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 Low-energy Antineutron Physics

horizon europe

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SEZIONE DI TORINO

The FLAP Collaboration

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- T. Higuchi

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- D. Calvo, A.F., A. Filippi

Marietta Blau Institute for Particle Physics, Austrian Academy of Sciences (AT)
- C. Amsler

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- 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 SPSC on May 1st, 2025 (https://cds.cern.ch/record/2930906).

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

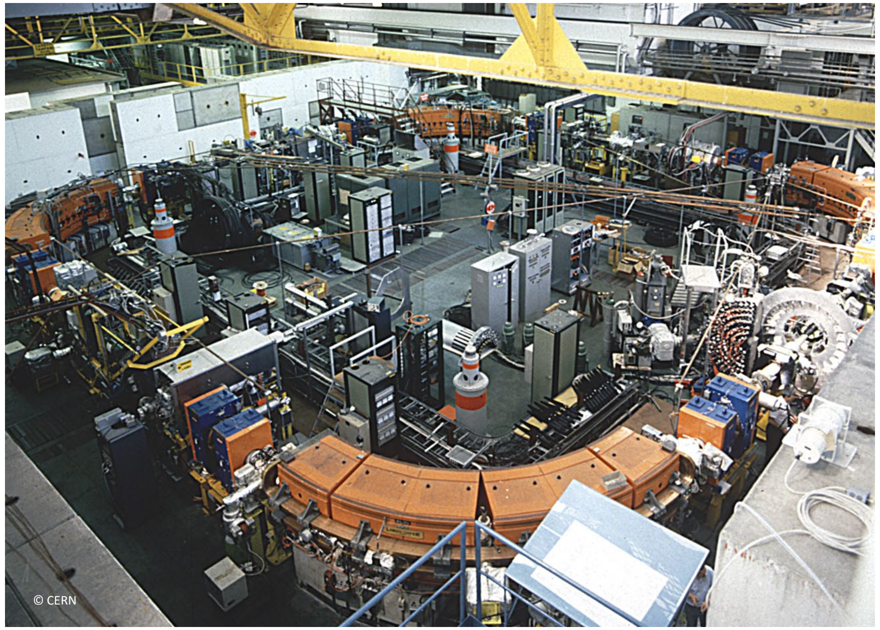
intrinsic experimental hardness:

- 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)

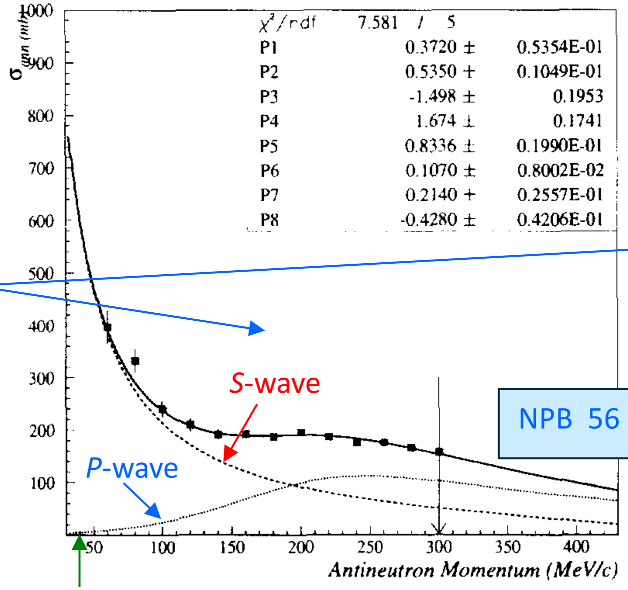
direct way to extract the *S*-wave scattering length

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

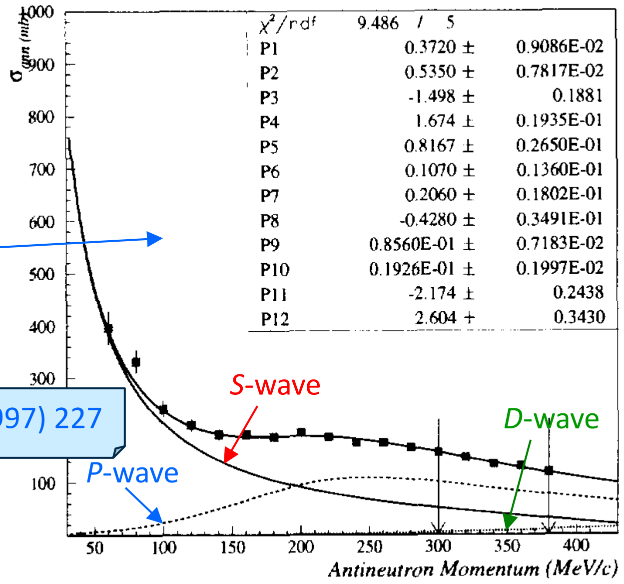
- the percentages of *partial* waves can be selected by tuning the $\bar{n}$ momentum

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

@ 300 MeV/c



@ 400 MeV/c



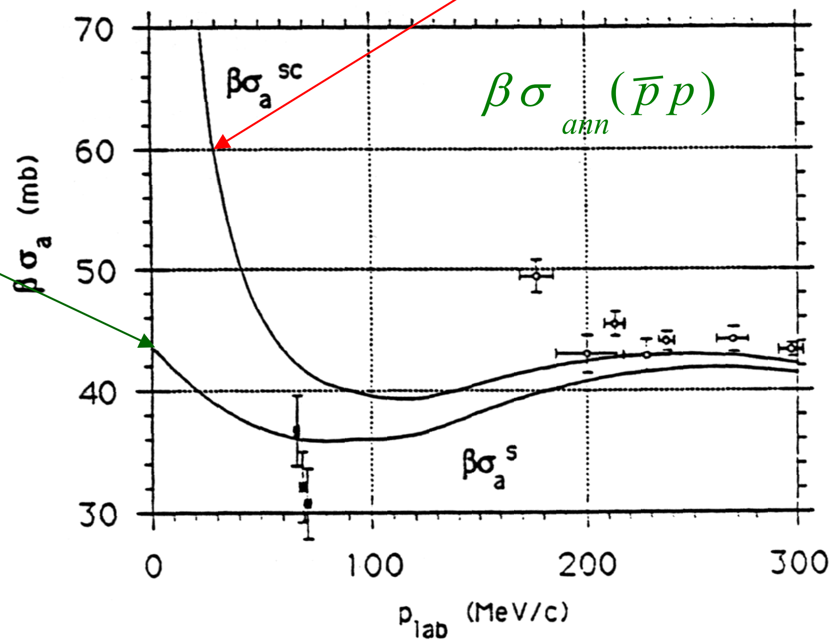
NPB 56 (1997) 227

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

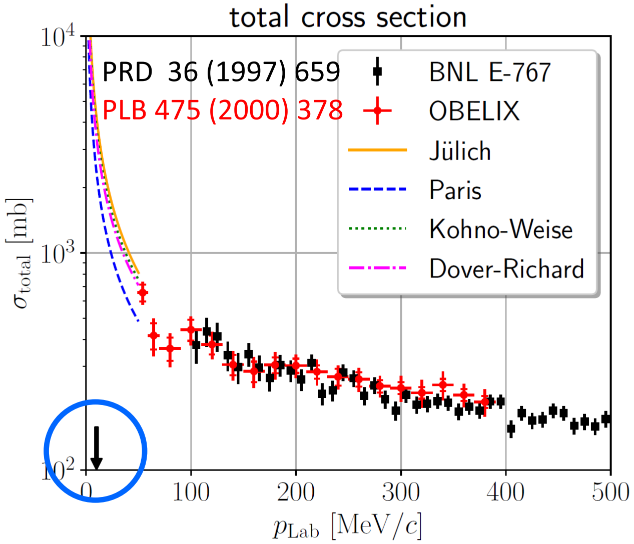


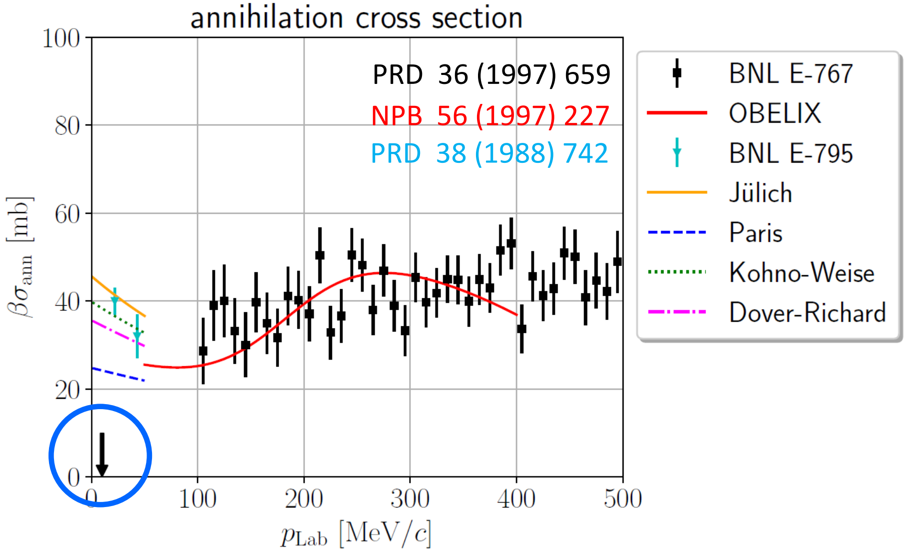
- target thickness is a "function" of $\bar{p}$ momentum

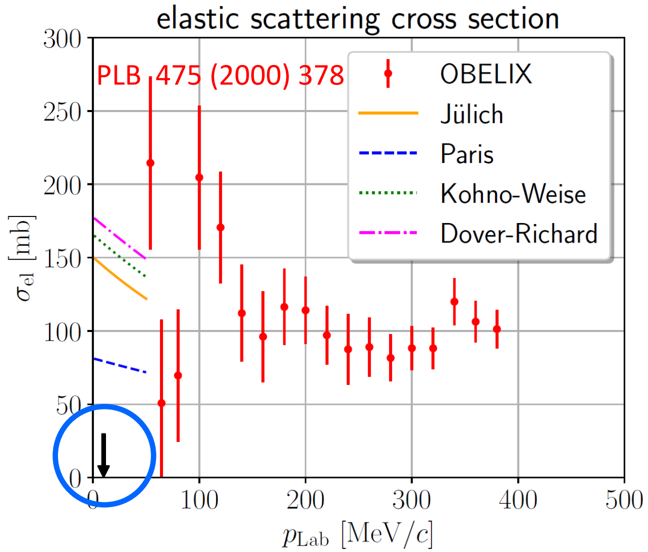
The physics case: low-energy $\bar{n}p$ scattering cross-sections

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

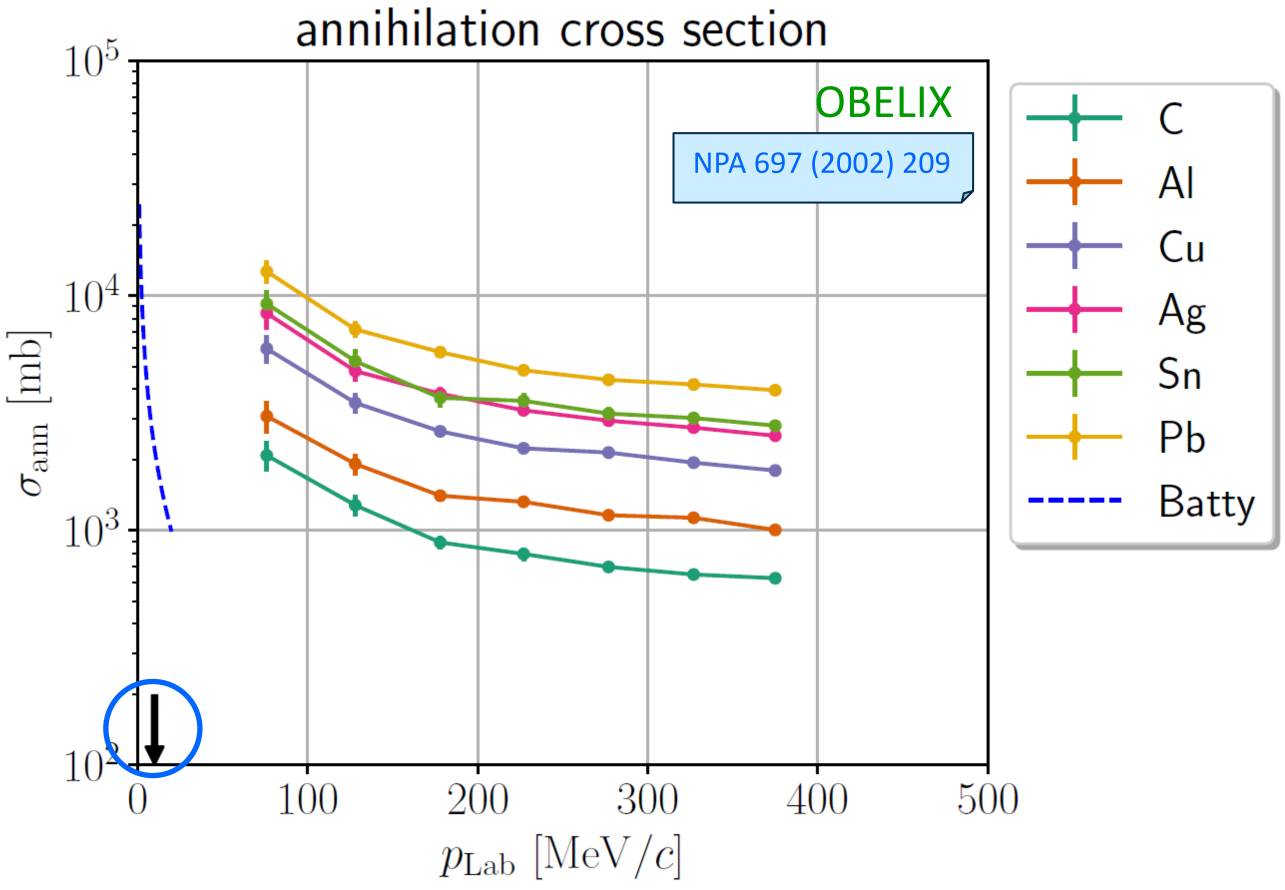


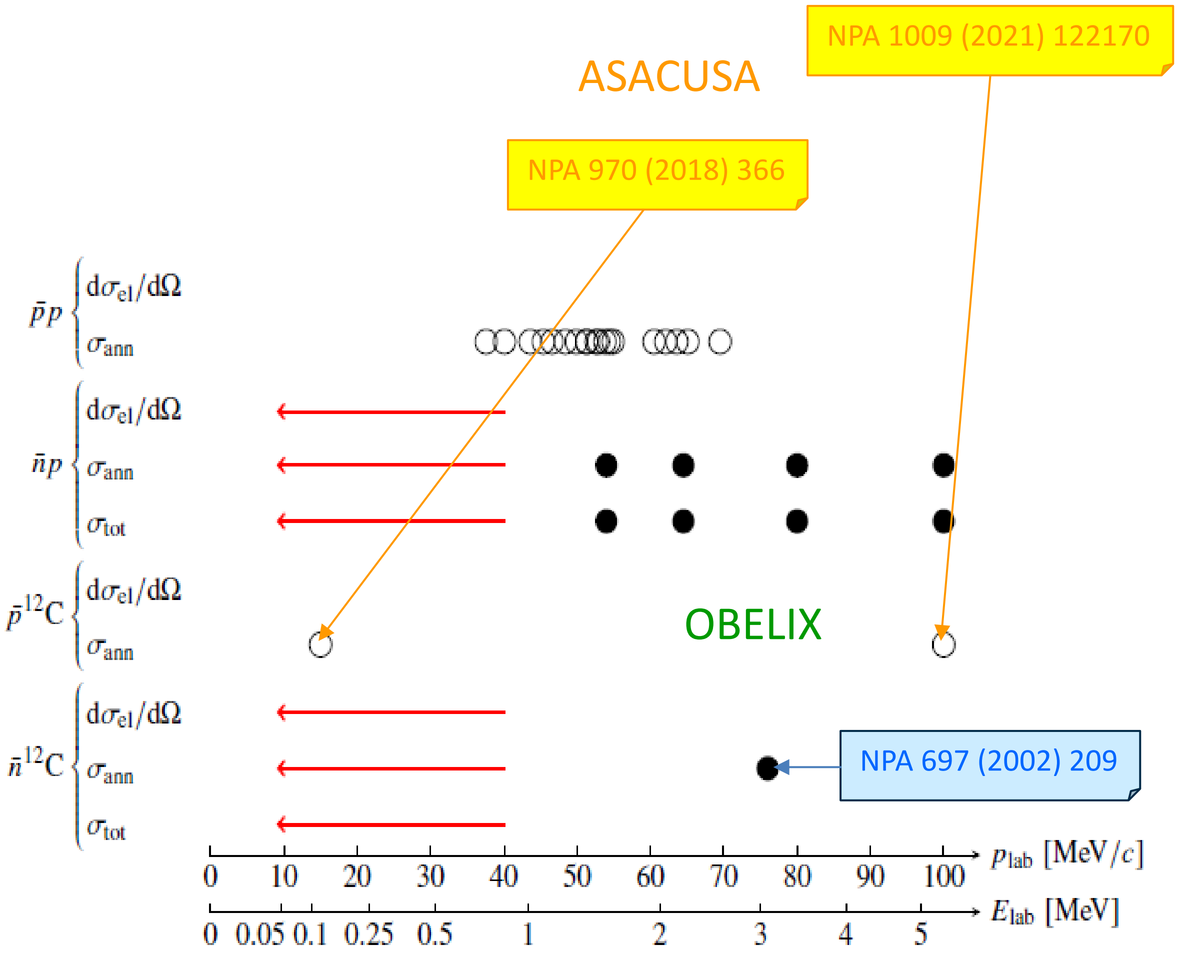




New measurements are essential to determine the *S*-wave scattering length in a model-independent way

$\bar{n}$ – nucleus scattering cross-section





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

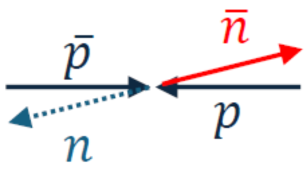
The leading *idea*

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

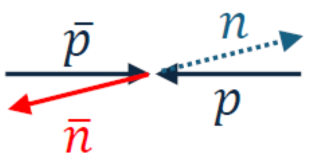
lab frame

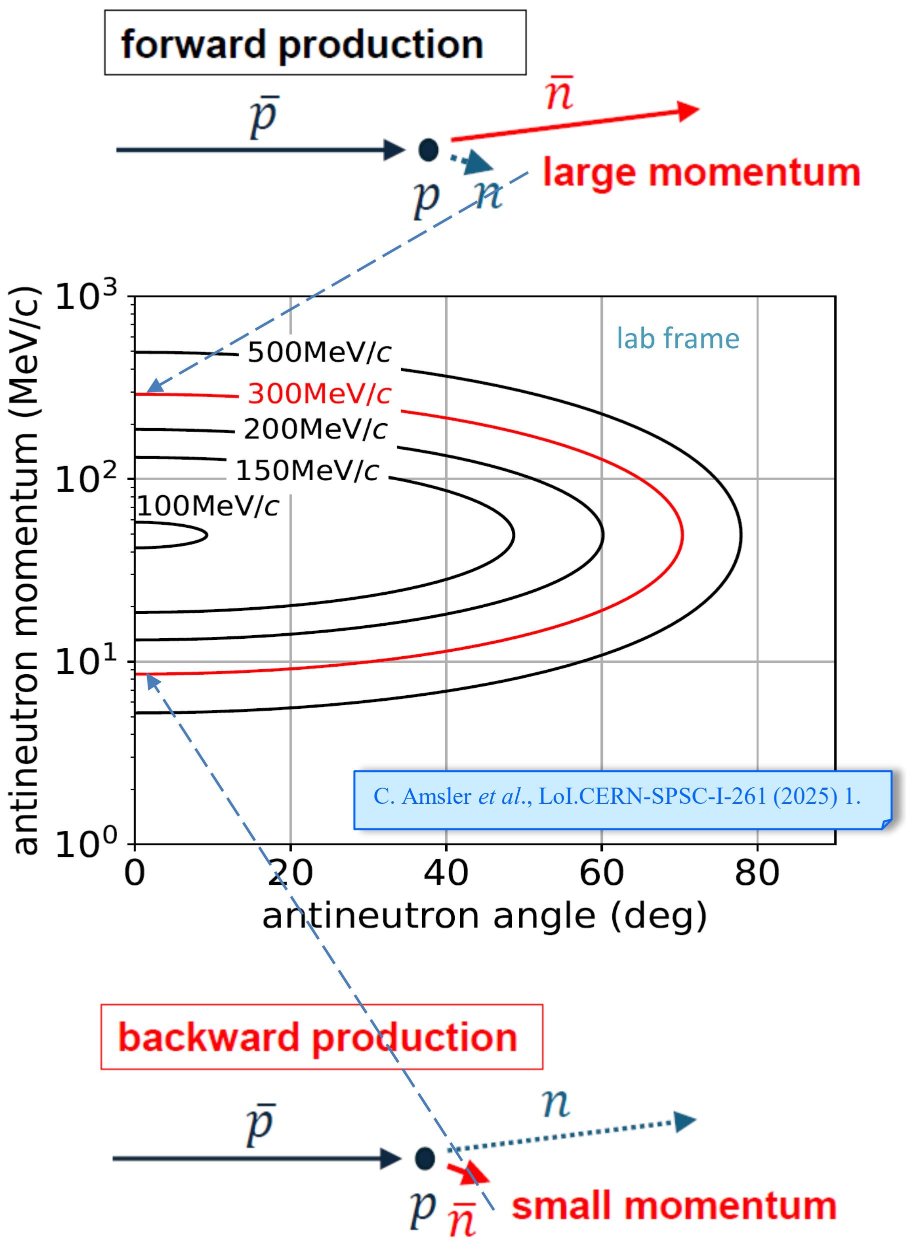
CM frame

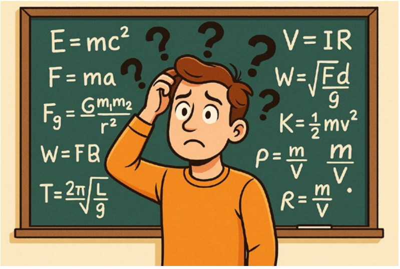
forward production



backward production







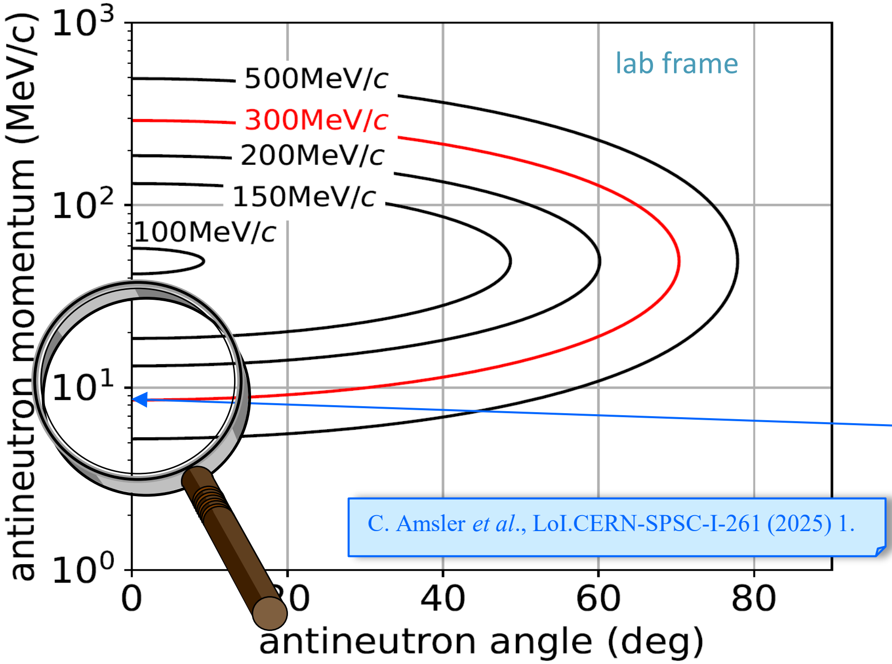
The leading *idea*

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

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

i.e.

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



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

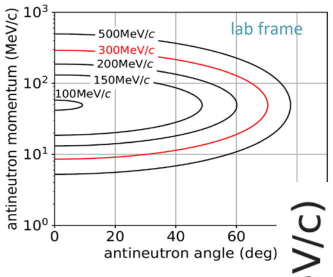
$p_{\bar{n}} \approx$ 9 MeV/c !!!

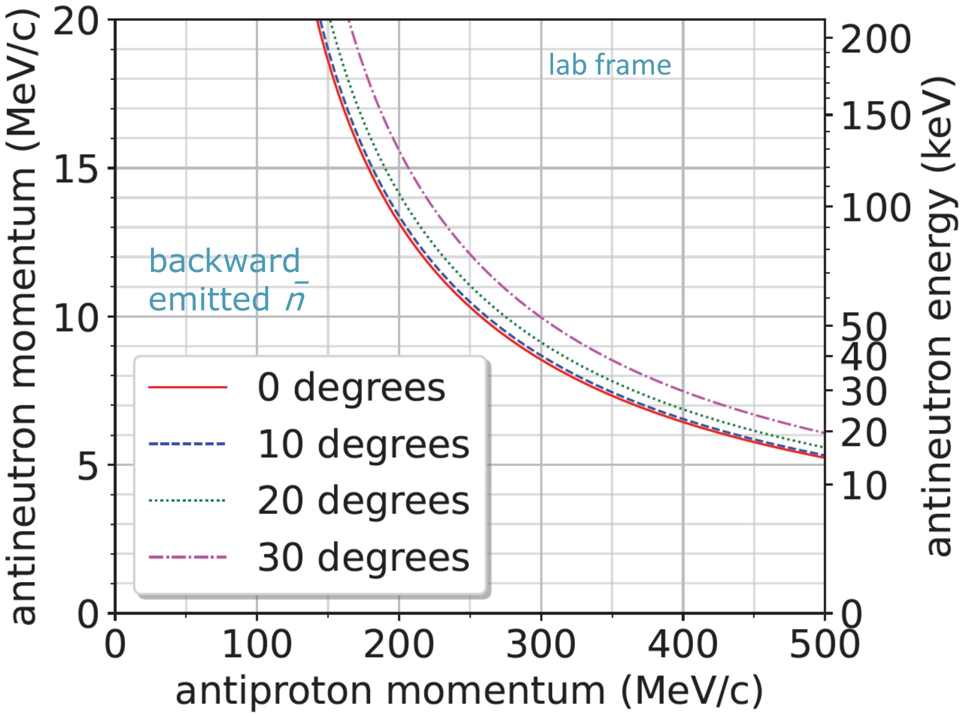
$$\left(\frac{d\sigma}{d\Omega}\right)_{\theta_{lab}\,=\,0^\circ}(\theta_{CM} = 180^\circ) = 4.7 \pm 1.9\ \mu\mathrm{b/sr}$$

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

Expected $\bar{n}$ yield

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





a little help from the kinematics of the reaction:

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 lenght:
0.44 g/cm^2 ≡ 6.2 cm (LH_2)

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

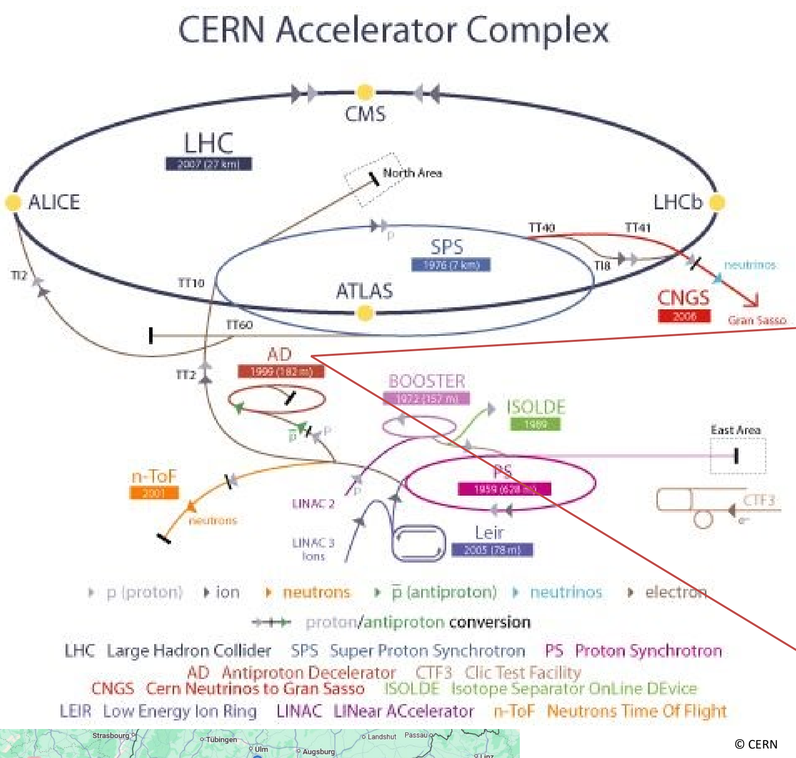
=

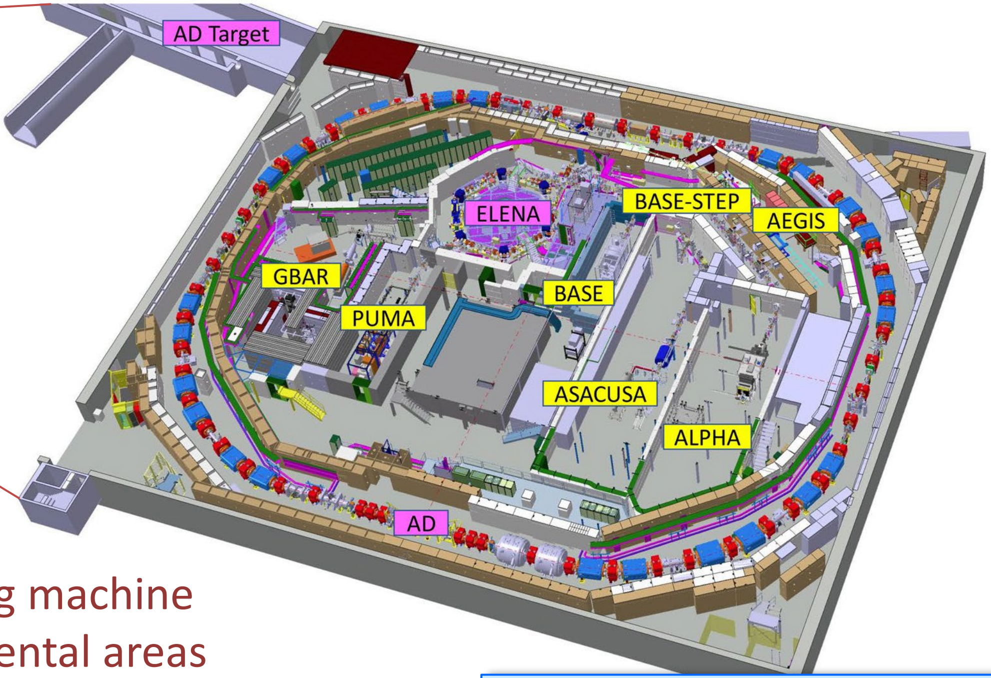
1 backward $\bar{n}$ per AD cycle (5×10^7 $\bar{p}$ / 120 s)*

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





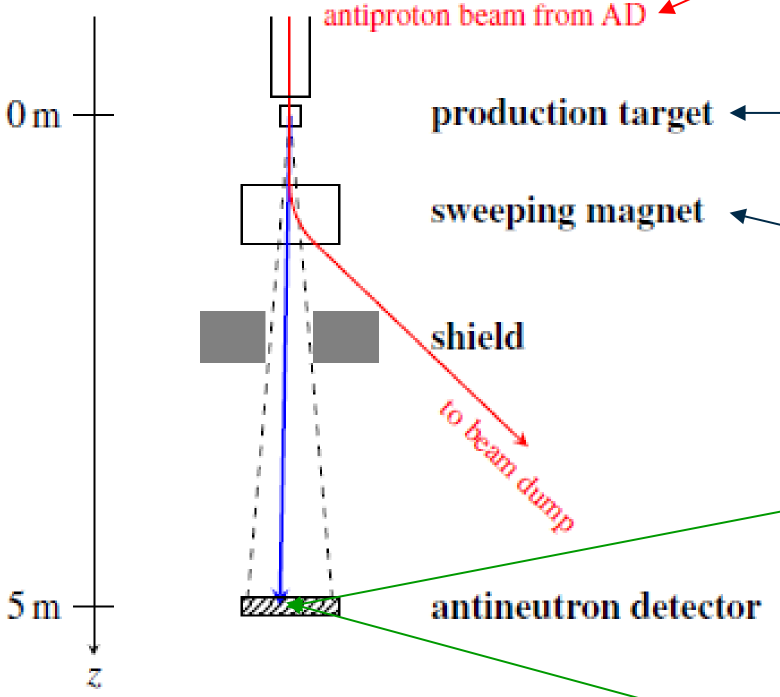
- 183 m long machine
- 7 experimental areas

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**

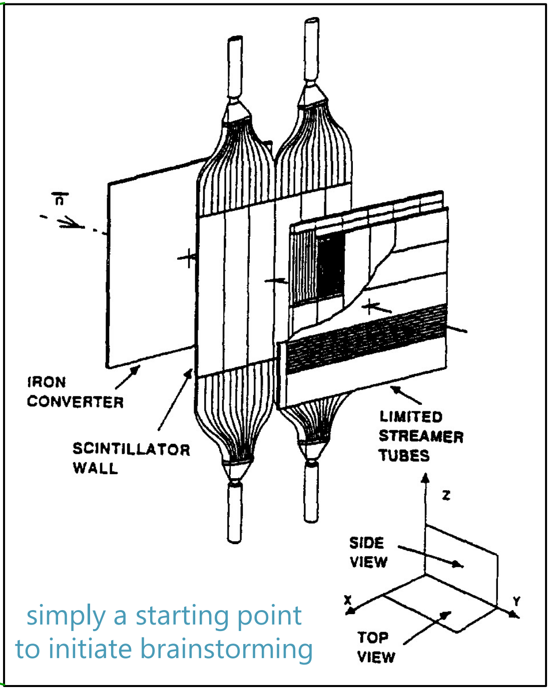
300 MeV/c



~ 6 cm long LH_2 target

background reduction

- non converted $\bar{p}$
- charged annihilation products



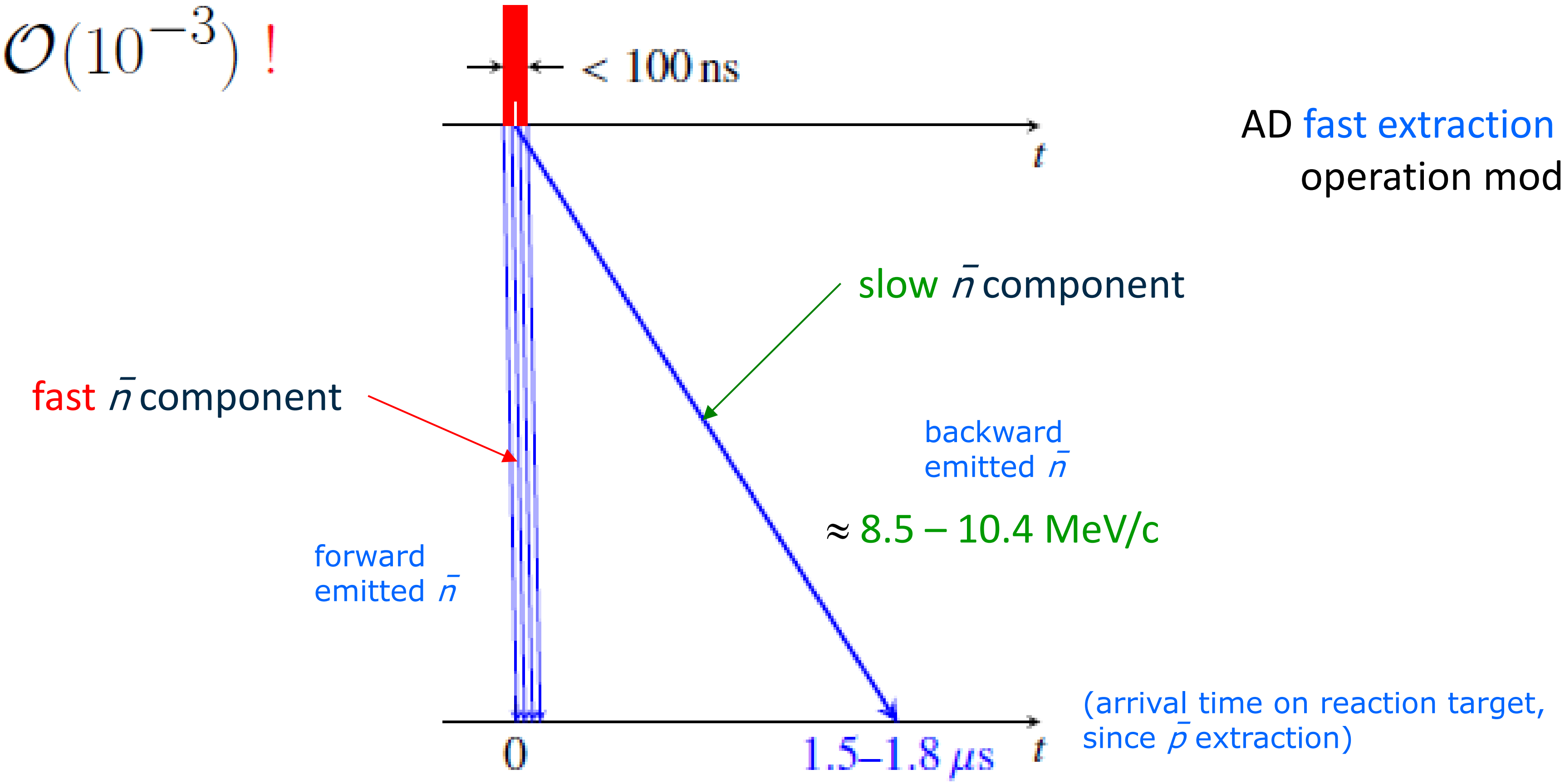
M. Agnello *et al.*, *Nucl. Instr. And Meth. In Phys. Res.* A 399 (1997) 11–26.

AD $\bar{p}$ bunch time structure

(background reduction)

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

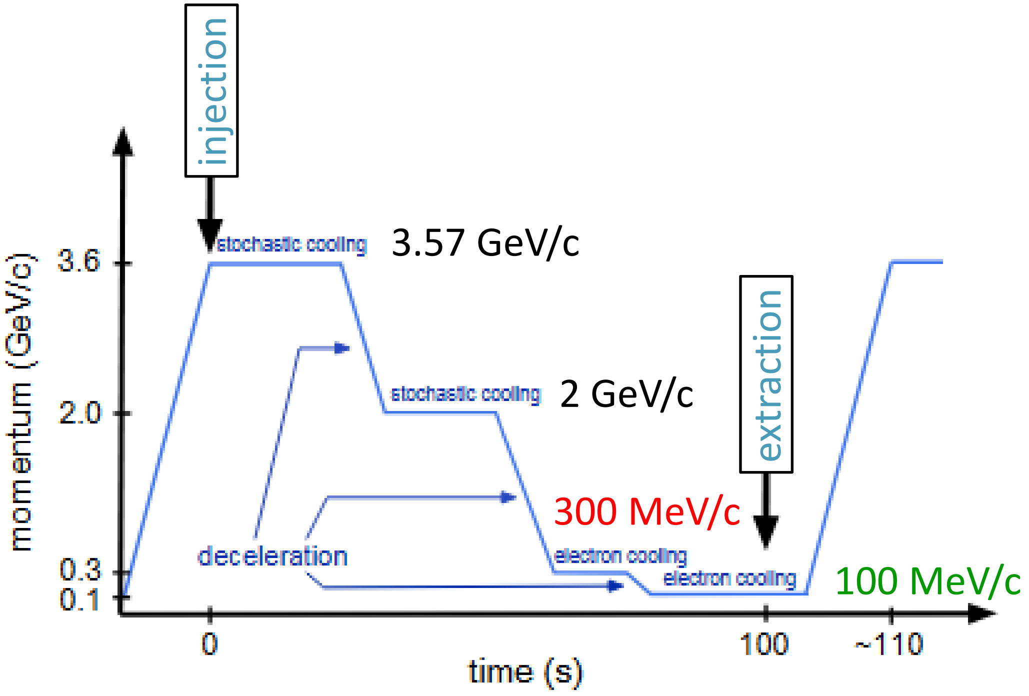
AD fast extraction operation mode



(over a flight path of 5 m)

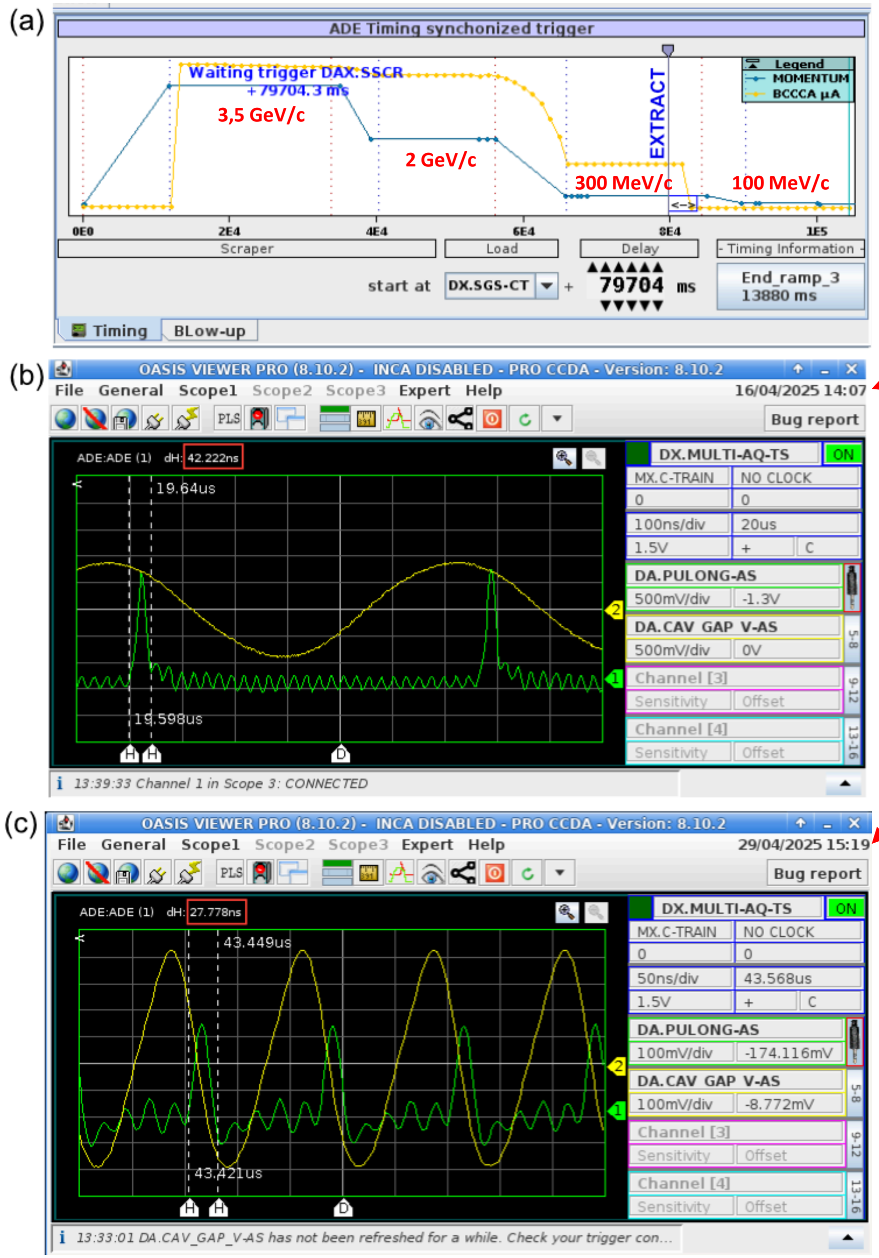
Requests to AD

- the current AD + ELENA operating scheme is not suitable for our needs: it provides to the experiments 100 MeV/c $\bar{p}$
- $\bar{p}p \rightarrow \bar{n}n$ 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



Alessandro Feliciello / Italy-Japan Symposium on Joint Activities in Fundamental Physics, March 9 - 12, 2026, Kore University of Enna, Italy

Strong interplay with CERN AD team

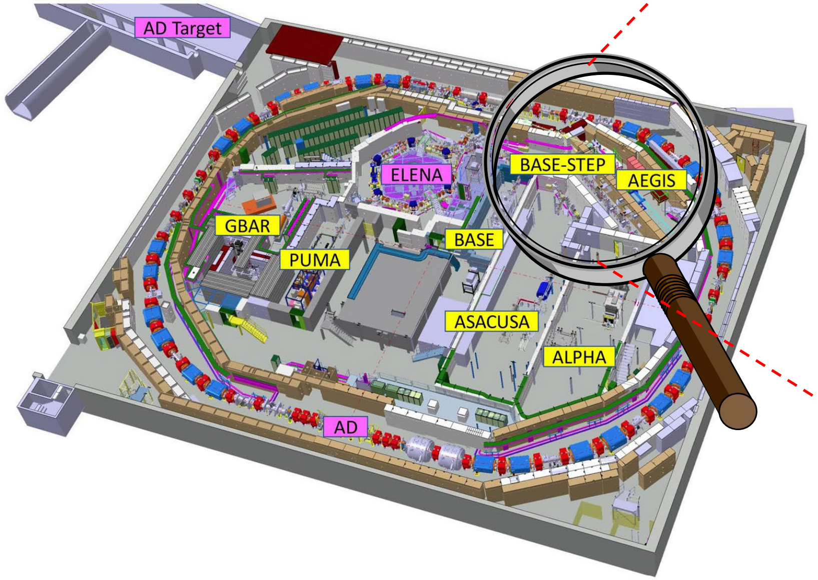


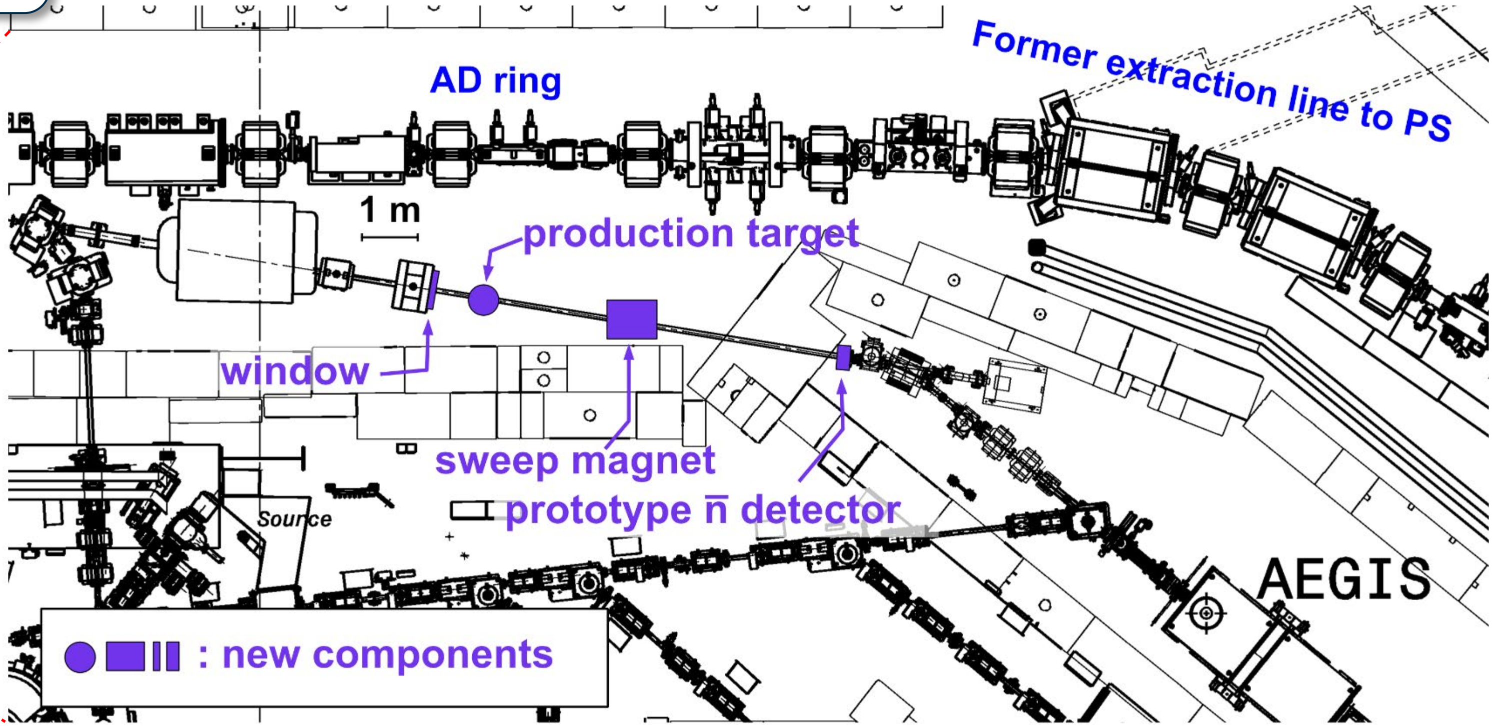
April 2025

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

the beam has been rebunched into 6 or 16 buckets

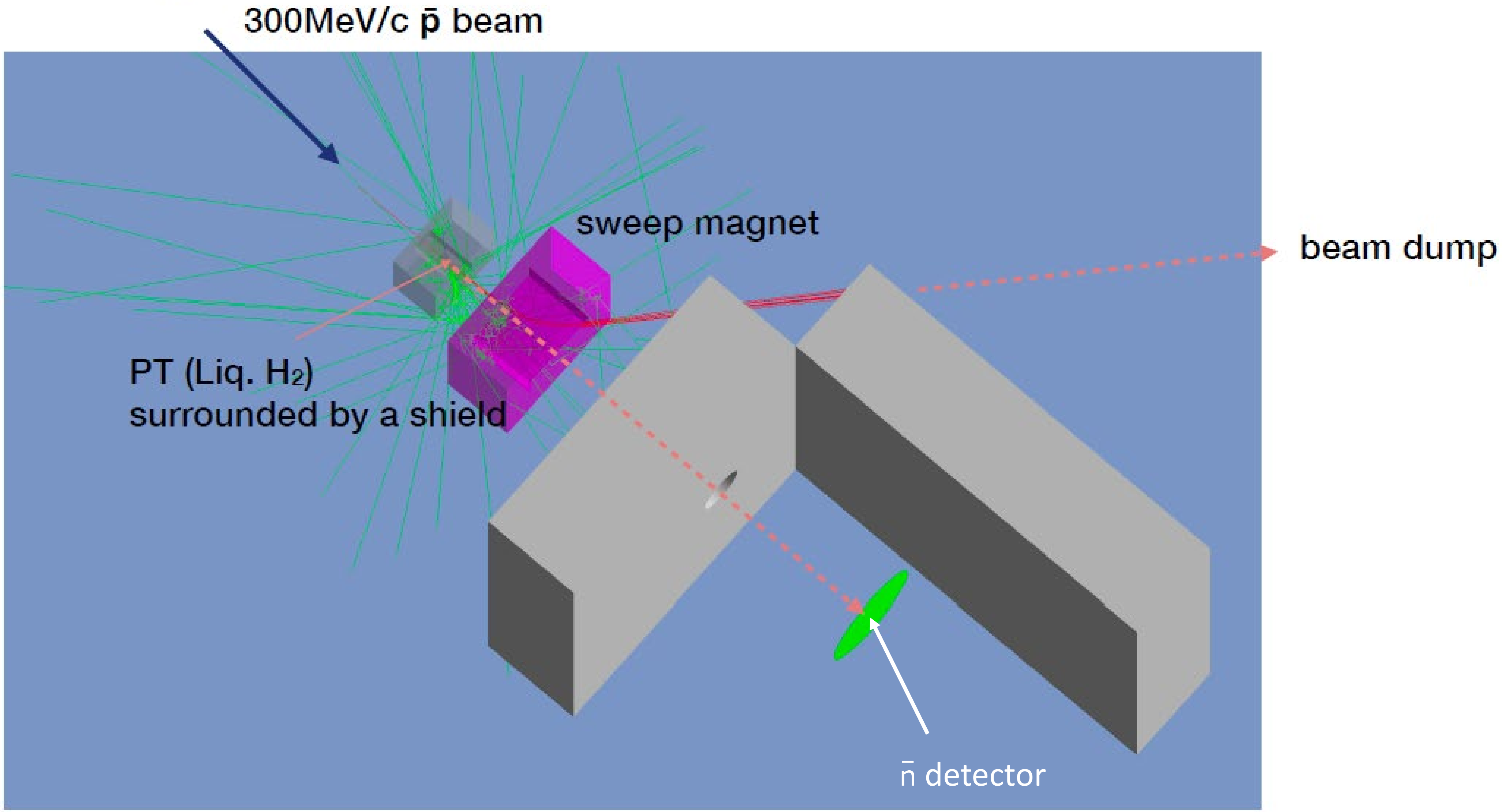
Short term tests





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

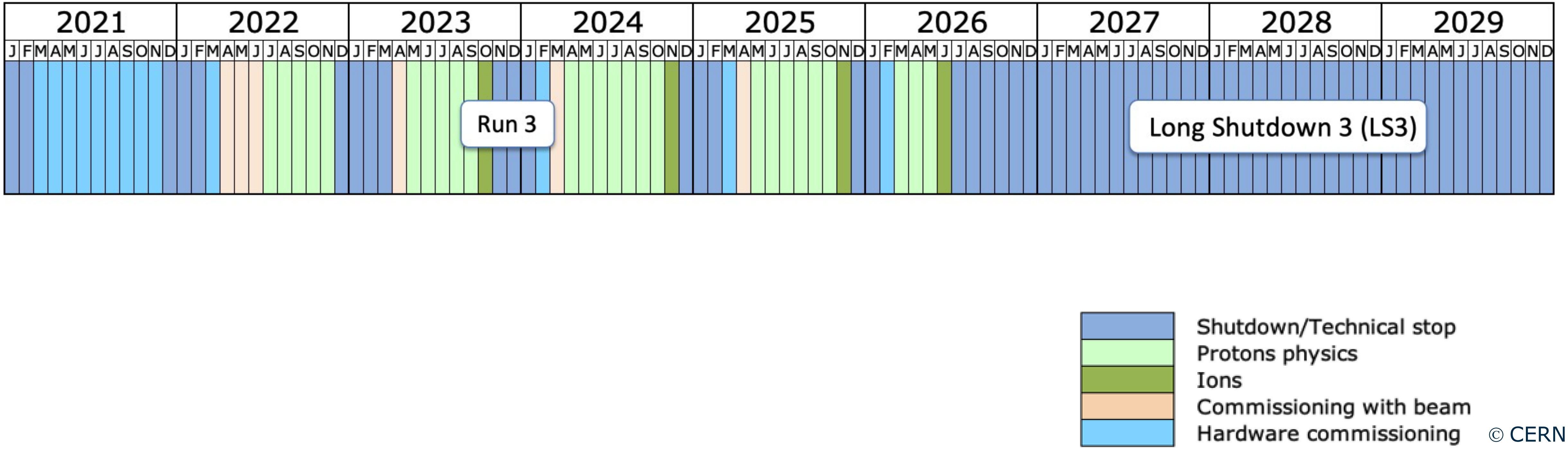
Experimental **design concept**



Timeline

Longer term LHC schedule

Short YETS 25/26
Extend Run 3 to end June 2026
Start LHC LS3 July 2026
Start final Hardware Commissioning January 2030
First beam June 2030
LS3 - beam to beam: 3 years 11 months, 47 months



FLAP @ CERN


May 1, 2025

Letter of Intent

Low-Energy Antineutron Beamline at the Antiproton Decelerator for Scattering Experiments

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[6] INFN, Sezione di Pavia

CERN-SPSC-2025-010 / SPSC-I-261
01/05/2025

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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 Commitee
- 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 sinergy