TESLA Technical Design Report

PART VI
Appendices

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Introduction

These appendices to the TESLA Technical Design Report (TDR) describe four additional particle-physics projects, which can be carried out at the TESLA e^+e^--collider. Two of them make use of HERA and thus require TESLA to be located at DESY.

The first program, the **Photon Collider at TESLA**, uses a high power laser to produce high-energy photon beams from one or both electron beams via Compton scattering. In this way the study of photon-photon and photon-electron interactions at energies similar to e^+e^--collisions and at similar luminosity become feasible. These experiments would be conducted in a second interaction region by a second experiment. They complement and add to the e^+e^--physics program of TESLA. A few examples of the exciting physics questions which can be studied with the "Photon Collider" are:

1. In photon-photon collisions, in contrast to e^+e^--interactions, the scalar Higgs-bosons can be produced singly. This allows on the one hand to explore Higgs-bosons with higher masses, and on the other hand to measure precisely the two-photon decay width of the Higgs, which is particularly sensitive to new heavy charged particles with masses well beyond the reach of planned accelerators.

2. The production cross-sections of pairs of any charged particles (supersymmetric particles, Higgs, etc.) are about a factor ten larger in photon-photon than in e^+e^--interactions and depend differently on physics parameters. This enhances the sensitivity for the study of such particles.

3. In photon-electron interactions certain types of charged supersymmetric particles can be produced with masses higher than in e^+e^--interactions.

4. Photon-photon and photon-electron scattering allow the study of the hadronic and electromagnetic structure of the photon in a new kinematic domain.

This experimental program is proposed and supported by a strong high energy physics community with a large overlap with the e^+e^--community. The detailed studies of the physics of photon-photon and photon-electron interactions at TESLA are only just starting and are far less advanced than for e^+e^-.

The remaining three projects are called THERA, TESLA-N and ELFE. They mainly concentrate on the physics of strong interactions and the structure of hadrons.

THERA: Electron Scattering at 1 TeV uses the polarised and/or unpolarised electrons from the linear collider and brings them into collision with the protons of

HERA in the W-hall of HERA on the DESY site. To achieve this, the direction of the protons in HERA has to be reversed and the TESLA tunnel, which is built tangential to the HERA-ring, has to be connected to the HERA tunnel. The electron energy can be either the full single beam TESLA energy (250 up to 400 GeV after the energy upgrade) or even twice the TESLA energy using both TESLA arms as accelerators in the same direction. In this way a wide range of electron-proton energies, up to 1.7 TeV, about five times the present HERA energy, becomes feasible.

Obtaining high luminosities for THERA is a big challenge. Initial studies show that $4 \cdot 10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ may be feasible for 250 GeV electrons on 920 GeV protons. A further increase beyond $10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ requires major studies to demonstrate its feasibility and technical realisation. For equal electron and proton energies (e.g. 500 GeV on 500 GeV when using both arms of TESLA for acceleration) a luminosity of $2.5{\cdot}10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ has been estimated.

The proposed physics is an extension of the successful HERA-program:

1. Strong interaction studies at small parton momenta and at high parton densities, where THERA has a real possibility to reach the new strong interaction domain of saturation and thus contribute to the understanding of the question of confinement.

2. Investigation of the transition from small distance to large distance QCD in an extended kinematic range.

3. Precision measurement of the strong coupling constant.

4. Extension of the measurement of the proton and photon structure as well as heavy flavour physics to smaller parton momenta and highest momentum transfers corresponding distance scales of 10^{-19} m.

5. Measurement of electro-weak parameters and search for new, exotic particles, in particular for leptoquarks and excited fermions.

A possible extension of this programme to electron-nucleon and to $\vec{\mathrm{e}}\vec{\mathrm{p}}$ scattering is also presented.

This physics program and first ideas for a detector have been designed and are strongly supported by members of the present HERA-experiments H1 and ZEUS and an enthusiastic theoretical community interested in a deeper understanding of the strong interactions.

TESLA-N: Electron Scattering with Polarised Targets at TESLA uses the interactions of the 250 - 400 GeV longitudinally polarised electrons of TESLA with a solid state target, which can be either longitudinally or transversely polarised. The maximum centre-of-mass energy is 30 GeV and a luminosity up to $10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ can be achieved; using several beam extraction points along the accelerator, centre-of-mass energies between 7 and 30 GeV are possible.

The main goal of TESLA-N is the precise measurement of the so far completely unknown transverse quark spin structure functions, which will provide complete information on the quark spin structure functions of the nucleon. In addition the polarised structure function of the gluon will be determined with high precision. The dependence of the structure functions on momentum transfer will provide unique precision tests of the predictive power of Quantum Chromodynamics (QCD) in the spin sector.

With the option of also using unpolarised targets and real photons, TESLA-N represents a versatile next-generation facility at the intersection of particle and nuclear physics. The program has been devised and is supported by members of the present lepton-hadron fixed-target experiments like HERMES at DESY and COMPASS at CERN.

ELFE: the Electron Laboratory for Europe uses 15 to 27.5 GeV electrons extracted from TESLA about 8 km from the electron source, reversed in direction, transported along TESLA and finally injected into the modified HERA electron ring. HERA is used in stretcher-mode with continuous extraction onto the target of the ELFE experiment. The repetition rate for injection into HERA is 10 Hz. The current stored in HERA is 150 mA for an extracted beam current of 30μA. Longitudinal electron polarisation can be obtained at 27.5 GeV. The centre-of-mass energies range from 5 to 7 GeV and luminosities between 10^{35} and 10^{38}cm^{-2}s^{-1} are obtained with a large duty cycle. This enables coincidence experiments for small cross section exclusive reactions, which are impossible otherwise. The small energy spread of the beam of 0.1 % together with a large acceptance spectrometer of superb momentum and angular resolution will enable the identification of exclusive reactions.

The detailed investigation of exclusive processes in electron-proton scattering allows the measurement of properties of the hadronic wave function which were hitherto not accessible. Examples are the determination of the orbital angular momentum of quarks in a hadron or the spin structure of unstable particles. The so called Skewed Parton Distributions (SPD) are the theoretical framework in which the data is discussed. The program is proposed and supported by a large fraction of the community of nuclear and particle physicists who now investigate the structure of hadrons at lower energy facilities like MAMI, GRAAL, ELSA and TJNAF, or high-energy facilities at CERN, DESY and FNAL.

The four projects outlined in the appendix have not been worked out in the same detail and depth as the remainder of the TESLA TDR. They represent high quality physics programs, which are supported by strong international communities and which can be performed at relatively modest additional cost if the TESLA linear accelerator is located at the DESY laboratory at Hamburg.