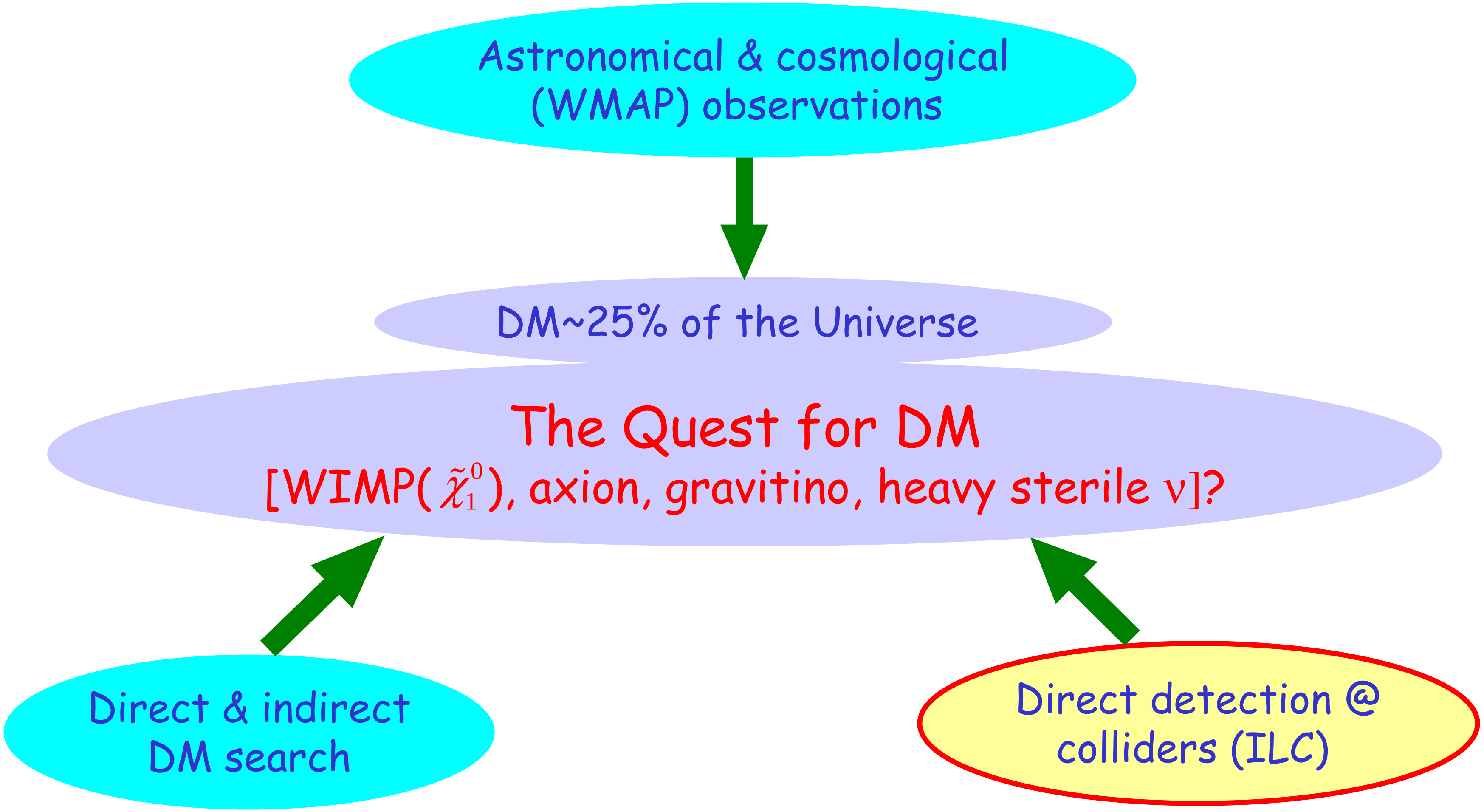
Importance of the FCAL (BeamCal) for SUSY Dark Matter Scenarios at ILC

- Motivation
- Unique role of the BeamCal in vetoing SM backgrounds
- Why PID capability desired
- Summary

Based on

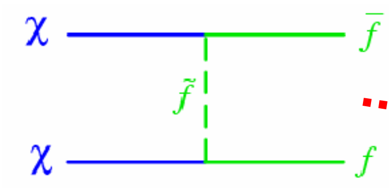
1. P. Bambade, V. Drugakov, W. Lohmann, physics/0610145
2. Z. Zhang, LCWS07 contribution + earlier studies

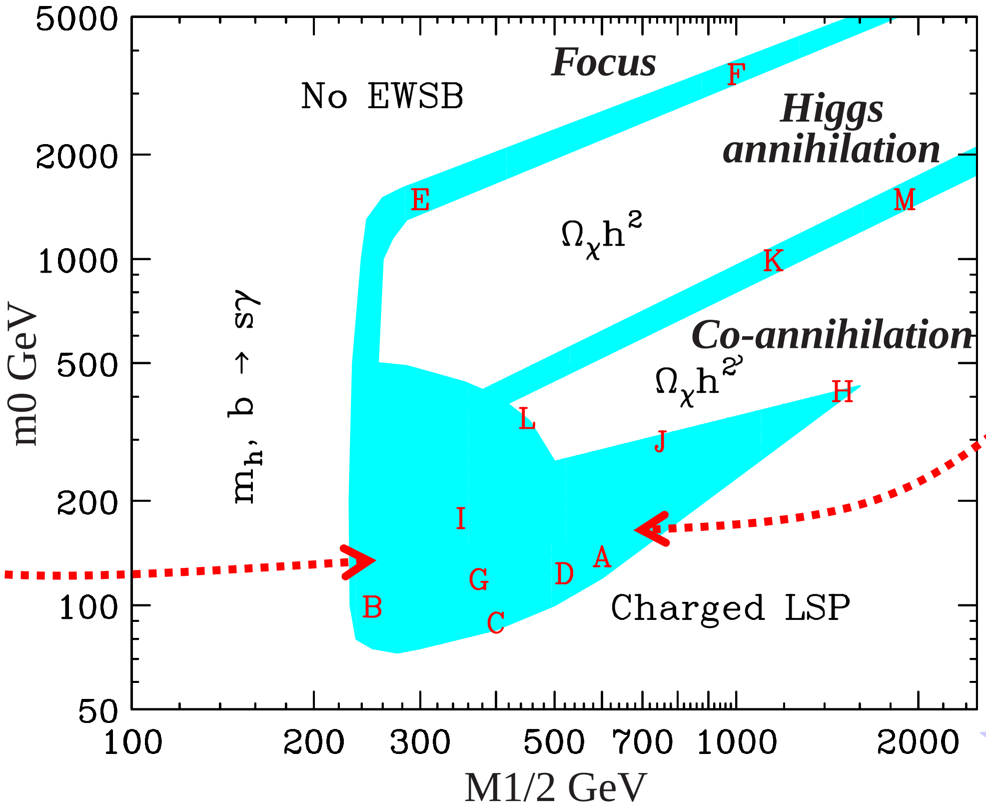
Motivation

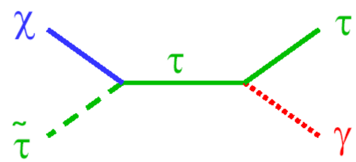

Astronomical & cosmological
(WMAP) observations
DM~25% of the Universe
The Quest for DM
[WIMP($\tilde{\chi}_1^0$), axion, gravitino, heavy sterile ν]?
Direct & indirect
DM search
Direct detection @
colliders (ILC)

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

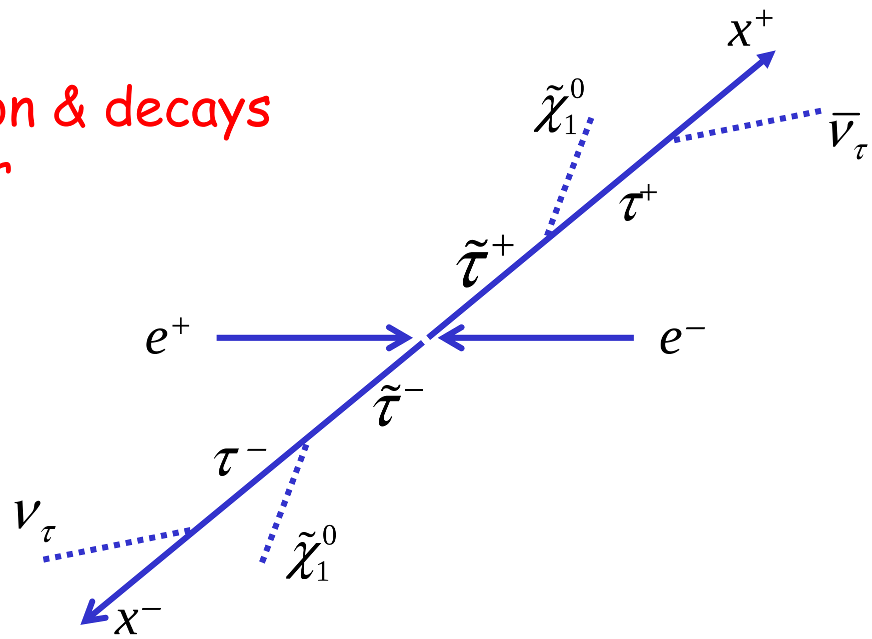
Challenging scenarios

➔ The precision on SUSY DM prediction depends on ΔM & thus

δm_χ ➔ Needs smuon (or selectron) analysis (relatively easy→skipped)
δm_{stau} ➔ Needs stau analysis

Expected Signature at an ILC Detector

Stau production & decays
@ e+e- collider



- Difficulty n° one:
  Missing energy from both LSP $\tilde{\chi}_1^0$
  and neutrino(s) in tau decay final state
- Difficulty n° two:
  Large SM background contributions

Cross Sections: Signal versus SM Backgrounds

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

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:

$\gamma^*\gamma^* \rightarrow \tau^+\tau^-(E_t>4.5GeV)$: $\sigma \sim 4.3 \times 10^5$ fb

$\rightarrow \mu^+\mu^-\ (E_t>2GeV)$: $\sigma \sim 5.2 \times 10^6$ fb

→ hadrons (direct*direct dominant)

ccbar $\sigma \sim 8.2 \times 10^5$ fb

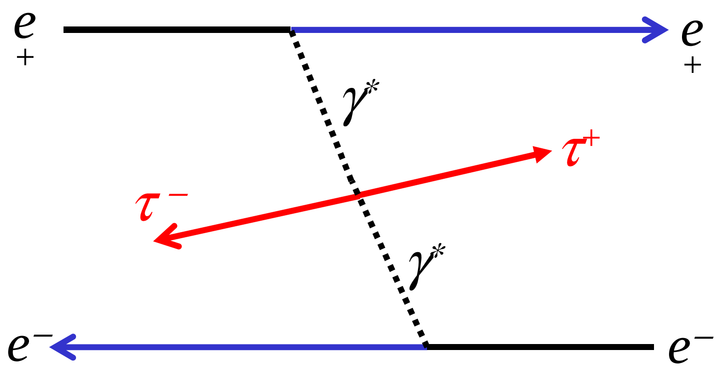
→ WW

$e^+e^- \rightarrow \mu^+\mu^-, \tau^+\tau^-$: $\sigma \sim 1.0 \times 10^3$ fb

→ WW

Example: Dominant γγ Background

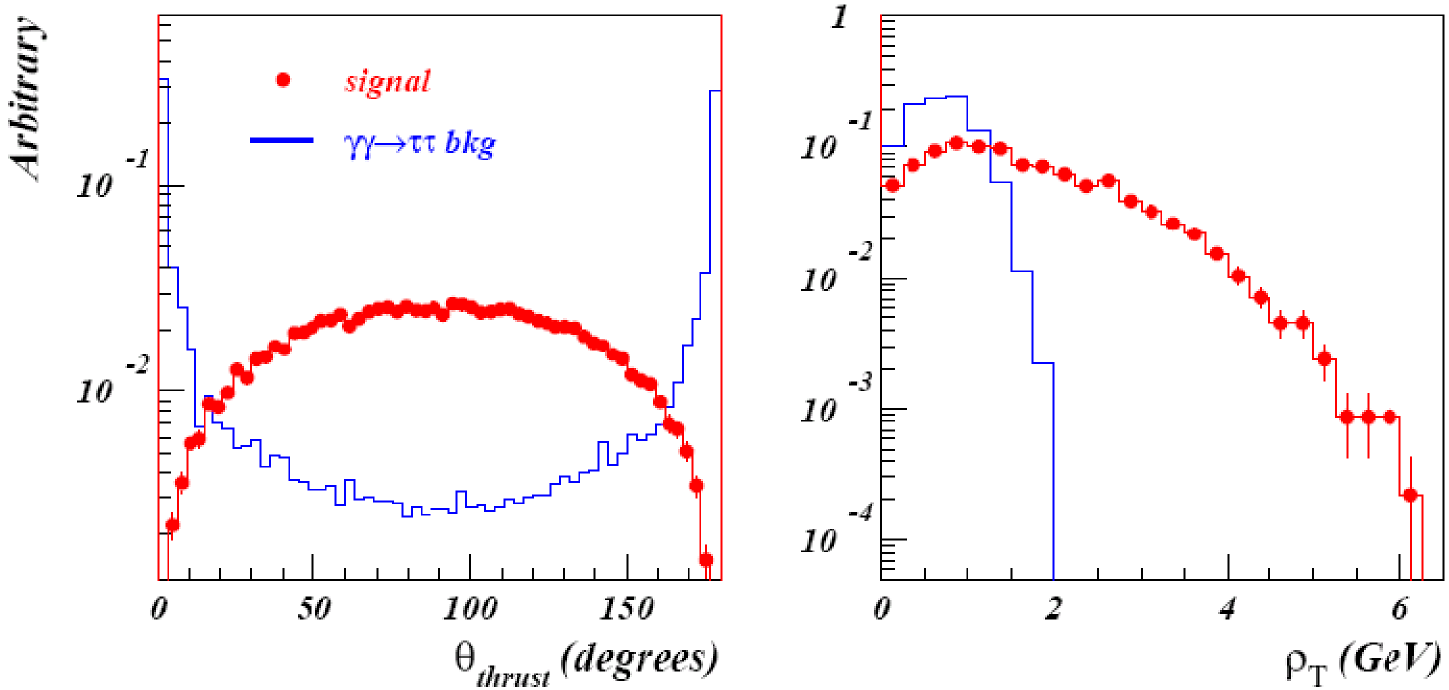
SM background production & decays @ e+e- collider



- 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

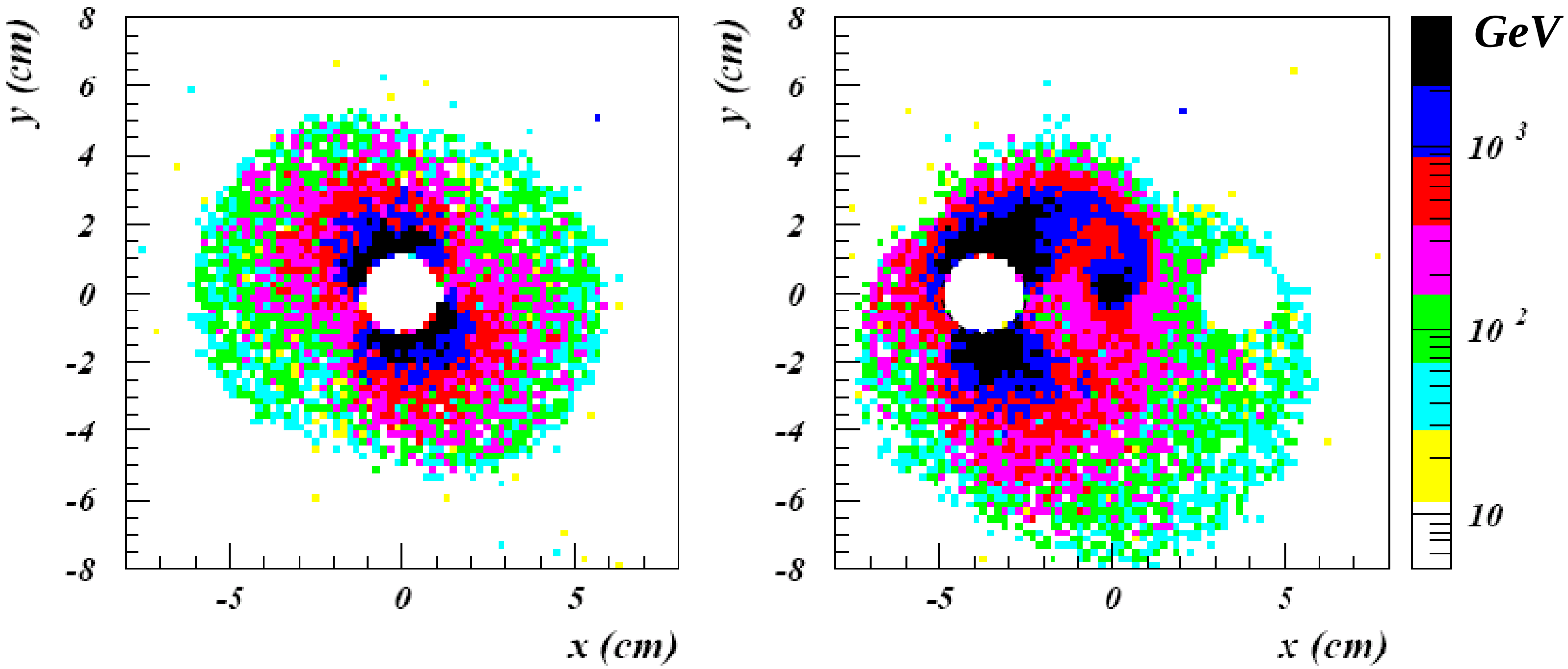


➔ A big fraction of background can be rejected using these cuts but not sufficient for a quasi-background free analysis

➔ Forward veto is needed

Forward (BeamCal) Veto

- Identify energetic spectator e+ and/or e- from $\gamma\gamma$ events
- Complication from beamstrahlung



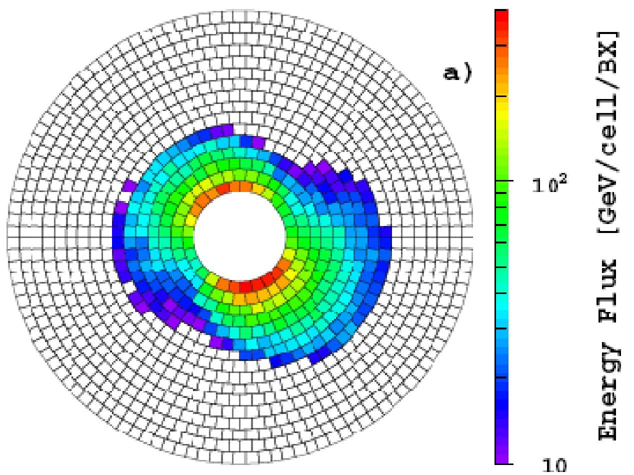
➔ Very challenging to have a radiation hard yet a very efficient BeamCal for e/γ ID

Forward (BeamCal) Veto Efficiency

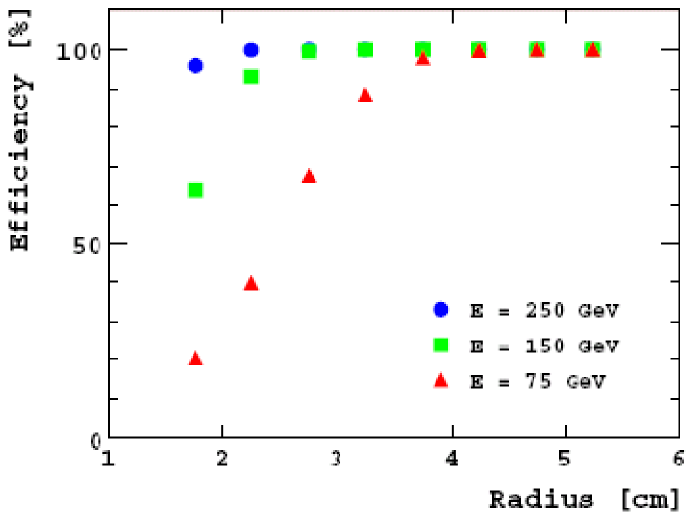
A study by P. Bambade, V. Drugakov, W. Lohmann, physics/0610145:

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

BeamCal @ 370cm



e/γ VETO efficiency



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

Efficiency is energy and angle dependent

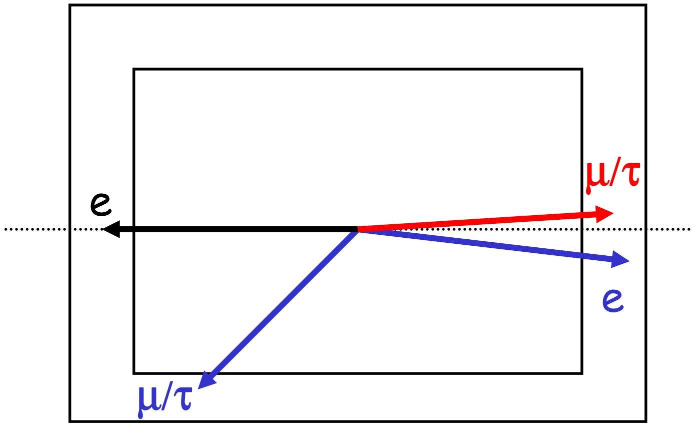
Vetoing Energetic μ/π Down to 20mrad?

Background free stau detection needs this capability:

$ee \rightarrow ee\mu\mu$, $ee \rightarrow ee\tau\tau$:

μ+e or τ+e visible in the detector ➔ signal like

Another e in the beam-pipe, another μ or $\tau \rightarrow \mu/\pi$ (energetic) @ low angle



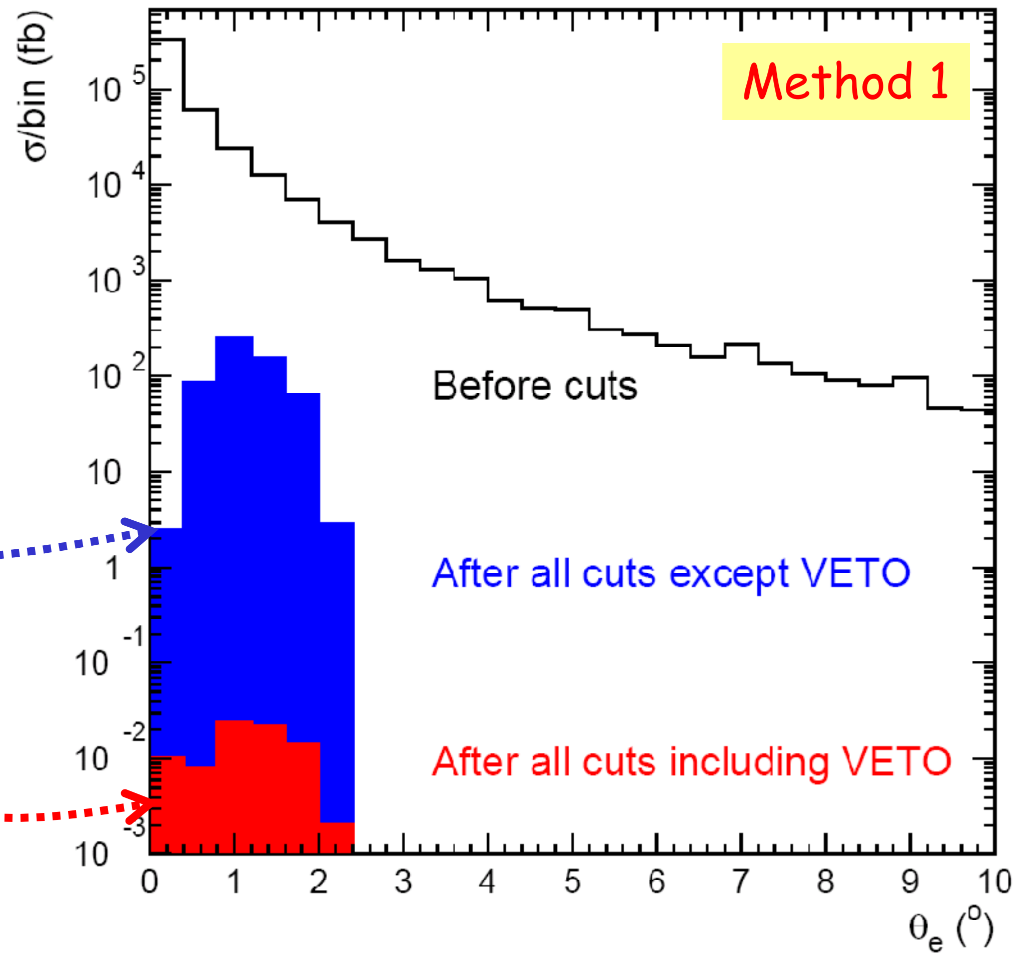
➔ This capability will significantly improve signal selection efficiency
(otherwise eX & $\mu\mu$ topologies have to be excluded)

Summary on Final Selection/Rejection

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

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

The angular distribution of spectator $e^{\pm}$



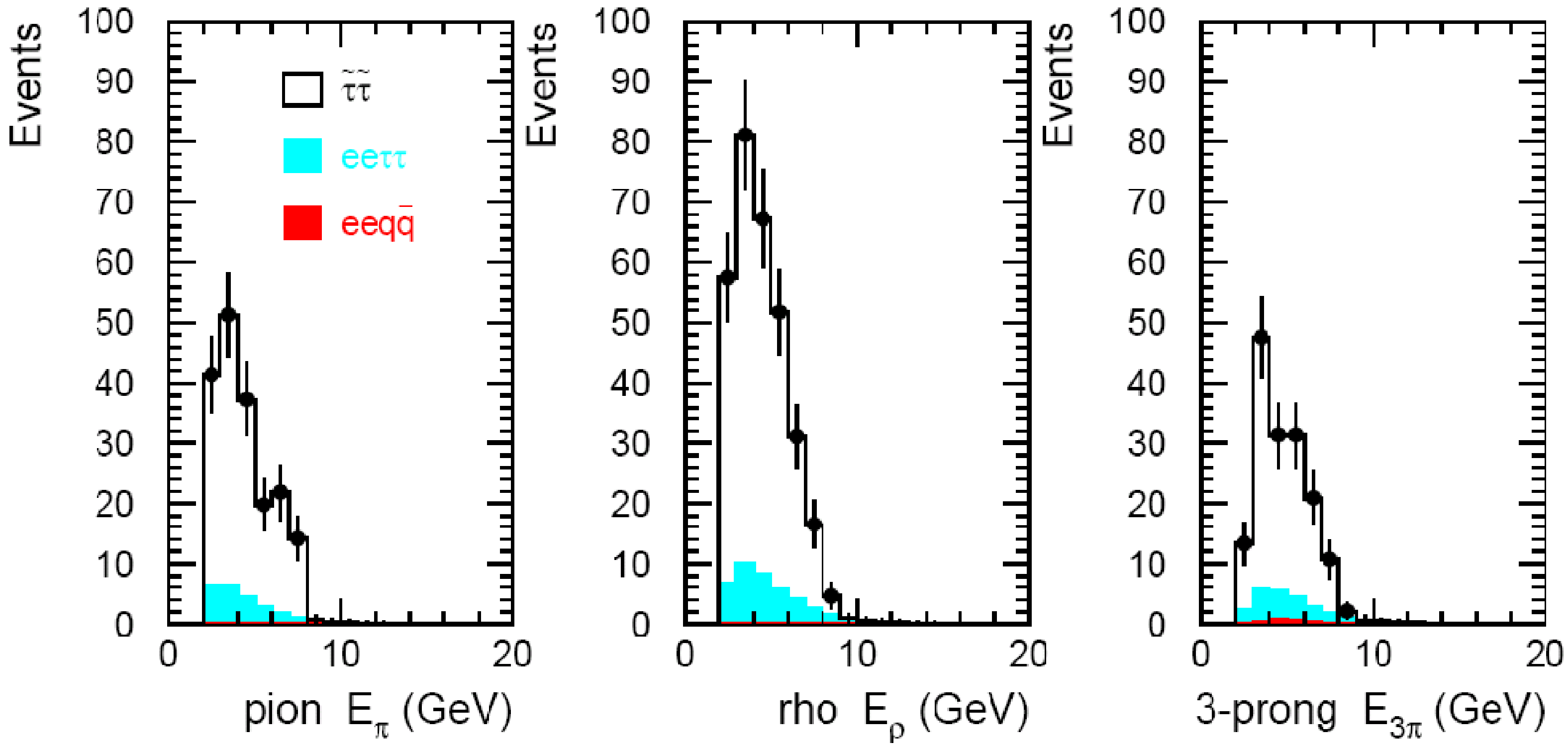
➔ VETO eff. is pretty good for method 1 but needs improvement for method 2

Energy Spectrum with Realistic VETO

Ecm=500GeV, L=300fb^{-1}, Polarization: 80% (e-), 60% (e+)

Method 2

After all cuts including VETO



➔ With realistic VETO efficiency, SM background contributions remain under control

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
δm_{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*

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
δm_{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

microMegas

Uli: 1.7* / 4.1* / 6.7* / 1.9 — This analysis: 1.4-1.7 / 1.8-2.2 / 1.7-2.6

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

Summary

- Excellent veto efficiency of the BeamCal is a must
- μ/π PID capability is also desirable
- Depending on SUSY scenario, DM density precision @ ILC can compete with expected precision from e.g. Planck