Alternative techniques to ^{3}Helium based neutron detectors for neutron scattering applications

International Collaboration for Neutron Detector Development

Status Report

K. Zeitelhack

- **July 2009: Formation of the "Technical Working Group"**

  Group of detector experts representing all major neutron scattering facilities

  Analysis of ^{3}Helium supply and demand for neutron scattering

  Discussion and prioritization of alternative techniques

- **October 2009: IEEE NSS-MIC 2009**

  Open "Workshop on alternatives to ^{3}Helium Neutron Detectors"

  Link with other communities active in neutron detection

- **January 2010: Proposal preparation meeting**

  22 participants representing 12 facilities

  Preparation of a proposal for a joint R&D programme

- **March 2010: Facility directors meeting**

  Joint R&D Proposal presented to facility directors and accepted

- **September 2010: Start of the Collaboration**

  Collaboration agreement of a joint R&D programme signed by 9 facilities

❍ Present Members of the Collaboration

ESS	*European Spallation Source*, *Sweden*
FRM II	*Forschungs-Neutronenquelle Heinz Maier-Leibnitz*, *Germany*
HZB	*Helmholtz Zentrum Berlin, Germany*
ILL	*Institut Max von Laue – Paul Langevin, France*
ISIS	*Science and Technology Facilities Council, UK*
JCNS	*Jülich Centre for Neutron Science, Germany*
J-PARC	*Japan Proton Accelerator Research Complex, Japan*
NIST	*Centre for Neutron Research, USA*
ORNL	*Neutron Science Directorate, Oak Ridge National Laboratory, USA*

Objectives of the R&D Programme

^{3}He demand for neutron scattering in 2009 – 2015

	Maintenance [liter / year]	New small detectors [liter]	New large detectors [liter]
Sum	**1,521**	**8,658**	**106,572**

Availability of ^{3}He: < 20kliter / y ➔ request out of scope

- Give priority to the development of alternative technologies for large area position sensitive detector arrays for inelastic neutron scattering
- Technologies and Know-How developed in the course of the programme will be as valuable in the design of smaller devices
- To shorten development time and minimize risk evaluate a number of potential development lines simultaneously
- Mindful of the resources and the size of the detectors transfer of technology to industrial partners is considered beneficial
- Spread results and technologies widely in the participating facilities

Detector characteristics to compete

Detector characteristics for large area inelastic scattering instruments based on ^{3}He detectors

Detector characteristics	10 bar 25 mm diameter ^{3}He
Neutron Efficiency	70% at 1 A
Gamma sensitivity	10^{-6}
Background	10 – 15 counts/ h / m
Width	25 mm
Length	1 - 3 m
Resolution	15 – 25 mm at FWHM
Local rate capability	50 kHz on a pixel
Global rate capability	50 kHz on a tube
Time resolution	1 µs
Area	15 – 40 m^2
Environment	Cryogenic vacuum

- **Scientillation Working Group** *(ISIS, JCNS, J-Parc, NIST, ORNL)*

  Investigation and development of scintillation detector technologies for large area detectors

  Build on experience with detectors based on ZnS:^{6}LiF(Ag) or ZnS:$^{10}B_2O_3$(Ag) scintillators read out by coded arrays of clear or wavelength shifting fibres

  Investigate scintillators, optics, light readout devices, encoding schemes

- **^{10}B-Working Group** *(ILL, ESS, FRM II, HZB, ORNL)*

  Development of solid ^{10}Boron multilayer arrangements in gaseous large area neutron detectors

  Study ^{10}B-coating processes

  Investigate and optimize design and fabrication of a multilayer detector in view of performance and cost

- **BF_3-Working Group** *(HZB, FRM II, ILL)*

  Investigate BF_3 as a potential fast and easy replacement of ^{3}He

  Study gas properties, performance and limitations of BF_3

  Investigate safety issues for large scale use

Structure of tasks in the work packages

- **Evaluation phase**

  Re-evaluation of existing Know-How

  Investigation of basic underlying principles

- **Design and study of small size detector concepts**

  Proof of detector principles

  Evaluation and comparison of performance

  Optimization of design and fabrication in view of large scale production

- **Fabrication of a reasonably sized scalable demonstrator**

  Proof of feasibility of large scale production, transfer of technology

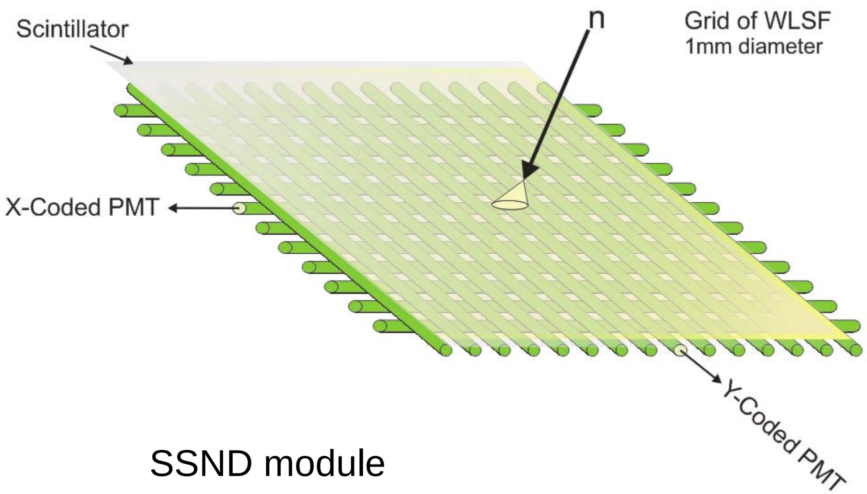
Duration of programme

Sz-WG, ^{10}B-WG: ~ 4 years

BF_3-WG: ~ 2 years

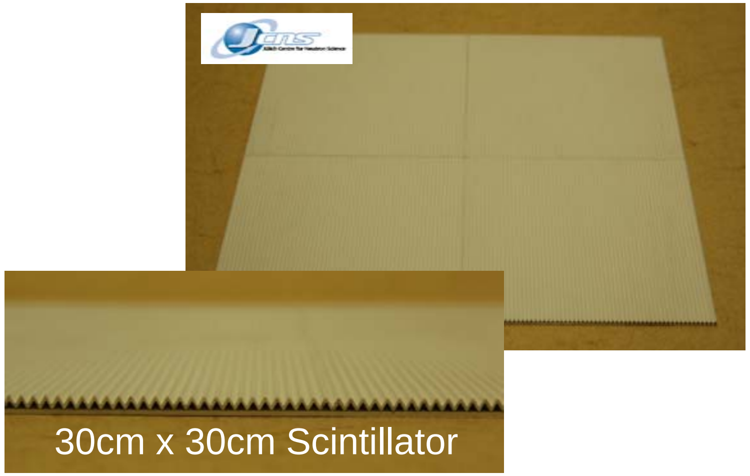
Scintillation detector technologies

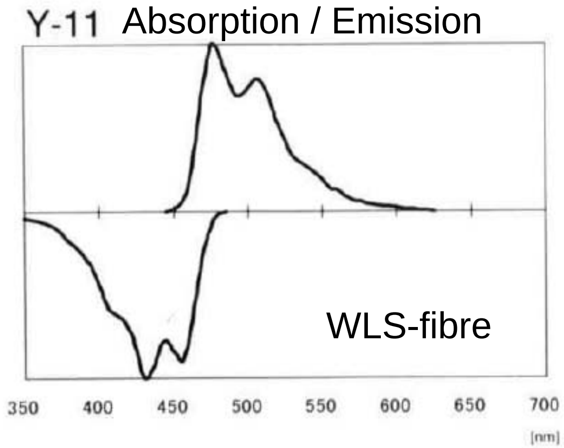
WLS-fibre readout of $^{6}LiF/ZnS$ & $^{10}B_2O_3$ /ZnS-scintillators



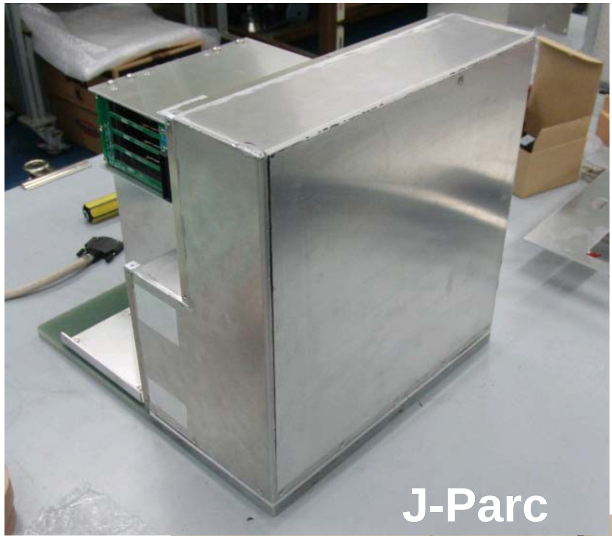
SSND module

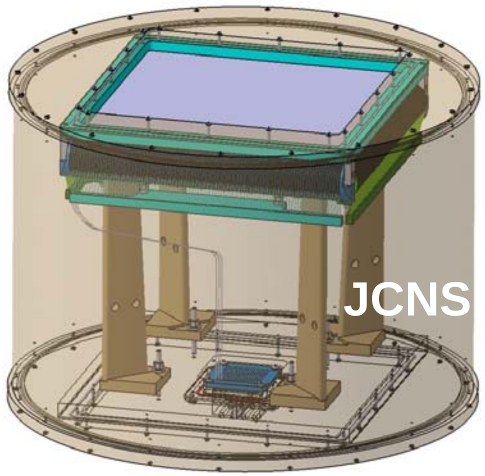
$^{6}LiF/ZnS$





Evaluation detectors





^{10}B-converter in gaseous detectors

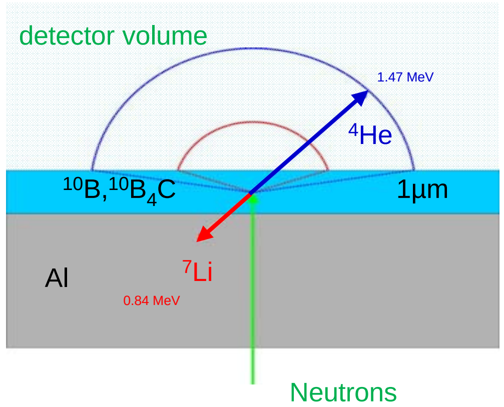
n + ^{10}B $\rightarrow$ ^{7}Li* + α + 2.31 MeV (93%)

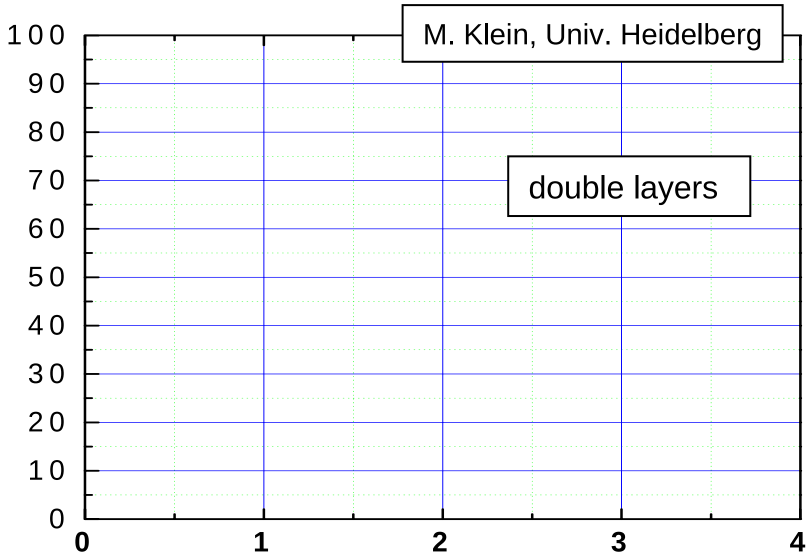
$\rightarrow$ ^{7}Li + α + 2.79 MeV (7%)

σ = 3836 barn

Single layer: ε_{det} < 5% for therm. neutrons

➔ 20 -30 layers required !





^{10}B-layers

Large scale production (~$10^2 m^2$)

Layer composition: ^{10}B, $^{10}B_4C$, …

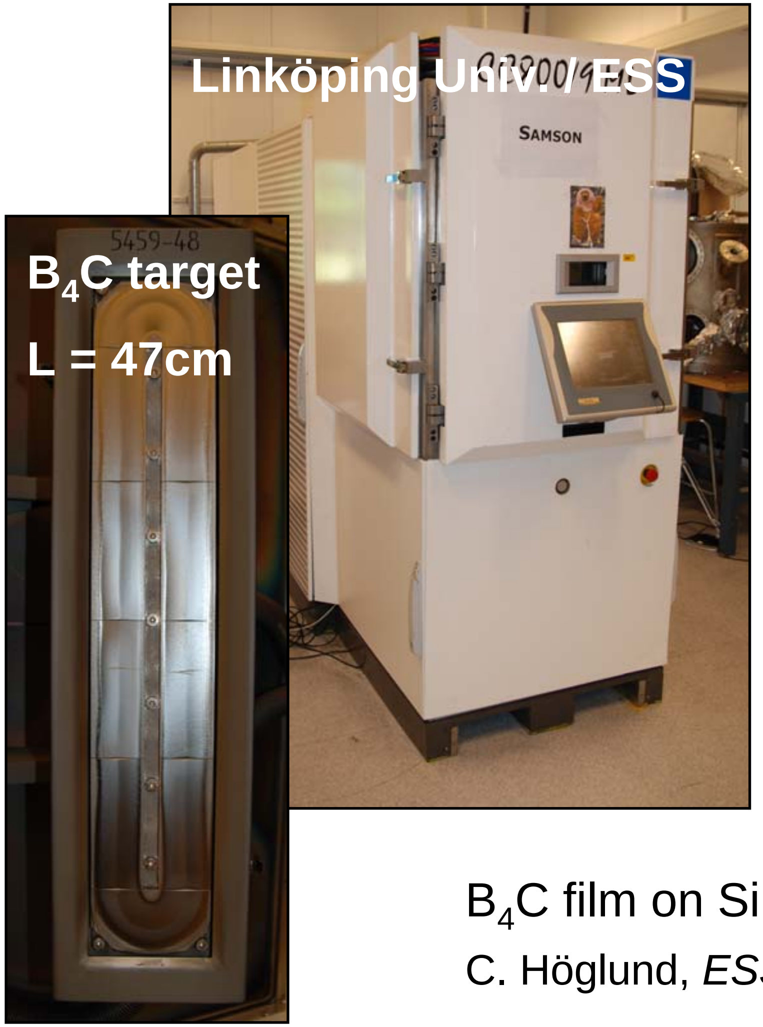
Deposition technologies

RF / DC sputtering, e-beam evaporation, others

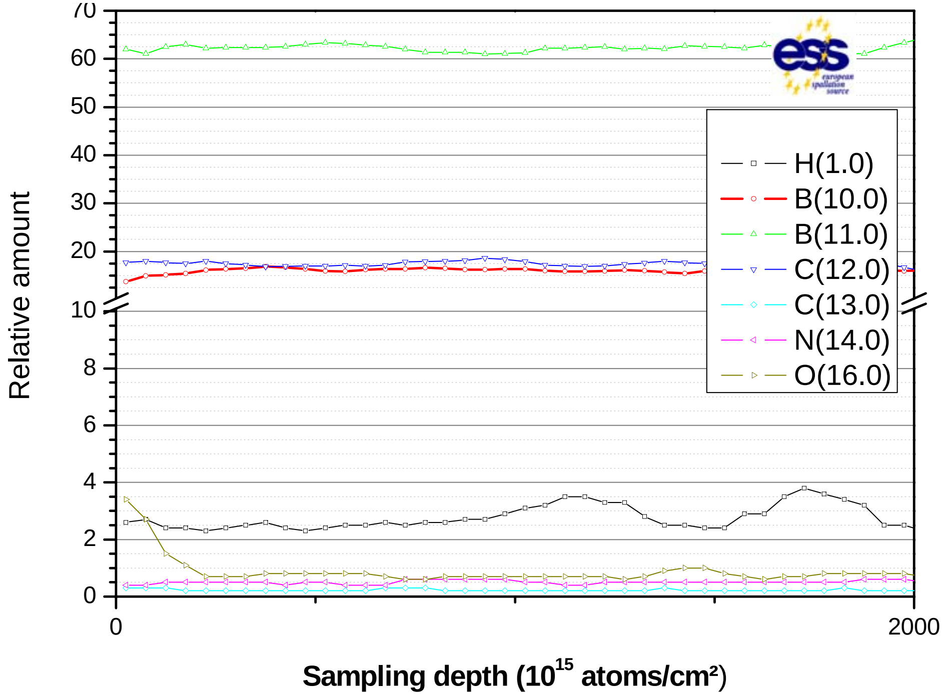
Layer stability: adhesion, ageing

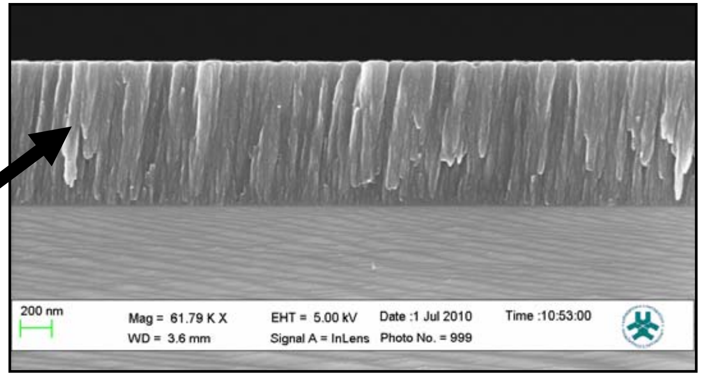
Homogeneity, substrate, topology

DC Magnetron sputtering facility



Layer composition meas. with ERDA



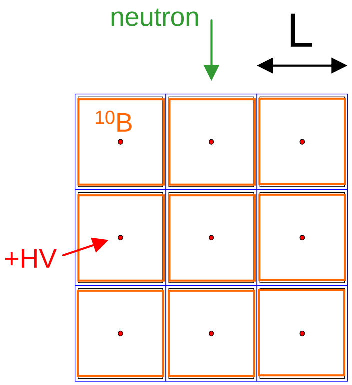


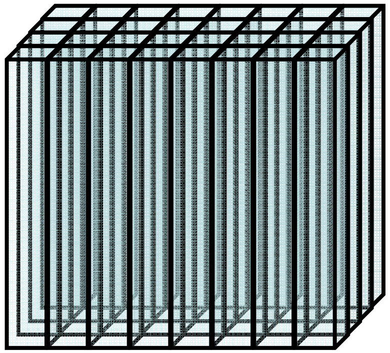
B_4C film on Si @ Linköping

C. Höglund, *ESS*

Multilayer detectors concepts

20 - 30 Boron-layers required to achieve adequate detection efficiency





Modular multi-cell structure

- ^{10}B coating on large area
- Low mass
- Electronic Readout Schemes
- Cost !

Different approaches & designs

- ILL: *“MultiGrid”*
- HZB: *“Microstructure profile”*
- *Other designs ?*

$^{10}BF_3$ - Detectors

Energy deposit 2.3 MeV / n

→ *good n / γ separation (~10^{-6})*

→ *good position resolution ($\Delta L/L = 0.6\%$)*

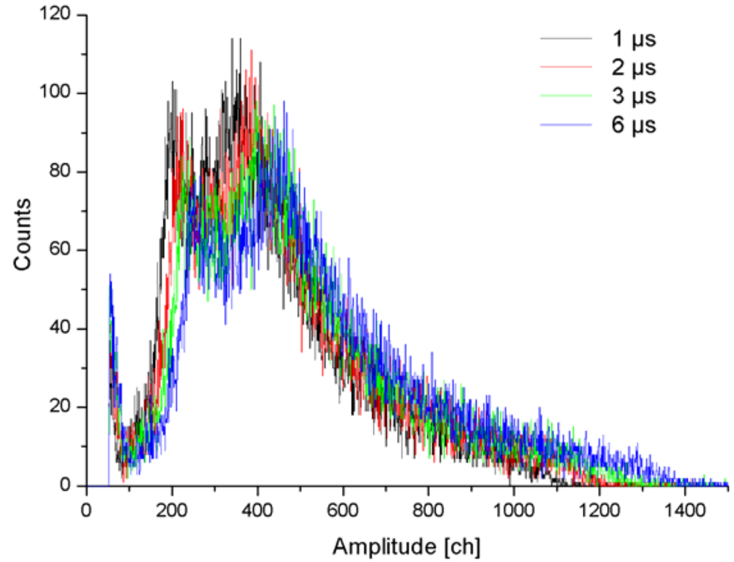
High toxicity !

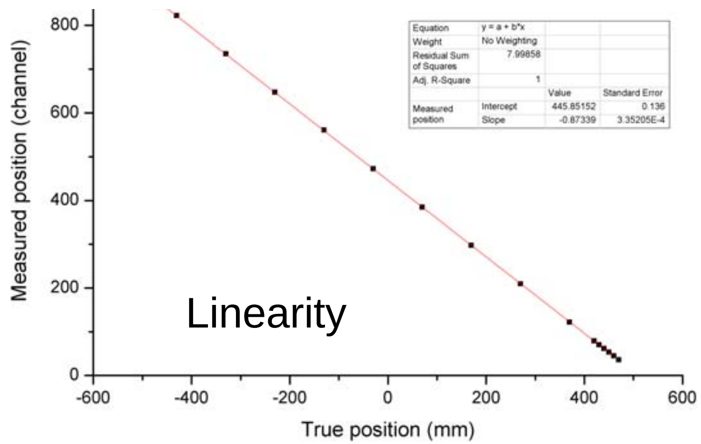
No high pressure operation – *really ?*

→ *low efficiency*

Talks by M. Platz, ILL & T. Wilpert, HZB

PSD - energy spectra





Summary

- **Collaboration agreement signed in September 2010**

- **Working Groups formed and joint R&D programmes started**

  work plans defined

  “Kick-off”-meetings held in Grenoble and Knoxville

- **Contacts:**

Scintillators:	WG-Coordinator:	N. Rhodes, *ISIS*
^{10}B	WG-Coordinator:	B. Guerard, *ILL*
BF_3	WG-Coordinator:	T. Wilpert, *HZ Berlin*
	Coordinator:	K. Zeitelhack, *FRM II*