Detector Concept for HEIMDAL

Participants

Comments included of: Richard Hall-Wilton, Malte Hildebrandt

Prof. Giuseppe GIUSEPPE GORINI
giuseppe.gorini@unimib.it, Milano-Bicocca University, Milano, ITALY
Dr. Richard HALL-WILTON
richard.hall-wilton@esss.se, European Spallation Source ERIC, Lund, SWEDEN
Prof. Paul HENRY
paul.henry@esss.se, European Spallation Source ERIC, Lund, SWEDEN
Dr. Malte HILDEBRANDT
malte.hildebrandt@psi.ch, Paul Scherrer Institut, Villigen PSI, SWITZERLAND
Dr. Lukas KELLER
lukas.keller@psi.ch, Paul Scherrer Institut, Villigen PSI, SWITZERLAND
Dr. Isabel LLAMAS JANSA
isabel.llamas@ife.no, Institute for Energy Technology, Kjeller, NORWAY
Dr. Marita MOSCONI
mmosconi@essbilbao.org, ESS Bilbao, Bilbao, SPAIN
Dr. Jean-Baptiste MOSSET
jean-baptiste.mosset@psi.ch, Paul Scherrer Institut, SWITZERLAND
Dr. Nigels J. RHODES
n.j.rhodes@rl.ac.uk, ISIS, Didcot, UNITED KINGDOM
Prof. Christian RUEGG
christian.rueegg@psi.ch, Paul Scherrer Institut, Villigen PSI, SWITZERLAND
Dr. Jürg SCHEFER
juerg.schefer@psi.ch, Paul Scherrer Institut, Villigen PSI, SWITZERLAND
Dr. Irina STEFANESCU
irina.stefanescu@esss.se, European Spallation Source ERIC, Lund, SWEDEN
Dr. Alexey STOYKOV
alexey.stoykov@psi.ch, Paul Scherrer Institut, Villigen, SWITZERLAND
Dr. Garrett SYKORA
jeff.sykora@stfc.ac.uk, STFC, Harwell Oxford, UNITED KINGDOM

Absent due to scheduling problems, but involved in setting up this summary:

Prof. Bjorn HAUBACK
bjorn.hauback@ife.no, Institute for Energy Technology, Kjeller, NORWAY
Prof. Mogen Christensen
mch@chem.au.dk, Department of Chemistry & iNano, Aarhus University, DENMARK

Group photo taken in the atrium of the Swiss Light Source (SLS), Paul Scherrer Institute, March 14, 2016.

Summary

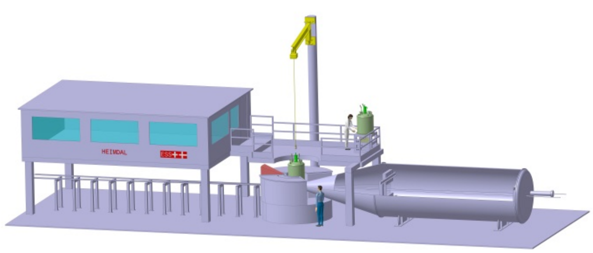
Based on the outcome of the workshop, we selected the concept of the central NPD detectors to be based on a PSI concept. The NPD detectors have to be available on day 1, two backup solutions in line with other ESS instruments have been out-lined consequently. The SANS detectors can be selected later following either the LOKI or the SKADI path. Due to the relaxed resolution requests for the imaging, the selection here is straight forward and can use existing solutions, for example the Medipix detector. Beam monitors can use existing ISIS concepts.

Concept Boundaries our detector proposal has to meet

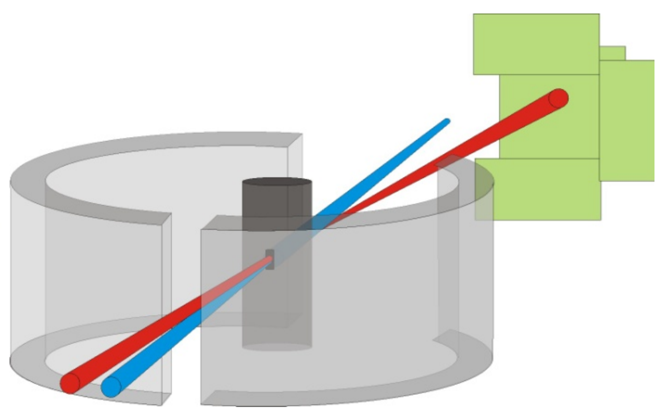
Goal of the workshop was finding a concept to fulfil the following tasks

- Meeting the HEIMDAL design specification as outlined below
- Keeping the time limit (operational 1 year before day 1)
- Industrial production possible with known companies
- Within the ESS detector concepts or accepted by ESS as a possible path with new detectors
- Whenever compatible with similar instruments at ESS, either within concept, electronics or best both

Part 1: Detector Specifications



HEIMDAL instrument layout with the NPD detectors around the sample tank and the SANS tank to the right. Backscattering detectors in red.



Schematic Arrangement of the HEIMDAL detectors: Grey: NPD-, green: SANS- and black: NI-detectors.

1.1 NPD Detector of HEIMDAL

Resolution:	3 mm wide (2Θ), 10 mm high (vertically)	defines the maximum pixel size
Local counting rate:	10'000 counts/sec/pixel (3mm by 10mm)	
Overall counting rate:	Powder-Lines: Neighboring pixels in the vertical direction have a similar counting rate as the central peak pixel.	Electronics has to meet this limit. Data from WISH should give here are reasonable values and scaled to1MW power in daily experiments.
Gaps between modules	up to 1 deg in 2Θ (corresponds to 25mm)	
Shape:	Cylindrical (vertical axis)	Radius: 1500mm, Height: 1000mm
Total Area: day 1 / final	3.4m2 / 6.8m2	
Coverage:	30 dig < 2Θ < 160 deg	
Efficiency:	>50% at 1 Å	Low wavelength critical
Stability:	< 0.5% per day, < 1% month	
Operation in vacuum:	no	
Priority:	High: day 1 operation	has to be ready two years before commissioning starts, at all geometrical dimensions and feed-through

Table 1.1: Specifications for the HEIMDAL NPD detectors

1.2 SANS Detectors of HEIMDAL

Resolution:	5mm by 5mm	defines the maximum pixel size
Local counting rate:	10'000 counts/sec/pixel (3mm by 10mm)	
Overall counting rate:	Not critical	Beam stop to be defined (may be a high counting rate detector)
Gaps between modules	To be avoided or covered by overlaps	

Shape:	flat	
Total Area:	2.505 m^2	
Efficiency:	>75% at 4 Å	
Stability:	< 0.5% per day, < 1% month	
Operation in vacuum:	eventually	
Priority:	medium: first upgrade phase	

Table 1.2: Specifications for the HEIMDAL SANS detectors

1.3 Radiography Detector of HEIMDAL

This detector will be placed on request directly after the sample and as close as possible not to lose resolution due beam divergence. It will be out of the beam when the NPD and SANS detectors are collecting data.

spatial resolution	20-50 μm in both directions
Area	50mm-100m in both directions, total area expected 0.01m^2
distance from sample	10-50mm
Time windows	Presently time resolutions is 0.3 to 300 seconds, should be lowered by a factor of 10 for ESS in the standard mode, a 5 μs mode is desirable be possible
Efficiency	Not critical value, but big signal/noise ratio must be achieved Efficiency must be stable by 0.1%/day or 2%/month (for calibration purposes)
Local counting rate	not critical
Overall counting rate	not critical
Stability	needs cooling to -50^{o}C if CCD's are used, 1% over 1 day
parallaxes	not a critical value if close to sample
Vacuum	No
Priority	Low, second upgrade phase

Table 1.3: Specifications for the HEIMDAL Imaging detectors

1.4 Backscattering Detectors of HEIMDAL

Design strongly related to final guide design close to the sample position, to be decided during phase 2. Should follow the concept of the NPD detectors whenever possible. Resolution and other request will be identical to the standard NPD detectors.

1.5 Beam-Monitors

size	100 mm x 50 mm
Distance to sample	~ 1000-1500mm
Readout	2D readout favorable (ISIS concept) to locate the beam position
Time resolution	1 ms
Efficiency	10^{-3} to 10^{-4} for wavelengths around 3A
Local counting rate	Not critical
Overall counting rate	Not critical
Stability	0.1 % over 1 day , 0.5% over 1 month High stability needed not to decrease the experimental statistics
Operation in vacuum	Eventually
Priority	High (day 1)

Table 1.5: Specifications for the HEIMDAL Beam Monitors

2. Detector solutions selected for HEIMDAL@ESS

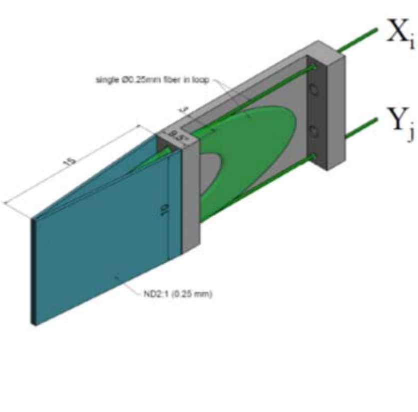
2.1 NPD

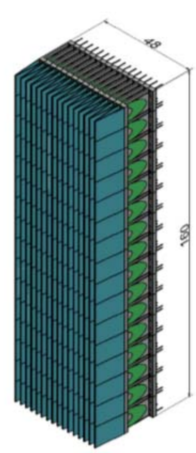
Out of the discussion, a main concept and two backup solutions have been selected. There was an agreement that backup-solutions are essential for the NPD detectors as building an operational detector within time is demanding and a failure would delay the instrument start-up significantly.

2.1.1 2D-Scintillator Concept of PSI (main concept)

- Development for a two dimensional sensitivity based on the 1D unit available as a prototype for POLDI@SINQ
- Silicon photomultipliers (SiPMs) used instead of traditional photomultipliers.
- Resolution of 3mm by 10mm pixel size is doable
- Counting rate per pixel of 10’000 c/s ok
- Overall counting rate for powder lines (neighboring pixels are similar high loaded) has to be checked. Can be solved by more sophisticated electronics readout, but at higher costs: SiPMs without coding: ~ 1.1-2.2 MEuro, with coding: ~140-280 kEuro.
- **Prototype** mandatory (needs 2 year technician, 2 year electronics, time scale: ready 2 year after hiring this staff, to be financed by in-kind contribution).
  Production:
  Company to be found with the following competences:
  - production of the aligned fibers embedded in scintillating material
  - provision of suitable electronics at reasonable price
- Quality control during production (geometrical quality, efficiency, e.g. with neutrons)
- Serial/parallel production of 180’000 pixels (space for storage/testing)

  Possible candidates: Arktis Radiation Detectors Ltd (Zurich/CH), Dectrics (Baden/CH, most likely not interested as neutron detectors are not their core business), Scientifica (Spain)

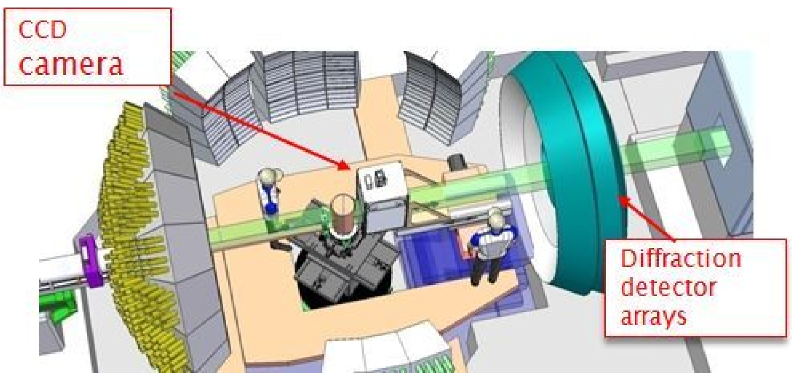




Pictures from: Conceptional Layout (Stoykov, Hildebrandt, Mosset, PSI Villigen)

2.1.2 Updated IMAT concept (NPD backup No. 1)

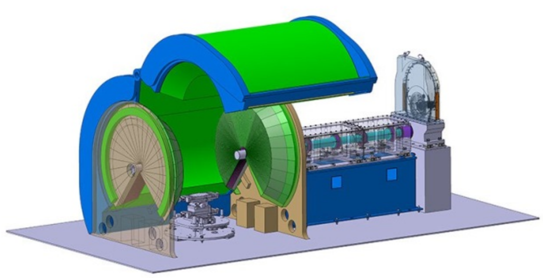
The present IMAT pixel size of 4 mm by 100mm has to be reduced to fit the HEIMAL request, which is considered a doable job. The counting rate is more demanding and needs development work for the electronics. All these tasks are also needed for developing the WISH-2 detectors and will be done anyway. Definitely, WISH-2 has priority within ISIS and finding a path for construction a detector for HEIMDAL would need finding a development and construction agreement. Potential synergy exists between these detectors.



IMAT detectors setup.
Sketch: ISIS

2.1.3 Commercial CDT Detector (NPD backup No. 2)

based on the concept of POWTEX@FRMII and DREAM@ESS.
Cylindrical unit with vertical access.



POWTEX detector setup, detector CDT.
The CDT detector shape is cylindrical, but the cylinder axis horizontal and not vertical as desired for HEIMDAL.
Sketch: FRM-2.

Two major concerns have been: 1) The POWTEX detector is not running yet, however the development risk looks presently to be low and 2) the capacities of CDT in building such huge detectors are limited and the CDT detector is the first choice of DREAM. A quotation of CDT has been asked, not only in respect of the technical maturity, but also budget considerations.

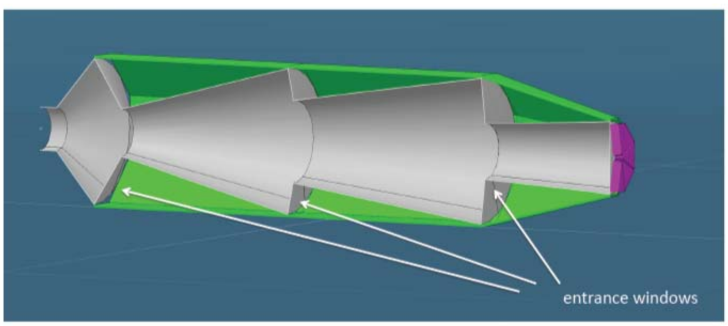
2.2 SANS

We will follow either the LOKI (Boron Array Neutron Detector [BAND] - GEM) concept or SKADI (Solid State Neutron Detector [SoNDe]) concept. Both these concepts have timelines compatible with the timeline for the HEIMDAL SANS detectors.

LOKI Path

In the LOKI design, not only the detector would fit the HEIMDAL needs, but also a downscaled tank design. The advantage of this tanks design is the arrangement of the detectors outside of the vacuum. However, possible background from multiple scattering from windows and structure has to be evaluated carefully.

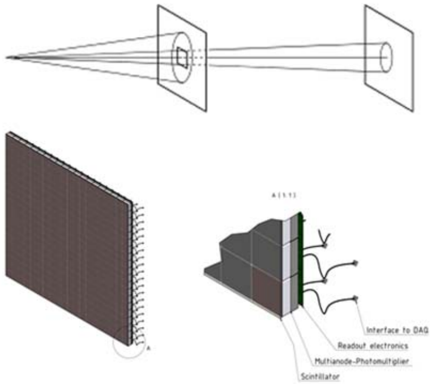
As noted during the discussion, the geometry decision for LOKI will be made during the summer. This development is funded through in-kind and is due to finish by 15Q4/16Q1.



Arrangement of the detectors as planned in a option of the LOKI design (Picture: contribution G. Gorini)

SKADI Path

SKADI has selected the design being developed by the SoNDe H2020 consortia. Here, the detector arrangement is a traditional one, with the detectors arranged in air boxes in vacuum. The SoNDe project runs into 2018, though the development will be completed significantly before this.

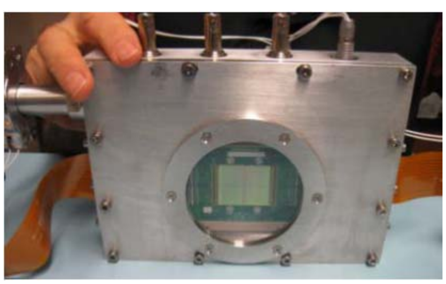


Dual detector arrangement schematic and SoNDe detector scintillation concept, courtesy of S. Jaksch

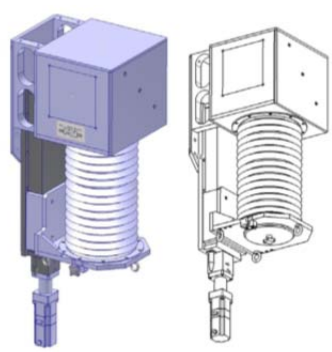
2.3 Neutron Imaging Detectors

We can follow here the concept outlined already in the instrument proposal (not further discussed within the workshop).

The Timepix/Medipix detector has two main advantages: 1) it allows time resolved Bragg edge imaging and 2) it can be placed much closer to sample, due to the absence of spacious mirror setups, which higher resolution can be obtained. The wish for resolution is down to ~50 µm for samples <50x50 mm^2. The Bragg-edge imaging will inherently have sufficient resolution $\Delta\lambda/\lambda$=1.5% at 4.5 Å due to the length of the instrument. The limitation of the present Timepix/Medipix detector is the low active area size (2.8x2.8 cm^2), which needs limited R&D. However, also in the present stage it can meet most of our demands.



Medipix detector with an active area of 28x28 mm^2 and a sampling rate of about 1200 Hz. (*right*) classical imaging setup made with fluorescent screen mirror and CCD. Picture: Medipix.



Geometrical setup (drive in from below). Drawing PSI.

2.4 Backscattering Concept

Based on the final design chosen in section 2.1, but designed after the detail design on the guide entrance to the sample area is available

2.4 HEIMDAL Beam Monitors

Not discussed within the workshop. Commercial solutions available from Quantum Detectors.

The ISIS pulsed neutron source operates 25 instruments for neutron scattering applications. Picture: Quantum detectors.

Developments of position sensitive monitors are in progress at the Milano Group (Prof G. Gorini, INFN, Sezione di Milano-Bicocca, Italy)

Villigen PSI, March 2016