

# Symposium Mass Matters: Prospects of Bridging Nuclear Physics, Mass Spectrometry, and Astrophysics (SYMM)

jointly organised by  
the Hadronic and Nuclear Physics Division (HK), and  
the Mass Spectrometry Division (MS)

Anton Wallner  
Helmholtz-Zentrum Dresden-Rossendorf  
Bautzner Landstrasse 400  
01328 Dresden  
anton.wallner@hzdr.de

Dennis Muecher  
Universität zu Köln  
Institut für Kernphysik  
Zülpicher Straße 77  
50937 Köln  
muecher@ikp.uni-koeln.de

The symposium will focus on the interplay between nuclear astrophysics, nuclear physics, and mass spectrometry, with particular emphasis on heavy element nucleosynthesis and the role of neutron capture rates. Measuring and understanding the nuclear masses of exotic nuclei are crucial for better constraining explosive nucleosynthesis processes. The afternoon session will spotlight ongoing efforts to measure neutron capture rates in the laboratory and explore their crucial role in shaping "live" remnants of explosive nucleosynthesis events in the cosmos, which are detected on Earth using Accelerator Mass Spectrometry (AMS).

## Overview of Invited Talks and Sessions

(Lecture halls Kurt-Alder HS Chemie and HS 1 Physik)

### Prepending Plenary Talks

PV III	Tue	9:00– 9:45	Kurt-Alder HS Chemie	<b>Nuclear Structure and Reaction Features in Nuclear Astrophysics</b> — ●MICHAEL WIESCHER
PV IV	Tue	9:45–10:30	Kurt-Alder HS Chemie	<b>Nuclear astrophysics with radioactive beams</b> — ●ARTEMIS SPYROU

### Invited Talks

SYMM 1.1	Tue	11:00–11:30	Kurt-Alder HS Chemie	<b>Mass measurements with RIBs</b> — ●GUY SAVARD
SYMM 1.2	Tue	11:30–12:00	Kurt-Alder HS Chemie	<b>LUNA -Experimental challenges in Underground Nuclear Astrophysics Laboratory</b> — ●ALBA FORMICOLA
SYMM 1.3	Tue	12:00–12:30	Kurt-Alder HS Chemie	<b>The r-process: connecting astrophysics and nuclear physics</b> — ●ALMUDENA ARCONES
SYMM 2.1	Tue	14:00–14:25	HS 1 Physik	<b>Neutron-induced reactions and open questions in the s-process</b> — ●ALBERTO MENGONI
SYMM 2.2	Tue	14:25–14:50	HS 1 Physik	<b>n-capture experiments in inverse kinematics</b> — ●RENE REIFARTH
SYMM 2.3	Tue	14:50–15:15	HS 1 Physik	<b>Single atom counting of live interstellar radionuclides in natural archives</b> — ●JOHANNES LACHNER

### Sessions

SYMM 1.1–1.3	Tue	11:00–12:30	Kurt-Alder HS Chemie	<b>Mass Matters: Prospects of Bridging Nuclear Physics, Mass Spectrometry, and Astrophysics</b>
SYMM 2.1–2.3	Tue	14:00–15:30	HS 1 Physik	<b>Focus Session: Neutron capture reactions in the cosmos and the lab (joint session HK/SYMM)</b>

## SYMM 1: Mass Matters: Prospects of Bridging Nuclear Physics, Mass Spectrometry, and Astrophysics

Time: Tuesday 11:00–12:30

Location: Kurt-Alder HS Chemie

**Invited Talk SYMM 1.1** Tue 11:00 Kurt-Alder HS Chemie  
**Mass measurements with RIBs** — ●GUY SAVARD — Argonne National Laboratory, Lemont, Illinois, USA

Mass measurements on short-lived isotopes provide key input to our understanding of many physical and astrophysical processes. The ability to make such measurements has grown tremendously over the last decade with a number of laboratories implementing new techniques that have provided higher sensitivity, higher accuracy, and in some cases both. These new approaches will be surveyed and some high profile results they have enabled presented. Coming new capabilities will also be highlighted.

**Invited Talk SYMM 1.2** Tue 11:30 Kurt-Alder HS Chemie  
**LUNA -Experimental challenges in Underground Nuclear Astrophysics Laboratory** — ●ALBA FORMICOLA — INFN-Roma- P.le Aldo Moro, 2 - 00185 Roma

Stellar evolution and related nucleosynthesis play a fundamental role in the understanding of the origin of the chemical elements, the generation of energy, the luminosity of neutrinos and in many related astrophysical problems. The main goal of nuclear astrophysics is to provide a firm base for all these studies. Thousands of nuclear interactions, either strong or weak processes, are of astrophysical interest. For most of them, the knowledge of their cross sections (or reaction rates) at relatively low energy is required to understand the synthesis of the elements. The Laboratori Nazionali del Gran Sasso (INFN) has been for a long time a unique infrastructure hosting an accelerator

devoted to Nuclear Astrophysics, the Laboratory for Underground Nuclear Astrophysics (LUNA). The LUNA Collaboration has shown that, by going underground and by using the typical techniques of low background physics, it is possible to measure nuclear cross sections down to the energy of the nucleosynthesis inside stars. I will give an overview of the experimental techniques adopted in underground nuclear astrophysics and will present a summary of the LUNA main recent results and achievements.

**Invited Talk SYMM 1.3** Tue 12:00 Kurt-Alder HS Chemie  
**The r-process: connecting astrophysics and nuclear physics** — ●ALMUDENA ARCONES — Institut für Kernphysik, Technische Universität Darmstadt, Germany — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Our understanding of the origin of heavy elements by the r-process (rapid neutron capture process) has made great progress in the last years. In addition to the gravitational wave and kilonova observations for GW170817, there have been major advances in the hydrodynamical simulations of neutron star mergers and core-collapse supernovae, in the microphysics included in those simulations (neutrinos and high density equation of state), in galactic chemical evolution models, in observations of old stars in our galaxy and in dwarf galaxies, and in nuclear theory and experiments. This talk will report on recent breakthroughs in understanding the extreme environments in which the formation of the heavy elements occurs, as well as open questions regarding the astrophysics and nuclear physics involved.

## SYMM 2: Focus Session: Neutron capture reactions in the cosmos and the lab (joint session HK/SYMM)

Time: Tuesday 14:00–15:30

Location: HS 1 Physik

**Invited Talk SYMM 2.1** Tue 14:00 HS 1 Physik  
**Neutron-induced reactions and open questions in the s-process** — ●ALBERTO MENGONI — INFN, Bologna and CERN, Geneva

Despite the enormous progress made in the investigation of the nucleosynthesis of the s-process, there are several open issues that need additional investigations, both experimentally as well as with the help of theoretical modeling. Among these, one of the most critical is the determination of the neutron capture rate for unstable branching points in the s-process path. While difficult to be measured (because of their radioactivity), the neutron capture cross section of branching points nuclei are useful for the determination of the astrophysical conditions in which the s-process is taking place (neutron densities, temperature).

Considerable progress has been made recently in the possibility to measure neutron capture cross section of unstable nuclei. Examples are recent measurements performed at experimental facilities such as n\_TOF at CERN, LANSCE at Los Alamos and LiLIT at SARAF. Further developments of these activities will be presented.

Additional aspects of the nuclear physics developments, including those related to the determination of the stellar neutron capture rates and their theoretical modeling, as well as their corresponding beta-decay rates in plasma conditions will be reviewed.

**Invited Talk SYMM 2.2** Tue 14:25 HS 1 Physik  
**n-capture experiments in inverse kinematics** — ●RENE REIFARTH — LANL, Los Alamos, USA

Virtually all of the isotopes heavier than iron would not exist without neutron-induced reactions. Despite their importance in many different astrophysical scenarios, there are almost no direct measurements for isotopes with half-lives shorter than a few years. A radically new approach is necessary to overcome this constraint.

Ion storage rings offer unprecedented possibilities to investigate radioactive isotopes of astrophysical importance in inverse kinematics. During the last years, a series of pioneering experiments proofed the

feasibility of this concept for the fusion of charged particles at the Experimental Storage Ring (ESR) at GSI. In the future, a combination of a free-neutron target and an ion storage ring can bring the half-life limit for direct neutron-induced reactions down to fractions of a minute.

I will review different astrophysical scenarios, status of current experiments as well as prospects of this new experimental endeavor.

**Invited Talk SYMM 2.3** Tue 14:50 HS 1 Physik  
**Single atom counting of live interstellar radionuclides in natural archives** — ●JOHANNES LACHNER — Helmholtz-Zentrum Dresden-Rossendorf

Recent nearby supernovae and other cosmic explosions produce also long-lived radionuclides that penetrate into the solar system and are collected in terrestrial and lunar archives. Accelerator Mass Spectrometry (AMS) is used to identify minute amounts of these live radionuclides in environmental samples. Such signatures provide insight into the location and frequency of recent nearby Supernova activity and r-process events.

However, only in a few cases the proper combination of environmental archive and long-lived radionuclide allows to identify a clear fingerprint of such a rare input. Measurements of Supernova-produced  $^{60}\text{Fe}$  ( $T_{1/2}=2.6$  Myr) in deep-sea sediments and FeMn crusts as well as in lunar soil point to multiple Supernovae occurring in our solar vicinity within the past 10 Myr. Besides  $^{60}\text{Fe}$ , recently also the pure r-process nuclide  $^{244}\text{Pu}$  ( $T_{1/2}=81$  Myr) was detected in deep-sea archives demonstrating that r-process indeed occurred within the past few 100 Myr.

In this presentation, I will also discuss present technical constraints in the detection of such radionuclides by AMS and ongoing work increasing the capabilities for the analysis of additional interstellar radionuclides, e.g.  $^{182}\text{Hf}$  and  $^{247}\text{Cm}$ .

**Common discussion: 15'**