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BEAM TESTS OF A 36 MM LITHIUM LENS

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1. *INTRODUCTION*

Following the work on a 2 cm diameter lithium lens, a 3.6 mm diameter lens was designed, constructed at CERN and filled with lithium at Karlsruhe. A transformer for 1.5 MA was designed and built in the Instutite of Nuclear Physics (INP) at Novosibirsk. This lens, used as an antiproton collector, was tested at the CERN antiproton source (AAC). For such a lithium lens a yield increase of about 40% was predicted. In 1987/1988 the lithium lens was tested, without beam, at INP, at a peak current of 800 kA and, for a few pulses, at 1.0 MA. At the beginning of 1988 it was proposed to continue the collaboration between CERN and Novosibirsk for a 1.0 MA system. Calculations showed that the gain in yield would not have been significant so a 1.3 MA system was proposed. Mechanical modifications were made to enable the target and lens to be mounted closer to each other.

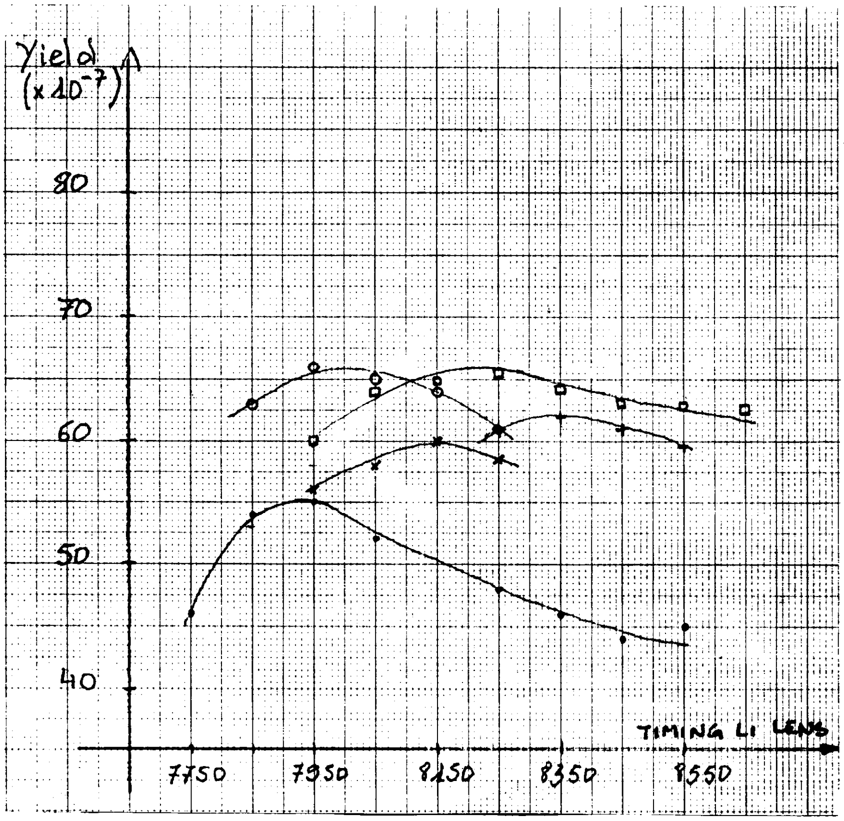
2. *TEST IN BEAM*

The 36 mm diameter lithium lens after being installed in the transformer at the beginning of 1989, was tested in the laboratory. Because of a flange failure after about 1000 pulses at 1.1 MA the testing in the beam was postponed until July 1989.

For antiproton production, the CERN Proton Synchrotron (PS) can deliver a 26 GeV/c beam with an intensity of $1.4 \cdot 10^{13}$ protons per pulse, 95% of which lie within a transverse emittance of less than 3π mm.mrad. The production beam is focused on the 3 mm diameter production target to a spot of 1 mm radius (95% of the beam) with two pulsed quadrupoles. However, to reduce the build-up of induced radioactivity, we started beam tests at an intensity of $2.0 \cdot 10^{12}$ protons per pulse. With this intensity, beam emittances are known to be smaller so that we anticipated higher yields than with the full intensity.

In July, the 36 mm lithium lens was pulsed at 1.1 MA giving a yield of $80 \cdot 10^{-7}$ antiprotons/proton after the injection line optics was optimized. To achieve the optimum antiproton yield the iridium target, embedded in graphite, had been placed as close as possible to the end of the lens.

The yield versus target position is shown in Fig. 1. When the target moved 6 mm towards the lens, the yield increased by about 20%. It was not possible to put the target closer because the mechanical pieces of the target and lithium lens did not allow it.



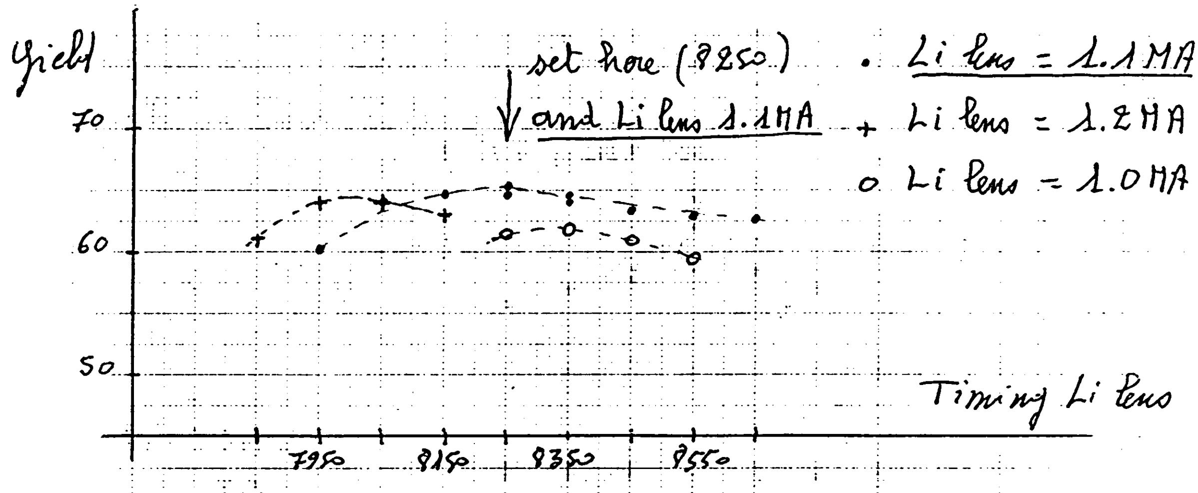
• 1.2 MA before moving target
x 1.0 MA " " "
+ 1.0 MA target moved towards target
□ 1.1 MA " " " "
o 1.2 MA " " " "

Figure 1

After setting up the AC, antiproton yield was measured as a function of lens peak current and the time difference between occurrence of the current peak value and the passage of the beam. The maximum yield was achieved with a current of 1.1 MA (Fig. 2).

The AC injection line was designed for operation with a 36 mm diameter lithium lens. The design had to satisfy two conditions:

to have a good transmission,



Timing Li lens	Yield (10^{7})
7950	60.5
8050	64.2 – 64.57
8150	64.67
[8250]	64.64 ⟶ 65.34
8350	64.22 – 64.78
8450	63.97
8550	63.43
8650	63.30

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<u>Figure 2</u>

- to collimate out secondary particles coming from the target, which are outside the AC acceptance, in the target area itself.

The beam optical requirements were:

- that antiprotons, with production angles up to 100 mrad, are to be collected (the lithium lens reduces the transverse angles to 14 mrad).
- that the injection line is matched to the AC, which is a strong focusing ring with FODO structure designed to have a transverse acceptance of 200π mm.mrad and a momentum acceptance of ±3%.
- that the power supplies available, which are capable of supplying a maximum energy of 25 kJ/pulse, can be re-used (this imposes constraints on the maximum apertures of the bending magnets).

- that the currents from these power supplies were limited to 4 kA.

With all these requirements and constraints the AC injection line was designed to have a transverse acceptance of 240π mm.mrad and a momentum acceptance of ±3%.

After optimization of beamline currents we obtained a yield of $80 \cdot 10^{-7}$ antiprotons/proton at the low intensity of $2.0 \cdot 10^{12}$ protons per pulse at the target (Figs. 3 and 4). To get this high yield the gradients of 4 quadrupole magnets were changed. This can be explained by the fact that calculation of the optics was only made to the first order without taking into account the air scattering in the line along about 40 m. Yield and the transverse emittances were measured versus the AC aperture (Table 1).

Table 1

Aperture	Yield	ε_H	ε_V
Open	79.82	152	137-142
200	80.00	147	137
175	75.45	142	137
150	66.40	128	122
125	51.83	110	108
100	41.62	85	91
75	27.28	67	68
50	17.18	40	48
25	5.75	18	22

When we plot the ratio of transverse emittance (defined at 95% of the beam) to AC acceptance (defined by the scrapers) we see that results are quite different in both planes (Fig. 5).

At the end it was also interesting to measure the yield with the highest production beam intensity (Table 2).

Table 2

Intensity (10^{12})	Yield (10^{-7} $\bar{p}$/p)	$\Delta Y/Y_0$ (%)
2.6	80.0	+38
10.0	72.1	+24
14.0	69.1	+19

In the last column of Table 2 we see the yield increase compared to the 20 mm Li lens (yield = $58 \cdot 10^{-7}$ antiprotons/proton). The yield measurement comparison between 20 mm and 36 mm Li lens is plotted in Fig. 6.

* Nb of $\bar{p}$ injected in AC ($\Delta p/p = 5.3\%$)

** Nb of $\bar{p}$ ($\Delta p/p = 1.5\%$) after bunch rotation

*** Nb of $\bar{p}$ in AC/Nb of p on target

	AC 5.3*	AC 1.5**	EFF	YIELD E-7***
441	1.97	1.74	.88	78.32
442	1.97	1.72	.87	79.49
443	1.95	1.76	.90	76.97
444	1.96	1.72	.87	79.09
445	1.98	1.78	.90	79.55
446	1.97	1.73	.87	79.14
447	1.97	1.70	.86	81.65
448	2.03	1.76	.86	83.68
449	1.92	1.71	.89	78.94
450	1.95	1.77	.90	81.23
ACWX:	AVERAGE VALUES FOR LAST 10 SHOTS:			
	1.97	1.74	.88	79.81

Figure 3

Yield = $80 \cdot 10^{-7}$

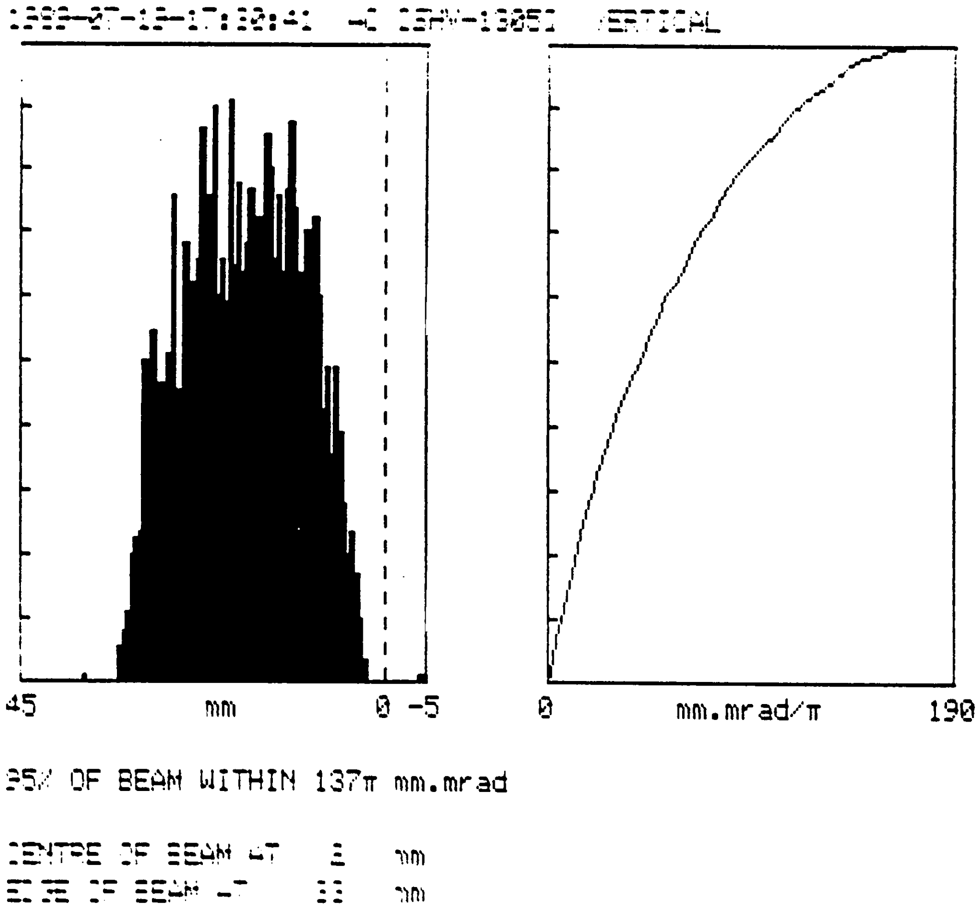
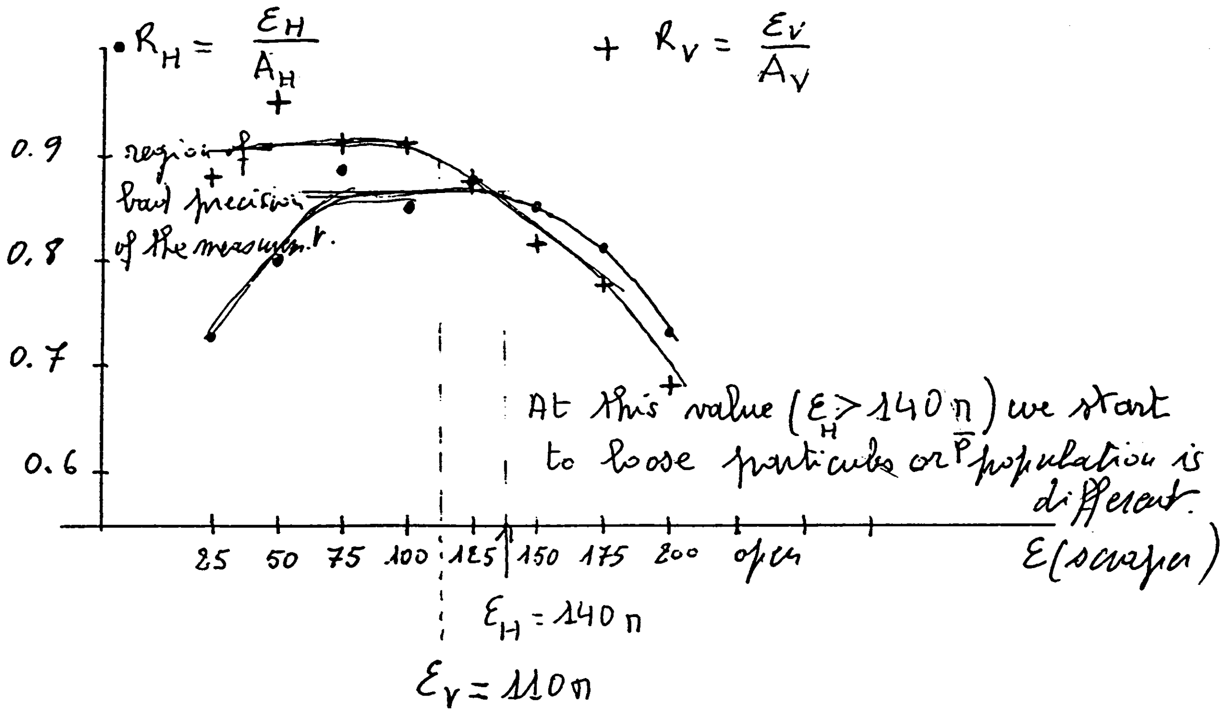


Figure 4 - Beam profile and emittance measurements



We start to loose particles for $\varepsilon_H > 140\pi$ and $\varepsilon_V > 110\pi$
or the population of $\bar{p}$ is different in both planes.

Figure 5

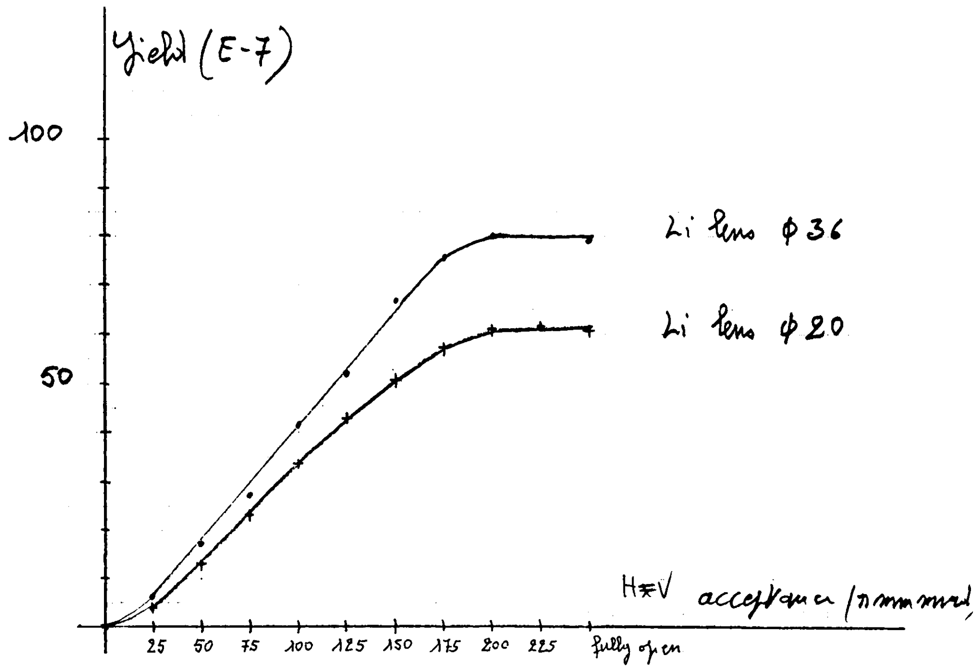


Figure 6 - Yield measurement comparison between 20 mm and 36 mm Li lens.

The maximum number of antiprotons injected into the AC was $9.5 \cdot 10^7$ (mean value over ten pulses). It should be fairly easy to reach a value of 10^8 antiprotons after further adjustment.

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