Light Scalar Top Study
Charm-Neutralino and Bottom-Chargino Channels at Future Linear Colliders

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Outline

- **Stop: Topologies and Strategies**
- **LEP and Fermilab Limits**
- **Assumptions for this TESLA Study**
- **News after the 1999 Sitges workshop.**
- **Results - Expectations for 500 GeV**
- **Alternative Analyses**
- **3 TeV CLIC**
- **Summary**

Production and Decay

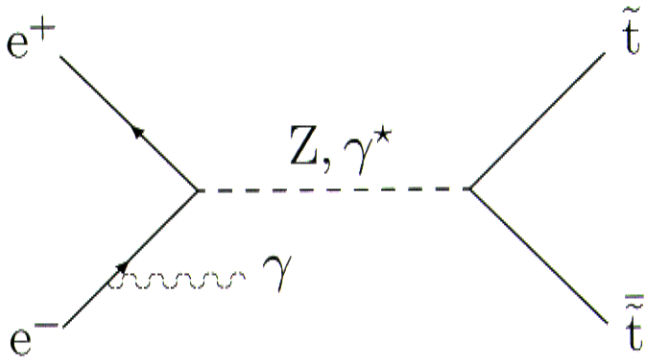
Scalar quarks:

- **SUSY partners of the quark helicity states.**
- **mixing proportional to the quark mass**
- **large mixing, large mass splitting for the third generation.**

$$\tilde{t}_1 = \tilde{t}_L \cos\theta_{LR} + \tilde{t}_R \sin\theta_{LR}$$

- $\tilde{t}_1$ **in LEP or FERMILAB discovery range ????**

Production process



Production via s-channel Z, γ exchange
Free parameters : mass and $\cos\theta_{LR}$
Minimum cross section for vanishing Z coupling

Production and Decay

DECAYS:

- **two-body decays :** $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$, $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$
- **three-body decays:** $\tilde{t}_1 \rightarrow bl\tilde{\nu}_l$

Searching for stop in two-body decays:

- **jets +** E_{miss} **with b and with c-tagging**

$\Delta m = m_{\tilde{t}_1} - m_{\tilde{\chi}}$ **less than W mass – no bW$^+\tilde{\chi}_1^0$ decay**

main backgrounds - depending on Δ**m**

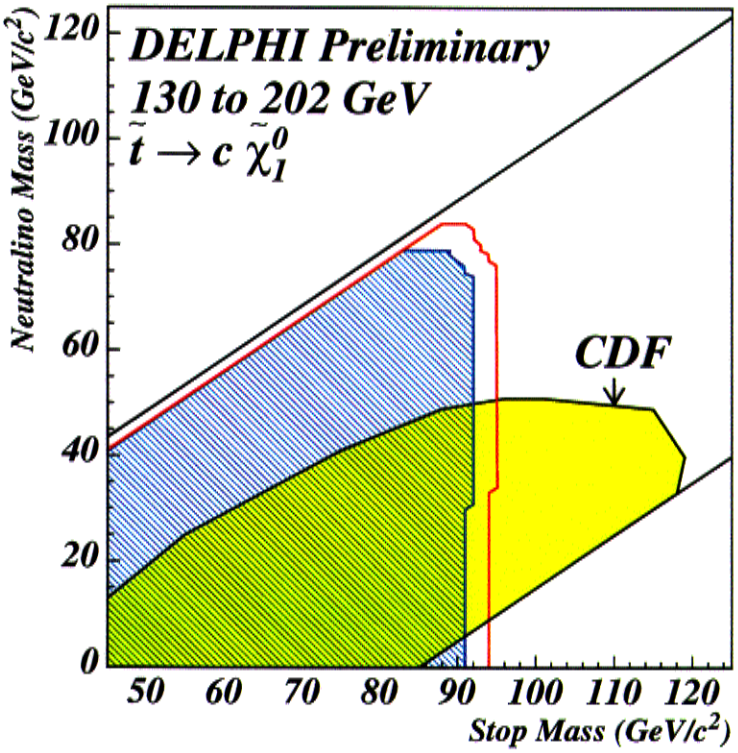
- **low** Δm **(5...10 GeV) : 2 photon processes**
- **medium** Δm **(20 ...40 GeV): 2f processes**
- **high** Δm **(50 ... 70 GeV): 4f processes (WW, ZZ)**

Stop Limits

All 4 LEP experiments have searched for $\tilde{t}_1$ and :

No evidence for any squark was found
$\rightarrow$ limits at 95% C.L.

Example: DELPHI results 1999



LEP combined : stop mass limit 97.5 GeV (LEPC Sep.5)

Fermilab: both experiments have searched for $\tilde{t}_1$ and :

No evidence for any squark was found
$\rightarrow$ limits at 95% C.L.

Assumptions

Case Studies

- **180 GeV** $\tilde{t}_1$
- **A: 100 GeV** $\tilde{\chi}_1^0$
- **B: 150 GeV** $\tilde{\chi}_1^\pm$ **and 60 GeV** $\tilde{\chi}_1^0$
- **Energy 500 GeV**
- **Luminosity 500** fb^{-1} **for each polarization state**
- **Branching ratio 100 %**

Goal :
How well can we determine
$m_{\tilde{t}_1}$ **and** $\cos\theta_{LR}$ **?**

- **Topology A: 2 c-jets +** E_{miss}
- **Topology B: 2 b-jets + 4 quark-jets +** E_{miss}

Preselection

TESLA simulation with SGV (fast simulation)

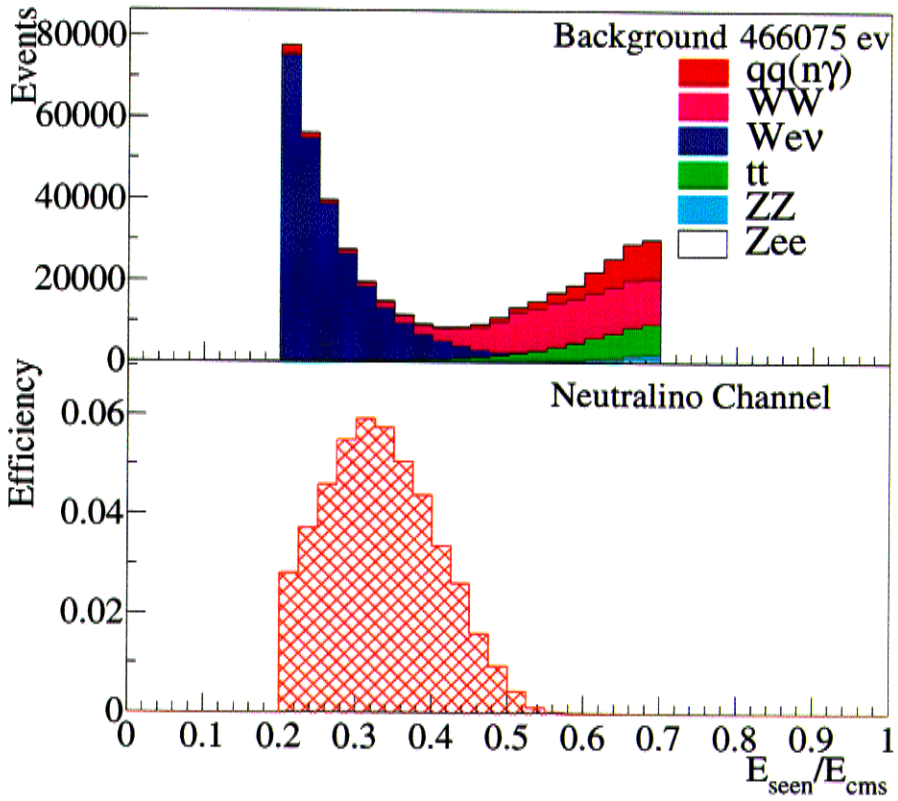
$\tilde{t}_1$ into c $\tilde{\chi}_1^0$ and b $\tilde{\chi}_1^{\pm}$ and SM backgrounds

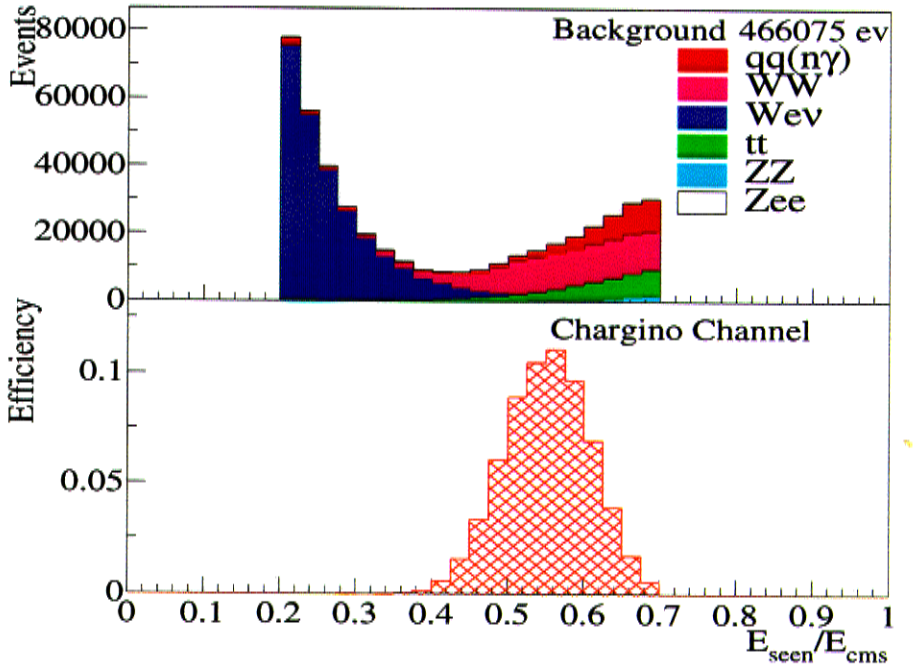
channel	No. gen. events	after presel.	Type
$c\tilde{\chi}_1^0$	50 k	47%	signal A
$b\tilde{\chi}_1^{\pm}$	50 k	66%	signal B
$q\bar{q}$	6250 k	46788	2f
$t\bar{t}$	350 k	43759	2f
Ze^+e^-	3000 k	4069	4f
$Z\ Z$	300 k	4027	4f
$We\nu$	2500 k	252189	4f
$W^+\ W^-$	3500 k	115243	4f

Preselection for both toplogies

Variable	lower value	upper value
$N_{cluster}$	25	110
E_{vis}/E_{cms}	0.2	0.7
E_{long}/E_{cms}	0.	0.5
Thrust	0.	0.95
$\lvert\cos\Theta_{thrust}\rvert$	0.	0.7

Preselection





IDA

IDA = Iterative Discriminant Analysis

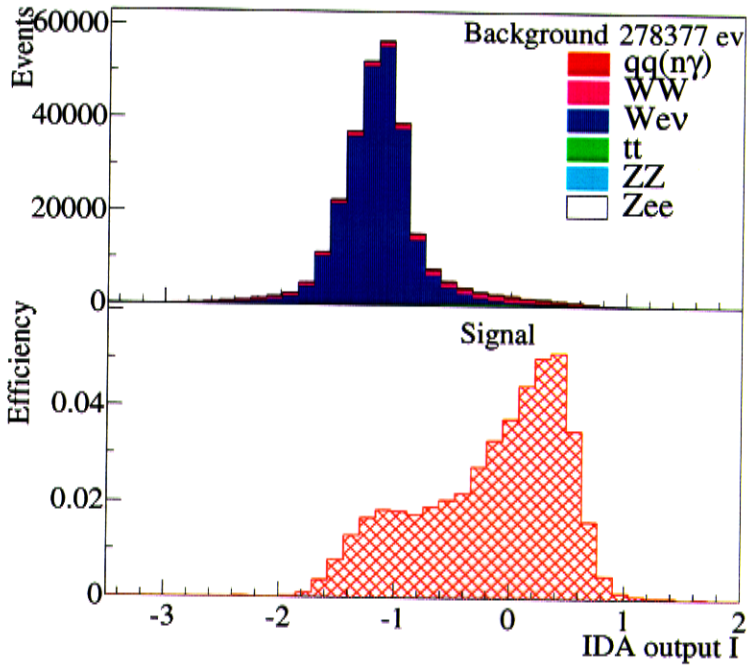
- **First MC half-sample used for training**
- **Second part for analysis after a more tight preselection.**

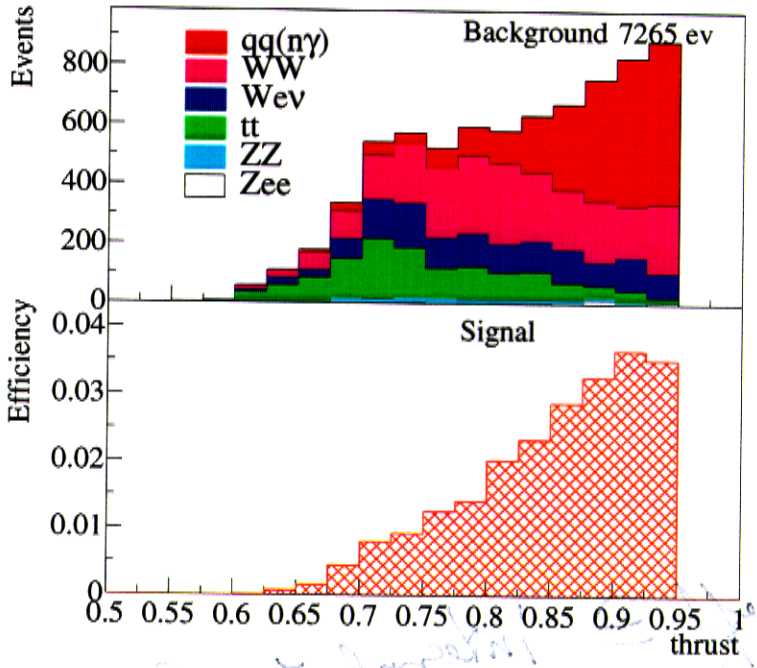
two step process : IDA 1 and IDA 2

IDA 1: signal reduced to 50%

IDA 2: fine-tuning

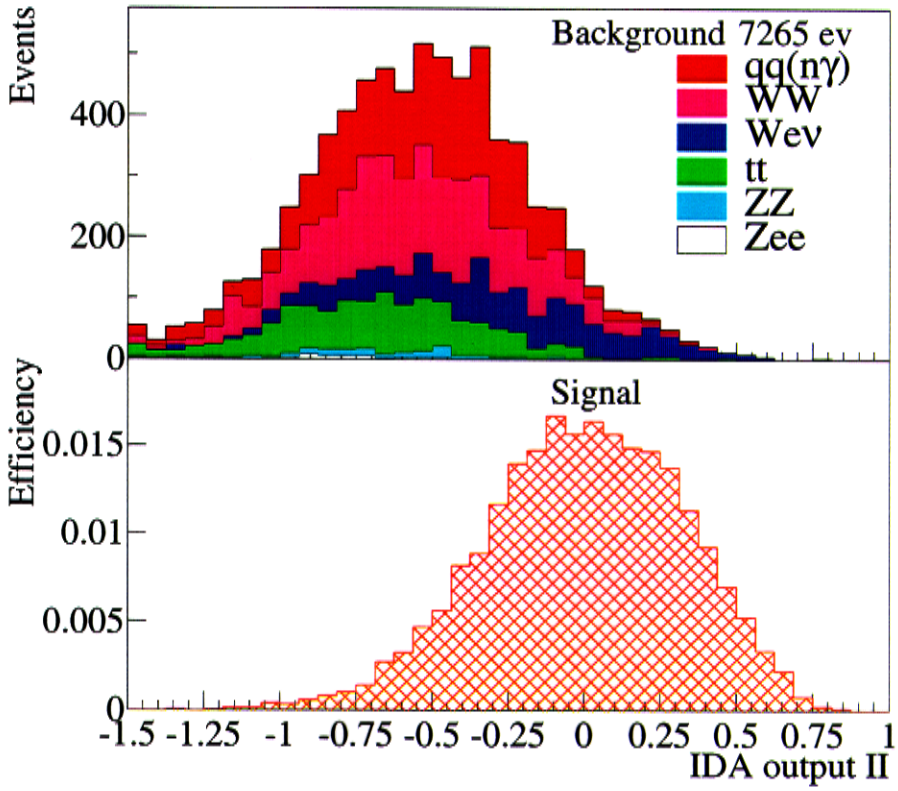
IDA


Events
60000
40000
20000
0
Background 278377 ev
qq(nγ)
WW
Wev
tt
ZZ
Zee
Efficiency
0.04
0.02
0
Signal
-3
-2
-1
0
1
2
IDA output I


Events
800
600
400
200
0
qq(nγ)
WW
Wev
tt
ZZ
Zee
Background 7265 ev
Efficiency
0.04
0.03
0.02
0.01
0
Signal
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
thrust

IDA

IDA 2:



Results:

- **signal/background ratio as a function of the IDA2 variable**

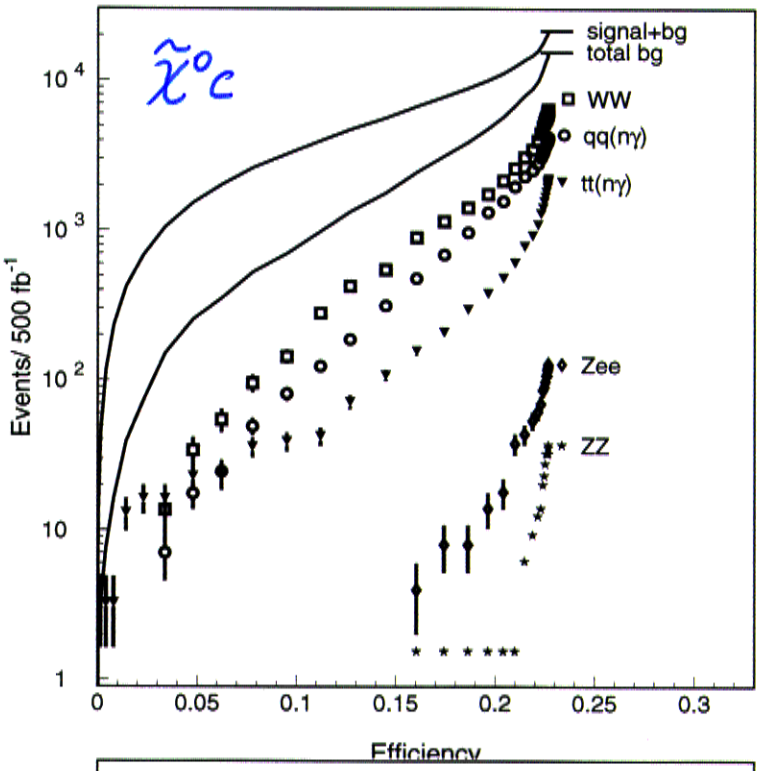
New Results

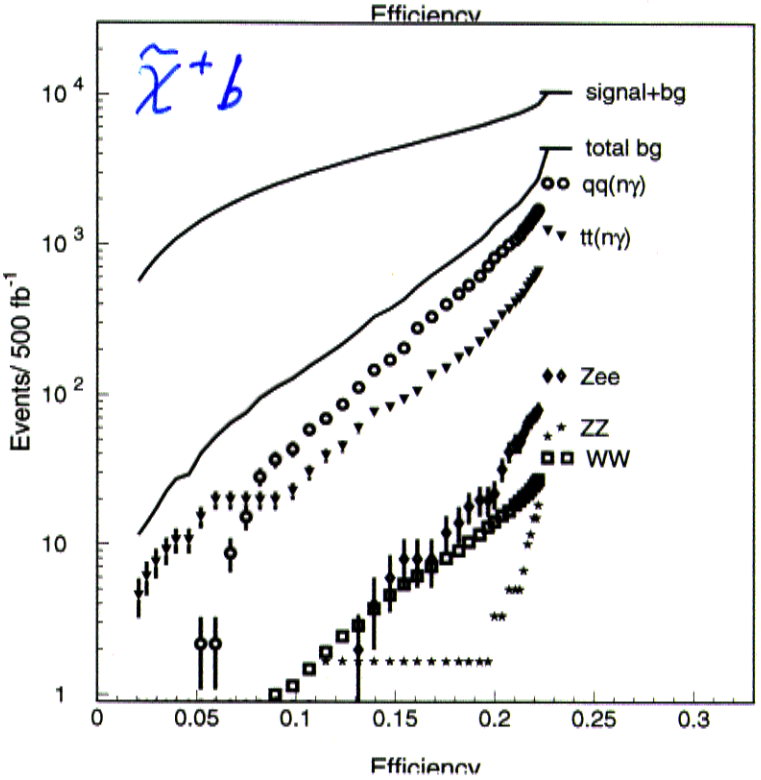
Polarization states : e^-/e^+ -80/60 versus 80/-60

Pol.	$\tilde{t}_1\tilde{t}_1$	$We\nu$	WW	$q\bar{q}$	$t\bar{t}$	ZZ
e^-/e^+	fb	pb	pb	pb	pb	pb
-.8/.6	81.81	10.72	22.64	21.49	1.113	0.909
-.9/0	55.18	6.86	14.9	14.4	0.771	1.17
0/0	53.46	5.59	7.86	12.1	0.574	0.864
.9/0	51.73	4.61	0.906	9.66	0.376	0.554
.8/-.6	76.41	1.780	0.786	13.99	0.542	0.464

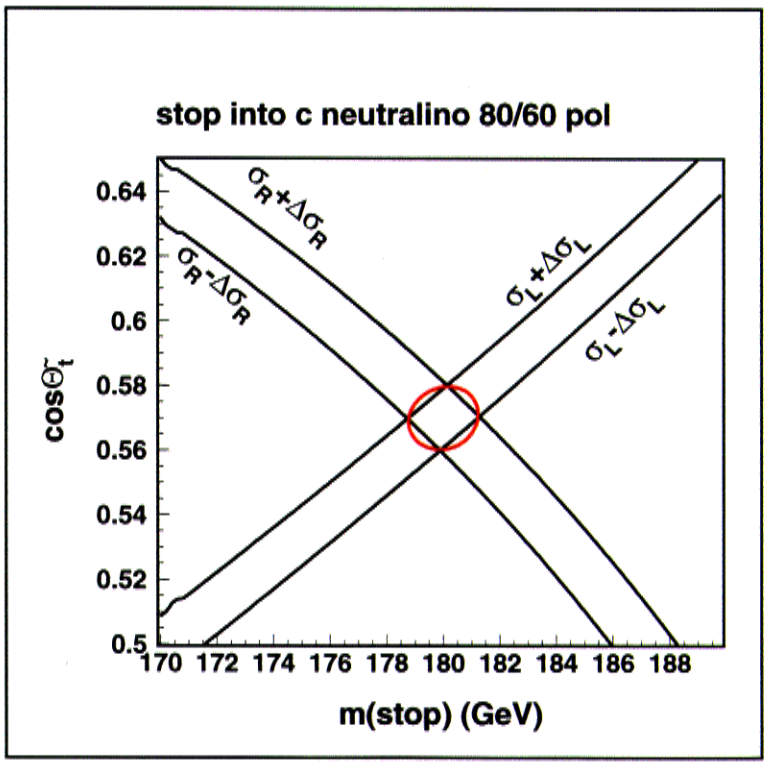
better signal/background ratio for 0.8/-0.6
use this machine operation for discoveries
case of minimum cross-section :

New Results


$\tilde{\chi}^0_c$
signal+bg
total bg
WW
qq(nγ)
tt(nγ)
Zee
ZZ
Events/ 500 fb^{-1}
Efficiency


$\tilde{\chi}^+ b$
signal+bg
total bg
qq(nγ)
tt(nγ)
Zee
ZZ
WW
Events/ 500 fb^{-1}
Efficiency

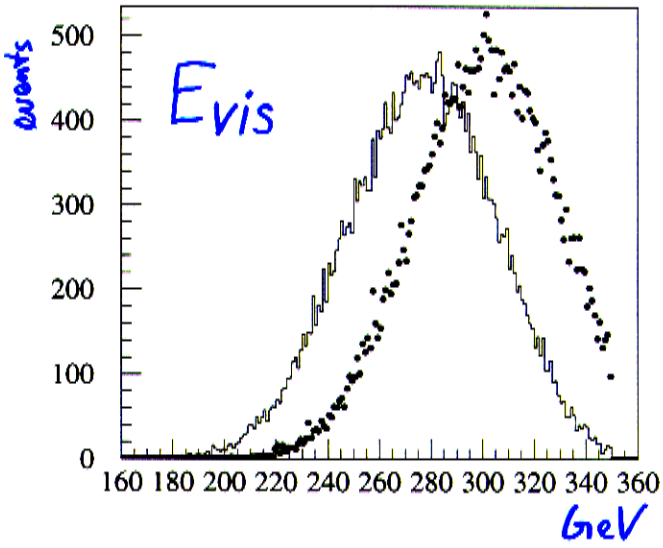
New Results

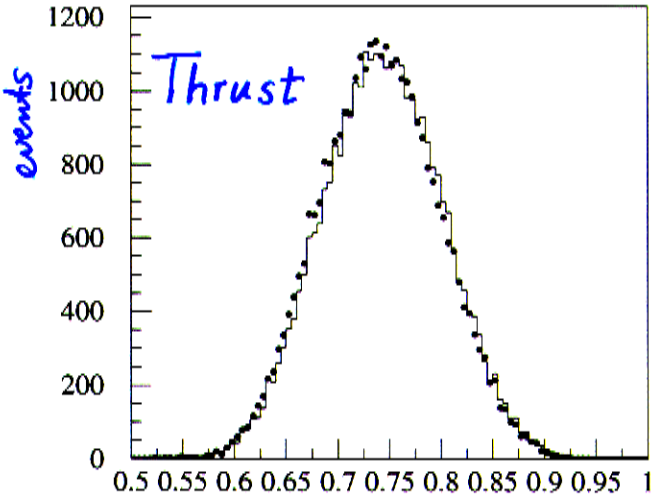


$\Delta m_{\tilde{t}_1} = 0.8$ **GeV and** $\cos\theta_{LR} = 0.008$

Alternative Analyses

New TESLA simulation: SIMDET (dots) cf. SGV (histos)





Some selection variable values change significantly, but little performance change is expected.

Alternative Analyses

Mass Determination:

A:

When the neutralino mass is known precisely, end-points of the min-mass (Feng, Kraml et. al.).

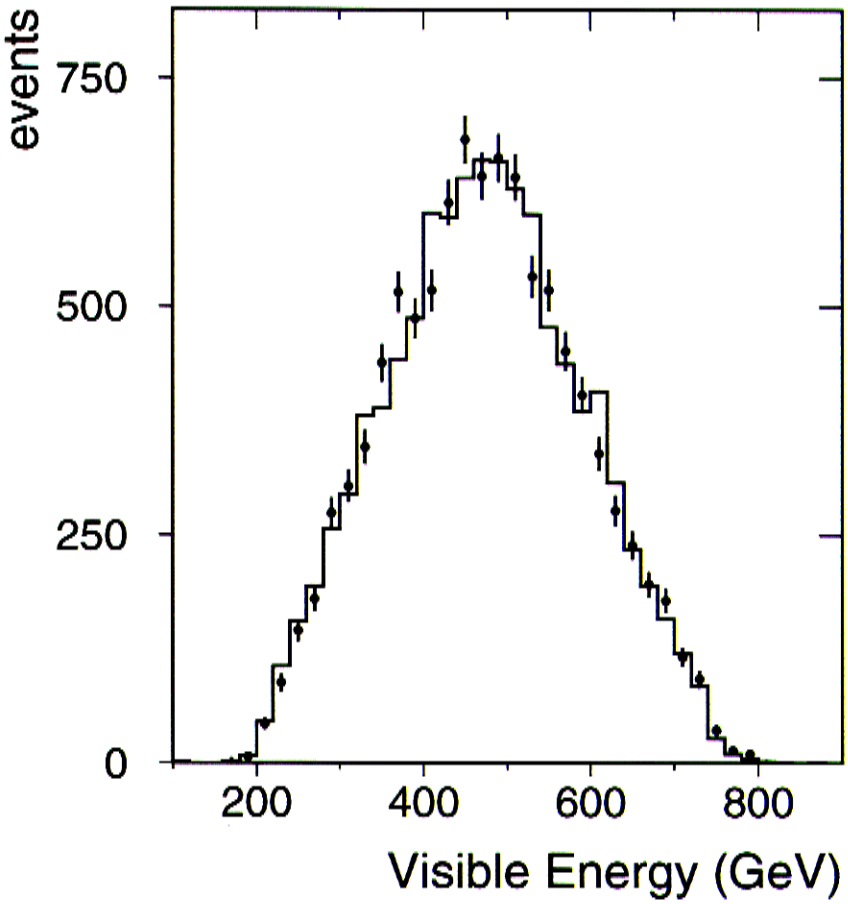
B:

Cross-section threshold scan as for the top mass, but more difficult, since $\sigma \propto \beta^3$.

Mixing Angle:

from asymmetry ($\sigma_{\mathrm{L}} - \sigma_{\mathrm{R}}$).

New CLIC simulation with SIMDET:
600 GeV stop and 120 GeV neutralino at 1.5 TeV.
Comparison of detector simulations TESLA (dots) and CLIC (histo).



Very small difference.
More important: BS spectrum, total luminosity, background rates (including SUSY particles), polarization.

Summary and Outlook

- **Polarization is essencial.**
  New (best) results for 80/60 configuration.

- **Both neutralino and chargino channels investigated.**

- **Precision measurements of mass and mixing angle.**

- **New large scale TESLA simulation with SIMDET,**
  also for masses near the production threshold.

- **Alternative mass determination**
  (jet-spectra, threshold scan) promissing.

- **LC vs. LHC: stops might be discovered first at a LC,**
  and precision measurements only at a LC.

- **CLIC: increase of the discovery mass range.**
  Scalar top analyses straightforward.

- **OUTLOOK:**
  more detailed detector simulation with SIMDET,
  study of SUSY background, and
  alternative methods for mass determination.