Karlsruhe Institute of Technology

FLUTE

Compact linear accelerator FLUTE: status update

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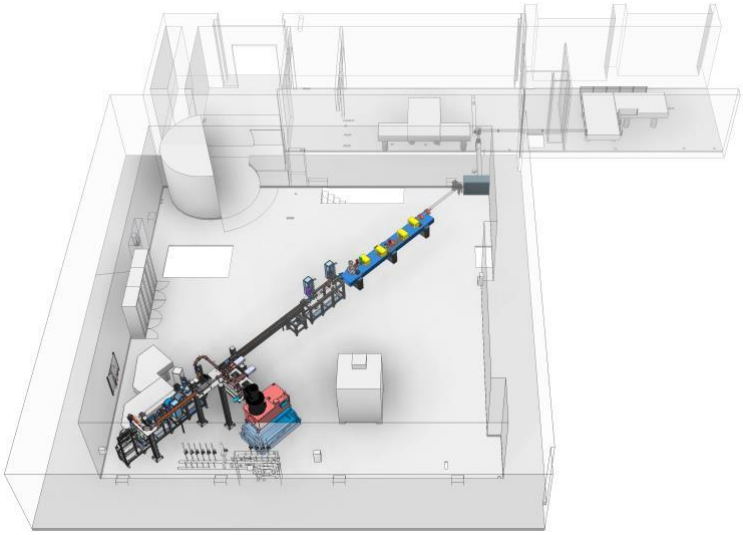
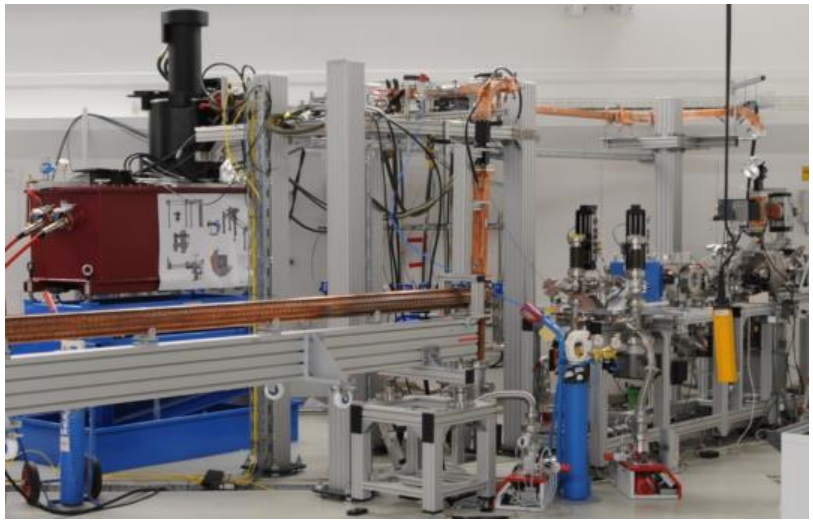
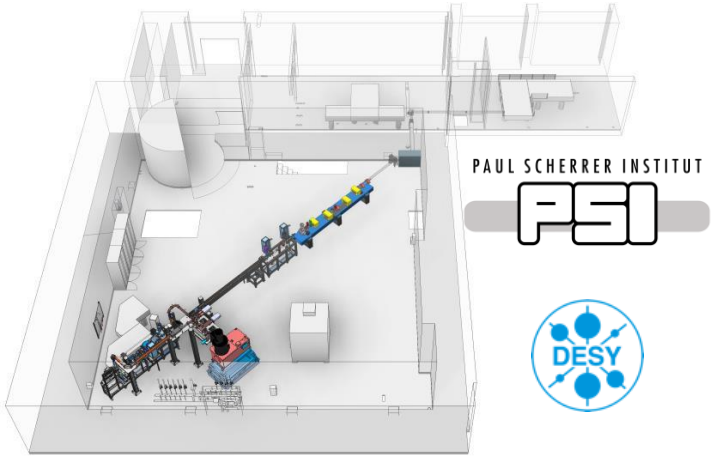
Institute for Beam Physics and Technology (IBPT)





FLUTE: Ferninfrarot Linac- Und Test-Experiment

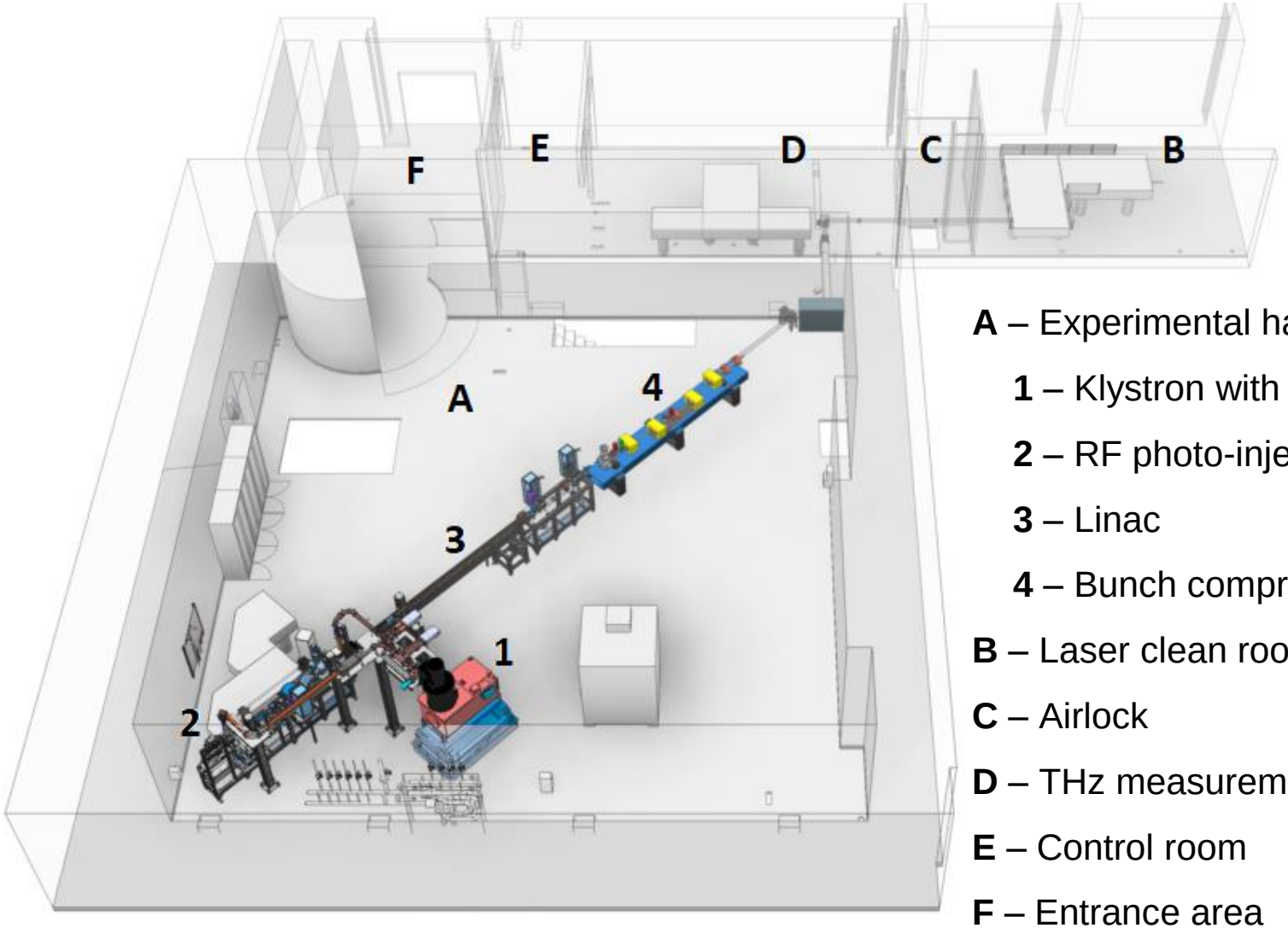
- **Main goals for FLUTE**
  - Test facility for accelerator physics
  - Compare CSR in simulation and experiment
  - Experiments with THz radiation
  - Test bench for new beam diagnostics



- **R&D topics**
  - Development of single-shot fs diagnostics
  - Synchronization on a femtosecond level
  - Systematic bunch compression and THz generation studies

Final electron energy	~ 41 MeV
Electron bunch charge	1 pC - 3 nC
Electron bunch length	1 - 300 fs
Pulse repetition rate	10 Hz
THz E-Field strength	up to 1.2 GV/m

FLUTE: Layout



A – Experimental hall:

- **1** – Klystron with auxiliaries
- **2** – RF photo-injector gun
- **3** – Linac
- **4** – Bunch compressor

B – Laser clean room

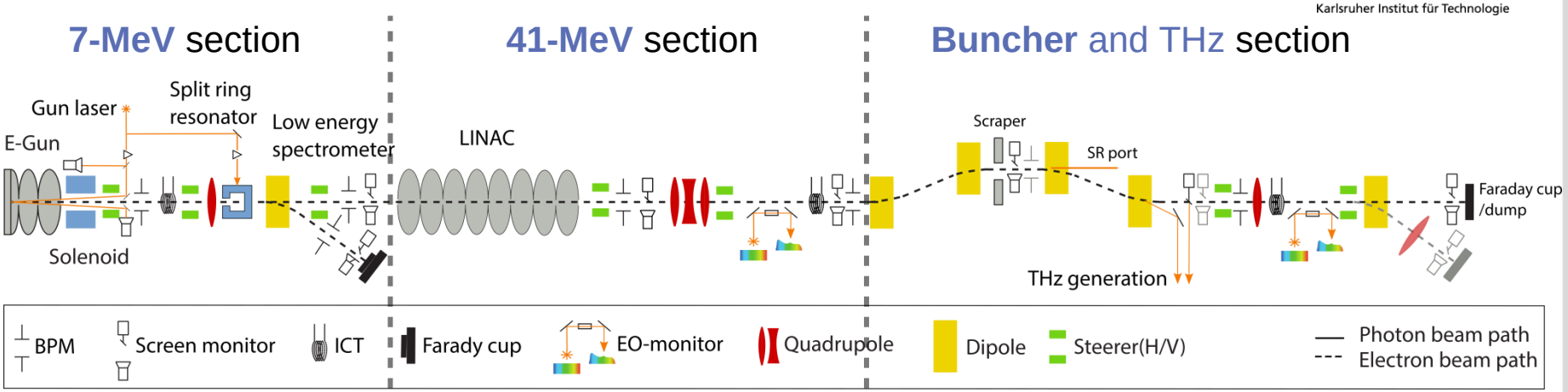
C – Airlock

D – THz measurement room

E – Control room

F – Entrance area

FLUTE: Layout & implementation

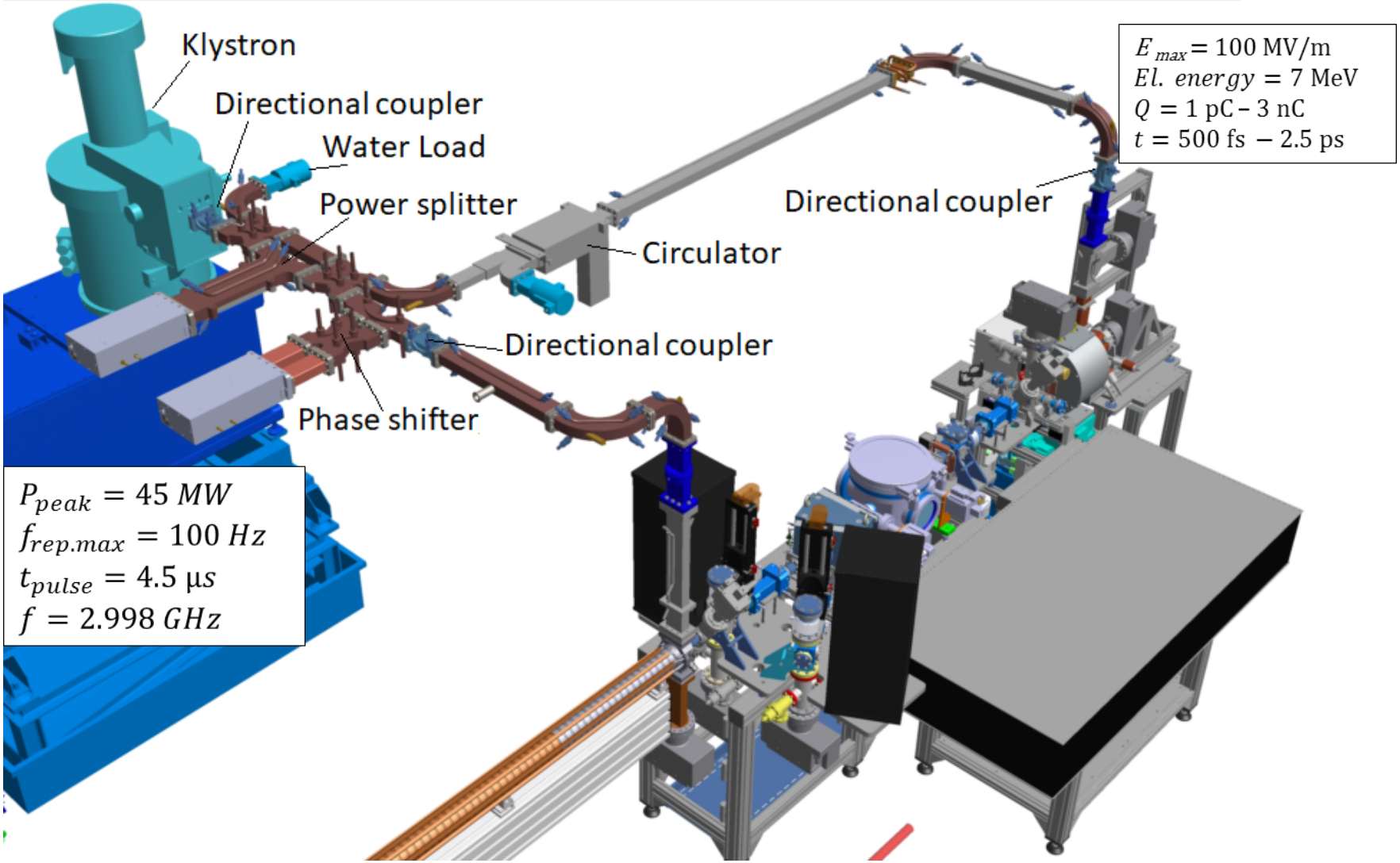


Energy	7 MeV
Bunch charge	**1 pC**-3 nC
Beam size	0.4-4.5 mm
Bunch length	**500 fs**-2.5 ps
Energy spread	0.14-0.8 %
λ (laser)	266 nm
Spot size	0.5-2.5 mm
Pulse length	500 fs-2 ps

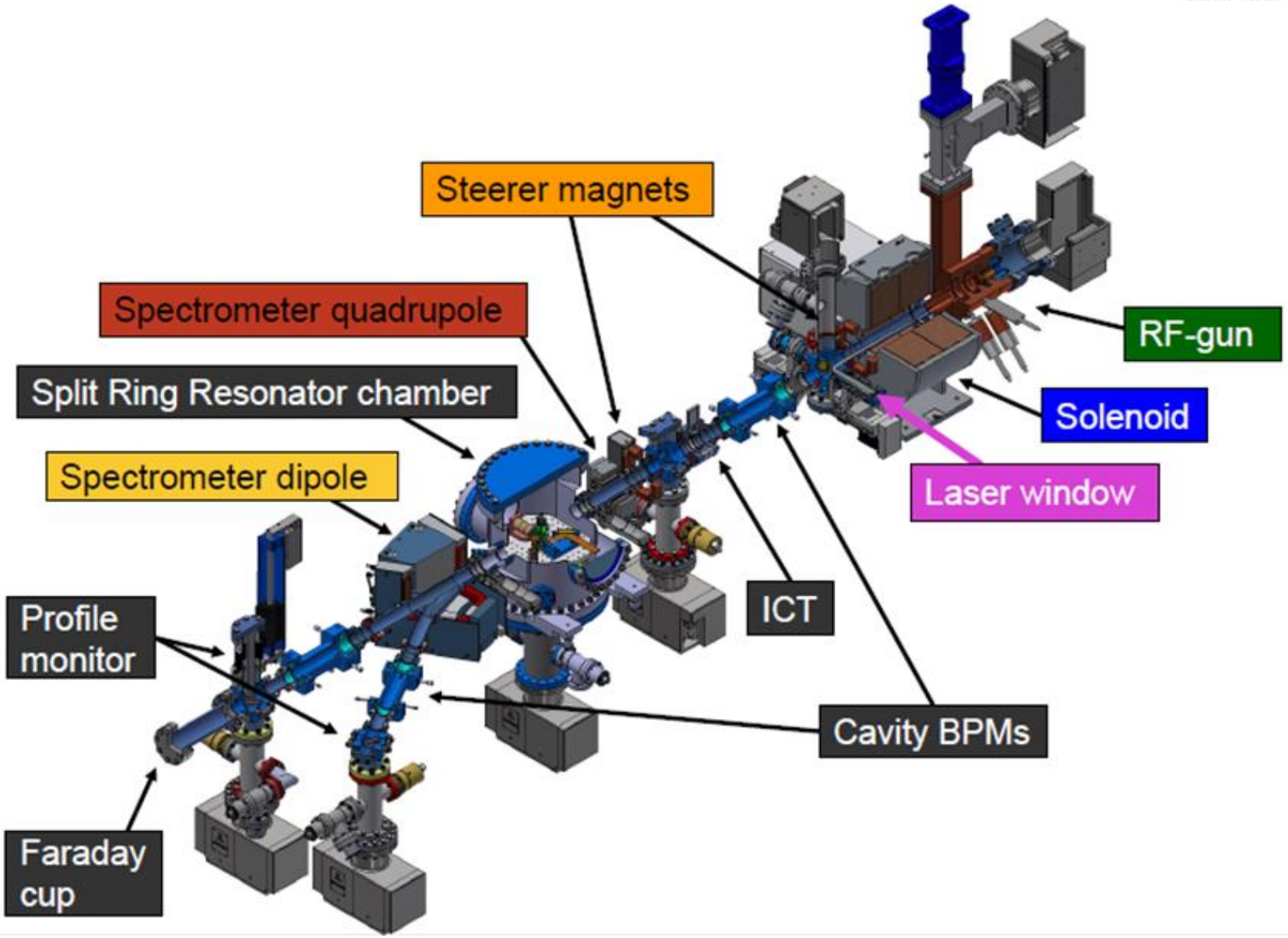
Energy	**41 MeV**
Bunch charge	**1 pC**-3 nC
Beam size	0.4-4.5 mm
Bunch length	500 fs-2.5 ps
Energy spread	0.24-1.8 %

Energy	41 MeV
Bunch charge	**1 pC** - 3 nC
Beam size	40µm - 3 mm
Bunch length	**few fs** - 500 fs
Energy spread	0.24 -1.8 %

RF system configuration

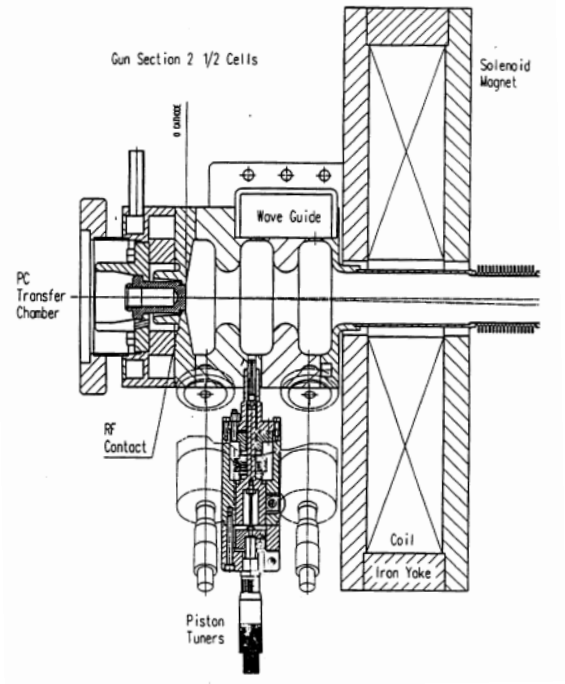


Beam diagnostics



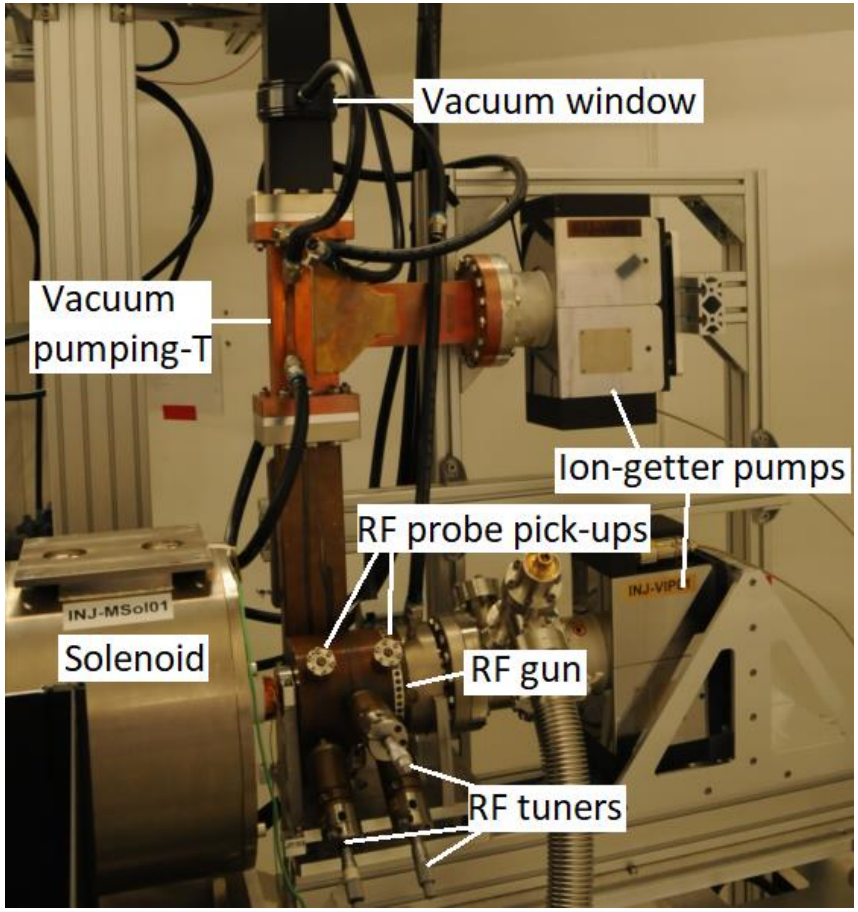
RF photo-injector configuration:

RF photo-injector parameters		
Frequency	2.998	GHz
Cells	2.5	
Peak E-field	100	MV/m
Peak power	20	MW
Output energy	7	MeV



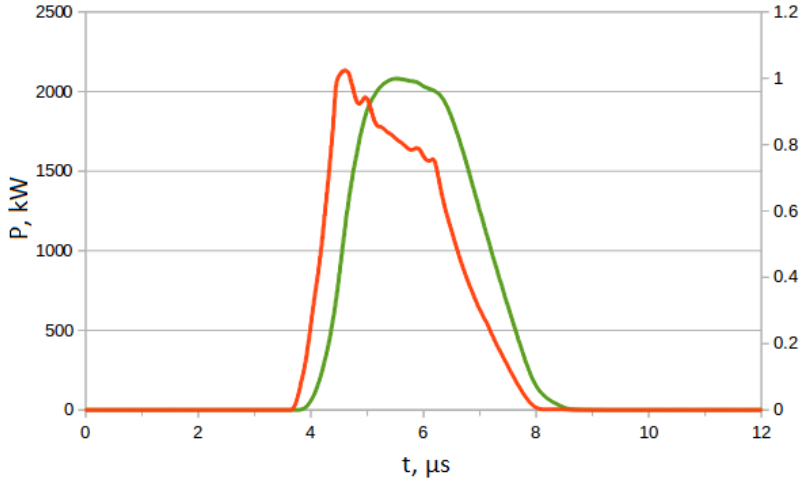
Maximum charge extracted from cathode per short:

- **Cu** cathode up to **700 pC** (assembled)
- **Cs_2Te** up to **3 nC** (planned)

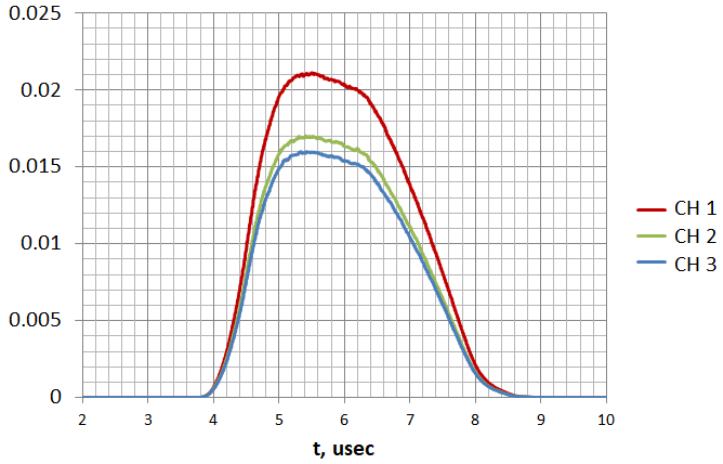


RF photo-injector commissioning results:

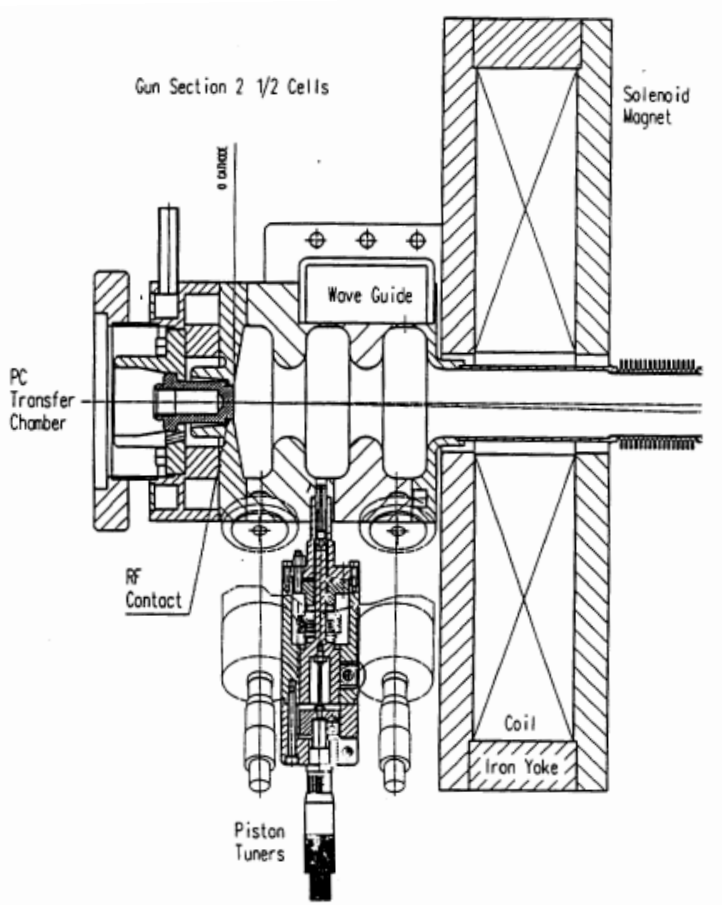
Input power from the klystron (red line – left axis) and normalised signal from the **RF probe pick-up** (first cell) (green line – right axis).



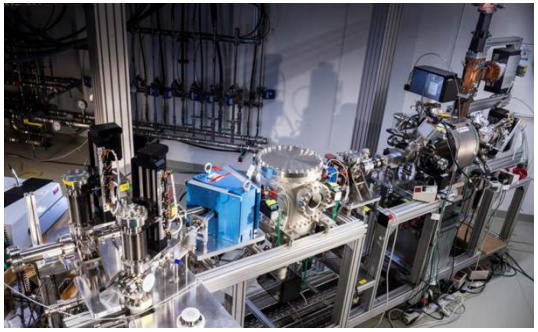
Signal from RF probe pick ups from three cells.
Red – first half-cell, **Green- second cell**, **Blue – third cell**.



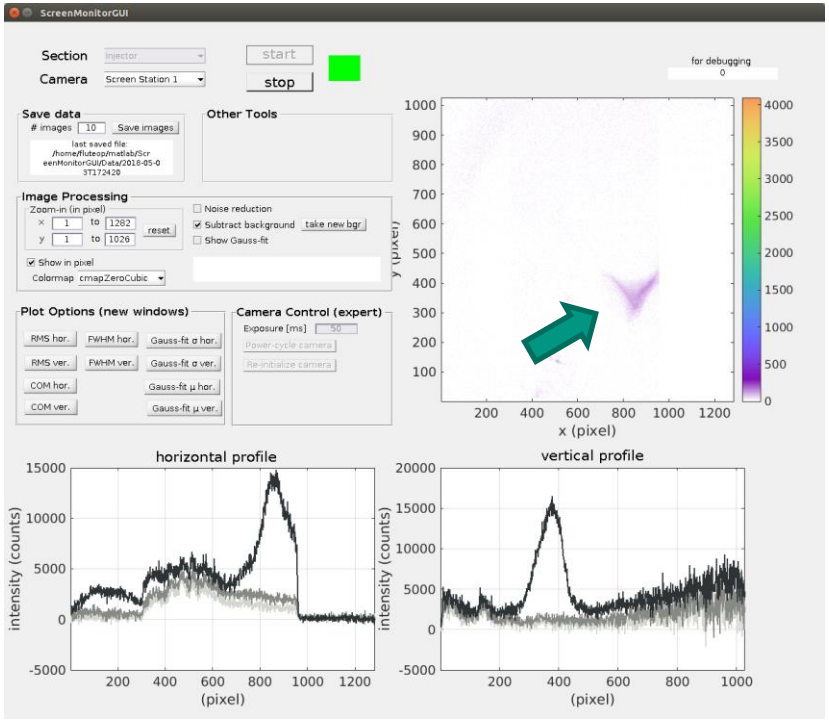
Input power into RF gun – **4 MW**
Electron beam energy – **2 MeV**

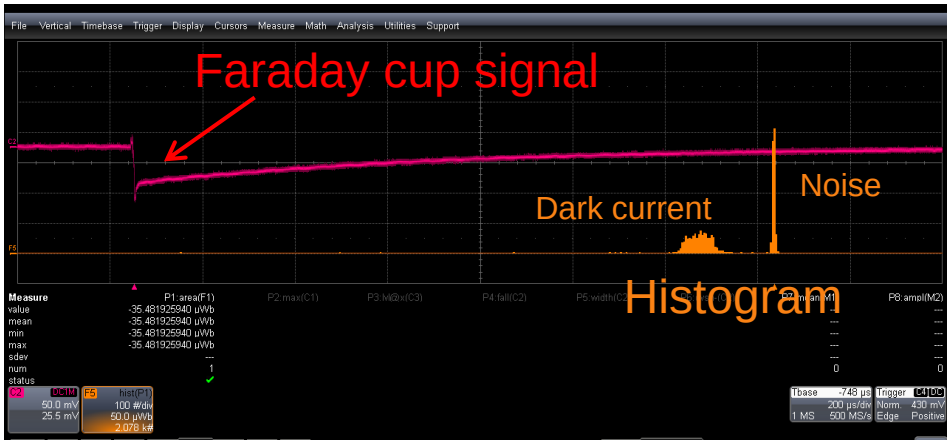


First electron beam:

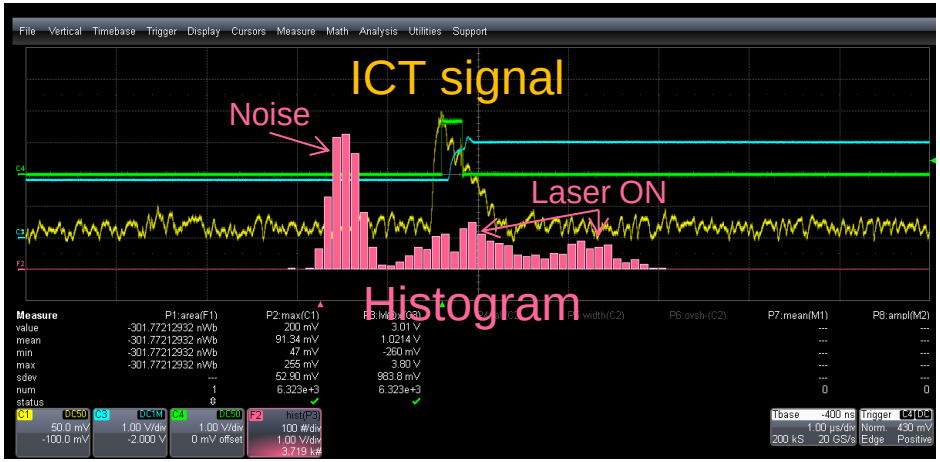


YAG screen monitor



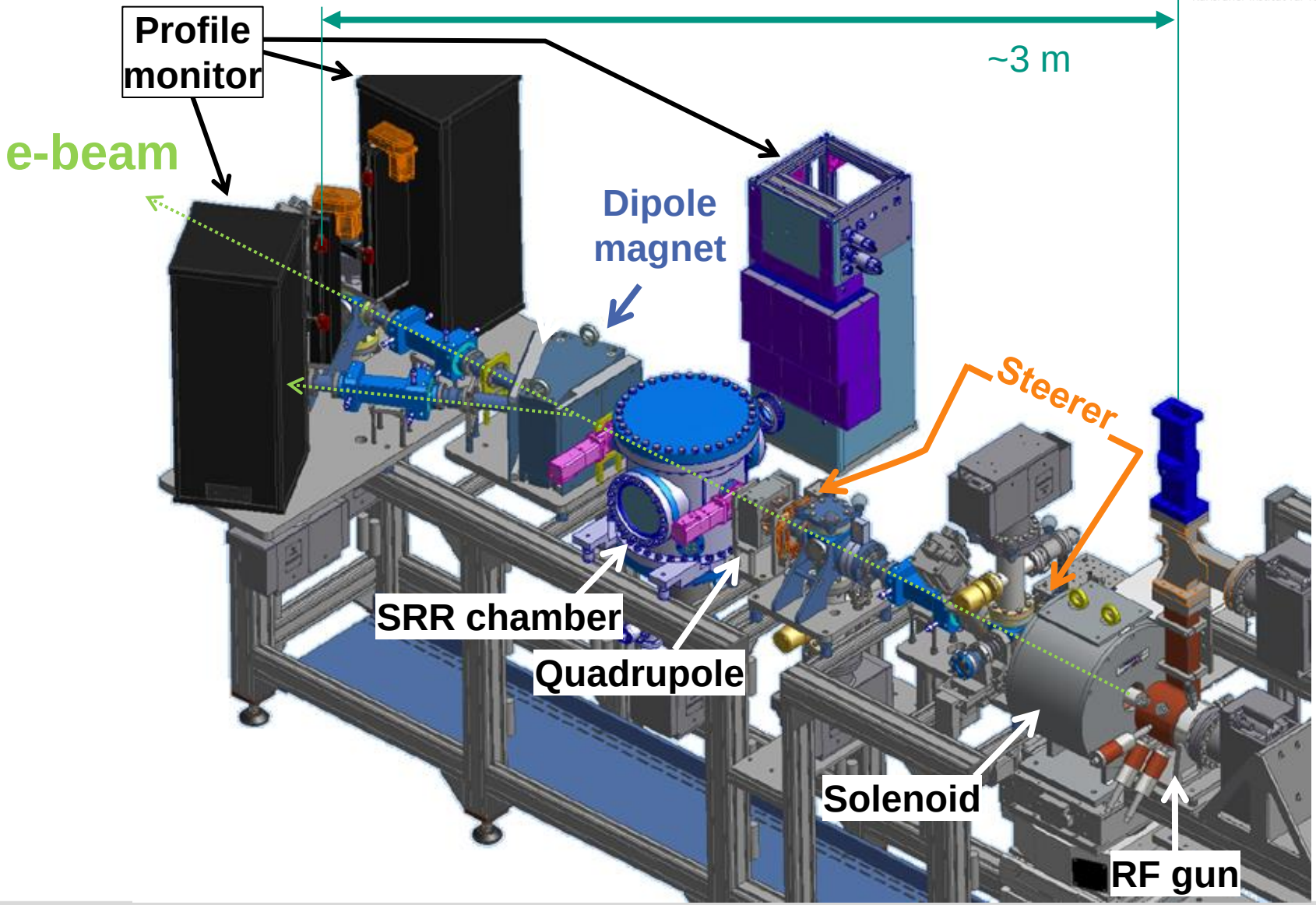


Typical Faraday cup output (connected via a coax cable to a 1 MΩ terminated oscilloscope). Orange curve shows the histogram of the Faraday cup signal.



Typical ICT signal. ICT trigger (green), ICT analog output (yellow), ICT capture and hold signal of the yellow trace (blue), histogram of the capture and hold signal (pink).

Split ring resonator experiment at FLUTE



Principle of SRR diagnostics

„Split ring resonator based THz-driven electron streak camera featuring femtosecond resolution“

J. Fabiańska, G. Kassier, T. Feurer, Sci. Rep. 4, 5645 (2014)

M. Yan et al., TUPG56, IBIC 2016, Barcelona, Spain.

- THz-range => **high frequency *f***
  - $LiNbO_3$ crystal => 35 fs pulse at 800 nm (FLUTE laser) converted to THz pulse
- Field enhancement in SRR gap => **large “kick” voltage *V***
  - Enhancement factor ~100 (at 0.3 THz)

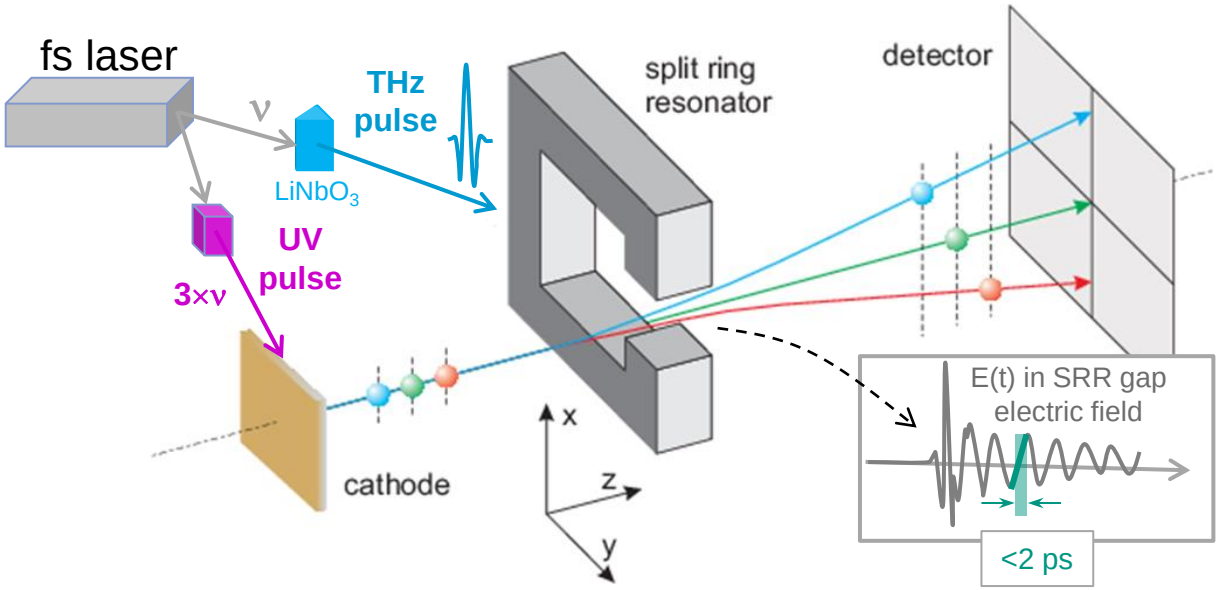


Table: Accelerator settings

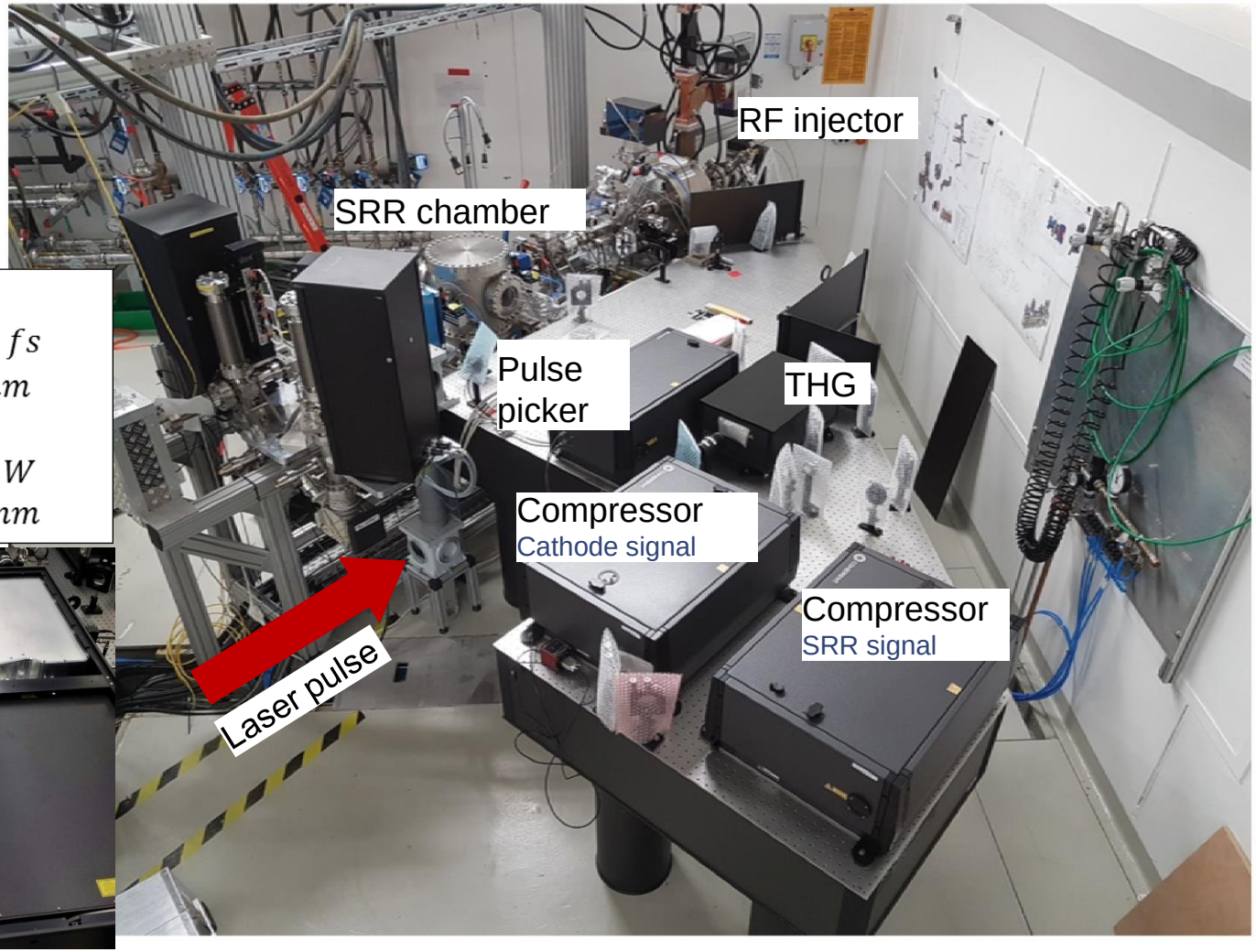
Laser rms pulse length	2 ps
Laser rms transverse size	5 µm
Bunch charge	50 fC
Gun gradient	120 MV/m
Gun phase	0 degree
Solenoid magnetic field	0.24 T
Bunch energy	7 MeV
Normalized rms transverse emittance	2.7nm

Table: SRR parameters

Gap size in x	20 µm
Gap size in y	20 µm
Gap width in z	10 µm
Resonant frequency	300 GHz
Peak electric field	500 MV/m
Integrated field	10kV

Laser system modifications:

New optical table has been installed next to the beam diagnostics section.



$P_{out} = 6\ W$
$t_{pulse} = \sim 35\ fs$
$\lambda_{out} = 800\ nm$
$f_{rep} = 1\ kHz$
$P_{THG} = \sim 1.2\ W$
$\lambda_{THG} = 266\ nm$

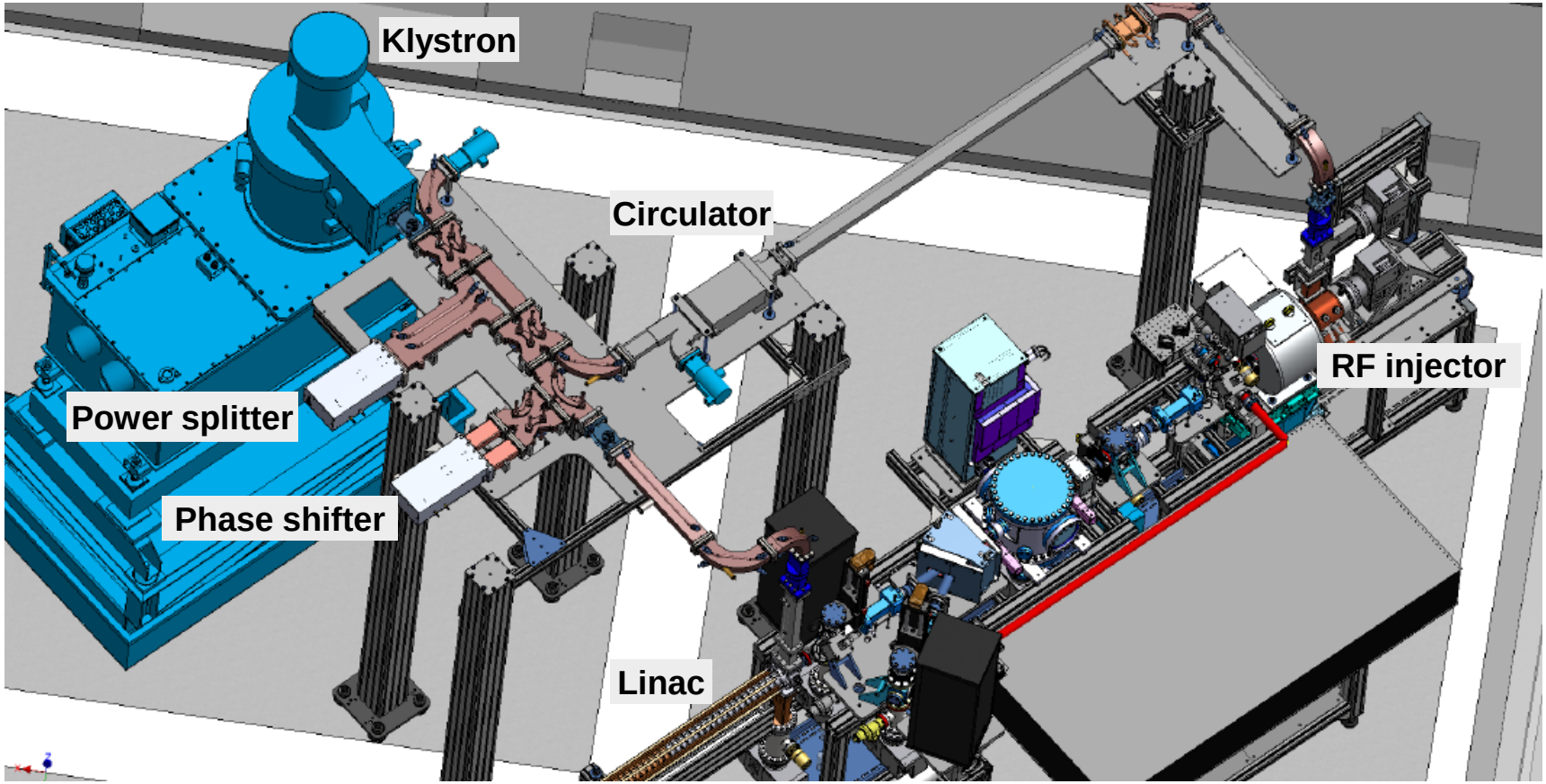
RF system commissioning

Problems and solutions:

- Leaks (SF_6 gas) were found in the power splitter and the phase shifter – have been fixed
- Circulator showed high insertion loss of 1.5 dB instead of 0.2 dB – new circulator was ordered expected delivery April 2019.

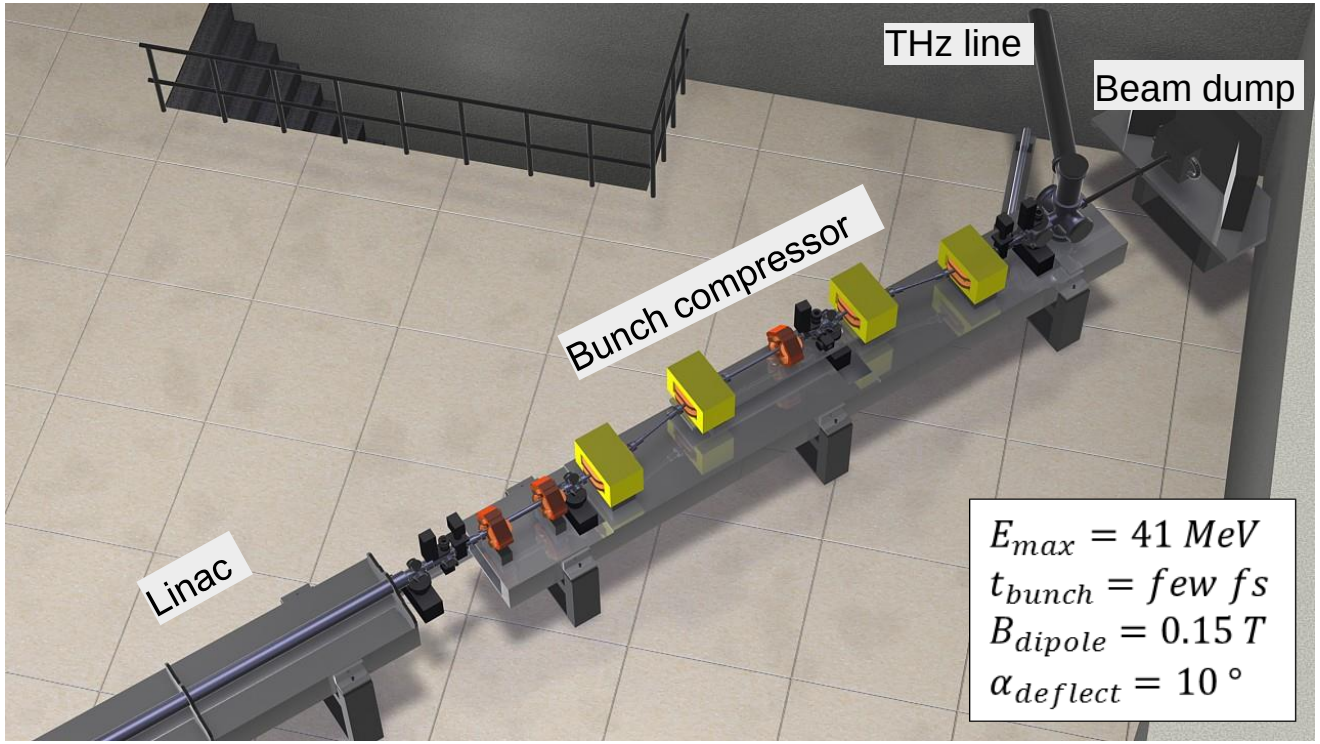
RF components and RF power:

- Power splitter – 45 MW (RF power)
- Phase shifter – 25 MW
- New circulator – 20 MW
- RF injector – 20 MW

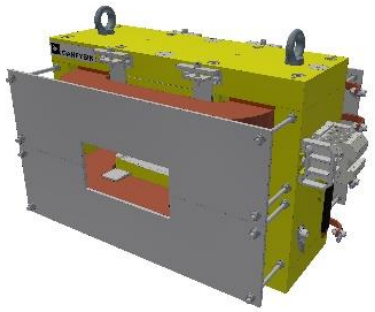


Bunch compessor

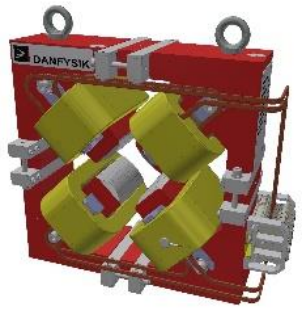
- Dipoles have been delivered, measurement of magnetic field distribution is in progress at KIT and compared to the specifications.
- Quadrupoles are in production.



Dipole



Quadrupole



Summary and Outlook

- Assembly of the FLUTE RF injector (7 MeV) and associated diagnostics completed, conditioning ongoing – **First electron beam measured**
- Conditioning results: RF power: 4 MW (limited by faulty circulator), Electron beam energy: 2 MeV, pulse length: 4.5 µs, repetition rate: 1 Hz has been reached
- New circulator will be installed on April 2019. This will allow to continue RF conditioning of different RF components. RF–laser synchronization is in progress.
- Dipoles for the bunch compressor have been delivered
- Next steps: commissioning of the new circulator, power splitter, phase shifter and RF gun at full power, RF-laser synchronization, assembling Linac and the Linac RF distribution system, conditioning Linac.
  Optimizing the design and assembly of the bunch compressor.

Thank you for your attention!