Test Beams at DESY

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Abstract

This document is motivated by the need of clarification of possible interference between the operation of PETRA III and the DESY test beam. The document is intended to describe shortly the DESY test beam performance and the expected conditions after the start-up of PETRA III. We evaluate the possible impact of PETRA III on the availability, the intensity, and the energy of the electrons/positrons provided to the test beam lines at DESY II. In the interest of a very large community of test beam users we intend to identify, and eventually resolve, possible conflicts between the two main programs of the DESY II machine, namely the filling of PETRA III and DORIS and the beam delivery to test beam facilities.

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1 Introduction

DESY at its site in Hamburg operates the DESY synchrotron. In its rings DESY II and DESY III, electrons and protons, respectively, are accelerated and, after acceleration, injected into PETRA or DORIS. In addition electrons from DESY II are generated four test beam areas (T21, T22, T24, T24/1), located in building 27 (hall 2).
Detector developments for the next generation of HEP experiments are done in worldwide collaborations, both for the future ILC and for upgrades of the LHC. Increasingly the focus of these developments is on precision detectors, both in the area of tracking and in the area of calorimeter detectors. A shift of emphasis is clearly visible, away from an approach centred on the energy of jets as a whole, to an approach where the individual particles are most important.
Test beam facilities are very important during the phases of research and development but also during the commissioning of a detector. This is also visible in the occupancy of the existing test beam facilities. During the last years many collaborations building detectors or developing new detector technologies used the DESY electron beam for important studies from the proof-of-principle to the final calibration of detector components [1]–[43].
The DESY testbeam is also a key infrastructure for the recently approved HGF Strategic Alliance between DESY, FZ Karlsruhe and 17 German universities. Its long term availability and ease to use makes it a very valuable facility for the development of future detectors both for ILC and LHC upgrade. The test area T24/1 has been recently equipped with a superconducting solenoid to be one of the key locations for a European test infrastructure sponsored by the EUDET project [44]. In the context of the EUDET project DESY is committed to provide the testbeam infrastructure until the end of 2009 to European groups applying through the Transnational Access scheme.
In chapters 2 and 3 the test beam and its current conditions are described. In chapter 4 the possible interferences between PETRA III running and test beam operations are described.

2 The DESY II Electron Beam

The operating parameters of DESY II are defined by the future main users, the synchrotron sources DORIS and PETRA, and secondarily by the test beam users. The beam in the DESY II ring accelerates and decelerates in sinusoidal mode with a frequency of 12.5 Hz. Therefore one DESY II magnet cycle takes 80 ms. In theory particles could be injected into the synchrotron every cycle. But typically when running in DORIS mode DESY II injects every second cycle (160 ms) single bunches with about $3 \cdot 10^9$ positrons at 4.5 GeV/c into DORIS. For PETRA it injects every fourth cycle (320 ms) single bunches with up to $3 \cdot 10^{10}$ electrons ($1 \cdot 10^{10}$ positrons) at 7 GeV/c. The ejection to DORIS and PETRA happens at maximum energy 40 ms after injection.
The electrons/positrons for the test beam are provided as sketched in Figure 1:
a Bremsstrahlung beam is generated by a 7 μm carbon fibre (primary target) in the

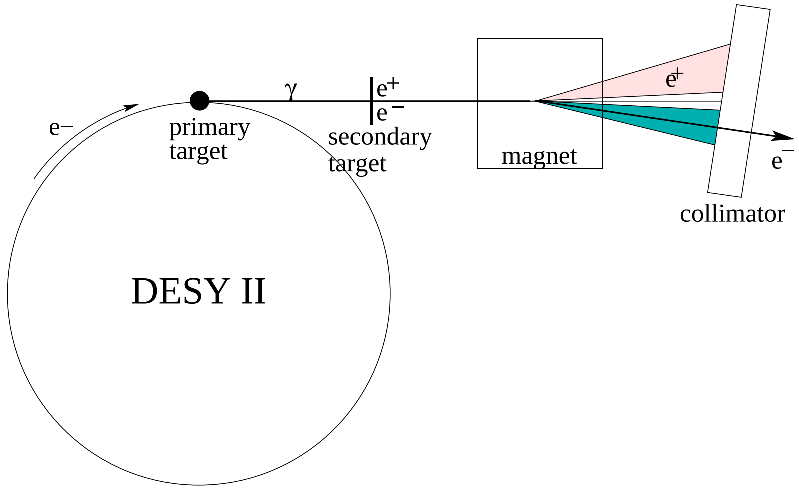

Figure 1: Generation of electrons for the test beam area 22.

circulating electron synchrotron beam DESY II, a metal plate (secondary target) is used to convert these Bremsstrahlung photons into electron/positron pairs, a dipole magnet spreads the beam out into a horizontal fan, and a set of collimators form the extracted beam. The magnet is used to control the energy of the beam. This parasitic test beam provides electron energies from 1 to 6 GeV/c. In this range the electrons are minimal ionising particles (MIPs). Therefore the physics of the test beam line is simple. The Bremsstrahlung spectrum has a $1/E$ dependence. The energy distribution of the electron/positron pair conversion is nearly flat.
The accelerator control room handles the fibre target and the beam intensity in DESY II. The test beam user contacts the control room if changes are necessary. The magnet settings for the selection of the momentum, the choice of the conversion target and the collimator settings are under control of the test beam user.

3 Test Beam Performance

The RF drive frequency is varied between injection and peak energy to reduce beam loading at injection and thus allow higher beam current to be stably accelerated. The

Beam [GeV/c]	1 mm Cu [Hz]	3 mm Cu [Hz]	1 mm Al [Hz]	3 mm Al [Hz]
3	1800	3700	700	1100
6	280	500	125	160

Table 1: Energies and rates ($1/cm^2$) available at the DESY II test beam facilities for different secondary targets.

machine group denotes this as frequency modulation (FM). Without this technique the maximum stable intensity is $\approx 10^{10}$ particles (1.6 mA). Using the FM method, acceleration of over 3×10^{10} electrons has been observed. Use of this procedure changes both the beam size and orbit position. Recent studies have shown that the rates in the test beams are about a factor of 20 higher without FM and therefore the following rates are all achieved without FM.

The performance of the test beam facility in terms of rate of particles per cm^2 are summarised in table 1. The testbeam rates versus the selected momenta for 6 GeV and 7 GeV machine energy are shown in Figure 2a. Both curves were measured at T22 with a 9×9 mm^2 threefold coincidence trigger, without FM, $\sim10^{10}$ electrons in DESY II, and a 1 mm Cu secondary target. The testbeam rates versus the selected momenta for different targets are presented in Figure 2b. Here the machine energy was set to 7 GeV, all other conditions were the same. A 10% error should be applied due to scaling uncertainties.

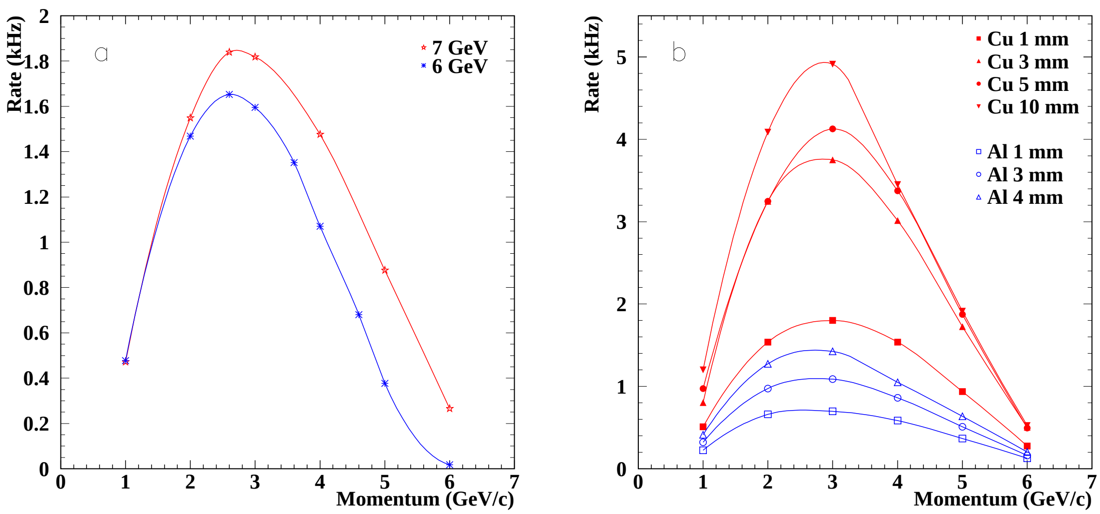

Figure 2: a: testbeam rates versus the selected momenta for 6 GeV and 7 GeV machine energy. Both curves were measured at T22 with a 9×9 mm^2 threefold coincidence trigger, without FM, 10^{10} electrons in DESY II, and a 1 mm Cu secondary target. b: testbeam rates for different secondary targets.

4 PETRA III running concurrent with Test Beams

In autumn 2008 the commissioning of PETRA III will start. In this section the different possible interferences which might arise from the combined operation of PETRA III and the test beams are summarised. For some issues we give a possible solution.

PETRA III running mode Three different phases of PETRA III will have different impacts on the test beam operation. In 2008 during the commissioning, positrons will frequently be injected in a similar running way as for DORIS at present. In 2009 a phase with low intensity positrons will follow. Later on (2010) high intensities will be required, then positrons will be injected every minute down to every 3.6 sec [45] in order to keep the beam intensity constant (this injection mode is referred to as top-up mode). The operation of PETRA III with electrons is not excluded also in the top-up mode, but this would imply that also DORIS has to run with electrons. Beam polarity switch in the top-up mode is excluded, as such a switch takes about 10 minutes .
For the first years of PETRA III the DESY II operation with positrons of 6 GeV/c is requested.

Positron Running One critical aspect for the reliability of DESY II running with positrons is the performance of the positron converter in the LINAC II. The converter can get extremely activated, resulting in necessary "cooling" phases before any possible repairs. This can take up to a couple of weeks. In order to minimise the activation the positron conversion would be turned off in between the PETRA III cycles. This is not possible when the test beam is in operation. Test beam operation would even worsen the problem as higher currents in DESY II are needed to achieve the desired rates hence higher doses are expected. The machine group is working on an improvement of this converter. A new converter is designed which has less risk to fail as in-vacuum welding joints are avoided. Two converter set will be available to minimise the beam down-time. A broken device would be covered with a lead cap and shifted aside. The second system would replace the broken system and repairs could follow after an adequate cooling time without disturbing the beam operations.
In order to decrease the current in DESY II during the test beam operation a thicker primary target could be used to increase the photon yield. As a result of the thicker target the low emittance needed for PETRA III filling could be destroyed. It is therefore proposed to operate DESY II during testbeam operation with orbit bumps during the cycle. These orbit bumps would move the beam from the nominal orbit further out by about 10 mm where the thicker target would be positioned. The orbit bumps can be switched between acceleration cycles. There should be enough bump coils available for this running mode. With such a running mode both users can ask for independent optimisation. The FH group has already started discussions with the machine group on beam optics and possible target thicknesses.
In case this bump solution would not be feasible a much less favourable running mode would be the result. In the first phase PETRA III will use positrons for injection in a similar way as DORIS currently. That could give time to change from positrons to electrons and to change the target for the test beam operation. This is not possible anymore for the top-up mode and it would be very difficult to get a test beam with reasonable rates at the same time as a reliable PETRA III running. The test beam needs 10^{10} particles per bunch at a rate of 3 Hz. PETRA III will request a similar intensity at the

highest currents of the stored beams but at a much lower rate of 0.3 Hz. Under these conditions the test beam will dominate the dose rate on the converter by a factor of 10. For lower currents for PETRA III the discrepancy would be even larger. On the other hand the duty cycle of the test beam usage will certainly be less than the running time of PETRA III. But eventually the discrepancy could result in a limitation of running time on the basis of integrated dose on the positron converter caused by the testbeam. The solution for all the problems is running PETRA III with electrons, requiring that DORIS also switches to electrons.

Beam energy The main operation of the DESY II machine is at 6 GeV but 7 GeV is also possible. In Figure 2 the testbeam rates (T22) versus the selected momenta for two different acceleration energies is shown. There is no difference for lower momenta, but above 3 GeV/c the rates differ significantly.
Though, the possibility to run the machine at 7 GeV should be maintained. Dedicated high energy runs could be agreed with the machine people on requests, which would allow to collect data up to 6 GeV/c or to increase the rates at the momenta above 3 GeV/c. The reach of 6 GeV/c is of significance for many detector studies especially in the field of calorimetry. It offers a link point to the lowest energy reachable at the CERN SPS facilities.

5 Conclusion

The test beams at DESY are of great importance for current and future detector development work. The current conditions of the test beams at DESY are satisfactory and it is requested to maintain these conditions in the future when PETRA III is running. It is in the opinion of the test beam users that the following parameter values should be preserved during combined operation with PETRA III: A particle rate of 1500 Hz for a selected momentum of 3 GeV/c, secondary target 1 mm Cu, no FM, 10^{10} leptons/bunch, and 6 GeV beam energy.
The urgent action needed is to establish a new orbit for testbeam running with the help of orbit bumps. This allows the use of thicker targets to cope with reduced positron currents and allows independent optimisations for all users. Studies on thicker targets should be prepared in the shutdown July 2007 to allows tests before the long shutdown in 2008. A first cost estimate shows a need 0.5 FTE from the machine group and an investment of 60 kEUR.
With these proposed modifications there is no problem to continue the test beam operation during PETRA III. The most preferred solution from test beam users' point of view is running DESY II with electrons for all users.

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