Study of diffractive bremsstrahlung at 13 TeV LHC

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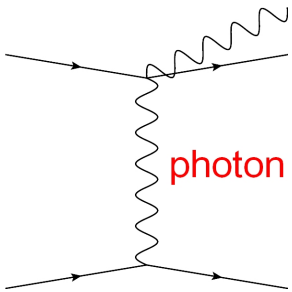
XXII Cracow Epiphany Conference
7-9 January 2016

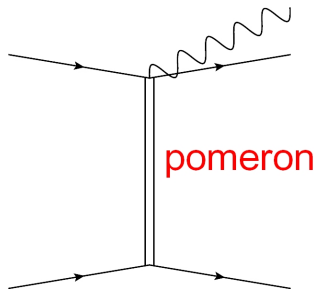
supported in part by NCN grant UMO-2012/05/B/ST2/02480

Bremsstrahlung

$$p + p \rightarrow p + p + \gamma$$

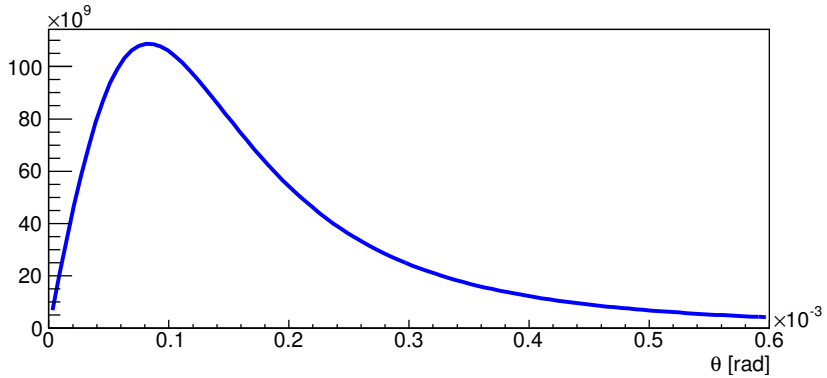


electromagnetic bremsstrahlung



diffractive bremsstrahlung

- at $\sqrt{s} = 13$ TeV and $100 < \mathrm{E}_\gamma < 1500$ GeV:
  $\boldsymbol{\sigma^{\mathrm{em}}_{\mathrm{int}} \approx 50\ \mathrm{nb}}$, $\boldsymbol{\sigma^{\mathrm{diff}}_{\mathrm{int}} \approx 2\ \mu\mathrm{b}}$
- angular distribution: $\frac{d\sigma}{d\theta_\gamma} \sim \frac{\theta_\gamma}{\left[\theta_\gamma^2 + \left(\frac{1}{\gamma_\mathrm{p}}\right)^2\right]^2}$
- maximum for $\theta_\gamma \approx \frac{1}{\gamma_\mathrm{p}}$
  - at $\sqrt{s} = 13$ TeV: $\theta_\gamma \approx 10^{-4}$ rad $\Leftrightarrow \eta \approx 14$
- **large $|\eta_\gamma|$ region**



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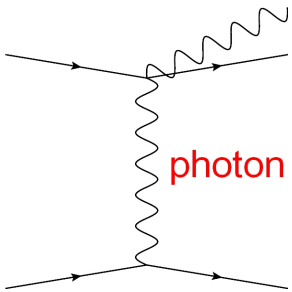

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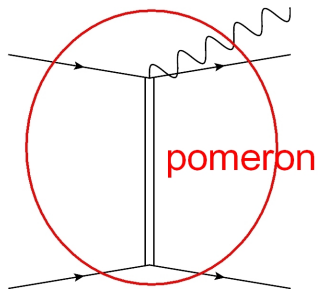

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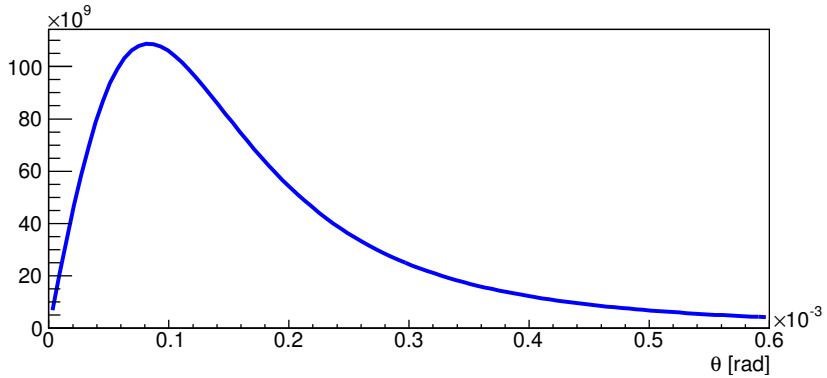
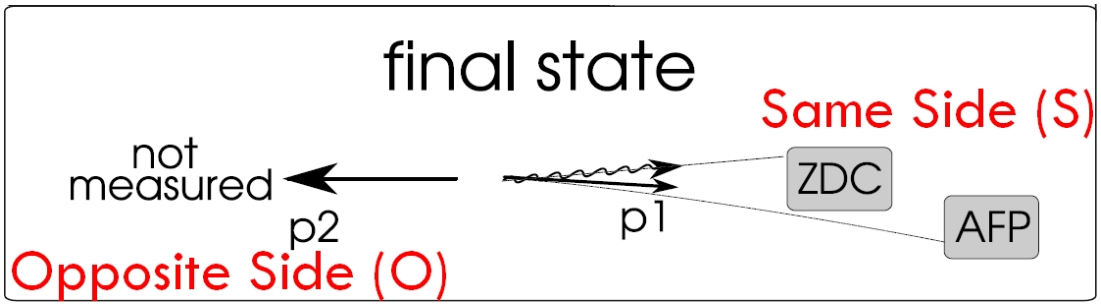


Measurement

discussed method uses the ATLAS apparatus but is also applicable for CMS and TOTEM



AFP – proton

- 210 m from IP
- $0.02 < \xi < 0.12$, $\xi = \frac{\Delta E}{E_{beam}}$
- $\sigma(E) \approx 10$ GeV

ZDC EM – photon

- 140 m from IP
- $|\eta| > 8.3$ (91.4 mm x 180 mm)
- $\sigma(x) = 0.5$ mm
- $\sigma(E) \approx 8$ GeV (at E = 100 GeV)

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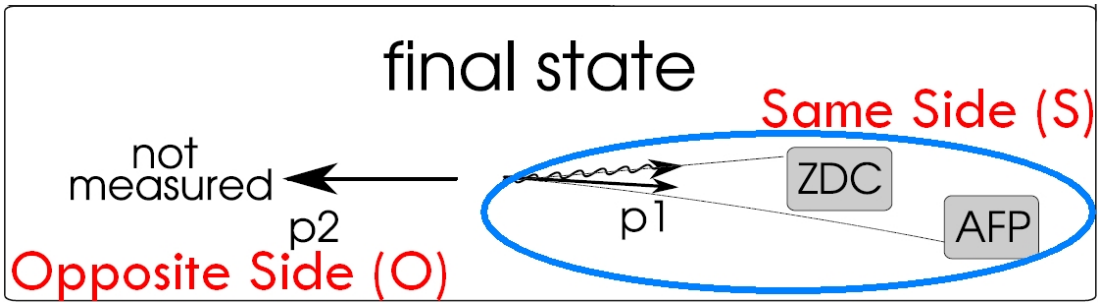

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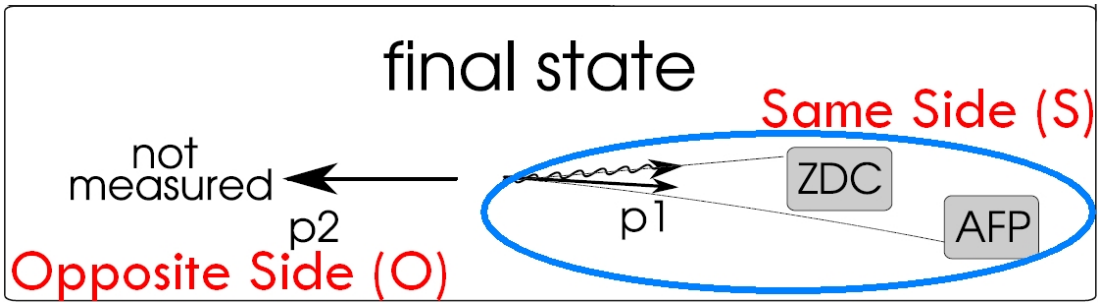

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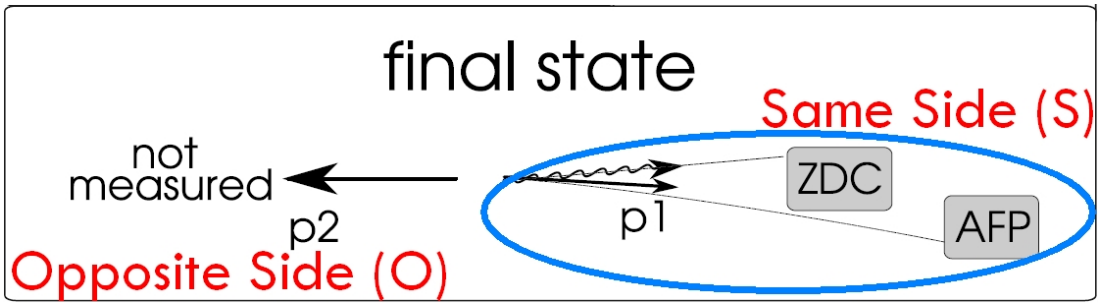

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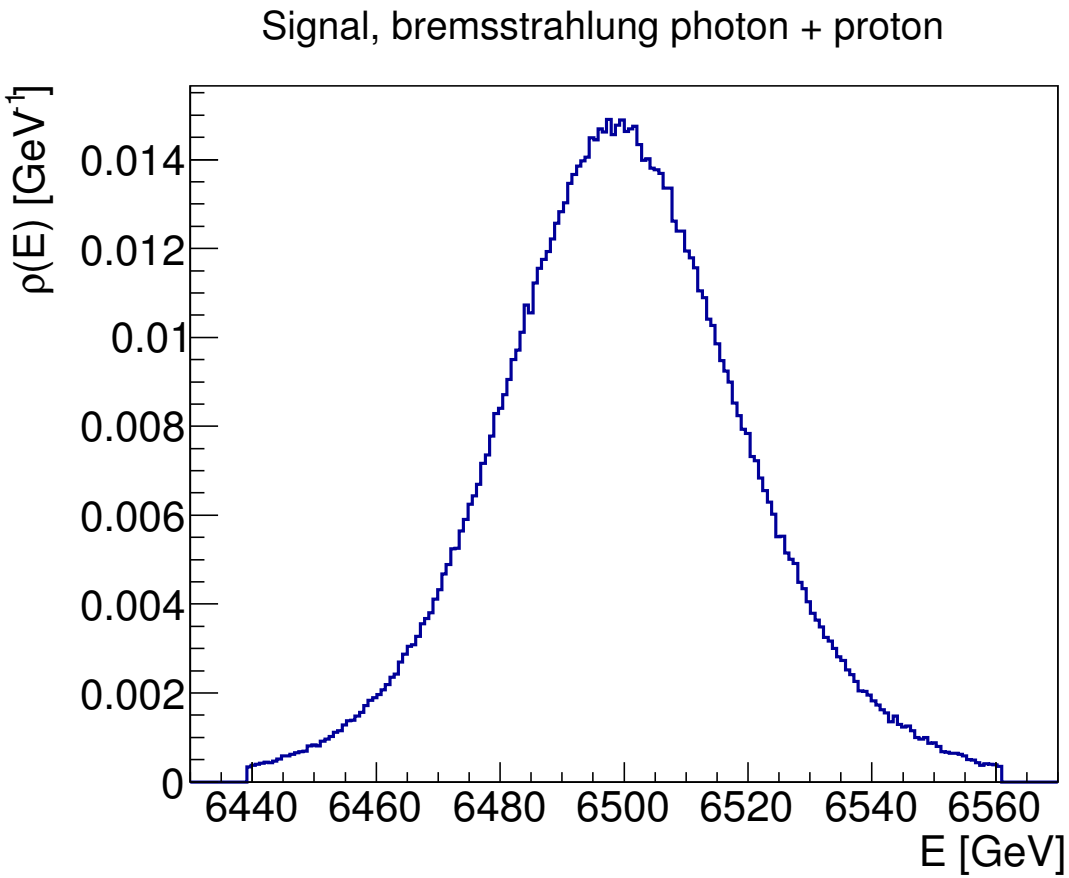
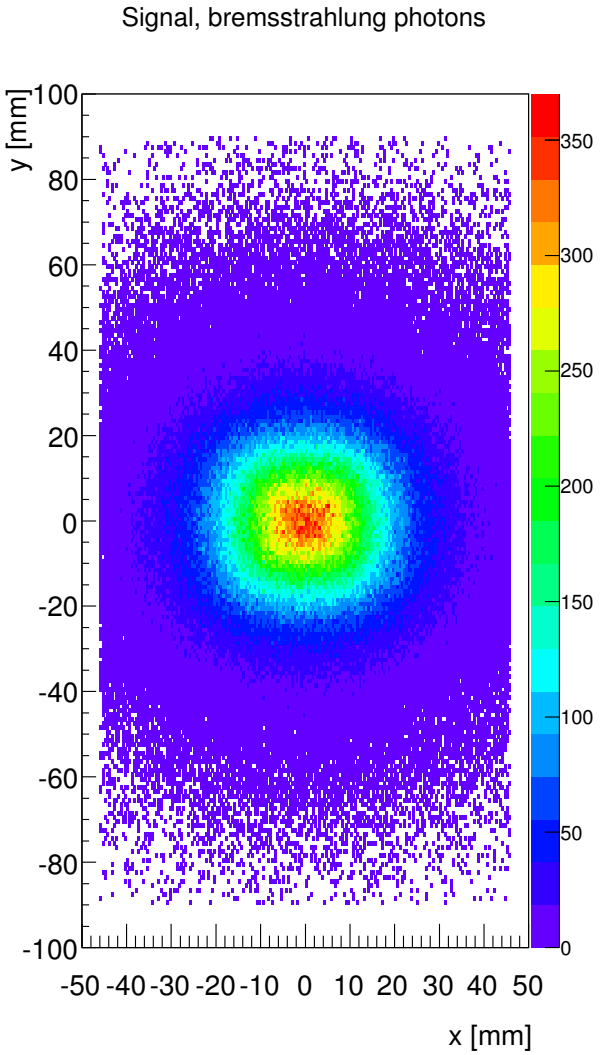
Signal

- signal generated with the GenEx generator, $E_{beam} = 6.5$ TeV

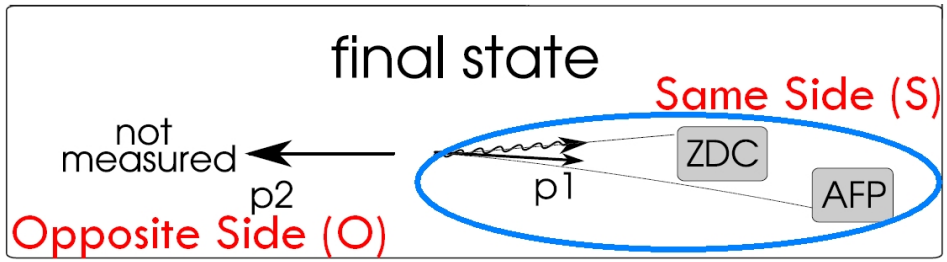


$E_p + E_\gamma \approx E_{beam}$, RMS $= 20.3$ GeV



- result: $\sigma^{sig}_{fiducial} \approx$ **850 nb**

Background rejection



Bremsstrahlung signature

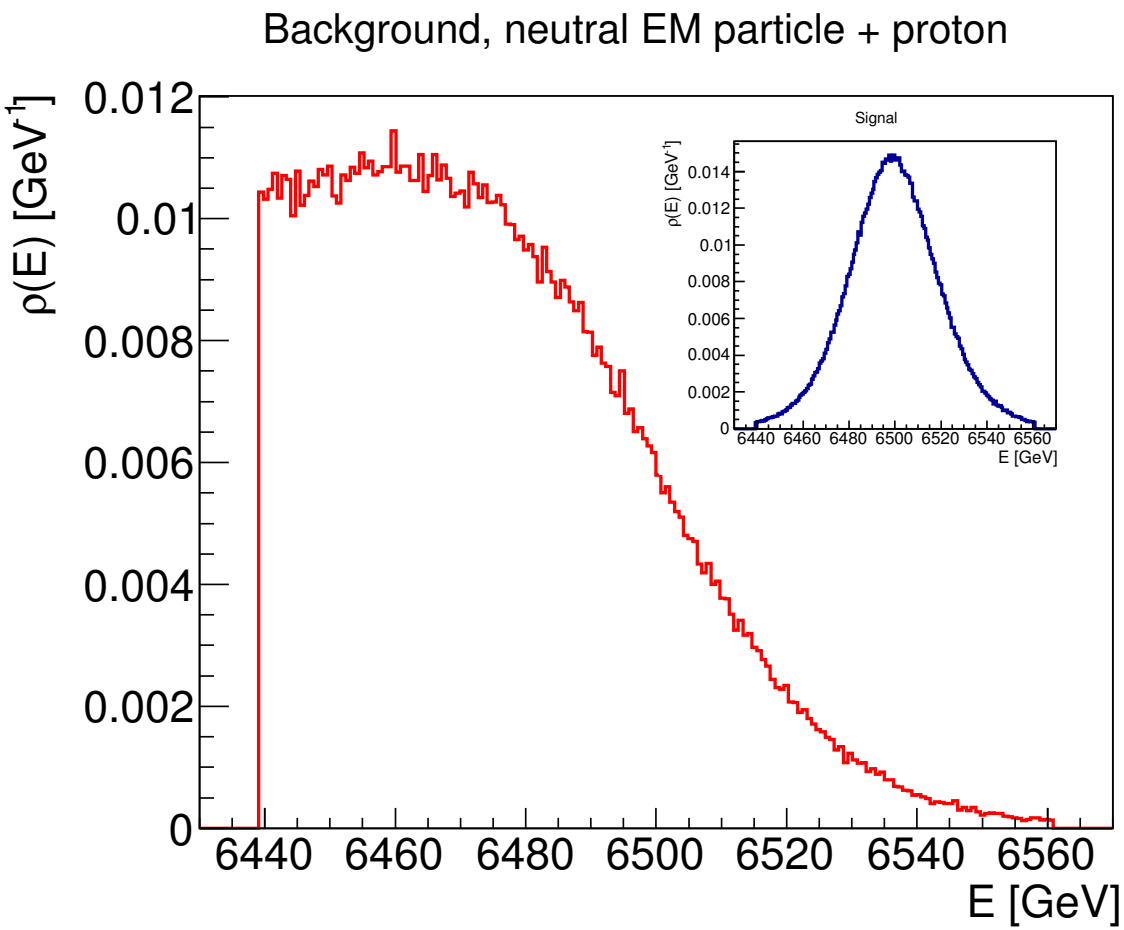
- one proton in $\mathrm{AFP_S}$
- one photon in $\mathrm{ZDC_S}$

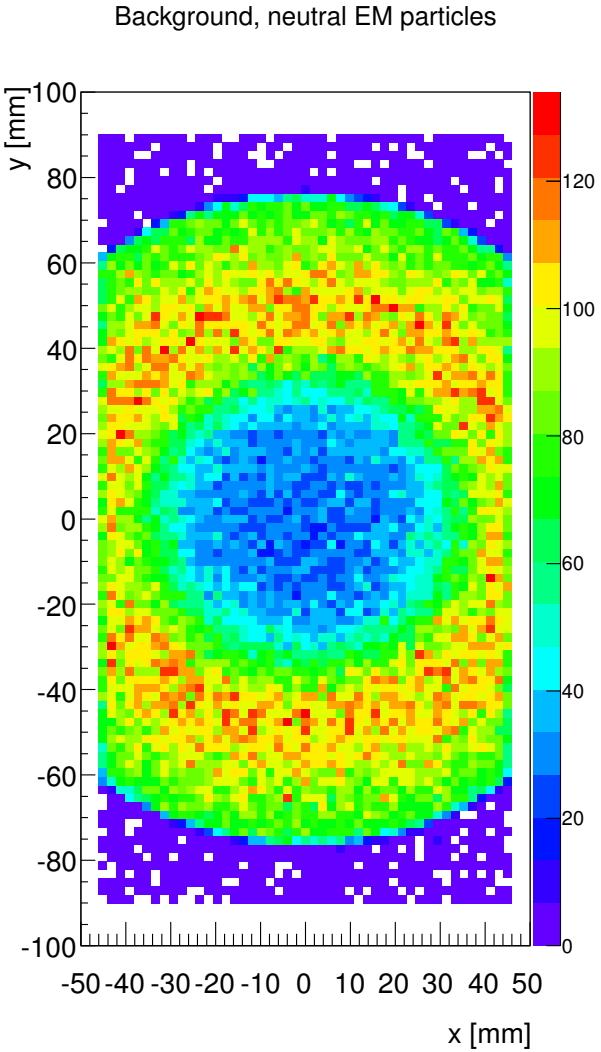
Detectors' energy resolution cuts

- $|\mathrm{E_{AFP_S}} + \mathrm{E_{ZDC,EM_S}} - \mathrm{E_{beam}}| < 60.9$ GeV
- absence of particles in other detectors
  - $\mathrm{E_{ZDC,\,EM_O}} < 10$ GeV (EM ZDC on the O side)
  - $\mathrm{E_{ZDC,H_{O/S}}} < 50$ GeV (hadronic ZDC)
  - $|\eta_{\mathrm{charged}}| > 2.5$ or $\mathrm{p_T} < 0.5$ GeV (Inner Detector)
  - $E < 1$ GeV or $|\eta| > 4.8$ (Calorimeter)

- background generated with PYTHIA 8.2, $\mathrm{E_{beam}} = 6.5$ TeV, diffractive and non-diffractive processes included
- main contribution: $p + p \rightarrow p + p + \pi^0 \rightarrow p + p + \gamma + \gamma$

Background





- result: $\sigma^{\mathrm{bg}}_{\mathrm{fiducial}} \approx \mathbf{20\ \mu b}$

Summary & Outlook

Summary

- analysis of the diffractive bremsstrahlung for 13 TeV was performed
- electromagnetic bremsstrahlung constitues only a small correction to the diffractive bremsstrahlung (about 2.5%)
- obtained fiducial cross sections: ~ 850 nb for signal and ~ 20 μb for background
- present signal to background ratio requires further background reduction

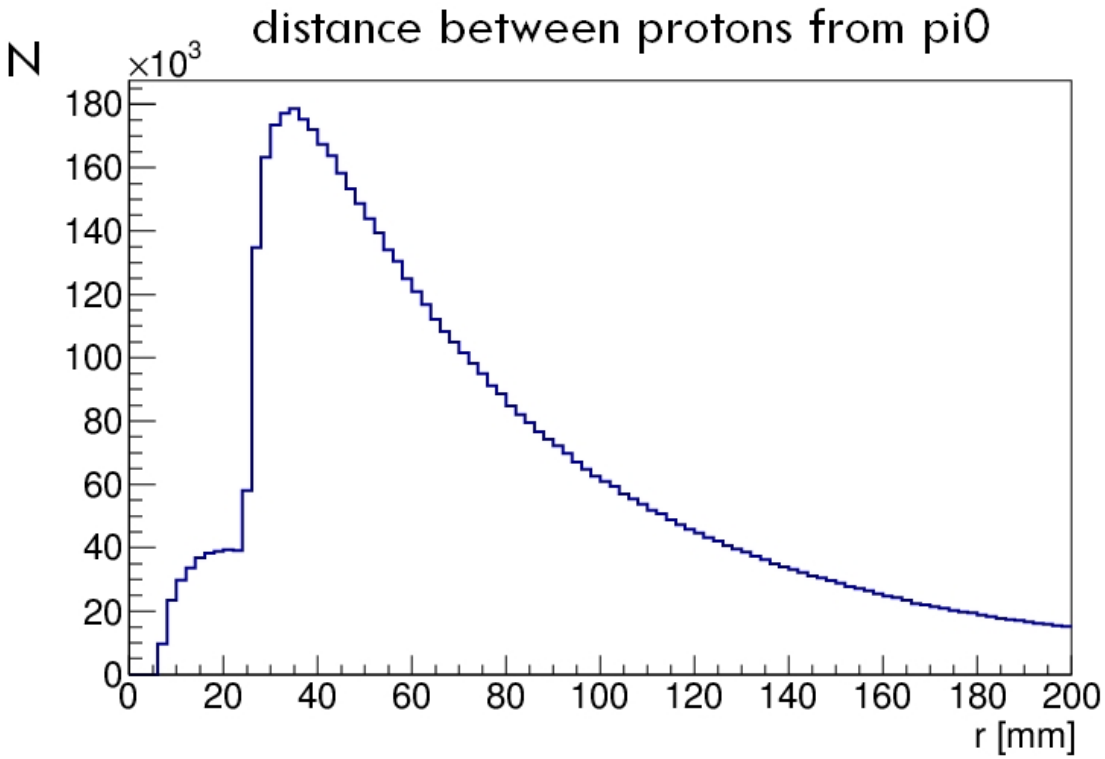
Outlook

- optimization of cuts: introducing cut for the distance from the center of the ZDC for the photon reaching ZDC
- enhancement of veto for the background: LUCID detectors ($p_T > 2.8$ GeV, $5.61 < |\eta| < 5.93$)
- implementation the proton transport (for various optics)

Thank you for the attention!

Backup

- distance between the protons in ZDC
  when more than one photon reaches ZDC, I exploit an electromagnetic cascade reconstruction properties (photons are being seen as one photon in ZDC, when every $r_{ij} < 6$ mm)



Backup

Application of the diffractive bremsstrahlung

- determination of the luminosity
- determination of the elastic cross section for the proton-proton elastic elastic scattering
- energy calibration of the AFP detector