



UNIVERSITÀ
DEGLI STUDI
DI ENNA "KORE"

Italy-Japan Symposium on Joint Activities
in Fundamental Physics

日伊基礎物理学共同研究活動シンポジウム

Enna, March 9 – 12, 2026.

FLAP

Facility for **L**ow-energy **A**ntineutron **P**hysics

horizon
europe

Alessandro Feliciello



Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO



UNIVERSITÀ DEGLI STUDI DI ENNA "KORE"
ENNA - ITALY
MARCH 9-11, 2026

- | | |
|---|--|
| <p>Organizing committee</p> <ul style="list-style-type: none"> A. Jossa (INFN & INFN-LNS) chair M. La Cognata (INFN-LNS) chair G. Casali (INFN-LNS) D. Lattuada (INFN & INFN-LNS) A. Napolitano (INFN & INFN-LNS) A. A. Chiu (INFN-LNS) G. C. Menon (INFN & INFN-LNS) M. L. Seng (INFN & INFN-LNS) S. Spurio (INFN & INFN-LNS) D. Torresi (INFN-LNS) | <p>Scientific committee</p> <ul style="list-style-type: none"> A. Bruschini (INFN-INFN) F. Bruschini (INFN-INFN) S. Choudhury (INFN & INFN-LNS) G. Colucci (INFN & INFN-LNS) T. Coughlan (INFN-INFN) A. Di Pace (INFN-LNS) A. Fukuda (INFN-INFN) T. Fukui (INFN-INFN) A. Galassi (INFN-INFN) K. Hagino (INFN-INFN) M. La Cognata (INFN-LNS) contact person E. Melega (INFN-INFN) T. Nakamura (INFN-INFN) E. Oset (INFN-INFN) G. Penzo (INFN & INFN-LNS) E. Serrano (INFN-INFN) A. Tamai (INFN-INFN) A. Tamai (INFN-INFN) contact person A. Tassone (INFN & INFN-LNS) contact person S. Ueda (INFN-INFN) E. Zappalà (INFN-INFN) T. Yoshida (INFN-INFN) Y. Yamaguchi (INFN-INFN) |
|---|--|

Steering committee

- S. Andriani (INFN-INFN)
- D. Bertoni (INFN)
- S. Garavito (INFN-INFN)
- D. Guadagnoli (INFN-INFN)
- T. Kuroki (INFN)
- T. Nakano (INFN)
- G. Nardulli (INFN)

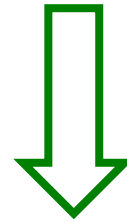
Workshop and contact
More information is available on the Symposium webpage: <https://www.infn.it/it/infnsymposium>
Inquiries related to the Workshop should be sent to the email address: infnsymposium@infn.it

The *FLAP* Collaboration

-  Department of Physics, Institute of Science Tokyo (JP)
● H. Fujioka
-  Dipartimento di Fisica, Università degli Studi di Torino (IT)
🇮🇹 E. Botta
-  Dipartimento di Ingegneria dell'Informazione, Università degli Studi di Brescia (IT)
🇮🇹 L. Venturelli
-  Institute for Integrated Radiation and Nuclear Science, Kyoto University (JP)
● T. Higuchi
-  Istituto Nazionale di Fisica Nucleare [PV, TO] (IT)
🇮🇹 D. Calvo, A.F., A. Filippi
-  Marietta Blau Institute for Particle Physics, Austrian Academy of Sciences (AT)
✚ C. Amsler
-  Trento Institute for Fundamental Physics and Applications (IT)
🇮🇹 R. Caravita

Main goal

To implement a **novel**, ultra-low-energy **antineutron beam line**
at the **CERN AD** facility.



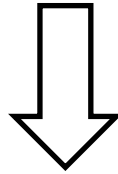
To offer the Community an **opportunity**
to pursue **new physics** programs

Letter of Intent submitted to the CERN SPCS on May 1st, 2025 (<https://cds.cern.ch/record/2930906>).

Why we want (we need) to use \bar{n}_s ?

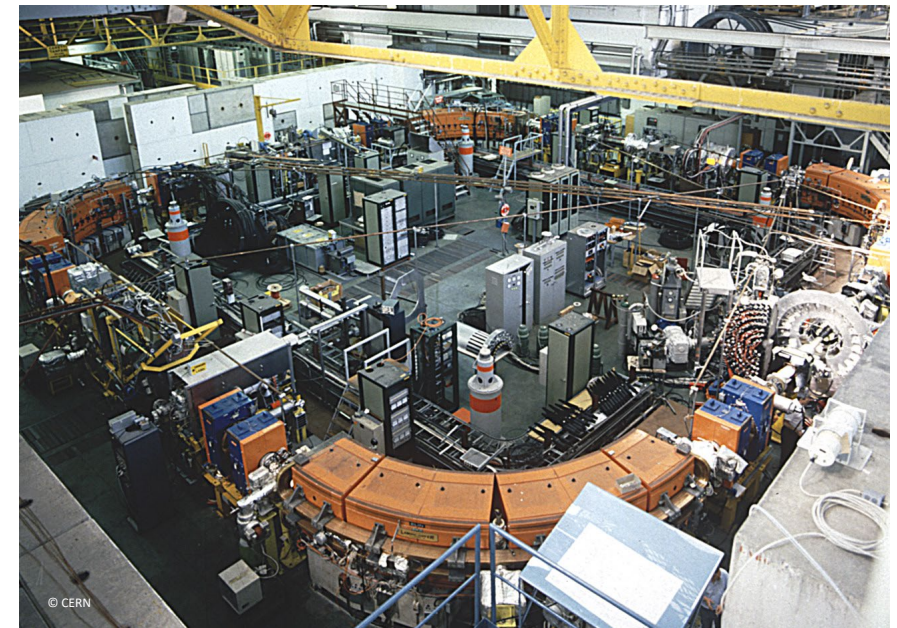
intrinsic experimental **hardness**:

- producing and handling of **neutral** particles is not an easy task in itself
- dealing with **antiparticles** is an even more **challenging** task



- no more experiments with \bar{n} since last millennium !!!

Low Energy Antiproton Ring @ CERN



1983 - 1996

Is it worth using \bar{n} ?

$\bar{n}p$ vs. $\bar{p}p$

- 👍 **pure** total $I = 1$ state:
 - **reduced** number of **initial states** involved (1S_0 and 3S_1 **only**)



direct way to extract the **S-wave scattering length**

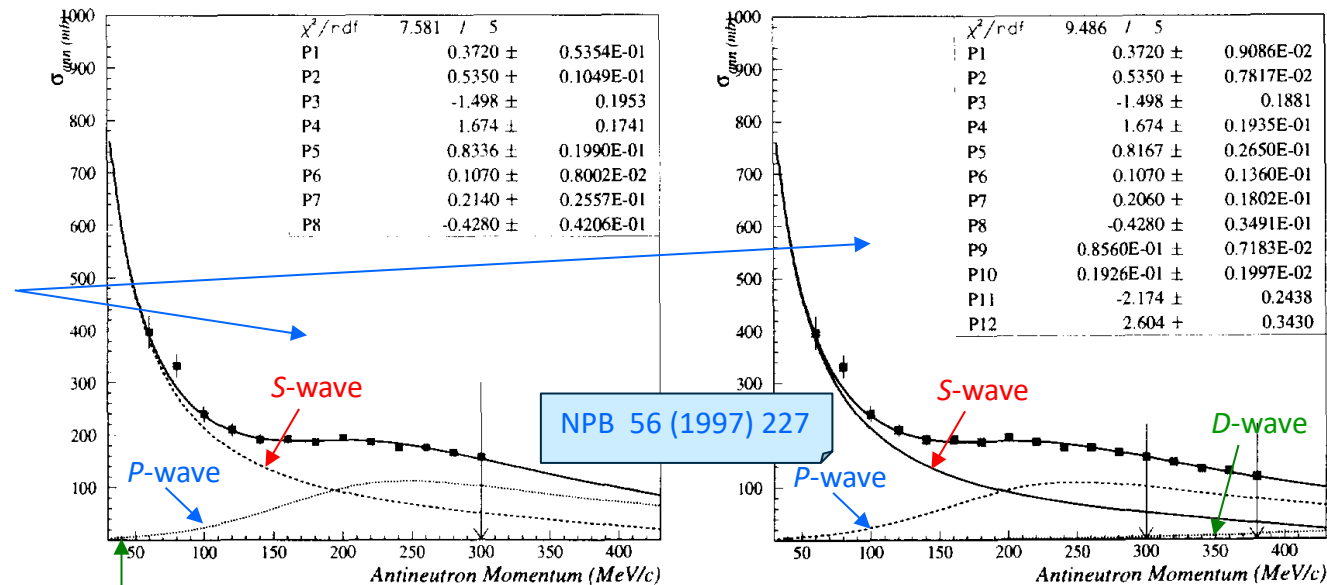
- 👍 the **percentages of partial waves** can be selected by tuning the \bar{n} momentum

- 👎 **mixture** of $I = 0$ and $I = 1$ amplitudes
 - **12 initial states** involved ($^1S_0, ^3S_1, ^1P_1, ^3P_{0,1,2}$) $\times 2$

$\sigma_{ann}(\bar{n}p)$

@ 300 MeV/c

@ 400 MeV/c



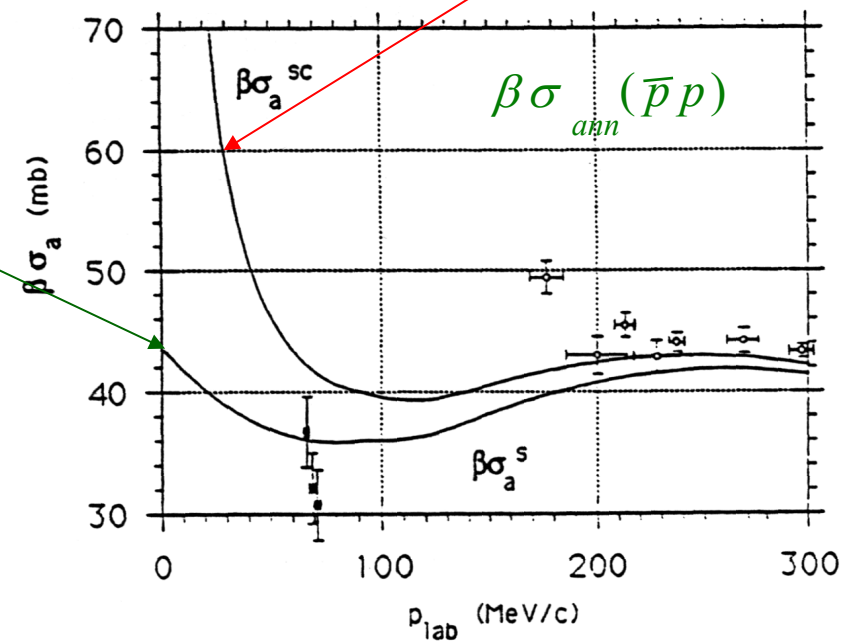
Further advantages of using \bar{n}

$\bar{n}p$ vs. $\bar{p}p$

- 👍 **absence of Coulomb interaction:**
 - no distortion of the σ trend in the low momentum region ($\sigma \propto 1/v$)

- 👍 **no energy loss in the target:**
 - only one target
 - possibility of precisely reconstructing the energy at which the interaction occurs
 - the target thickness can be increased to obtain higher counting rates

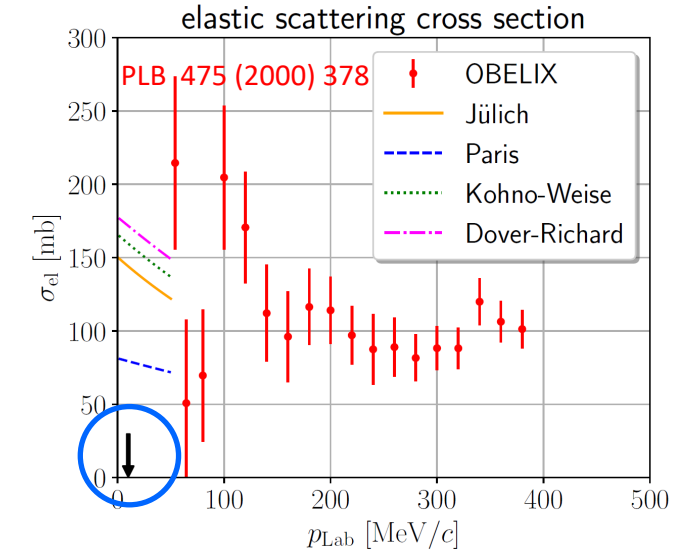
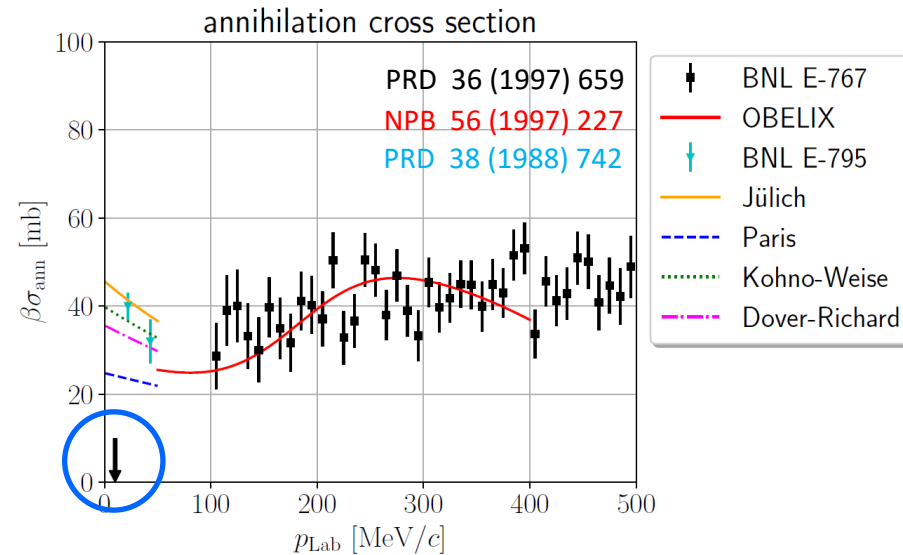
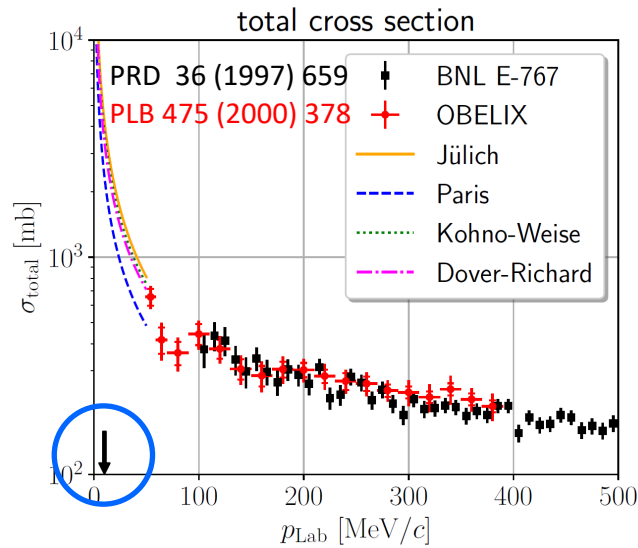
- 👎 experimental observation: $\sigma \propto 1/v^2$
- 👎 **Coulomb focusing effect** ($\sigma \propto 1/v$)
 - corrections must be applied



- 👎 target thickness is a "function" of p momentum

The physics case: low-energy $\bar{n}p$ scattering cross-sections

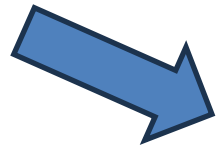
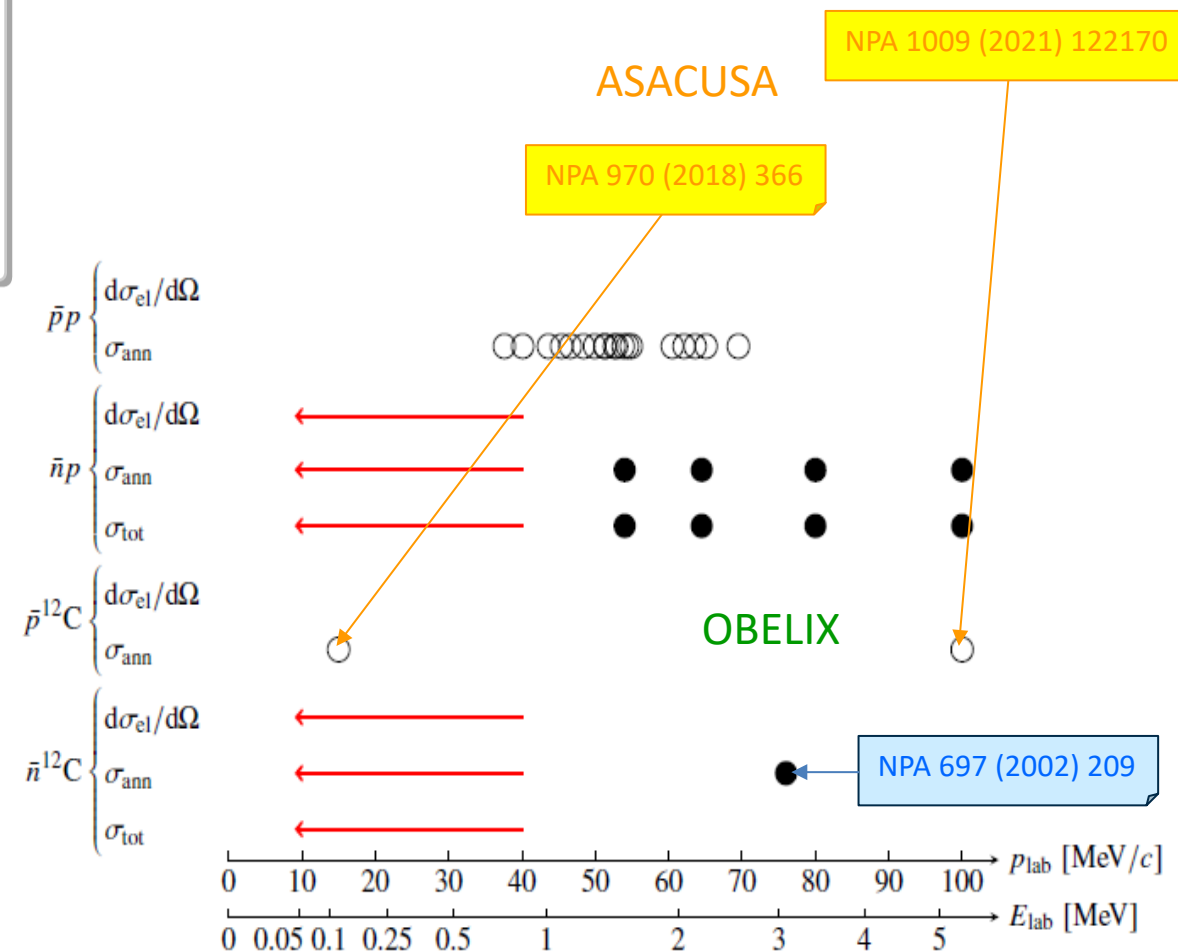
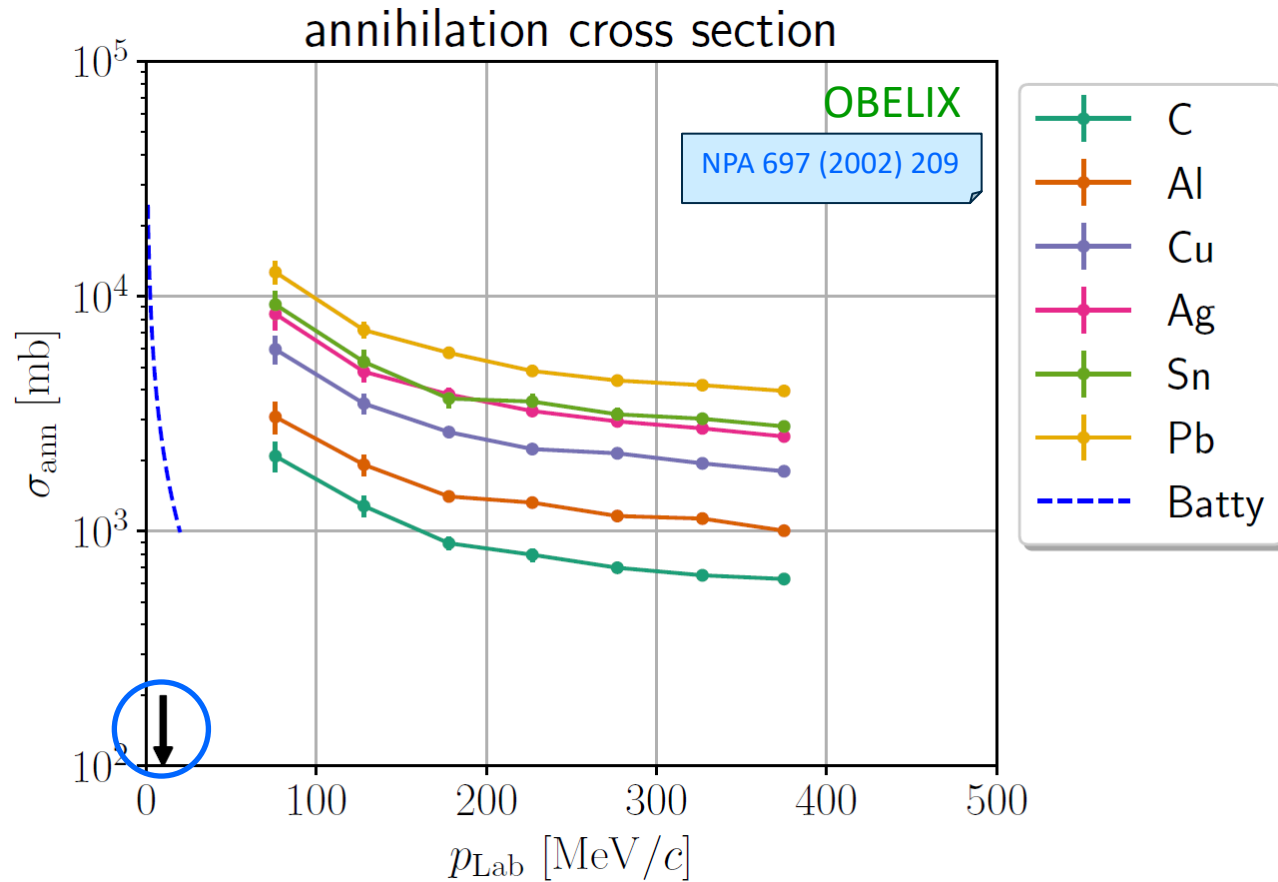
We need \bar{n} cross-section data at the **lowest possible energies** to **improve** and **deepen** our current understanding of low-energy **antinucleon interactions**



LEAR heritage:
PS201 experiment
OBELIX

New measurements are **essential** to determine the **S-wave scattering length** in a **model-independent** way

\bar{n} - nucleus scattering cross-section



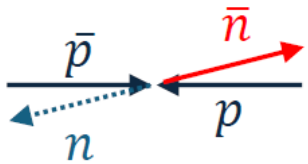
- medium effect
- $n\bar{n}$ oscillation?

The leading idea

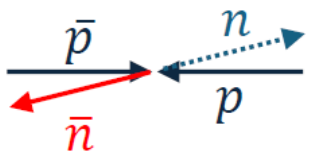
$$p\bar{p} \rightarrow n\bar{n} \quad @ \quad p_{\bar{p}} = 300 \text{ MeV/c}$$

CM frame

forward production

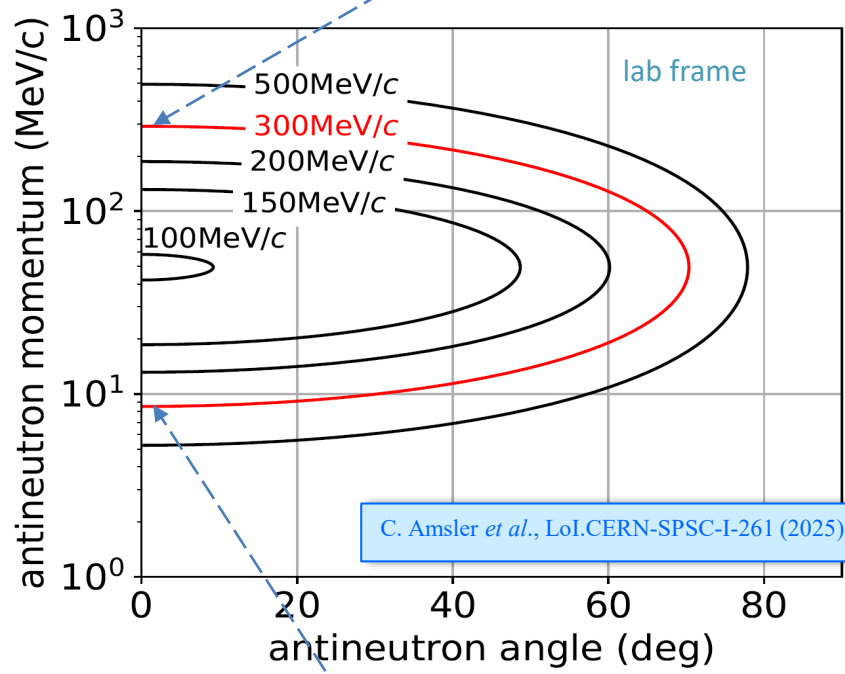
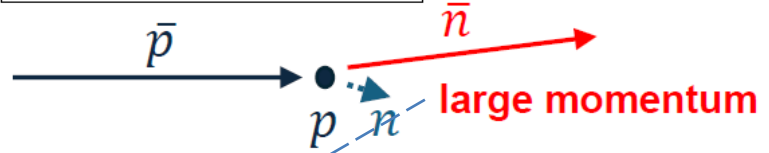


backward production



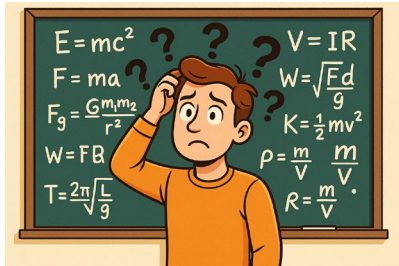
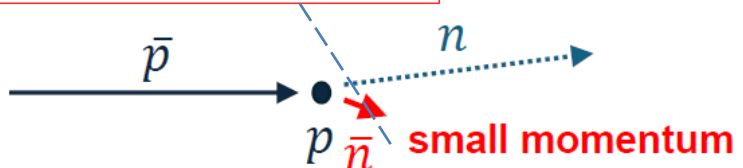
lab frame

forward production



C. Amsler *et al.*, LoI.CERN-SPSC-I-261 (2025) 1.

backward production



The leading idea

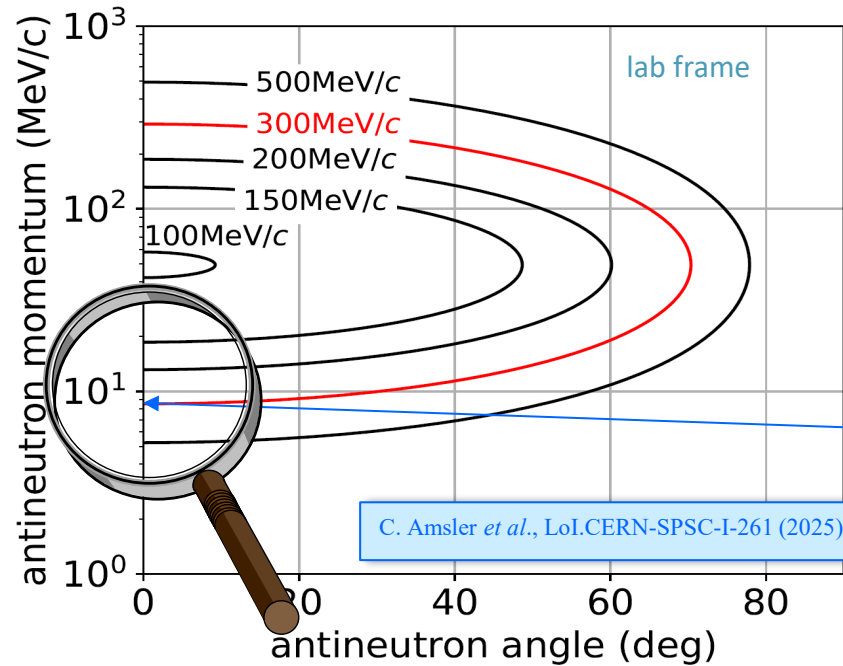
$$p\bar{p} \rightarrow n\bar{n} \quad @ \quad p_{\bar{p}} = 300 \text{ MeV}/c$$



to take into account the 2nd solution for the \bar{n} momentum

i.e.

to select backward emitted \bar{n} in the C.M. frame

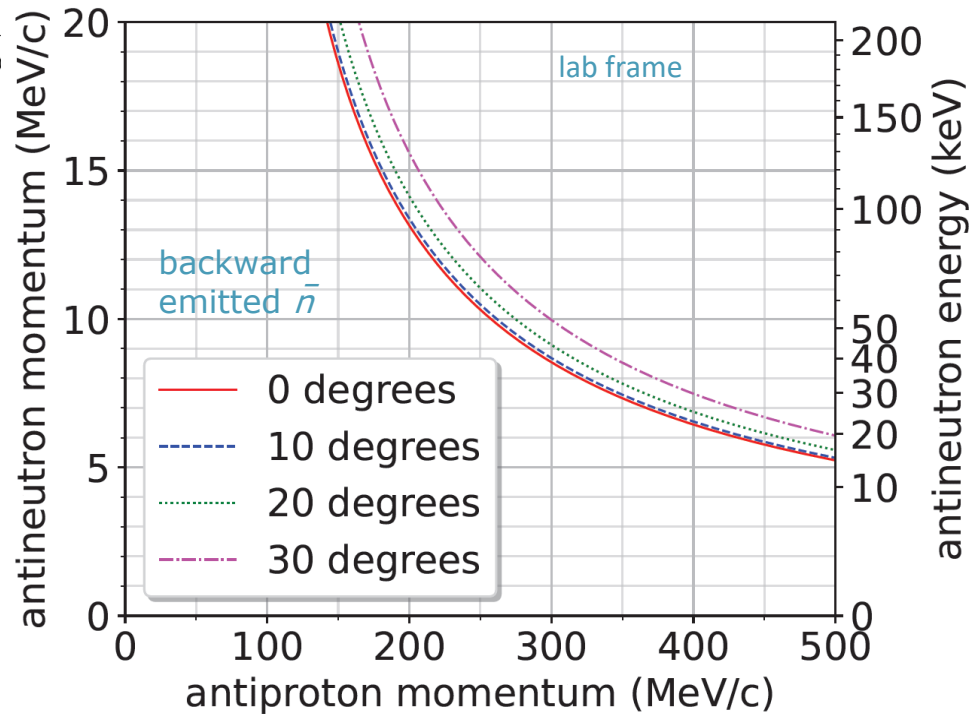
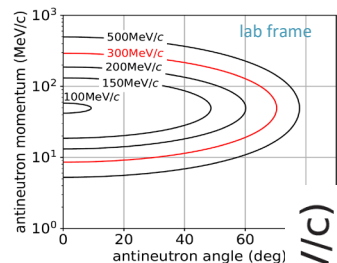


$$p_{\bar{n}} \approx 9 \text{ MeV}/c \quad !!!$$

$$\left(\frac{d\sigma}{d\Omega}\right)_{\theta_{lab} = 0^\circ} (\theta_{CM} = 180^\circ) = 4.7 \pm 1.9 \mu\text{b}/\text{sr}$$

estimated @ $p_{\bar{p}} = 300 \text{ MeV}/c$ on the basis of previous measurements at LEAR [PLB 169 (1986) 302]

Expected \bar{n} yield

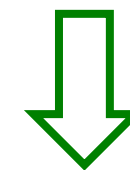


a little help from the kinematics of the reaction: 20

by slightly increasing the angular acceptance for backward produced \bar{n} (5°), it will be possible to partially compensate the low cross-section value

+

reasonable production target length:
 $0.44 \text{ g/cm}^2 \equiv 6.2 \text{ cm (LH}_2\text{)}$



- \bar{p} momentum range: 250 – 300 MeV/c
- \bar{n} momentum range: 8.5 – 10.4 MeV/c
- \bar{n} transmission 62%

=

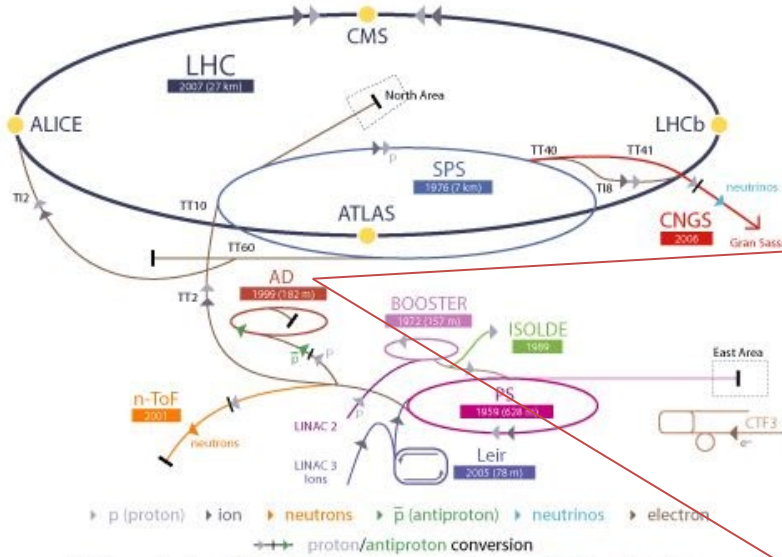
1 backward \bar{n} per AD cycle ($5 \times 10^7 \bar{p} / 120 \text{ s}$)*

percent level precision
 scattering cross section measurement
 within 2 weeks

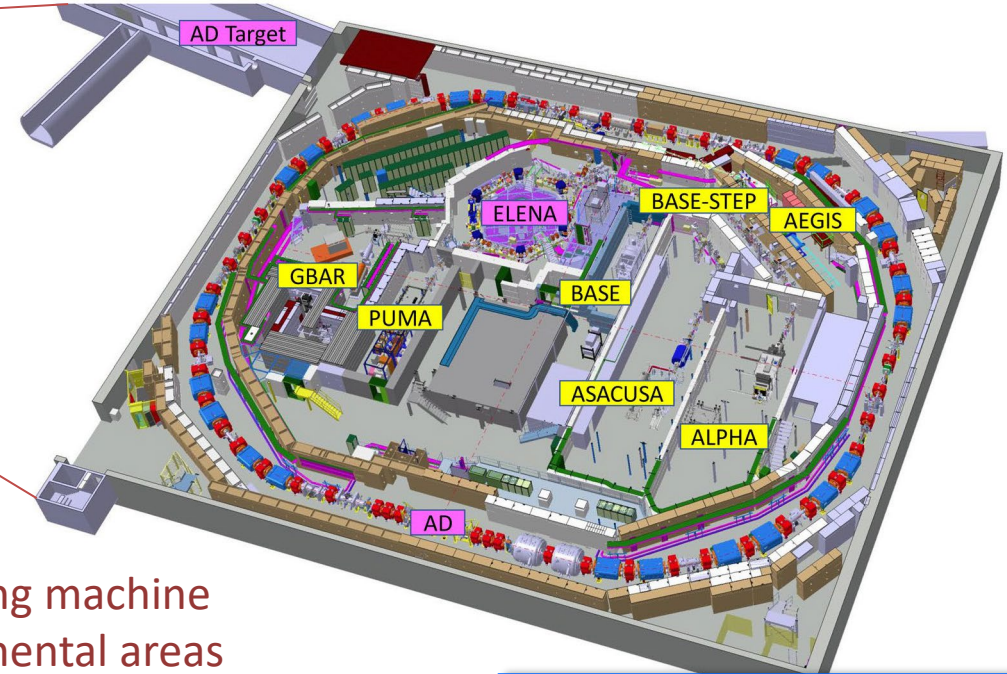
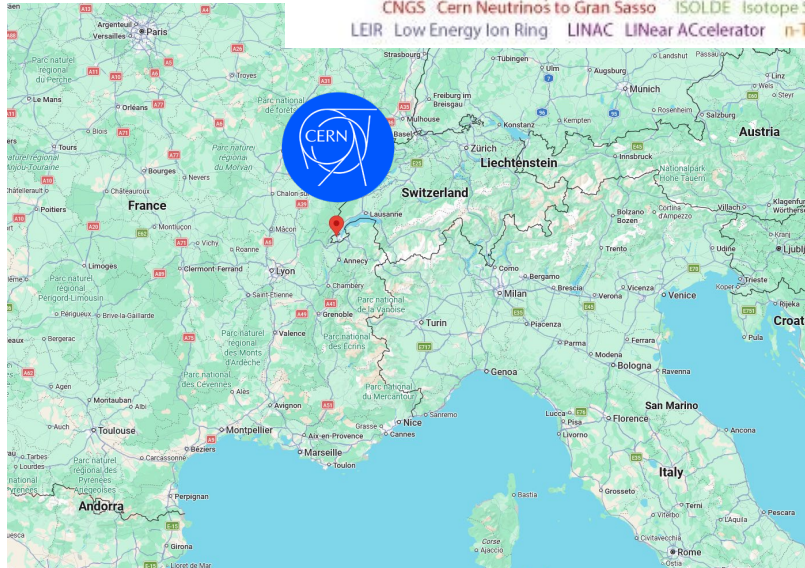
* cfr. OBELIX: 13-56 (forward) $\bar{n} / 10^6 \bar{p}$

The CERN antimatter factory

CERN Accelerator Complex



LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron
 AD Antiproton Decelerator CTF3 Clc Test Facility
 CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice
 LEIR Low Energy Ion Ring LINAC LINear Accelerator n-ToF Neutrons Time Of Flight



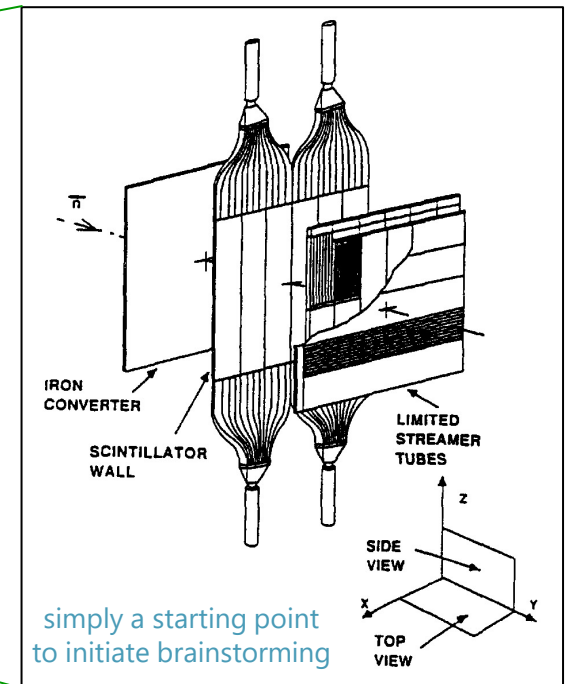
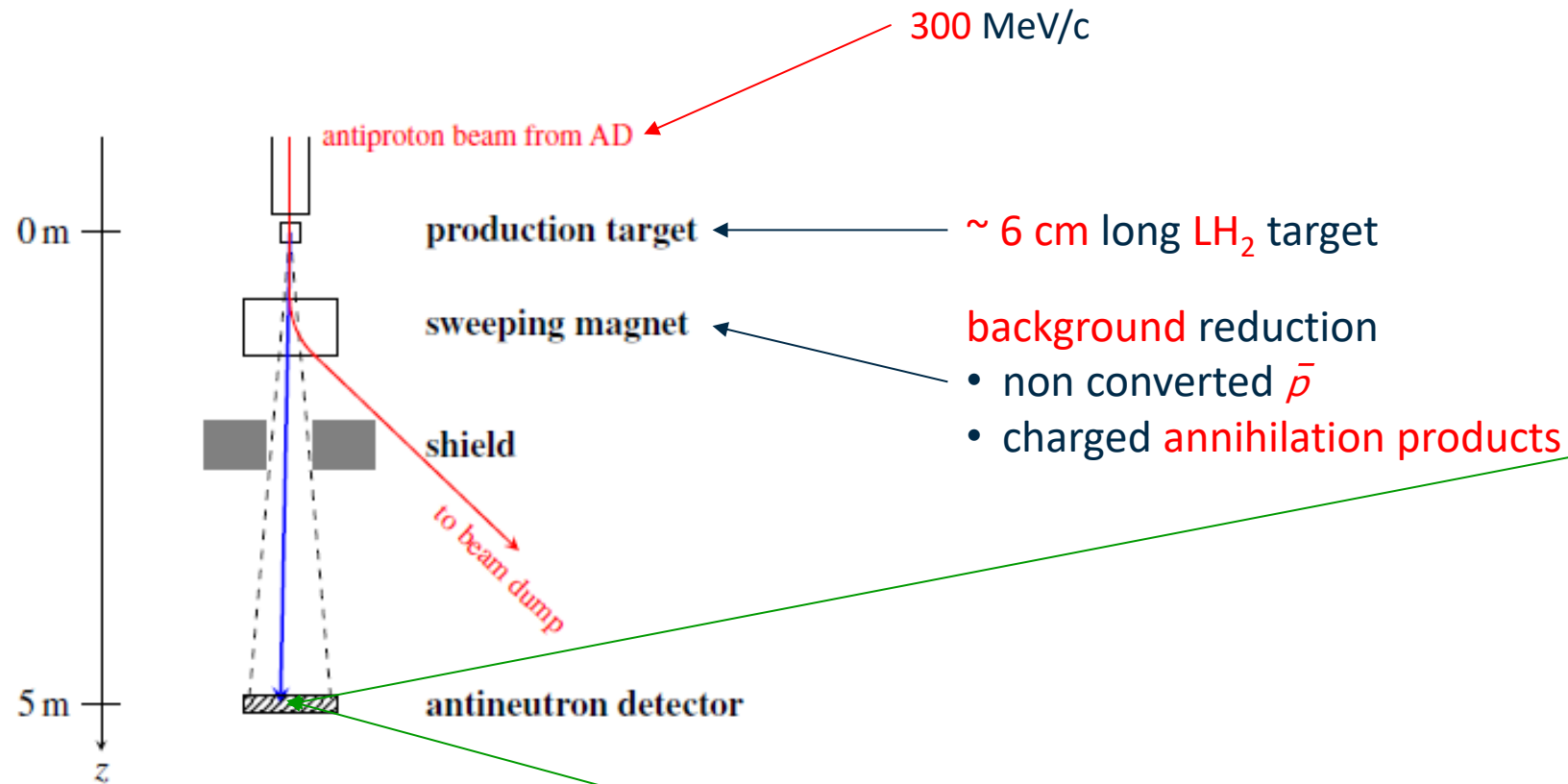
© CERN

- 183 m long machine
- 7 experimental areas

no realistic alternative \bar{n} source for the next 20 years

C. Carli et al., *Nuclear Physics News*, 32(3) (2022) 21–27.
<https://doi.org/10.1080/10619127.2022.2100646>

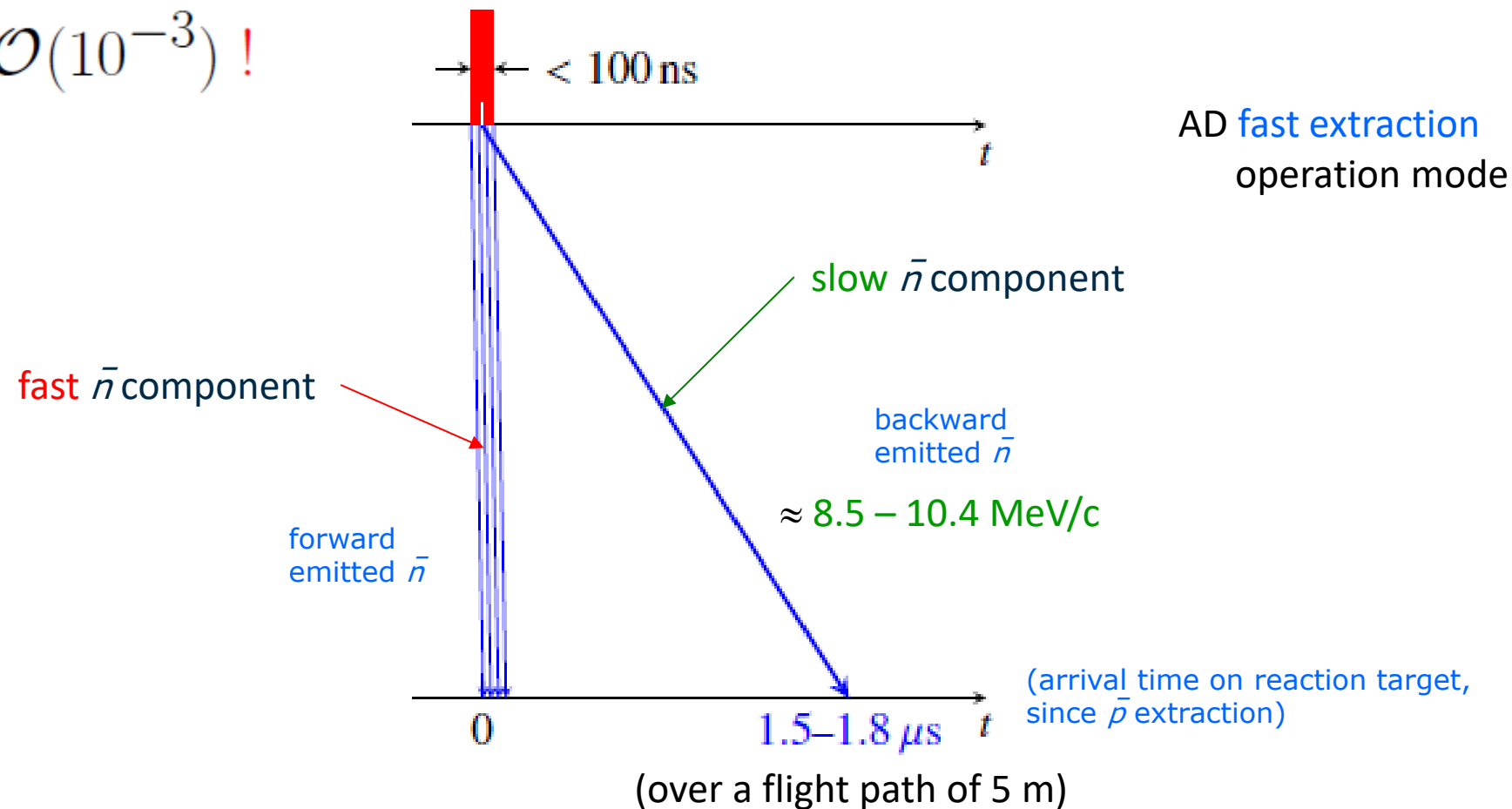
Schematic layout of the FLAP beamline



AD \bar{p} bunch time structure

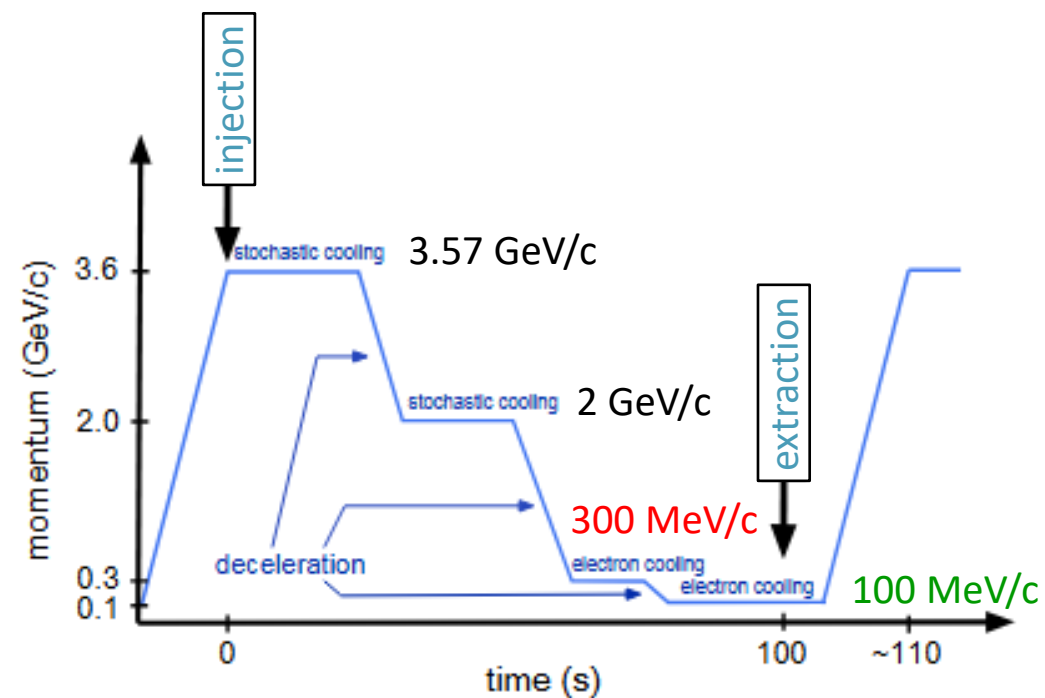
(background reduction)

$$\frac{\text{backward } \bar{n}}{\text{forward } \bar{n}} = \mathcal{O}(10^{-3}) !$$

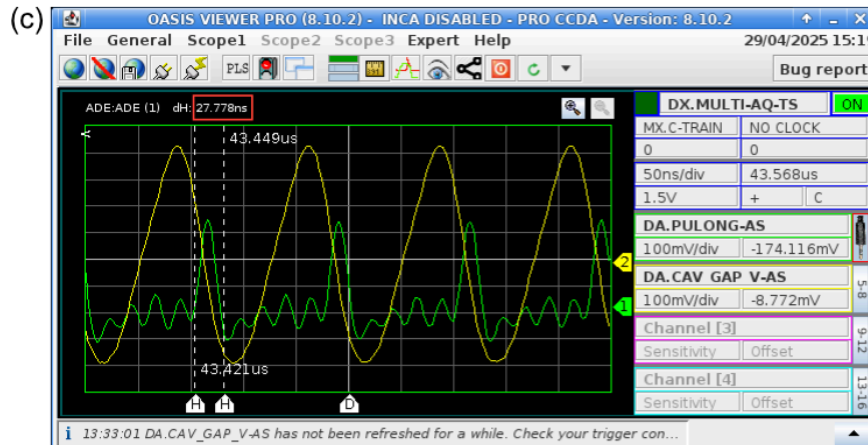
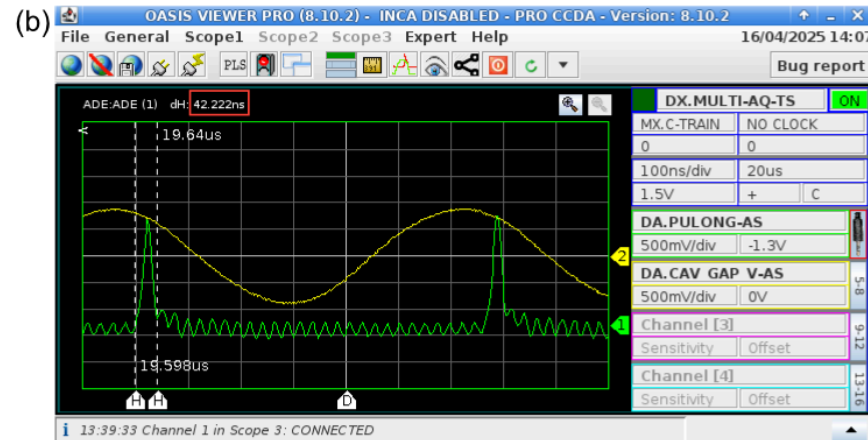
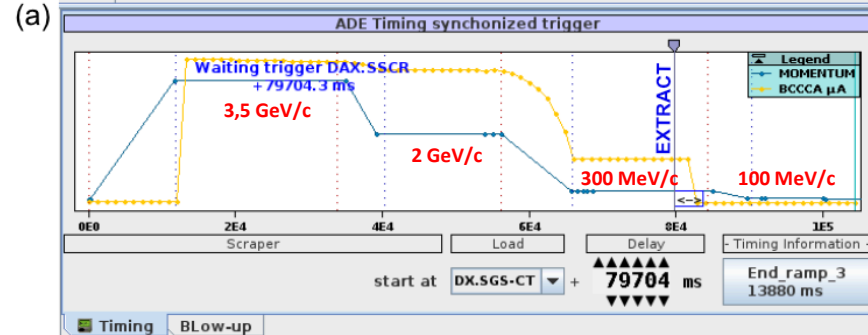


Requests to AD

- the current AD + ELENA operating scheme is **not suitable** for our needs: it provides to the experiments **100 MeV/c \bar{p}**
- $p\bar{p} \rightarrow n\bar{n}$ reaction has a threshold: **98 MeV/c**
- we need (at least) **300 MeV/c**
- we require the implementation of a **direct extraction line** from the AD



Strong interplay with CERN AD team

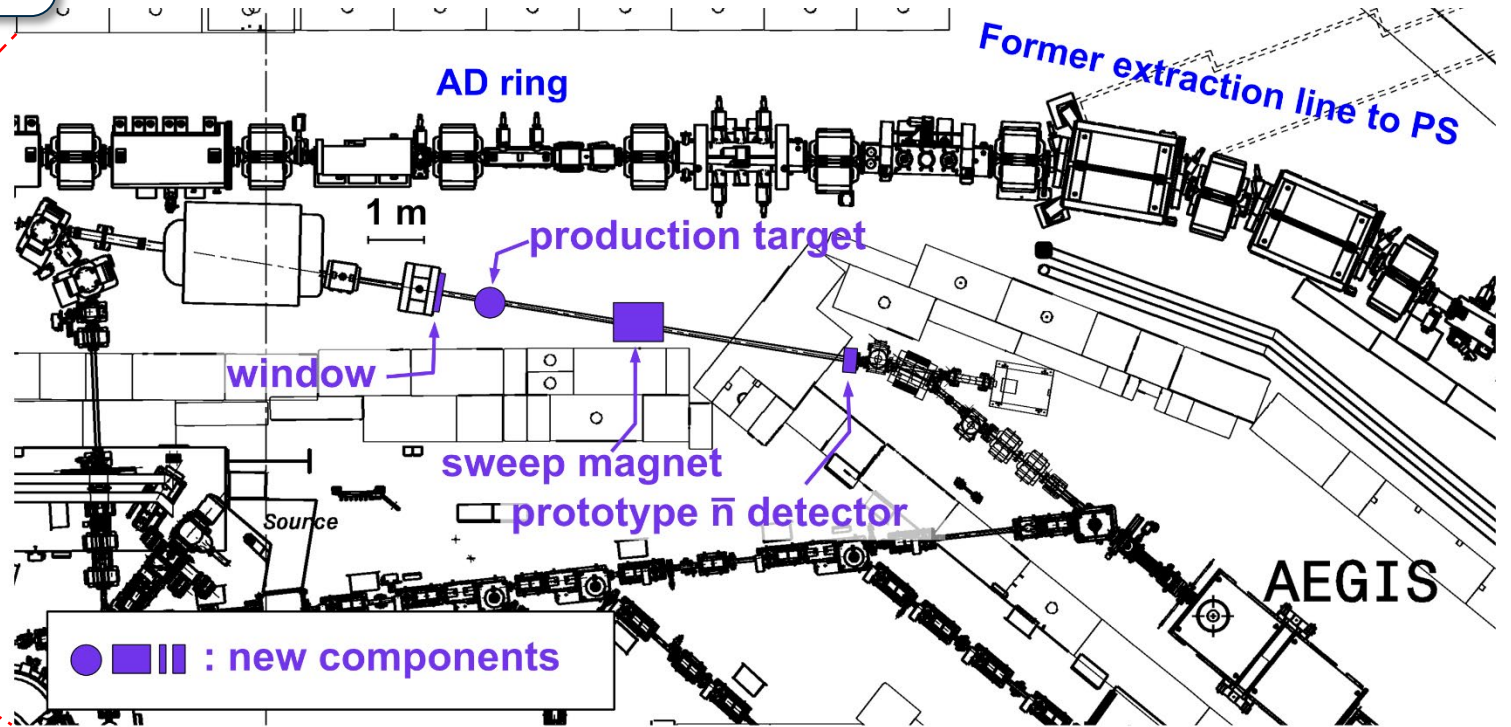
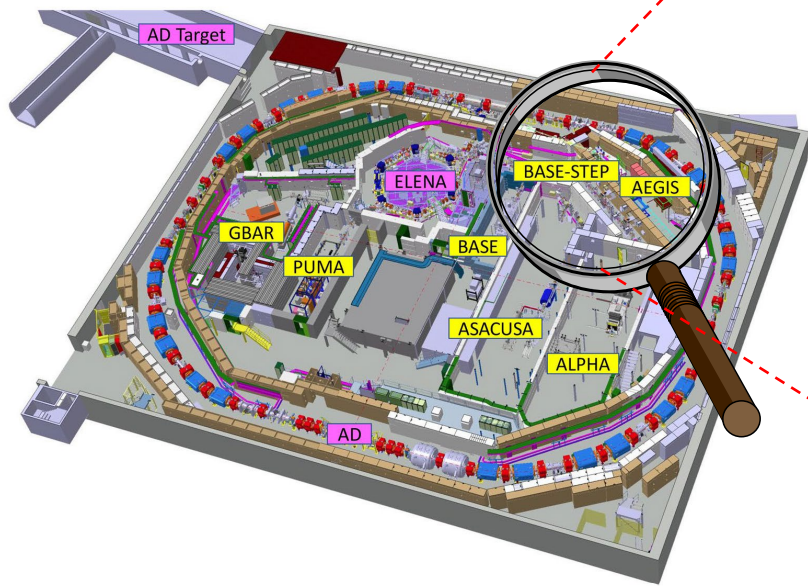


April 2025

we are already collaborating closely with members of the AD machine team

the beam has been rebunched into 6 or 16 buckets

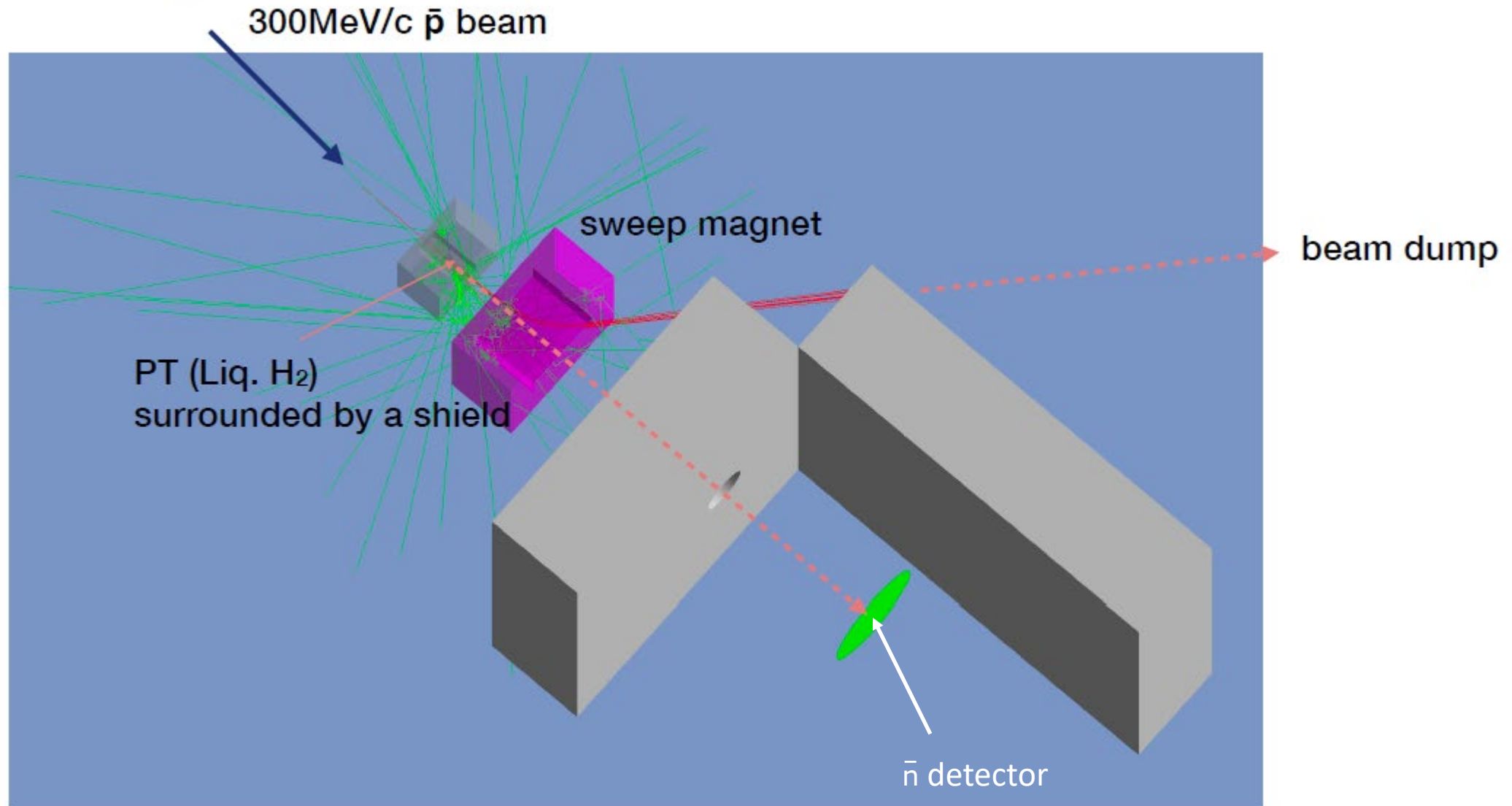
Short term tests



A direct transfer line from the AD already exists near the AEGIS experimental area



Experimental design concept



FLAP @ CERN

Letter of Intent submitted to the CERN SPSC on May 1st, 2025
<https://cds.cern.ch/record/2930906>



FLAP within the Horizon Europe initiative

- one of the 40 **selected** projects (out of ~ 70 submitted LoIs) by the HADRON 2030 Consortium Steering Committee
- FLAP is part of the HADRON 2030 Proposal **submitted** to EU last September
- the HADRON 2030 has been **accepted** on last February 5th
- expected **start date** of FLAP: 1st of October 2026

A successful synergy

