Two photon exclusive production of SUSY pairs at the LHC

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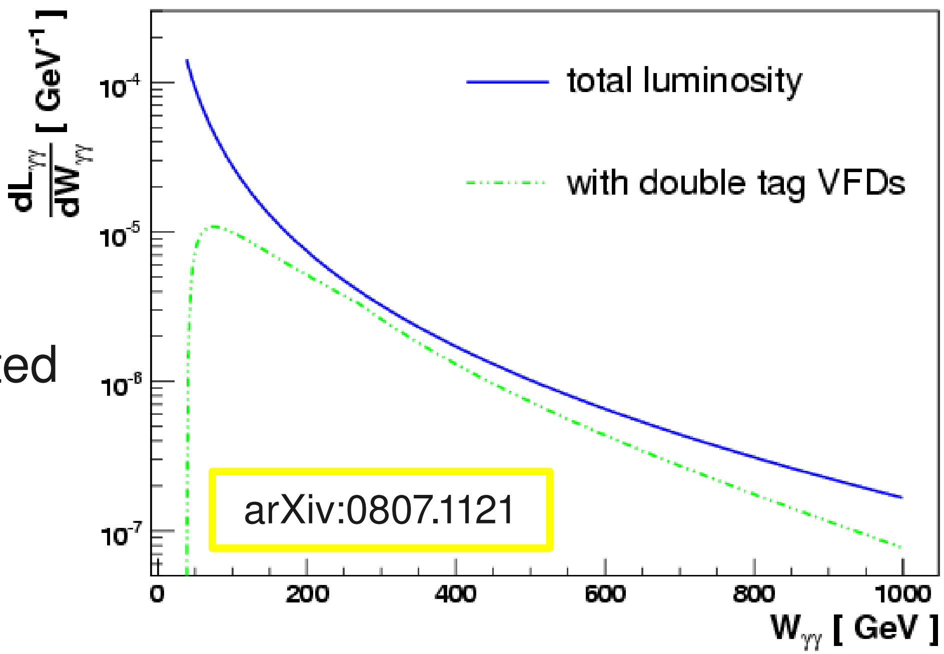
Outline:

1. The LHC = photon collider
2. Detection of exclusive supersymmetric pairs
3. The LHC = proton spectrometer
4. Precise SUSY masses reconstruction
5. Accidental coincidence background

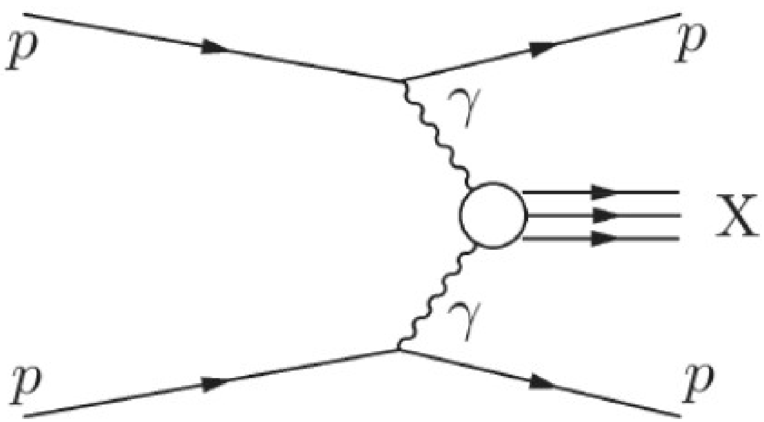
LHC is a γγ collider

A **significant** fraction of *pp* collisions at the LHC will involve photon-interactions

--> relative γ-γ luminosity reaches
1% for $W_{\gamma\gamma} > 23$ GeV
0.1% for $W_{\gamma\gamma} > 225$ GeV



--> the low relative luminosity is compensated by
* better known initial conditions
* simpler final states.



Striking experimental signatures for events involving photon exchanges:

- **very forward scattered protons**
- **large rapidity gap in forward regions**

LHC is a γγ collider

- **Pair** production of **charged** particles is the most interesting production channel

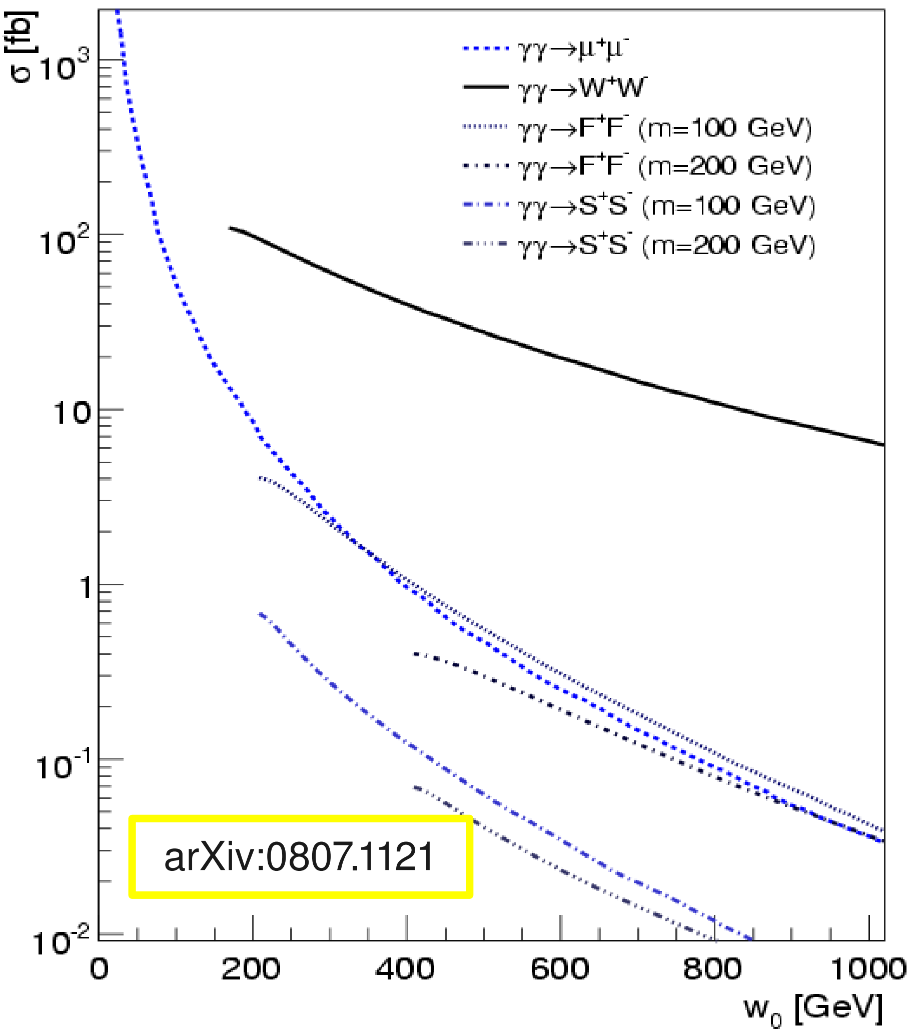
- Significant cross-sections. Ex:

$$\sigma(\gamma\gamma\text{->}F^+F^-,\ m_F\text{=100GeV}) = 4.1\text{ fb}$$

$$\sigma(\gamma\gamma\text{->}S^+S^-,\ m_S\text{=100GeV}) = 0.7\text{ fb}$$

- Provided efficient measurements of these very forward protons, one can study **high-energy photon interactions at the LHC**

- Since low Q² photons are exchanged
  --> high survival probabilities, little re-scattering
  --> good control on the cross-section



Complementarity physics to *pp* interactions

=> high-energy γγ physics (BSM ?)

In $\gamma\gamma$ collisions, low-mass supersymmetry production is of interest of study.
As an example,l **LM1** benchmark point in **mSugra** model is presented here:

m_0 = 60 GeV, $m_{1/2}$ = 250 GeV, tg(β) = 10, A_0 = 0, $\mu > 0$ (LM1)

Slepton right: $\sim e_R^+$, $\sim \mu_R^+$ 118 GeV

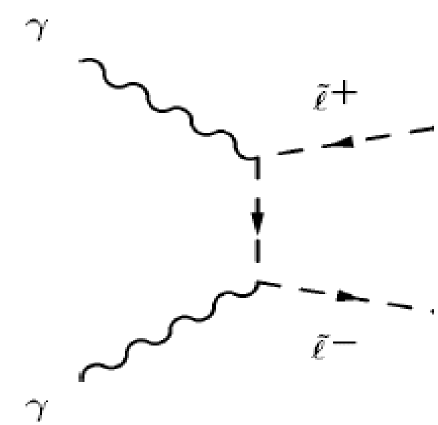
Slepton left: $\sim e_L^+$, $\sim \mu_L^+$ 187 GeV

Stau : $\sim \tau_1^+$, $\sim \tau_2^+$ 111 , 190 GeV

Chargino : $\sim \chi_1^+$, $\sim \chi_2^+$ 178 , 360 GeV

Higgs : H^+ 381 GeV

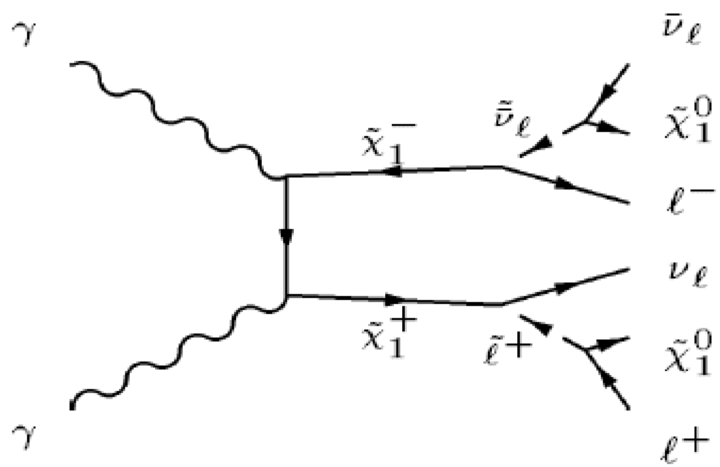
Neutralino : $\sim \chi^0_{1\to 4}$ 96 -> 369 GeV --> σ(LM1) = 2.23 fb

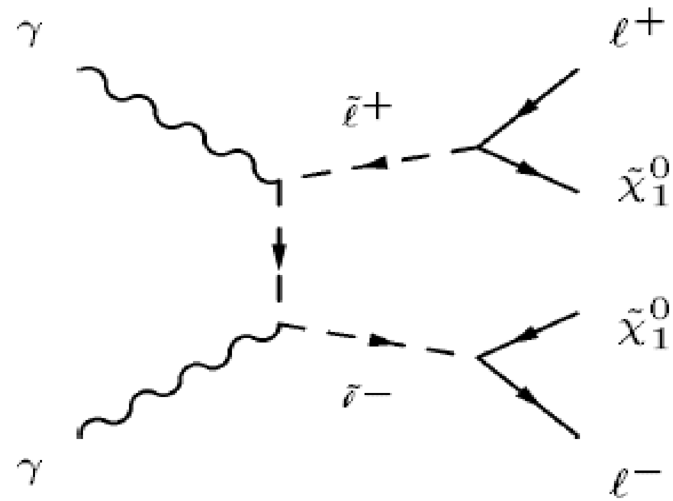


Detection of exclusive susy pairs

Dileptonic (Very clean) final state:

2 fwd protons **+** 2 isolated leptons **+** missing energy + acoplanarity





Only one irreducible background: $\gamma\gamma \rightarrow W^+ W^- \rightarrow l^+ \nu\, l^- \bar{\nu}$ (σ = 108.5 fb)

Only 50% of it if requiring **same flavour** leptons

In low tg(β) models, couplings to tau and stau are lower:

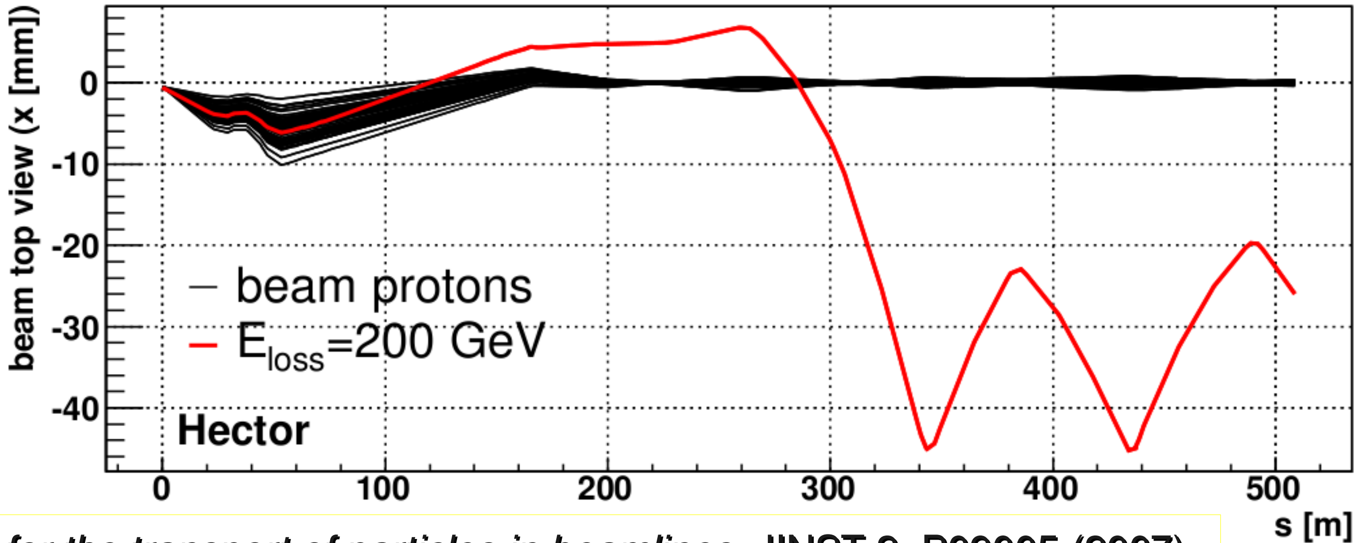
Can tag lepton-tau using **transverse vertex** position (ε = 65% for 1mm)

$\gamma\gamma \rightarrow e^+ e^-$, $\gamma\gamma \rightarrow \mu^+ \mu^-$, $\gamma\gamma \rightarrow \tau^+ \tau^-$

are suppressed using E_{mis} and acoplanarity cut.

LHC is a proton spectrometer

Scattered protons are more **deflected** (because of energy loss) than those from the beam



Hector: a fast simulator for the transport of particles in beamlines, JINST 2, P09005 (2007), arXiv 0707.1198

With dedicated proton detectors placed at 420m and 240m from the IP, one can:

* tag photon interactions

* reconstruct proton energy with *max(E_γ/100, 1.5GeV)* energy resolution

* reconstruct the initial conditions of the event $W_{\gamma\gamma} = 2\sqrt{\omega_1\omega_2}$

* reconstruct the missing energy $E_{miss} = \omega_1 + \omega_2 - E_{\ell_1} - E_{\ell_2}$

Detection of exclusive susy pairs

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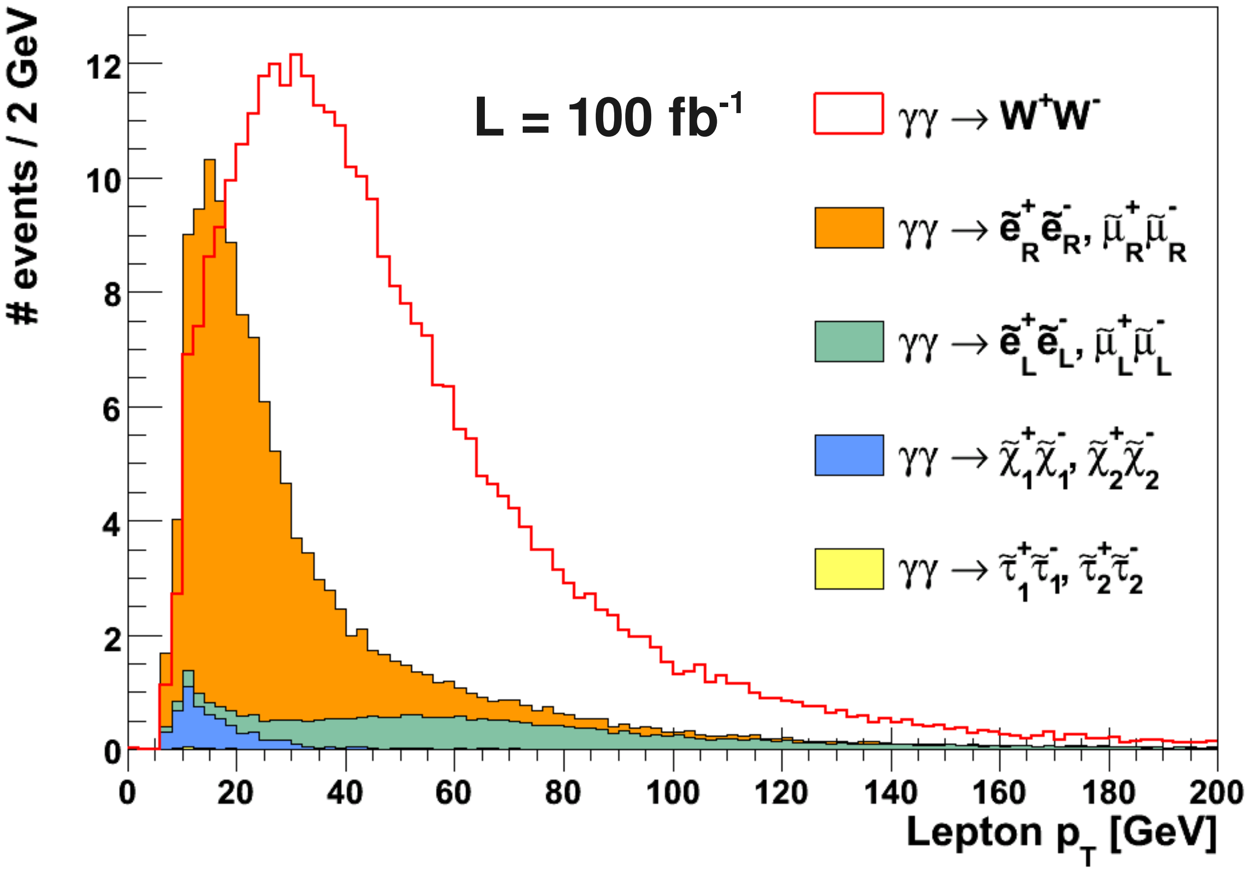


Using CalcHEP or MadGraph generator + modified Pythia

Acceptance cuts:

$p_T(e^{+/-}) > 10$ GeV

$p_T(\mu^{+/-}) > 7$ GeV

$|\eta| < 2.5$

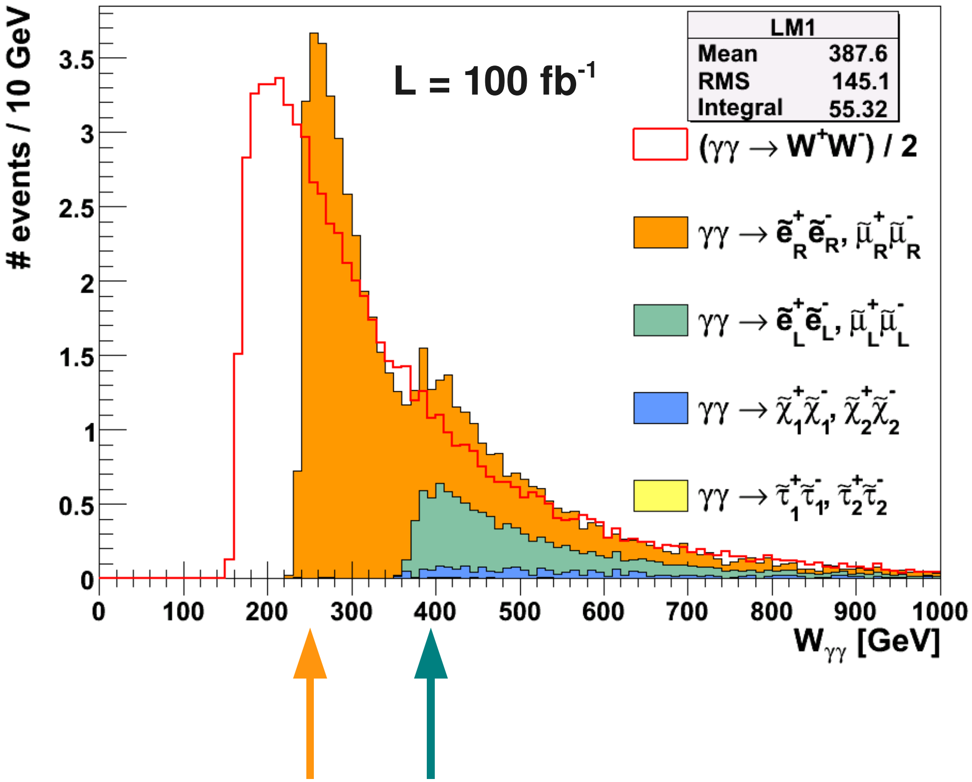
vtxT < 1mm

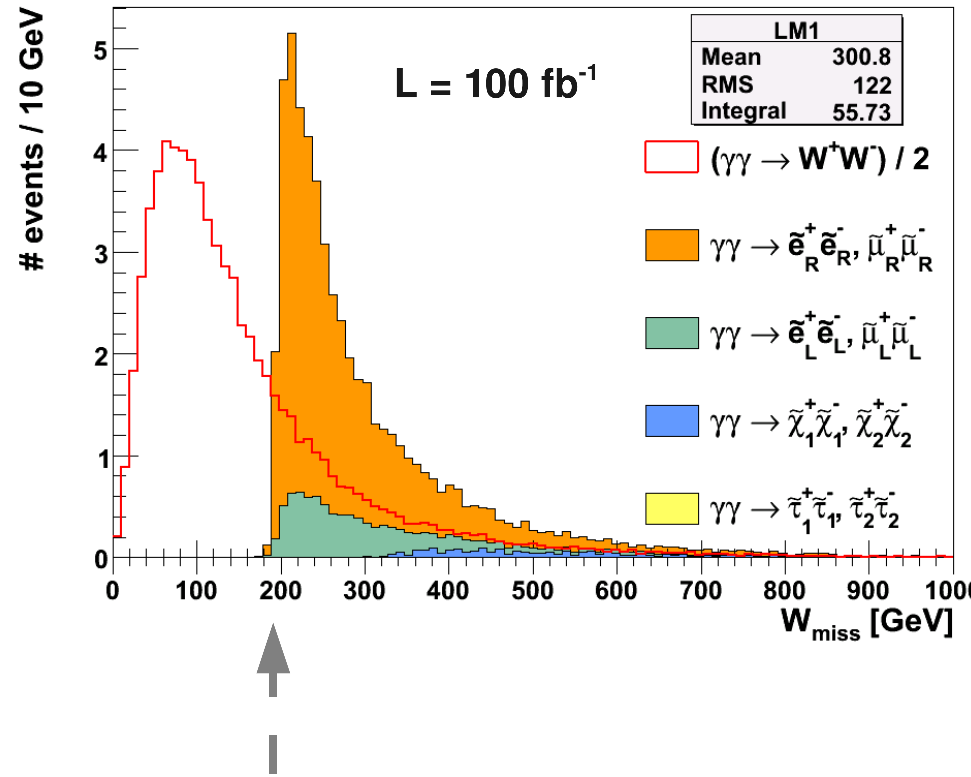
ee/μμ pairs only

σ(LM1 signal) = 2.23 fb --> σ_{acc}(LM1 signal) = 0.706 fb

σ(WW bkg) = 108.5 fb --> σ_{acc}(WW bkg) = 3.368 fb

$\gamma\gamma$ / missing invariant mass





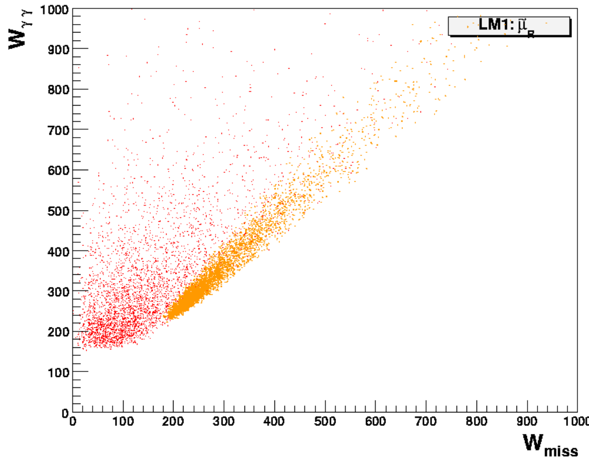
- Mass edge study can give first hints of left and right slepton masses
- SUSY scenarios could be constrained

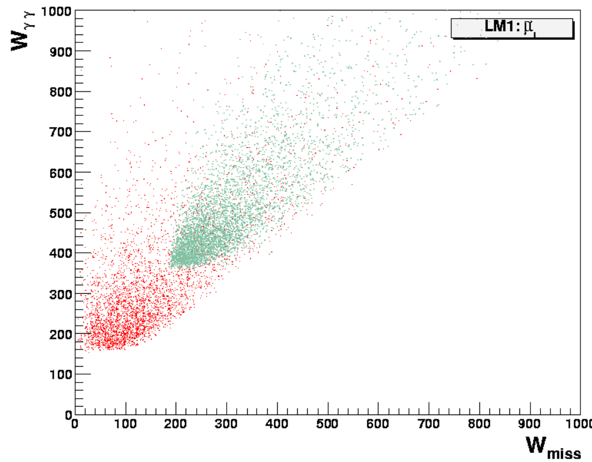
- Mass edge study can provide Lightest Susy Particle mass
- SUSY scenarios could be constrained

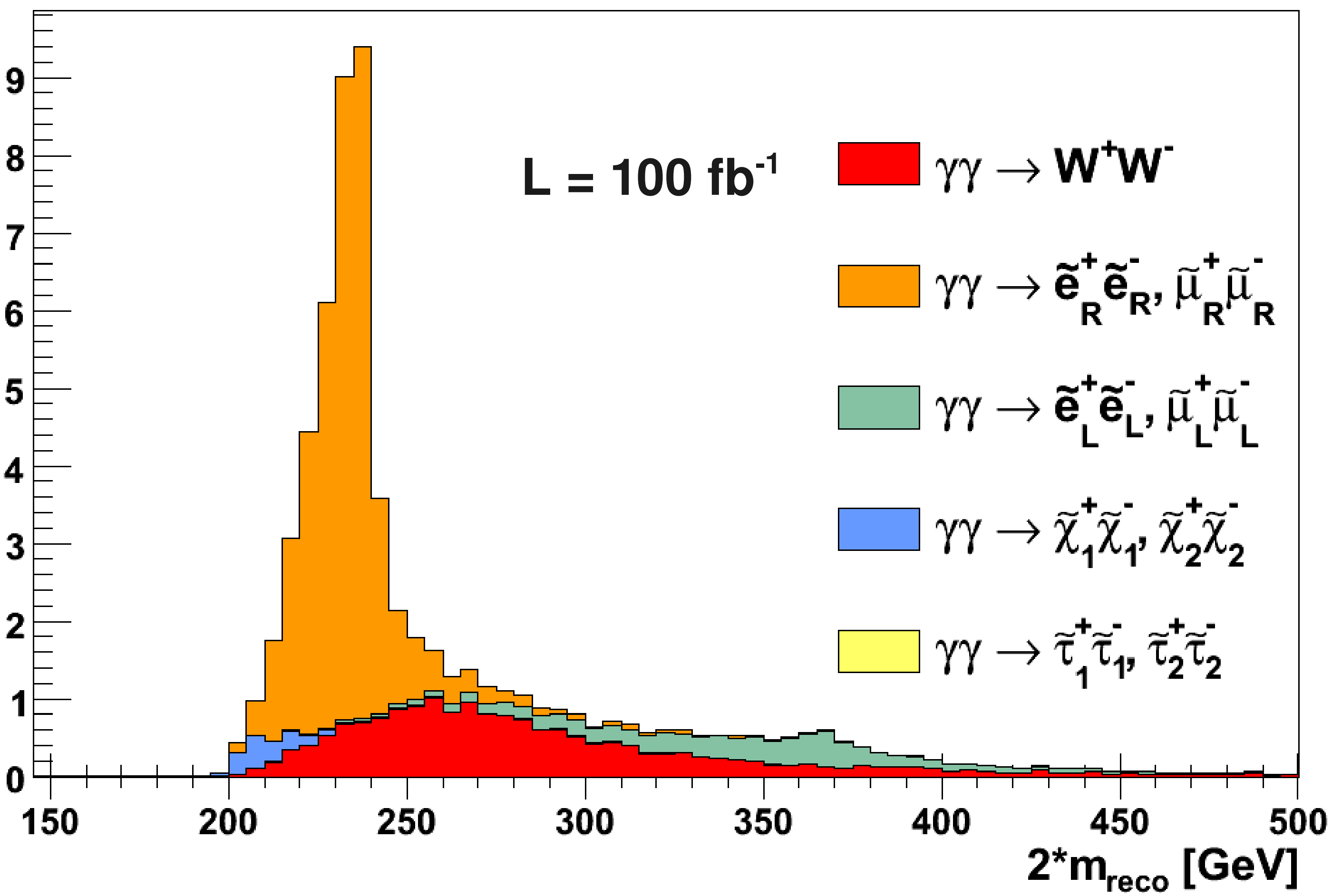
- Cuts on $W_{\gamma\gamma}$ and W_{miss} will provide large background rejection from exclusive WW

Reconstructed mass

$$(2m)^2 = W_{\gamma\gamma}^2 - \left([W_{miss}^2 - 4m_{\tilde{\chi}_1^0}^2]^{1/2} + [W_{lep}^2 - 4m_{lep}^2]^{1/2} \right)^2$$



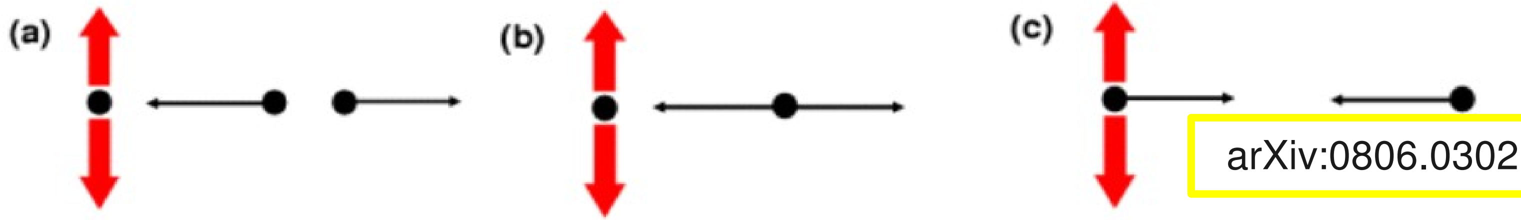




==> Mass determination with few GeV resolution for right selectron and smuon

Accidental coincidence

Additionnal background arises from **accidental coincidence** where the detected system X in the central detector and the forward protons in VFD do not come from the same vertex.



arXiv:0806.0302

At the LHC, **<$N_{pile-up}$>** is 3.63 events for $\mathcal{L} = 2{*}10^{33}$ cm^{-2} s^{-1} Poisson distributed

19.18 events for $\mathcal{L} = 1{*}10^{34}$ cm^{-2} s^{-1}

Fake hits in FP420 and FP240 detectors rate is 1.7% / minimum bias in FP420

2.4% / minimum bias in FP240

because of single diffraction (MUSB 92-93) and low p_T production (MSUB 95) events

New **inclusive backgrounds** to take into account are :

WW	σ =	7.4×10^3 fb*
ZZ		1.1×10^4 fb
drell-yan		1.3×10^7 fb**

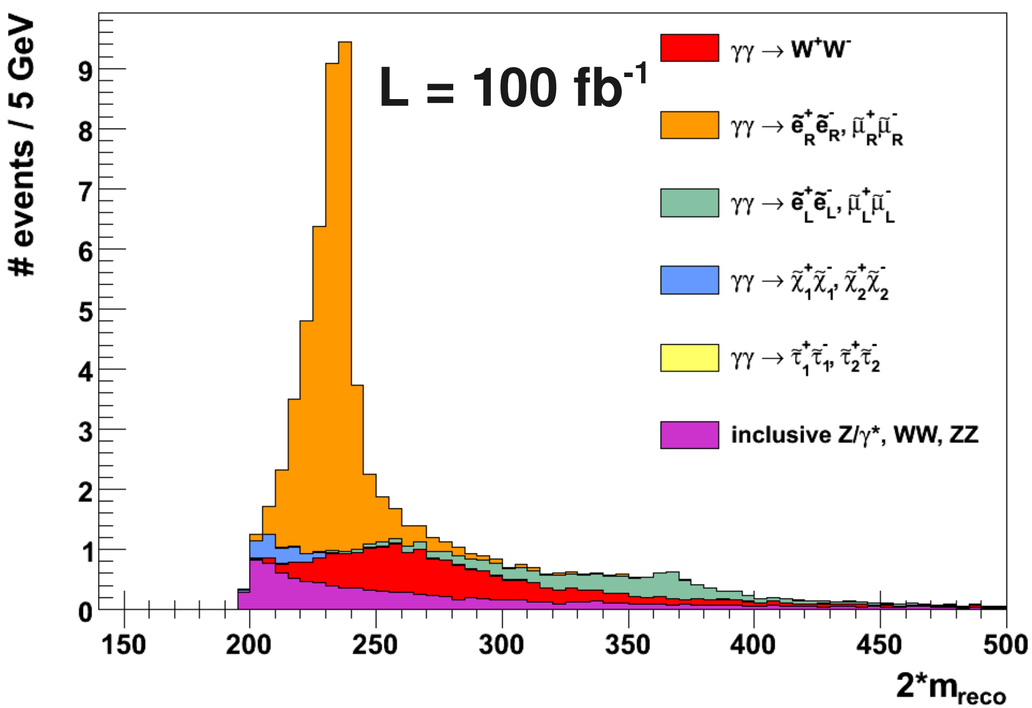
* = only leptonic decay ** = with sqrt(s) > 14 GeV

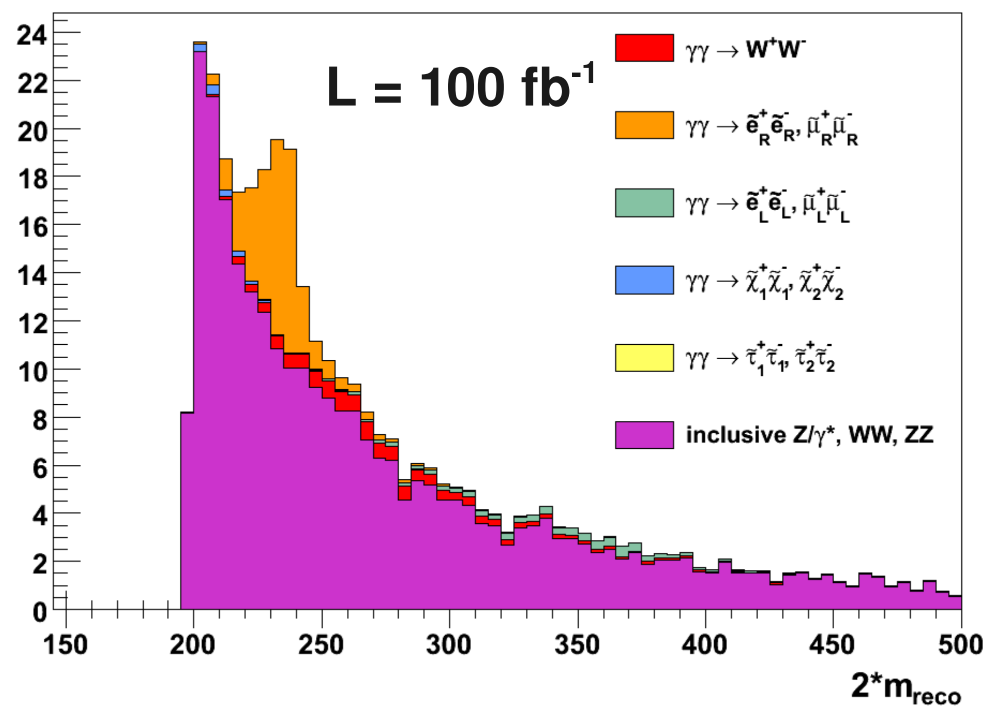
Accidental coincidence

Exclusivity conditions can further reduce the inclusive pp-induced background

<u>No extra track</u> with pT > 0.5 GeV

$\mathcal{L} = 2*10^{33}\ cm^{-2}\ s^{-1}$ (88 < W_{lep} < 94 GeV) $\mathcal{L} = 1*10^{34}\ cm^{-2}\ s^{-1}$





In order to further reduce inclusive contributions, **Timing detectors**, capable to measure the difference in the time arrival of the 2 protons with **few ps resolution** are mandatory

Conclusion

Two-photon physics offer a complementary way to study new physic:

--> Detection of sleptons (with N_s = 47 and N_{WW} = 18 after 100 fb-1)

--> Constraint the MSSM plane (for low mass scenario)

--> Measure mass of the LSP

--> Measure mass of light SUSY charged particles (resolution of few GeV)

--> ...

The detection of scattered protons gives us lot of information about the event kinematics.

Track-based exclusivity conditions can be use can reduce accidental coincidence background at « low » luminosity, but timing detectors are needed for higher luminosities.