Two-photon exclusive production of spairs @ LHC

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- Introduction: LHC as a high energy $\gamma\gamma$ collider
- SUSY exclusive $\gamma\gamma$ processes
- First acceptance studies
- Summary/Outlook

Louvain Photon group :

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LHC as a High Energy $\gamma\gamma$ Collider

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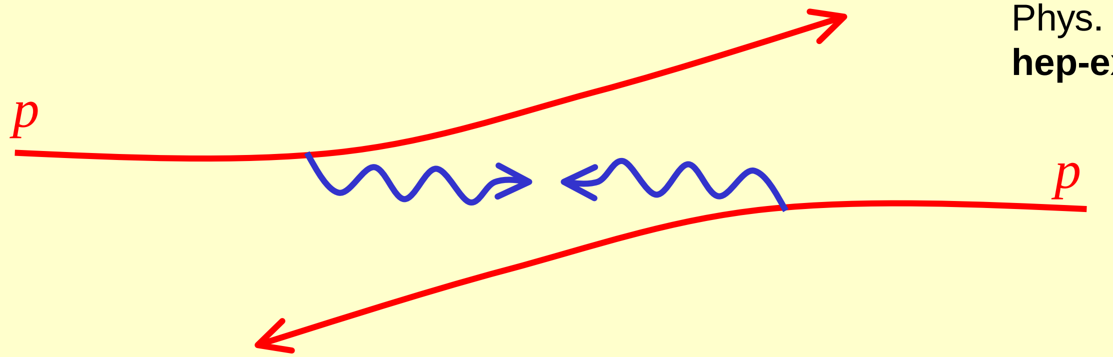
hep-ex/0201027



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

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

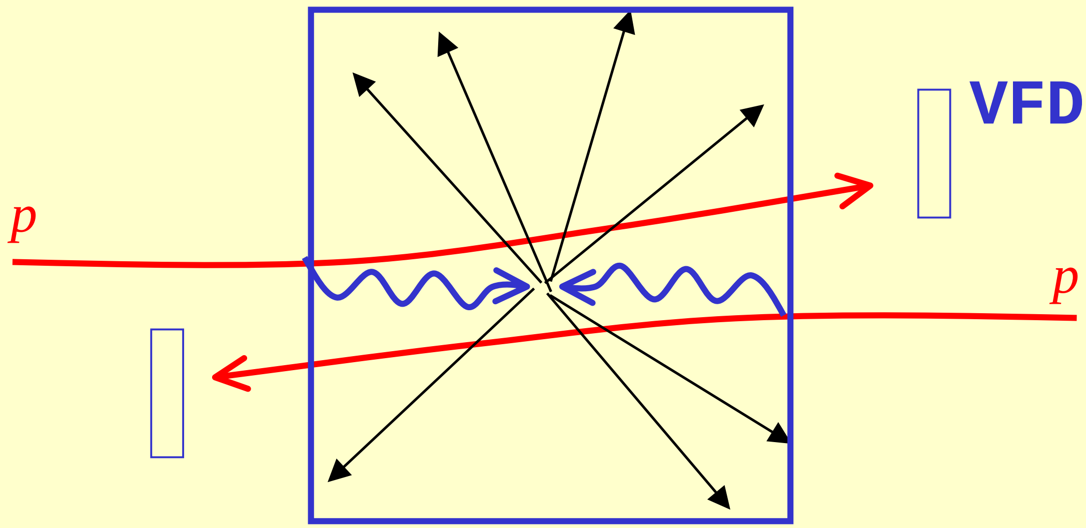
DESY 93–173
UCD–93–39
December 1993

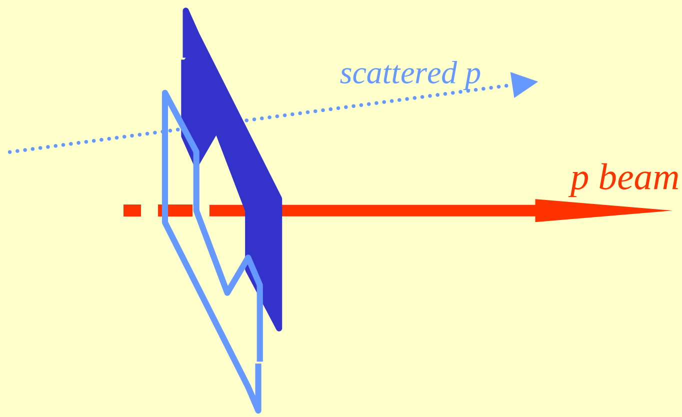
$\gamma\gamma$ PRODUCTION OF NON–STRONGLY INTERACTING $\mathcal{SUSY}$ PARTICLES AT HADRON COLLIDERS

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)





Needed VFDs: 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 !**

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}

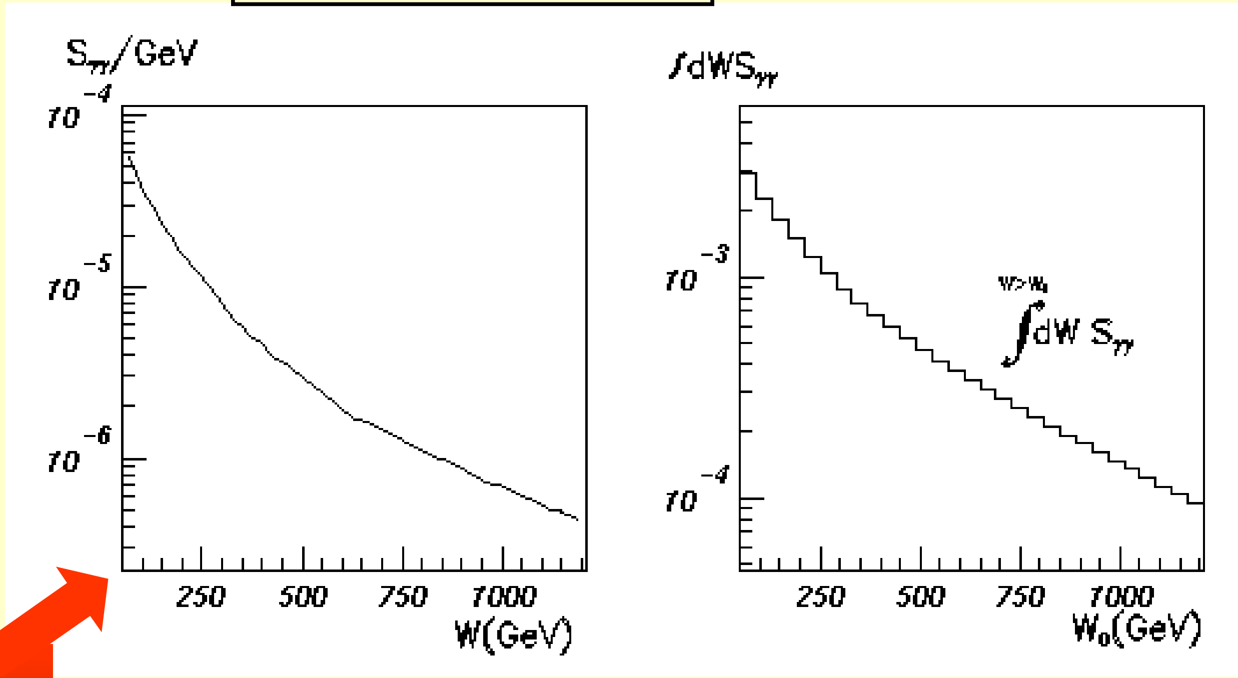
$W^2 = s\, x_1\, x_2$

Photon flux $\propto 1/Q^2$

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

protons scattered at \`zero-degree' angle

for x>0.0007, Q²<2GeV²



Use EPA à la *Budnev et al.**

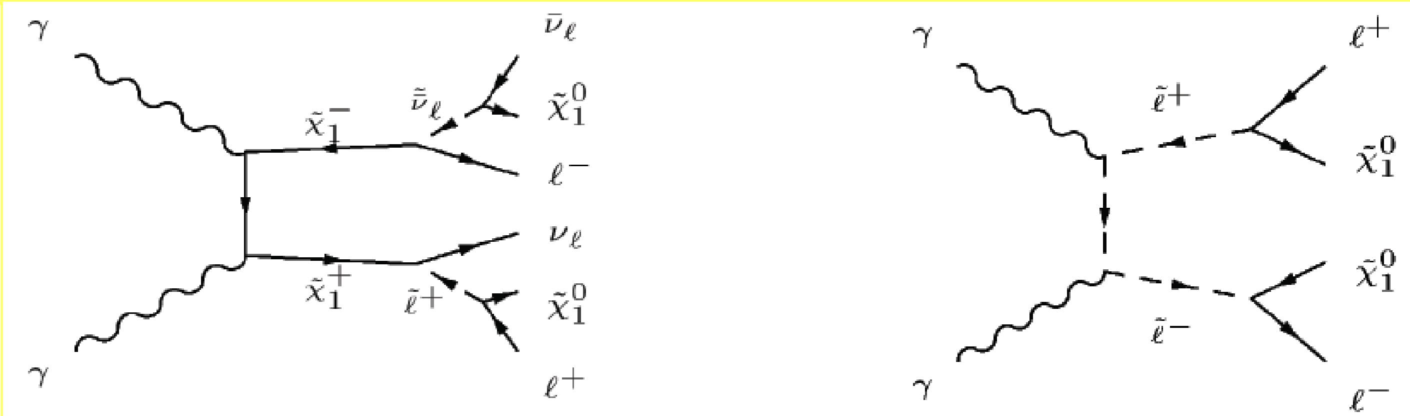
** error found in the elastic (Q² integrated) γ flux for protons!*

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

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

Exclusive two-photon production of charged SUSY pairs – Production x-sections defined only by mass, charge and spin!

• Very clean signature: Two (and only two) opposite charged leptons and missing energy



Three post-WMAP mSugra benchmark points checked:

• LM1: light LSP, light sleptons & charginos, Tan(β)=10
• LM2: medium LSP, heavy sleptons&charginos, Tan(β)=30
• LM6: heavy LSP, medium right sleptons, Tan(β)=10

m [GeV]	LM1	LM2	LM6
$\tilde{\chi}_1^0$	97	141	162
$\tilde{l}_R^+$	118	229	175
$\tilde{l}_L^+$	184	301	283
$\tilde{\tau}_1^+$	109	155	168
$\tilde{\tau}_2^+$	188	313	285
$\tilde{\chi}_1^+$	180	265	303
H^+	386	448	592

First acceptance studies: Modified CalcHep for $\gamma\gamma \rightarrow$ SUSY pair generation, and Pythia for decays

Lepton (e/μ) acceptance cuts: $p_T > 3\ (10)$ GeV, $|\eta| < 2.5$; irreducible background due to $\gamma\gamma \rightarrow$ WW

Benchmark		LM1	LM2	LM6
σ [fb]	$\tilde{l}^+_R \tilde{l}^-_R$	0.805	0.087	0.220
	$\tilde{l}^+_R \tilde{l}^-_R$	0.185	0.032	0.040
	$\tilde{\tau}^+_i \tilde{\tau}^-_i$	0.611	0.180	0.148
	$\tilde{\chi}^+_1 \tilde{\chi}^-_1$	0.605	0.144	0.087
	$H^+ H^-$	0.006	0.003	0.001
	$W^+ W^-$		103	
σ acc	$\tilde{l}^+_R \tilde{l}^-_R$	0.633(0.479)	0.075(0.074)	0.177(0.087)
	$\tilde{l}^+_R \tilde{l}^-_R$	0.144(0.135)	0.014(0.012)	0.036(0.035)
	$\tilde{\tau}^+_i \tilde{\tau}^-_i$	0.023(0.006)	0.008(0.001)	0.003(0.001)
	$\tilde{\chi}^+_1 \tilde{\chi}^-_1$	0.103(0.029)	0.006(0.001)	0.033(0.028)
	$W^+ W^-$		4.057(3.512)	

Large signal acceptance, and not very sensitive to minimal accepted lepton p_T

Irreducible WW background issue

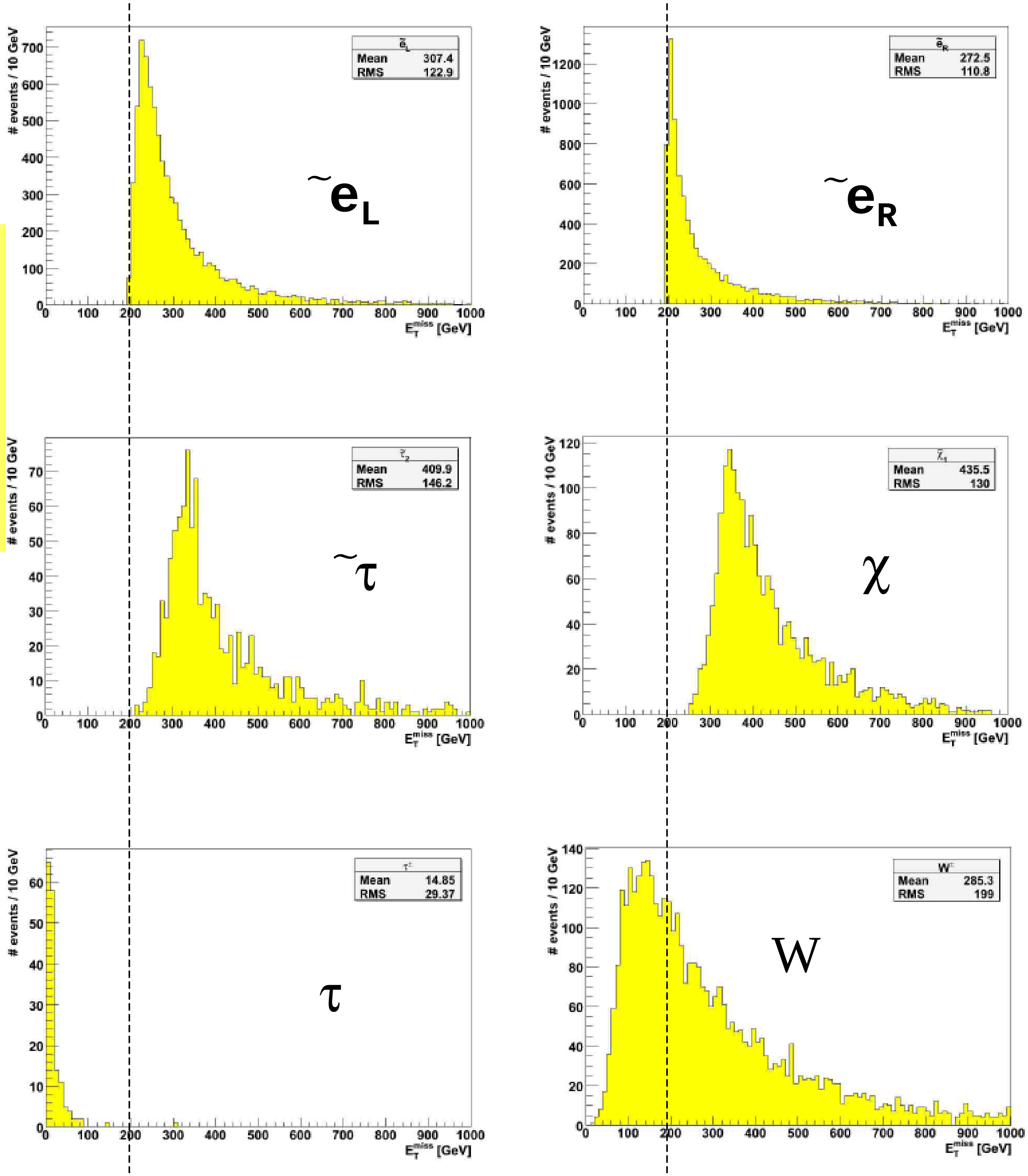
• Use lepton flavor sharing in final state:
For example, in SUSY case sharing between ee−eμ/μe−μμ is 45−10−45%, and for WW decays 25−50−25%

• (To increase statistics: Consider inclusion of tau-jets in analysis)

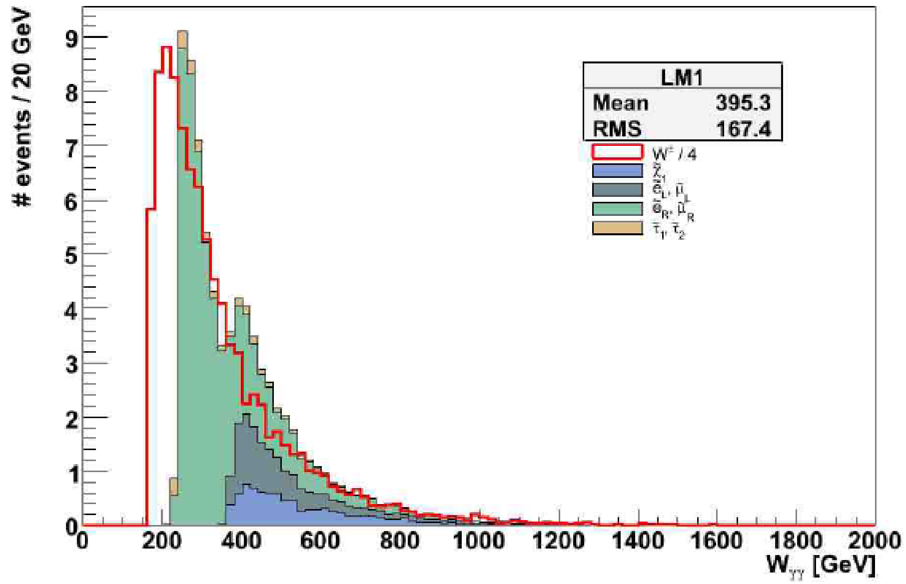
• In SUSY case much more missing energy due to LSPs → first, missing E_T can be tried...

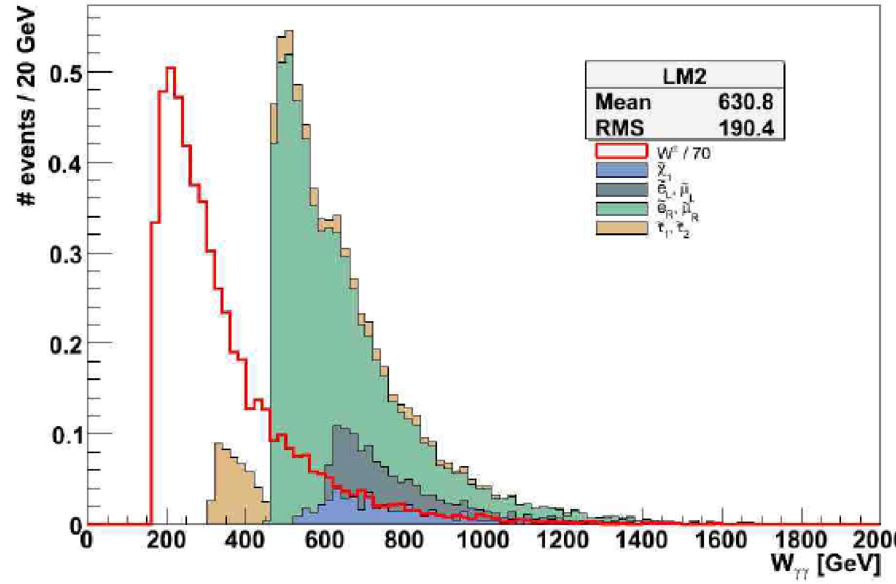
• Finally, assuming installed VFDs, event kinematics can be fully reconstructed by measuring forward protons (~75% acceptance possible); however, thanks to significant cross-sections interesting measurements should be possible already at low luminosity using central detectors <u>only</u>...

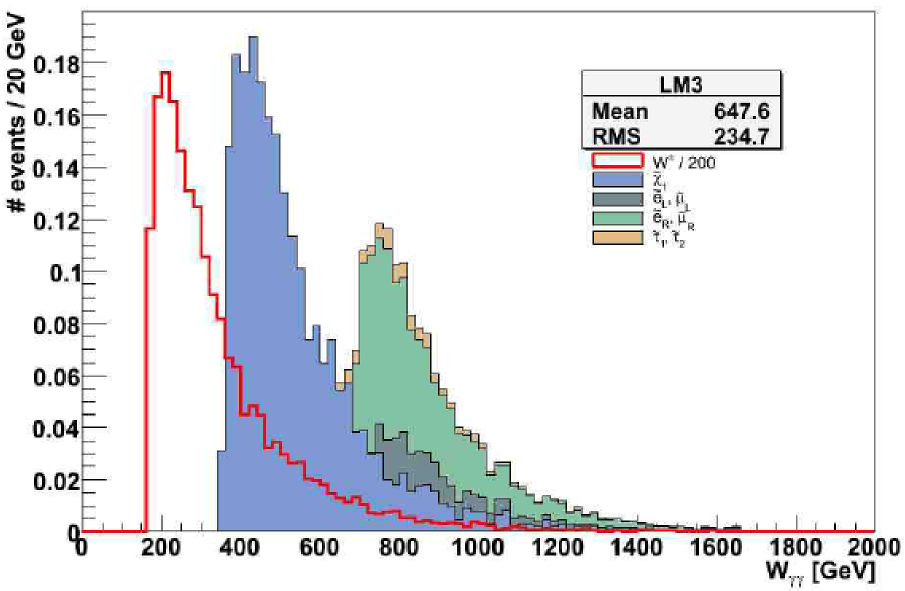
LM1 point:
WW suppression by factor ~2 using missing E_T; two-photon $\tau^+\tau^-$ pairs excluded

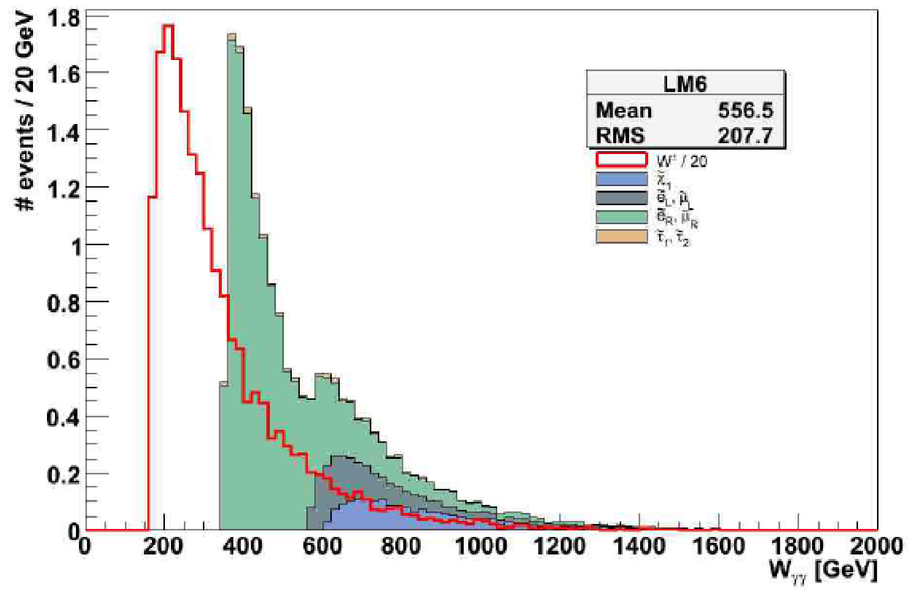


Could be further tightened using reconstructed $W_{\gamma\gamma}$ …


LM1
Mean 395.3
RMS 167.4
W± / 4
events / 20 GeV
W_γγ [GeV]


LM2
Mean 630.8
RMS 190.4
W± / 70
events / 20 GeV
W_γγ [GeV]


LM3
Mean 647.6
RMS 234.7
W± / 200
events / 20 GeV
W_γγ [GeV]


LM6
Mean 556.5
RMS 207.7
W± / 20
events / 20 GeV
W_γγ [GeV]

Preliminary observations

Exclusive two-photon production of SUSY pairs is sizeable at LHC for sparticle masses below ~200 GeV

• Large signal acceptance and low irreducible WW background

• Very forward proton detectors crucial for exclusive event selection at high luminosity (triple coincidence condition)/ background control and suppression/data interpretation

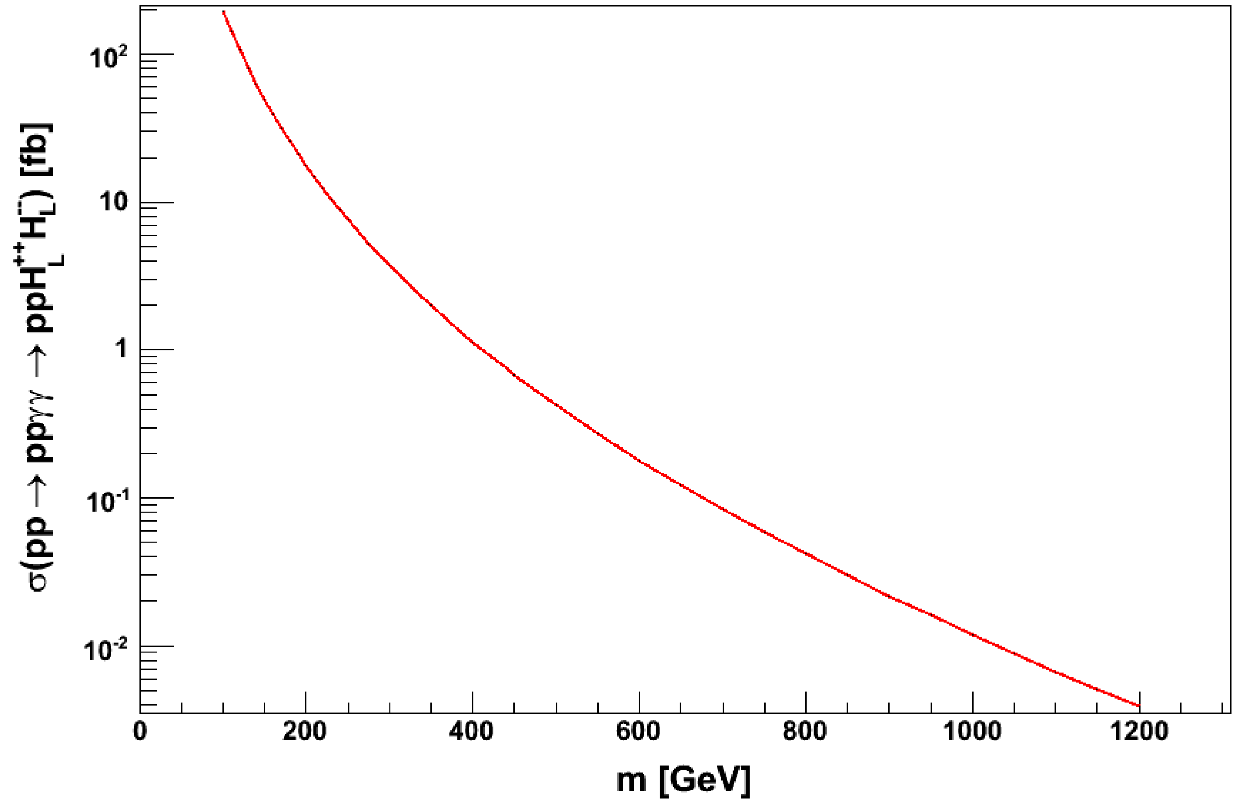
• This is a very interesting, novel laboratory for searches for any new phenomena in high-energy $\gamma\gamma$ collisions…

As for example, due to recently proposed sweet-spot SUSY, with light (~116 GeV) long-lived staus…

Or, due to multi-charged particles production…

Doubly charged Higgs bosons

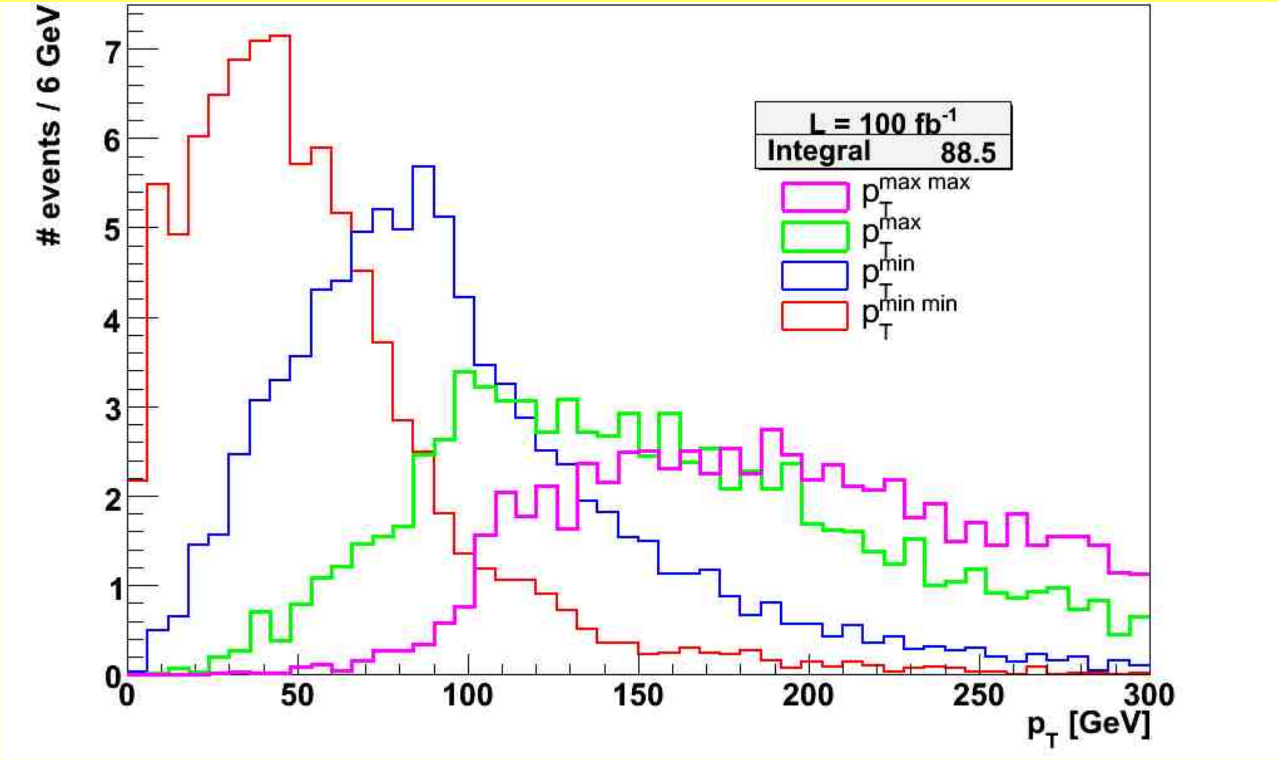
L-R symmetric model implemented in CalcHep for $\gamma\gamma$ event generation, then passed to Pythia for $H^{++/--}$ decays (tau decays suppressed)



Signal amplified by factor 16, with unique signature…

Doubly charged Higgs bosons, cont'd

Example: 200 GeV Higgs case – use 4 lepton 'golden' events:
$e^+e^+\mu^-\mu^-$ **or** $e^-e^-\mu^+\mu^+$ with acceptance cuts,
$p_T > 3$ GeV, $|\eta| < 2.5$:



Note: 'Irreducible' background $\gamma\gamma \rightarrow \tau^+\tau^+\tau^-\tau^- \rightarrow e^+e^+\mu^-\mu^-$ or $e^-e^-\mu^+\mu^+$ negligible!

Summary/Outlook

• High-energy (at electroweak scale and beyond) photon interactions have significant cross-sections at the LHC!

• Tagging high energy photon (and diffractive) interactions at LHC, and at high luminosity, can be done by supplementing central detectors with very forward proton detectors.

• Using double tagging, two-photon exclusive production, for example di-leptons (+ missing E_T) can be studied at nominal LHC luminosity.

• This offers novel, exciting and complementary SUSY studies

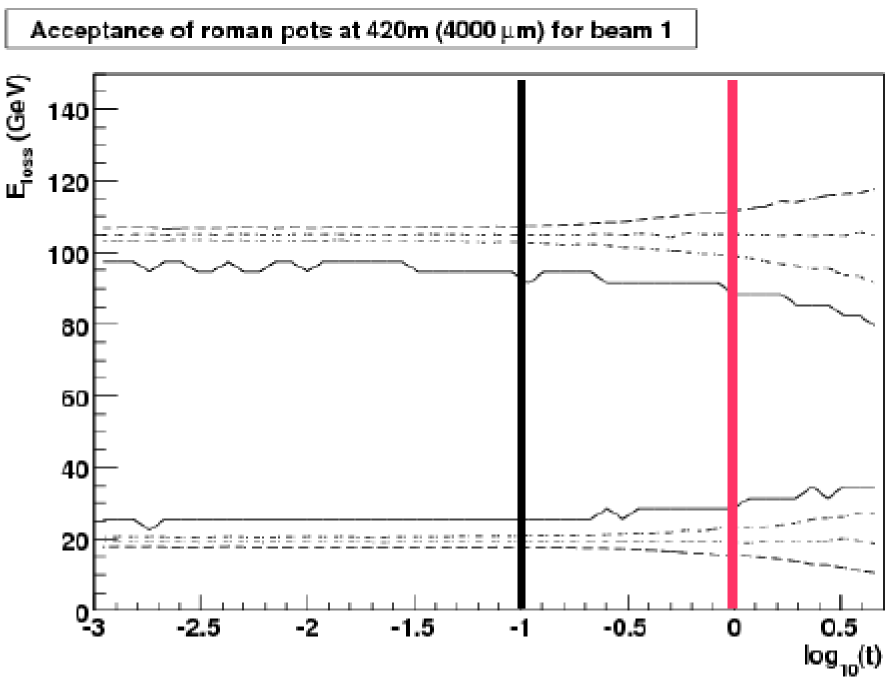
• Note: Triggering (at Level 1) of photon interaction is almost 'given', since both ATLAS and CMS are designed to trigger well on high p_T leptons!

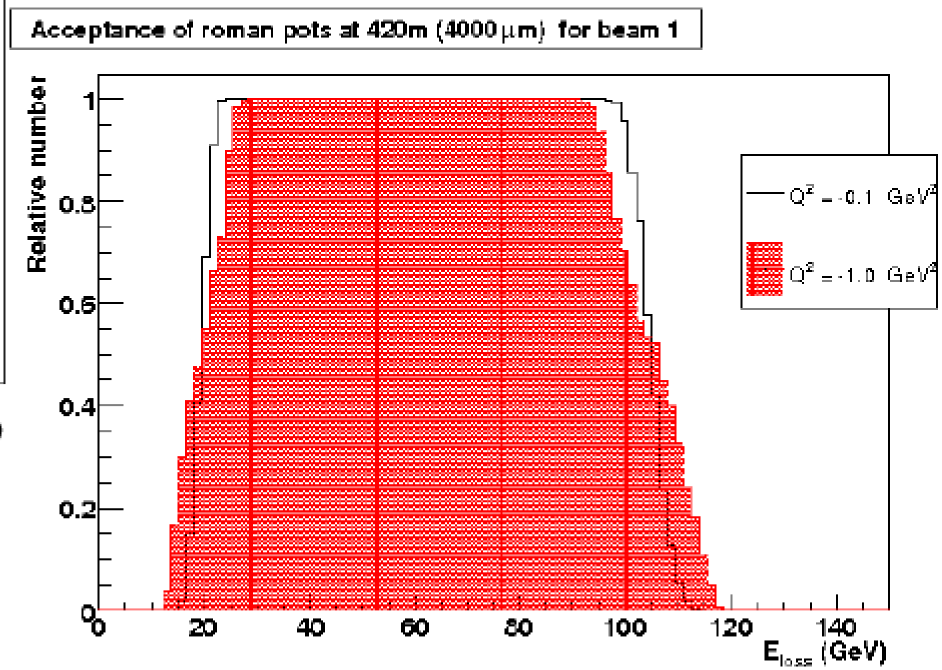
We cannot miss it!

Extra slides

Hector Direct physics output (II)

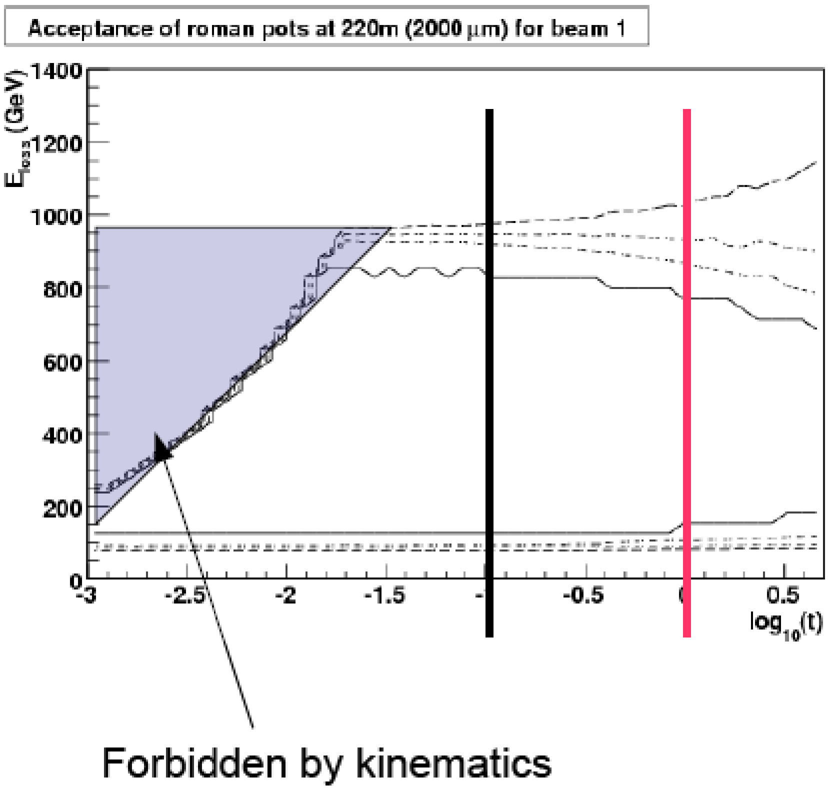
RP acceptances (420m) beam 1



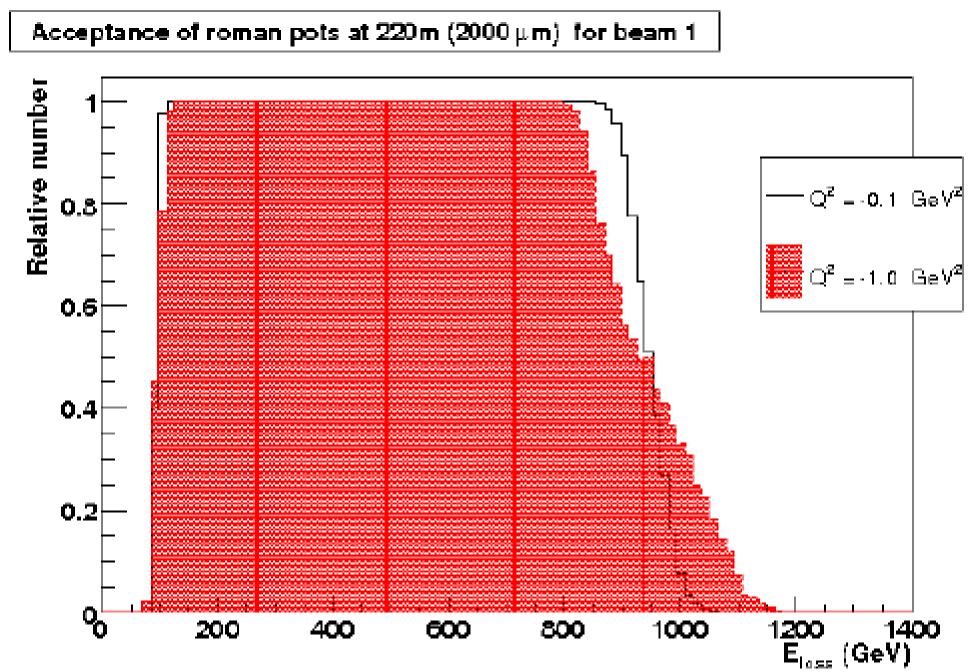


Direct physics output (II)

RP acceptances (220m) :



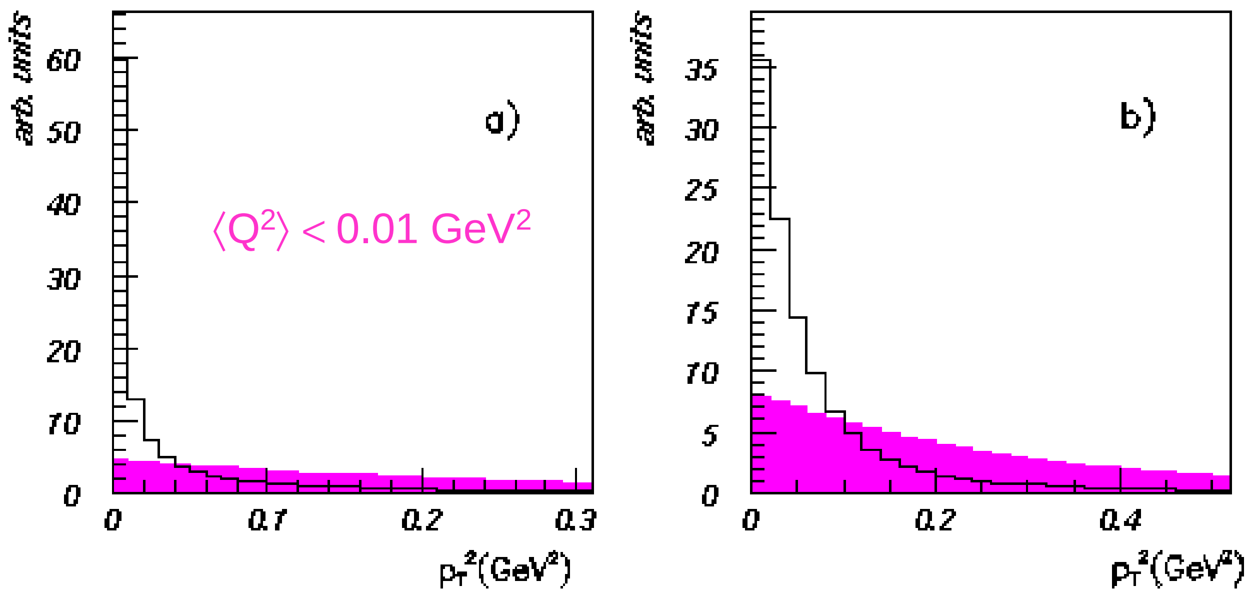
Which protons are detected ?



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

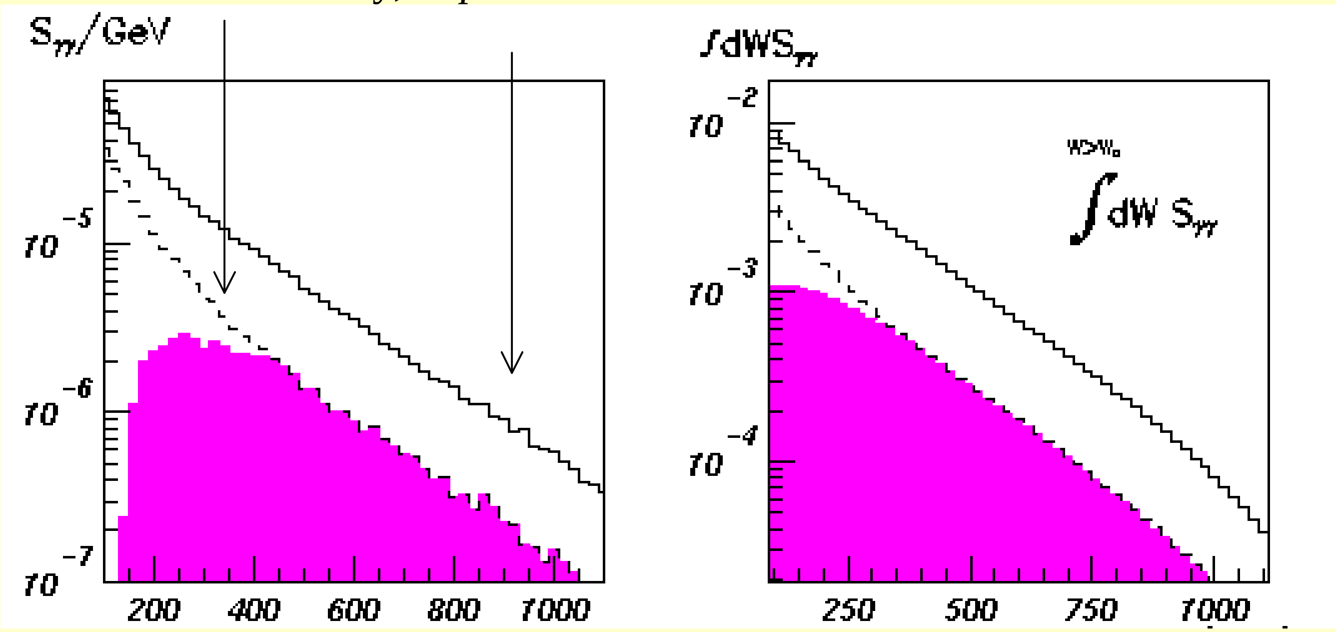
Tagging two-photon events

Assume detector stations at ~220 m where approximately $x > 0.01$ range accessible

Note: If only one forward *p* detected – single tag, but then non-elastic, *p* dissociative photon emission is possible

Assume 0.1>x>0.01, and Q^2<2 GeV^2 and for dissociative mass M_N < 20 GeV

Single tags:
elastic only, or *p-diss.* incl.



Color: double-tags, hence *elastic* scattering only