

THE TOPOLOGIES OF SUPERSYMMETRY SIGNALS AT LEP

GIACOMO SGUAZZONI

European Laboratory for Particle Physics (CERN)
CH-1211 Geneva 23, Switzerland

Abstract

The topologies arising from the production of supersymmetric particles at the LEP collider are briefly reviewed recalling detector requirements, simulation and other experimental issues.

1 Introduction

Two years after the dismantling of LEP, most of the results of the dedicated searches for production of supersymmetric particles have been published or are close to publication [1]. The analysed topologies are here briefly reviewed focusing on the experimental issues faced by SUSY hunters. The huge experience gained on this field is an important part of the LEP legacy. Hopefully, it will turn out to be very useful for SUSY searches at the upcoming experiments.

2 Overview of topologies

R-parity conservation is assumed: the LSP (Lightest Supersymmetric Particle) is stable, and, most probably, also neutral and weakly interacting; at LEP the sparticles are pair produced; the decay processes bring to final states containing at least one LSP.

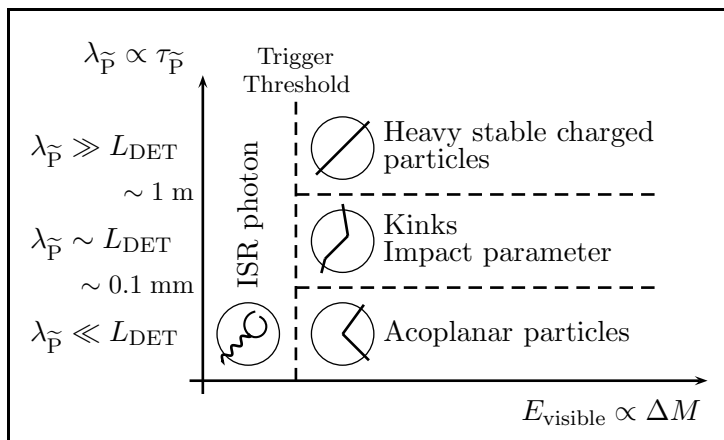


Figure 1: A schematic diagram of the $\lambda_{\tilde{p}}$ vs. E_{visible} plane reporting the relevant topologies within the R-parity conserving scenario.

The variety of supersymmetric models leads to a very wide phenomenology. For each type of final state (hadronic jets, leptons, γ 's) many topologies exist, depending on E_{visible} , the energy of the visible system, and on $\lambda_{\tilde{p}}$, the sparticle decay length. At a given collision energy, E_{visible} is proportional to the mass difference between the sparticle and the escaping LSP ($\Delta M = M_{\tilde{p}} - M_{\text{LSP}}$) and $\lambda_{\tilde{p}}$ is related to the couplings and to ΔM by means of the sparticle lifetime $\tau_{\tilde{p}}$.

An exhaustive search for SUSY at LEP has been pursued by using several different analyses, which, however, can be roughly grouped by experimental topologies, as illustrated in Figure 1:

- energy of the visible system above the detector sensitivity (\sim GeV trigger threshold): *acoplanar particles*, *impact parameter* or *kinks* and *heavy stable charged particles*, respectively for $\lambda_{\tilde{p}}$ smaller, comparable or greater than the typical detector dimension;
- energy of the visible system below the detector sensitivity: *ISR photon*, the hard initial state radiation photon being used for trigger.

The analyses for the R-parity violating scenario, also widely faced at LEP, search for a different set of topologies, not discussed here.

Acoplanar particles. The main signature of this topology, arising in case of pair production of sparticles decaying promptly, is the missing energy and momentum from escaping LSP's, hence the hermeticity is the main detector requirement. The selections often implement fiducial cuts to avoid missing energy and momentum to be faked by cracks or dead zones in

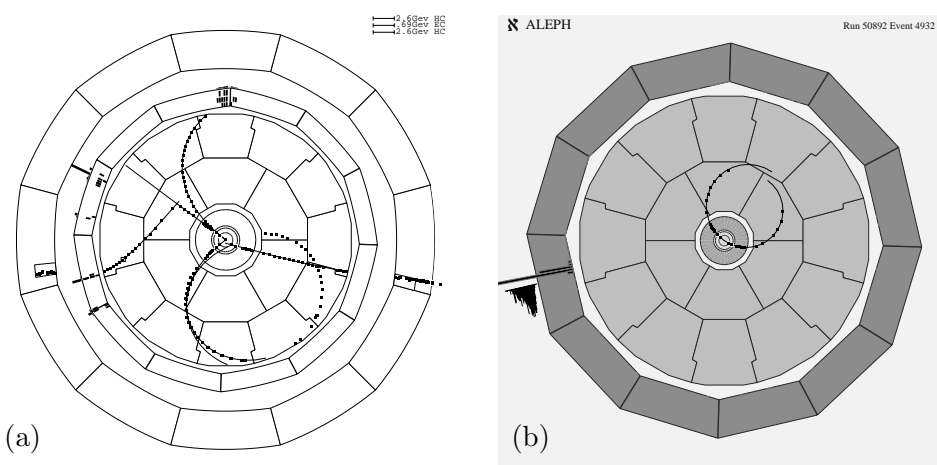


Figure 2: (a) Simulated event with long-lived sparticle pair leading to a kink and a track with large impact parameter. (b) Very small ΔM sparticle signal candidate with the triggering hard ISR photon.

calorimeters and luminosity monitors.

Signal event shape and backgrounds, and thus selections, heavily depend on ΔM . The small ΔM region is the most problematic since the visible system is soft and the dominant background, $e^+e^- \rightarrow \gamma\gamma$, has a huge cross section ($\gtrsim 10\text{nb}$) to be compared with the typical SUSY cross sections ($\sim 0.1\text{pb}$). The strong $\gamma\gamma$ rejection factor required ($\sim 10^5$) results in degraded signal efficiencies. Large efforts have been spent to get the background estimation reliable despite the large samples needed and the complex physics underlying the elementary $\gamma\gamma$ processes.

Powerful anti- $\gamma\gamma$ criteria exist; requiring small energy deposition in the forward directions ($|\theta| \lesssim 10^\circ$) is one example. Unfortunately, the beam pipe and other passive materials (as radiation shields) make this region intrinsically not hermetic, complicated in geometry and affected by beam-related noise and backgrounds so that the evaluation of the detector response is often difficult. These issues are taken into account within the systematic uncertainties or overcome by applying cuts to safely over-reject $\gamma\gamma$'s.

Impact parameter or kinks. This peculiar signature, illustrated by the simulated event in Figure 2(a), can be identified at LEP by means of the powerful tracking, even if the reconstruction algorithms had in some cases to be suitably modified. The non-negligible source of background due to material effects (splash-backs and nuclear interactions), for which simulations

are normally not accurate enough, is kept under control by using topological cuts or by requiring low vertex multiplicity. Cosmic rays recorded as e^+e^- interaction events can also fake tracks not coming from the primary vertex. Good timing capability are usually useful to reject these accidentals.

Heavy stable charged particles. Heavy stable charged particles, produced with relatively low momentum, can be easily tagged by means of particle identification capabilities. Most commonly dE/dx measurements are used, profiting of the large specific ionization loss.

In case of heavy stable hadrons, a big issue is represented by the simulation of the aspects related to the hadronization and to the strong interaction into the calorimeters. The simulations are based on some reasonable extrapolation of the behaviour of known particles; however, as an extra safety margin, the selections have been designed to make minimal use of the calorimetric informations.

ISR photon. If ΔM falls below few hundreds of MeV's, the triggering on the sparticle signal relies only on hard photons from initial state radiation. As an example, Figure 2(b) reports a candidate event selected in such type of analyses. The method allows to extend the sensitivity down to ~ 150 MeV; reliable ISR simulations are crucial for a correct evaluation of the resulting tiny efficiencies ($\lesssim 1\%$).

3 Conclusion

Despite the frustrating negative outcome, hunting for Supersymmetry at LEP turned out to be a challenging search for topologies not present or rare in the Standard Model. The experimental issues required a stimulating and deep comprehension of the detectors and the development of new techniques and dedicated algorithms.

4 Acknowledgments

I would like to thank P. Azzurri and G. Ganis for their valuable help and many useful discussions.

References

- [1] F. Mazzucato, *Search for Supersymmetry at LEP2*, and references therein; these proceedings.