Summary / Prospects for Detector Concepts: Tracking

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outline

- Solid state detector (pixels and Si wrapper)
- Tracker alternatives
  - Pure Si detector
  - TPC
  - Drift Chamber
- Particle identification
- Timing layer
- Muon Detector
- Electronics
- Mechanical engineering design
- Common tools for test

Solid state Detector

- For **MAPS**, France and Italy are working with different foundries **LFoundry** and **TowerJazz** which have different features and complementarities in possible configuration of the active part of the sensors. **Such complementarity in R&D are needed at this stage**
- **A direct practical collaboration is therefore not easy to implement.**
- However, there can be interest in a proper comparison of the figures of merits of the two technologies and of their perspective. This applies not only the **Pixel VD** but also to the **Si/wrapper layers** (and possibly the Si-sensors in a **HGCAL**).
- To be investigated how much this can make sense, not necessarily as of today but on **medium term**
- Possibly more independent of the foundry, at least in terms of architecture, it could be interesting to compare these architectures and especially their approach to **power consumption**. In this area it may be more possible to implement synergies.

Solid state Detector

- Concerning the overall design of a **vertex detector**, the efforts in France and Italy are again complementary: France working in the TJ with **stitching** is targeting **large area** and **bent sensors**, while Italy has not yet investigated the stitching options at LFoundry.
- **Synergies** could be in investigating the benefit or drawback for X/X0.
- As well considering environmental aspects such as services, especially for **airflow cooling** (although no effort yet was presented on this aspect)
- The MDI region with the option to **couple the first layer to the beam pipe** is being investigated in Italy in the framework of the Arcadia concept, **some synergies could also appear here**.

Tracker alternatives: Pure Si tracker - drawbacks

- **Multiple scattering**

  Contribution to momentum resolution due to multiple scattering dominates up to larger momenta than in a gaseous tracker

- **Redundancy**

  Only a limited number N of layers can be implemented, hindering the momentum resolution, proportional to $\sigma/\sqrt{N}$, despite the excellent spatial resolution σ (is it really needed?) (25 µm/√6 = 100 µm/√100)

- **Inefficiencies for "kinks" and "vees"**

  Lack of redundancy against hit inefficiencies and background hits

- **particle identification**

  No dE/dx possible, maybe TOF if order of 10 ps resolution can be granted over many m^2

- **system complexity**

  Order of $10^8 – 10^9$ channels for a limited number of space points on a track with a lever arm compatible with the momenta to be measured

- **Stability of relative and absolute alignment**

Tracker alternatives: TPC

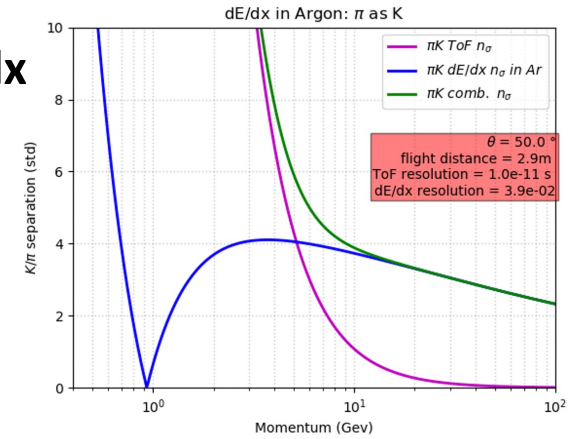
Despite the very interesting results on TPC R&D presented by Paul Colas, His conclusions were:

Conclusion

- The R&D for a TPC at an e+e- factory evolves since 1996
- Recent and ongoing studies show that running a TPC at the Z pole and at the 2 10^{36} $cm^{-2}s^{-1}$ is difficult because of positive ions creating distortions.
- Machine background studies need to be revisited

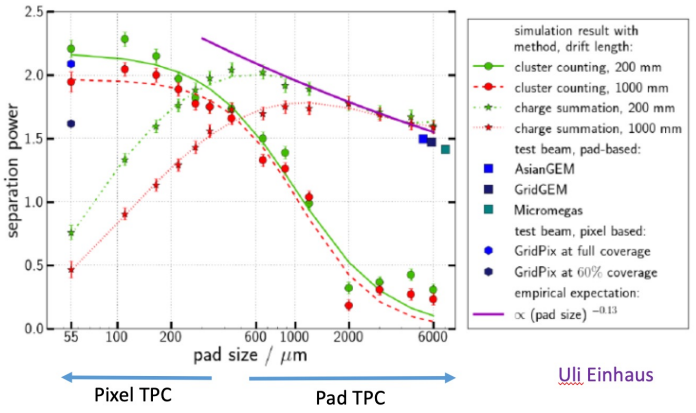
- My personnal conclusion is that it is very difficult to optimize a detector both for EW-heavy flavour physics and for HZ and ttbar physics

dE/dx



R. Aleksan

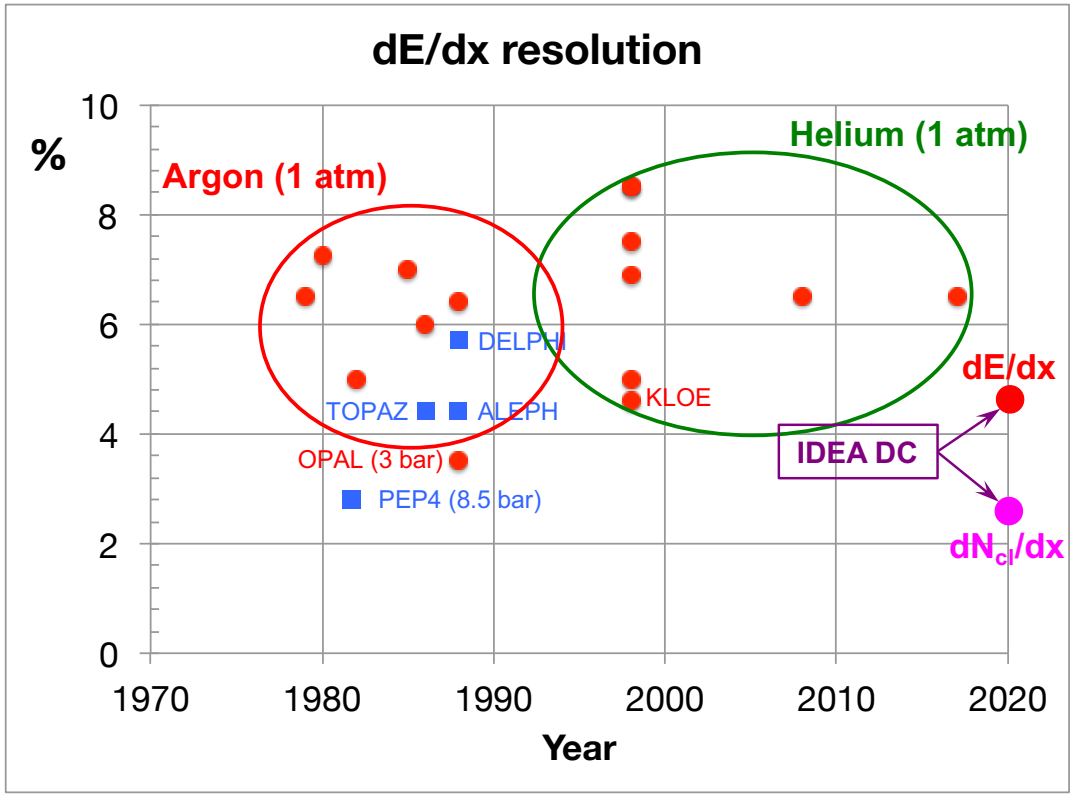
cluster counting



Uli Einhaus

Drift Chamber and Particle Identification

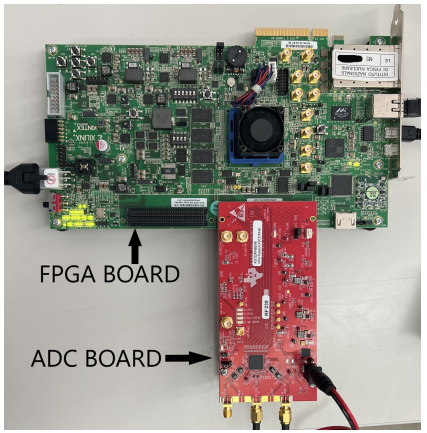
- Cluster Counting as a breakthrough in particle identification after over 40 years of no progress in the dE/dx techniques.
- Many open grounds for stimulating sharing of responsabilities on **electronics**:
  - Low power consumption preamplifier ASICs (60,000 channels per side)
  - High sampling rate digitizers (>12 bits)
  - Data reduction and pre-processing boards
- … and on **mechanics** …

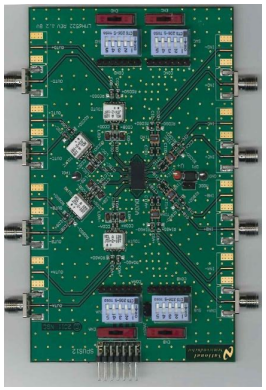


Current R&D efforts: DAQ

- Data readout and pre-processing board for **cluster counting/timing DAQ system** (sponsored by AIDA innova)
  - Successfully accomplished on a single channel board.
  - The objective is to be able to implement, on a single FPGA, CCT algorithms for the parallel pre-processing of as many (contiguous) channels as possible in order to define proximity correlations between hit cells, for track segment finding and for triggering purposes.
  - Further advantage is to reduces the data transfer rate and the amount of information stored.
  - Three different approaches are being attempted:
    - ADC TEXAS INSTRUMENT ADC32RF45
    - CAEN digitizer
    - NALU SCIENTIFIC ASoCv3

FPGA + ASoC





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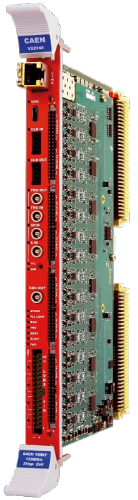
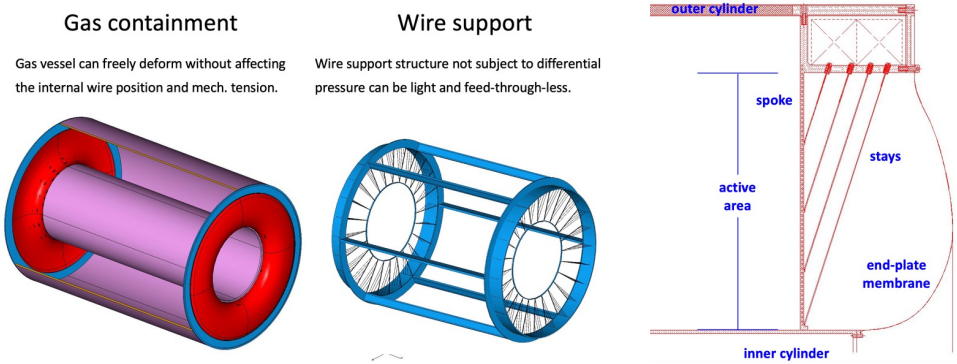
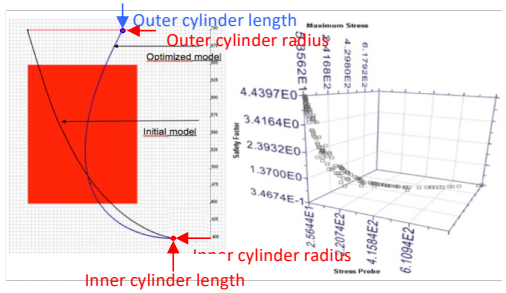
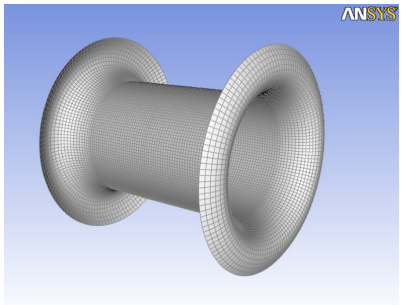


Current R&D efforts: Mechanical structure

- Model of the drift chamber **mechanical structure** (sponsored by eurizon European network for developing new horizons for RIs).
  - Simulation of the mechanical components of the wire cage structure has just started in the framework of ANSYS in collaboration with EnginSoft and Politecnico di Torino (expect to complete a Master Thesis by April 2023 and a PhD thesis by 2025).
  - Goal is to provide a solid base for the design of a full length prototype to verify the electrostatic stability of different wire types (aluminum, titanium and carbon monofilamets for field and guard wires and tungsten and molibdenum for sense wires) of different diameters.
  - Also, to optimize the wire tension compensation scheme proposed to minimize the end-plates material budget.
  - Lastly, to minimize the material budget of the carbon fiber gas vessel by the proper choice of the envelope profile.







parameters	Initial model	Optimized model
Maximum stress	357.5 MPa	58.7 MPa
Stress at inner boundary	267.4 MPa	26.6 MPa
Safety factor	0.783	4.44

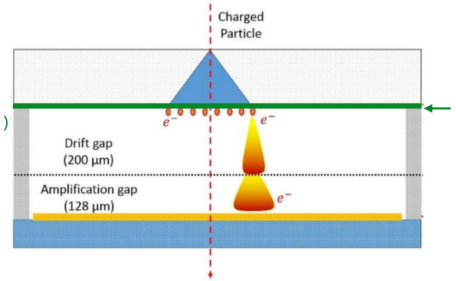
For more details see: *F. Grancagnolo, "Mechanical features of the IDEA drift chamber", Kick-Off Workshop on Detector Optimization and Benchmarking for FCC-ee, 23.06.2022*

Timing layer: solid state

- On the side of **precise timing**, there is an ongoing effort at IRFU/ Saclay in LFoundry technology to exploit at its best a pad design w/o amplification layer while there is an effort in Italy to also implement an amplification layer.
- **It could be a point of synergy to investigate**. There is also interest at IJClab for design with amplification in the framework of the replacement in LS4/5 of the ALTAS HGTD LGAD inner sensors, for which the electronics has been designed by Omega
- IRFU/Saclay has also experience in the development of the ultra precise clock distribution for the CMS timing layers and calorimeters
- To be noted that there are also interests in France to investigate the ultimate time resolution that coud be achieved in the TJ technology.

Timing layer: alternatives

- **mRPC** have proven their validity in several systems. They are compatible with the required resolution (50 to 100 ps) and can easily fit the space allowed between the tracker and the calorimeter, both in the barrel and in the end-caps. Their thickness in terms of radiation length is tolerable (there is a French effort here to implement them in calorimetry)
- **Time of propagation** of Cherenkov light represent a valid alternative to mRPC. The experience gained with the **TOP** detector in Belle II, with the **TORCH** full scale prototypes for LHCb and with the **PANDA DIRC** barrel and end-cap detectors, represent convincing evidence about the applicability of such techniques to FCC-ee (for a stimulating speculation see: *R. Forty, https://indico.cern.ch/event/766859/contributions/3255803/attachments/1776523/2888463/FCC-ee-TORCH.pdf*)
- **picosec MicroMegas design**



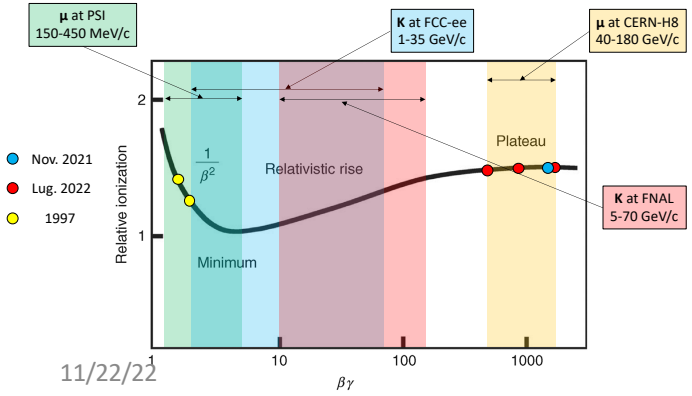
- Can we afford the **material budget** and the **real estate** taken by these devices?

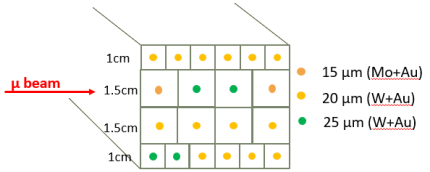
Muon Detector

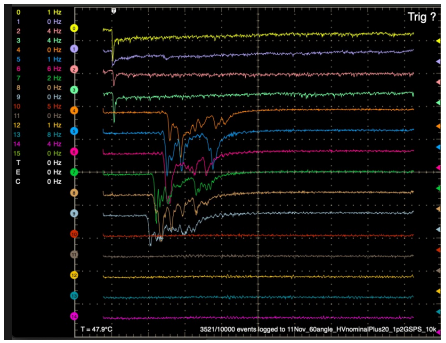
- I leave it to the discussion with Paolo Giacomelli to search for possible synergies on the various aspects of the current design and of the potential modifications/additions to the muon detector.

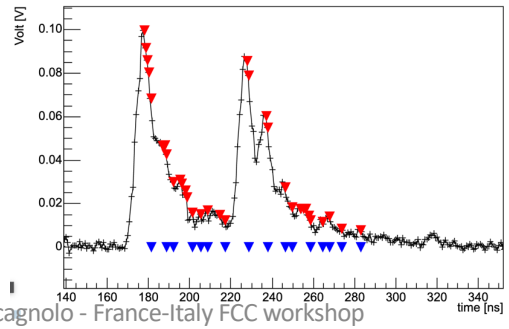
Current R&D efforts: Beam tests

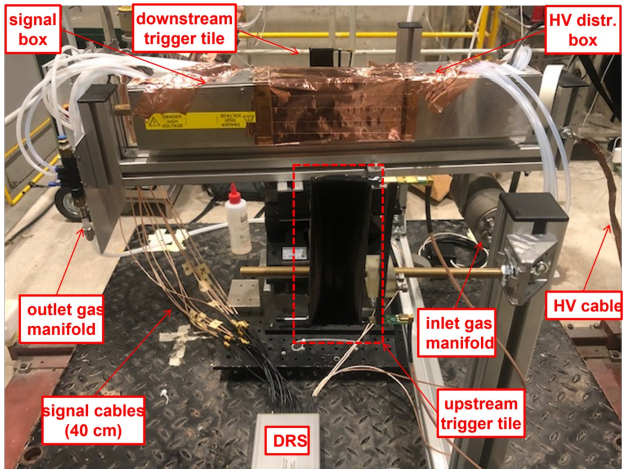
- Beam tests to experimentally asses and optimize the **performance of the cluster counting/timing** techniques in strict collaboration with the IHEP Beijing group
  - Two beam test performed at CERN-H8 (βγ > 400) in Nov. 2021 and July 2022
  - More tests planned in 2023 at CERN and PSI (βγ = 1−4) in 2023
  - Ultimate test at FNAL-MT6 with π and K (βγ = 10−140) to fully exploit the relativitic rise



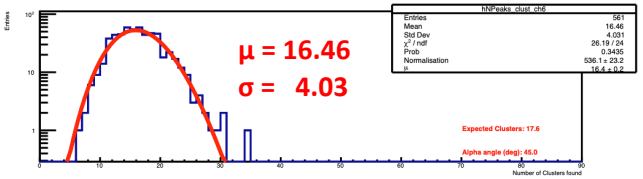


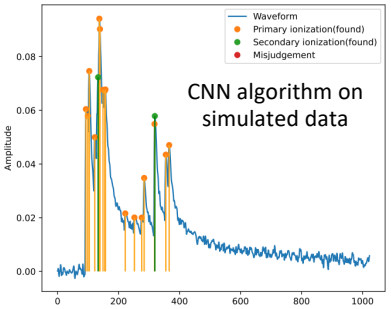






number of clusters





Credit to IHEP