Two-photon exclusive production of supersymmetric pairs at the LHC

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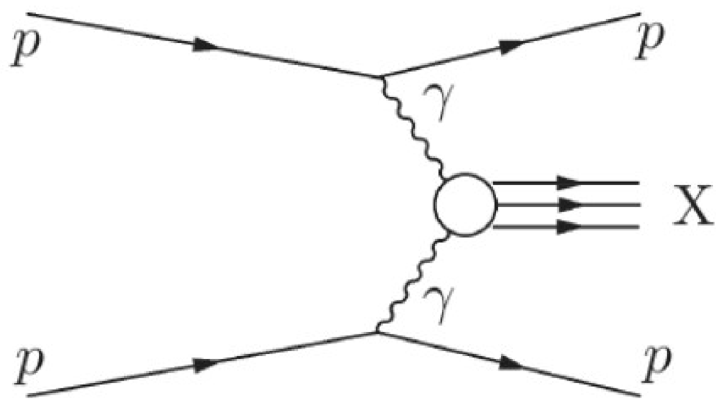
OUTLINE:

1. Detection of exclusive SUSY pairs
2. Use of HPS for precise mass reconstruction
3. Overlap events and accidental coincidence background
4. Exclusivity conditions and timing detectors
5. Pileup effect

LHC is a γγ collider



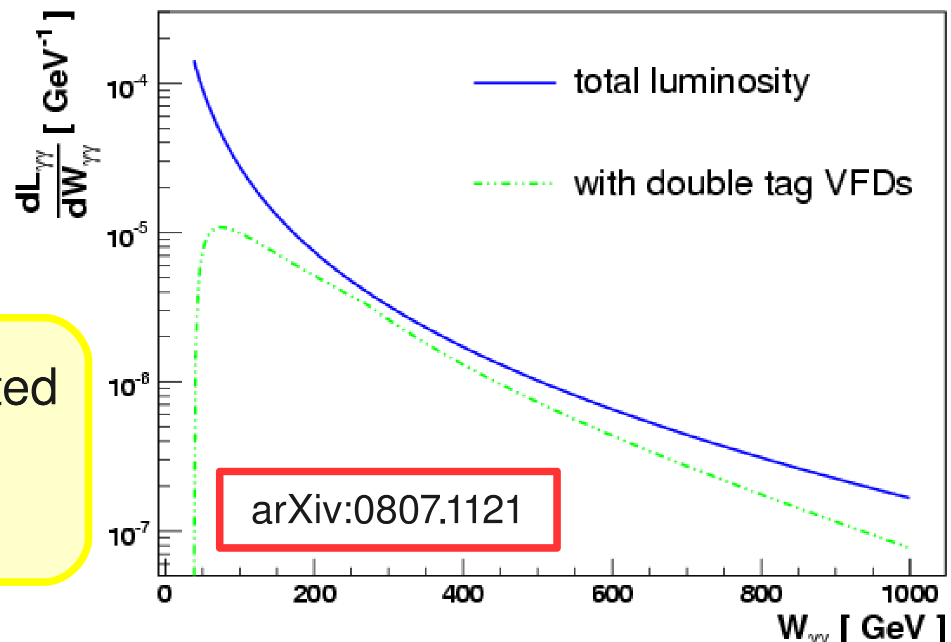
Striking experimental signatures for events involving photon exchanges:

- **2 very forward scattered protons**
- **large rapidity gap in forward regions**
- **in general, a few particles produced**

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.



LHC is a $\gamma\gamma$ collider

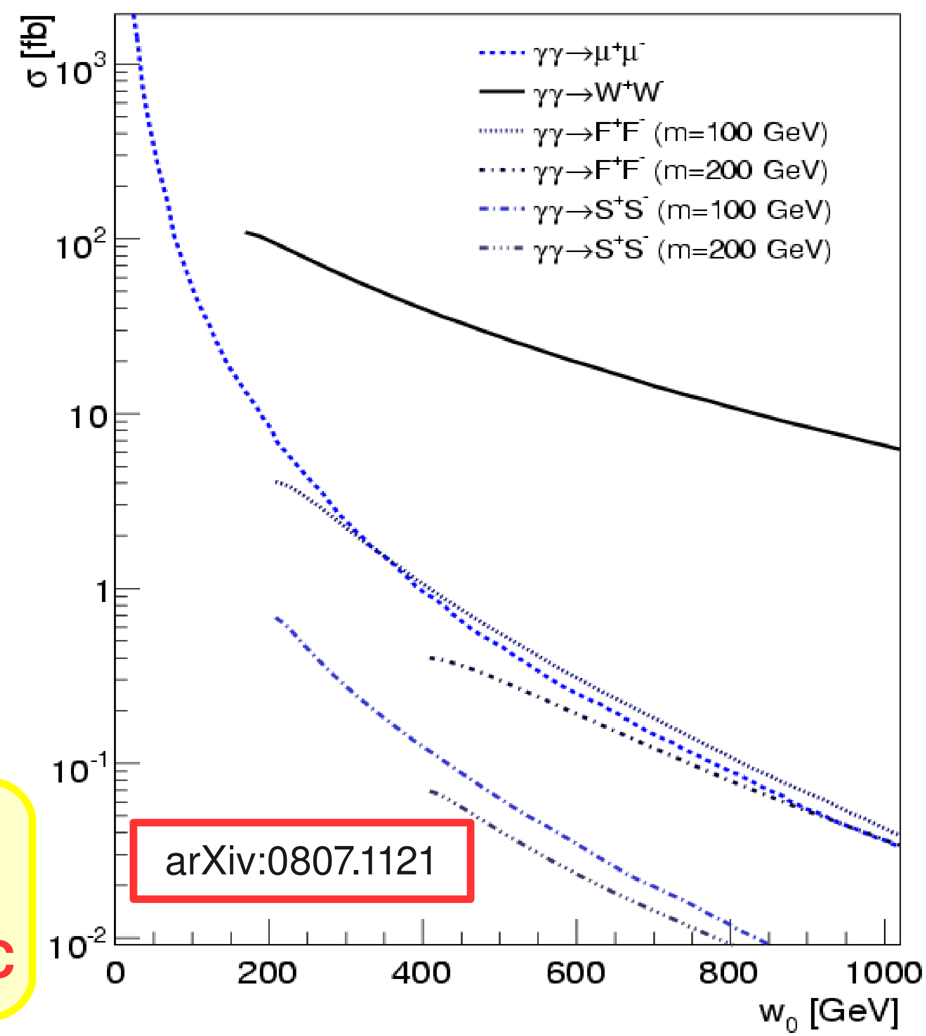
Pair production of *non-strongly interacting* **charged** particles is the most interesting production channel :

- Significant cross-sections. Ex:

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

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

- Since low Q^2 photons are exchanged
  --> high survival probabilities, little re-scattering
  --> good control on the cross-section



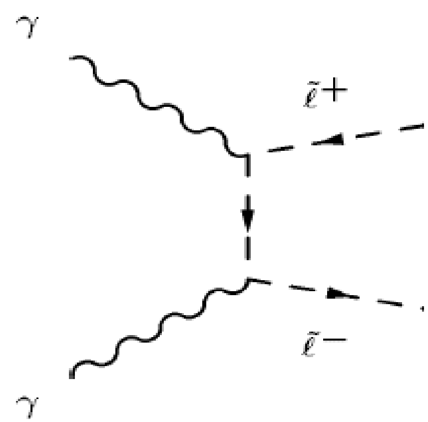
Provided efficient measurements of the very forward protons, one can study **high-energy photon interactions at the LHC**

Complementarity physics to *pp* interactions
=> high-energy $\gamma\gamma$ physics (BSM ?)

In $\gamma\gamma$ collisions, low-mass supersymmetry production is of interest of study.
As an example, **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)

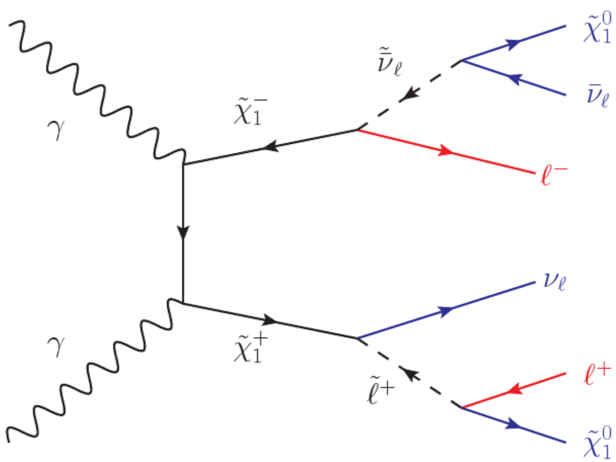
Slepton right:	$\sim e_R^+$, $\sim \mu_R^+$	118 GeV
Slepton left:	$\sim e_L^+$, $\sim \mu_L^+$	187 GeV
Stau :	$\sim \tau_1^+$, $\sim \tau_2^+$	111 , 190 GeV
Chargino :	$\sim \chi_1^+$, $\sim \chi_2^+$	178 , 360 GeV
Higgs :	H^+	381 GeV
Neutralino :	$\sim \chi^0_{1->4}$	96 -> 369 GeV

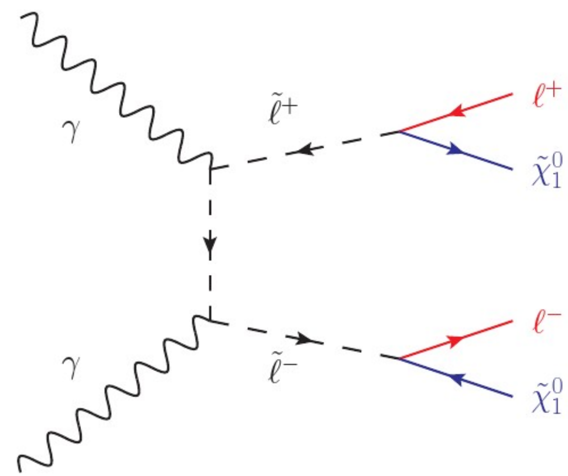


--> σ(LM1) = 2.23 fb

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:

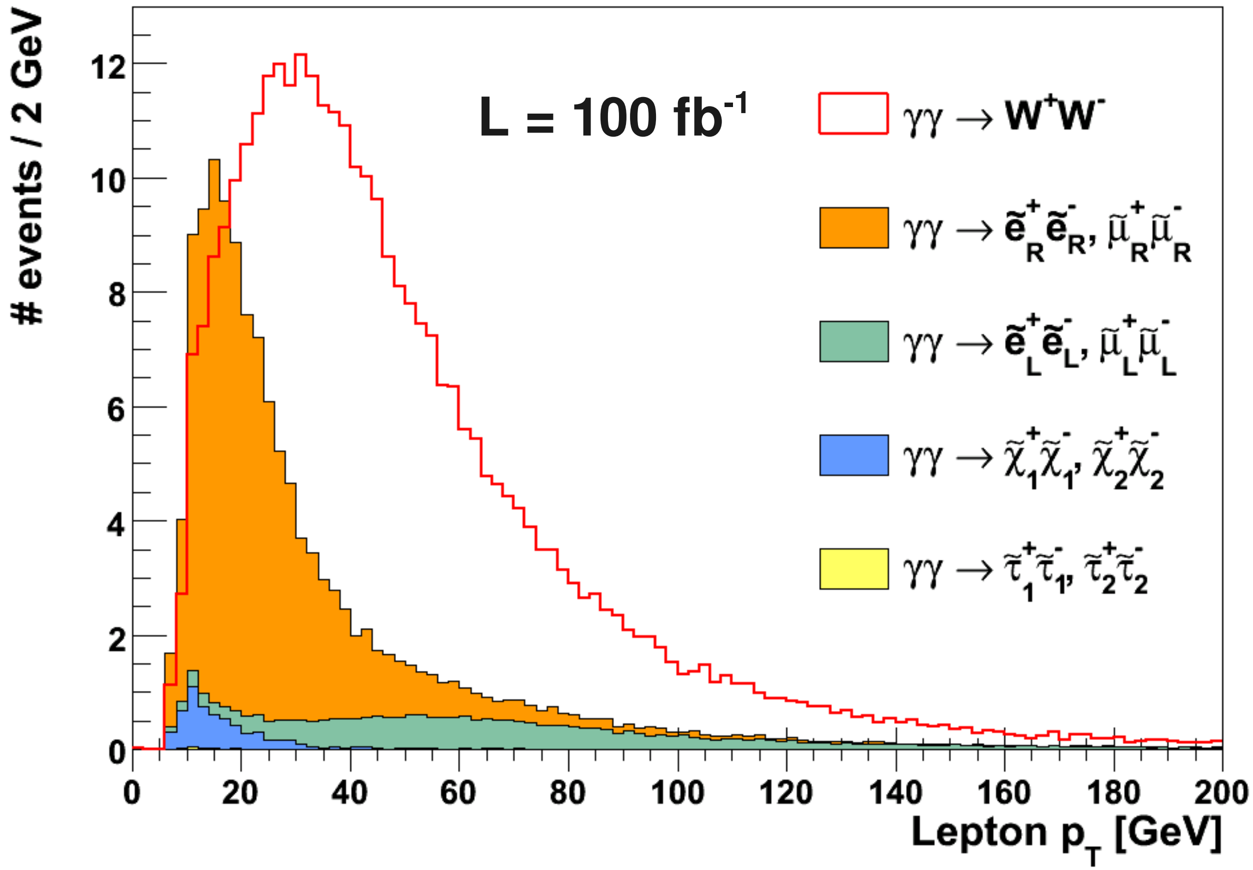
Can tag lepton-tau using **transverse vertex** position (ε = 65% for 1mm)

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

are suppressed using E_{mis} and acoplanarity cut.

Detection of exclusive susy pairs

Dileptonic (Very clean) final state:
~~2 fwd protons~~ **+** 2 isolated leptons **+** missing energy + acoplanarity



Using CalcHEP or MadGraph generator + modified Pythia

Acceptance cuts:

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

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

$|\eta| < 2.5$

vtxT < 1mm

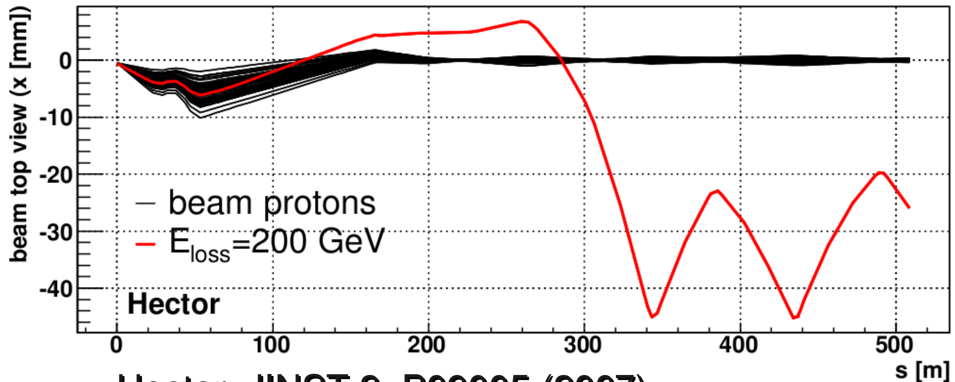
ee/μμ pairs only

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

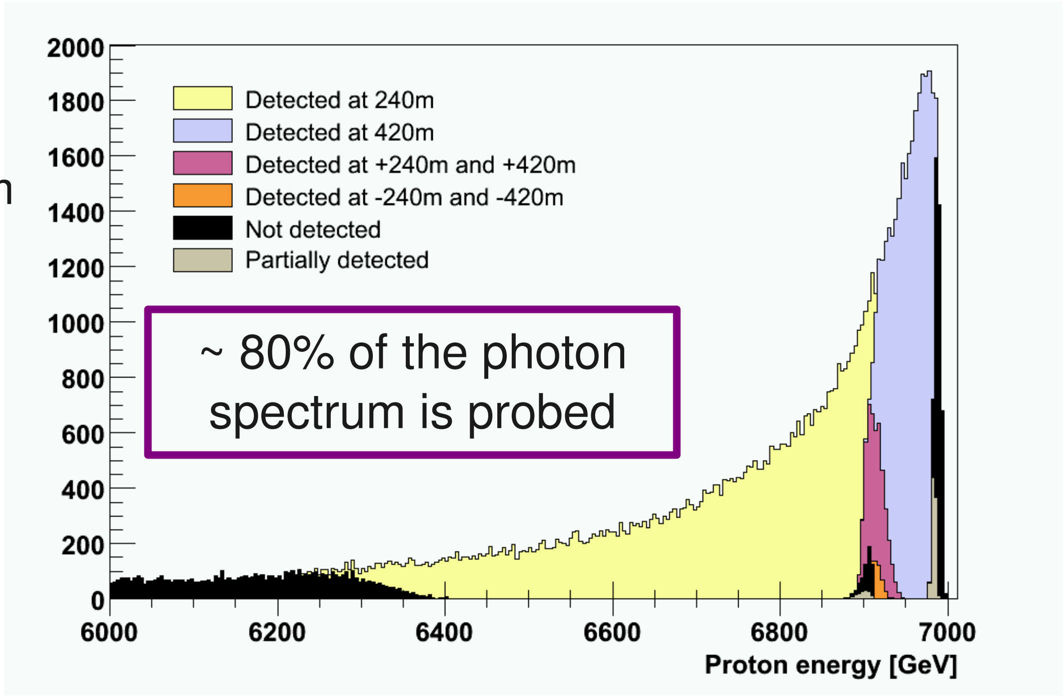
σ(WW bkg) = 108.5 fb --> σ_{acc}(WW bkg) = 1.828 fb

Proton spectrometers (HPS / FP420):

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



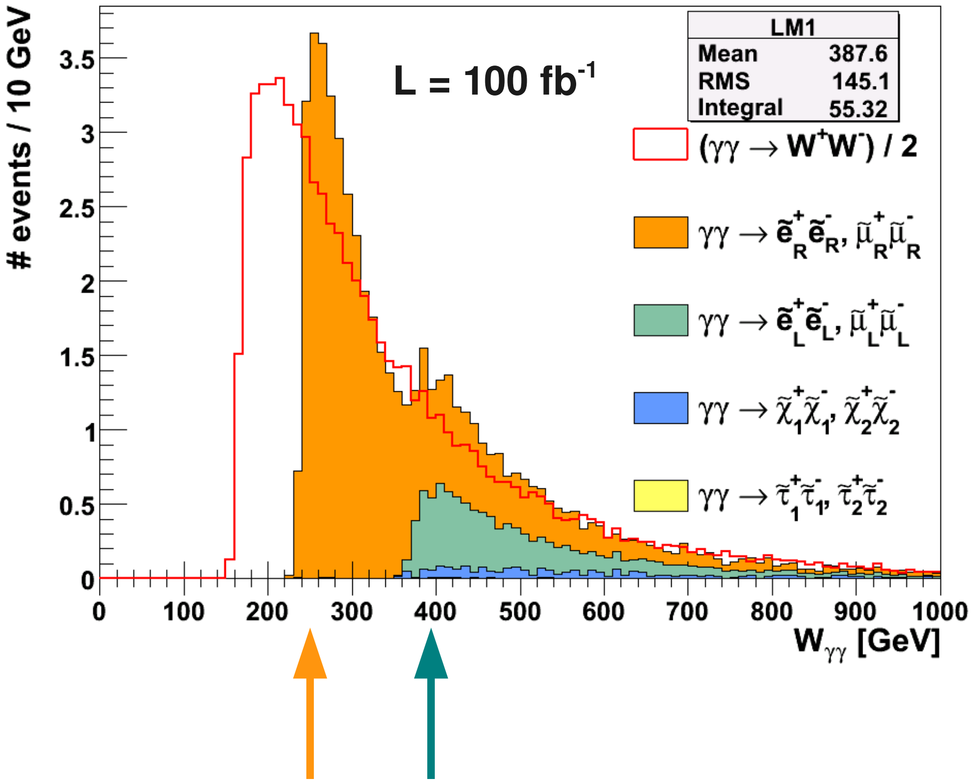
Hector, JINST 2, P09005 (2007)

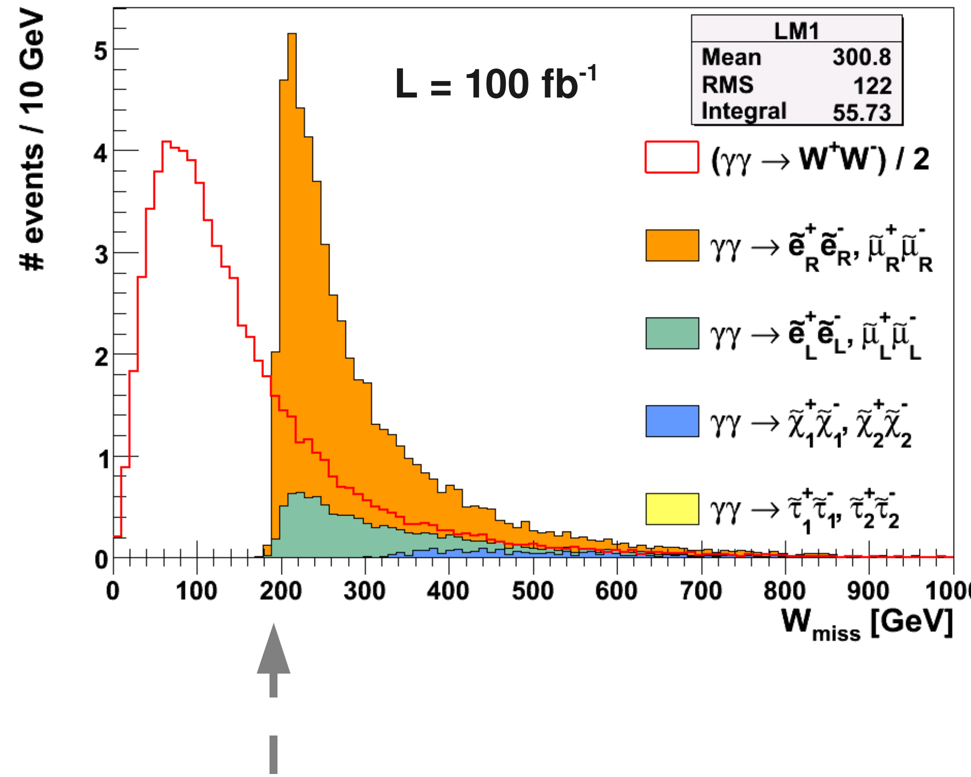


With dedicated proton detectors placed at ±**420m** and ±**240m** from the IP, one can:

* tag photon interactions
* reconstruct photon energy with (approximated) energy resolution of $max(E_\gamma/100, 1.5\text{ GeV})$
* reconstruct the initial conditions of the event $W_{\gamma\gamma} = 2\sqrt{E_{\gamma_1} E_{\gamma_2}}$
* reconstruct the missing energy $E_{miss} = E_{\gamma_1} + E_{\gamma_2} - E_{\ell_1} - E_{\ell_2}$

γγ / missing invariant mass





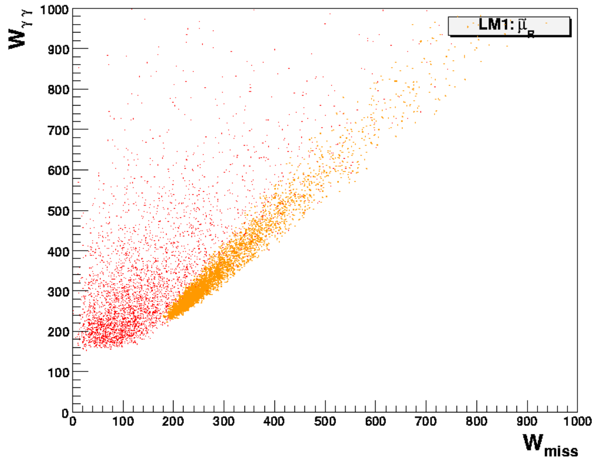
- Mass edge study can give first hints of left and right slepton masses
- SUSY scenarios could be constrained

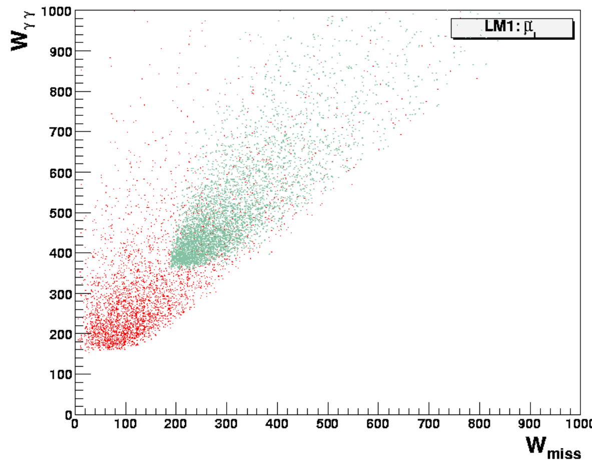
- Mass edge study can provide Lightest Susy Particle mass
- SUSY scenarios could be constrained

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

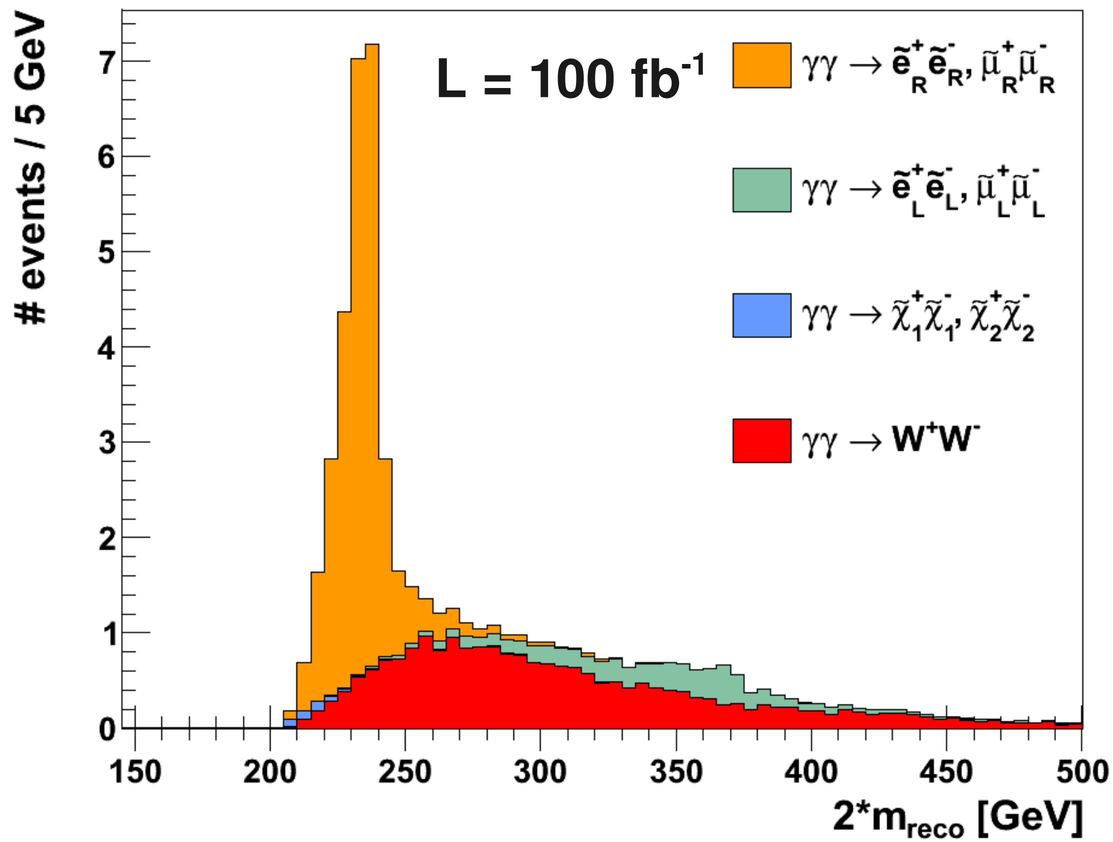
Reconstructed mass

Applying cuts:
- W_{miss} > 194GeV and $W_{\gamma\gamma}$ > 236 GeV
- $|\Delta pT|$ > 1.5 GeV and $|\Delta\phi|/\pi < 0.9$





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

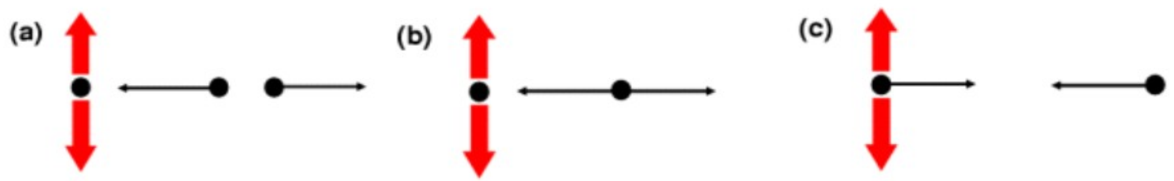


==> Mass determination with few GeV resolution for right-handed selectron and smuon

Accidental coincidence

Sensitive to fb-level cross-sections ==> high luminosity runs ==> Overlap events

Additional background arises from **accidental coincidence** where the detected system X in the central detector and the forward protons in HPS do not come from the same vertex :



At the LHC, **<$N_{pile\text{-}up}$>** is	~5 events	for $\mathcal{L} = 2*10^{33}$ cm^{-2} s^{-1}	*Poisson* distributed
	~25 events	for $\mathcal{L} = 1*10^{34}$ cm^{-2} s^{-1}	

Accidental coincidence

Assuming FP420 @ 4mm and FP240 @ 2mm from beamline

* **Single diffraction** (pp->Xp, pp->pX)

σ = 14.30 mb

ε_{FP240} = 16%

ε_{FP420} = 12%

* **Double diffraction** (pp->XY)

σ = 10.21 mb

ε_{FP240} = 3%

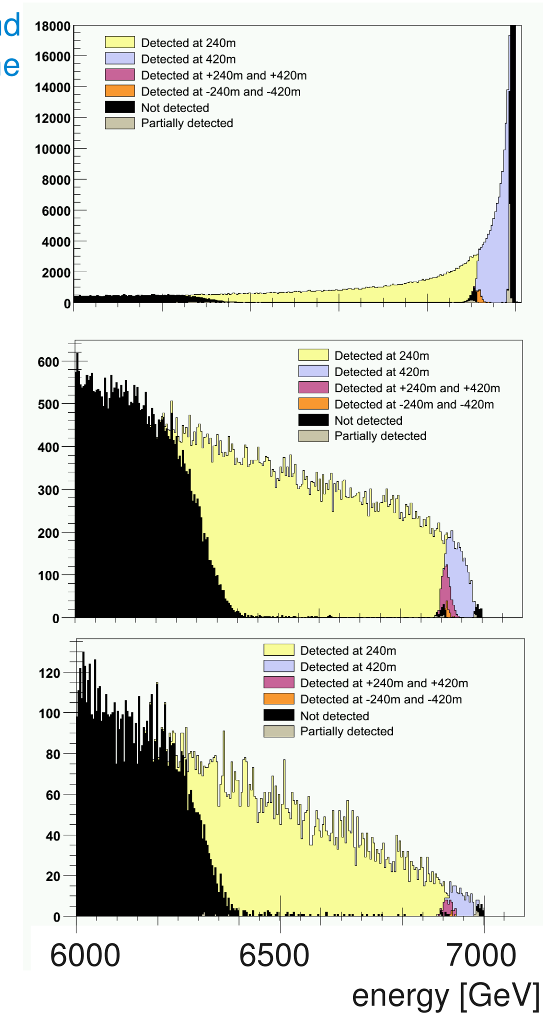
ε_{FP420} = 0.15%

* **Non-Diffractive inelastic** (pp->X)

σ = 54.71 mb

ε_{FP240} = 0.65%

ε_{FP420} = 0.02%



==> Global: **$\langle\varepsilon_{FP420}\rangle$= 1.84%** **$\langle\varepsilon_{FP240}\rangle$= 3.76%** of MinBias events

==>Probability to have 2 accidental proton hits (one on each side) is:
1,19% for 'low' lumi **23,81% for 'high' lumi**

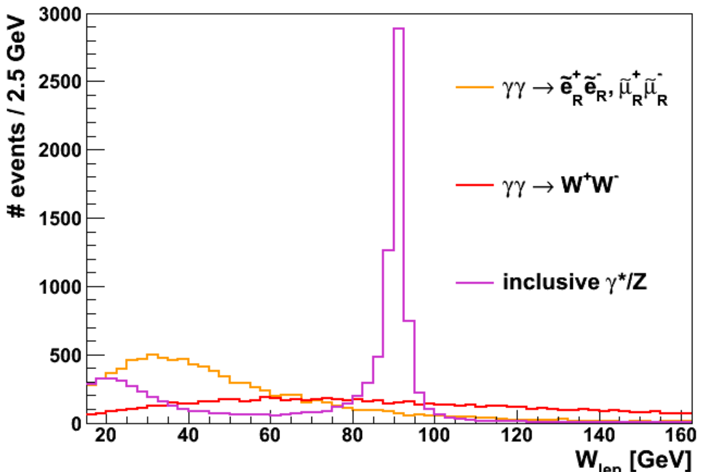
Accidental coincidence

==>Probability to have 2 accidental proton hits (one on each side) is:
1,19% for 'low' lumi **23,81% for 'high' lumi**

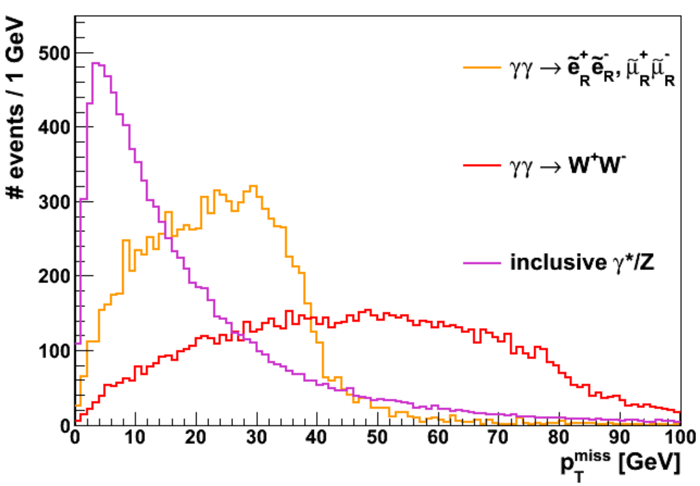
Inclusive background:

W^+W^- :	$\sigma = 7.37 \times 10^3$ fb	*$W^+ \rightarrow l^+\nu$ only*
ZZ :	$\sigma = 1.11 \times 10^4$ fb	
Z/γ^* :	$\sigma = 1.32 \times 10^7$ fb	*sqrt($\hat{s}$) > 14 GeV*

-> Drell-Yan contribution reduced cutting on W_{lep} (Z) and p_T^{miss} (γ^*) computed with information from the central lepton only:



$W_{lep} \notin$ [87 GeV, 95 GeV]



p_T^{miss} > 10 GeV

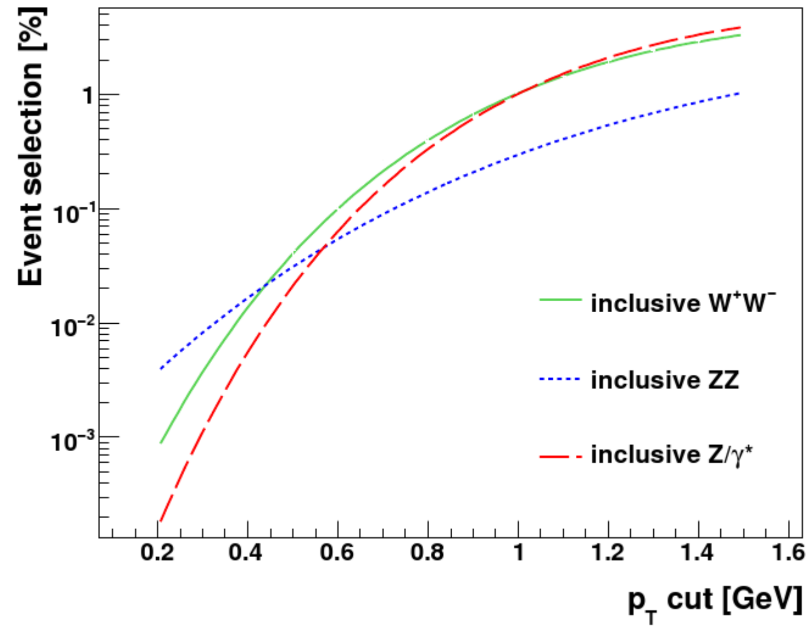
Accidental coincidence

--> Exclusivity conditions:

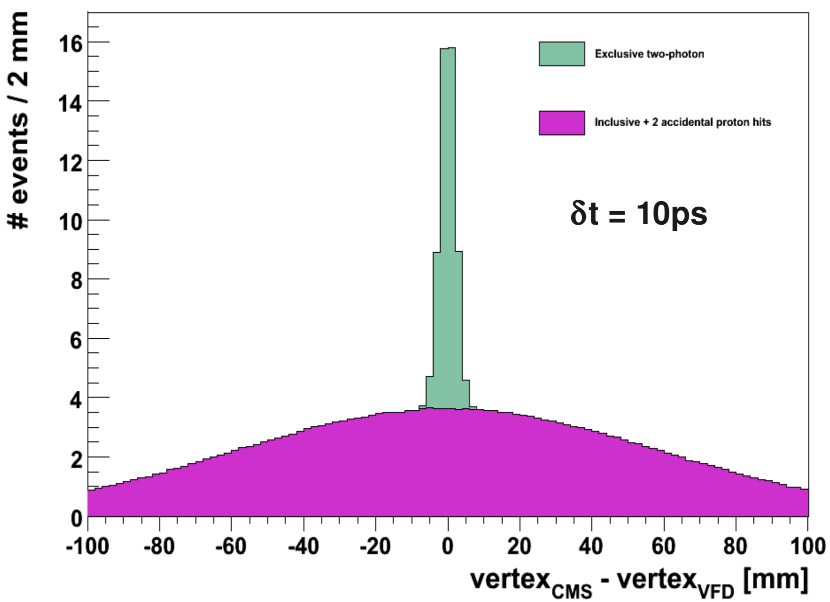
In general, number of tracks associated to the central vtx is much smaller in exclusive events than in inclusive ones.

No extra track with p_T > 0.5 GeV

--> strongly dependent on multiple interaction on/off



--> Proton time of arrival:



We can measure the *relative* time arrival:

$$\Delta t = \frac{L+z}{c} - \frac{L-z}{c} = \frac{2z}{c}$$

and request a matching between the reconstructed *pp* vertex and the central vertex

A timing resolution δt = 10ps leads to δz_{pp} = 2.1mm

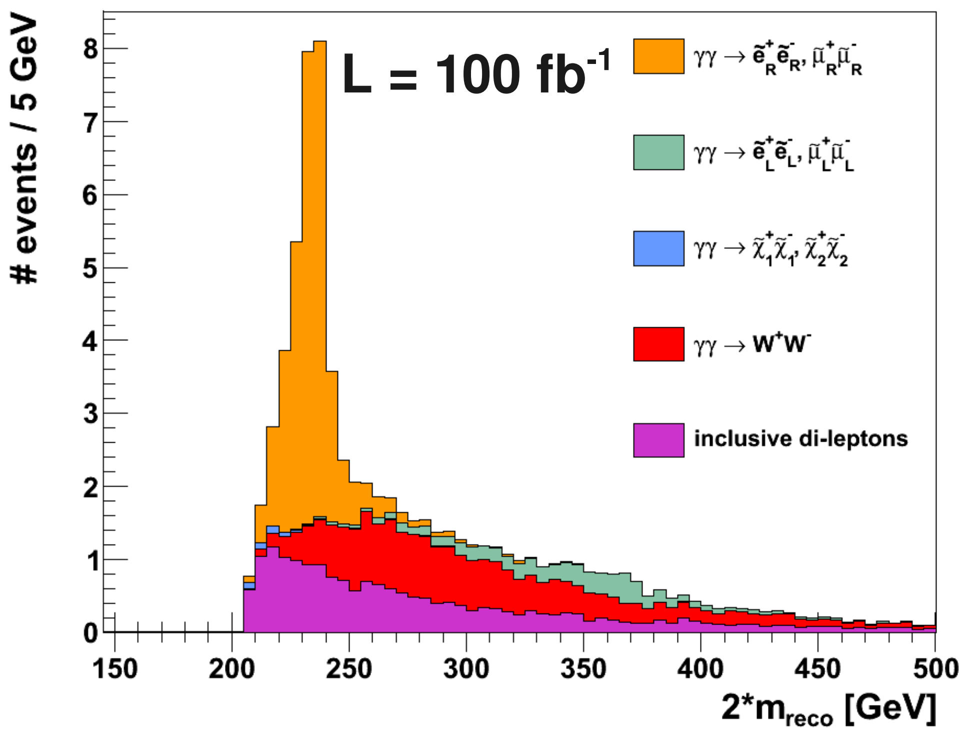
==> Ex: ±1.5 δz_{pp} range will select 87% of signal

4% of bkg

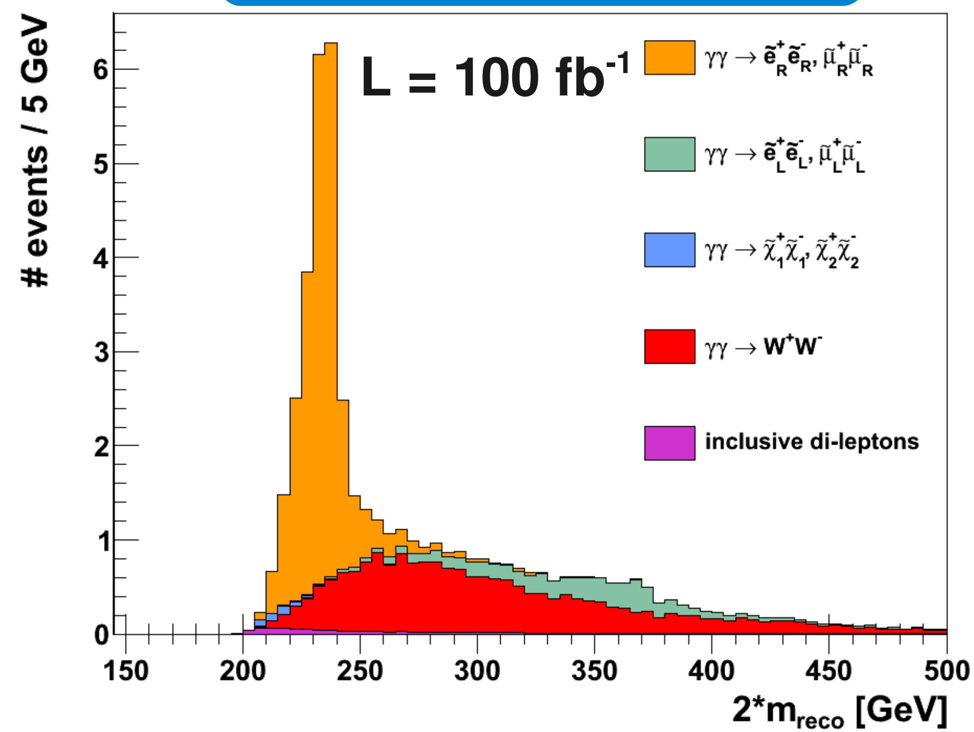
Reconstructed mass

For « low » luminosity: $\mathcal{L} = 2{*}10^{33}\ cm^{-2}\ s^{-1}$ $\langle N_{pile\text{-}up} \rangle$ is ~5 events

--> Exclusivity conditions:



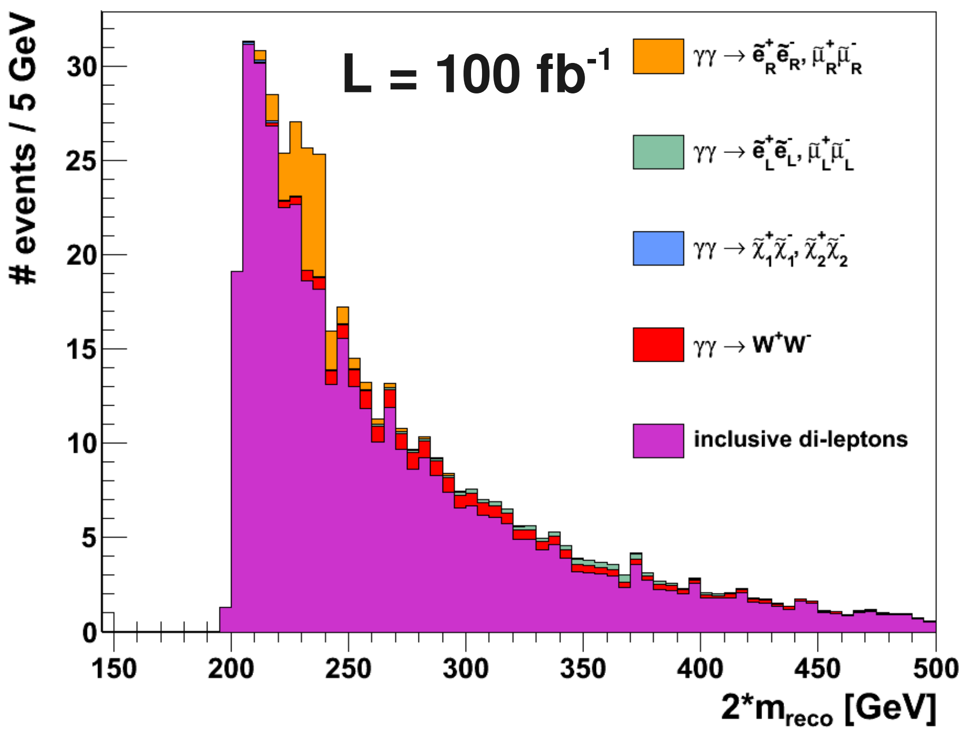
--> Exclusivity conditions + 10ps timing detector:



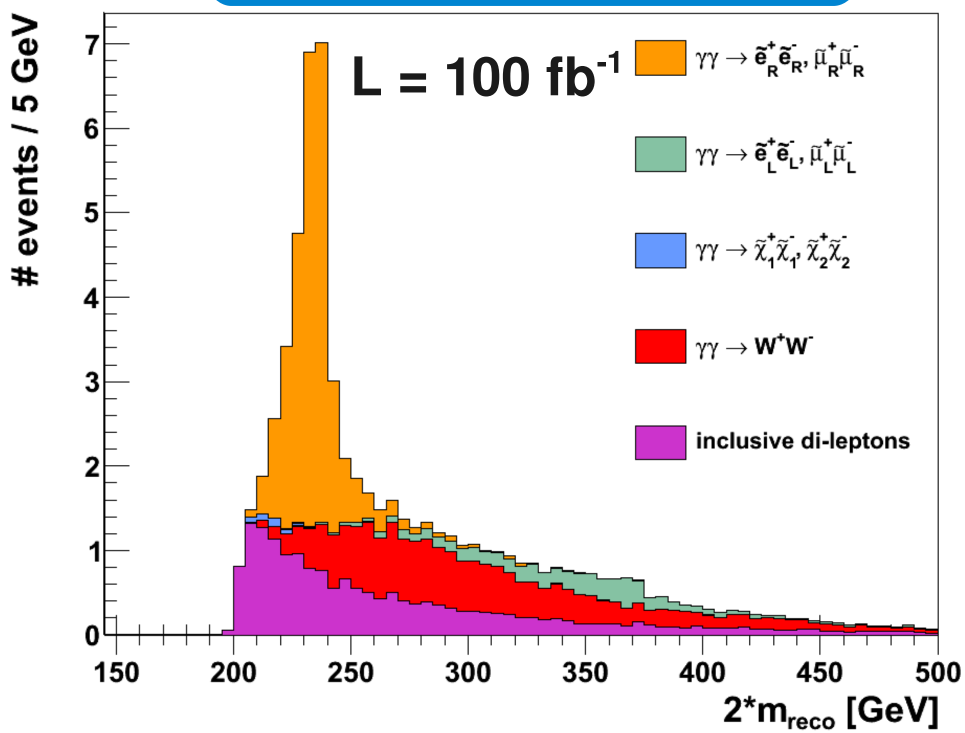
Reconstructed mass

For « high » luminosity: $\mathcal{L} = 1*10^{34}\ cm^{-2}\ s^{-1}$ $<N_{pile-up}>$ is ~25 events

--> Exclusivity conditions:



--> Exclusivity conditions + 10ps timing detector:



Conclusion

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

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

--> Constrain SUSY scenarios (for low mass scenario)

--> Measure mass of the LSP

--> Measure mass of light SUSY charged particles

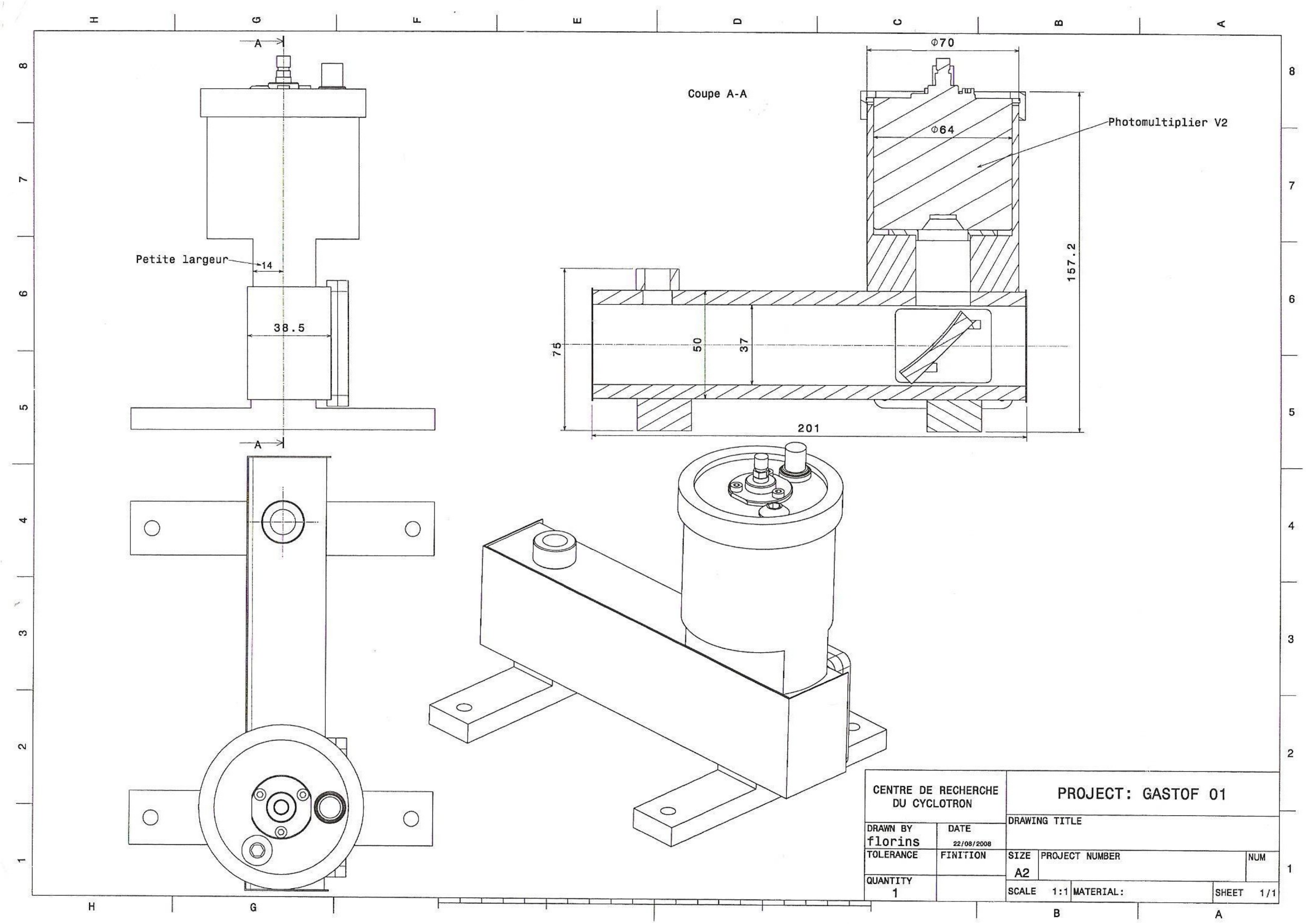
} (resolution of few GeV)

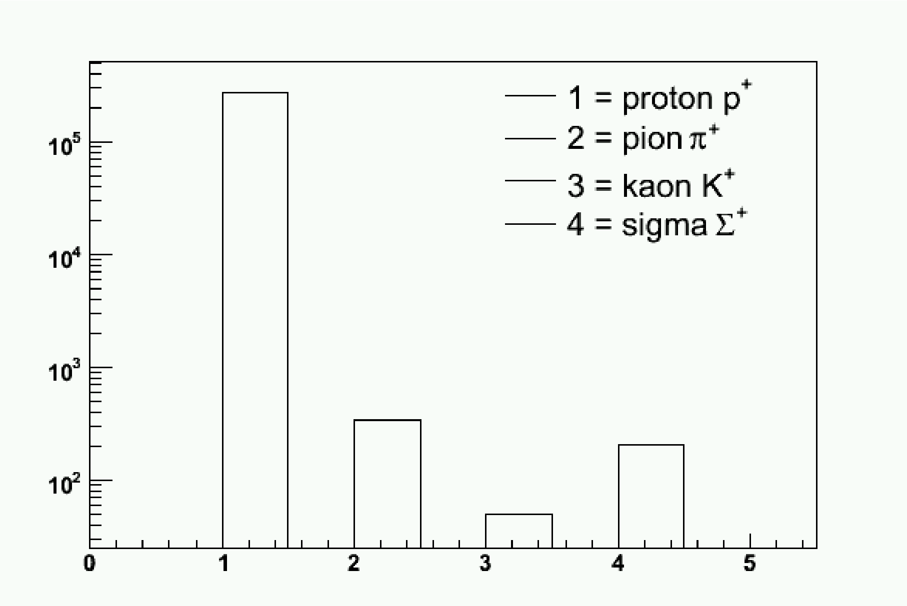
--> ...

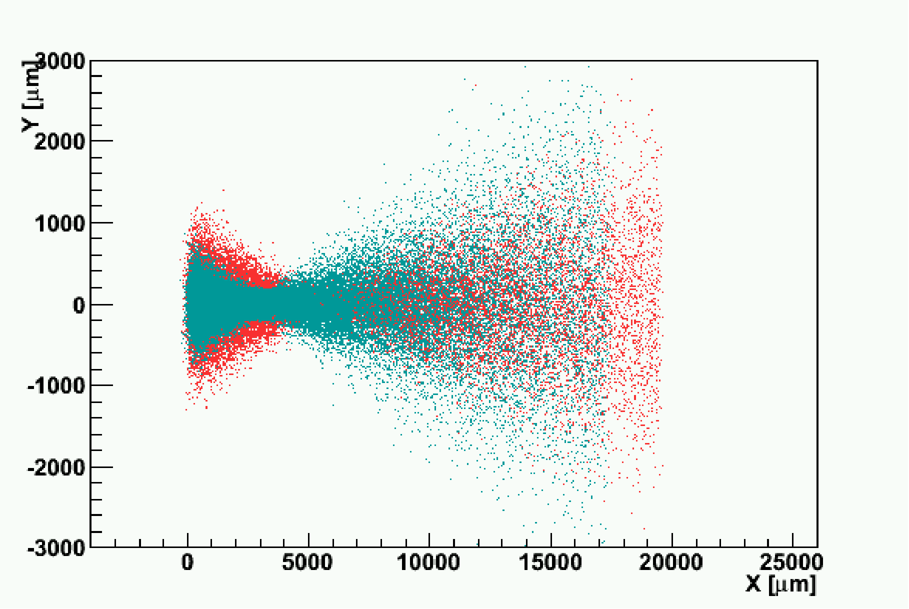
The detection of scattered protons provides a lot of information about the event kinematics.

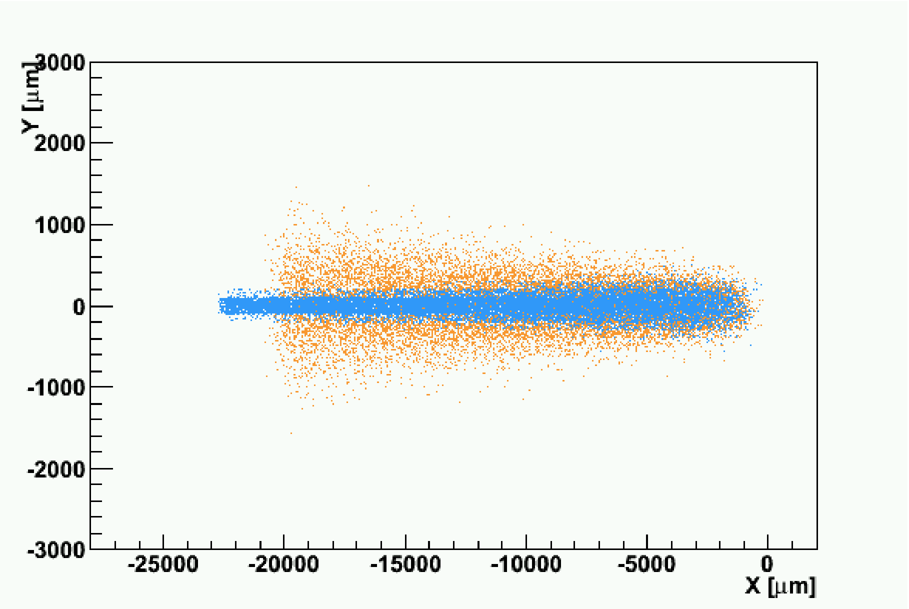
Track-based exclusivity conditions can be use can reduce accidental coincidence background at « low » luminosity, but timing detectors are needed for higher luminosities.

Backup


A
Petite largeur
14
38.5
A
Coupe A-A
Φ70
Φ64
Photomultiplier V2
157.2
75
50
37
201
CENTRE DE RECHERCHE DU CYCLOTRON
PROJECT: GASTOF 01
DRAWN BY florins
DATE 22/08/2008
DRAWING TITLE
TOLERANCE
FINITION
SIZE A2
PROJECT NUMBER
NUM
QUANTITY 1
SCALE 1:1
MATERIAL:
SHEET 1/1

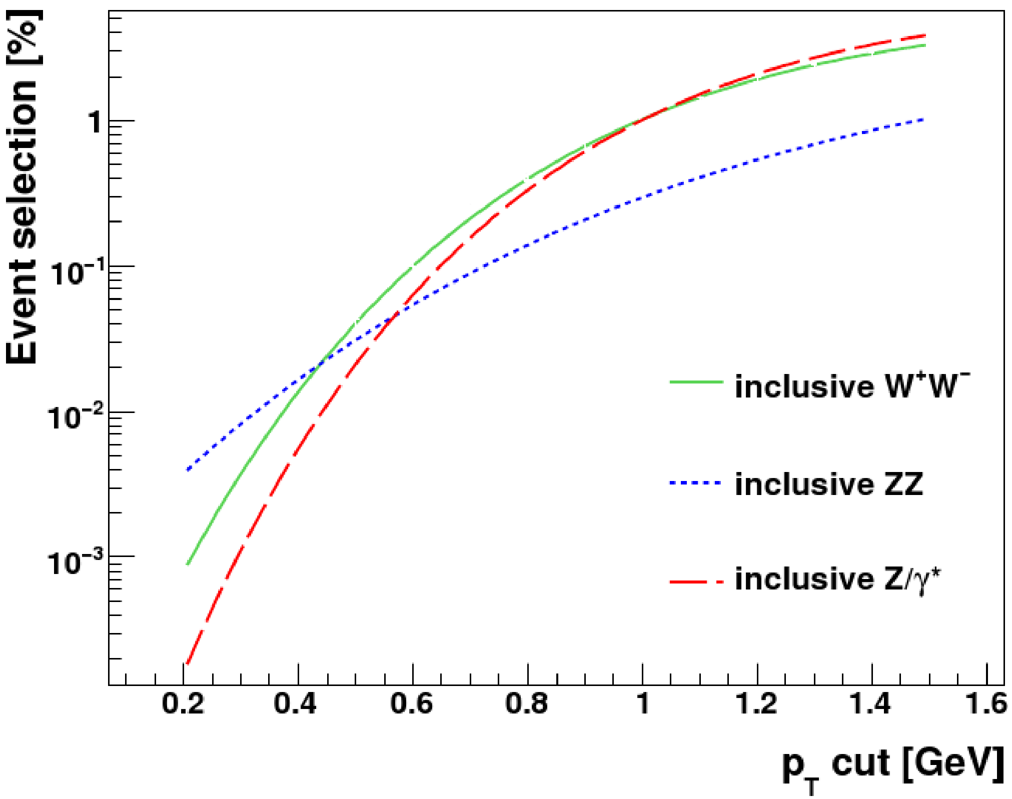

1 = proton p^+
2 = pion π^+
3 = kaon K^+
4 = sigma Σ^+


Y [µm]
X [µm]


Y [µm]
X [µm]

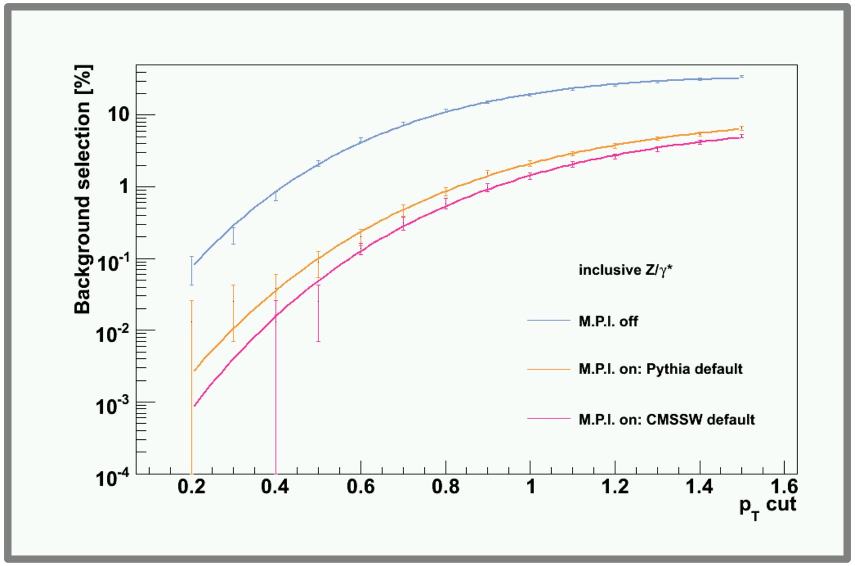
Accidental coincidence

--> Exclusivity conditions:



Rejection factor is ~4'500 for DY ...!
~3'000 for ZZ
~2'500 for WW

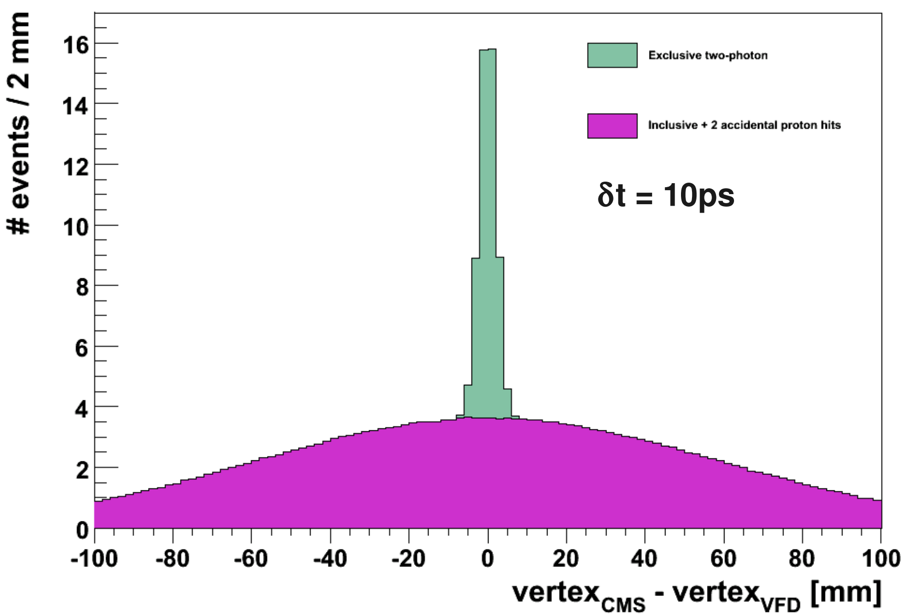
Efficiency of rejection from extra tracks multiplicities is strongly dependent on the Multiple Parton Interaction model under consideration →

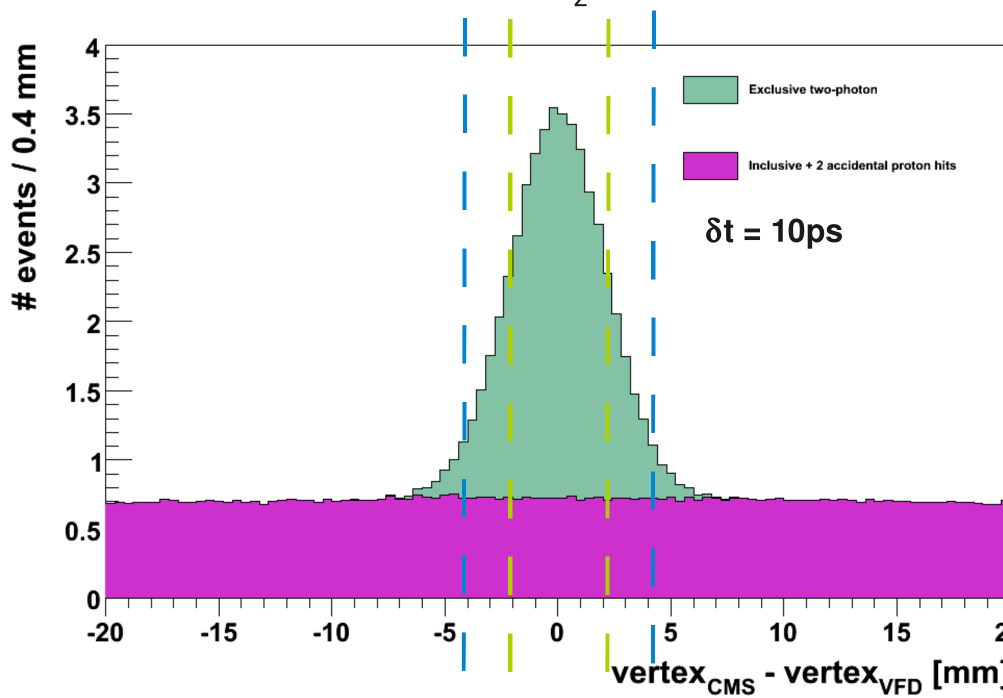


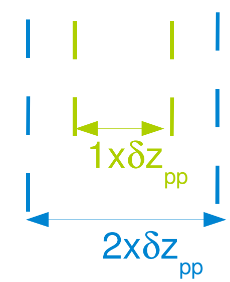
Accidental coincidence

--> Proton time of arrival:

The *N* overlap events are gaussian distributed, within the bunch, with σ_z = 48.2mm







	$\pm 1 \times \delta_{pp}$	$\pm 1.5 \times \delta_{pp}$	$\pm 2 \times \delta_{pp}$
S	68%	87%	95%
B (10ps)	2.8%	4.2%	5.6%
B (20ps)	5.6%	8.4%	11%