Status of MultiGrid Detector Development for CSPEC and TREX

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Isaak Lopez Higuera

www.europeanspallationsource.se

Sep 28, 2017

Outline

B10 detector development (Anton Khaplanov)

Multi-Grid detector Characterization highlights

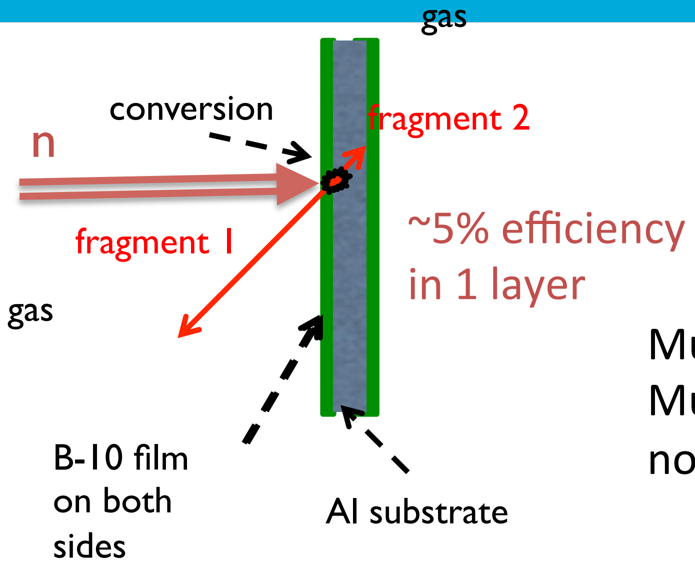
- **Intrinsic background suppression**
- **Gamma sensitivity**
- **Current development**

Multi-Grid ToF results from CNCS, SNS

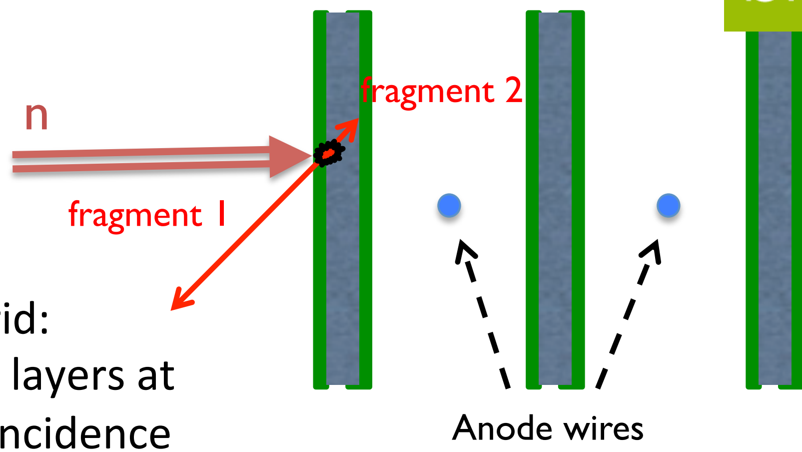
Engineering the Multi-Grid (Isaak Lopez Higuera)

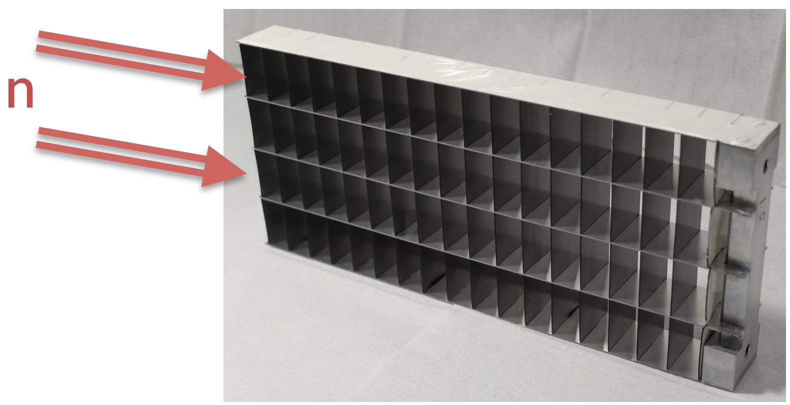
- **MG.CNCS**
- **MG.SEQ**
- **Conceptual design for CSPEC**

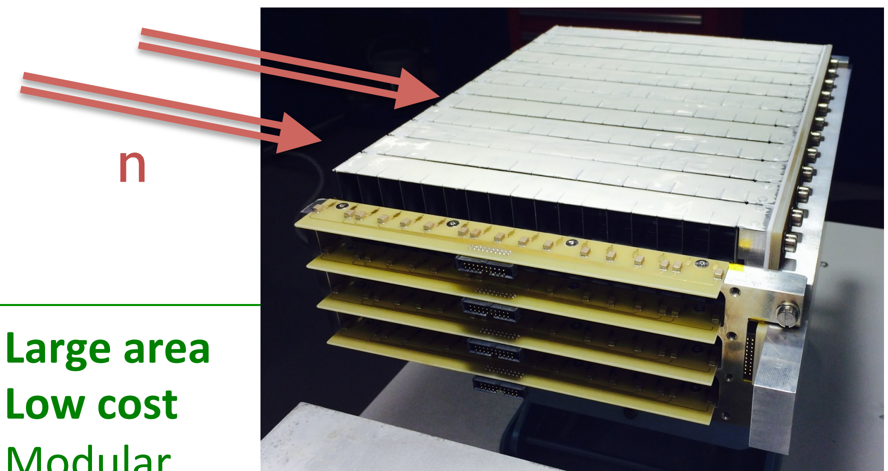
B10 Detectors as Alternative to He3



Multi-Grid:
Multiple layers at
normal incidence







- **Large area**
- **Low cost**
- Modular
- High total efficiency
- Many layers – lower local rate
- No need for resistive readout – low gain

Introduced at ILL, jointly developed by ILL and ESS under CRISP project, now under BrightnESS

Multi-Grid Prototypes for Characterization

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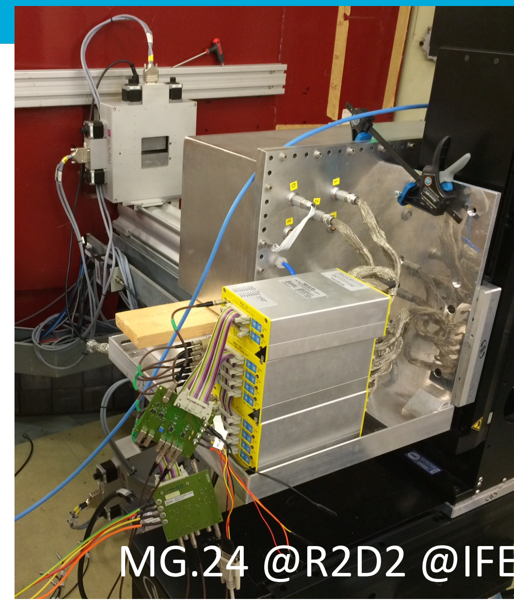
Measurements:

- Absolute efficiency
- Uniformity
- Position reconstruction
- γ sensitivity
- Rate tests
- Ageing

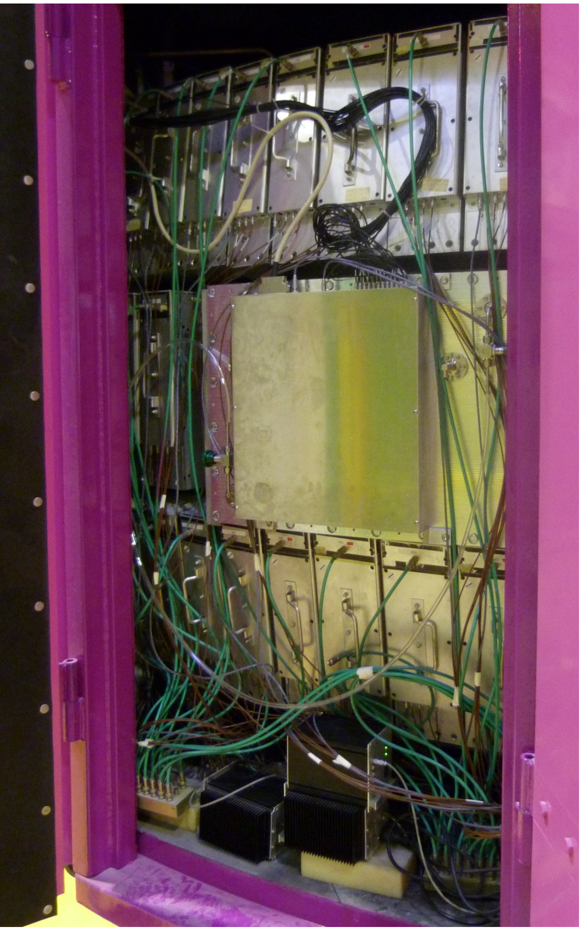


MG.24 @R2D2 @IFE

Proto 1 at CT1 @ILL

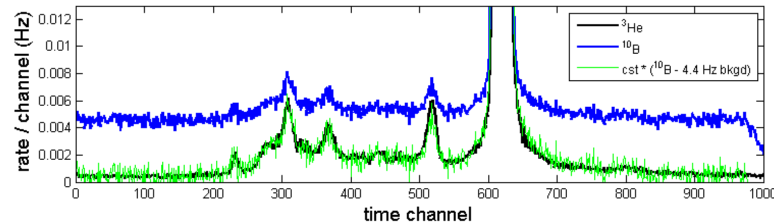
Proto 2 at CT2 @ILL

First Multi-Grid tested on an Instrument



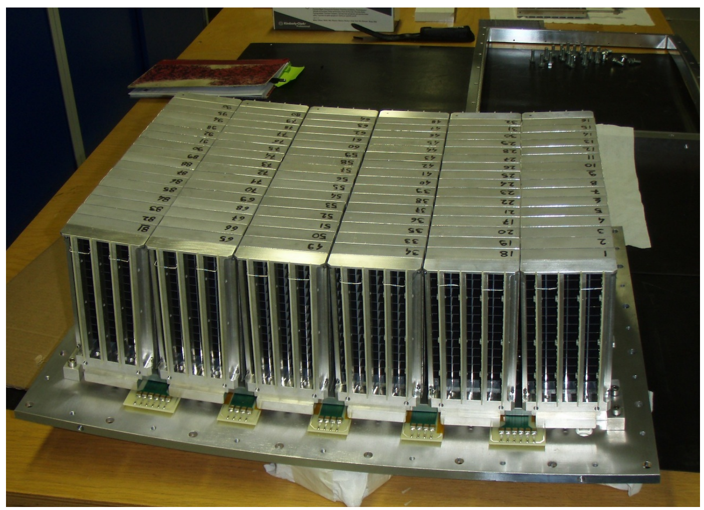
Detector tested on cold chopper spectrometer IN6 @ILL

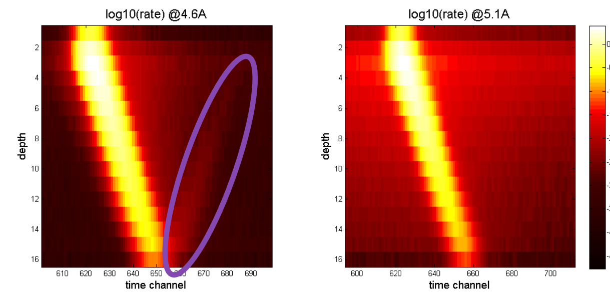
- Active Area 30 x 45 cm2
- 96 grids in 6 modules of 16 grids, 360 anode wires
- Operated for ~2 weeks, replacing 25 He3 tubes
- @ 4.1, 4.6 and 5.1 Å incoming wavelength

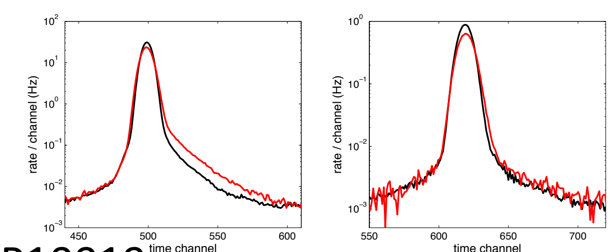


Main topics of the test:

- First ToF spectra
- Background investigation
- Elastic line shape







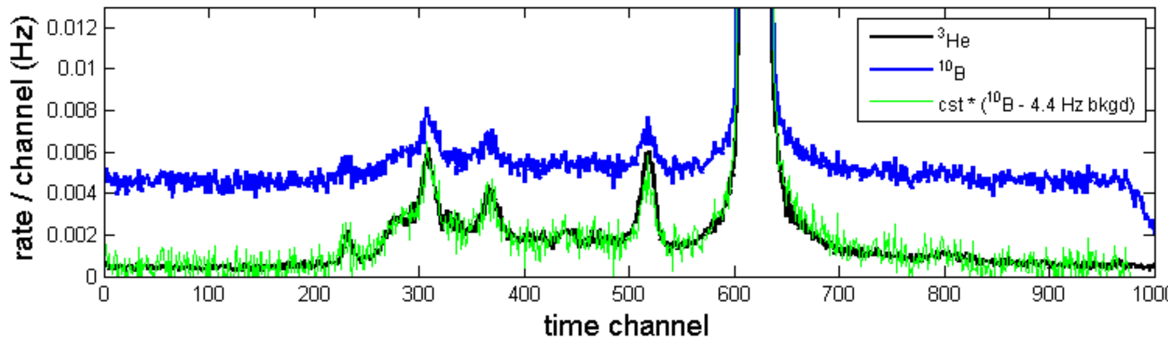
*A. Khaplanov et al. 2015 JINST 10 P10019

*A. Khaplanov et al. J. Phys: Conf Ser 528 (2014) 012040

Intrinsic background

Spectrometers work with a very large dynamic range → very high signal-to-noise is required.

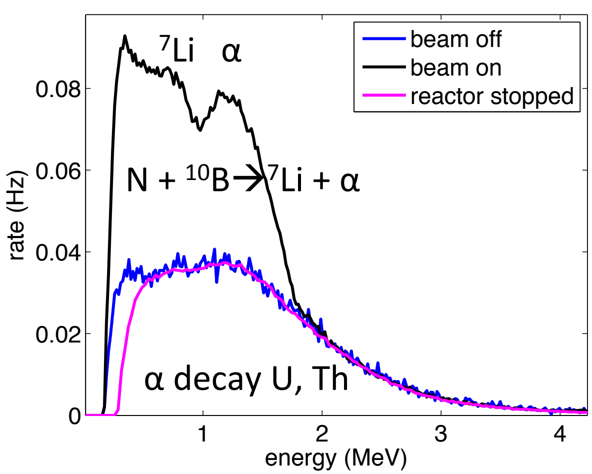
Intrinsic background often found in Al due to α emitter impurities (U and Th).

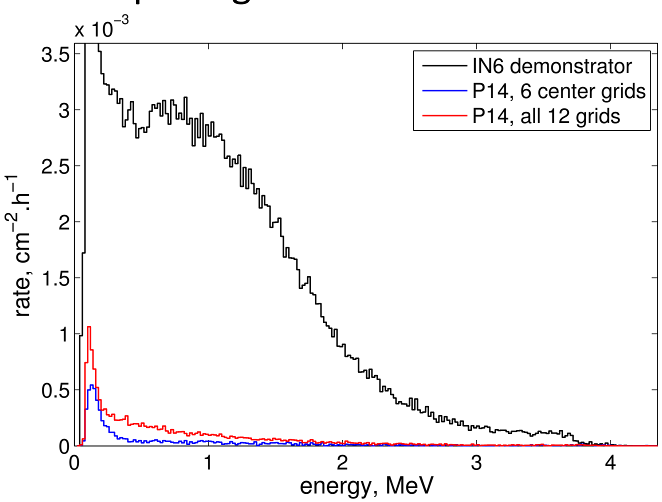


x50-x100 background reduction using:

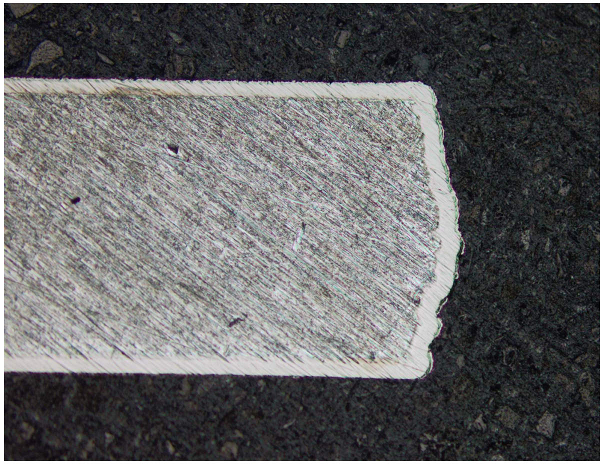
- high-purity Al
- Ni-plating

Spectrum from standard Al





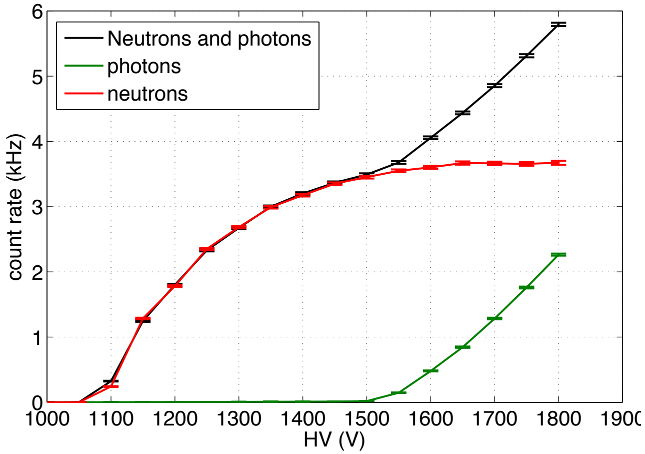
Ni-plating on a 0.5mm Al blade

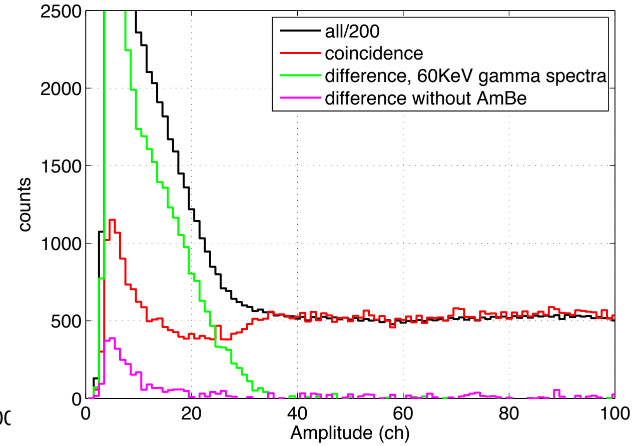


A. Khaplanov et al. 2015 JINST 10 P10019

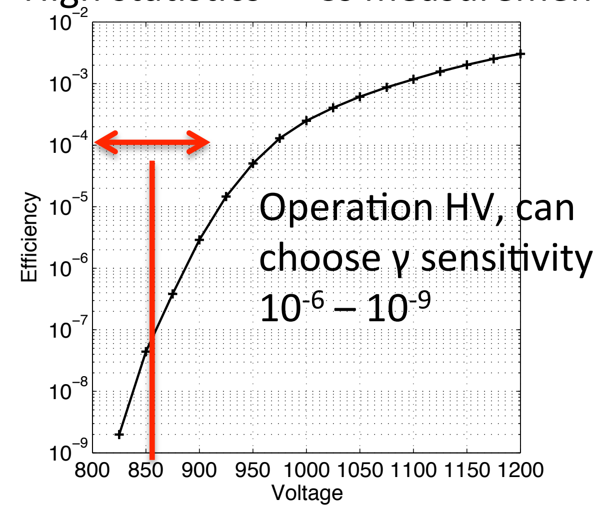
γ Sensitivity Investigated

Beam + source setup for γ sensitivity measurement

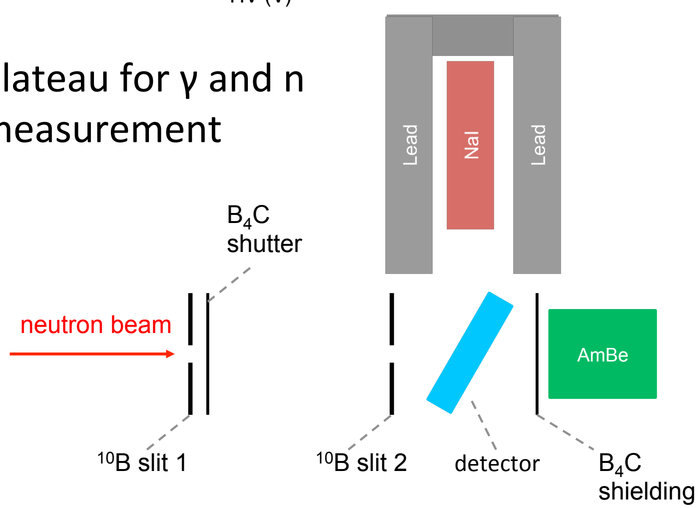




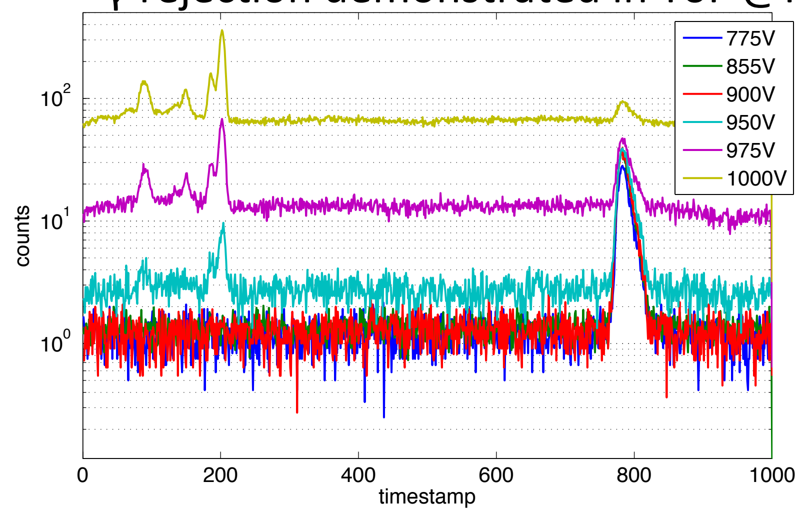
High statistics ^{137}Cs measurement



Plateau for γ and n measurement



γ rejection demonstrated in ToF @IN6



* A. Khaplanov et al., JINST 8, P10025 (2013), arXiv:1306.6247

Test on CNCS, Cold Neutron Chopper Spectrometer

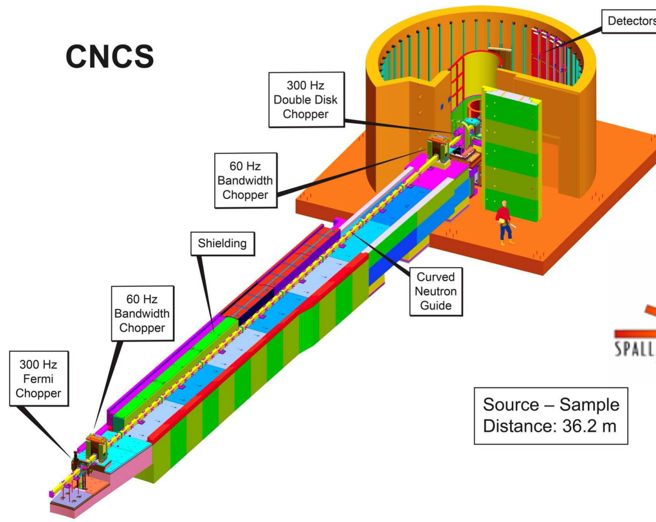
- A kind offer by K. Herwig to test MG at SNS
- Recommendation of 2015 ESS annual review

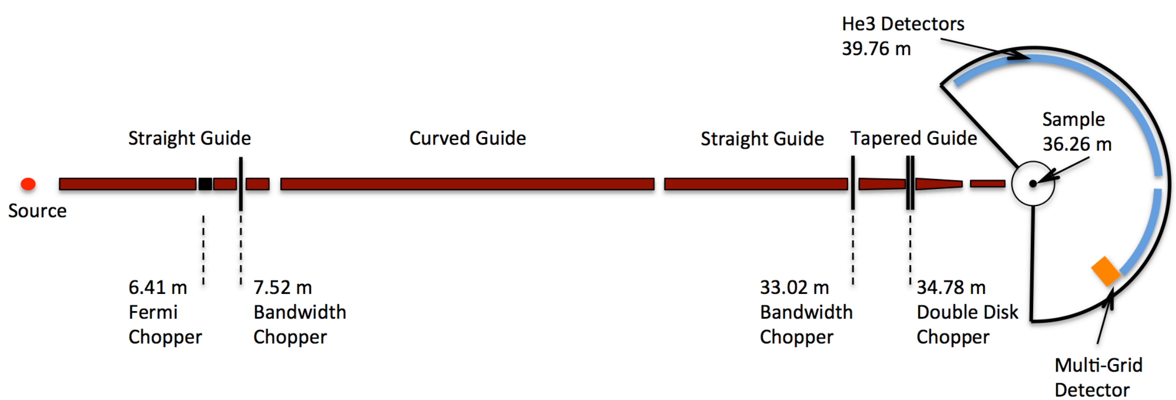
Goals:

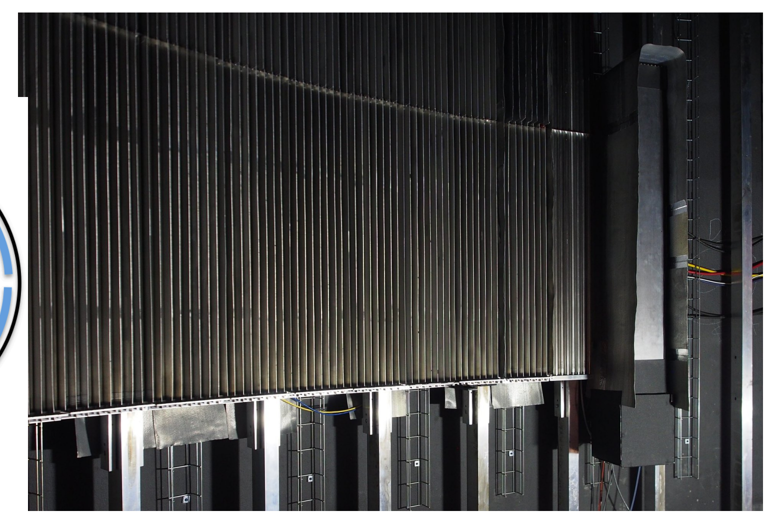
- Test at spectrometer
- Side-by-side comparison to He3
- In parallel with user experiments
- Dedicated tests

Solution:

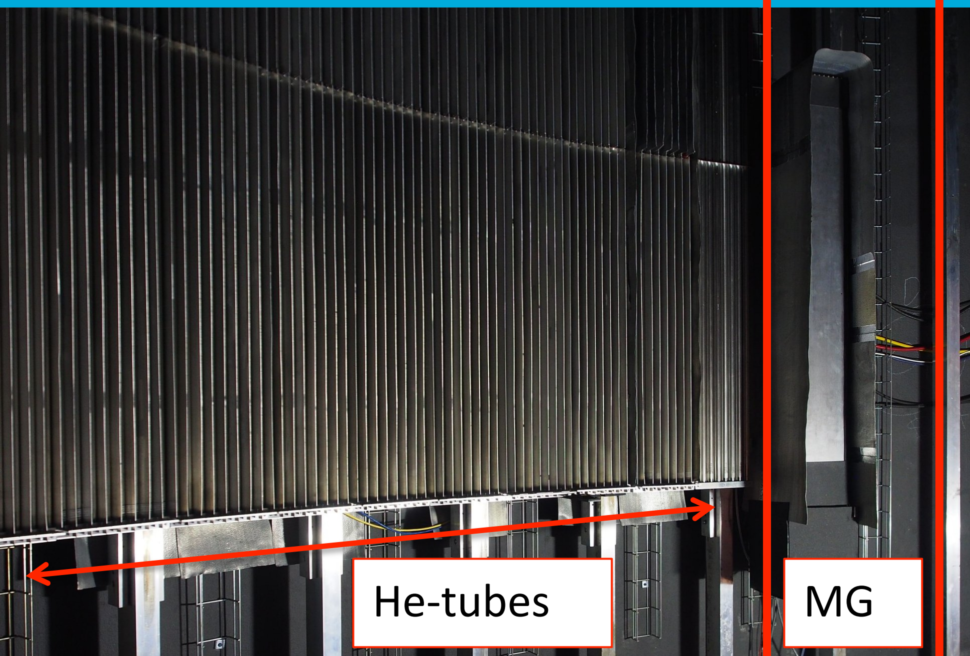
- Size = half of "8-pack" module – 1.1m x 19cm
- Installation June-July 2016
- **Operated July 2016 to June 2017**

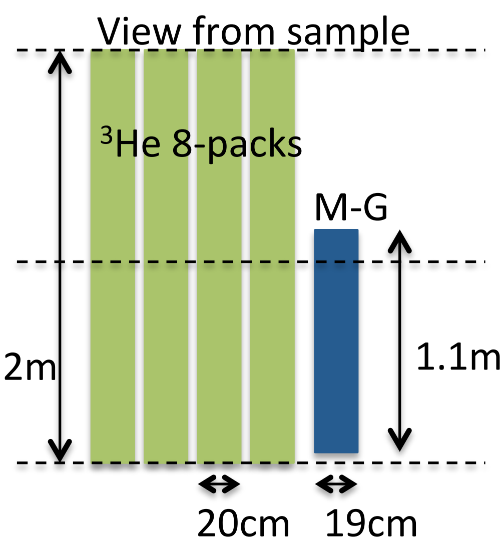






Multi-Grid installed at CNCS

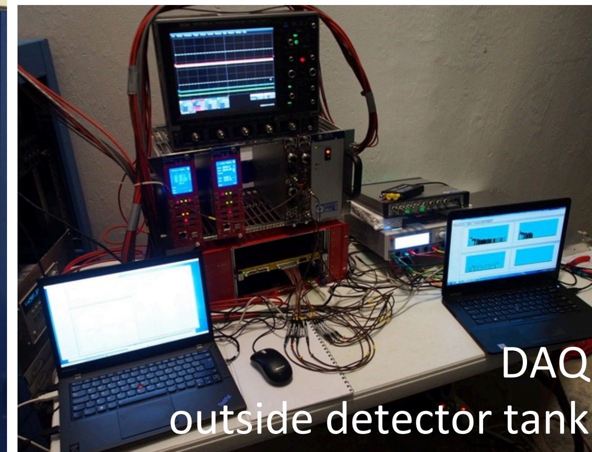


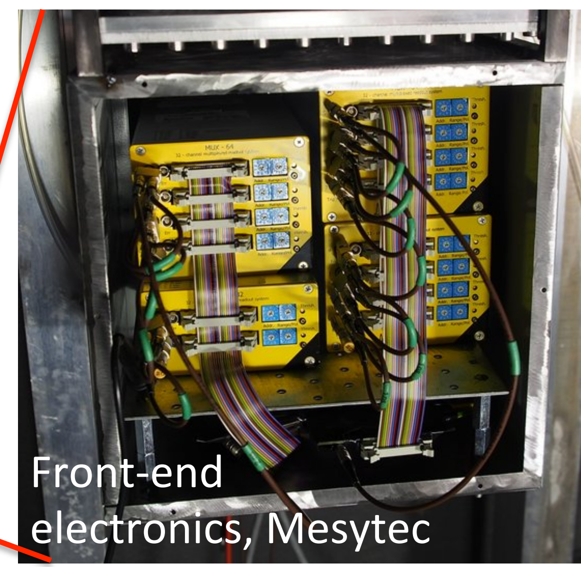


Detector installed at 57° scattering angle

Inaccessible between summer and winter shutdowns

DAQ setup outside, accessible remotely





Methods Used for Tests

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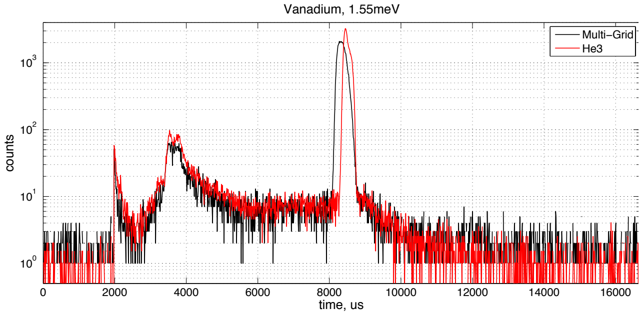
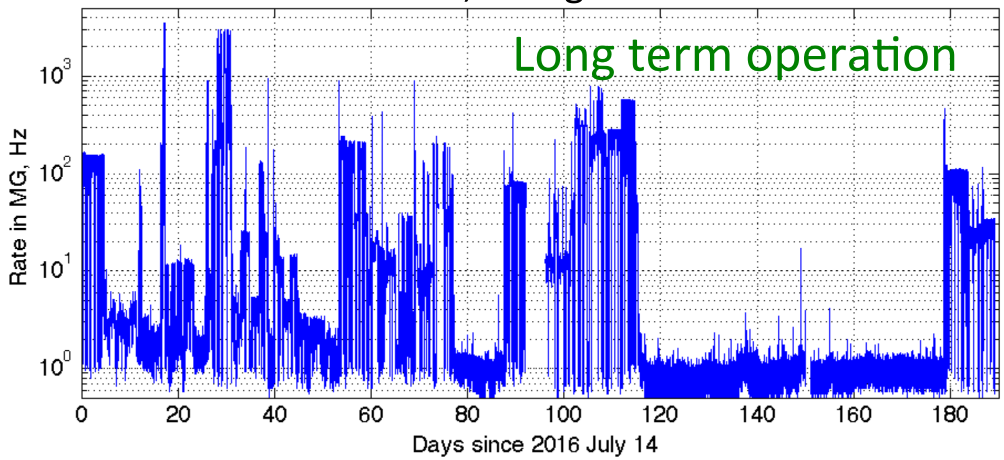
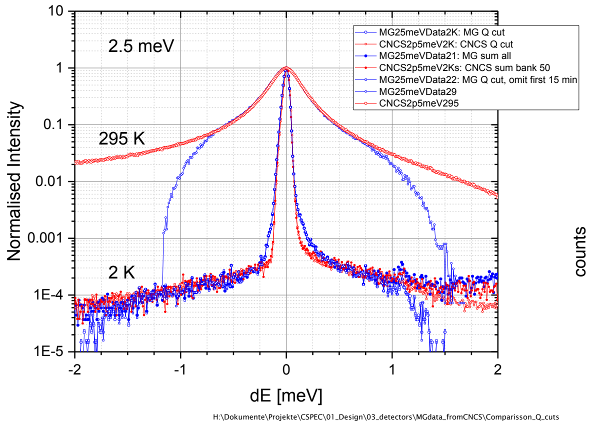
Vanadium



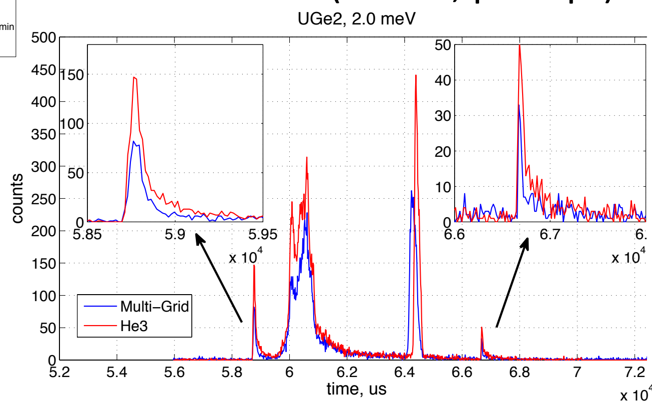
Counts over time, background



Water, Ice

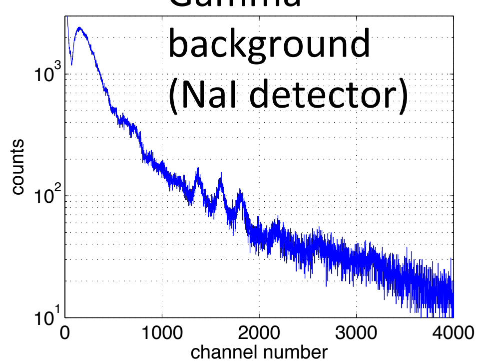


Fast neutrons (fission, prompt)



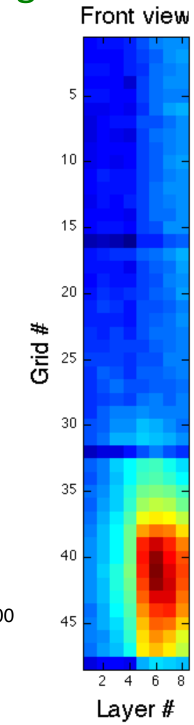
x2 lower fast n counts in MG

Gamma background (NaI detector)



Single crystal

High local rate



Allowing to measure:

Energy resolution – efficiency, scattering – background sensitivity – saturation

Elastic Energy Resolution

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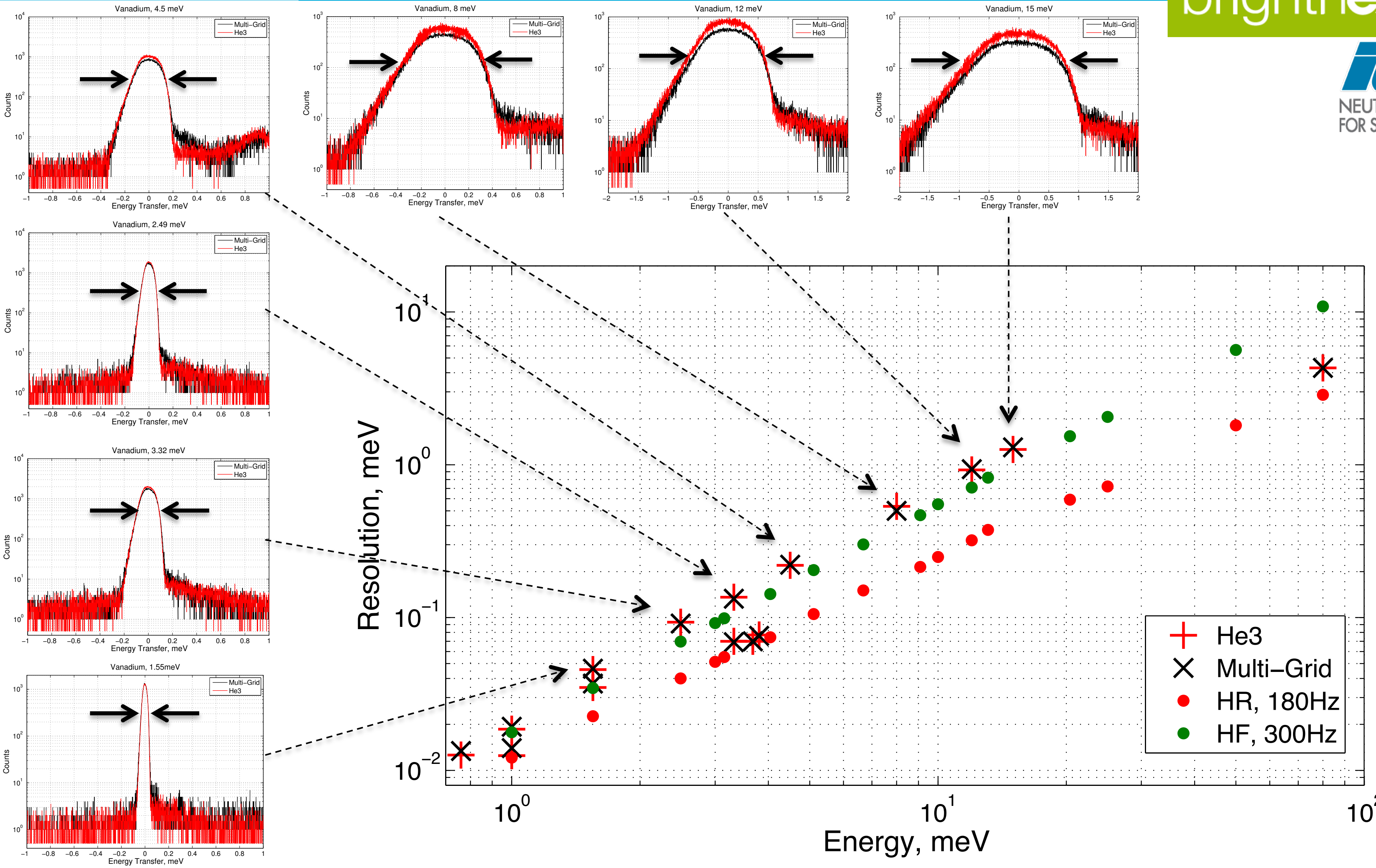
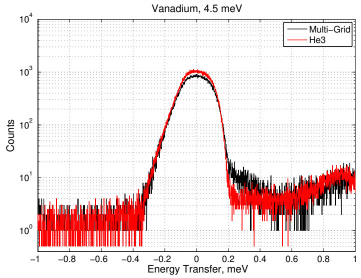
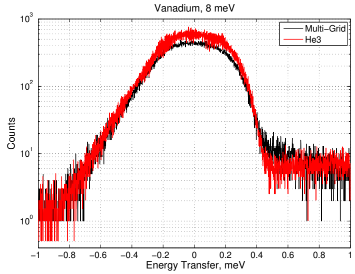
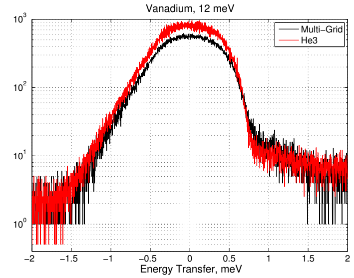
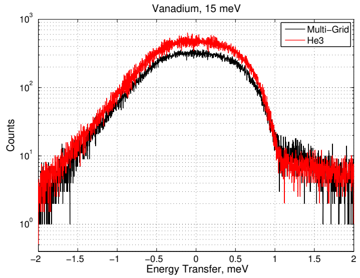


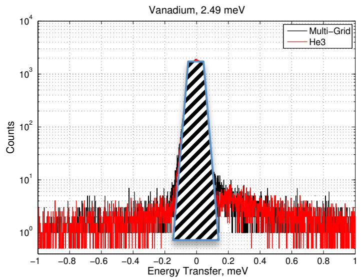
Efficiency

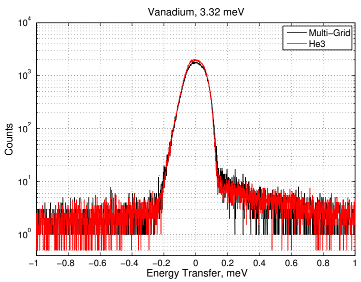


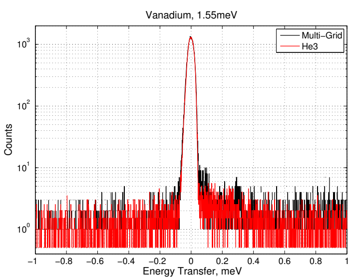


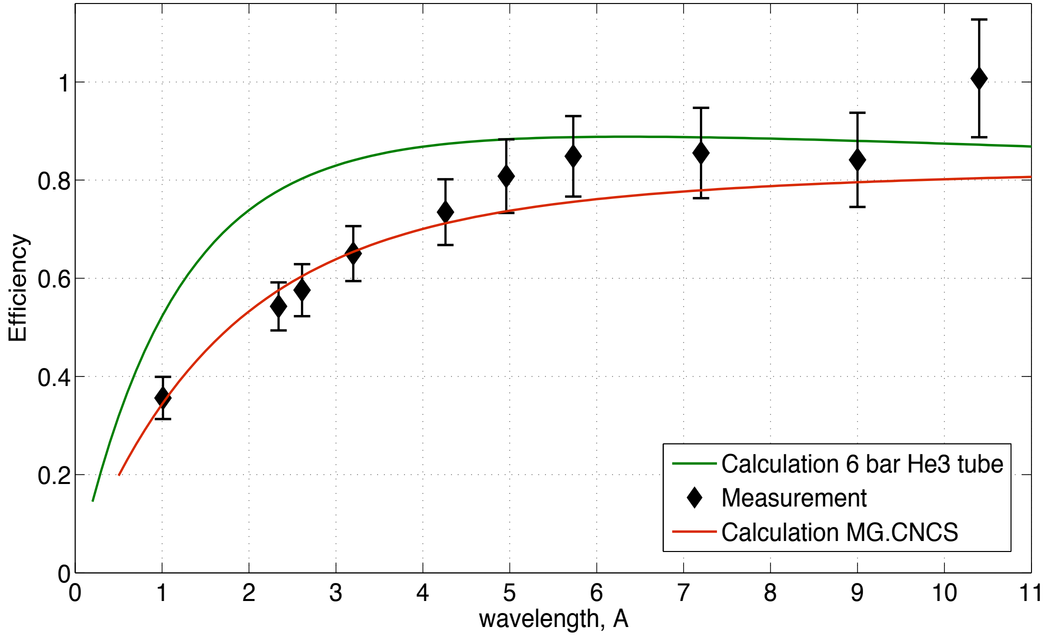












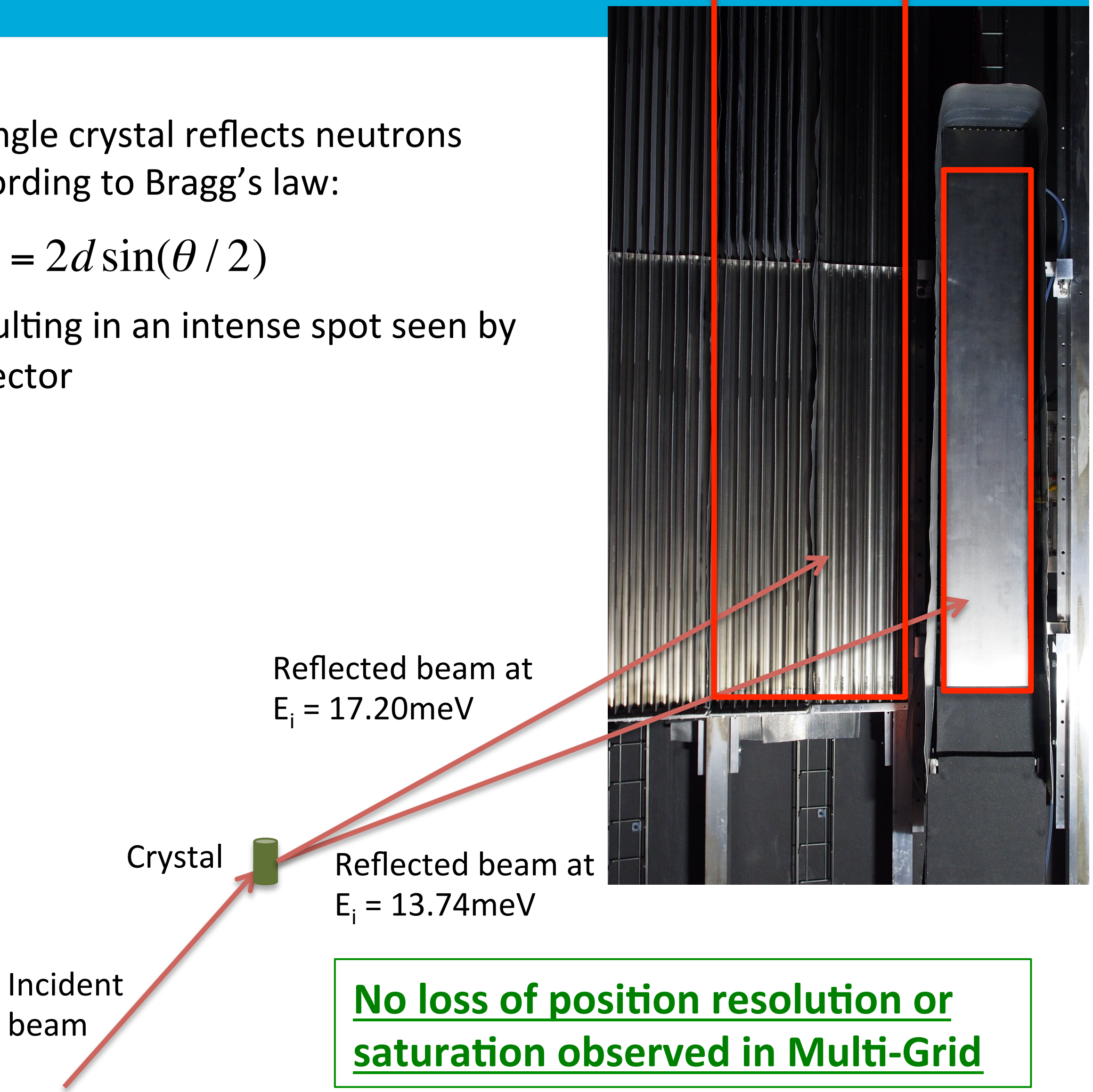
Counts from integral of the elastic peak in dE
Efficiency measured relative to the nearest He3 tubes
Error bars: 5-8%, agrees with prediction

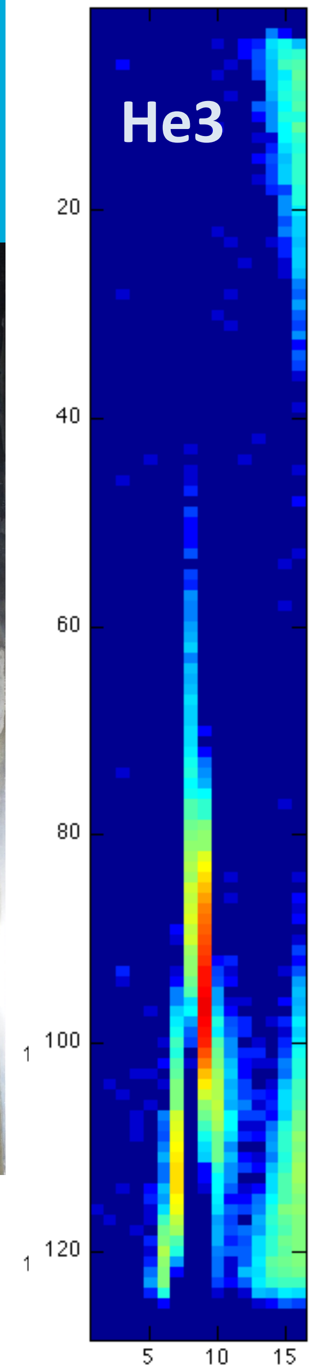
Single Crystal Reflection

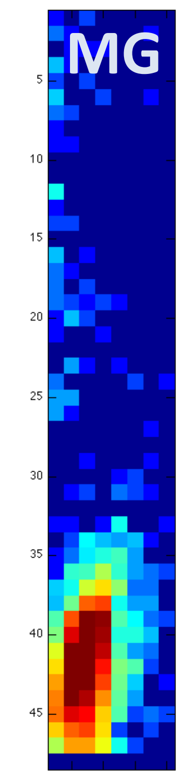
A single crystal reflects neutrons according to Bragg's law:

$$n\lambda = 2d\sin(\theta/2)$$

Resulting in an intense spot seen by detector

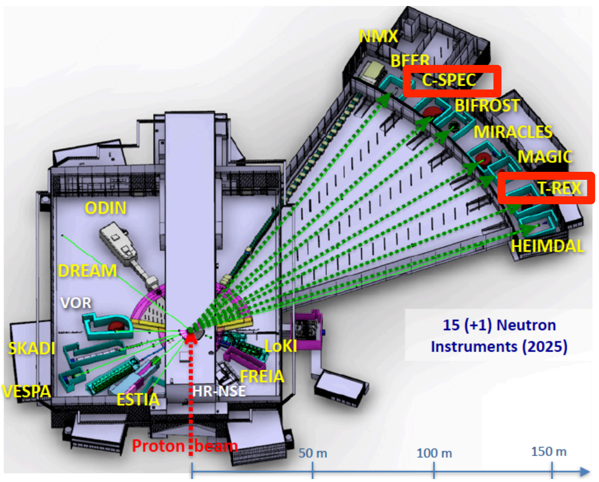






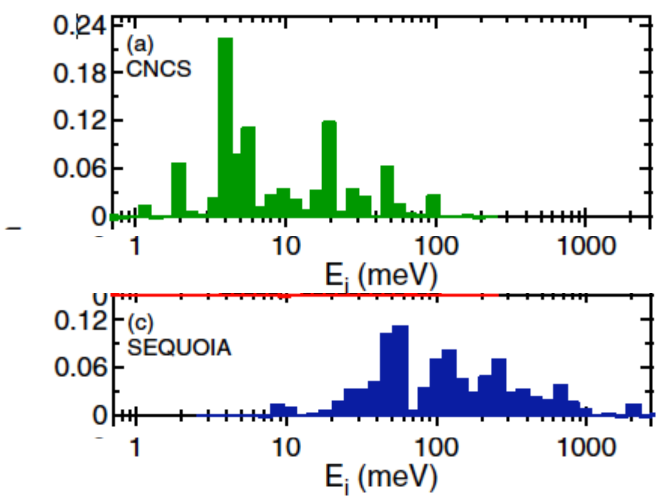
No loss of position resolution or saturation observed in Multi-Grid

Energy Ranges for ESS Spectrometers



Energy ranges of the first ESS ToF spectrometers

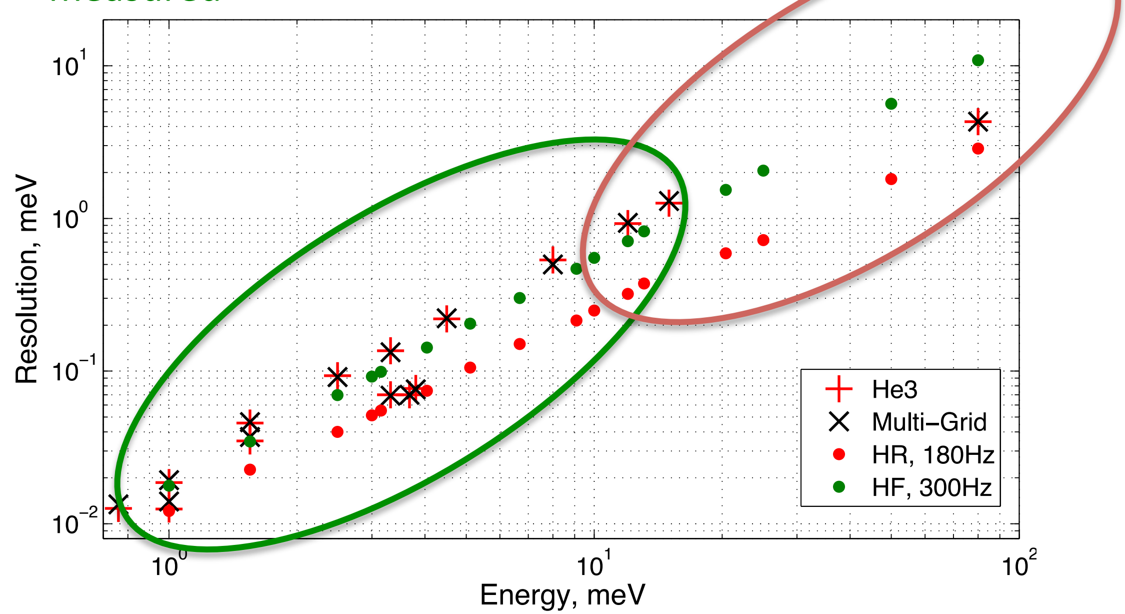
	CSPEC	T-REX
Typical initial λ, Å (meV)	2 to 15 Å (20 to 0.36 meV)	0.7 to 6.4 Å (160 to 2 meV)



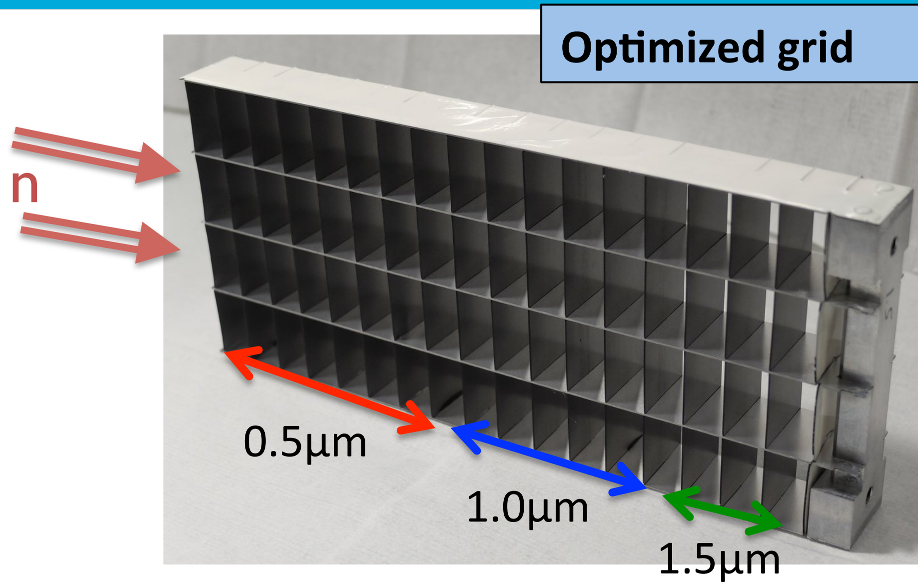
Incident energies used at CNCS and SEQUOIA (M. Stone et al.)

Cold range, 0.76 to 15 meV measured

Measurements needed for thermal range, up to 160 meV



Efficiency Optimizations

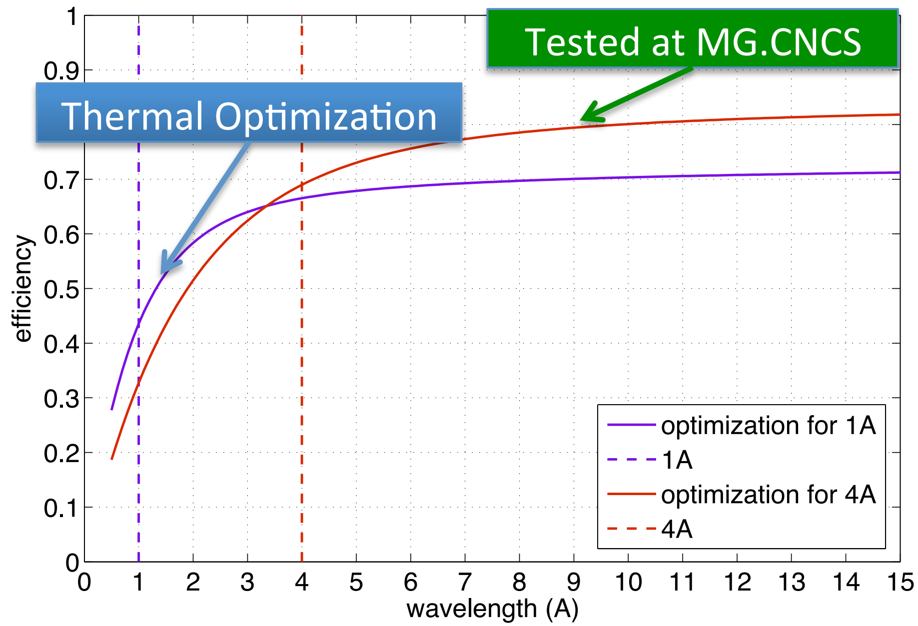


Layer thicknesses in MG.CNCS (16 blades):
7 blades 0.5µm,
7 blades 1.0µm,
3 blades 1.5µm

Thermal optimization

20 blades total:
4 blades 1.0µm,
10 blades 1.25µm,
6 blades 2.0µm.

Efficiency as a function of wavelength for MG optimized for cold vs. thermal spectrum



- Cold – optimization centered on 4Å
- Thermal – optimization centered on 1Å

*F. Piscitelli, P. van Esch, 2013 JINST 8, P04020

Multi-Grid Thermal Demonstrator test

Proposal made to do the test at SEQUOIA, at SNS

In addition to what was done for CNCS test:

Performance in thermal (and epithermal) flux
- Efficiency optimization
- Energy resolution
- Line shape
- Scattering

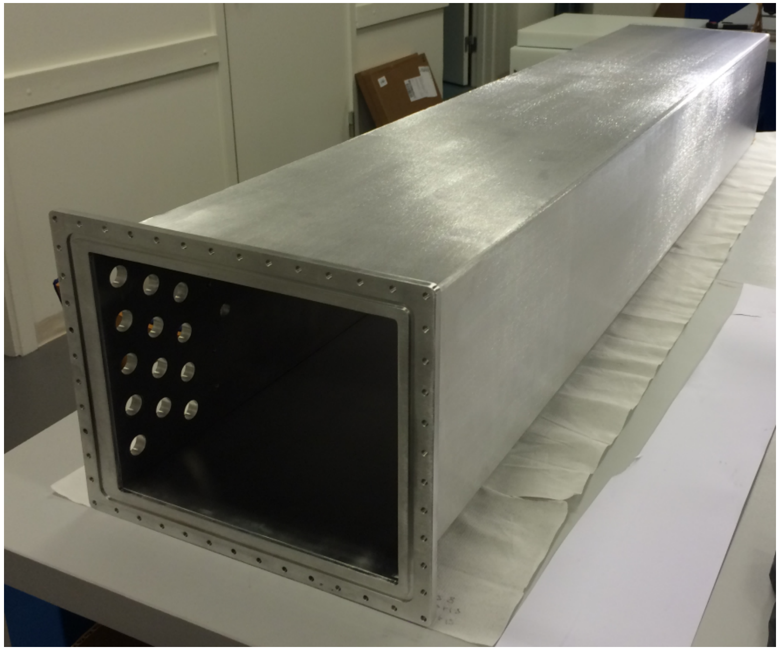
Detector construction
- Vacuum compatibility

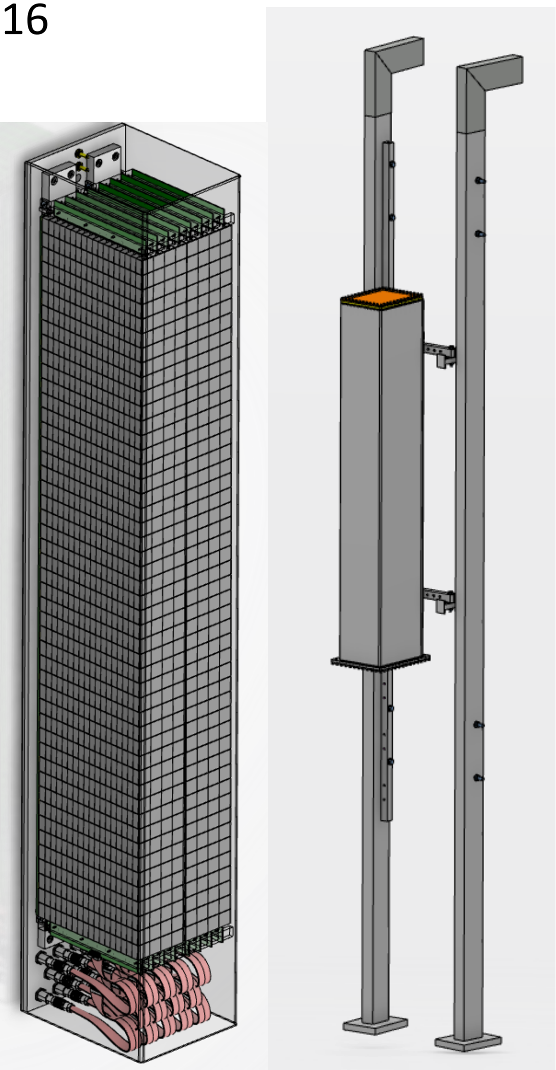
Online data acquisition, visualization and diagnostics
- (to be developed by DMSC)

MG.CNCS

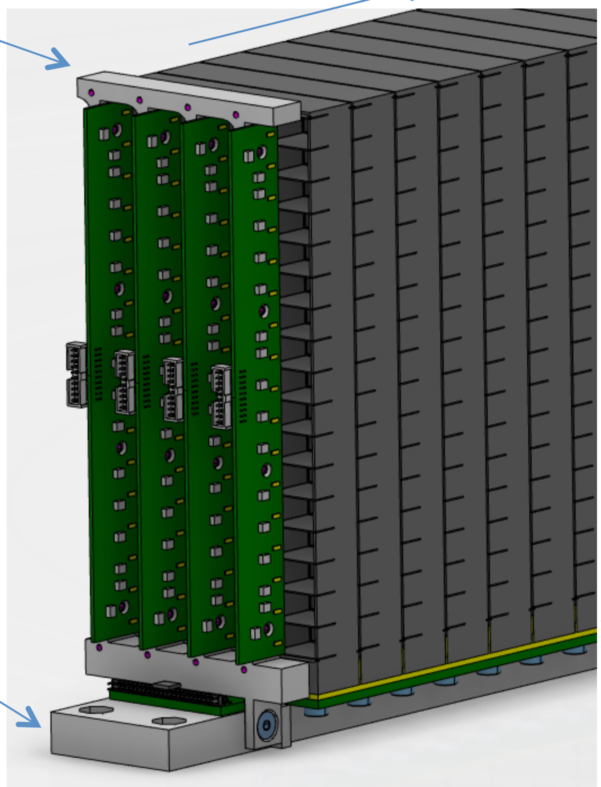
- Installed at SNS in the CNCS instrument during June 2016
- Optimized for cold neutrons
- 2 columns of 48 grid each
- Active area 1100 x 185 mm
- Voxel volume 22.5 x 22 x 11 mm

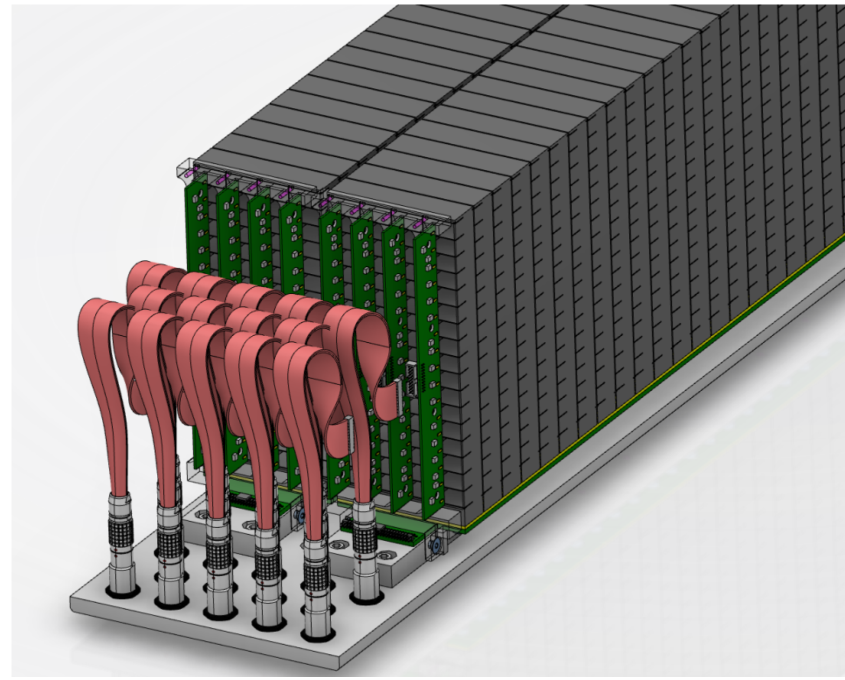
1394 x 200 x 250mm





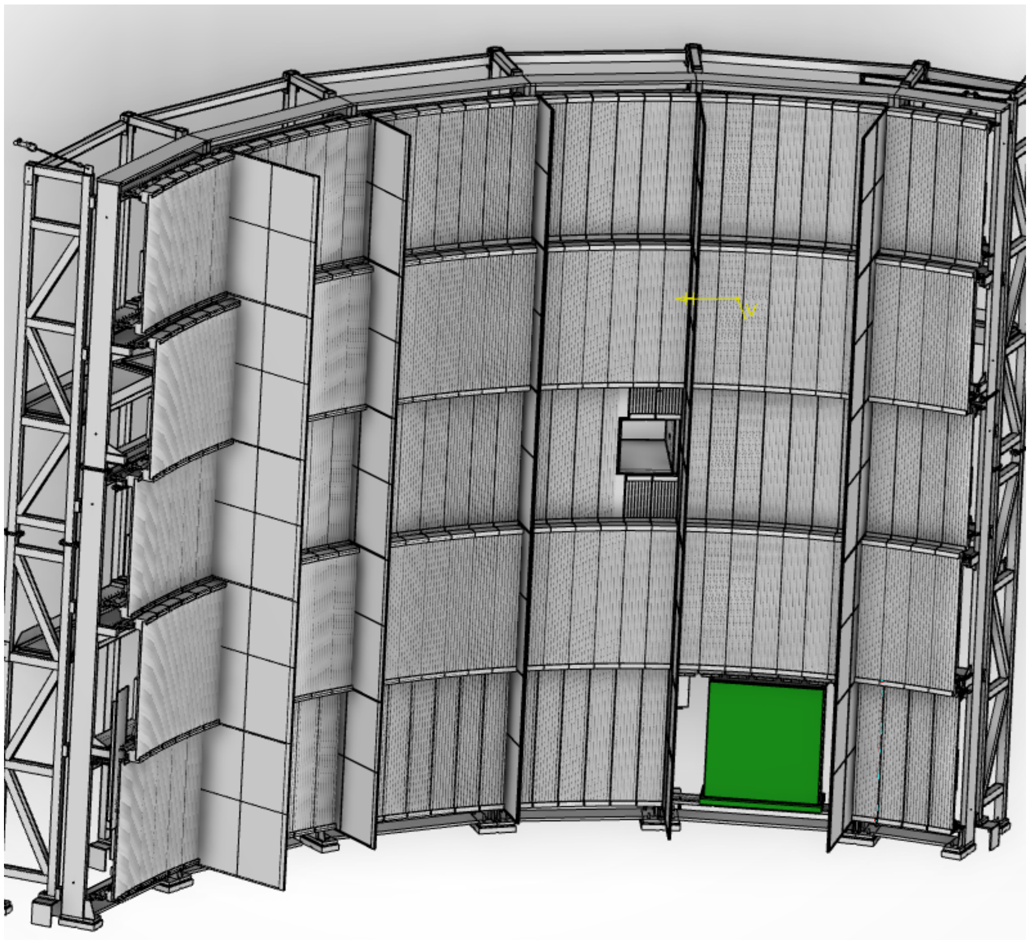
MG.CNCS


Grid assembly
End-Grid
Bottom insulator
Bottom PCB
Backbone

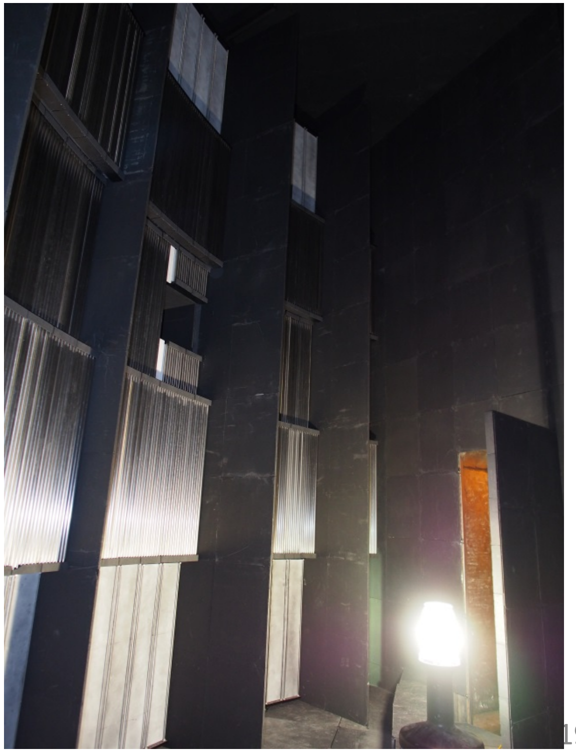


MG.SEQ

Installation **proposal** at SNS in the SEQUOIA instrument



- Test with thermal/epithermal neutrons
- First large area detector under vacuum
- Mounted in the lower bank ~5m and 25˚ from sample



MG.SEQ

Installation proposal at SNS in the SEQUOIA instrument

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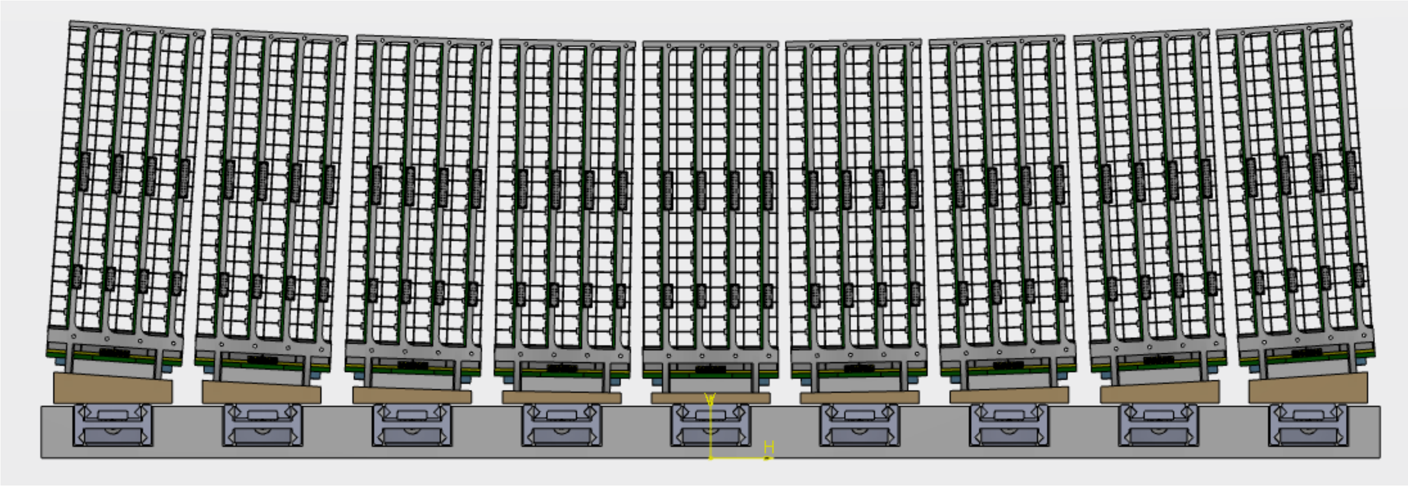
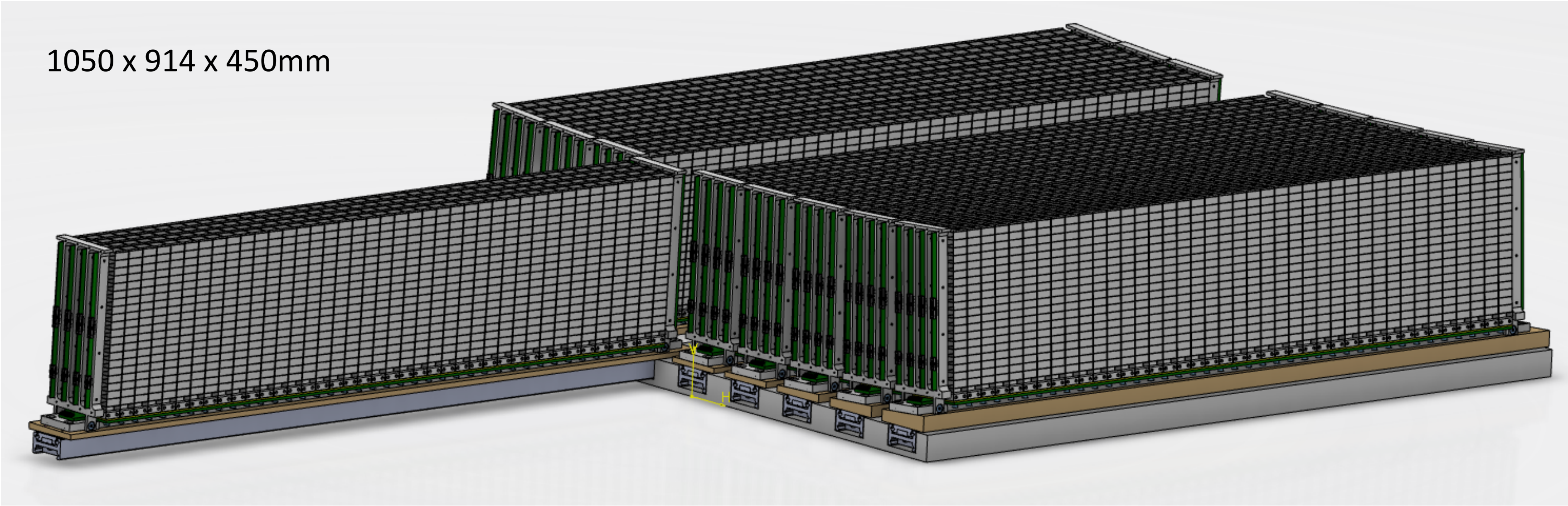
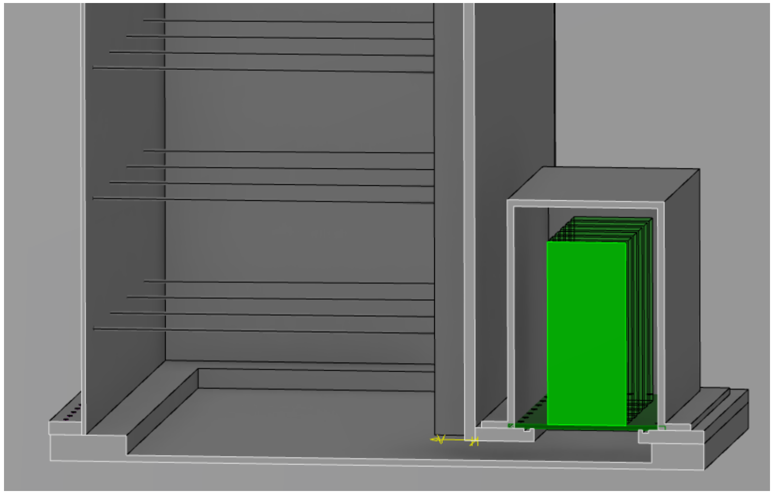
- 9 columns, 40 grids in each
- Telescopic sliders to access grid assemblies
- Use of inclined wedges so all grids are at the same distance from the sample





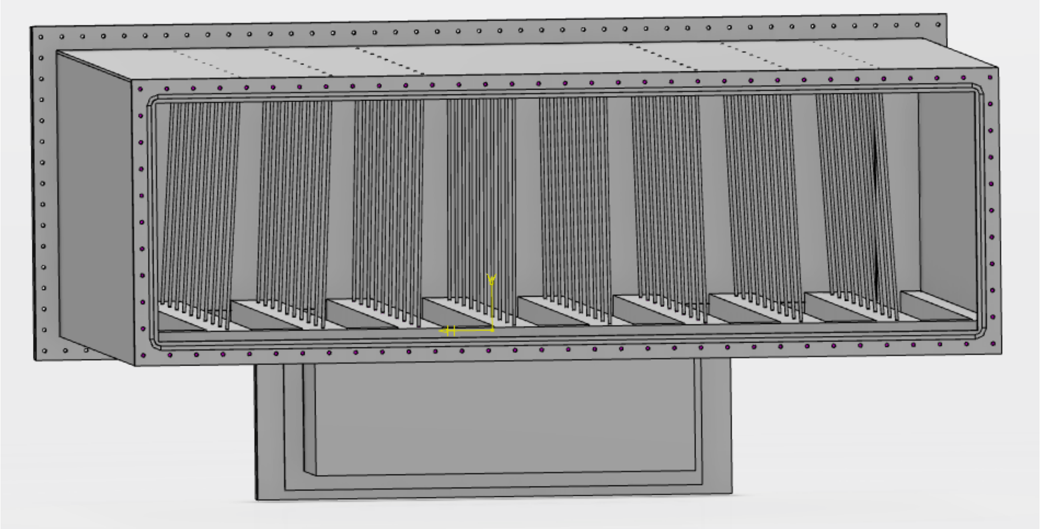
MG.SEQ



- Intermediate PCB layer, separates both atmospheres
- Groove in the cover to guide flat cables to the PCB layer
- Electronics plugged to the PCB layer

Mesytec 128 channel front-end
Preamp, shaper, multiplexer
60 x 140 x 20 mm^3
1 per detector module
9 required in total

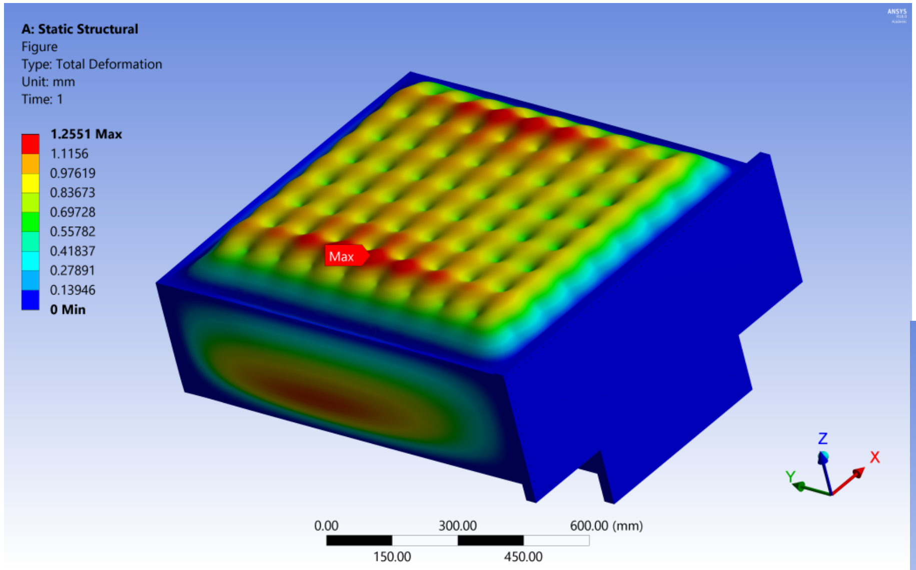
- 3mm thickness window
- 8 rows of 10 rods, Ø3mm



MG.SEQ

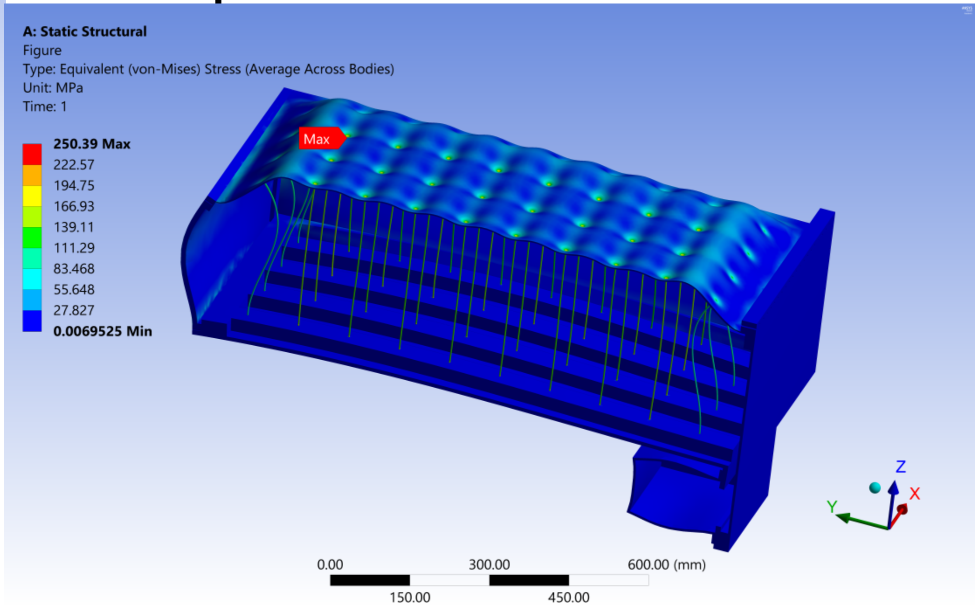
FEA of the vessel

Total deformation



Amplified 80 times

Equivalent stress



Amplified 80 times

CSPEC at ESS

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Cold spectrometer

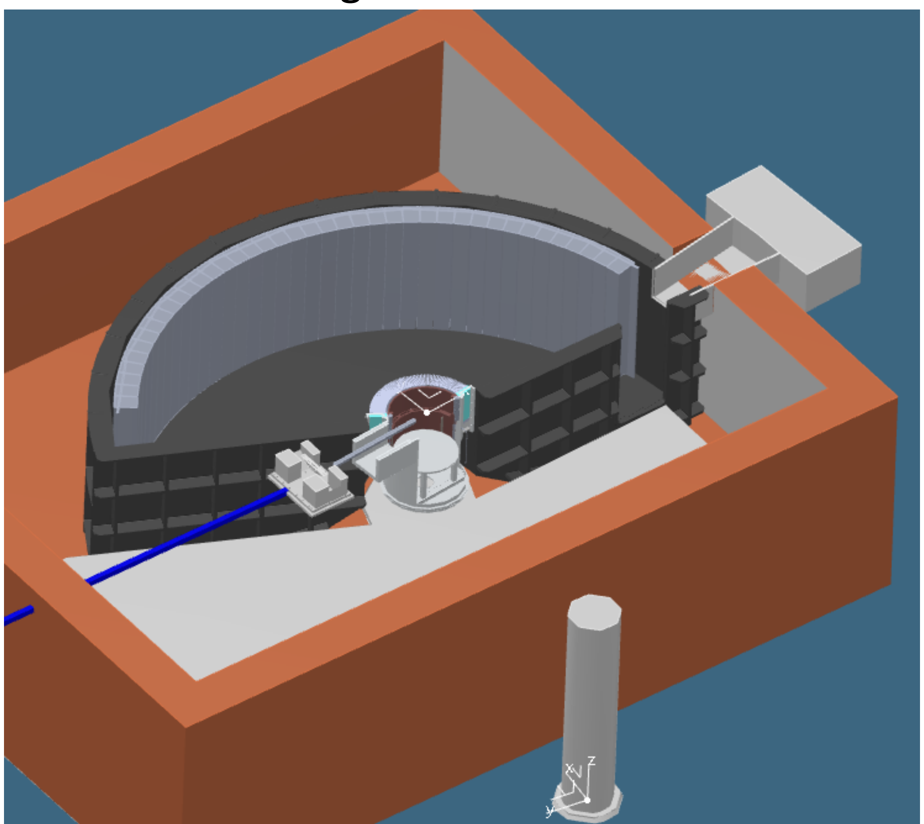
0.2 meV < E_i < 20 meV

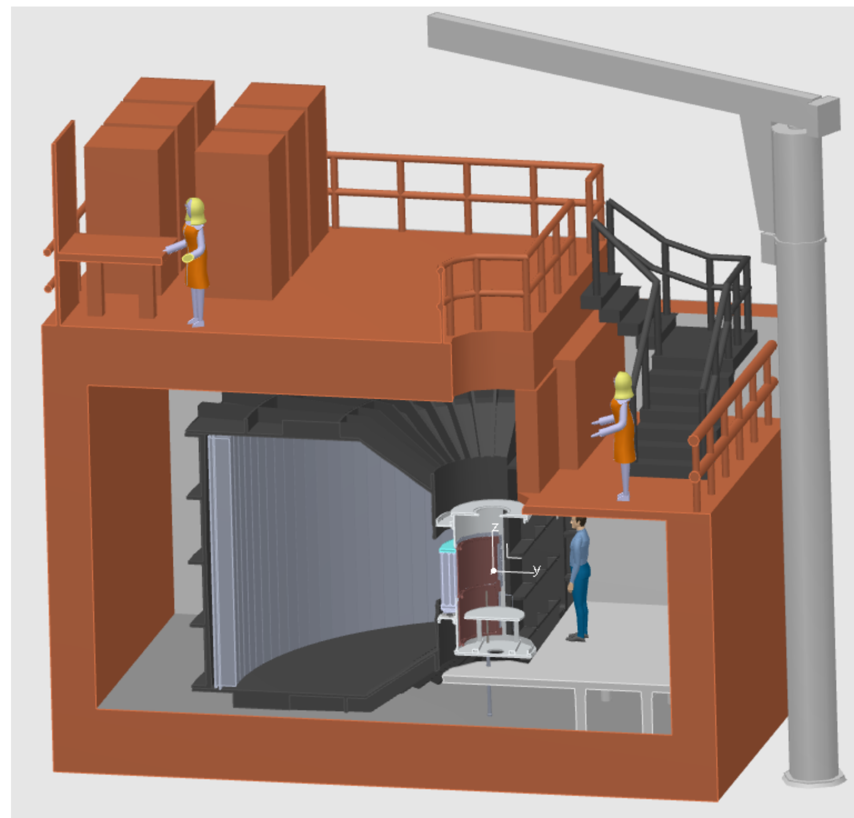
29m^2 detector

Horizontal coverage 5° to 135°

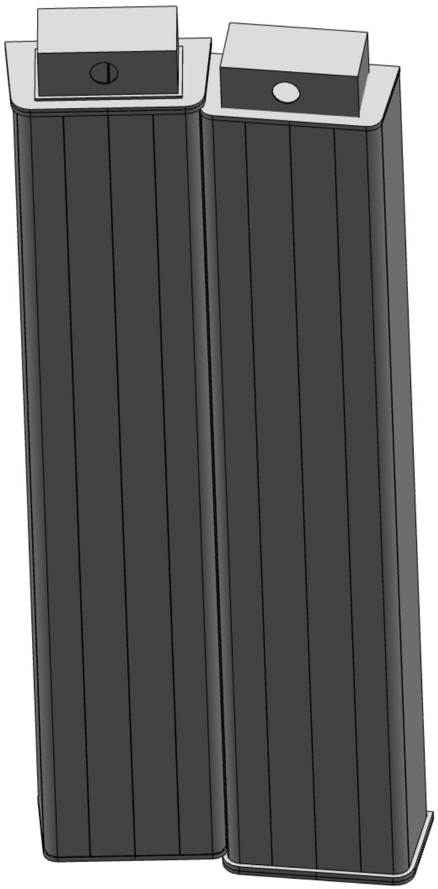
Vertical coverage -25° to 25°

TECHNISCHE UNIVERSITÄT MÜNCHEN

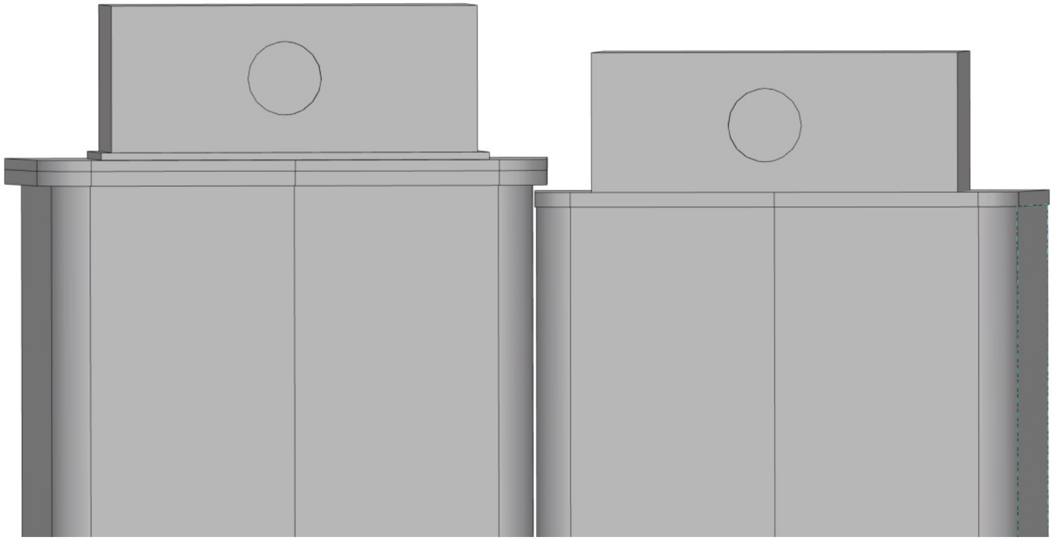




C-SPEC



- Neighbour vessels configuration, minimizing dead spaces



Conclusion

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WP 4.3: Large-Area Detectors

- Multi-Grid developed and characterized.
- **Large-Area detectors possible again**
- Operated at CNCS over 11 months.
- Multi-Grid baseline detector for

  CSPEC and T-REX at ESS
- Test at SEQUOIA proposed
- Instrument-focused design is underway

Thanks to the colleagues at SNS for this opportunity and cooperation!

PREPARED FOR SUBMISSION TO JINST

Multi-Grid Detector for Neutron Spectroscopy: Results Obtained on Time-of-Flight Spectrometer CNCS

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ABSTRACT: The Multi-Grid detector technology has evolved from the proof-of-principle and characterisation stages. Here we report on the performance of the Multi-Grid detector, the MG.CNCS prototype, which has been installed and tested at the Cold Neutron Chopper Spectrometer, CNCS at SNS. This has allowed a side-by-side comparison to the performance of He-3 detectors on an operational instrument. The demonstrator has an active area of $0.2 m^2$. It is specifically tailored to the specifications of CNCS. The detector was installed in June 2016 and has operated since

2017 JINST 12 P04030

(https://arxiv.org/abs/1703.03626)

Acknowledgements and Publications

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Centre for Energy Research (Hungary):
Eszter Dian

Linköping University:
Jens Birch, Lars Hultman, (also *)

SNS:
Ken Herwig, Georg Ehlers, Michelle Everett, Kevin Berry

Earlier – the participants of the CRISP project on Large-Area detectors.

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Horizon 2020 grant agreement 676548

WP 4.3: Large-Area Detectors

Earlier publications:

B4C layers:

*C. Höglund et al, J of Appl. Phys. 111, 104908 (2012)

Characterization:

*A. Khaplanov et al., arXiv:1209.0566 (2012)

*B Guerard et al., NIMA, 720, 116-121 (2013), http://dx.doi.org/10.1016/j.nima.2012.12.021iJ

*J. Correa et al., Trans. Nucl. Sc. (2013), DOI: 10.1109/TNS. 2012.2227798

*A. Khaplanov et al., (2014) *J. Phys.: Conf. Ser.* **528** 012040 doi:10.1088/1742-6596/528/1/012040

Gamma sensitivity:

*A. Khaplanov et al., JINST 8, P10025 (2013), arXiv:1306.6247

Alpha background:

*A. Khaplanov et al., JINST 10, P10019 (2015); doi:10.1088/1748-0221/10/10/P10019

Latest publication:

A.Khaplanov et al. *"Multi-Grid Detector for Neutron Spectroscopy: Results Obtained on Time-of-Flight Spectrometer CNCS"* https://arxiv.org/abs/1703.03626

2017 JINST 12 P04030

Extra slides

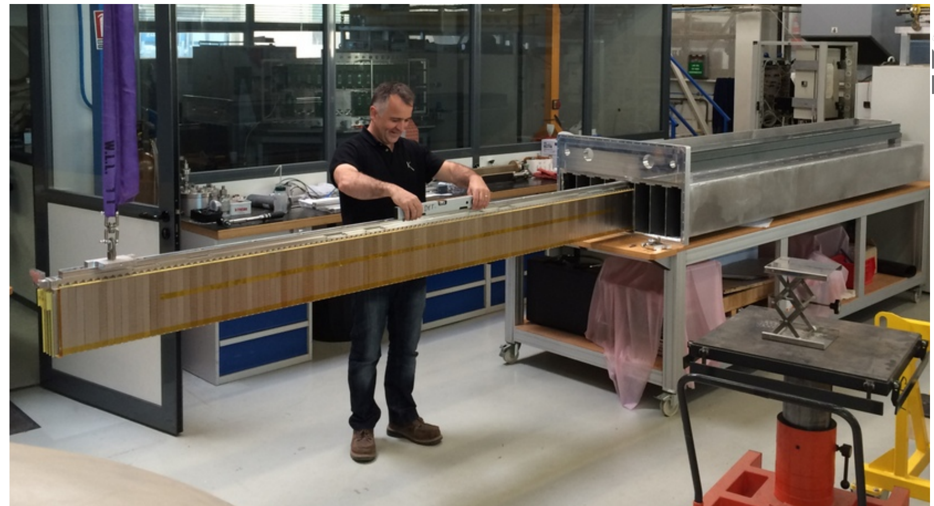
IN5 Demonstrator – Large-Scale

3 m

80cm

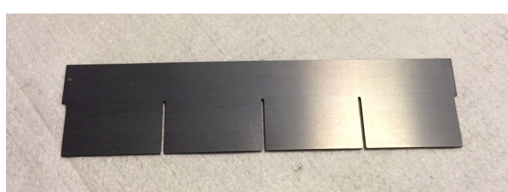
Detector:
2.4 m^2 active area

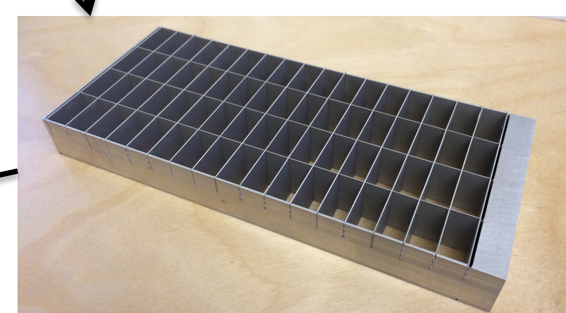
Module **x8**:
wire-frame
coincident
readout



Grid **x1024**:
low activity,
minimal dead material

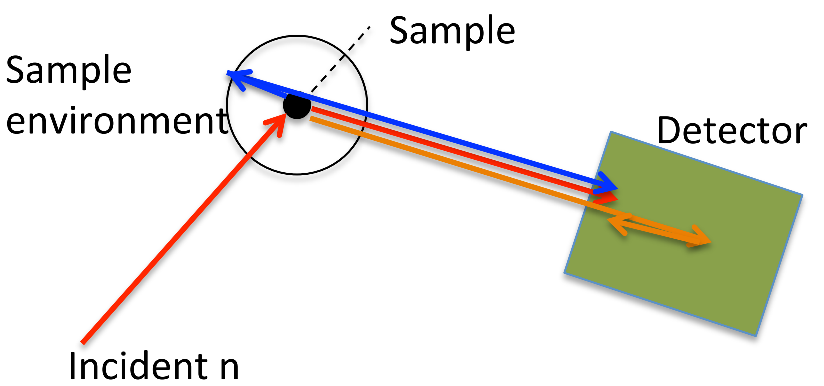
Blade **x18432**:
enriched B4C coating
good adhesion, uniformity,

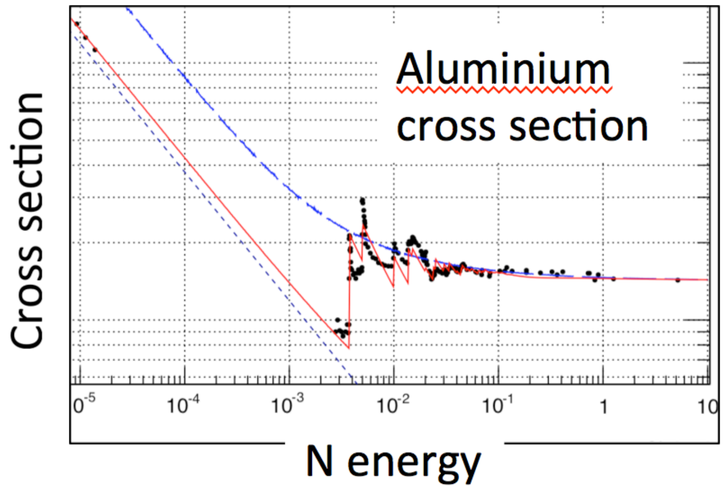


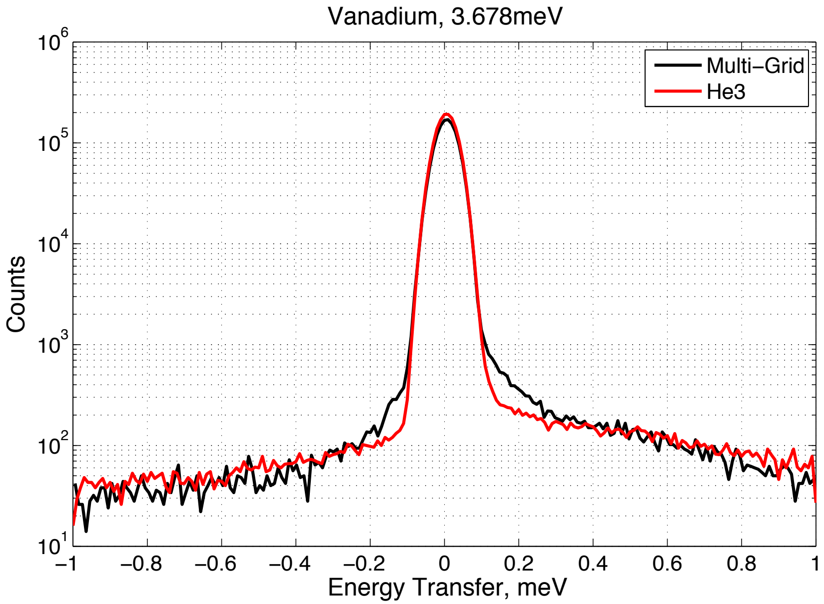


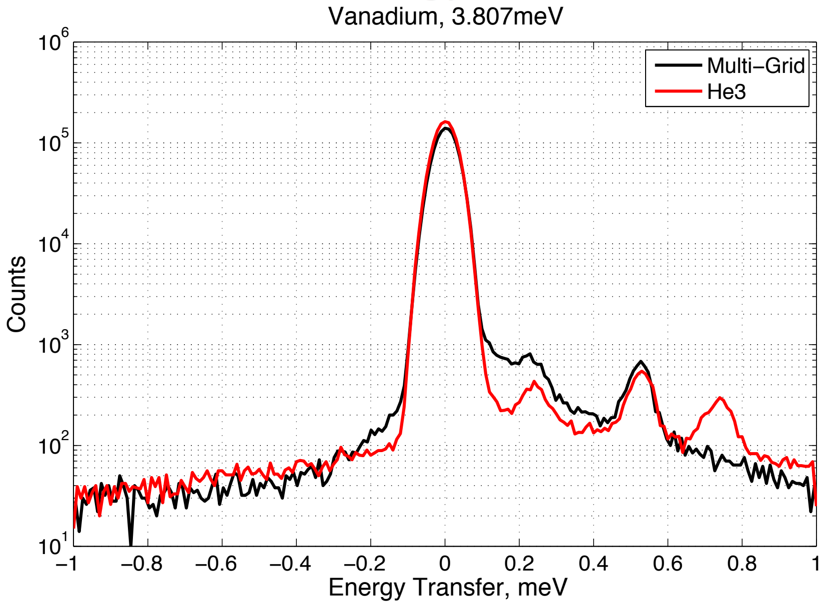
Aluminium Bragg Edge

Scattering effects from SE and detector

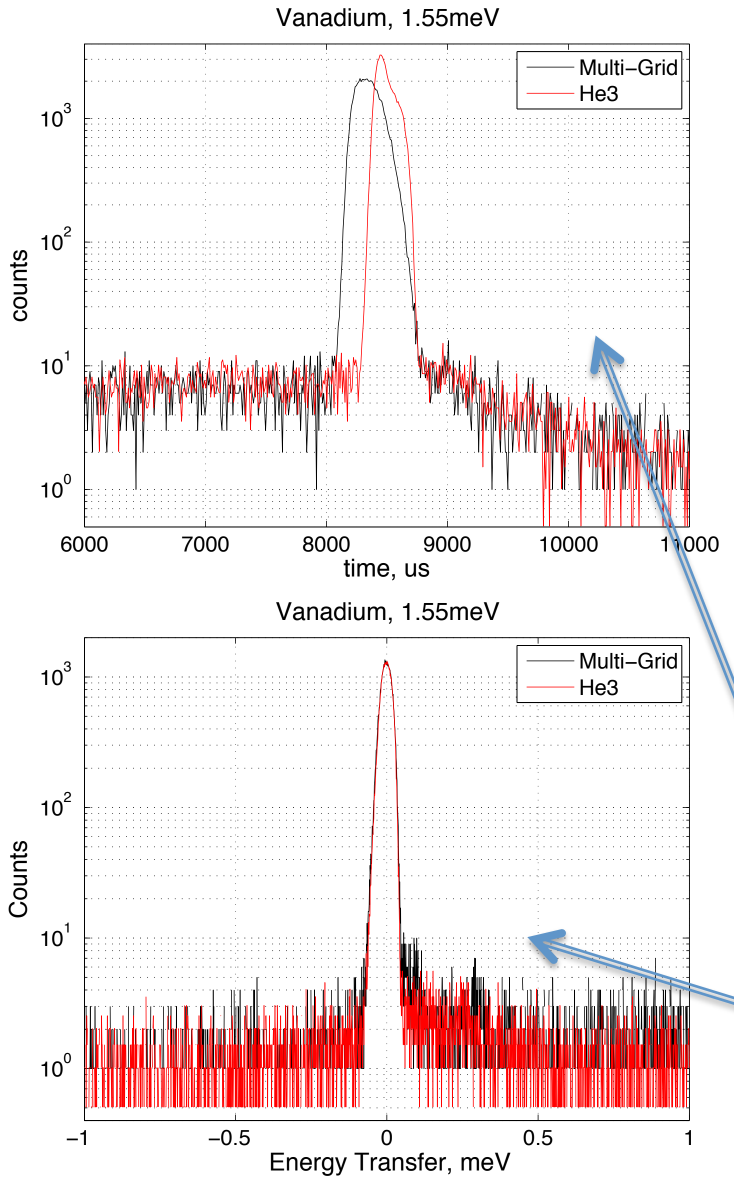




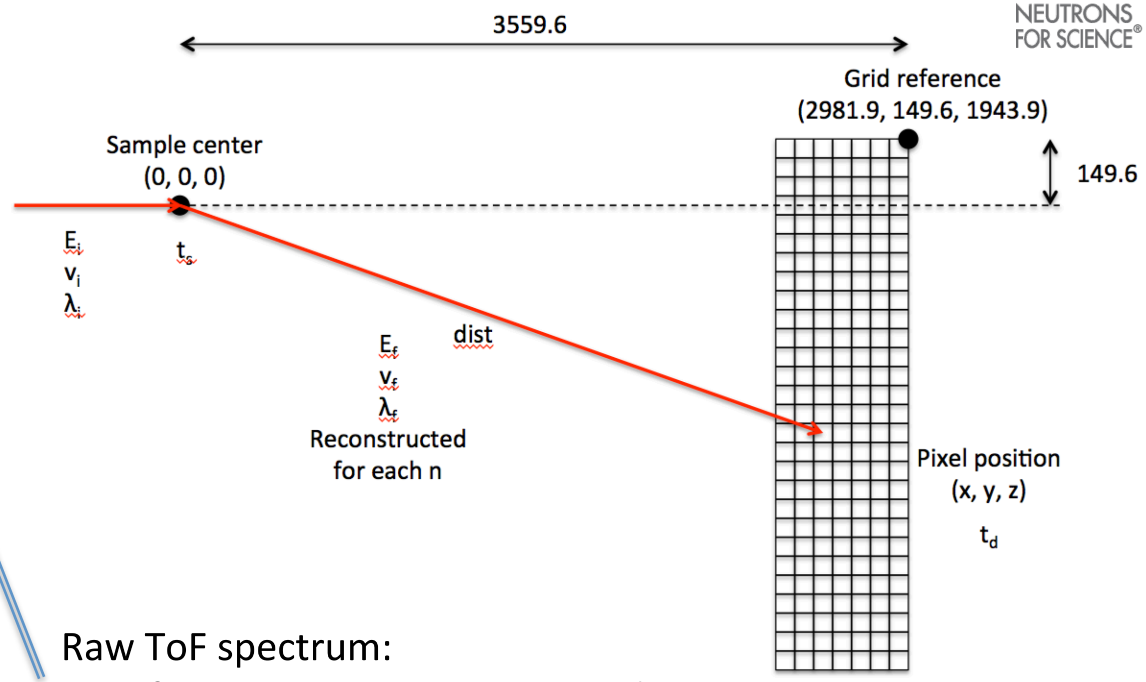




Energy Reconstruction



Energy transfer: E_f-E_i



Raw ToF spectrum:
no information on geometry used

dE spectrum: Including information on position of each detected neutron.

Single Crystal Reflection

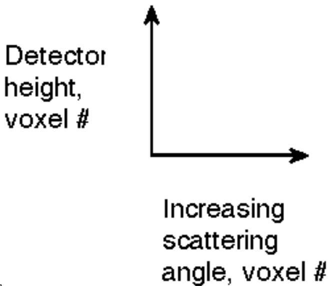
Image recorded in each detector as a function of time during elastic peak

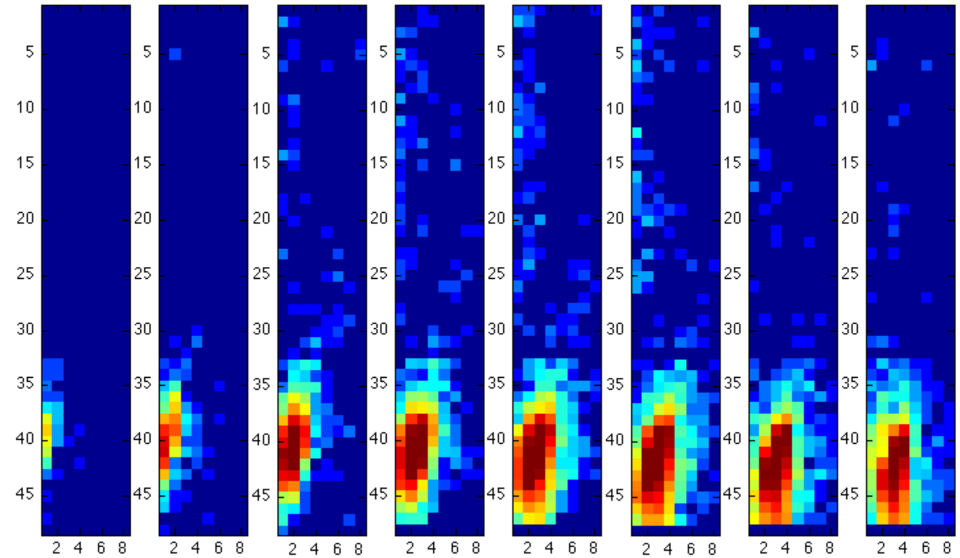
Each frame advances 30 µs

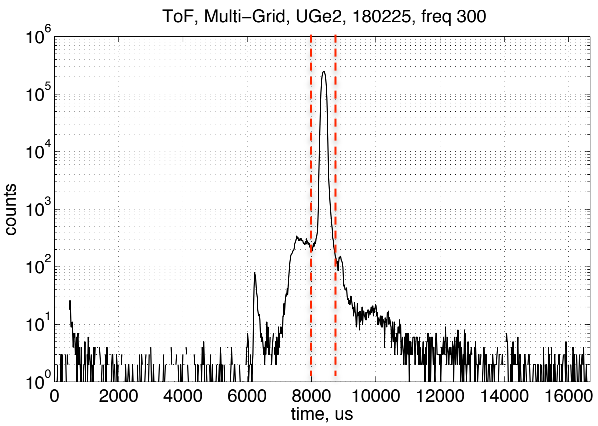
Multi-Grid image

View from sample

Multi-Grid



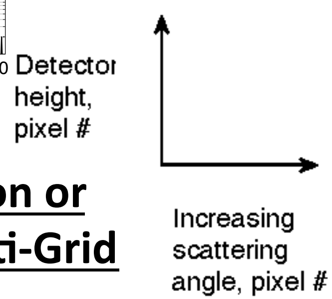


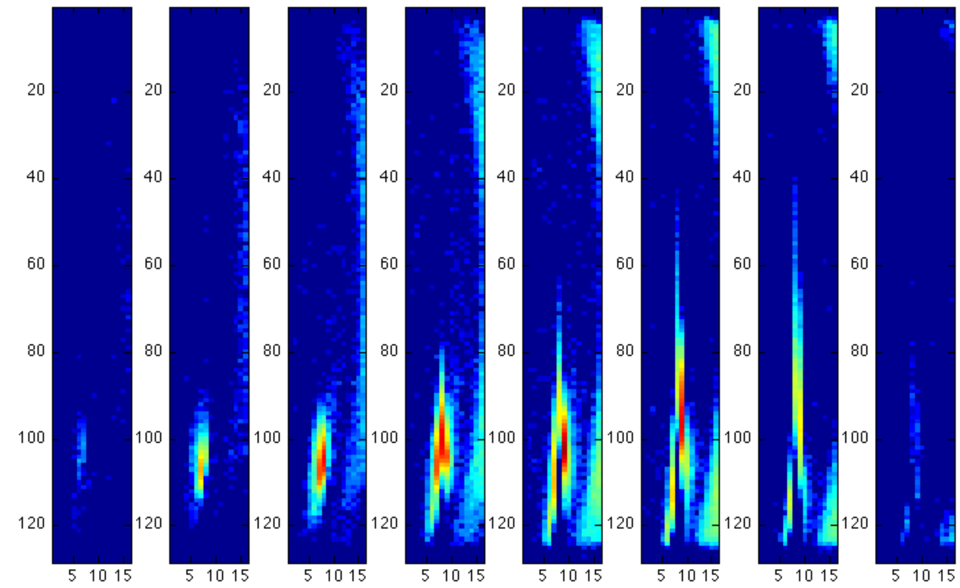


He3 bank #49 and #50

View from sample

He3





No loss of position resolution or saturation observed in Multi-Grid