FP7 2 NMI3

Work Package 21

Detectors

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WP 21 Detectors

Aim: Development of suitable detector technologies to replace 3He in Neutron Scattering Applications.

Driver: Lack of availability of 3He
High cost

Demand outstrips supply

WP 21 Detectors

Large area arrays of 3He detectors are no longer a possibility

LET IN5 MERLIN

International working Group set up in 2009 under Karl Zeitelhack to investigate possible alternatives.

Three proposals

BF3 Scintillator 10B

Application – larger area detectors
20 x 20 mm2 resln.

This proposal seeks to take forward the latter two proposals.

WP 21 Detectors

Work package structure

Two tasks

Seven funded partners and two observers

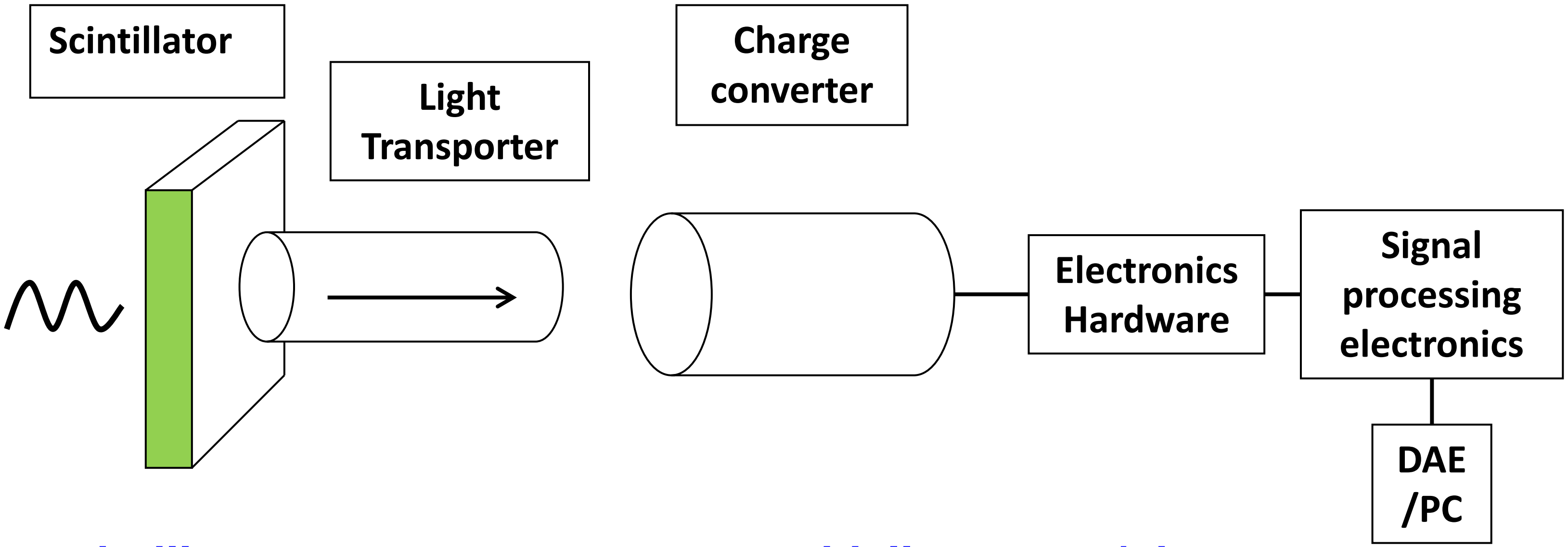
Task 21.1
Development of scintillation detectors based on wavelength shifting fibre

Task 21.2
Development of gas detectors based on solid 10B converter

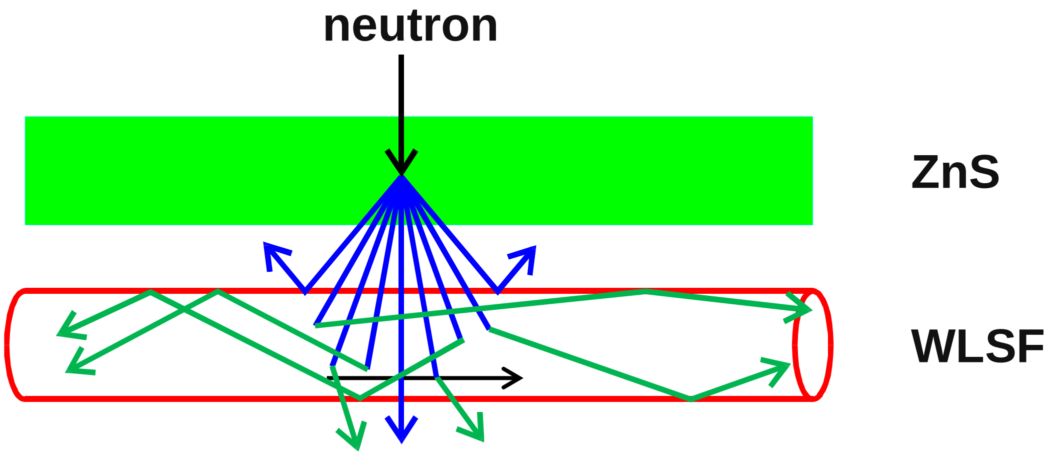
WP 21 Detectors

Task 21.1 Scintillation Detector Development

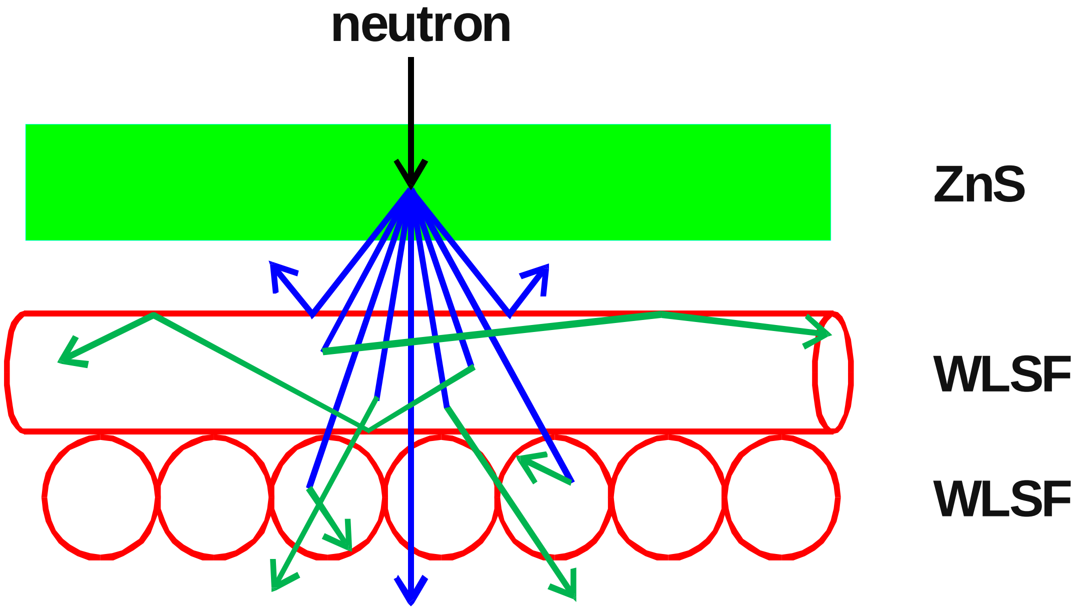
In any scintillator detector the components are similar



Scintillator	Initially ZnS:Ag/LiF
Light Transporter	WLS Fibre
Light to charge converter	Vacuum or Silicon PMTs
Electronics hardware Signal processing electronic	In development



1-Dimensional PSD detector



2-Dimensional PSD detector

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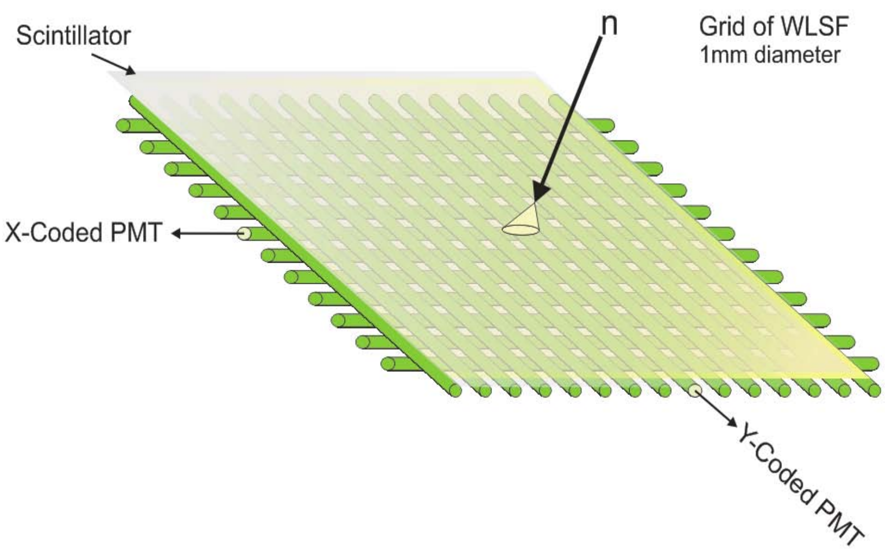
Task 21.1 Scintillation Detector Development

Task 21.1.1 Detector Development

- Detectors with wavelength-shifting-fiber light readout
- Vacuum PMTs
- Key issues:

  Large area with minimum dead space, fiber layout, low γ-sensitivity position resolution, detection efficiency
- Study of $^{6}LiFZnS:Ag$ Scintillator
- New scintillator developments with an adequate light yield and parameter
  as above



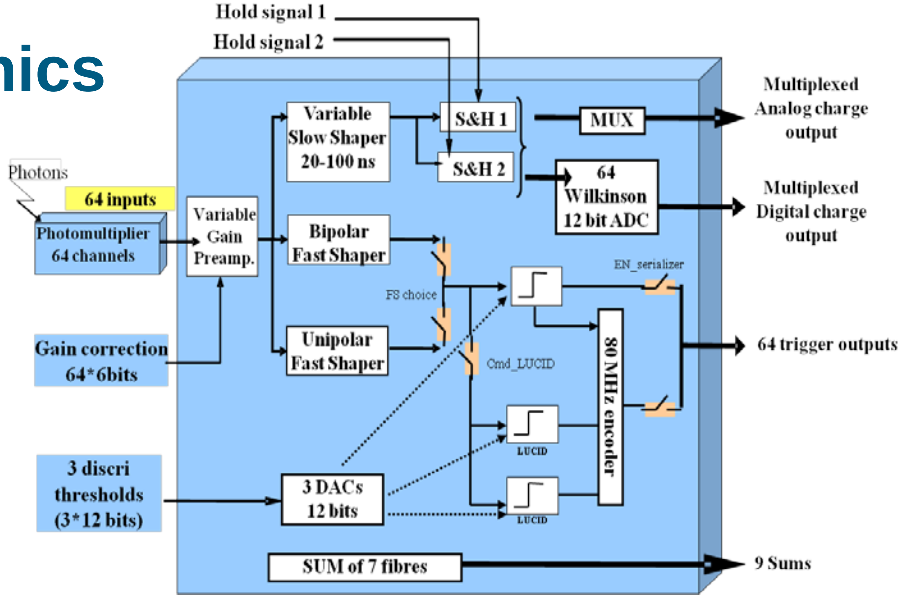
Picture of the H7546

WP 21 Detectors

Task 21.1 Scintillation Detector Development

Task 21.1.2 Readout Electronics

- MAROC ASIC from Omega
  - Variable gain preamplifier 0-4
  - Fast bipolar and unipolar shaper (15 ns) with discriminator for each channel
  - 100% trigger efficiency at 1/3 p.e (= 50fC), Q_{max} = 5pC
  - Slow shaper with 2 S&H for on-chip Wilkinson-ADC



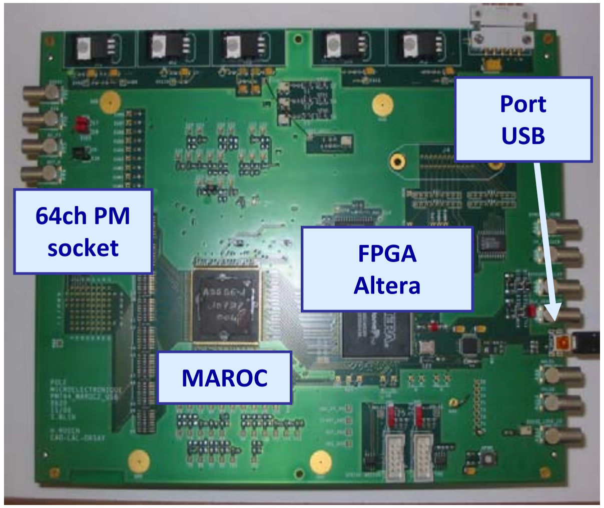


Photo & Graph P.Barillon

- Benefits:
  - Correction of PMT non uniformity
  - 64 trigger outputs for photon counting
  - Analog information for calibration
  - Low Power Consumption: 5 mW/ch.
- Chip is currently tested with evaluation board at ZEL

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Task 21.1 Scintillation Detector Development

Task 21.1.2 Readout Electronics

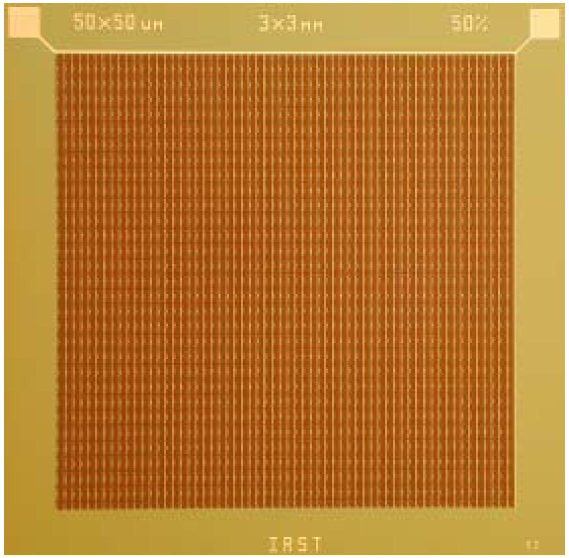
At ISIS the signals are digitized immediately

Shaping etc.. done digitally in the FPGA along with the signal processing

Task 21.1.3 Signal Processing

Development of suitable signal processing Algorithms is critical to achieving required detector performance

Task 21.1.4 Silicon PMT Evaluation



FK-IRST (Trento, Italy)
3 x 3 mm2 PMT
50x50 μm pixel size

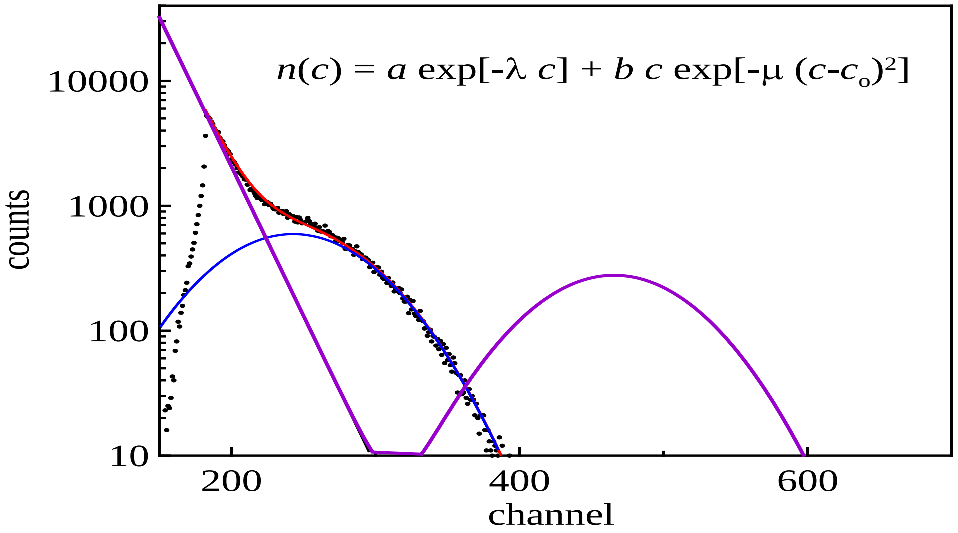
Advantages

Compact
Operate at low voltages
Operate in high magnetic fields
Operate in vacuum
Easily integrated into processing electronics

Disadvantages

Very high single p/e noise – 1MHz
Small active area

Task 21.1.4 Silicon PMT Evaluation



GS20 Glass scintillator coupled to SiPMT

Pulse height spectrum collected at FRM2. No light reflector is used. The purple line simulates the spectrum when an ideal reflector is used.

Very active industrial development

Devices continuing to improve

Above 7 p/e devices are very quiet

Together with bright scintillators and efficient light collection devices can these devices contribute significantly to neutron detector applications in the future?

WP 21 Detectors

Task 21.1 Scintillation Detector Development

Task 21.1.5 Detector evaluation

Outcome of Task 21.1

Construct two ~ 30 x 30 cm2 detectors with 20 x 20 mm2 resln.

Julich

- Low coding of fibre arrays
- PMTs with higher numbers of anodes
- ASIC based electronics with optical link to PC for additional post processing

ISIS

- Highly coded fibre arrays with
- PMTs with single or small numbers of anodes
- All digital signal processing

CNR

- Improve understanding of potential of Si PMTS for large area Neutron Detectors

JÜLICH FORSCHUNGSZENTRUM

Science & Technology Facilities Council ISIS

Consiglio Nazionale delle Ricerche

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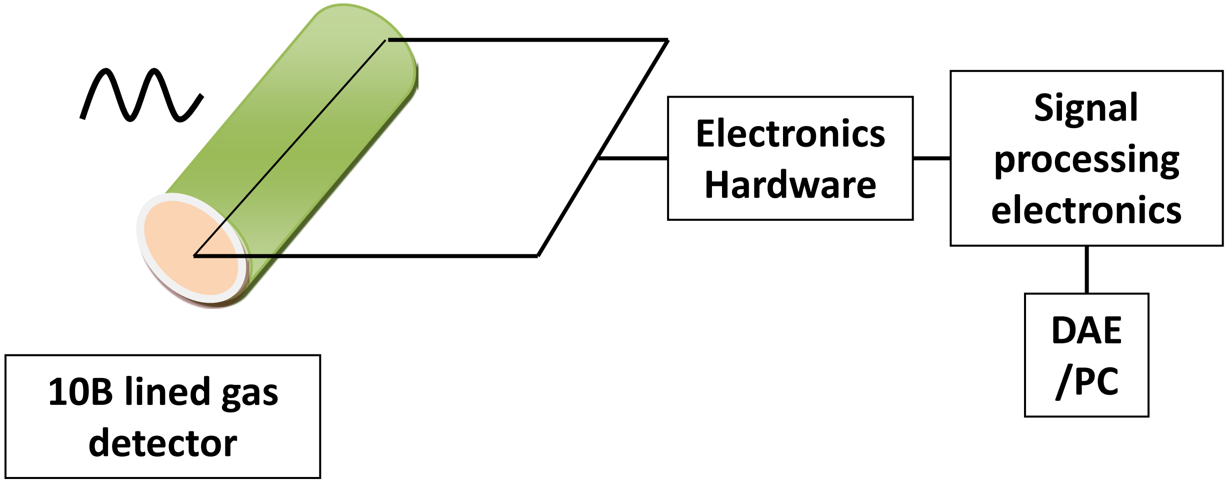
Task 21.2 Solid 10B Gas Detector Development

In any gas detector the components are similar



^{10}B + ^{1}n → ^{7}Li + ^{4}He - 2.3 MeV + 0.48MeV γ (93%)

^{7}Li + ^{4}He - 2.7 MeV (7%)

Range of reaction products very low

Require many layers of 10B to be sensibly efficient e.g. ~ 30

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Task 21.2 Solid 10B Gas Detector Development

Quality of the 10B layers are critical in achieving adequate detector properties

Key issues: efficiency, composition, homogeneity, adhesion, long term stability, large areas, cost

Task 21.2.1

Production, characterisation and optimisation of both the 10B layer and the substrate are critical in controlling these issues

Initial technique Magnetron Sputtering as a reference

Compare quality with that obtained by the ILL / ESS in the ESFRI CRISP project

HZB and BNC equipped for production

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Task 21.2 Solid 10B Gas Detector Development

Task 21.2.1 Production and Characterisation of 10B layers

Magnetron sputtering stations at MR

Preliminary experiments:
- The optical transmission measurement shows that the obtained 2000 Å thick layers contain mostly boron oxide.
-The boron deposition time was 24 hours.
- The magnetron sputtering of boron layers should be optimised

Balzers box evaporation ESQ 110 e-gun at OPTILAB

- 1000 nm thick boron layer - 356 sec.
- optical transmission: pure boron
- Neutron transmission at λ = 4.28 Å proved: layer thickness is 1000 ± 3 nm

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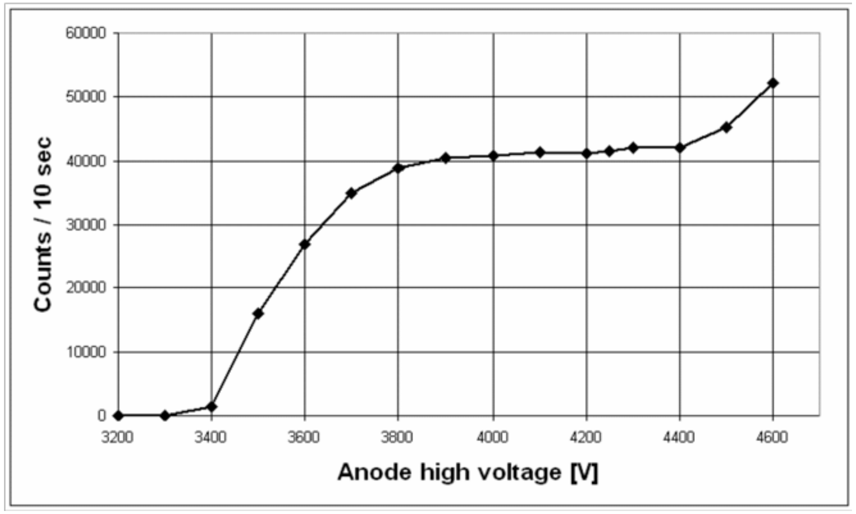
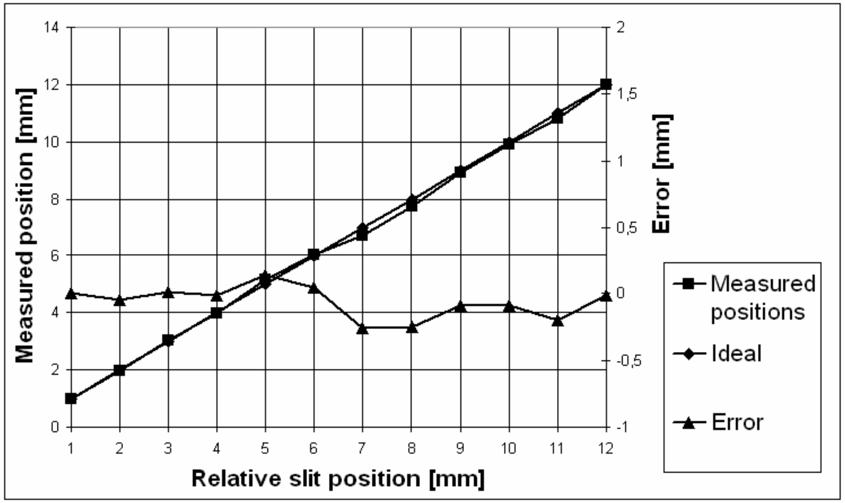
Task 21.2 Solid 10B Gas Detector Development

Task 21.2.1 Production and Characterisation of 10B layers

Detector characterisation





Preliminary experiments: Counts and position

Characterisation of boron layaers

-Optical spectroscopy

-X-ray reflectivity, AFM

-Auger spectroscopy, PIXE

-High precision neutron transmission

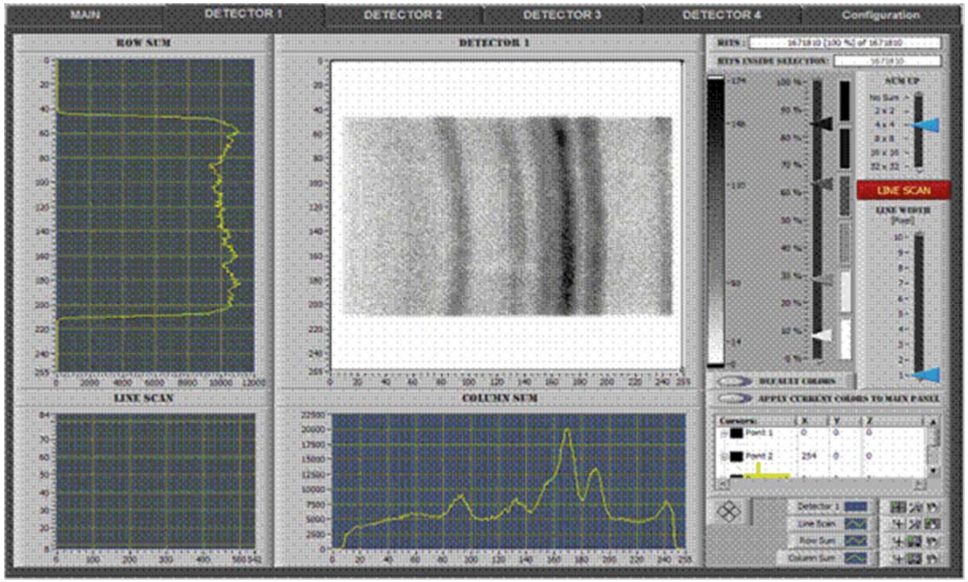
- Neutron radiography (cold/thermal beam)

Testing of prototype detectors

-HV characteristics, gamma sensitivity

-Efficiency

-Position resolution, diffraction experiments



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Task 21.2 Solid 10B Gas Detector Development

Task 21.2.2 Exploration of alternative coating techniques

- Sputtering by magnetron rather expensive, good reference!
- Focus on alternative techniques including non-vacuum options e.g.:
  - Electron beam evaporation
  - Non-vacuum coating techniques
    - electrophoresis
    - plasma-spray
    - rotogravure
    - inkjet
- Always similar critical points:
  - Efficiency, composition, uniformity, inclusions, adhesion, long-term stability, large areas, cost

List of ideas and research topics, no final solution!

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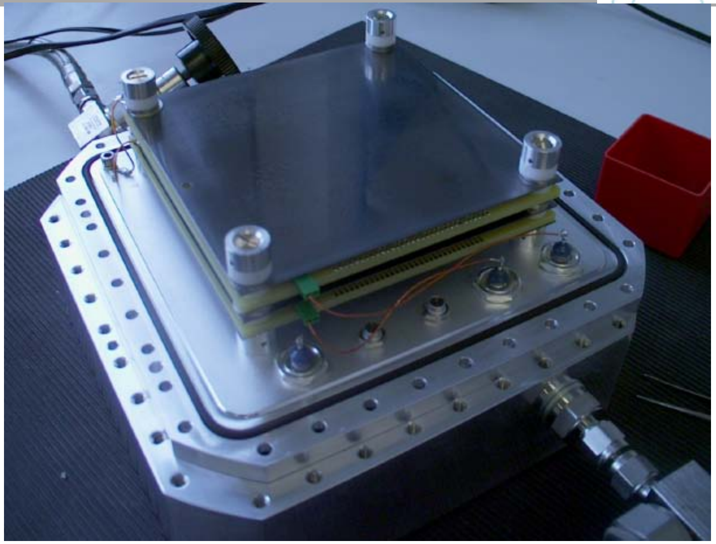
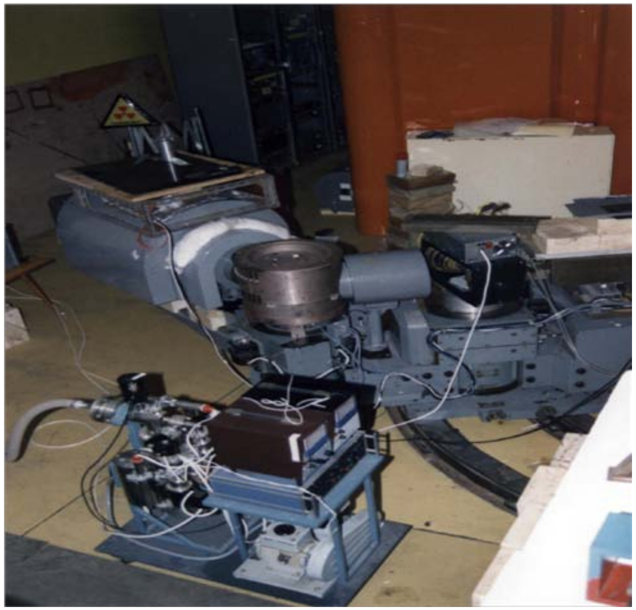
Task 21.2 Solid 10B Gas Detector Development

T21.2.3: Measurement with Test Detector

- Design and construction of a common small size test detector provided by TUM
- Evaluate performance of most promising coatings in test device at test beam facility TREFF @ FRM II





Cold beutron beam testing facility at BNC

- HZB
- BCN
- LLB
- All have neutron facilities and are able to support neutron detector evaluation.

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Task 21.2 Solid 10B Gas Detector Development

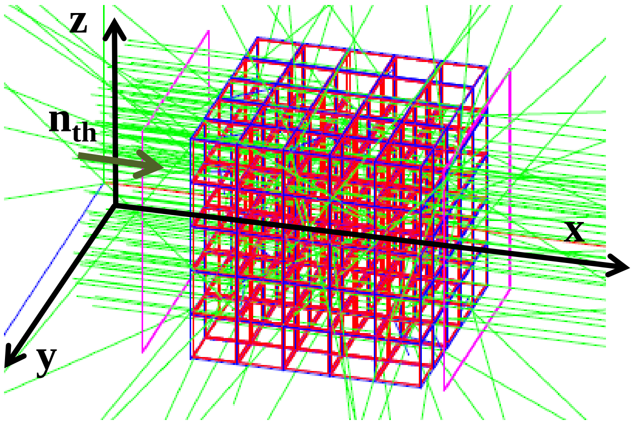
FRM II Forschungs-Neutronenquelle Heinz Maier-Leibnitz

Technische Universität München

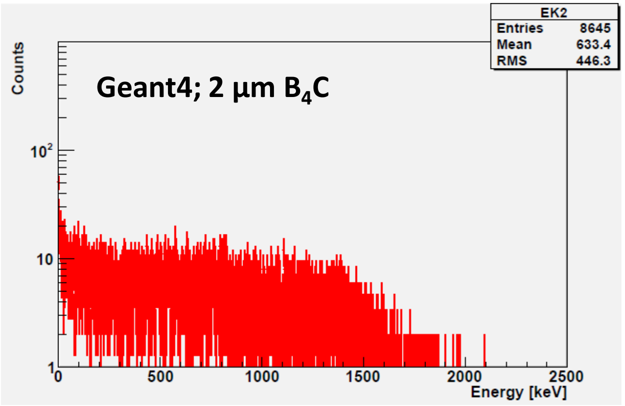
T21.2.4: Concept study for a large area detector - TUM

- Evaluate potential configurations for a large area detector, focusing on affordable production techniques
- Simulate configuration with GEANT4 to determine detector response, pulse height spectra, efficiency…

Multi-cell structure

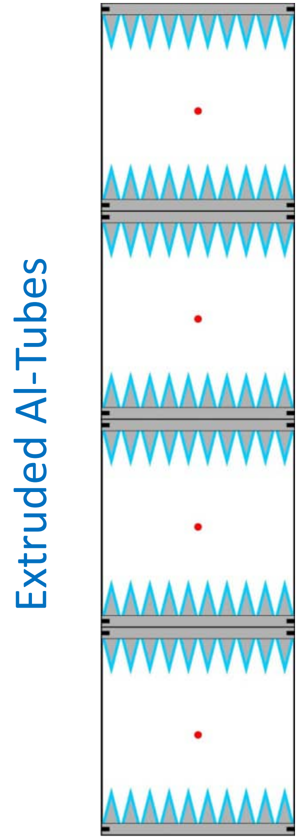


Calc. pulse height spectrum



- Build in cooperation with HZB a modular and scalable prototype of ~ $1m^2$ active area

Multi-cell structure proposed by HZ Berlin



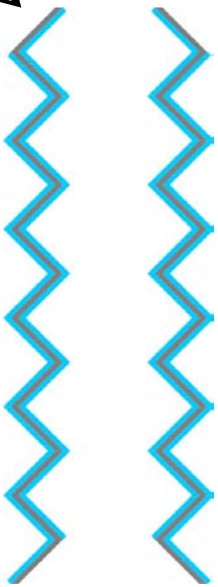
Short converters, inserted in long tubes

T21.2.4: Proposal-HZB (Z-Profile)

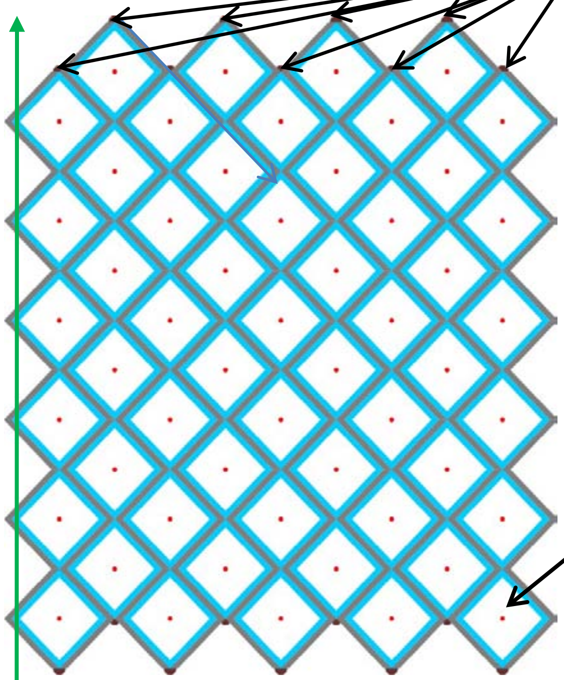
Idea together K. Zeitelhack/FRM II

45°: Gain = 1.41

Top view!



Very simple
identical Z-profiles (Al)
by extrusion molding,
covered with boron-coated foils



Homogeneous response: absorption & efficiency!

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Task 21.2 Solid 10B Gas Detector Development

T21.2.4: Concept study for a large area detector - Saclay LLB/IRFU

Aim :
Take advantage of experience of Irfu at CERN on Bulk-Micromegas detectors to design a low cost, large area, neutron detector with ^{10}B layers.

Work program :

- Do the conceptual design adapted to thermal neutron detection
- Do the evaluation of the efficiency of detection of a single unit
- Do the evaluation of the efficiency of detection of piled-up units
- Do the evaluation of costs
- Built a small scale single unit prototype
- Test the prototype

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Task 21.2 Solid 10B Gas Detector Development

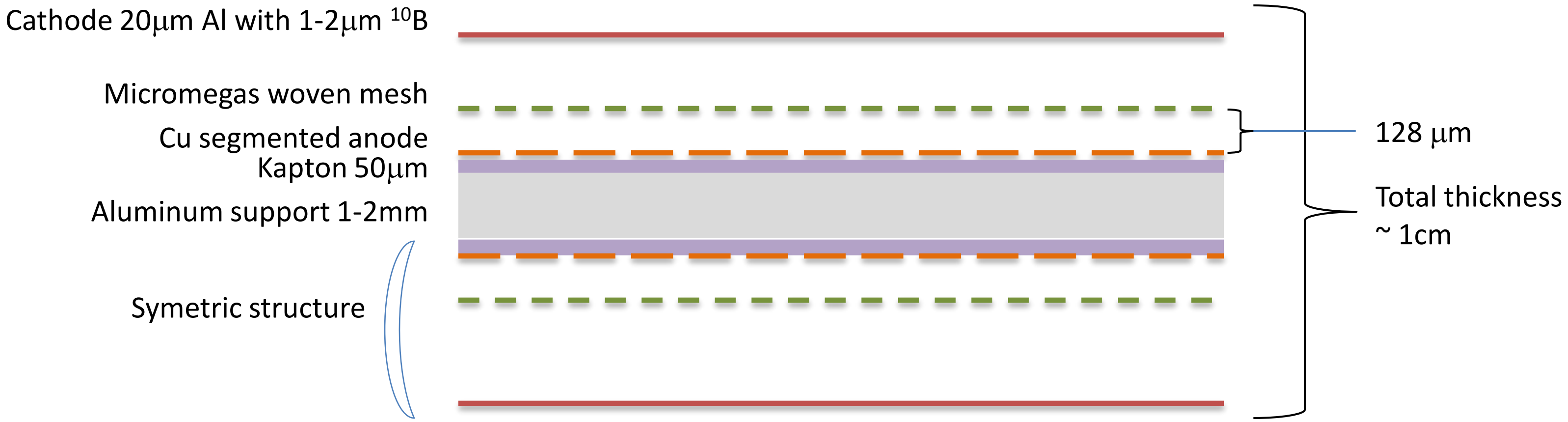
T21.2.4: Concept study for a large area detector - Saclay LLB/IRFU

Conceptual design

- Back-to-back structure with bulk-micromegas
- Expected efficiency of a single unit ~7%
- Expected # of modules to pile-up : 10 for ~50% efficiency
- Expected surface of each module : 50 x 50 cm^2
- Electronic readout to be chosen depending on resolution and acquisition rates

First tests to be done soon on a small surface (5cm^2), single sided structure.

Expected design of a single back-to-back unit



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Conclusion

Two tasks

21.1 Development of scintillation detectors based on wavelength shifting fibre

21.2 Development of gas detectors based on solid 10B converter

The Question: Can you keep the costs down whilst:

Approaching

Equalling the performance that has been achieved with 3He detectors.

Bettering

THANK YOU FOR YOUR ATTENTION!

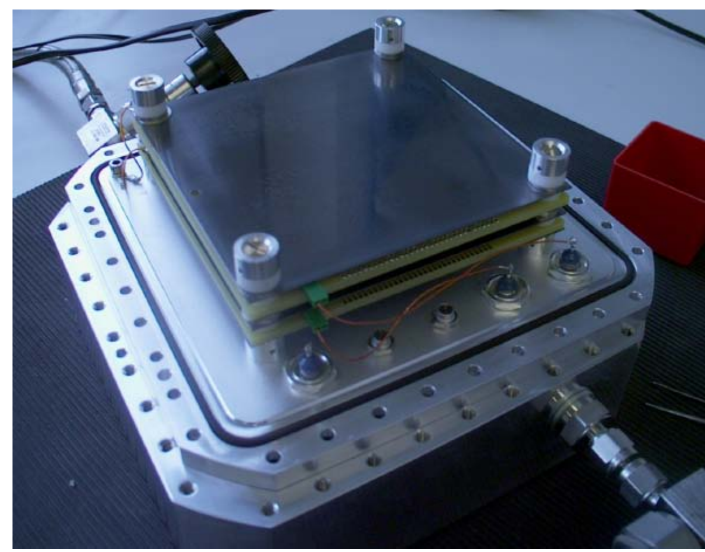
Gaseous Detector with solid ^{10}B converter

B_4C coatings on 13cm x13cm on AlMg3 substrate

T2.2: Production Techniques

- Study vacuum and non-vacuum deposit techniques of ^{10}Boron converter and the potential use in gaseous neutron detect
- Key issues: efficiency, composition, homogeneity, adhesion, long term stabi, large areas

T2.3: Measurement with Test Detector



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WP 21 Detectors

Two tasks

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