MATS and LaSpec: Status and first experiments

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International Conference on Science and Technology for FAIR in Europe 2014
Worms, October 2014
Precise Measurements on very short-lived nuclei using an Advanced Trapping System

Laser Spectroscopy on very short-lived nuclei

in NUSTAR

at the end of the Low Energy Branch (LEB) of the Super-FRS
Outline

- Physics motivation
- The collaborations and the facilities
- Staging at FAIR
- Developments with prospects for MATS and LaSpec
- Summary & outlook
Motivation for MATS at FAIR
Precise mass measurements on short-lived isotopes

(talk by K. Blaum)
1. Nuclear structure
2. SHE
3. Halo nuclei
4. Astrophysics
5. Fundamental interactions
6. Neutrino physics
7. Discovery of new isotopes
8. In-trap decay spectroscopy
9. Trap-assisted spectroscopy
10. Spectroscopy on HCI
11. Laser-spec on HCI with LaSpec
Motivation for LaSpec at FAIR
Laser Spectroscopy on short-lived isotopes

1. Isotope shifts
2. Charge radii
3. Nuclear spins
4. Hyperfine structure
5. Nuclear magnetic moments
6. Electric quadrupole moments

Further from Stability
→ Collinear Resonance Ionization (CRIS)

Refactory Elements around Shell Closures → Bunched Beams + RFQ-Optical Pumping

Clusters and Halos

High accuracy required → Simultaneous collinear and anti-collinear spectroscopy
<table>
<thead>
<tr>
<th>ISOL</th>
<th>Fusion</th>
<th>IGISOL</th>
<th>Neutron Induced fission</th>
<th>Spontaneous fission</th>
<th>Photo-induced fission</th>
<th>Fragmentation</th>
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<tr>
<td>ISOLTRAP</td>
<td>SHIP TRAP</td>
<td>JYFL TRAP</td>
<td>TRIGA-TRAP</td>
<td>CARIBU Laser Spec</td>
<td>ALTO (Orsay)</td>
<td>LEBIT Laser Spec</td>
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<td>Laser Spec</td>
<td>Laser Spec</td>
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Motivation for MATS & LaSpec at FAIR
Complementarity of MATS & LaSpec with other facilities

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## The MATS and LaSpec collaborations

12 countries, 37 institutes, ~ 110 members

<table>
<thead>
<tr>
<th>Country</th>
<th>Institutions</th>
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</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Universite Bruxelles, KUL</td>
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<tr>
<td>Canada</td>
<td>TRIUMF</td>
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<tr>
<td>Finland</td>
<td>JYFL, UH</td>
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<td>France</td>
<td>CSNSM-IN2P3, CNRS, CENBG, US</td>
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<td>Germany</td>
<td>EMAU, FAIR, FAU, GSI, TUD, JGU, MPIK, JLU, LMU, PTB</td>
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<td>Great Britain</td>
<td>UL, UM</td>
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<td>India</td>
<td>VECC, RGC</td>
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<td>Russia</td>
<td>PNPI, PSU</td>
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<td>Spain</td>
<td>UHU, UGR, IFIC</td>
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<td>Sweden</td>
<td>SU, UU</td>
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<td>Switzerland</td>
<td>ISOLDE/CERN, PSI</td>
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<td>USA</td>
<td>LLNL, MSU, LSU</td>
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[http://www.fair-center.eu/for-users/experiments/nustar/experiments/laspec.html](http://www.fair-center.eu/for-users/experiments/nustar/experiments/laspec.html)
The MATS and LaSpec facilities
TDR approved in 2010

- Gas catcher (Giessen, GSI, Jyväskylä, KVI) (talk by S. Purushothaman)
- Dipole magnet (Jyväskylä)
- RFQ buncher (Jyväskylä)
- MR-TOF-MS (Giessen)
- MATS Penning traps (LMU, Granada, GSI, Mainz, MPIK, Sweden, VECC)
- EBIT (MPIK)
- Spectroscopy setup (IFIC)
- Beam line, ion sources, identification (Greifswald, PNPI)
- In-trap decay (LMU, PNPI)
- β-NMR (KUL)
- Atomic and ion Beamlines (TUD, Mainz, Manchester, Jyväskylä)

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Gas catcher (Giessen, GSI, Jyväskylä, KVI)
(talk by S. Purushothaman)
Staging at FAIR
Phases 1 & 2

- Phase 0: Off-line
- Phase 1: First experiments
- Phase 2: Full program
Developments with prospects for MATS & LaSpec

Phase 0 @ TRIGA

Common beamline

30 keV

LaSpec

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First experiments with MATS & LaSpec at FAIR
Phase 0 → Phase 1

- The accessibility will depend on the performance of the Super-FRS and the ion-gas catcher (TDR of the ion catcher in preparation)

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Requirements to run MATS & LaSpec at FAIR Phases 1 & 2

I. The ion-gas catcher and MR-TOF device (Phase 1)
   - On-line test with $^{238}$U projectile fragments produced at 1 GeV/u at the FRS in October 2011 and July/August 2012.
   - Another beamtime takes place at present at GSI.

Giessen, GSI (FRS), Jyväskylä, KVI
W.R. Plass et al., NIMB, 317 (2013) 457

II. Other Penning traps and detection techniques (Phase 2)
   - Faster measurements (PI-ICR)
     MPIK, GSI (SHIPTRAP), Greifswald, PNPI
   - Developments for beam preparation, new traps and single-ion detection
     Jyväskylä (JYFLTRAP), GSI (SHIPTRAP), Granada (TRAPSENSOR), MPIK
   - Construction of a trap comprised of detectors
     LMU (MLL-TRAP)
   - New funding applications (VECC)

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III. Laser spectroscopy on highly charged ions (Phase 2)
   - Laser spectroscopy on doubly-charged ions Jyväskylä

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Requirements to run MATS & LaSpec at FAIR Phases 1 & 2

Superconducting magnet
Identical to SHIPTRAP, JYFLTRAP, TRIGA-TRAP and MLLTRAP magnets

Preparation Penning trap

From Laser Ion-source end of tof-section

Diagnostics & Ion optics

Transfer Section

B = 7 T
10 ppm

B = 7 T
0.143±0.1 ppm

J.M. Cornejo et al, NIMB, 317 (2013) 522

3.9 m
Requirements to run MATS & LaSpec at FAIR Phases 1 & 2

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MATS and LaSpec will use the high production yields at FAIR to extend precision experiments to very exotic nuclei.

The TDR was approved in 2010 and the two facilities will be built in two stages.

The prototypes to run first at FAIR (TRIGA-SPEC and TRIGA-TRAP), are currently in operation at the TRIGA reactor in Mainz.

Mass measurements on transuranium isotopes and collinear-laser spectroscopy measurements on stable Ca$^+$ ions have been performed.

The results show that the systems meet the requirements to perform first experiments during phase 1 at FAIR, provided the Super-FRS and the ion catcher are in operation.

Further developments are on-going at several universities and laboratories to reach the full capability of MATS and LaSpec: MLL-TRAP, SHIPTRAP, MPIK, JYFL, T.U. Darmstadt, Manchester, JYFLTRAP, TRAPSENSOR, PNPI, U. Giessen, U. Greifswald, VECC,…
Thank you very much for your attention!!

- Thank you very much to the MATS and LaSpec collaborators who made most of the work I have presented here as well as those, whose work was not presented, for their understanding.

- Picture from the LaSpec-MATS collaboration meeting in Matalascañas (Spain) October 2008 (Decision on the contents of the TDR) FAIR newsletter no. 11

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