Long-lived Stau

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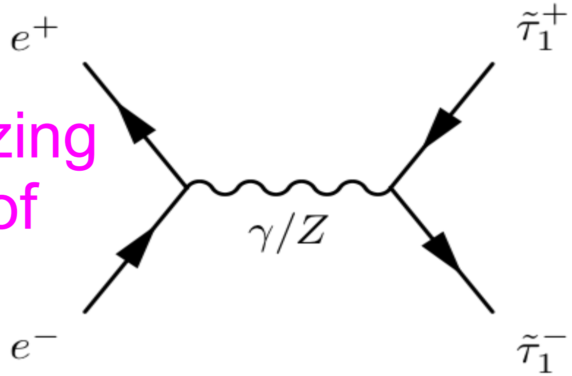
Introduction

- In the GMSB scenario,the stau can be lighter than the lightest neutralino. When the stau is lighter than the lightest neutralino and it is long lived,
  - -neutralino can decay into the stau
  - -its lifetime is long enough to escape the detector.
- Stau interacts with detector and can be discovered with a good accuracy.
- Long-lived stau is important not only to determine its properties but also quantum numbers of neutralino.

·We study such a stau and neutralino decaying into a stau and a tau,emphasizing feasibilities of precision measurements of Their masses,using the MC simulations.



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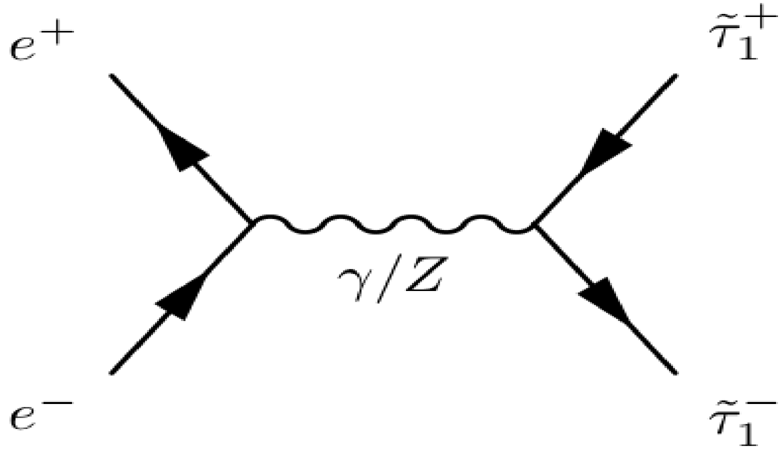
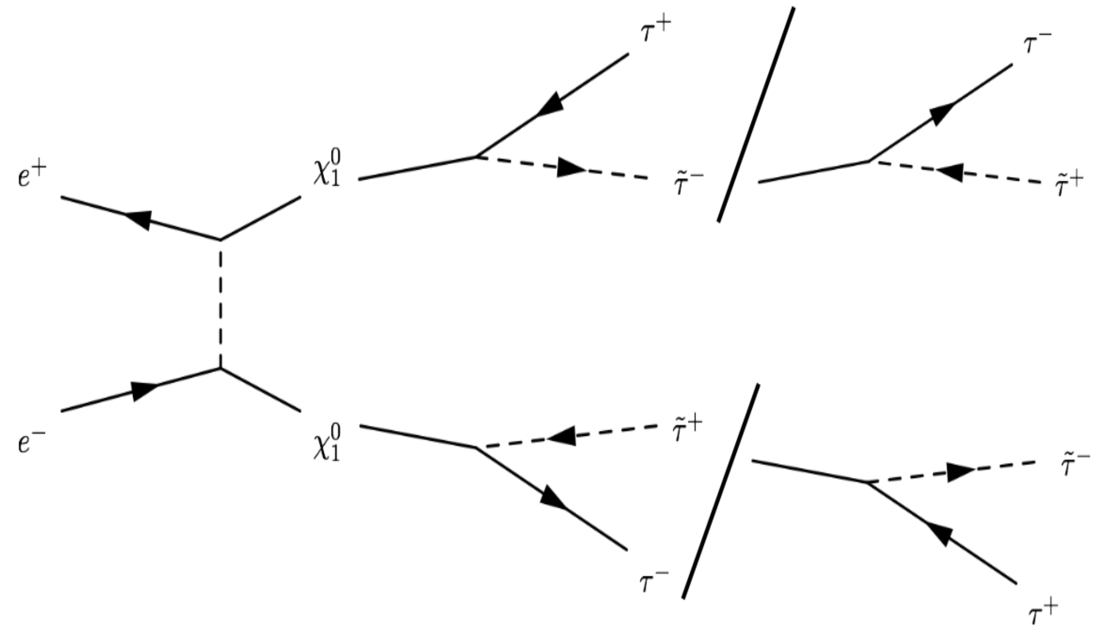
Decay Mode

- Stau pair mode
- Via Neutralino mode





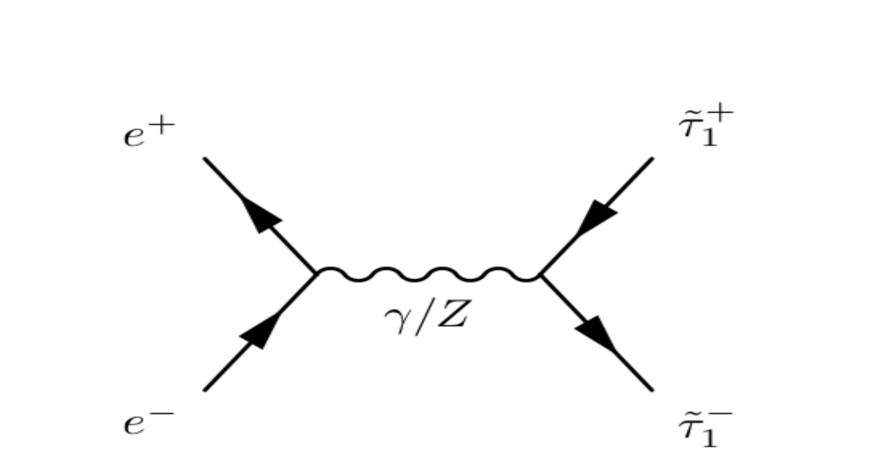
·Cross section of stau pair mode determines quantum numbers of stau($m_{\tilde{\tau}_1}$, J, I_3, Y).

· $m_{\tilde{\tau}_1}$ can be determined from dE/dx ,TOF and threshold scan.

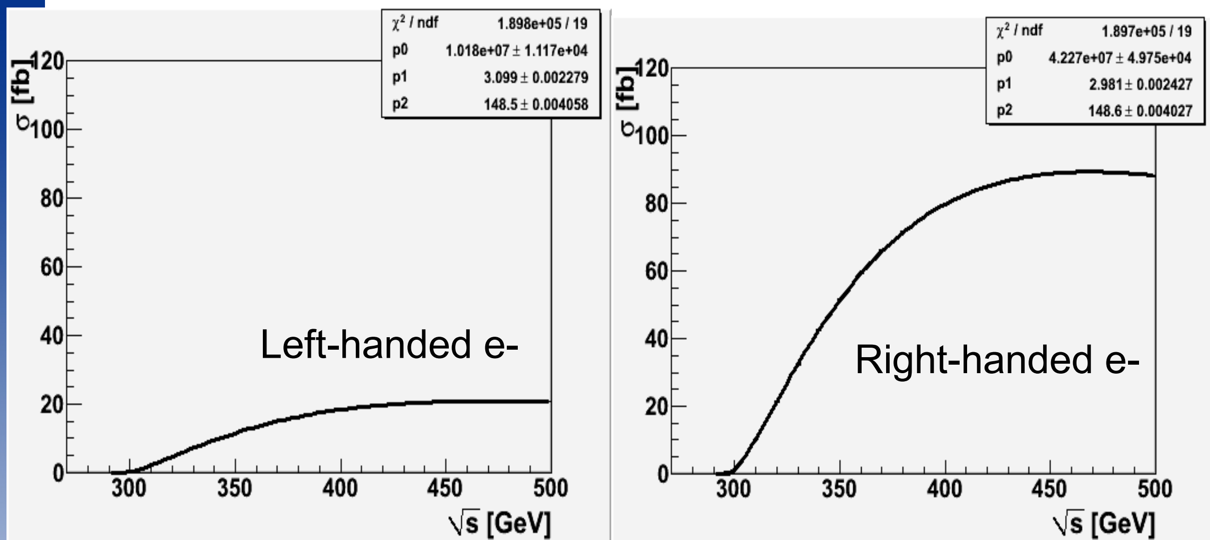
·Life time of stau is measured at HCAL.

·Via neutralino mode determines quantum numbers of neutralino.

Stau Pair Mode



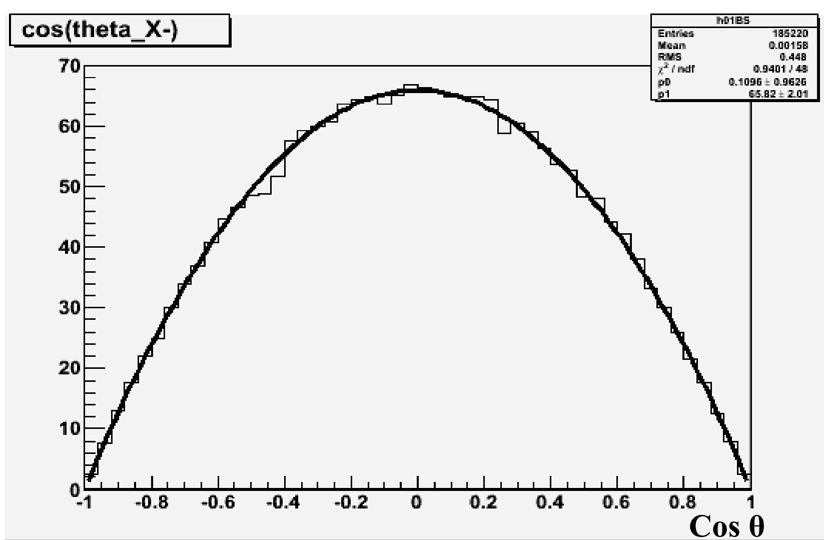
Stau Pair Mode



Cross section in the case of right handed electron is bigger than that in case of left handed electron.

Cross section of stau pair mode

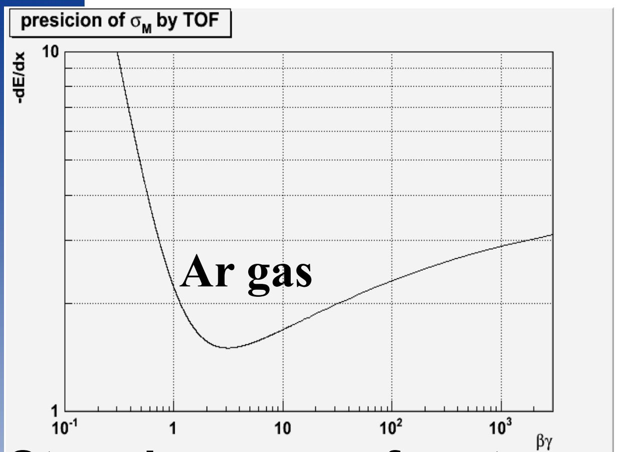
Stau mass : 148.8 GeV



Angular distribution

Many staus reach the barrel.
It is evidence that stau's spin is 0.

Precision of Stau Mass Measurement by dE/dx

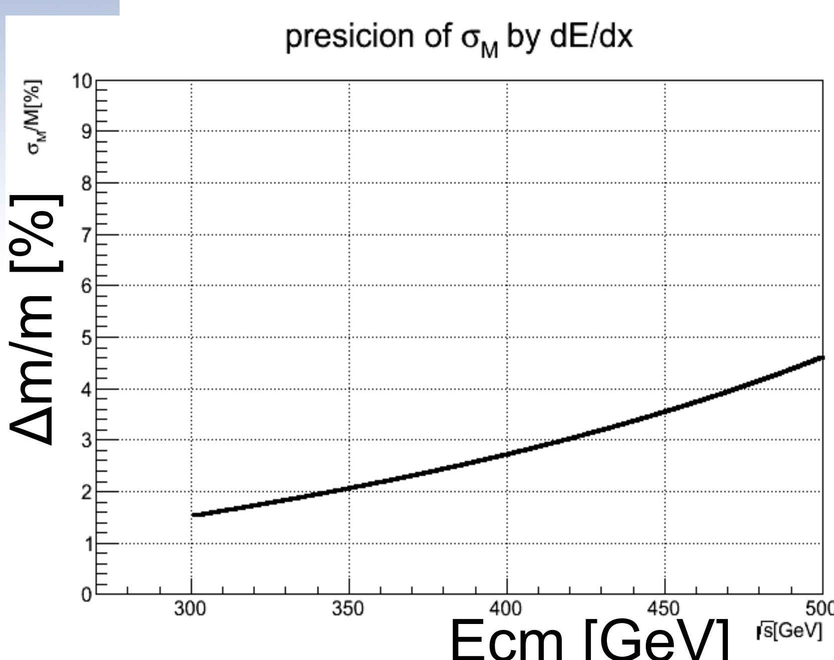


Stopping power for stau

Energy loss for heavy charged particles is measured at TPC. By energy loss measurement,stau mass can be measured.

$$M = E \cdot \sqrt{1 - \beta^2}$$

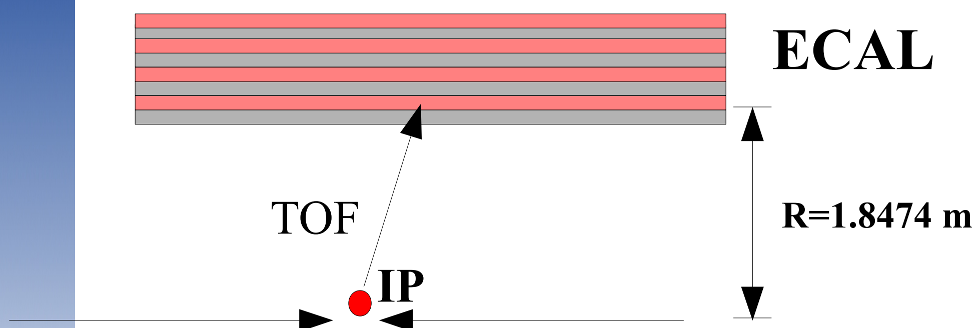
However, energy loss measurement has 5% resolution.



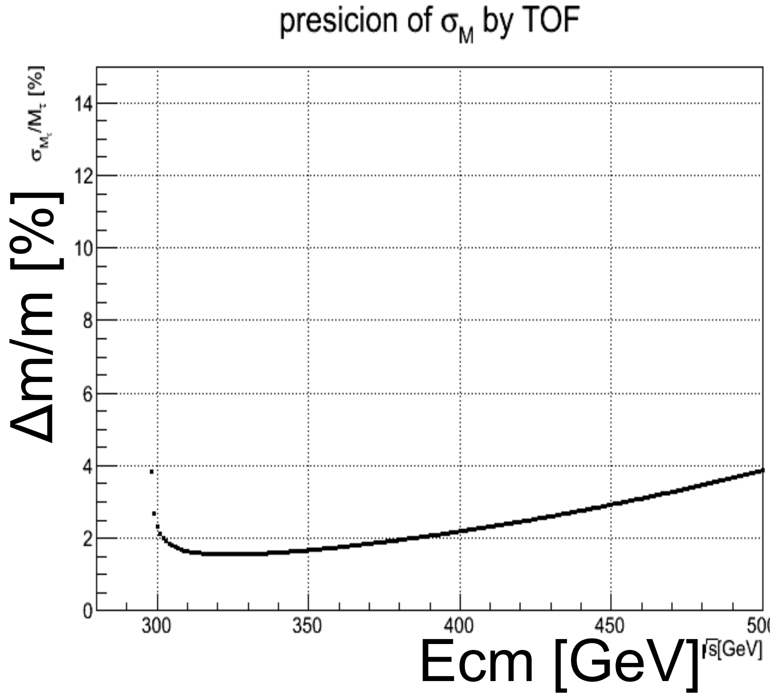
This figure mass measurement resolution by dE/dx for beam energy.
From this figure,mass measurement by dE/dx is best at energy threshold.

Precision of Stau Mass Measurement by TOF

Stau mass is given by Time Of Flight measurement. If we can measure TOF precisely,stau mass is determined good accuracy. ECAL is superior to TPC or SET the point of the time resolution,so we measure TOF at ECAL.

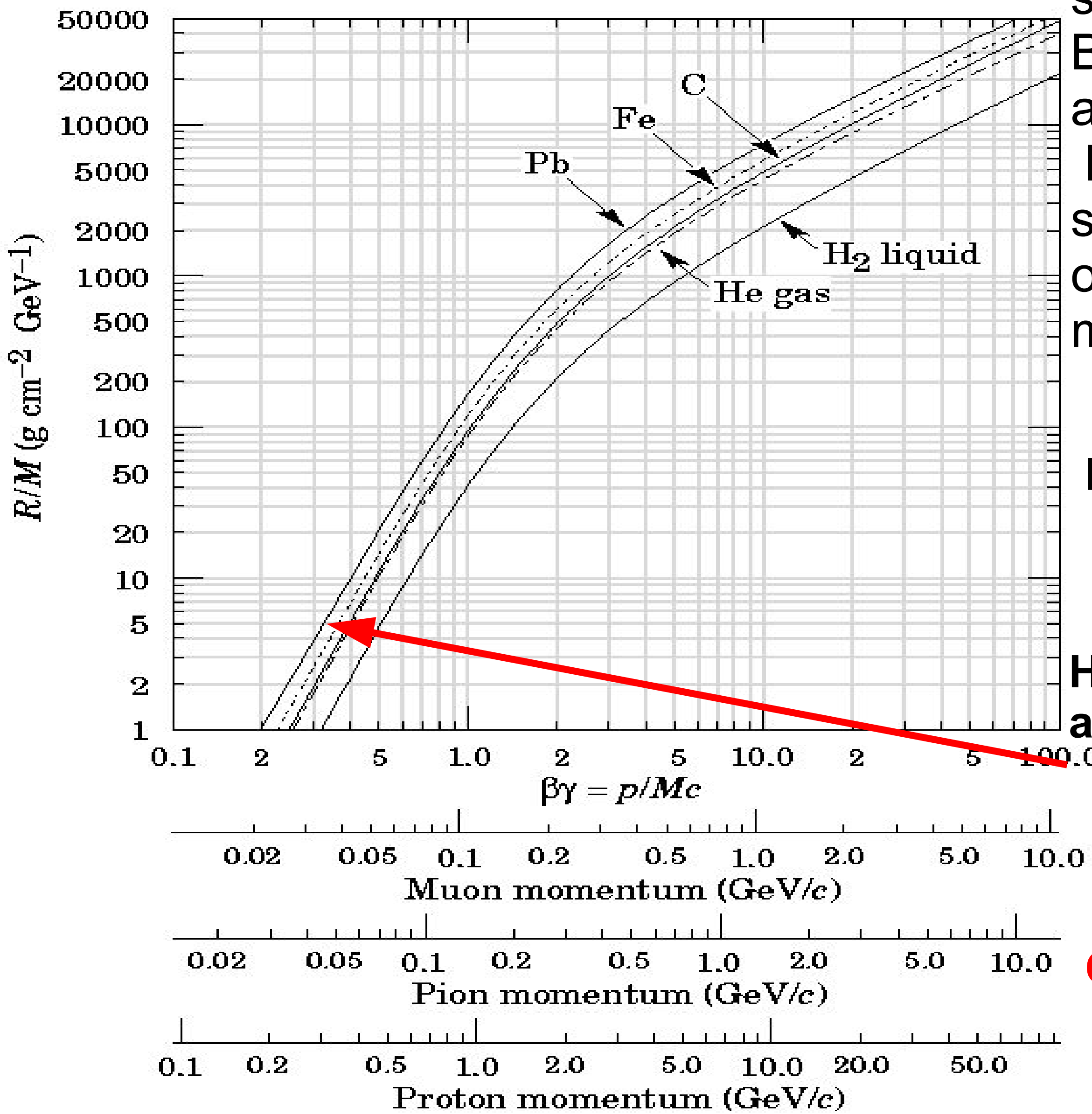


$$\beta = \frac{R\,[\mathrm{GeV}^{-1}]}{T\,[\mathrm{GeV}^{-1}]}, M = E \cdot \sqrt{1-\beta^2}$$



ScECAL has about 1ns time resolution. Stau mass is determined good accuracy when beam energy is about 320-330 GeV.

Life Time



Life time is measured in HCAL.So,a stau should be stopped in HCAL. Because of tunable beam energy, ILC allow us to control decay place of stau. Maximum beam energy when a stau stops in HCAL is calculated from range of heavy particles, because life time measurement is required many events.

Precision of life time measurement

$$\frac{\sigma_\tau}{\bar{\tau}} = \frac{1}{\sqrt{L \cdot \sigma_s}}$$

HCAL consists of 48 steel plates, and each plate has 20mm thickness.

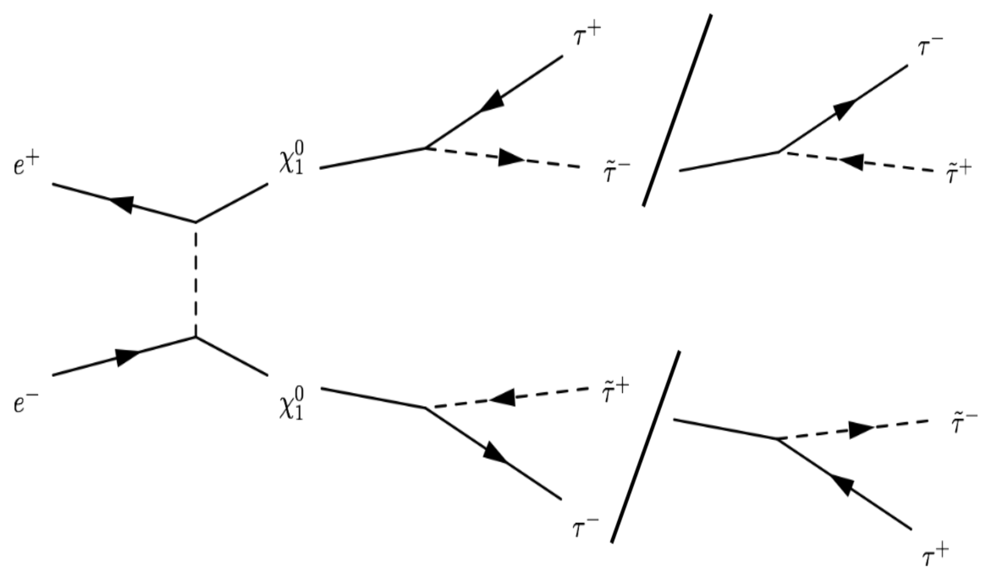
R/M=5.079 , βγ=0.35±0.01

√s=315.4±1.0[GeV]

Cross section: 9.3±0.3[fb]

$$\frac{\sigma_\tau}{\bar{\tau}} = 2.4 \pm 0.1 \ \%$$

Neutralino Mode



Background

Signal

$$e^+e^- \rightarrow \chi_1^0 \chi_1^0 \rightarrow \tilde{\tau}_1^\pm \tilde{\tau}_1^\pm \tau^\mp \tau^\mp$$

2 staus and 2 tauons

Regarded background

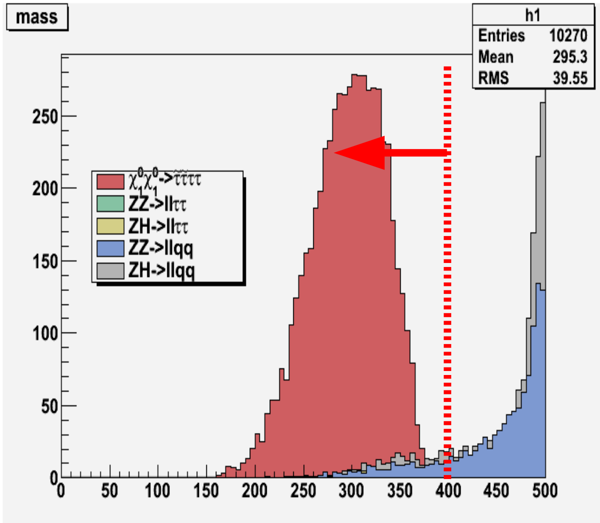
e+e- →ZZ
e+e- →ZH → **2 leptons and 2 jets**

	Cross section (fb) at 500GeV	
	Pol(-0.8,+0.3)	Pol(+0.8,-0.3)
$\chi_1^0 \chi_1^0 \rightarrow \tilde{\tau}_1^\pm \tilde{\tau}_1^\pm \tau^\mp \tau^\mp$	3.191	**34.484**
$ZZ \rightarrow l\,l\,\tau\,\tau$	4.073	2.349
$ZH \rightarrow l\,l\,\tau\,\tau$	4.983	3.744
$ZZ \rightarrow l\,l\,q\,q$	18.991	10.874
$ZH \rightarrow l\,l\,q\,q$	4.623	24.178

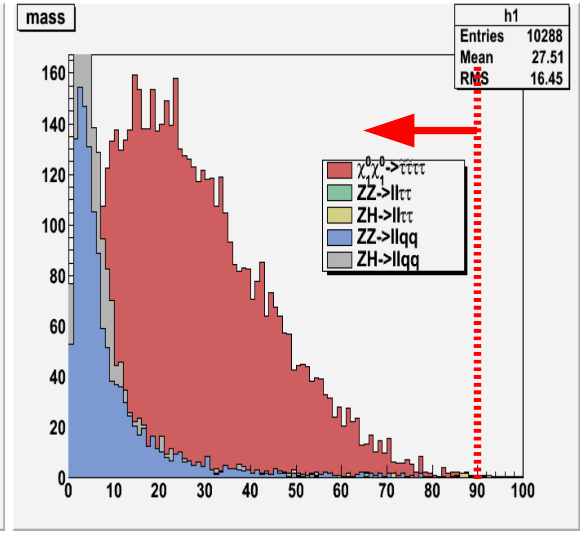
Pol(e-,e+)

Should use Right-handed electron!

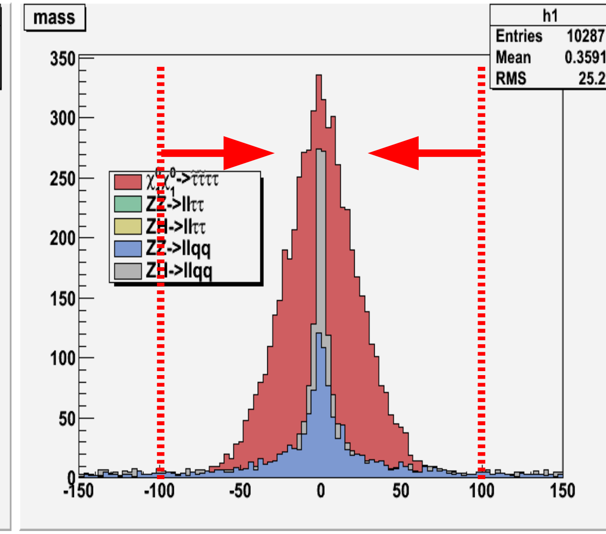
Event Selection



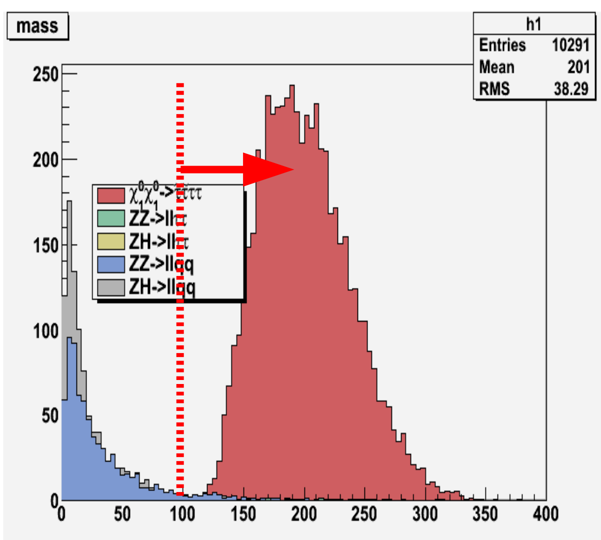
Visible energy<400GeV



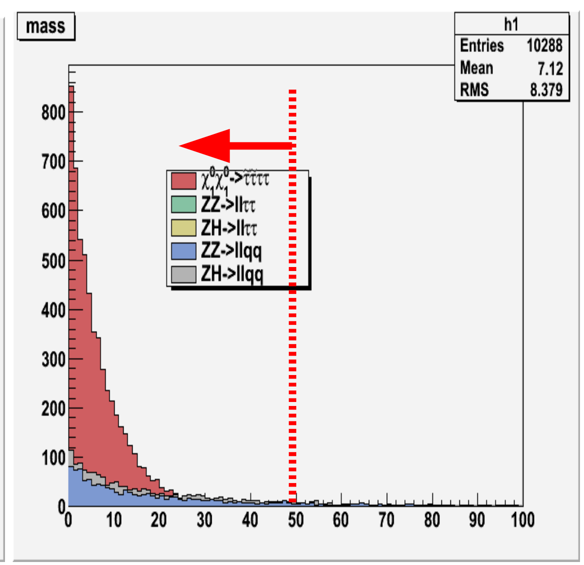
Pt<90GeV



|Pl|<100GeV

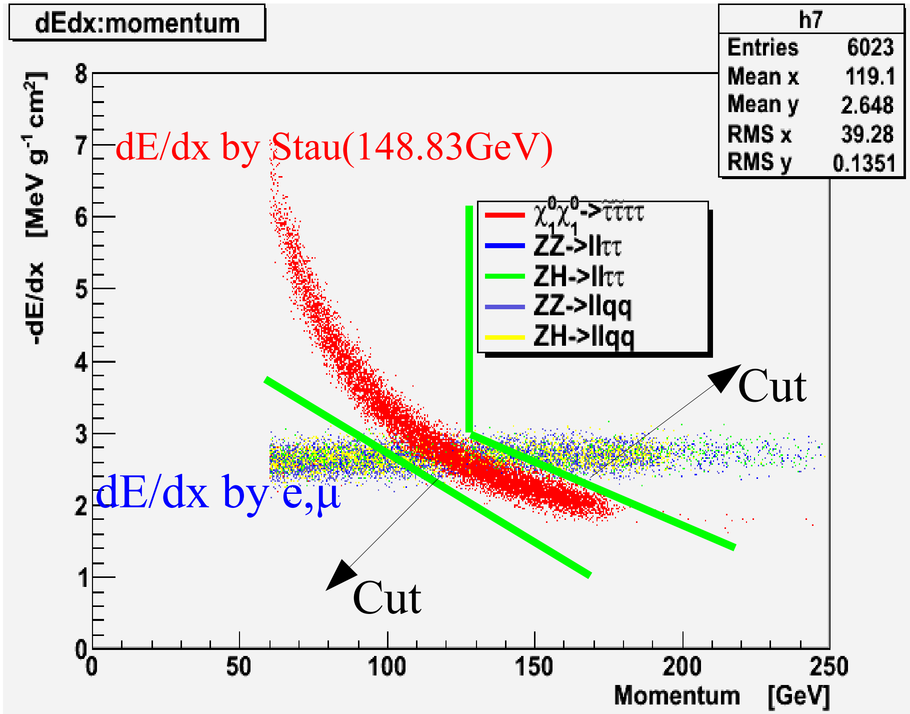


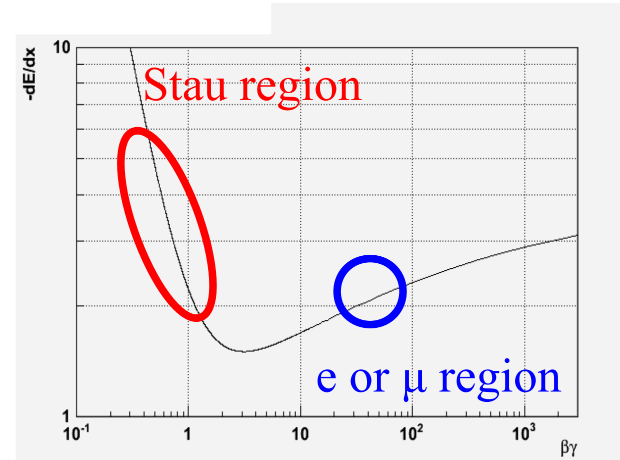
Missing mass>100GeV



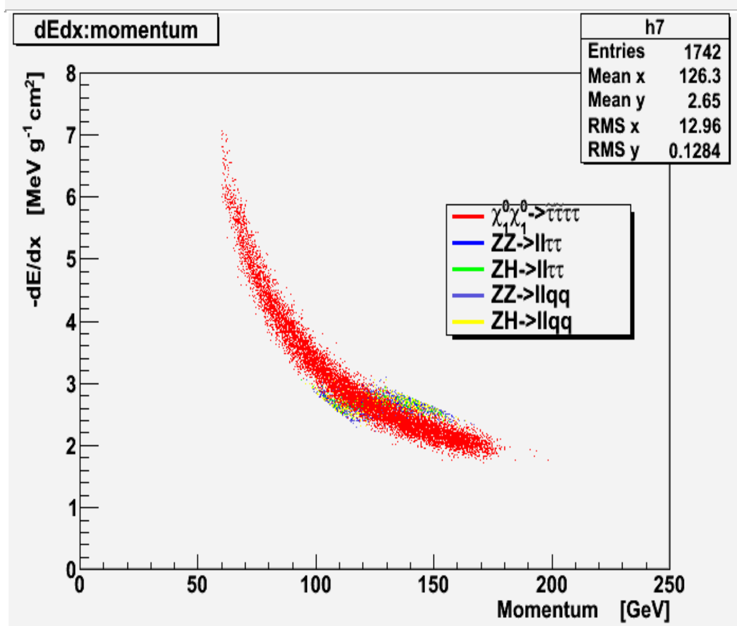
Acoplanarity<50

dE/dx Cut





Region of Energy loss of stau and lepton



Distribution of energy loss by stau,muon and electron for momentum are different. So,it is possible to separate stau from muon/electron by cuts.

Event Selection

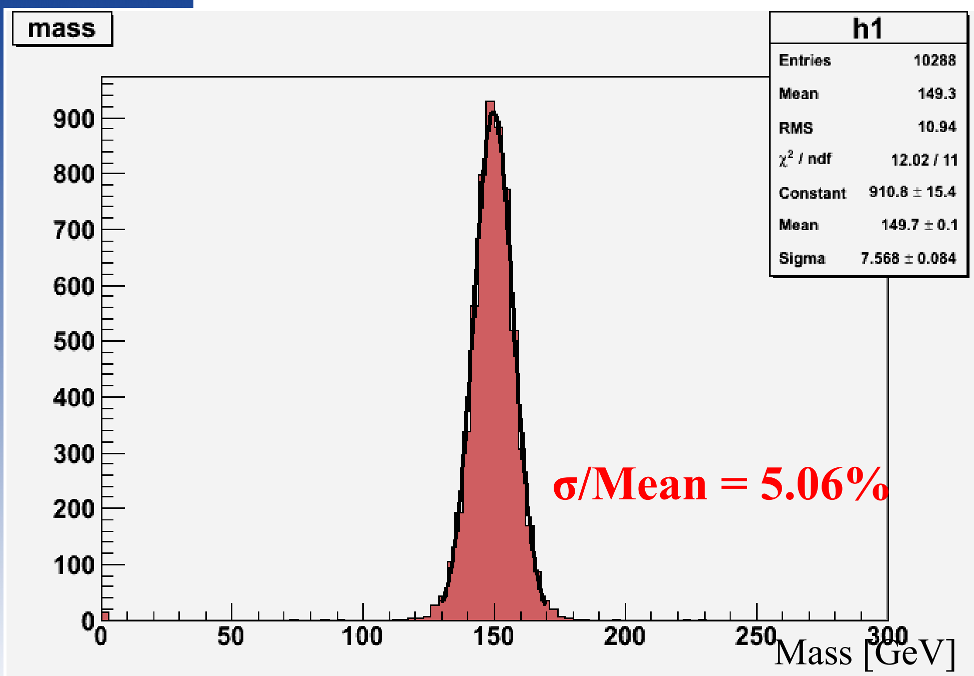
	No Cut	evis	pt	|pl|	dE/dx	slptrk	Njets	ejets
$\chi_1^0\chi_1^0 \rightarrow \tilde{\tau}\tilde{\tau}\tau\tau$	6897	6864	6863	6773	6373	6099	5940	5939
ZZ->llll	470	275	225	106	21	4	4	4
ZH->llll	749	276	180	161	32	5	5	5
ZZ->llqq	2175	1367	1364	359	14	6	5	4
ZH->llqq	4835	1437	1221	273	11	7	4	3

	Fluctχ_1^0mass	missing mass	acop	efficiency
$\chi_1^0\chi_1^0 \rightarrow \tilde{\tau}\tilde{\tau}\tau\tau$	5935	5933	5904	85.6%
ZZ->llll	4	1	1	0.21%
ZH->llll	4	3	2	0.27%
ZZ->llqq	3	2	1	0.05%
ZH->llqq	2	1	1	0.02%

Slptrk : number of tracks == 2
Njets : number of jets == 2
Ejets : energy of jet >5GeV
Fluctχ_1^0mass: $|M_{j,\tilde{\tau}} - m_{\chi_1^0}|$ < 50GeV

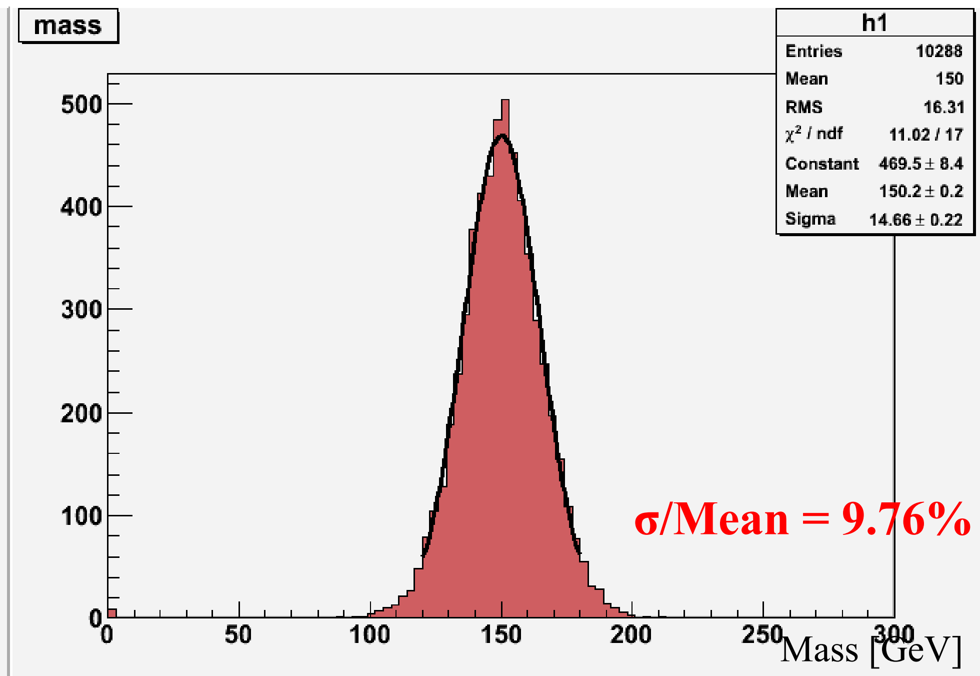
Integrated luminosity
$200\,\mathrm{fb}^{-1}$

Precision Measurement of Stau Mass



Stau mass measurement by dE/dx

Deviation from input value:0.59%



Stau mass measurement by TOF

Deviation from input value:0.92%

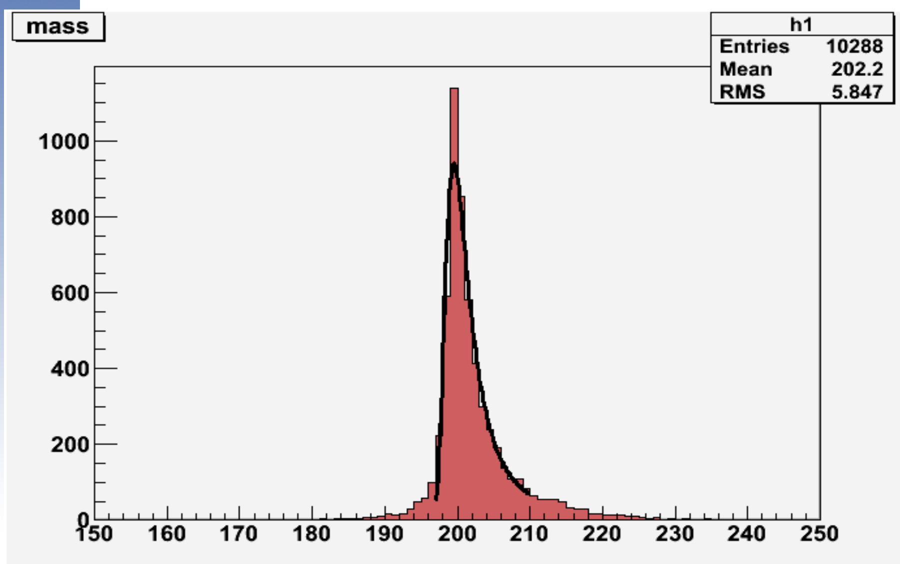
These figure precision measurement of stau mass by dE/dx or TOF in neutralino mode.
Measurement of stau mass by dE/dx is more precise than that of TOF.

Neutralino mass

We can calculate neutralino mass by 4 momenta of tau jet and stau.

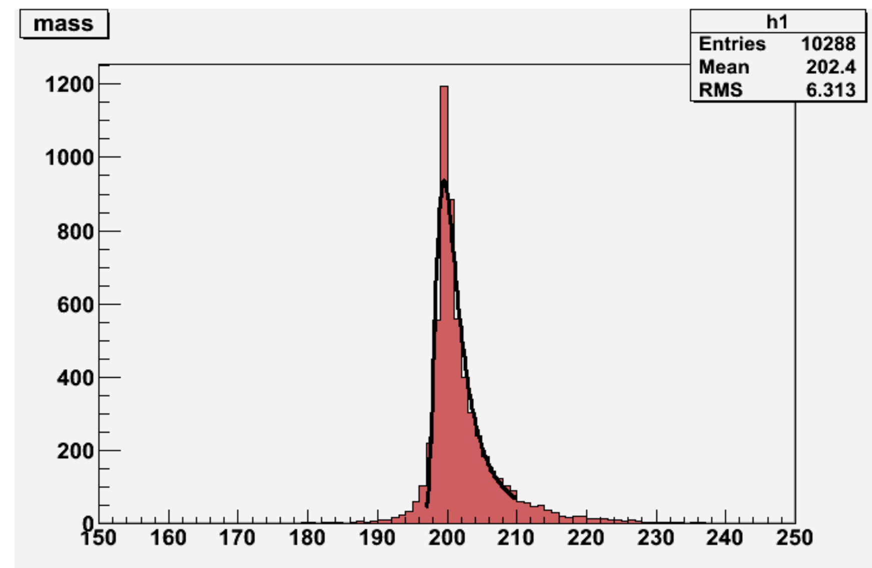
$$M_{j_\tau \tilde{\tau}} \equiv \sqrt{\left(p_{j_\tau} + p_{\tilde{\tau}}\right)^2} = m_{\chi_1^0}$$

Input value of $m_{\chi_1^0}$ is 200.0 GeV



$m_{\chi_1^0} = 199.74 \pm 0.05$ GeV

Deviation from input value:0.10%



$m_{\chi_1^0} = 199.72 \pm 0.05$ GeV

Deviation from input value:0.14%

Summary&Plan

Summary

· Properties of a stau determined from stau pair mode.
· Stau mass can be measured by dE/dx and TOF.

· If we can stop stau at HCAL, we observe stau's decay.

·Polarization is important,because it determines a stau mixing angle.

· Neutralino decay into a stau and tau have a good efficiency with dE/dx Cut.

Future plan

· Selection by TOF should be considered.
·Angular distribution of neutralino should be measured.