

Estudio de variables discriminantes entre la señal del modelo Little Higgs $Z_H \rightarrow t t^-$ y su fondo irreducible $gg \rightarrow t t^-$ en el experimento ATLAS.

Santiago González de la Hoz, Elena Oliver, José Salt, Eduardo Ros, Miguel Villaplana, Marcel Vos

Instituto de Física Corpuscular
(CSIC-UVeG)

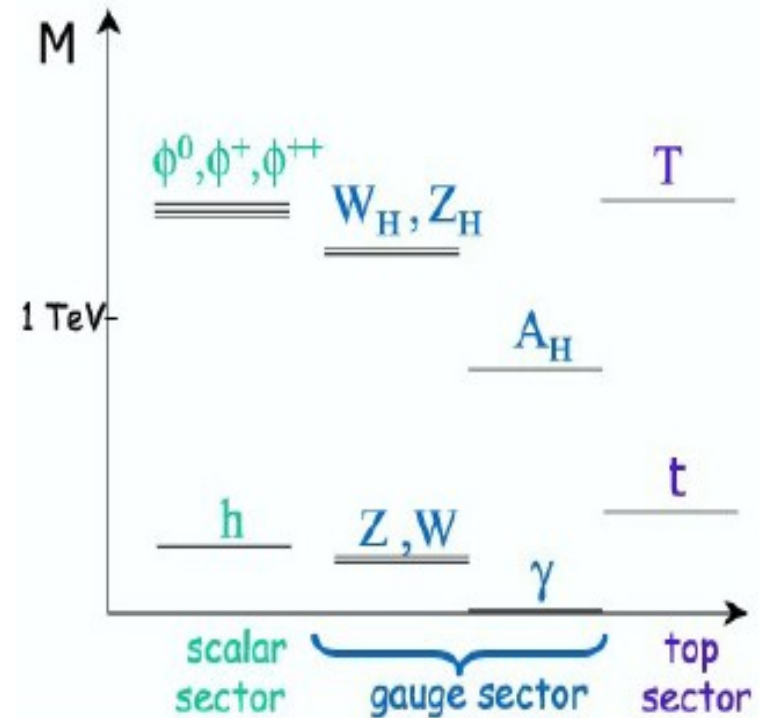


Index

- Little Higgs Model
- Analysis Description
- Discriminant variables
 - ΔR
- Reconstruction
 - Best Jet Algorithm
 - High p_T btagging
 - ΔR cut
- Conclusions

Little Higgs Model

- This model solves hierarchy problem of SM including new particles to cancel radiative corrections:
 - T quark with charge 2/3.
 - Heavy gauge bosons.
 - Scalar particles, including Higgs.
- Only **two** parameters: mass and angle between W_H and Z_H .
- Littlest Higgs: **minimum** particles are needed.



This plot shows Littlest Higgs Model with quarks top and T, four gauge bosons and four scalars.

References:

Theory: Arkani-Hamed et al., JHEP 207 (2002) 34

Phenomenology: Han et al. Phys. Rev. D67 (2003) 95004

W_H and Z_H are interesting because they have a **high cross section**.

Analysis Description

Target: to **discriminate** Signal from Irreducible Background.

- Simulation (GRID, Tier-2), **20000** events at $\sqrt{s}=14$ TeV.
- Signal Channel (Littlest Higgs) semileptonic:

- $\sigma=19\text{pb}$ BR=1/8

$$Z_H \rightarrow t \bar{t} \rightarrow W^+ b, W^- \bar{b} \rightarrow l \nu, jj \quad m_{Z_H} = 1\text{TeV}$$

- Irreducible Background of high energy:

- $\sigma=167\text{pb}$ BR=0.54

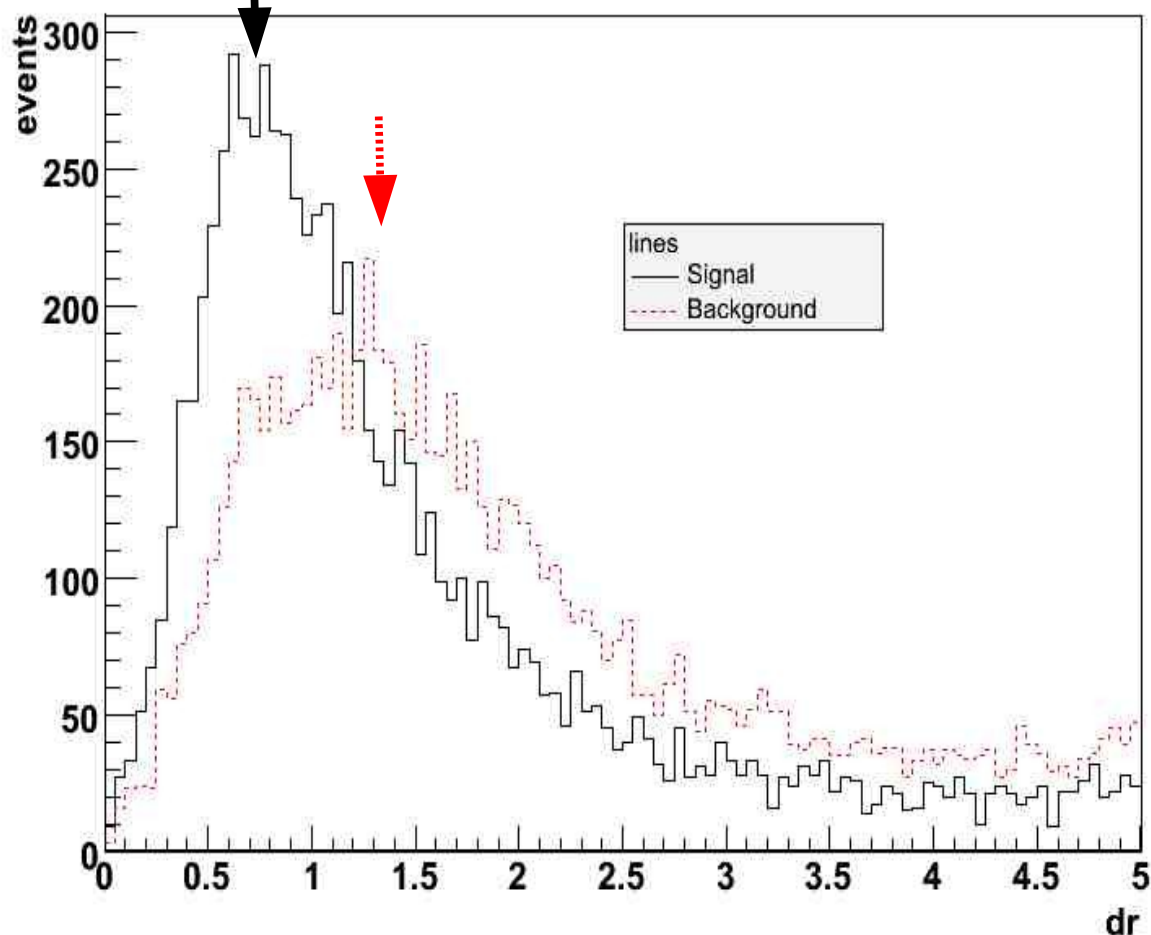
$$g g \rightarrow t \bar{t} \quad \sqrt{s} > 500 \text{ GeV} \quad p_t > 100 \text{ GeV}$$

Discriminant variables

This study is done with parton data (information without detector simulation).

- Angle between tops $\cos \theta = \frac{\vec{p}(t) \cdot \vec{p}(\bar{t})}{|\vec{p}(t)| |\vec{p}(\bar{t})|}$
- Subtraction momenta $p_t(t) - p_t(\bar{t})$
- Relations lepton and top $\cos \theta_{lep} = \frac{\vec{p}(t) \cdot \vec{p}(l)}{|\vec{p}(t)| |\vec{p}(l)|}$ $|\vec{p}(t)|$ vs $p_t(l)$
- $\Delta R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2}$

dr from jets of l nu in Truth



$$\Delta R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2}$$

Difference:
Means are different

Signal mean = 0.9
sigma = 0.5
BKG mean = 1.3
sigma = 0.9

We can use this
discriminant variable.

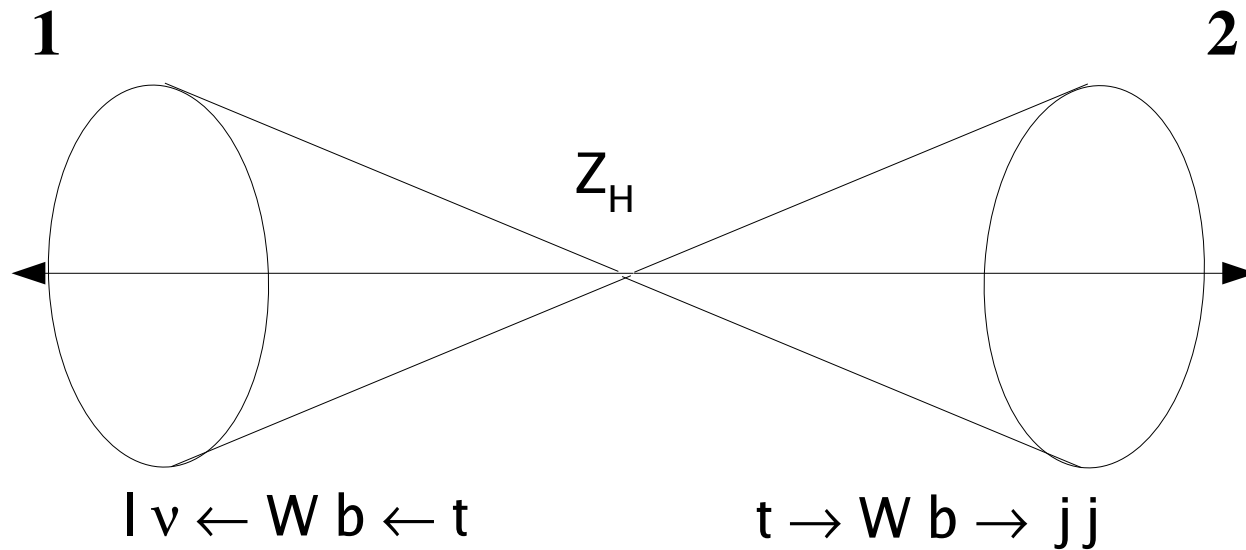
Reconstruction Z_H boson

This study is done in Full Simulation

- Jet Algorithm election
- Btagging performance
- Discriminant variables cuts

Reconstruction Z_H

Semileptonic Signal



$$\Delta R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2}$$

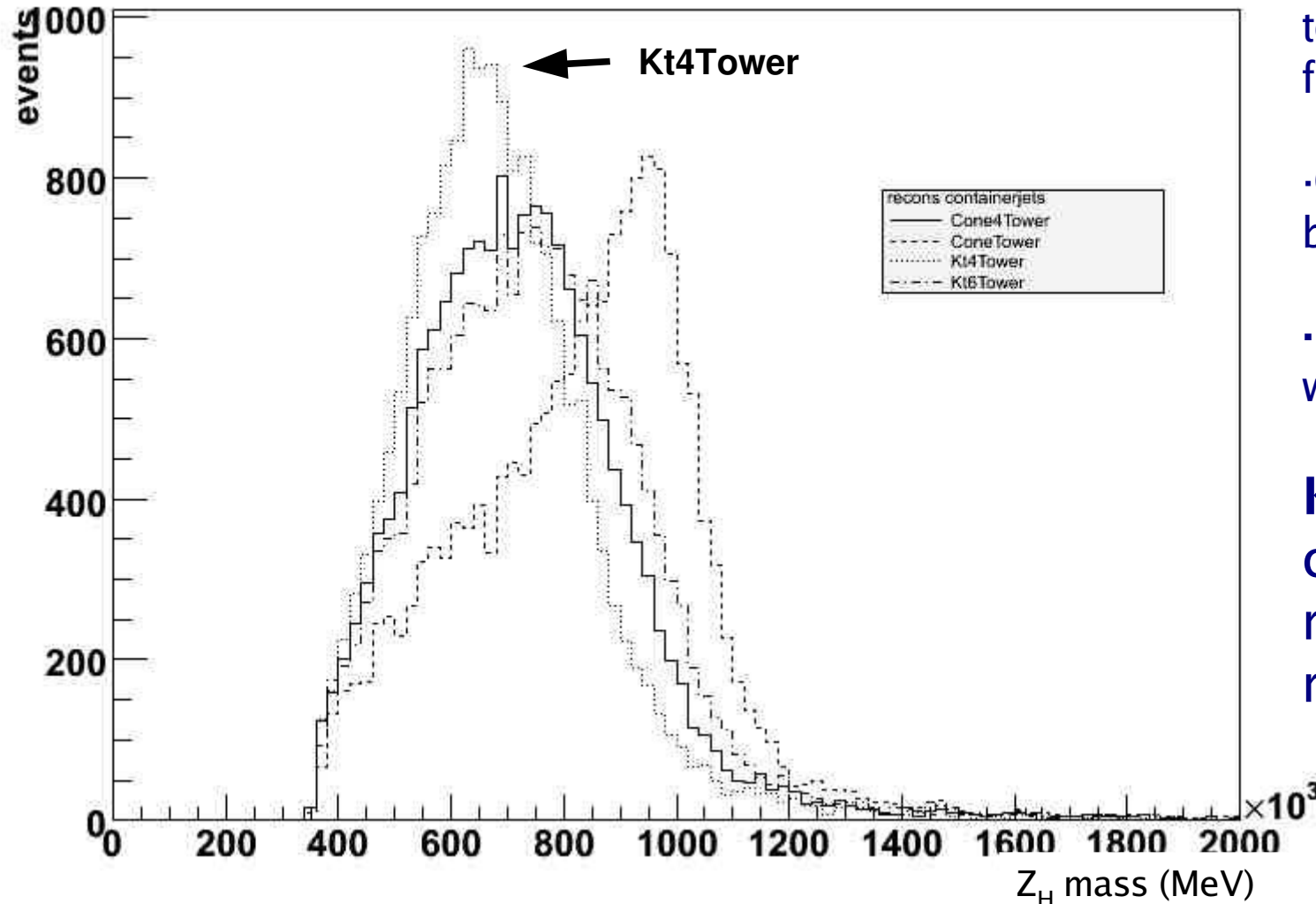
bjet closer to the lepton

$$bjet1 \quad 0.05 < \Delta R < 2$$

$$bjet2 \quad \Delta R > 2$$

Best Jet Algorithm

- 20000 events, only signal reconstruction, four jet algorithm types:
 Z_H mass reconstruction



- No changes 'Topo' to 'Tower'. ('Tower' fixed)

- **Cone** (0.7) irregular behavior.

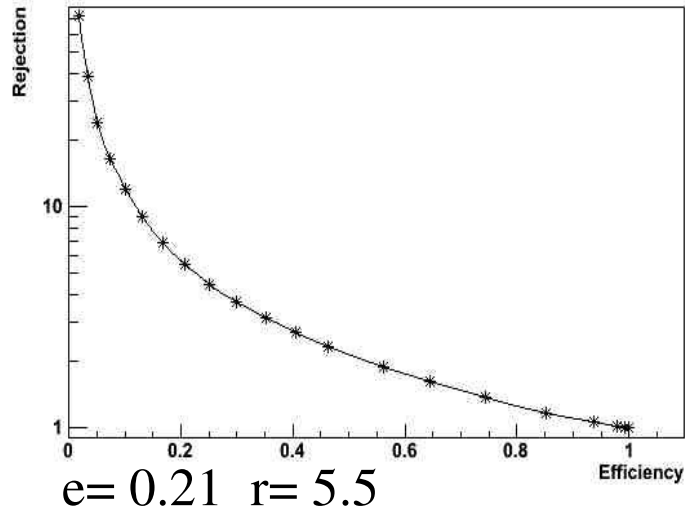
- **Kt4** the lowest width.

- **Kt4Tower** is chosen for the rest of the reconstruction.

High pT btagging

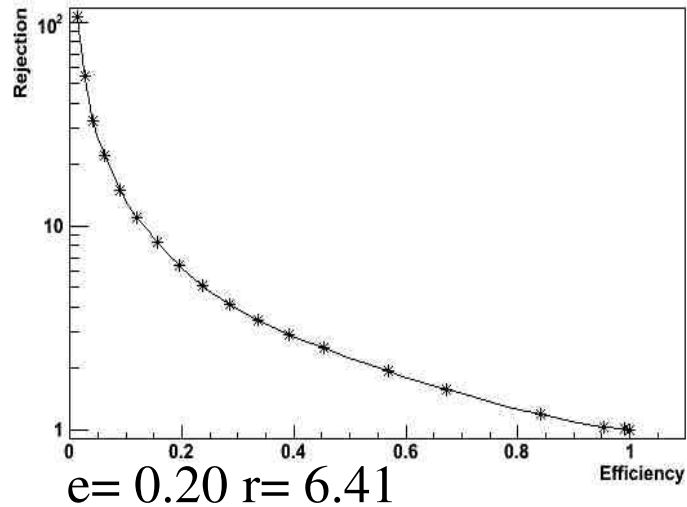
1 GeV

Rejection vs Efficiency, IP3DTrackSelector.pTMin=1GeV



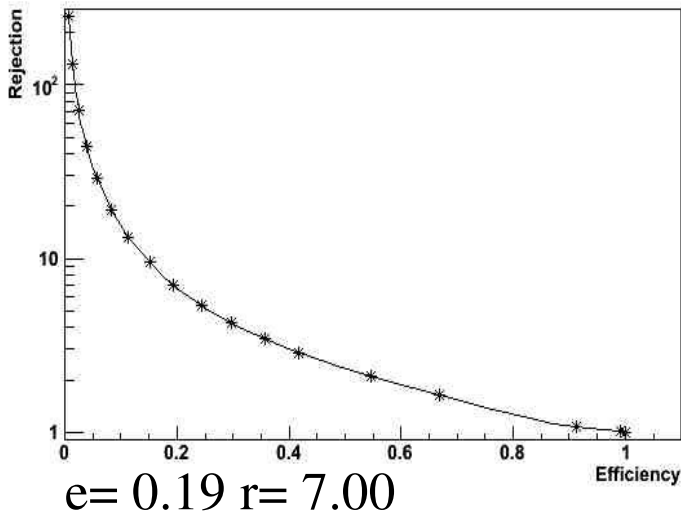
5 GeV

Rejection vs Efficiency, IP3DTrackSelector.pTMin=5GeV



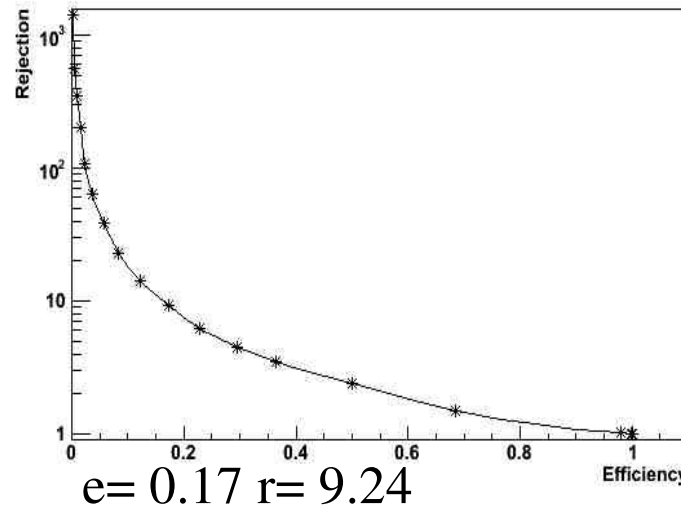
10 GeV

Rejection vs Efficiency, IP3DTrackSelector.pTMin=10GeV



20 GeV

Rejection vs Efficiency, IP3DTrackSelector.pTMin=20GeV



The standard btagging fails in high pT, so we are looking for improvements changing parameters.

Rejection vs Efficiency.

Target: The best rejection is got for an efficiency around 0.20.

Adding IP3D+SV1 of 2 bjets (weight).
Several Values of pTMin of IP3D.
Over 20 GeV, statistic is missed.

Weight cuts

Weight Cuts	S events	B events	S Efficiency	B Efficiency	$e(\text{bj})^2$ S	$e(\text{bj})^2$ B	N_S	N_B	$N_S/\sqrt{N_B}$
Without btg	17641	15766	0.88	0.84	0.19	0.16	31251.4	945745.2	32.14
$w \geq -2$	17084	15413	0.86	0.83	0.22	0.17	35428.3	1037291.4	34.62
$w \geq -1$	4756	2644	0.24	0.14	0.6	0.57	27051.7	584317.8	35.39
$w \geq 0$	3893	2107	0.19	0.11	0.7	0.68	25678.1	552155.4	34.56

$$N = L \cdot \sigma \cdot BR \cdot \epsilon$$

$$\epsilon = \epsilon_{kin} \cdot \epsilon_b^2 \cdot 2 \cdot BR(W \rightarrow l \nu) \cdot BR(W \rightarrow jj)$$

$$\text{significance} : \frac{N_S}{\sqrt{N_B}}$$

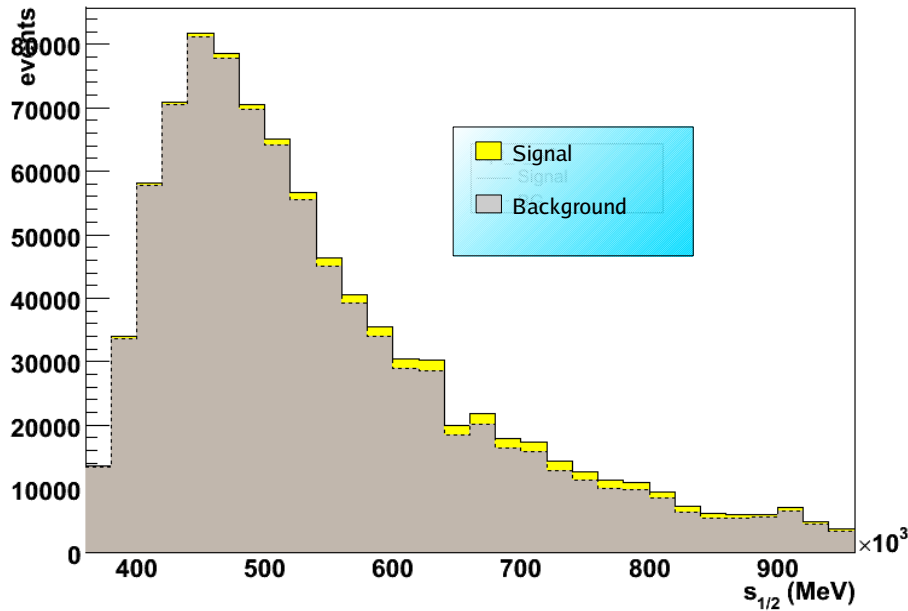
Z_H is reconstructed at **luminosity** $3 \cdot 10^5 \text{ pb}^{-1}$ with different cuts of the bj weights.

The efficiency drops but the significance is better.

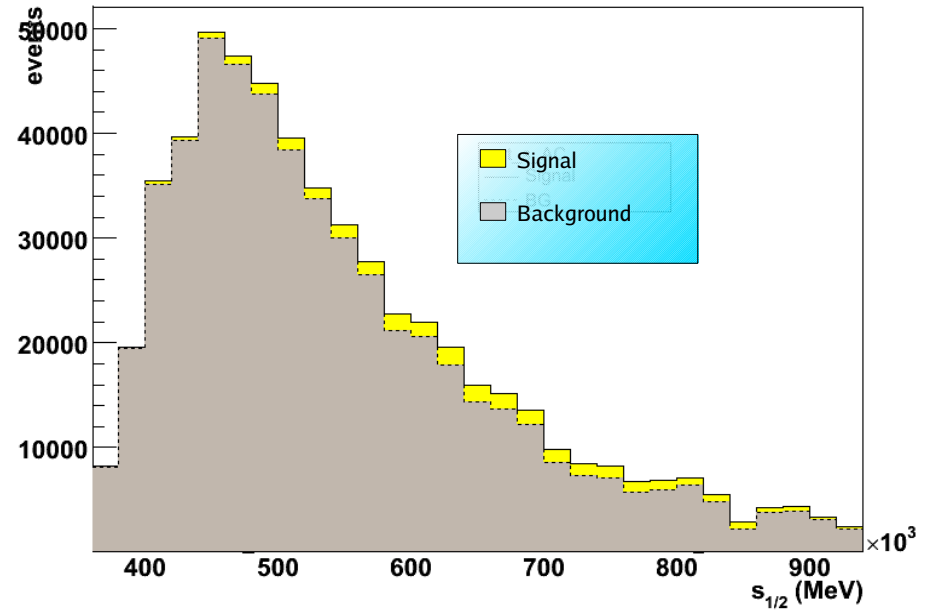
$w \geq -1$ fixed

Before and after btagging

No weight cuts



-1 weight cut



Z_H reconstruction normalized before and after applied btagging with a zoom in an interval $-2 \times \text{signal_width}$, $-2 \times \text{signal_width}$ around signal mean.

ΔR cut

Weight Cuts	S events	B events	S Efficiency	B Efficiency	$e(\text{bjet})^2$ S	$e(\text{bjet})^2$ B	N_S	N_B	$N_S/\sqrt{N_B}$
Without btg	17641	15766	0.88	0.84	0.19	0.16	31251.4	945745.2	32.14
$w \geq -1$	4756	2644	0.24	0.14	0.6	0.57	27051.7	584317.8	35.39
ΔR cut	4427	2261	0.22	0.12	0.61	0.58	25503.6	510112.08	35.71

In the reconstruction phase, b-jets with $\Delta R \geq 2$ are assigned to hadronic decays, while $\Delta R < 2$ to leptonic decays.

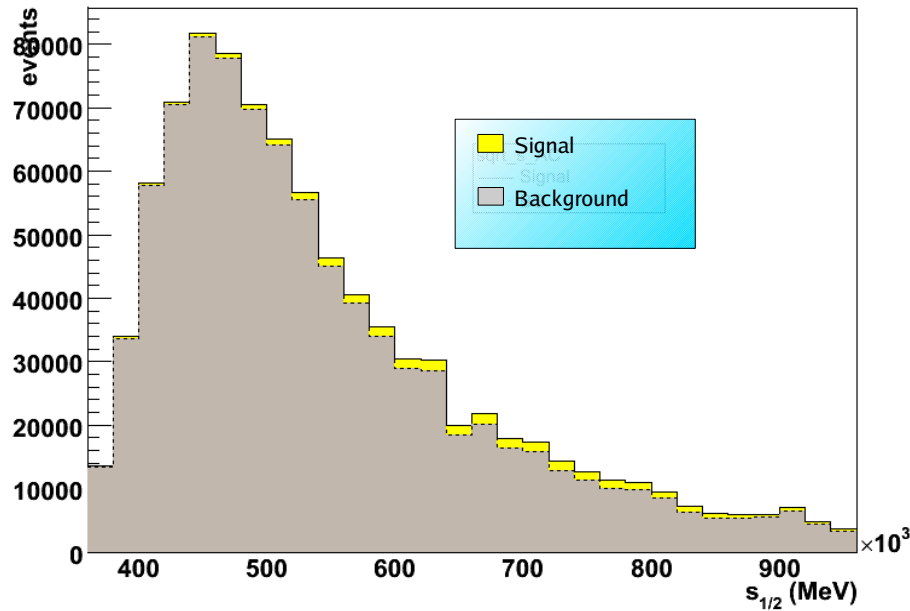
Remember the previous study of ΔR with MC information: different peaks in signal and irreducible background.

We are performing a cut on ΔR , $\Delta R \leq 1.4$, this cut has been established because it is the sum of the signal ΔR mean (0.9) + signal ΔR width (0.5)

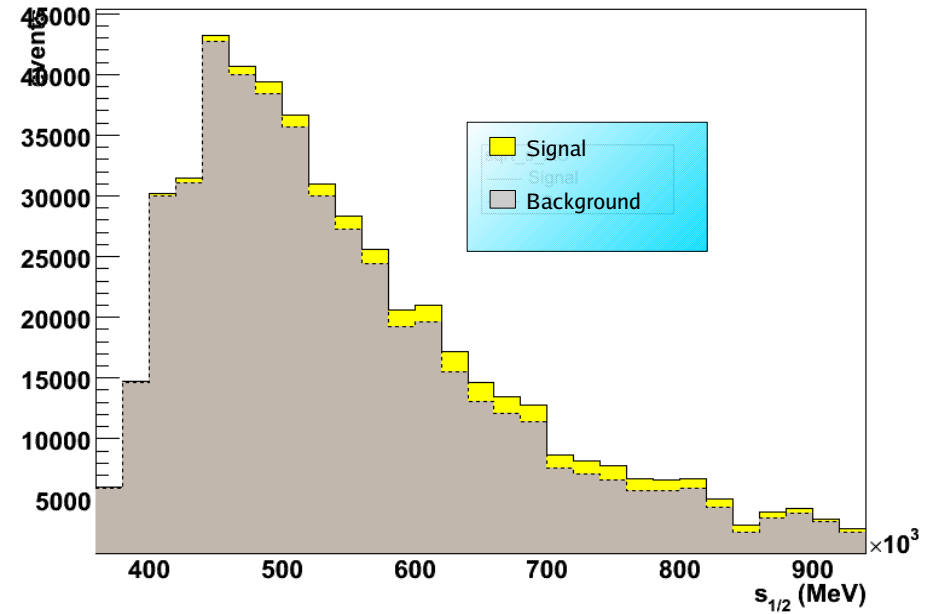
A soft improvement.

Before and after changes

No changes



DeltaR cut



Z_H reconstruction normalized before and after applied all the changes with a zoom in an interval $-2 \times \text{signal_width}$, $-2 \times \text{signal_width}$ around signal mean.

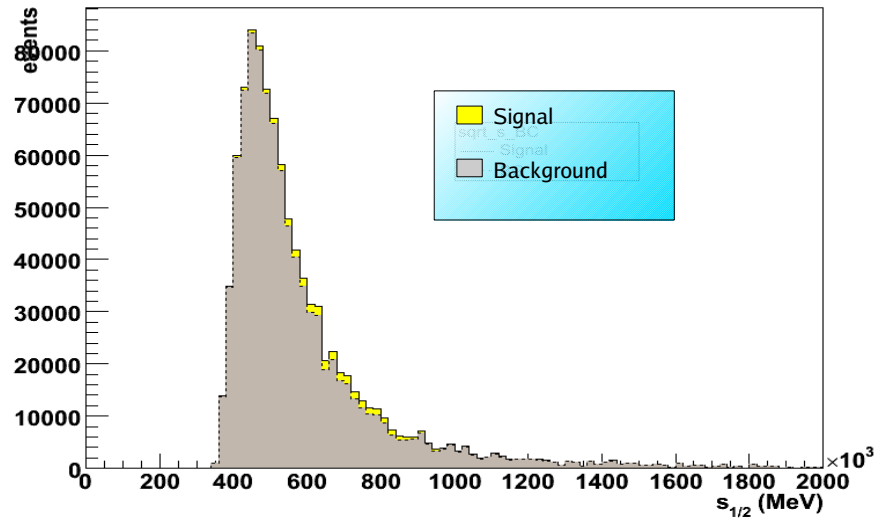
Conclusions

- Only a tested variable can be used efficiently as discriminant variable, ΔR . We can **increase** the **significance** (>5) with btagging and ΔR cut but that is not enough to see the signal clearly because background just peaks in the signal.
- The Z_H reconstruction does not have the mean in **1TeV**, it could be a **jet calibration** problem and would resolve with new ATLAS software.
- We will study other discriminant variables and others reconstruction models, if the discrimination can be improve.

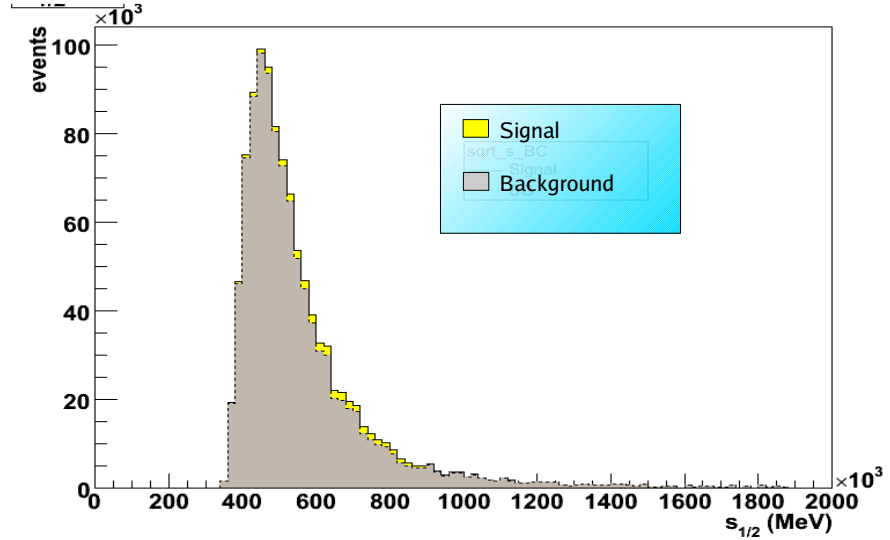
Backups

Reconstruction weight cuts

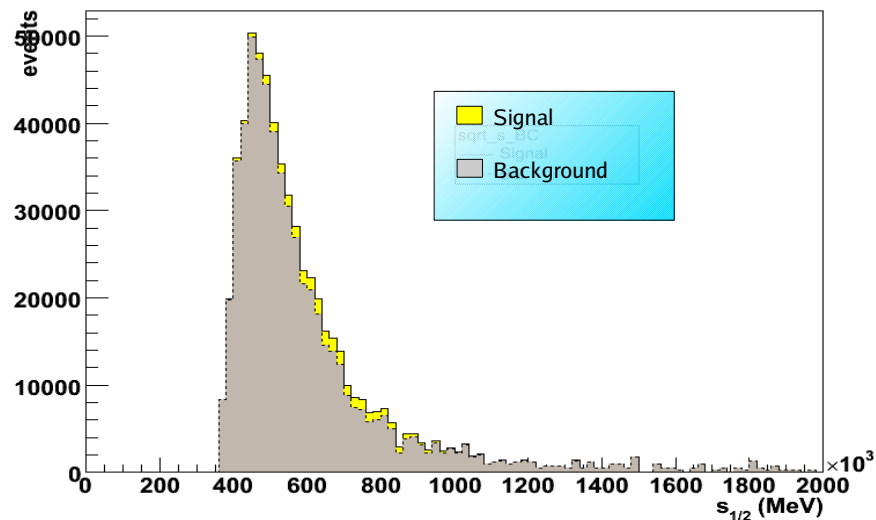
No weight cuts



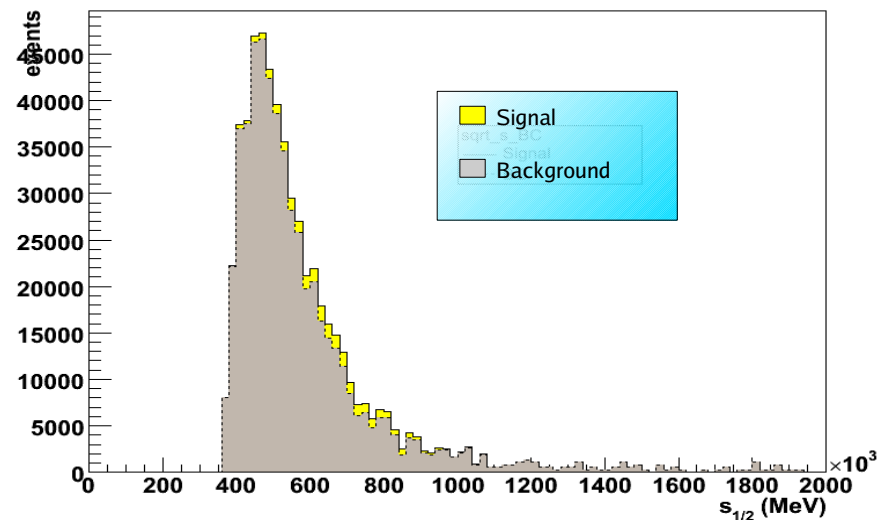
-2 weight cut



-1 weight cut

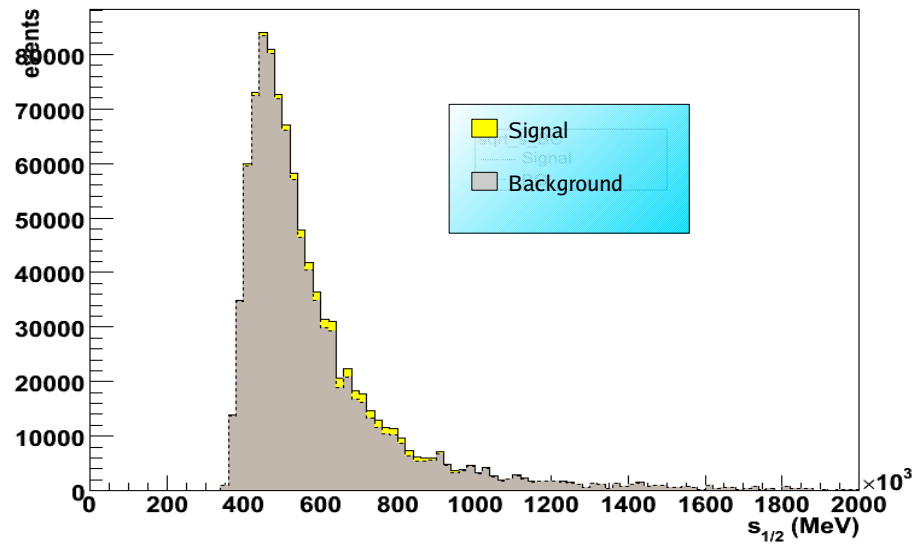


0 weight cut

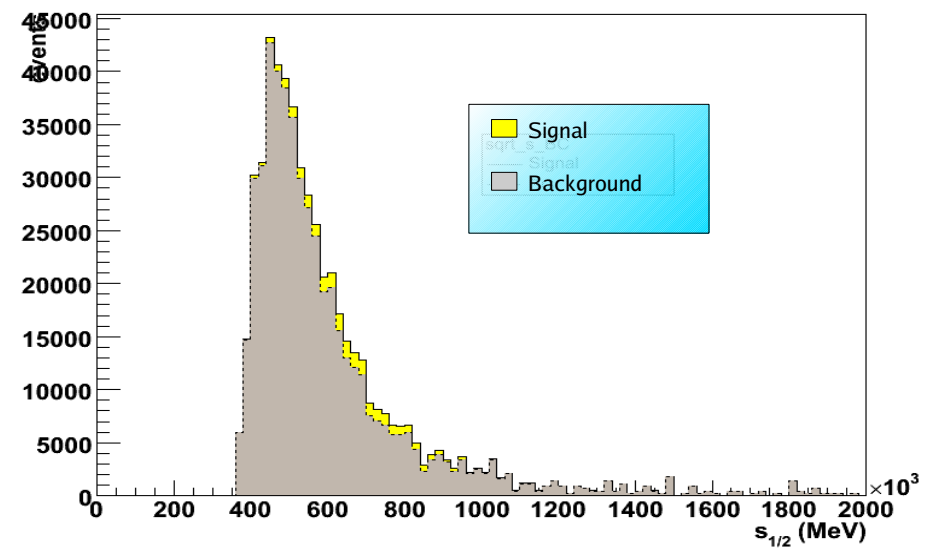


ΔR cut

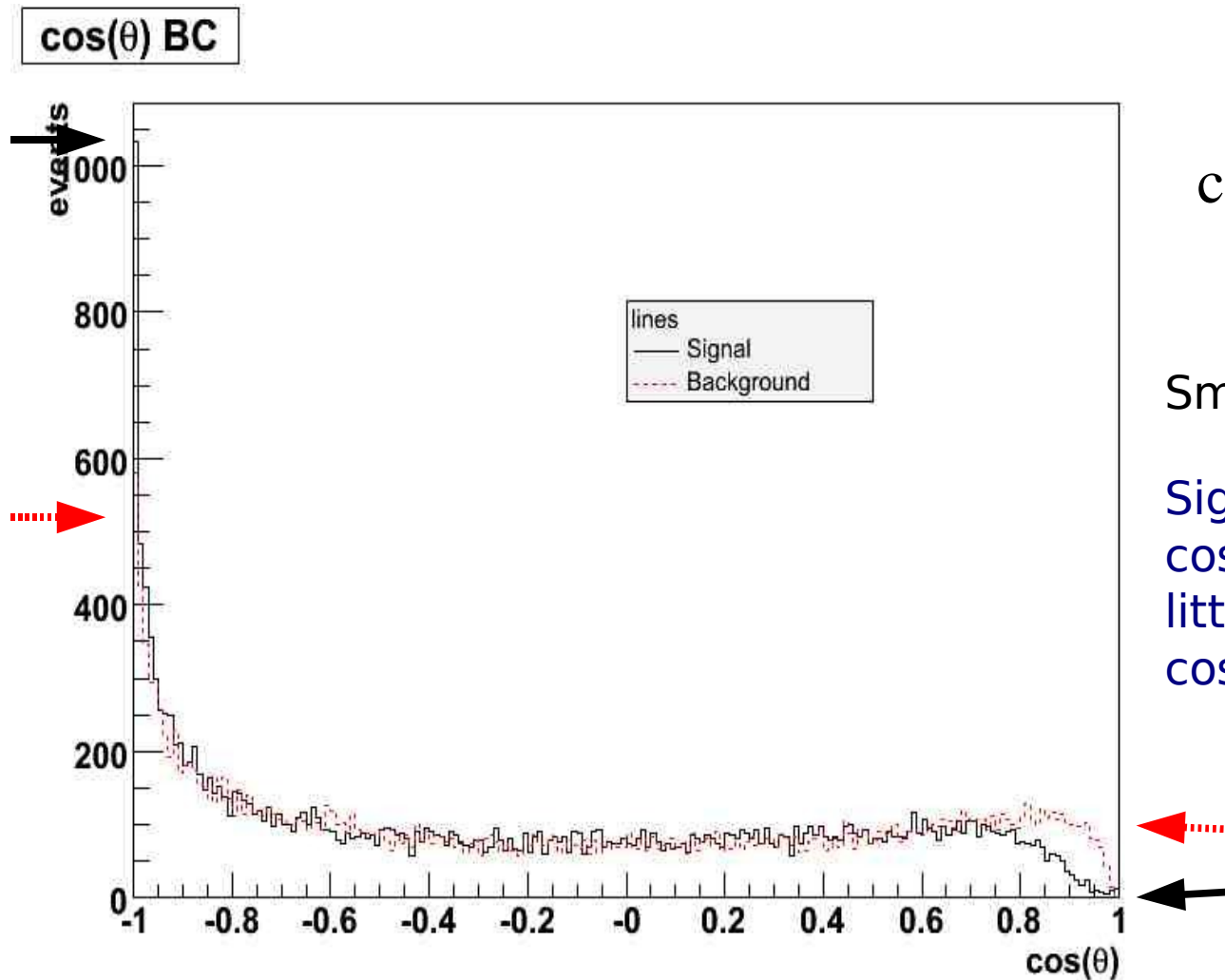
No changes



DeltaR cut



Angle between top and antitop

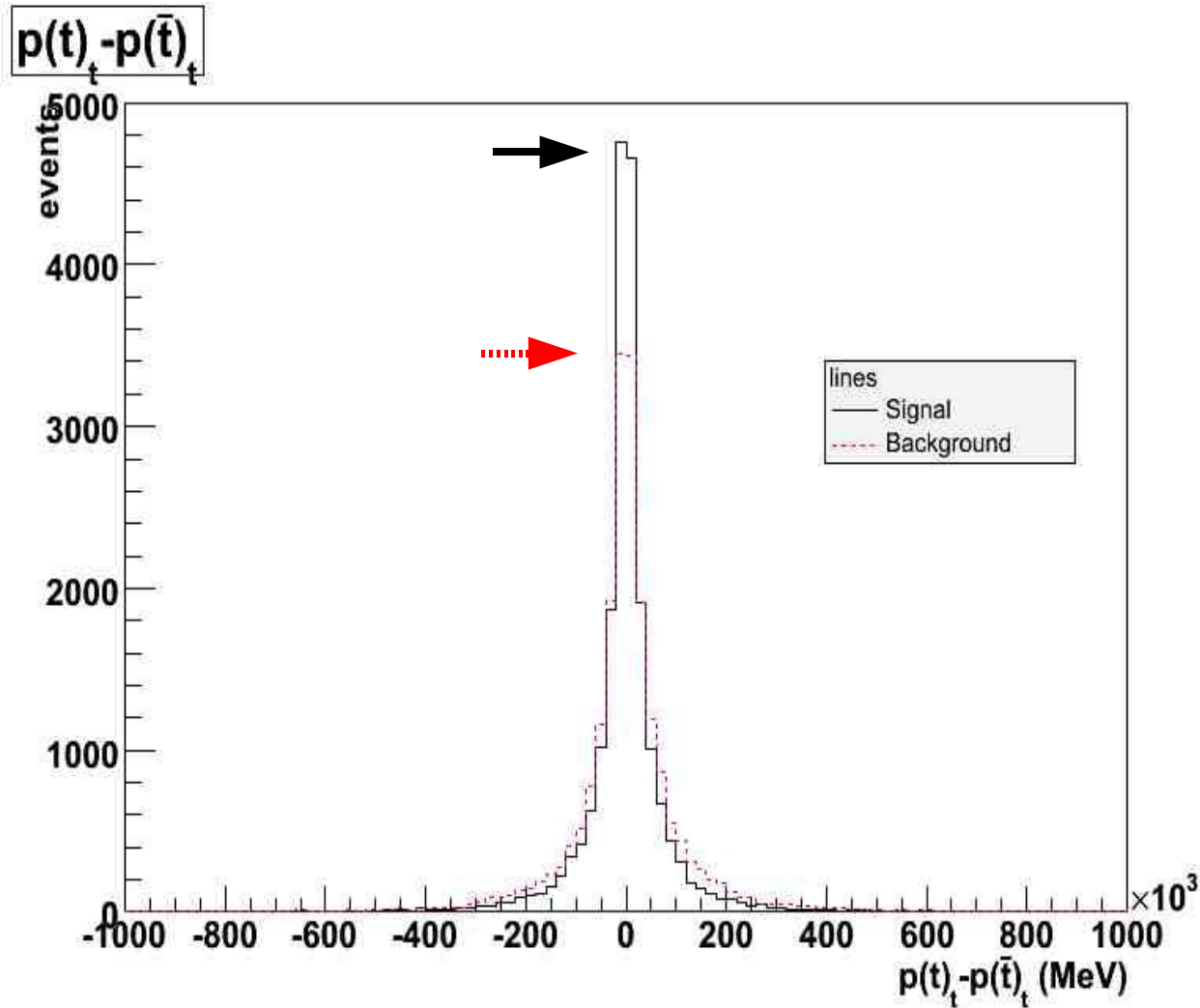


$$\cos \theta = \frac{\vec{p}(t) \cdot \vec{p}(\bar{t})}{|\vec{p}(t)| |\vec{p}(\bar{t})|}$$

Small differences:

Signal has more events with $\cos(\theta) = -1$ and Background a little bit more events with $\cos(\theta) = 1$

Subtraction Momenta

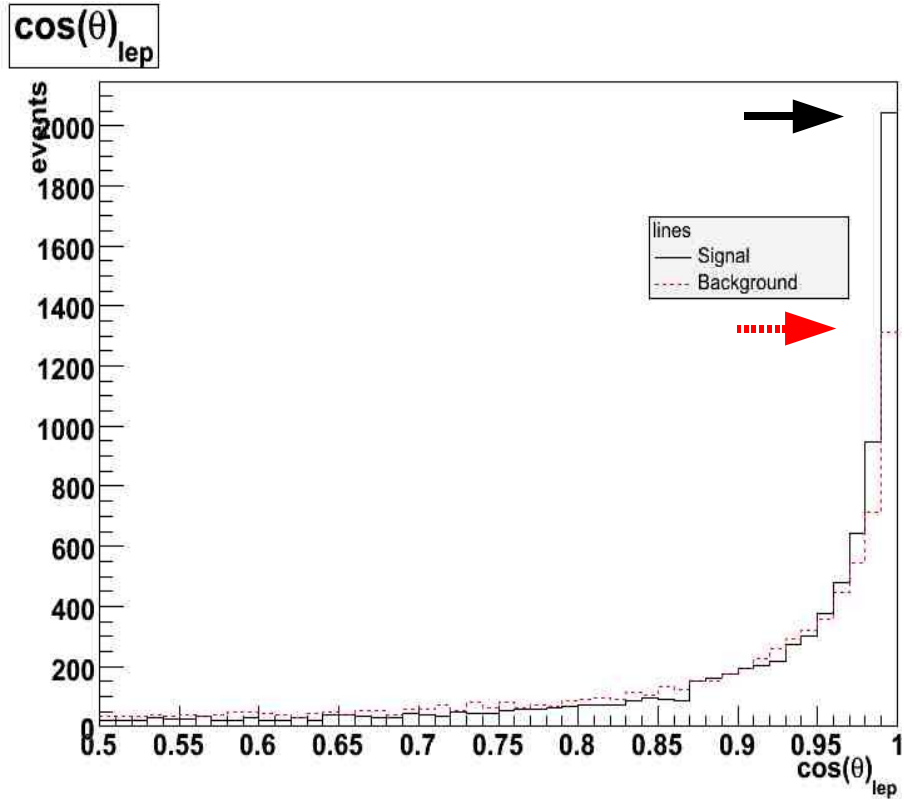


$$p_t(t) - p_t(\bar{t})$$

Small difference:

Signal has more events
with value zero

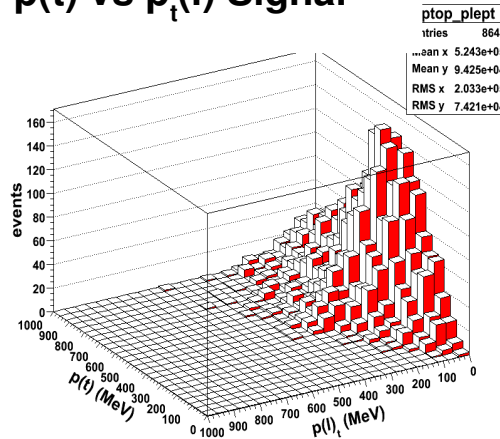
Relations lepton (e, μ) and top



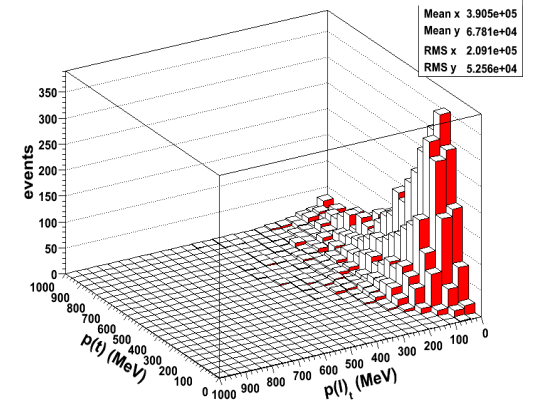
$$\cos \theta_{lep} = \frac{\vec{p}(t) \cdot \vec{p}(l)}{|\vec{p}(t)| |\vec{p}(l)|}$$

Difference:
Signal has more events with value 1

p(t) vs p_t(l) Signal



p(t) vs p_t(l) Background



$$|\vec{p}(t)| \text{ vs } p_t(l)$$

Difference:
No differences, same behavior

email addresses

- Elena Oliver García:
 - Elena.Oliver@ific.uv.es
- José Salt Cairols:
 - Jose.Salt@ific.uv.es
- Santiago González de la Hoz:
 - Santiago.Gonzalez@ific.uv.es