

PUMA

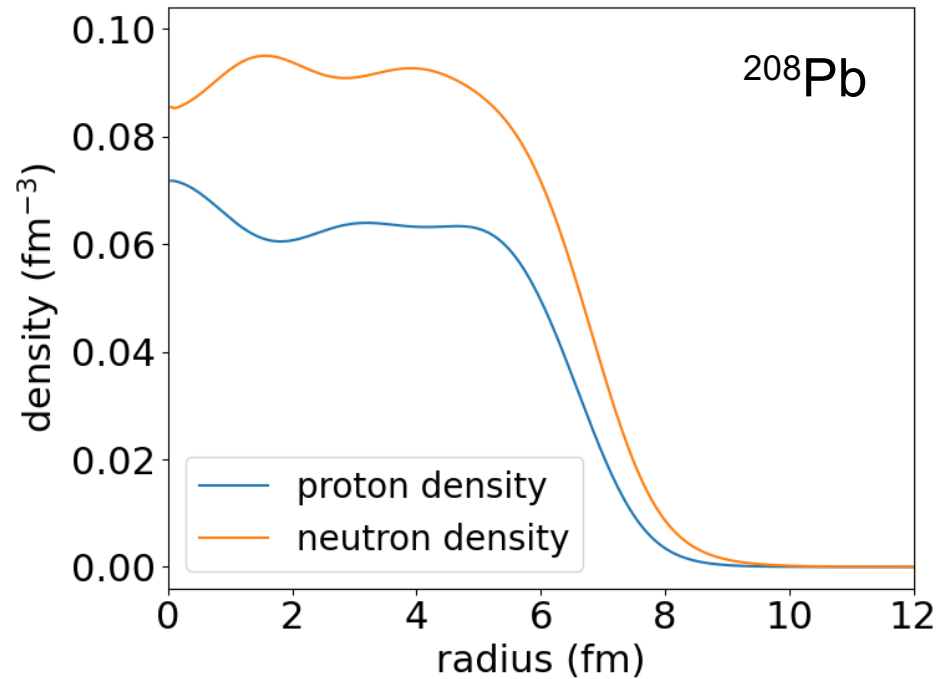
PROBING THE NEUTRON SKIN WITH ANTIPROTONS

Light-ion collisions 2026
Kirchhoff-Institut für Physik, Heidelberg

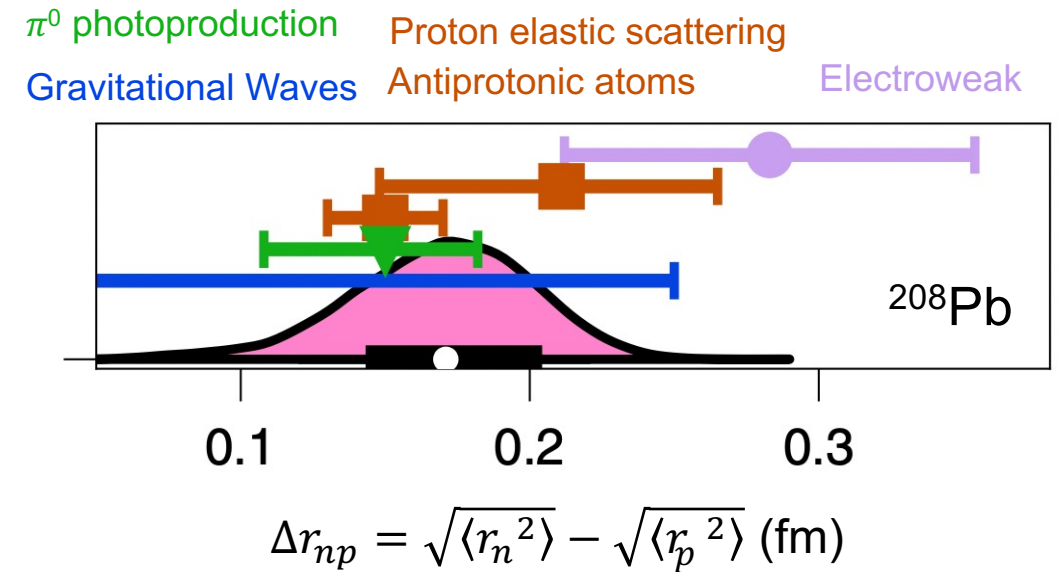
Alexandre Obertelli, TU Darmstadt
On behalf of the PUMA collaboration (<https://puma.web.cern.ch>)



NEUTRON SKINS

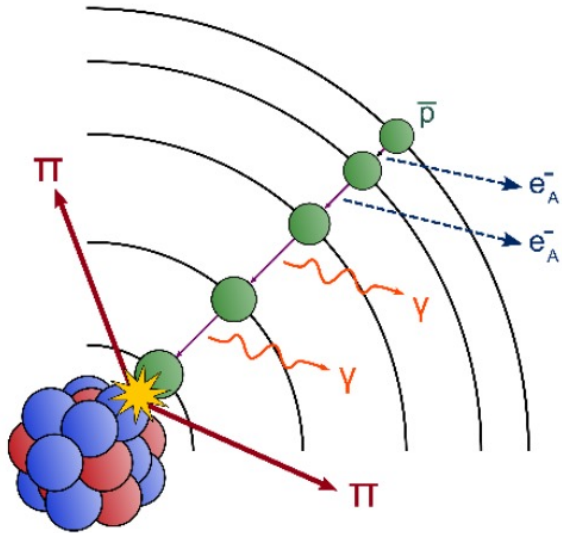


from Hu et al., Nature Phys. (2022)



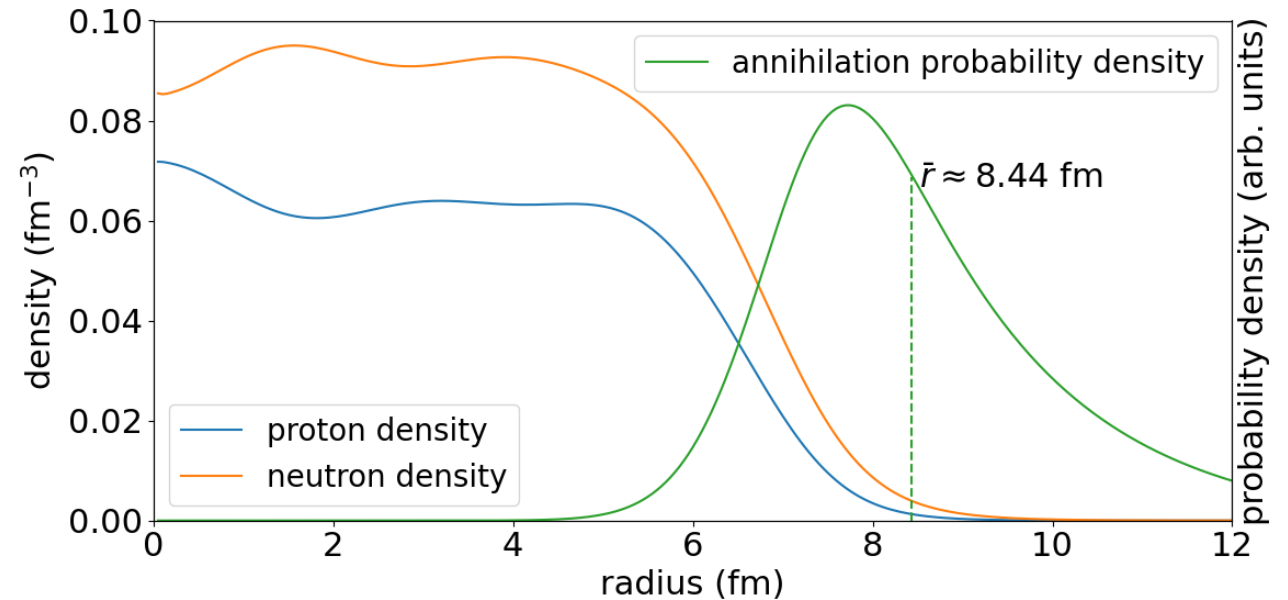
- Charge radius from electron elastic scattering or laser spectroscopy
- Matter or neutron distribution information experimentally challenging to access

LOW ENERGY ANTIPROTONS AS PROBE



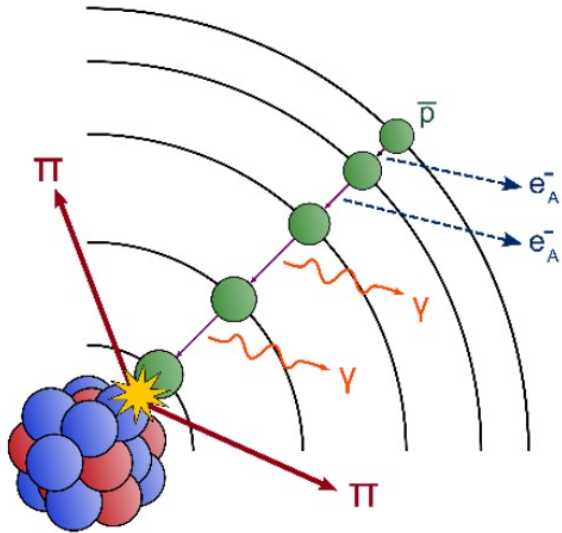
- $\bar{p}$ captured in antiprotonic orbital
- annihilation in tail $\rho_{n/p}(r)$
- conservation of electric charge

$$\sum_{\pi} q_{\pi} = \begin{cases} 0 & \text{for } \bar{p}p \\ -1 & \text{for } \bar{p}n \end{cases}$$



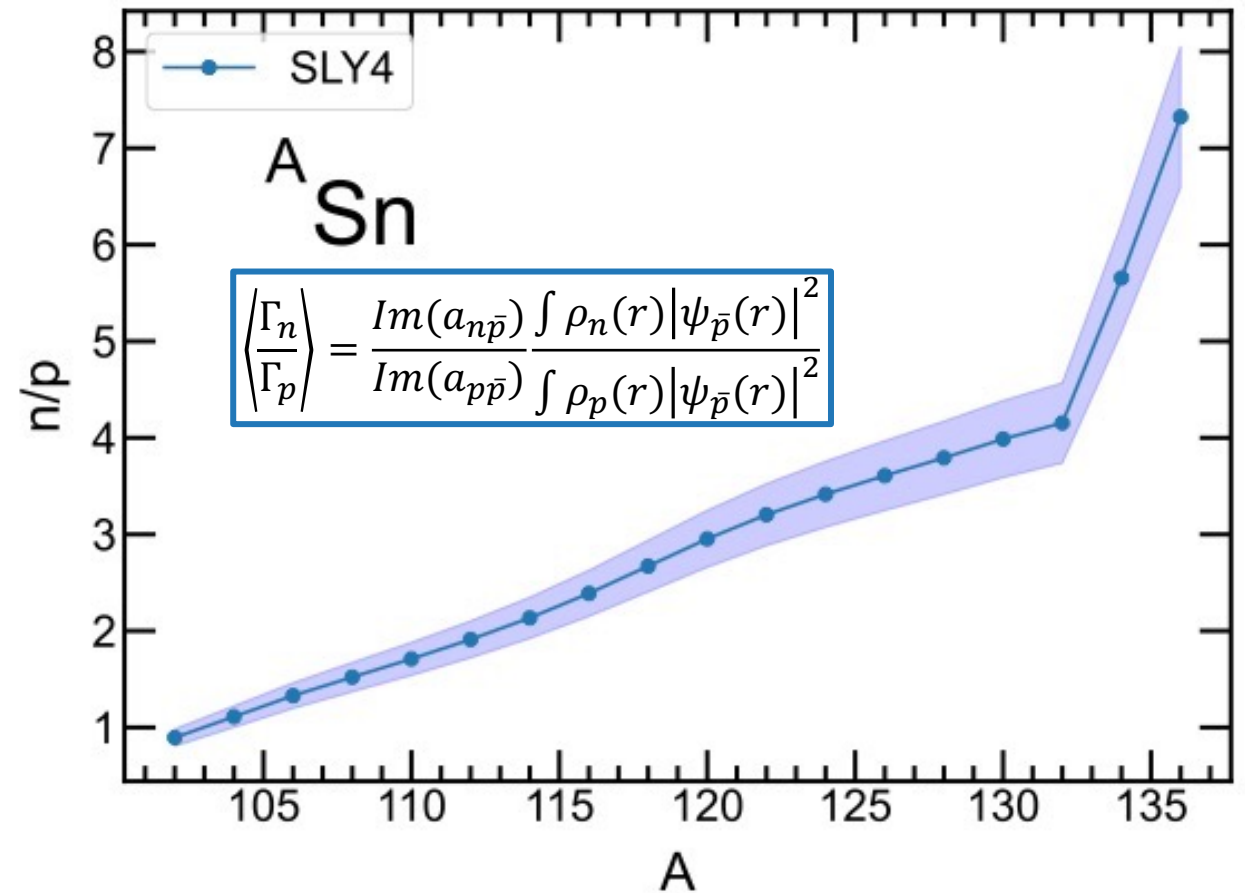
- First application of method in 1973 — Bugg et al., PRL (1973)
- Application to rare isotopes proposed by Wada, Yamazaki — Wada and Yamazaki, NIM B (2004)
- **Expected sensitivity: 10%**, dominated by FSI

LOW ENERGY ANTIPROTONS AS PROBE



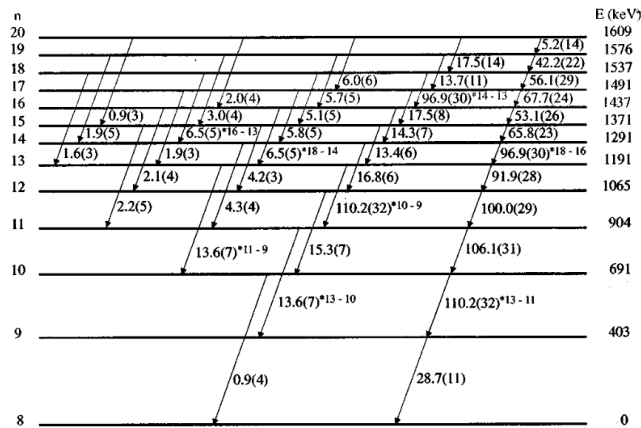
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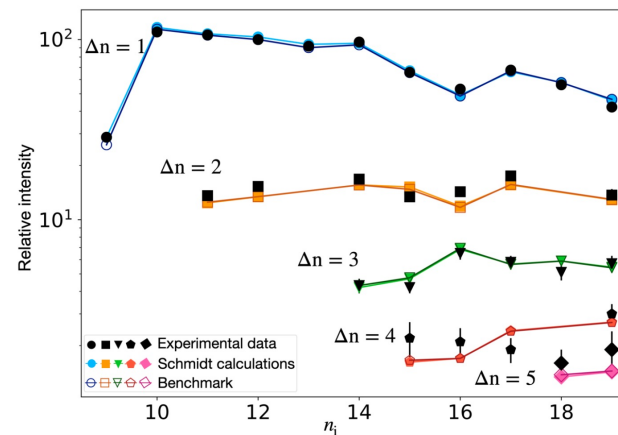


THEORY

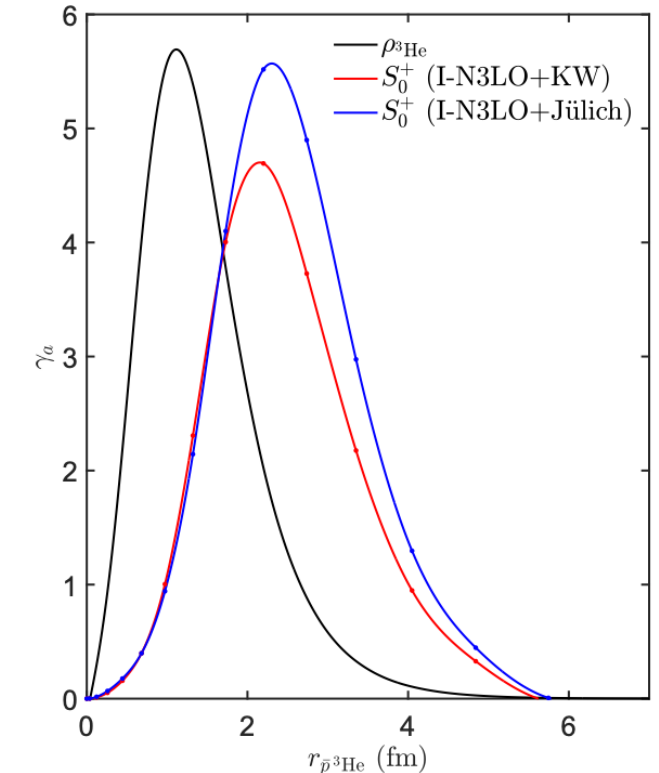
- Antiproton – nucleus optical potentials: LEC tuned on energy shifts and widths
Ex. Kohn-Weise, NPA 454 (1986), Jülich JHEP 7 (2017)
- Annihilation peripheral and probability proportional to density
Lazauskas and Cabonell, PLB 820 (2021), Duerick and Lazauskas, PRC 113 (2026)
- No-Core Shell Model + continuum: extension to mass $A \sim 10$
Dehghani et al., PRC 114 (2026)
- Towards an EFT for medium mass and heavy antiprotonic atoms
Hammer and Rusetsky, arXiv:2609.06624 (nucl-th)



Schmidt et al, PRA 58 (1998)



Zacarias, TUDa PhD thesis (2022)



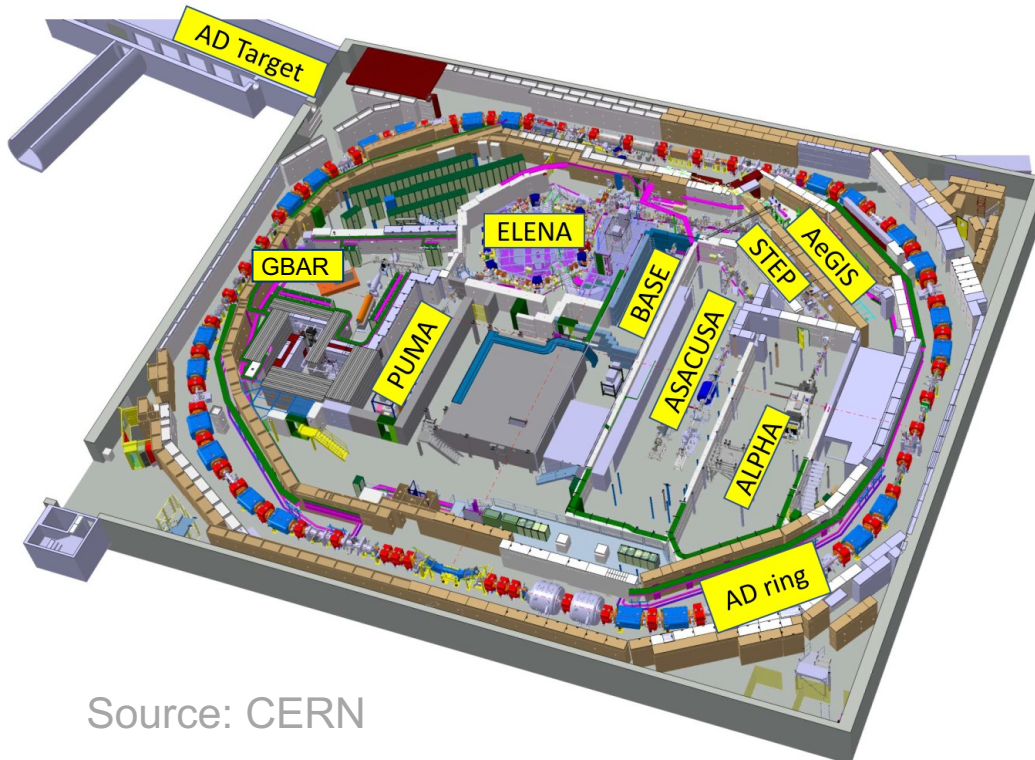
$$\gamma_a^{(\alpha)}(z) = \int |\Psi_\alpha(x, y, z)|^2 \text{Im}[W(x, y, z)] x^2 y^2 z^2 dx dy dz,$$

Duerick and Lazauskas, PRC 113 (2026)

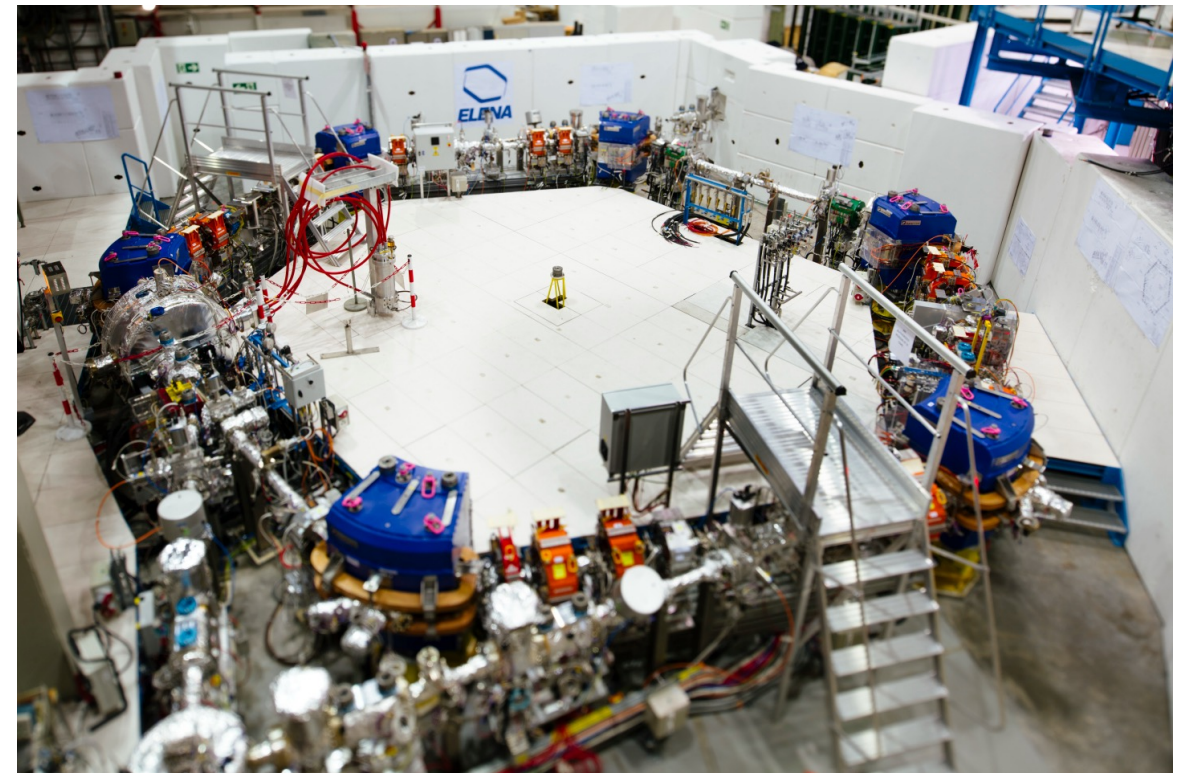
THE ANTIMATTER FACTORY, CERN



- $1.5 \cdot 10^{13}$ protons at 26 GeV/c from PS
- $3 \cdot 10^7$ antiprotons at AD
- Deceleration: 5.3 MeV (AD), 100 keV (ELENA, since 2021)
- $\sim 8 \cdot 10^6$ antiprotons (100 keV) every 2 min



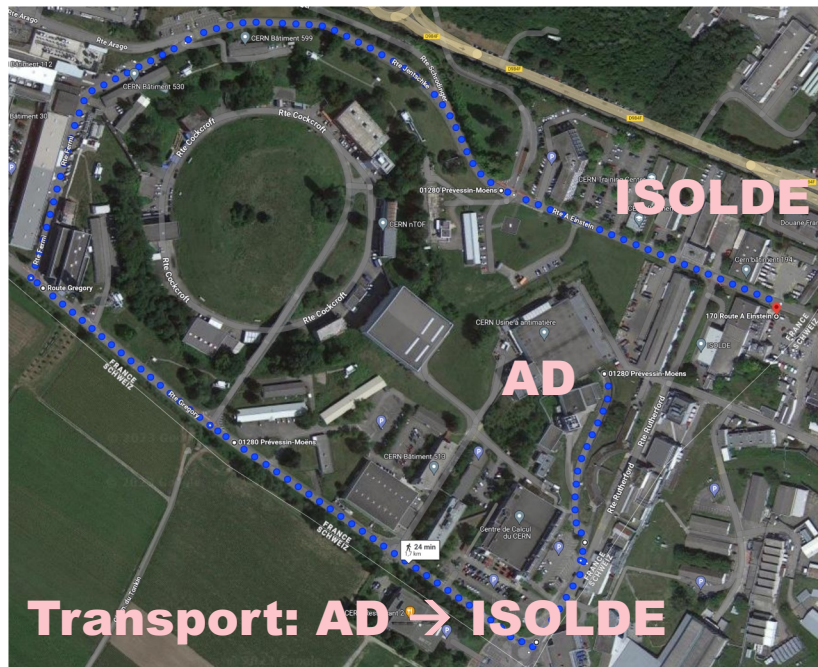
Source: CERN



THE $\bar{p}$ PUMA EXPERIMENT

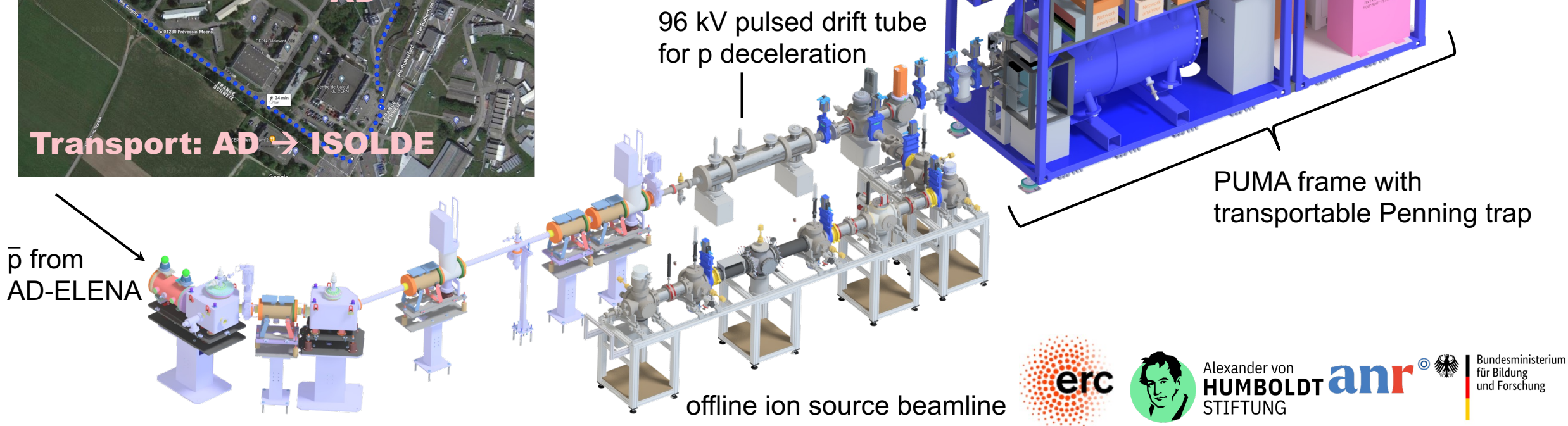


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Aumann et al. (PUMA collaboration), EPJA 58 (2024)

CERN experiment since 2021



$\bar{p}$ from
AD-ELENA

96 kV pulsed drift tube
for p deceleration

PUMA frame with
transportable Penning trap

offline ion source beamline



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anr

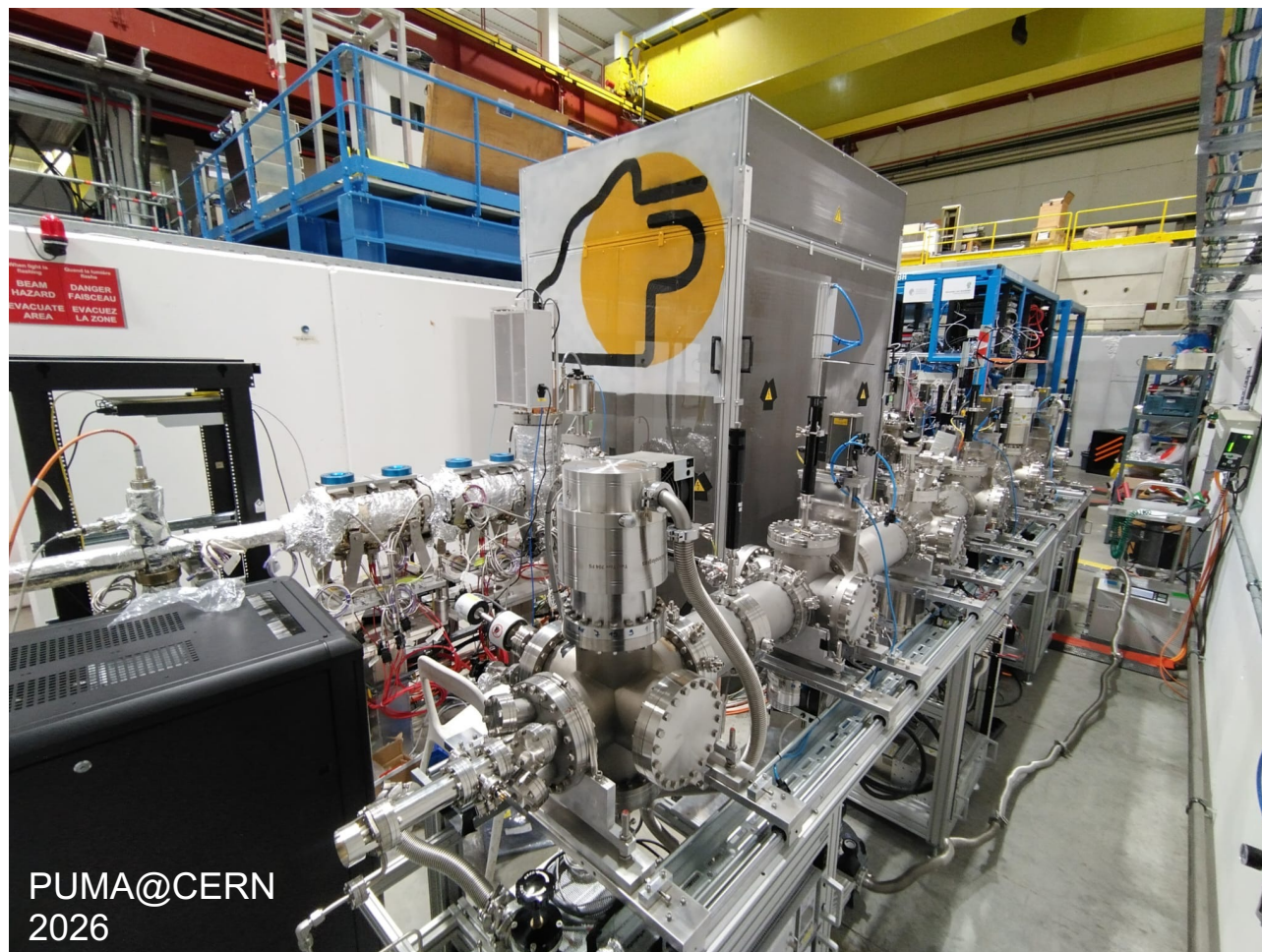


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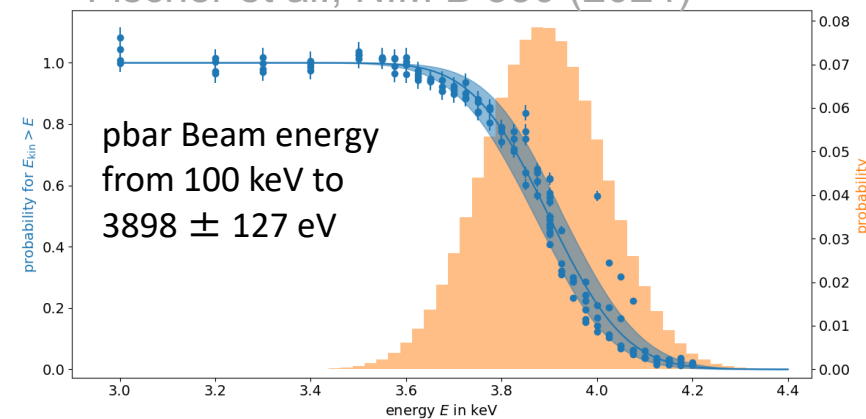
THE $\bar{P}$ UMA EXPERIMENT



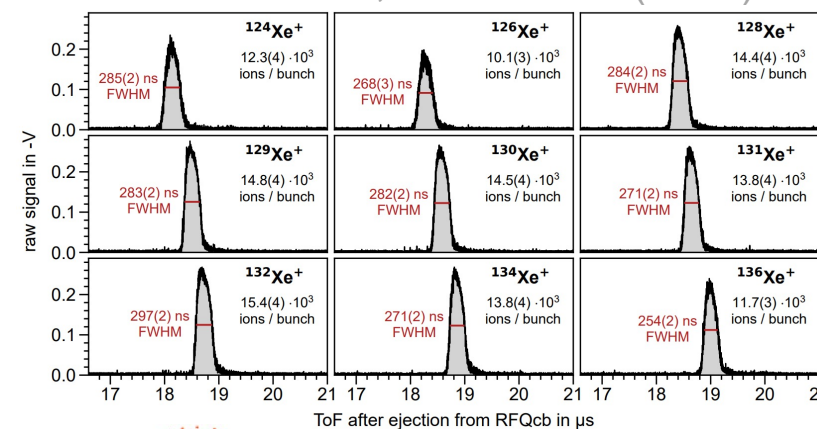
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Fischer et al., NIM B 550 (2024)



Schlaich et al., NIM A 1080 (2025)

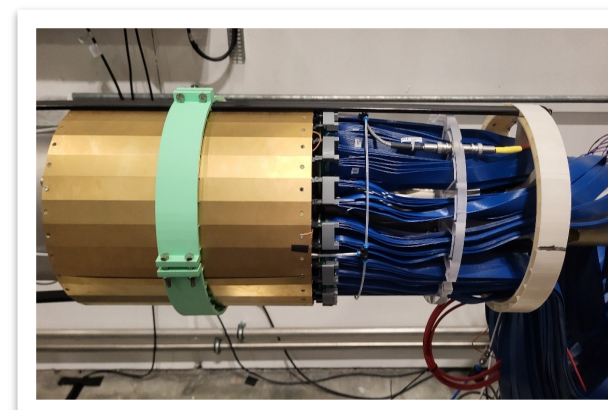
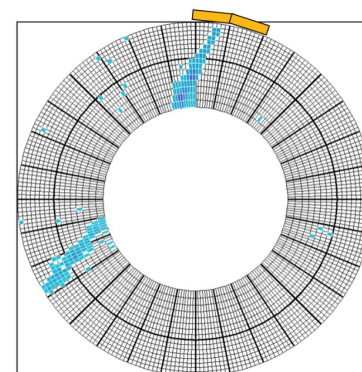
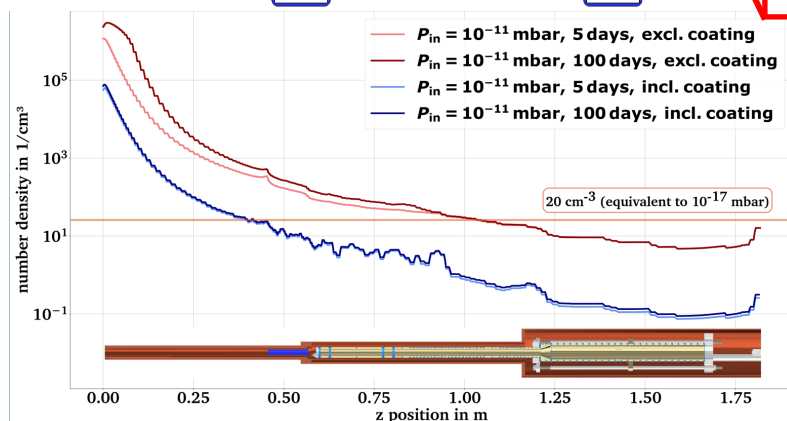
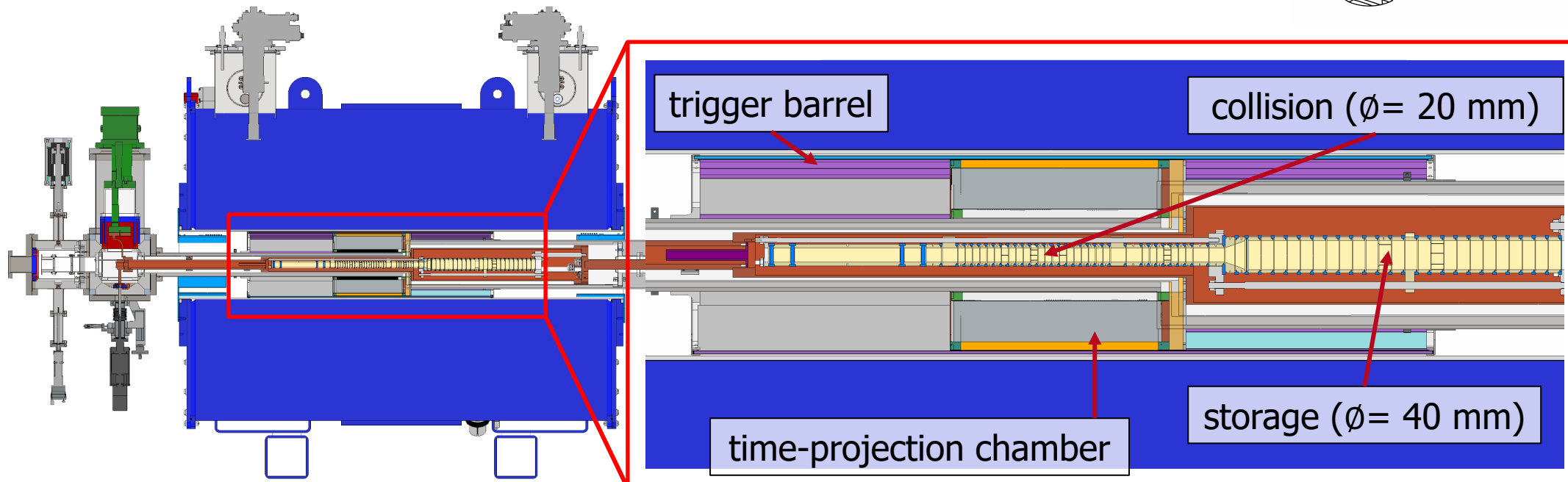


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THE $\bar{P}$ UMA EXPERIMENT



LATEST RESULTS AND FUTURE PLANS



First achievements before LS3:

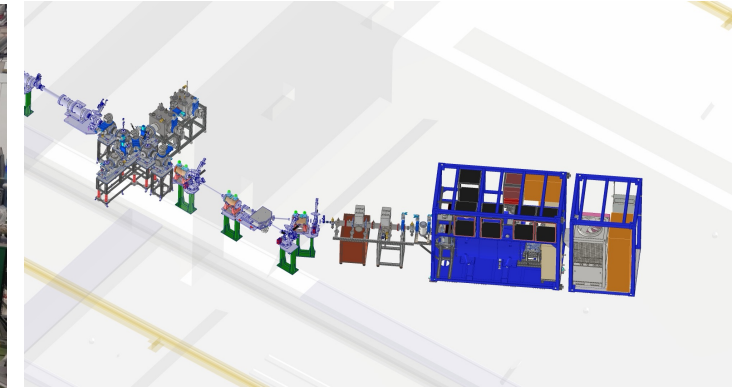
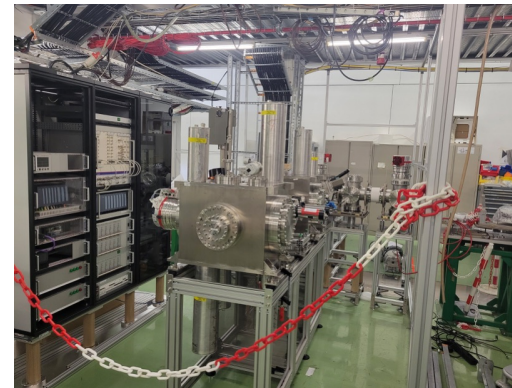
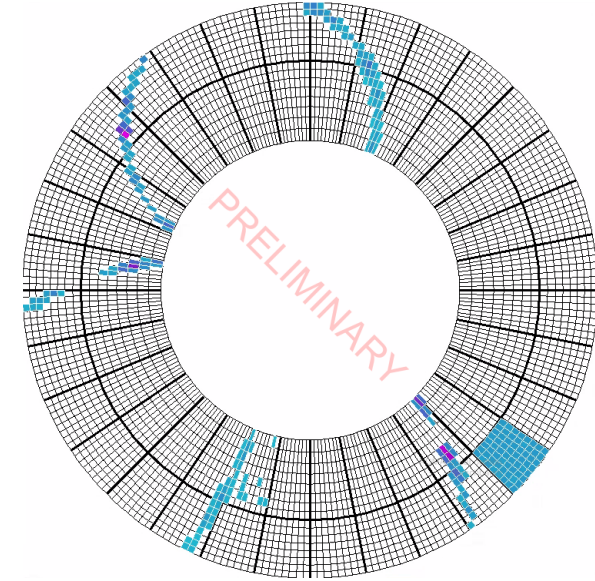
- Trapping of antiprotons (tested up to 1000 s)
- First annihilations with residual gas molecules

Post LS3 physics program at ELENA:

- Few-nucleon systems: p, d, t, ^3He , ^4He
- Stable rare gases: ^{16}O , $^{20,21}\text{Ne}$, $^{78-86}\text{Kr}$, $^{124-136}\text{Xe}$
- Metals: $^{40,48}\text{Ca}$, $^{112-124}\text{Sn}$, $^{206,208}\text{Pb}$

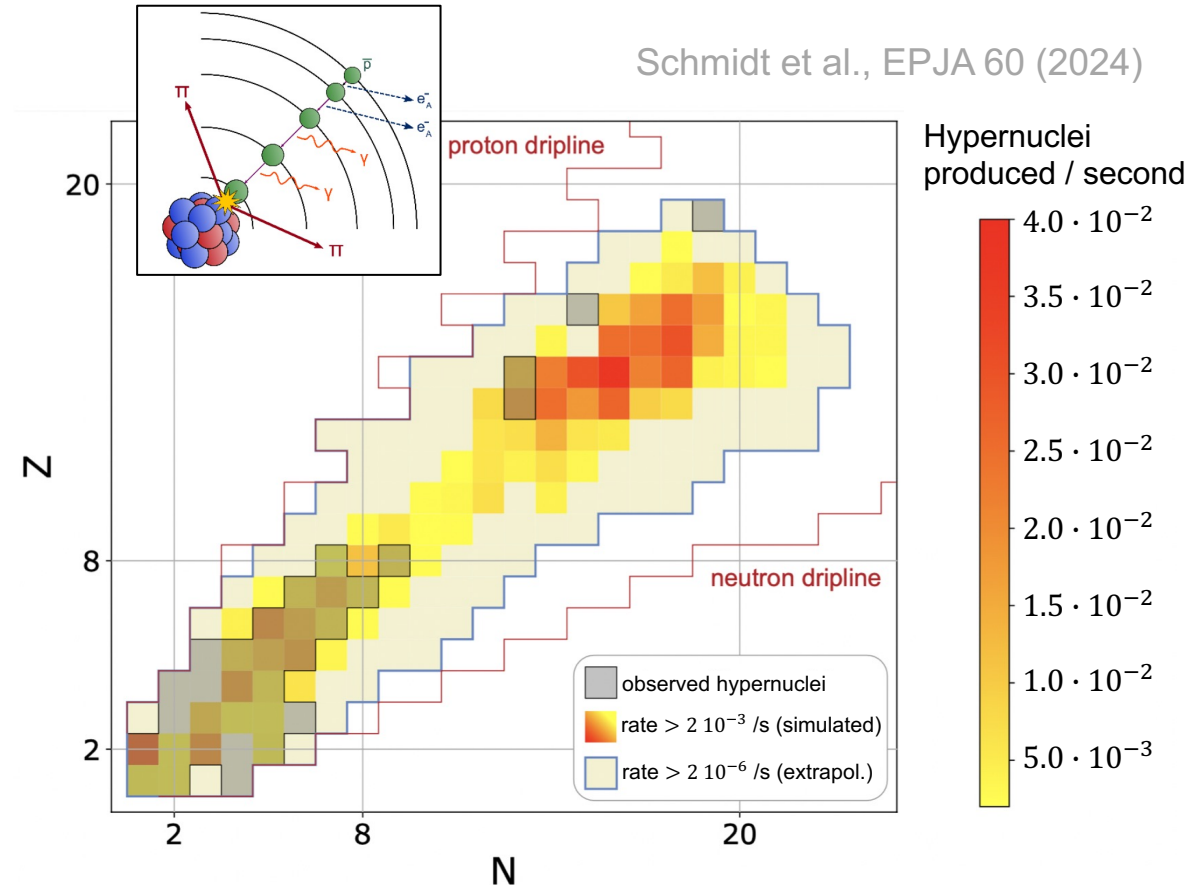
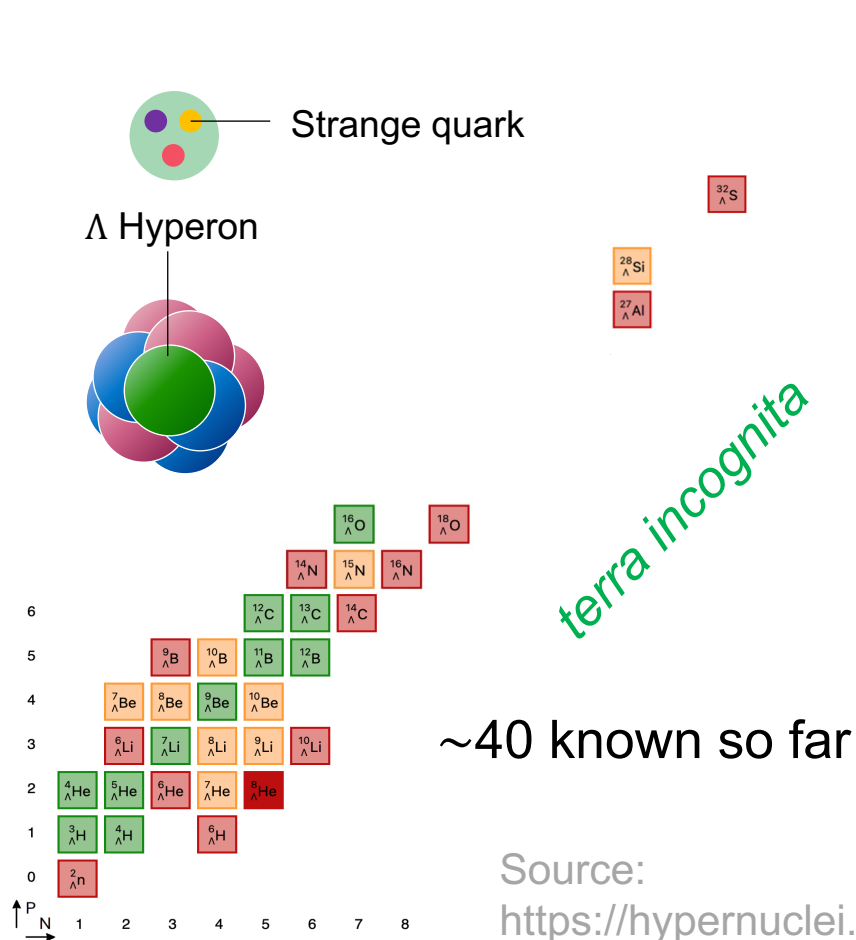
At ISOLDE (beam line in construction):

- Exotic Xe isotopes (accepted proposal)
- Neutron rich and deficient Sn isotopes
- Proton and neutron halos
- ...



HYPERNUCEI FROM ANTIPROTONS

- 1% of annihilations lead to a hypernucleus
- **~2 hypernuclei / second**



SUMMARY



- **Antiprotonic atoms** offer unique opportunities
- World-unique **Antimatter Factory at CERN**
- Probing the **n/p content of the tail of the nuclear density**
- **PUMA** is in final phase of installation at CERN
- Experiment accepted in 2021, measurements started in 2026
- Stable (ELENA) and short-lived nuclei (ISOLDE) from 2028
- Investigation of the neutron skin beyond its thickness;
connection with recent **light ion collisions** and flow studies
- Annihilations lead to **hypernuclei** in 1% of the annihilations
- **HYPER** has the potential for a hypernuclei factory at CERN
- Started in 2026

