# ISOLDE Workshop and Users meeting 2008

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CERN

# Book of Abstracts

# Contents

**Nuclear Phenomena / 0**

## TRIGA-TRAP: High-precision mass measurements on heavy nuclides

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Nuclear masses are fundamental quantities in nature, reflecting the binding energy of the nucleons. In particular, experimentally determined masses of heavy nuclides provide new information on nuclear structure and test theoretical mass models in this region of the nuclear chart [1,2]. Masses of a few nobelium isotopes have been recently determined by SHIPTRAP (GSI, Darmstadt, Germany). However, none of the masses between uranium and californium has been directly measured yet, but most of them are linked to known species by alpha-decays [3].
We recently installed the double-Penning trap mass spectrometer TRIGA-TRAP at the nuclear research reactor TRIGA Mainz [4], which is dedicated in a first measurement period to off-line mass determinations of heavy nuclides between uranium and californium. For this purpose, a non-resonant laser ablation ion source has been developed, also providing carbon cluster ions for the calibration. The actual mass measurement can be carried out via the common Time-of-Flight-Ion-Cyclotron-Resonance (TOF-ICR) technique, where the mass value is determined by exciting and ejecting the ions from the trap and observing the minimum time of flight as a function of the excitation frequency. In a later stage, especially for nuclides with very low production rates of a few ions per minute but rather long half-lives above several tens of seconds, the non-destructive Fourier Transform-Ion Cyclotron Resonance (FT-ICR) technique will be employed for the first time for mass measurements on radionuclides. This method is based on the detection of image currents induced by the ions in the trap electrodes without the need for ion ejection, enabling repeated measurement cycles on the same stored charged particle. In future, this technique will be applied at the on-line facility SHIPTRAP for mass measurements on superheavy elements [5].
Besides mass measurements on heavy nuclides, TRIGA-TRAP will be connected to the research reactor TRIGA Mainz to exploit the field of neutron-rich nuclides produced by fission of 249Cf using the reactor. The status of the experiment as well as first mass measurements will be presented.

[1] Y. Oganessian, J. Phys. G 34 (2007) R165–R242.
[2] D. Lunney et al., Rev. Mod. Phys. 75 (2003) 1021.
[3] A. Wapstra et al., Nucl. Phys. A 729 (2003) 129.
[4] J. Ketelaer et al., Nucl. Instr. Meth. A 594 (2008) 162.
[5] M. Block et al., Eur. Phys. J. D 45 (2007) 39.

**Ground State Properties / 1**

## Correlating nuclear masses, radii and E0 transitions

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Improvements of the liquid-drop mass formula are proposed based on the introduction of (i) surface effects in the symmetry and Coulomb energies and (ii) shell effects through the counting of the number of valence nucleons. Inspired by these efforts, similar corrections in the description of nuclear radii are suggested.
To include the influence of deformation on masses and radii requires microscopic modelling. As an example, a systematic study of the spectroscopic properties of nuclei in the rare-earth region is carried out in the framework of the interacting boson model (IBM), leading to an accurate description of the spherical-to-deformed shape phase transition in the different isotopic chains. The resulting IBM hamiltonians are then used for a simultaneous and consistent calculation of nuclear radii and electric monopole transitions with the same effective operator.

**Nuclear Phenomena** / **2**

## Beta-delayed fission in the Pb region

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Beta-delayed (EC/b+, b-) fission is a rare nuclear decay process in which the beta-decaying parent nuclide populates excited states in its daughter, which may then fission. This process allows studies of low-energy fission properties, e.g., the poorly known isospin dependence of the fission barriers of neutron-rich and neutron-deficient nuclei which do not decay via spontaneous fission at all.
In the presentation, recent experiments at ISOLDE(CERN) and at the velocity filter SHIP (GSI, Darmstadt) will be reviewed, in which ECDF was unambiguously observed for the first time in several very neutron-deficient nuclides in the Pb-Fr region.

The studies were performed by the Leuven-Darmstadt-CERN-Bratislava-Liverpool-Orsay collaboration.

**Spectroscopy** / **3**

## Spins and moments of cooled and bunched neutron-rich Ga isotopes: First results using the ISCOOL-COLLAPS apparatus

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The need for increasing the sensitivity of collinear laser spectroscopy has motivated the development of ion beam manipulation techniques. The ISOLDE ion beam cooler-buncher (ISCOOL) is well suited for this purpose. It has recently been installed at the focal plane of the high resolution separator magnets and is able to reduce the beam emittance by an order of magnitude, as well as release the beam in bunches with a well defined time structure.

Laser spectroscopy using cooled and bunched beams from ISCOOL was applied for the first time for the study of neutron rich gallium isotopes, as part of the IS457 experiment. The bunched ions from ISCOOL were neutralized in a charge-exchange cell and excited with a co-propagating frequency-doubled Ti:Sa laser. The ions were Doppler-tuned as a function of a voltage applied to a retardation plate. The subsequent laser induced fluorescence decay was recorded with a blue-sensitive photomultiplier tube as a scan was taken on the retardation plate.

ISCOOL provided around 20 ion bunches per second, each bunch with a temporal length of 20 microseconds. A gate was set on the photomultiplier signal to accept the fluorescent photons within the time window defined by the bunch. With a resultant background suppression of up to four orders of magnitude, the hyperfine structures of 67-80Ga were measured on the 417nm and 403nm transitions. The analysis of the spectra allowed the spins, moments and isotope shifts to be determined, and a tentative interpretation of these measurements will be presented.

**Coulex** / **4**

## Narrowing of the neutron sd-pf shell gap in 29Na

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The wave-function composition for the low-lying states in 29Na was explored by measuring their electromagnetic properties using the Coulomb-excitation technique. A beam of radioactive 29Na ions, postaccelerated to 70 MeV using ISAC-II at TRIUMF, bombarded a 110Pd target with a rate of up to 600 particles per second. Six segmented clover detectors of the TIGRESS gamma-ray spectrometer were used to detect deexcitation gamma rays in coincidence with scattered or recoiling charged particles in the segmented silicon detector, BAMBINO. A reduced transition matrix element |<5/2+ ||E2|| 3/2+>| = 0.237(21) eb was derived for 29Na from the measured gamma-ray yields for both projectile and target. This first-time measured value is consistent with the most recent Monte Carlo shell-model calculation (MCSM) of Utsuno et al., predicted to be 0.232 eb [1]. This is suggestive of a strongly-mixed first-excited state comprising a 30 ˜ 40% admixture of 2p-2h configurations in the wave function, and also provides evidence for the narrowing of the sd-pf shell gap from 6 MeV for stable nuclei to ˜3 MeV for 29Na.

This result can also be interpreted at the phenomenological level. Within the framework of the rotational model and assuming a prolate deformation, the transition quadrupole moment, Q_{t}= 0.524(46) eb, is deduced from the measured transition matrix element for 29Na. This value also bears good agreement with the above MCSM calculation, Q_{t}= 0.513 eb [1]; a calculation utilising an effective interaction based on a shell-model space incorporating the full sd space and the two lower orbits of the pf space, with the inclusion of the cross-shell mixing terms in the effective Hamiltonian. Contrasting behaviour in the static and dynamic-nuclear properties of 29Na, arising from differences in the underlying single-particle configurations of the ground and excited states, may explain the difference between the present measurement and that of an earlier experimental result using beta-NMR spectroscopy, Q_{0}= 0.430(15) eb [2]. This intrinsic quadrupole moment, derived from the ground-state spectroscopic quadrupole moment, 0.086(3) eb, also compares well with the MCSM calculation, Q_{0} = 0.455 eb.

[1] Y. Utsuno et al., Phys. Rev. C 70, 044307 (2004).
[2] M. Keim et al., Eur. Phys. J. A 8, 31 (2000).

**Summary**:

This work describes a Coulomb-excitation measurement that has quantitatively established the role of normal (sd) and intruder (pf) configurations in the first excited state in 29Na. In addition, this measurement describes a significant accomplishment in Coulomb excitation of low-intensity radioactive ISOL beams with only a few hundred particles per second, while maintaining the same beam quality as stable-beam experiments.

**Coulex / 5**

## Evolution of nuclear shape in the light radon isotopes

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One of the remarkable properties of the nucleus is its ability to minimise its energy by adopting different deformed nuclear shapes. In some cases, this can lead to competing minima very close together. This phenomena has been widely tracked through the neutron-deficient lead, mercury and platinum isotopes, where the shape coexistence has been discussed in terms of intruder states based on proton particle-hole excitations across the Z=82 shell gap [1].

Particle-hole intruder states similar to those found in the light lead nuclei are expected to be present in nuclei above the Z=82 closure, for example 4p2h and 6p2h configurations in the polonium and radon isotopes. Such phenomena have been most extensively investigated in the light polonium nuclei, where low-lying excited 0+ states have been observed following the alpha decay of 200,202Rn [2] and the beta decay of 200,202At [3]. Energy systematics and branching ratios have been used to interpret such states as intruders, which appear to mix with the spherical ground-state configurations in isotopes lighter than 200Po [4]. Candidates have been found in 202,204Rn for deformed intruder states [5], which coexist with the spherical ground-state shape however this assignment can be no more than speculation given the absence of any detailed experimental information such as electromagnetic matrix elements.

Coulomb excitation (Coulex) with radioactive beams has shown to be a highly successful method for establishing the evolution of nuclear shape. Notable examples of this class of measurement include the Coulex of 74,76Kr at SPIRAL [7] and 70Se at REX-ISOLDE [7]. Recently a number of experiments have been performed at REX-ISOLDE studying shape coexistence in the light mercury isotopes with Coulex. These highly successful measurements have recently been extended to study shape coexistence in even heavier nuclei.

Preliminary results from our recent Coulex experiment studying shape coexistence in the light radon isotopes, 202Rn and 204Rn, will be presented.

[1] J.L. Wood et al., Phys. Rep. 215, 101 (1992)
[2] J. Wauters et al., Z. Phys. A 344, 29 (1992); Phys. Rev. Lett. 72, 1329 (1994)
[3] N. Bijnens et al., Phys. Rev. Lett, 75, 4571 (1995); Phys. Rev. C 58, 754 (1998)
[4] R. Julin, J. Phys. G 27, R109 (2001)
[5] D.J. Dobson et al., Phys. Rev. C 66, 064321 (2002)
[6] E. Clement et al., Phys.Rev. C 75, 054313 (2007)
[7] A.M. Hurst et al., Phys. Rev. Lett. 98, 072501 (2007)

**Drip Line Phenomena / 6**

## Studies along the dripline at relativistic beam velocities

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The light nuclei region in the chart of nuclei is recently subject to intense theoretical studies starting from ab initio calculations or using phenomenologic
few body approaches. All of these have in common, that they reveil or explore an intrinsic property of these systems: the appearance of strong clustering effects, showing the importance of residual interactions in a mean field picture. We have studied bound and unbound system produced in breakup reactions of light halo nuclei at large kinetic energies at the accelerator facilities of the GSI Darmstadt. The method allows for background free production of even unbound very neutron rich systems by removing protons (or alphas) from bound nuclei
that are already at the outskirts of the nuclear landscape. Selected results of these studies will be shown and the most exotic Lithium isotopes will be presented in the course of my talk.

**Spectroscopy / 7**

## The Many Faces of Laser Spectroscopy at ISOLDE: Probing the Nuclear Structure of Exotic Be, Mg, Cu and Ga Isotopes

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The most recent highlights from collinear laser-spectroscopy at ISOLDE-CERN will be presented, including the charge-radius of the one-neutron halo 11Be as well as the spins and moments of 21Mg

and of 71-75Cu. Specialized techniques have been used in each of these cases to further extend the reach of collinear laser spectroscopy to the extremes. Absolute frequency determinations with a frequency comb have allowed isotope-shifts measurements of very light radioactive isotopes for the first time with sufficient precision to extract charge radii. Beta-asymmetry detection was used for magnesium and cooling and bunching with ISCOOL was applied for the first time in order to study copper and gallium isotopes. This emphasizes the diverse capabilities of modern laser spectroscopy.

The charge radii of 7,9,10,11Be have been determined [1] by high-precision collinear-anticollinear spectroscopy combined with absolute frequency determination by a frequency comb. The achieved accuracy of the isotope-shifts in the transition 2s 1/2->2p 1/2 of Be+ is better than 1 MHz. Accurate atomic-physics calculations are used to eliminate the mass-dependent isotope shift and extract the nuclear volume effect. The charge radii decrease from 7Be to 10Be and increase again for the halo nucleus 11Be. From a simple frozen-core two-body model a root mean square distance of about 7 fm between the halo neutron and the center of mass in 11Be is obtained.

The spin and magnetic moment of 21Mg have been measured with highly sensitive beta-asymmetry detection [2]. These are important parameters for studying the nuclear mirror symmetry in the pair 21F-21Mg (T=3/2). A discussion in terms of isoscalar and isovector parts of the magnetic moment will be presented. The isoscalar moment surprisingly lies outside the empirical boundaries given by the Schmidt moments. Shell-model calculations taking in to account isospin nonconservation can reproduce this effect.

The very first results from online laser spectroscopy with the ISOLDE radio-frequency cooler and buncher (ISCOOL) will be presented, namely the hyperfine-structure and isotope-shift measurements of neutron-rich gallium and copper isotopes. The case of copper, in particular, will be discussed in terms of the shell model and the monopole migration of the proton 1f5/2 orbital [3].

[1] W. Nortershauser et al., Phys. Rev. Lett., submitted September 2008, http://arxiv.org/abs/0809.2607.
[2] J. Kramer et al., publication in progress.
[3] K. T. Flanagan et al., publication in progress.

**Technical Session ll / 8**

## The REX low-energy toolbox

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Over the last few years the low-energy part of REX, consisting of a Penning trap and Electron beam ion source, has developed from a pure bunching and charge-breeding system to an elaborate set of tools that can be used for different purposes. For instance, half-life determination of 38Ca directly after the trap by making use of the molecular beam cleaning method, as well as providing single charged ions to the WITCH setup have already been reported on.

With the arrival and successful commissioning of the ISOLDE RFQ cooler REX has now the possibility to take either CW or pulsed beams from ISOLDE, and to use or shoot through the REXTRAP. The tests have only commenced, but already now we can present the first very encouraging results of pulsed injection from the RFQ cooler. This allowed us to implement the mass-selective method in the trap while maintaining a high overall efficiency for REX.

This year we've also demonstrated that the low energy system, particularly the EBIS, can be used for in-trap decays. That means also elements that are normally difficult to extract from the ISOLDE target-ion source (e.g. refractory elements such as Fe) can be delivered to the experiments by letting the straightforwardly produced mother-nuclei decay in the EBIS before being accelerated. Furthermore, injection tests into the REXTRAP confirms that beams from the MINIMONO ECRIS coupled to an ISOLDE target can be accommodated with a high efficiency, which gives access to a number of otherwise difficultly produced beams, for instance C.

Finally, tests have shown that elements up to at least K (Z=19) can be can stripped to hydrogen-like electron configuration. This, in combination with the proposed beam-line design connecting the REX mass separator to the WITCH experiment, will open up the possibility for exciting studies of few-electron systems.

**Spectroscopy / 9**

## Technical Developments for Precision Spectroscopy of light Isotopes in Collinear Laser Spectroscopy (IS449)

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The aim of proposal IS449 is the determination of charge radii of the beryllium isotopic chain 7,9,10,11Be. For a precise extraction of charge radii, a precision of laser spectroscopy on the order of 1 MHz is needed. We have now used for the first time collinear laser spectroscopy to measure the isotope shift of radioactive isotopes to the accuracy required to extract charge radii by overcoming the uncertainty in the acceleration voltage of the ions.
In collinear laser spectroscopy with a fixed-frequency laser, the ions are Doppler-tuned across the resonance with the laser light by accelerating or decelerating them by applying an offset potential to the optical fluorescence detection region. The sensitivity of the measured transition frequency to the applied total acceleration voltage, the so-called Doppler-coefficient for 7Be is about 40 MHz/V at typical ISOLDE ion beam energies of about 50 keV. This would require knowledge of the ion acceleration potential of better than 1 ppm to obtain isotope shifts with the required accuracy. This hindered precision laser spectroscopy of light isotopes with collinear spectroscopy so far.
In this talk we report about a new technique to overcome this limitation which we applied for laser spectroscopy in Beryllium but can be generally applied for highest precision laser spectroscopy of light nuclei at COLLAPS. Applying two laser beams in collinear and anti-collinear geometry to the ion beam, we determined the resonance frequencies in parallel and anti-parallel direction. Multiplication of both frequencies then yield the transition frequency at rest, independent of any uncertainties in the voltage or ion beam energy determination. To fully exploit the precision provided by this approach, we applied frequency locking of the laser system to a frequency comb.
This technique was tested on stable 9Be beam time employing 8 shifts for test of systematic limitations and uncertainties of this approach. After the successful test 12 shifts have been used to perform on-line spectroscopy on the beryllium isotope chain which will be reported in another contribution.
In these runs we achieved an uncertainty in the absolute frequency determination of about 800 kHz and an uncertainty of about 1 MHz in the isotope shift determination.
As a spin-off of our studies we could detect an offset between the ISOLDE high-voltage dividers ASTEC-1 and ASTEC-2 and recalibrated those by the result of the laser spectroscopic measurement and an electronic measurement with a 1 ppm voltage divider from the KATRIN collaobration.

**Coulex / 10**

## Coulomb Excitation of Light Mercury Isotopes at REX-ISOLDE

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In light, even mass Hg isotopes, a weakly deformed oblate ground state band is found to coexist with a more deformed prolate band. To investigate the origin and evolution of shape coexistence in the N = 102-108 mid shell region Coulomb excitation measurements of 182,184,186,188Hg were performed at REX-ISOLDE using the MINIBALL detector array. The radioactive Hg beams were provided by ISOLDE and post accelerated by REX, for the first time, to an energy of 2.85 MeV/u and delivered to the target position of MINIBALL. In this presentation preliminary results from the ongoing analysis will be presented.

**Summary**:

Coulomb excitation, Shape coexistence, MINIBALL

**Nuclear Phenomena / 11**

## Improved formalism for superallowed Fermi beta decay between analogs and half-lives of rp-process waiting point A~70 nuclei

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We present a variational treatment of the effects of the isospin-symmetry
breaking on the superallowed Fermi $\beta$ decay of medium mass nuclei dominated

by shape coexistence and mixing allowing for a simultaneous description of the
analog as well as significant non-analog branches.
The Gamow-Teller strength distributions and the half-lives for the beta decay of
the ground state and the lowest-excited states of the waiting point nuclei
are self-consistently described and the influence of shape mixing, comparison
with the available data and estimates of the effects in the astrophysical
environment of the X-ray bursts are disscused within the {\it complex} Excited
Vampir variational approach.

**Summary**:

A self-consistent approach to calculate the effects of the isospin-symmetry-breaking corrections to the superallowed Fermi beta decay between T=1 0+ analog states will be presented and results for analogs in the A˜70 mass region will be reported.
The Gamow-Teller strength distributions and the half-lives for the beta decay of the ground state and the lowest-excited states of waiting point nuclei in this mass region are obtained using the same variational approach, complex Excited Vampir approach.
The model allows to describe self-consistently the shape coexistence and mixing in both parent and daughter nucleus using a large model space and realistic effective interactions obtained renormalizing the G-matrix for nuclear matter based on OBEP potential (Bonn A / Bonn CD). The results are compared with the available data and estimates of the effects in the astrophysical environment of the X-ray bursts are disscused.

**Polarization** / **12**

## New Tilted-Foils Plus beta-NMR Setup at REX-ISOLDE. Polarized Nuclei for Nuclear and Solid-State Physics Experiments.

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The possibility of obtaining spin-polarized nuclei is an essential asset for performing nuclear physics experiments with radioactive nuclei. The nuclear magnetic-dipole and electric quadrupole moments are of key importance for the profound understanding of the nuclear structure, especially when one moves away from the stability line. Obtaining an ensemble of polarized nuclei is a primary requirement for this type of experiments.

One way to obtain an ensemble of polarized nuclei is by the use of the Tilted Foils (TF) technique [1] in which an atomic spin-polarization is obtained via the surface interaction of ions traversing a multifoil stack at an oblique angle. The atomic polarization thus produced is subsequently transferred to the nuclear spins. The TF polarization technique has been used up to now for nuclear-moment measurements [1] and the experimentally observed polarization has been of the order of 1%. Much more favourable conditions for the application of the TF technique can be achieved at beam energies of about 1 MeV/u. Therefore we are planning to install a TF setup after REX-ISOLDE followed by a beta-NMR setup that will be provided by HMI, Berlin. The new setup will alleviate numerous conceptual and technical issues that hampered previous experiments at ISOLDE on the High-Voltage platform [1].

An additional possibility is to use the TF + NMR setup for solid-state physics applications; for this, a polarization of the order of 10% or higher is required. Provided that such conditions are feasible, this presents great advantage for solid-state physics experiments since a beta-NMR experiment with polarized nuclei increases the sensitivity over a conventional NMR by more than 10 orders of magnitude. This would provide the ability to probe, for example, surface states and thin film layers, such as those increasingly being considered for next-generation magnetic devices, e.g. single molecule magnets [2].

The necessary developments in order to make the project a success will be discussed together with the perspectives for nuclear- and solid-state physics programs that can profit from the installation of such a setup at ISOLDE.

[1] L. Baby et al., J. Phys. G 30, 519 (2004); and references therein.
[2] Z. Salman et al. Nano Letters 7(6) 1551 (2007).

**Spectroscopy / 13**

# Results from Transfer Experiments in the Island of Inversion

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Thirty years after the discovery of the "island of inversion" [1] the borders of the island are still not well determined and in particular the evolution of the single-particle structure is not well investigated.

Transfer reactions yield important spectroscopic information, i.e. spin and parity assignments as well as spectroscopic factors, complementary to the information obtained in Coulomb excitation [2]. Since the transfered nucleon can occupy excited states, the properties of these states can be studied as well.

In order to study transfer reactions in inverse kinematics at REX-ISOLDE with MINIBALL a new setup was built covering a large solid angle. This new setup overcomes the limitations of previous transfer experiments performed at REX-ISOLDE [3].

In the first experiment the nucleus $^{31}$Mg which is right on the edge of the "island of inversion" was studied via the d($^{30}$Mg, $^{31}$Mg)p reaction.

Preliminary results of this beam time which took place last year will be shown as well as future plans for transfer experiments at REX-ISOLDE.

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[2] O. Niedermaier et al., Phys. Rev. Lett. 94, 172501 (2005)

[3] M. Pantea, PhD Thesis, TU Darmstadt, Germany (2005)

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**Drip Line Phenomena / 14**

# Li, here we go again···

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The post-accelerator for radioactive beams, REX-ISOLDE, provides beams of energies of 0.3-3.1 MeV/u. Thus, it enables the study of the majority of the nuclides available at CERN-ISOLDE through low-energy reactions. This opens the possibility to use Coulomb excitation, fusion and transfer reactions as spectroscopic tools for studying exotic nuclei.

Exotic light nuclei are being studied through a campaign of transfer-reaction experiments. The present aim is to investigate the structure of neutron-rich lithium isotopes. The scientific motivation for these studies is manifold. First, the isotopic chain of lithium ends in the emblematic two-neutron halo nucleus 11Li. Second, spectroscopic factors for known and hitherto unobserved excited states are being predicted by ab-initio and shell model calculations and can thus be tested experimentally. Third, these loosely bound systems present a challenge to our modelling of reaction mechanisms.

The project described here is a benchmark experiment where a beam of 8Li was impinging on a deuterated polypropylene target in inverse kinematics. This mainly gives information on 9Li through a one neutron pick-up reaction, which in the inverse kinematics corresponds to a (d,p)-reaction. However, the reaction channels (d,d) and (d,t) can also be studied. The goal of the experiment is to study the reaction mechanism and the coupling to the continuum.

This presentation will be a status report. All steps (calibration of the detectors, background subtraction, acceptance corrections, excitation energies and simulations) leading up to the angular distributions on an absolute scale have been performed. At present the angular distributions await theoretical interpretations.

**Polarization / 15**

## NMR/ON measurement of magnetic moments of high-spin K-isomers in Hf isotopes.

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In a recent experiment at the NICOLE on-line nuclear orientation facility, gamma decay anisotropy and nuclear magnetic resonance measurements were made on Hf isotopes. A HfF3 beam was used to implant separated Hf isotopes into a magnetized pure iron foil cooled to temperatures down to 15 millikelvin.

NMR/ON resonance was observed in the 37/2- K-isomer of 177Hf and angular distributions measured for many gamma transitions in the decay of this isomer and the 25/2- isomer in 179Hf.

Data analysis is in progress and preliminary results will be reported.

**Ground State Properties / 16**

## the WITCH experiment: status and perspectives

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The WITCH set-up (Weak Interaction Trap for Charged Particles) combines a double Penning trap system to store radioactive ions and a retardation spectrometer to probe the energy of the daughter recoil ions. The primary aim is to search for scalar or tensor interactions in nuclear beta decay by precisely determining the beta-neutrino
correlation coefficient a. This can be extracted from the measured energy spectrum of the recoiling nuclei after beta decay. The two Penning traps serve to provide a pure and scattering free source for this.
All parts of the set-up are now operational and the first recoil ion spectrum was measured in 2006 in the decay of 124In. Although statistics were not yet sufficient to extract weak-interaction information, the charge state distribution of the recoiling daughter nucleus 124Sn could be derived from this.
In 2007 the aim was to measure a via the recoil spectrum of 35Ar. This turned out to be difficult due to a large contamination of 35Cl in the beam (factor 20), and the rapid loss of 35Ar both in REXTRAP and in WITCH due to charge exchange. Further, it was found that unwanted particles are also trapped in several regions inside the WITCH setup due to a combination of the electric and magnetic fields. Therefore, instead of taking radioactive beam time this year, it was decided to first solve these problems. This is in progress now.
At the same time a magnetic-shielding for the REX-EBIS beam line is being constructed, which will allow to power up the magnet to 9T without interfering with beams in the REX beam line. Also a small buffer gas filled RFQ to transform the beams from the WITCH surface ion source into bunched is being developed. This will then make the WITCH experiment independent of other experiments and will increase significantly our tuning and testing possibilities. Finally, the installation of a tape station for precision nuclear spectroscopy, making direct use of the pure and high intensity sample in the WITCH Penning trap, is being prepared too.

**Solid State Physics / 17**

## Diffusion behaviour of short lived isotopes in II-VI semiconductors

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Understanding and control of diffusion profiles of intrinsic and extrinsic defects in semiconductors is of central importance for developing electronic and optoelectronic devices. In previous studies [1] it was shown that diffusion of Ag in CdTe can lead to uncommon diffusion profiles. The diffusion of Ag and Cu in CdTe crystals after implantation of 111Ag or 67Cu with 60 keV and annealing at 800 K for 60 min under Cd pressure showed symmetrically and peak-shaped depth profiles with respect to the center of the crystal. Thus the Ag or Cu atoms must have diffused from regions of low concentration to regions of higher concentration (up-hill diffusion) contrary to what is usually expected in diffusion experiments.
Simulations of the diffusion profiles taking into account the charge state and drift of the different defects are able to quantitatively explain the observed profiles [2]. Thereby, the shape of the profiles is reproduced if the dopant atoms Ag or Cu are dominantly present as positively charged interstitials. The penetration of interstitial Cd atoms, originating from the external Cd pressure, changes the initially Cd vacancies rich, p-type material, into n-type. The dopant profile then maps the position of the Fermi level, which reflects the profile of the intrinsic defects and the steep gradients of the dopant profile indicate the positions of pn junctions.
Here, new diffusion experiments using short lived radiotracers of other elements (Mn, Fe, K, Au, Co and Ni) implanted into II-VI semiconductors at ISOLDE are summarized.
The diffusion of Mn, Fe, and K did not show uncommon profiles upon diffusion annealing.
In contrast, the diffusion profiles of Au and Na showed almost the same features like Ag and Cu upon diffusion under Cd pressure. Furthermore, the penetration depth of Au indicates a diffusion coefficient being much larger than values published in the literature. The fast diffusion of Au observed here may be related to the ability to detect much lower concentrations due to the use of radiotracers (> 108 cm-3) as compared to "classical" techniques, like SIMS or RBS.
Also Co and Ni exhibit uncommon diffusion profiles which, however, are distinctively different from those observed for Ag, Cu, or Au. The profiles observed in CdZnTe under Cd pressure show box shaped profiles, ranging from the implanted surface up to the first pn junction. These profiles can be explained assuming that Ni and Co are highly mobile only in Cd rich material and that at diffusion temperature they are present as negatively charged interstitials.
The financial support of the BMBF under contract 05 KK1TSB/5 is gratefully acknowledged.

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**Solid State Physics / 18**

## COMPLEX OXIDE THIN FILMS AND HETEROSTRUCTURES-SCIENTIFIC OPPORTUNITIES-TECHNOLOGICAL CHALLENGES

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Mastering the technological challenges in semiconductor thin film physics has been the baseline for the microelectronic revolution in the second half of the last century. Similarly, complex oxides with strong electron correlation, characterized by their plethora of functionalities - ranging from superconductivity to ferromagnetism - are expected to play a similar role in electronics in this century.
In my talk I will give a survey of the physics of complex oxides with strong electron correlation and the relevant thin film technologies required for device fabrication. As a case study for novel physics emerging from the technological mastering of complex oxide thin film technology an analysis of the mutual interaction of superconducting and ferromagnetic nanoscale heterostructures and superlattices is presented. Special emphasis is given to advanced diagnostic techniques probing the electronic properties at the interfaces of heterostructures and superlattices.

**Technical Session ll / 19**

## FEBIAD ion source development at ISOLDE: efficiency improvement for all the elements

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Within the Marie Curie "HIGHINT"project a detailed study of the FEBIAD ion sources has been done at ISOLDE. As a result, two FEBIAD prototypes have been proposed and successfully tested. For the noble gases, the ionization efficiency was this way increased by about a factor 9, which allowed the identification of the new isotope 229Rn at ISOLDE. Due to this development, an increase of the ionization efficiency of about a factor 3 is expected also for the other elements produced at ISOLDE with FEBIAD ion sources.
The justifications for these developments are presented, as well as the modeling of the results.

**Technical Session ll / 20**

## Target and Ion Source Development

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The activities related to Radioactive Ion Beam development at ISOLDE will be reviewed.

**Ground State Properties / 21**

## Nuclear structure research and the discovery of a new isotope with the Penning trap mass spectrometer ISOLTRAP

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In August 2008 the masses of neutron rich Xe and Rn isotopes were measured at the tandem Penning trap mass spectrometer ISOLTRAP with a relative mass precision down to a 1x10-8. During this online period the masses of 143-146Xe and 223-229Rn were measured, many of them for the first time directly. In addition the short-lived nuclide 229Rn has been observed for the very first time and aside of its mass also a preliminary life-time measured has been performed. With these new mass values one can study the proton-neutron interaction deltaVpn and therefore get information about the nuclear structure like collectivity, the onset of deformation or the geometrical shapes in atomic nuclei [1]. The experimental results as well as the impact on the theoretical models will be presented.
[1] R.B. Cakirli et al, Phys. Rev. Lett. 94, 092501 (2005).

**Ground State Properties** / **22**

## Isoltrap harvest 2008

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The ISOLDE mass-spectrometer Isoltrap has recently successfully addressed a number of scientific highlights across the entire nuclear chart, among others: the question of proton-halo character of 17Ne, and the "restoration" of the 132,134Sn and 80,81Zn shell closures, of great relevance for the astrophysical r process. The latest results include masses of neutron-rich Ag and Cd isotopes which are important due to the proximity of Z = 50, and masses of neutron-deficient Cd isotopes relevant for the magicity of N = 50.
Also 2008 gave us many very nice results: masses around Z=82 interesting for neutrino-mass determination; masses of 126,128Cd, 143-146Xe and 223-229Rn interesting for nuclear-structure questions: residual neutron-proton interaction reflected in the so called dVnp values, and compared to IBA calculations, and –presently ongoing- masses and trap-assisted decay spectroscopy on neutron-rich Hg isotopes. During our investigations we even discovered a new nuclide, 229Rn. The presentation will give a comprehensive review of the above results, followed by an outlook.

**Polarization** / **23**

## A new method to determine the beta asymmetry parameter for nuclei, in search for a tensor type weak interaction

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A new method to determine the beta asymmetry parameter in the decay of polarized nuclei was developed. The nuclei are polarized with the low temperature nuclear orientation method and beta particles are observed with Si and Ge detectors operating inside the 4 Kelvin part of the nuclear orientation set-up. Essential to the method is further the newly developed Geant4 based Monte Carlo code for beta particles that accounts for the determination of the solid angle as well as for scattering and magnetic field effects.
First measurements were performed with 114In and 60Co. These have provided the as yet most precise values for the beta asymmetry parameter in nuclear beta decay, yielding new information on a possible tensor type component in charged current weak interactions.

**Nuclear Phenomena / 24**

## A new determination of the |V_ud| quark mixing matrix element

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Recently, a complete analysis of the half-lives and branching ratios for the beta transitions between isospin T = 1/2 isospin doublets in mirror nuclei, together with detailed calculations of the radiative, isospin-symmetry breaking and nuclear structure corrections, have provided the corrected Ft-values for these mirror transitions up to A = 45.
Combining these Ft-values with results from correlation measurements that were performed with several of these mirror nuclei provides a new and independent source for the determination of the quark mixing matrix element |V_ud|.

**Polarization / 25**

## First-principles calculations and perturbed angular correlation experiments in BaMnO3 and MnAs

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We report on perturbed angular correlation (PAC) spectroscopy studies on magnetic compounds BaMnO3 and MnAs. Hyperfine parameters, e.g., the local Electric Field Gradient and Hyperfine Magnetic Field were measured by using the isotope probes 111Cd in BaMnO3 and 77Se in MnAs. MnAs was measured in a short range of temperatures near the first order magneto-structural transition at T=45 C. For the case of BaMnO3 we present results in the hexagonal 6-layered phase, from

liquid nitrogen temperature until 700 C.
To model the hyperfine parameters obtained in the PAC experiments we are using the FP-APW+lo ( full potential - augmented plane waves + local orbitals) method of density functional theory, as implemented in the Wien2k code [1]. The simulations consider the use of supercells that characterize different lattice sites and local configurations of the probe atoms, with increasing dilution to account for the ppm concentration range of the radioactive probes used in the experiments.
On these preliminary experimental-theoretical combined studies we provide now the information of the probe site, interpret the structural charge and magnetic local properties around the probe and prepare more detailed studies of the materials behavior upon temperature changes.

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**Spectroscopy / 26**

## Biological Applications of Perturbed Angular Correlations of γ-Ray Spectroscopy

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Perturbed angular correlation of γ-rays (PAC) spectroscopy is a techinque routinely used in solid state physics, however, it has also proved to be a method that allows for studies of biological problems, such as local structure at metal ion binding sites, dynamics of protein folding or protein–protein interactions [1].
In this work we illustrate that PAC spectroscopy is a suitable tool to investigate HAH1 binding properties towards Hg(II) in a wide pH and temperature range. Our findings show that HAH1 interaction with Hg(II) may reflect metal ion transfer between proteins via formation of HgS4 species [2]. We have also shown that by using PAC it is possible to monitor the metal ion coordination chemistry in metallothionein MT3, a metal-binding protein which plays a protective role against heavy-metal poisoning and is also related to Alzheimer's disease [3]. Until now functions and metal components of MT3 have not been fully examined and therefore the studies undertaken may significantly contribute to the recent findings on MT3 and might provide a better uderstanding of physiological role of this protein. Moreover, the in vivo experiments using 199mHg-PAC spectroscopy clearly show that this technique is capable of providing (surprisingly good) experimental data even in very complex systems.
In addition, several PAC experiments on 199mHg small model complexes have also been performed in order to determine the unknown partial NQIs for many important biological ligands coordinated to this metal ion, such as sulfur, nitrogen or oxygen.

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**Solid State Physics / 27**

## LOCAL PROBE STUDIES IN MANGANITES AND COMPLEX OXIDES

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Complex oxides, particularly manganites (R-D)MnO3 present a wealth of behaviours associated with coupled spin, lattice, charge and orbital degrees of freedom, that can be controlled by chemical doping. Perturbed Angular Correlation (PAC) studies in several systems were performed to locally probe these effects using the electric field gradient (EFG) and magnetic hyperfine field generated by the charge and spin distribution around the probe. A comprehensive account, based on the real-space atomic-scale information obtained, first-principle calculations and complementary macroscopic properties studies is given on phenomena like:
-lattice and polaron dynamics, phase separation, intrinsic local inhomogeneities [1]
-charge-ordering and electric polarization [2]
-the role of structural distortions and symmetry changes on magnetic and multiferroic materials
Some prospects for new challenging phenomena and systems to be studied using radioactive isotopes are also anticipated.

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**Solid State Physics** / **28**

## Recent results from electron emission channeling on-line experiments

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This talk reports on the results from the electron emission channeling on-line run of the ECSLI collaboration, which took place during this year's Mn beam time in September. We were able to determine the lattice sites of implanted 56Mn (2.6 h) in ZnO, Ge and GaAs, and of 61Co (1.6h) in GaN during the run. We found that Mn in ZnO prefers substitutional Zn sites and Mn in Ge substitutional Ge sites. Mn in GaAs occupies substitutional sites as well, but distinguishing between Ga and As

sites will only be possible after careful analysis due to the very similar nuclear charges of these two elements. For the study of Co in GaN we exploited the decay chain 61Mn(4.6 s)->61Fe (6 min)->61Co (1.6 h), i.e. 61Mn was implanted and after a waiting period of 30 min lattice location was done on 61Co. We found that Co occupies substitutional Ga sites in GaN. In addition, by means of using the decay chain 59Mn (0.71 s)->59Fe (45 d), we prepared samples of SrTiO3 and KTaO3 doped with 59Fe, for which the lattice location of Fe will be determined during the following months. Finally we prepared a number of InP samples implanted with 111In (2.5 d) in order to do studies of the emission channeling effect as a function of measurement temperature. Measurements were made at 50 K, 100 K, 150 K, 200 K and room temperature. These experiments are intended as a test of our new sample cooling stage, and 111In in InP has been chosen as a model system since the low Debye temperature of InP results in a strong temperature dependence of the emission channeling effect, and due to the fact that substitutional 111In on In sites is not expected to suffer from any other temperature dependence than the InP lattice vibrations.

**Solid State Physics** / **29**

## Emission Channeling Studies in Dilute Magnetic Semiconductors: Transition Metal doped ZnO and GaN

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Magnetically doped semiconductors (dilute magnetic semiconductors - DMS) are seen as strong candidates to make use of the carriers spin in spintronic devices. Latest results of both experiment and theory are driving the research focus towards wide-gap semiconductors doped with 3d transition metals. However, any attempt to understand the room temperature ferromagnetism observed in these systems, something which still remains far from being accomplished, must start from a detailed structural understanding of the systems, in particular a quantitative knowledge of the (magnetic) impurities lattice sites.

We present preliminary analysis of recent emission channeling experiments on the lattice location of implanted Fe (off-line experiments) and Co and Mn (on-line experiments) in wurtzite ZnO and GaN. Together with some results on the magnetic properties, by means of SQUID magnetometry, and structural (disorder) characterization, by means of Raman spectroscopy, these experiments pave the way for the research to follow.

**Drip Line Phenomena** / **31**

## New vistas at energies around the Coulomb barrier at GANIL

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Finding avenues towards uncovering new phenomenon in regions of extreme of isospin both in nuclear structure and/or its effects on the reaction mechanism is one of the goals of current and next generation facilities. .At energies near the Coulomb barrier, reactions are characterized by a delicate interplay between mean-field (potential) and the collective and nucleonic degrees of freedom. Thus reactions studies with beams nuclei both far and near from stability provide a unique opportunity

to measure and understand the many facets of multidimensional tunneling and also provide us with a very powerful arena for the production of neutron rich nuclei.

The talk we will highlight results from two of the three axis at GANIL using heavy stable beams and light radioactive ion beams. We will present recent physics highlights obtained mainly using the EXOGAM gamma array in conjunction with the large acceptance spectrometer VAMOS the neutron wall at energies around the barrier. In particular new limits reached in beam gamma spectroscopy of neutron rich nuclei at these energies using heavy stable beams around and complete reactions studies using borromean beams to understand the influence of the structure on the reaction mechanism will be presented. Future plans for increasing the measurement sensitivity at GANIL for accessing presently unattainable gaols will also be presented.

**Drip Line Phenomena** / **32**

## Exploration of the Driplines at the NSCL

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The discovery of new isotopes is the first step in the exploration of the properties of the most exotic nuclei. At the NSCL we applied different techniques to produce and identify new isotopes. With the Modular Neutron Array (MonA) it is possible to study the spectroscopy of nuclei close to and even beyond the neutron dripline.

**Coulex** / **33**

## Coulomb excitation at REX-ISOLDE with the MINIBALL Germanium array

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The Miniball germanium array has been in use at REX-ISOLDE for more than six years now. Over these years, Coulomb excitation experiments have been performed on a variety of isotopes ranging from Mg (Z=12) to Rn (Z=86). Many of these Coulomb excitation experiments aim at the study of shell evolution far off the line of beta stability by measuring transition probabilities between low lying states (ex. A=30,31,32 Mg, A=74,76,78,80 Zn, A=106,108,110 Sn, …). Other experiments aim at the investigation of shape coexistence, for example between Z=28 and Z=40 (ex. A=70 Se and A=96 Sr) and in recent years in the lead region (Z=82), ex. A=184,186,188 Hg, A=202,204 Rn. Some illustrative examples from the past years will be shown. Furthermore, a brief overview will be given of the setup and the possibilities that are offered by this. New developments and plans for the future will be highlighted as well.

**Technical Session l** / **34**

## Upgrade of laser setup at ISOLDE RILIS

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At ISOLDE RILIS the resonance ionization of isotopes is provided by high pulse rate dye lasers. Till 2008 the dye lasers were pumped by copper vapor lasers built in Russia and delivered to CERN on 1989. With the progress in laser technology it became possible to replace the copper vapor lasers by contemporary solid state lasers. In spring 2008 a 100W Nd:YAG laser has been installed at RILIS. The first year of RILIS operation with the new laser was rather successful in spite of few technical problems. Plan of further upgrade and development of RILIS laser system will be presented.

**Technical Session l / 35**

## ISCOOL, operational aspects

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ISCOOL operational aspects and results during the Isolde 2008 run

A summary on the overall preformance of ISCOOL, the RFQ cooler and buncher at Isolde, which was installed in October 2007 in the HRS separator beamline. A brief overview of the installed hardware, the functionality and aspects of operation in CW and bunch mode in it's first year of operation, 2008.

**Introduction / 36**

## Introduction

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Welcome of participants and brief news items from ISOLDE.

**Spectroscopy / 37**

## A study of the 1+n+ scenario with the Phoenix booster at ISOLDE

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At ISOLDE / CERN, an on-line test bench is dedicated to charge breeding experiments with a 14 GHz Phoenix ECRIS. The investigation of the 1+−>n+ scenario with exotic ion beams provides useful information for the design of the next generation of radioactive ion beam post-accelerators. The program of tests for the on-line performances was concluded this year. Possibilities of beam purification with the charge breeder were actively studied for applications to physics experiments. The production of pure beams of neutron-rich nuclei for nuclear astrophysics using the ECR charge breeder was tested at ISOLDE in August. This contribution will present an overview of the latest results and some perspectives for the future use of the Phoenix booster for physics experiments at ISOLDE.

**Technical Session ll / 38**

## HIE-ISOLDE: news from the other side

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The increase in proton beam intensity, due to the both completion of Linac 4 and a change in the basic period of the PSB cycle, is an essential criterion for the success of the full HIE-ISOLDE project. In order to accommodate a possible 10μA proton-beam to ISOLDE, a complete overhaul of the existing target area infrastructure is required. A factor of 5 proton-beam increase inevitably leads to higher radiation levels and consequently, a need to improve shielding and a re-design of the target and frontend systems. Auxiliary equipment, such as the remote handling robots, will also have to be modified. This talk will outline the relative issues associated with this upgrade and will summarize progress.

**Special Seminar / 39**

## Very high energy gamma-ray astronomy : The HESS experiment

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Over the past few years, very-high-energy gamma-ray astronomy has emerged as a truly observational discipline, with many detected sources representing different galactic and extragalactic source populations-supernova remnants, pulsar wind nebulae, giant molecular clouds, star formation regions, compact binary systems, and active galactic nuclei. The H.E.S.S. array of imaging atmospheric Cherenkov telescopes has revealed a sky full of sources of very high energy gamma rays, challenging our knowledge of particle acceleration (either hadronic or leptonic) and propagation in environments with extreme conditions.

The talk will illustrate some of the key results from H.E.S.S., mention some of the open questions, and give a general overview of the future plans.

**Technical Session l / 40**

## HIE-ISOLDE

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The HIE-ISOLDE proposal is gathering momentum with important contributions from Belgium, Sweden, UK and the collaboration already committed. I will in this presentation give an overview of the proposal, review the status of the different activities and give an outlook on how the different activities could evolve over the coming years provided the necessary funding is becoming available.

**Technical Session l / 41**

## Update from the LARIS lab

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The LARIS lab is an off-line development lab for the ISOLDE-RILIS group. With increasing demand for the Resonance Ionization Laser Ion Source (RILIS) at ISOLDE there is little opportunity to develop new or improve existing laser ionization schemes. The limiting factor in resonant laser ionization is usually the final step above the ionization energy (IE) and it is desirable to use a transition to an autoionizing state. Unfortunately the region above IE is typically less well know and it is often necessary to look for good candidates by probing different excited energy levels over a wide frequency range. The LARIS (LAser Resonance Ionization Spectroscopy) laboratory was funded as part of the RILIS laser upgrade and is a separate laser lab where much of this time-consuming ionization scheme development will be carried out for stable isotopes.

This presentation will give an overview of the lab and the first tests on the most urgently needed schemes/elements.

**Technical Session l / 42**

## New products from CAEN

New products from CAEN