On Polarization of a Beam Extracted with a Bent Crystal

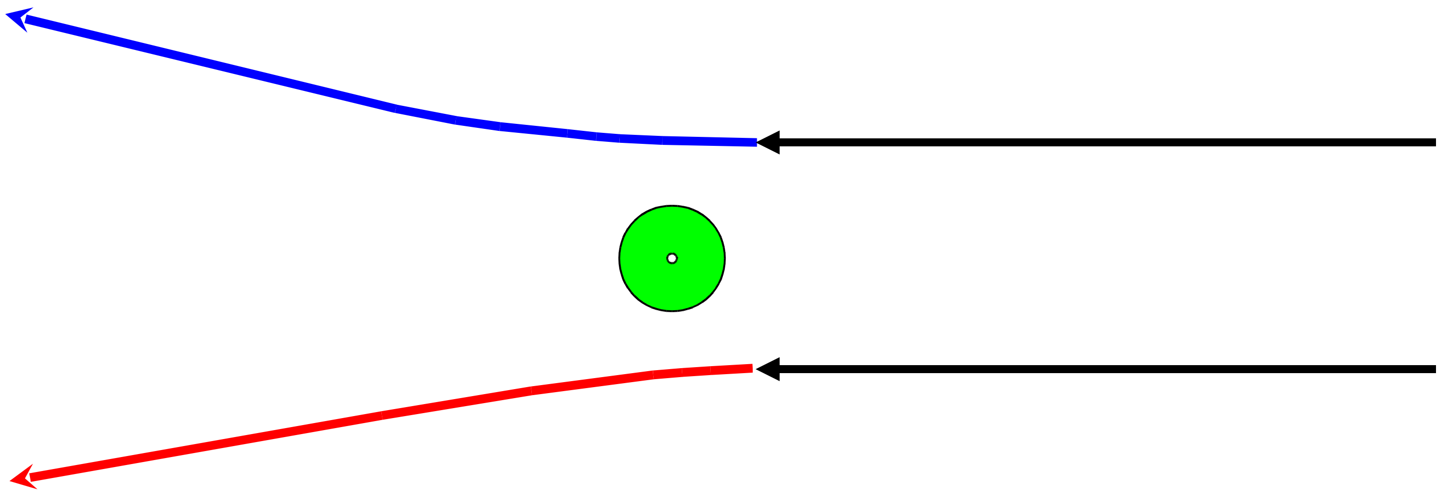
M. Ukhanov
IHEP Protvino

Outline

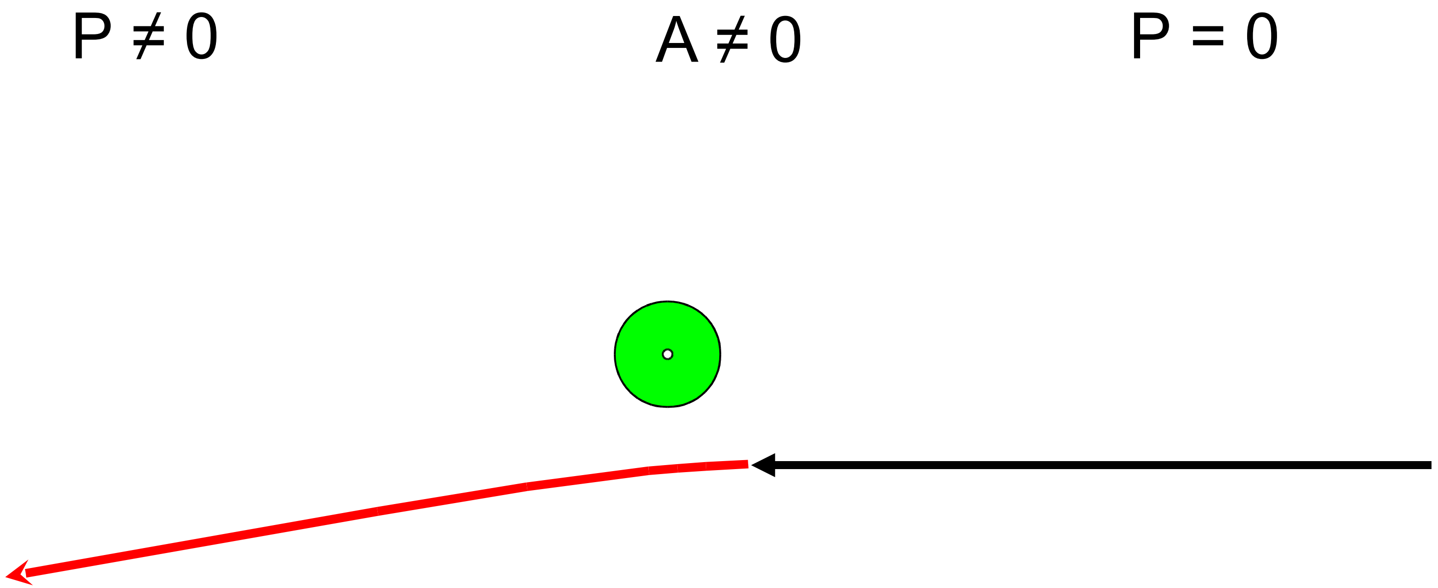
- Basics of the phenomenon
- Numerical example
- Estimation of a volume reflection capabilities
- Conclusions

Definition

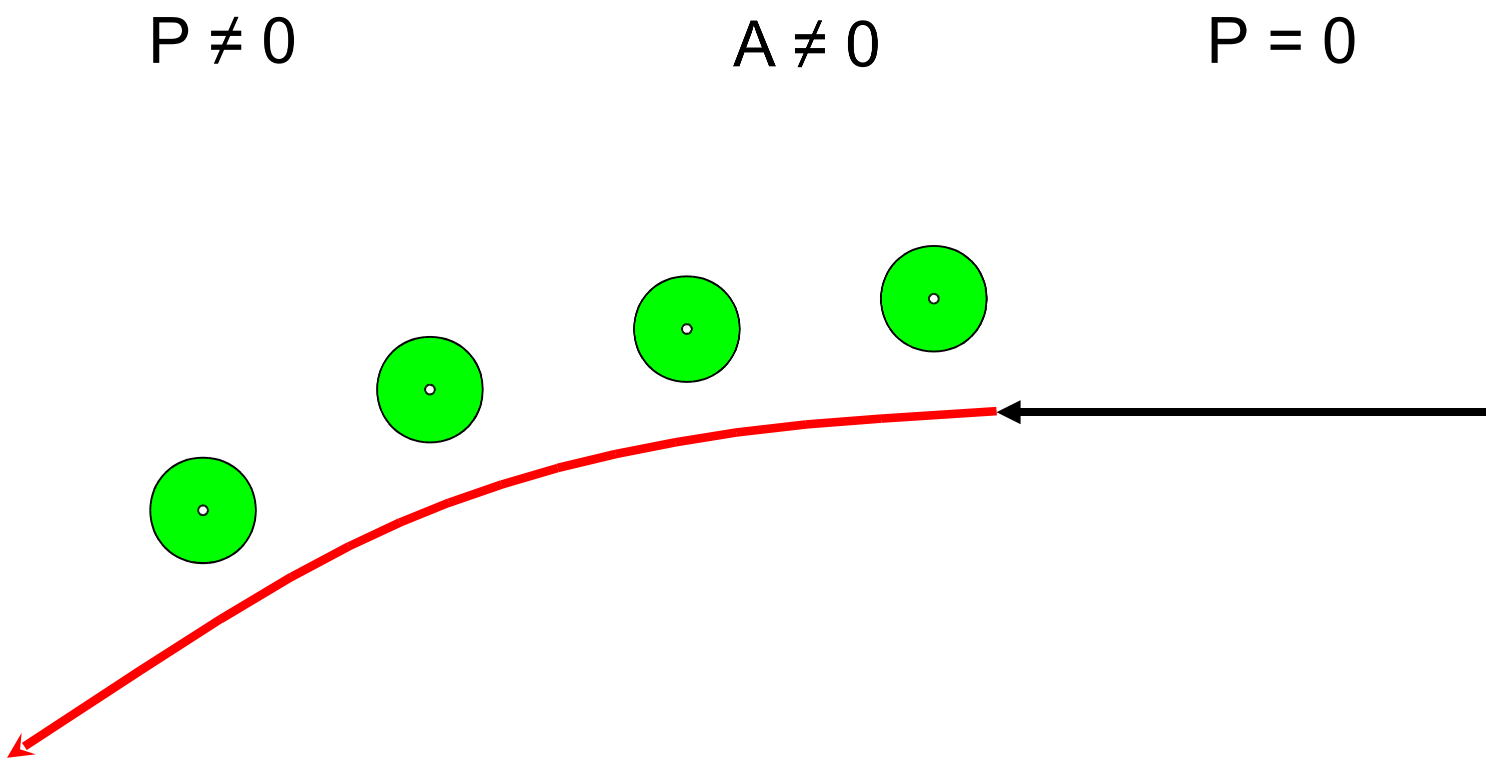
$P \neq 0$ $A \neq 0$ $P = 0$



Junior hunter exercise



Senior hunter exercise



Consequences from the definition

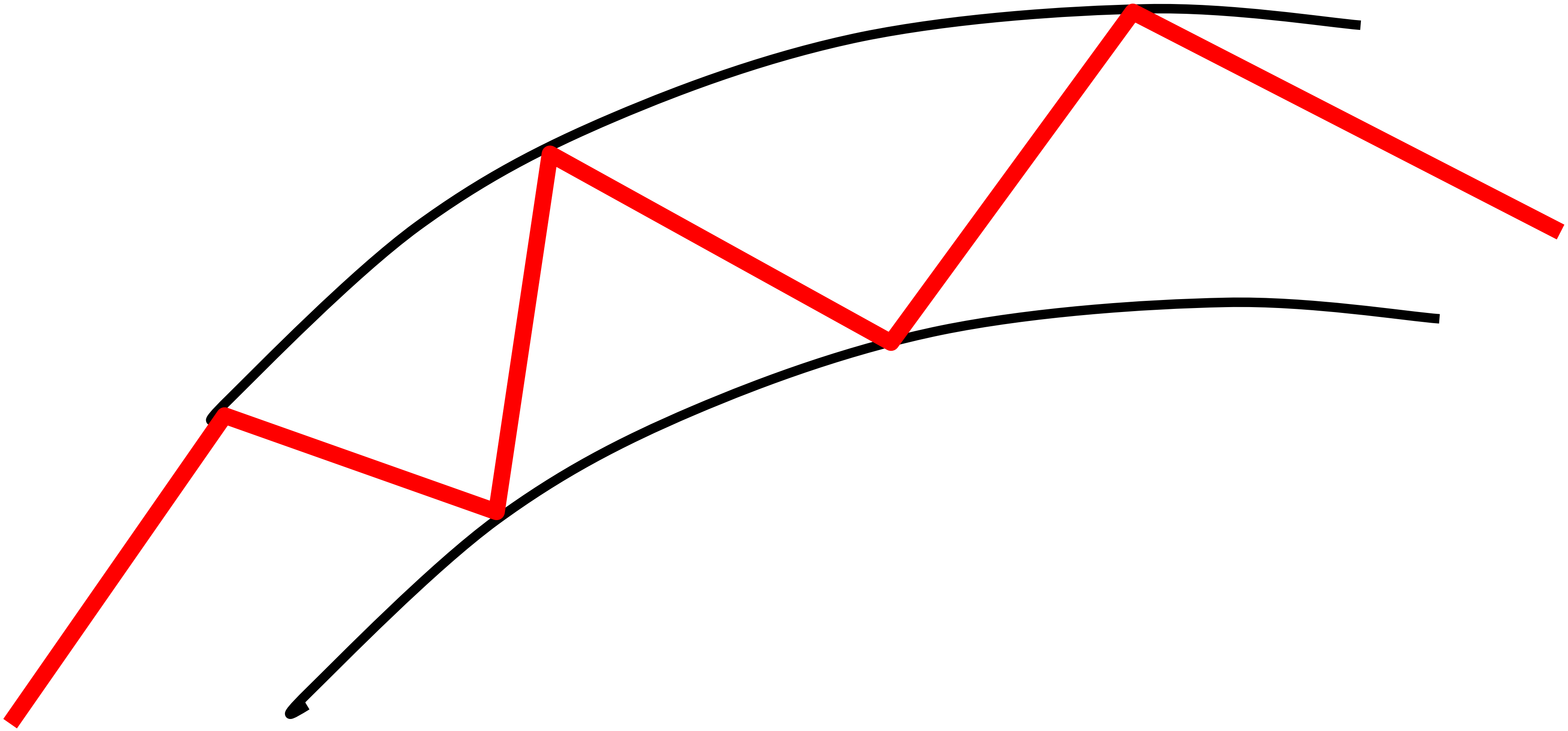
A beam,
extracted by means of a bent crystal,
must be polarized
by definition
if an analyzing power is not zero.

Polarization calculation

$$P = \frac{(1+A)^N - (1-A)^N}{(1+A)^N + (1-A)^N}$$

Lemma:

$$\sum \theta_i = \text{Crystal Bent} \pm \theta_{critical}$$



Assumptions

To get a numerical estimation let us assume
linear dependence
of an analyzing power on the scattering angle

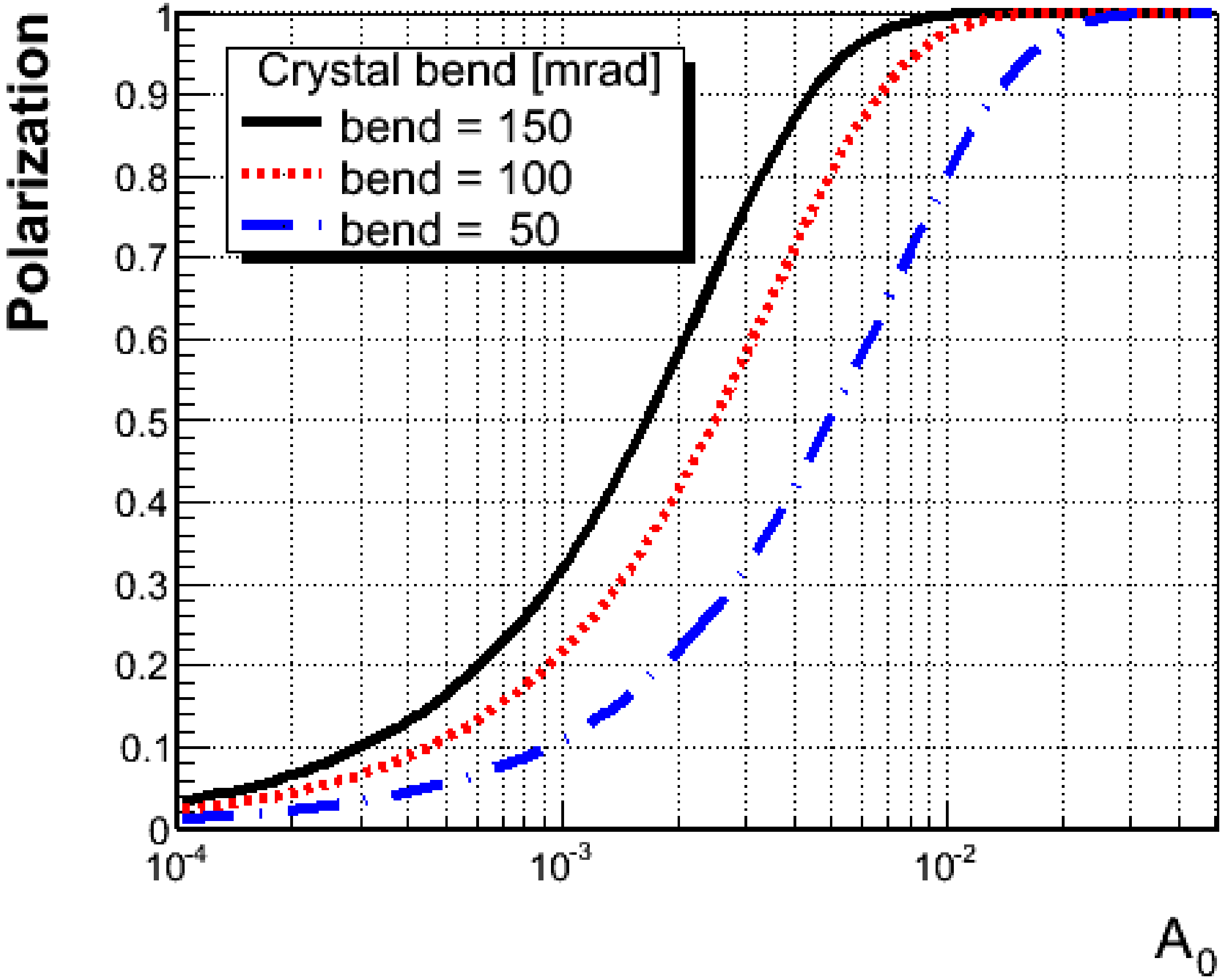
$$A(t) = A_0 \cdot |t/t_0|^{1/2}$$

for very small $|t| < |t_0| = 10^{-3}\ (GeV/c)^2$

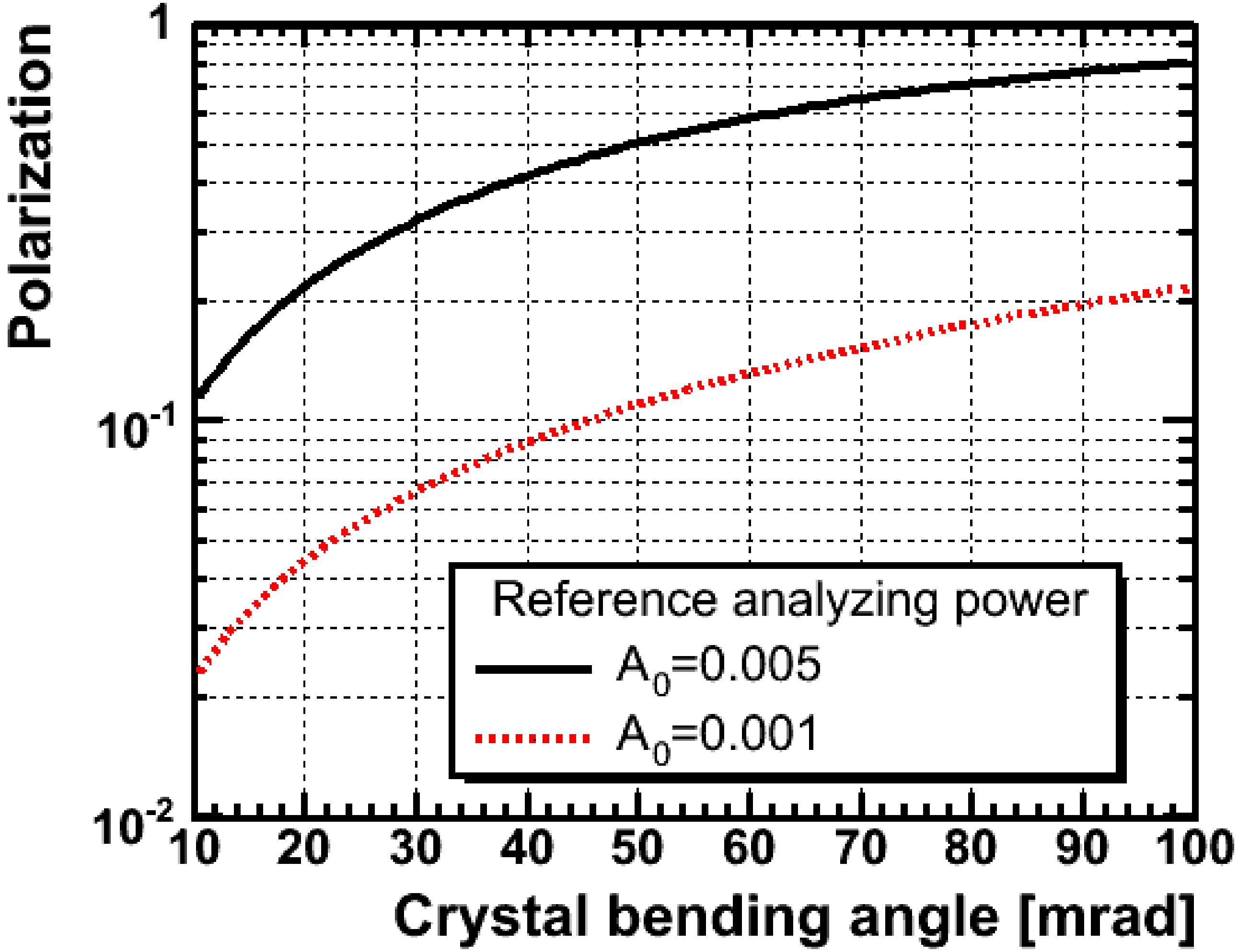
If we consider the channeling as a sequence of scatterings off the crystal lattice then the result does not depend on the beam trajectory inside the crystal.

Polarization depends only on the crystal bent.

Dependence on the A_0



Dependence on the crystal bent



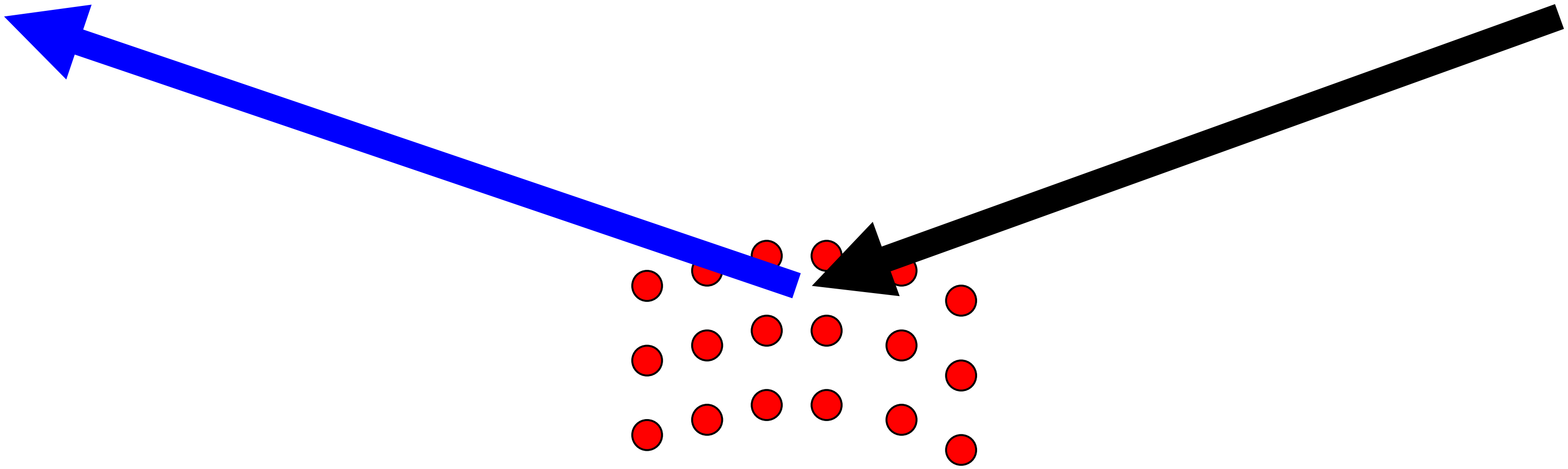
Remark on a general case

- If the analyzing power dependence on the scattering angle is not linear function then a resulting polarization will depend on a trajectory of the particle inside the crystal.
- Channeling in a crystal occupies the transfer momentum domain at

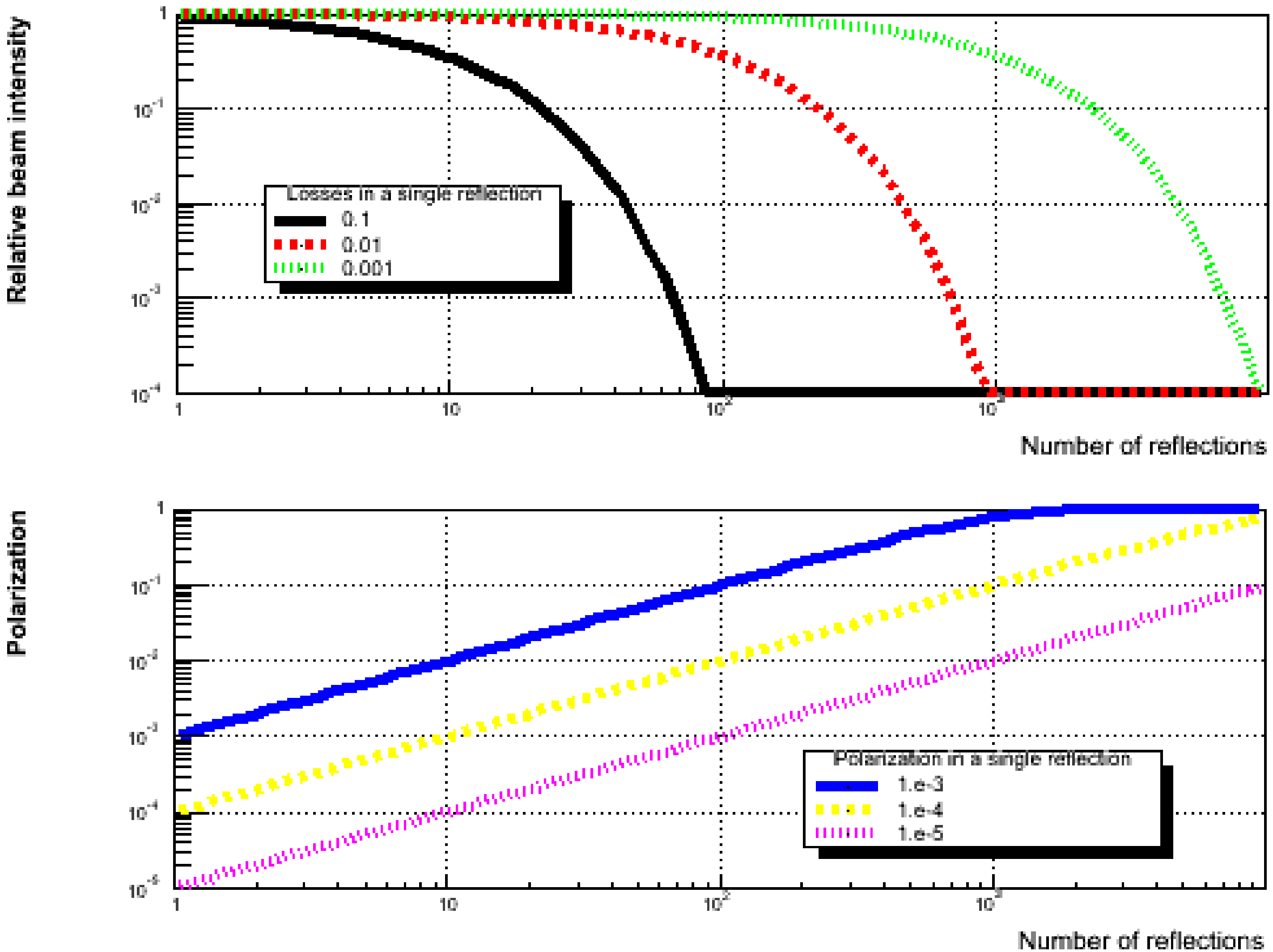
$$|t| < 10^{-5}\ (GeV/c)^2$$

- No experimental data on the analyzing power exists today in this domain.

Volume reflection



Estimation of volume reflection capabilites



Conclusions

- Bent crystal extraction provides a polarization in the resulted beam (*strict*).
- With certain assumptions a beam polarization could be measurable
- … or even big enough for practical needs.
- It is also possible to get a beam polarization using a multi turn volume reflection off a bent crystal.
- Using the volume reflection techniques one can utilize *a la RICH* polarimeter to make measurements.
- Since there is no experimental data today the measurements of a beam polarization provides a tool for a physics in $|t| < 10^{-5}\ (GeV/c)^2$ domain which is hardly, if not at all, attainable with the other methods.

Analyzing power at small |t|

Excerpt from talk by A. Bravar (BNL) at Spin05

$$A_N = C_1 \phi_{flip}^{em} {}^* \phi_{non-flip}^{had} + C_2 \phi_{flip}^{had} {}^* \phi_{non-flip}^{had}$$

In absence of hadronic spin – flip contributions A_N is exactly calculable (Lapidus & Kopeliovich):

$$A_N = \sqrt{\frac{8\pi Z\alpha}{m_p^2 \sigma_{tot}^{pA}}} \frac{y^{3/2}}{1+y^2}(\mu - 1) \qquad y = \frac{\sigma_{tot}^{pA} t}{8\pi Z\alpha}$$

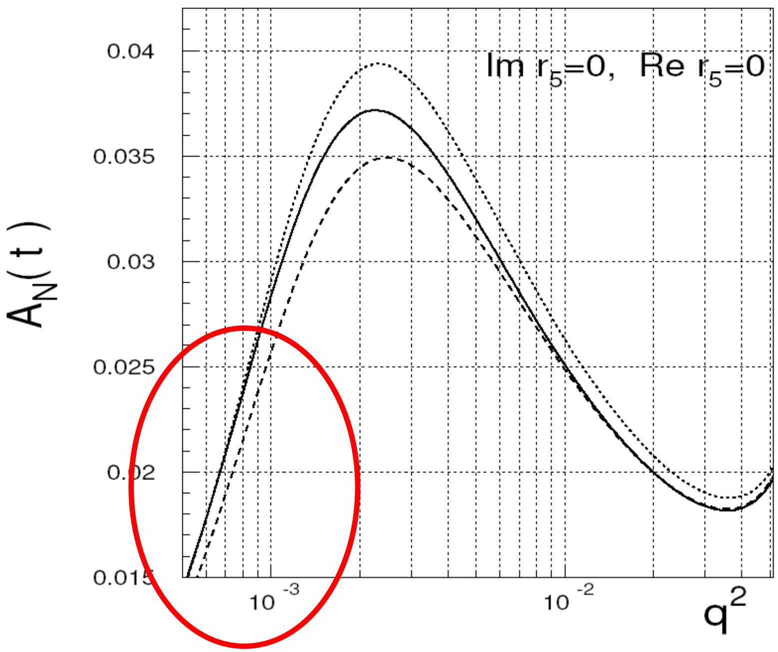
For very small $|t|$ A_N can be approximated by

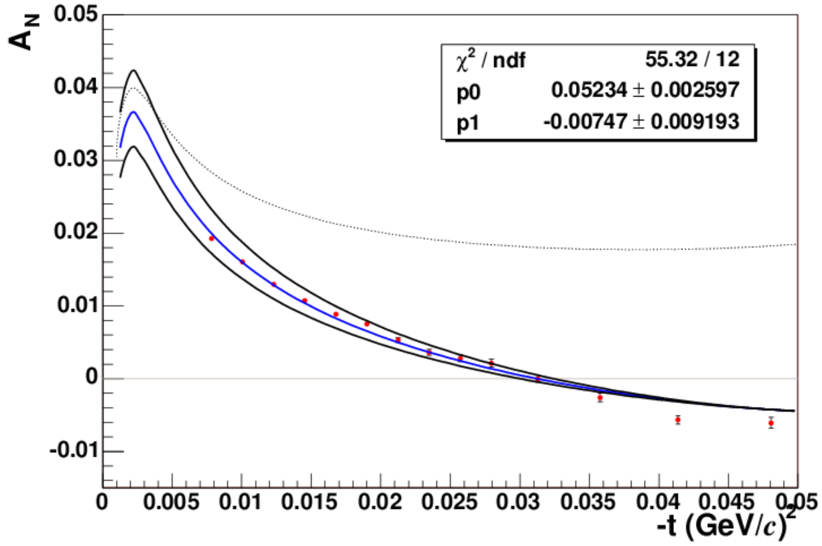
$$A_N \approx |t|^\alpha f(s)$$

where α – depends on helicity of initial and final state particles, *f(s)* – is a function of the total energy.

Analyzing power at small |t|

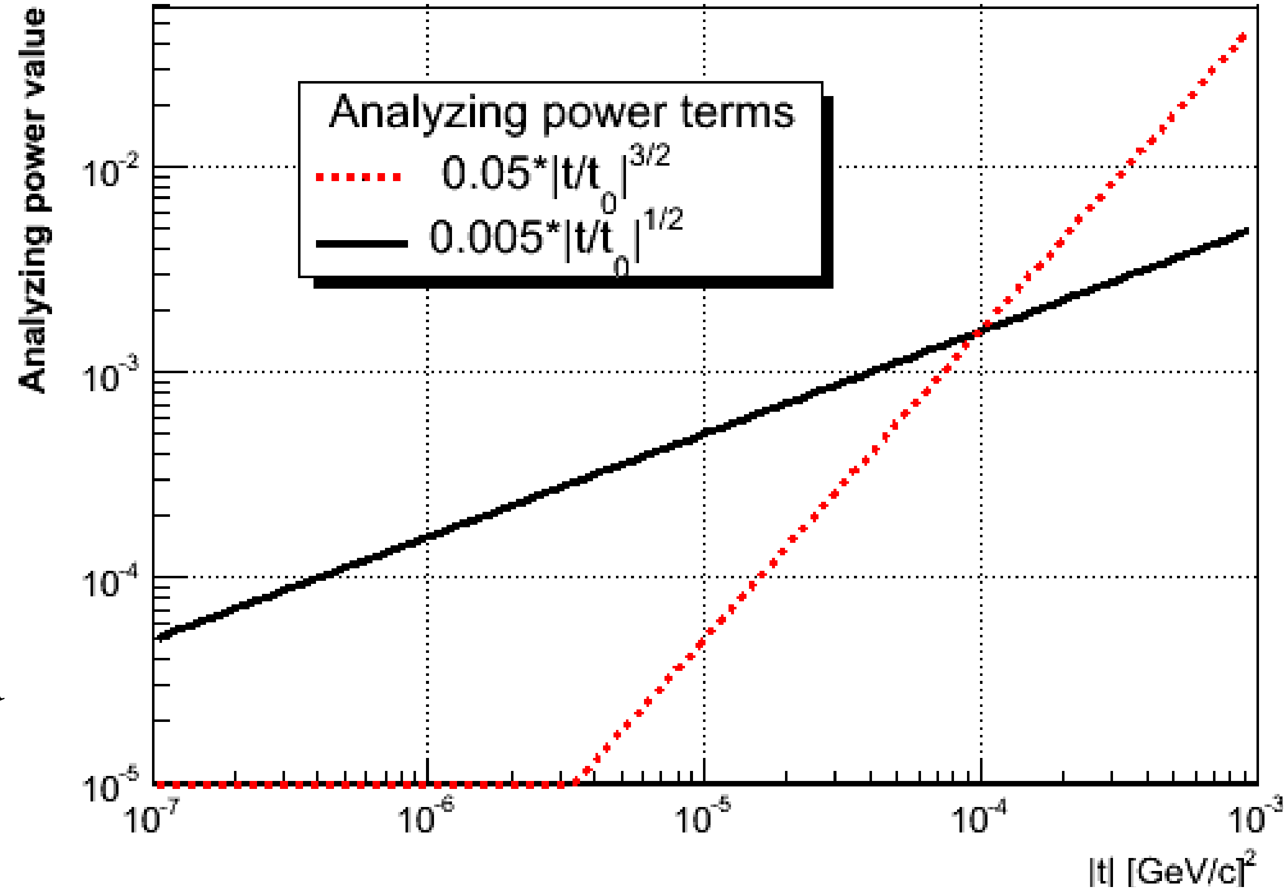
B.Z. Kopeliovich and T.L. Trueman, hep-ph/0012091





Kopeliovich –
Truemann model
PRD**64** (01) 034004
hep-ph/0305085

Analyzing power evolution at small *t*



Example:

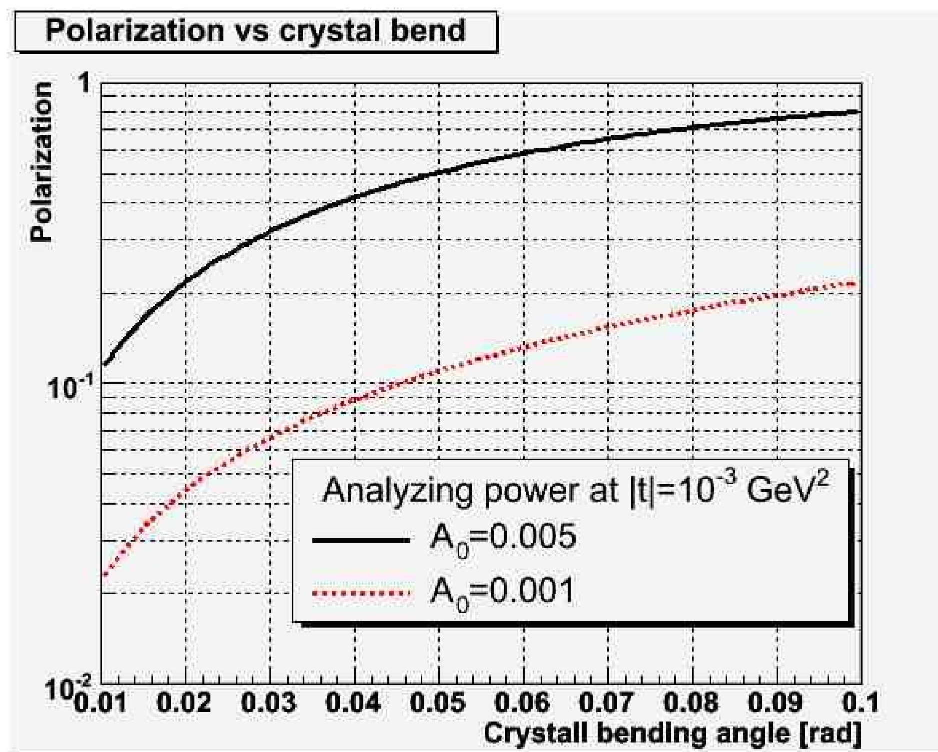
At 400 GeV/c and

$\Theta = 5\ \mu rad$

$-t = 0.8 \cdot 10^{-6}\,(GeV/c)^2$

Estimation of the net polarization

$$P = \frac{(1+A(t))^N - (1-A(t))^N}{(1+A(t))^N + (1-A(t))^N}$$



Critical channeling angle in *Si*

$\theta = 5\ \mu rad / p^{1/2} (TeV/c)^{1/2}$

$@\, p = 70\ GeV/c \Rightarrow \theta \approx 20\ \mu rad$

$100\ mrad$ bend gives $N = 5000$

If $A(t) = A_0 \cdot |t/t_0|^{1/2}$

for very small $-t < t_0 = 10^{-3}\ GeV^2$

and $A_0 = A(10^{-3}\ GeV^2) = 0.005$

Then $P \approx 0.8$

Independence on the channeling assumptions