**2.3 Cluster Counting/Timing Drift Chamber: R&D activities**

**2.3.1 Objectives**

 The proposed Cluster Counting/Timing technique, which consists in measuring the arrival times on the sense wires of each individual ionization cluster generated in a drift cell, offers the possibility of greatly improving both the momentum resolution and the particle identification capabilities of this kind of gas sampling detectors (separation powers of better than a factor two with respect to the traditional method of dE/dx have been demonstrated experimentally). The drift chamber proposed for the IDEA detector exploits the peculiarities of such a tracking system.

 The objectives of the R&D projects are relative to the three different tasks listed as follows.

1. *Development of new wire materials.*

 In this context, high polar angle coverage and high granularities, i.e. long and closely spaced wires, contrast the secure limits on drift cell electrostatic stability, requiring larger mechanical tensions applied to the wires and, as a consequence, larger yield strengths, (therefore heavier materials or larger diameter wires), with the drawback of increasing both the multiple scattering contribution to the momentum measurement and the applied load on the chamber endplates.

 New solutions involving light polymeric fibers or Carbon monofilaments, coated with easy to solder low Z metals, like tin, zinc, copper or their common alloys, as opposed to the usual silver or gold coatings, represent a breakthrough in technology and must be operatively tested.

 Alternative proposals, contemplating direct soldering of Carbon monofilaments on PCB by means of newly developed solder alloys or the implementation of conductive glues, may also represent intriguing solutions needing large-scale verification.

 The aim of this activity is to find suitable proposals for new wire materials together with the corresponding technologies for anchoring the wires to the endplates.

1. *Development of a DAQ board specific to Cluster Counting/Timing for data reduction and pre-processing of drift chamber signals sampled at high rates.*

 The widespread use of helium based gas mixtures in modern drift chambers, aimed at minimizing the multiple scattering contribution to the momentum measurement for low momentum particles, because of the low ionization cluster densities produced, introduces a sensible bias in the impact parameter reconstruction, particularly for short impact parameters and, hence, for small drift cells.

 The proposed Cluster Counting/Timing technique overcomes this impasse and offers the possibility of greatly improving also the particle identification capabilities of gas sampling detectors. However, in order to apply this technique, it is necessary to have read-out interfaces capable of processing high speed signals to efficiently isolate amplitude peaks due to different ionization clusters. Requirements on drift chamber performance impose bandwidth of at least of 1 GHz and analog to digital conversions at sampling rates of the order of 2 GSa/s with at least 10-bit resolution. These constraints, together with maximum drift times, typically of the order of several hundred ns, and with a large number of readout channels, of the order of tens of thousand, as in the drift chamber proposed for the IDEA detector, impose some sizeable data reduction, which, however, must preserve all relevant information.

 To this purpose, fast readout and processing algorithms have been successfully implemented online in real time on FPGA’s at a single channel level to identify ionization electrons peaks in the digitized signal spectra. This procedure, once applied to each one of the tens of thousand readout channels, results in data reduction by factors between one and two orders of magnitude with respect to the full sampled signals.

 The goal of the proposed activity is to be able to implement, within a single FPGA board, sophisticated peak finding algorithms on as many analog to digital conversion channels as possible (128 being the ultimate goal), for parallel pre-processing, in order to reduce costs and system complexity, and to gain on flexibility in determining proximity correlations among hit cells for track segment finding and triggering purposes.

1. *Construction of a full length drift chamber prototype*

 We propose to build a full-length drift chamber prototype (at least 4 m long, approximately the length of the IDEA detector, with analogous cell dimensions of the order of 1 cm) to test the electrostatic stability against the mechanical tension applied to the wires.

 In addition, the application of new concepts on mechanical design of the end plates for adjustable compensations of the wire tension by means of spokes, made of composite materials, and stays, made of polymeric fibers, will lead to solutions allowing for strong reductions of the total radiation length in front of the end-cap electromagnetic calorimeters.

 The aim of this activity is to perform a full mechanical test of the proposed innovative technologies on the new types of wires and of the new concepts on the design of the drift chamber wire structure placed inside a light gas-tight envelope.

 Moreover, the prototype, instrumented with the developed cluster counting/timing DAQ electronics will be tested with cosmic rays in laboratory and, successively, brought to test beams to assess the limits on the obtainable performance figures.

**2.3.2 Funding available and anticipated schedule of completion**

 Task a) has received some funding (4.5 keuro) from INFN CSN1 for the design of a 4-channel FPGA board to be completed by the end of 2020. This will represent the starting point of a more complex, larger channel density board to be implemented successively.

 A funding request is being placed by groups of INFN Lecce and Bari within the framework of the AIDA++ proposal, specifically for the drift chamber of the IDEA detector. The objectives of this request are a somewhat downsized version of the ones described above. The expected funding, at the beginning of 2021, is around 130 keuro. Completion of tasks is expected at the end of 2024.

 Further funding has been approved under the Horizon Cremlin+ European grant (approximately 360 keuro) for a tracking and particle identification detector (“TraPId”) at the proposed Super Charm-Tau Factory of the Budker Institute for Nuclear Physics in Novosibirsk, Russia, to be developed and tested by groups from INFN Lecce, INFN Bari and BINP. TraPId is a down sized drift chamber of the larger one designed and proposed for the IDEA detector at both FCC-ee and CEPC. The objective of this grant is the construction of a limited size “TraPId” prototype, to be used as the tracking detector for the CMD-3 experiment at VEPP-2000, BINP, Novosibirsk. The plan is to complete the construction of this tracking detector by the end of 2023.

**2.3.3 Manpower resources available for the project**

 At the current time we can count on a just started graduate student from INFN Lecce and two part time (shared with CMS) graduate students from INFN Bari.

 A fellow position at INFN Bari (shared with CMS) will be filled in the next couple of months (application deadline is Dec. 11, 2019).

 As soon as funds from Cremlin+ became available (beginning of February 2020), we plan to fill in a post-doc position fully dedicated to R&D of the TraPId drift chamber and, indirectly, of the IDEA drift chamber.

 Further manpower (one post-doc) will be hired with the availability of funds from the AIDA++ project, at the beginning of 2021.

 As far as staff members are concerned, we can count, at INFN Bari and Lecce, on a number between 5 and 7 part-time senior physicists for the equivalent of around 1.5 FTE for the next 4-5 years, dedicated to R&D on the drift chamber. We will also share a couple of part-time engineers each from the Mechanics and Electronics facilities at both INFN Sections.