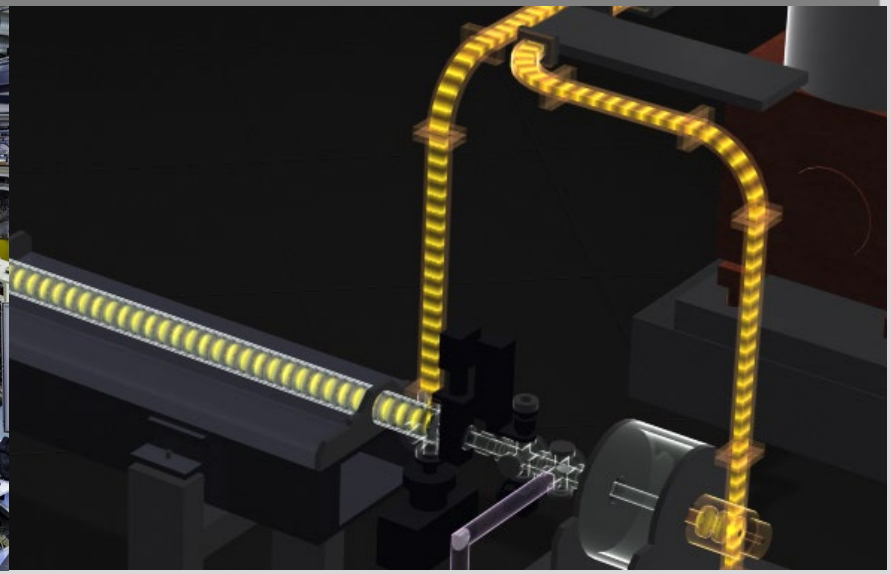
Karlsruhe Institute of Technology

Radiation safety at KARA, FLUTE and its future upgrades

Pawel Wesolowski for KARA and FLUTE

RadSynch23, Grenoble, 1.06.2023

KIT – IBPT



Authors

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In deep waters

carrying a lot of water

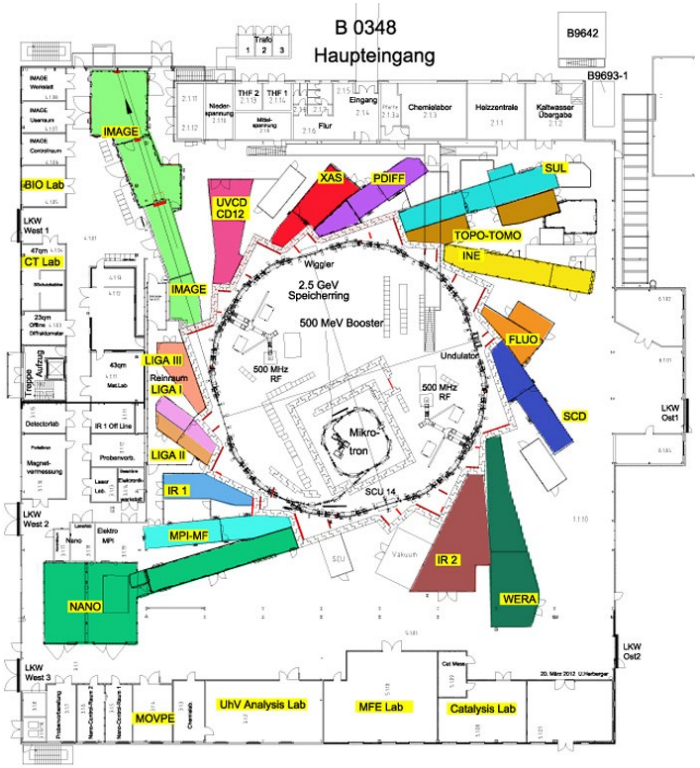
relaxing at Rhine waters

Outline

- Accelerator Test Facilities at IBPT
- KARA (Karlsruhe Research Accelerator) at glance
- Radiation Safety at KARA
- KARA upgrades
- FLUTE (*Ferninfrarot Linac- und Test-Experiment*) concept
- Inherited Assets – historic
- General Radiation Safety at FLUTE
  - PSS
  - Dump Activation
  - Linac Activation
  - Vacuum tube Activation
  - Hall Air Activation
- Future upgrades
  - cSTART, LPA
- Summary

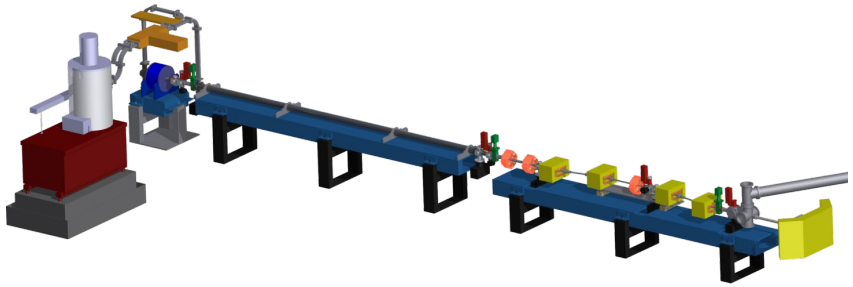
Accelerator Test Facilities at IBPT

- KARA



KIT Light Source –
scheduled until end of 2024

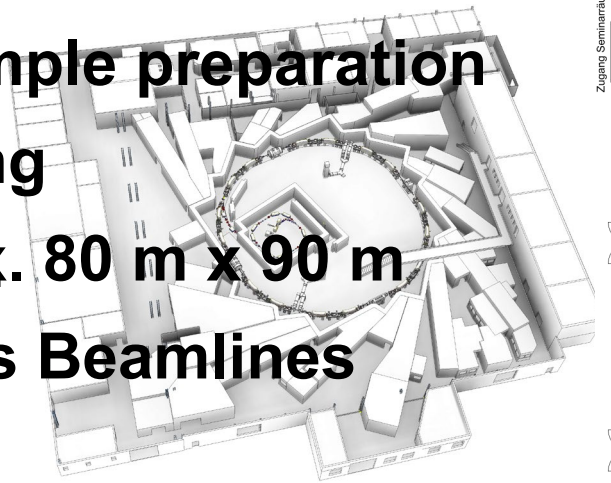
- FLUTE

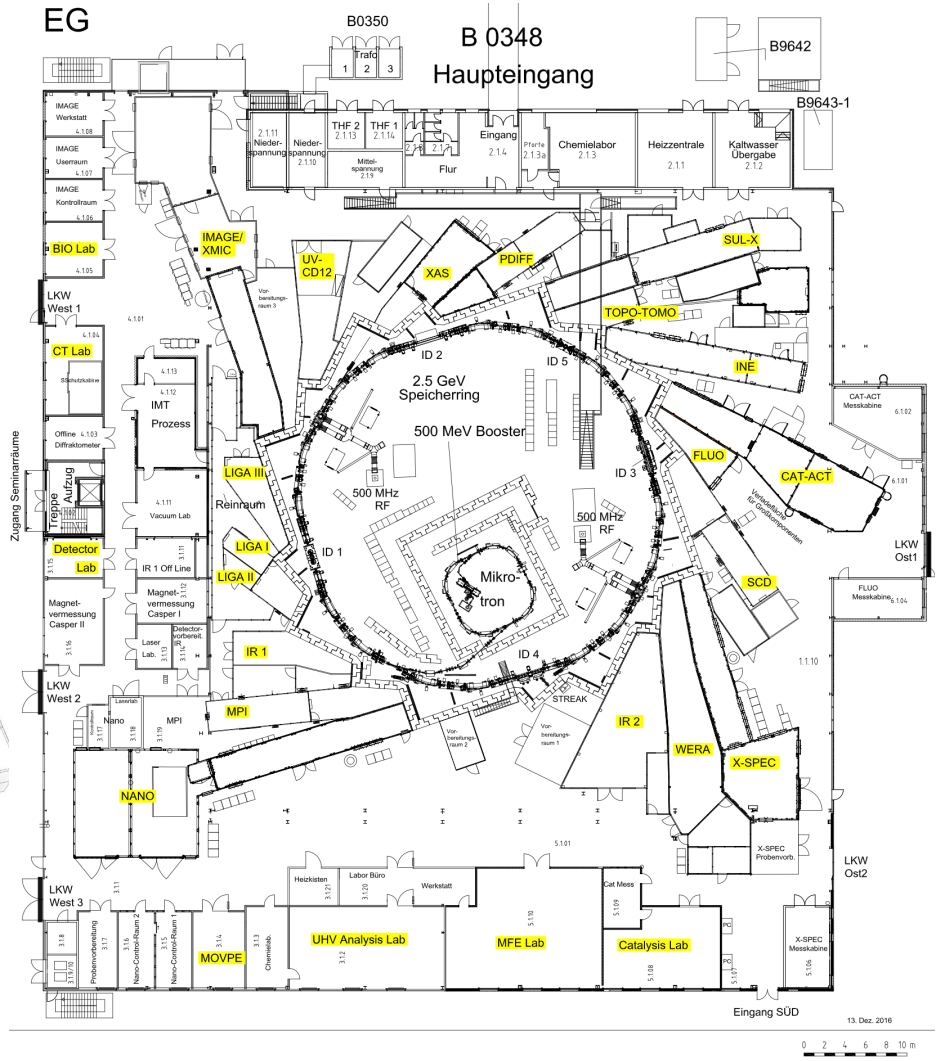


Low energy operation,
now being upgraded

Karlsruhe Research Accelerator KARA

- Circular accelerator with tangential beamlines
- Associated laboratories for sample preparation
- Building approx. 80 m x 90 m
- various Beamlines

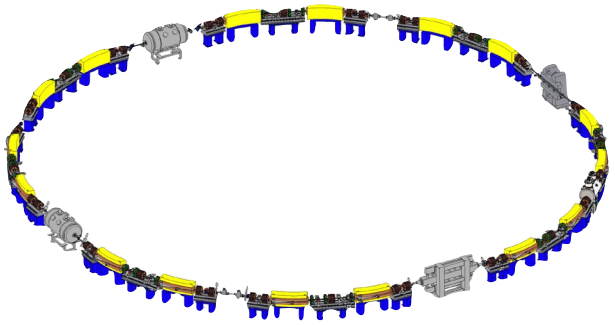




Karlsruhe Research Accelerator (KARA)

- KIT synchrotron light-source & accelerator test facility

Parameters	Values
Circumference	110.4 m
Energy range	0.5 – 2.5 GeV
RF frequency / period	500 MHz / 2 ns
Revolution frequency / period	2.715 MHz / 368 ns
Beam current	up to 200 mA
RMS bunch length	45 ps (2.5 GeV) a few ps (1.3 GeV)



www.ibpt.kit.edu/kara

Radiation Shielding at KARA

Lead bricks

6 RPOs
2 at RadSynch

Concrete wall

Experimental hutch

KARA Operation Status

- Operation modes in 2022:
  - 0.5/2.3/2.5 GeV user optics, 0.5/1.3 GeV low-alpha, 0.5/1.3 GeV negative alpha
- Power supply refurbishment program
  - Kicker and septum magnets in booster and storage ring: **Done in 2021**
  - Storage ring sextupole magnet: **In operation since September 2022**
  - Booster bending and quadrupole magnet: **Commissioned March 2023**
  - Storage ring bending magnet: **Installed – commissioning now**

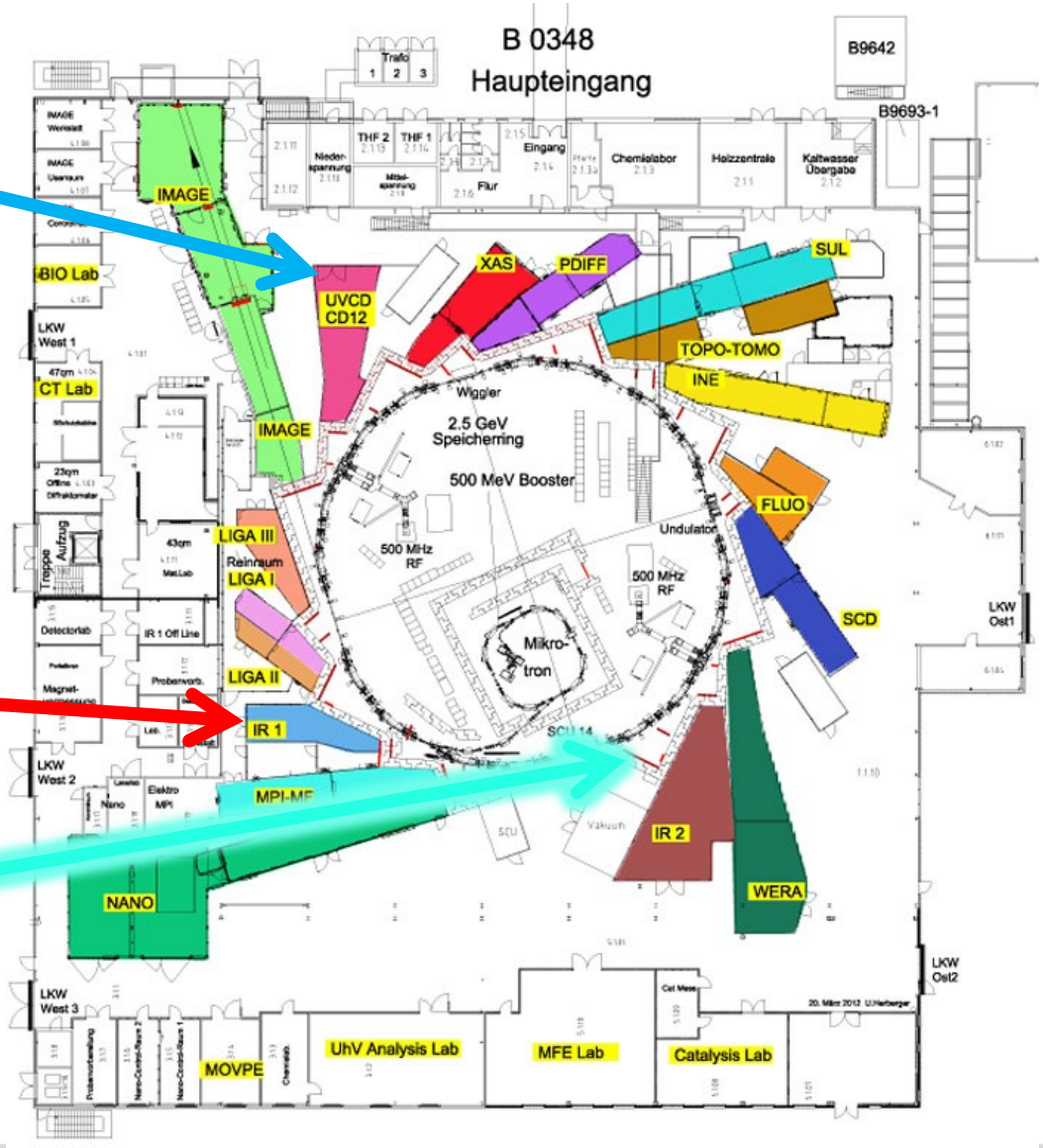
Upgrades less relevant to RS

Specifics of BLs at KARA

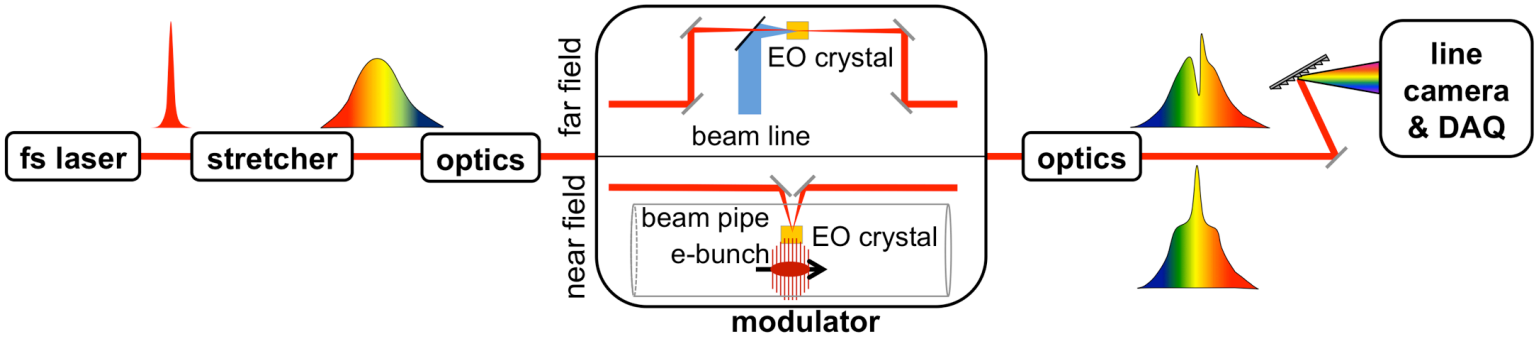
UV (2 mirrors)

IR (4 mirrors)

VLP



Example - EO diagnostic port at IBPT

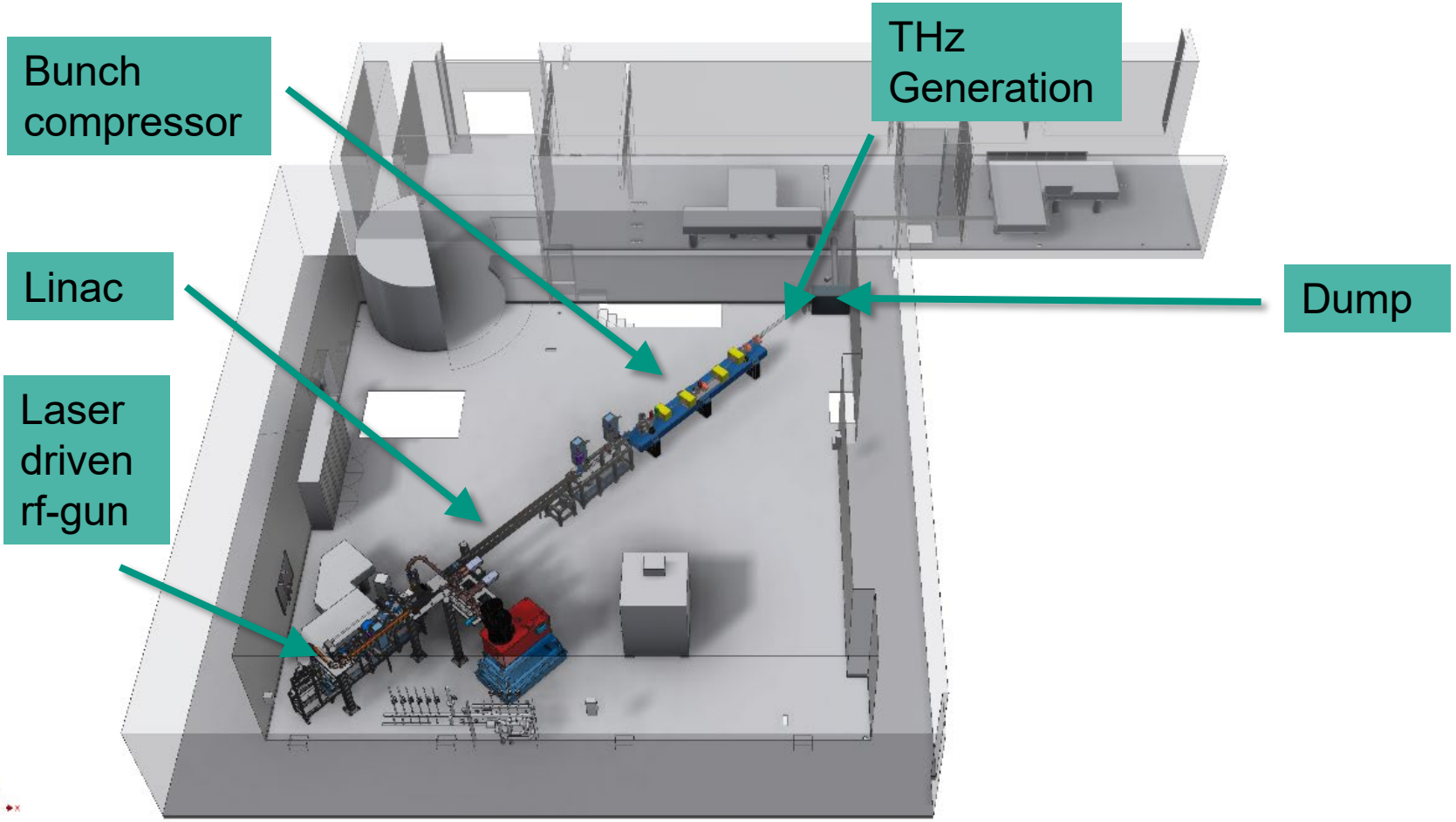


SeeTalk VLP

High Energy Scattered Synchrotron Radiation at the KARA Visible Light Diagnostic Port

David Batchelor (this Workshop)

FLUTE in a massive housing

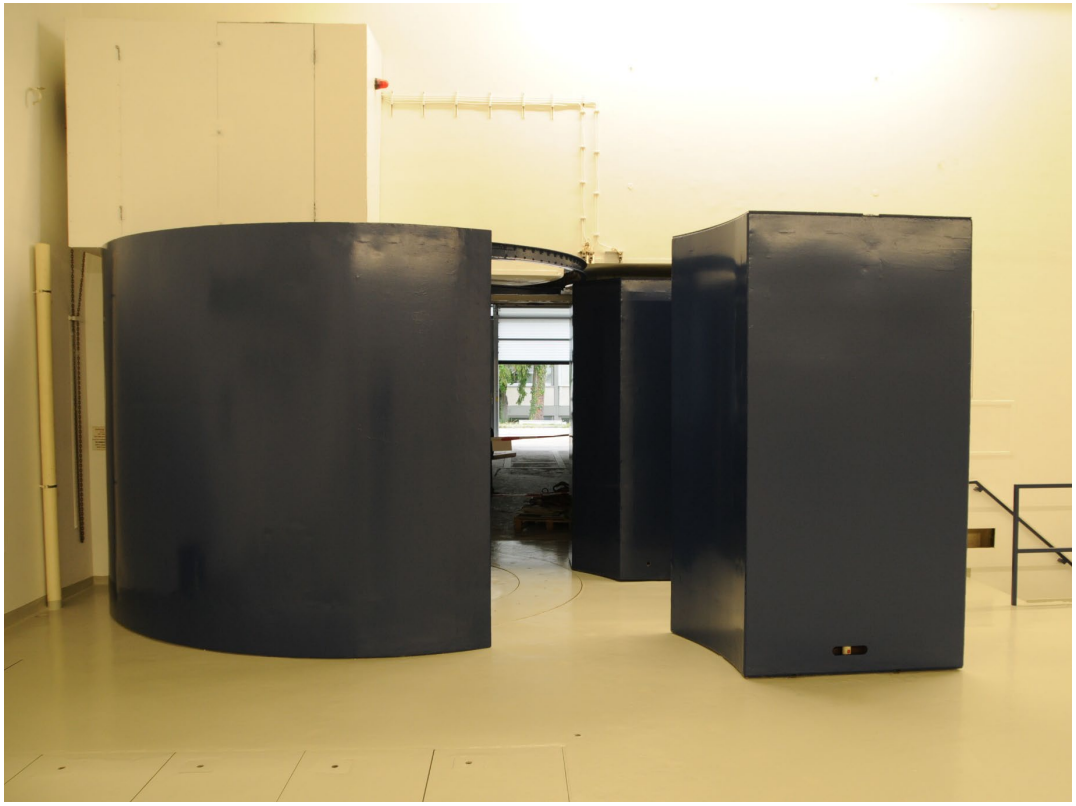


Radiation shielding and safety at FLUTE

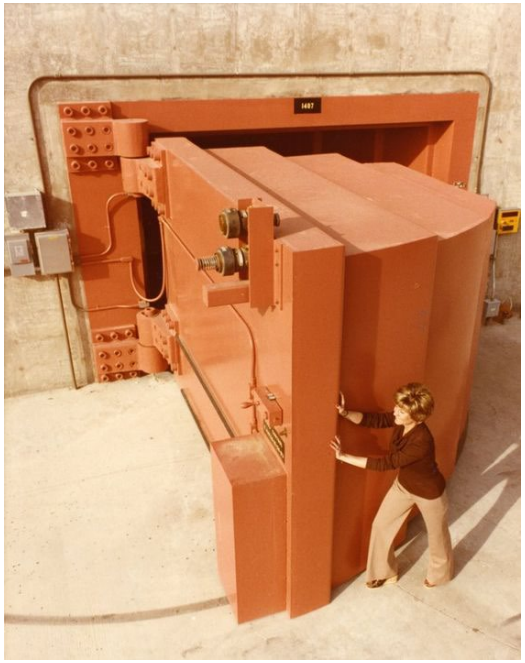
Concrete wall

- Hall 15 m x 14.5 m inside
- Minimum 1.5 m concrete
- Equivalent around labyrinths
- Local shieldings – lead bricks
- Massive revolving door
- Restricted area when rf on
- Space for upgrades / new devices
- Location at KIT Campus North
- Activation measurements monthly

Massive revolving door



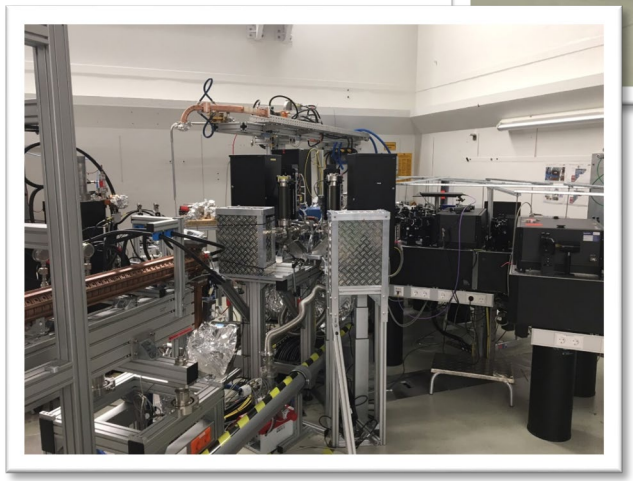
- FLUTE door



- Unidentified large door ☺

Karlsruher Zyklotron , ZAG , FLUTE

- 1974 „Karlsruher Zyklotron“
- Commercial operation for isotope production
- Since 2013 – Constructing, Commissioning and Operation of FLUTE in the former experimental hall of Cyclotron.
- 2023 upgrades

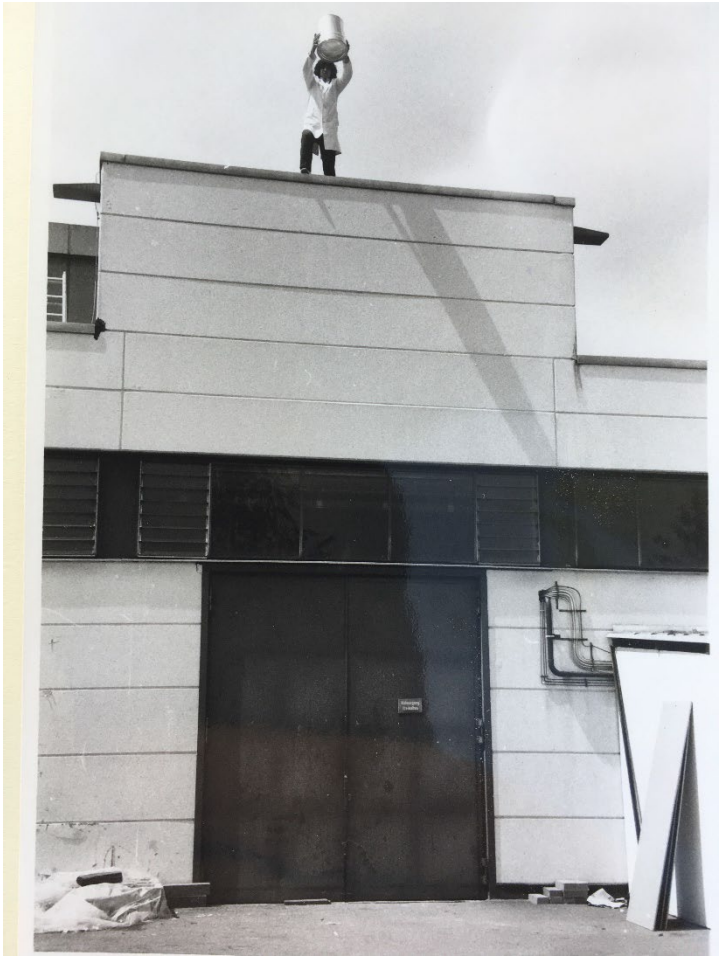


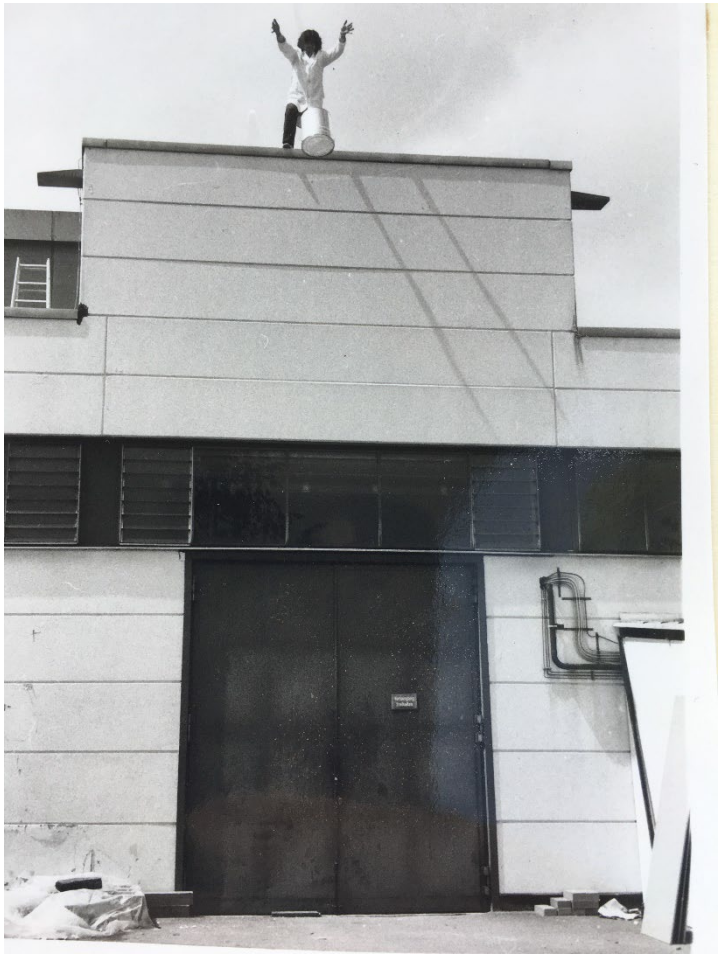
Some challenging heritage

Chemistry pipe

Air filters

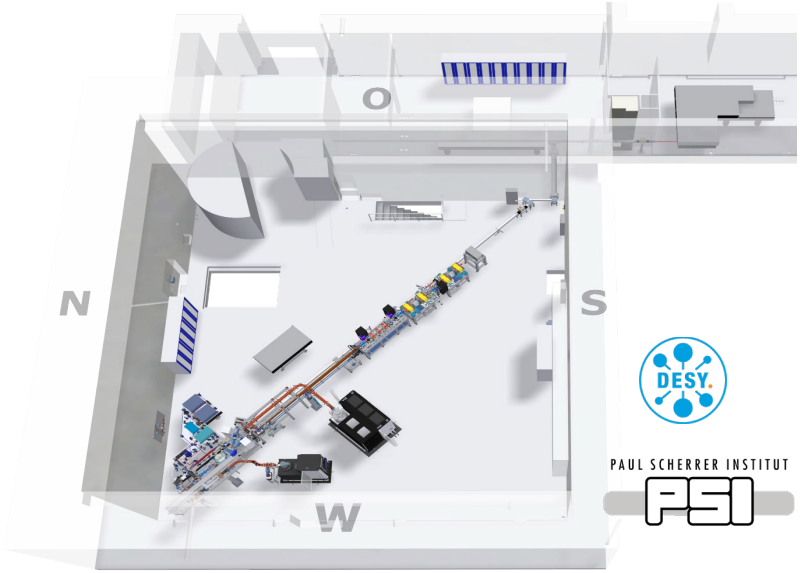
RSO risking live(s) for quality assurance (hist)





FLUTE: Accelerator Test Facility at KIT

- FLUTE (Ferninfrarot Linac- Und Test-Experiment)
  - Test facility for accelerator physics within ARD
  - Experiments with THz radiation

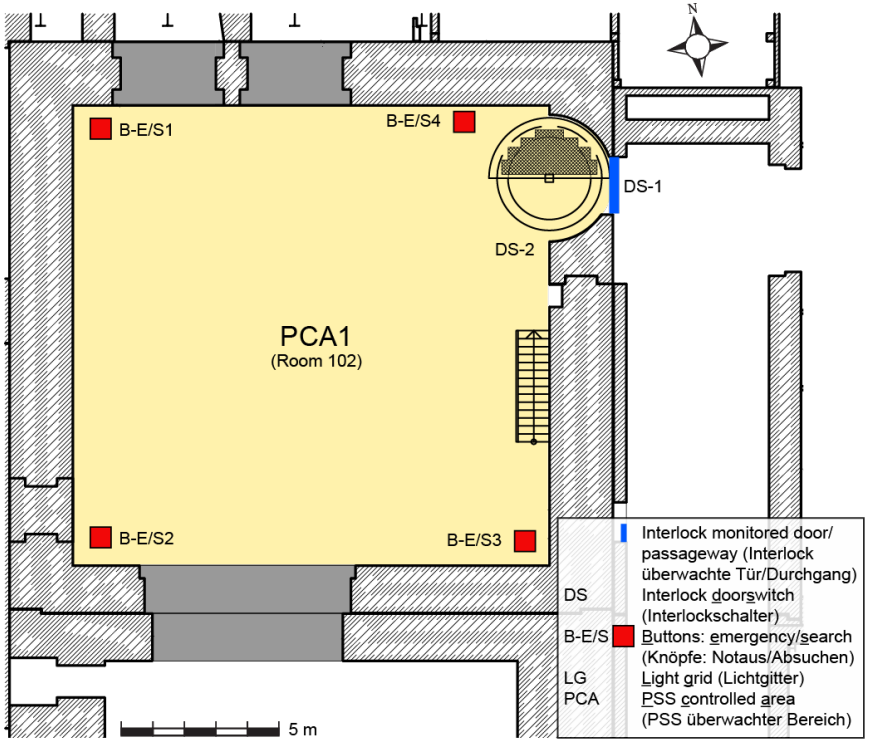


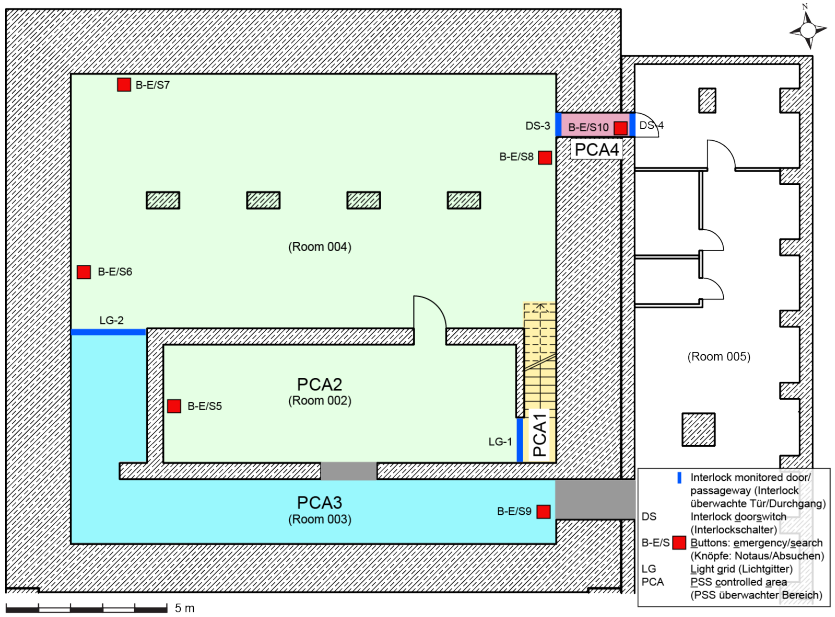
Final electron energy	~ 41	MeV
Electron bunch charge	0.001 - 1	nC
Electron bunch length	1 - 300	fs
Pulse repetition rate	10	Hz
THz E-Field strength	up to 1.2	GV/m

- R&D topics
  - Serve as a test bench for new beam diagnostic methods and tools
  - Systematic bunch compression and THz generation studies
  - Develop single shot fs diagnostics
  - Synchronization on a femtosecond level

www.ibpt.kit.edu/flute

FLUTE - Personal Safety System

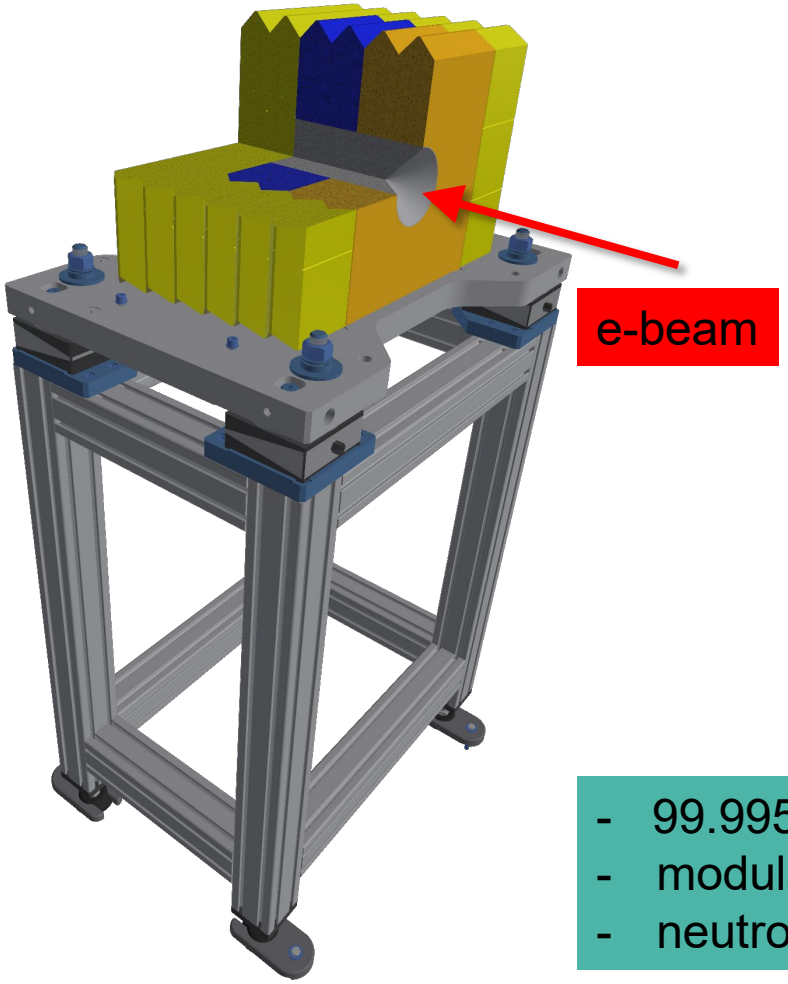


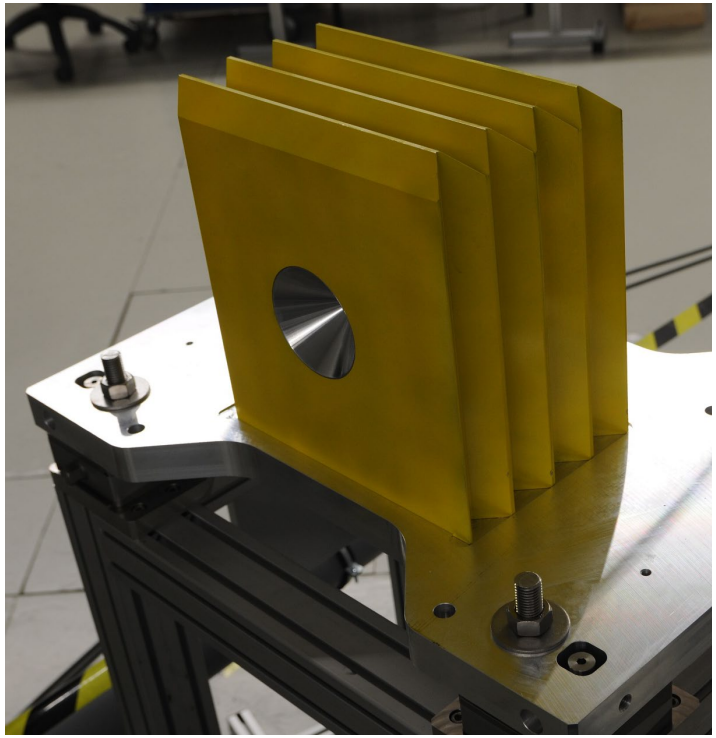


ground floor

basement

Beam Dump (Full Energy)





- 99.995% Al absorber
- modular Pb shielding
- neutron shielding “if necessary“

Activation in aluminum absorber of the Beam Dump

target	nuclide	T1/2	Threshold	Saturation activity (GBq / kW) at electron beam energy (MeV)						activity pure material
				10	15	20	25	30	35	MBq
Al	Na-24	14.96h	23.71	0	0	0	0.02	0.37	1.1	1.155
	Al-26m	6.37s	13.03	0	0.74	37	140	244	325	341.25

total charge	3	nC
rep. frequency	10	Hz
Energy	35	MeV

Activation in iron impurity of absorber

Absorber Aluminum			
99.995	ppm		
Fe	24.7	Mg	1.75
Si	6.38	Mn	0.84
Cu	4.05	Ga	0.46
Zn	2.88	Sn	0.3
P	2.12	Ti	0.29
		B	0.2

susceptibility to irradiation
Moderately susceptible
Highly susceptible

target	nuclide	T1/2	Threshold	Saturation activity (GBq / kW) at electron beam energy (MeV)						activity pure material	content in Alu	activity scaled
				10	15	20	25	30	35	MBq	ppm	Bq
Fe	Mn-54	303d	20.4	0.0	0.0	0.0	5.9	17.0	22.0	23.1	24.7	570.6
	Mn-56	2.57h	10.6	0.0	0.1	0.5	0.9	1.1	1.2	1.3	24.7	31.1
	Fe-53	8.51m	13.6	0.0	0.4	9.6	19.0	25.0	27.0	28.4	24.7	700.2

Negligible activation in any operational stage

Activation in a copper structure of linac

target	nuclide	T1/2	Threshold	Saturation activity (GBq / kW) at electron beam energy (MeV)						activity pure material
				10	15	20	25	30	35	MBq
Cu	Cu-61	3.32h	19.73	0	0	0.004	8.5	24	32	33.6
	Cu-62	9.76m	10.84	0	28	177	318	407	407	427.35
	Cu-64	12.80h	9.91	0.0004	22	103	155	177	185	194.25

Potential activation in steel

target	nuclide	T1/2	Threshold	Saturation activity (GBq / kW) at electron beam energy (MeV)						activity pure material	content in steel	activity scaled
				10	15	20	25	30	35	MBq	%	MBq
Fe	Mn-54	303d	20.4	0.0	0.0	0.0	5.9	17.0	22.0	23.1	71.0	16.4
	Mn-56	2.57h	10.6	0.0	0.1	0.5	0.9	1.1	1.2	1.3	71.0	0.9
	Fe-53	8.51m	13.6	0.0	0.4	9.6	19.0	25.0	27.0	28.4	71.0	20.1
Ni	Ni-56	6.10d	22.5	0.0		0.0	0.1	1.3	2.4	2.5	8.0	0.2
	Co-56	77.3d	-									
	Ni-57	36.0h	12.2	0.0	3.7	44.0	96.0	133.0	155.0	162.8	8.0	13.0
	Co-57	270d										

No activation at <10 MeV

Experimental Hall air activation

					limit		
nuclide	$t_{1/2}$	activation	activation	inhalation	submersion	after App VII	exploited
	h	Bq	Bq/m^3	Bq/m^3	Bq/m^3	Bq/m^3	
^{13}N	1.66E-01	1.00E+05	5.90E+01	n.a.	2.00E+03	2.00E+04	2.95E-03
^{15}O	3.39E-02	1.07E+04	6.30E+00	n.a.	1.00E+03	1.00E+04	6.30E-04
^{14}C	4.99E+07	5.15E+00	3.03E-03	6.00E+00	n.a.	6.00E+01	5.05E-05
^{41}Ar	1.83E+00	6.94E+04	4.08E+01	n.a.	2.00E+02	2.00E+03	2.04E-02
^{11}C	3.39E-01	3.77E+04	2.22E+01	6.00E+02	3.00E+03	6.00E+03	3.69E-03
Sum							0.028

Operational approval

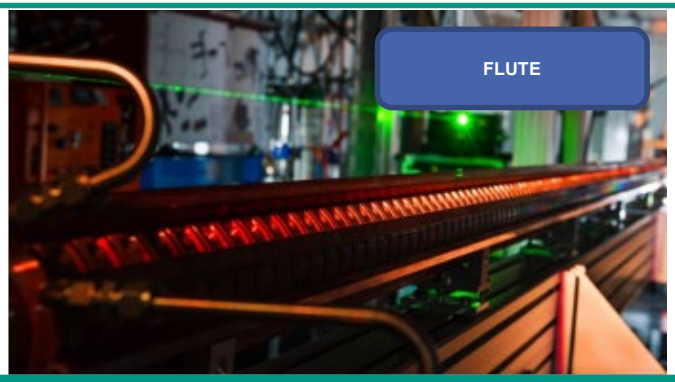
Baden-Württemberg
REGIERUNGSPRÄSIDIUM KARLSRUHE
ABTEILUNG 5 - UMWELT

Karlsruhe

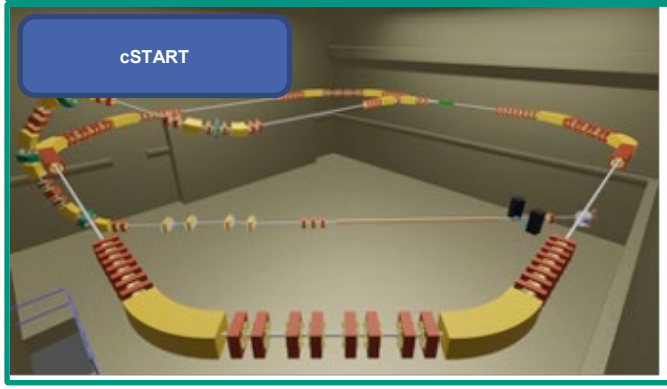
Eingang SUM
L | BG | DL | RL | ST | ZB
01. Juni 2021
Ablage: K-09.02 FLUTE

Karlsruhe 21.05.2021

Test Facilities at IBPT – Present & Upgrades

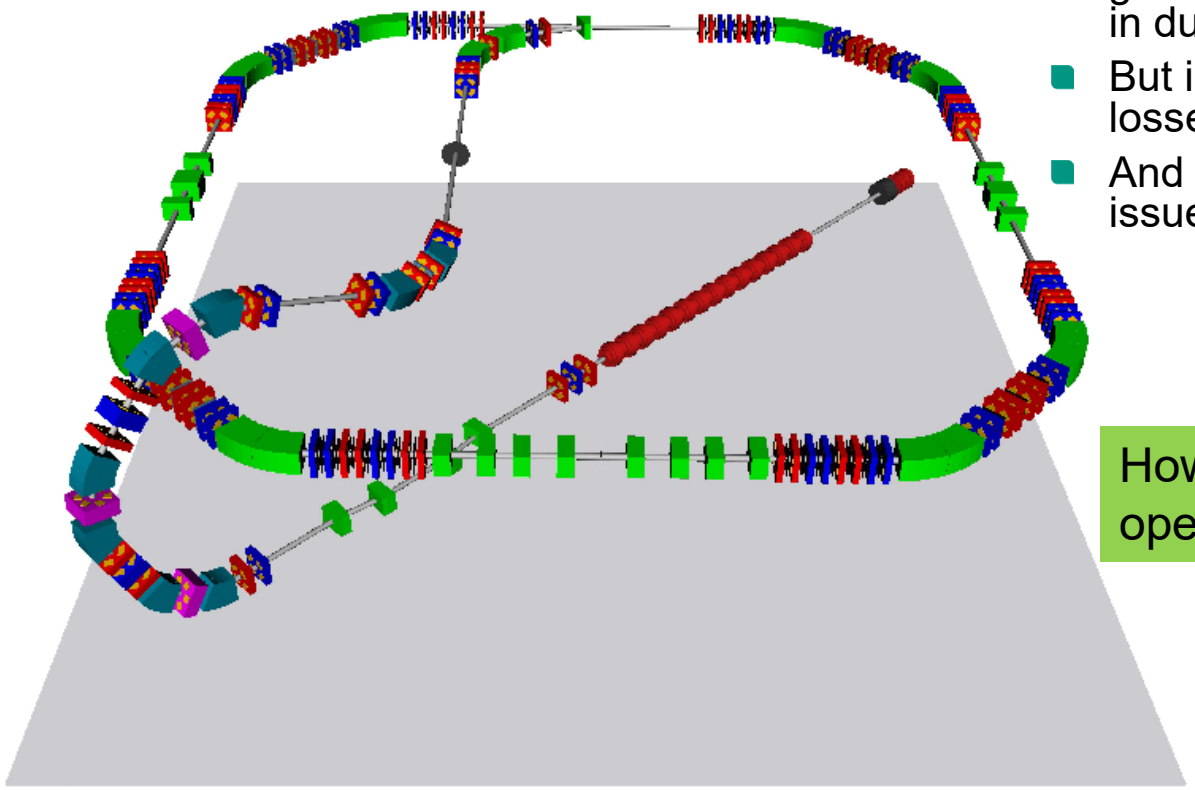


in operation



under construction

Artistic view of the cSTART facility in the first stage Very Large Acceptance compact Storage Ring



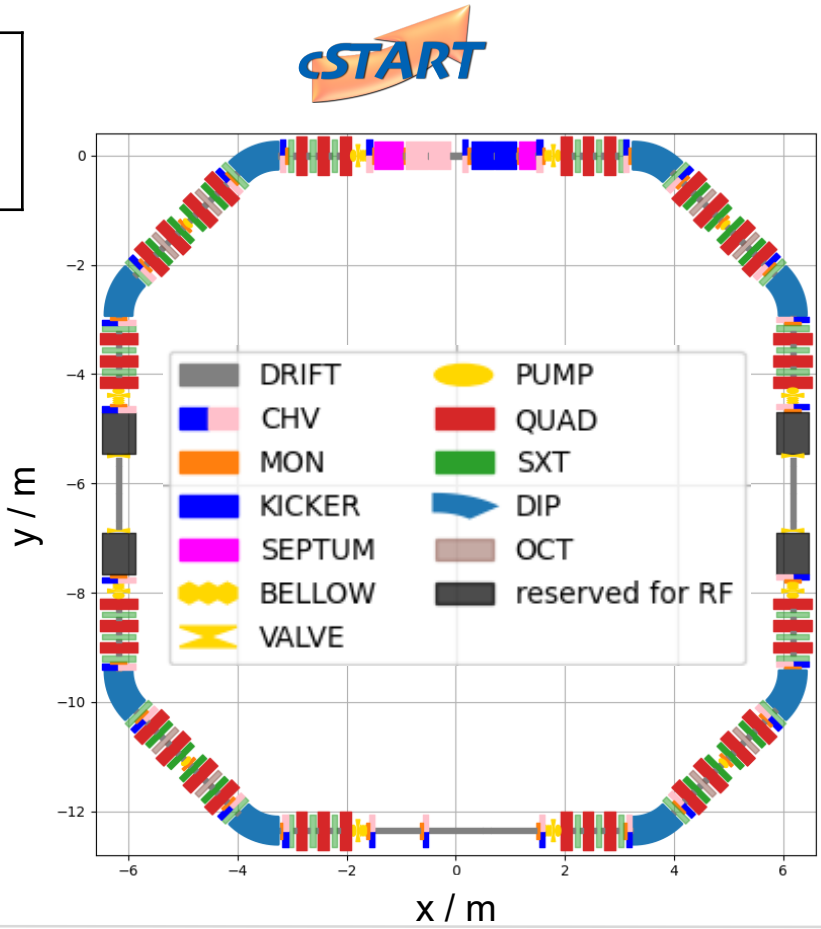
- Will be placed above FLUTE
- N turns in cSTART do not generate more bremsstrahlung in dump
- But increase radiation to losses
- And amplifies a non-shielding issue

How to be handled in the operational license?

cSTART Project

Circumference	43.2 m
Lattice	90 degree DBA
Revolution time	144 ns

- **Motivation:** Storage of ultra-short (fs) electron bunches with high repetition rate
- Compact storage ring with very large momentum acceptance and dynamic aperture
- FLUTE with new transfer line as injector
- Status:
  - Conceptual design and specification: finished
  - Transfer line magnets: first magnets delivered
  - Test diagnostics at KARA booster: ongoing



cSTART Project

- FLUTE will serve initially as injector
- Option probably under existing operational license
- A very large momentum acceptance and dynamic aperture enables an injection of a low quality electron beam like, e.g., LPA
- Losses in transfer section and in the machine will substantially increase radiation in the hall.
- LPA will have a major impact on existing operational license

Summary

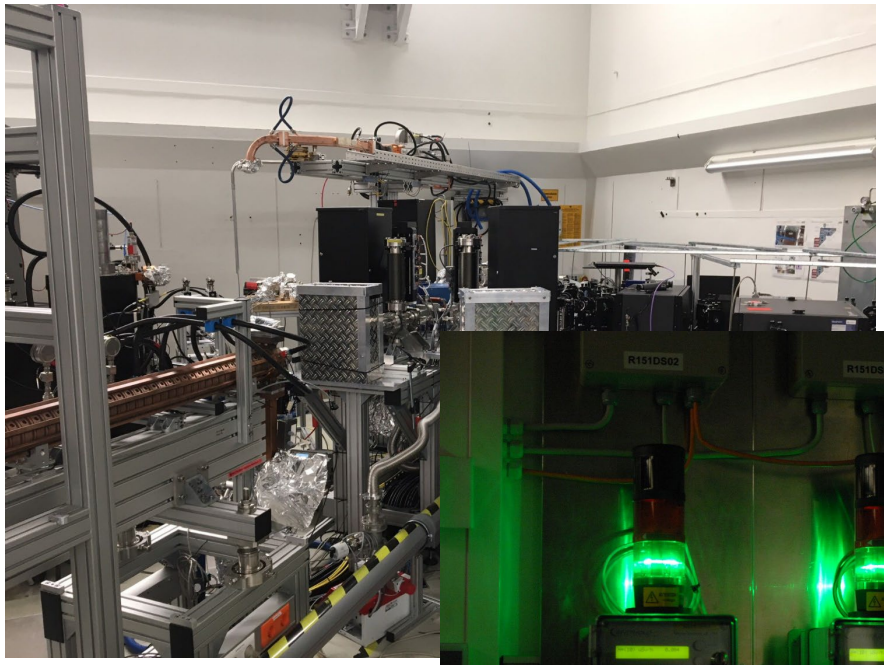
KARA

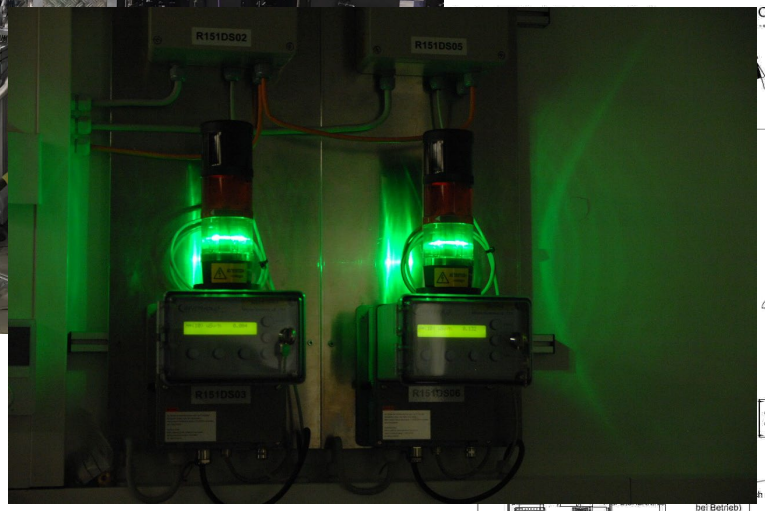
- KARA operational until at least 2024
- KARA upgrades less relevant to RS

FLUTE

- FLUTE is operational
- Upgrade to full energy operation
- Relevant activations are calculated.
- Air activations in the experimental hall comply with German Radiation Safety Ordinnance
- Permanent operational license obtained 2021
- Safety relevant parameter will increase in the future with cSTART
- LPA will probably require a new operational license.

Thank you

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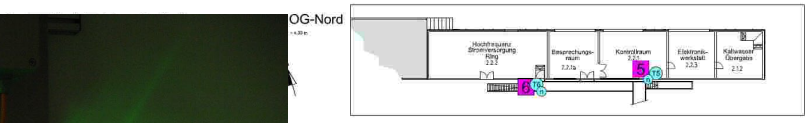
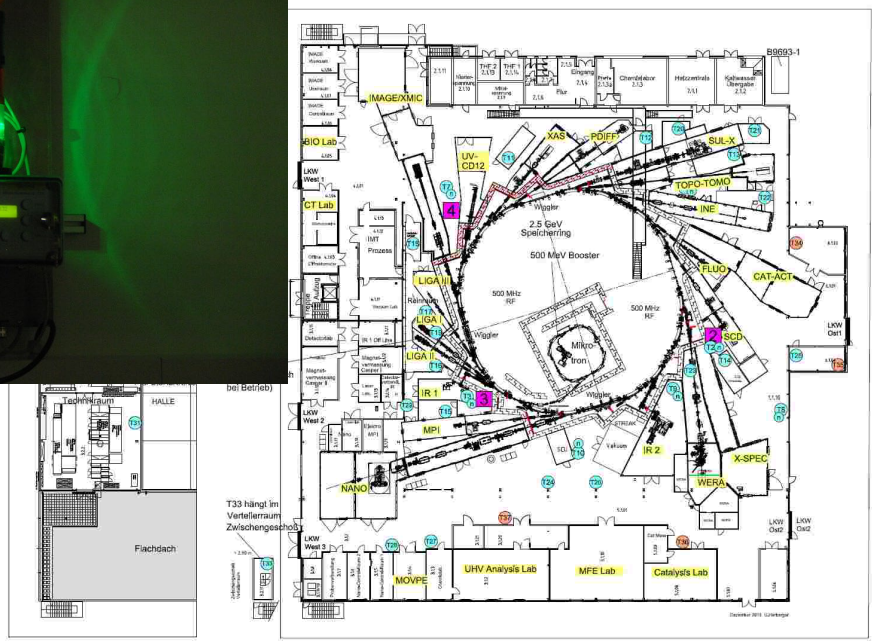
R151DS05
R151DS03
R151DS06


OG-Nord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IMAGE/XMIC
BIO Lab
GT Lab
XAS
PDIFF
UV-CD12
SUL-X
TOPO-TOMO
INE
2.5 GeV Speicherring
500 MeV Booster
FLUO
CAT-ACT
SCD
LIGA II
LIGA I
IR 1
IR 2
MPI
NANO
X-SPEC
WERA
MOVPE
UHV Analysis Lab
MFE Lab
Catalysis Lab
Technikraum
HALLE
Flachdach