Detector rate estimate for the BIFROST instrument at ESS

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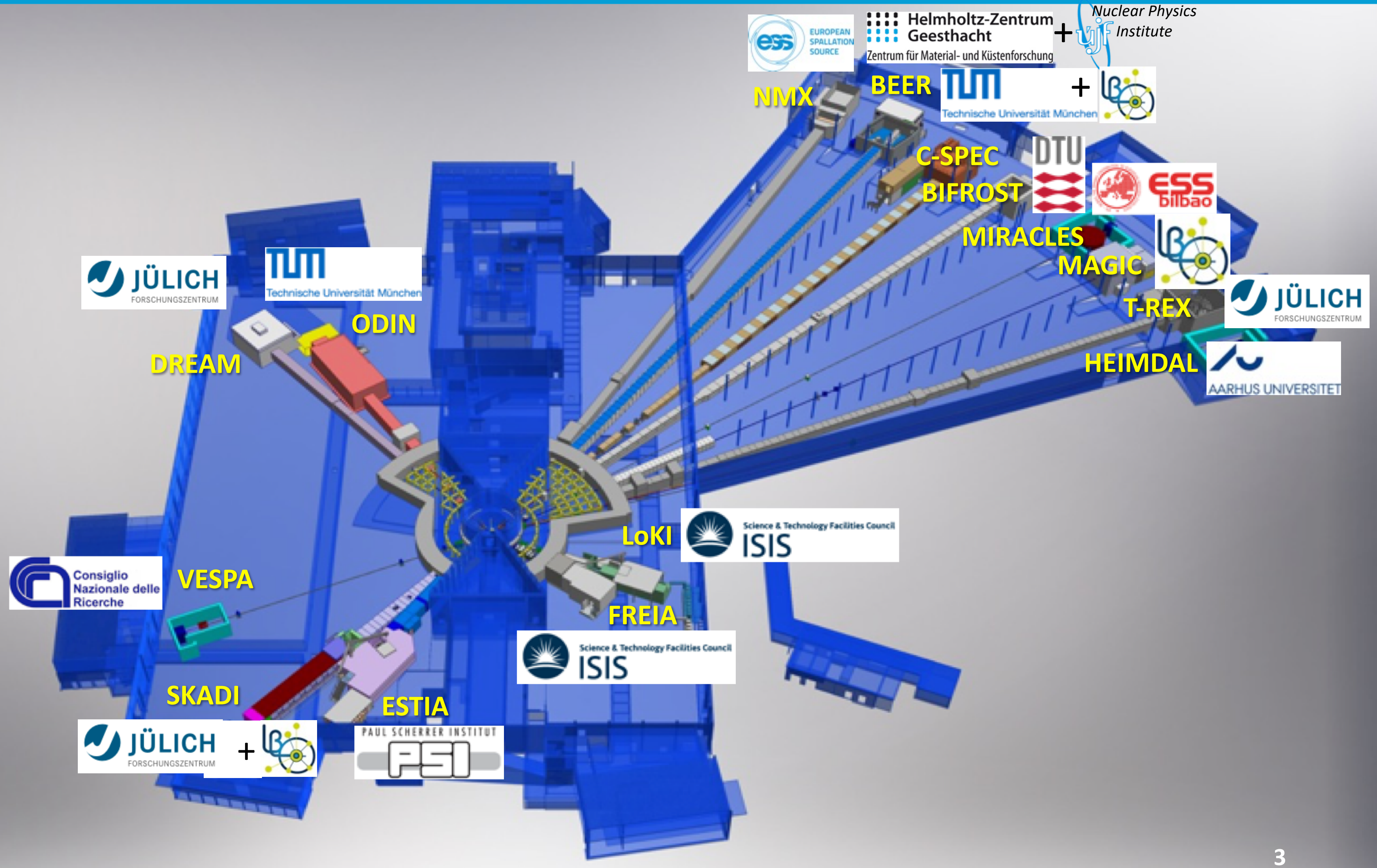
Outline

EUROPEAN SPALLATION SOURCE

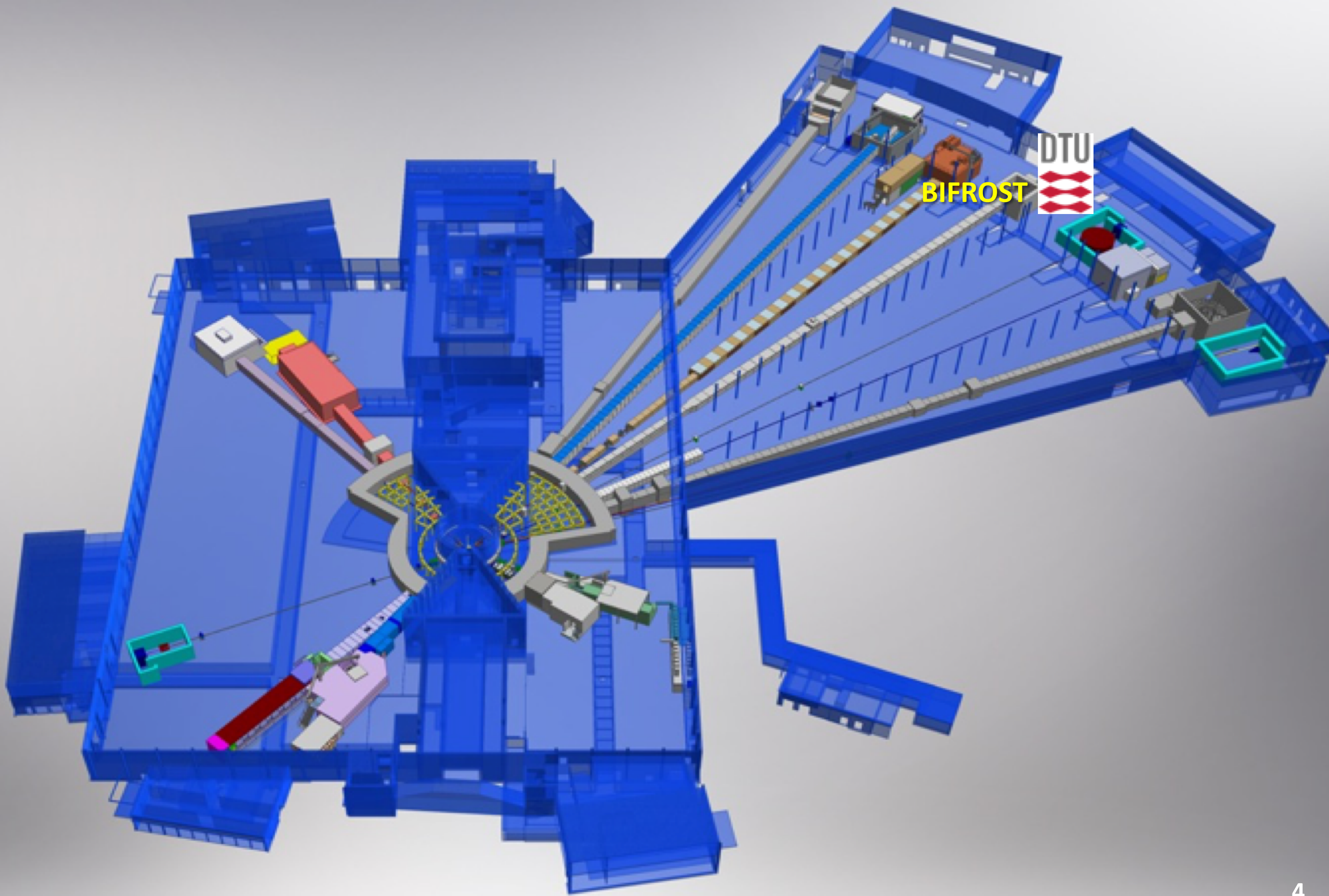
- **BIFROST Instrument**
- Simulation Tools
- Simulation Model
- Results
- Outlook

ESS - Instruments

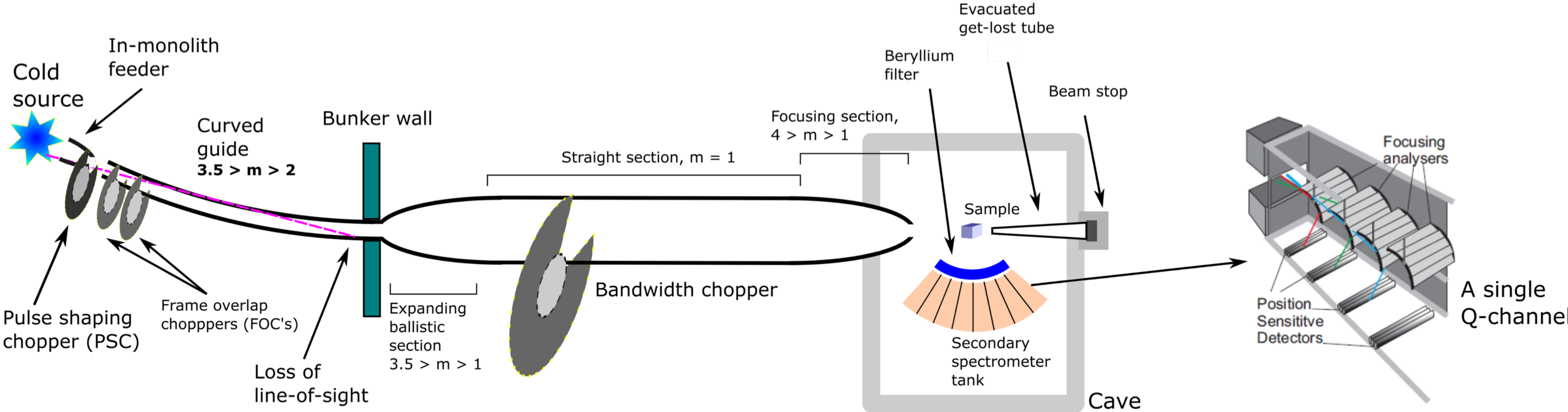


Location of BIFROST

EUROPEAN SPALLATION SOURCE

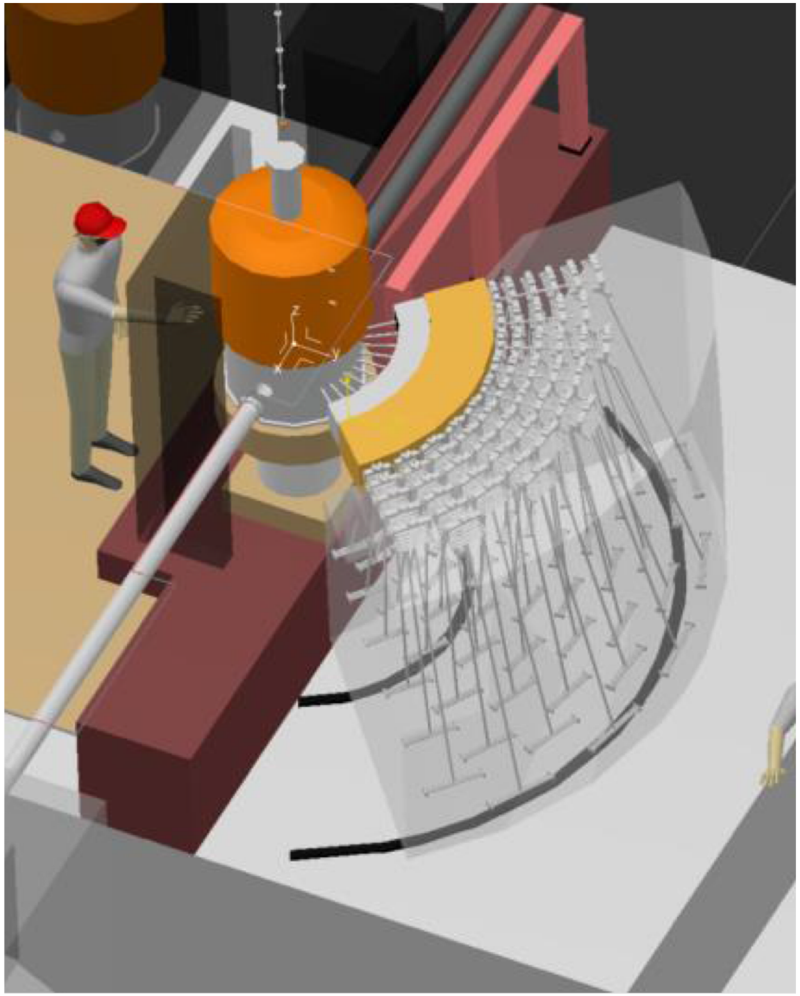


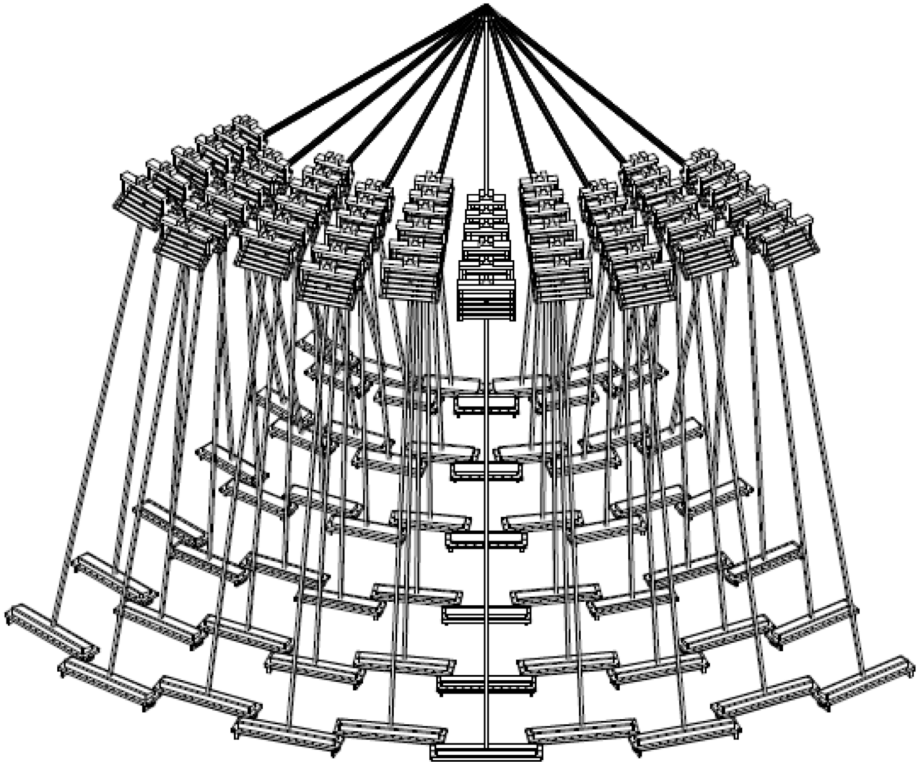
Bifrost instrument



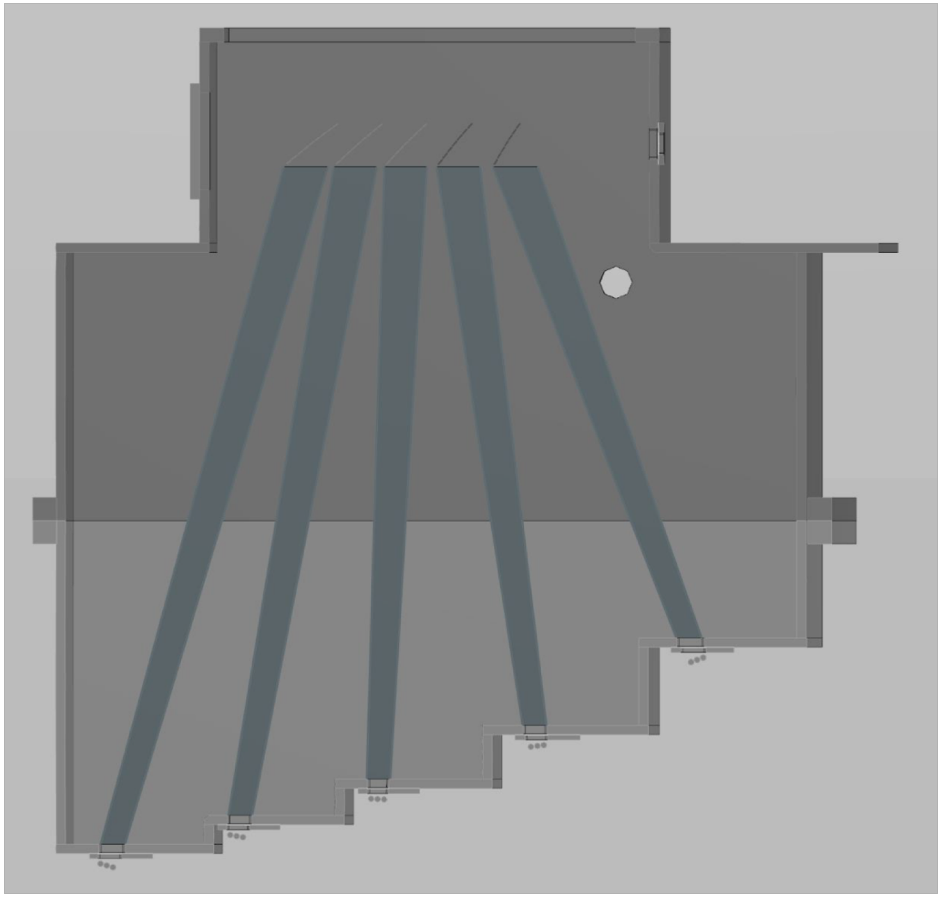
- High flux indirect geometry cold spectrometer
- Small sample (1 mm^3) in extreme environment
- Relatively simple beam transport and conditioning system
- Option to use full ESS pulse in low resolution mode

Scattering Characterization System





Scattering Characterization System



- **10^{10} n/s/cm^2** flux on sample
- Detect weak inelastic signal
- Survive intense Bragg peak
- Important to define the incident detector rate

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Simulation Tools - Options

Guide

Sample + analyzers

Detectors

Simulation Tools - Options

EUROPEAN SPALLATION SOURCE

Guide

Sample + analyzers

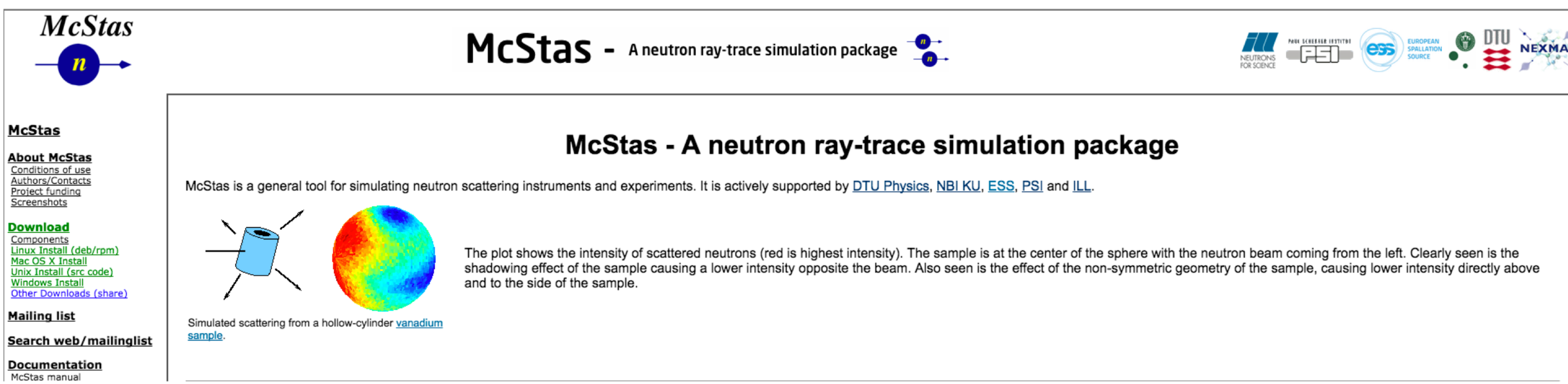
Detectors

McStas

Simulation Tools - McStas

- Simulation of neutron scattering instruments and experiments
- Monte Carlo ray-trace algorithm
- Cross-platform, open source
- Version 2.5 (December, 2018)

- Collaboration:
  - DTU Physics
  - University of Copenhagen
  - Paul Scherrer Institute
  - Institut Laue-Langevin



Source: http://mcstas.org/

Simulation Tools - Options

Guide

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McStas

GEANT4
A SIMULATION TOOLKIT

Simulation Tools: Geant4 + DG Framework

EUROPEAN SPALLATION SOURCE

– General purpose
– Developed in CERN
– Application in various fields

– Detector Group Framework
  - Code repository + build system
  - Tools, issue tracker, wiki
  - Geant4, C++, Python

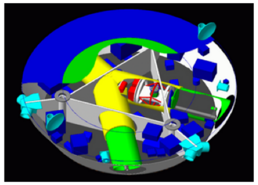
Geant 4

Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The two main reference papers for Geant4 are published in *Nuclear Instruments and Methods in Physics Research* A 506 (2003) 250-303, and *IEEE Transactions on Nuclear Science* 53 No. 1 (2006) 270-278.

Applications

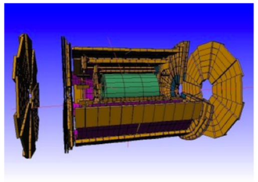
A sampling of applications, technology transfer and other uses of Geant4

User Support



Getting started, guides and information for users and developers

Publications



Validation of Geant4, results from experiments and publications

Collaboration

Who we are: collaborating institutions, members, organization and legal information

T. Kittelmann, et al., Geant4 based simulations for novel neutron detector development, J. Phys. Conf. Ser. 513 (2014) 022017

Source: http://geant4.cern.ch/

Simulation Tools - Options

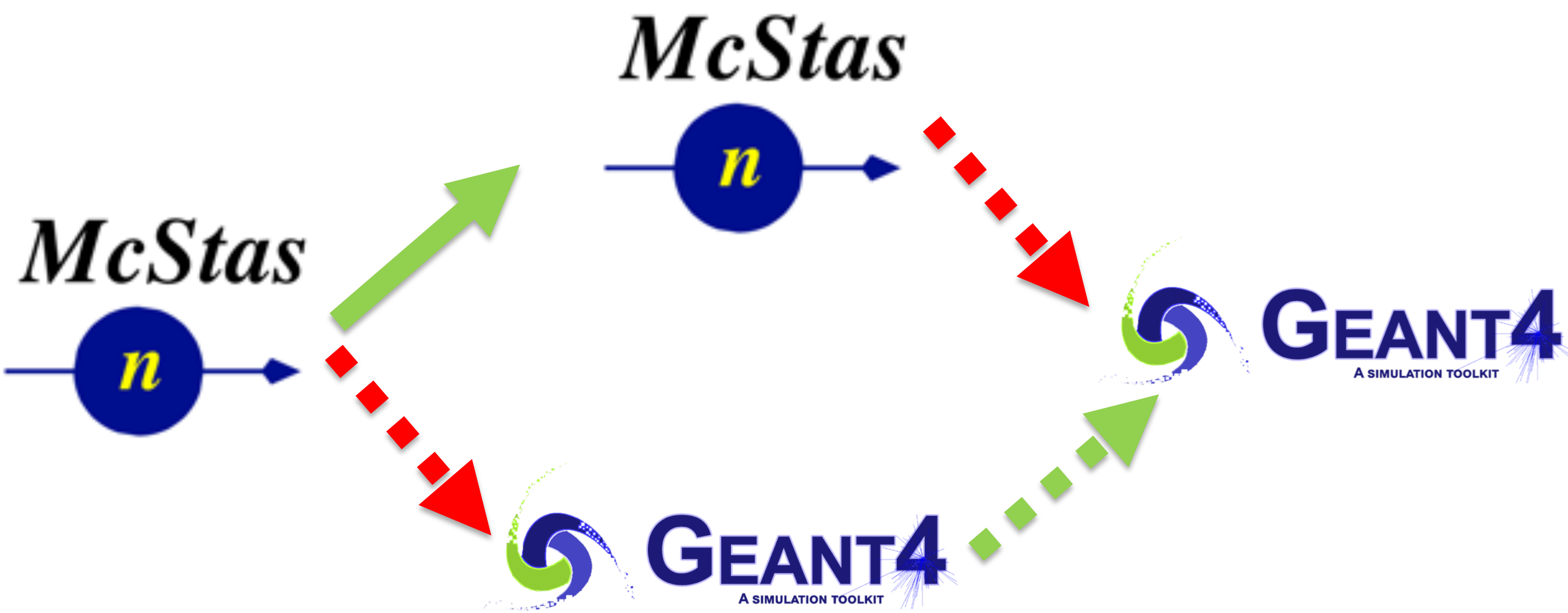
Guide	Sample + analyzers	Detectors
McStas	McStas, Geant4	Geant4

Simulation Tools - Options

Guide

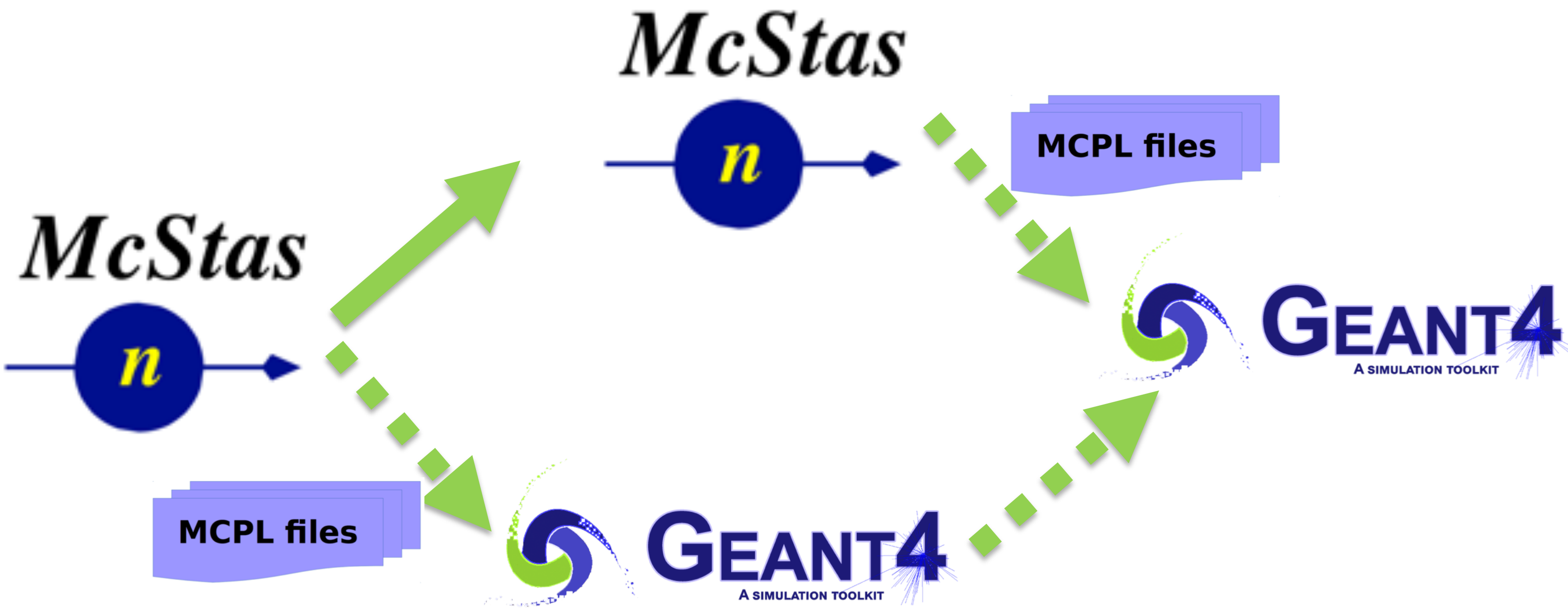
Sample + analyzers

Detectors



Simulation Tools - Options

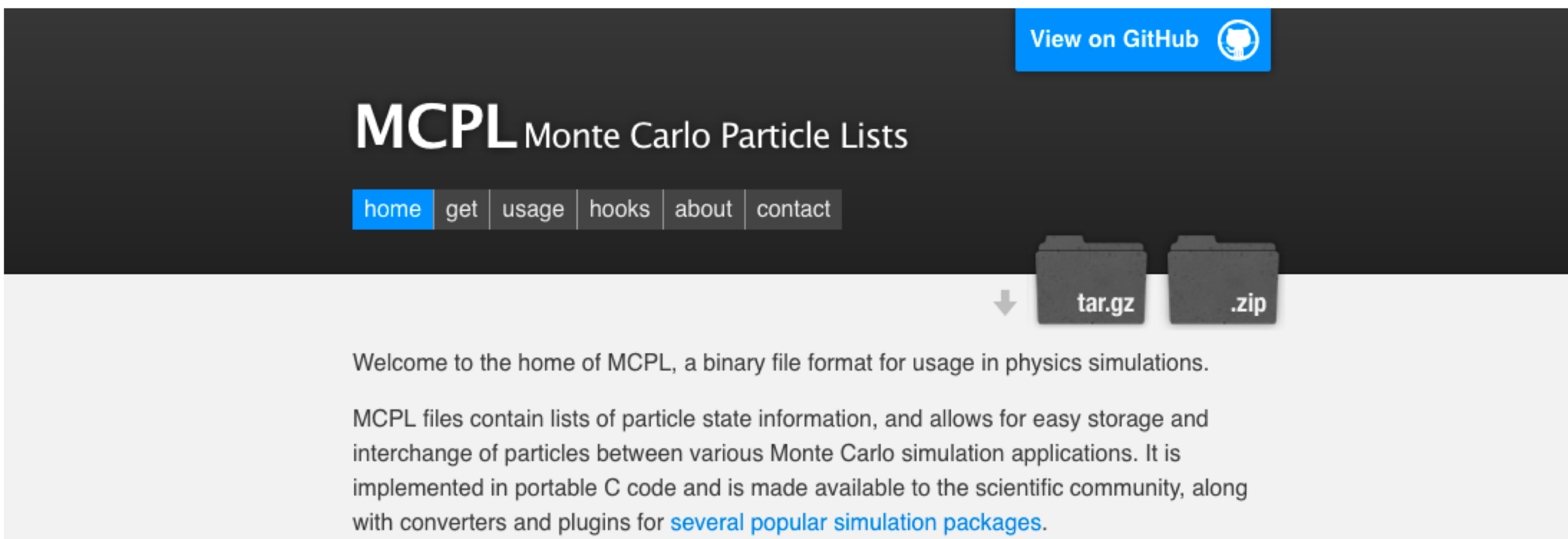
Guide | Sample + analyzers | Detectors



Monte Carlo Simulation: MCPL

- **M**onte **C**arlo **P**article **L**ist
- Binary format
- Open source

- Compatible MC tools
  - McStas
  - McXtrace
  - Geant4
  - MCNP6, MCNPX



T. Kittelmann et al., Monte Carlo Particle Lists: MCPL, Computer Physics Communications 218 (2017) 17-42.

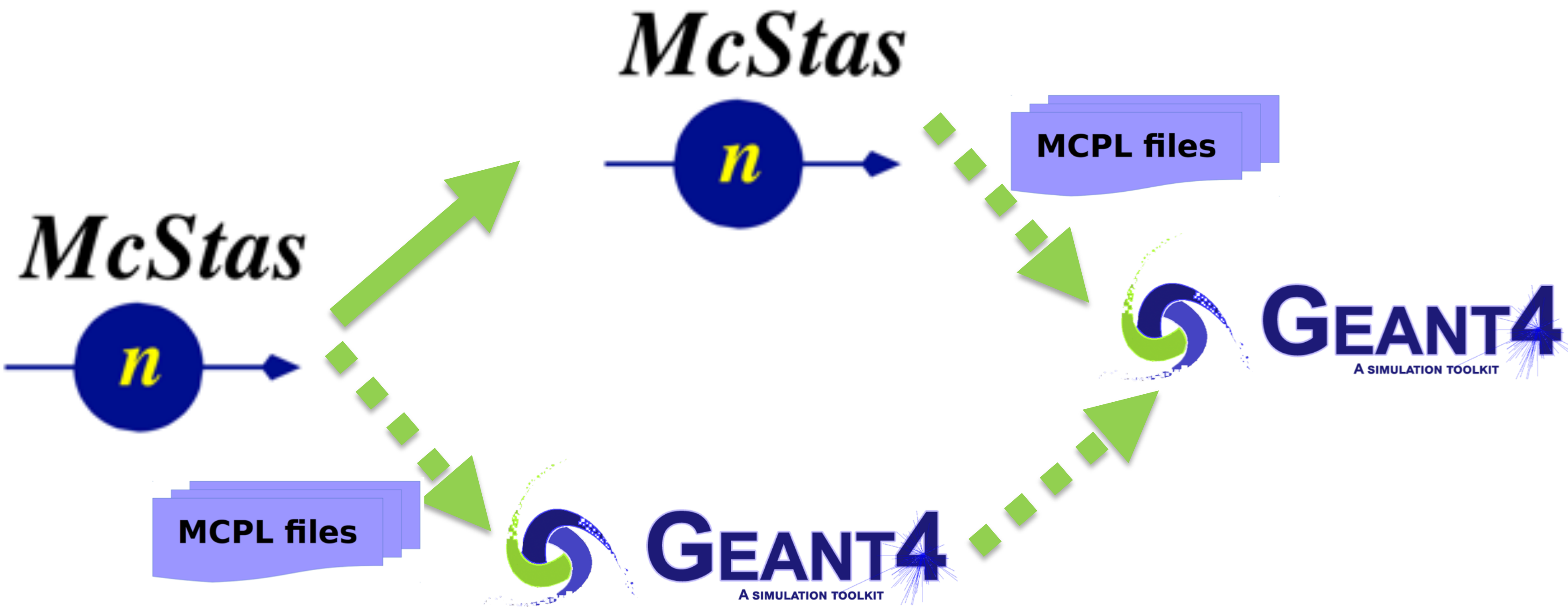
Source: https://mctools.github.io/mcpl/

Simulation Tools - Options

Guide

Sample + analyzers

Detectors



Simulation Tools - Options

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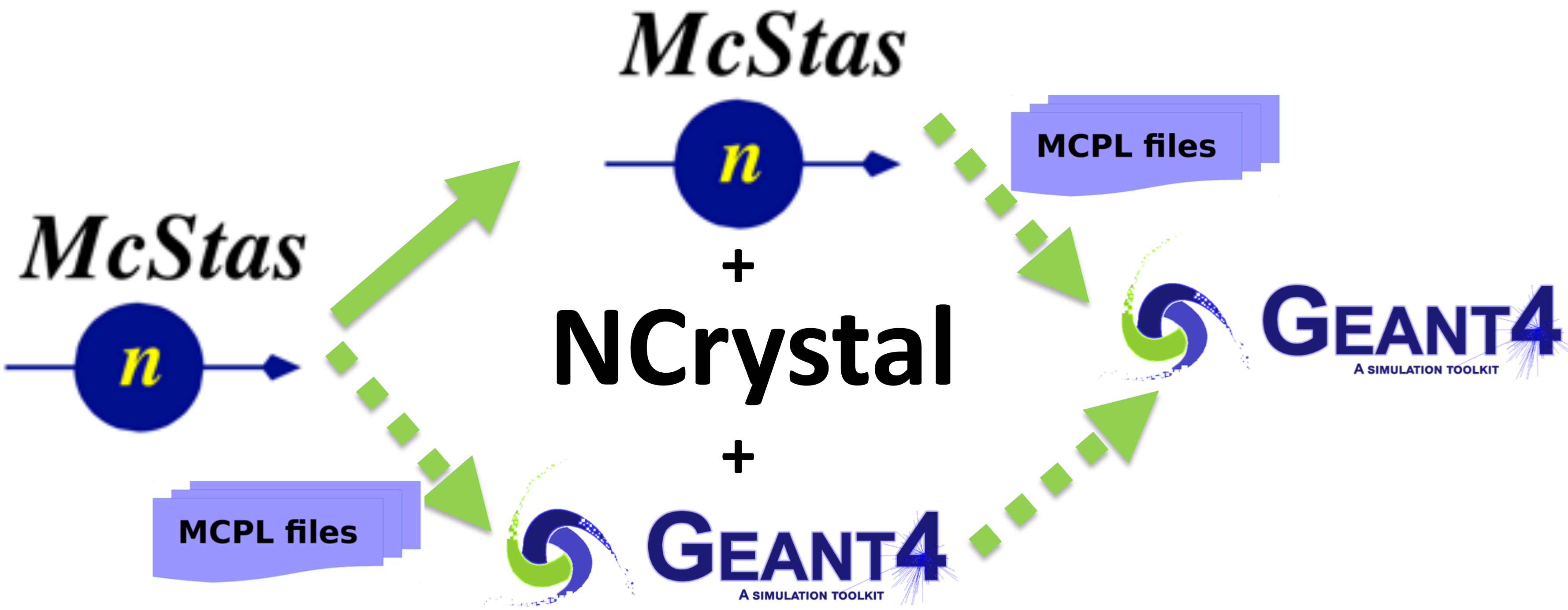
Sample + analyzers

Detectors

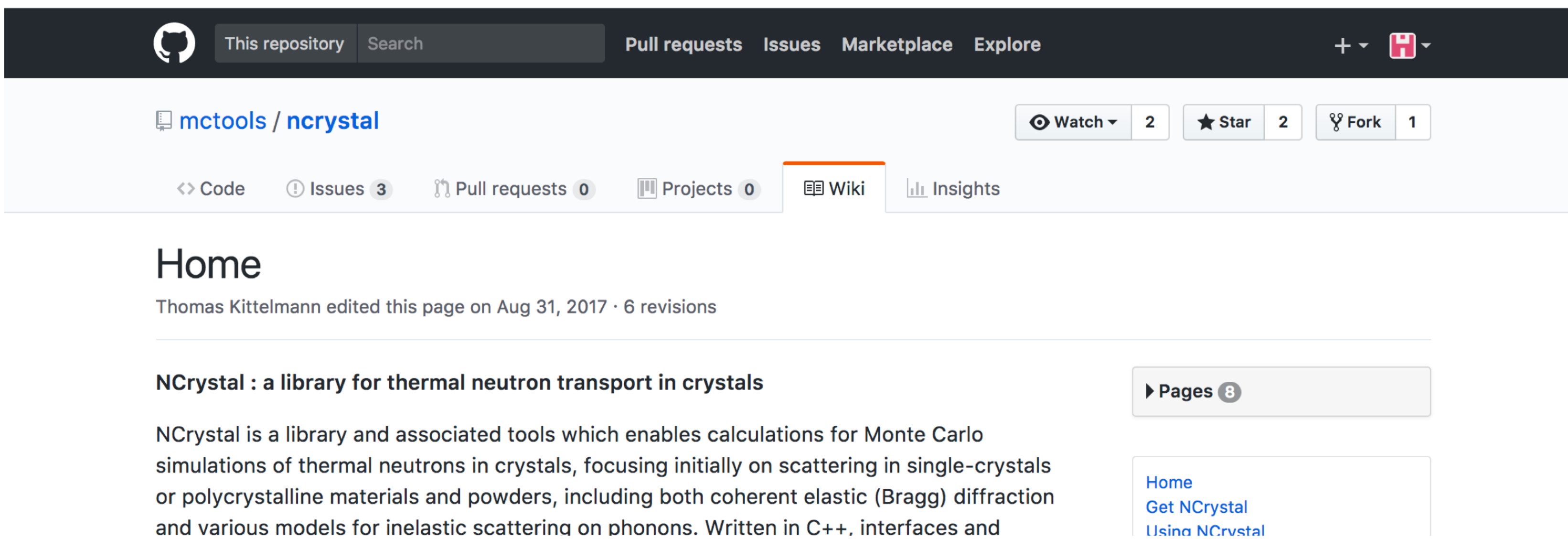


Simulation Tools: NCrystal

EUROPEAN SPALLATION SOURCE

– Library + tools for thermal neutron transport in crystals
– Cross-platform, open source, v1.0.0
– Multiple interfaces (Geant4, McStas, …), validated results

– Collaboration:
  • Xiao Xiao Cai (CNCS)
  • Thomas Kittelmann (ESS)
– Supported by:
  • BrightnESS (No 676548)



X. X. Cai, T. Kittelmann, NCrystal: a library for thermal neutron transport, Computer Physics Communications (2019)

Source: https://mctools.github.io/ncrystal/

Simulation Tools: NCrystal

EUROPEAN SPALLATION SOURCE

- Enables Monte Carlo simulation of neutrons in crystals
- Single-crystals
- Polycrystalline/powder materials
- **Anisotropic layered crystals: pyrolytic graphite**
- Coherent elastic (Bragg) diffraction
- Includes ”background” (inelastic/incoherent)
  - Harmonic approximation
  - Incoherent approximation
  - Debye approximation

Source: https://mctools.github.io/ncrystal/

Simulation Tools - Options

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Sample + analyzers

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Simulation Tools - Options

Guide

Sample + analyzers

Detectors

Simulation Tools - Options

EUROPEAN SPALLATION SOURCE

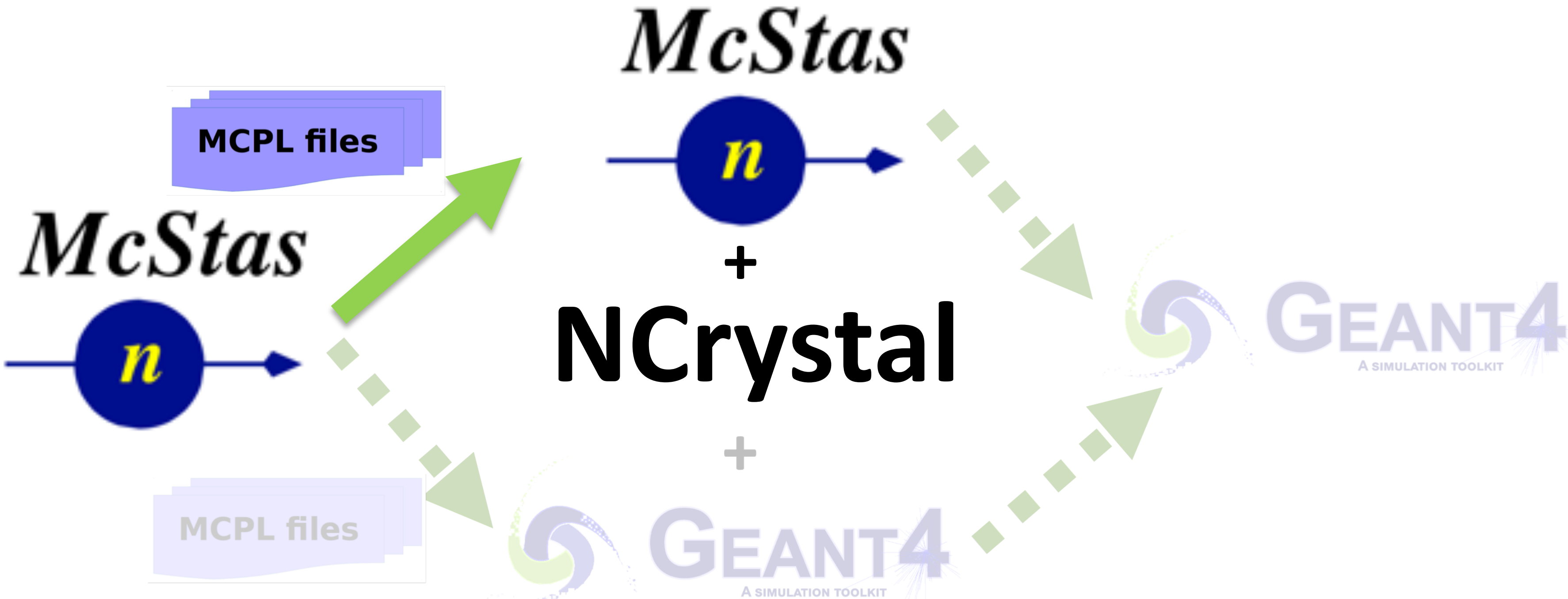
Guide	Sample + analyzers	Detectors

Simulation Tools - Options

Guide

Sample + analyzers

Detectors



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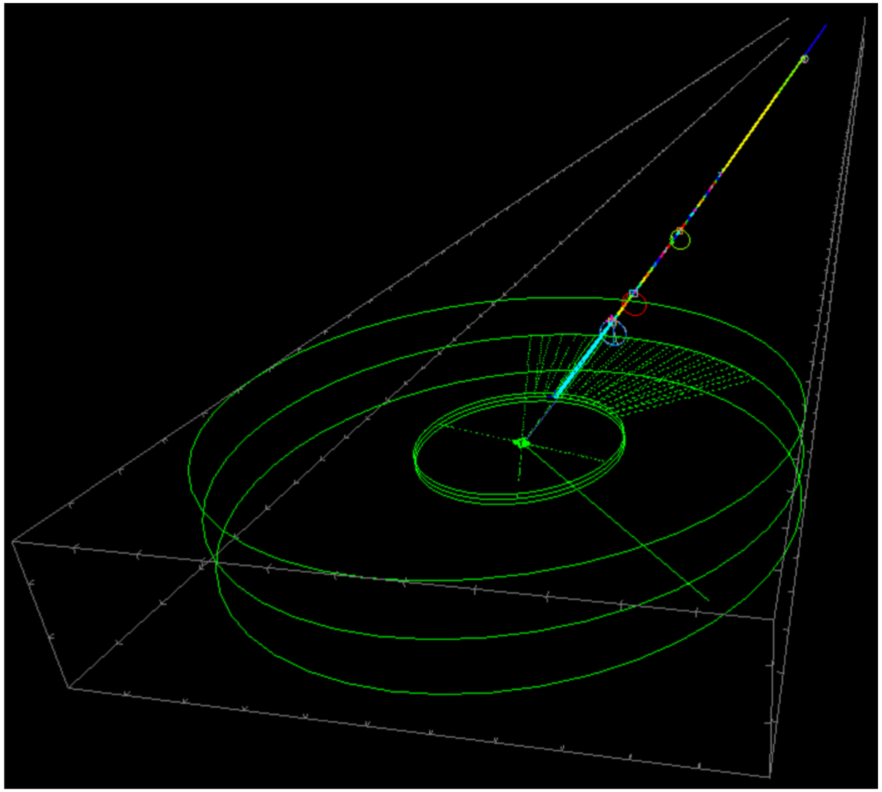
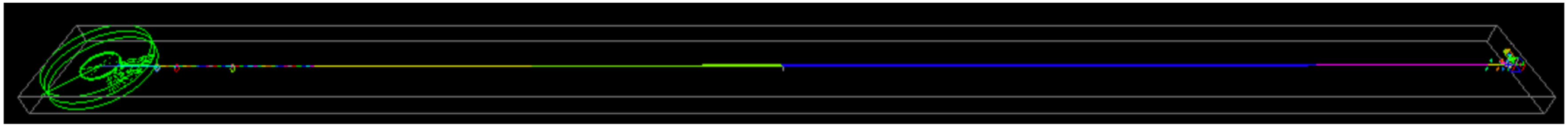
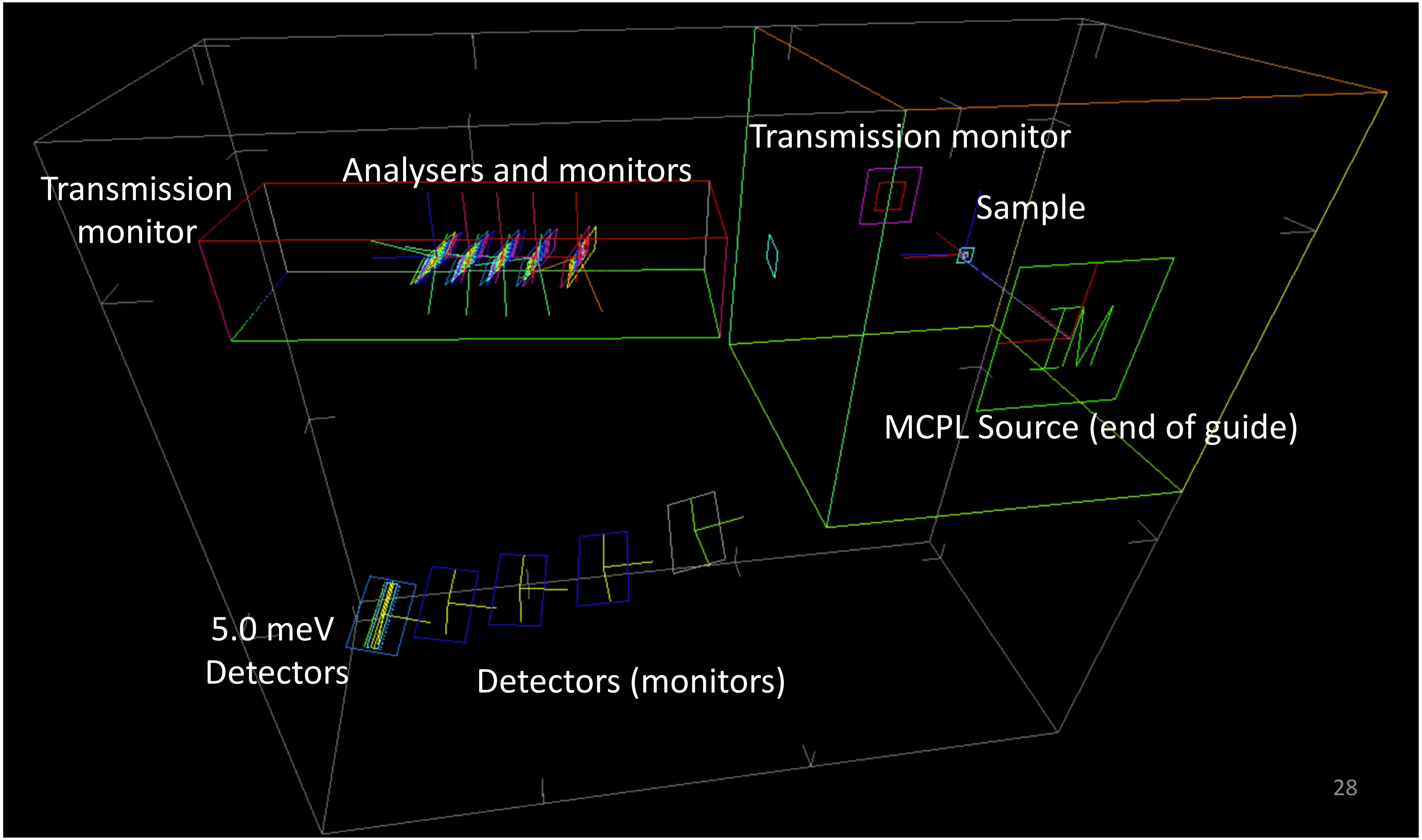
McStas Model – Full Instrument



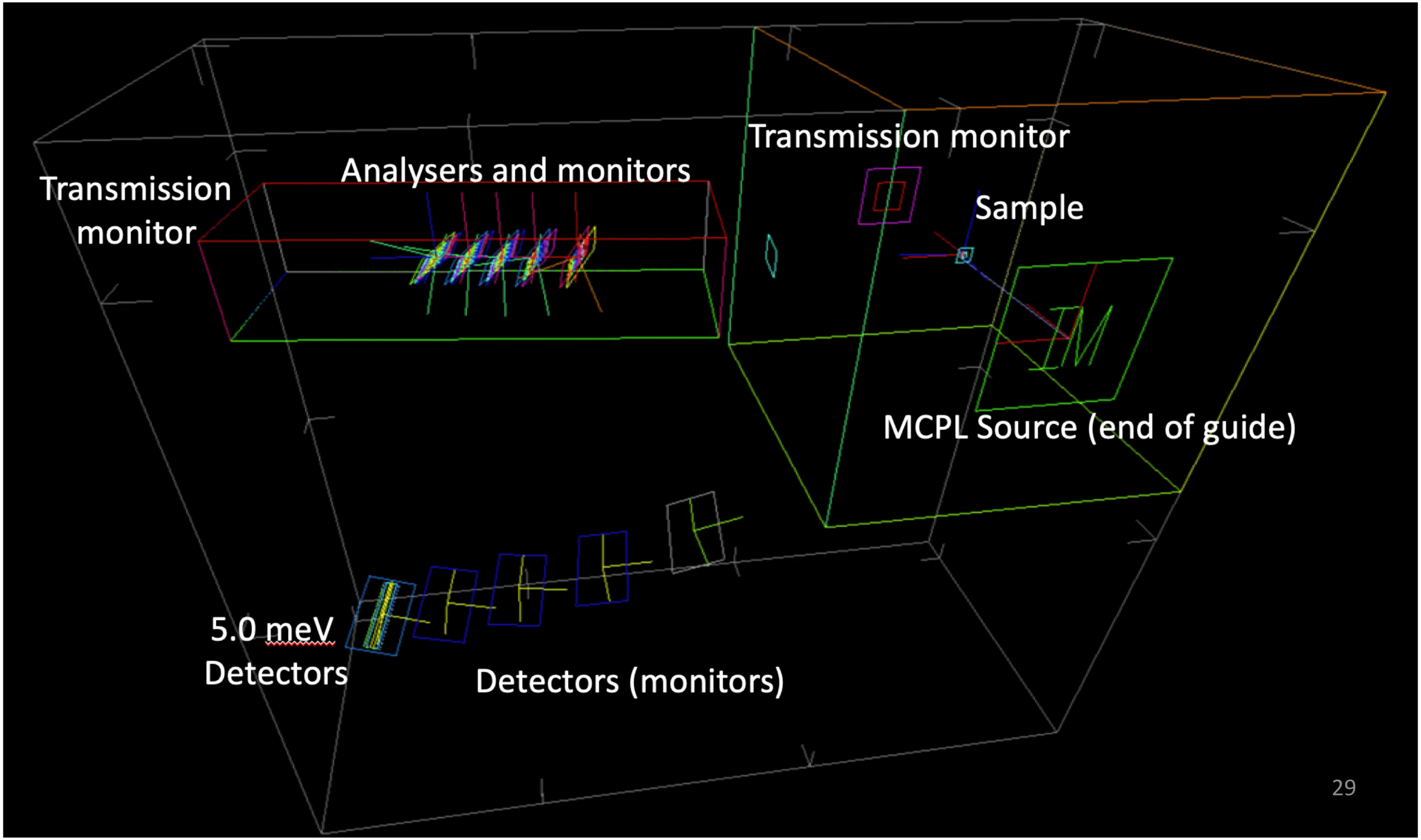
- ESS Butterfly source
- 4 choppers, all guide sections
- Authors:
  Rasmus Toft-Petersen
  Jonas Okkels Birk
  Martin Olsen



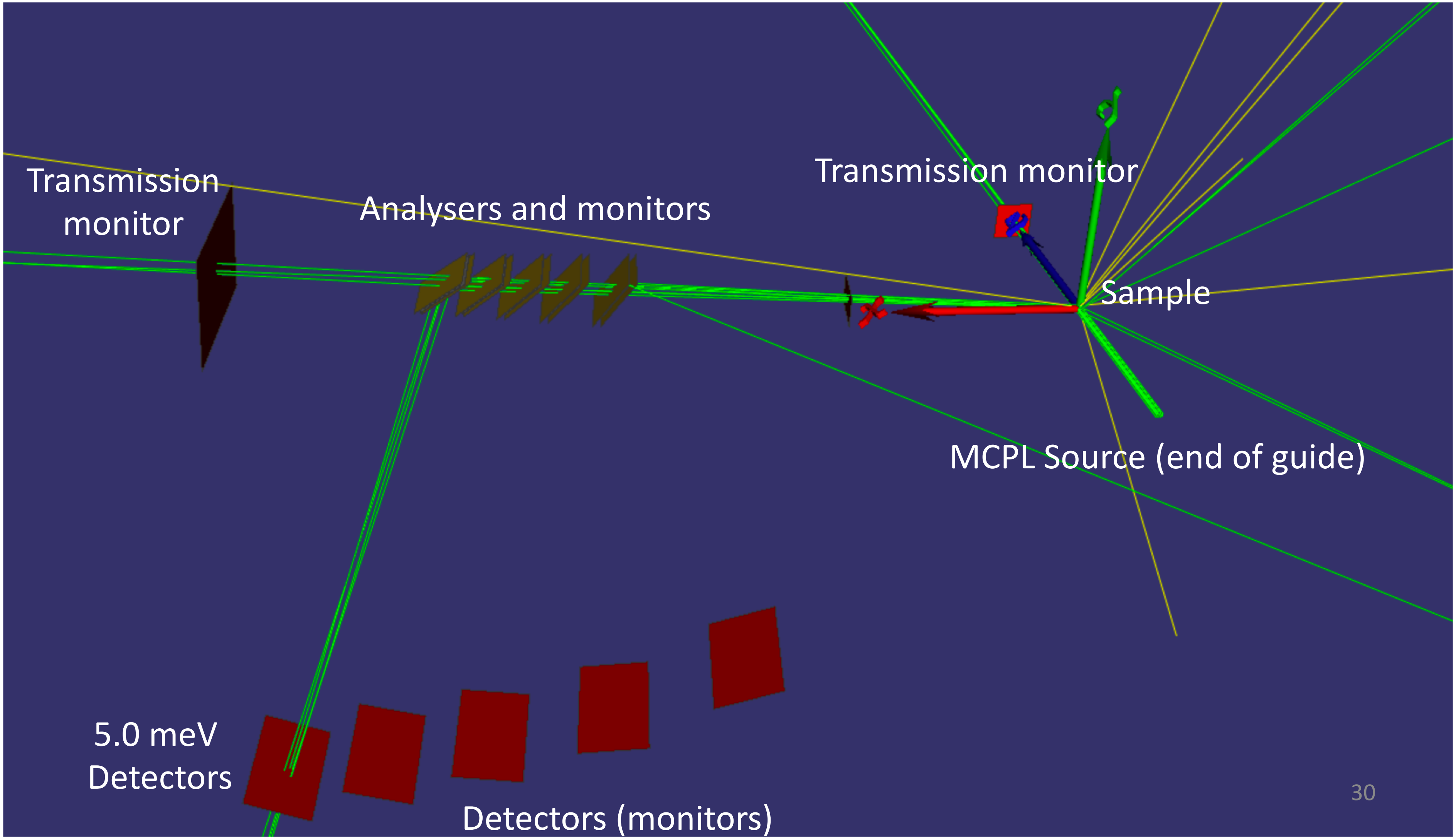
McStas Model – Analyzer-Detector system



McStas Model – Analyzer-Detector system



Geant4 Model – Analyzer-Detector system



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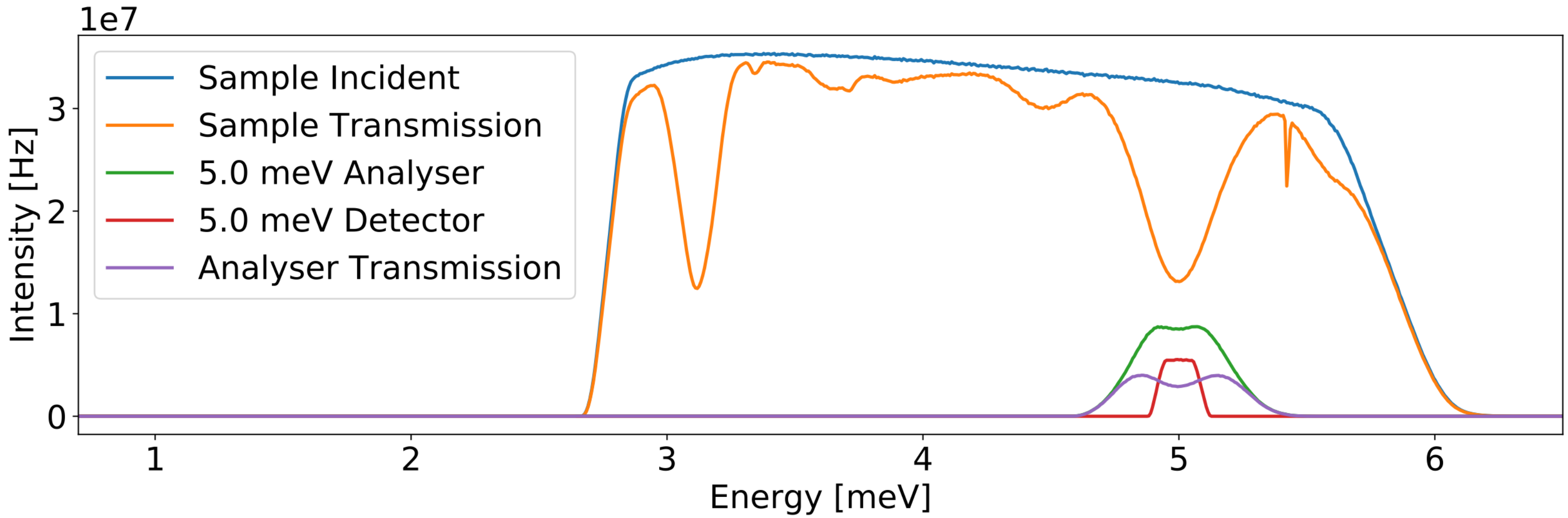
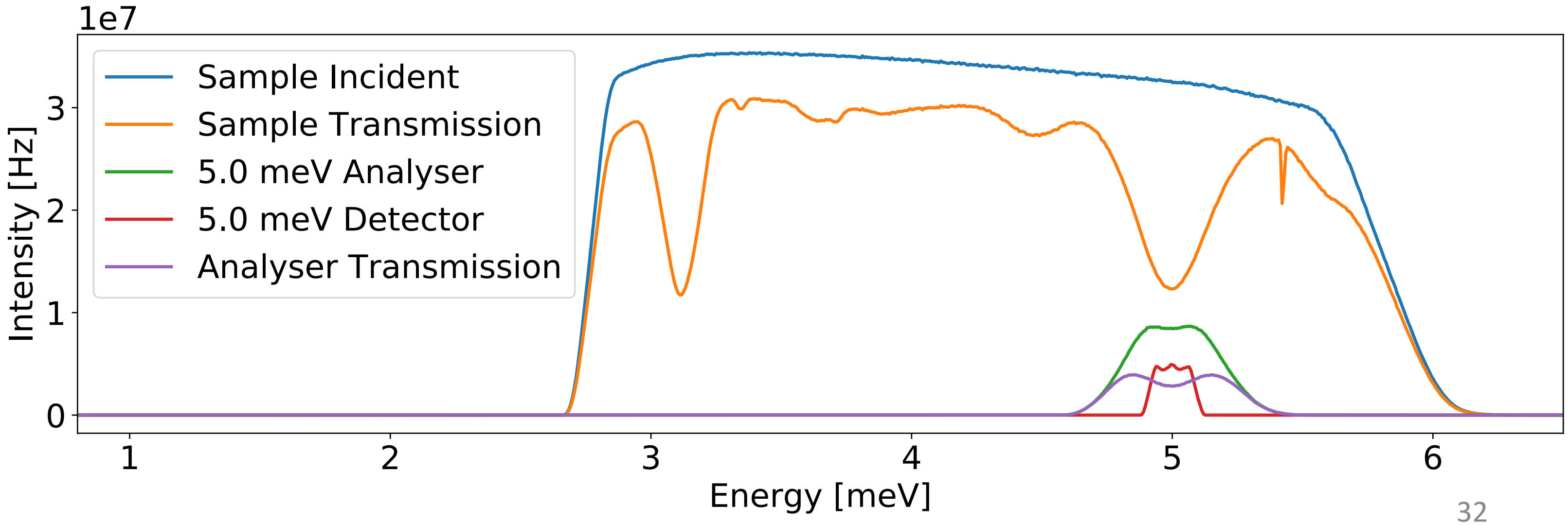
Change of energy spectrum after sample

McStas

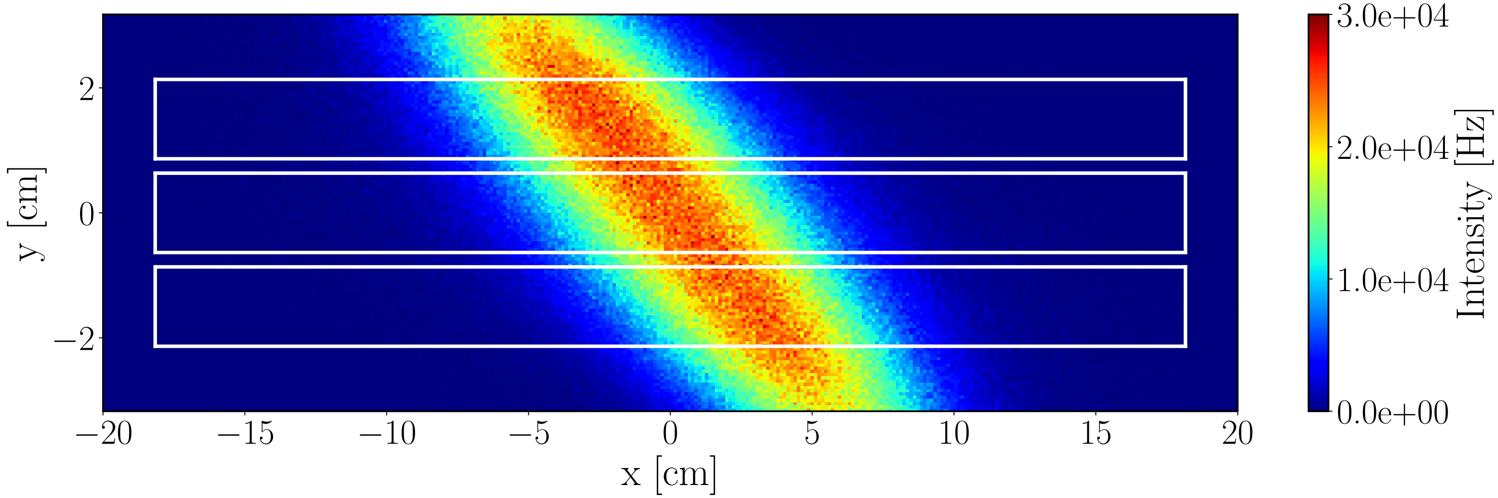


Geant4

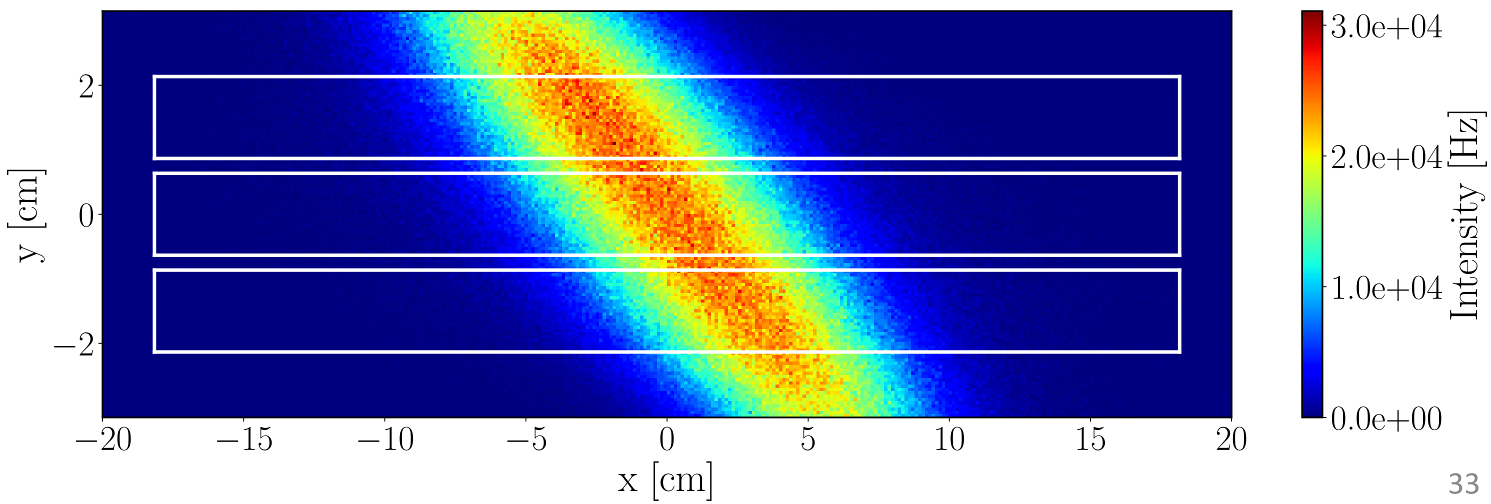


Intensity on detector

McStas

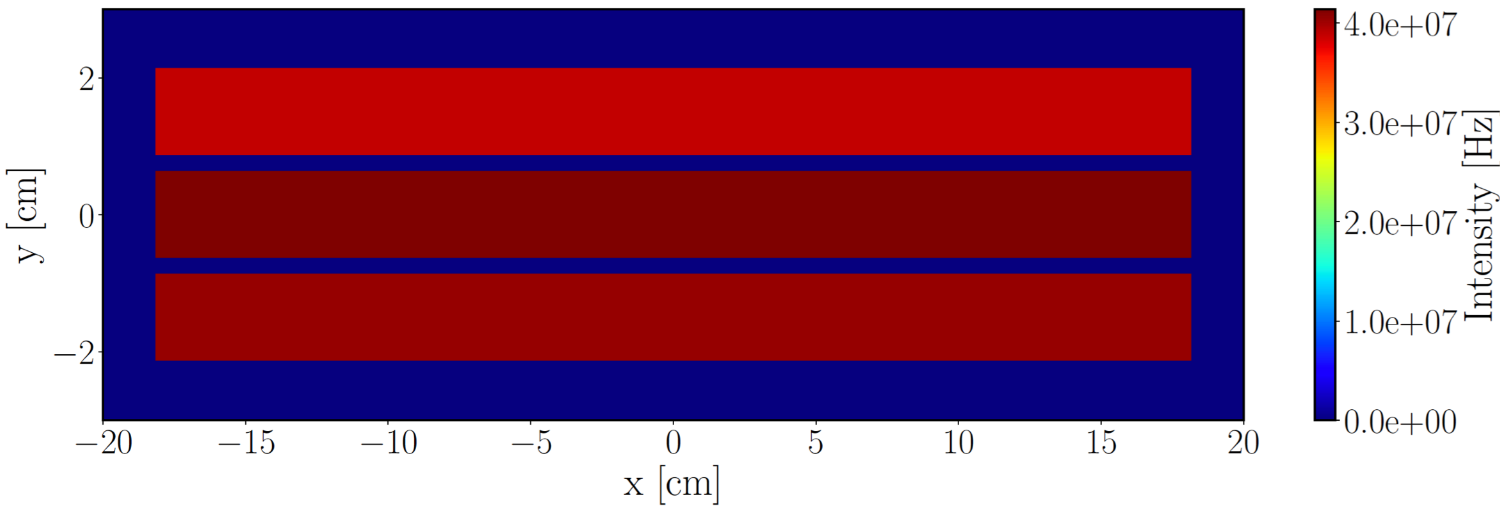


Geant4

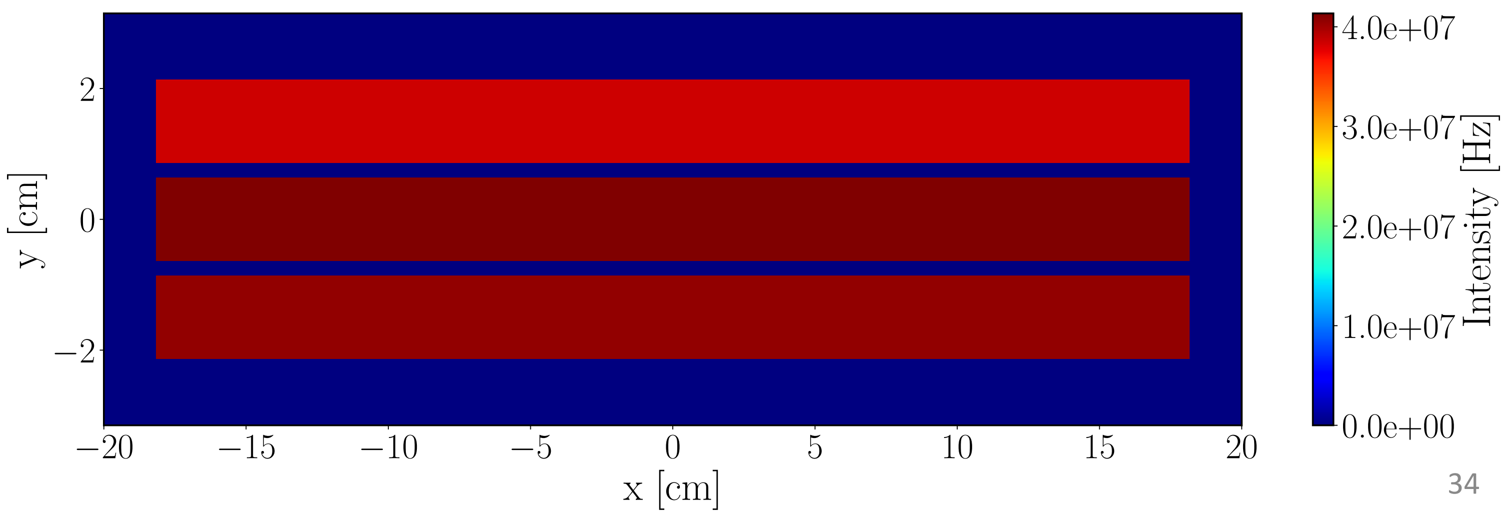


Time averaged incident rate

McStas

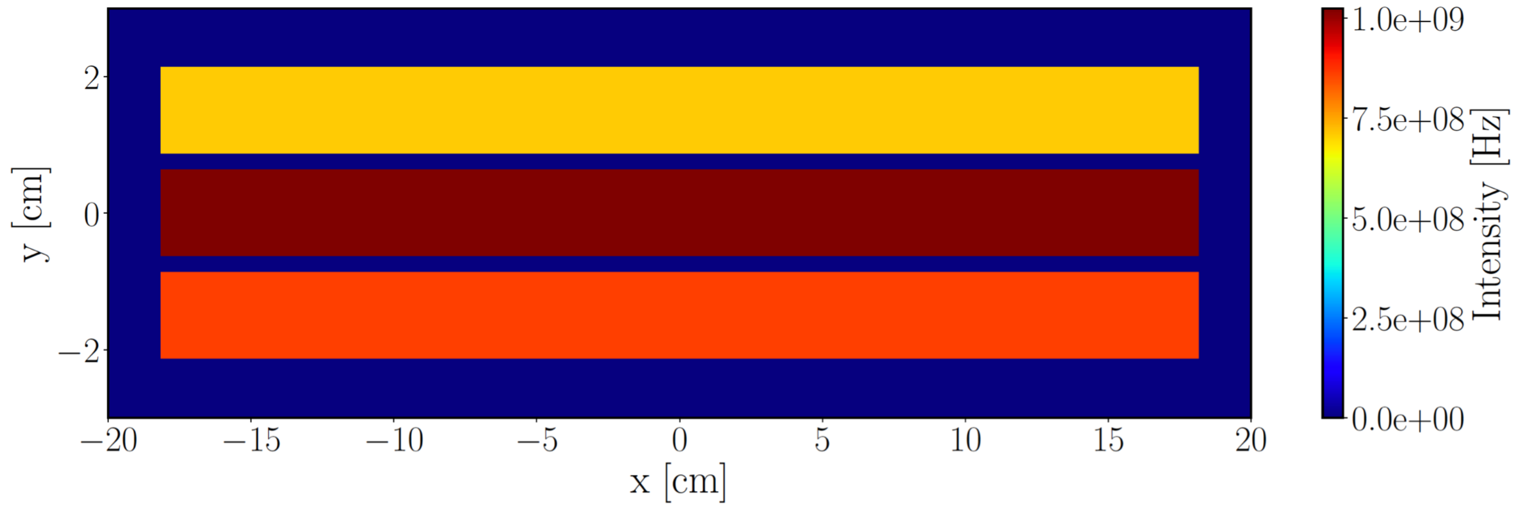


Geant4

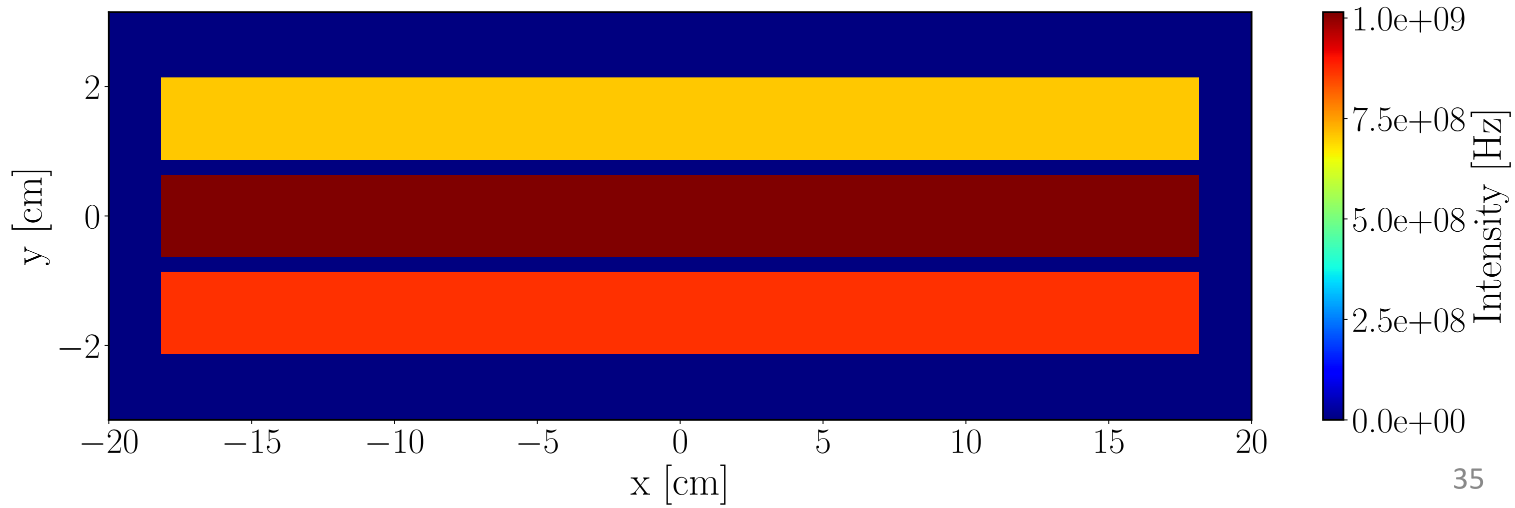


Peak instantaneous incident rate

McStas



Geant4



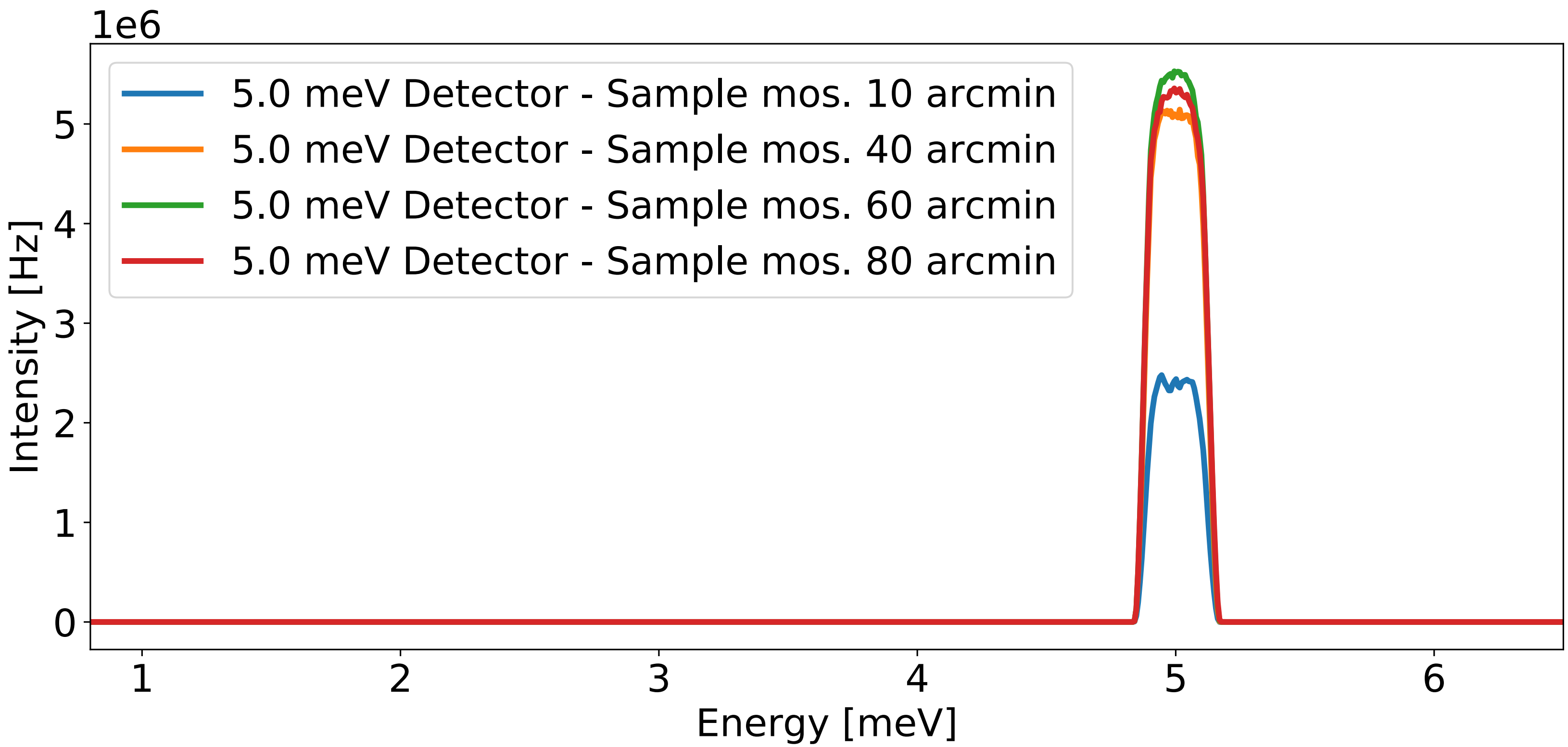
Conclusion

- Parameters:
  - Sample: Y_2O_3 single-crystal, hkl=2,-2,-2 (d_{hkl} = 3.0724 Å)
    cylindrical h=d=15 mm, mosaicity = 60 arcmin
  - Analyzer: thickness = 1 mm, mosaicity = 60 arcmin
  - Source power = 5 MW
  - PSC opening time = 5 ms (full ESS pulse)

- Time averaged incident rate on one He-3 tube: 4e7 Hz
- **Peak instantaneous incident rate on one tube: 1e9 Hz**

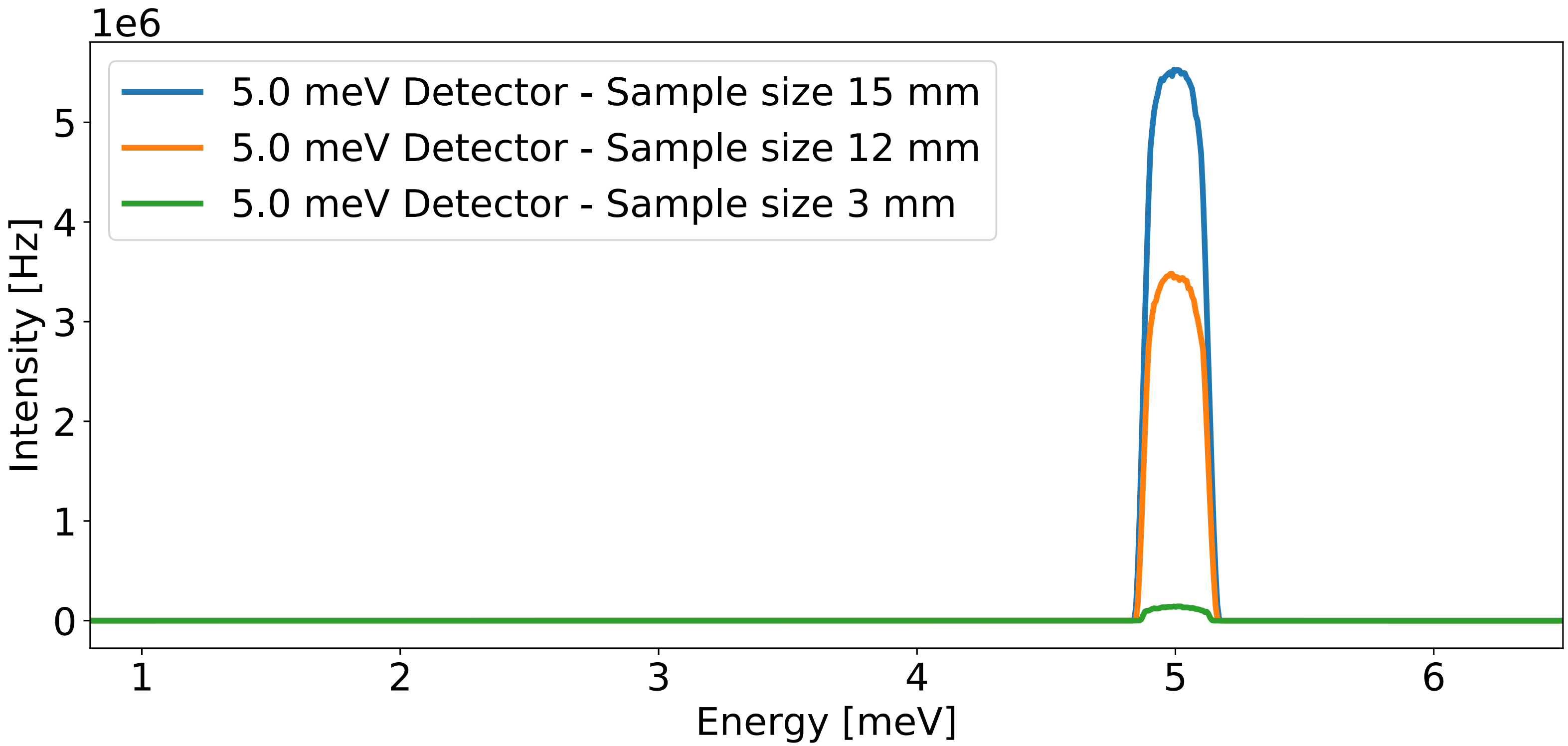
Effect of sample mosaicity

- Sample mosaicity matching the analyser mosaicity (60 arcmin) gives the highest incident rates



Effect of sample size

- Detector rates drop significantly with smaller sample size:
- 15 mm -> 12 mm (h=d) a factor of 1.4 rate drop
- 15 mm -> 3 mm (h=d) a factor of 40 rate drop



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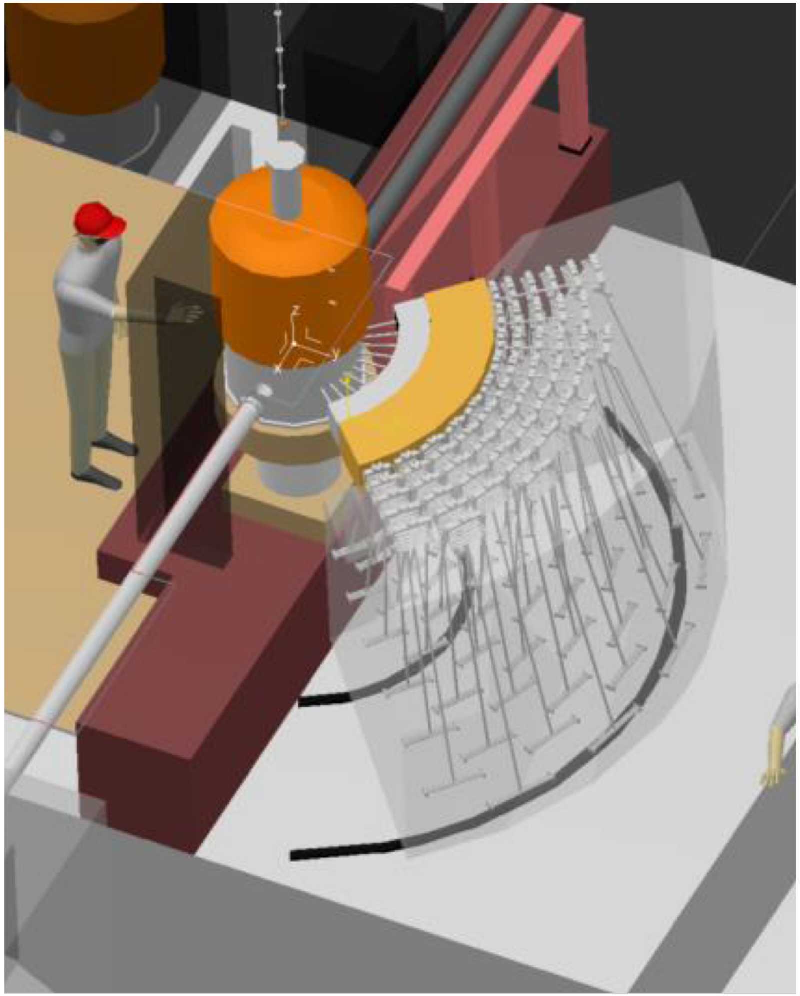
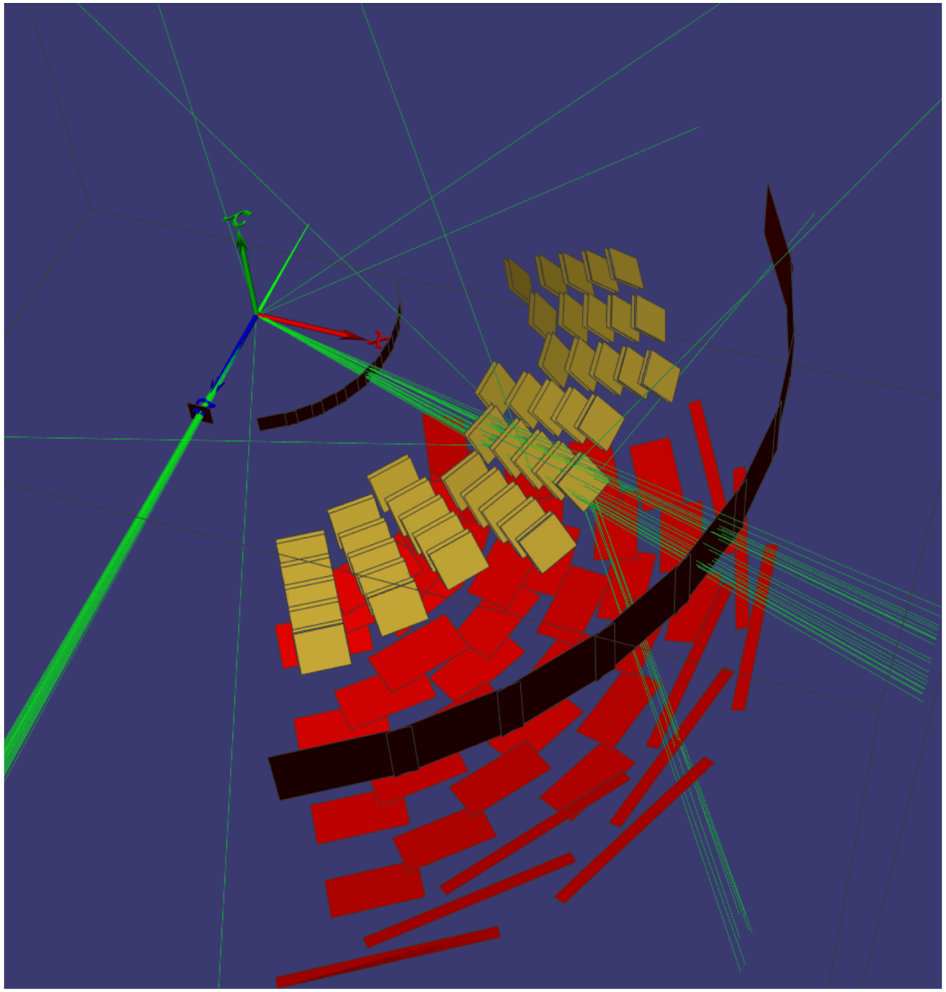
Geant4 model with all Q channels

EUROPEAN SPALLATION SOURCE





Ongoing and possible studies

- Simulation of calibration sample (vanadium) with full model
- Study the effect of PSC opening time on energy resolution and rates

- Beryllium filter + radial collimator
- Detectors
- Cross-talk shielding
- Backscattering
- Connect to Mantid

Acknowledgments

EUROPEAN SPALLATION SOURCE

- Xiao Xiao Cai, Peter Willendrup
- Data Management&Software Centre (DMSC)

Thank you for your attention!