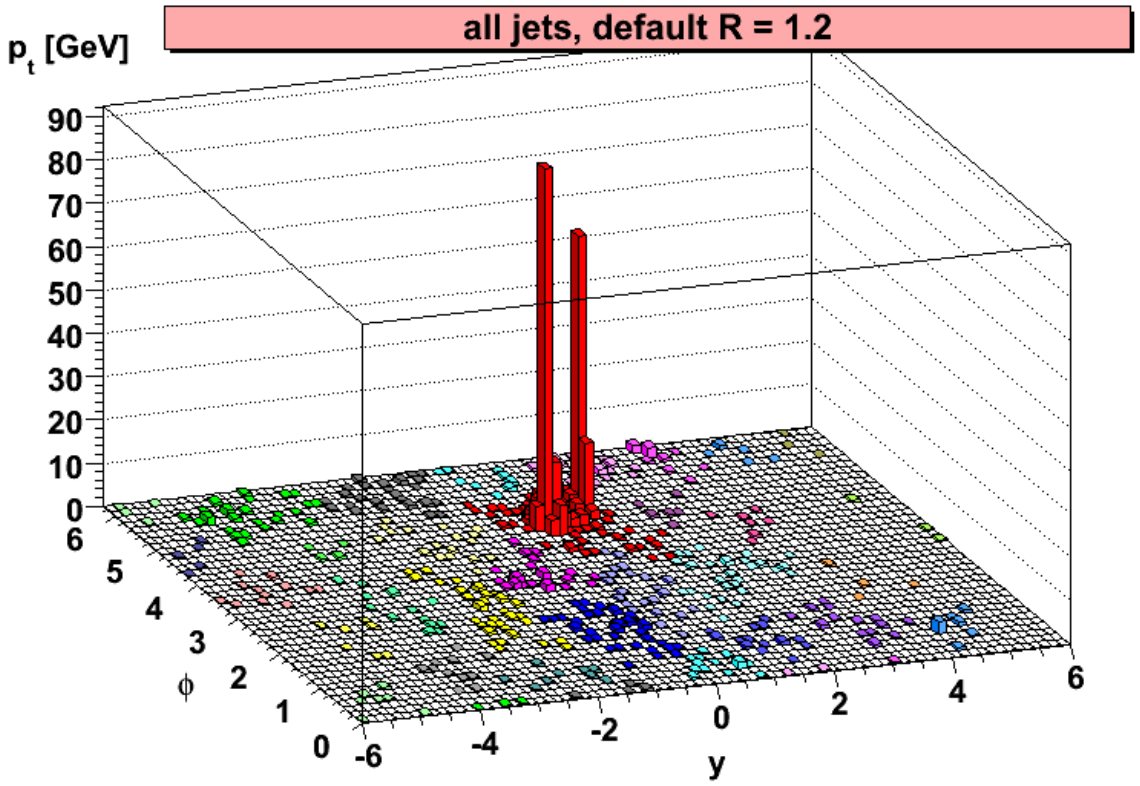
$$R \gtrsim \frac{m}{p_t} \frac{1}{\sqrt{z(1-z)}}$$

Method: start with a hard (C/A, radius R) jet j

1. Undo the last clustering $\rightarrow j_1, j_2$
2. If $\max(m_1, m_2) < 0.67m$, we have a mass drop, else back to 1
   idea: find the 2 b-jets, dynamically find R_{bb}
3. Require symmetric splitting $y_{12} \approx \frac{\min(z_1,z_2)}{\max(z_1,z_2)} > 0.09$, else go to 1
   idea: remove QDC asymmetric splittings
4. Require 2 b taggings
5. Filter *i.e.* uncluster down to $R_{\rm filt}$, keep the 3 hardest subjets
   idea: keep “hard” QCD radiations, reduce UE

Boosted Higgs: one event, effects on S/B

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



Cluster C/A, R=1.2

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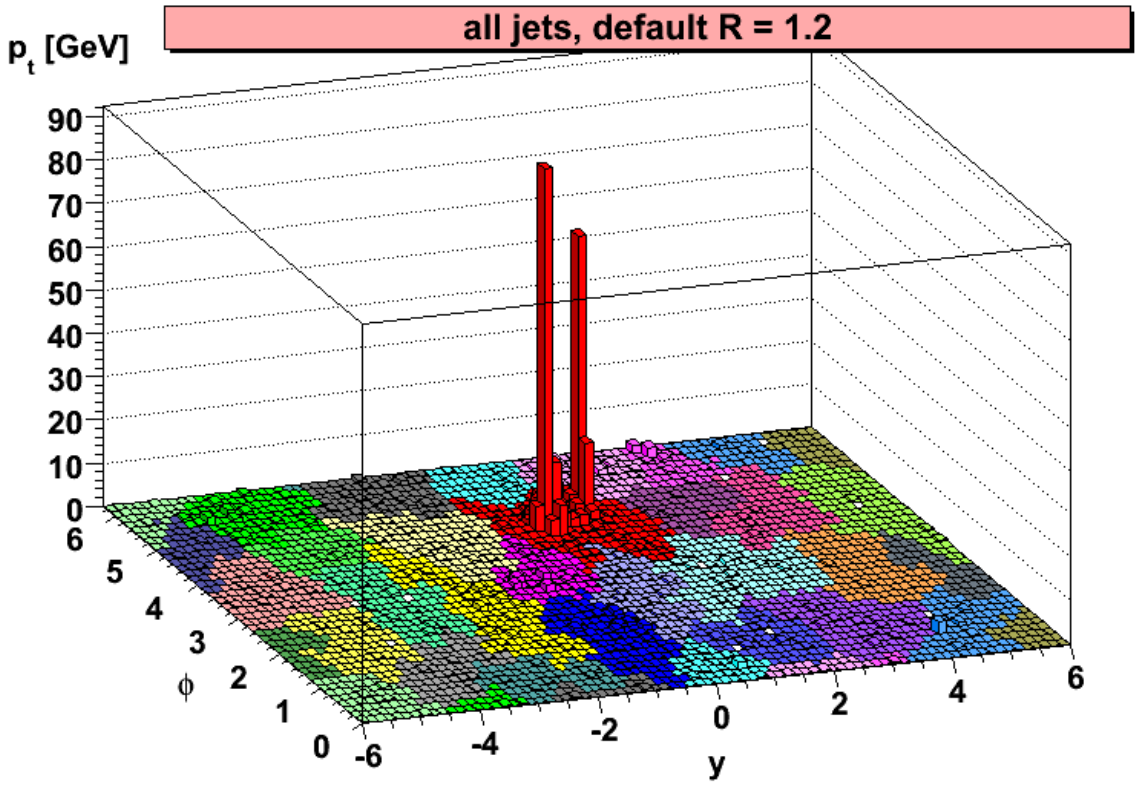

Show jets more clearly

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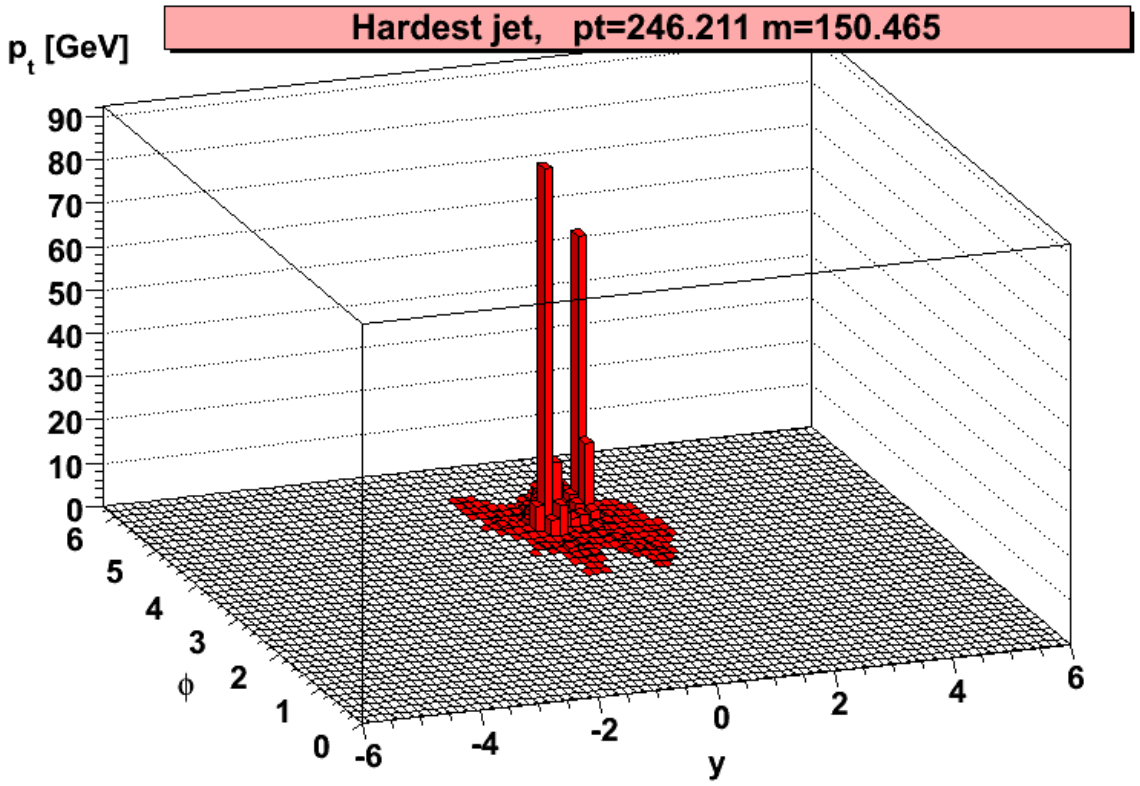
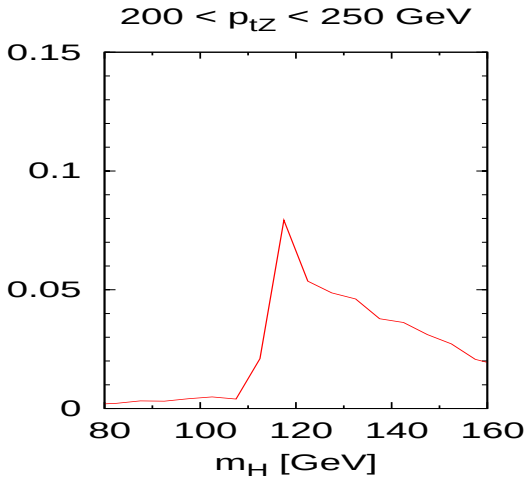
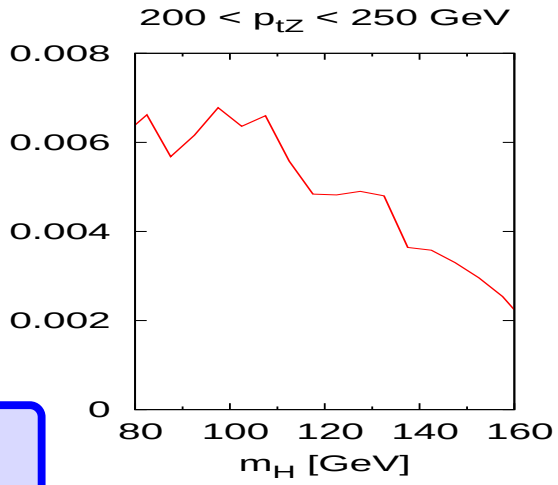


HZ Signal



Zbb Background



Hardest jet ($m = 150$ GeV)

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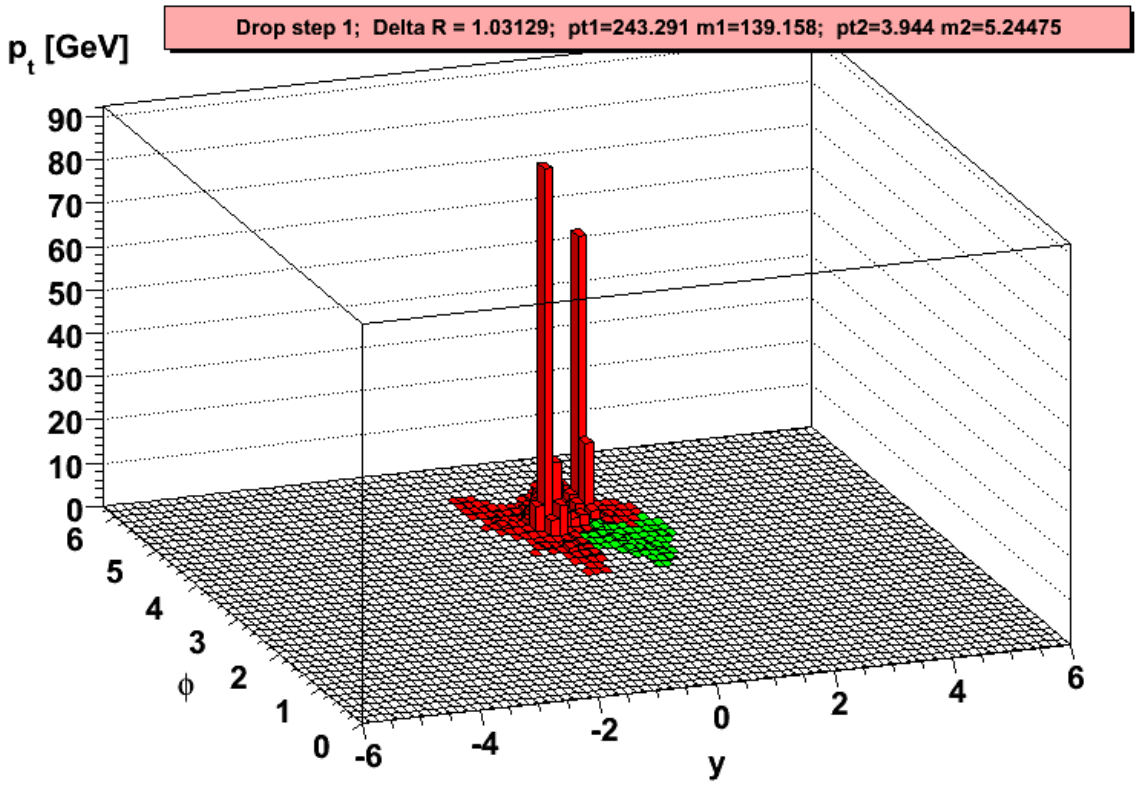

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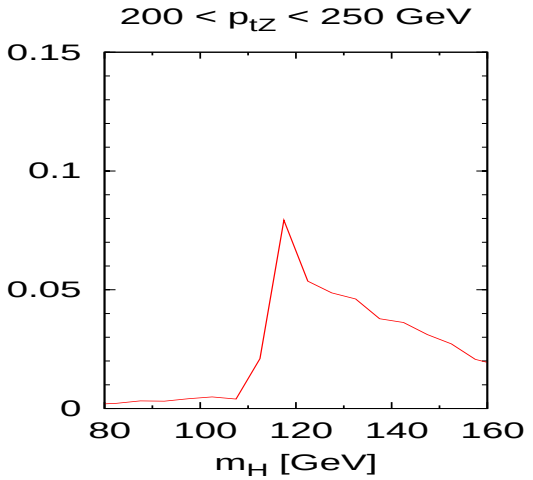

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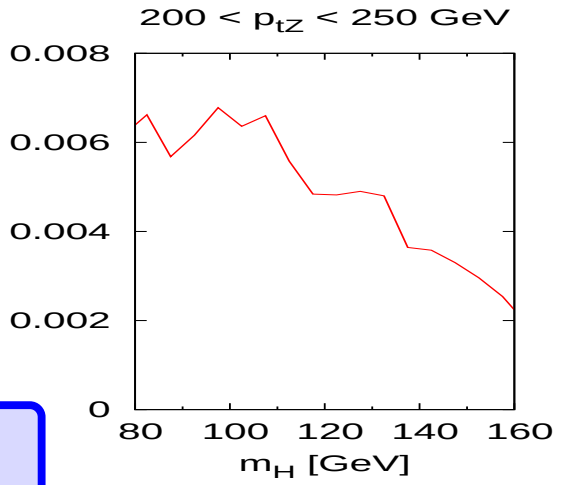

Split: $\frac{\max(m_1,m_2)}{m} = 0.92$, repeat ($m = 150$ GeV)

Boosted Higgs: one event, effects on S/B

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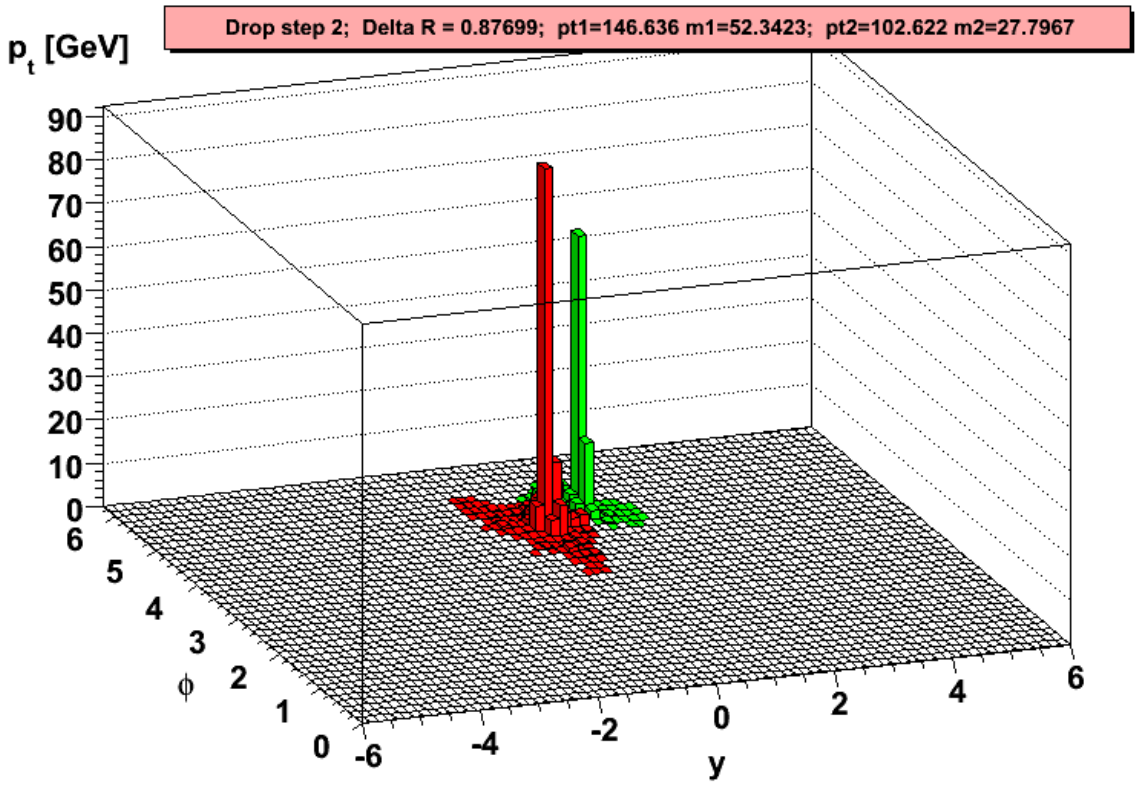

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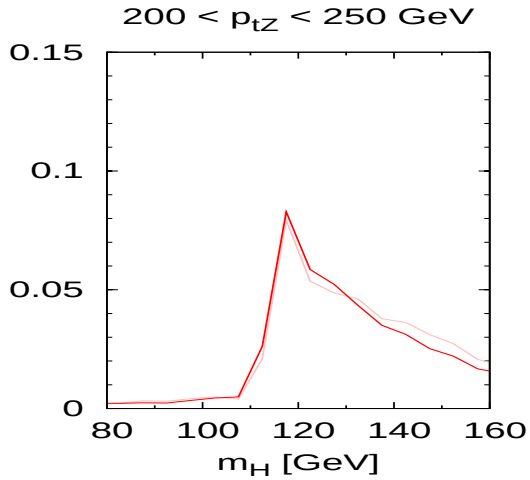

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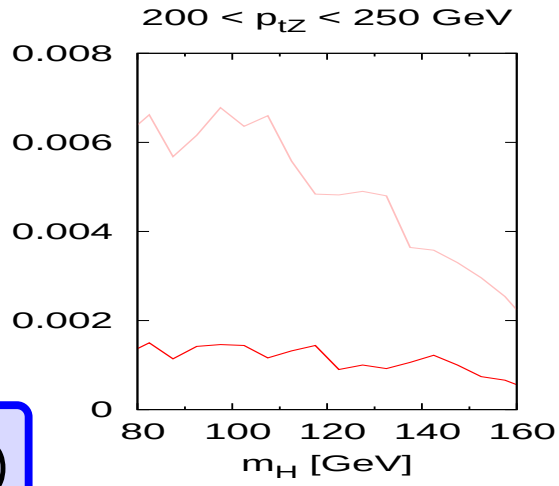

Split: $\frac{\max(m_1,m_2)}{m} = 0.37$, mass drop ($m = 139$ GeV)

Boosted Higgs: one event, effects on S/B

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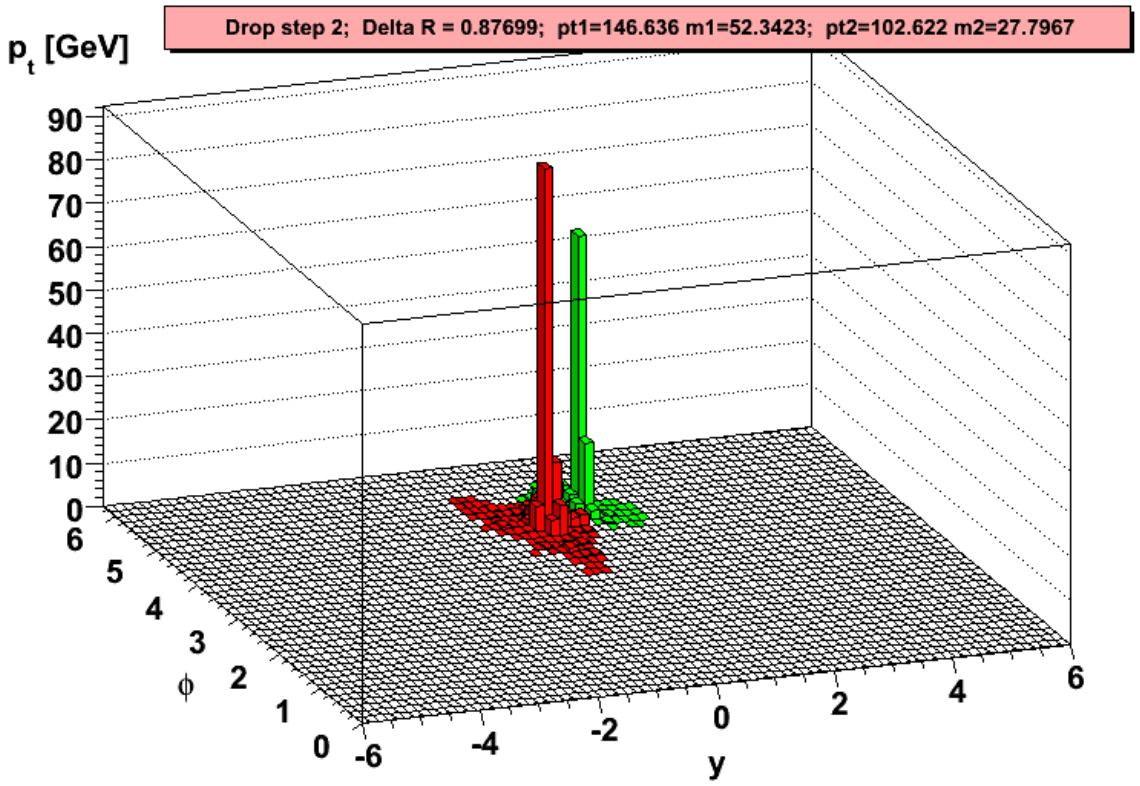

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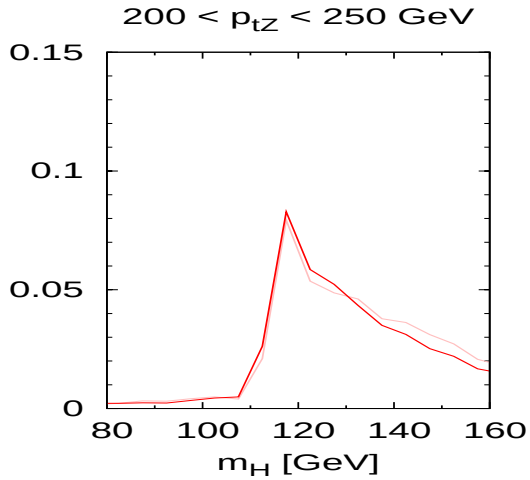

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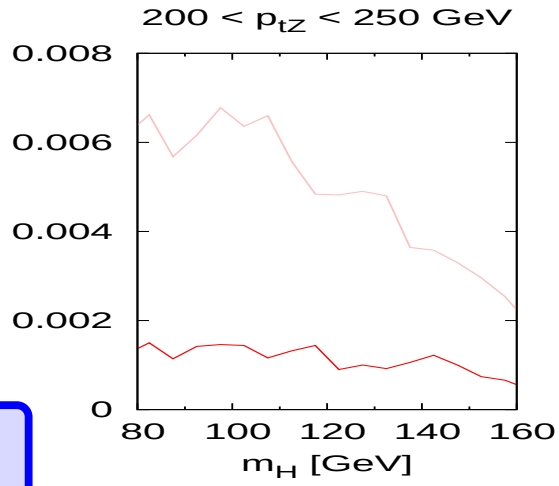

Split: $y_{12} = 0.7$, 2 b tags $\Rightarrow$ OK ($m = 139$ GeV)

Boosted Higgs: one event, effects on S/B

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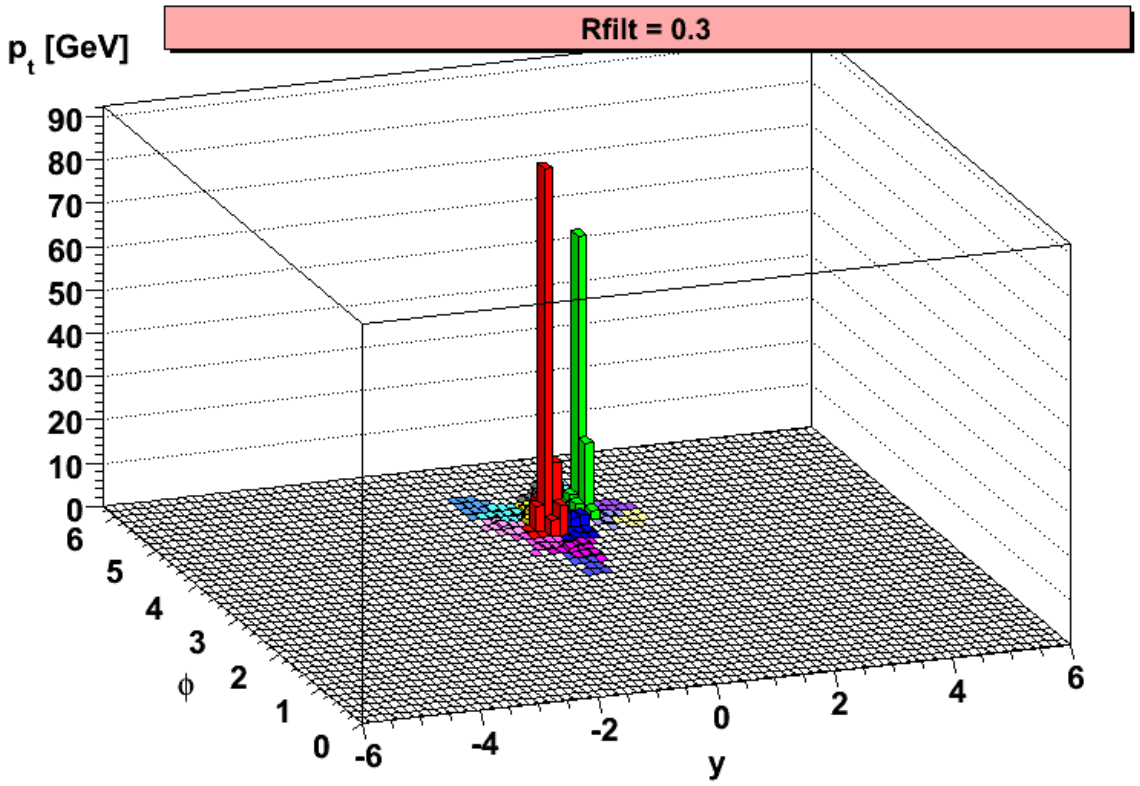

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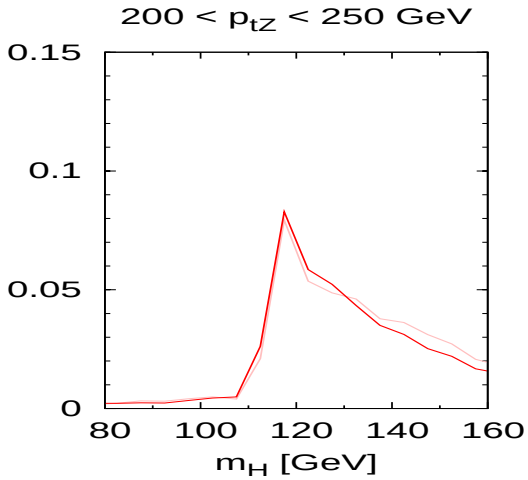

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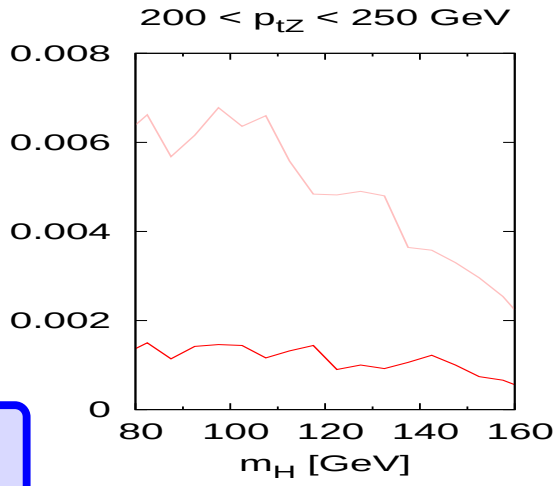

Re-cluster: $R_{\mathrm{filt}} = 0.3$

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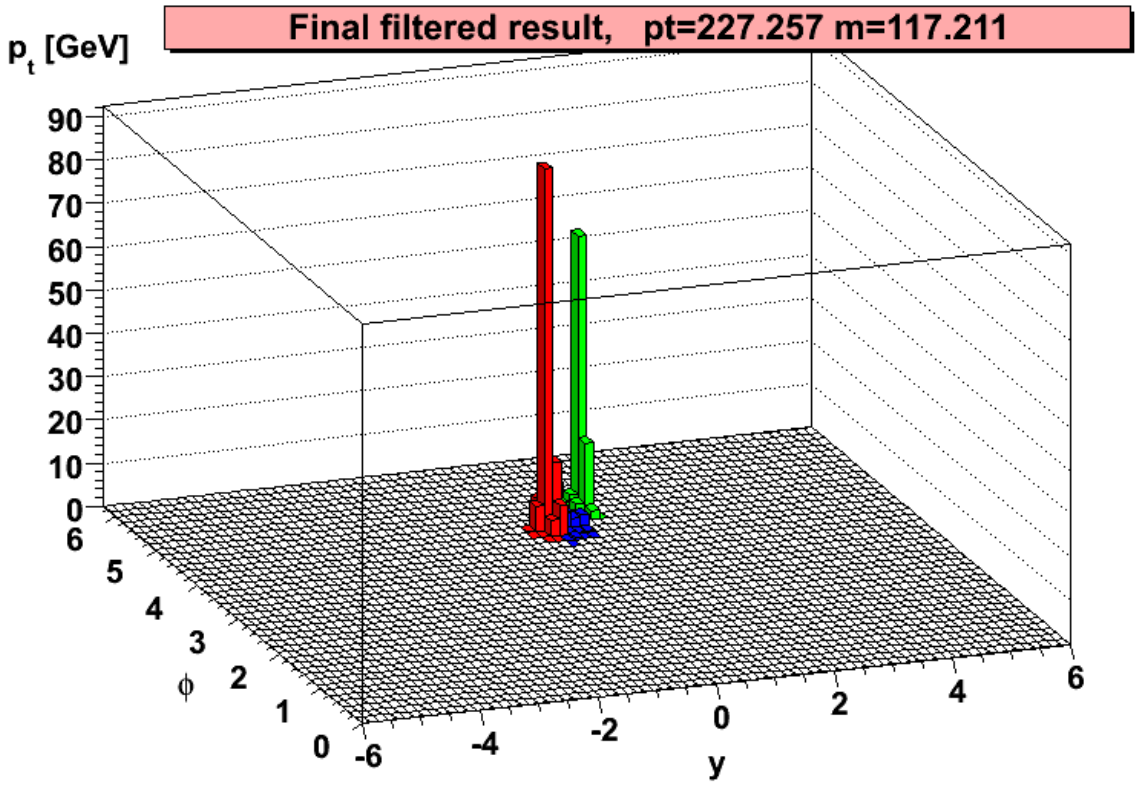

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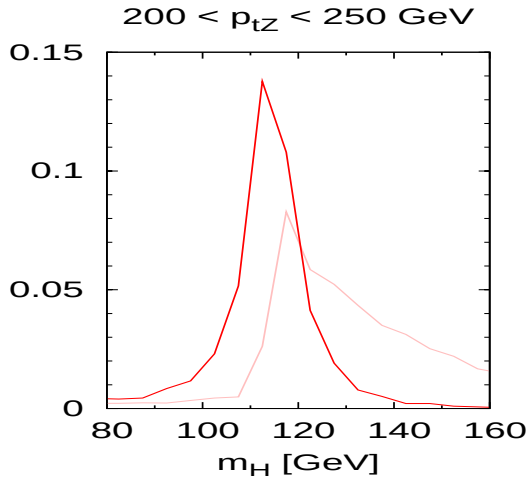

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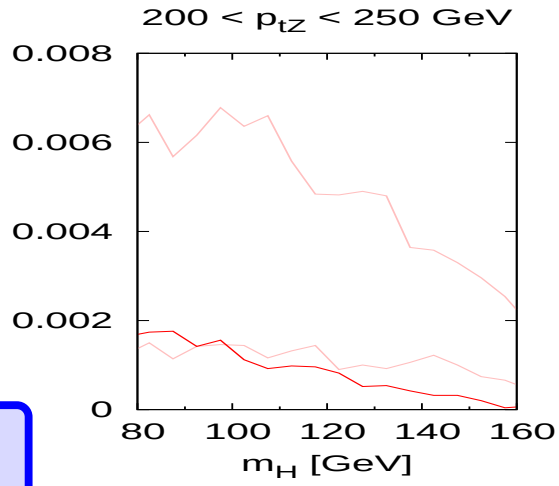

Filter: keep 3 hardets ($m = 117$ GeV)

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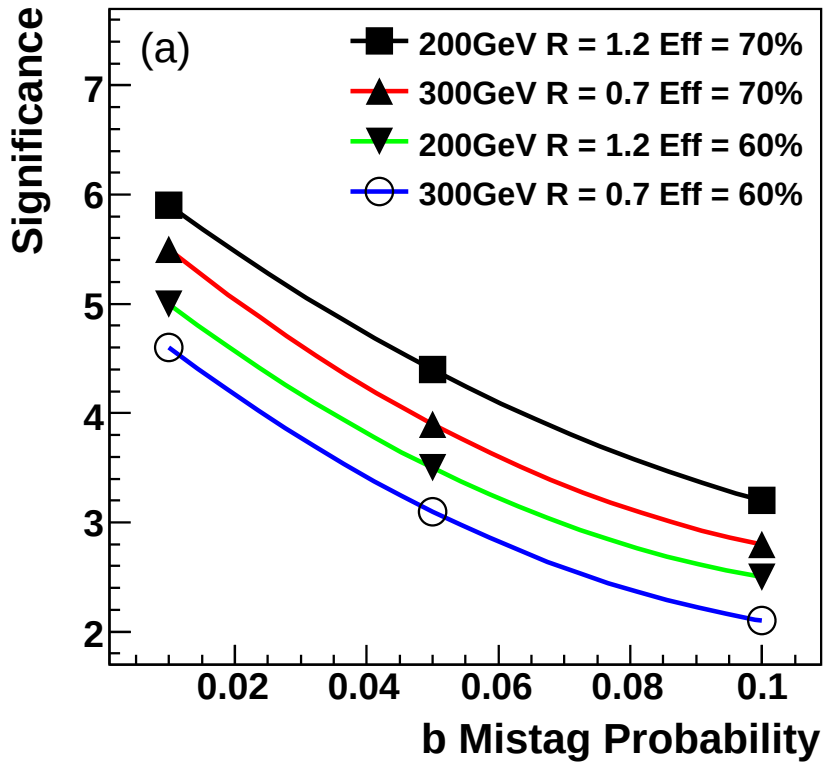

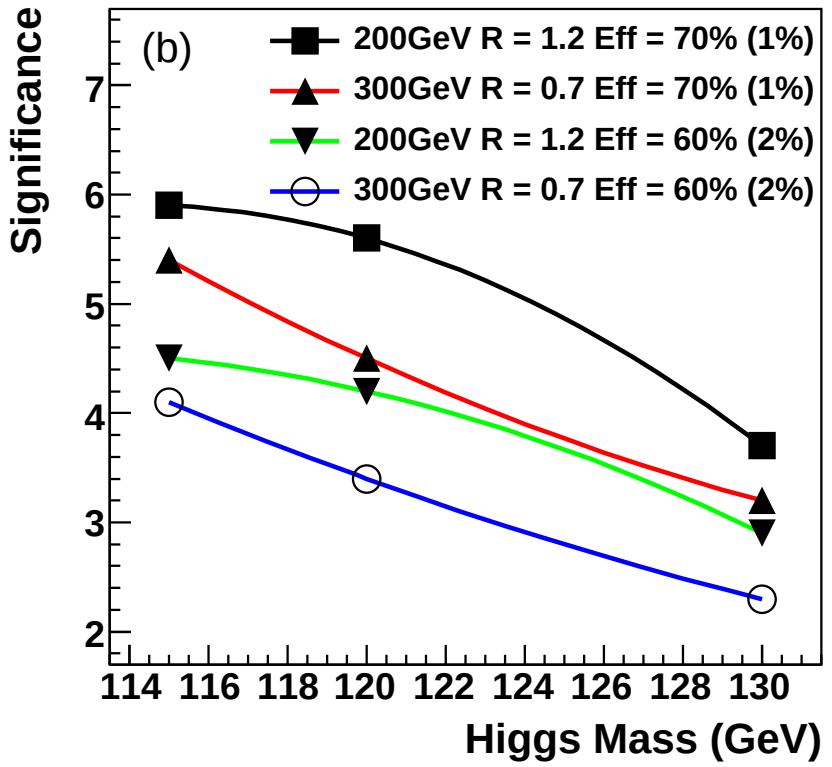

More than 3σ for most scenarios (30 fb^{-1})