PROCEEDINGS OF SCIENCE

The IDEA detector concept for FCC-ee

, **Gabriella Gaudio**[a,*]

[a] *INFN Pavia, via A. Bassi 6, 27100 Pavia, IT*

E-mail: gabriella.gaudio@pv.infn.it

The Future Circular Collider (FCC) will allow to perform detailed studies on particle physics thanks to the available high statistic and the precision with which the particle energy and beam polarization will be known. In order to exploit such opportunities, very high performance experiments have to be installed at the interaction points. The two baseline options, included in the Conceptual Design Report of FCC are CLD, based on the ILC-like detector design, and IDEA. This last proto-experiment is described in details here below, with particular reference to the achievable performance.

41st International Conference on High Energy physics - ICHEP2022
6-13 July, 2022
Bologna, Italy

*Speaker

PoS(ICHEP2022)337

1. General Detector Requirements

Some physics processes of interest of the Future Circular Collider [1], which have a critical requirement on the detector performance, have been identified. In Table 1 some of those processes have been reported, together with the detector which play a key role for that measurement and the level of precision which would need to be reached. The performance will be described and discussed in the following sections, where the IDEA sub-detectors will also be described.

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} =$ $5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

Table 1: Performance requirements and benchmark physics processes are reported, together with main detector involved in the measurements. [5]

2. The IDEA Concept

The IDEA conceptual experiment (Innovative Detector for e^+e^-Accelerator) is based on innovative technologies developed in recent years. It features a Silicon Inner Tracker, surrounded by a very light Drift Chamber and by a Silicon wrapper. The Inner detector is immersed in a 2 T B-field, generated by a very thin superconducting solenoid. A dual readout calorimeter is positioned outside the magnet, and within the return joke of the magnet. A muon tracker, based on μ-Rwell technology, is interleaved with the return joke material. This same technology also provides a layer of preshower in front of the calorimeter. An artistic and cut away view of the experiment are represented in Fig.1.

2.1 The Inner Detector

Due to the fact that most of the tracks have a rather low momenta ($p_T \leq 50$ GeV), detector transparency is more relevant than asymptotic momentum resolution for this type of experiment. For this reason the Inner detector is optimised to feature an as low as possible material budget. As an example, the Higgs recoil mass for the Higgs-strahlung process is shown in Fig. 2 left. The core of the tracker is a Drift Chamber, which inherits the technology from both KLOE and MEG II

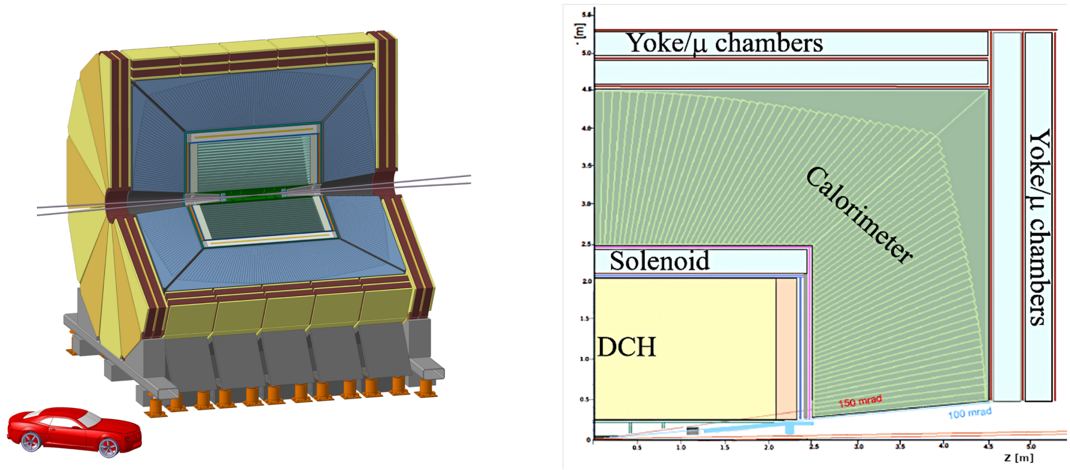

Figure 1: Artistic view (left) and cut away view (right) of the IDEA proto-experiment

experiments. It features only 1.6% of X_0 at 90^o, mainly due to the Tungsten wires in the chamber. It will be operated with a gas mixture of 90% He and 10% iC_4H_{10}. The detector will also provide particle identification capability, based on the cluster counting technique (dN_c/dx) which shows a better resolution with respect to the dE/dx method. The drift chamber will be assisted by a Silicon layer which will allow to increase the momentum resolution and extend the tracking coverage on the forward/backward region. Two technologies are at the moment under evaluation: silicon microstrips and DMAPS. This last technology has been also proposed for the vertex detector. MAPS are inspired by ALICE ITS tracker and are being developed in the ARCADIA R&D project. The proposed inner tracker features a low material budget (15% of X_0), an excellent spatial resolution (3 μm) and a very low power consumption (20 mW/cm^2). Current development is based on 110 nm CMOS CIS technology, with $25 \times 25 \mu$m^2 pixel size.

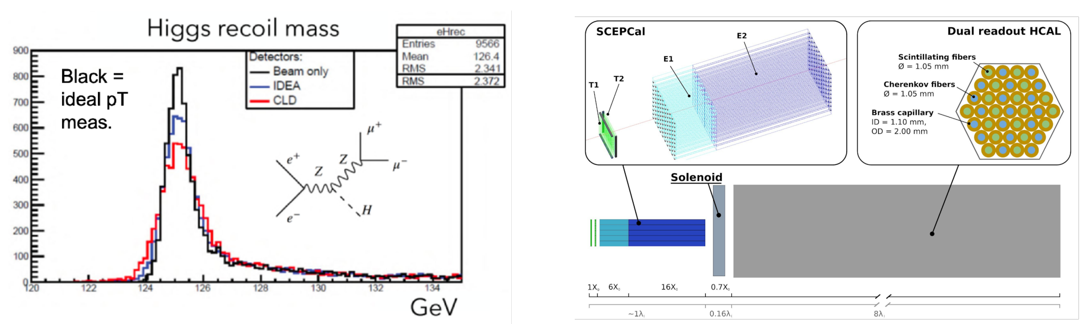

Figure 2: Higgs recoil mass distribution in the Higgs-strahlung process for ideal resolution and IDEA and CLD expected momentum resolution (left). Layout of the Dual-Readout calorimeter in the hybrid crystal plus fiber option (right).

2.2 The Calorimeter

The IDEA calorimeter is based on the Dual Readout technique [2]. This concept allows to obtain a superior hadronic energy resolution, thanks to the capability to measure the electromagnetic fraction on an event-by-event basis and remove therefore the relative fluctuation in the hadronic shower. This can be achieved by measuring the same shower with two different media, one sensitive to the deposited energy (scintillation light) and one sensible only to the electromagnetic component of the hadronic shower, namely electrons and positrons, which produce Cherenkov light.
The dual-readout calorimeter for the IDEA detector features an unsegmented fiber calorimeter which acts as both electromagnetic and hadronic calorimeter. The achievable energy resolution is compatible with the 3% resolution required to distinguish jets coming from W, Z and Higgs decays, and with a $10 - 20\%/\sqrt{E}$ resolution for the measurement of the Higgs $\rightarrow \gamma\gamma$ decay channel. The design of the calorimeter is based on a very fine granularity, with a fiber-to-fiber pitch of the order of 2 mm. This also brings an excellent position and angular resolution, A better resolution for the electromagnetic performance may be needed for the heavy flavour physics. This should require an electromagnetic energy resolution around $3 - 5\%/\sqrt{E}$, which may be achieved by a crystal section [3], again based on dual readout technique, in addition to the fiber calorimeter (see Fig. 2 left).

2.3 The Pre-shower and the Muon Detector

The μ-Rwell detector [4] is a MicroPattern Gas Detector, which is both used for the pre-shower, to provide high resolution space points before the calorimeter to improve cluster reconstruction, and for the muon detector. μ-Rwell is a detector well suited for mass production and the cost per FEE channel can be optimised. Cell size and resolution will be different for either pre-shower (0.4 mm pitch, 100 μm resolution) or muon detector (1.5 mm pitch, 400 μm resolution).

3. Status and Perspective

The community proposing the IDEA detectors shows a very lively R&D activity, both addressing the optimisation of the detector and its feasibility, in term of scalability. At present, the characteristics of each sub-detector, and of the experiment as a whole, seam to be suitable for the performance requirements coming from the physics.

References

[1] The FCC Collaboration, *Eur. Phys. J.* **C, 79 6**, 474 (2019)

[2] S. Lee et al. Dual-readout calorimetry *American Physical Society (APS)* **2** 90 (2018)

[3] M. Lucchini at al, New perspectives on segmented crystal calorimeters for future colliders *IOP Publishing* **15** (2020)

[4] G. Bencivenni, et al., *J. Instrum.* **12, C06027** (2017)