Detecting Elastic pp Scattering by Radiative Photons at the LHC

Hanna Grönqvist

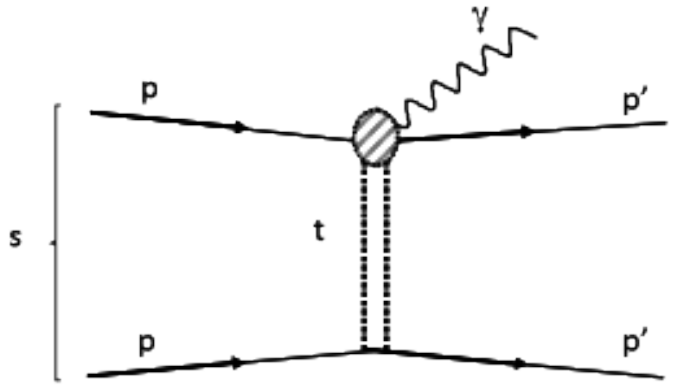
In collaboration with :
V.A. Khoze, J.W. Lämsä, M. Murray, R. Orava and M.G. Ryskin

21. September 2010

Outline

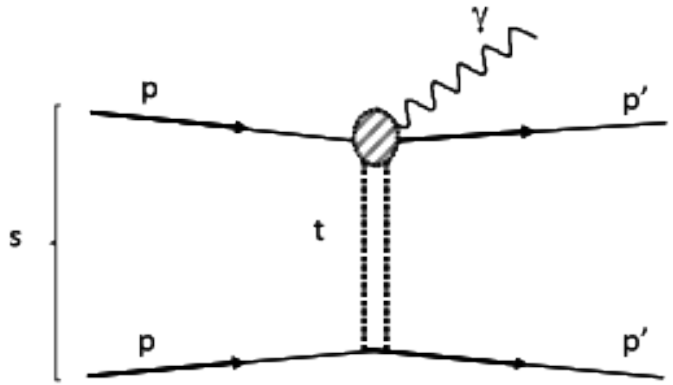
Introduction

Why study brehmsstrahlung photons at the LHC?



Introduction

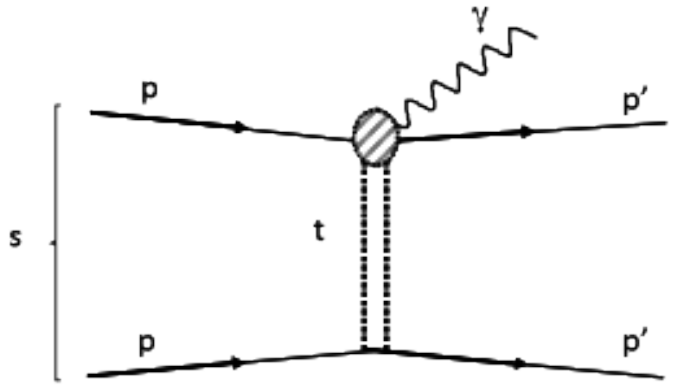
Why study brehmsstrahlung photons at the LHC?



- Identification of elastic pp events and measurement of the elastic pp cross section (assuming the elastic slope is known).

Introduction

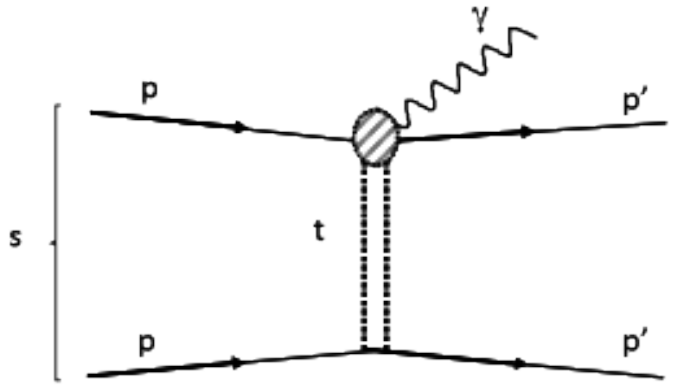
Why study brehmsstrahlung photons at the LHC?



- Identification of elastic pp events and measurement of the elastic pp cross section (assuming the elastic slope is known).
- Evaluation of total pp cross section and luminosity, since the radiative cross section is proportional to the ratio $(\sigma_{el}/\sigma_{tot})^2$.

Introduction

Why study brehmsstrahlung photons at the LHC?



- Identification of elastic pp events and measurement of the elastic pp cross section (assuming the elastic slope is known).
- Evaluation of total pp cross section and luminosity, since the radiative cross section is proportional to the ratio $(\sigma_{el}/\sigma_{tot})^2$.
- Alignment of the Zero Degree Calorimeters (ZDCs).

Theory

The probability to radiate a photon with energy $k << E$ is given by

(V.A Khoze, J.W. Lämsä, R. Orava, M.G. Ryskin : 'Forward Physics at the LHC, Detecting Elastic pp Scattering by Radiative Photons, arXiv/hep-ph:1007.3721)

$$\frac{4\pi}{\rho}\frac{\mathrm{d}\sigma_k}{\sigma_{el}^{pp}} = \frac{\alpha_{em}}{\pi}\,\mathrm{d}\cos\theta_k\frac{\mathrm{d}k}{k}\int_0^1 \theta_s \mathrm{d}\theta_s \exp(-\rho\frac{\theta_s^2}{2})\int_0^{2\pi}\mathrm{d}\phi\,\mathcal{F}$$

Theory

The probability to radiate a photon with energy $k << E$ is given by

(V.A Khoze, J.W. Lämsä, R. Orava, M.G. Ryskin : 'Forward Physics at the LHC, Detecting Elastic pp Scattering by Radiative Photons, arXiv/hep-ph:1007.3721)

$$\frac{4\pi}{\rho}\frac{\mathrm{d}\sigma_k}{\sigma_{el}^{pp}} = \frac{\alpha_{em}}{\pi}\,\mathrm{d}\cos\theta_k\frac{\mathrm{d}k}{k}\int_0^1 \theta_s \mathrm{d}\theta_s \exp(-\rho\frac{\theta_s^2}{2})\int_0^{2\pi}\mathrm{d}\phi\,\mathcal{F}$$

where

$$\mathcal{F} = \frac{4\theta_k^2}{\left[\frac{m^2}{E^2}+\theta_k^2\right]^2} + \frac{4\theta_{k'}^2}{\left[\frac{m^2}{E'^2}+\theta_{k'}^2\right]^2} + \frac{8\theta_k(\theta_k-\theta_s\cos\phi)}{\left[\frac{m^2}{E^2}+\theta_k^2\right]\left[\frac{m^2}{E'^2}+\theta_{k'}^2\right]}$$

Theory

The probability to radiate a photon with energy $k << E$ is given by

(V.A Khoze, J.W. Lämsä, R. Orava, M.G. Ryskin : 'Forward Physics at the LHC, Detecting Elastic pp Scattering by Radiative Photons, arXiv/hep-ph:1007.3721)

$$\boxed{\frac{4\pi}{\rho}\frac{\mathrm{d}\sigma_k}{\sigma_{el}^{pp}} = \frac{\alpha_{em}}{\pi}\,\mathrm{d}\cos\theta_k\frac{\mathrm{d}k}{k}\int_0^1 \theta_s \mathrm{d}\theta_s \exp(-\rho\frac{\theta_s^2}{2})\int_0^{2\pi}\mathrm{d}\phi\,\mathcal{F}}$$

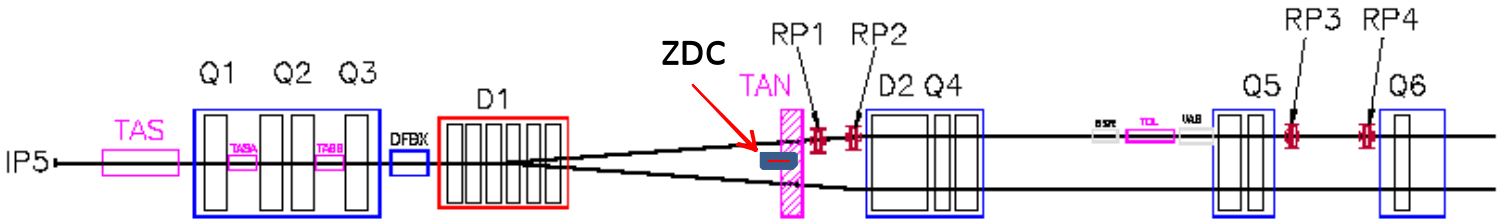
where

$$\mathcal{F} = \frac{4\theta_k^2}{\left[\frac{m^2}{E^2}+\theta_k^2\right]^2} + \frac{4\theta_{k'}^2}{\left[\frac{m^2}{E'^2}+\theta_{k'}^2\right]^2} + \frac{8\theta_k(\theta_k-\theta_s\cos\phi)}{\left[\frac{m^2}{E^2}+\theta_k^2\right]\left[\frac{m^2}{E'^2}+\theta_{k'}^2\right]}$$

At small angles $\frac{\mathrm{d}\sigma_{el}^{pp}}{\mathrm{d}t} \longrightarrow \sigma_{el}^{pp} B\exp(-B|t|)$, since $|t| \to p^2\theta_s^2 = p_t^2$

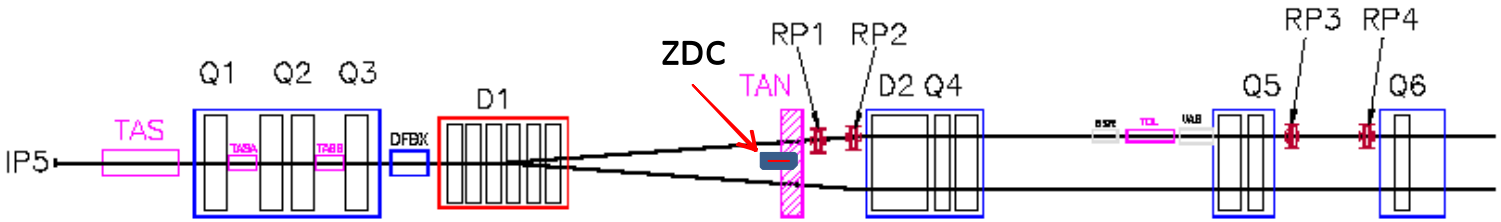
Experimental setup

- The soft photons are observed at the Zero Degree Calorimeters (ZDCs) :



Experimental setup

- The soft photons are observed at the Zero Degree Calorimeters (ZDCs) :



- These photons give a distinct physical signal, since the distribution the photons give rise to peaks at zero degrees.

The design of the ZDC

- The ZDCs of CMS have electromagnetic (EM) and hadronic (HAD) sections as in the following layout :

(Pictures from "Performance of the combined zero degree calorimeter for CMS", O A Grachov et al, Journal of Physics: Conference Series 160, 2009)

- The EM section has five quartz fiber towers between absorber plates of tungsten, all aligned horizontally, the detector covering a range $x, y \in [-4, 4]$ cm.

Triggers and Backgound

- Main background consists of photons emitted in ineastic diffractive events.
  Non-diffractive events constitute a secondary background.

Triggers and Backgound

- Main background consists of photons emitted in ineastic diffractive events.
  Non-diffractive events constitute a secondary background.

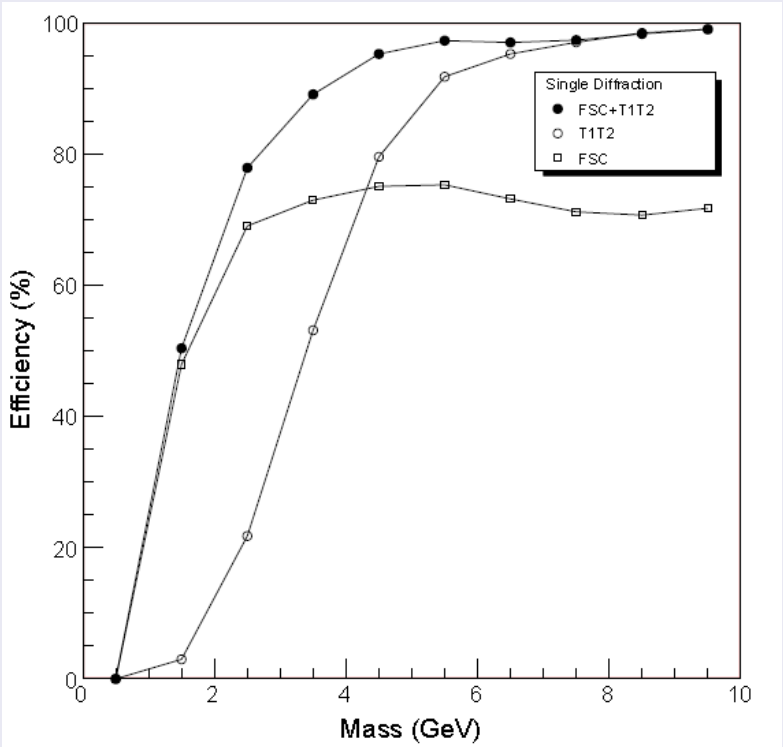
- For the chosen energy range 50-500 GeV the backgound-to-signal ratio is estimated to be $< 5\%$

Triggers and Backgound

- Main background consists of photons emitted in ineastic diffractive events.
  Non-diffractive events constitute a secondary background.

- For the chosen energy range 50-500 GeV the backgound-to-signal ratio is estimated to be $< 5\%$

Efficiencies of detecting SD events

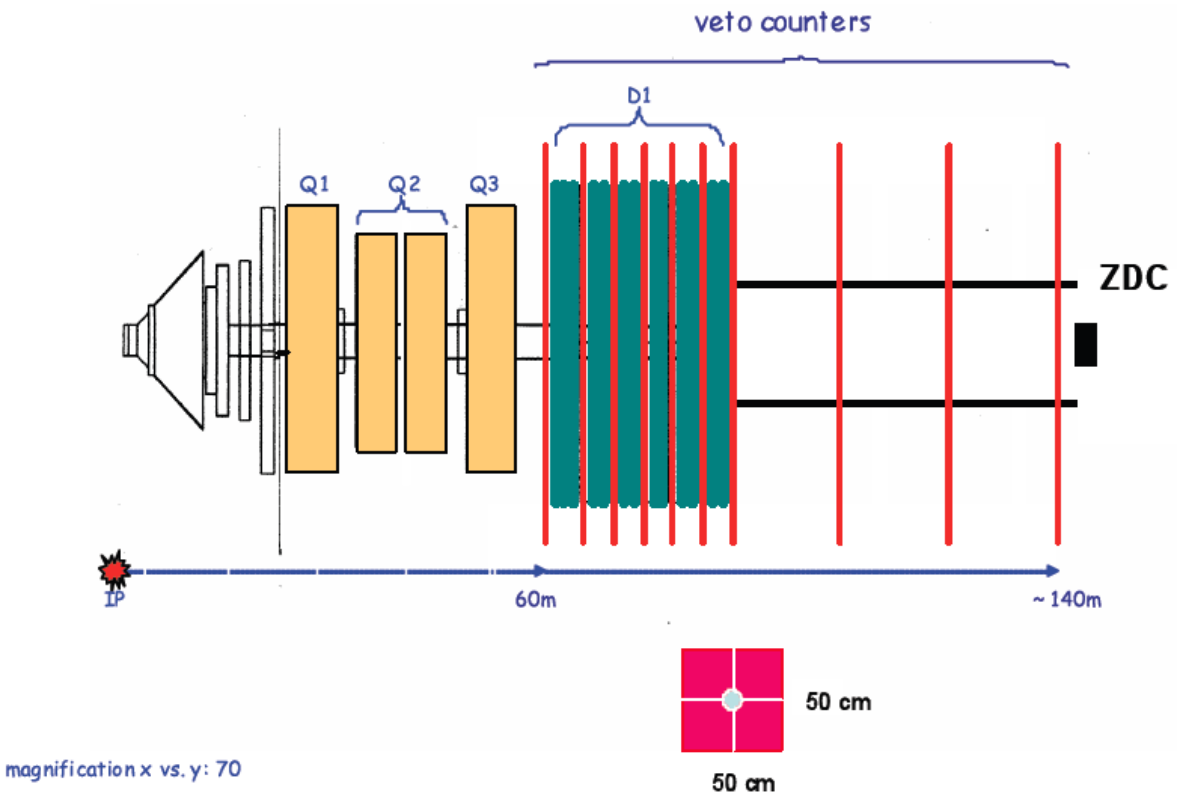


Proposed Forward Shower Counters

- To reduce background further, Forward Shower Counters, FSCs, can be added closely surrounding the beam pipes, at $z \in (60, 120)$m from the interaction point

Proposed Forward Shower Counters

- To reduce background further, Forward Shower Counters, FSCs, can be added closely surrounding the beam pipes, at $z \in (60, 120)$m from the interaction point



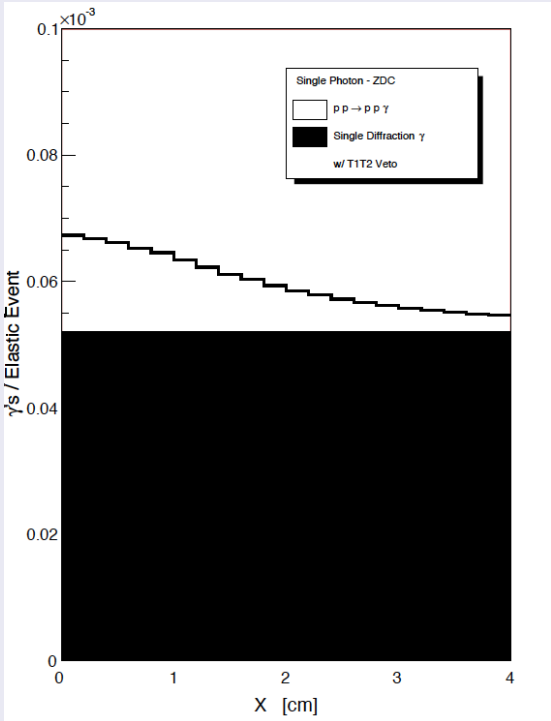
Results from simulations

- According to simulations the probability of detecting a single photon in the ZDC from radiative elastic scattering is :

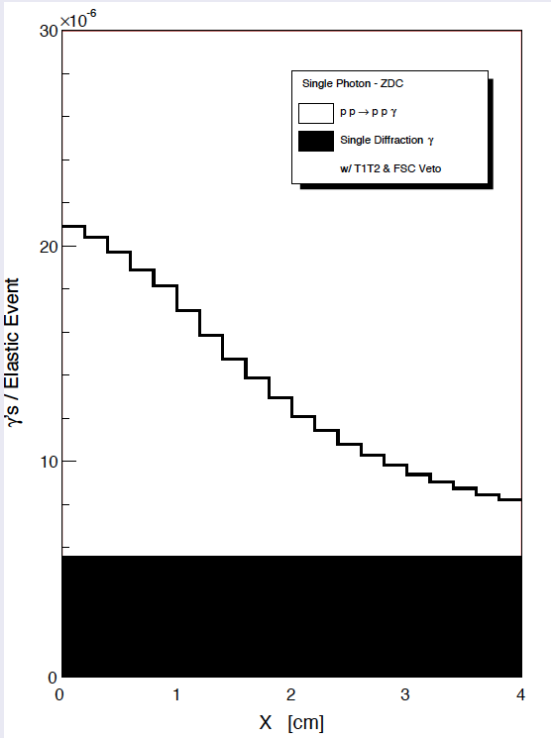
Results from simulations

- According to simulations the probability of detecting a single photon in the ZDC from radiative elastic scattering is :

T1T2 Veto



T1T2 & FSC Veto



Short explanation of the method

- The photons that hit the ZDC produce showers of known Molière radius, and the energy is spread out in the form of a 3d Gaussian.

Short explanation of the method

- The photons that hit the ZDC produce showers of known Molière radius, and the energy is spread out in the form of a 3d Gaussian.
- We reconstruct the vertex by examining ratios of energies such that we compare the tower with next highest energy to the one with the highest measured energy $\frac{\mathrm{E(2nd\ most)}}{\mathrm{E(max)}}$.

Short explanation of the method

- The photons that hit the ZDC produce showers of known Molière radius, and the energy is spread out in the form of a 3d Gaussian.
- We reconstruct the vertex by examining ratios of energies such that we compare the tower with next highest energy to the one with the highest measured energy $\frac{\text{E(2nd most)}}{\text{E(max)}}$.
- The energy measurements in the towers are simulated from the expected resolution of the ZDC

('Status of Zero Degree Calorimeter for CMS Experiment' O A Grachov et al, AIPConf.Proc.867:258-265, 2006):

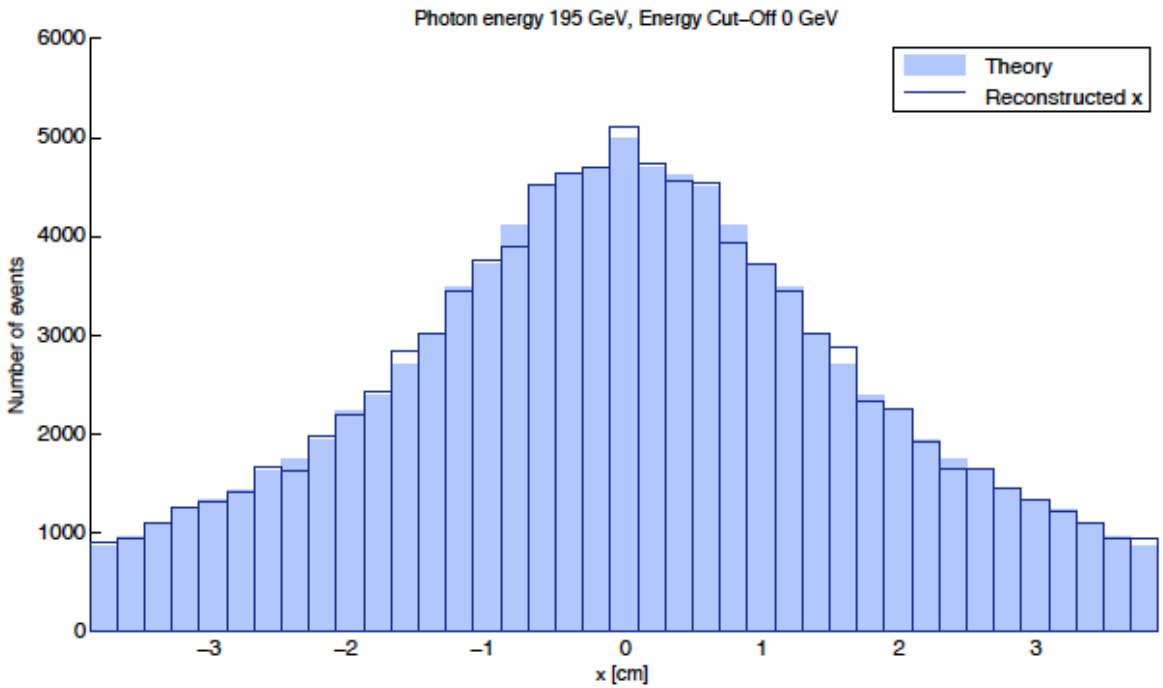
$$\frac{\sigma}{E} = \sqrt{\left(\frac{0.70}{\sqrt{E}}\right) + (0.03)^2}$$

Results

- The vertex is then reconstructed by comparing the measured energy ratio to the ratios given by calculations :

Results

- The vertex is then reconstructed by comparing the measured energy ratio to the ratios given by calculations :



Conclusions

- Radiative photons could be used to identify elastic pp events and measure the cross section of these events.

Conclusions

- Radiative photons could be used to identify elastic pp events and measure the cross section of these events.
- The photons are expected to give a clear physical signal, which can be distinguished from the background. This signal can be reconstructed, taking into account the design of the ZDCs.

Conclusions

- Radiative photons could be used to identify elastic pp events and measure the cross section of these events.
- The photons are expected to give a clear physical signal, which can be distinguished from the background. This signal can be reconstructed, taking into account the design of the ZDCs.
- Further applications are evaluation of the total pp cross section and alignment of the ZDCs.

Thank you for your attention!