TECHNISCHE UNIVERSITÄT DARMSTADT

PUMA
SPSC MEETING 2023

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AGENDA

1 Experiment overview

2 ELENA beam line

3 Offline ion source

4 Traps

5 Pion detection

6 The ISOLDE low-energy beam line

7 Theory

8 Agenda for 2023

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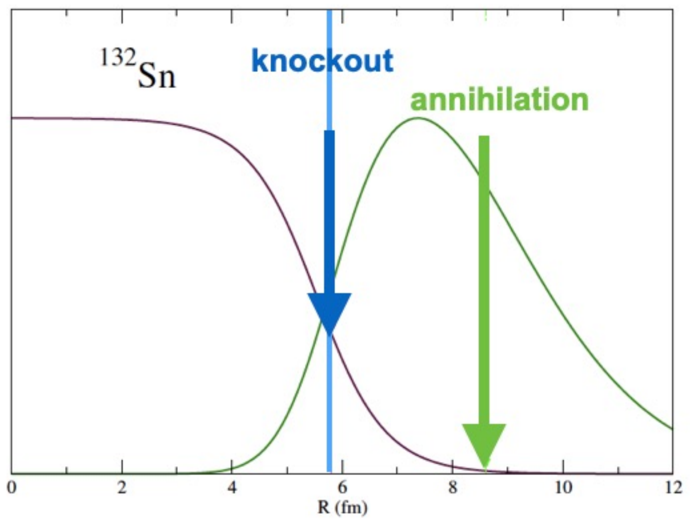
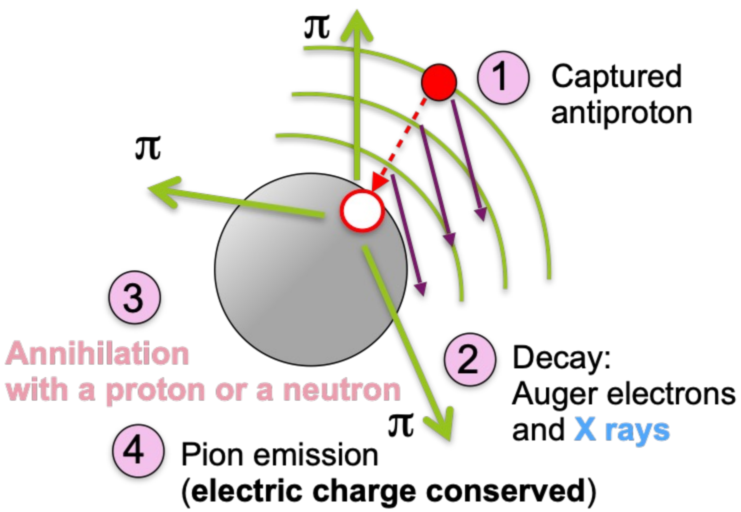
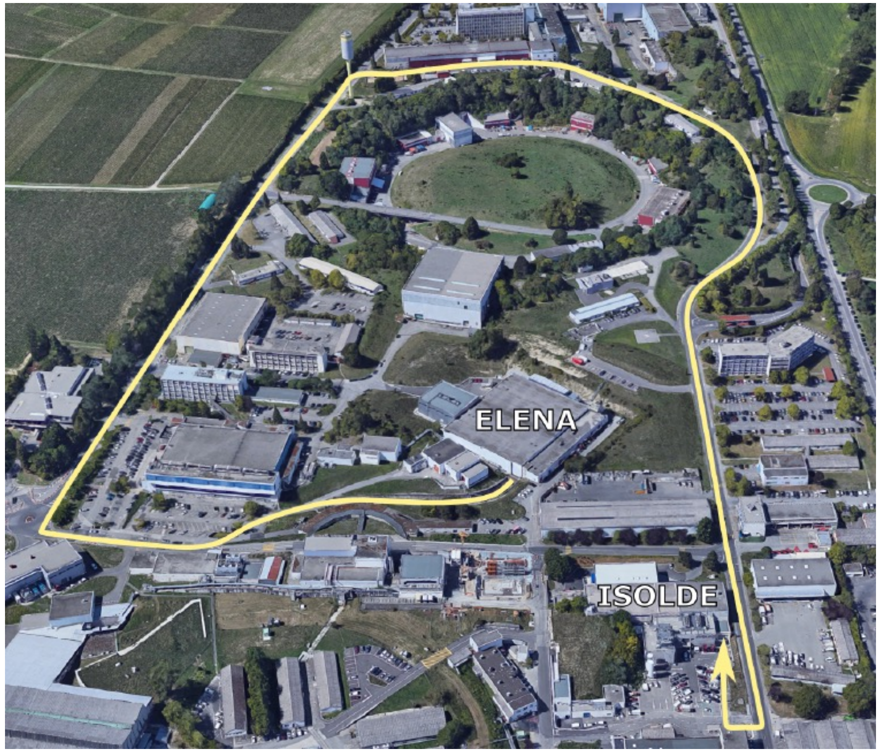
NEUTRON SKINS AND HALOS







PUMA aims at characterizing the neutron-to-proton content of the nuclear density tail of stable and unstable nuclei from antiproton-nucleus annihilations.

T. Aumann *et al.* (PUMA Collaboration), EPJA 58, 88 (2022).

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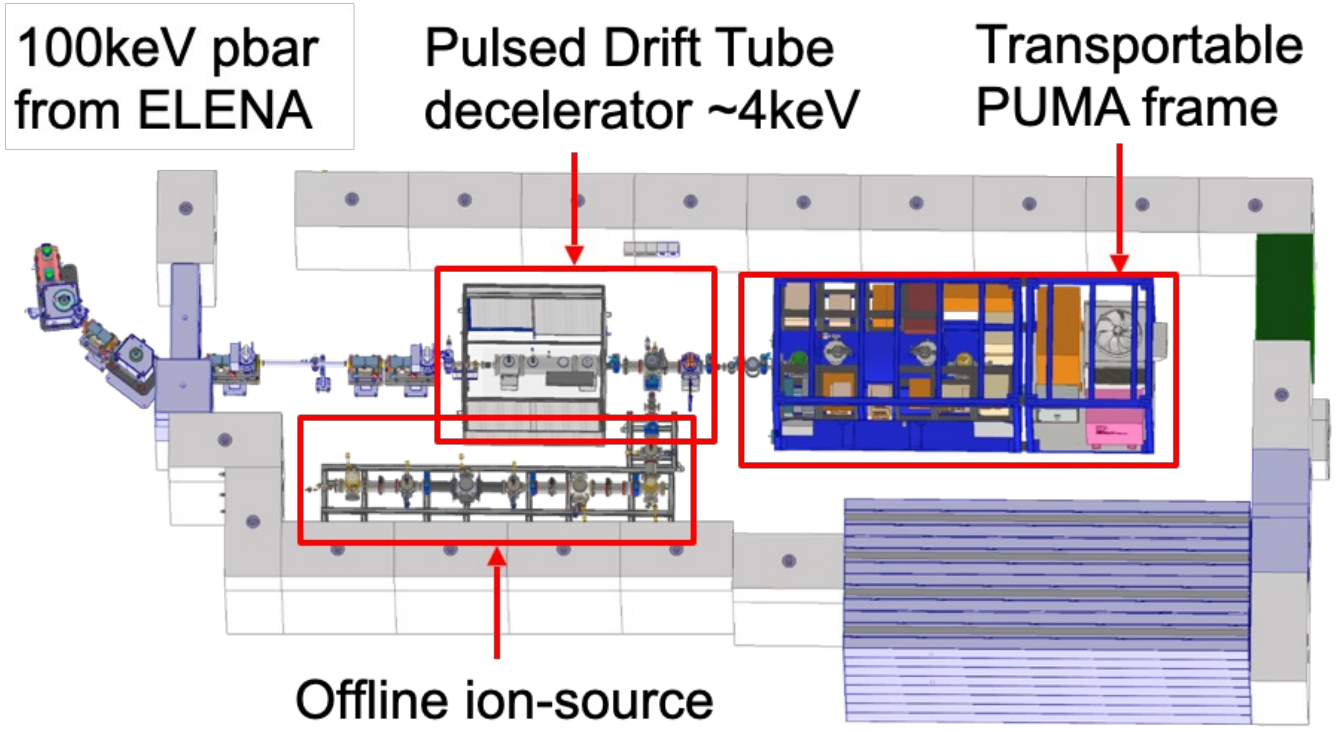
PUMA @ ELENA

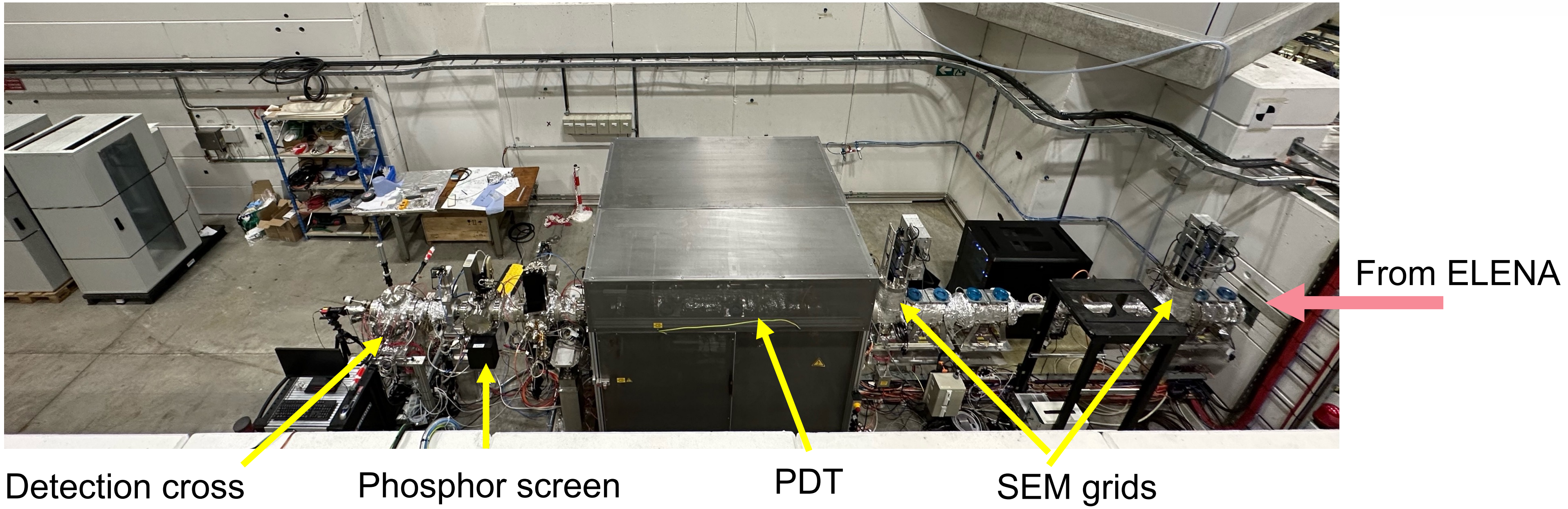
Three main sections at ELENA:

- The 4 keV antiproton beam line
- The transportable apparatus (trap and detection)
- The offline ion source

All parts under construction.

Completion planned for 2023.





MILESTONES REACHED IN 2022:

- CERN infrastructure completed and PUMA antiproton beam line installed
- NEG coating activated and validated (1.6 10^{-11} mbar at PDT, slightly better than simulations)
- Pulsed Drift Tube (PDT): built, safety cage installed and validated, PDT conditionned up to 100 kV
- Transmission of antiprotons and slowing down to 4 keV (November 2022)

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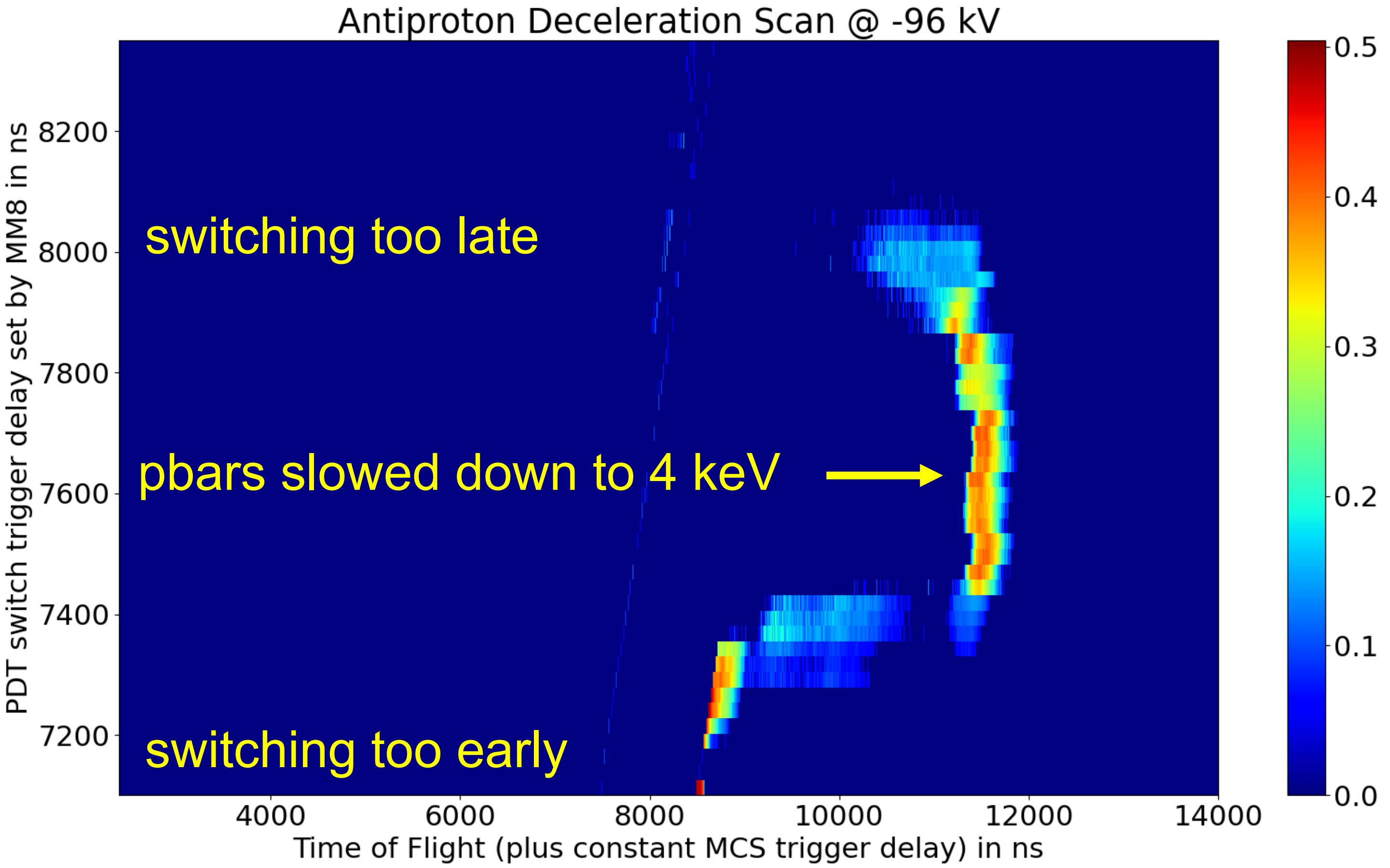
SLOWING $\bar{p}$ TO 4 KEV

The pulsed drift tube was switched from -96 kV to 0 V in 80 ns (1/e). The timing of the switching was adjusted. Antiprotons were slowed down to 4 kV in a reproducible manner with 166(7) eV energy spread and 302(20) ns length [25 cm].

PDT was brought to HV few seconds before the beam arrival to minimize vacuum degradation.



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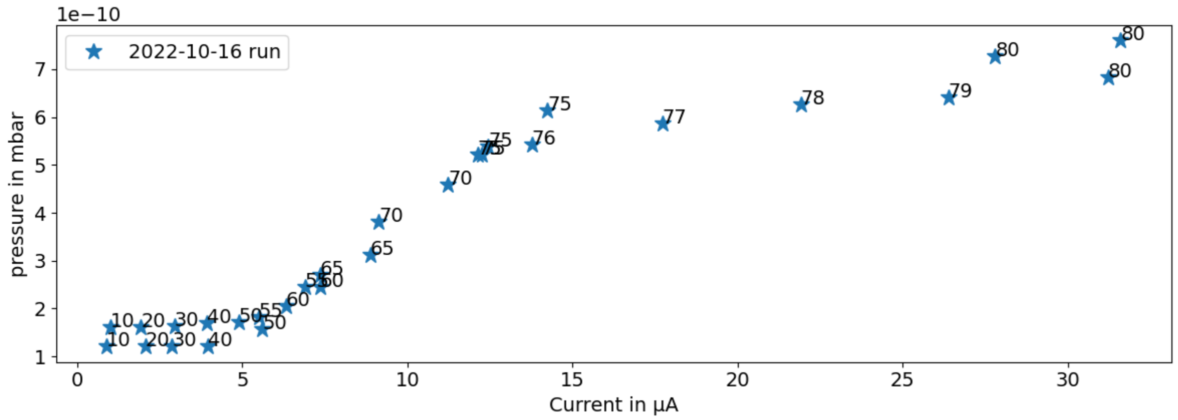
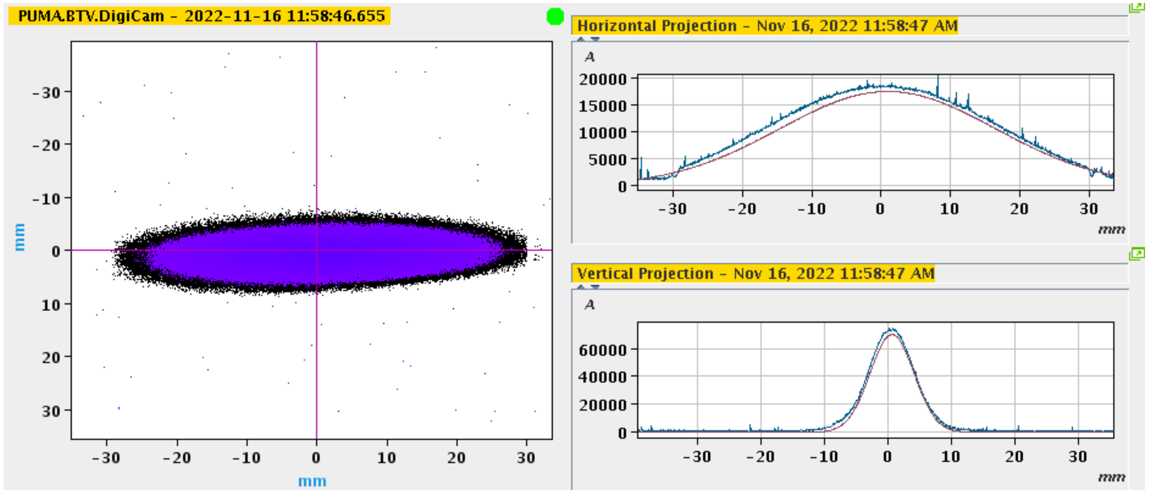
PLANS FOR 2023

During this first beam time, one focusing Einzel lens could not be brought to nominal voltage (85 kV) due to large leakage current. We believe that it was caused by the lens design with too close distance between electrode to ground. This will be modified in February 2023.



ELENA beam optics for short bunches led to large „x“ beam size (40 mm FWHM at BTV).



Milestones until June 2023:

- Change of Einzel lens design
- Optimisation of PDT HV-to-ground distances
- Measurement and optimisation of transmission with $\bar{p}$

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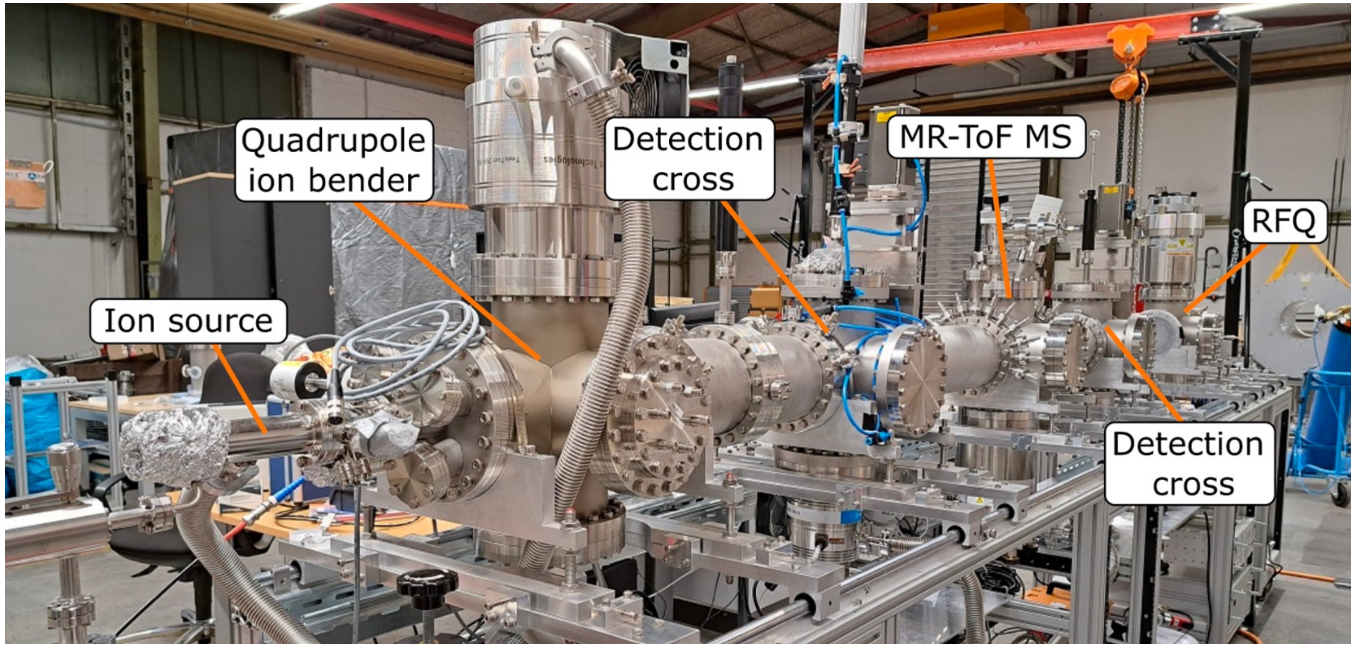
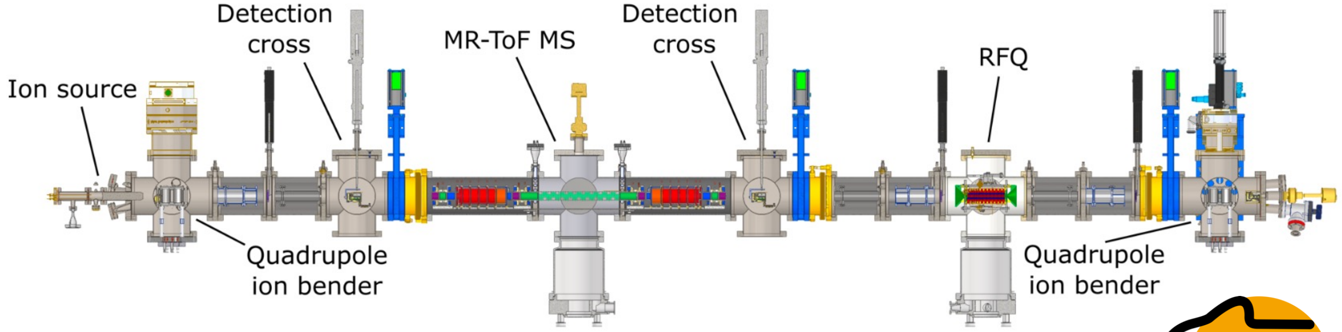
ISOTOPICALLY PURE STABLE ION SPILLS

- Source, MR-TOF and Paul trap built
- All assembled at TU Darmstadt
- Vacuum validated to 10^{-9} mbar

Milestones in 2023:

- Operation of full beam line at TU Darmstadt
- Characterisation (purity, spill structure, optics)
- Assembly at ELENA
- Injection of ions inside PUMA





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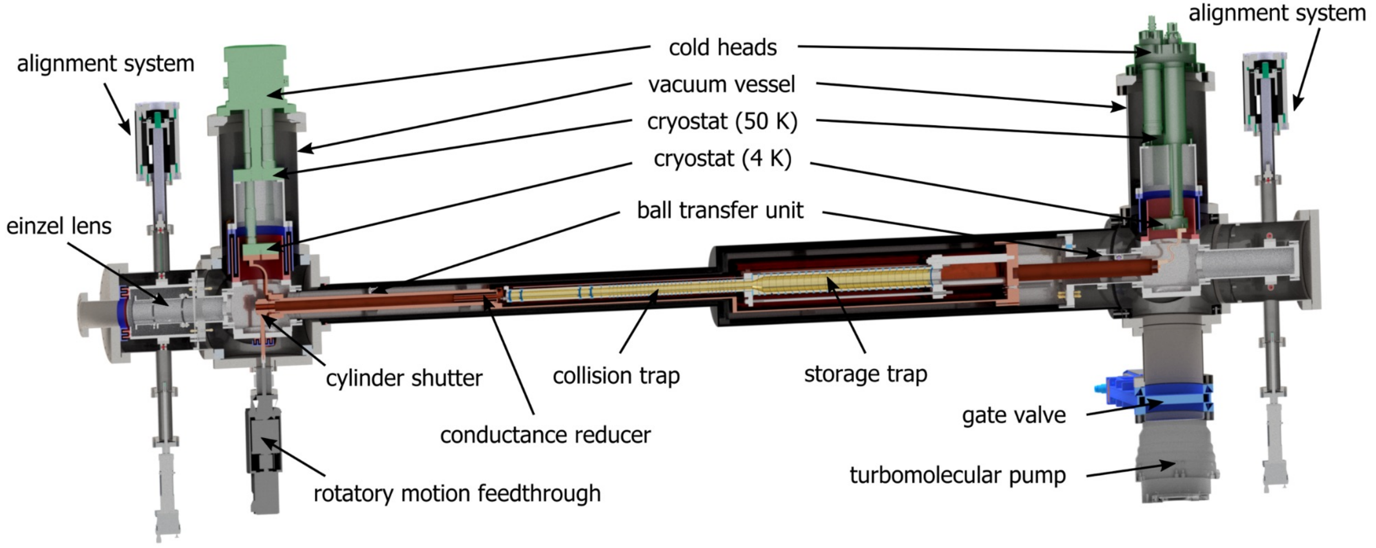
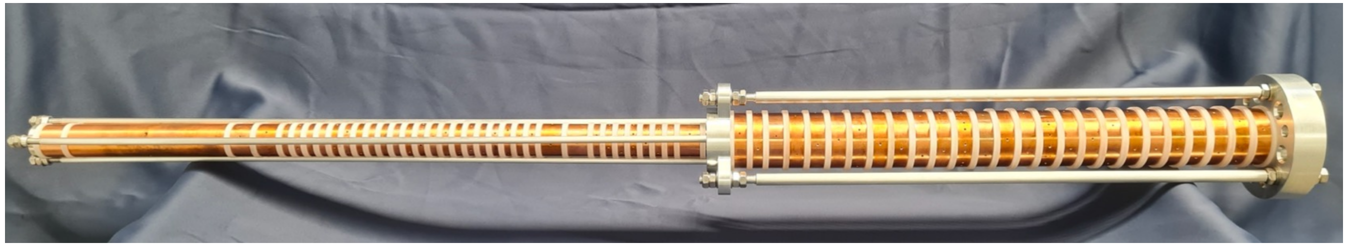
TRAP & CRYOSTAT

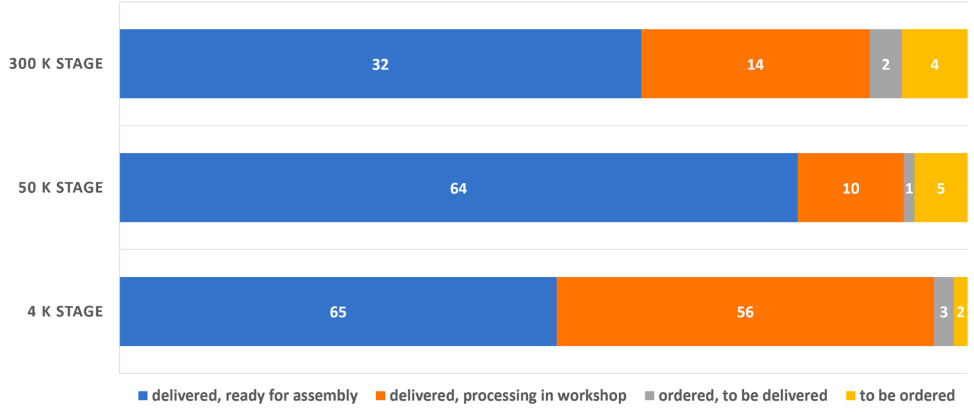
- design completed
- > 90% of components received
- front rotating beam shutter last item designed



Milestones in 2023:

- Full assembly inside magnet
- Electronics filter boards at 300 K
- Development of plasma simulations and test setup at TUDa





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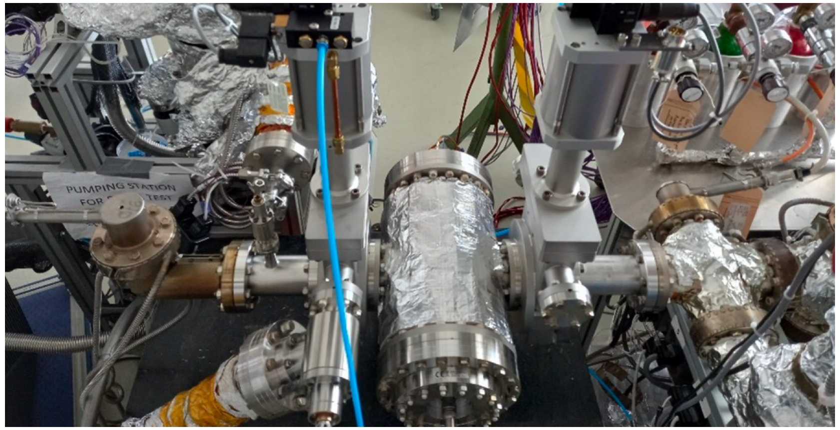
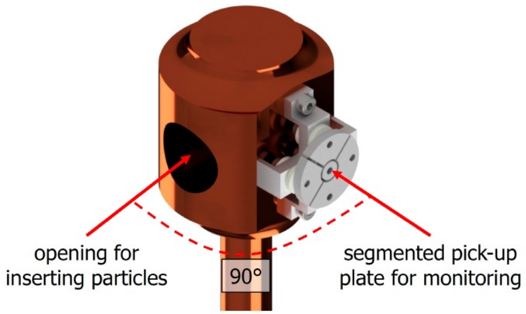
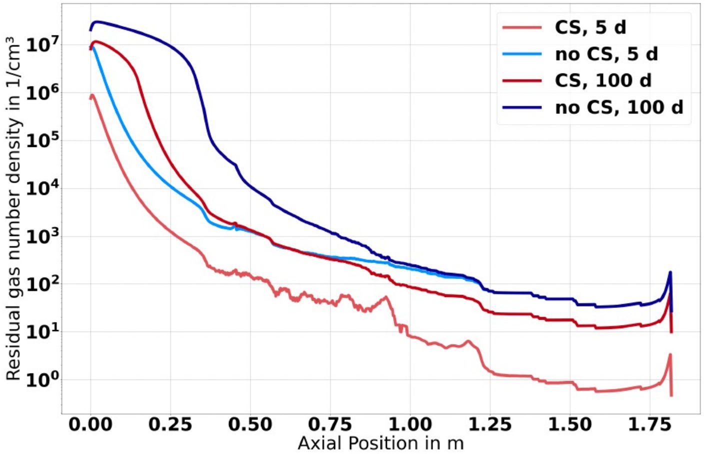
VACUUM IN FRONT OF PUMA

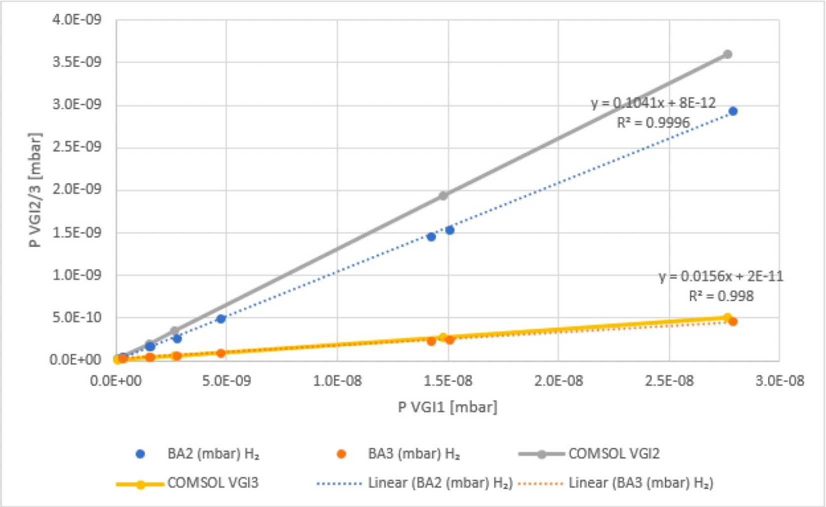
A major requirement of the antiproton beam line is to bring the vacuum down to 10^{-11} mbar in front of the apparatus. This is reached by a NEG coated cross connected to two Z1000 NEG pumps. The cross was tested. Results agree with simulations.

A rotating beam shutter to reduce conductance in front of the trap will be implemented. Parts are being procured.









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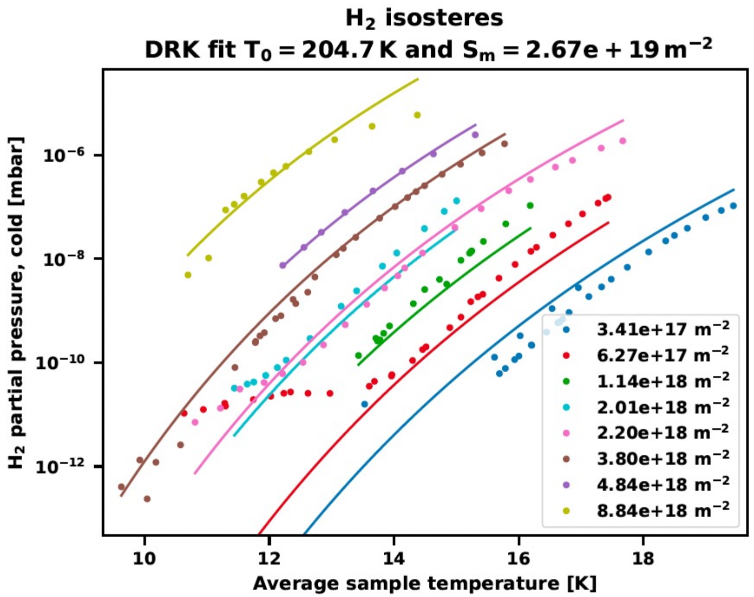
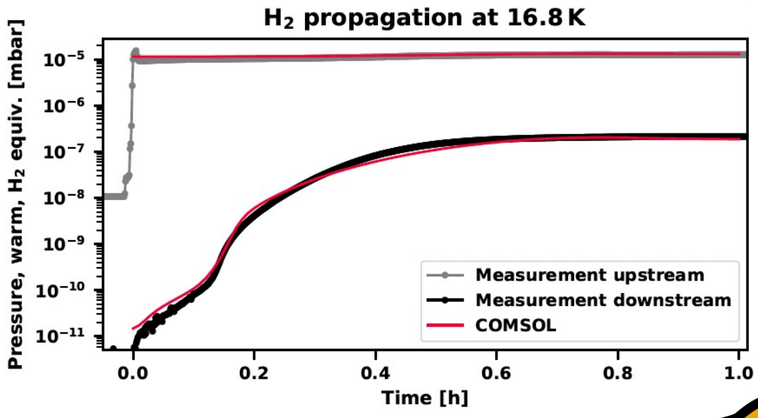
MEASUREMENTS OF H_2 AND HE ISOSTERES

The high vacuum required in the PUMA traps is reached by cryosorption with sub-monolayer coverage of cold surfaces. The DRK model is the most probable model to be valid in this regime. The parameterization of its two free parameters S_m and T_0 were uncertain. A series of isostere measurements were performed for H_2 and He.

Experimental results compared to COMSOL simulations with DRK parameterization.

Preliminary results are: $S_m(H_2)$=2.7 10^{19} m^{-2}, $T_0(H_2)$=205 K, leading to slightly better vacuum than with the initial parameterisation used for the design of PUMA.





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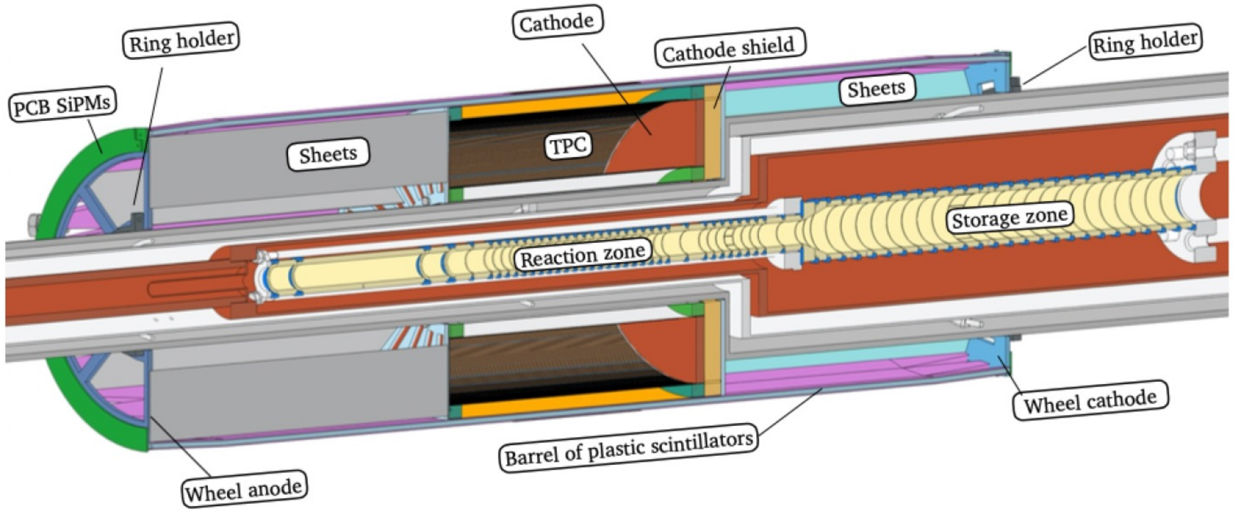
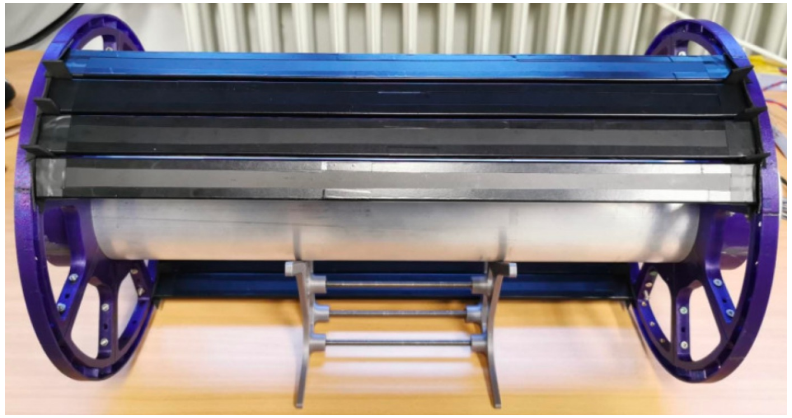
TPC AND TRIGGER BARREL

- TPC under completion at CERN
- TPC readout (ARC, CEA) procured and tested
- Gas system under completion
- Prototype plastic barrel with SiPM readout built
- Barrel readout (TRB3, GSI) procured and tested

Milestones until July 2023:

- ^{55}Fe validation of Micromegas
- Assembly of TPC and barrel
- Cosmic-ray validation
- Final (long) plastic barrel completion





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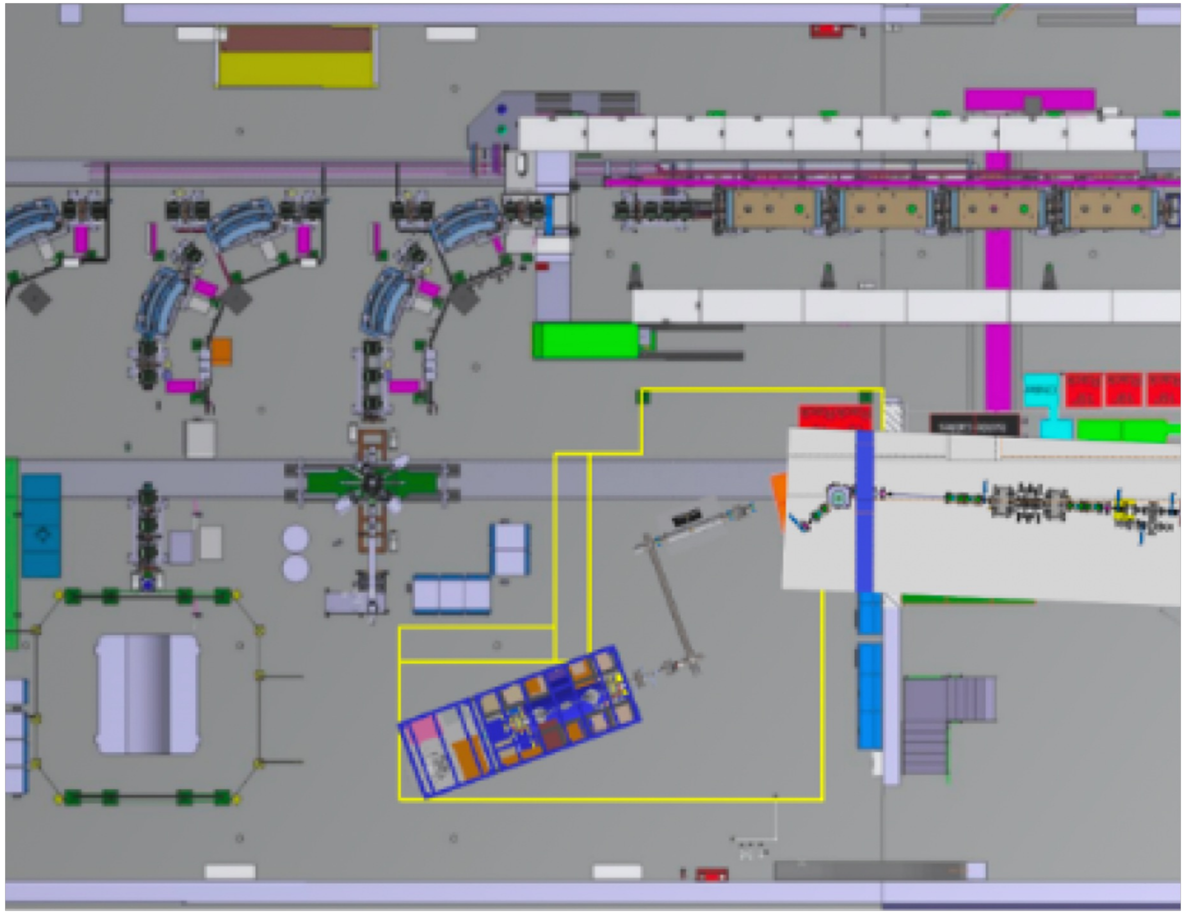
PUMA @ ISOLDE

CERN as a host has the responsibility of the low-energy beam line aiming at providing bunches of isotopically pure radioactive ion bunches. The PUMA collaboration has the responsibility of the transfer line from the HOP to PUMA.

- Dedicated CERN project initiated (leader: O. Aberle)
- First emittance measurements
- First design of the low-energy beam line



Milestones in 2023:

- Finalisation of emittance measurements
- Vacuum and optics simulations
- Finalisation of beam line design
- Collection of all elements, start installation
- PUMA@ISOLDE ECR submitted
- First physics proposal submitted to ISOLDE

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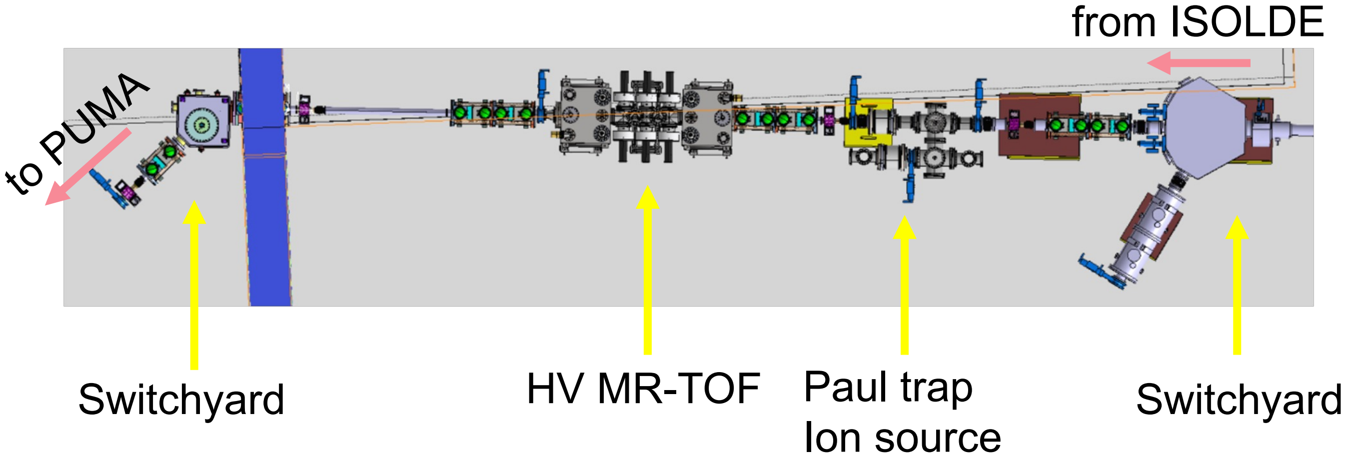
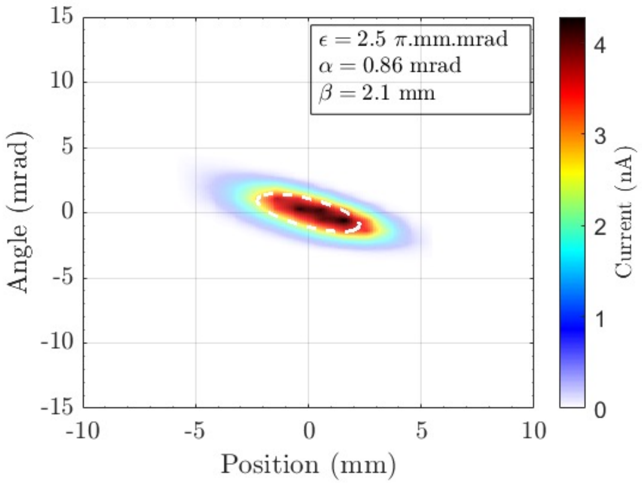
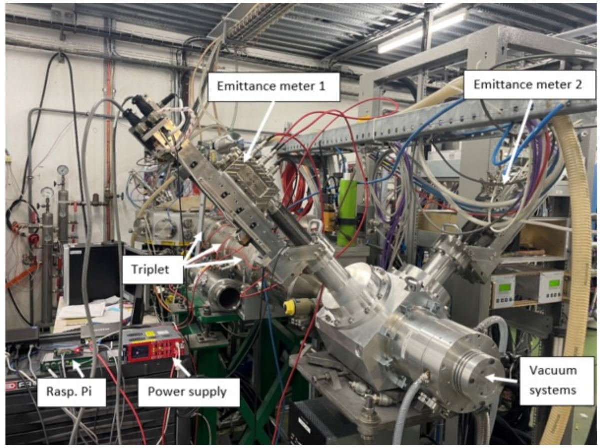
THE RC6 LOW-ENERGY BEAM LINE



- Paul trap and HV MR-TOF from MIRACLS
- Use of existing magnets and switchyards
- First emittance measurements in December 2022:
    - Allison scanners from TRIUMF
    - 30 keV $^{39}K^{+}$ ions (80 nA)
    - transmission of 95%
    - emittance of 2.5-3.9 π mm.mrad





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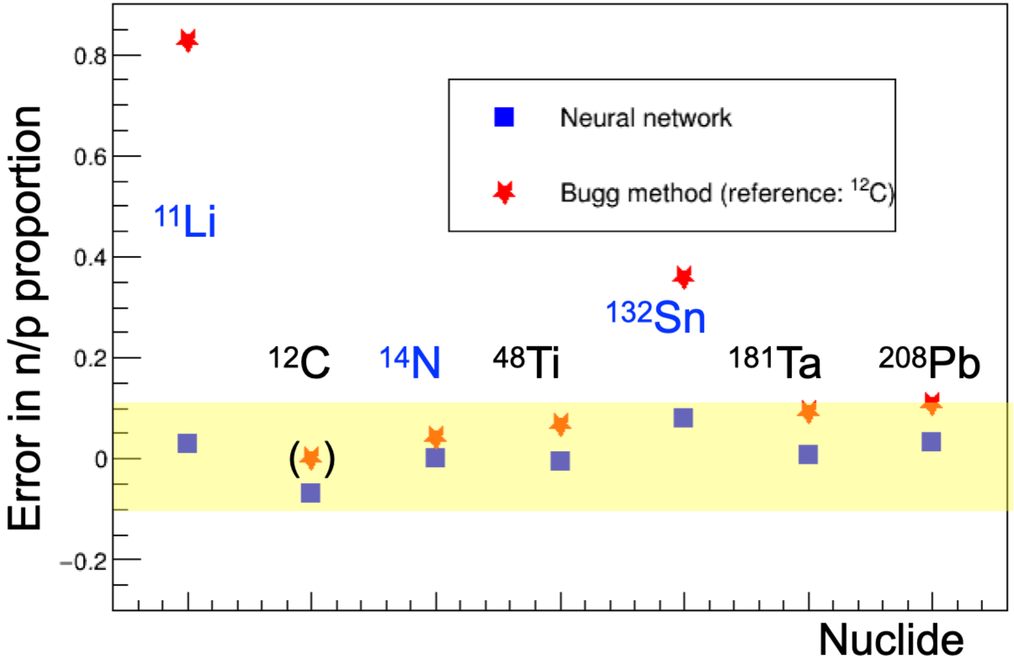
AB INITIO AND ANALYSIS METHODS

The physics of PUMA depends on theoretical interpretation. Theory developements within the collaboration aim at computing (1) the nuclear densities of studied nuclei from ab initio methods, (2) the observable of PUMA. In particular, the sensitivity of PUMA is limited by the final-state interactions (FSI) of pions with the residual nucleus after annihilation. (3) We also aim at an improved microscopic description of the capture process.

Achieved in 2022:

- Improvement of $N\bar{N}$ potentials towards ab initio calculations
- Data-driven analysis method based on neural network, starting from the initial idea by Wychech, Wada and Yamazaki to correct from FSI



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MILESTONES AND TIMELINE

ELENA

- Validation of full antiproton beam line (June 23)
- Full assembly of PUMA at ELENA (Sep. 23)
- Installation of offline ion source (Sep. 23)
- First antiproton trapping and vacuum estimate (Nov. 23)

If possible, an attempt of antiproton transport will be made.

ISOLDE

- Final design of RC6 and transfer lines (May 23)
- Collection of elements for RC6 beam line (Nov. 23)

	Feb. '23			May. '23			Aug. '23			Nov. '23		
Antiproton beam line modifications	■	■										
Antiproton beam line validation				■	■◆							
Assembly PUMA cryostat at TUDa			■	■	■							
Trapped e^- and transport (TUDa)					■	■						
PUMA apparatus installed at ELENA								■◆				
Antiproton trapping and vacuum estimates									■	■◆		
Characterization offline ion source (TUDa)	■	■	■	■								
Installation of offline ion source at ELENA							■	■				
Ion injection and trapping into PUMA											■	■
Emittance measurements at ISOLDE	■											
Design of ISOLDE beam lines		■	■	■◆								
Procurement and collection of elements					■	■	■	■	■	■◆		
Start of installation of ISOLDE lines											■	■