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RITA-type triple axis spectrometers

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Historically, the importance of triple-axis neutron spectrometers for our understanding of excitations in condensed matter physics is indisputable. Today, other types of instruments ranging from the spin-echo-technique to time-of-flight spectrometers at pulsed sources have extended the range of obtainable energy resolution and absolute energy transfers. But as we strive to understand new phenomena and materials, such as low-dimensional magnetism, quantum phase transitions, high-Tc superconductors etc., it is often not the energy resolution or the energy range but rather the weak scattering intensity, which is the limiting factor.

In general, the only improvements over the original triple-axis spectrometer design have been increasing the flux reaching the instrument from the source and incorporation of focusing monochromators and analysers in stead of the collimated beam configuration. The latter has been motivated by a trend to study signals, which being broader and weaker require sacrificing resolution for counting rate. However, significant improvements can be obtained by exploiting advances in amongst other neutron-optics and detector technology. The RITA spectrometer at Risø National Laboratory was the first to incorporate a complete re-thinking of the neutron-path from source, through detector to analysis [slide 1, ref. 1 and references herein]. Since then, other RITA-type spectrometers such as SPINS at NIST, RITA-II at PSI have been built, and several new spectrometers around the world are adapting the same philosophy [slide 2].

The front end of spectrometers inevitably has to be adapted to the source and environment they are built in, but the original RITA spectrometer serves as a good example of the re-thinking philosophy. A sapphire filter suppressed the fast neutron background from the source, aided by pre-monocromating velocity selector, which acted as tuneable filter for suppression of higher order wavelength contamination. The development of better shielding materials also contributed to a very low background while at the same time allowing a short spectrometer to decrease the effect of divergence and hence improve the flux. From the monochromator, the neutrons were focused by tapered super mirror guides to give an overall enhancement in flux at the sample position of a factor of 2-4 over conventional front-ends.

But the main novelty of RITA was the introduction of a single back-end tank featuring both an analyser block with multiple individually turnable analyser blades and a 2D position sensitive detector [slide 3]. The total size of the multiblade analyser at a short distance from the sample represents a gain of about a factor of 5 in solid angle coverage compared to standard analyser-detector systems. The challenge is to exploit this solid angle potential in actual experiments. A standard focusing analyser of a similar size would result in a resolution ellipsoid considerably extended both in q and energy. Only in special cases would it be possible to place the long principal axis of such an ellipsoid along the dispersion of an excitation (resolution focusing) or along an unimportant direction in (q,w)-space (low-dimensional integration). However, the individually turnable analyser blades can be considered as a series of smaller resolution ellipsoids [slide 4], which can be arranged with respect to each other more adequately in (q,w)-space. In other words, the total resolution volume can be controlled to obtain so-called resolution focusing conditions [slide 5].

A 2D position sensitive detector in general gives more information at no or at least very little loss in total counting efficiency. In the same spirit, the commissioning RITA-II at PSI incorporates an additional detector behind the analyser. While in many cases, the counts in that detector will have a direct physical meaning, it will be an excellent tool for diagnosing the background - and be at no cost neutron wise. Even if the PSD is used as a single detector, it offers the possibility to detect spurious signals, and to optimise the signal to noise ratio by choosing the effective detector size during the analysis after the experiment. But more importantly, the neutron positions in the PSD can be converted to individual points in (q,w)-space, so that in one data acquisition, a small region of reciprocal space is mapped [slides 6-8, refs. 2-3]. This can be done even with a normal flat analyser and two radial collimators, but again, much more flexibility in adapting the mapping to the given experiment is provided by combining the PSD with a multiblade analyser.

Of course the added flexibility and the possibility of mapping adds complexity to the experimental situation. This has been overcome by macro-programmable control program and a set of utilities based on the MATLAB package for visualisation and analysis. Various modes of operation of the multianalyser-PSD system are discussed in reference [1], but the main point is that it gives the flexibility to optimise the spectrometer to each individual experiment. In the same spirit, a modular system for mounting various collimators (parallel and radial), beryllium and beryllium oxide filters and unforeseen additional motorised equipment is invaluable for the practical optimisation of the experimental conditions.

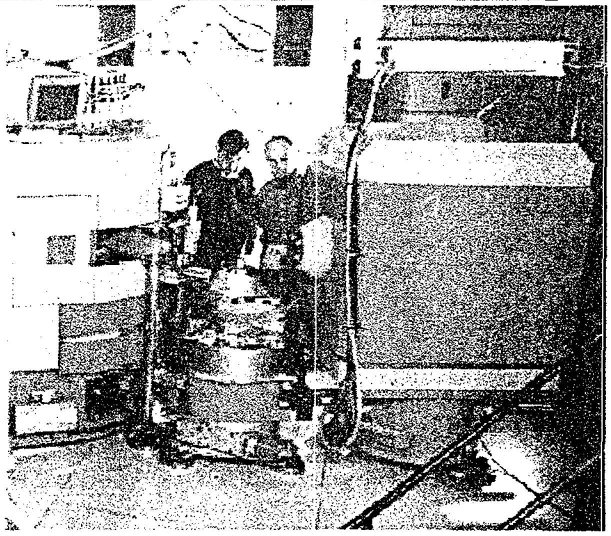
As mentioned in the beginning, both cold and thermal neutron triple-axis spectrometers continue to solve essential problems in condensed matter physics. Several new triple-axis spectrometers are presently being built at existing and future sources and I am happy to see that almost all of them have learnt from the experience with RITA. But in addition, it is my opinion that the applicability of the RITA concept should be considered also for existing instruments - if timely - through a complete upgrade. But even partial implementations can lead to big improvements in the performance of a spectrometer.

[1] K. Lefmann, D. F. McMorrow, H. M. Rønnow *et al.*, Physica B **283**, 343 (2000)
[2] B. Lake, G. Aeppli, T. E. Mason *et al.*, Nature **400**, 43 (1999)
[3] S.-H. Lee, C. Broholm, T. H. Kim *et al.*, Phys. Rev. Lett. **84**, 3718 (2000)

RITAs The RITA spectrometer at RISØ

Re-Invented Three Axis spectrometer

- Filtered, focusing front-end
- Back-end tank with multi-blade analyser and position sensitive detector
- Modular and flexible design of components



KN Clausen, DF McMorrow, T Mason, G Aeppli, K Lefmann and others

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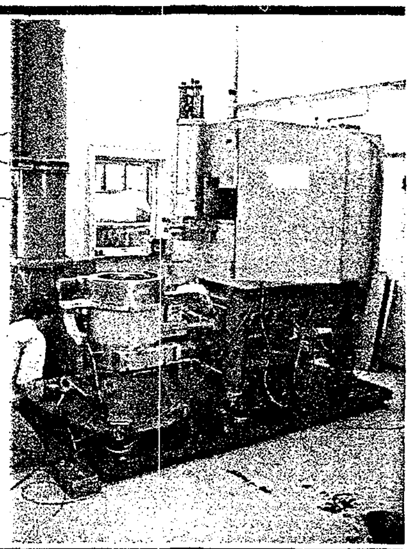
RITAs RITA-type spectrometers

- PSI: RITA-II ❾
  RITA-I (2002)
- NIST: SPINS (compact, very productive)
- Münich: PUMA (thermal neutrons)



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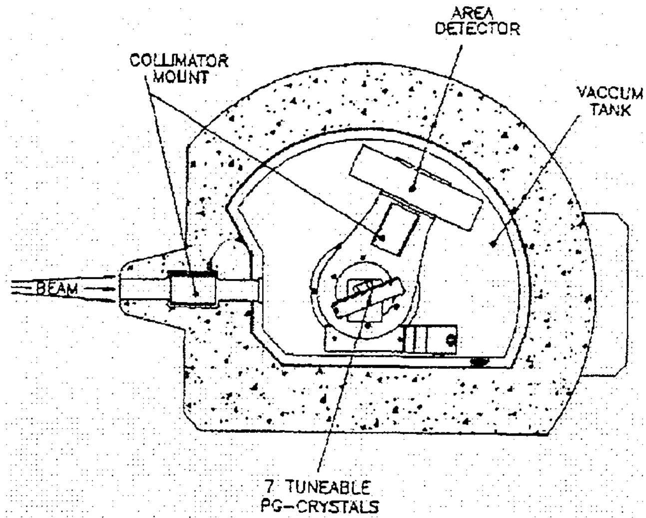
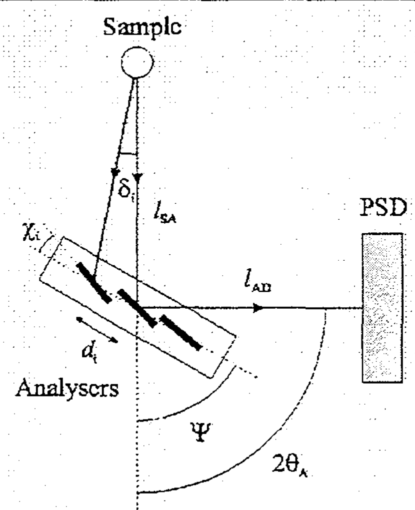
Back-end tank

- A single back-end tank with:
- Array of 7 individually turnable analyser blades
- Position sensitive detector on a short analyser arm



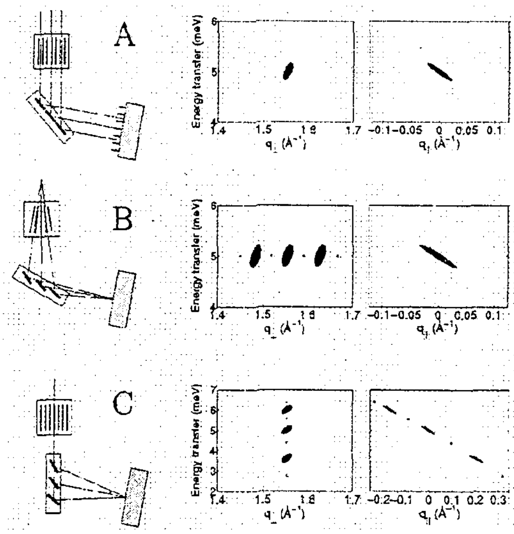
Multi-blade focusing and mapping

- We can consider each blade as an analyser
- By turning the block, we have some freedom in positioning the blades
- Each blade has its own little resolution ellipse in (q||, q⊥, E)
- Focusing or mapping



Focusing configurations

- A) Standard analyser, size of ellipse depends on collimation.
- B) Focusing in energy
- C) Focusing in Q♈
- Relaxing focal point on detector gives freedom in Q/E range
- Any combination possible



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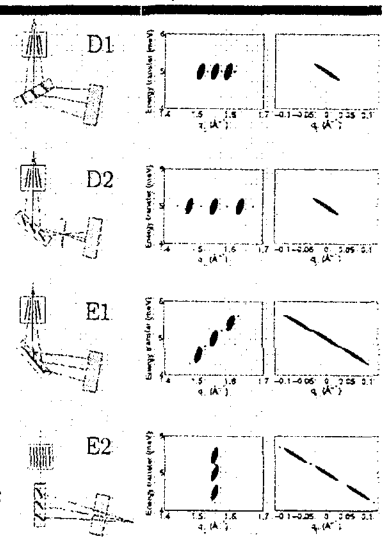
Mapping configurations

- D1) Multiplexing along Q
- D2) Wider version - requires longer analyser-detector arm
- E1) Flat analyser + 2 radial collimators (Broholm on SPINS)
- E2) Multiplexing along E, near-field for narrow E-spacing, far-field for broad E-spacing
- Almost any combination possible



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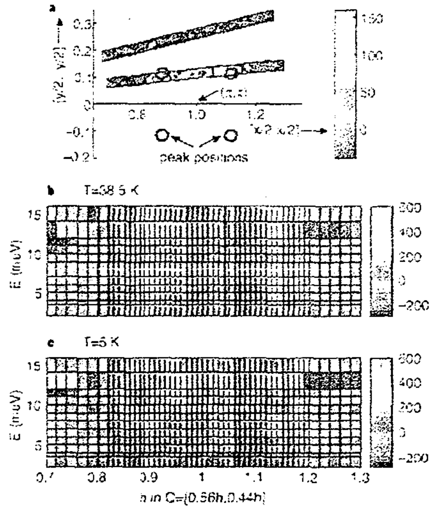
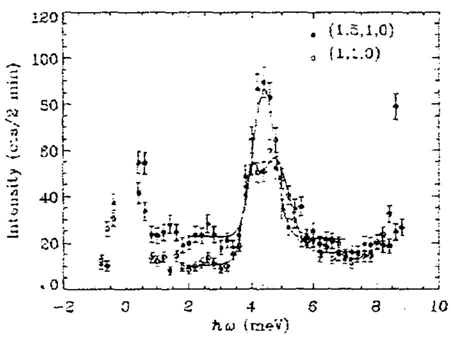
RITAS PSD: simultaneous background

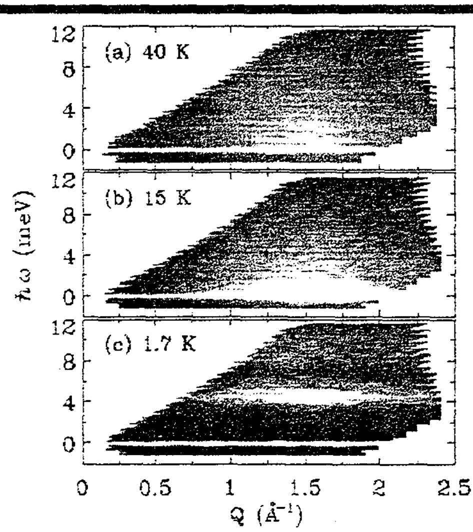
- Incommensurate fluctuations and the gap in superconducting $La_{2-x}Sr_xCuO_4$
- Middle part of PSD for signal, top+bottom for background
- System is away from the gap well suited for focusing along energy.



RITAS Example: mapping (q,E)

- Frustrated magnet $ZnCr_2O_4$
- From frustrated paramagnet to local spin resonance
- Take cuts in data for details





SPINS, Lee *et al* 1999