Detector requirements for future strong field QED experiments

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- Introduction
- Initial beam parameters
- Properties of final-state photons, electrons and positrons

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Introduction

We have a detector session at our August workshop; we have also been trying to get detector experts involved.

So we needed to give information on the requirements:

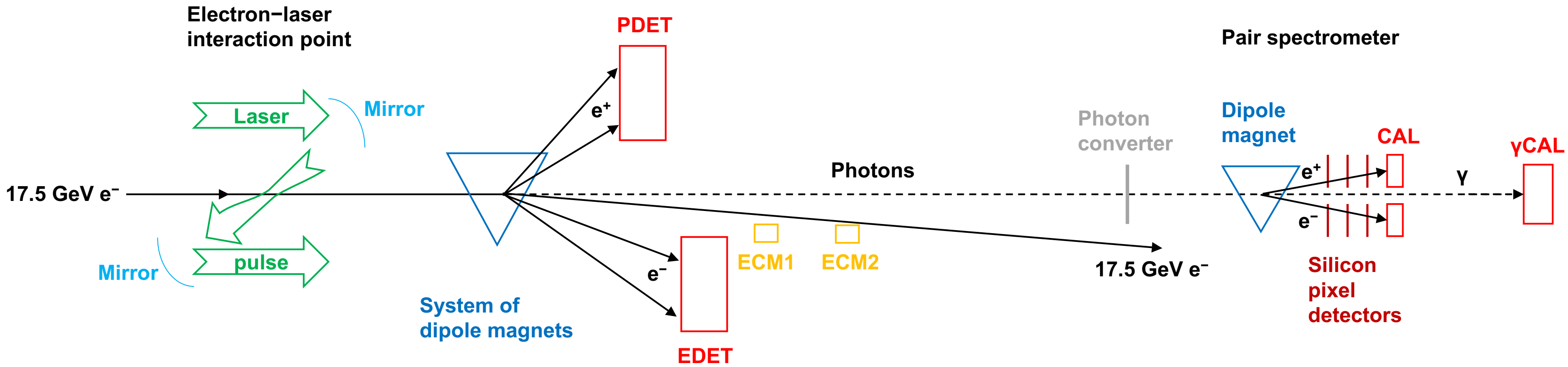
- What do we want to measure ?
- What is the rate ?
- Are there different experimental configurations ?
- Etc.

	Introduction on parameters and requirements	Matthew WING	DESY	13:35 - 13:45
14:00	Semi-conductor detectors	Chris KENNEY	DESY	13:50 - 14:05
	Calorimeters for strong-field QED experiments	Prof. Halina ABRAMOWICZ et al.	DESY	14:10 - 14:25
	The ILC polarimeter and cerenkov detectors	Dr. Jenny LIST	DESY	14:30 - 14:45
15:00	Laser-wakefield experiments	Gianluca SARRI	DESY	14:50 - 15:05
	Discussion	Thomas KOFFAS et al.	DESY	15:10 - 15:40

We came up with some ideas, based on a set of initial parameters and assuming an E144-like set-up.

This encompasses LUXE and plans at SLAC (and elsewhere).

Generic E144-like experiment



- We have electron−laser (i.e. *eγ*) and also *γγ* interactions.
- We want to measure final-state electrons, positrons and photons.

Initial electron beam

Initial electron bunches are assumed to be like those found at EU.XFEL (LUXE) and SLAC (LCLS/FACET-II):

- an electron energy, $5 < E_e < 20\,\mathrm{GeV}$;
- a bunch charge of $N_e = 10^8 - 10^{10}$ electrons;
- a bunch length of $\sigma_z \sim$ few $- 100\,\mu\mathrm{m}$;
- the repetition rate will be dictated by the laser frequency;
- a beam size of $\sigma_{x,y} \sim$ few $- 50\,\mu\mathrm{m}$, although maybe this is not so relevant for the detector requirements.

Initial laser beam

- a $\sim 100\,\mathrm{TW}$ [$\sim 1\,\mathrm{PW}$] laser system, e.g. $\sim 2.5\,\mathrm{J}$ [$\sim 25\,\mathrm{J}$] in $\sim 25\,\mathrm{fs}$;
- a typical focal area of $(10\,\mu\mathrm{m})^2$, implying an intensity of $10^{20}\,\mathrm{W\,cm^{-2}}$ [$10^{21}\,\mathrm{W\,cm^{-2}}$];
- the laser is most likely a Ti:sapphire system (800 nm central wavelength, i.e. typical photon energy: 1.55 eV);
- this implies a reduced vector potential of $a_0 = \xi \approx 5$ [$a_0 = \xi \approx 15$] and a quantum parameter of $\chi = \Upsilon \approx 0.6$ [$\chi = \Upsilon \approx 1.8$] for head-on collisions with a 10 GeV electron/photon[1] ;
- the repetition rate will be in the range $0.1 - 10\,\mathrm{Hz}$;
- the laser is linearly polarised (full control of the polarisation, i.e. linear over elliptical to circular possible), thus there is the possibility of producing polarised photons and electrons and positrons;
- near backscattering with electron and/or gamma beam;
- some level of frequency conversion and longitudinal pulse shaping will be available at reduced intensities.

Final-state photons

At E144, up to 10^7 photons were produced. For future experiments, the initial e^- beam is similar, but we expect much increased laser intensities. We expect:

- up to $\sim 10^{11}$ photons, i.e. up to 10 photons per incident electron;
- the transverse size of the photon bunch at the interaction point will be about $10\,\mu$m, i.e. $<$ mm for $\mathcal{O}\,(10\,\text{m})$ downstream (can change with different emittance of electron beam);
- typical energy will be $1 - 10\,\text{GeV}$.

We want to measure the number of photons and the energy spectrum.

- However, when there is no chance of measuring individual photons, we will need to measure the integrated signal.
- Alternatively, could e.g. reduce number of initial electrons and so produce fewer photons.
- Is a system with a foil to convert the photons to an electron−positron pair useful ?

Final-state electrons

We expect three types of electrons:

a. electrons which have not (or only minimally) radiated

b. electrons which have radiated a hard photon

c. electrons produced via $\gamma \rightarrow e^+ e^-$

Those from b. and c. have a transverse momentum of ~ 5 MeV along the laser polarisation direction and ~ 0.5 MeV along the orthogonal direction.

In eγ collisions, we expect:

- $\sim 10^{10}$ electrons, i.e. one electron per incident electron;
- the electrons will be separated from the positrons and will also have some spread due a magnetic spectrometer;
- typical energy will be $1 - 10\,\mathrm{GeV}$.

Final-state electrons

Some issues/questions:

- Provides a cross-check of the photon signal (and vice-versa).
- Could we use the same type of detector for electrons and photons ?
- Would this be a calorimeter or (silicon) trackers or a combination of both ?
- To what extent does a magnetic spectrometer simplify the system ?
- We want to distinguish electrons in pair production from those in Compton scattering.

Final-state positrons

The number of e^+e^- pairs depends strongly on the input parameters. We expect:

- $1 - 10^9$ positrons, i.e. up to 0.1 electron–positron pair per incident electron;
- the positrons will be separated from the electrons and will also have some spread due a magnetic spectrometer;
- typical energy will be $1 - 10\,\text{GeV}$.

We could have a low number of pairs where we measure e^+ and e^- separately and correlate them. Then at higher rates, we would need to sum as for electrons and photons in $e\gamma$ collisions.

- Can we have a detector that can do both ?
- What resolution is required to associate pairs ?
- Is timing important ?