Update on Stau Production

with contributions from
A. De Roeck,
D. Schulte
M. Stanitzki

O. Çakır
Ankara University

collaborative study with
OC, ITC, JE, ZK
hep-ph/0703121

CLIC08 Workshop, CERN, 14-17 October 2008

Outline

- >>An <u>update</u> on the previous study "stau searches at CLIC" taking into account both the beam spectra and the detector effects.
- >>New study on the angular distributions of staus from direct production, and from right-handed selectron and smuon decays.
- >>New MC analysis done within JAS3 framework (stdhep).
- >>Includes CLIC000 detector simulation (slcio) and analysis.

Framework

- Supersymmetry (SUSY) is one of the most widely studied theory of physics beyond the Standard Model (SM). Searches for signatures of new physics predicted within the SUSY models are central to the physics program of the upcoming experiments at the TeV range.
- Our study is based on the scenarios in the mSUGRA model with the stau NLSP and the gravitino LSP.
- Meta-stable heavy stau in certain points of parameter space [Feng05]
- mSUGRA parameters:

  $m_{1/2}$ = common gaugino mass
  m_0 = common scalar mass
  A_0= trilinear coupling
  tan β = ratio of VEVs
  sign(μ) = sign of Higgs mixing parameter

mSUGRA Points

- Consistent with present data from particle physics and BBN constraints
- Astrophysics and cosmology constrain metastable particles such as staus
- Agreement between calculated and observed abundance of light elements

Points:

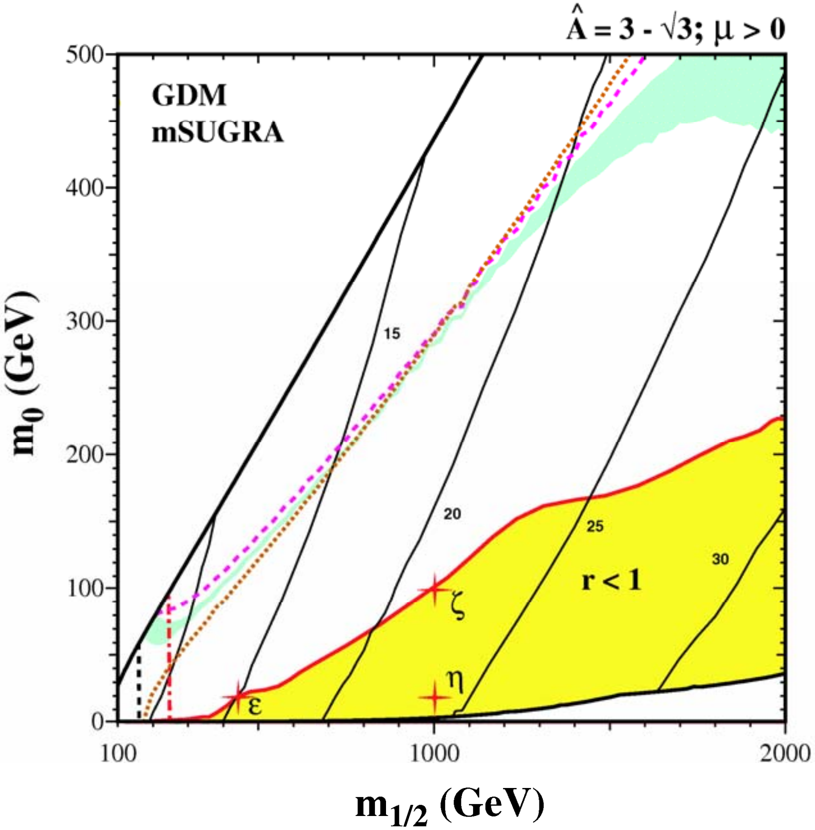
ε - low m_0, low $m_{1/2}$, low $\tan\beta$
ζ - high m_0, high $m_{1/2}$, high $\tan\beta$
η - low m_0, high $m_{1/2}$, high $\tan\beta$
θ - high m_0, high $m_{1/2}$, low $\tan\beta$

(ε, ζ, η): De Roeck *et al.* 05

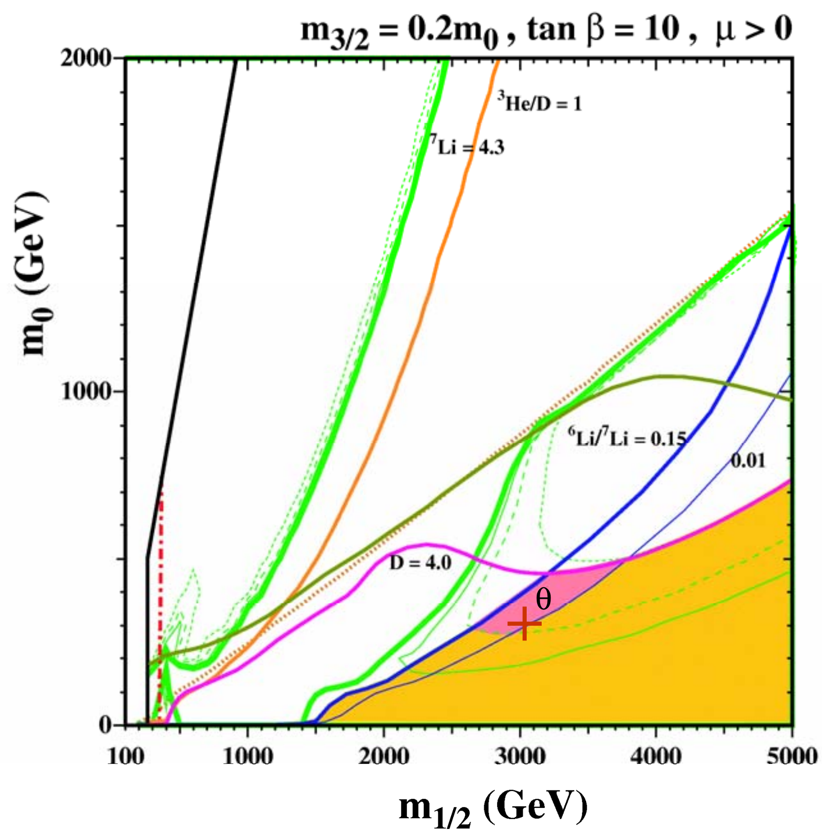
(θ): O. Cakir *et al.* 07

in some certain parameter space of mSUGRA, good agreement between BBN calculations and observed $^{6,7}Li$ abundances

mSUGRA benchmark scenarios with gravitino LSP and stau NLSP: ε, ζ, η and θ



Three benchmark points with astrophysical constraints



Agreement between BBN calculations and the observed Li abundances

The properties of the benchmark points of mSUGRA

Point ε:

t=2.9x10^6 s

= 33.7 day

This point could be probed at LHC, ILC and CLIC

Point ζ:

t=1.7x10^6 s

= 19.4 day

These points could be probed at LHC and CLIC

Point η:

t=6.4x10^4 s

=0.7 day

Point θ:

t=1.35x10^3 s

This point could be probed only at CLIC

Model	ϵ	ζ	η	θ
m_0	20	100	20	330
$m_{1/2}$	440	1000	1000	3000
A_0	-25	-127	-25	0
$\tan\beta$	15	21.5	23.7	10
sign(μ)	+1	+1	+1	+1
$\tilde{e}_L, \tilde{\mu}_L$	303	676	669	1982
$\tilde{e}_R, \tilde{\mu}_R$	168	382	369	1140
$\tilde{\nu}_e, \tilde{\nu}_\mu$	289	666	659	1968
$\tilde{\tau}_1$	154	346	327	1140
$\tilde{\tau}_2$	304	666	659	1966
$\tilde{\nu}_\tau$	284	651	643	1944
$\tilde{u}_L, \tilde{c}_L$	935	1992	1989	5499
$\tilde{u}_R, \tilde{c}_R$	902	1913	1910	5248
$\tilde{d}_L, \tilde{s}_L$	938	1994	1991	5500
$\tilde{d}_R, \tilde{s}_R$	899	1903	1900	5217
$\tilde{t}_1$	703	1534	1541	4285
$\tilde{t}_2$	908	1857	1855	5130
$\tilde{b}_1$	858	1823	1819	5104
$\tilde{b}_2$	894	1874	1867	5203
$\tilde{g}$	1023	2187	2186	6089
$\tilde{\chi}_1^0$	179	425	424	1336
$\tilde{\chi}_2^0$	337	802	802	2467
$\tilde{\chi}_1^\pm$	338	804	804	2472

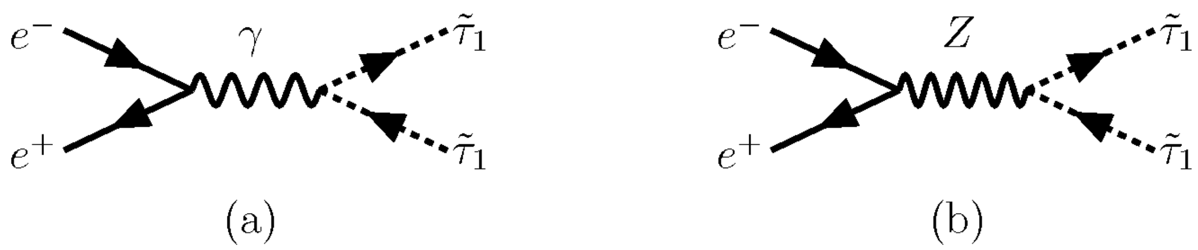
Stau NLSP

- For small tanbeta, the mass splitting between the stau(1), selectron(R) and smuon(R) is small, rendering them co-NLSP's which decay into leptons and gravitinos.
- In the large tanbeta region, the stau is the sole NLSP.
- Interest on the decay mode

$$\tilde{\tau} \to \tau \tilde{G}$$

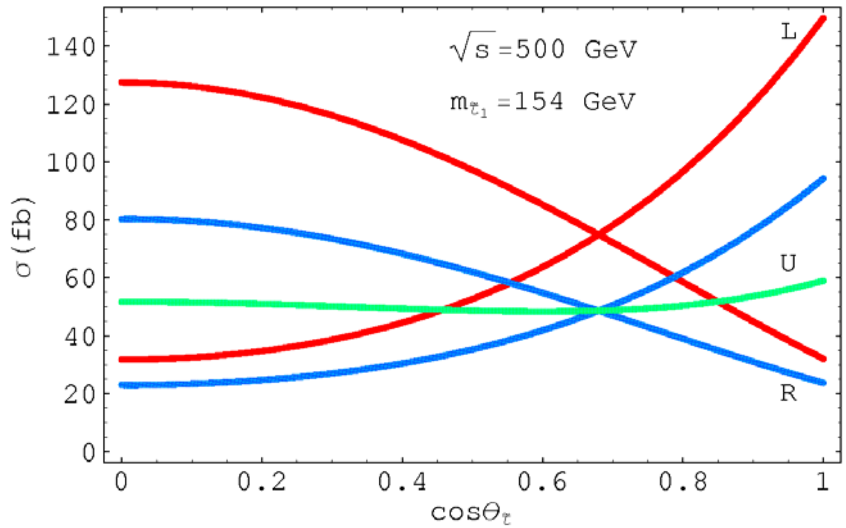
Stau pair production

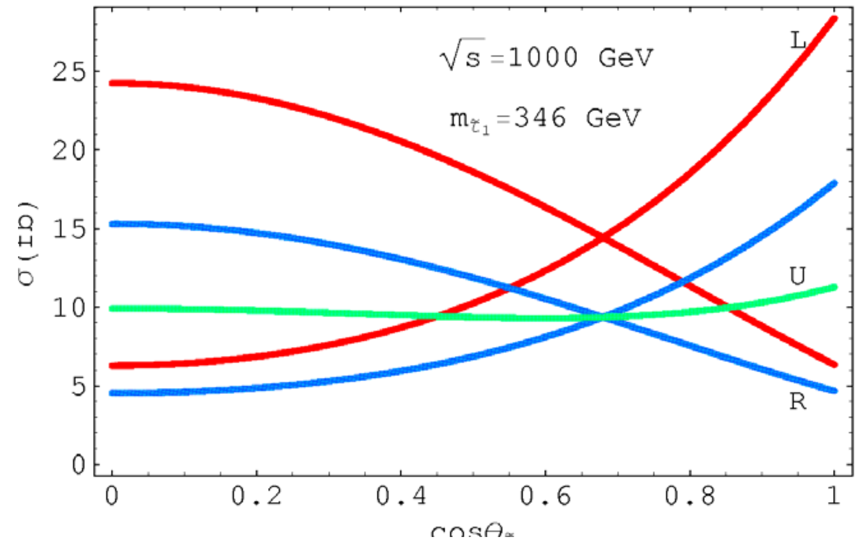
SUSY R-parity conservation → pair production at colliders



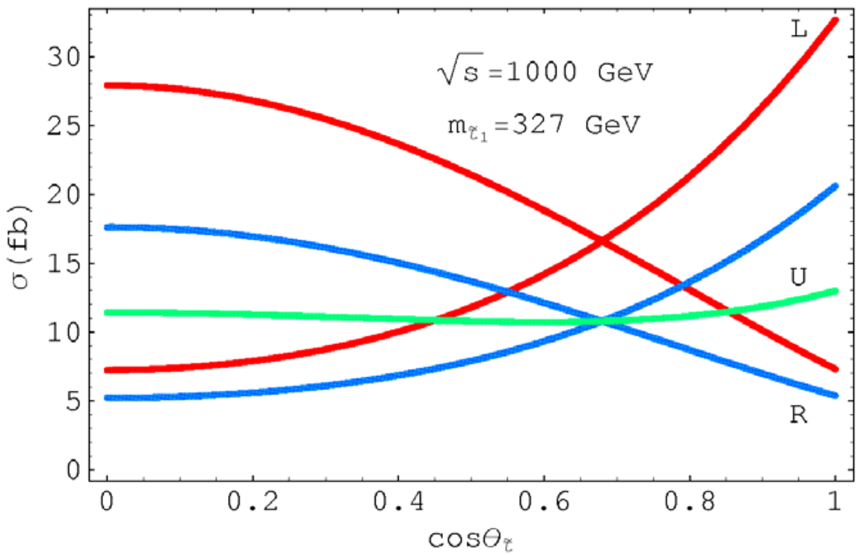
$$\sigma = \frac{\pi\alpha^2\beta^3}{3s}\Bigg[(1-P_-P_+) + \frac{I_3\cos^2\theta_{\tilde{\tau}} + \sin^2\theta_W}{2\cos^2\theta_W\sin^2\theta_W}[v_e(1-P_-P_+) - a_e(P_- - P_+)]P_{\gamma Z}$$
$$+ \frac{(I_3\cos^2\theta_{\tilde{\tau}} + \sin^2\theta_W)^2}{16\cos^4\theta_W\sin^4\theta_W}[(v_e^2 + a_e^2)(1-P_-P_+) - 2v_e a_e(P_- - P_+)]P_{ZZ}\Bigg]$$

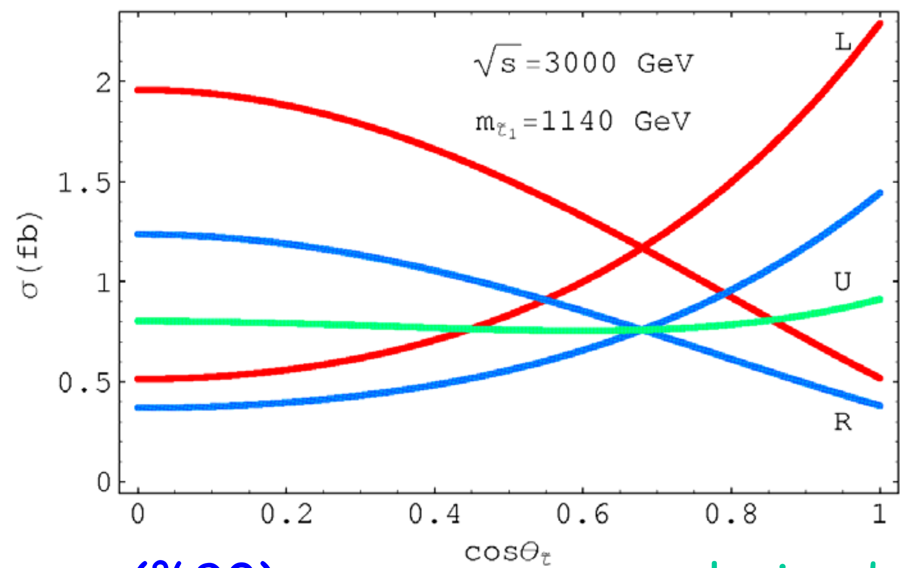
$$P_{ZZ} = \frac{s^2}{(s-m_Z^2)^2 + m_Z^2\Gamma_Z^2} \quad , \qquad P_{\gamma Z} = \frac{s(s-m_Z^2)}{(s-m_Z^2)^2 + m_Z^2\Gamma_Z^2}$$





Unpolarized and polarized cross-sections





Red: e- (%90), e+ (%60) ; blue: e- (%90); green: unpolarized

Measuring the cross section from polarized beams we obtain the mixing angle and the mass of stau.

The total cross section (pb)

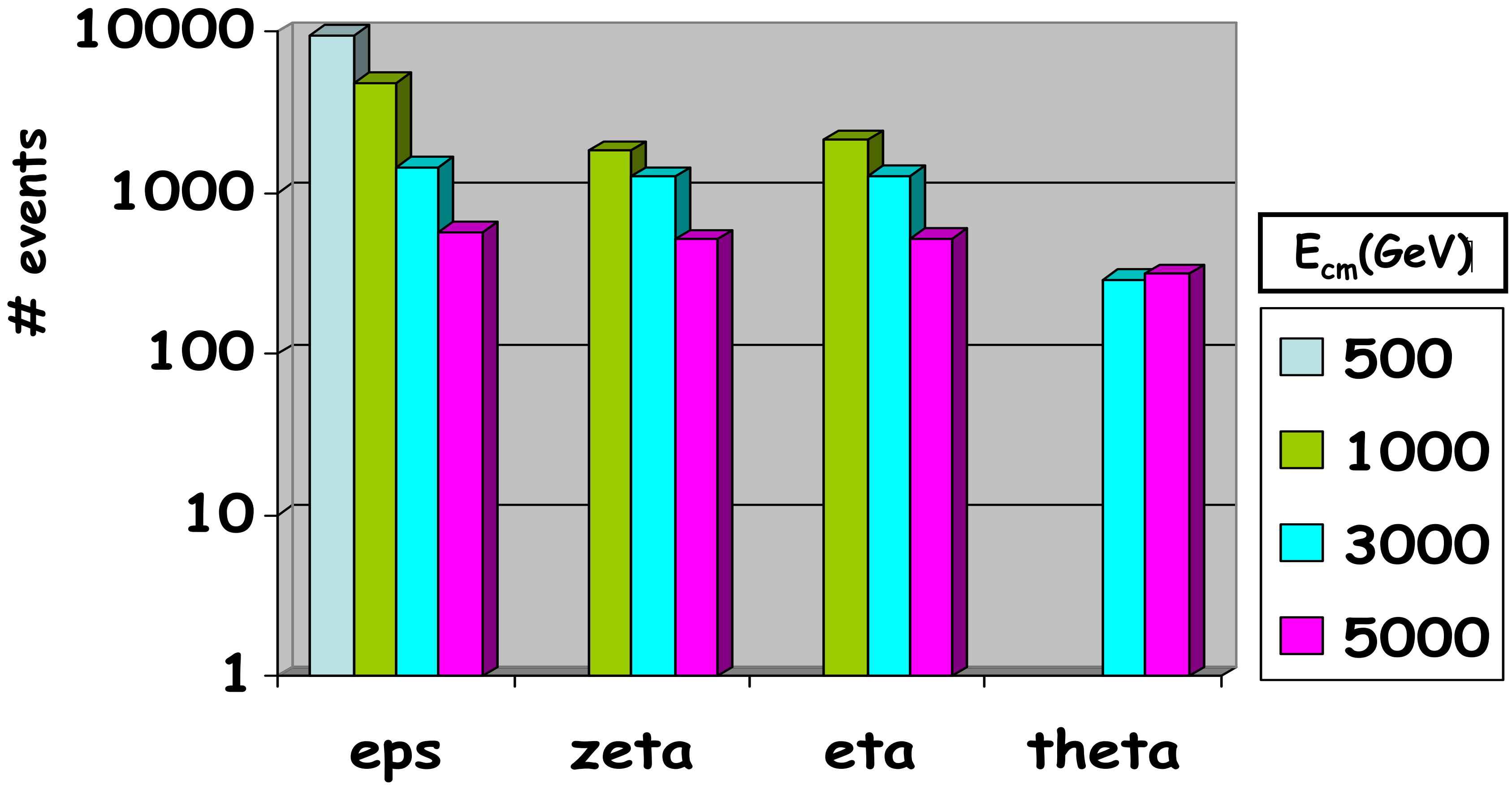
We use PYTHIA with the full ISASUGRA spectrum including both initial and final state radiation (ISR+FSR)

	Benchmark points	ϵ	ζ	η	θ
	$m_{\tilde{\tau}_1}(\mathrm{GeV}) =$	154	346	327	1140
	500	4.799×10^{-2}	–	–	-
$\sqrt{s}(\mathrm{GeV})$	1000	2.441×10^{-2}	9.230×10^{-3}	1.075×10^{-2}	-
	3000	3.665×10^{-3}	3.142×10^{-3}	3.197×10^{-3}	7.235×10^{-4}
	5000	1.432×10^{-3}	1.299×10^{-3}	1.311×10^{-3}	7.889×10^{-4}

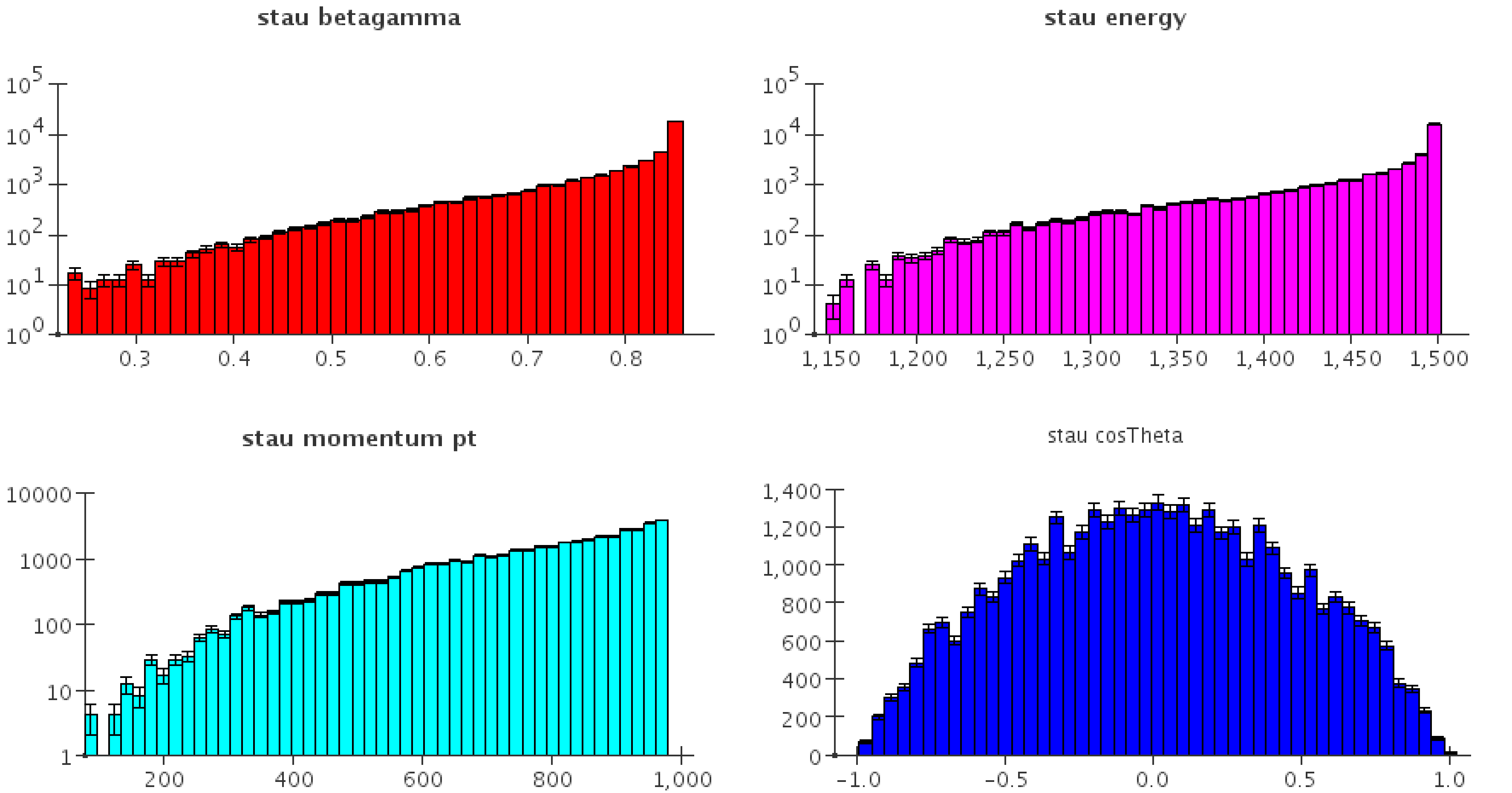
Number of stau pairs produced at:

E_{cm} = 500, 1000 GeV with L=200 fb^{-1}

E_{cm} = 3000, 5000 GeV with L=400 fb^{-1}

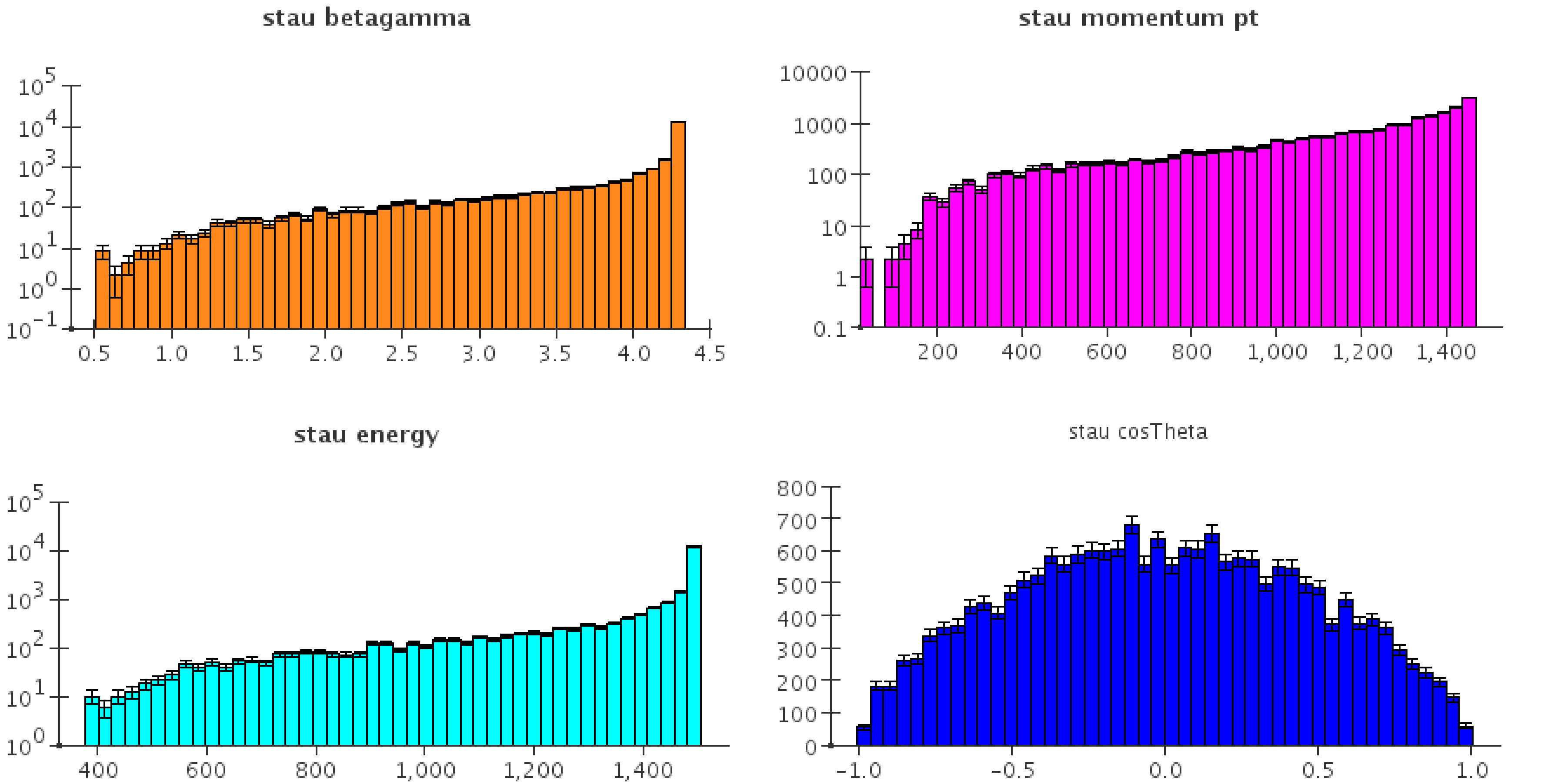


Distributions of staus at point θ

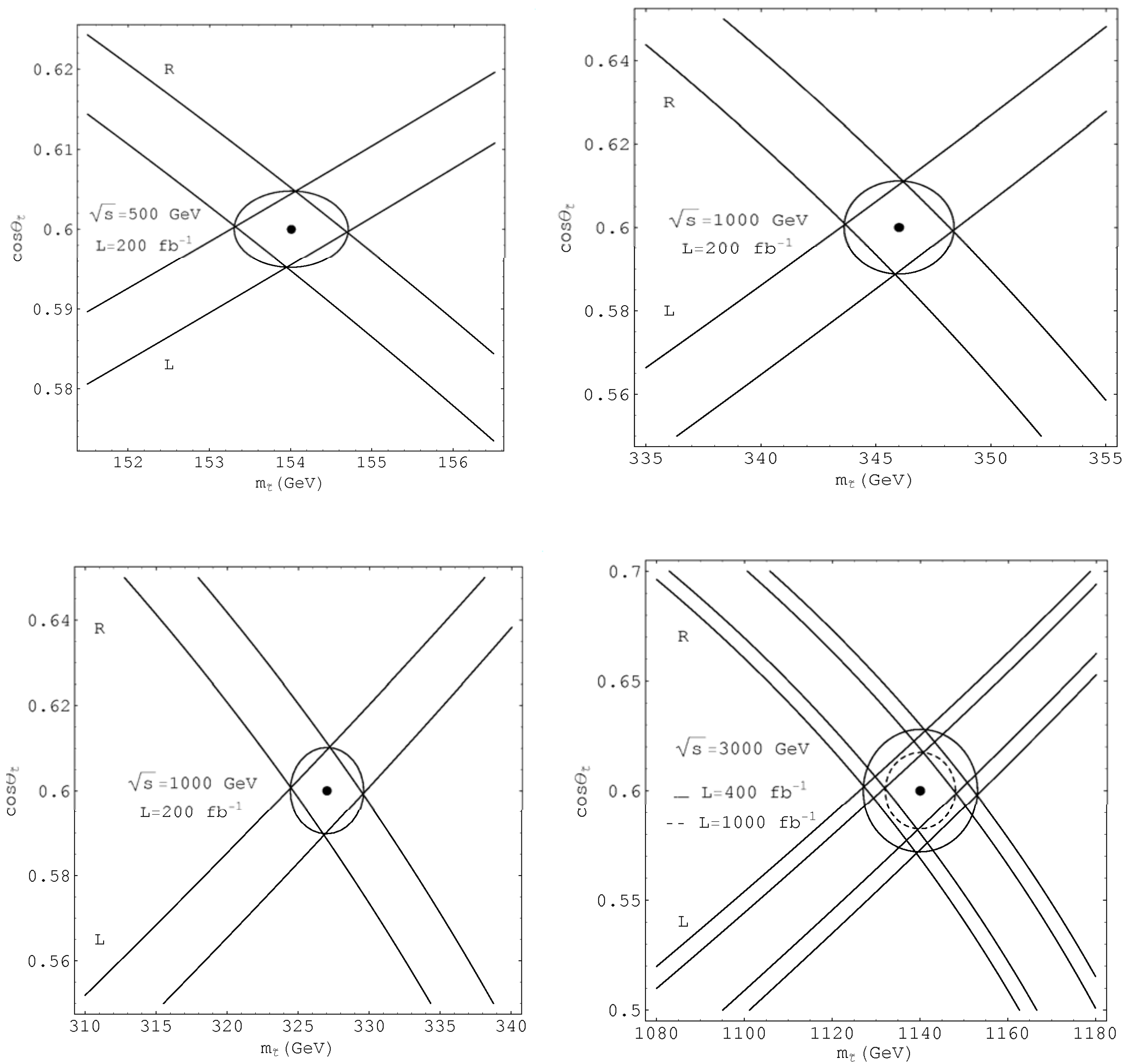


Includes the ISR and beamstrahlung effects

Distributions of staus at point ζ



No ISR and beamstrahlung effects



Polarization

e- %90

e+ %60

accuracies on the measure:

$(\Delta m_{\tilde{\tau}_1}, \Delta \cos\theta_{\tilde{\tau}})$

(0.7, 0.005) for ε

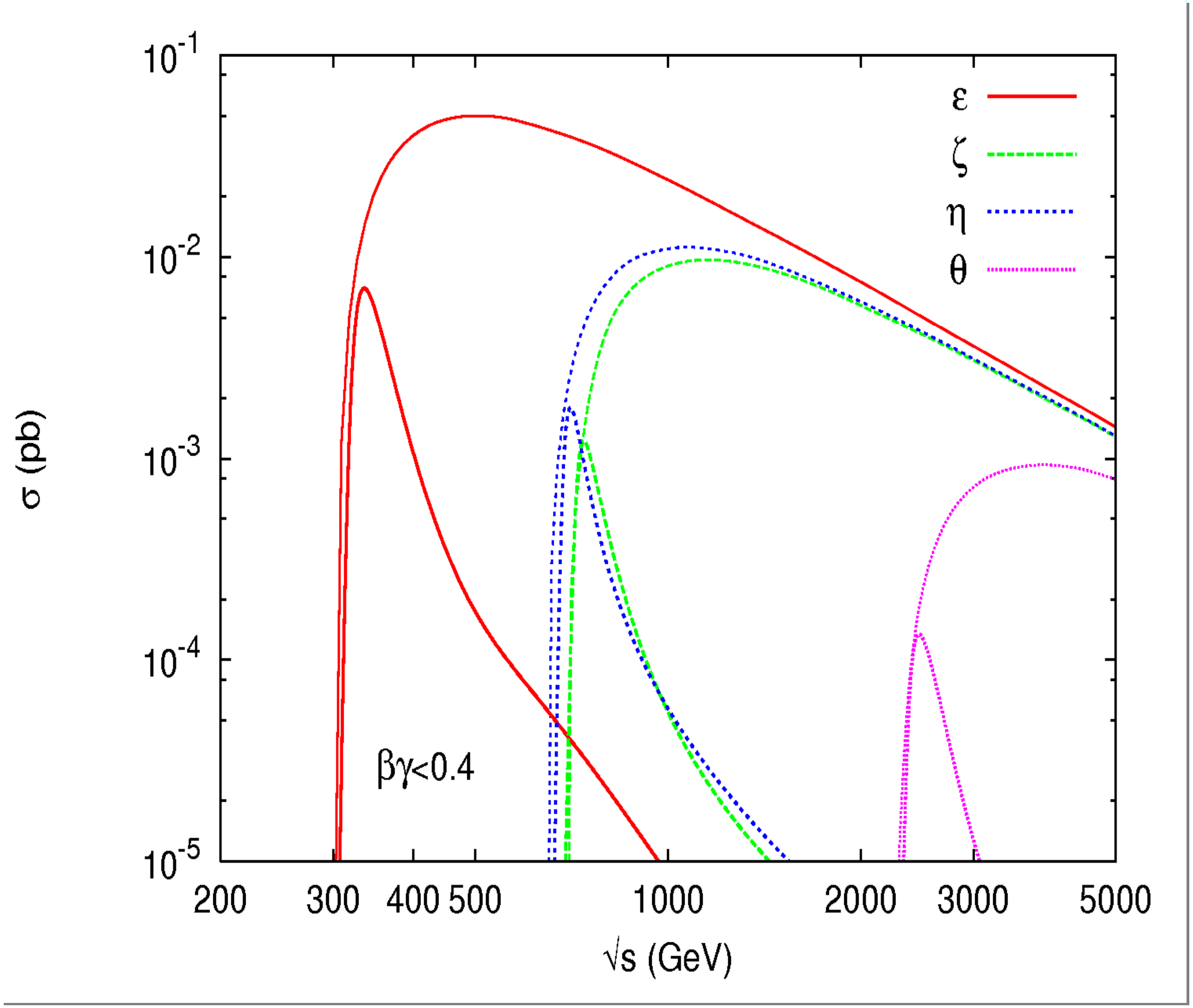
(2.4, 0.01) for ζ, η

at Ecm=1000 GeV;

(8, 0.02) for θ

at Ecm=3000 GeV

Stau pair production at benchmark points and optimal energies for slow-staus with βγ<0.4



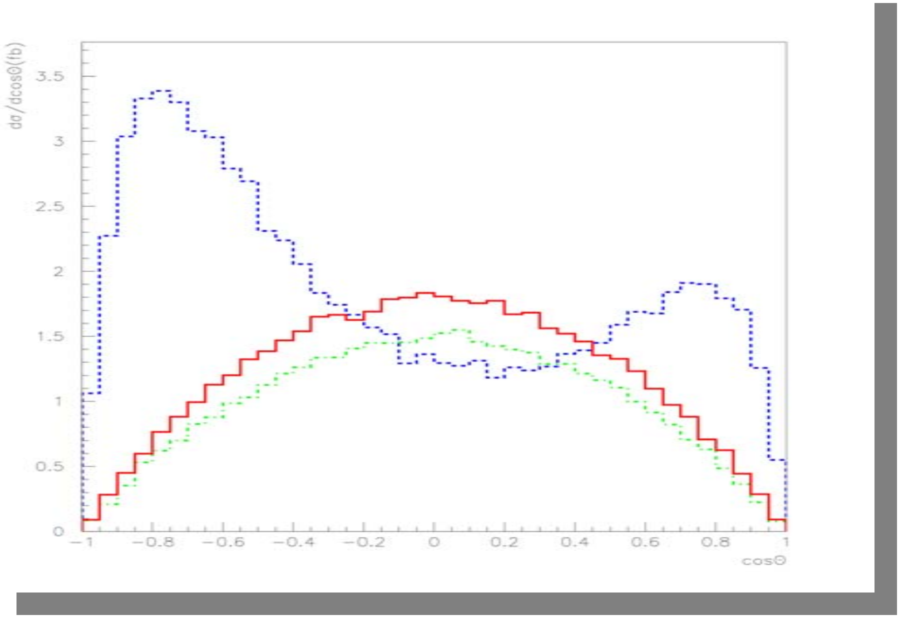
330 GeV for ε

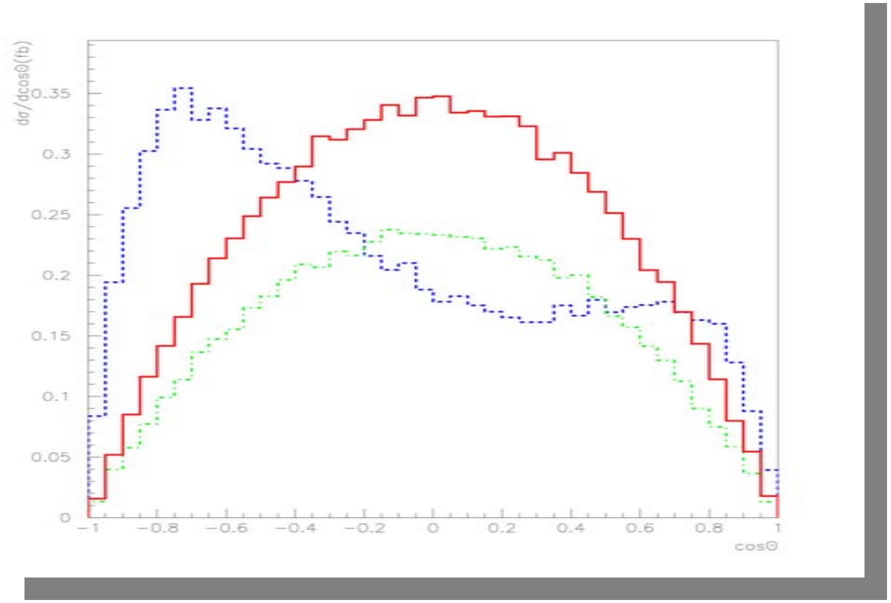
730 GeV for ζ

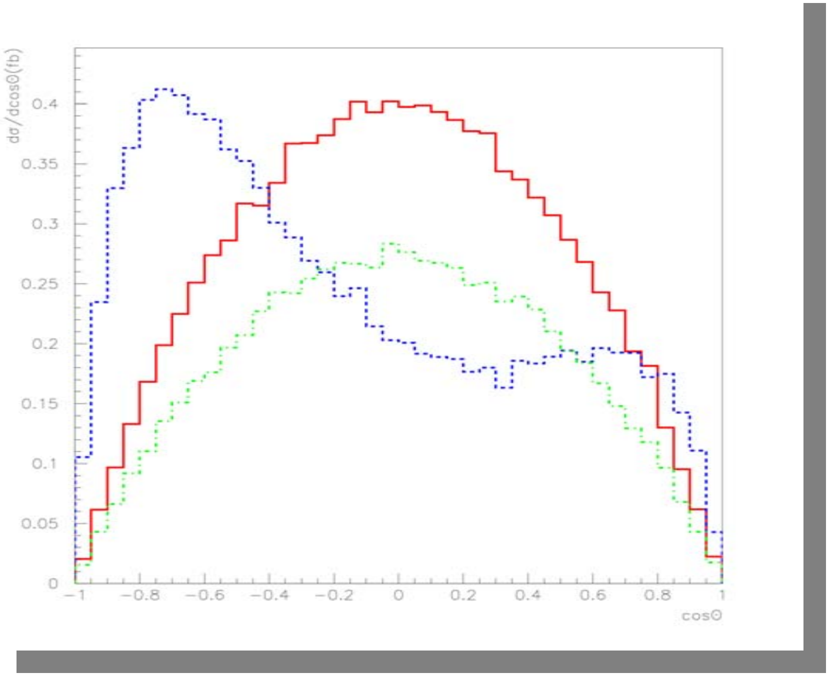
700 GeV for η

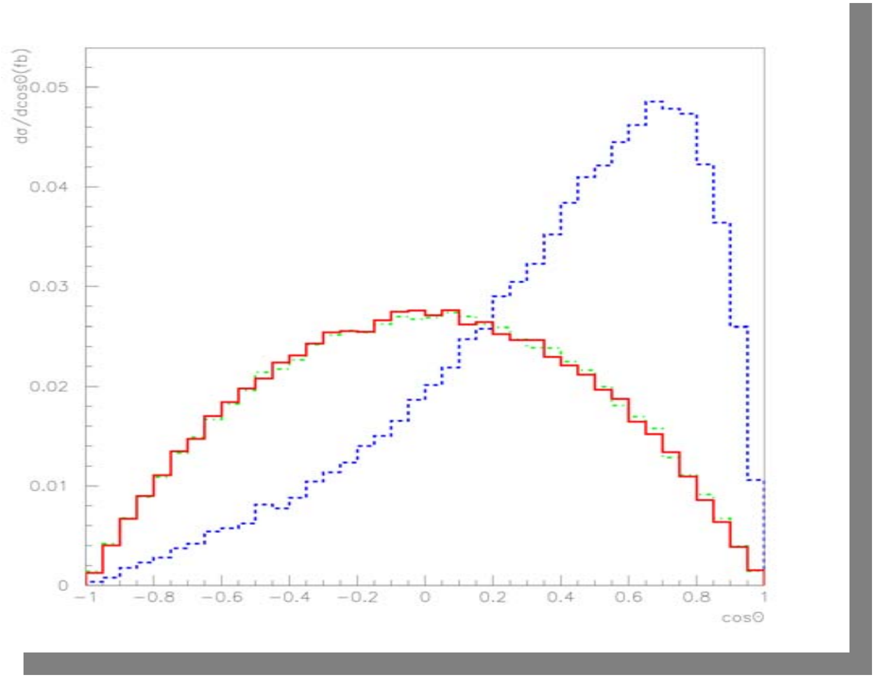
2500 GeV for θ

Angular distributions of staus:
<u>blue</u> sele_R-->stau_1X, <u>green</u> smuon_R->stau_1X and <u>red</u> stau_





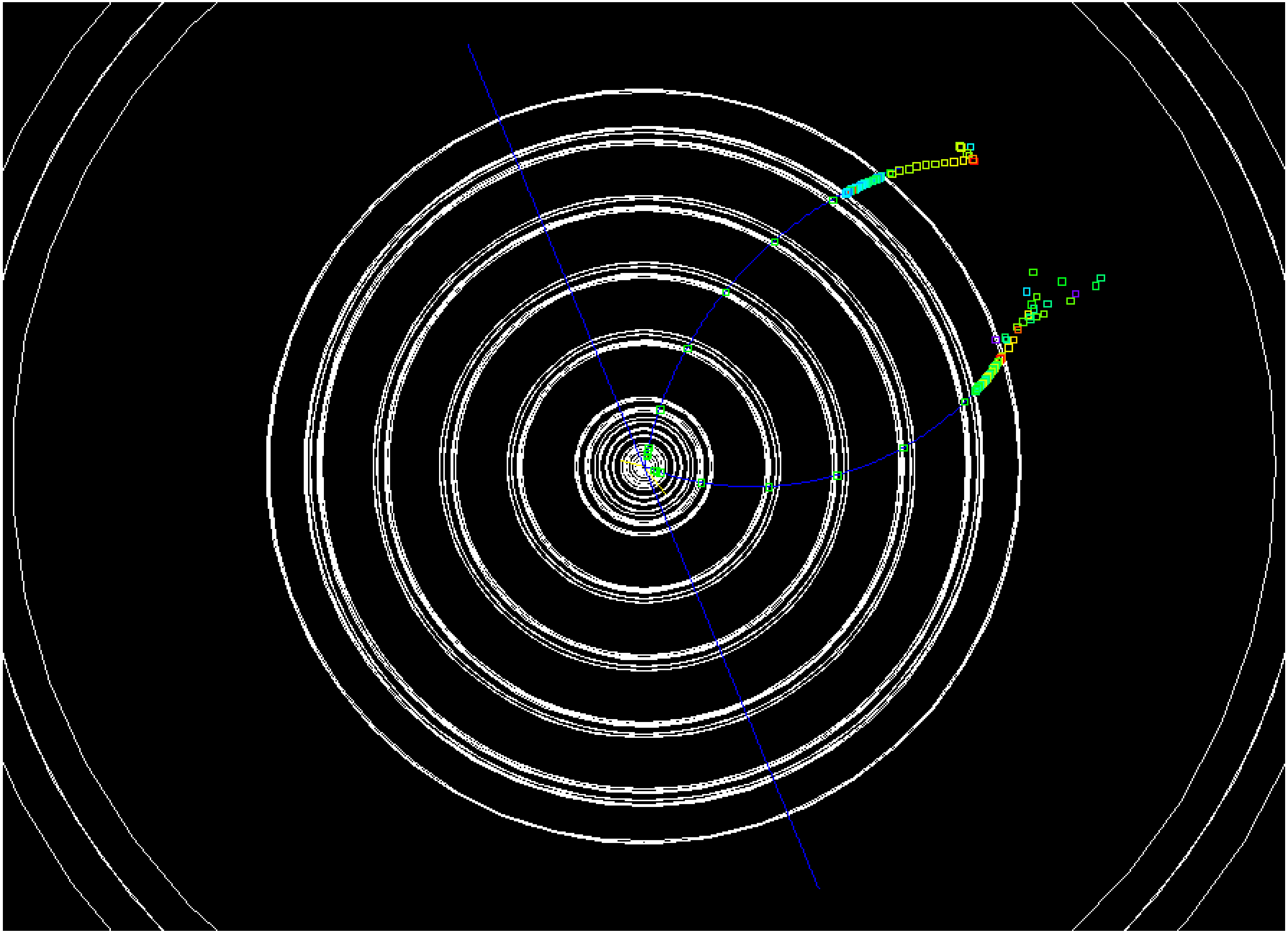




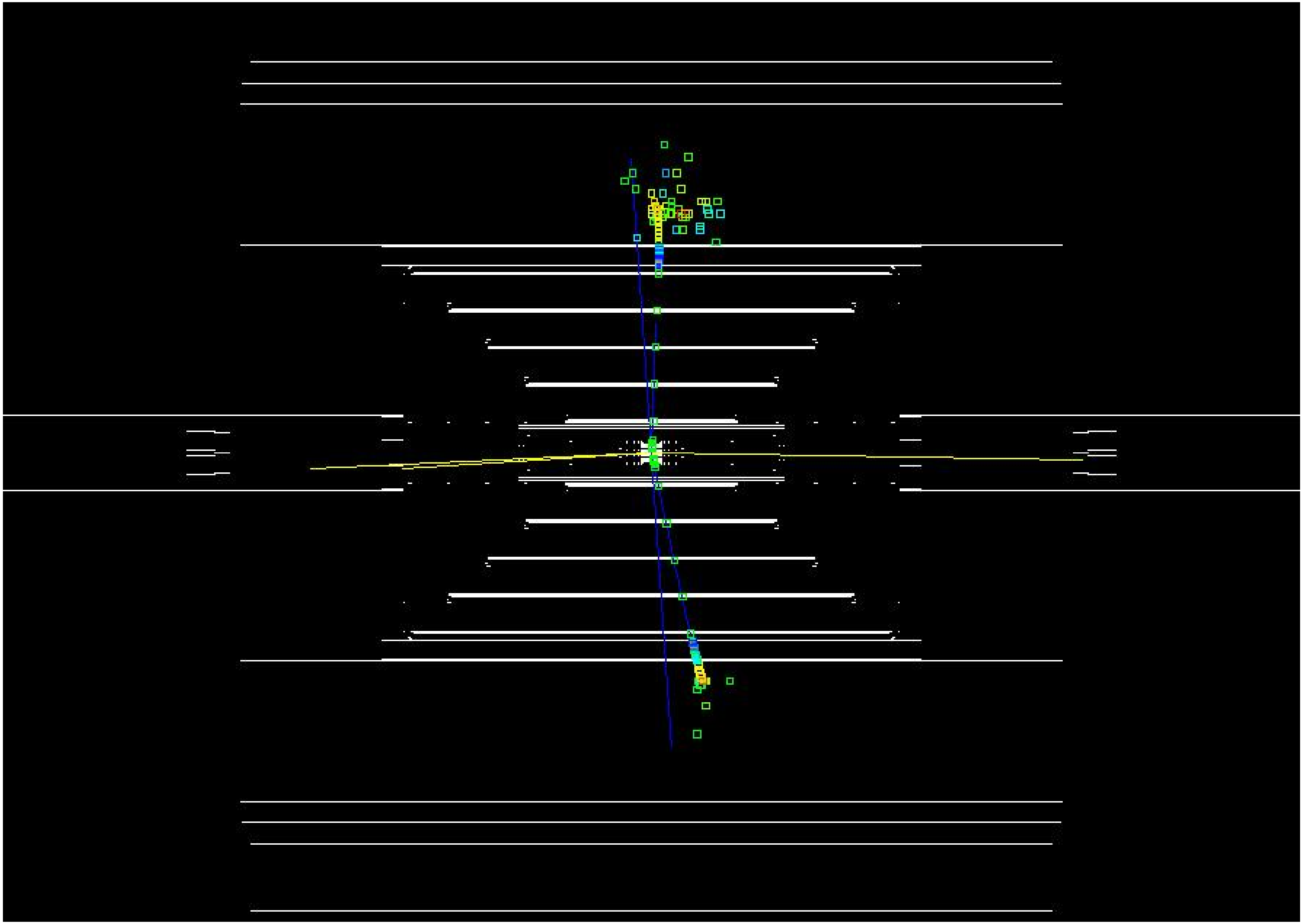
The coresponding values of βγ<0.4 for staus stopping in different detector parts for the benchmark points ε, ζ, η and θ

$\sqrt{s}$(GeV)	500	1000	3000	Optimal for	Maximal including
L_{int}(fb^{-1})	200	200	400(1000)	pair prod'n	other prod'n processes
ϵ	34	4	4(10)	1500	1700
ζ	-	12	4(10)	254	700
η	-	10	4(10)	370	600
θ	-	-	8(20)	56(140)	140(350)

Stau->tau+G events as seen in CLIC000



Stau->tau+G events other view



CONCLUSIONS

- We have discussed the measurement of the stau mass and the mixing angle of staus resulting a good resolution (δm, $\delta \cos\theta$)

- Stau decay to tau and gravitino is also implemented, and TAUOLA is used for further tau to hadronization, CLIC000 can detect stau (long-lived) with ionized tracks.

- The optimal energies (~2m) for having largest number of stoppable staus are different from the center of mass energies where the maxima of the pair production cross section appear.

- ^{6,7}Li friendly point θ features relatively heavy sparticles beyond the reach of either the LHC or the ILC, but within the kinematic reach of CLIC.