# Impact of Efficient e Veto on Stau SUSY Dark Matter Analyses at ILC

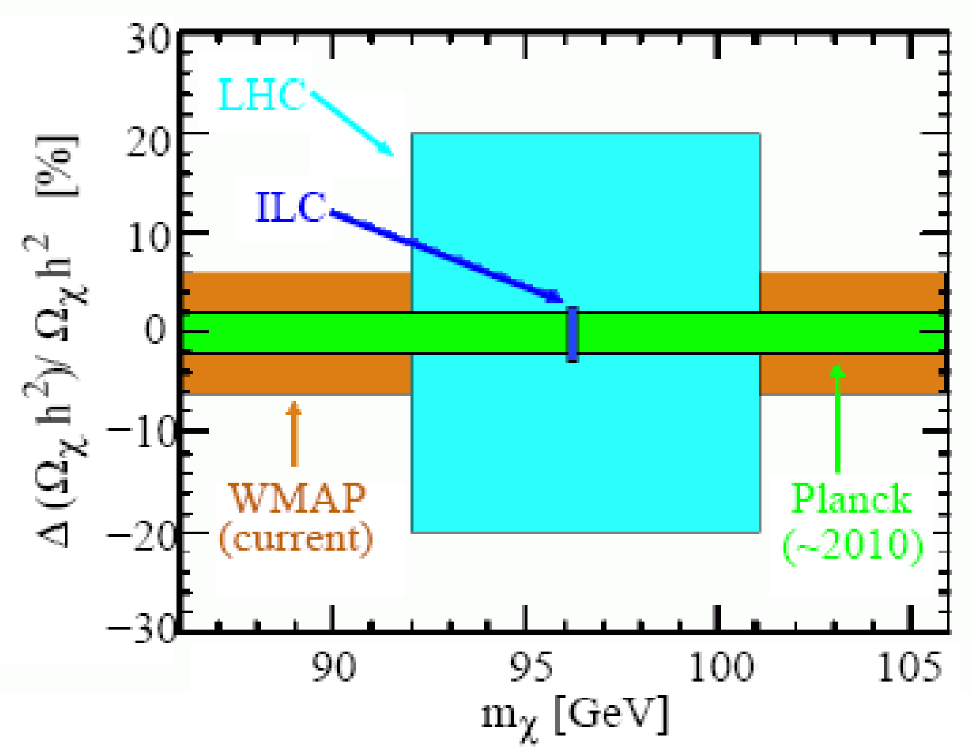
- ☐ Introduction
- ☐ BeamCal for e vetoing SM backgrounds
- ☐ Desired other PID capability
- ☐ Summary

Based on

1. P. Bambade, V. Drugakov, W. Lohmann, physics/0610145
2. Z. Zhang, arXiv:0801.4888v1 & earlier studies

# Introduction

Search for DM and understanding its nature is a key subject



ILC is expected to play a unique role

However the precision achievable at ILC does not come without effort

# Example Results on Relic DM Density

**Method one:** ($L=500fb^{-1}$)

| Scenario | A | C | D | G | J |
|---|---|---|---|---|---|
| ΔM (GeV) | 7 | 9 | 5 | 9 | 3 |
| Ecm (GeV) | 505 | 337 | 442 | 316 | 700 |
| σ (fb) | 0.216 | 0.226 | 0.456 | 0.139 | 3.77 |
| Efficiency (%) | 10.4 | 14.3 | 5.7 | 14.4 | <1.0 |
| $\delta m_{stau}$ (GeV) | 0.49 | 0.16 | 0.54 | 0.13 | >1.0 |
| $\delta\Omega h^2$ (%) | 3.4 | 1.8 | 6.9 | 1.6 | >14* |

microMegas

**Method two:** ($L=$ $200fb^{-1}$ $300fb^{-1}$)

| Scenario | Modified SPS 1a | | | D | | | |
|---|---|---|---|---|---|---|---|
| ΔM (GeV) | 8 | 5 | 3 | 5 | | | |
| Ecm (GeV) | 400 | | | 600 | | | 500 |
| Pol 0.8(e-)/0.6(e+) | yes | yes | yes | yes | | no | yes |
| σ (fb) | 140 | | | 50 | | 20 | 25 |
| Efficiency (%) | 18.5 | | | 7.6 | | 7.7 | 6.4 |
| $\delta m_{stau}$ (GeV) | 0.14 | 0.22 | 0.28 | 0.15 | 0.11-0.13 | 0.14-0.17 | 0.13-0.20 |
| $\delta\Omega h^2$ (%) | 1.7* | 4.1* | 6.7* | 1.9 | 1.4-1.7 | 1.8-2.2 | 1.7-2.6 |

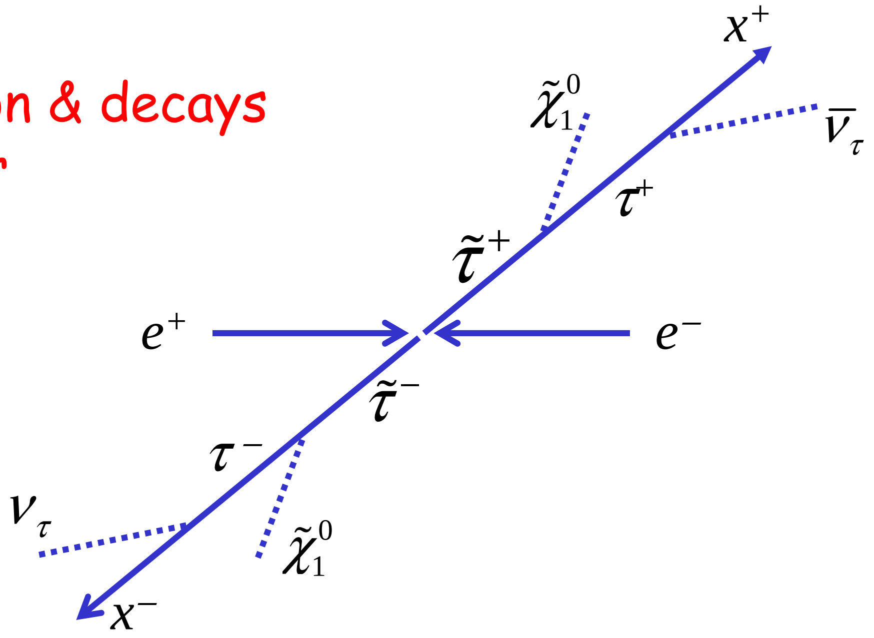
*: $\Omega h^2<0.094$(WMAP lower limit)

H.U.Martyn
hep-ph/060822

Z. Z. arXiv:0801.4888v1
[hep-ph]

# Expected Signature at an ILC Detector

Stau production & decays
@ e+e- collider



- Difficulty nº one:
  Missing energy from both LSP $\tilde{\chi}_1^0$
  and neutrino(s) in tau decay final state
- Difficulty nº two:
  Large SM background contributions

# Cross Sections: Signal versus SM Backgrounds

- Signal (Scenario D'): $m_{\tilde{\tau}^0} = 217 GeV, \quad m_{\tilde{\chi}_1^0} = 212 GeV$

| Ecm (GeV) | Beam Pol. | σ (fb) |
|---|---|---|
| 442 | Unpol. | 0.456 |
| 500 | Unpol. | 10 |
| 500 | 0.8(e-)/0.6(e+) | 25 |
| 600 | Unpol. | 20 |
| 600 | 0.8(e-)/0.6(e+) | 50 |

→ **Method one:** Optimal Ecm (hep-ph/0406010)

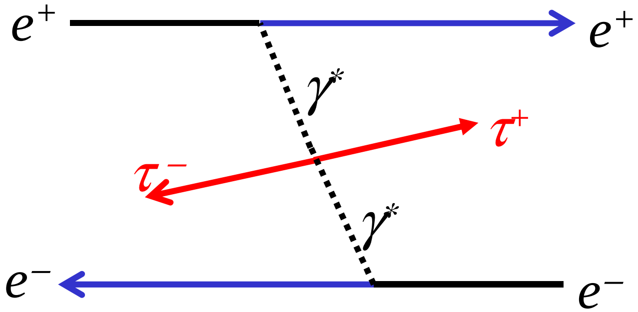
**Method two:** Large Ecm (hep-ph/0608226)

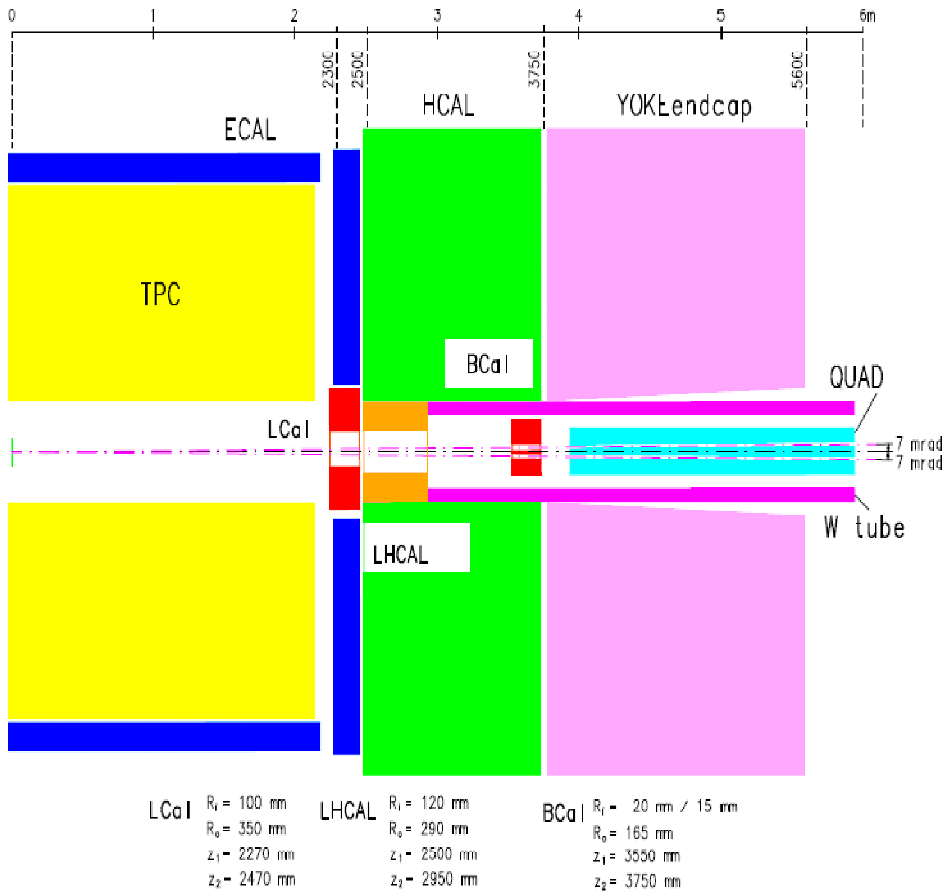
- SM Backgrounds:

$\gamma^*\gamma^* \rightarrow \tau^+\tau^-(E_t > 4.5GeV)$: σ~4.3x$10^5$ fb
$\rightarrow \mu^+\mu^-\ (E_t > 2GeV)$: σ~5.2x$10^6$ fb
→ hadrons (direct*direct dominant)
ccbar σ~8.2x$10^5$ fb
→ WW
$e^+e^- \rightarrow \mu^+\mu^-, \tau^+\tau^-$: σ~1.0x$10^3$ fb
→ WW

# Example: Dominant γγ Background

SM background production & decays @ e+e- collider

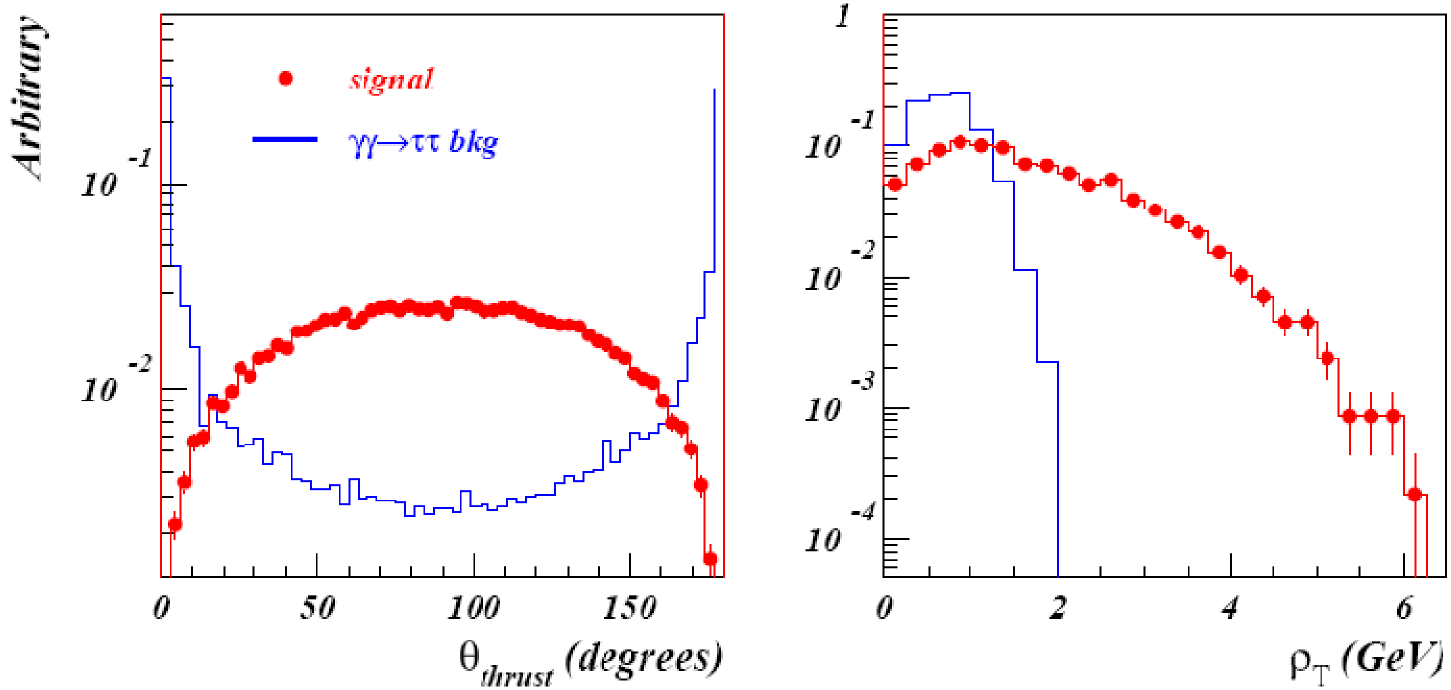




- Tau decay final states:
  Measured in the main detector
- Spectator e+ and e-
  Mostly going into the BeamCal

# Background Rejection

- Analysis cuts relying on the main detector

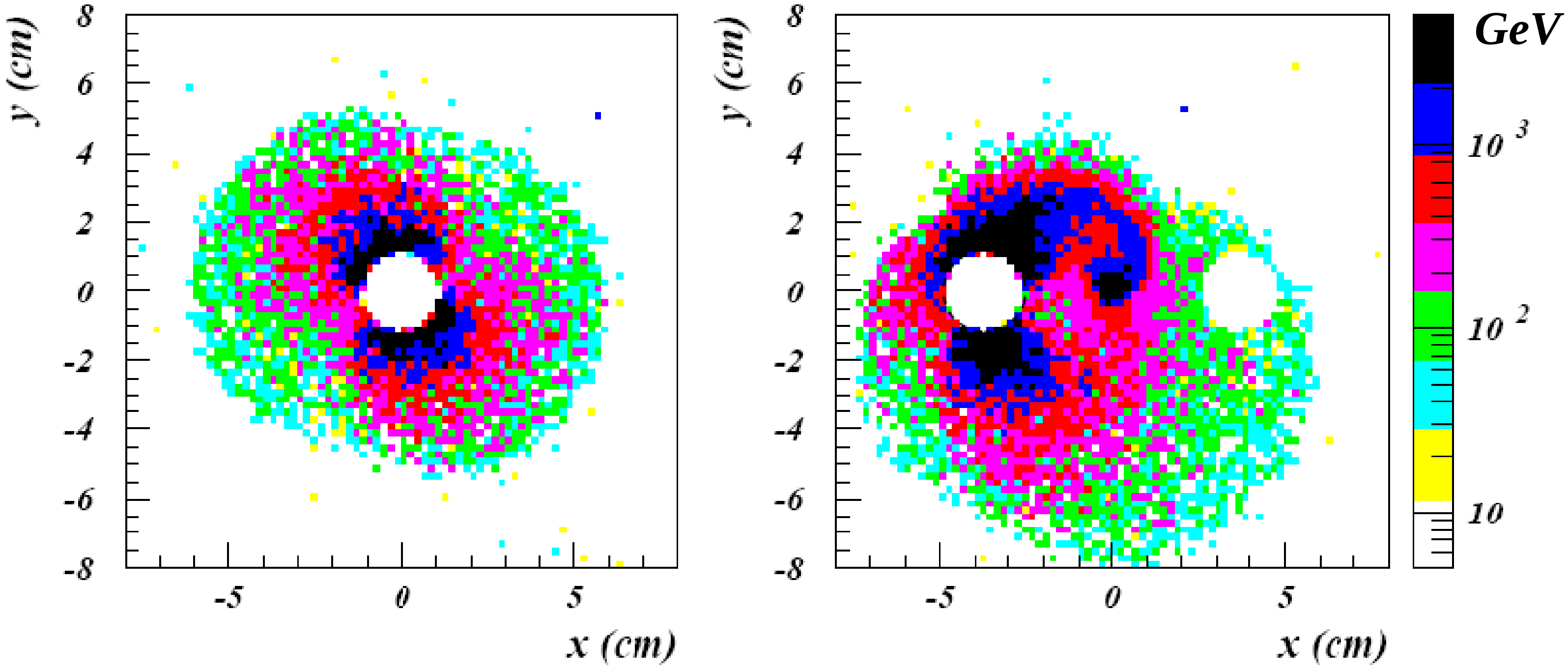


➔ A big fraction of background can be rejected using these cuts but not sufficient for a quasi-background free analysis

➔ Forward veto is needed

# Forward (BeamCal) Veto

- ❑ Identify energetic spectator e+ and/or e- from γγ events
- ❑ Complication from beamstrahlung



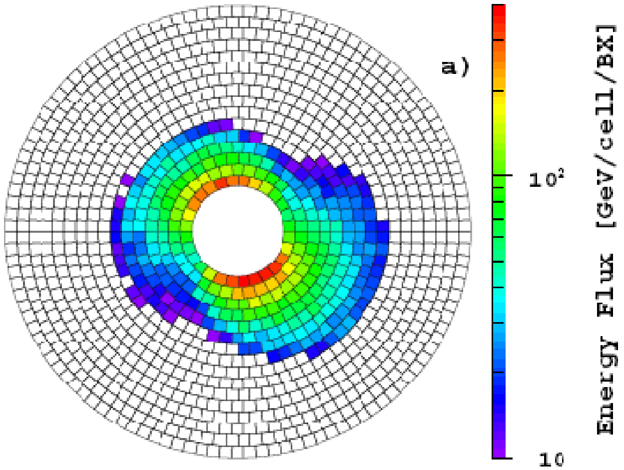
➔ Very challenging to have a radiation hard yet a very efficient BeamCal for e/γ ID

# Forward (BeamCal) Veto Efficiency

A study by P. Bambade, V. Drugakov, W. Lohmann, physics/0610145:

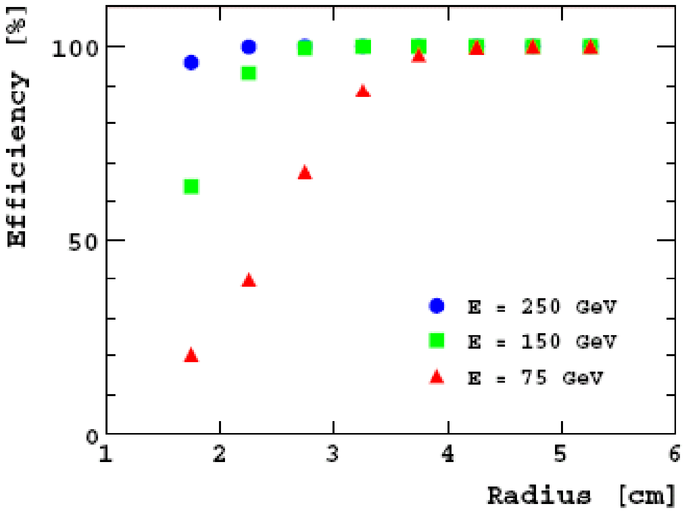
- Fine granularity tungsten/diamond sample calorimeter @ 370cm from IP
- Design depends on beam configuration

BeamCal @ 370cm



Identify spectator e+/e- out of huge beamstrahlung e+e- pairs

e/γ VETO efficiency



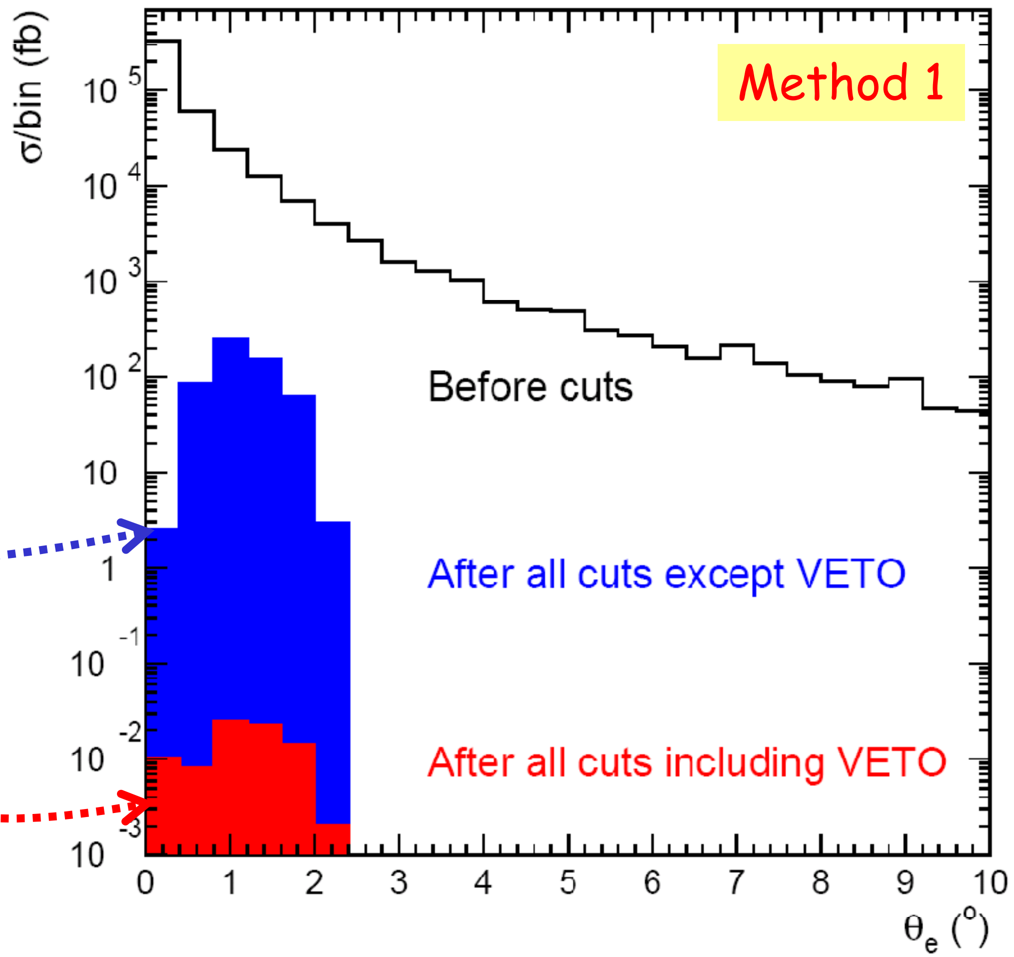
Efficiency is energy and angle dependent

# Summary on Final Selection/Rejection

SM background $\gamma\gamma \rightarrow \tau\tau$ generated
at Ecm of 500GeV

| Method | 1 | 2 |
|---|---|---|
| $\sigma_{signal}$[fb]*$\varepsilon_{eff}$ | 0.456*5.7% | 10*6.4% |
| $\sigma_{bkg}$[fb] (w/o VETO) | 561 | 168 |
| $\sigma_{bkg}$[fb] (+VETO) | 0.08 | 0.26 |
| S/B | ~0.3 | ~2.5 |

The angular distribution of spectator e±



→ VETO eff. is pretty good for method 2 but needs improvement for method 1

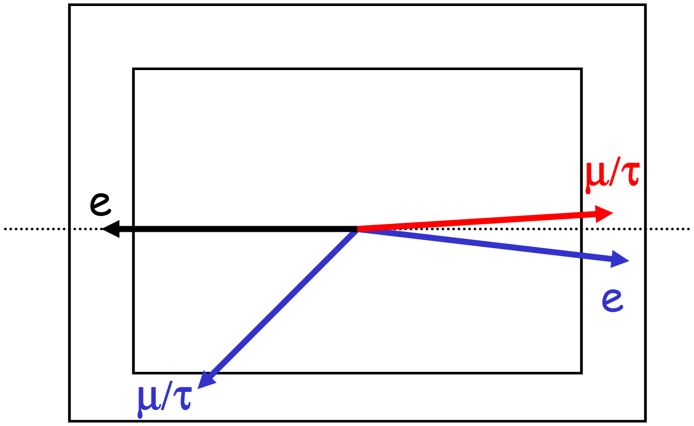
# How to Improve?

Very limited efficiency (e.g. ~6% in method one for scenario D')
one reason: μμ & eX topologies excluded (>20% eff. lost)

To improve on this, one needs to improve/extend PID to low angles

**Background free stau detection needs this capability:**

**ee→eeμμ, ee→eeττ:**
μ+e or τ+e visible in the detector ➔ signal like
Another e in the beam-pipe,
another μ or τ→μ/π (energetic) @ low angle



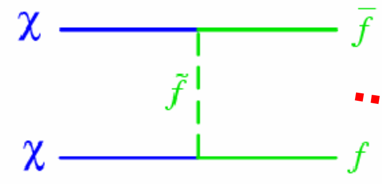
For more details refer to my ILD contribution on Friday

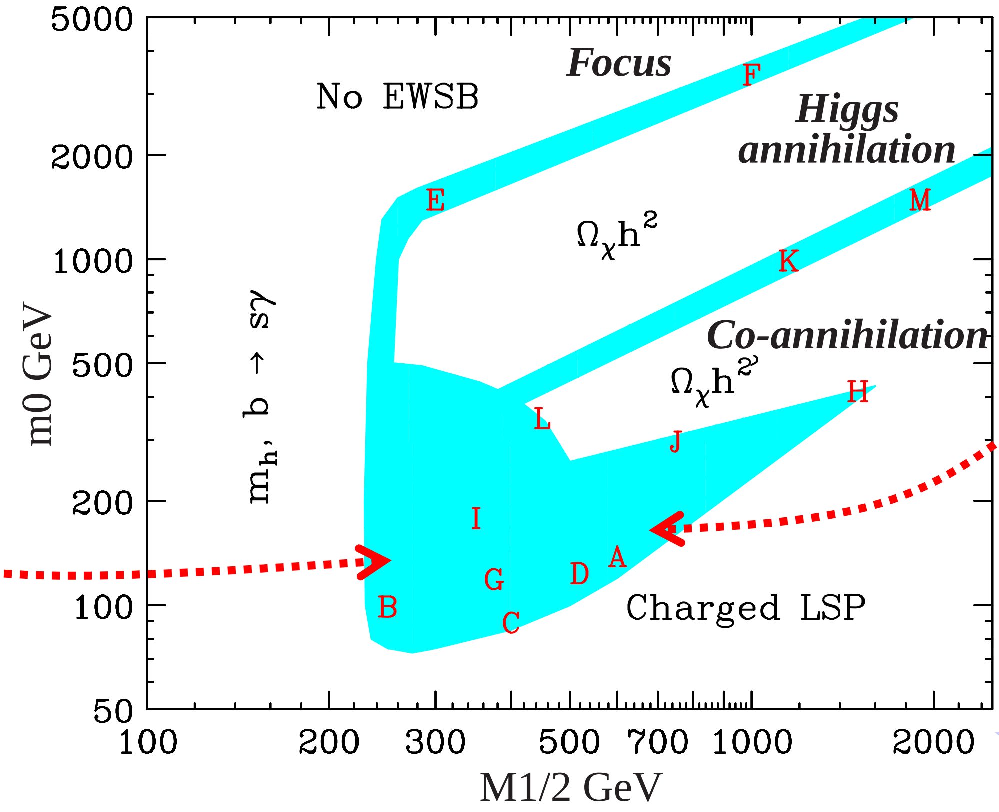
# Summary

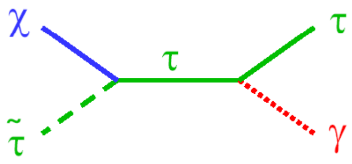
- Excellent veto efficiency of the BeamCal is a must
- $\mu/\pi$ PID capability at low angles is also desirable
- Depending on SUSY scenario, DM density precision @ ILC can compete with expected precision from e.g. Planck

# mSUGRA SUSY DM Scenarios after WMAP

**Benchmark points:**
Battaglia-De Roeck
Ellis-Gianatti-Olive
-Pape,
hep-ph/0306219







important
when
$\Delta M = m_{stau} - m_\chi$
is small

Challenging scenarios

➔ The precision on SUSY DM prediction depends on $\Delta M$ & thus

$\delta m_\chi$ ➔ Needs smuon (or selectron) analysis
$\delta m_{stau}$ ➔ Needs stau analysis