CP3 Lunch Seminar

Search for Standard Model Higgs boson with WH, H$\longrightarrow$WW channel using two same sign leptons

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- Introduction:
- Leptons identifications:
  - Electrons
  - Muons
- Events selection:
  - Online and leptons selection
  - Jets selection
  - Results

- “2 Same Sign Lepton” Cut
- Uncertainties:
  - Statistical uncertainties
  - Systematic uncertainties
- Significance

Signal

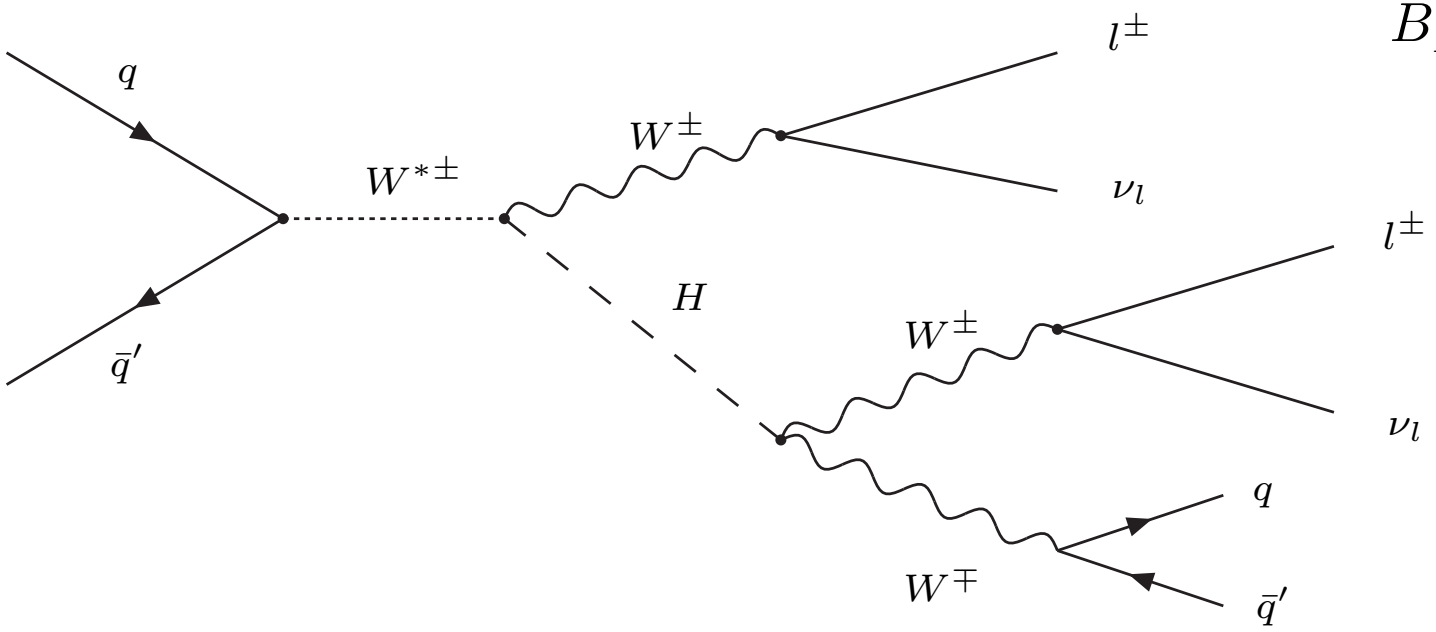
$WH, H \rightarrow WW, 2s.s.l.$

$m_H = 140$ GeV/c^2 $\rightarrow 180$ GeV/c^2

$\sigma(pp \rightarrow WH) \simeq 1060$ fb

$B_{H \rightarrow W^+W^-} \simeq 0.5$

$\rightarrow \sigma \simeq 36$ fb



- $3l$
- 2 same sign l + $2j$
- 2 opposite sign l + $2j$, $1l$+$4j$, $6j$

C. Delaere

D. Teyssier and J.C.

$S/\sqrt{B}$ too small

Online and leptons selection

Online selection: HLT + 3 streams:

- e-e: dielectrons subtrigger
- μ-μ: dimuons subtrigger
- e-μ: single electron subtrigger or single muon subtrigger

Leptons selection: depends on the channel:

- e-e:
  - Only 2 same sign reconstructed electrons.
  - These two electrons satisfy former conditions (quality, isolation, charge).
  - No reconstructed muons with $P_t > 16$ GeV/c.
- μ-μ:
  - Only 2 same sign reconstructed muons.
  - These two muons satisfy former conditions (isolation, P_t).
  - No reconstructed electrons with $P_t > 16$ GeV/c.
- e-μ:
  - Only 2 same sign reconstructed electron and muon.
  - This electron satisfies former conditions.
  - This muon satisfies former conditions.

Jets selection

Jets selection:

- $\tau-$jet rejection:

For each tracks with $P_t > 8$ GeV/c, if there is at least one track with $P_t > 3$ GeV/c in a 0.2 cone, the event is conserved.

- jets P_t:

For the two first jets sorted by P_t,
the first must have a P_t between 30 and 130 GeV/c.
the second must have a P_t between 22 and 70 GeV/c.

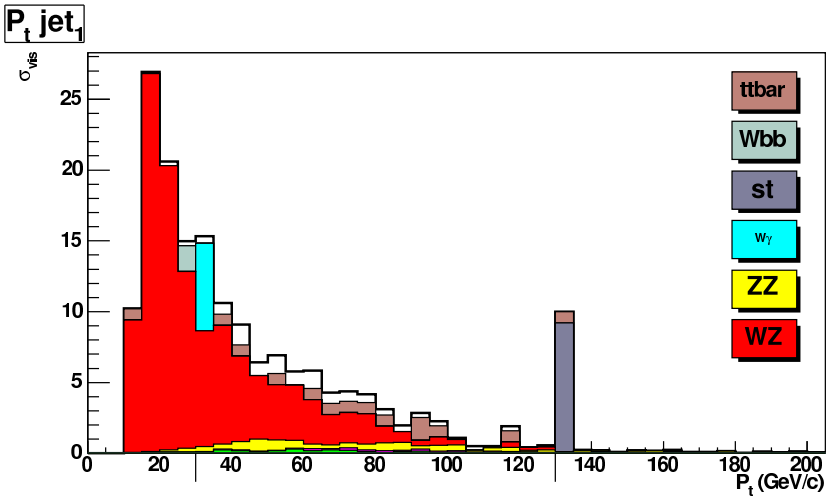
- btag:

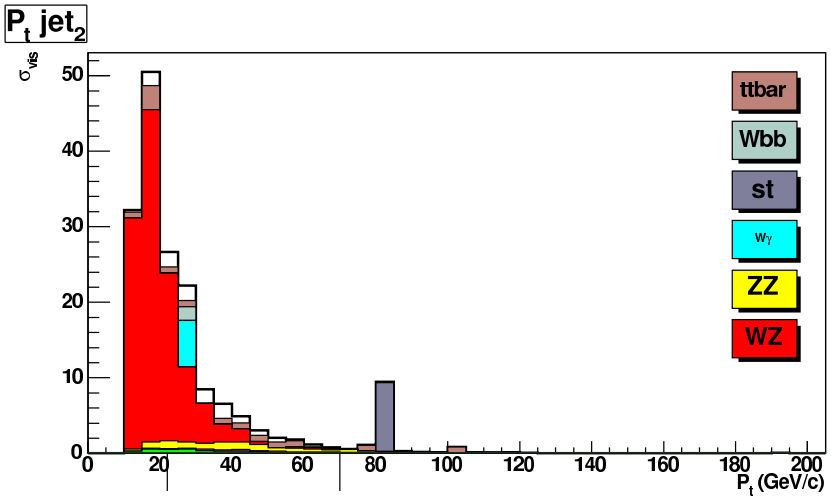
The two first jets must be not b-tagged.

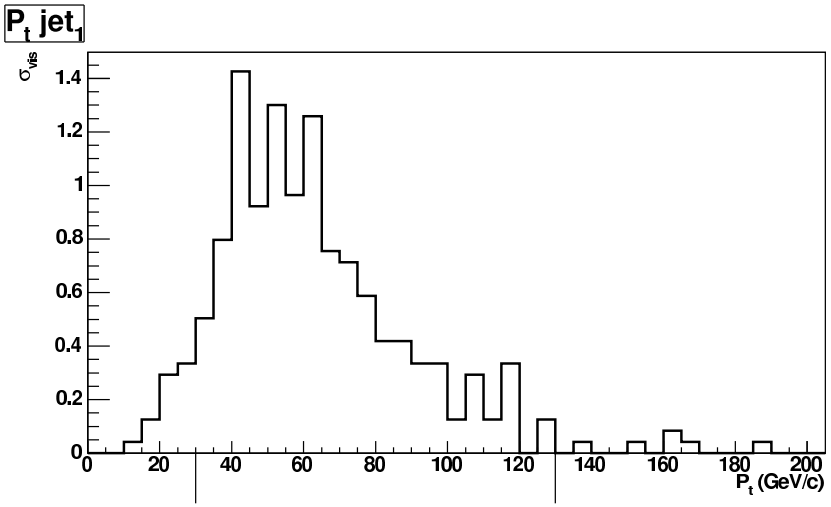
- dijet mass:

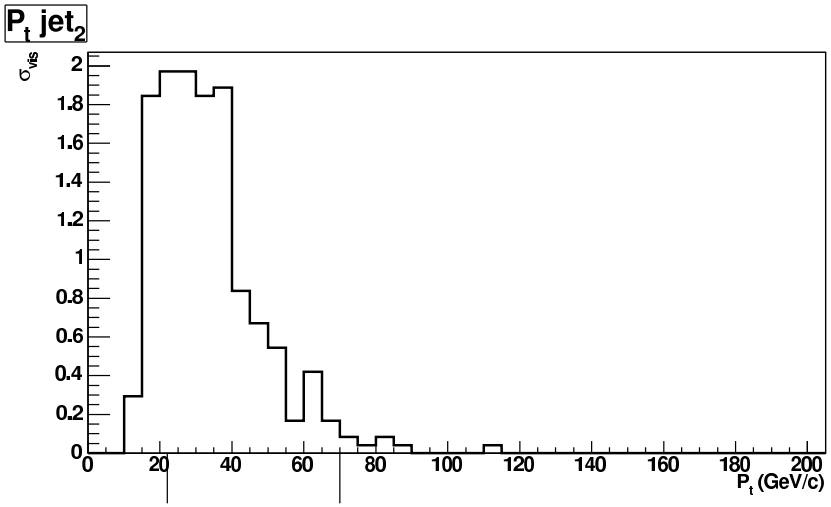
The reconstructed dijet mass from the two jets must be between 50 and 130 GeV/c^2.

Jets selection



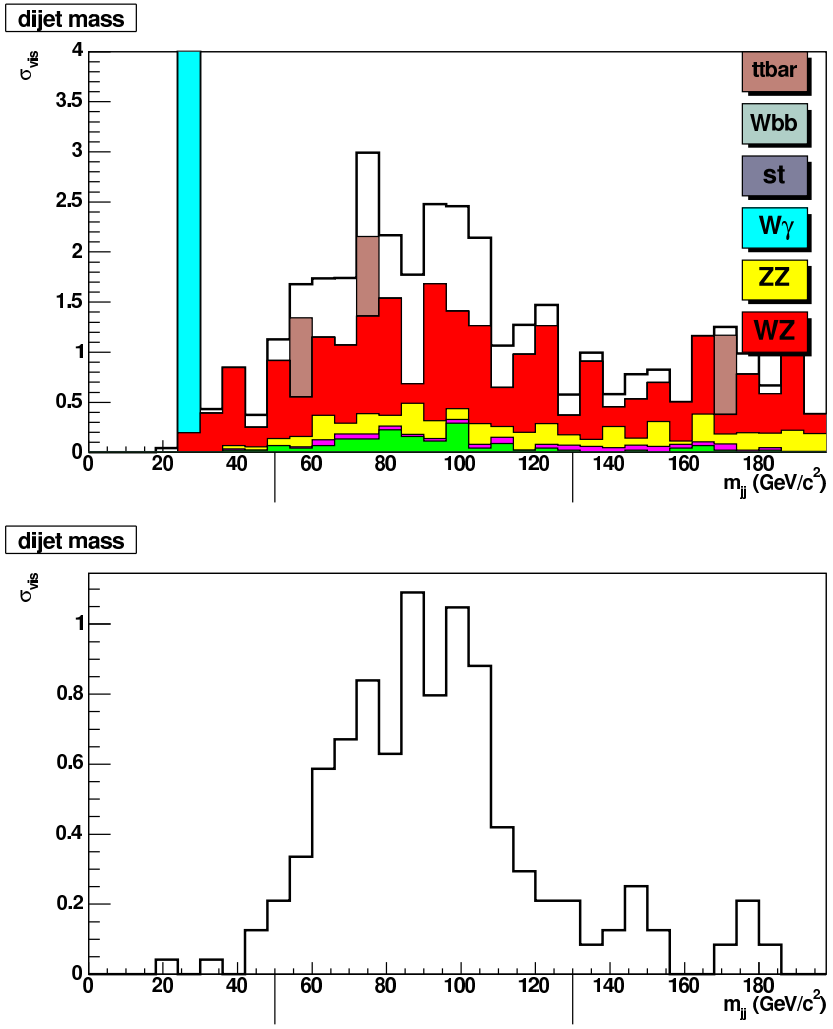






Jet_1 Jet_2

Jets selection



Results

e-e channel

	none	HLT	subtrigger	2ssl	τ-jet	P_t jets	b-tag	dijet mass	
s170	37.2	24.184	2.5848	0.2635	0.1924	0.1548	0.1422	0.1129	27
wbb	106594	29152	168.4113	0	0	0	0	0	0
ttbar	86016	63927	7960.3447	0.1584	0.1584	0	0	0	0
st	83971	36304	1222.1431	0	0	0	0	0	0
wγ	12646	8246.2818	507.3642	0	0	0	0	0	0
wt	5562	5562	596.1689	0	0	0	0	0	0
wz	1714	1167	279.4989	1.8309	1.1297	0.2143	0.2143	0.0584	3
zz	171	118.7	38.415	0.0886	0.0517	0.0222	0.0222	0.0074	2
ww	43.1	34.93	9.827	0.0775	0.073	0.0355	0.0322	0.0115	6
www	10.9	7.102	0.695	0.036	0.0315	0.0135	0.009	0.0067	3
wjets	413 10^5	11246617	952823	0	0	0	0	0	0
zjets	71.8 10^5	2329237	519510	0	0	0	0	0	0
ttbar incl.	955733	437786	24599	0	0	0	0	0	0
dy $\mu\mu$	15.8 10^5	1514935	24.433	0	0	0	0	0	0

$S/\sqrt{B} \simeq 3$ for 60 fb^{-1}

Results

μ-μ channel

	none	HLT	subtrigger	2ssl	τ-jet	P_t jets	b-tag	dijet mass	
s170	37.2	24.184	2.38	0.548	0.435	0.3221	0.2886	0.2133	51
wbb	106594	29152	153.91	0.3626	0.1813	0	0	0	0
ttbar	86016	63928	9144	1.109	0.7921	0.4752	0.1584	0.0792	1
st	83971	36304	209.0	0	0	0	0	0	0
wγ	12646	8246	5.088	0	0	0	0	0	0
wt	5562	5562	684.802	0	0	0	0	0	0
wz	1714	1169	354.35	7.518	4.986	0.838	0.779	0.429	22
zz	171	118.69	47.678	0.225	0.118	0.0665	0.0628	0.0148	4
ww	43.1	34.9	2.897	0.447	0.407	0.21	0.1918	0.0648	27
www	10.9	7.102	0.681	0.220	0.205	0.1124	0.0967	0.0697	31
wjets	413 10^5	11246617	1407003	0	0	0	0	0	0
zjets	71.8 10^5	2329237	752375	34.116	8.0556	4.0278	4.0278	0	0
ttbar incl.	955733	437786	16485	0	0	0	0	0	0
dy $\mu\mu$	15.8 10^5	1514935	1270955	40.722	24.433	0	0	0	0

$S/\sqrt{B} \simeq 2$ for 60 fb^{-1}

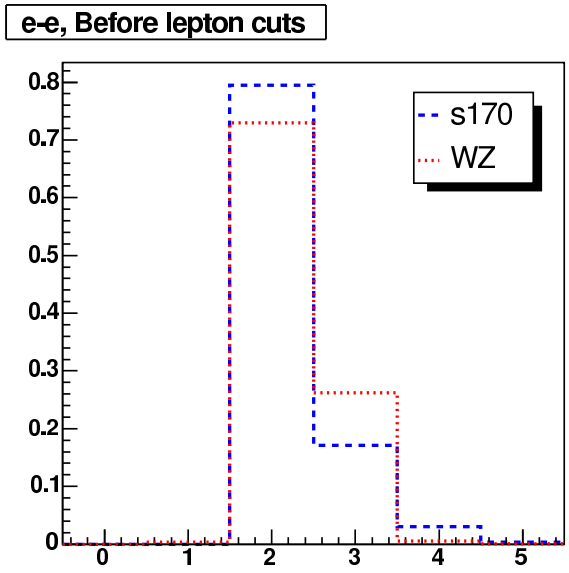
Results

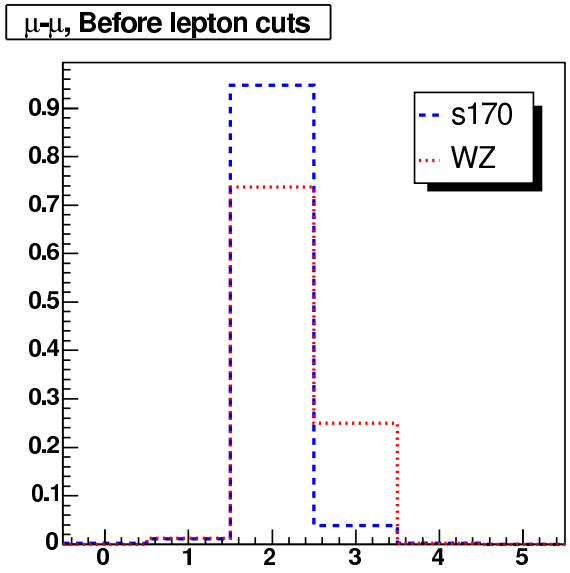
e-μ channel

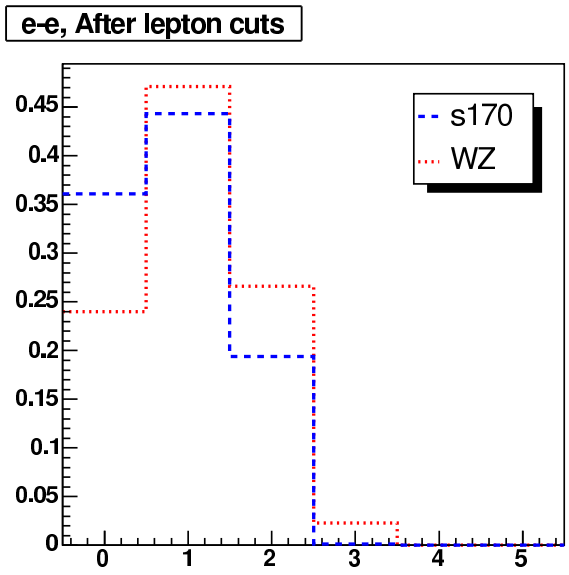
	none	HLT	subtrigger	2ssl	τ-jet	P_t jets	b-tag	dijet mass	
s170	37.2	24.184	20.28	0.937	0.778	0.552	0.510	0.3764	90
wbb	106594	29152	28142.9914	0.3626	0.1813	0	0	0	0
ttbar	86016	63928	54763.3698	1.6634	1.3465	0.5545	0.3168	0.0792	1
st	83971	36304	29723.9085	0.9127	0.9127	0	0	0	0
wγ	12646	8246	4845.9437	0.6252	0.6252	0.6252	0.6252	0	0
wt	5562	5562	4690.6353	0	0	0	0	0	0
wz	1714	1169	1080.3459	9.2517	5.9211	1.714	1.6166	0.4675	24
zz	171	118.69	105.287	0.3729	0.2474	0.1809	0.1809	0.0665	18
ww	43.1	34.9	24.7571	0.4453	0.4121	0.2328	0.2225	0.0833	37
www	10.9	7.102	5.9504	0.1934	0.1687	0.0967	0.0742	0.0562	25
wjets	413 10^5	11246617	10443156	50.676	50.676	0	0	0	0
zjets	71.8 10^5	2329237	2101077	44.2229	14.1196	6.0491	6.0491	0	0
ttbar incl.	955733	437786	114060	10.215	8.172	8.172	2.043	0	0
dy $\mu\mu$	15.8 10^5	1514935	1474401	0	0	0	0	0	0

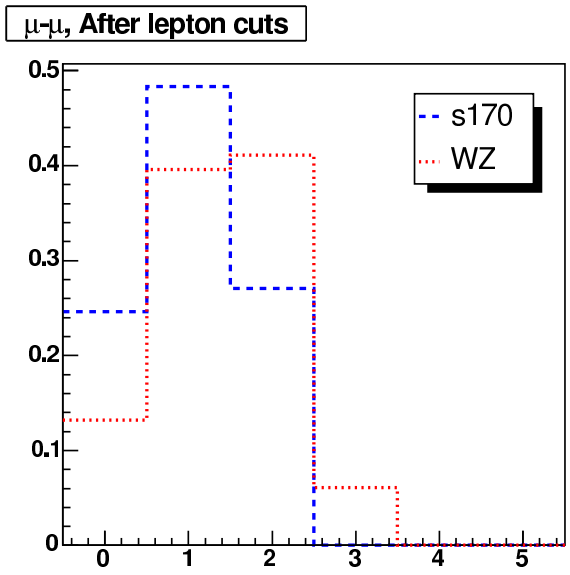
$S/\sqrt{B} \simeq 3.4$ for 60 fb^{-1}

“2 Same Sign Leptons” cut









Statistical uncertainties

- Low number of selected events:

$\longrightarrow$ large uncertainties, used in the significance computation.

- Large cross-section of rejected processes:

$\longrightarrow$ large weight by event, can be reduce by cuts factorisation method.

cuts factorisation:
For uncorrelated cuts, efficiency of a selection equals the product of the efficiencies of the cuts.

1. 2 same sign leptons
2. cuts on the P_t of the two jets and their reconstructed dijet mass
3. b-tag veto

$$\longrightarrow \epsilon_{comb} = \epsilon_{\text{HLT+subtrigger}} \times \epsilon_1 \times \epsilon_2 \times \epsilon_3 > \epsilon_{true}$$

where ϵ_j is the efficiency of the cut j on the sample selected by HLT and subtrigger.

Statistical uncertainties

Efficiencies (percent) and visible cross-section (fb), for e-e channel:

Process	ϵ_1	ϵ_2	ϵ_3	σ_{comb}
$t\bar{t}$	1.7 10^{-3}	20	40	0.019
Wbb	< 2.6 10^{-2}	28	61	< 0.070
$W\gamma$	< 4.1 10^{-2}	18	92	< 0.51
$W+j$	< 5 10^{-2}	21	98	< 35.0567

Dangerous backgrounds (but it's an upper limit):

- e-e: $W\gamma$, $W+j$, $Z+j$
- μ-μ: $W\gamma$, $W+j$, $Z+j$, dy $\mu\mu$
- e-μ: $W\gamma$, $W+j$, $Z+j$, incl. $t\bar{t}$

Systematic uncertainties

- Parton luminosity: 6.4%
- Lepton reconstruction: $2 \times 2\% = 2\% \oplus 2\% = 2.8\%$
- B-tag: 5%
- Backgrounds normalisation
- Cuts variation

Backgrounds normalisation:

- WZ:

Selection of **3** leptons that satisfy the conditions defined before (isolation, quality, P_t, charge).
From the two opposite sign pairs, the closest reconstructed mass to m_{Z^0} is found.

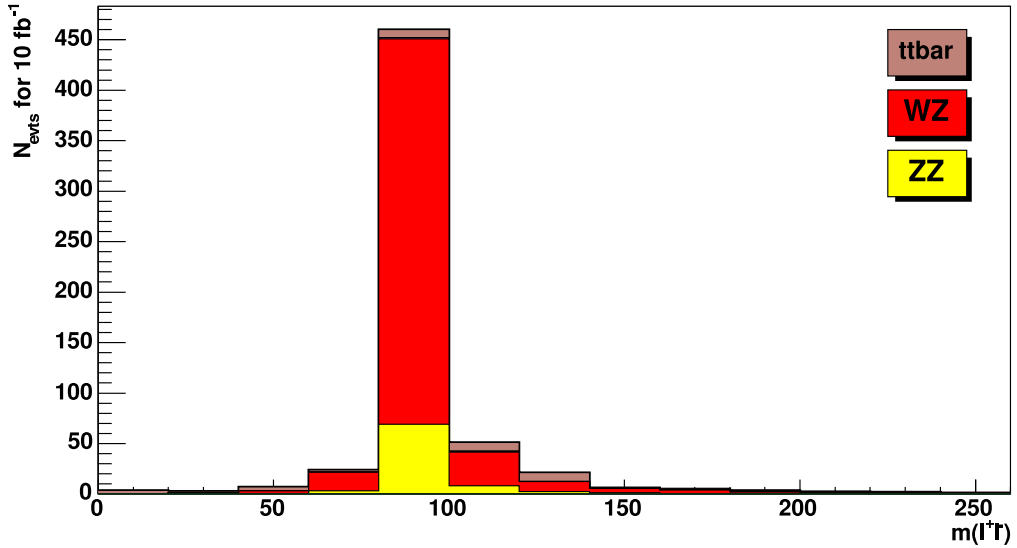
- ZZ:

Same method with **4** leptons.

- WWW and WW: Irreducibles!

Systematic uncertainties

WZ control region

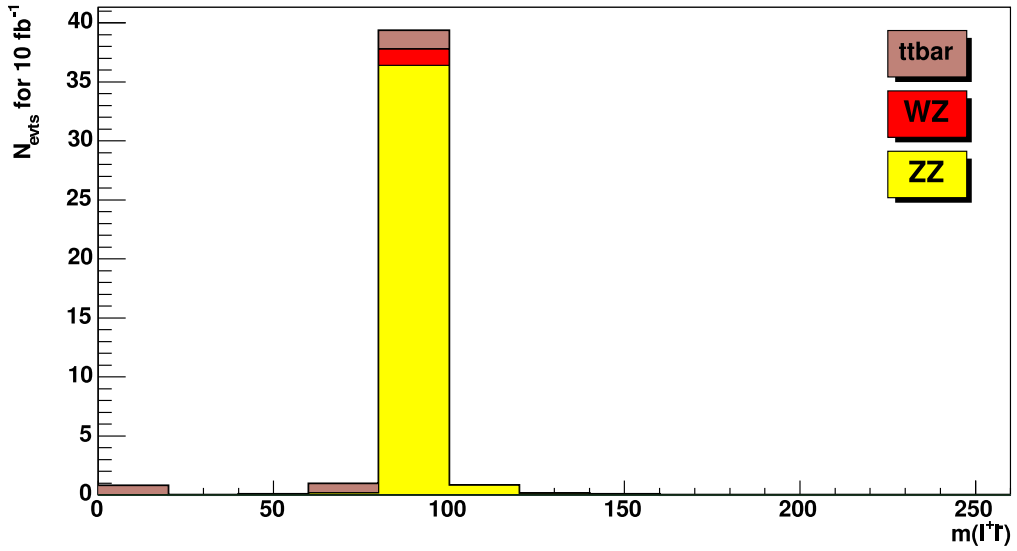


- WZ:

77% of WZ. $\sim$ 459 events at 10 fb^{-1}.

$\longrightarrow$ 5 %.

ZZ control region



- ZZ:

89% of ZZ. $\sim$ 38 events at 10 fb^{-1}.

$\longrightarrow$ 16 %.

In the selection, $\sim$ 45% WZ and 4% ZZ.

$\longrightarrow (0.44 \times 0.05) \oplus (0.04 \times 0.16) \simeq$ 2.3 %

Systematic uncertainties

Cuts variation, jets:

- JES:

10 %	$P_t \leq 20$
10% - (7% $\times$ (E-20)/30)	$20 < P_t < 50$
3%	$P_t \geq 50$

- Resolution:

$$E'_t = E_t + \text{Gauss}(0, 0.46 \times \sigma(E_t, \eta))$$

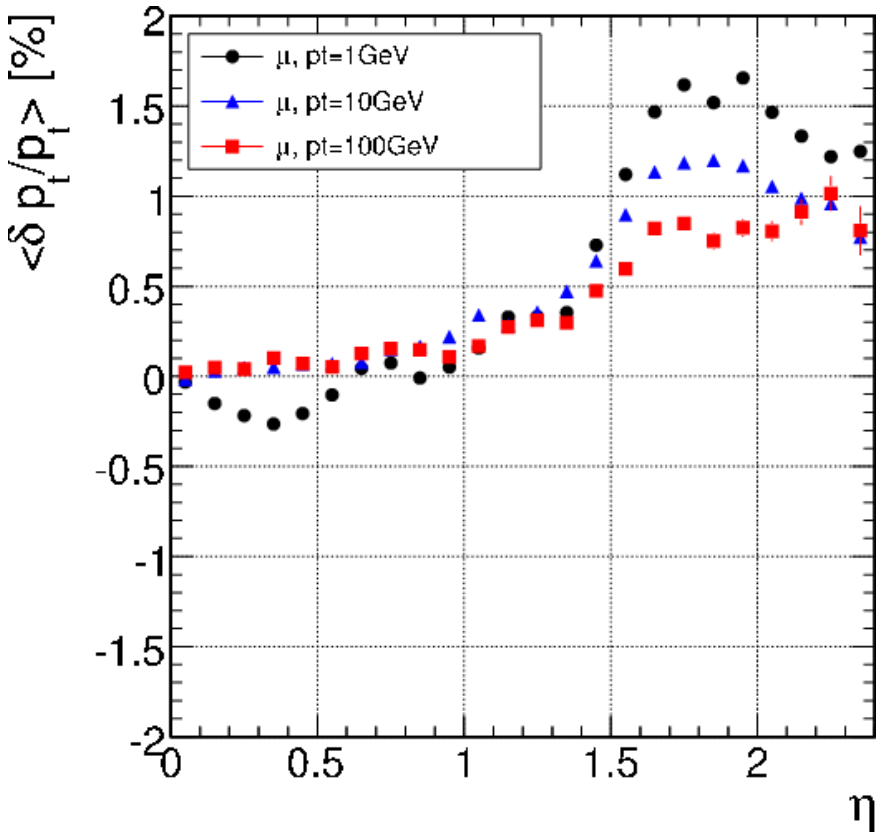
$$\sigma(E_t, |\eta| < 1.4) = 5.8 \oplus 1.25\sqrt{E_t} \oplus 0.033E$$

$$\sigma(E_t, 1.4 < |\eta| < 3.0) = 4.8 \oplus 0.89\sqrt{E_t} \oplus 0.043E$$

$$\sigma(E_t, 3.0 < |\eta| < 5.0) = 3.8 \oplus 0.085E$$

Systematic uncertainties

Cuts variation, tracks and electrons:



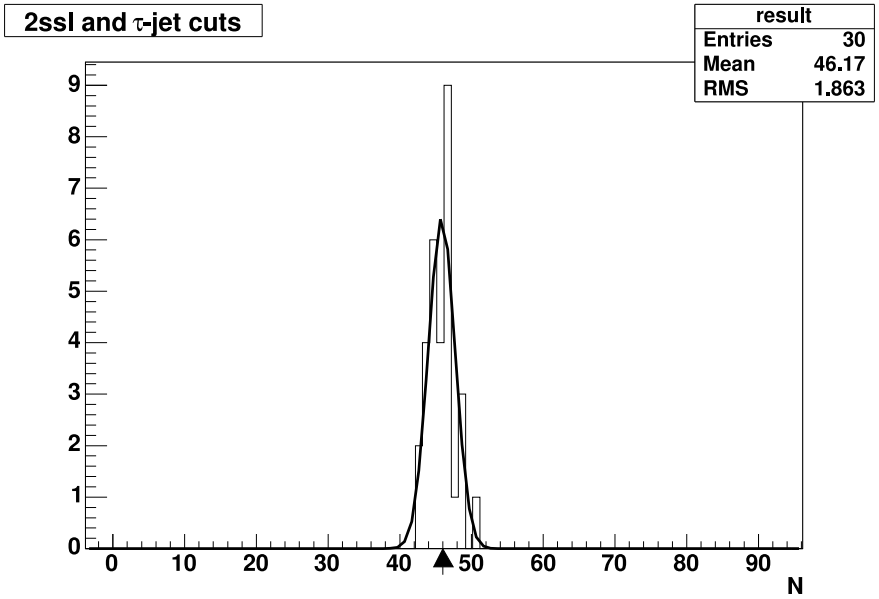
→ 2% for tracks.
→ 5% for electrons.

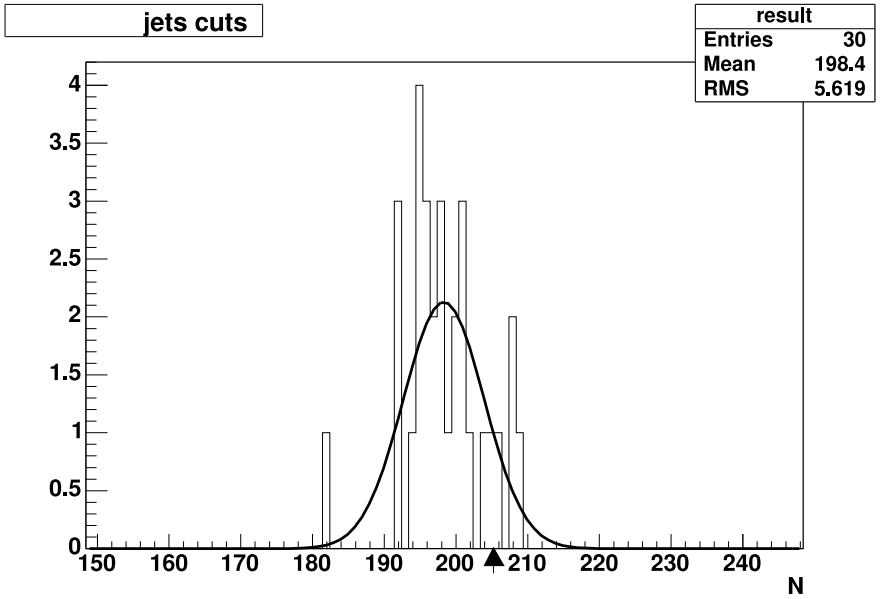
Systematic uncertainties

Cuts variation, results:

$$\frac{abs(N_0 - N_v)}{N_0}$$

where N_0 (N_v) is the number of events passing a cut before (after) applying the smearing.





$\longrightarrow$ 4% + 9% = 13%

Significance

CL_s method:

$$CL_{s+b} = P_{s+b}(X \leq X_{obs}) = \int_{-\infty}^{X_{obs}} \frac{dP_{s+b}}{dX} dX \qquad CL_b = P_b(X \leq X_{obs}) = \int_{-\infty}^{X_{obs}} \frac{dP_b}{dX} dX$$

$$CL_s = \frac{CL_{s+b}}{CL_b} \qquad \text{(or } = CL_{s+b} + (1 - CL_b) \times e^{-s}\text{)}$$

Estimator:

CL_s based on pdfs of $-2\ln(Q)$,

$Q = \mathcal{L}(s+b)/\mathcal{L}(b)$ ($\mathcal{L}$: Likelihood)

Combinaison of channels:

X_i^j : pdf for the i^{th} channel if j events are expected.

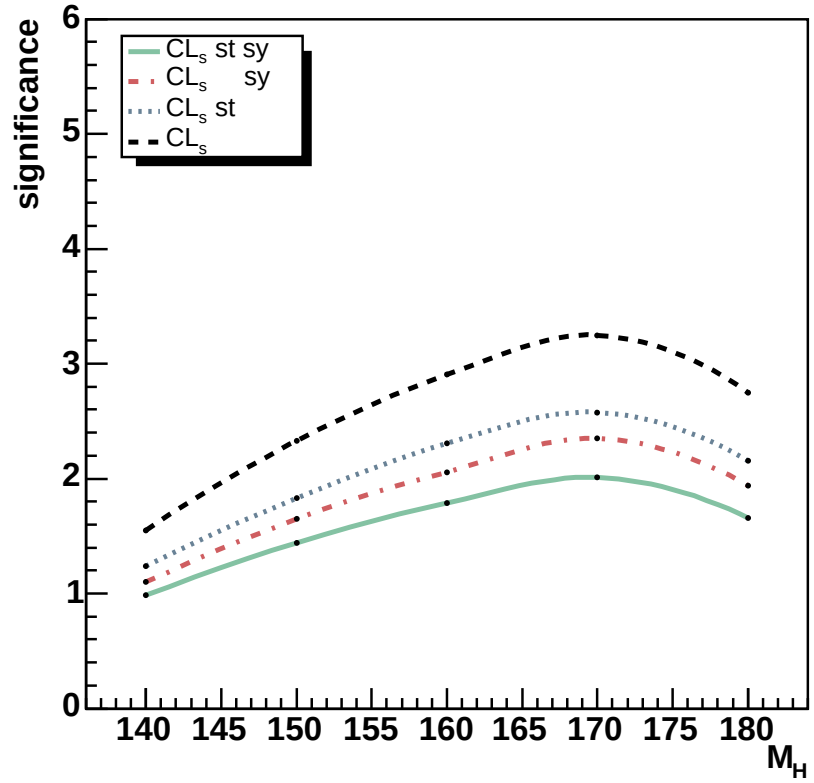
p_i^j : probability of selecting j events in the i^{th} channel (for $s+b$ or b).

$(X_i^j, p_i^j) + (X_{i'}^{j'}, p_{i'}^{j'}) \rightarrow (X_i^j X_{i'}^{j'}, p_i^j p_{i'}^{j'})$ (+ approx.)

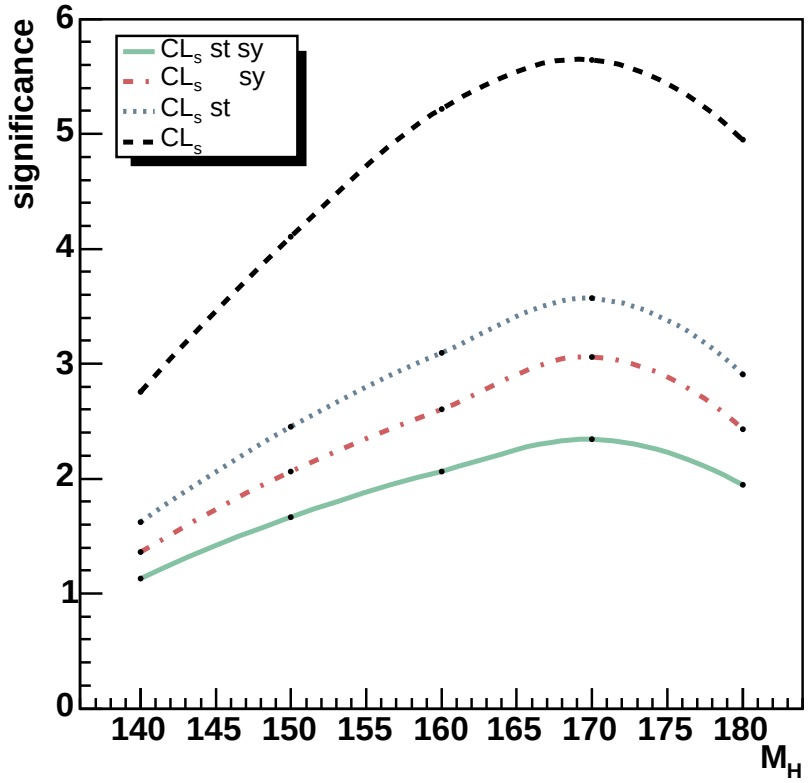
$\rightarrow (X_c^j, p_c^j)$

Significance

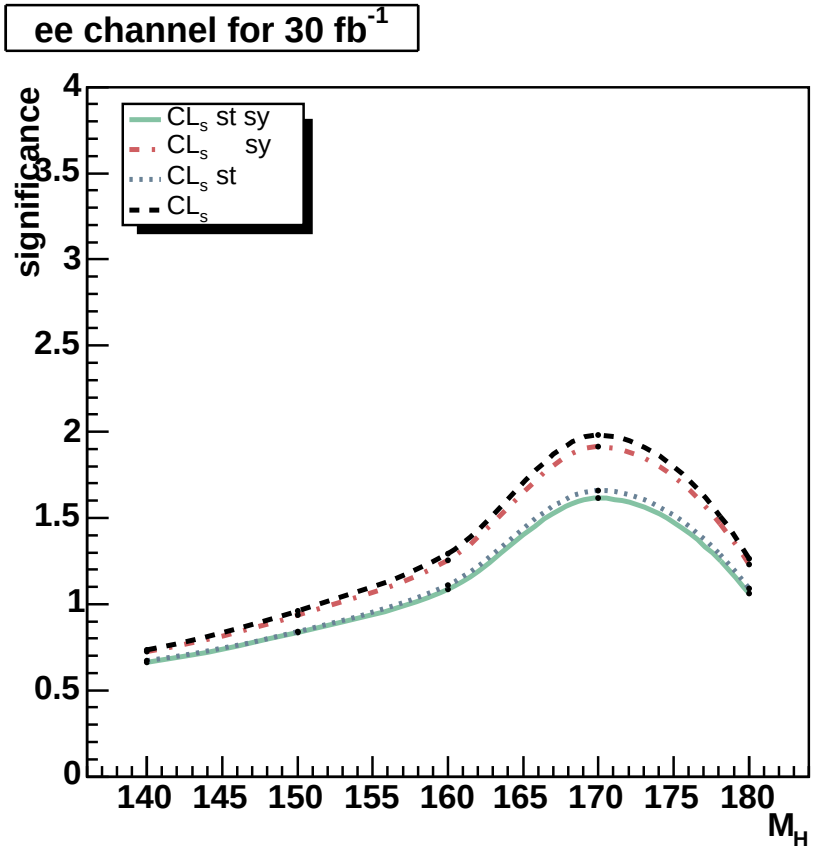
ee, eμ and μμ channels combination for 30 fb^{-1}

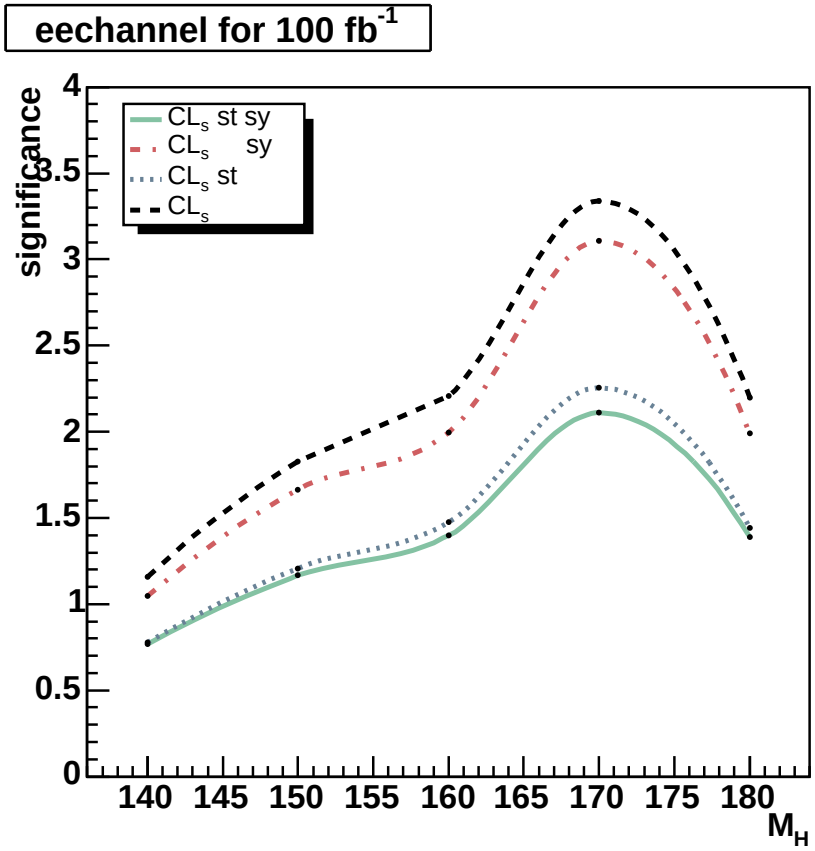


ee, eμ and μμ channels combination for 100 fb^{-1}



Significance





Significance

Integrated luminosity (fb^{-1}) needed to reach 3 and 5 sigma, for the signal with $m_H = 170$ GeV/c^2.

		st sy	st –	– sy	– –
3σ					
	3l	12.71	13.03	13.10	12.17
	2ssl	/	50.83	97.08	25.91
	3l+2ssl	10.47	8.91	9.85	8.21
5σ					
	3l	37.91	41.65	36.91	35.77
	2ssl	/	456	/	70.64
	3l+2ssl	50.75	29.96	33.10	24.27

Conclusion

- Increase the Christophe's results for 3σ.
- Statistical uncertainties (and be carefull with some backgrounds).
- A stronger "2 same sign muons" cut.