Higgs Hunting with Template Overlap Method

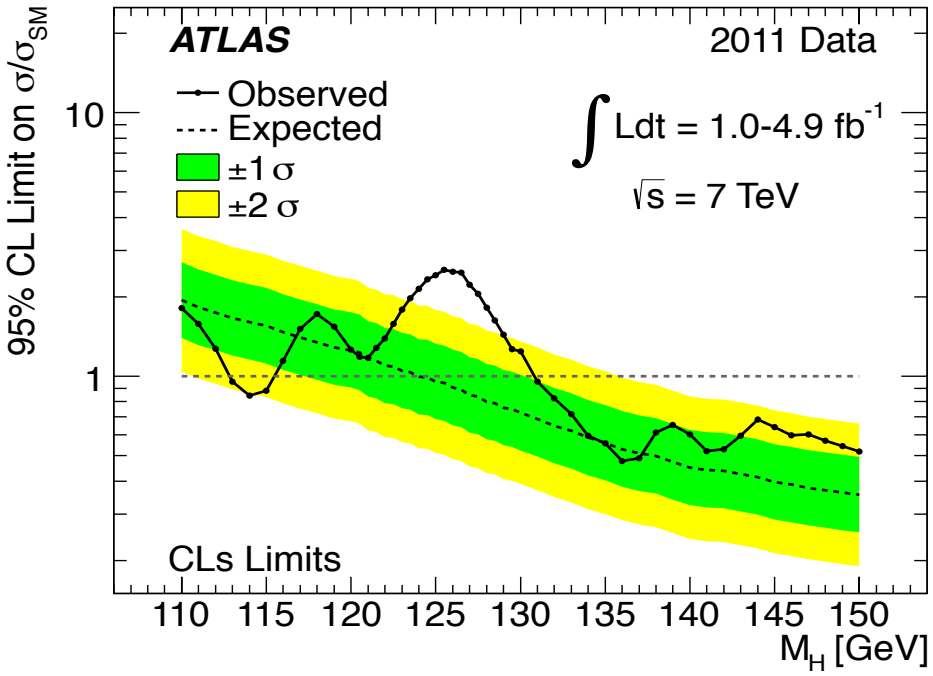
Mihailo Backovic, Jose Juknevich,
Gilad Perez, Jan Winter

In Progress

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

Current Status of the Higgs Searches

Current CMS, ATLAS analysis:

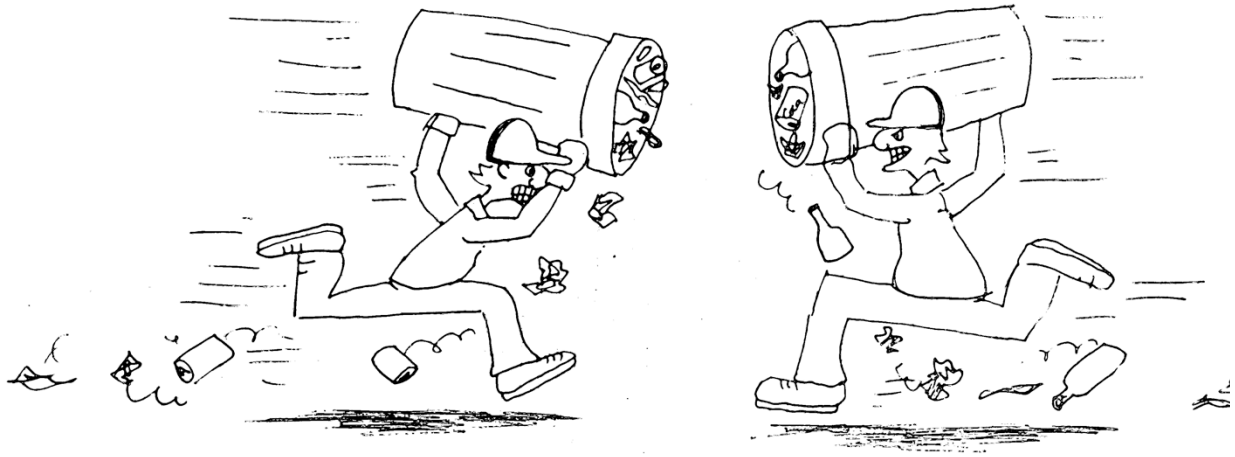


Favors light / Standard Model like Higgs.

Current analysis does not include hadronic Higgs decay channels.

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

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



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 [...]"

- Hadronic channels are "dirty".
- At LHC pileup is a big problem for jet substructure.
- S/B is very low

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

1. You will not discover the Higgs by looking at only one channel.

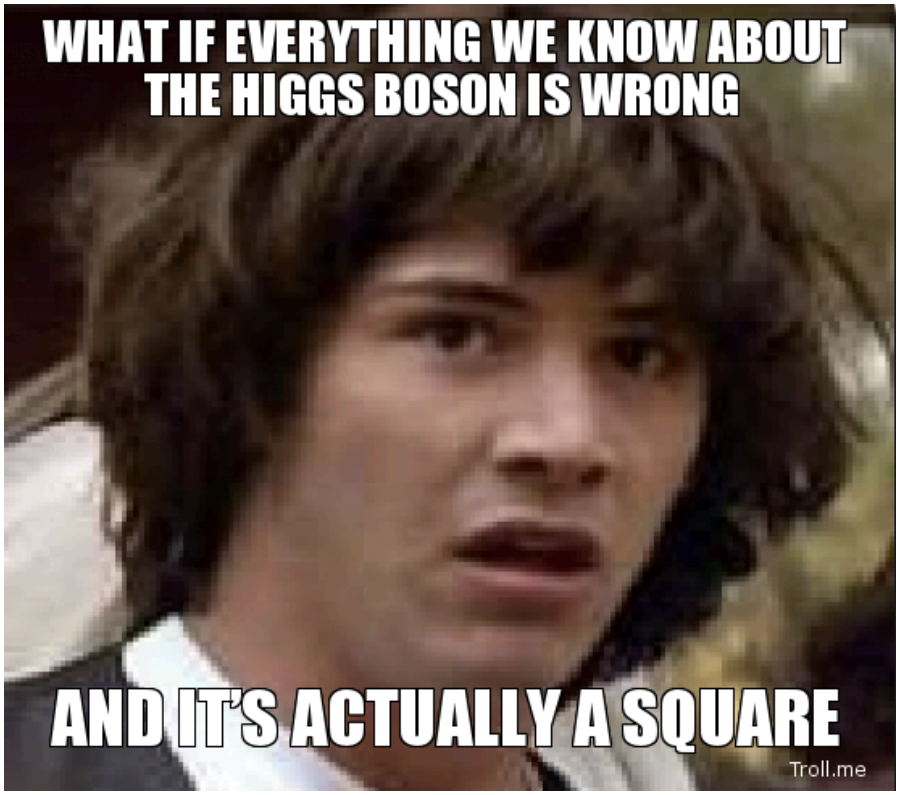
Any events/channels you can add to the analysis will help!

Remember, only 41 events
So far

"Take a look at this everyone - it just could be the signature we've been looking for!"

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

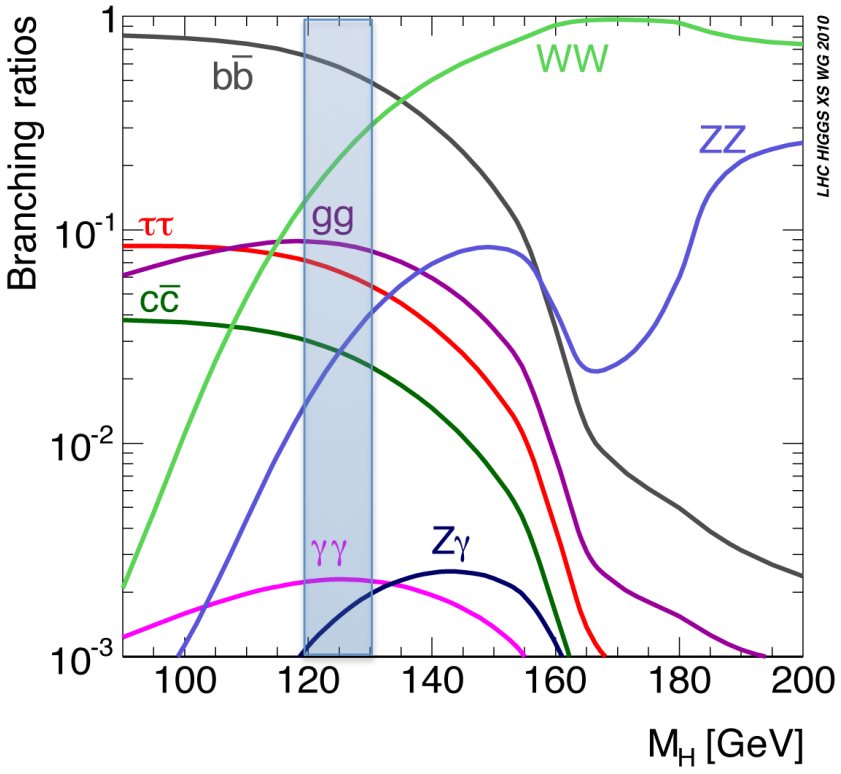
2. <u>It gives you a great probe of the VVB vertex!</u>



We ought to test all the details of the Standard Model!!!

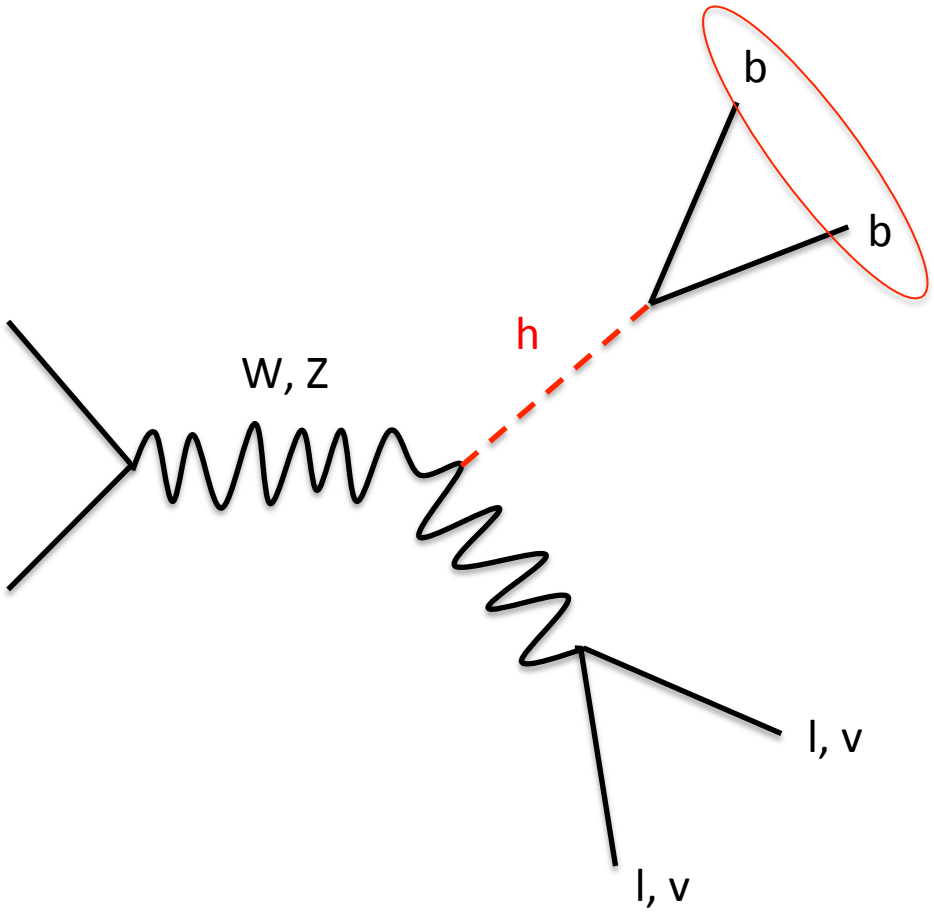
Why care about $h \to b\bar{b}$?

3. <u>We expect a light Higgs</u>. ⇨ Large branching ratio to b-quarks.



מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

Process to consider



Look at boosted jets!

Kinematic Cuts:

$$p_T^j > 200GeV$$

$$p_T^l > 15GeV$$

$$\eta_j < 2.5$$

$$\eta_l < 2.5.$$

$$R = 1.2.$$

מכון ויצמן למדע

WEIZMANN INSTITUTE OF SCIENCE

Things we can do nothing about

$$at\ \sqrt{s} \sim 7TeV$$

MCFM

	Wj+Zj	Wh+Zh
NLO (LO Γ)	32.8 pb	4.4 fb
NLO (NLO Γ)	32.8 pb	6.2 fb
K (LO Γ)	2.5	1.6
K (NLO Γ)	2.5	1.6
Pythia (m_j cut, w/ K fact.)	1.2 pb	3.2 fb
Pythia (no m_j cut, w/ K fact.)	39.4 pb	8.1 fb

With 5 fb^{-1} expect
15 events w/ the mass cut
and
40 events w/o the mass cut

$$\frac{S}{B}(115GeV < m_j < 135GeV) = \frac{33..2fb}{1.2pb} \approx 3 \times 10^{-3}$$

$$\frac{S}{B}(m_j > 0) = \frac{8.2fb}{39.4pb} \approx 2 \times 10^{-4}$$

Not much but
Better than nothing!

A few things about Monte-Carlos

MCFM

	Wj+Zj	Wh+Zh
NLO (LO Γ)	32.8 pb	4.4 fb
NLO (NLO Γ)	32.8 pb	6.2 fb
K (LO Γ)	2.5	1.6
K (NLO Γ)	2.5	1.6
Pythia (m_j cut, w/ K fact.)	1.2 pb	3.2 fb
Pythia (no m_j cut, w/ K fact.)	39.4 pb	8.1 fb

ERASE

K-factors not affected.

NOTE:

- Pythia uses a LO estimate for the higgs width. MCFM uses NNLO.
- Pythia uses running b mass. m_b = 0 in MCFM.
- Non-matching renormalization scales.

Differences between MCFM and Pythia in the signal cross section at LO can be up to 100%.

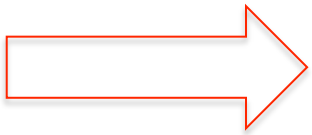
Things we can improve – Higgs tagging

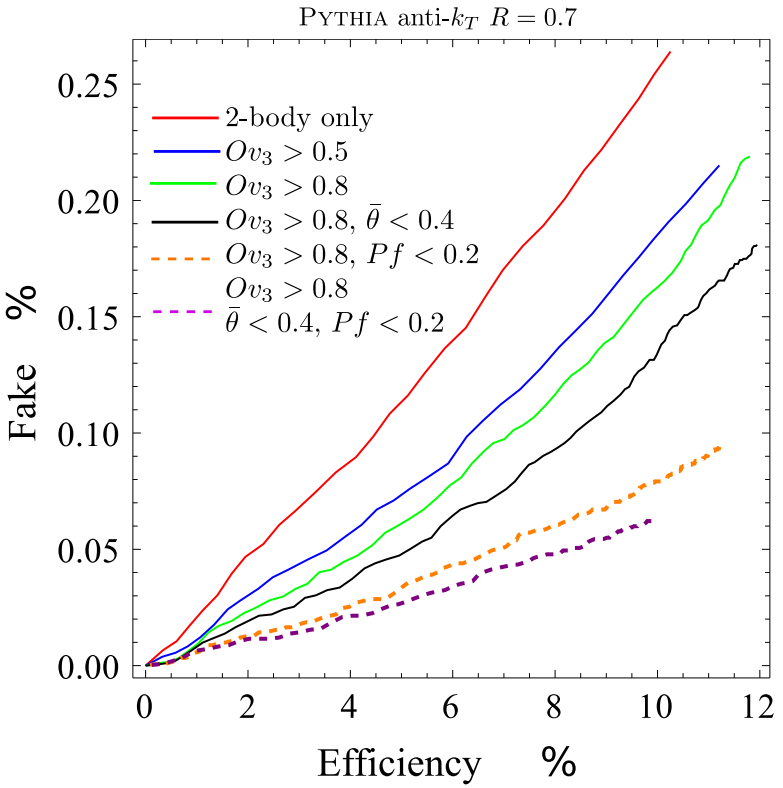
Template Overlap works well for TeV jets:

Three-particle templates for boosted Higgs

Leandro G. Almeida[a], Ozan Erdoğan[b], José Juknevich[c], Seung J. Lee[d], Gilad Perez[c,e], George Sterman[b]

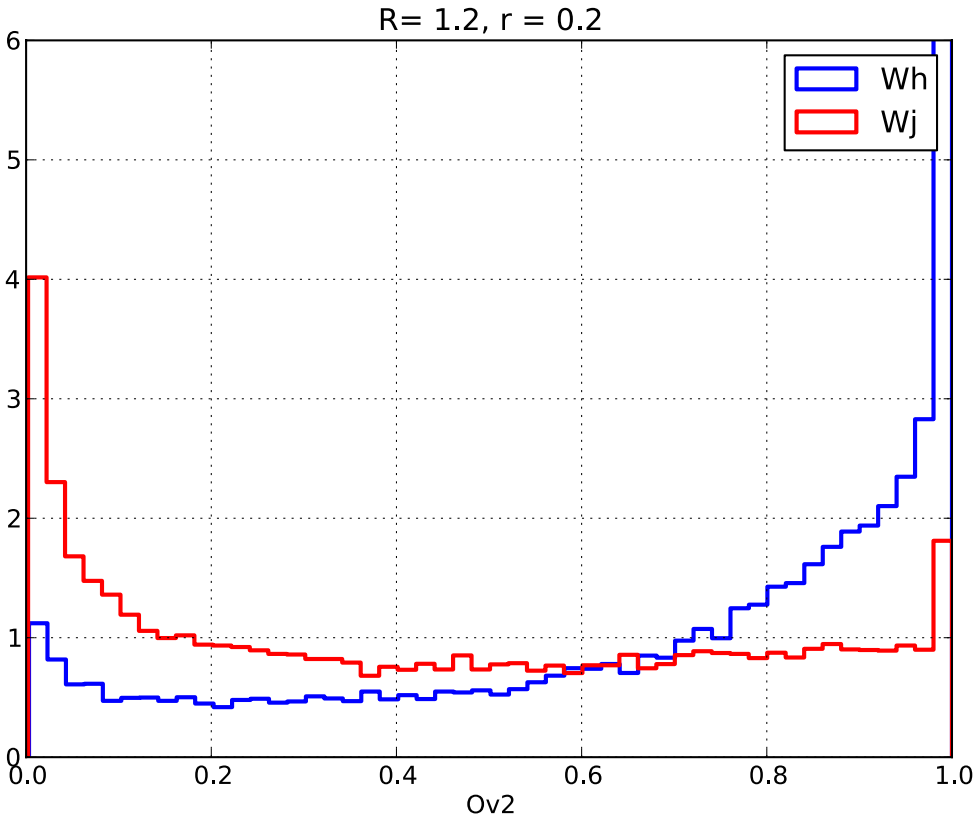
Rejection rates of ~ 100
Before b tagging possible
With efficiency of 10%





Can we do the same
(or better) for
$p_T \approx 200GeV$
????

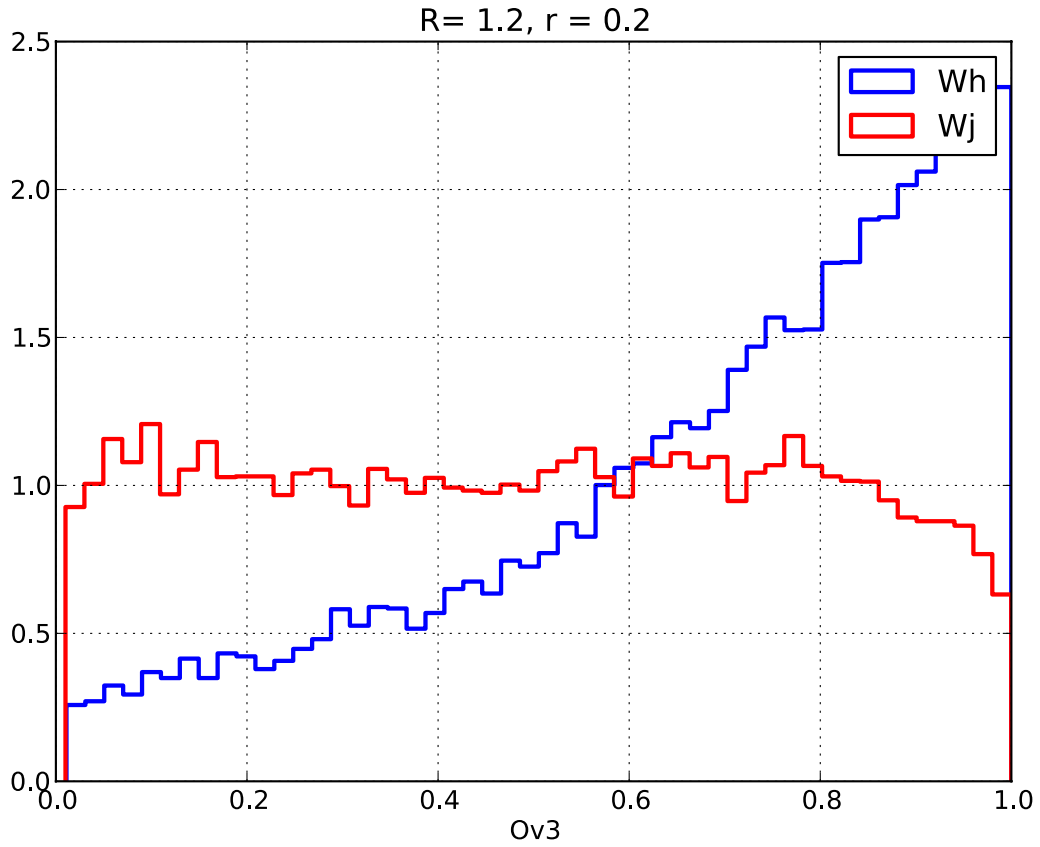
Two Body Overlap



$$p_T \approx 200GeV$$

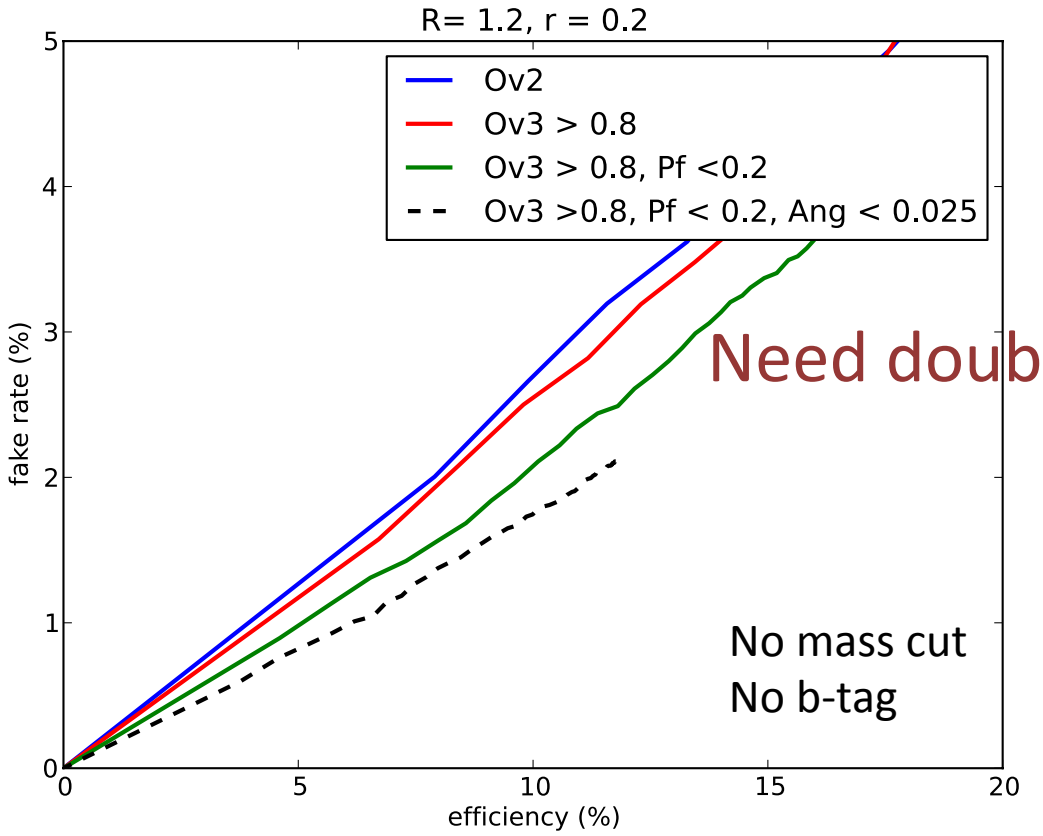
Clear separation of signal and background still present.

Three body overlap



$$p_T \approx 200GeV$$

Rejection Rate



For 10 % efficiency rejection
Factor of ~ 5.

Total rejection factor:

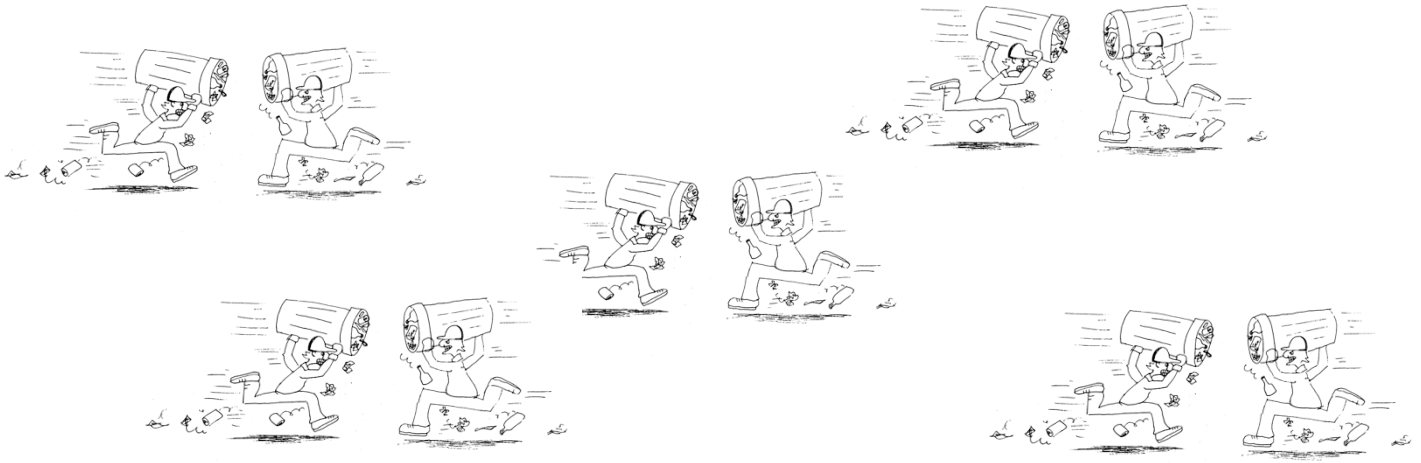
Need double b tag

15	-	*mass cut*
x 40	-	*b-tagging*
x 5	-	*template+pf*

= 3000

Need to test new observables as well!!

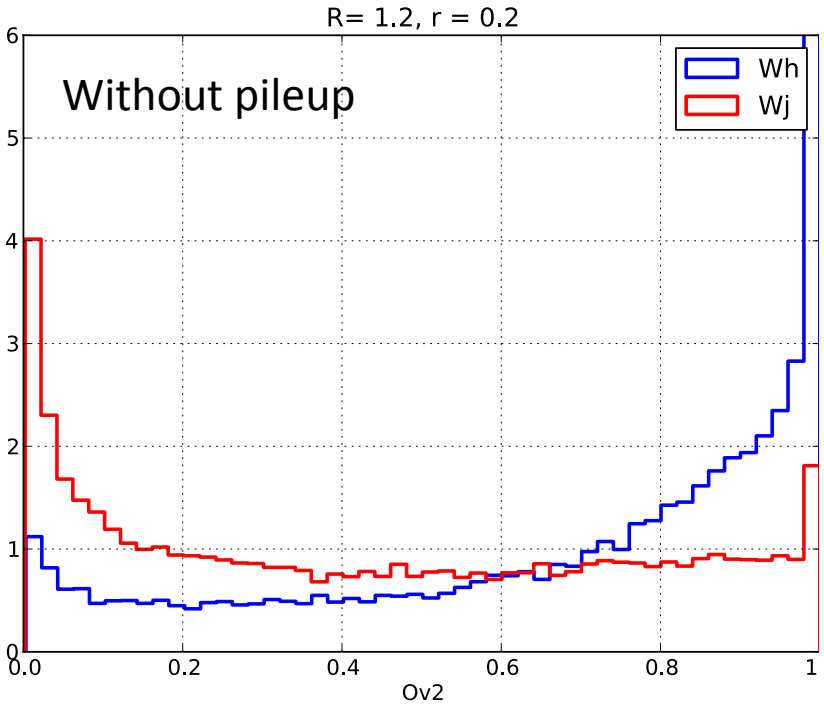
Pileup

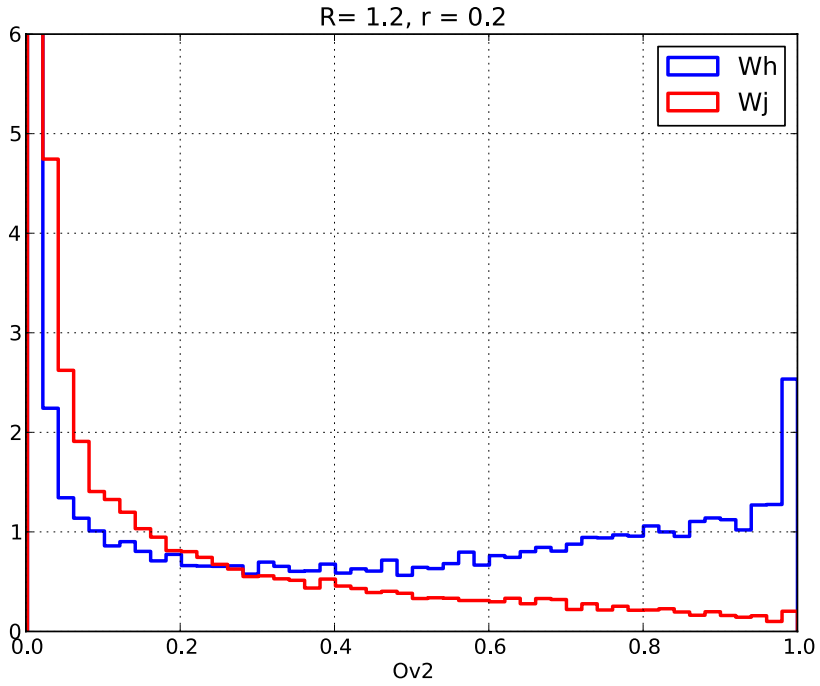


- Can be a major problem for all jet substructure analysis.
- Currently there are on average 8.8 interactions per bunch crossing at the LHC.
- Things are going to get much worse in the future!

The following slides are based on a simulation using PYTHIA8.
PYTHIA6 analysis in a few days.

Two Body Overlap w/ pileup



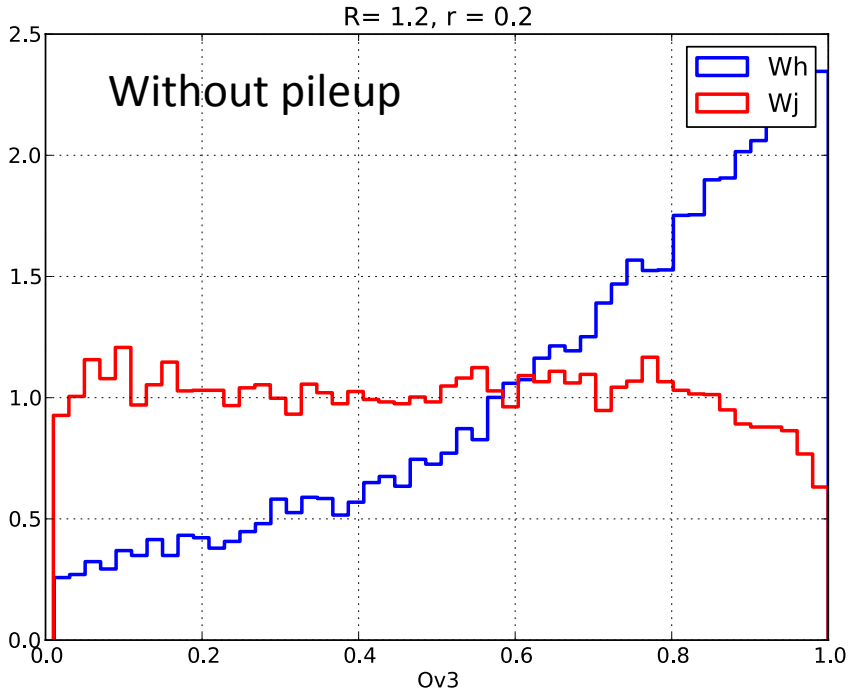


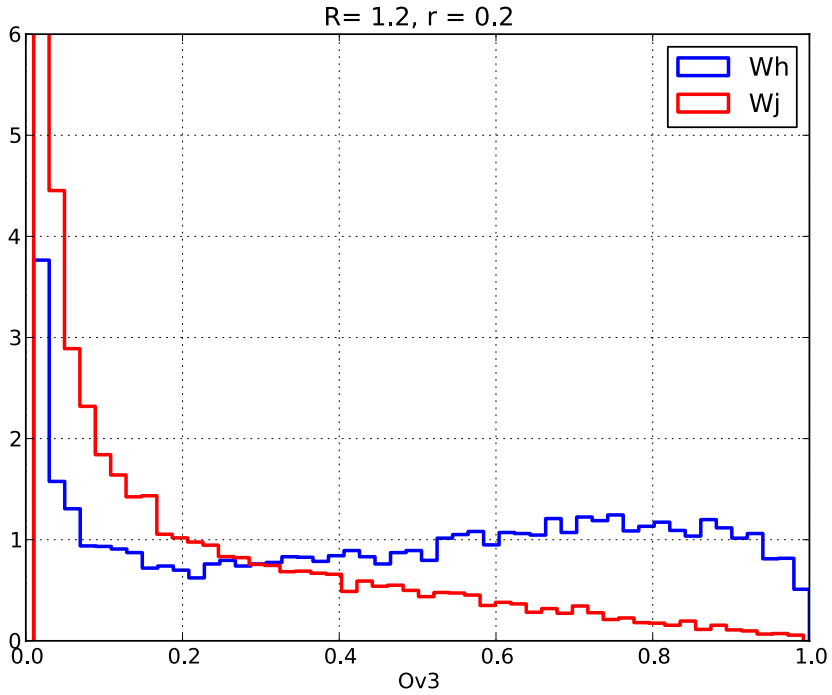
Pileup

As expected, pileup pushes both distributions towards lower values of maximum overlap.

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

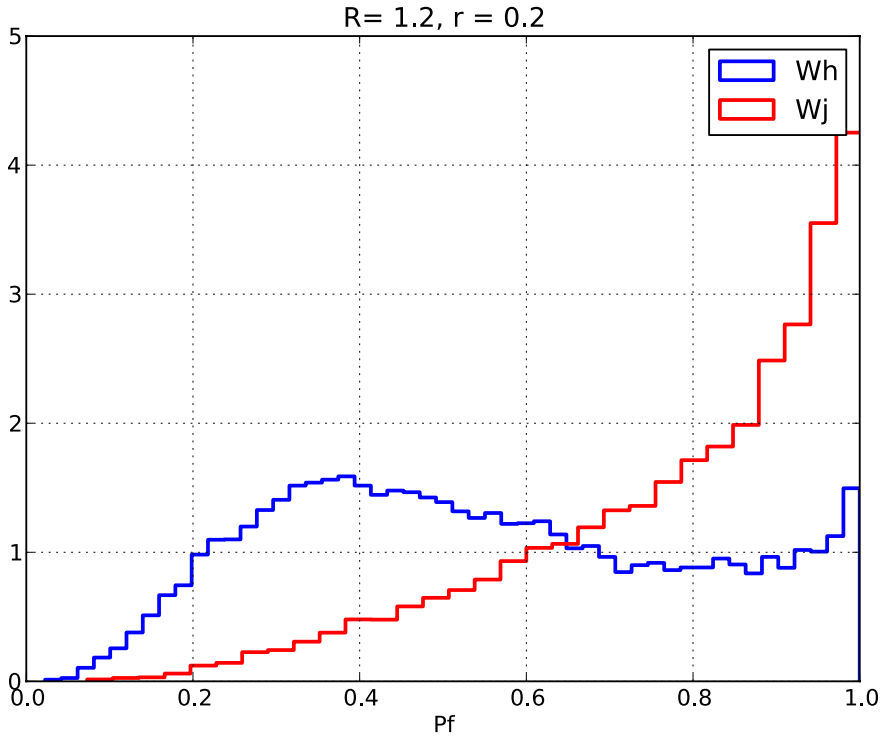
Three body overlap w/ pileup





Pileup

Planar flow



Pileup makes jets look more "round" and uniform

Larger planar flow

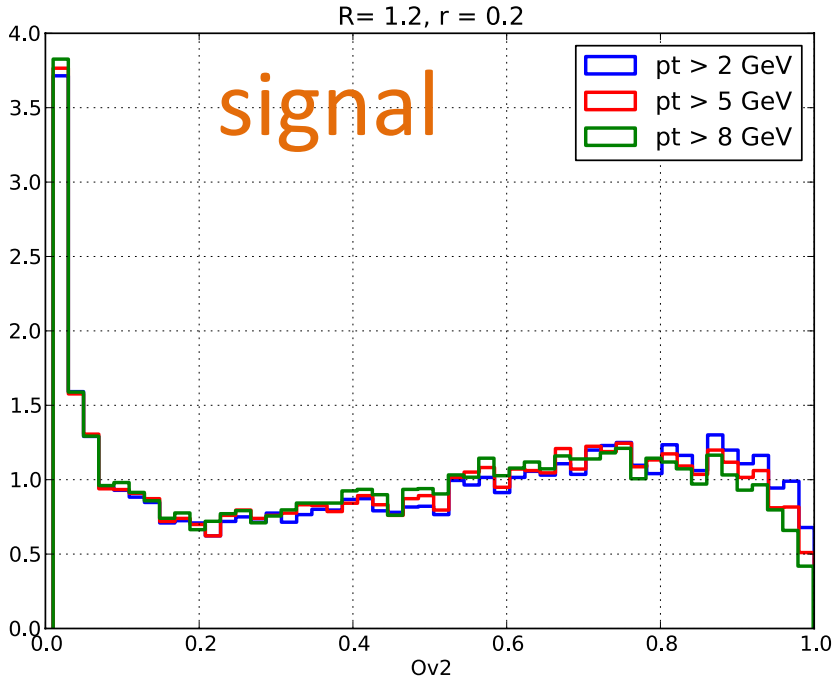
Why such dramatic effect on background?

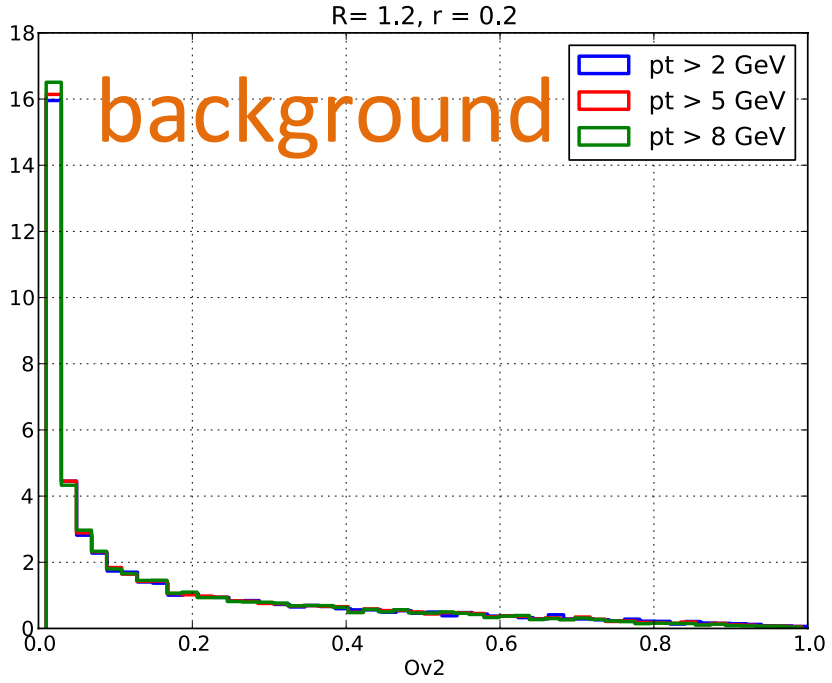
We are working on it ….

Minimum pt cutoff

Does a cutoff on the minimum p_T of all template momenta change things?

Three body maximum overlap distributions





Very little effect!

If all else fails… try new things

What about the discrete symmetries of the jet substructure observables?

Quick example: Planar Flow & Parity

$$Pf = \frac{4\det(I_\omega)}{\mathrm{tr}(I_\omega)^2}, \quad \Rightarrow \quad \sim \epsilon_{ab} k^a k'^b \sim sin(\phi_a - \phi_b)$$

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

Odd Parity

Other parity even / odd observables possible!

For more details look at:

MB, J. Ralson: **arXiv:1101.1965**

Gur-Ari, M. Papucci, G. Perez: **arXiv:1101.2905**

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

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'' formed at the Weizmann Institute

If it works