



Relativistic transformation of proton polarization vector from decay

$$\Lambda \rightarrow p + \pi^{-}$$

and it's practical applications

4th September 2007
Dubna

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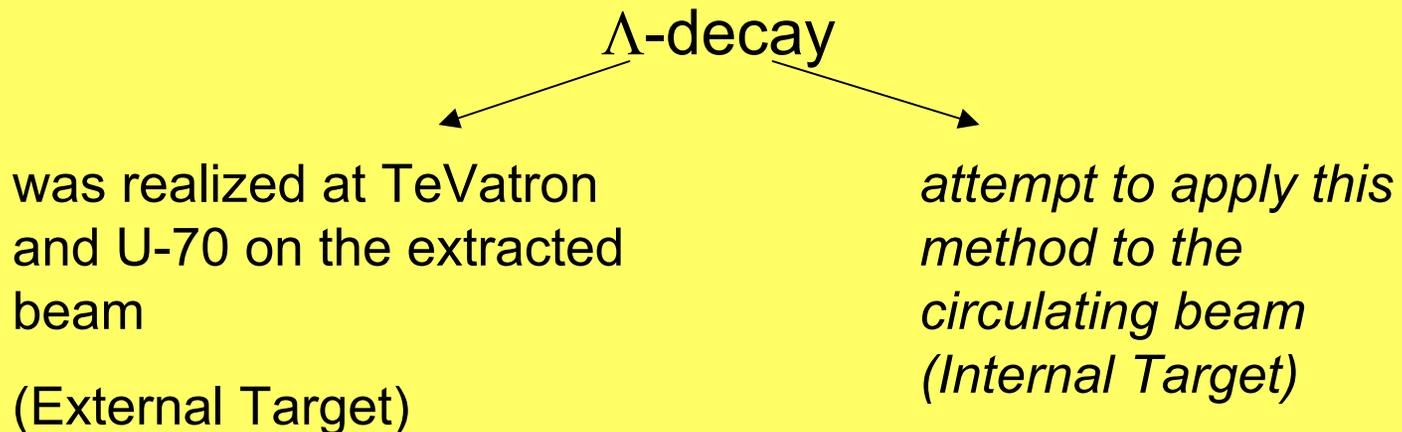
1. Introduction

The progress in the High Energy Spin Physics mainly depends on

- *the availability of the high quality polarized beams*
- *polarized targets*

Production of the polarized proton beam:

- accelerating of the polarized protons
- Λ -decay



2. Lorentz transformation of the polarization vector

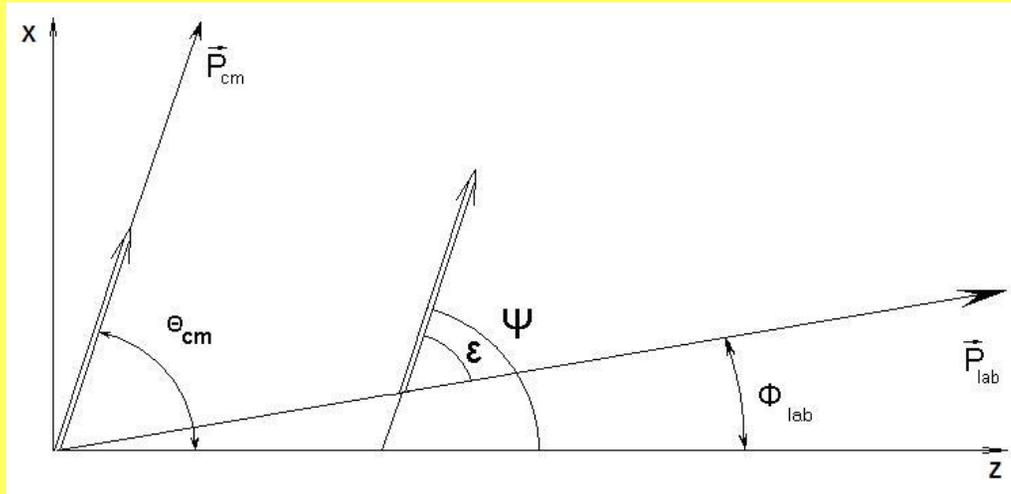


Fig.1. Lorentz transformation of the polarization vector from c.m.s. to the laboratory system. Double line arrows mean polarization vector, one line arrows label particle momentum.

$$\operatorname{tg} \varepsilon = \frac{\sin \theta_{cm}}{\gamma_0 \left(\cos \theta_{cm} + \frac{\beta_0}{\beta_\Lambda} \right)}$$

- [1]. O.E. Overseth, Polarized Protons at the 200-GeV Accelerator. National Accelerator Laboratory, 1969 Summer Study Report, SS-118 2250, vol. 1, pp 19-25.

$$\vec{s} = \vec{s}' + \vec{\beta}\gamma\left(\frac{\gamma}{\gamma+1}\vec{\beta}\bullet\vec{s}' + s'_0\right), \quad s_0 = \gamma(s'_0 + \vec{\beta}\bullet\vec{s}')$$

$$\mathbf{s}\cdot\mathbf{u}=0$$

$$\mathbf{s}^2 = -1$$

$$s_{lx} = \gamma_0 \sin \theta_{cm} \quad s_{lz} = \gamma_0 \gamma_c (\cos \theta_{cm} + \beta_c \beta_0),$$

$$s_{l0} = \gamma_c \gamma_0 (\beta_0 + \beta_c \cos \theta_{cm})$$

$$\operatorname{tg} \psi = \frac{\sin \theta_{cm}}{\gamma_c (\cos \theta_{cm} + \beta_c \beta_0)}$$

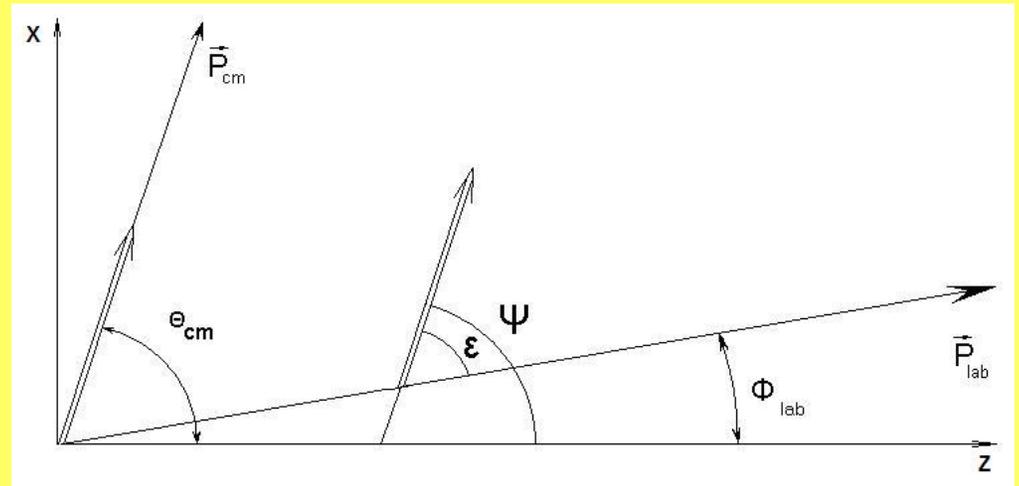
$$\operatorname{tg} \phi = \frac{\sin \theta_{cm}}{\gamma_c \left(\cos \theta_{cm} + \frac{\beta_c}{\beta_0} \right)}$$

$$\psi = \varepsilon + \phi,$$

$$\operatorname{tg} \varepsilon = \frac{\operatorname{tg} \psi - \operatorname{tg} \phi}{1 + \operatorname{tg} \psi \operatorname{tg} \phi}$$

$$\operatorname{tg} \varepsilon = \frac{\gamma_c \beta_c \sin \theta_{cm}}{\beta_0 \gamma_0^2 \left[\gamma_c^2 (\cos^2 \theta_{cm} + \cos \theta_{cm} (1 + \beta_0^2) \frac{\beta_c}{\beta_0} + \beta_c^2) + \sin^2 \theta_{cm} \right]}.$$

$$\operatorname{tg} \varepsilon = \frac{\sin \theta_{cm}}{\gamma_0 \left(\cos \theta_{cm} + \frac{\beta_0}{\beta_\Lambda} \right)}$$



$$\Theta^* = 90^\circ \quad 50 < \gamma_\Lambda < 3765 \quad \beta_0 \approx 0,107 \quad \gamma_0 \approx 1,006$$

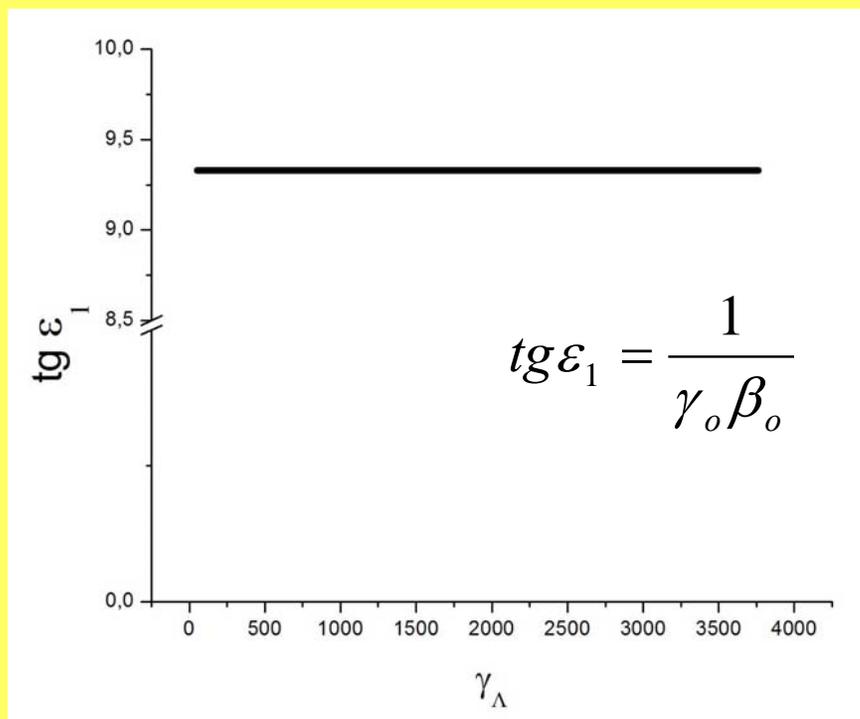


Fig. 2.

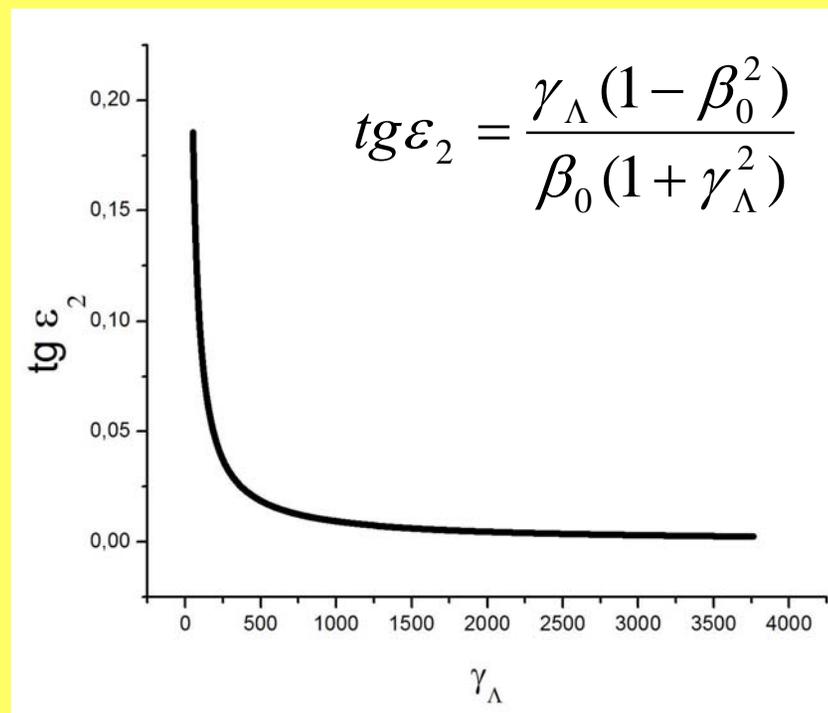


Fig. 3.

3. Production of the polarized proton beam on the External and Internal Targets

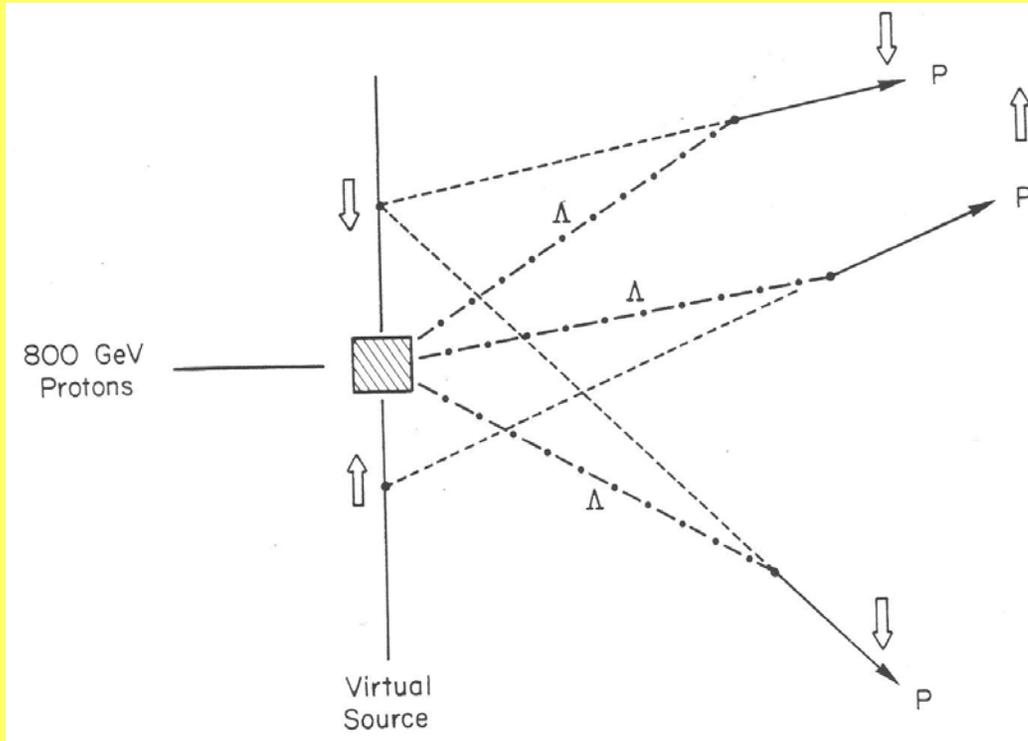


Fig. 4. Diagram of the primary production target, Λ -decay process, and virtual source of polarized protons. The polarization state of the proton is correlated with the position in the plane of the virtual source.

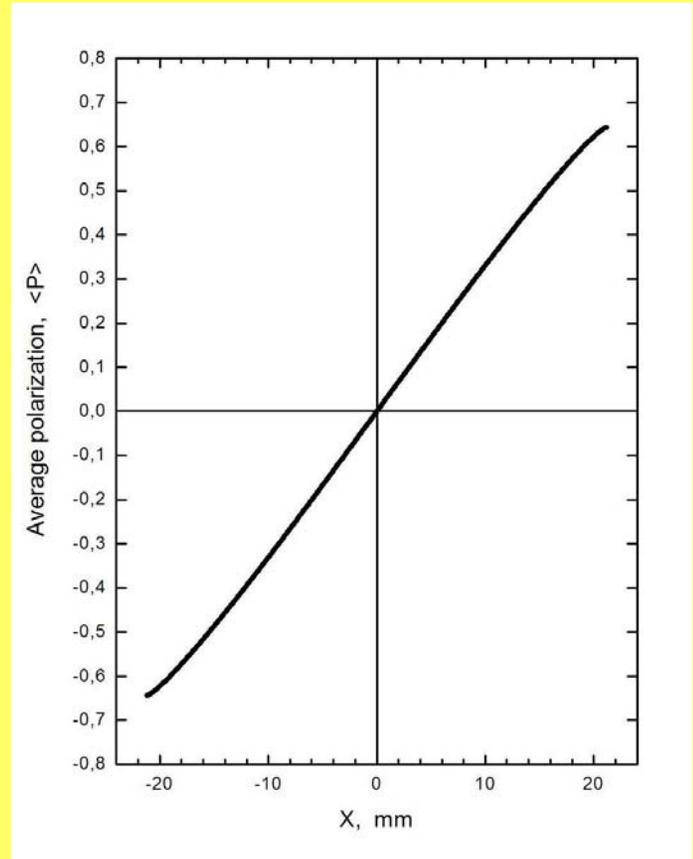


Fig.5. Correlation between the average particle polarization and the horizontal position at the intermediate focus for 70 GeV/c protons.

FNAL – E581/704 Experiment

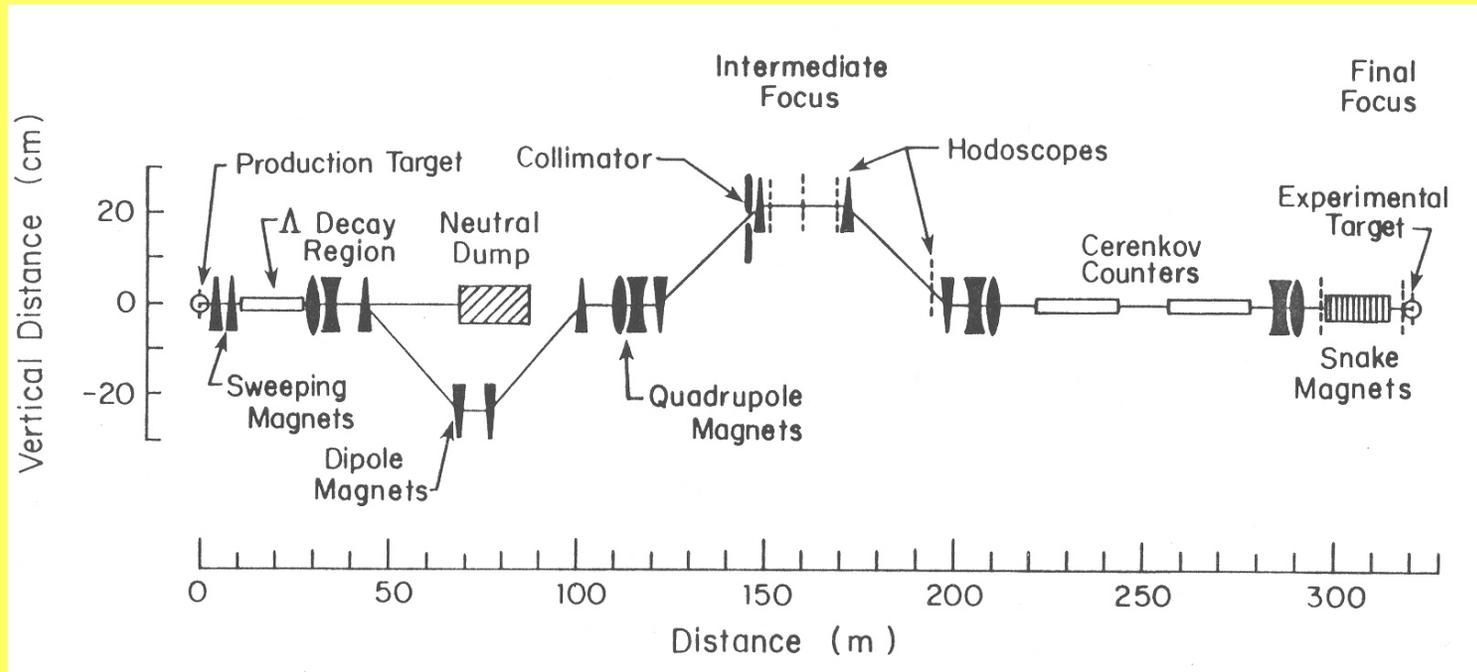


Fig. 6. Layout of elements along the MP polarized beam line. Shown here is a side view of the polarization target, neutral particle dump, adjustable collimator, beam-tagging region, snake magnets, Cherenkov counters, and experimental target.

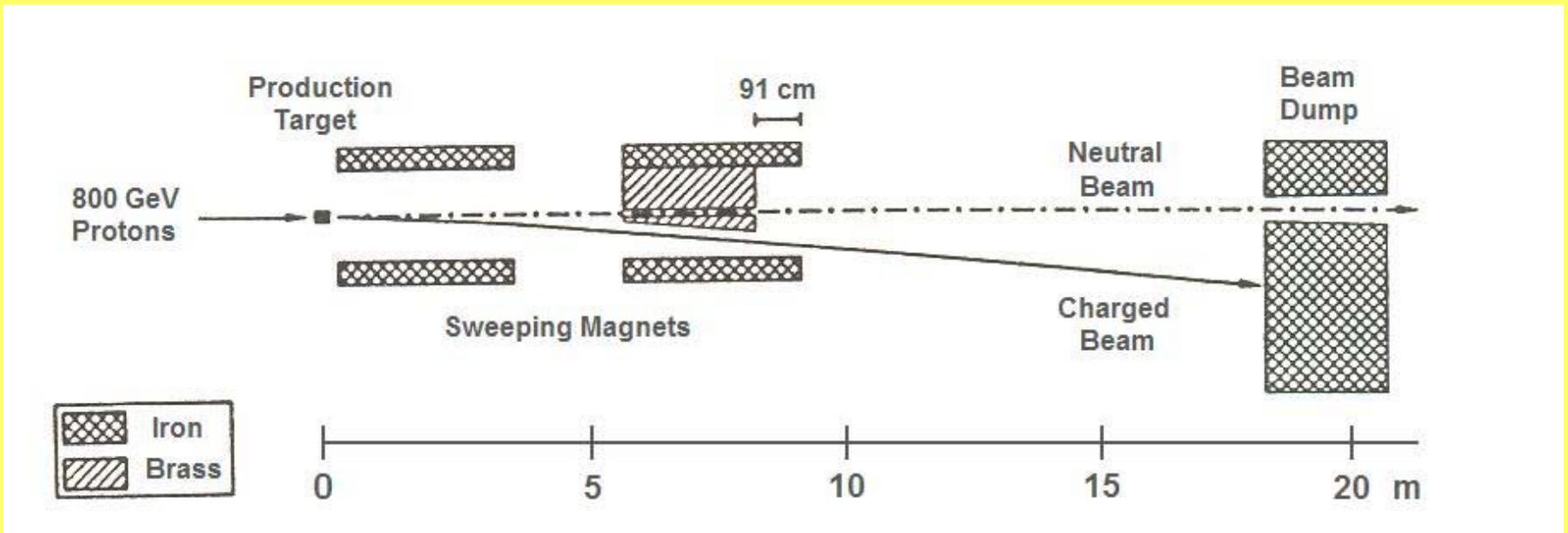


Fig. 7. Side-view layout of the production target and primary beam dump area. Separation of neutral and charged particles by magnetic sweeping of the beam by two dipole magnets is shown. A collimator inside the second magnet determines the size of the neutral beam. The charged particle beam passes below the collimator in the second magnet and is deflected into the charged primary beam dump. The dimensions transverse to the beam are not to scale.

Polarized proton beam at U-70 accelerator

Table 1.

Parameter	External Target (Al, 30cm)
Luminosity at production target, $cm^{-2}s^{-1}$	$3,6 \cdot 10^{36}$
Momentum band, %	$\pm 4,5$
Intensity per second	$3 \cdot 10^6$
Polarized beam momentum, p, GeV/c	40
Average beam polarization,%	$40 \pm 2\%$
Beam profile at final focus, $x \times y$, mm (max)	$10,6 \times 8,1$
Beam divergence, $x' \times y'$, mrad	$\pm 6,5 \times \pm 6,0$ (max)

Polarized Proton Beam from the Internal Target at U-70

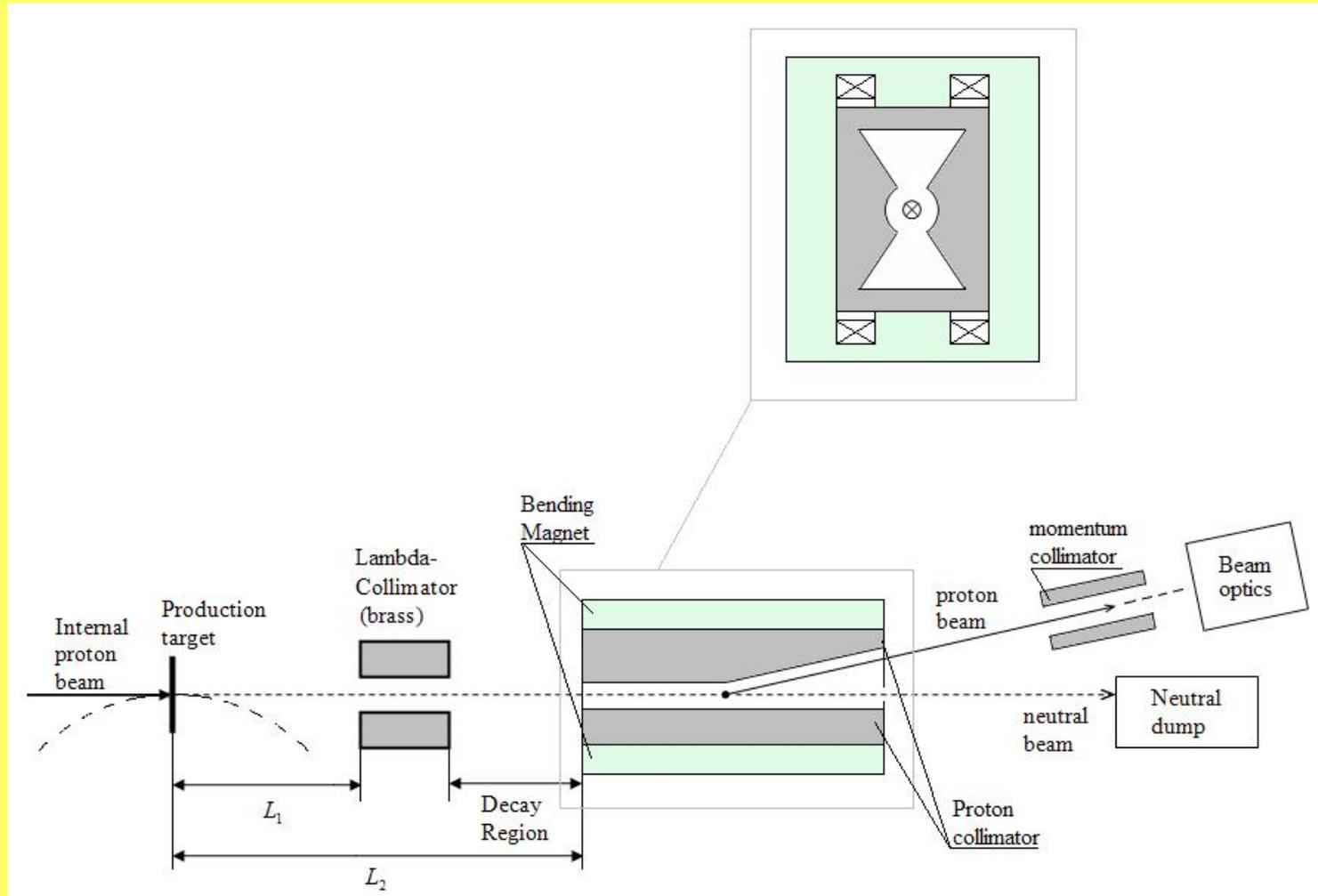


Fig. 8. Sketch of obtaining the polarized proton beam from Internal Target (IT) at U- 70

Polarized proton beam at U-70 accelerator

Table 2.

Parameter	Internal Target (Carbon)
Luminosity at production target, $cm^{-2}s^{-1}$	$3,2 \cdot 10^{36}$
Momentum band, %	± 10
Intensity per second	10^7
Polarized beam momentum, p, GeV/c	50 ± 4
Average beam polarization,%	$40 \pm 2\%$
Beam profile at final focus, $x \times y$, mm (max)	$\pm 4 \times \pm 4$
Beam divergence, $x' \times y'$, mrad	$\pm 2 \times \pm 2$ (max)

Polarized Proton Beam from the External Target at LHC

Table 3.

Parameter	External Target (Carbon)
Luminosity at production target, $\frac{1}{\text{spill} \cdot \text{cm}^2}$	$1,1 \cdot 10^{39}$
Momentum band, %	± 5
Intensity per second	$3,23 \cdot 10^{14}$
Polarized beam momentum, p, GeV/c	3765
Average beam polarization,%	32
Number of polarized protons, pol. prot /sec	$5,7 \cdot 10^8$
Number of polarized anti-protons, pol. antiprot/sec	$5,7 \cdot 10^5$

LHC

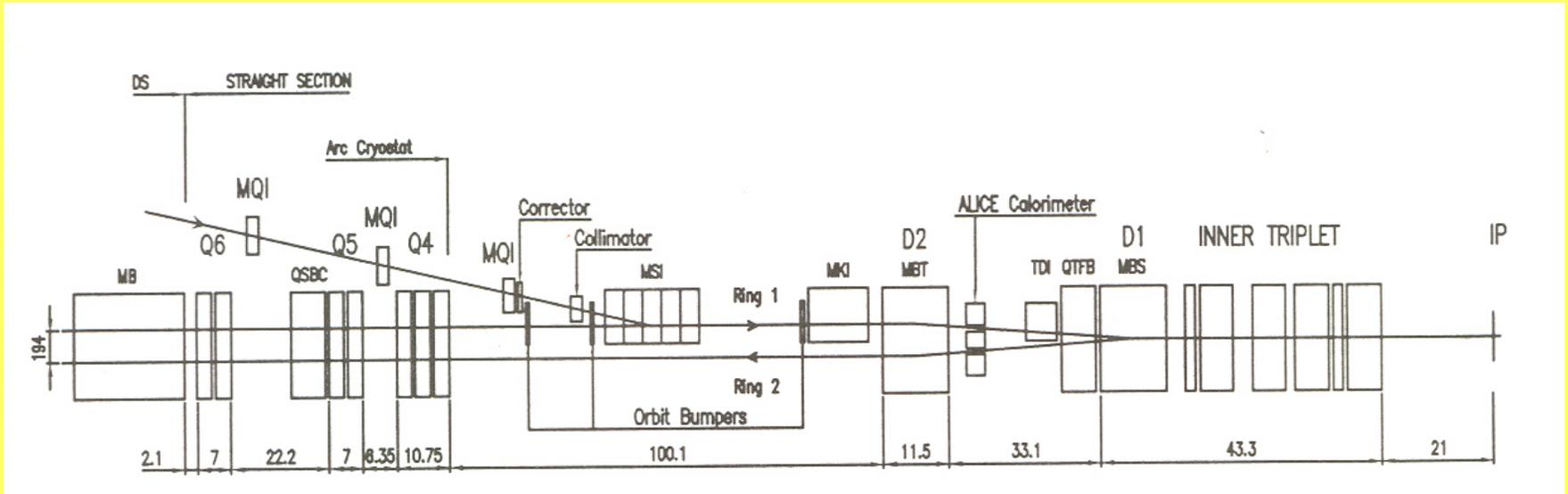


Fig. 9. Layout of the left part of the low- β insertion at IP2

Polarized Proton Beam from the Internal Target at LHC

Table 4.

Parameter	Internal Target	
	Gas target:	C target:
Luminosity at production target, $cm^{-2}s^{-1}$	$1,1 \cdot 10^{35}$	$2,7 \cdot 10^{37}$
Momentum band, %	± 5	$\pm 5,7$
Intensity per second	$3,23 \cdot 10^{14}$	$3,23 \cdot 10^{14}$
Polarized beam momentum, p, GeV/c	3765 GeV/c	
Average beam polarization,%	32	32
Beam life-time	22hrs	34,5 sec
Number of polarized protons, pol. prot /sec	$6 \cdot 10^6$	$6,6 \cdot 10^9$
Number of polarized anti-protons, pol. antiprot/sec	$6,6 \cdot 10^3$	$6.6 \cdot 10^6$

4. Summary

- We checked the Lorentz transformation of proton polarization from proton rest frame to Λ -rest system and to the Laboratory frame.
- We estimated the possibility of obtaining the polarized proton beam from the internal target at U-70. Advantages of using very thin target:
 - 1) The multiple coulomb scattering angle will be small
 - 2) The absorption of the produced Λ by the production target would be negligible in contrast to the external target
 - 3) The quality of the internal circulating beam is better than the extracted primary proton beam
- For LHC we do not know several beam parameters (Λ -yields, long decay region and special beam optics). Nevertheless LHC might be the source of high energy polarized antiproton beam of highest energy at present.

Acknowledgements

We would like to express our thanks for useful discussions and practical help to professors A. Efremov, M. Ryskin, J. Soffer and doctors E. Troyanov, V. Zapolsky

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