DPG Frühjahrstagung
Hadronen und Kerne, HK 2.7
Mainz, March 19, 2012

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Impact of the antiproton-proton elastic scattering on the inner tracking systems at $\bar{P}$ANDA

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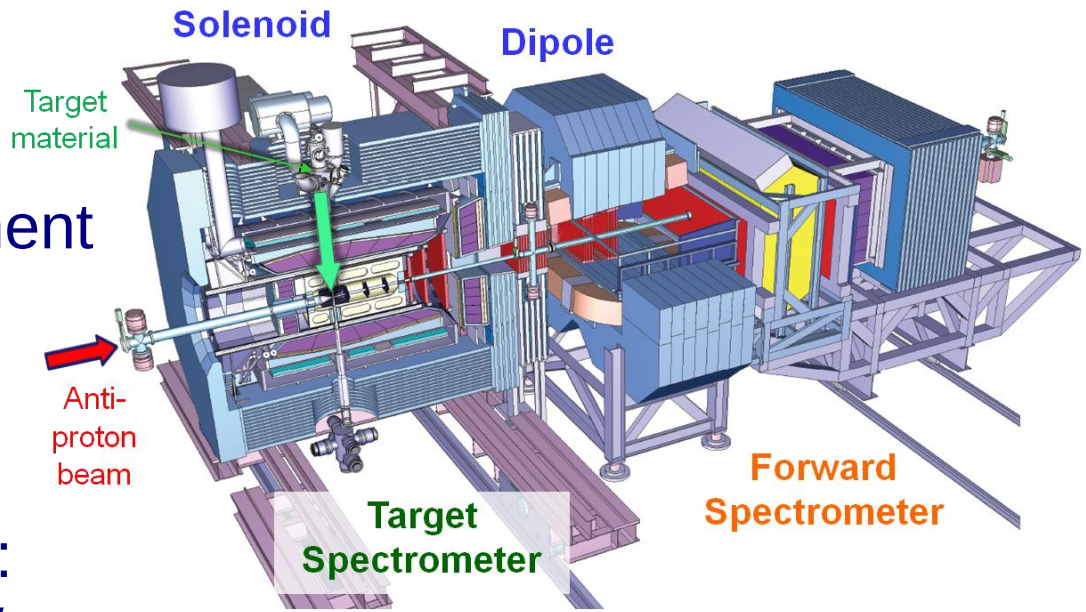
Motivation

- $\bar{p}$anda
  - Fixed target experiment
  - Antiproton beam: (1.5 ... 15) GeV/c
  - High interaction rate: 2×10^7 interactions / s → Non-ordered time structure
  - Inner tracking systems* close to IP and along beam pipe

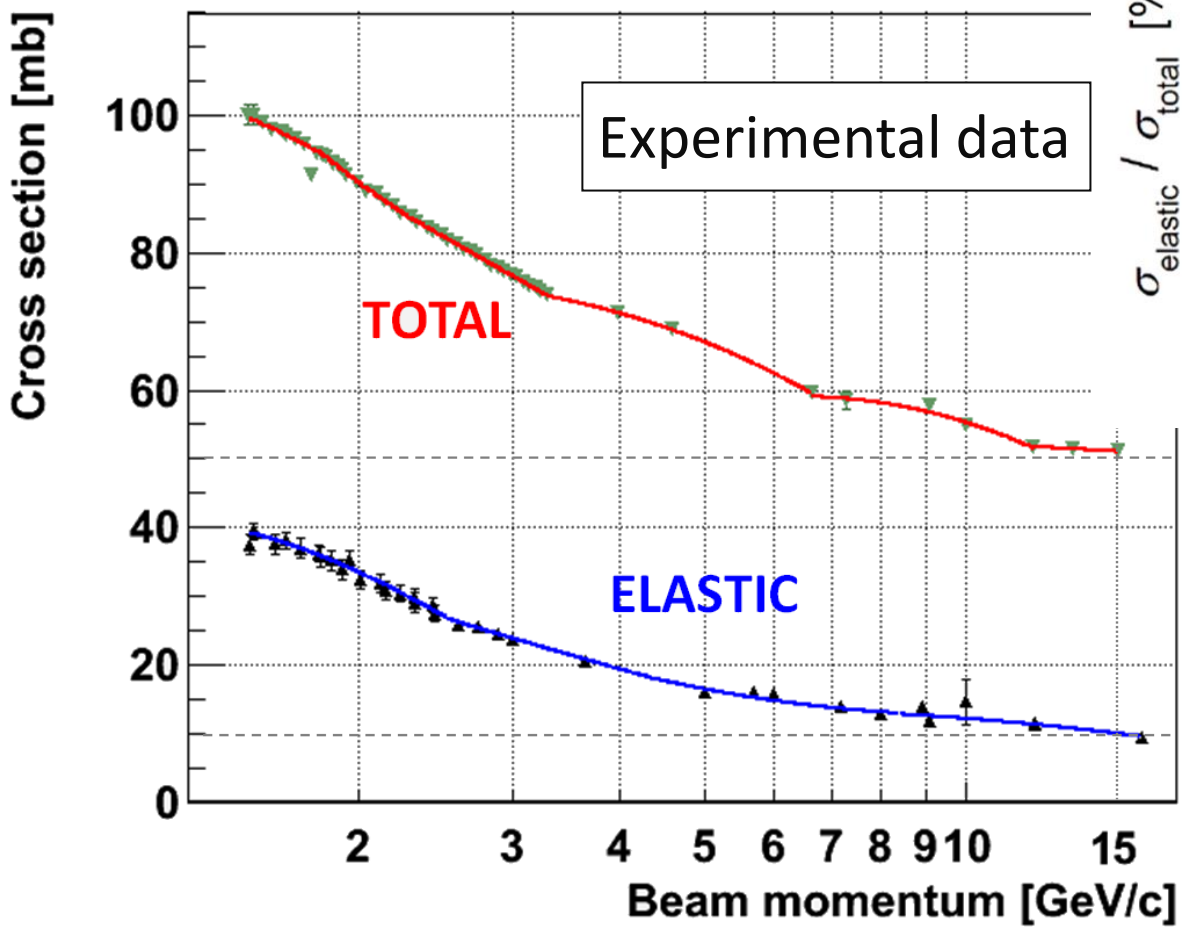


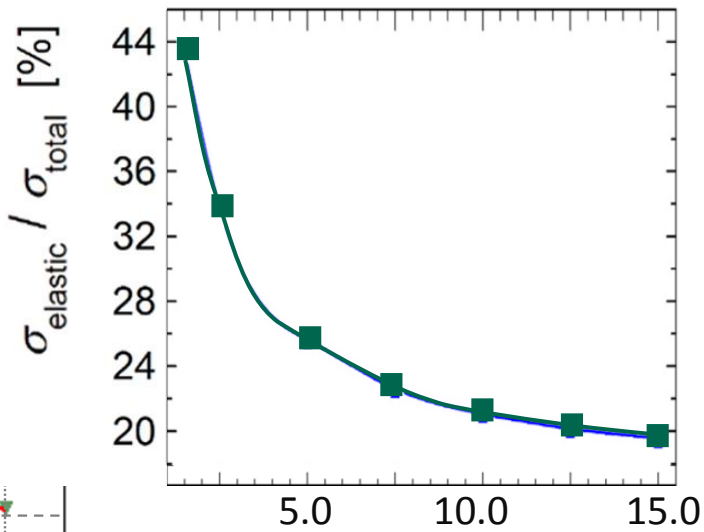
Impact of elastic interactions
→ Forward direction: Fast antiprotons
→ Central part: Slow recoil protons

* Details: HK 27.2 (STT), 41.1 (MVD), 53.34 (Fwd)

Motivation

- $\bar{p}p$ - Elastic Scattering

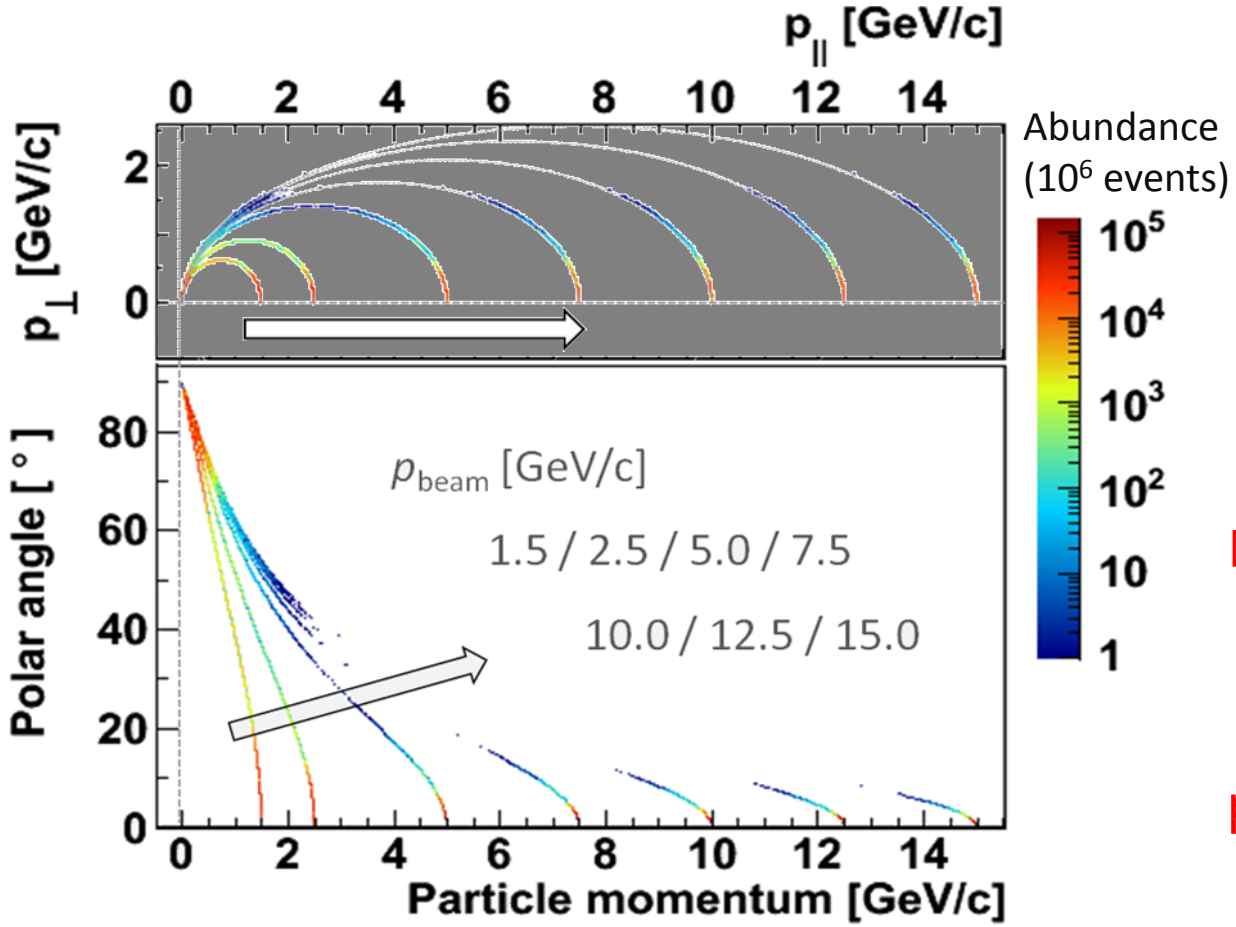




(1) Large (macroscopic) total cross section

Motivation

- $\bar{p}p$ - **Elastic Scattering**



(1) Macroscopic cross section

(2) Kinematic constraints

(3) Relative abundance

Large track densities at small polar angles (antiprotons) and in central part at polar angles around 90° (recoil protons)

Elastic scattering

- **Kinematics**
  - Relativistic description: Four momentum transfer ↔ t

$$-t = 2m_p T_p = \frac{4m_p^2 c^2 \sin\alpha}{(1/\beta_{\mathrm{CM}}^2 - \sin^2\alpha)}$$

$$1/\beta_{\mathrm{CM}}^2 = (E_{\mathrm{beam}} + m_p c^2)/(E_{\mathrm{beam}} - m_p c^2)$$

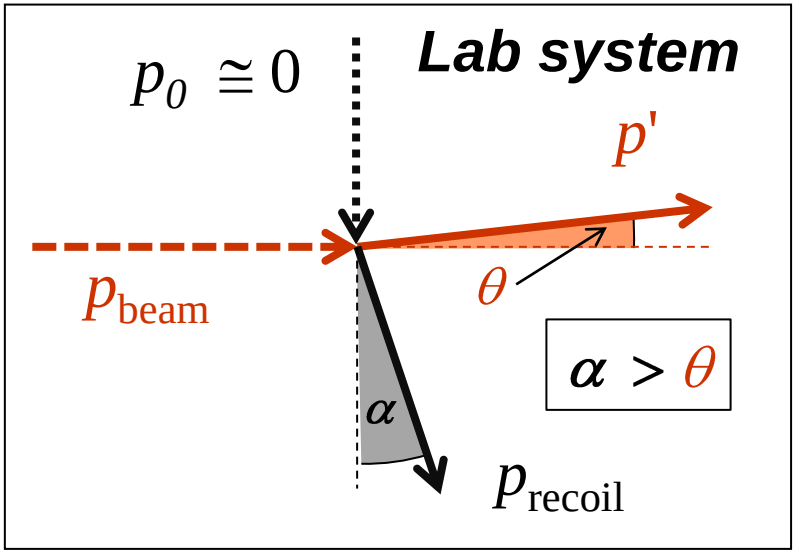
$$E_{\mathrm{beam}} = \sqrt{(m_p c)^2 + (p_{\mathrm{beam}} c)^2}$$

(1) t ↔ Beam momentum

(2) t ↔ Recoil momentum

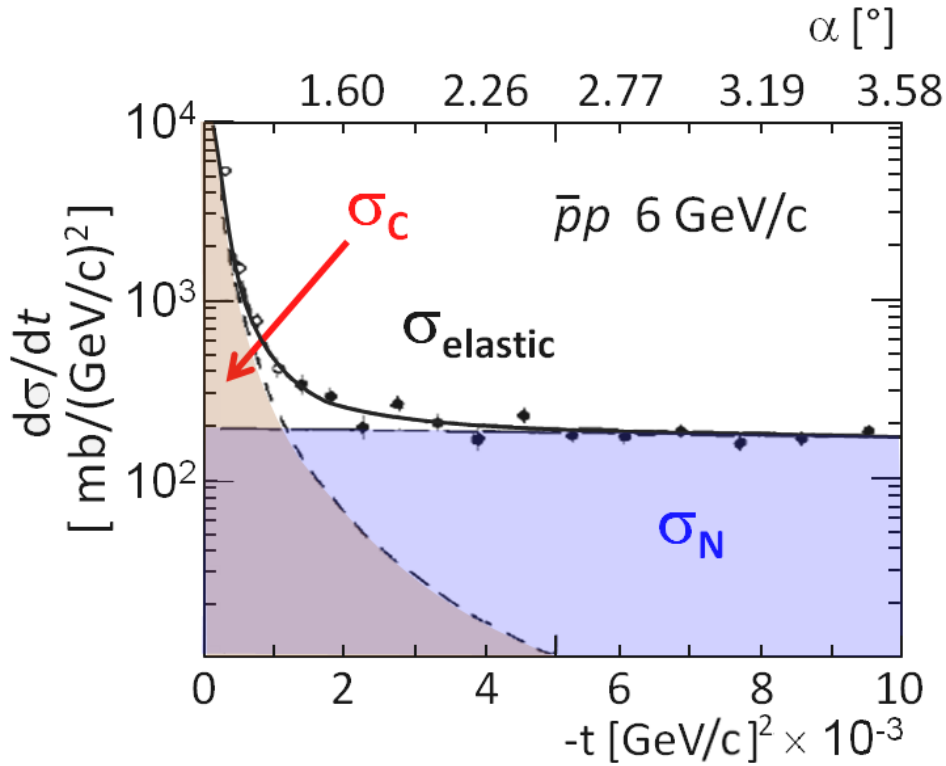
(3) t ↔ Recoil angle, α

(4) α ↔ Scattering angle, θ



Elastic scattering

- **Differential cross section**
  - Small momentum transfer



(1) Nuclear region (σ_N)
$|t| > 10^{-3}$ (GeV/c)^2

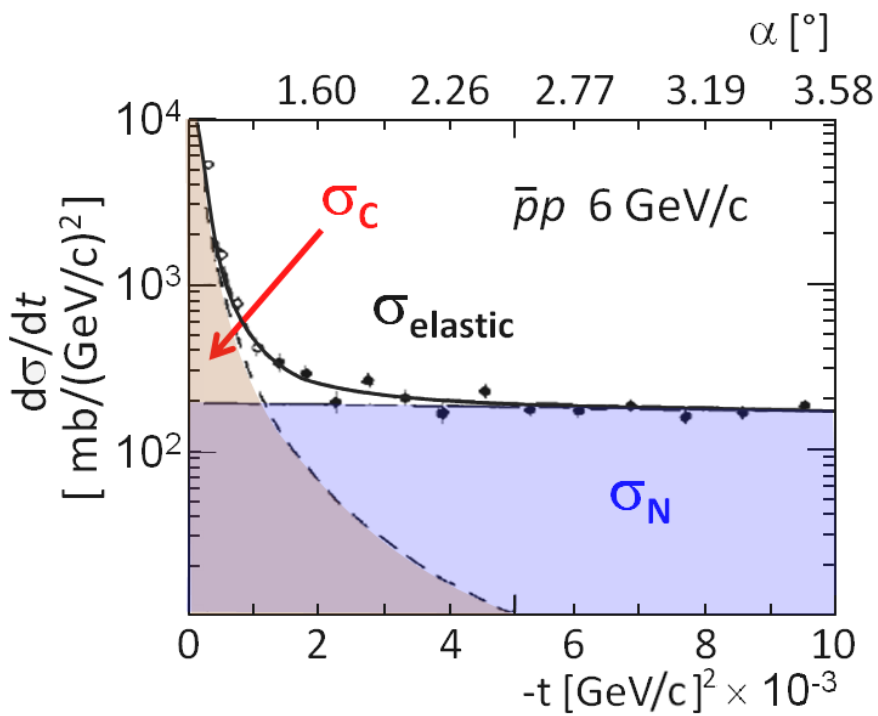
(2) Coulomb dominated region (σ_C)
$|t| < 0.5 \times 10^{-4}$ (GeV/c)^2

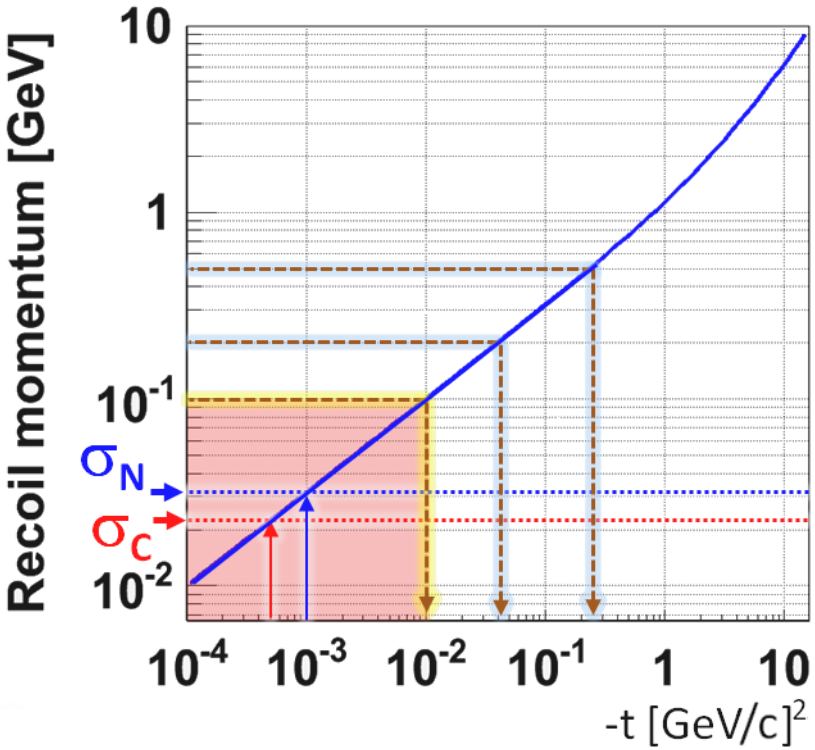
(3) Interference region
$|t| << 10^{-3}$ (GeV/c)^2
$|t| > 0.5 \times 10^{-4}$ (GeV/c)^2

Divergent Coulomb term
→ Impact of very slow recoil protons?

Elastic scattering

- **Differential cross section**
  - Small momentum transfer



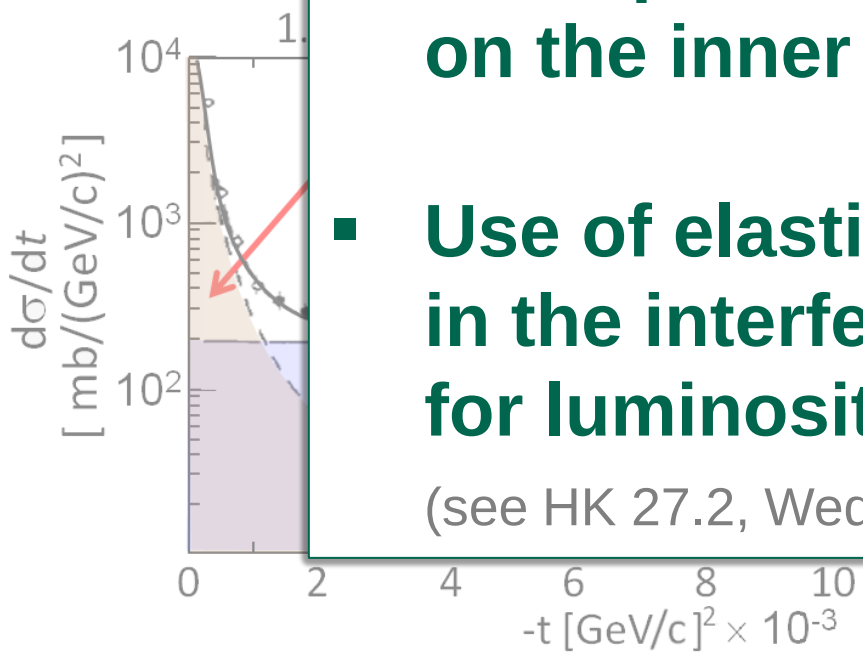


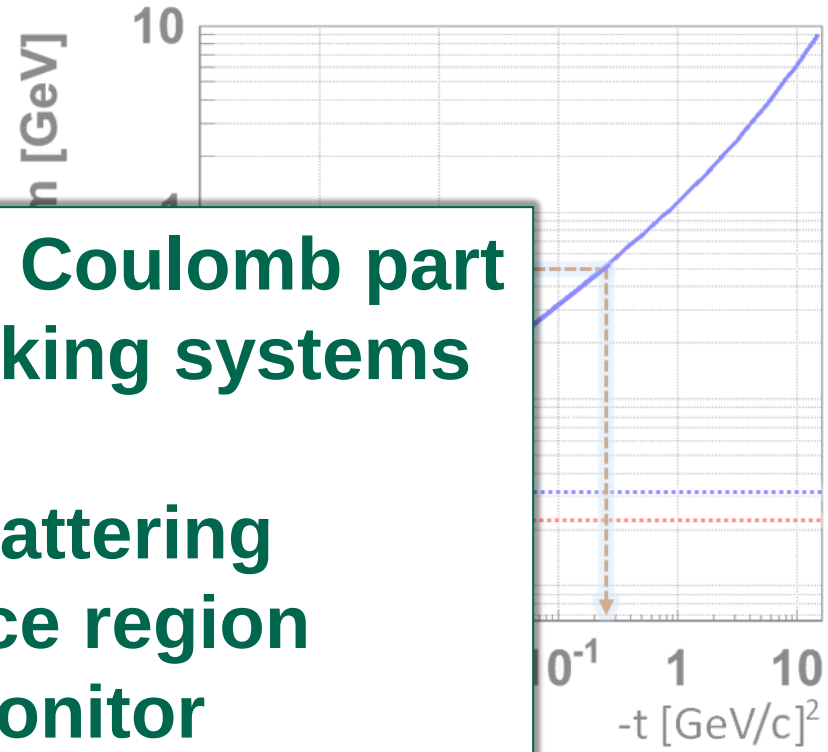
Impact of very slow recoil protons?
Minimum momentum to cross beam pipe

Particle	$\lvert\vec{p}_{min}\rvert$, $\alpha_{inc} = 90°$	$\lvert\vec{p}_{min}\rvert$, $\alpha_{inc} = 45°$
$p, \bar{p}$	~89 MeV/c	~98 MeV/c

Elastic scattering

- **Differential cross section**
  - Small momentum transfer





- **No impact of the Coulomb part on the inner tracking systems**
- **Use of elastic scattering in the interference region for luminosity monitor**

(see HK 27.2, Wednesday)

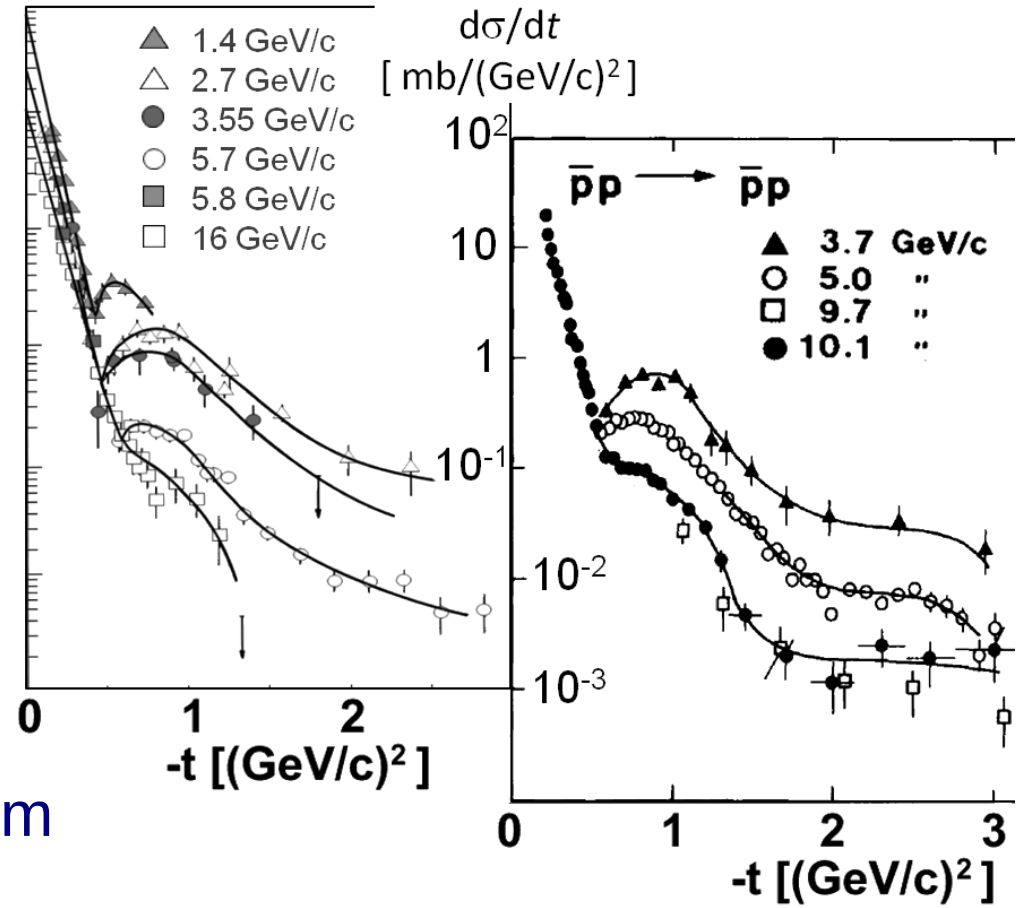
l protons?

ss beam pipe

Particle	$\lvert\vec{p}_{\min}\rvert$, $\alpha_{\text{inc}} = 90°$	$\lvert\vec{p}_{\min}\rvert$, $\alpha_{\text{inc}} = 45°$
$p, \bar{p}$	~89 MeV/c	~98 MeV/c

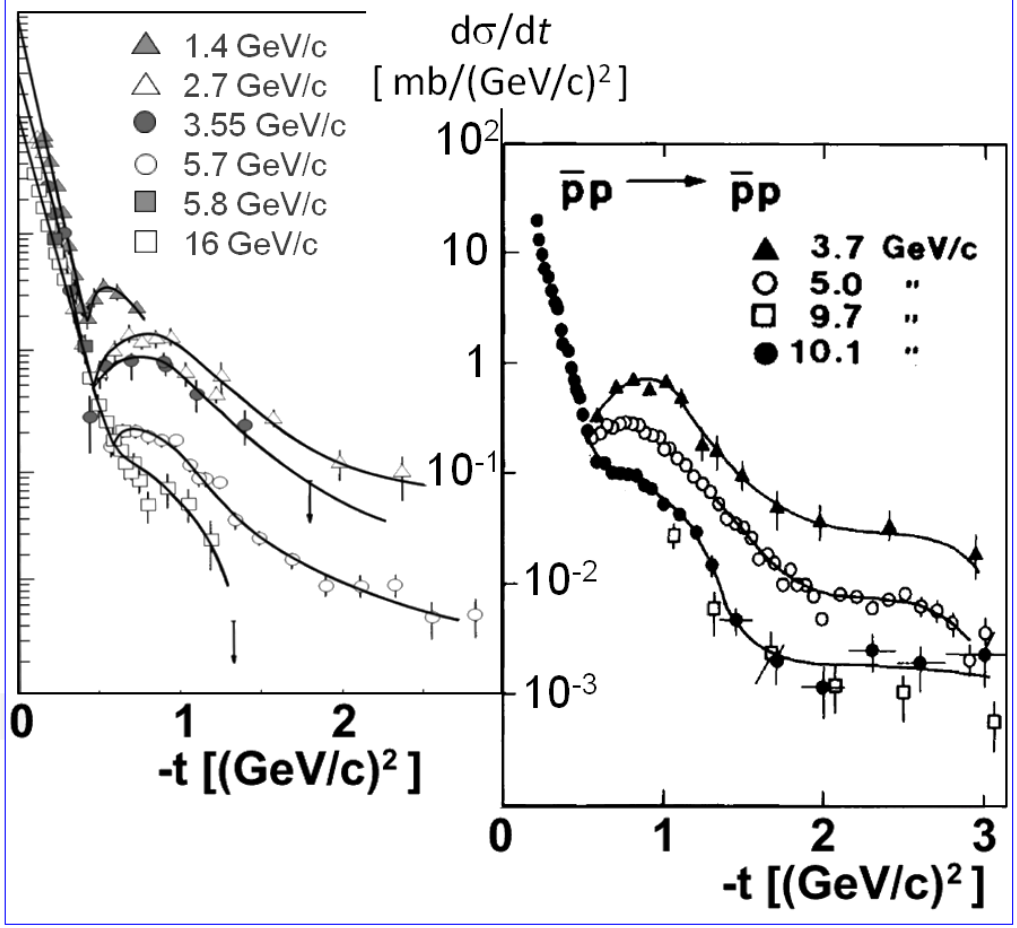
Elastic scattering

- **Differential cross section (ctd.)**
  - Larger | ***t*** | values:
    - → Fast drop-off by (at least) two orders of magnitude
    - → Further structure at higher momentum transfer



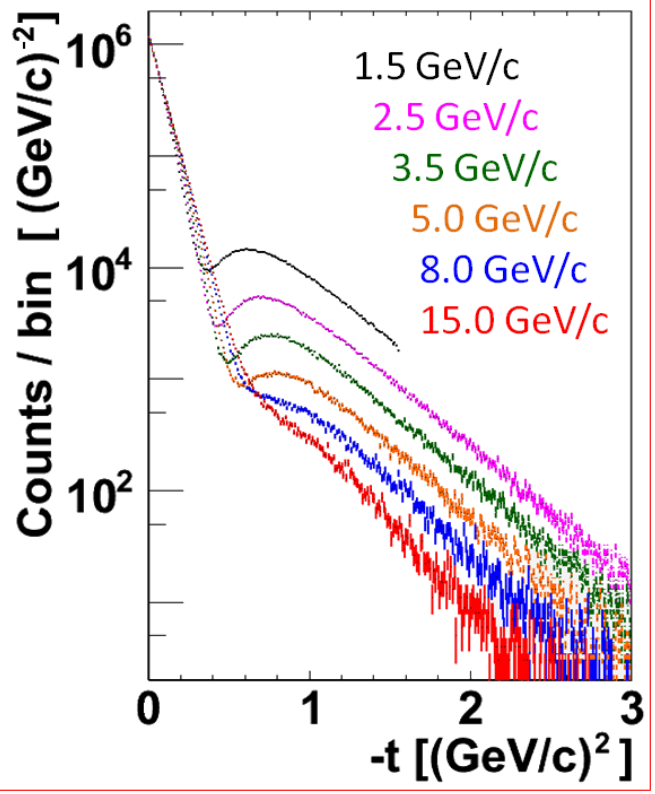
DPM event generator

Measurement data



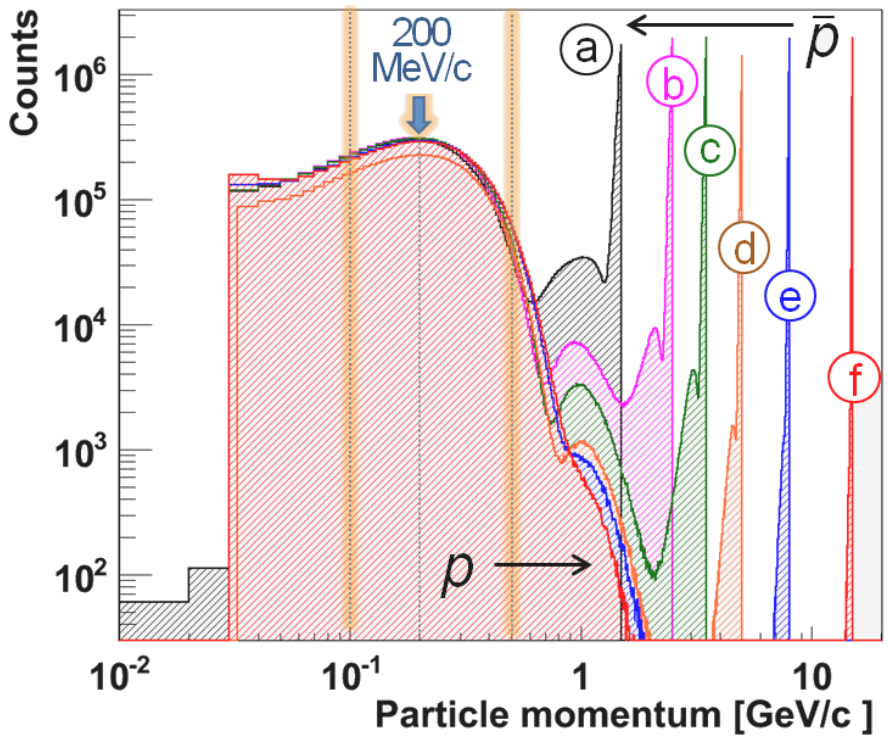
DPM (10 million events)

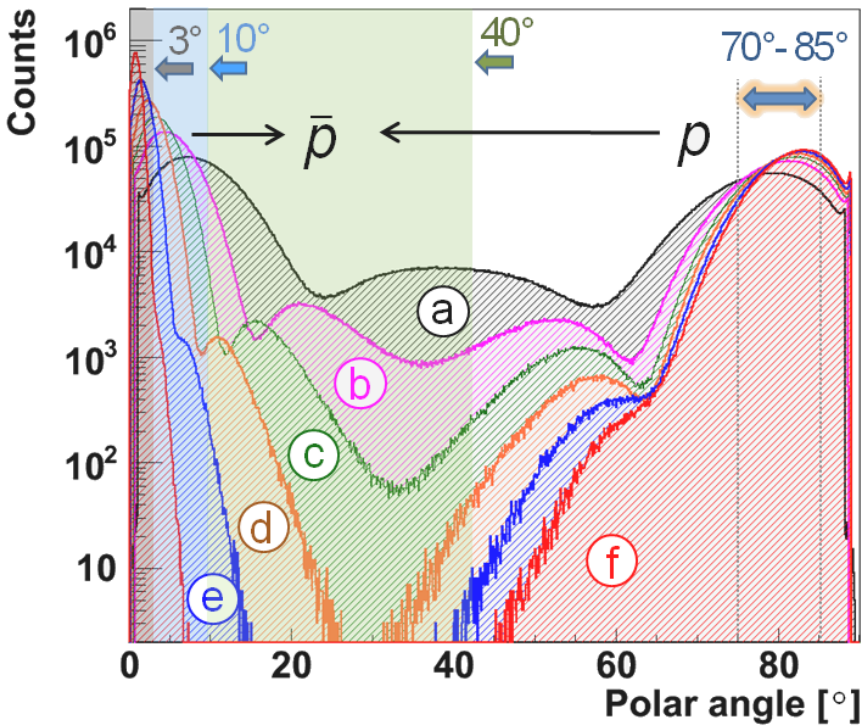
bin size: 0.01



DPM event generator

Only elastic scattering





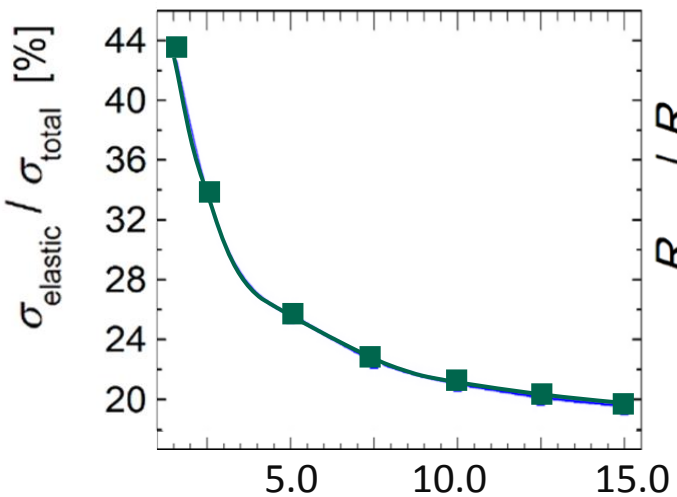
Recoil protons peaking at **200 MeV/c** independent from beam momentum

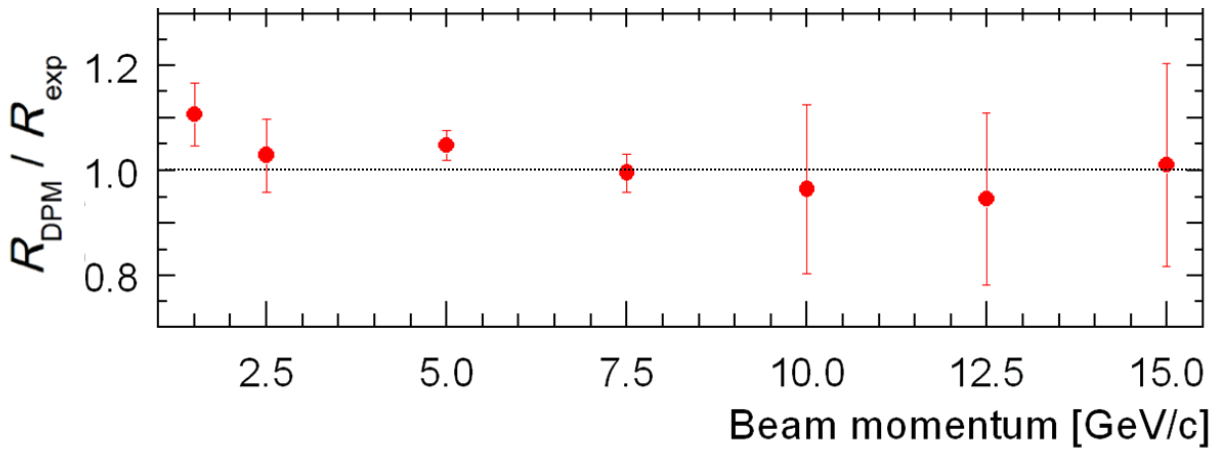
Recoil protons mostly emitted between polar angles of 70° to 85°

Scattered antiprotons to be considered at lower beam momenta

DPM event generator

Elastic and inelastic processes





- Ratio of cross sections: Elastic / Inelastic

  Good agreement DPM ↔ experimental data

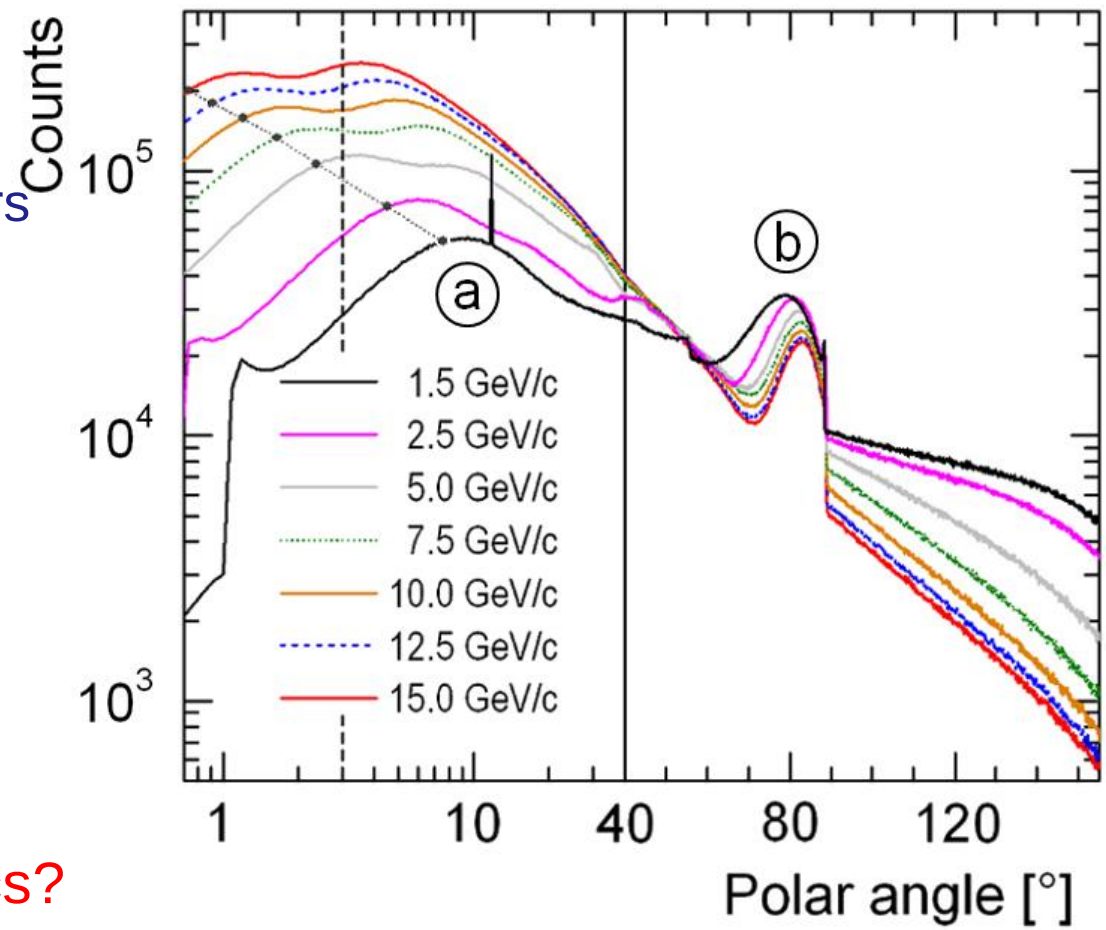
DPM event generator

Elastic and inelastic processes

(a) Antiprotons:
→ Elastic peak shifted to inner regions of forward tracking layers
→ Highest track density still due to Lorentz boost of inelastic part

(b) Recoil protons:
→ Clearly dominating particle abundance in central part

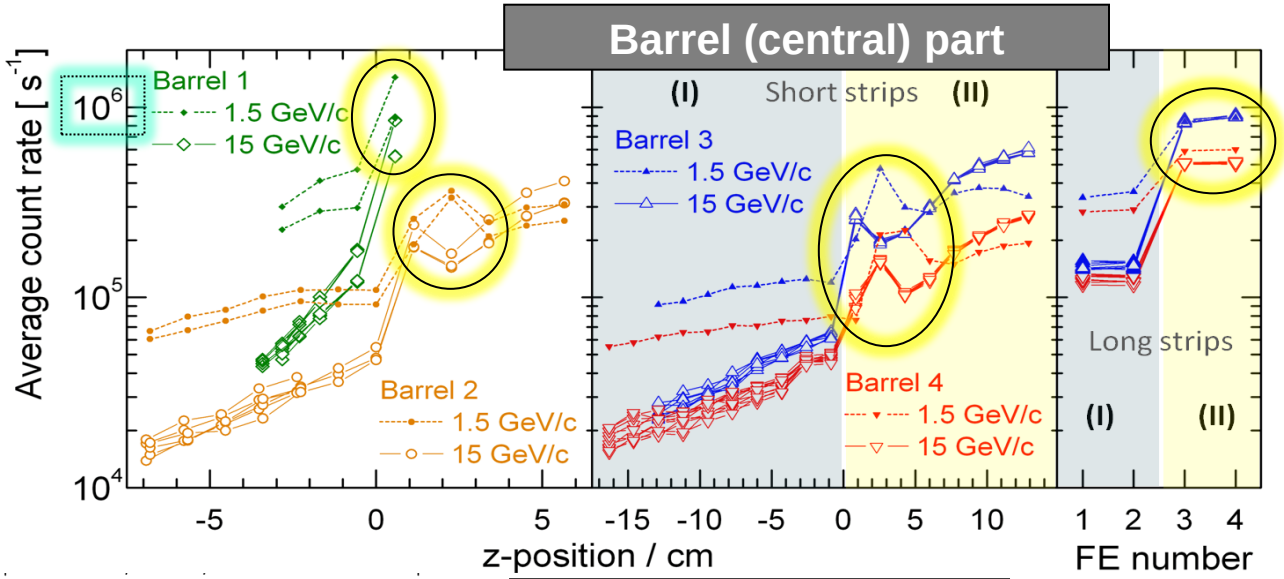
Impact on count rates, i.e. specifications for the readout electronics?

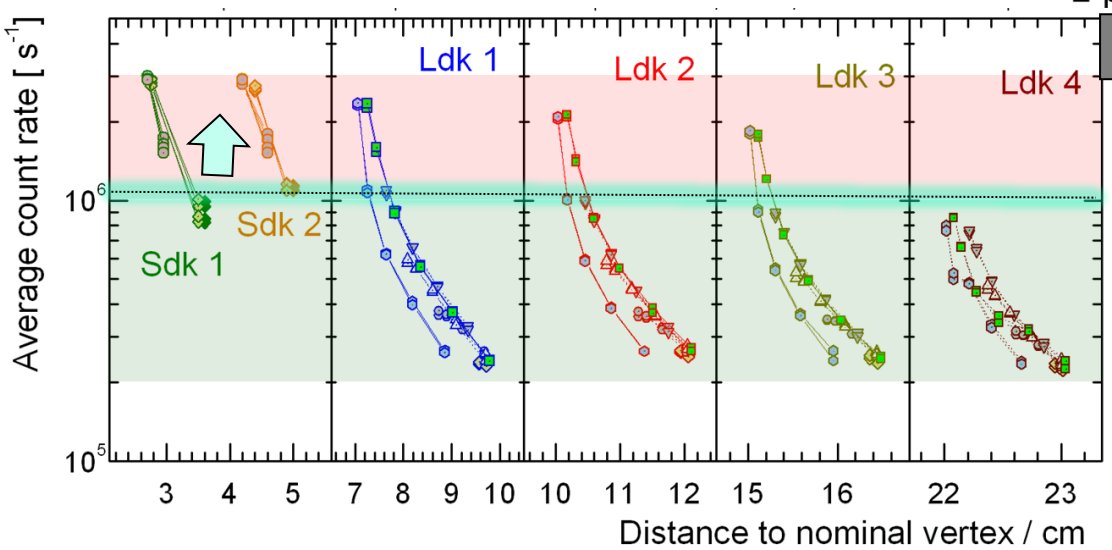


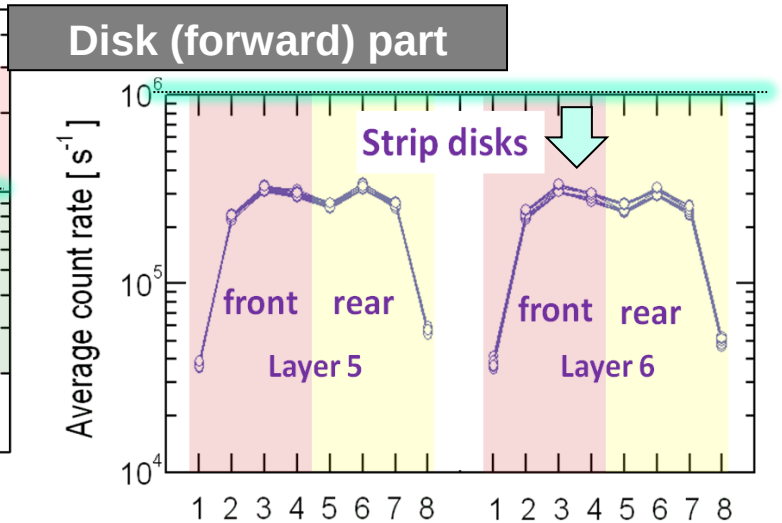
Detector simulation (MVD)

- Impact of elastics on count rates (frontend electronics)

→ **Maximum** count rate given as specification for strip frontend considers influence of recoil protons

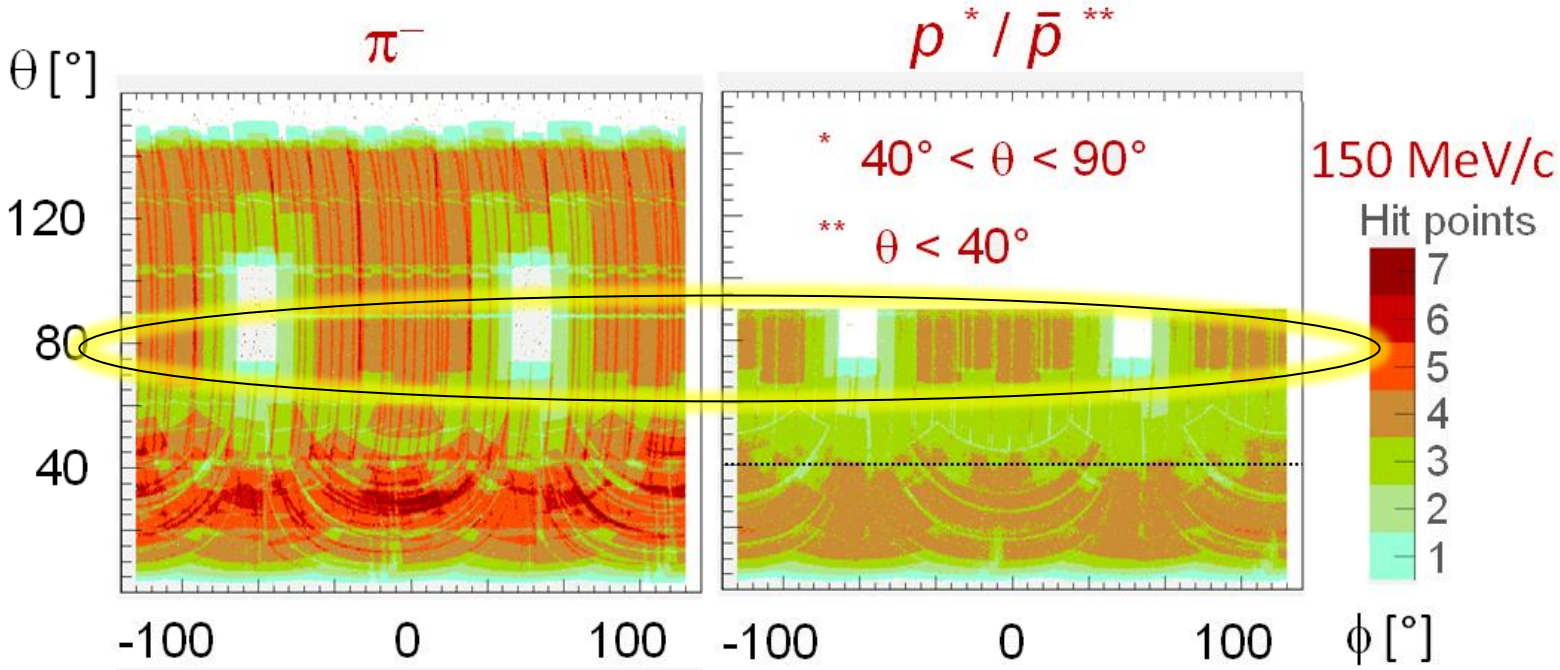






Detector simulation (MVD)

- Impact of recoil protons on outer tracker (STT)



→ Strong attenuation effects:
Recoil protons will be absorbed within the MVD volume to large extent

Summary

- Elastic process has to be considered carefully at P̄ANDA
- Existing event generator (DPM) allows for dedicated studies of the expected particle distribution
- Important hardware specifications taking into account the impact of elastic scattering

Backup slides

Detector simulation (MVD)

- Impact of elastics in terms of radiation tolerance

Design optimisation of the PANDA Micro-Vertex-Detector for high perfomance spectroscopy in the charm quark sector

Dissertation
zur Erlangung des akademischen Grades
Doctor rerum naturalium
(Dr.rer.nat)

vorgelegt

von

Dipl.-Phys. Thomas Würschig
geboren am 03.10.1978 in Dresden

DPM (Dual Parton Model)

A. Capella et al. Dual parton model. *PHYSICS REPORTS*, 236(4 & 5):225–329, 1994.

https://subversion.gsi.de/fairroot/pandaroot/trunk/pgenerators/DpmEvtGen

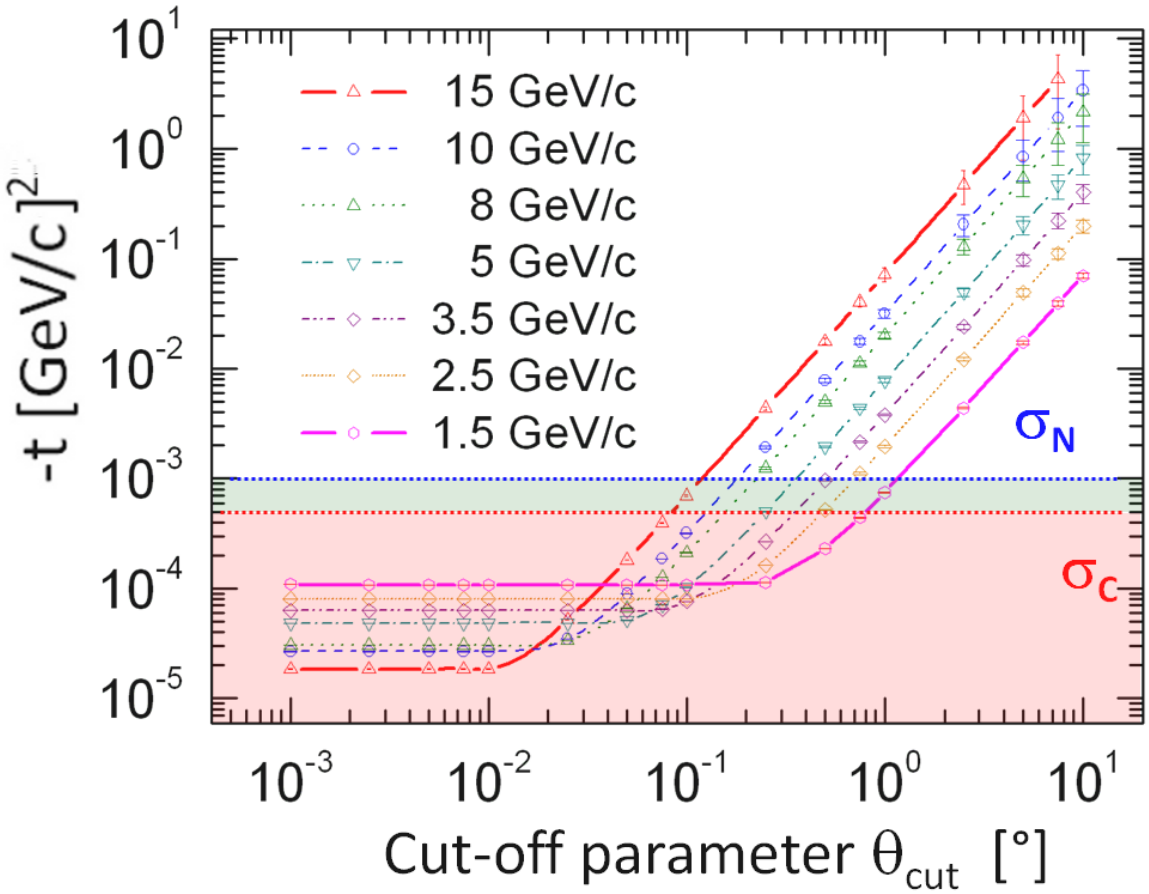
Revision: 8208

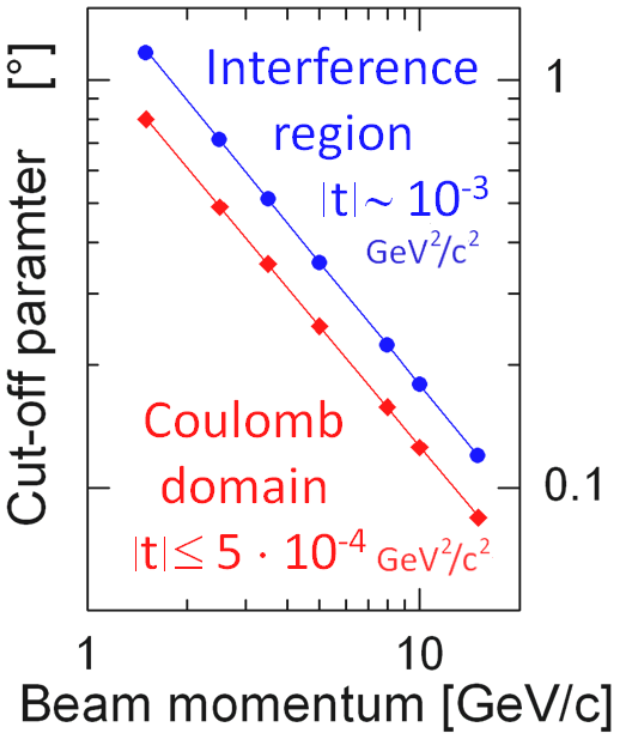
Last Changed Author: galoyan

Last Changed Rev: 6395

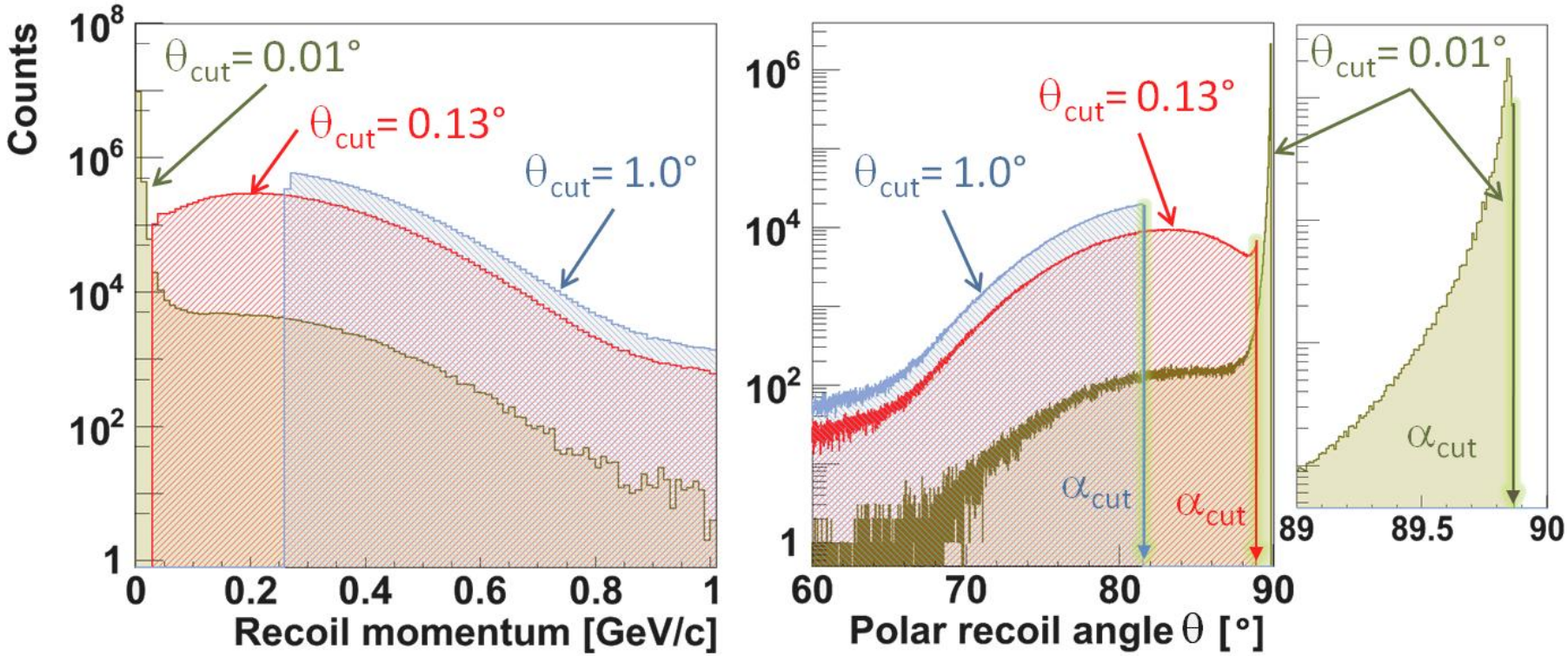
Last Changed Date: 2009-09-03 15:13:14 +0200 (Thu, 03 Sep 2009)

DPM cut off


15 GeV/c
10 GeV/c
8 GeV/c
5 GeV/c
3.5 GeV/c
2.5 GeV/c
1.5 GeV/c
σ_N
σ_C
-t [GeV/c]^2
Cut-off parameter θ_{cut} [°]


Interference region
$|t| \sim 10^{-3}$ GeV^2/c^2
Coulomb domain
$|t| \leq 5 \cdot 10^{-4}$ GeV^2/c^2
Cut-off paramter [°]
Beam momentum [GeV/c]

DPM cut off


Counts
10^8
10^6
10^4
10^2
1
θ_{cut}= 0.01°
θ_{cut}= 0.13°
θ_{cut}= 1.0°
0
0.2
0.4
0.6
0.8
1
Recoil momentum [GeV/c]
10^6
10^4
10^2
1
θ_{cut}= 0.13°
θ_{cut}= 1.0°
α_{cut}
α_{cut}
60
70
80
90
Polar recoil angle θ [°]
θ_{cut}= 0.01°
α_{cut}
89
89.5
90