New Physics in High Energy Photon Interactions at the LHC

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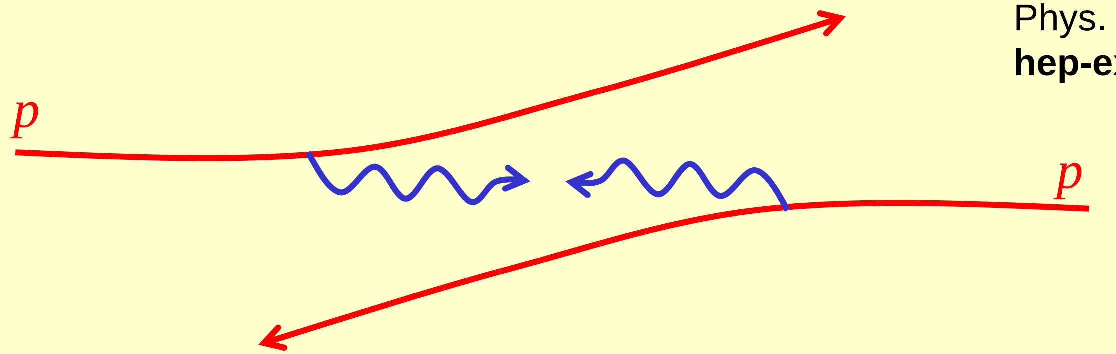
UCL

- LHC as a powerful high energy $\gamma\gamma$ and γp physics lab
- $\gamma\gamma \rightarrow$ WW (ZZ) case
- SUSY and exotica
- γp and top
- Summary/Outlook

LHC as a High Energy γγ Collider

Phys. Rev. **D63** (2001) 071502(R)
hep-ex/0201027



Observation:
Provided <u>efficient</u> measurement of very forward-scattered protons one can study high-energy γγ collisions at the LHC

<u>Highlights</u>:
- **γγ CM energy *W* up to/beyond 1 TeV (and under control)**
- **Large photon flux *F* therefore significant γγ luminosity**
- **Complementary (and clean) physics to *pp* interactions, eg studies of exclusive production of heavy particles might be possible ➡ opens new field high energy γγ (and γp) physics**

<u>DISCLAIMER</u>:

This is <u>NOT</u> meant for studying all photon interactions at the LHC but those for which the QCD background can be strongly suppressed, as for example in the exclusive production of pairs of charged particles.

This <u>IS</u> meant for studying production of *selected* final states in photon interactions at the LHC.

Note: At Tevatron available energy too small for EW physics (but enough for lepton pairs – CDF recently published measurement of exclusive two-photon production of *ee* pairs)

Initial inspiration:

DESY 93–173
UCD–93–39
December 1993

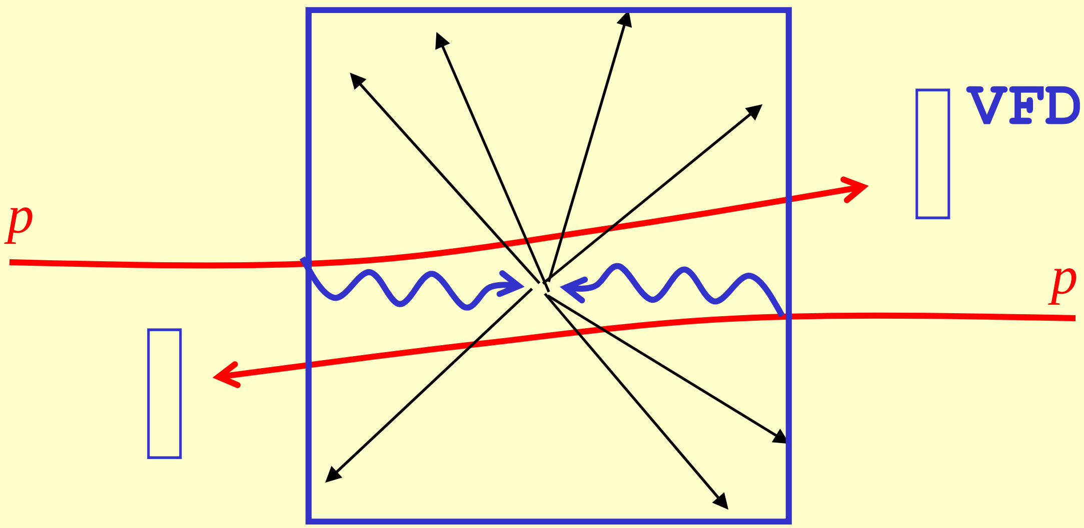
$\gamma\gamma$ PRODUCTION OF NON–STRONGLY INTERACTING

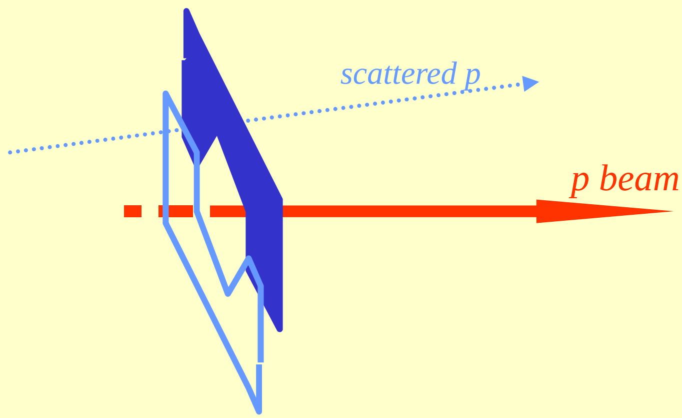
$\mathcal{SUSY}$ PARTICLES AT HADRON COLLIDERS

J. Ohnemus[1], T.F. Walsh[2], and P.M. Zerwas[3]

How measure these events?

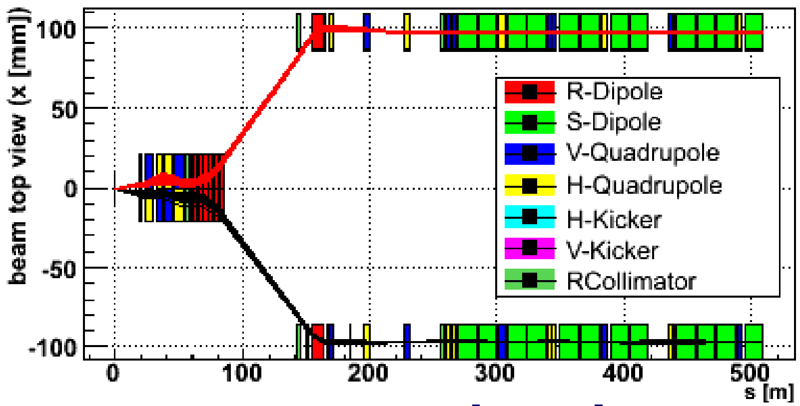
Measure ($\gamma\gamma \rightarrow$) X in the **CMS or ATLAS** detector and scattered protons using **very forward detectors** (thanks to proton energy loss)



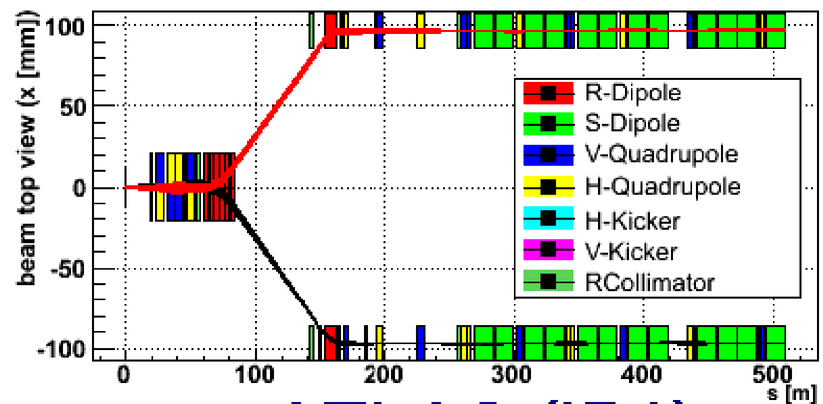


VFDs needed – capable of running at high luminosity, installed as far (> 100 m) from IP and as close to the beam (≥2 mm) as possible – detector proposals under preparation (e.g. by FP420 R&D collab.); expected photon energy resolution of **2–5 GeV !**

Two optimal places found
At 220/240m and 420m from IP:

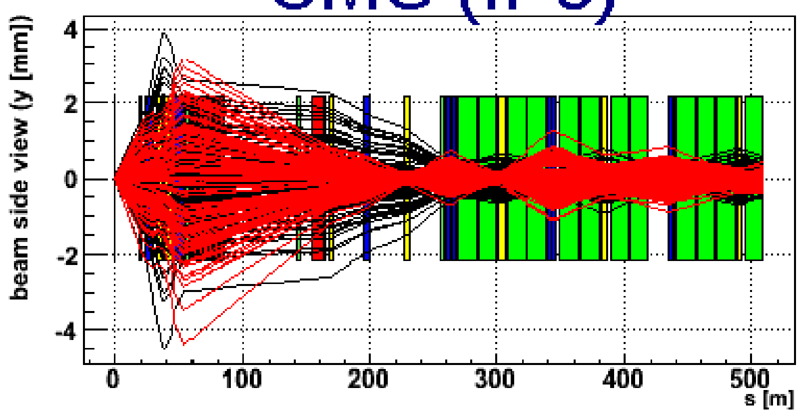


top

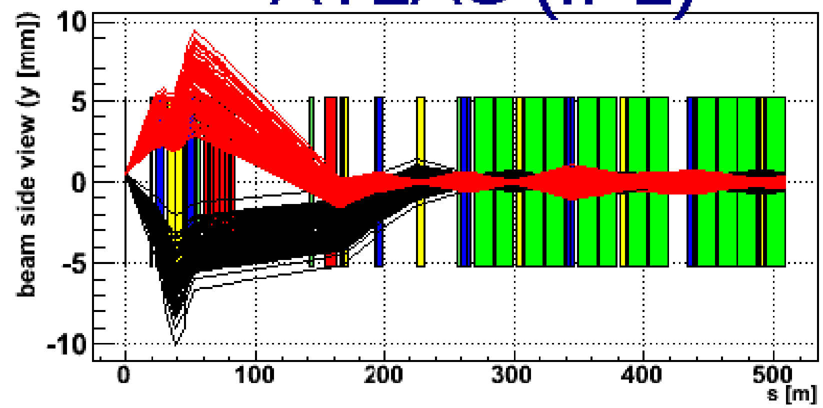


CMS (IP5)

ATLAS (IP1)



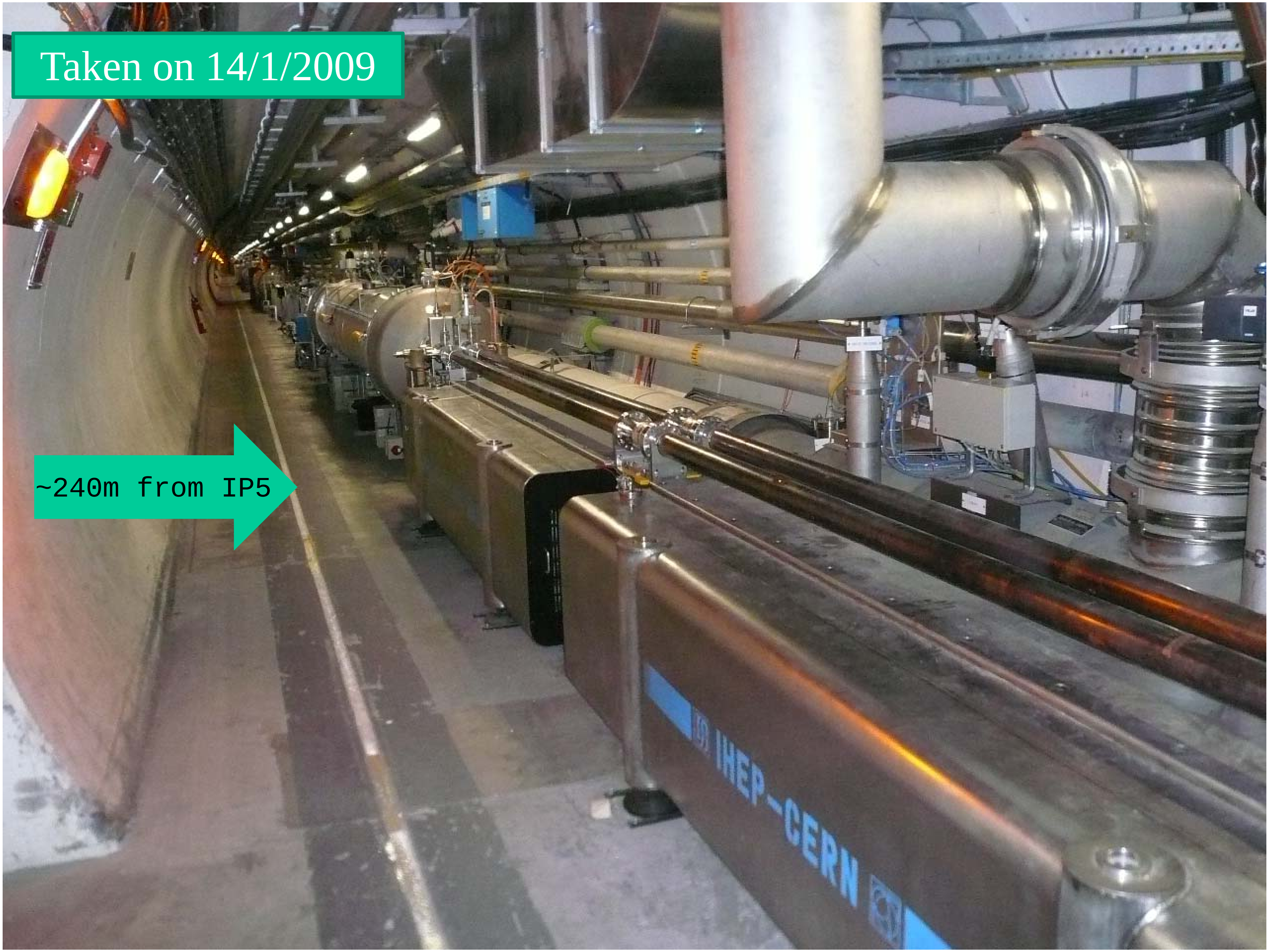
side



Horizontal crossing plane

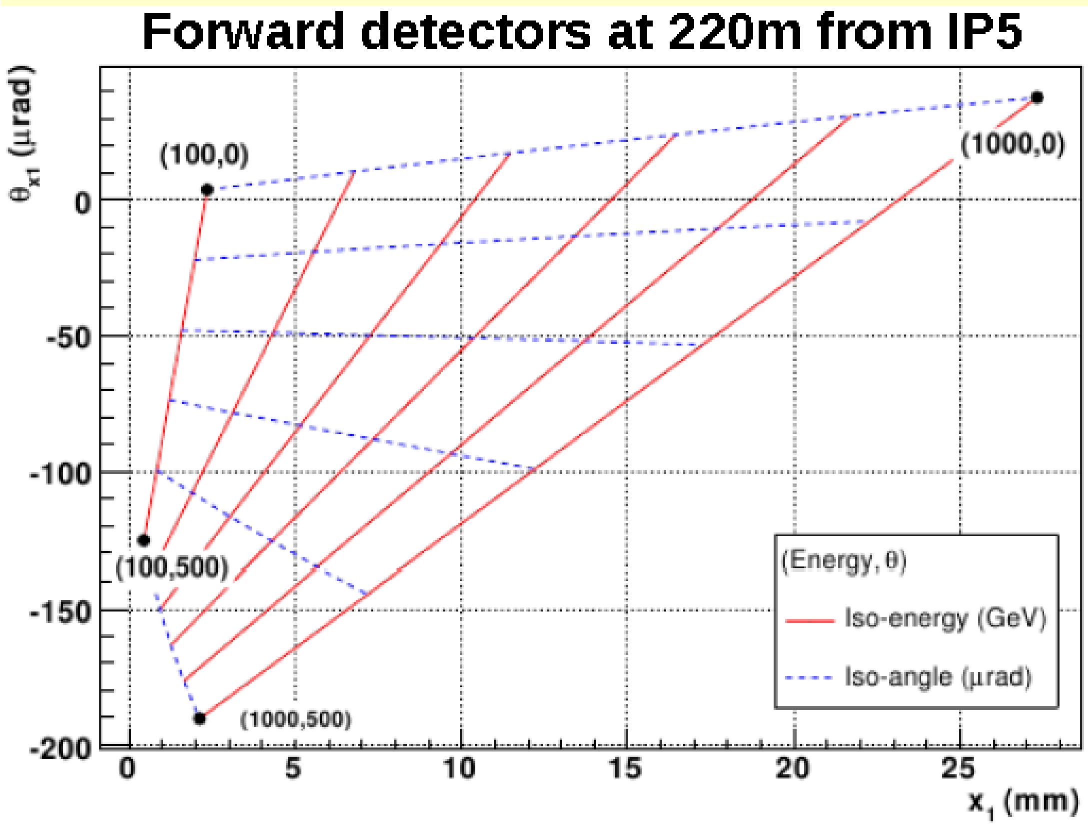
Vertical crossing plane

HECTOR: JINST 2, P09005 (2007)


Taken on 14/1/2009
~240m from IP5
IHEP-CERN

Forward Proton Kinematics Reconstruction

- Measure (lateral) position and angle at 240 or 420m from IP and derive energy + scattering angle:



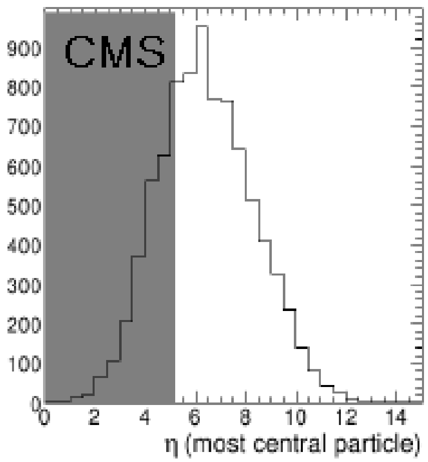
1) Choose a proton, with a given energy loss and initial angle
2) Propagate it to your 2 roman pots.
3) Measure x, x'

Exclusive dimuons

After 100 pb^{-1} :

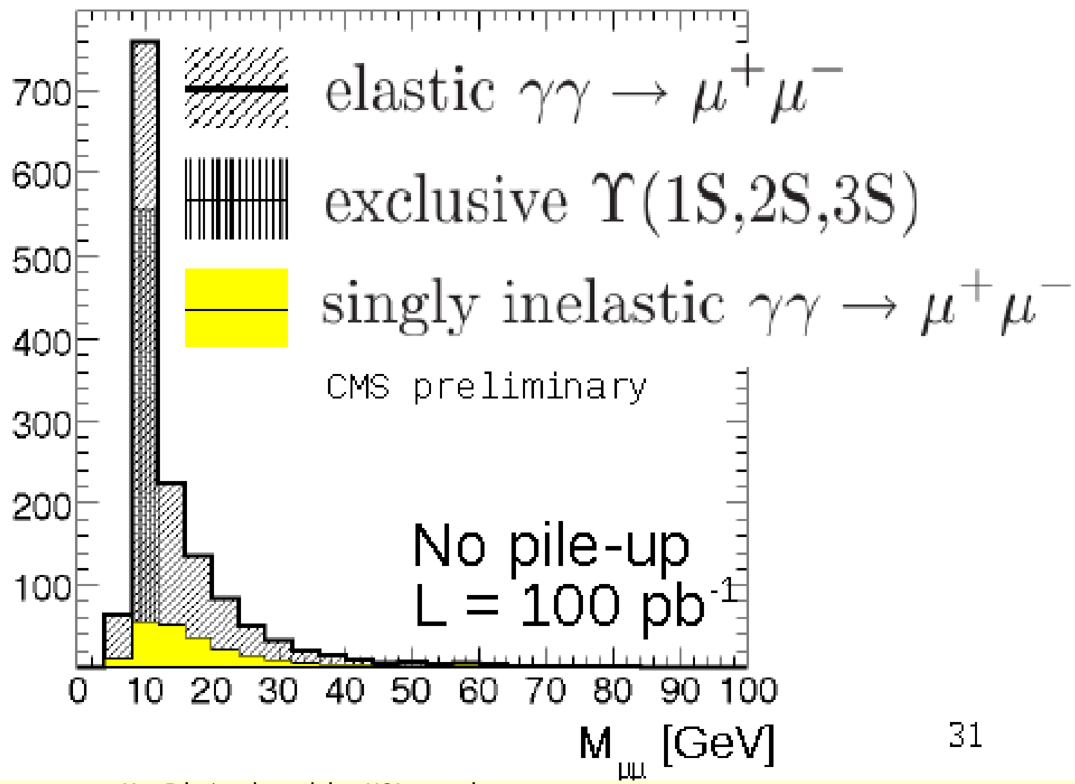
CMS Coll. [CMS PAS DIF-07-001]

$$N_{elastic}(\gamma\gamma \rightarrow \mu^+\mu^-) = 709 \pm 27(stat)$$
$$N_{inelastic}(\gamma\gamma \rightarrow \mu^+\mu^-) = 636 \pm 25(stat) \pm 121(model)$$



$$N^{w/veto}_{inelastic}(\gamma\gamma \rightarrow \mu^+\mu^-) = 223 \pm 15(stat) \pm 42(model)$$

Using
CASTOR & ZDC
to veto inelastic events



- **Luminosity normalization ~ 4%**
- **Forward detector calibration**

Y. Rouby

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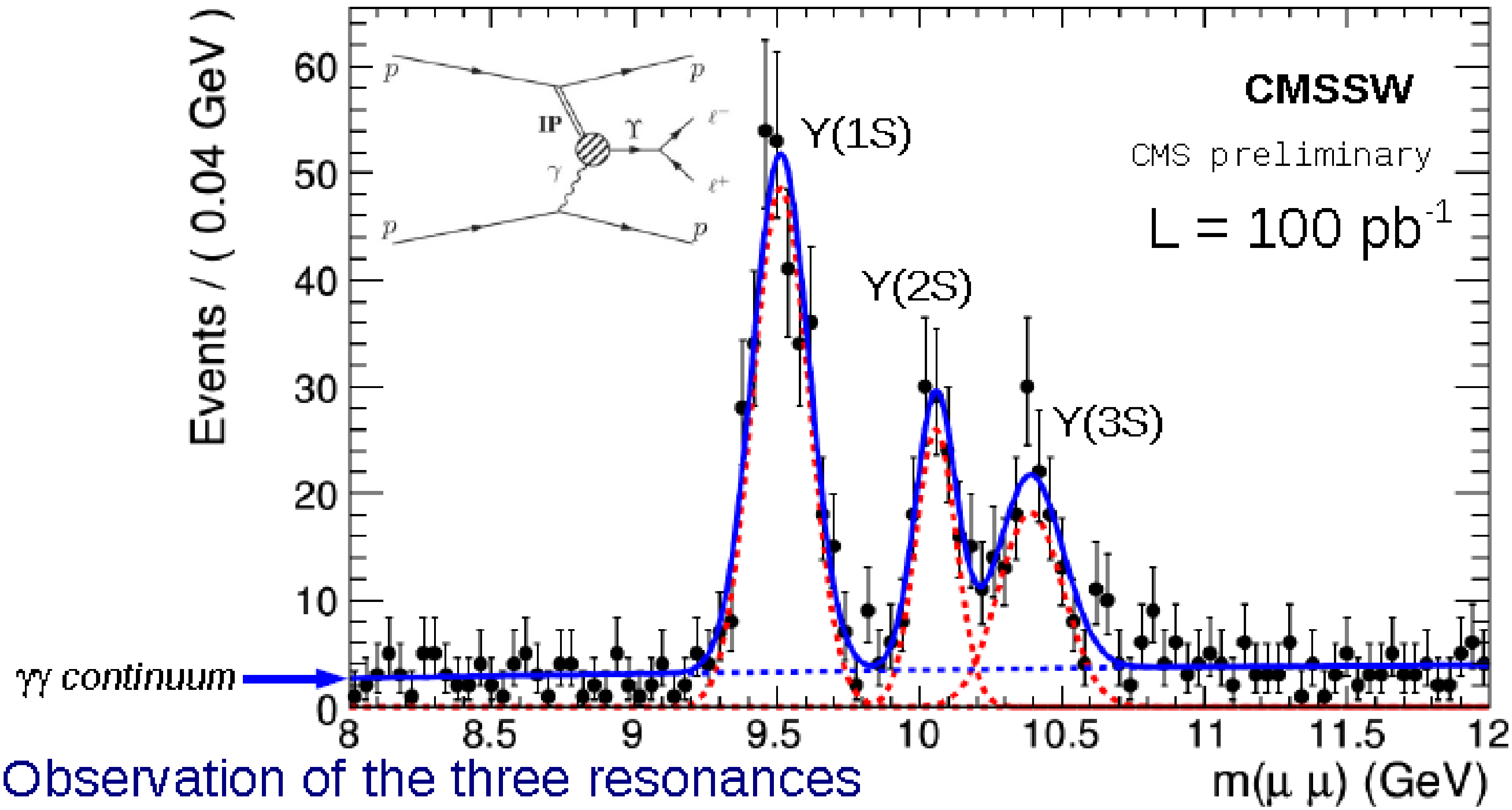
Upsilon: measurement

Selection of the dimuon pairs as for $\gamma\gamma$ events



CMS Coll. [CMS PAS DIF-07-001]

Observation of the three resonances

– cross section measurement

– low p_T track calibration

– detector alignment

– sensitivity to t distribution slope

Experimental Highlights:

• Virtualities of photon exchanges are very small at the LHC (dumped from above by proton EM form-factors) -> photons really quasi-real + zero-degree forward protons

• Thanks to low Q^2 (-> large impact parameters) high survival probabilities, little of re-scattering -> good control of cross-sections

• We focus on two-photon exclusive production non-strongly interacting pairs of (heavy) charged particles

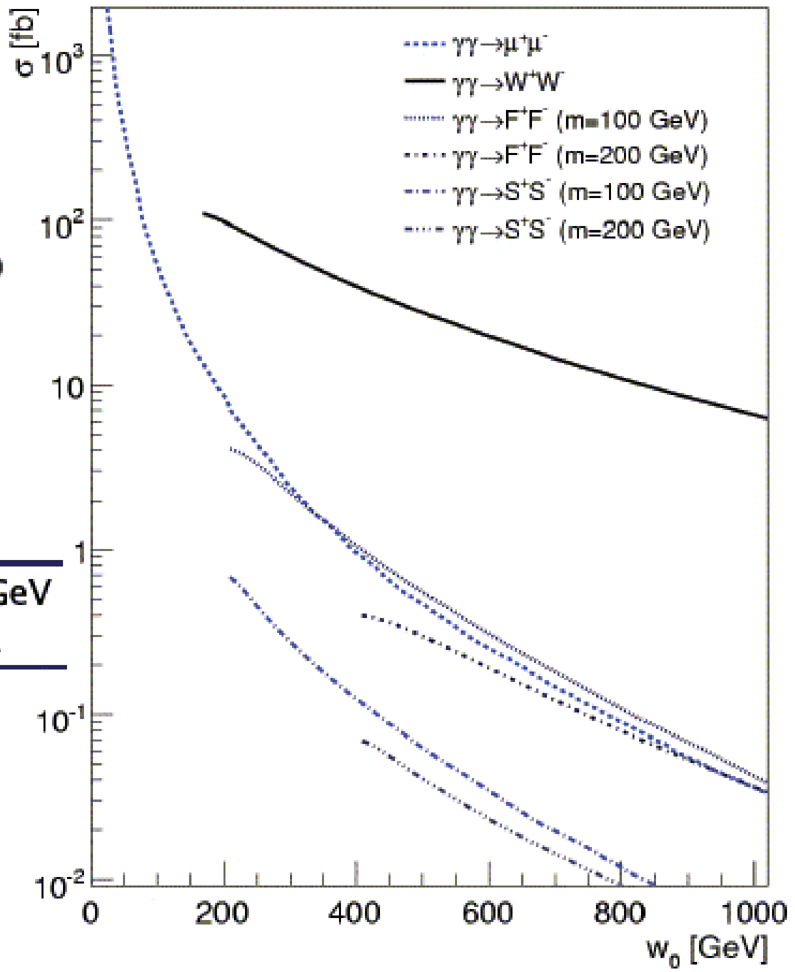
• Nicely complementary to all diffractive/gluon mediated exclusive processes and both FP240 and 420 are essential

• Little background expected (-> little event pileup) and forward detectors very efficient for kinematical constrains/ reconstructions

T. Pierzchala

- $\gamma\gamma \to \mu\mu$ first $\gamma\gamma$ process to be seen
- $\gamma\gamma \to W^+W^-$ very interesting SM process 108fb
- New physics !

Processes	[fb]	Generator
$\gamma\gamma \to \mu\mu$	72 500	LPAIR pt > 2 GeV $\lvert\eta\rvert$ < 3.1
$\gamma\gamma \to WW$	108	
$\to$ FF (m=100GeV)	4.06	MadGraph
$\to$ FF (m=200GeV)	0.40	/
$\to$ SS (m=100GeV)	0.68	MadEvent
$\to$ SS (m=200GeV)	0.07	



Cross sections for $\gamma\gamma$ processes as a function of the minimal $\gamma\gamma$ cms energy W_0

moreover :
lepton final states
clear signature – background suppression

WW/ZZ **pairs in two-photon production:**

• Excellent test-bench for electroweak gauge sector - in particular for anomalous quartic couplings (AQCs), $\gamma\gamma VV$

Note: AQCs poorly constrained so far and difficult at hadron colliders (with standard methods)

• For example, anomalous QCs can be tell-tale signs of new heavy boson exchanges

• Several approaches explored -> effective lagrangians:

- Impose local gauge U(1) x SU(2) invariance with Higgs, usually assumed for ATGCs limits (*eg. Nachtmann et al.* and next talk)
- Impose local gauge U(1) x SU(2) invariance without Higgs (*eg. Eboli et al.)*
- Add genuine (-> not affecting SM gauge part –> no need of associated ATGCs) AQCs to largrangian, but watch unitarity bounds…

T. Pierzchala

Following LEP2 choice:

we use Lagrangian for genuine anomalous quartic vector boson couplings which conserves C, P as well as local $U(1)_{em}$

$$L_6^0 = \frac{-e^2}{8}\frac{a_0^W}{\Lambda^2} F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_\alpha - \frac{e^2}{16\cos^2\Theta_W}\frac{a_0^Z}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}Z^\alpha Z_\alpha$$

$$L_6^C = \frac{-e^2}{16}\frac{a_C^W}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_\beta + W^{-\alpha}W^+_\beta) - \frac{e^2}{16\cos^2\Theta_W}\frac{a_C^Z}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}Z^\alpha Z_\beta$$

This gives a general auxiliary formula for a cross section (total or differential, with or without cuts) as a function of the anomalous parameters:

$$\sigma = \sigma_{SM} + \sigma_0 a_0 + \sigma_{00} a_0^2 + \sigma_C a_C + \sigma_{CC} a_C^2 + \sigma_{0C} a_0 a_C$$

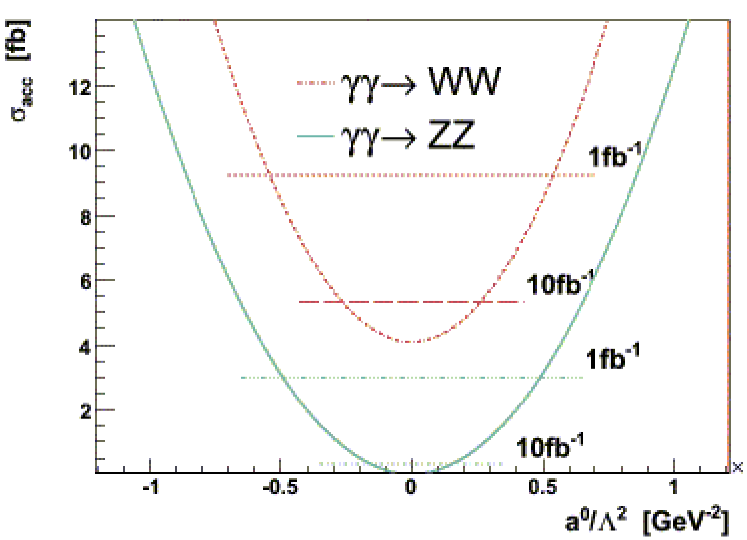
T. Pierzchala

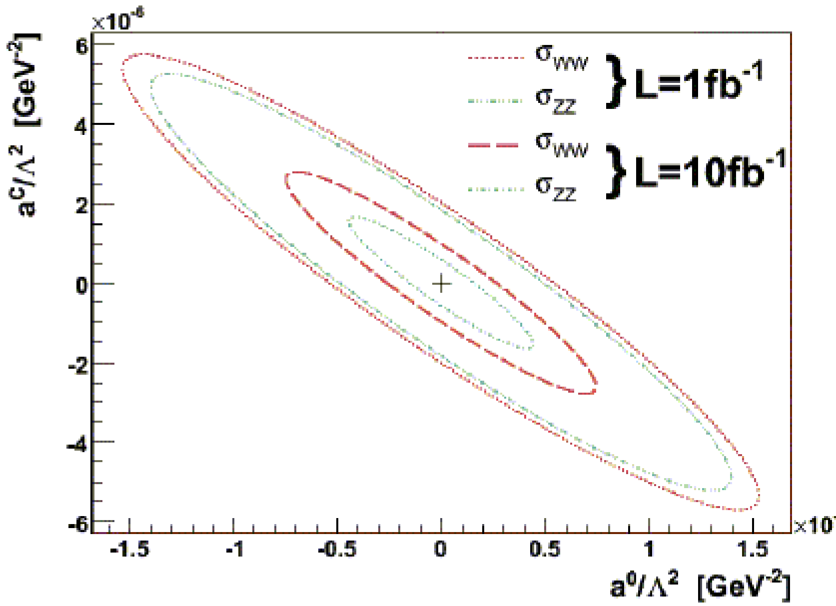
Assuming leptonic decays and using basic acceptance cuts:

The calculated cross section CL=95% upper limits are :

σ^{up} [fb]	$\gamma\gamma \to W\,W$ $\sigma^{SM}_{cuts} = 4.081$ fb	$\gamma\gamma \to ZZ$ $N_{obs} = 0$, $\lambda^{up} = 2.996$
$L = 1\ fb^{-1}$	9.2	3.0
$L = 10\ fb^{-1}$	5.3	0.3

can be easily converted to the limit on the anomalous quartic couplings





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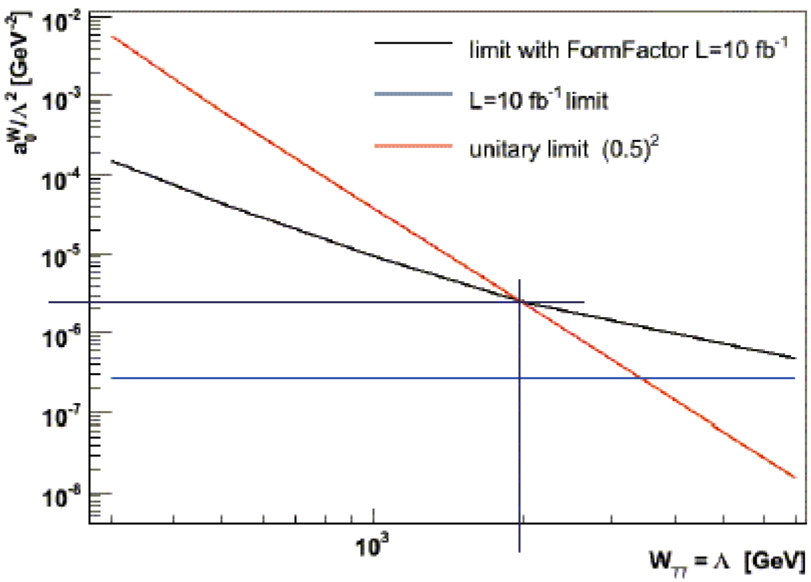
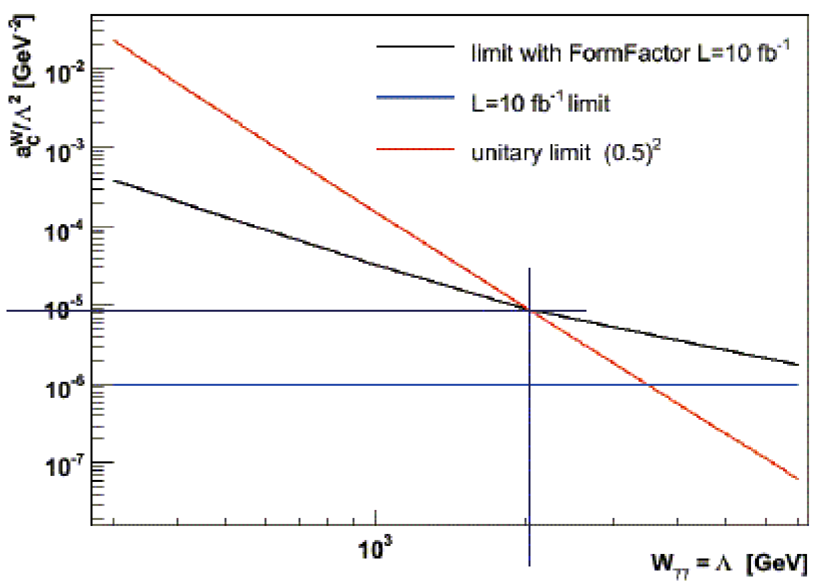
Taking into account unitarity bounds:





dipole form-factor

$$a \to \frac{a}{\left(1+\frac{W_{\gamma\gamma}^{2}}{\Lambda^{2}}\right)^{2}}$$

Limits including form-factor :

$a_0^W < 2.5 \cdot 10^{-6}\ \mathrm{GeV}^{-2}$

$a_Z^W < 9 \cdot 10^{-6}\ \mathrm{GeV}^{-2}$

whilst LEP :

$a_0^W < 2.0 \cdot 10^{-2}\ GeV^{-2}$

$a_Z^W < 3.7 \cdot 10^{-2}\ GeV^{-2}$

for L = 10 fb^{-1}

about 10 000 times better !!!

WW/ZZ pairs in two-photon production:

• Encouraging results -> will extend to semi-leptonic + more complete analysis (differential distributions) and show impact of event pileup (expected small)

• Show in detail relevance of forward detectors (FP220 crucial here, but FP420 also very important)

• Provide results for AQCs while imposing global custodial SU(2) symmetry (protects ρ parameter)

• Extend to other approaches (interesting preliminary results from Nachtmann et al.) -> in particular, what is sensitivity to strongly interacting WW sector (Higgsless scenario)

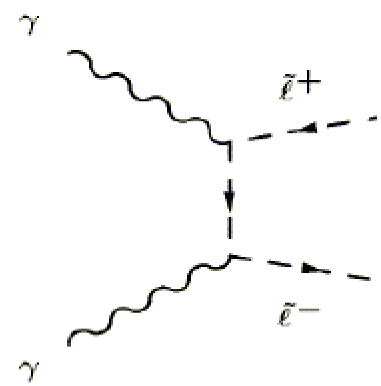
BOTTOM LINE:

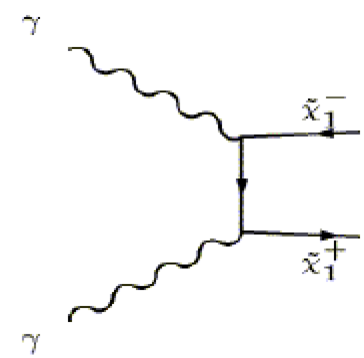
This is a 'guaranteed' physics output from FP420/220!

LM1 spectrum

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

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 :	$\sim\chi^0_{1\text{->}4}$	96 -> 369 GeV





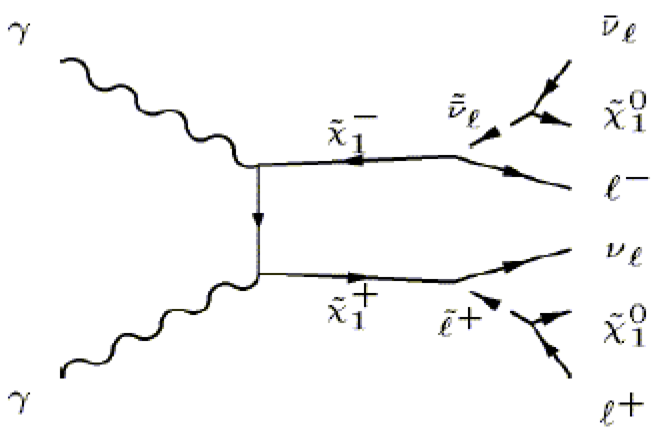
N. Schul

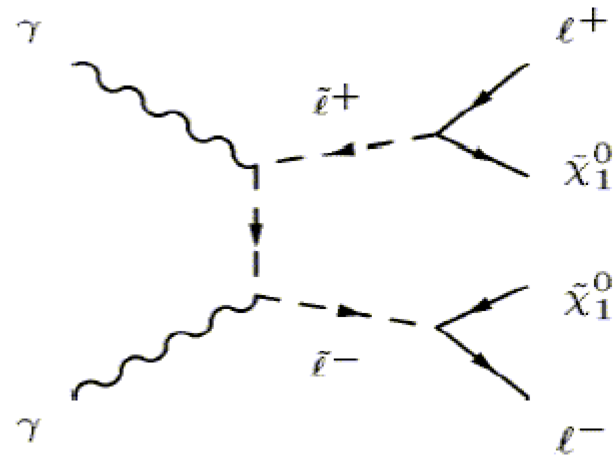
Start with fully leptonic signatures:

Susy detection

Very clean final state:

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





Only one irreducible background

$\gamma\gamma \rightarrow W^+ W^- \rightarrow l^+ \nu \, l^- \bar{\nu}$

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

are suppressed because of E_{miss} and acoplanarity

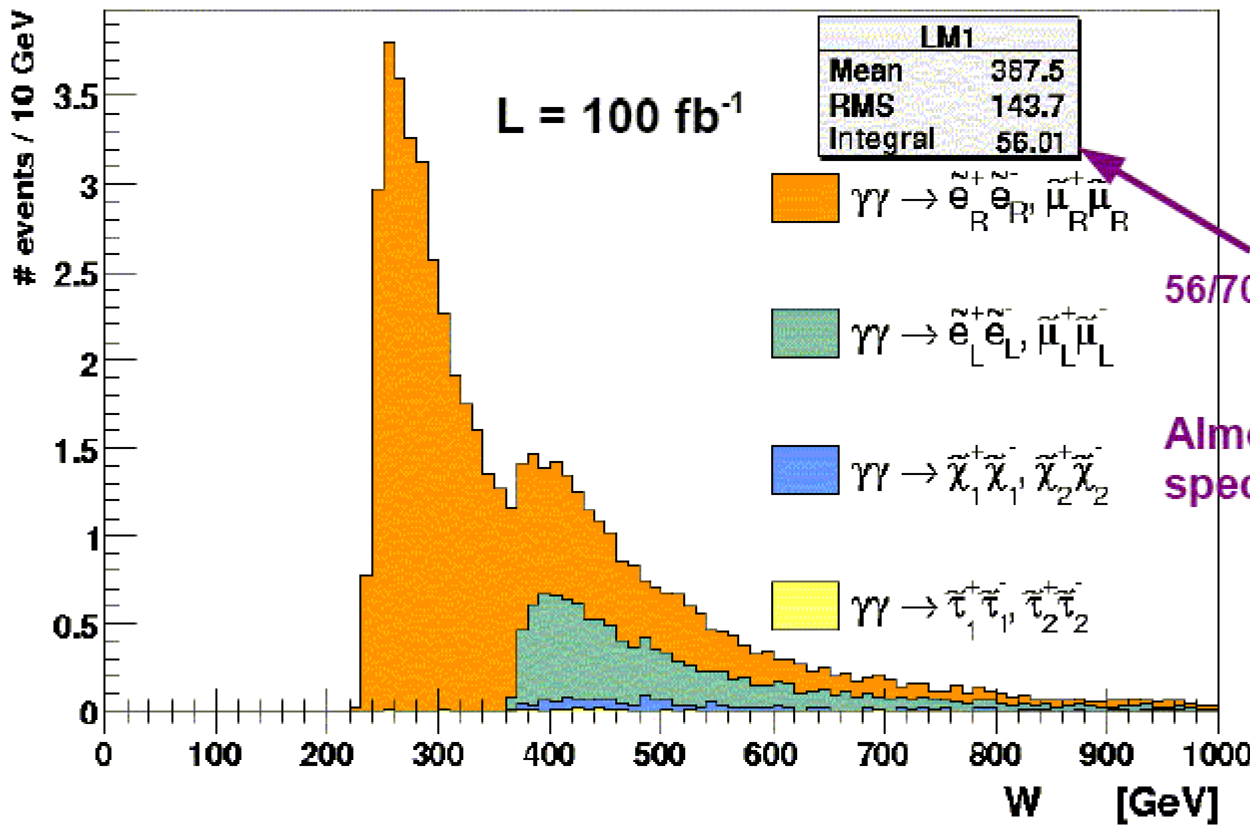
N. Schul

LM1 point – invariant mass signals :

$\gamma\gamma$ invariant mass

$$W_{\gamma\gamma} = 2\sqrt{\omega_1\omega_2}$$

Assume **smearing** of proton energy :
Gaussian, max(0.01 E_p, 1.5 GeV)



56/70 = 80%
= double tag ε

Almost all the photon spectrum is probed

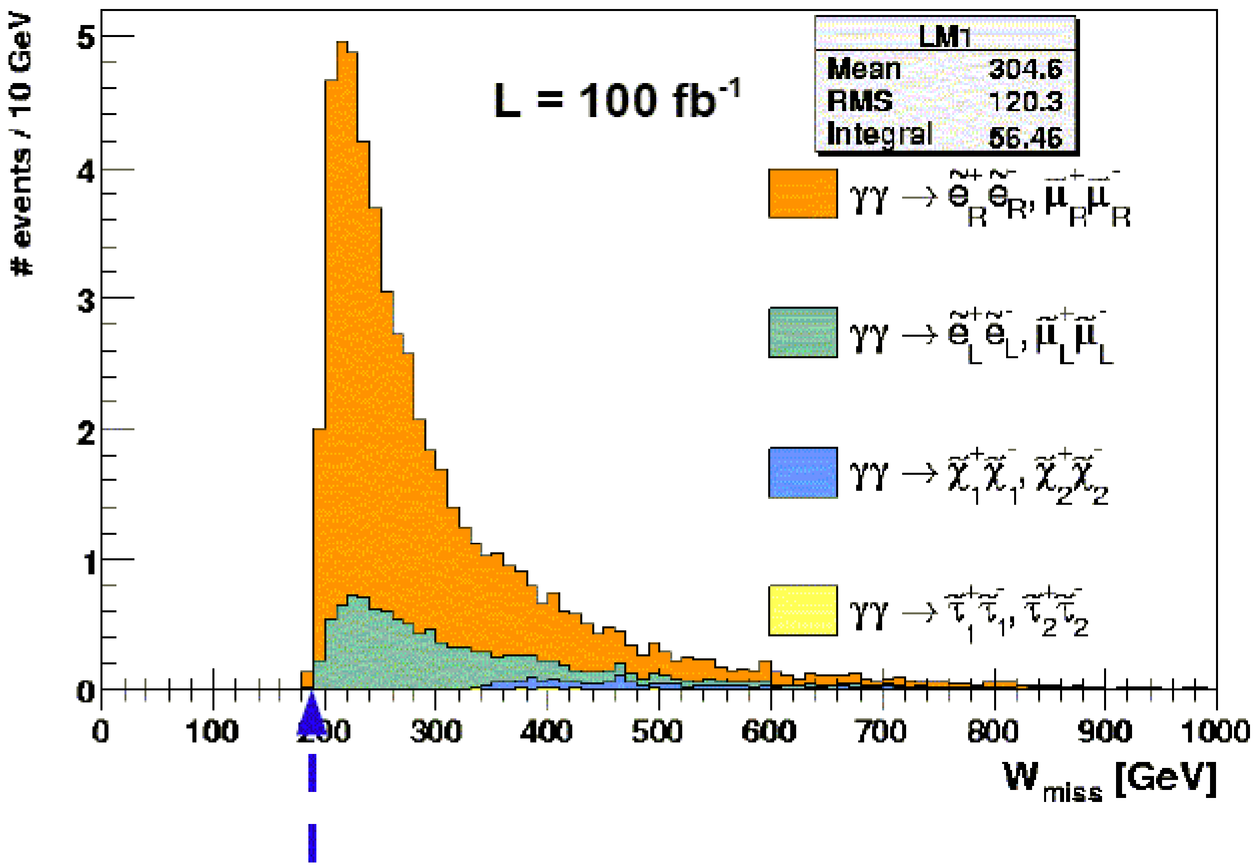
N. Schul

LM1 point – missing invariant mass signals :

missing invariant mass

$$E_{miss} = \omega_1 + \omega_2 - E_{\ell_1} - E_{\ell_2}$$

Assume **smearing** of proton energy :
Gaussian, max(0.01 E_p, 1.5 GeV)



Allow for LSP mass determination !

Detection of two-photon exclusive production of supersymmetric p

Masses of LM1 MSSM particles derived from running the RGE for $m_0 = 60$ GeV, $m_{1/2} = 250$ GeV, $tg(\beta) = 10$, $A_0 = 0$, $\mu > 0$. ($\ell = e, \mu$)

	mass [GeV]		
$\tilde{\ell}_R^\pm$	118	$\tilde{\chi}_1^\pm$	178
$\tilde{\ell}_L^\pm$	187	$\tilde{\chi}_2^\pm$	360
$\tilde{\tau}_1^\pm$	111	$H^\pm$	381
$\tilde{\tau}_2^\pm$	190	$\tilde{\chi}_1^0$	96

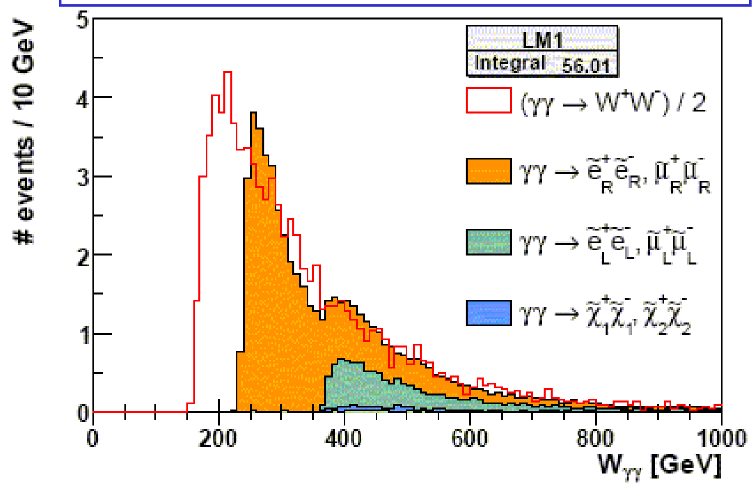


Figure 2. Distribution of two-photon invariant mass $W_{\gamma\gamma}$ for the LM1 benchmark and integrated luminosity L = 100 fb^{-1}. Two visible peaks are due to production thresholds of $\tilde{\ell}_R^+\tilde{\ell}_R^-$ and $\tilde{\ell}_L^+\tilde{\ell}_L^-$ pairs. Various contribution are added cumulatively. The background distribution of WW pairs is shown separately, and is rescaled to obtain similar size as signal.

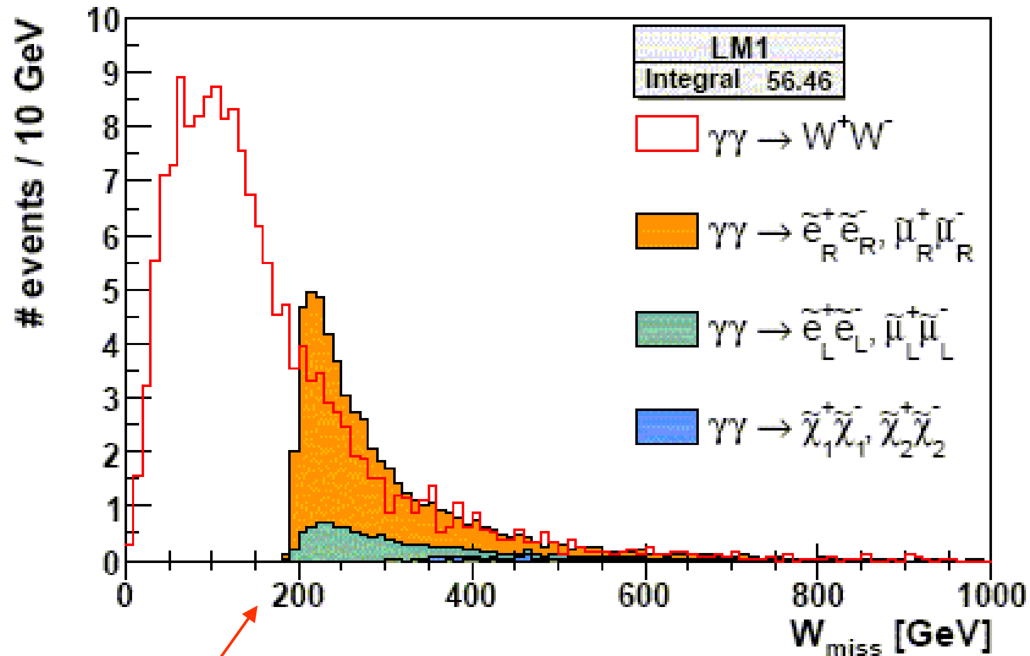


Figure 3. Distribution of missing invariant mass W_{miss} for the LM1 MSSM benchmark for the integrated luminosity L = 100 fb^{-1}. It starts at about $2\, m_{LSP}$ for SUSY, at zero for the WW background.

$$W_{miss} = \sqrt{E^2_{miss} - P^2_{miss}}$$

Detection of two-photon exclusive production of supersymmetric

Note: FP smearing included 097v1

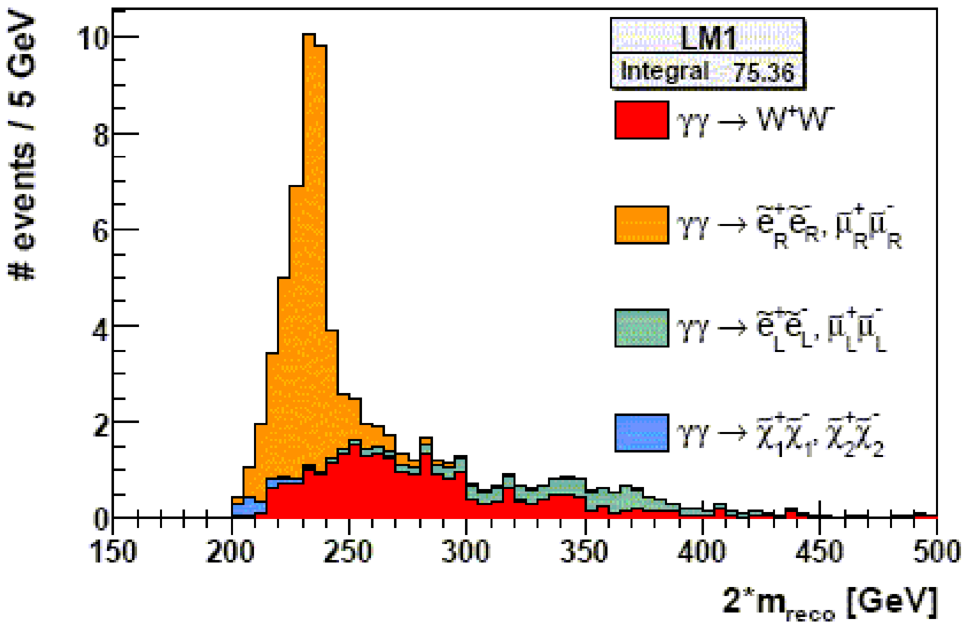


Figure 6. Cumulative distributions of the reconstructed mass $2m_{reco}$ for the LM1 signal and the WW background for the intergrated luminosity L = 100 fb^{-1}.

The 5σ discovery for the LM1 left and right sleptons is then reached already after 25 fb^{-1} thanks to strong suppression of the irreducible background. It could still be improved by using additional cuts exploring the correlation between $W_{\gamma\gamma}$ and W_{miss} as it is done for the LM9 study below. Finally, it could be improved even further by including the inelastic two-photon production, in this case however only one proton is detected and the kinematical reconstruction is not so effective. For the same benchmark point, the nominal proton-proton studies claim 5σ discovery after about 10 fb^{-1}[13]. However, determination of sparticle masses in this case is much more complicated.

Similar two-photon analyses can be done for other benchmark points with low slepton masses as LM2, LM4 and LM6.

HECTOR simulations of forward protons from slepton events consistent with LM1 benchmark point indicate that the TOTEM 220 m detectors will have both protons tagged for only 30% of events. Addition of detectors at 420 m increases that to 90% of events.

N. Schul

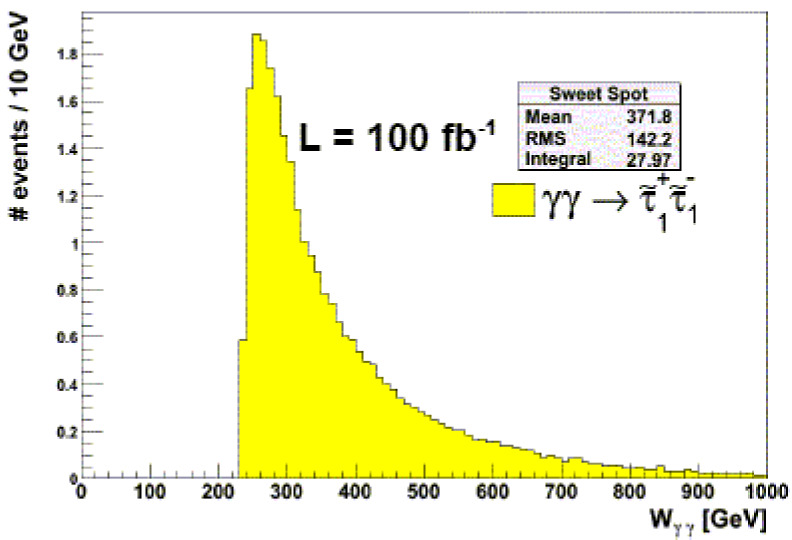
Sweet spot susy

Example of two-photon exclusive production of heavy stable particles

M. Ibe and R. Kitano, JHEP08(2007)016

Stau_1 $\tilde{\tau}_1^+$ - is the NLSP

- is quasi-stable, O(3000s)



m_{stau1} = 116 GeV

↓

σ = 0.43 fb

--> detection via dE/dx method

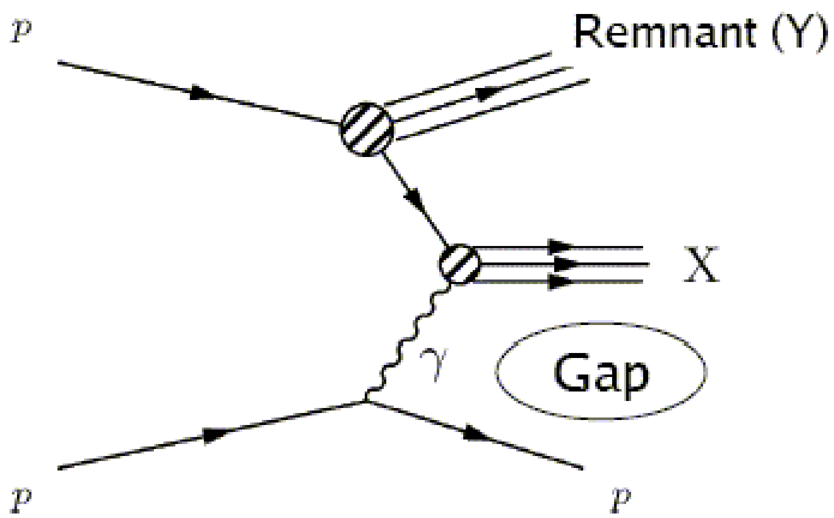
2 ~Heavy Stable Charged Particles + 2 forward protons

Note: FPs crucial for interpretation of such events

S. Ovyn

Photoproduction is traditionally studied at e-p collisions

pp (γq/g → XY) p



- γp events can also be tagged at the LHC

  ➡ e.g. Using Large Rapidity Gaps (LRG)

- Higher luminosity than γγ events

- Probe electroweak sector up to/beyond 2 TeV !

Using EPA

$$\sigma_{pp} = \int \sigma_{\gamma q/g}(\hat{W}_{\gamma q/g}) f_{\gamma}(x_1) f_{q/g}(x_2, Q^2)\, dx_1\, dx_2$$

where $\hat{W}^2_{\gamma q/g} = 4 E_p x_1 x_2$

BUT pp events are more dangerous backgrounds than in γγ interactions!

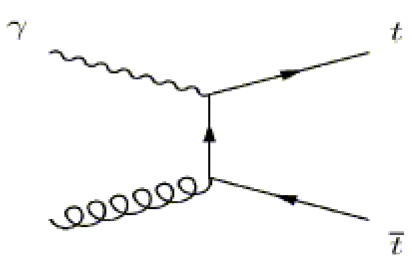
S. Ovyn

γp cross sections

Obtained using MadGraph/MadEvent

- Large variety of processes
- Significant cross sections up to 2 TeV

e.g.

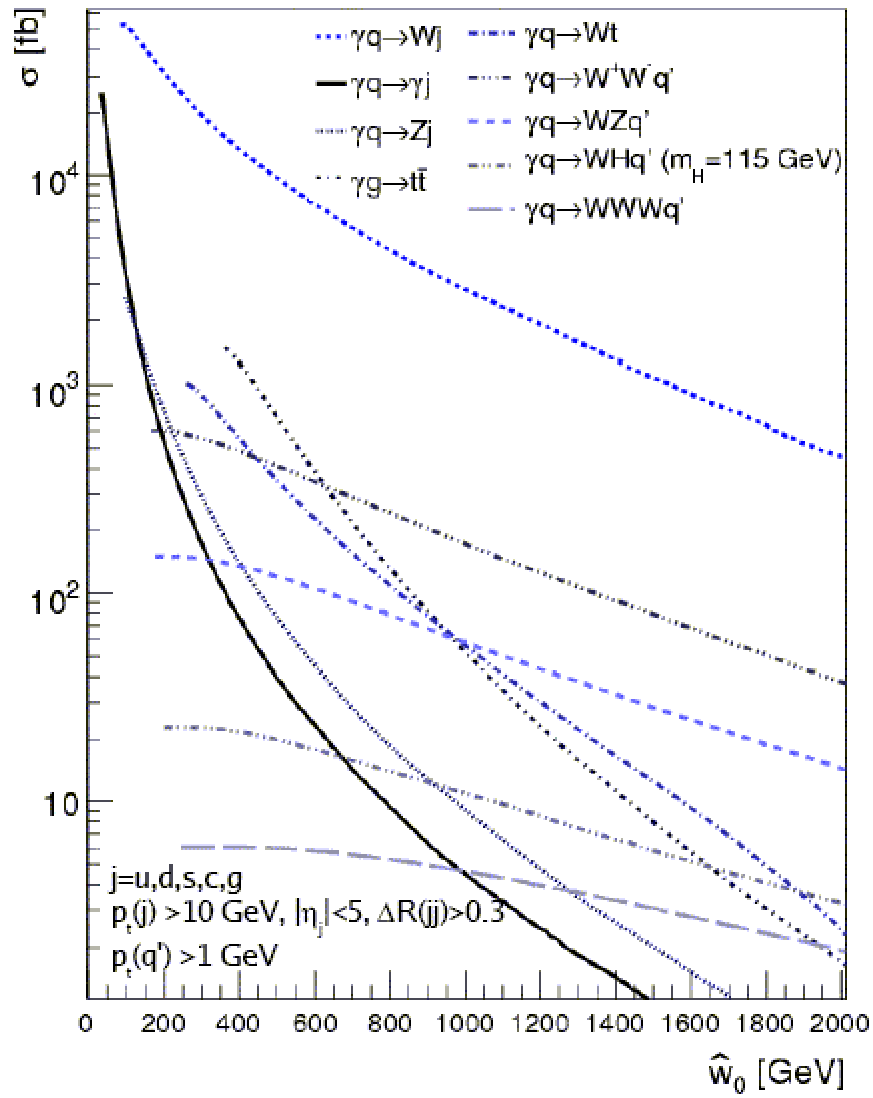


1.5 pb

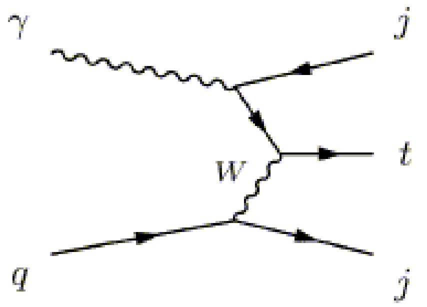
- Alternative way to pp interactions to study

1. Higgs search
2. Top physics (e.g. $|V_{tb}|$)
3. New phenomena up to 2 TeV

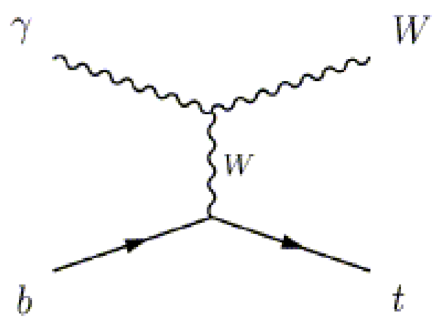
- Very good S/B expected



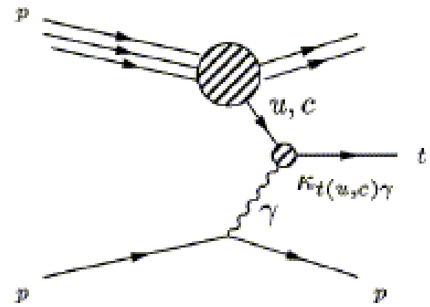
J. de Favereau and S. Ovyn



t-channel



Wt-channel



Anomalous top

Physics highlights

- Wt and t-channel related to V_{tb}
- Sensitivity to new physics : FCNC
- Possibility to study top properties (mass, charge,...)

pp vs γp cross sections

pb	pp	γp
Wt-channel	~ 60	~ 1
t-channel	~ 245	~ 0.006
Wjj	~ 35000	8.7
tt	~ 720	1.5

- Wt-channel : more favorable background condition than pp case
- What kind of uncertainty is reachable on $|V_{tb}|$?

$$\frac{\sigma_{Wt}}{\sigma_{tt}} \simeq 0.7$$

Single top quark photoproduction at the LHC
J. de Favereau and S. Ovyn, arXiv:0806.4886v1 [hep-ph]

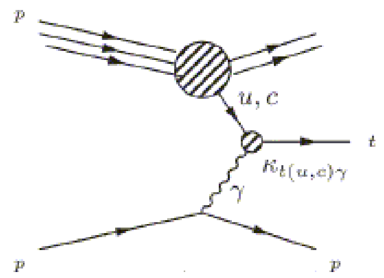


Figure 4. Main diagram for FCNC production of single top.

With FP420/220 (50/50%) possible to measure at L = 2.10^{33} $cm^{-2}s^{-1}$! Possibility to improve world limits already after 100 pb^{-1} …

While for 30 fb^{-1} at higher luminosity using the VFDs to tag photoproduction the final sample is composed of :

$$\text{Signal}: 1554 \pm 39(\text{stat.}) \pm 138(\text{syst.}) \text{ events}$$
$$\text{Background}: 327 \pm 18(\text{stat.}) \pm 30(\text{syst.}) \text{ events}$$

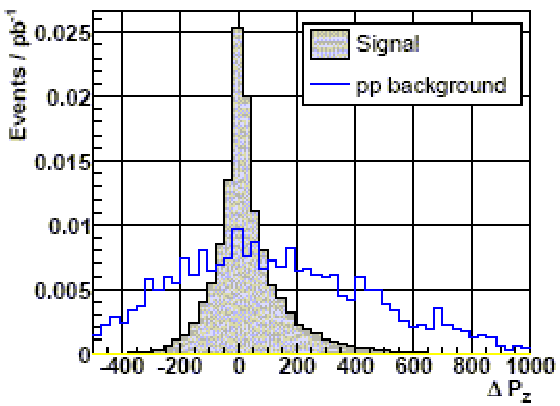


Figure 5. Distribution of the difference between the top quark longitudinal momentum reconstructed from the central detector and from a VFD. The distribution is shown for the anomalous top signal (full) and for the partonic background(empty).

Good example of possibility of measuring photoproduction with presence of pileup using FP420/220 -> competitive to *pp* studies! If good timing possible with central detectors (< 100 ps) could much improve pileup background control!

Side remark: Main (EM) CAL timing

• Good timing of EM calorimeters very interesting for reducing pileup backgrounds (proposed by S. White)

• Both ATLAS and CMS claim ~100 ps resolutions of their EM calorimeters at test beams. This already would give ~2 factor background reduction!

• We need to make sure all possible is done to reach it at LHC (and maybe even better for superLHC):

LEVER ARM:
Can use it also to reduced pileup backgrounds in
inclusive $H \to \gamma\gamma$!!

Note: Factor 2 makes huge impact on H discovery sensitivity…

Summary/Outlook

• Two-photon exclusive pair production offers strong research program – its success crucially on FP420 and FP220 detectors!

• There is interesting physics in high energy photo-production too, assuming FP220/420

• So far we made analyses at generator level (+ fast detctor simulations) ; all irreducible backgrounds are calculated; for reducible bckgrs estimates/strategies are described -> move to full detector simulation studies

• Note: In general, triggering (at Level 1) of these events is 'given', since both ATLAS and CMS are designed to trigger well W and Z bosons anyway!

• This offers new, exciting and complementary physics studies in parallel to exclusive diffraction.

Results for photon physics at the LHC has been obtained within

UCLouvain Photon Group of CP3

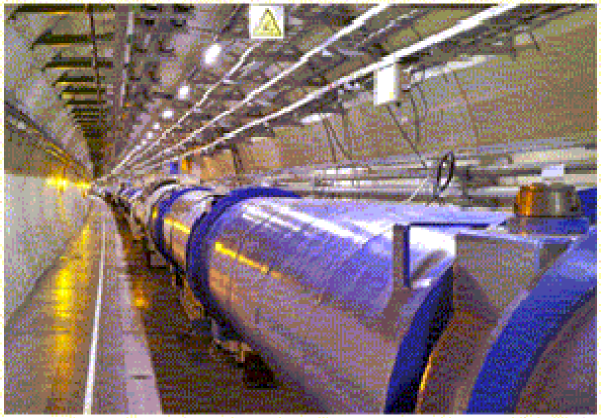
J.de Favereau, V. Lemaître, Y. Liu, S. Ovyn, T. Pierzchała, KP, X. Rouby, N.Schul, M. Vander Donckt

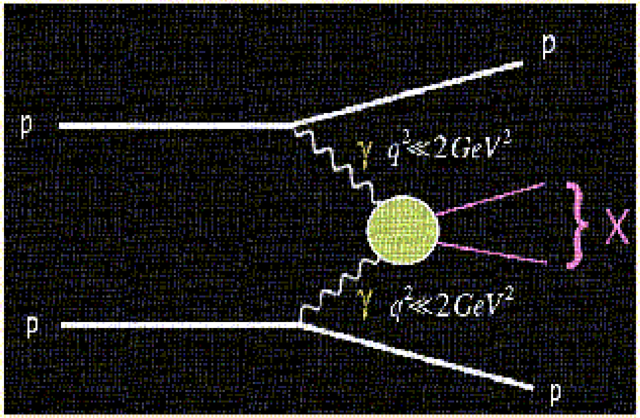
from **Tuesday 22 April 2008 (08:00)**
to **Friday 25 April 2008 (22:50)**
at CERN

Workshop on "High energy photon collisions at the LHC"

chaired by: ***David d'Enterria (CERN)*** , ***Michael Klasen (Grenoble)*** , ***Krzysztof Piotrzkowski (Louvain-la-Neuve)***
support: schul@fynu.ucl.ac.be

Description:





The workshop aims at discussing the physics of high-energy photon-induced collisions. In particular, perspectives will be studied for searches of physics Beyond Standard Model at the LHC in photon-photon and photon-proton interactions (both with proton and ion beams). In addition, reports of studies of two-photon processes at the B-factories and ILC/PLC will be given, as well as experimental and theoretical reviews of photoproduction at HERA, and results from Tevatron on photon-anti-proton and photon-photon interactions, as well as from RHIC on electromagnetic processes.

Tuesday 22 April 2008 | Wednesday 23 April 2008 | Thursday 24 April 2008 | Friday 25 April 2008 |

Tuesday 22 April 2008

top

09:00->*18:00* HERA, Tevatron and LEP results

09:00	Welcome (30')	Krzysztof Piotrzkowski
09:30	Photon-induced collisions at HERA and the Tevatron (1h00')	Jiri CHYLA
10:30	Coffee break	
11:00	High-p_T processes and the structure of the photon (30')	Thomas SCHOERNER-SADENIUS
11:30	Single W and anomalous top production (30')	David SOUTH
12:00	Lunch break	

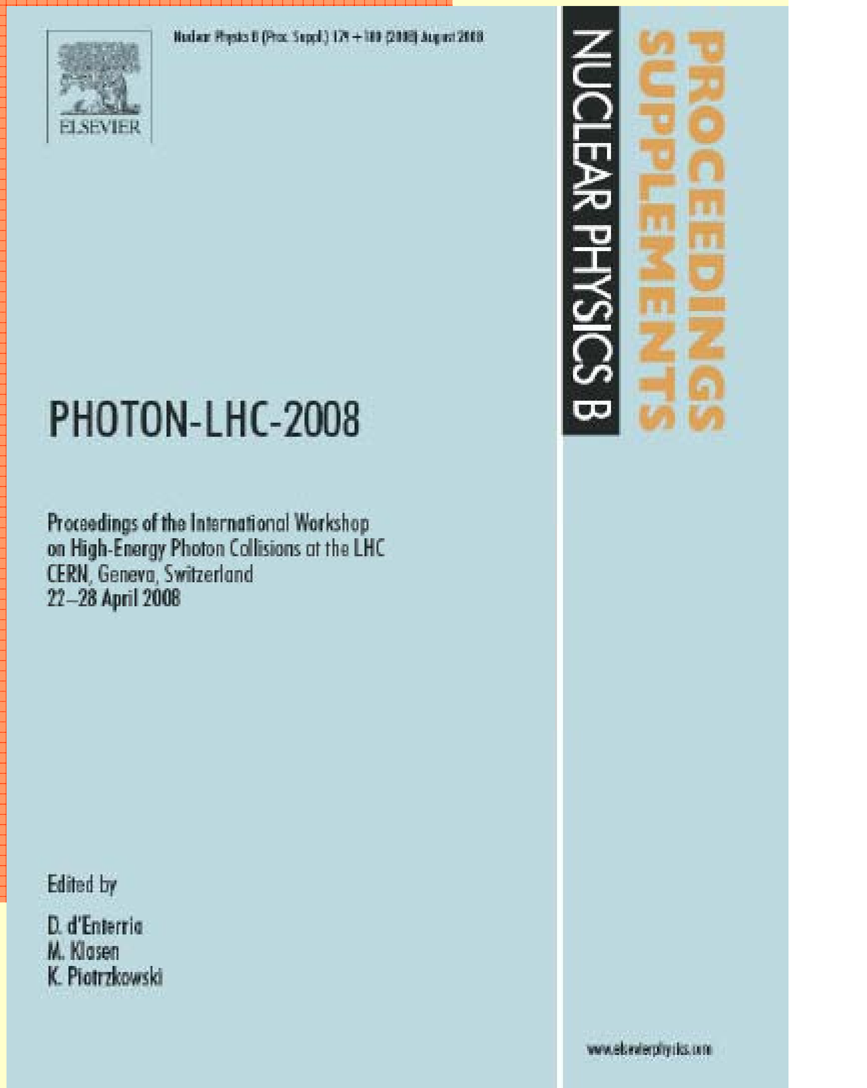
CERN Workshop on Photon Physics @ LHC

http://indico.phys.ucl.ac.be/conferenceDisplay.py?confId=228

- Proceedings published with
> 40 contributions – many on arXiv

- More than 50 participants across
many fields – all collider exps present

- Next time: May'09 at DESY in
NP and EWK session at the
PHOTON conference



Backup slides

Detection of two-photon exclusive production of supersymmetric pairs at the LHC
N. Schul, K. Piotrzkowski arXiv:0806.1097v1 [hep-ph]

Sensitivity to anomalous quartic gauge couplings in photon-photon interactions at the LHC
T. Pierzchala, K. Piotrzkowski arXiv:0807.1121v1 [hep-ph]

Associated W and Higgs boson photoproduction and other Electroweak photon induced processes at the LHC
S. Ovyn, arXiv:0806.1157v1 [hep-ph]

Single top quark photoproduction at the LHC
J. de Favereau and S. Ovyn, arXiv:0806.4886v1 [hep-ph]

Kinematics/γγ Luminosity

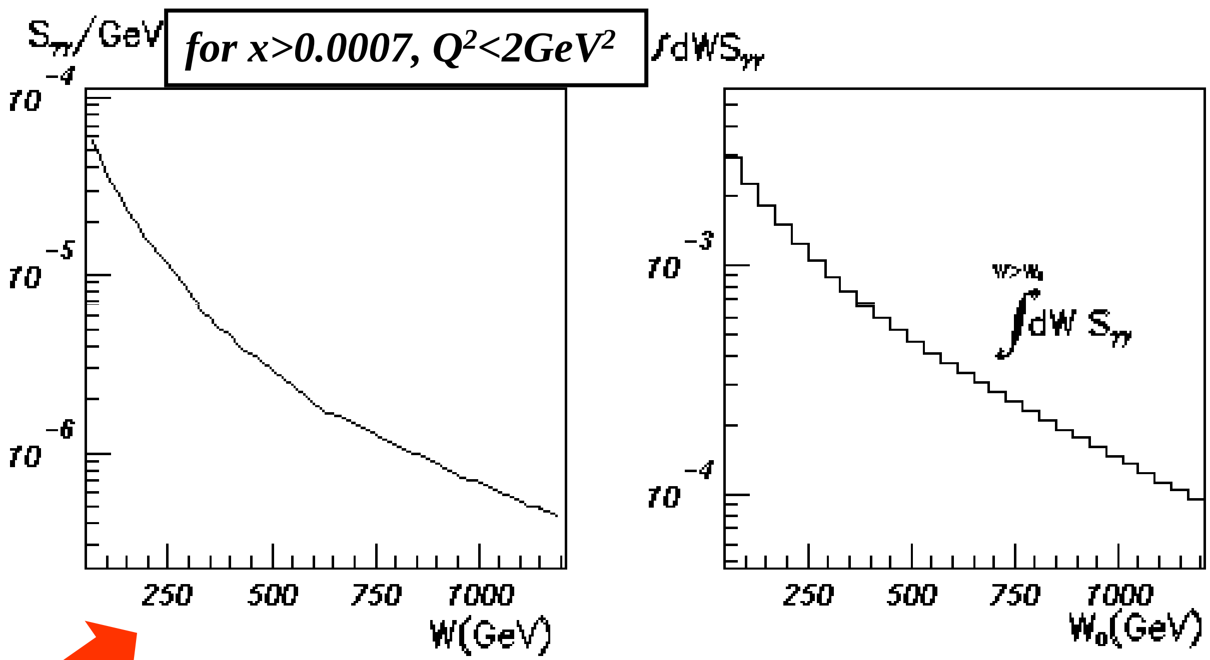
Virtuality Q^2 of colliding photons vary between kinematical minimum = $M_p^2 x^2/(1-x)$ where x is fraction of proton momentum carried by a photon, and Q^2_{max} ~ *1/proton radius*^{2}

$W^2 = s\, x_1\, x_2$

Photon flux $\propto 1/Q^2$

$Q^2 - Q^2_{min} \approx s\theta^2/4$

protons scattered at \`zero-degree' angle



Use EPA à la *Budnev et al.**

** error found in the elastic (Q^2 integrated) γ flux for protons!*

$\int dW S_{\gamma\gamma}$ = *'γγ : pp luminosity'*

Note: it's few times larger if one of protons is allowed to break up

Parameters, cuts and covariance matrix features

Choices and assumptions:

- fully leptonic decays $\Rightarrow$ clean signature
- double tag for both $p \Rightarrow$ full reconstr. of final state
- $m_{Higgs} = 120$ GeV

Cuts:

- both charged leptons: $|\eta| \leq 2.5$
- both charged leptons: $p_T \geq 10$ GeV
- both photons:
  - 120 GeV $\leq E_\gamma \leq$ 900 GeV for “VFD 220m”, or
  - 20 GeV $\leq E_\gamma \leq$ 900 GeV for “VFD 220m + 420m”

Covariance matrix:

- CP even - CP odd correlations vanish

Comparison of sensitivities

preliminary

	present	LHC estimates	ILC estimates		
	LEP, SLD, Tevatron (*)	$\gamma\gamma \to WW$ leptonic	$ee \to WW$ (*)	$\gamma\gamma \to WW$ unpolarised	$\gamma\gamma \to WW$ $J_z = 0$
	h_i $[10^{-3}]$	δh_i $[10^{-3}]$	δh_i $[10^{-3}]$	δh_i $[10^{-3}]$	δh_i $[10^{-3}]$
measurable CP conserving couplings:					
h_W	-69 ± 39	44	0.3	0.6	0.3
h_{WB}	-0.06 ± 0.79	155	0.3	1.7	0.7
$h_{\varphi WB}$	$\times$	118	$\times$	2.4	0.9
$h_\varphi^{(3)}$	-1.15 ± 2.39	$\times$	36.4	$\times$	$\times$
measurable CP violating couplings:					
$h_{\tilde{W}}$	68 ± 81	45	0.3	0.7	0.3
$h_{\tilde{W}B}$	33 ± 84	190	2.2	2.0	0.9
$h_{\varphi\tilde{W}\tilde{B}}$	$\times$	74	$\times$	2.1	0.6

3 more anomalous couplings unaccessible by these methods:

$h_\varphi^{(1)}, h'_{\varphi WB}, h'_{\varphi \tilde{W}\tilde{B}}$

(*) Nachtmann, Nagel, Pospischil

- best for $h_{WB}, h_\varphi^{(3)}$: Giga Z

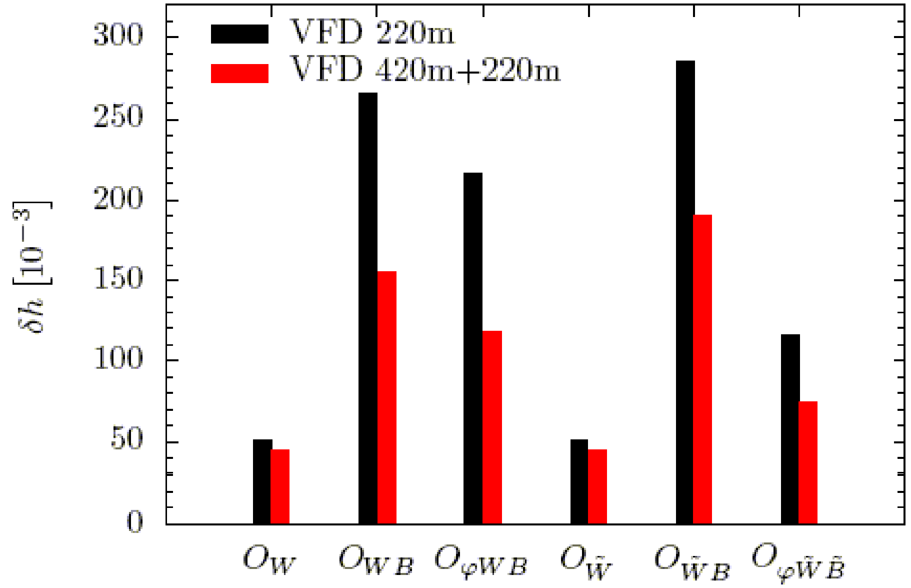
Results: Sensitivities at the LHC

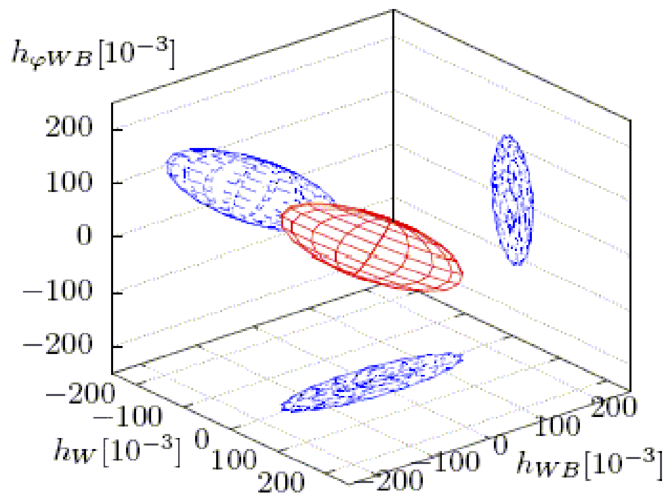
elastic spectrum, leptonic channels, double tag VFD

preliminary

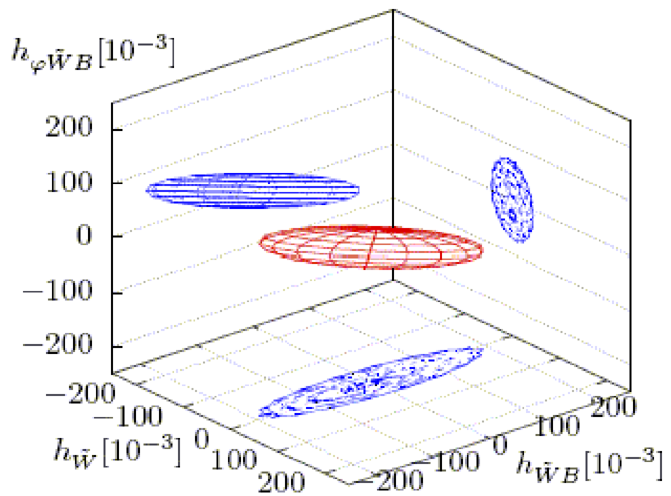
$\int L_{pp} = 30\ \text{fb}^{-1}$,

accept. events = 26 (VFD 220m), 94 (VFD 420m+220m)





CP even (VFD 420m+220m)

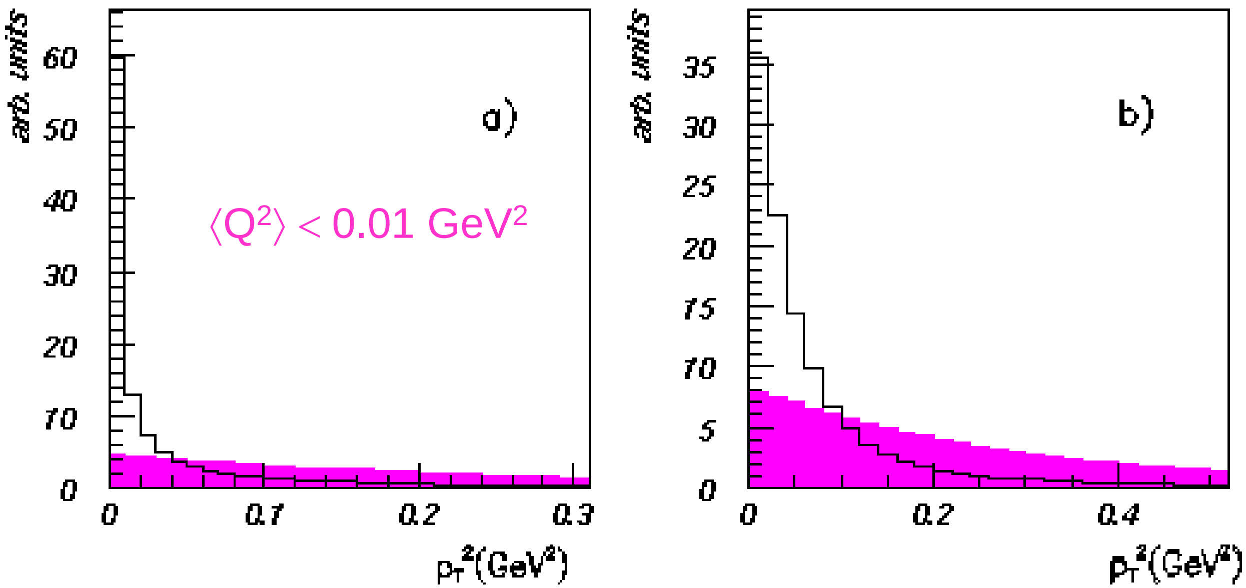


CP odd (VFD 420m+220m)

Problem: Same signature (one or two very forward protons) has also *central diffraction* (i.e. *pomeron-pomeron* scattering) in strong interactions

Both processes weakly interfere, and transverse momentum of the scattered protons are in average much softer in two-photon case

a) `true’ distributions; b) distributions smeared due to beam intrinsic p_T; all plots normalized for $p_T^2 < 2\ GeV^2$



p_T gives powerful separation handle provided that size of $\gamma\gamma$ and pomeron-pomeron cross-sections are not too different

Assuming ultimate p_T resolution ≈ 100 MeV; i.e. neglecting detector effects