EoIs related to Volume Gas Detectors

Franco Grancagnolo and Burkhard Schmidt

AIDA++ Open Meeting

September 4, 2019

Introduction

Only 5 EoIs in this category:

1. EoI 16: Prototype of a large **ultra-light drift chamber with new materials** for the next generation of lepton colliders
2. EoI 17: **Data reduction and pre-processing** of Drift Chamber signals (Cluster Counting/Timing)
3. EoI 122: **Novel Gas Mixtures in High-Pressure Gas TPCs** (HPgTPC) for accelerator based Neutrino Physics experiments
4. EoI 101: **Development of readout and DAQ systems for HPgTPCs** (Proposal is more DAQ related)
5. EoI 162: Response of **gaseous detectors under high-lumi operation**, identification of pollutants and mitigation effects

Prototype of an ultra-light drift chamber with new materials for the next generation of lepton colliders

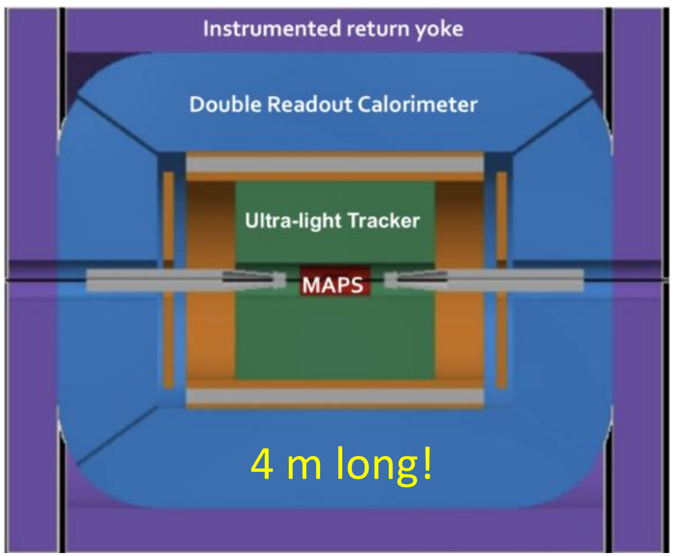
Proponents: F. Grancagnolo (INFN Lecce), N. De Filippis (INFN Bari), G. Zavarise – INFN Torino, I. Logashenko (BINP, Novosibirsk), F. Vivaldi (EnginSoft S.p.A. Trento)

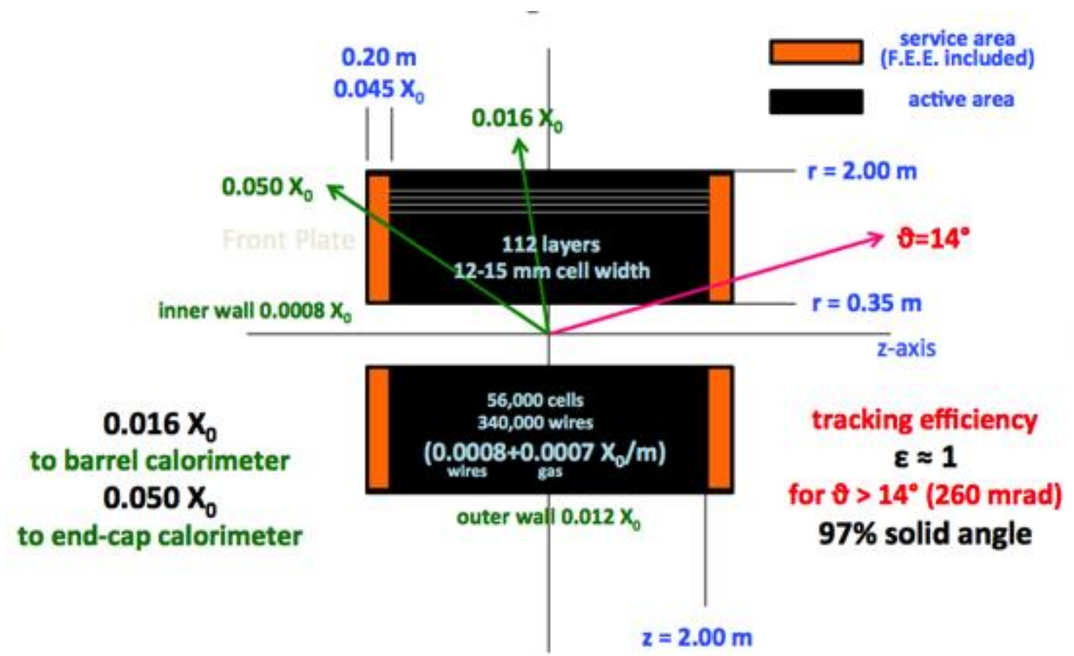
Resources: Total: 486kEuro , EU contribution 162 kEuro (60 kEuro for Personnel, 102kEuro consumables)

Drift Chamber for the IDEA Detector

(4 m long!)

CERN – FCCee or IHEP – CEPC





similar proposal for the **Super Charm-Tau Factory** at BINP, Novosibirsk

A smaller Drift Chamber (2m x 0.6m) is presently under commissioning for the MEG Experiment at PSI

Prototype of an ultra-light drift chamber with new materials for the next generation of lepton colliders

Electrostatic stability condition $$T > \frac{C^2 V_0^2 L^2}{4pew^2}$$

T = wire tension
C = capacitance per unit length
V_0 = anode-cathode voltage
L = wire length, w = cell width

IDEA Drift Chamber: **C = 10 pF/m, V_0 = 1500 V, L = 4.0 m, w = 1.0 cm** **T > 0.32 N**

20 µm W sense wire (Y.S. ≈ 1200 MPa): **T_{max} = 0.38 N** ; 40 µm Al field wire (Y.S. ≈ 300 MPa): **T_{max} = 0.38 N (both marginal)**

Alternatives:

- 40 µm **Titanium** (Y.S. ≈ 550 MPa): **T_{max} = 0.70 N**
  Ti G5 (90%Ti-6%Al-4%V) hard to draw in such sizes ("galling phenomenon") → **need R&D**
- **35 µm Carbon monofilament** (Y.S. > 860 MPa): **T_{max} > 0.83 N**
  metal coating for soldering to PCB's or new anchoring solutions → **need R&D**

SPECIALTY MATERIALS, INC.
Manufacturers of Boron and SCS Silicon Carbide Fibers and Boron Nanopowder

CARBON MONOFILAMENT

TYPICAL PROPERTIES

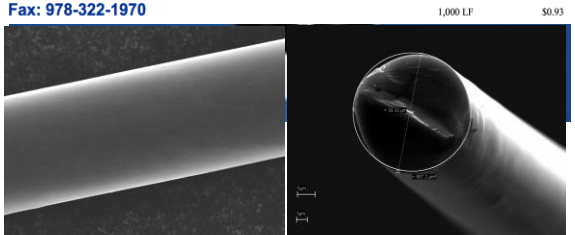
Diameter:	0.00136 +/- 0.0001" (34.5 +/- 2.5 µm)
Tensile Strength:	125 ksi (0.86 GPa)
Tensile Modulus:	6 msi (41.5 GPa)
Electrical Resistivity:	3.6 x 10^{-3} ohm cm
Density:	1.8 g/cc

Specialty Materials, Inc.
1449 Middlesex Street
Lowell, Massachusetts 01851

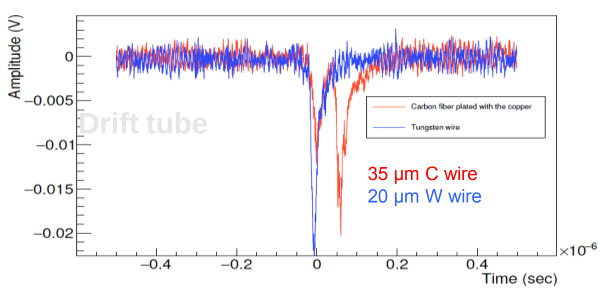
Phone: 978-322-1900
Fax: 978-322-1970

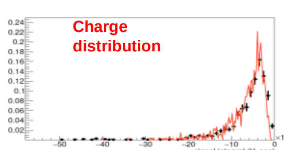
CARBON MONOFILAMENT PRODUCT PRICE LIST
Effective October 1, 2017

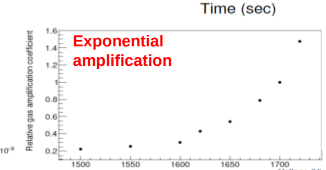
Product	Quantity	Price LF
CARBON MONOFILAMENT	1 Million LF	$0.02
	500,000 LF	$0.03
	1,000 LF	$0.93



HiPIMS: High-power impulse magnetron sputtering





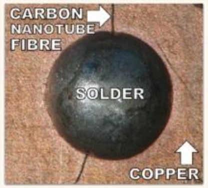


Soldering of Carbon Materials Using Transition Metal Rich Alloys

Marek Burda,*,† Agnieszka Lekawa-Raus,† Andrzej Gruszczyk,‡ and Krzysztof K. K. Koziol*,†

†Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, CB3 0FS, Cambridge, U.K. and ‡Welding Department, Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland

ABSTRACT Joining of carbon materials *via* soldering has not been possible up to now due to lack of wetting of carbons by metals at standard soldering temperatures. This issue has been a severely restricting factor for many potential electrical/electronic and mechanical applications of nanostructured and conventional carbon materials. Here we demonstrate the formation of alloys that enable soldering of these structures. By addition of several percent (2.5−5%) of transition metal such as chromium or nickel to a standard lead-free soldering tin based alloy we obtained a solder that can be applied using a commercial soldering iron at typical soldering temperatures of approximately 350 °C and at ambient conditions. The use of this solder enables the formation of mechanically strong and electrically conductive joints between carbon materials and, when supported by a simple two-step technique, can successfully bond carbon structures to any metal terminal. It has been shown using optical and scanning electron microscope images as well as X-ray diffraction patterns and energy dispersive X-ray mapping that the successful formation of carbon−solder bonds is possible, first, thanks to the uniform nonreactive dispersion of transition metals in the tin-based matrix. Further, during the soldering process, these free elements diffuse into the carbon−alloy border with no formation of brazing-like carbides, which would damage the surface of the carbon materials.



Data reduction and pre-processing of drift chamber signals sampled at high rates

Proponents: F. Grancagnolo (INFN Lecce), N. De Filippis (INFN Bari),
I. Logashenko (BINP, Novosibirsk), F. Vivaldi (CAEN Viareggio)

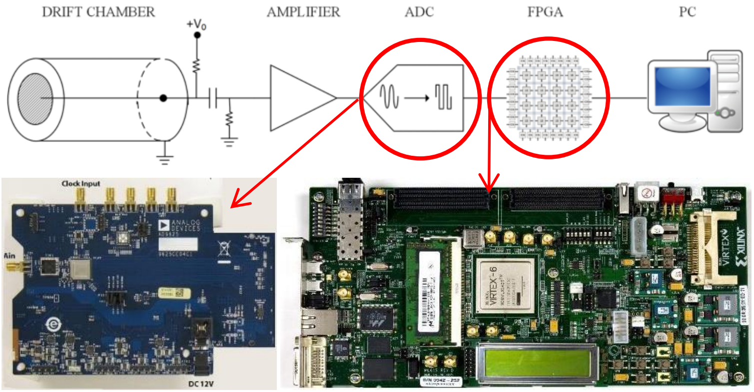
Resources: Total: 486kEuro , EU contribution 162 kEuro (60 kEuro for Personnel, 102kEuro consumables)

- The data generated by the high speed digitization (2 GSa/s, for an efficient exploitation of the cluster counting / timing techniques) of the IDEA drift chamber, running at the Z-pole, will reach transfer rates in excess of 1TB/s.
- An effective approach to data reduction consists in transferring, for each hit drift cell, only the minimal information relevant to the application of the **cluster counting/timing techniques**, i.e. **the amplitude and the arrival time of each peak associated with each individual ionisation electron**.
- This can be accomplished by using a **FPGA** for the real time analysis of the data generated by the drift chamber and successively digitized by an ADC.

Verified solution for a <u>**single channel**</u>

A fast readout algorithm (**CluTim**) for identifying, in the digitized drift chamber signals, the individual ionization peaks and recording their time and amplitude has been developed as **VHDL/Verilog** code implemented on a **Virtex 6 FPGA**, which allows for a maximum input/output clock switching frequency of **710 MHz**. The hardware setup includes also a 12-bit monolithic **pipeline sampling ADC** at conversion rates of up to **2.0 GSPS**.

G. Chiarello, C. Chiri, G. Cocciolo, A. Corvaglia, F. Grancagnolo, M. Panareo, A. Pepino and G. Tassielli
The Use of FPGA in Drift Chambers for High Energy Physics Experiments
ISBN 978-953-51-3208-0, Print ISBN 978-953-51-3207-3, May 31, 2017, doi:10.5772/66853, http://dx.doi.org/10.5772/66853



AD9625-2.0EBZ Evaluation Board

Xilinx ML605 Evaluation Board

- **The goal of the proposed activity is to implement in a single FPGA board more sophisticated peak finding algorithms on as many ADC channels as possible for parallel pre-processing, in order to reduce costs and system complexity and gain on flexibility in determining proximity correlations among hit cells for track segment finding and triggering purposes.**

Novel Gas Mixtures in High-Pressure Time Projection Chambers for Accelerator-Based Neutrino Physics Experiments

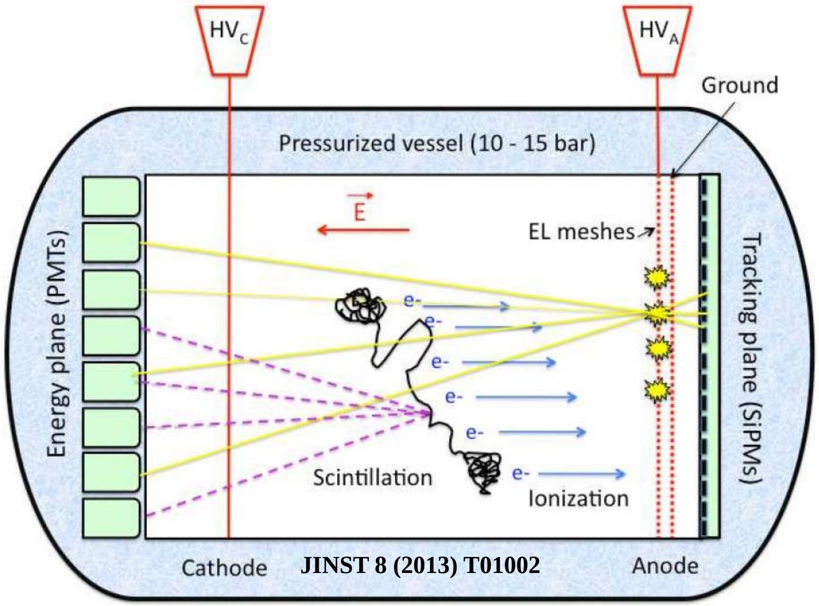
Proponents: Xianguo Lu (Oxford, UK), Justo Martín-Albo (IFIC, Spain)

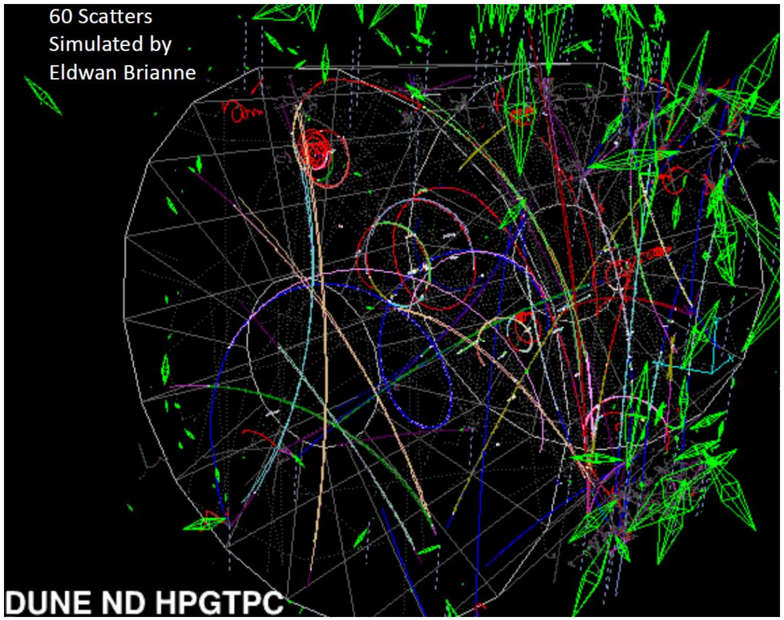
Resources: 200k€ from EU (160k€ Personnel)

- Find a gas mixture that enables the determination of t_0 via primary-scintillation tagging

NEXT → DUNE near detector

Neutrino-less double β-decay — Primary scintillation tagging — Hits integrated over full spill



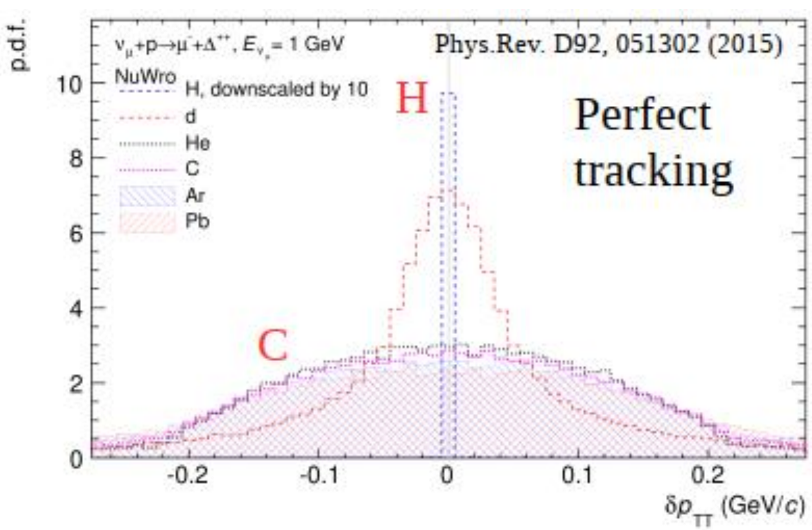


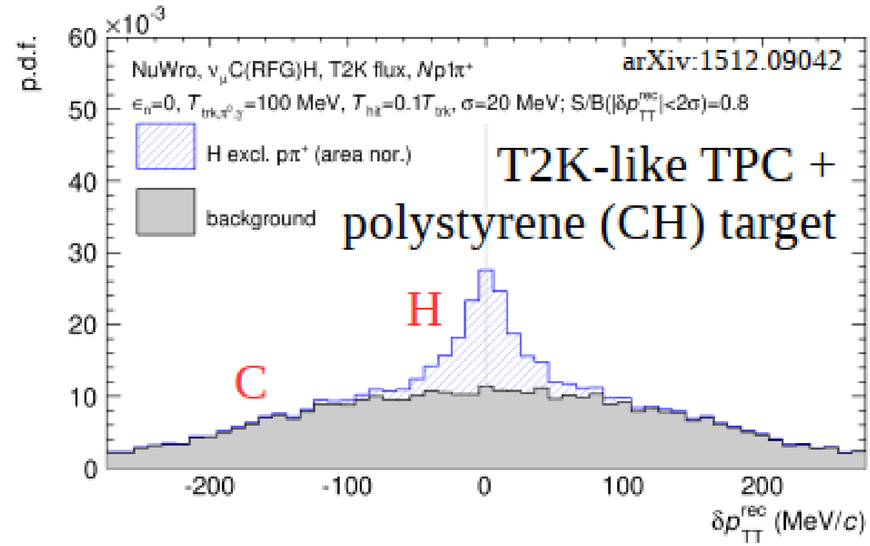
Primary scintillation in High-Pressure gas TPCs to determine t_0 (start-of-event time)

- New concept to **separate different events within same spill**, enabling self-triggering
- Requirements: Stable operation with high gain at high pressure
  High yield of fast scintillation
- Candidate mixtures to be tested: $Ar+Xe+CH_4$ and $Ar+N_2+CF_4$

Novel Gas Mixtures in High-Pressure Time Projection Chambers for Accelerator-Based Neutrino Physics Experiments

➢ Find a safe hydrogen-rich gas mixture for the direct measurement of ν-H interactions





Double p_T imbalance

- Extracting neutrino-hydrogen interactions from complex compound
- High-pressure gas TPC can achieve **95% ν-H purity** with alternative gas mixtures:

  50% He + 50% CH_4 or 50% He + 50% C_2H_6

Name	Formula	Signal rate	Background rate	S/B
pure hydrogen	H_2	1 (ref.)	-	-
polystyrene (solid)	$(C_8H_8)n$ or CH	-	-	0.17
P-10	90% Ar + 10% CH_4	0.2	8.4	0.02
P-50	50% Ar + 50% CH_4	1	6	0.17
helium-methane (50:50)	50% He + 50% CH_4	1	2	0.5
helium-ethane (50:50)	50% He + 50% C_2H_6	1.5	3.5	0.43

1.5×

3× improvement

Response of gaseous detectors under high luminosity operation, identification of pollutants and potential mitigation effects of radiation damage due to high accumulated charge

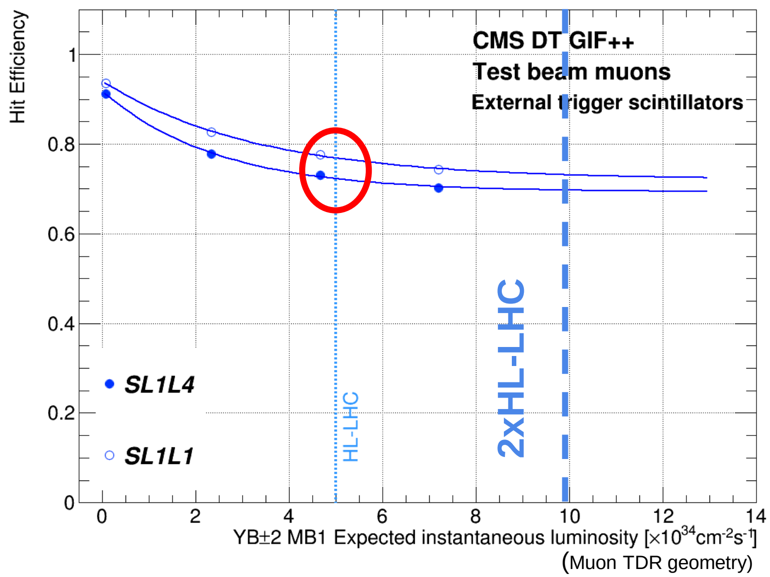
Drift Tube chambers (~1000 l) **instrument the CMS barrel yoke providing μ-trigger and reconstruction**

CMS DT long term irradiation studies at GIF++:

In the last years full spare chambers were irradiated at CERN GIF++ facility up to a dose ~2 HL-LHC with **aging rates ~>10 times** expected at HL-LHC

A significant reduction of gain was observed, measuring a **moderate degradation of hit efficiency** with the muon beam and cosmics.

The impact on the muon system performance was simulated to be **negligible for η<0.8 and ~2 % in barrel-endcap overlap region with safety factor 2.**



Around **75%** **hit efficiency** for MB1 in the most external wheels at HL-LHC **background rate** (5×10^{34} cm^{-2} s^{-1}) after **1.2 HL-LHC run** (3600 fb^{-1})

MB1(1 ton,2.5x2.1 m)@ ~5 m from the GIF++ source


Spare DT chamber as seen from the GIF++ source

- Now chambers are outside GIF++ and the infrastructure has been dismantled.
- The expanded GIF++ bunker allows installation further away from the source, providing more realistic conditions.

Proposed deliverables

- **Deliverable 1:** Install a drift tube chamber in the expanded GIF++ bunker, which allows lower aging acceleration rates.
  - Perform a precise mapping of the geometrical dose distribution far away from the source .
  - Measure the vertical and horizontal profiles of the muon beam at GIF++ profiting from the large DT acceptance and 3d measurement capability.
- **Deliverable 2:** Study the performance degradation of a CMS DT chamber at GIF++ with and without beam at different irradiation intensities and gas fluxes at aging rates closer to those expected at HL-LHC.
- **Deliverable 3:** Make use of improved gas chromatography, chemical traps and/or low scale detection devices to study the outgoing pollutants from the chamber, its quantity and its chemical composition.

Participating institutes or potentially interested:

Participating institute / company	Main contact person	E-mail
CIEMAT	Ignacio Redondo	ignacio.redondo@ciemat.es
Universidad de Oviedo	Isidro Gonzalez	Isidro.Gonzalez.Caballero@cern.ch
INFN Sezione di Padova	Anna Meneguzzo	anna.meneguzzo@pd.infn.it
INFN Sezione di Bolonia	Potentially interested	
INFN Sezione di Torino	Potentially interested	
RWTH Aachen	Potentially interested	

Resources: Total 240kEuro, EC contribution 80kEuro (mainly personnel)

Summary and Conclusions

- The proposal for the large ultra-light drift chamber with new materials is certainly **very innovative**
- The proposal for data reduction and pre-processing of drift chamber signals is **an important complementary part**.

➢ **The two EoIs could be combined (same proponents)**

- Also the proposal for novel Gas Mixtures in HPgTPCs for Neutrino Physics Experiments is **very innovative**.
- Adopt the FELIX based readout system to HPgTPCs (links to what is developed for ATLAS and proposed for DUNE).

➢ **The proponents are different, more difficult to combine EoIs**

- The study of the response of Drift Tubes under high luminosity operation is very **application specific**, but has synergies with the EoIs on irradiation facilities.