RD_FCC: attività, anagrafica e richieste finanziarie per 2026

N. De Filippis
Politecnico/INFN Bari

Bari
Giugno/Luglio 2025

European Strategy

FCC Feasibility Study

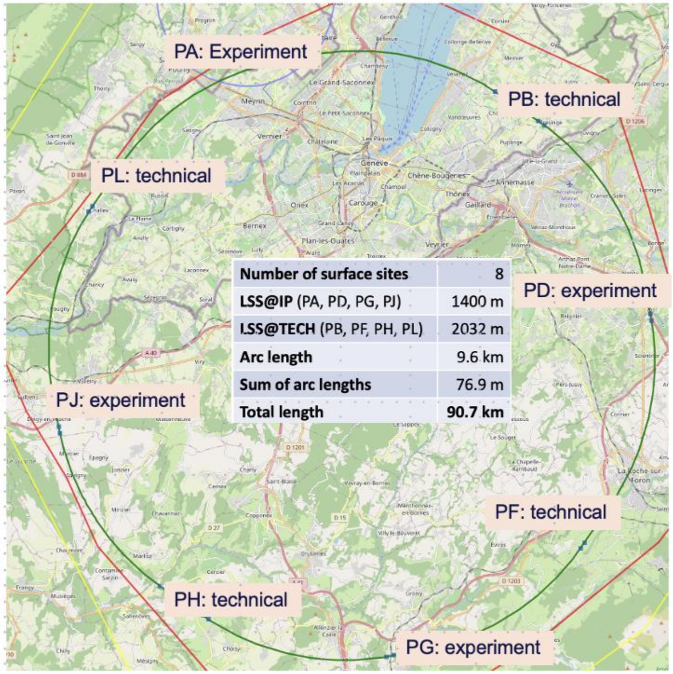
- Started in 2021 → Report completed in March 2025, earlier than initially planned, to align with ESPP input submission deadline
- It covers the geological, technical, environmental and territorial feasibility of a 91-km ring and its infrastructure in the Geneva basin, and scientific potential and required technologies for FCC-ee and FCC-hh. Good progress also on financial aspects (→ see later)
- Total cost-to-completion: 83 MCHF

Vol. 1: Physics, Experiments and Detectors (~ 260 pages)
Vol. 2: Accelerators, Technical Infrastructure and Safety (~ 600 pages)
Vol. 3: Civil Engneering, Implementation and Sustainability (~ 330 pages)

An extraordinary collective effort by the FCC community, involving some 1500 contributors from 162 institutions in 38 countries

The **breadth and depth of the results are unprecedented for a project at this stage of development.**

Report being reviewed by expert committee, and then by Council and its subordinate bodies before end of year.



Number of surface sites	8
LSS@IP (PA, PD, PG, PJ)	1400 m
LSS@TECH (PB, PF, PH, PL)	2032 m
Arc length	9.6 km
Sum of arc lengths	76.9 m
Total length	90.7 km

Ring placement selected out of ~ 100 variants taking into account geological, environmental, surface (land availability, access to roads, etc.), infrastructure (water, electricity, transport) constraints, machine performance, etc.

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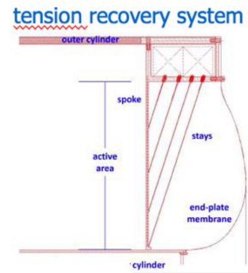
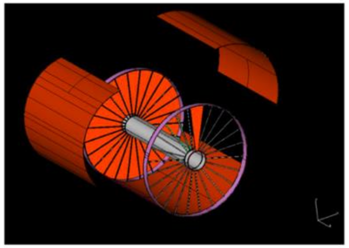
Drift chamber for IDEA@FCC: hardware and detector simulation

INFN Bari and Lecce

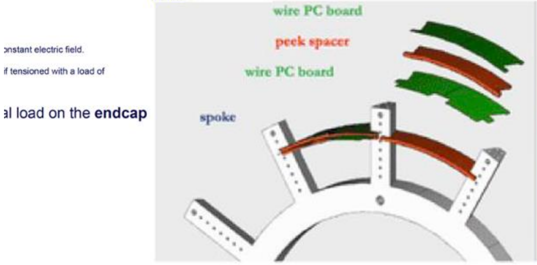
Hardware:

- studies about mechanical design of a drift chamber for the IDEA proposal at FCC-ee





- DCH is a unique-volume, high granularity, fully stereo, low-mass cylindrical
- gas: He 90% - iC_4H_{10} 10%
- inner radius R_{in} = 0.35m, outer radius R_{out} = 2m
- length L = 4m, drift length ~1 cm, drift time up to 400ns
- σ_{xy} < 100 μm, σ_z < 1 mm
- 12÷14.5 mm wide square cells, 5 : 1 field to sense wires ratio
- 112 co-axial layers, at alternating-sign stereo angles, arranged in 24 identical azimuthal sectors, with frontend electronics
- 343968 wires in total:

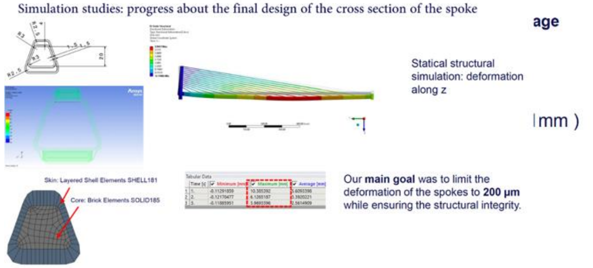


Big Problems to manage!

- σ_{xy} < **100 μm** → accuracy on the position of the anodic wires < **50 μm**.
- The anodic and cathodic wires should be parallel in space to preserve the constant electric field.
- A 20 μm tungsten wire, 4 m long, will bow about 400 μm at its middle point, if tensioned with a load of approximately 30 grams.

30 gr tension for each wire → **10 tonnes** of total load on the **endcap**

Simulation studies: progress about the final design of the cross section of the spoke



A realistic complete model ready:

- mechanically accurate
- precise definition of the connections of the cables on the structure
- connections of the wires on the PCB
- location of the necessary spacers
- connection between wire cage and gas containment structure

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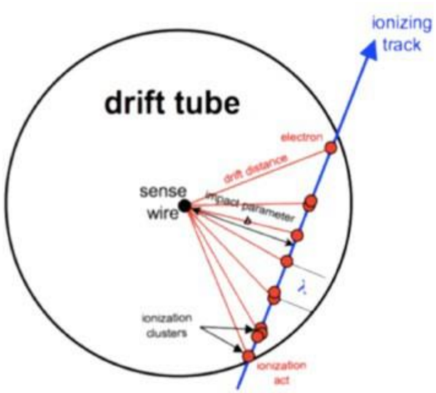
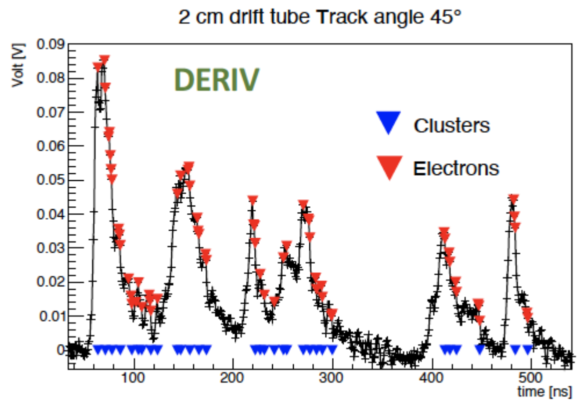
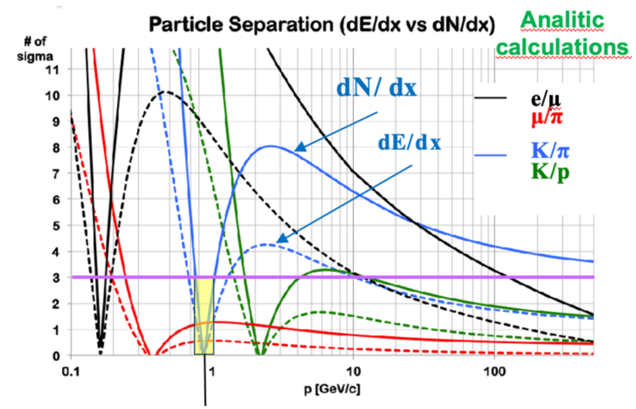
Drift chamber for IDEA@FCC: hardware and detector simulation

Principle: In He based gas mixtures the signals from each ionization act can be spread in time to few ns.

- By counting the number of ionization acts per unit length (dN/dx), it is possible to identify the particles (P.Id.) with a better resolution w.r.t the dE/dx method.

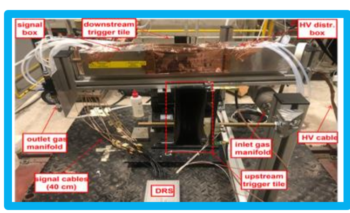


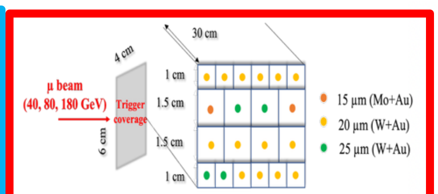


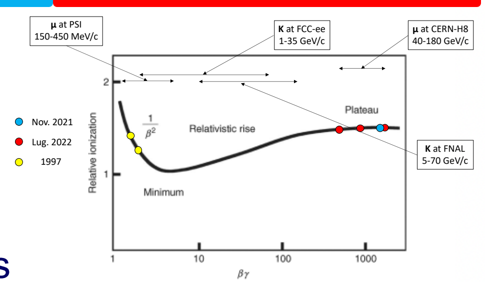


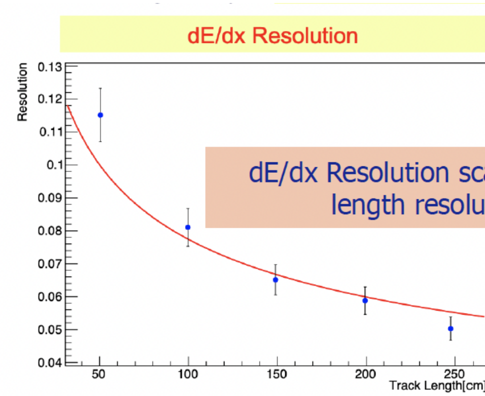
Beam tests to experimentally asses and optimize the **performance of the cluster counting/timing:**

- to muon beam tests at CERN ($\beta\gamma > 400$) in Nov. 2021+July 2022 (p_T =165/180 GeV)

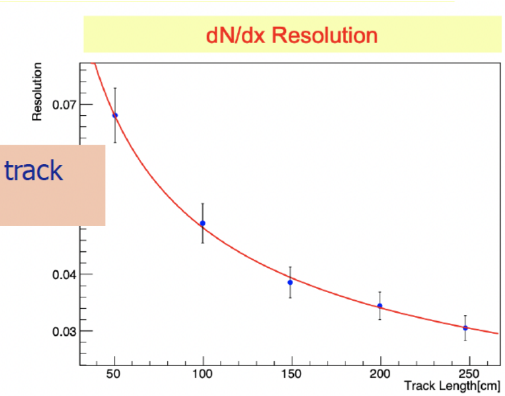








dE/dx Resolution scan vs track length resolution



dE/dx resolution dependence on the track length $L^{-0.37}$ dN/dx resolution dependence on the track length $L^{-0.5}$

~ 2 times improvement in the resolution using dN/dx method

N. De Filippis

Plans for a full-length prototype: Goals

- **Check the limits of the wires' electrostatic stability at full length and at nominal stereo angles**

- **Test different wires**: uncoated Al, C monofilaments, Mo sense wires, …, of different diameters
  - Test different wire anchoring procedures (soldering, welding, gluing, crimping, …) to the wire PCBs
  - Test different materials and production procedures for spokes, stays, support structures and spacers
  - Test compatibility of proposed materials with drift chamber operation (outgassing, aging, creeping, …)

- Validate the **concept of the wire tension recovery scheme** with respect to the tolerances on the wire positions
  - Optimize the layout of the wires' PCBs (sense, field and guard), according to the wire anchoring procedures, with aim at minimizing the end-plate total material budget

- Starting from the new concepts implemented in the MEG2 DCH robot, **optimize the wiring strategy**, by taking into account the 4m long wires arranged in multi-wire layers

- Define and validate **the assembly scheme** (with respect to mechanical tolerances) of the multi-wire layers on the end plates
  - Define the front-end cards channel multiplicity and their location (cooling system necessary?)

- **Optimize the High Voltage and signal distribution** (cables and connectors)

- Test performance of **different versions of front-end, digitization and acquisition chain**

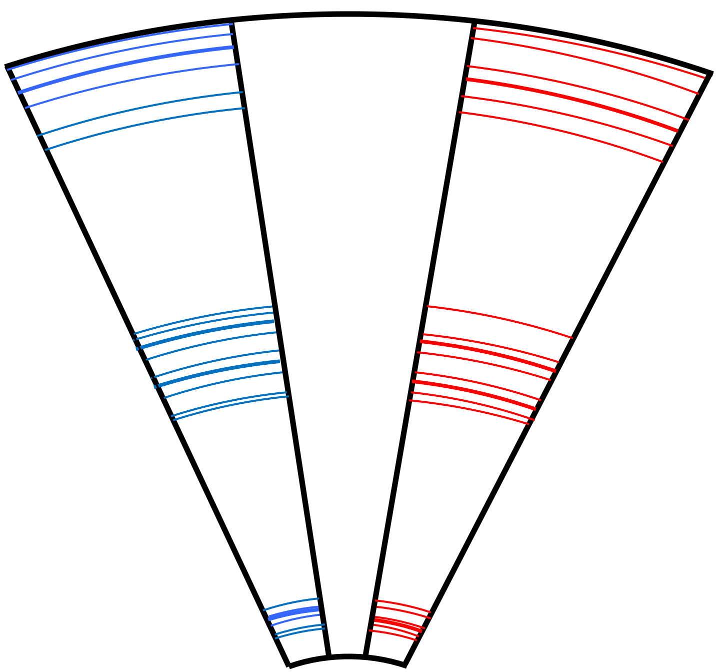
▸ ***Full-length prototype necessary***

○ ***Can be done in parallel on small prototypes***

Plans for a full-length prototype: Configuration

Target: a full length DCH prototype with 3 sectors per endcap

- 8 spokes (4 per endcap)
- Internal ring
- part of the outer ring
- part of the cylindrical panel



First two layers of superlayer #1
V and U guard layers (2 x 9 guard wires)
V and U field layers (2 x 18 field wires)
U layer (8 sense + 9 guard)
U and V field layers (2 x 18 field wires)
V layer (8 sense + 9 guard)
V and U field layers (2 x 18 field wires)
V and U guard layer (2 x 9 guard wires)

Last two layers of superlayer #7
V and U guard layers (2 x 21 guard wires)
V and U field layers (2 x 42 field wires)
U layer (20 sense + 21 guard)
U and V field layers (2 x 42 field wires)
V layer (20 sense + 21 guard)
V field layer (42 field wires)

First two layers of superlayer #8
U field layer (46 field wires)
U layer (22 sense + 23 guard)
U and V field layers (2 x 46 field wires)
V layer (22 sense + 23 guard)
V and U field layers (2 x 46 field wires)
V and U guard layer (2 x 23 guard wires)

Last two layers of superlayer #14
V and U guard layers (2 x 35 guard wires)
V and U field layers (2 x 70 field wires)
U layer (34 sense + 35 guard)
U and V field layers (2 x 70 field wires)
V layer (34 sense + 35 guard)
V and U field layers (2 x 70 field wires)
V and U guard layer (2 x 35 guard wires)

TOTAL LAYERS: 8
Sense wires: 168
Field wires: 965
Guard wires: 264

PCBoards wire layers: 42
Sense wire boards: 8
Field wire boards: 22
Guard wire boards: 12
HV values: 14

Readout channels: 8+8 +16+16+16+16 + 16+16 = 112

Tentative Timeline for the full length prototype

- ✓ First attempt (an exercise) to have a time schedule to realize the prototype → main steps, supposing T0 = OK from INFN to the clean room:

2025	*OK from INFN to give funds to make the clean room operational*
2026	*carry out the bureaucratic steps for entrusting the contract to a company*
2026	*Procurement of the needed materials/mechanics for the prototype*
2027	*clean room ready and operational*
2027	*prototype wiring in the clean room*
2027	*Procurement of the needed electronics for the prototype readout*
2028	*Test the prototype on cosmics*
2029	*Test the prototype on a beam facility*

Spending profile for the full length prototype

2025:

prototype mechanics:

- **spokes (already funded by EURIZON) 20 k€**
- **stays + strain gage controller 5 k€ 120 elements +spares**
- **inner cylinder (probably only) half cylinder**
- **outer ring 1/6 (= 60˚) of full ring 10 k€**

2025: prototype mechanics/electronics		
• Controller misuratori di tensione per prototipo 2 k€		
• outer cylinder	10 k€	1/6 (= 60°) of full cylinder
• lateral panels		
• spacers	10 k€	PEEK foils to be machined (Bari)
• wire PCB cards	15 k€	200 cards of 42 different design + HV distribution + termination network
• field and guard wires	10 k€	7+2 Km
• elettronica di lettura : 2 schede MOSAIC per sviluppo firmware ed hardware (6kEuro +IVA ciascuna)		
2026: prototype wiring		
• Bari clean room refurbishment:	200 k€	contribution by "Giunta" + CSN1 ?
• wiring robot refurbishment	15 k€	including transport from Pisa to Bari
• sense wires	2 k€	already procured
• consumables for wiring	10 k€	too many items to list
2027: prototype readout electronics		
• cosmic trigger tiles	12 k€	24 tiles 30x30 in three planes + iron slab for low p cut + support system
• HV distribution	3 k€	HV power supply procured (14 different values) + distribution
• readout electronics (CAEN VX2751)	200 k€	(8 modules x 16 channels) to be negotiated with CAEN
• dedicated PC + ancillary equipment	5 k€	

Spending profile for the full length prototype

2028:	cosmic ray test:		
	• consumables	10 k€	gas system + gas consumption + …
2029:	beam test (assume CERN PS-T9/T10):		
	• transport	5 k€	two ways
	• consumables	5 k€	gas consumption + miscellanea
	• travel expenses	30 k€	2 weeks x 10 people

Totale 387 keuro (200 dei quali da capire meglio e 30 di missioni) + 200 giunta + ?? missioni Le-Ba per filatura)

Other activities of the Drift Chamber team

Tests with wires with standard protocols

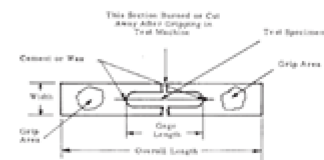
Tests started in a small clean room at INFN Bari:

A. Miccoli, F. Procacci, N. De Filippis

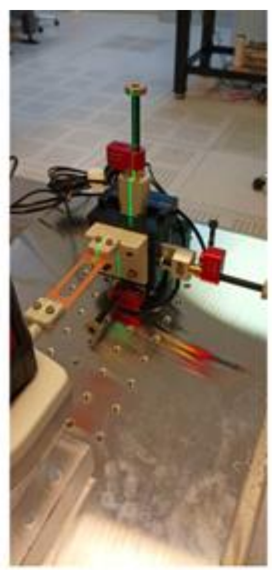
- **Tungsten coated with gold**
- **Molibden coated with gold**
- **Carbon monofilament**
- **Aluminium (to be tested yet)**

Standard ASTM D 3379 – 75

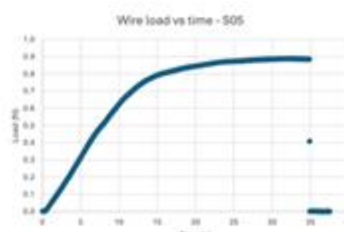
- **Scope**: Tensile Strength and Young's modulus for High-Modulus (>21 GPa) Single-Filament Materials (gage length > 2000*wire diameter)
- **Summary**: The filaments are center-line mounted on special slotted tabs. The tabs are gripped so that the test specimen is aligned axially in the jaws of a constant-speed movable-crosshead test machine. The filaments are then stressed to failure at a constant strain rate.

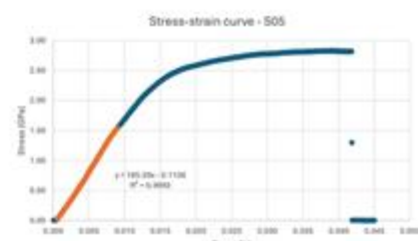


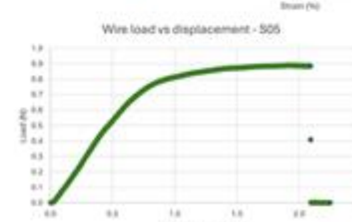
Setup



Specimen 05

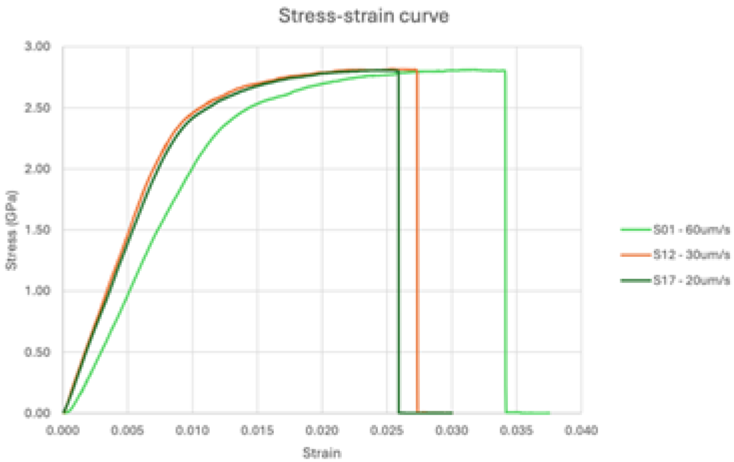


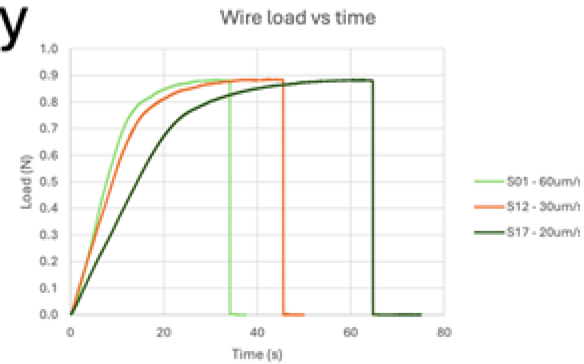


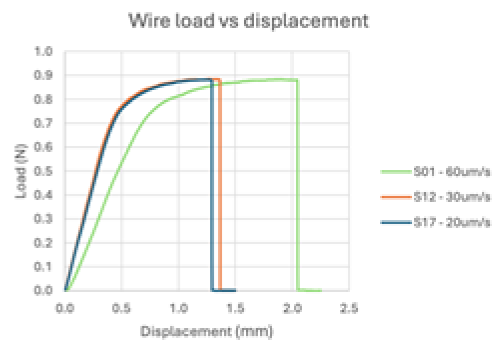


Tests with wires with standard protocols

Dependence on test velocity







Specimen number	Tensile Strength - UTS (GPa)	Young module (Gpa)	R^2	Effective test time (s)	Total wire elongation (mm)	Elongation (%)	Fracture strain - ε_f (%)	Elongation at break (%)	Elastic limit strain - ε_y(%)	Yield Tensile Strength - YTS (GPa)
01	2.811	186.561	0.998975	34.15	2.049	4.098	0.04098	4.098	0.0090	1.673
02	2.820	172.631	0.997992	35.23	2.1135	4.227	0.04227	4.227	0.0090	1.548
03	2.814	178.624	0.999497	38.90	2.334	4.668	0.048	4.800	0.0075	1.334
04	2.718	172.790	0.999843	40.00	2.4	4.800	0.048	4.800	0.0090	1.550
05	2.833	185.590	0.999311	34.88	2.0925	4.185	0.04185	4.185	0.0090	1.665

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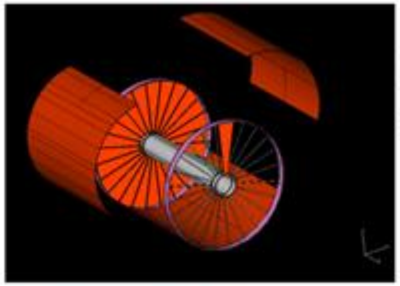
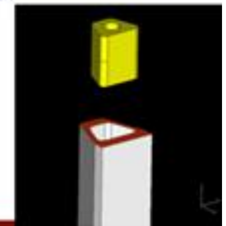
Tests with wires with standard protocols



- ✓ **Outer cylinder** made of 3 panels **2 cm** thick → 3 layers (2 monolithic CF with Al honeycomb structure in the middle)
- ✓ **External and internal ring** in monolithic CF
- ✓ **Endplates** made of 48 **Spokes** (24 per endcap), defining 24 azimuthal sectors.
- ✓ Each **spoke** (length **l = 165cm)** is supported by 15 **Stays.**
- ✓ **Inner cylinder** thickness **200 µm** CF – not structural



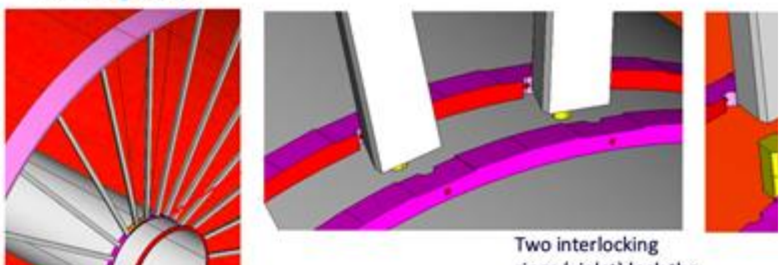
MEG2 chamber

in contact also with experts from MEG at INFN Pisa

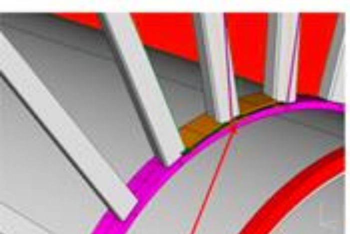
Outer ring/spoke details

On the outer part the spoke has an internally glued female joint (yellow) which locks the spoke to the outer ring (pink)

Inner ring details



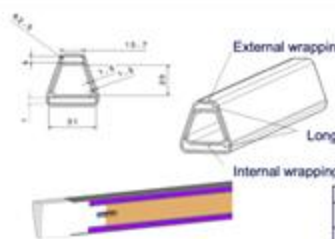
Two interlocking rings (violet) lock the spokes (grey)



Spacers (yellow) and PCBs (green) are inserted between the spokes. The spacers have holes for the gas distribution

The edge of the PCB acts as a stop on the spoke, providing a reference.

The supporting cables of the spokes are anchored to some spacers appropriately shaped



Carbon foam core **6x** lighter than aluminum (FOAM ROHACELL® 35 HTC)

Spoke prototype (50 cm long):
- ✓ The core was milled with a numerically controlled machine.
- ✓ The winding foils were manually cut into strips of the sizes above.
- ✓ The PEEK side inserts were glued with acrylic adhesive

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CF thickness # of CF layers total thickness

Peek side inserts

- ✓ **Simulation plans:**
  - Study the stability of the outer and inner rings with all the connections
  - Study the best solution for connect the stays at the spokes
  - Buckling analysis on outer cylinder
- ✓ **Production plans:**
  - More spokes prototypes
  - Mechanical test with torsion, compression, bending
  - Internal and external rings with the connections
- ✓ **Plans for test to be done in parallel:**
  - Characterize the wires we have (micrometer positioning stages)

Testbeam analysis: 2021-2022 data

Prepared for submission to JINST

Enhancing Particle Identification in Helium-Based Drift Chambers Using Cluster Counting: Insights from Beam Test Studies

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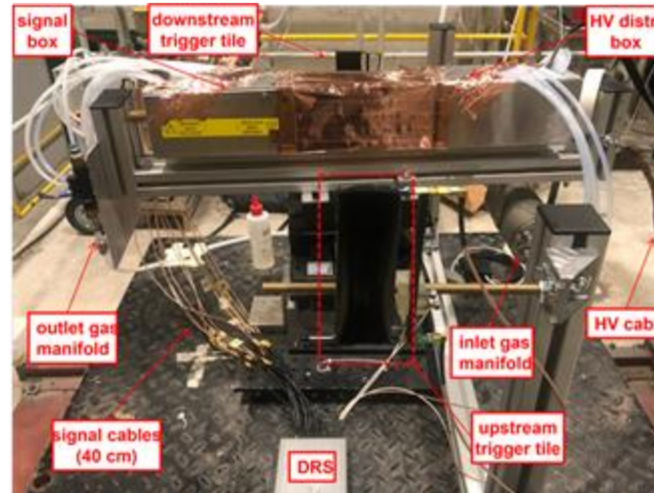
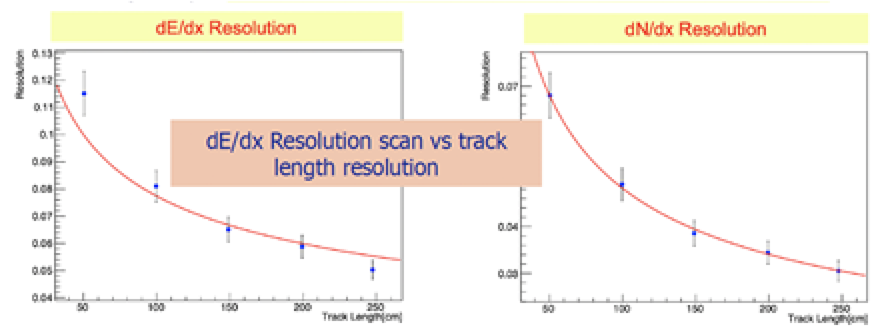
Abstract: Particle identification in gaseous detectors traditionally relies on energy loss measurements (dE/dx); however, uncertainties in total energy deposition limit its resolution. The cluster counting technique (dN/dx) offers an alternative approach by leveraging the Poisson-distributed nature of primary ionization, providing a statistically robust method for mass determination. Simulation studies with Garfield++ and Geant4 indicate that dN/dx can achieve twice the resolution of dE/dx in helium-based drift chambers. However, experimental implementation is challenging due to signal overlap in the time domain, complicating the identification of electron peaks and ionization clusters. This paper presents novel algorithms and modern computational techniques to address these challenges, facilitating accurate cluster recognition in experimental data. The effectiveness of these algorithms is validated through four beam tests conducted at CERN, utilizing various helium gas mixtures, gas gains, and wire orientations relative to ionizing tracks. The experiments employ a muon beam (1 GeV/c–180 GeV/c) with drift tubes of different sizes and sense wire diameters. The analysis explores the Poisson nature of cluster formation, evaluates the performance of different clustering algorithms, and examines the dependence of counting efficiency on the beam particle impact parameter. Furthermore, a comparative study of the resolution achieved using dN/dx and dE/dx is presented.

Keywords: Gaseous detectors, drift chambers, cluster finding, algorithms



90%He-10%iC$_4$H$_{10}$ nominal HV+20, 45°, Gas gain ~ $2 \cdot 10^5$, 165 GeV/c



dE/dx resolution dependence on the track length $L^{-0.37}$ dN/dx resolution dependence on the track length $L^{-0.5}$

~ 2 times improvement in the resolution using dN/dx method

N. De Filippis

Plans for Testbeam 2025→2026

Plans

✓ Finalize data analysis of the two test beams at CERN T10 performed in July 2023 and July 2024 with muons (1-12 GeV)

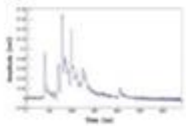
✓ Original plan for 2025: test beam at **FNAL-MT6** with π and **K ($\beta\gamma$ = 10–140)** → important to fully exploit the relativitic rise. **This option does not seem feasible at the moment** (TB facility at FNAL is closed at least until the end of the year, due to an accident occurred), then we are exploring the option to perform the test beam at CERN. **Franco requested** to the responsibles at CERN:

- We are interested in a beam of π and K in the range between 1 and 30 GeV/c.
- Any wide interval contained in this range will suits us.
- Momentum spread up to a few % is acceptable.
- Beam intensity of the order of $1e^4$ over a 10x10 cm^2 is our target.
- A π/K discrimination is necessary (Cherenkov)
- We could probably sort out a muon veto and/or an electron filter.
- It looks like that positive beam at T9 might be the best option with K identified in the range 4.5 to 16 GeV/c, but T10 could also be ok.

Reply from the PS/SPS Physics Coordinator: currently the T9 beam line is fully booked for 2025, there is some possibility to have some late minute cancellations, but staying in a waiting list.

Challenge: Data reduction and pre-processing

The excellent performance of the **cluster finding** algorithms in offline analysis, relies on the assumption of being able to transfer the full spectrum of the digitized drift signals.
However …



according to the **IDEA drift chamber operating conditions**:

- 56448 drift cells in 112 layers (~130 hits/track)
- maximum drift time of 500 ns
- cluster density of 20 clusters/cm
- signal digitization 12 bits at 2 Gsa/s

… and to the **FCC-ee running conditions at the Z-pole**

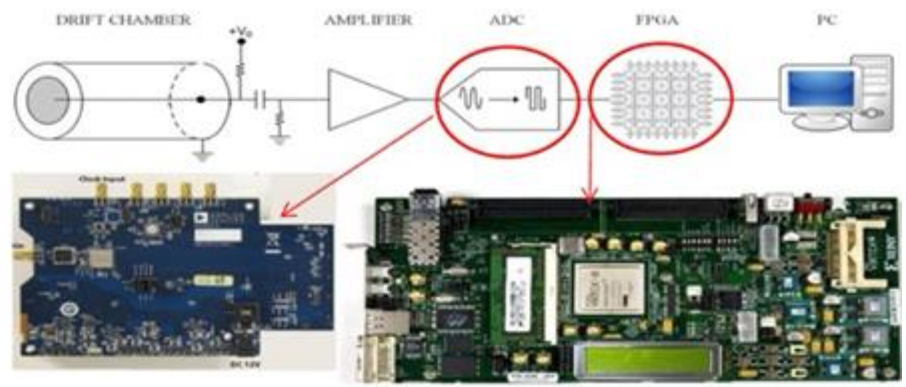
- 100 KHz of Z decays with 20 charged tracks/event multiplicity
- 30 KHz of $\gamma\gamma \longrightarrow$ hadrons with10 charged tracks/event multiplicity
- 2.5% occupancy due to beam noise
- 2.5% occupancy due to hits with isolated peaks

Reading both ends of the wires, ⇨ data rate ≥ 1 TB/s !

Solution consists in transferring, for each hit drift cell, instead of the full signal spectrum, only the minimal information relevant to the application of the **cluster timing/counting 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.

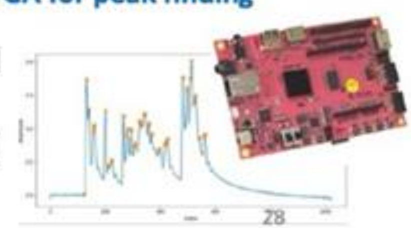


Single channel solution has been successfully verified.

G. Chiarello et al., The Use of FPGA in Drift Chambers for High Energy Physics Experiments May 31, 2017
DOI: 10.5772/66853

With this procedure **data transfer rate is reduced to ~ 25 GB/s**
Extension to a 4-channel board is in progress. Ultimate goal is a multi-ch. board (128 or 256 channels) to **reduce cost** and complexity of the system and to gain flexibility in determining the **proximity correlations** between hit cells for track **segment finding** and for **triggering** purposes.

Implementing ML algorithms on FPGA for peak finding



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N. De Filippis

Electronics

G. De Robertis and F. Loddo from INFN Bari + J. Verdejo Palacios (Ph.D)

Bari: Enable testing of the HDSoC v1 (Naluscientific) waveform digitizer → starting to develop a dedicated communication block to interface MOSAIC with HDSoC v1.

✓ **MOSAIC Board Key Features**

- Designed for detector testing in high-energy physics.
- Supports 10 high-speed serial links (up to 6.6 Gbps) and 126 slower LVDS channels.
- Xilinx XC7A200T FPGA with:
  - 215,360 Logic Cells, 730 Block RAMs (12.8 Mb)
  - 16 Low-Power Gigabit Transceivers (up to 6.6 Gb/s)
  - High-speed data transfer via DDR3
  - Gigabit Ethernet interface with 120 MB/s transfer rate
  - Integrated 8-bit microprocessor for configuration & monitoring

✓ **Waveform Digitizer HDSoC v1 Features**

- Sampling Rate: 1 GSa/s
- 32 channels
- 2k Sample Buffer
- > 600MHz Analog Bandwidth
- < 100 ps Timing Resolution
- Internally configurable triggering schemes

Plans

- Final design and implementation of the MOSAIC-HDSoC interface block.
- Initial firmware test with simulated data.
- Full integration and testing with the HDSoC waveform digitizer.

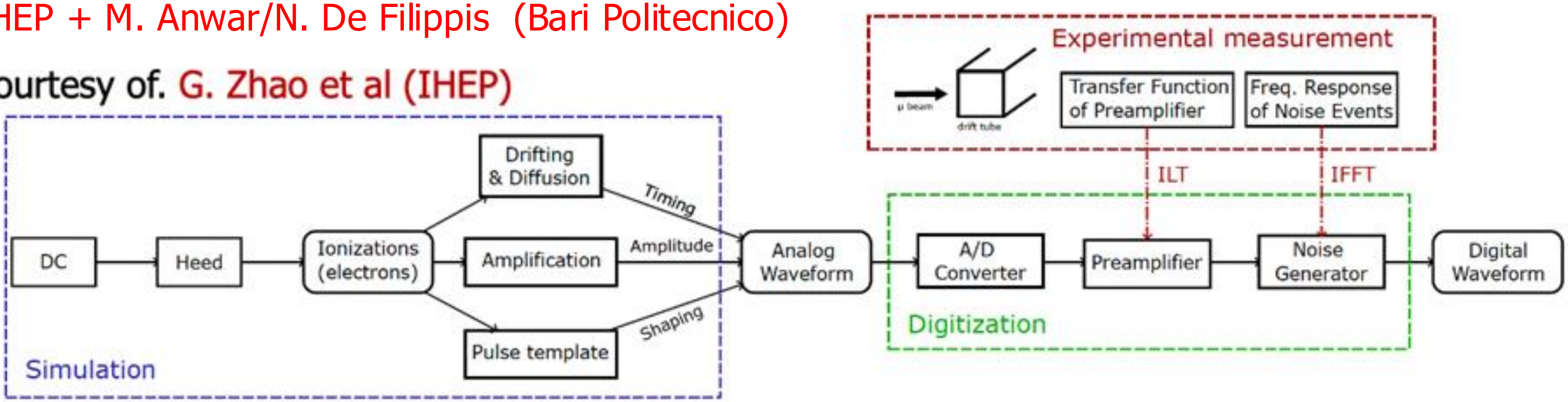
Responsabilità/Coordinamento RD_FCC:

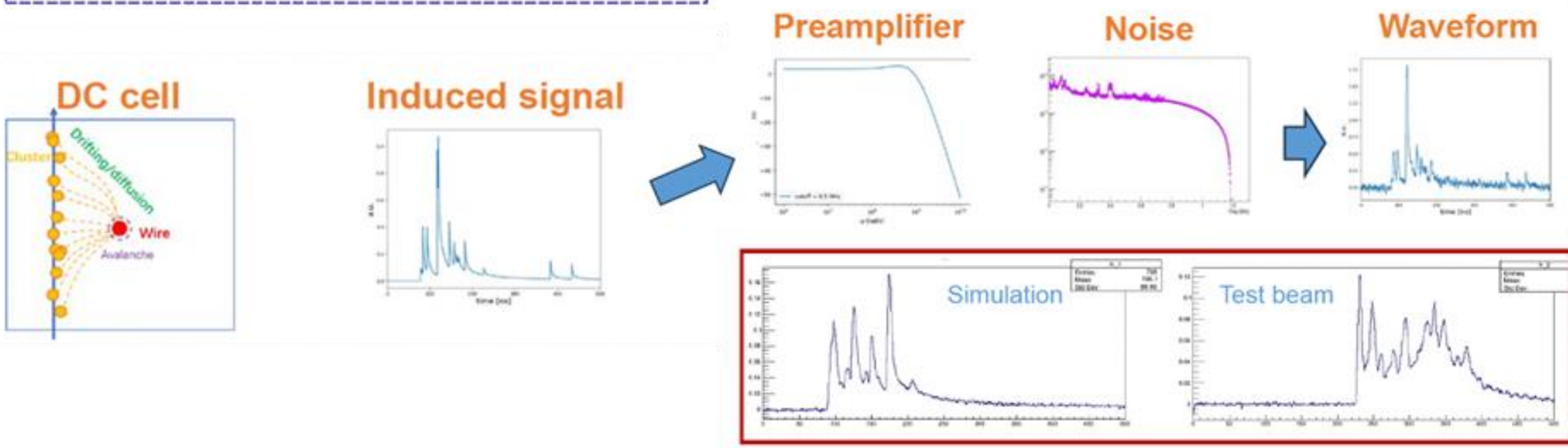
N. De Filippis: Fisica, Simulazione e Software di RD_FCC Italia

Garfield fast/full simulation chain

IHEP + M. Anwar/N. De Filippis (Bari Politecnico)

Courtesy of. G. Zhao et al (IHEP)





"Peak finding algorithm for cluster counting with domain adaptation"

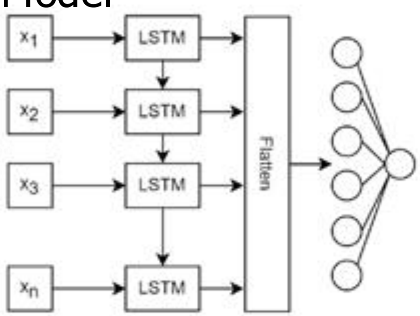
Comp. Phys. Comm., 300, 2024, 109208, https://doi.org/10.1016/j.cpc.2024.109208

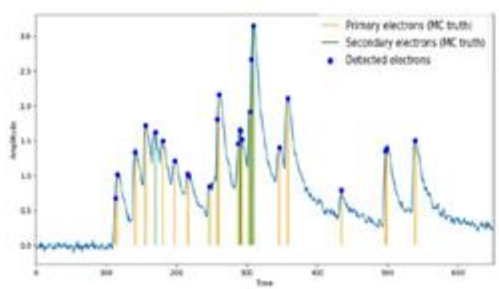
Simulation of Cluster Counting: GARFIELD + NN

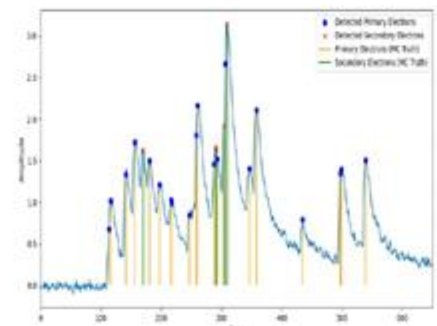
IHEP + M. Anwar/N. De Filippis (Bari Politecnico)

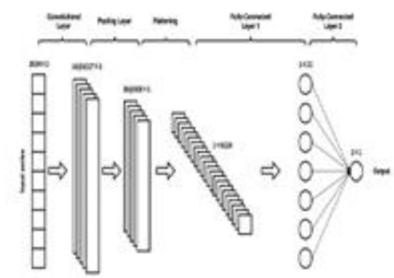
The task of peak finding can be framed as a classification problem in machine learning

- The waveforms are divided into segments, each comprising 15 bins. Each segment can represent either a signal or a noise
- The list of the amplitudes of a segment, subtracted by their mean and normalized by their standard deviation, is served as the input feature for the neural network
- The data of waveform is time sequence data, which suitable for Long Short Term Memory Model









- We applied a Long Short-Term Memory (LSTM) model to the waveform to classify signals (primary and secondary electrons) from the Noise using a peak-finding algorithm known as classification
- Detected peaks from both primary and secondary electrons are shown by blue dots

- A regression problem to predict Number of primary clusters based on the primary detected peaks by using Convolutional Neural Network (CNN) model
- The peaks found by peak finding algorithm would be training sample of this algorithm

- Labels: Number of clusters from MC truth
- Features: Time list of the detected times in the previous step encoding in an (1024, 1) array.
- A regression problem

Simulation of Cluster Counting: GARFIELD + NN

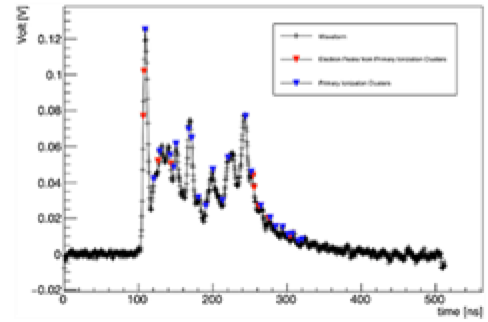
IHEP + M. Anwar/N. De Filippis (Bari Politecnico)

Momentum of Muon	Primary Cluster(MC)	Standard Deviation (MC)	Cluster Size (Full Range)	Primary Cluster(LSTM	Standard Deviation (LSTM)	Primary Cluster (CNN)	Standard Deviation (CNN)
2 Gev/c	15.85	3.9	1.55	14.4	3.75	14.26	3.2
4 GeV/c	17.16	4.189	1.54	15.85	4.015	15.77	3.42
6 GeV/c	17.65	4.178	1.605	16.47	4.104	16.21	3.43
8 GeV/c	18.38	4.228	1.54	16.96	4.05	16.57	3.37
10 Gev/c	18.61	4.282	1.54	17.34	4.065	16.86	3.13

→ new complete full simulation on going

Strategy of digitization for the IDEA DCH in FCC software

- Result of a hit cell digitization at the lowest level, L_0, must be a **waveform**



- Parameters of the waveform are:
  - time bin size
  - amplitude bit size
- At a higher level, L_1, results of hit digitization are:
  - list of electron peak positions and relative amplitudes (i.e., ionization electrons after peak finding – red markers in the picture) or
  - list of ionization cluster positions and relative amplitudes (after electrons clusterization algorithm – blue markers in the picture)
- At an even higher level, L_2, results of hit digitization are:
  - impact parameter d_{DCA}
  - number of clusters n_{cl}

❑ Presented at the FCC Physics week in January 2025

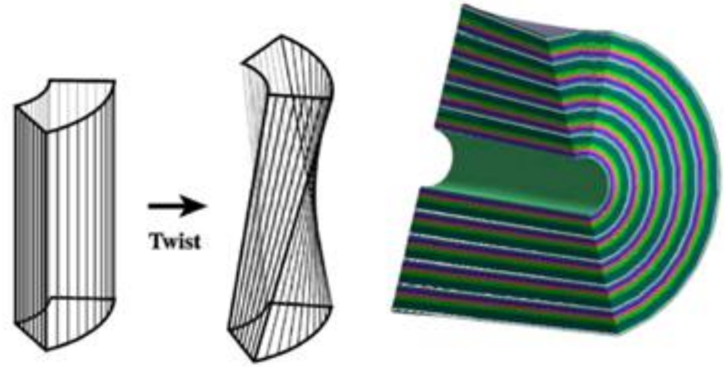
❑ Details at link: https://indico.cern.ch/event/1439509/contributions/6289570/attachments/2997087/5280386/DeFilippis_Digitizer_v1.pdf

Full simulation of the IDEA drift chamber in DD4HEP

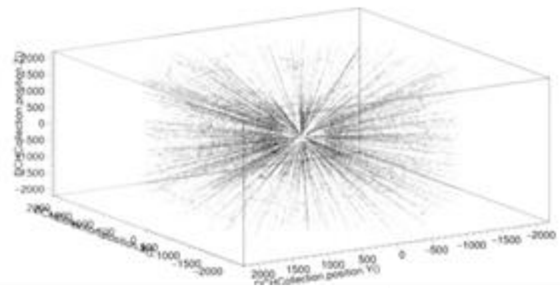
Activity started (in collaboration with CERN)

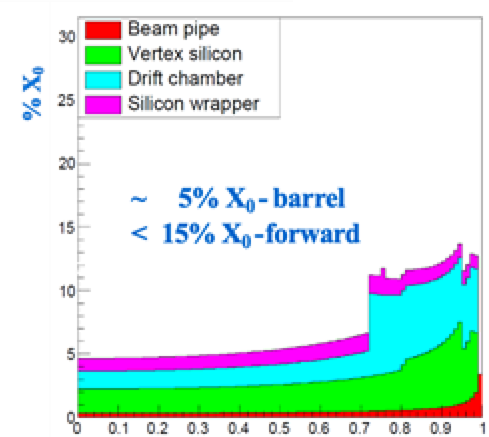
Large-volume extremely light drift wire chamber Evolving from the detectors built for KLOE and MEG2 experiments: is a full-stereo unique volume, co-axial with the 2T solenoid field, with high granularity, low mass and short drift path.

- Cylindrical wall made of carbon fiber
- Cylindrical volume filled of gas mixture.
- 112 hyperboloidal layers filled with gas mix.
- Cells are twisted tubes (twisted tube results from layer segmentation in phi, keeping the twist angle), made of gas mix. These cells are the sensitive volumes!
- Field (x5) and sense (x1) wires inside each cell.
- The new version (v02) is in k4geo.



DriftChamber o1_v02 Twisted tubes.





Activity started (in collaboration with Purdue U.) to derive the material budget by using the latest implementation of the DCH in DD4HEP/Geant4 →

ZH, Z→(qq/νν) H→ZZ*→4l studies

Yehia Mahmoud and Nicola De Filippis

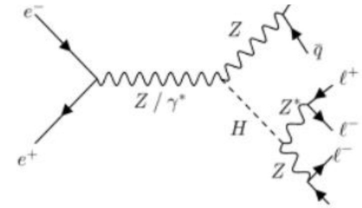
Samples:

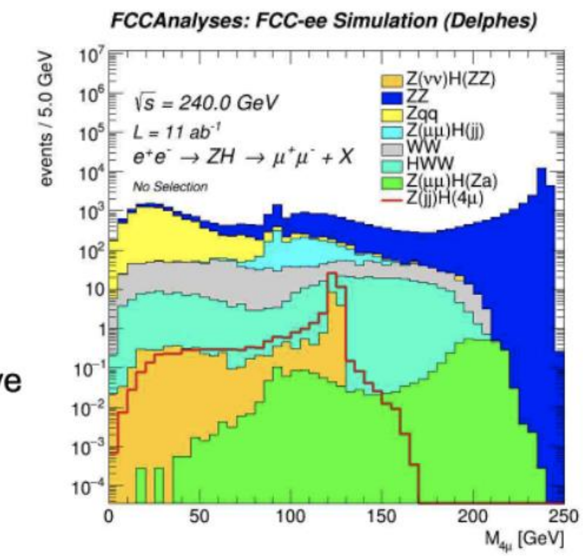
Produced by WHIZARD+PYTHIA for event generation and Delphes (IDEA detector card) for detector simulation. FCCee Winter 2023 Samples. Events produced at $\sqrt{s}$ = 240 GeV and L = 10.8 ab^{-1}.

Backround -> ZZ/ WW/ Zqq/ HWW/ Hjj/ HZa

Lepton Selection criteria (Same for hadronic and invisible channels):

- First pair of leptons (From On-shell Z)
  - Oppositely charged leptons
  - The pair which minimises $|M_{ll} - M_Z|$
- Second Pair of leptons (From off-shell Z)
  - Oppositely charged leptons
  - Highest momentum oppositely charged pair of the remaining
- Additional cut for 2e2mu: On-shell Z mass > 60 GeV. This is to remove contribution from Off-Shell Z leptons.





Analysis cuts:

- Momentum of the softest lepton (
  P_{min} > 5 GeV.
- Missing momentum cut:
  P_{miss} < 40 GeV for Z(jj), P_{miss} > 100 GeV for Z(vv)
- Visible energy of all the reconstructed particles excluding the 4 leptons
  E_{vis} > 30 GeV
- Invariant mass of dimuon pair from the Off-shell Z*
  10 < M_{Z^*} < 65 GeV
- Invariant mass of the 4 leptons:
  124 < M_{4l} < 125.5 GeV

Channel	**Signal yield**	**Total Bckg**	**s/√(s+b)**
Z(jj)H(4μ)	26	3	4.82
Z(jj)H(4e)	19	8	3.6
Z(jj)H(2e2μ)	20	5	4.0
Z(vv)H(4μ)	9	4	2.496
Z(vv)H(4e)	6	2	2.12
Z(vv)H(2e2μ)	7	3	2.21

DRD1 WP2:
Inner and central tracking with PID (Drift Chambers)

Responsible:
Nicola De Filippis
Politecnico and INFN Bari

Participating institutes

- Laboratoire de Physique des 2 Infinis Irène Joliot-Curie(IJCLab-IN2P3)
- INFN, Bari (INFN-BA)
- INFN, Lecce (INFN-LE)
- INFN, Rome (INFN-RM)
- US cluster (US):
  - - U. Mass Amherst, U. Michigan, Irvine, Tufts U., BNL, FIT, U. Florida, U. Wisconsin
- Nankai University (Nankai U.)
- Tsinghua University (Tsinghua U.)
- Institute of High Energy Physics, Chinese Academy of Sciences (IHEP-CAS)
- Wuhan University (Wuhan U.)
- Jilin University (Jilin U.)
- University of Science and Technology of China (USTC)
- Institute of Modern Physics, Chinese Academy of Sciences (IMP-CAS)
- Bose Institute (Bose)

R & D Tasks for WP2

Task ID	Task	Performance Goal	ECFA DRD Theme	
T1	Development of front-end ASIC for cluster counting	Design/construction/test of a prototype of the frontend ASIC for cluster counting (with High bandwidth, High gain, Low power consumption, Low mass)	1.1, 1.2, 1.3	STARTED
T2	Development of a scalable multichannel DAQ board	Working prototype of a scalable multichannel DAQ board (with High sampling rate, Dead-time-less, DSP and filtering ability, Event time stamping, for Track triggering)		STARTED
T3	Mechanics: new wiring procedures and new endplate concepts	Conceptual designs of novel wiring procedures (feed-through-less wiring procedures) and full design of innovative concepts of more transparent endplate (< 5% X_0).		ADVANCED
T4	Increase rate capability and granularity	Measurements of performance on prototypes of drift cells at different granularities (smaller cell size and shorter drift time) and with different field configurations (higher field-to-sense ratio).		TO BE RESTARTED
T5	Consolidation of new wire materials and wire metal coating	Evaluation of the electrostatic stability of wires with High yield strength, Low mass, low Z, High conductivity. Study of aging effects. Evaluation of existing or a sputtering facility for metal coating of carbon wires.		STARTED
T6	Study ageing phenomena for new wire types	Tests of prototypes built with new wire types at beams and irradiation facilities. Measurement of performance on total integrated charge and establish charge collection limits.		ADVANCED
T7	Optimization of gas mixing, recuperation, purification and recirculation systems	Measurement of the performance of hydrocarbon-free gas mixtures with High quenching power, Low-Z, High radiation length. Design of a recirculating system.		NOT STARTED

International collaboration

INFN Bari + Lecce involved in all the tasks
NEW: INFN Pisa expression of interest of MEG DCH experts

G. Iakovidis group from BNL (US): wire procurement
A. Jung group from Purdue U. (US):

- coating / manufacturing facility at composite center Purdue would allow manufacturing all kinds of materials
- existing supported R&D on US side
  - composite R&D for thicker high TC / electric C CFs
  - reconstruction / tracking for FCC folded GEANT work of implementing CF into sim
  - prototype of CF and reference of tungsten being constructed in lab

G. Charles group from IJCLAB (France)

- any test with wire material, choice for the prototype chosen but new ones could be tested. Produce charaterization of strength, maybe with a micrometric motor. Test different kind of wires
- test also of anchoring the wire (crimp, gluing, soldering)
- activity on mechanical design and realization of prototypes

China:

→ well established collaboration with IHEP for NN-based cluster counting algorithm

Richieste per personale e servizi

- **Richiesta di servizio di officina meccanica (1 m.u) e progettazione meccanica (1m.u.)** per realizzazione di componenti per vari prototipi di camera a a drift e progettazione di un nuovo prototipo in scala

  In contatto con:
  - C. Pastore (OM)
  - M. Mongelli (SPM)

- **Richiesta di servizio elettronico (1 m.u.)** per test componenti elettronici

  In contatto con:
  - F. Loddo

- **Richiesta di servizio alta tecnologie (1 m.u.)** per test su fili

  In contatto con:
  - G. Ciani

Anagrafica RD_FCC 2026

INFN- Bari	2026
N. De Filippis (Assoc. Prof.)	30%
M. Abbrescia (Assoc. Prof.)	20%
M. Louka (PhD)	100%
M. Saiel (PhD)	100%
A. Ali (PhD)	100%
M. Anwar (PhD)	20%
J. Verdeios Palacios	50%
W. Elmetenawee (Postdoc INFN)	30%
D. Diacono (Tecn. INFN)	10%
F. Procacci (PhD)	100%
G. Pappalettera (Assoc. Prof.)	20%
G. De Robertis (Tecn. INFN)	20%
TOT	**6 FTE**