Analysis of Two Challenging SUSY Dark Matter Scenarios at ILC

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Motivations

- **Current precision on Dark Matter(DM) from WMAP:** 10%

  or in 2σ range: $0.094<\Omega_{DM}h^2<0.129$

  (Future precision expected from PLANCK: 2%)

- **What are these non-baryonic DM?**

- **Can ILC reveal the nature of DM?**

  If yes,

  → What are requirements on the machine and detectors?

  → How precise can one measure the DM relic density?

Two Challenging SUSY DM Scenarios at ILC

- **Scenario one:**

  Mass degeneracy between stau and LSP χ^0

  ➔ **Details on Next slides**

  Already studied earlier:

  "Experimental Implications for a Linear Collider of the SUSY Dark Matter Scenario"

  by

  P. Bambade, M. Berggren, F. Richard, Z. Zhang

  [hep-ph/0406010] & contribution to LCWS'04

  Impact of larger uninstrumented region in BeamCal with 20mrad x-angle

- **Scenario two:**

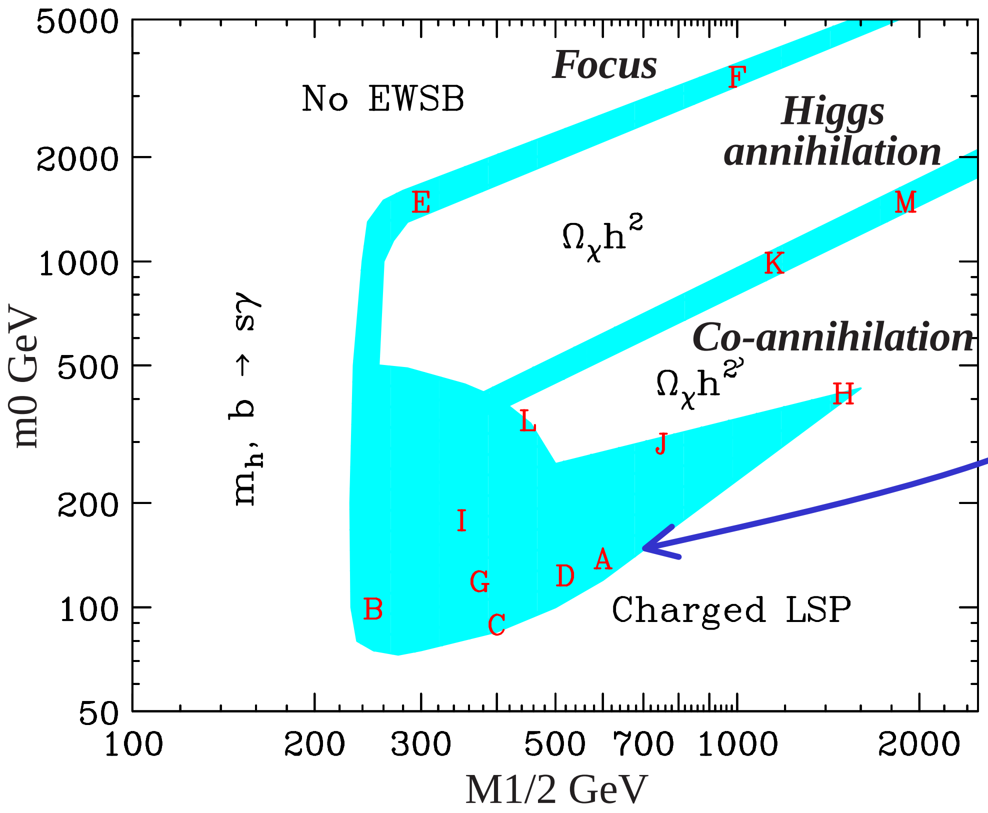
  Mass degeneracy between χ^+_1 and LSP χ^0

New

Scenario One

Benchmark point D from Battaglia et al, hep-ph/0306219:

[$M_{1/2}$=525GeV, m_0=101GeV, tanβ=10, μ<0, m_χ=212GeV, $m_{s\tau}$=217GeV, $\Omega_{DM}h^2$=0.09]



χ stau ($s\tau$) annihilation

Important when

$\Delta M = m_{s\tau} - m_\chi$ is small

(5 GeV for point D)

➔ The precision on SUSY DM prediction depends on ΔM

Need to measure $m_{s\tau}$ and m_χ with best possible precision

Main Challenges for the Stau Analyses

$$e^+e^- \rightarrow stau^+ \, stau^- \rightarrow \chi^0\tau^+ \, \chi^0\tau^-$$

Cross sections: 10fb @ 500GeV, 4.6fb @ 442GeV

- **Missing energy and soft final state**
  → Additional missing energies from neutrinos in tau decay
  → Final state particles very soft:
  due to small $\Delta M<10$GeV & little Lorentz boost

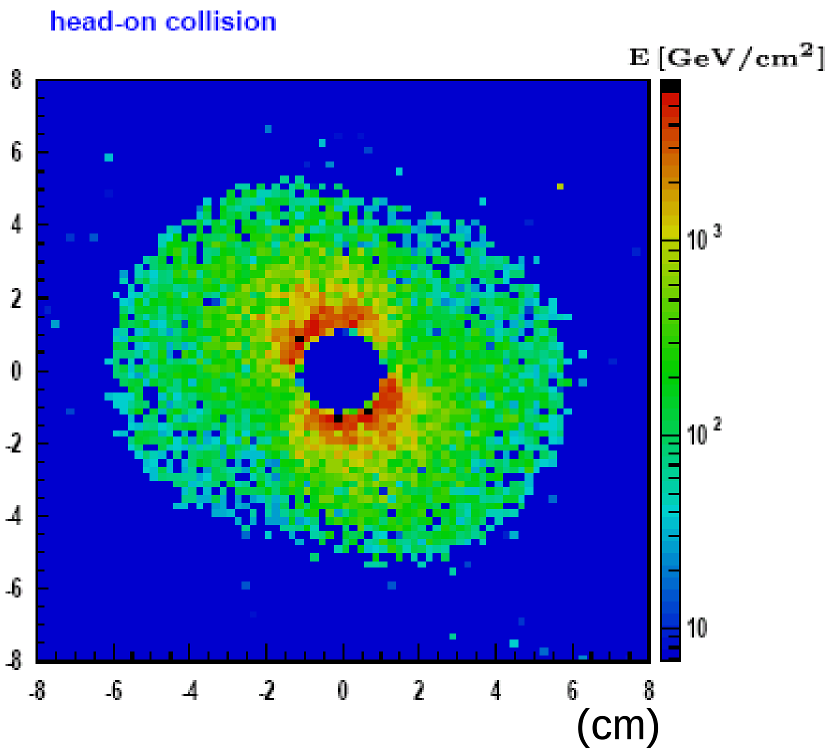
- **SM backgrounds are many orders of magnitude larger**
  → Need very efficient veto at low angles

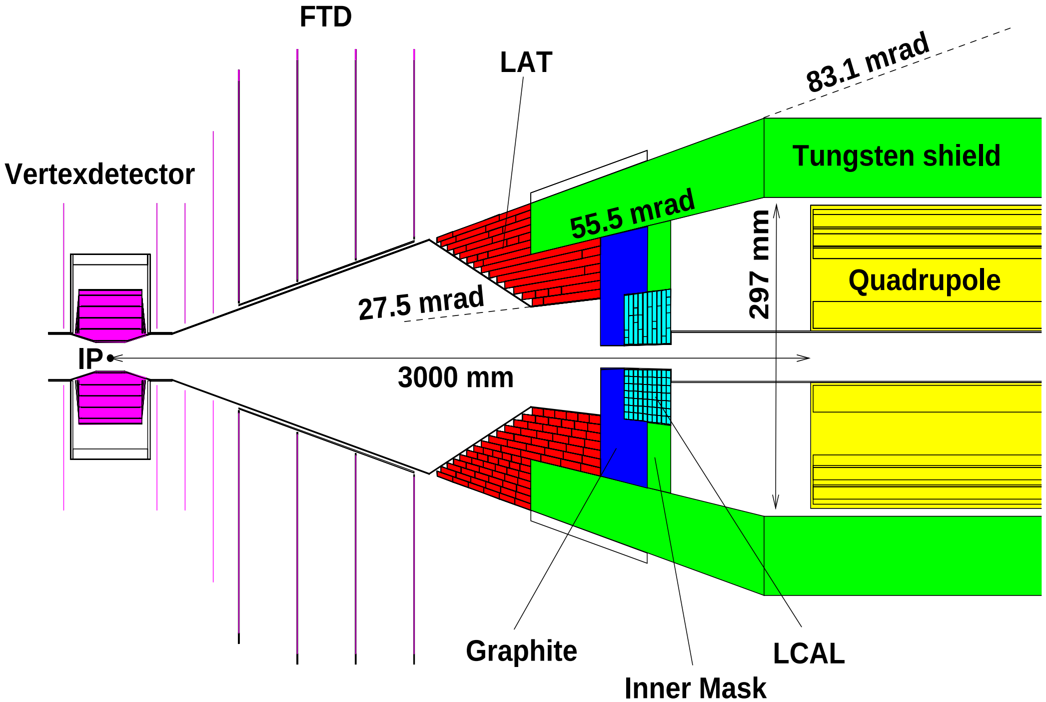
- **Additional complication if crossing-angle collisions**

Vetoing Against Energetic e^+/e^- from $\gamma\gamma$ out of Huge Number Soft Beamstrahlung Background

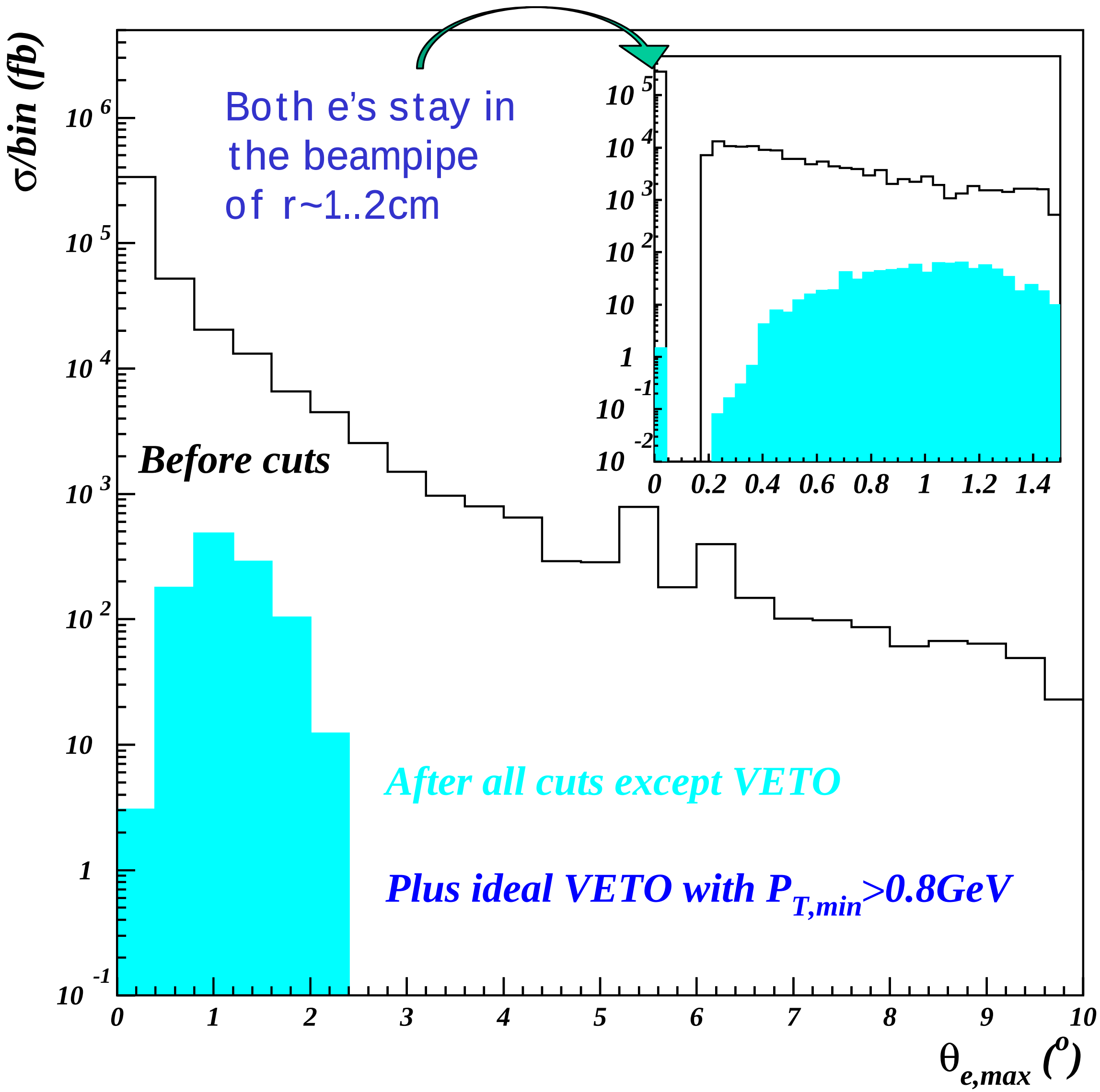
- **e^+/e^- from ee→eeff:** Few e's per event but energetic
- **Beamstrahlung background:** Huge number e,γ/event but soft

e.g. the energy density/event in LCAL @ z=3.7m simulated by K. Buesser





Low Angle Veto in Head-on Collisions



Angular distribution of the spectator e from ee→eeττ

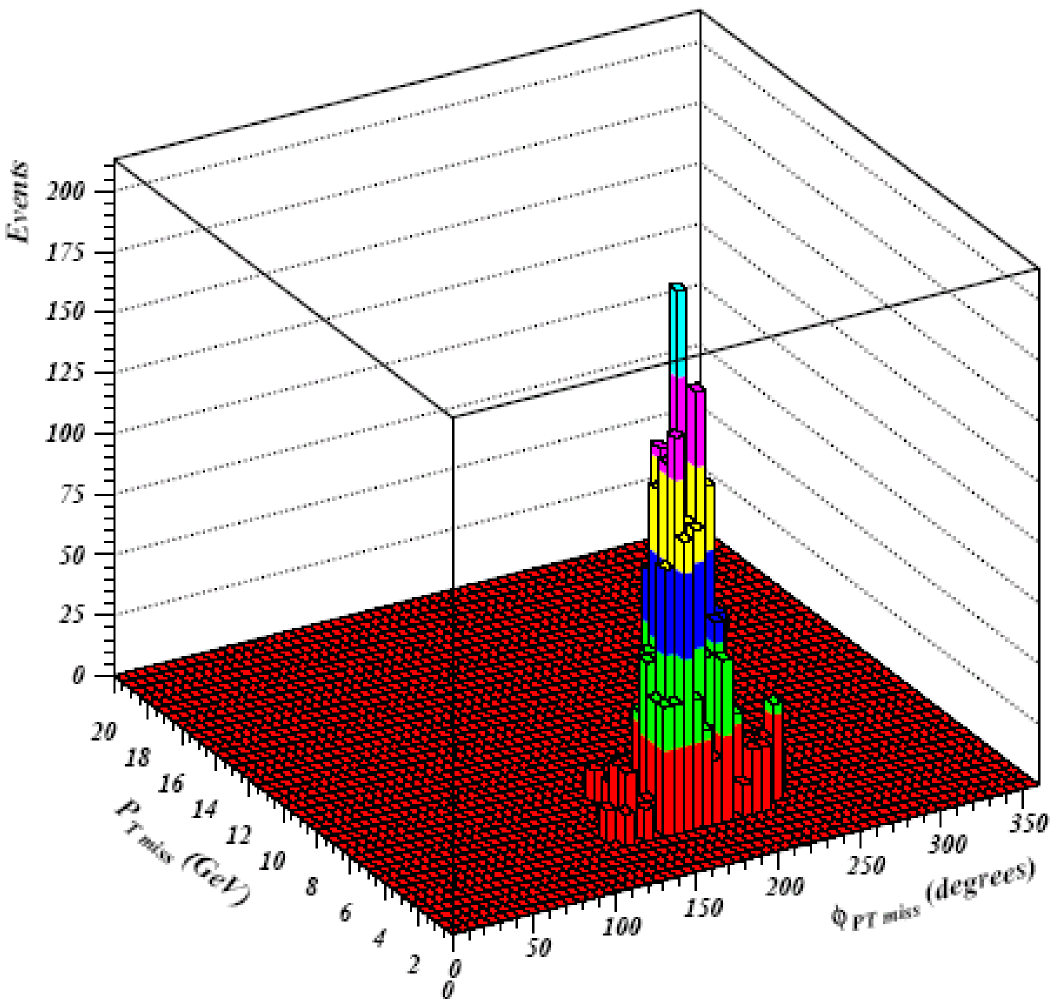
Total σ ~ 0.43x10^6 fb of which 3/4 with both e's staying in the beampipe corresponding to the peak at zero in the inset

Analysis cuts reject most of the background

An ideal veto with
$P_{T,min}$>0.8GeV
is sufficient to suppress all remaining γγ→ττ background events except those with energetic μ/π at low angles

Remaining Background in Cross-Angle Mode

ee→eeττ



10mrad half crossing angle

For an incoming beam hole of r=1.2cm the probability for a spectator e+/e- to enter the hole is 10^{-3}.

Remaining background events correspond (mainly) to those with e+/e- goes into the incoming beam hole.

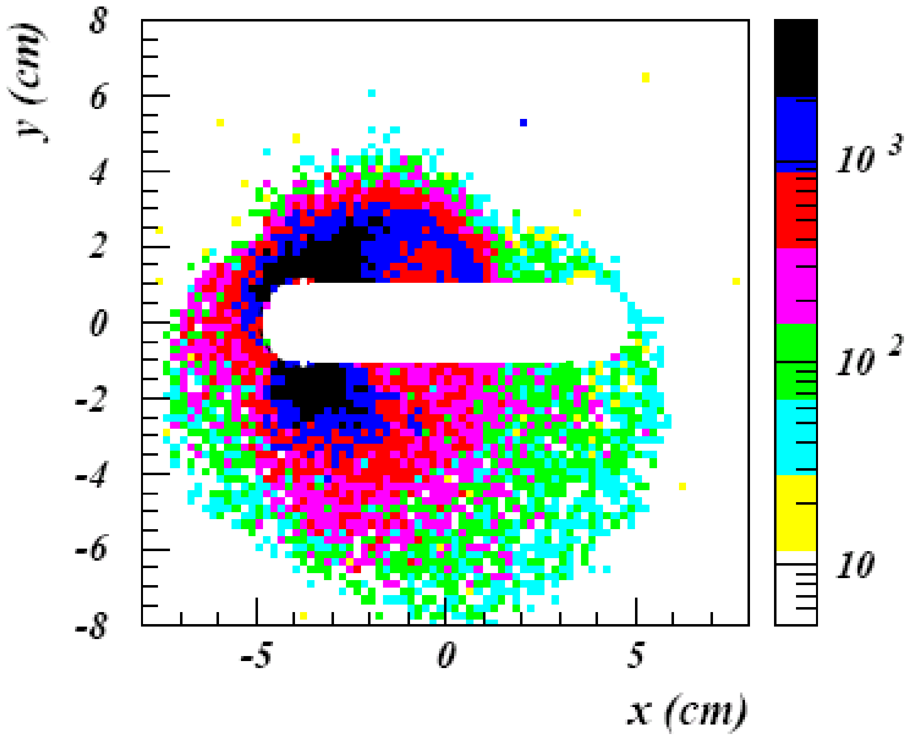
Additional cuts remove essentially all these events.

A price to pay however:
25% efficiency reduction
e.g. for benchmark point D @ Ecm=442GeV
from ~5.7% to ~4.3%

New Analysis with Larger Inefficient Region

1) If beam hole radius increases from 1.2cm to 1.5cm

2) If additional blind region



Question:

What's the consequence for the stau analysis?

Answer:
The additional cuts need to be modified introducing larger inefficiency from 25% to 30% w.r.t. the head-on analysis

Scenario Two

Common feature: (very) heavy sfermions even beyond the reach of LHC

(cf talk of F. Richard in “cosmological connections” session on 23.8.2005)

Scenario	M_1, M_2, $m_{1/2}$(GeV)	μ(GeV), m_0(TeV)	tanβ
Focus	407, 724, 900	427, 12.5	10
Split SUSY	281, 560, 700	340, 10^6	5
h-annihilation	78, 156, 201	–400, 10^6	5
EGRET	68, 128, 165	212, 1.4	51
LEP	60, 117, 151	900, 2.0	20
Degenerate	5000, 5000 (AMSB)	300, 5.0	20

This talk concentrates on small mass difference χ^+_1-χ

More on the Degenerate Scenario

Some freedom on μ parameter is possible:

μ (GeV)	Mass χ, χ_2 (GeV)	Mass χ^+_1 (GeV)	$\Omega_{DM}h^2$
300	298.8, 300.9	299.8	0.0094
200	198.8, 200.9	199.8	0.0043

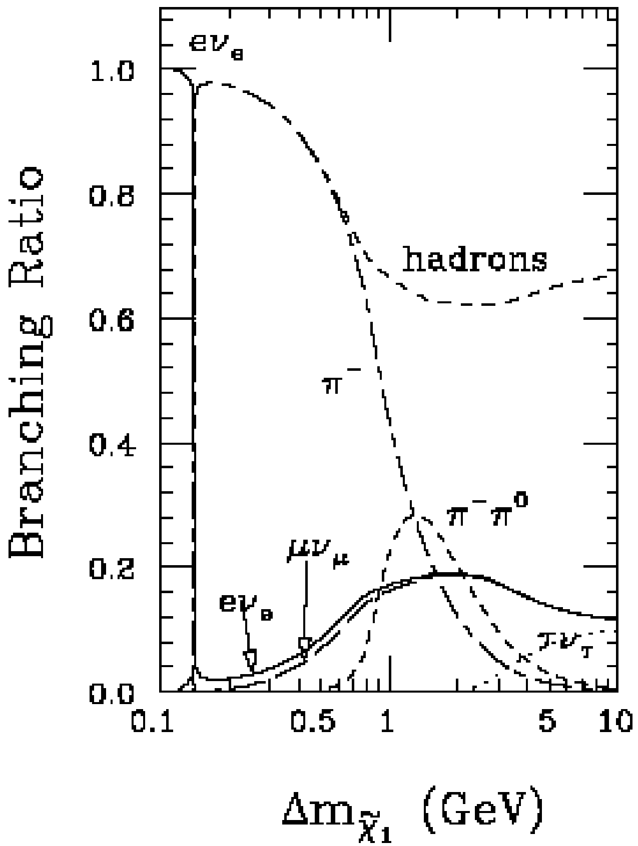
- Interesting scenario not saturating DM density allowing other (non-)SUSY DM contribution (gravitino,axion,…)
- Mass difference between χ^+_1 and χ only 1 GeV
  → very soft decay final state X (=π^+, $\pi^+\pi^0$, …) of $\chi^+_1 \rightarrow \chi$ X
- Choose μ=200GeV with ECM=500GeV
  → fairly large cross section ($e+e- \rightarrow \chi^+_1\, \chi^-_1(\gamma)$) : 352 fb
  → energetic ISR photons up to ~90GeV
  → share the same bkg files produced for scenario 1

Selection Strategy (for Head-on)

- 1γ + 2 charged particles allowing 1 additional neutral one
- $2.5^0 < \theta_\gamma < 175.5^0$
- $E_\gamma > 35$ GeV, $E_{total\ neutral} < 100$ GeV, $E_{total\ charged} < 3$ GeV
- Veto condition $P_T > 0.8$GeV

➔ Bkg processes considered and checked to be negligible

$\gamma^*\gamma^* \rightarrow \tau^+\tau^-(E_t>4.5\text{GeV})$: $\sigma \sim 4.3\times10^5$ fb
$\rightarrow \mu^+\mu^-(E_t>2\text{GeV})$: $\sigma \sim 5.2\times10^6$ fb
$\rightarrow$ hadrons (direct*direct dominant)
ccbar $\sigma \sim 8.2\times10^5$ fb
$\rightarrow$ WW
$e^+e^- \rightarrow \mu^+\mu^-, \tau^+\tau^-$: $\sigma \sim 1.0\times10^3$ fb
$\rightarrow$ WW

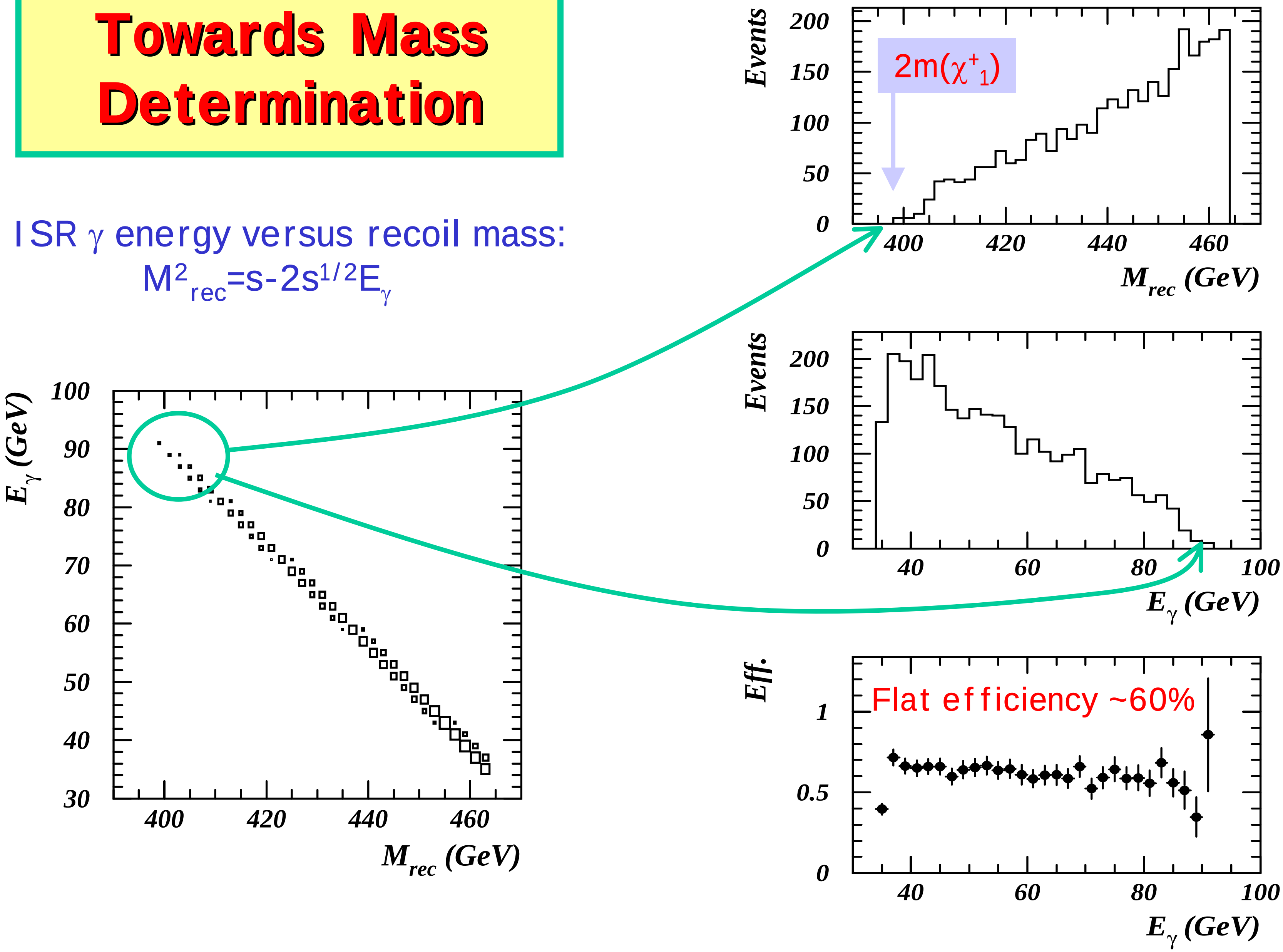


➔ Overall signal efficiency: 1.7% but …

Towards Mass Determination

ISR γ energy versus recoil mass:

$M^2_{rec}=s-2s^{1/2}E_\gamma$



Summary

- Two challenging SUSY DM scenarios studied
- Scenario one (LSP stau annihilation) shows
  20mrad x-angle collision is possible provided
  the realistic veto efficiency is comparable with P_T>0.8GeV
- Scenario two (LSP chargino mass degenerate) shows
  the ISR method is feasible
  (so far only head-on collision studied)