The sensitivity of the International Linear Collider to the χ_2^0 in the di-muon final state

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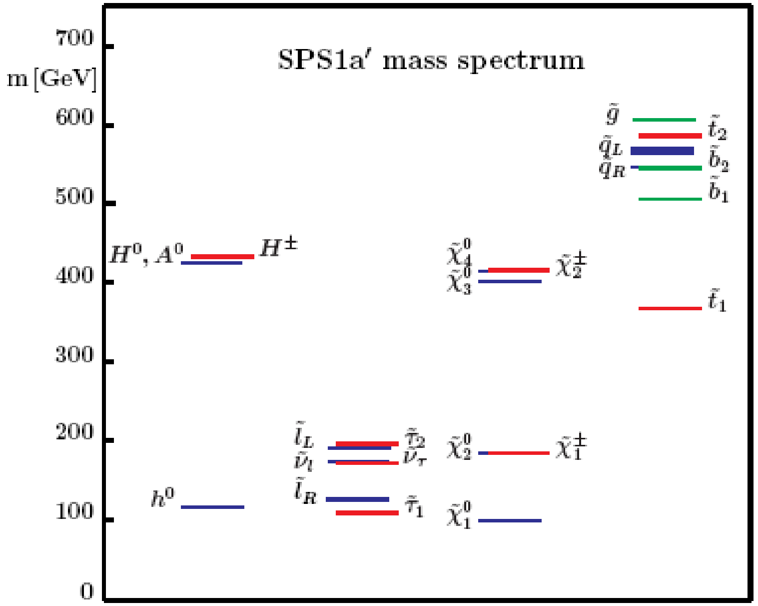
- **Physics motivations**
- **Signal vv. Backgrounds . The experimental challenges.**
- **Statistical analysis tools and results**
- **What do we learn for the design of the detector?**

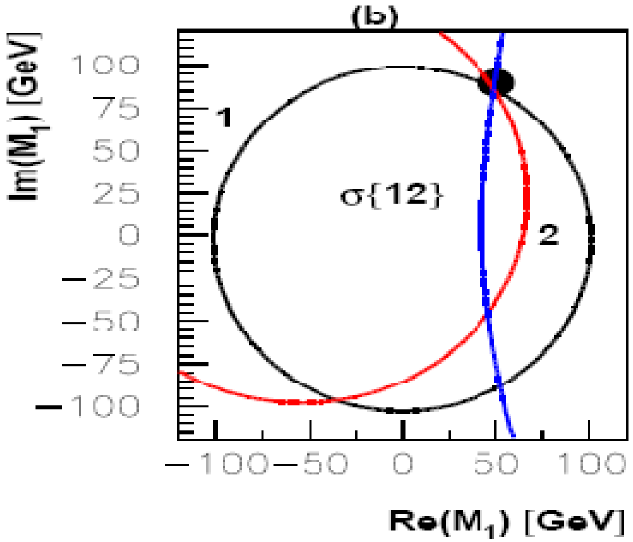
Parameters of the analysis presented in this talk :

1. WHIZARD event generator
   - Beamstrahlung, ISR, FSR
2. MOKKA, **LDCPrime_02Sc**
3. Beam Polarization: **(-0.8,0.6)**

2° ILD Workshop Cambridge
11-14/09/08

Motivations





S.Y.Choi hep-ph/0108117

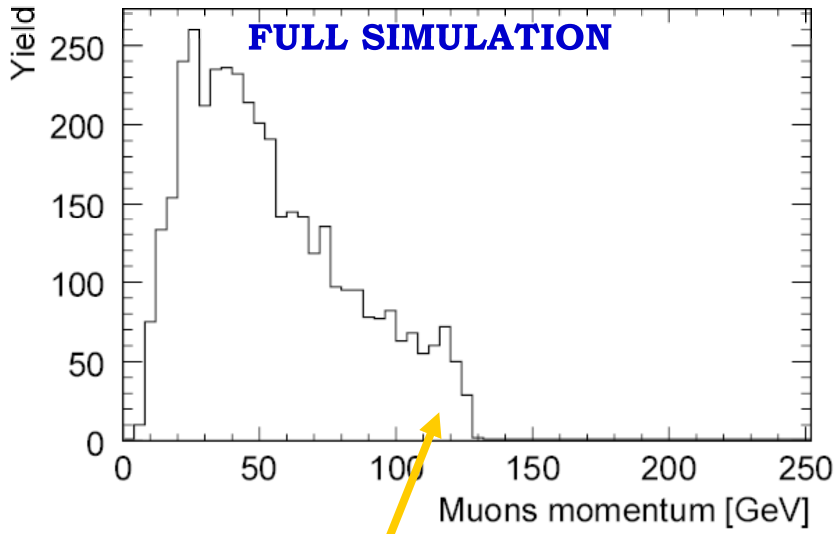
- The SU(2) gaugino parameter M_2 , the higgsino mass μ and tan(β) can be determined in the chargino system (hep-ph 0002033)

- **The SU(1) gaugino mass M_1 can be analysed in the neutralino system**

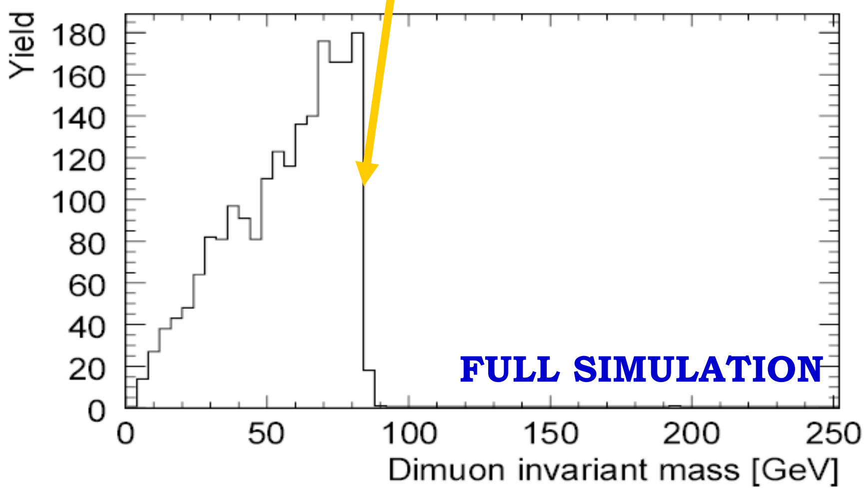
- **A precise measurement of the SUSY parameters requires a maximal set of observable measured with precision (see FITTINO)**

We study the χ_2 in the final state $\mu_R\,\mu$.
σBR = 4.2 fb → 2000 events
in the first 4 years of operation @ (-0.8,0.6) beam polarization and @500 fb^{-1}

The signal



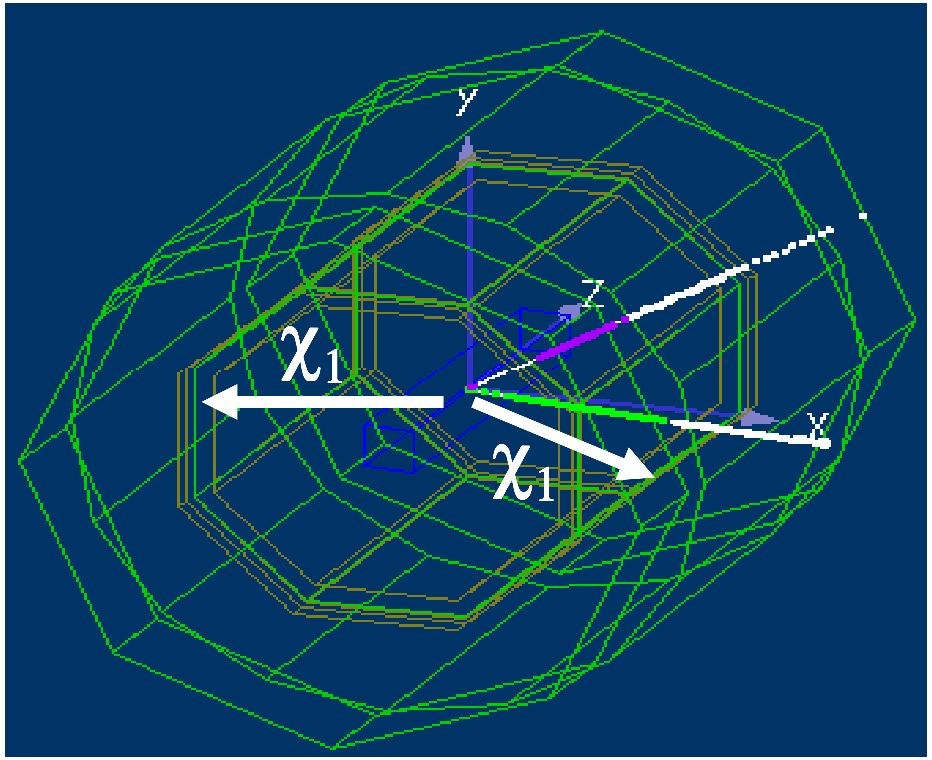
MOMENTUM RESOLUTION



- The mass can be measured using the edge of the momentum distribution or of the invariant mass distribution
  - Invariant mass : sharp
  - Momentum : more smeared

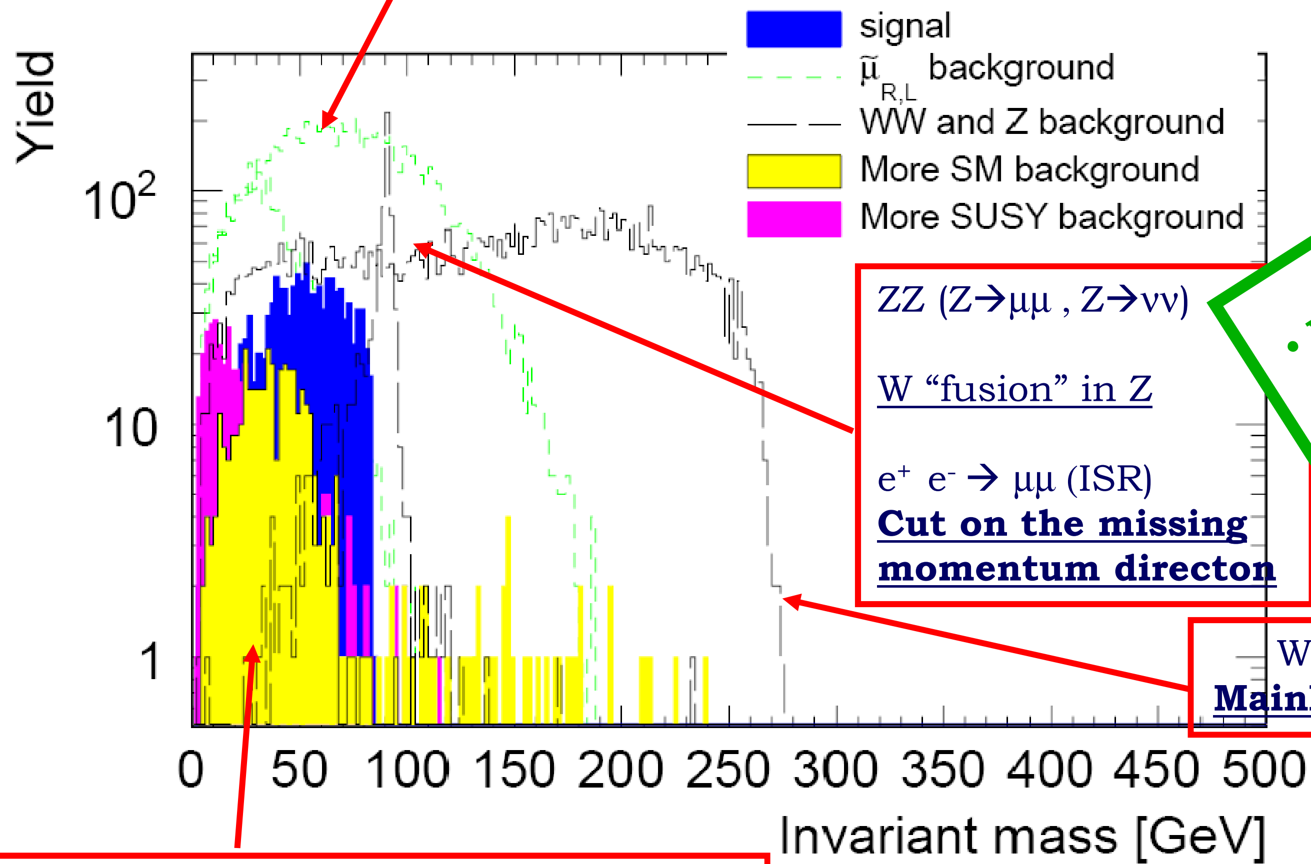
- Missing energy : more than 330 GeV
  - **HERMETICITY**

- The signal is largely acoplanar and acollinear



Backgrounds and selection cuts

μ_L pair production: irreducible background



ZZ (Z→μμ , Z→νν)

W "fusion" in Z

$e^+ e^- \to \mu\mu$ (ISR)

Cut on the missing momentum directon

HERMETICITY

- **Photon detection in the Forward Region**
- **Beamstrahlung**

WW production (W → μ ν)

Mainly not signal like: collinear

Low energy muon pairs from other SUSY channels (see back slides) and SM

Removed with a cut on the invariant mass (s>20)

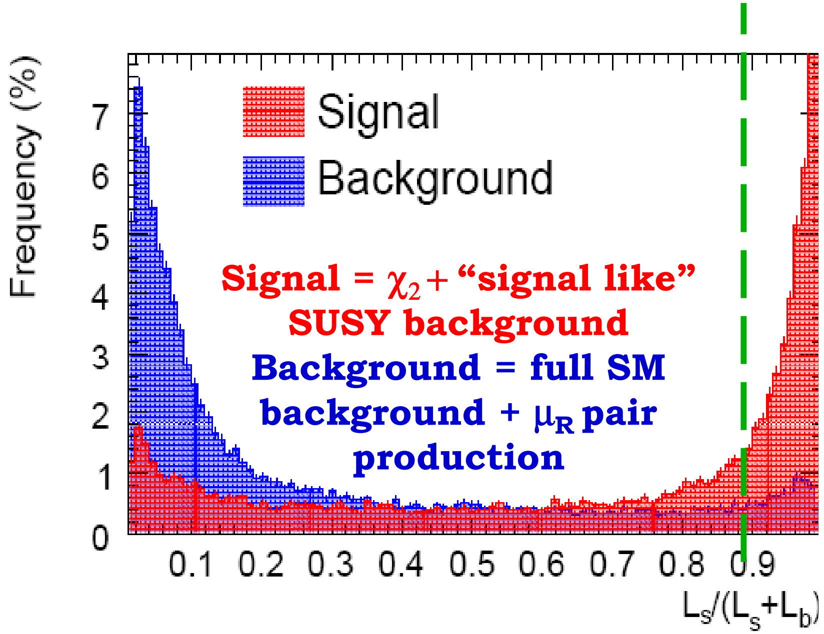
1) γγ **background at low pt! No evidence of interest in this analysis. To be verified!**

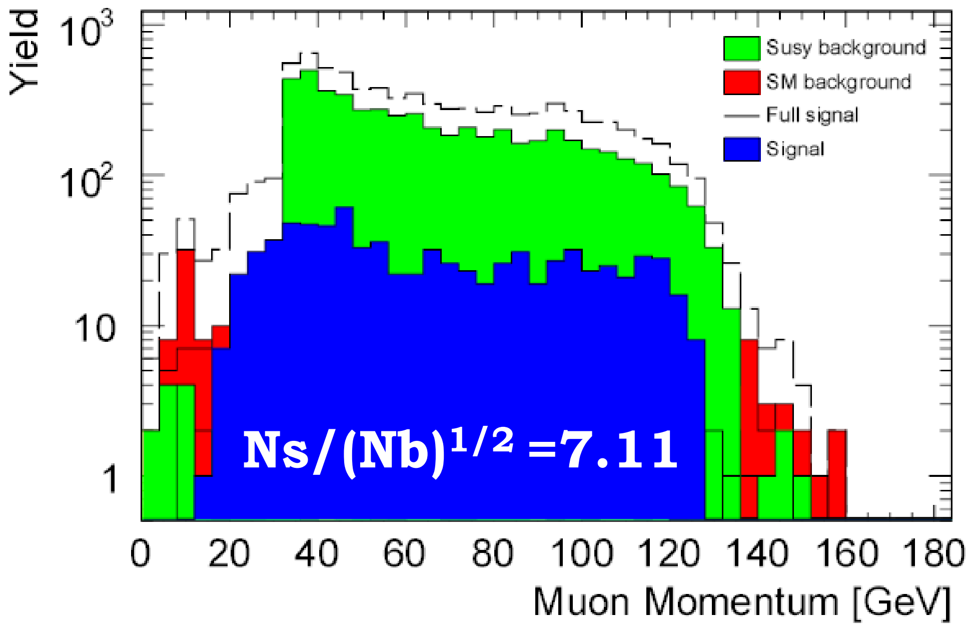
2) 2 10^6 muon pairs expected from SM and **60000** from SUSY.

The signal after the selection

Acollinearity >0.1 π
pt > 30 GeV
Emiss>330 GeV
$0.1<\Theta_{miss}<0.9$
20 GeV<Invariant Mass<87 GeV

• 2 "isolated" cuts found
• No limitation on photons clusters
(the energy of the photons is used to update the missing energy)
• **MUON ID?**



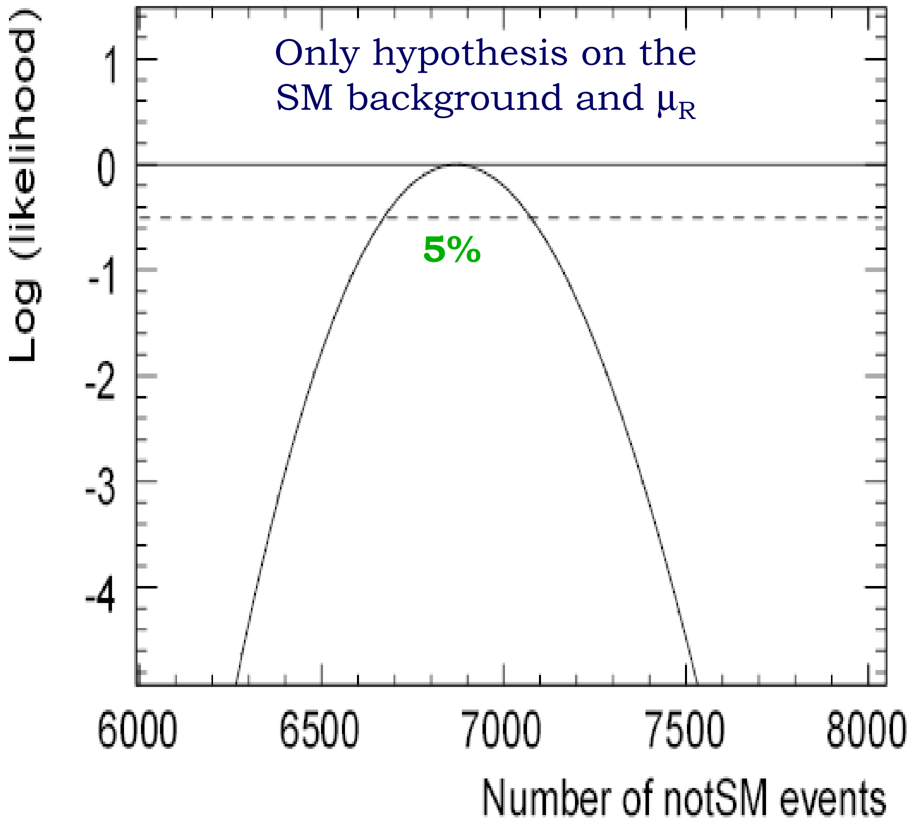


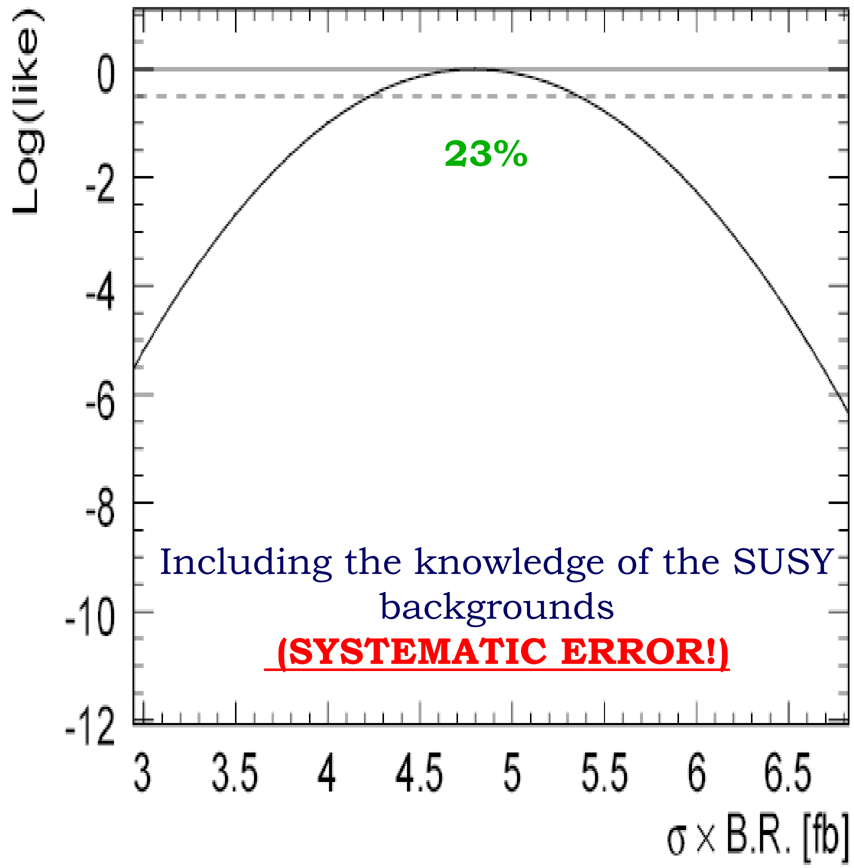
$$L=\frac{(N_s+N_b)^{N_{obs}}\,e^{-(N_s+N_b)}}{N_{obs}!}\prod_{i=1}^{N_{obs}}(P_{acol}\times P_{acop}\times P_{pt1}\times P_{pt2}\times P_{Emiss})$$

1) The cuts are robust respect to the hermeticity (same study for different photons acceptance in the BEAMCal didn't show any difference in significance)
2) The knowledge of the beamstrahlung energy lost introduce a 10% in the sensitivity (6→7)

Sensitivity to new physics

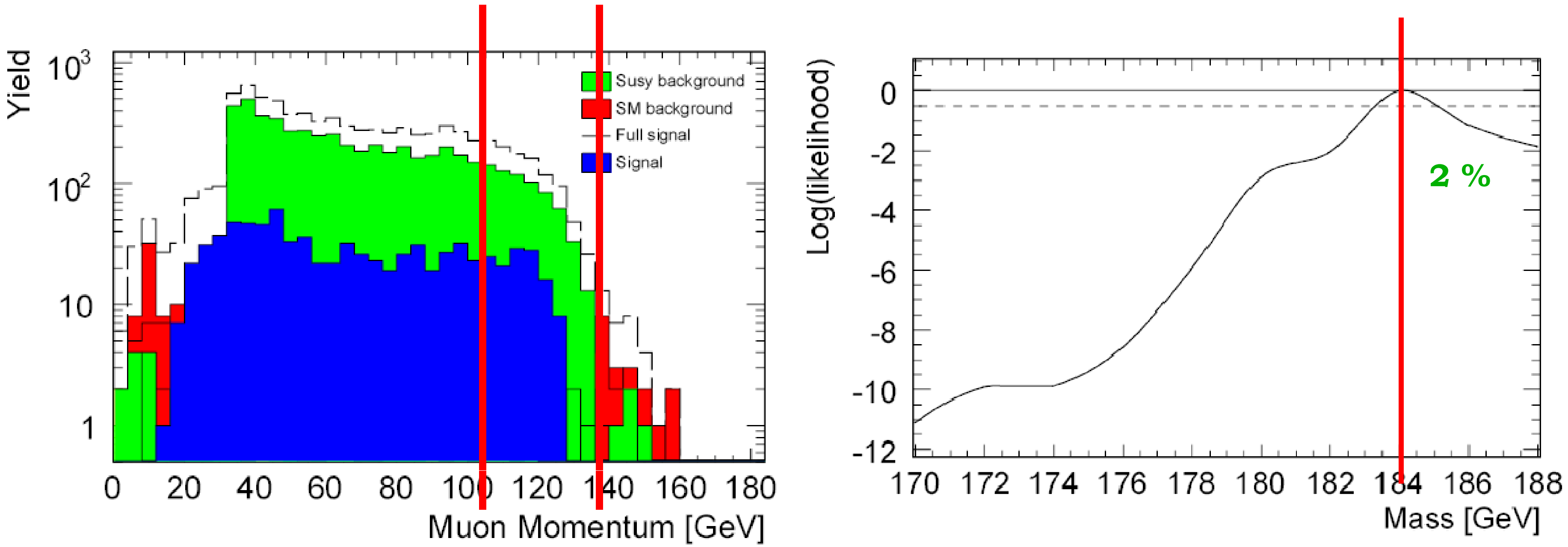
$$L_{ext} = \frac{(N_B + \mathbf{L} \times \sigma_L)^{N_{obs}} e^{-N_{obs}}}{N_{obs}!} \prod_{i=1}^{N} (L_B(\varepsilon_i, \varepsilon_j, \ldots) \times N_B + L_S(\varepsilon_i, \varepsilon_j, \ldots) \times \sigma_L \times \mathbf{L})$$





1) New physics signatures can be put in evidence with good sensitivity
2) Systematic errors still to be included

Determination of the mass of the neutralino



1) A binned likelihood estimation is performed using Monte Carlo simulations of the signal at different masses (2 GeV bins)
2) This statistical method helps to find “evidence” of the small statistics signal edge.
3) No significative statistical effects from the efficiency of the photon detection in the forward region.

What do we learn for the design of the detector?

- Strong cuts make the analysis of the high missing energy, high pt events independent on the hermeticity of the detector
  - 23 % confidence belt @ 68% C.L. for σ B.R. → MODEL DEPENDENT
  - 2 % confidence belt @ 68% C.L. for the mass → STRONG SYSTEMATC UNCERTAINTY !
- Relax the cut on the invariant mass and on the θ_{miss} (to be done)
  - The impact on the mesurement of the ISR photon tagging in the forward region has to be studied
  - The mass measurement on the invariant mass distribution would be affected of less systematics
- No particular problems observed in the tracking.

  $\Delta p/p = 10^{-5}$ is even better than needed!
- Muon identification?
- We have now a full statistical analysis chain which quantifies the sensitivity of the ILD detector to the small signals, which are relevant for a full understanding and fitting of the SUSY scenario

BACK UP SLIDES…

List of SUSY background channels and CUT flow

Final State	Processes	Events	Cuts 1	Cuts 2	Cuts 3
$\mu\mu\chi_1^0\chi_1^0$	$\tilde\mu_R\bar{\tilde\mu}_R$ $\tilde\mu_L\bar{\tilde\mu}_L$	19800 26000	1250 1500	800 870	
$\mu\mu\nu_e\nu_e\chi_1^0\chi_1^0$	$\tilde\mu_L\bar{\tilde\mu}_L \longrightarrow \chi_1^0\chi_2^0$ $\chi_2^0\chi_2^0 \longrightarrow \mu^\pm\tilde\mu^\mp\nu_e\tilde\nu_{e,L}$	800	70	70	
$\mu\mu\nu_\mu\nu_\mu\chi_1 0\chi_1^0$	$\tilde\mu_L\bar{\tilde\mu}_L \longrightarrow \chi_1 0\mu\nu_{mu}\tilde\mu_\mu$ $\chi_2^0\chi_2 0 \longrightarrow \mu^\pm\mu\tilde{R}^\mp\nu_\mu\tilde\nu_\mu$ $\tilde\mu_L\tilde\mu_L \longrightarrow \chi_1^0\mu^\pm\chi_1^\mp\nu_\mu$ $\chi_1^\pm\chi_1^\mp \longrightarrow \mu\tilde\nu_\mu\mu\tilde\nu_\mu$	4600	110	110	
$\mu\mu\nu_\tau\nu_\tau\chi_1^0\chi_1^0$	$\tilde\mu_L\bar{\tilde\mu}_L \longrightarrow \chi_1^0\chi_2^0$ $\chi_2^0\chi_2^0 \longrightarrow \mu\tilde\mu\nu_{tau}\nu_\tau$	800	90	90	
$\mu^\pm\mu^\mp\nu_\mu\nu_\tau\nu_\mu\nu_\tau\chi_1^0\chi_1^0$	$\tilde\tau_1\tilde\tau_1$ $\tilde\tau_1\tilde\tau_1$	3000	110	110	
$\mu^\pm\mu^\mp\nu_\mu\nu_\tau\nu_\mu\nu_\tau\nu_\mu\nu_\mu\chi_1^0\chi_1^0$	$\tilde\tau_1\tilde\tau_2 \longrightarrow \chi_1^0\tau\chi_2^0\tau$ $\tilde\tau_2\tilde\tau_2 \longrightarrow \chi_1^0\tau\chi_2^0\tau$ $\chi_2^0\chi_2^0 \longrightarrow \tau\tilde\tau\nu_\mu\tilde\nu_\mu$	300	88	40	
$\mu^\pm\mu^\mp\nu_\mu\nu_\tau\nu_\mu\nu_\tau\nu_\tau\nu_\tau\chi_1^0\chi_1^0$	$\tilde\tau_2\tilde\tau_2 \longrightarrow \chi_1^0\tau\chi_2^0\tau$ $\tau_2\tau_2 \longrightarrow \chi_1^0\tau\chi_1^\pm\nu_\tau$ $\tau_2\tau_2 \longrightarrow \chi_1^0\tau\chi_1^\pm\nu_{tau}$ $\tau_1\tau_2 \longrightarrow \tau\chi_1^0\tau\chi_2^0$ $\tilde\tau_1\tilde\tau_2 \longrightarrow \tau\chi_1^0\chi_1^\pm\nu_\tau$ $\chi_2^0\chi_2^0 \longrightarrow \tau\tilde\tau\nu_\tau\tilde\nu_\tau$ $\chi_1^+\chi_1^- \longrightarrow \tau\nu_{\tilde{tau}}\tau\nu_{\tilde{tau}}$ $\chi_1^+\chi_1^- \longrightarrow \tau\nu_{\tilde{tau}}\tilde\tau\nu_{tau}$	3600	3	3	
$\mu^\pm\mu^\mp\nu_\mu\nu_\tau\nu_\mu\nu_\tau\nu_e\nu_e\chi_1^0\chi_1^0$	$\tilde\tau_2\tilde\tau_2 \longrightarrow \chi_1^0\chi_1^0\tau\tau$ $\tilde\tau_1\tilde\tau_2 \longrightarrow \tau\chi_1^0\tau\chi_2^0$ $\chi_2^0\chi_2^0 \longrightarrow \tau\tilde\tau\nu_e\tilde\nu_e$	360	40	40	
$\mu^\pm\mu^\mp\nu_\mu\nu_\tau\nu_\mu\nu_\tau\nu_\mu\nu_\tau\chi_1^0\chi_1^0$	$\chi_1^\pm\chi_1^\mp \longrightarrow \mu\tilde\nu_\mu\tau\tilde\nu_\tau$ $\chi_1^\pm\chi_1^\mp \longrightarrow \mu\tilde\nu_\mu\nu_\tau t\tilde{a}u$ $\tilde\mu_L\tilde\mu_L \longrightarrow \chi_1^0\mu\chi_1^\pm\nu_\mu$	1600 1700 150	0 0 0	0 0 0	0 0 0