international linear collider

Hadronic jets and search for scalar top quarks in e^+e^- collisions at ILC

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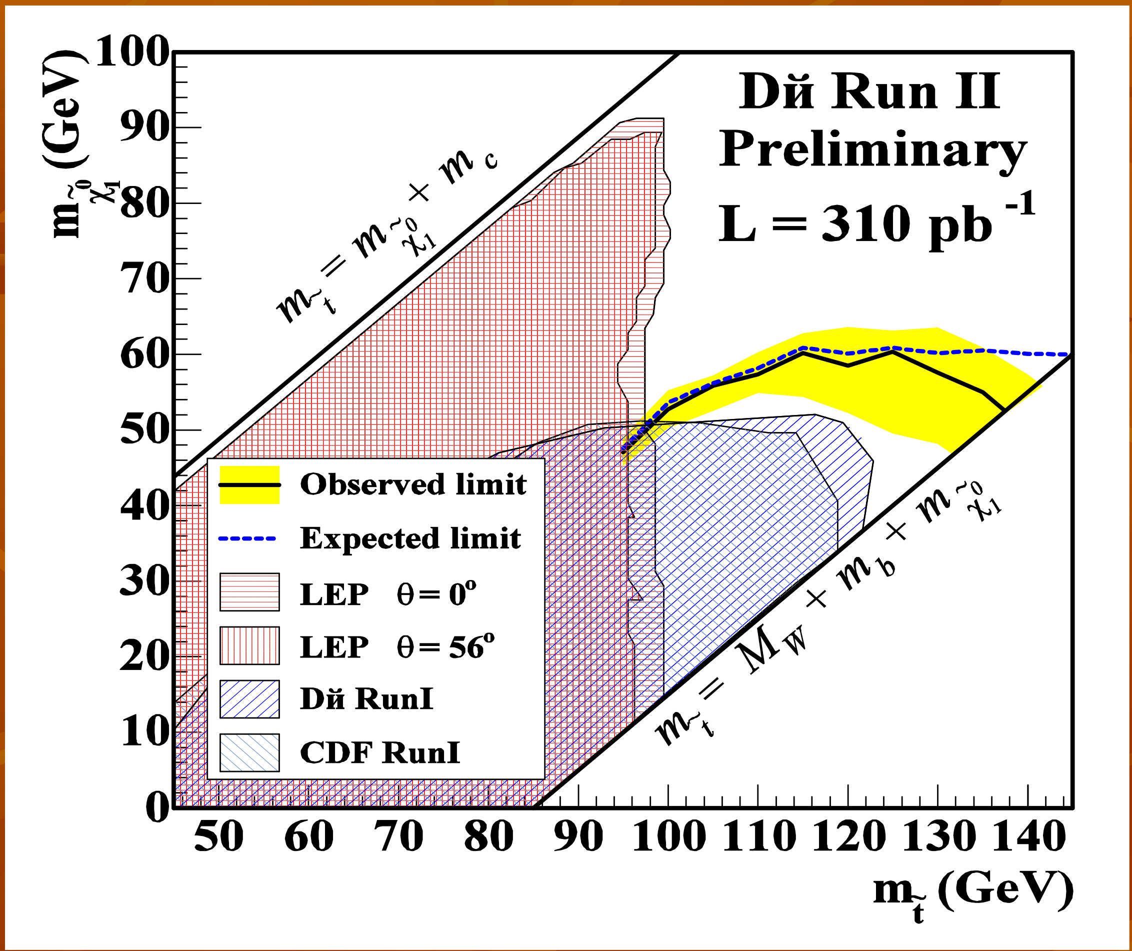
Experimental restrictions on the STOP mass



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

D0 Note 5134-CONF

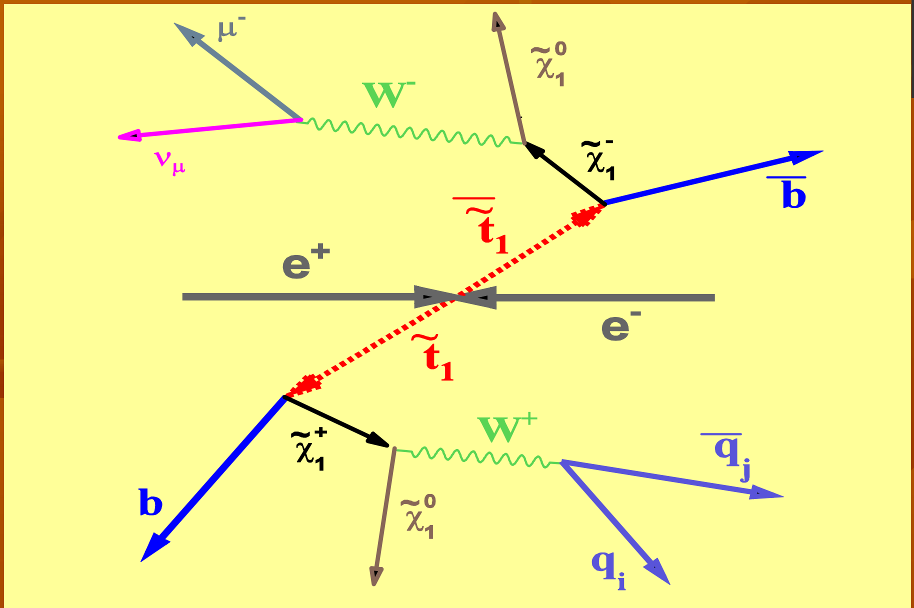
7 June 2006

Fermilab-Pub-06/396-E

hep-ex/0611003

Phys. Lett. B645 (2007) 119-127

Simulation is done by use of PYTHIA 6.4 + CIRCE 1



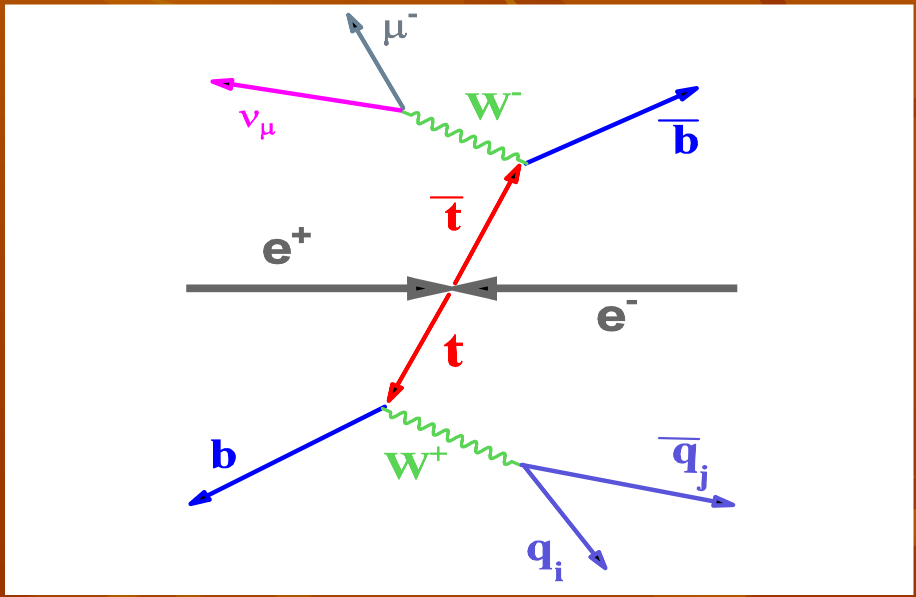
$e^+ e^-$ CM energy = 500 GeV

STOP pair production cross section

$\sigma = 2.37$ 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
- $\tan\beta = 5$
- M_1 = 80 GeV
- M_2 = 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:

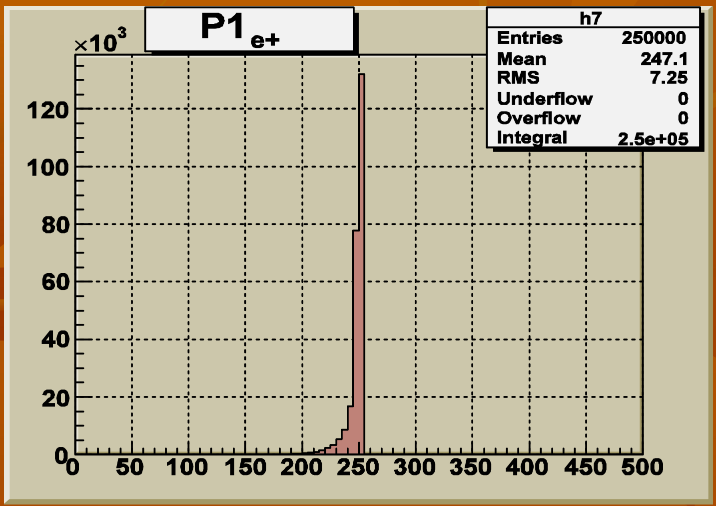
- ***To find out physical variables (Energy, PT, angle and invariant mass distributions) most suitable for signal (stop) / background (top) separation***
- ***To estimate the corresponding values of cuts on these variables***

Cross section dependence on E_{beam}

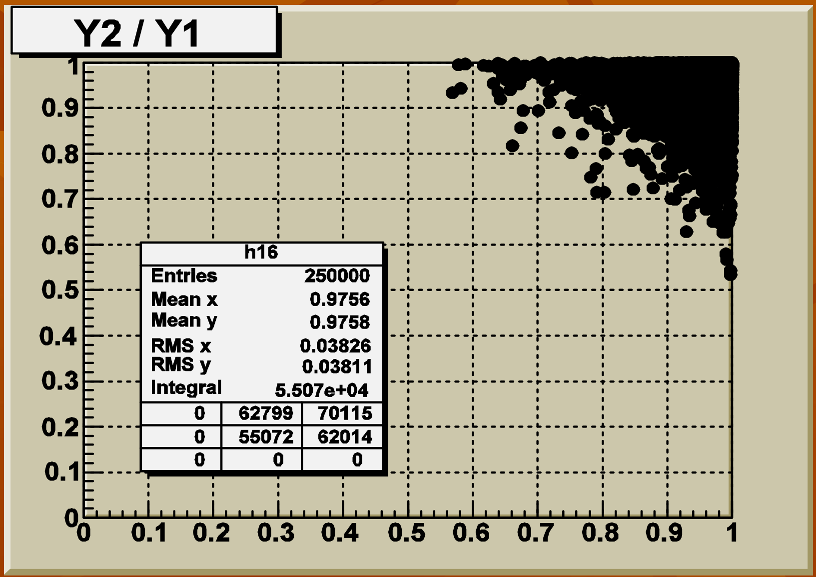
(without any cuts)

$2E_{beam}$[GeV]	σ_{stop} [fb]	N_{stop}	σ_{top} [fb]	N_{top}
350	0.23	233	13.76	13750
400	1.34	1347	38.79	38740
<u>500</u>	<u>2.37</u>	<u>2378</u>	<u>35.94</u>	<u>35950</u>
800	1.89	1809	17.36	17359
1000	1.42	1265	11.66	11656

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



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



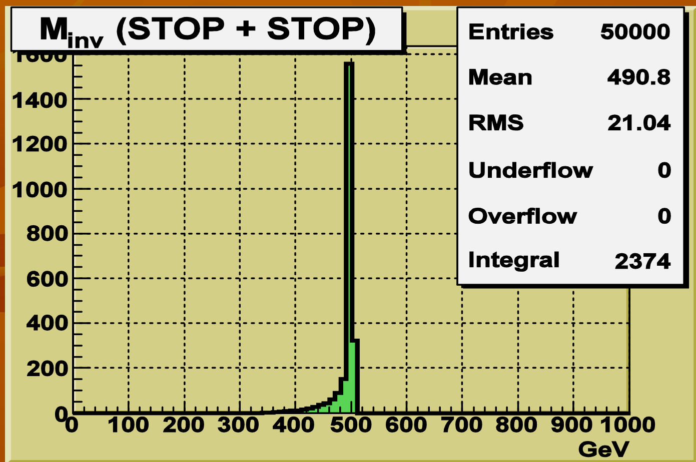
Correlation between e^+ and e^- beam spectra

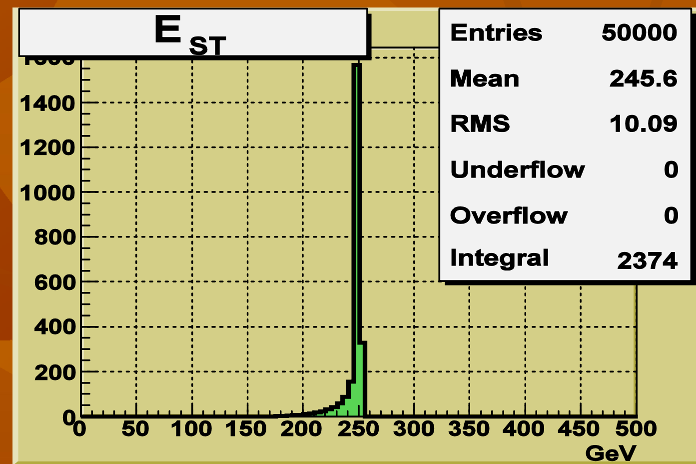
$Y_i = E^i / E^i_{beam}$ $(i = e^+, e^-)$

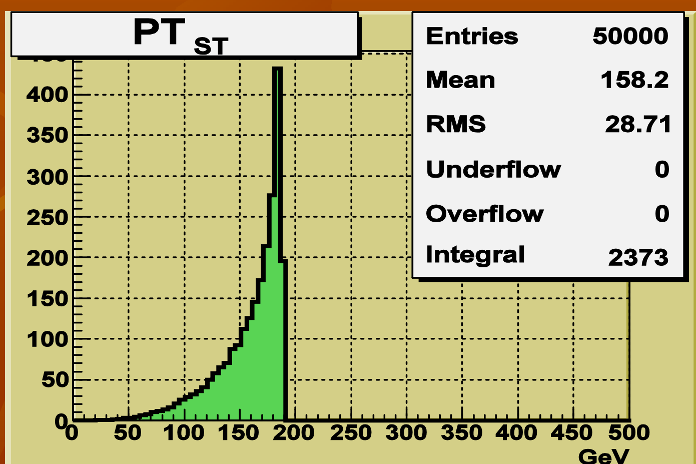
The peak luminosity is supposed to be $2 \cdot 10^{34} cm^{-2} s^{-1}$.

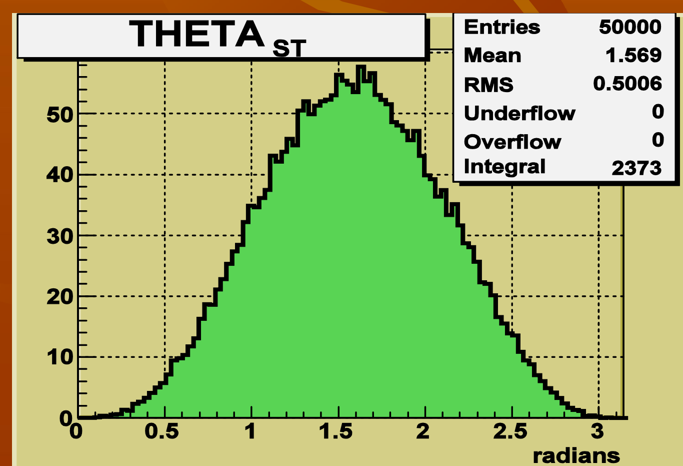
The total luminosity required is 1000 fb^{-1} during the first phase of operation at $2E^e_{beam} = \sqrt{S_{ee}} = 500$ GeV.

Main Scalar top quark distributions



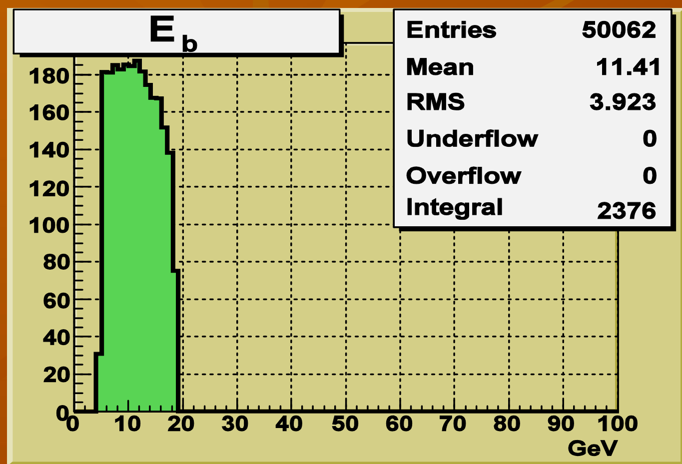


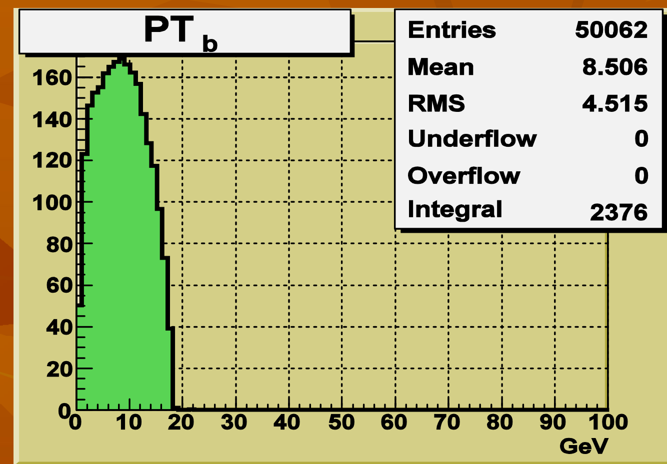




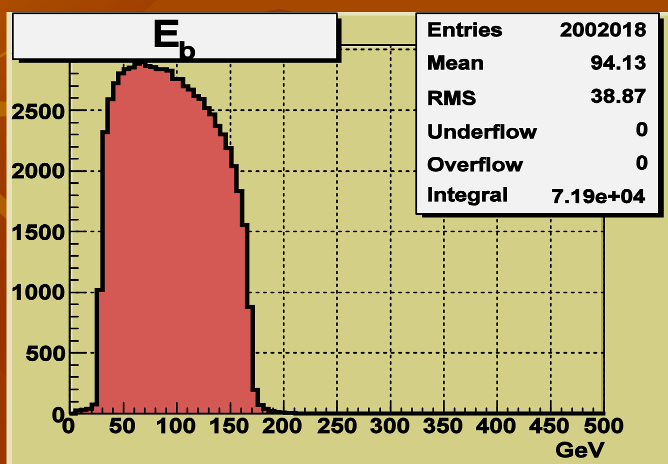
B-quarks distributions

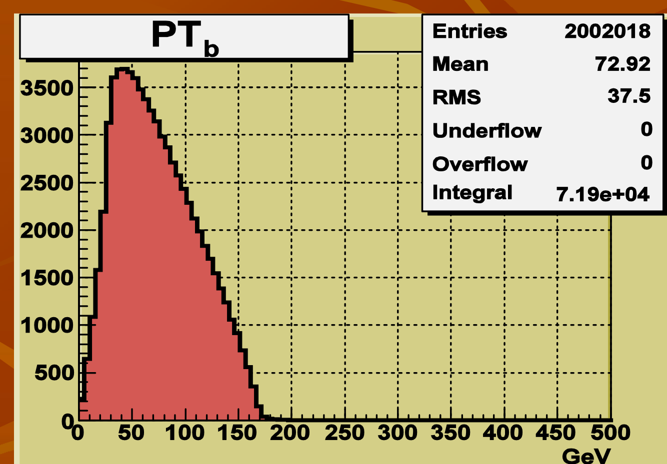
STOP





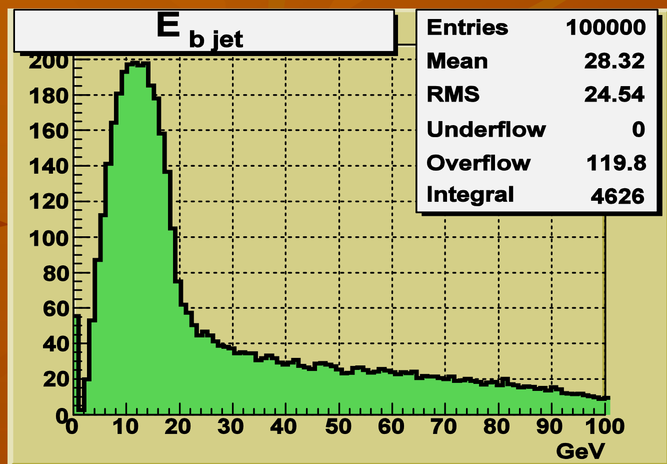
TOP

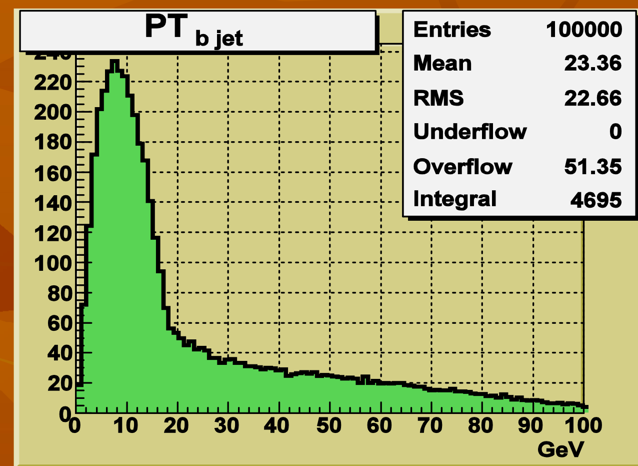




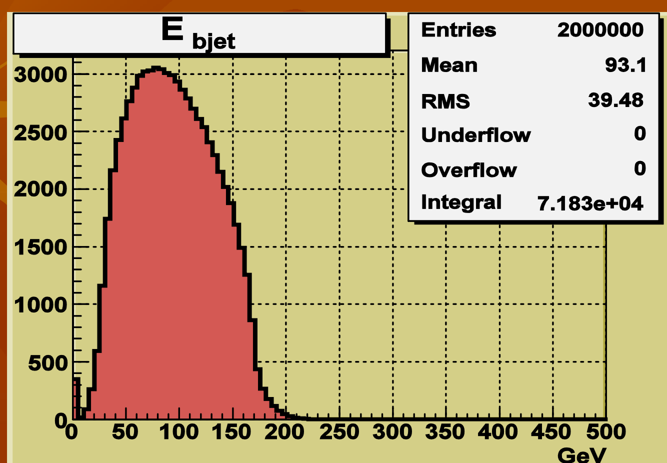
B-jets distributions

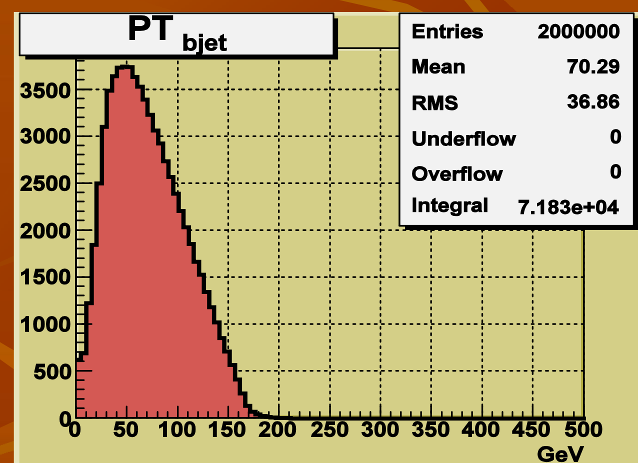
STOP





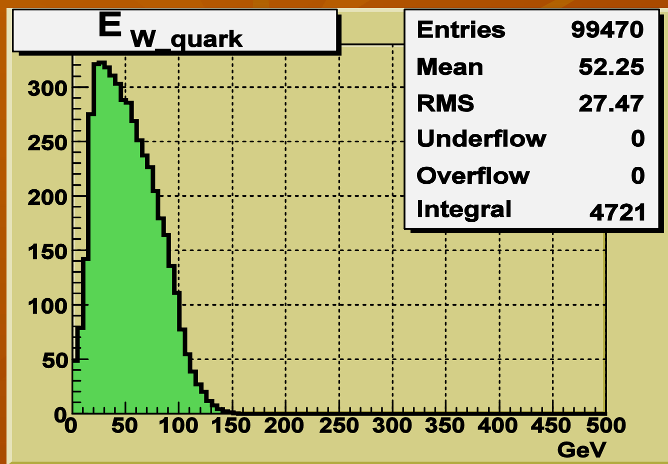
TOP

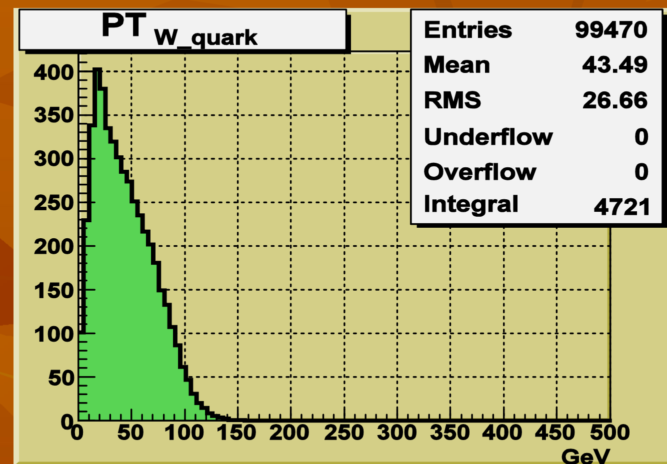




W-quarks distributions

STOP





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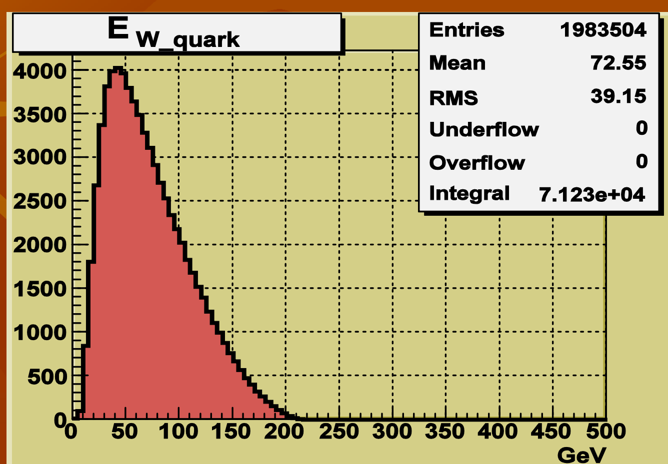
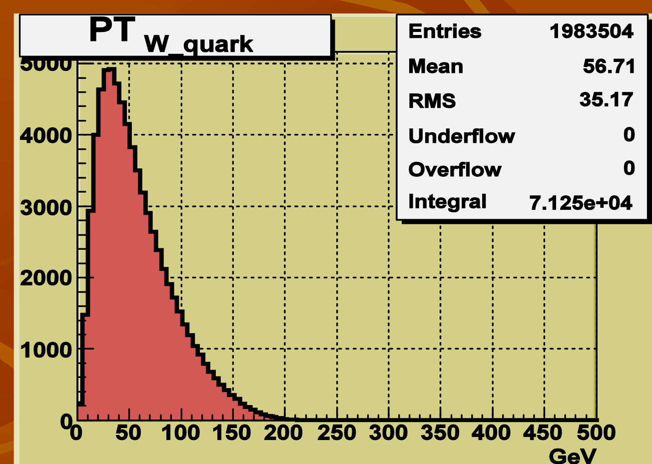
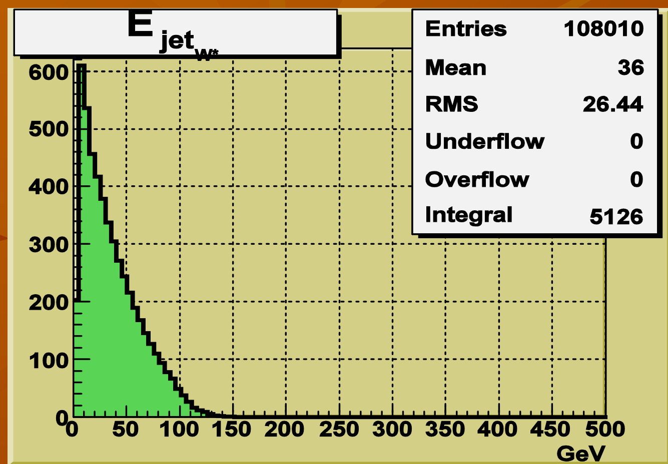
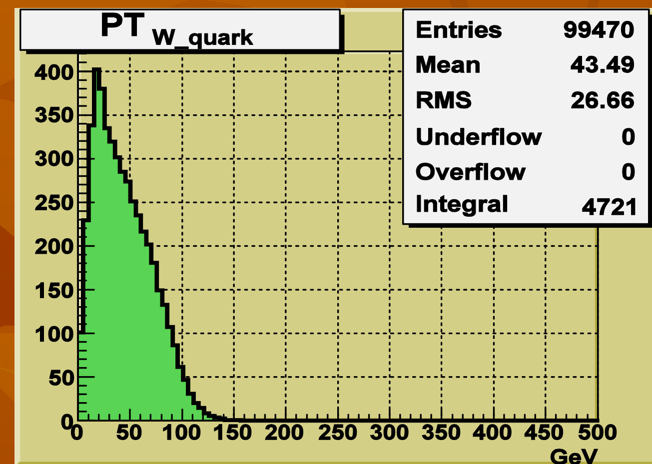




Distributions of jets from W decay

STOP





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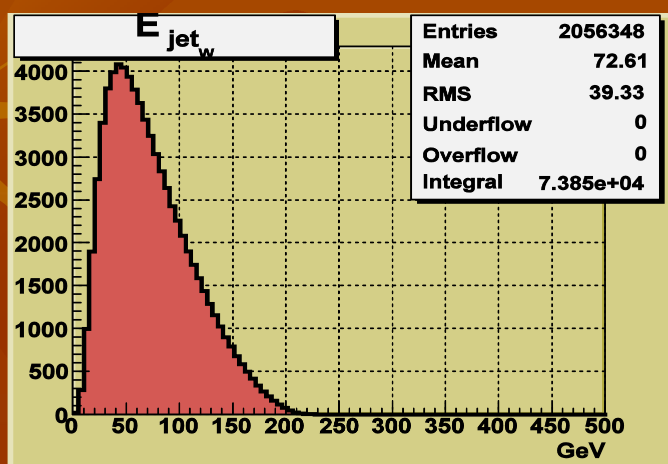
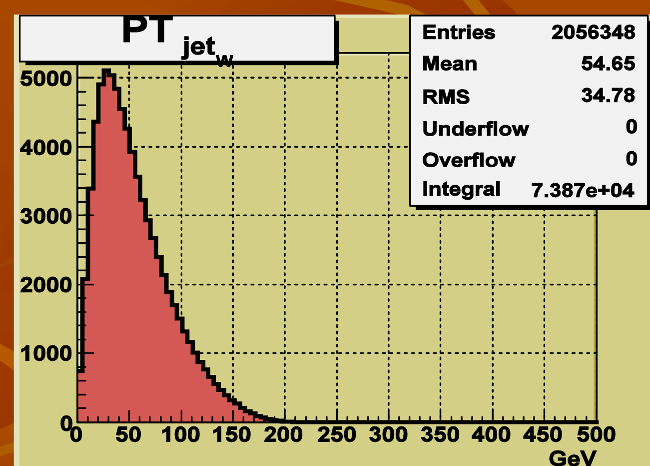


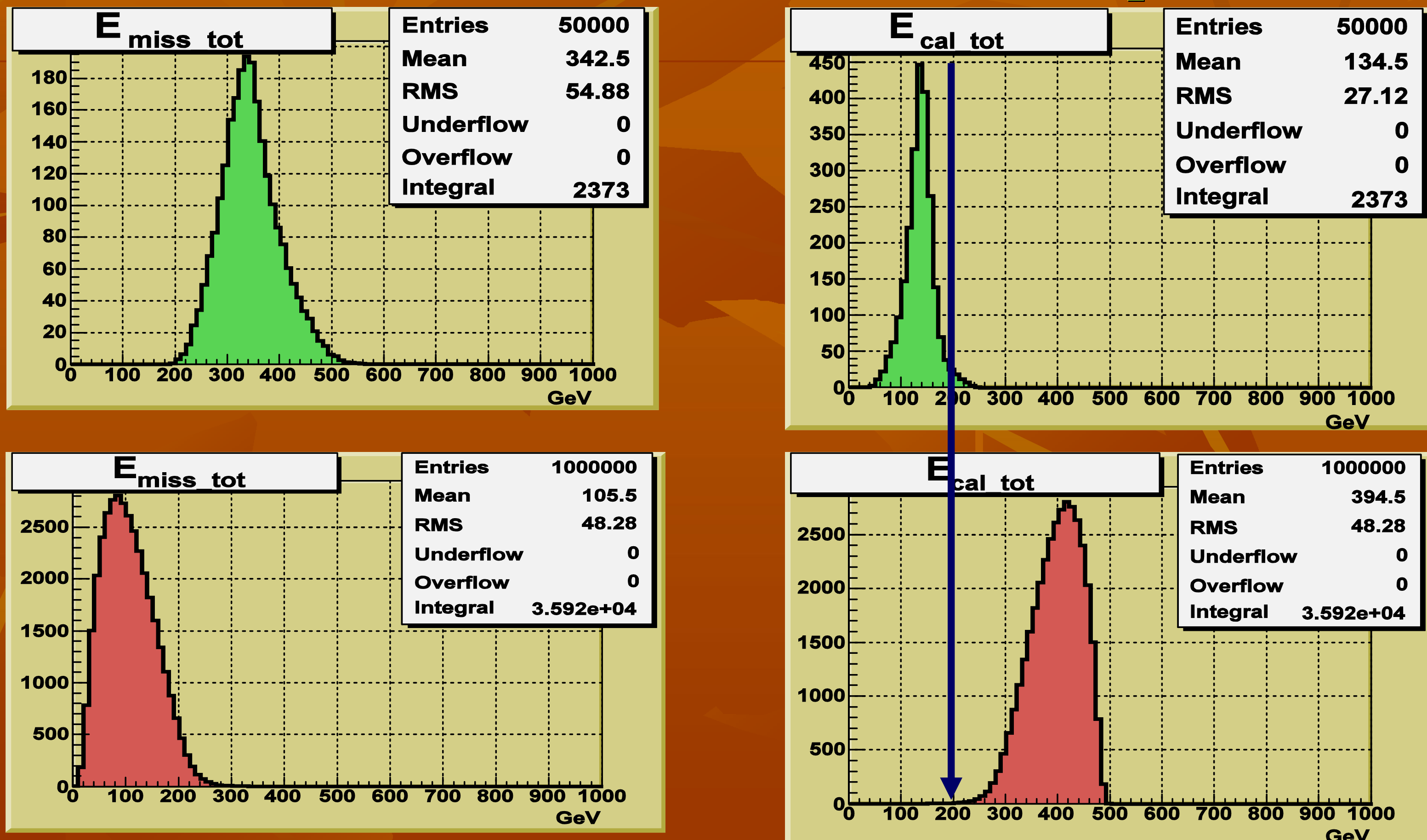


Missing energy (ν_μ , $\sim\chi_1^o$, beam pipe) and detected energy distributions

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

STOP

TOP



Missing energy

Detected energy

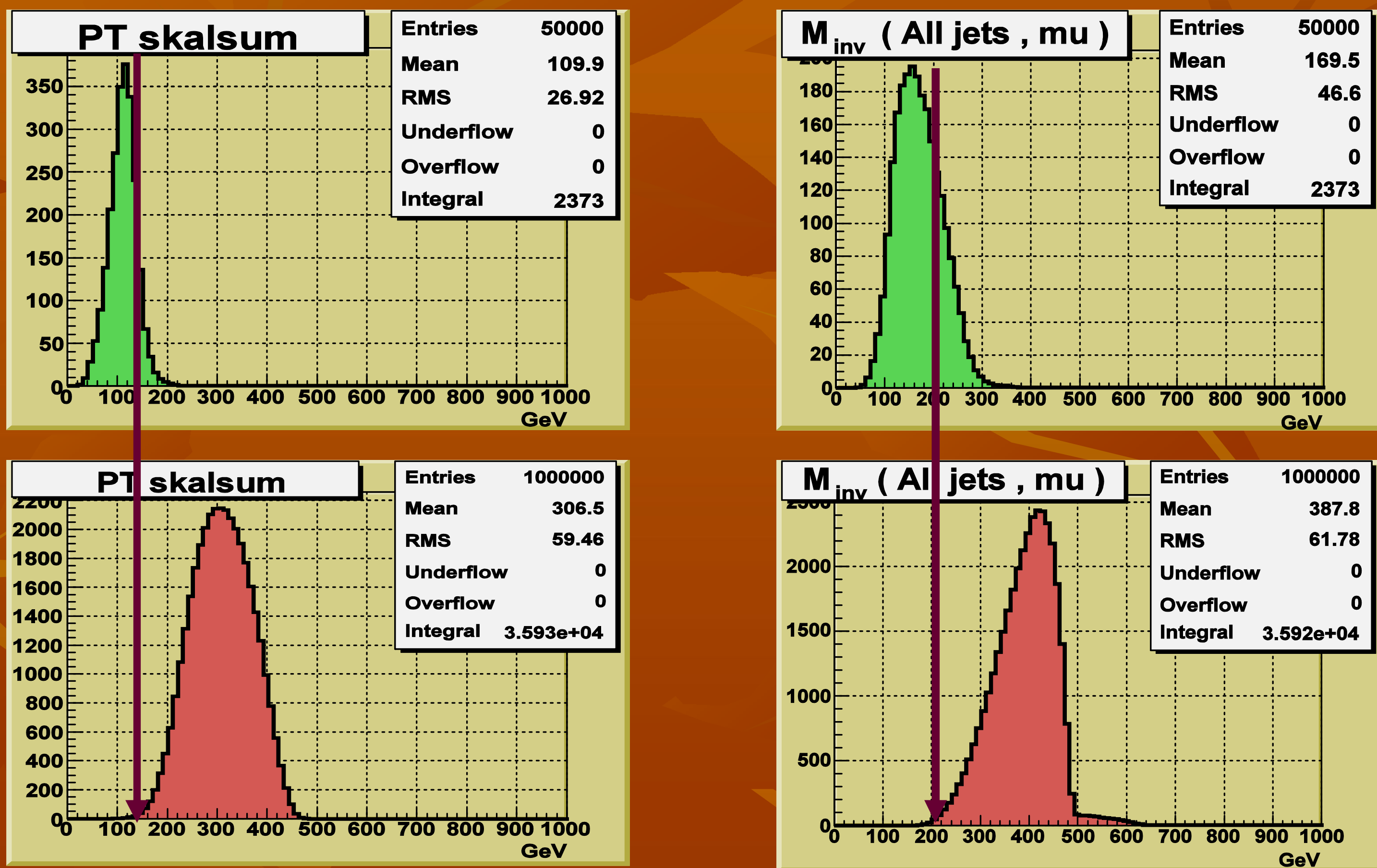
Total scalar Σ PT and Invariant mass of 4jets + μ

Good for Signal / Background separation with the cuts

$PT_{skalsum} < 150$ GeV and M_{inv} (4 jets + μ) < 200 GeV !

STOP

TOP



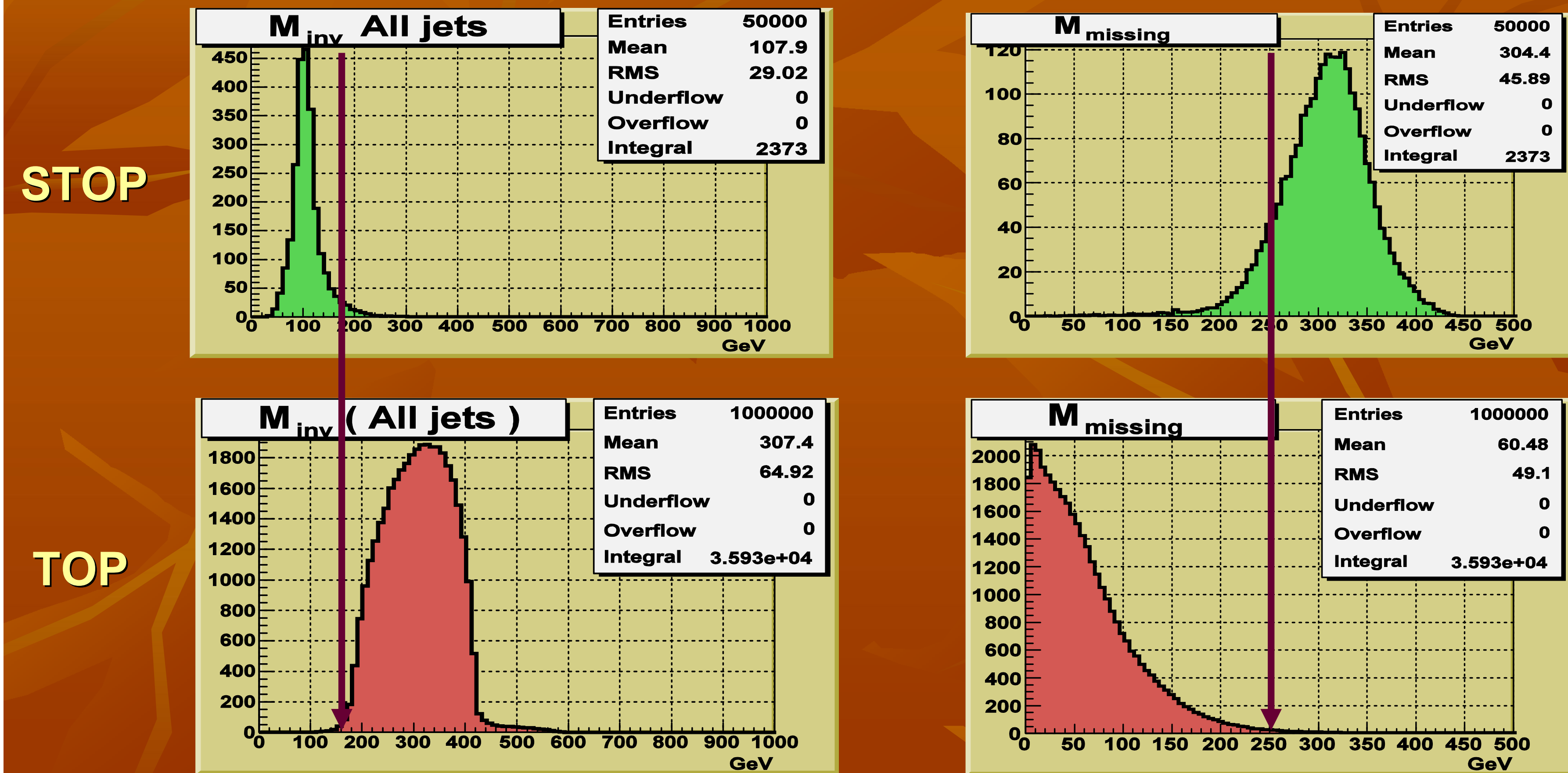
Scalar Σ PT

M_{inv} (4 jets + μ)

Invariant mass of 4 jets and $M_{missing}$ variable

Good for Signal / Background separation cut

M_{inv} (4 jets) < 160 GeV and $M_{missing}$ > 250 GeV



M_{inv} (4 jets) $M_{missing}$

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 only 50% efficiency of the B-jets and B_{bar}-jets separation and the 80% of the corresponding purity is expected

2.) Invariant mass of 4 jets (b_{jet}, $bbar_{jet}$, $2jets_W$) M_{inv} (All jets) < 160 GeV

together with the cut above

Stop cut efficiency = 0.78 *Top cut efficiency = 0.001*

3.) Invariant Missing mass M_{miss} > 250 GeV

together with the cuts above

Stop cut efficiency = 0.94 *Top cut efficiency = $6*10^{-6}$*

Achieved S/B ratio = 143

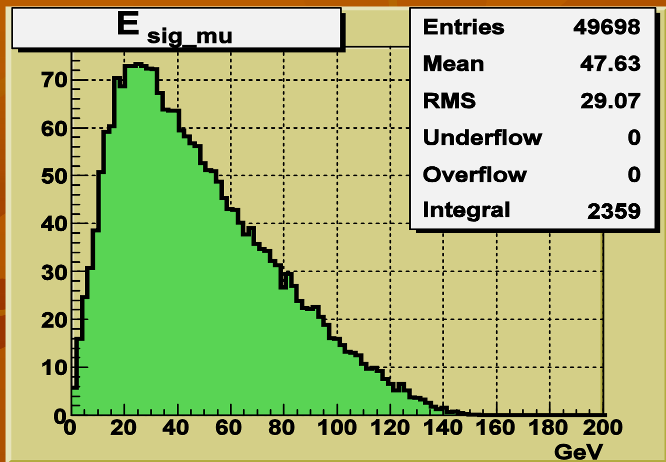
The rest is only 13 background events per year, while for the Signal events – 1086/year (for the integrated Luminosity L=1000 fb^{-1}/year)

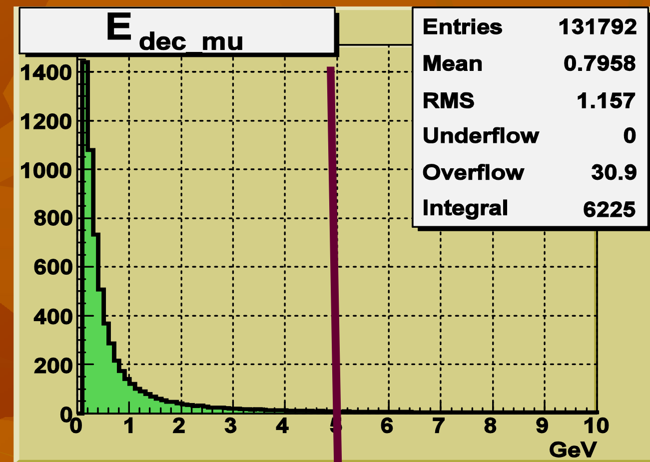
Cross section dependence on E_{beam}

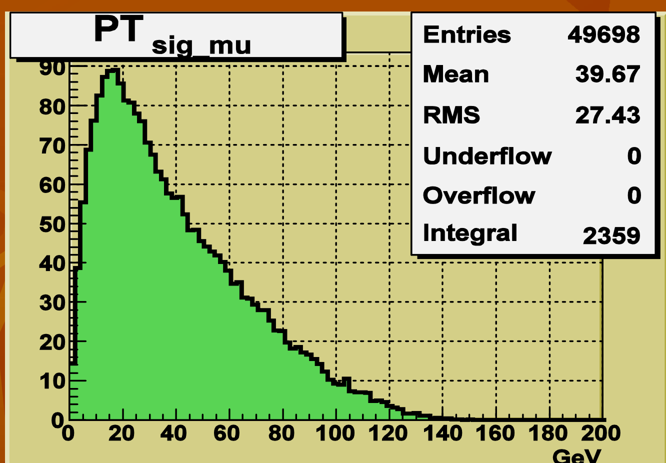
(with the cuts above)

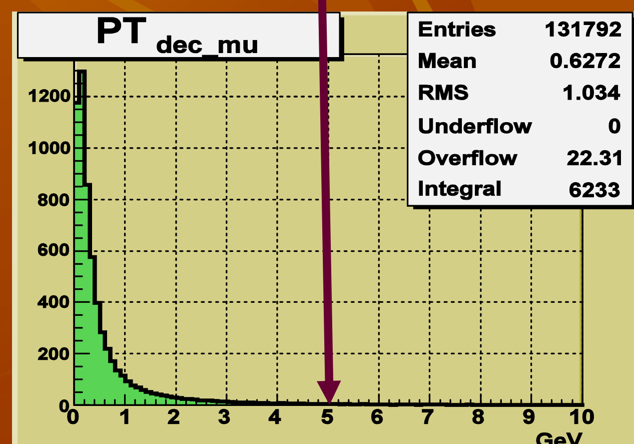
$2E_{beam}$[GeV]	σ_{stop} [fb]	N_{stop}	σ_{top} [fb]	N_{top}
350	0.0089	8	0	0
400	0.52	521	$2.32 * 10^{-4}$	0.2
<u>500</u>	<u>1.80</u>	<u>1806</u>	<u>$2.26 * 10^{-2}$</u>	<u>12.6</u>
800	0.99	995	$1.08 * 10^{-2}$	10
1000	0.41	410	$6.26 * 10^{-3}$	6

μ distributions in the signal events









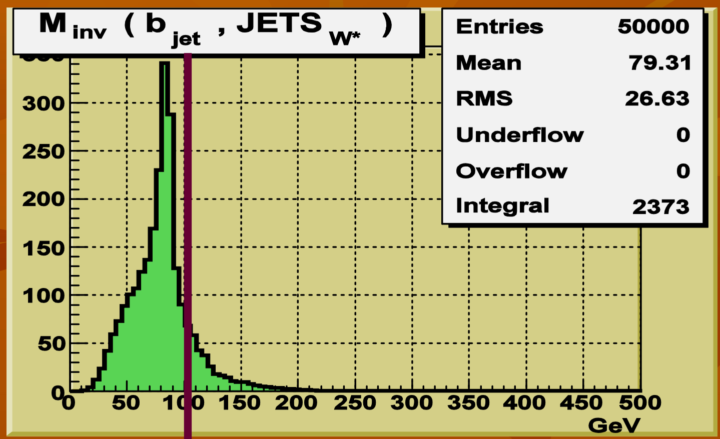
Signal μ's

Fake μ's

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

Good for Signal / Background separation cut M_{inv} (b_{jet}, $2jets_w$) < 100 GeV!

STOP



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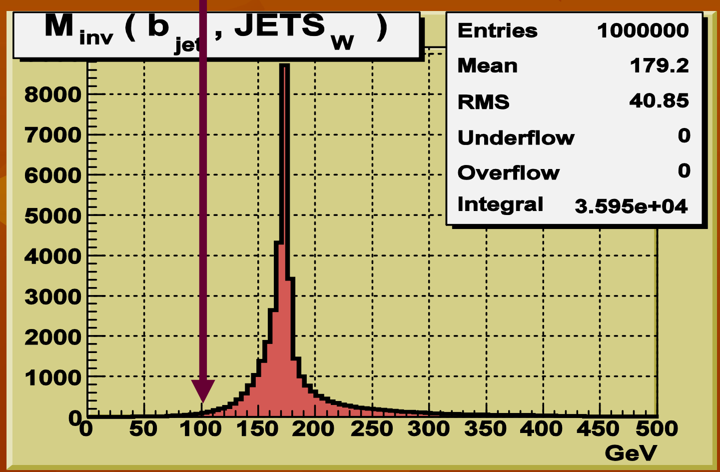


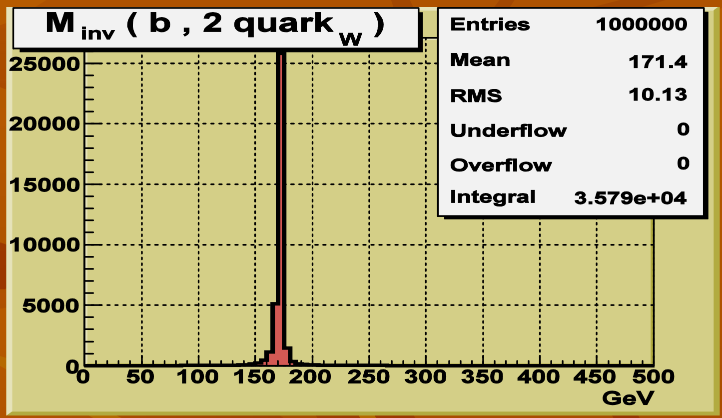
Minv (b-jet, $2jets_W$)

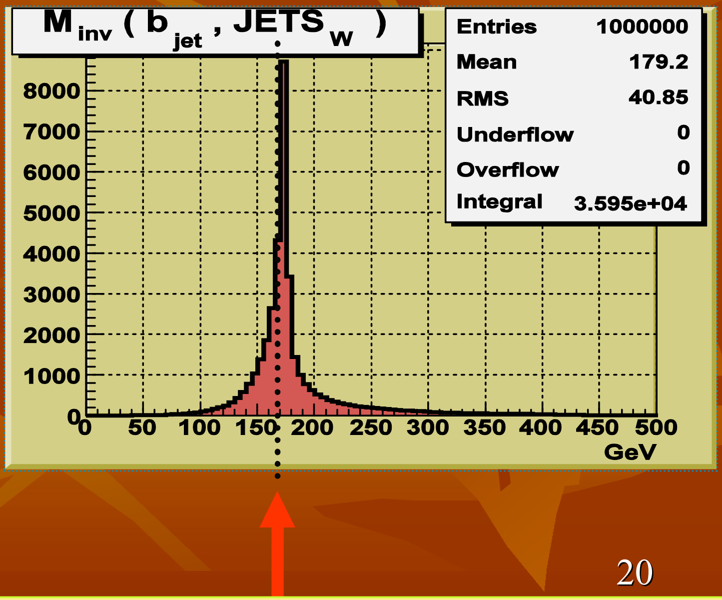
The most important variable - invariant mass of b_{jet} & $2jets_W$

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

it gives

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





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

Stop invariant mass

The reconstruction of the STOP

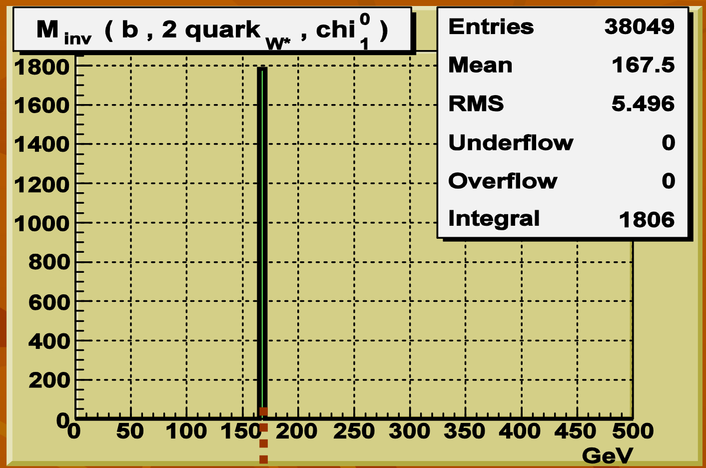
invariant mass M_{STOP} (167.9 GeV):

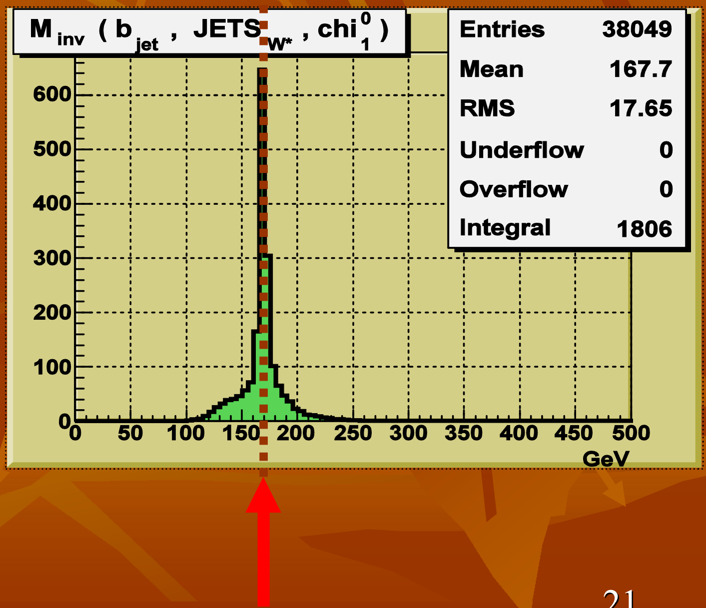
$M_{inv}(STOP) =$

$M\,\chi_1^o + M_{inv}(b_{jet},\, 2jets_W) =$

$= M\,\chi_1^o + \sqrt{(P_{b_{jet}} + P_{jet1_W} + P_{jet2_W})}$

But χ_1^o – is not detactable particle



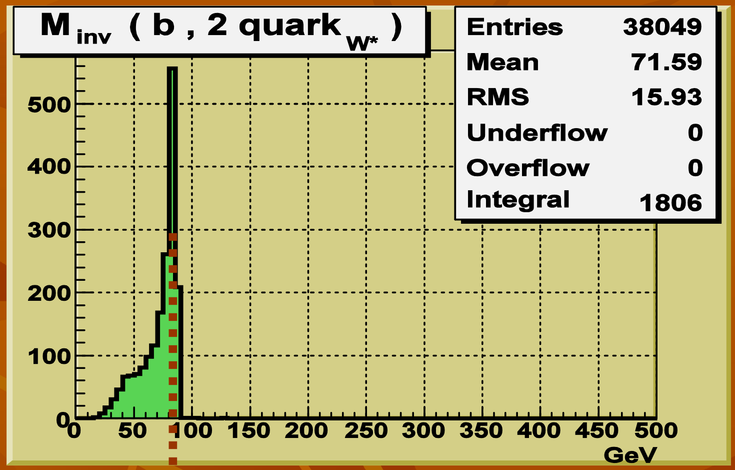


Invariant mass of b_{jet} & $2jets_W$ gives

For the case of

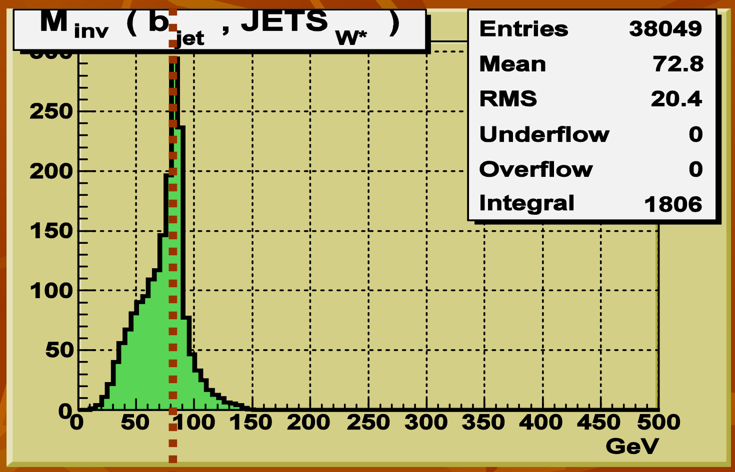
STOP pair production

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



The peak of $M_{inv} (b_{jet}, 2jets_W) \approx 87$ GeV

$M \chi_1^o \approx 80.9$ GeV

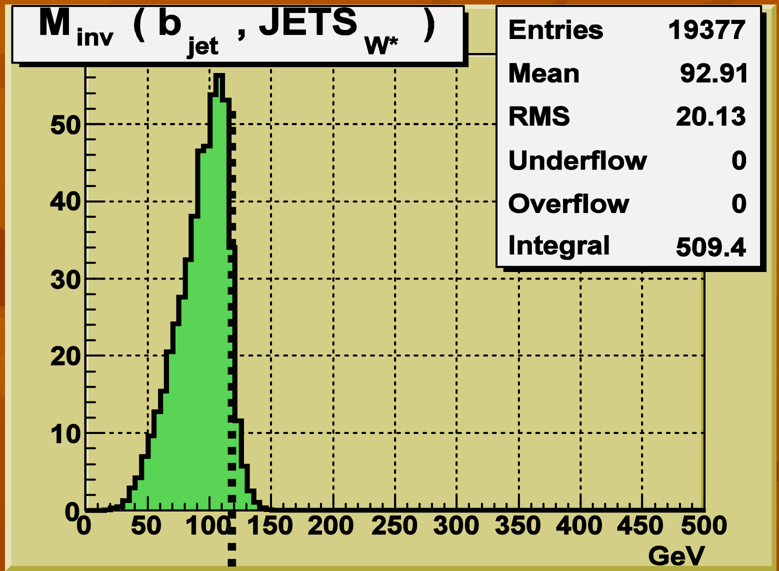


$M_{stop} = M \chi_1^o + M_{inv}(b_{jet}, 2jets_W) =$

$= 167.9$ GeV

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 the peak of M_{inv} (b_{jet} , $2jet_W$) ≈ 120 GeV

$M \chi_1^o \approx 80$ GeV

$M_{stop} = M \chi_1^o + M_{inv}(b_{jet}, 2jet_W) = 200$ GeV

509 events

S/B = 40

Conclusion

1. **The MC (PYTHIA 6.4 + CIRCE 1) study of stop pair production in e^+e^- collisions 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 = 143.**

3. **A possibility of a good reconstruction of the M_{STOP} from the peak position of M_{inv} (3 jets, i.e. b_{jet} + 2 $jets_W$) distribution is demonstrated.**

So, finally, the channel

$$\mathrm{STOP\ STOP} \rightarrow b\ \chi_1^+\ \bar{b}\ \chi_1^- \rightarrow b\ \bar{b}\ q\ \bar{q}'\ \mu^-\nu_\mu\ \chi_1^o\ \chi_1^o$$

is very promissing for STOP quark search!

Publications & previous presentations

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

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

  arXiv: 0804.2125, ILC-NOTE-2008-042

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

  Talk at the "QUARKS-2008" (http://quarks.inr.ac.ru/)

15th International Seminar on High Energy Physics
Sergiev Posad, Russia, 23-29 May, 2008.

To be published in the proceedings

Publications & previous presentations

- *" Stop pair production in polarized photon-photon collisions".*

  A.Bartl, W.Majerotto, K.Moenig, A.Skachkova, N.Skachkov.

Talk at the "International Conference on Linear Colliders", LCWS04, 19-23 April 2004 , Paris, France
Proceedings of the "International Conference on Linear Colliders"; LCWS 04 , volume II, p.919-922

- *"Stop pair production at ILC"* *(http://www.linearcollider.org/cms/?pid=1000364)*

  Talk at the International Linear Collider Workshop (14-17 November 2005, Vienna, Austria)

- *"Stop pair production in photon-photon collisions at ILC"*

Десятая научной конференции молодых ученых и специалистов ОИЯИ. Дубна, 6-10 февраля 2006 г.
Труды десятой научной конференции молодых ученых и специалистов ОИЯИ. Дубна, 6-10 февраля 2006 г. стр. 135-138, ISBN 5-9751-0024-0

- *"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

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

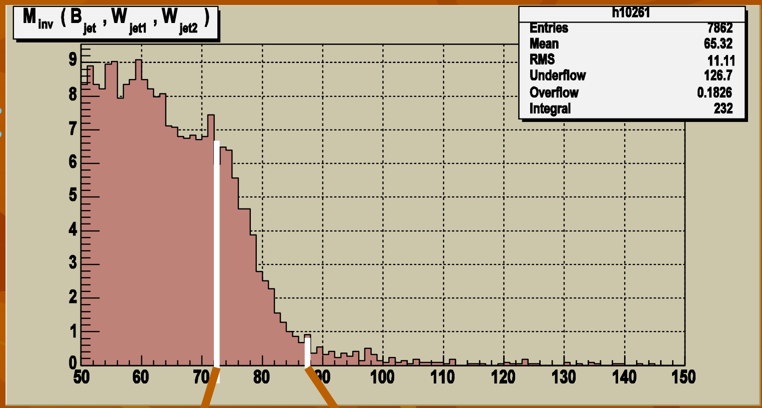
Invariant mass of B_{jet} & $2jets_W$ gives

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

$M\chi_1^o \approx 80.9$ GeV

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

167.9± 0.1 GeV

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