



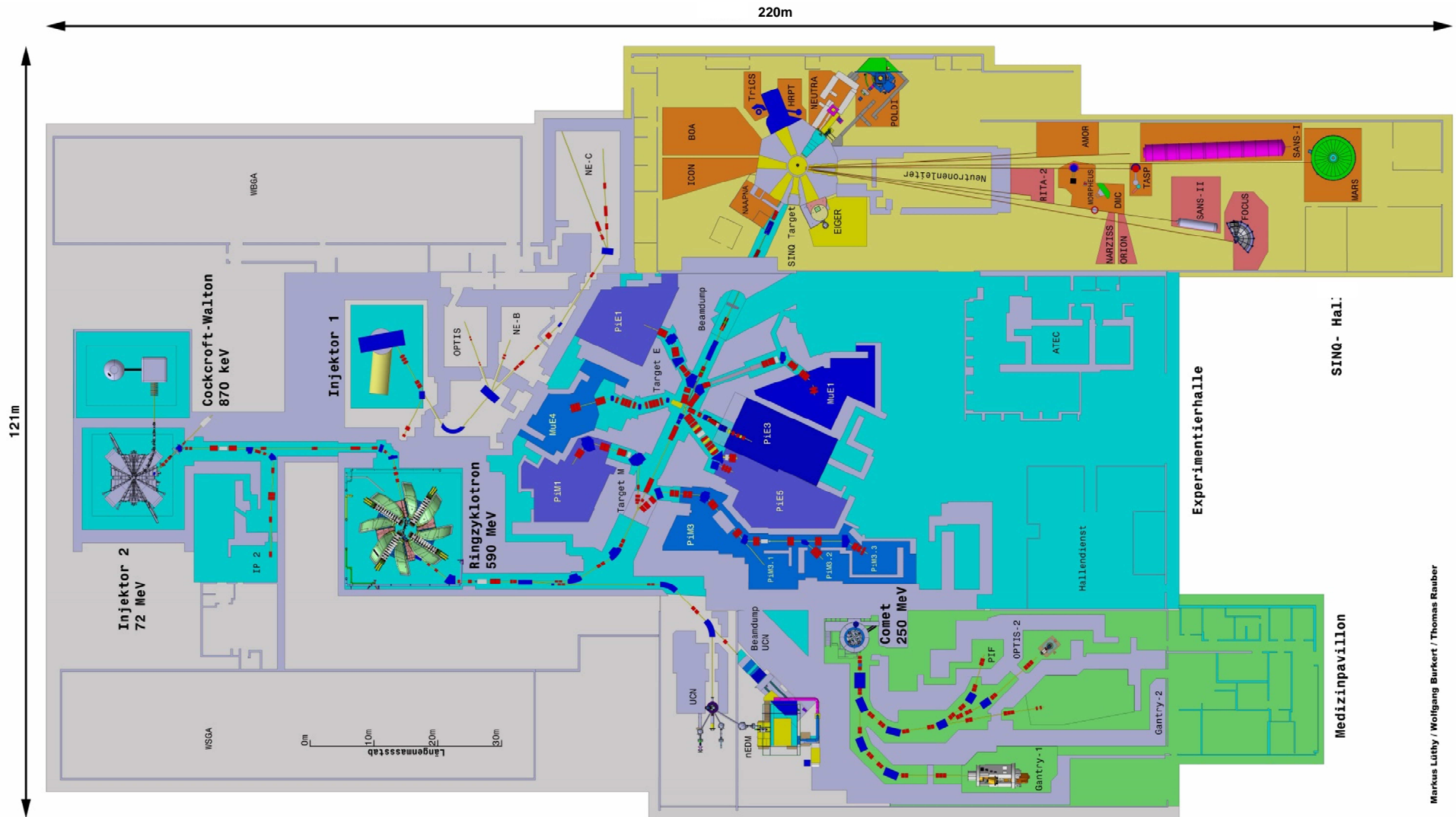
Paul Scherrer Institute

M. Hildebrandt

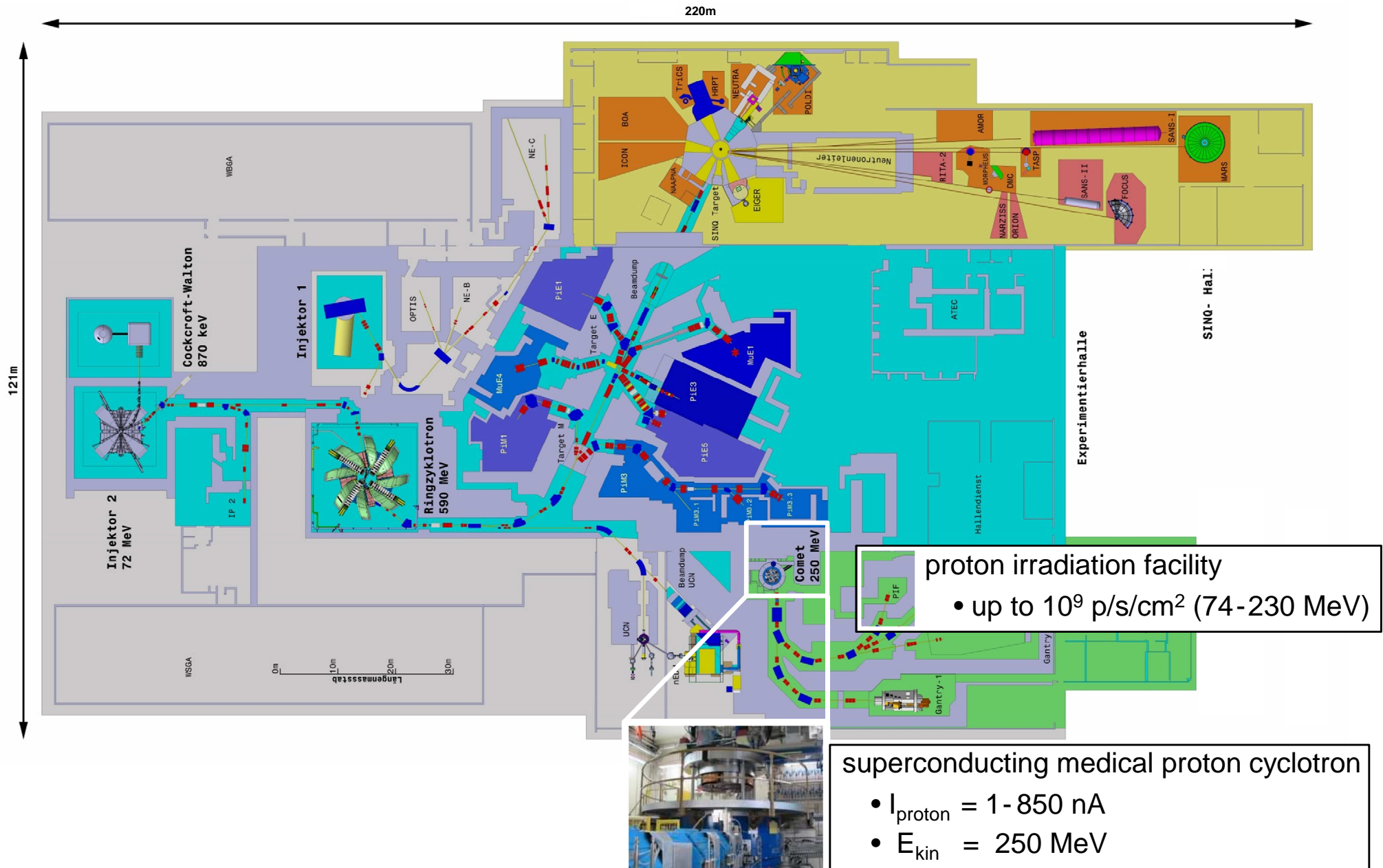
Neutron detectors at SINQ/PSI – further opportunity for MPGDs?

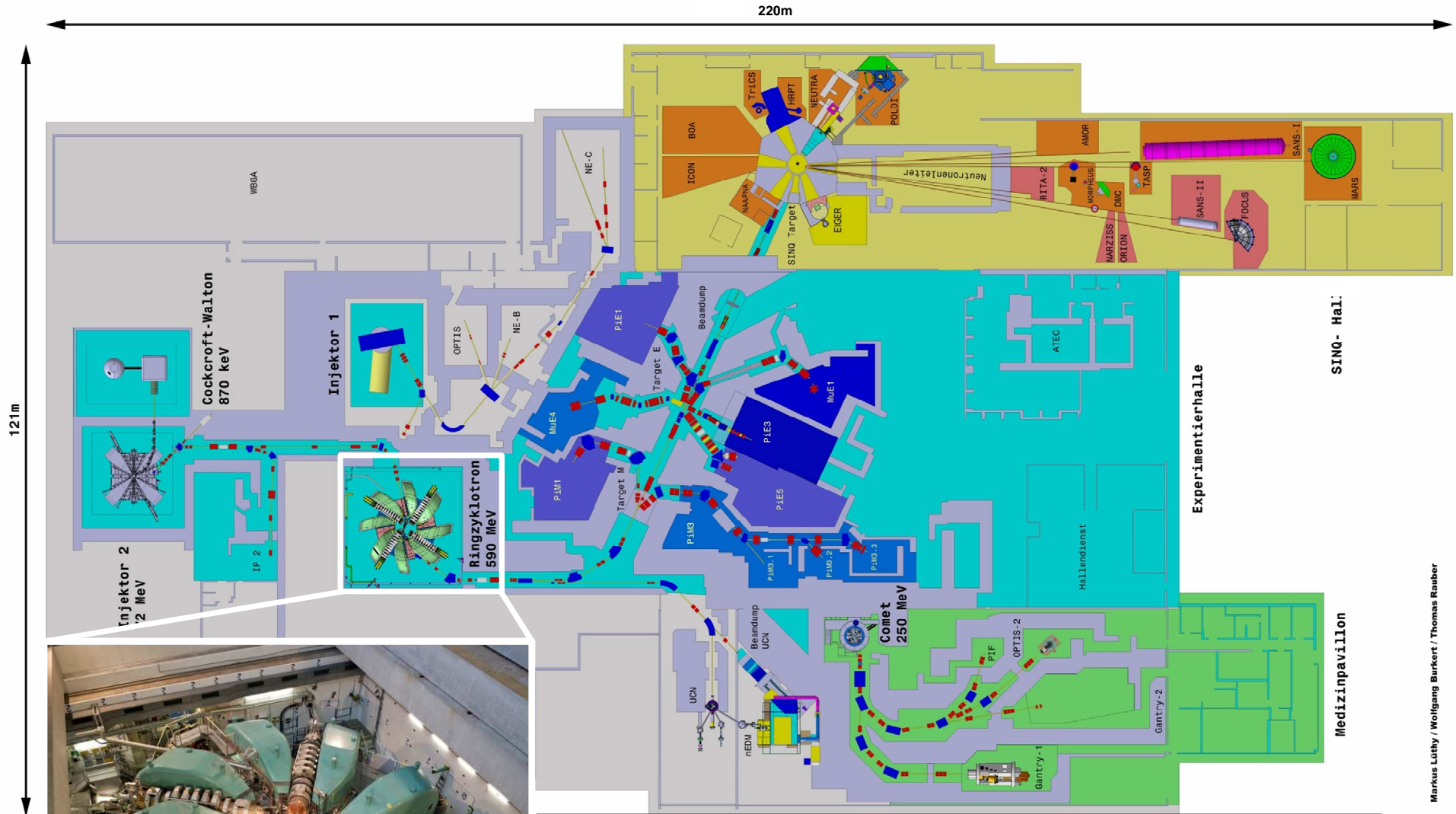
Current R&D project and first thoughts about future projects

Second Special Workshop on Neutron Detection with MPGDs
CERN, March 16th – 17th, 2015



Markus Lüthy / Wolfgang Burkert / Thomas Rauber



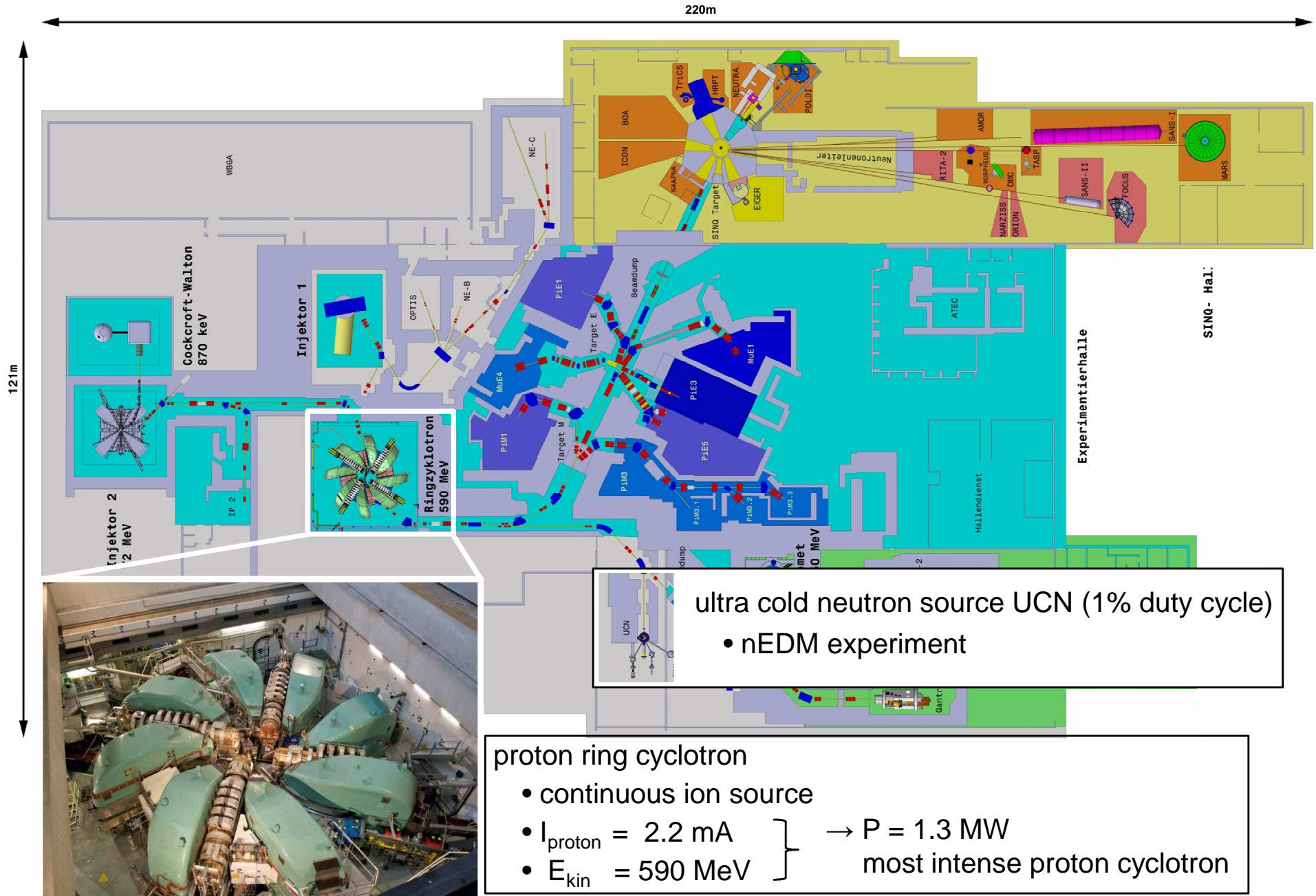


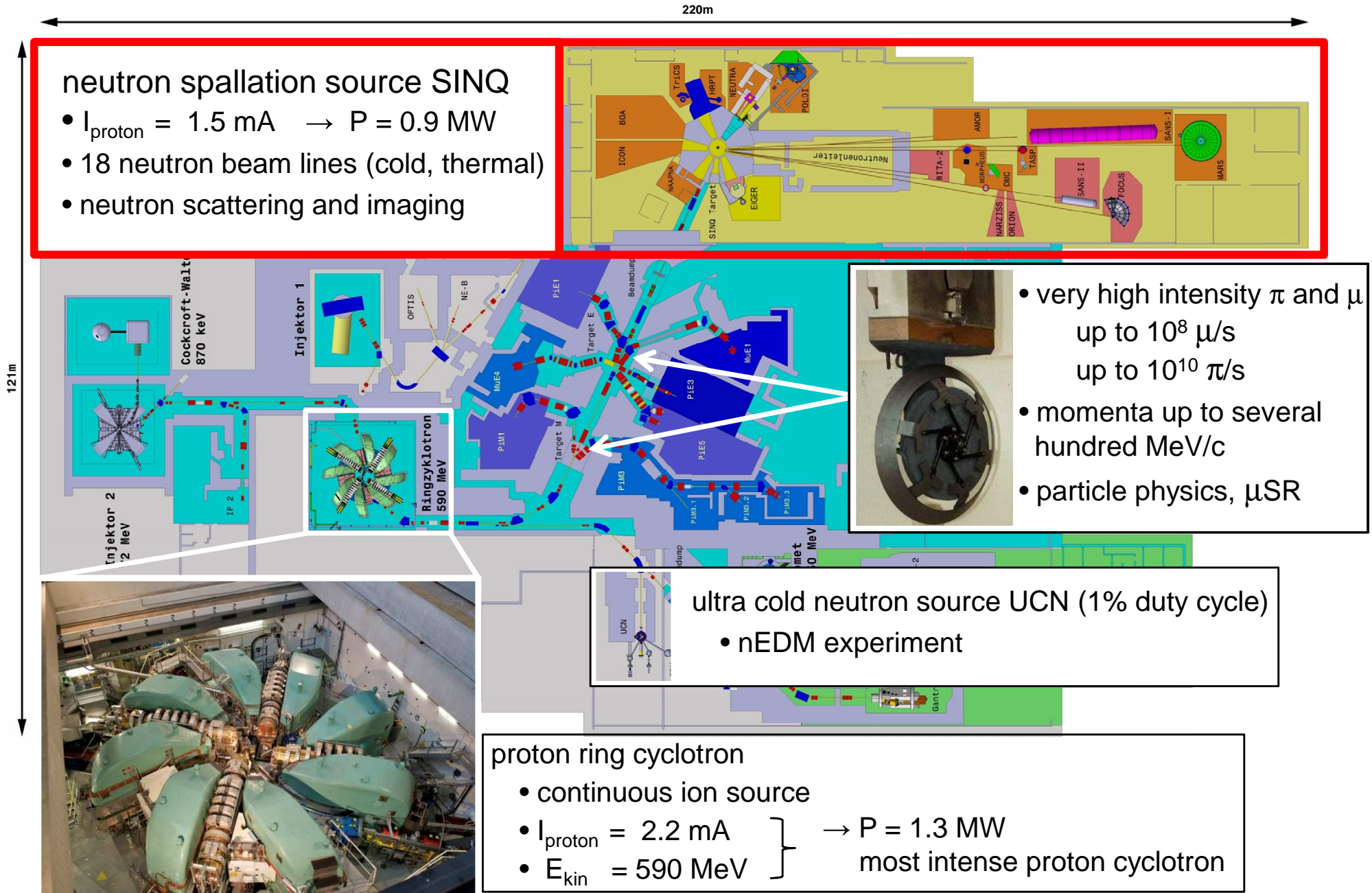
proton ring cyclotron

- continuous ion source
- $I_{\text{proton}} = 2.2 \text{ mA}$
- $E_{\text{kin}} = 590 \text{ MeV}$

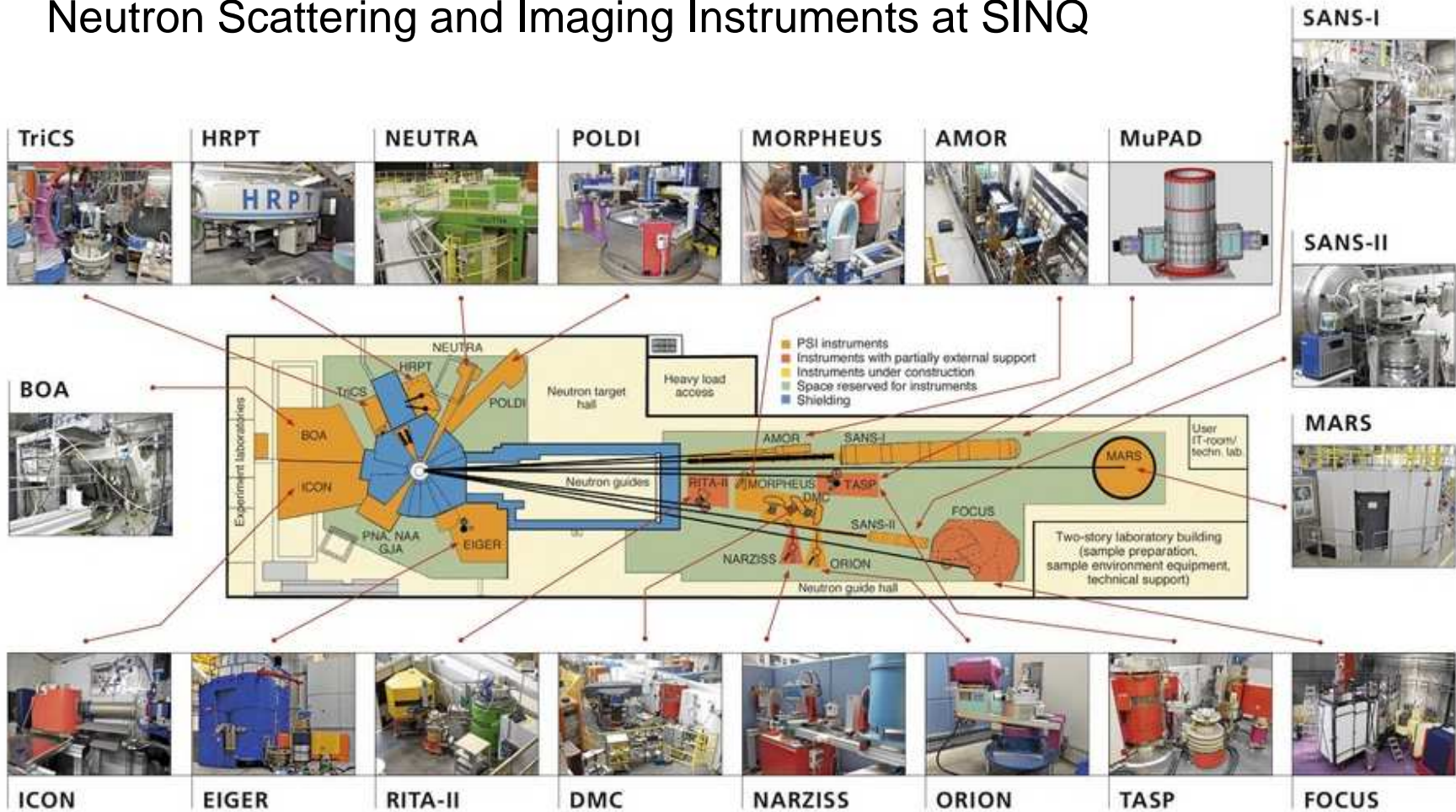
→ $P = 1.3 \text{ MW}$
most intense proton cyclotron

Markus Lüthy / Wolfgang Burkert / Thomas Rauber





Neutron Scattering and Imaging Instruments at SINQ



Neutron Scattering and Imaging Instruments at SINQ

TriCS



HRPT



NEUTRA



POLDI



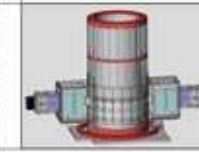
MORPHEUS



AMOR



MuPAD



SANS-I



SANS-II



MARS



BOA



typically:

- BF_3 / ^3He multi-wire chambers, ^3He tubes
- large pixel size ~2-5 mm (1-d, 2-d)
- high efficiency >65% @ 1.2Å , >80% @ 4Å
- surface (gapless) 0.2×0.2 m² up to 0.75×0.75 m²,
Ø 60 cm, 0.2×400 m²
- timing resolution 1-10 μs
- counting rates 10³-10⁵ Hz / pixel, 10³-10⁵ Hz overall



ICON



EIGER



RITA-II



DMC



NARZISS



ORION



TASP



FOCUS

Neutron Scattering and Imaging Instruments at SINQ

TriCS



HRPT



NEUTRA



POLDI



MORPHEUS



AMOR



MuPAD



SANS-I



SANS-II



MARS



BOA



- typically:
- BF_3 / ^3He multi-wire chambers, ^3He tubes
 - large pixel size ~2-5 mm (1-d, 2-d)
 - high efficiency >65% @ 1.2Å , >80% @ 4Å
 - surface (gapless) 0.2x0.2 m² up to 0.75x0.75 m²,
Ø 60 cm, 0.2x400 m²
 - timing resolution 1-10 µs
 - counting rates 10³-10⁵ Hz / pixel, 10³-10⁵ Hz overall



ICON



EIGER



RITA-II



DMC



NARZISS



ORION



TASP



FOCUS

- detectors used in "user operation"
- operated by non-detector-experts
 - detector needs to be robust, performance reliable
 - low maintenance and repair work required

SINQ Instrumentation – Upgrades

TriCS / ZEBRA

resolution 2 mm (2-d)
 efficiency 80% @ 4Å
 surface 0.3×0.3 m² (gapless)

POLDI

resolution 2.5 mm (1-d)
 efficiency >65% @ 1.2Å
 surface 0.2×1.0 m² (gapless)

SANS-I



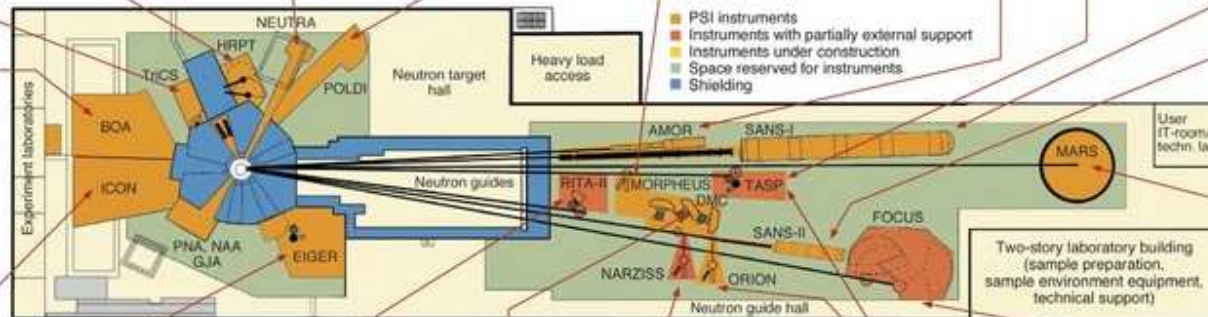
SANS-II



MARS



BOA



RITA-II / CAMEA:

³He tubes (0.5" Ø, 38" long, 7 atm)
 vert. resolution 5-8 mm vertical
 surface ~1 m² (8×13 tubes)

DMC

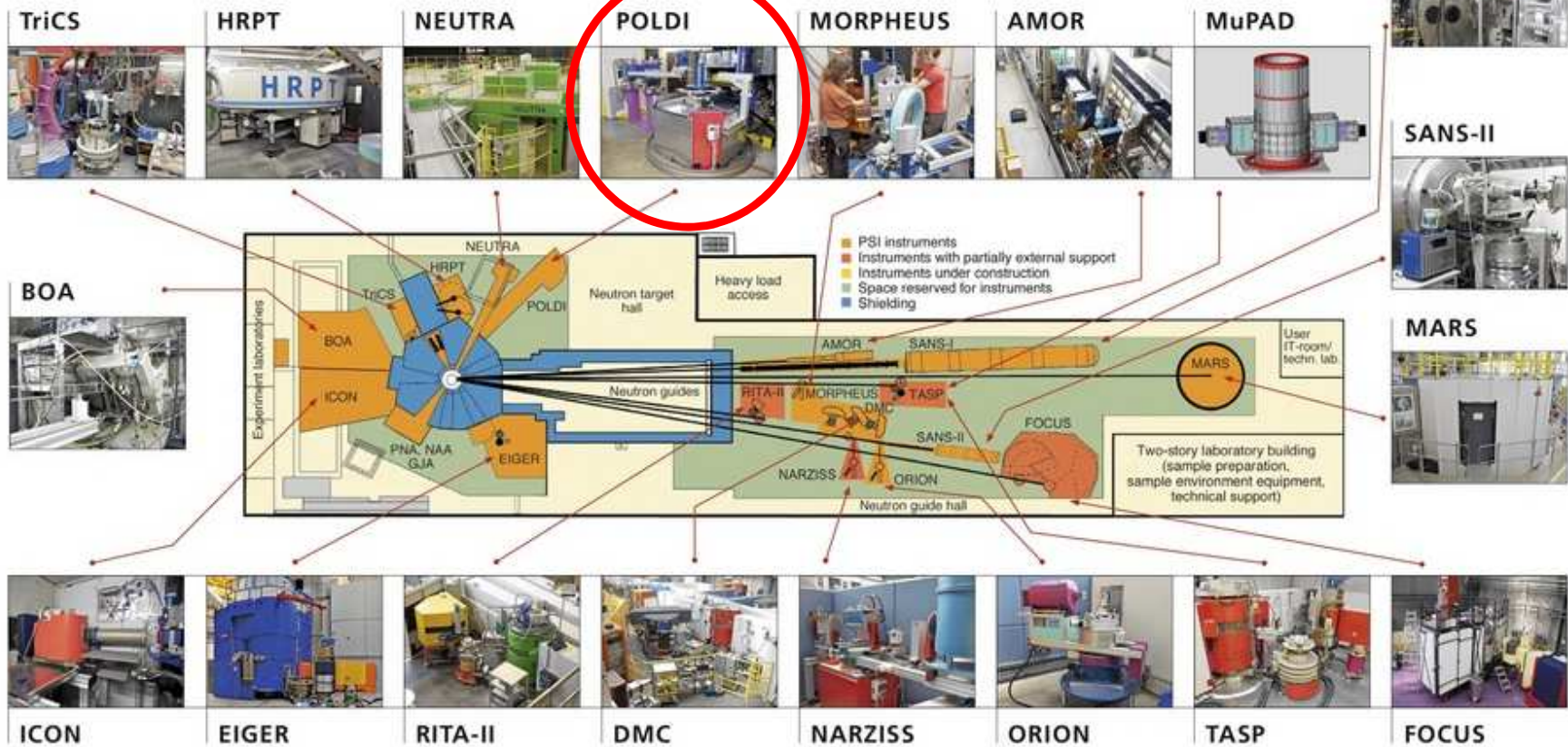
resolution ~2-5 mm (2-d)
 efficiency >75% @ 1.8Å
 surface 0.2×1.6 m² (gapless)

SANS-II

resolution 3-5 mm (2-d)
 efficiency >70% @ 5Å
 surface 1m² (gapless?)

SINQ Instrumentation – Upgrades

POLDI
 resolution 2.5 mm (1-d)
 efficiency >65% @ 1.2Å
 surface 0.2×1.0 m² (gapless)



POLDI beam line at SINQ (PSI)

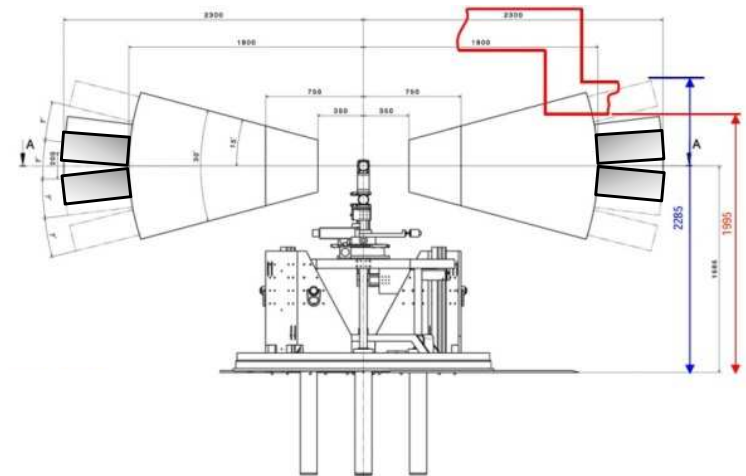
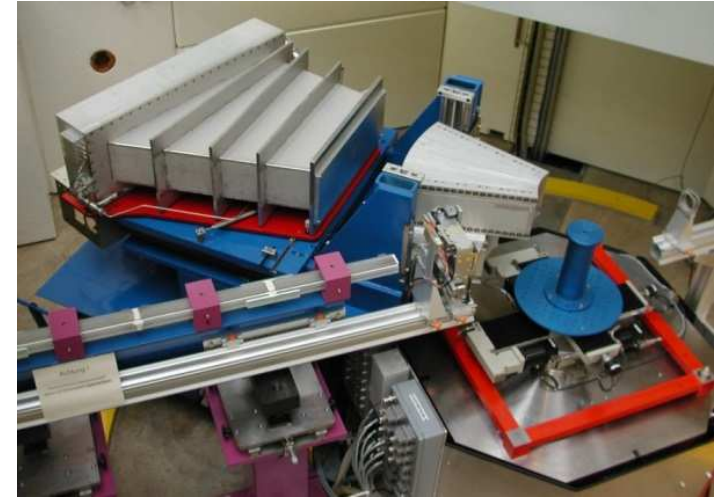
- time-of-flight neutron diffractometer
- strain measurements: accurate determination of lattice spacings

current detector

- single ^3He multi-wire chamber (1-dimensional)

upgrade program (started in 2013):

- two oppositely placed detector banks to allow in-situ deformation measurements of axial and transverse strain component



POLDI beam line at SINQ (PSI)

- time-of-flight neutron diffractometer
- strain measurements: accurate determination of lattice spacings

current detector

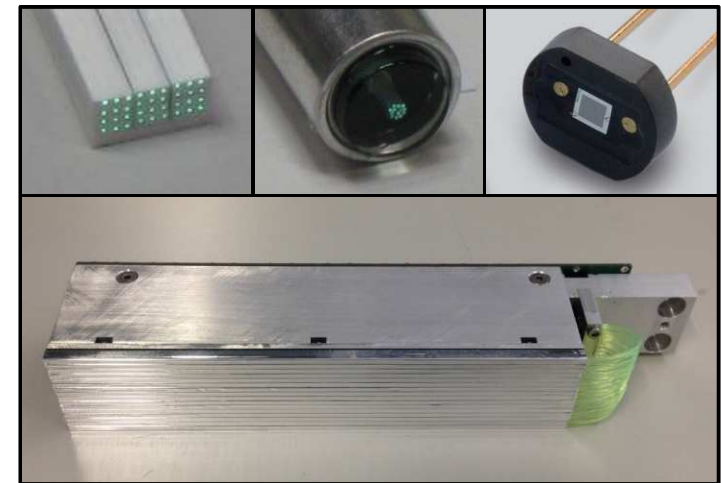
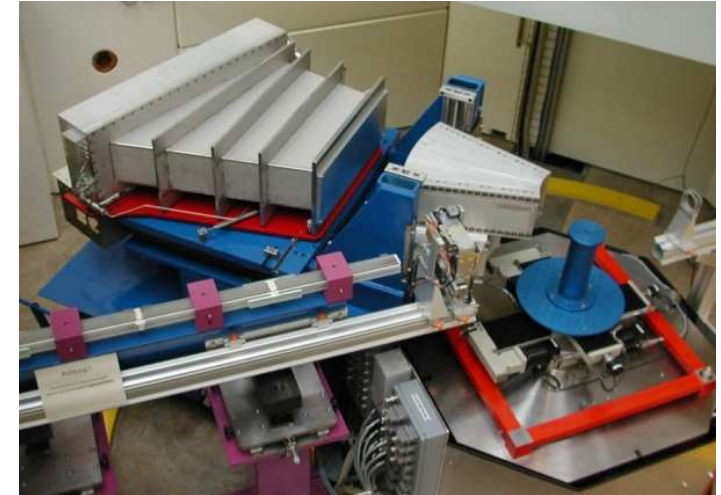
- single ^3He multi-wire chamber (1-dimensional)

upgrade program (started in 2013):

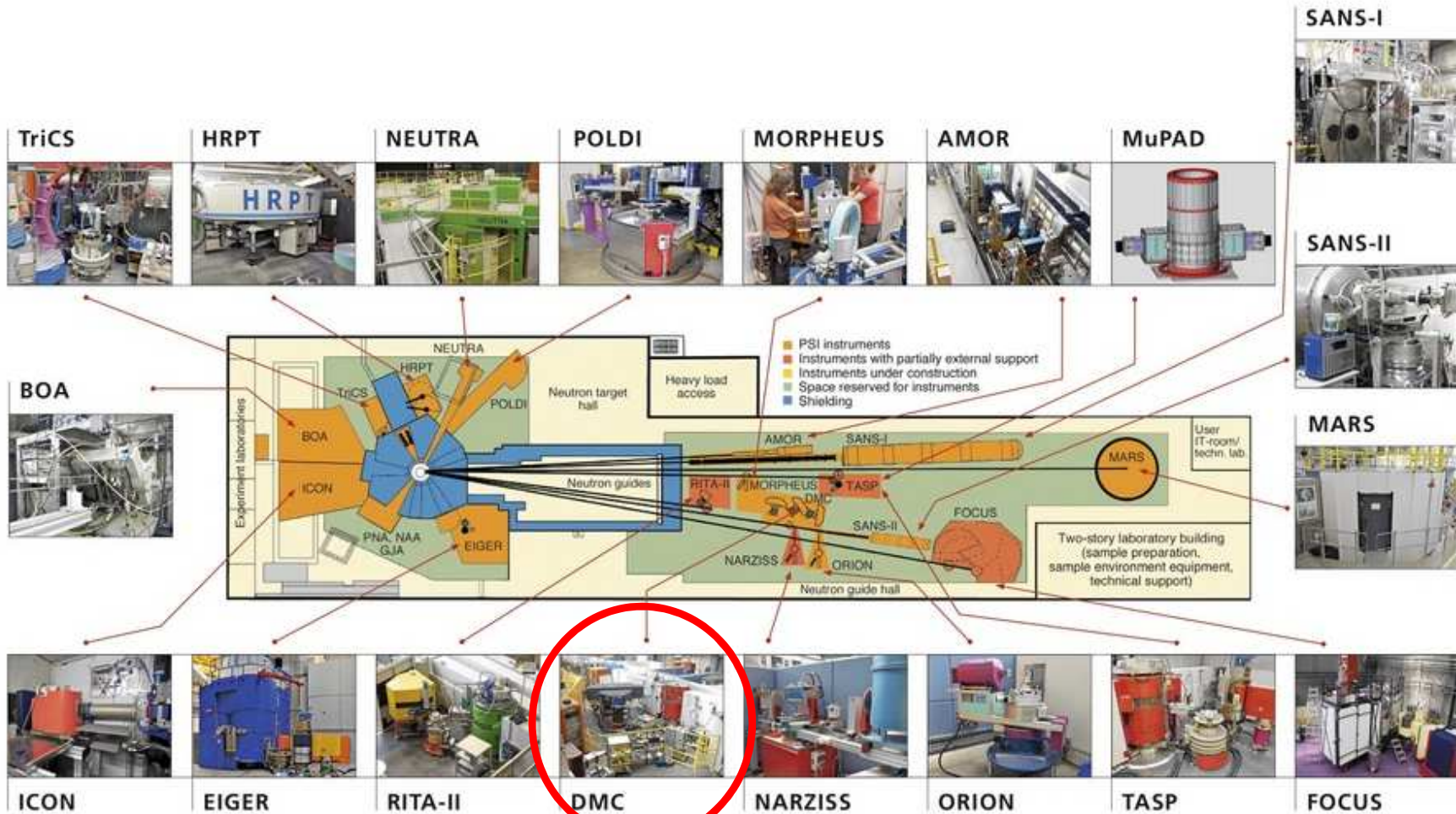
- two oppositely placed detector banks to allow in-situ deformation measurements of axial and transverse strain component

detector requirements:

detector modules	2 x 2 (radius 2000 mm)
channel width / height	2.5 mm / 200 mm
channels per module	400
neutron wavelength	1 - 6 Å
detection efficiency	$\geq 65\%$ @ 1.2 Å
time resolution	$\leq 1\ \mu\text{s}$
sustainable count rate	4 kHz (per channel)
gamma sensitivity	$< 10^{-6}$
quiet background rate	$< 0.003\ \text{Hz}$ (per channel)



- status:
- proof of principle for $\text{ZnS:Ag}/^6\text{LiF}$ with WLS fibres and SiPM readout achieved
 - 16-channel module build, goal: 400-channel module (25× 16-ch module) in 2015(?)



DMC
 resolution ~2-5 mm (2-d)
 efficiency >75% @ 1.8Å
 surface 0.2×1.6 m² (gapless)

DMC beam line at SINQ (PSI)

- cold neutron powder diffractometer, option for single crystal
- crystallography, solid state physics, chemistry, material science

current detector

- single volume BF_3 multi-wire chamber (1-dimensional)
- since more than 30 years in operation

upgrade program:

- curved high-pressure ^3He multi-wire chamber (2-dimensional)
→ total intensity gain factor 2-10



DMC beam line at SINQ (PSI)

- cold neutron powder diffractometer, option for single crystal
- crystallography, solid state physics, chemistry, material science

current detector

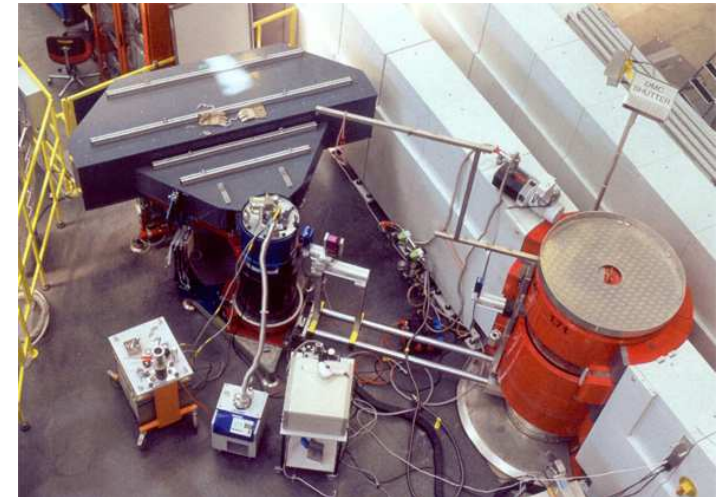
- single volume BF_3 multi-wire chamber (1-dimensional)
- since more than 30 years in operation

upgrade program:

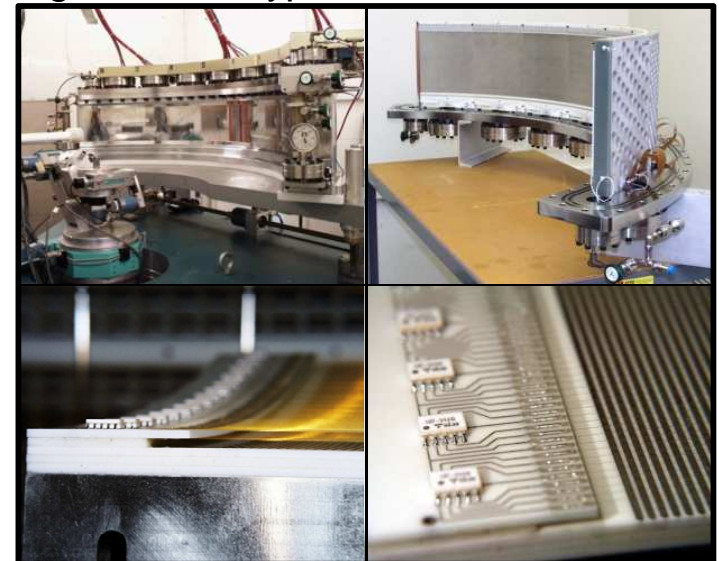
- curved high-pressure ^3He multi-wire chamber (2-dimensional)
→ total intensity gain factor 2-10

detector requirements (FRM2/TUM-PSI-ILL):

horiz / vert aperture	$\geq 120^\circ / \geq 200 \text{ mm}$
radius	800 mm
anode wire pitch	1.6 mm (0.125°)
cathode strip pitch	1.6 mm (0.125°)
detection efficiency	$\geq 75 \% @ 1.8 \text{ \AA}$
count rate	50 kHz / wire $\geq 200 \text{ kHz / segment}$
dead time	10% @ 200kHz / segment
volume	< 250 litres



goal: "BNL-type" ^3He wire chamber



status: • finalisation of common specifications & design in order to build prototype

G.Smith, VCI2007

SINQ Instrumentation – Upgrades

TriCS / ZEBRA

resolution 2 mm (2-d)
 efficiency 80% @ 4Å
 surface 0.3×0.3 m² (gapless)

POLDI

resolution 2.5 mm (1-d)
 efficiency >65% @ 1.2Å
 surface 0.2×1.0 m² (gapless)

SANS-I



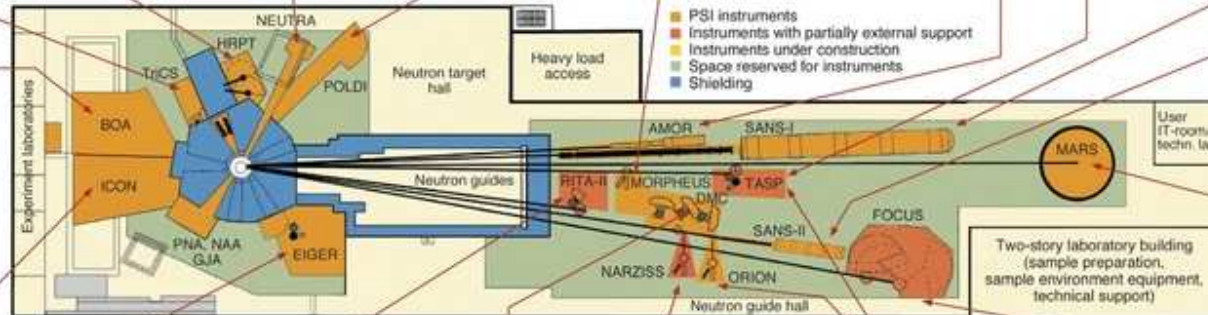
SANS-II



MARS



BOA



RITA-II / CAMEA:

³He tubes (0.5" Ø, 38" long, 7 atm)
 vert. resolution 5-8 mm vertical
 surface ~1 m² (8×13 tubes)

DMC

resolution ~2-5 mm (2-d)
 efficiency >75% @ 1.8Å
 surface 0.2×1.6 m² (gapless)

SANS-II

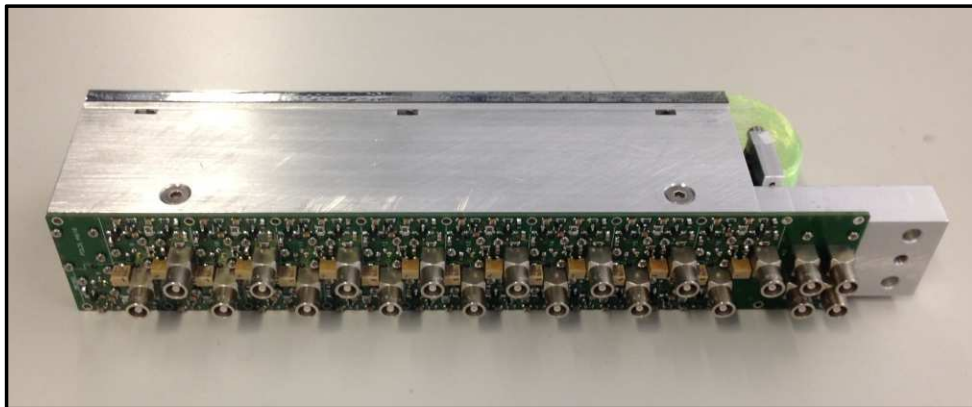
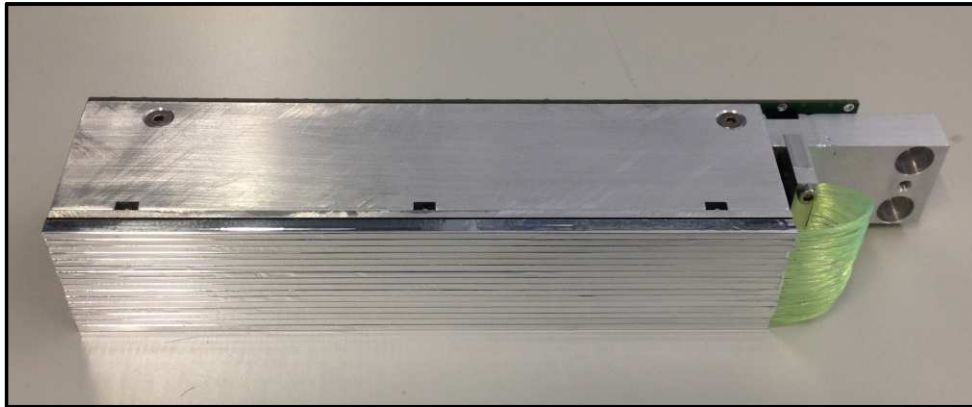
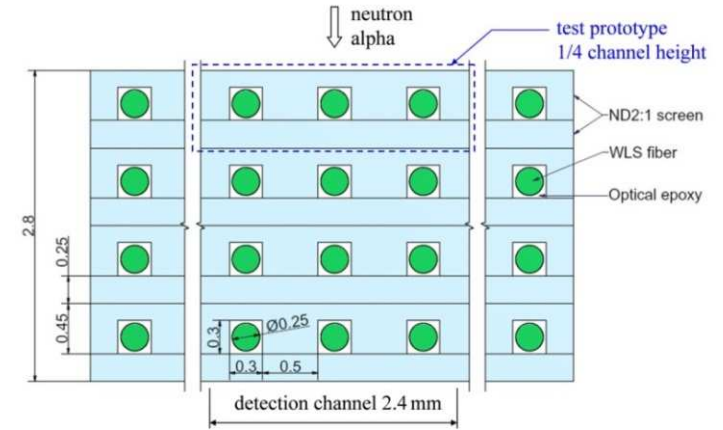
resolution 3-5 mm (2-d)
 efficiency >70% @ 5Å
 surface 1m² (gapless)

backup slides

- new approach:
- ZnS:Ag/⁶LiF with WLS fibres and SiPM readout
 - efficient light collection and single photon counting

detection unit

- ZnS:Ag/⁶LiF ND2:1, d = 2.8 mm → $e_{n-abs} > 80\%$ @ 1.2 Å
- WLS fibres Y11(400) → efficient & uniform light collection
- 12 WLS fibres (1 ch) → connected to individual (1×1) mm² SiPM



- new approach:
- ZnS:Ag/⁶LiF with WLS fibres and SiPM readout
 - efficient light collection and single photon counting

detection unit

- ZnS:Ag/⁶LiF ND2:1, d = 2.8 mm → $e_{n-abs} > 80\%$ @ 1.2 Å
- WLS fibres Y11(400) → efficient & uniform light collection
- 12 WLS fibres (1 ch) → connected to individual (1×1) mm² SiPM



signal processing system

- single photon counting → analyse temporal distribution of SiPM pulses to suppress SiPM dark counts
- multi-stage filter based on consecutive delayed self-coincidence on SD-pulse sequence
 - suppression of SiPM cell-to-cell cross-talk
 - elimination of single-pulse and late after-glow photons
 - allows to distinguish SiPM dark count and neutron event

