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On behalf of the **RD-FA** Collaboration

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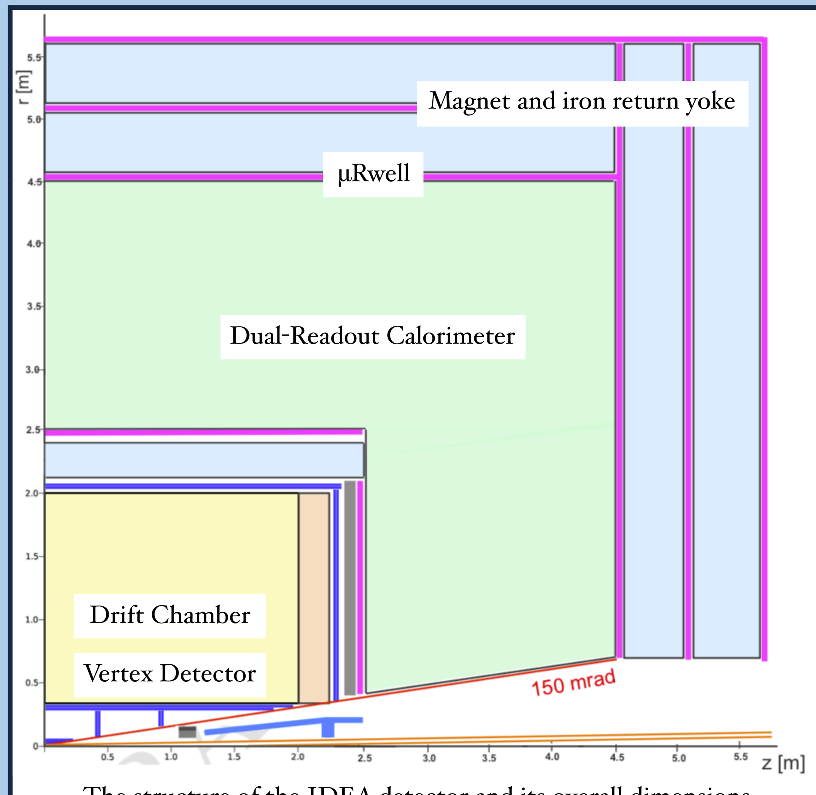
IDEA: AN ALTERNATIVE DETECTOR CONCEPT FOR CEPC

IDEA (Innovative Detector for Electron-positron Accelerator) is a detector concept designed for a future leptonic collider operating as Higgs factory. The detector layout has been studied to match the requirements set by the CEPC machine and it is considered as a viable solution in the Conceptual Design Report. It is based on innovative detector technologies developed over years of R&D.

Design requirements

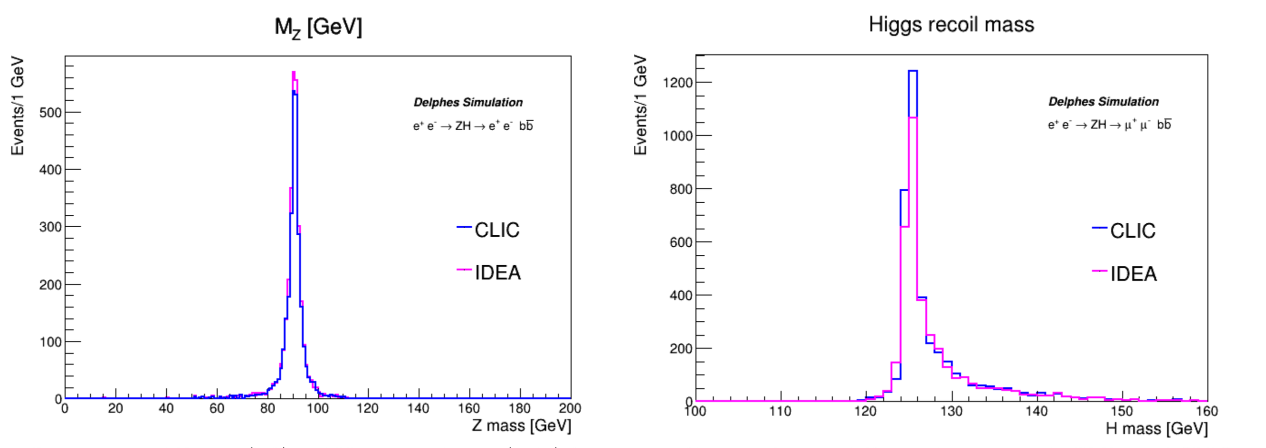
IDEA is based on cost performance optimisation and relies on state of the art sub-detectors technologies:

1. A key element is a 30 cm thick and low mass (0.8 X_0) solenoid with a magnetic field of 2 T located between the calorimeter and the tracking volume. The low-magnetic field minimizes the impact on emittance growth and allows for manageable fields in the compensating solenoids.
2. Since at the Z pole the average charged particles momenta are in a range over which the multiple scattering contribution to the momentum measurement is significant, a high transparency is a strong requirement for precision electroweak physics. A full stereo Drift Chamber, evolving from the successful detector of KLOE and MEG2 [1] experiments, fulfill this requirement.
3. For a significant measurement of the Higgs boson couplings to the IVBs, it is mandatory to statistically separate the 4j final states from $H \to WW^*$ and $H \to ZZ^*$, where the only discriminant is the W/Z invariant mass. This requires to reconstruct the IVB masses with a resolution of 3-4 GeV, i.e. a jet energy resolution of ~30%/√E. Dual-Readout calorimetry [2] aims at providing such a performance with, at the same time, excellent electromagnetic resolution and particle ID capabilities.
4. The choice of a Micro Pattern Gaseous Detector (MPGD) such as the micro-Resistive WELL (μ-RWELL) [3] would perfectly match the specifications required for a muon detection system in an e+e- circular collider in term of performances, leading to a significant reduction of the cost to equip extremely large surfaces with tracking chambers outside the calorimeter volume.



The structure of the IDEA detector and its overall dimensions

Fast simulation: preliminary results



Reconstructed Z mass (left) and Higgs recoil mass (right) from pairs of leptons for two different detector cards: IDEA and CLIC

The IDEA detector concept was implemented in Delphes (one of the major framework for fast simulation). The tracker sub-system has being parametrised using efficiency and momentum resolution of the Drift Chamber; the geometry of the Dual-Readout calorimeter as being implemented and the different response to the electromagnetic and hadronic components of the shower have been accounted for. Currently, the IDEA fast simulation has been qualified tough simple analyses with a cross comparison with the CLIC based detector concept.

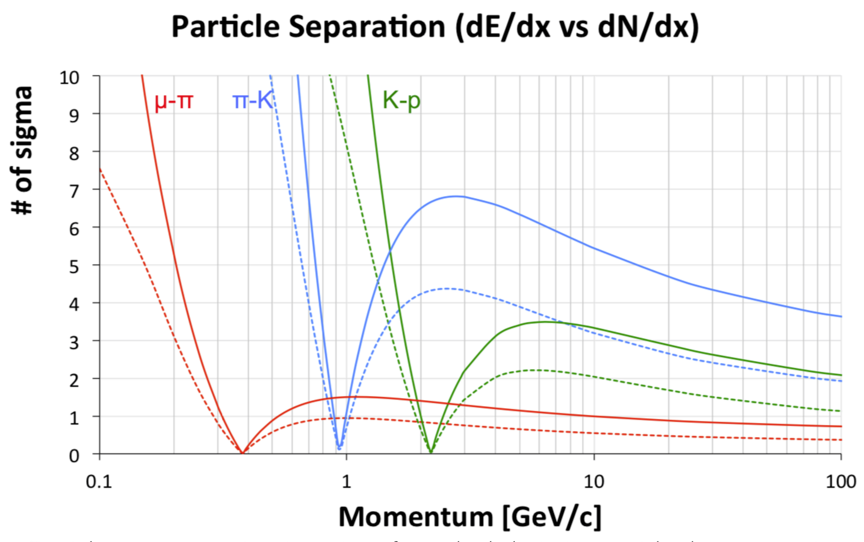
IDEA Tracker detectors

Vertex Detector

The Vertex Detector will be based on monolithic active pixel sensors. In particular, technologies relying on fully depleted high resistivity substrates [4] are being considered, together with architectures implementing on-pixel sparsification and data driven, time-stamped read-out schemes. The ongoing activities are targeting resolutions at a few micron level, thickness in the 0.15-0.30% X_0 range and power dissipation not exceeding 20 mW/cm^2.

Drift Chamber

The Drift Chamber is a full stereo, low mass, unique volume, co-axial to the 2 T solenoidal field. The special feature of this detector is its high transparency: the total amount of material in radial direction, towards the barrel calorimeter, is of the order of 1.6% X_0, whereas, in the forward and backward directions, this is equivalent to about 5.0% X_0. The drift chamber is 400 cm long, with an inner radius of 35 cm and an outer one of 200 cm. The sensitive volume comprises 56 448 squared drift cells with an edge ranging between 12 to 14.5 mm. The chamber operates with a very light gas mixture, 90%He-10%iC_4H_{10}, corresponding to about 400 ns maximum drift time for the largest cell size. The number of ionization clusters generated by a MIP in this gas mixture is about 12.5 cm^{-1}, allowing for the exploitation of the cluster counting/timing techniques for improving both spatial resolution (σ_X < 100 μm) and particle identification ($\sigma(dN_{cluster}/dx)/(dN_{cluster}/dx) \approx 2\%$). For the whole range of momenta, particle separation with cluster counting outperforms dE/dx technique by more than a factor of two, estimating an expected pion/kaon separation better than three standard deviations for all momenta below 850 MeV and slightly above 1.0 GeV.



Particle type separation in units of standard deviations, with cluster counting (solid lines) and with dE/dx (dotted lines) as a function of the particle momentum. A cluster counting efficiency of 80% and a dE/dx resolution of 4.2% have been assumed.

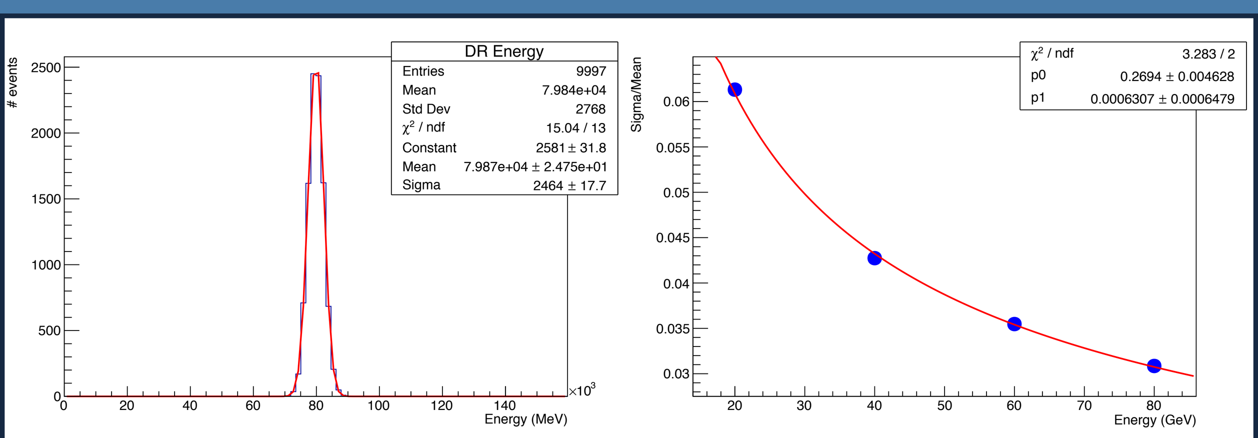
μ-RWELL

The μ-RWELL is a compact single amplification stage intrinsically spark protected MPGD. It is composed of only two elements: the drift cathode and the μ-RWELL PCB, which merges, in a unique structure, a WELL patterned matrix as single amplification stage, a resistive layer and a rigid PCB readout electrode. The best option for equipping very large surfaces of the muon detector is using tiles of μ-RWELL detectors of a size 50 × 50 cm^2 to realize three or four detector stations. Each station could be equipped with a couple of layers of μ-RWELL detectors. This would make the whole muon system very modular with components which can be mass produced by industry. Muon detection systems in large HEP experiments need to identify muons and measure their momentum with accurate precision. This newer technology of MPGD provides good tracking efficiency and both precise space resolution on the coordinates of a muon track (about 200-300 μm) and good time resolution.

IDEA Calorimeter

Dual-Readout calorimeter

The variation of the e.m. fraction (f_{em}) is intrinsic to hadronic showers. The Dual-Readout technique addresses this problems extracting f_{em} by the simultaneous measurement of Cherenkov (C) and scintillation (S) light produced by the shower particles. The results obtained so far with prototypes, support the statement that fiber-sampling Dual-Readout calorimeters may reach resolutions of the order of 10%/√E or better for em showers and around 30%/√E for hadronic showers, together with particle ID capabilities. The use of standard PhotoMultiplier (PM) tubes to readout the S and C light has so far limited its development towards a full-scale system compliant with the integration in a particle detector at a colliding beam machine. These limitations is overcomes using Silicon-PhotoMultipliers (SiPMs), low-cost solid-state sensors of light with single photon sensitivity, magnetic field insensitivity and design flexibility. Thanks to their higher photon detection efficiency with respect to a standard PM, the higher number of Cherenkov photoelectrons should result in an improved resolution for both em and hadronic showers. The millimetric spatial resolution achievable with a SiPM based readout gives also access to an extremely refined two-dimensional imaging of showering particles. Tests done in the last two years [5] by the RD-52 and RD-FA collaborations indicate that effective solutions for small-scale prototypes are very close already now.



80 GeV pions beam: the simulated energy reconstruction (left) and the hadronic resolution obtained (right)

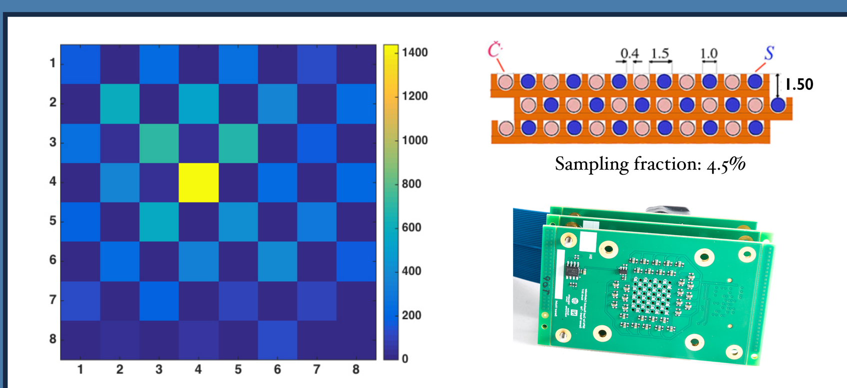
After a calibration with electrons, signals are given by:

$$S = E\left[f_{em} + (h/e)_S(1-f_{em})\right]$$

$$C = E\left[f_{em} + (h/e)_C(1-f_{em})\right]$$

$$\frac{C}{S} = \frac{f_{em} + (h/e)_C(1-f_{em})}{f_{em} + (h/e)_S(1-f_{em})}$$

$$E = \frac{S-\chi C}{1-\chi} \qquad \chi = \frac{1-(h/e)_S}{1-(h/e)_C}$$



10 GeV e- beam event display

The SiPMs readout

[1] G. Chiarello, JINST 12 (2016) no. C03062
[2] All the DREAM/RD52 publications are available at: http://www.phys.ttu.edu/ dream/index.html
[3] G. Bencivenni et al., JINST 10 (2015) no. 02, P02008
[4] S. Panati et al. , IEEE-NSS (2017) Conf. record
[5] M. Antonello et al., NIM A (2018) A899 ,52 - 64