Higgs Hunting with Boosted Jets

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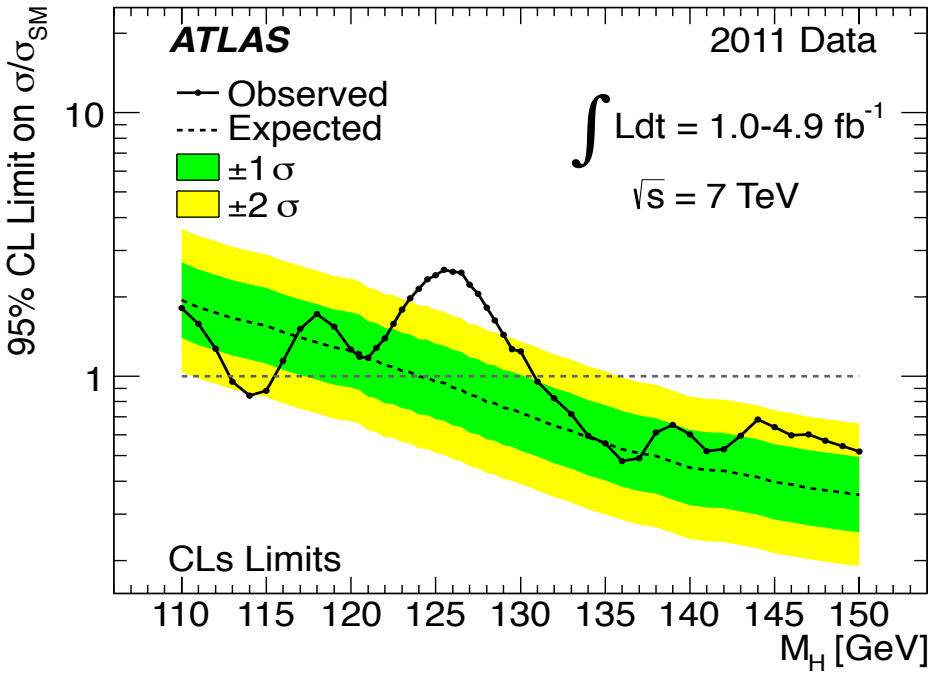
Current Status of the Higgs Searches

Current ATLAS , CMS analysis:



Favors light, Standard Model like Higgs.

Leptons and Photons… what about bb?

Why not care about $h \to b\bar{b}$?

- Hadronic channels are “dirty”.
- At LHC pileup/UE is a big problem for jet substructure.
- S/B is very low (Vj, ttbar, Wbb …)

Conclusion (ATLAS TDR):

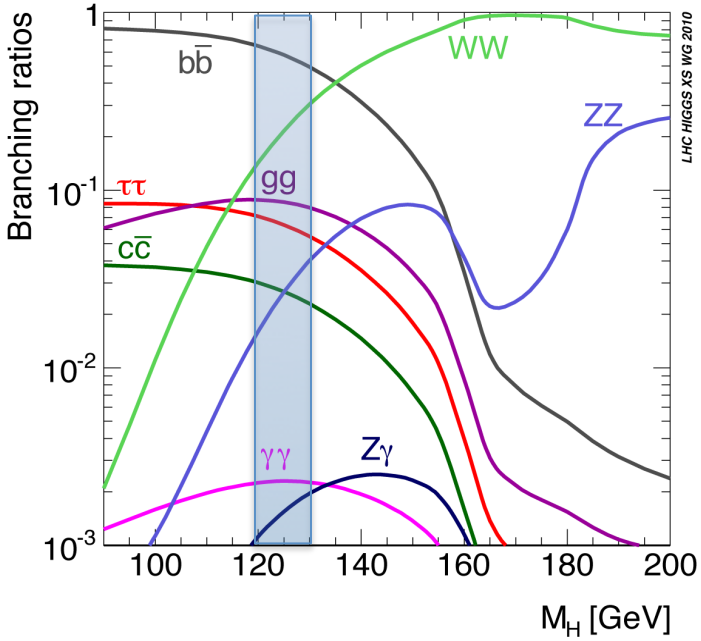
“The extraction of a signal from $H \to b\bar{b}$ decays in the WH channel will be very difficult at the LHC, even under the most optimistic assumptions […]”

Why care about $h \to b\bar{b}$?

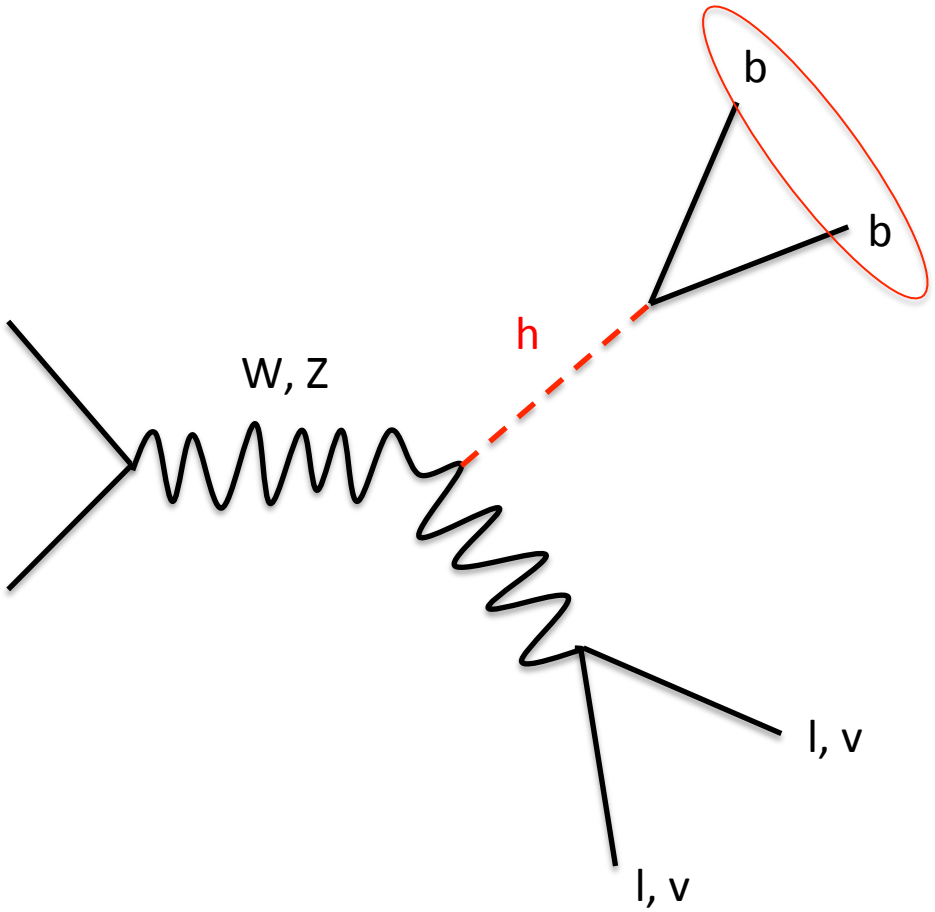
1. Higgs production rates small. Any events/channels you can add to the analysis will help!

2. We expect a large $h \to b\bar{b}$ branching ratio

3. We need to be able to measure the $h \to b\bar{b}$ to make sure it is an SM Higgs. (possible new physics?)



Process to Consider



Look at boosted jets!

Kinematic Cuts:

$$p_T^j > 200GeV$$

$$p_T^l > 15GeV$$

$$\eta_j < 2.5$$

$$\eta_l < 2.5.$$

R = 1.2 - 1.4

Template Overlap Method

Almeida, Lee, Perez, Sterman, Sung: **Phys.Rev. D82 (2010) 054034**
Almeida, Erdogan, Juknevich, Lee, Perez, George Sterman: **arXiv:1112.1957**

"Templates'' are sets of 4-momenta with a sub-cone of radius r around them (subjets).

We model the templates after boosted decay of the higgs.
(appropriate choice of pt, mass, subcone radius)

$$Ov(j,f) = \max_{\tau_n(R)} \exp\left[-\sum_{a=1}^{2}\frac{1}{2\sigma_a^2}\left(\sum_{k=i_a-1}^{i_a+1}\sum_{l=j_a-1}^{j_a+1}E(k,l)-E(i_a,j_a)^{(f)}\right)^2\right]$$

Maximize over the template phase space

Measures the difference between the energy deposited in a cone of radius r and the energy of a template state.

One can consider 2, 3 … n body templates.

Template Overlap Method

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We
(ap
gs.

In a nutshell:
Template Overlap Method is designed to pick out areas of large energy deposition within the jet

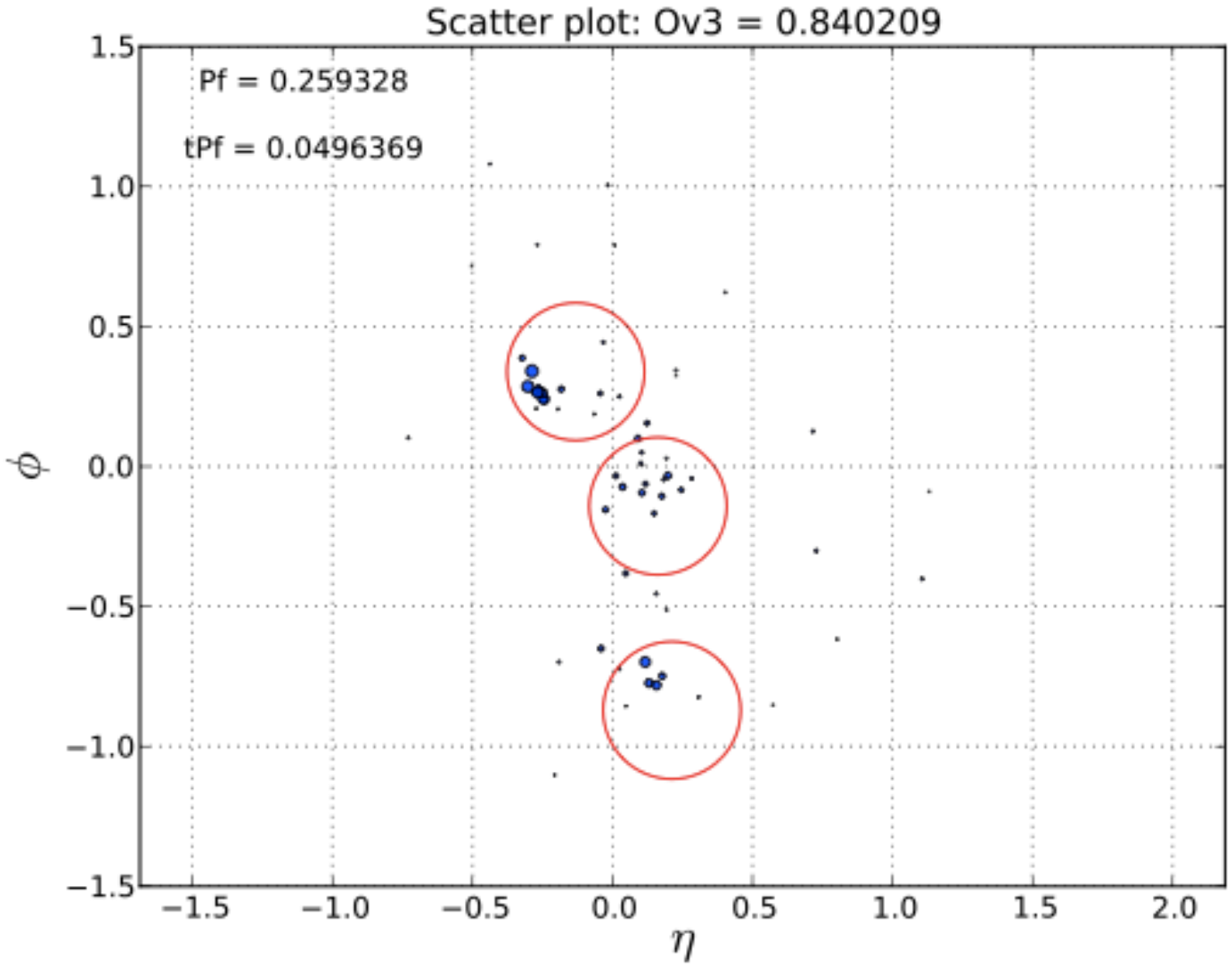
$$Ov(j,f) \qquad \left(i_a, j_a\right)^{(f)} \Big)^2 \Big]$$

Maximize over the template phase space

Measures the difference between the energy deposited in a cone of radius r and the energy of a template state.

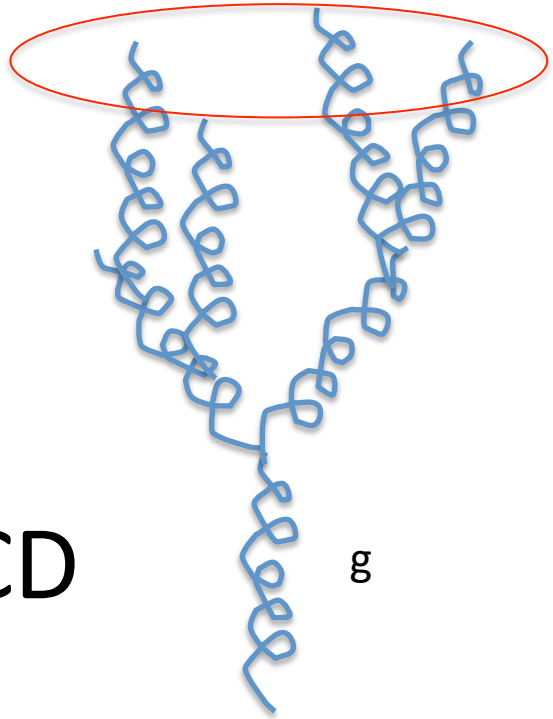
One can consider 2, 3 … n body templates.

Simulated example (higgs)



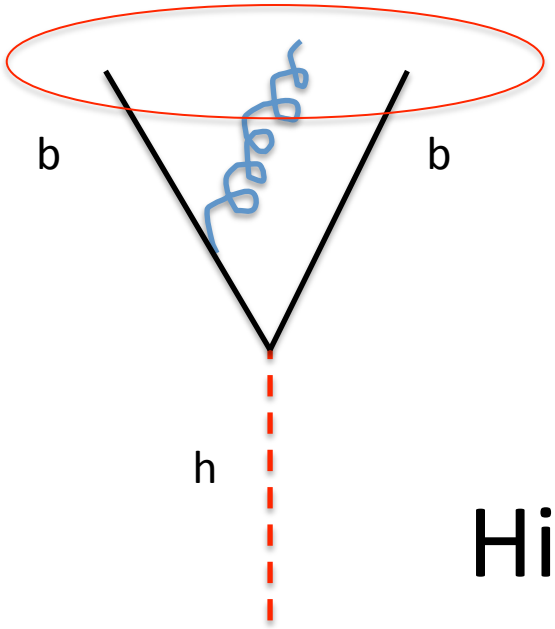
''Three body'' template

Strategy for template design



QCD

g



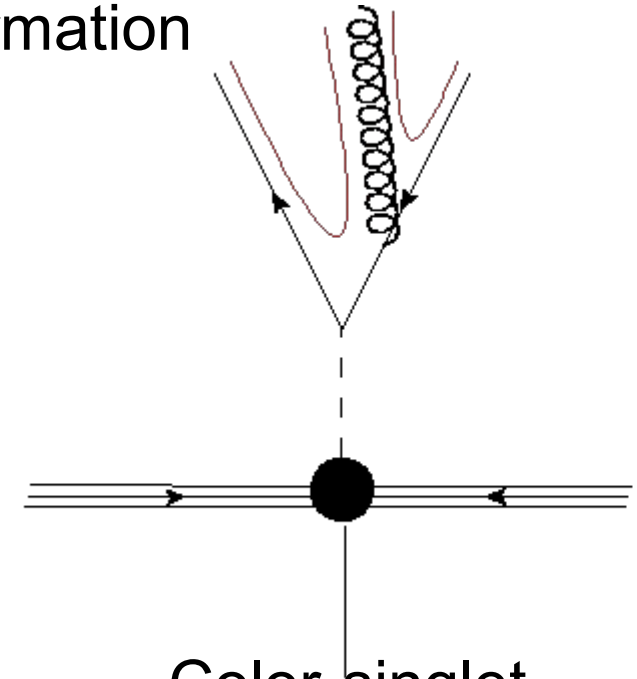
Higgs

Jet substructure
can look different, even though
the mass, pt, etc. are the same.

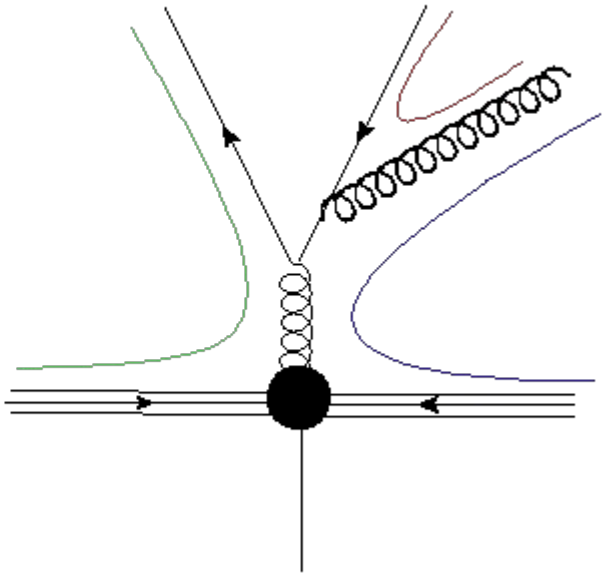
We want to exploit this!

Strategy for template design

The templates can be systematically improved by including the effects of gluon emissions, which contain color flow information



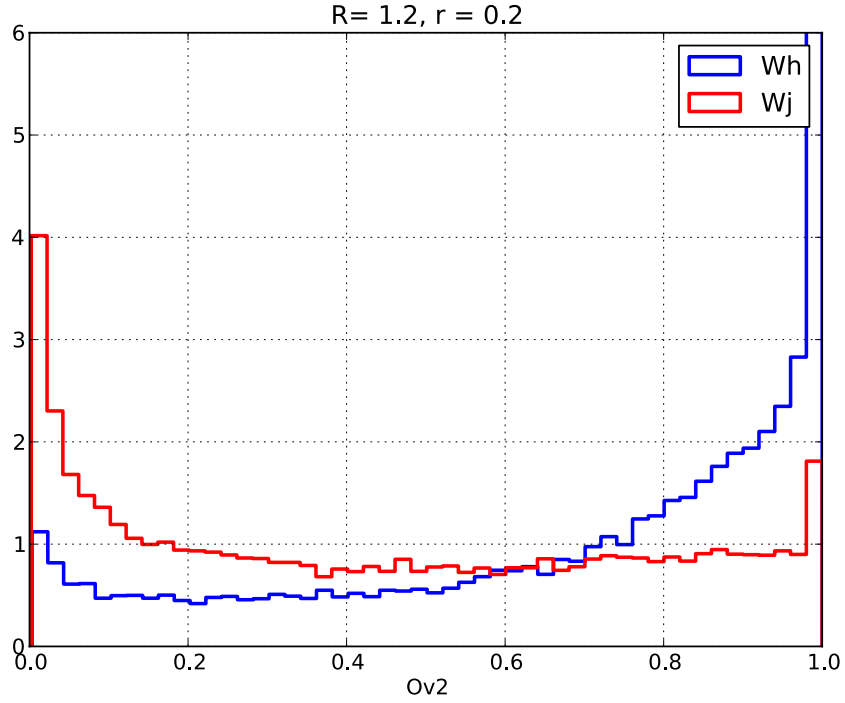
Color-singlet

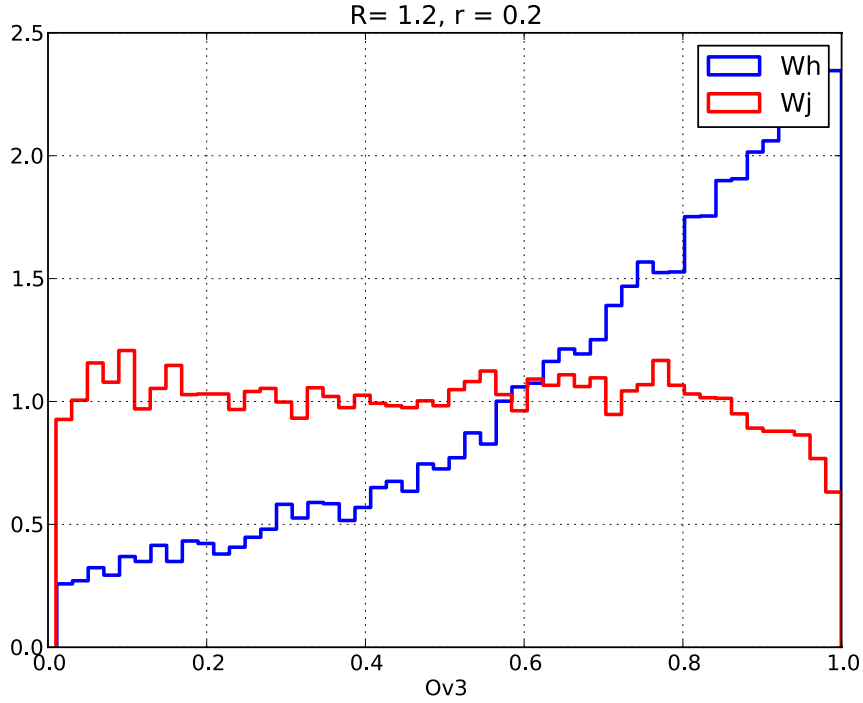


Non-singlet

2 and 3 - body Overlap

$$p_T \approx 200GeV$$





2 body

Clear separation of signal and Background!

3 body

Other Observables (formed from templates)

Three body angular variable:

$$\bar{\theta} = \sum_i \sin\theta_{iJ}$$

Soft template angle:

$$1 - \cos\tilde{\theta}_s = \frac{z\, x_s\, m_J}{2E_s}$$

Planar Flow:

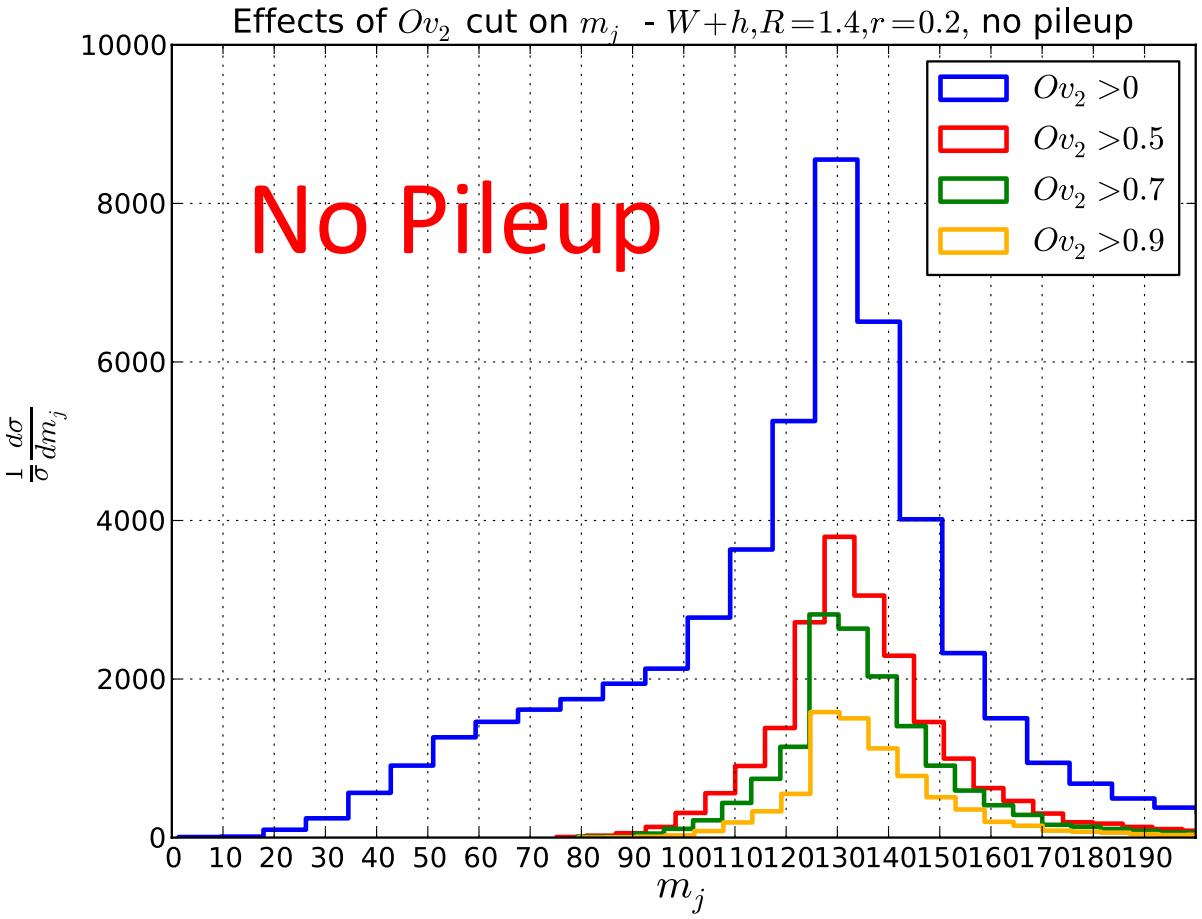
$$Pf = \frac{4\det(I_\omega)}{\mathrm{tr}(I_\omega)^2},$$

$$I_\omega^{kl} = \frac{1}{m_J}\sum_i \omega_i \frac{p_{i,k}}{\omega_i}\frac{p_{i,l}}{\omega_i},$$

Etc…

Effects of Pileup

- Past LHC run averaged 8.8 interactions per bunch crossing.
- Things will get much worse in the future (20 – 30 interactions per bunch crossing expected)



Template Overlap Picks out the right Higgs mass

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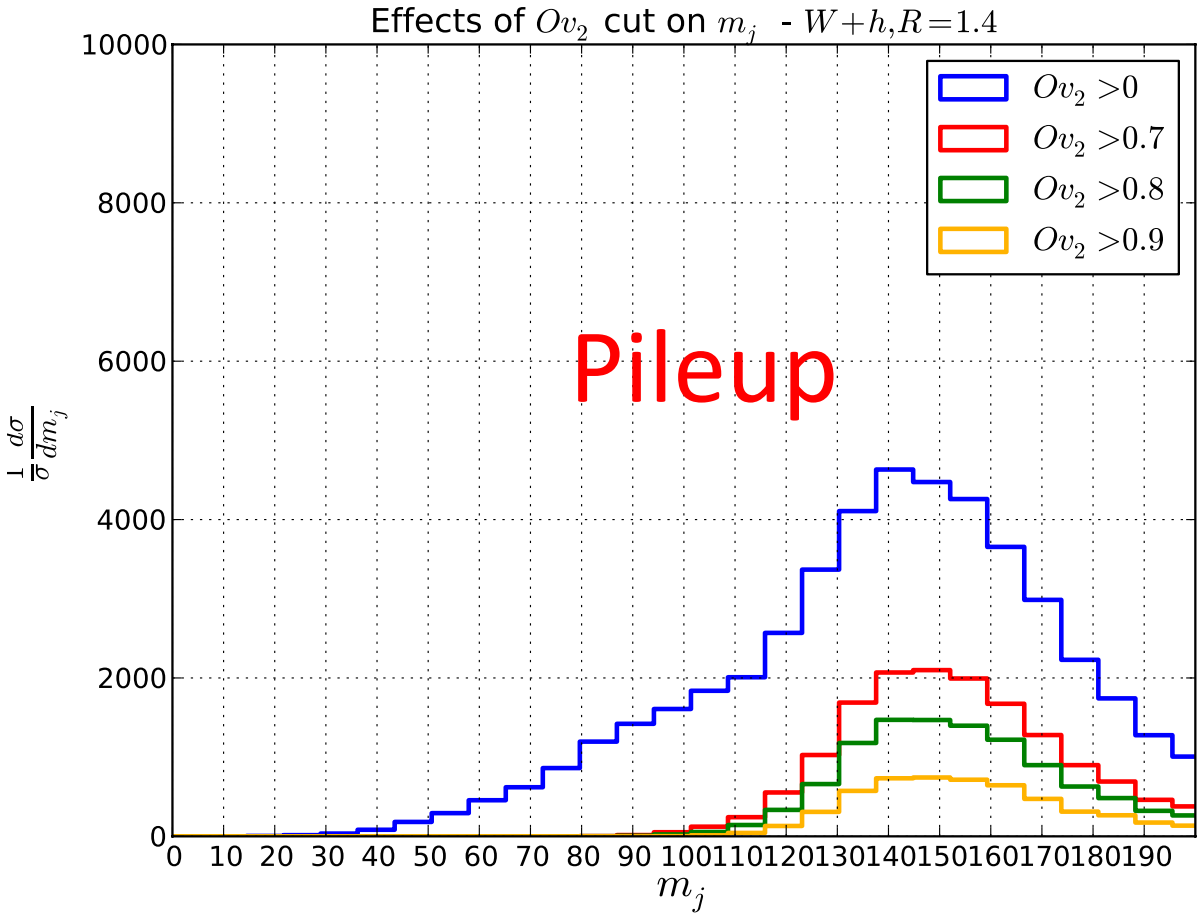
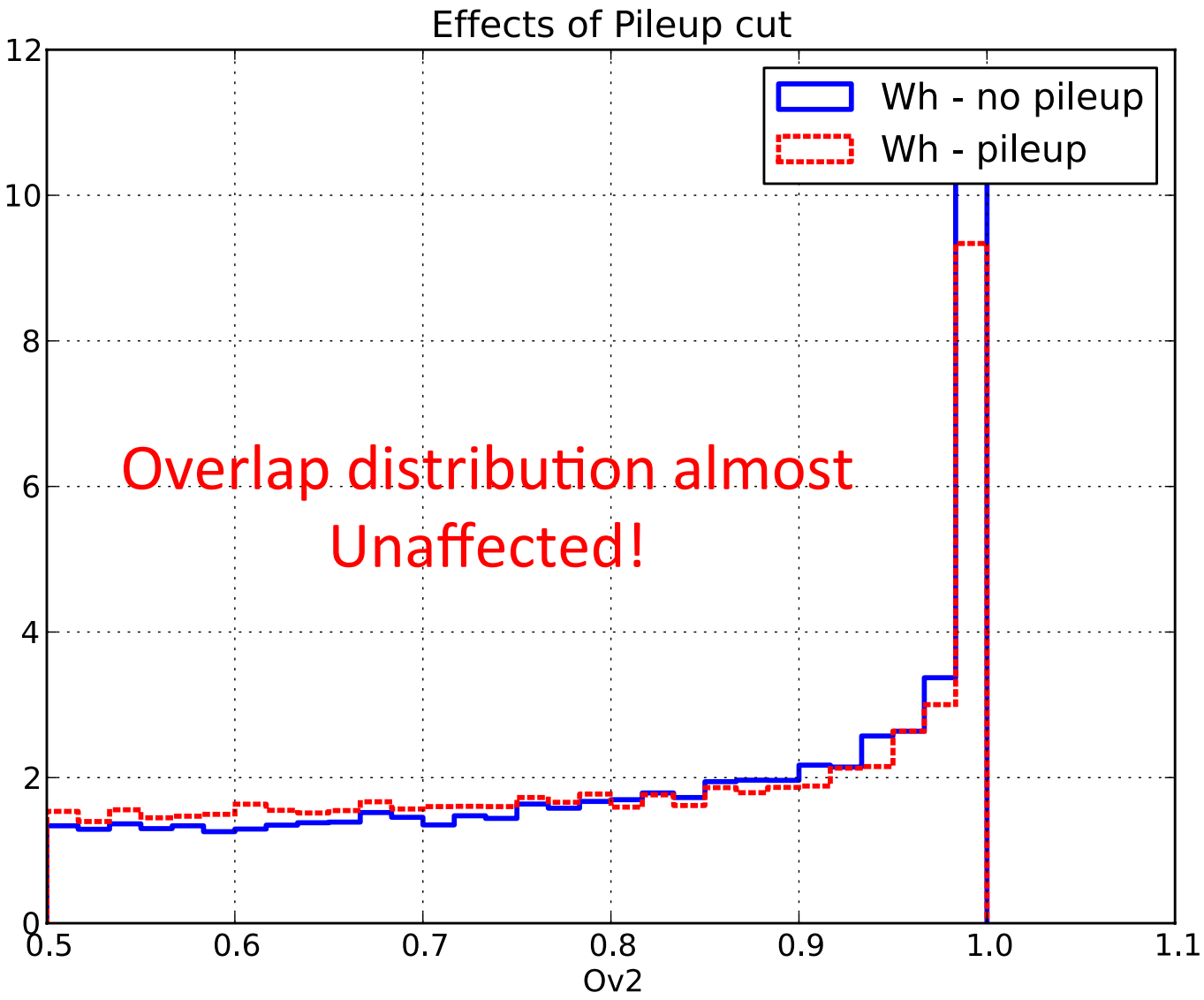
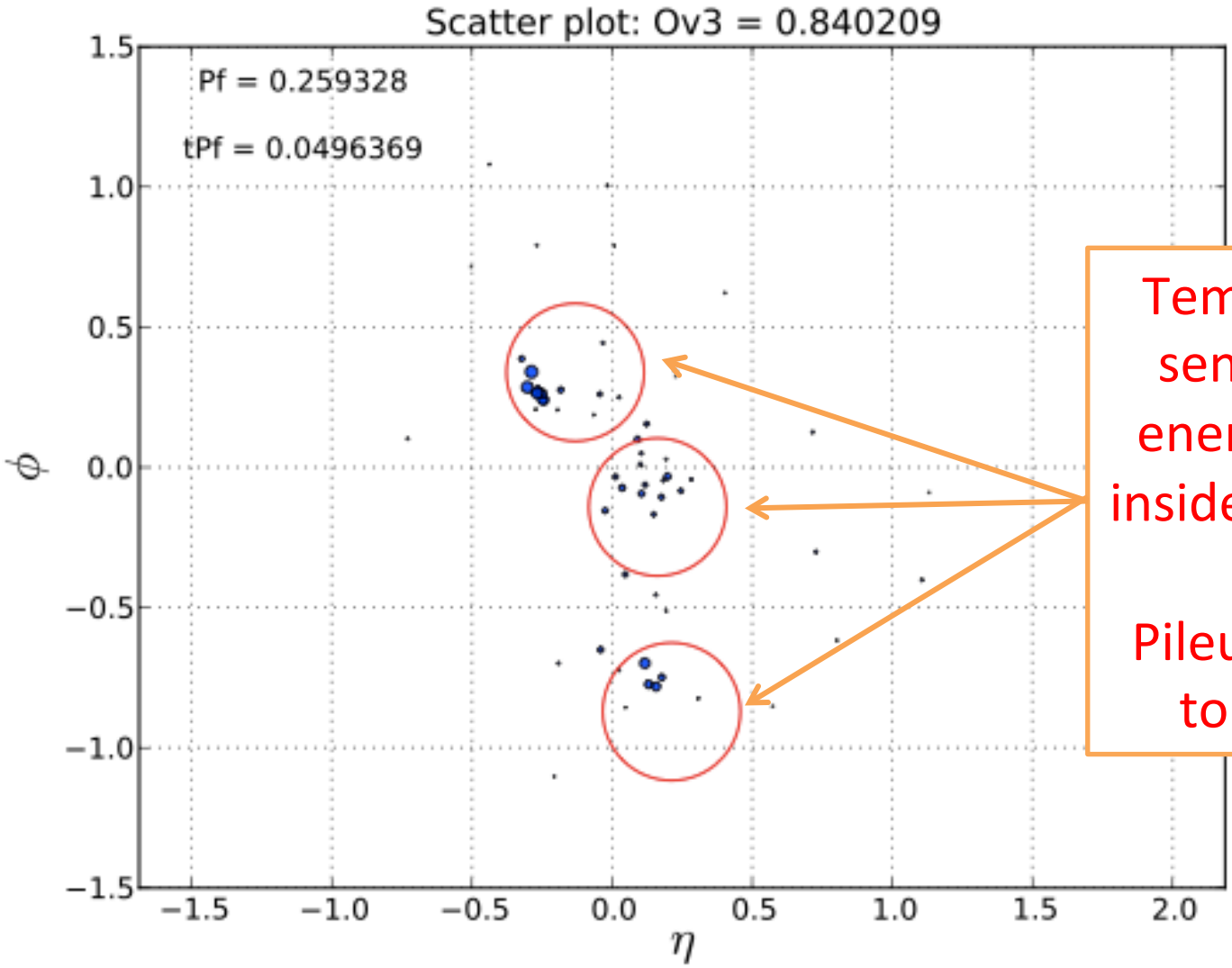


Template Overlap
Picks out "shifted"
Jet mass!!!


Effects of Pileup cut
Wh - no pileup
Wh - pileup
Overlap distribution almost
Unaffected!
12
10
8
6
4
2
0
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Ov2

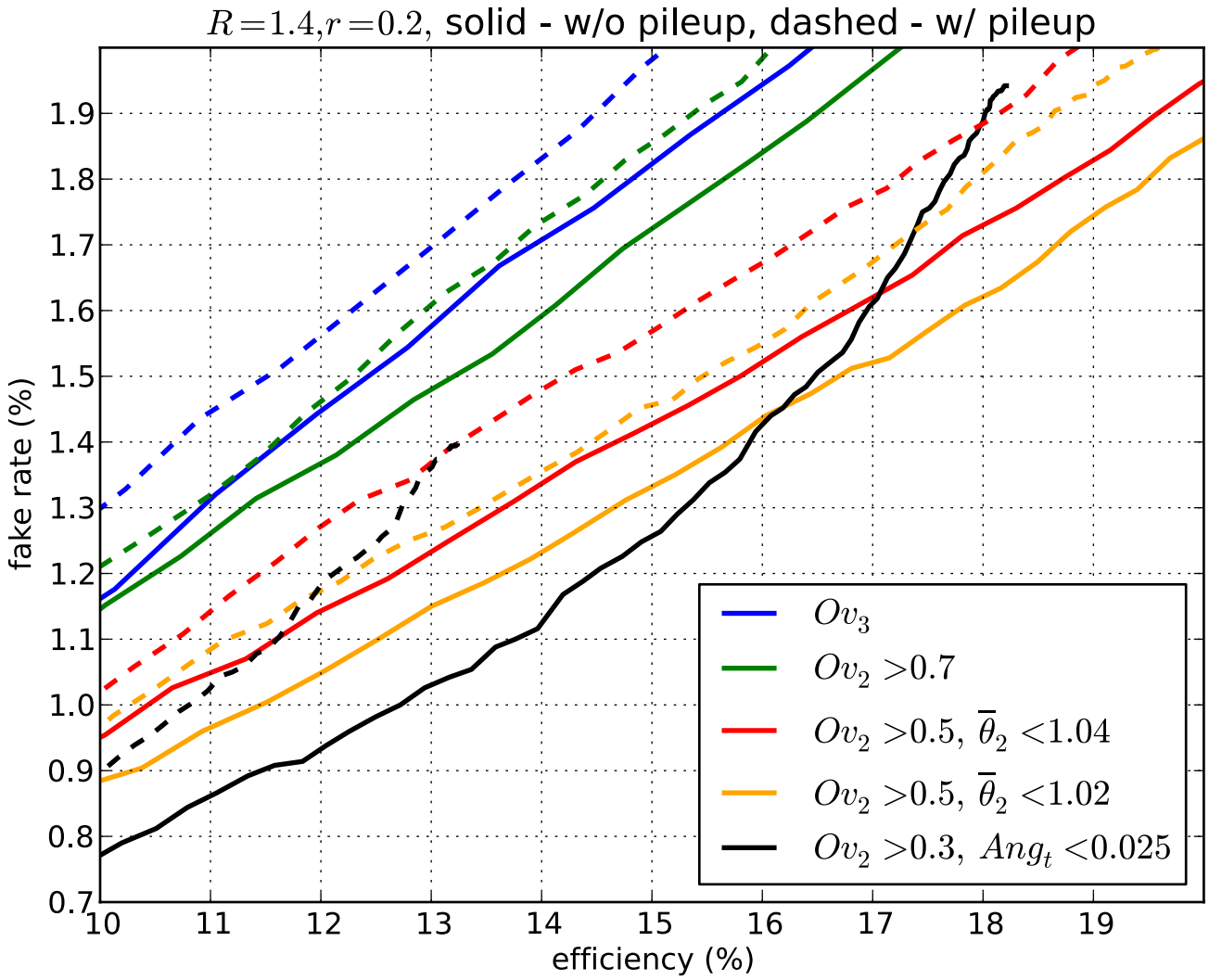
To explain, recall the earlier example



Template overlap sensitive only to energy deposition inside the subcones.

Pileup is supposed to be uniform.

Some results (Wj rejection power)



No mass cut!
No b-tag!

Effects of pileup not severe (at 9 interactions per bunch crossing)!

Template Overlap showing good performance

We are at a point where we need to subject the Template Overlap method to severe experimental scrutiny.

All details matter!!!

Stay tuned …

ATLAS affiliated Template Overlap ''Task Force'' in full power at WIS.

If it works