PSI Center for Neutron and Muon Sciences

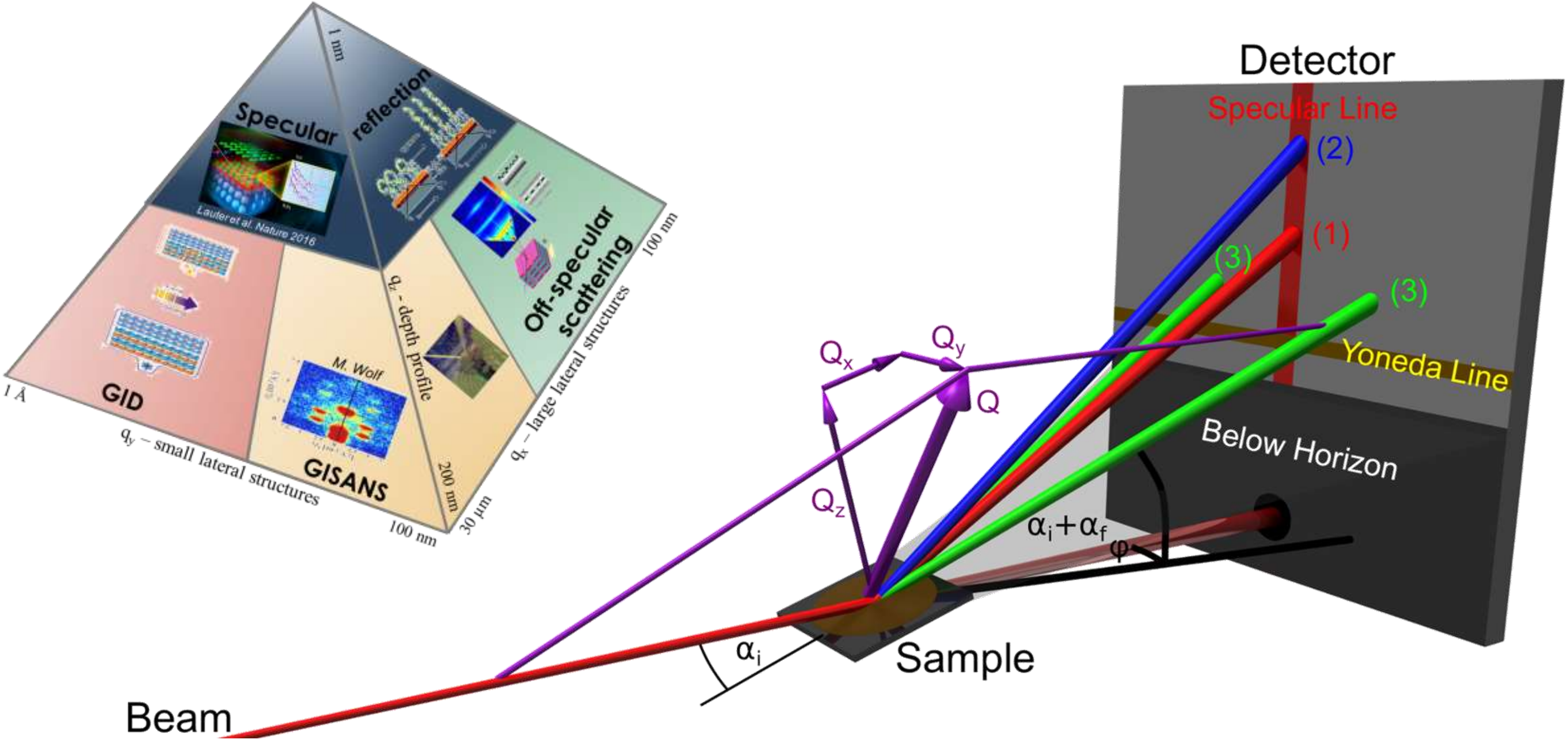
AMPLIFY

a grazing incidence instrument concept for SINQ

Adjustable **M**onochromator to **P**erform
Liquid grazing **I**ncidence, **F**ocused
or magnetic **Y**oneda scattering

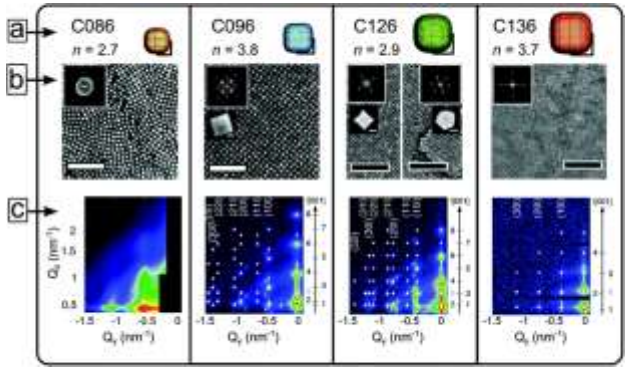
Artur Glavic
SPS Neutron Session, 10 August 2024

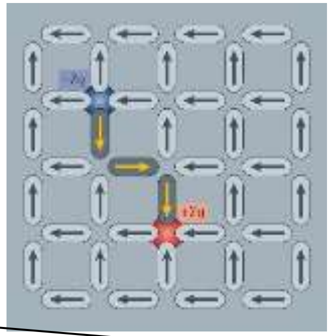
Grazing Incidence Small Angle Scattering (GISAS)

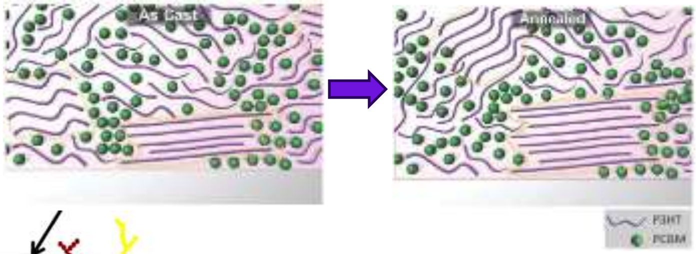


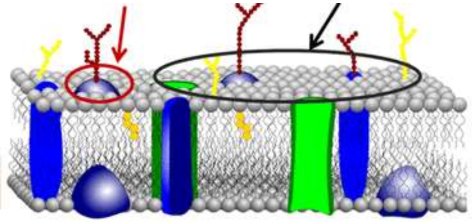
GISANS Applications

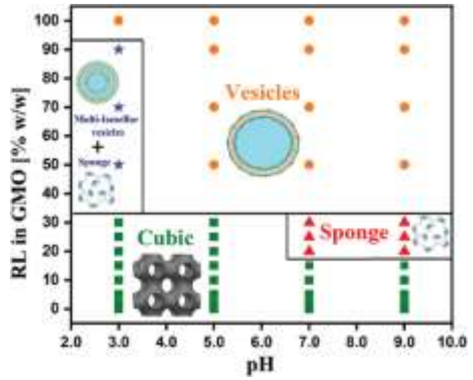
- Self-assembly of (magnetic) nanoparticles [2]
- Artificial spin-systems [3]
- Complex spin-textures (e.g. Skyrmions)
- Correlated magnetic domains in multilayers [4]
- Neutron optics characterization
- (Organic) photovoltaics and fuel cells [5,7]
- Adsorbed microgels [6]
- Biology (structure within membranes, large molecules on surfaces, membranes in structured environments)
- Food science [9]







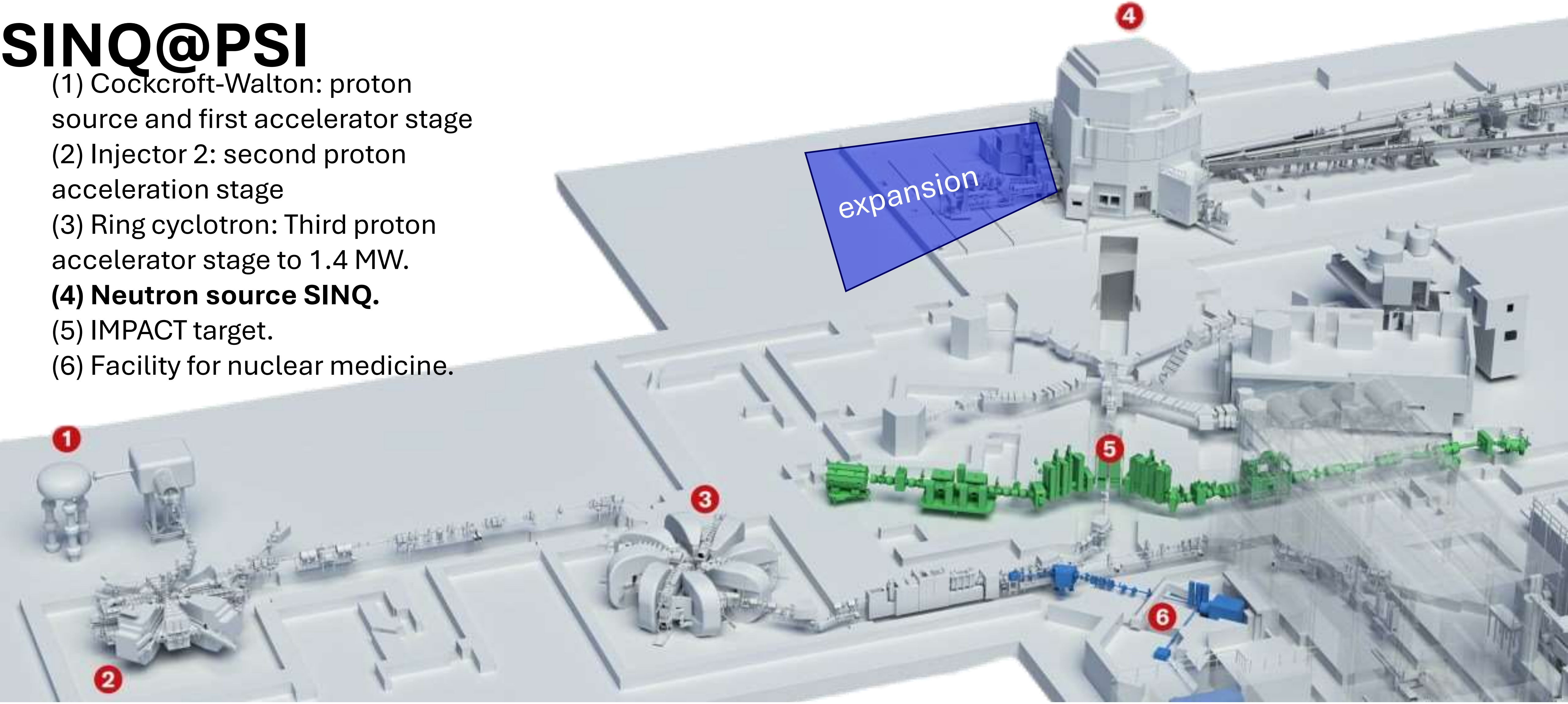




[1] N. Paul, J.-F. Moulin, G. Mangiapia, A. Kriele, P. Müller-Buschbaum, M. Opel, and A. Paul, Scientific Reports **10**, (2020).
[2] E. Wetterskog, et al., Nanoscale, **8**, (2016).
[3] P. Pip, A. Glavic, S. H. Skjærvø, A. Weber, A. Smerald, K. Zhernenkov, N. Leo, F. Mila, L. Philippe, and L. J. Heyderman, Nanoscale Horizons **6**, 474 (2021).
[4] E. Kentzinger, et al., Physica B: Condensed Matter **397**, 43 (2007). / A. Stellhorn, et al., J. Magnetism and Magnetic Materials **476** (2019)
[5] P. Müller-Buschbaum, Advanced Materials **26**, 7692 (2014).
[6] T. Kyrey, M. Ganeva, K. Gawlitza, J. Witte, R. von Klitzing, O. Soltwedel, Z. Di, S. Wellert, and O. Holderer, Physica B: Condensed Matter **551**, 172 (2018).
[7] J. Schlipf, L. Bießmann, L. Oesinghaus, E. Berger, E. Metwalli, J. A. Lercher, L. Porcar, and P. Müller-Buschbaum, The Journal of Physical Chemistry Letters **9**, 2015 (2018).
[8] S. Ueda, S. Koizumi, A. Ohira, S. Kuroda, and H. Frielinghaus, Physica B: Condensed Matter **551**, 309 (2018).
[9] P. Kadakia, et al., Adv. Healthcare Mater. **13**, 2302596 (2024)

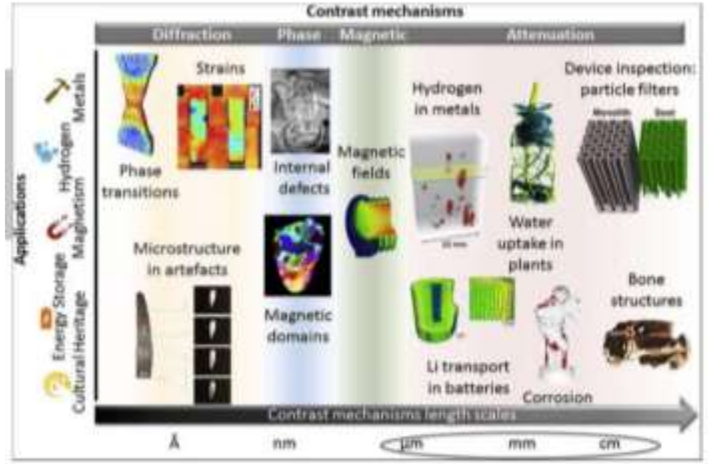
HIPA Accelerator, Muons and SINQ@PSI

(1) Cockcroft-Walton: proton source and first accelerator stage
(2) Injector 2: second proton acceleration stage
(3) Ring cyclotron: Third proton accelerator stage to 1.4 MW.
(4) Neutron source SINQ.
(5) IMPACT target.
(6) Facility for nuclear medicine.



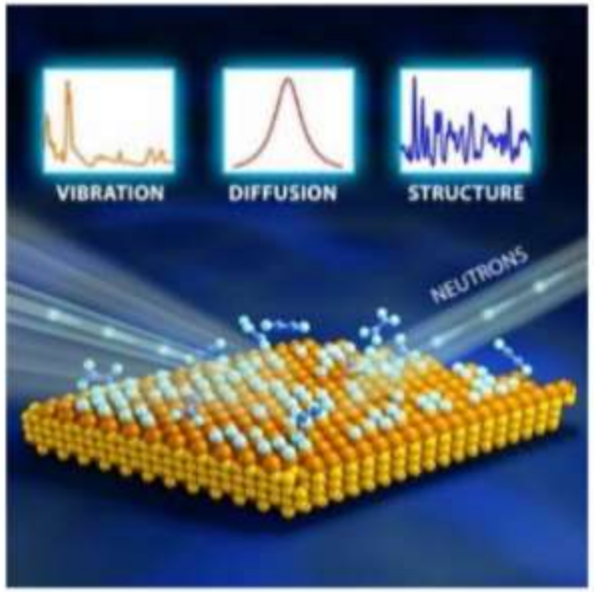
Science Drivers for a SINQ expansion

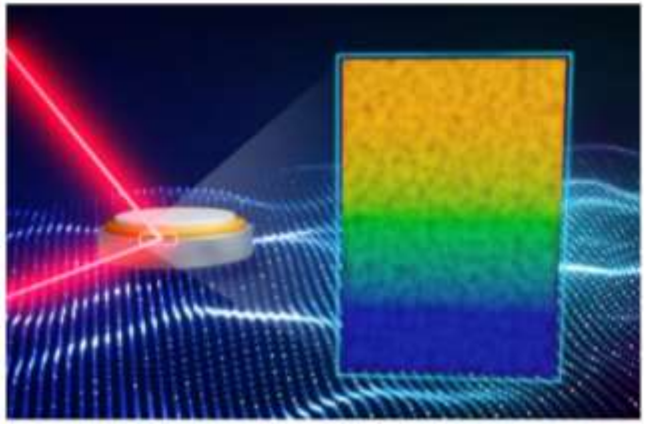
PSI



Science and Society

- Hierarchical architectures
- Applied materials, systems, engineering
- Multimodal imaging across multiple lengthscales
- Understanding biological systems / hydrogenated systems
- Non-ideal systems : Chemistry, disorder, interfaces, non-heterogeneity, environment, batteries
- *In-situ* studies of active / energy materials
- Quantum materials : coherence, devices, dynamics





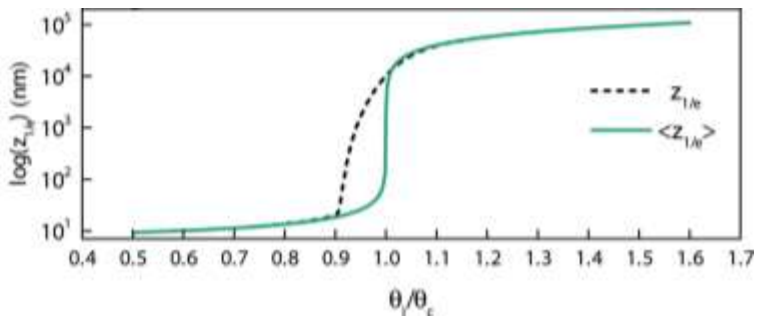
Instrument Whish-List

- Flexibility in wavelength resolution to control k_{iz}:
  - ~1% for depth sensitivity
  - ~10% for critical edge enhancement

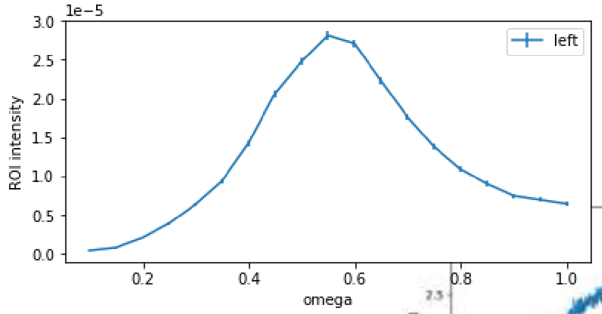
- Independent resolution
  - Vertical: depth resolution, reflectometer like
  - Horizontal: in-plane resolution, SANS like
- Multiple beam stops for direct, reflected beams
- Long wavelengths (FOM=I·λ^4)

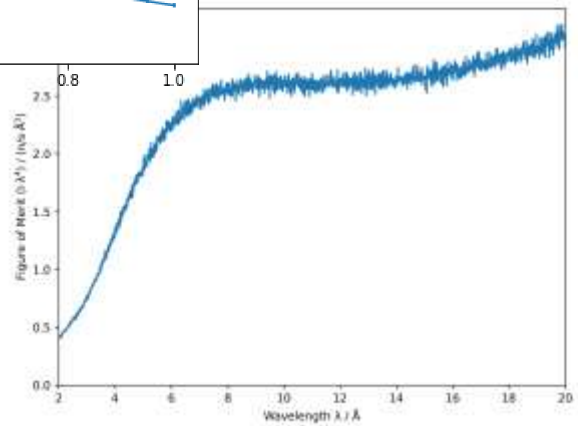
- Definition of incident angle on free liquid surface
- Specific sample environments (e.g. sheer cell)
- Polarization analysis (Yoneda line)
- Very low instrument background

Depth-sensitivity requires high q_z resolution [a]



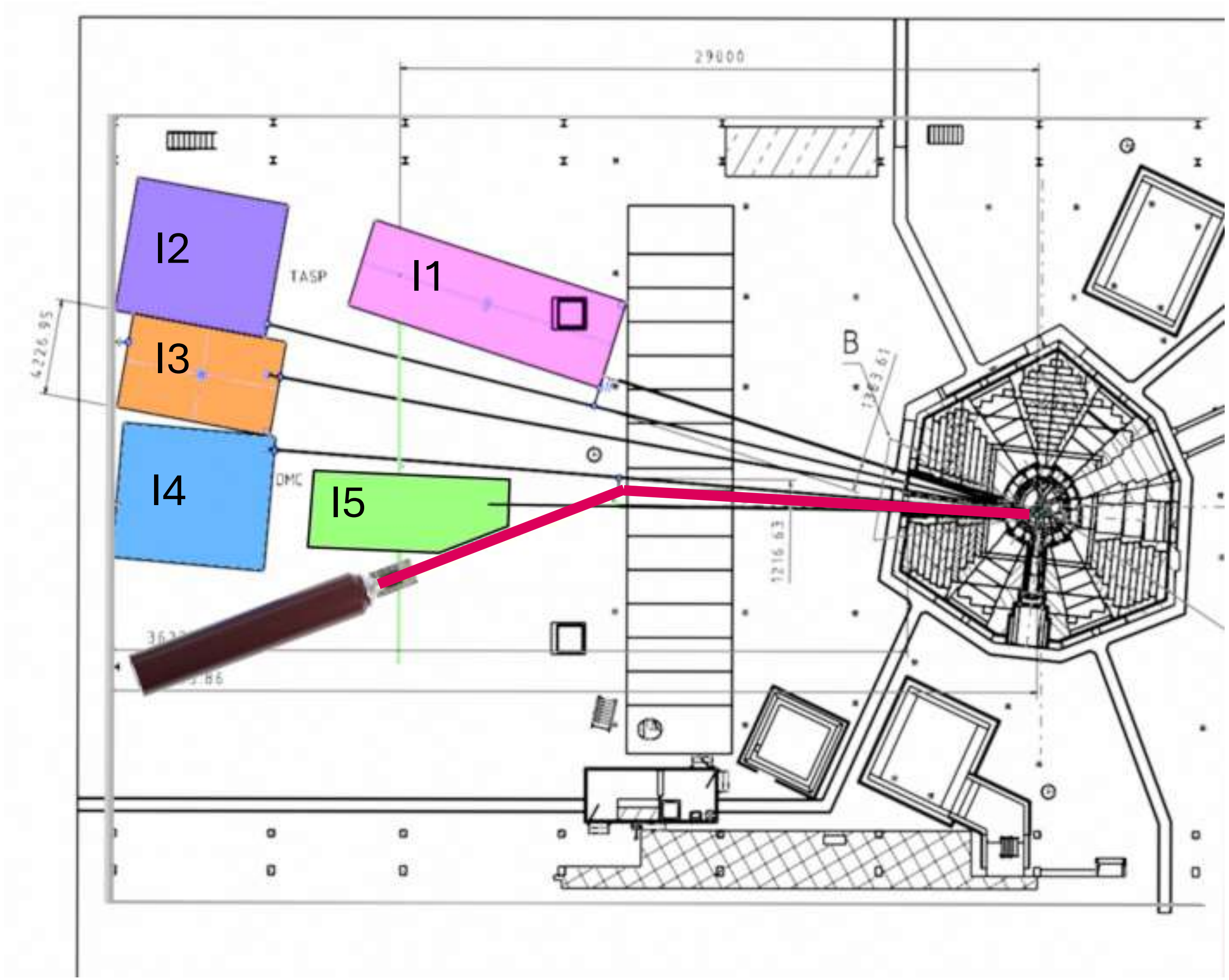
GISANS Bragg-peak vs. incident angle





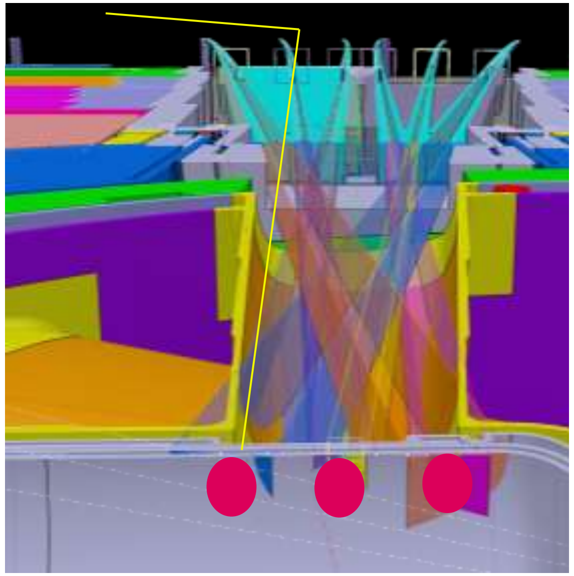
[a] S. Nouhi, M. S. Hellsing, V. Kapaklis, and A. R. Rennie, Journal of Applied Crystallography **50**, 1066 (2017).

Possible location for AMPLIFY

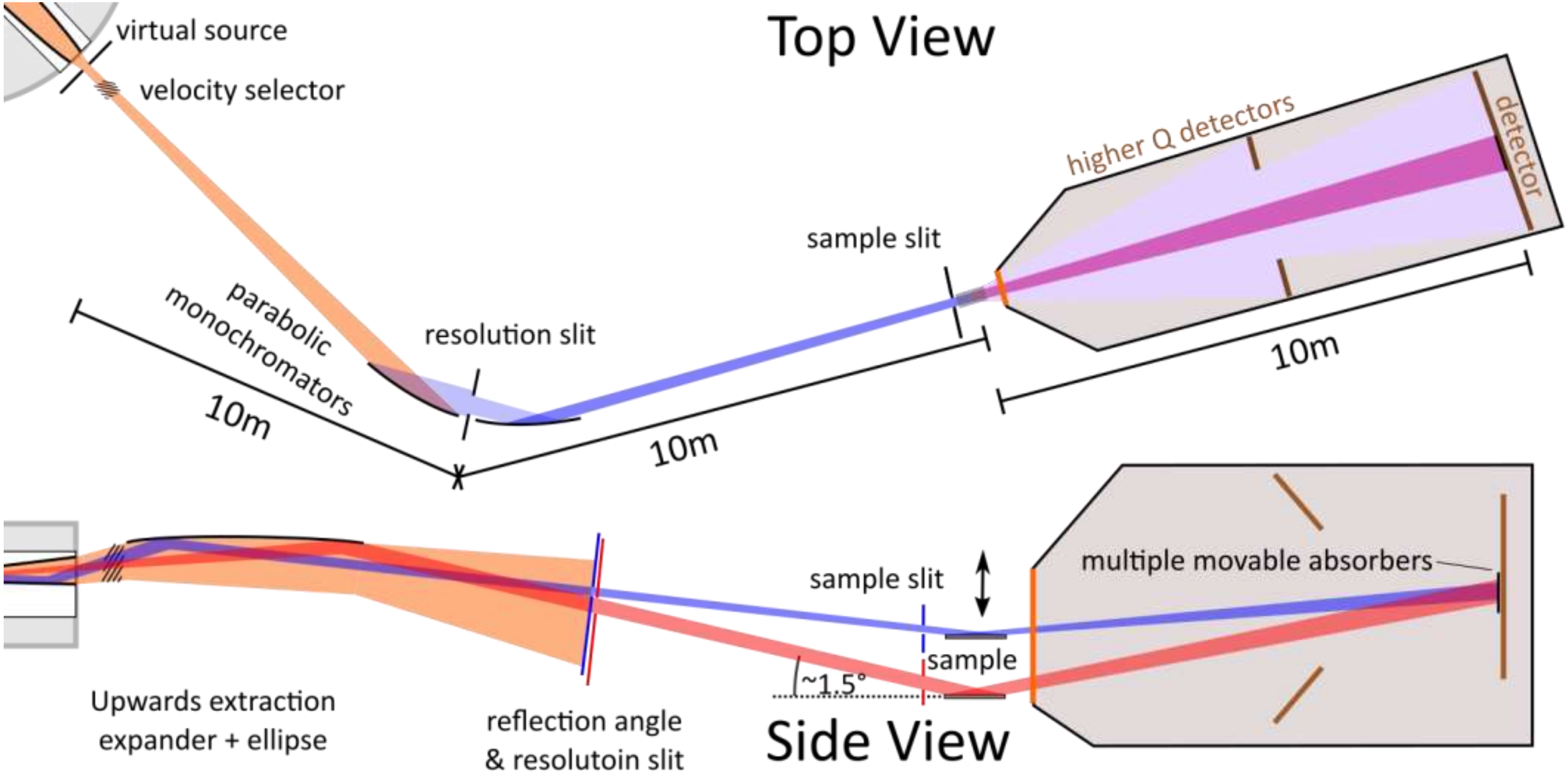


- Coldest part of source
- Deflect at 17 m

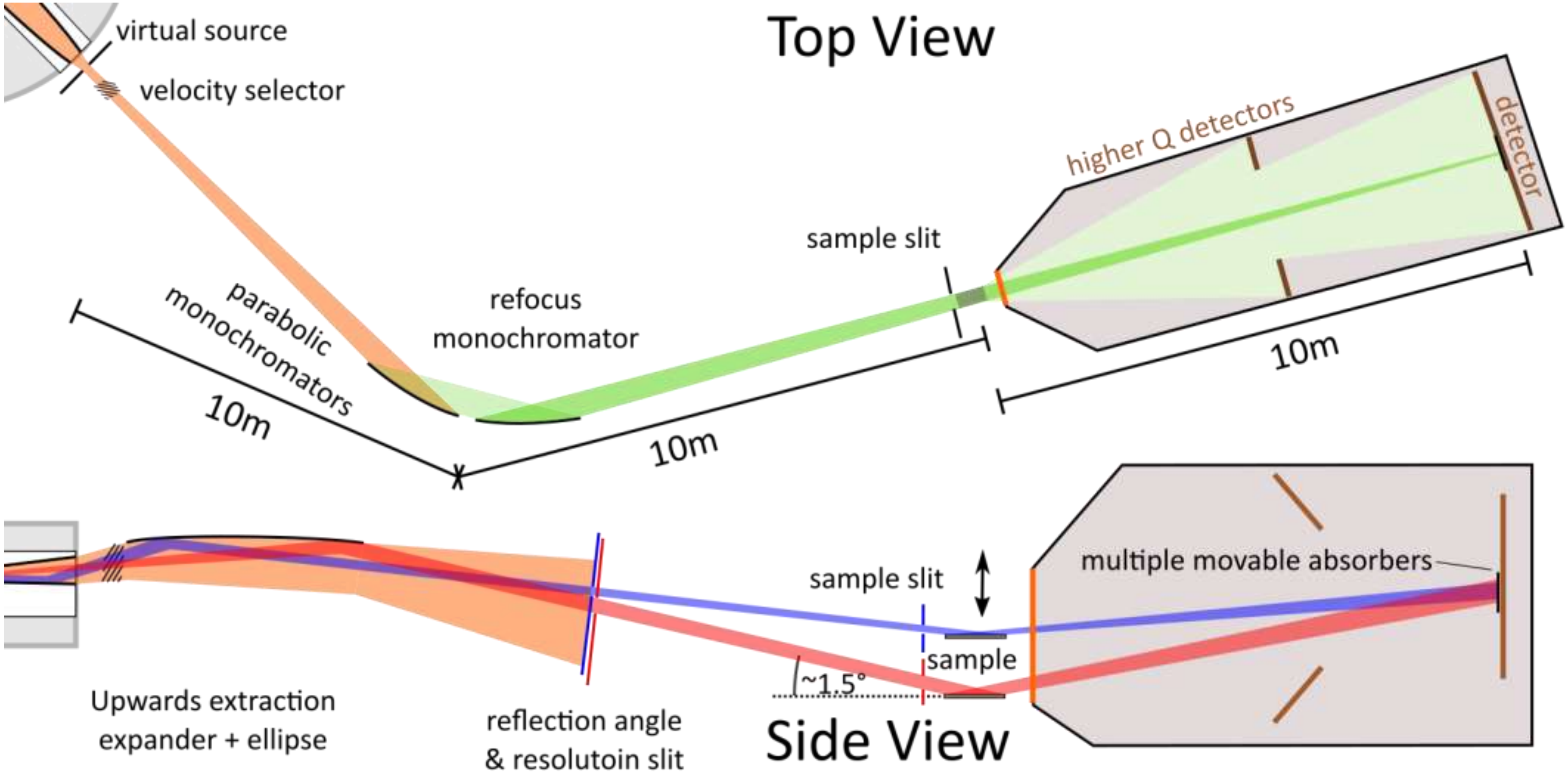
➔ Largest distance to other instruments and direct line-of-sight



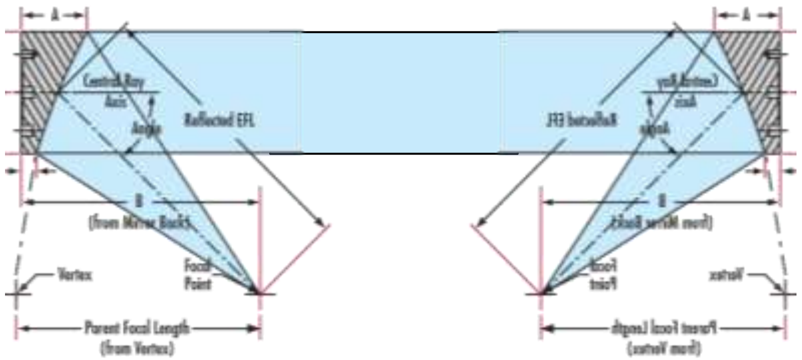
Instrument Concept - AMPLIFY



High-Res Mode w/ Refocusing

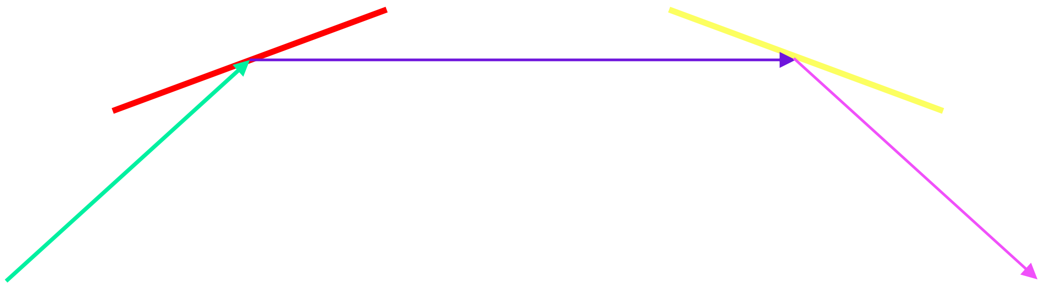


Monochromator Concept - AMPLIFY

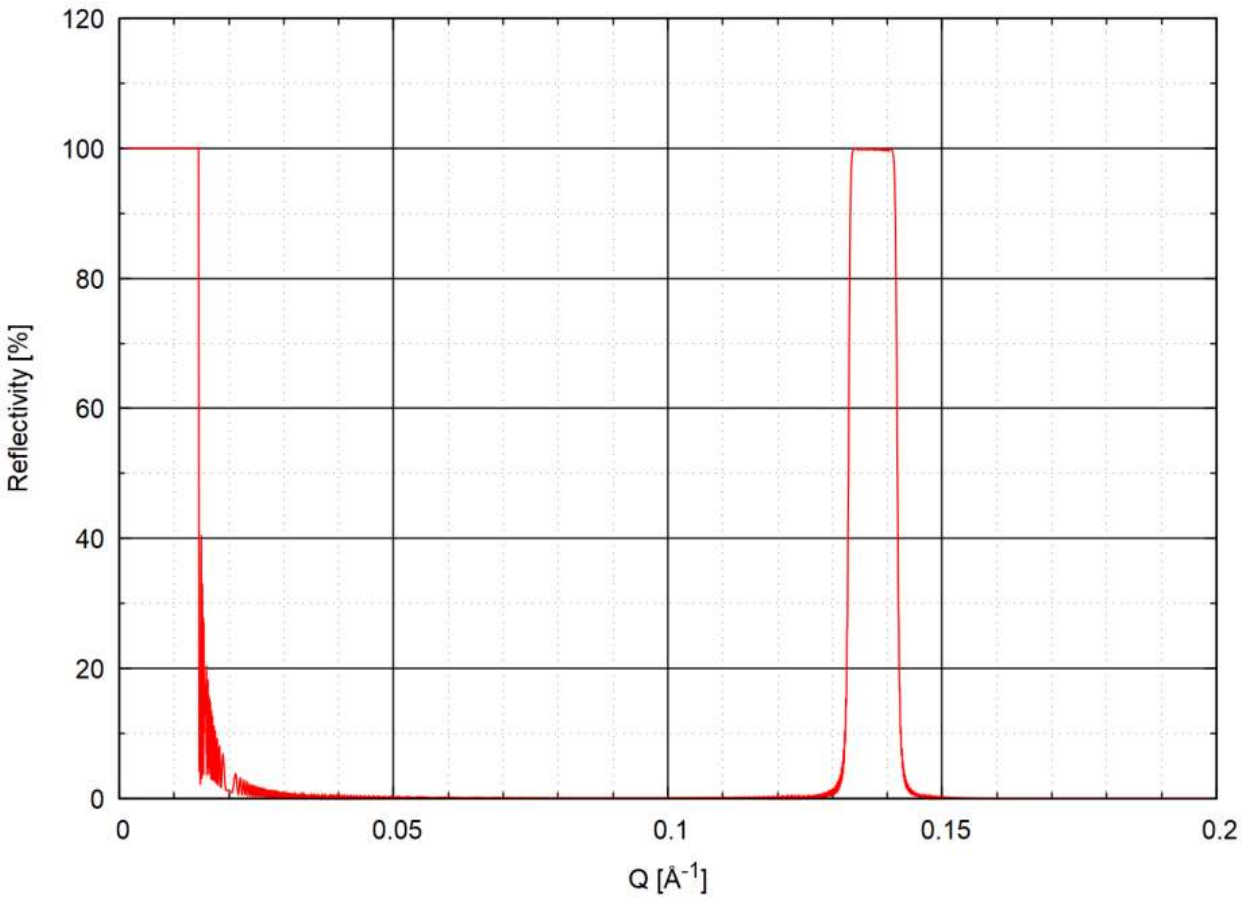


Parabola:

Divergent ➔ Parallel ➔ Focused



Highly reflective Ni/Ti coating (~2000 bilayers)



Monochromator Concept - AMPLIFY

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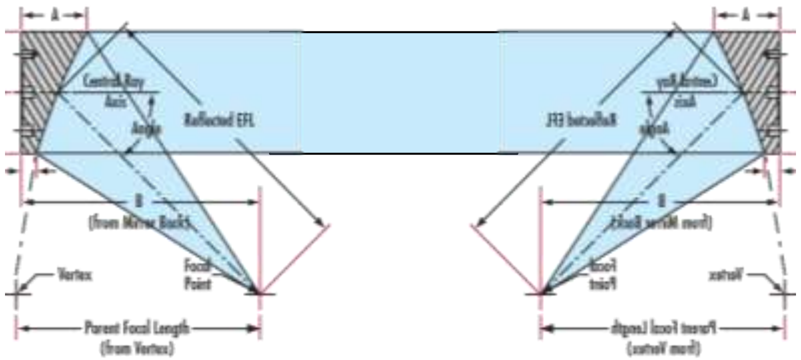
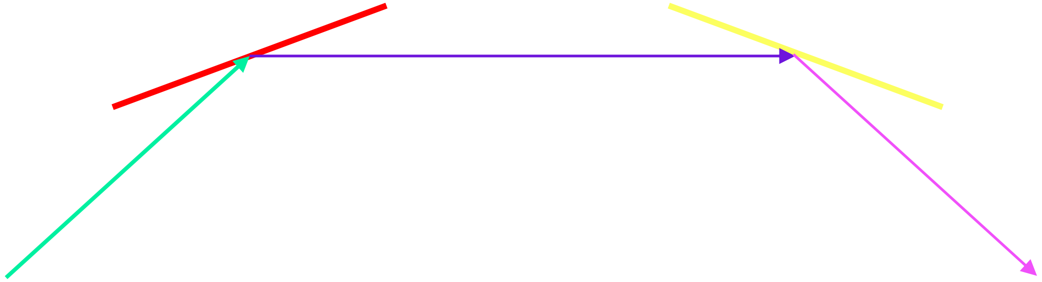


Parabola:

Divergent ➔ Parallel ➔ Focused

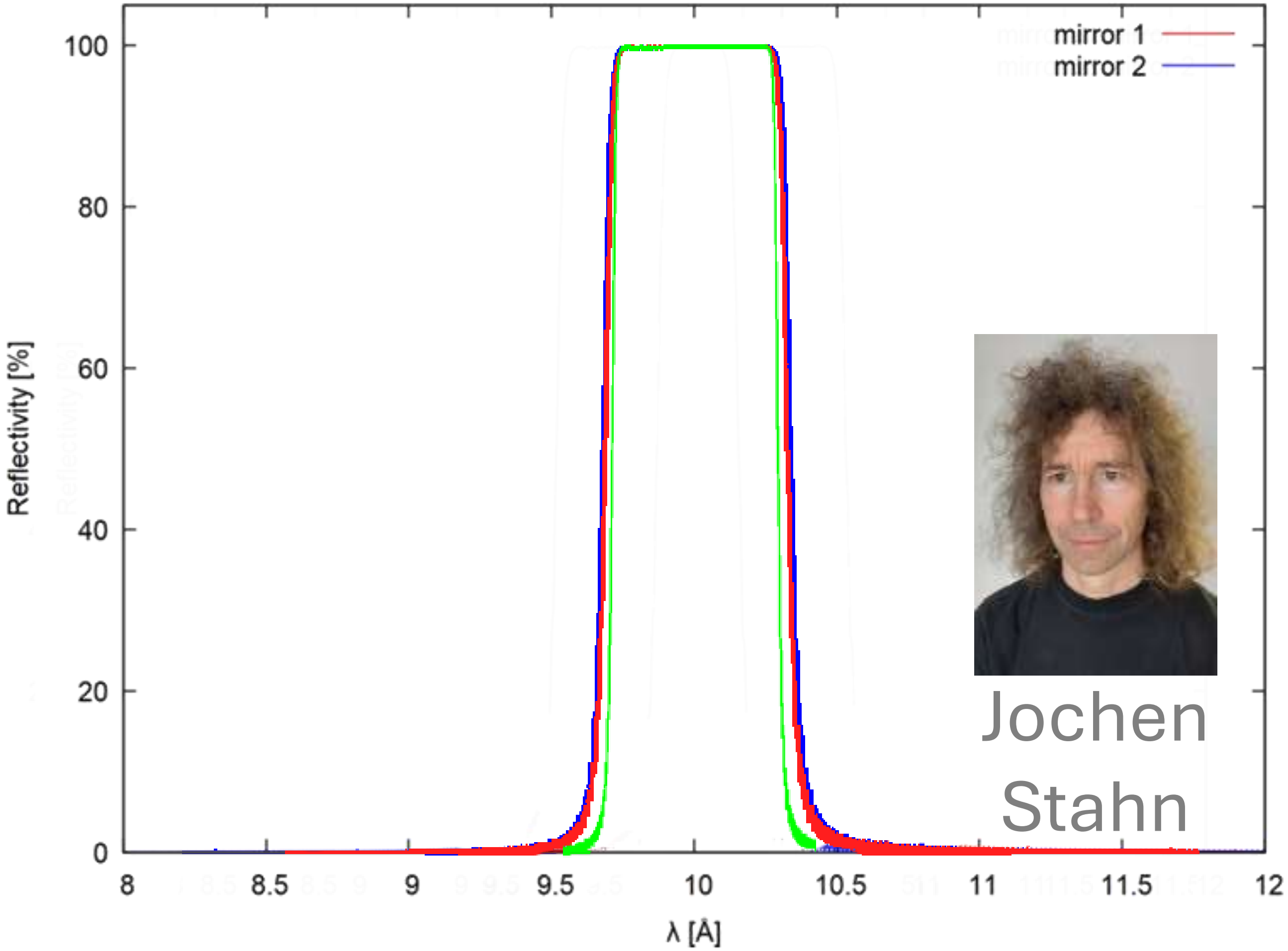


decrease angle
➔ shorter wavelength

increase angle
➔ longer wavelength

Highly reflective Ni/Ti coating (~2000 bilayers)

Total transmission is the product

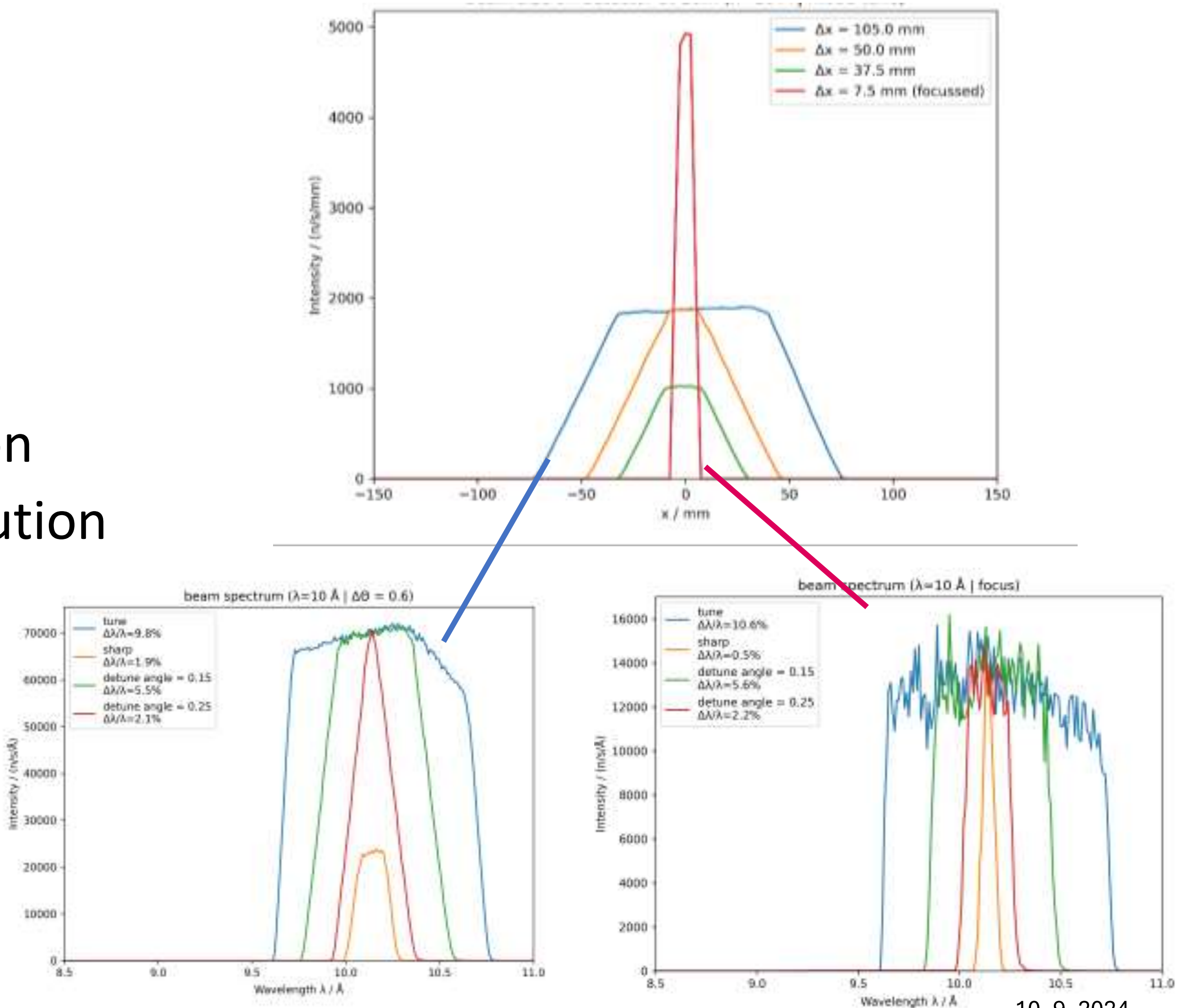


Jochen Stahn

AMPLIFY Gift Bag

- Low background
  - Distance to other instruments
  - Low amount of unused neutrons
- Continuous wavelength resolution
  - Optimized for experiment
  - Independent of angular resolution
- Separate vertical and horizontal resolution
- Medium to high in-plane resolution due to switch to focus on detector ($3.8e^{-3}$ to $2.5e^{-4}$ $Å^{-1}$)

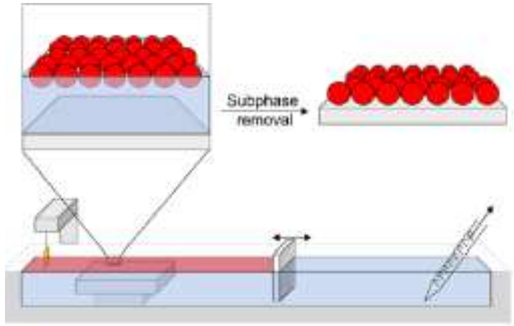
horizontal beam size



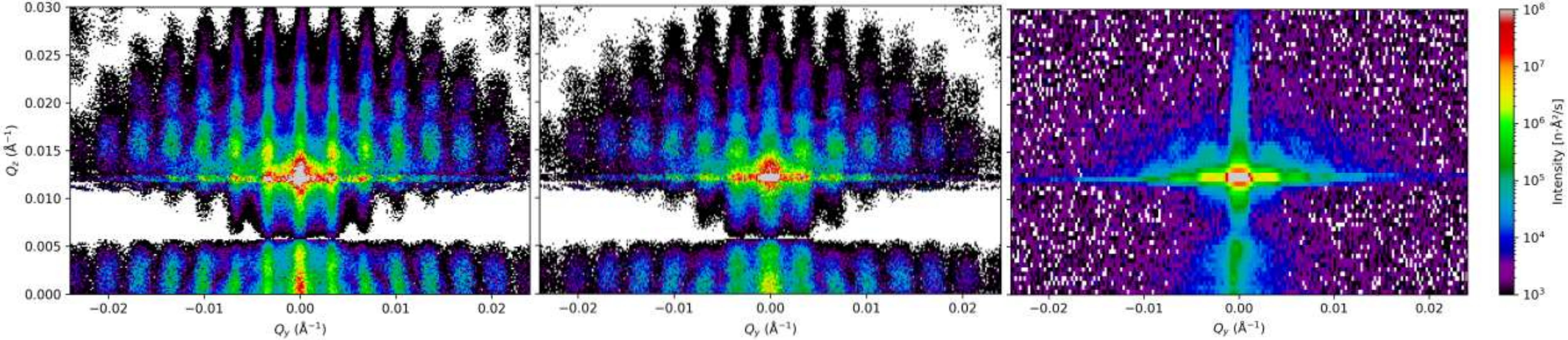
wavelength spread

Simulation of Example Samples

- Integrated McStas with BornAgain DWBA calculations to simulate performance of AMPLIFY on various model systems
- Use published measurement on SiO_2 nano-spheres, self-organized in a monolayer near the Si-D_2O interface [1]
- Losses from windows/air scattering not included



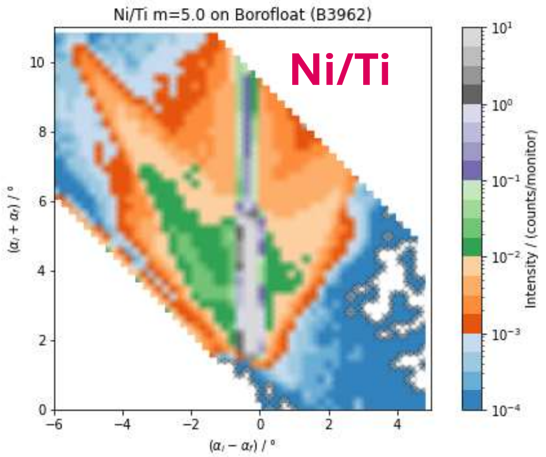
AMPLIFY – Focusing Mode | AMPLIFY – Pinhole Mode | D22 - 200nm Si-spheres (3h)

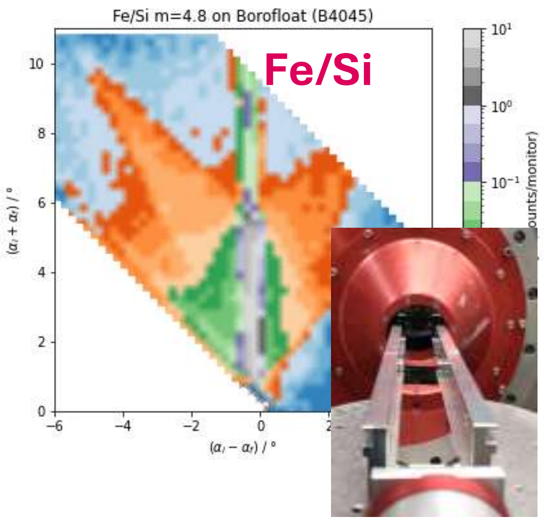


[1] N. Paracini, et al., Appl. Mater. Interfaces 2023, 15, 3772-3780

Neutron Experiment Results on Mirrors

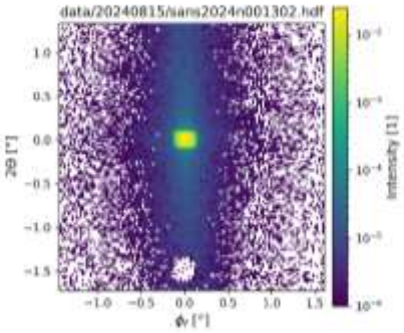
- Experimental amount of scattering not prohibitive, mostly in off-specular direction
- Higher m-value mirrors only slightly increase scattered intensity
- Sample-sample variations of factor 2-4 for same m-value (substrate quality?)
- Even with improvised guide field (thanks Jochen), magnetic mirrors are in same range

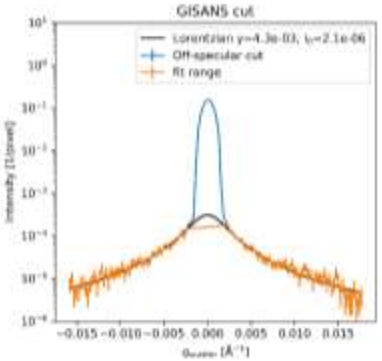


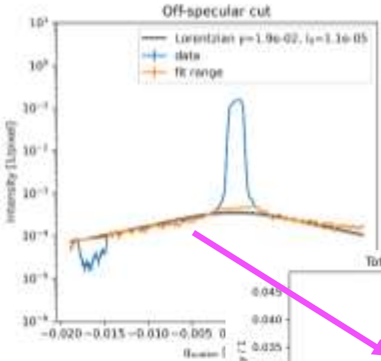


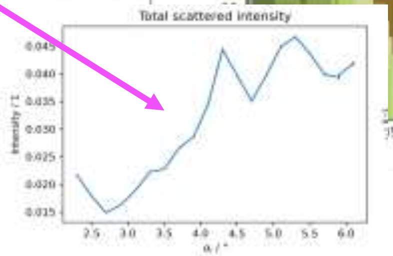
m=6 => m=7

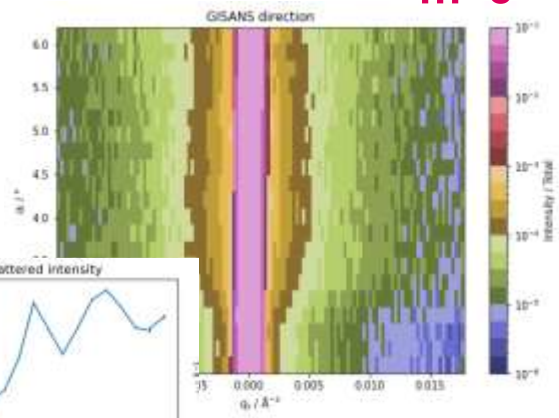
m=6 => m=7

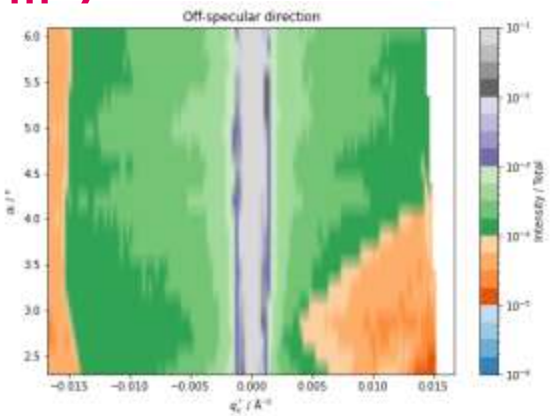






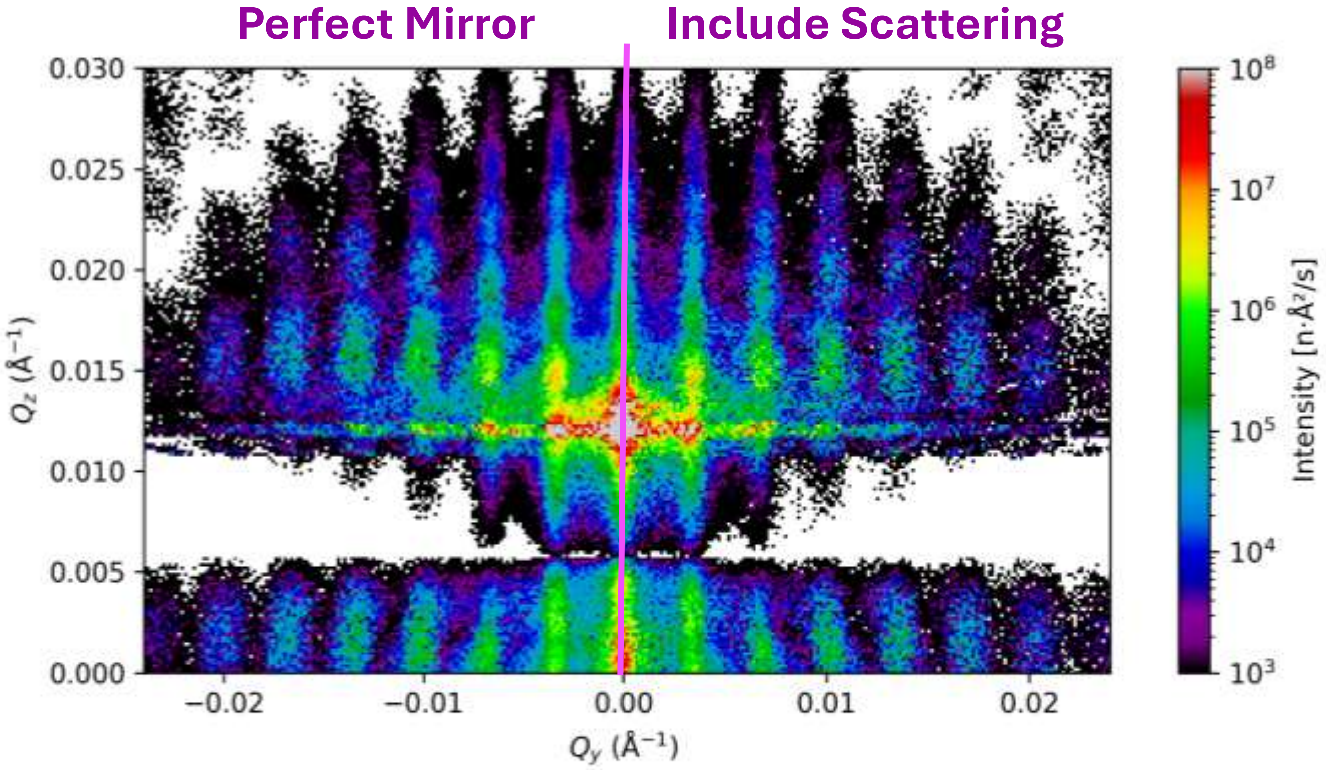


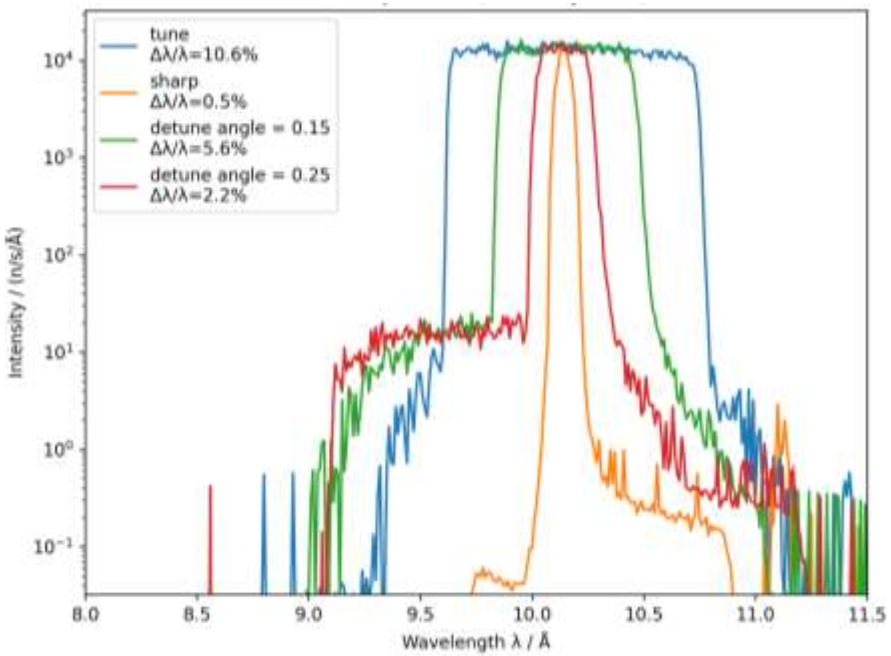




Simulated Influence of Scattering on Focusing

- Simulation of scattering on focusing experiments and monochromator using McStas
- Limited influence on wavelength suppression when detuning mirrors
- No noticeable different in the reference sample simulation





Thank you for your Attention

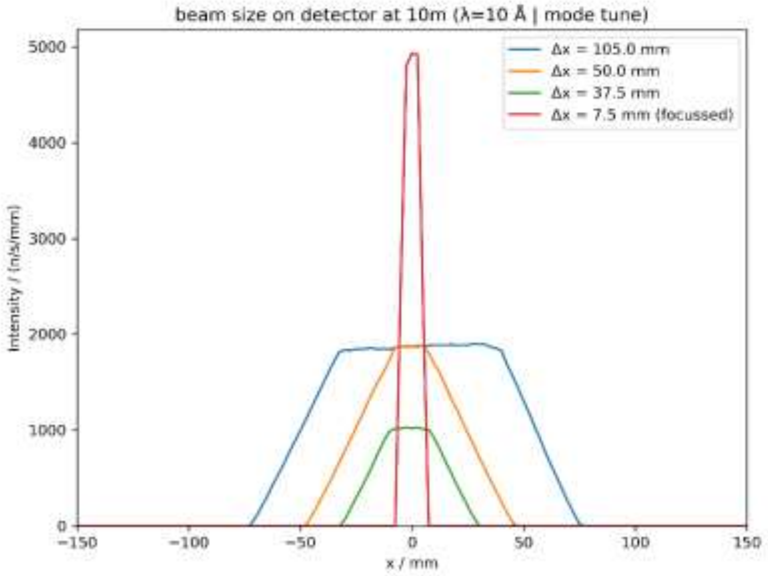
- AMPLIFY combines
  - Advantage of a continuous source to do GISANS with fixed k_i
  - Monochromator concept gives independent flexibility of wavelength, horizontal and vertical angular resolution
  - Technologies are already possible, with some R&D the performance could further be improved (monochromator transmission and scattering)

- Expert support needed!
  - If you'd like to support the project by contributing to the science case description for the instrument proposal until fall 2024, please contact me at artur.glavic@psi.ch

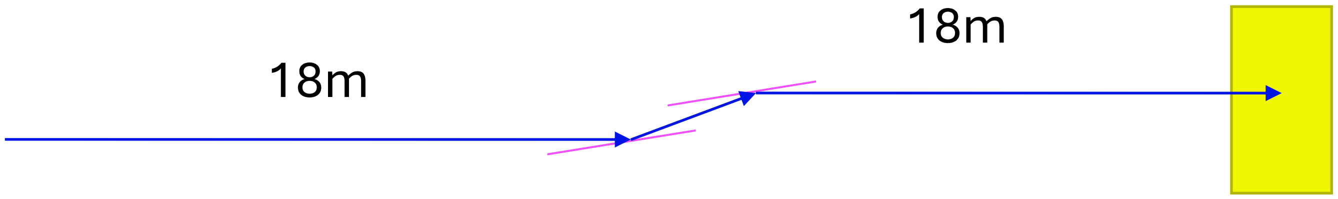
Possible Influence of Scattering on Focusing

- Focusing on detector to improve high-resolution performance
- Off-specular and GISANS scattering from the Mirrors might blur the beam and prohibit this application

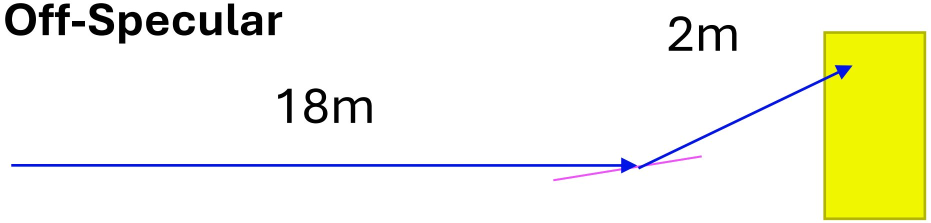
- Performed test experiment at SANS-I @ PSI
- Measurement of up to m=7 off-specular and GISANS scattering up to m=6
- Additionally, a set of polarizing mirrors (Fe/Si) for comparison

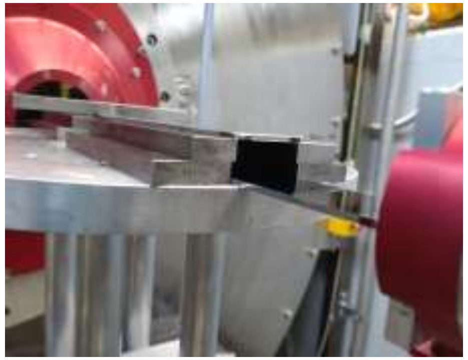


GISANS

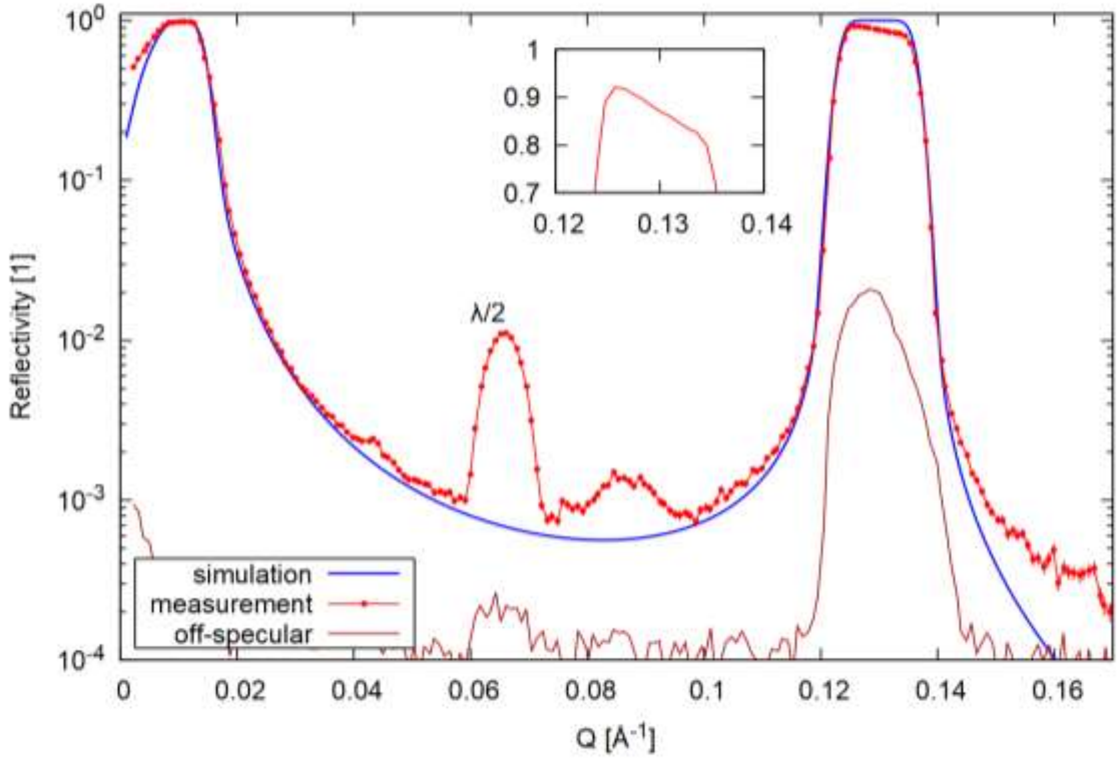


Off-Specular





Test of Monochromator Performance



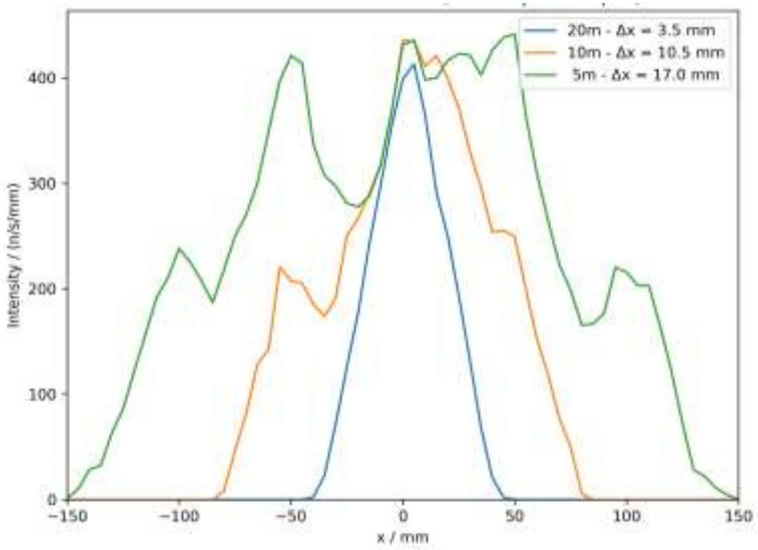
- Monochromator structure with linear thickness gradient
- Optimal model ~100% reflectivity
- Real system 80%-90% reflectivity
- Sharpness of wavelength suppression follows ideal curve
- Space for improvement with limited R&D

One-shot test sample by SwissNeutronics

Comparison to Conventional Concept

- Reference concept:
  - SANS-like straight guide with bender and flexible collimation length (ignore incident angle requirement)
  - Wavelength resolution from velocity selector and possible improvement to 1%/3% with (Fermi-)chopper
- Result compared to AMPLIFY:
  - Lower intensity for same resolution
  - Horizontal resolution structured by bender influence
  - Longer collimation required, still best resolution 4x worse than with focusing
  - Chopped beam spreads over 10% band with different intensity further reducing efficiency
  - But resolution could be relaxed further (<5m collimation)

horizontal beam size



wavelength spread