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

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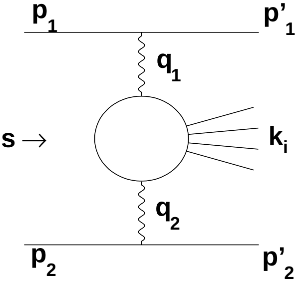
April 25, 2008
Photon Workshop, CERN

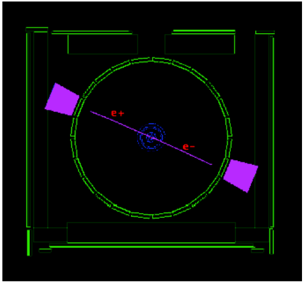
- WW production in photon induced processes
- Sensitivity to $WW\gamma$ anomalous coupling

Photon induced processes



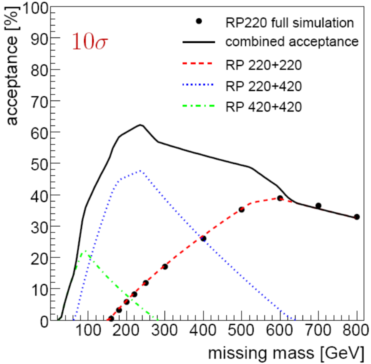
- photon momentum $q_i = p_i - p'_i$
- fractional momentum loss of the proton $\xi_i = (p_{iz} - p'_{iz})/p_{iz}$
- mass of created system $W^2 = (q_1 + q_2)^2 \sim s\xi_1\xi_2$
- main contribution when $q_i^2 \to q_{min}^2$
- energy of photons ω_i

- first observation of photon-photon production at the Tevatron
- $\gamma\gamma \to e^+e^-$ - $\sigma = 1.71\,\mathrm{pb}$
- $\gamma\gamma \to \mu^+\mu^-$ - analysis under way



J. Pinfold, DIS 2008

Atlas forward detectors



- 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)

A. Kupčo

Physics aim:

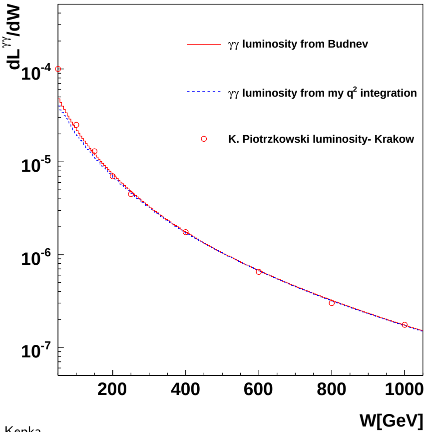
- exclusive double pomeron exchange
  - mass and quantum numbers of Higgs boson
  - discovery in supersymmetric extensions of SM
- but also standard QCD: DPE, SD, GPDs
- photon-photon interactions

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

- 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 $N(\omega)$ - (corrected) Budnev et al., Phys. Rept. **15** (1974) 181



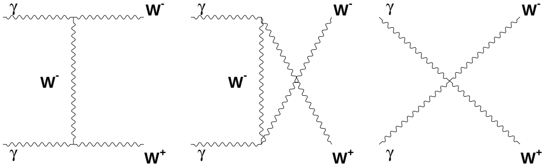
- $W^2 = 4\omega_1\omega_2$

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

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

WW production in Standard model

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



- $\sigma^{pp\rightarrow pWWp} = 95.5\,\text{fb}$ - pure Standard Model
  - $\omega_{1,2} > 5\,\text{GeV}$, $Q^2_{max} = 2\,\text{GeV}^2$, no detector acceptance

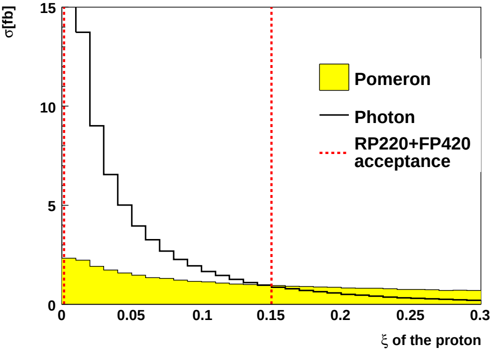
- selecting photon events using forward detectors
- final state - $p_T^l > 30\,\text{GeV}$
  - lepton + jet
  - lepton + lepton
  - jet+jet - reject, high QCD background

- particle level study

Background, acceptance effects

- most important background
  - WW produced in double pomeron exchange $\sigma_{INC}^{pp \to pWWp} = 64\,\text{fb}$
  - pile-up - not studied yet, but important for high luminosity run

- common acceptance $0.0015 < \xi_{1,2} < 0.15$
  - coincidently selects the region in which photon events are dominant



- QED contribution grows faster when ξ decreases $\rightarrow$ suppression of the background
- $\sigma_{\text{signal}}^{n_l>0,acc} = 28\,\text{fb}$
- $\sigma_{\text{back}}^{n_l>0,acc} = 2.2\,\text{fb}$

WWγ triple gauge boson vertex

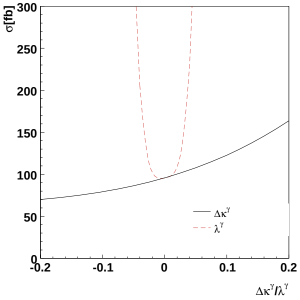
- new physics that occurs at an energy scale well above that probed experimentally modify the self-interaction of gauge bosons

- effective Lagrangian conserving C and P separately - two parameters:

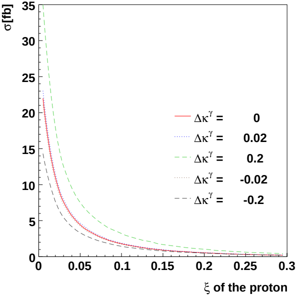
$$\mathcal{L}/ig_{WW\gamma} = (W^{\dagger}_{\mu\nu}W^{\mu}A^{\nu} - W_{\mu\nu}W^{\dagger\mu}A^{\nu}) + (1+\Delta\kappa^{\gamma})W^{\dagger}_{\mu}W_{\nu}A^{\mu\nu} + \frac{\lambda^{\gamma}}{M_W^2}W^{\dagger}_{\rho\mu}W^{\mu}{}_{\nu}A^{\nu\rho}$$

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

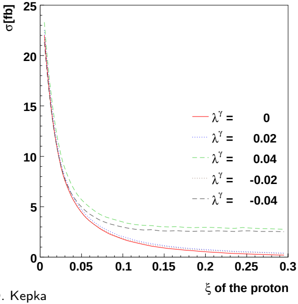
- deviation from the SM $\Delta\kappa^{\gamma}, \lambda^{\gamma}$
- σ increases with $|\lambda^{\gamma}|$
- σ increases with $\Delta\kappa^{\gamma}$



Lost momentum fraction, acceptance cut



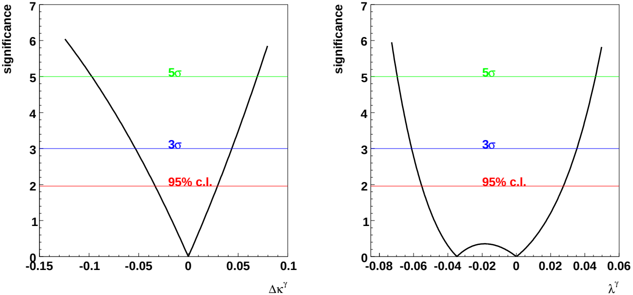
- $\Delta\kappa^\gamma \rightarrow$ enhancement of the signal within the detector acceptance $0.0015 < \xi < 0.15$



- $\lambda^\gamma \rightarrow$ loosing sensitivity due to the acceptance cut outside the region where signal is enhanced

Sensitivity to anomalous coupling - # of events

- when $\Delta\kappa^\gamma, \lambda^\gamma \neq 0$, # of observed events is different than in SM
- for $\mathcal{L} = 30\,\text{fb}^{-1}$ (840 standard model events), 95% c.l.



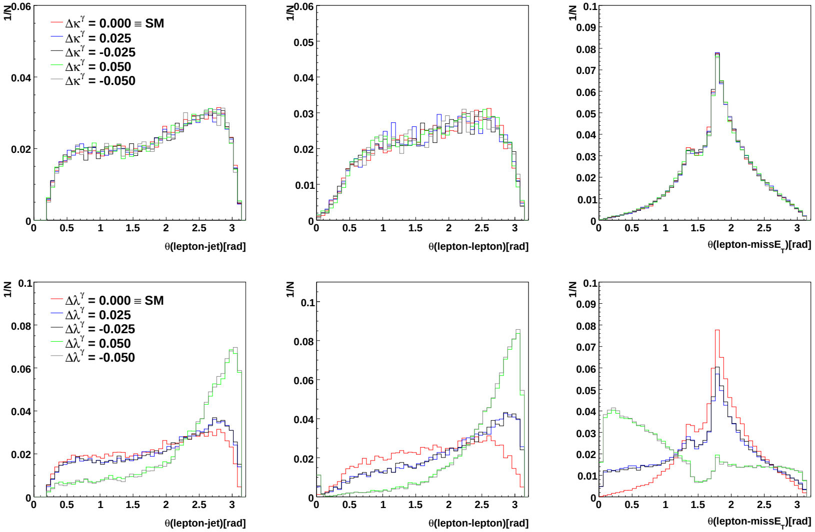
$-0.035 < \Delta\kappa^\gamma < 0.03 \qquad -0.054 < \lambda^\gamma < 0.0275$

- current best limits (95% c.l.) from Tevatron - non-diffractive channel $W\gamma$ DIS 2008 (Yurii Maravin), arXiv:0803.0030:

$$-0.51 < \Delta\kappa^\gamma < 0.52 \quad -0.12 < \lambda^\gamma < 0.13$$

- improvement by factor 15 and by 2-5 for $\Delta\kappa^\gamma$ and λ^γ, respectively

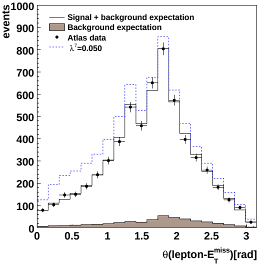
Angular distributions $\Delta\kappa^{\gamma}$, λ^{γ}

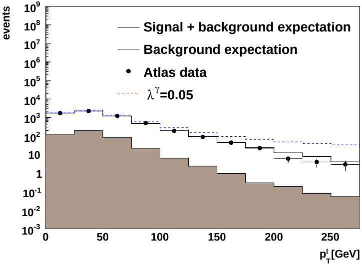


- shape of the distributions is mainly sensitive to λ^{γ}, lepton-missing E_T
- without acceptance

Distributions for λ^γ

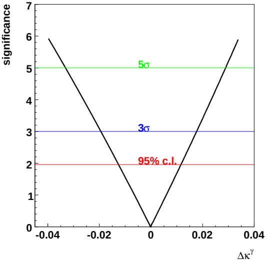
- acceptance reduces sensitivity to λ^γ
- anomalous coupling is enhancing number of high p_T leptons
- $\mathcal{L} = 200\,\text{fb}^{-1}$

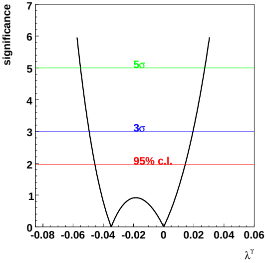




High luminosity

- for $\mathcal{L} = 200\,\text{fb}^{-1}$ (5600 standard model events), 95% c.l.





$$-0.013 < \Delta\kappa^{\gamma} < 0.012$$
$$-0.045 < \lambda^{\gamma} < 0.014$$

- comparable precision in $\Delta\kappa^{\gamma}$ but worse precision in λ^{γ} in comparison to inelastic channel $W\gamma$ (ATLAS) M .Dobbs, arXiv:hep-ph/0506174

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

- fit of lepton p_T spectrum for $30\,\text{fb}^{-1}$

Summary

- hadron-hadron collider can be used as the $\gamma\gamma$ collider
- allow us to study various $\gamma\gamma$ induced processes, WW production in particular

- improvement of current precision of $\Delta\kappa^{\gamma}$ and λ^{γ} by factor 15 and 2-5, respectively in three years of running
- for $\Delta\kappa^{\gamma}$ - as precise measurement using forwrd taggers as in the conventional inelastic channel $W\gamma$

$$-0.035 < \Delta\kappa^{\gamma} < 0.03 \qquad -0.054 < \lambda^{\gamma} < 0.0275$$

Backup Slides

- older 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