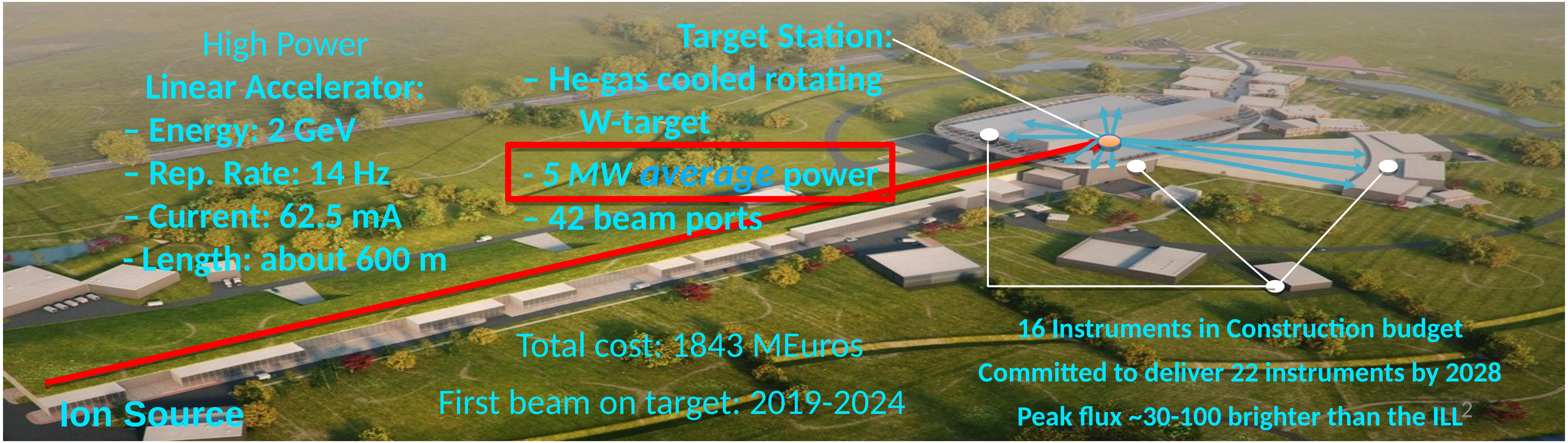
UiO Research Towards ESS
Status of the ESS

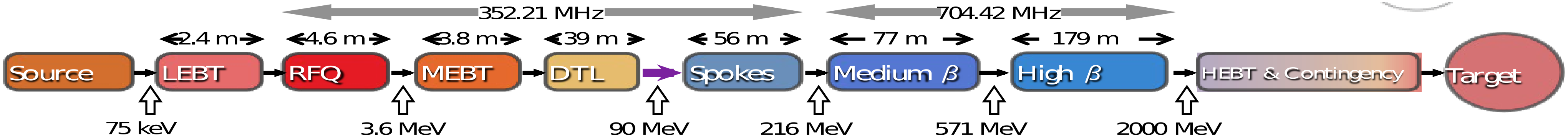
Eric Fackelman, Masters Student, Universitetet i Oslo
15 September 2022
NorCC Workshop September 2022

European Spallation Source

EUROPEAN SPALLATION SOURCE

World’s most powerful neutron research facility, Lund, Sweden.



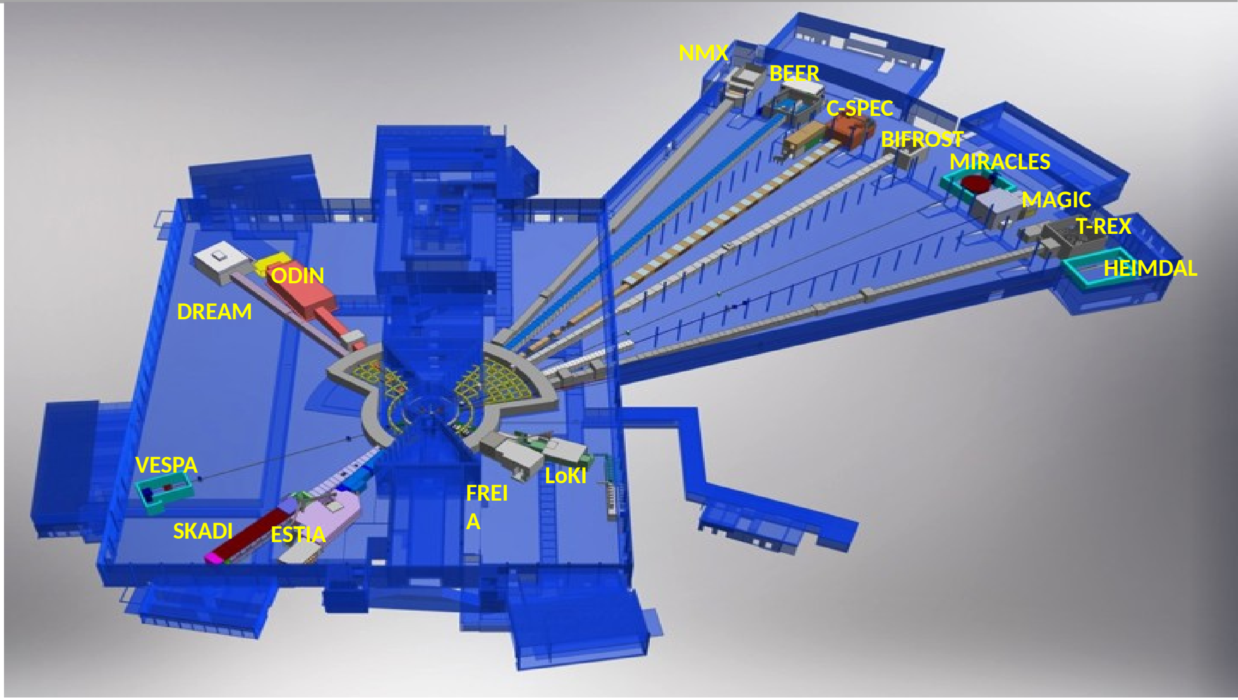


Credit: Adli FYS4565

World-leading neutron-scattering instruments for science in Europe

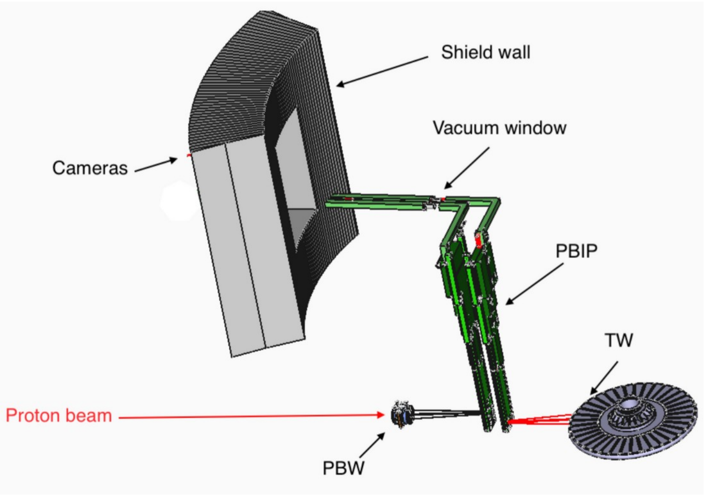
EUROPEAN SPALLATION SOURCE

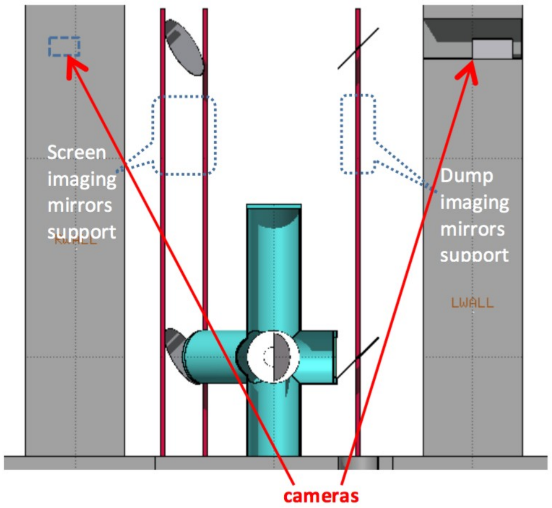
- Life science
- Soft condensed matter
- Chemistry of materials
- Energy research
- Magnetism and superconductivity
- Engineering and geo-sciences
- Archaeology and heritage conservation
- Fundamental and particle physics

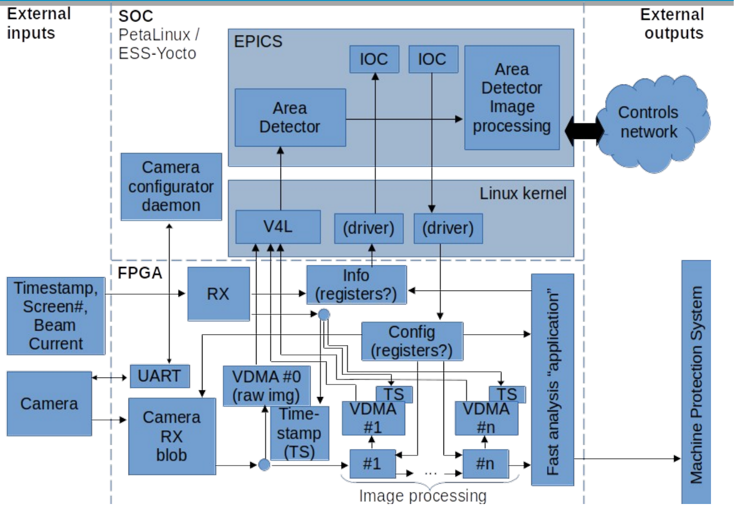


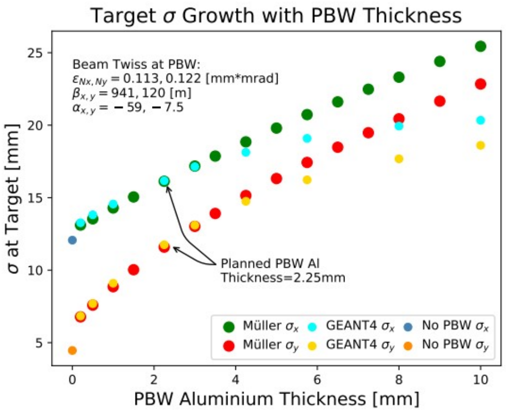
Credit: https://confluence.esss.lu.se/display/SD/ESS+slides
'2017 ESS Instruments overview 3.pptx'

UiO In-Kind Accelerator Contributions









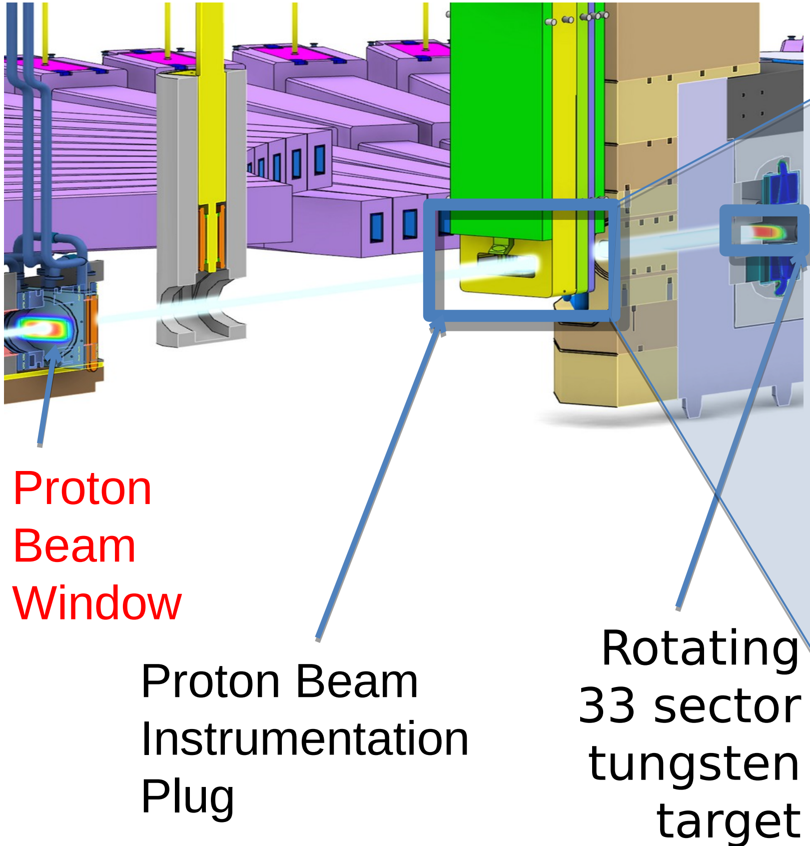
Target Imaging Systems
Tuning Dump Imaging Systems
Image Processing with FPGAs
Beam Diagnostics and Failure Studies

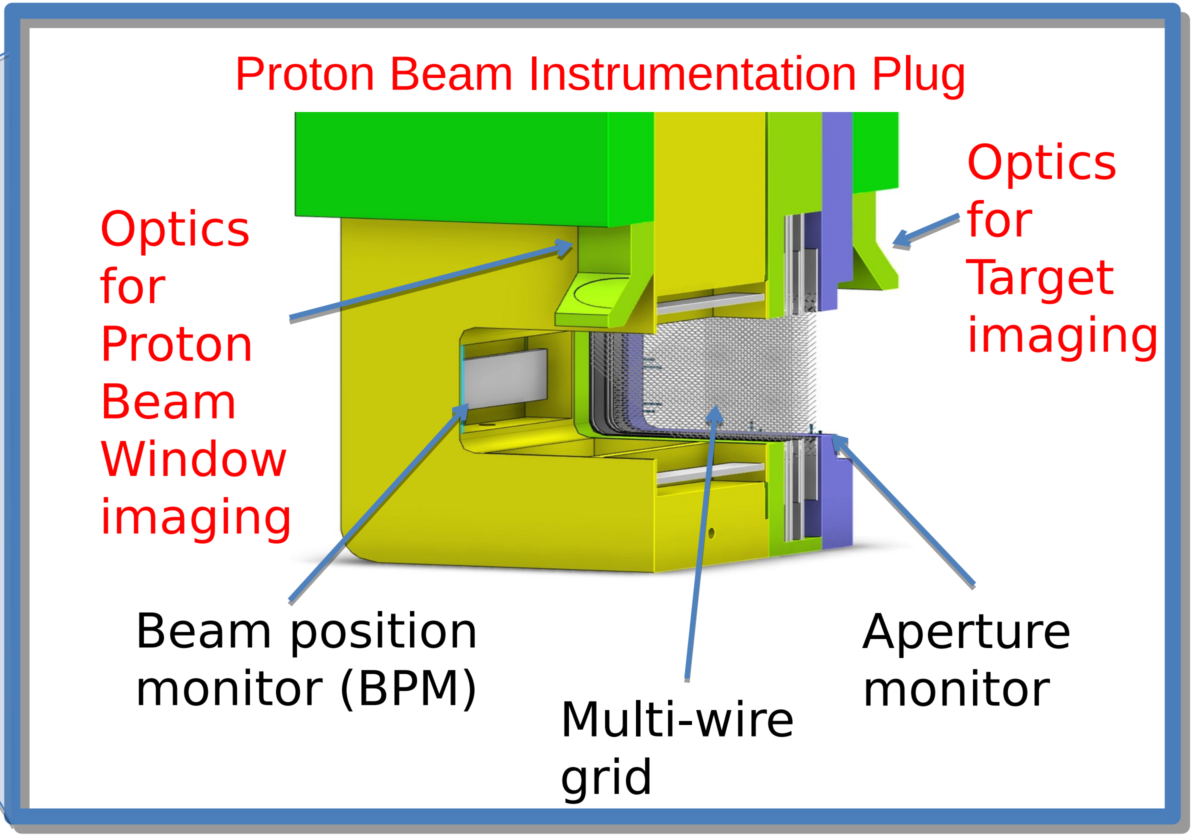
Credit: Adli Nov 2017, Sjobak Sep 2022, Fackelman 2022

Target Systems: inside the monolith

Beam Profile Monitors inside a 5 MW target area

Two systems at the target :

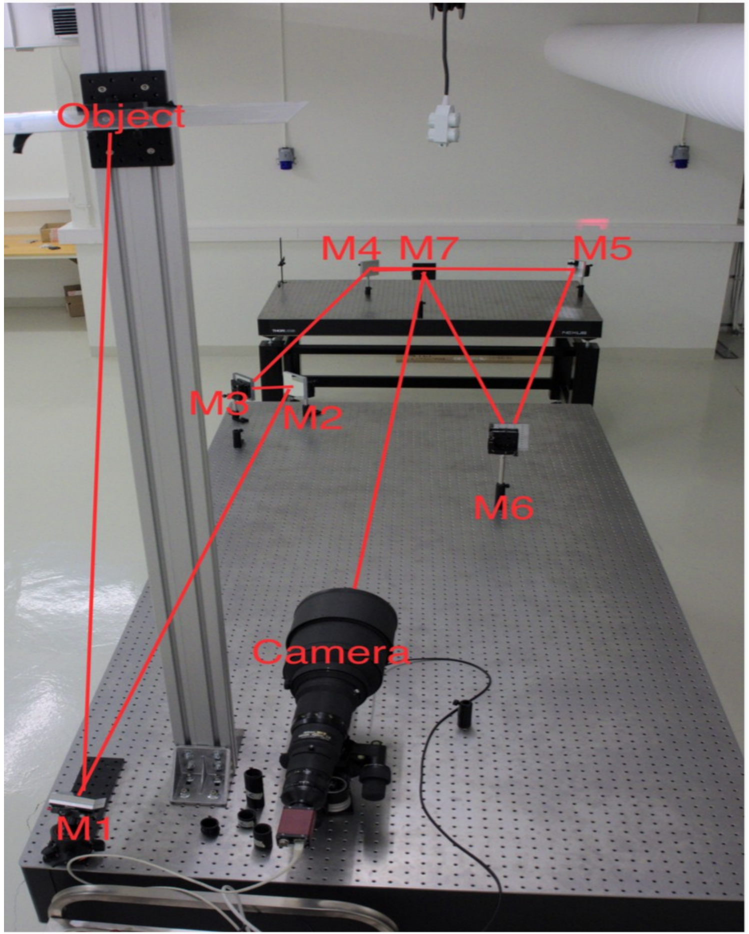


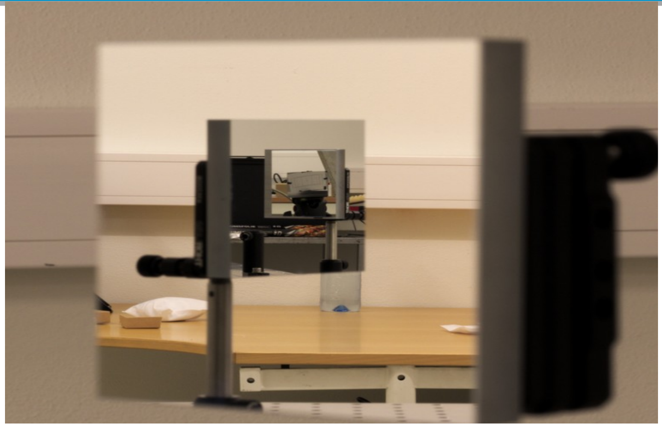


Upstream: position, current, aperture, and loss monitors

Credit: Adli Nov 2017

Target Imaging System Prototype





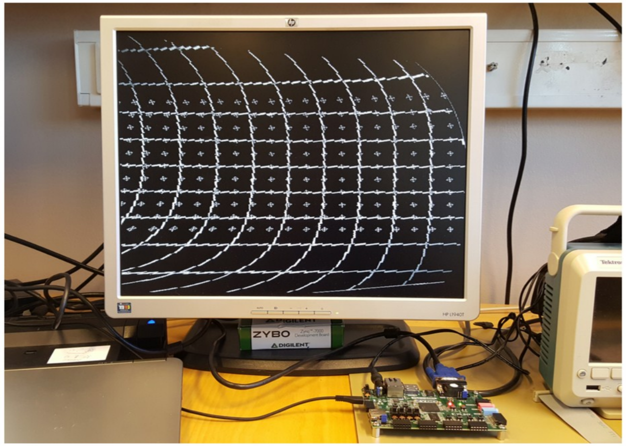
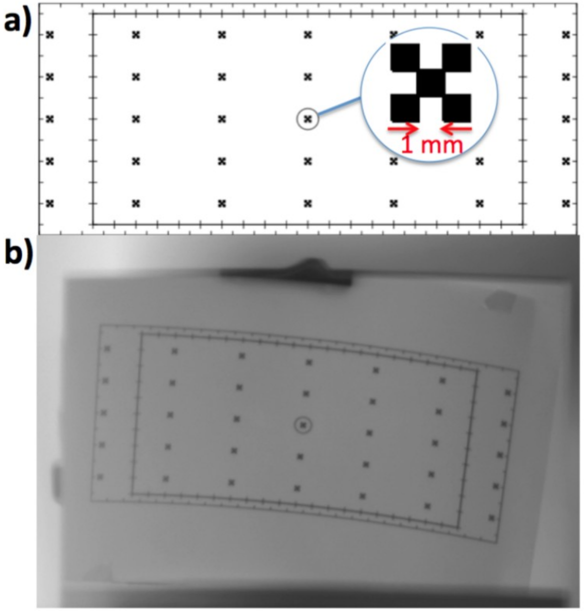


Figure 12: Distorted grid image running with a distortion correction mapping

- Prototype constructed at Oslo
- Invaluable for tolerance and alignment studies
- Performance assumptions verified (resolution of 1 mm)



Credit: Adli Nov 2017

Tuning Dump Imaging Systems

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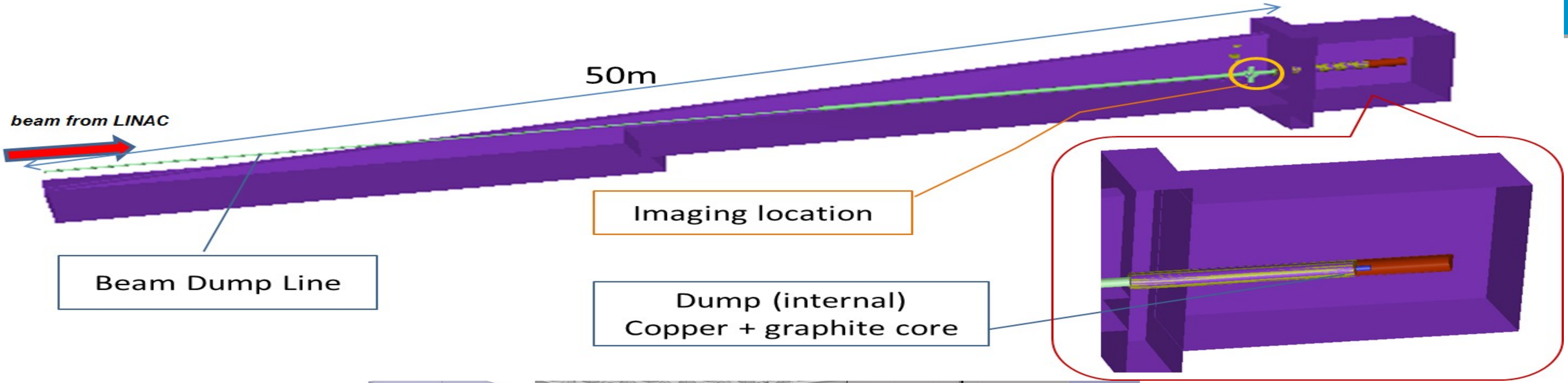
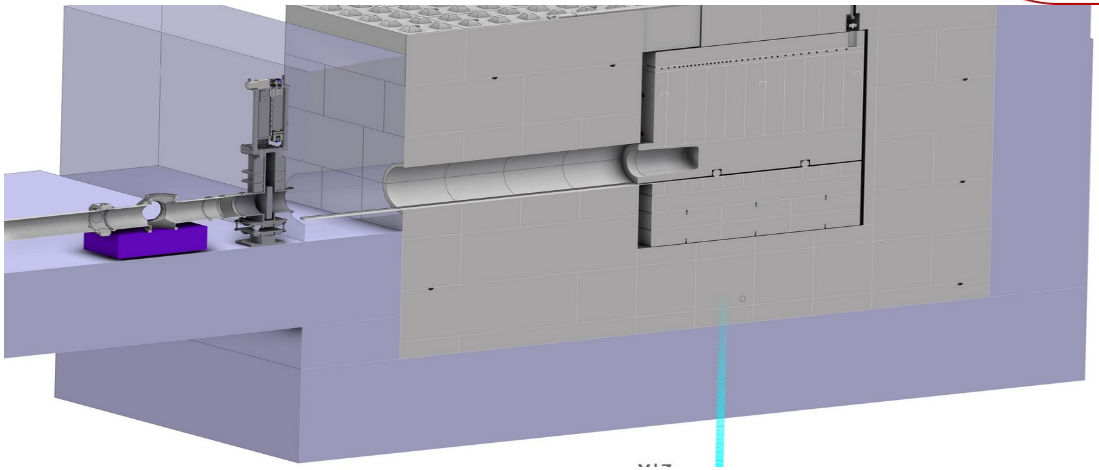
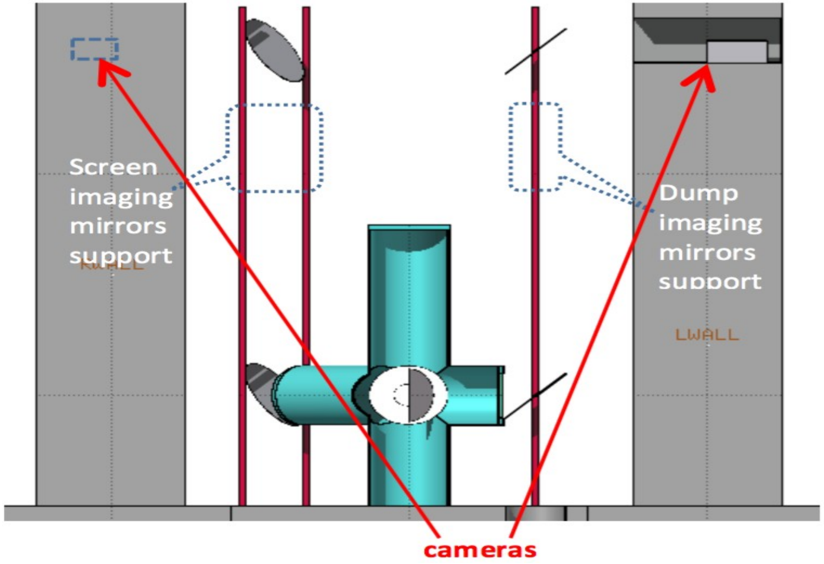


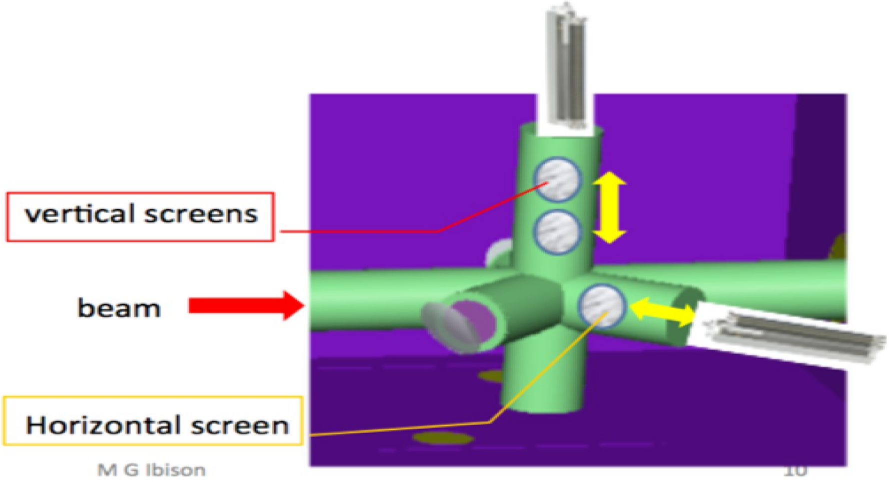


Credit: Adli Nov 2017

Simple optical system, cameras in tunnel

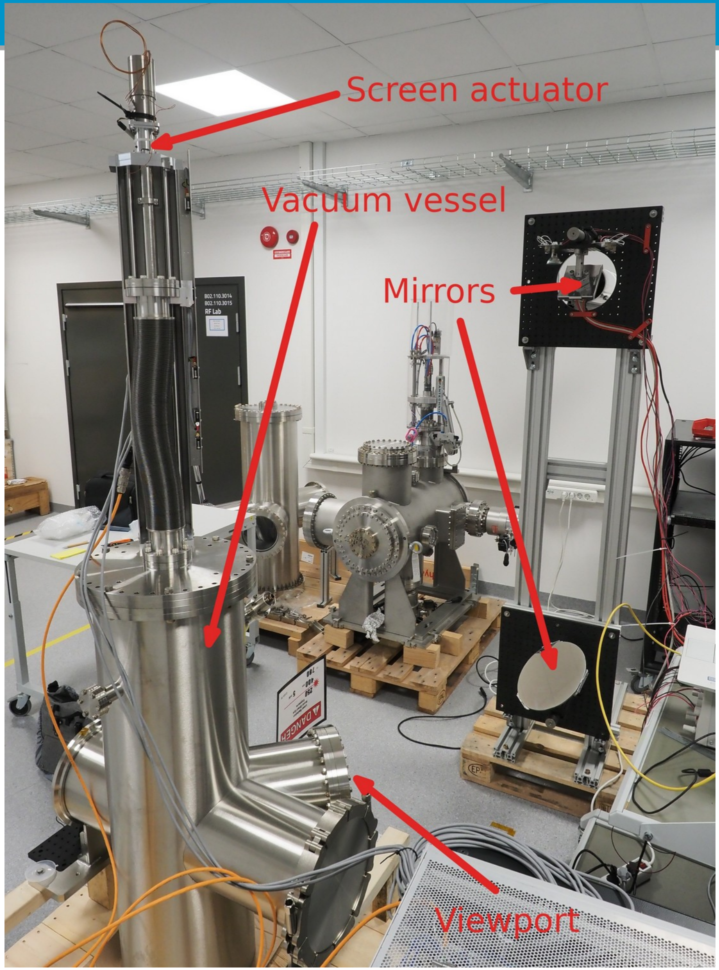
- Radiation studies points to optimal camera locations (high alcoves inside wall)
- Keeps optical system simple.
- Access to replace cameras and parts has been studied
- Multiple-screen actuator system design, based on proven accelerator technology
- Interfaces with vacuum vessel and dump well understood, due to continuous dialog Oslo (Ibison) and Cockcroft





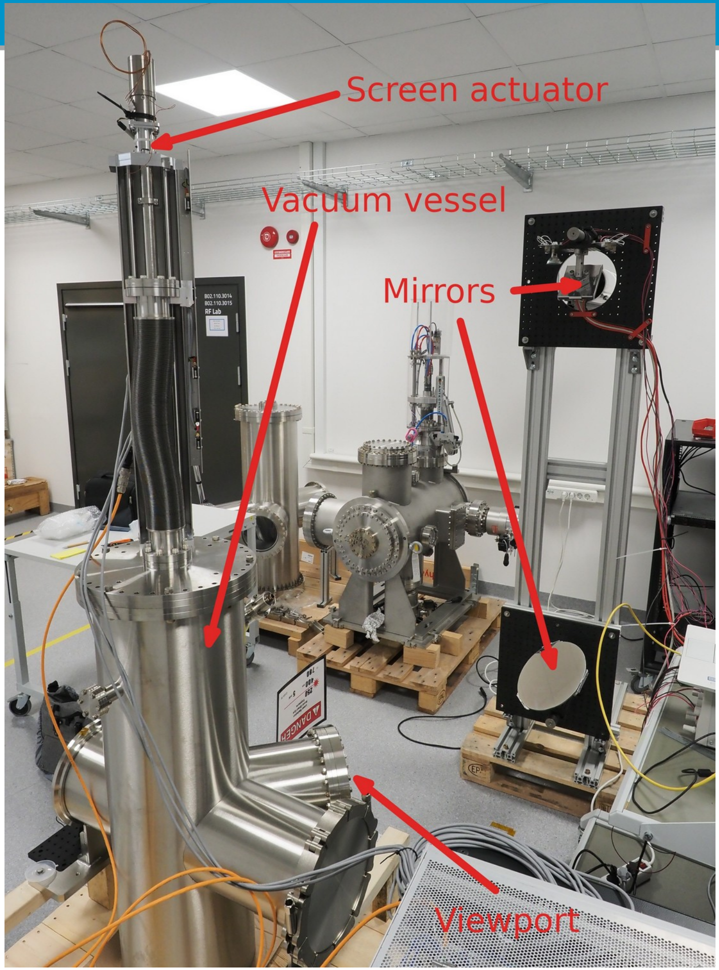
Credit: Adli Nov 2017

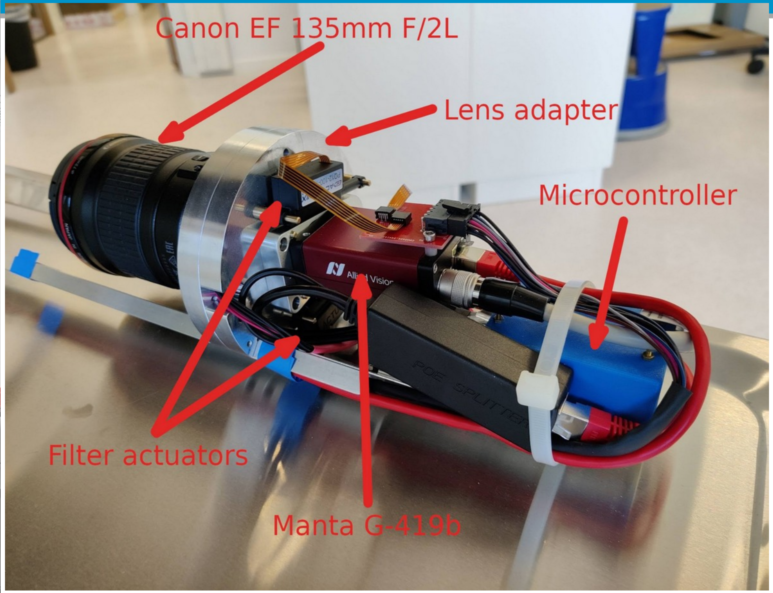
Screen Actuator & Camera



Credit: Gjersdal LINAC22, Sjobak https://confluence.esss.lu.se/display/PBIIMG/2022-06-16+UiO+to+ESS+trip

Screen Actuator & Camera





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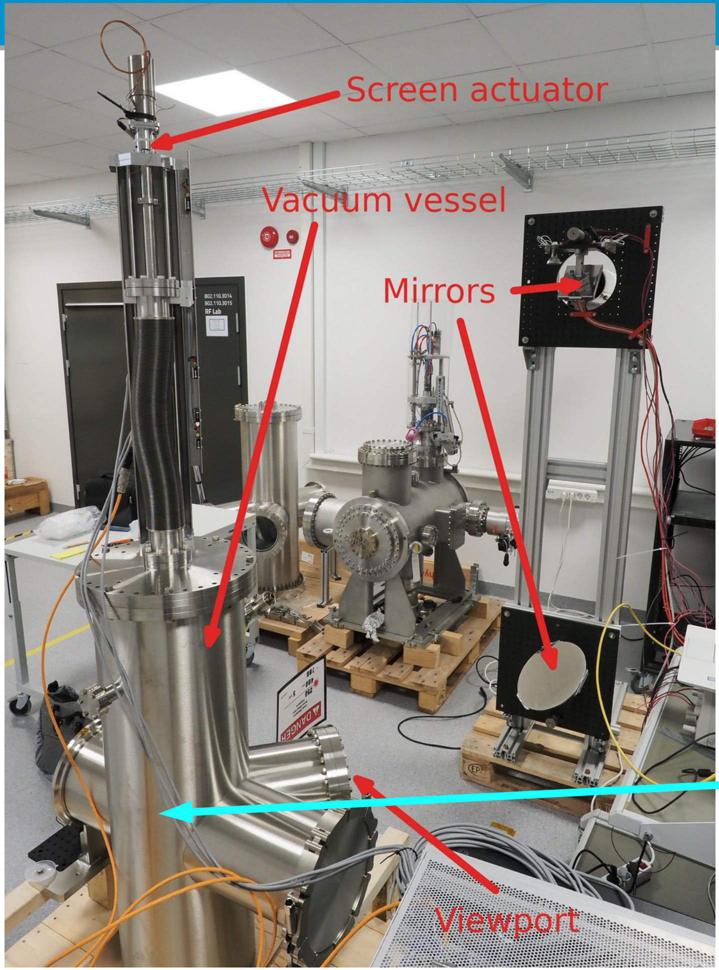
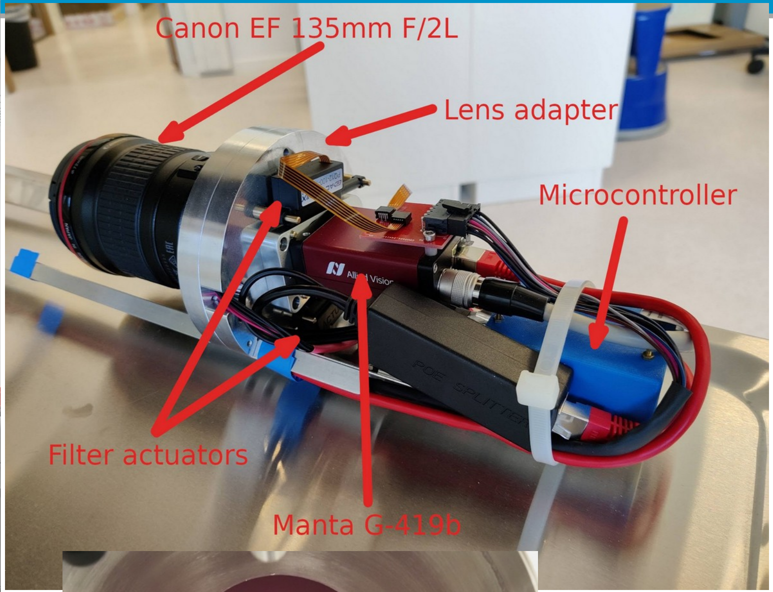
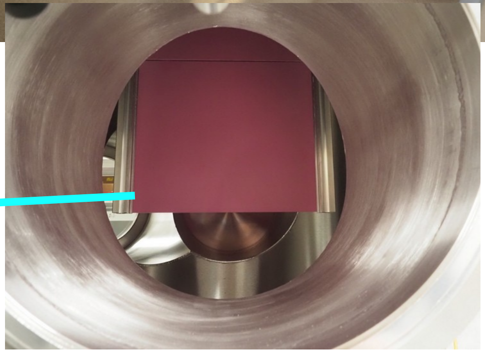
Screen Actuator & Camera

EUROPEAN SPALLATION SOURCE







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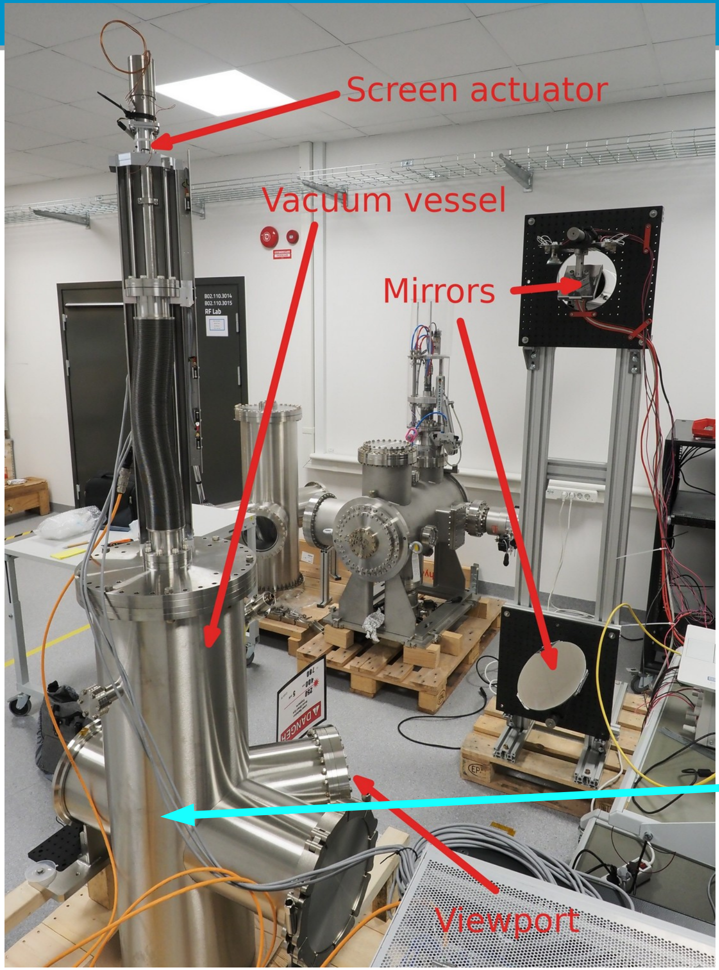
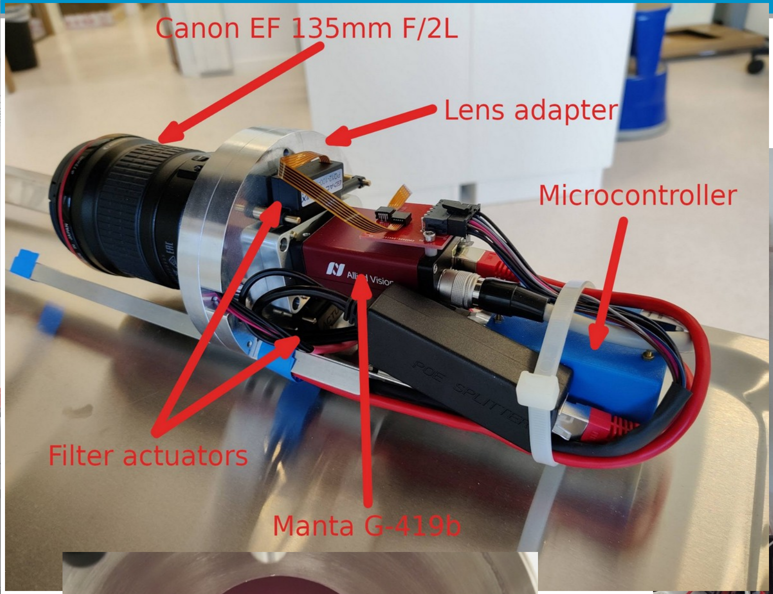
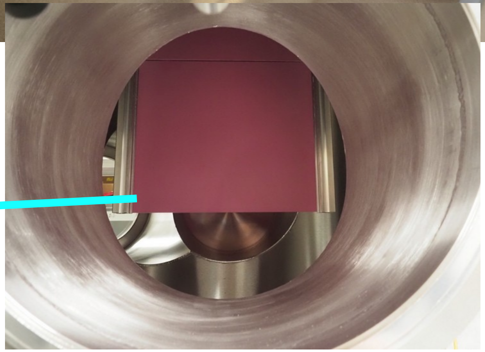
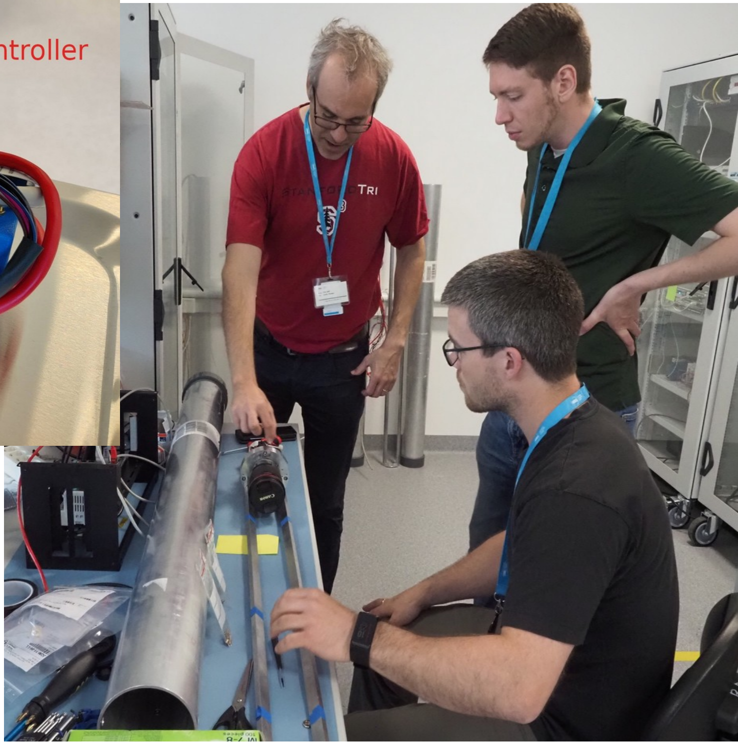






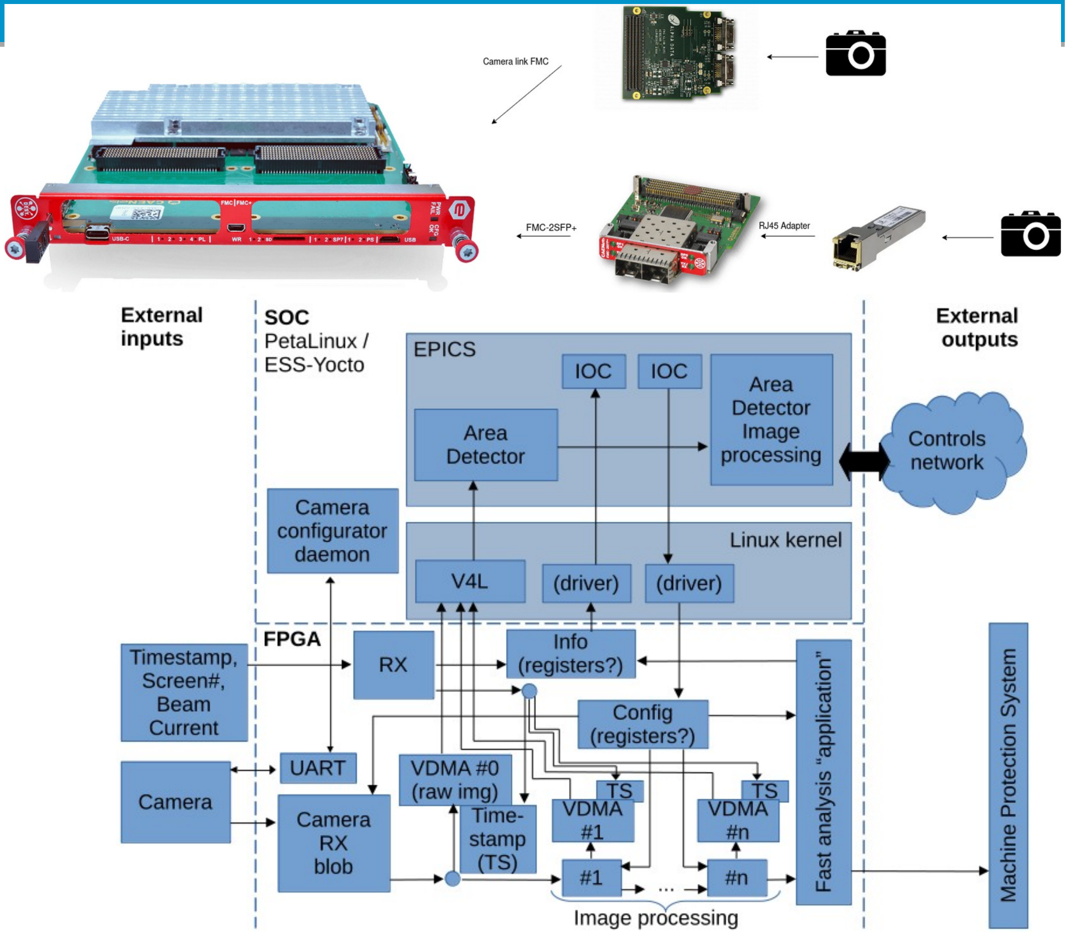


Credit: Gjersdal LINAC22, Sjobak https://confluence.esss.lu.se/display/PBIIMG/2022-06-16+UiO+to+ESS+trip

Image Processing with FPGAs

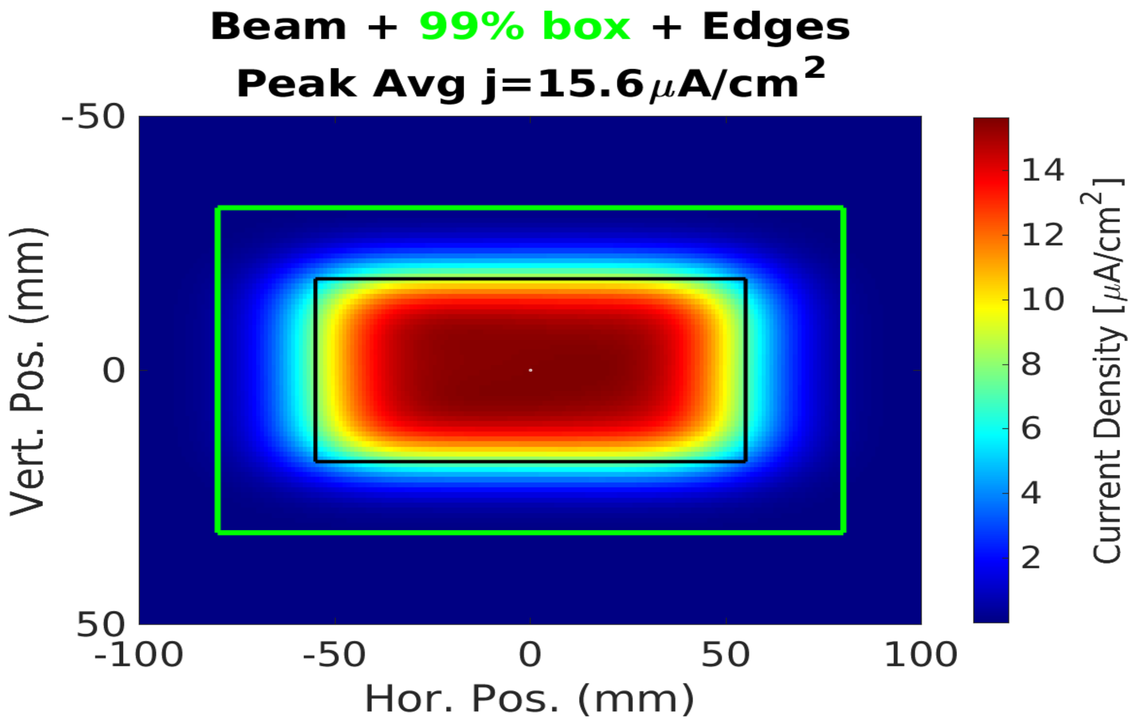
EUROPEAN SPALLATION SOURCE

- UiO-developed camera systems will be staring at the Proton Beam Window, the main target, and tuning dump screens
- Images to be used for beam interlock
  => Analysis in real-time and time-critical! 14Hz!
- Fast analysis to be done on FPGA:
  - Peak current density
  - Fraction of beam outside the expected footprint
  - Image correction for optical aberrations and camera noise etc.
- On-chip SOC running Linux to be used to control the FPGA and cameras
  - EPICS on Linux used to make images available to accelerator operators
- FPGA image extraction and basic filtering has been implemented, Linux system in development based on Xilinx/AMD PetaLinux



Credit: Sjobak Sep 2022 https://cernbox.cern.ch/index.php/s/5nNktqkSg6rsi5v

Beam Diagnostics and Failure Studies



Credit: Fackelman 2022 https://confluence.esss.lu.se/display/PBIIMG/Beam+Dynamics+and+Failure+Studies

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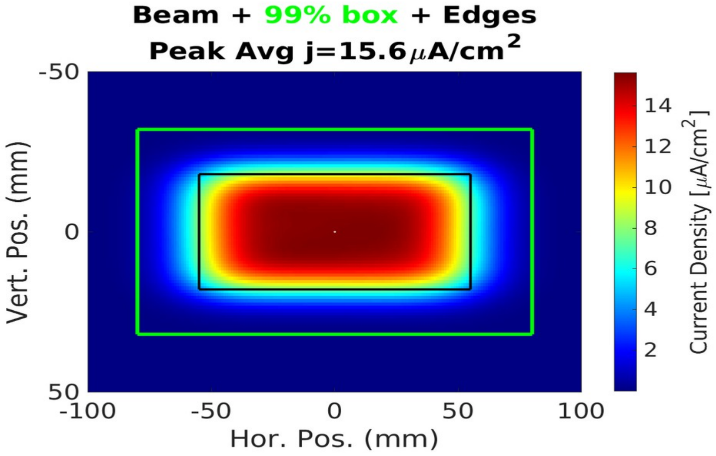

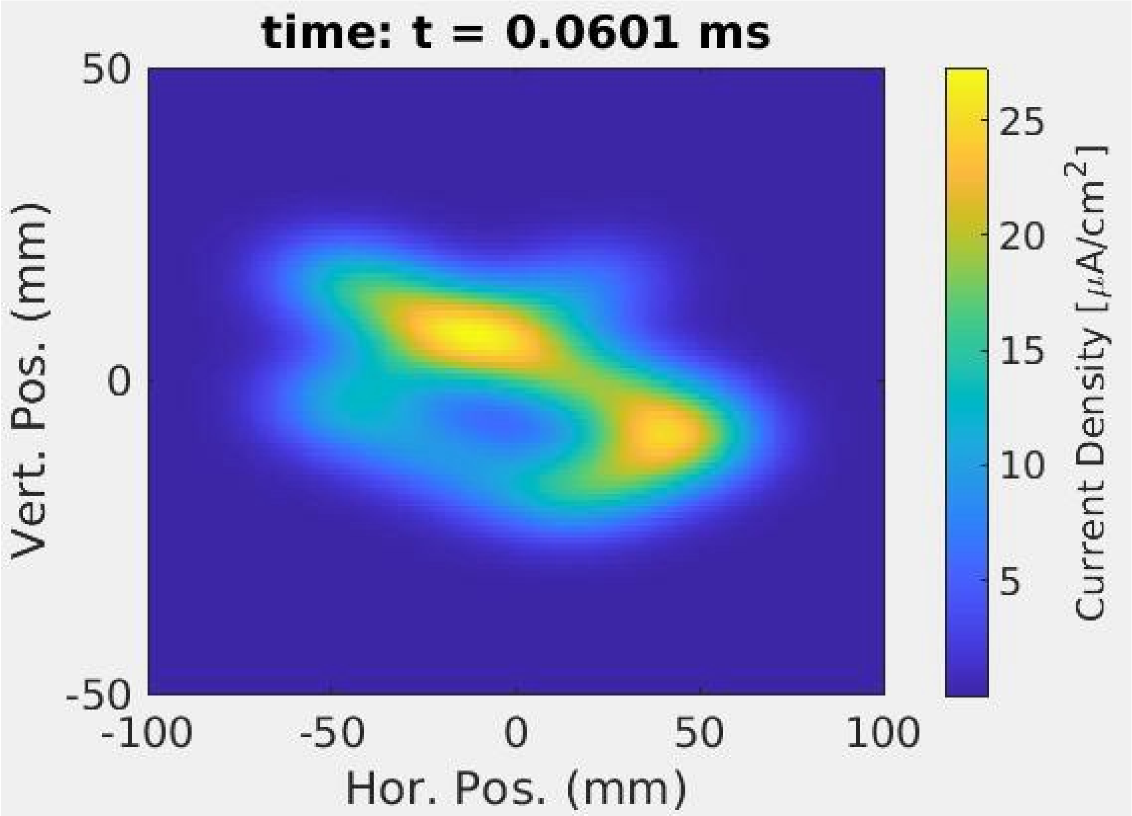

Credit: Thomas 2021

Credit: Fackelman 2022 https://confluence.esss.lu.se/display/PBIIMG/Beam+Dynamics+and+Failure+Studies

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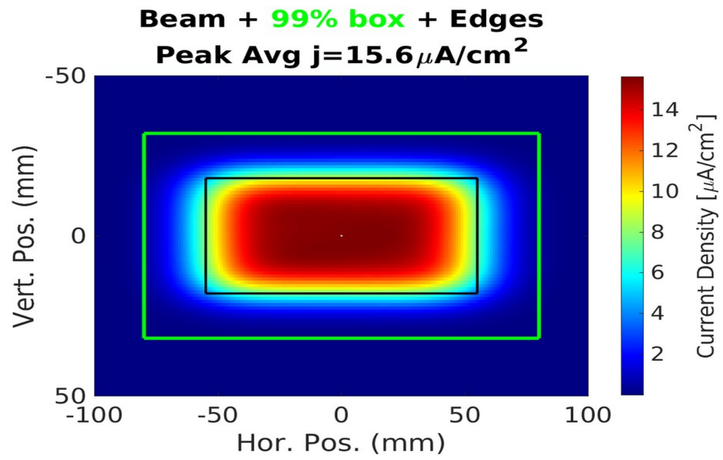

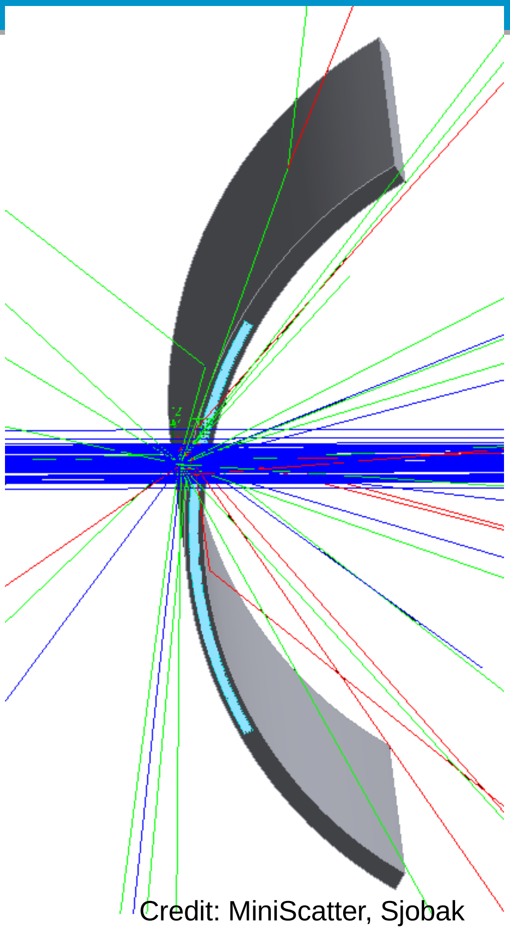

Credit: MiniScatter, Sjobak

Credit: Fackelman 2022 https://confluence.esss.lu.se/display/PBIIMG/Beam+Dynamics+and+Failure+Studies

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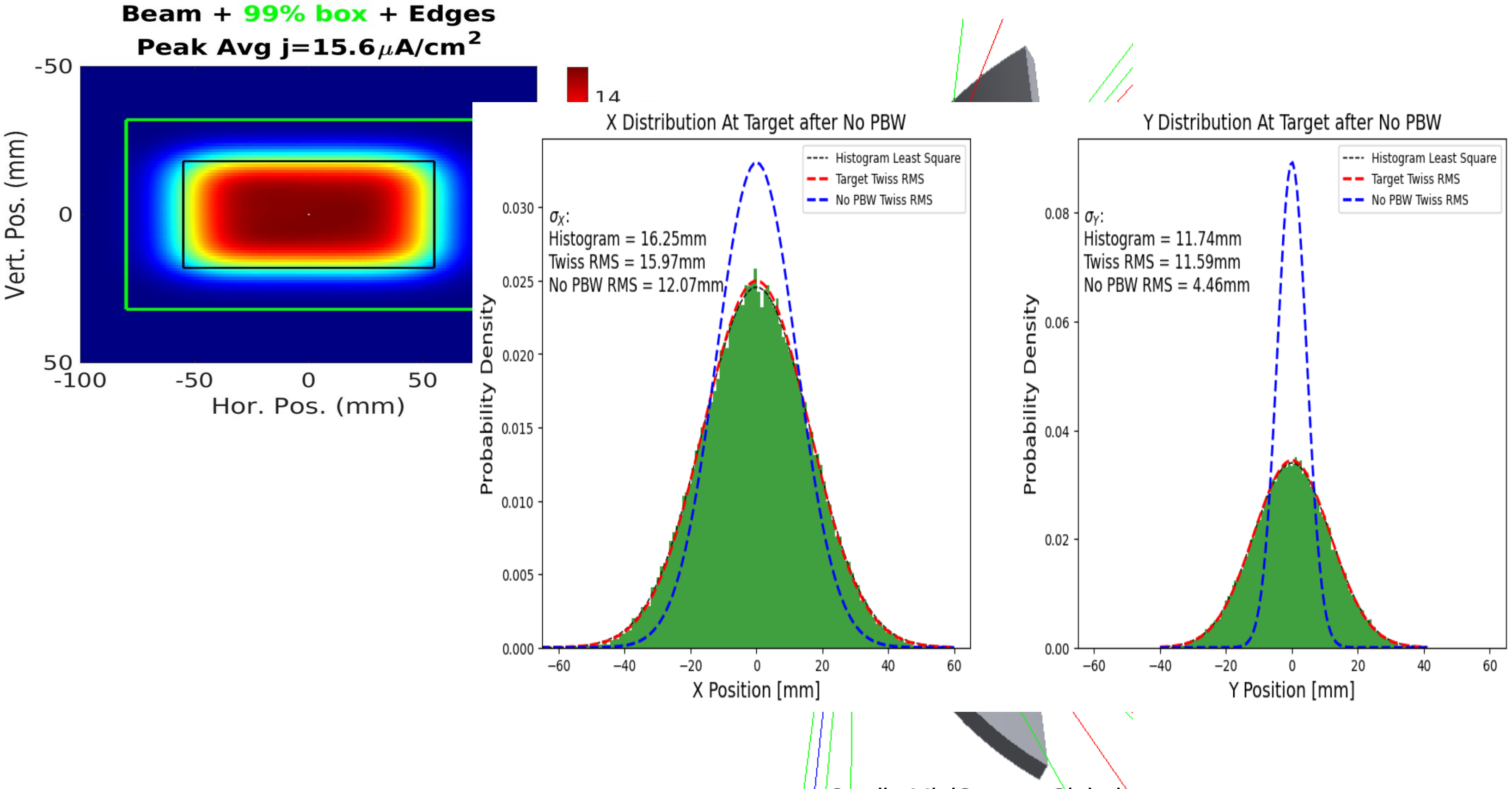

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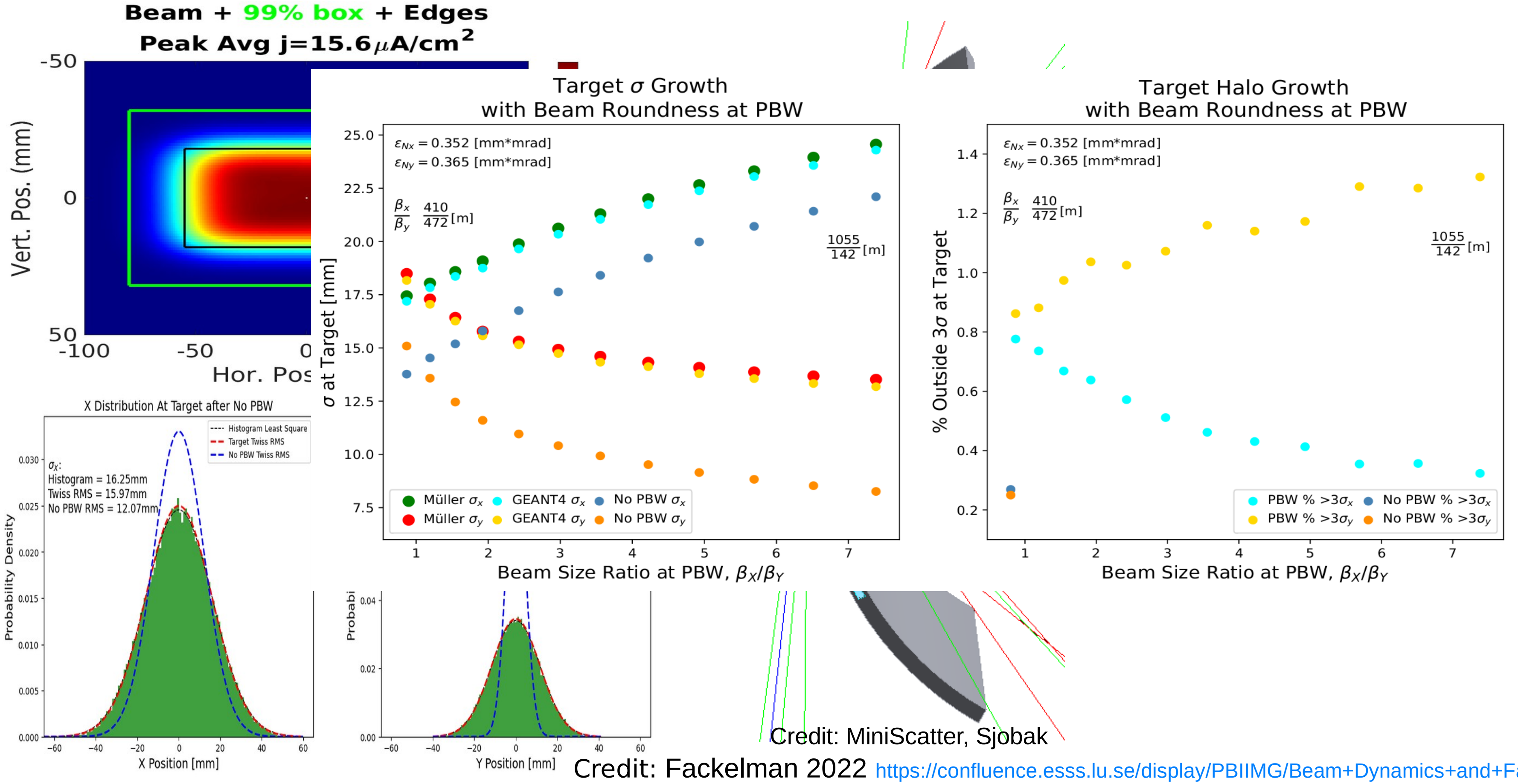

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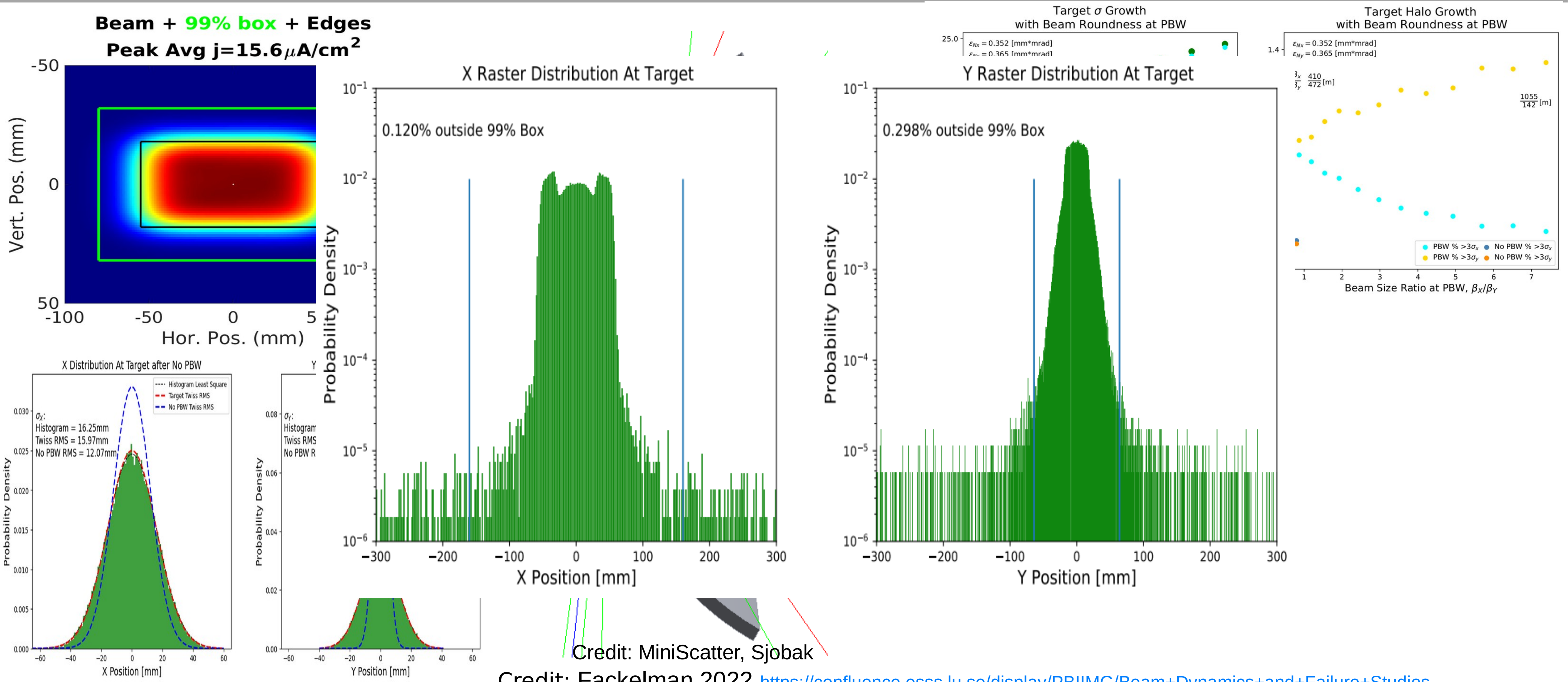


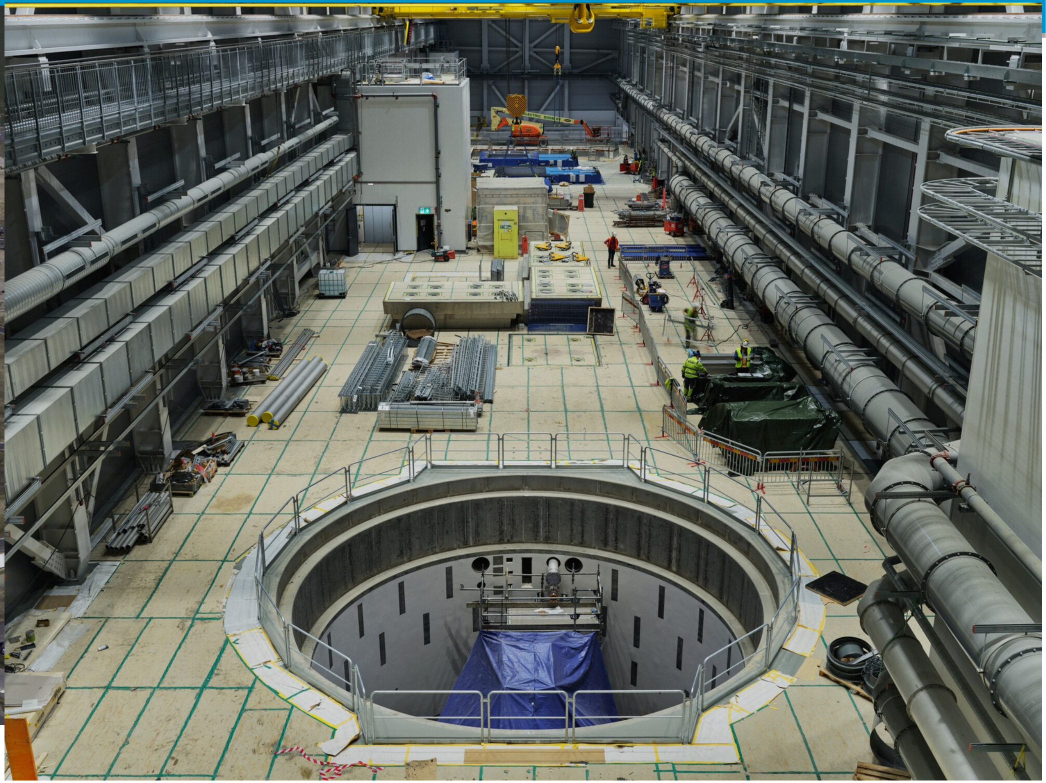
Credit: MiniScatter, Sjobak

Credit: Fackelman 2022 https://confluence.esss.lu.se/display/PBIIMG/Beam+Dynamics+and+Failure+Studies

Current Stage

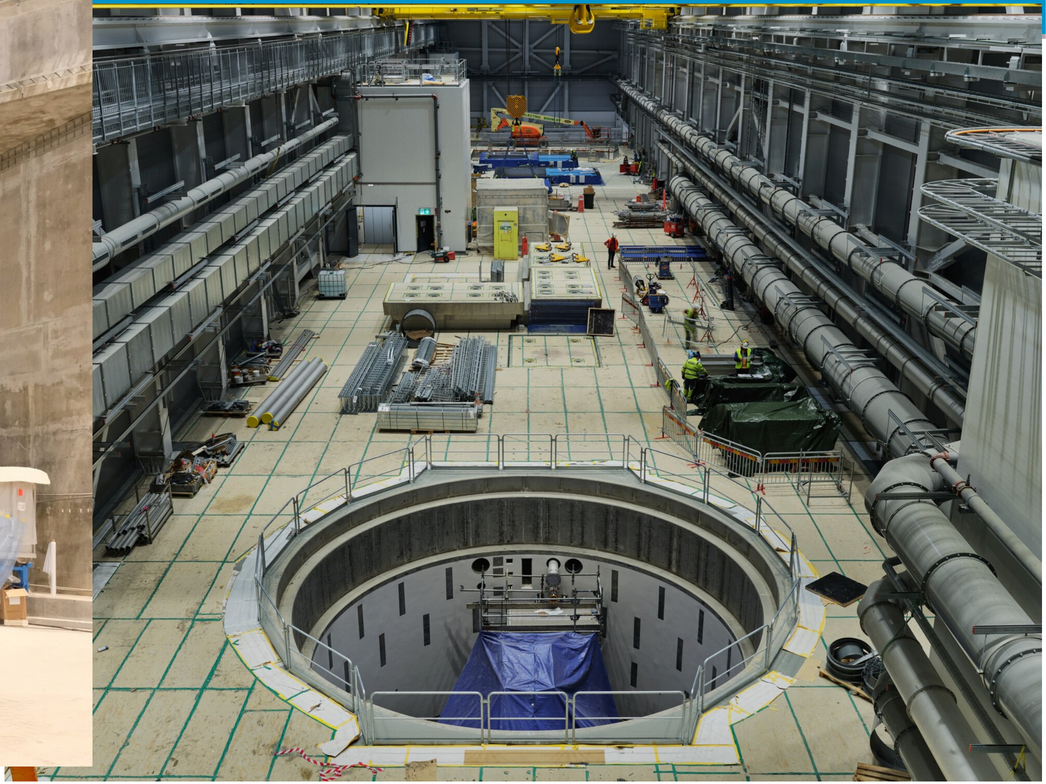
Credit: https://europeanspallationsource.se/media-bank

Current Stage



Credit: https://europeanspallationsource.se/media-bank

Current Stage



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Current Stage: UiO ESS Visit June 2022

EUROPEAN SPALLATION SOURCE

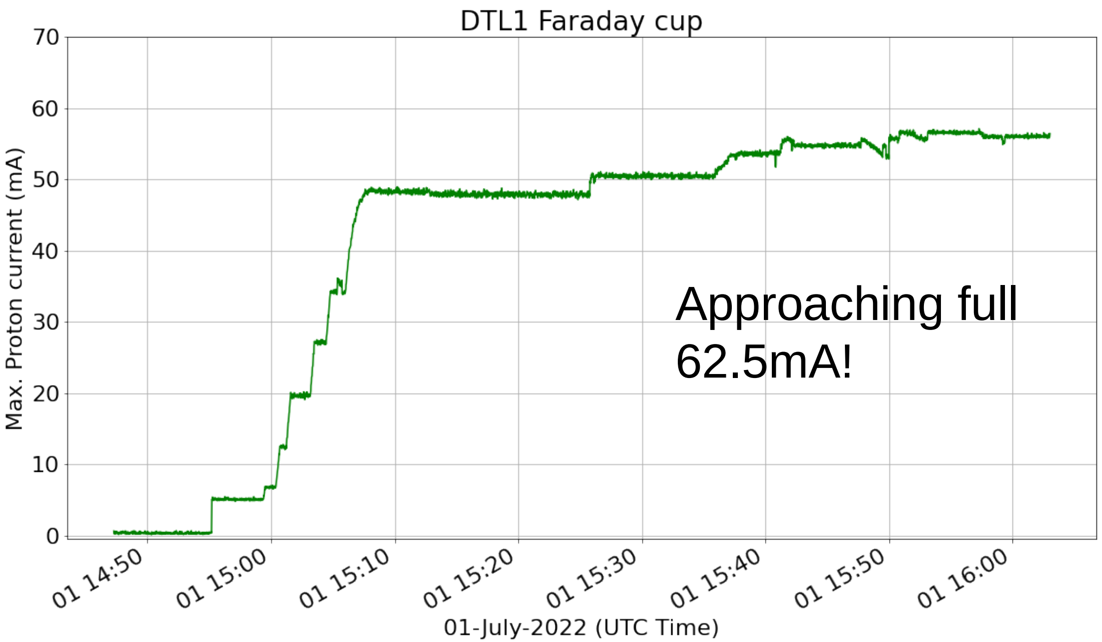
Credit: Fackelman 2022

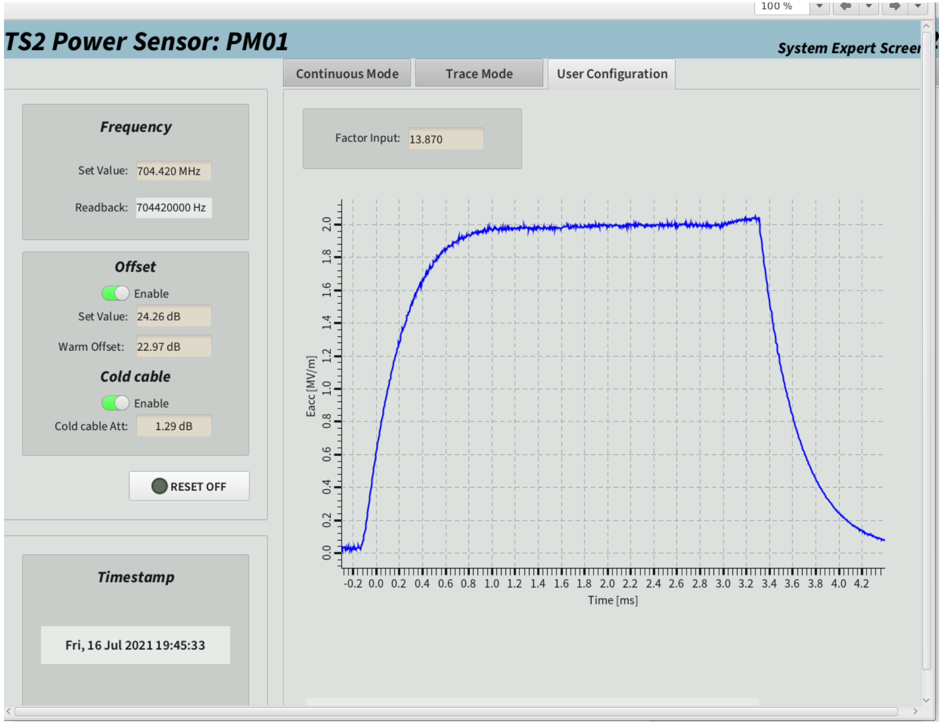
Current Stage: UiO ESS Visit June 2022

EUROPEAN SPALLATION SOURCE

Credit: Fackelman 2022

Current Stage: Beam Commissioning





~3ms pulse!

Credit: https://confluence.esss.lu.se/category/acc

Current Stage: Coating of Target Wheel

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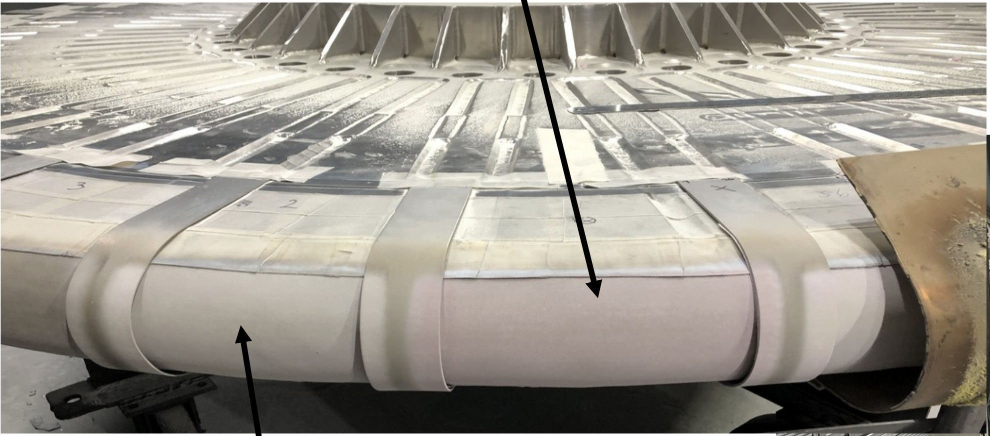
ESS Chromia Alumina



Brodmann Chromia Alumina as in SNS

ESS YAG

Credit: Thomas May 2022

Coming Soon…

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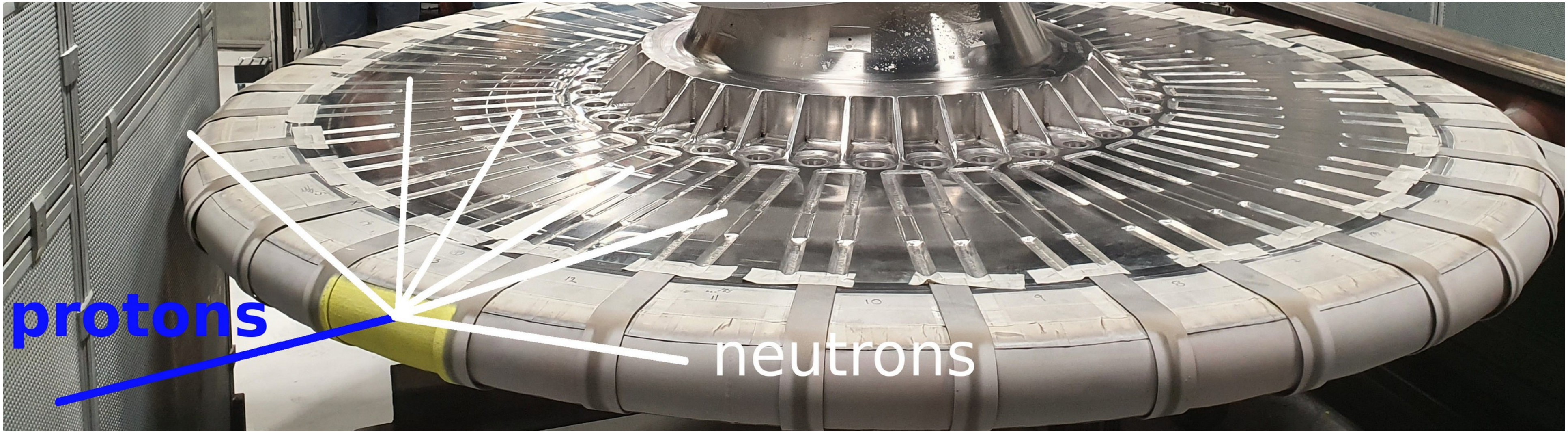
Coming Soon…

EUROPEAN SPALLATION SOURCE

Beam On Target!!!



Originally planned for December 2019, now looking like June 2024

ESS is committed to all instruments being operational by 2028

Norway's Future Involvement in ESS?

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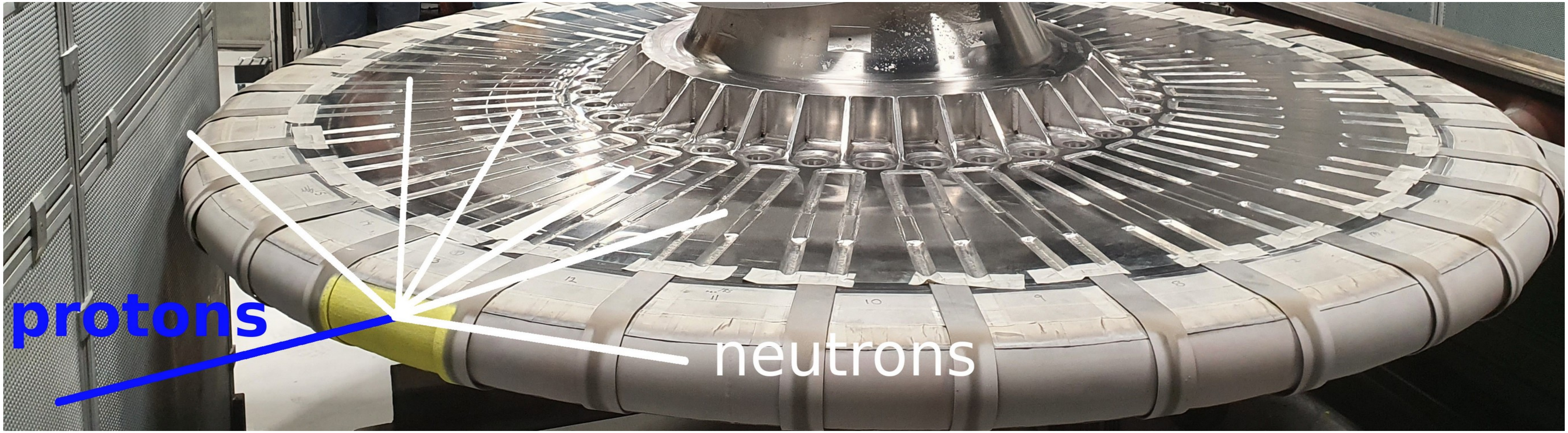
Beam On Target!!!



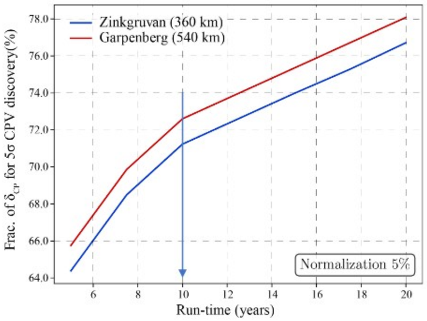
Originally planned for December 2019, now looking like June 2024

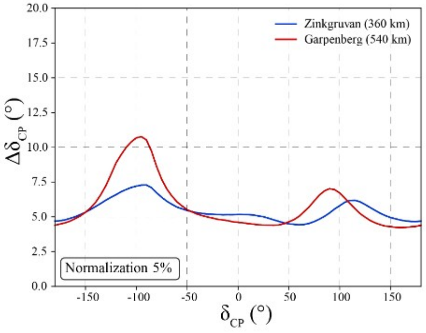
ESS is committed to all instruments being operational by 2028

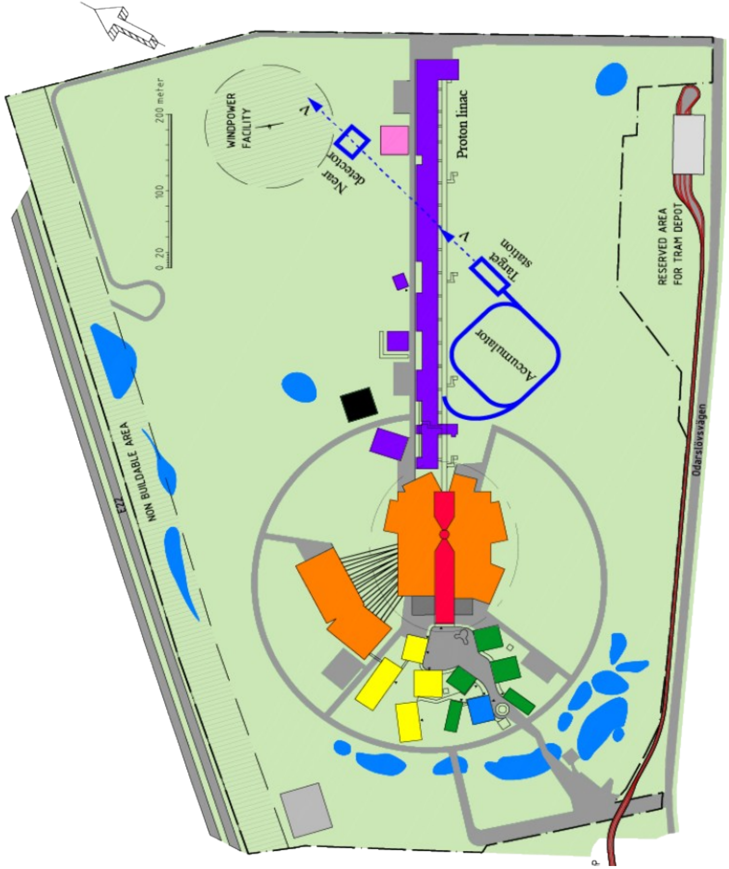
Extras

Extras ESS → ESSvSB

- ESS (construction of buildings and landscape is completed)
- ESSvSB [3M€ from 2018 - 2022]
  - Aim: feasibility study of producing neutrinos from protons at the ESS linac and measure oscillations at the 2nd maximum with large water Cherenkov detectors in existing mines in northern Sweden
  - Outcome: A Conceptual Design Report (CDR) published on June 6th 2022 [arxiv:2206.01208]
    - After 10 years of data taking **covering more than 70% of δ_{CP}** with a confidence level of more than 5σ to reject the no-CPV hypothesis
    - Measurement **precision of δ_{CP} is better then 8°** for all δ_{CP} values



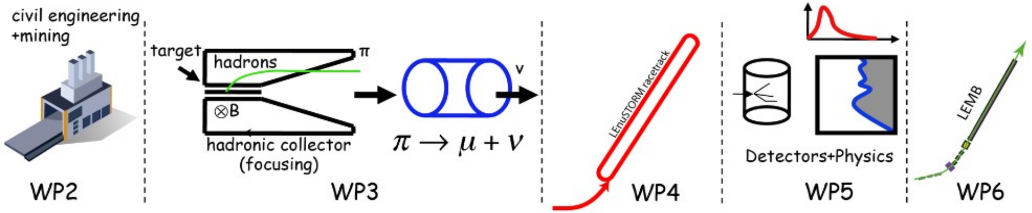


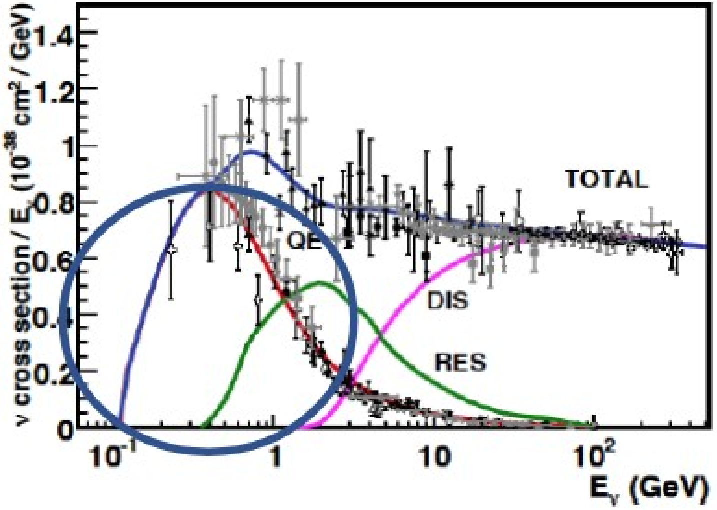


Credit: Eirik Gramstad

Extras ESS → ESSνSB+

- ESSνSB+ [3M€ through Horizon Europe - 4 years]
  - accepted by EU in June this year
    - Study of civil engineering at ESS and mining
    - Low energy (LE) nuSTORM facility which will provide ν_e and ν_μ beams from the decay of low energy muons confined within a storage ring
      - measure cross-sections [low energies]
      - sterile neutrinos
    - Low energy monitored neutrino beam (LEMNB)
      - Investigate Cross-sections!
    - Explore additional physics opportunities with LEnuSTORM and LEMB





ESSνSB+ provides a strong physics programme in the construction phase of ESSνSB

Credit: Eirik Gramstad

Extras

Oslo personnel involved in the ESS In-Kind delivery.

The ESS project:
Utilizing a **broad spectrum of Oslo resources**. Increasing Oslo competence for future participation in accelerator projects.

The Electronics laboratory

Elektronikklaboratoriet er en fellestjeneste for hele instituttet, og har kompetanse på blant annet utlegg og bestykning av komponentbærere og bruk av avanserte DAK-verktøy og kretskortdesign. Ved laboratoriet jobber vi blant annet med instrumentering av vitenskapelige raketter og satellitter, og vi har lang erfaring som leverandør av produkter og tjenester til CERN.

Røhne, Ole Myren
Forsker
(Part of the high-energy physics section)

Co-manager for the electronics and software part of the project.

Supports us for :
- Electronics architecture
- Software development
- FPGA developments
- Coating tests hardware

Dorholt, Ole
Senioringeniør

Bang, David Michael
Head Engineer

Oslo project management

Gjersdal, Håvard
Forsker

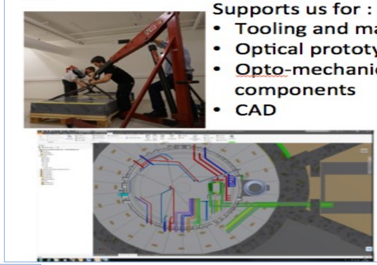
- Daily leader for the Oslo in-kind contribution.
- Optical system and coating development.
- Employed 100% by the project (as only person), for the full project period.

Adli, Erik
Associate Professor

- Responsible for the Oslo in-kind contribution. Overall Project manager.
- Schedule, budget and resource control.
- Representing in ESS boards and committees.

The Instrument Workshop

Verkstedet samarbeider med alle de vitenskapelige gruppene ved instituttet. Instrumentmakerne lager blant annet utstyr som benyttes i raketter og satellitter, og er underleverandør til flere eksperimenter ved det europeiske forskningssenteret CERN.



Supports us for :
- Tooling and machining
- Optical prototype
- Opto-mechanical components
- CAD

Borg, Hans
Avdelingsleder

Ringnes, Jonas
Avdelingsingeniør

Lithun, Maren Charlotte
Overingeniør

The Oslo XRD laboratory

Wragg, David
Senioringeniør
Laboratory Manager
Norwegian National Centre for X-ray Diffraction and Scattering

X-rad diffraction performed on different coatings (before and after irradiation), in order to examine crystal structure.

HV samples
The eta-alumina phase probably has a significant level of stacking defects. Strong preferred orientation of Al substrate in the (001) direction. Main variation is in the corundum to eta-alumina ratios.

	weight %			Lvol-IB size (nm)		lattice parameters (Å)			Rwp
sample	corundum	eta alumina	aluminium	corundum	eta alumina	corundum a	corundum c	eta alumina	
HV1	41.0(4)	53.6(4)	5.4(2)	61.1(13)	18.2(6)	4.7587(12)	12.9935(5)	7.8965(3)	19.55
HV3	9.8(4)	77.5(4)	12.7(2)	54(5)	17.7(5)	4.7595(3)	12.9933(13)	7.8960(4)	21.77
HV7	55.0(4)	36.4(4)	8.55(13)	69(1)	22.5(8)	4.75858(8)	12.9939(3)	7.9011(3)	17.83
HV10	3.6(3)	83.6(4)	12.8(2)	55(11)	17.2(4)	4.7592(6)	12.988(3)	7.8953(4)	21.13

Allows, for example to quantify % of Alumina phase (scintillating alpha phase, vs. eta-phase)

Instruments at the XRD lab

The X-ray laboratory has facilities for powder and single crystal X-ray diffraction (XRD) which are open to all SMN students and researchers.

The X-ray laboratory is located in room ØU34 in "Kjemibygningen", the Dpartment of Chemistry..

APEX
Our single crystal XRD instrument. A Bruker D8 3-circle diffractometer with area detector and nitrogen cryostat.
Read more...

D500
High temperature XRD. Fitted with a furnace. Rather old.
Read more...

DIFF 1
Transmission powder XRD. Usually in capillary mode but can also be used for flat plate transmission measurements.
Read more...

DIFF 2
Surface diffraction. Bruker D5000 with parallel beam Goebel mirror optics. Used for Grazing incidence diffraction and reciprocal space mapping. Contact the instrument responsibles for more information and to get trained

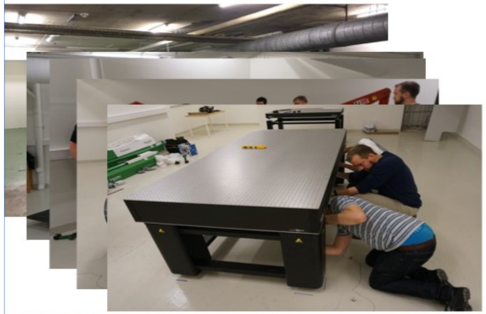
DIFF 3
Our powder XRD workhorse. A Bruker D5000 in Bragg-Brentano geometry (flat plate reflection) with a 40 position robotic sample changer. Running more or less continuously for 15 years!
Read more...

Huber
Low and high temperature transmission powder XRD. Guinier Camera with image plate.
Read more...

Credit: Adli Nov 2017

New accelerator development lab. infrastructure

Will be used for Optical system prototype, laser tests and, in future, other accelerator development.



Danielsen, Kjell Martin
Senior Engineer

Purchasing.

Loose, Dag Magnus
Principal Engineer

Room manager.

- **Room and refurbishment contribution to the project from the Department of Physics**
- **Thanks to everyone who worked hard to get the new lab in good shape for the ESS visit!**

The Oslo Cyclotron Laboratory (OCL)

- OCL houses the only rese archaccelerator in Norway, a MC-35 Cyclotron (p, d, ^{3}He, ^{4}He, up to 35 MeV p). The laboratory serves as an experimental center for various fields of research and applications
- OCL has been very welcoming to our project, very good collaboration!
- Proton test beams available during proton runs (parts of the year).

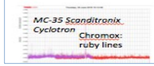
Görgen, Andreas
Professor

Semchenkov, Andrey
Senior Engineer - Nuclear and Energy Physics

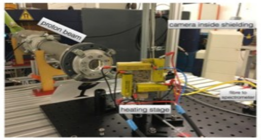
Siem, Sunniva
Professor

Müller, Jan Christian
Senior Engineer

Sobas, Pawel Andrzej
Head Engineer

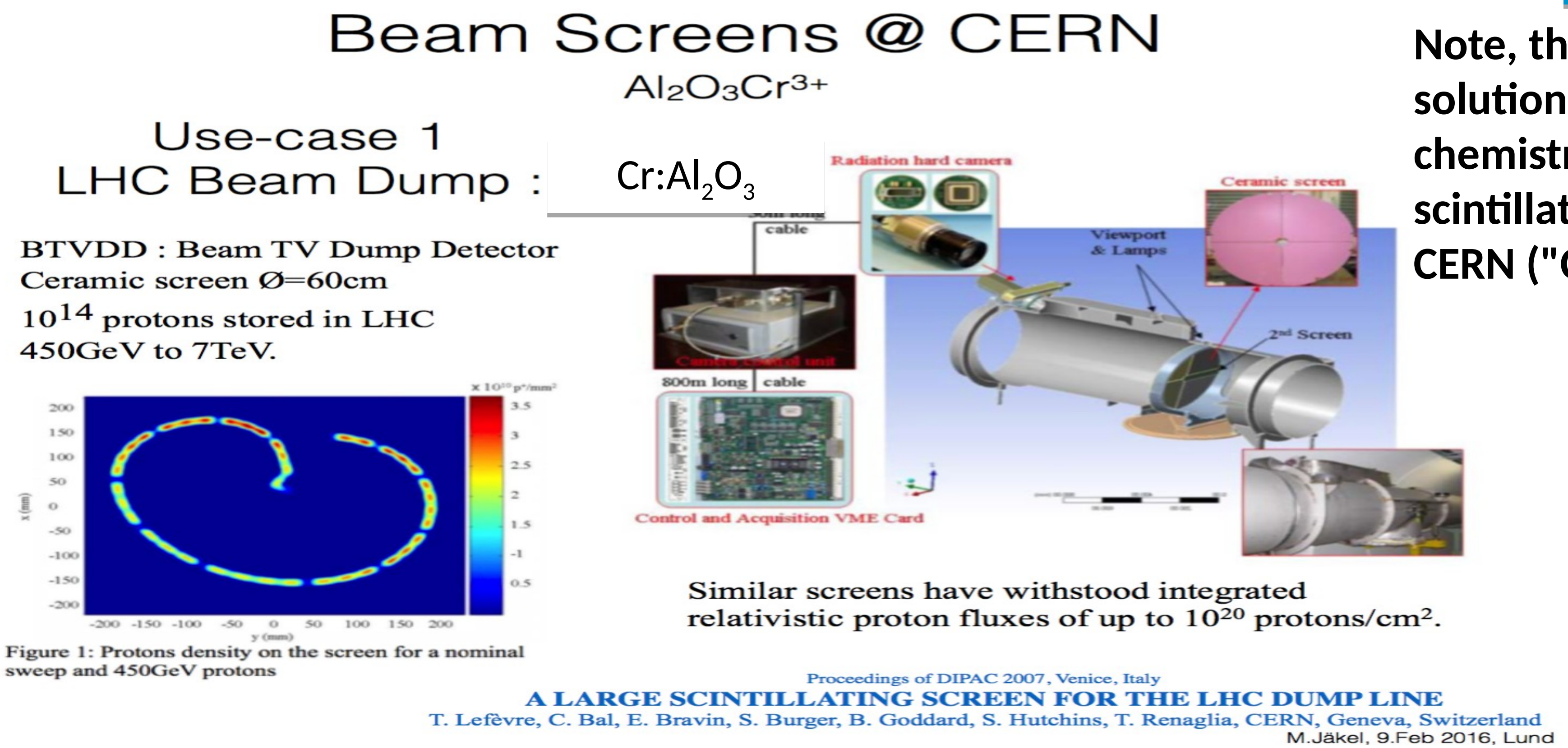


OCL Beam set-up



- ***Successful testing campaign completed May-June 2016***
- ***Hoping for more beam***

Extras



Note, the baseline solution : same chemistry for scintillators as used at CERN ("Chromox")

The accelerator community, worldwide, seems to have not pushed scintillator development the last few decades. Opportunity to make progress?

Credit: Adli Nov 2017

Extras Other risks to the system

- Target atmosphere specifications changed (or, concretized) from 1 atm He, to "0.1 – 1 mbar air". Not received any formal specification document (still under discussion?)
- Poor vacuum has seemingly lead to corrosion at SNS and KEK
- At SNS the corrosion has lead to critical failure of their imaging system
- Protective coating may help, however, risk for schedule delay
- Strategy: tests of protective coating (acid, radiation) together with SNS

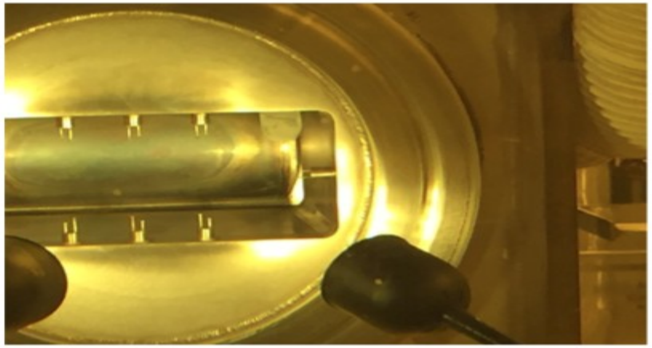


Figure 1: Image of the first mirror of SNS target imaging system, taken on the hotcell after been removed from its plug. The mirror in the top right corner is totally corroded.

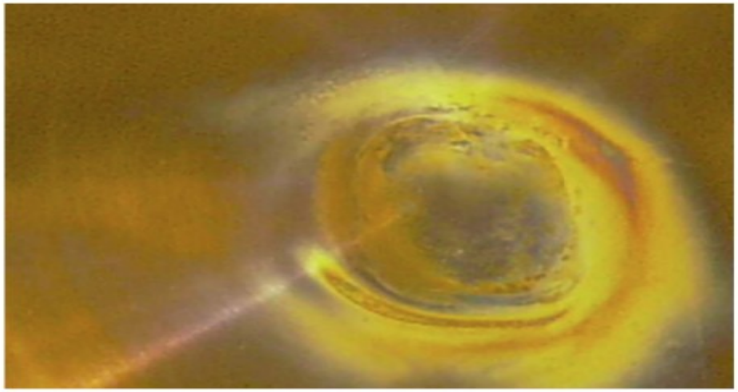


Figure 2: T2K Beam Window replaced after 1.8 DPA. Visual inspection shows corrosion.

Credit: Adli Nov 2017

Extras Studies and selection of optimal cameras: target

Main criterion for target systems: maximize sensitivity.

x 10 more expensive than for dump: several factors better sensitivity, different interface (CameraLink)

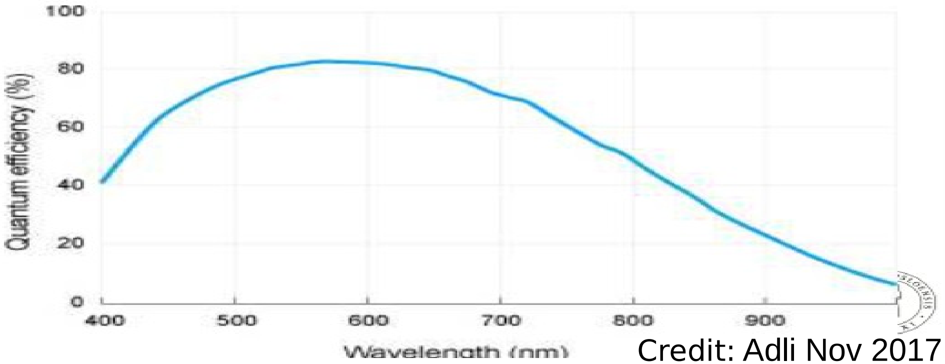
Features and specifications

Sensor type	Hamamatsu sCMOS
Quantum efficiency	82 % @ 560 nm
Pixel size	$6.5 \times 6.5 \mu m^2$
Pixel count	2048×2048
Full well capacity	30 ke^- (typ)
Readout noise	1.4 e^- (rms)
Resolution ADC	16 bit
Interface	Camera Link, USB 3.0
Frame rate	30 — 100 fps

ORCA:Flash

Baseline low-noise camera

Unit cost: 12 kEUR. Integrating the camera, including the Camera Link (or USB 3.0) interface represents a significant effort on behalf of the ICS team.



Testing/prototyping: Allied Vision Manta G-419B

Unit cost: 2 kEUR. GigE Vision interface already integrated.
Resolution 4 Mpix, pixel size $5.5 \times 5.5 \mu m^2$.
Full well 13.5 ke^-, noise floor 13 e^-. Dynamic range 60 dB, much below the ORCA-Flash4.0.

Credit: Adli Nov 2017