



# PUMA: physics with antiproton at ISOLDE

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First meeting PUMA@ISOLDE  
June 1<sup>st</sup>, 2022

# PUMA collaboration

- 7 collaborating institutes (4 experiment / 3 theory)
- 40 collaborators (about 15 FTE)
- Canada, France, Germany, Switzerland

T. Aumann, N. Azaryan, W. Bartmann, A. Bouvard, O. Boine-Frankenheim, A. Broche, F. Butin, D. Calvet, J. Carbonell, P. Chiggiato, P.-Y. Dureinck, H. De Gerssem, R. De Oliveira, T. Dobers, F. Ehm, J. Ferreira Somoza, J. Fischer, M. Fraser, M. Gomez-Ramos, J.-L. Grenard, G. Hupin, P. Indelicato, B. Jenniger, K. Johnston, C. Klink, M. Kowalska, Y. Kubota, R. Lazauskas, S. Malbrunot-Ettenauer, N. Marsic, W. Müller, S. Naimi, R. Necca, D. Neidherr, U. Niedermayer, A. Obertelli, Y. Ono, S. Pasinelli, N. Paul, E. C. Pollacco, L. Riik, D. Rossi, H. Scheit, M. Schlaich, A. Schmidt, L. Schweikhard, R. Seki, S. Sels, E. Siesling, A. Stoeltzel, M. Vilen, F. Wienholtz, S. Wycech, C. Xanthopoulou, S. Zacarias

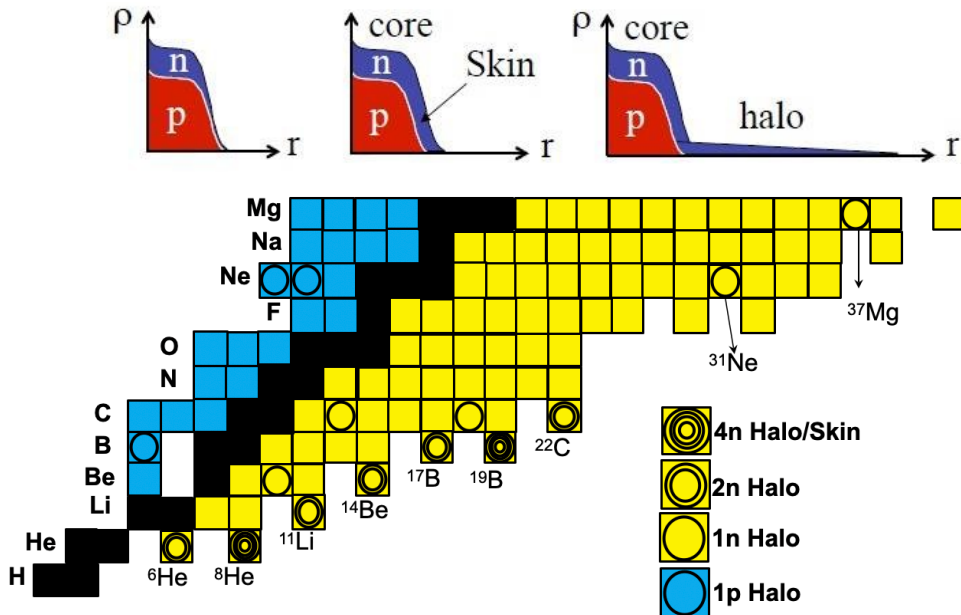


- Experiment accepted in March 2021 as AD-9
- First Collaboration Board meeting in November 2021
- Spokesperson: A. Obertelli (TUDa), Technical Coordinator: F. Butin (CERN)
- WG leaders nominated; WG Beam Lines leader: M. Kowalska (CERN)
- MoU in preparation



# Nuclear skins and halos at the nuclear surface

## PUMA: a nuclear physics experiment



## Objectives of PUMA

- Provide a new observable for the nuclear density tail
- Characterize and evidence halos and skins
- Quantify correlations in low-density nuclear matter

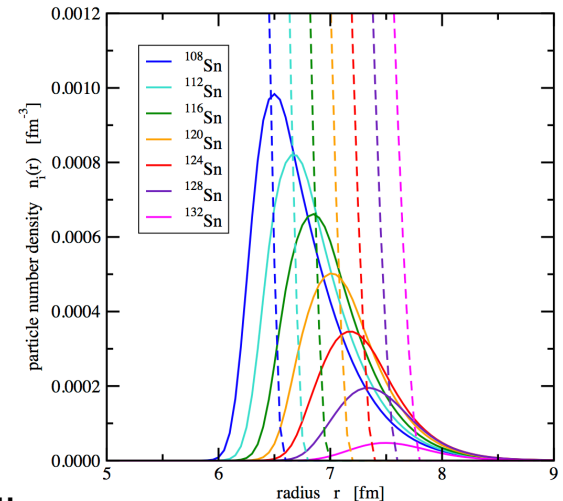
## REPORT

### NUCLEAR PHYSICS

### Formation of $\alpha$ clusters in dilute neutron-rich matter

Junki Tanaka<sup>1,2,3\*</sup>, Zaihong Yang<sup>3,4\*</sup>, Stefan Typel<sup>1,2</sup>, Satoshi Adachi<sup>4</sup>, Shiwei Bai<sup>5</sup>, Patrik van Beek<sup>1</sup>, Didier Beaumel<sup>6</sup>, Yuki Fujikawa<sup>7</sup>, Jiaxing Han<sup>5</sup>, Sebastian Heil<sup>1</sup>, Siwei Huang<sup>5</sup>, Azusa Inoue<sup>4</sup>, Ying Jiang<sup>5</sup>, Marco Knösel<sup>1</sup>, Nobuyuki Kobayashi<sup>4</sup>, Yuki Kubota<sup>2</sup>, Wei Liu<sup>5</sup>, Jianling Lou<sup>5</sup>, Yukiue Maeda<sup>8</sup>, Yohei Matsuda<sup>9</sup>, Kenjiro Miiki<sup>10</sup>, Shoken Nakamura<sup>4</sup>, Kazuyuki Ogata<sup>4,11</sup>, Valerii Panin<sup>3</sup>, Heiko Scheit<sup>4</sup>, Fabia Schindler<sup>1</sup>, Philipp Schrock<sup>12</sup>, Dmytro Symochko<sup>1</sup>, Atsushi Tamir<sup>4</sup>, Tomohiro Uesaka<sup>3</sup>, Vadim Wagner<sup>1</sup>, Kazuki Yoshida<sup>13</sup>, Juzo Zenihiro<sup>3,7</sup>, Thomas Aumann<sup>1,2,14</sup>

J. Tanaka *et al.*, Science 15 (2021)

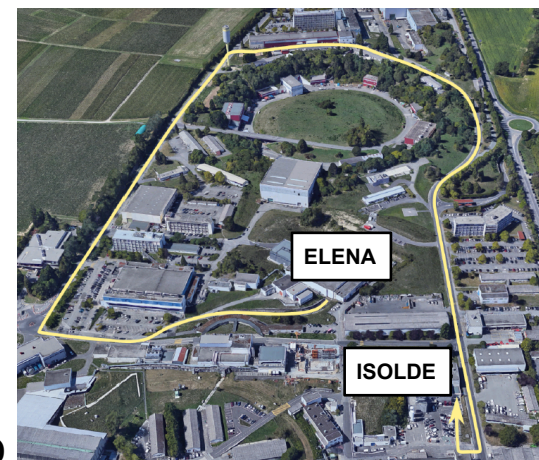


S. Typel, PRC 89 (2014)



# The PUMA experiment

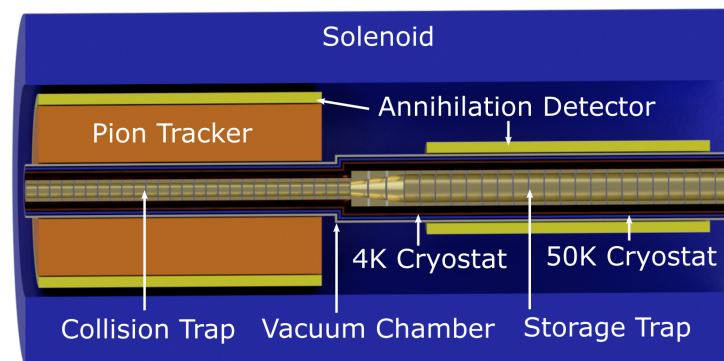
- **Transport antiprotons** from ELENA to ISOLDE
- Store  **$10^9$  (first phase:  $10^7$ ) antiprotons** at **ELENA**
- Antiproton plasma **half-life > 30 days**
- Low energy (<100 eV) ions at **ELENA & ISOLDE**
- Measure charged pions resulting from annihilation
- Charge conservation: neutron-to-proton annihilation ratio



**Extracted from data**

Emitted pions  
Multiplicity  $M$   
Total charge  $\Sigma$

$$\Leftrightarrow \left( \frac{N_n}{N_p} \right) \Leftrightarrow \frac{\rho_n}{\rho_p} \text{ density tail}$$



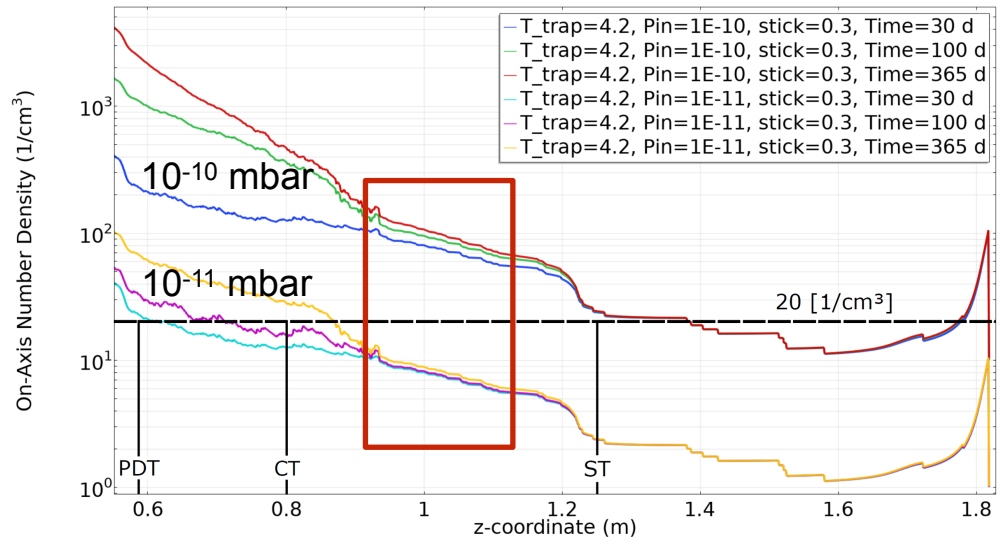
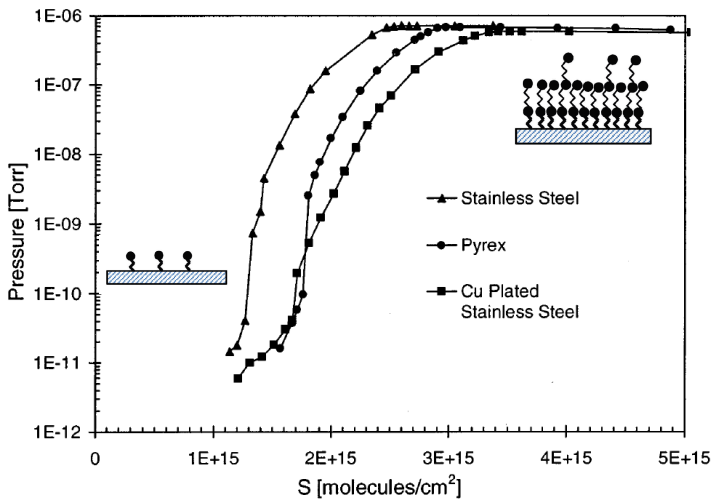
*Acknowledgement: PUMA relies on techniques developed by AD experiments over the past years.*

PUMA collaboration, submitted for publication (2022)

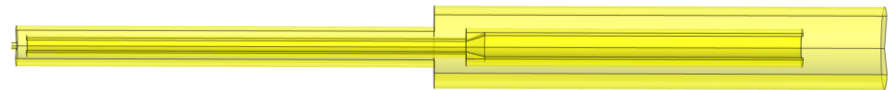




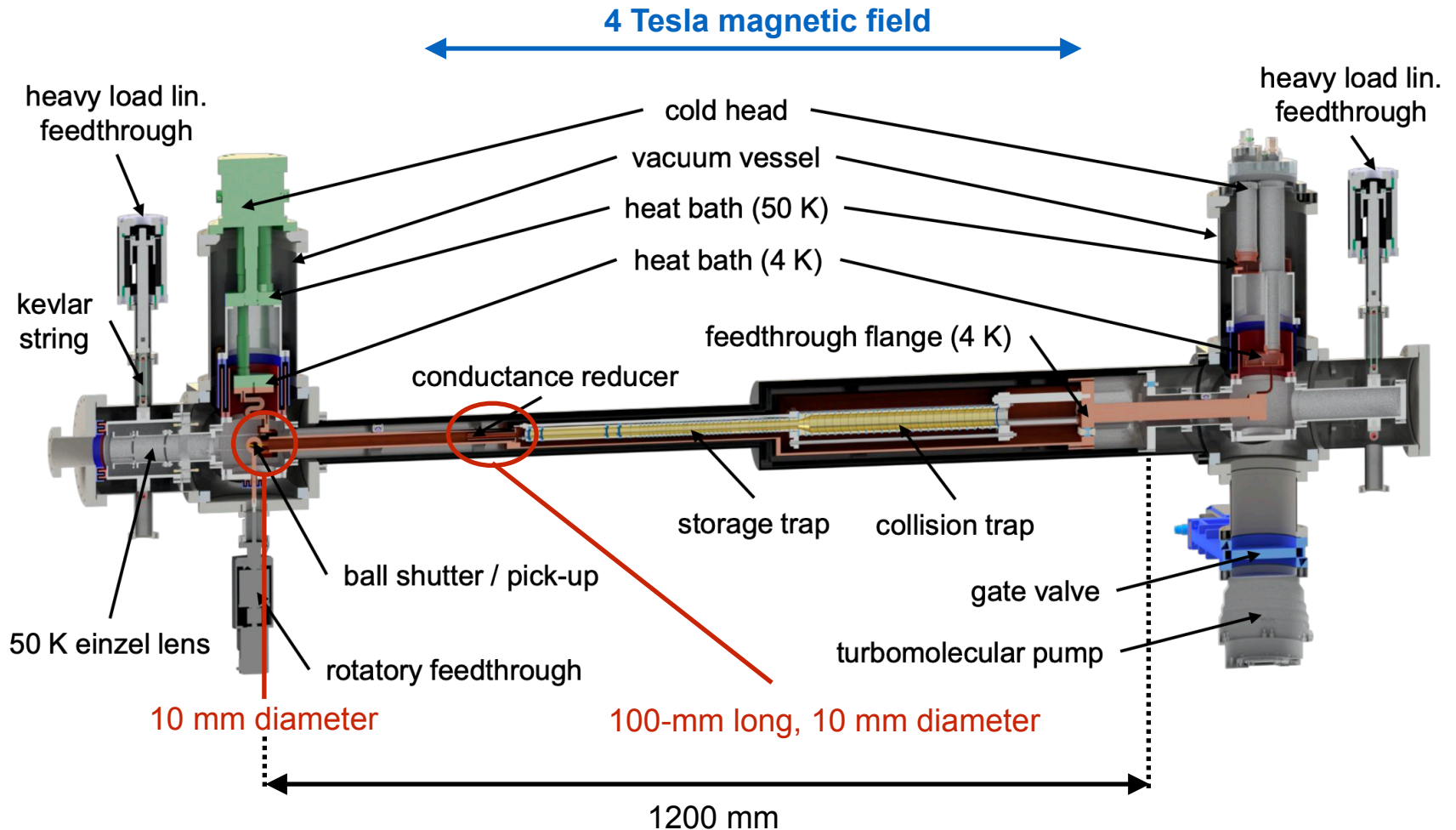
- Antiproton-cloud lifetime and measurement background driven by residual gas
- Extreme vacua (XHV) reached by sub-monolayer cryosorption
- PUMA cryostat designed for  $< 20 \text{ cm}^{-3}$  residual gas for  **$10^{-11}$  mbar at entrance**



- R&D and simulations by / with TE-VSC group

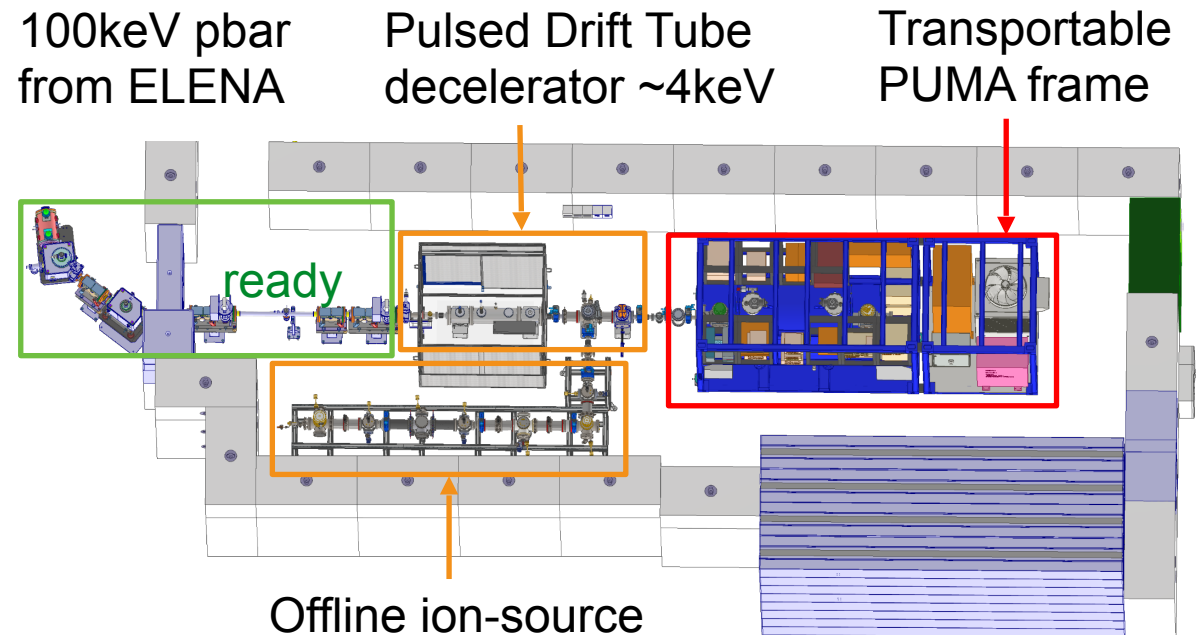
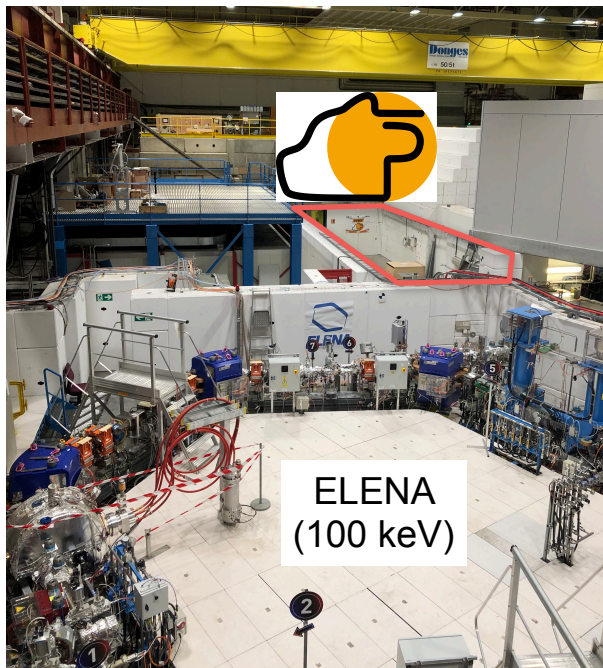


# Trap geometry



# PUMA at ELENA

- Experimental line LNE51
- Antiproton beam line: deceleration (to 4 keV), focusing and monitoring, XHV
- Offline ion source: isotopic separation, cooling and bunching, XHV
- Beam line to be **finalised in 2022**



# PUMA at ELENA



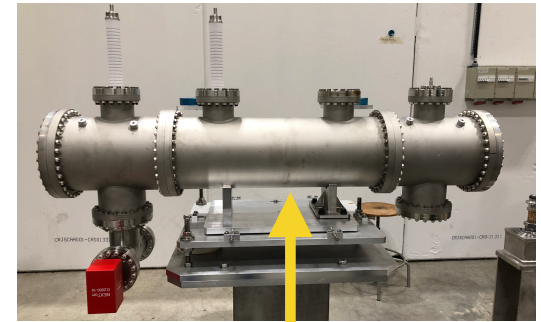
TECHNISCHE  
UNIVERSITÄT  
DARMSTADT

## Antiproton beam line:

- NEG coating of beam-line elements validated
- assembly finalized at 90%
- pulsed drift tube (PDT) installed
- most of Faraday cage mounted
- Vacuum PDT:  $1 \cdot 10^{-11}$  mbar (NEG activated)
- full beamline (NEG not activated):  $1 \cdot 10^{-9}$  mbar
- detection for beam transmission tests in progress
- diesel power generator purchased
- Power line on ELENA 50t crane installed

## Next steps:

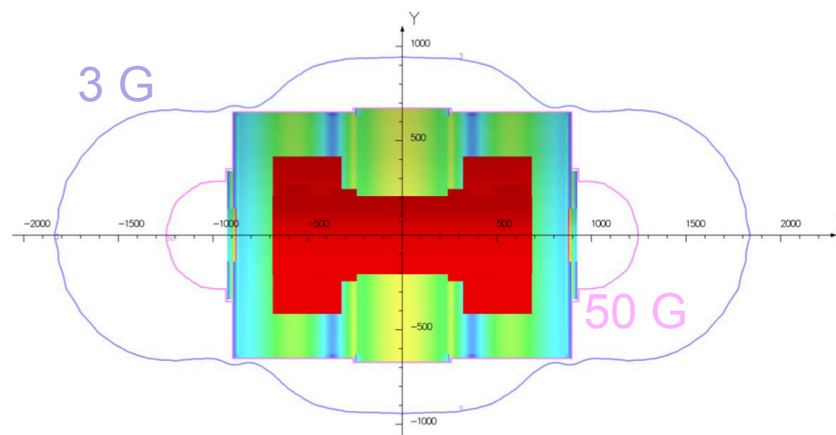
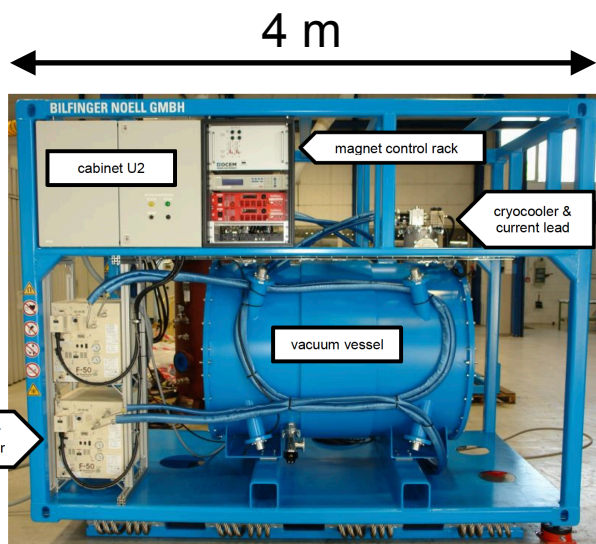
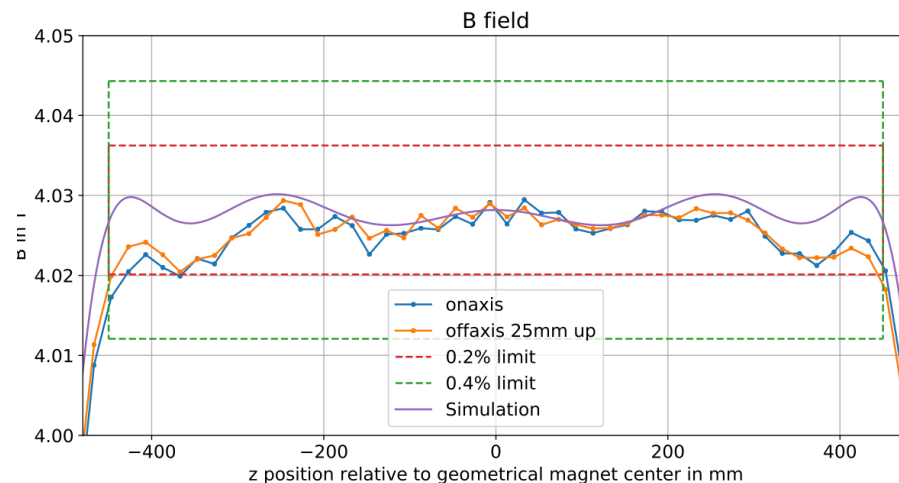
- finalisation antiproton beam line (June 22)
- PDT validation (July 22)
- transmission of antiproton beam (July 22)**
- offline ions source at ELENA (Feb 23)
- full PUMA system at ELENA (May 23)**





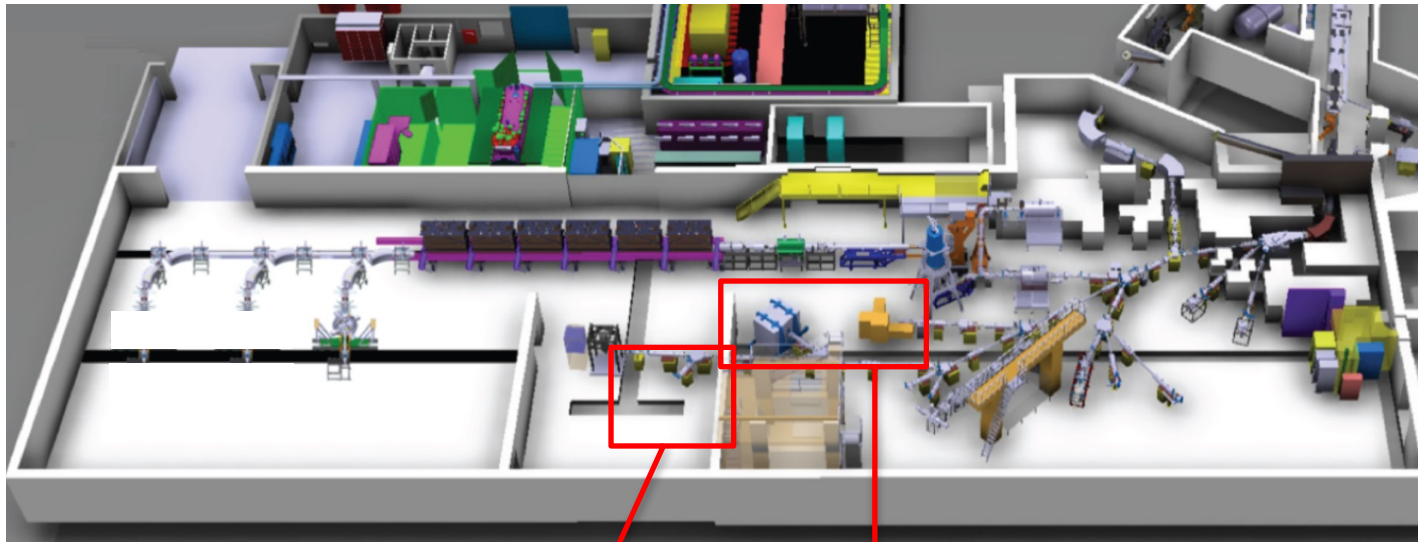
# The PUMA solenoid

- Transportable 4 T solenoid **delivered**
- 28-cm warm bore
- Homogeneity < 0.2%
- Dry (no helium)
- Active and passive shielding
- Switch and UPS for power changes
- Total weight: 9 tons
- Built by Noell - Bilfinger (Germany)



# PUMA at ISOLDE

- First experiments at ISOLDE foreseen in Q1/2024
- Low-energy beam line is CERN responsibility (ISL-LJ-EC-0006). **Today's topic.**
- Project leader: O. Aberle



## PUMA experimental zone

- XHV ( $10^{-11}$  mbar)
- Beam size  $< 2$  mm

## Low energy beam line

- Bunching (Paul trap)
- Isotopic selection (MR-TOF)
- UHV (better than  $1 \cdot 10^{-8}$  mbar at HOP)

