$WW\gamma$ coupling in photon-photon processes at the LHC

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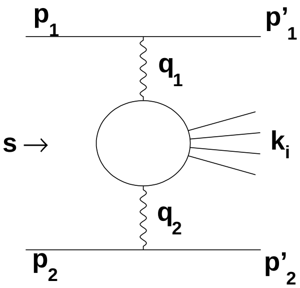
- Photon-photon interactions
- WW production in photon induced processes
- $WW\gamma$ anomalous triple gauge boson vertex
- Measurements to constrain $WW\gamma$ coupling

Photon induced processes



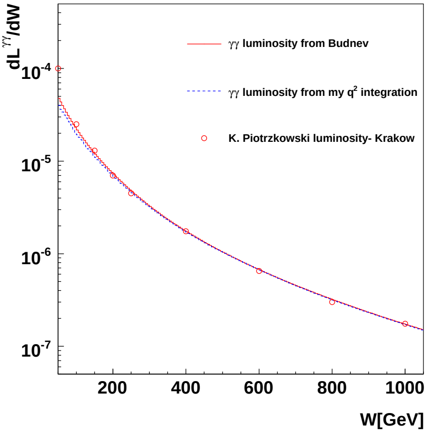
- photon momentum $q_i = p_i - p'_i$
- fractional momentum loss of the proton $\xi_i = (p_{iz} - p'_{iz})/p_{iz}$
- mass of created system $W^2 = (q_1 + q_2)^2 \sim s\xi_1\xi_2$
- main contribution when $q_i^2 \to q_{min}^2$
- energy of photons ω_i

- EPA (Equivalent photon approximation) - for low q_i^2 cross section factorizes

$$d\sigma = \sigma_{\gamma\gamma}(W = \sqrt{4\omega_1\omega_2})N(\omega_1)N(\omega_2)\frac{d\omega_1}{\omega_1}\frac{d\omega_2}{\omega_2}$$

- photon flux $N(\omega)$ - Budnev et al. [1]

Effective $\gamma\gamma$ luminosity in $pp \to p\gamma\gamma p$



- $W^2 = 4\omega_1\omega_2$

$$d\sigma = \sigma_{\gamma\gamma}(W)\frac{dL}{dW}dW$$

- $\gamma\gamma$ luminosity calculated from photon flux $N(\omega)$
- independent of the subprocess
- $\omega_{1,2} > 5$ GeV, $Q^2_{max} = 2$ GeV^2

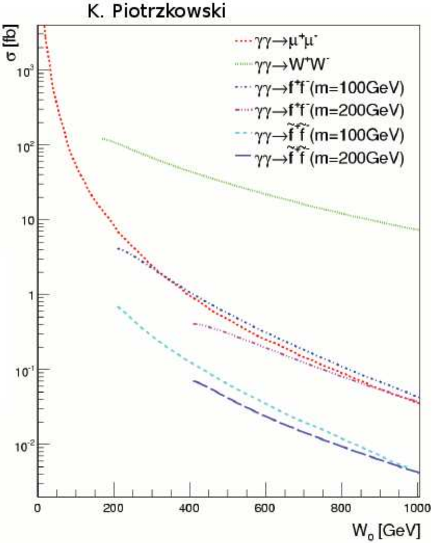
Cross sections for some processes

as a function of W_0 - minimal $\gamma\gamma$ mass

$$\sigma(W_0) = \int_{W_0}^{W_{max}} d\sigma_{\gamma\gamma\to i\ \bar{i}}(W)\frac{dL}{dW}dW$$

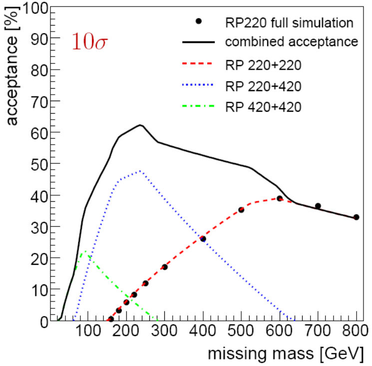
- largest signal $\gamma\gamma \to \mu\mu \doteq 70\,\text{pb}$
- interesting process $\gamma\gamma \to W^+W^- \doteq 96\,\text{fb}$
- hypotetical heavy leptons
  $f^+f^- \doteq 4\,\text{fb}$ (m=100 GeV)
  $f^+f^- \doteq 0.4\,\text{fb}$ (m=200 GeV)

- lumi in 3 years $30\,\text{fb}^{-1}$
- day (10^5s) with $\mathcal{L} = 10^{33}\,\text{cm}^{-2}\text{s}^{-1}$
  - $\sim$ 7000 $\mu\mu$ events
  - $\sim$ 10 WW events



Cross sections for γγ processes as a function of the minimal γγ cms energy W₀

AFP - Atlas forward physics collaboration



- forward detectors at 220m and 420m
  - movable beam pipe with silicon 3D detectors
  - timing detectors for high luminosity operation to suppress pileup
- 3D silicon detectors close to beam
  - 2mm (220m), 5mm (420m)
- common acceptance $0.001 < \xi < 0.2$

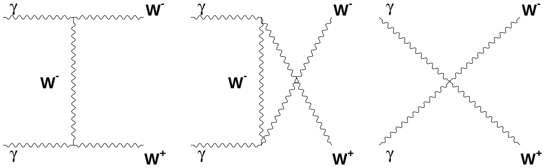
A. Kupčo

Physics aim:

- exclusive double pomeron exchange
  - mass and quantum numbers of Higgs boson
  - discovery in minimal supersymmetric extensions of SM (MSSM)
- but also standard QCD: DPE, SD
- photon-photon interactions

WW production in Standard model

process $p + p \to p\gamma\gamma p \to pW^+W^-p$

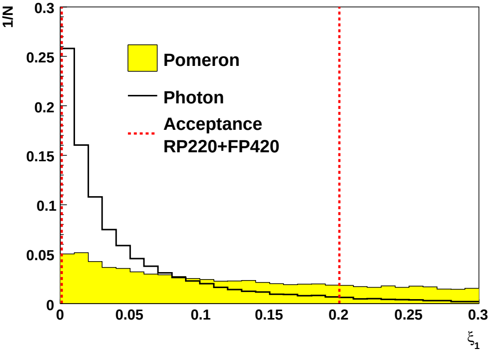


- $\sigma^{pp \to pWWp} = 95.5\,\text{fb}$
  - $\omega_{1,2} > 5\,\text{GeV}$, $Q^2_{max} = 2\,\text{GeV}^2$, no detector acceptance
- final state
  - lepton + jet
  - lepton + lepton
  - jet+jet - reject, high QCD background
- selecting photon events using forward detectors, clean events
- particle level study

Background, acceptance effects

- most important background
  - WW produced in double diffraction $\sigma_{INC}^{pp\to pWWp} = 64\,\mathrm{fb}$
  - pile-up - not studied yet, but important for high luminosities

- common acceptance $0.001 < \xi_{1,2} < 0.2$



- QED contribution grows faster when ξ decreases $\to$ suppression of the background
- $\sigma_{\mathrm{signal}}^{n_l>0,acc} = 21\,\mathrm{fb}$
- $\sigma_{\mathrm{back}}^{n_l>0,acc} = 2\,\mathrm{fb}$

WWγ triple gauge boson vertex

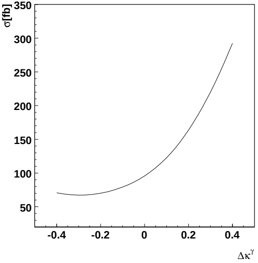
- potential scenario:
  - new physics modify the self-interaction of gauge bosons
  - it occurs at an energy scale well above that probed experimentally
  - at low scale - effective couplings

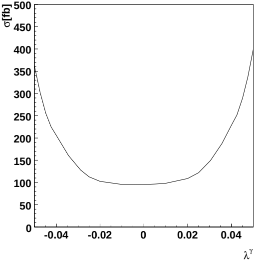
- most general effective Lagrangian (conserving C and P separately):

$$\mathcal{L}/g_{WW\gamma} = i(W^{\dagger}_{\mu\nu}W^{\mu}A^{\nu} - W_{\mu\nu}W^{\dagger\mu}A^{\nu}) + i\kappa^{\gamma}W^{\dagger}_{\mu}W_{\nu}A^{\mu\nu} + i\frac{\lambda^{\gamma}}{M_W^2}W^{\dagger}_{\rho\mu}W^{\mu}{}_{\nu}A^{\nu\rho}$$

$$W_{\mu\nu} \equiv \partial_{\mu}W_{\nu} - \partial_{\nu}W_{\mu}, \qquad g_{WW\gamma} = -e$$

- recovering SM
  - $\kappa^{\gamma} \to 1$
  - $\lambda^{\gamma} \to 0$
- deviation from the SM
  $\Delta\kappa^{\gamma}, \lambda^{\gamma}$





Sensitivity to anomalous coupling - # of events

- when $\Delta\kappa^\gamma, \lambda^\gamma \neq 0$, # of observed events is higher than in SM
- the difference grows with luminosity
- for $\mathcal{L} = 30\,\text{fb}^{-1}$ (510 standard model events), 95% c.l.
  - for 0.001$< \xi < 0.01$ - mainly photon events

$\Delta\kappa^\gamma <$0.05 -0.06 $< \lambda^\gamma <$ 0.04

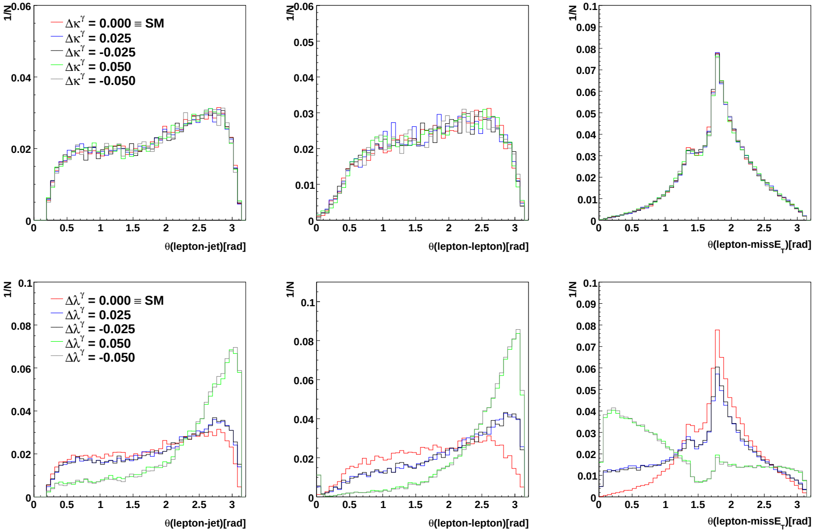
- current limits (95% c.l.):

CDF(2007)	-0.46 $< \Delta\kappa^\gamma <$0.39	-0.18 $< \lambda^\gamma <$ 0.17
LEP	-0.13 $< \Delta\kappa^\gamma <$0.13	-0.089 $< \lambda^\gamma <$ 0.20

- combined fit (p_T),W or Z exchange, assume $\Delta\kappa^\gamma = \Delta\kappa^Z, \lambda^\gamma = \lambda^Z$
- advantage - in $\gamma\gamma$ interaction Z exchange does not contribute
- gain in precision with AFP - about factor 2 for $\Delta\kappa^\gamma$ and 5 for λ^γ

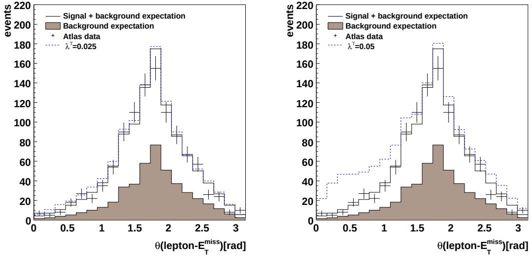
$$\frac{S}{\sqrt{B}} = \frac{N(\Delta\kappa^\gamma, \lambda^\gamma, \mathcal{L})}{\sqrt{N_{SM}(\mathcal{L}) + N_{\mathbb{P}}(\mathcal{L})}}$$

Angular distributions $\Delta\kappa^\gamma$, λ^γ



- shape of the distributions is mainly sensitive to λ^γ, lepton-missing E_T
- without acceptance

Improving sensitivity to λ^γ



- for 30fb^{-1}
- 0.001$< \xi < 0.02$

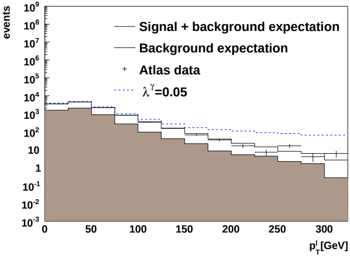
- cutting out the region where background high

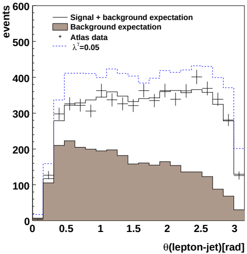
95% c.l.	$\lambda^\gamma < 0.05$	$-0.035 < \lambda^\gamma < 0.025$
3σ c.l.	$\lambda^\gamma < 0.075$	$-0.040 < \lambda^\gamma < 0.032$
5σ c.l.	$\lambda^\gamma < 0.12$	$-0.050 < \lambda^\gamma < 0.042$

Limits for high luminosity

- limits for $\mathcal{L} = 200\,\text{fb}^{-1}$

  95% c.l. $\lambda^\gamma < 0.026$ -0.025 $< \lambda^\gamma < 0.018$
- roughly 5 resp. 10 more sensitive in κ^γ resp. λ^γ than current limits
- more statistics, likelihood fit to pt, or angular spectra possible





Conclusion

- first time in history hadron-hadron collider can be used as the $\gamma\gamma$ collider
- allow us to study various $\gamma\gamma$ induced processes

- counting number of observed events
  - current limits can be improved by factor 2 and 7 for $\Delta\kappa^\gamma$ and λ^γ resp. in three years of running

  95% c.l. $\lambda^\gamma < 0.05$ $-0.035 < \lambda^\gamma < 0.025$

- comparable precision in $\Delta\kappa^\gamma$ but worse precision in λ^γ in comparison to inelastic channel $W\gamma$ (ATLAS) [2]

  $-0.075 < \Delta\kappa^\gamma < 0.076$ $-0.0035 < \lambda^\gamma < 0.0035$

  - fit of lepton p_T spectrum for 30fb^{-1}

Reference:

V. M. Budnev, I. F. Ginzburg, G. V. Meledin and V. G. Serbo, Phys. Rept. **15** (1974) 181.

M. Dobbs, AIP Conf. Proc. **753** (2005) 181 [arXiv:hep-ph/0506174].