676548

Evaluation of detector characteristics with Geant4 simulation

E. Dian[1,2], G. Galgóczi[3], M. Klausz[1,2]

[1]HAS Centre for Energy Research
[2]European Spallation Source ESS ERIC
[3]HAS Wigner Research Centre for Physics

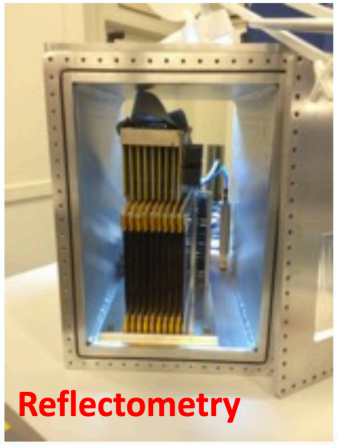
28 September 2017, IKON13, Lund

The ESS detector challenge

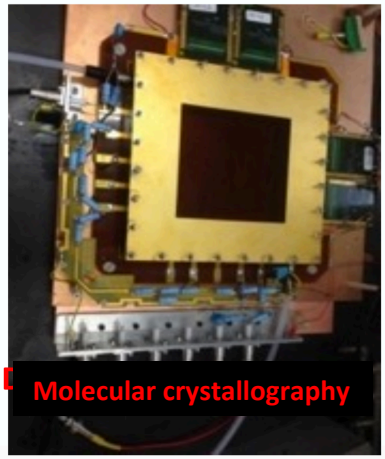
- Various detectors for various instruments at ESS
- All with **different designs**, all have to be **optimised** for respective instrument requirements

Serious efforts on detector simulations @ ESS DG

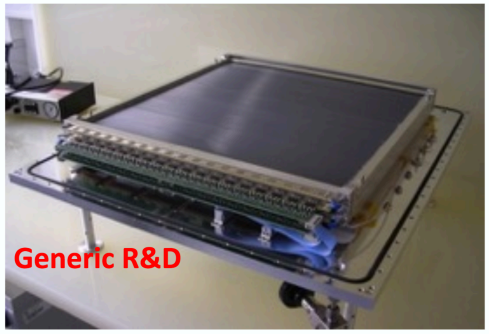
MultiBlade (ESS/Wigner/LU/LiU)



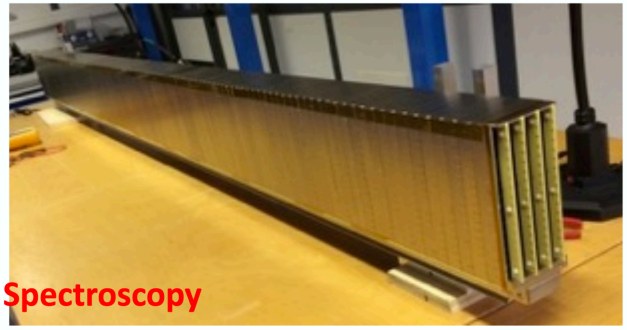
Gd-GEM (ESS/CERN/LiU)



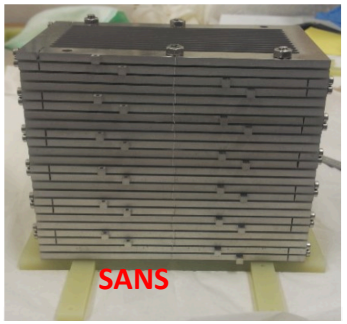
B-MWPC/ Macrostructures (ESS/FRM2)



MultiGrid (ILL/ESS/LiU)



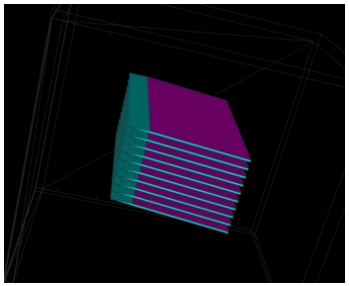
BandGEM (Milan/CNR/INFN/CERN/ESS)



The ESS DG simulation projects

- Several projects, the majority of detector demonstrators have been modeled (E. Dian, G. Galgóczi, K. Kanaki, M. Klausz, D. Lucsányi, V. Maulerova, D. Pfeiffer, I. Stefanescu, C. Sørgaard)
  - Multi-Grid
  - Multi-Blade
  - He-3
  - BAND-GEM
  - macro-structured MWPC
  - flat MWPC
  - plastic scintillators
  - Source Testing Facility@LU
  - B/Gd-GEM
  - Jalousie
  - Si sensors
  - boron-coated straws

Multi-Blade



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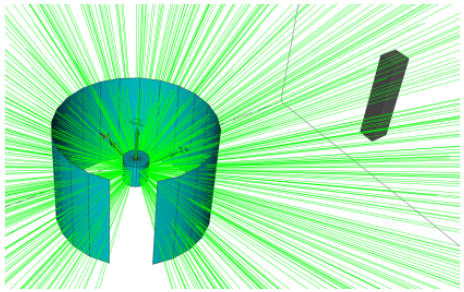
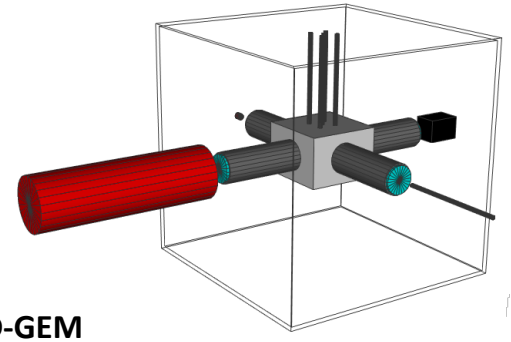
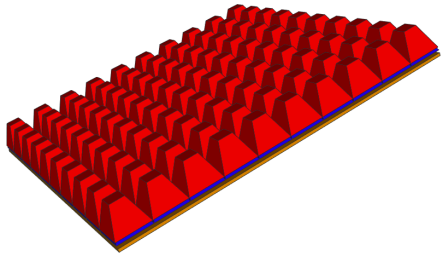


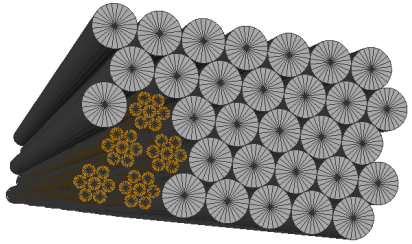
Source Testing Facility



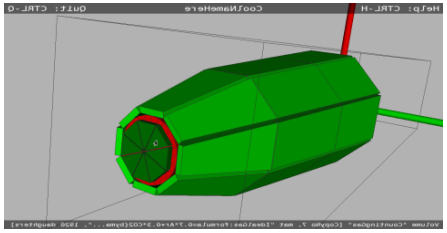
Si sensors

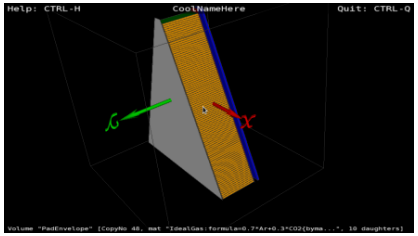


Boron-coated straws

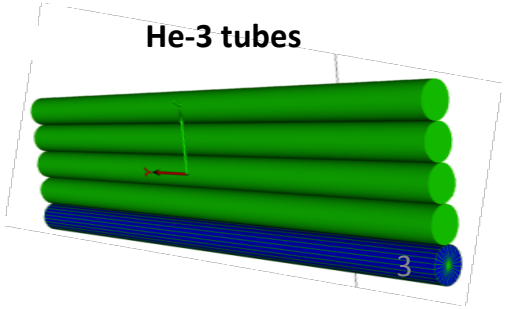


BAND-GEM





He-3 tubes



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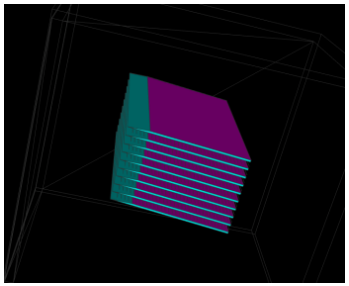

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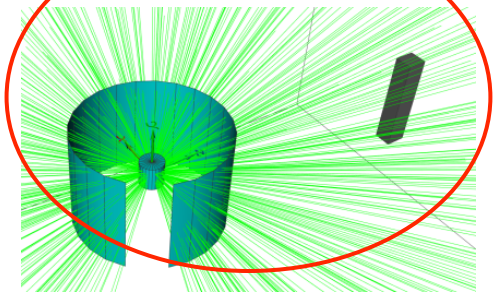

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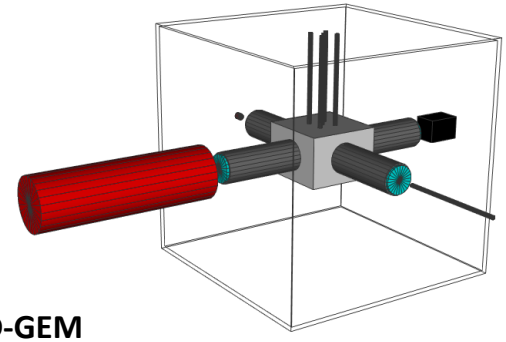

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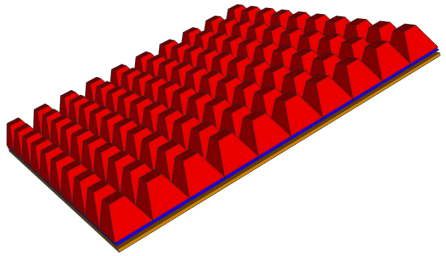

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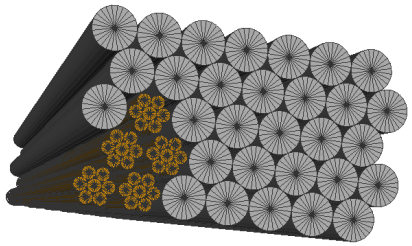

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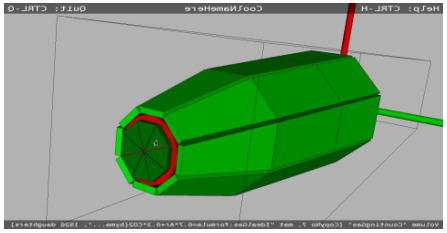

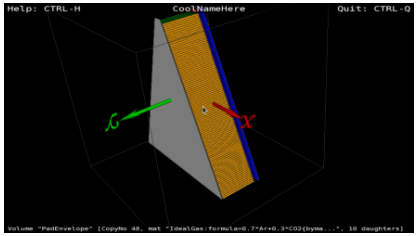

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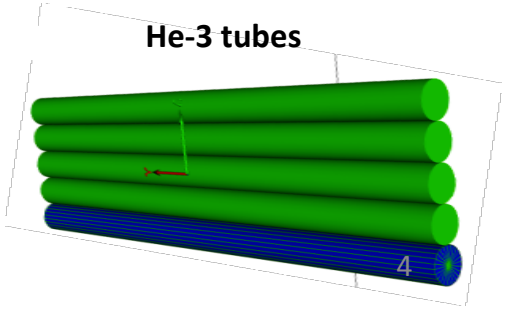

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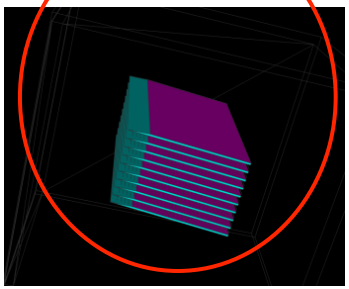

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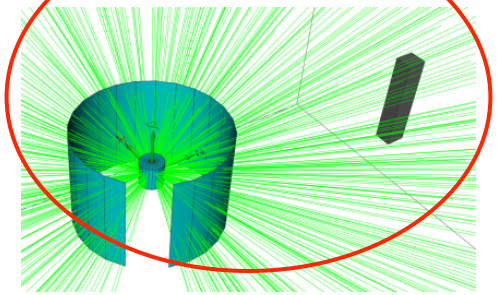

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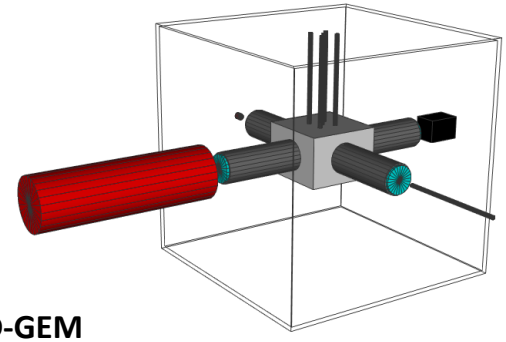

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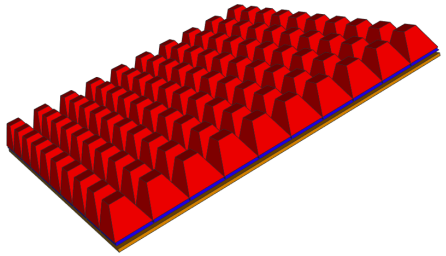

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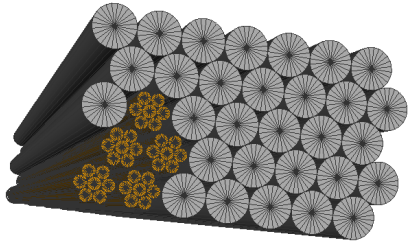

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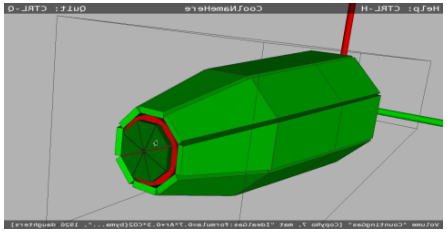

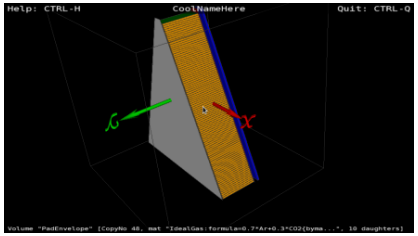

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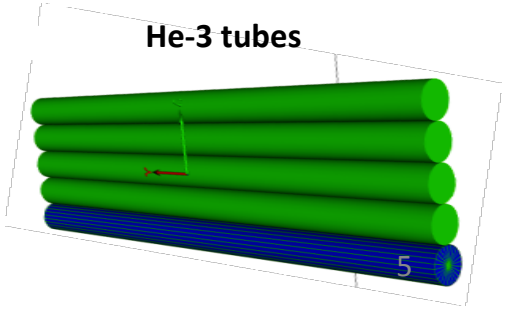

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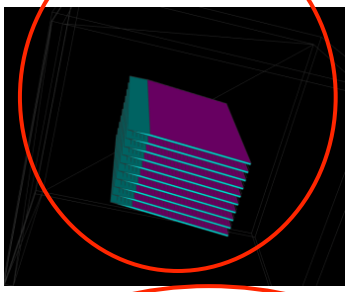

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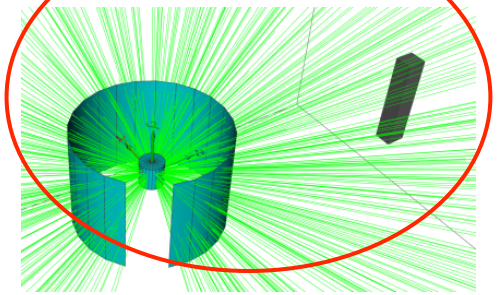

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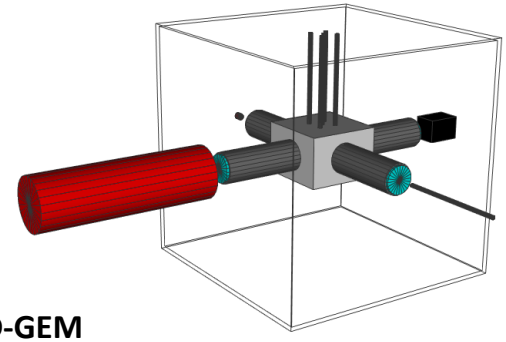

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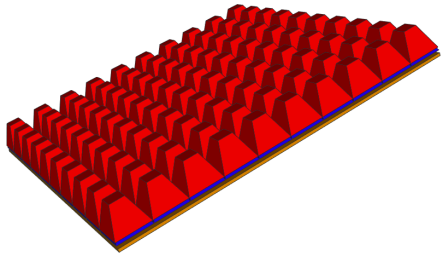

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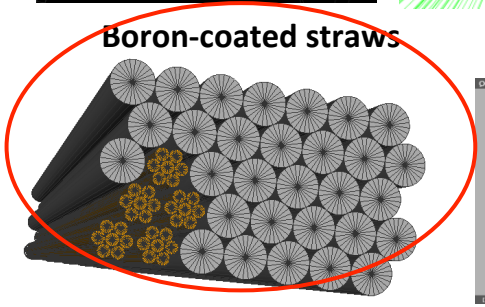

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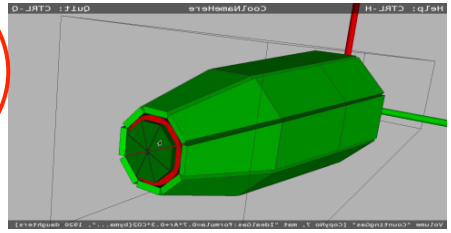

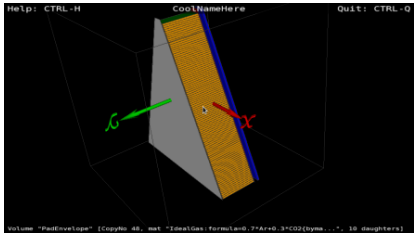

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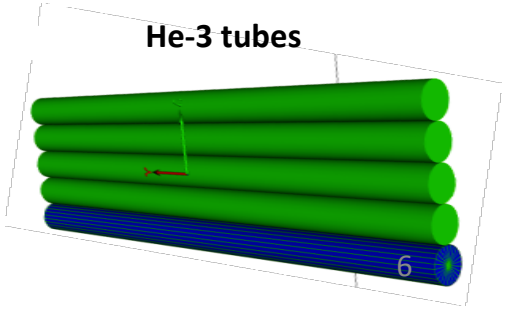


Simulation tools

- New tools & utilities are recently developed for neutron studies
  - Physics
    - Coherent scattering
    - Inelastic scattering
    - Single- and poly-crystals…
  - And more
    - Communication
    - Visualisation
    - Ready-to use…

NXSG4
doi:10.1016/j.cpc.2014.11.009
http://nxsg4.web.cern.ch/nxsg4/

NCrystal
https://github.com/mctools/ncrystal/wiki

MCPL -
Monte **C**arlo **P**article **L**ist
https://mctools.github.io/mcpl/

ESS Coding Framework -
Geant4 simulation framework Developed by ESS Detector Group
doi:10.1016/S0168-9002(03)01368-8
doi:10.1088/1742-6596/513/2/022017

Detector background study with Monte Carlo codes

- Sources of neutron detector background
  - Neutron induced gamma background (MCNP6)
    - Prompt gamma radiation from neutron capture
    - Decay gammas from neutron activation

^{41}Ar activity saturates at **128 mBq/cm^3** → low

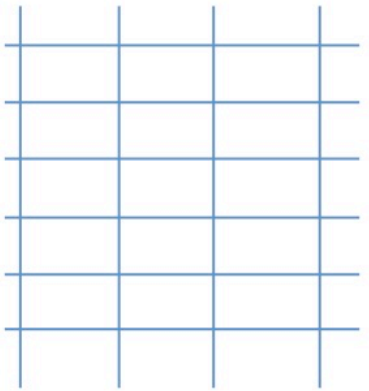
Negligible signal from self-activation

  - Scattered neutrons (Geant4)
    - Elastic, inelastic
    - Coherent, incoherent

Great impact of Coding Framework!

General neutron activation study prepared with MCNP6 for ESS operation conditions
- Ar/CO_2 counting gas
- Aluminum-frame

E. Dian et al.
10.1016/j.apradiso.2017.06.003



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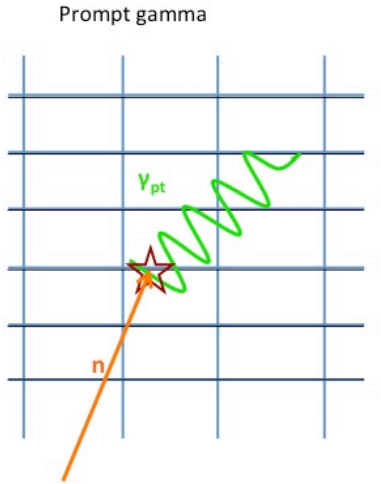

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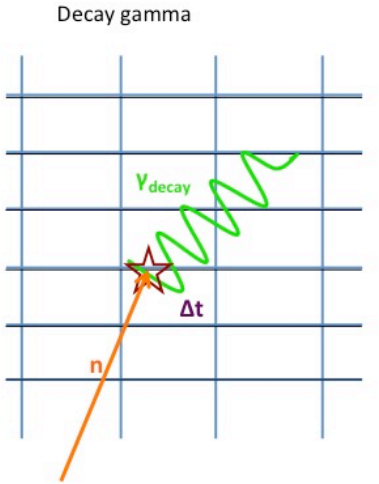

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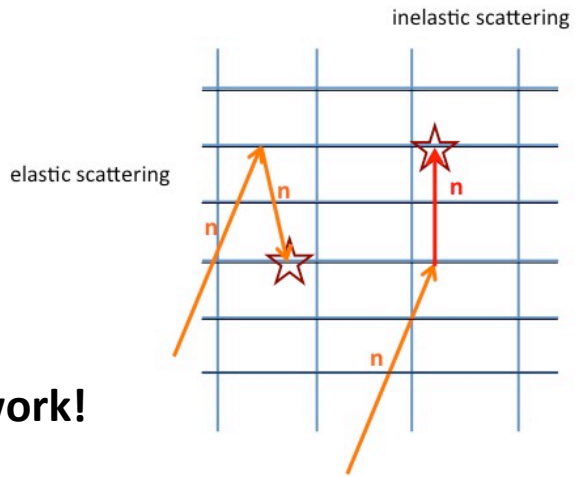


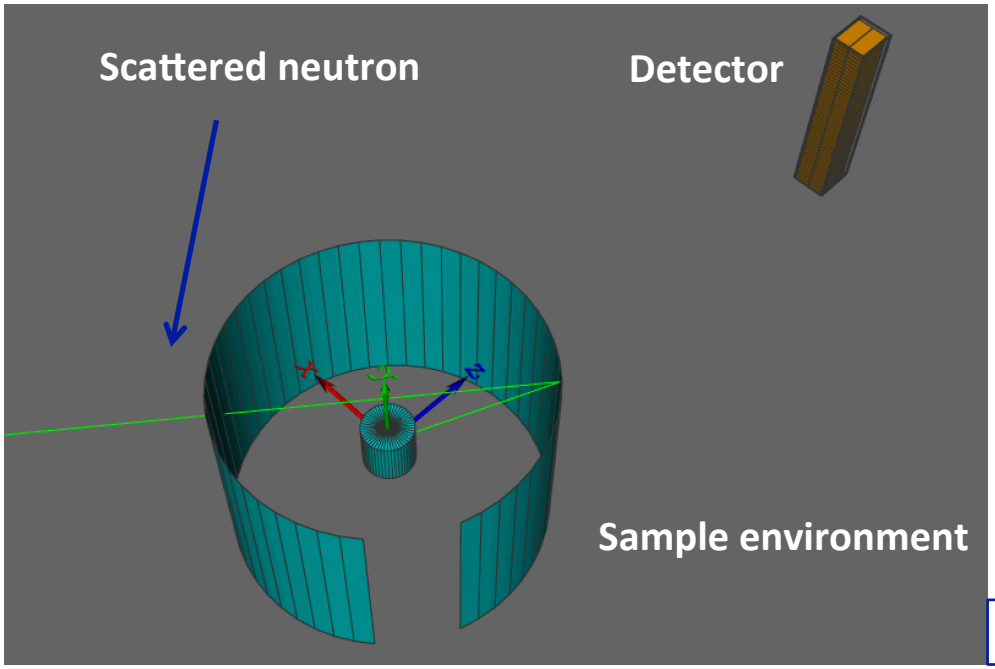
Scattered neutron background

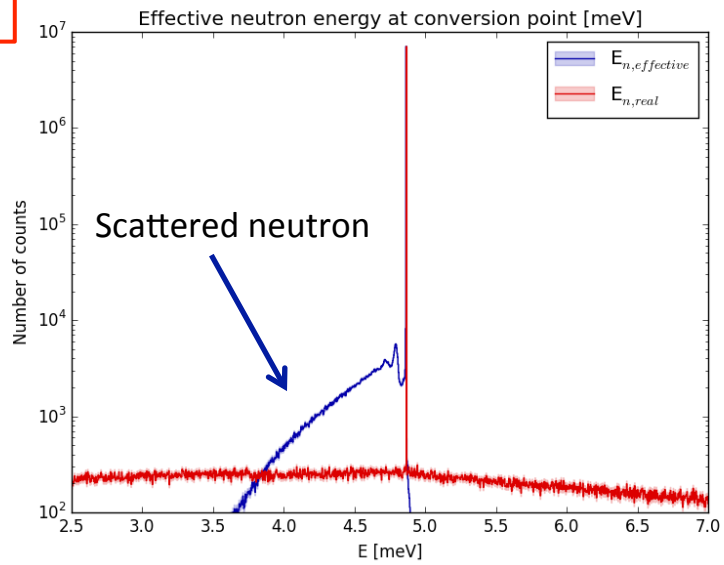
- Neutron scattering on detector and environment
- Study and distinguish background effects
- Guidelines for detector design

Prototype → Full-scale detector model

Validation → **Optimization**

Realistic simulation





Real and measurable neutron energy

Geant4 @Coding Framework

EUROPEAN SPALLATION SOURCE

676548

The Multi-Grid Detector Model

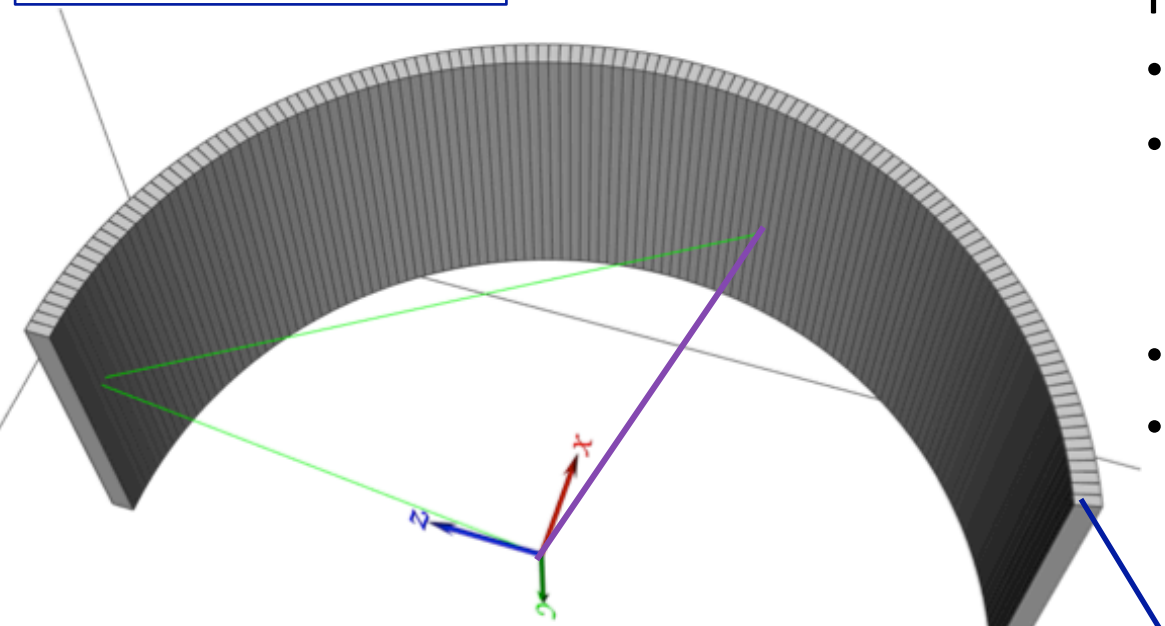
Eszter Dian[1,2], Kalliopi Kanaki[2], Anton Khaplanov[2]
dian.eszter@energia.mta.hu

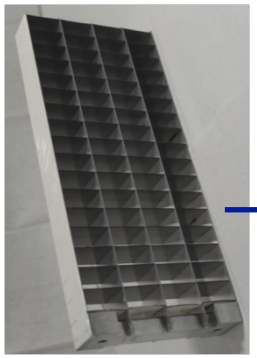
[1]Hungarian Academy of Sciences, Centre for Energy Research
[2]European Spallation Source ESS ERIC

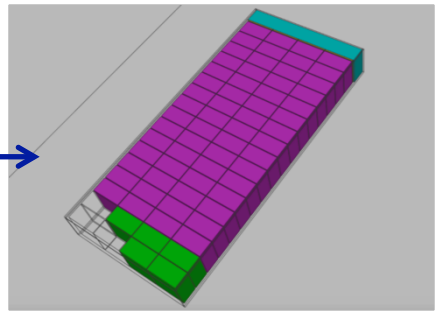
28 September 2017, IKON13, Lund

Large area detector for chopper spectroscopy – Multi-Grid

Geant4 @Coding Framework







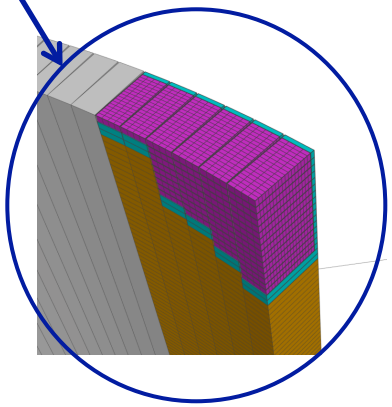
Multi-Grid

- Large area detector
- Inelastic instrument, chopper spectroscopy

Low background is essential

- Solid B_4C converter + Ar/CO_2
- Aluminium frame – **crystalline Al**

Scattered neutron background induced in detector

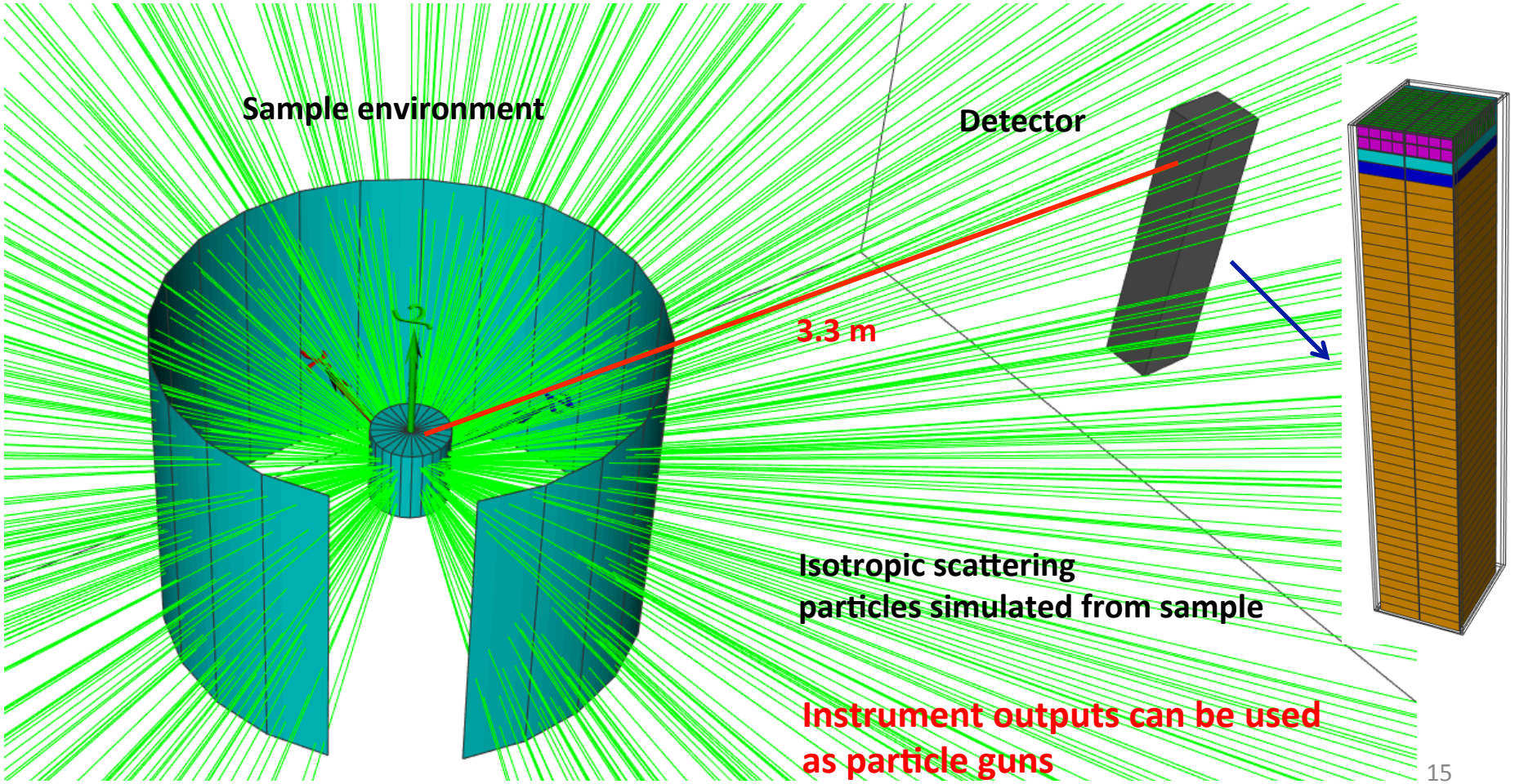


A. Khaplanov et al.
http://dx.doi.org/10.1016/j.nima.2012.12.021

Multi-Grid detector test at CNCS, SNS

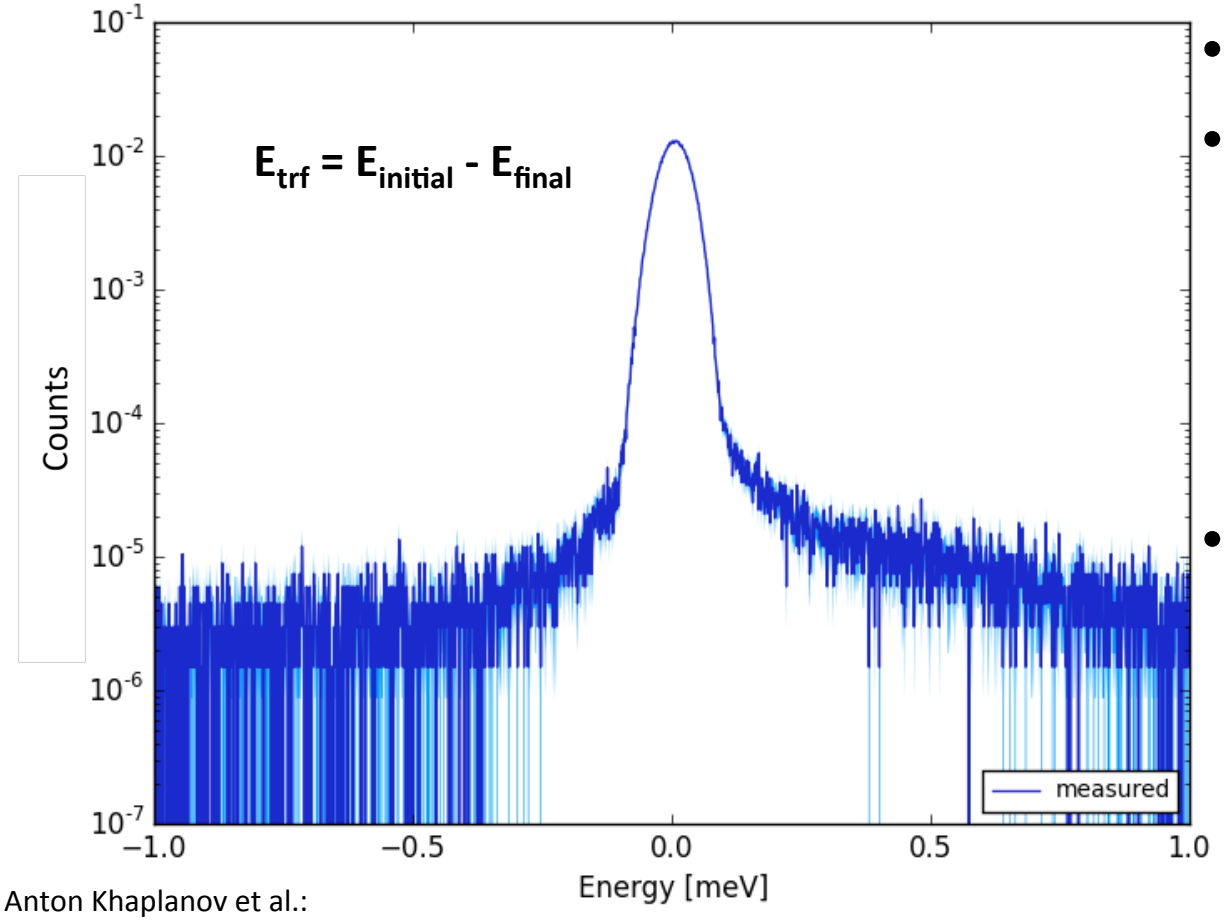
Geant4 @Coding Framework

NXSG4



MultiGrid detector test at CNCS, SNS

Derived energy transfer at 3.678 meV from measurement



- Chopper spectroscopy
- Measured quantities:
  - ToF
  - detection-coordinates

↓

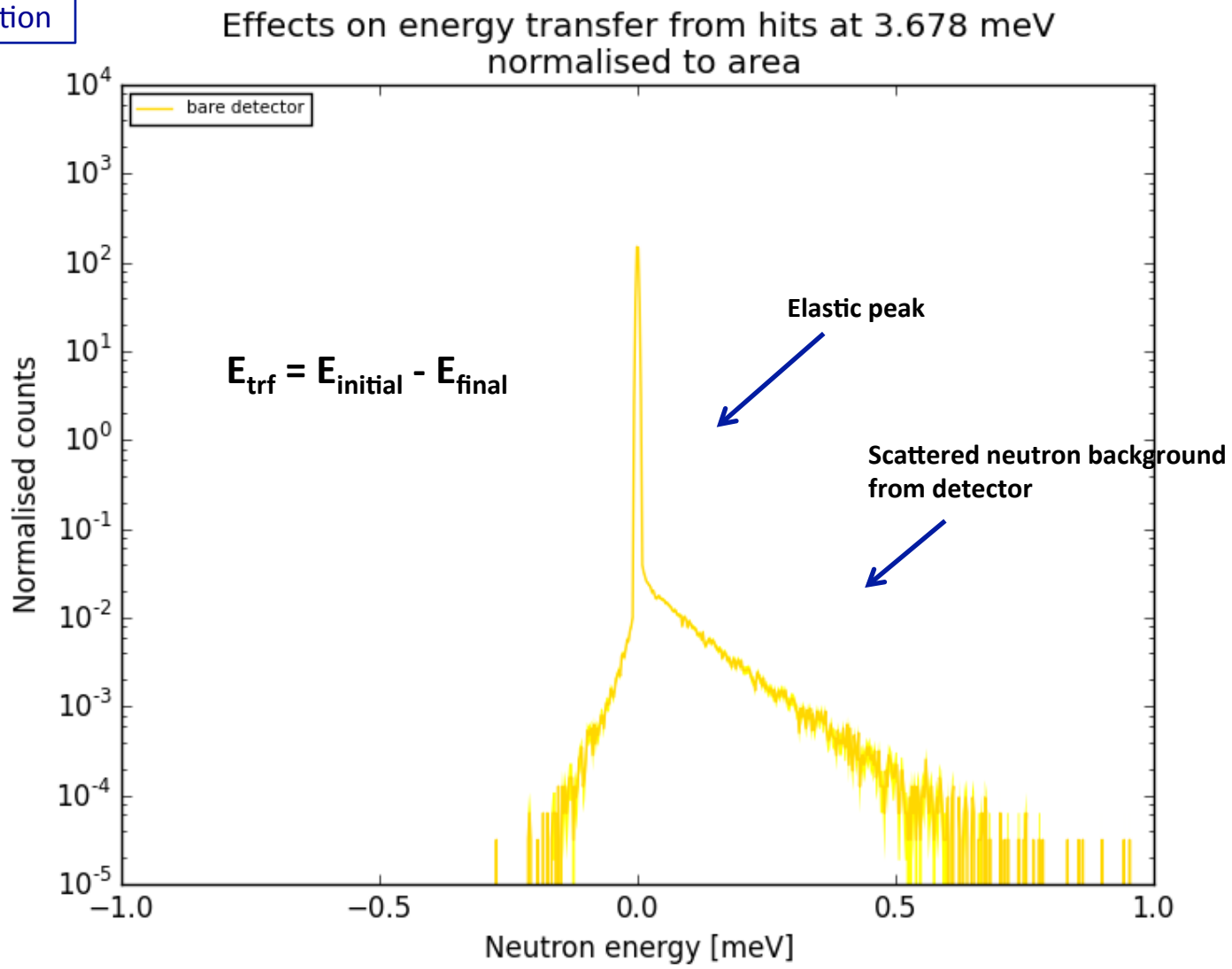
- Energy transfer:
  $E_{trf} = E_{initial} - E_{final}$

Anton Khaplanov et al.:
Multi-Grid Detector for Neutron Spectroscopy: Results Obtained on Time-of-Flight Spectrometer CNCS
doi:10.1088/1748-0221/12/04/P04030, https://arxiv.org/abs/1703.03626

MultiGrid detector test at CNCS, SNS

Geant4 simulation

NXSG4



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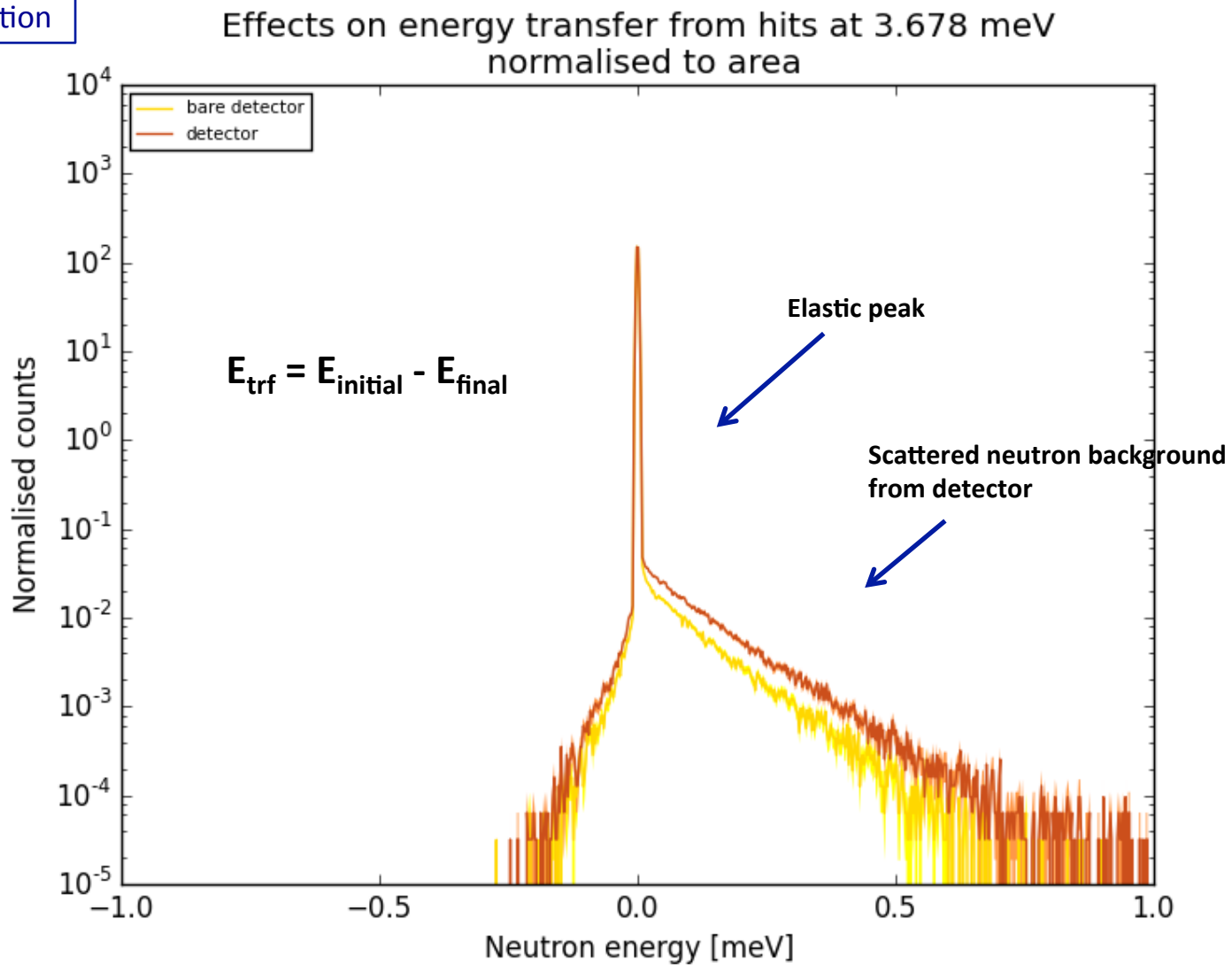

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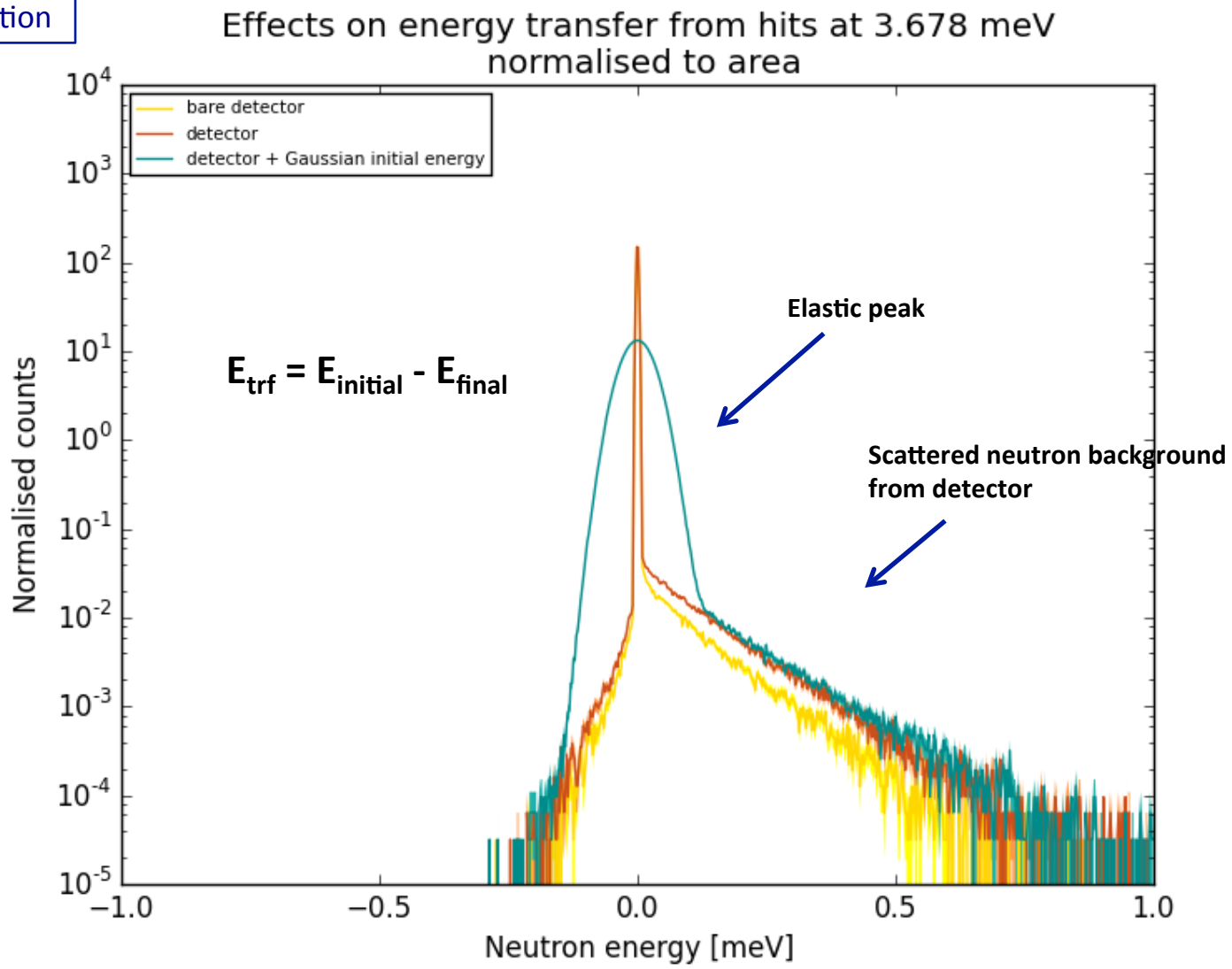

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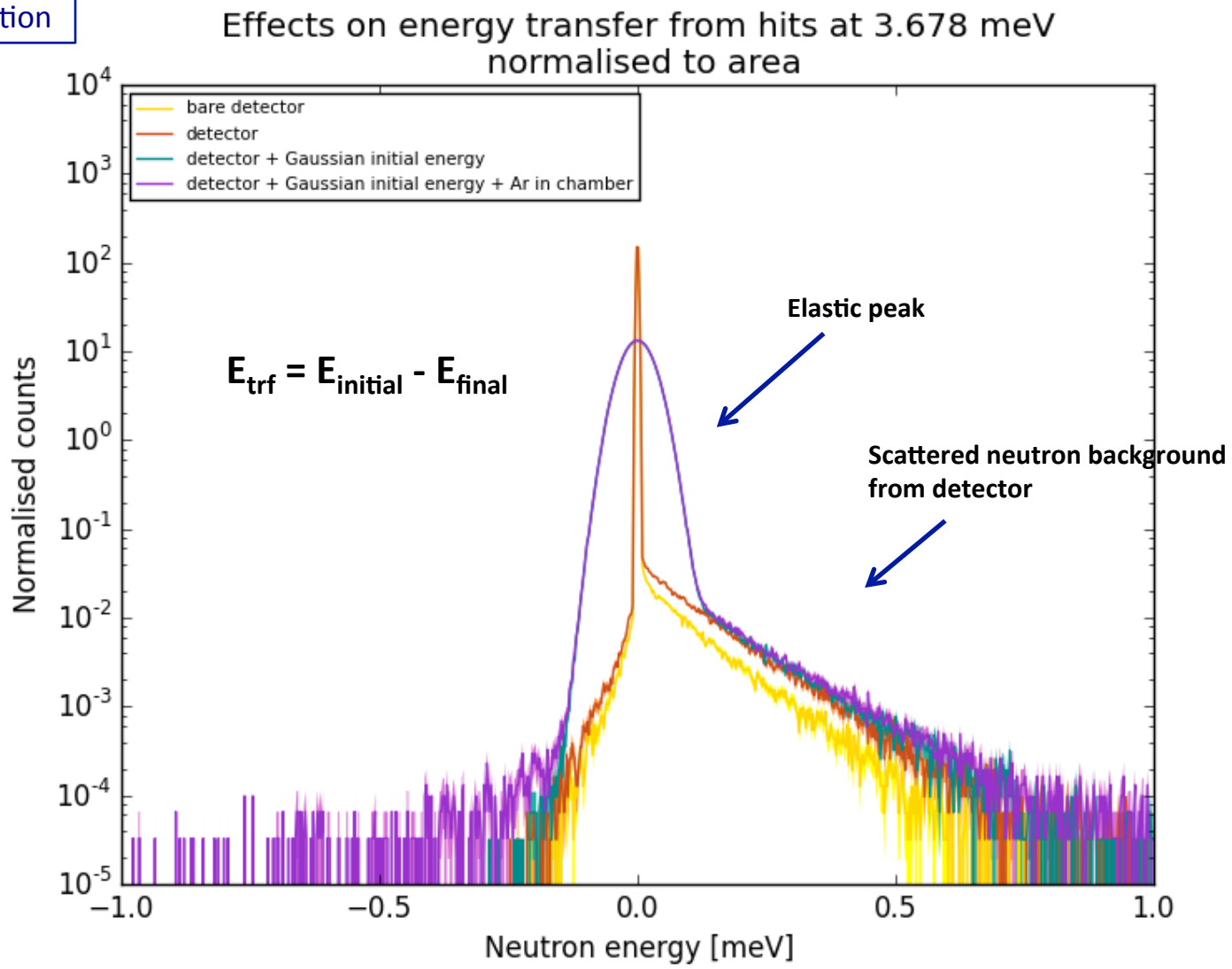
NXSG4



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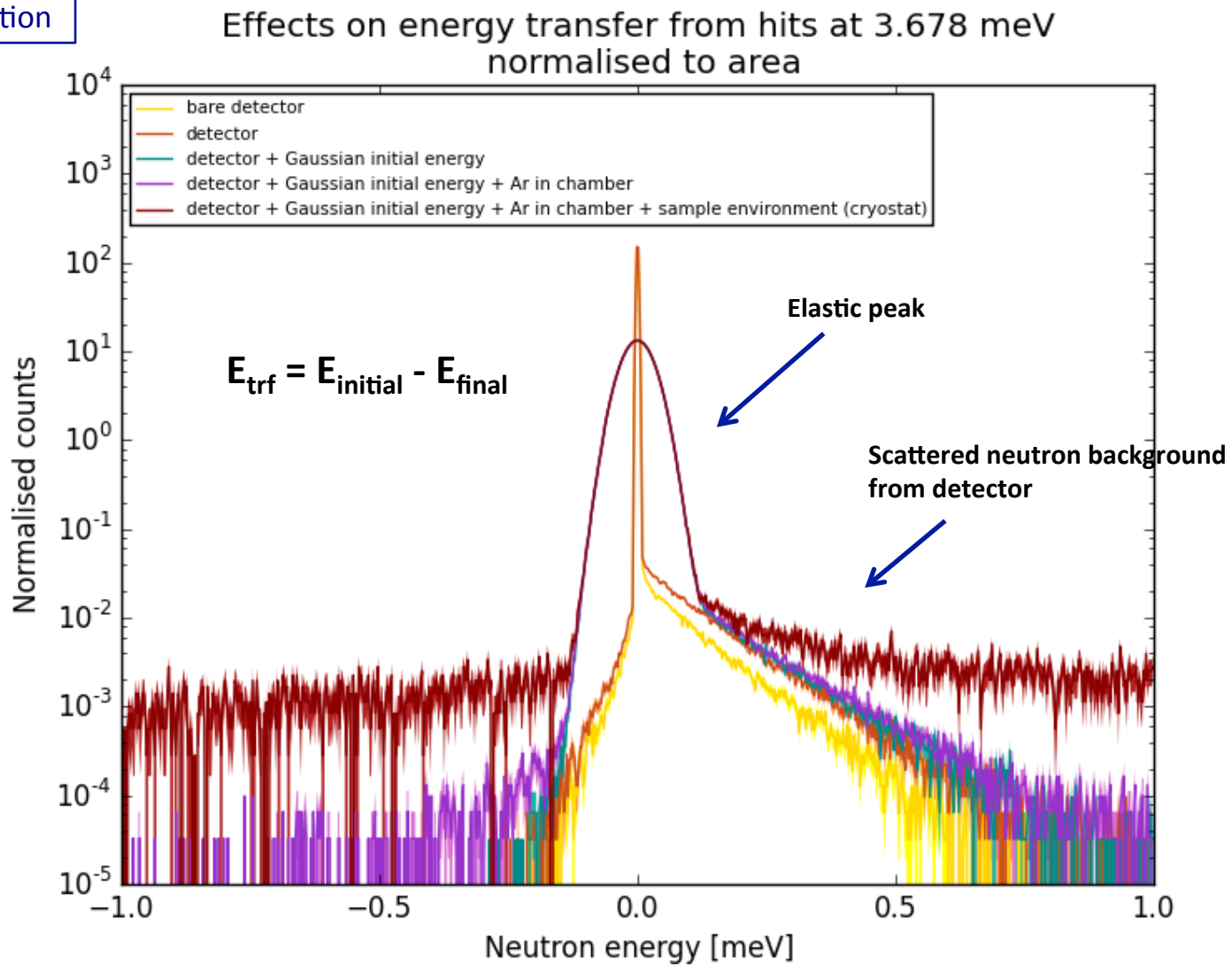

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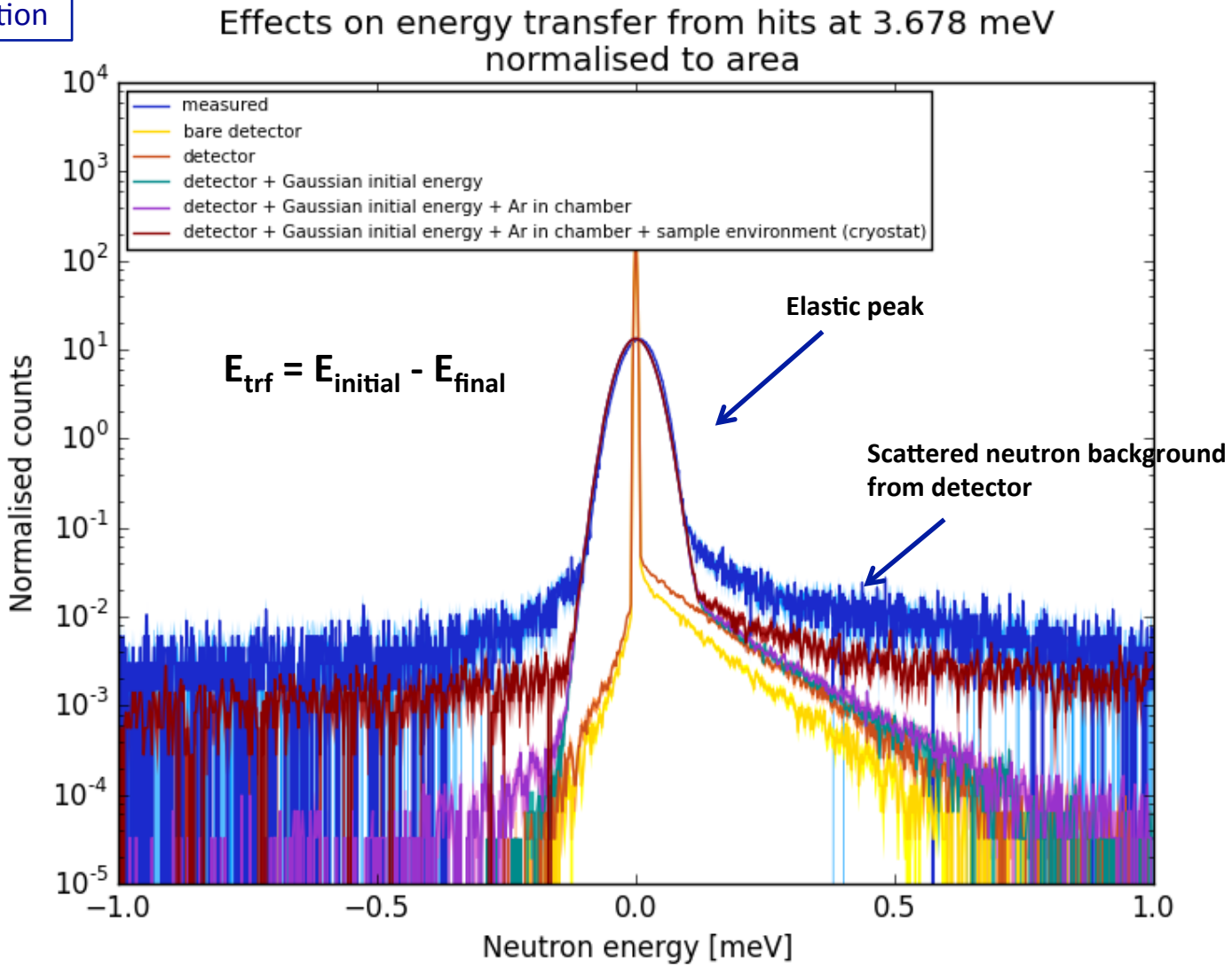

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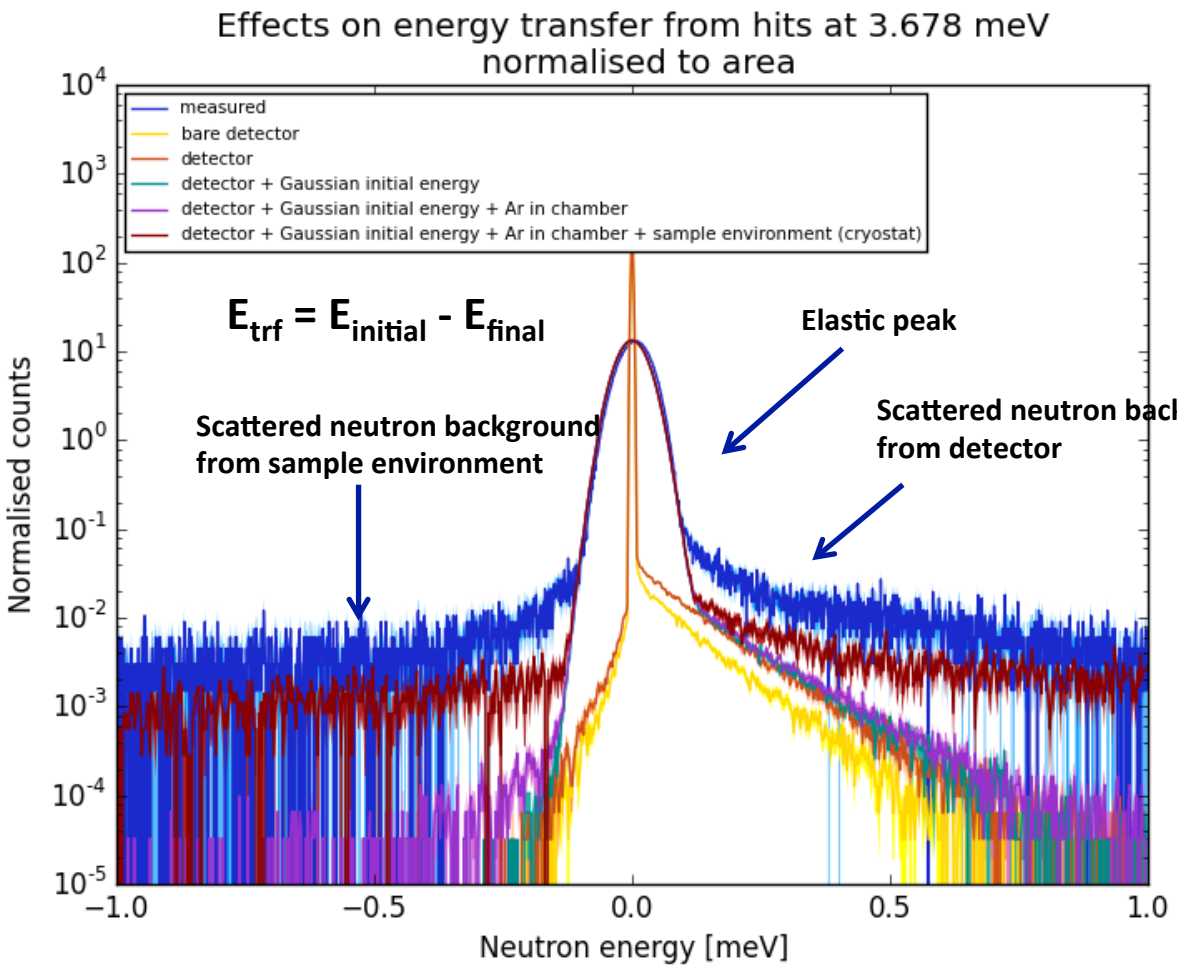

Validation

Energy transfer reproduced with simulation at 3.678 meV

Distinguish different sources of background

Detailed analysis and quantification of background effects

Optimization

Conclusion

- Realistic Multi-Grid model built
  - reproduced measured results from IN6 and CNCS experiments
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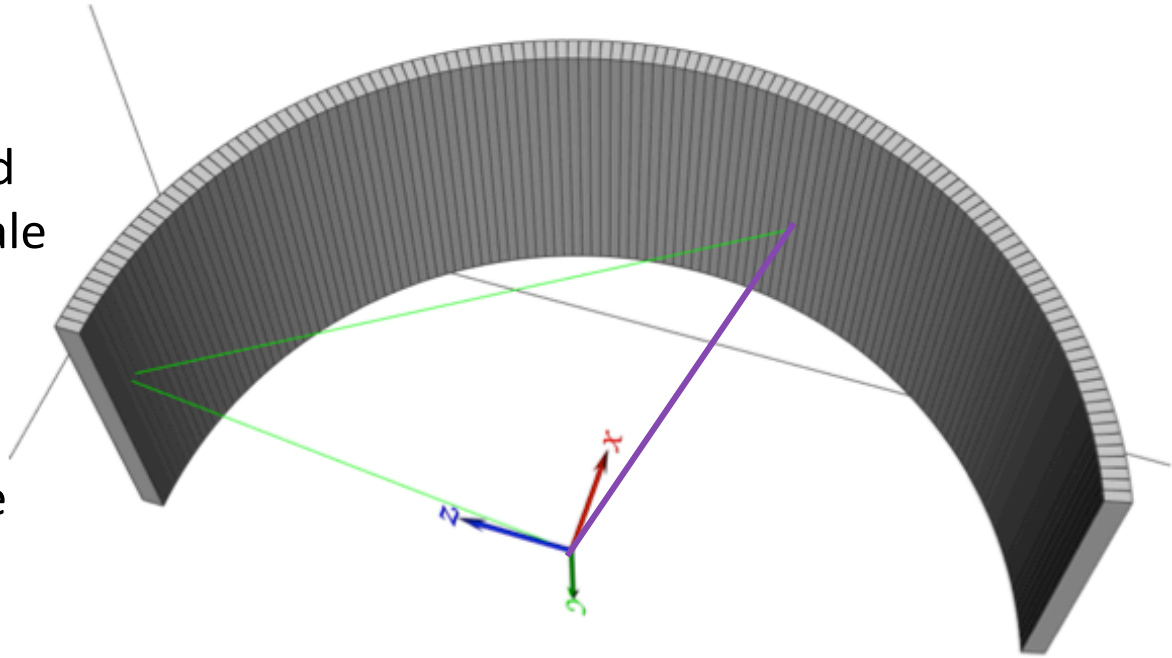


Backup slides

Multi-Grid detector test at ILL

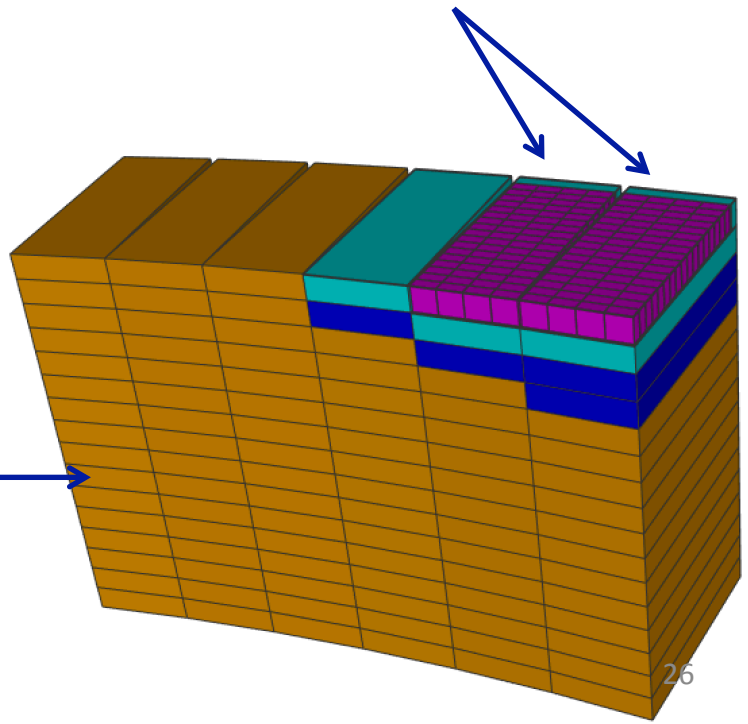
Geant4 @Coding Framework

In-beam test of the Boron-10 Multi-Grid neutron detector at the IN6 time-of-flight spectrometer at the ILL

S. Agostinelli et al
doi:10.1016/S0168-9002(03)01368-8
T. Kittelmann et al
doi:10.1088/1742-6596/513/2/022017

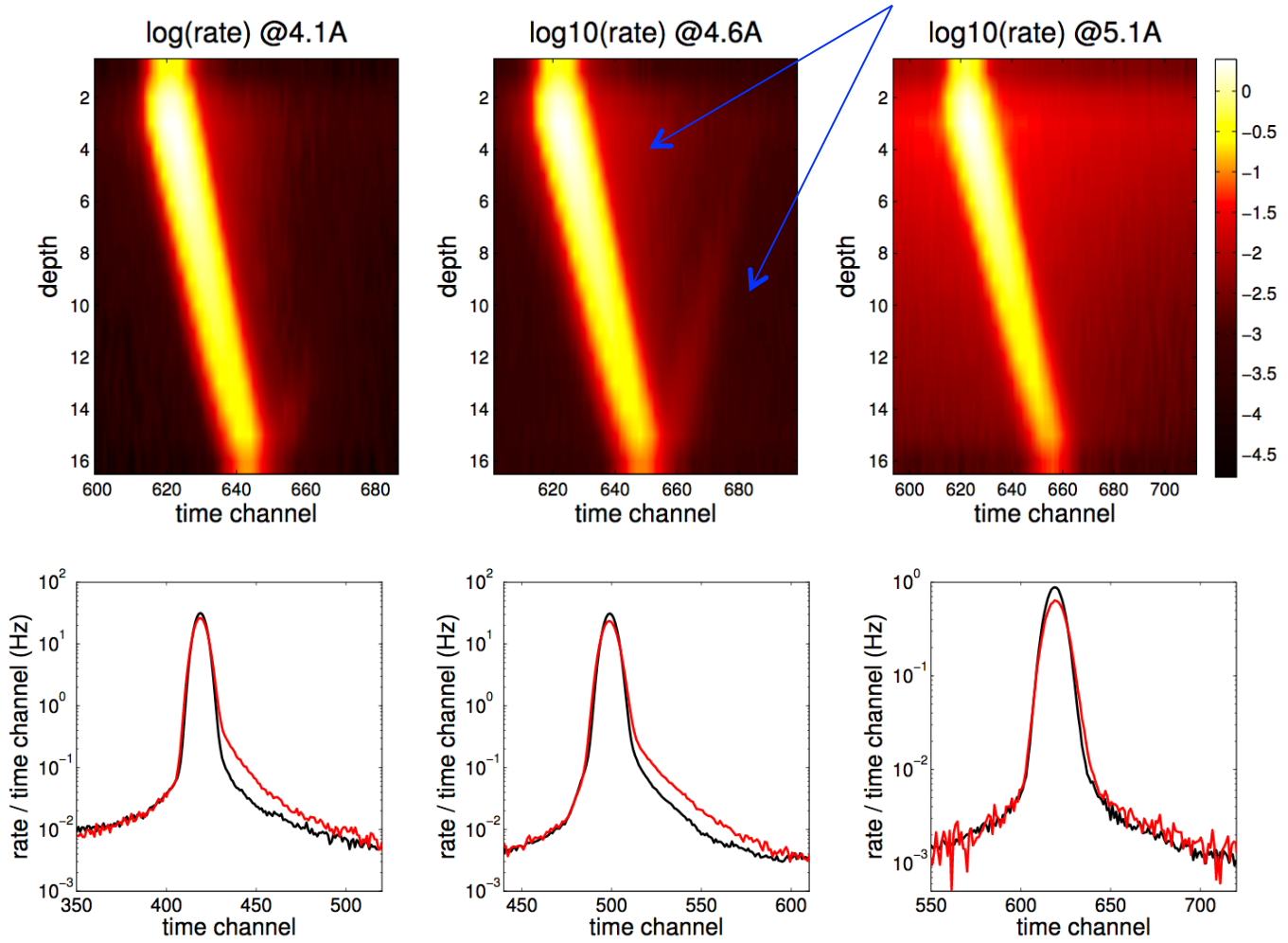
A. Khaplanov et al.
http://iopscience.iop.org/article/10.1088/1742-6596/528/1/012040/pdf

No shielding on the rear wall of grids



Multi-Grid detector test at ILL
Measured data (ToF, depth of detection)

Measured scattering phenomena can be studied with simulation inside the detector



MultiGrid detector test at ILL

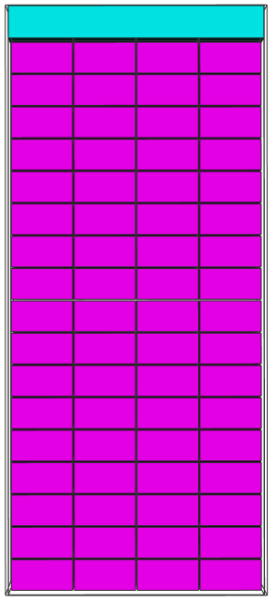
Measured and simulated ToF-depth of detection

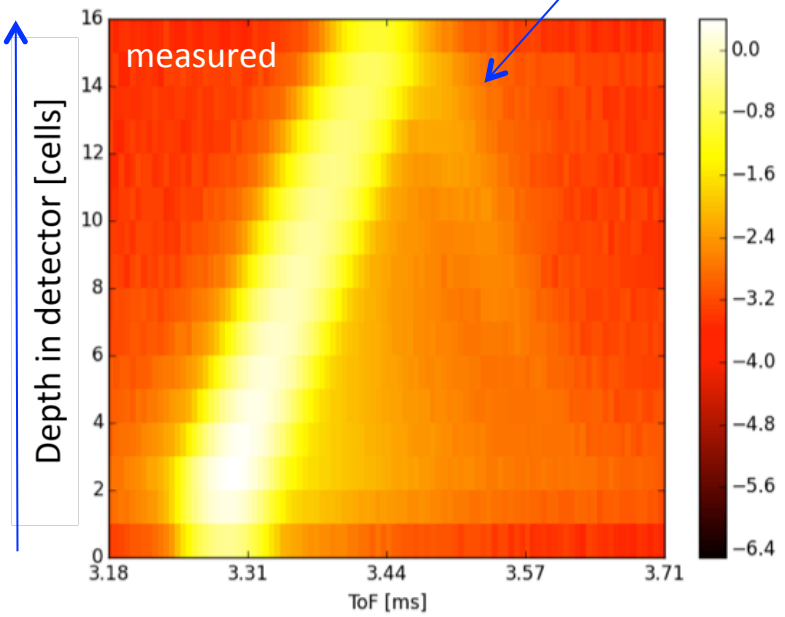
Geant4 @Coding Framework

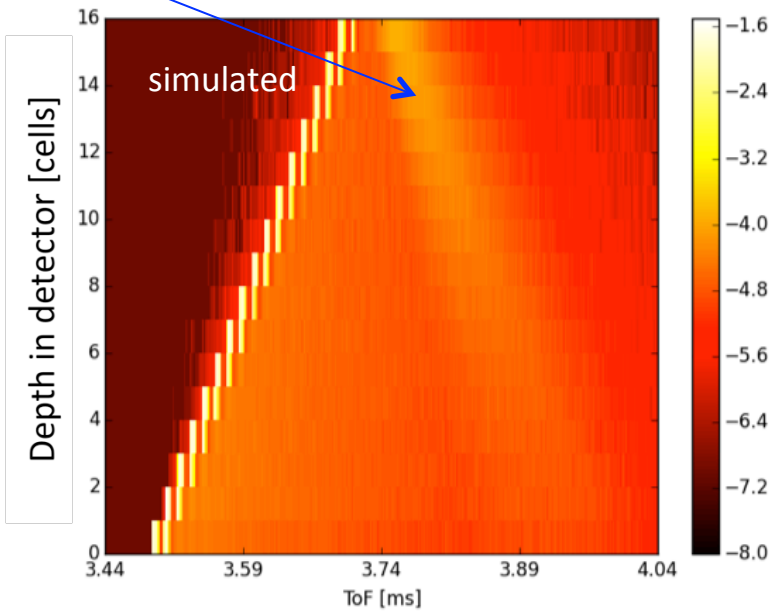
NXSG4

http://nxsg4.web.cern.ch/nxsg4/

Backscatter from the unshielded rear wall of the detector at 4.6 Å







ToF

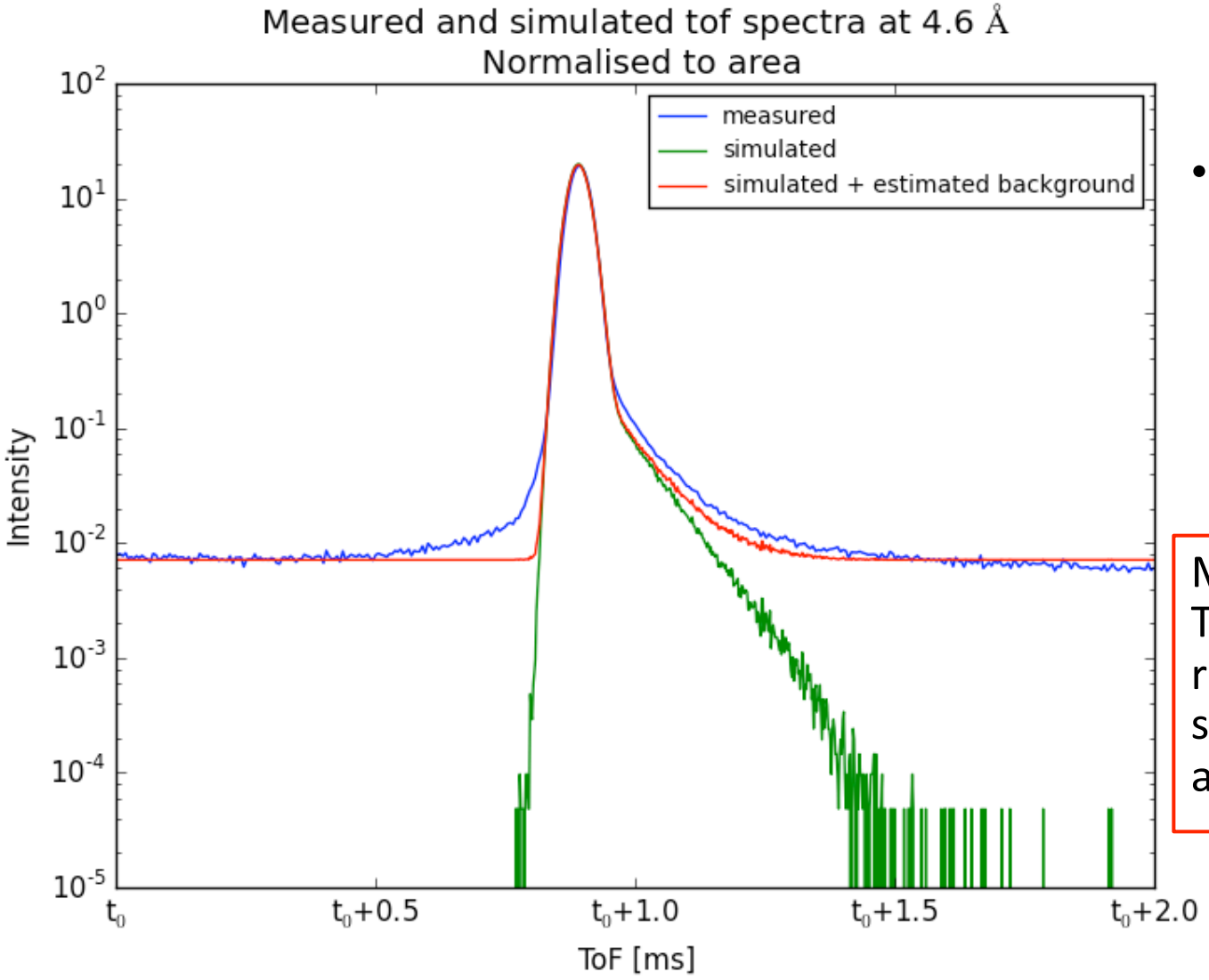
Validation

Measured ToF-depth characteristic and backscatter phenomena reproduced with simulation at 4.1 and 4.6 Å

MultiGrid detector test at ILL

Measured and simulated ToF spectra

NXSG4



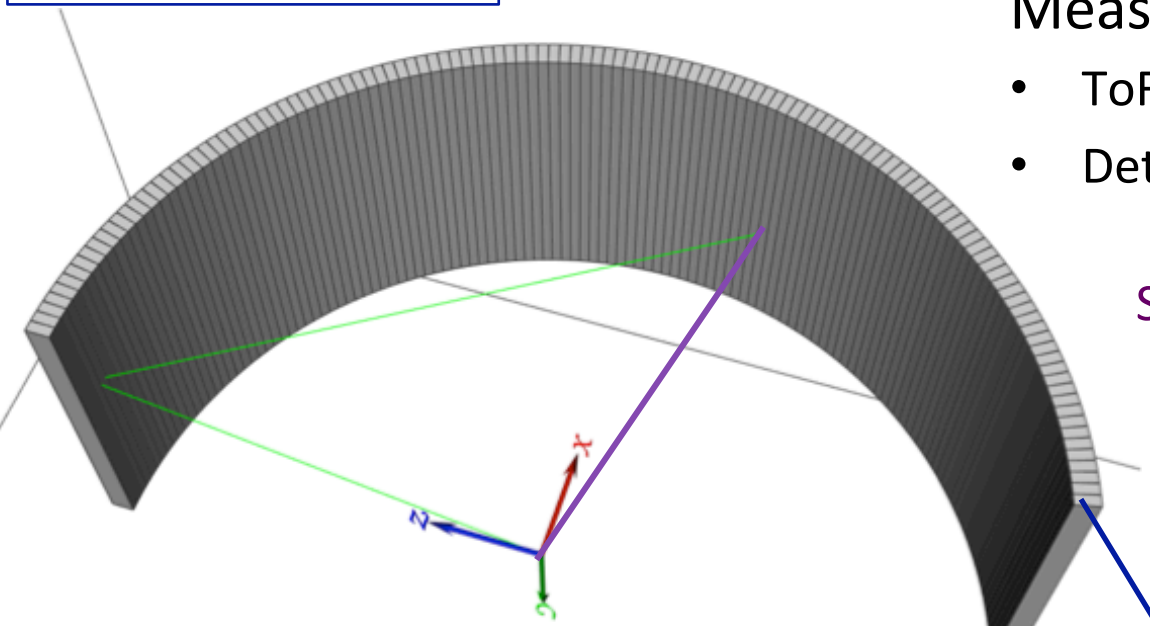
- Estimated flat alpha-background added (red), unique for this prototype

Measured ToF-spectrum reproduced with simulation at 4.1 and 4.6 Å

Validation

Large area detector for chopper spectroscopy – Multi-Grid

Geant4 @Coding Framework



Measured data:

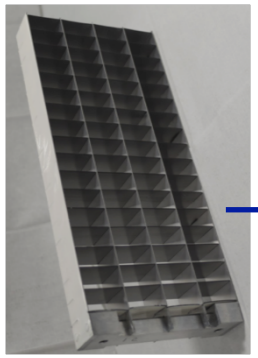
- ToF
- Detection point coordinates

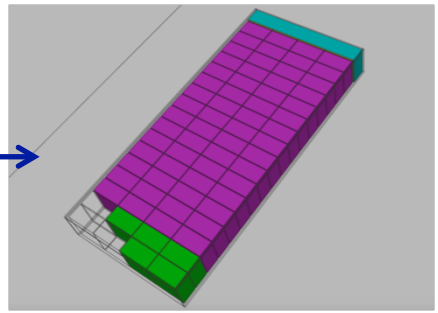
} Energy

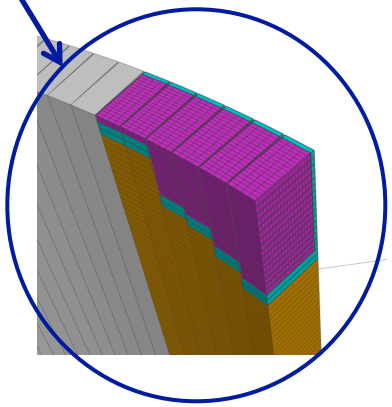
Sample – detection point distance

≠

Real neutron path





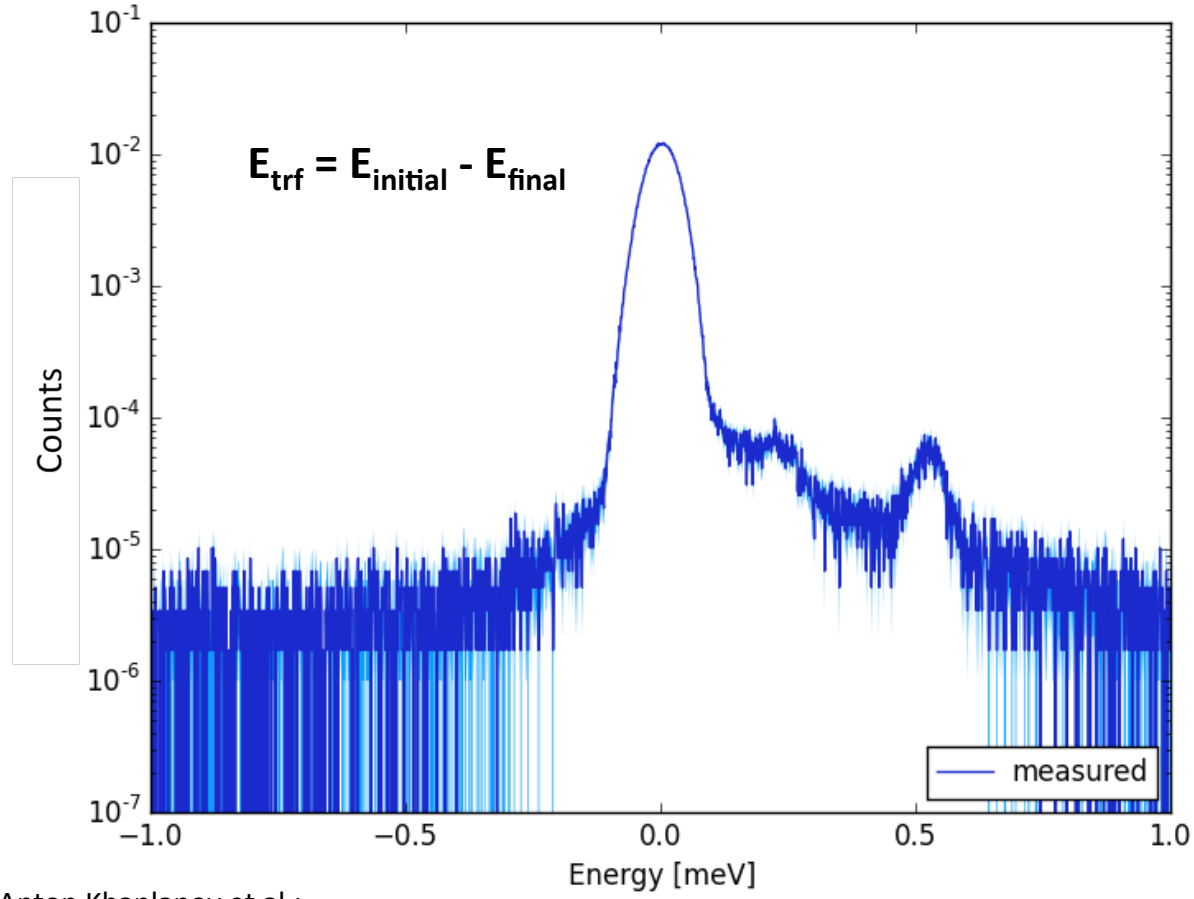


A. Khaplanov et al.

http://dx.doi.org/10.1016/j.nima.2012.12.021

MultiGrid detector test at CNCS
[Anton Khaplanov]

Derived energy transfer at 3.807 meV from measurement



- Chopper spectroscopy
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Anton Khaplanov et al.:
Multi-Grid Detector for Neutron Spectroscopy: Results Obtained on Time-of-Flight Spectrometer CNCS
Submitted to JINST arXiv:1703.03626

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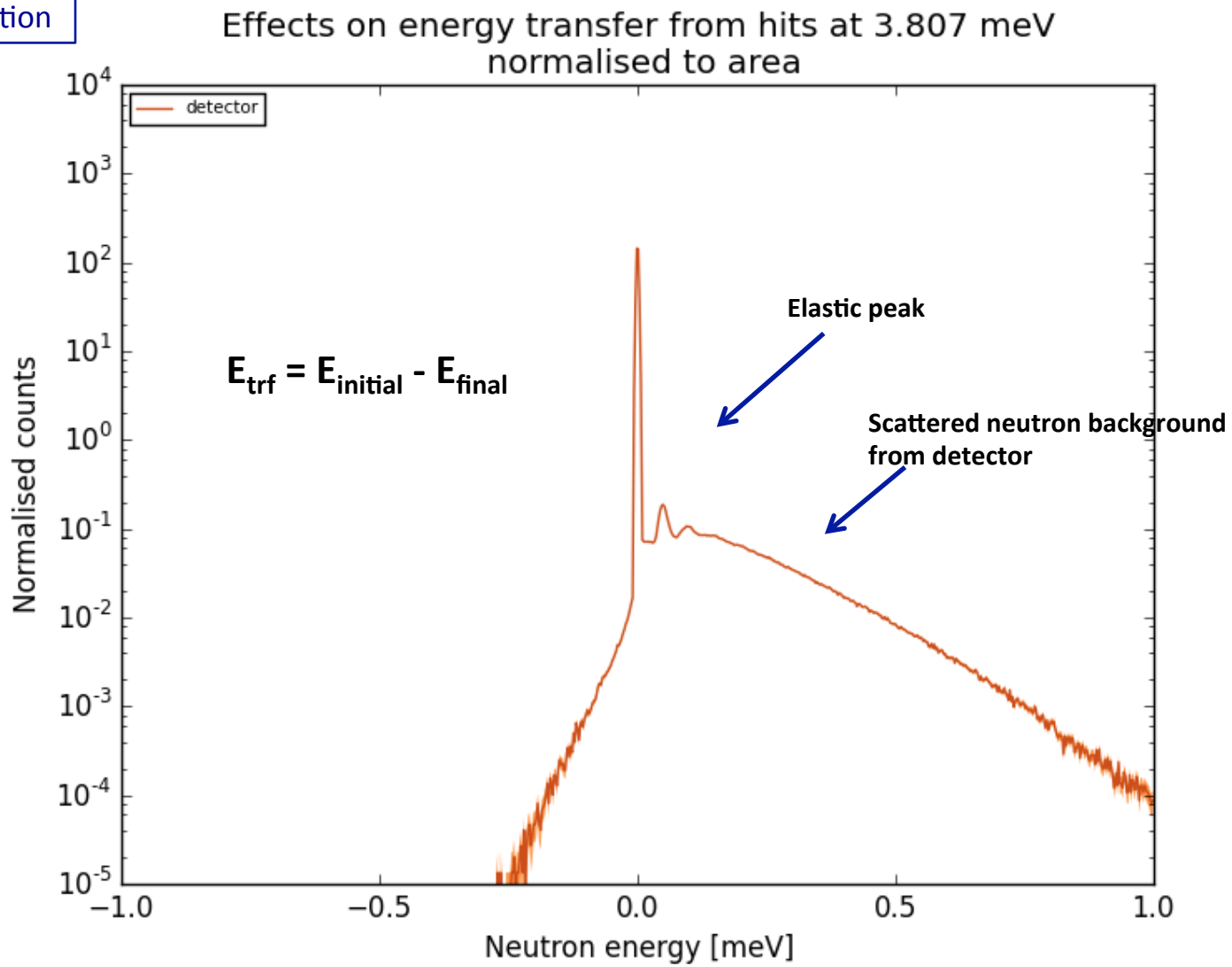

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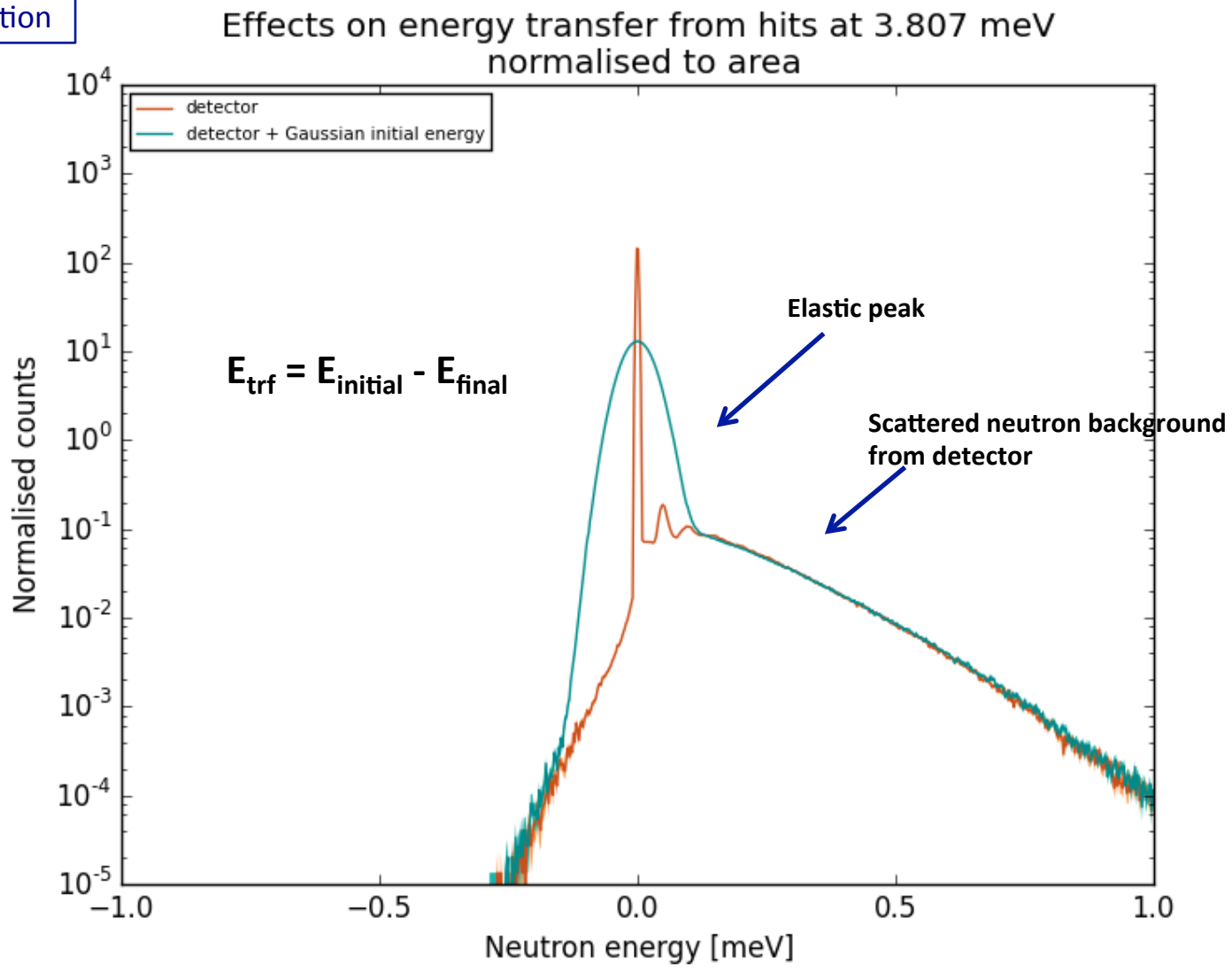

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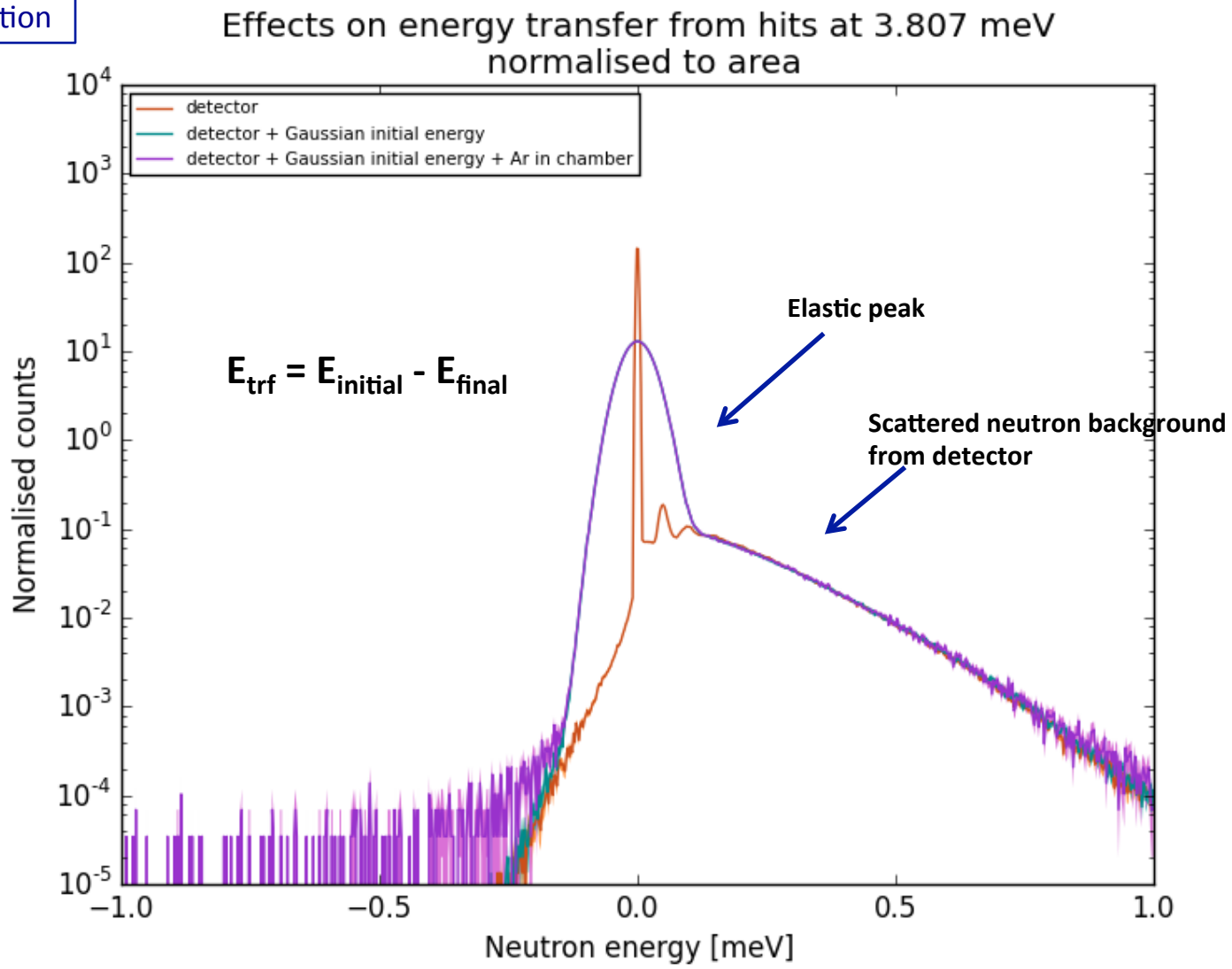

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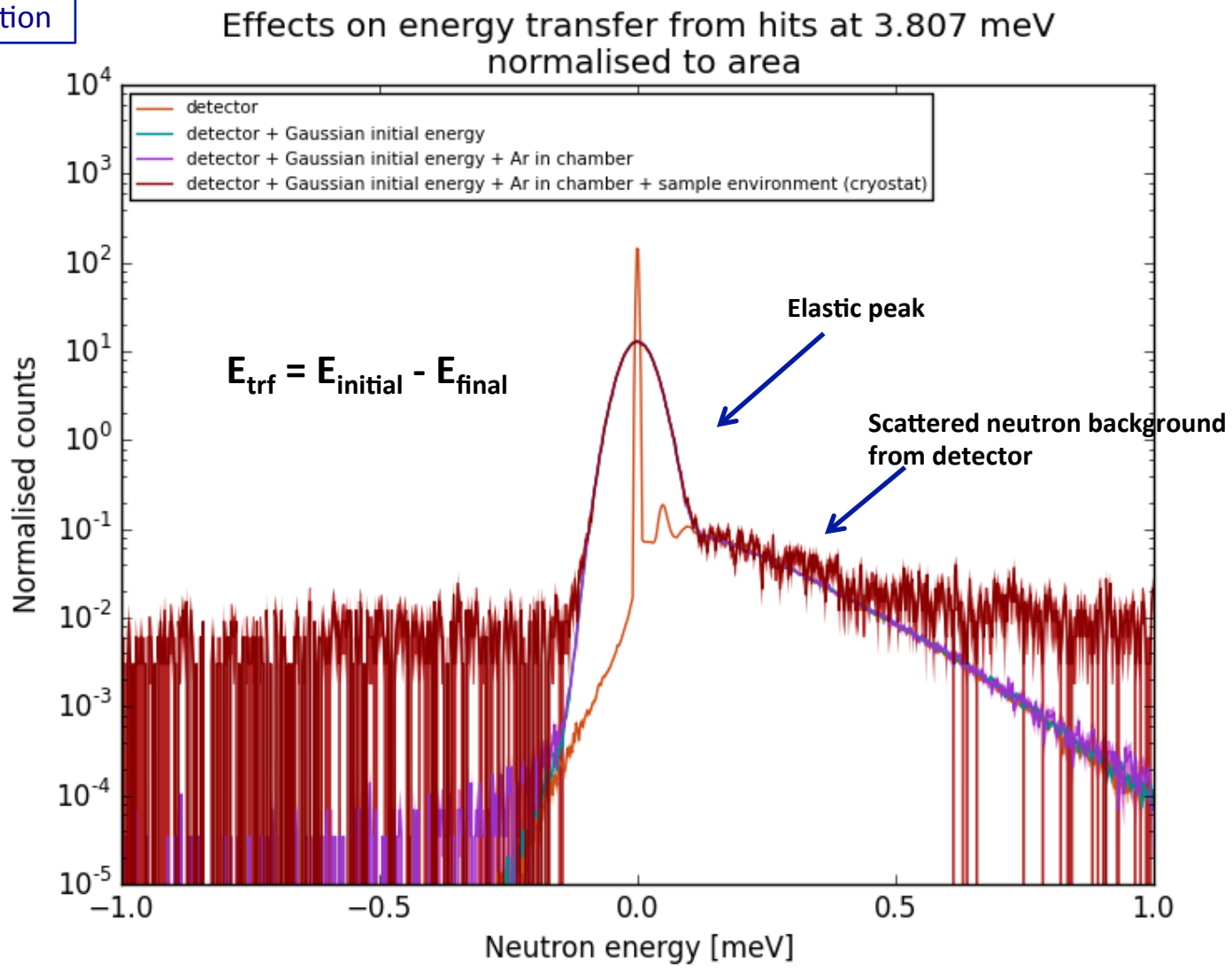

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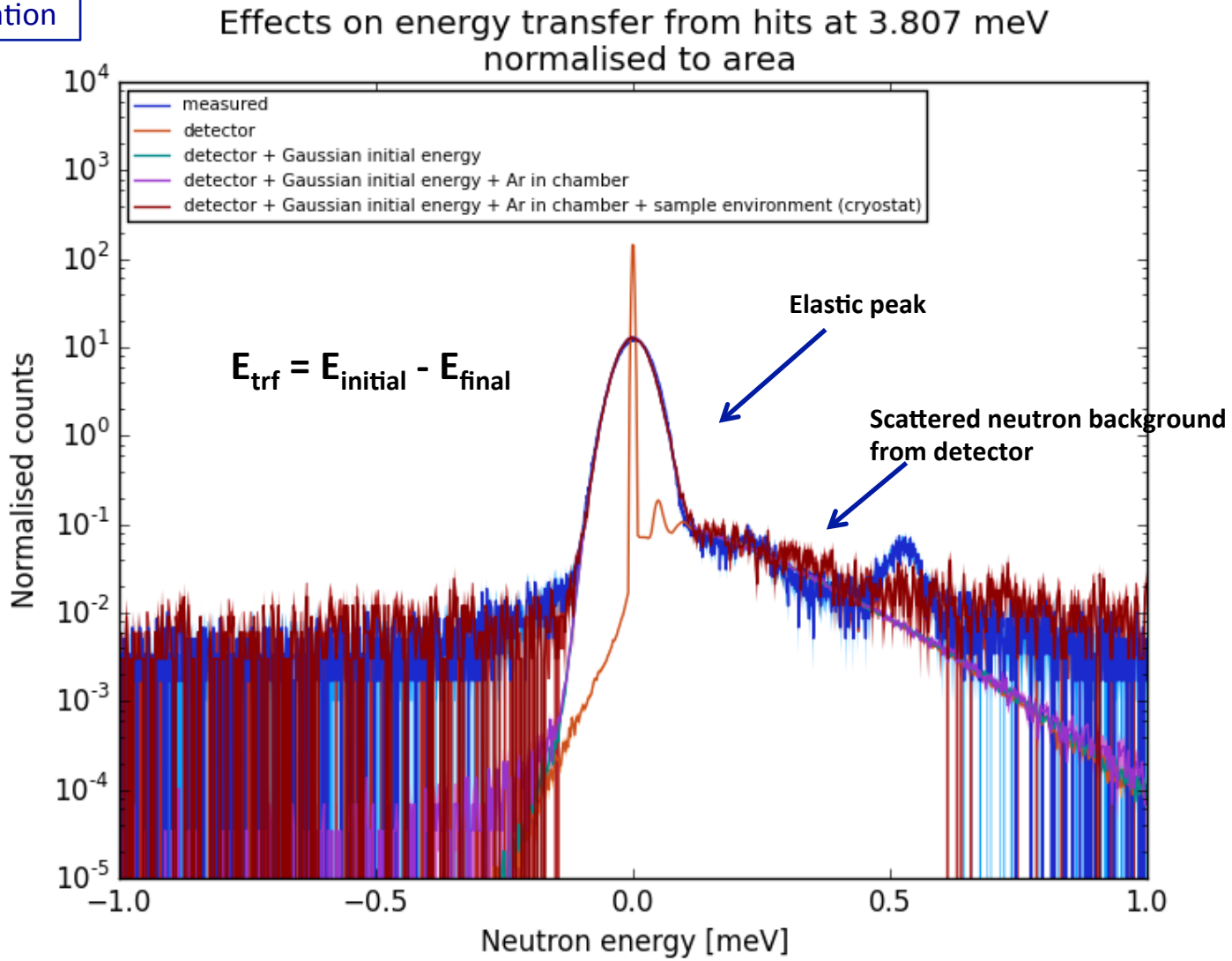

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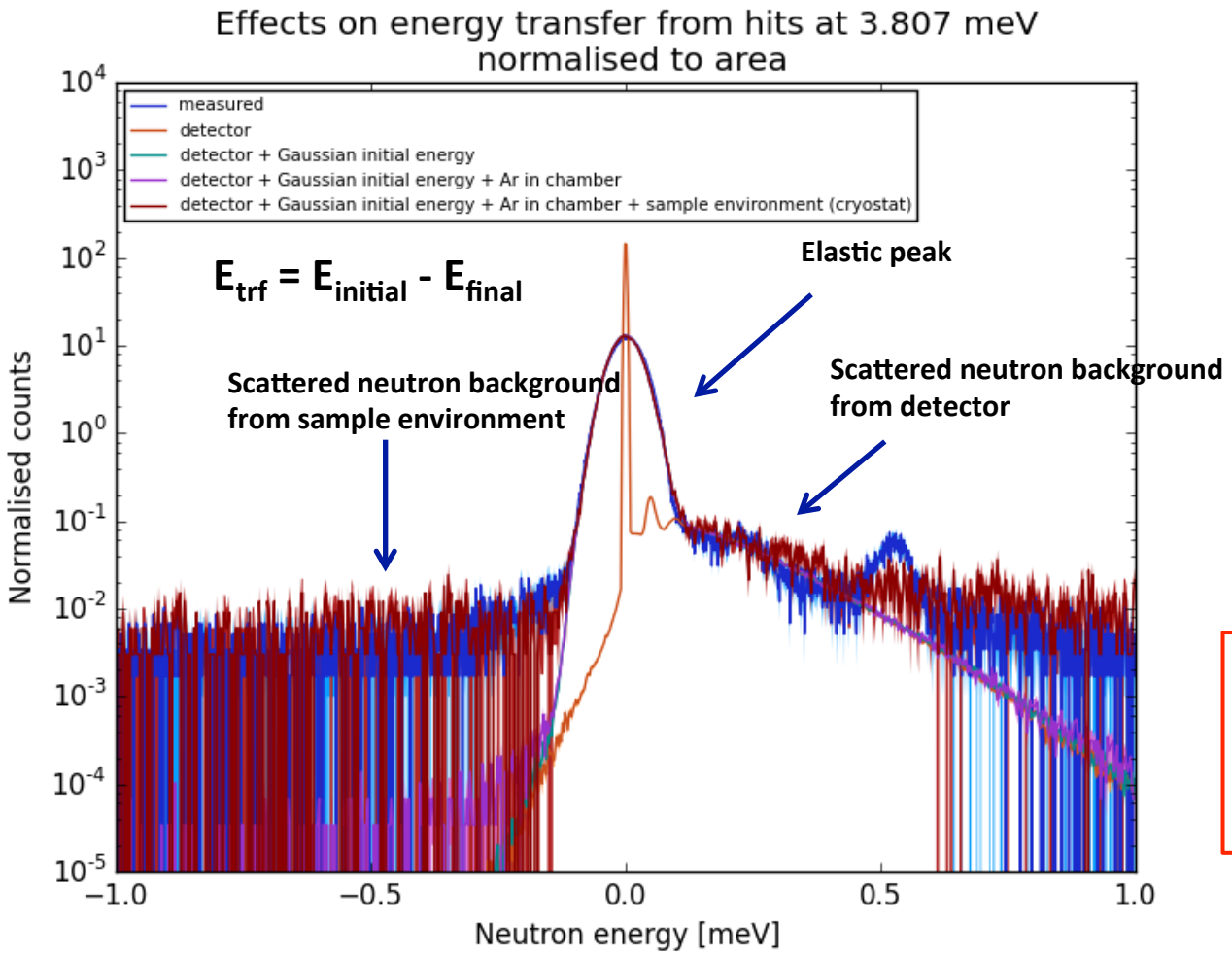

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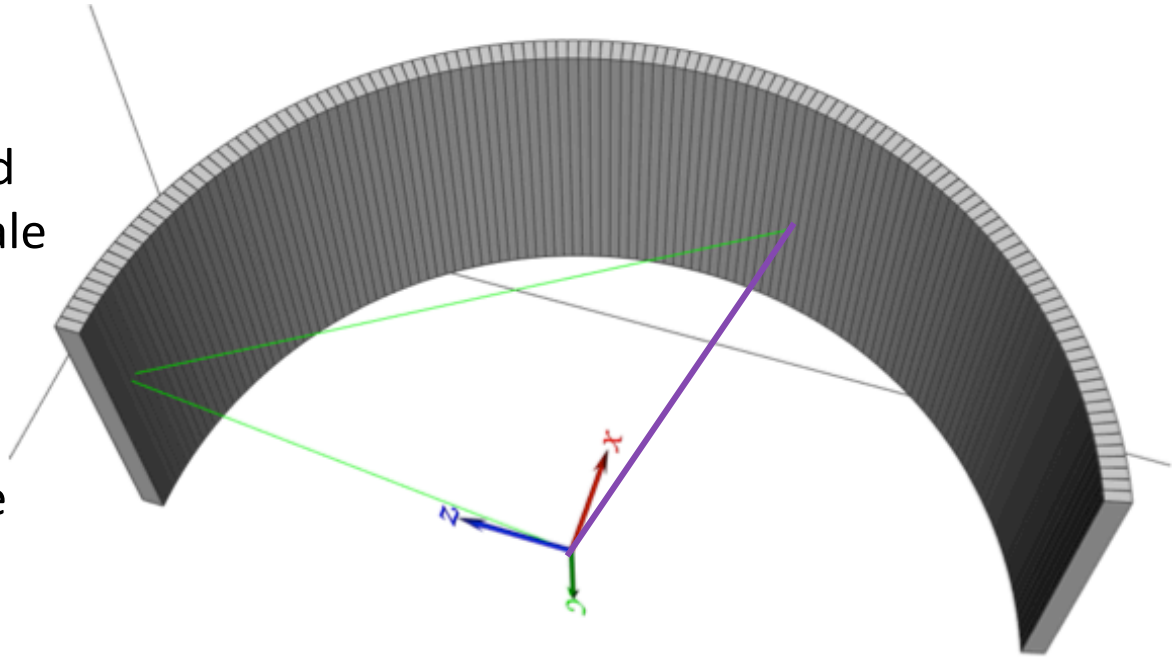

Thank you for your attention!