MLLTRAP & LINO projects in France

Framework: "adaptation of experimental devices for their use with DESIR"
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2014 – 2022→2023: Commissioning of LINO and measurement campaign @ ALTO
DESIR Laser workshop 14/11/2019

2016 – 2025→2026: Commissioning and upgrade of MLLTRAP + mass measurement campaign @ ALTO
DETRAP workshop 16/06/2020
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People involved at IJCLab

Scientific poles: Accelerator and Nuclear Physics:
E. Minaya Ramirez, A. Leite, L. Perrot, D. Lunney, K. Hauschild, A.Lopez-Martens,
V. Manea, S. Franchoo, D. Yordanov

+ strong support Mechanical engineering from Engineering pole and ALTO platform

Postdocs: P. Chauveau (2017-2019)
**MLLTRAP & LINO : Physics cases**

**MLLTRAP**

**MLLTRAP**

**Fundamental observables to test state-of-the-art nuclear theories**

1. **B(N,Z)**: Nuclear binding energy

2. **M_{\text{atom}}(N,Z) = M_{\text{nuc}}(N,Z) + Z^*M_e - B_{\text{el}}(Z)**

3. **M_{\text{nuc}} = Z^*M_p + N^*M_n - B(N,Z)**

**LINO**

1. **I** (Spin)
2. **µ** (Magnetic moment)
3. **Q_s** (Quadrupole moment)
4. **δ<r^2>** (Charge radii)

- Structure \ Wave function
- Correlations and deformation
- Shape coexistence

**Collinear (high-resolution) laser spectroscopy (I, µ, Q_s, δ<r^2>)**

**β-NMR and β-γ asymmetry (I, parity)**
High-precision mass measurement of silver isotopes (A=113 – 129) towards the N=82 shell closure

> First request of silver isotopes at ALTO

2019 Jyväskylä: masses measured up to $^{125}\text{Ag}$

Laser spectroscopy of $^{111}$-$^{120}\text{Ag}$
Ground-state electromagnetic moments and rms charge radii measurements.

laser spectroscopy $^{96}\text{Ag}$ to $^{121}\text{Ag}$
First operational RIB facility based on photo-fission → populating the GDR of $^{238}\text{U}(\sim 10^{11} \text{ f/s})$

- 50 MeV & 10 µA e⁻ beam
- UCx target (~70g, ~140 pellets)
- Magnetic dipole PARRNe → A selection (M/ΔM = 1500)
- **RIALTO : laser source** → Z selection of elements

Switch between both laser schemes successfully validated during offline commissioning (09/2022)
ALTO-LEB : Robotic Frontend (FRISAL)

https://alto.ijclab.in2p3.fr/
ALTO-LEB: reliability and sustainability

June 2022

Emittance meter from


Identification station/COeCO

TETRA / FRØZEN

BEDO

Kicker-Bender (35°)

Master project connected to DESIR

MLLTRAP & LINO @ ALTO: setups

- Beam manipulation
- Beam preparation
- Beam transport

**RIB ~ 0.1 keV**

**RIB ~ 3 keV**

**RIB ~ 30 keV**

**MLLTRAP**

**LINO**
MLLTRAP & LINO @ ALTO: setups

**MLLTRAP**

- Beam manipulation
- Beam preparation
- Beam transport

- RIB ~ 0.1 keV
- RIB ~ 3 keV
- RIB ~ 30 keV

**LINO**

- Faraday cup
- Electrostatic optics
- Post-acceleration & neutralization
- Merging bender
- Fluorescence detection
- Valve
- Exit window

- RFQCB 90° Bender
- 90° Bender
- 59° Bender
- 35° Bender

- Bender 59°
- Bender 35°
In-trap decay spectroscopy for MLLTRAP

- Decay experiments with carrier-free particles stored in a Penning trap enable studies on ideal ion samples.
- The improved energy resolution can be exploited for high-resolution α- and electron-decay spectroscopy.

- Design fixed, all mechanical parts and insulators received in 2020.
- Gold plating of all the electrodes performed in October 2022
- The next step is the mechanical assembly

P. Chauveau et al., NIMB 982 (2020) 164508
P. Chauveau et al., NIMB 463 (2020) 371
LINO (Laser-induced nuclear orientation ($\mu, Q, J^p$))

Offline commissioning of LINO → October 2019

Figure 2. Fluorescence spectrum of the $D_1$ line in $^{23}$Na ($I^\pi = 3/2^+$). Each transition is denoted in parentheses by the total angular-momentum quantum numbers of the lower and the higher state, respectively. The frequency scale is relative to the fine-structure splitting.

D.T. Yordanov et al., Journal of Instrumentation, 15 06004 (2020)
LINO (Laser-induced nuclear orientation (μ,Q, J^p))

New Millennia eV, 532 nm pump laser bought to replace the old Ar-ion laser in order to be ready for on-line experiments.
Organized by S. Franchoo

- Possibility of using LINO through a new collaboration around molecular beams.
- Measurement of Emittance required to estimate the beam temperature.
Beam transport

MLLTRAP @ ALTO-LEB : Beam transport

59° Bender

Beam transport

Delivery expected 11/2022 → 05/2023

Beam profile monitor from

Electrores Orak-3T - A4F

Simulation covered a large energy range: 1, 10, 30 and 50 kV were validated

→ Ready to be commissioned

Alkali source
Einzel lens
90° Bender
High voltage ion source

21/07/2022
Enrique Minaya Ramirez – GCM - DESIR Session - Caen
MLLTRAP @ ALTO-LEB : Beam preparation

Paul trap

\[ \Phi_0(t) = V_{dc} - V_{RF} \cos(\Omega t) \]

Deceleration area

RFQ Cooler & Buncher

Pulse drift tube

HV - 3 kV

DC potential

0 kV

HV

He gas

trapping

ejection

Distance

Time

RFQCB: Radio-Frequency Quadrupole Cooler and Buncher
SIMION simulations at the injection point (blue color) and after having been cooled and bunched (in red).

Emittance at injection ~ 20 \( \pi \).mm.mrad and ~ 3 \( \pi \).mm.mrad at ejection, both at 60keV.

• Electronics and pumping material received with a large delay.
• All the mechanical parts have been delivered. The assembly of the different parts are in progress.
• The alignment of the supports are currently in progress at ALTO
MLLTRAP @ ALTO-LEB : Beam manipulation

- Alignment of the vacuum tube axis with magnetic field lines was impacted by the installation and validation of the magnetic probe. The alignment is now finished (misalignment angle : 1.1 ± 0.1 mrad)

- Bender, injection electrodes and diagnostic system (faraday cup and microchannel plate) operational (tested with an alkali ion source).

- Upgrade of the control system in progress. Coupled with the installation of the MCP delay line (for PI-ICR).

- Installation of Penning traps in progress.
MLLTRAP @ ALTO – Beam manipulation

- Probe developed by Caylar to track magnetic field evolution in real time.
- Probe located in the gap between bore’s magnet and the vacuum tube.  
  → non-linear field drifts during long measurements

- Coupled to the bore temperature. Currently $10^{-7}$ precision.
MLLTRAP @ ALTO-LEB : Beam manipulation

- Pumping barrier
- Measurement Trap (MT)
- Purification Trap (PT)
- Diaphragm

**Beam manipulation**

- Mass resolving power of 1,000,000 → separation of isomers

- Time of Flight Ion-Cyclotron-Resonance (TOF-ICR)

- Mass resolving power of 100,000 → separation of isobars
MLLTRAP @ ALTO-LEB: Beam manipulation

Mass resolving power of 100 000 → separation of isobars

Phase Imaging Ion-Cyclotron-Resonance (PI-ICR)

$$\varphi + 2\pi n = 2\pi v t$$

$$\Delta \nu = \frac{\Delta \varphi}{2\pi t} = \frac{\Delta R}{\pi t R}$$
MLLTRAP @ ALTO-LEB: Beam manipulation

Mass resolving power of 100 000 → separation of isobars

\[ \phi + 2\pi n = 2\pi vt \]

\[ \Delta \nu = \frac{\Delta \phi}{2\pi t} = \frac{\Delta R}{\pi t R} \]
MLLTRAP and LINO : Perspectives

- LINO was commissioned off-line in October 2019.
- Preparation and manipulation sections of MLLTRAP are under progress.
- The Offline commissioning of MLLTRAP will be performed with a high voltage source.
- Both experiments could benefit of the future radioactive beams produced at ALTO.

Thank you for your attention !