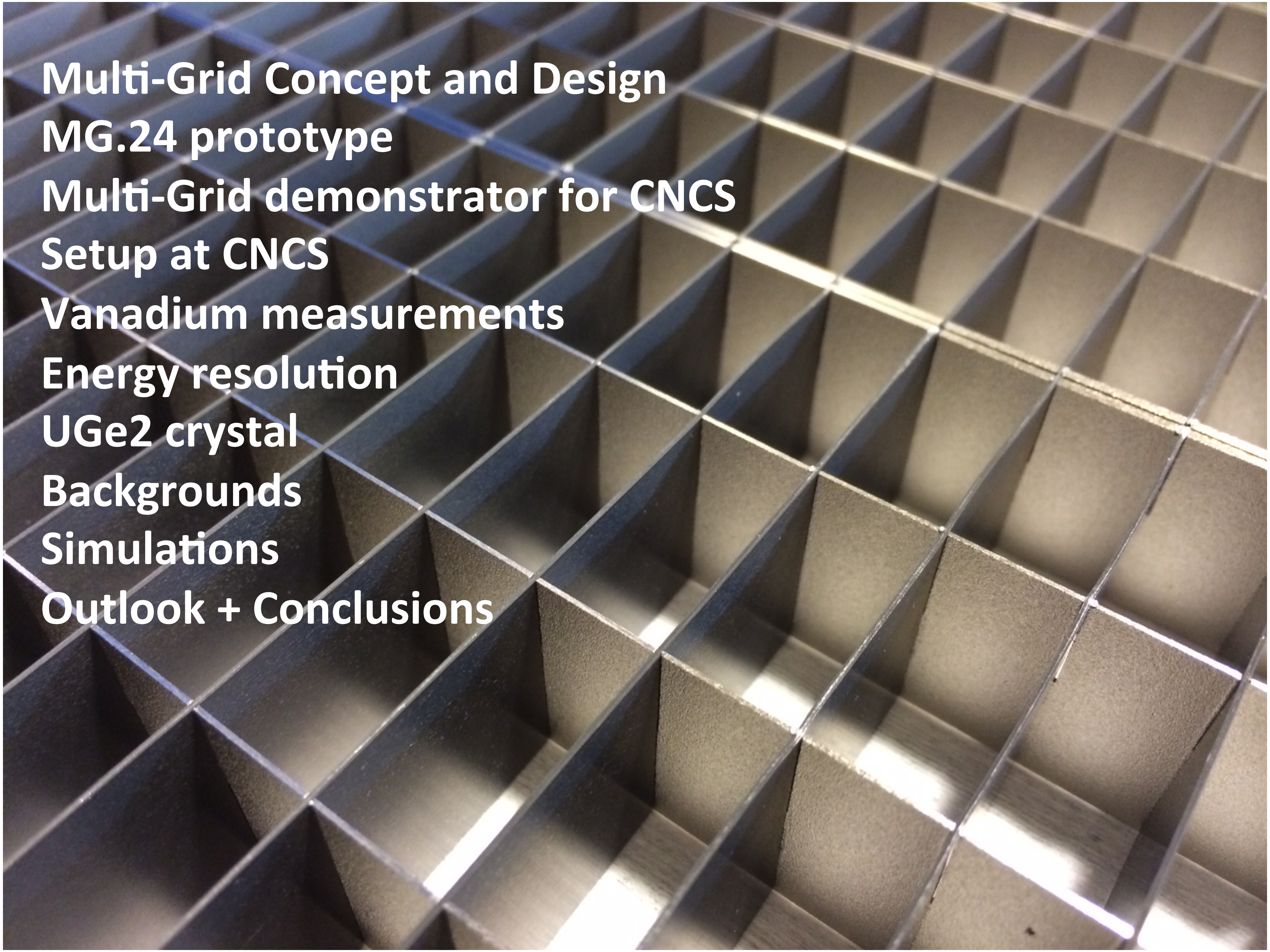
Multi-Grid Detector Test at CNCS

Anton Khaplanov
ESS Detector Group

www.europeanspallationsource.se
September 12, 2016


Multi-Grid Concept and Design
MG.24 prototype
Multi-Grid demonstrator for CNCS
Setup at CNCS
Vanadium measurements
Energy resolution
UGe2 crystal
Backgrounds
Simulations
Outlook + Conclusions

Introduction

EUROPEAN SPALLATION SOURCE

ILL:
Bruno Guerard, Jean-Claude Buffet,
Jean-Francois Clergeau, Anthony Leandri

ESS:
Anton Khaplanov, Fatima Issa, Richard Hall-Wilton, Oliver Kirstein, Tomasz Brys, Michail Anastasopoulos, Isaak Lopez Higuera, Richard Bebb, Sara Arranz, Carina Höglund*, Linda Robinson*, Susan Schmidt*

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.

brightness

WP 4.3: Large-Area Detectors

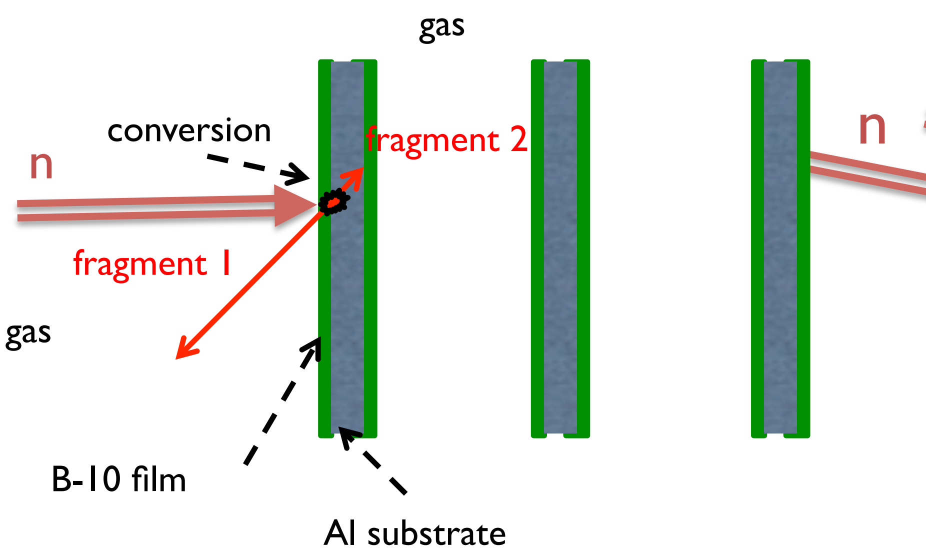
Previous publications:

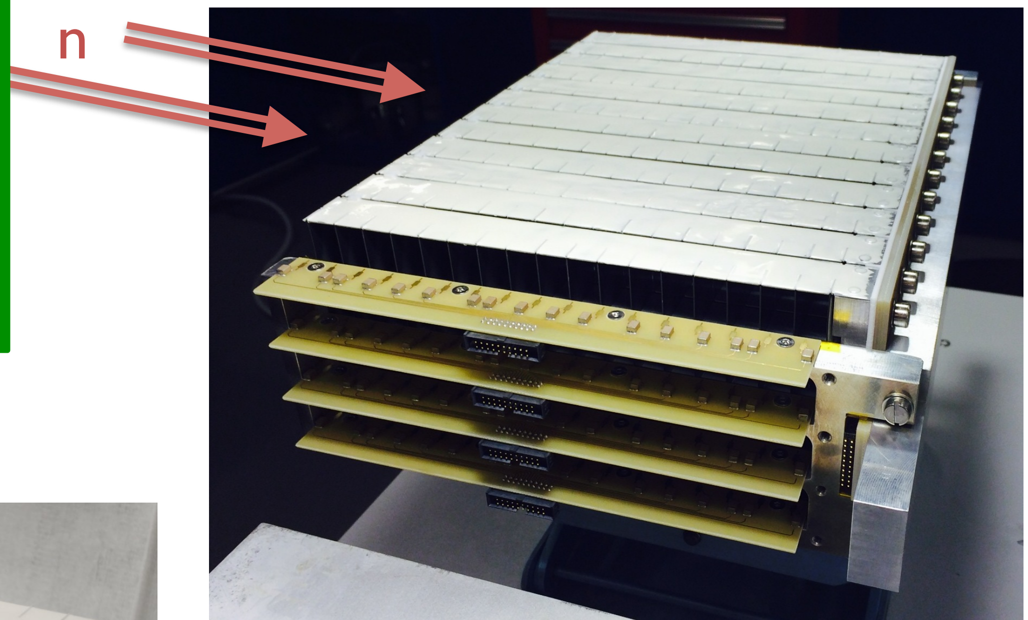
B4C layers:
*C. Höglund et al, J of Appl. Phys. 111, 104908 (2012)
Characterization:
*A. Khaplanov et al., arXiv:1209.0566 (2012)
*B Guerard et al., NIMA, 720, 116-121 (2013), http://dx.doi.org/10.1016/j.nima.2012.12.021iJ
*J. Correa et al., Trans. Nucl. Sc. (2013), DOI: 10.1109/TNS.2012.2227798
*A. 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

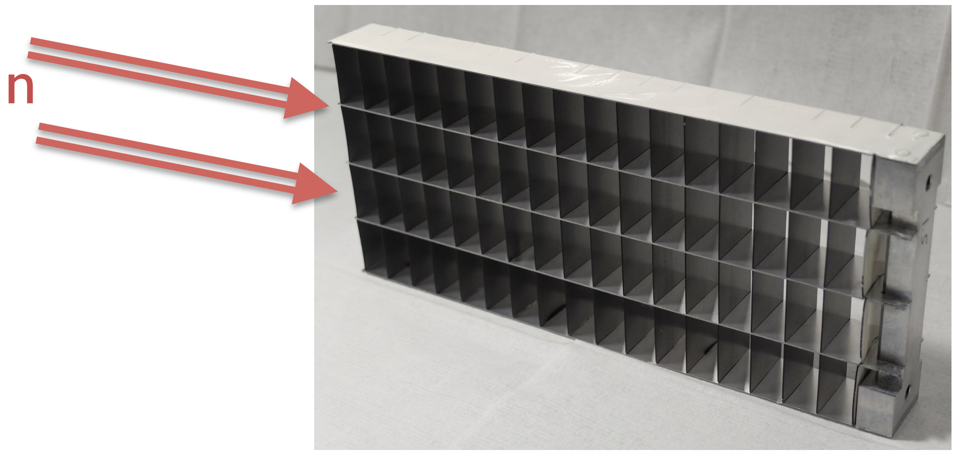
Introduction

- A kind offer by K. Herwig to test MG at SNS
- Recommendation of 2015 annual review
- Multi-Grid detector has been installed at CNCS, SNS in June 2016
- First beam data was taken July 11-14
- Since July 14 it has operated continuously
- No access to detector possible until next major beam outage in about 6 months
- All results shown here are **preliminary and subject to change**.
- The analysis is ongoing and is expected to be complete end of 2016

Introduction







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

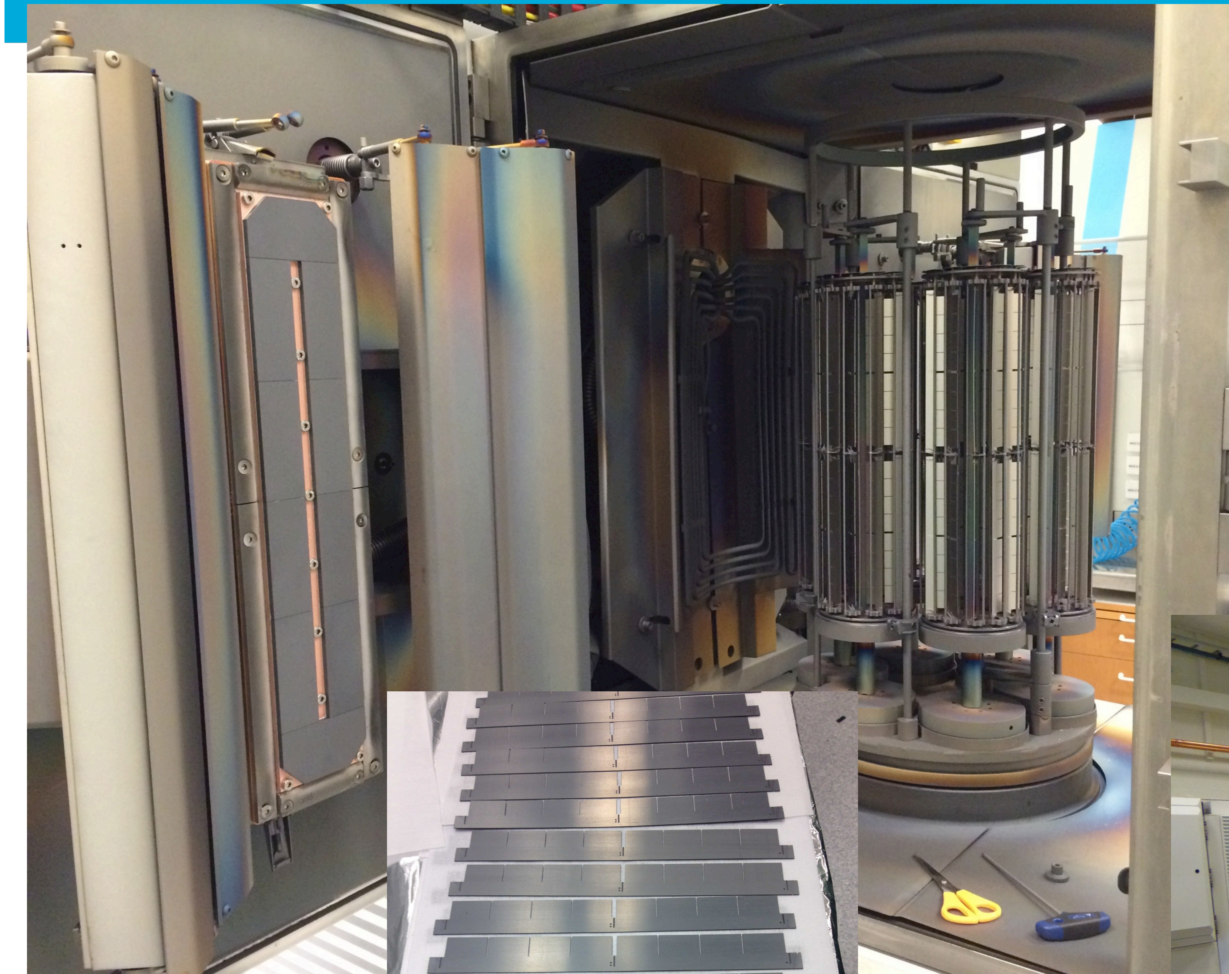
$^{10}B_4C$ Layers

EUROPEAN SPALLATION SOURCE

brightness

NEUTRONS FOR SCIENCE

LINKÖPINGS UNIVERSITET



Earlier Prototypes

EUROPEAN SPALLATION SOURCE

brightness

NEUTRONS FOR SCIENCE®

CRISP

Proto1 – 6 / 12 grids – Dec 2010

IN6 demo – 96 grids – Oct 2012

Proto2 – 96 grids – Jul 2011

Multi-Grid Detector – IN5 Demonstrator

CRISP

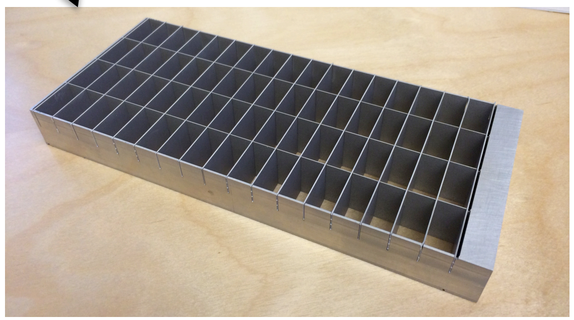
NEUTRONS FOR SCIENCE

EUROPEAN SPALLATION SOURCE

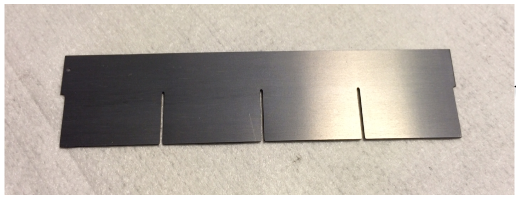
brightness

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

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



Blade **x18432**:
enriched B_4C coating
good adhesion, uniformity,



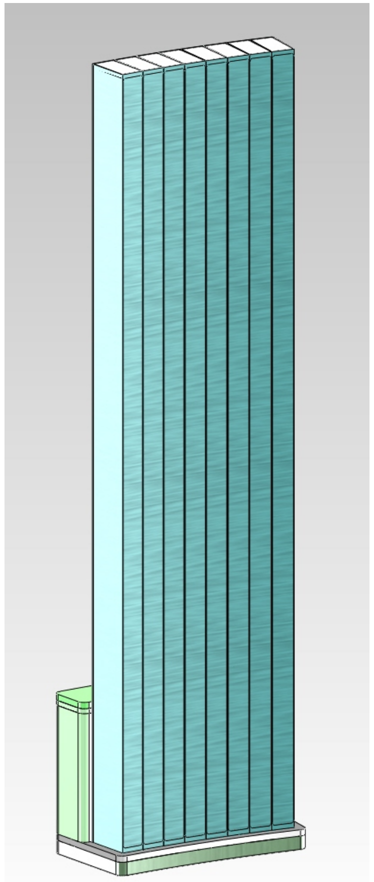
Detector:
2.4 m^2
active area

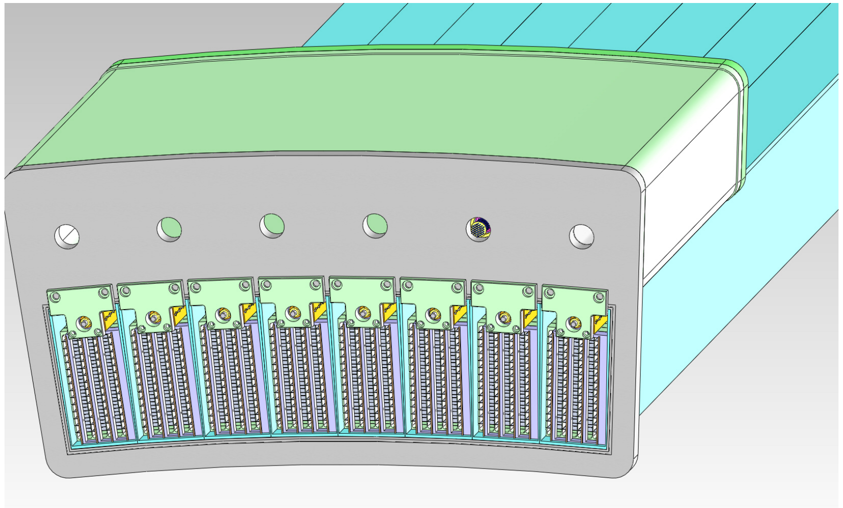
Multi-Grid – Instrument Concept

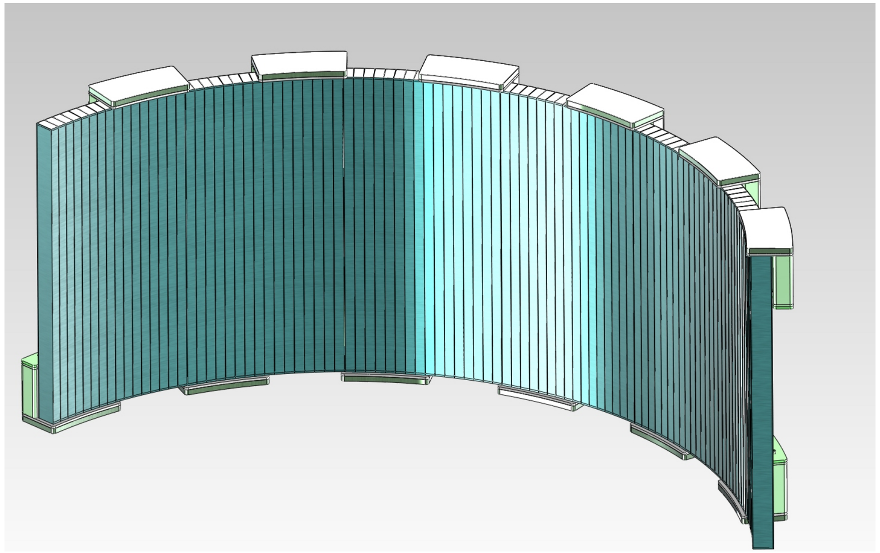
EUROPEAN SPALLATION SOURCE

brightness

NEUTRONS FOR SCIENCE®







Direct Spectrometers for the ESS

Instrument (type)	C-SPEC (cold)	T-REX (thermal (bispectral))	VOR (bispectral)
Source – sample, m	155.4	166.3	30.2
Sample – detector, m	4	3	3
Detector coverage, deg	-30 to 140 +-26	-30 to 150 -15 to +25	-40 to +140 +-26
Detector area, m2	50 or 35	21	37
λ range, Å	1.5-20	0.7-20	1-20
Typical initial λ, Å (meV)	2 to 15 Å (20 to 0.36 meV)	0.7 to 6.4 Å (160 to 2 meV)	1 to 9Å (80 to 1 meV)
Max energy transfer, meV	~80% E_i_max	~80% E_i_max Up to 140 meV	~80% E_i_max

Baseline Detector Parameters

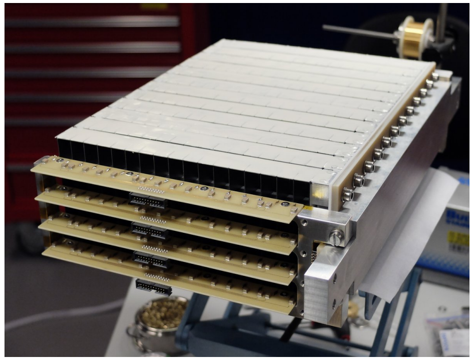
Instrument	Detector area (% of 4π)	Multi-Grid configuration	# grid channels	# wire channels
C-SPEC Cold	$50m^2$ or $35m^2$; (25% or 17%)	16 cells 120 or 80 columns; 160 grids high;	19200 or 12800	7680 or 5120
T-REX Bispectral	$21m^2$ (18%)	20 cells 96 columns; 96 grids high;	9216	7680
VOR Bispectral	$37m^2$ (20%)	16 cells 96 columns; 160 grids high;	15360	6144

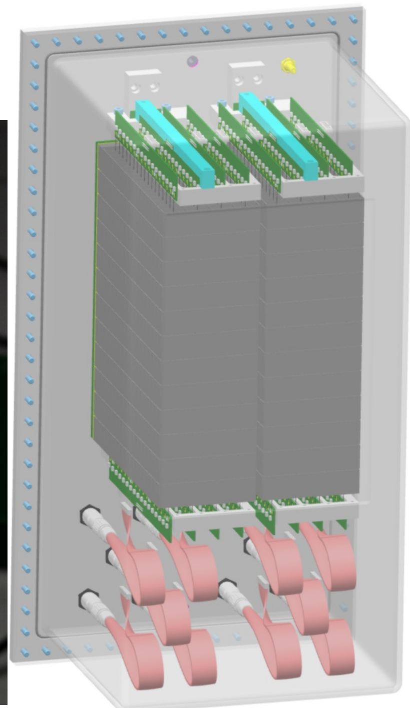
Multi-Grid Design and testing at ESS

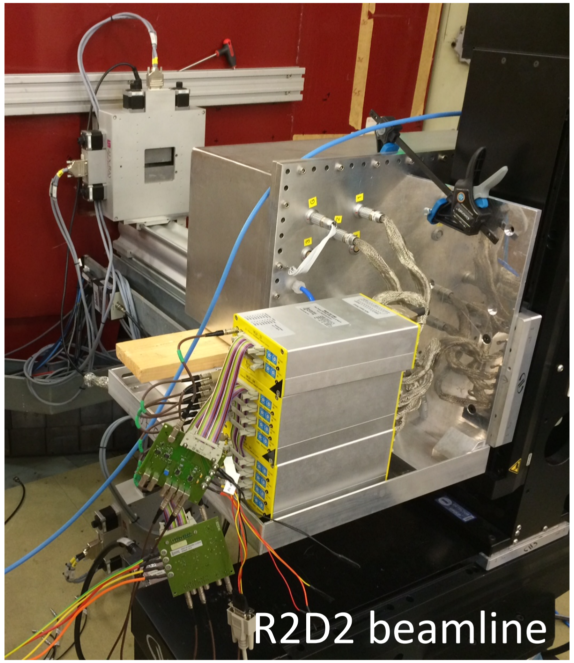
MG.24

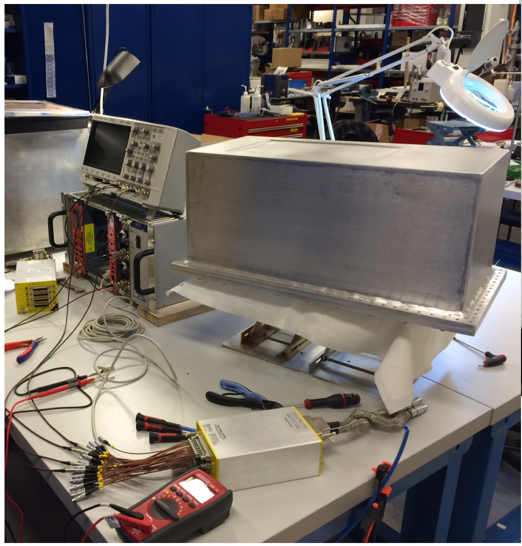
- 24-grid test detector
- 2 modules of 12 grids
- 32 layers
- Individual channel readout
- Flow-through

Used at ESS Lund (source, background, readout); IFE, Norway (beam).









Multi-Grid test at CNCS

MG.CNCS

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

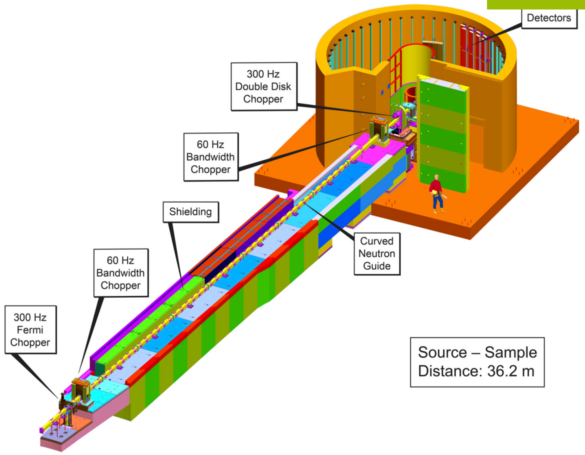
Goals:

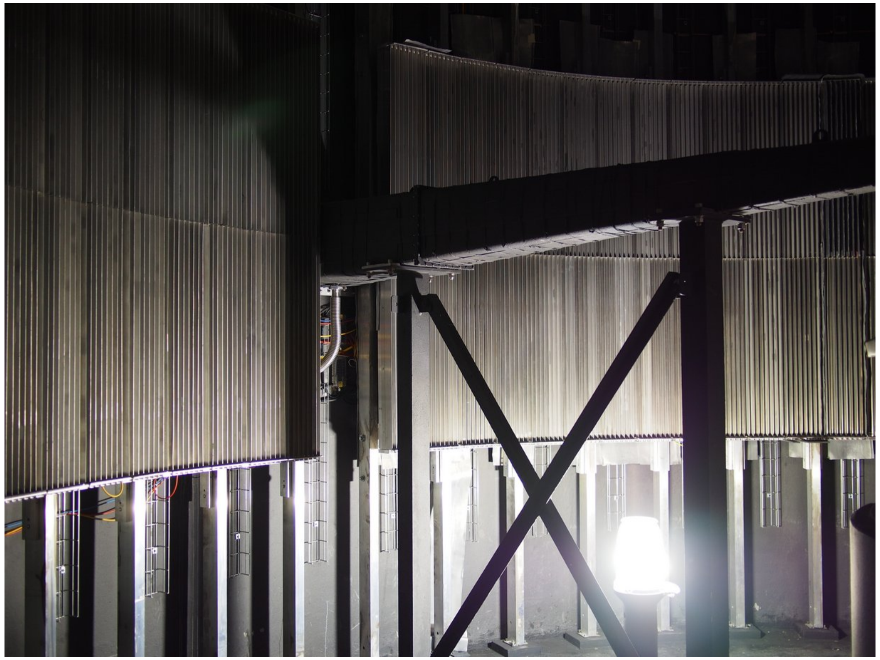
- Test at spectrometer
- Operation for 6+ months
- Side-by-side comparison to He3
- User experiments

Solution:

- Size = half of “8-pack” module – 1.1m x 19cm
- Installation June-July 2016
- 96 grids
- 2 modules of 48 grids
- 32 layers
- Adapted layer thickness
- Gas flow-through

Currently running as experiment 17219



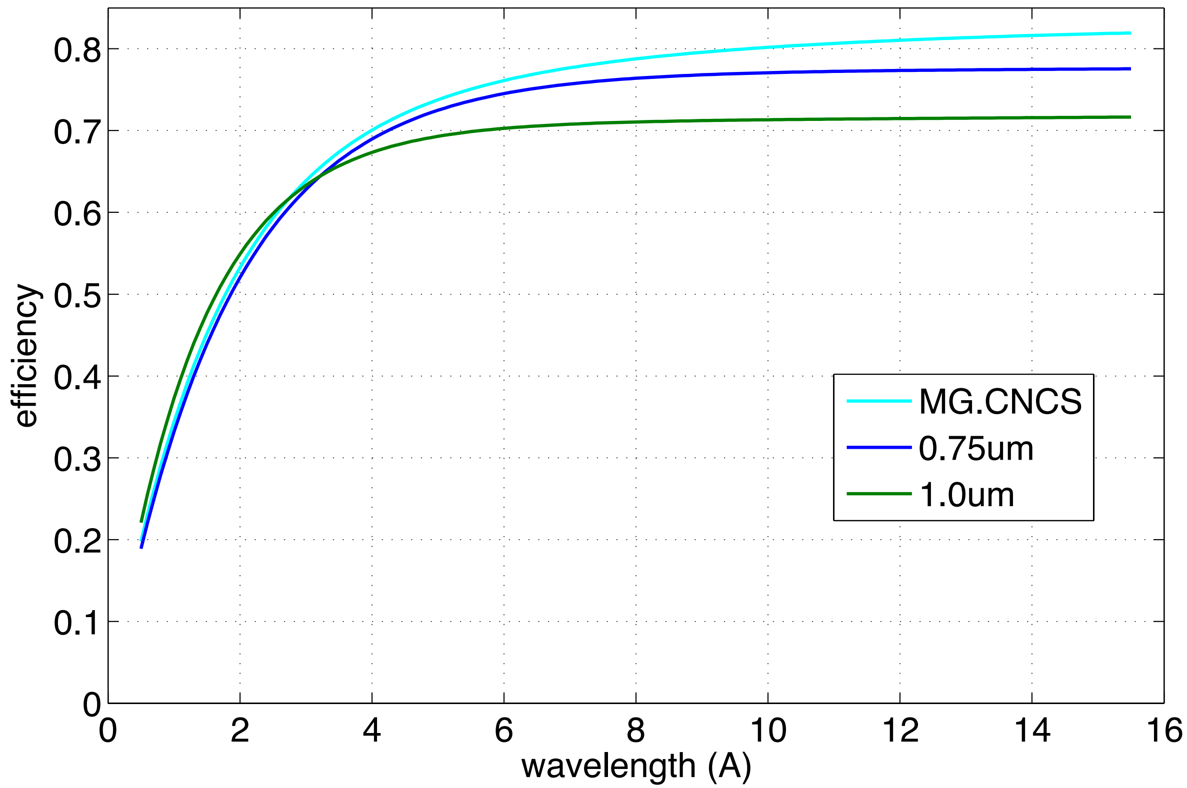


Multi-Grid test at CNCS

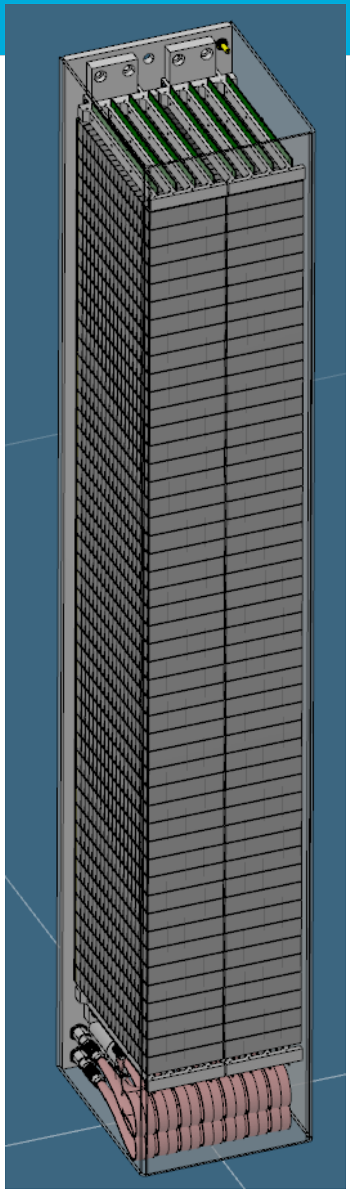
Efficiency optimized depending on the wavelength range

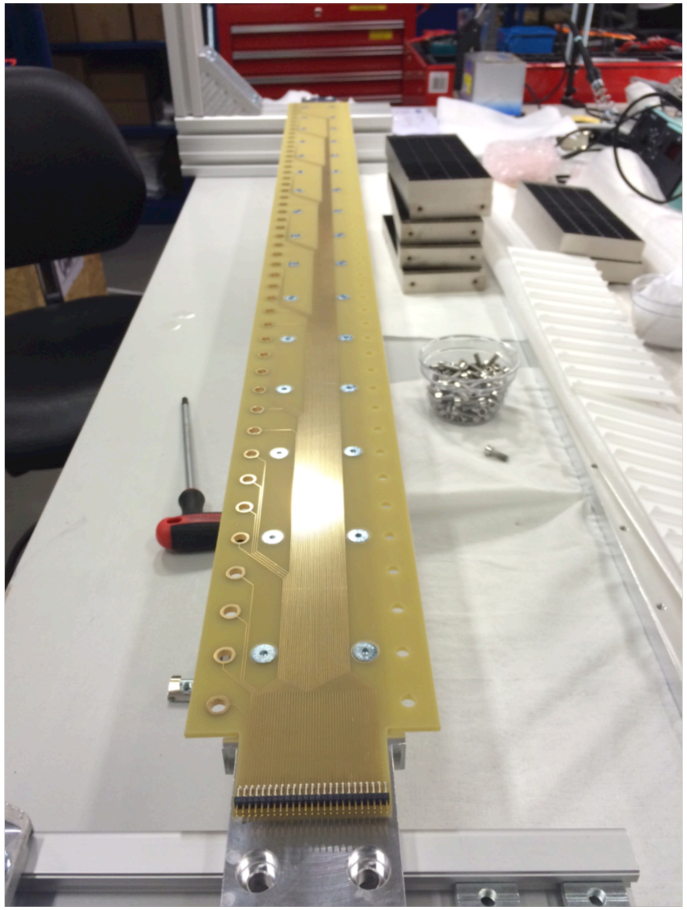
Efficiency for CNCS:
Using 32 layers (16 cells) and **optimized for 4Å**

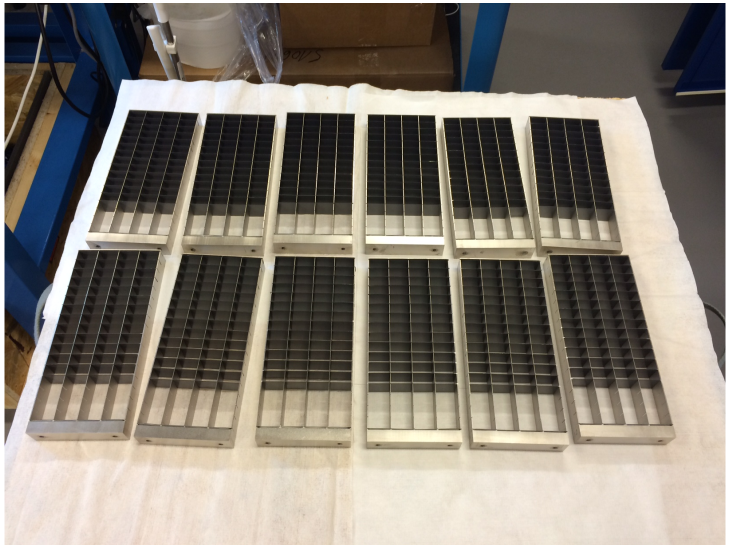
Constant layer thickness: 0.75um optimal.
~2% improvement using varied thickness:
7blades 0.5um,
7blades 1.0um,
3 blades 1.5um



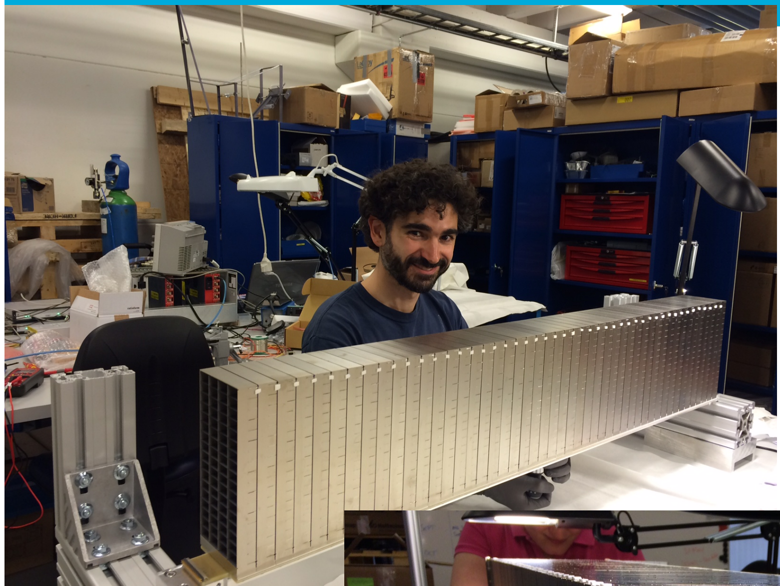
Construction of MG.CNCS in Lund

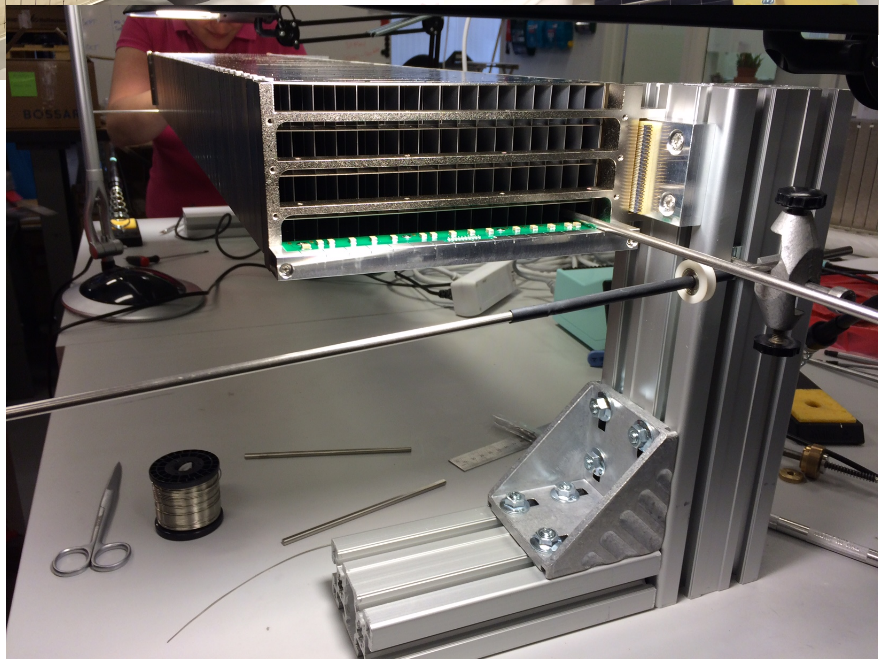




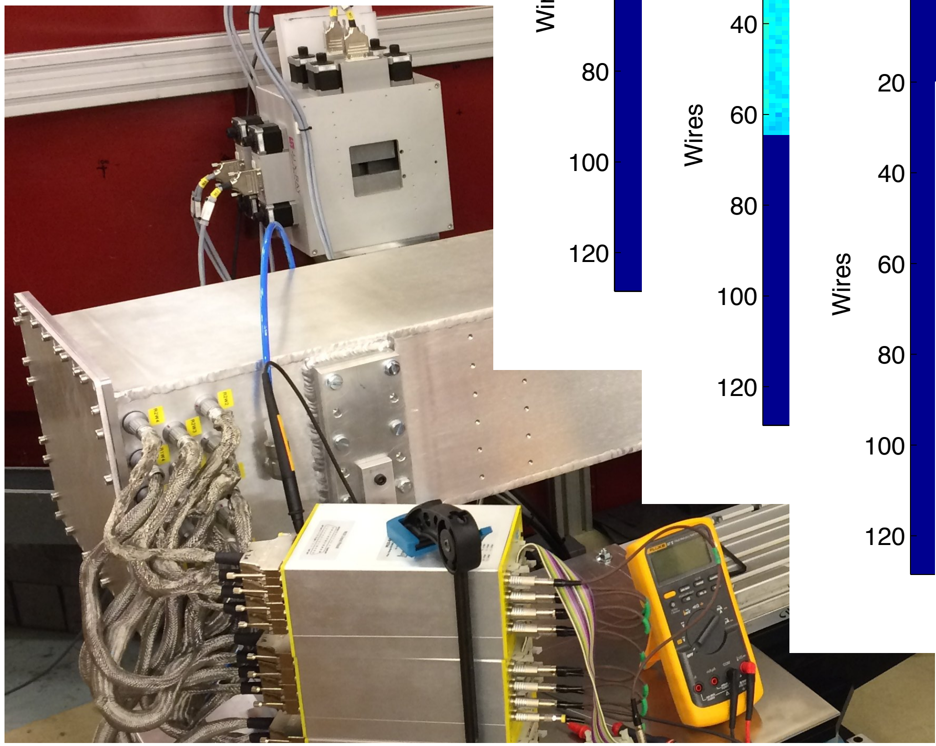


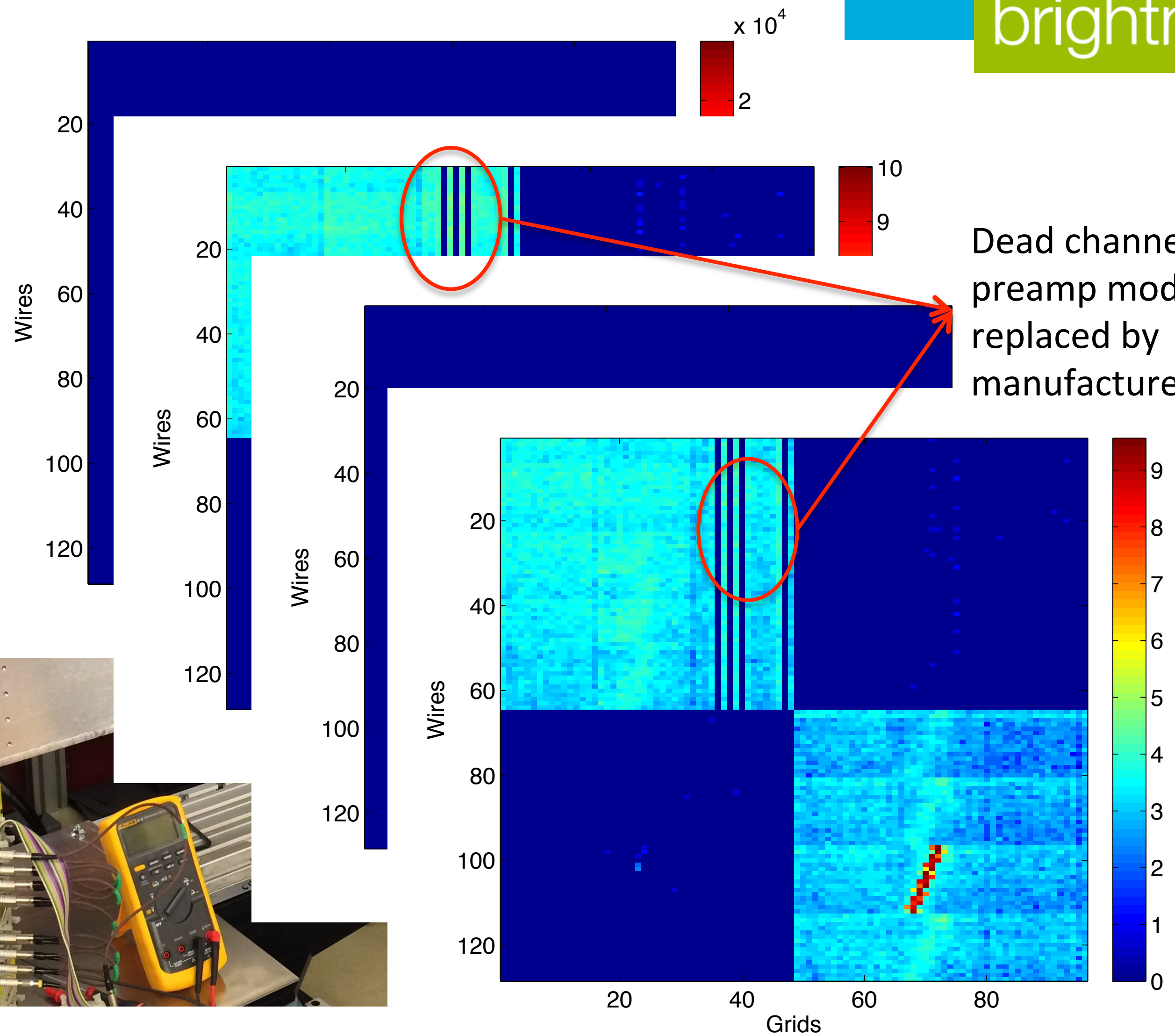
Construction of MG.CNCS in Lund





Testing in beam, IFE, Norway

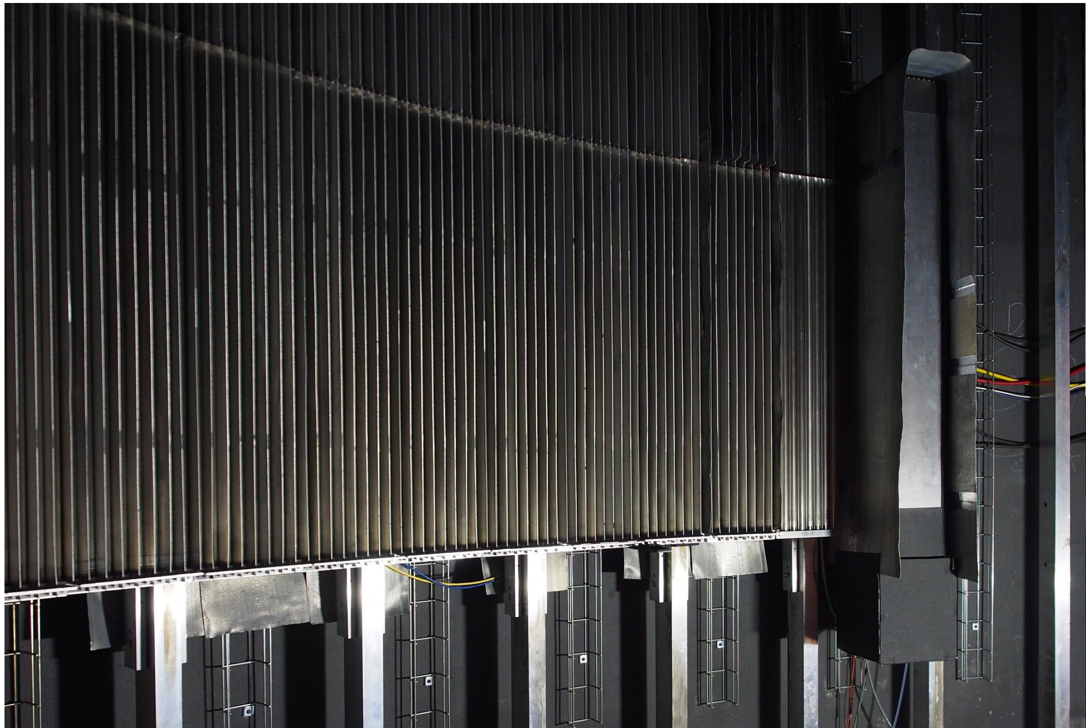




Dead channels in 1 preamp module – replaced by manufacturer

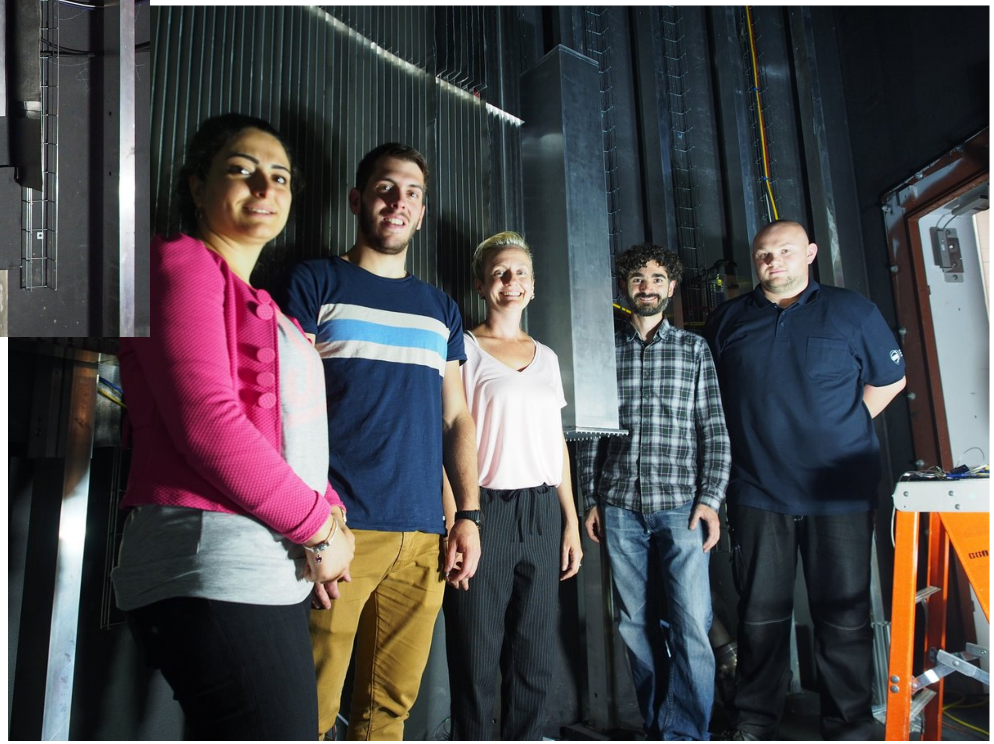
Initial test at R2D2 at IFE. Thanks to I. Llamas, M. Riktor, T. Haraldsen

Multi-Grid test at CNCS



Detector shielded with
boron and cadmium

Installation completed!
Detector inaccessible
for next 6 months



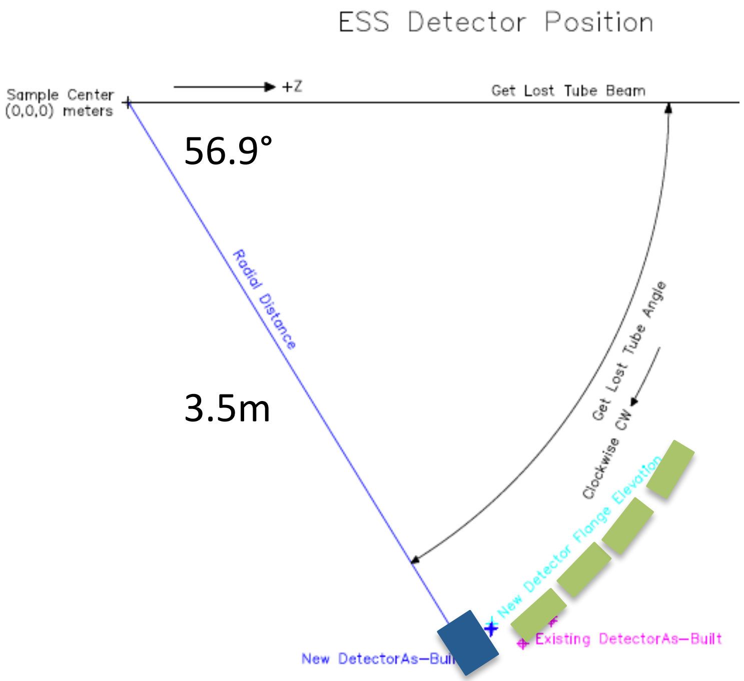
Detector Position

EUROPEAN SPALLATION SOURCE

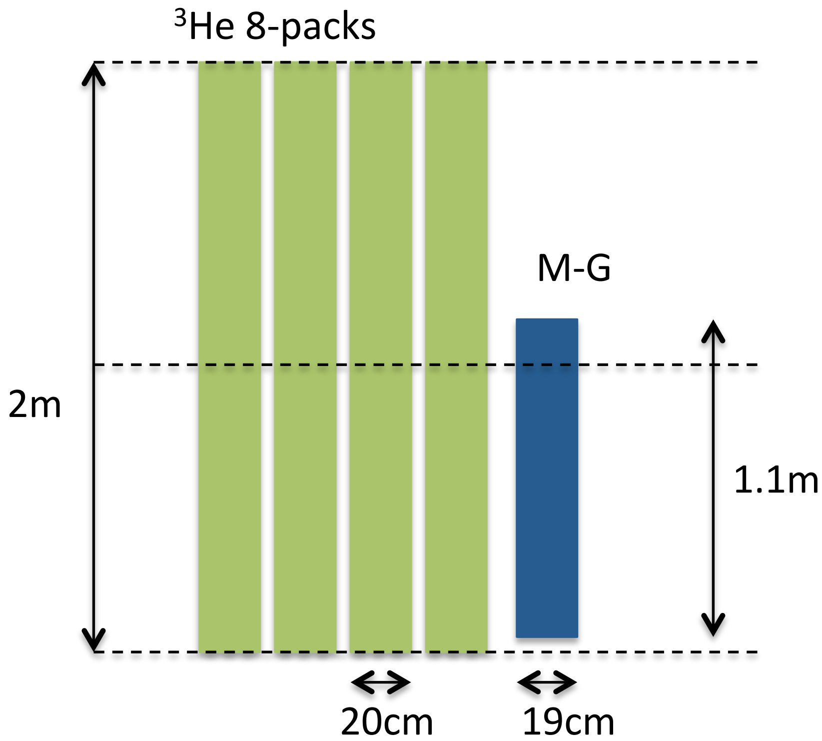
brightness

NEUTRONS FOR SCIENCE®

View from above



View from sample



Front-end Electronics

128 anode channels
96 grid channels

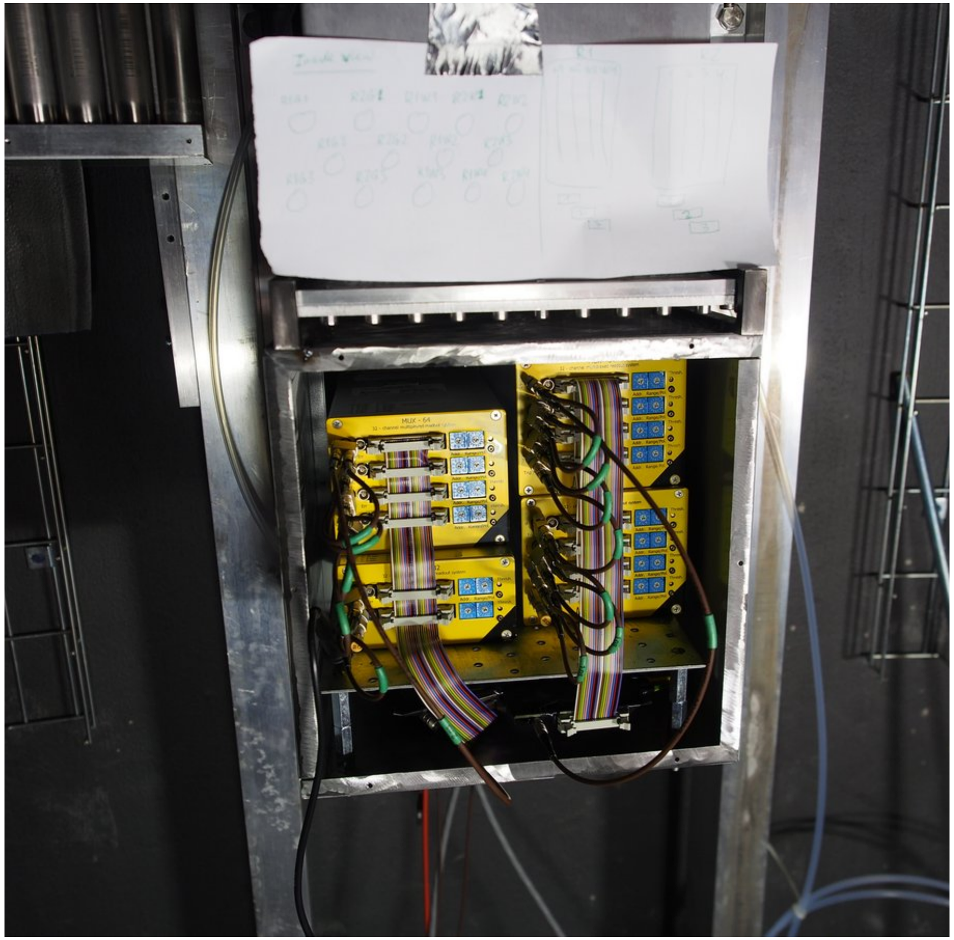
Off-the-shelf elecronics
Mesytec MUX-16 multiplexing boards

8 boards for anodes
6 boards for cathodes

Output:
Channel amplitude, channel ID
Multiplicity 2

Total 8 channels to be digitized
Gate signal from grids and wires

12-m cables to Back-end electronics



Data Acquisition

2 systems:

MCA4 – Fast ComTec

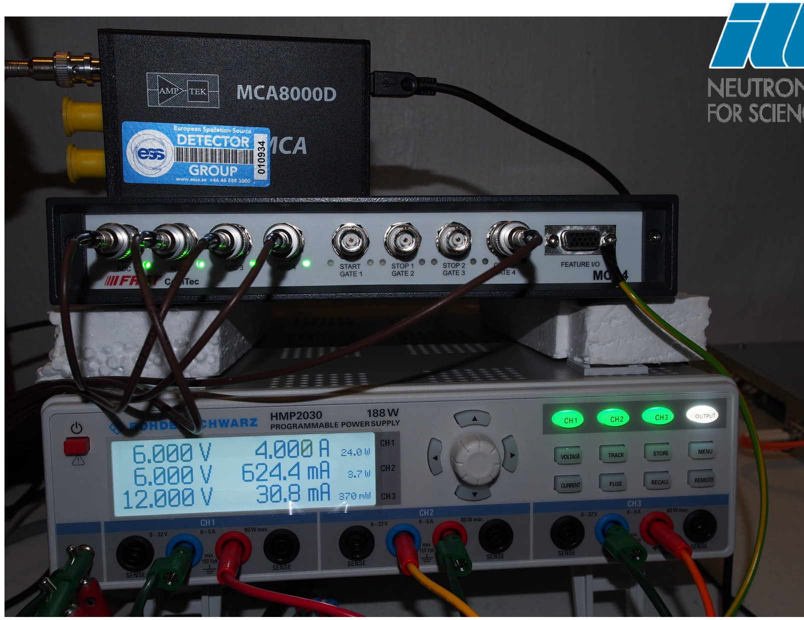
- 4 channels,
- asynchronous acquisition,
- 8 ns timestamp
- 14 bit resolution

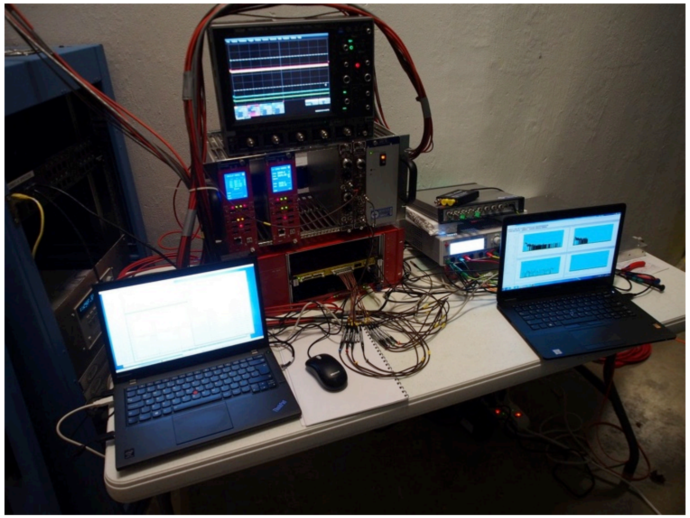
MADC-32 – Mesytec

- 32 channels,
- synchronous acquisition,
- 62 ns timestamp,
- 13 bit resolution

Acquisition on 2 computers

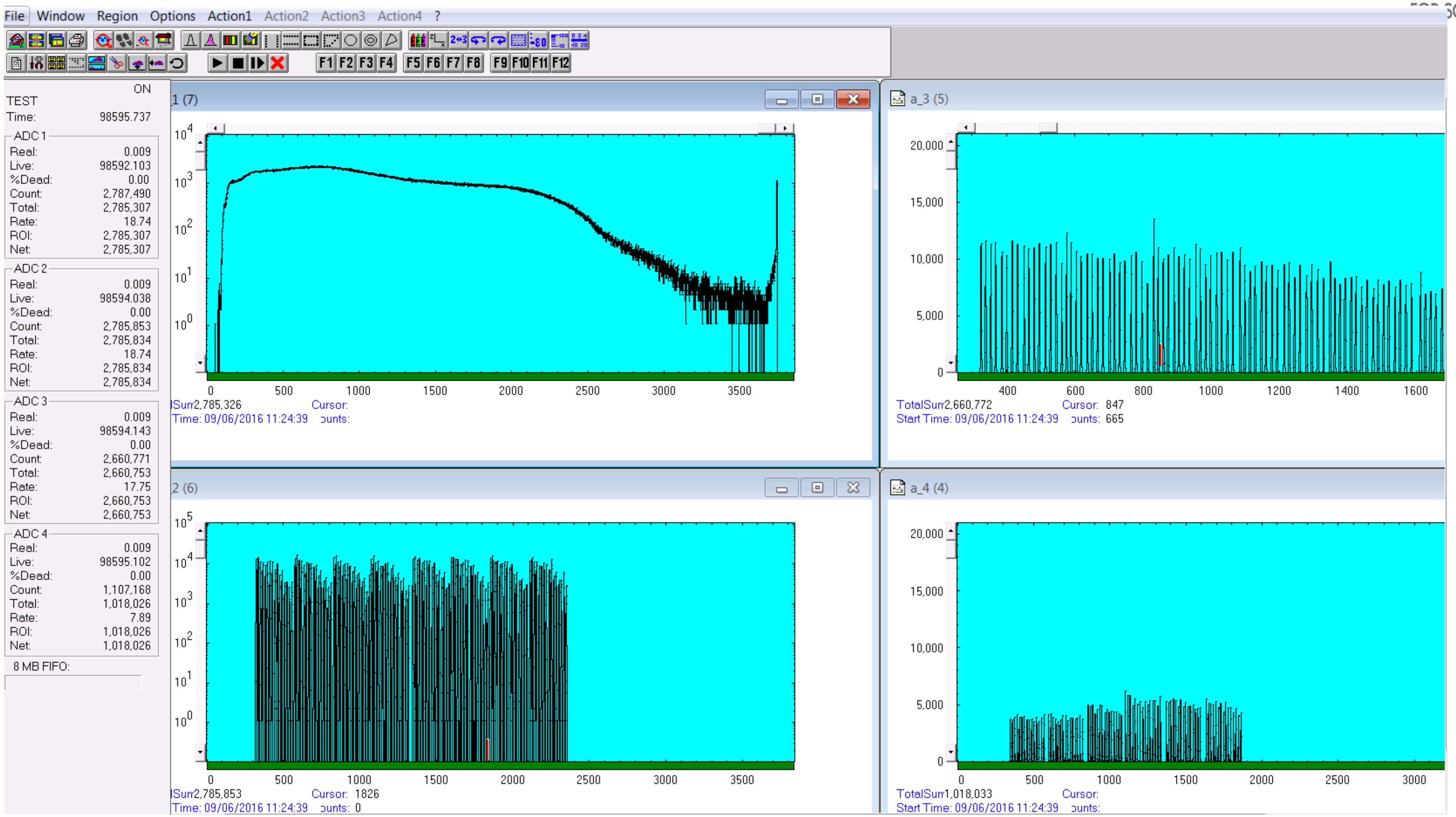
Data accessible continuously





Raw Data Monitoring

Pulse height spectra and channel counts monitored on-line

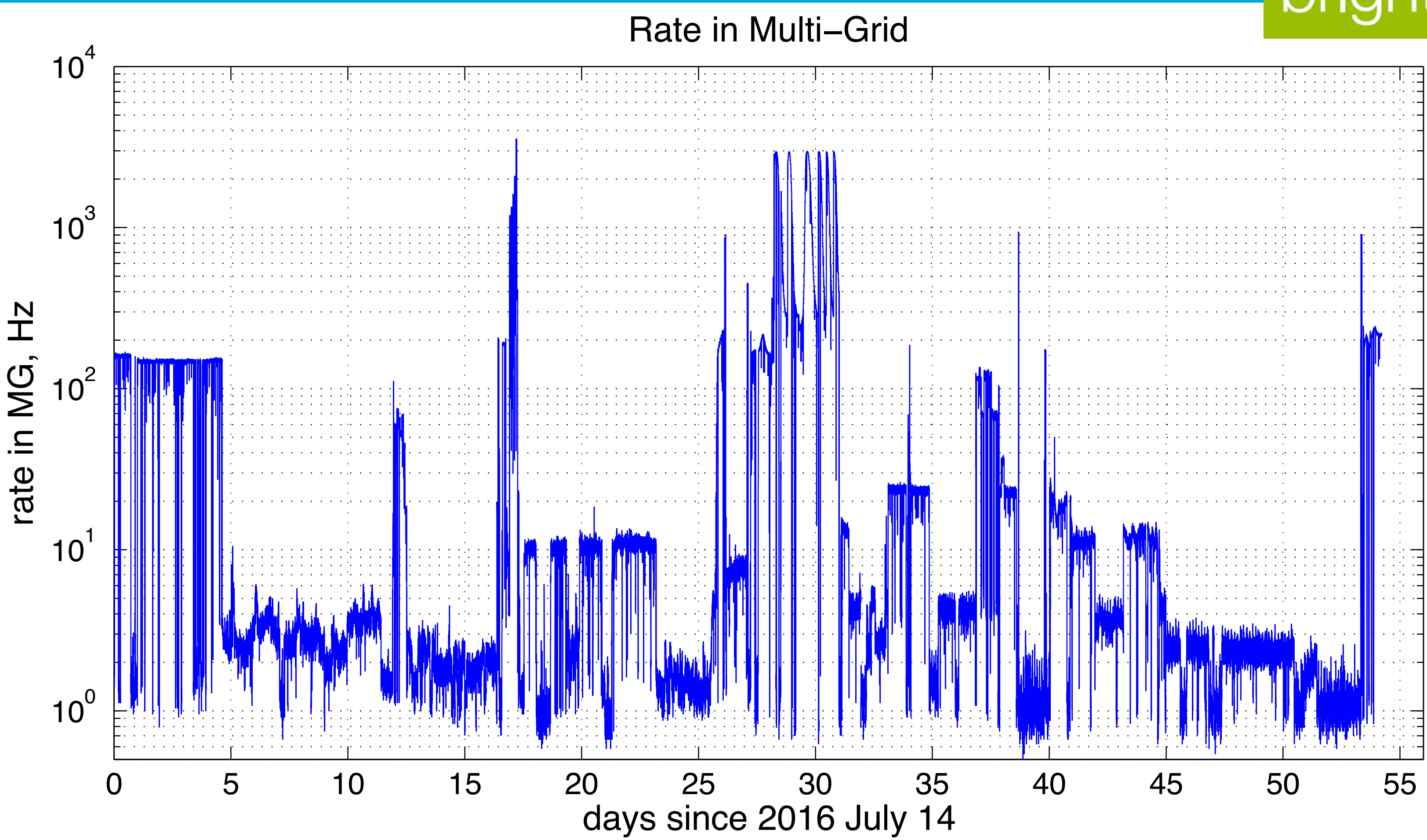


Operation since 2016-07-14

EUROPEAN SPALLATION SOURCE

brightness

NEUTRONS FOR SCIENCE®



Operating without possibility of access since installation

Count rate stable to within 1-2% for a constant setting

Available data

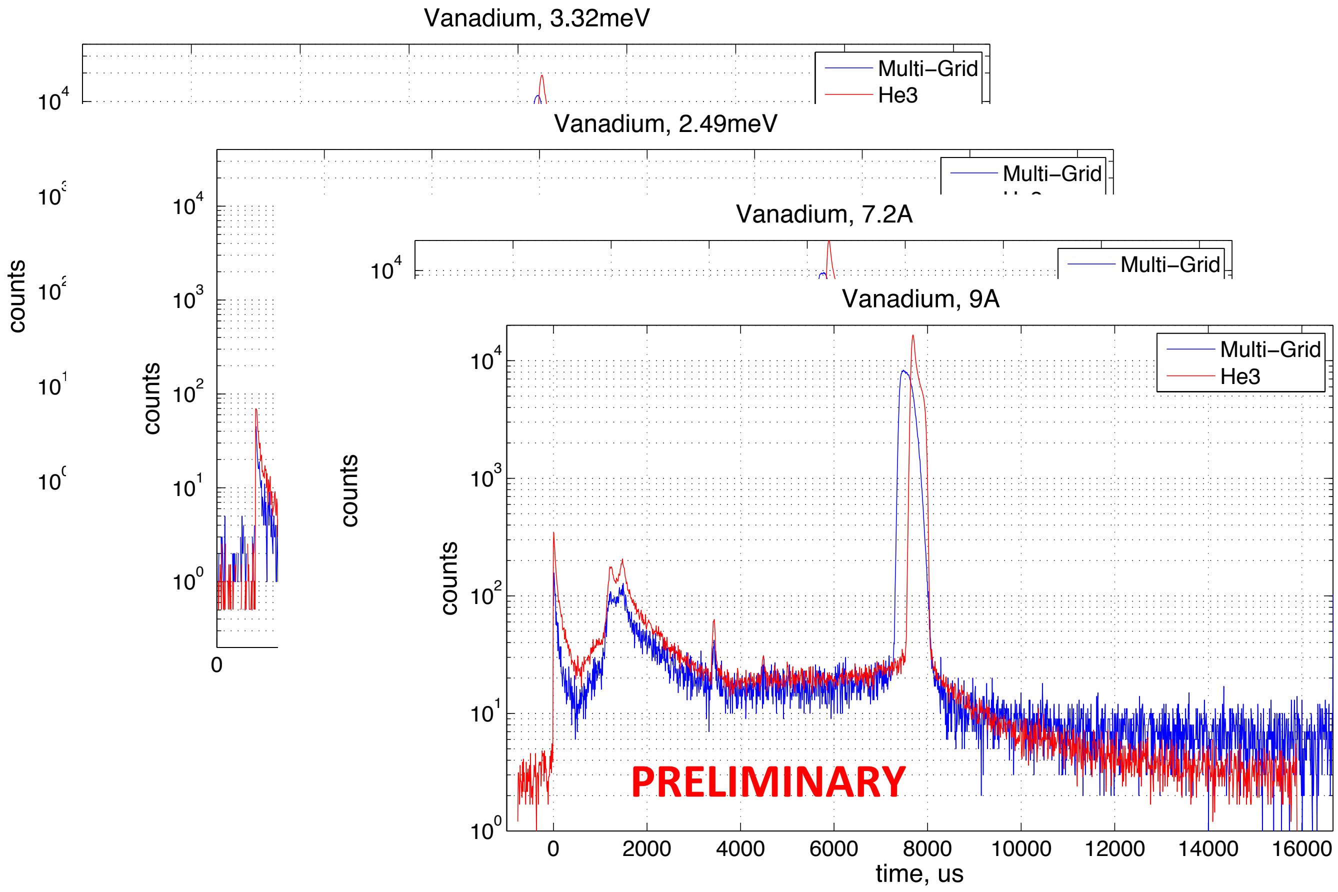
Measurement	Energy, meV	Wavelength, Å	Notes
Vanadium, HF, 300Hz	0.76	10.4	
Vanadium, HF, 300Hz	1.0	9.0	
Vanadium, HF, 300Hz	1.55	7.2	
Vanadium, HF, 60Hz	3.32	4.96	Low resolution, high flux
User experiments			
Vanadium, HF, 300Hz	1.55	7.2	
Vanadium, HF, 300Hz	2.49	5.73	
Vanadium, HF, 300Hz	3.32	4.96	
Vanadium, HF, 300Hz	4.5	4.26	
Vanadium, HF, 300Hz	8.0	3.20	
Vanadium, HF, 300Hz	12	2.61	
Vanadium, HF, 300Hz	15	2.34	
User experiments			
UGe2, 300…60Hz	13.74	2.44	Reflection in MG, U prompt peak
UGe2, 300…60Hz	17.20	2.18	Reflection in He3, U prompt peak
UGe2	3.5	4.83	Reflection not in MG, U prompt peak
UGe2	2.5	5.72	Reflection not in MG, U prompt peak
UGe2	2.0	6.40	Reflection not in MG, U prompt peak
UGe2	1.3	7.93	Reflection not in MG, U prompt peak
UGe2	8	3.20	Reflection not in MG, U prompt peak
UGe2	32	1.60	Reflection not in MG, U prompt peak
User experiments			(some high rate experiments)
Various times: background			Beam off

Experiment 17219 for MG testing runs
Data from He3 array available

Data from closest 8-pack available for other runs

Vanadium Measurements

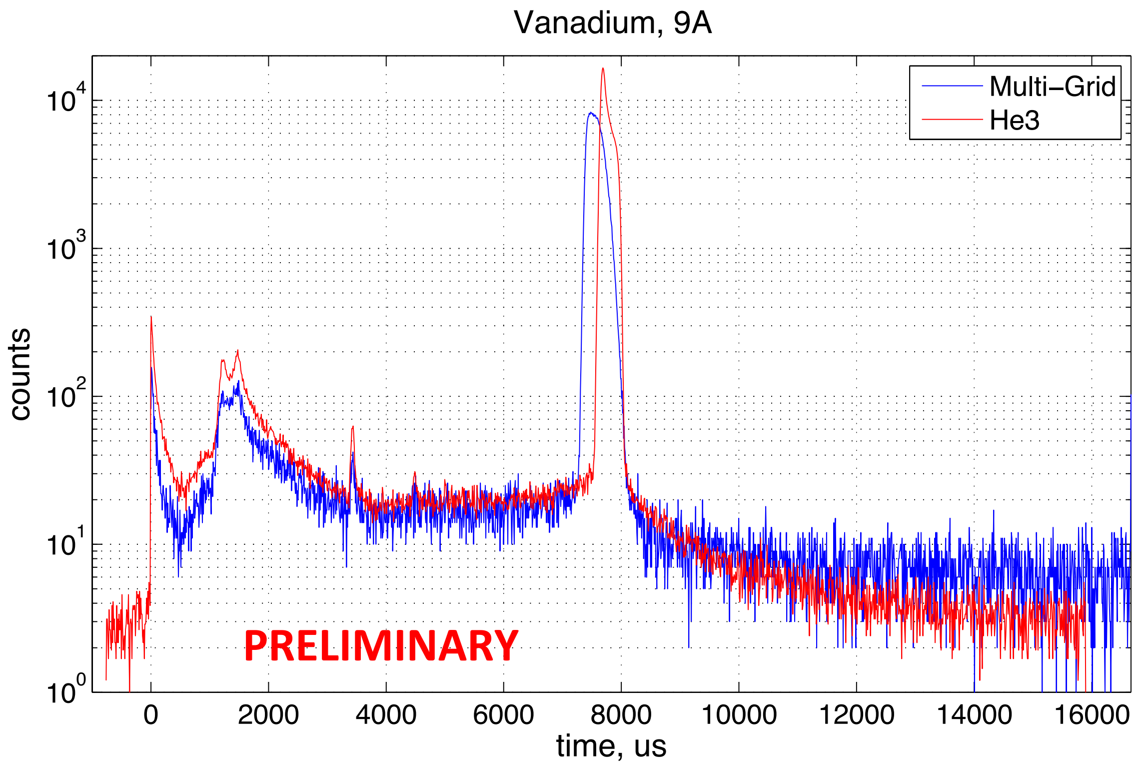
meV	Å
0.76	10.4
1.0	9.0
1.55	7.2
2.49	5.73
3.32	4.96
4.5	4.26
8.0	3.20
12	2.61
15	2.34



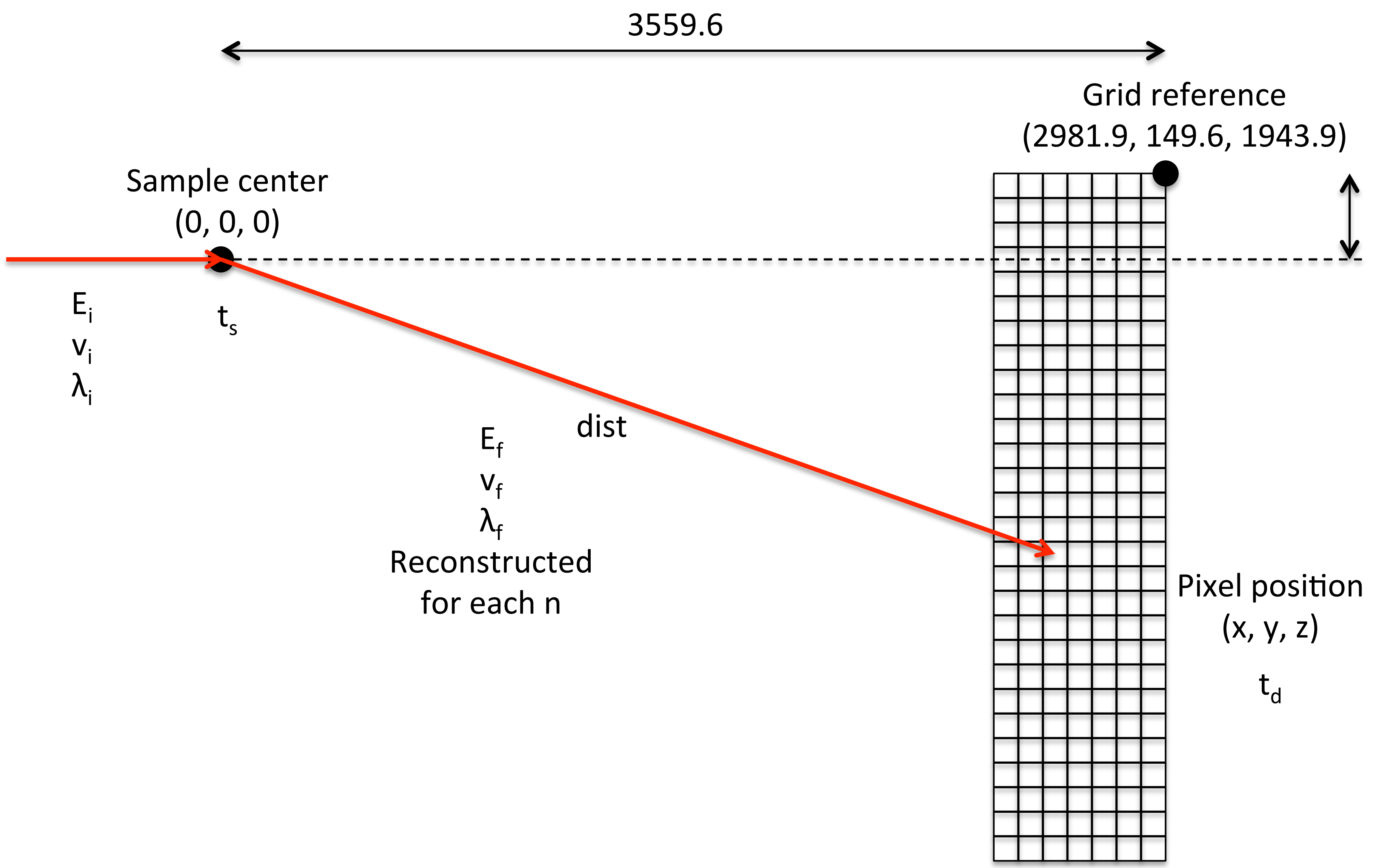
Relative Efficiency

Spectra normalized to detector area and acquisition time
Peak ratio ≈ relative efficiency
(peak counts in MG) / (peak counts in He3)
Peak ratio trend correct, but values not fully understood yet

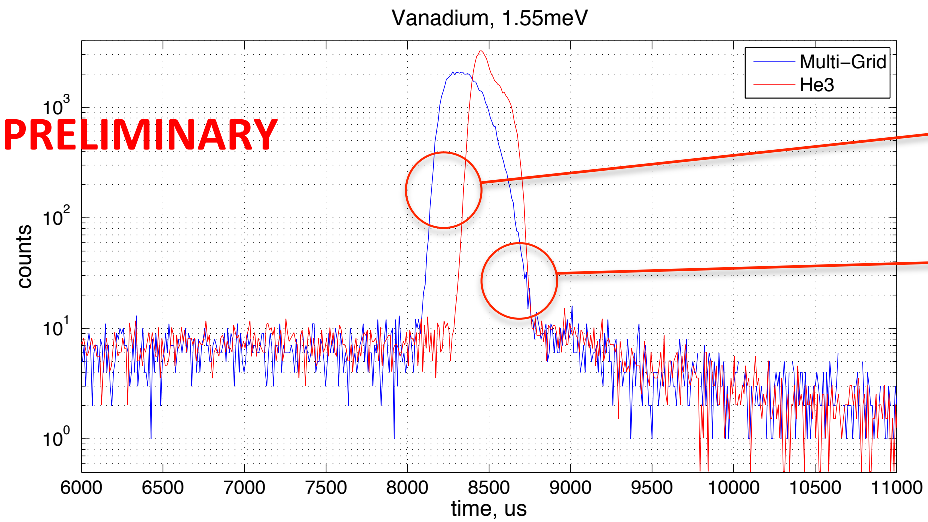
meV	Å	Peak ratio
0.76	10.4	1.18
1.0	9.0	1.12
1.55	7.2	1.03
2.49	5.73	0.956
3.32	4.96	0.913
4.5	4.26	0.846
8.0	3.20	0.769
12	2.61	0.715
15	2.34	0.702



Energy Reconstruction



Energy Reconstruction



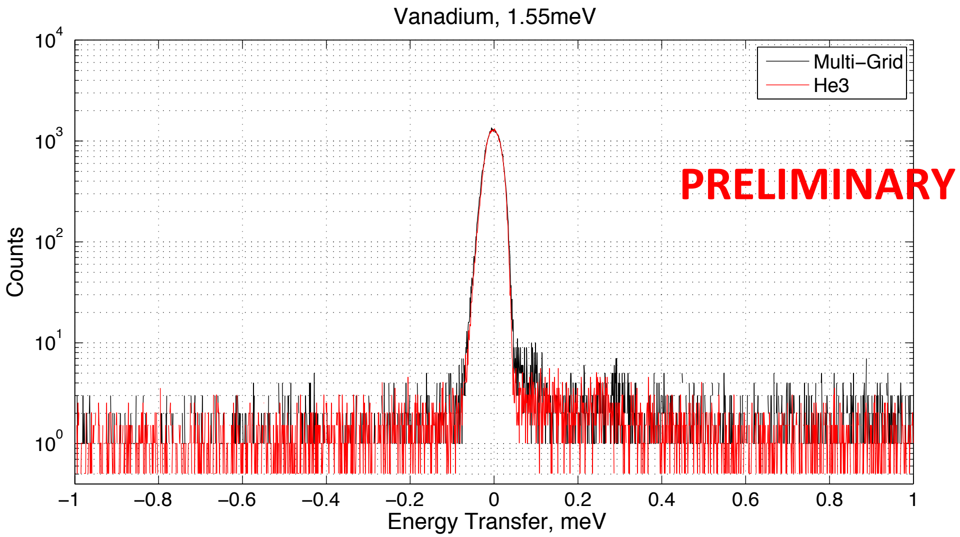
Front of MG ~20cm closer to sample

Back of MG ~same distance as He3

ToF

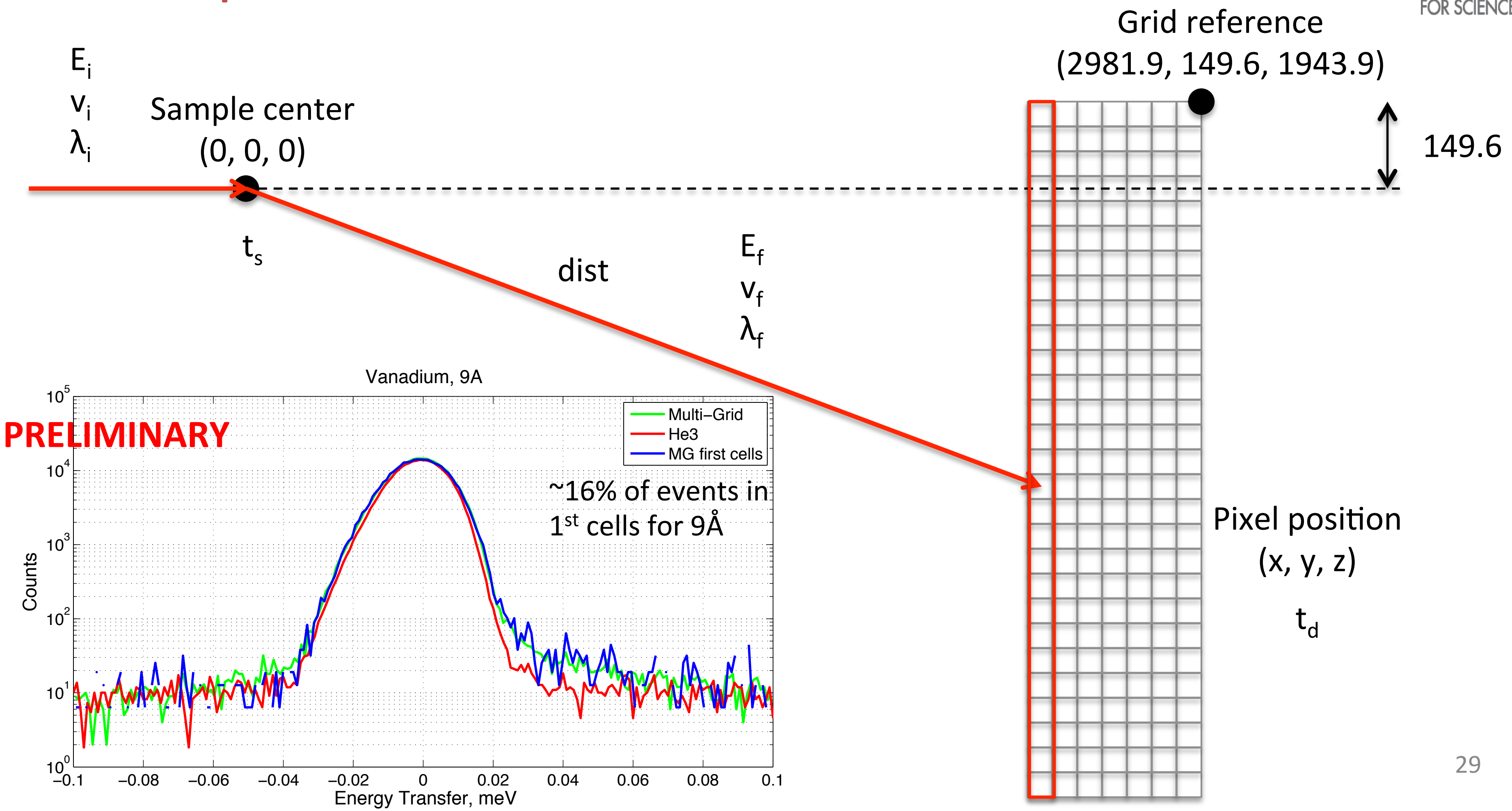
(dist, t)

E_i-E_f

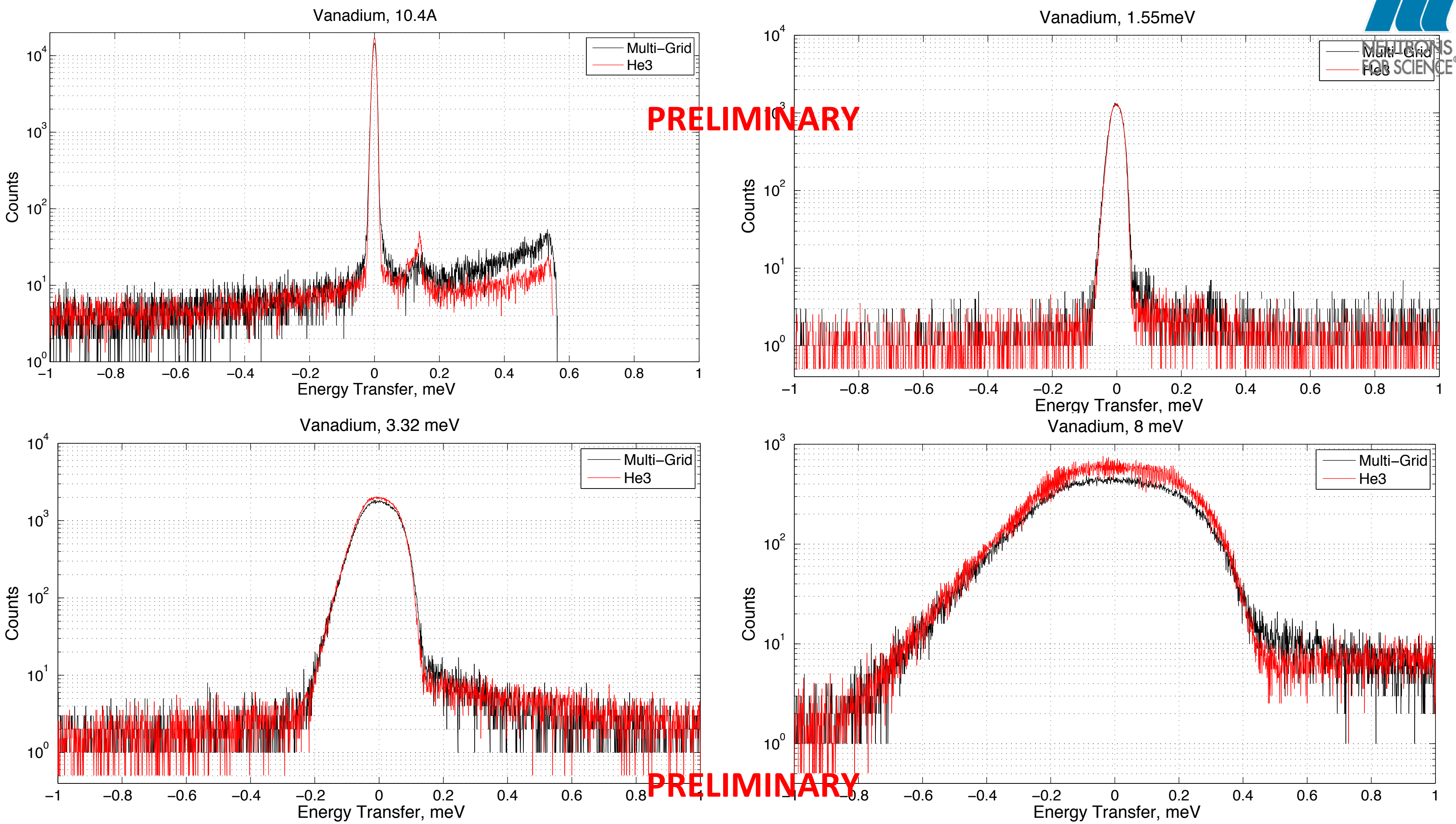


Energy Reconstruction
Front Cells Only

Correction for depth does not compromise data quality
Detector equivalent to a flat detector

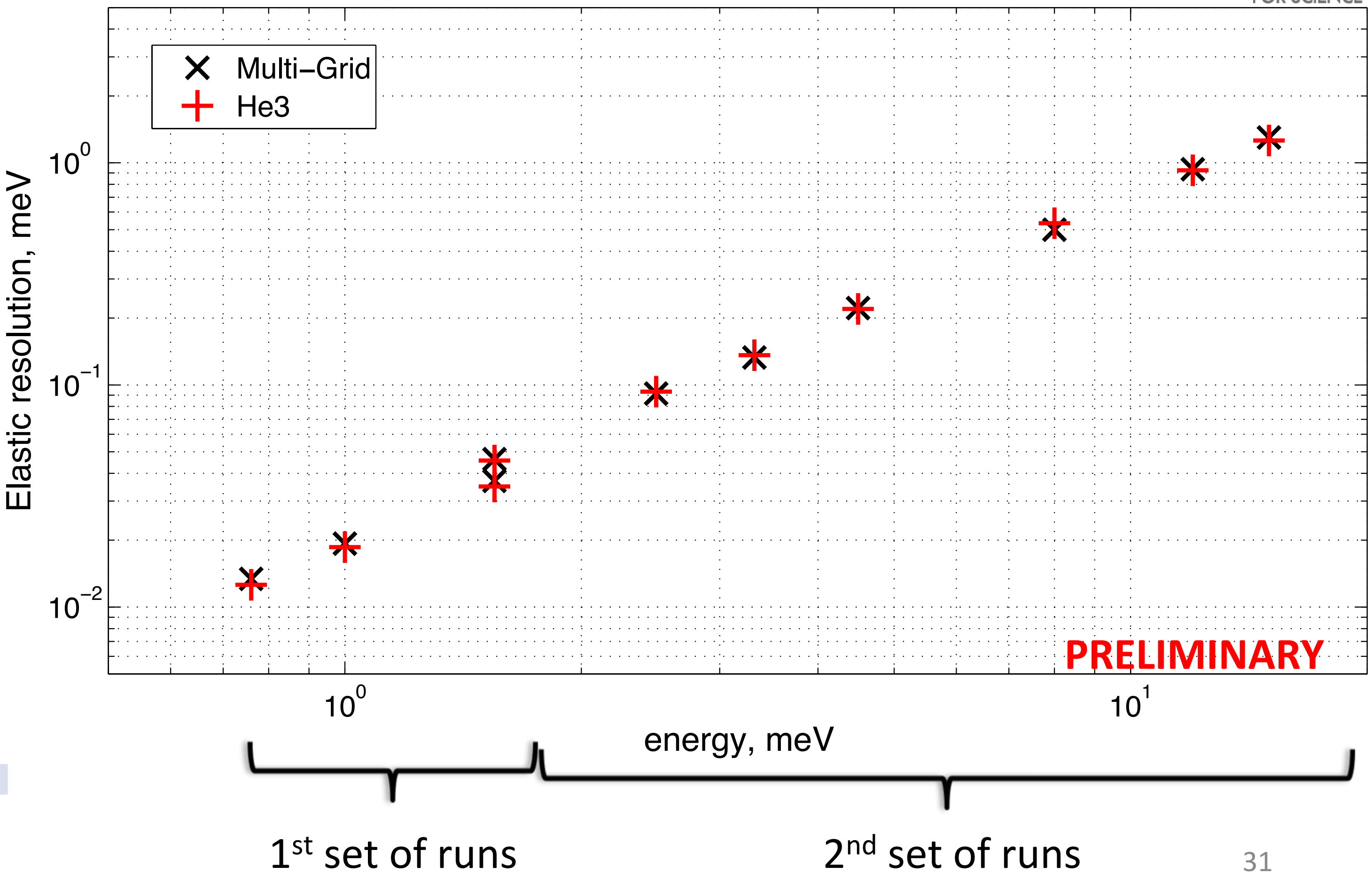


Energy Transfer Histograms

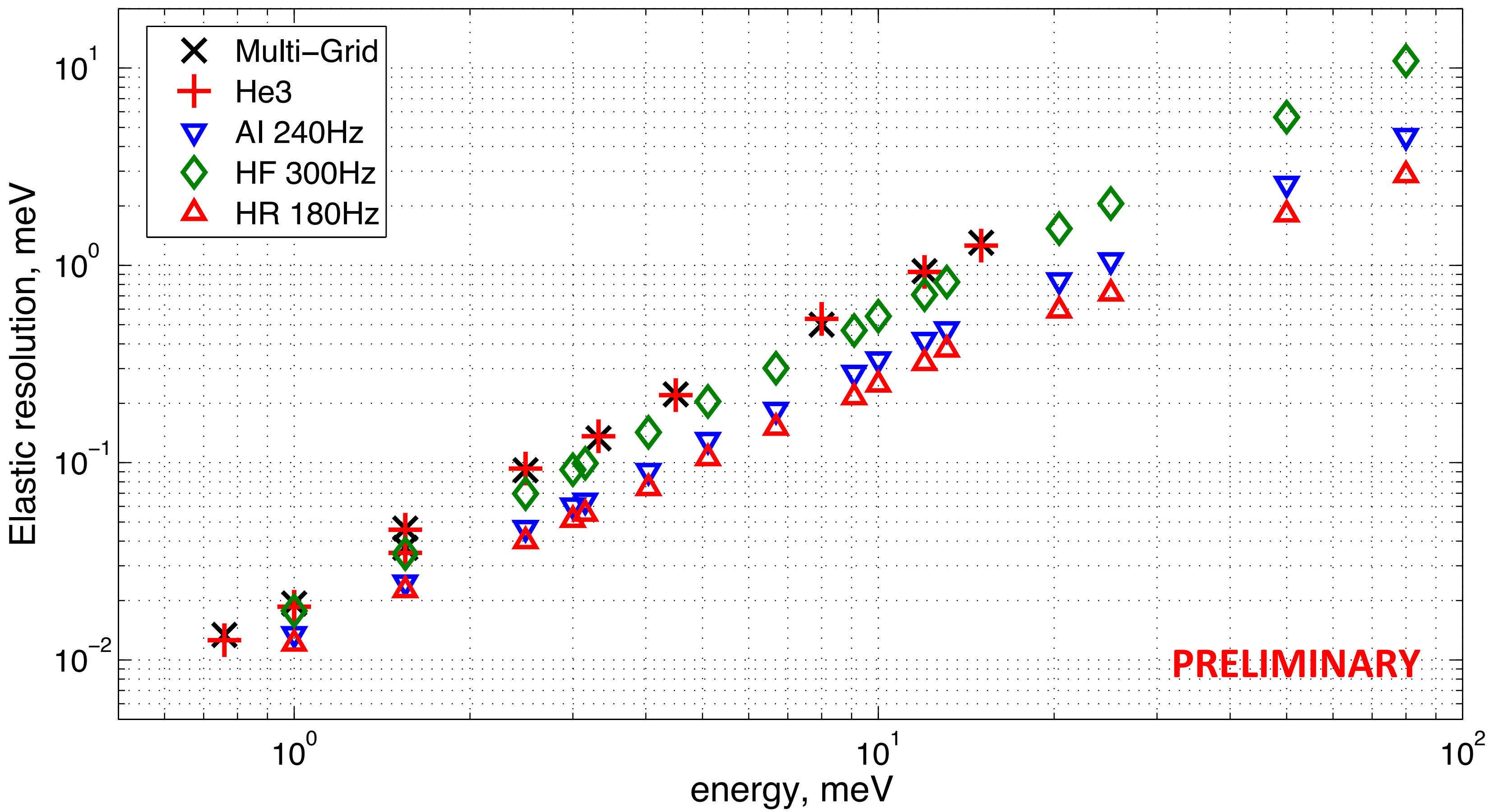


Instrument Energy Resolution

Energy, meV	FWHM, MG	FWHM, He3
0.76	0.0134	0.0126
1.0	0.0193	0.0186
1.55	0.0370, 0.0463	0.0349, 0.0457
2.49	0.0915	0.0933
3.32	0.133	0.136
4.5	0.222	0.220
8	0.500	0.535
12	0.935	0.925
15	1.30	1.26



Instrument Energy Resolution

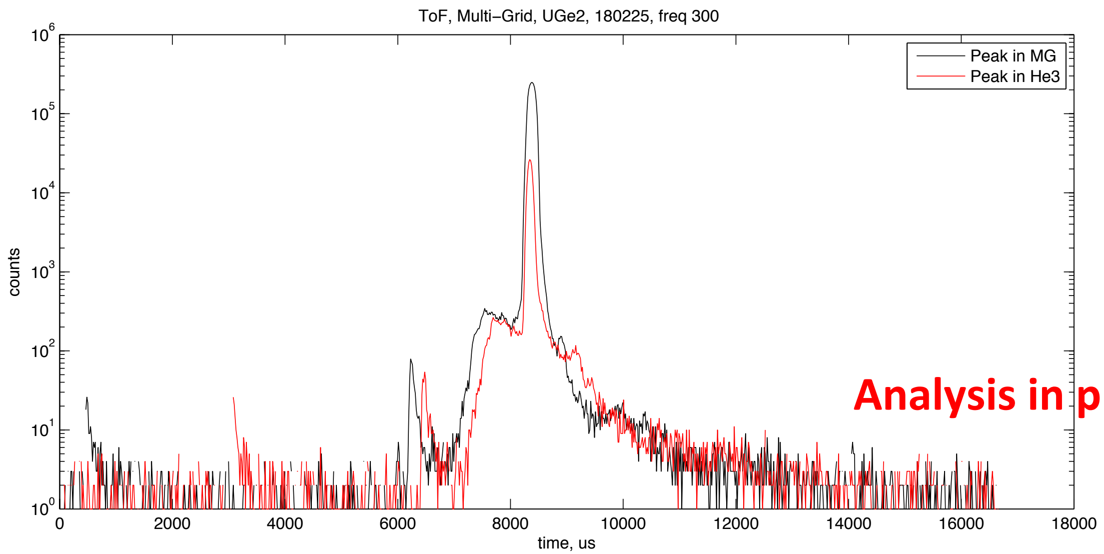


To be followed up with a high resolution measurement

Data for Al 240Hz, HF 300Hz, HR 180 Hz from http://sns.gov/cncs

UGe2 Crystal Measurement

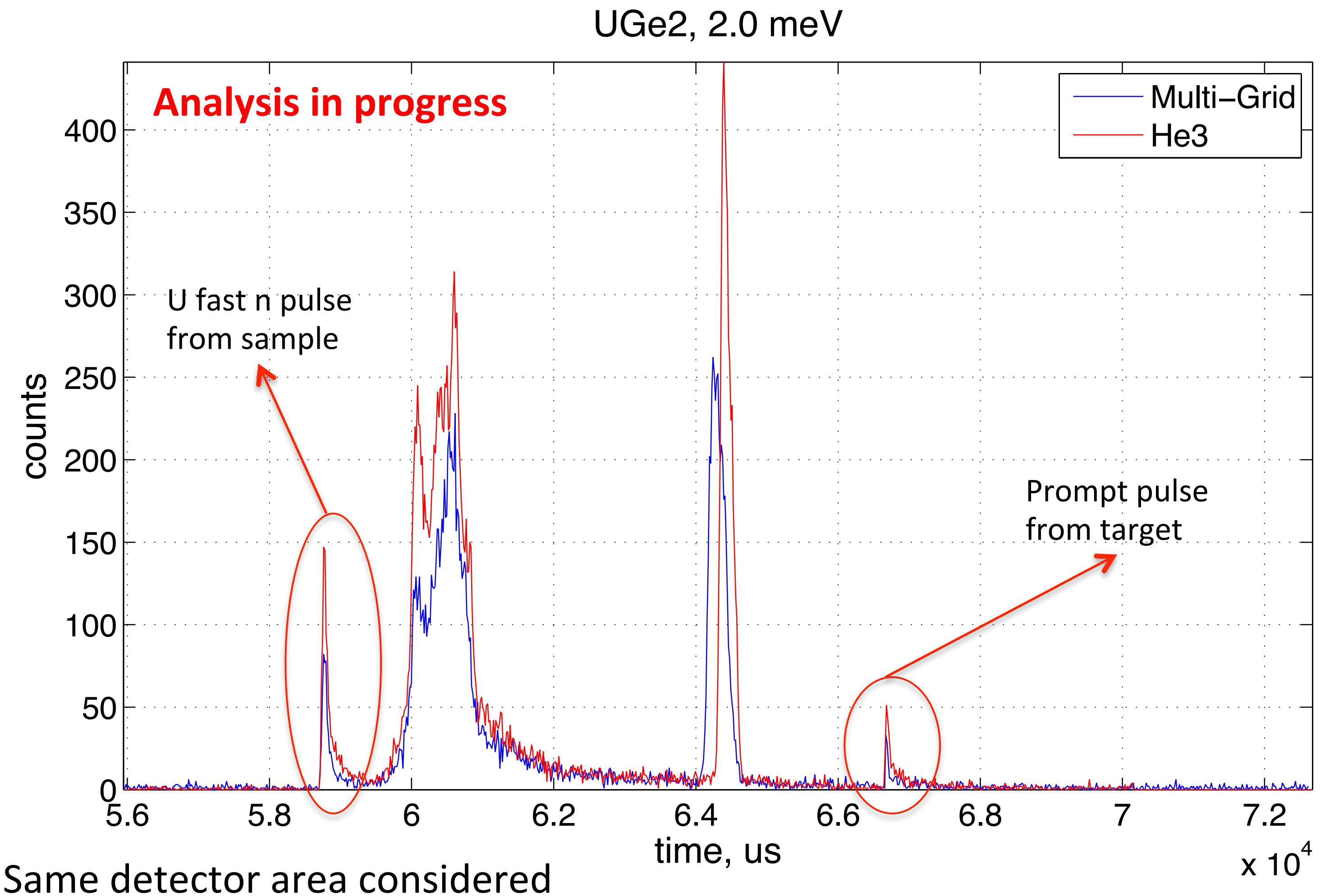
Measurement	meV	Å	
UGe2, 300…60Hz	13.74	2.44	Reflection in MG, U prompt peak
UGe2, 300…60Hz	17.20	2.18	Reflection in He3, U prompt peak
UGe2	3.5	4.83	Reflection not in MG, U prompt peak
UGe2	2.5	5.72	Reflection not in MG, U prompt peak
UGe2	2.0	6.40	Reflection not in MG, U prompt peak
UGe2	1.3	7.93	Reflection not in MG, U prompt peak
UGe2	8	3.20	Reflection not in MG, U prompt peak
UGe2	32	1.60	Reflection not in MG, U prompt peak



Measurements with a reflection hitting the MG vs He3
Can be used to study high local instantaneous rate
Fast n sensitivity

Analysis in progress

Fast Neutrons

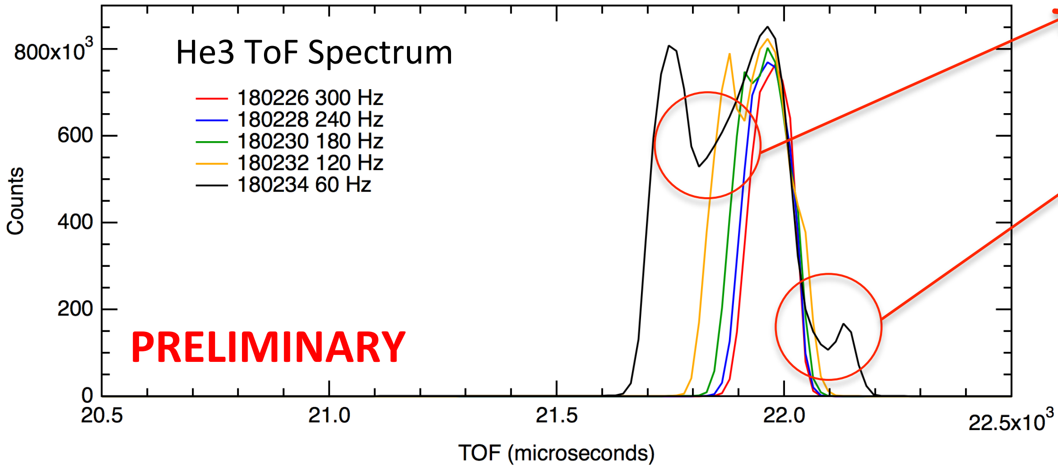


Same detector area considered
Fast n pulses appear to be ~ x2 lower in MG
Under investigation

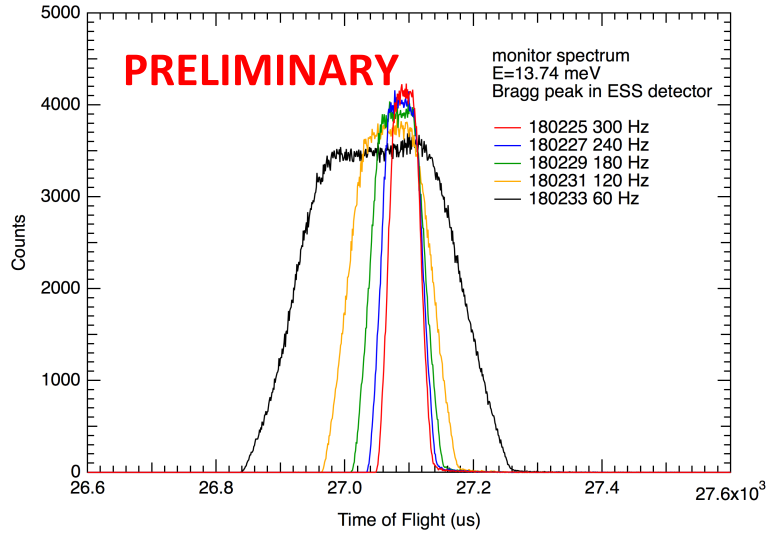
Rate

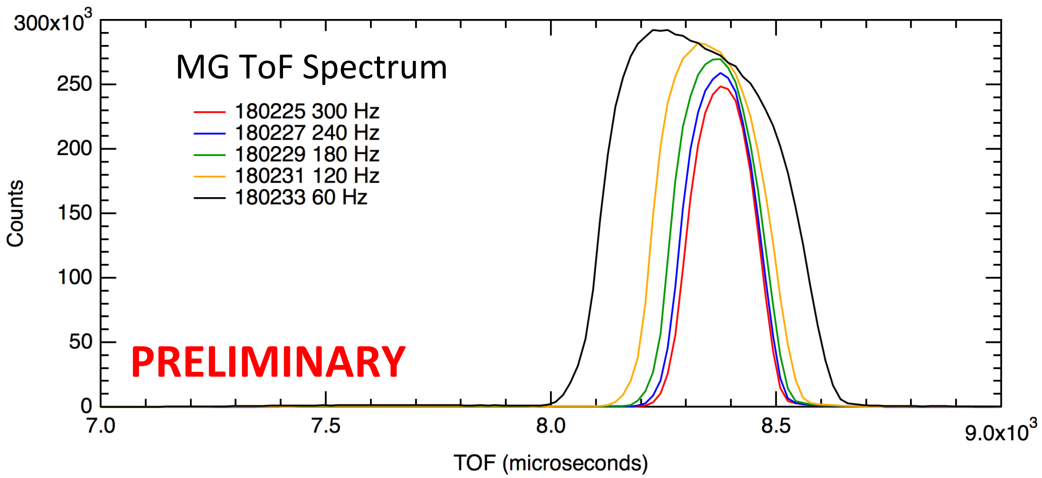
Recovery after 1x dead time?

Recovery after 2x dead time?



CNCS July 31, 2016, E=17.2 meV, Bragg peak in 3He detector





CNCS July 31, 2016, E=13.74 meV, Bragg peak in ESS detector

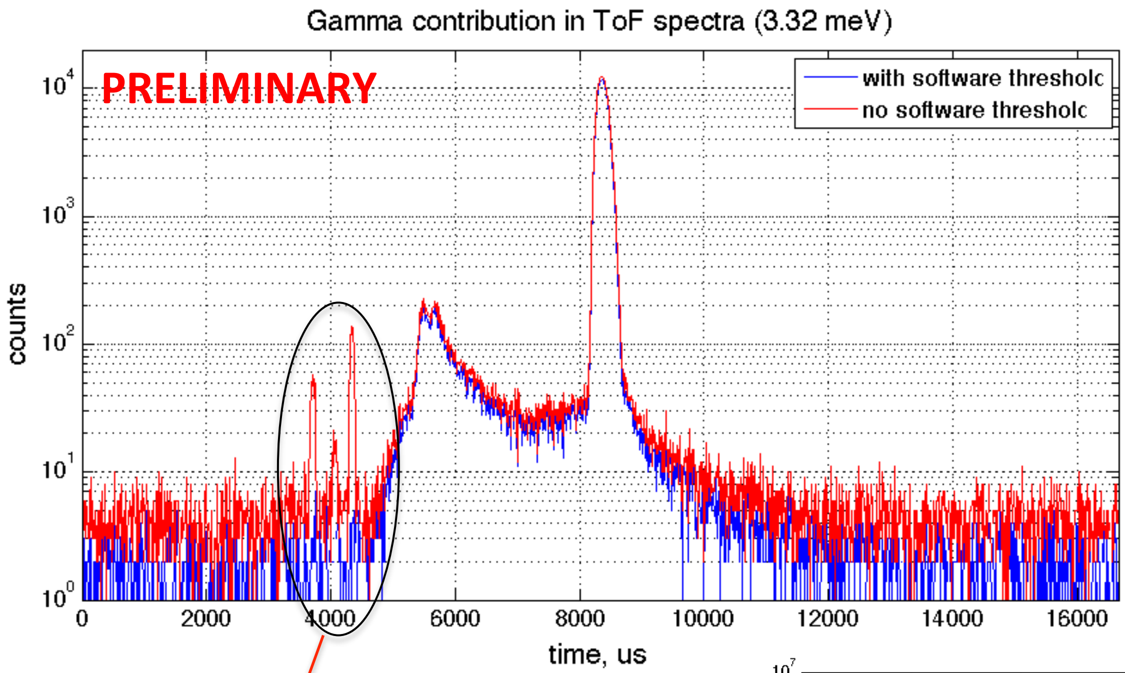
- Single-crystal reflection in detector
- Saturation due to dead time visible in He3
- No saturation in MG at this rate
- Detailed analysis to be done
- Instant rate in MG from tests so far >140kHz without saturation

Gamma Sensitivity

EUROPEAN SPALLATION SOURCE

brightness

NEUTRONS FOR SCIENCE®

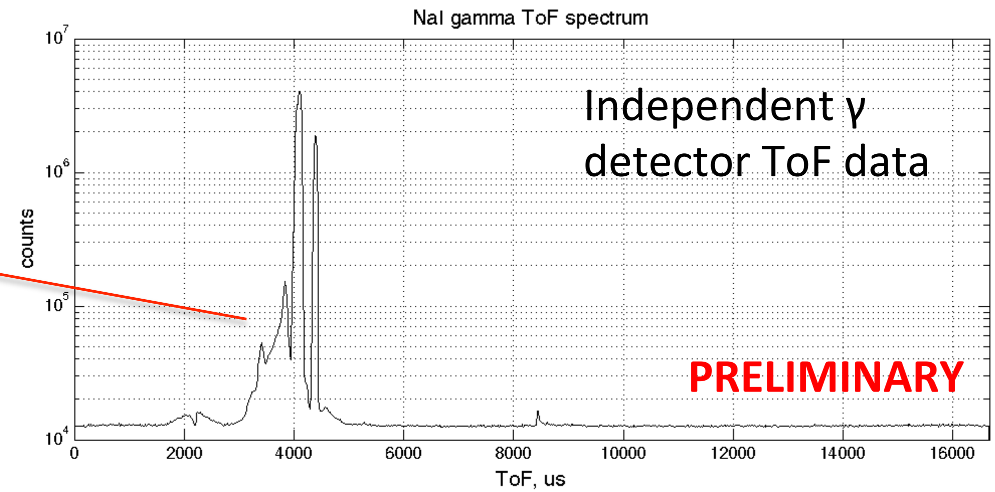


MG threshold set so γ just barely detected

Fully removed using software threshold

All data shown is with the threshold on

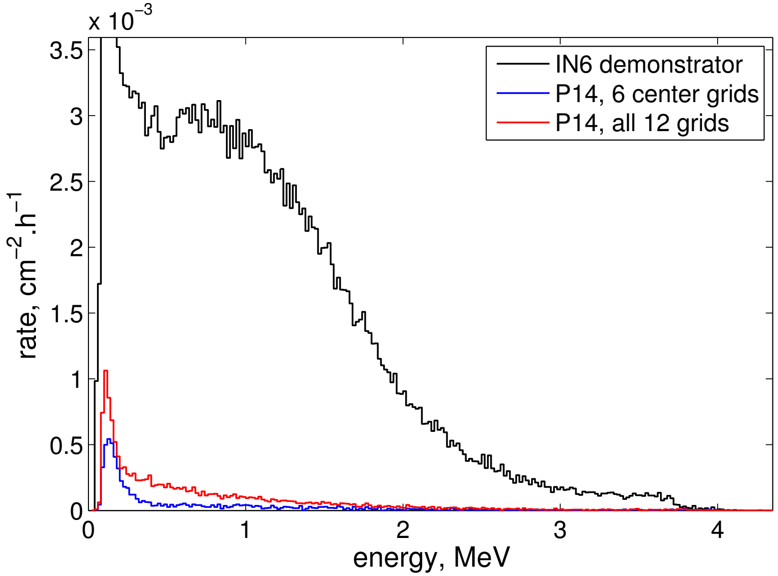
γ flashes as neutrons approach sample



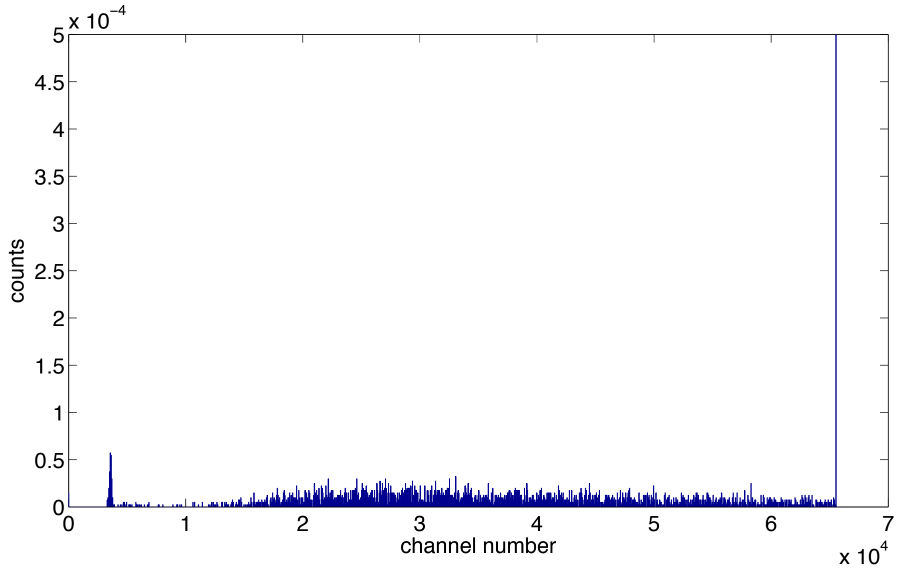
Alpha background reduction demonstrated

Tests done at ILL using Proto1 and at ESS using MG.24 to reduce background
x50 reduction confirmed in both

Proto 1



MG.24



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

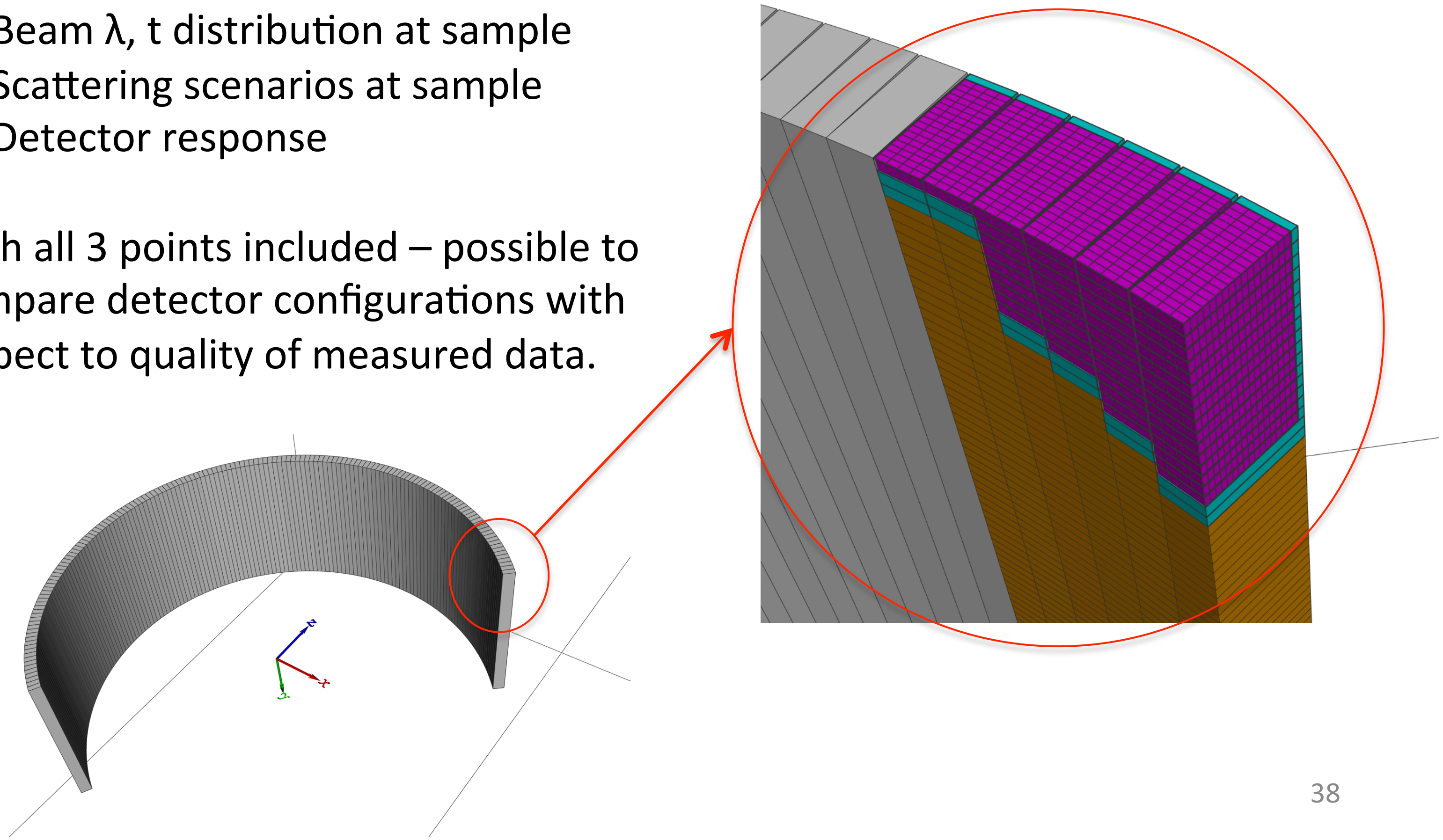
Multi-Grid Simulations

To investigate performance further, full simulation is needed:

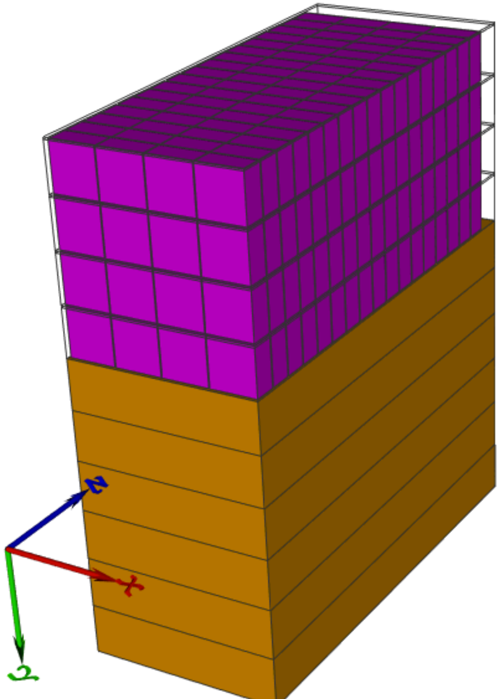
McStas:
- Beam λ, t distribution at sample
- Scattering scenarios at sample

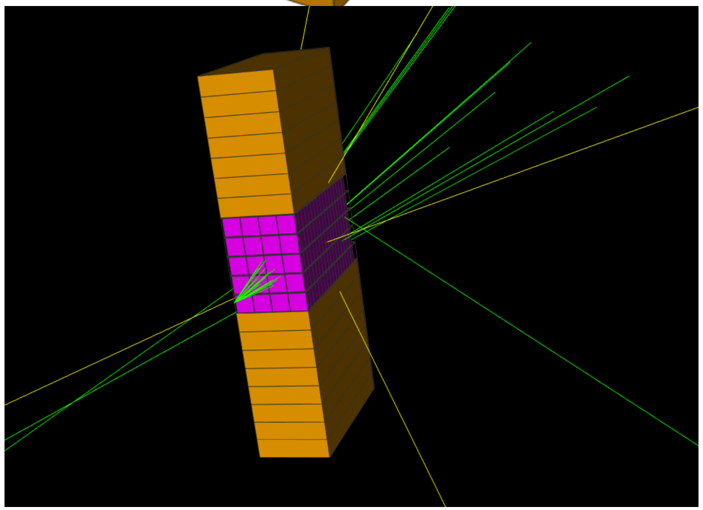
Geant4:
- Scattering scenarios at sample
- Detector response

With all 3 points included – possible to compare detector configurations with respect to quality of measured data.



Multi-Grid Simulations



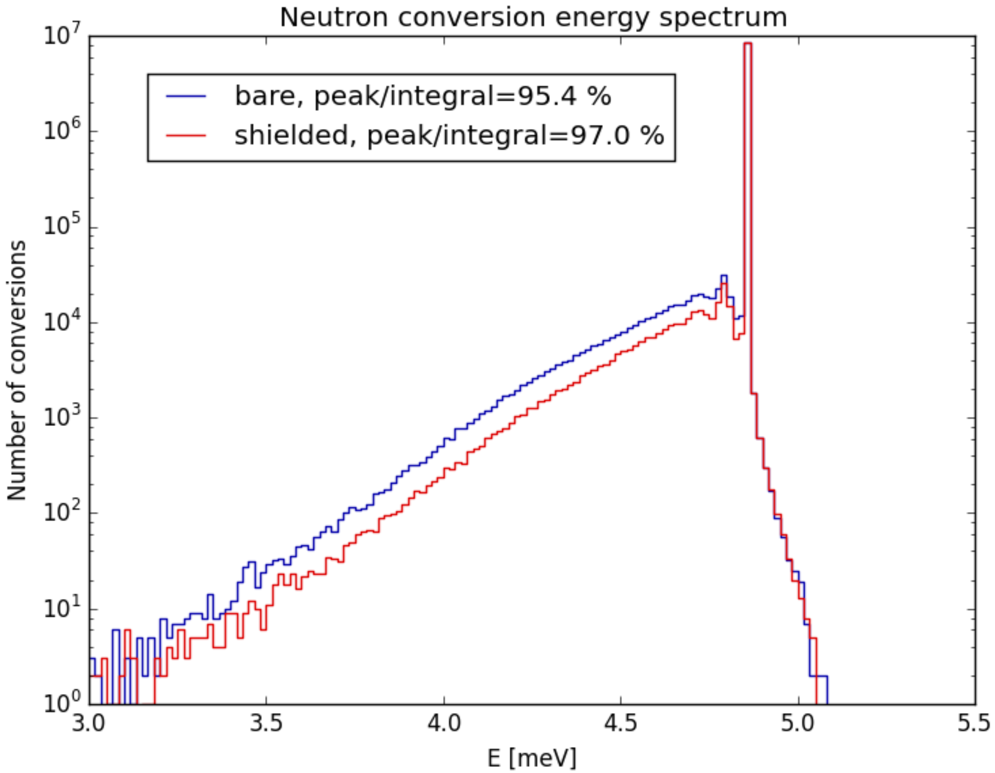


- Complete simulation in GEANT4
- ESS Detector Group Framework
- Extension of GEANT4 including crystal structure and interactions of thermal neutrons

- Work of Eszter Dian
- CER, Hungary in-kind contribution

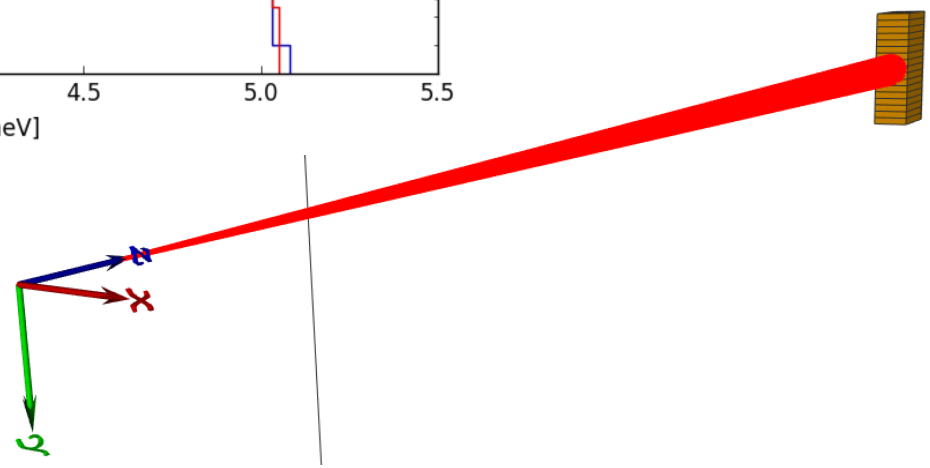
Simulation package:
*T. Kittelmannet al., "Geant4 Based Simulations for Novel Neutron Detector Development", (CHEP) (2013); doi: 10.1088/1742-6596/513/2/022017;
*arXiv:1311.1009v1.
T. Kittelmann, M. Boin. "Polycrystalline neutron scattering for Geant4: NXSG4", Computer Physics Communications 189, 114-118 (2015); doi:10.1016/j.cpc.2014.11.009

Multi-Grid Simulations



- Monochromatic n incoming
- Interaction with detector
- Detected E reconstructed from ToF
- E broadened due to additional flight time of scattered neutrons
- To be compared to measurement

Will allow to model and compare scattering contributions for varying configurations



Outlook

Efficiency: can be derived from V runs;
Not ideal as the 2 detectors never measure the same beam;
Only relative measurements available;
MG tuned for 4Å.

Rate: needs to be analyzed in detail

Scattering: need to analyze ToF as a function of detection position;
Comparison to simulation.

UGe2 data: further analysis of fast n peak;
Spatial distribution of hits

Background: analysis of time-independent background

More test measurements whenever possible. Continued operation during user program.

Conclusions

Operation with no access for 2 months so far.

All data compared to He3.

Spectra comparable between MG and He3. All known features in both.

Backgrounds on similar levels. Some better in He3, some in MG.

Energy resolution of He3 reproduced. Not influenced by the depth of the detector.

Detailed simulations in progress

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

Horizon 2020 grant agreement 676548