PAUL SCHERRER INSTITUT

EUROPEAN SPALLATION SOURCE

The ESS Small Sample Reflectometer

Ἑστία

Artur Glavic, Sven Schütz

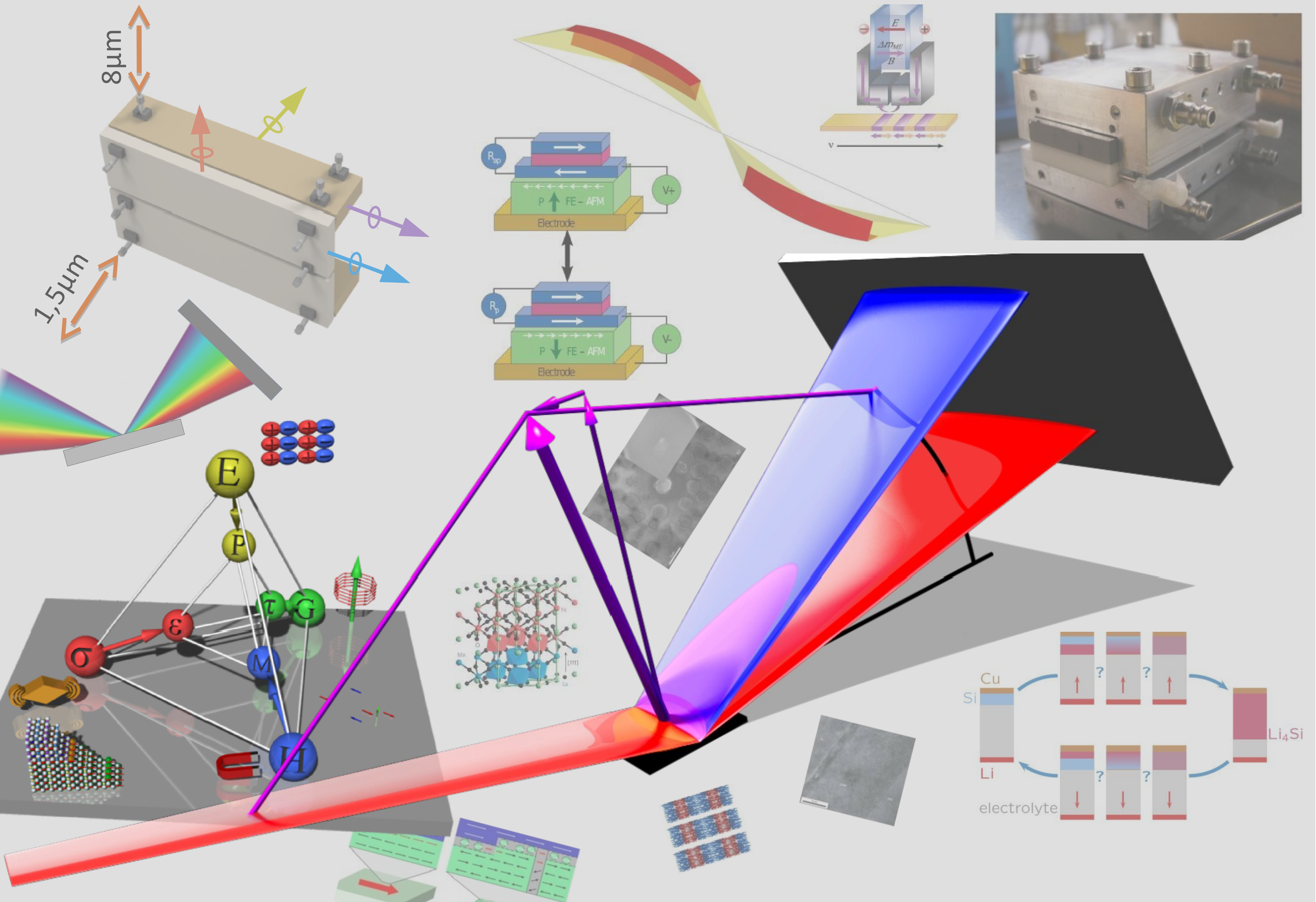
Toll Gate 2 Meeting ESS
Lund, 29.11. 2016

Outlook

1) Science Case
2) High level system requirements
3) Functional overview
4) Preliminary System Design
5) Initial Operation
6) Instrument staging and upgrade path

Outlook

1) Science Case
2) High level system requirements
3) Functional overview
4) Preliminary System Design
   - Bemline overview
   - In-bunker components
   - Selene neutron guide
   - Shielding concept
   - Experimental cave
5) Initial Operation
6) Instrument staging and upgrade path

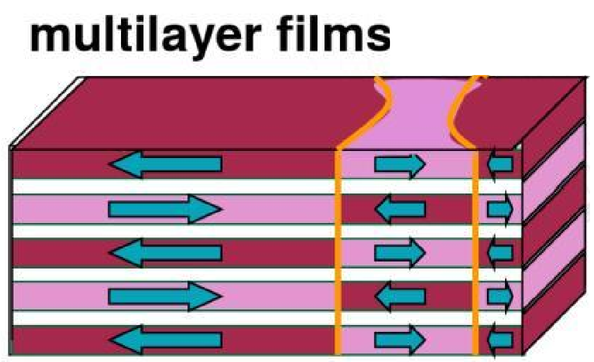


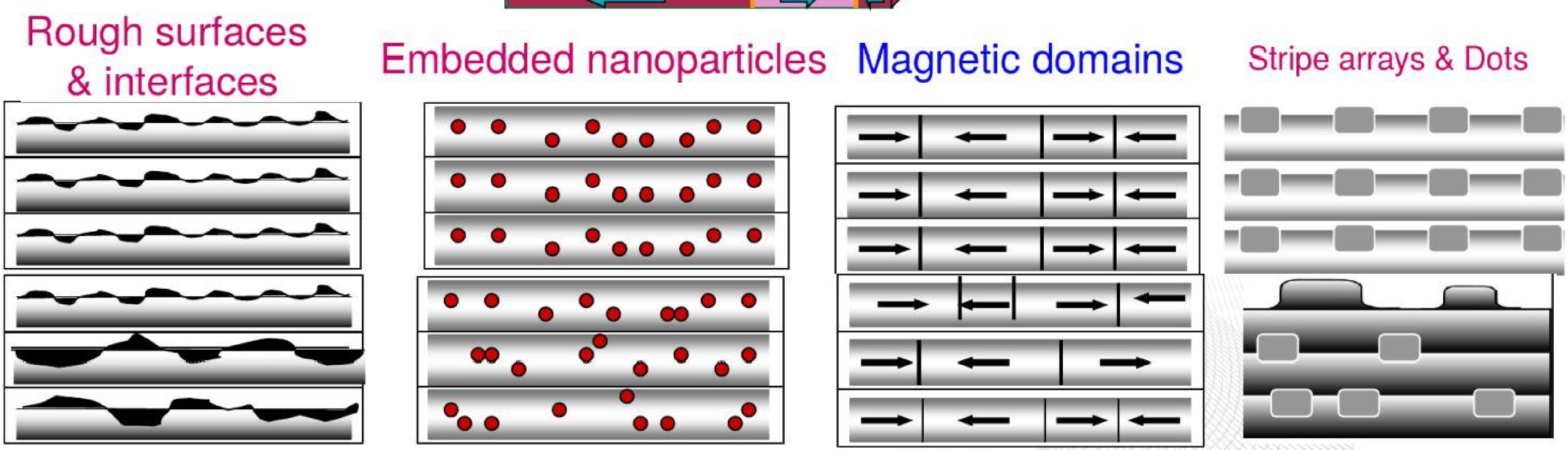
Science Case & System Requirements

Method

(Polarized) Neutron Reflectometry:

- Chemical and magnetic profile in thin films
- Nano-structures
- Penetrate into sample, not only surface
- Structure sizes 1nm-100nm (off-specular 100nm-10µm)

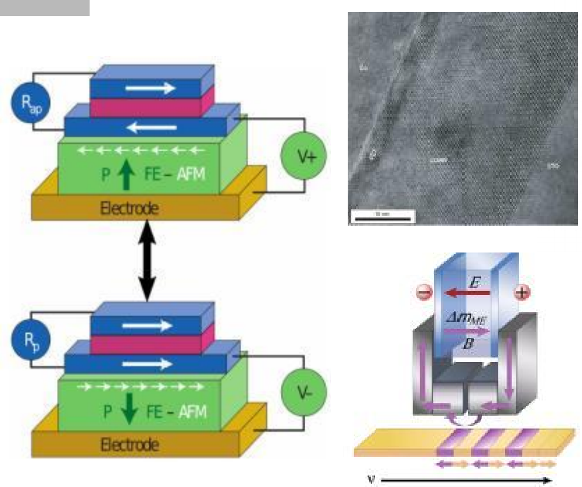




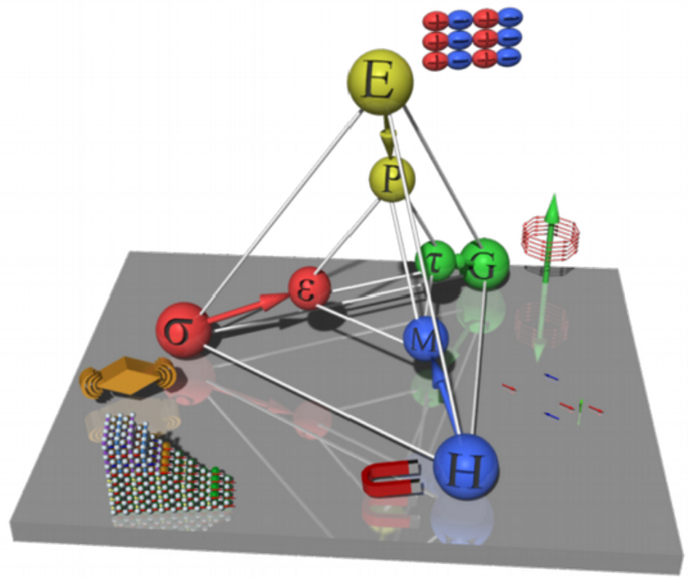
Science Case Focus for Estia

Broad range of science

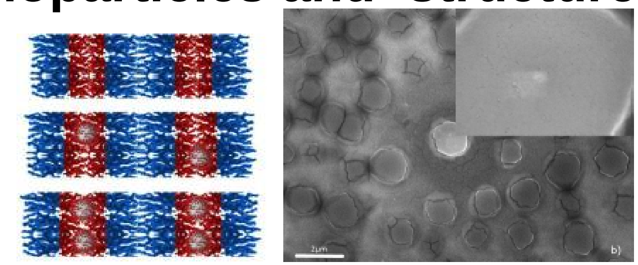
Spin-tronics Devices



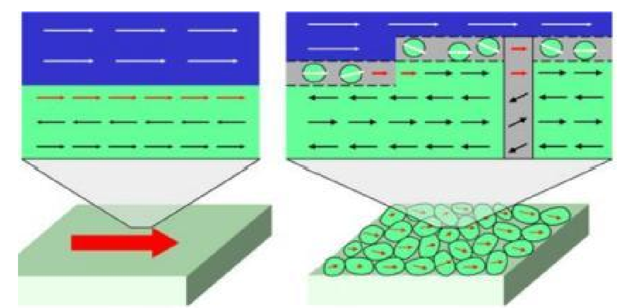
Multiferroics



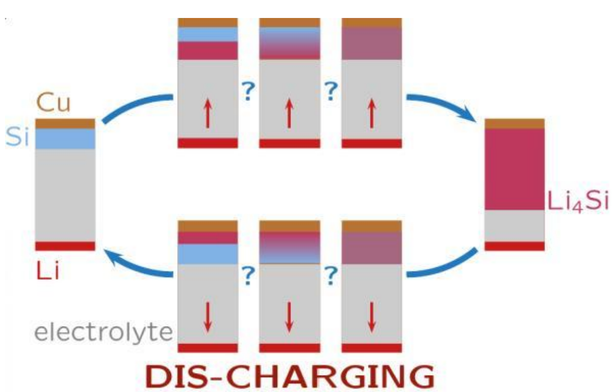
Nanoparticles and -structures



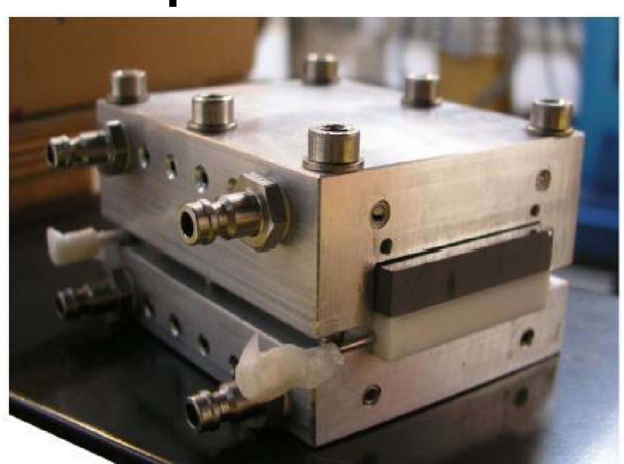
Exchange Bias



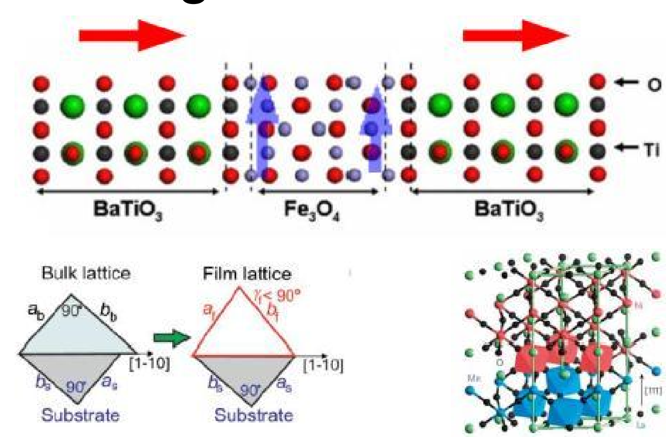
Batteries



Liquid Interfaces



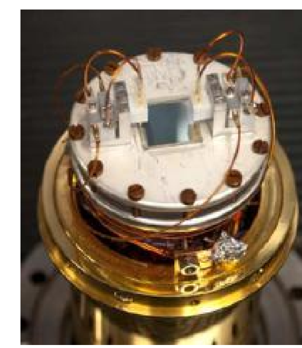
Emergent Phaenomena

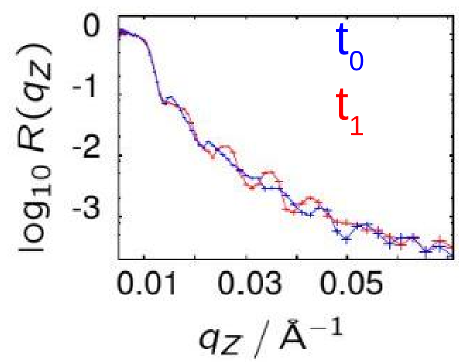


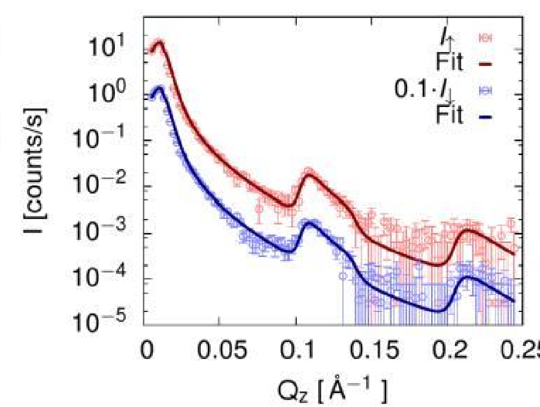
Science Case Focus for Estia

High intensity is necessary to...

- measure size limited samples (<10x10mm²) due to
  - limitations for homogeneous film deposition
  - existing samples made for other methods (e.g. 5x5mm² SQUID samples)
  - investigations on functional devices/ sample environment restrictions
- perform time dependent studies
- explore large q-range





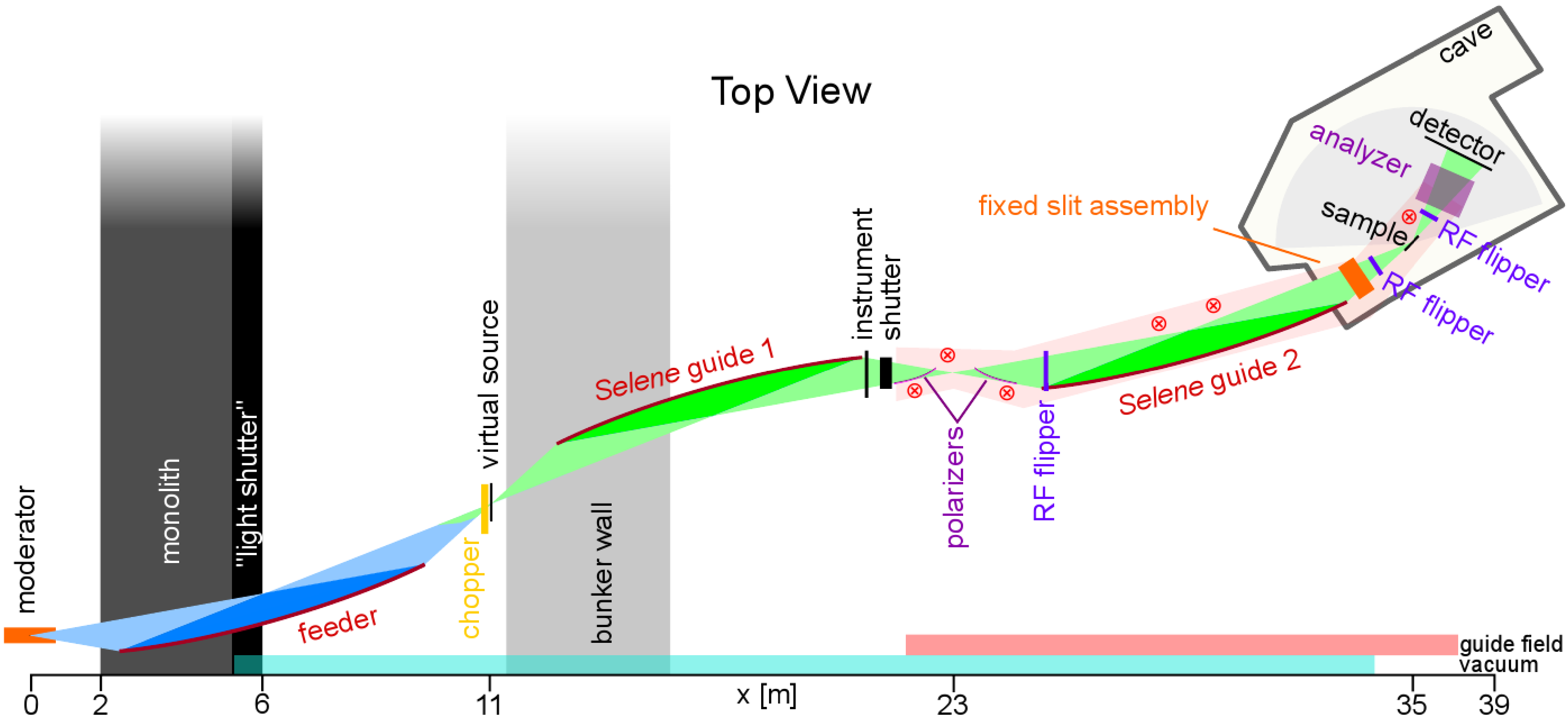


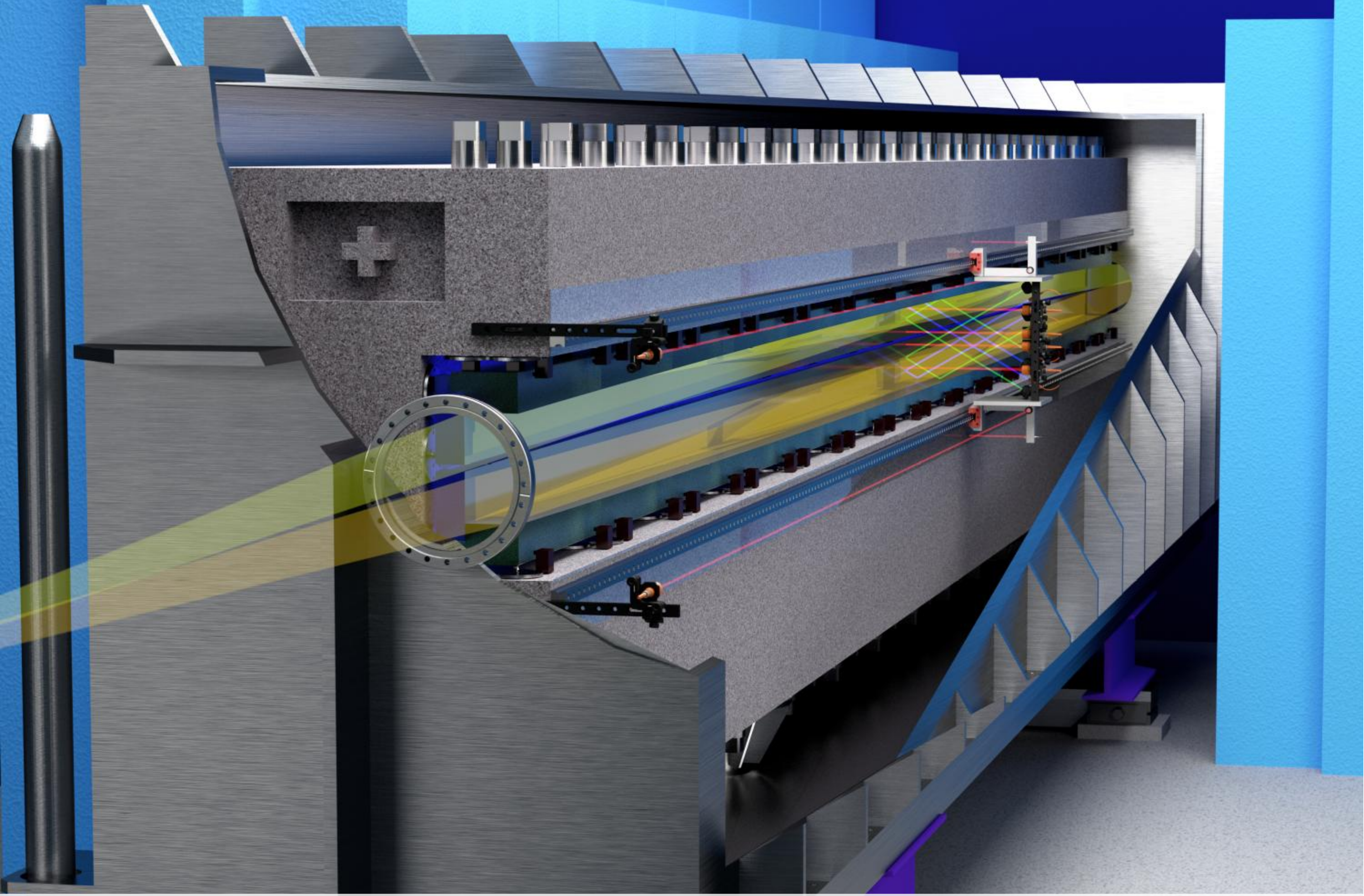
High Level System Requirements

Science Case => Design Goals:

- Allow specular reflectivity measurements from samples between 1x1 mm^2 and 10x10mm^2
- Provide neutron polarization analysis with P>95%
- Beam size at sample controllable
- Minimize the background
- Fast sample changes within ~10 min
- Options for off-specular scattering and GISANS
- Higher resolution option for thick samples

Functional Overview

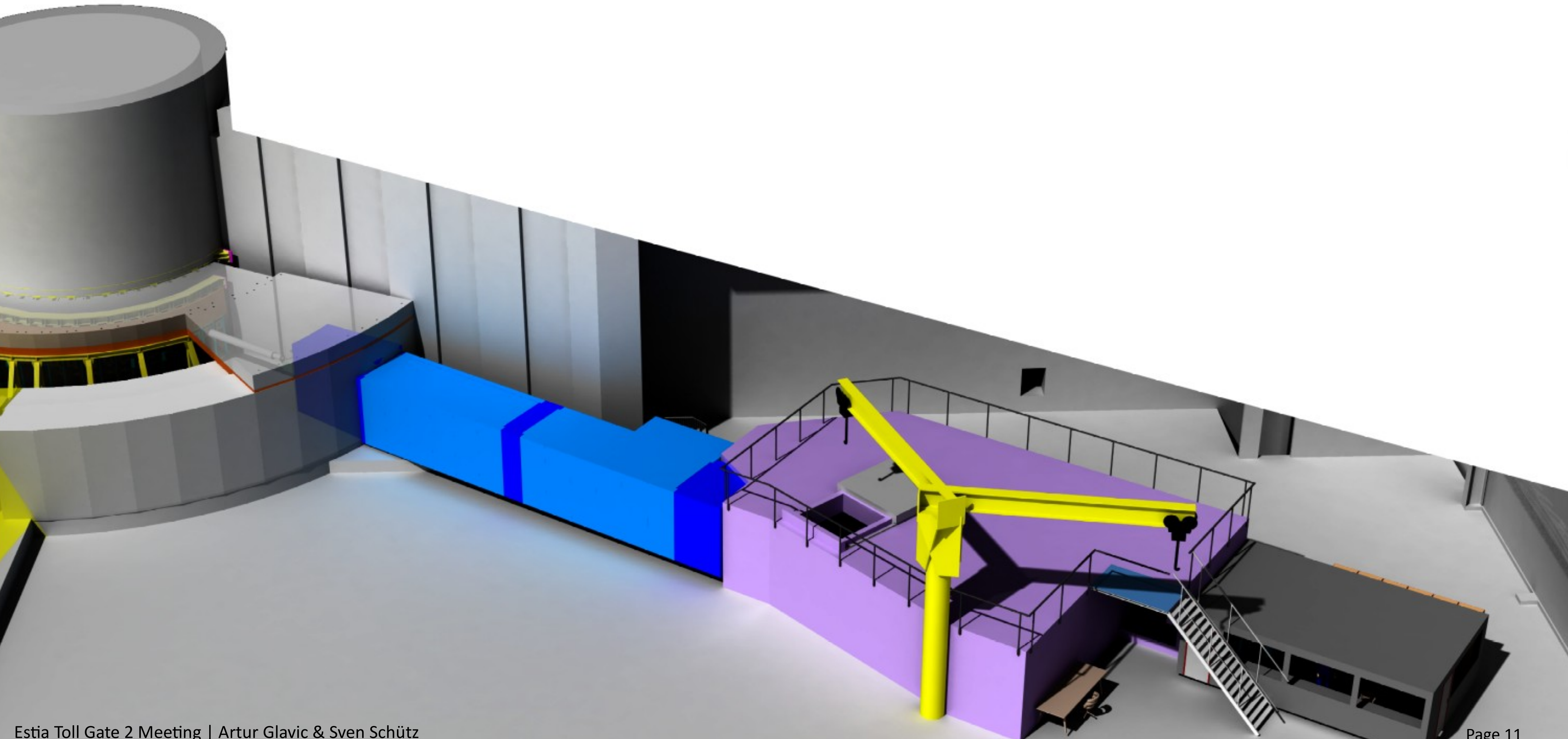




Preliminary Design I:
In-Bunker, Guides, Shielding, Structure

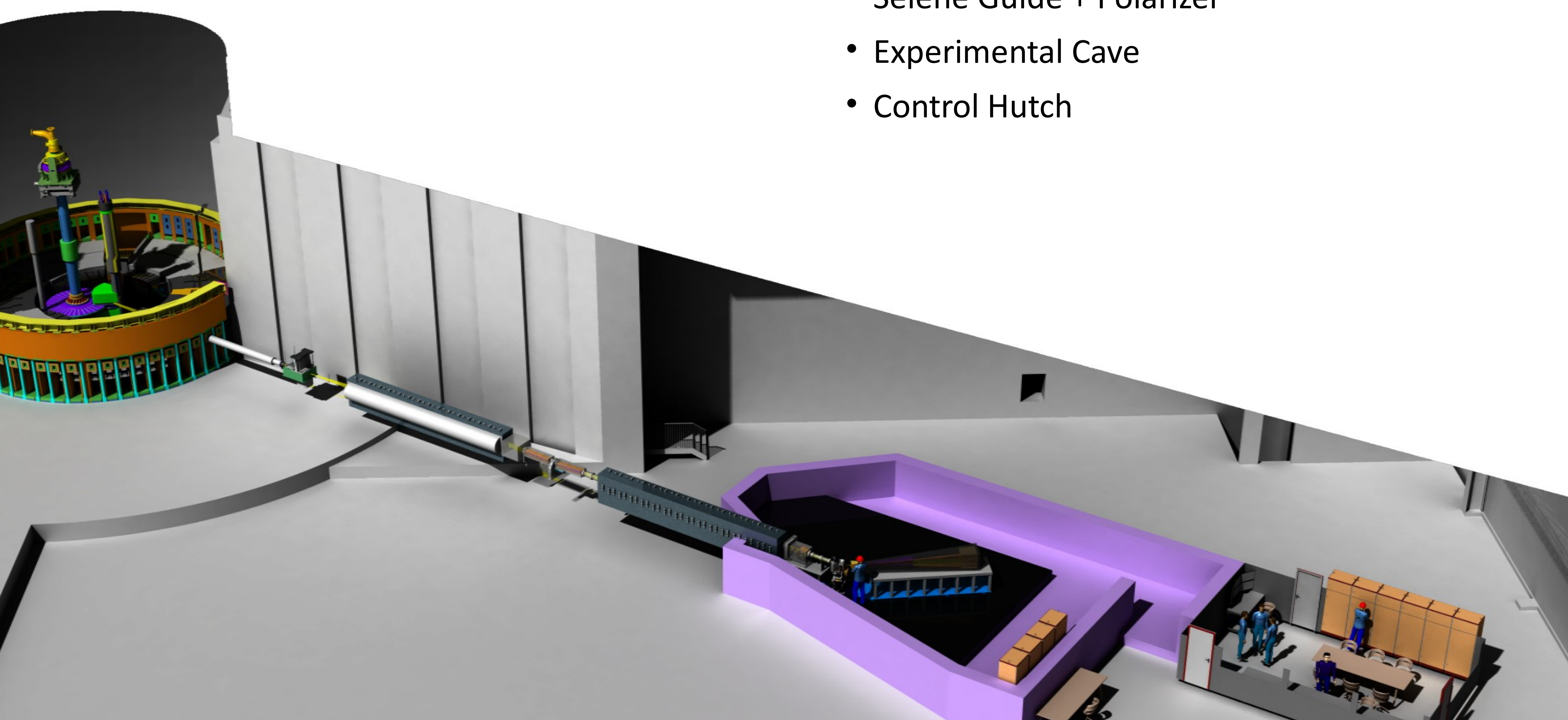
ESTIA Instrument Overview

- East sector (E2); cold moderator



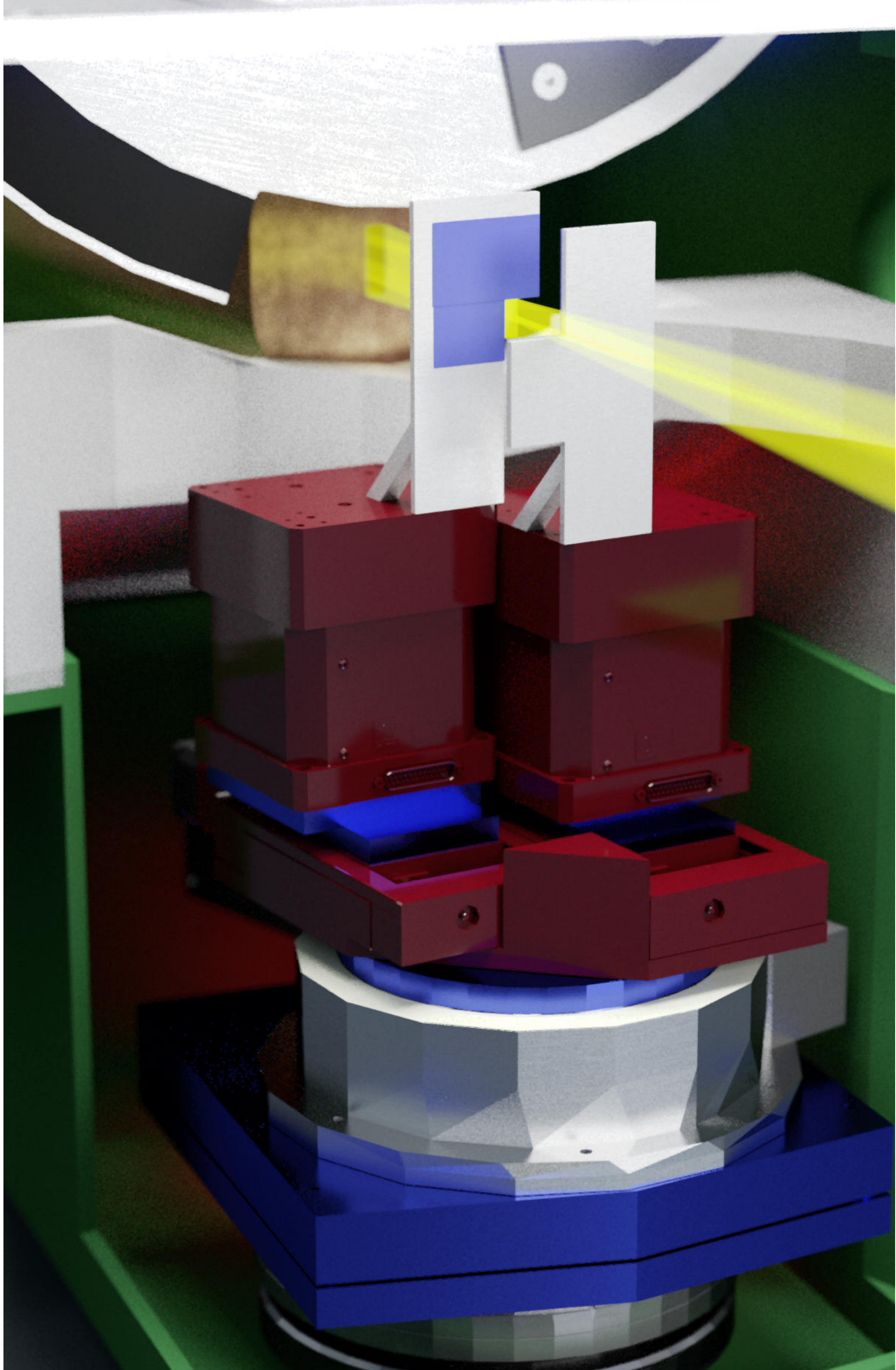
ESTIA Instrument Overview

- East sector (E2); cold moderator
- Single BW Chopper
- Elliptic feeder to Virtual Source
- Selene Guide + Polarizer
- Experimental Cave
- Control Hutch

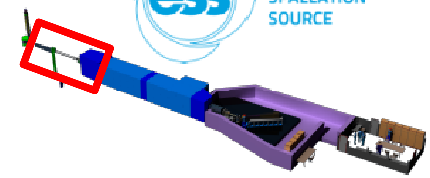


In-Bunker Parts

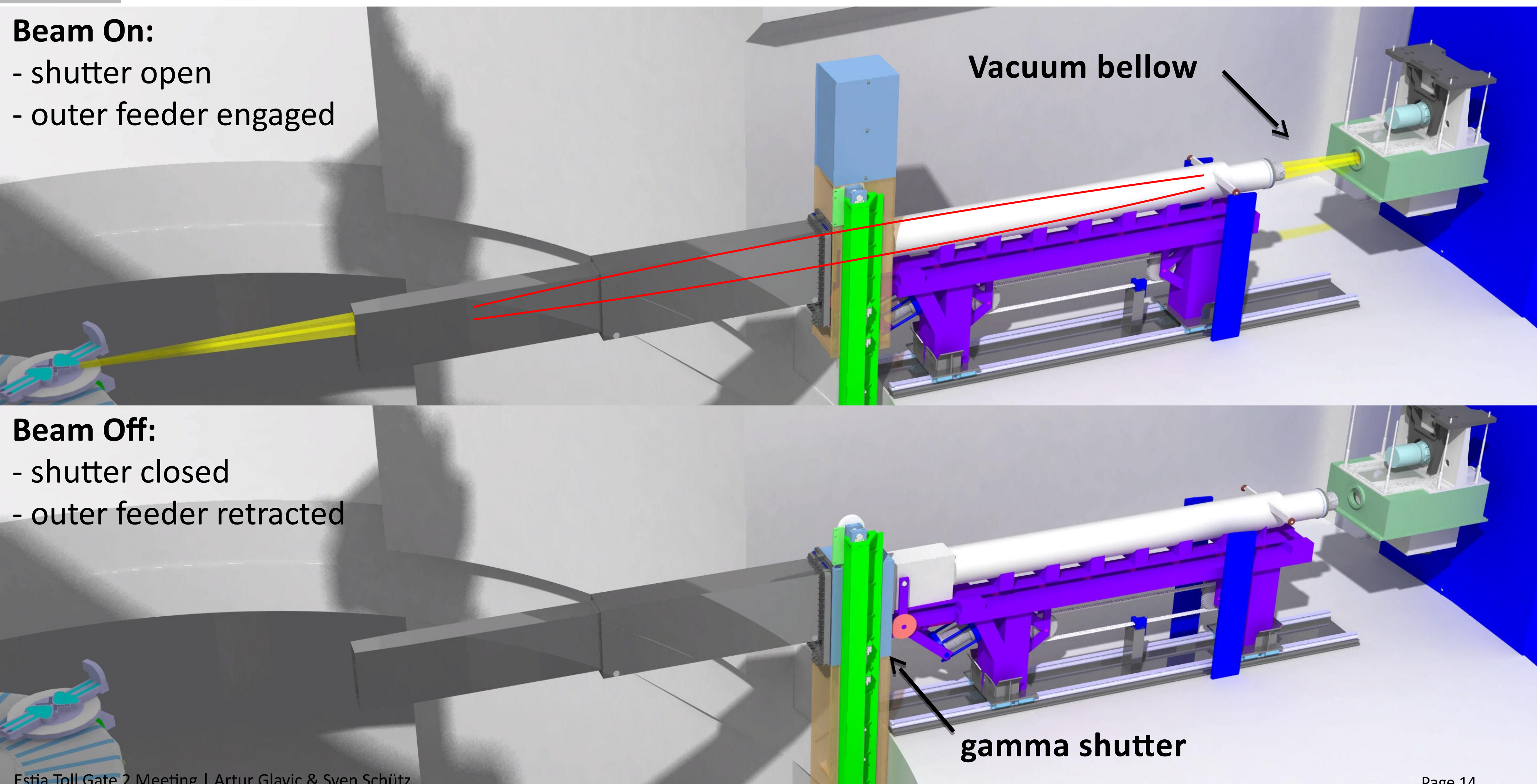
- Neutron Feeder
- Chopper
- Virtual Source
- Heavy Collimation



Neutron Feeder



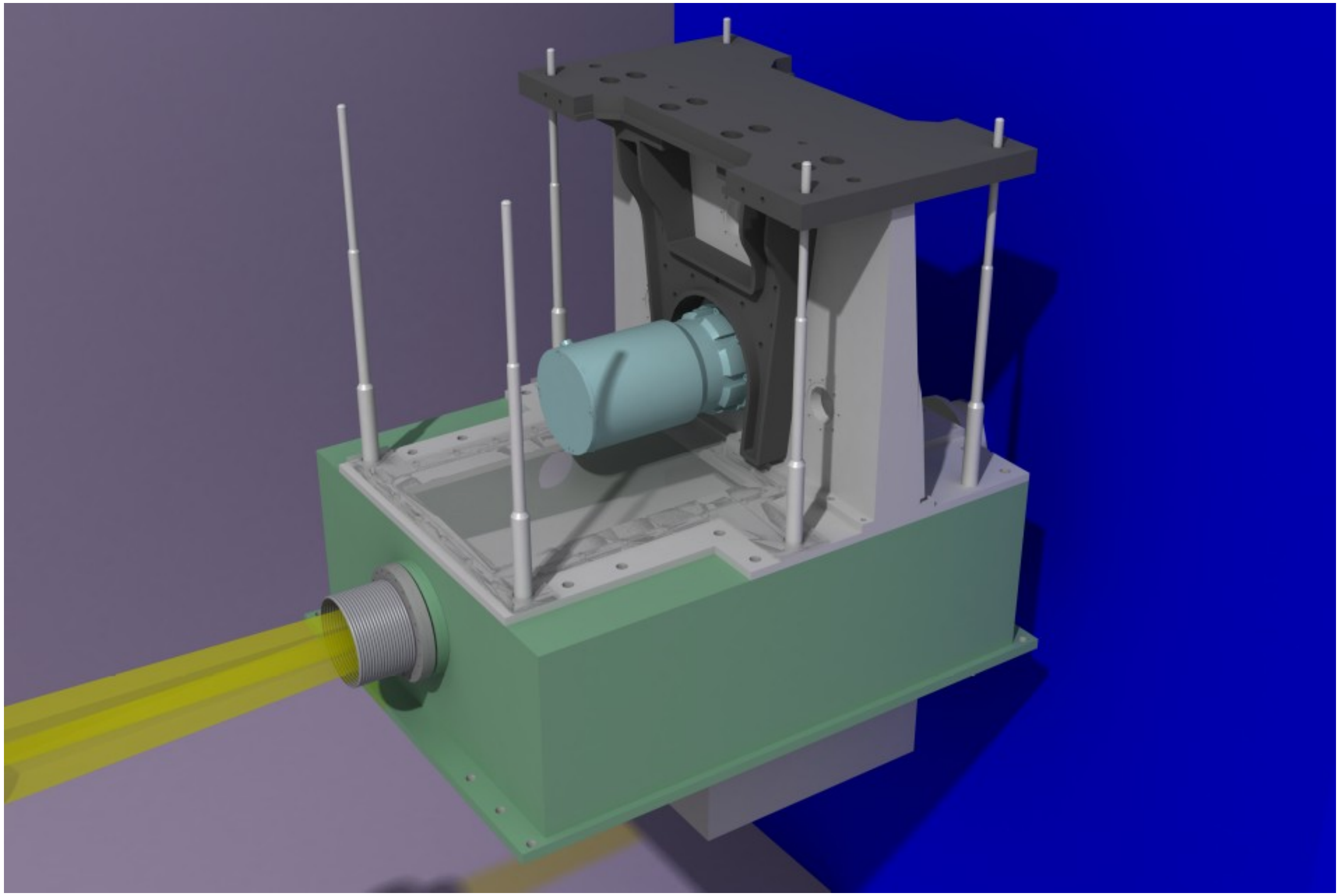
- Part 1: inside insert
- Part 2: moved in when light shutter open



Chopper and Virtual Source

Chopper Pit

- Standard 14 Hz Chopper
- Shared vacuum

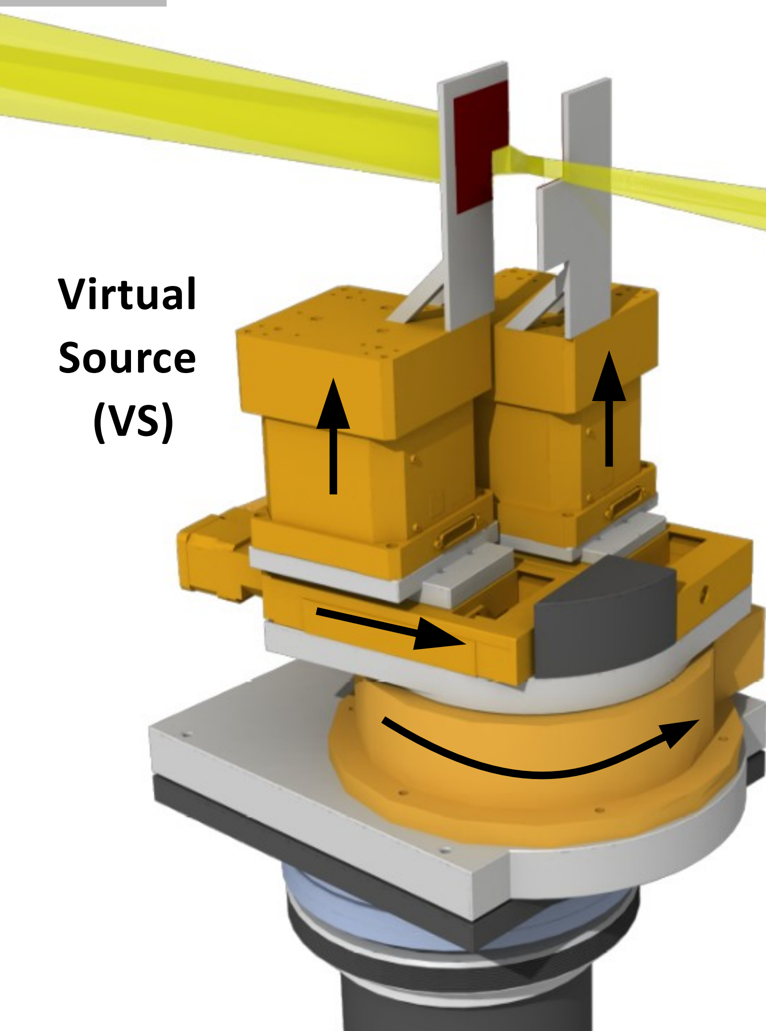


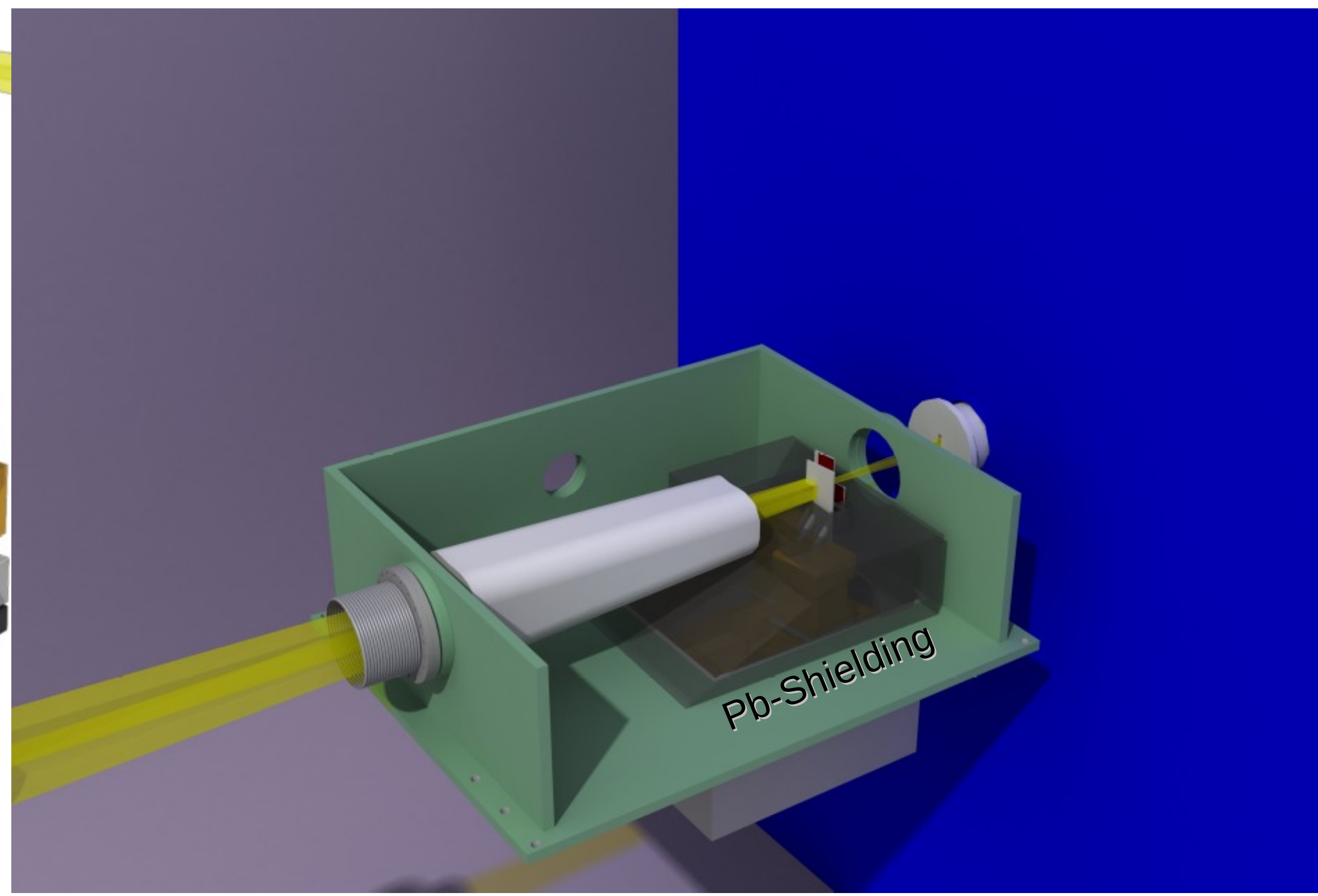
Chopper and Virtual Source

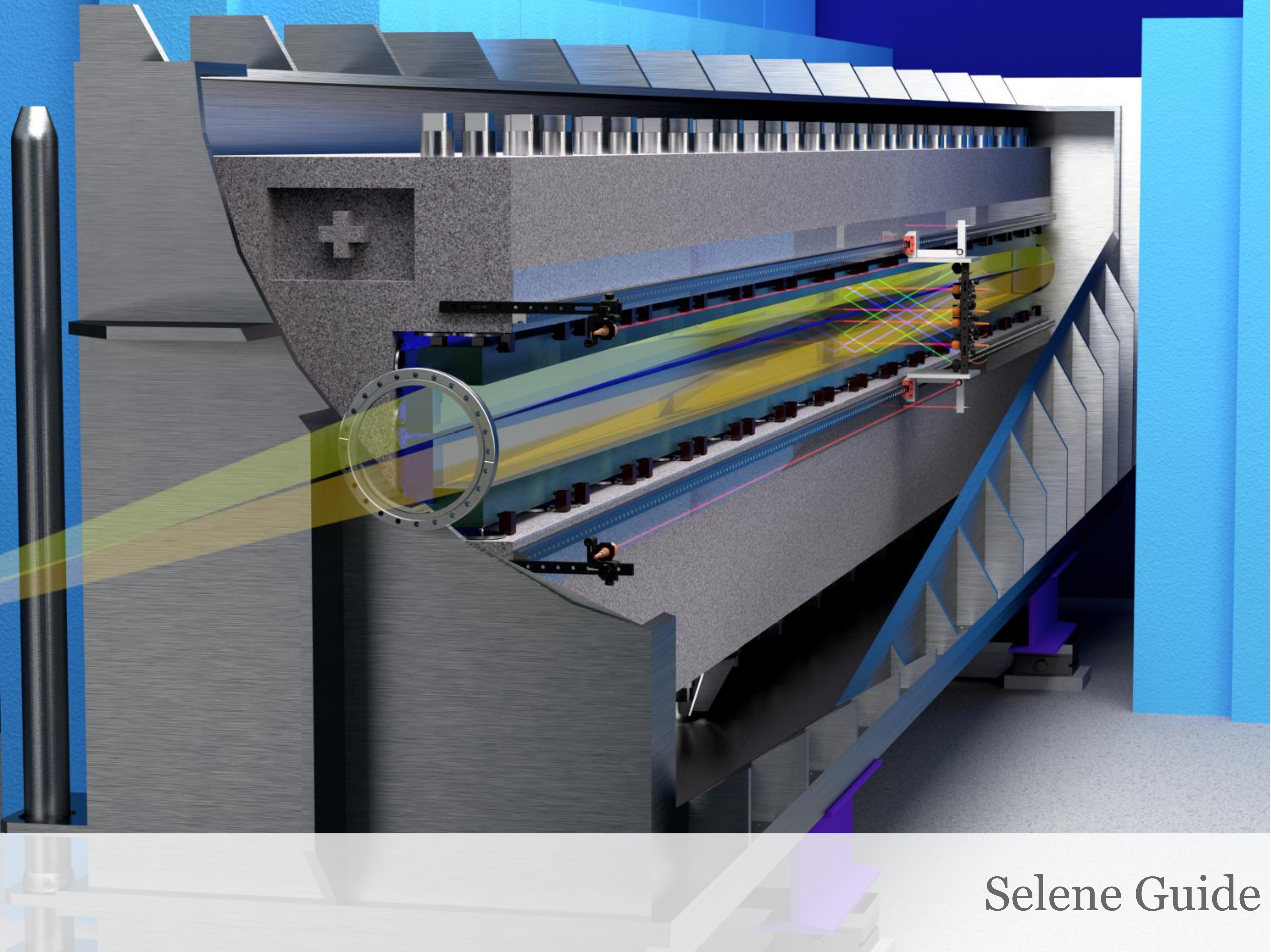
Chopper Pit

- Standard 14 Hz Chopper
- Shared vacuum
- Houses shielding and VS

Virtual Source (VS)

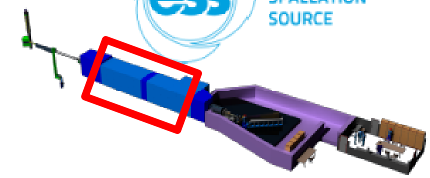


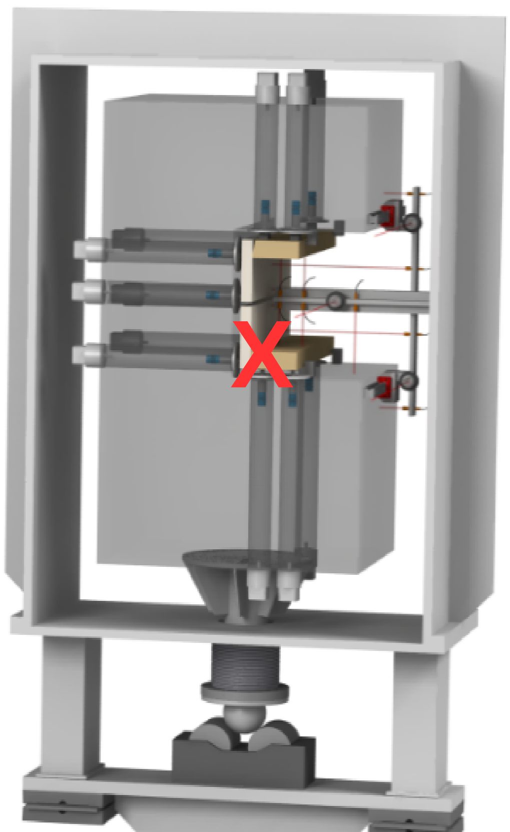


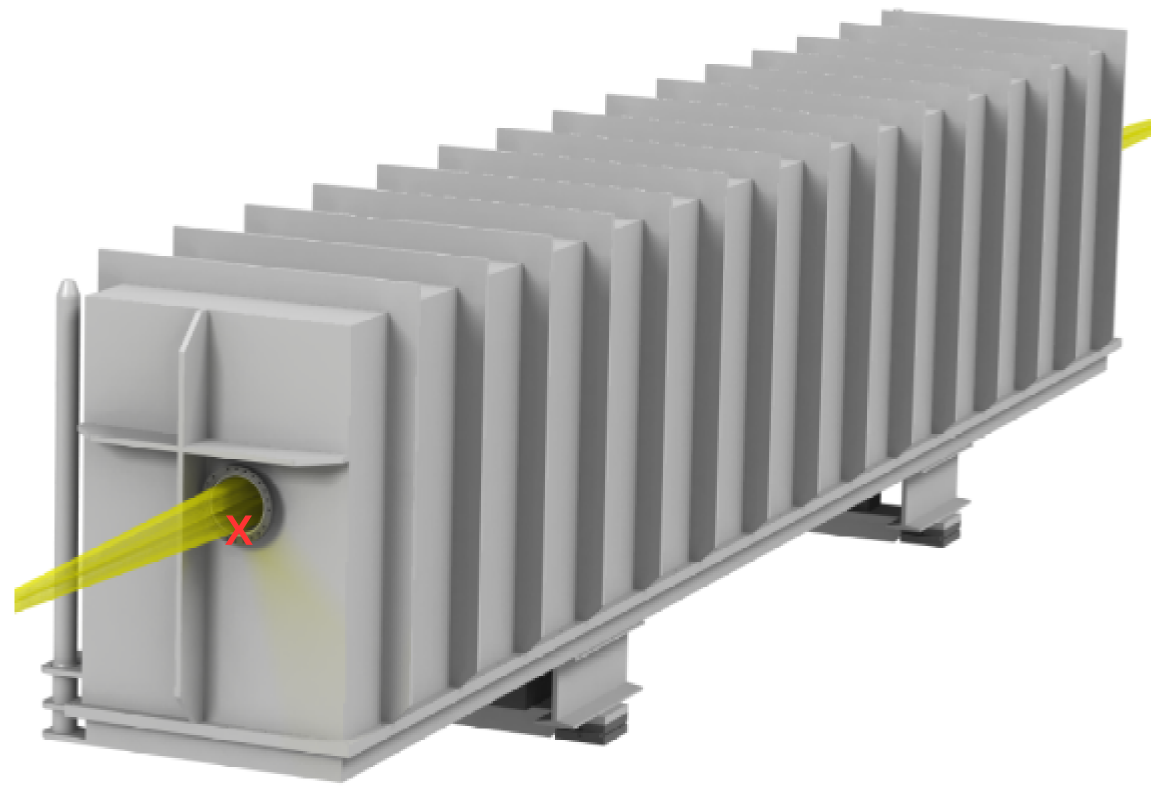


Selene Guide

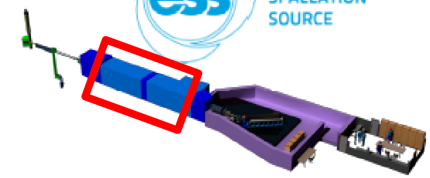
Selene Guide - Vacuum





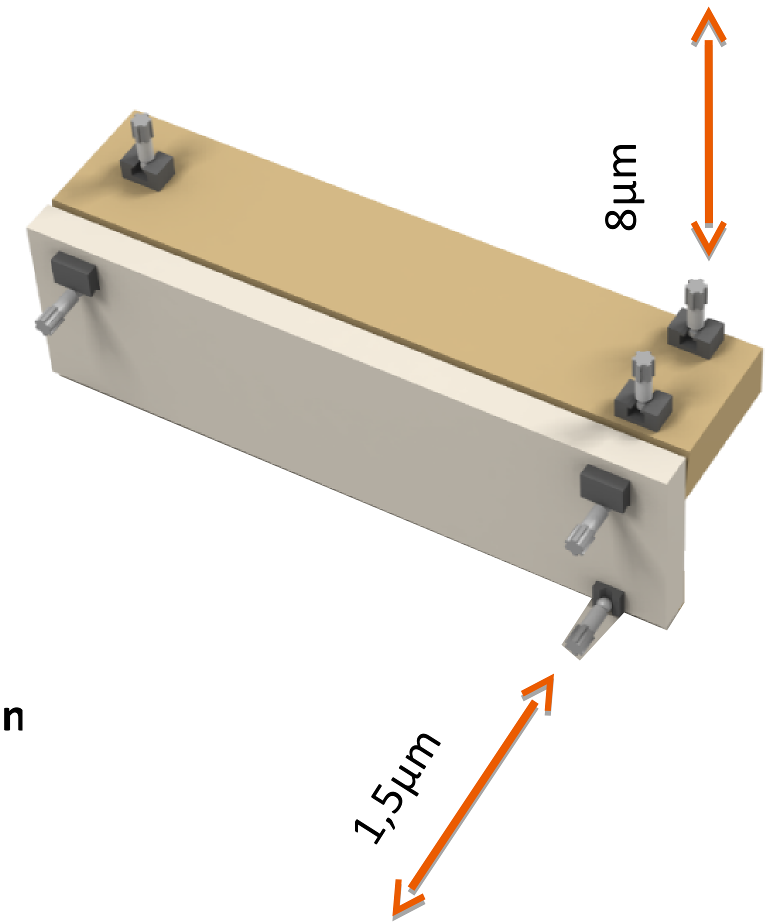


Actuator / Segment Alignment

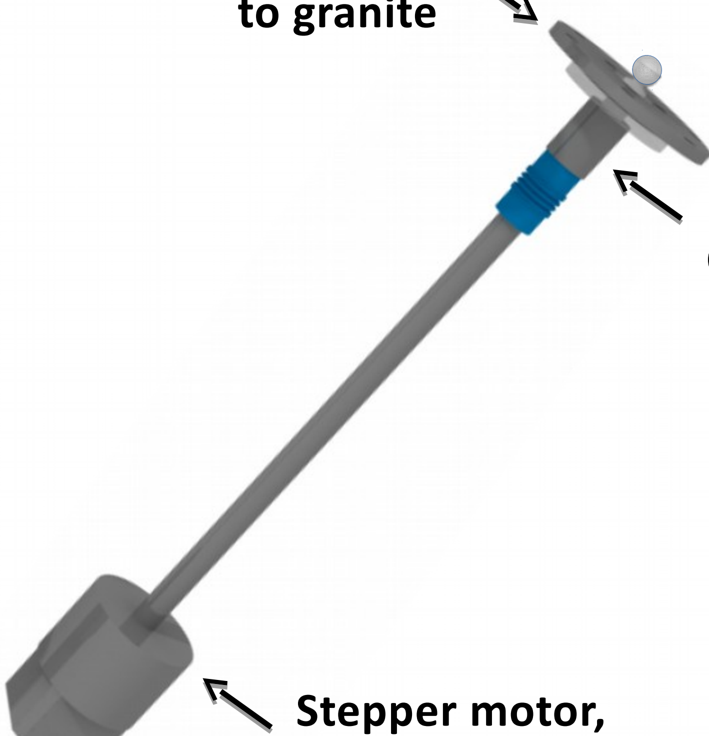


Requirements

- Self-retraining
- Radiation resistance
- Alignment in vacuum
- Price



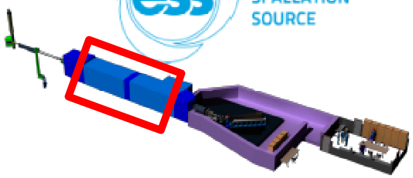
Flange attaches to granite

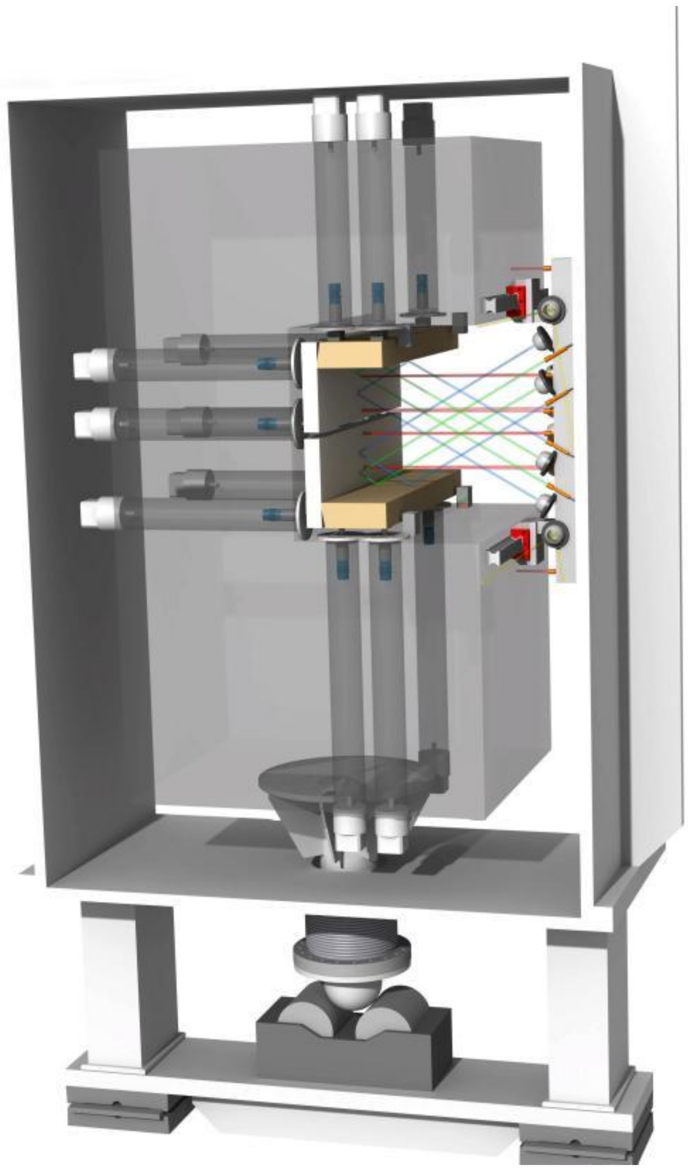


Length Compensation

Stepper motor, Gear

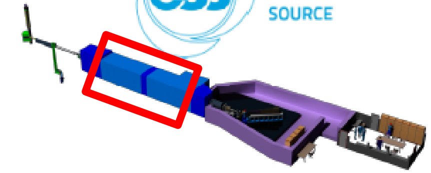
Selene Guide – Alignment System



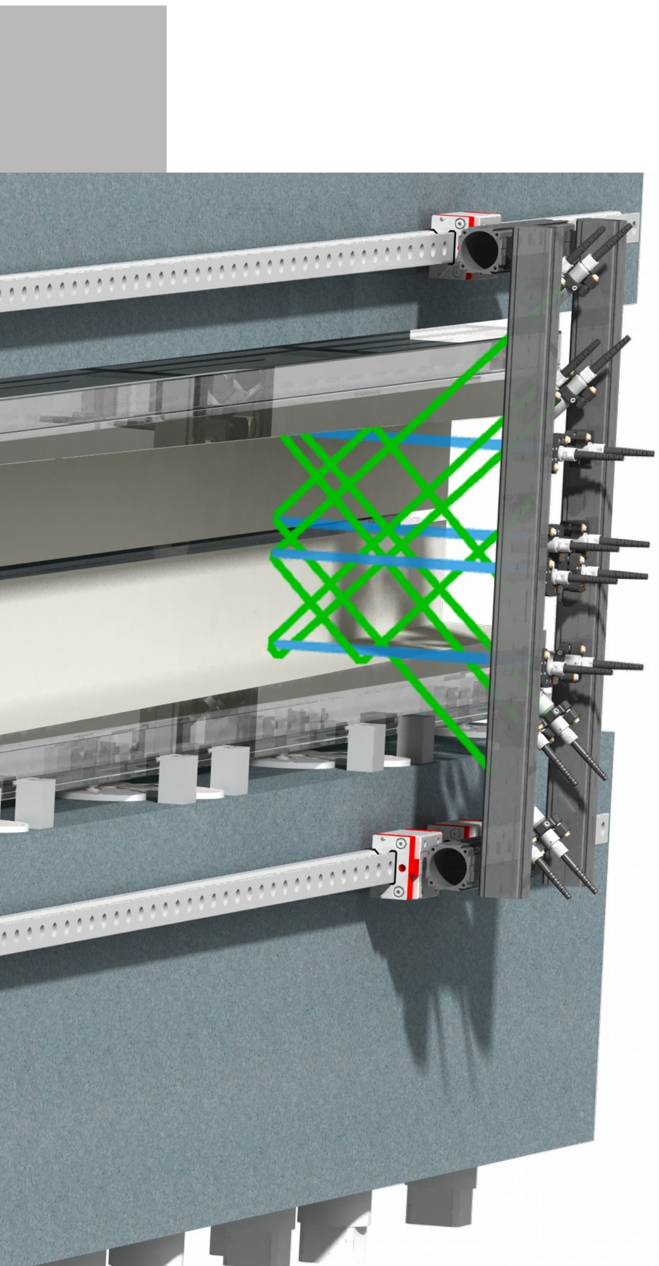


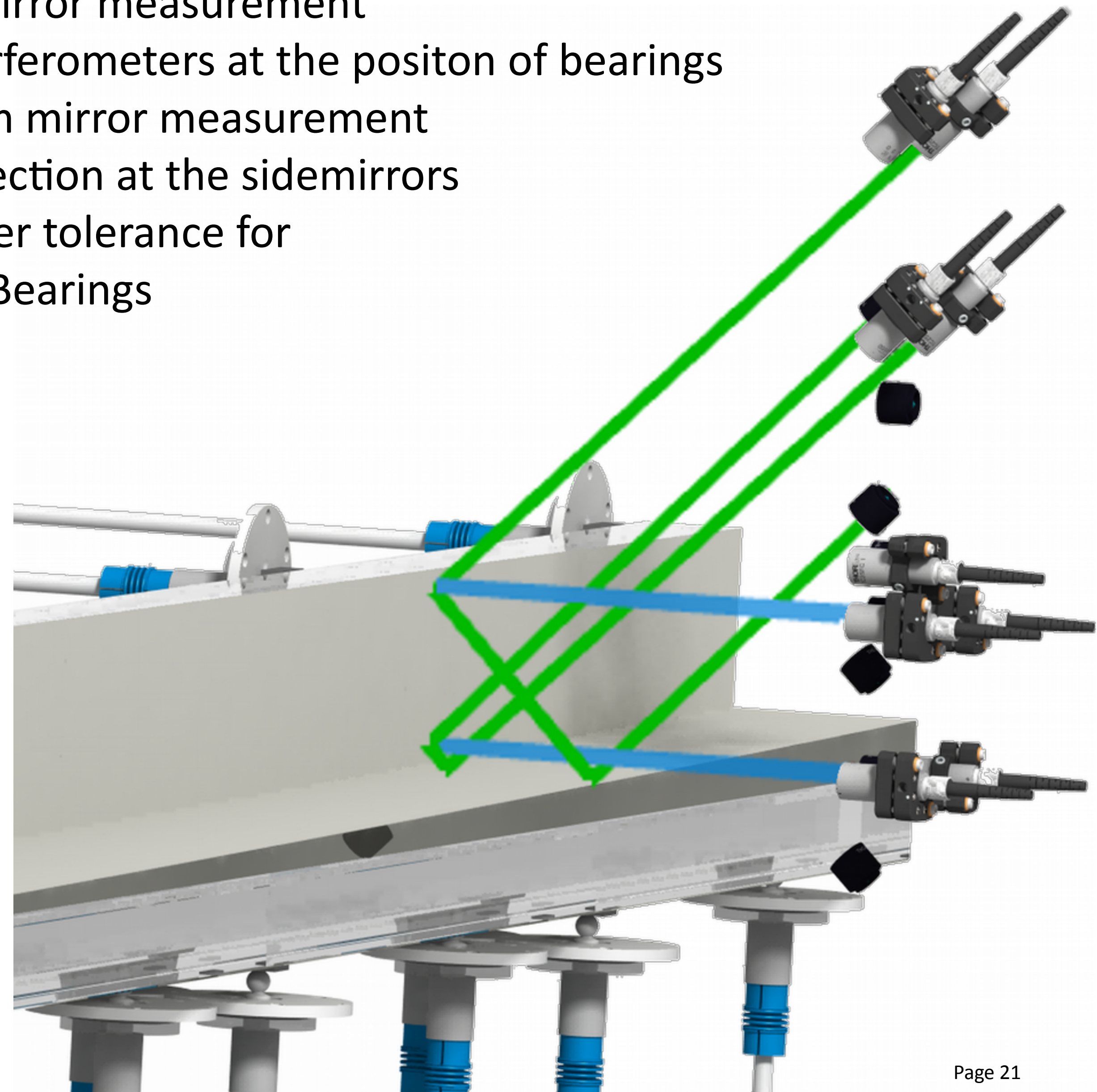
- Multi-fiber absolute distance interferometers
- One beam for each adjustable degree of freedom
- Simultaneous measurement with <1µm precision
- Reference to flat granite surface or reference laser

Selene Guide – Alignment System

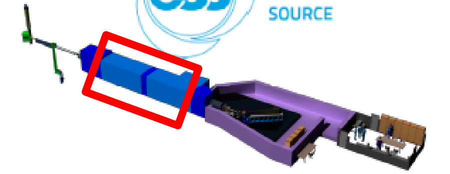


- Side mirror measurement
  - Interferometers at the positon of bearings
- Bottom mirror measurement
  - Reflection at the sidemirrors
  - Larger tolerance for the Bearings

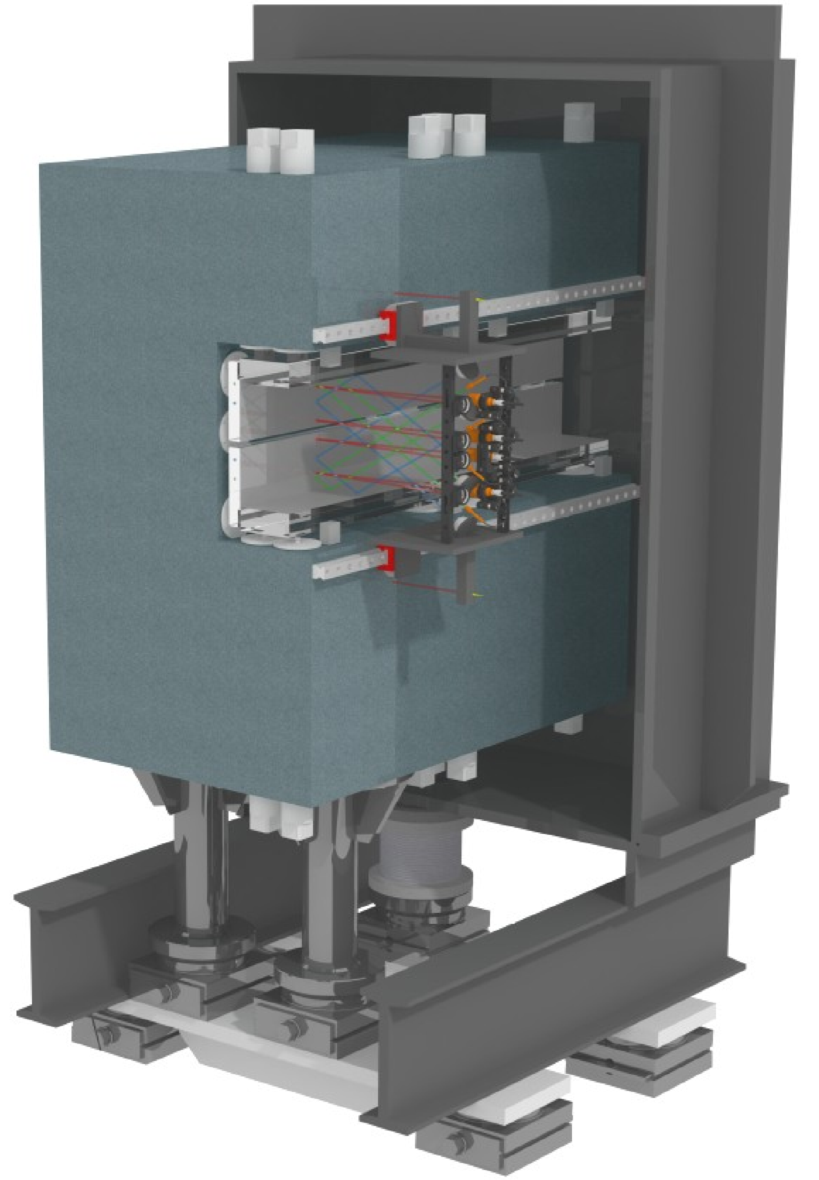




Selene Guide – R&D Project

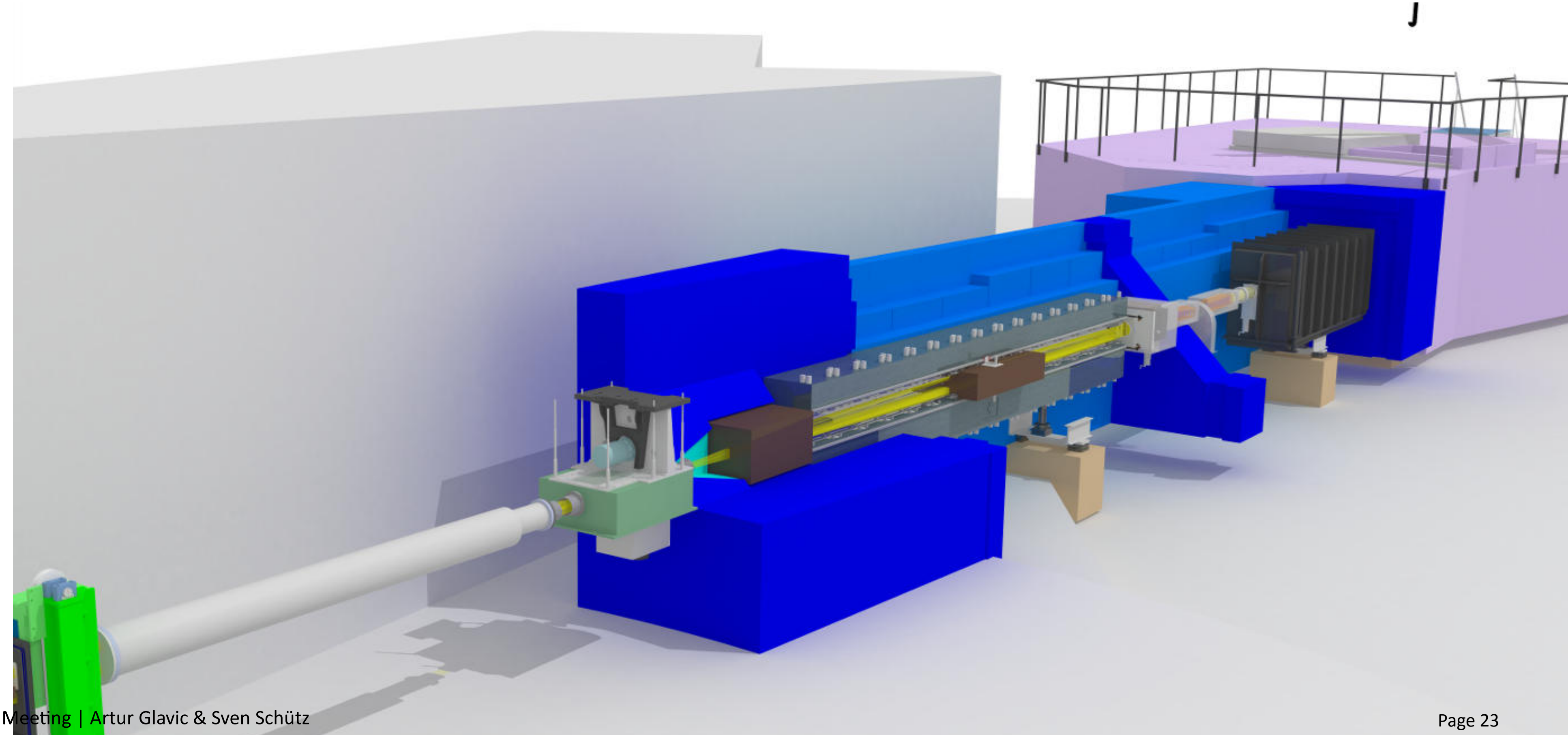


- Analysis of vacuum to the guide system
- Testing the metrology-cart segment measuring
- Testing the metrology cart positioning concept
- Comparing different actuator concepts
- Carrier Bearings
  - Structural integrity
  - Heat input analysis



Shielding Concept

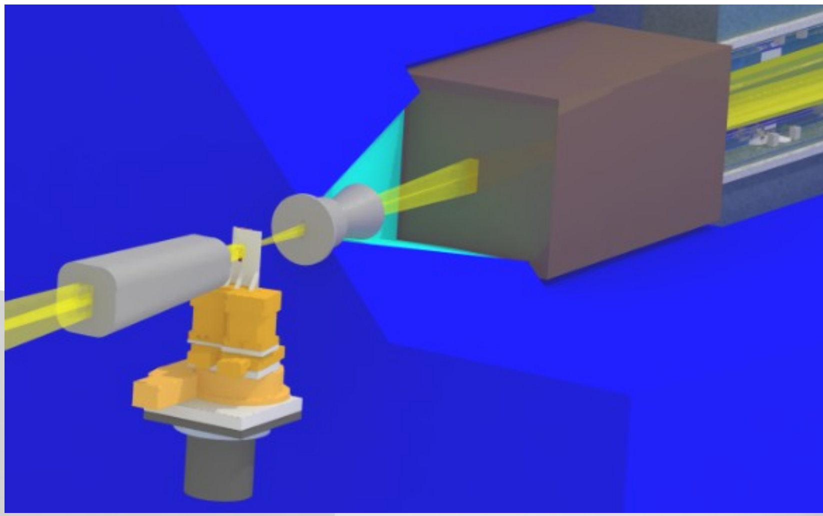
- In-Bunker Shielding
- Heavy Collimation
- Beamline Shielding
- Experimental Cave Shielding

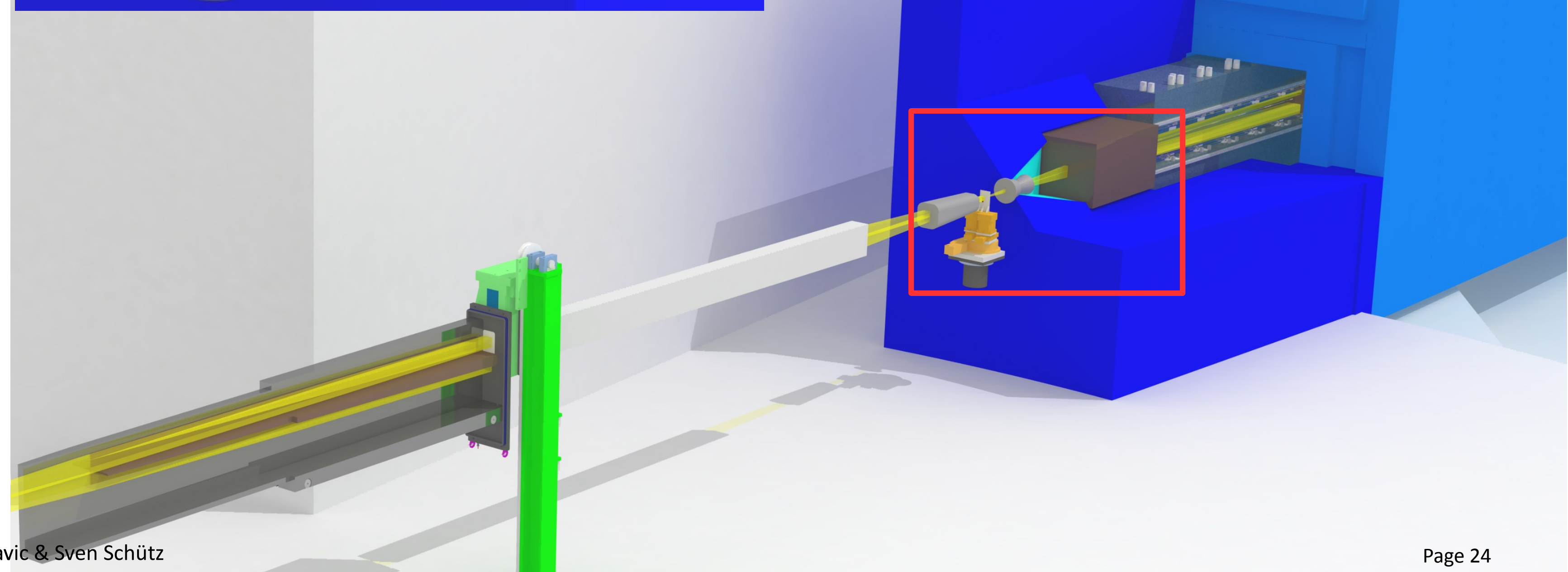


Neutron Guide Shielding (Heavy Collimation)

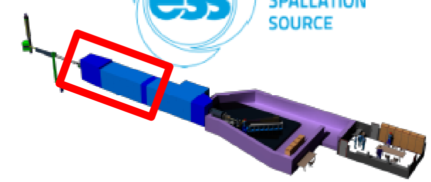
Virtual Source collimator

FeNi W Cu + x





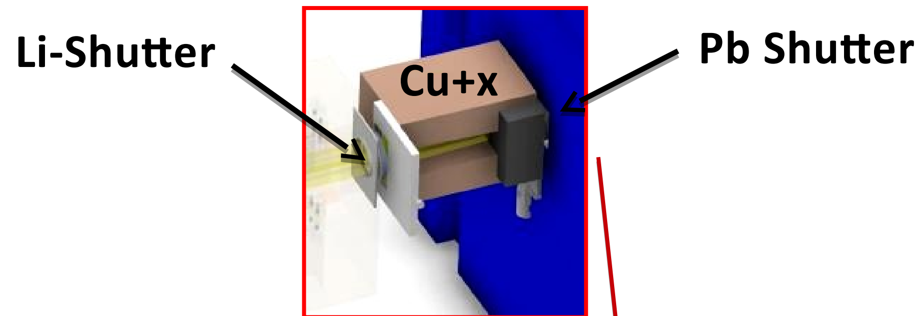
Neutron Guide Shielding (Heavy Collimation)

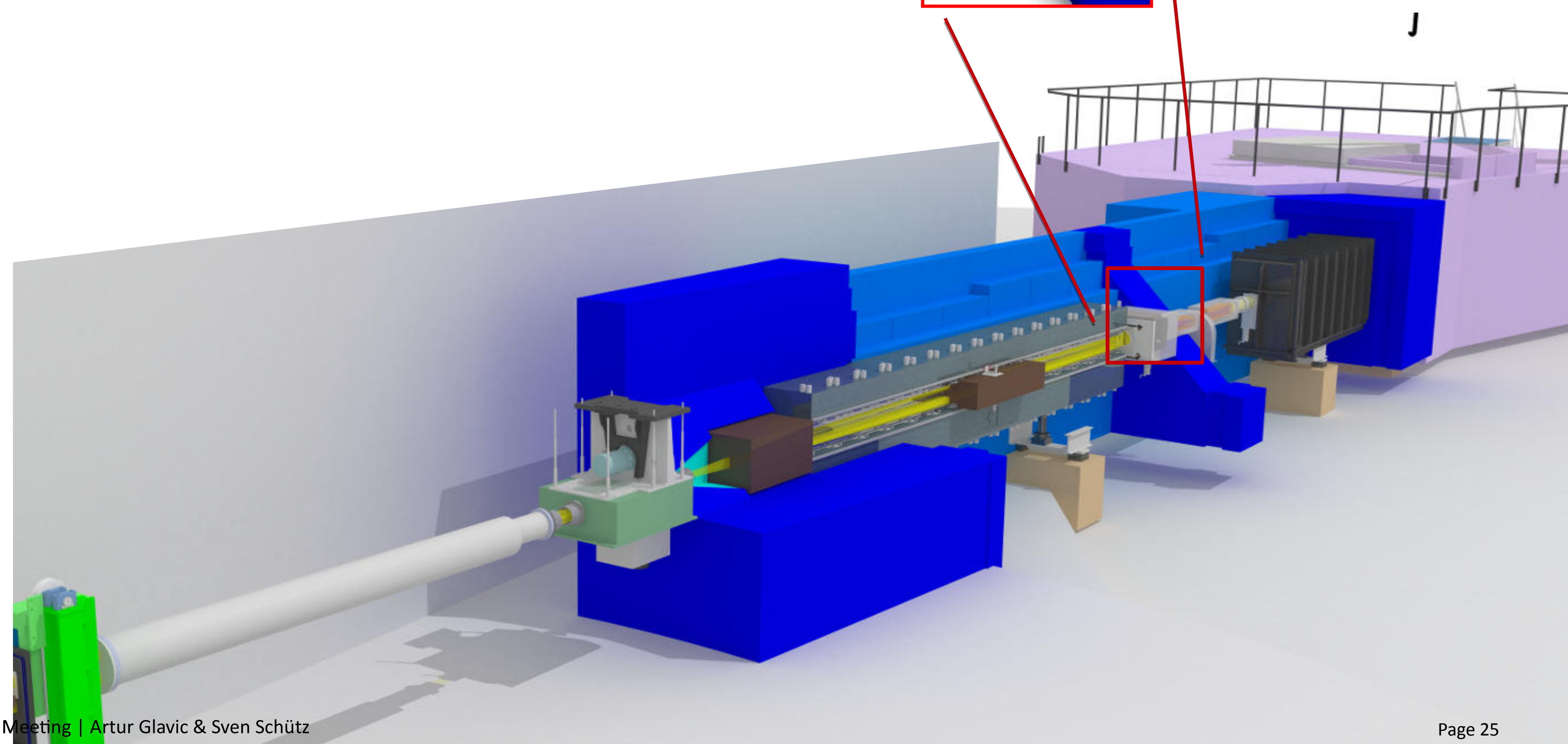


Selene 1

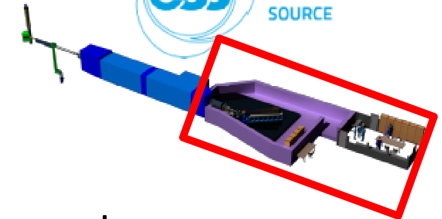
- Fast neutron collimation (Cu+X)
- Instrument Shutter
- No access when the beam is on

Instrument Shutter



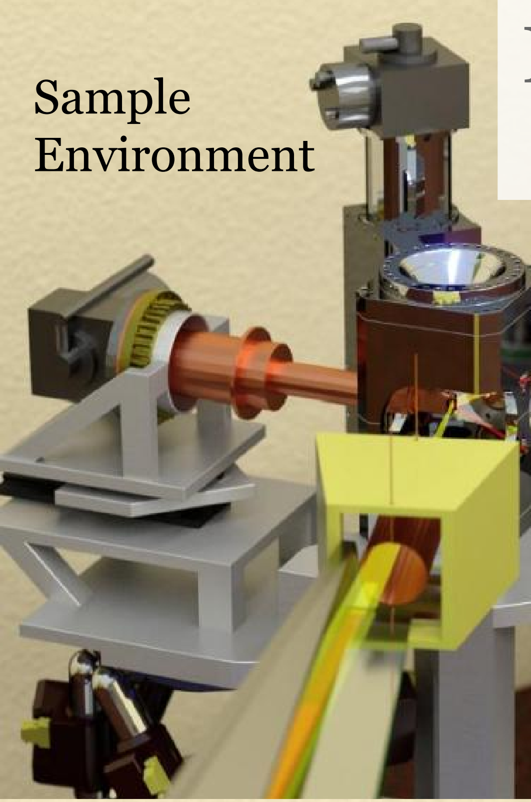


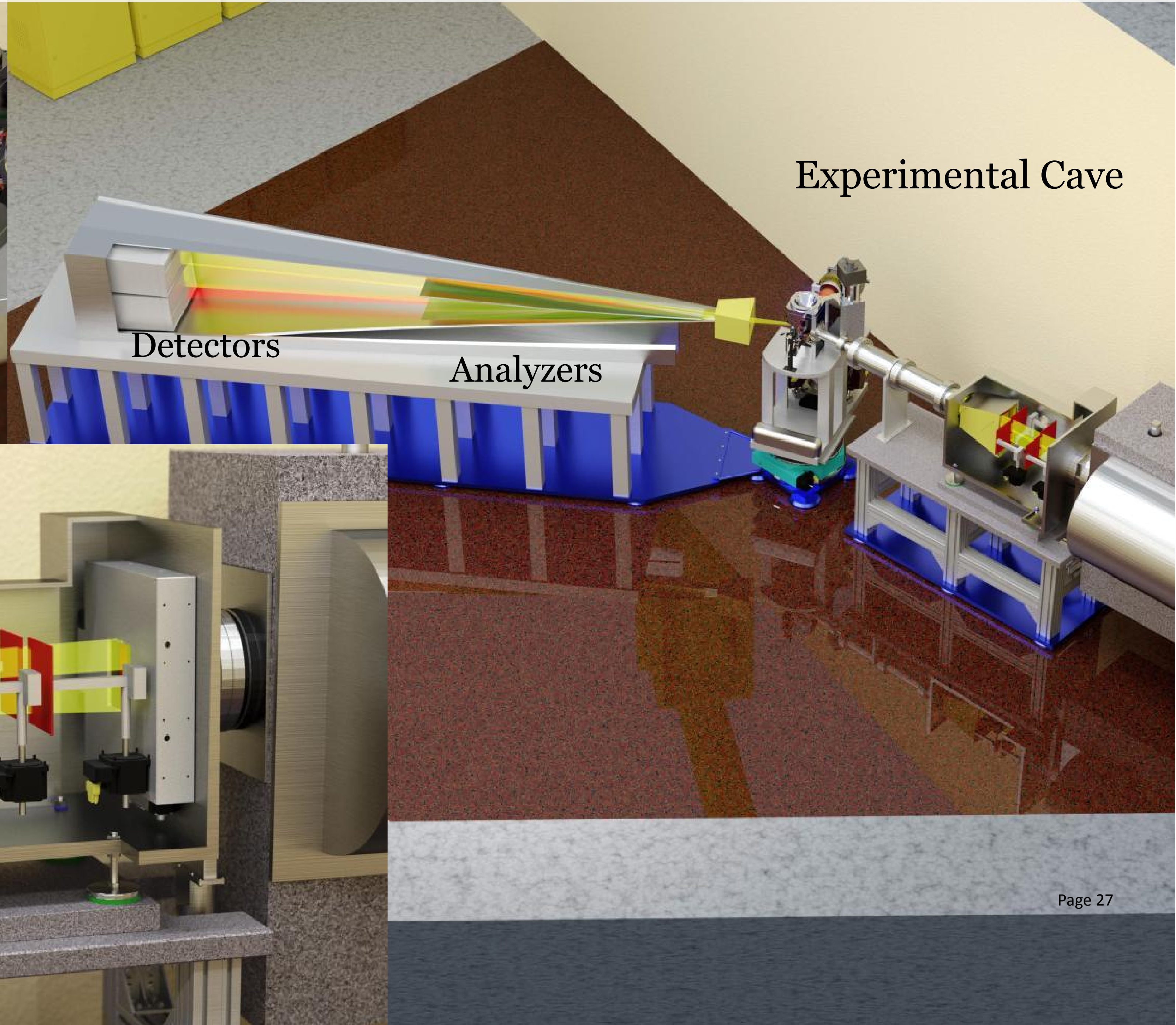
Cave Shielding and Control Hutch

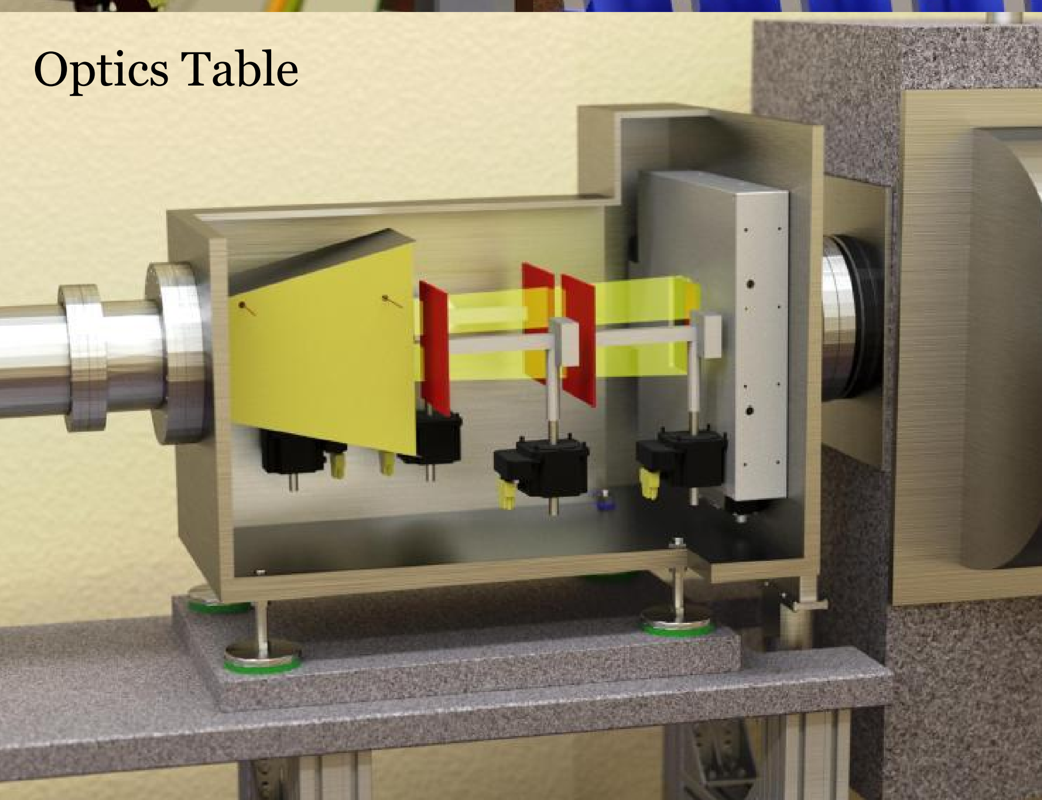


- Cave acts as biological and background suppression (skyshine, etc.) shielding
- Current design uses steel can with B-wax
- Rack access from within hutch
- Enough space for two experimental teams

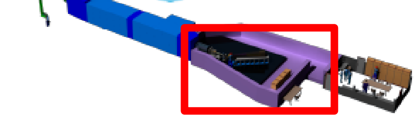
Preliminary Design II: Sample Environment, Detector and Polarization

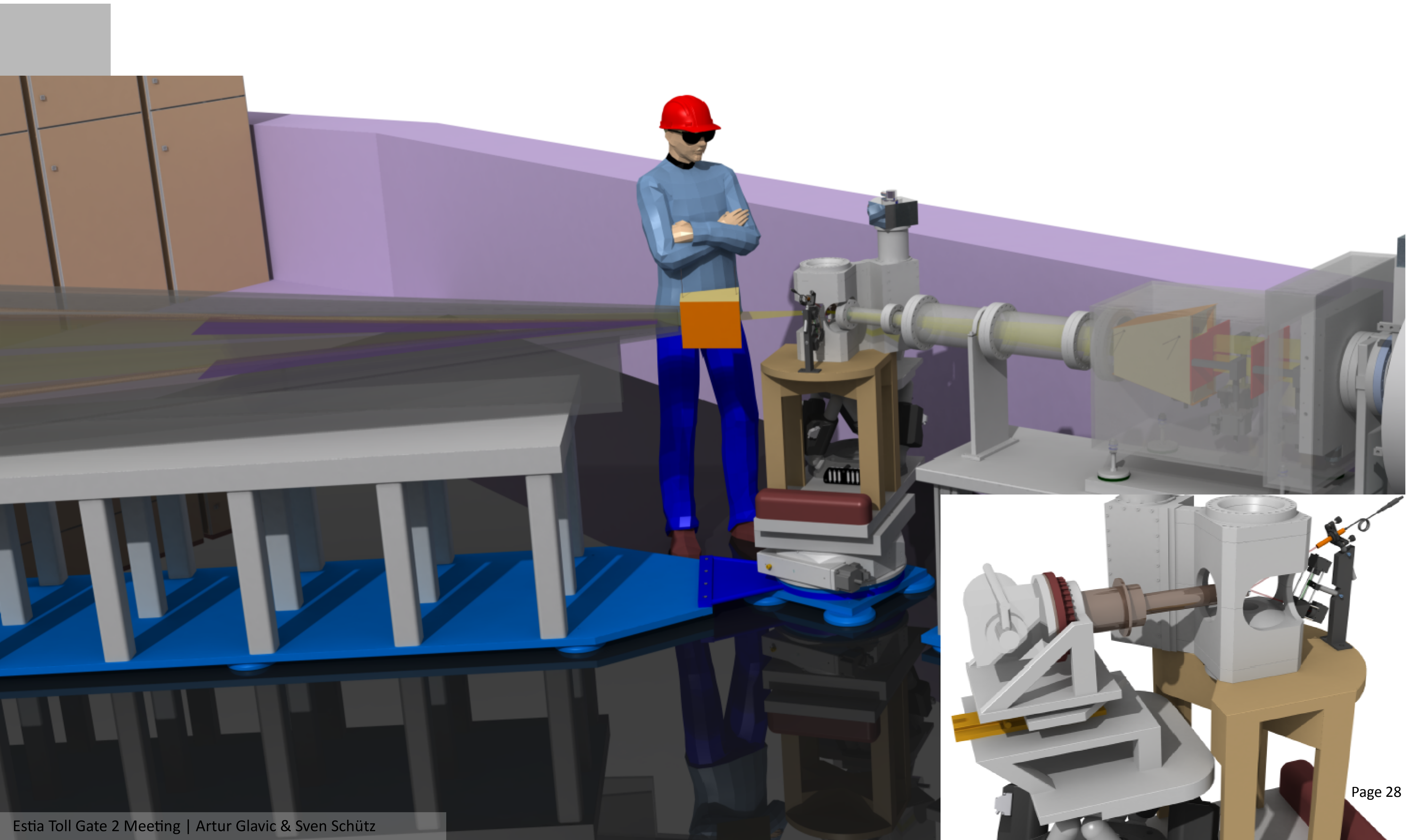






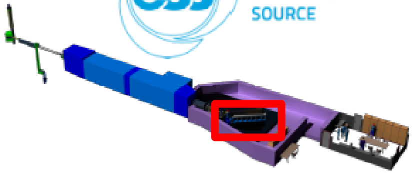
Overview Experimental Cave

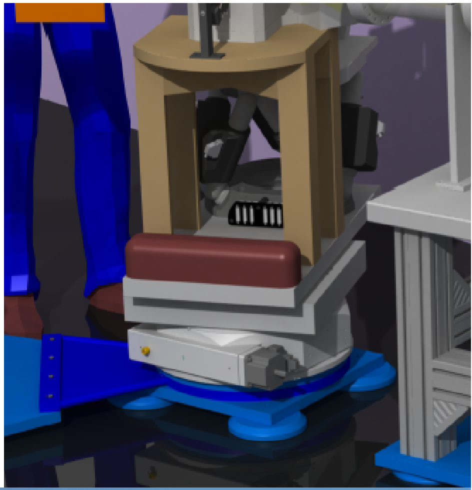


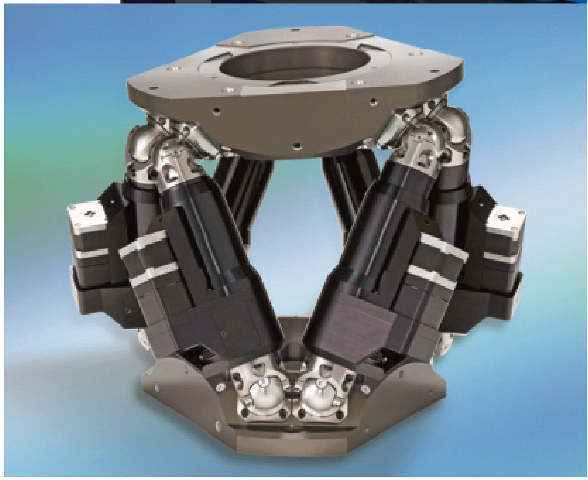


Sample and Detector Positioning

- All components on air pads for felxibility
- Alternative separate rotation arc for huge SE
- Fixed heavy weight omega stage
- Fixed magnet table
- Separate mechanical hexapod for sample



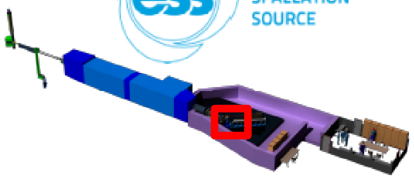




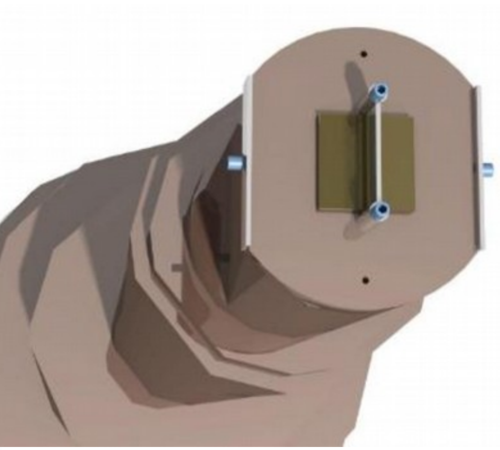
Newport Hexapod

Large user supplied sample environment

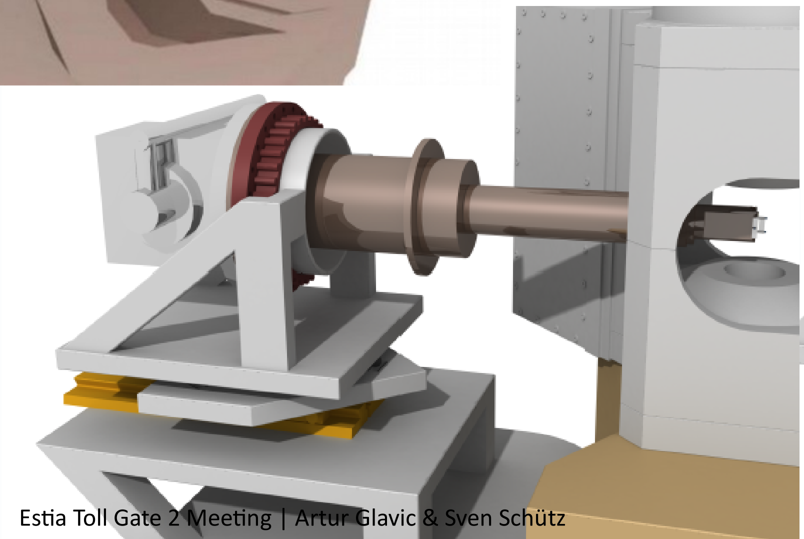
Hard Matter Specific SE

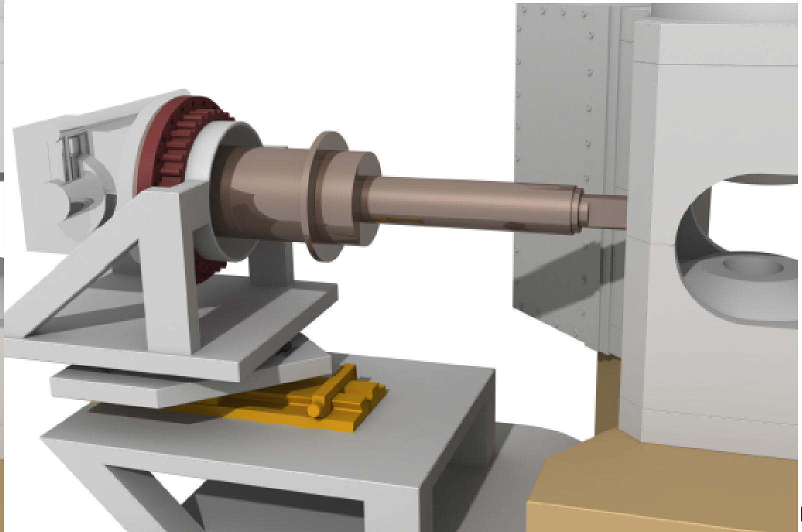


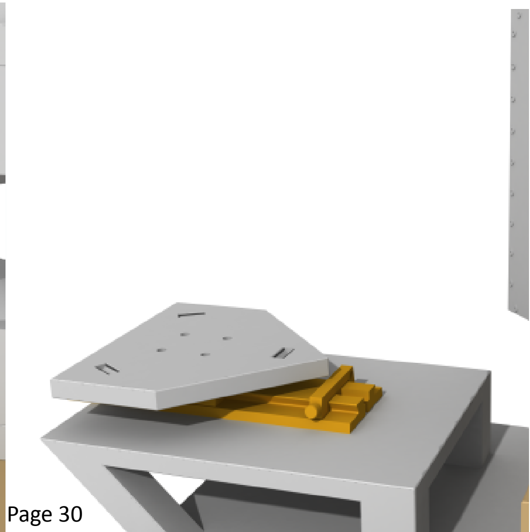
- “Pool” Electromagnet
- Small in-vacuum sample chamber
- Coldfinger with removable sample plate
- Low cost LHe flow system
- Light weight (~3 kg)
- ~15 min cool down from RT
- <3 K



Translation below kinematic mounting plate

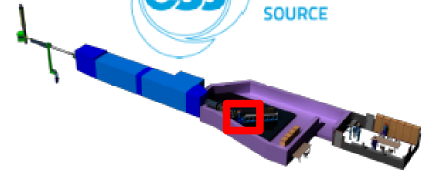


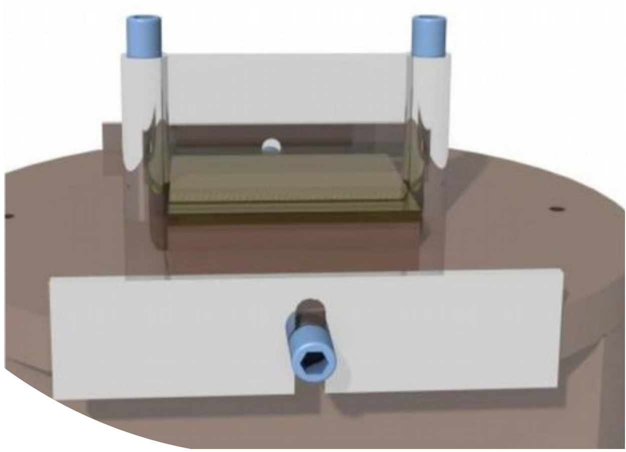


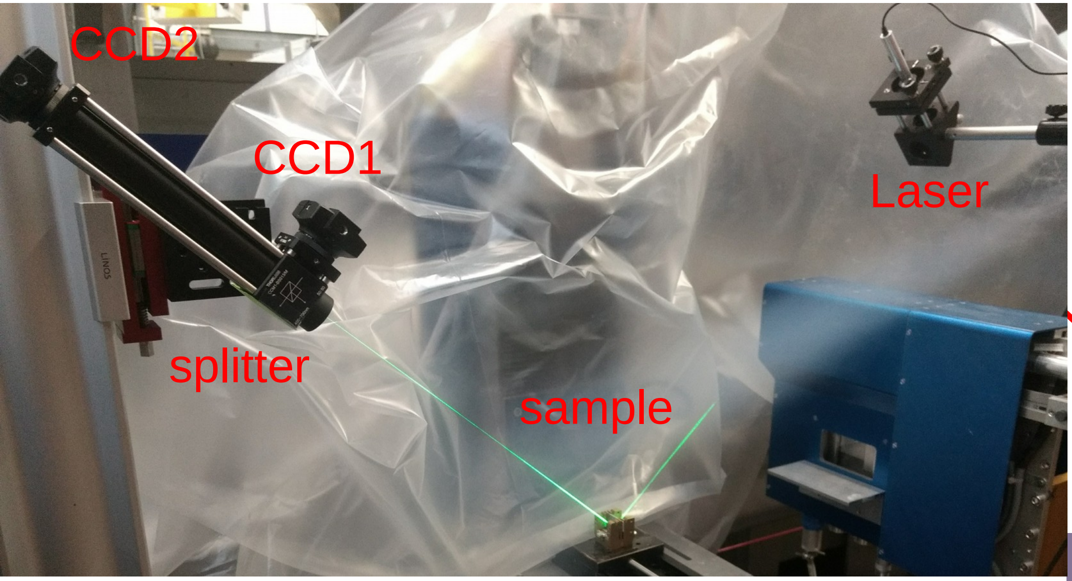


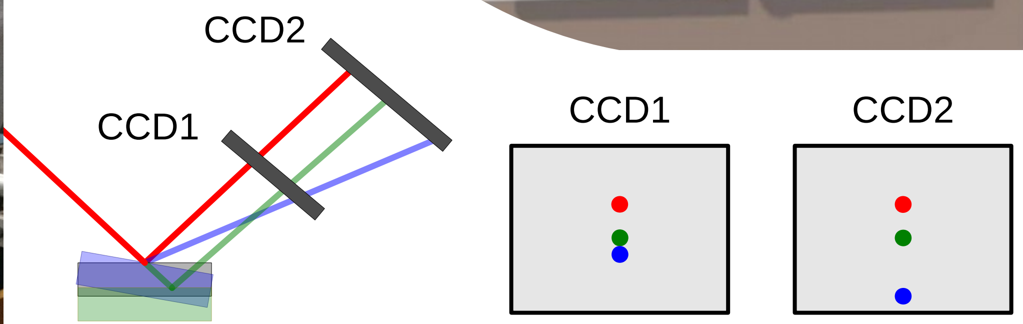
Fast change and BG management

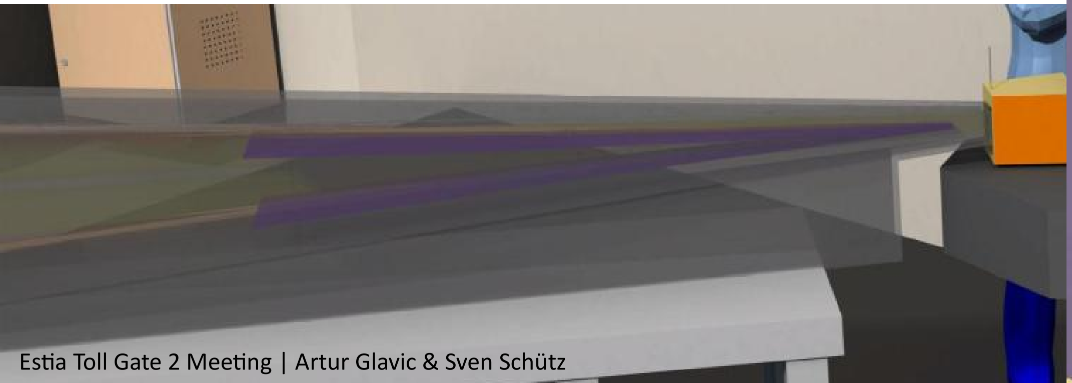
- Vacuum until Saphire window close to sample
- Exchangable holder, off-instrument mounting/alignment
- Absorber before, after and above sample
- Laser alignment system, RT sample chain-ger

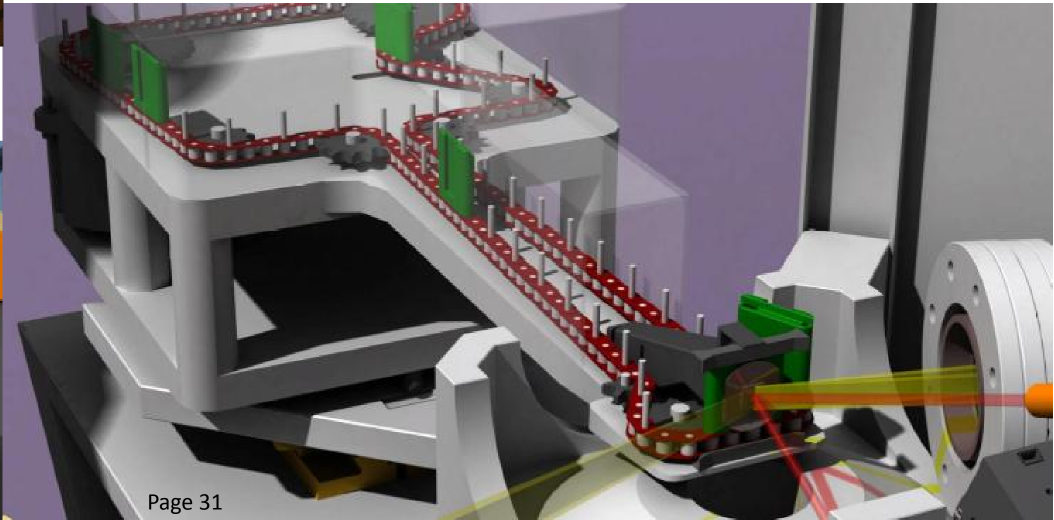






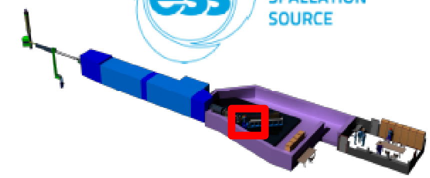






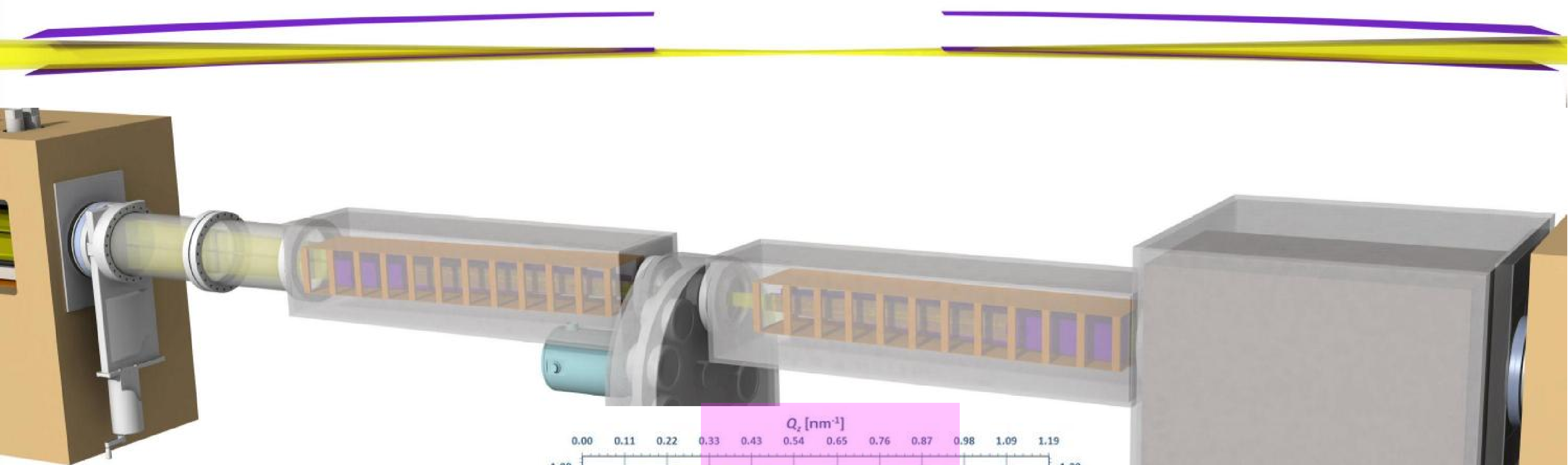
Soft Matter Specific SE

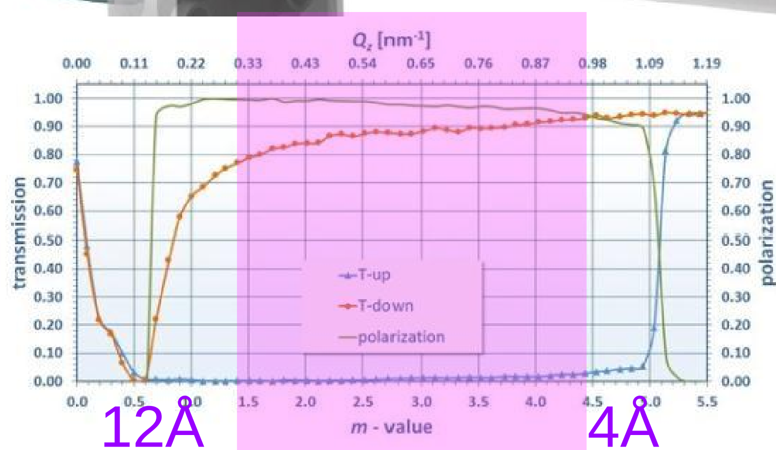
- Essential items to investigate liquid-solid interfaces
- Sample cell changer with suitable number of LS-cells
- Water bath to control temperatures (-20°C - +80°C)
- 4-channel HPLC pump
- Syringe pump



Polarization Components

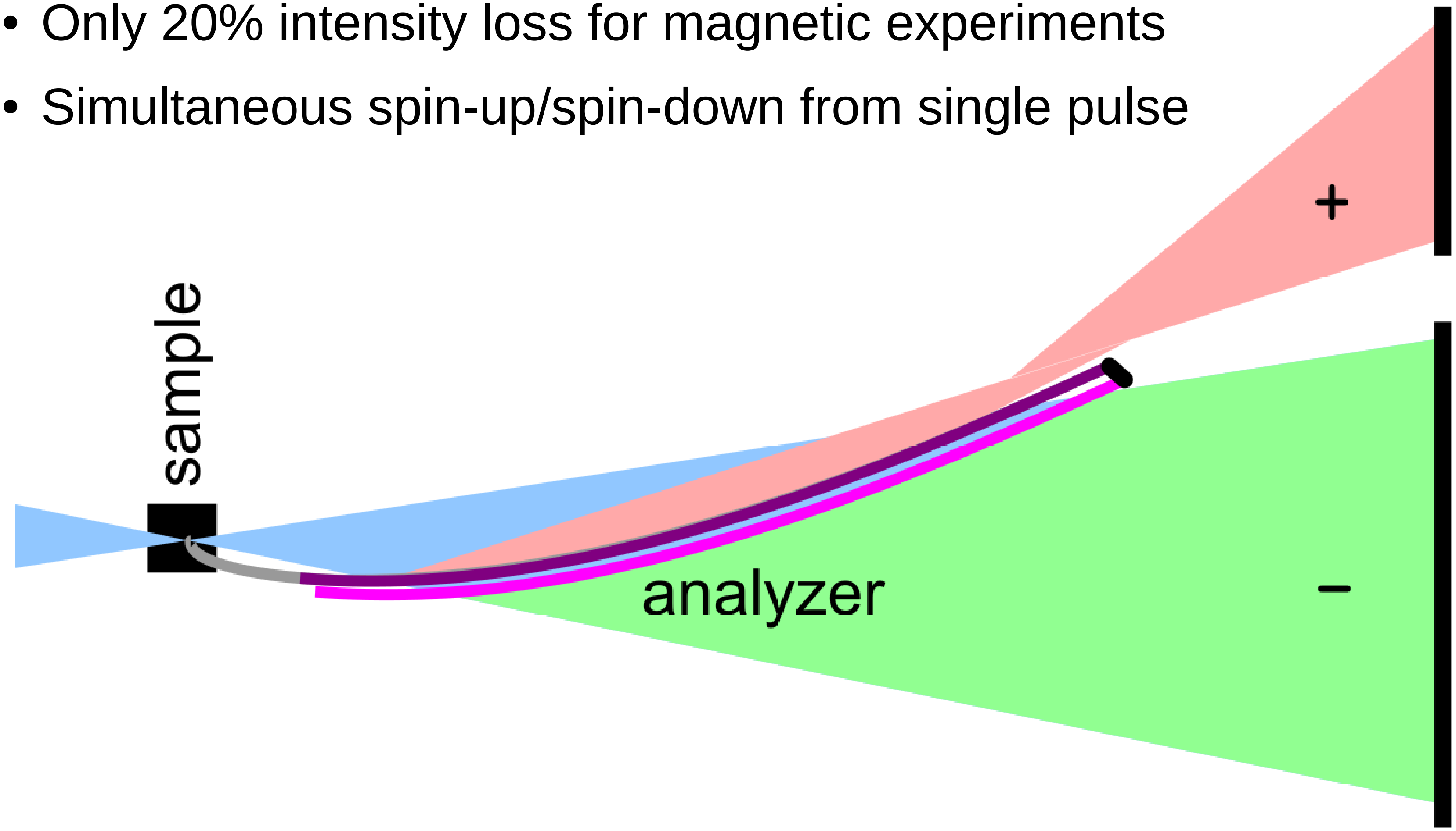
- Two mirrors to compensate refraction effects
- Expected P>99%, T_{down} ~ 60% (12Å) - 88% (4Å)



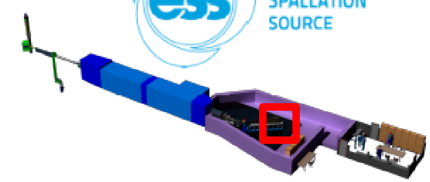


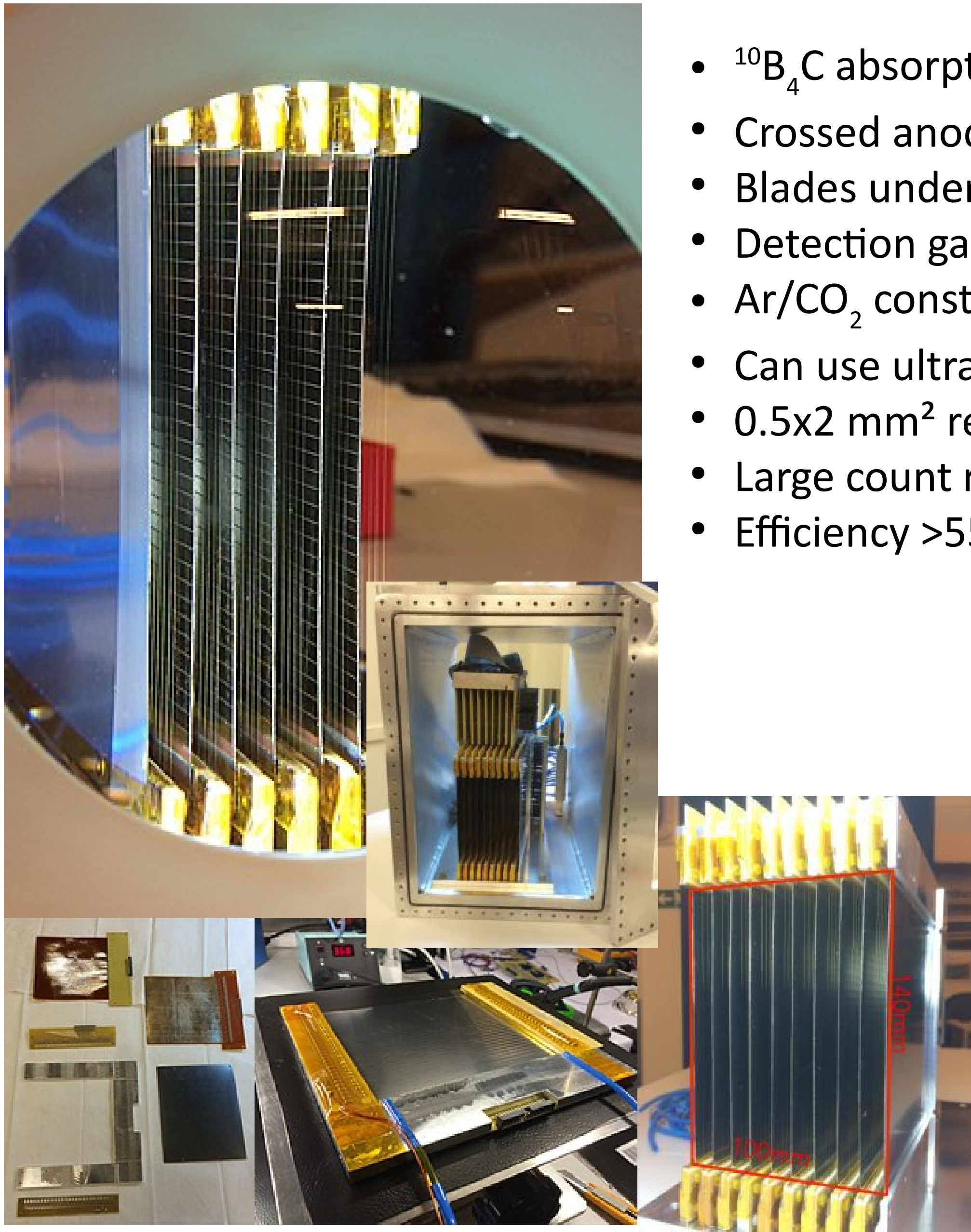
Polarization Components

- Two subsequent supermirrors
- Capture transmitted and reflected beam
- Split spin-up and spin-down on detector
- Half-polarized measurements with unpolarized beam
  - Only 20% intensity loss for magnetic experiments
  - Simultaneous spin-up/spin-down from single pulse

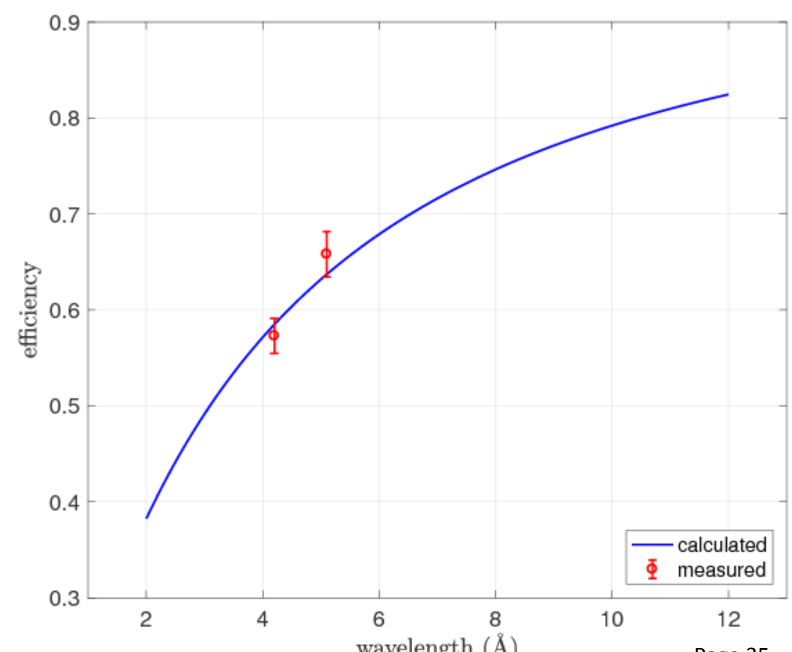


Multi-blade detector



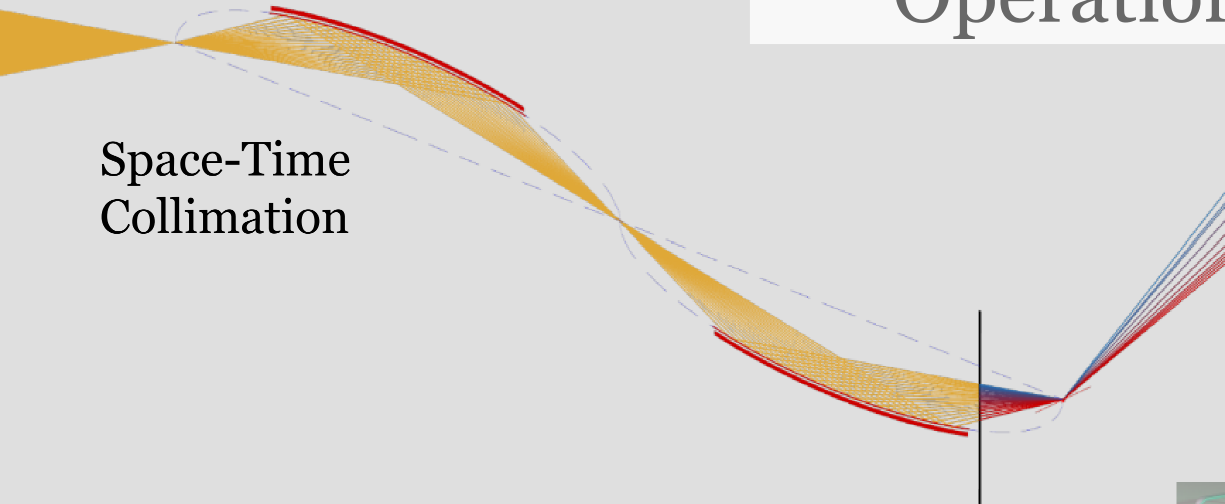


- $^{10}B_4C$ absorption layer
- Crossed anode wires and cathode strips
- Blades under 5° angle
- Detection gas under ambient pressure
- Ar/CO_2 constantly flushed at 1 atm.
- Can use ultra-thin entrance window
- 0.5x2 mm² resolution
- Large count rate >100kHz/mm²
- Efficiency >55%@4Å

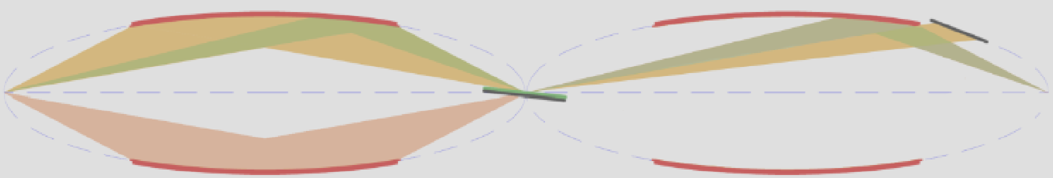


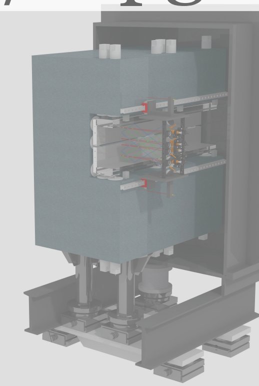
Operations & Staging / Upgrades

Space-Time Collimation

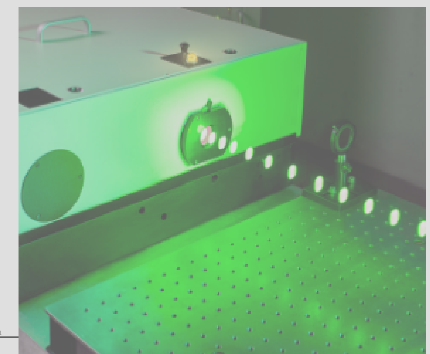


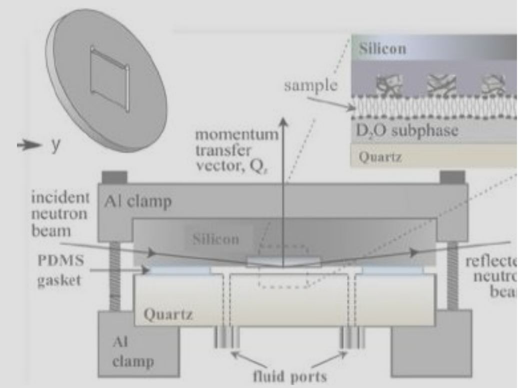
Ultra-Focus Option

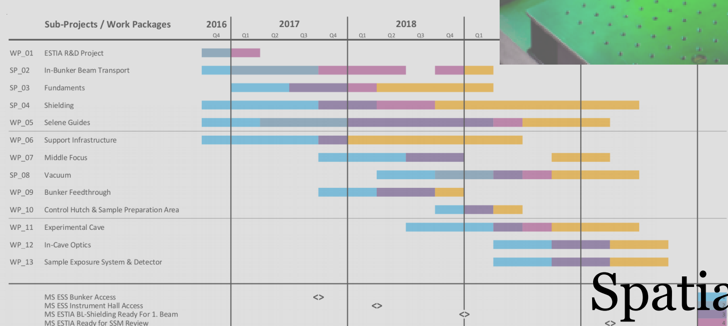




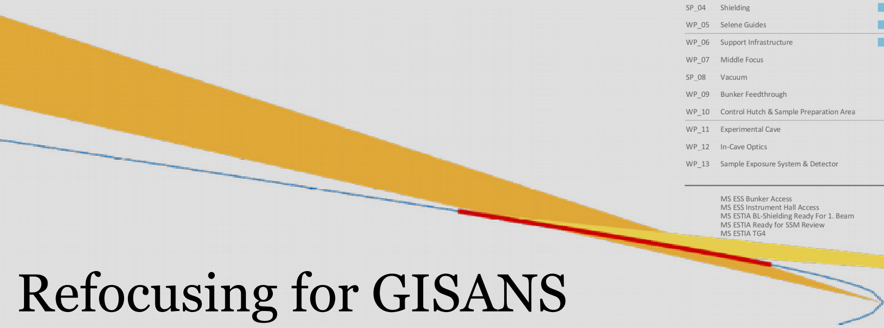
Sample Environment



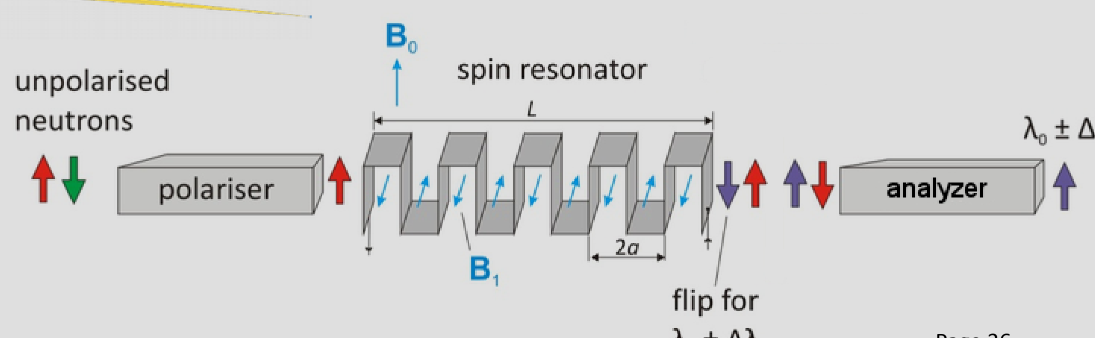




Spatial-Spin-Resonance Flipper



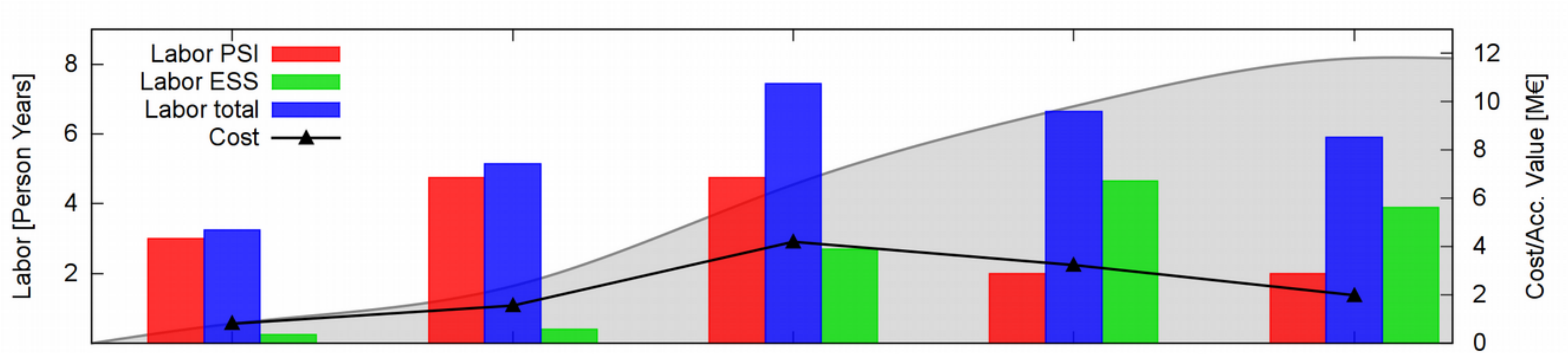
Refocusing for GISANS

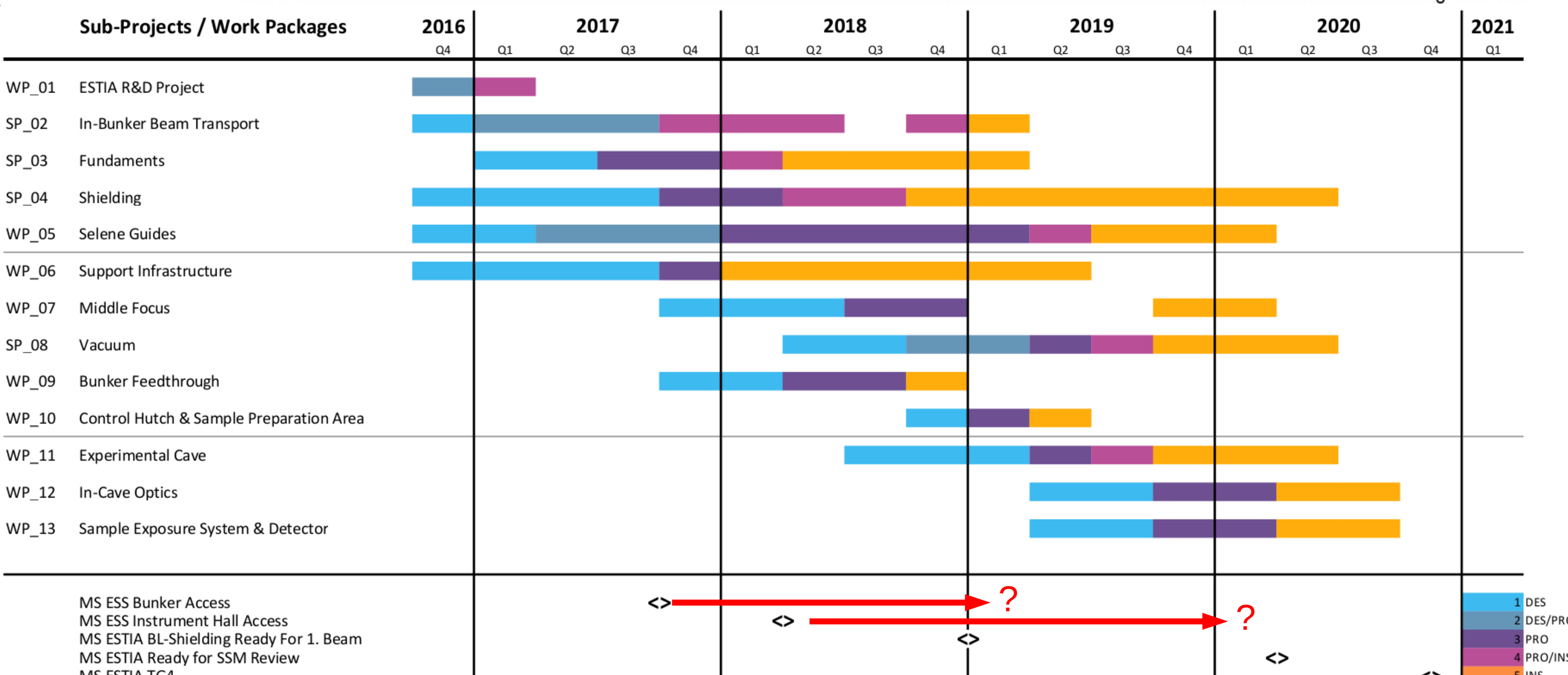


Estia Costing (Cost Book Value)

	PBS Item	Cost [k€] Labor	Non-Labor	Total	Work Units [person-years] 02 P. Management	03 Design	04 Construction	05 Installation	06 Commissioning	Total Work
1	Beam Transport and Conditioning System	1 668.5	4 752.0	6 420.5	0.970	4.580	3.080	3.390	2.010	14.030
2	Sample Exposure System	218.6	372.4	591.0	0.110	0.640	0.390	0.290	0.340	1.780
3	Scattering Characterization System	183.4	521.0	704.4	0.200	0.460	0.400	0.360	0.220	1.650
5	Experimental Cave	287.4	665.0	952.4	0.190	0.800	0.180	1.200	0.090	2.450
6	Control Hutch	36.5	71.0	107.5	0.070	0.040	0.070	0.180	0.010	0.370
7	Sampe Preparation Area	15.1	11.2	26.3	0.020	0.030	0.000	0.110	0.000	0.160
8	Utilities Distribution	5.6	28.0	33.6	0.020	0.030	0.000	0.000	0.000	0.050
9	Support Infrastructure	65.5	180.0	245.5	0.030	0.190	0.000	0.290	0.130	0.640
10	Control Racks	421.6	146.3	567.9	0.220	1.160	0.090	1.940	0.610	4.020
	Travel	81.0	0.0	81.0						
	R&D Selene Guide	150.5	209.5	360.0						
	Phase 1	480.0	50.0	530.0						3.250
	Contingency			1 180.0						
	Sum	3 613.7	7 006.4	11 800.0	1.830	7.958	4.205	7.754	3.412	28.408

Work Package Staging and Labor

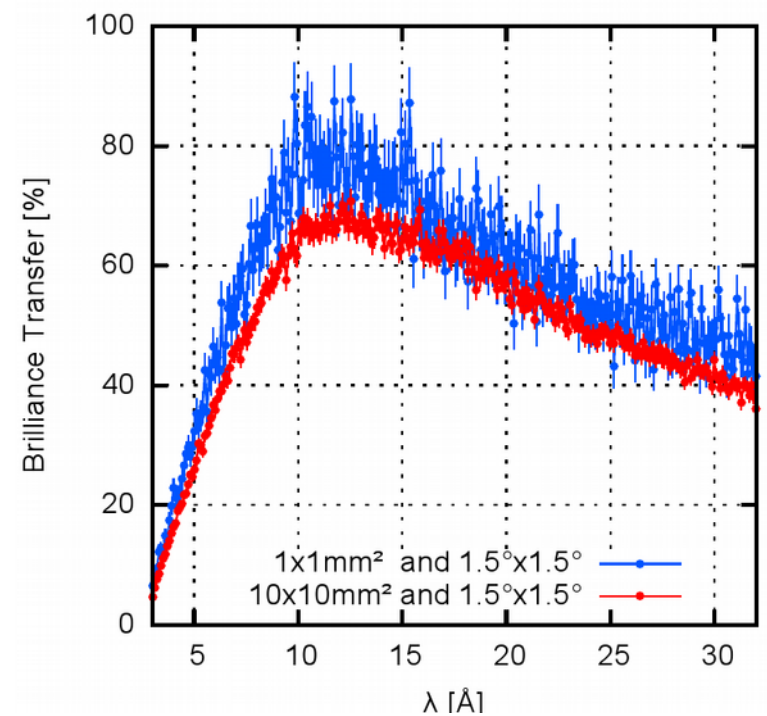


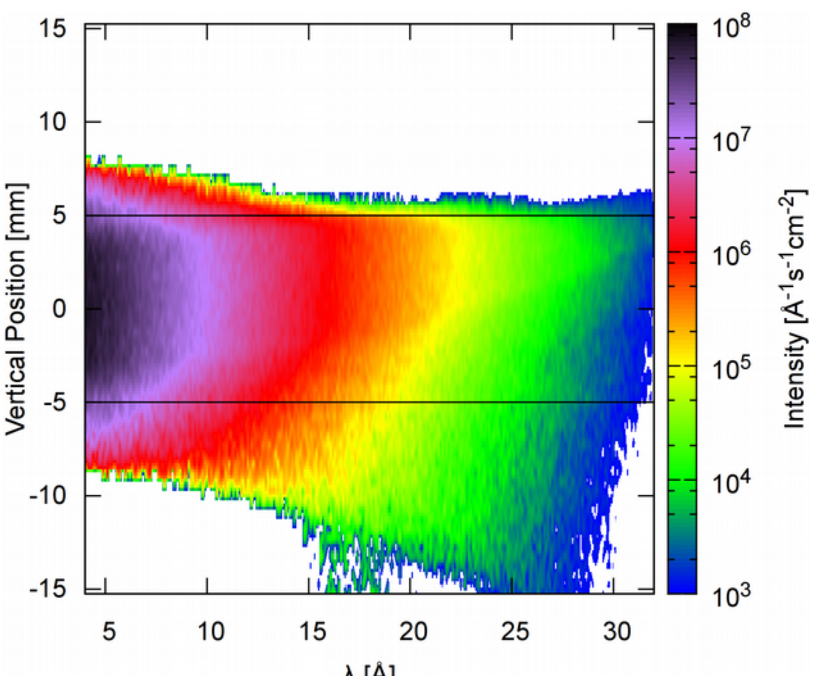


Expected Performance (2 MW)

SM m-value limited transmission performance:

- Imaging of Selene
  => good transport of usable neutrons
- Most unused neutrons rejected at virtual source within the bunker





Full control over beam foot-print and divergence:

- Large fraction of neutrons in the cave are actually used (improved signal/noise)
- Resolution can be optimized between σ=7% and <2%, independent of sample size
- Select specific sample area down to ~3x1 mm²

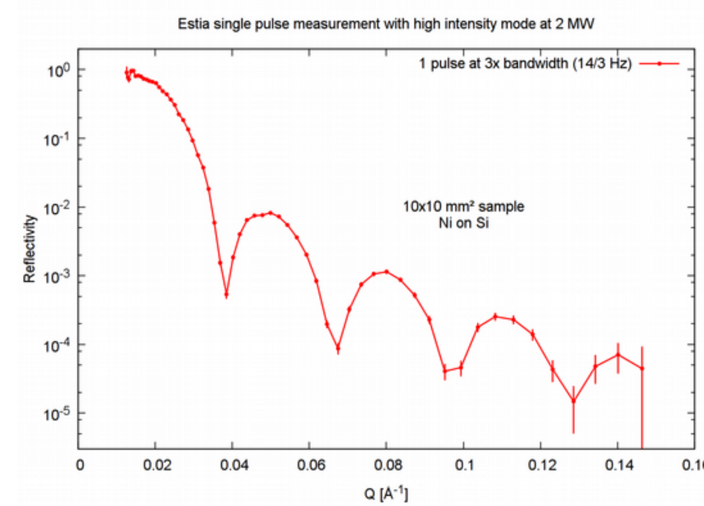
Expected Performance (2 MW)

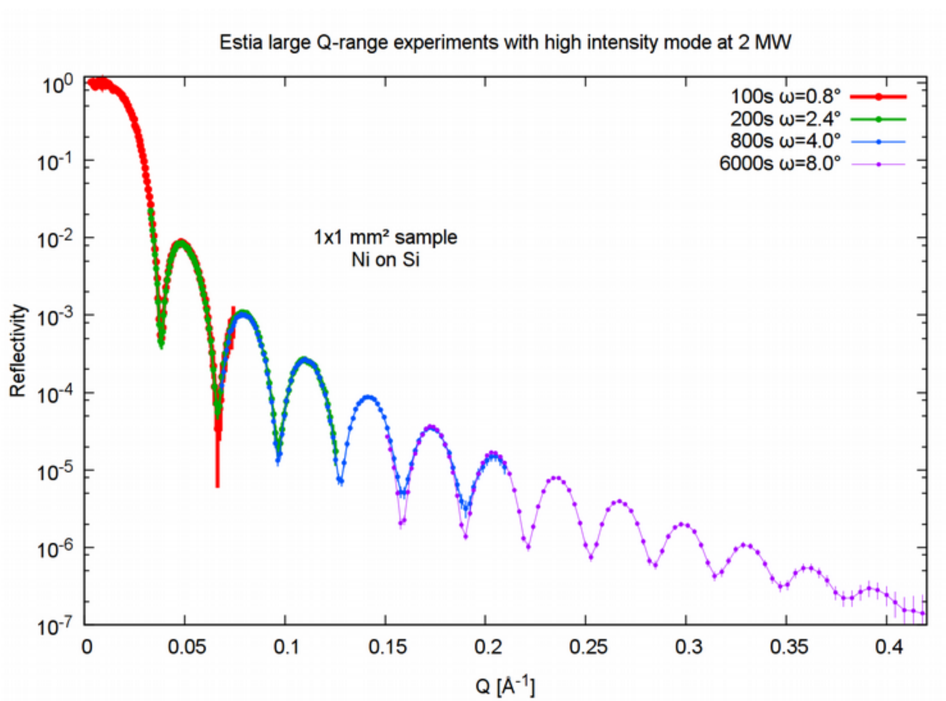
Fast measurements on standard samples (10x10mm²)

Typical Q-range experiment in a single pulse

=>

- Unprecedented time resolution (0.2 s)
- Map parameter space with dense coverage (e.g. 4-300 K in steps of 0.1 K performed in <1h)
- No need to move any motor during experiment





Large Q coverage on tiny samples (1x1 mm²)

Experimental times comparable with current instrument on large samples (2-12 h)

=>

- Investigate selected sample surface regions
- Attract users from different community as no new samples have to be grown (e.g. microscopy samples of <5x5 mm² size)
- Inhomogeneous systems
- Devices in operation w/ e.g. electric contacts

Instrument Operation Planning

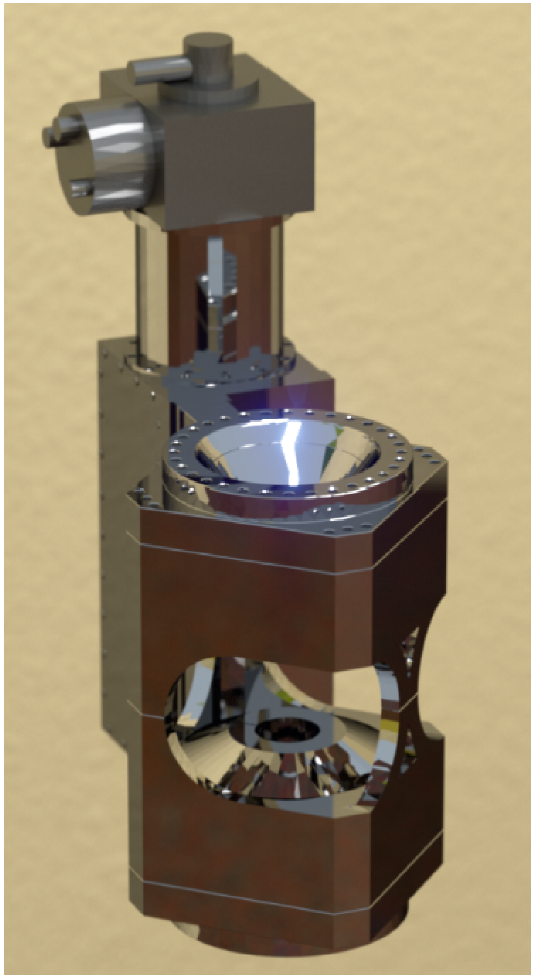
- Allows fast experiments =>
  - Sample and user group exchanges need to be streamlined
  - Need optimized sample environment and enough sample holders to limit beamtime loss during changes
- At beginning of user operation need for full high intensity mode data reduction and sample alignment software
- Full software support for polarization analysis must be provided form day 1
- Need support for users to analyze data (fitting)

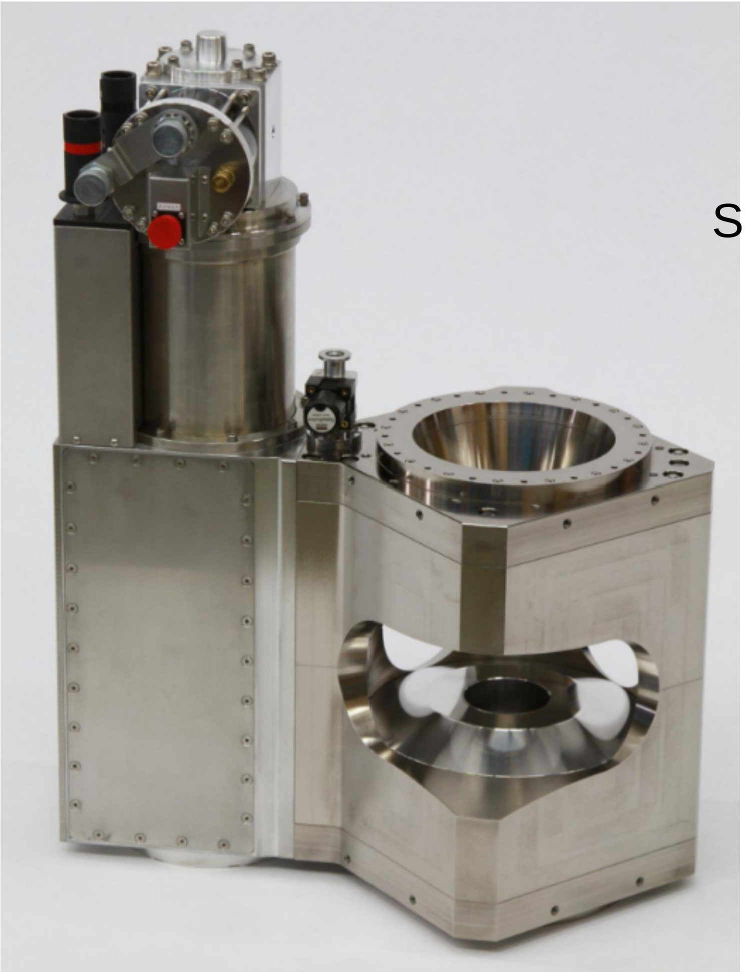
=> Instrument team of 3-4 scientists plus engineer

Instrument Specific Magnet

- ~8 cm room temperature bore cryomagnet
- No material in beam
- Large scattering angle up to 145°
- Compact and light weight
- Moderate field (>2 T)

Proposed model

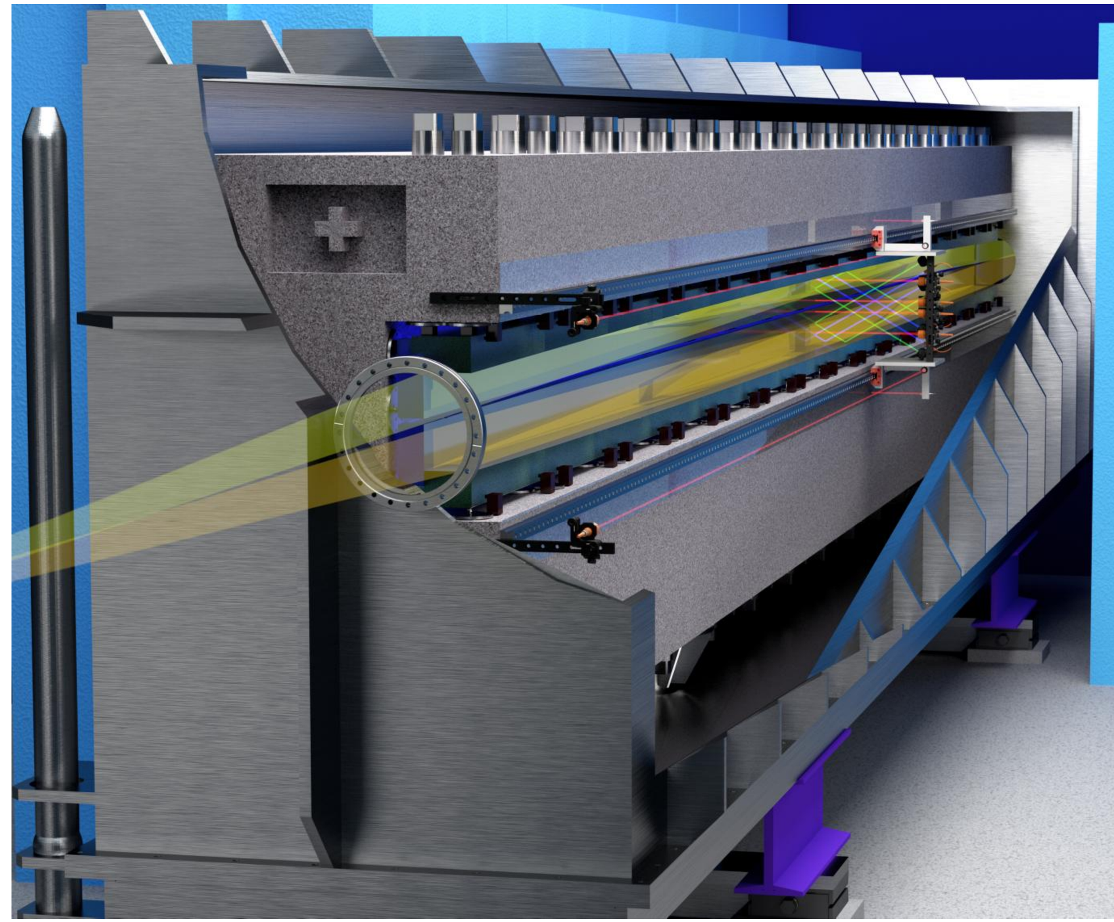


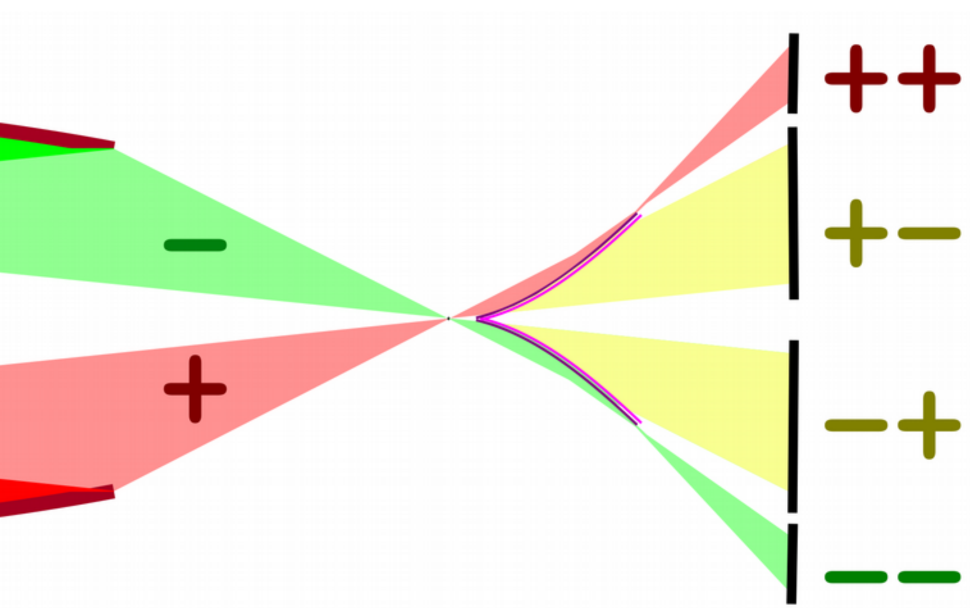


Similar system used at MLZ (2.5 T)

Second Beam Path

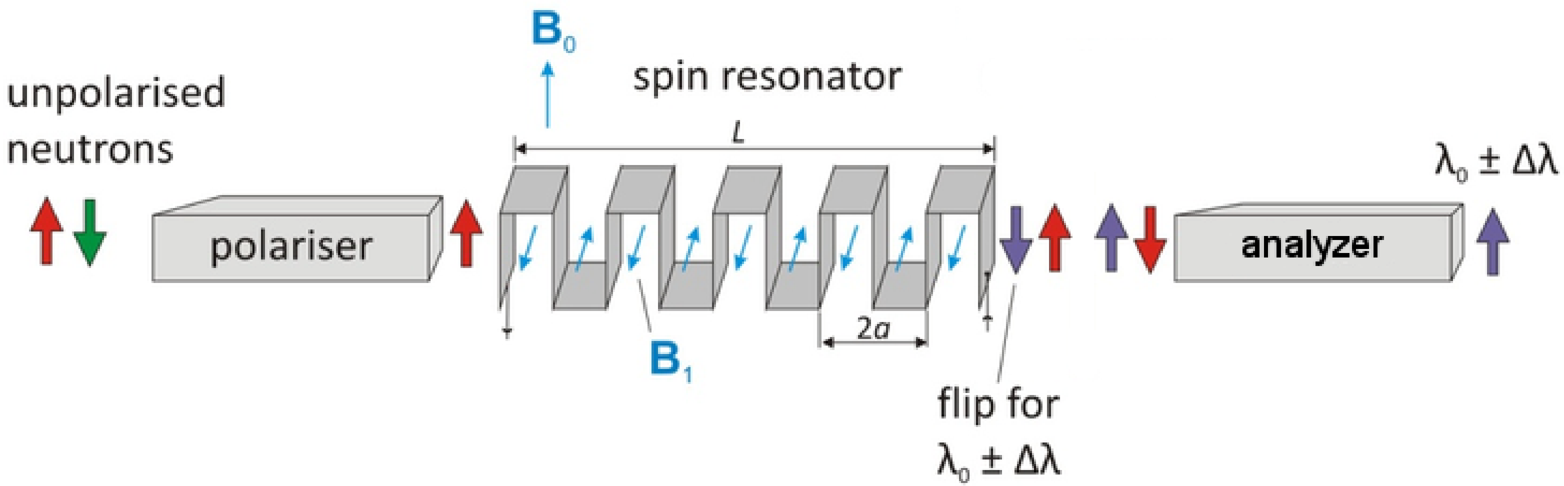
- Double beam intensity
- Simultaneous spin-up and spin-down beams incident on sample
- Enable 4-spin state at once with splitting analyzer (++/--/+-/-+)

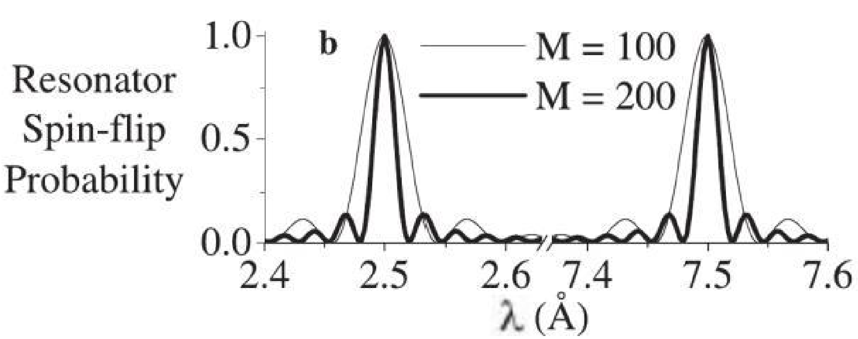




Spatial-Spin-Resonance Flipper

- Current through folded flat plates creates periodic field
- Flip only resonant wavelength
- Resolution defined by selecting L
- Scanning current with ToF allows to keep resonance in center of pulse

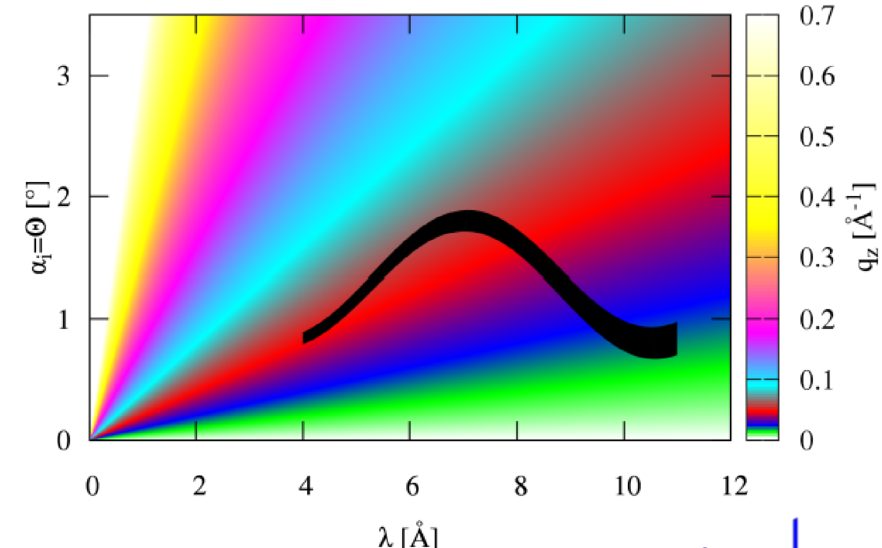


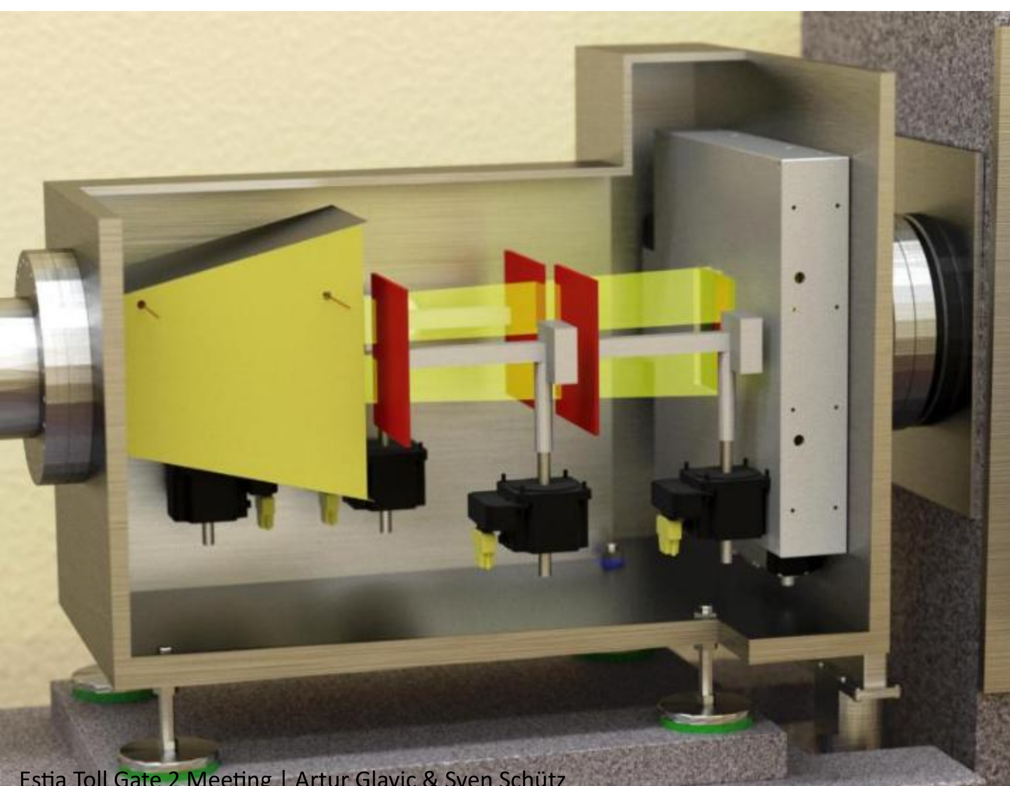


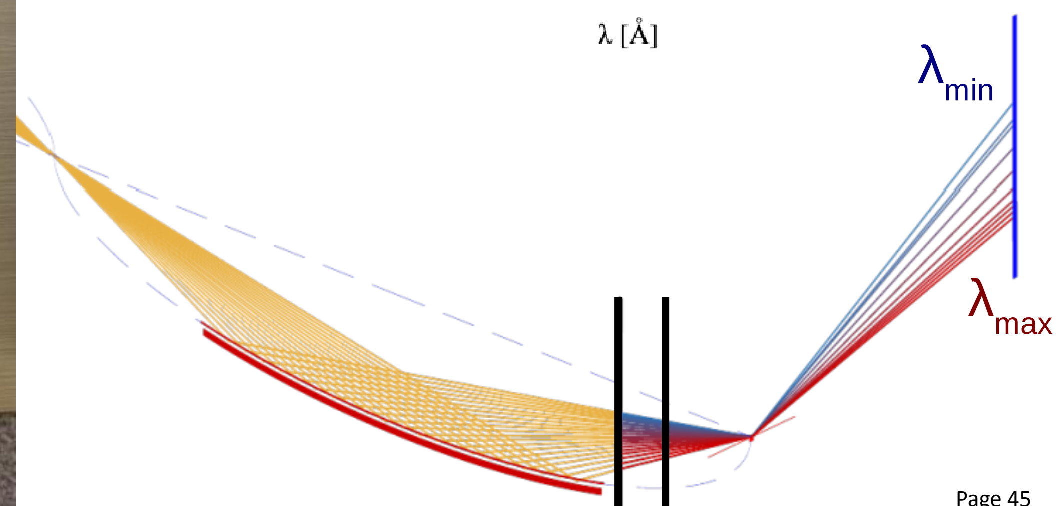
- Can be used to improve Δλ of full divergent beam
- Second device after sample would allow inelastic experiments

Space-Time Collimator

- 4 absorbers scanned trough beam after Selene 2
- 14 Hz operation
- Allows λ-θ encoding => expanded q-range collimated beam
- Can improve Δλ
- Allow constant Δq/q measurement



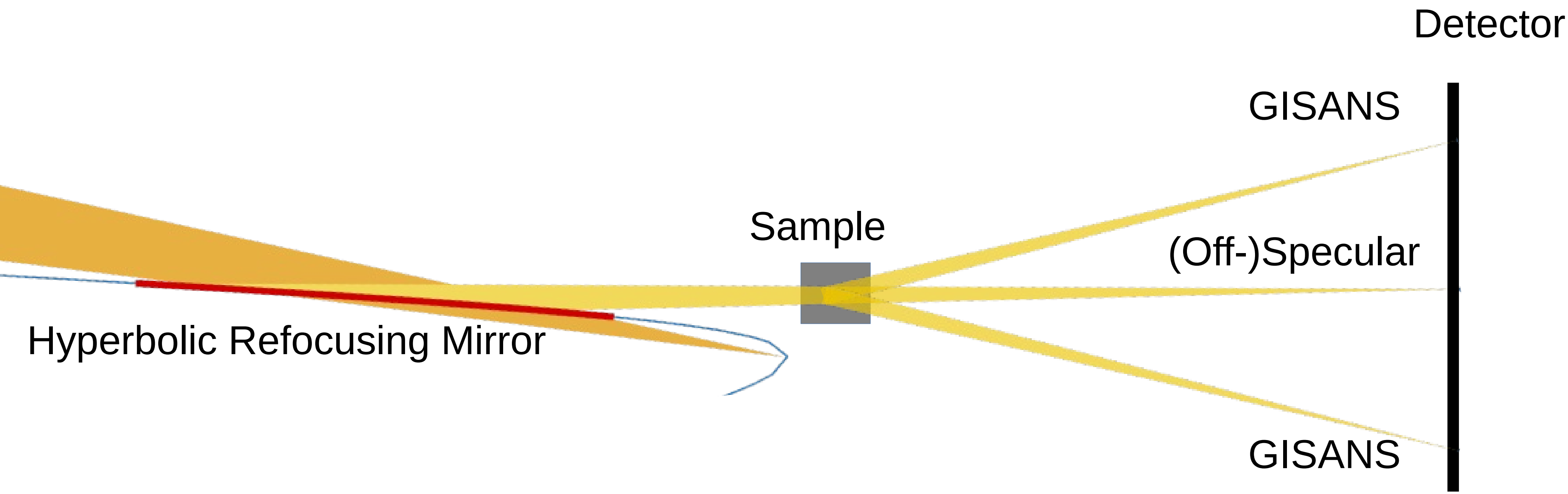




Refocusing for GISANS

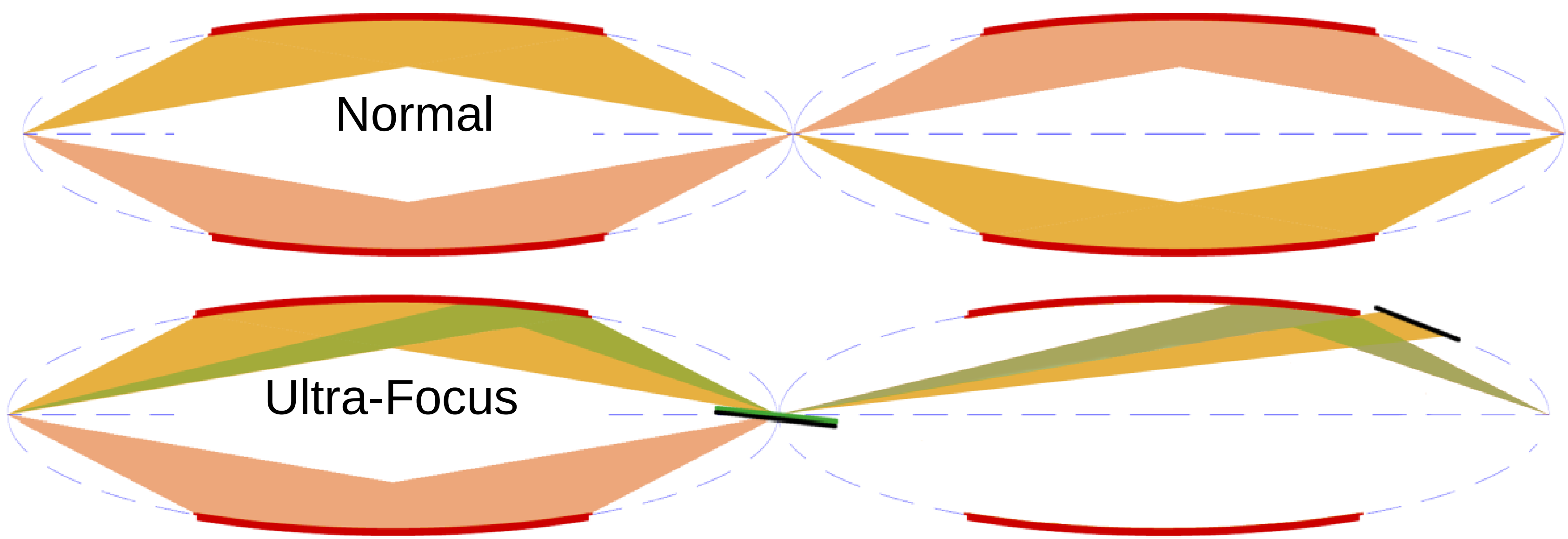
- Precise horizontal supermirror between Selene 2 and sample
- Refocus onto detector position
- GISANS resolution given by VS height
- Almost no intensity loss for large enough samples (~40mm)

- BG reduction for specular measurements from strong incoherent scattering samples



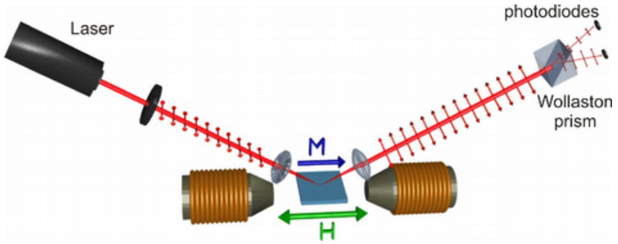
Ultra-Focus Option

- Additional supermirror at middle focus
- Reflect end part of Selene 1 onto end part of Selene 2
- Decreases beam size/intensity ~ factor 3^2 - 6^2



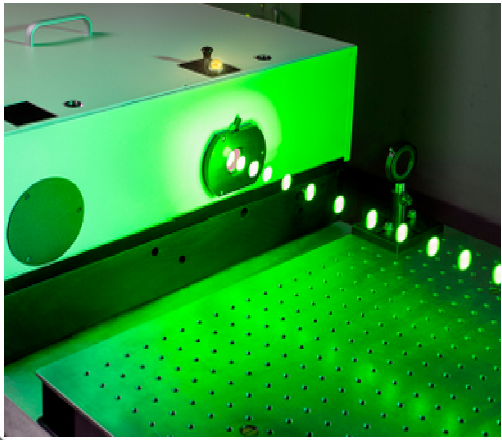
- Improved focus up to 10µm x 100µm
- Allows selective reflectivity and magnification imaging (after adding an imaging detector to the instrument)
- Precise pinhole at focus could be used for unprecedented neutron microscopy

Additional Sample Environment

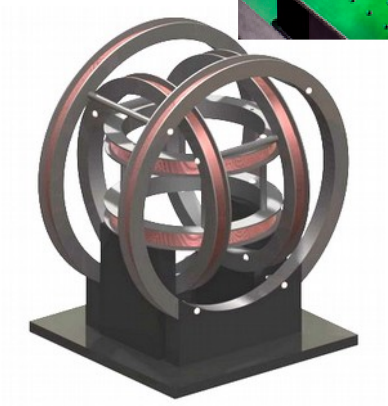


- Kerr-effect add-on for adjustment laser

- Additional cryostats for fast sample changes (cooling new sample while measuring old)

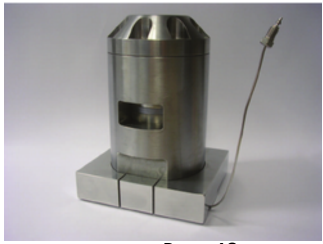


- Pump laser for dynamic experiments

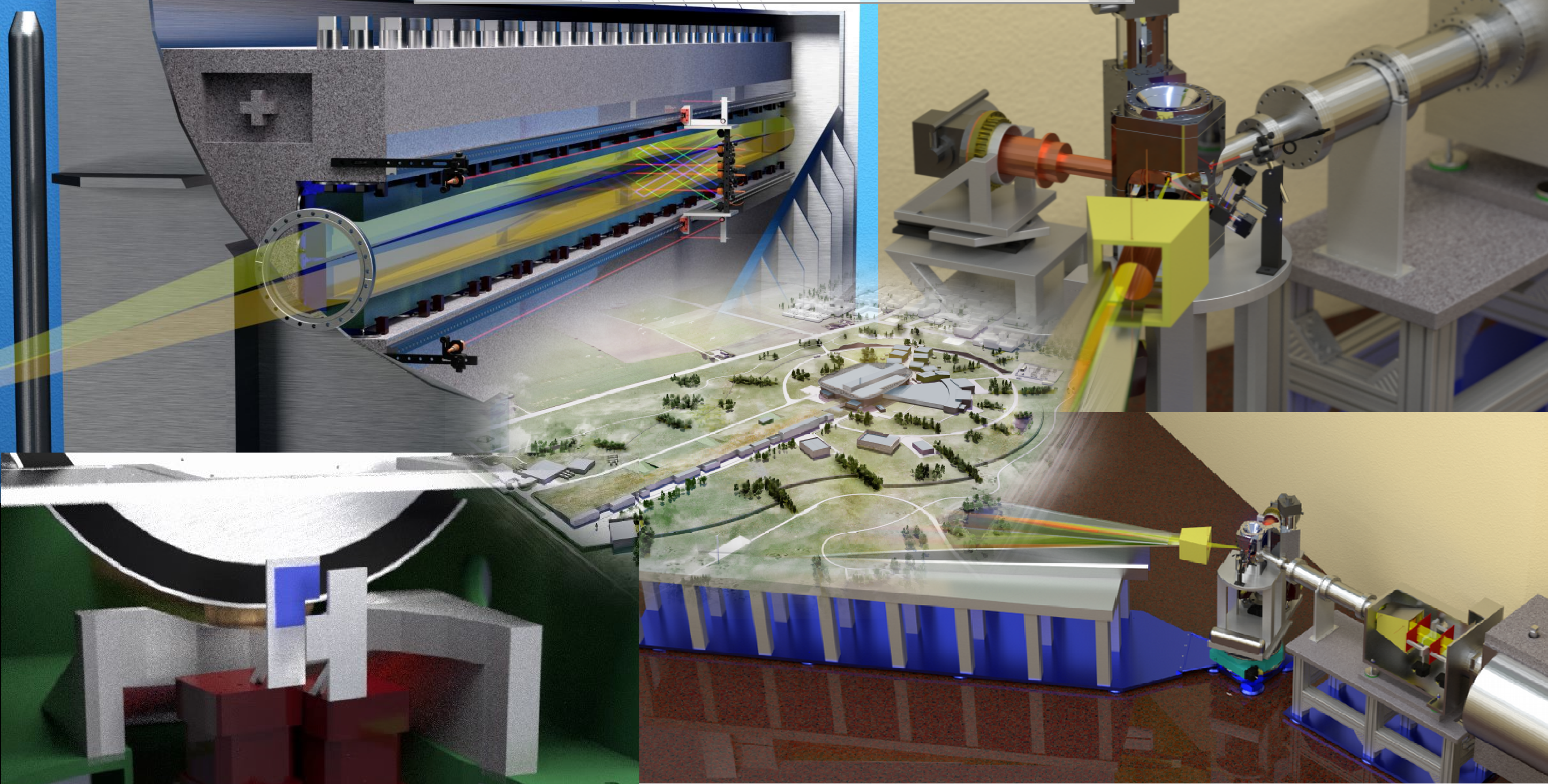


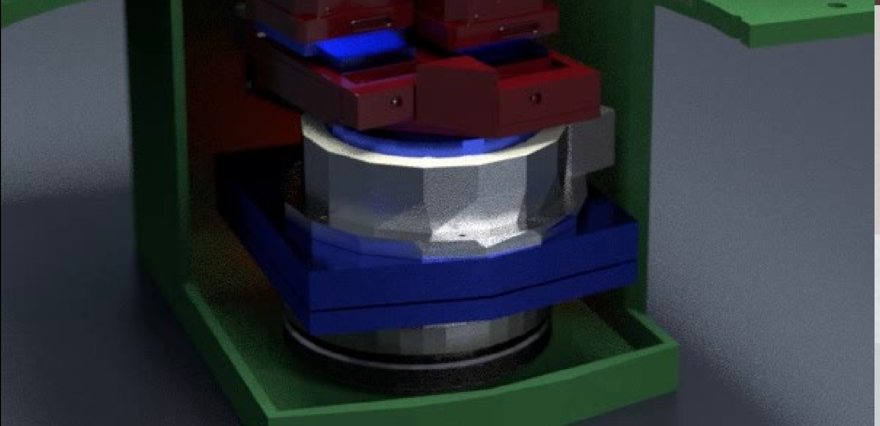
- Helmholtz coils for XYZ-polarization analysis

- Pressure cell for low T as advised by STAP



Thank you for your attention!





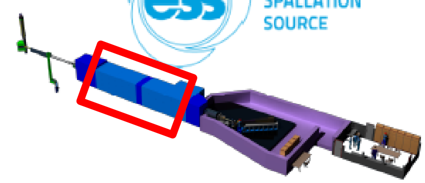
Thanks to Jochan Stahn, Uwe Filges, Christine Klauser, ESS MCA Group,
and every body participating in various discussions for their support!

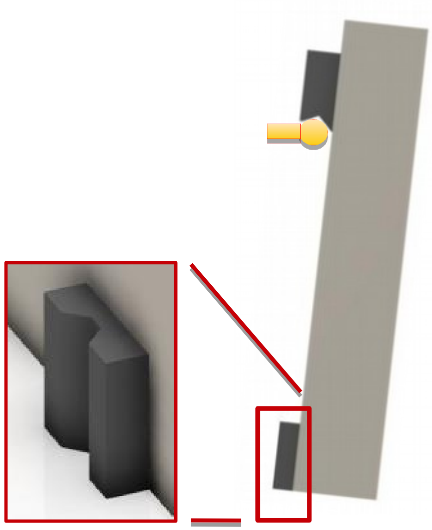
… any questions?


SINQ

Side-Segment Alignment

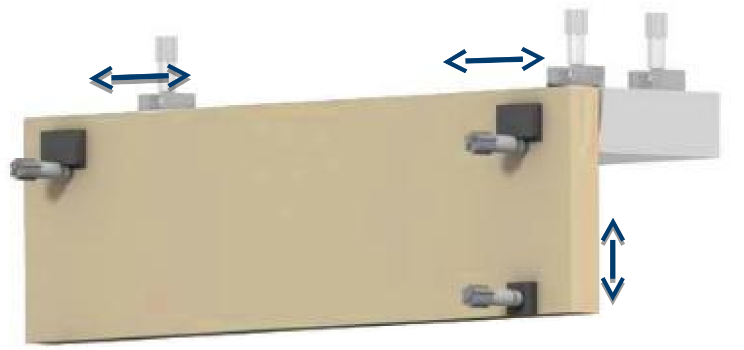
- Zero backlash segment mount
- No tools required for mounting

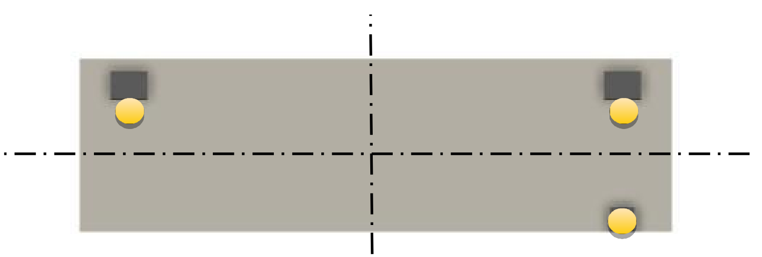


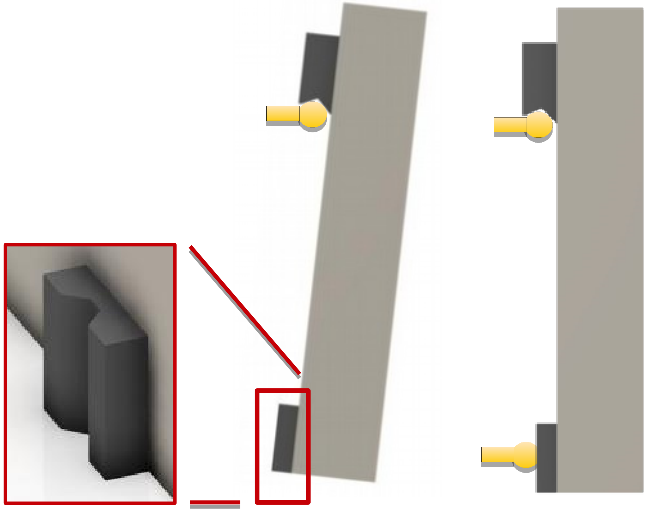


Side-Segment Alignment

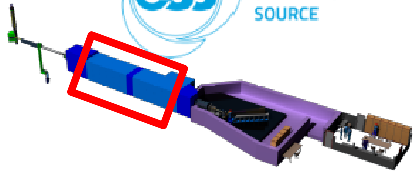
- Zero backlash segment mount
- No tools required for mounting
- Self centering position
- Max. distance to turning-axis enlarge required increment (~0.5µm)
- Protection against dropping with top and bottom segment

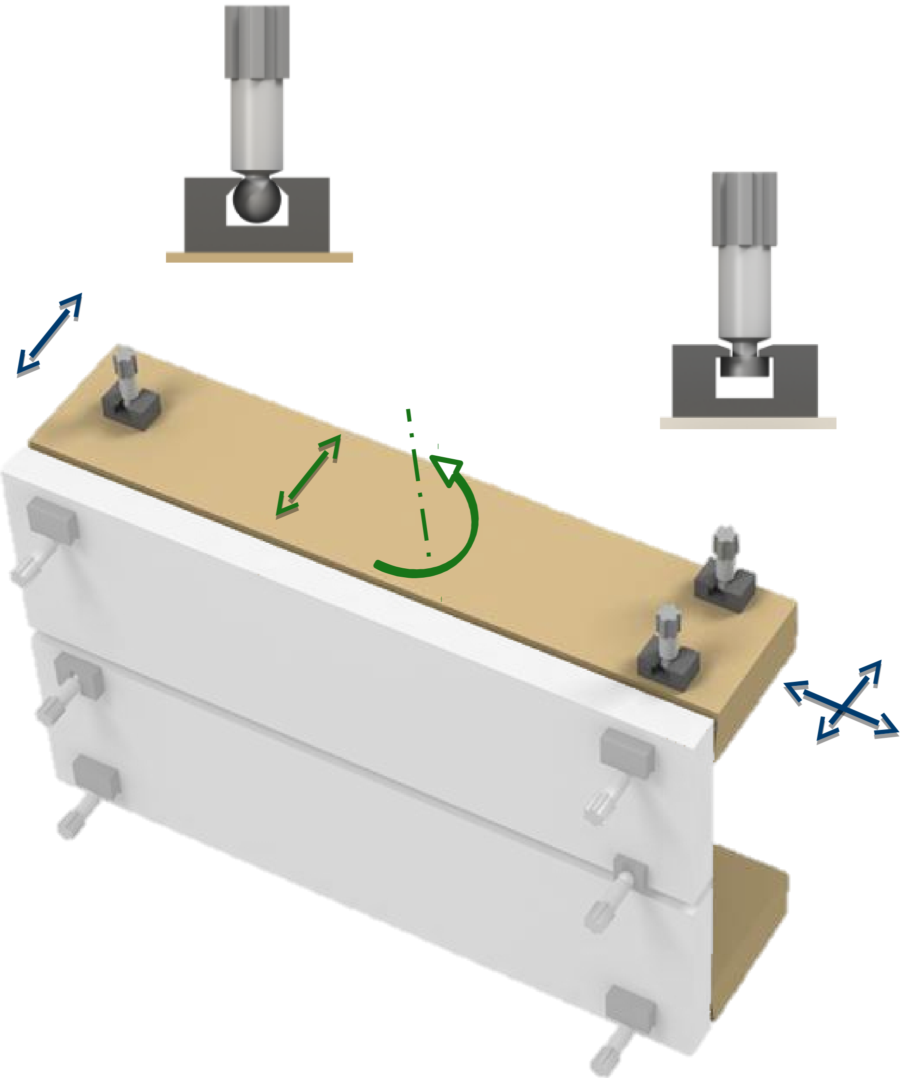


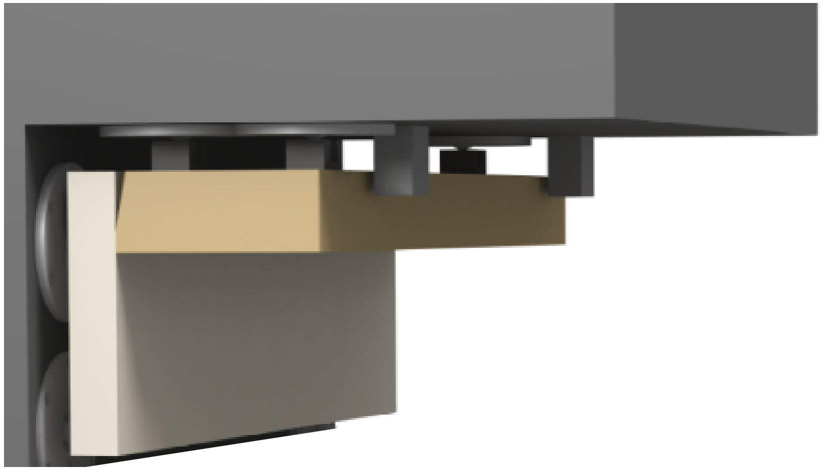




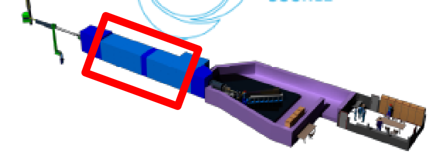
Top-Segment Alignment



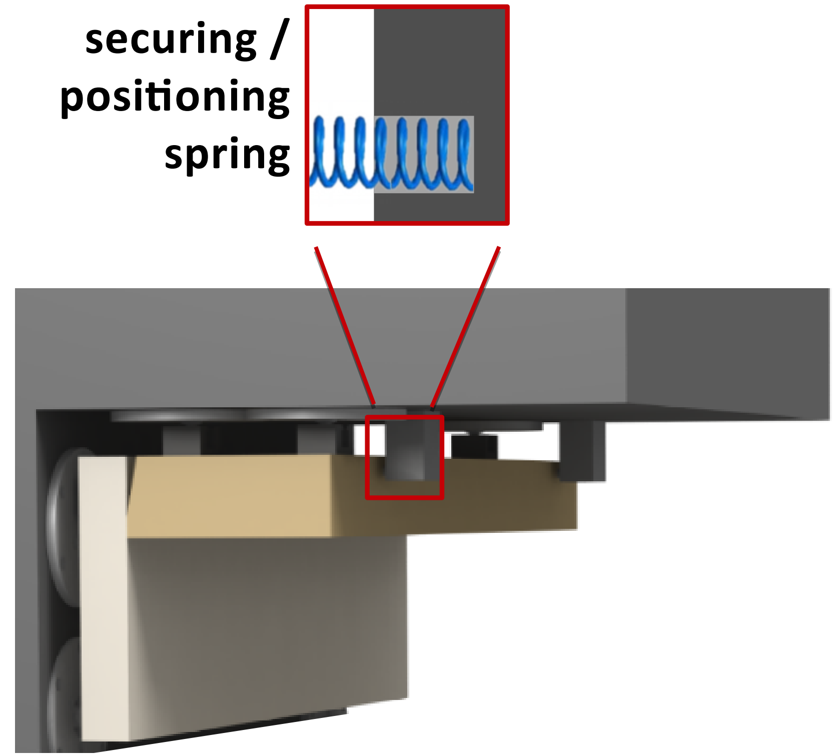




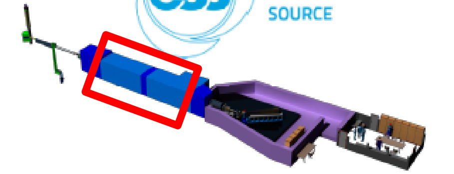
Top-Segment Alignment



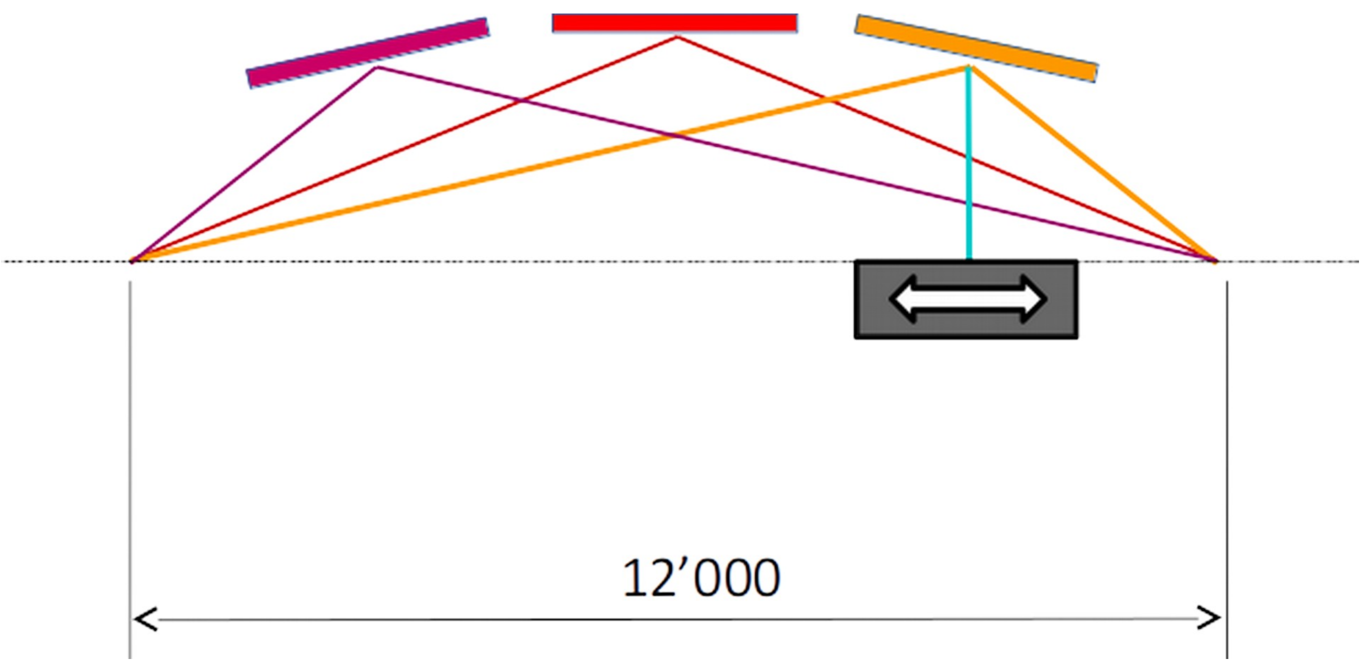
- Segment mounting from one side without tools
- Defined distance between top- and side segment
- Secured against dropping
- Simple exchange of individual segments
- Defined distance between top- and side-segment

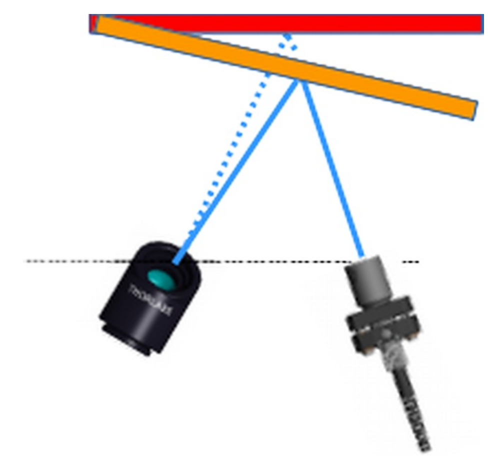


Selene Guide – Alignment System



- Measurement cart with a translation parallel to the C-axis
- Position measurement with an absolute-interferometer
  - **Collimator** is tilted
  - **Corner cube** reflects the beam

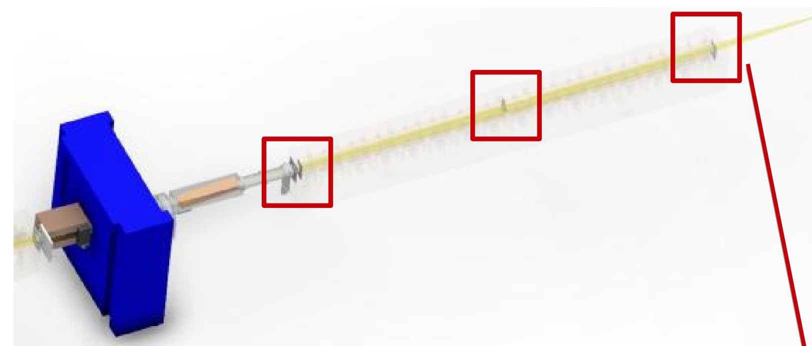


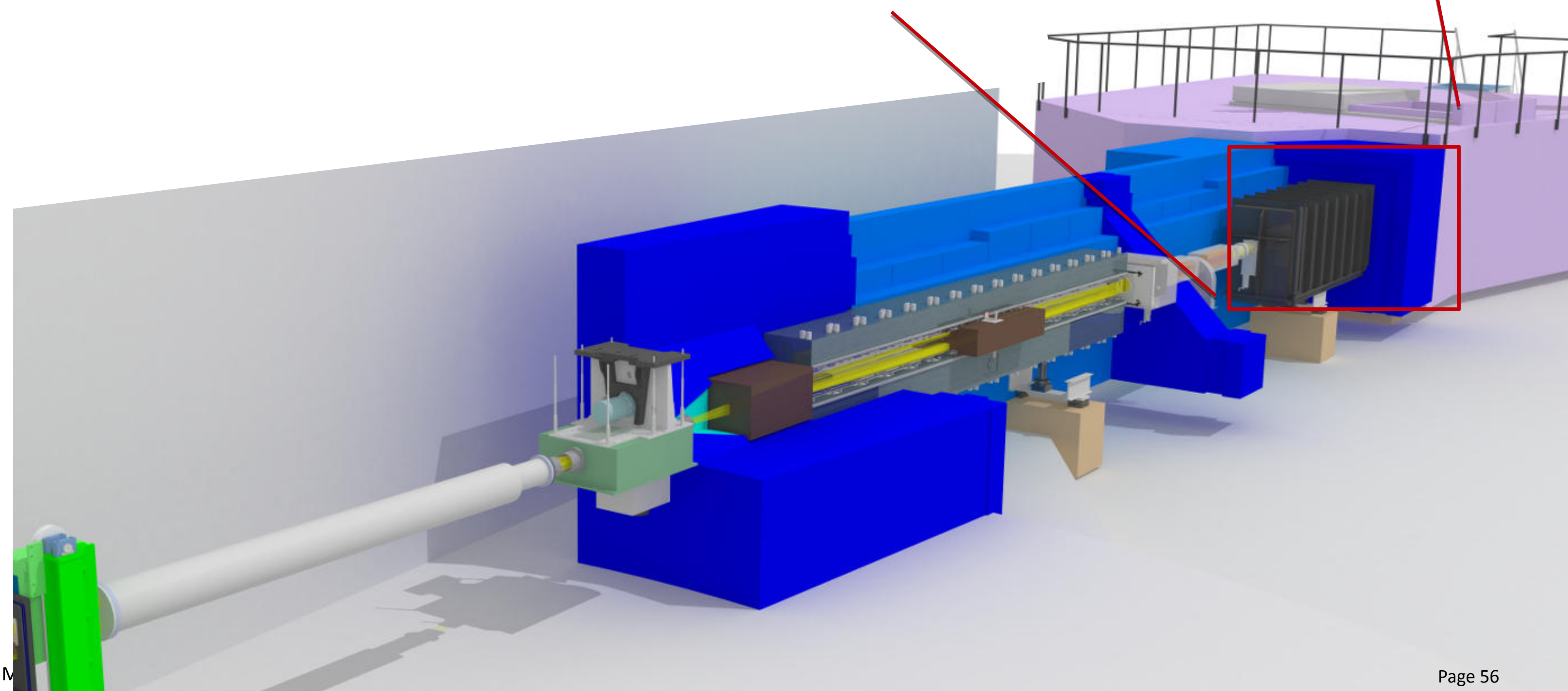


Neutron Guide Shielding (Heavy Collimation)

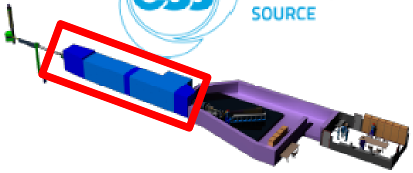
Selene 2

- Thermal neutron collimation (BAl) (depending on upcoming shielding-calculations)
- Access when the beam is on





Beamline Shielding (Biological Shielding)



- Bunker Feed-Through
- Selene 1 Shielding
  - Beamline Shielding
  - Instrument Shutter
- Selene 2 Shielding
  - removable when the beam is on target