Stau Production at Linear Colliders

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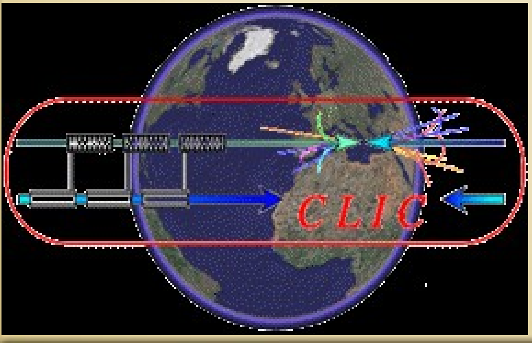
An update on

OC, ITC, JE, ZK
hep-ph/0703121



Ankara HEP Days 2009, 29-30 May 2009

Outline

- >>An update on the previous study "hep-ph/0703121" 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 CLIC001 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.
- Meta-stable heavy stau in certain points of parameter space
- mSUGRA parameters:

[Feng05]

m1/2 = common gaugino mass
m0 = common scalar mass
A0= trilinear coupling
tan β = ratio of VEVs
Sign(mu) = 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

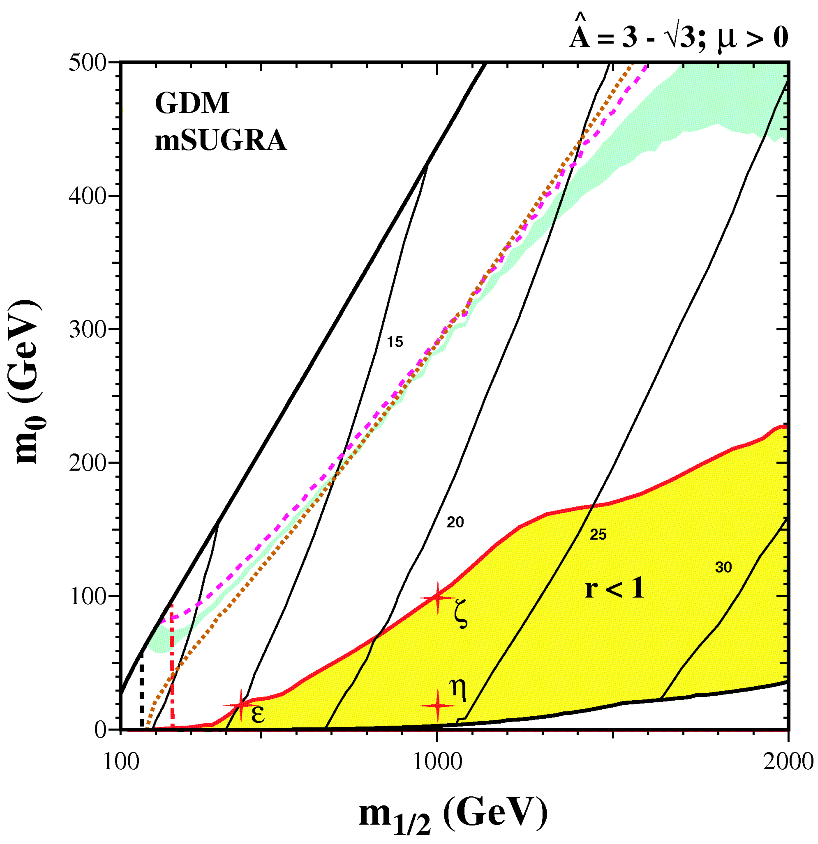
Points:

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)
} De Roeck *et al.* 05

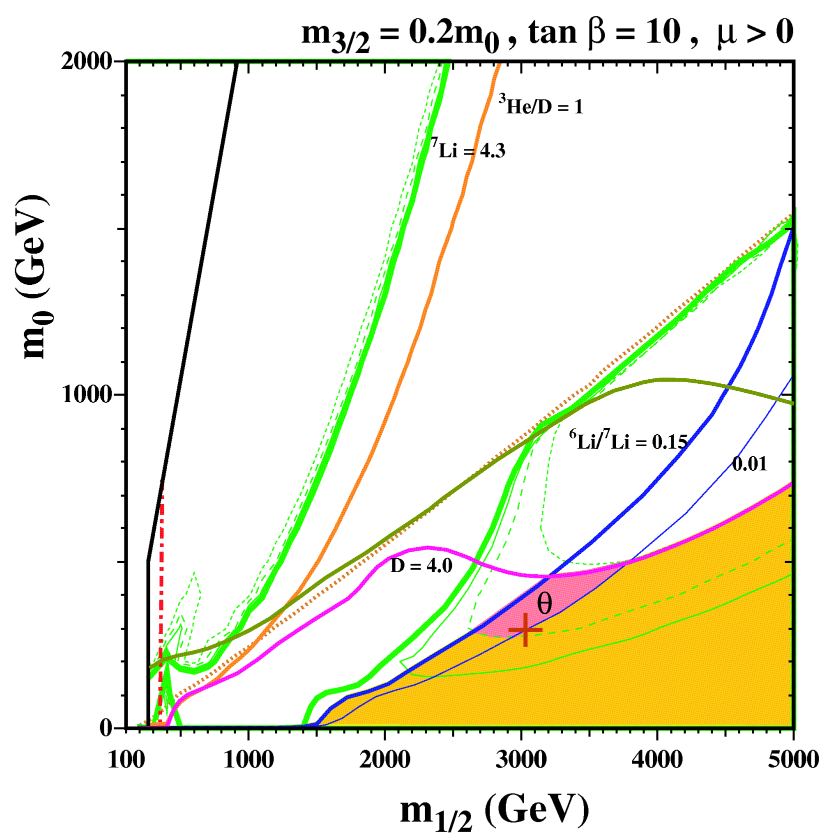
θ - high m_0, high $m_{1/2}$, low tan(beta) } O. Cakir *et al.* 07

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

mSUGRA benchmark scenarios with stau NLSP:



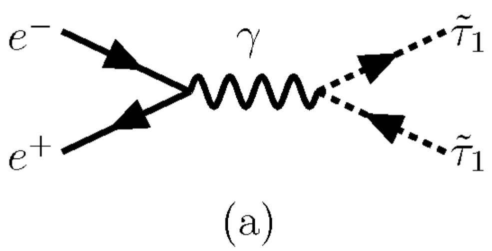
Three benchmark points with astrophysical constraints



Agreement between BBN calculations and the observed Li abundances

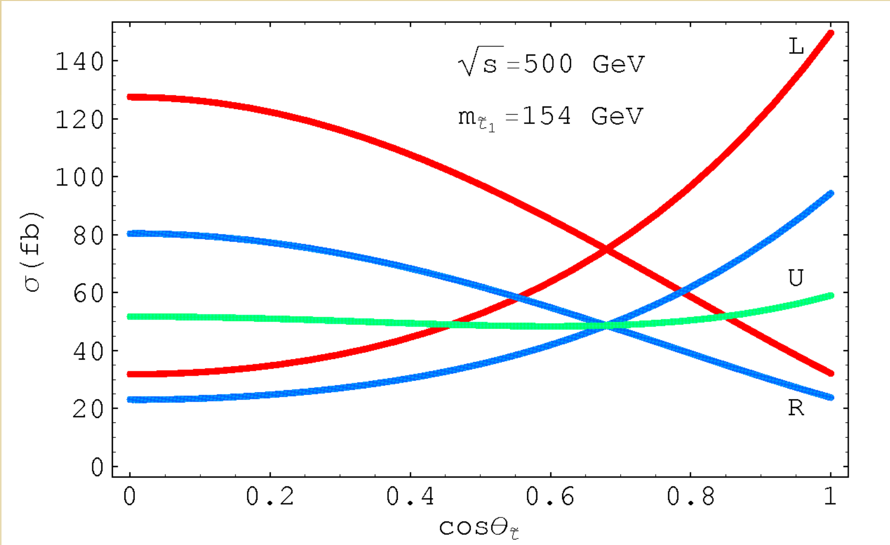
Stau pair production

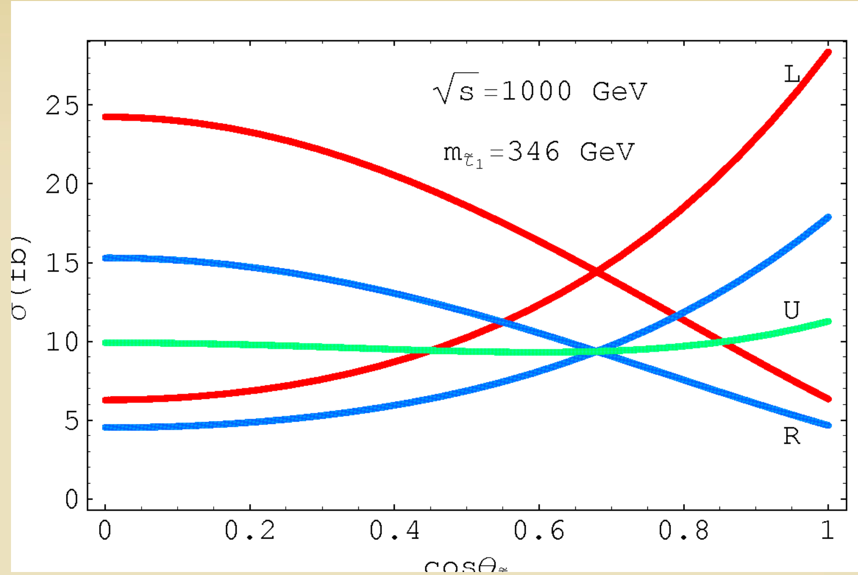
SUSY R-parity conservation → pair production at colliders



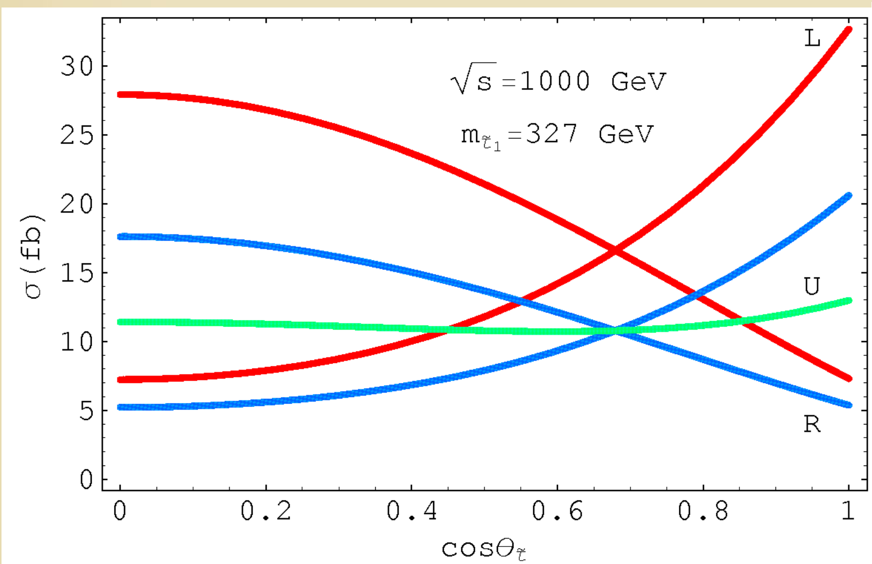
$$\sigma = \frac{\pi\alpha^2\beta^3}{3s}\Bigg[(1-P_-P_+) + \frac{I_3\cos^2\theta_{\tilde{\tau}} + \sin^2\theta_W}{2\cos^2\theta_W\sin^2\theta_W}[v_e(1-P_-P_+) - a_e(P_- - P_+)]P_{\gamma Z}$$
$$+ \frac{(I_3\cos^2\theta_{\tilde{\tau}} + \sin^2\theta_W)^2}{16\cos^4\theta_W\sin^4\theta_W}[(v_e^2+a_e^2)(1-P_-P_+)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

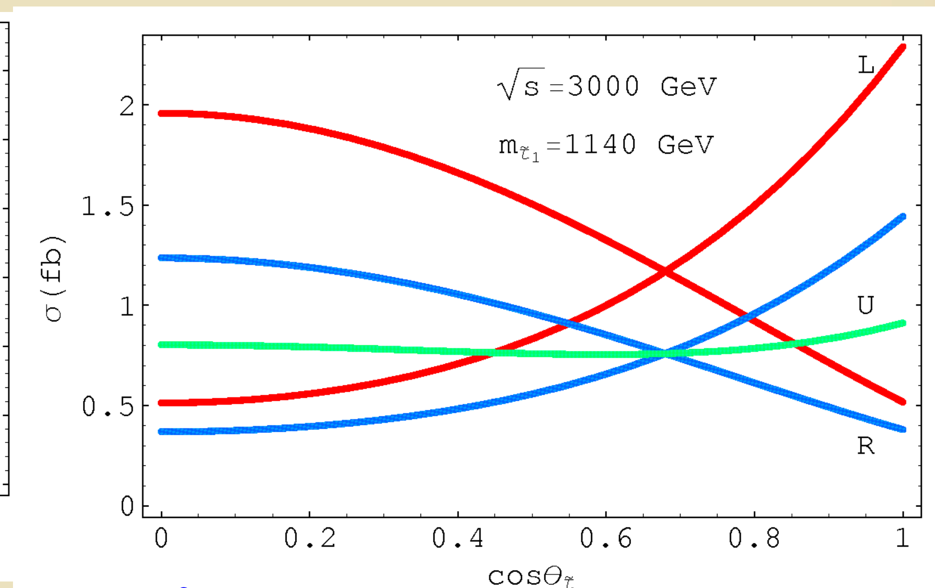
$$P_{ZZ} = \frac{s^2}{(s-m_Z^2)^2 + m_Z^2\Gamma_Z^2} \quad , \qquad P_{\gamma Z} = \frac{s(s-m_Z^2)}{(s-m_Z^2)^2 + m_Z^2\Gamma_Z^2}$$





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.

ISAJET/ISASUGRA

IsaJet : bash

File Edit View Scrollback Bookmarks Settings Help

```
ocakir@linux-ww1m:~/IsaJet> ./isasugra.x
 ENTER output filename in single quotes:
'point1.txt'
 ENTER SUSY Les Houches Accord filename [/ for none]:
point1.slha
 ENTER Isawig (Herwig interface) filename [/ for none]:
/
 ENTER 1 for mSUGRA:
 ENTER 2 for mGMSB:
 ENTER 3 for non-universal SUGRA:
 ENTER 4 for SUGRA with truly unified gauge couplings:
 ENTER 5 for non-minimal GMSB:
 ENTER 6 for SUGRA+right-handed neutrino:
 ENTER 7 for minimal anomaly-mediated SUSY breaking:
 ENTER 8 for non-minimal AMSB:
 ENTER 9 for mixed moduli-AMSB:
 ENTER 10 for Hypercharged-AMSB:
1
 ENTER M_0, M_(1/2), A_0, tan(beta), sgn(mu), M_t:
20,440,-25,15,1,172
 Run Isatools? Choose 2=all, 1=some, 0=none:
0
ocakir@linux-ww1m:~/IsaJet>
```

IsaJet : bash

The properties of the benchmark points of mSUGRA

Point 1:

t= 33.7 day

This point could be probed at LHC, ILC and CLIC

Point 2:

t= 19.4 day

These points could be probed at LHC and CLIC

Point 3:

t=0.7 day

Point 4:

t=1.35 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

The total cross section (pb)

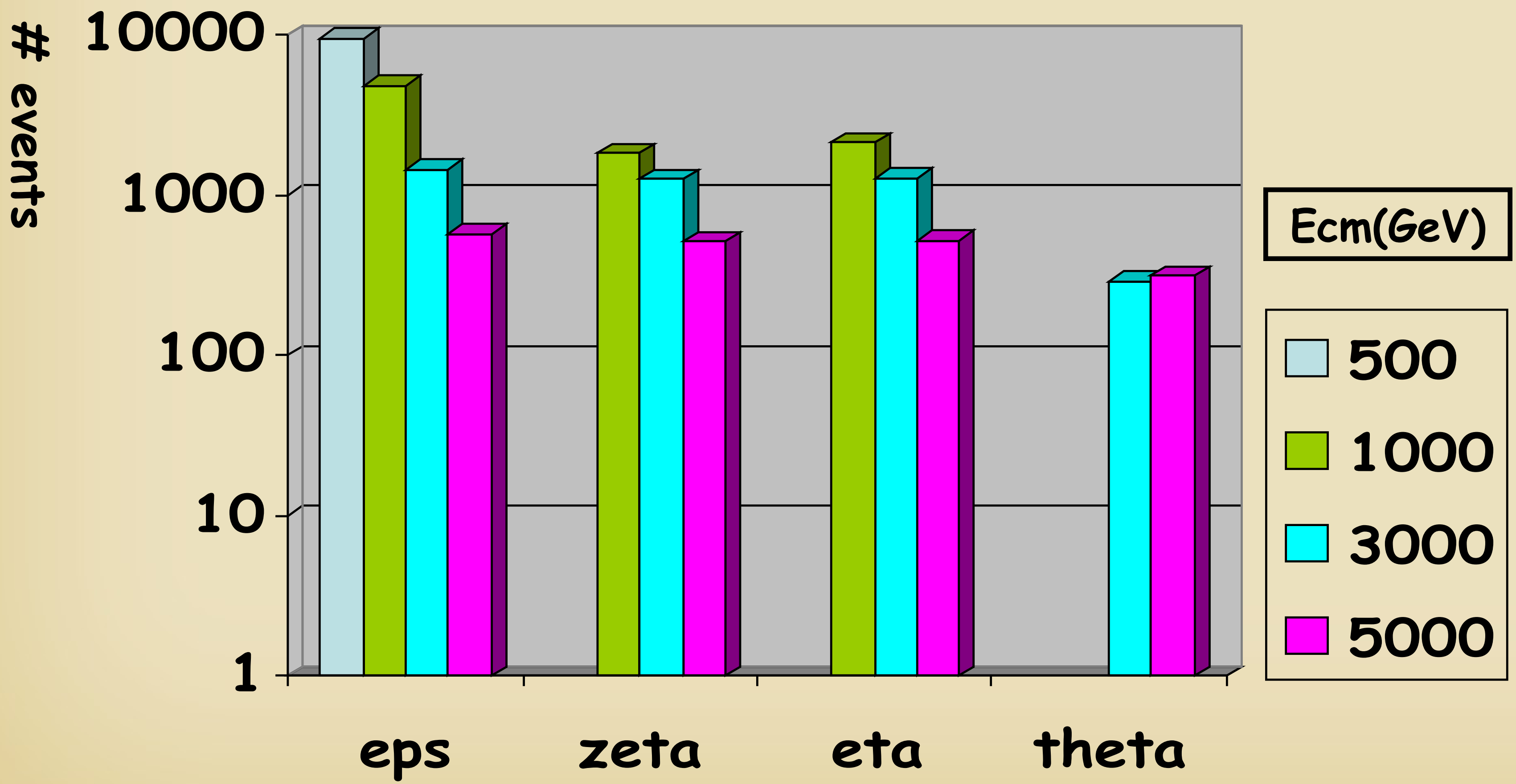
We use PYTHIA with the full ISASUGRA spectrum including both initial and final state radiation (ISR+FSR)

	Benchmark points	ϵ	ζ	η	θ
	$m_{\tilde{\tau}_1}(\text{GeV}) =$	154	346	327	1140
$\sqrt{s}(\text{GeV})$	500	4.799×10^{-2}	–	–	-
	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}

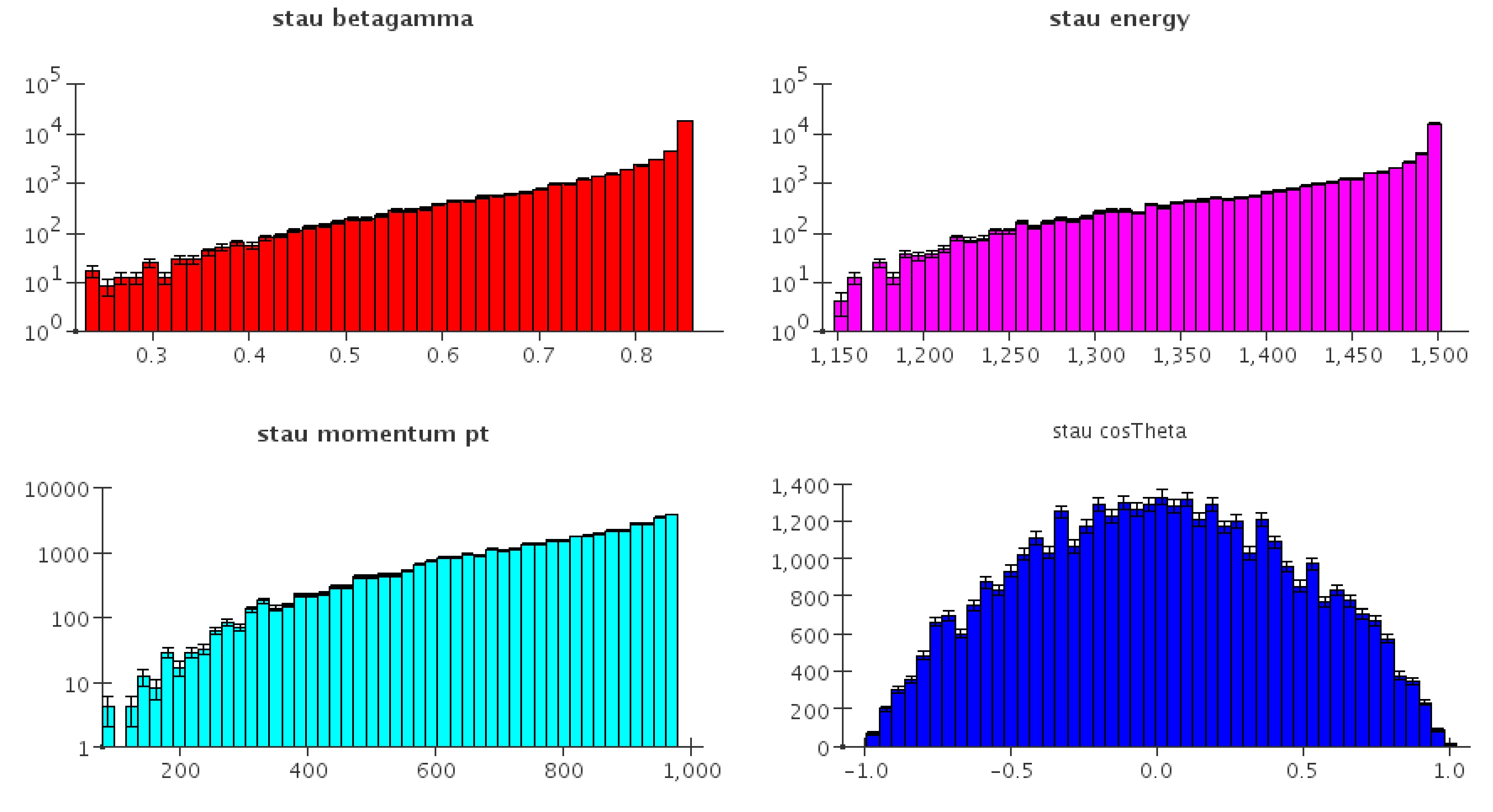
Number of stau pairs produced at:

Ecm = 500, 1000 GeV with L=200 fb^(-1)

Ecm = 3000, 5000 GeV with L=400 fb^(-1)

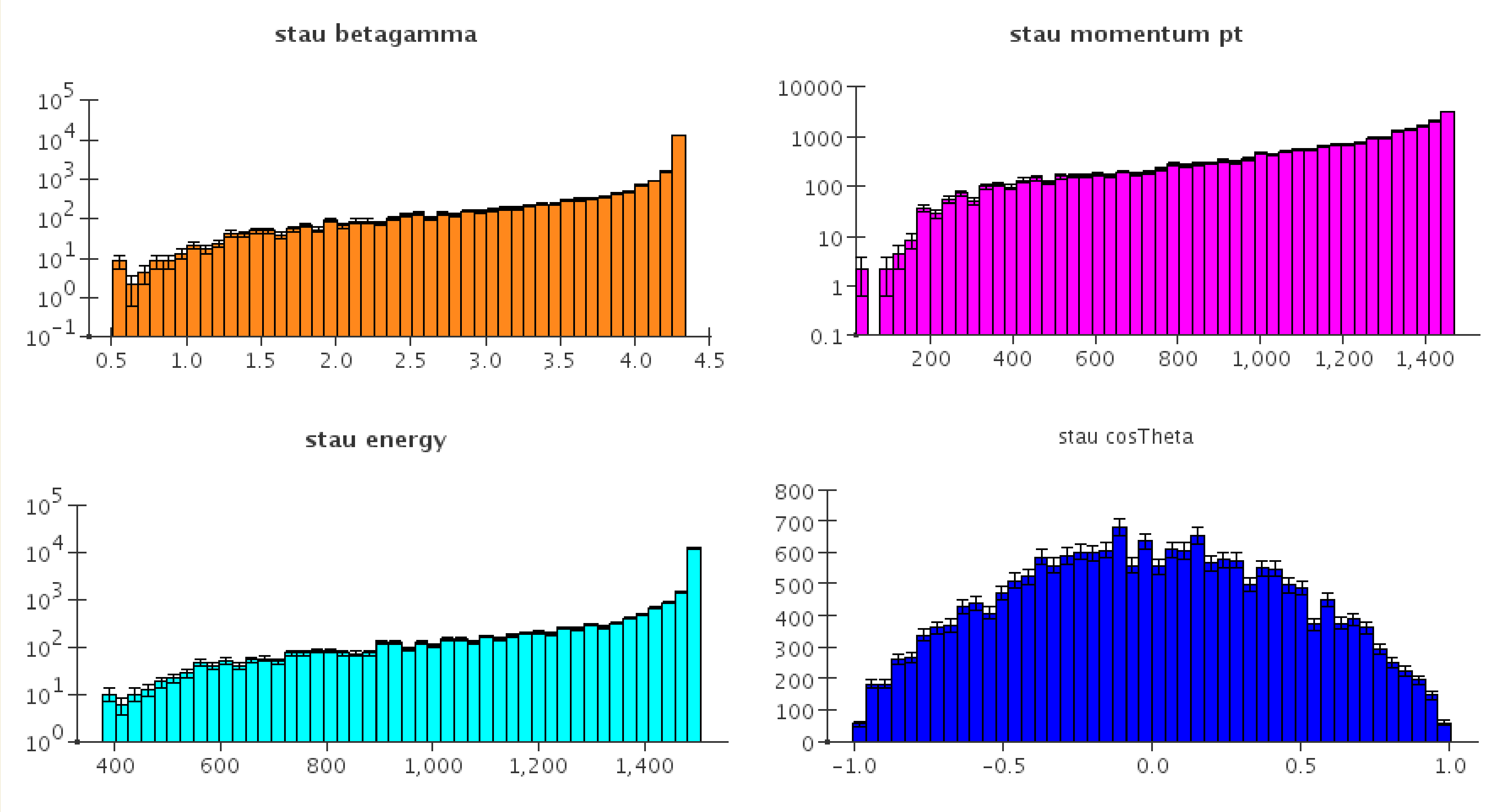


Distributions of staus at point ε

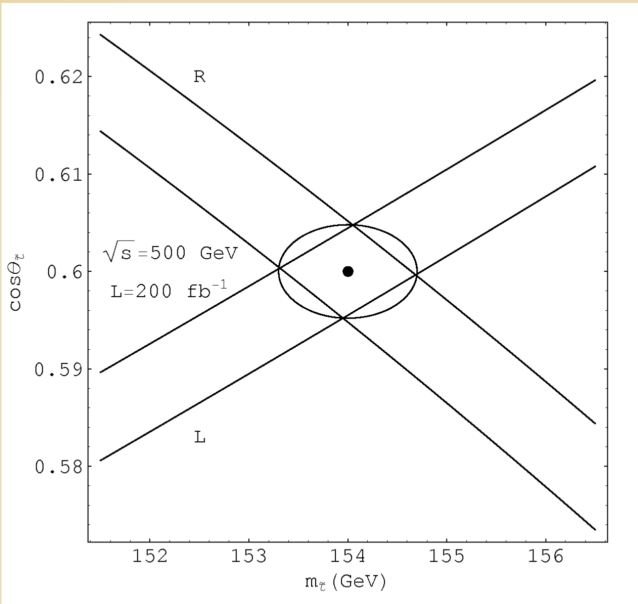


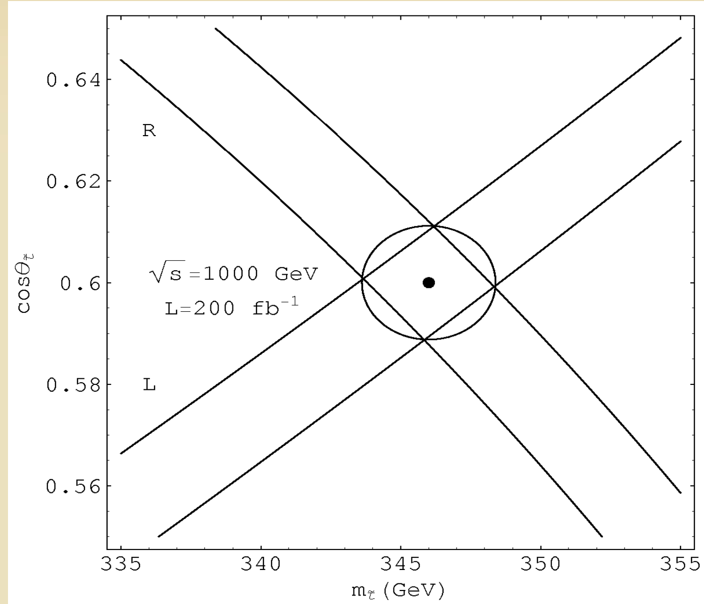
Includes the ISR and beamstrahlung effects

Distributions of staus at point ζ



No ISR and beamstrahlung effects

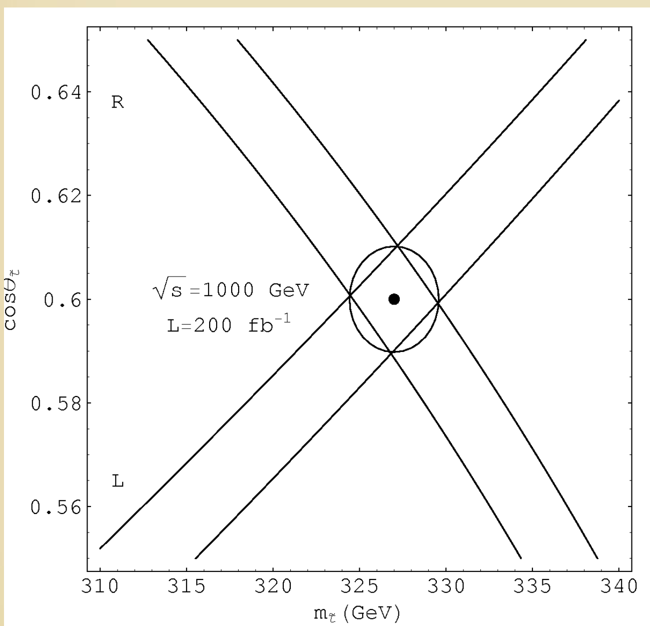


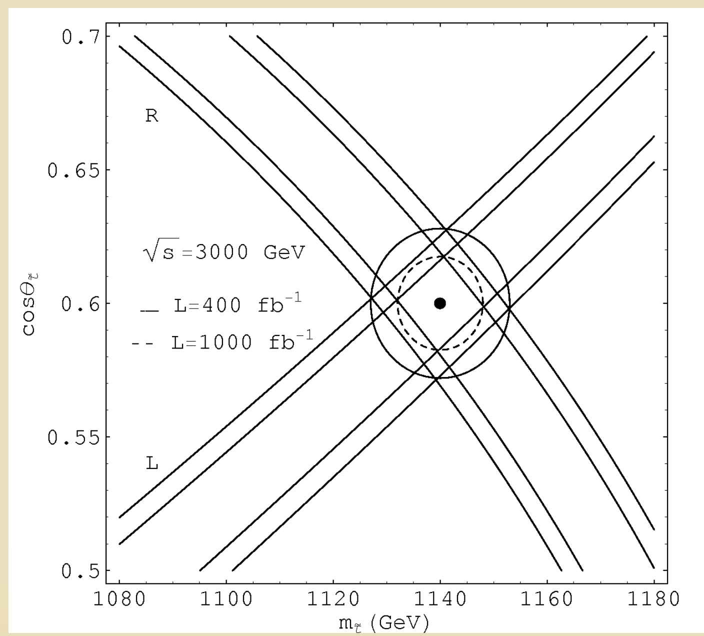


Polarization

e- %90

e+ %60





accuracies on the measure:

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

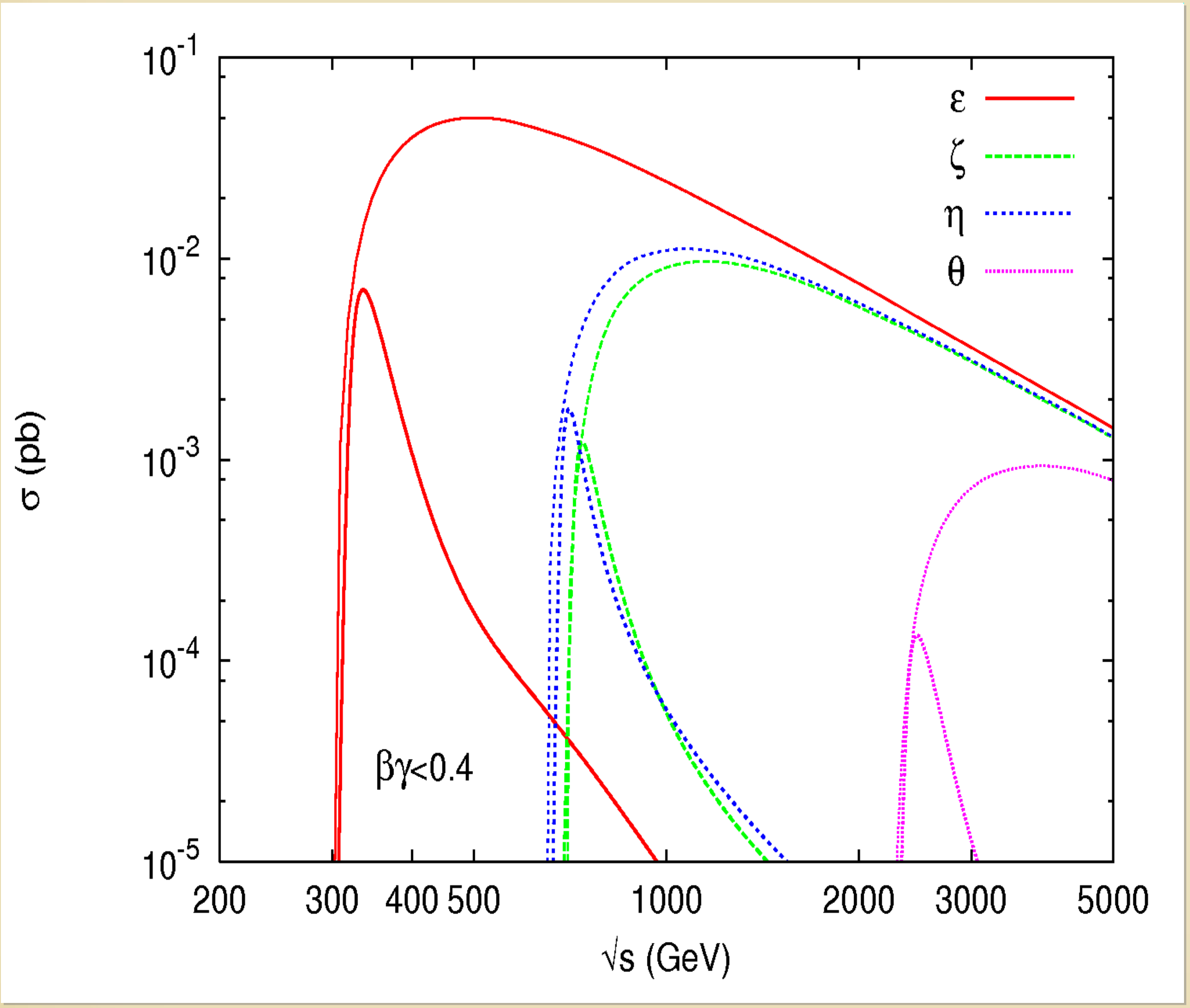
(0.7, 0.005) for epsilon ε ε

(2.4, 0.01) for zeta, eta

at Ecm=1000 GeV;

(8, 0.02) for theta at Ecm=3000 GeV

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



330 GeV for ε

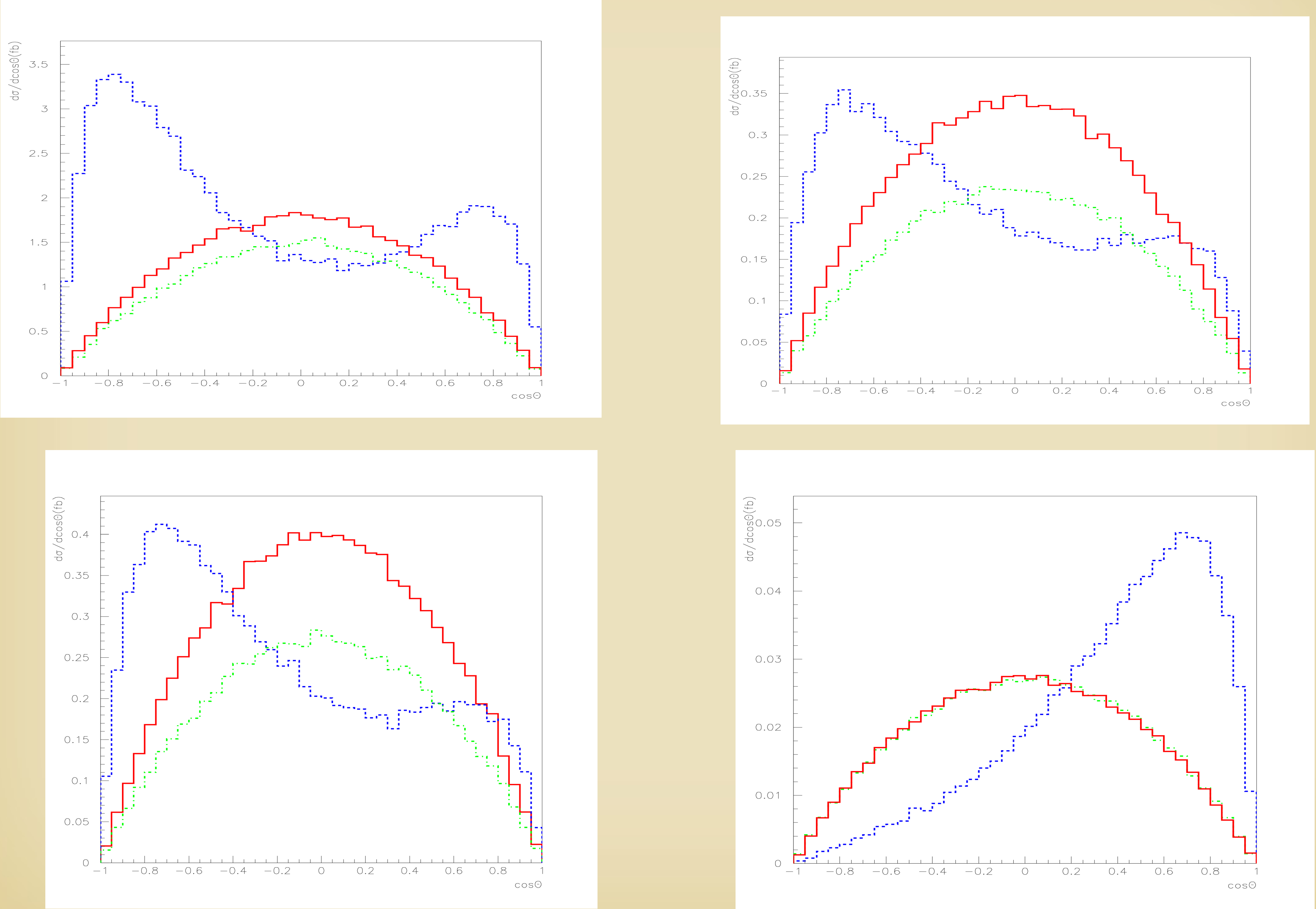
730 GeV for ζζ

700 GeV for η

2500 GeV for θ

Angular distributions of staus:

blue sele_R-->stau_1X, green smuon_R->stau_1X and red stau_1



The coresponding values of N for staus stopping in different detector parts for the benchmark points

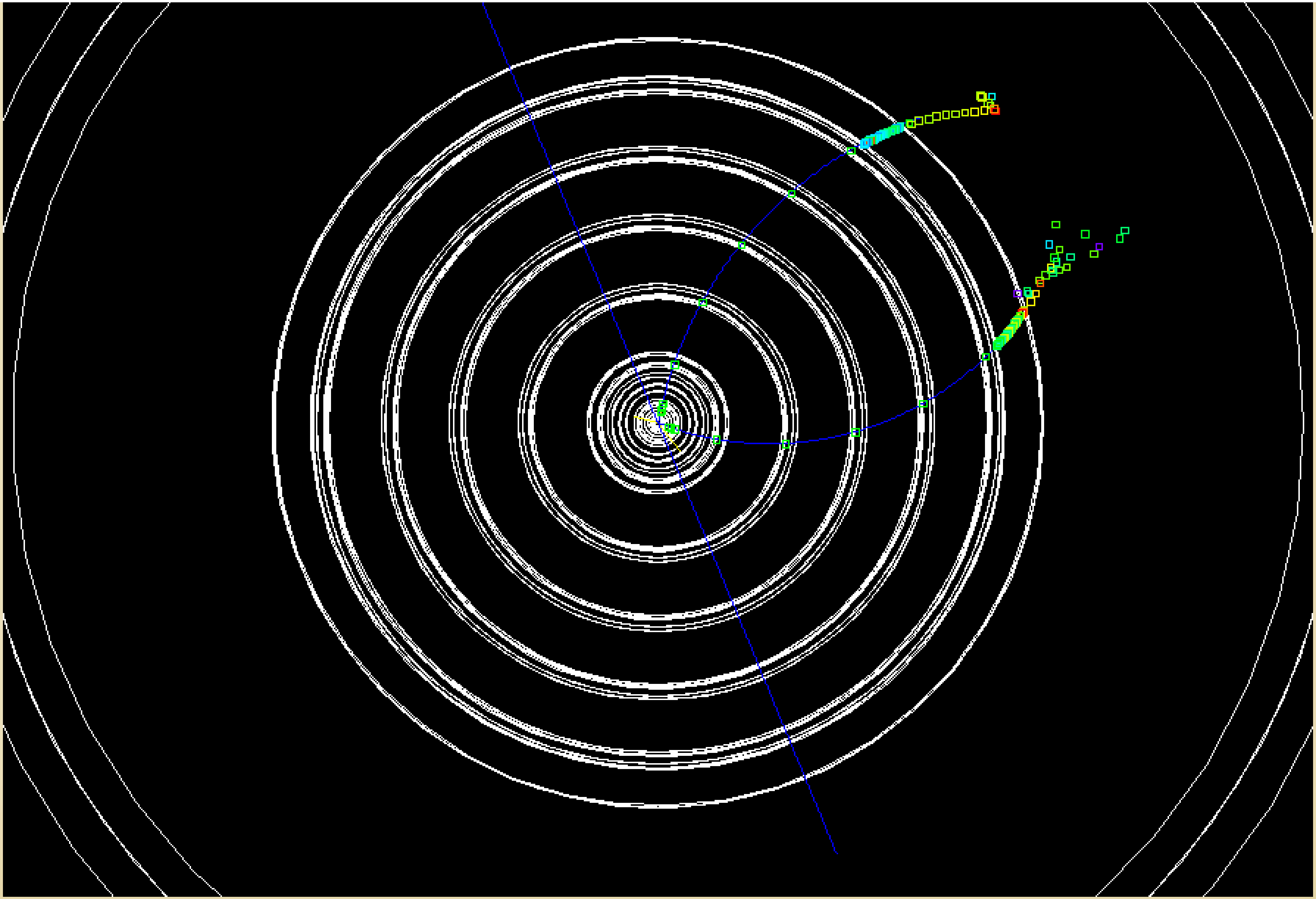
$\sqrt{s}$(GeV) L_{int}(fb^{-1})	500 200	1000 200	3000 400(1000)	Optimal for pair prod'n	Maximal including other prod'n processes
ϵ	34	4	4(10)	1500	1700
ζ	-	12	4(10)	254	700
η	-	10	4(10)	370	600
θ	-	-	8(20)	56(140)	140(350)

Stau NLSP

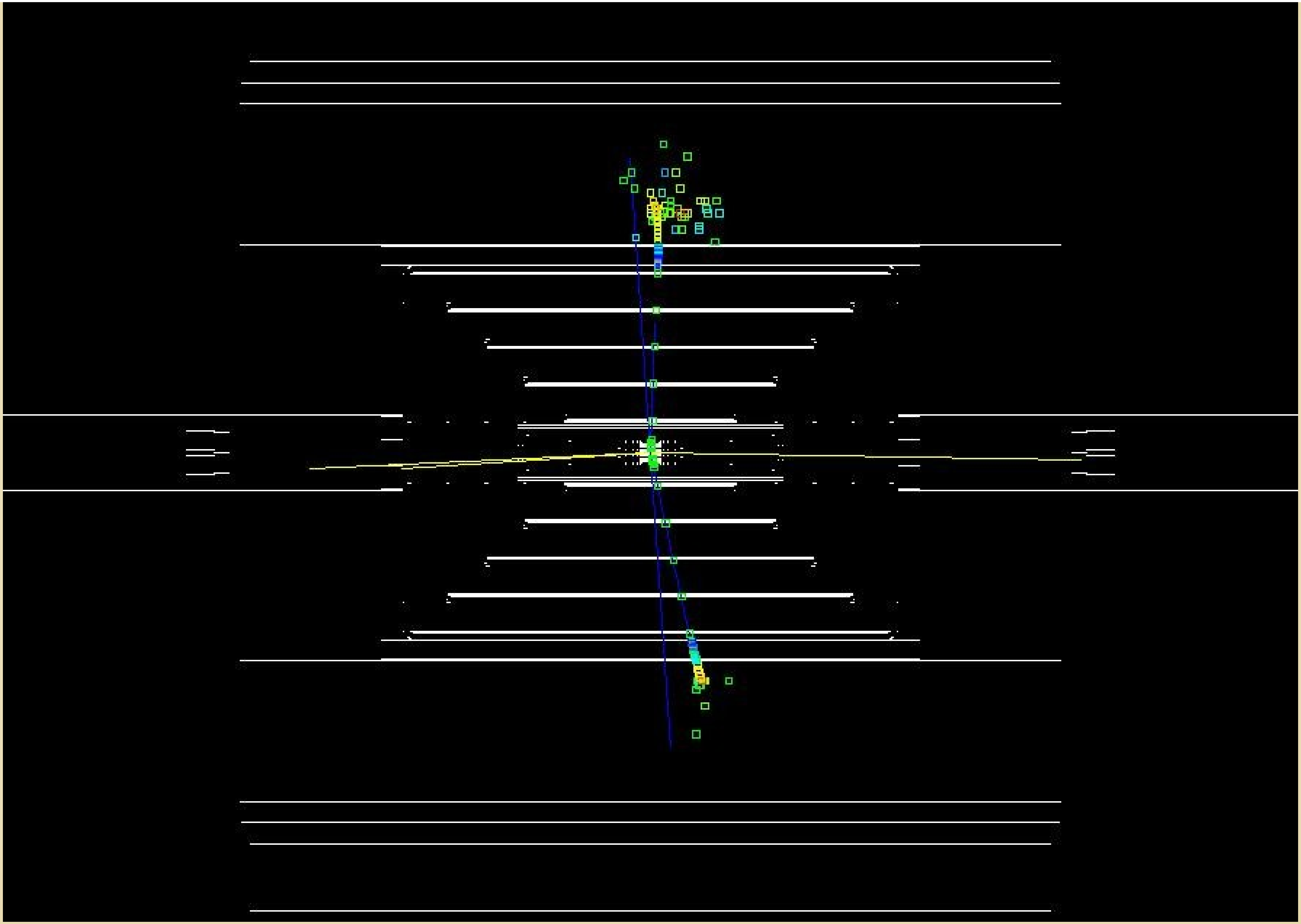
- For small tanβ, the mass splitting between the stau(1), selectron(R) and smuon(R) is small, rendering them co-NLSP's which decay into leptons and gravitinos.
- In the large tanβ region, the stau is the sole NLSP.
- Interest on the decay mode

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

Stau->tau+G events as seen in CLIC001



Stau->tau+G events (rho-z)



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, CLIC001 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.

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