Detector possibilities for LoKI

Kalliopi Kanaki

Topics to be addressed

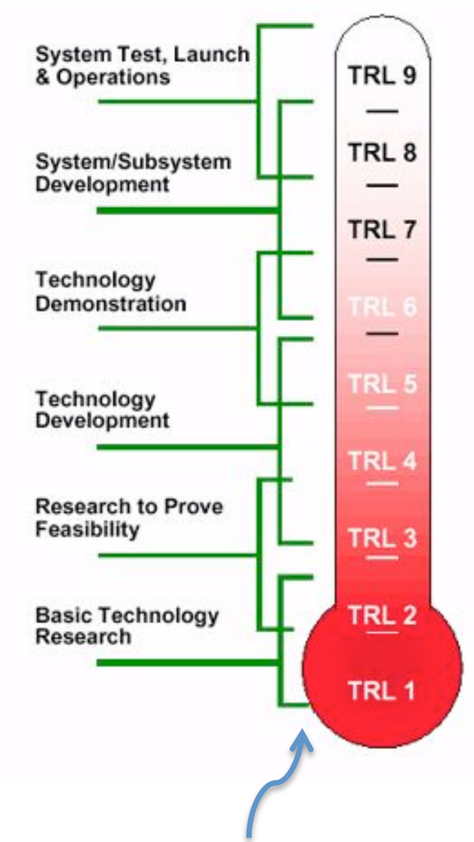
- Detector options for LoKI
- Related detector group R&D activities
- Highlights of results
- Instrument phase 1

Making decisions

What should we take into account?

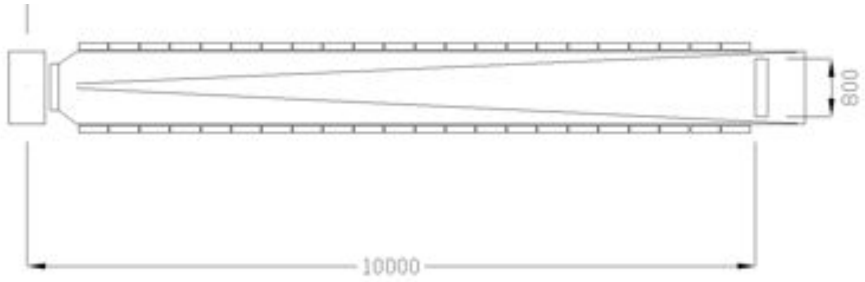
- Requirements matching
- Cost
- Technology availability
- Technology readiness level (TRL)

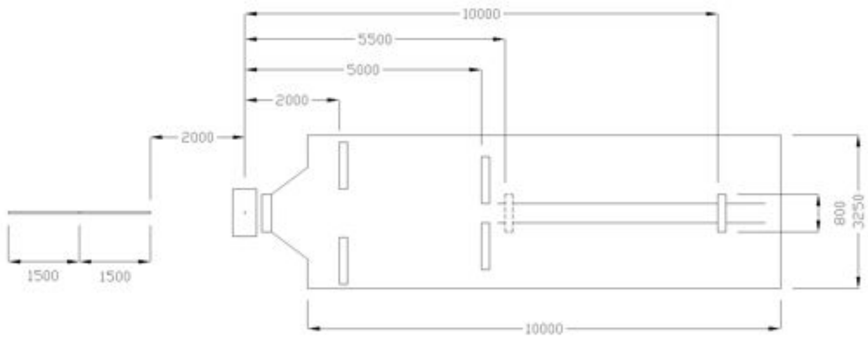
Technology Readiness Level	Description	Responsibility
TRL1	Basic principles observed and reported	Universities
TRL2	Technology concept and/or application formulated	Universities / Detector Systems
TRL3	Analytical experimental critical function / characteristic proof-of-concept	Universities / Detector Systems
TRL4	Component validation in laboratory environment	Universities / Detector System
TRL5	Component validation in relevant environment	Detector Systems
TRL6	System/subsystem model or prototype demonstration on a relevant beamline	Detector Systems
TRL7	System prototype demonstration on an instrument	Detector Systems / Instrument Projects
TRL8	Actual system completed and "Flight qualified" through test, cold commissioning	Instrument Projects
TRL9	Actual system "Flight Proven" through hot commissioning	Instrument Commissioning / Detector Operations



NASA TRL (wikipedia)

LoKI options





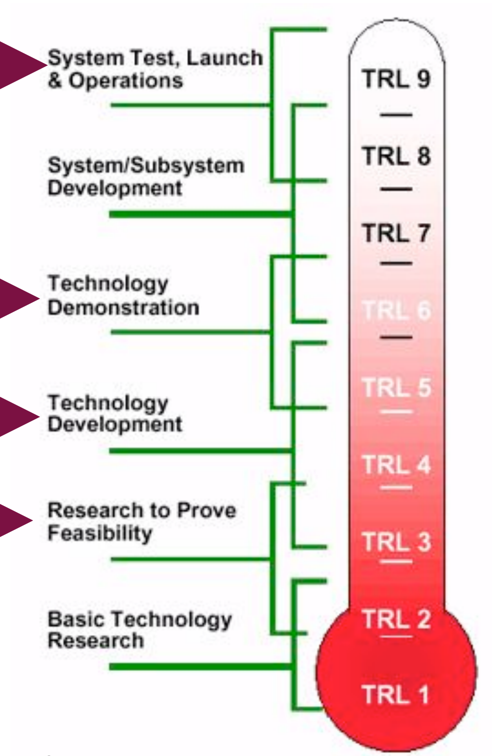
- Zero angle detector
- Low angle
    - Anger cameras
    - MultiBlade
    - MultiGrid
    - bGEM
- High angle
    - ^{10}B tube

Anger Cameras

Multiblade and Jalousie

B-10 Tube Geometry

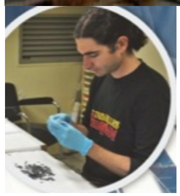
B-GEM



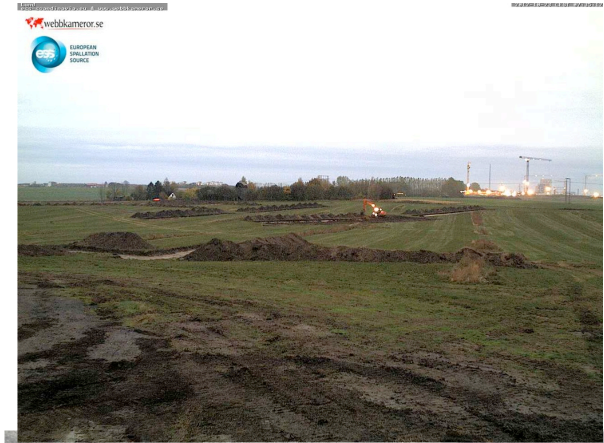
- Zero angle detector
- Low angle
    - Anger cameras
    - bGEM
    - MultiBlade
- Mid-angle
    - Anger cameras
    - bGEM
    - MultiBlade
- High-angle
    - Macrostructures
    - MultiGrid

Rate & resolution limitations make ^{3}He an unrealistic option

The ESS Detector Group

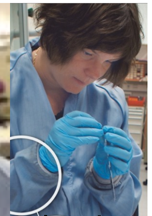


Anton
Khaplanov

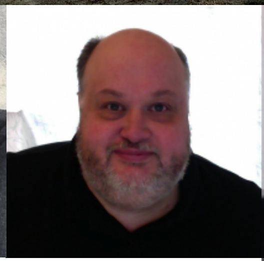


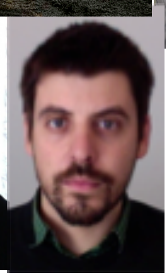
Richard Hall-Wilton
Kalliopi Kanaki
Thomas Kittelmann
Scott Kolya
Luis Ortega

(31 Dec 2010, detector group comprised of ... Carina!)



Carina Höglund
Mewlude Imam*

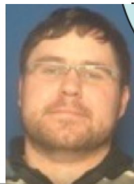




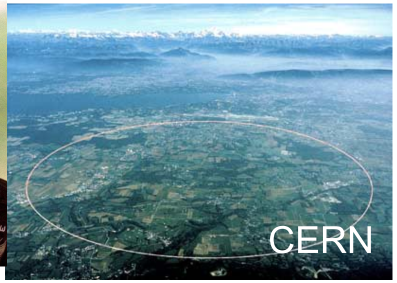
Isabel Llamas
Xiao Xiao Cai
Thomas Haraldsen

3 PhD Students (*)
(+5 bachelors/Masters Projects+2 interns)

Kevin Fissum
Björn Nilsson
Julius Scherzinger*
Vladimir Pastukov*



Dorothea
Pfeiffer



5

reorganization of the group & work breakdown structure to change focus from R&D to instrument classes and construction

LoKI related ESS R&D activities

- ^{10}B technology (ILL/ESS/FRM-II/Linköping)
  - Multi-Grid detector (multiple converter layers)
  - Macrostructures (multiple converter layers)
  - Tube detector (single converter layer)
  - B_4C coatings
- bGEM (Italy/CERN)
- Simulation framework
- Neutron energy determination

Technology strategies

- No ^{3}He developments internally
- Expect a need of ca. 2000 bar-litres of ^{3}He
- Do not buy ^{3}He directly, secured by in-kind partners

- B^4C coatings can be mass produced very cheaply
- New deposition machine at Linköping will provide 100-300% of expected ESS needs
- Production will be partly by ESS, partly by in-kind partners
- Act as centre of excellence for the technology: i.e. simulation, standards, expertise concentrated at ESS

- Numerous groups already working on scintillator technologies: ISIS, SNS, Jülich, JPARC
- Resources not available: ESS should be a client for scintillator technologies
- In-kind ISIS (WLS), Jülich (WLS, Anger cameras)

Multi-Grid design (ILL/ESS/Linköping)

- Multiple conversion layers (30)
- MWPC concept

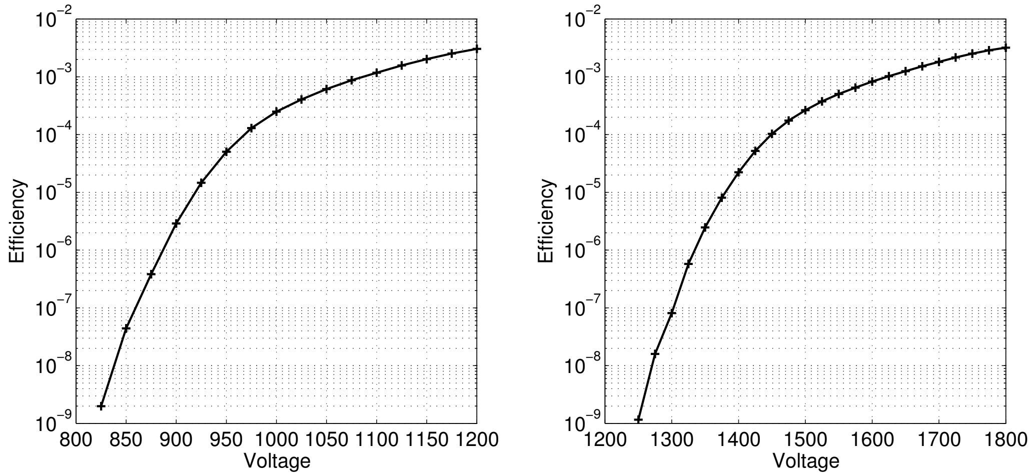
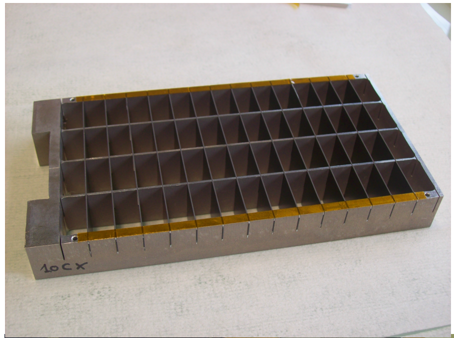


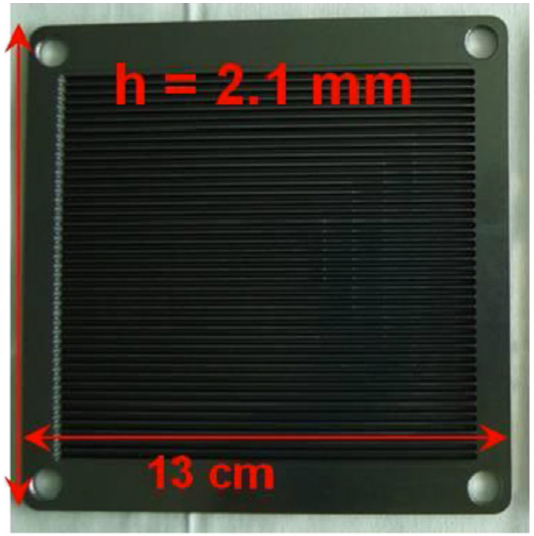
Figure 8: Plateau measurement with the Multi-Grid ^{10}B detector (left) and a Multi-Tube ^{3}He detector (right) with a strong ^{137}Cs source.

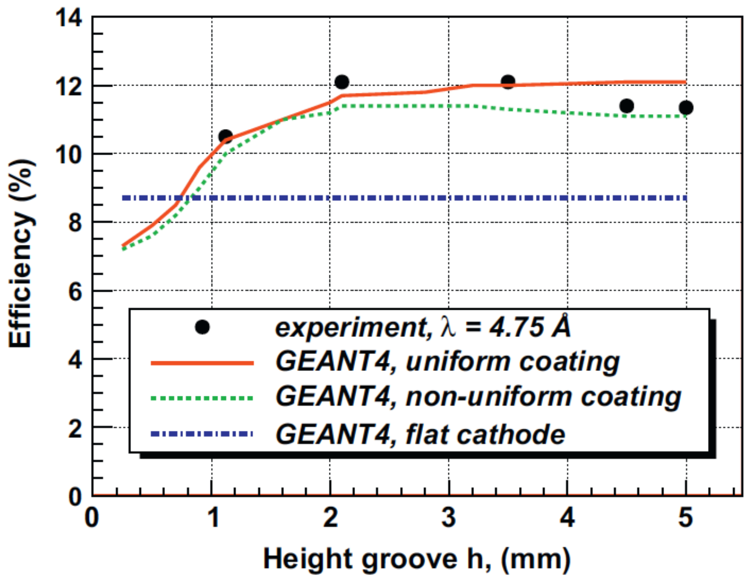


- neutron efficiency: analytically calculated, simulated, measured, understood
- γ efficiency comparable to ^{3}He
- scattering understood
- detector induced background understood
- large scale IN5 detector to be produced by October 2014, 3m x 0.8m
- working on definition of detector standards for reliable comparisons

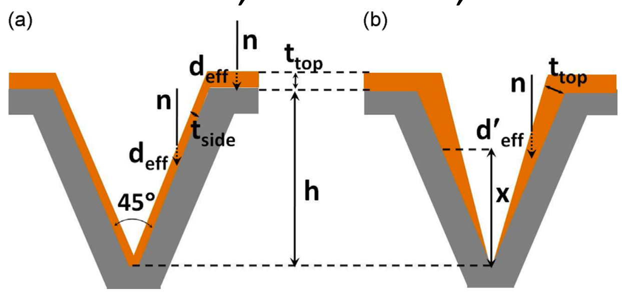
A. Khaplanov et al., Nucl Instr. & Meth. in Phys. Res. A, 720, 116-121 (2012)
A. Khaplanov et al., JINST 8, P10025 (2013)
F. Piscitelli and P. van Esch, JINST **8**, P04020 (2013)
F. Piscitelli, Ph.D. thesis, University of Perugia (2013)

Macrostructures design (FRM-II/ESS)



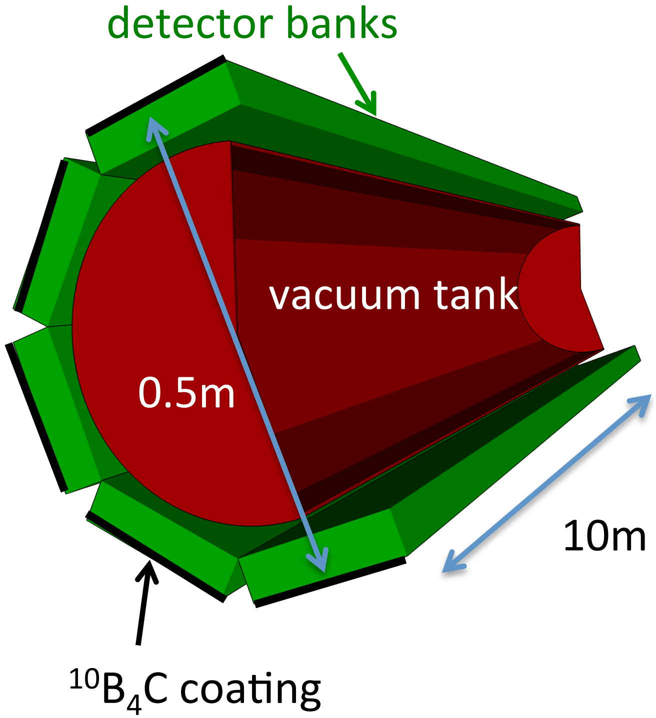


- Multiple conversion layers (5)
- MWPC concept
- Uniform coating performs better
- Macrostructures increase (layer) efficiency by a factor 1.5
- Performance simulated, measured, understood

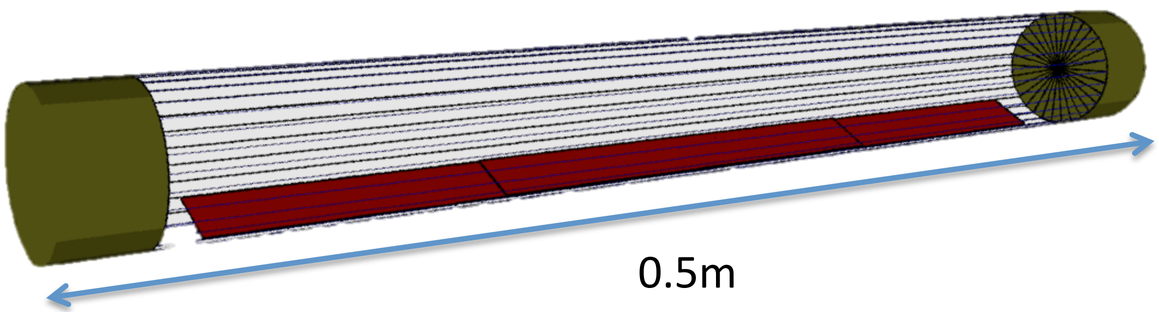


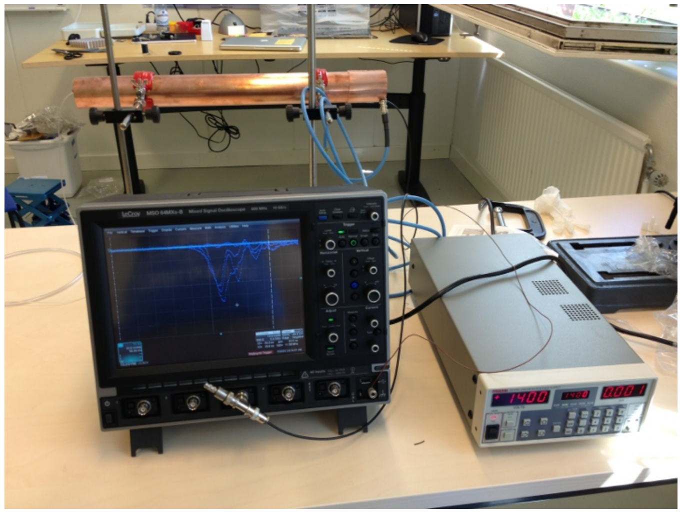
I. Stefanescu et al., Nucl. Instr. Meth & Phys. Res. A, 727, 109-125 (2013)
I. Stefanescu *et al* 2013 *JINST* **8** P12003

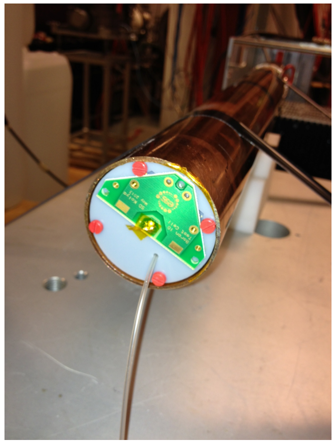
Tube detector

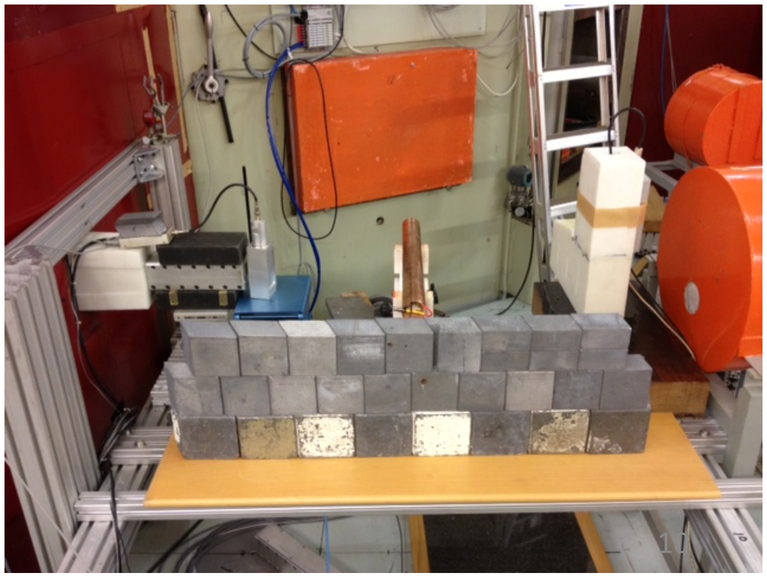


- Analytical calculations in place
- Detailed simulations in progress
- Prototyping phase (proportional counter)
- Tests with AmBe source and beam in progress

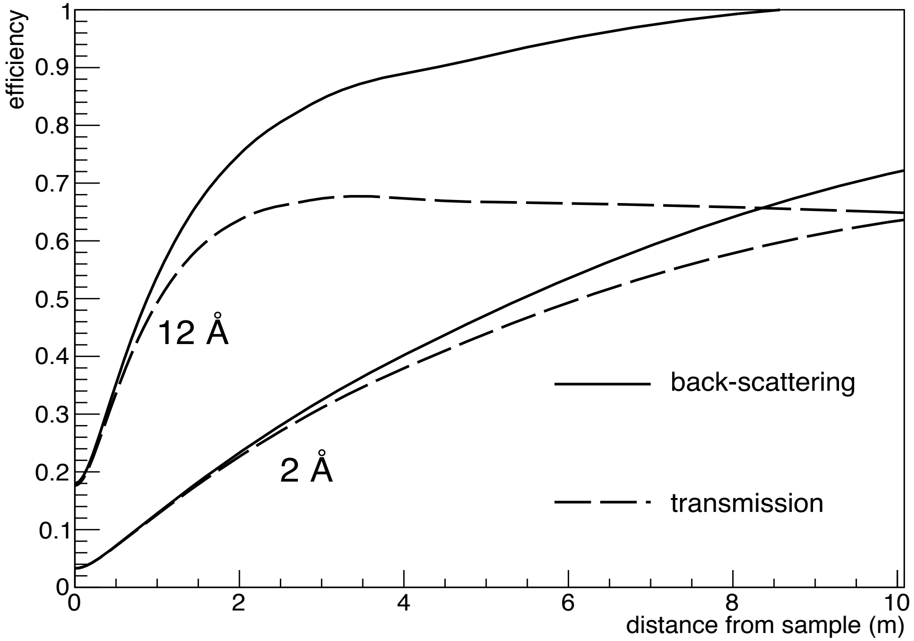


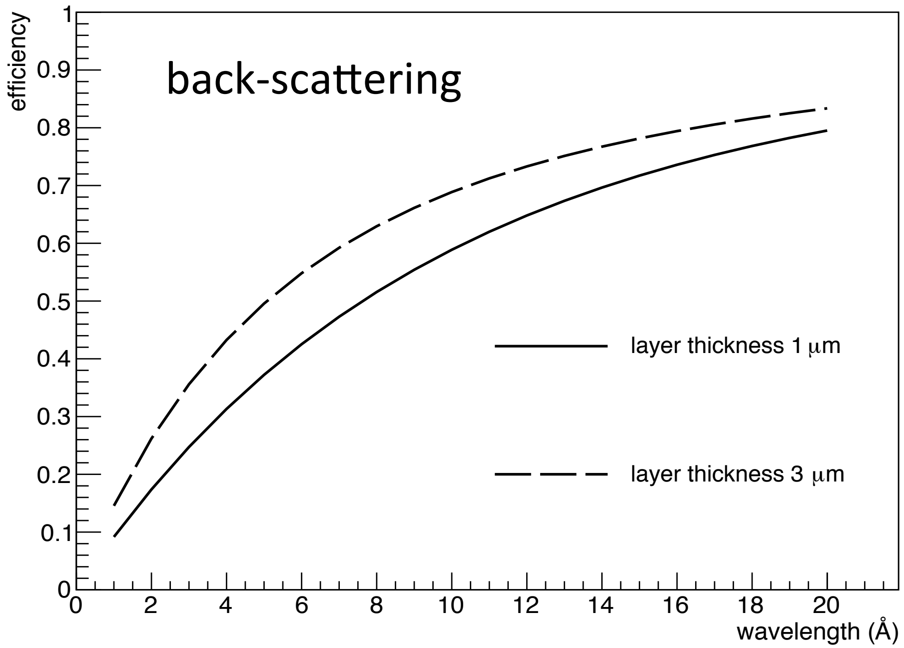






Analytical evaluation I: Efficiency

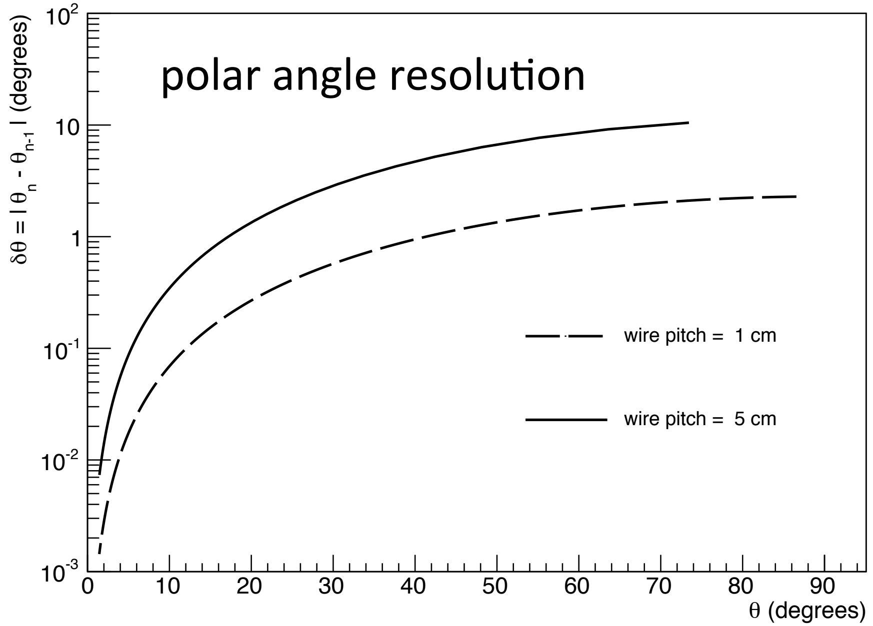


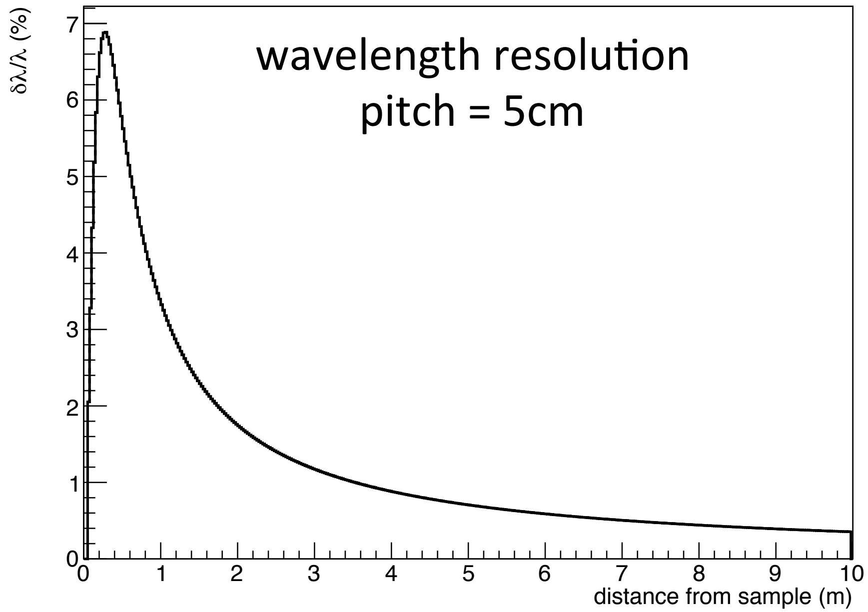


- Capture and ion escape included in the calculations
- **Back-scattering efficiency higher than transmission -> working choice**
- Room for optimization by
  - further increasing the neutron incident angle
  - varying the boron layer thickness
  - additional converting layers

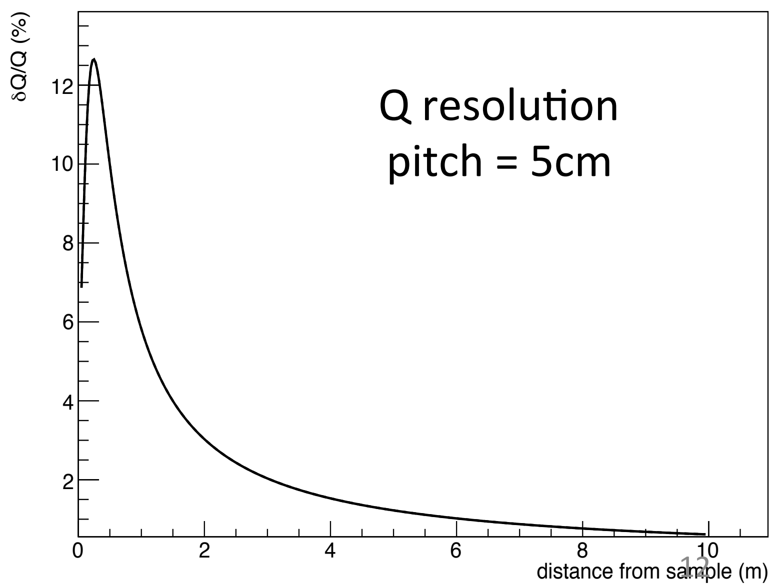
K.Kanaki et al., J. Appl. Cryst. **46**, 1031–1037 (2013)
F. Piscitelli and P. van Esch, JINST **8**, P04020 (2013)
F. Piscitelli, Ph.D. thesis, University of Perugia (2013)

Analytical evaluation II: Resolution



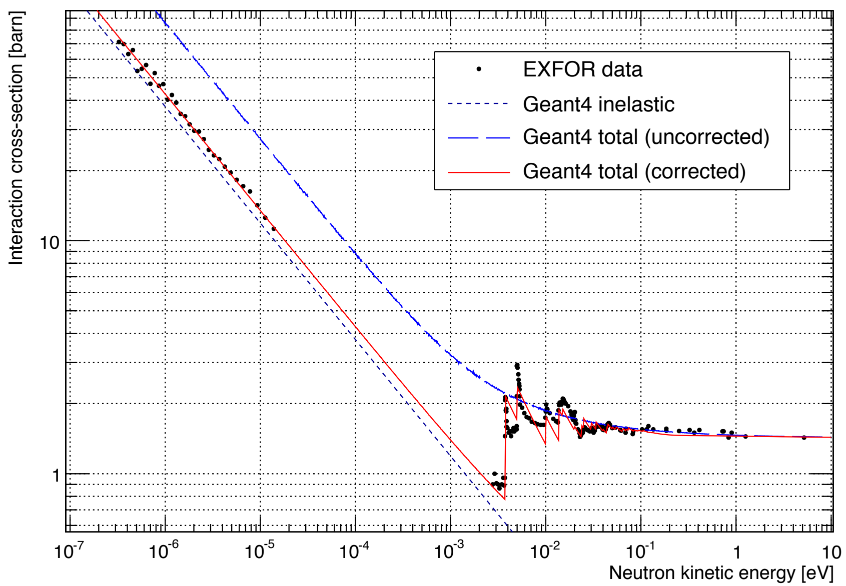


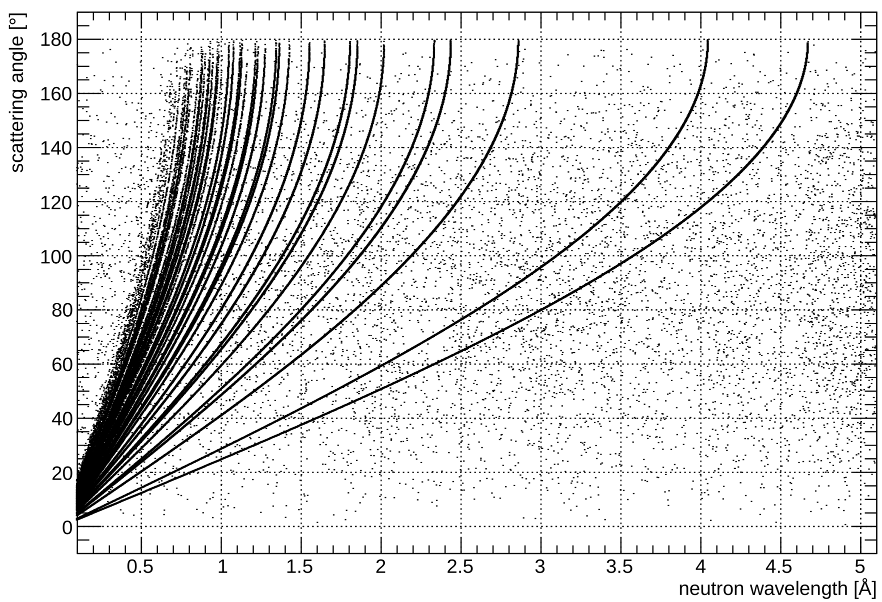
- $\delta\theta = |\theta_n - \theta_{n-1}|$
- **$\delta\theta/\theta$ < 10% at the detector area with highest occupancy, far better than what required**
- λ and Q resolutions are detector-specific
- Impact of azimuthal angle negligible
- Resistive wires or segmented cathodes can be used for 2D resolution



Simulation tools: Diffractive processes in Geant4

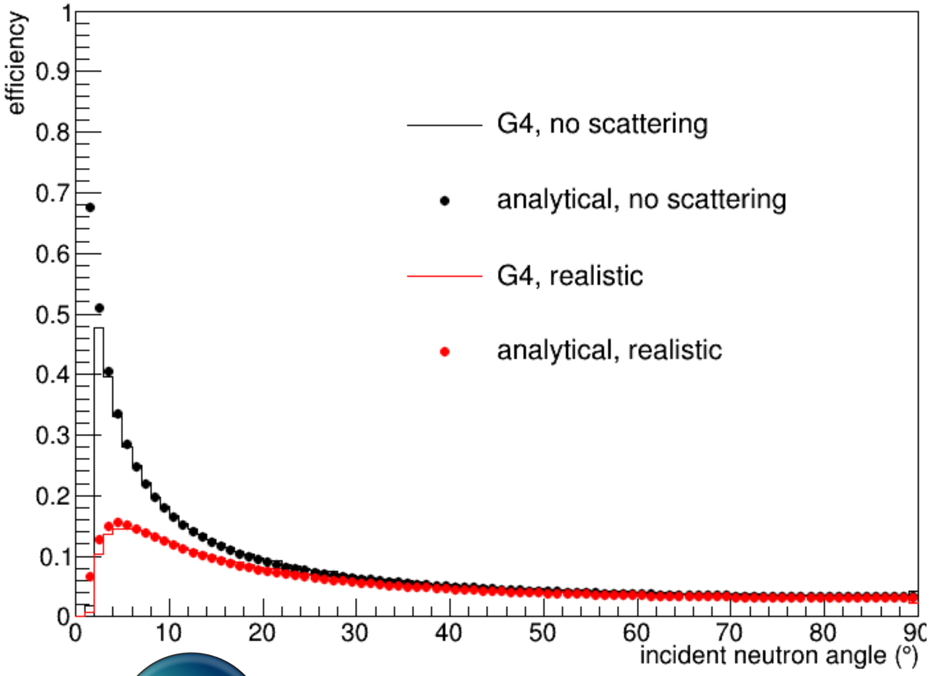
- For neutrons of a few Å diffractive scattering becomes important
- Respective physics processes not included in Geant4
- Functionality added with the integration of NXSLib library from McStas
- **NXSLib – Geant4 integration extends the capabilities of Geant4 to become a complete tool for investigations at neutron scattering facilities**



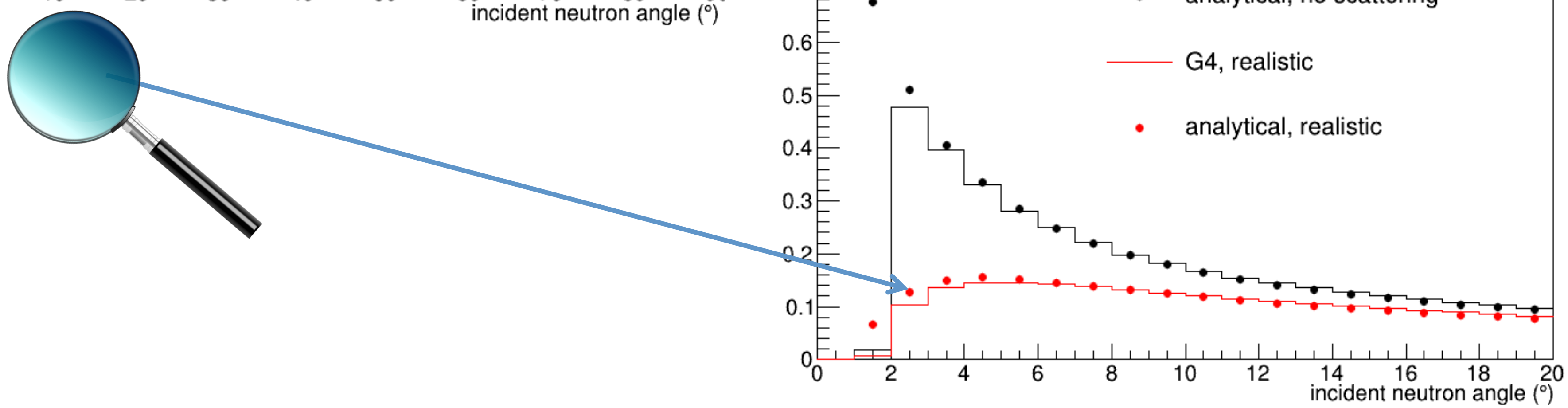


T. Kittelmann, poster NPO2-138, NSS IEEE 2013
T. Kittelmann, CHEP 2013 proceedings

Efficiency: Geant4 vs. analytical



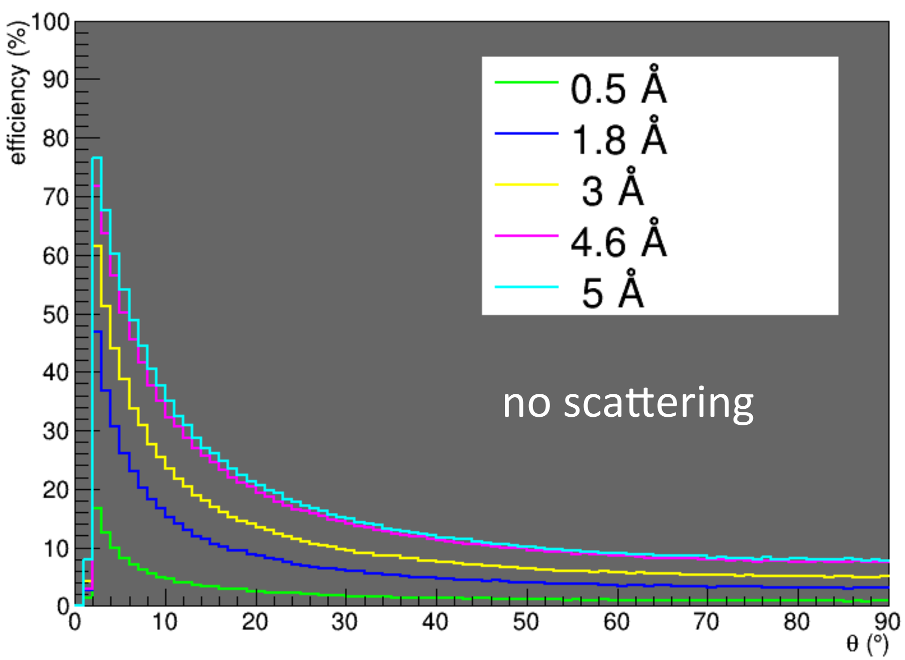
- simplified cylindrical geometry
- neutron wavelength = 2 Å
- Al vacuum vessel window = 0.3cm
- Al detector window = 0.3cm
- below 2°-3° the comparison is not reliable due to detector edge effects

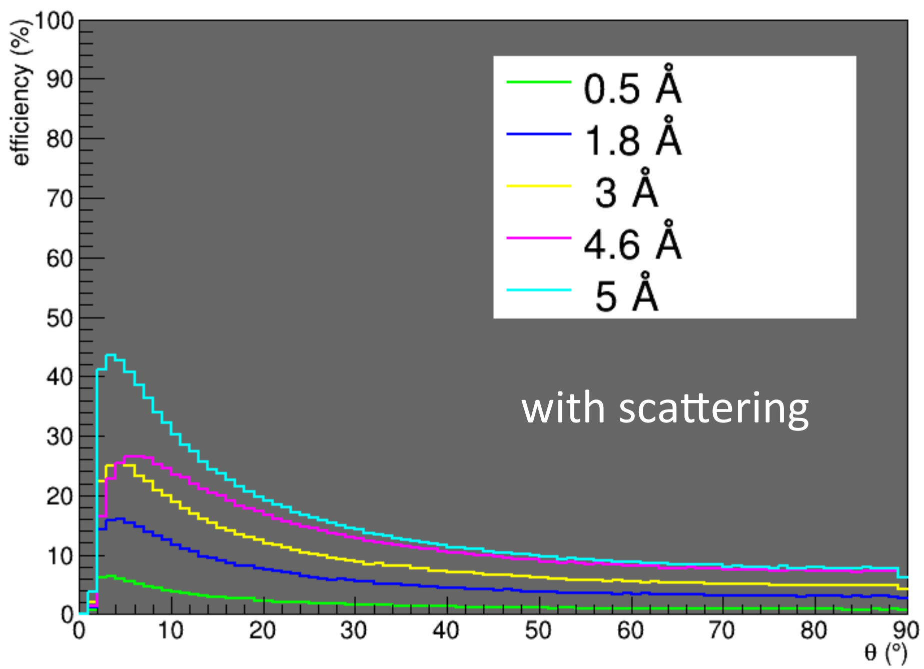


Geant4 is validated for coherent neutron scattering!!

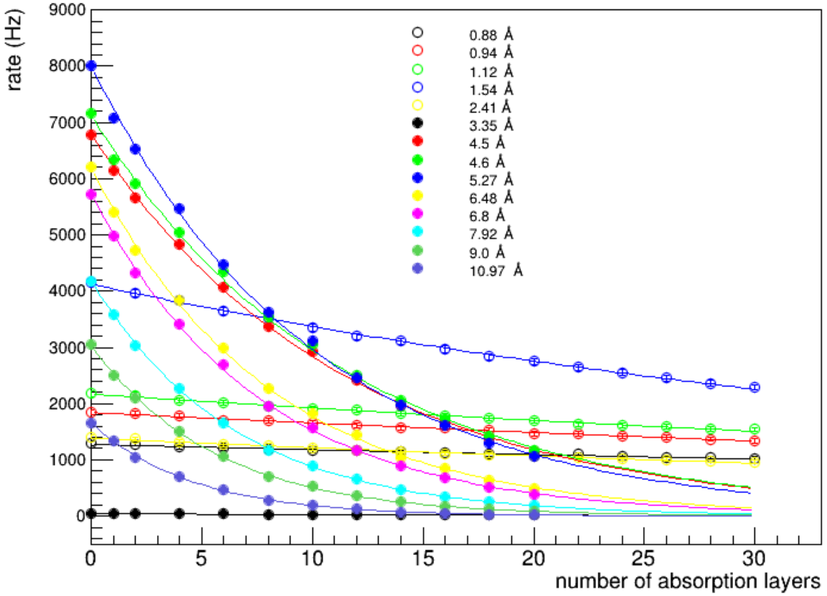
Impact of scattering on efficiency

- Geant4 realistic LoKI geometry with octagonal cross section
- Al vacuum vessel window = 0.3cm
- Al detector cathode window = 0.1cm
- **Scattering impact on efficiency has to be minimized**

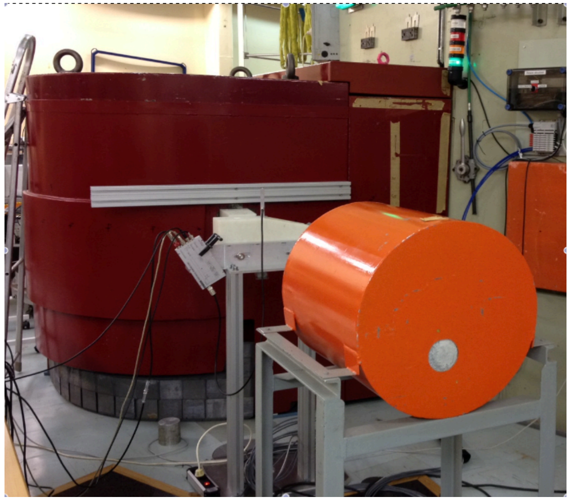


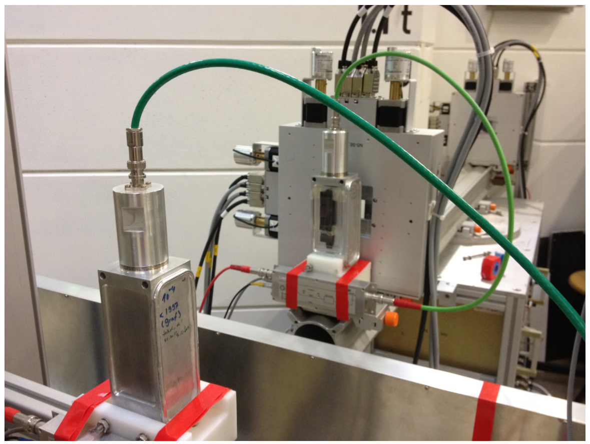


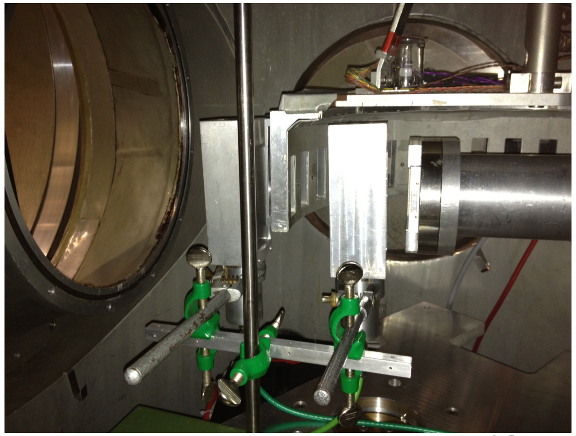
Neutron energy determination



- Idea: deconvolution of neutron energy spectrum with statistical inference methods
- Method is applicable for all multi-layer detectors
- Bonner sphere-like deconvolution
- Exploit the depth of interaction
- Absorption profile measurements from 3 facilities as first approach (monochromator & chopper lines)
- 1 MSc and 1 PhD student working on the topic
- First results are very encouraging!







Deliverables for Phase 1:
documents to be prepared by November 2014

Location: detectorDocumentsLOKI

view@rev « 14 » follow current branch

search file list | add new file

mercurial screenshot

Name	Size	Mimetype
Budget		
DraftCommissioningPlan		
FinalDesign		
Instrument3DCADModel		
InstrumentPID		
Proposal		
Requirements		
RiskAssessment		
Schedule		
SystemsEngineering		
TechnicalGroupDesign		
WorkUnitDocuments		
.hgignore	219 B	text/plain
README	190 B	text/plain

communication folders (Proposal, Requirements)

forgotten in the official list, added by us (RiskAssessment)

Monthly discussions & quarterly document revisions with:

- instrument scientist (Andrew)
- instrument engineer (Stewart)
- detector scientist (Kelly)

Snapshot of the LoKI detector schedule

2014 Instrument Conceptual Design: Detectors Work Units – /Users/kalliopikanaki/detectorDocumentsLOKI/WorkUnitDocuments

		Name	Duration	Start	Finish	Predecessors	Resource Names
1		⊟SANS / LOKI	105 days	1/1/14 8:00 AM	5/27/14 5:00 PM		
2		⊟1. Requirements	30 days	1/1/14 8:00 AM	2/11/14 5:00 PM		
3		IS provides proposal requirements	0 days	1/1/14 8:00 AM	1/1/14 8:00 AM		IS: Andrew
4		IS+DS refine requirements	10 days	1/1/14 8:00 AM	1/14/14 5:00 PM		IS: Andrew[50%];DS: Kelly[50%]
5		IS provides simulated data after sample	0 days	1/14/14 5:00 PM	1/14/14 5:00 PM	4	IS: Andrew
6		IS + DS define S:B and FOM	5 days	1/15/14 8:00 AM	1/21/14 5:00 PM	5	IS: Andrew[50%];DS: Kelly[50%]
7		Technology choices	15 days	1/22/14 8:00 AM	2/11/14 5:00 PM	6	DS: Kelly
8		Report on requirements	0 days	2/11/14 5:00 PM	2/11/14 5:00 PM	6;7	DS: Kelly
9		⊟2. Beam Monitor requirements	45 days	2/12/14 8:00 AM	4/15/14 5:00 PM	2	
10		Conceptual requirements of beam monitors	10 days	2/12/14 8:00 AM	2/25/14 5:00 PM		IS: Andrew[50%];DS: Kelly[50%]
11		Envelope reservation	20 days	2/26/14 8:00 AM	3/25/14 5:00 PM	10	Detector Engineer
12		Electronics concept	5 days	3/26/14 8:00 AM	4/1/14 5:00 PM	11	DS: Kelly
13		Cable path reservations	10 days	4/2/14 8:00 AM	4/15/14 5:00 PM	12	Detector Engineer
14		Report on Beam Monitors	0 days	4/15/14 5:00 PM	4/15/14 5:00 PM	13	DS: Kelly
15		⊟3. Determine demonstrator detectors for phase 2	75 days	2/12/14 8:00 AM	5/27/14 5:00 PM	2	
16		Background optimisation	20 days	2/12/14 8:00 AM	3/11/14 5:00 PM		DS: Kelly
17		DS creates detector simulation	20 days	2/12/14 8:00 AM	3/11/14 5:00 PM		DS: Kelly
18		DE creates conceptual model	20 days	2/12/14 8:00 AM	3/11/14 5:00 PM		Detector Engineer
19		DS work on FoM optimisation option 1	20 days	3/12/14 8:00 AM	4/8/14 5:00 PM	17	DS: Kelly
20		DS work on FoM optimisation option 2	20 days	4/9/14 8:00 AM	5/6/14 5:00 PM	17;19	DS: Kelly
21		Electronics concept	15 days	5/7/14 8:00 AM	5/27/14 5:00 PM	20	DS: Kelly
22		Report: definition of demonstrator	0 days	5/27/14 5:00 PM	5/27/14 5:00 PM	19;20;21	DS: Kelly
23		⊟4. Conceptual design and definition of strategy and partners	145 days	1/15/14 8:00 AM	8/5/14 5:00 PM		
24		Initial conceptual model A	10 days	1/15/14 8:00 AM	1/28/14 5:00 PM	4	Detector Engineer
25		Initial conceptual model B	10 days	1/29/14 8:00 AM	2/11/14 5:00 PM	24	Detector Engineer
26		FEA vacuum tank model A	20 days	1/29/14 8:00 AM	2/25/14 5:00 PM	24	Detector Engineer
27		Revised conceptual models A+B	20 days	5/28/14 8:00 AM	6/24/14 5:00 PM	24;25;15;26	Detector Engineer
28		Cabling envelopes reservation	20 days	6/25/14 8:00 AM	7/22/14 5:00 PM	27	Detector Engineer
29		Services Requirements	5 days	7/23/14 8:00 AM	7/29/14 5:00 PM	28	Detector Engineer
30		Readout requirements	5 days	7/30/14 8:00 AM	8/5/14 5:00 PM	29	DS: Kelly
31		Report on Conceptual Design	0 days	8/5/14 5:00 PM	8/5/14 5:00 PM	27;30	Detector Engineer
32		⊟5. Cost and Schedule	20 days	8/6/14 8:00 AM	9/2/14 5:00 PM	23;15;9	
33		Cost	10 days	8/6/14 8:00 AM	8/19/14 5:00 PM		DS: Kelly
34		Schedule	10 days	8/20/14 8:00 AM	9/2/14 5:00 PM	33	Detector Engineer
35		Report on Cost and Schedule	0 days	9/2/14 5:00 PM	9/2/14 5:00 PM	34	Detector Engineer

- Not redone yet
- Covers first year
- Assumes all people are already hired
- Generic approach for beam monitors: will be done commonly for all instruments

Summary

- Extensive ^{10}B technology development at ESS/ILL/FRM-II
- Several geometries are considered
- Other technologies monitored and supported
- Final decisions on LoKI detectors in 2016
- Advanced simulation tools in place for detector optimization
- The outlook is positive ☺