international linear collider

Pair production of scalar top quarks in e^+e^- collision at ILC

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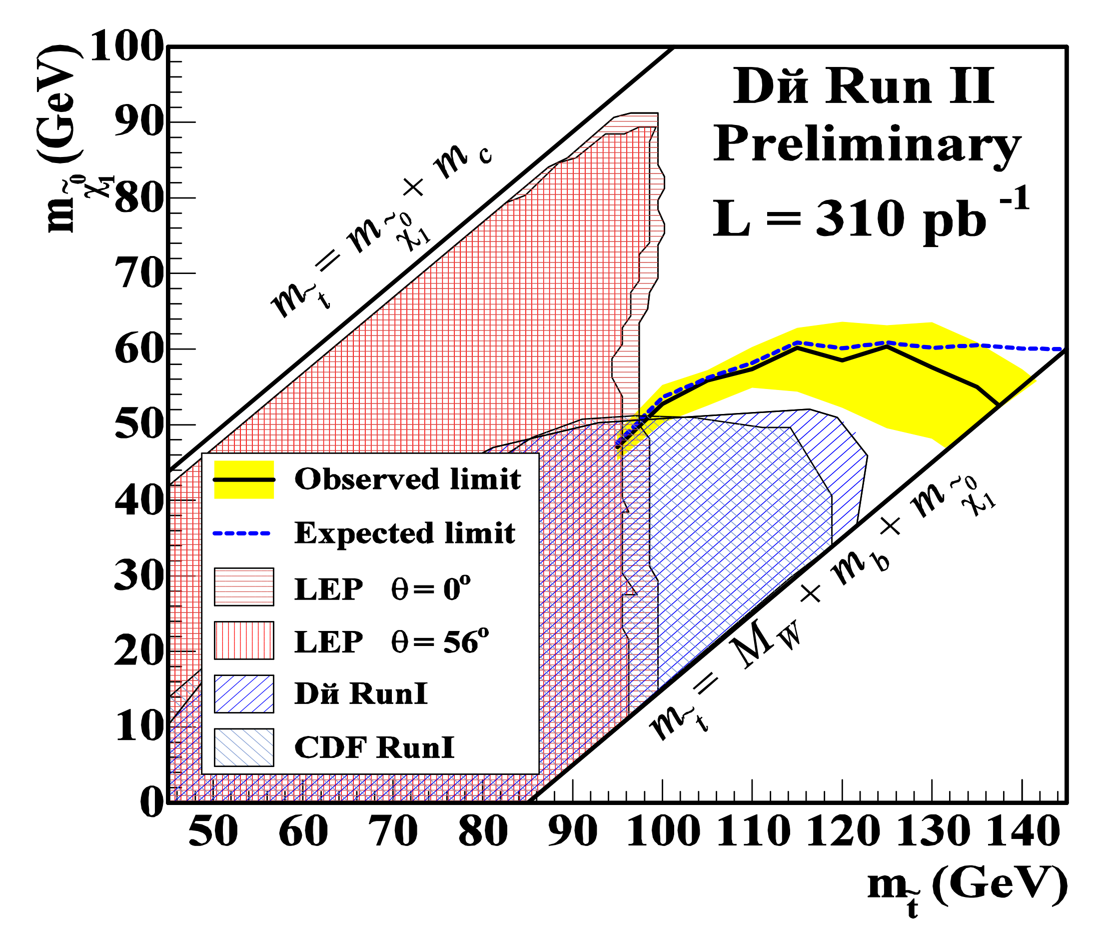
Experimental restrictions on the STOP mass



" Search for the pair production of scalar top quarks in the acoplanar charm jet final state in p pbar collisions at $\sqrt{S}$ = 1.96 TeV"

D0 Note 5134-CONF

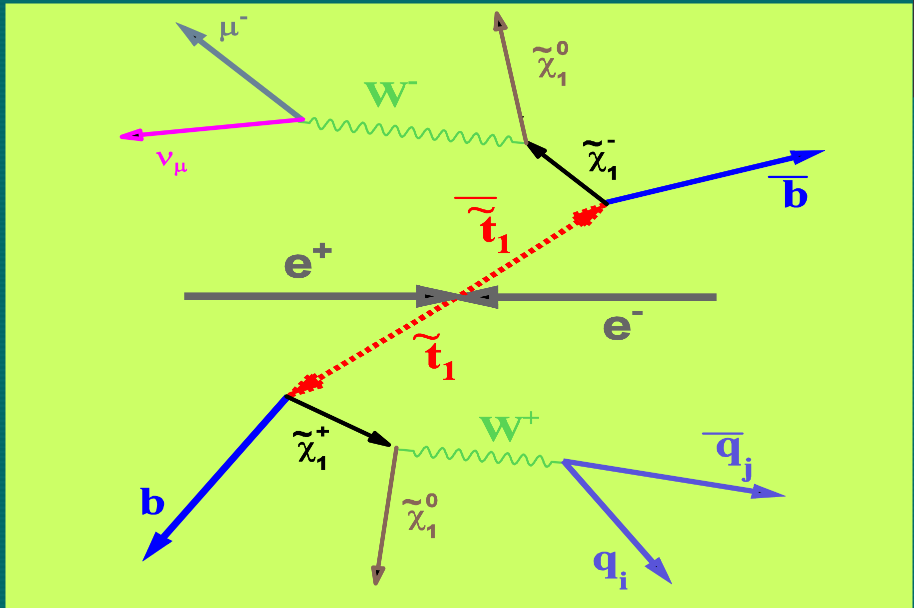
7 June 2006

Fermilab-Pub-06/396-E

hep-ex/0611003

Phys. Lett. B645 (2007) 119-127

Simulation is done by use of PYTHIA 6.1 + CIRCE 1



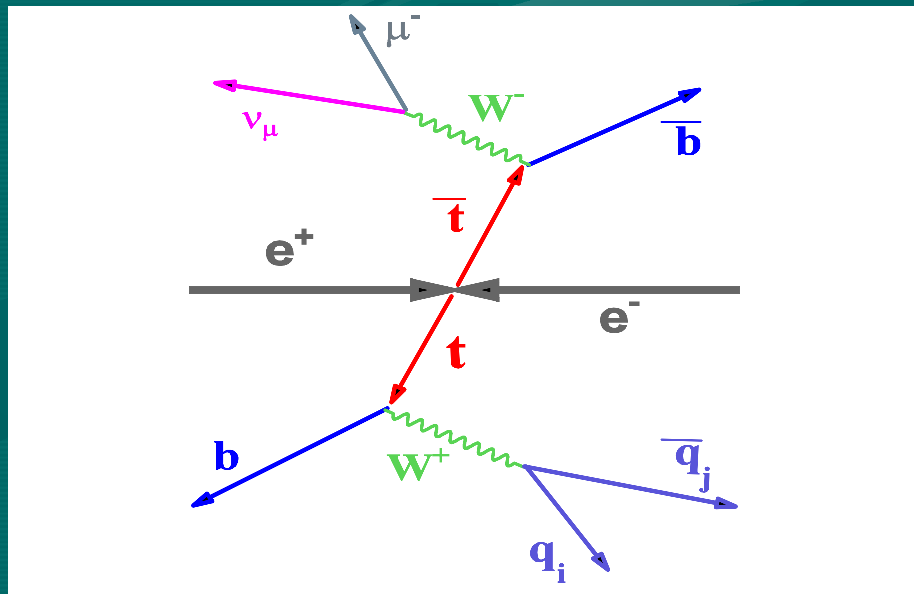
$e^+ e^-$ CM energy = 500 GeV

STOP pair production cross section

$\sigma = 23.1$ fb

TOP pair production cross section

$\sigma = 35.9$ fb



The subsequent decay channels have been considered:

- **STOP STOP** $\rightarrow b\ \chi_1^+\ b_{bar}\ \chi_1^- \rightarrow b\ b_{bar}\ q_i\ q_{j\,bar}\ \mu^-\ \nu_\mu\ \chi_1^o\ \chi_1^o$
- $t\ t \rightarrow b\ W^+\ b_{bar}\ W^- \rightarrow b\ b_{bar}\ q_i\ q_{j\,bar}\ \mu^-\ \nu_\mu$

The only difference of STOP / TOP production is the presence of the two non-detectable neutralinos in the case of stop pair production.

The quarks hadronize into jets. Jets are determined by use of PYCLUS jetfinder based on "Durham" cluster distance measure algorithm.

Both the signal and background events have the same experimental signature (b & b_{bar} - jets, 2 jets from W → $q_i\ \bar{q}_j$ decay and μ^-).

In order to simulate the STOP pair production, we assumed the following scenario for the MSSM model parameters:

- **$M_{\sim Q} = M_{\sim t\,L}$ = 270 GeV** (left squark mass)
- **$M_{\sim U} = M_{\sim t\,R}$ = 270 GeV** (right squark mass)
- **At = -500 GeV** (top and bottom trilinear coupling)
- **μ = - 370 GeV**
- **tanβ = 5**
- **M1 = 80 GeV**
- **M2 = 160 GeV**

Corresponds to

M_{stop} = 167.9 GeV,

$M_{\chi 1^o}$ = 80.9 GeV

$M_{\chi\, 1+}$ = 159.2 GeV

Our aim is:

- ***To find out physical variables (Energy, PT, angle and invariant mass distributions) most suitable for signal (stop) / background (top) separation***
- ***To estimate the corresponding values of cuts on these variables***

Cross section dependence on E_{beam}

(without any cuts)

E_{beam}[GeV]	σ_{stop} [fb]	N_{stop}/year	σ_{top} [fb]	N_{top}/year
350	0.29	58	13.76	2752
400	1.89	378	38.80	7761
500	3.39	677	35.93	7187
800	2.73	546	17.35	3472
1000	1.72	283	11.67	2348

Used cuts for S/B separation

1.) The events with clear recognized 2 B-jets (according to PYTHIA)

(B-jet is determined as a jet that includes b-meson)

Stop cut efficiency = 0.84 *Top cut efficiency = 0.94*

But, in the experiment inly 50% efficiency of the B-jets and B_{bar}-jets separation and the 80% of the corresponding purity is expected

2.) Invariant mass of quarks from W decay Mw < 70 GeV

together with the cut above

Stop cut efficiency = 0.81 *Top cut efficiency = 0.15*

3.) Invariant mass of b-jet $M_{b\ jet}$ < 10 GeV

together with the cuts above

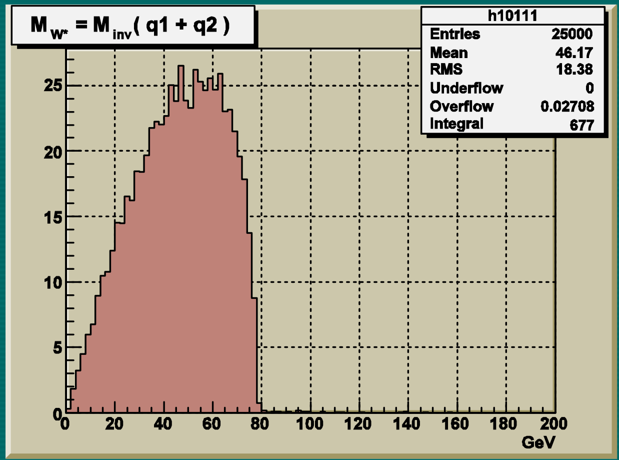
Stop cut efficiency = 0.40 *Top cut efficiency = 0.0012*

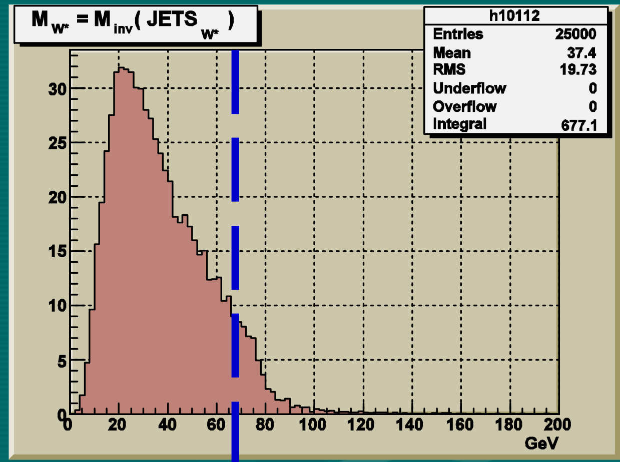
Achieved S/B ratio = 30

The rest is only 8 background events per year, while for the Signal events – 273/year

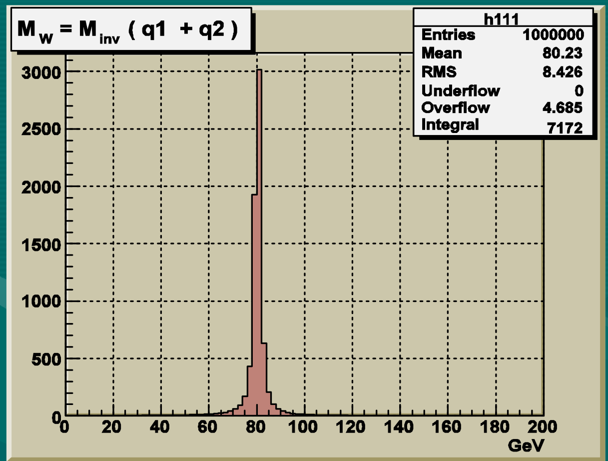
W mass reconstruction as M_{inv} of 2 W_{jets}

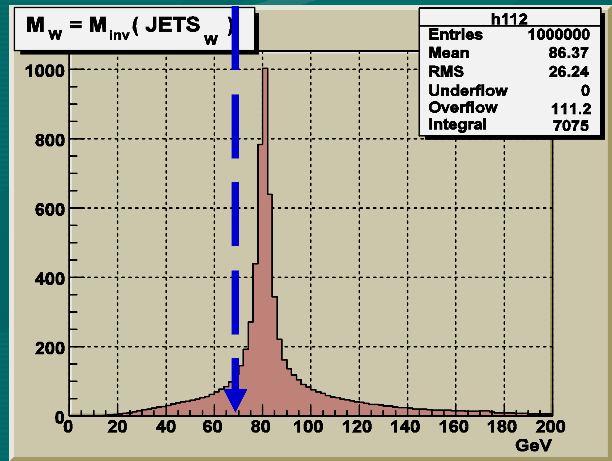
STOP





TOP





Partonic level

Level of jets

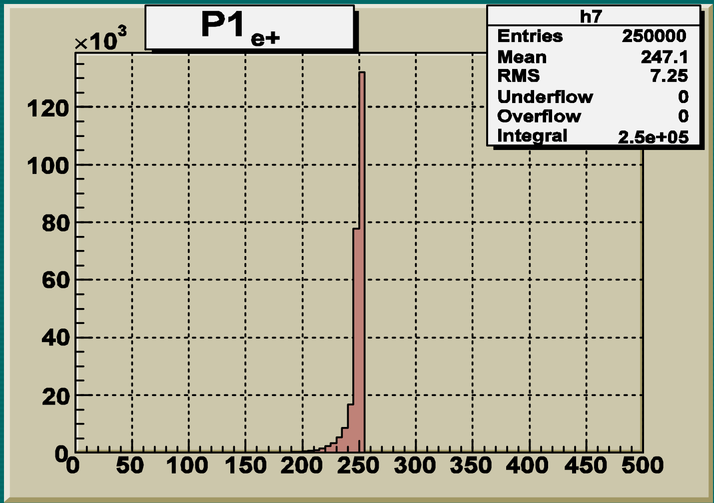
Used for Signal / Background separation !

Cross section dependence on E_{beam}

(with the cuts above)

E_{beam}[GeV]	σ_{stop} [fb]	N_{stop}/year	σ_{top} [fb]	N_{top}/year
350	0.10	21	$3.60 * 10^{-2}$	7
400	0.74	148	$7.46 * 10^{-2}$	14
<u>500</u>	<u>1.38</u>	<u>273</u>	<u>$9.93 * 10^{-2}$</u>	<u>8</u>
800	1.02	203	$8.33 * 10^{-4}$	2
1000	0.11	22	$4.11 * 10^{-5}$	0

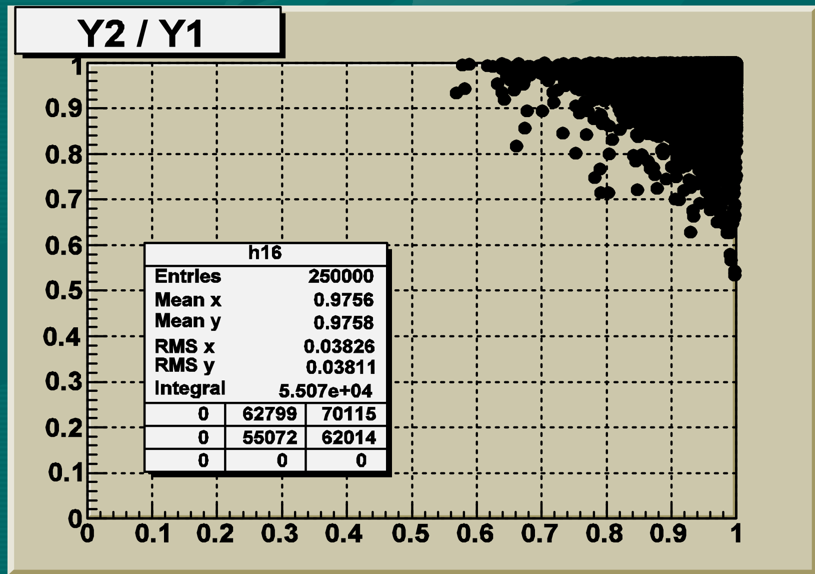
e^+, e^- beam energy spectrum from CIRCE 1



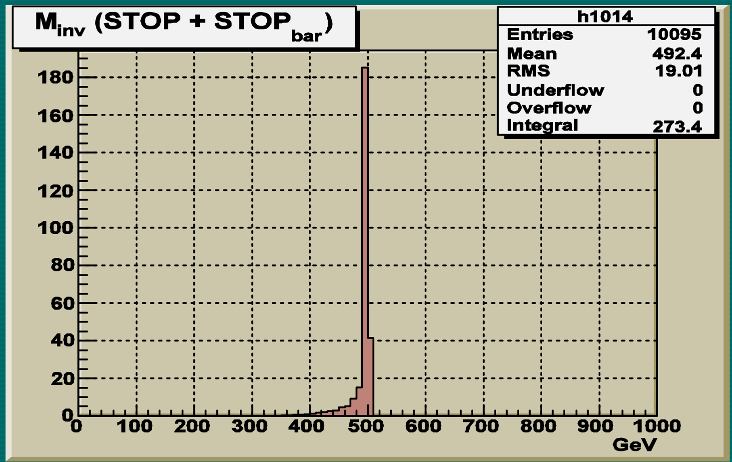
Electron e^- (positron e^+) beam energy with account of beamstrahlung

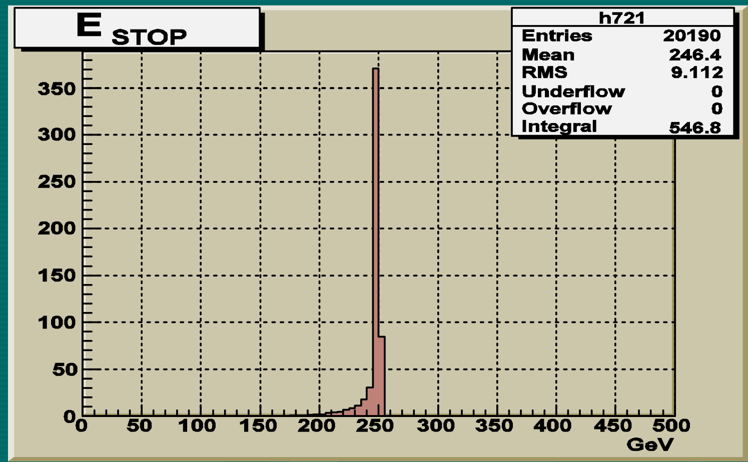
Correlation between e^+ and e^- beam spectra

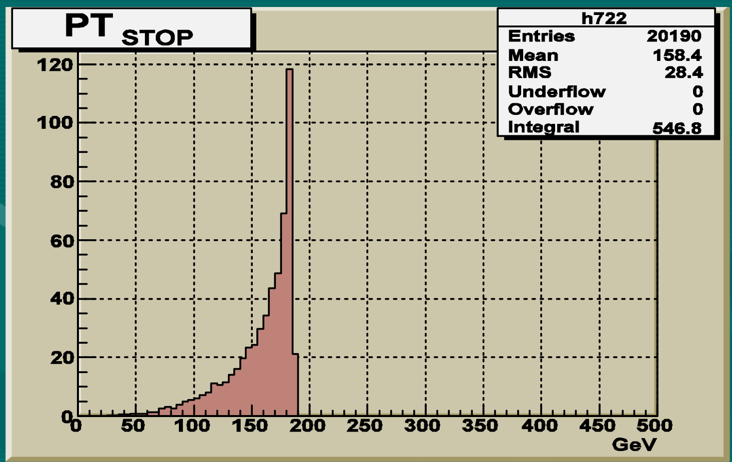
$Y_i = E^i / E^i_{beam}$ $(i = e^+, e^-)$

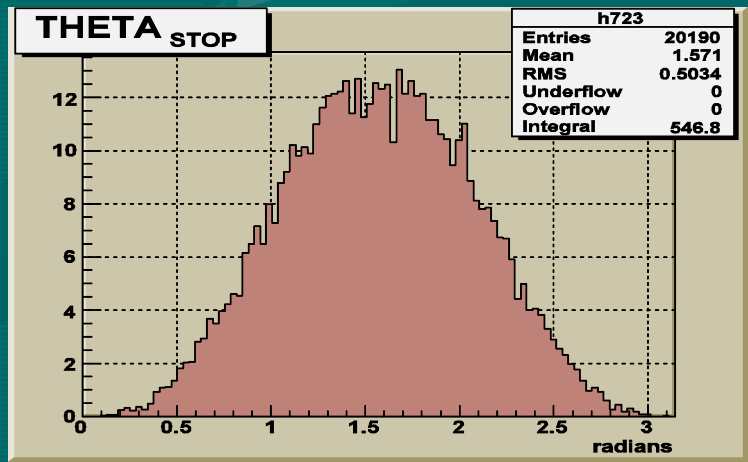


Main Scalar top quark distributions



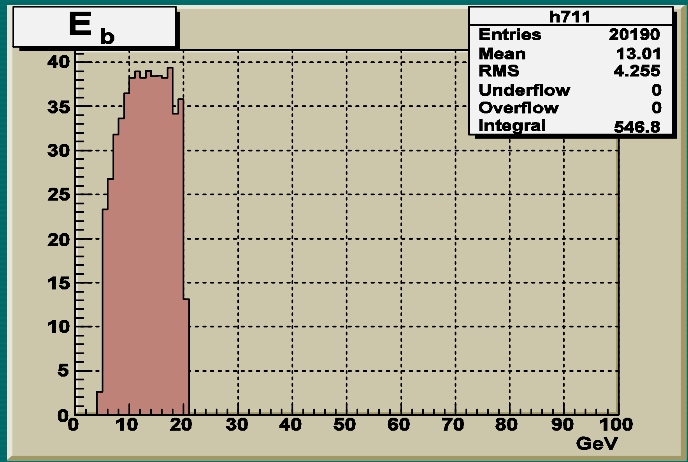


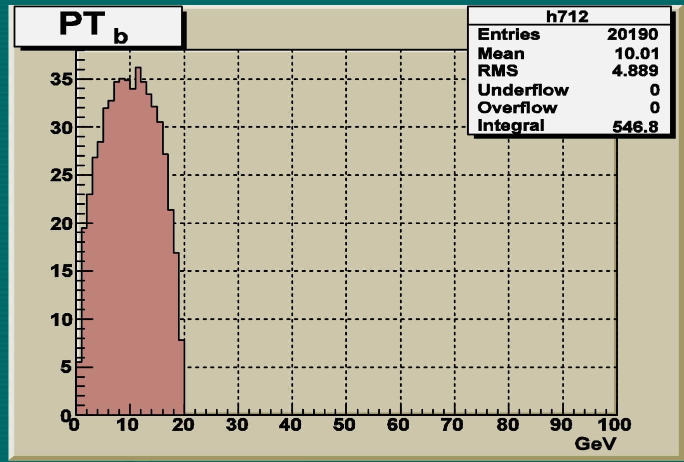




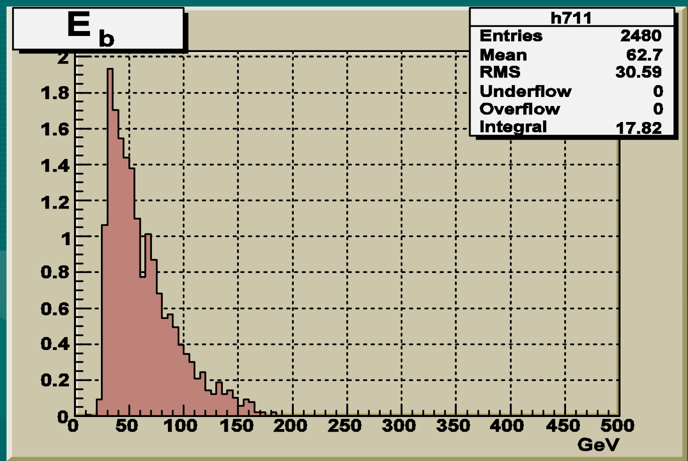
B-quarks distributions

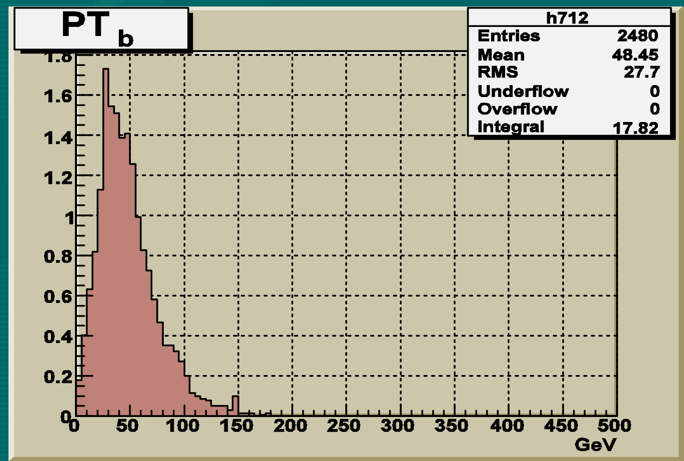
STOP





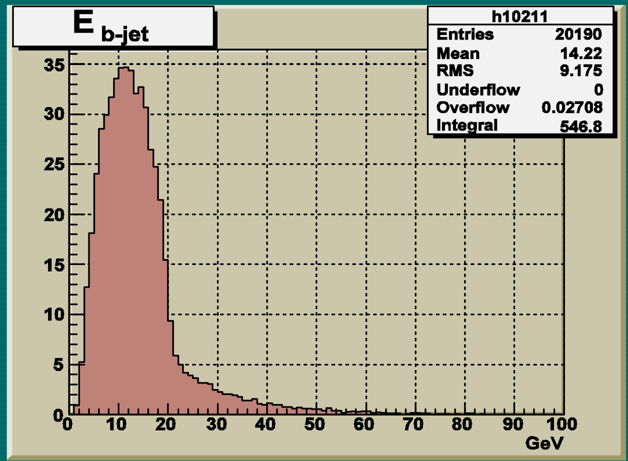
TOP

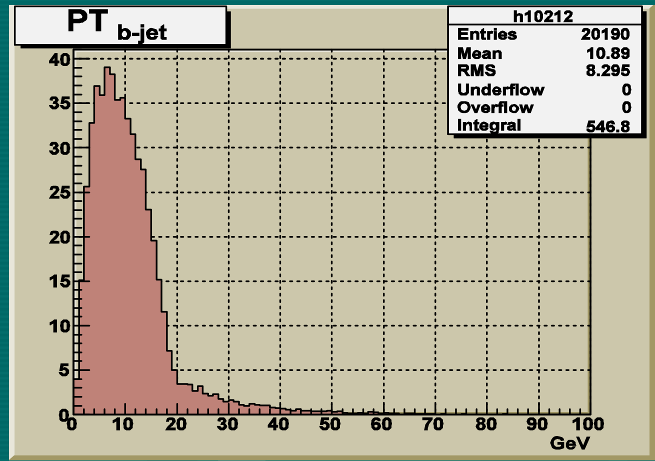




B-jets distributions

STOP





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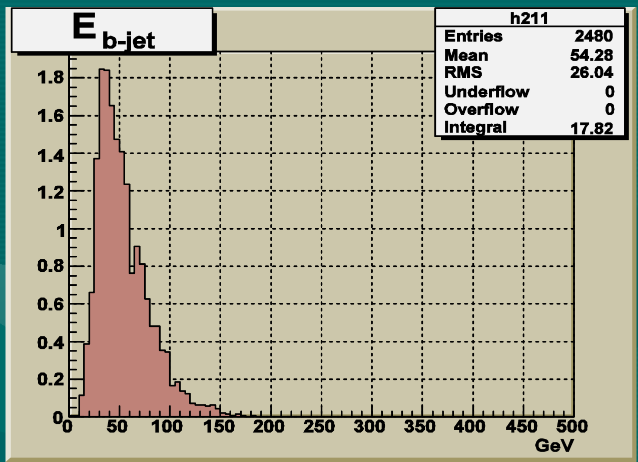
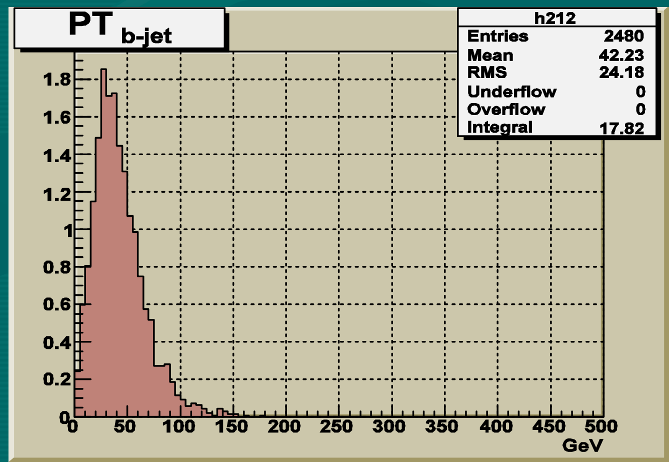


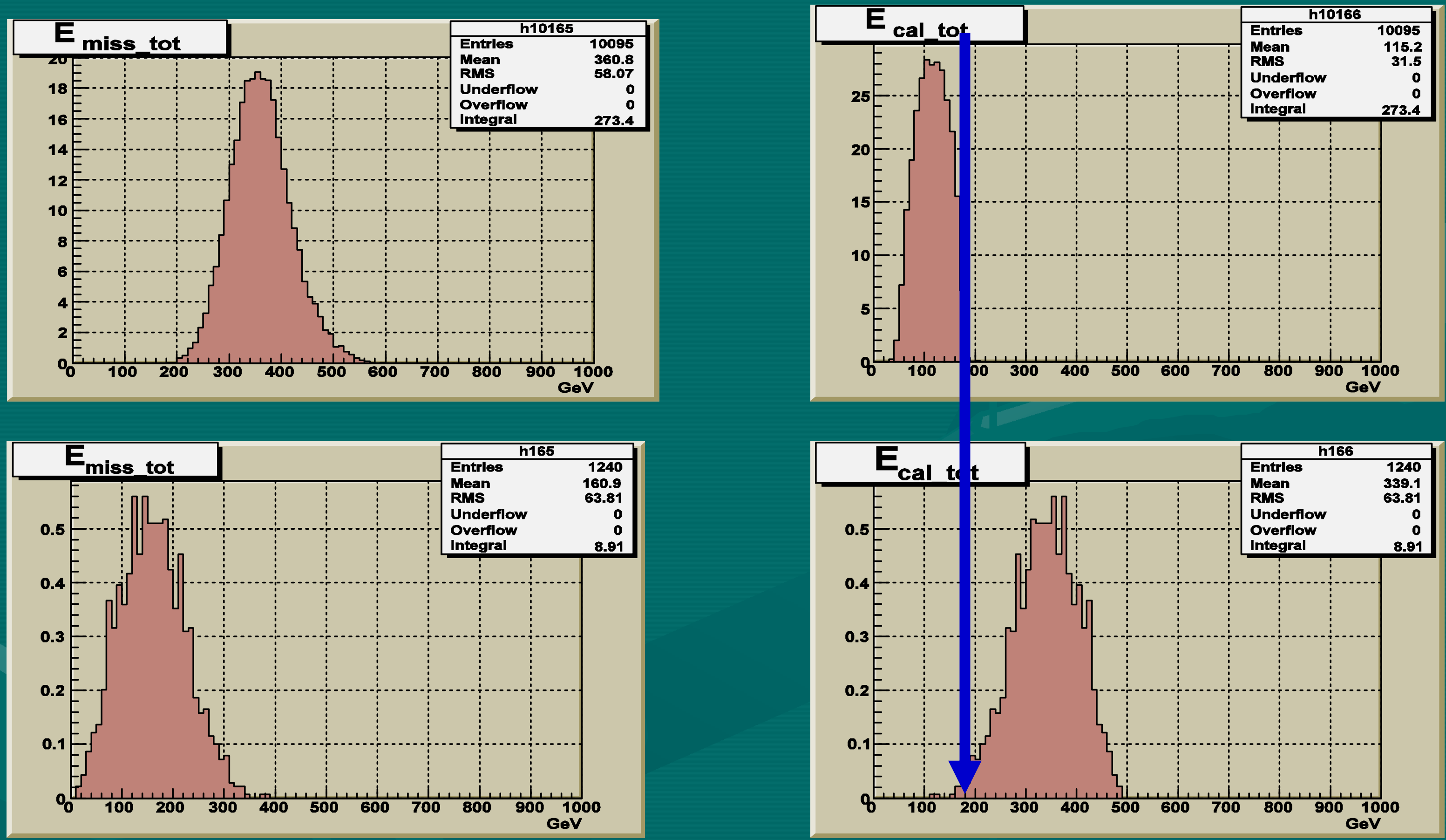


Missing energy (ν_μ , $\sim\chi_1^o$, beam pipe) and detected energy distributions

Good for Signal / Background separation with cut E_{cal_tot} < 180 GeV !

STOP

TOP



Missing energy — Detected energy

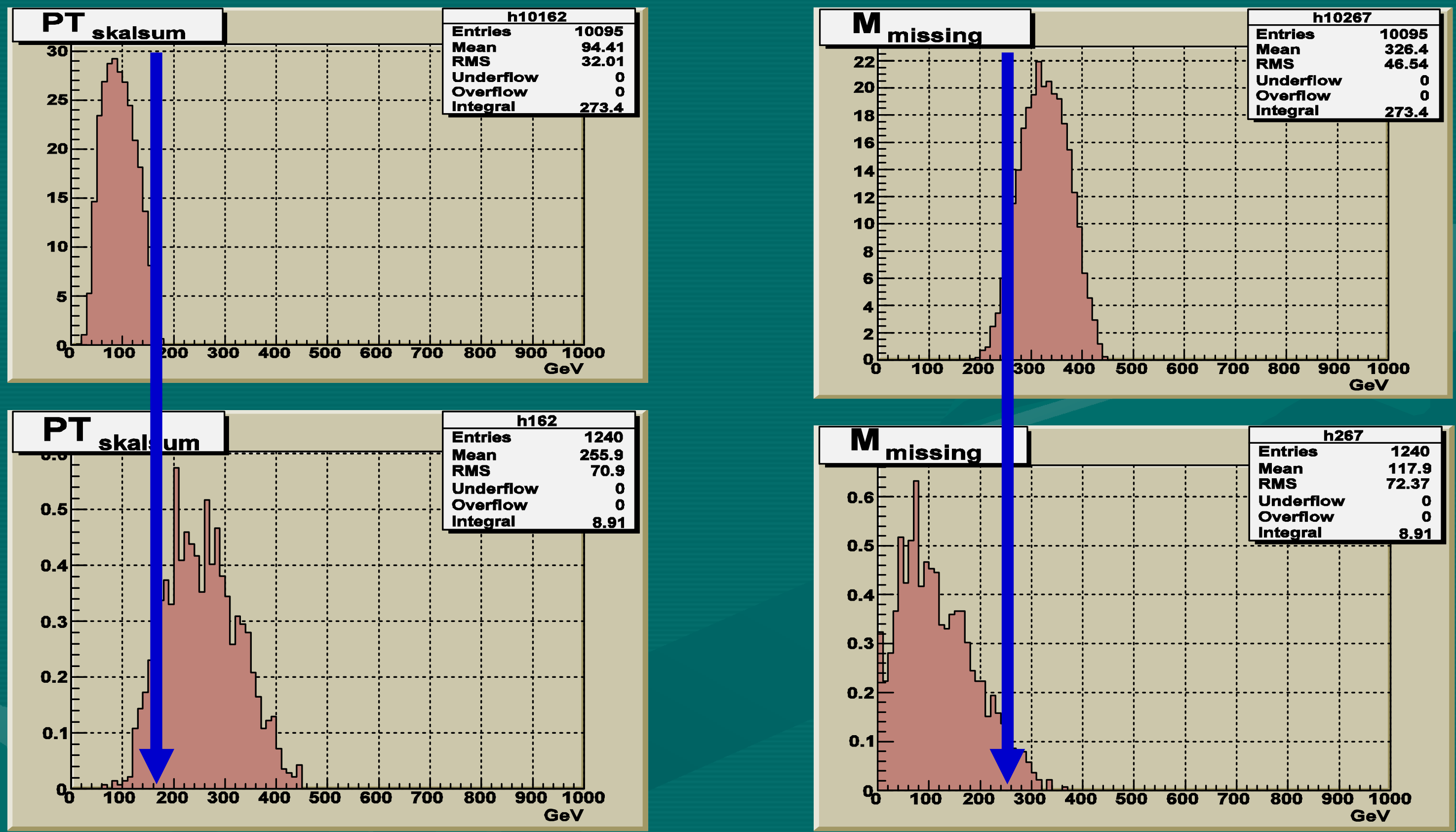
Total scalar Σ PT and $M_{missing}$ variable

Good for Signal / Background separation with the cuts

$PT_{skalsum}$ < 150 GeV and $M_{missing}$ > 250 GeV !

STOP

TOP



Scalar Σ PT

$M_{missing}$

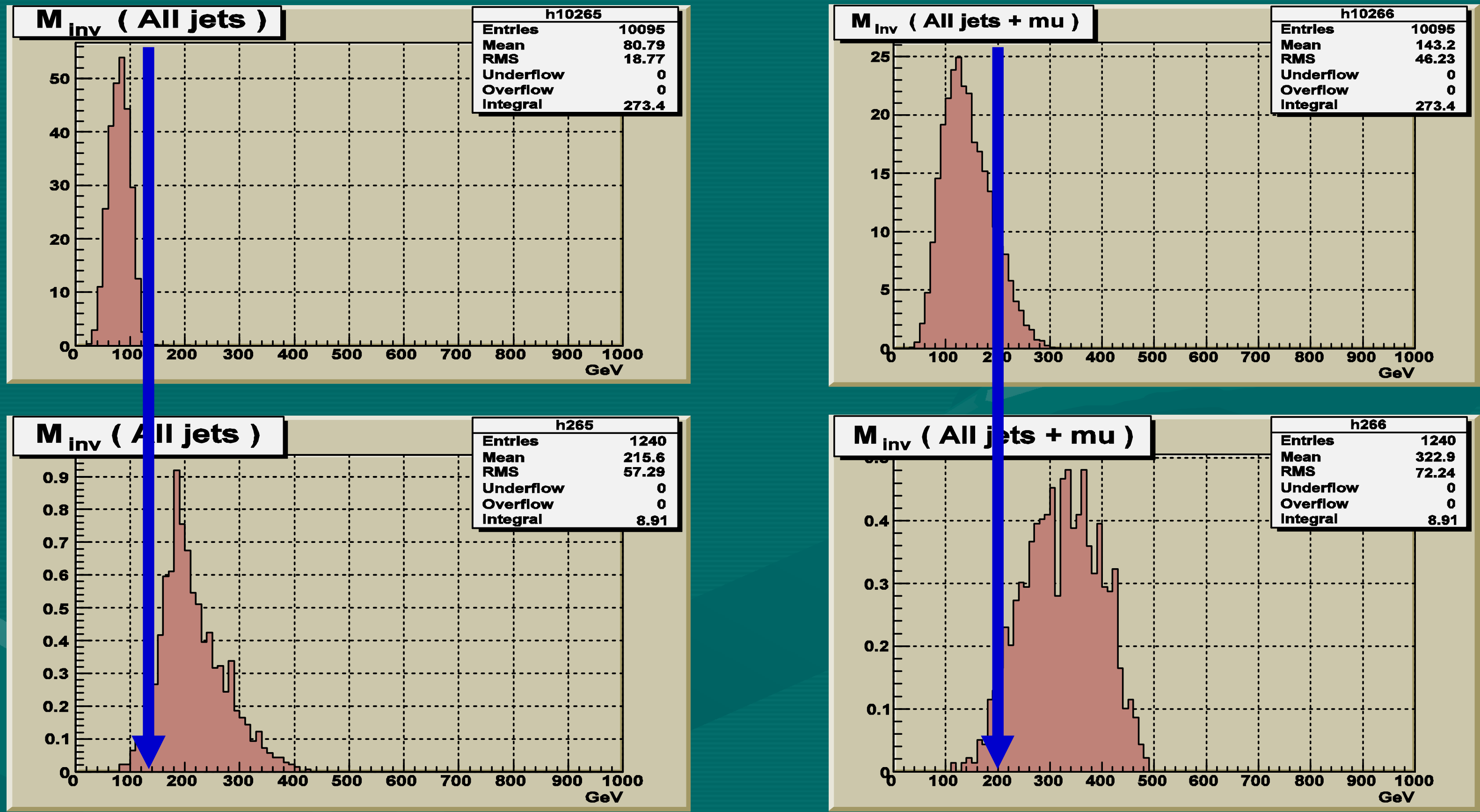
Invariant mass of 4 jets, 4jets + μ

Good for Signal / Background separation cut

M_{inv} (4 jets) < 120 GeV and M_{inv} (4 jets + μ) < 200 GeV !

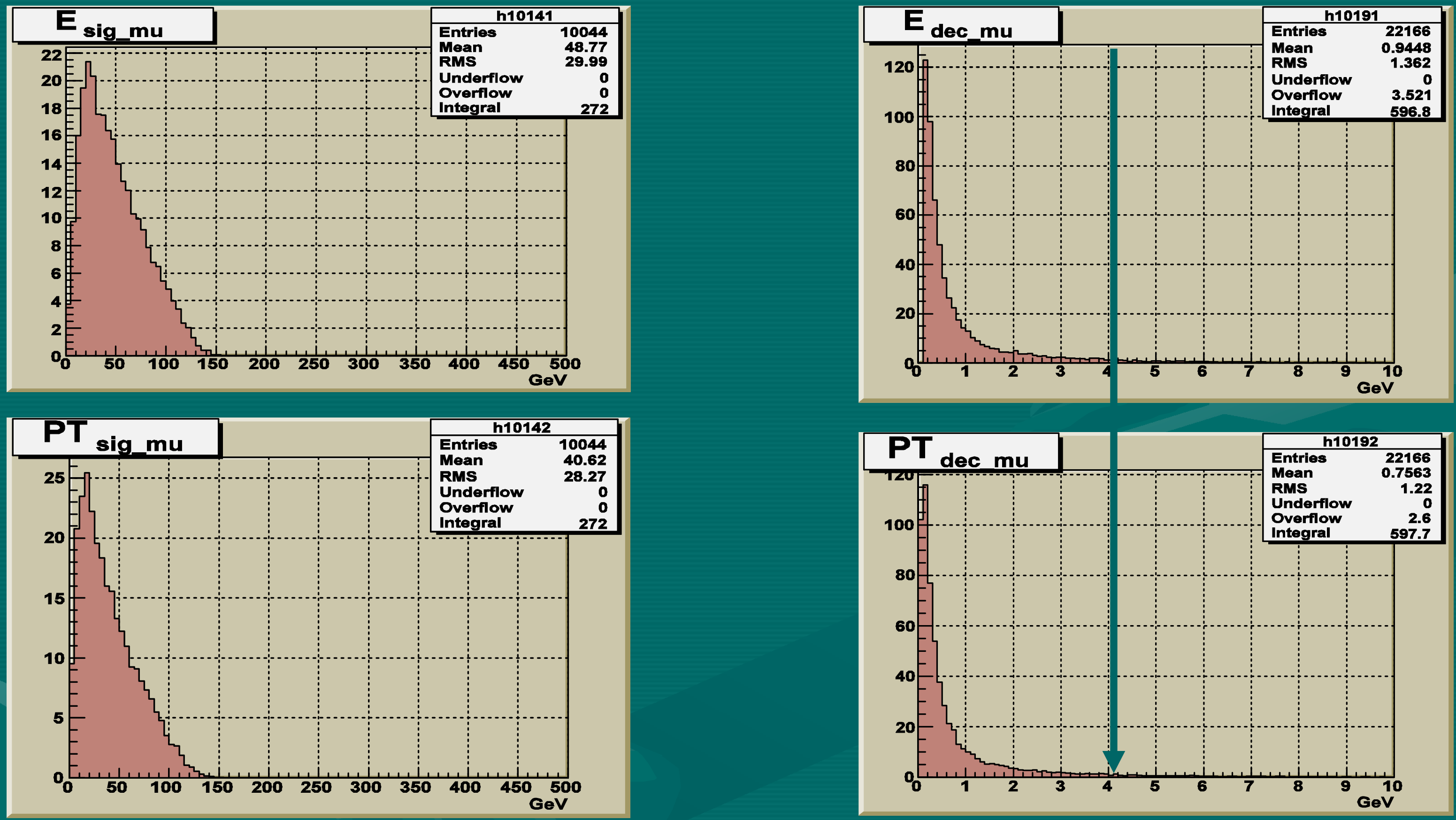
STOP

TOP



M_{inv} (4 jets) M_{inv} (4 jets + μ)

μ distributions in the signal events



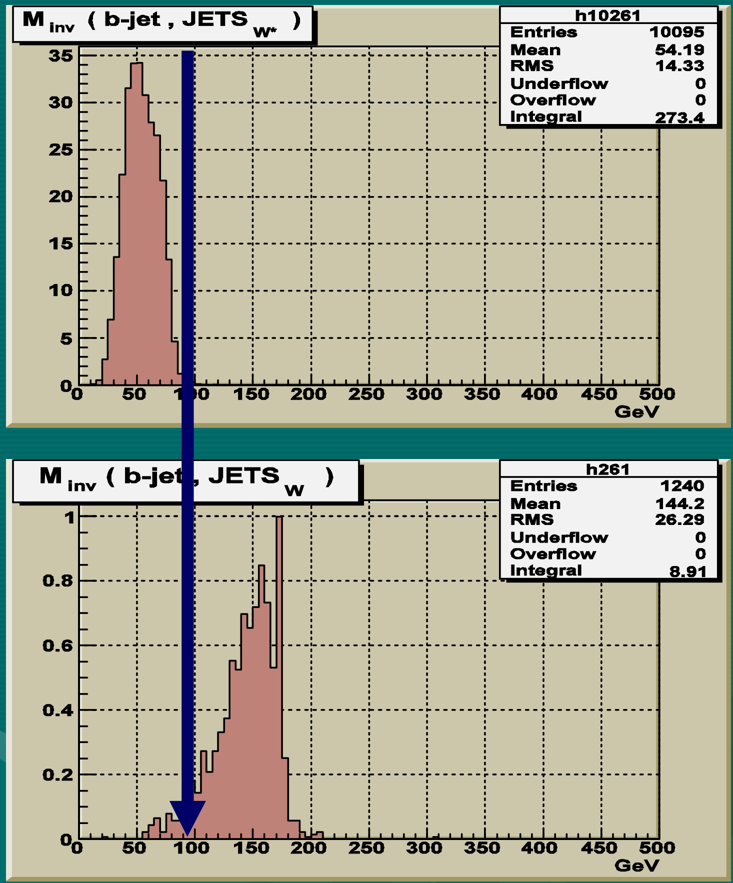
Signal μ's **Fake μ's**

Invariant mass of B_{jet} & $2jets_W$

Good for Signal / Background separation cut M_{inv} (b-jet, JETSw) < 100 GeV!

STOP

TOP



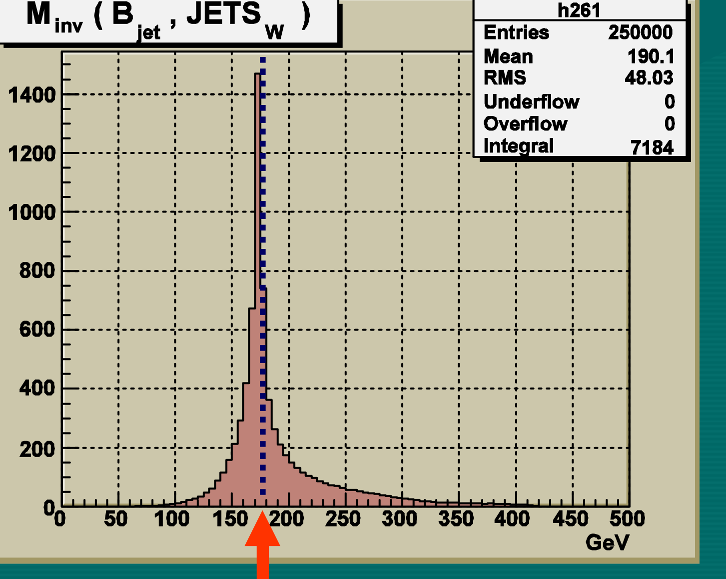
Minv (b-jet, JETSw)

The most important variable - invariant mass of B_{jet} & $2jets_W$

In the case of ***TOP pair*** production it gives

The reconstruction of M_{Top} (175 GeV) :

$$M_{inv}(B_{jet} \ \& \ 2jets_W) = M_{Top}$$



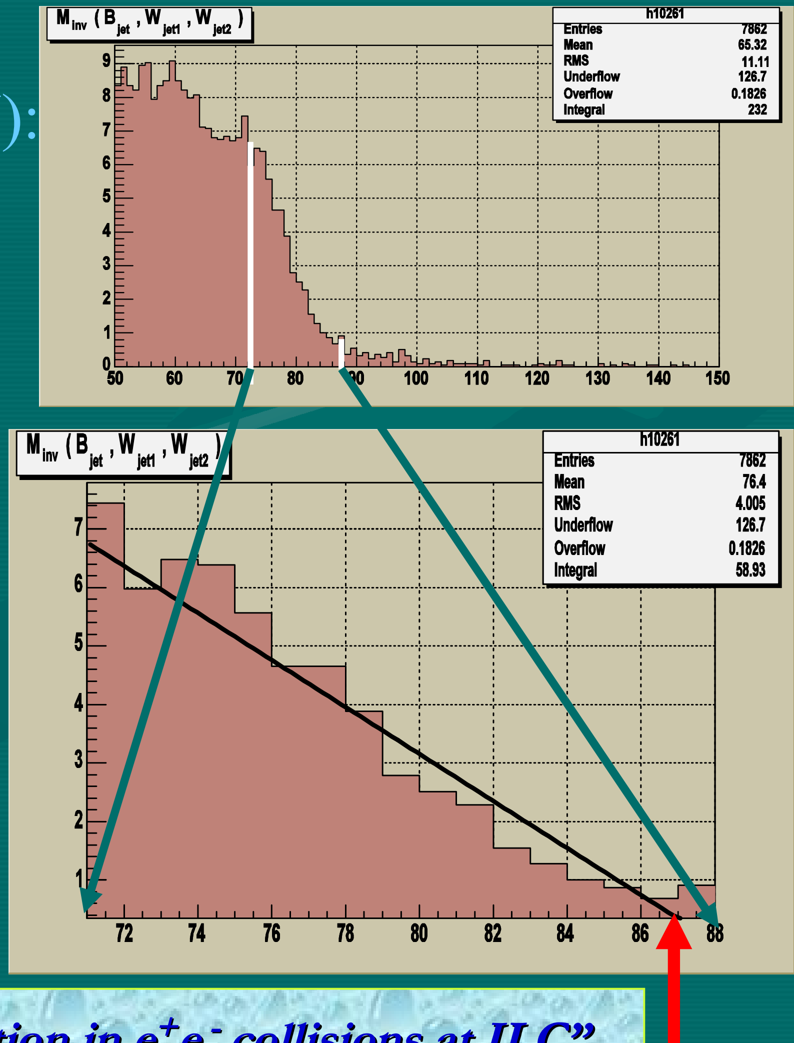
Invariant mass of B_{jet} & $2jets_W$ gives

For the case of *STOP pair* production

The reconstruction of M_{STOP} (167.9 GeV):

$M_{inv}(STOP) = M\,\chi_1^o + M_{inv}(B_{jet}, 2jet_W) =$

$= M\,\chi_1^o + \sqrt{(P_{Bjet} + Pjet1_W + Pjet2_W)^2}$



Right edge of M_{inv} (Bjet , 2jetW) ≈ 87 GeV

$M\,\chi_1^o$ ≈ 80.9 GeV

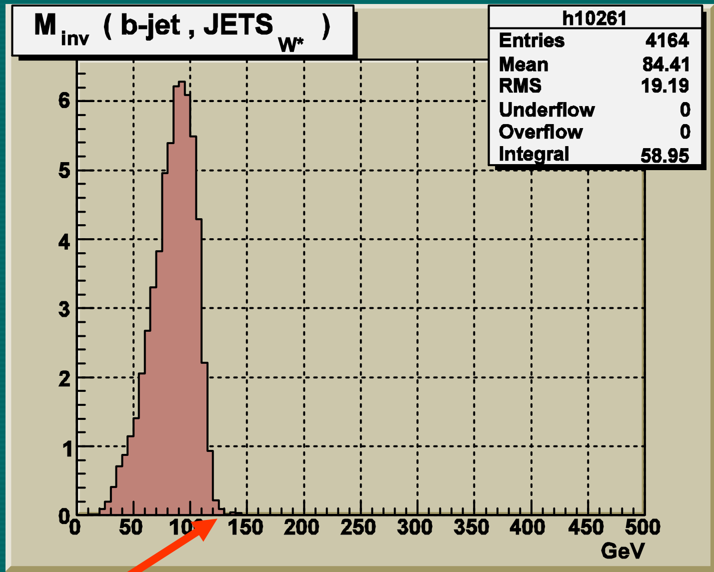
$M_{stop} = M\,\chi_1^o + M_{inv}$(Bjet , 2jetW) =

167.9 ± 0.1 GeV

The fitting function : $f(x) = p_1 + p_2 * x$

The test of the other Scalar top mass

- M_{stop} = 200.1 GeV
- $M\ \chi 1^o$ = 80.9 GeV
- $M\ \chi\ 1+$ = 159.6 GeV



Right edge of M_{inv} (Bjet , 2jetW) ≈ 120 GeV

$M\ \chi_1^o \approx 80$ GeV

$M_{stop} = M\ \chi_1^o + M_{\ inv}$(Bjet , 2jetW) = 200 GeV

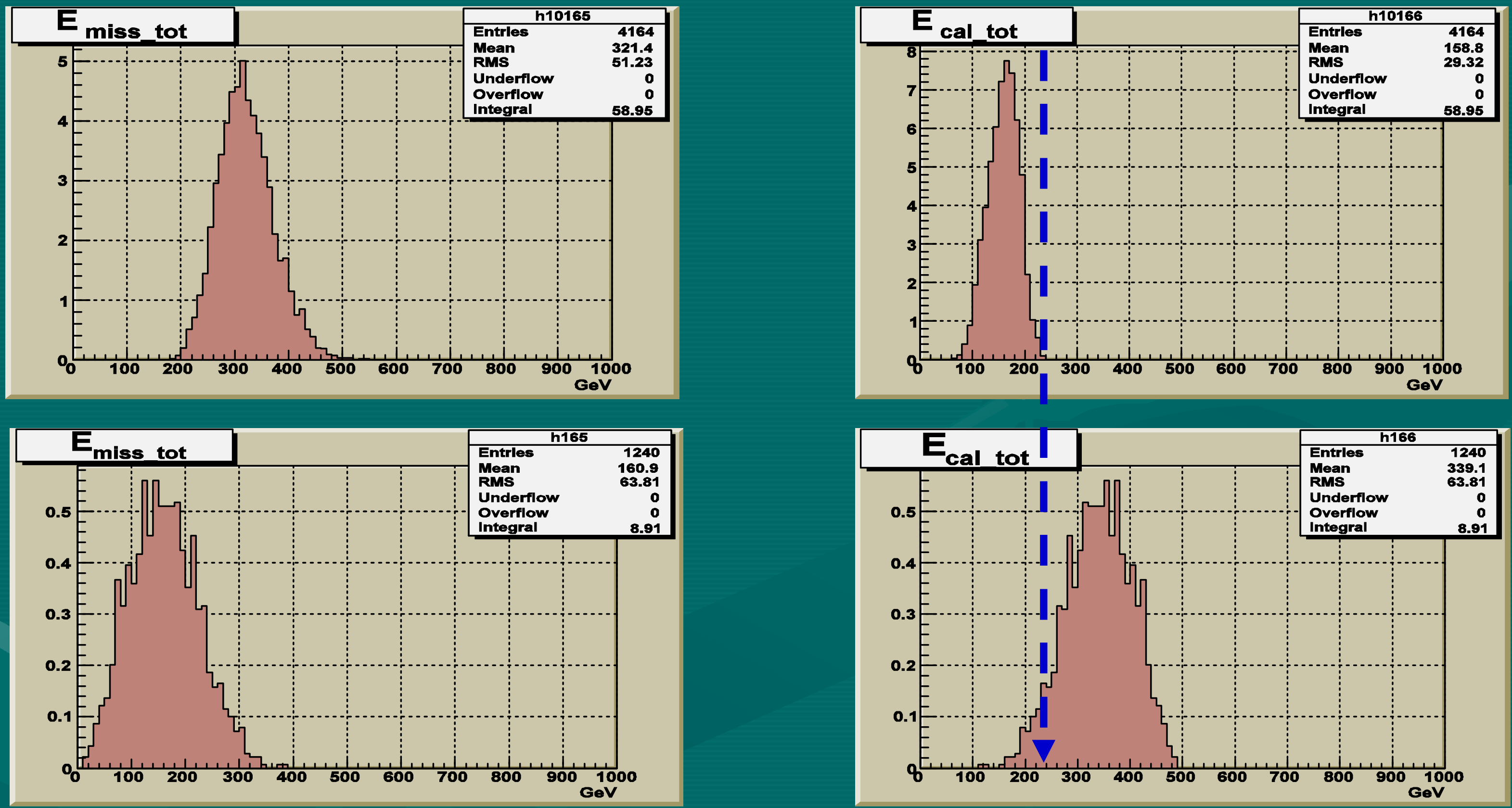
58 events / year

Missing energy (ν_μ, $\sim\chi_1^o$, beam pipe) and detected energy distributions

Good for Signal / Background separation with cut E_{cal_tot} < 220 GeV !

STOP

TOP



Missing energy

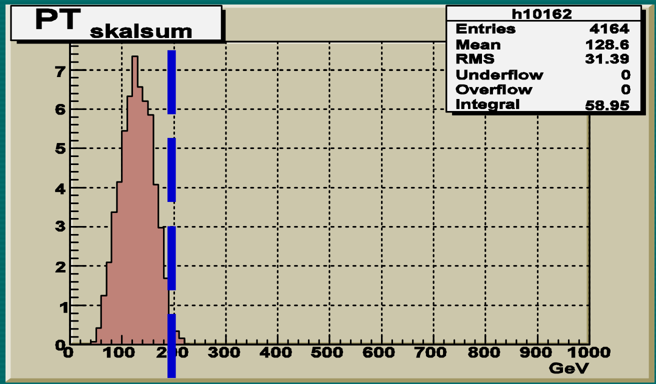
Detected energy

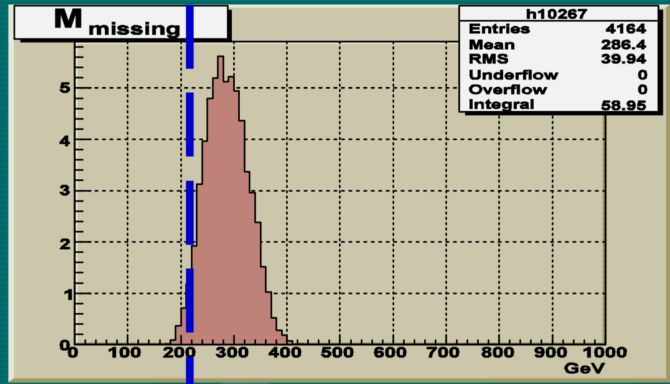
Total scalar Σ PT and $M_{missing}$ variable

Good for Signal / Background separation with the cuts

$PT_{skalsum} < 180$ GeV and $M_{missing} > 220$ GeV !

STOP





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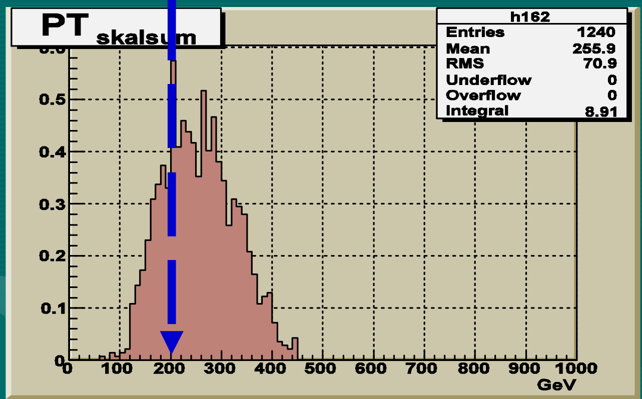
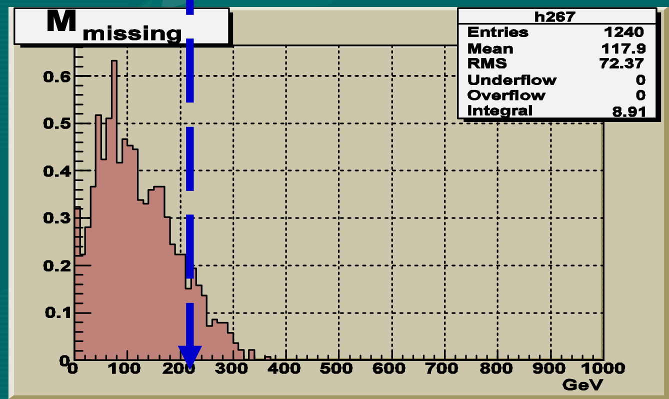




Scalar Σ PT **$M_{missing}$**

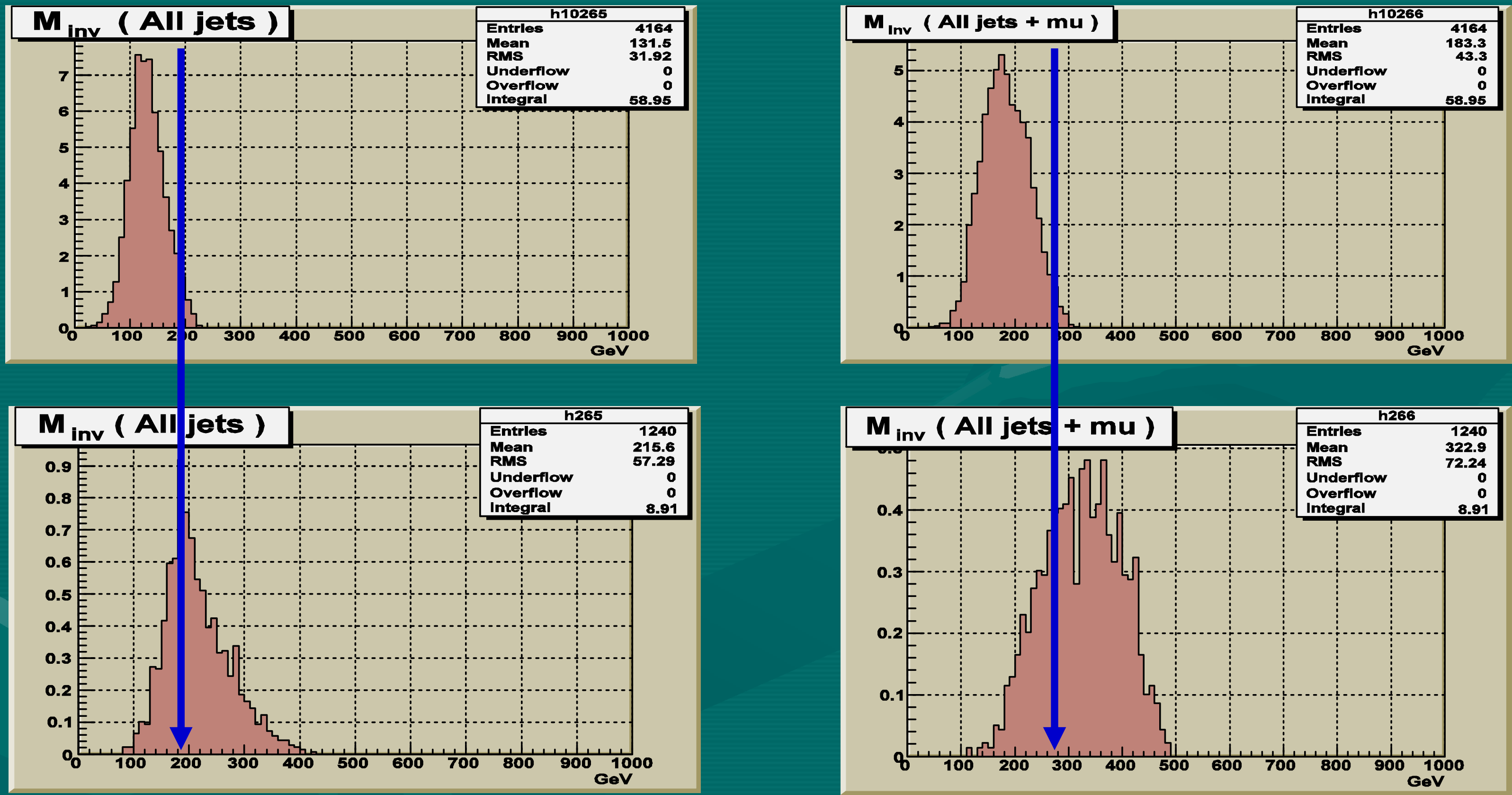
Invariant mass of 4 jets, 4jets + μ

Good for Signal / Background separation cut

M_{inv} (4 jets) < 190 GeV and M inv (4 jets + μ) < 270 GeV !

STOP

TOP

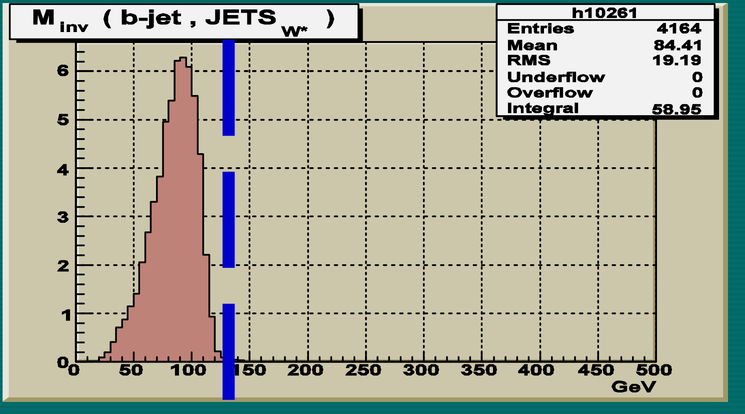


Minv (4 jets) Minv (4 jets + μ)

Invariant mass of B_{jet} & $2jets_W$

Good for Signal / Background separation cut Minv (b-jet, JETSw) < 130 GeV!

STOP



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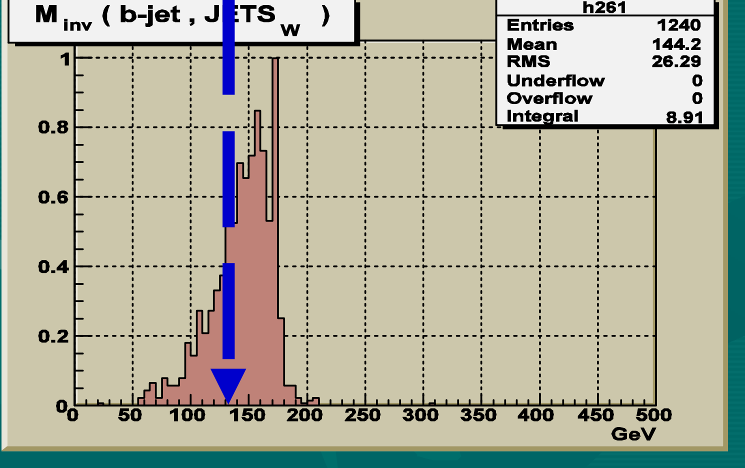

Minv (b-jet, JETSw)

Conclusion

1. The MC (PYTHIA 6.1 + CIRCE 1) study of stop pair production in e+e- collision was done at $\sqrt{S_{ee}}$ = 350, 400, 500, 800, 1000 GeV.

2. The detailed analysis done at $\sqrt{S_{ee}}$ = 500 GeV has shown that proposed 3 cutes allow to reach S/B =30.

3. It is shown also that the invariant mass of the final state objects (jets, leptons) and missing energy variable turns out to be most efficient for signal / background separation.

4. A possibility of a good reconstruction of the M_{STOP} with the error ± 0.1 GeV from the right-hand edge point of Minv (3 jets, i.e. Bjet + 2 $jets_W$) is demonstrated.

So, finally, the channel

$$\text{STOP STOP} \rightarrow b\ \chi_1^+\ \bar{b}\ \bar{\chi}_1^- \rightarrow b\ \bar{b}\ q\ \bar{q}'\ \mu^-\nu_\mu\ \chi_1^\circ\ \chi_1^\circ$$

<u>is very promising for STOP quark search!</u>

Publications

- ***"Pair production of scalar top quarks in e+e- collisions at ILC. "***

  Authors: A.Bartl, W.Majerotto, K.Mönig, A.N.Skachkova, N.B.Skachkov

  arXiv:0804.2125, ILC-NOTE-2008-042, submitted to JHEP

- ***"Pair production of scalar top quarks in polarized photon-photon collisions at ILC. "***

  Authors: A.Bartl, W.Majerotto, K.Mönig, A.N.Skachkova, N.B.Skachkov

  arXiv:0804.1700, ILC-NOTE-2007-036, submitted to EPJ C