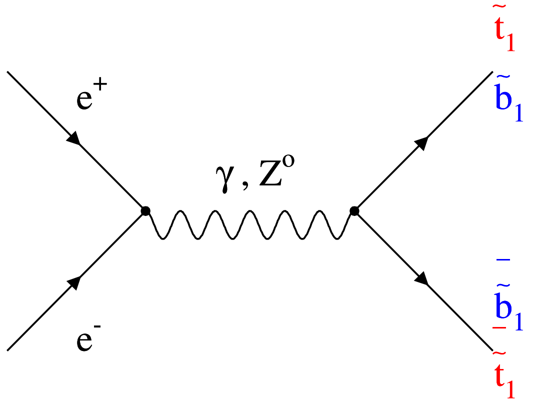
Introduction

Squark Searches from 189 to 208 GeV



$$\tilde{t}_1 \rightarrow c\widetilde{\chi}^0_1$$
$$\tilde{b}_1 \rightarrow b\widetilde{\chi}^0_1$$

2 acoplanar jets + missing energy

Outline :

- **Data/MC comparison**
- **Neural network training**
- **Results**
- **Systematics**

Analysis Framework

- **SUSANA:**
  - The squark analysis is integrated in the SUSANA ntuples.
  - Data and Monte-Carlo from 189 to 208 GeV have been processed and are available on the 2 PC's DELSUSY1 and DELSUSY2.
  - All the informations to use those ntuples are available at the URL:

    http://delphiwww.cern.ch/teams/searches/delwww/susy/index.html

- **Analysis description:**
  - A common preselection for the stop and sbottom analysis is aplied.
  - Events are forced in 2 jets using the Durham algorithm.
  - The final selection is performed using Neural networks trained for each mass window of the stop and sbottom analysis.

Data/MC samples

Data/MC samples

- **The main backgrounds are:**

2-fermions	$e^+e^- \rightarrow q\bar{q}(n\gamma)$	**PYTHIA 5.7** **PYTHIA 6.135**	**at $\sqrt{s}$ =189 GeV** **at $\sqrt{s}$ ≥192 GeV**
4-fermions	**WW-like** $e^+e^- \rightarrow \nu\nu qq$ $e^+e^- \rightarrow e\nu qq$	**EXCALIBUR** **EXCALIBUR** **GRACE**	**available at all $\sqrt{s}$**
$\gamma\gamma \rightarrow$ **hadrons**	**(no-tag)**	**TWOGAM 2.02** **PYTHIA 6.143**	**Biased samples** **at 189 and 200 GeV** **Used as cross-check** **at the preselection level**

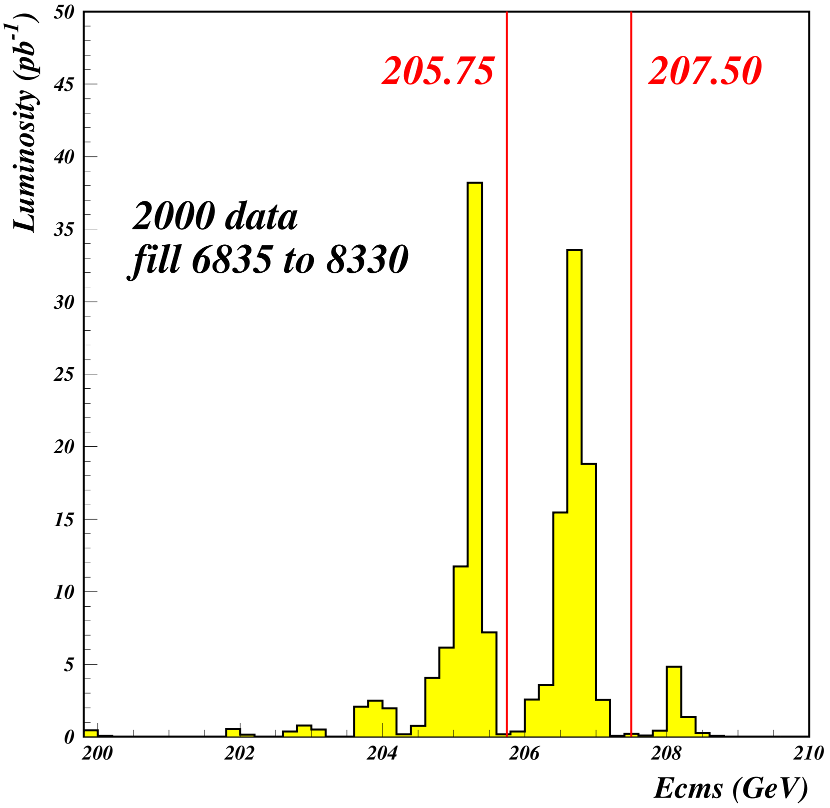
- **Data Samples:**

  - **All lumisosity from STILUM data files.**
  - **2000 data until fill number 8330**
(TPC "without" sector 6 since fill 8332)

$\sqrt{s}$ (GeV)	189	192	196	200	202	≥ 204
$\mathcal{L}$ (pb^{-1})	158.	25.85	76.42	83.37	40.64	162.11

2000 data

- Centre-of-mass energy versus luminosity :
  (from STILUM00.30AUG00)



$\Longrightarrow$ 3 Ecms analysis windows :

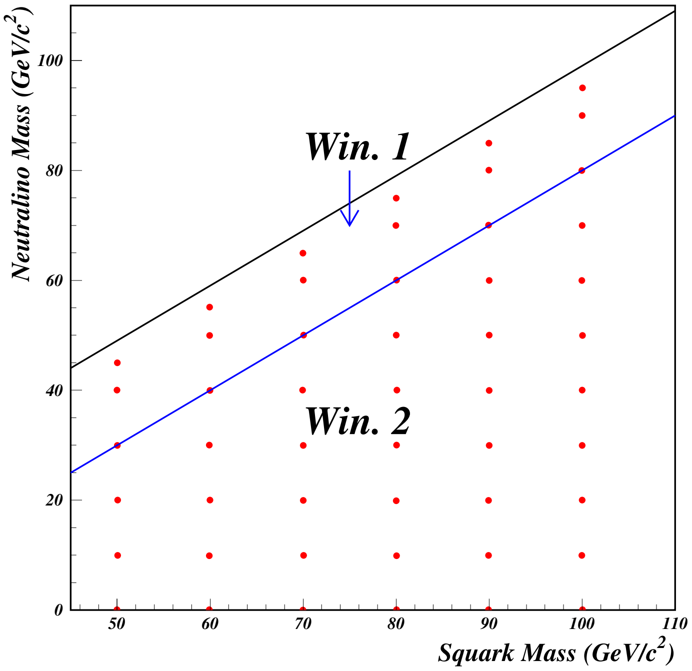
	$\sqrt{s}$	$\mathcal{L}$	$\langle\sqrt{s}\rangle$	MC samples
window 1	$\leq$ 205.75	77.92	204.8	204
window 2	$\in$]205.75,207.5]	76.95	206.6	206
window 3	$>$ 207.5	7.24	208.1	208

Mass Analysis Windows

• 2 mass analysis windows:

- **ΔM < 20 GeV:** $\gamma\gamma \rightarrow$ **hadrons**
- **ΔM ≥ 20 GeV: QCD and 4-fermions**

Analysis are optimised until $\Delta M = 5\ GeV$



• Signal samples:

Signals simulated with full detector response (DELSIM+DELANA)

- **Stop : (generator from M. Besançon) at 189, 200 and 206**
- **Sbottom : (SUSYGEN) at 189, 200 and 206**

$\sim$ **1000 events per points in the plane** $(m_{\tilde{q}_1}, m_{\tilde{\chi}_1^0})$

Preselection

- **Common preselection from 189 to 208 GeV**

- **Efficiency after the DELANA event filter (at 200 GeV)**

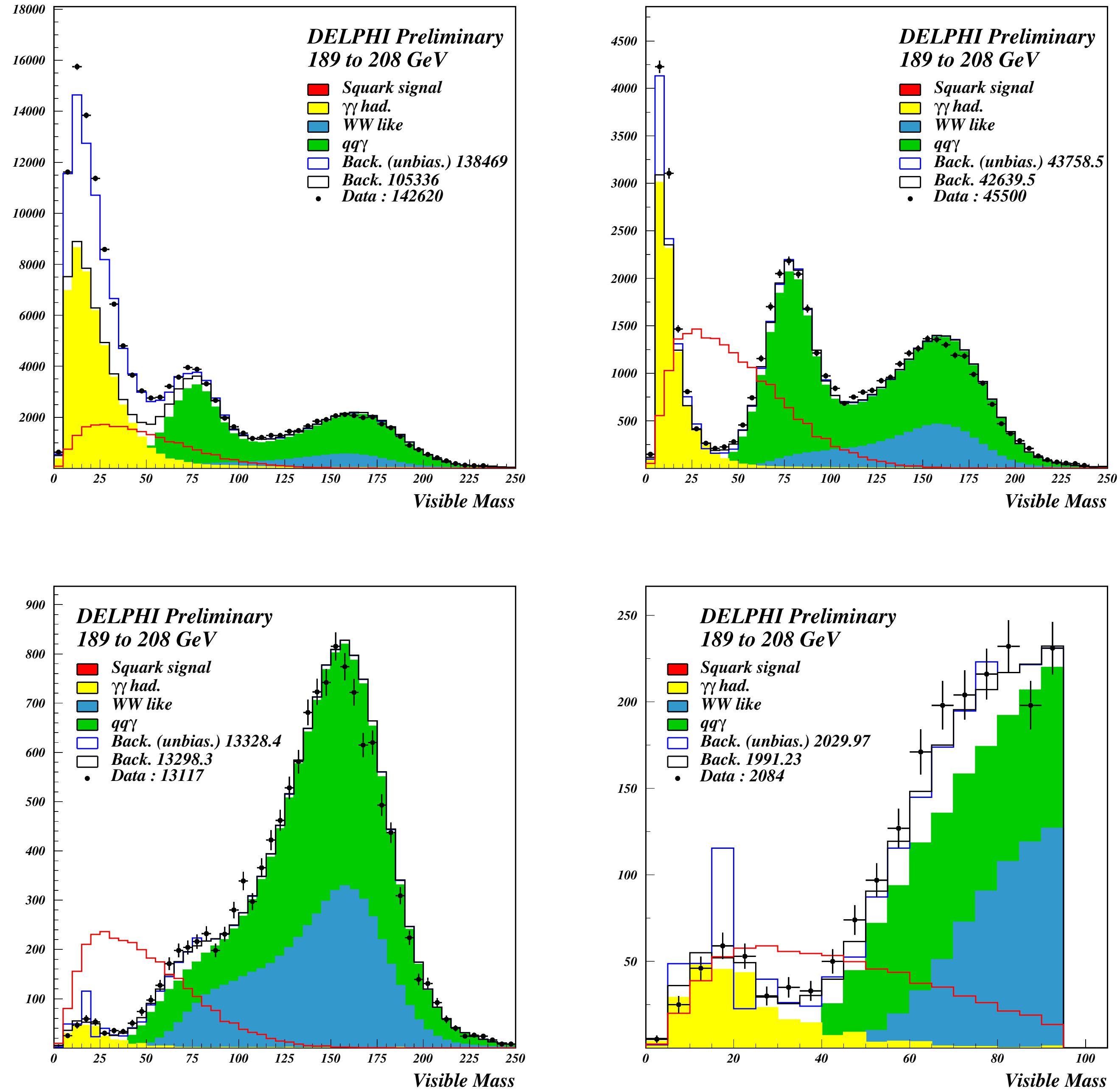
	(50,40)	(50,45)	(90,80)	(90,85)
Stop	97.6	94.6	98.0	84.2
Sbottom	98.4	95.4	94.2	52.2

- **SUSANA selection:**
  - **Transverse Energy greater than 4 GeV**
  - **At least 1 charged particles with $P_t > 1.5$ GeV/c**
- **Hadronic selection, anti-$\gamma\gamma$:**
  - **At least 4 TPC tracks**
  - $E_{STIC}/E_{vis} < 0.7$
  - $\theta_{thrust} \in]30,150[$
  - $P_{TPC}/E_{cha} > 0.55$
  - **at least 6 charged particles**
  - **Hermiticity cut : IHER(1) from SUSANA**
  - $E^{max}_{neut.} < 40$ **GeV**
- **Pre-selection:**
  - P_t^{mis} **greater than 4** GeV/c
  - $\theta_{P_{mis}} \in]24,156[$
  - $E_{20}/E_{vis} < 0.1$
  - **Visible mass less than 95** GeV/c^2

Data MC comparison

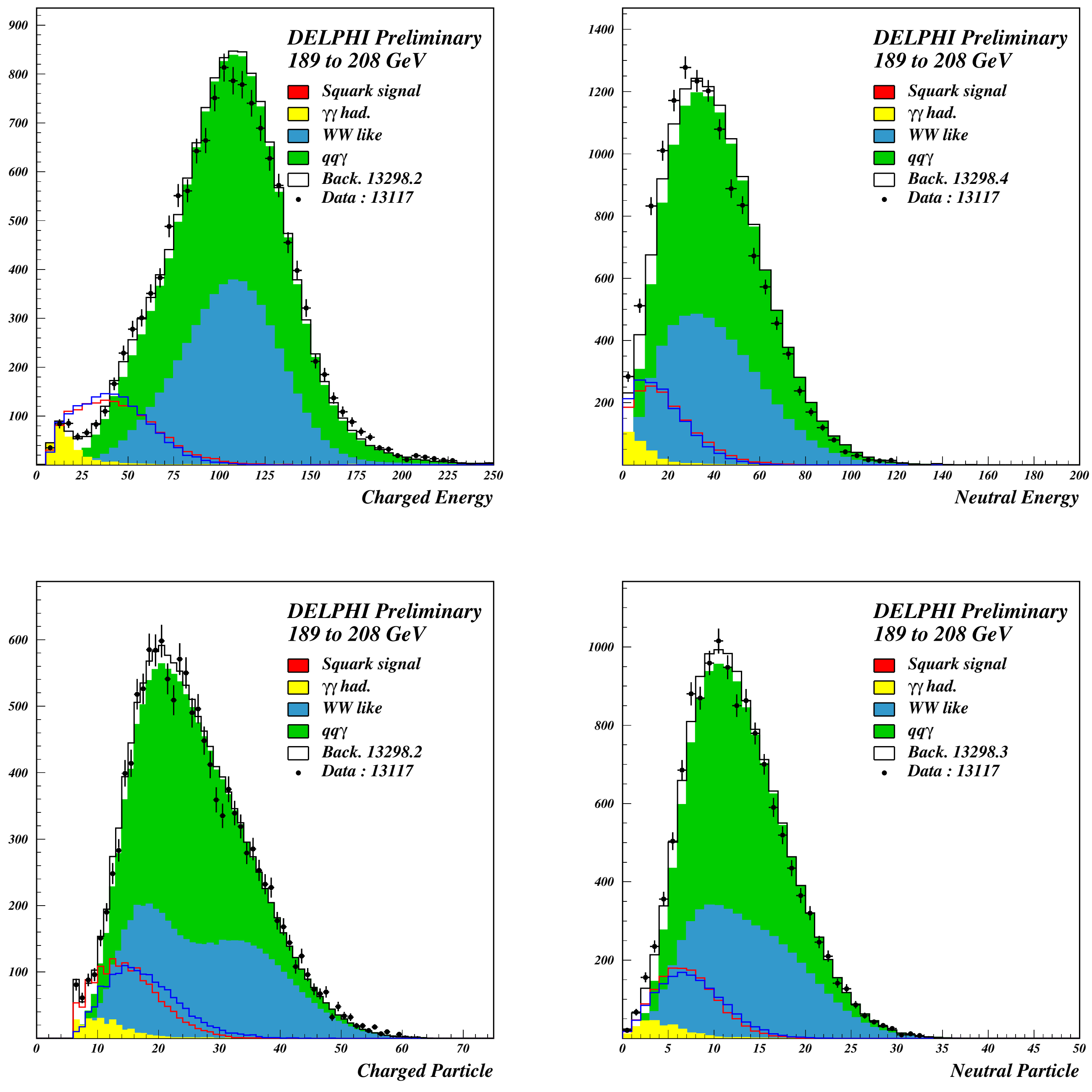
• Visible mass during the pre-selection step

- (1) After "$E_{STIC}/E_{vis} < 0.7$"
- (2) After "at least 6 charged particles"
- (3) After "$E_{20}/E_{vis} < 0.1$"
- (4) After "visible mass less than 95 $\mathrm{GeV/c^2}$"

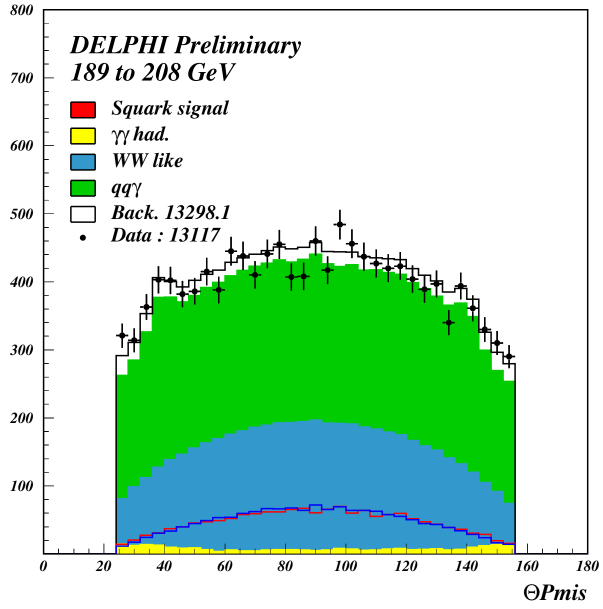


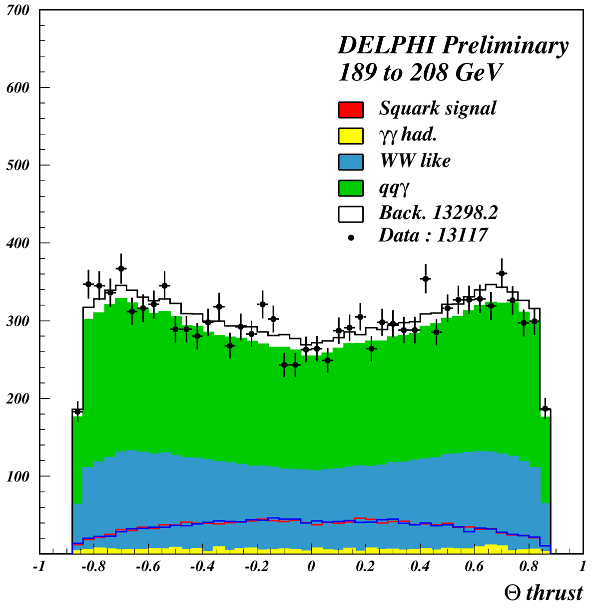
Data MC comparison

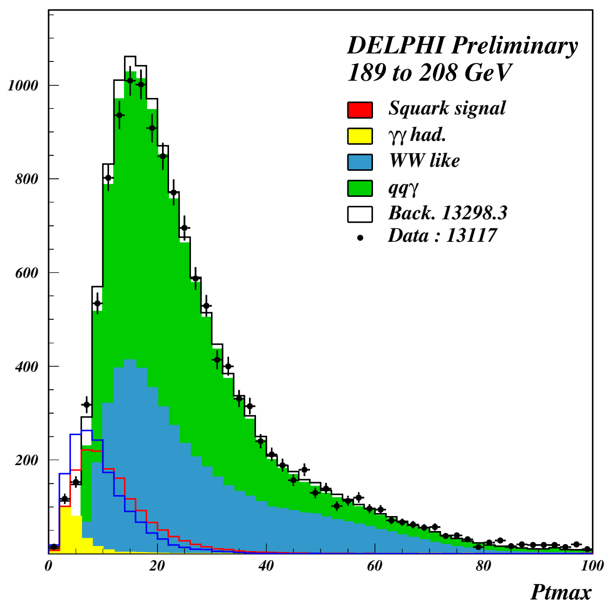
- **Before the cut on visible mass**

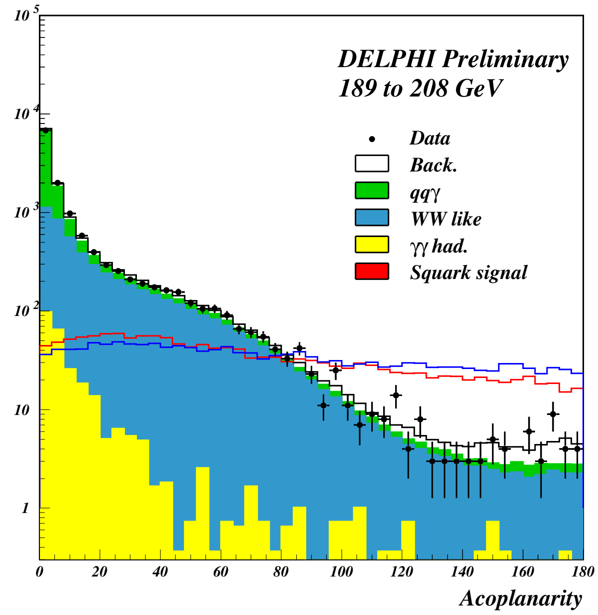


Data MC comparison



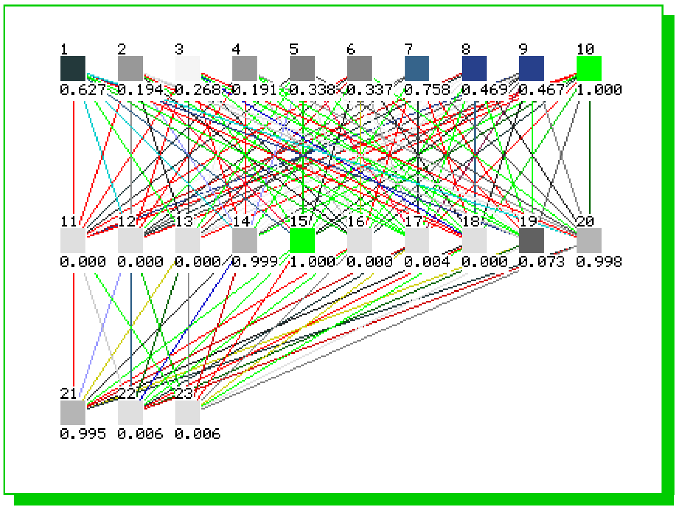






Neural Networks

- **Neural network structure:**
  - 10 inputs
  - 10 hidden nodes
  - 3 output nodes



- **Neural networks:**

Neural networks are trained at 189 and at 200 GeV
$\Longrightarrow$ 8 NN for the stop and sbottom analysis are used

	node 1	node 1	node 3
Signal	1	0	0
QCD,4-Ferm.	0	1	0
$\gamma\gamma \rightarrow$ had.	0	0	1

- **Training and validation samples:**
  - Stop or sbottom signal of the mass window
  - PYTHIA QCD and 4-fermions (ZZ,Wev,Zee) + EXCALIBUR (vvqq) + GRACE (evqq)
  - TWOGAM GGM1 sample (and GGM3 at 189 GeV)

Training samples are not used to evaluate the background in the analysis, except the $\gamma\gamma \rightarrow$ *hadrons* backgrounds (GGM1).

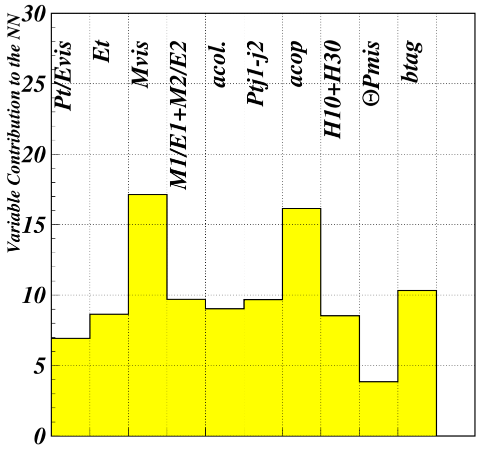
Neural Networks

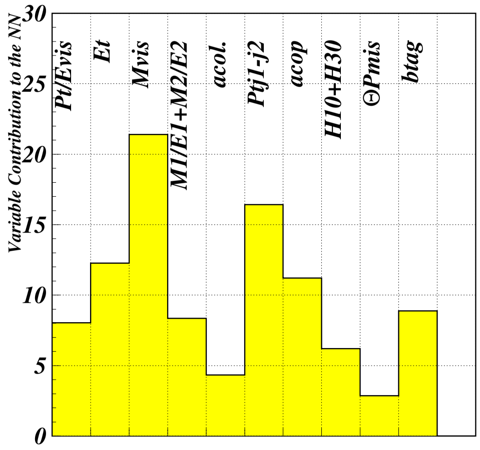
- **Neural network inputs:**

- The 10 input variables are the same for all NN
- They are normalised between 0. and 1.

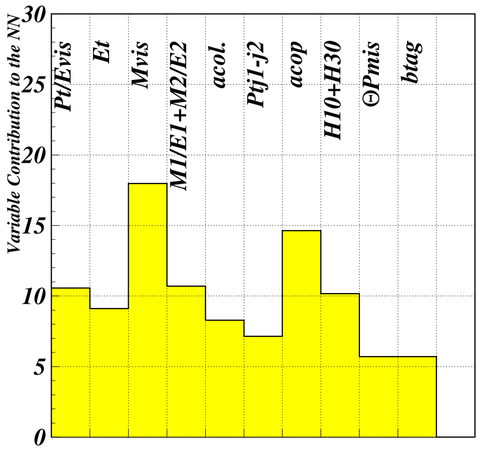
• P_t^{mis}/E_{vis}	• $\sqrt{P_{t1}^2 + P_{t2}^2}$
• E_t	• acoplanarity
• M_{vis}	• H10+H30
• $M_{j1}/E_{j1} + M_{j2}/E_{j2}$	• θ_{Pmis}
• acolinearity	• Prob(Z^o) 2 (jets Durham)

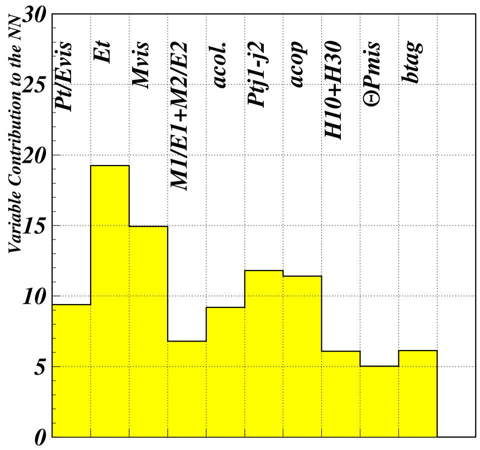
Sbottom NN at 189 GeV





Stop NN at 189 GeV

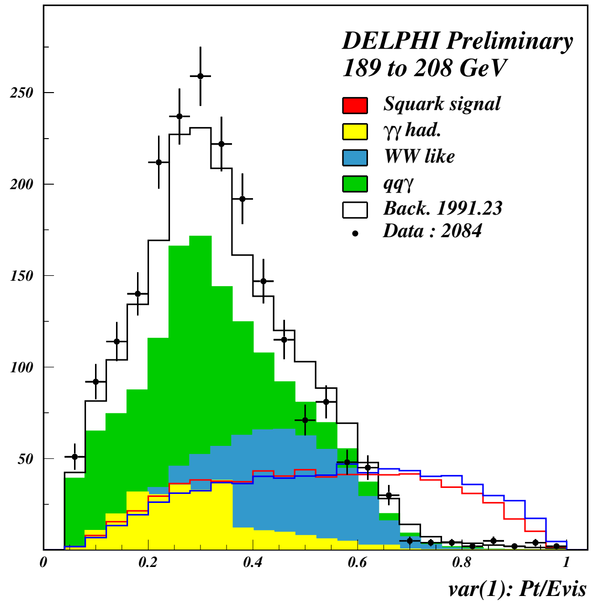


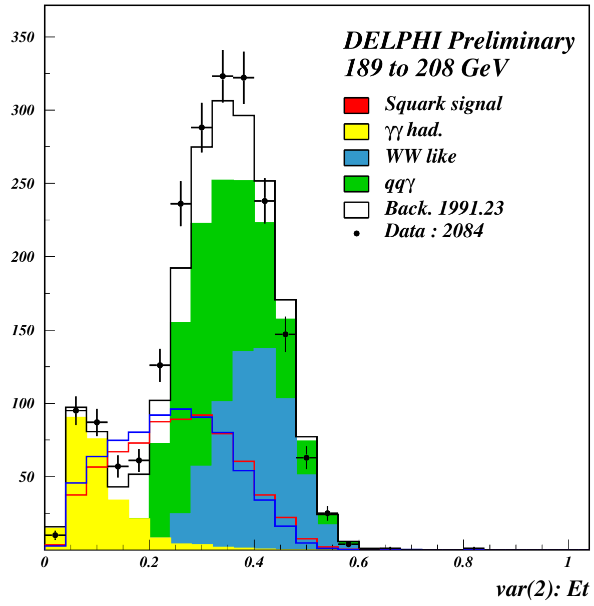


Neural Networks Inputs

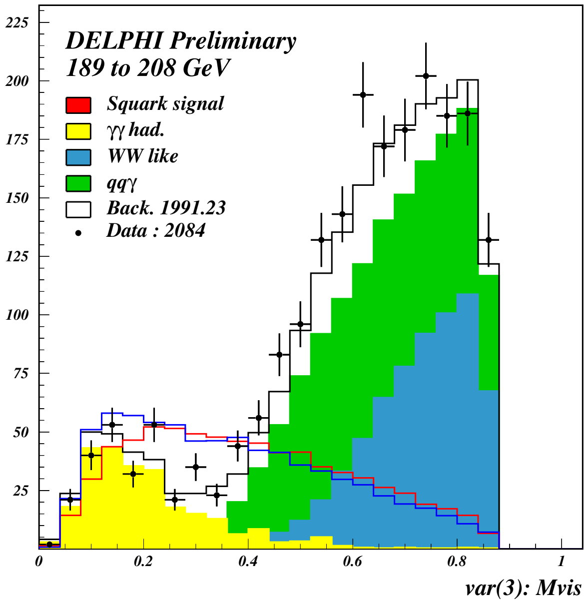
• Neural network outputs:

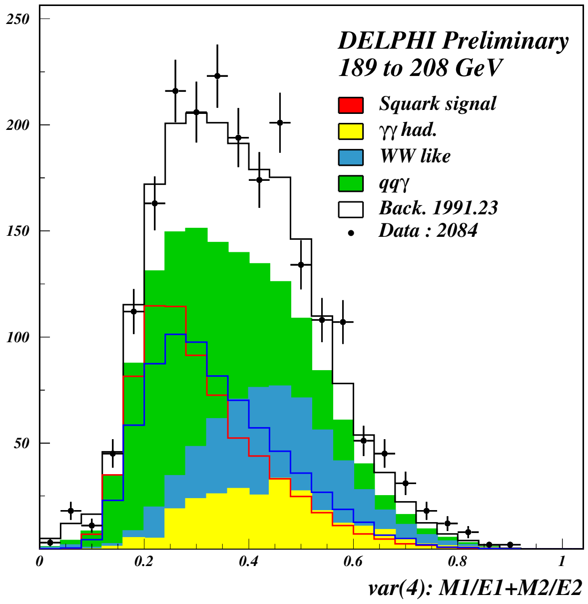
- Neural Networks **trained at 189 GeV**
  ⟹analysis at 189
- Neural Networks **trained at 200 GeV**
  ⟹analysis at 192,196,200,202,205,207,208

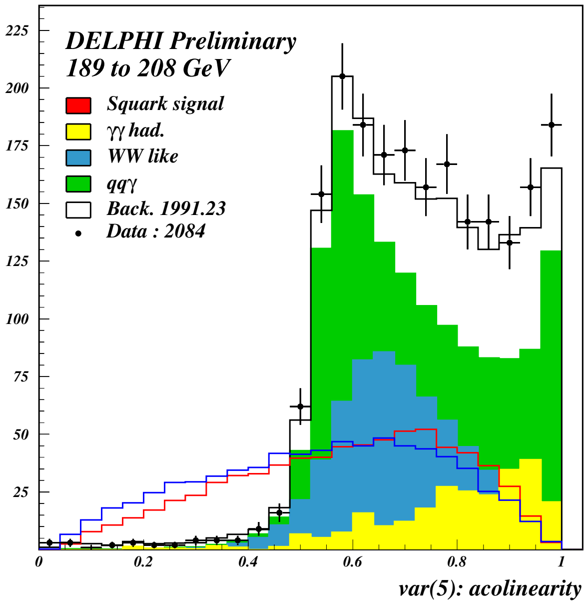


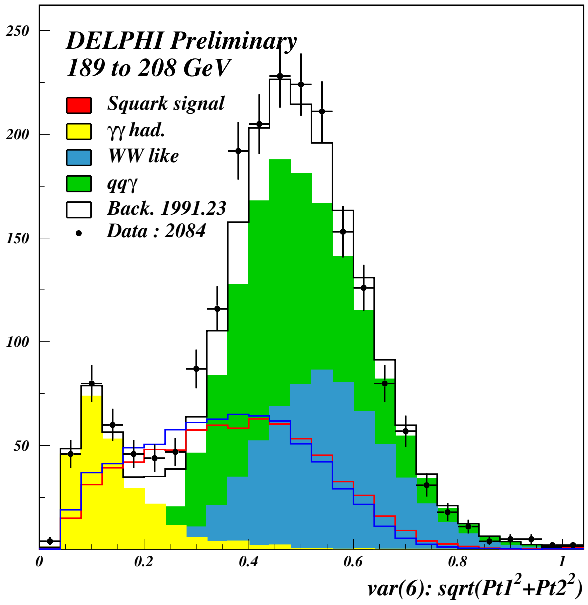


Neural Networks Inputs

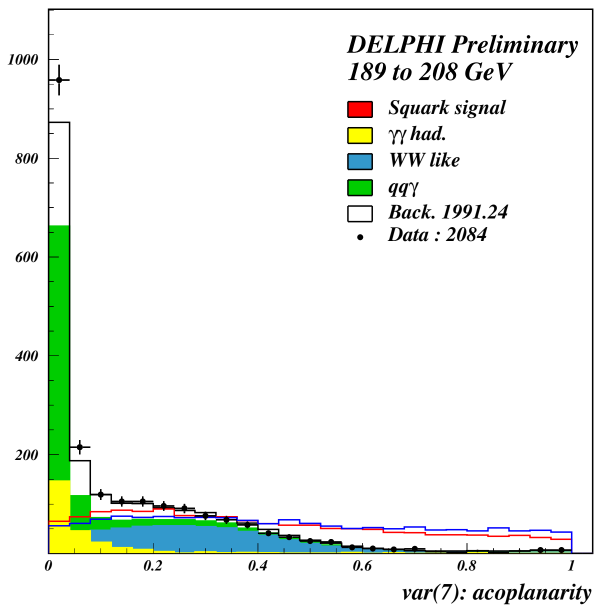


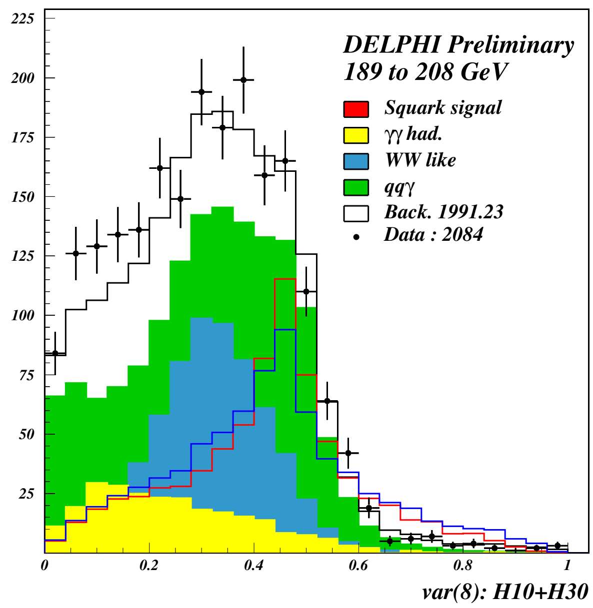


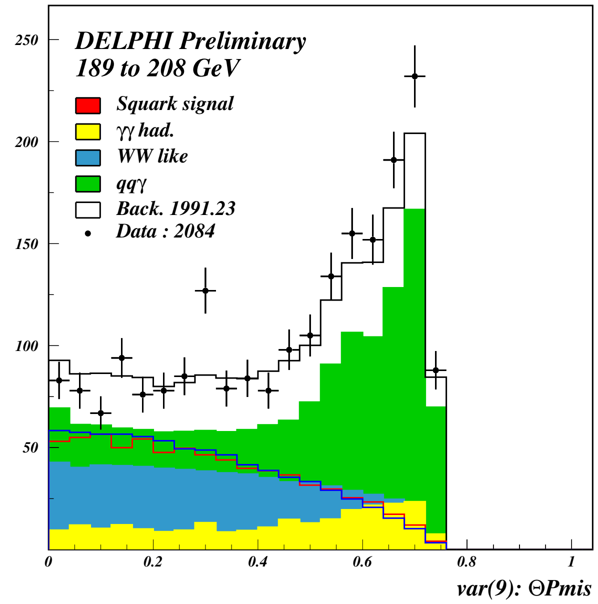


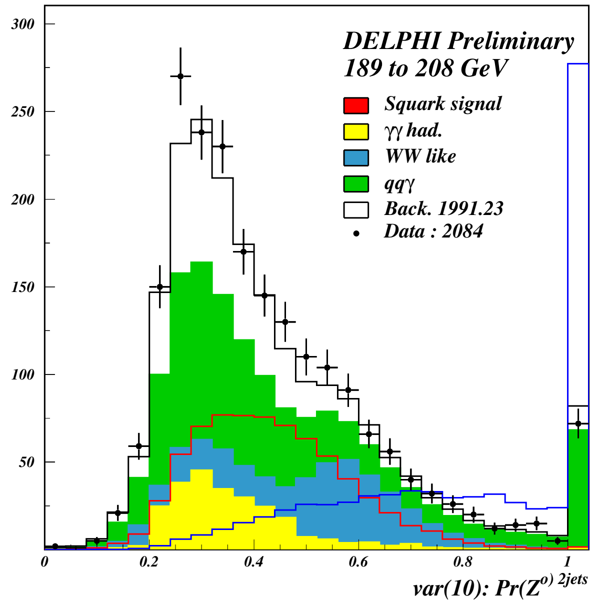


Neural Networks Inputs

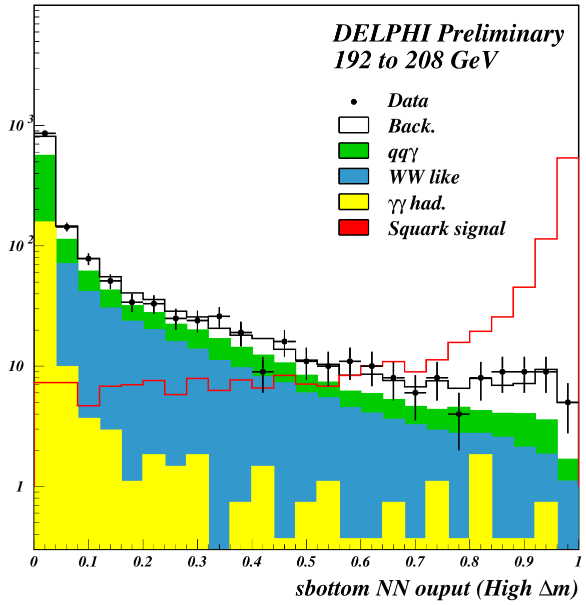


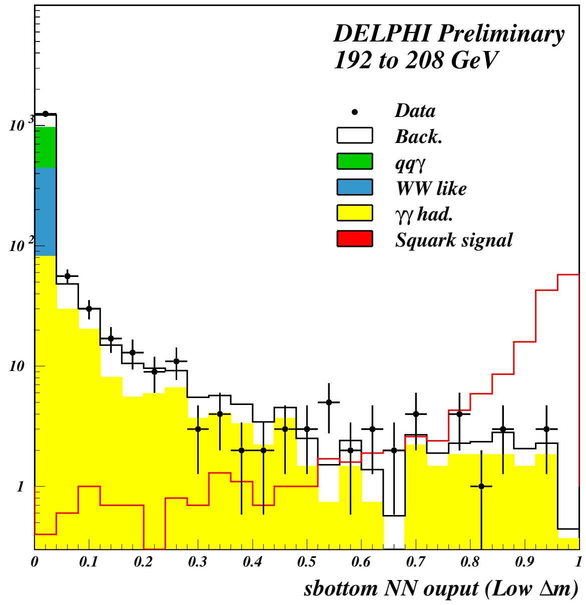


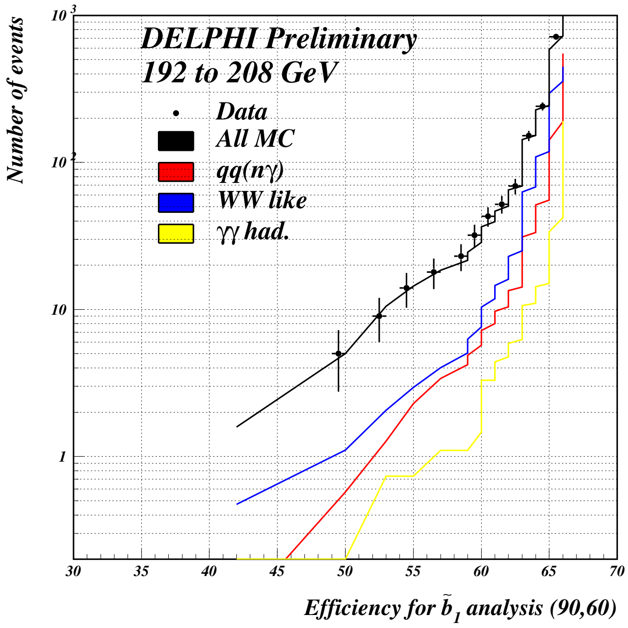


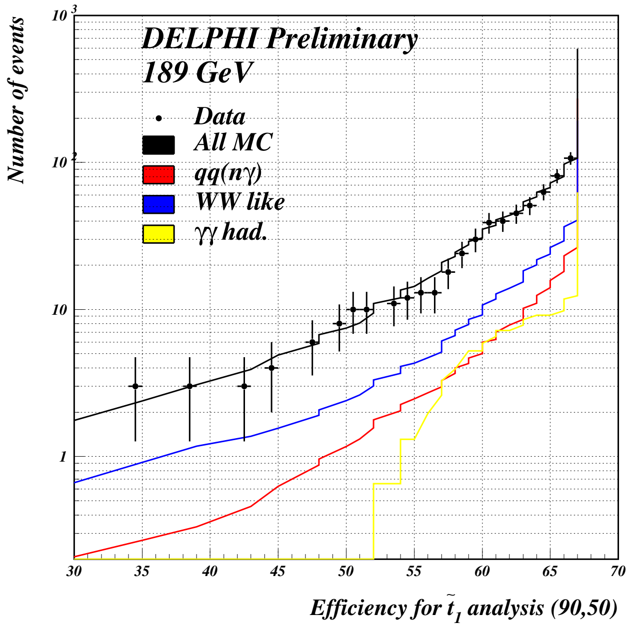


Neural Networks Outputs









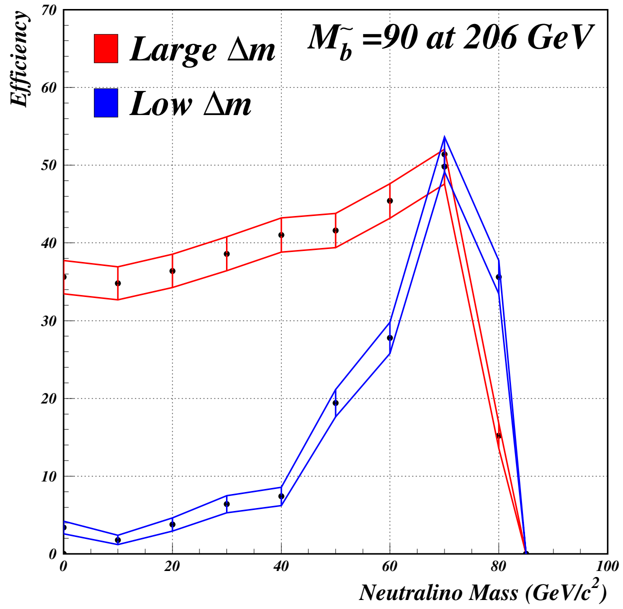
Results

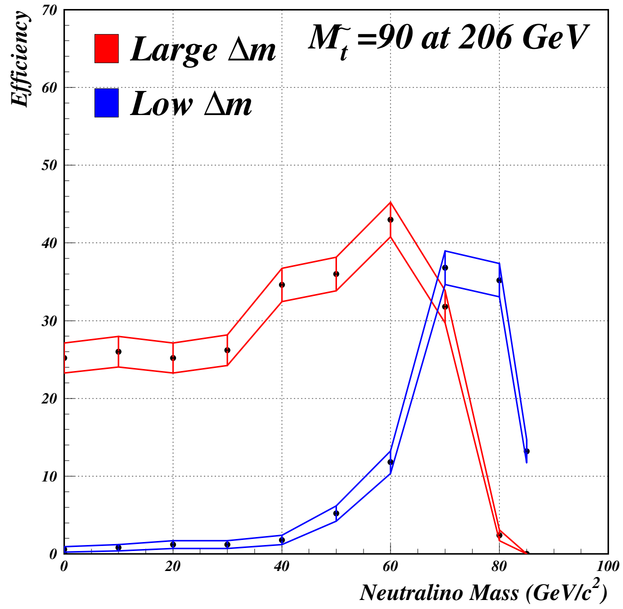
Sbottom analysis				
	$\Delta M \geq 20 GeV/c^2$		$\Delta M < 20 GeV/c^2$	
	data	MC	data	MC
188.7	3	1.16	0	1.72
191.6	0	0.18	0	0.29
195.6	0	0.66	1	0.92
199.6	0	0.57	0	1.05
201.7	0	0.28	1	0.52
204.8	1	0.70	1	1.01
206.6	0	0.52	0	0.92
208.1	0	0.06	0	0.09
Total	4	4.13	3	6.52

Stop analysis				
188.7	3	3.92	2	3.64
191.6	2	1.03	0	0.47
195.6	2	2.95	2	1.37
199.6	1	2.71	0	1.59
201.7	1	1.51	0	0.83
204.8	5	2.38	0	1.51
206.6	2	2.65	2	1.60
208.1	0	0.21	0	0.15
total	16	17.4	6	11.15

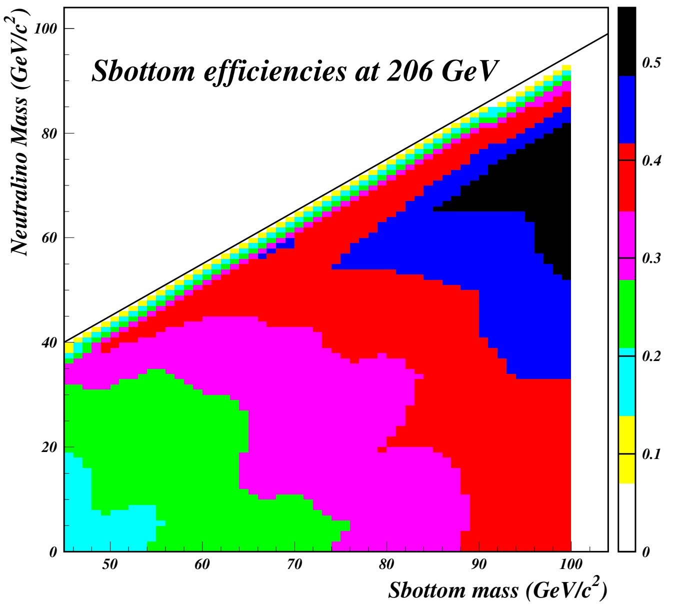
- Problem of statistic in the low ΔM:
  - Sbottom $\Delta M < 20$: 10 MC events $\Longrightarrow 3.7 \pm 1.1$
  - Stop $\Delta M < 20$: 11 MC events $\Longrightarrow 4.0 \pm 1.1$
- The same events are selected from 192 to 208 GeV

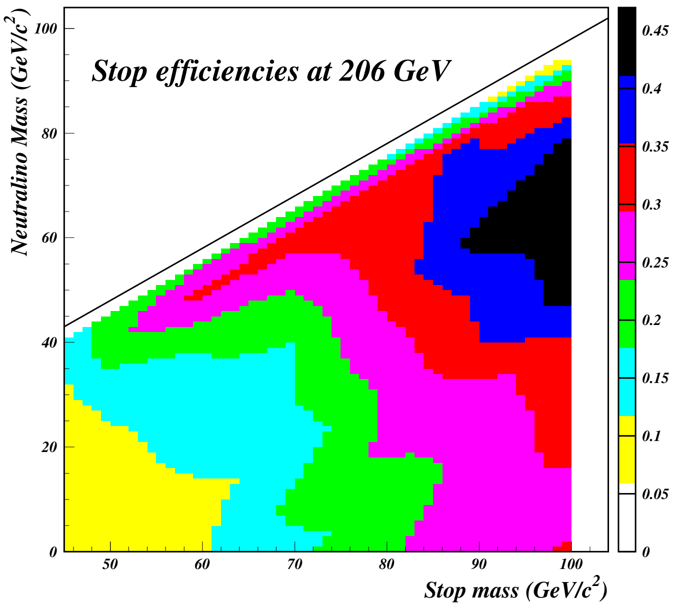
Signal Efficiencies





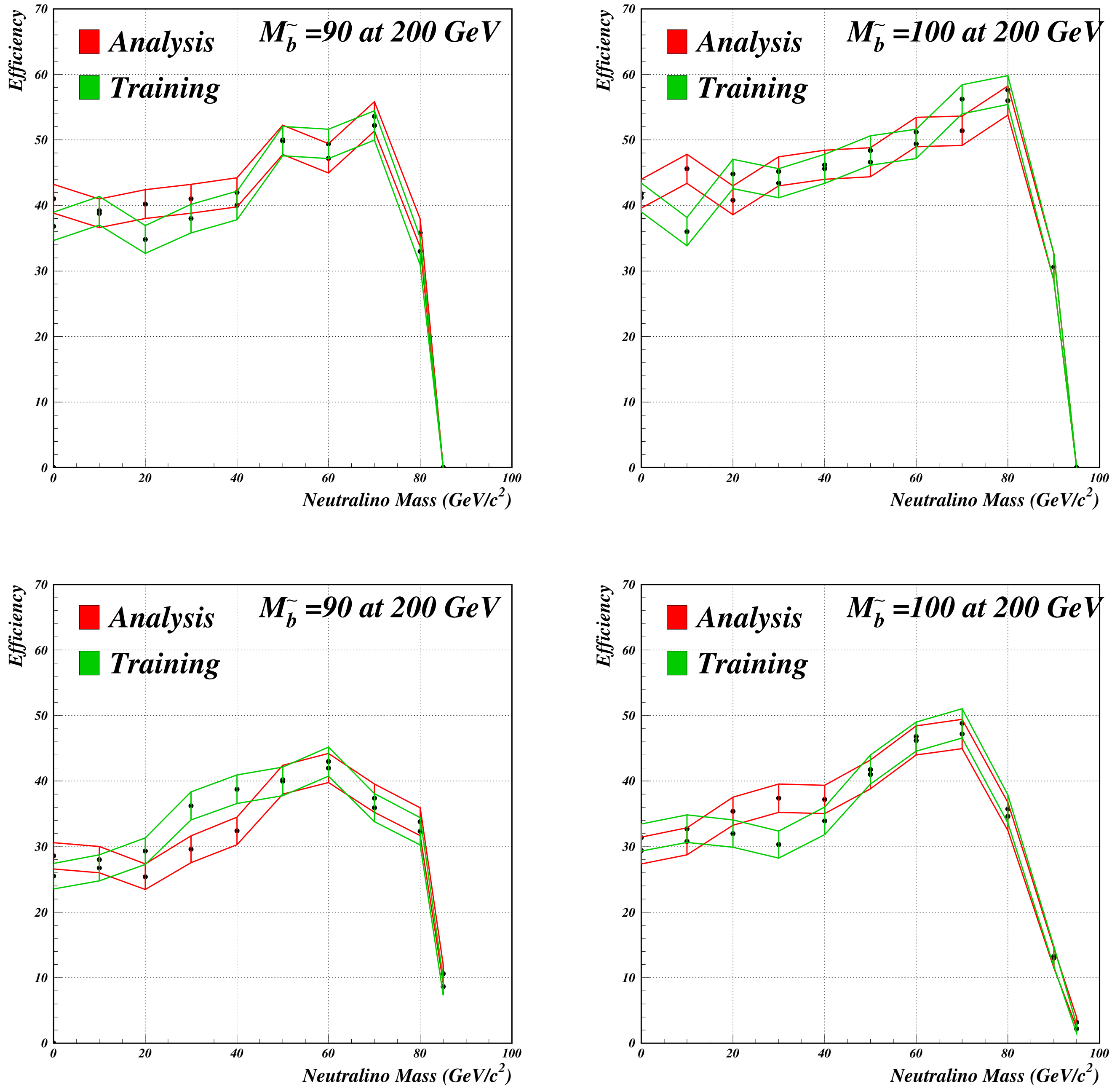
- Eficiencies are interpolated in the plane $(m_{\tilde{\mathrm{q}}_1}, m_{\tilde{\chi}^0_1})$: (1 GeV step)





Signal Efficiencies

- Comparison between training and analysis samples:



- Globally, no systematic difference is found
- Training sample is not used to evaluate the signal efficiencies

Systematics

All results are under studies, very preliminary

• Where are the problems:

- **In the background simulation:**
  - Problem of normalisation
  - local disagreements, shifts (neutral energy...)
- **In the signal simulation:**
  - Idem +
  - The stop hadronisation model

• Sbottom simulation:

- Events with another generator than SUSYGEN have to be simulated (SPYTHIA ?)
- Nabil ghodbane found a systematic difference between SUSYGEN and SPYTHIA of 5 % in the slepton channel

Signal simulation

• Stop hadronisation

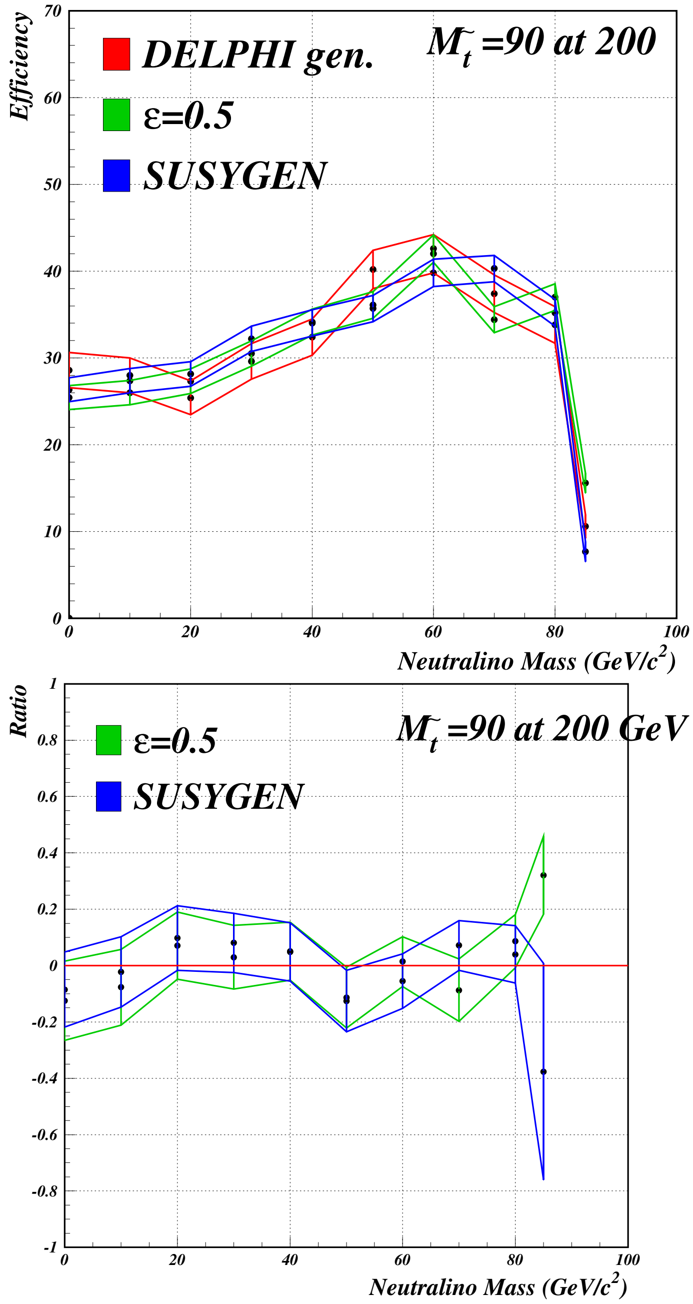
- Stop hadronisation models used two parameters:
  - The value of $\epsilon\tilde{t}_1$ in the fragmentation step

    $$\epsilon = \epsilon_{\tilde{t}_1} {m_{\tilde{t}_1}}^2 = \epsilon_b m_b^2$$

    natural values of ϵ are around 0.09
  - The effective spectator mass M_{eff}
    It should take value between 0.1 and 1 GeV/c^2
- Generators available:
  - from Marc Besançon (analysis sample)
  - STOPGEN ($\epsilon\tilde{t}_1$ and M_{eff} in the data card)
  - SUSYGEN: the hadronisation is not performed
- Samples at 189, 200, 206 GeV have been generated (DELPHI+DELANA) with the 2 other generators for $m_{\tilde{t}_1}$=90 GeV/c^2:
  - ϵ=0.05 and 0.5 (and M_{eff}=0.35 GeV/c^2)

Signal simulation

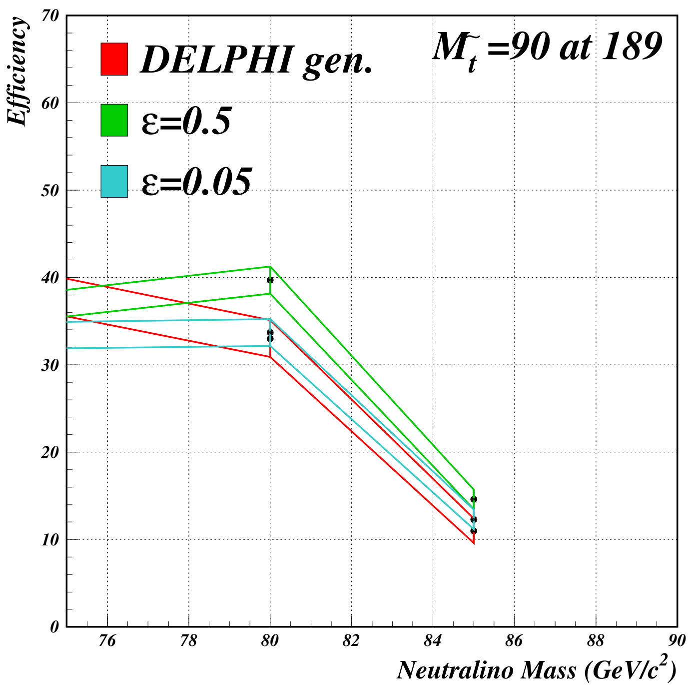
• $\Delta M > 10 \text{GeV}/c^2$

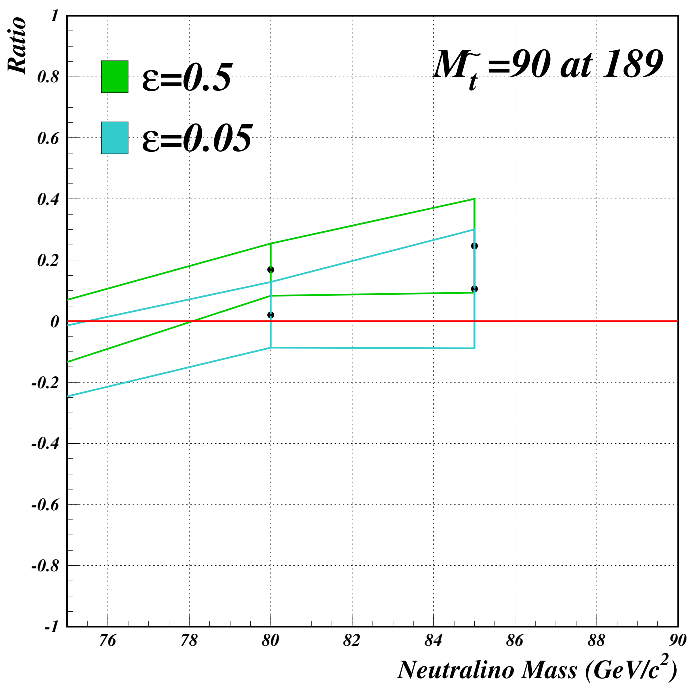


- No major difference is seen (even in models without hadronisation)
- An average relative errors calculated on all the points give a 3 % systematic effect in this region

Signal simulation

- ΔM $\leq$ 10GeV/c^2



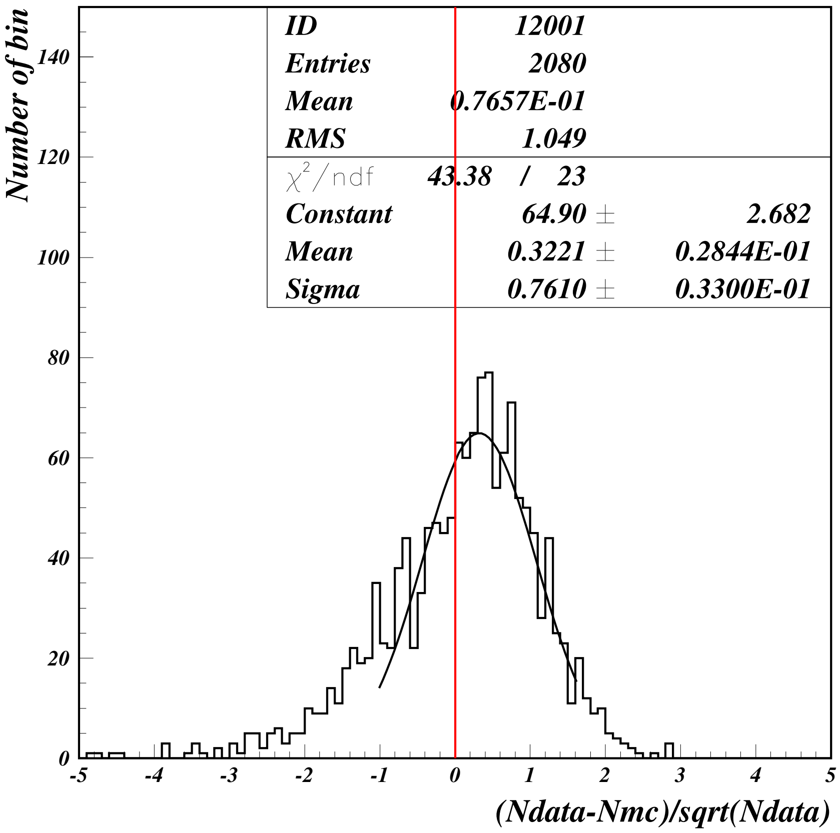


- Sample with lowered value of ϵ gives higher efficiencies compared to the sample used in the analysis
- It could explain the higher efficiencies obtain by ALEPH-OPAL at $\Delta M = 10, 5$ GeV/c^2 (same level of background)

- A systematic difference of 10 % between the sample ϵ=0.05 and 0.5 is observed
- Events have to be generated with different values of both ϵ and M_{eff}

Background simulation

- Each variable used in the neural network is separated into 25 bins
- The variables are normalised between 0. and 1.



- **Problem of normalisation**

- At the preselection level, an average difference of 5 % (combining 189 to 208 GeV data/MC) is observed.
- At each energy, the ratio Ndata/Nmc is calculated.
  $\Longrightarrow$ it translates into systematic error for the events selected by the neural network by multiplying the weight of the MC events by the ratio Ndata/Nmc observed at the preselection level.

Background simulation

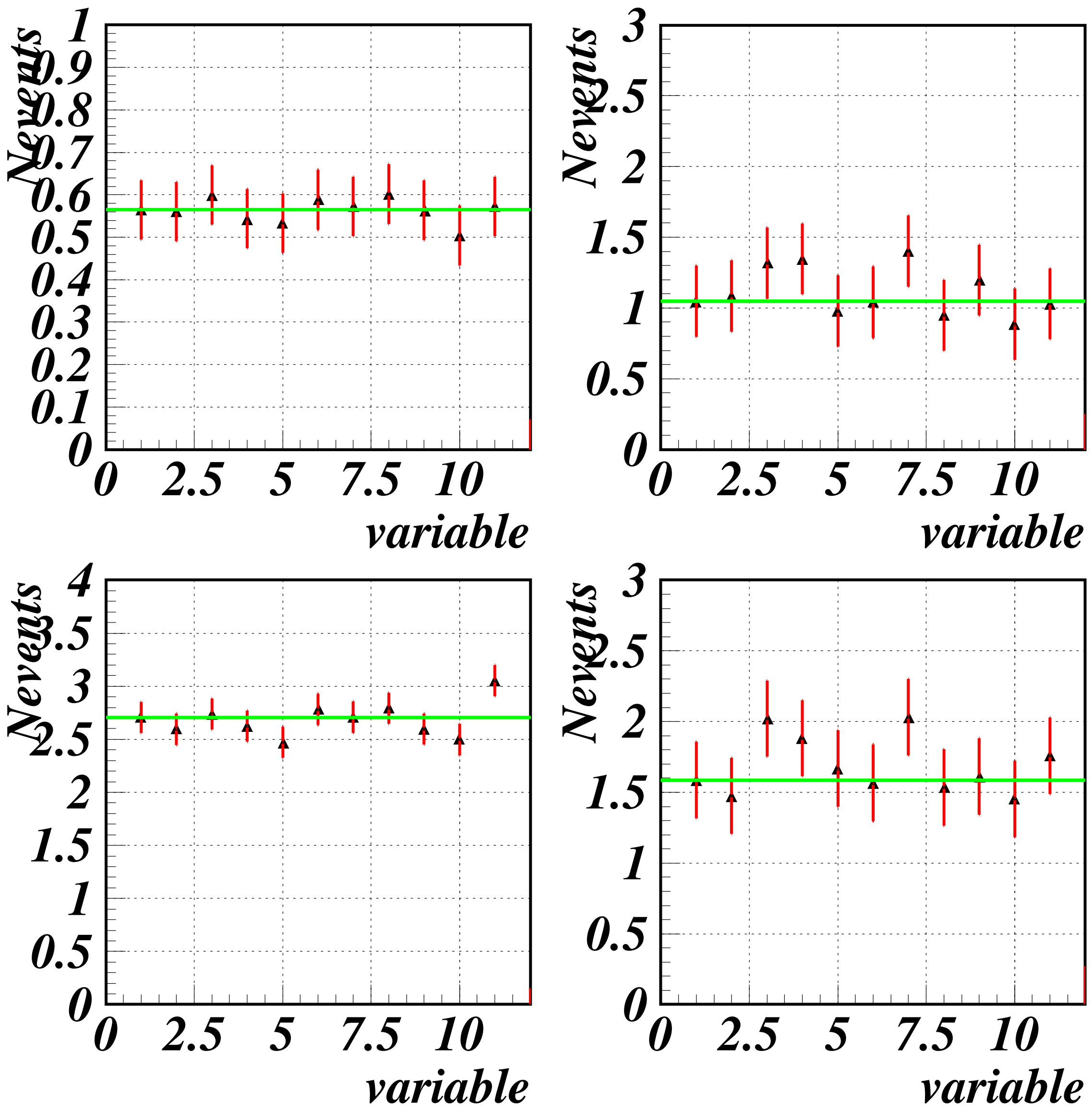
- **Problem of shape**

(after the normalisation procedure)

- **At the preselection level, for each input variable in turn:**
  - the ratio 1.-Ndata/Nmc is calculated for each bin of the input variable
  - for each event passing the neural network cut: the weight of the event is multiplied by the ratio 1.-Ndata/Nmc of the bin to which it belongs
  - The background is estimated with these new weights
- It allows :
  - to keep exactly the same Monte-Carlo sample and not to introduce new statistical fluctuation
  - to study the variable independantly
  - after varying the weights to have one perfect distribution, we can look at the effect of these new weights on the other distributions and study the correlations between variables.
  - The neural network outputs have not to be re-calculated

Background simulation

Analysis at 200 GeV



- Negative and positive effects are separated
- The quadratic sum is performed
- It is combined with the error coming from normalisation

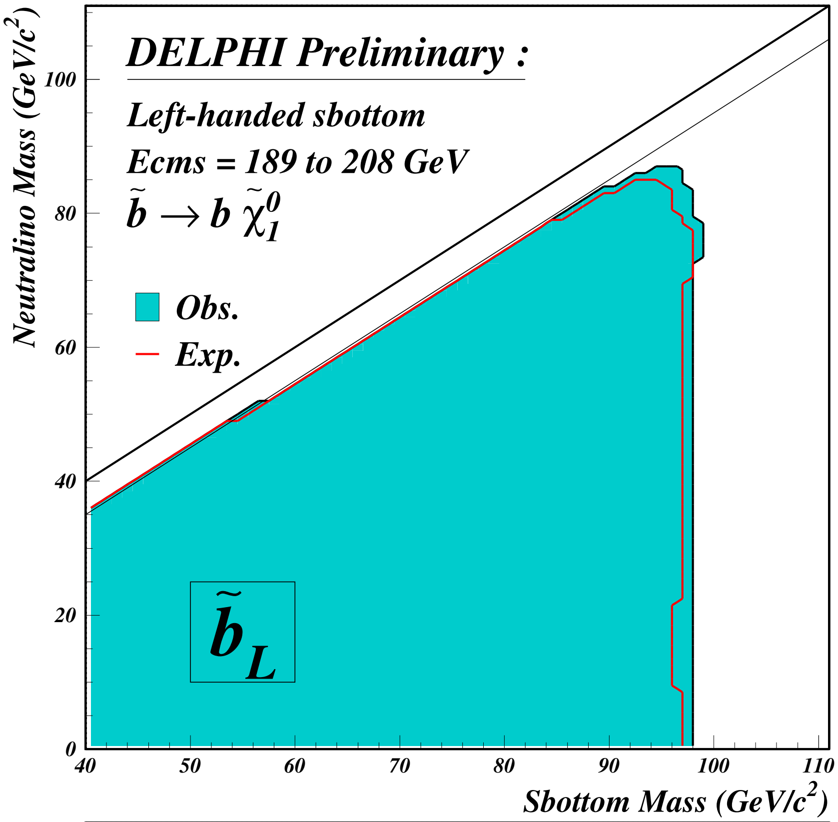
Results

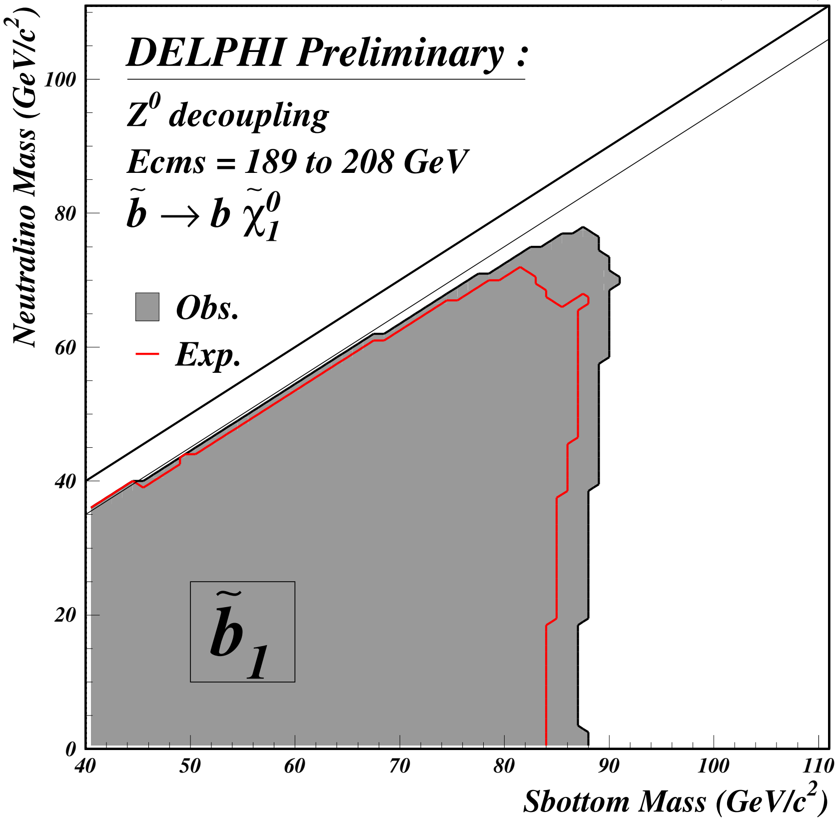
Sbottom analysis				
	$\Delta M \geq 20\mathrm{GeV/c^2}$		$\Delta M < 20\mathrm{GeV/c^2}$	
	data	MC	data	MC
188.7	3	$1.16 \pm 0.12^{+0.14}_{-0.04}$	0	$1.72 \pm 0.93^{+0.34}_{-0.08}$
191.6	0	$0.18 \pm 0.02^{+0.01}_{-0.02}$	0	$0.29 \pm 0.07^{+0.01}_{-0.03}$
195.6	0	$0.66 \pm 0.08^{+0.03}_{-0.01}$	1	$0.92 \pm 0.23^{+0.04}_{-0.10}$
199.6	0	$0.57 \pm 0.07^{+0.01}_{-0.01}$	0	$1.05 \pm 0.25^{+0.31}_{-0.04}$
201.7	0	$0.28 \pm 0.04^{+0.02}_{-0.01}$	1	$0.52 \pm 0.12^{+0.04}_{-0.02}$
204.8	1	$0.70 \pm 0.07^{+0.01}_{-0.02}$	1	$1.01 \pm 0.24^{+0.01}_{-0.24}$
206.6	0	$0.52 \pm 0.05^{+0.02}_{-0.01}$	0	$0.92 \pm 0.24^{+0.06}_{-0.04}$
208.1	0	$0.060 \pm 0.007^{+0.016}_{-0.002}$	0	$0.092 \pm 0.023^{+0.024}_{-0.001}$

Stop analysis				
	$\Delta M \geq 20\mathrm{GeV/c^2}$		$\Delta M < 20\mathrm{GeV/c^2}$	
	data	MC	data	MC
188.7	3	$3.92 \pm 0.29^{+0.66}_{-0.16}$	2	$3.64 \pm 1.17^{+1.07}_{-0.12}$
191.6	2	$1.03 \pm 0.11^{+0.15}_{-0.15}$	0	$0.47 \pm 0.09^{+0.01}_{-0.05}$
195.6	2	$2.95 \pm 0.24^{+0.23}_{-0.10}$	2	$1.37 \pm 0.25^{+0.07}_{-0.14}$
199.6	1	$2.71 \pm 0.15^{+0.13}_{-0.13}$	0	$1.59 \pm 0.27^{+0.51}_{-0.04}$
201.7	1	$1.51 \pm 0.08^{+0.02}_{-0.01}$	0	$0.83 \pm 0.13^{+0.10}_{-0.06}$
204.8	5	$2.38 \pm 0.13^{+0.11}_{-0.14}$	0	$1.51 \pm 0.28^{+0.02}_{-0.49}$
206.6	2	$2.65 \pm 0.13^{+0.06}_{-0.04}$	2	$1.60 \pm 0.27^{+0.09}_{-0.20}$
208.1	0	$0.207 \pm 0.014^{+0.055}_{-0.010}$	0	$0.146 \pm 0.026^{+0.039}_{-0.005}$

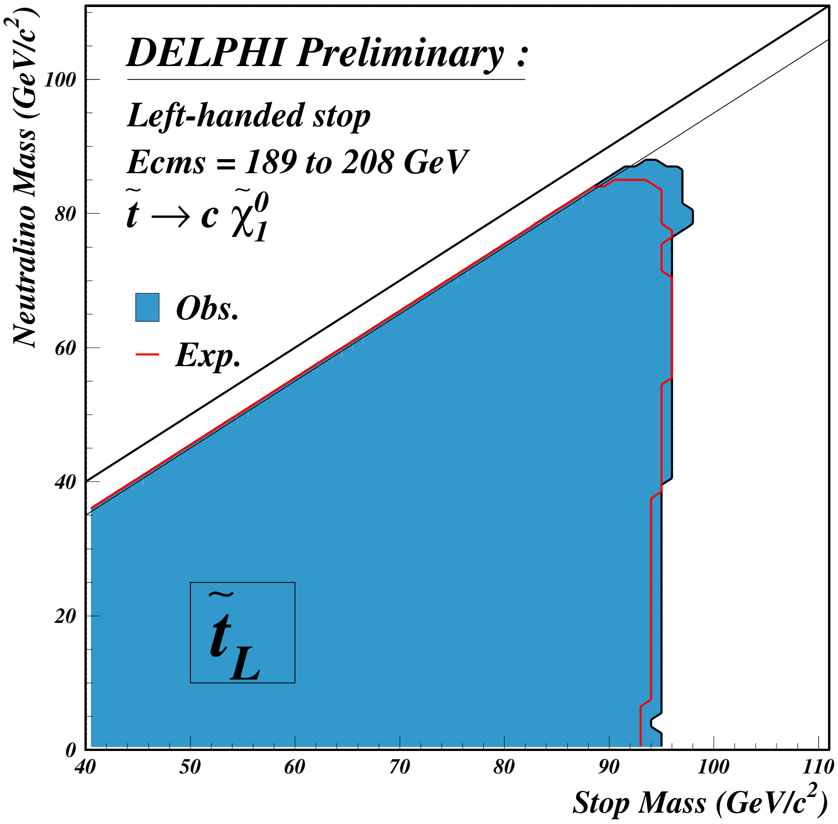
- These tables + efficiencies with signal sytematics are given to the program CLSUSY (ALRMC+SUSYGEN)
- errors are taken into account in the exclusion at 95 % CL

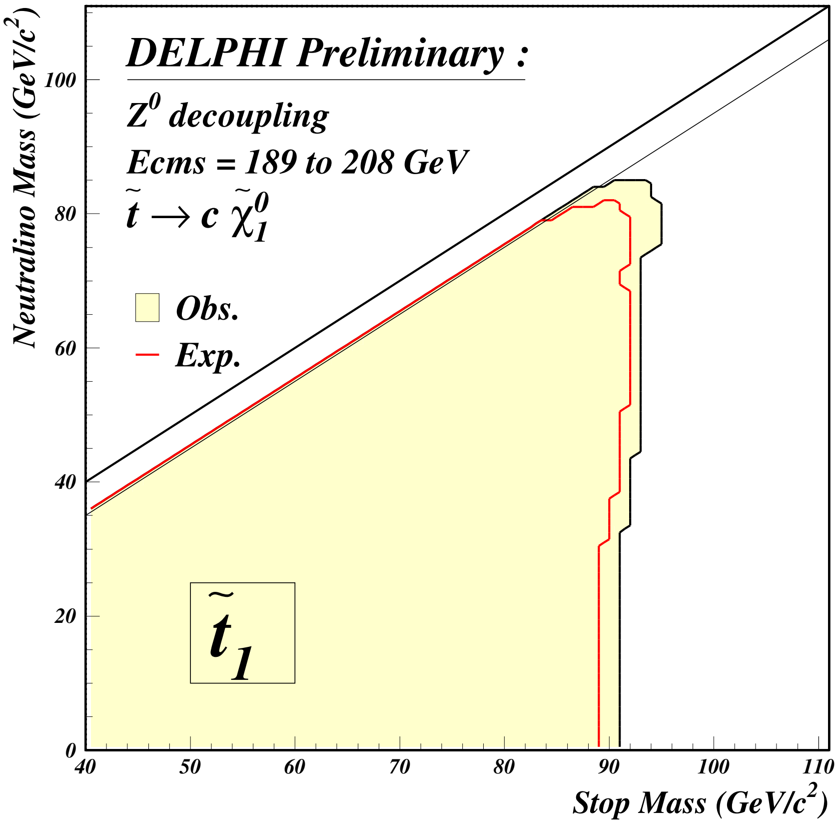
Excluded region





Excluded region

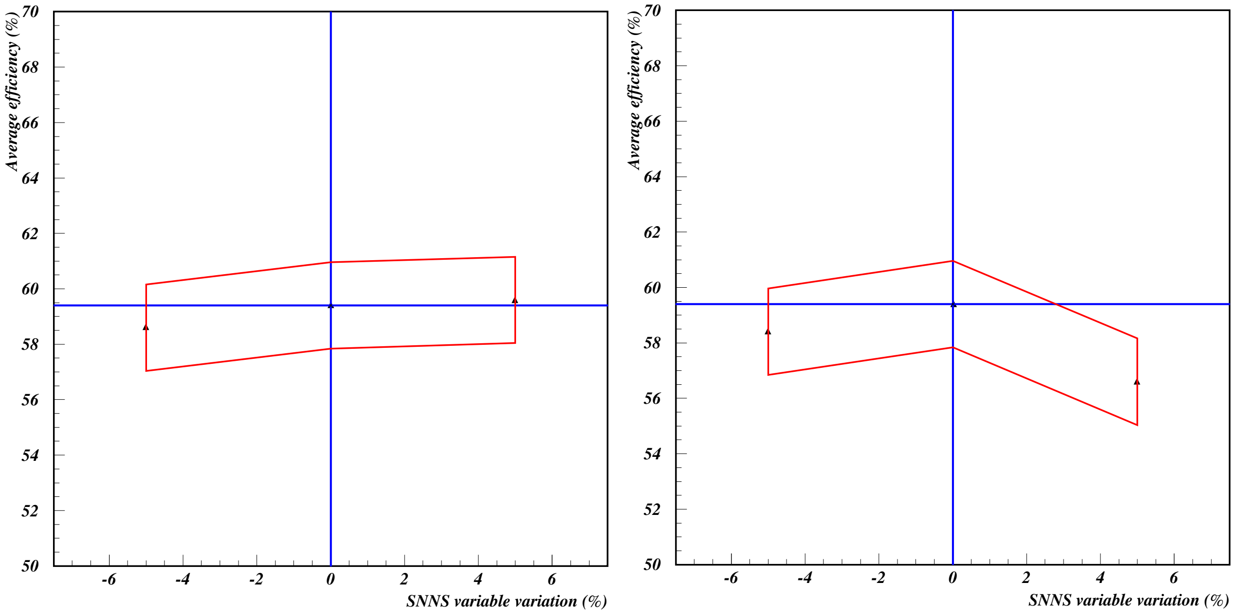




Other cross-checks

Two other cross-check of the stability of the neural network method have been performed: (not taken into account for the systematics)

- varying each input variables by the average difference in mean value observed between data and simulation at the pre-selection level. Then, the neural network outputs are re-calculated and the same cuts are applied.
  This has the incovenient to modify the statistic of the Monte-Carlo sample
- At the training level, the input variables are shifted by $\pm$ 5%. Neural networks are re-trained with shifted variables.
  Then, the analysis with non-shifted variables is applied.



var(1) : Pt/Evis *var(7) : Acoplanarity*

Conclusion

- The systematic study is performed by varying the weight of the MC
- work to be done:
  - to study the correlations between variables
  - to study the effect of this procedure on the signal
  - more signal samples are needed
- The introduction of the errors has a limited effect on the limits given at 95 % CL

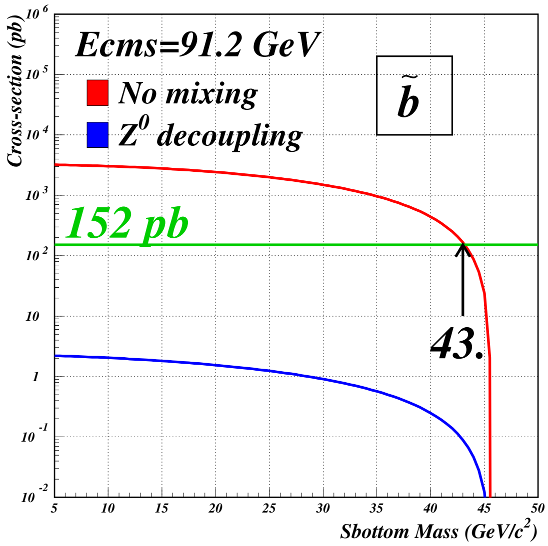
	Sbottom		Stop	
	a=0.	a=68.	a=0.	a=56.
$\Delta M \geq 7$	93.	78.	92.	89.
$\Delta M \geq 10$	97.	87.	94.	91.
$\Delta M \geq 15$	98.	87.	94.	91.

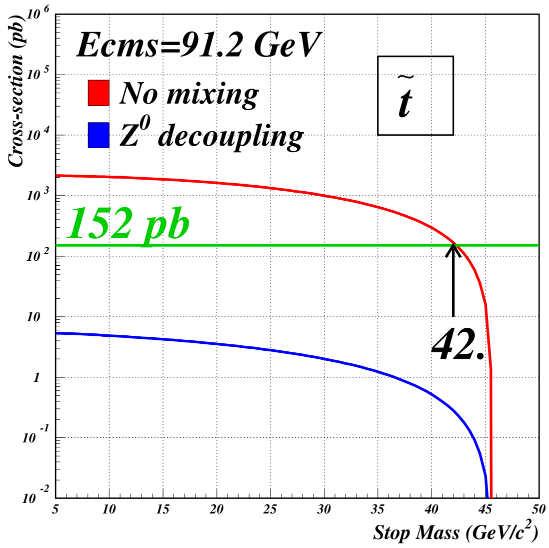
- to analyse this year data taken after the 30 august
- Final results and paper for the next DELPHI week

LEP1 exclusion

- **Squark exclusion from LEP1 data:**

$$\Gamma^{\mathrm{inv.}}_{\mathrm{Z^o}} \Longrightarrow \sigma^{\mathrm{exclu.}}_{\mathrm{NP}} = 152\ \mathrm{pb}$$





- **Purely left-handed** squarks with M $<$ 40 GeV are excluded
- **No constraints** for M $<$ 40 GeV at the $\mathrm{Z^o}$ decoupling

Excluded region