Boosted Higgs search

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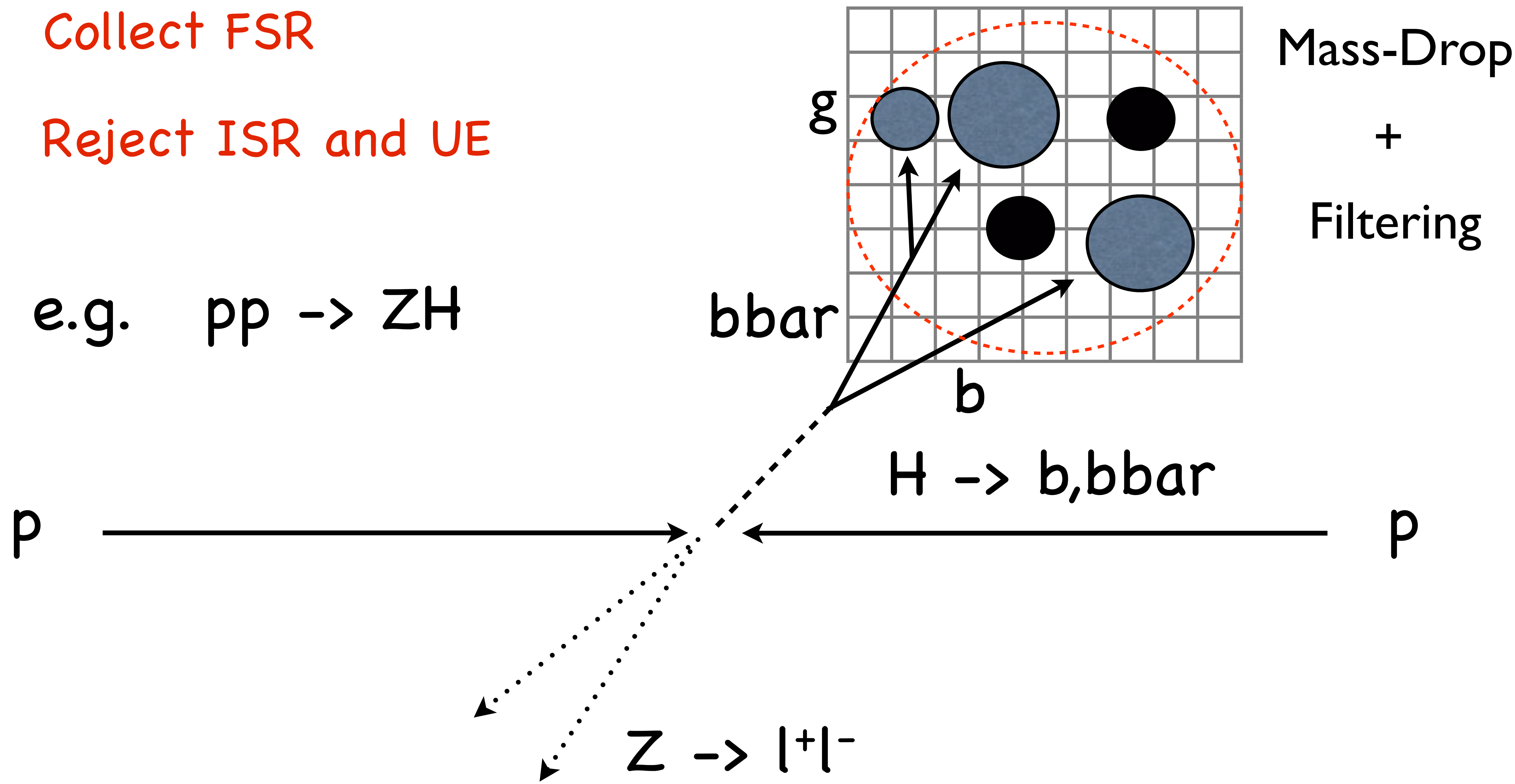
Basic idea of subjet analysis

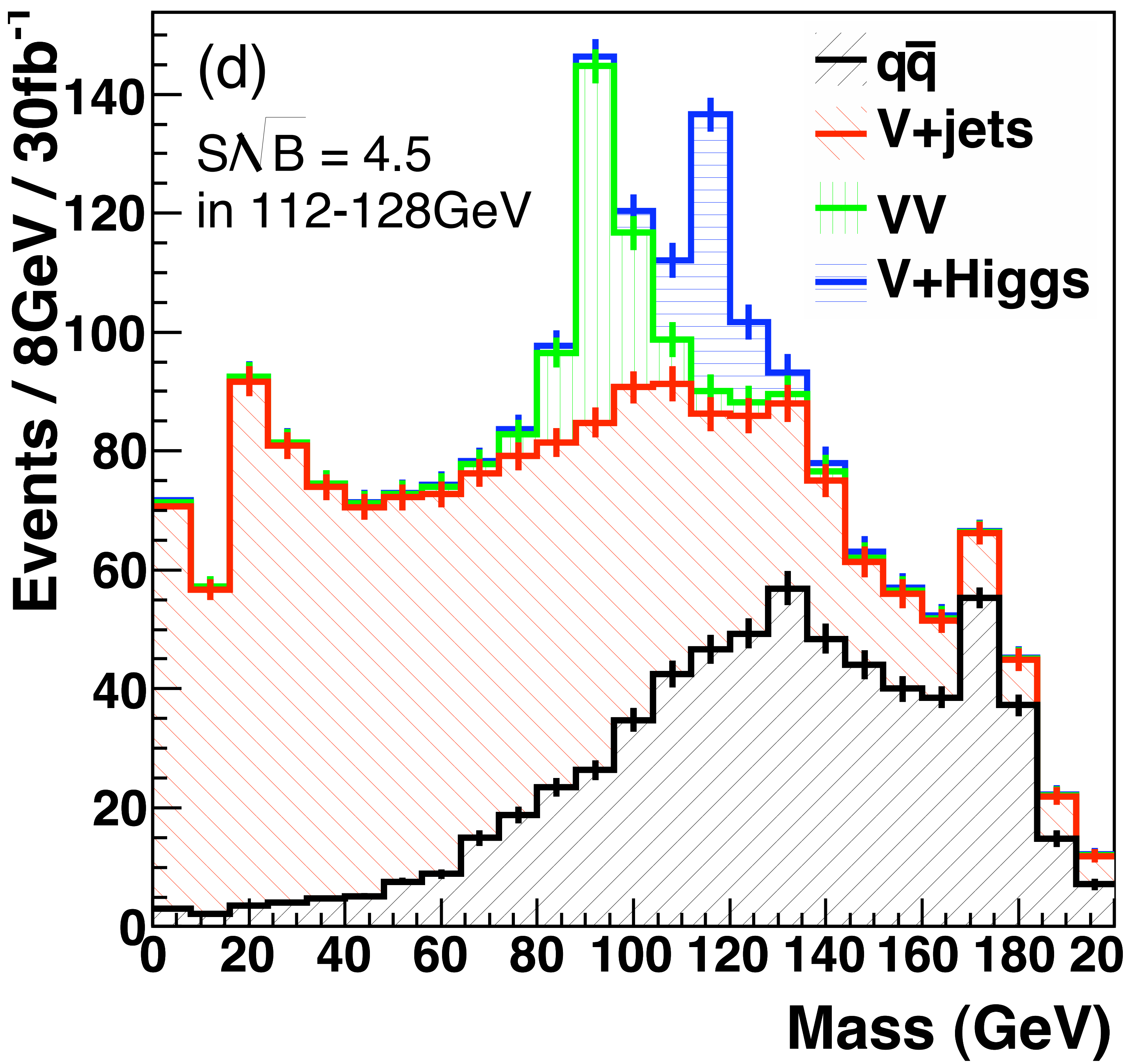
Collect FSR

Reject ISR and UE

e.g. pp -> ZH



Result for ZH and WH combined:



Confirmed by ATLAS analysis with only slightly smaller significance
[ATL-PHYS-PUB-2009-088, G. Piacquadio]

Further techniques for jet grooming

Pruning

[PRD 80 (2009), S.Ellis, Vermilion and Walsh]

- Run CA or kT algorithm on constituents of found jet (large cone: R). At each recombination $i, j \to p$ test if:

$$z = \frac{\min(p_{T_i}, p_{T_j})}{p_{T_p}} < z_{\text{cut}} \quad \text{and} \quad \Delta R_{ij} > D_{\text{cut}}$$

- If both conditions are full-filled, veto on the recombination - discard the lower pT daughter and continue.
- The resulting jet is the new (pruned) jet

Trimming

[JHEP 1002 (2010), Krohn, Thaler and Wang]

- Run a jet algorithm (kT) on a found jet (Anti-kT, large cone R), with Rsub smaller than R
- Discard all subjets with $p_T = f_{\text{cut}} \Lambda$
- Remaining subjets from the new (trimmed) jet

Pruning vs Trimming

David Krohn`s conclusion at the Workshop in Seattle:

- Trimming and Pruning are complementary techniques:
  - Trimming is for QCD jets, Pruning for boosted heavy objects

http://silicon.phys.washington.edu/JetsWorkshop/Krohn.pdf

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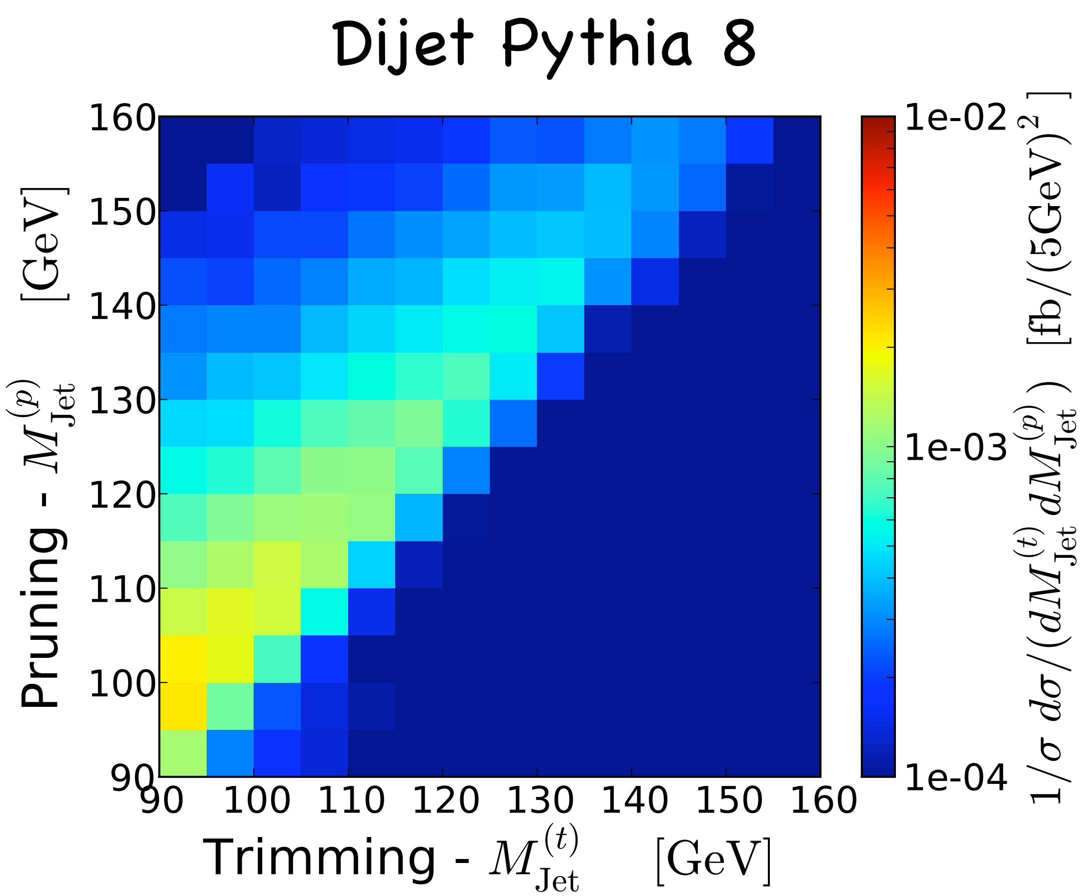
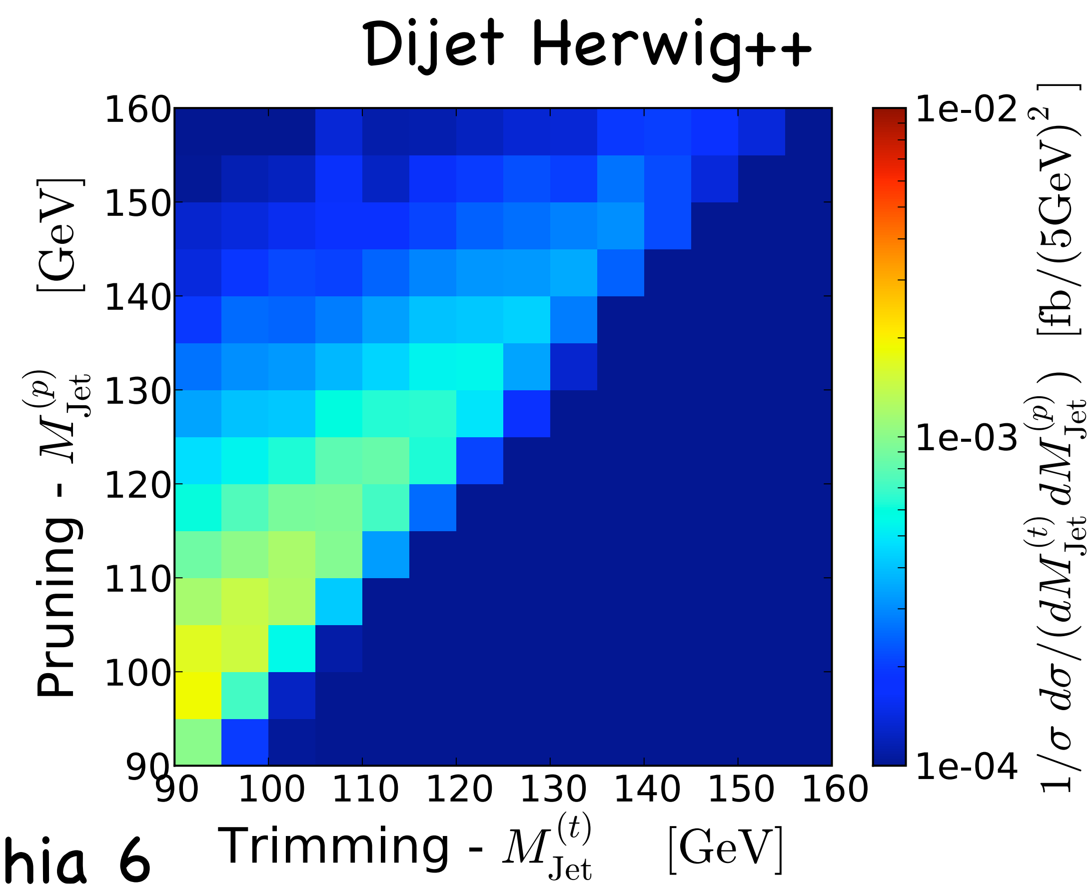
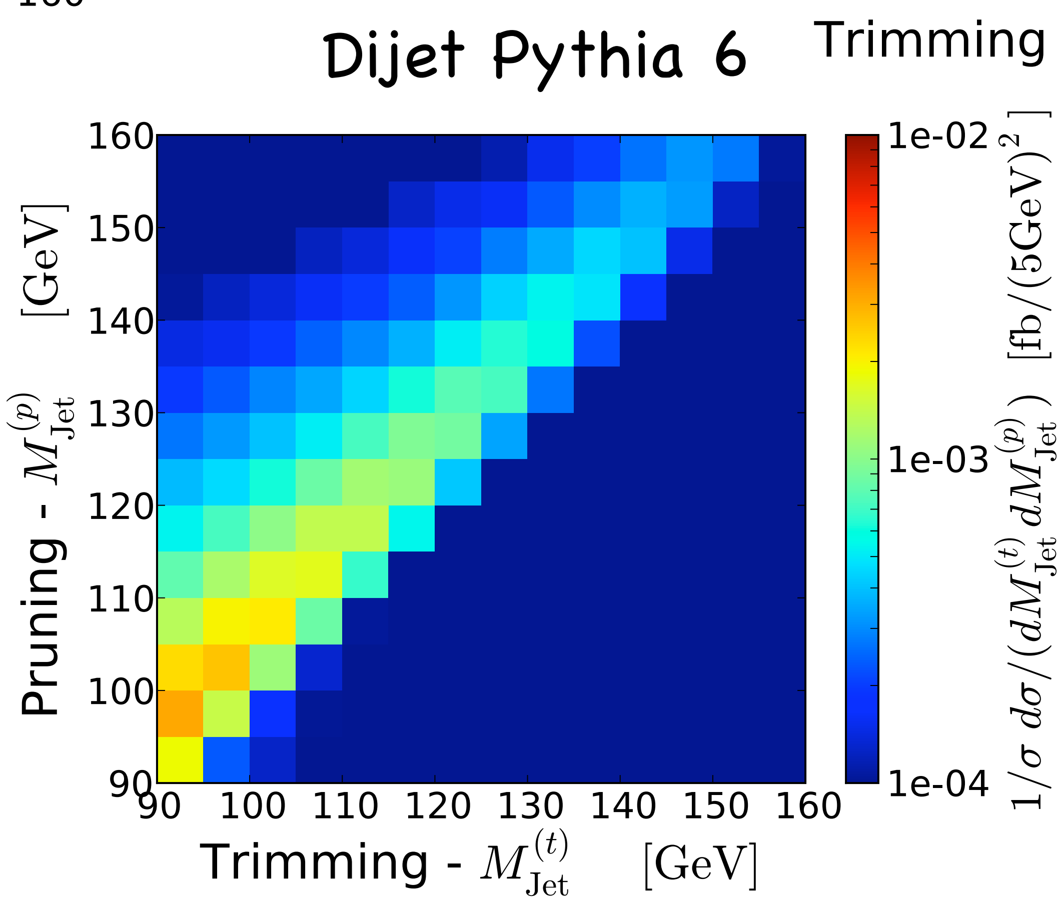
Both do their job -
but differently

Use it!

What happens if we run Pruning and Trimming simultaneously?







- hardest jet pT > 150 GeV
- With granularity and cell pT cut of 0.5 GeV

chosen:
R=1.2
Pruning (CA)
Trimming (aKT,KT)

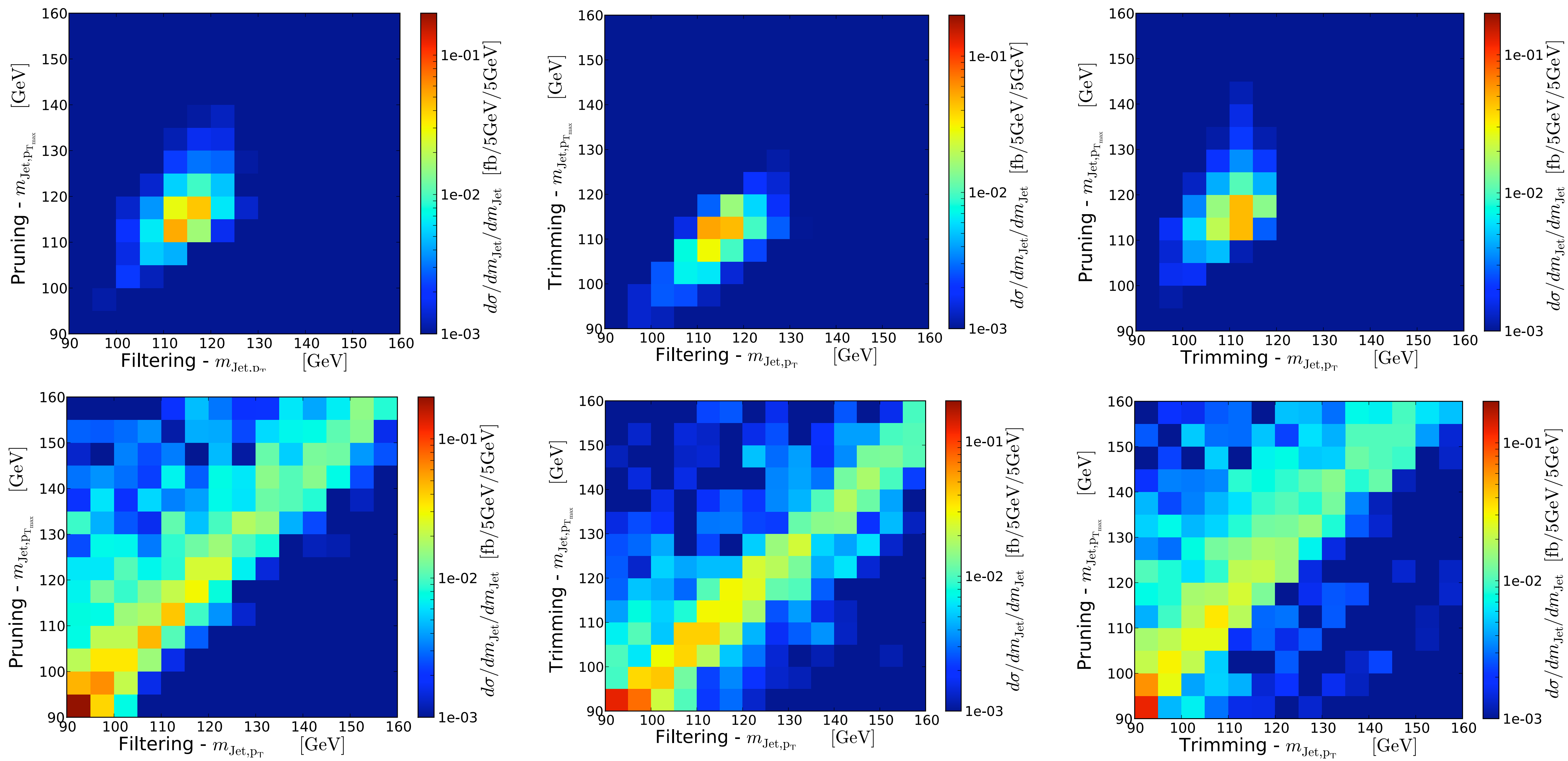
Thanks to Christoph Hackstein

Combine Pruning, Trimming and Mass-Drop/Filtering

[Soper, MS, 1005.0417]

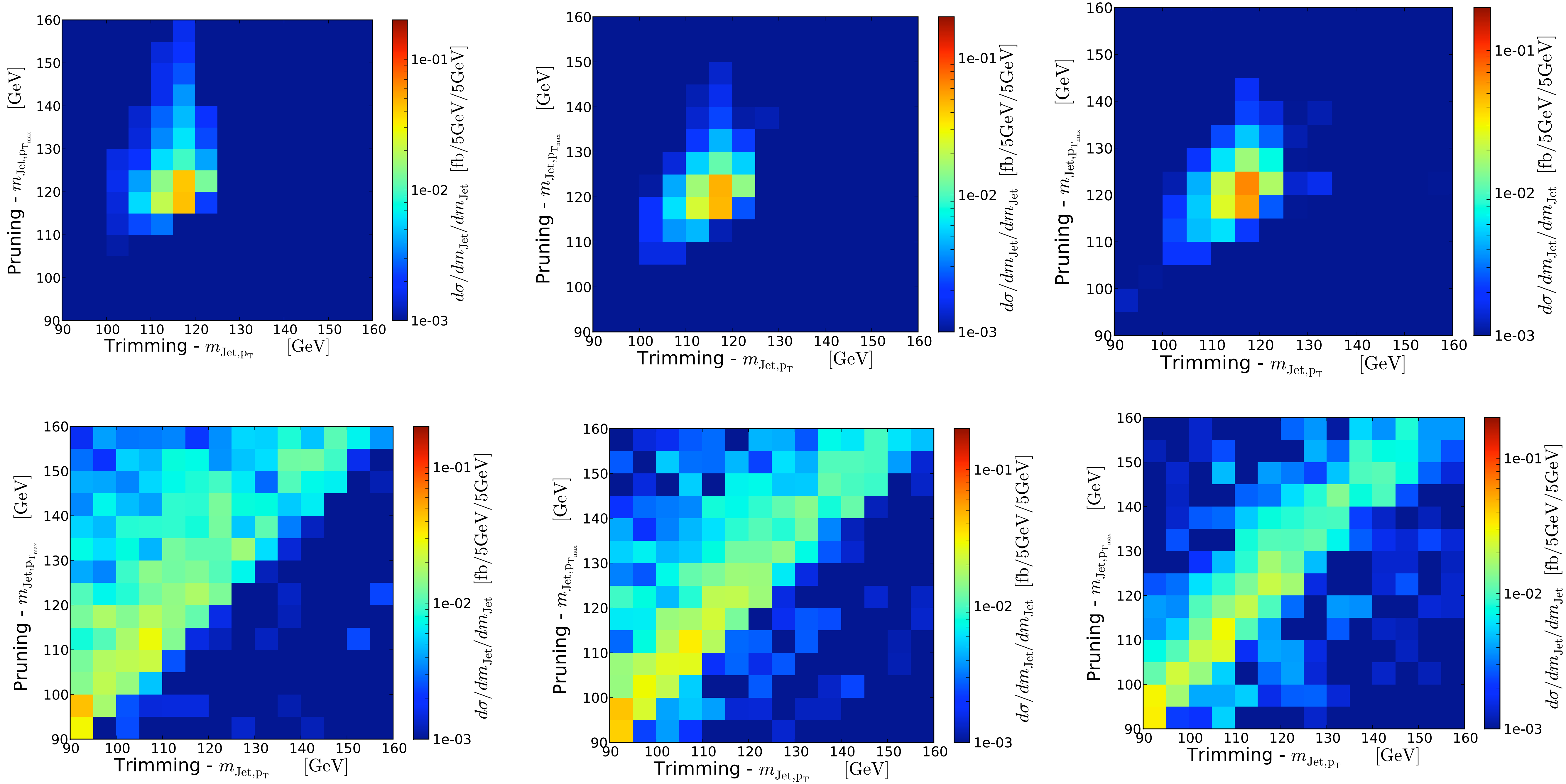
Run BDRS analysis for ZH production

Apply pruning and trimming on Higgs candidate



‘Optimize‘ procedure

Z=0.05 Z=0.1 Z=0.2



Exploitation of asymmetry

Cut based approach

Exp. Likelihood Ratio $\langle \mathcal{L}(\{n\}) \rangle_{\rm SB} = \sum_J \left[(s_J + b_J) \log\left(1 + \frac{s_J}{b_J}\right) - s_J \right]$

	$M_{\rm Jet}^{(f)} \in W_f$	$M_{\rm Jet}^{(f)} \in W_f$ $M_{\rm Jet}^{(t)} \in W_t$	$M_{\rm Jet}^{(f)} \in W_f$ $M_{\rm Jet}^{(p)} \in W_p$	$M_{\rm Jet}^{(p)} \in W_p$ $M_{\rm Jet}^{(t)} \in W_t$	$M_{\rm Jet}^{(p)} \in W_p$ $M_{\rm Jet}^{(t)} \in W_t$
Signal cross section [fb]	0.20	0.18	0.17	0.17	0.16
Backgrnd cross section [fb]	0.30	0.20	0.17	0.16	0.13
s/b	0.67	0.90	1.0	1.1	1.3
$s/\sqrt{b}$ $(\int dL = 30\ {\rm fb}^{-1})$	2.0	2.2	2.3	2.3	2.4
$\langle \mathcal{L}(n) \rangle_{\rm SB}$ $(\int dL = 30\ {\rm fb}^{-1})$	1.7	1.9	2.0	2.1	2.2

Z=0.1　　　　Z=0.05

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Z=0.1

Z=0.05

Stronger as a team

Filtering

Trimming

Pruning

Pruning

Trimming

Filtering

Generic resonance tagger should run comb. of procedures

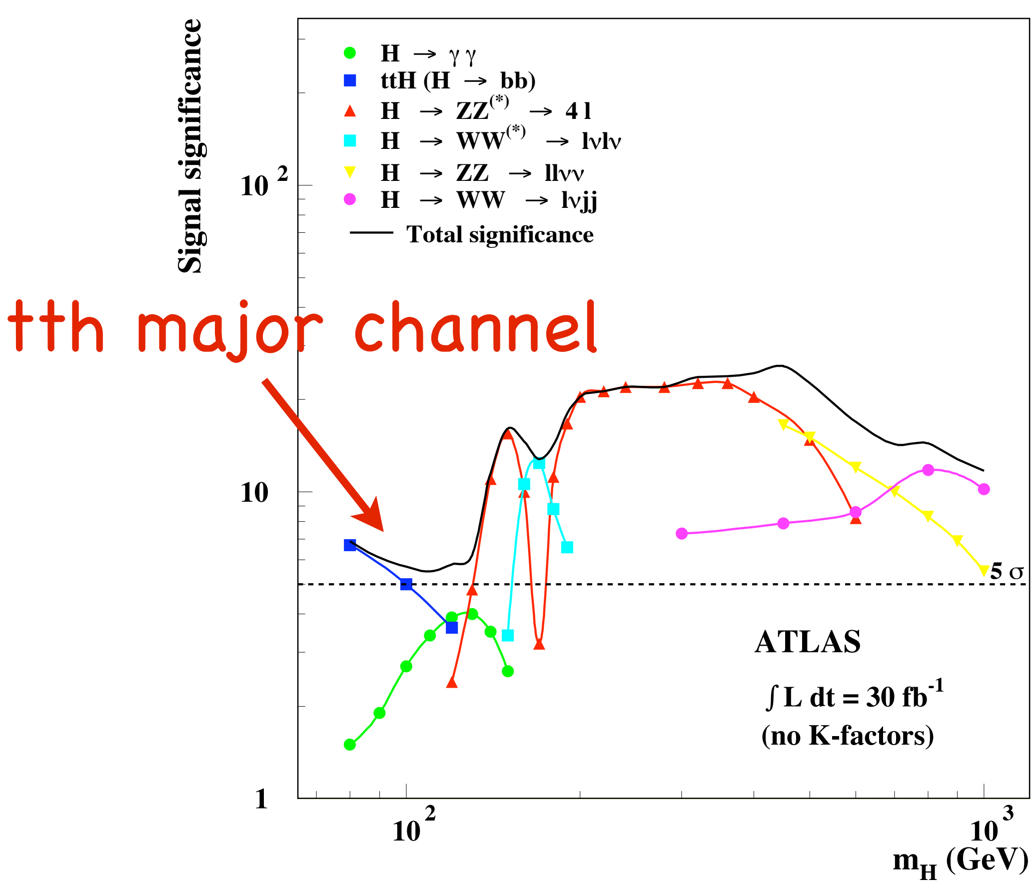
Maybe we can gain insight to improve on subjet procedures

Brief summary of tth

[Plehn, Salam, MS, PRL 104 2010]

Motivation:
- sizable cross-section
- Higgs discovery contribution in low mass range
- access to t- and b-Yukawa couplings

High expectations:



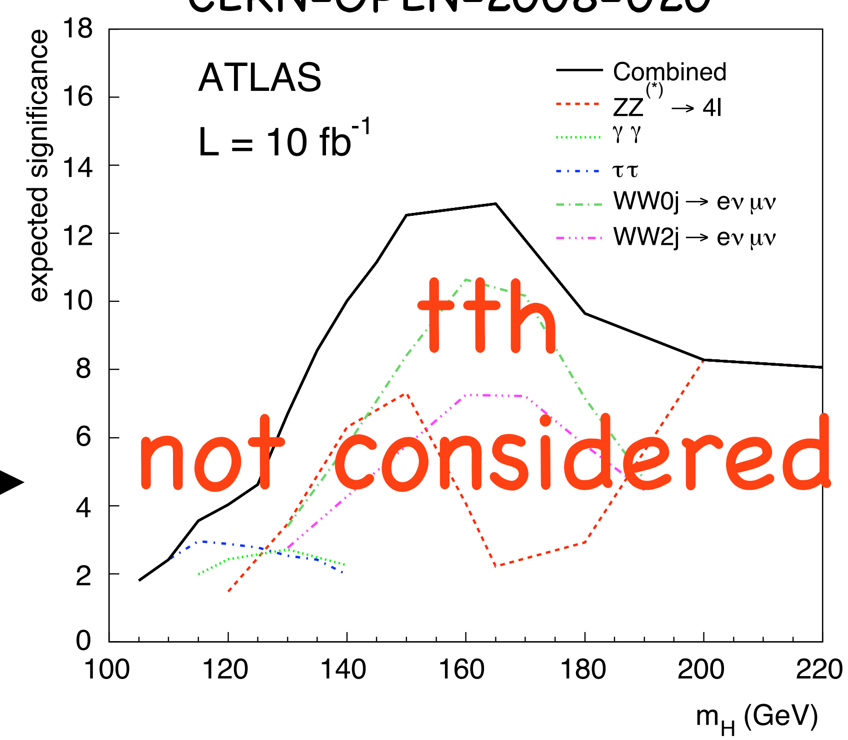
[ATLAS TDR 1999]

Cammin and Schumacher (ATLAS)

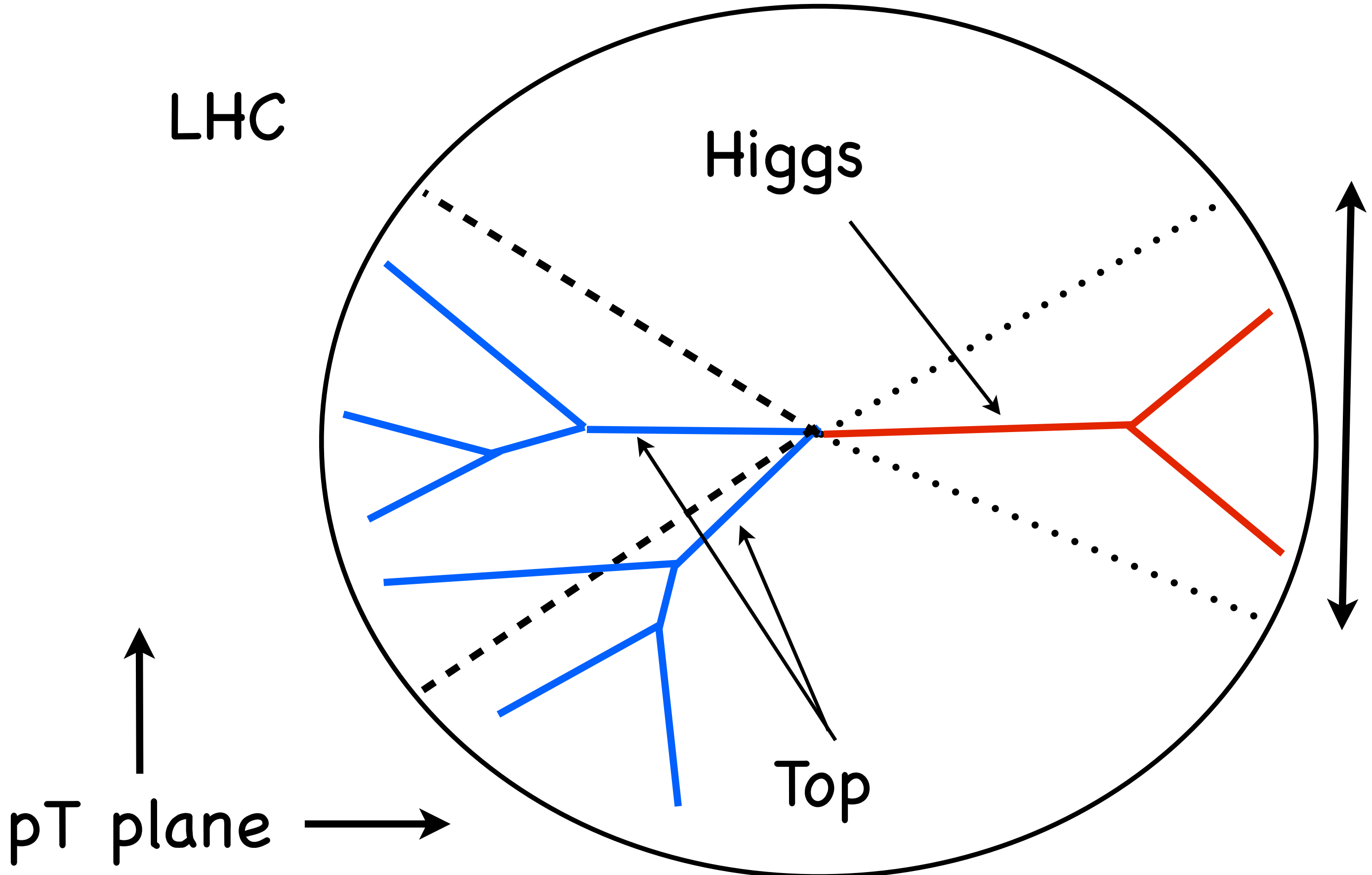
$S/B \simeq 1/9$

$S/\sqrt{B} \simeq 2.2$

Expected Performance of the ATLAS Experiment, CERN-OPEN-2008-020



Boosted scenario should help!



Cambr/Aachen
Jet-algorithm

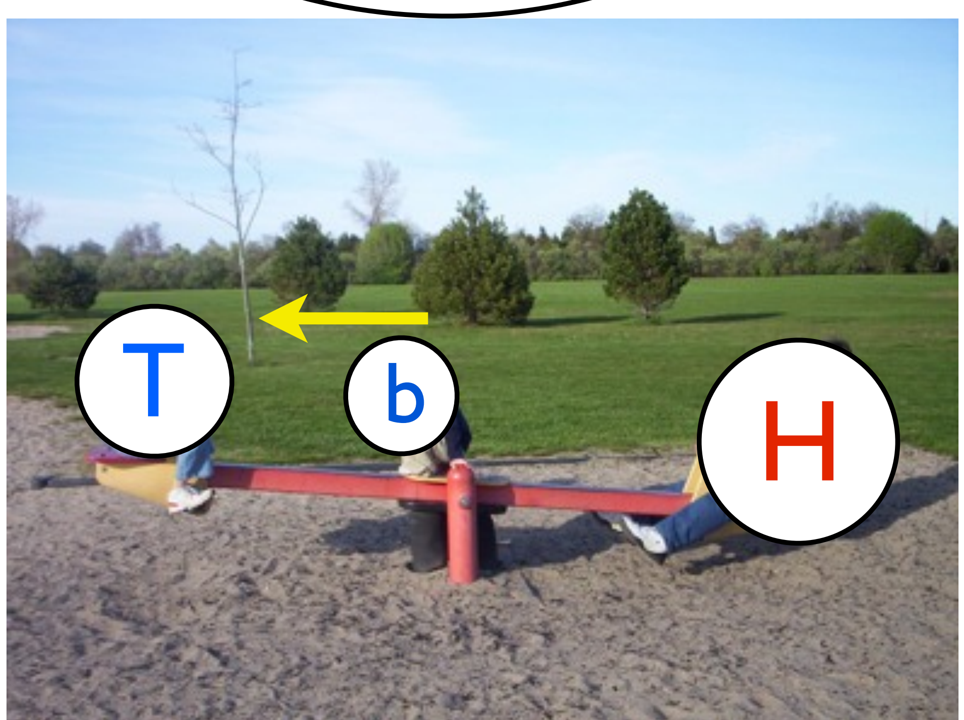
R=1.5

min. selection cuts:

2 Jets with
$p_{T,j} \geq 200$ GeV

isolated Lepton with
$p_{T,l} \geq 15$ GeV

Signal ~ 24.1 fb



Only 2 or 3 b in one
cone reduces
combinatorics

Nasty backgrounds.....

tth (Signal)

Beenakker et al., PRL 87 2001; Reina et al., PRD 65 2002

↳ K=1.57

ttbb

Bredenstein et al., PRL 103 2009; Belivacqua et al., JHEP 0909 2009

↳ K=2.3

tt+jets

Dittmaier et al, PRL 98 2007 Bevilacqua et al., PRL 104 2010

↳ K=1.0

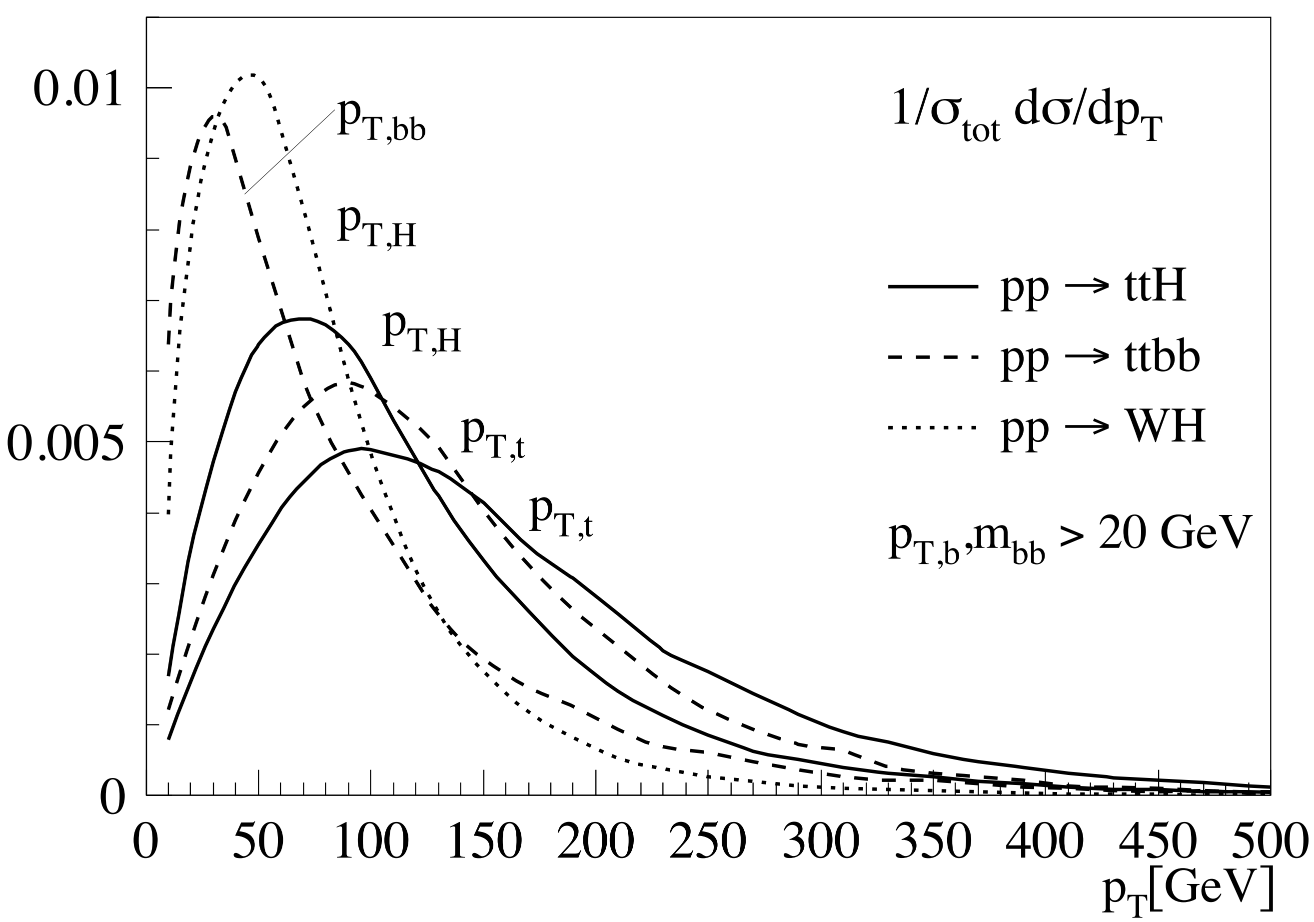
ttz

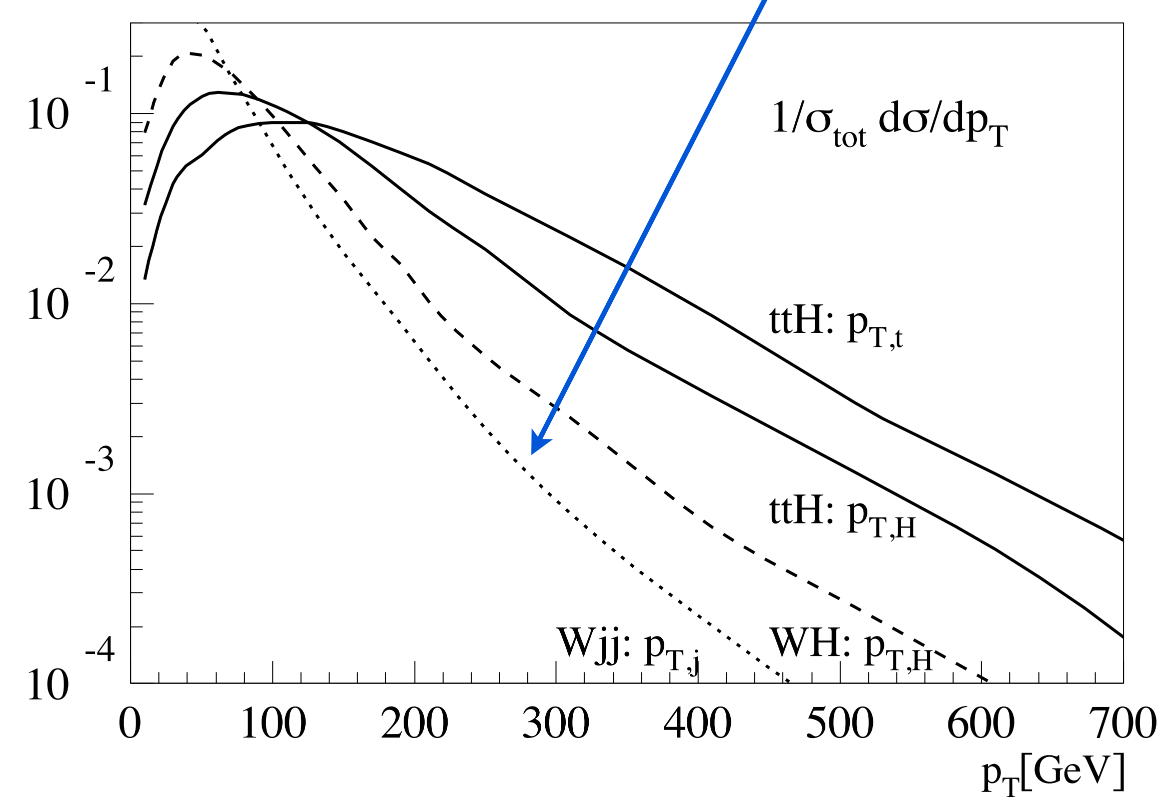
Lazopoulos et al., PLB 666 2008

↳ k=1.53

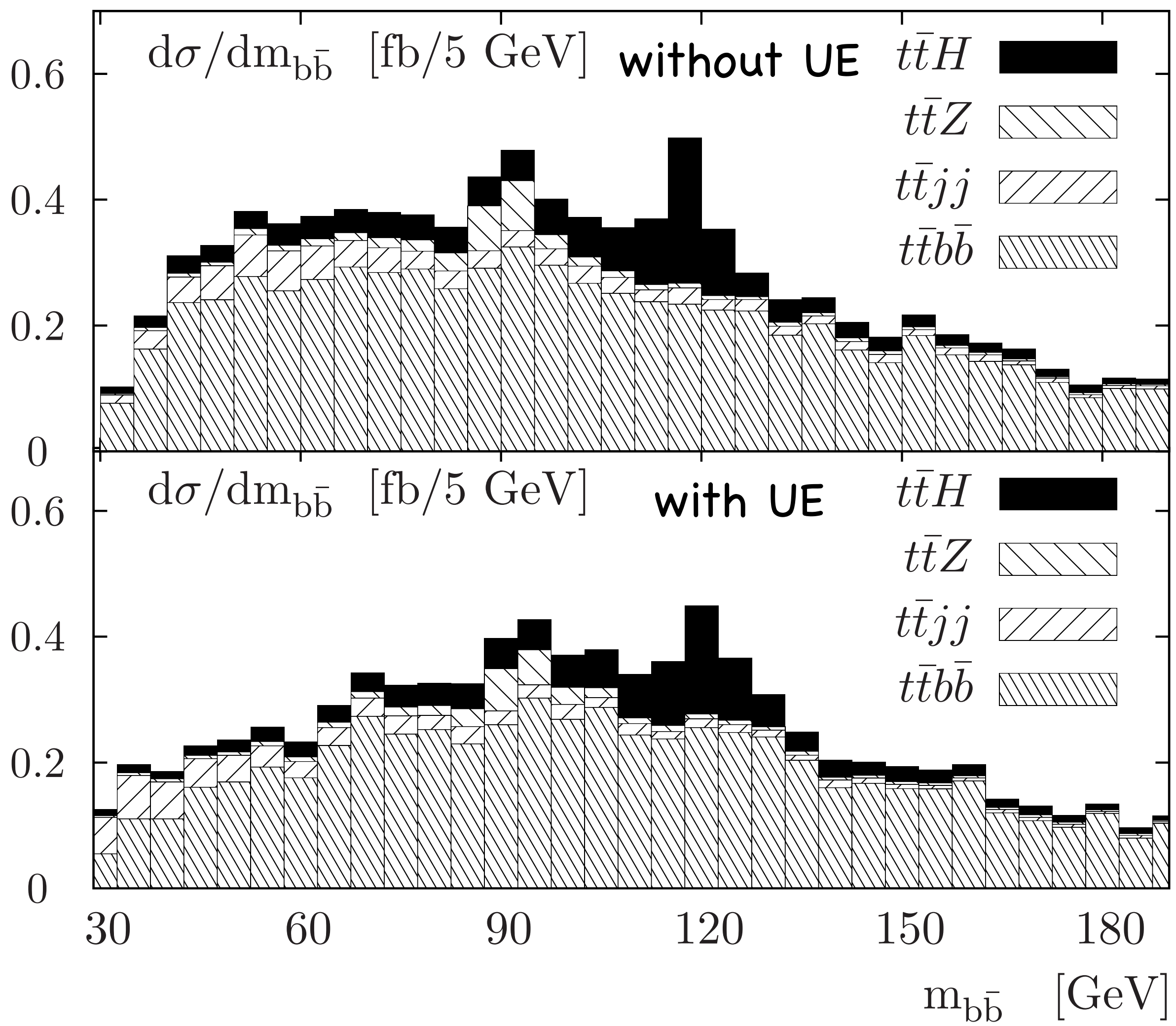
w+jets

negligible after b-tags and taggers





Results



for 100 1/fb

with 2 b-tags	$S[\text{fb}^{-1}]$	$B[\text{fb}^{-1}]$	S/B	$S/\sqrt{B}$
m_H = 115 GeV	1.2	3.8	1/3.2	6.2
120 GeV	1.0	3.8	1/3.8	5.1
130 GeV	0.51	3.3	1/6.5	2.8

with 3 b-tags	$S[\text{fb}^{-1}]$	$B[\text{fb}^{-1}]$	S/B	$S/\sqrt{B}$
m_H = 115 GeV	0.57	1.18	1/2.1	5.2 (5.7)
120 GeV	0.48	1.15	1/2.4	4.5 (5.1)
130 GeV	0.29	1.03	1/3.6	2.9 (3.0)

→ tremendous improvement on S/B in tth

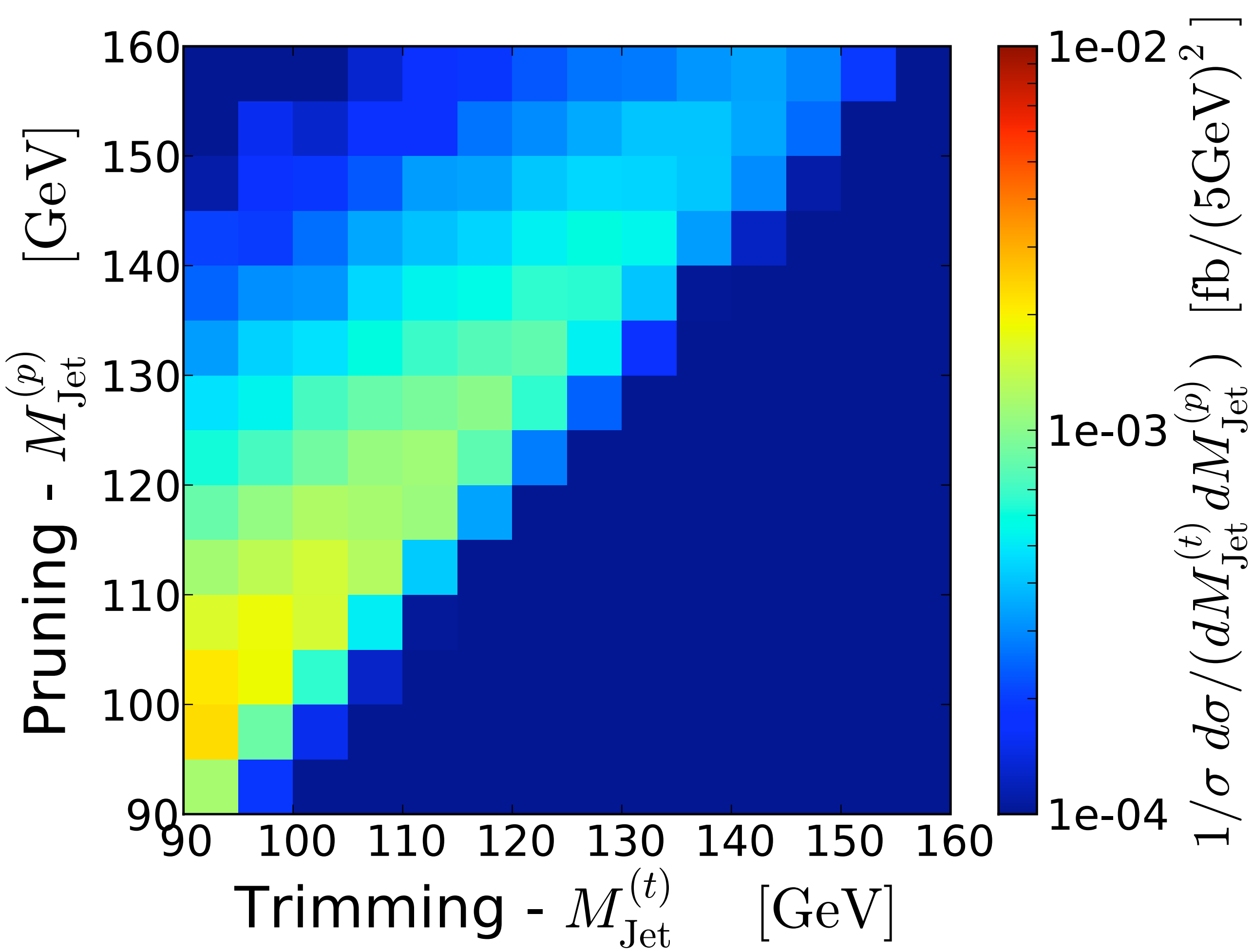
→ tth might contribute to Higgs discovery

→ tth might be a window to Higgs-top coupling

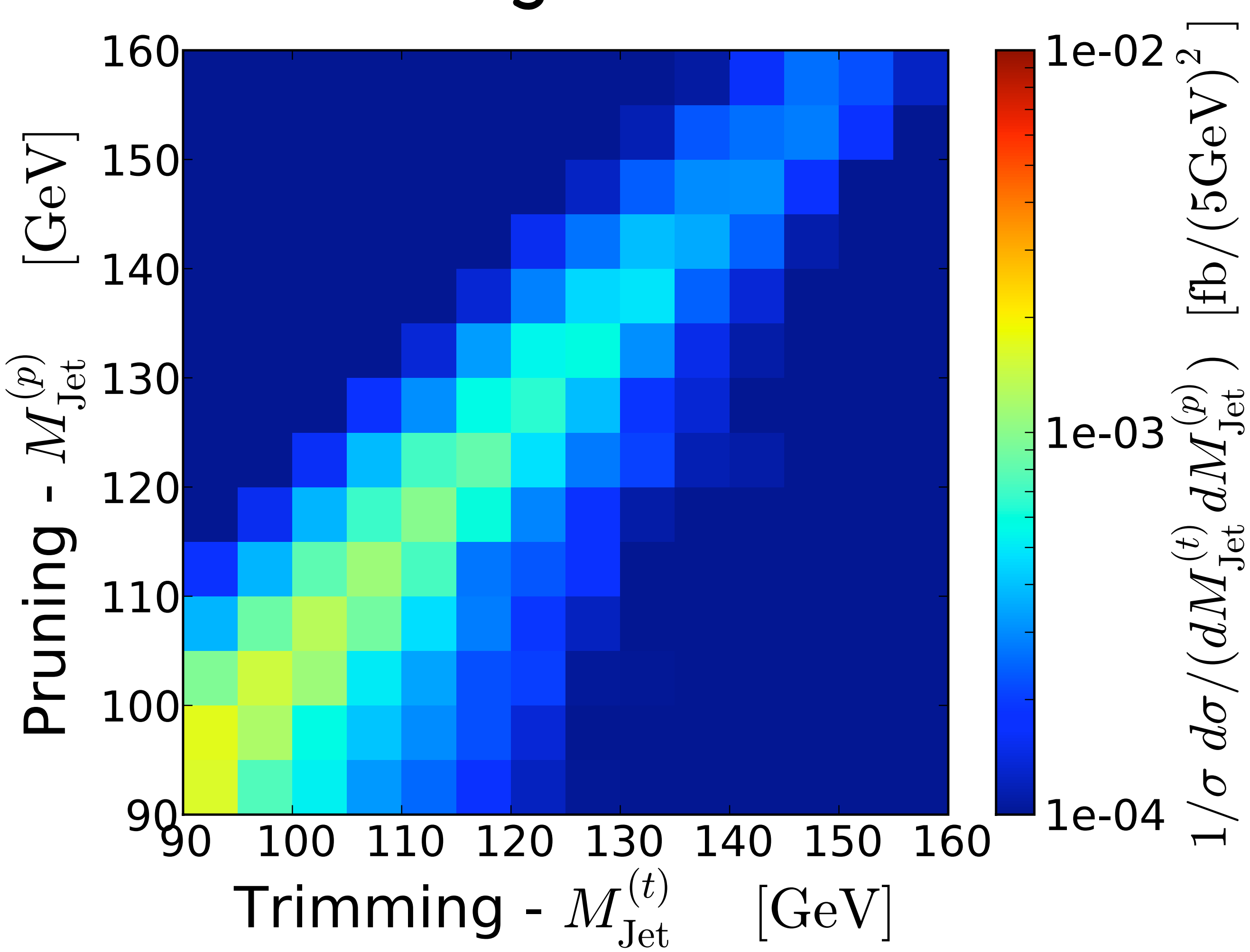
Backup

Pruning vs Trimming for same fat-jet definition

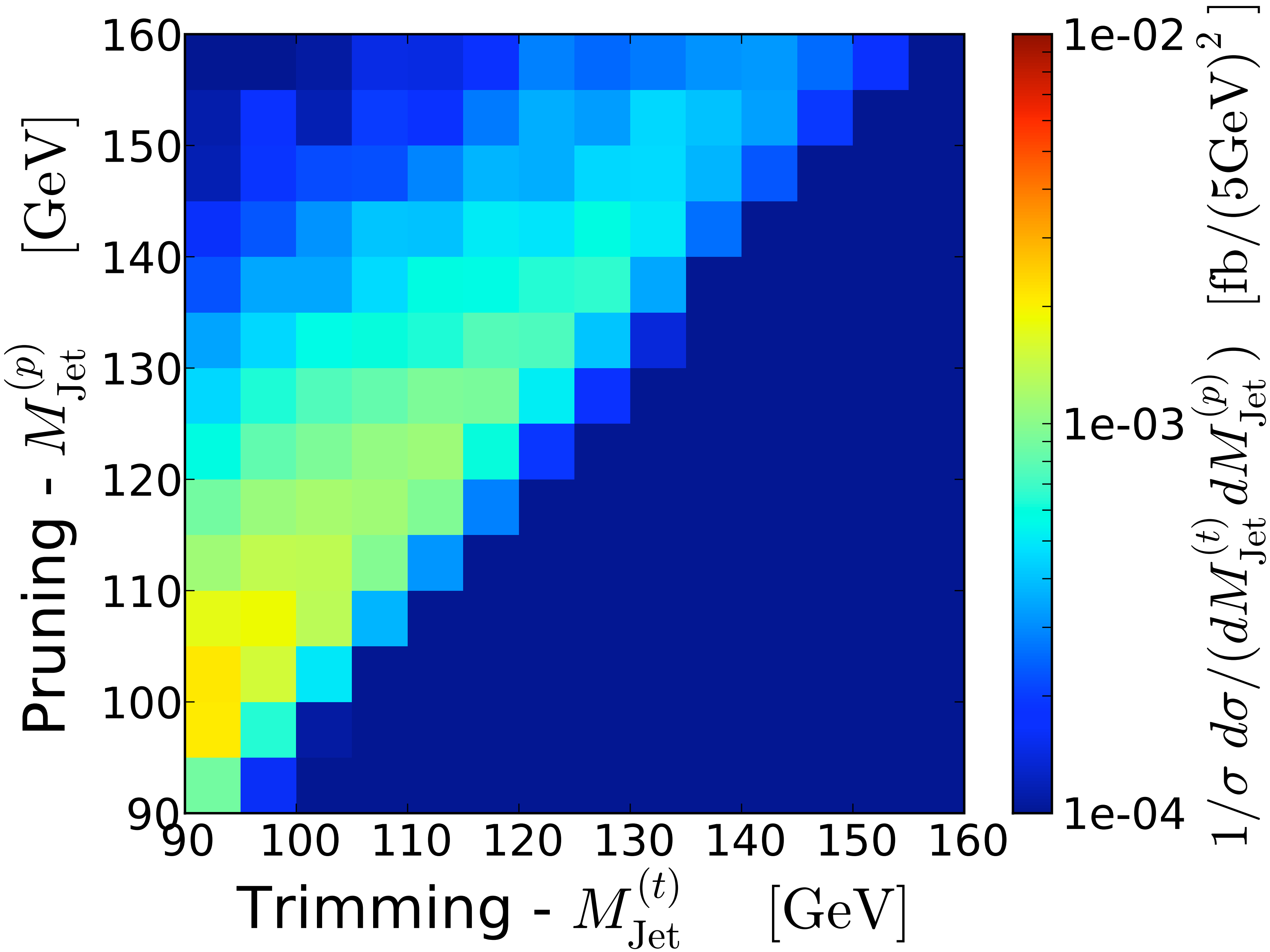
fat jet definition: CA
pruning definition: CA
trimming definition: kT



fat jet definition: anti-kT
pruning definition: CA
trimming definition: kT



Pruning and Trimming using CA



Log Likelihood Ratio

Poisson distributions for background and signal + background:

$$P_{\rm B}(\{n\}) = \prod_J \frac{1}{n_J!}\,(b_J)^{n_J} e^{-b_J} \qquad P_{\rm SB}(\{n\}) = \prod_J \frac{1}{n_J!}\,(b_J + s_J)^{n_J} e^{-b_J - s_J}$$

Likelihood ratio

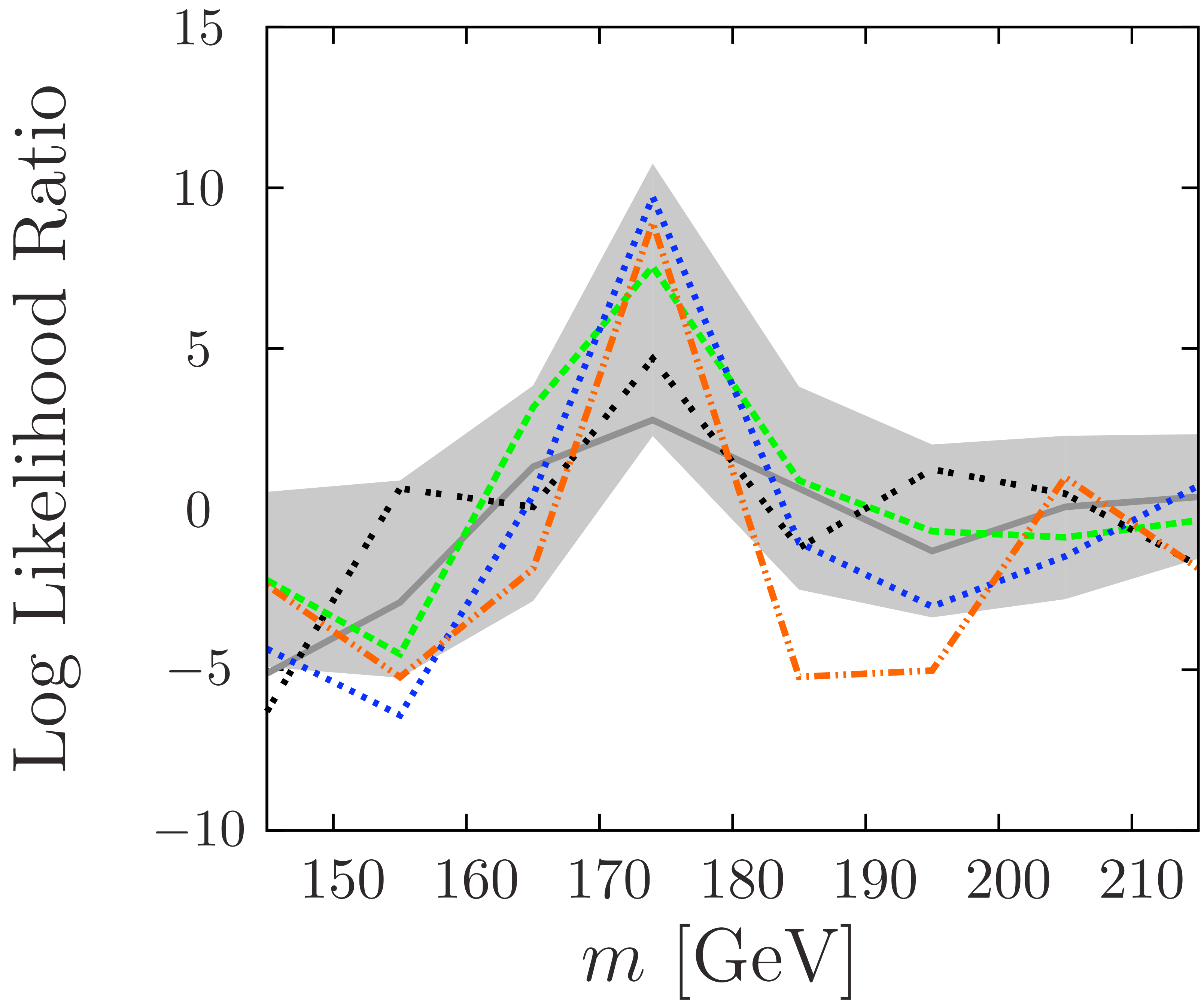
$$R(\{n\}) = \frac{P_{\rm SB}(\{n\})}{P_{\rm B}(\{n\})} \qquad R(\{n\}) = \exp \mathcal{L}(\{n\})$$

Log Likelihood ratio

$$\mathcal{L}(\{n\}) = \sum_J [n_J \log(1 + s_J/b_J) - s_J]$$

Exp. Log Likelihood ratio

$$\langle \mathcal{L}(\{n\}) \rangle_{\rm SB} = \sum_J \left[(s_J + b_J) \log\left(1 + \frac{s_J}{b_J}\right) - s_J \right]$$



Variance $$\langle(\mathcal{L} - \langle\mathcal{L}\rangle_{\rm SB})^2\rangle_{\rm SB} = \sum_J (b_j + s_J(M_{\rm top})) \left[\log\left(1 + \frac{s_J(m)}{b_J}\right)\right]^2$$

plotted $$\mathcal{L} \pm [\langle(\mathcal{L} - \langle\mathcal{L}\rangle_{\rm SB})^2\rangle_{\rm SB}]^{1/2}$$