

# Status of the Dortmund Electron Test Accelerator Facility

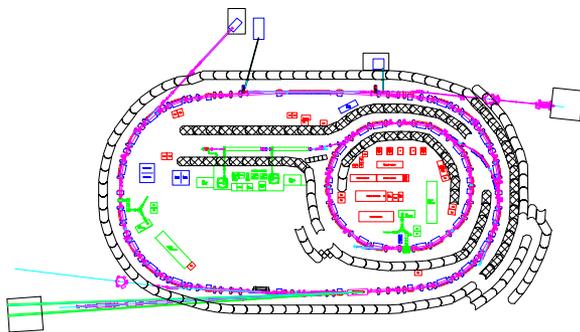
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## Abstract

The commissioning of DELTA, the 1.5 GeV electron storage ring facility at the University of Dortmund, is nearly finished. During 1997 both booster and storage ring have been run at energies between 300 MeV and 1.5 GeV. Electron currents up to 160 mA at 1 GeV and lifetimes of several hours have been reached in the low emittance optics. End of 1997 user operation was started with the commissioning of the Free-Electron-Laser experiment FELICITA I [1]. This paper will present the present status of the accelerator facility, emphasising two aspects, low energy single/few bunch operation, as this is essential for the operation of UV - VUV FEL devices, and the high current multibunch operation at the nominal energy of 1.5 GeV.

## 1 INTRODUCTION

The storage ring facility DELTA is operated by the Institute for Accelerator Physics and Synchrotron Radiation of the Physics Department of the University of Dortmund. The facility consists of a 100 MeV LINAC, the ramped injector storage ring BoDo and the main storage ring DELTA (Fig.1 and Table 1).

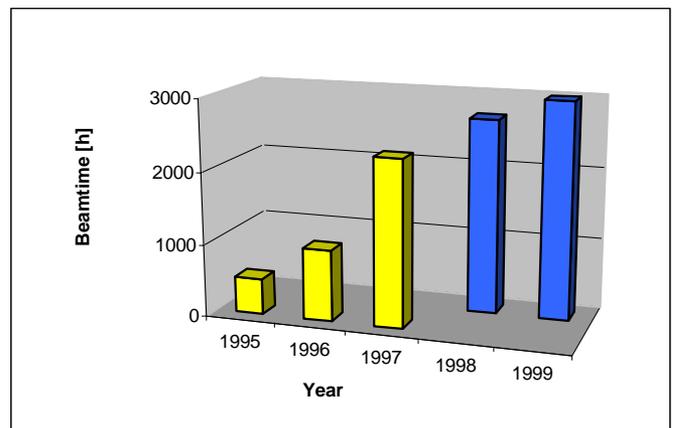


**Fig 1:** Layout of the facility. All essential components are located inside the radiation shielding.

Concerning the mission the DELTA facility is unique, as the machine was not designed to serve SR users only. The main goal is has been to operate as a testbed for accelerator technology and as a dedicated driver for Free-Electron-Lasers (FEL). Due to a high demand for a local SR facility in Northrhine-Westfalia, the mission of DELTA has slightly been changed. From 1999 50% of the scheduled 3000 h beam time will be provided for user

operation, and 1500 h will be scheduled for accelerator physics experiments and FEL. As in the case of SR use, DELTA will also be open for proposals of external groups, presenting new ideas and developments for accelerator physics and technology.

During the commissioning of the facility the operation in the energy regime of 300 MeV to 1.5 GeV was demonstrated. Currents up to 160 mA at 1 GeV as well as single bunch peak currents of 85 A at 450 MeV have been demonstrated.



**Fig. 2:** Evolution of operating hours of DELTA. The steady state with 3000 h/year will be reached in 1999

Fig. 2 shows the increase of the operating hours since 1994 as well as the number of hours scheduled in 1998 and 1999.

Up to now several sources for SR radiation are available or foreseen at the facility. Five bending magnets are equipped with SR ports, one of them is already used to serve an X-ray beamline, designed for the LIGA technique [2]. By inserting mirrors, this beamline can also be used for IR experiments. It is also planned to install a 2<sup>nd</sup> mirror to use VUV radiation from this port. A second dipole port is in operation for electron beam diagnostic by the machine group. Concerning insertion devices, DELTA already operates the U250 FEL undulator. This electromagnetic device, used to serve the FEL, operates also for a beamline for photoabsorption and -emission experiments in the 10-400 eV regime [3]. For the use of X-rays a superconducting asymmetric wiggler (SAW) is already in house [4]. This device will produce circular polarised X-rays ( $E_c = 8.2$  keV) and will serve 3 beamlines. The third insertion device is an undulator with 55

mm period length (U55), designed for operation in the VUV and soft x-ray regime. The installation of the wiggler and the U55 undulator is foreseen for fall 98, followed by the commissioning of the beamlines.

## 2 STATUS OF THE COMMISSIONING OF DELTA

As shown in Fig. 1 the facility has a very compact layout. All essential components of the accelerators including power supplies and transmitters are located inside the radiation shielding. The whole facility is installed in a simple ground level hall without any air conditioning.

### 2.1 LINAC

The LINAC of the DELTA facility is based on the old 400 MeV LINAC formerly operated at the University of Mainz. Using the components of the old power electronics and two of the accelerating structures, together with a new buncher section, focusing and vacuum system a 100 MeV injector LINAC was constructed. Due to limitations of the old components of the 3 GHz transmitters, the maximum energy of this machine is currently limited to 80 MeV [5]. Because of the low repetition rate of the booster, the current delivered from the LINAC within a single injection has to be high. Different electronics for the gun provides initial mean currents of about 1 A in 2 ns (single bunch injection) or 15 ns (single bunchtrain injection). This corresponds to accelerated currents within 1 % energy spread of 200 mA.

During fall 98 one of the old 3 GHz power klystrons will be replaced by a transmitter system using a state of the art 35 MW tube (Thomson TH2100). This will cure the existing limits on energy and energy spread. In 1999 the 2<sup>nd</sup> 3 GHz power klystron will also be replaced by an identical new system.

### 2.2 Booster BoDo

As already mentioned the full energy booster of the DELTA facility is a ramped storage ring. The electron beam is injected at 75 MeV and accelerated to energies of 300 MeV to 1.5 GeV within cycle times between 2.4 s and 7.1 s. Accelerated currents of 5 mA (bunch train) and 2 mA (single bunch) have been demonstrated.

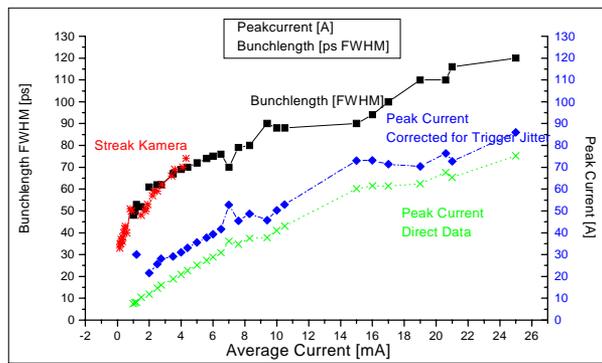
The computer control of the power supplies uses a special VME hardware, automatically synchronising all devices to be changed during the accelerating cycle. It is not only used for the dipole and quadrupole power supplies, but also to ramp the RF power, and the bumper magnets for extraction (The same hardware is used for the main ring. Therefore, it is possible to ramp DELTA in the same way, if required). Up to now BoDo is operated without steering. This will be changed in the near future by installation of new power supplies that will also be included in the synchronisation chain. Diagnostics to monitor the tune and orbit during the acceleration have

been developed, as it is essential to provide high injection current for the main ring due to the low repetition rate [6].

Another unique feature are the new designed kicker magnets of the facility. All kickers are from the slotted pipe type, in order to keep the impedance of the vacuum system low. During the commissioning they have proven the expected performance up to the design energy of 1.5 GeV [7]. For the booster there are 3 kicker magnets available, providing the possibility of low energy accumulation. First tests of accumulation have shown promising results.

### 2.3 Storage Ring DELTA

The first electron beam in DELTA has been stored in summer 1996 in a high emittance commissioning optics at 1 GeV, followed by a first phase of commissioning at 1 GeV within this optics to condition the vacuum system. Currents up to 140 mA in 16 15 ns bunch trains have been demonstrated in this configuration. During the summer 1997, the optics was changed to the low emittance optics. Shortly after this change a current of 160 mA and several hours of life time was reached at 1 GeV. During fall 1997 the emphasis was put on operation at different energies, demonstrating the energy regime from 300 MeV to 1.3 GeV. This topic was followed by a period of single bunch operation at 450 MeV for FEL experiments [1]. Peak currents up to 85 A at a bunch length of about 120 ps could be achieved (Fig. 3).



**Fig. 3:** Bunch length and peak current in single bunch operation mode versus average current, measured with a fast photodiode and a streak camera<sup>1</sup> at 450 MeV.

During the 97/98 winter shutdown the power supplies needed for 1.5 GeV operation had been installed. In spring 98 the machine was commissioned at 1.5 GeV. To obtain a 1.5 GeV beam the first attempt was to ramp a beam stored at 1.3 GeV to 1.5 GeV. This was possible without significant losses. A few days later also the full

<sup>1</sup> Thanks to Hamamatsu, Germany, for providing the dual scan streak camera for a demonstration experiment at DELTA.

energy injection and accumulation at 1.5 GeV was demonstrated. Up to now electron beams of 40 mA with a lifetime of about 7 h could be stored at 1.5 GeV.

During the winter shutdown a system for beam based calibration of the closed orbit measuring system was installed[8]. As the DELTA quadrupole magnets are powered by groups up to 4 magnets, it was necessary to install an extra cabling plus power supply to allow for a variation of the k-value of individual magnets. By steering the beam in the quadrupole and minimising the orbit distortion induced by the change of the k-value it is possible to determine the magnetic centre of the quadrupole and to get an absolute calibration of the BPM system. The first calibration of the 43 BPMs of DELTA shows an average absolute offset of 0.5 mm for both directions. This system provides also the possibility to measure the local beta-function of each quadrupole magnet by measuring the tune shift induced by a variation of the k-value of a single quadrupole.

An overview of the parameter set of the facility is shown in table 1.

Table 1: Operation Parameter of the DELTA facility

Parameter	Design	Measured/ Available
Lattice	Triplet	
Circumference	115.2m	
RF Frequency	499.664 MHz	499.812 MHz
RF Power	64 kW	55 kW
Bending Ports	5	5
Insertion Device Beamlines	5	5
Energy	1.5 GeV	0.3-1.5 GeV
Current (1.5 GeV)	200 mA	40 mA
Lifetime (1.5 GeV)	> 10 h	3 -7 h
Emittance (1.5 GeV)	15 nm rad	90 nm rad
Critical Energy (Dipole)	2.26 keV	
Critical Energy (Wiggler)	8.2 keV	

### 3 MILESTONES AND SCHEDULE

The schedule of DELTA foresees the following milestones for 1998:

- High current operation @ 1.5 GeV (200 mA multibunch operation)
- FEL lasing @ 470 nm (450 MeV)
- Installation of the superconducting wiggler and the U55 undulator
- Replacement of one 3 GHz power klystron of the LINAC
- Commissioning of the SAW II and U55 beamlines

To reach this milestones 2700 hours of operation are scheduled. For the year 1999 DELTA shall start routine operation with 3000 h of beam time per year.

### ACKNOWLEDGEMENT

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