Phase 1 Design for LOKI at ESS: performance evaluation of suitable detector technologies

Or how to build detectors for ESS

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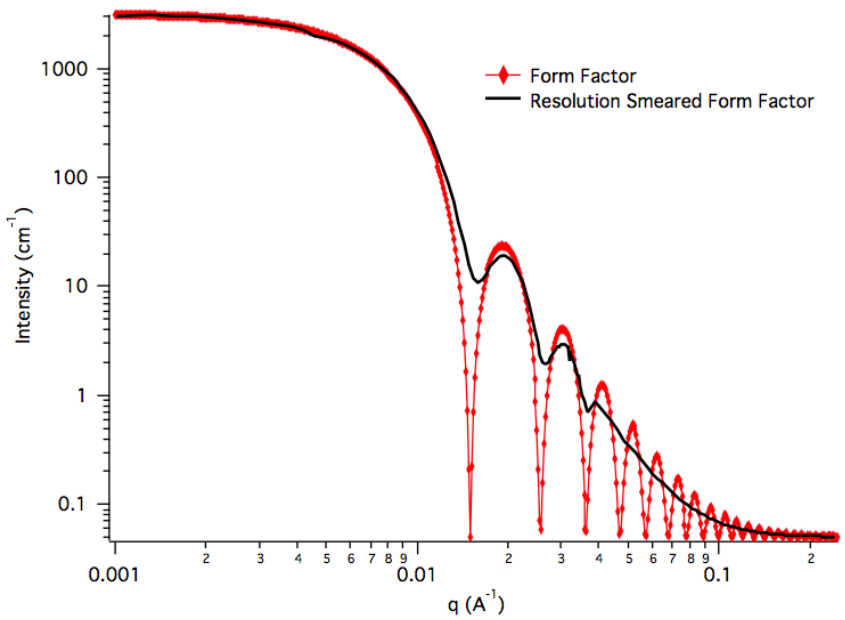
Outline

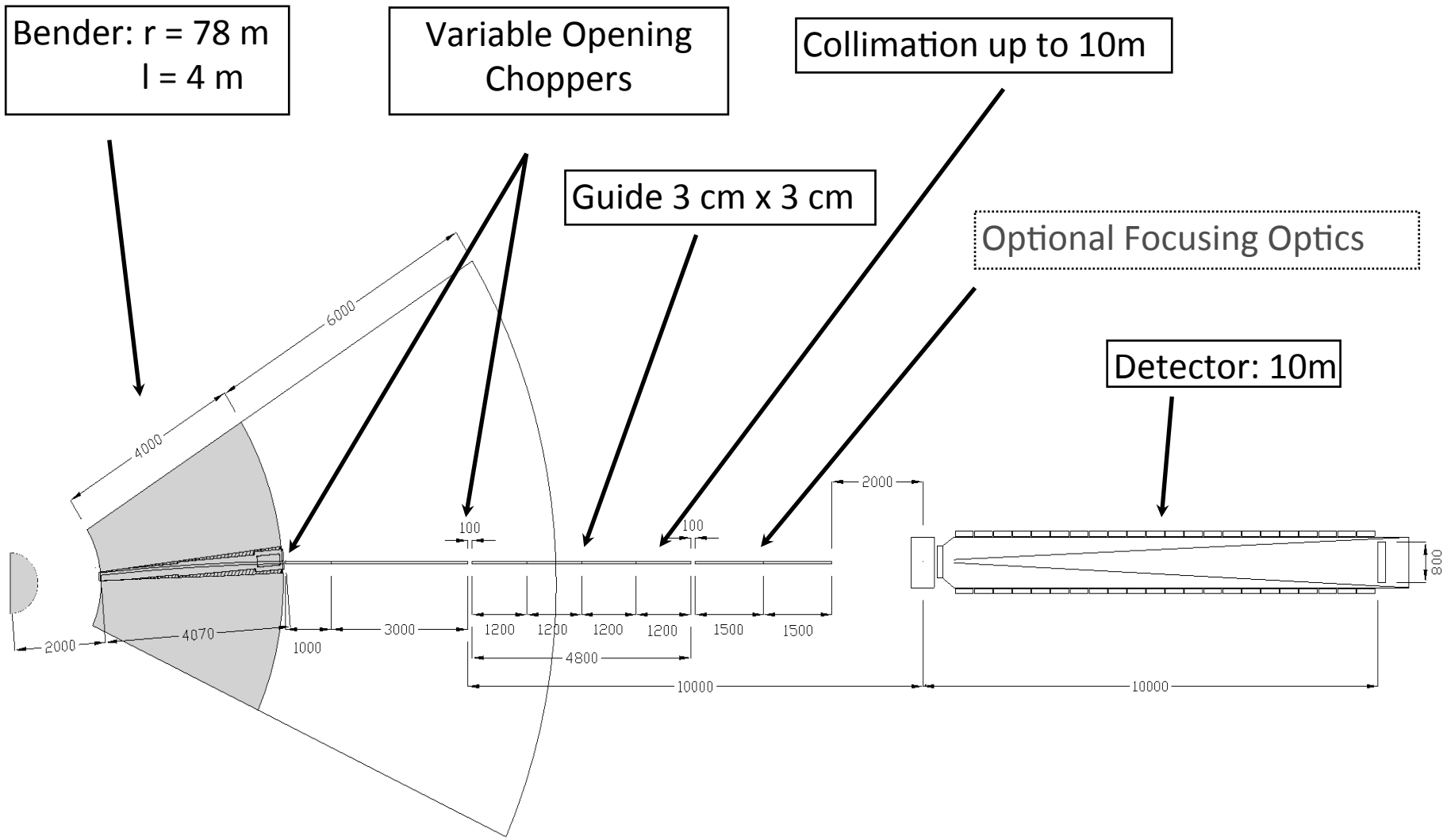
- Three neutron instruments approved by the ESS Steering Committee (STC) in 2013 for preliminary design phase 1:
  - NMX: Neutron Macromolecular Crystallography
  - Odin: Optical and Diffraction Imaging with Neutrons
  - LOKI: small angle neutron scattering (SANS)
- Introduction to LOKI
- Project phases until start of operations
- Functional detector requirement analysis
- Evaluation tools and preliminary results

Small Angle Neutron Scattering with LOKI

- Soft matter, biophysics and material studies
- Emphasis on spatial and temporal heterogeneity
- Spatial resolution down to nm scale
- Sub-second time resolution
- High neutron flux (10^9 n/cm^2/s on sample)
- Broad λ band (2Å-12Å) and wide-angle scattering
- Wide Q range accessed simultaneously (10^{-3}- few Å^{-1})

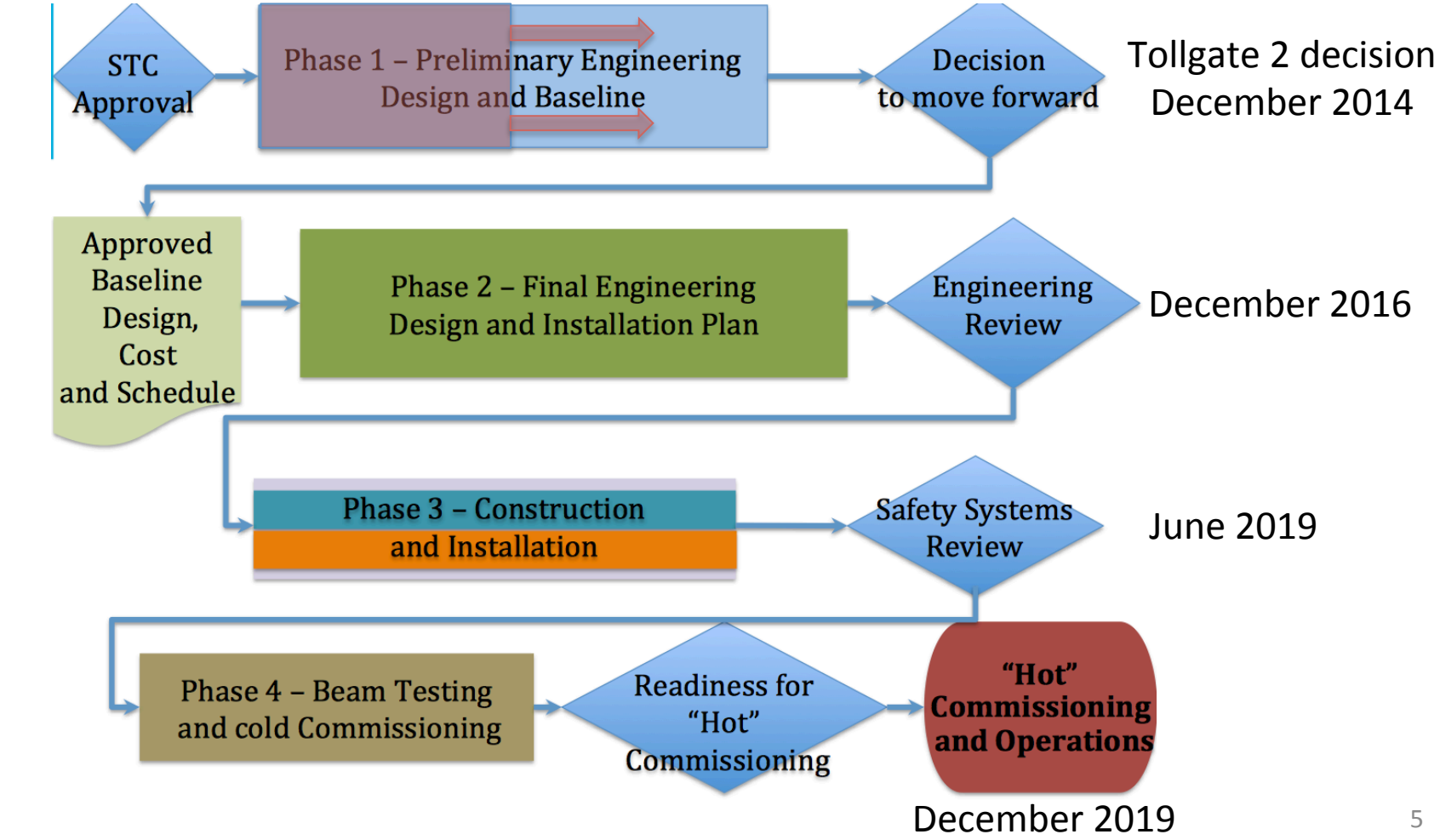


LOKI at a glance

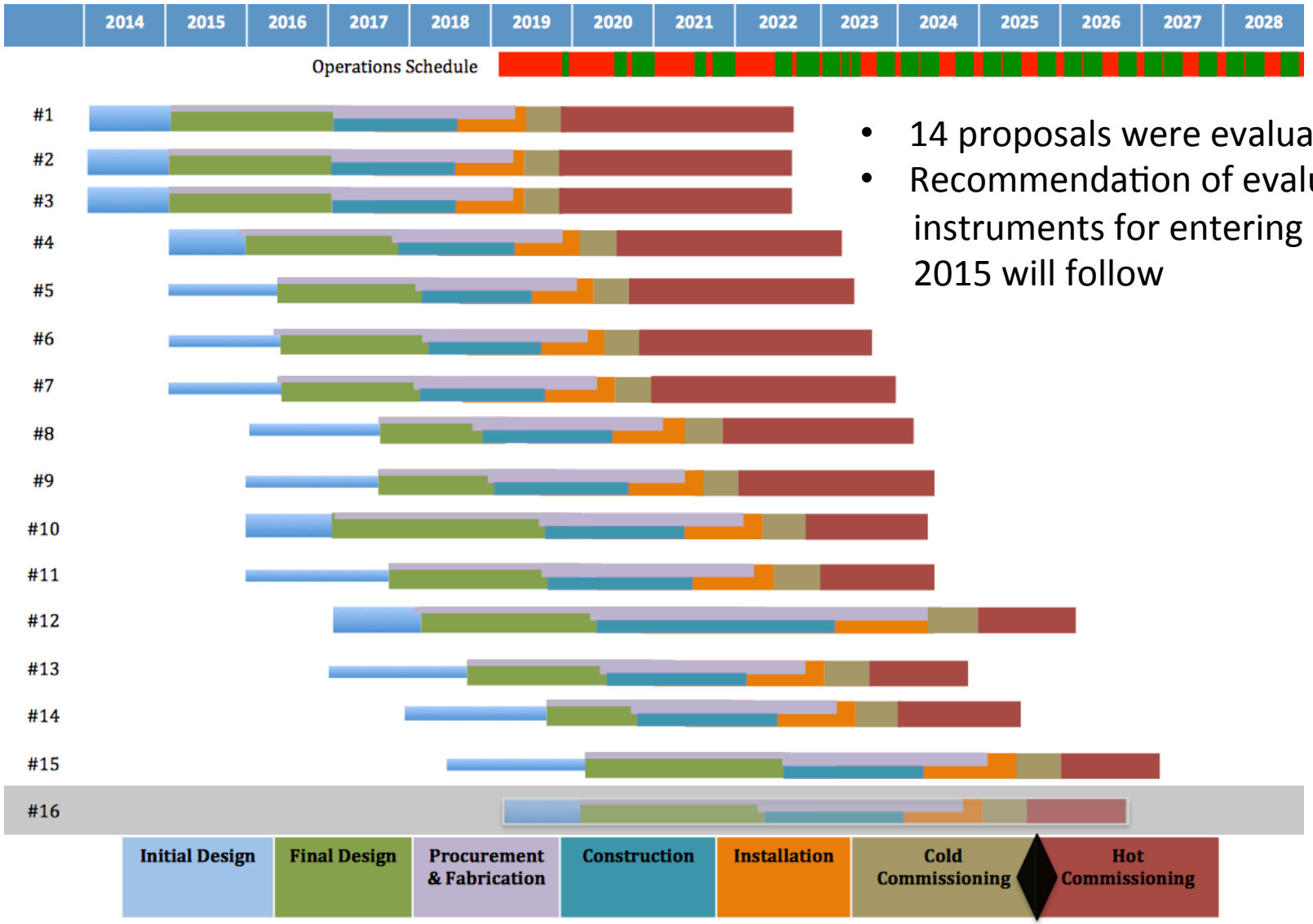


Approved Instrument Project Phases

LOKI



From Construction to Operations



- 14 proposals were evaluated in May
- Recommendation of evaluated instruments for entering phase 1 in 2015 will follow

Phase 1 Design Duties

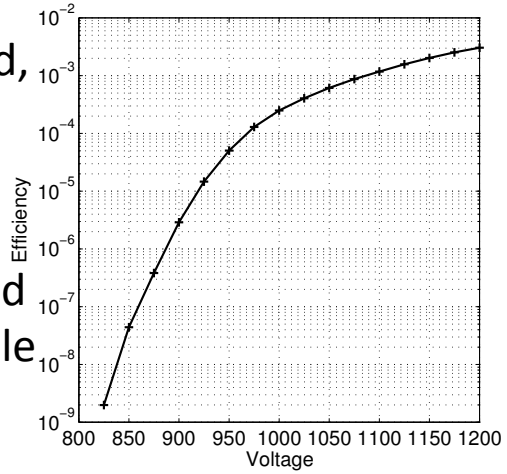
- **Conceptual development of the instrument detectors**
- **Performance evaluation**
- **Geometry & technology selection to be fully pursued during final design phase 2**
- **Schedule**
- In-kind plan for construction
- Define envelopes in engineering drawings
- Draft commissioning plan (cold & hot)
- Budget estimate
- Risk mitigation strategy
- Interface identification (organizational & physical)

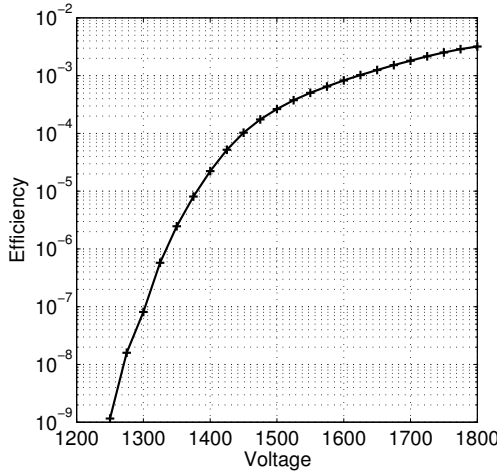
Functional requirements for LOKI detectors

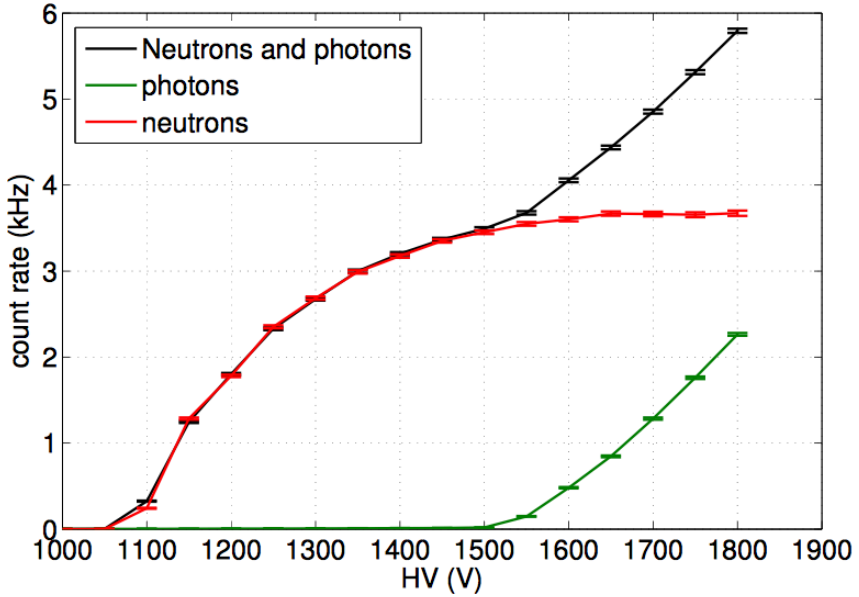
- Polar angle resolution
- Wavelength resolution
- Time of Flight resolution
- Detection efficiency
- Instantaneous rate capability
- Stability
- Background tolerance (intrinsic detector noise, natural components activity, cosmics, prompt pulse & secondaries escaping the guides - γ and fast neutrons - shielding, neighbouring instruments, sample-dependent background (incoherent, inelastic scattering))
- Separate studies per detector technology, geometry and particle species

Studies on γ induced background (MultiGrid detector, ILL/ESS/Linköping collaboration)

- neutron efficiency: analytically calculated, simulated, measured
- γ efficiency comparable to ^{3}He
- scattering understood
- detector induced background understood
- working on detector standards for reliable comparisons







A. Khaplanov et al., JINST 8, P10025 (2013)

Collaborative background studies with PSI

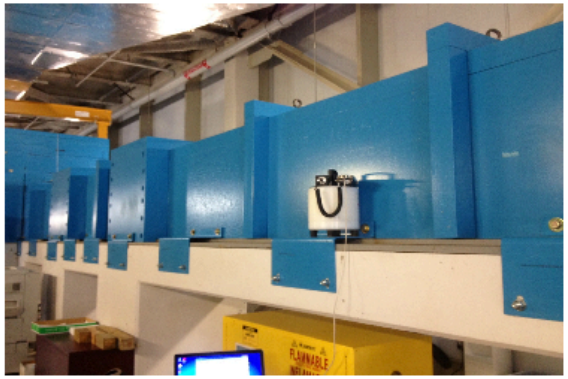
ESS Detector & Neutron Optics and Shielding groups

measurements at the SINQ target

paper in preparation
N. Cherkashyna et al.

Collaborative background studies with SNS

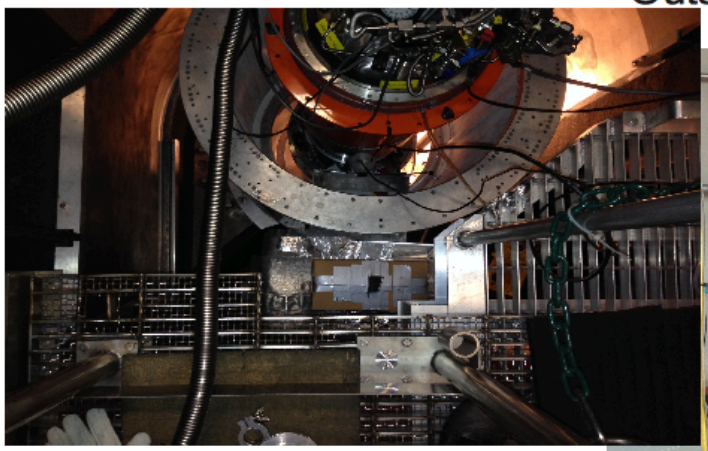
ESS Detector & Neutron Optics and Shielding groups



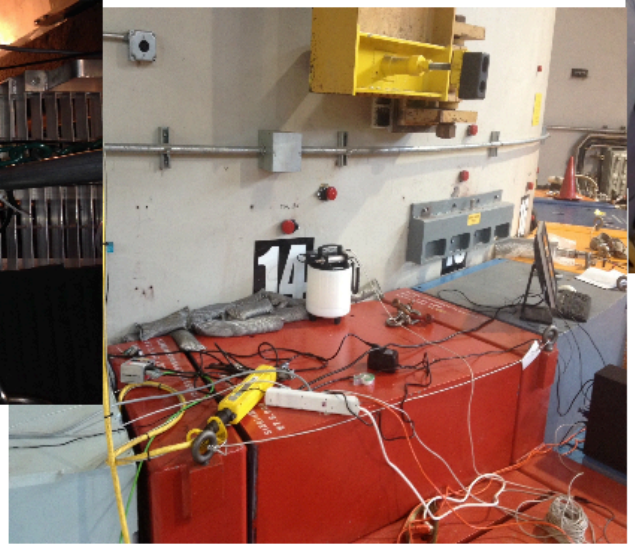
Along basis-curved beamline

Outside: ring2target

Between BL13 & BL14



Inside CNCS

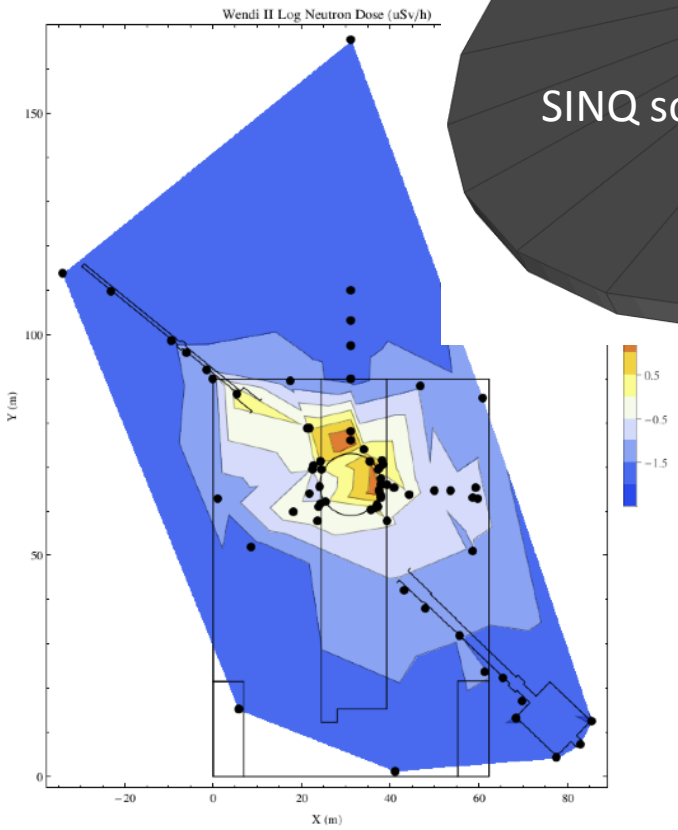


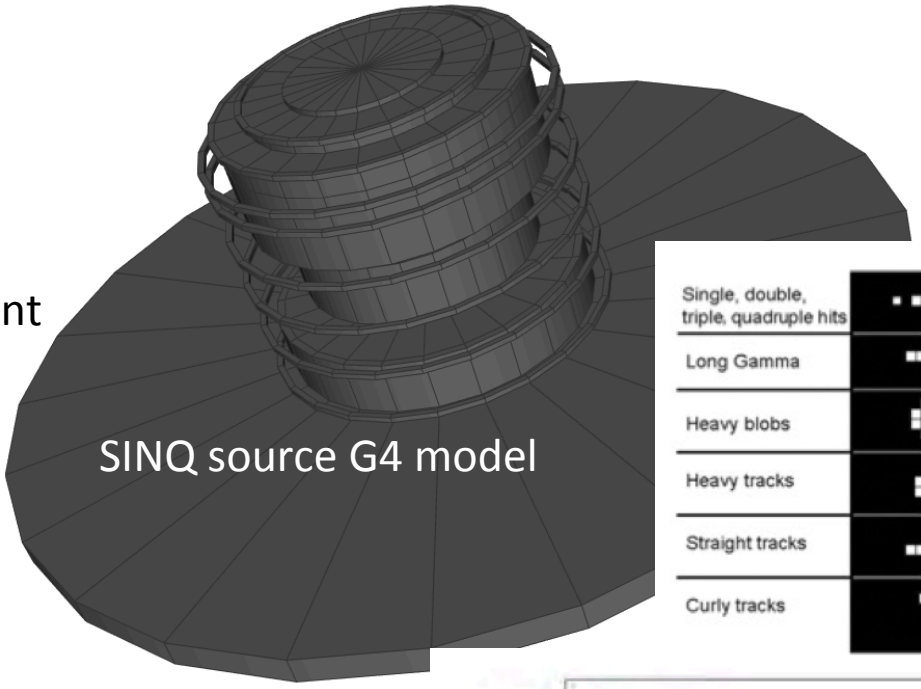
On top of BL14

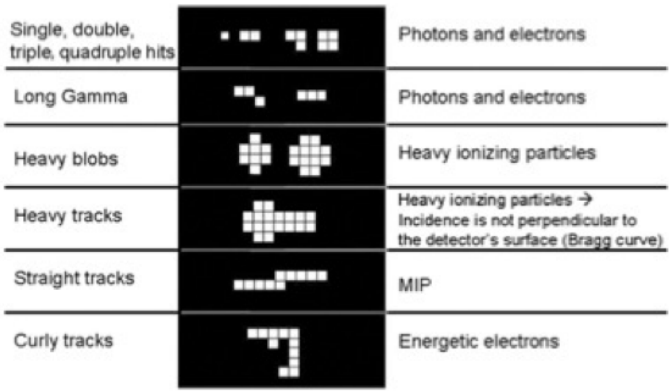
paper in preparation
D. DiJulio et al.

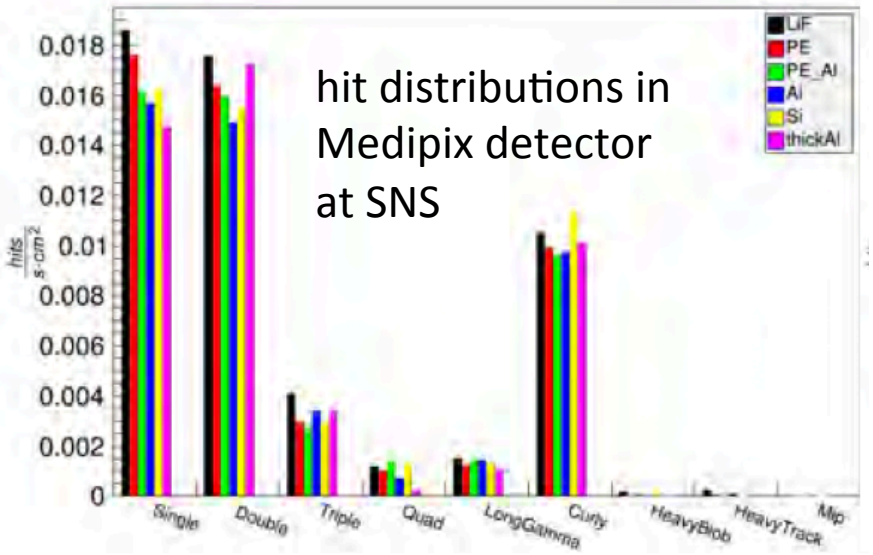
Measurements & Simulations

neutron dose map
around the SNS target
and POWGEN instrument

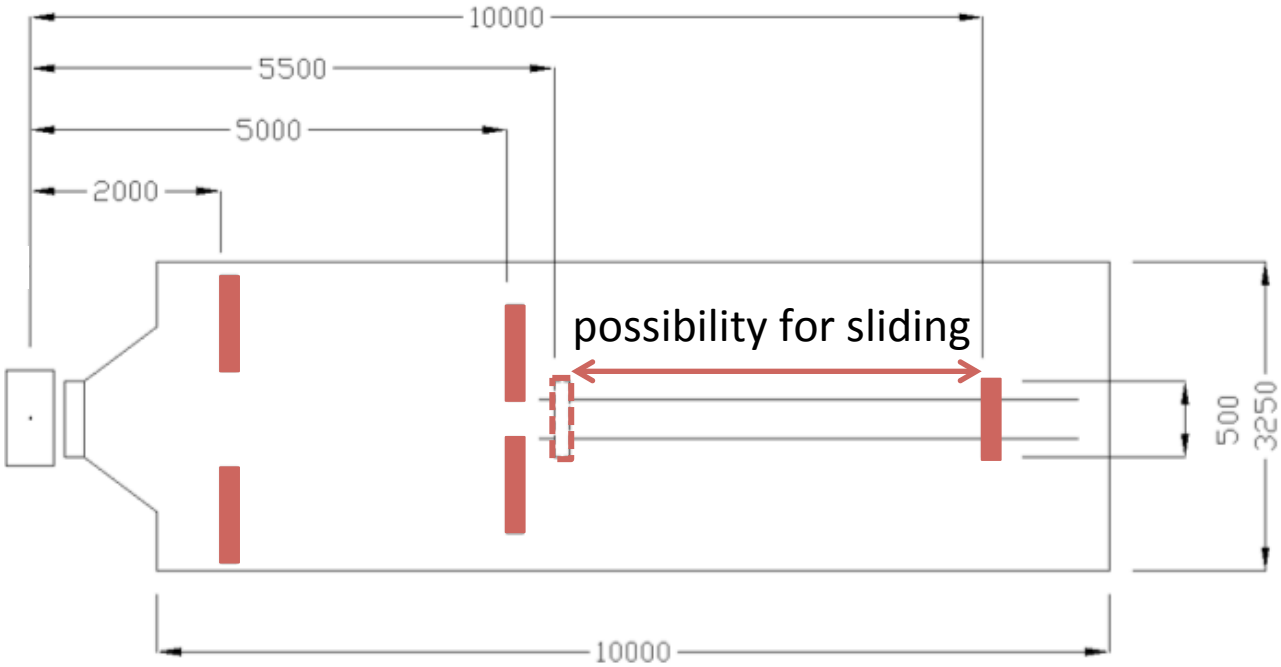






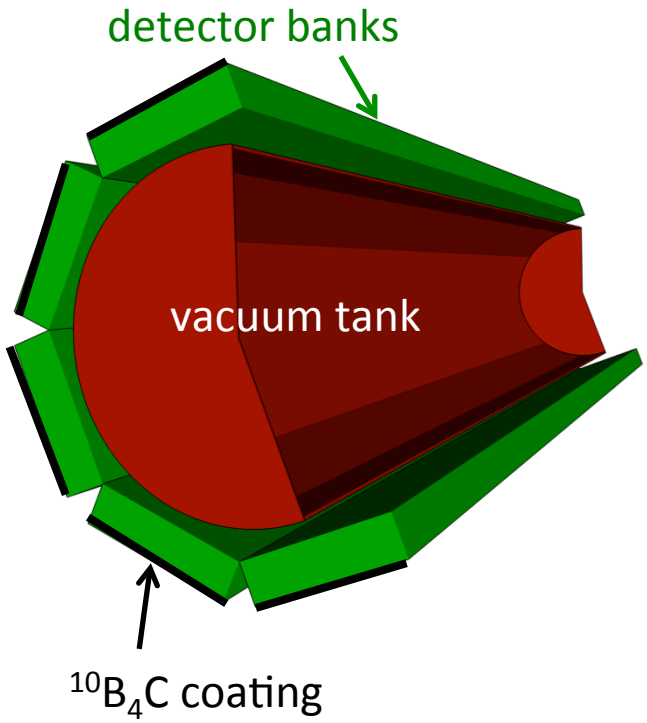


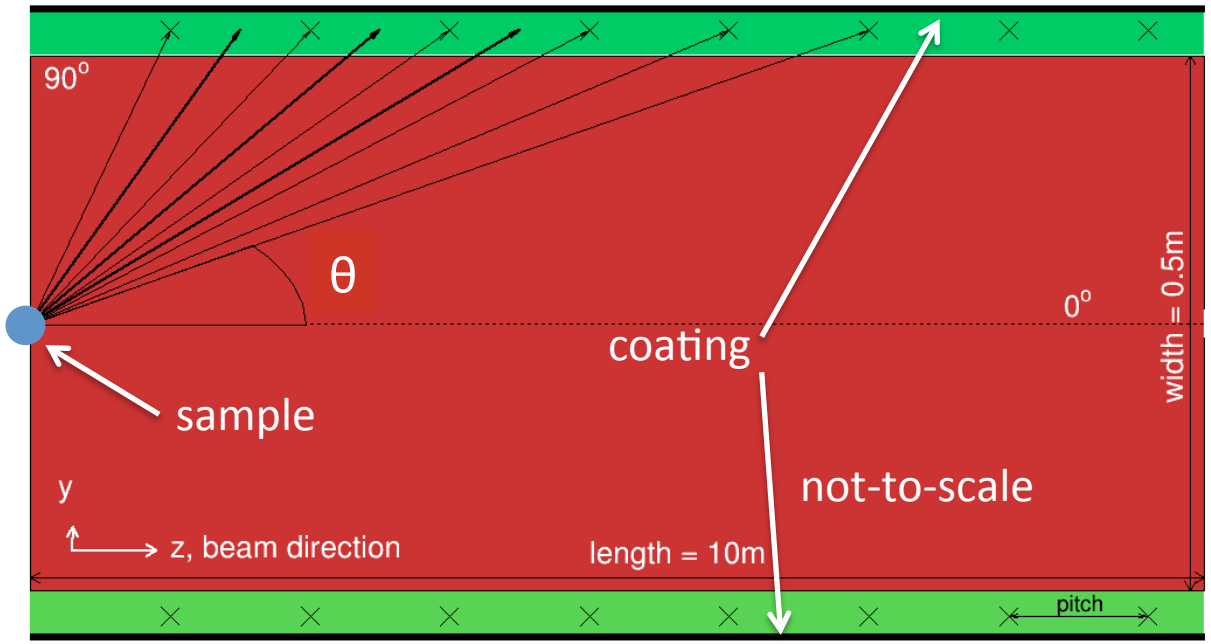
Possible LOKI detector geometries: window frame



- outer frame: 3m x 3m, inner empty frame: 1m x 1m
- outer frame: 2.4m x 2.4m, inner empty frame: 0.4m x 0.4m
- 0.5m x 0.5m

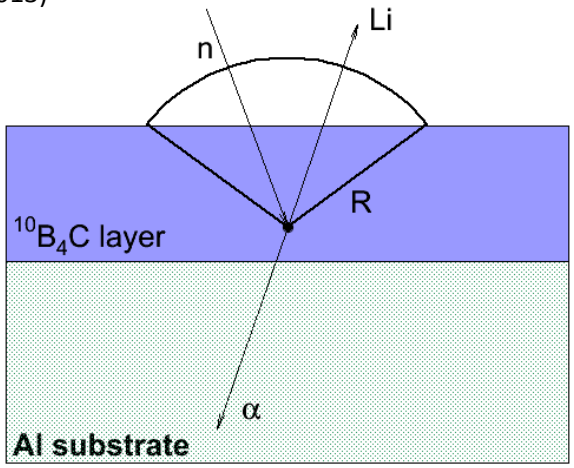
Possible LOKI detector geometries: ^{10}B-lined barrel





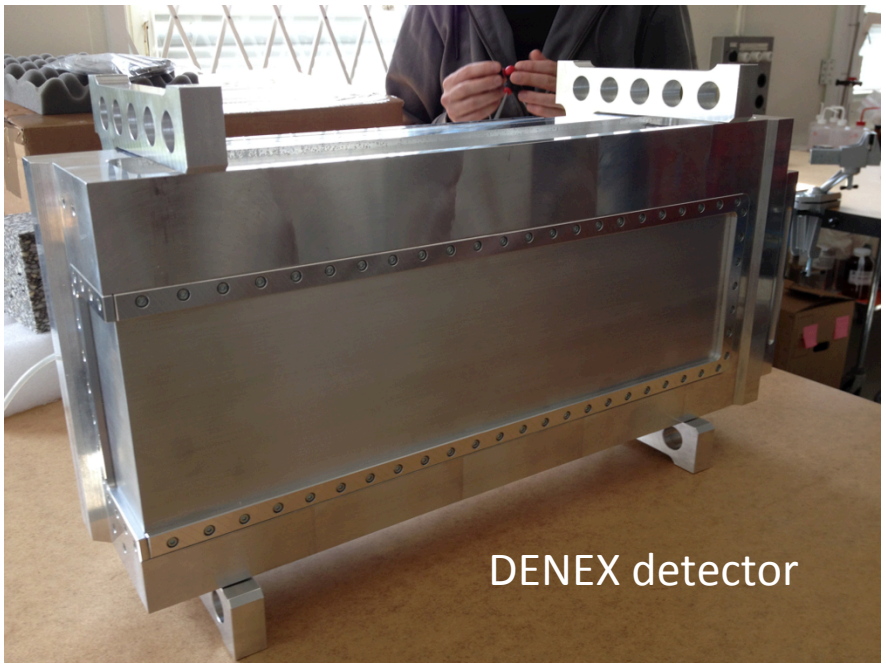
K. Kanaki et al., J. Appl. Cryst. **46**, 1031–1037 (2013)

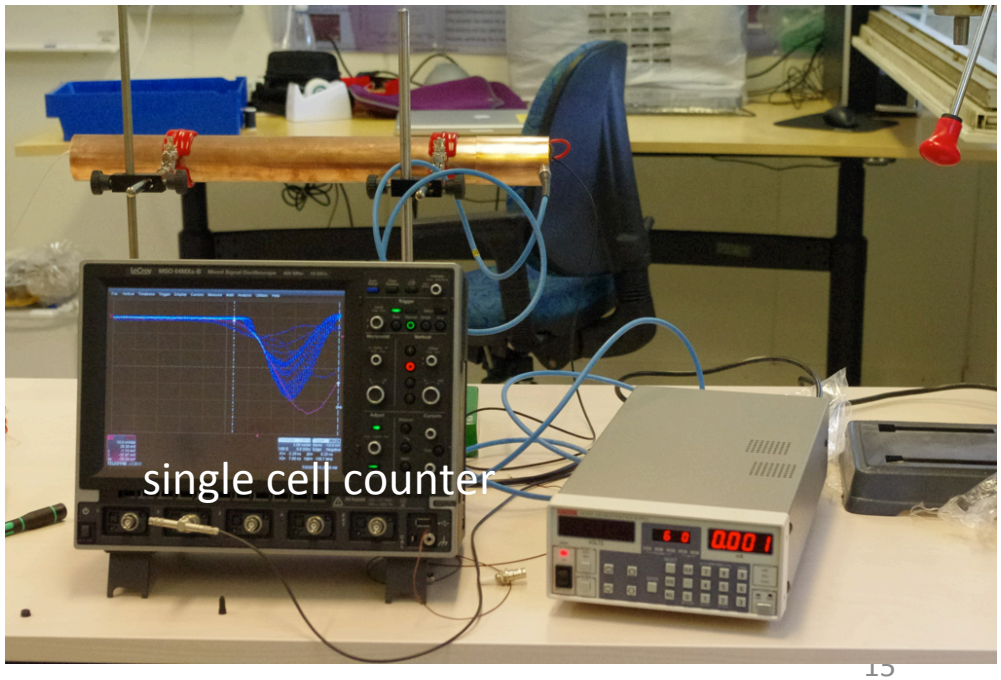
- 2π solid angle coverage for efficient data taking
- Length = 10 m, width = 0.5 m, $^{10}B_4C$ layer thickness = 1 μm
- Back-scattering detection mode with MWPC
- Higher efficiency and resolution at forward angles
- Detector and electronics outside the vacuum tank
- Cheap, simple and easy to handle arrangement
- Small size vacuum tank due to tube dimensions
- Multi-parameter optimization



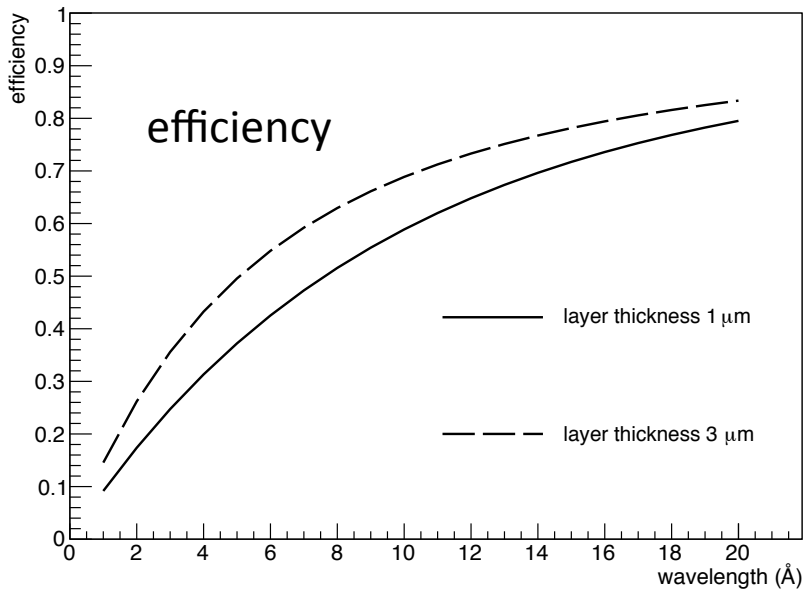
Evaluation Tools

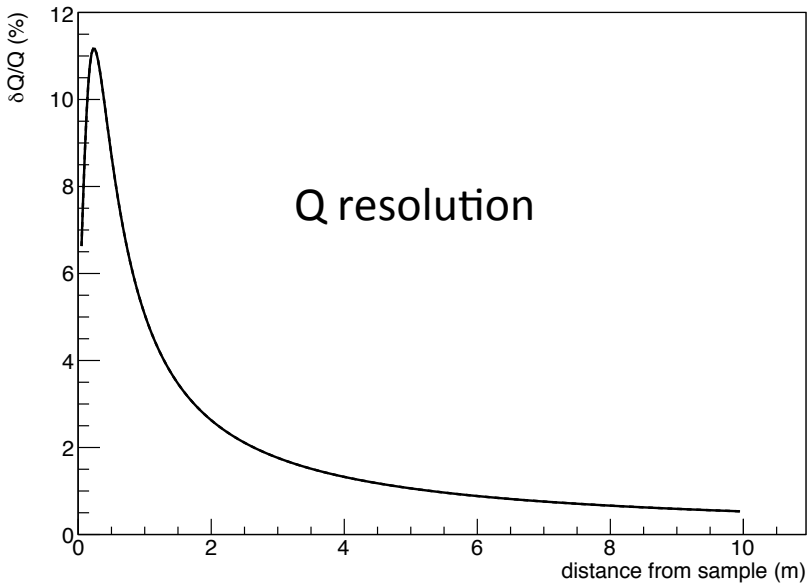
- Analytical calculations
- McStas (MC): neutron ray-trace simulation package
- Geant4 (MC): particle tracking and interactions
- Garfield/Garfield++: ionization in gases, signal formation
- Prototyping
- R&D running in parallel


DENEX detector


single cell counter

Polar angle resolution (analytical)
^{10}B-lined barrel



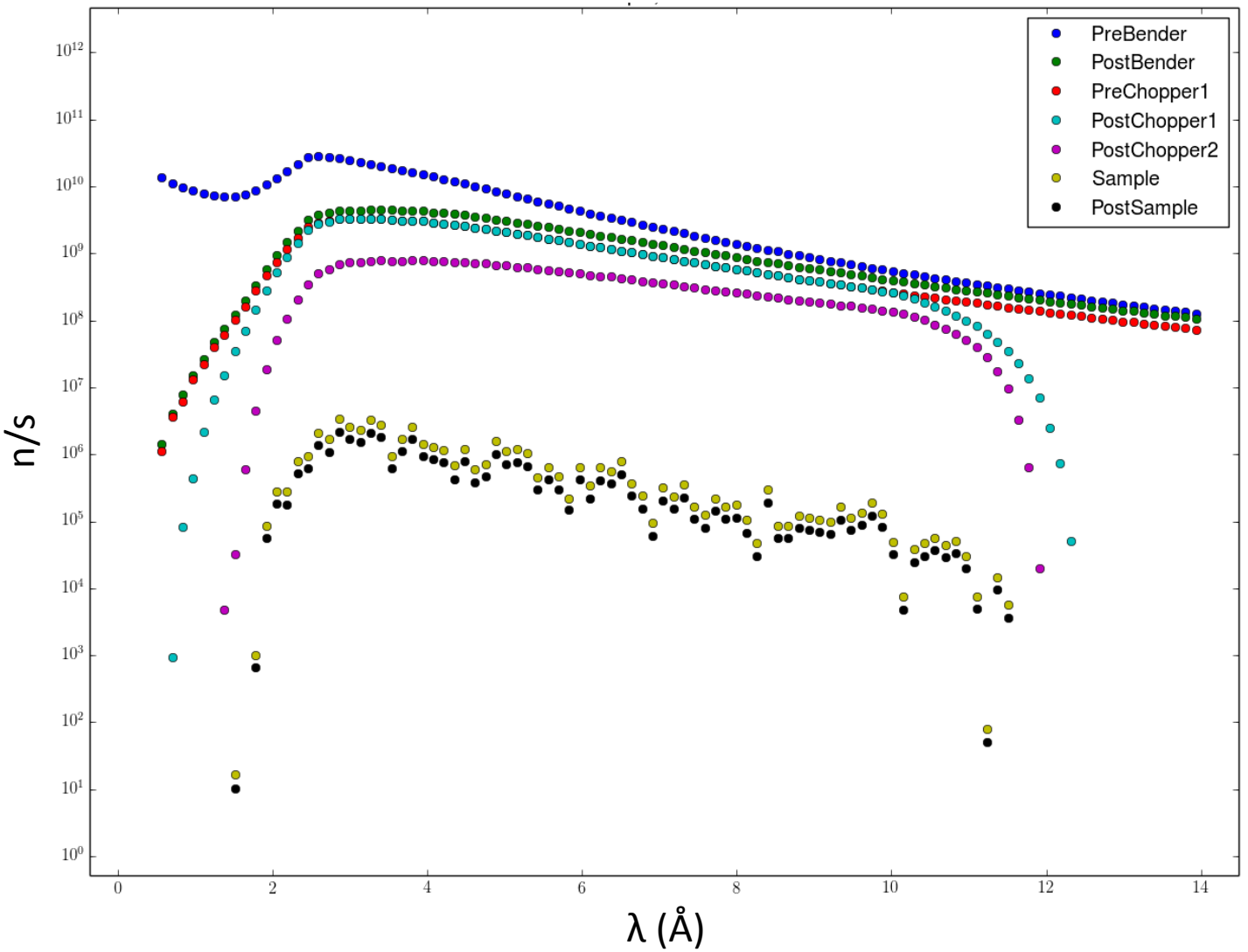


- Capture and ion escape included in the calculations
- Back-scattering efficiency
- Q resolution is detector-specific

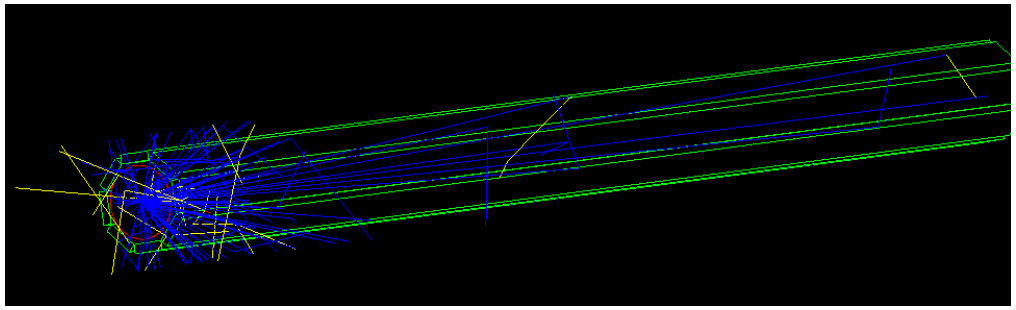
K.Kanaki et al., J. Appl. Cryst. **46**, 1031–1037 (2013)
F. Piscitelli and P. van Esch, JINST **8**, P04020 (2013)
F. Piscitelli, Ph.D. thesis, University of Perugia (2013)

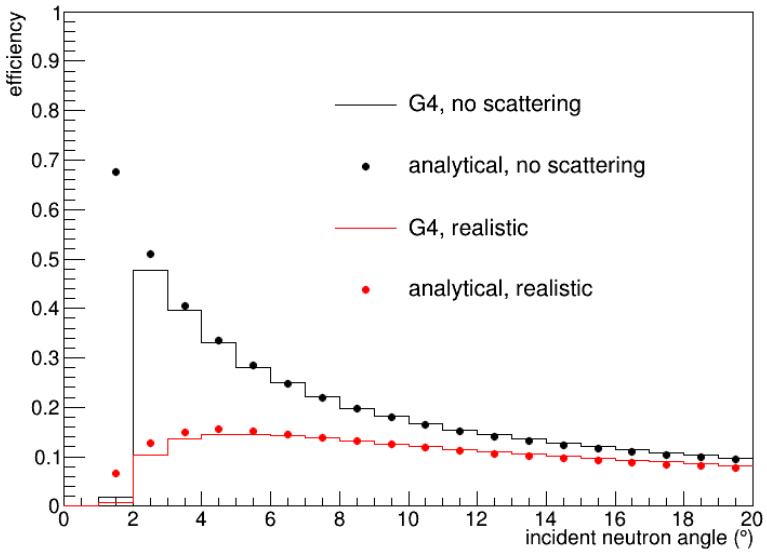
Pre- and post sample λ distribution (McStas)

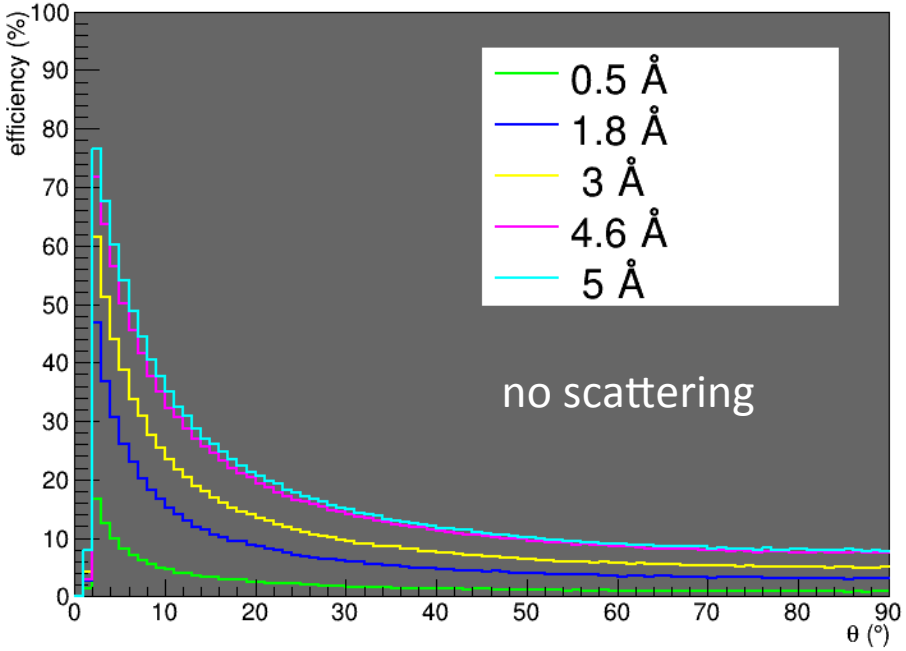
water sample, 2m collimation

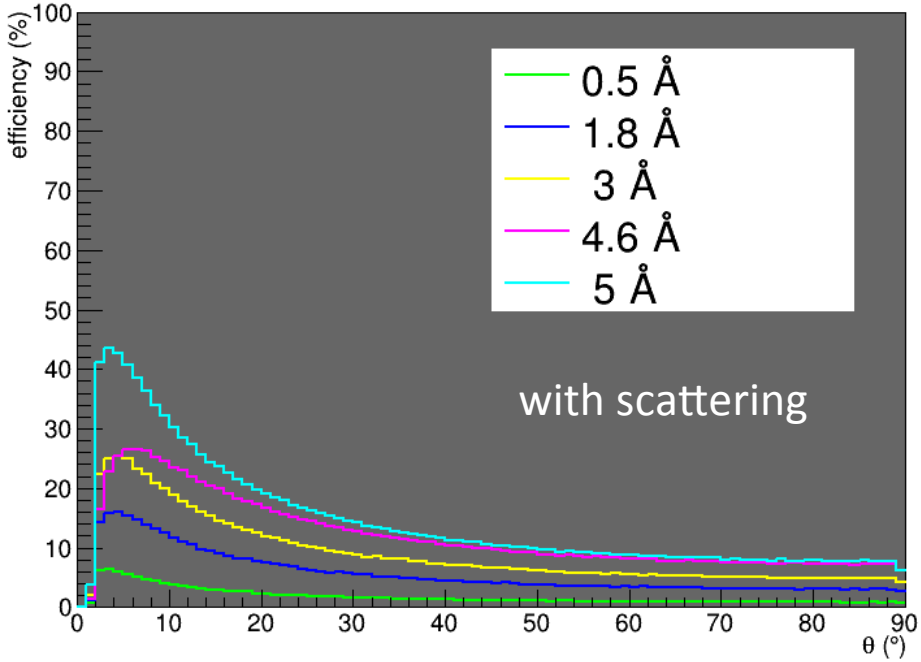


Efficiency & Scattering Studies (Geant4)

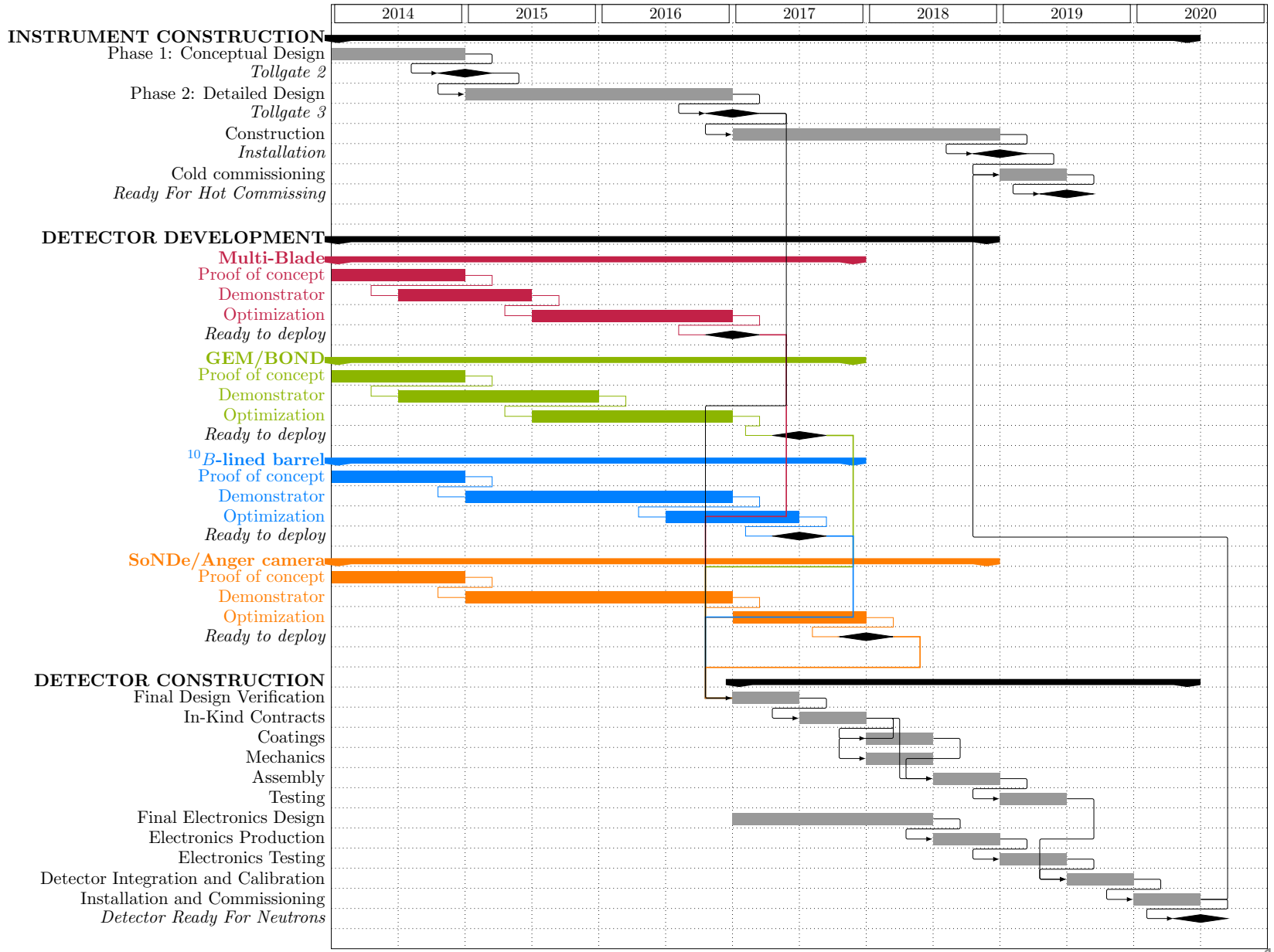








LOKI schedule for detector R&D and construction



Summary

- LOKI entered conceptual design phase in 2014
- Multiple front effort
  - analytical calculations
  - simulations
  - R&D
  - measurements in spallation facilities
  - evaluation for different detector geometries
- Evaluation tools in place
- Requirements collection process on-going
- Performance of detector solutions on-going
- Tollgate decision end of 2014 for technologies entering final design phase
- Instrument construction at ESS is underway