Why Do We Need PID Capability in HCAL (and BeamCal)? – A Case Study

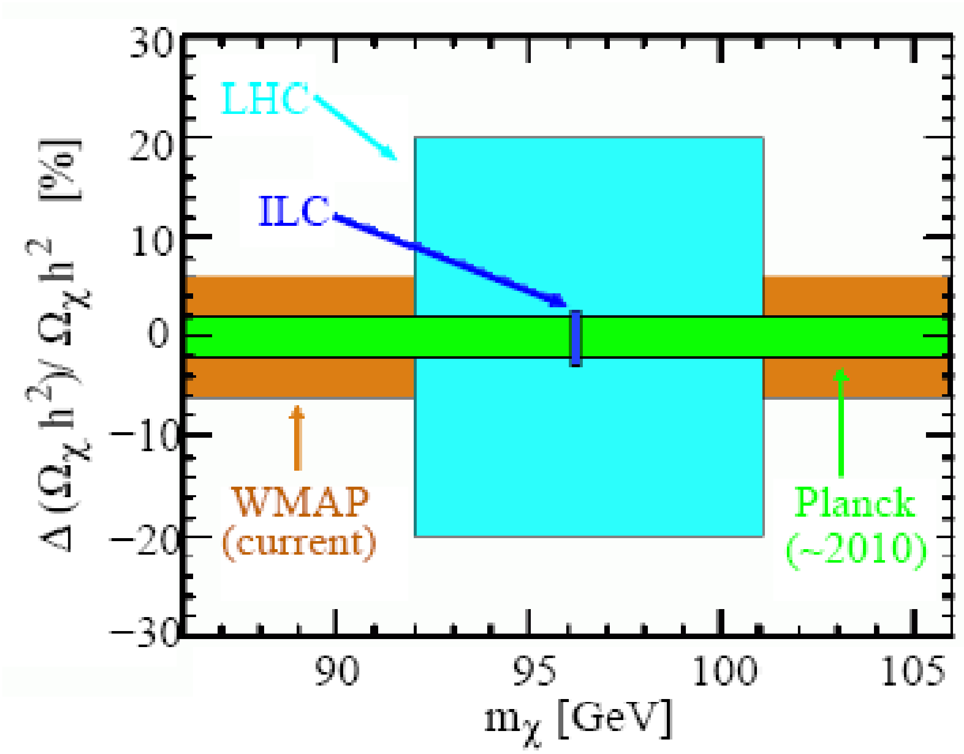
- Motivation
- BeamCal for e vetoing SM backgrounds
- Desired other PID capability in HCAL/BeamCal
- Summary

Based on

1. P. Bambade, V. Drugakov, W. Lohmann, physics/0610145
2. Z. Zhang, arXiv:0801.4888v1 [hep-ph] + new and 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

microMegas

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

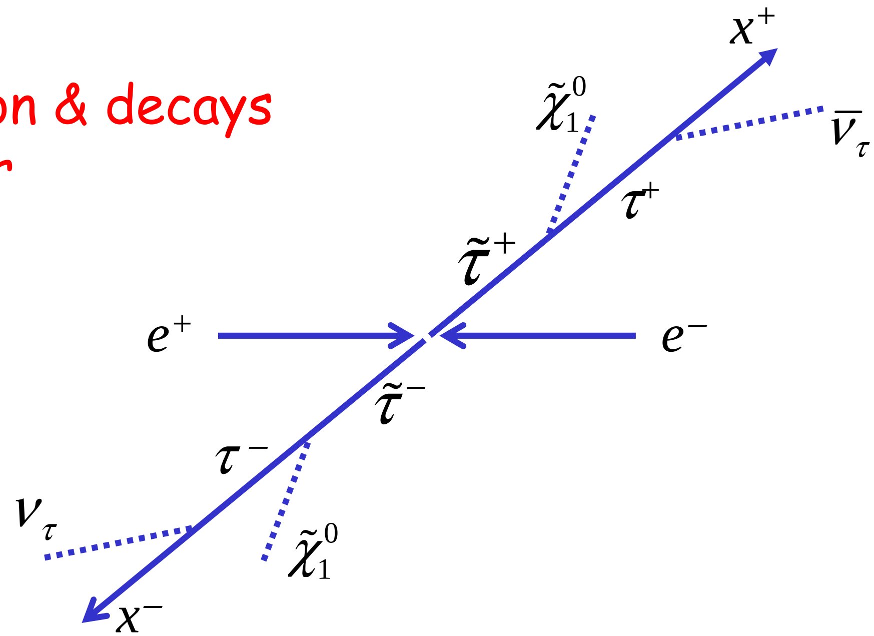
*: Ωh^2<0.094(WMAP lower limit)

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)

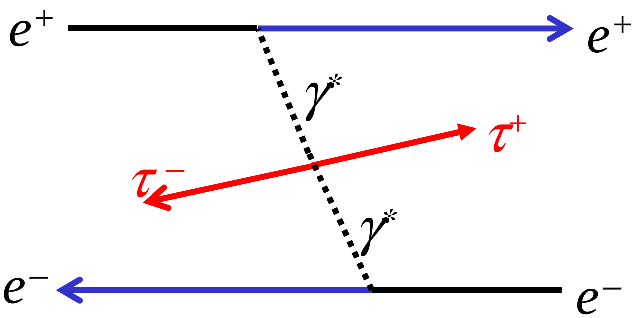
Method two: Large Ecm (hep-ph/0608226)

- SM Backgrounds:

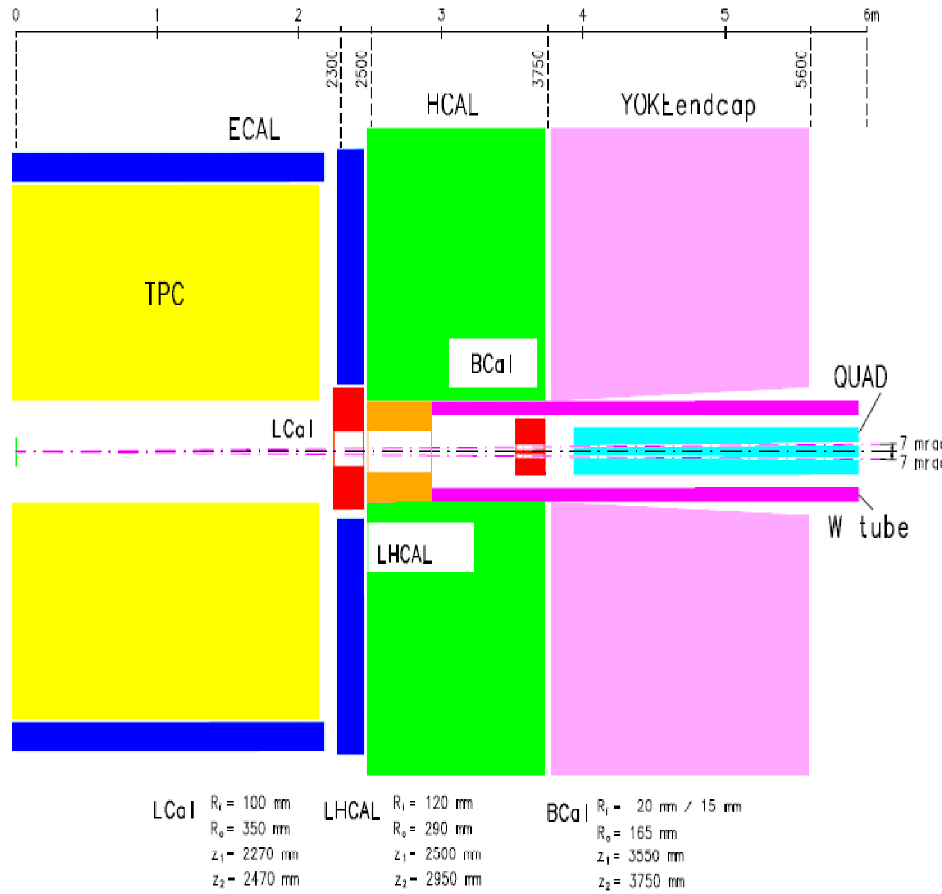
$\gamma^*\gamma^*$ → $\tau^+\tau^-$(E_t>4.5GeV): σ~4.3×10^5 fb
→ $\mu^+\mu^-$ (E_t>2GeV): σ~5.2×10^6 fb
→ hadrons (direct*direct dominant)
ccbar σ~8.2×10^5 fb
→ WW
e^+e^- → $\mu^+\mu^-$, $\tau^+\tau^-$: σ~1.0×10^3 fb
→ WW

Example: Dominant $\gamma\gamma$ Background

SM background production & decays @ e+e- collider

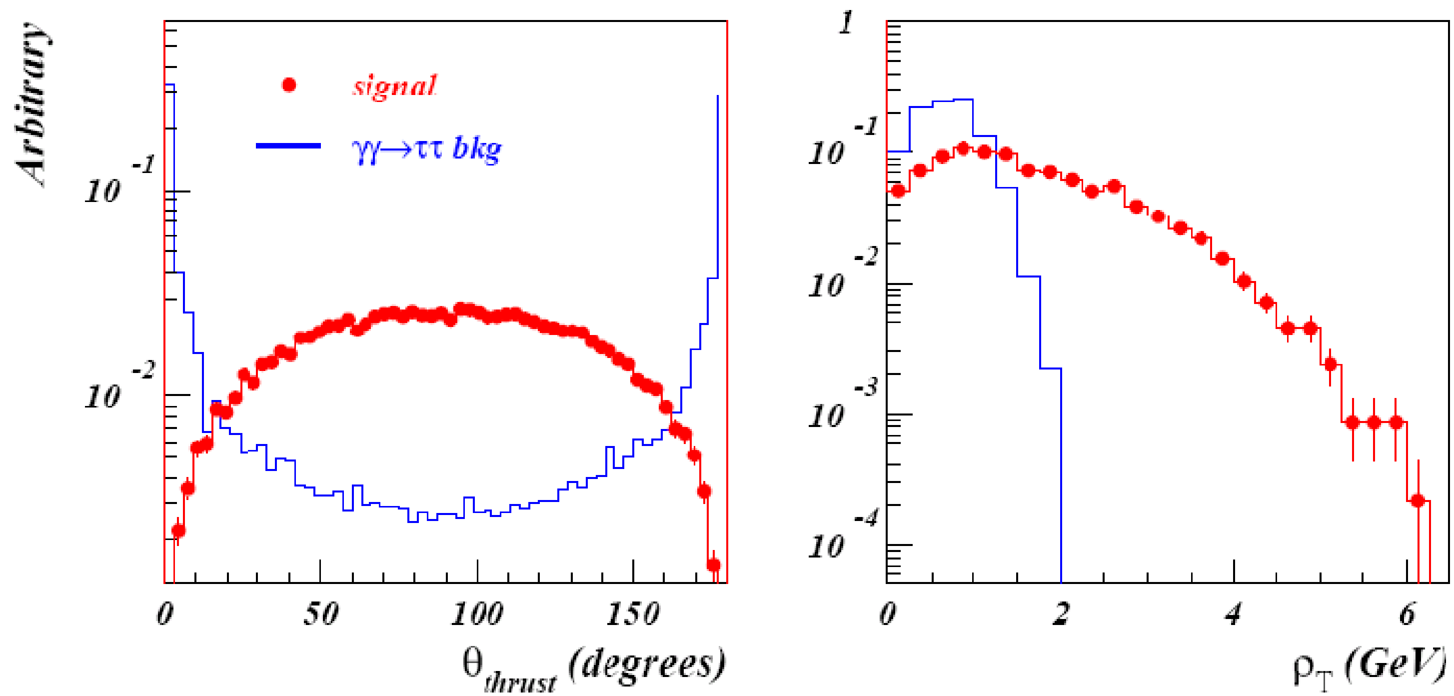


- Tau decay final states:
  Measured in the main detector
- Spectator e+ and e-
  Mostly going into the BeamCal



Background Rejection

- Analysis cuts relying on the main detector

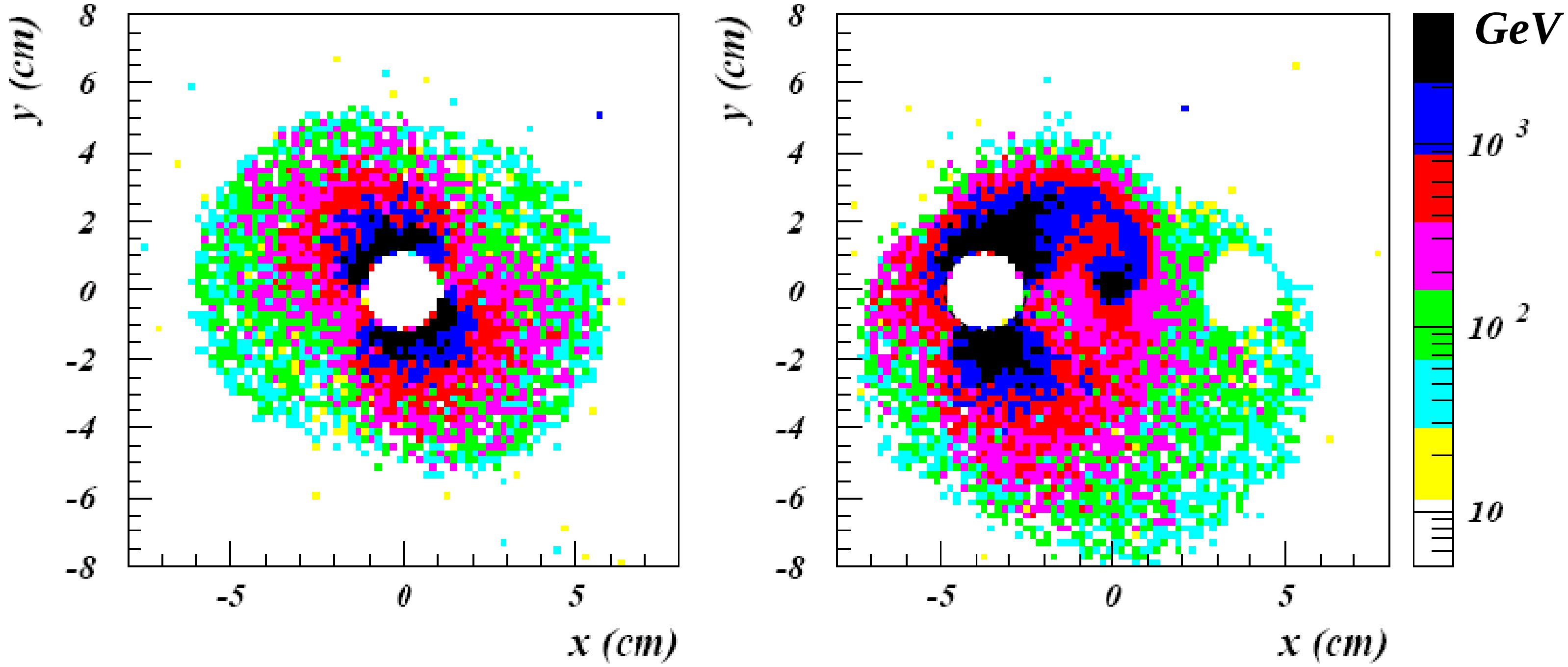


➔ A big fraction of background can be rejected using these cuts but not sufficient for a quasi-background free analysis

➔ Forward veto is needed

Forward (BeamCal) Veto

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



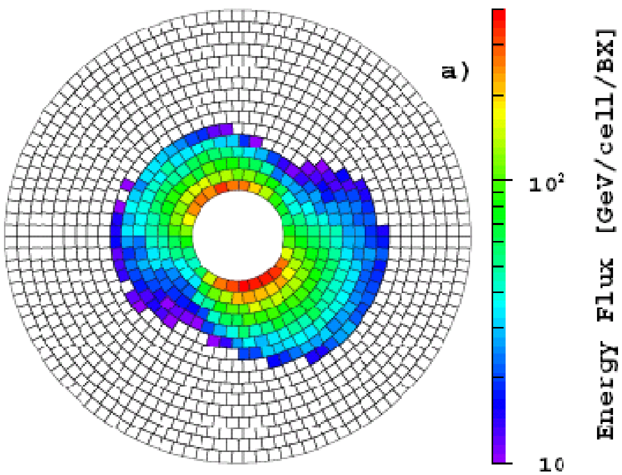
➔ Very challenging to have a radiation hard yet a very efficient BeamCal for e/γ ID

Forward (BeamCal) Veto Efficiency

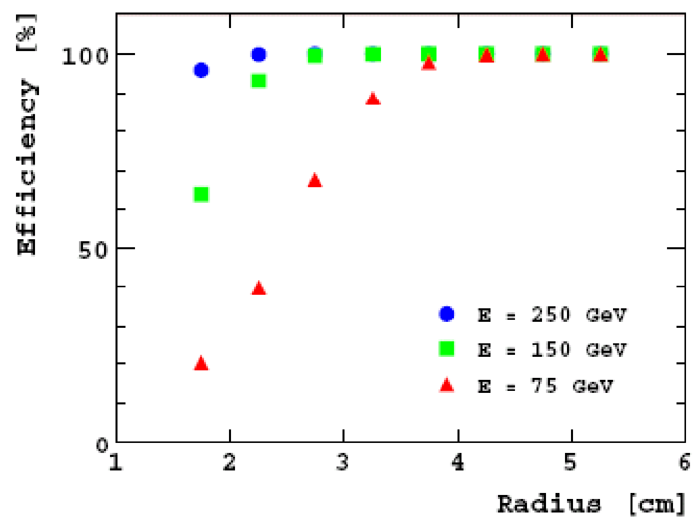
A study by P. Bambade, V. Drugakov, W. Lohmann, physics/0610145:

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

BeamCal @ 370cm



e/γ VETO efficiency



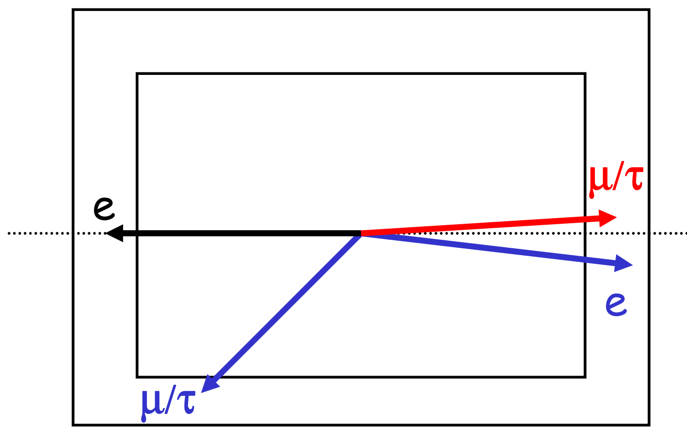
Identify spectator e+/e- out of huge beamstrahlung e+e- pairs

Efficiency is energy and angle dependent

Vetoing Energetic μ/π Down to 20mrad?

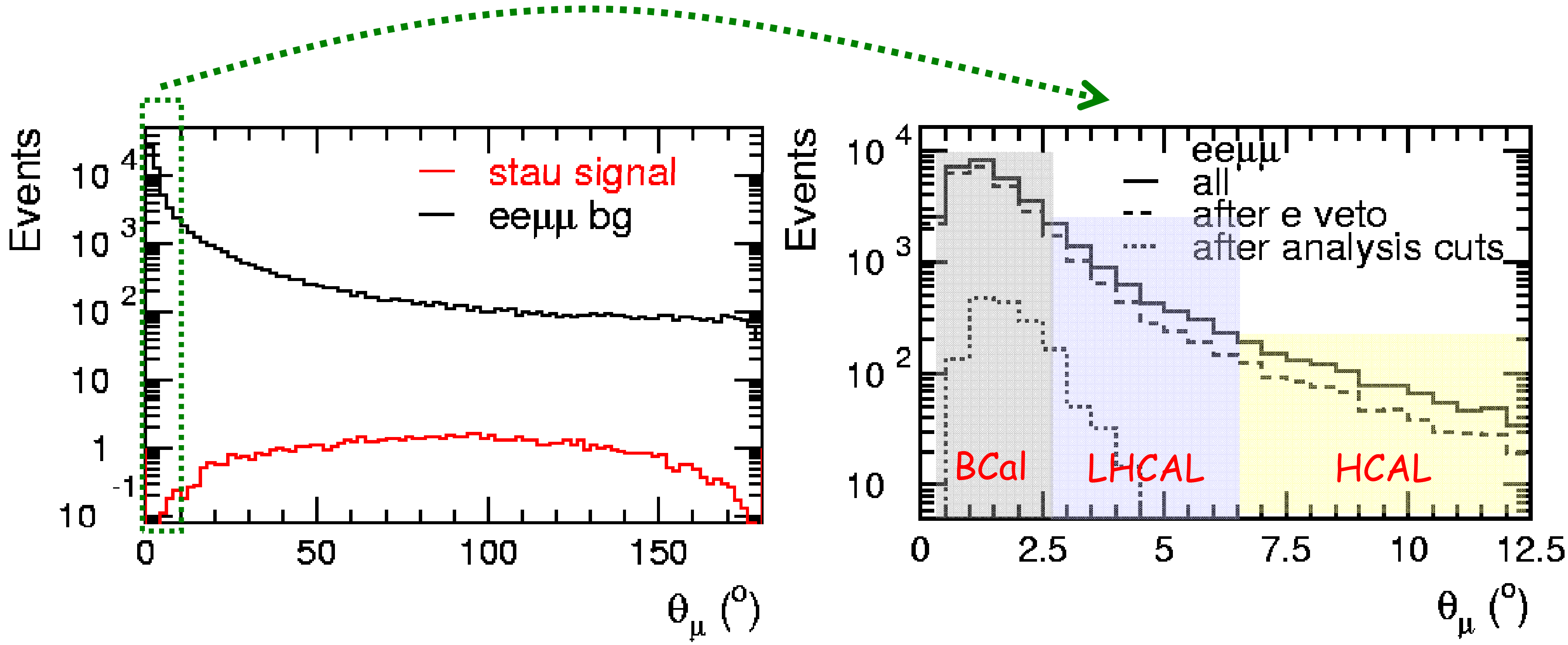
Background free stau detection needs this capability:

ee→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



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

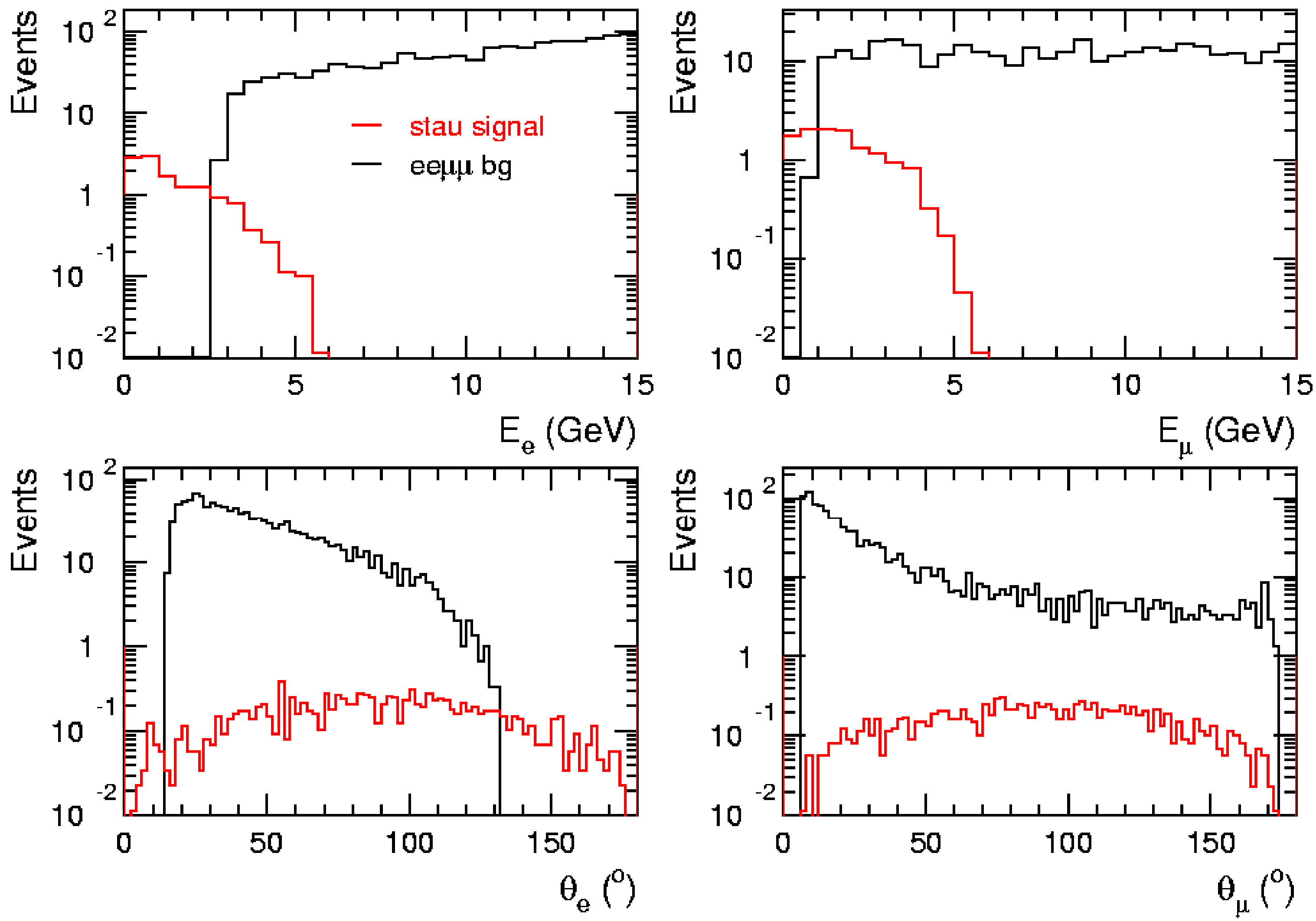
Importance of PID in LHCAL and BeamCal



Muons (taus) from 2 photons backgrounds peak at low angles

➔ Important to veto these muons (taus) as much as one can

Distri. of Other e,μ with one μ in LHCAL/BCAL

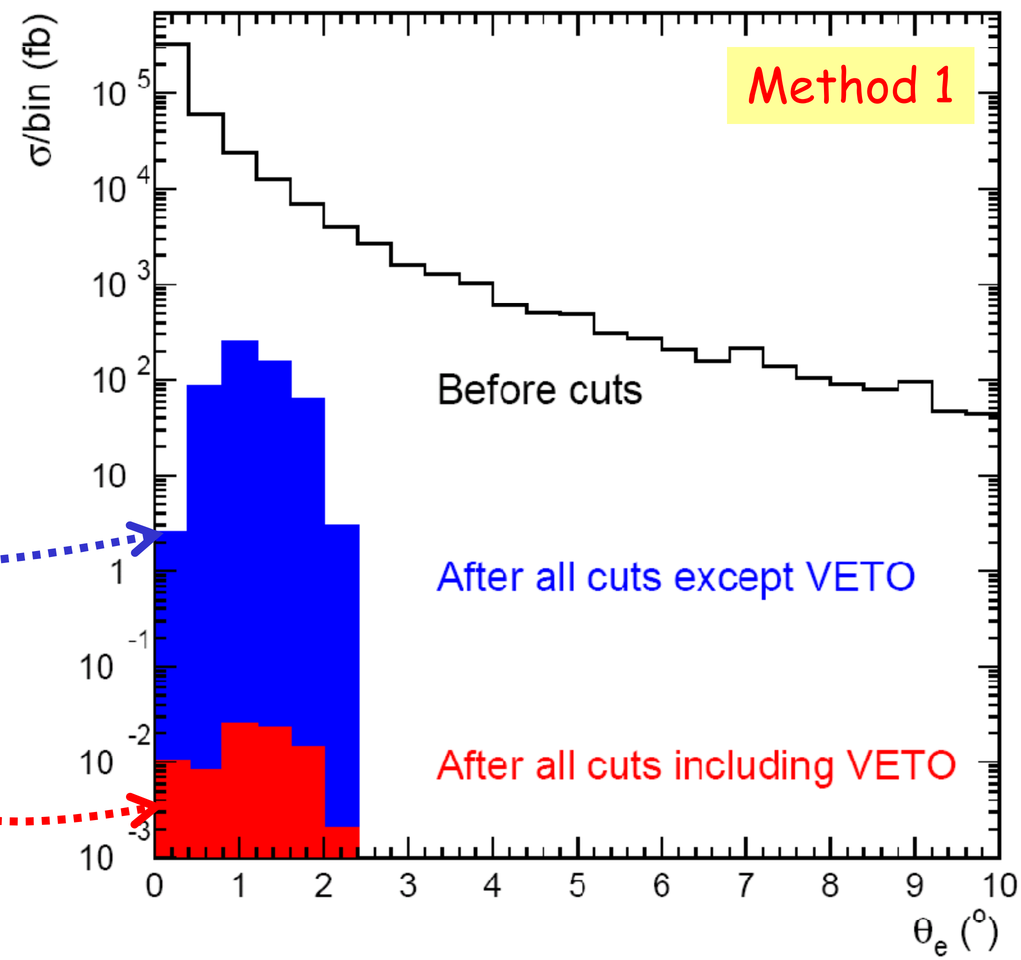


Summary on Final Selection/Rejection

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 $e^{\pm}$



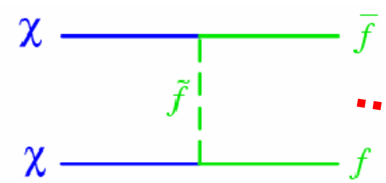
➔ VETO eff. is pretty good for method 2 but needs improvement for method 1

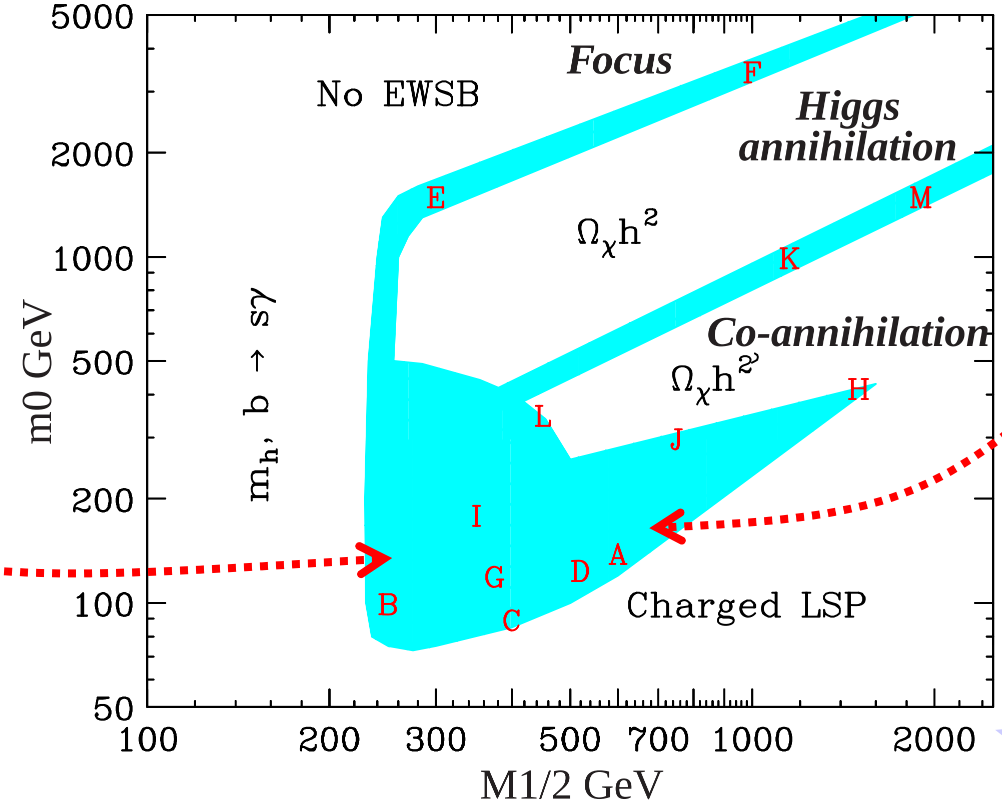
Summary

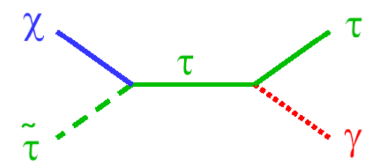
- Excellent veto efficiency of the BeamCal is a must
- μ/π PID capability is strongly desirable to lowest angles
- Depending on SUSY scenario, DM density precision @ ILC can compete with expected precision from e.g. Planck

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 ΔM & thus

δm_χ ➔ Needs smuon (or selectron) analysis

δm_{stau} ➔ Needs stau analysis