WG3:
Industrial applications, Isotope production and Neutron Activation Analysis

The Danish CANS workshop 2016 included 3 Working Groups and topics. WG3 had Søren Pape Møller, AU as chairman AU and Mikael Jensen, DTU as secretary. WG3 should cover applications in general, with the following sub-topics a) **Industrial applications, b) Isotope production and c) Neutron Activation Analysis.** A summary is presented below. This will also be the basis for the following work, to result in a report with first draft by the end of the year 2016.

- **Industrial applications**

  - Material analysis with neutrons: SANS (hard materials) scattering experiment, NAA, radiography of large and dense materials, and tomography (industrial inspection). Also stress scanning and analyses from the life sciences industry could be relevant.
  - A question is whether a pulsed CANS is needed, beneficial for some scattering experiments or whether a CW accelerator, could be sufficient for most experiments.
  - Materials modifications including doping of Si, which was an important area for Topsil; Topsil was for many years a valuable customer for Risø. Maybe Topsil would also be interested in NAA? Fluxes of 10^9-10^{10}/cm^2/s are needed. What is the importance of possible fast neutrons contamination?)
  - Other companies could be Topsøe (catalyst studies), the Danish Turbine companies (materials analysis for thick samples), and Maersk (for interrogation).
  - Potential interest in DK could also be the oil industry with imaging in pipelines by the use nearby weak source and detector. Imaging could also be both slow and fast neutrons. Also investigations of concrete might be interesting.
  - A by-product could be the technology development of the accelerator components by DANFYSIK. A spontaneous idea was a proton buncher/accumulator ring able to transform a cheaper CW accelerator (cyclotron) into a more expensive pulsed accelerator. Maybe a prototype should be built? Such low-energy rings have not been built for this purpose.
  - Industrial analysis at a CANS with NAA could include semiconductors, plastics and packaging (done at NUTEC), and detection of impurities (need 10^{10}-10^{12}/cm^2/s).
  - Dansk Dekommissionering could study concrete, and maybe use CANS in relation to the release lab@DD; probably not a significant business.
  - At the Hokkaido CANS facility, the automobile and telecom industry has been users; it was mentioned that there are additional advantages of a small CANS regarding less strict safety rules and possible long-term measurements as compared to a large facility.

- **Isotope production using neutrons**
  - In relation to research applications, where a steady supply of isotopes are not needed, the investment in a production facility using CANS neutrons is probably not justified. Other possibilities and the surviving research reactors can provide the present needs.
  - A few “technical-use isotopes” (Br-82 and Na-24) could be produced with a CANS having thermal flux 10^{10}-10^{11}/cm^2/s. This could provide a replacement for present production at the aging JEEP-2 reactor at Kjeller in Norway. Cost and feasability needs further study. These isotopes have occasional use also in the oil industry (off-shore).
  - For the medical sector, the situation could be different and significant income could be made on some isotopes. These isotopes are however proton-produced, and need not the neutron converting target station or any moderator. An industrials scale cyclotron may have sufficient beam and two output beamlines to supply both uses (CANS and isotope production) at the same time.
  - Interesting medical isotopes could include Ge68, Ac225. There is a global need and both isotopes have a “commercial“ demand. The construction and operation of such production facilities are far from trivial and require substantial development. Especially the Ac-225 production based on Ra-226 targets is an ambitious goal and has no existing counterpart in the world. Nutech with its placement inside the fence of the Risø campus could be suitable for this.
  - The global demand and the projected supply crisis” for Mo-99/Tc99m is on production scale beyond present capability of a CANS. Given the many international initiatives and the lack of secure projections for alternative supply of Russian, Indian or Australian Mo-99, this part of the medical supply market is risky to use as justification for a CANS.
- **Neutron Activation Analysis (NAA)** (excluding industrial applications treated above)
  - NAA is an important analytical technique, especially for heavy metals. The biggest advantage is to analyse “large samples” (from grams to kilograms without the need for sample preparation or sample digestiation. This application often benefits from high thermal flux to boost sensitivity, but the flexible access to a CANS and possibility of large sample irradition could open up new applications.
  - Alternatives to NAA would be PIXE; also x-ray fluorescence is an alternative. NAA is competitive, e.g. with PIXE at 10^{12} n/cm^2/s, whereas 10^{10} n/cm^2/s would be uninteresting. PIXE cannot investigate thick samples.

ADDITIONAL POINTS kept at this time

- A new project LINX, funded by Innovation Fund Denmark, will help Danish businesses exploit the ESS and MAX4 in Lund; 14 industries are involved.
- Scattering experiments like SANS can advantageously exploit pulsed beams although facilities like ESS shows that many experiments can be made by quasi-continuous sources!
- A factor of 10 increase compared to existing CANS would be ambitious but that we should aim for!.
- Maybe a significant factor, 2-10, can be found by optimizations of moderators and coupling to instrument.
- For electronics, the space industry would be interested in addition to telecom; companies like GOMSpace and TERMA.
- The beamline at Hokkaido, 20 MDKK, 50 pps, gives 10^5/cm2/s@target for SANS
- Esben Klinkby; CuTaBe target, 30 MeV protons, maybe some gains can be found with advanced moderator design, some forward peaking?

Requirements to the CANS facility

- neutron requirements ->

    1. which beam? p, ?
    2. Which energy? 30 MeV
    3. which accelerator? DC, cyclotron, RFQ, linac, ?
    4. which target etc?
    5. Time-structure: is a pulsed beam needed? With accumulator?