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"Calorimetry requirements for NNbarX experiment"

Yuri Kamyshkov/ University of Tennessee
email: kamyshkov@utk.edu

Idea of n→nbar detection experiment

Slow free neutron in vacuum with shielded zero magnetic field develops probability of transformation to antineutron as

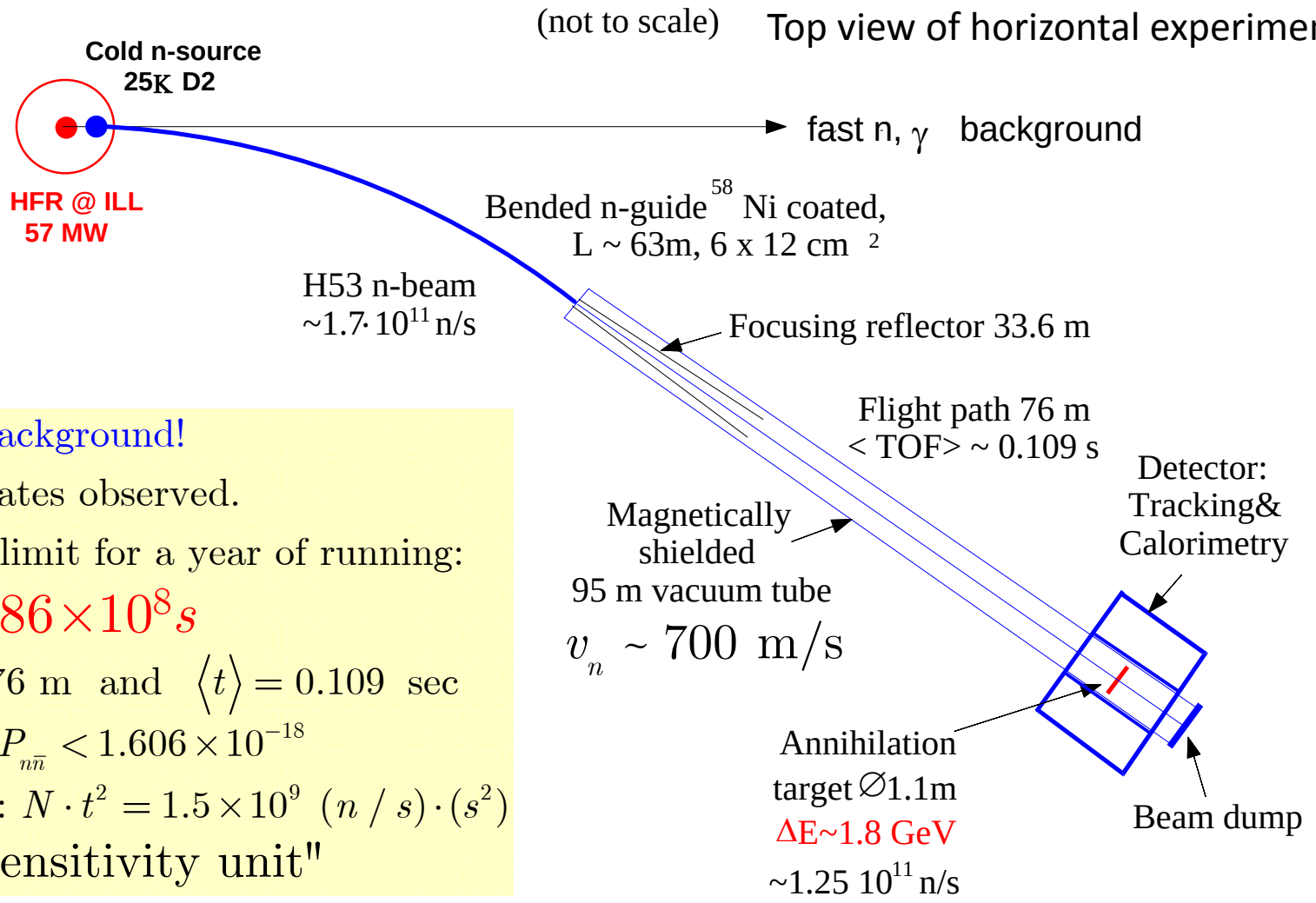
$$P_{n\to\bar{n}} = \left(\frac{t}{\tau_{n\bar{n}}}\right)^2$$ where t is neutron flight time and $\tau_{n\bar{n}}$ is oscillation time predicted by theory

When n is transformed to antineutron, the latter will annihilate in the thin Carbon target producing a star of 5 pions (aver.) that need to be reconstructed to the annihilation point.

Previous n-nbar search experiment with free neutrons

At ILL/Grenoble reactor in 89-91 by Heidelberg-ILL-Padova-Pavia Collaboration

Z. Phys., C63 (1994) 409



No GeV background!

No candidates observed.

Measured limit for a year of running:

$\tau_{n\bar{n}} > 0.86 \times 10^8 s$

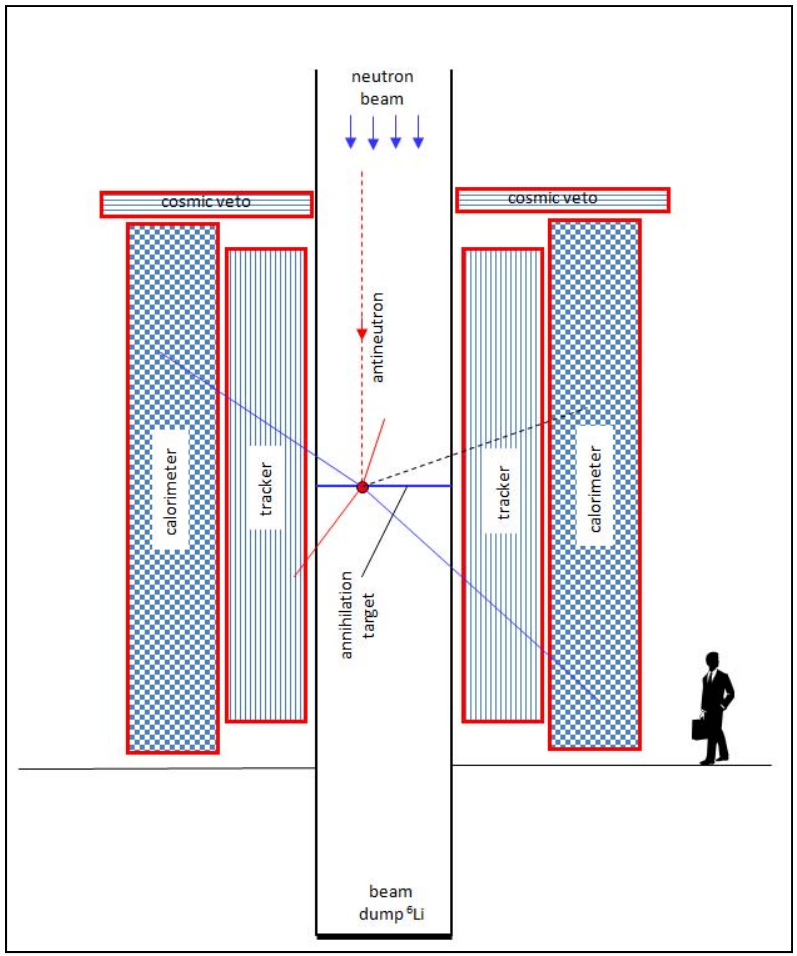
with L ~ 76 m and $\langle t \rangle = 0.109$ sec

measured $P_{n\bar{n}} < 1.606 \times 10^{-18}$

sensitivity: $N \cdot t^2 = 1.5 \times 10^9 \ (n/s) \cdot (s^2)$

$\doteq$ "ILL sensitivity unit"

Annihilation Detector for NNbarX



$$\text{Annihilation feature: } \overline{n} + C \rightarrow \langle 5\pi \rangle$$

- Use ideas of backgroundless ILL detector;
- That can be Vertical and Horizontal;
- Tracker for vertex to thin carbon target;
- Calorimeter for trigger and energy reco;
- TOF before and after tracker to remove vertices of particles coming from outside;
- Veto system to suppress cosmic bkgr;
- Trigger: Calorimeter · TOF · VETO
- Shielding to minimize (n,γ) emission.

Final states of nbar annihilation

BRs as determined in Super-K from Bubble Chamber $\overline{p}$ d and pbar-p data

anti-n + p

$\pi^+\pi^0$	1%
$\pi^+\pi^0\pi^0$	8%
$\pi^+\pi^0\pi^0\pi^0$	10%
$\pi^+\pi^+\pi^-\pi^0$	22%
$2\pi^+\pi^-2\pi^0$	36%
$2\pi^+\pi^-\omega$	16%
$3\pi^+2\pi^-\pi^0$	7%

anti-n + n

$\pi^+\pi^-$	2%
$\pi^0\pi^0$	1.52%
$\pi^+\pi^-\pi^0$	6.48%
$\pi^+\pi^-\pi^0\pi^0$	11%
$\pi^+\pi^-\pi^0\pi^0\pi^0$	28%
$2\pi^+2\pi^-$	7%
$2\pi^+2\pi^-\pi^0$	24%
$\pi^+\pi^-\omega$	10%
$2\pi^+2\pi^-\pi^0\pi^0$	10%

From Ken Ganezer

Anti-neutron annihilation detector of the Heidelberg-ILL-Padova-Pavia Collaboration (1994)

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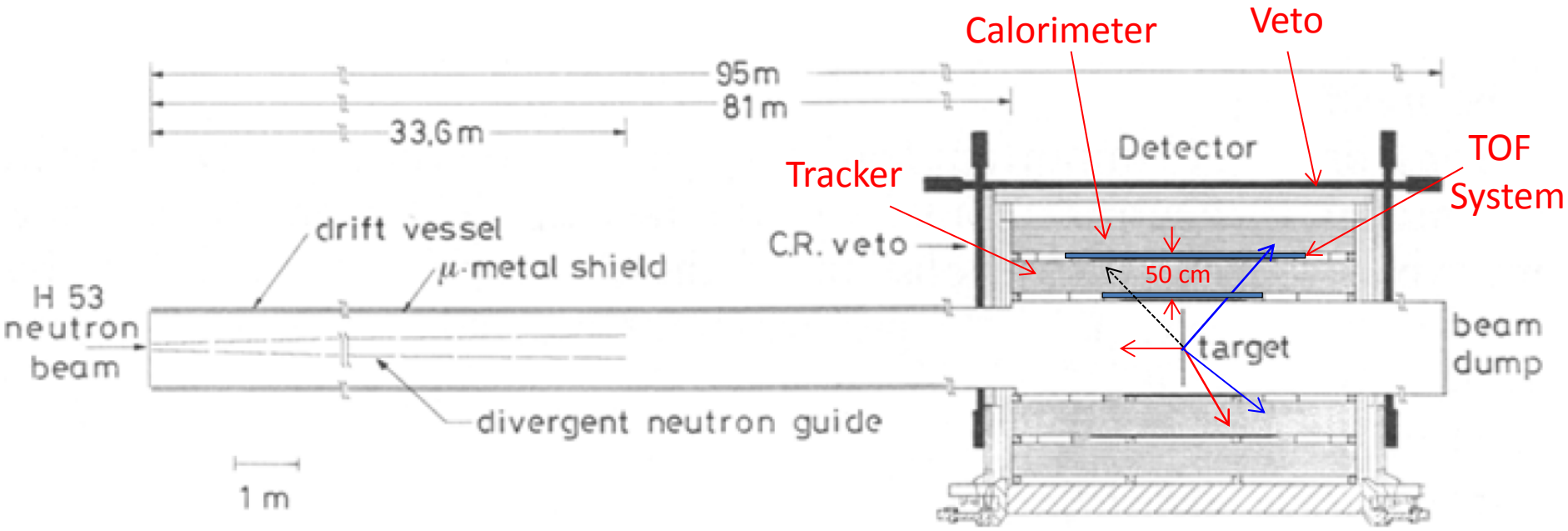

- Calorimeter function: be part of the trigger > ~ 500 MeV; provide energy measurement of ranging pions for final energy selection (1 GeV < ΔE < 2 GeV);
- Following tracker and scintillator TOF counters. Tracker reconstructs to the target thickness (~ 0.1 mm C); calorimeter calculates azimuth momentum disbalance;
- 12 layers of Limited Streamer Tubes interlaid Al and Pb layers of mm thickness;
- Segmentation in both φ and θ-projections is essential;
- Total ~1MeV γ field ~ 10^7/s – related to segmentation.

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ZEITSCHRIFT
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A new experimental limit on neutron-antineutron oscillations

M. Baldo-Ceolin[3], P. Benetti[4], T. Bitter[1], F. Bobisut[3], E. Calligarich[4], R. Dolfini[4], D. Dubbe
M. Genoni[4], D. Gibin[3], A. Gigli Berzolari[4], K. Gobrecht[2], A. Guglielmi[2], J. Last[2], M. Laved
F. Mattioli[3], F. Mauri[4], M. Mezzetto[3], C. Montanari[4], A. Piazzoli[4], G. Puglierin[3], A. Rappol
D. Scannicchio[4], A. Sconza[3], M. Vascon[3], L. Visentin[3]

[1] Physikalisches Institut, University of Heidelberg, D-69120 Heidelberg, Germany
[2] Institut Max von Laue-Paul Langevin (ILL), Grenoble, France
[3] Dipartimento di Fisica "G. Galilei", University of Padova and I.N.F.N. Sezione di Padova, Padova, Italy
[4] Dipartimento di Fisica Nucleare e Teorica, University of Pavia and I.N.F.N. Sezione di Pavia, Pavia, Italy

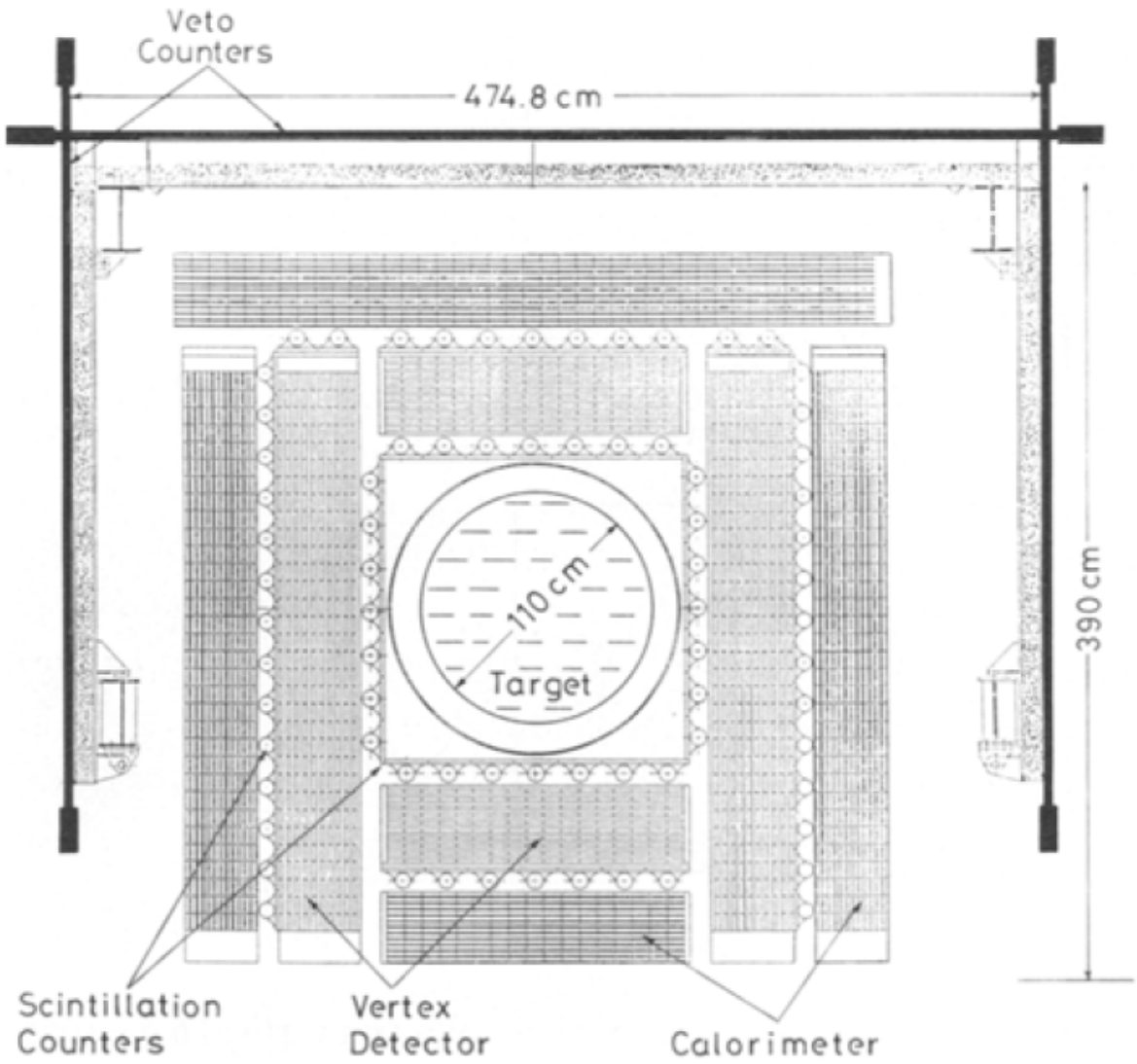

Fig. 5. The $\bar{n}$ annihilation detector (cross sectional view)

Nuclear Instruments and Methods in Physics Research A313 (1992) 477–482
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The suppression of beam-related background in the ILL neutron–antineutron oscillation experiment

F. Eisert, W. Lippert, P. El-Muzeini, T. Bitter, U. Kinkel and R. Werner
Physikalisches Institut der Universität, Philosophenweg 12, D-6900 Heidelberg 1, Germany

K. Gobrecht
Institut Laue–Langevin, 156X, F-38042 Grenoble Cedex, France

D. Dubbers
Fakultät für Physik, E21, Technische Universität München, D-8046 Garching, Germany

D. Gibin, A. Guglielmi, M. Laveder and M. Mezzetto
Istituto Nazionale di Fisica Nucleare, Sezione di Padova and Dipartimento di Fisica dell'Università di Padova, Italy

F. Mauri, A. Rappoldi and G. Raselli
Istituto Nazionale di Fisica Nucleare, Sezione di Pavia and Dipartimento di Fisica dell'Università di Pavia, Italy

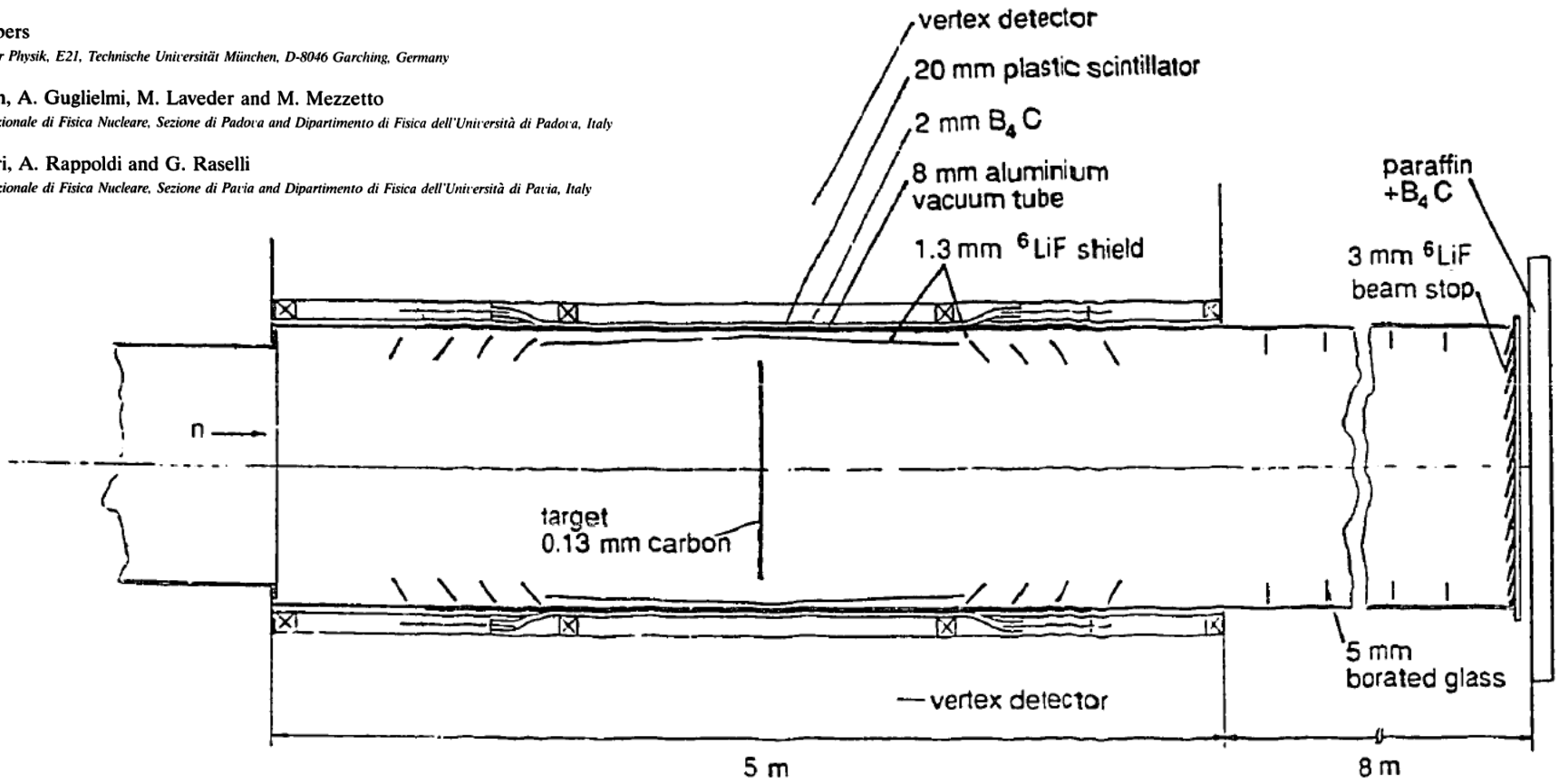

Fig. 1. The target region of the nn̄ experiment and its surroundings.