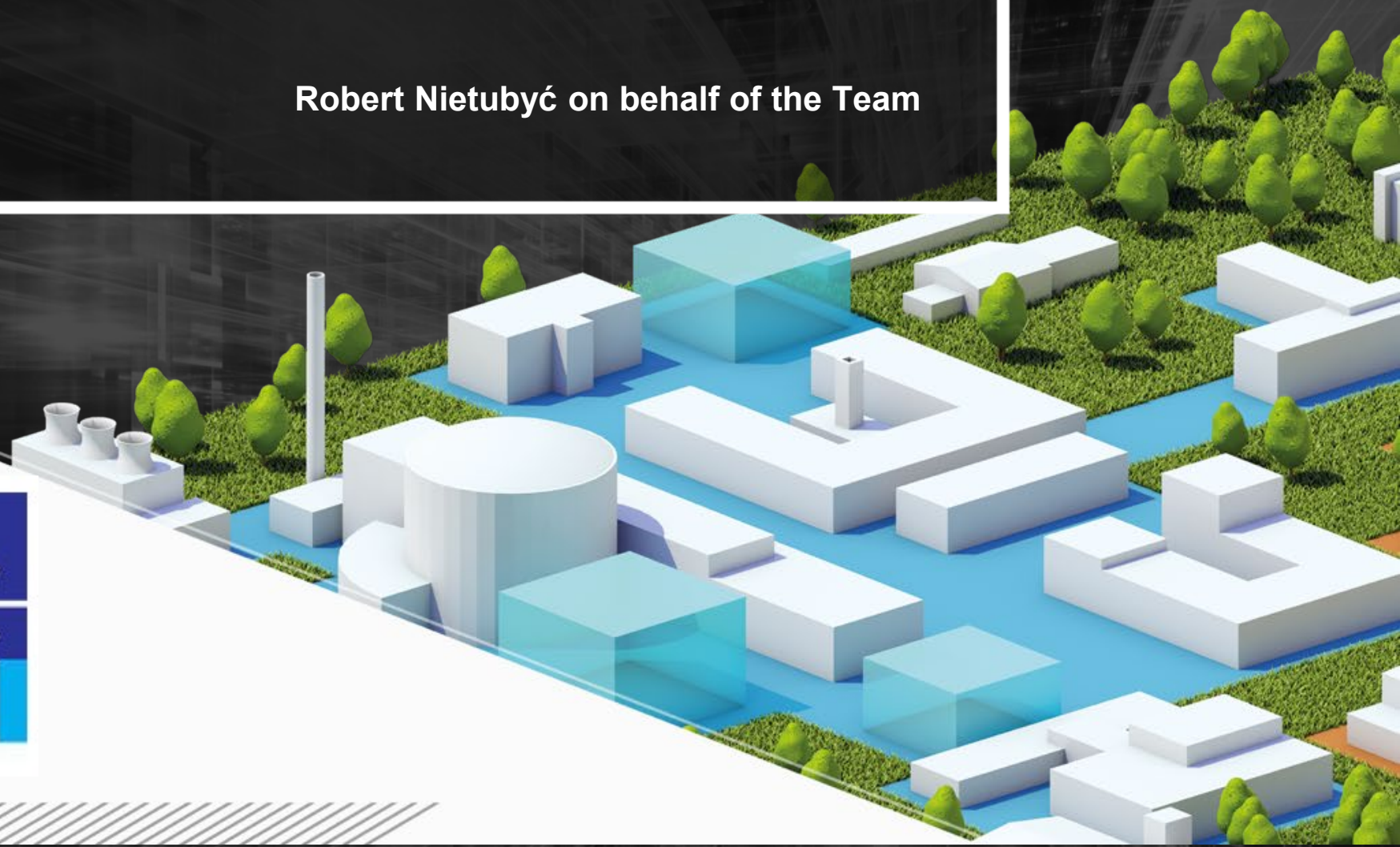
Overview of beam diagnostics for PolFEL

Robert Nietubyć on behalf of the Team



PolFEL will be a THz – VUV ranged FEL fed with 180 MeV SRF Tesla type linac, operated in cw and lp modes.

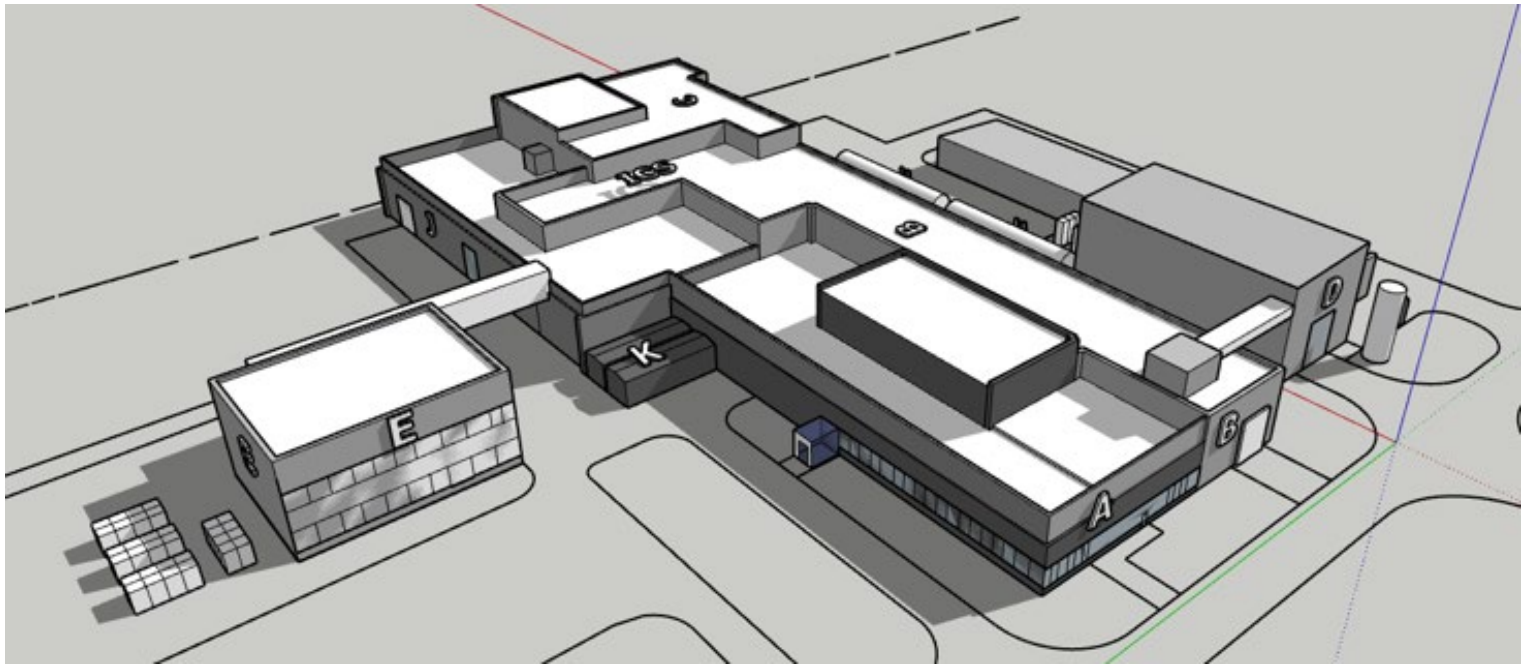
In addition, it will contain an inverse Compton Scattering gamma ray source, ultra-fast electron diffration station, SRF cryomodules test stand, and auxiliary laboratories: magnetic measurements, photocathode and laser, clean assembly room.

Goals:

- **having a light source**
- **establish an accelerator laboratory**

Consortium

- ❑ National Centre for Nuclear Research
- ❑ Military University of Technology - beamlines
- ❑ Warsaw University of Technology - LLRF
- ❑ Technical University Łódź - synchronisation
- ❑ Jagiellonian University -e beam diagnostics, survey
- ❑ Wrocław University of Science and Technology -cryogenics
- ❑ University of Zielona Góra – HVAC
- ❑ University of Białystok - inverse Compton scattering station



Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
ŚWIERK
instytut kategorii A+, JRC collaboration partner

Warsaw University of Technology

Lodz University of Technology

JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS
NATIONAL SYNCHROTRON RADIATION CENTRE

UNIVERSITY OF ZIELONA GÓRA

Wojskowa Akademia Techniczna

UNIVERSITY OF BIALYSTOK

Wrocław University of Technology

polfel

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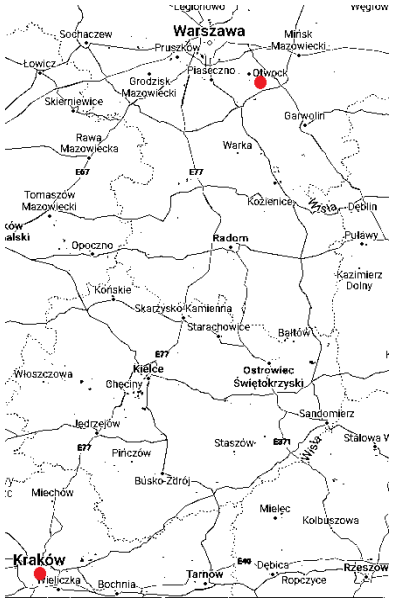
National Centre for Nuclear Research, Świerk in Otwock,

30 km SE from Warsaw, 300 km NE from Kraków



Project is supported by UE with the Smart Growth Operational Programme

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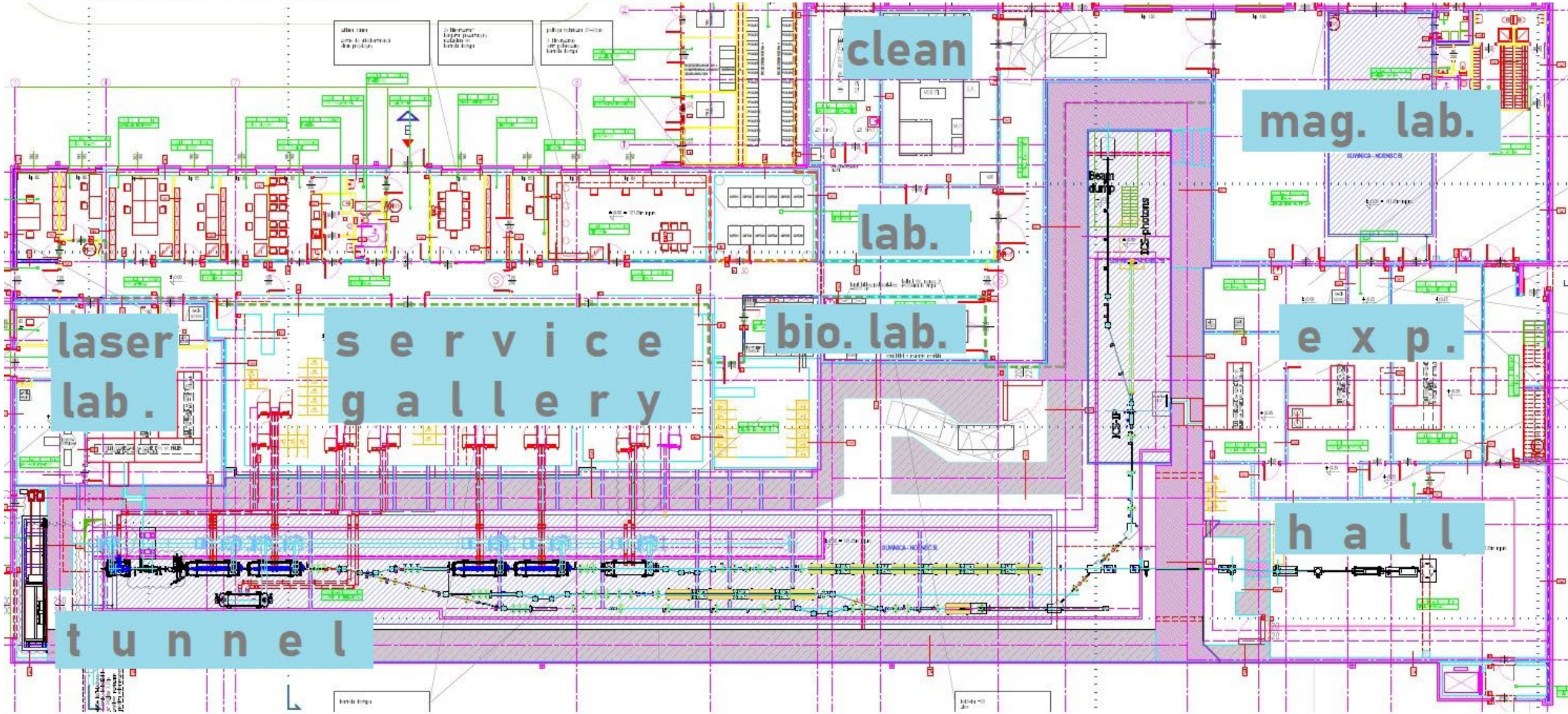
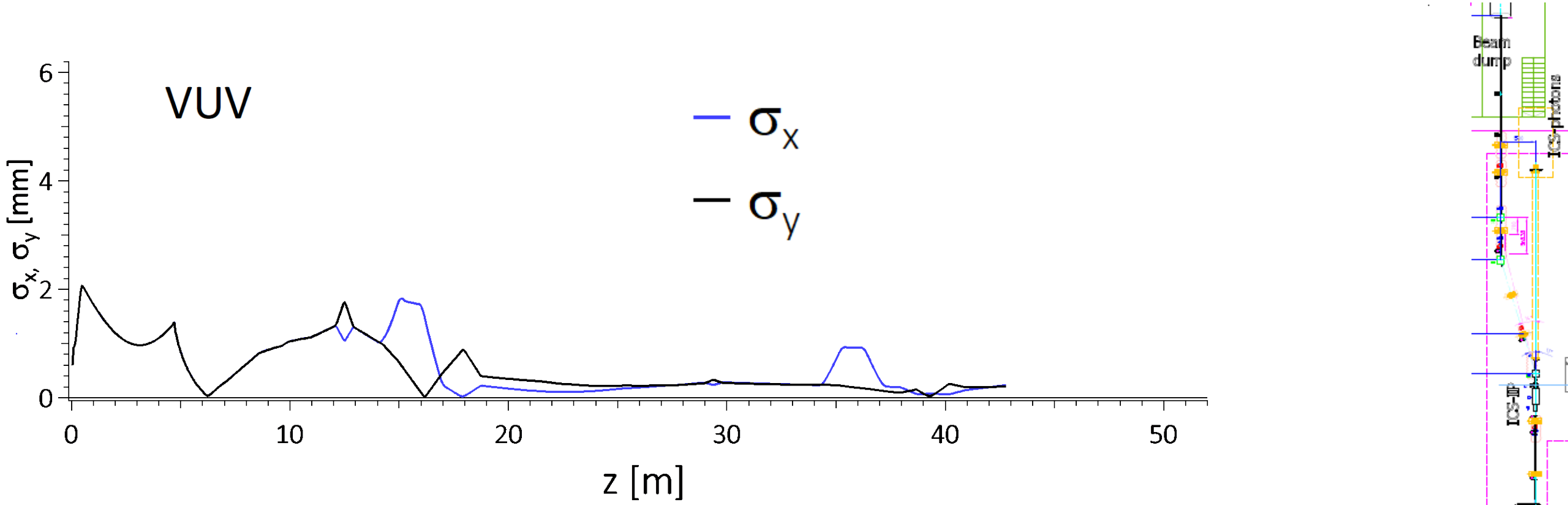
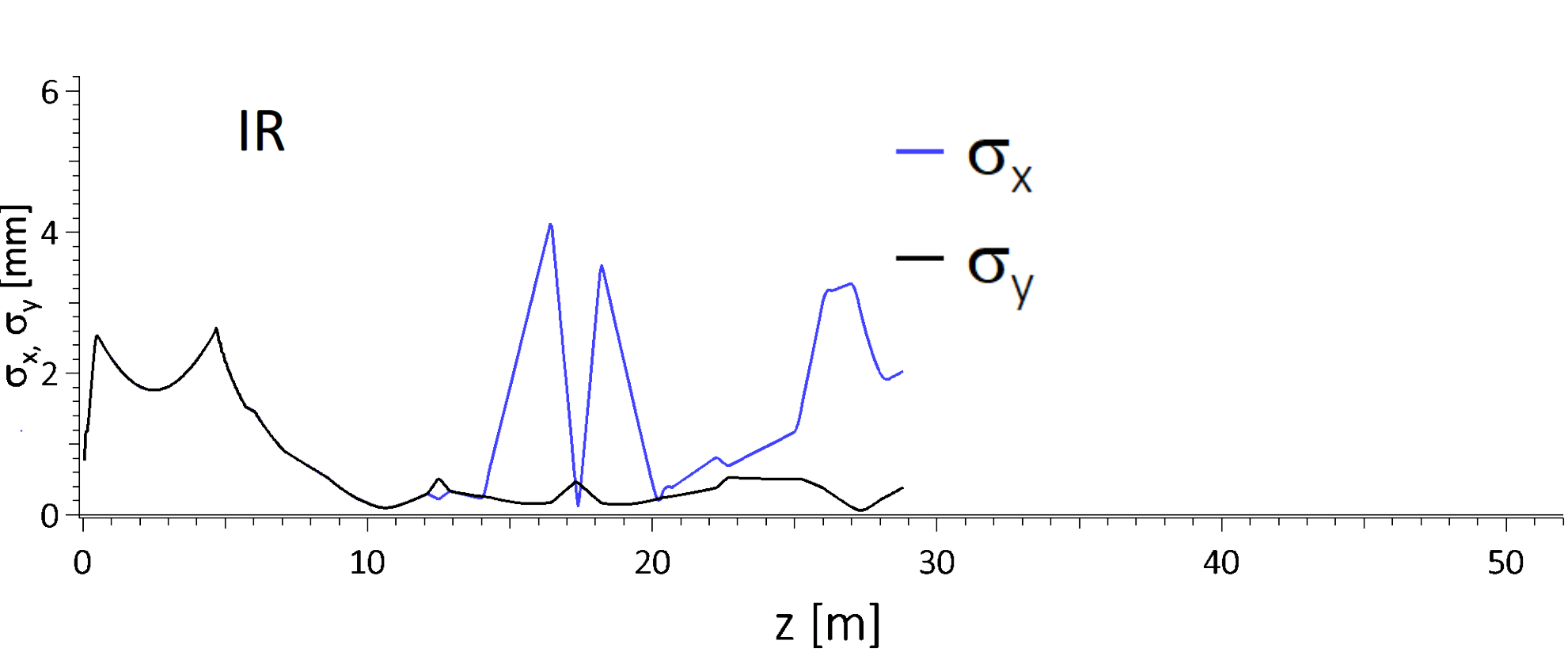
polfel

Main building

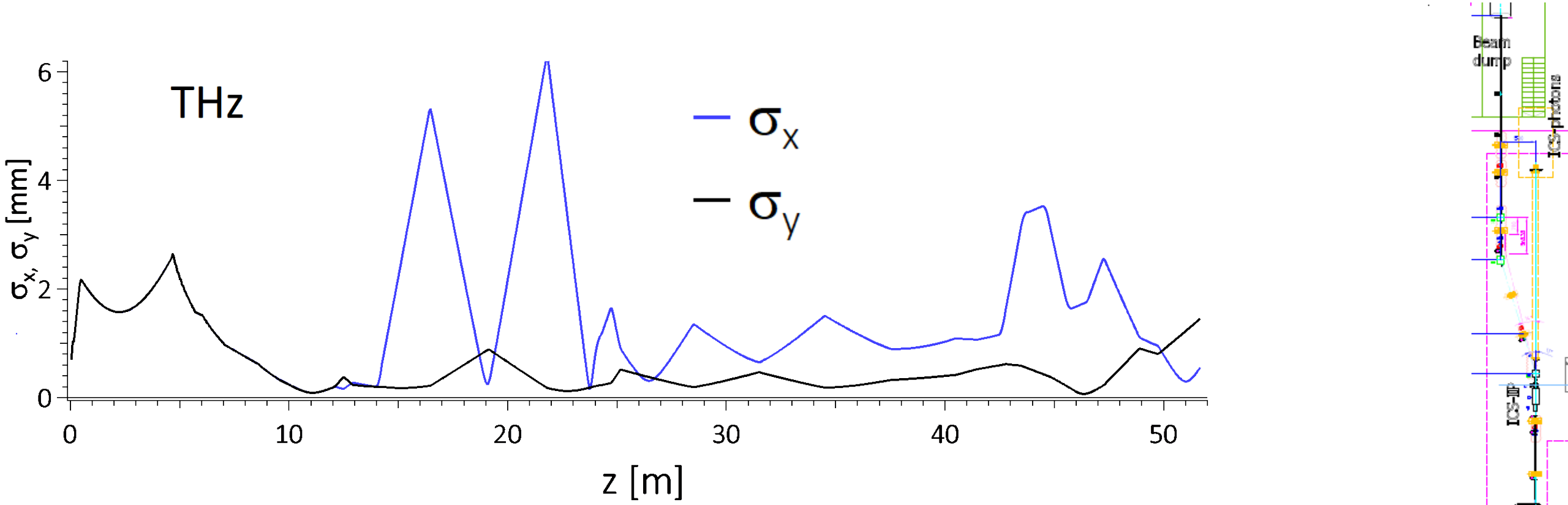



VUV
σx
σy
σx, σy [mm]
z [m]
0
2
4
6
0
10
20
30
40
50

Beam dump
IGS-photons
IGS-UP

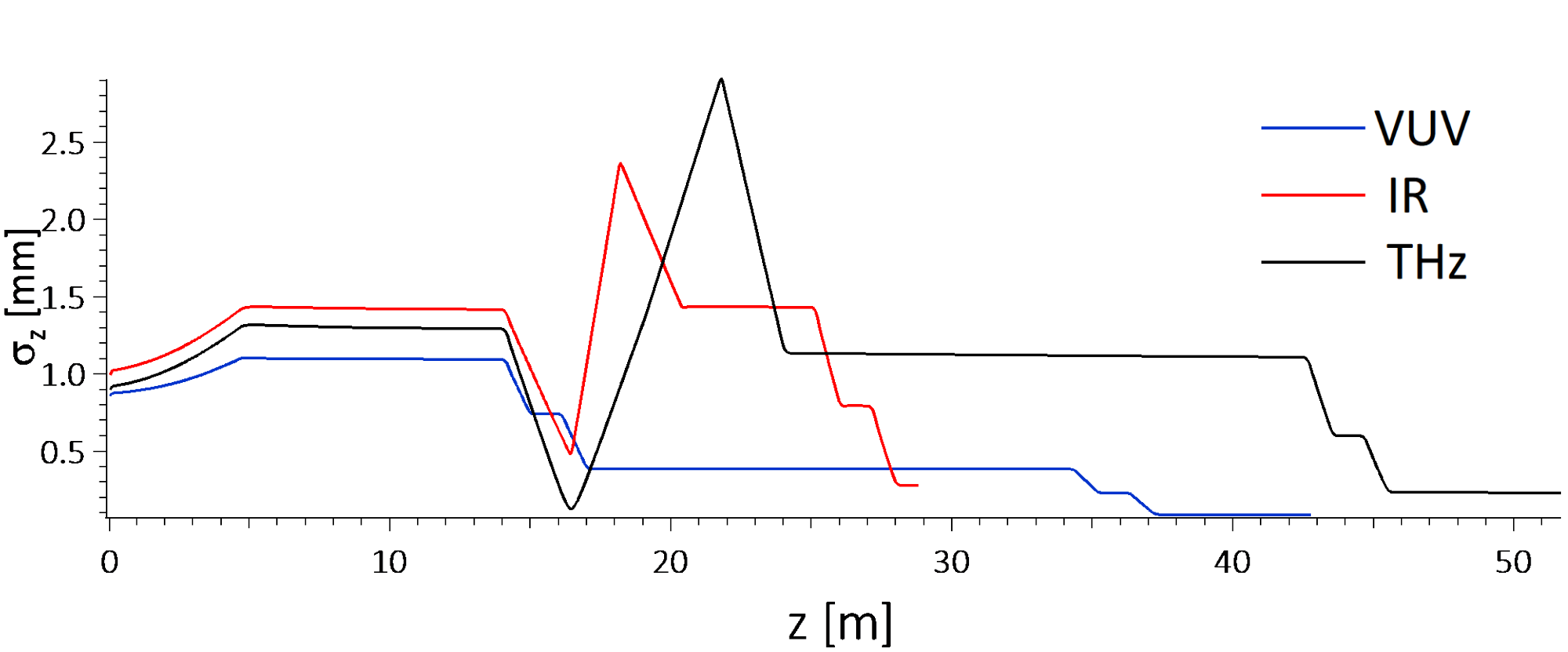

IR
σ_x
σ_y
σ_x, σ_y [mm]
z [m]
0
2
4
6
0
10
20
30
40
50

Beam dump
IP-SI

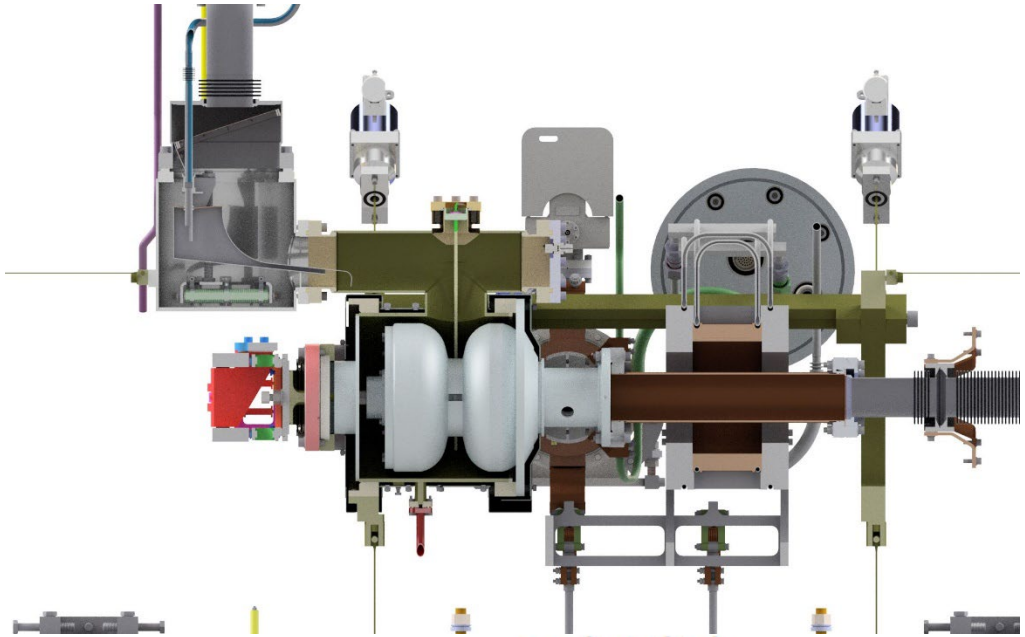

THz
σx
σy
σx, σy [mm]
z [m]
0
2
4
6
0
10
20
30
40
50

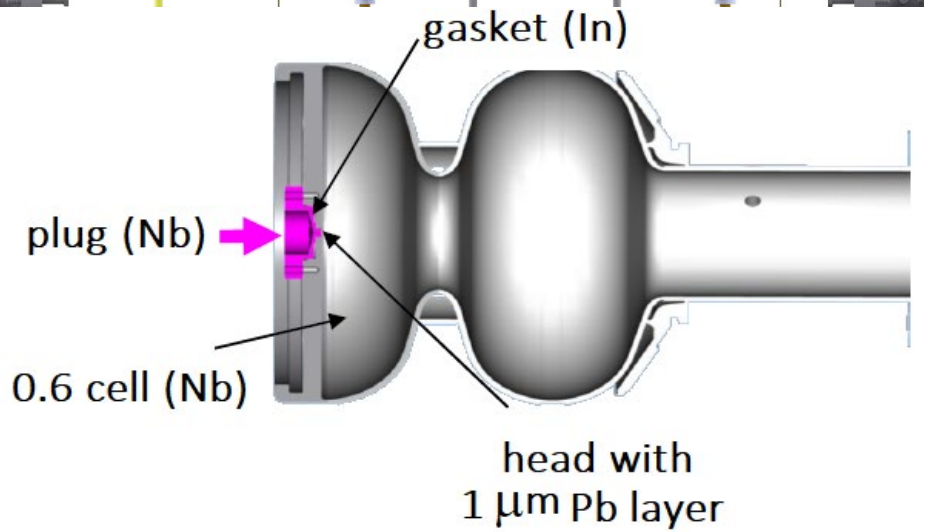
Beam dump
IC-IP
IC-photons

Accelerator

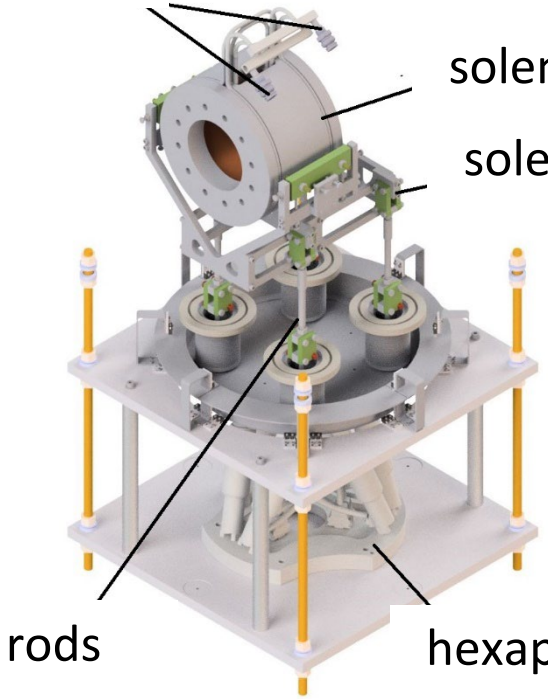


Injector





LHe connections



- QE and its homogeneity and stability in time
- dark current
- plug head retraction and other geometric issues
- UV laser pulse shaping (we aim at a flat top eventually)
- energy excess $h\nu - \Phi$
- use of other materials, even thise normal conducting

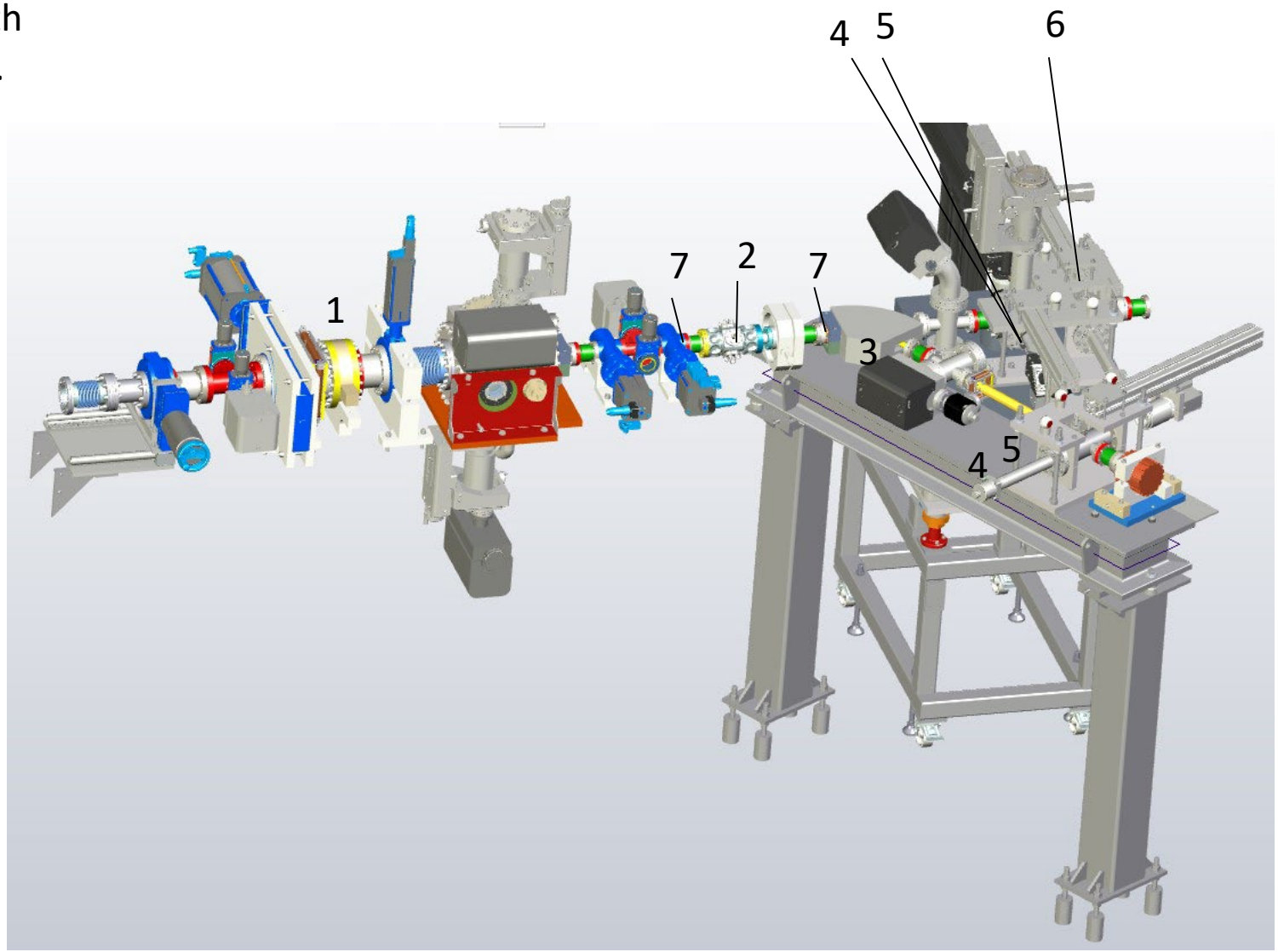
Injector and linac parameters

parameter	value
accelerating frequency	1.3 GHz
accelerating gradient at cw	> 18 MeV
energy behind the injector	4 MeV
energies in IR and THz branches cw	4 MeV - 78 MeV
energies in VUV branches cw	up to 155 MeV
energies in VUV branches lp	up to 187 MeV
Relative energy spread dE/E	$< 5 \cdot 10^{-3}$
repetition rate	50 kHz
UV wavelength	257 nm ± 1.25 nm 4.82 eV ± 0.02 eV
Pb work function	4.25 eV
UV spot size at photocathode	0.45 mm-1.5 mm
UV pulse duration	8 ps – 12 ps
bunch charge	100 pC – 250 pC
bunch length	90 µm – 3 mm
beam transverse dimension	< 6.2 mm at dispersive sections < 2.4 mm at injector section < 2 mm elsewhere
beam pipe Ø (in the most of sites at linac)	16 mm

Injector diagnostics

Initial section of linac will be widely furnished with diagnostic tools for ASG injector characterisation.

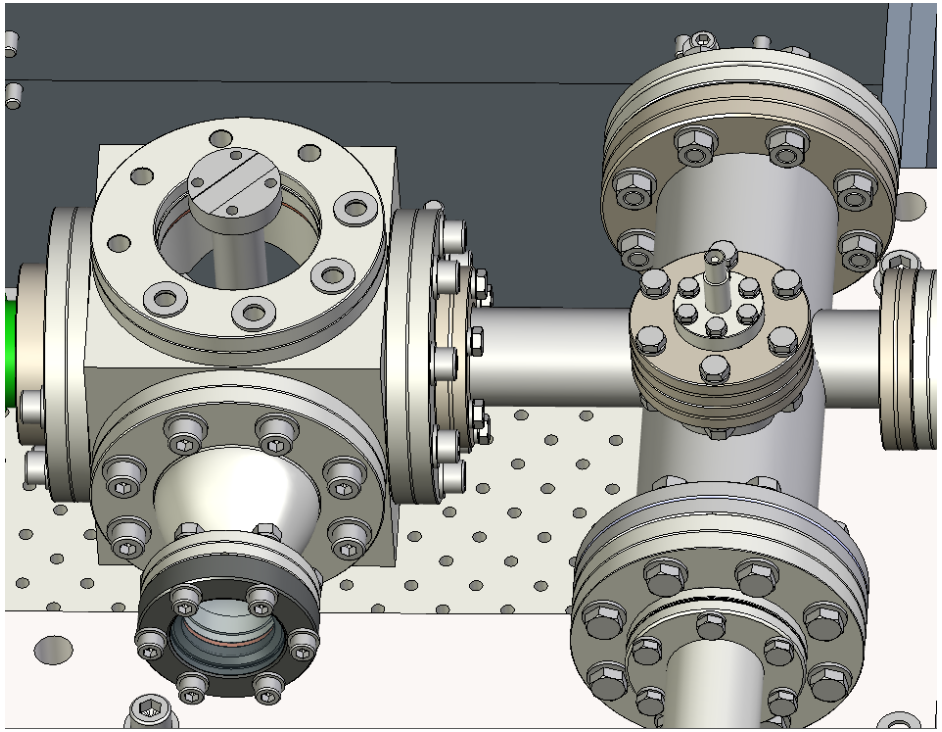
- bunch charge
- position
- energy spectrum
- beam current
- transverse dimension
- length
- emittance

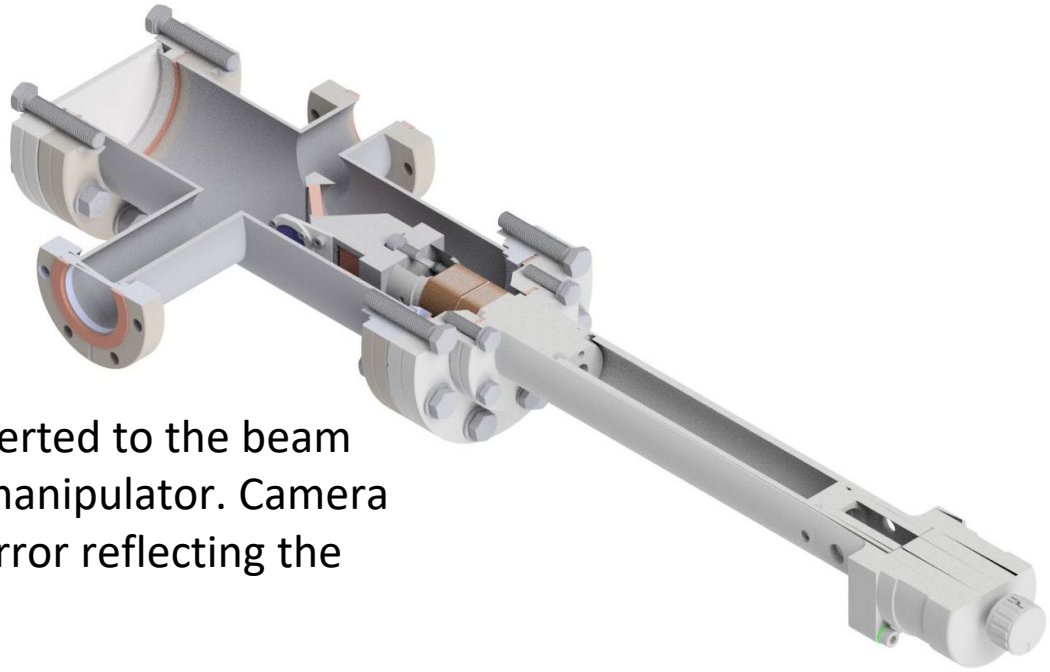


- high resolution current transformer (1)
- BPM (2)
- 60° spectrometer (3)
- two Faraday cups (4)
- two YAG screens (5)
- CDR radiator (6)
- additionally two quads for emittance measurement (7)

YAG, FC and CD radiator chambers (FCY and FCYR)

- FCY is a cylindrical chamber hosting FC and YAG. Its design basd on Solaris documentation. FCY is used in spectrometers.
- FCYR is a connectioin of two parts: FCY and radiator cubic chamber.





YAG or FC is inserted to the beam with two step manipulator. Camera watches the mirror reflecting the screen view

Radiator emits GHz radiation outward to the optical bench settled on the breadboard nearby

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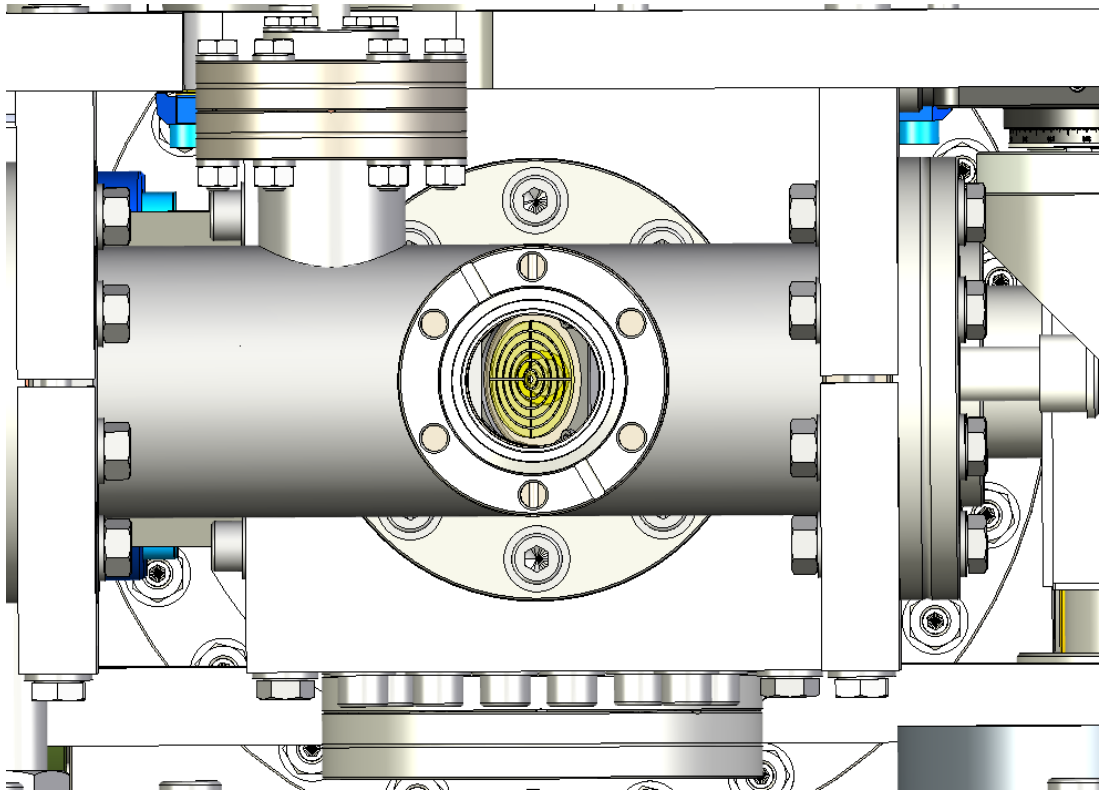

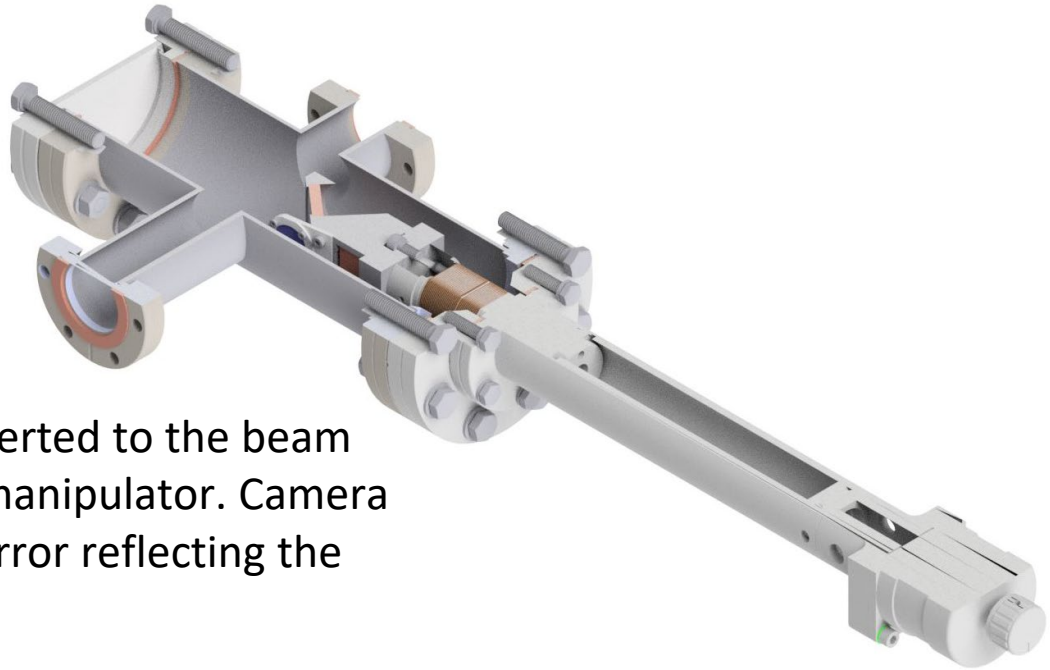

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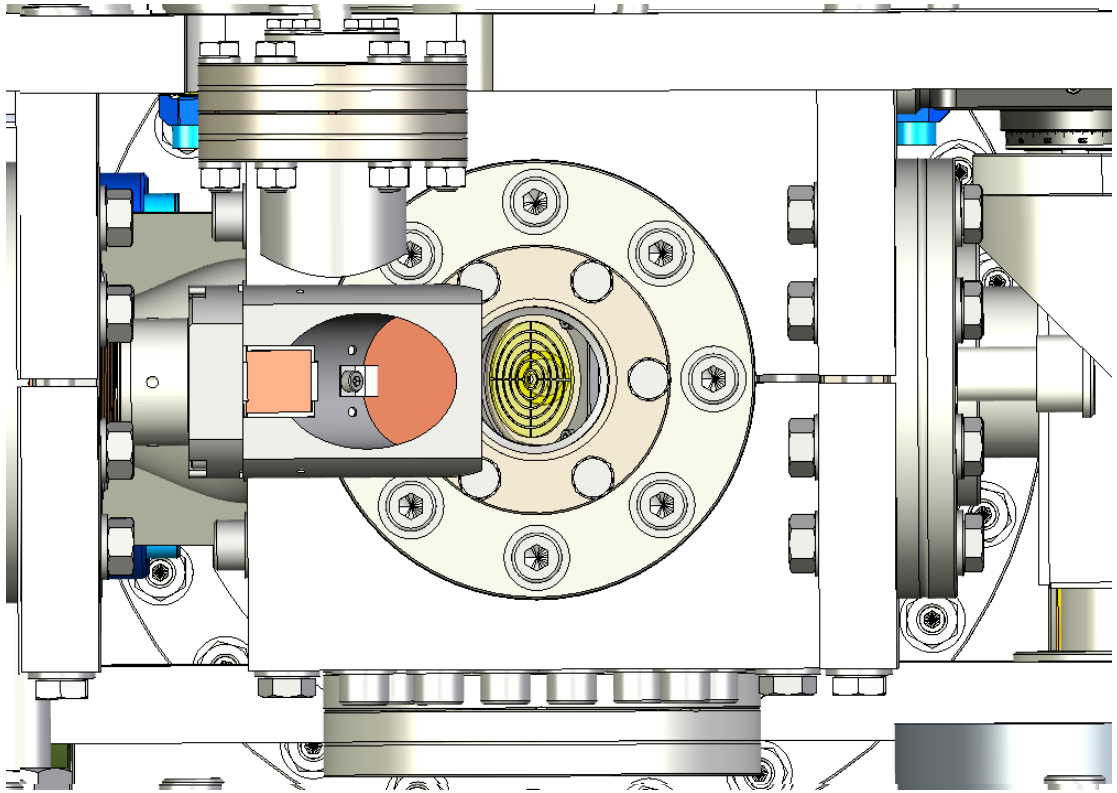

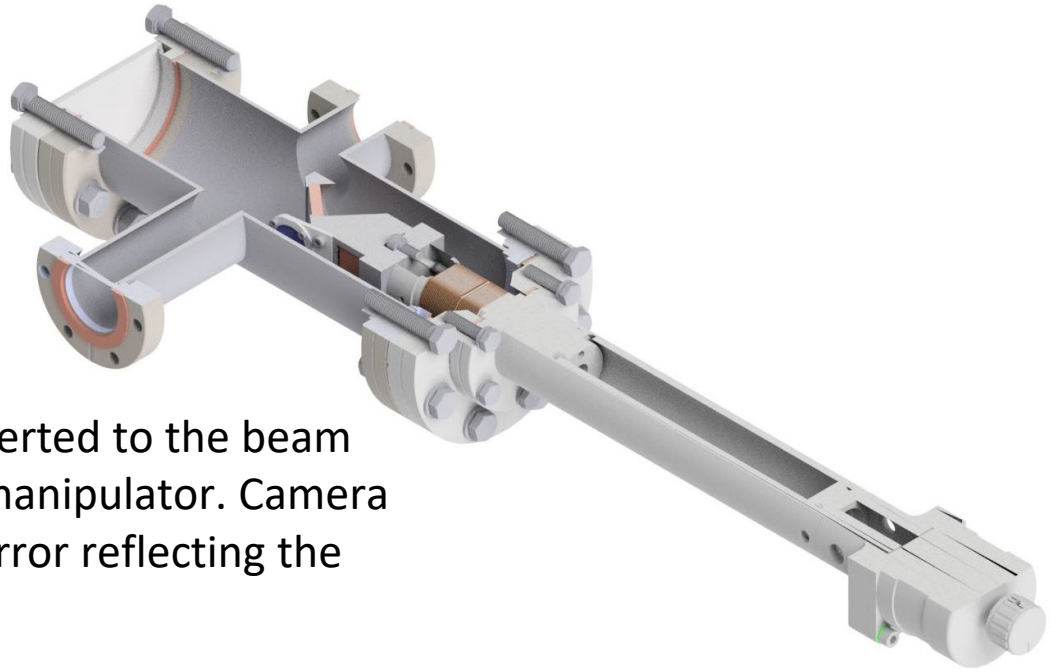

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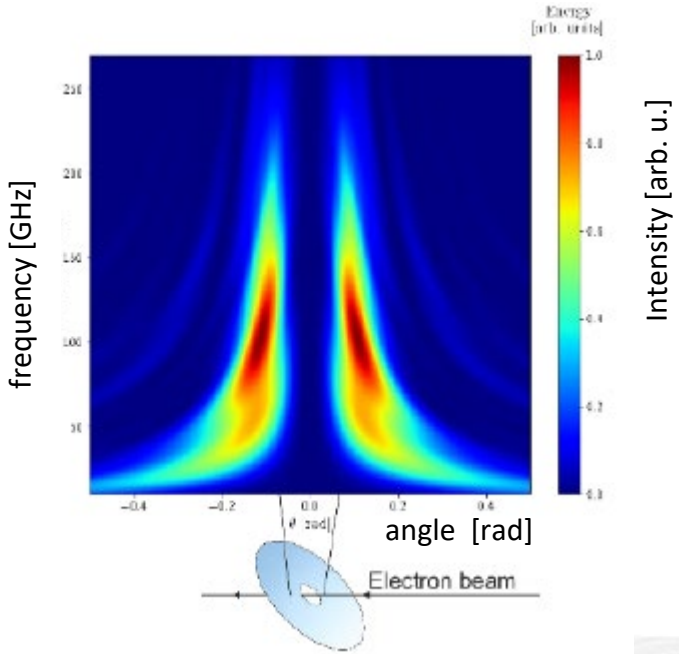
GHz sensing

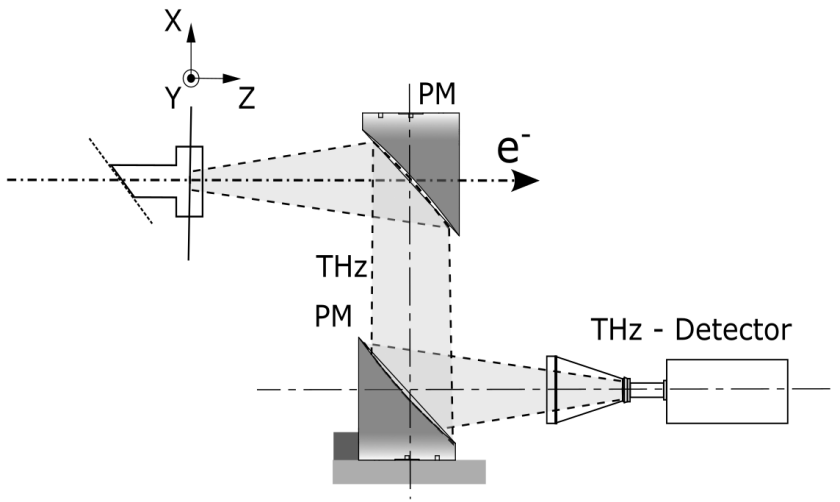
FCYR chambers are located in the injector section, behind the first BC, in front of each undulators chain and in front of ICS-IP. These sites differ in bunch length thus in CDR frequency

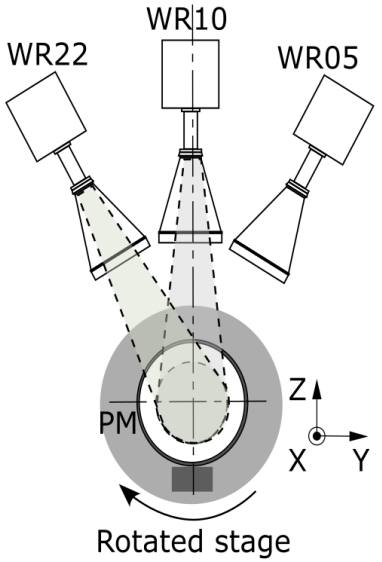
Two methods of signal analysis are being considered:

1. recording the spectrum in wide range with and interferometer and wide range diode
2. comparison of intensities measured in 3 narrow ranges of the spectrum with 3 narrow band diodes

source 1 or 2







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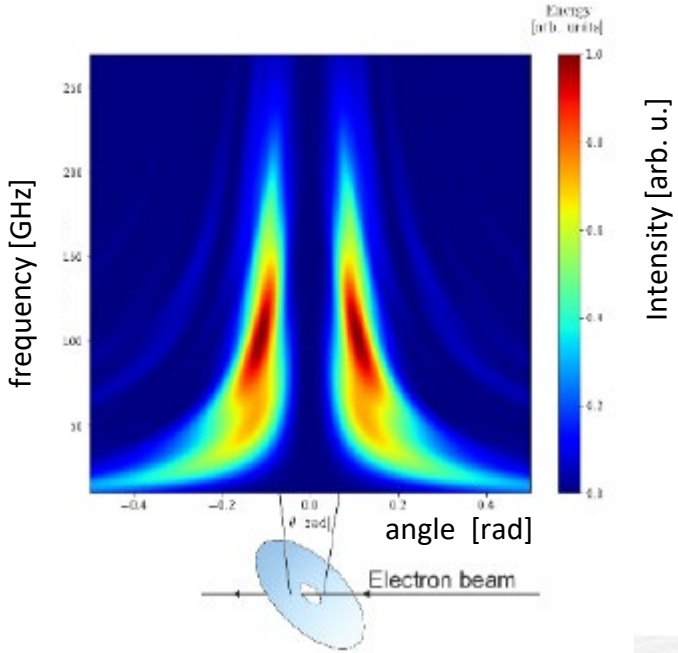
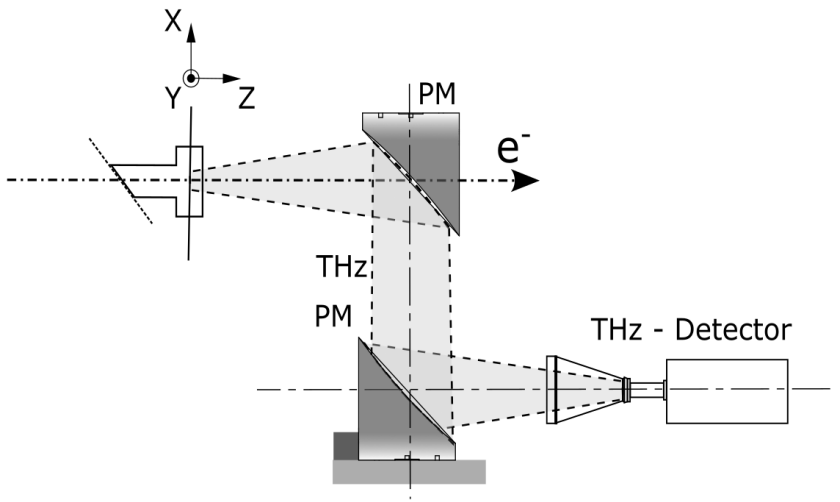
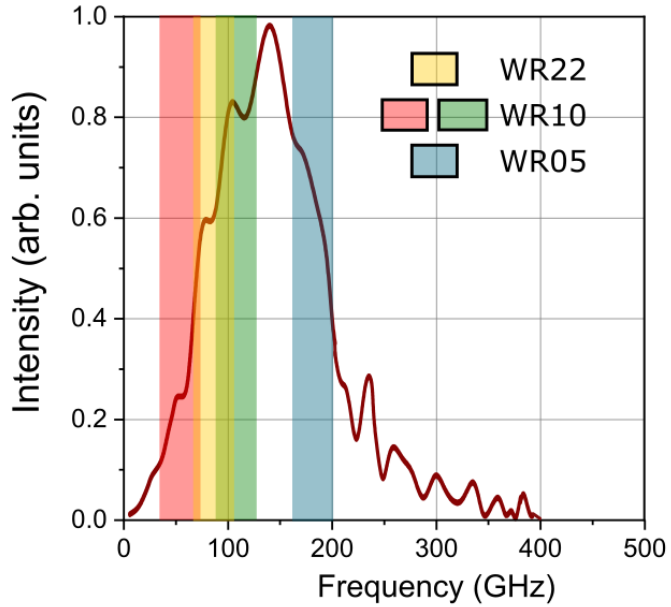
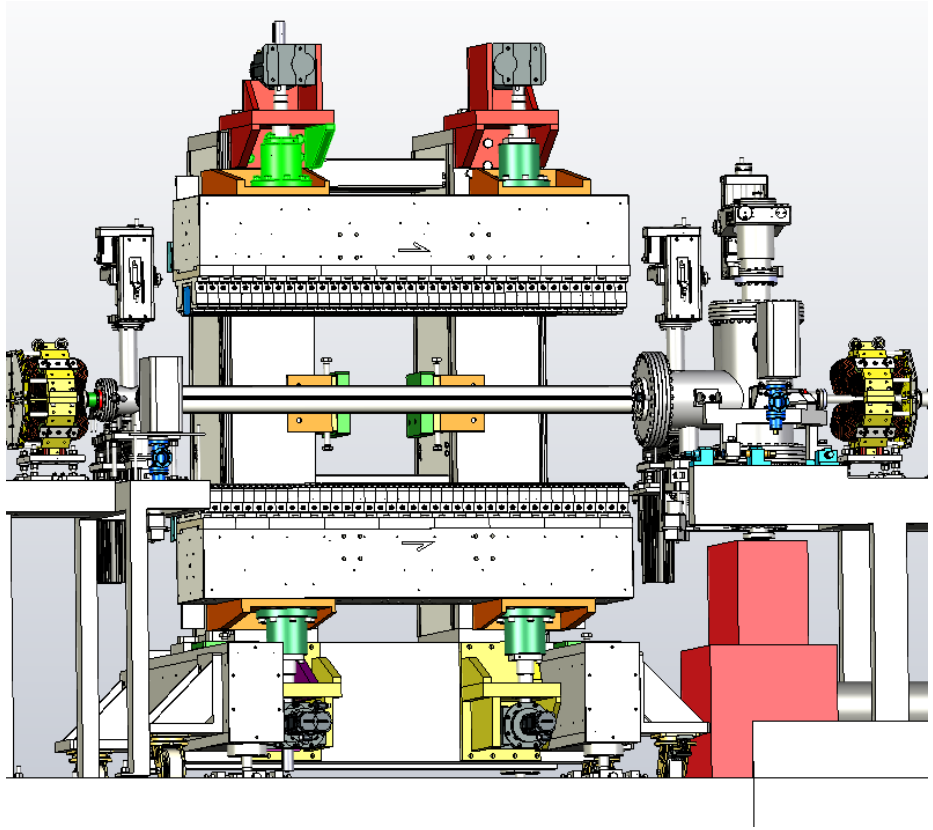






Pin holes + He-Ne laser (P)



THz undulator alignment with pinholes

1. Find a magnetic axis of the undulator with Hall probe bench and assign it relative to undulator beams fiducials
2. Set pinholes on the magnetic axis of the undulator, using pinhole fiducials
3. Steer the electron beam through the pinholes i.e. along U magnetic axis
4. Visualize it with He-Ne beam and observe along the beamline

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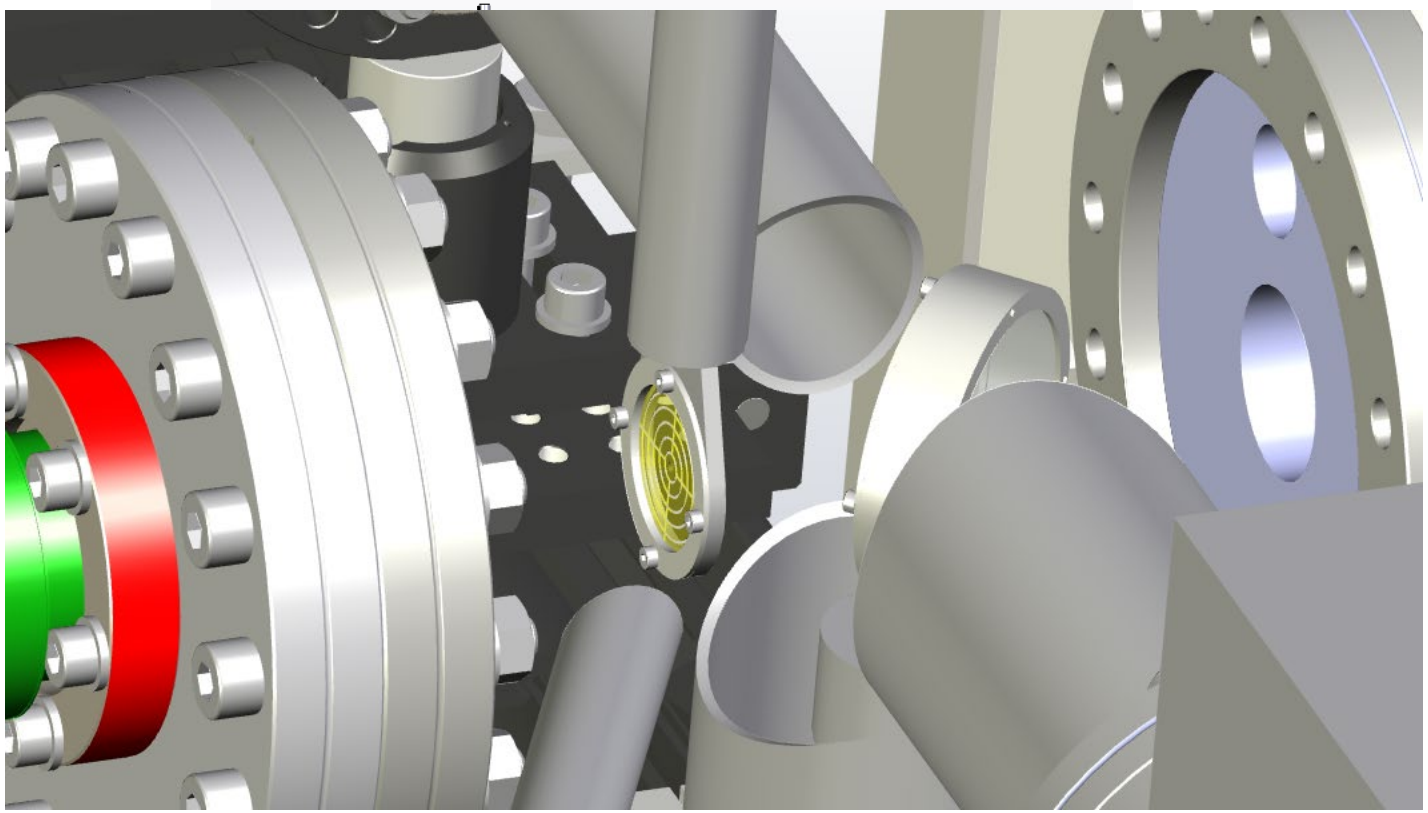

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Chambers locations along the linac

		duty	FC	Yag	CDR	Pin	E [MeV]	q [pC]	τ [ps]	rep [kHz]
INJ	**FCYR**	Gun diagnostics	■	■	■		2.0 -5.0	<250	3.3	<50
INJ	**FCY**	Spektrometer	■	■			2.0 -5.0	<250	?	<50
LIN1	**FCYR**	Compression diagnostics	■	■	■		70 - 200	<250	1.2	<50
LIN2	**FCYR**	U-VUV input diagnoistics	■	■	■		70 - 200	<100	0.27	<50
DOG	**FCY**	Spektrometer	■	■			15-70	<250		<50
LIN3	**FCYR**	U-IR diagnostics	■	■	■		15-70	<250	1.0	<50
LIN4	**FCYR**	U-THz, input diagnostics	■	■	■		15-70	<250	0.6	<50
LIN4	**P**	U-THz alignment				■	15-70	<250	0.6	<50
LIN4	**P**	U-THz alignment				■	15-70	<250	0.6	<50
LIN5	**FCYR**	ICS input diagnostics	■	■	■		70 - 200	<250	?	<50

Current transformers

1. High resolution CT

Aim is to measure a separate bunch charge

Achieved with performing Fourier filtering of the signal in at least 5 MHz bandwidth around 180 MHz

Average current will be measued for BPMs calibration

There will be two Bergoz – ICT Turbo installed:

- in the injector diagnostics section
- in front of THz undulator then travelled to other U. This one will be furnished with calibrated pulser.

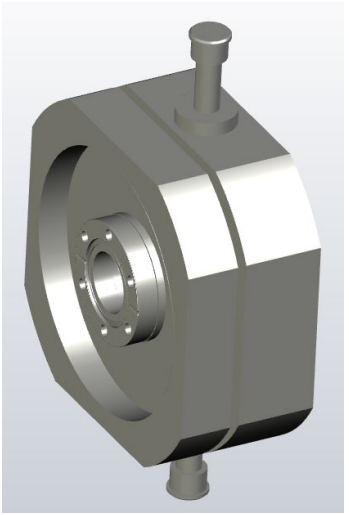
2. Regular current transformers

4 of them will be distributed along the linac and clamped in changing sites of interest like those behind bends, cryomodules, at the dump etc to control beam througput.

Dark current monitor

Two DCMs are planed:

- in service of e-gun diagnostics,
- behind the last CM, dedicated to control the field emission in the accelerating structures

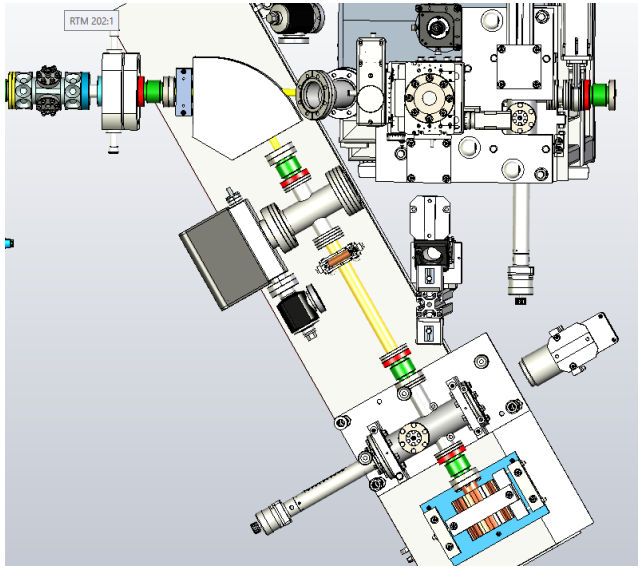


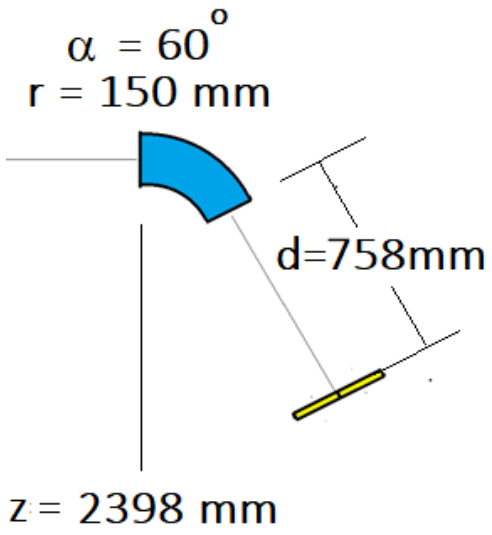
Courtesy of DESY

Collaboration PolFEL - DESY

- 1.3 GHz chamber(s) will be acquired from DESY.
- readout system will be designed and built at NCBJ: low pass filter, amplifier, U(t) → P(t) output in V, ADC. Single PCB in µTCA chassis

60° dipole + FCY





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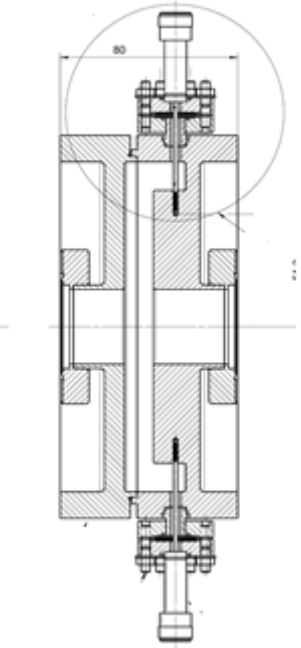

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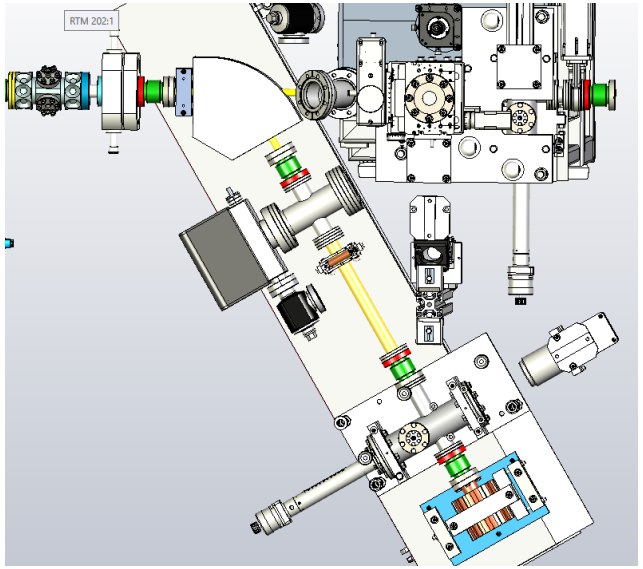
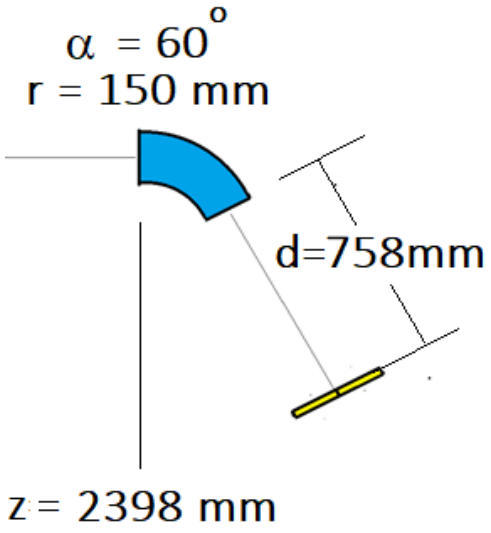
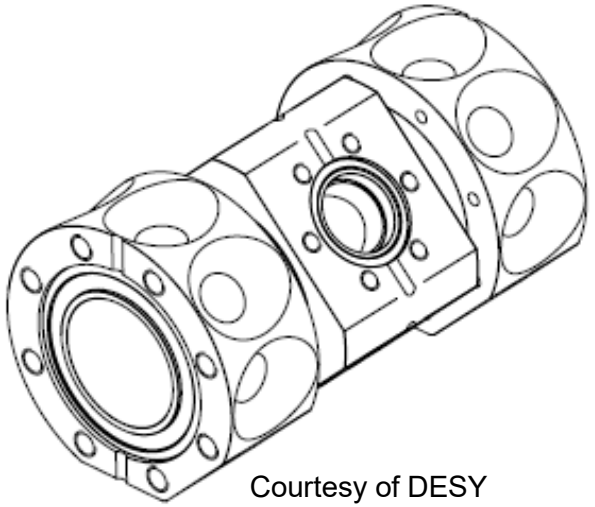




Beam position monitors

40 button BPMs of the following chracteristics:

- resolution: ±10 μm
- sensing range: ±3 mm
- button radius:16 mm
- clearance between buttons:



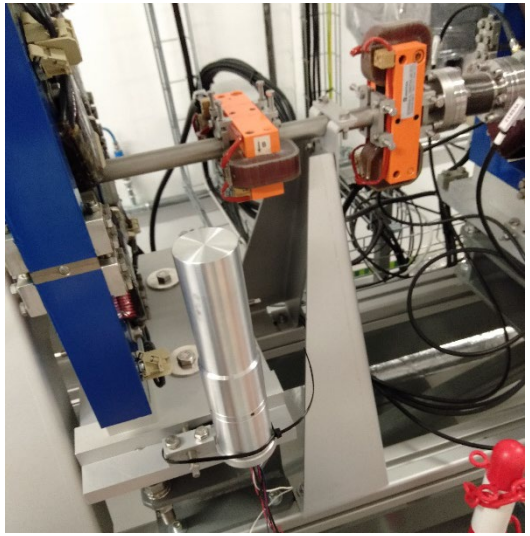
Courtesy of DESY

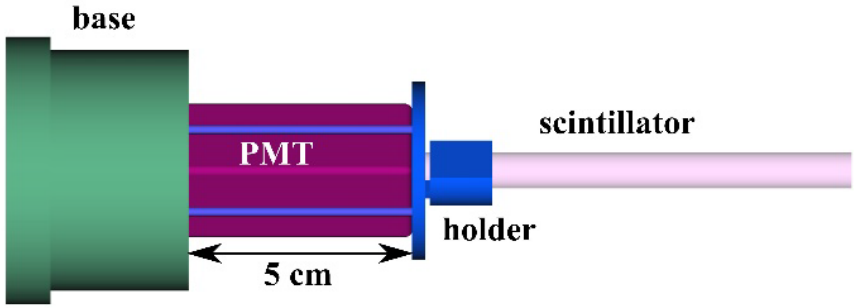
- Bodies, feedthroughs and electrodes will be produced accordingly to specification obtained from DESY and by the the manufacturers previously involved in E-XFEL jobs.
- Then the assembly will be performed at NCBJ with the help of DESY and under its supervision
- First relieses will be tested at Solaris
- During these tests a signal processing method will be optimised
- Libera Spark processors will be used for signal analysis

Energy-BPM are planned to be installed at the BC chicanes, dogleg and 45°bend, that subject however has not been uptaken yet

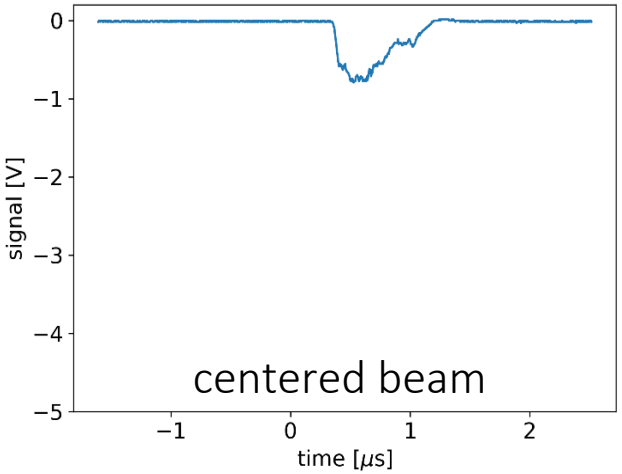
Beam loss monitors

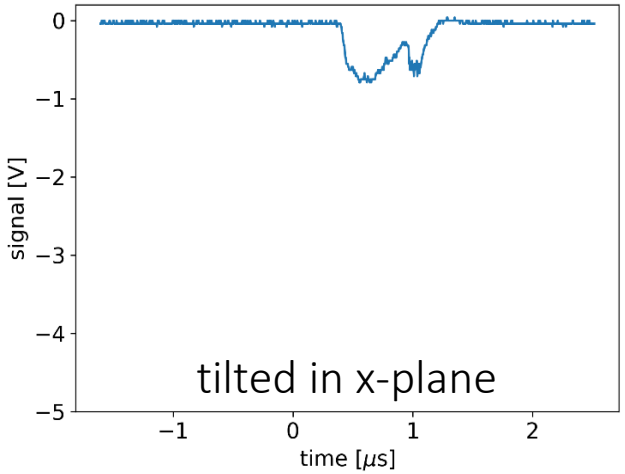
Integrated PMT module with plastic scintillator
Aimed at facility protection

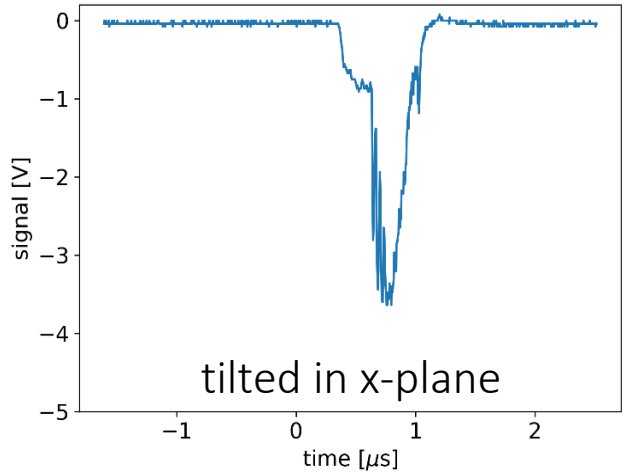


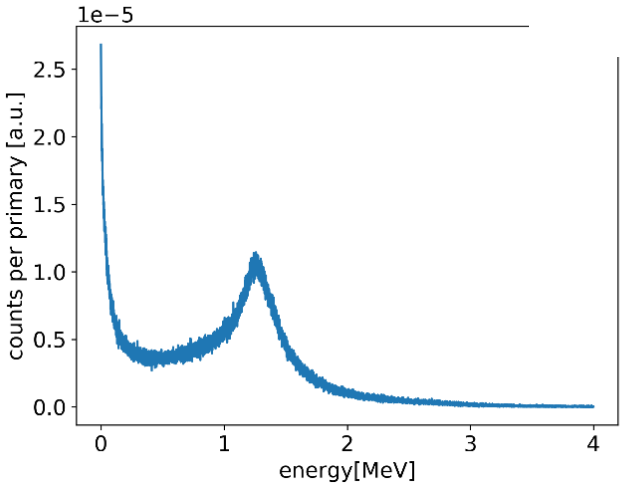


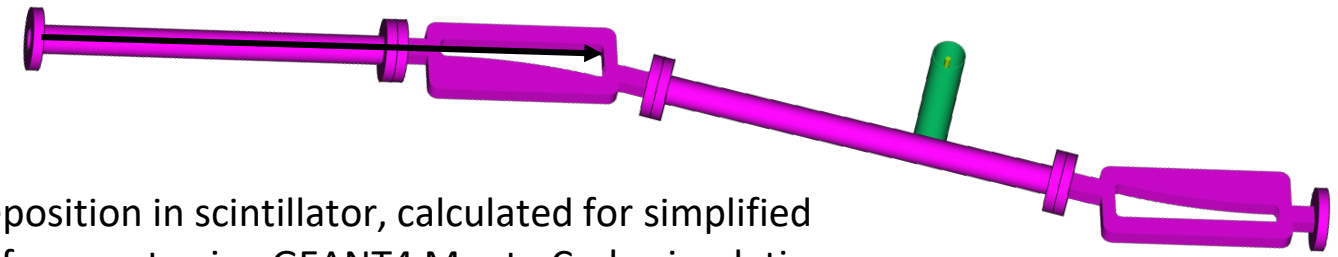
Signals recorded during tests with 100 MeV electron beam.







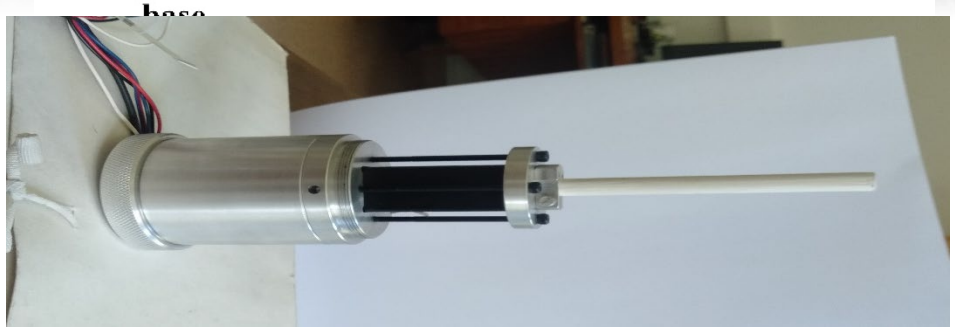


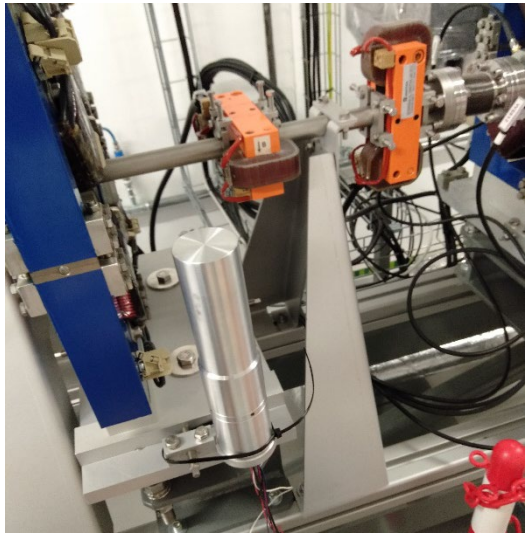


Energy deposition in scintillator, calculated for simplified beamline fragment using GEANT4 Monte Carlo simulations

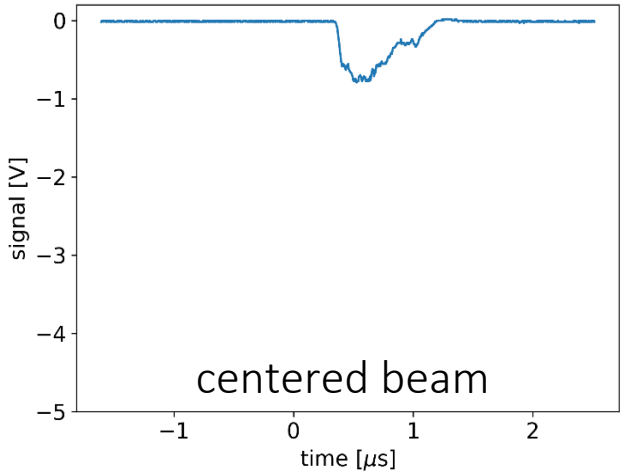
Beam loss monitors

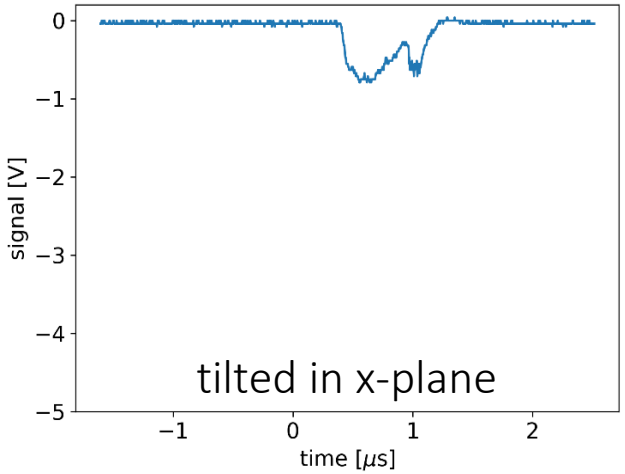
Integrated PMT module with plastic scintillator
Aimed at facility protection

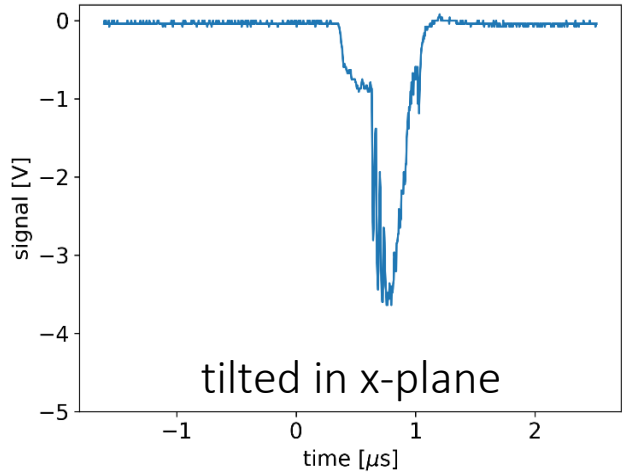


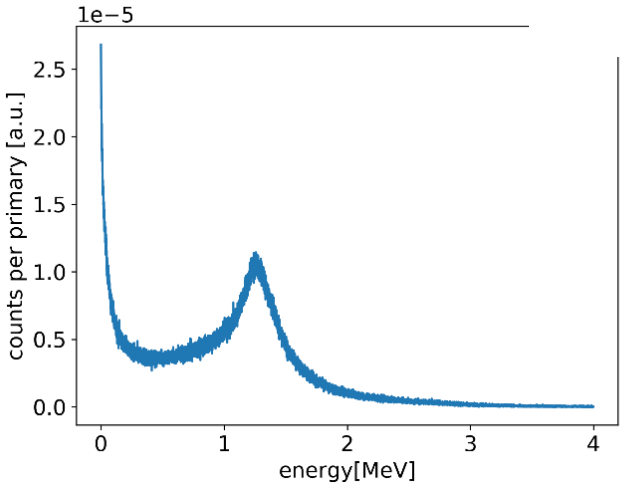


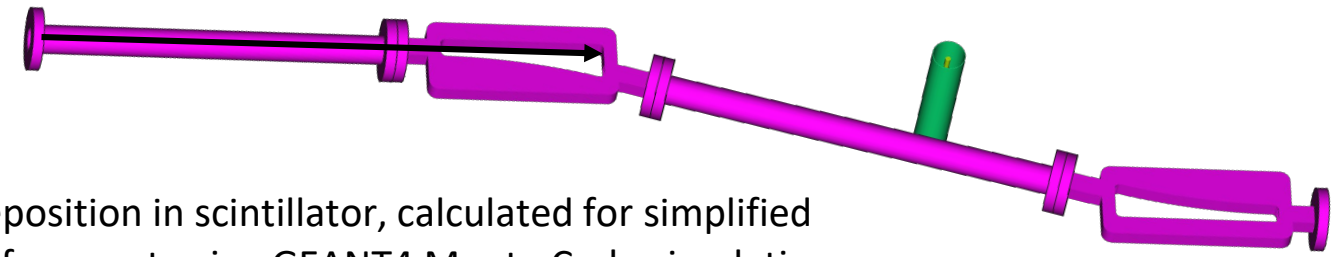
Signals recorded during tests with 100 MeV electron beam.





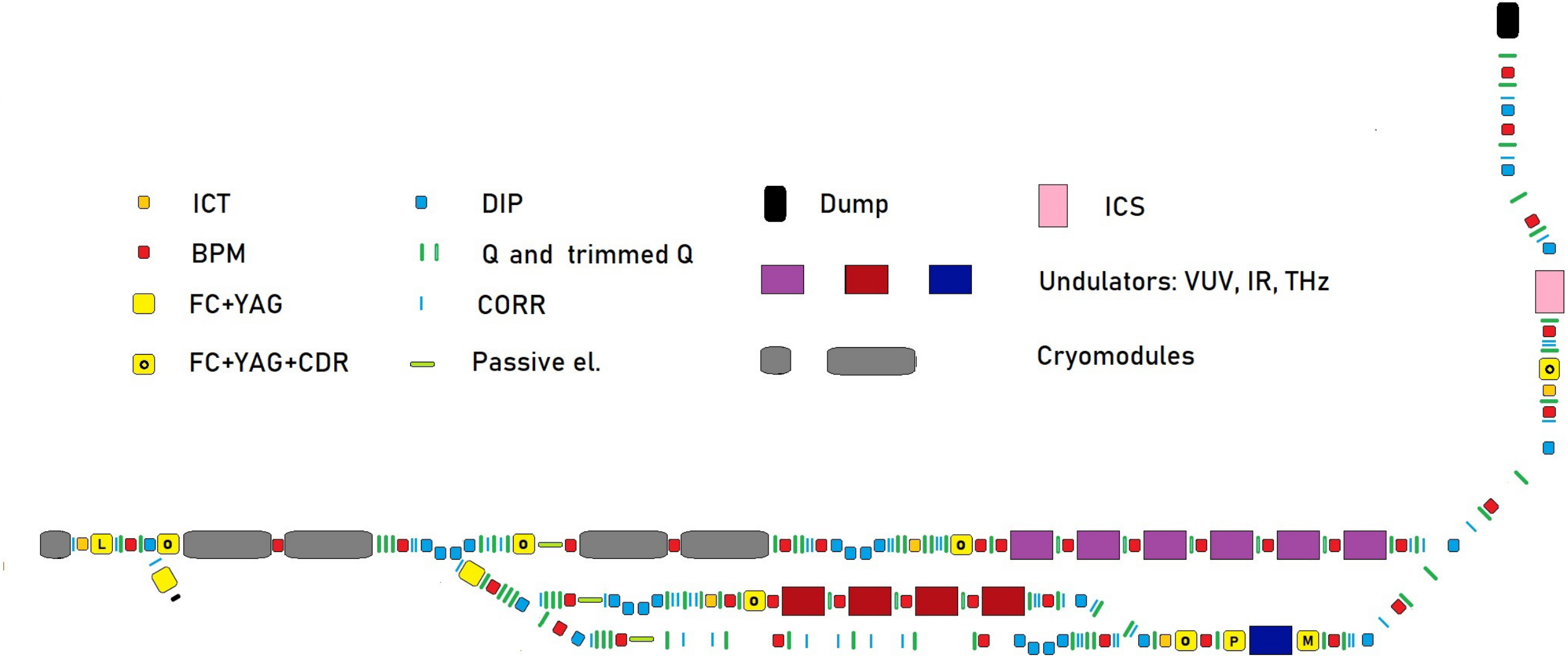




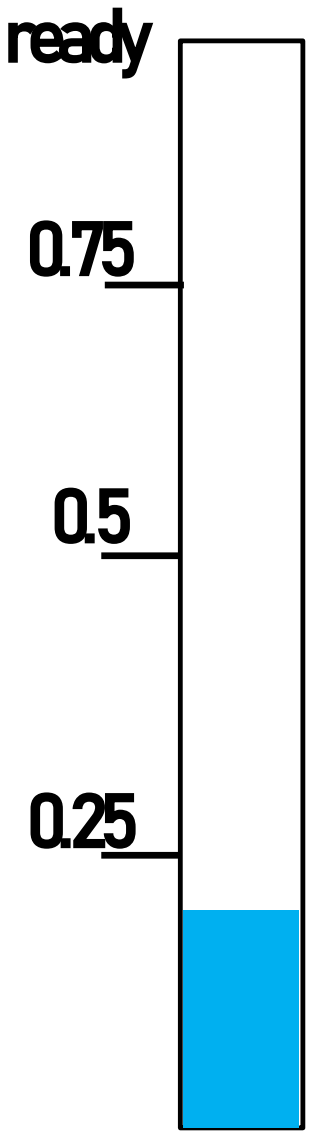


Energy deposition in scintillator, calculated for simplified beamline fragment using GEANT4 Monte Carlo simulations

Instrumentation distribution along linac



Current status



instrument	achievements	proximate actions planned
CT:	Public tender will be issued these days	• Tests…
BPM:	Public tender will be issued these days	• Assembly workshop to be build • Assembly • Tests at Solaris and readout tuning • Production…
EBPM		• Adopt already matured model …
Spectrometer	Mechanical and vacuum design 75% done	• Beam dynamics evaluations • Dipole procurement…
DCM:	Readout electronics design 50% done	• Prototype assembly • Tests at DESY…
FCY, FCYR:	Mechanical and vacuum part 3D design 90% done	• Electric design • Specification for manufacturer • Procurement …
CDR, GHz signal processing:	General concept is being considered	• Decision • Specification • Procurement • Assembly • Tests at Solaris …
Pinholes and He-Ne inlet	Mechanical and vacuum part 3D design 40% done	• Completion • Specification…
BLM:	Prototype ready and tested	• Output signal analysis • Tests at Solaris • Production…

The work is been carried out by:

Solaris team: Ada Wawrzyniak, Andrzej Marendziak, Roman Panaś, Grzegorz Kowalski
NCBJ team: Roch Kwiatkowski, Paweł Czuma, Marcin Terka, Marcin Staszczak, Paweł Krawczyk, Marek Wójtowicz, Dmytro But

I thank them for the efforts

Thank you for the attention

Dziękuję za uwagę

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