Squark searches

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

Data vs Monte Carlo at 192, 196, 200 and 202:

- New skelana version
- Comparison between the B1 and C1 processing
- Comparison between the two $\gamma\gamma$ samples

Results with Neural Networks

Limits on the squark masses

Skelana version 2.0

- New track selection ...

Neural networks

- Still trained with 189 GeV Monte-Carlo

Selection :

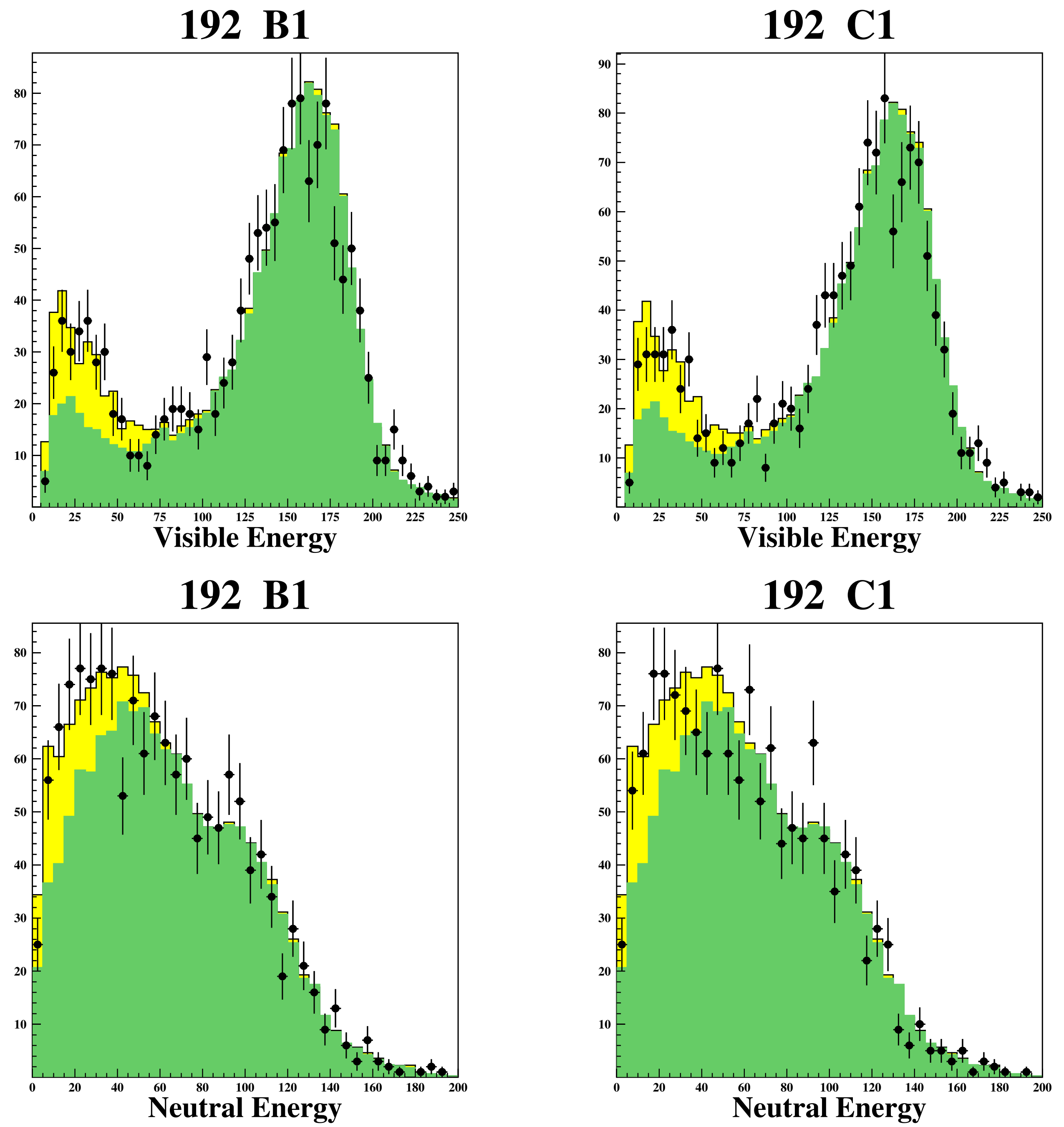
- Preselection :
  at least 5 charged particles,
  $E_t > 5\ GeV$,
  at least 1 particle with $P_t > 1.2\ GeV$
- Cut 1 : $\mid \cos(\theta^{miss}) \mid < 0.9$
- Cut 2 : $P_t^{miss} > 4$

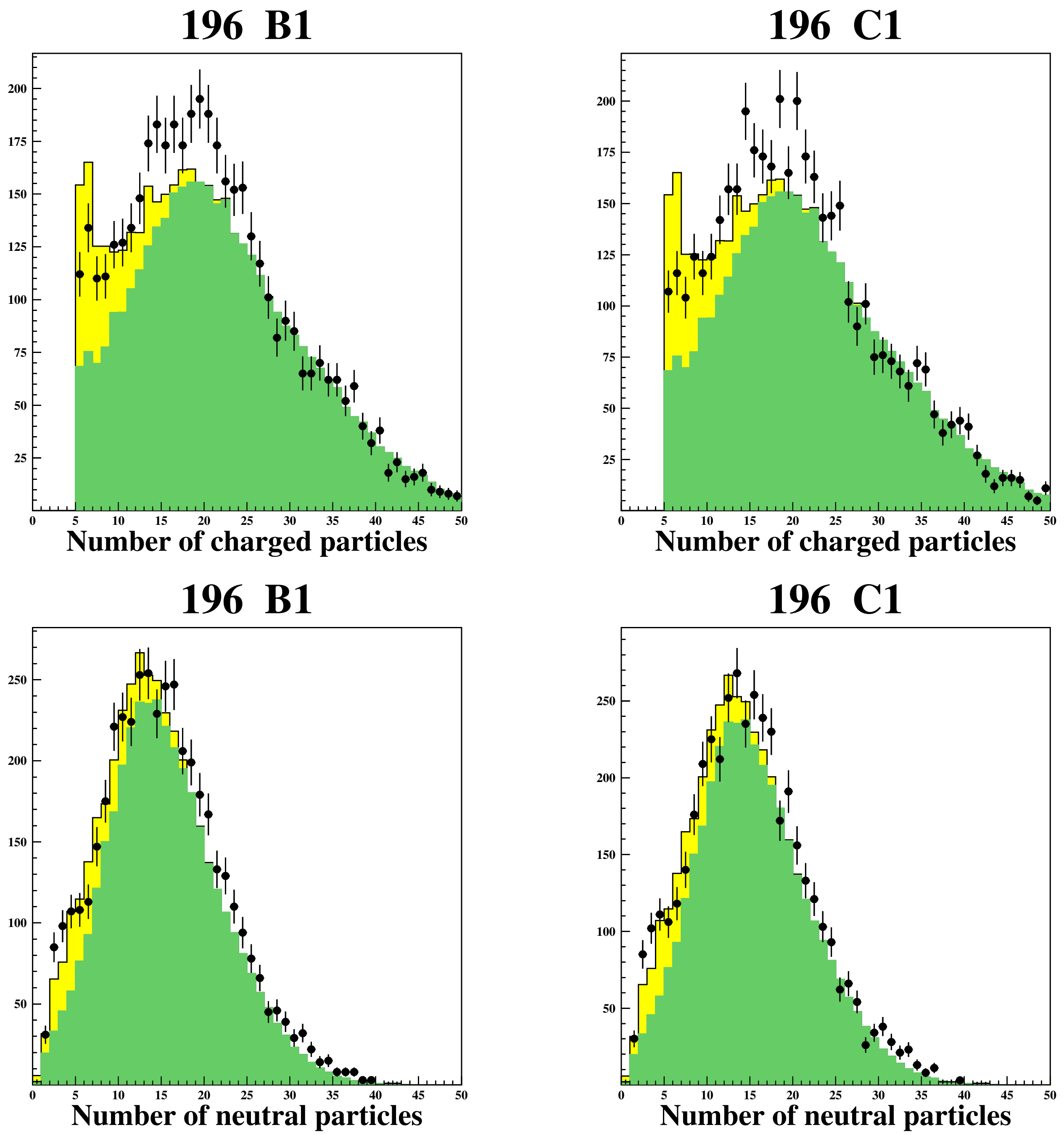
	data B1	data C1	MC (S1)	MC (S3)
	17269	17242	13800. ± 117.	21532. ± 146.
cut1	3501	3517	2656. ± 51.	3760. ± 61.
cut2	1459	1428	1344. ± 36.	1493. ± 38.

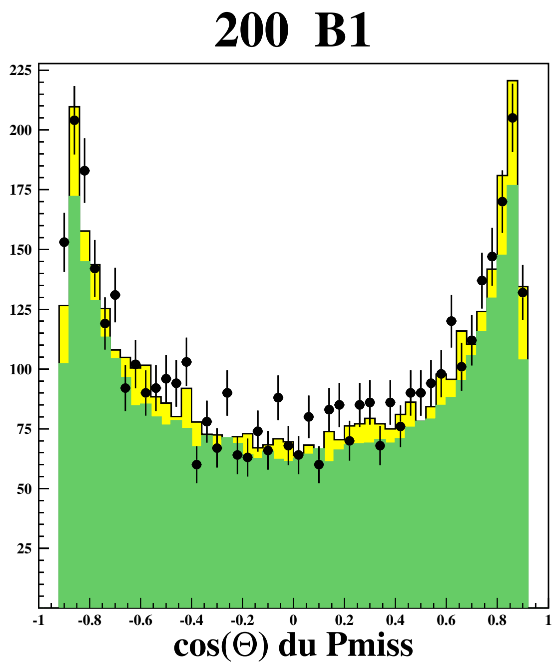
	data B1	data C1	MC (S1)	MC (S3)
	51234	51173	40884. ± 202.	64302. ± 253.
cut1	10521	10393	7632. ± 87.	10980. ± 104.
cut2	4402	4356	3730. ± 61.	4182. ± 64.

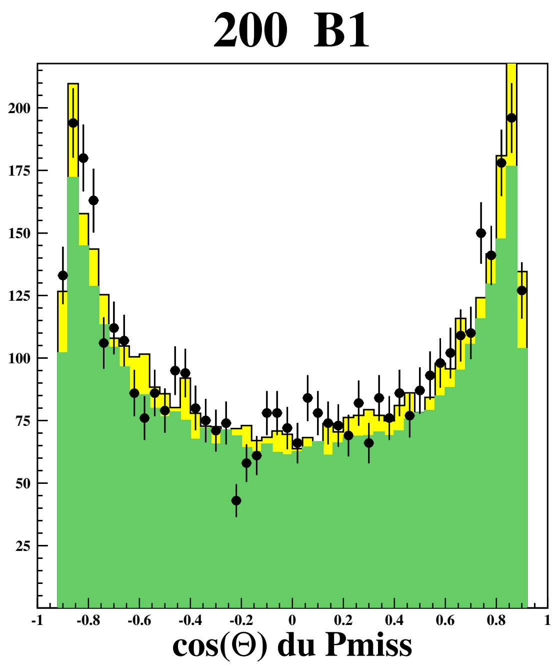
	data B1	data C1	MC (S1)	MC (S3)
	56601	54507	45186. ± 212.	70969. ± 266.
cut1	11650	11183	8350. ± 91.	12039. ± 109.
cut2	4658	4507	4019. ± 63.	4518. ± 67.

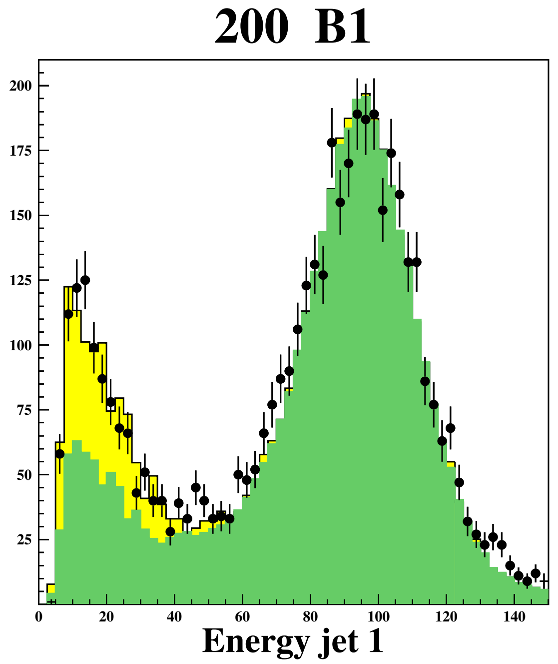
	data B1	data C1	MC (S1)	MC (S3)
	26519	26544	21948. ± 148.	34577. ± 185.
cut1	5459	5474	4040. ± 63.	5842. ± 76.
cut2	2250	2253	1931. ± 43.	2174. ± 46.

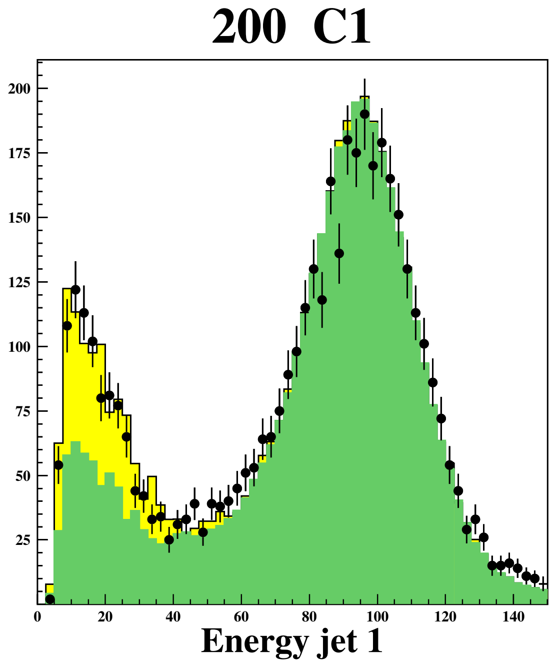

192 B1
Visible Energy
192 C1
Visible Energy
192 B1
Neutral Energy
192 C1
Neutral Energy


196 B1
196 C1
Number of charged particles
Number of charged particles
196 B1
196 C1
Number of neutral particles
Number of neutral particles

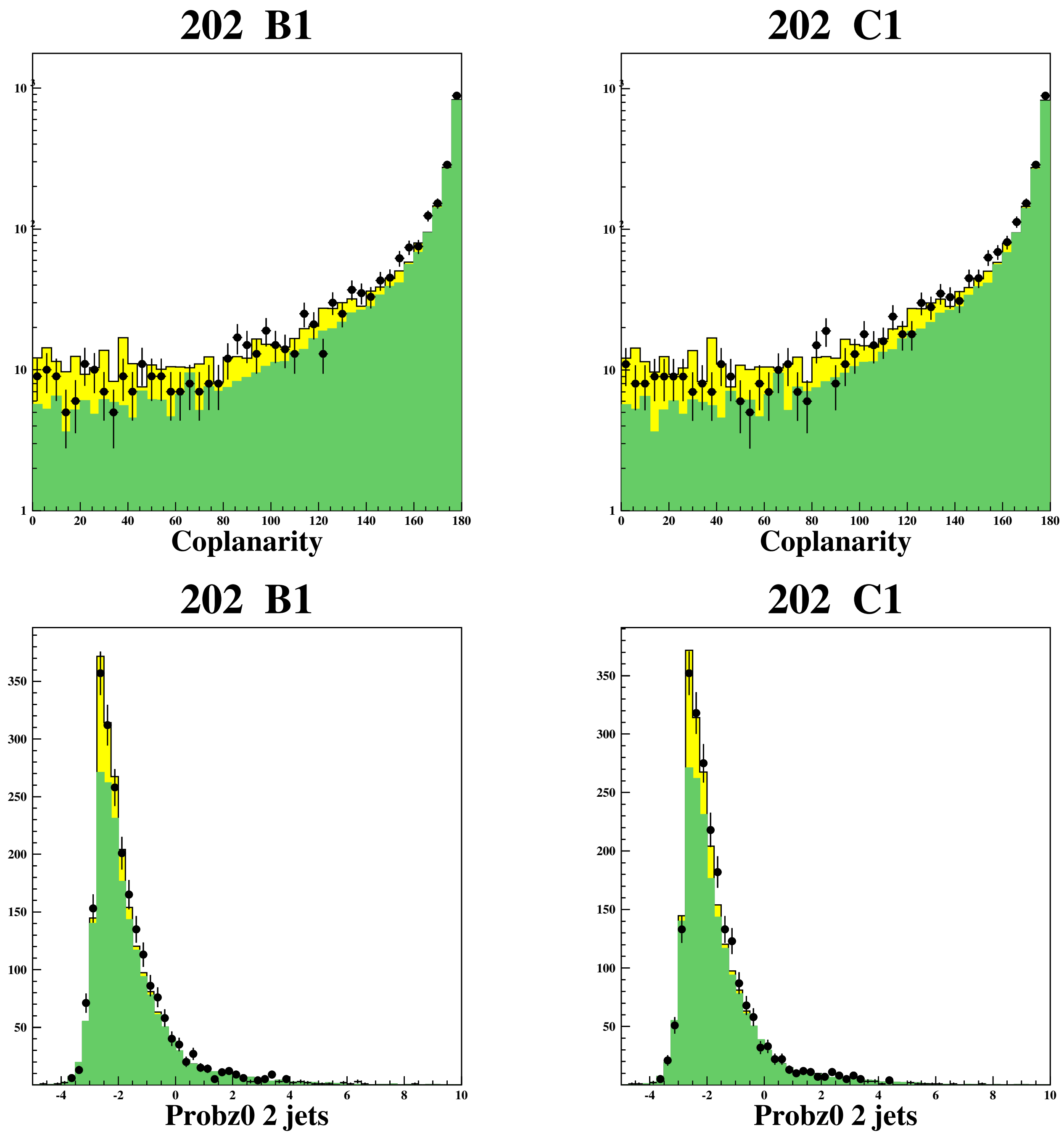

200 B1
cos(Θ) du Pmiss


200 B1
cos(Θ) du Pmiss


200 B1
Energy jet 1


200 C1
Energy jet 1

202


202 B1
Coplanarity
202 C1
Coplanarity
202 B1
Probz0 2 jets
202 C1
Probz0 2 jets

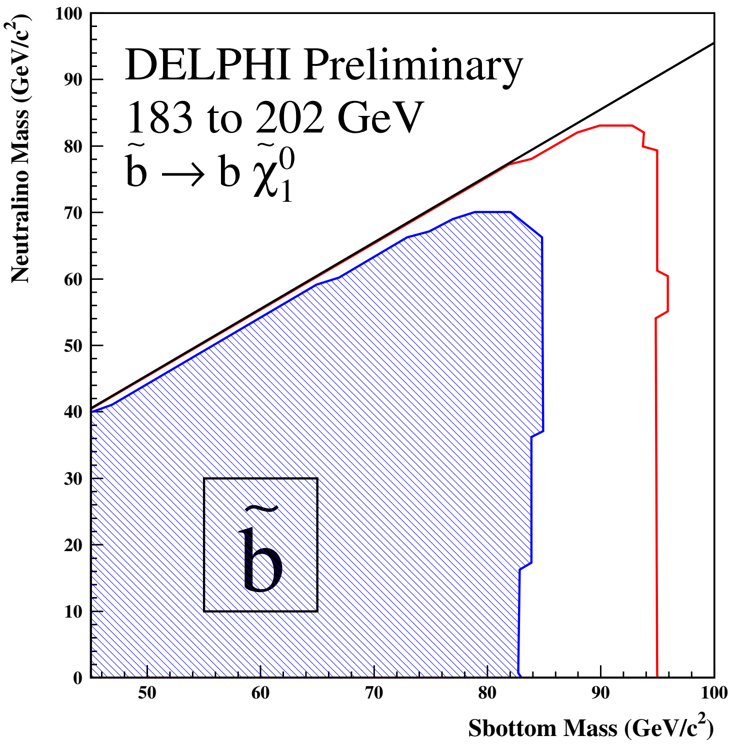
Results :

	192 GeV			196 GeV		
	B1	C1	MC	B1	C1	MC
$\widetilde{b}_1$	0	2	$0.52 \pm .122$	0	0	$1.24 \pm .211$
$\tilde{t}_1$	3	2	$0.95 \pm .150$	1	1	$2.90 \pm .396$
$\tilde{q}$	3	4	$1.24 \pm .177$	1	1	$3.79 \pm .445$
	200 GeV			202 GeV		
$\widetilde{b}_1$	2	2	$1.62 \pm .144$	0	0	$0.55 \pm .105$
$\tilde{t}_1$	1	0	$3.23 \pm .407$	3	3	$1.56 \pm .242$
$\tilde{q}$	3	2	$4.38 \pm .426$	3	3	$1.95 \pm .260$

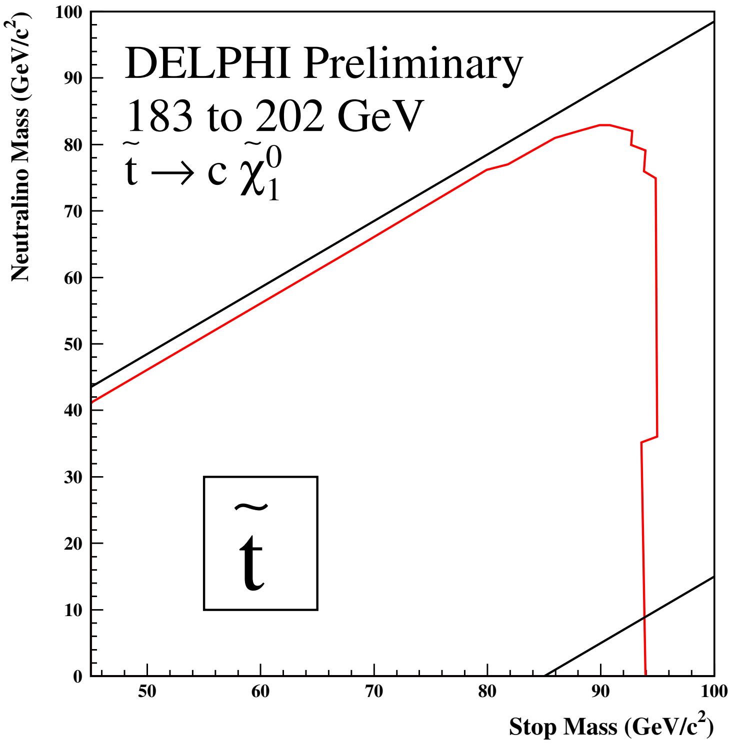
	Total		
$\widetilde{b}_1$	2	4	3.93 ± 0.30
$\tilde{t}_1$	8	6	8.64 ± 0.64
$\tilde{q}$	10	10	11.36 ± 0.69

$\Longrightarrow$ No excess of data

- Evaluation of the efficiencies using the squark signals generated at 200 GeV
- Exclusion in the plane $(M_{\tilde{q}}, M_{\tilde{\chi}_1^0})$



DELPHI Preliminary
183 to 202 GeV
$\tilde{b} \to b\,\tilde{\chi}_1^0$
$\tilde{b}$
Neutralino Mass (GeV/c^2)
Sbottom Mass (GeV/c^2)



DELPHI Preliminary
183 to 202 GeV
$\tilde{t} \to c\,\tilde{\chi}_1^0$
$\tilde{t}$
Neutralino Mass (GeV/c^2)
Stop Mass (GeV/c^2)

Mass limits for $\Delta M \geq 15$

	$\theta^{mix} = 0$	Z^0 decoupling
$\tilde{b}_1$	$>$ 95 GeV	$>$ 83 GeV
$\tilde{t}_1$	$>$ 92 GeV	

- Reasonable agreement between Data and Monte-Carlo
- $\Longrightarrow$ Trainning of the neural networks at 192, 196, 200 and 202 GeV
- Systematic studies

A gluino as the LSP (or NLSP)

Conventionnally in SUGRA model :

- Common mass scale at GUT : $m_{1/2}$
- $\Longrightarrow$ RGE evolution

$$M3 : M2 : M1 \sim \alpha_3 : \alpha_2 : \alpha_1$$

$m_{\tilde{g}} \sim M3$ is heavier then $\widetilde{\chi}_1^0$
(Light gluino scenario $m_{\tilde{g}} < 6$ studied in this context)

- Models exists where $m_{\tilde{g}} <$ M1,M2

A gluino as the LSP (or NLSP) :

Model 1 : (Brignole, Ibanez, Munoz)

- 0-II String model $M3 : M2 : M1 \sim -(3+\delta_{GS}) : (1-\delta_{GS}) : (33/5-\delta_{GS})$
- if $\delta_{GS} \sim -3$ (preferred value) : M3 lightest

Model 2 : (S. Raby)

- GMSB context : light gluon mixing between Higgs and messenger fields (α_1, α_2, α_3 at messenger scale)

$$M_3 = \frac{\alpha_3}{\pi} \Lambda b^2$$

$$M_2 = \frac{\alpha_2}{4\pi} \Lambda(1+4b^2)$$

$$M_2 = \frac{3}{5}\frac{\alpha_1}{4\pi} \Lambda(1+\frac{20}{3}b^2)$$

(+ D terms)
e.g : $b \sim 0.1$, $\Lambda = 10^5\ GeV$, $M_3 = 13\ GeV$, $M_2 = 330\ GeV$

Gluino form stable color singlet hadrons :

The lightest are :

• Isoscalar	$R_o = \tilde{g}g$		(gluballino)
• Isotriplet	$\tilde{\rho} = \tilde{g}q\bar{q}$	$(\tilde{\rho}^{\pm},\tilde{\rho}^{o})$	(glumesino)
• flavor singlet	$S_o = \tilde{g}uds$	(baryon)	(glubarino)
	$n\tilde{g} = \tilde{g}\tilde{g}$		(gluinoball)

$n\tilde{g}$: $m_{n\tilde{g}} > m_{R_o} > m_{glueball}$ is unstable, producing multipions

• R_o LSP :

$$\tilde{\rho}_o \rightarrow R_o + \pi \quad \tilde{\rho}_o \rightarrow R_o + l + \nu_l$$
$$S_o \rightarrow R_o + \pi$$

• $\tilde{\rho}_o$ LSP :

$\tilde{\rho}^{\pm}$ cannot be stable (heavy isotropes, accelerators)

$\Delta M(\tilde{\rho}^{+} - \tilde{\rho}_o) \sim$ few MeV

$\tilde{\rho}^{+} \rightarrow \tilde{\rho}_o + e^{+} + \nu_e$

$\rightarrow T_{\tilde{\rho}^{+}} \sim T_{neutron}$

$\Longrightarrow$ stable for colliders

$R_o \rightarrow \tilde{\rho} + \pi$

- S_o LSP :

Possible otherwise decays as the Λ^o

There is no reliable limits on R_o, $\tilde{\rho}_o$, S_o :

- Cosmology : Ωh^2
- Stable heavy isotopes (too short range interactions) : They cannot get attached to heavy nuclei.

$\Longrightarrow$ In the next we consider 2 generic gluino hadron states :

$$R_o \ , \ R^{\pm}$$

There is a contraversial limit $m_{\tilde{g}} \ > \ 6$ GeV from 4 jet rates (ALEPH)

How are they produced ?

$$
\begin{array}{llcll}
e^+e^- & \widetilde{\chi}^0_1\widetilde{\chi}^0_1 & \longrightarrow & \mathrm{qq'}\tilde{g}\ \mathrm{qq'}\tilde{g} & \text{(6 jets)} \\
 & \widetilde{\chi}^+\widetilde{\chi}^- & \longrightarrow & \mathrm{qq'}\tilde{g}\ \mathrm{qq'}\tilde{g} & \text{(6 jets)} \\
 & \tilde{\mathrm{t}}_1\tilde{\mathrm{t}}_1 & \longrightarrow & c\tilde{g}\tilde{g} & \text{(4 jets)}
\end{array}
$$

But also independently from $m_{\widetilde{\chi}^+}$, $m_{\widetilde{\chi}^0_1}$, $m_{\tilde{\mathrm{t}}_1}$:

$$e^+e^- \longrightarrow q\bar{q}\tilde{g}\tilde{g}$$

$$e^+e^- \longrightarrow \tilde{g}\tilde{g}\ (loops)$$

$$Br(Z^o \longrightarrow \tilde{g}\tilde{g}) \sim 1\!-\!2\!\times\!10^{-4}\, for \tilde{m} \sim 200\, GeV \sim \frac{1}{\tilde{m}^2}$$

But what is a $\tilde{g}$ jet ?

Fragmentation of a gluino LSP

Fragmentation (Peterson function):

$$D_{\tilde{g}}^{R} = C z^{-1} \left[1 - \frac{1}{z} - \frac{\epsilon_{\tilde{g}}}{1-z} \right]^{-2} ,$$

$$\epsilon_{\tilde{g}} = (0.3 GeV / m_{\tilde{g}})^2$$

Energy deposition to a calorimeter:

$$R_0 N \longrightarrow R_0 X$$

$$\Delta E = \frac{m_X^2 - m_N^2 + |t|}{2m_N}$$

(1) $\frac{d\sigma}{d|t|dm_X} \propto 1$ for $|t| \leq 1GeV^2$, 0 above.

(2) $\frac{d\sigma}{d|t|dm_X^2}$ given by a triple-Pomeron form:

$$\frac{d\sigma}{d|t|dm_X^2} \propto \frac{1}{m_X^2}\beta^2(|t|)\left(\frac{s}{m_X^2}\right)^{2(\alpha_P(|t|)-1)} \left[m_X^2\right]^{\alpha_P(0)-1}$$

(3) $\frac{d\sigma}{d|t|dm_X} \propto 1$ for $|t| \leq 4GeV^2$, 0 above.

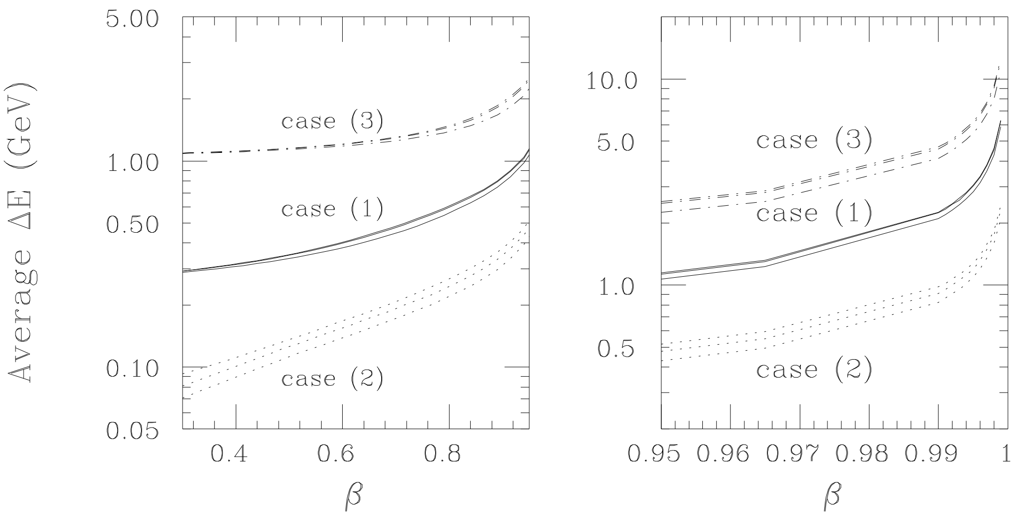
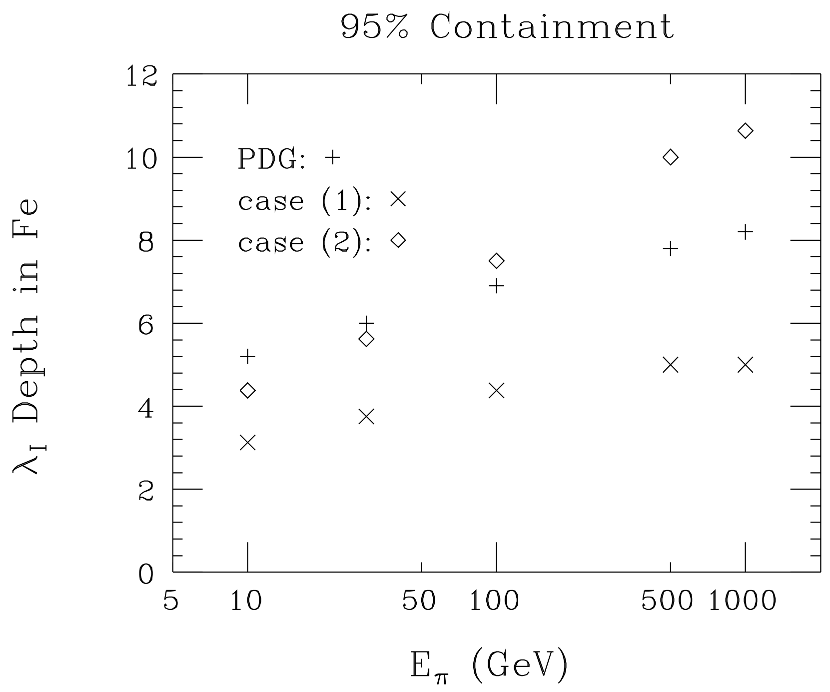


Figure 1: Average energy loss, ΔE, in a collision as a function of β for the three cases described in the text. Results are shown for $mR0 = 5$, 25 and $140e$. At high β, curves are ordered according to increasing $mR0$.

Energy deposition of a gluino LSP



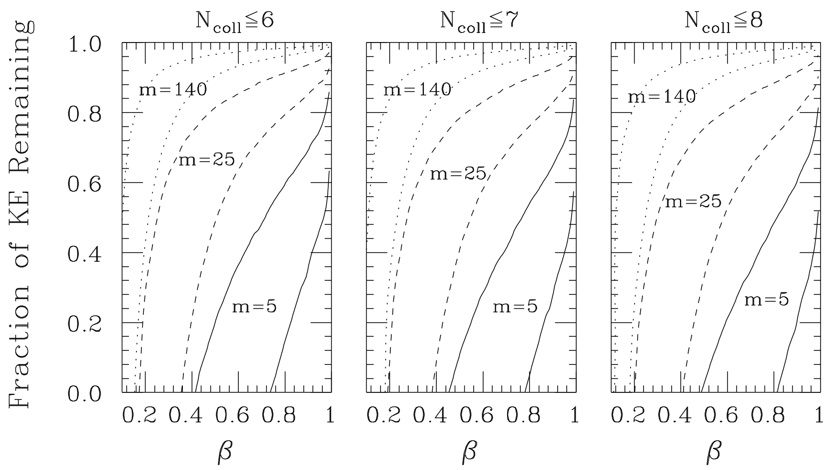


Figure 2: The fraction of kinetic energy retained by the is plotted as a function of its initial β for the cases of $N_{\rm coll} \leq 6$, 7 and 8 for $mR0 = 5$, 25 and 140 GeV. Upper and lower curves for a given mass are for ΔE cases (2) and (1), respectively.

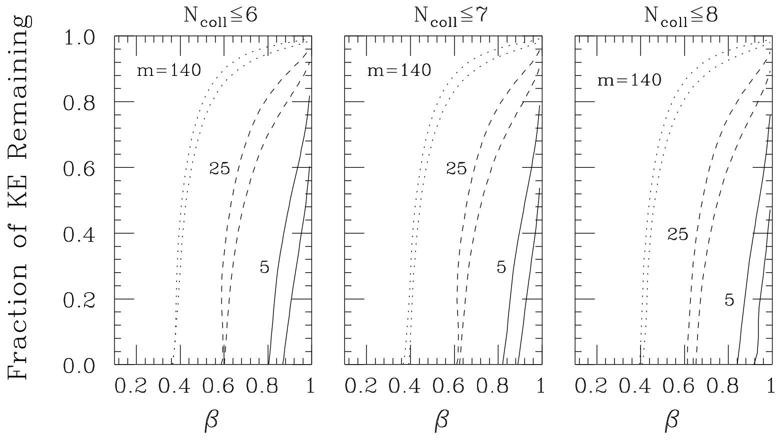


Figure 3: The fraction of kinetic energy retained (that is not deposited) by a singly-charged $\tilde{g}$ bound state is plotted as a function of its initial β for the cases of $N_{\rm coll} \leq 6$, 7 and 8 for $m = 5$, 25 and 140 GeV. Upper and lower curves for a given mass are for ΔE cases (2) and (1), respectively.

Without $R^{\pm}$:

- $\lambda_I(\pi) = 17cm$, $\lambda_T(\pi) = 11cm$
- $\lambda_T(R_0) = 19cm$ (double or half possible)
- OPAL $\sim 6\lambda_T(R_0)$
- For a 25 GeV gluino, with $\beta \sim 0.5$ after 7 interactions 20% of the kinetic energy is deposited
- Missing energy:

$$E_{miss} = m_{\tilde{g}}(\beta\gamma - X(\gamma - 1))$$

- X function of the deposited kinetic energy

With $R^{\pm}$ two effects:

- Probability P: to fragment to a quasi stable charged R giving a heavy ionising particle
- Probability P: (assumed the same) of charge exchange
- The charged particles give anomalously high dE/dx
- The first effect measured at DELPHI , a limit on P can be given
- The dE/dX in the calorimeter increases the deposited energy
- Complications: (compensation, simulate a muon, interactions at the last parts of the detector)
- Energy of the $\tilde{g}$ jet:

$$E_{\tilde{g}} = m_{\tilde{g}} X(\gamma - 1) + dE/dx$$

Experimental strategy :

Lazy strategy :

disregard the hadronic calorimeter and any neutral hadrons starting at the electromagnetic calorimeter and apply the stop analysis

Proper strategy :

include in SUSYGEN the following change :

$$\tilde{g} \; \longrightarrow \; K_L^o$$

$$E_{K_L^o} \; = \; X \; m_{\tilde{g}}(\gamma - 1) + < \; \frac{dE}{dX} \; >_p$$

let for the user compute :
λ_{INT}, N_{INT}, P , model, randomly for each event

$\tilde{g} \longrightarrow X^+$? , is it necessary ?

Can we anyway apply our previous analysis ? (heavy ion, can DELSIM handle it ?)

How a glueballino should look like

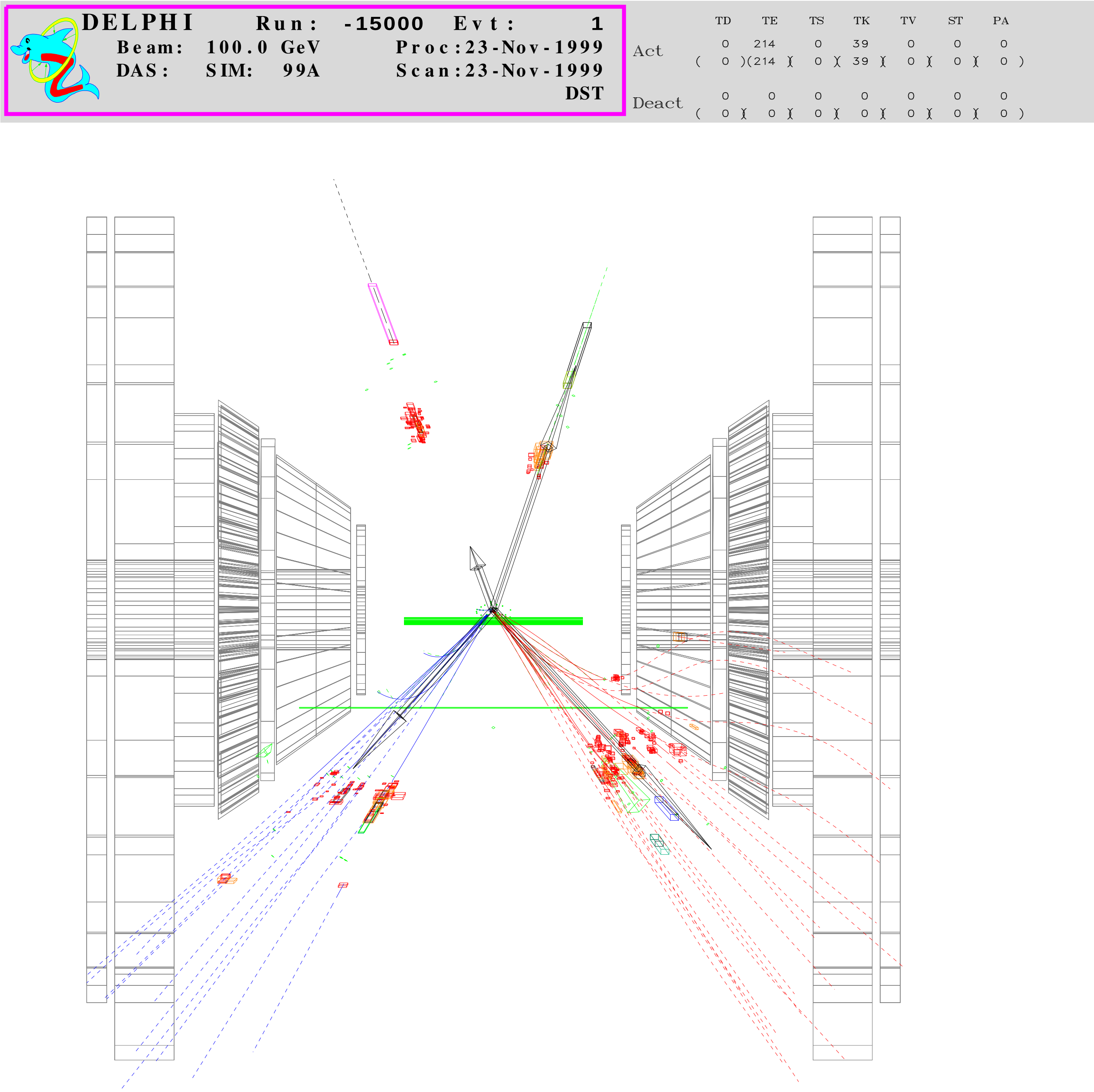
The analysis :

- Neutral tracks having deposited energy in the hadron calorimeter are removed
- The same analysis as for the decay : $\tilde{q} \to q\ \tilde{\chi}_1^0$ is applied

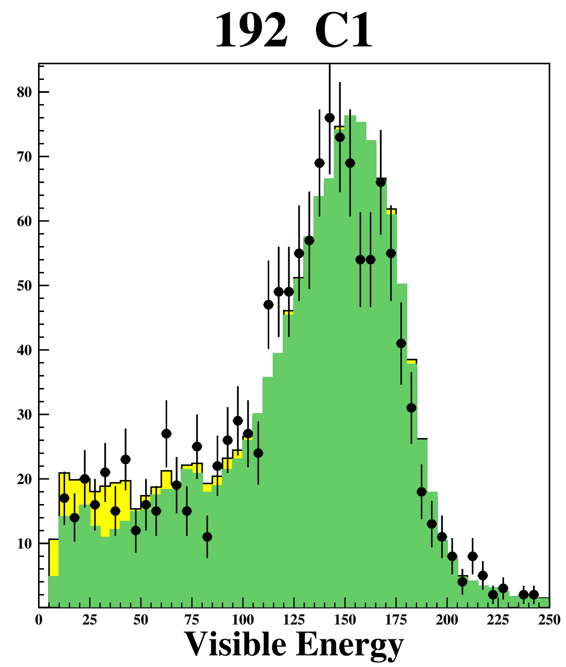
Preliminary results :

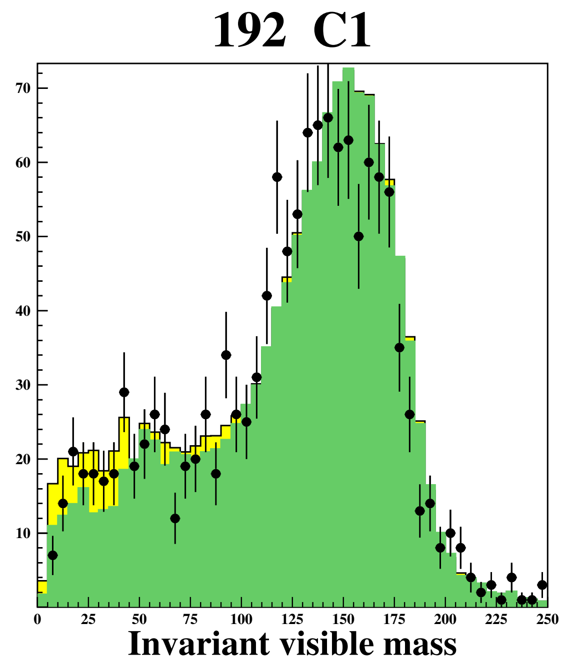
- The analysis is perfomed at 192, 196, 200 and 202 GeV
- Evaluation of the signal efficiencies is perfomed using the squark signals generated at 200 GeV

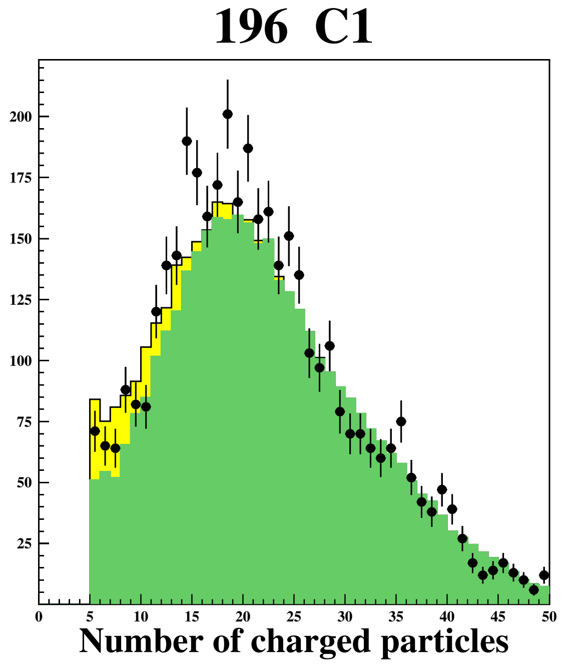
Glueballino event :

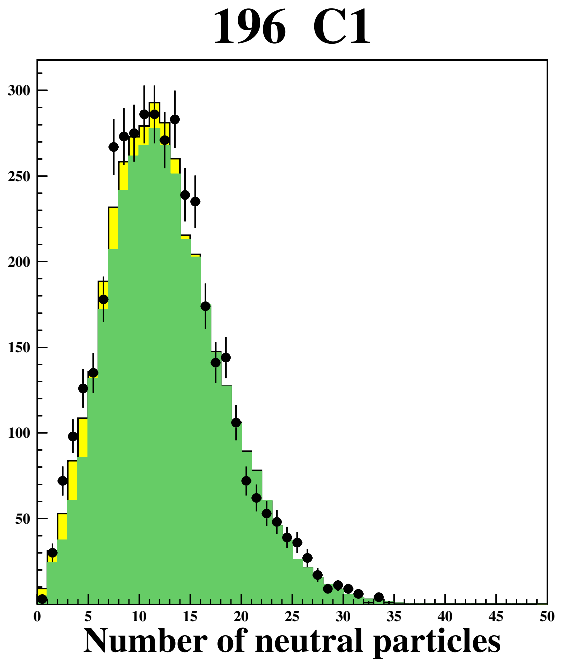


Monte-Carlo vs Data



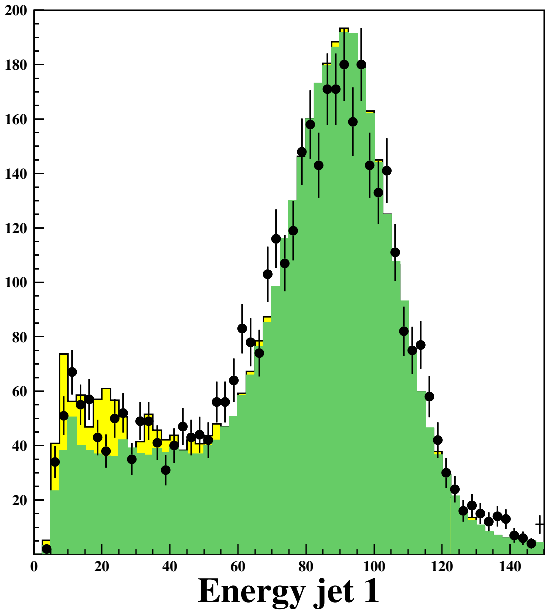




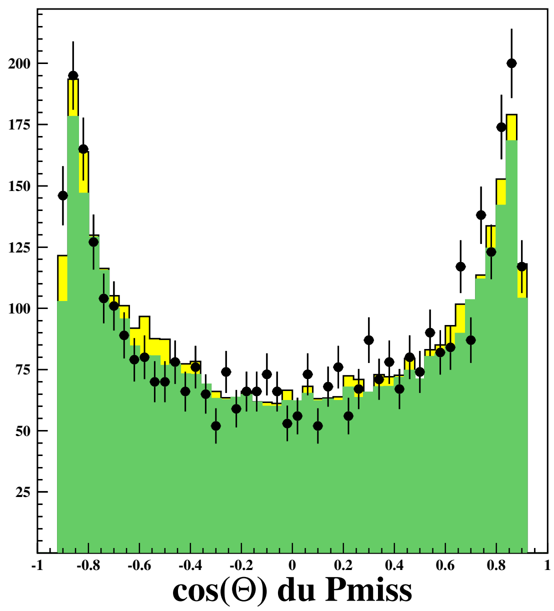


Monte-Carlo vs Data

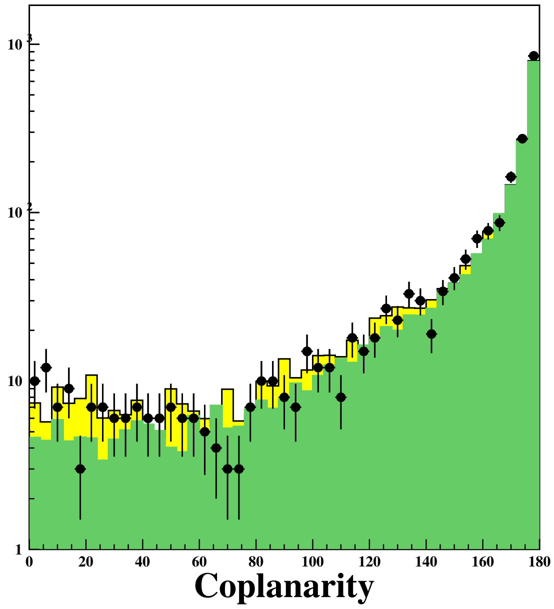
200 C1



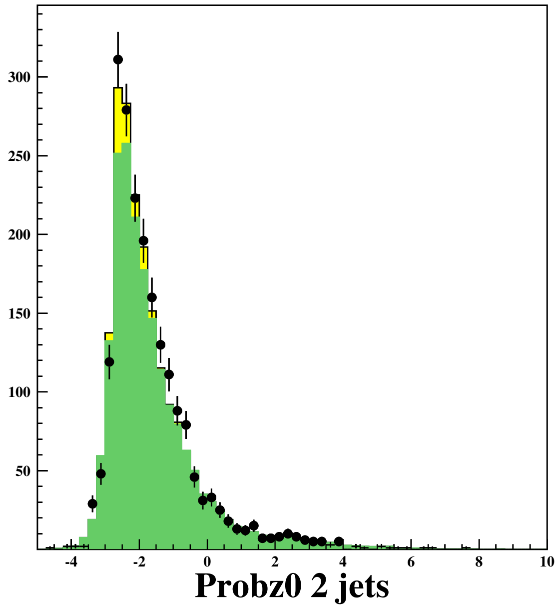
200 C1

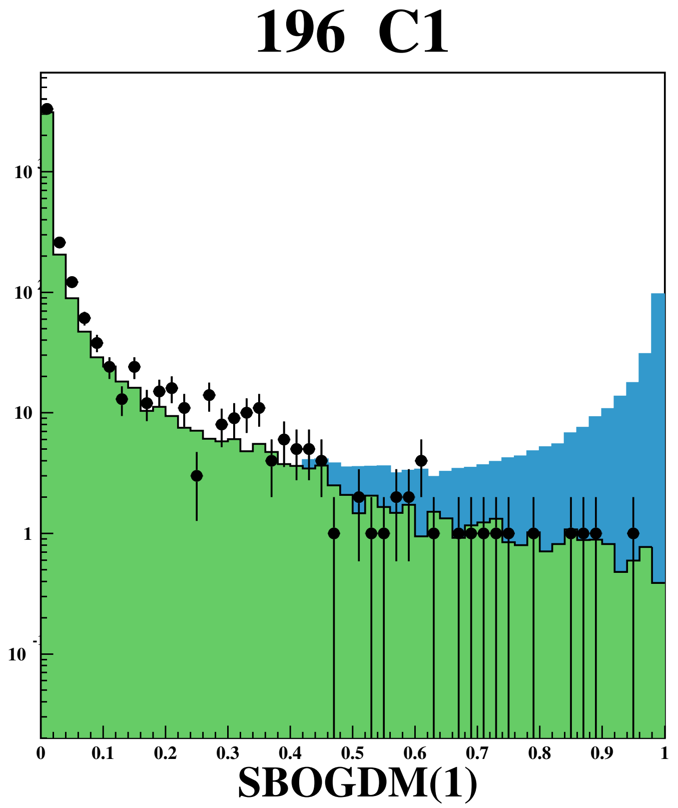


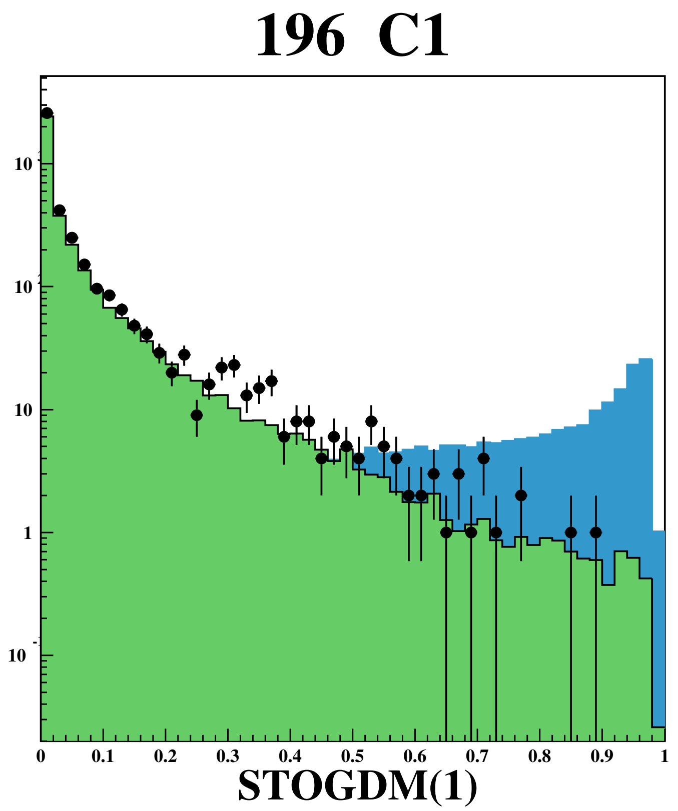
202 C1

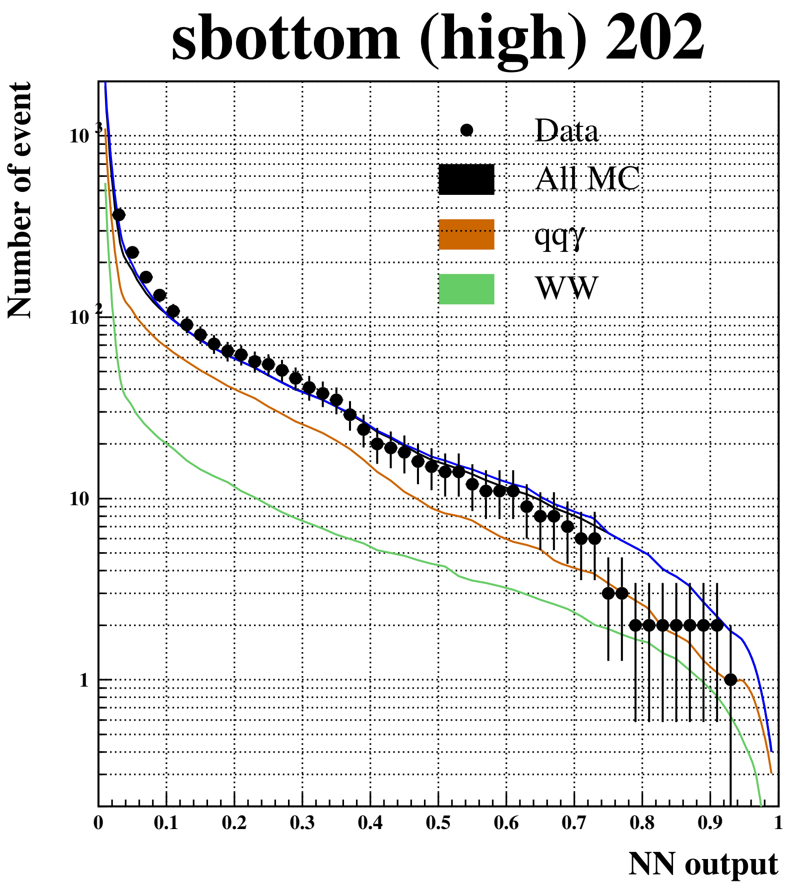


202 C1




196 C1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
SBOGDM(1)


196 C1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
STOGDM(1)


sbottom (high) 202
Number of event
10^3
10^2
10
1
Data
All MC
qqγ
WW
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
NN output

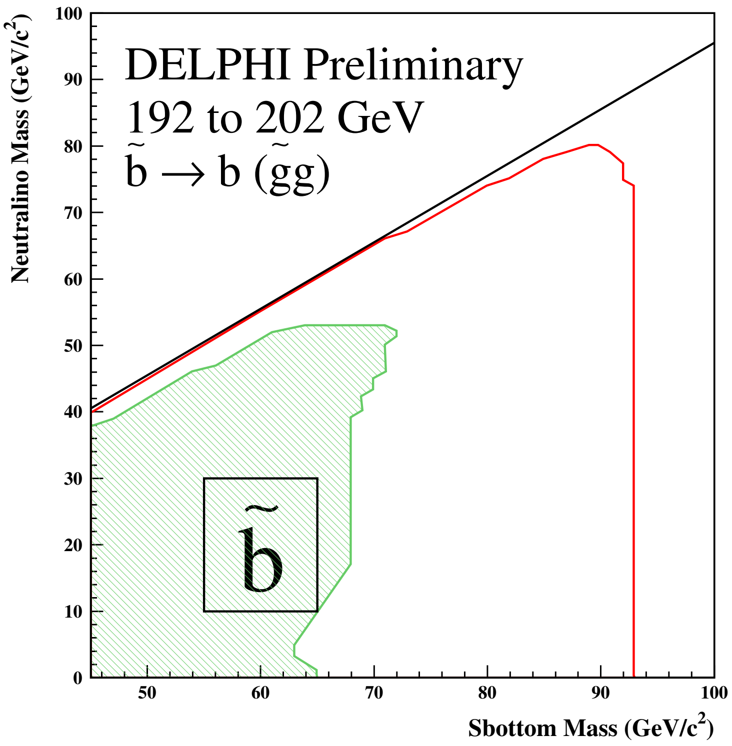
	192 GeV		196 GeV	
	C1	MC	C1	MC
$\tilde{b}_1$	4	1.39 ± 0.23	1	3.13 ± 0.36
$\tilde{t}_1$	3	1.74 ± 0.21	3	4.64 ± 0.36
$\tilde{q}$	7	2.74 ± 0.29	4	6.82 ± 0.47
	200 GeV		202 GeV	
$\tilde{b}_1$	5	3.72 ± 0.23	2	2.32 ± 0.30
$\tilde{t}_1$	1	5.45 ± 0.26	4	3.13 ± 0.32
$\tilde{q}$	6	8.24 ± 0.33	4	4.63 ± 0.40

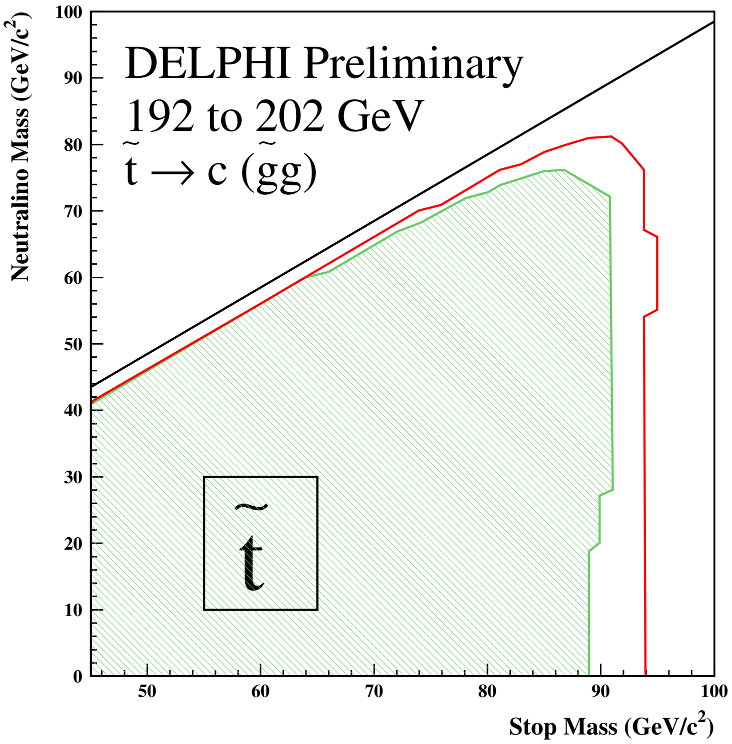
	Total	
$\tilde{b}_1$	12	10.56 ± 0.57
$\tilde{t}_1$	11	14.96 ± 0.59
$\tilde{q}$	21	22.43 ± 0.76

$\Longrightarrow$ No excess of data

- Evaluation of the efficiencies using the squark signals generated at 200 GeV
- Exclusion in the plane $(M_{\tilde{q}}, M_{\tilde{\chi}_1^0})$

Results :


DELPHI Preliminary
192 to 202 GeV
$\tilde{b} \rightarrow b\ (\tilde{g}g)$
$\tilde{b}$
Neutralino Mass (GeV/c^2)
Sbottom Mass (GeV/c^2)
0
10
20
30
40
50
60
70
80
90
100
50
60
70
80
90
100


DELPHI Preliminary
192 to 202 GeV
$\tilde{t} \rightarrow c\ (\tilde{g}g)$
$\tilde{t}$
Neutralino Mass (GeV/c^2)
Stop Mass (GeV/c^2)
0
10
20
30
40
50
60
70
80
90
100
50
60
70
80
90
100

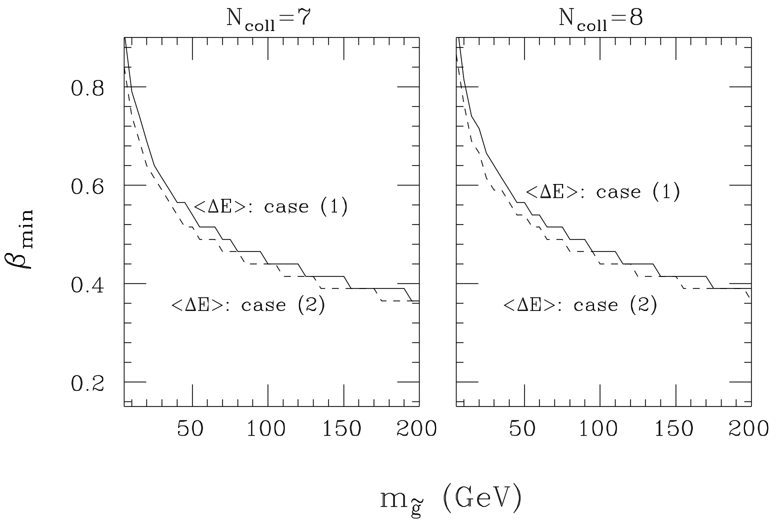


Figure 4: The minimum velocity $\beta_{\min}$

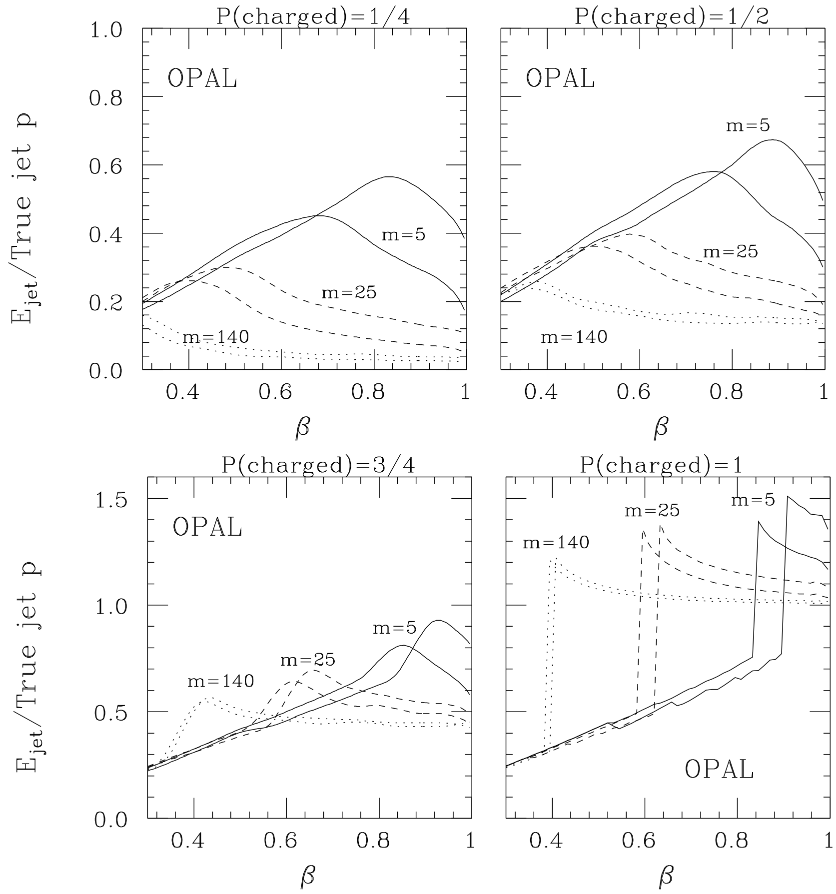


Figure 5: For $P = 1/4$, $1/2$, $3/4$ and 1, we plot, vs. the gluino's initial β, the average jet energy [computed using the OPAL procedures, cf. Eq. (**??**)] as a fraction of the gluino's initial momentum. Results are given for $m = 5$, 25 and 140 e, taking $r = 1.6$. The two curves for a given mass are for ΔE cases (1) and (2). Raggedness in the numerical results, reflecting the fact that in our approximation the hadronic interactions only occur at precise intervals of 19 cm whereas ionization losses occur continuously, has been smoothed out in the plots.

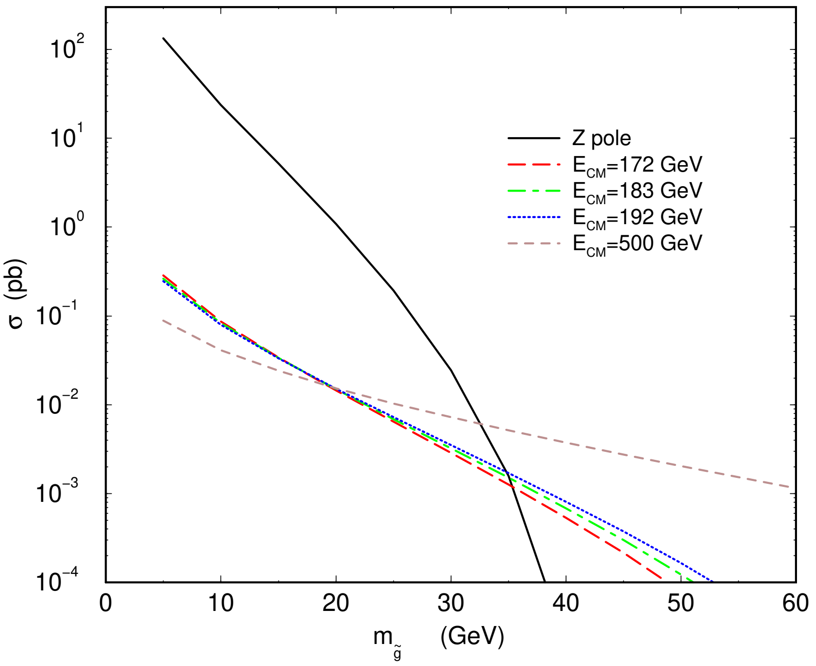


Figure 6: $\sigma(\rightarrow qq)$ as a function of for = (solid), 172 GeV (dashes), 183 GeV (dot-dash), 192 GeV (dots) and $500 GeV$. No cuts.

Results :

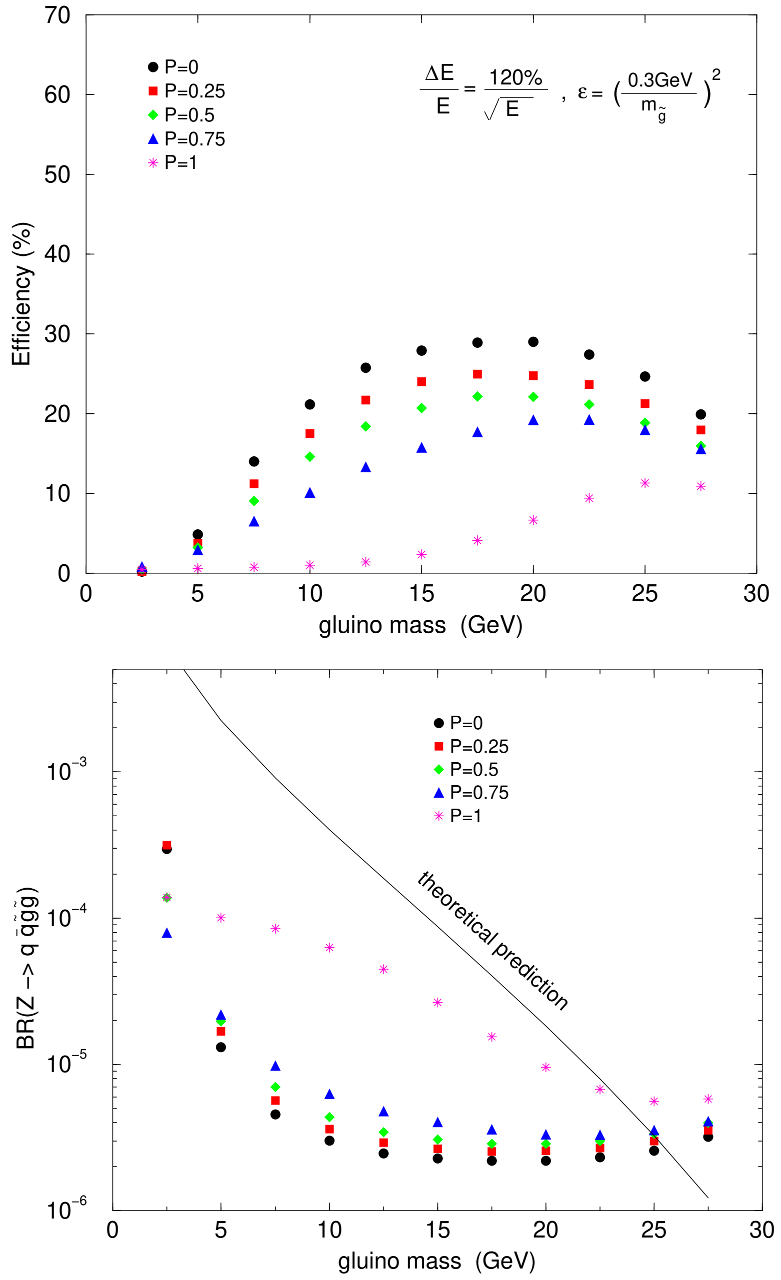
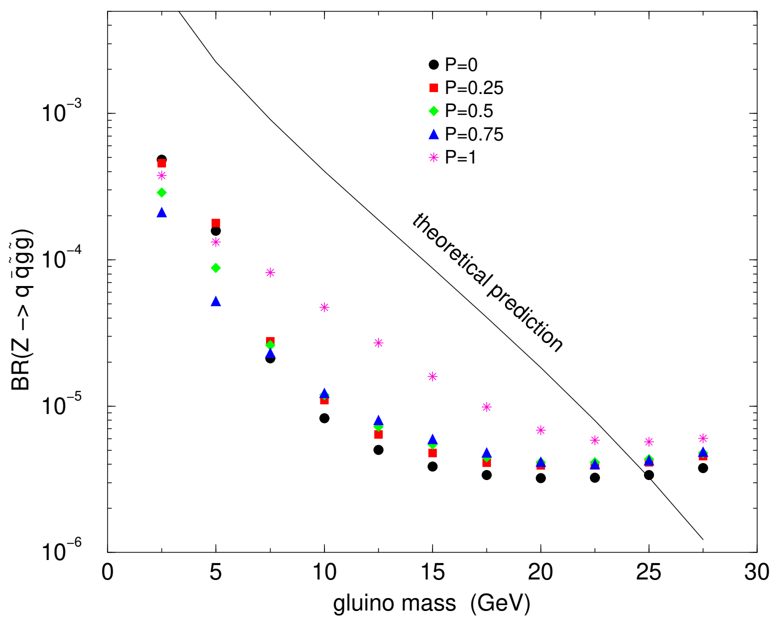


Figure 7: In the upper window, we plot the OPAL qq event efficiency (after all cuts) in the $P = 0, 1/4, 1/2, 3/4, 1$ cases, as computed using event-by-event determination of [using Eq. (**??**)] for each . For $P \neq 0, 1$, changes of the R-hadron charge as it passes through the detector are randomly implemented. Both smearing and fragmentation effects are included. The lower window gives, as a function of , the corresponding 95% CL upper limits compared to the theoretical prediction for $(Z \to qq)$. Results are for the SC1 choices of $\lambda_T = 19$ cm and ΔE case (1).



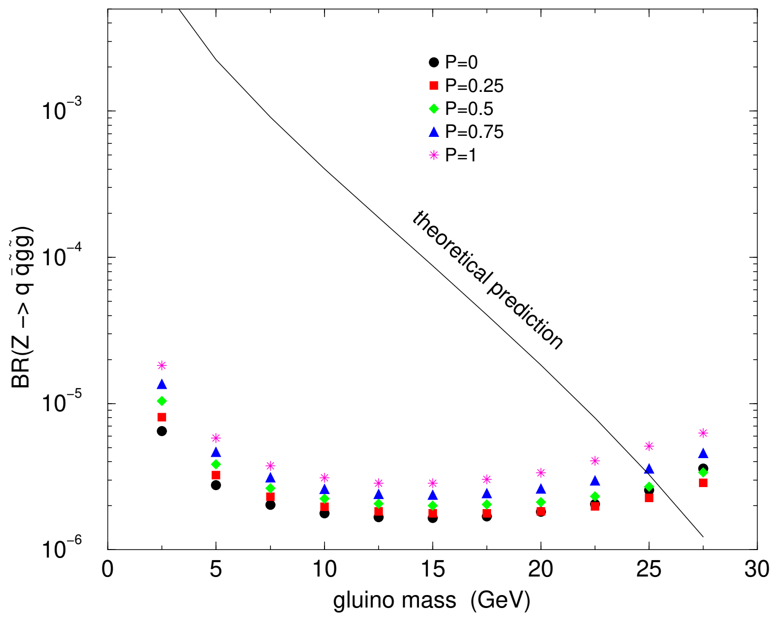


Figure 8: 95% CL upper limits as in Fig. 7 except that we use the SC2 choices of $\lambda_T = 9.5$ cm and ΔE case (1) in the upper window and the SC3 choices of $\lambda_T = 38$ cm and ΔE case (2) in the lower window.