Detector Strategy for LoKI

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Outline

- Quantification of detector requirements
- Detector technology options for LoKI
- Time schedule & technology decision ‘tree’
- Costing
- Status of TG2 documents

Detector performance standards

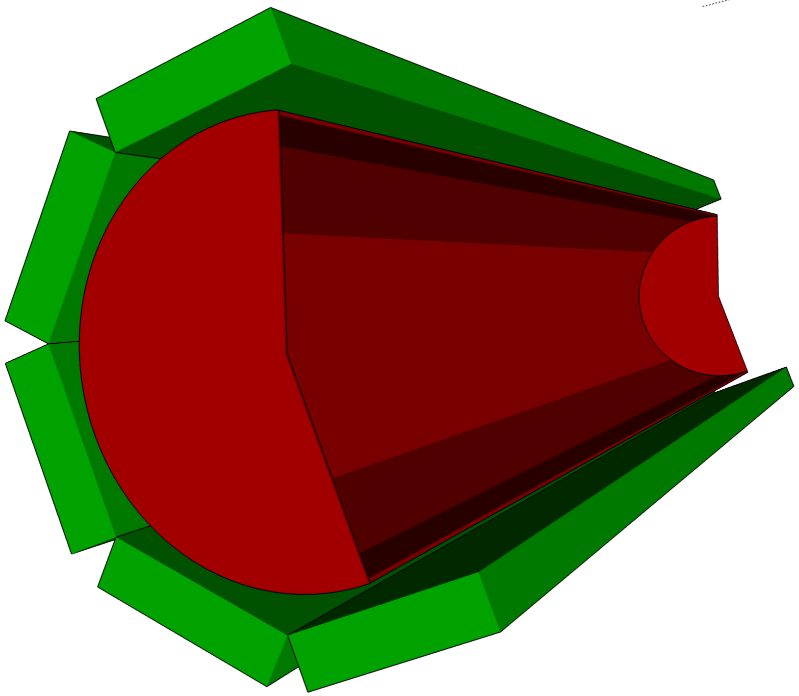
- Spatial resolution
- Rate capability
- Efficiency
- Time resolution
- Background
- Dynamic range

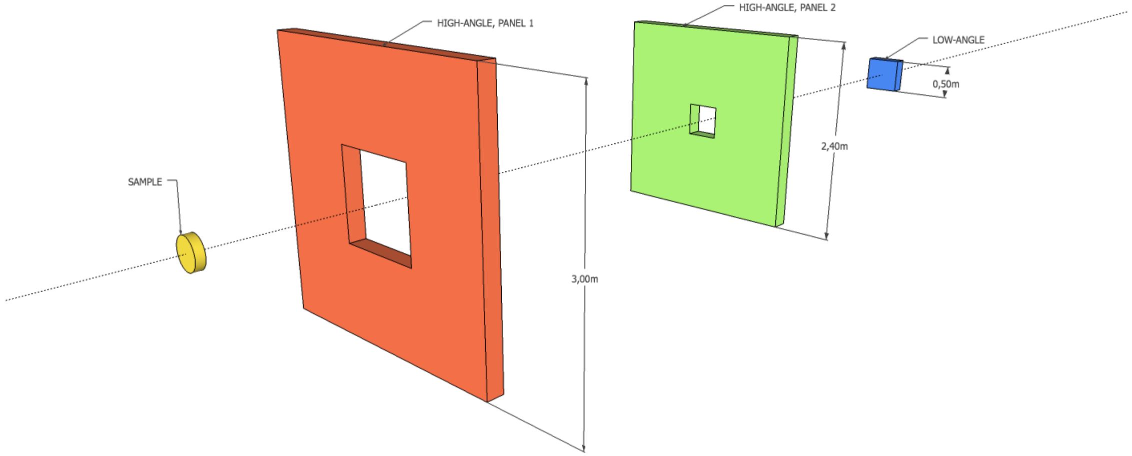
Detailed standards definitions and measurement methods are in the process of documentation (prepared by the ESS DG).

Technologies under examination must tick all the necessary boxes before being endorsed as solution for an instrument (no detector prototypes installed at ESS).

Preliminary geometry considerations starting point of evaluation

‘Barrel’ geometry (B)





‘Window frame’ geometry (WF)

Definitions:

- zero-angle: detectors lying on the path of the direct beam (0°-0.5°)
- low angle: covering 0.5°-2°/4° depending on position of rear detector
- high angle: rest of the angles 2°/4°-56°/90°

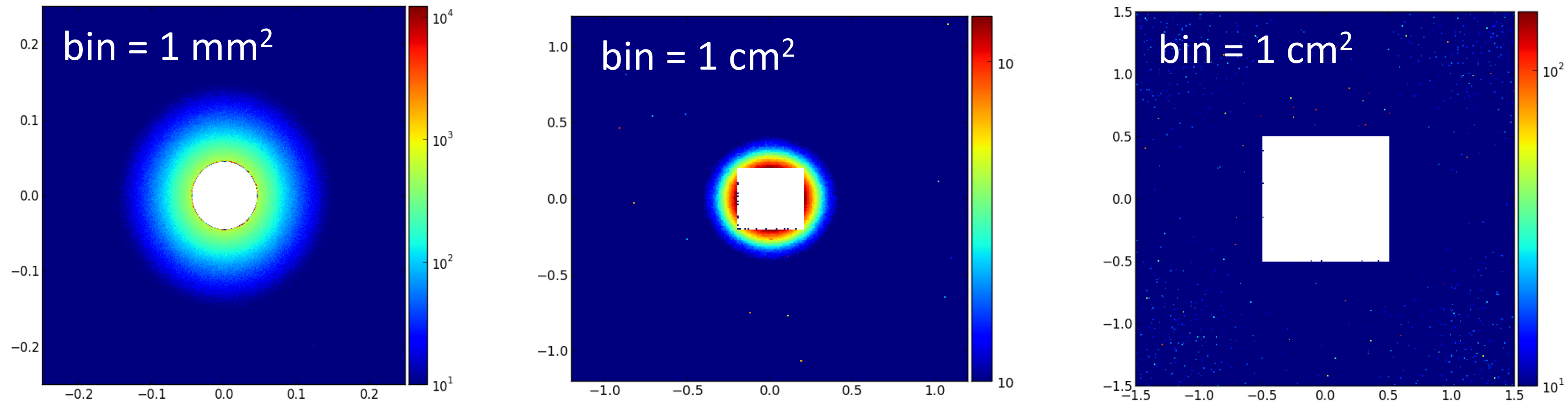
LoKI detector requirements & evaluation tools

- Need for justification of the detector specs on scientific basis
- Need for quantitative means to choose our compromises
- Analytical calculations for efficiency, time (tof) and position resolution
- Simulations with McStas 'realistic' samples: e.g. spheres (200 Å), water, etc.
  - Window frame geometry implemented
  - 'Barrel' geometry partly evaluated, geometry implementation in progress
- Simulations with Geant4 reading the McStas output
  - 'barrel' geometry implemented
  - window frame geometry implementation pending
- Local rates and resolutions for the main LoKI detectors have been quantified and are in the process of refinement (-> instantaneous rates)
- Beam monitor/transmission detector requirements will follow
  - taking a broader view on this since the requirements are not only LoKI-specific

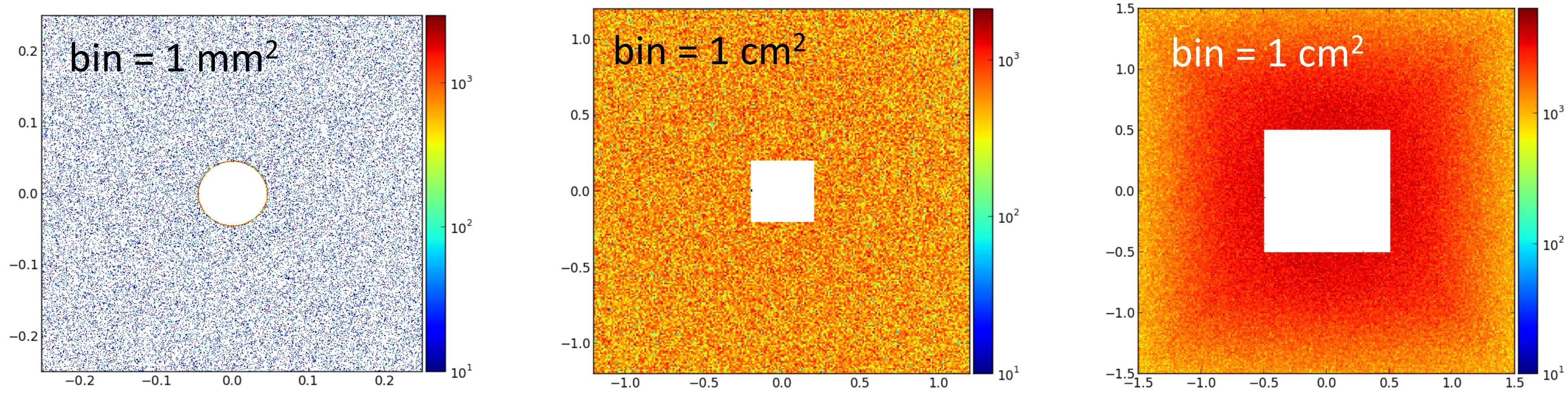
	active area	θ coverage	spatial resolution	time resolution	local rates
zero-angle	$\sim$70 cm^2	$0°$-$0.5°$	sub-mm ??	µs	9×10^8 Hz/cm^2
low-angle	0.25-1 m^2	$0.5°$-$4°$	3 mm	µs	500 Hz/mm^2(S), <70 Hz/mm^2(W)
high-angle (WF)					
mid-panel	6 m^2	$4°$-$27°$	0.5-1 cm	µs	140 Hz/cm^2(S), 1.3 kHz/cm^2(W)
front-panel	8 m^2	$27°$-$56°$	1-3 cm	µs	3 Hz/cm^2(S), <5 kHz/cm^2(W)
high-angle (B)	16-34 m^2	$3°$-$90°$	1-3 cm	µs	<3 kHz/$\theta\phi$ bin (S), 3 kHz/$\theta\phi$ bin (W)

Local rates (n/mm^2-cm^2/s): WF

rear mid front

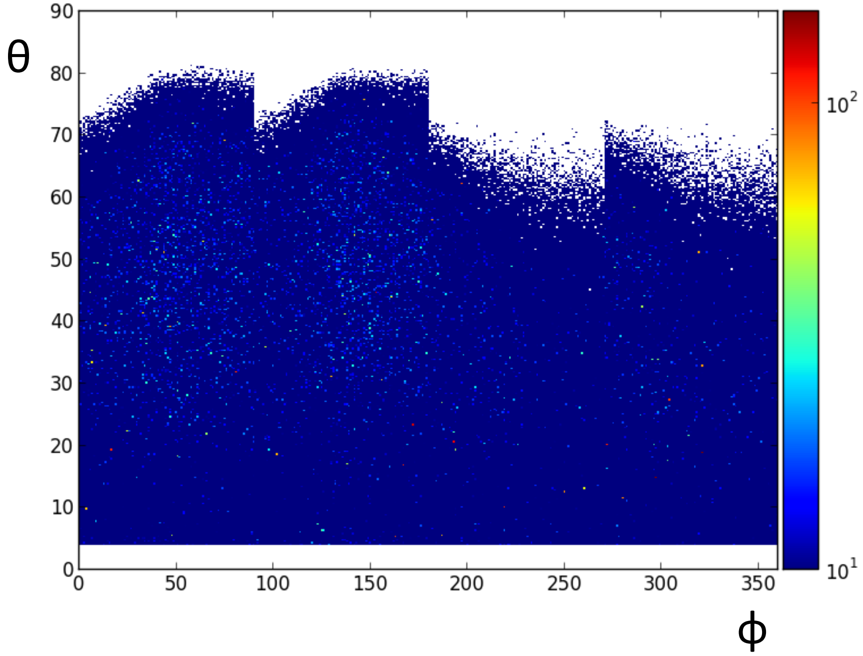


xy neutron hit distributions for spheres (up) and water (down)

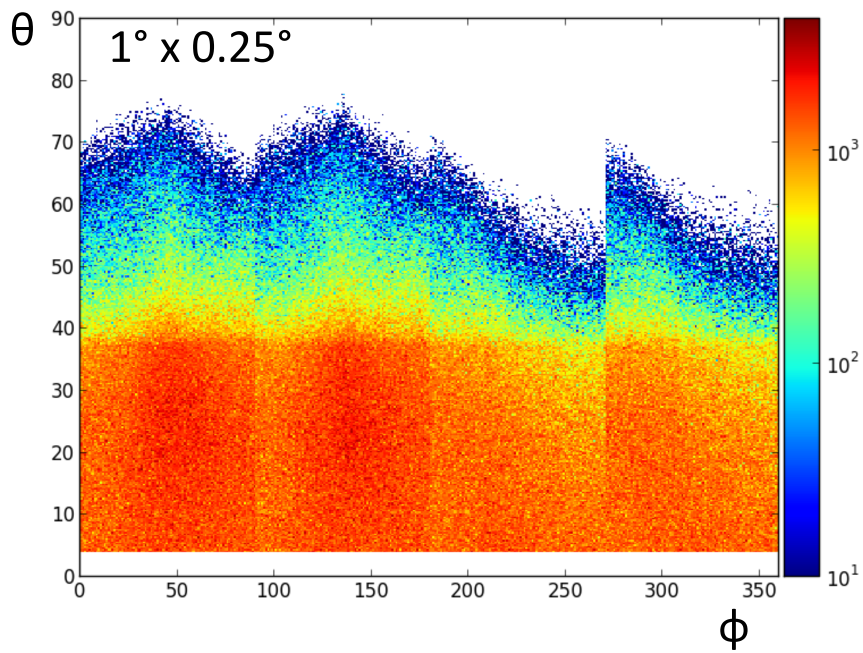


Local rates: barrel

spheres



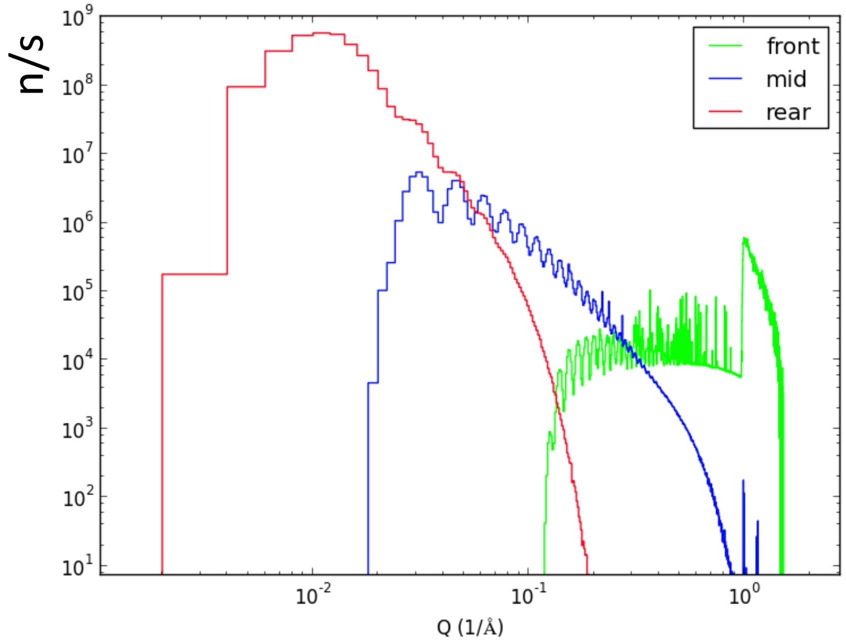
water



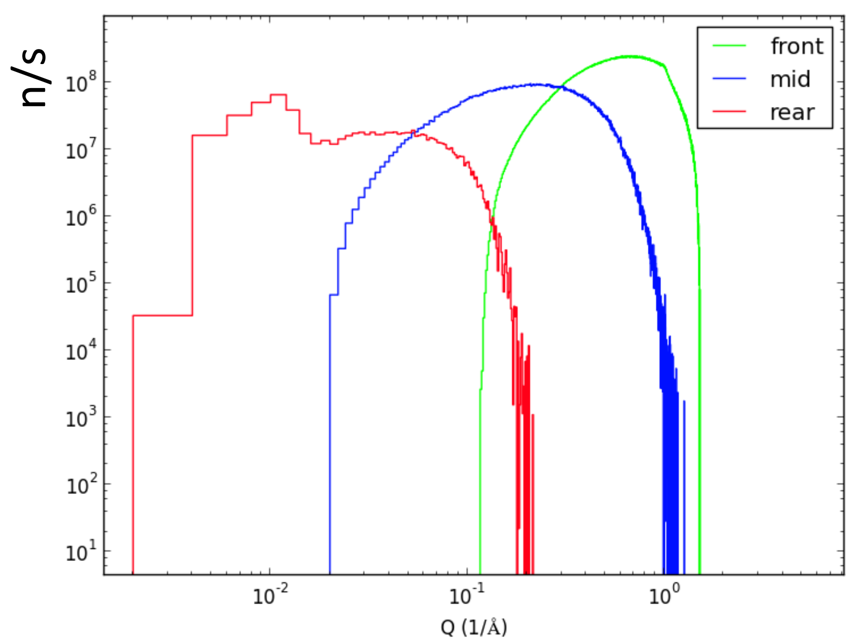
Q distributions from McStas nD_monitor (WF)

(no detector resolution included)

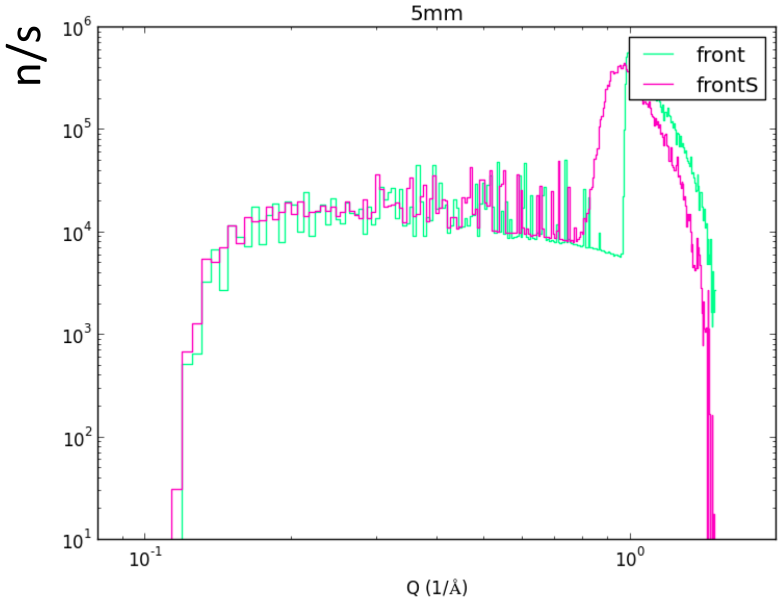
spheres (200 Å)



water

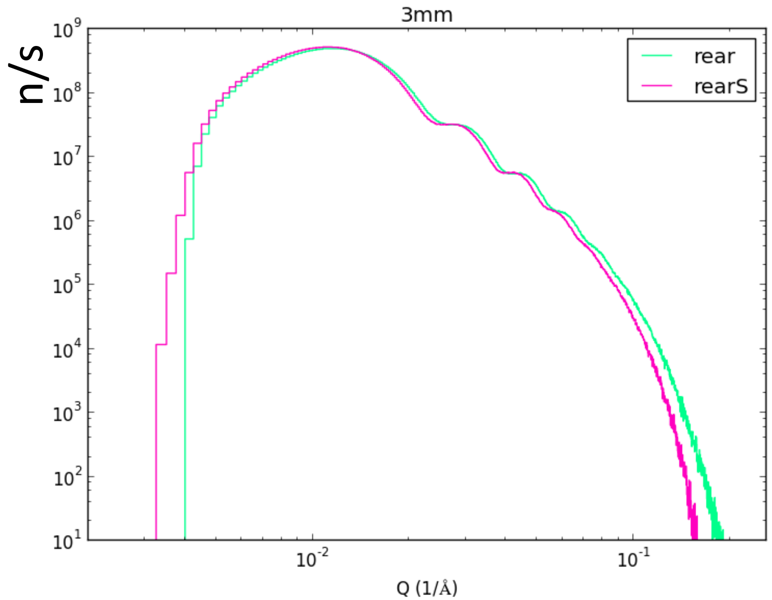


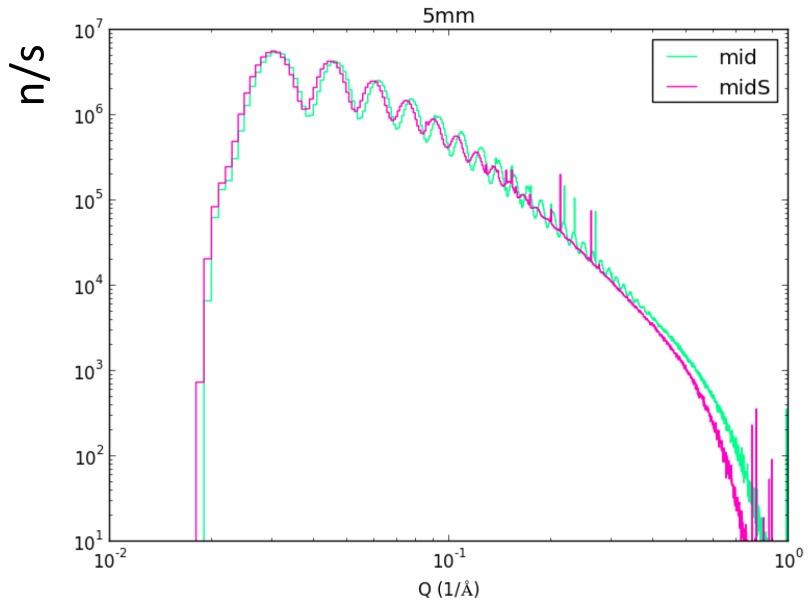
Q distributions
folded with detector position resolution (WF)



$\sigma_x = \sigma_y$ = 3-5 mm (not FWHM)

- Methodology of performance evaluation follows the data reduction steps in event mode
- McStas output can serve as input to Geant4
- Same data reduction/corrections for the output of Geant4
- Aim to demonstrate the full analysis chain is possible with any geometry (DG<->DMSC interface, Torben)
- Optimization based on Q resolution as a function of Q will be possible analytically & numerically
- Justification method for resolution requirements
    - clarifies why 3 mm are needed for the rear detector



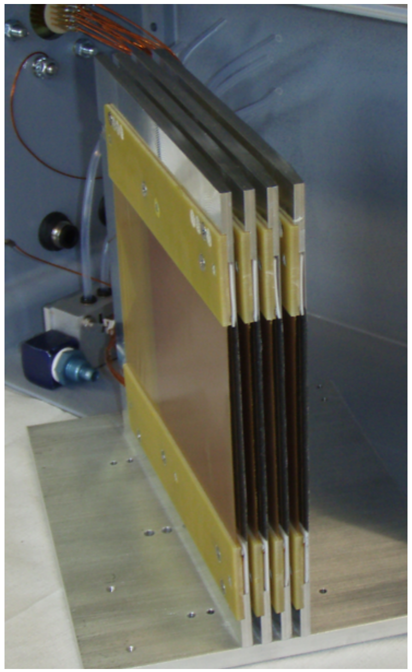


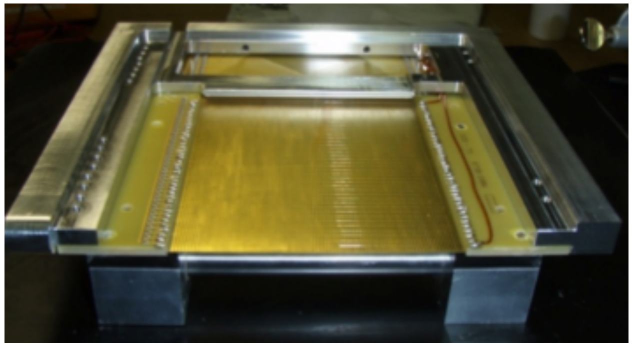
Detector technologies: options and maturity

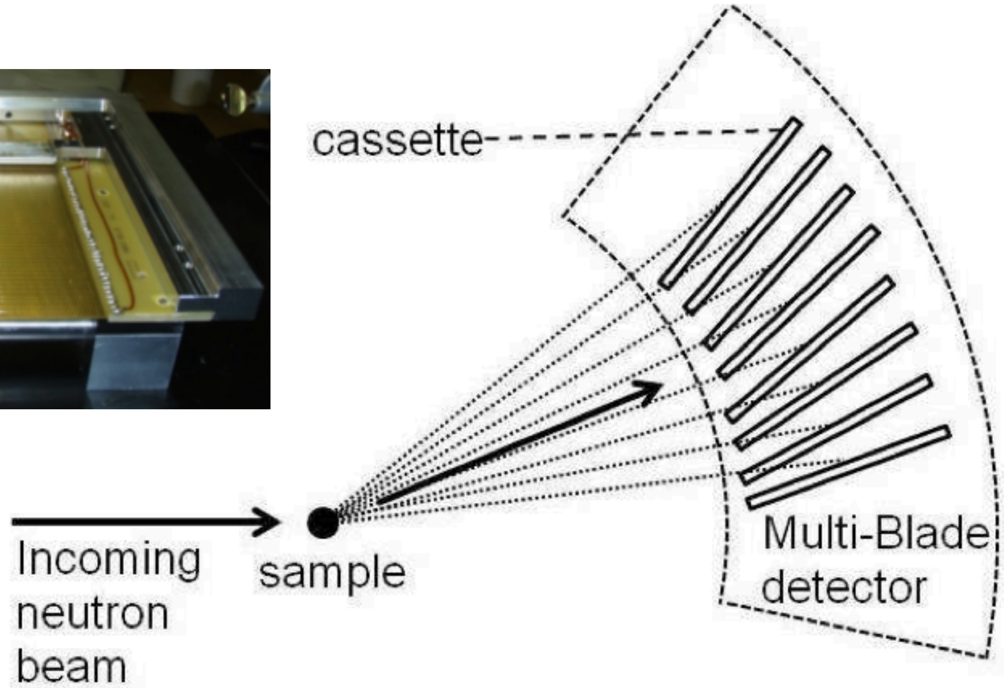
	spatial resolution	rate capability	cost	maturity
zero-angle				
gaseous detectors	ok	maybe	ok	development
scintillators	ok	maybe	ok	development
semiconductors	ok	ok	maybe	concept
fission chambers	ok	maybe	ok	development
micromegas	ok	ok	ok	concept
low-angle				
Multi-Blade	ok	ok	ok	prototype
MPGD	ok	ok	ok	concept
A1-CLD	ok	maybe	maybe	prototype
scintillators	maybe	maybe	maybe	development
^{3}He	no	no	no	mature
high-angle (WF)				
Multi-Blade	ok	ok	ok	prototype
MPGD	ok	ok	ok	concept
scintillators	ok	ok	no	N/A
^{3}He	ok	ok	no	N/A
high-angle (B)				
MWPC	ok	ok	ok	development
GEM	ok	ok	ok	development
scintillators	ok	ok	no	N/A
^{3}He	ok	ok	no	N/A

Multi-Blade detection principle (ILL/ESS/Linkoping)

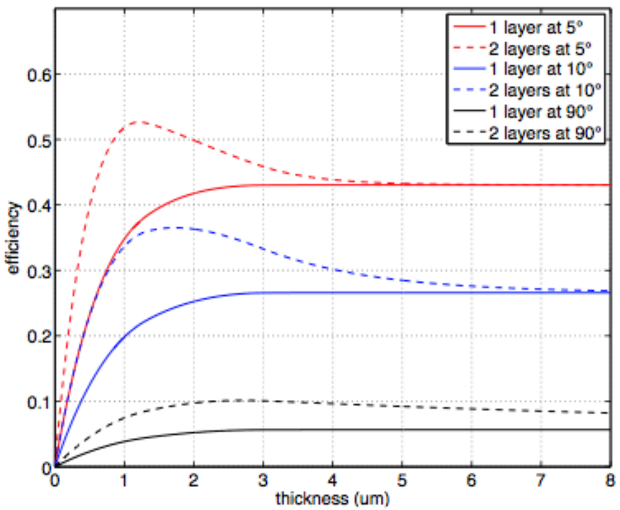
- Position sensitive ^{10}B (MWPC) gaseous detector originally developed for reflectometry
- Exploits grazing angle for high efficiency
- The inclined geometry results in improved spatial resolution and rate capability
- Resistive wires readout and cathode strips in coincidence for position information

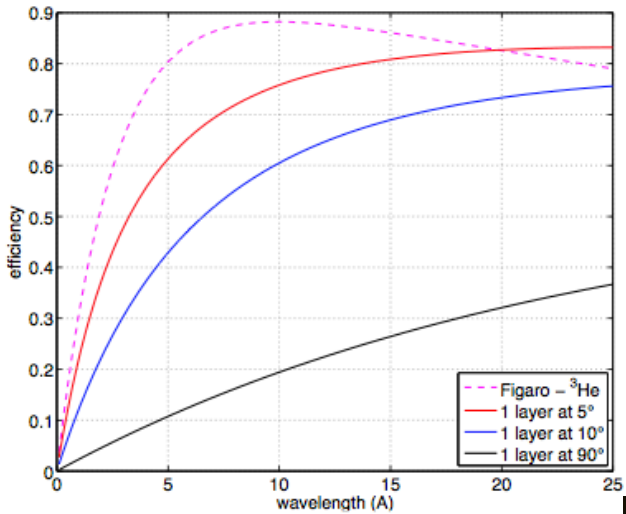


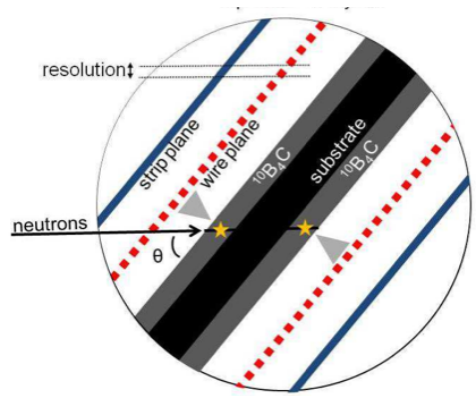


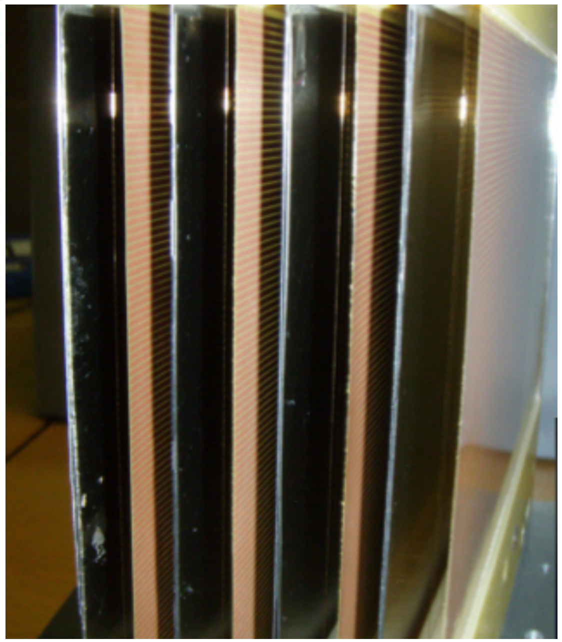


Multi-Blade prototype performance



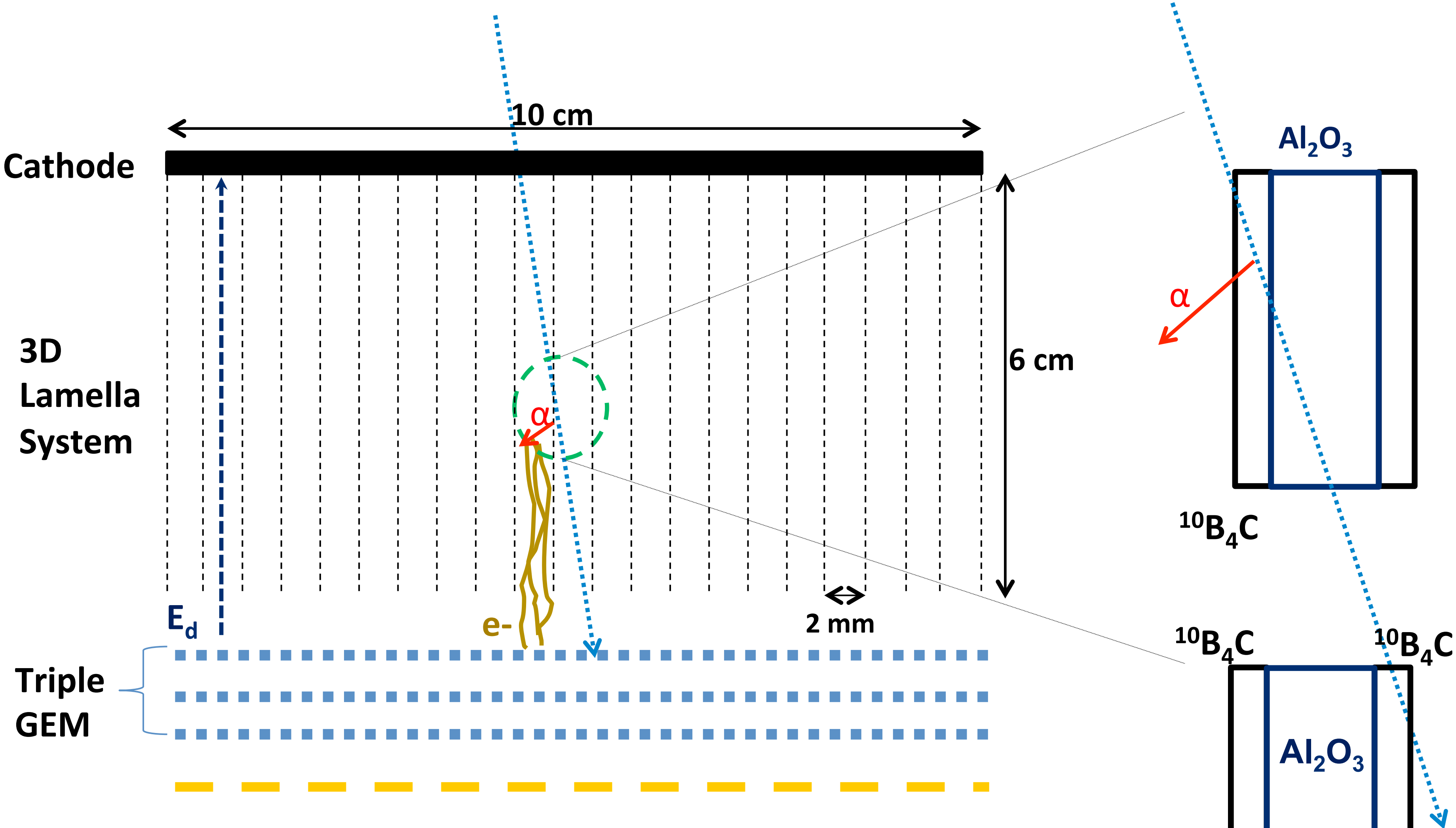






- position resolution: 0.6 mm x 4.4 mm for 10°, single-coated
  0.3 mm x 4 mm for 5°, double-coated
- rate capability: 2 kHz/mm^2
- Further developments planned
  - alternative readout for eliminating scattering effects
  - improvements in the response uniformity

Triple GEM with ^{10}B lamellae/BAND (U. Milan Bicocca)



Padded Anode

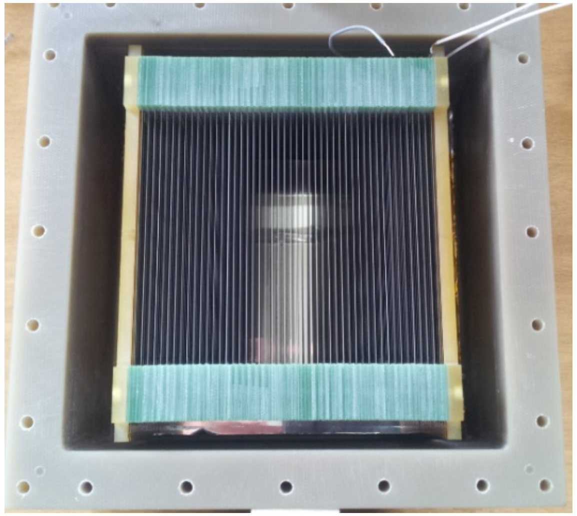
Alumina Lamellas coated on both sides with $^{10}B_4C$

Using low θ values (few degs) the path of the neutron inside the B_4C is increased → Higher efficiency when detector is inclined

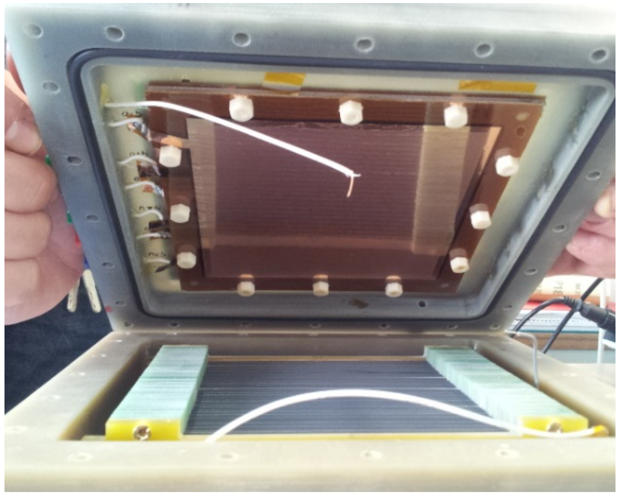
BAND prototype performance

coating the lamellae

installation of lamellae

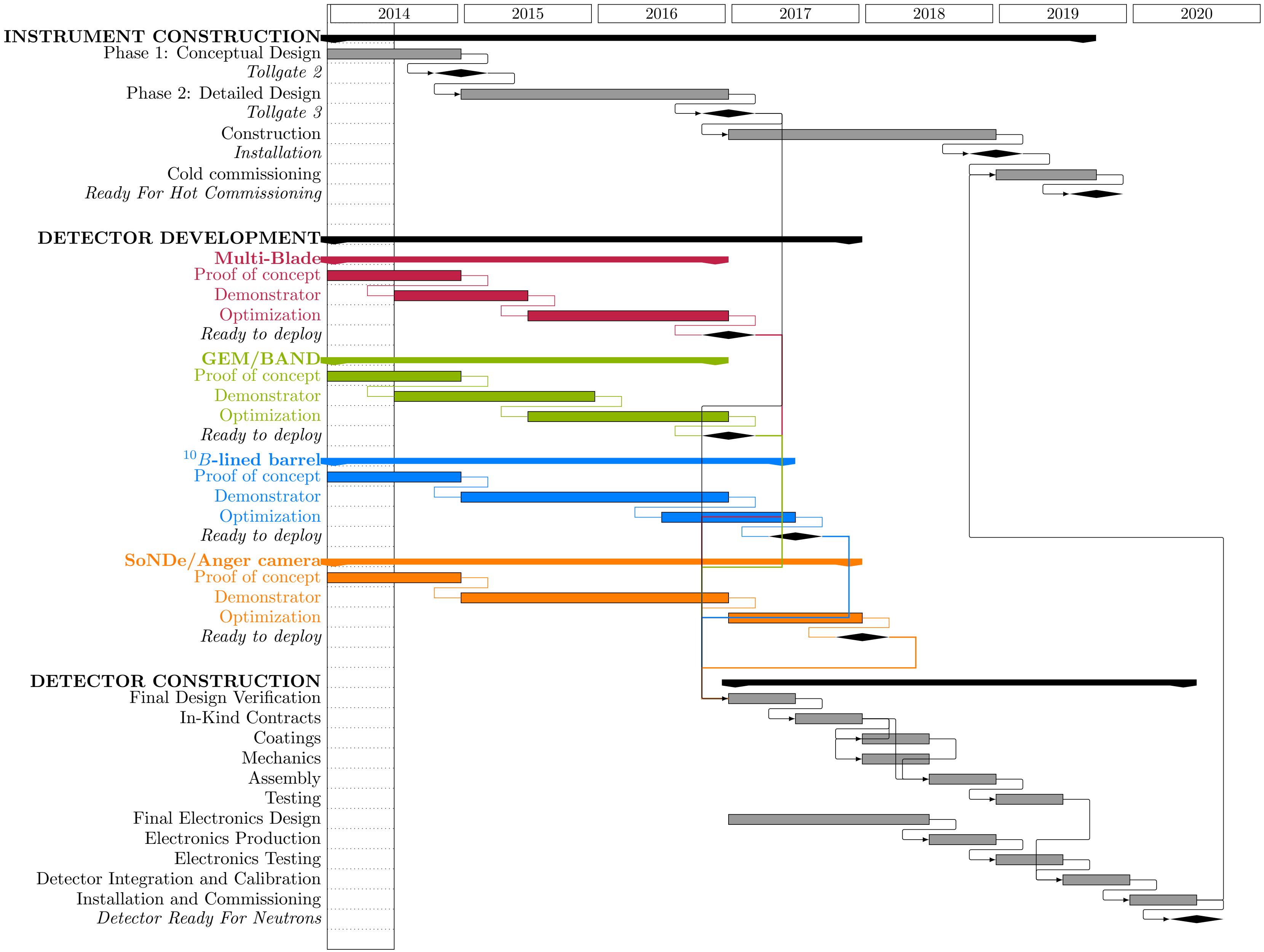


GEM readout installation

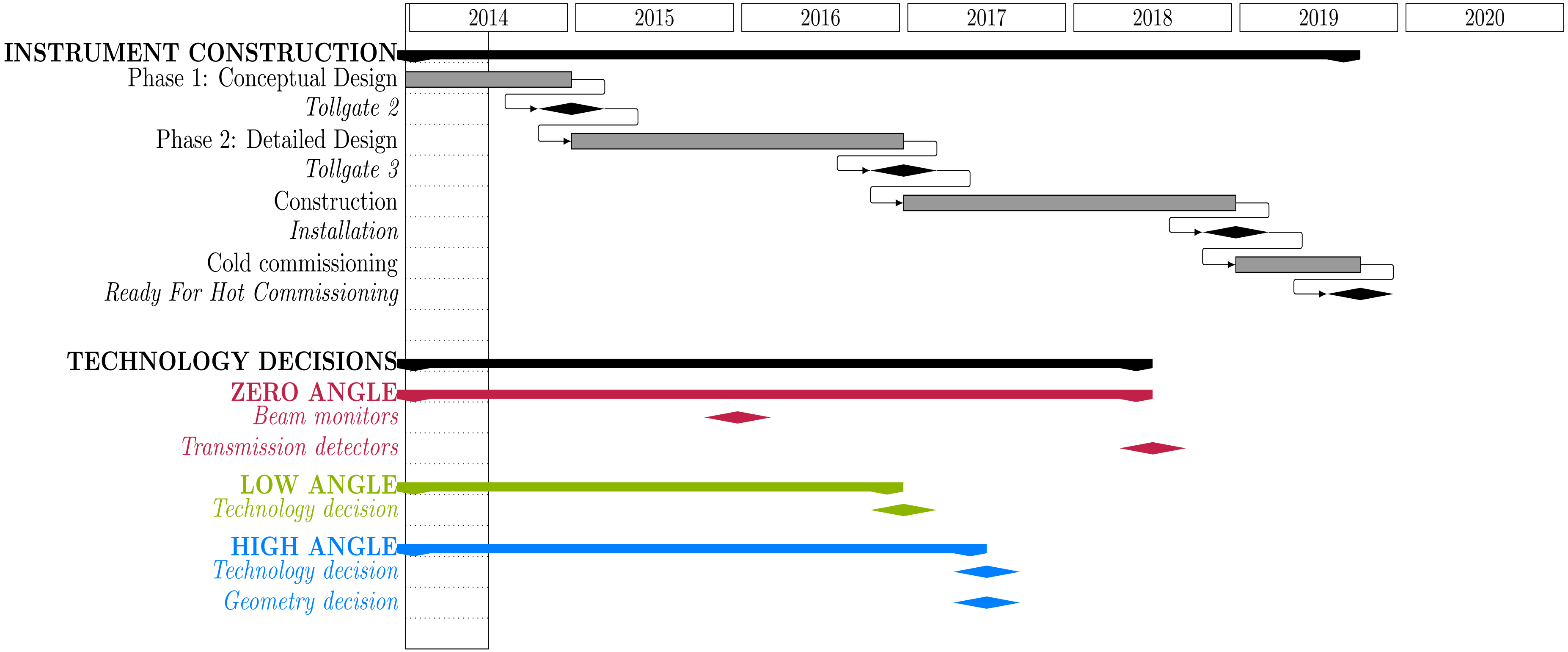


- low neutron incident angle
- position resolution: < 100 µm
- rates: 1 MHz/mm^2
- efficiency expected to be similar to other inclined geometries, e.g. A1CLD (50%-60%)
- simulations are complete
- first measurements in November at the R2D2 beamline at IFE, Norway

Time schedule to hot commissioning



Detector technology decision graph



- Decision points estimated based on current state of assigned resources
- The low angle detector is the key driver for the scientific performance of LoKI.
- The decision for the high angle detector is less time critical due to the looser requirements and due to the fact it is in fact a geometry decision.
- It'll be very beneficial for the project if we explore our options further, especially for the budget.
- Better making a low risk decision in the future than a high risk decision now.

Costing

proposal budget tables for ^{10}B

in k€	Phase 1 (Design and Planning)			Phase 2 (Final Design)			Phase 3 (Procurement and Installation)			Phase 4 (Beam Testing and Cold Commissioning)			Total			
	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Staff (years)
Integrated Design	0	360	36	0	600	60	0	480	48	0	240	24	0	1680	168	14.00
Systems Integration	0	0	0	0	30	3	0	120	12	0	60	6	0	210	21	1.75
Detectors and Data Acquisition	0	30	3	0	30	3	6000	60	6	200	120	12	6200	240	24	2.00
Optical Components	0	30	3	0	30	3	500	30	3	20	60	6	520	150	15	1.25
Choppers	0	30	3	0	30	3	250	30	3	20	30	3	270	120	12	1.00
Detector Vessel	0	30	3	0	30	3	1500	30	3	0	10	1	1500	100	10	0.83
Sample Environment	0	0	0	0	30	3	500	10	1	200	60	6	700	100	10	0.83
Shielding	0	30	3	0	60	6	1500	60	6	20	60	6	1520	210	21	1.75
Instrument Specific Support Equipment	0	0	0	0	30	3	100	120	12	20	30	3	120	180	18	1.50
Instrument Infrastructure	0	30	3	0	30	3	100	60	6	20	30	3	120	150	15	1.25
Total	0	540	54	0	900	90	10450	1000	100	500	700	70	10950	3140	314	26.17
Grand total (no VAT)	**14090**															

Figure 6.2: Costing for LoKI with "window frame" style detectors using ^{10}B

in k€	Phase 1 (Design and Planning)			Phase 2 (Final Design)			Phase 3 (Procurement and Installation)			Phase 4 (Beam Testing and Cold Commissioning)			Total			
	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Hardware	Staff (k€)	Staff (months)	Staff (years)
Integrated Design	0	360	36	0	600	60	0	480	48	0	240	24	0	1680	168	14.00
Systems Integration	0	0	0	0	30	3	0	120	12	0	60	6	0	210	21	1.75
Detectors and Data Acquisition	0	30	3	0	30	3	4000	60	6	200	120	12	4200	240	24	2.00
Optical Components	0	30	3	0	30	3	500	30	3	20	60	6	520	150	15	1.25
Choppers	0	30	3	0	30	3	250	30	3	20	30	3	270	120	12	1.00
Detector Vessel	0	30	3	0	30	3	1000	30	3	0	10	1	1000	100	10	0.83
Sample Environment	0	0	0	0	30	3	500	10	1	200	60	6	700	100	10	0.83
Shielding	0	30	3	0	60	6	1500	60	6	20	60	6	1520	210	21	1.75
Instrument Specific Support Equipment	0	0	0	0	30	3	100	120	12	20	30	3	120	180	18	1.50
Instrument Infrastructure	0	30	3	0	30	3	100	60	6	20	30	3	120	150	15	1.25
Total	0	540	54	0	900	90	7950	1000	100	500	700	70	8450	3140	314	26.17
Grand total (no VAT)	**11590**															

Figure 6.3: Costing for LoKI with "lined tube" ^{10}B detectors

- In the process of recosting all the options
- We expect the budget to be significantly lower (> 1 MEUR)
- ^{3}He price quote exists BUT
  - not an option for the low angle detector due to performance issues
  - not an option for the high angle detector due to cost issues (price>LoKI budget!!)

Status of TG2 detector documentation

- Detector requirements quantified and in the process of refinement
- Interfaces (physical & organizational) identified
- Draft commissioning plan: actions list, schedule to be prepared
- Risk document in place
- Non-functional requirements collected