Status and Operation of the ANKA/FLUTE RF System

Nigel Smale
On behalf of the ANKA Machine/THz group

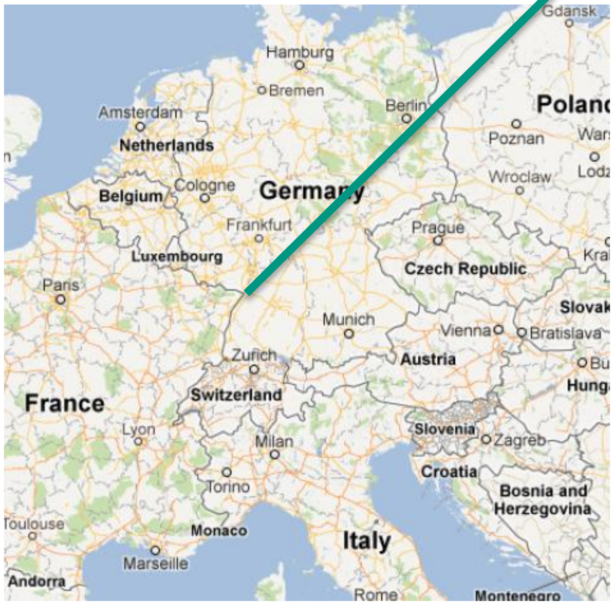
ANKA Synchrotron Radiation Facility

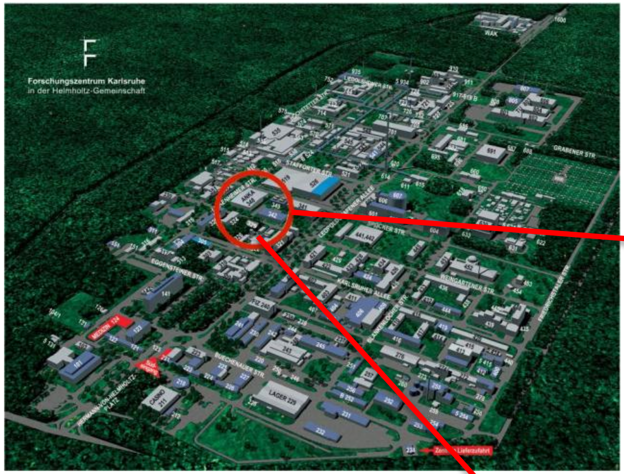
Outline

- KIT, ANKA and FLUTE
- ANKA Syncrotron RF
  - Fixes past, present and future
  - Cavity coupled mode instabilities
- FLUTE THz source
  - FLUTE layout
  - FLUTE RF components
- Summary

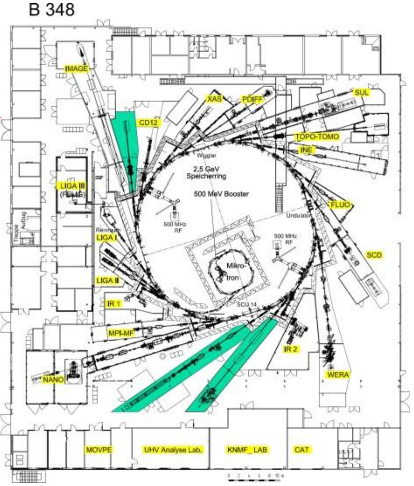
On October 01, 2009, the Karlsruhe Institute of Technology (KIT) was founded by a merger of Forschungszentrum Karlsruhe and Universität Karlsruhe.

- Energy
- NanoMicro
- Elementary Particle and Astroparticle Physics
- Climate and Environment
- Mobility Systems.

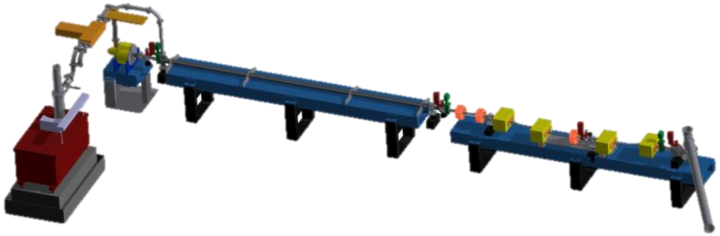




ANKA a 110.4m 2.5GeV synchrotron



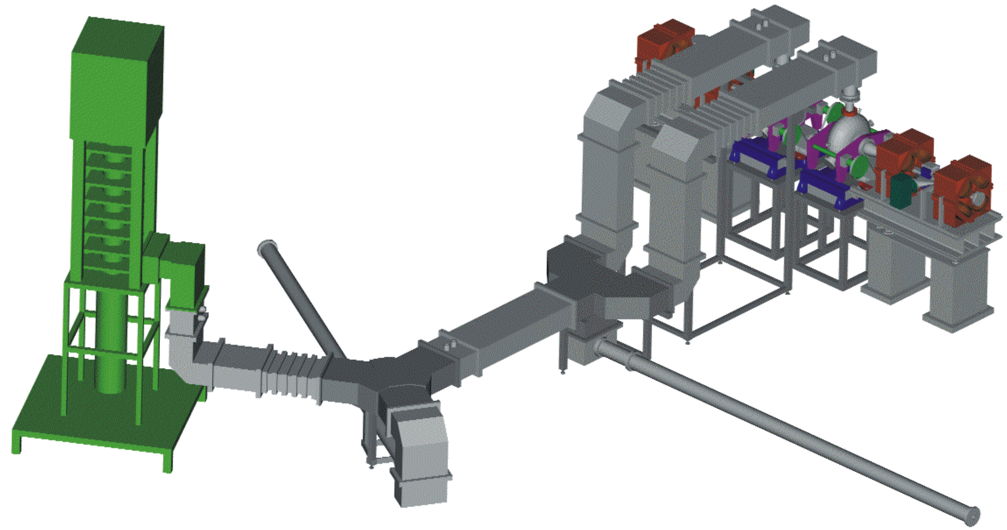
FLUTE a new THz source



One of Two ANKA RF Stations

Design Parameters	Value
Beam Energy	2.5 GeV
Energy Loss per Turn	662 keV
Design Beam Current	400 mA
Harmonic Number	184
RF Frequency	499.65 MHz
Momentum Compaction Factor	0.0081
Energy Spread	0.09 %
Total RF voltage	2 MV
Energy Acceptance	1.5 %
Synchrotron Frequency	36 kHz
Synchronous Phase	160.7 °
Bunch Length	9.8 mm
Number of Cavities	4

Quality factor: 40000
Shunt Impedance: 3.3 MΩ



250kW 4k hours/year (77k hours so far).
Inspection 2011 gave good results.

Schematic taken from ‘Proceedings of the 1999 Particle Accelerator Conference, New York, 1999’

Fixes in 2011

- ➜ 500 MHz low-level calibrated with C.Pasotti (ELETTRA)
- ➜ 500 MHz klystron input failed (cabling replaced)
- ➜ Cavity cooling failed (replaced with digital PID)
- ➜ 500 MHz preamplifier failed (see next slide)
- ➜ 3 GHz preamplifier failed (see next slide)

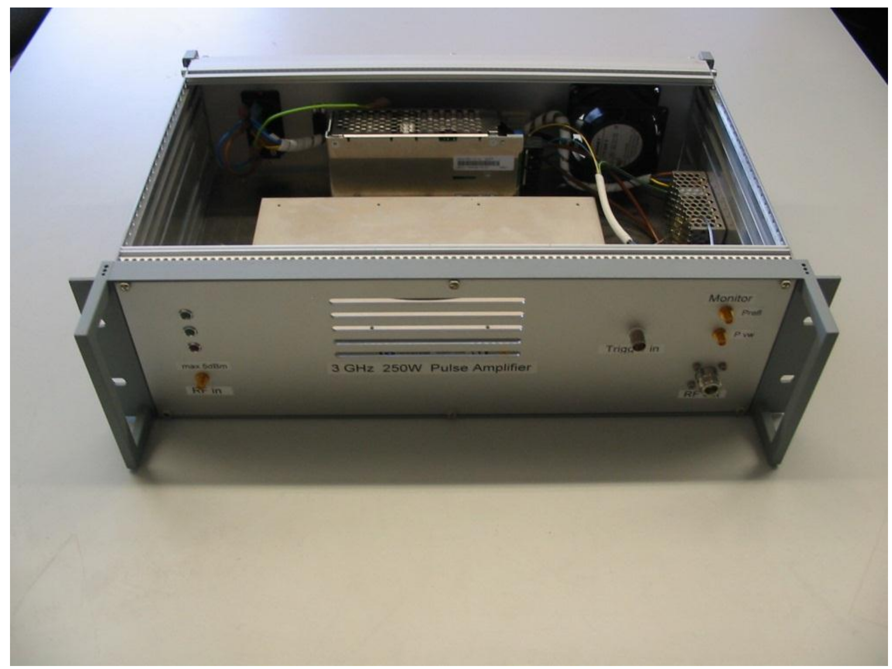
- RF expert hired in Feb.11 2011(Andreas Böhm)

Fixes in 2011

Both units built in house (Andreas Böhm).

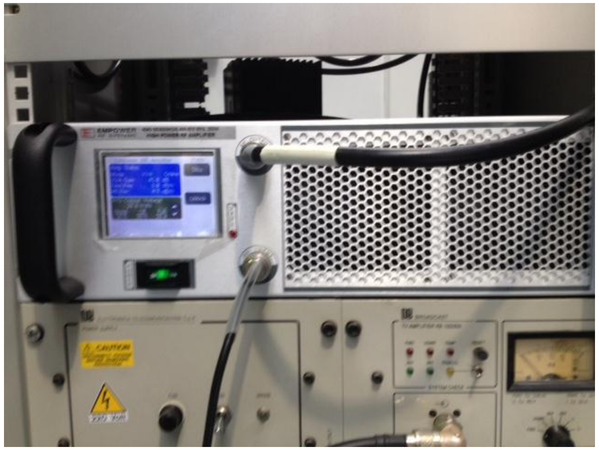
520 MHz 50dB gain, output 50dBm (CW 100W)
Amplitude module inside is Empower 1094
Total cost ~3000 euros

E-Gun Klystron, 3 GHz 5dBm input, output 250W gain 20dB, pulsed (7us at 20Hz).
Amplitude module is AM82-3S2
Total cost ~9000 euros



Fixes in 2012

- Mechanical phase shifters, jumping phase and belts
- Migration to a new control system as old one does not give back correct values and logging is limited.
- Amplitude loop replaced, phase stable attenuator (UMCC AT-AB00) good to 5 degrees from 0..40dB.
- Vertical coupled-mode instabilities in the cavities removed with Libera bunch by bunch system (see later).
- Replacement of booster amp.



For booster 500MHz RF cavity.
EMPOWER 4043 RF Systems 250W
50dB gain

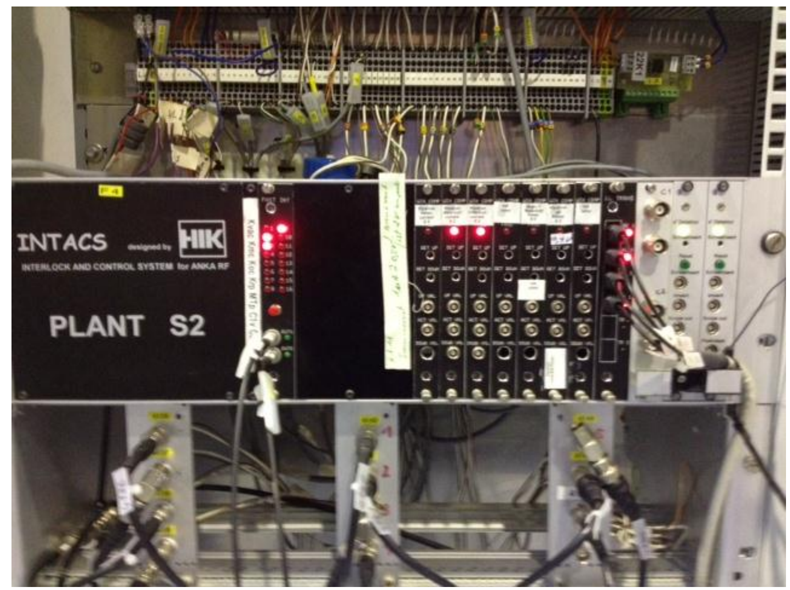
- RF heater failed (see next slide).

Fixes in 2013

High voltatge (40kV) heater unit for kylstrons fails occasionally: shunt resistor burnt out, fibre optic interlock system unstable, gauges display wrong value. Exchange to a floating PLC system. Also need to replace the the INTACS system; maybe with an FPGA based PLC system for speed.

Heater system

INTACS interlock system

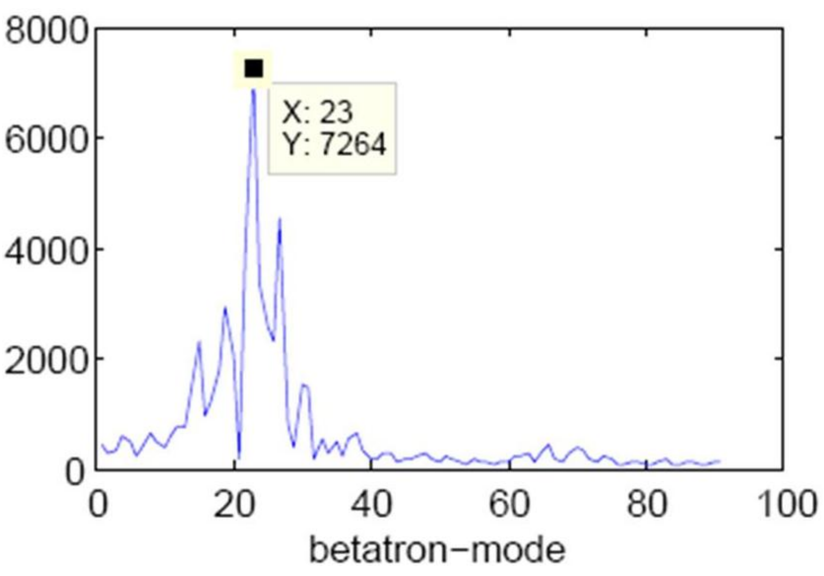


We would like to replace the present analogue LLRF to a digital system.

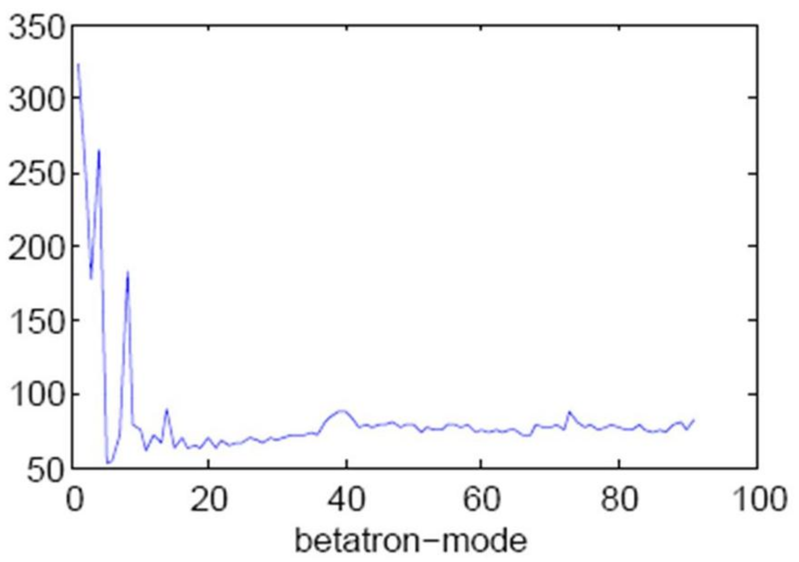
Bunch-by-Bunch Feedback System

- 1D system (vertical) installed at ANKA
  - now routinely used at 2.5 GeV to damp vertical instabilities
  - analyzing tool: identification of unstable modes

feedback OFF



feedback ON

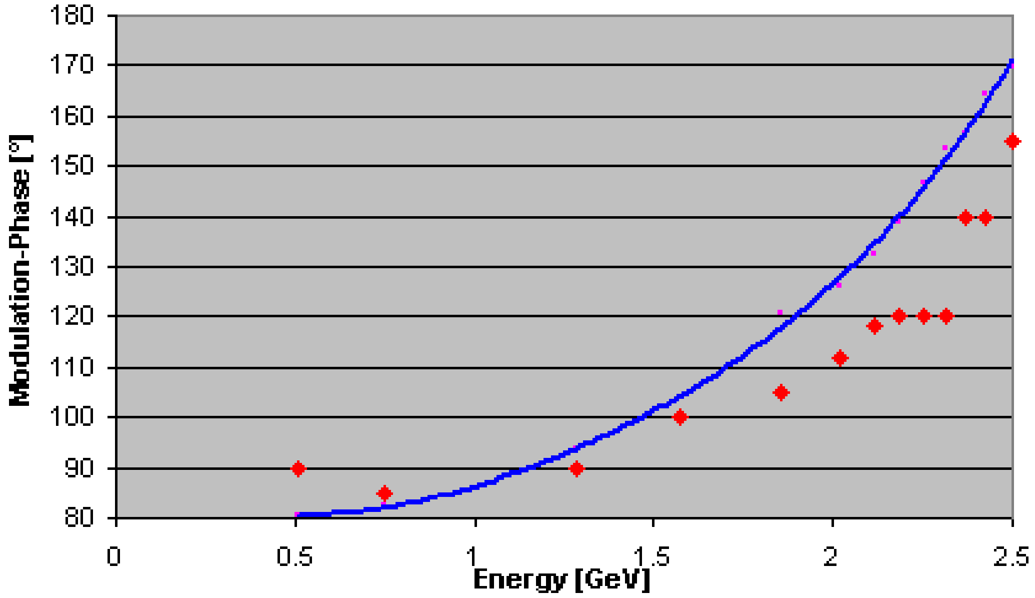


Bunch-by-Bunch Feedback System

Karlsruhe Institute of Technology

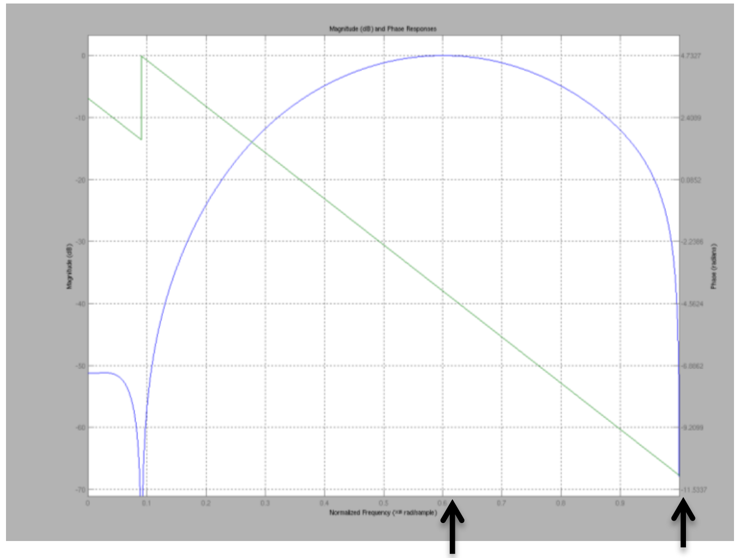
BEHAVIOUR DURING RAMP

Feed-back is only used at 2.5 GeV i.e. not during the 0.5-2.5GeV ramp. Synchronous phase is changing during the ramping process by about 30°. Due to the frequency tripling of the RF frontend this causes a phase shift of 90°.



Plot shows the measured and calculated change of phase during the ramp. Since the ramping is done in 4 minutes a proper adjusted control system should cope with this problem. This task is in progress.

Bunch-by-Bunch Feedback System

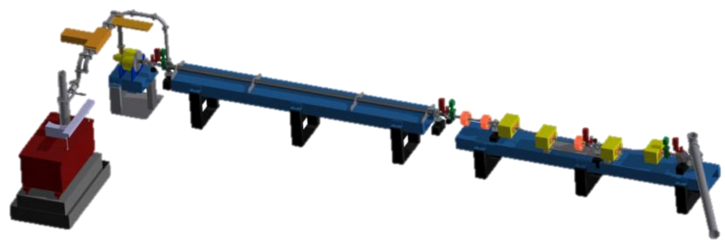


Vertical tune~0.83MHz 1.36MHz

FIR10 tap band pass filter is used centered around the transverse tune frequency of 813 kHz and a -3dB width of 300 kHz and a suppression of the DC component by 35 dB. Further filters had been tested without any significant change in the performance.

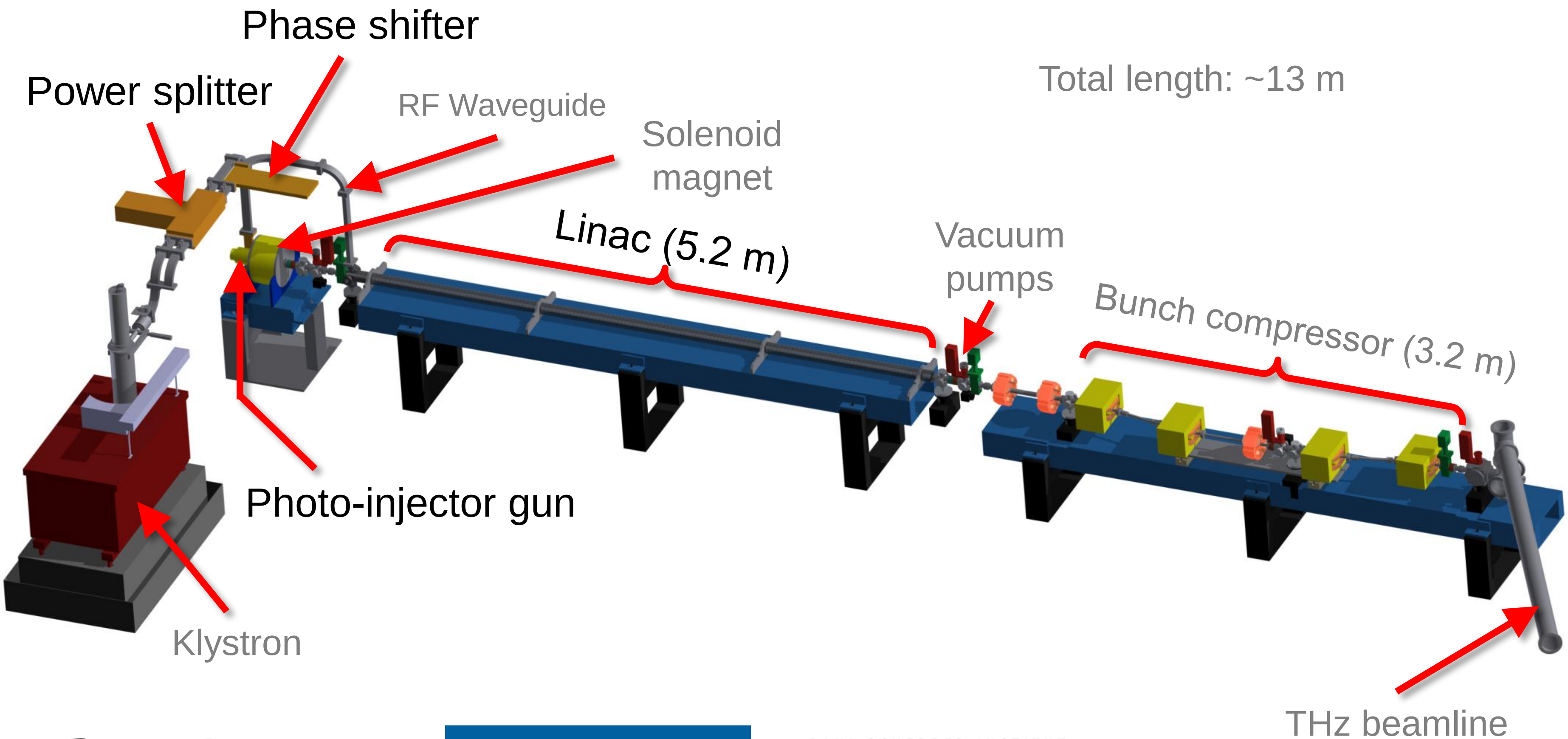
Goals for FLUTE

- Study for a **future** compact, broadband accelerator based **THz source**
- Test bench for new beam **diagnostics & instrumentation**
- Compare in simulation and experiment:
  - Coherent *Synchrotron* Radiation (CSR)
  - Coherent *Transition* Radiation (CTR)
  - Coherent *Edge* Radiation (CER)



- Systematic **bunch compression** studies:
  - Different compression schemes
  - 0.1–3 nC → Study **space charge** and **CSR induced effects** and instabilities
- **Experiments** with THz & X-rays, e.g.: Pump-probe, 2D spectroscopy, new materials,...
- Test facility for accelerator studies within the **Helmholtz "ARD" initiative**

FLUTE

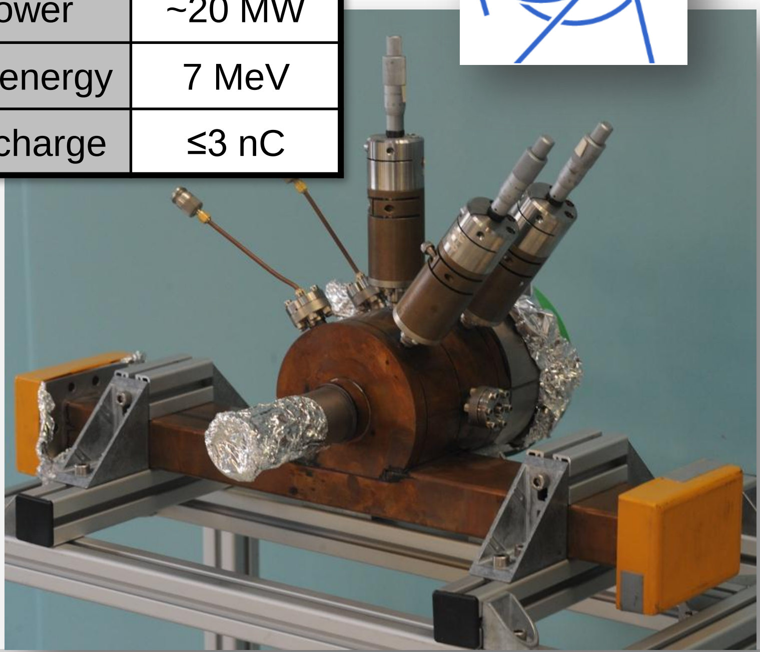

Phase shifter
Power splitter
RF Waveguide
Solenoid magnet
Total length: ~13 m
Linac (5.2 m)
Vacuum pumps
Bunch compressor (3.2 m)
Photo-injector gun
Klystron
THz beamline

FLUTE

Laser photo-injector gun

- CERN CTF 2 (CLIC Test Facility) gun
- Designed for high current

Property	Value
Frequency	2.998 GHz
Cells	2.5
Acc. gradient	~100 MV/m
Peak power	~20 MW
Output energy	7 MeV
Bunch charge	≤3 nC



- Laser system
  - Ti:Sa
- Cathode material
  - Starting phase: Cu
  - High current phase: Mg or Cs_2Te

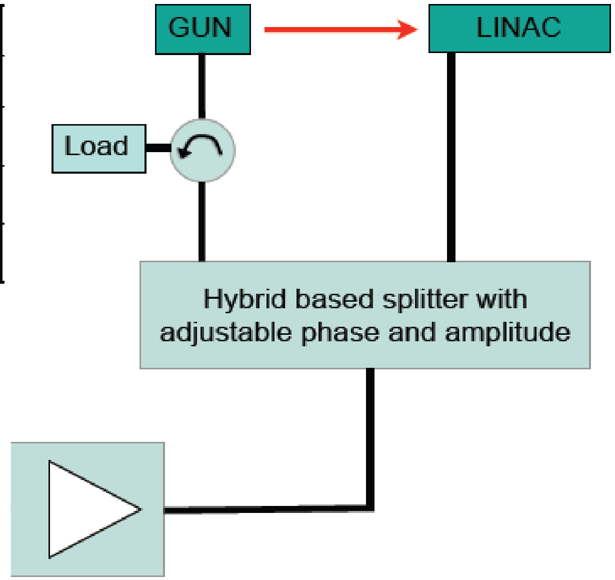
  → In vacuum changer system needed

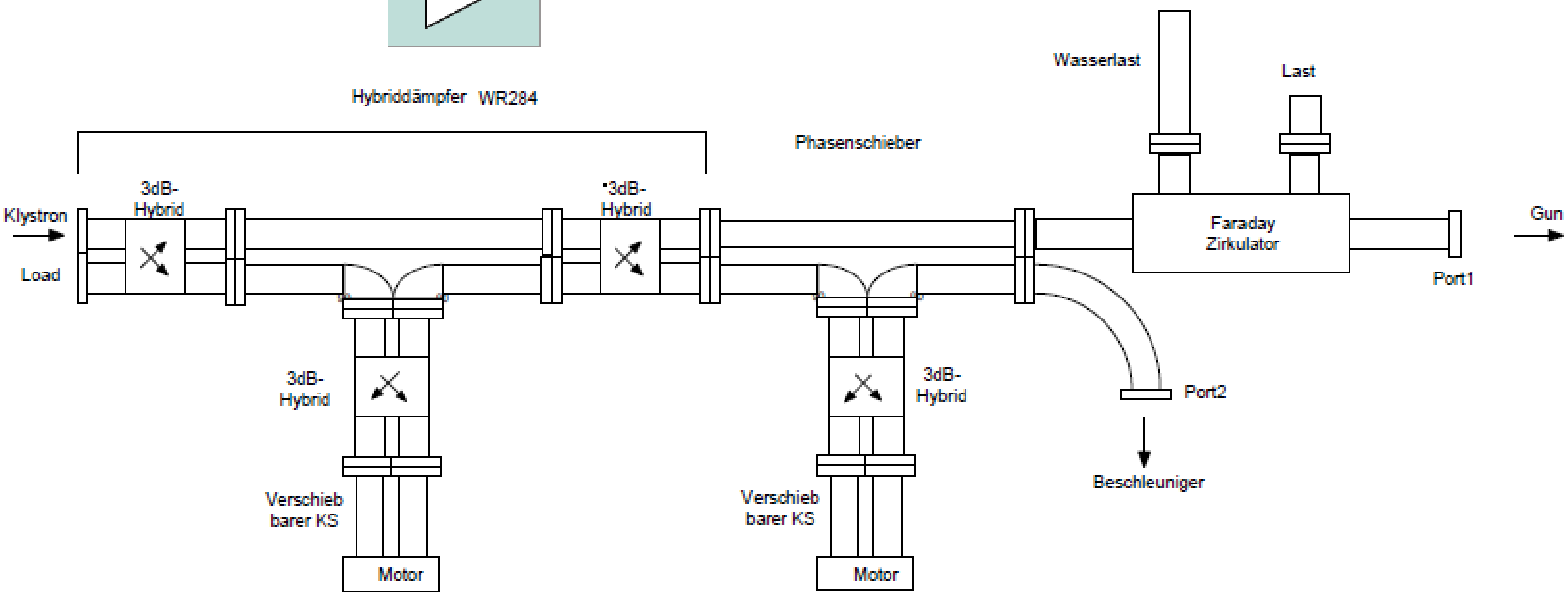
Property	Value
Repetition rate	10 Hz
Pulse length	1–4 ps
Wavelength	266 nm
Pulse energy on cathode	0.3 mJ

FLUTE

- Klystron properties:

Property	Unit	Value
Frequency	GHz	2.998
Peak power	MW	45
Pulse length	μs	≤ 3.0
Max. rep. rate	Hz	100



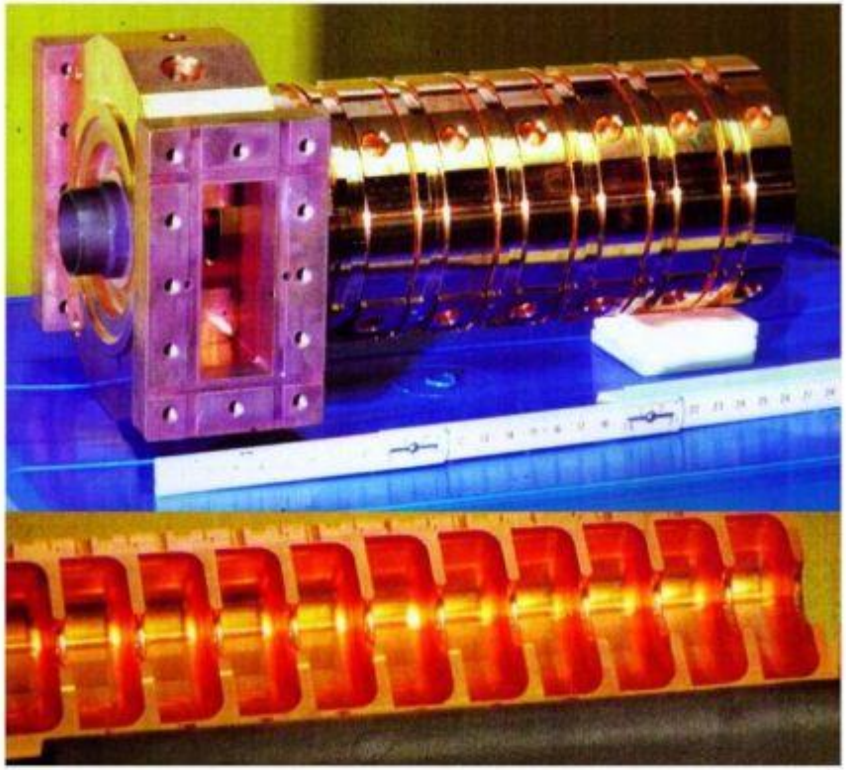


FLUTE

Traveling Wave Linac

- DESY Linac II Structure
- 2/3π structure with 156 cells
- Operation scheme for FLUTE:

Came from DESY late 90s, then in PSI test stand and now at ANKA



Property	Unit	Value
Frequency	GHz	2.998
Length	m	5.2
Acc. gradient	MV/m	~10
Peak power	MW	~20
Output energy	MeV	~41

Summary

- The 12 year old ANKA RF system has suffered few failures in its time. Running at reduced power has extended its life considerably.

- Coupled mode instabilities in the cavities are damped for 2.5GeV, but work is needed for the injection.

- FLUTE is in the process of being built up now. Accelerator structures already on site and the detailed layout of the system is in preperation (exciting times ahead).

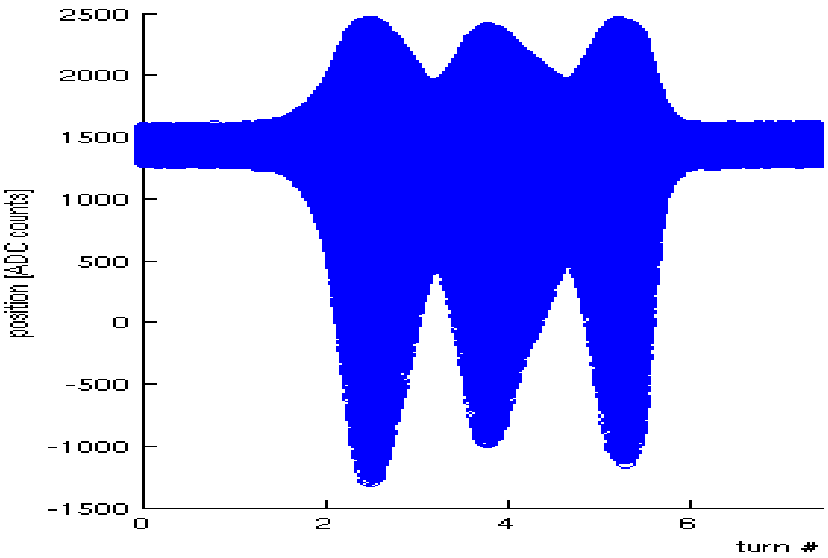
Thank you for listening

Extra Slides

Bunch-by-Bunch Feedback System

BBB INSTABILITIES AND CHROMATICITY

The vertical instabilities do not necessarily cause a beam loss. They rather cause a periodic blow up where they grow to a certain amplitude at which time they are damped due to a dependence on the chromaticity. Fig.7 shows such a grow damp behaviour. For this measurement the BbB feedback signal was turned off after 10,000 turns and turned on again after 60000 turns.



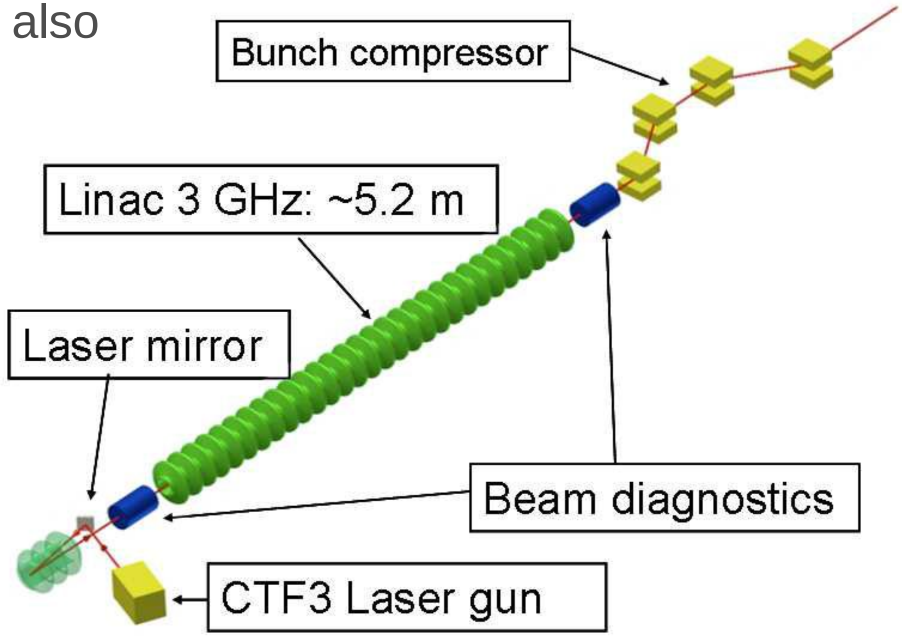
Vertical instabilities at a chromaticity of +3. Scale x10000 turns.

FLUTE

FLUTE (Ferninfrarot Linac- Und Test Experiment) based on a 30 -50 MeV S-band linac with bunch compressor, that aims at not only producing high field THz pulses but also at serving as a test facility to study accelerator physics issues.

PAUL SCHERRER INSTITUT

PSI



S. Naknaimueang et al., IPAC2012, TUPO007, FLUTE, a Linac Based THz Source.

ARD

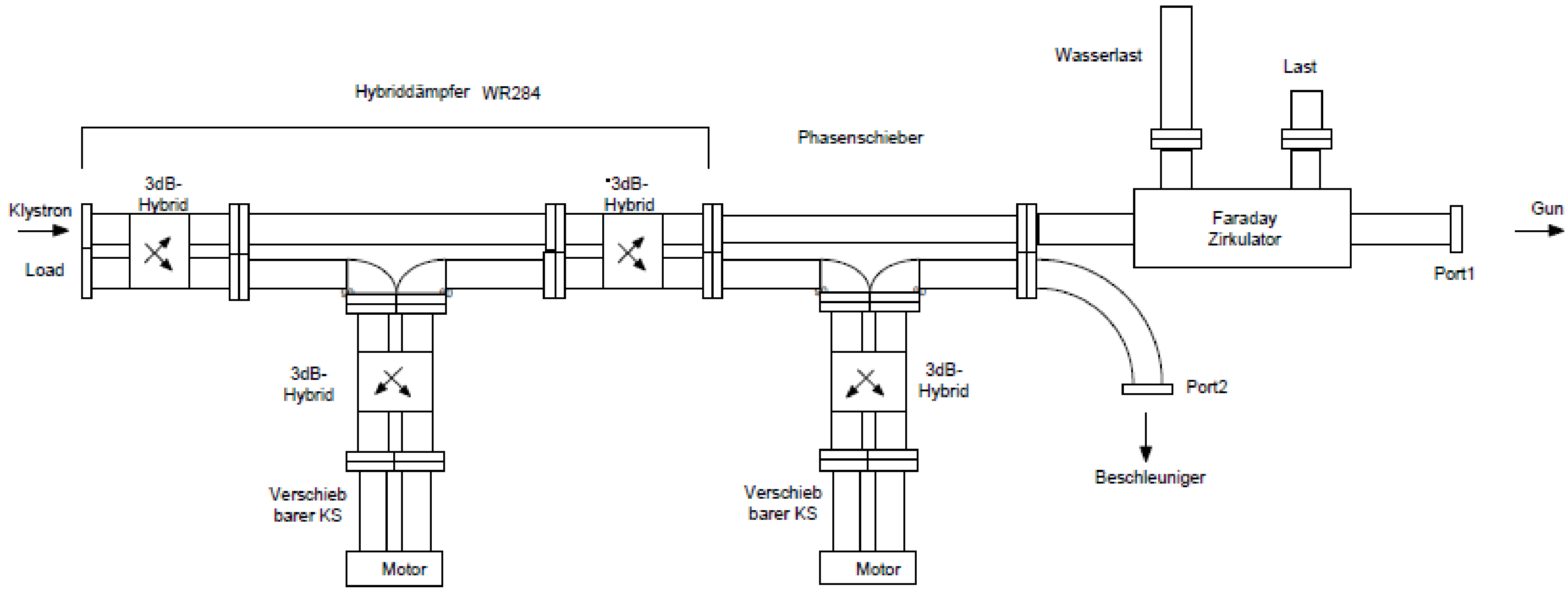
Helmholtz Initiative for Accelerator Research & Development (ARD) was established to strengthen future-oriented development in accelerator physics and technology and to substantially secure international competitiveness.

Apart from DESY; Forschungszentrum Jülich, Helmholtz-Zentrum Berlin, Karlsruhe Institute of Technology, Helmholtz-Zentrum Dresden-Rossendorf and GSI Helmholtzzentrum für Schwerionenforschung are on the list of participants.

On 1 July, the Helmholtz Association's senate decided to include the accelerator research programme as a new theme into the portfolio of the Structure of Matter research field and to fund it for the period from 2011 to 2014 with a total sum of 12.7 million Euros. In October, the senate will decide on an additional increase of two million Euros for the years 2013 and 2014, on recommendation of the senate´s commission. As from 2015, the ARD programme will be transferred into the third period of the Helmholtz Association's programme-oriented funding.

FLUTE

Titanium Safire
For high current



Flansch CPR 284F / G kombiniert mit Dichtring
An kritschen Stellen sind arc Detektoren vorzusehen
Klystron F= 2,9985 GHz Ppeak= 45 MW Pave= 20kW
Mittels verschiebbaren KS1 ist die Aufteilung der Power
auf Port1/ Port2 einstellbar. Phase muss dann nachjustiert werden.

Die Reflexionen von Port1 laufen in die Wasserlast
Sind vom Beschleuniger Reflexionen zu erwarten, so ist
hier auch ein Zirkulator erforderlich