

Feasibility Studies of the Diffractive Bremsstrahlung Measurement at the LHC

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Bremsstrahlung

Simple three particle final state: particles at very large rapidities

Can we use an attractive tool for the AFP calibration?

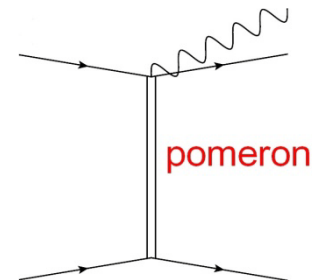
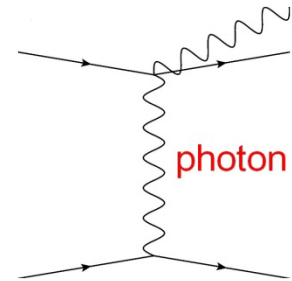
EM bremsstrahlung in the UPC approximation of pp
has the cross-section of about 60 nb for $100 \text{ GeV} < E_\gamma < 1500 \text{ GeV}$

V. A. Khoze et al. JINST **6** (2011) P01005

Measure bremsstrahlung accompanying elastic pp scattering
The cross-section of the order of microbarns

Considerably extended by P.Lebiedowicz and A. Szczurek (formfactors, re-scattering, ...)
Phys. Rev. D87 (2013) 114013

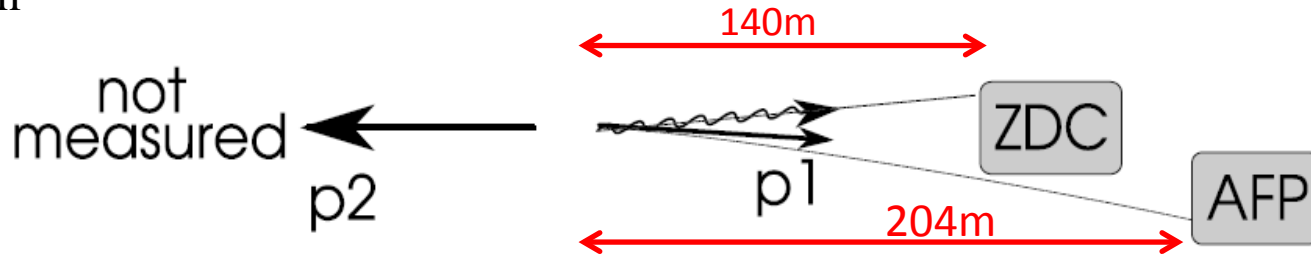
Implemented into the GenEx generator, R. Kycia et al. arXiv:1411.6035 [hep-ph]



Measurement

$$\beta^* = 0.55 \text{ m}$$

$$E_{\text{beam}} \approx E_\gamma + E_p$$



Angular distribution of photons:

$$\frac{d\sigma}{d\Theta_\gamma} \sim \frac{\Theta_\gamma}{\left(\frac{m_p^2}{E_p^2} + \Theta_\gamma^2\right)^2}$$

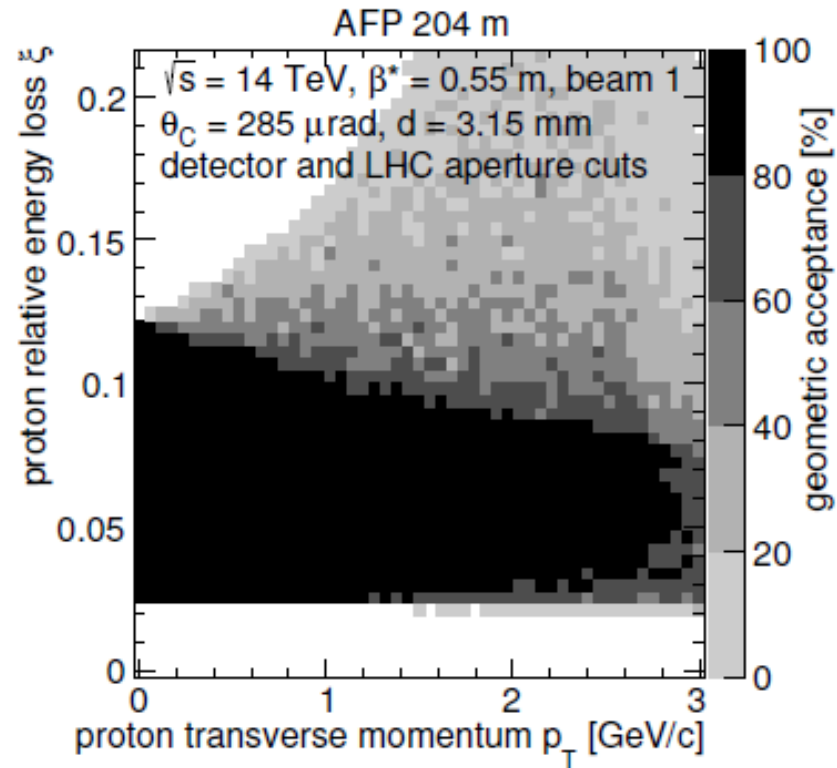
$$|E_{\text{beam}} - (E_{\gamma, \text{ZDC}} + E'_{\text{AFP}})| < \delta$$

$E_{\gamma, \text{ZDC}}$ – photon energy measured in the ZDC

E'_{AFP} – unfolded proton energy (resolution 10 GeV)

Proton energy range: $0.02 \leq \xi \leq 0.12$

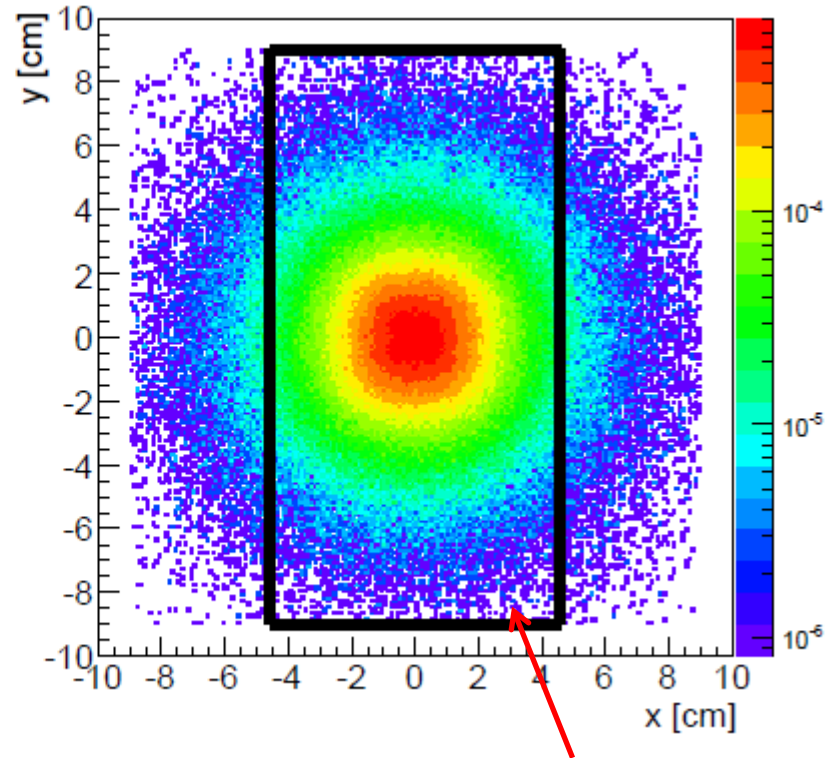
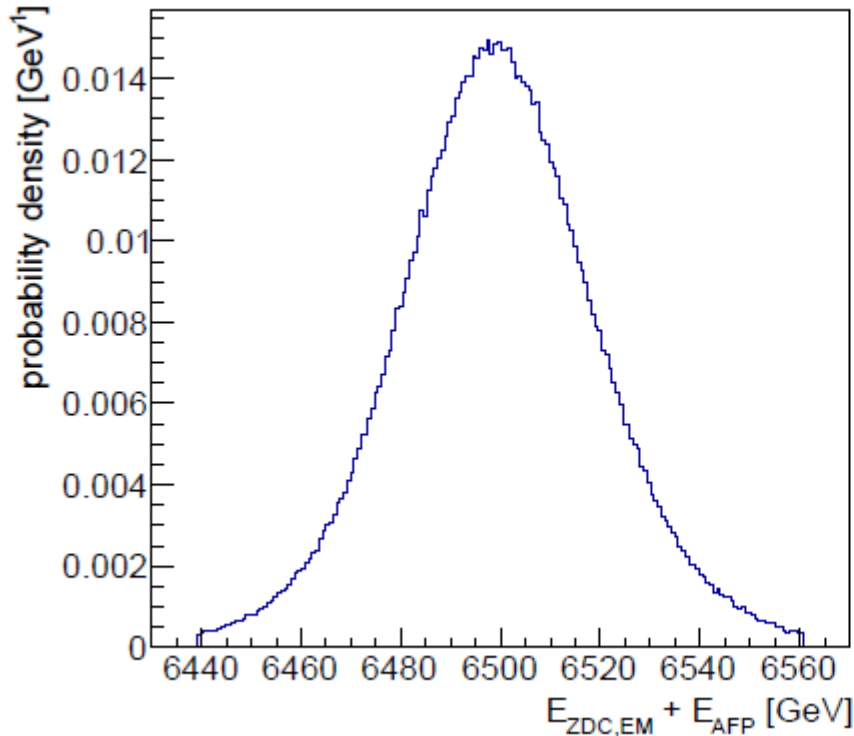
Important factor: beam-AFP detector distance



Measurement

$$\sigma_{\text{gen,signal}}(100 < E_\gamma < 1500 \text{ GeV}) = 1.75 \mu\text{b}$$

Photon position at the ZDC face



δ set to triple width of the $(E_{\gamma,\text{ZDC}} + E'_{\text{AFP}})$ distribution

ZDC fiducial area

$$\delta = 78 \text{ GeV}$$

Backgrounds

$$|E_{\text{beam}} - (E_{\text{ZDC}} + E_{\text{AFP}})| < \delta + \text{``empty'' ATLAS detector}$$

``empty'' ATLAS detector:

the inner tracker veto: no particle with $p_T > 1$ GeV and $|\eta| < 2.5$
the calorimeter veto: no particle with $E > 1$ GeV and $|\eta| < 4.8$ } High mass diffractive and ND processes

ZDC hadronic energy below 30 GeV (both sides)
EM energy measured in the ``other side'' ZDC below 30 GeV } Mainly double diffractive processes

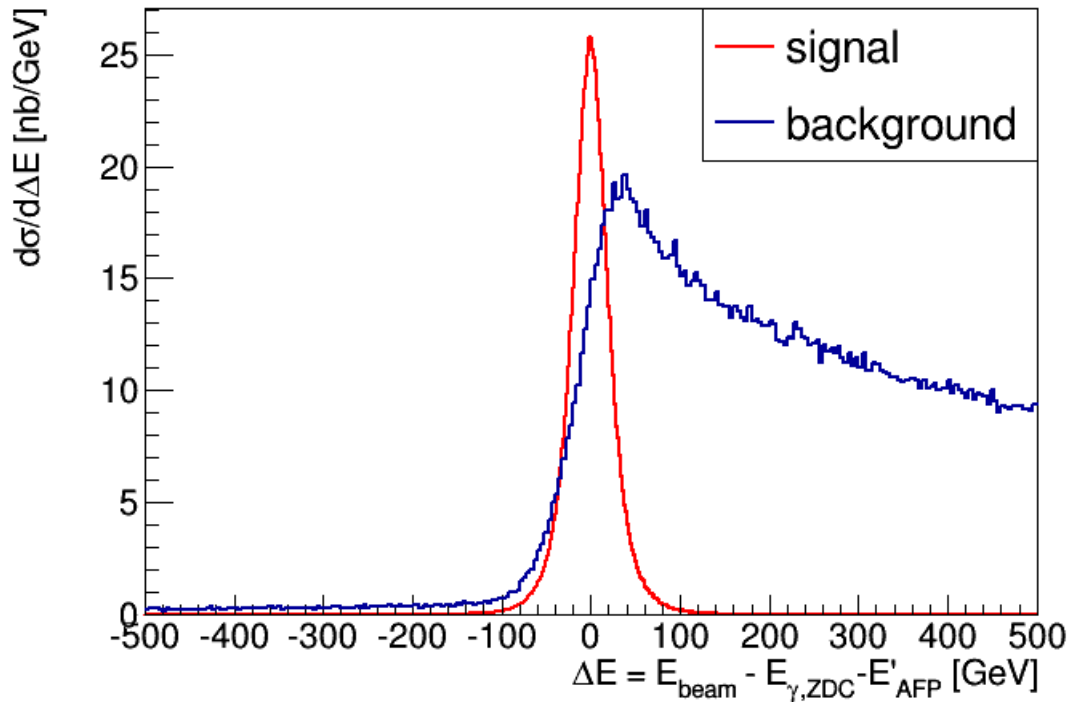
Events generated with PYTHIA 8

Single and double diffractive dissociation; reported cross-section: 21.4 mb
Sample: 1 000 000 000 events

Dominating process: $p+p \rightarrow p p \pi^0$

Use the ZDC spatial resolution to reduce its influence
 π^0 decay photons not closer than 5 mm at the ZDC face

Cuts optimisation



Largely different shapes

Background shifted towards large values

Request:

$$|E_{\text{beam}} - (E_{\gamma,\text{ZDC}} + E'_{\text{AFP}})| < 78 \text{ GeV} - \text{effectively rejects background}$$

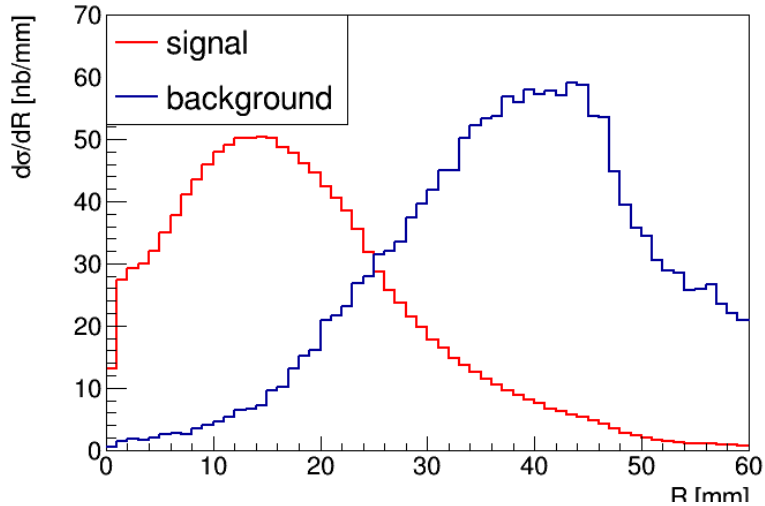
results:

$$\sigma_{\text{vis,signal}} = 1.31 \mu\text{b}$$

$$\sigma_{\text{vis,background}} = 1.88 \mu\text{b}$$

Cuts optimisation

Photon position w.r.t. the "beam position" at the ZDC face

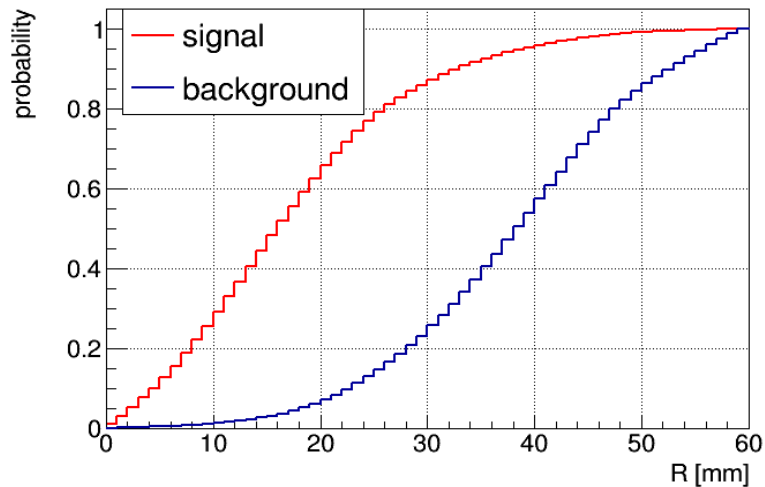


Signal:

a clear maximum at about 14 mm,
quickly falling tail

Background:

increasing with increasing R ,
plateau 32 mm - 44 mm,
rapid decrease



Probability $P(r < R)$:

if $R = 30$ mm then

about 85% of the signal is kept
while about 75% of the remaining
background is rejected

Hence,

$$\sigma_{\text{vis,signal}} = 1.12 \mu\text{b}$$

$$\sigma_{\text{vis,background}} = 394 \text{ nb}$$

Results

The AFP acceptance depends on the active detector – beam distance

This distance depends on the beam properties and is measured in units of the local beam width, $\sigma = 0.14$ mm.

Additional 0.5 mm includes the 0.3 mm pot floor thickness and 0.2 mm floor – detector edge.

distance	$\sigma_{\text{vis,signal}}$ [nb]	$\sigma_{\text{vis,signal}}$ [nb]	S/B
10 σ	1047	280	3.5
15 σ	915	291	3.1
20 σ	745	299	2.5
25 σ	614	298	2.1
30 σ	497	290	1.8

Summary

- Feasibility studies of the diffractive bremsstrahlung measurement at the $\beta^* = 0.55$ m LHC running at the centre of mass energy of 13 TeV were presented
- The signal visible cross-section ranges between 1050 nb and 500 nb depending on the detector-beam distance (10σ to 30σ)
- The signal to background ratio decreases from 3.5 to about 2 with increasing beam-detector distance from 10σ to 30σ
- The measurement could be performed assuming a single interaction per bunch crossing i.e. using the data gathered in the LHC runs with very low pileup
- The influence of the machine background is unknown and has to be studied experimentally
- Possible extension to ALFA + ZDC for the $\beta^* = 90$ m LHC running – exclusive measurement