The RISING Project

Status of the RISING experiment S269

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for the RISING collaboration

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The RISING experiment has been set up at the S4 area of the fragment separator FRS at GSI and several commissioning and experimental runs with fast exotic beams have been performed this autumn. Following a request by the GSI Experiment Ausschuss we report on the technical success of these runs, first preliminary results of the data analysis and conclusions for waiting and future experiments. Moreover, competition by work performed at other facilities is being addressed.

1. Summary

The preparation of the RISING experiment went on as planned. The beam line and particle detectors were set-up and tested early in advance. In April and May 2003 the Euroball Cluster Ge detectors and associated VXI electronics and equipment were moved from Strasbourg to GSI. At the same time the Hector array was delivered. As last item the holding structure was delivered from Daresbury in June. On August 5 the system was ready in time to take beam. During a commissioning run (August 5-11) employing a ^{132}Xe primary beam all detectors and sub systems were tested and proofed to work. However, the expected discrete line in the γ spectra from Coulomb excitation was not visible. The break before the next run in September was used to improve the shielding of the Ge detectors and to slightly modify the arrangement of the FRS tracking detectors.
The scheduled time for the planned first experiment (S269-3) in September was agreed by the collaboration to be used to continue the commissioning with a ^{84}Kr beam. During this run the reason for the missing line was discovered to be loss of synchronisation of part of the FRS VME readout channels. When this problem was fixed the Coulomb excitation line of ^{84}Kr was established as expected. Thereafter experiment S269-4 was started with Coulomb excitation of the secondary ^{56}Cr beam. This run suffered from 3 days losses due to a major power failure and computer network problems at GSI. Taking into account the set-up time for the FRS, only 40 hours beam on target were available, thus no second run could be performed. In the next run (S269-2) in October mirror nuclei in the mass $A \approx 50$ region were investigated employing secondary fragmentation reactions. By selecting individual charges with the CATE calorimeter γ transitions in several isotopes were nicely identified already on line. Finally two runs were performed for experiment S269-6, aiming at Coulomb excitation of ^{112}Sn and ^{108}Sn. It turned out that in this case the limited on-line (respectively near line) analysis capability resulted in too long accumulation times until the peak indications allowed for a proper judgement of the data quality. Therefore no third isotope was tried to be measured.

date	**planned experiment**	**performed experiment**
Aug.05-Aug.11	^{132}Xe commissioning experiment	set-up optimisation, uncorrelated data
Sep.13-Sep.21	^{68}Ni Coulomb excitation	^{84}Kr commissioning experiment
Sep.22-Sep.28	^{56}Cr Coulomb excitation	^{56}Cr Coulomb excitation
Oct.11-Oct.19	^{53}Ni fragmentation	^{53}Ni fragmentation
Oct.20-Oct.26	^{108,112}Sn Coulomb excitation	^{108,112}Sn Coulomb excitation

In conclusion the runs performed so far demonstrated that Coulomb excitation and secondary fragmentation experiments can be performed with RISING as expected. In the few weeks since the end of the very demanding first campaign the preliminary offline analysis shows, for the cases taken so far, an impressive improvement in the peak to background ratio in the γ spectra. Only careful calibrations and elaborate analysis conditions, which are being developed now, will further improve the spectra quality. The resulting analysis routines will be incorporated into the near line analysis, which will be performed in future by disc replay, to speed up the judgement of the quality of accumulated data.

The collaboration kindly asks the EA not to charge the 7 days of beam time for the second commissioning run and to agree to the changes in the isotopes to be investigated in experiment S269-4 as discussed below.

2. Experimental set-up

All individual γ-ray spectroscopy experiments described in this report were performed with radioactive beams after in-flight isotope separation. The exotic beams were produced by fragmentation of a heavy stable primary beam (max. beam intensity from the SIS synchrotron of 10^9/s for medium heavy beams, e.g. ^{124}Xe) on a ^{9}Be target (typical thickness ≈ 2-4g/cm^2) in front of the fragment separator, FRS. The FRS was operated in a standard achromatic mode, which allows a separation of the beam of interest by combining magnetic analysis with energy loss in matter. The transmission through the FRS was typically 20-50% for fragmentation depending on the actual isotope. The separated ions were identified on an event-by-event basis with respect to mass and atomic number via combined time-of-flight, position tracking, and energy loss measurement. The standard particle identification set-up consisted of plastic detectors, multiwire proportional chambers (MWPC) and a MUSIC ionisation chamber, which were optimised for high event rates ($\leq$50 kHz). A typical example is shown in fig.1 for the fragmentation of ^{86}Kr ions and the separation of a mixed secondary beam consisting of ^{57}Mn, ^{56}Cr and ^{55}V, which was used for the Coulomb excitation of ^{56}Cr on a Au target. Theoretical predictions are in excellent agreement with measured fragment distributions.

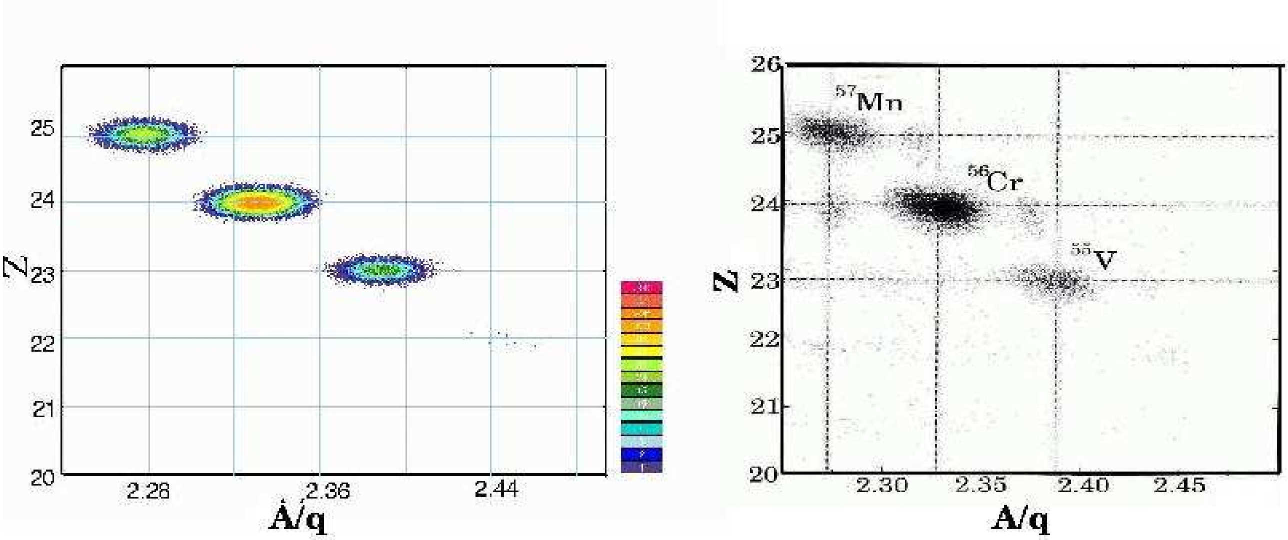

Figure 1: MOCADI calculations for ^{86}Kr ions at 419 MeV/u hitting a 2.5 g/cm^2 Be and passing through a 5 g/cm^2 Al degrader. Calculated (left) and measured (right) Z versus A/Q correlations are compared for mixed secondary beams of ^{57}Mn, ^{56}Cr and ^{55}V.

After passing the identification system the radioactive ions at relativistic energies (≈100 MeV/u) were focussed onto a secondary target of 7x7 cm dimension, positioned approximately 4m behind the last FRS magnet in the experimental area S4. Massive slits, absorbing most of the radiation produced by hitting ions, were used to reduce the amount of unwanted species reaching the secondary target. Behind the target the calorimeter telescope, CATE, was used for reaction channel selection. CATE consists of an array of 9 pairs of position sensitive Si ΔE detectors (lab. angular range $\pm 3^0$) with charge resolution and thick CsI scintillators for total energy measurement E with a measured resolution of ≈1/100. For medium heavy nuclei (A≈60) the mass resolution should be sufficient to discriminate single masses. Fig.2 shows the scatter plots of the pulse heights of the ΔE-detector versus the pulse heights of the E-detector for reactions with ^{56}Cr (left) and ^{108}Sn (right) on a Au target at beam energies $\geq$100 MeV/u. In both cases the element number of the different reaction channels can clearly be identified.

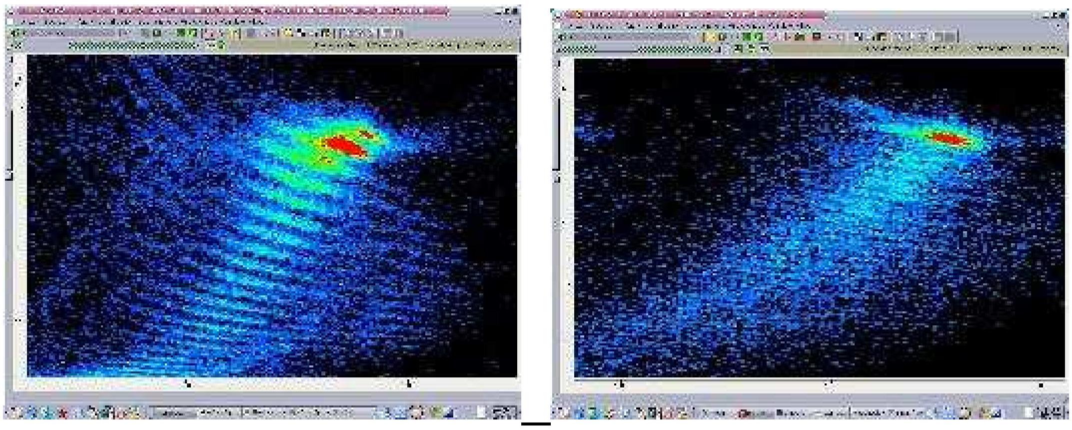

Figure 2: Particle identification with CATE using the ΔE-E correlation for reactions with mixed secondary beams of ^{57}*Mn,* ^{56}*Cr and* ^{55}*V (left) and* ^{108}*Sn (right) on a Au target at a beam energy of ≥100 MeV/u.*

For the excited fragments moving at a high velocity (v/c=0.43 at a fragment energy of 100 MeV/u) the γ detectors have to be positioned at either forward or backward angles in order to minimize Doppler broadening. The best possible configuration of the 15 Cluster Ge detectors available for experiments with fast beams is displayed in fig. 3. The first ring of 5 Cluster Ge-detectors is positioned at 68cm to the target in order to achieve 1% energy resolution. If this resolution is required, the target distance of ring two (three) needs to be 112cm (137cm). For all performed experiments the Cluster Ge-detectors in the 2nd and 3rd rings were moved closer to the target position, for an increased efficiency but a lower overall resolution. If both rings are placed at a minimum distance of ~70cm then the configuration reaches a total efficiency of 2.9%.

For the investigation of the giant dipole resonance 8 large volume BaF_2 detectors were mounted at backward angles.

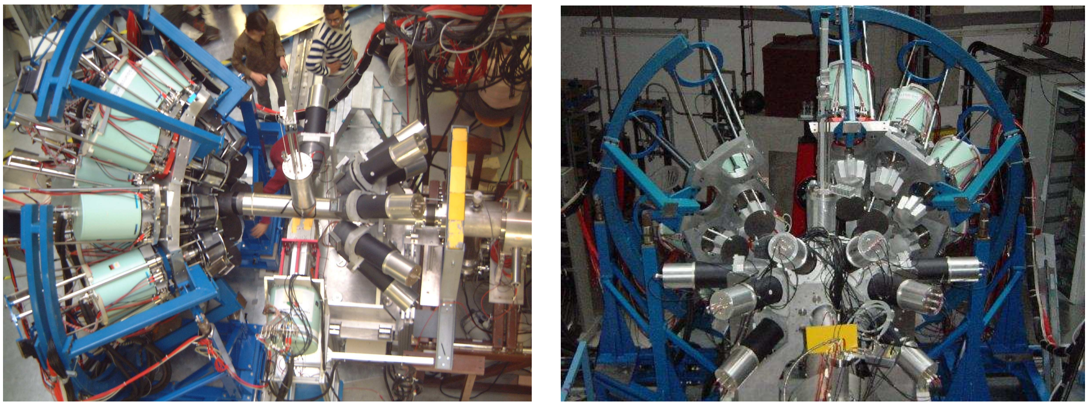

Figure 3: Top and front view of the RISING set-up for 15 Cluster Ge-detectors positioned at forward angles (15.0^0*,* 26.5^0*,* 34.0^0*) and 8* BaF_2 *detectors mounted at backward angles (*90^0*,* 143^0*).*

3. Overview of runs performed in 2003

3.1 Commissioning experiment with stable beams

During the first commissioning run employing ^{132}Xe primary beam all detectors and sub systems were tested and proofed to work. Additional slits and lead absorbers were mounted in front of the target to reduce secondary beam related γ-radiation and particles causing severe background contributions in the Cluster Ge-detectors. However, the expected discrete line in the γ-spectra from Coulomb excitation was not visible. Therefore, the scheduled time for the RISING experiment (S269-3) was used to continue the commissioning with a ^{84}Kr beam, which was agreed by the collaboration. During this run the reason for the missing γ-ray line was discovered be loss of synchronisation of part of the FRS VME readout channels.

Coulomb excitation of ^{84}Kr using a stable beam (≈100 MeV/u) at the S4 FRS focal plane was identified by requiring beam like ions down-stream in the CATE array. The ΔE-E information gave a sufficiently clean identification of Kr ions and a clear separation of secondary fragments. The γ-ray events and the ΔE-E data were correlated to produce a Coulomb excitation γ-ray spectrum "gated" by Z=36. However, the requirement of outgoing Kr ions is not sufficient to discriminate the interesting inelastic excitation from elastic scattering and other peripheral reactions. The additional requirement of a scattering angle dependence (θ_{lab}=0.3^0-2.5^0) on the γ-ray emission was crucial to select the Coulomb excitation events. A Doppler shift corrected γ-ray spectrum of ^{84}Kr is displayed in fig.4, which is of better quality than the online result of the MSU group.
In summary, experiments with primary beams are decisive for a well defined beam energy and a small beam size at the FRS focal plane enabling accurate online Doppler shift corrections and good online scattering angle determination. Therefore, the tracking detectors before the target need not to be included in the analysis, which is the main difference with respect to secondary beams.

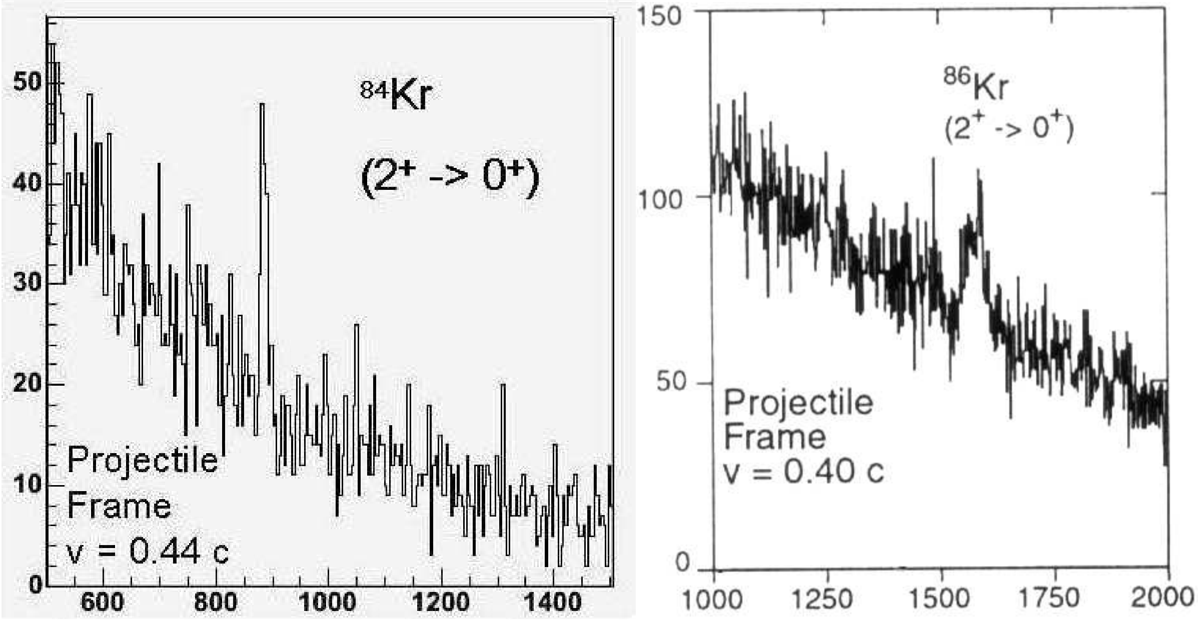

Figure 4: Doppler corrected γ-spectrum from Coulomb excitation of ^{84}Kr (E(2$^+$-0$^+$)=882 keV) measured with the RISING set-up at a beam energy of ≈100 MeV/u (left) and the online result of a similar MSU measurement on ^{86}Kr published by T. Glasmacher in the proceedings of the Hirschegg 2003 conference.

3.1.1 Background radiation investigated by HECTOR

The 8 BaF_2 detectors from the HECTOR array, in addition to their primary role for measuring the high-energy gamma rays from the Giant and Pigmy Resonances, turn out to be excellent probes for the investigation of the source of the unwanted background radiation in the RISING experiments. This was due to their very good time resolution (<1 ns) and high efficiency.
Figure 5 shows the time spectra measured in one of the BaF_2-detector. The green line displays the spectrum as obtained in the very first commissioning experiment, in which the 150 MeV/u ^{132}Xe beam and 0.2 g/cm^2 Au target were used. One can see that the spectrum is dominated by large background radiation, preceding by 2-8 ns the prompt radiation from the target (narrow peak at t=0). This indicated that the source of this background radiation is positioned at the distance 1-4 m upstream from the target. Indeed, after building a 6 cm thick lead-wall shielding the detectors from the part of the beam line, this radiation has been drastically suppressed. The improvement can be seen in the Figure 1, red line. The shown spectrum has been taken in the second pilot experiment, in which ^{84}Kr beam at 100 MeV/u was used. To demonstrate that the background is not related to the reaction on target, spectrum plotted in blue color has been taken with the empty target frame.

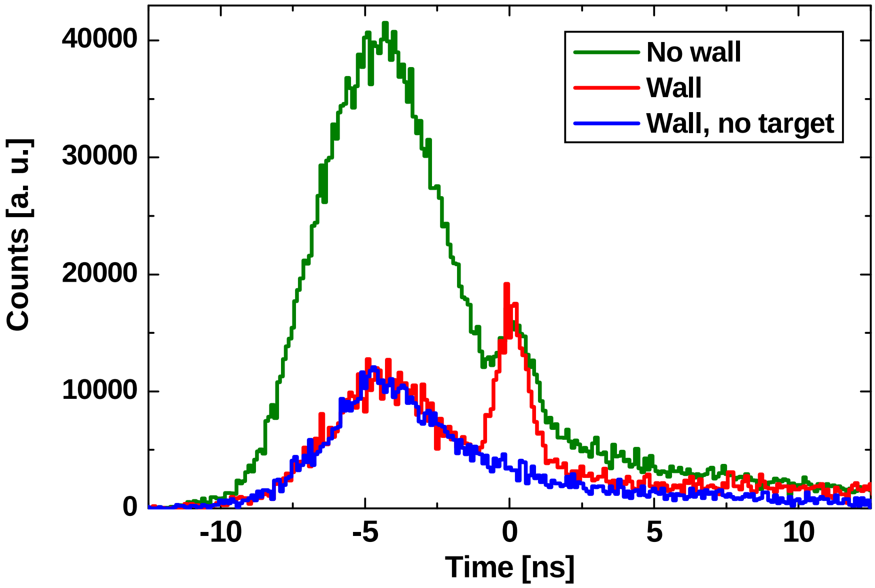

Fig. 5. Time spectra in respect to start signal given by the plastic scintillator SC41, measured in the BaF_2 detector positioned at 143°. Green line: in the case without the lead wall, with 150 MeV/u ^{132}Xe beam and 0.2 g/cm^2 Au target; red line: in the case with the lead wall mounted, with 100 MeV/u ^{84}Kr beam and 0.2 g/cm^2 Au target; blue line: same as the previous case, but with empty frame instead of target.

Further investigation of the origin of the remaining background shown, that it is caused by hitting the beam line by the light particles and nuclei, after fragmentation of the incoming beam in the gas or entrance foils of different FRS detectors. Figure 6 shows two time spectra gated by the energy deposited in MUSIC detector. The spectrum plotted in green corresponds to the gate set on the low-Z fragments detected in the MUSIC-detector. As can be seen, the spectrum is basically showing only the background contribution. It is completely different from the spectrum plotted in red, which is gated by the Z-values corresponding the primary ^{84}Kr beam. In this spectrum the prompt peak coming from the target is clearly seen. The remaining background is related, most probably, to the fragmentation reactions occurring after MUSIC. Additionally in this figure one can clearly see the different components of the radiation seen by the BaF_2 detector: apart from the background radiation and the radiation from the target, one can see neutrons from the target (7-12 ns after prompt radiation), as well as the gamma radiation from the reaction caused by hitting the CATE detector by the Kr beam (17 ns after the prompt radiation).

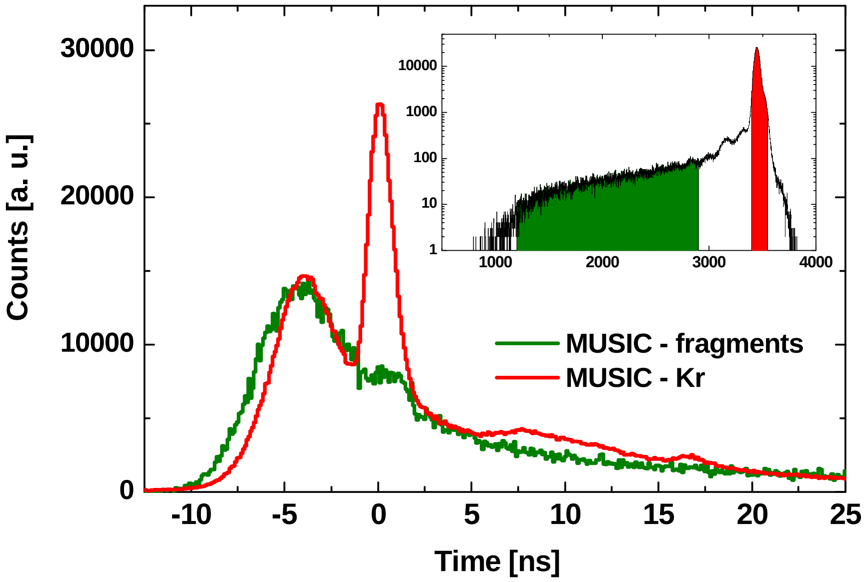

Fig. 6. Time spectra gated by the energy deposit in the MUSIC chamber (see inset). The green line shows the spectrum gated by the low-Z fragments detected in MUSIC, the red line – gated by Z of the primary beam Kr.

3.2 Report on RISING Proposal S269-2

‘***Isospin symmetrie and Coulomb effects towards the proton drip-line***’
by M. A. Bentley et al.

Main motivation for the measurement was the search for excited states in exotic proton-rich nuclei in the $f_{7/2}$-shell. In particular, the principal aim was to detect excited states in $N=Z-3$ ($T_z=-3/2$) nuclei such as ^{53}Ni, as there is no spectroscopic data on excited states of such nuclei in this region. The physics case was to investigate, through comparison with the mirror nuclei (e.g. $T_z=+3/2$ ^{53}Mn), the Coulomb energy differences and study the extent to which isospin symmetry holds as the drip-line is approached.

To study ^{53}Ni, a secondary fragmentation experiment was performed – this was ^{58}Ni→^{55}Ni→^{53}Ni (primary beam → secondary beam → final nucleus). A primary beam of 600 MeV/A ^{58}Ni impinged on a 2.3 gcm^{-2} Be primary target where relativistic secondary ions were produced by a fragmentation process. These ions were separated, identified and selected by the FRS to yield a secondary beam of ^{55}Ni at around 170 MeV per nucleon. These fragments were identified using time-of-flight and energy loss and tracked onto the secondary target – which was 700 mgcm^{-2} of Be – at the target position of RISING. Fragmentation reactions occurred in the secondary target, the prompt γ-rays from which were recorded in Cluster Ge-detectors. The final nuclei produced were identified with the CATE ΔE-E detector. The final nuclei need to be identified very cleanly – the Z information coming from the energy loss in the Si (ΔE) detector and the A information coming from the total energy (E) – which in this mass region should work well. In addition, prompt high-energy γ-rays were recorded using the HECTOR detectors.

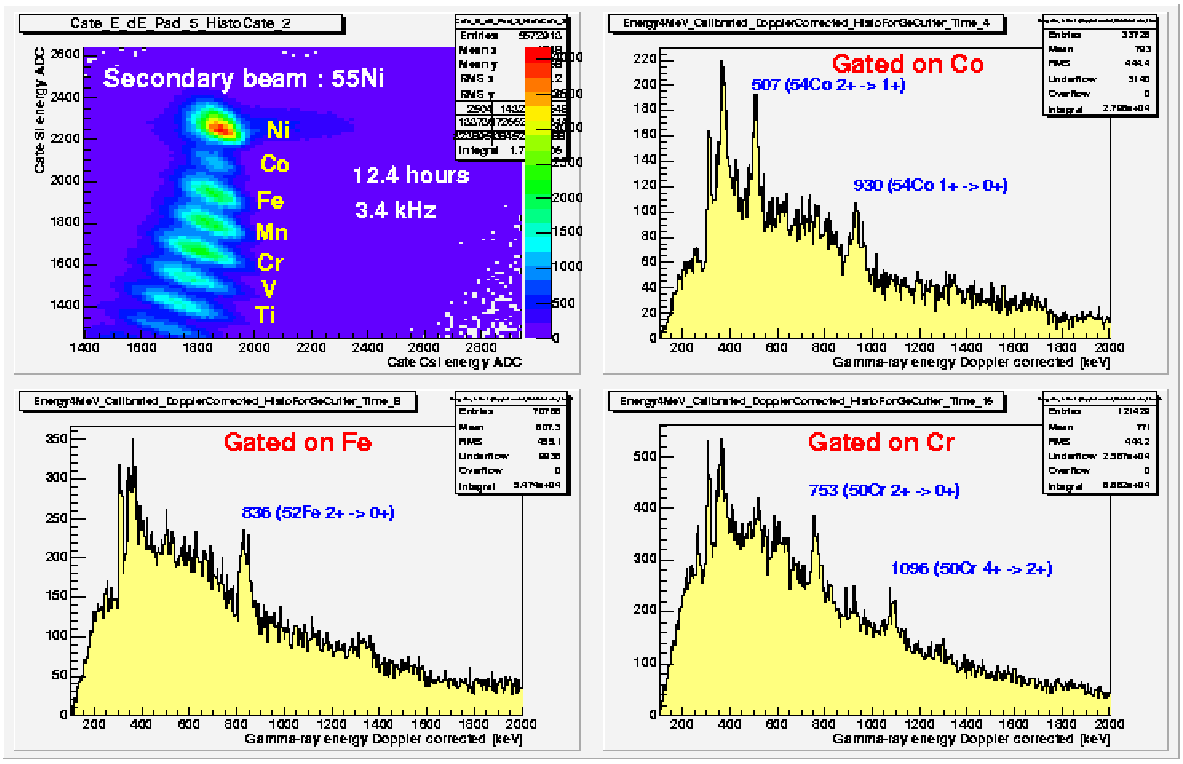

Figure 7: Doppler corrected γ-spectra from fragmentation reactions of ^{55}Ni ions on a 0.7 g/cm^2 Be target measured with the RISING set-up at a beam energy of 170 MeV/u. The produced γ-ray spectra are gated on the Z of the final nucleus measured with CATE.

All of the four detector systems (FRS, CATE, Cluster-Ge, HECTOR) worked as expected in the experiment, with clear correlations between the detector branches. The FRS was able to produce a virtually pure (and identified) ^{55}Ni beam, and all 9 of the CATE CsI and Si detectors produced sensible and consistent spectra which enabled identification of the final fragments. The γ-spectra gated by different regions of the CATE ΔE-E plots showed that there was a perfect correlation between the detector branches (see fig.7).

In addition to the main ^{58}Ni→^{55}Ni→^{53}Ni reaction (2n removal in the final stage) we also ran for around one day on the reaction to populate the known mirror nucleus ^{53}Mn (^{58}Ni→^{55}Co→^{53}Mn) – which was a 2p removal in the final stage. This was performed so that the two "mirror" spectra could be compared to enable construction of the final ^{53}Ni level scheme. Taking into account periods of time for calibration and testing, roughly one day was spent on ^{58}Ni→^{55}Co→^{53}Mn and five days on ^{58}Ni→^{55}Ni→^{53}Ni. We operated with around 5000 ^{55}Ni per second incident on the secondary target. This was somewhat lower than had been suggested in the proposal, and was limited in part by the lower than expected primary beam intensity and also by the fact that we were possibly over-cautious in not overloading (damaging) the detectors for the following runs.

To date, the analysis is only at a very preliminary stage (although the results are already very encouraging). In particular, identification of the very weakest channels is going to need very careful final-nucleus identification using CATE. The Z-identification is already perfect from the ΔE detector (clear separation between the different Z's is observed all the way from Z=28 to at least Z=16 or below). To obtain A-identification, we need a very good measure of the total energy in the CsI detectors. It is known, from the commissioning experiment, that the energy resolution of CATE is highly position dependent, but that good resolution can be achieved once this is corrected for. Thus we require detailed offline corrections which will require careful position calibrations of the CATE and MW detectors in order to develop the correction algorithms. The γ-ray spectra produced so far have therefore only been gated on the Z of the final nucleus, with no A-information at present. The spectra have also only had a rough Doppler correction algorithm applied, with no information on particle tracking incorporated or corrections to the v/c from the time-of-flight measurements.

Nevertheless, even at this very preliminary stage and with only a rough Doppler correction applied, the quality of the spectra is very encouraging. The Z-gated spectra show 100% separation between the different Z's, with each spectrum only containing γ-rays from known excited states in nuclei of that Z. The cross-sections for most of the strong fragmentation reactions (few proton knockout etc) are typically in the 20-50 mb range, and these γ-rays (e.g. from ^{50}Cr, ^{52}Fe, ^{54}Co, etc) are clearly visible in the Z-gated spectra, with strong peaks observed online in a few hours. Regarding the weakest channels (proton rich) we have already been able to identify the 4^+-2^+ and 2^+-0^+ transitions in $N = Z - 2$ ^{54}Ni. This was observed only by Z-gating on the Ni-region in the CATE spectra. The only γ-rays expected from Ni are from Coulomb excitation of the beam (improbable with ^{9}Be), or from fragmentation to ^{54}Ni or ^{53}Ni. Thus ^{54}Ni should be the strongest component in the spectrum. Although the predicted cross-section is 5mb, these γ-rays were visible in the online spectra after a few shifts. These states have only been observed very recently[1] in a full Euroball+Euclides+n-wall experiment, and the data are as yet unpublished. These are the heaviest known $N = Z - 2$ excited states. Based on this, we are very confident that with offline mass identification, we shall be able to identify presently unknown excited states in proton-rich nuclei such as $N = Z - 2$ ^{52}Co (predicted 1mb cross section) and ^{53}Ni.

3.3 Report on RISING Proposal S269-4

'***New shell structure at N>>Z - Relativistic Coulex in N=28-34 and N=40-50 nuclei'***
by H. Grawe, H. Hübel, P. Reiter

First measurements with radioactive ^{56}Cr beams

After the successful RISING commissioning beam time with a stable ^{84}Kr beam, proposal S269-4 was selected to be the first experiment employing secondary radioactive beams from FRS. Proposal S269-4 suggested to measure energies and B(E2) values of first excited states in sequences of medium mass nuclei using Coulomb excitation at relativistic energies. Aim of the first experiment were measurements of neutron-rich Chromium (^{56,58}Cr) and Titanium isotopes (^{52,54}Ti) in order to investigate the possible sub-shell closures at N=32,34.

The experimental procedure of S269-4 was identical with the commissioning experiment and therefore the identical set-up was used for the radioactive beam including the same electronics, trigger scheme and data acquisition. The primary beam of ^{86}Kr from SIS at 419 MeV/u energy impinged on a ^{9}Be production target (2.5 g/cm^{2}) in front of the FRS. The FRS was used to select fragments around ^{56}Cr. Following the FRS, at the target position of the RISING array, the secondary beam of fragments hit a second, high Z ^{197}Au target of 1 g/cm^{2}, at an energy of ~136MeV/u. The incoming ^{56}Cr ions were identified on an event-by-event basis with respect to mass and atomic number via combined time-of-flight (scintillators at S2 and S4), position tracking (MWPC), and energy loss measurement (MUSIC chamber). After passing the identification set-up, the radioactive ions were focussed onto the secondary ^{197}Au target. Additional slits and lead absorbers were mounted during the commissioning phase in front of the target to reduce secondary beam related γ-radiation and particles causing background contributions in the Cluster Ge detectors. Gamma decays from radioactive fragments induced reactions were measured with 15 RISING cluster detectors. Behind the Au target the calorimeter telescope, CATE, was used successfully for channel selection. CATE consisted of position sensitive Si ΔE detectors (lab. angular range ±3°) with a charge resolution of $\Delta Z/Z \sim 1$ % and CsI scintillators for total energy measurement

Strategy and aim of the first radioactive beam experiment with RISING was to reproduce the feasibility of Coulomb excitation also with the fragmentation beam. The experiment started with a composition of ^{55}V, ^{56}Cr, ^{57}Mn fragments. The secondary beam rate was calculated to be sufficient to detect 200-300 counts in the 2^{+} transition of ^{56}Cr within two shift. However, the experimental obstacles to observe online a convincing peak from the 2^{+}-0^{+} transition in ^{56}Cr had proven to be insurmountable during the measuring period. The online selection of Coulomb excitation events is very challenging due to the very similar signature of beam induced background in the Ge detectors which is also enriched by the online trigger condition of particle-gamma coincidences. While performing the first online and offline analysis for the first radioactive fragmentation beam (which was part of the commissioning) the gamma spectra showed only hints of a peak from Coulomb excitation of ^{56}Cr. Therefore, the change to a second more neutron-rich but less intense secondary beam of Chromium or Titanium was not justified at this stage of the experiment.

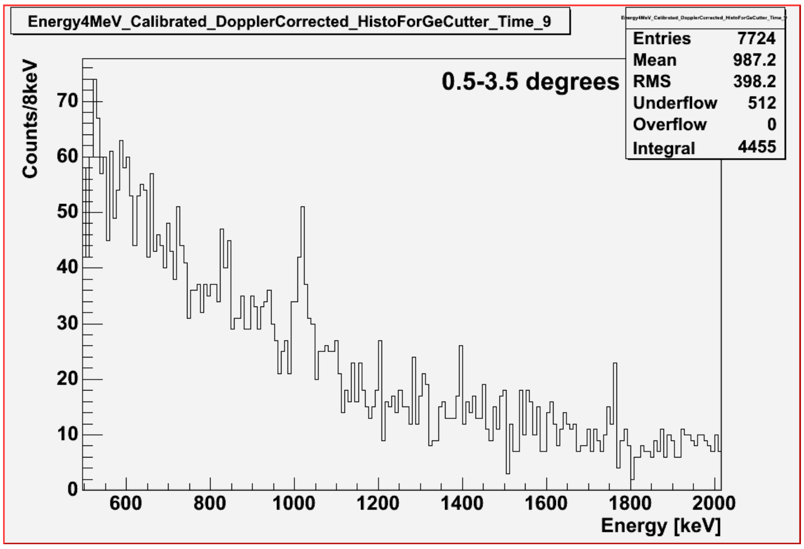

Figure 8: Doppler corrected γ-spectrum from Coulomb excitation of ^{56}Cr ($E(2^{+}\text{-}0^{+})=1007$ keV) at a beam energy of 129 MeV/u. No background subtraction is applied.

Meanwhile, the preliminary results of the ongoing analysis of the ^{56}Cr experiment shows a peak from the 2^{+}-0^{+} transition after Coulomb excitation of ^{56}Cr (see fig. 8). Different from the first online analysis procedure it turned out to be essential to apply very accurate analysis conditions, which are based on precise calibrations (including non-linear corrections, count rate dependencies…) of all ancillary detectors, in order to obtain the Doppler corrected γ-spectrum. The following steps and analysis conditions were applied on an event-by-event basis to select the Coulomb excitation events: (i) Z identification of in front and behind the target, (ii) mass determination in front of the target, (iii) scattering angle range from 0.5 to 3.5 degrees from position measurements in front and behind the target, (iv) velocity measurement, (v) prompt time gates in all detectors. Further improvements will be achieved in the near future e.g. by proper background subtraction, mass identification of the projectile like nuclei behind the target, which is not included yet.

Due to a power failure and computer network problems the effective time of beam on target was only 40 hours. During the offline analysis it turned out that additional accelerator problems obviously resulted in changed beam properties further reducing the usable statistics. Meanwhile analysis procedures are available to monitor on line the required beam quality.

In summary Coulomb excitation of ^{56}Cr at 136 MeV/u with a secondary beam of radioactive fragment has proven to be feasible with the RISING spectrometer. Considering the unexpected short measuring period and a preliminary analysis efficiency the measured spectrum of fig. 8 is in agreement with the rate estimate of the proposal. Improvements of the analysis procedure are ongoing and better Coulomb excitation result are expected in the near future.

3.4 Report on RISING Proposal S269-6

Relativistic Coulomb excitation of nuclei near ^{100}Sn

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The goal of the S269-6 proposal was to measure B(E2: $2^+ \rightarrow 0^+$) values in the light Sn isotopes.
The information on the E2 polarizability and shape response of the doubly-magic ^{100}Sn core will grow significantly from measurements of the E2 correlation of the nuclei close to it which are presently accessible. Already for this region of nuclei the experimental conditions at GSI are better compared to other in-flight fragmentation facilities. This has its reasons in higher beam energies available, which lowers the possible charge-states contamination of the secondary beam.
Coulomb excitation is the only way to measure more detailed than excitation energy the properties of 2^+ states in this region. The existence of high-spin isomeric states above the 2^+ states in most of the even isotopes makes the lifetime measurement impossible. The B(E2: $2^+ \rightarrow 0^+$) values are not known so far for any of the light Sn isotopes except of the stable ^{112}Sn which was chosen as a calibration case.

The light Sn isotopes were produced by means of projectile fragmentation reactions of ^{124}Xe at 700 MeV/u primary beam impinging 4 g/cm^2 ^{9}Be target. The secondary beam of fragments was separated in the FRS and tracked even by event by means of time-of-flight, Bς, ΔE and position measurement with the set of the routinely used detectors. In the middle focal plane a relatively thick degrader was mounted to obtain a pure beam of nearly one isotope at the end of the FRS. In addition, slits mounted just before the final focal plane were allowing only for fragment coming in the range covered by the secondary target of 7x7 cm dimensions. The secondary beam of the fragment of interest at 147 MeV/u impinged on the 400 mg/cm^2 ^{197}Au Coulomb excitation target. Prompt gamma rays emerging from the target were registered in the RISING setup in coincidence with the final nuclei identified in CATE ΔE-E setup of the active area of 0-3 degree.

The calibration of the FRS setup was the most difficult from the so far performed RISING experiments and additional cautious procedure had to be undertaken which assures the identification of the final beam. This procedure including optimization of the primary beam took in total 48 hours.

For the run on ^{112}Sn 34 hours of the effective beam time was used. The fragment beam intensity at the secondary target was 3500 particles per second. The rate was lower than assumed in the proposal as special care was taken for the tracking detectors to prevent them from permanent damage. After that the secondary beam was optimised to ^{108}Sn fragment and served for 2 days effective measurement. This fragment beam was of the same intensity as ^{112}Sn. In the on-line or near-line analysis there was only an indication of the Coulomb excitation peak of the two measured nuclei, therefore the next step of going to lighter mass Sn isotopes was not taken.

However, already during the measurement it was clear that all detectors were working correctly and the right beam was selected. In fig.2 the ΔE-E spectrum of one element of the CATE array is shown. Sufficient Z resolution is obtained in the raw spectra even for this region of nuclei. The mass resolution, like all the other results, requires a detailed analysis including a number of corrections performed on the event-by-event base.

As the S269-6 experiment was the last one in the campaign, the analysis is only in a very preliminary state. The data appears to be very sensitive for the small changes of any parameter used for the Doppler correction, like beam identification, time-of-flight, position information and scattering angle after the secondary target. Therefore, before final results can be obtained all the calibration have to be implemented systematically including gain shifts stability correction, and other cross correction of different detector system influencing the final background suppression and the width of the Coulomb excitation peak. The most challenging will be the mass resolution in this region of nuclei. The separate analysis on this subject focusing on the general method of unfolding the E-detector information is on the way. Based on the count rate estimates from the experiment and known life-time of the 2^+ state in ^{112}Sn, the peak should be visible after careful data analysis of the present data. After a successful data analysis there is an intention to propose a continuation of this measurement in the lighter isotopes, as it was impossible with the present beam time.

4 Future measurements of proposal S269

Within the last year, after the proposals were accepted by the GSI Experiment Ausschuss, main ideas of the following four RISING proposals: S269-4 **'**New shell structure at N>>Z - Relativistic Coulex in N=28-34 and N=40-50 nuclei', S269-5 'Investigation of the origin of mixed-symmetry states using relativistic COULEX of N=52 isotones', S269-6 'Relativistic Coulomb excitation of nuclei near ^{100}Sn', S269-9 'Magnetic moments of Xenon and Tellurium isotopes near doubly magic ^{132}Sn at relativistic energies' moved into the focus of attention at other radioactive beam facilities. Beside the fragmentation beams of Michigan State University, National Superconducting Cyclotron Laboratory (MSU, NSCL) and GANIL, also post-accelerated radioactive beams - delivered by the ISOL facilities at Oak Ridge National Laboratory (ORNL) and REX-ISOLDE at ISOLDE, CERN – will be employed to investigate the nuclei of interest. The four RISING proposals were already discussed during RISING workshops in 2000 and 2001 and the submitted proposal were produced in winter and spring 2001/2002. To our knowledge the proposals from other facilities were accepted after the EA meeting in June 2001. The following table summarizes the accepted proposals and one performed experiment from other facilities competing with RISING proposals S269.

S269 No.	Nuclei of Interest	Facility	Proposal	Experiment type
4	^{52,54,56}Ti	MSU, NSCL	02002	Coulex, intermediate energies
4	^{68,70,72}Ni,^{66}Fe	MSU, NSCL	01019	Coulex, intermediate energies
4	^{68,70}Ni	GANIL	measured	Coulex, intermediate energies
4	^{74,76}Zn, ^{68}Ni	ISOLDE	IS412	Coulex, Barrier energies
4	^{82}Ge	ORNL	RIB-110	Coulex, Barrier energies
4	^{86,88}Se	MSU, NSCL	01031	Coulex, intermediate energies
5	^{88}Kr	ISOLDE	IS423	Coulex, Barrier energies
6	^{106,108}Sn	ISOLDE	IS418	Coulex, Barrier energies
9	^{132,134,136}Te	ISOLDE	IS415	Coulex, Barrier energies

Table 1: Accepted proposals from other facilities competing with RISING proposals S269.

4.1 Proposal S269-4:

'***New shell structure at N>>Z - Relativistic Coulex in N=28-34 and N=40-50 nuclei'***

by H. Grawe, H. Hübel, P. Reiter

4.1.1 Continuation and modification of proposal S269-4:

The proposal aims at the investigation of shell structure at N=50,40 and the expected new shell closure at N=32,34 by means of Coulomb excitation with fast beams. A first experiment was performed on the N=32 nucleus ^{56}Cr. Due to unresolved accelerator problems a continuation towards heavier Cr isotopes and the ^{54}Cr calibration could not be carried out during the first experiment in September 2003. It is suggested to continue this part of the original proposal with 15 shifts of the remaining beam time with the aim to approach ^{64}Cr$_{40}$ and ^{66}Fe$_{40}$ (corresponding to ^{32}Mg in N=20) as close as possible.

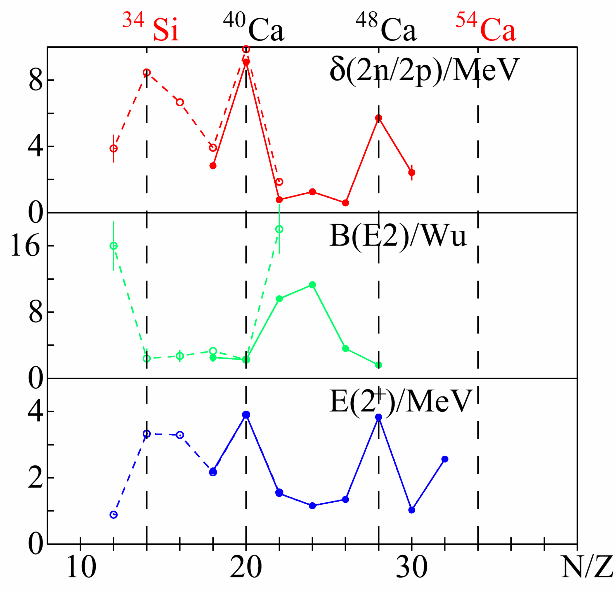

Figure 9: Excitation energies of the 2^+ states, the E2 strengths B(E2) and the second difference of the g.s. binding energies δ_{2n}, resp. δ_{2p} for the Ca isotopes and the N=20 isotones (dotted lines), which are the isospin mirrors for the light N<20 Ca isotopes. There is evidence for (sub)-shell closures at N, Z=14, 16 and N=32, (34).

The experimental status of the remaining nuclei on the list presented in the proposal due to competition by alternative methods and facilities has drastically changed since submission to the PAC. Considering the fierce competition with routinely operating groups in the N=40 and N=50 isotones and the neutron-rich N=28-34 isotopes we expect by the end of 2003 that Coulex experiments will be (have been) performed on the neutron-rich isotopes (see Table 1).
It is therefore suggested to devote 17 shifts of proposal 269-4 of the remaining alotted beam time to another aspect of the shell driving mechanism addressed in the proposal.

If the new N,Z=14(16) shell stabilisation and the N=20 shell quenching in ^{32}Mg$_{20}$ is dominated by the monopole part of the two-body interaction and not or little affected by the small neutron binding energy, the scenario is symmetric in isospin projection T_z [1]. The only site in the Segre chart where this can be verified is the N=20 mirror region along the light Ca (Z=20) isotopes. It is suggested to study the ^{34}Si, ^{35}P, ^{36}S and ^{35}S mirror nuclei $^{34-36}$Ca and ^{35}K at the N=14,16 shell closure. Single particle states, core excitations and shell gaps provide the signature for shell structure. The lightest Ca isotope with detailed spectroscopy is ^{38}Ca and no excited states are known for the N=14,16 isotopes. The levels and gamma-rays expected from the known N=20 mirrors are shown in Fig. 10.

Recently the Coulomb energy difference (CED) of isobaric analogue states (IAS) in connection with precise large-scale shell model calculations has proven to be a sensitive spectroscopic probe to investigate orbital radii in excited states [2] and reduced overlap of identical proton and neutron orbitals at the driplines [3] .
The CED defined as

$$\mathrm{CED}(I) = E_x(I,T_z=-T) - E_x(I,T_z=+T)$$

will be positive (CED>0) for increasing spin I due to alignment and therefore reduced Coulomb repulsion. This can be partly counterbalanced by reduced orbital overlap as this quenches the two-body matrix elements. For the mirror pair ^{38}Ca and ^{38}Ar the CED of the first excited 2^+ state (^{38}Ca;2^+ - ^{38}Ar;2^+ =39 keV) is positive, which is expected due to the different Coulomb repulsion in the 0^+ ground state. However, a negative CED is anticipated by approaching the proton dripline. Here the question arises whether the quenching of the two-body interaction due to a reduced orbital overlap may cause the opposite CED shift. First evidence can be deduced from the proposed CED measurement (^{36}Ca;2^+ - ^{36}S;2^+).

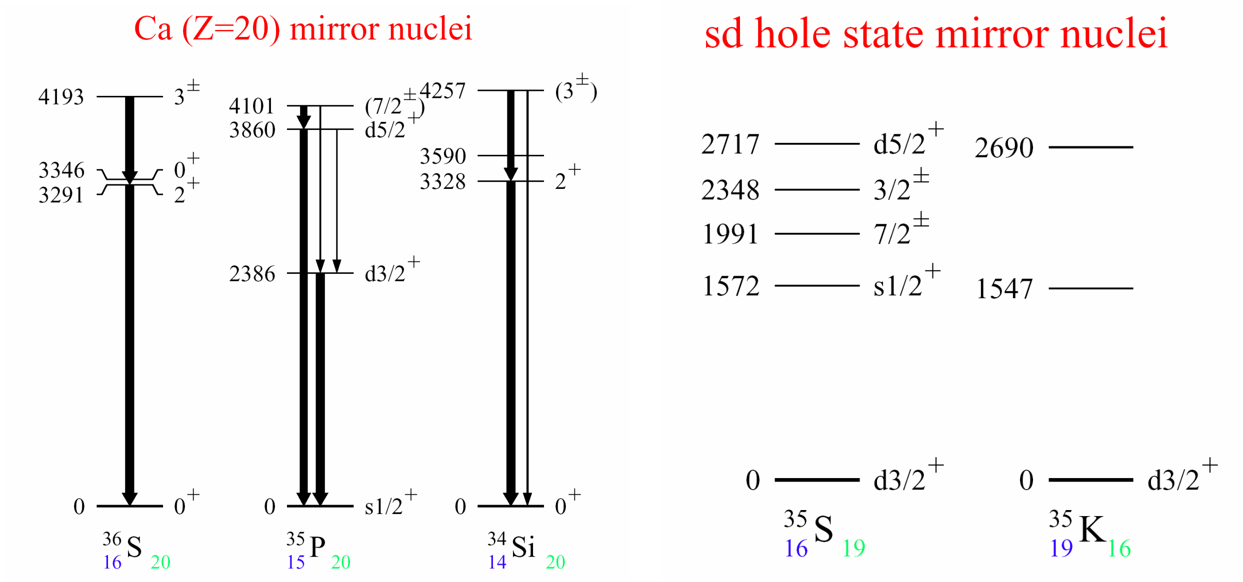

Figure 10: Level schemes of N,Z=19,20 mirror nuclei

4.1.2 Experimental Details

The method applied will be secondary fragmentation, which has been proven to be very successful in the pilot experiments at RISING [4]. In Table 1 EPAX cross sections for the pilot experiment of Bentley S269-2 and the proposed experiments are listed for different production paths and compared by introducing a figure of merit (FoM). It is defined as the ratio of the product of the two fragmentation cross sections involved. The numbers prove that experiments on ^{35,36}Ca and ^{35}K are feasible now, while ^{34}Ca needs further development of the method. It is expected that for the second few-nucleon removal step the EPAX cross sections are rather lower limits**.**

fragmentation path	σ_{EPAX} [µb]	Figure of Merit
58Ni ->55Ni	165	
55Ni ->53Ni	86	1
40Ca ->38Ca	1883	
38Ca ->36Ca	61	8.1
38Ca ->35Ca	1.1	0.15
38Ca ->35K	468	62
38Ca ->34Ca	0.021	0.003
40Ca ->37Ca	38.9	
37Ca ->36Ca	1804	4.9
37Ca ->35Ca	13	0.036
37Ca ->35K	4160	11.4
37Ca ->34Ca	0.116	0.0003

Table 2: Comparative EPAX cross sections and Figure of Merit

In order to obtain the highest yield of ^{36}Ca in secondary fragmentation reactions the EPAX code has been used to predict the cross-sections in various double fragmentation scenarios with Ca isotopes. As a result a beam of incoming ^{38}Ca fragments at the S4 focal plane should impinge on the secondary RISING target. The following optimised setting was obtained from MOCADI calculations (fig.9): A primary ^{40}Ca beam (intensity of 10^9 s^{-1}) is hitting the primary ^{9}Be target (4 g/cm^2) at an energy of 450 MeV/u, and a 700 mg/cm^2 secondary ^{9}Be target (limited to keep straggling and velocity spread at acceptable levels) will be used. The

FRS transmission efficiency for ^{38}Ca fragments is 34%. The FRS rates at the S2 and S4 focal plane will be acceptable. At the secondary RISING target position mainly ^{38}Ca ions (56 kHz) will hit the target and only a minor contribution (3 kHz) from ^{37}K will also be part of the beam composition. The ^{37}K beam component can be selected from the interesting ^{38}Ca beam by measuring the charge with the MUSIC detector. The EPAX cross-section yields a production rate of 0.14 Hz for ^{36}Ca after secondary fragmentation reactions.

For a rate estimate we used: (i) a photo peak gamma efficiency at 3 MeV including the Lorentz boost of 2% from Monte-Carlo simulations. (ii) Excited states in ^{36}Ca are populated with a 50% propability. (iii) The required intensity of a gamma-ray peak in ^{36}Ca should exceed 300 cts. Based on these numbers we ask for the remaining 17 shifts of proposal 269-4 including also 2 shifts for FRS tuning time.

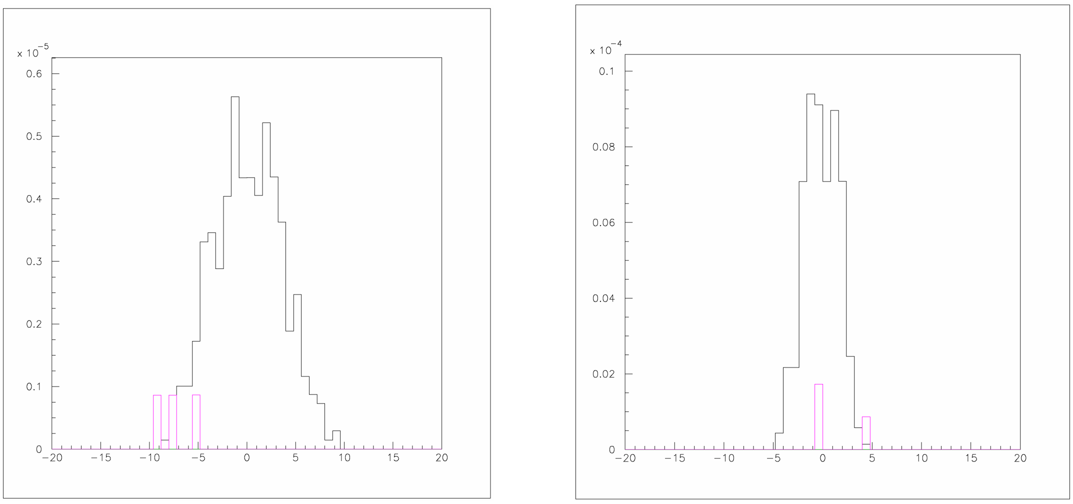

Figure 11: MOCADI calculations for ^{40}Ca ions at 450MeV/u hitting a 4 gcm^{-2} Be target. Fragment distribution for ^{38}Ca (black) and ^{37}K (red) fragments at the FRS S2 focal plane (left panel) and the RISING target position

References (only part 269-4)

[1] H. Grawe et al., Act. Phys. Pol. B34, 2267 (2003) and Proc. 31. Int. Workshop on Gross Properties of Nuclei and Nuclear Excitations, nuclear stucture and dynamics at the limits, Hirschegg 2003, edt. H. Feldmeier et al., (GSI Darmstadt, ISSN 0720-8715, 2003), p. 94

[2] S.M. Lenzi et al., Phys. Rev. Lett. 87, 122501 (2002) and A.P. Zuker et al., Phys. Rev. Lett. 87, 142502 (2002)

[3] G. de Angelis et al., Eur. Phys. J. A 12, 51 (2001)

[4] M. Bentley, progress report on S269-2

4.2 Proposal S269-5:

'S269-5 'Investigation of the origin of mixed-symmetry states using relativistic COULEX of N=52 isotones' by D. Tonev now J. Jolie et al.

At REX /ISOLDE a proposal to measure excited states using multiple COULEX of a 2.2 and 3.1 MeV/u beam of ^{88}Kr was submitted and accepted. A first experiment at 2.2 MeV/u allowed us recently to measure the excitation of the first 2+ state, which will allow the determination of the B(E2;0^{+}->2^{+}_{1}) value in ^{88}Kr. The experiment is complementary in the sense that the method (multiple Coulex at low energy and relativistic Coulex) will yield some cross checks on the measured B(E2) values and will populate different states. To have the cross checks is of importance when using a new method.

4.3 Proposal S269-6:

'Relativistic Coulomb excitation of nuclei near ^{100}Sn' by C. Fahlander et al.

After a successful data analysis there is an intention to propose a continuation of this measurement in the lighter Sn isotopes. The situation with possibly competing experiments at other facilities will be closely followed and appropriate action will be taken if necessary.

4.4 Proposal S269-9:

***Magnetic moments of Xenon and Tellurium isotopes near doubly-magic ^{132}Sn at relativistic beam energies* '** by K.-H. Speidel et al.

The physics issue concerns the measurement of *g* factors of short-lived 2_1^+ states of radioactive Te and Xe isotopes close to ^{132}Sn. The technique applied is projectile Coulomb excitation combined with transient magnetic fields (TF).

The same project has been proposed and accepted for the REX-ISOLDE facility at CERN as well as for SIS/FRS beams at the GSI in Darmstadt using MINIBALL and RISING detector arrays, respectively. Differences in the experimental conditions are as follows:

a) in the CERN measurements Coulomb excitation in inverse kinematics is used for beam energies of 3.1 MeV/u where the transient field strengths, associated with *low-velocity ions*, based on many experimental data of stable ion beams are well known; no great unforeseen experimental surprises are expected.

b) in contrast, the RISING experiment is dealing with *high-velocity H-like ions* (due to beam energies of about 100 MeV/u) for which the TF strength is associated with its strongest component, the *1s* electron Fermi contact field; moreover, large Coulomb excitation cross-sections are expected. These features make this technique particularly attractive as it would also allow to determine *g* factors of nuclear states in the sub-*ps* lifetime range. In addition, the angular correlation of the emitted gamma rays with their strong Lorentz boost will be explored for the first time. For all these exceptional and new conditions no data are currently available. Hence, the proposed RISING *g* factor experiment must be essentially seen in the context of methodology bearing, however, a large potential of rather unique applications.