IDEA Drift Camber
stato e preventivi 2019

F. Grancagnolo
INFN – Lecce

Milano, 5 luglio 2018

SOMMARIO

- ❑ Consuntivo attività 2017-2018
- ❑ Attività prevista 2019
- ❑ Richieste 2019
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Consuntivo attività 2017-2018

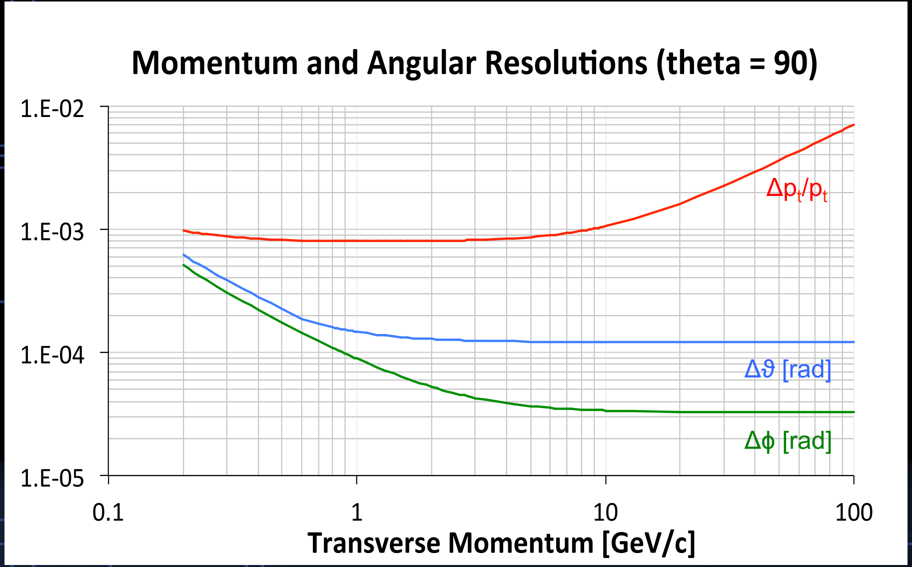
- Talks e posters
- Organizzazione WG11 (Detector Design) Meetings at CERN
- Simulazione e studio delle performance della DCH
- Studi su algoritmi di tracciamento
- Beam test del prototipo di DCH al PSI (Sept. 2017)
- Stima occupancy da Incoherent Pair production in FCCee
- Stima data transfer da DCH
- Stesura CDR di CEPC e di FCCee
- Studi su fili di carbonio rivestiti
- Preparazione beam test al CERN (slice test ad H8)

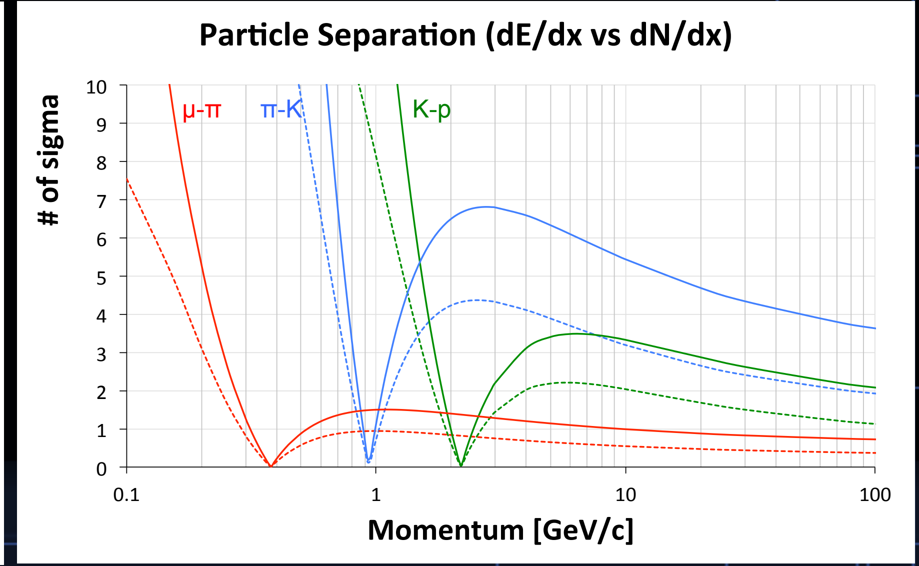
Talks e Posters 2017-2018

1. F. Grancagnolo, *A drift chamber option for CEPC* – IAS HEP, Hong Kong January 2017
2. F. Grancagnolo, *IDEA tracking highlights* – CEPC Workshop, Wuhan April 2017
3. F. Grancagnolo, *"Full" Simulation of the IDEA Drift Chamber at FCC-ee* – FCC/WG11 CERN May 2017
4. G. Tassielli, *IDEA tracking simulation status and future plans* – FCC/WG11 CERN June 2017
5. G. Tassielli, *Update on the integration of the simulation packages of the IDEA detector* – FCC/WG11 CERN July 2017
6. G. Tassielli, *Very preliminary results from a beam test of a drift chamber prototype* – FCC/WG11 CERN October 2017
7. F. Grancagnolo, *An ultra-light drift chamber with particle identification capabilities* – International Workshop on High Energy CEPC, Beijing November 2017
8. M. Dam, *Tracker resolution studies* – FCC/WG11 CERN November 2017
9. F. Grancagnolo, *Drift chamber tracker* – FCC/WG11 CERN January 2018
10. G. Tassielli, *IDEA drift chamber* – FCC/WG11 CERN March 2018
11. N. Alipour Tehrani, *Beam background impact in the IDEA drift chamber* – FCC week, Amsterdam April 2018
12. N. Alipour Tehrani, *Simulation of the drift chamber for the FCCee IDEA detector concept within FCCSW* – FCC week, Amsterdam April 2018
13. G. Tassielli, *IDEA drift chamber* – FCC week, Amsterdam April 2018
14. G. Chiarello et al., *Application of the cluster counting and timing techniques to improve the impact parameter estimate of the drift chamber*, Poster – FCC week, Amsterdam April 2018
15. G. Chiarello et al., *The automatic system for the construction of drift chambers for modern high energy physics experiments*, Poster – FCC week, Amsterdam April 2018
16. G. Chiarello et al., *Improving spatial and PID performance of the high transparency Drift Chamber by using the Cluster Counting and Timing techniques*, Poster, Pisa meeting on advanced detectors, May 2018
17. F. Grancagnolo, *State-of-the-art of drift chambers*, Super c-tau factory workshop, BINP Novosibirsk, May 2018
18. F. Grancagnolo, *The IDEA drift chamber: the occupancy "saga" and other considerations* – FCC/WG11 June 2018

Simulazione e performance

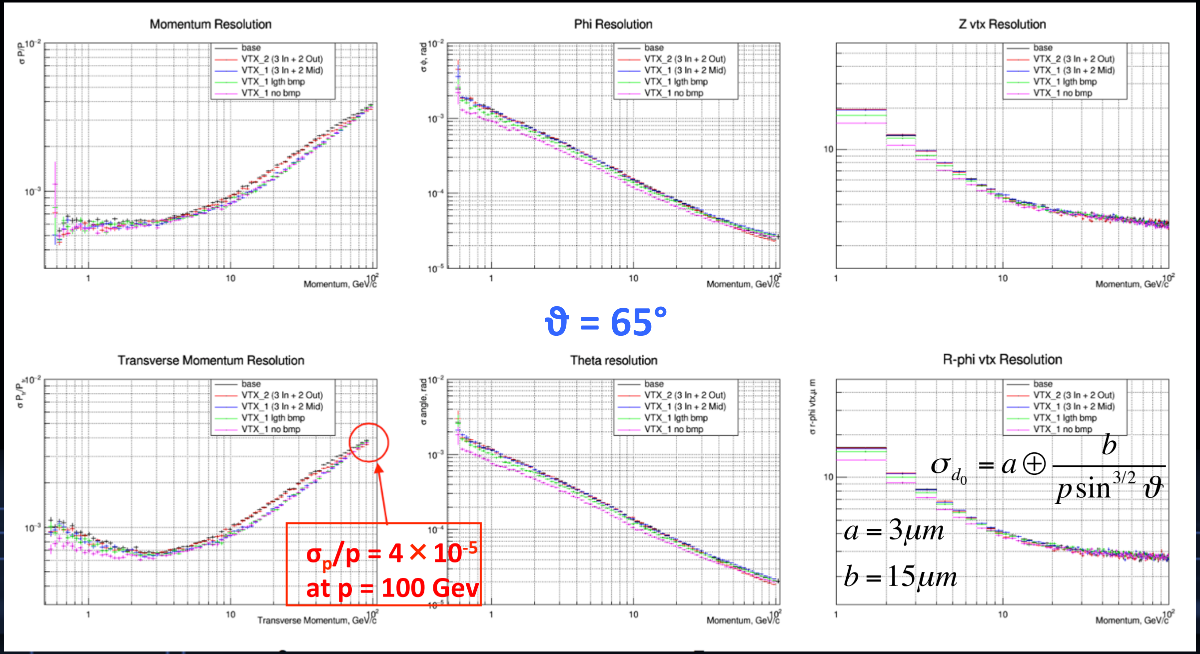
DCH Performance: Analytical calculations (FG)

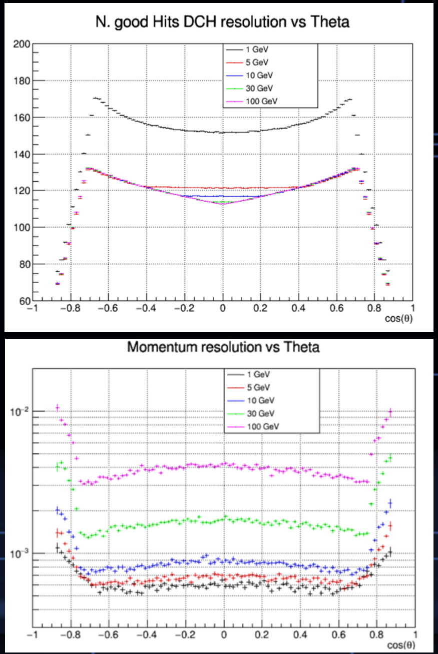




Simulazione e performance

IDEA integrated tracking simulation (Tassielli, Dam, Ignatov)



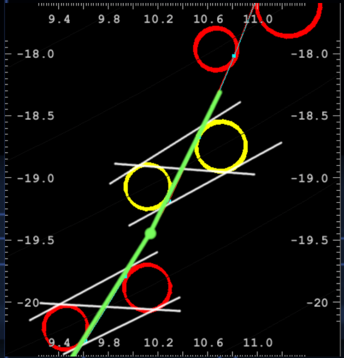


Algoritmi di tracciamento

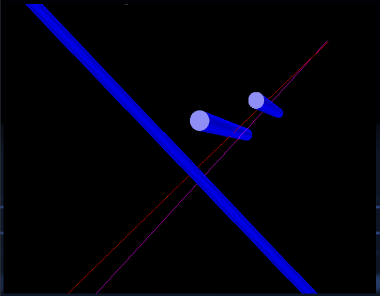
tracking strategy (Ignatov, Tassielli)

- constructing of track seeds
- adding hits by following seed through detector layers
- improving seed with Kalman filter techniques

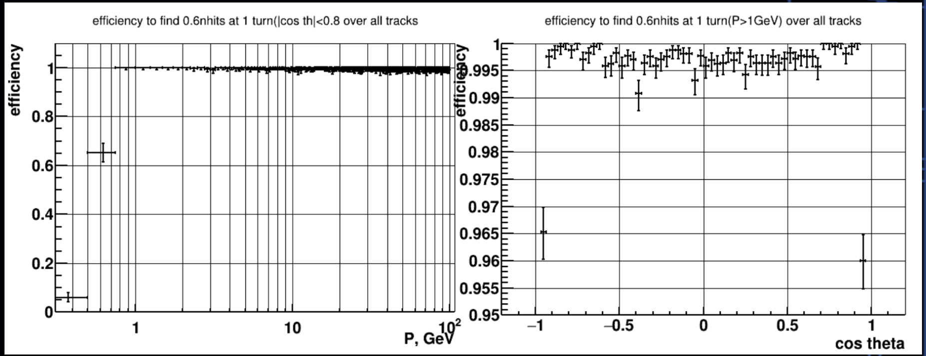
seeding from 2 pairs of hits (each pair on same layer) pointing at the origin



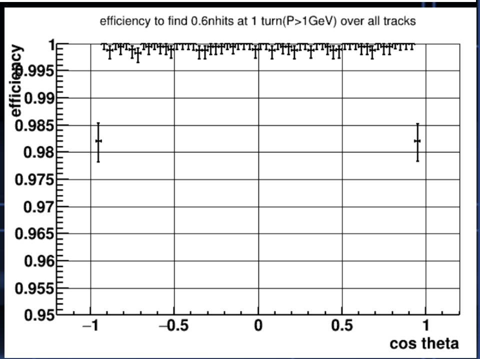
seeding from 3 hits in different layers with origin constraint



tracking efficiency (no longitudinal info)



using charge division and time difference $\sigma_z \approx 3$ cm

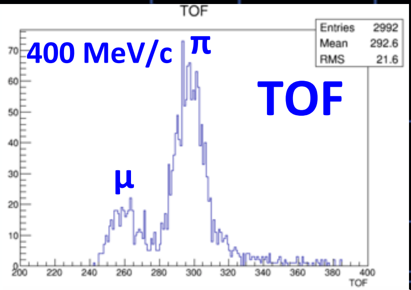


beam test PSI – Settembre 2017

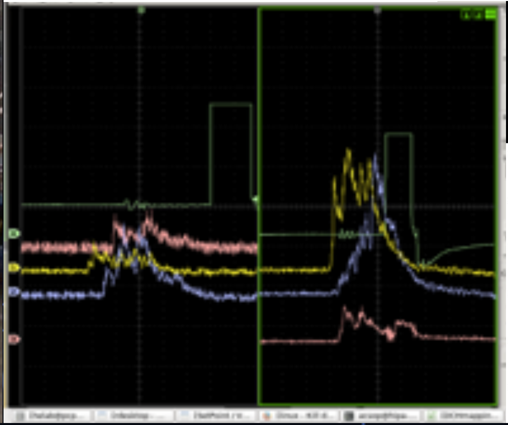
- **cluster timing** for spatial resolution (impact parameter bias)
- **cluster counting** for particle identification

beam test PSI – Settembre 2017

- A test beam was performed in πM1 on Sep. 13th-27th with a drift chamber prototype to test the **cluster counting/timing technique**
  - ~ 120 channel drift chamber
  - same FE electronics of MEG-II (different PCB layout)
  - Readout of 19 channels with 2 DRS4 evaluation board and 3 large-bandwidth oscilloscopes
  - Pair of silicon detectors (Medipix) for external tracking

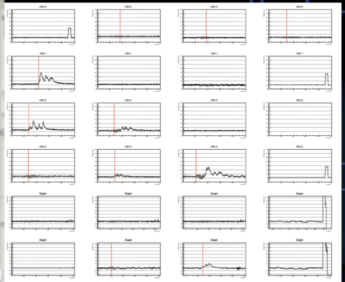


momentum range very limited
time-of-flight marginal



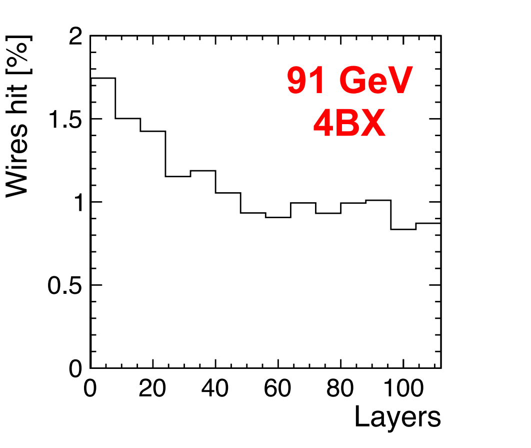
scope readout

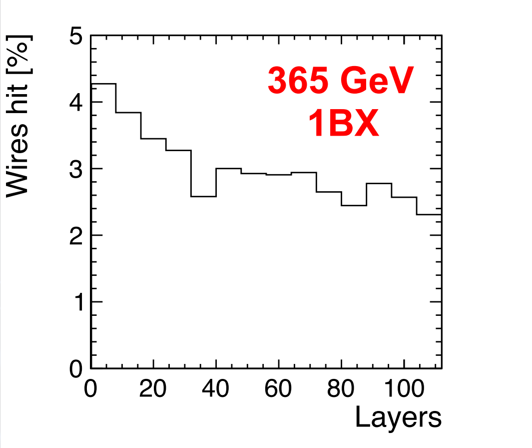
DRS4 readout



Consideration about occupancy

- In the case of 20 ns inter-bunch crossing time (at 91 GeV) and 400 ns maximum drift time, assuming that the hits are all from ionisation track segments and not from isolated Compton electrons from photons, it would be straightforward to integrate the occupancy over 20 BX.
- However,
  - hits associated to BX_i and BX_j are separated in time and will not contribute to the occupancy if **$(i-j)\times 20$ ns $\geq \delta t_{cl}$** (average cluster separation time).
  - assuming conservatively **$\delta t_{cl} \approx 100$ ns**, the occupancy must be integrated over **4 BX** at most.





(Alipour Tehrani)

Data Transfer: Example

Running conditions

- **91 GeV** c.m. energy
- **200 KHz** trigger rate
  - **100 KHz** Z decays
  - **30 KHz** γγ → hadrons
  - **50 KHz** Bhabha
  - **20 KHz** beam backgrounds

D.C. operating conditions

- drift cells: **56,000** , layers: **112**
- max drift time (≈1 cm): **400 ns**
- cluster density: **20/cm**
- gas gain: **6×10^5**
- single e^- p.h.: **6 mV**
- r.m.s. electronics noise: **1 mV**
- e^- threshold: **2 mV**; rise time **1 ns**
- signal digitization:
  12 bits at 2×10^9 bytes/s

Traditional data transfer

- **Z decays:**
  10^5 events/s × 20 tracks/event × 130 cells/track × 4×10^{-7} s × 2×10^9 bytes/cell/s ≅ **200 Gb/s**
- **γγ → hadrons:**
  3×10^4 events/s × 10 tracks/event × 130 cells/track × 4×10^{-7} s × 2×10^9 bytes/cell/s ≅ **30 Gb/s**
- **Bhabha:**
  5×10^4 events/s × 2 tracks/event × 0 cells/track × 4×10^{-7} s × 2×10^9 bytes/cell/s ≅ **0 Gb/s**
- **Beam noise** (assume 2.5% occupancy):
  2×10^4 events/s × 1.5×10^3 cells/event × 4×10^{-7} s × 2×10^9 bytes/cell/s ≅ **25 Gb/s**
- **Isolated peaks** (assume 2.5% occupancy):
  2×10^5 events/s × 1.5×10^3 cells/event × 4×10^{-7} s × 2×10^9 bytes/cell/s ≅ **250 Gb/s**

Transferring all digitized data (reading both ends of wires):

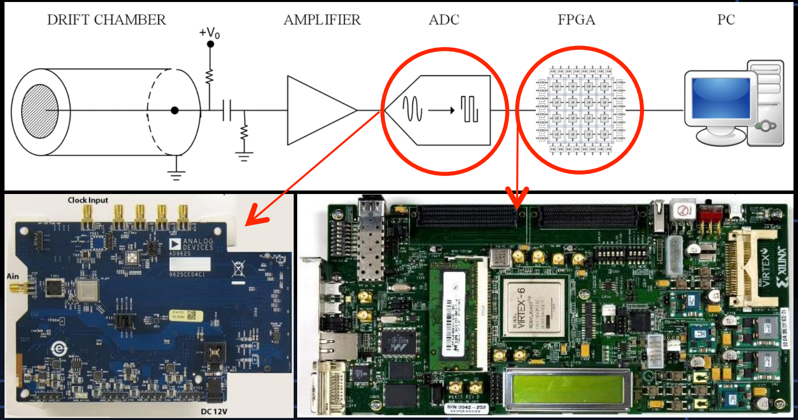
≥ 1 TB/s!

The solution

The solution consists in transferring, for each hit drift cell, **instead of the full spectrum of the signal**, 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 is accomplished by using a **FPGA** for the real time analysis of the data generated by the drift chamber and successively digitized by an ADC.

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

CluTim data transfer

- **Z decays:**

  10^5 events/s × 20 tracks/event × 130 cells/track × 20 peaks/cell × 2 bytes/peak ≅ **10 Gb/s**
- **γγ → hadrons:**

  3×10^4 events/s × 10 tracks/event × 130 cells/track × 20 peaks/cell × 2 bytes/peak ≅ **1.6 Gb/s**
- **Bhabha:**

  5×10^4 events/s × 2 tracks/event × 0 cells/track × 20 peaks/cell × 2 bytes/peak ≅ **0 Gb/s**
- **Beam noise** (assume 2.5% occupancy):

  2×10^4 events/s × 1.5×10^3 cells/event × 0 peaks/cell × 2 bytes/peak ≅ **0 Gb/s**
- **Isolated peaks** (assume 2.5% occupancy):

  2×10^5 events/s × 1.5×10^3 cells/event × 0 peaks/cell × 2 bytes/peak ≅ **0 Gb/s**

Transferring only time and amplitude of each electron peak (reading both ends of wires):

≈ 25 GB/s!

New wire materials

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

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

Assuming: **C = 10 pF/m, V_0 = 1500 V, L = 4.5 m, w = 1.0 cm**

T > 0.40 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**
  => shorten chamber (loss of acceptance) ("transverse chamber"?)
  => increase cell size (increase occupancy)
  => increase wire thickness (increase multiple scattering)

or,

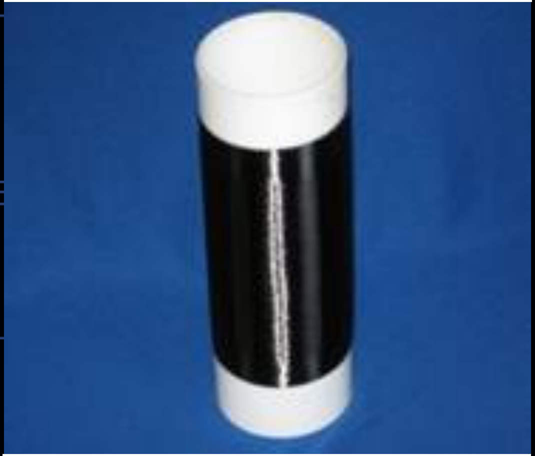
=> replace 40 μm Al with **Titanium** (Y.S. ≈ 550 MPa): **T_{max} = 0.70 N**
=> replace 20 μm W and 40 μm Al with **35 μm Carbon monofilament** (Y.S. ≈ 860 MPa): **T_{max} = 0.83 N**

New wire materials

SPECIALTY MATERIALS, INC.

Manufacturers of Boron and SCS Silicon Carbide Fibers and Boron Nanopowder

CARBON MONOFILAMENT



TYPICAL PROPERTIES

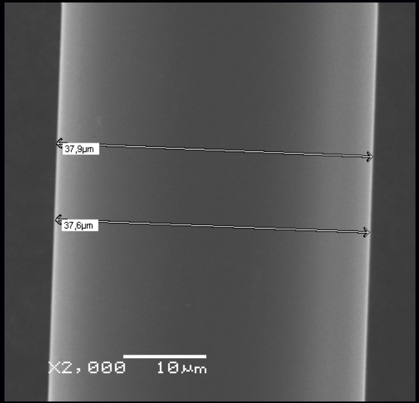
Diameter:	**0.00136 +/- 0.0001" (34.5 +/- 2.5 μm)**
Tensile Strength:	**125 ksi (0.86 GPa)**
Tensile Modulus:	**6 msi (41.5 GPa)**
Electrical Resistivity:	**3.6 x 10^{-3} ohm cm**
Density:	**1.8 g/cc**

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

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

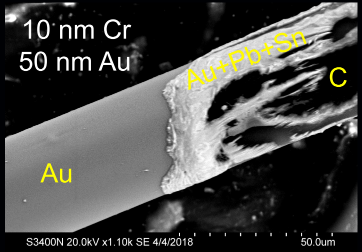
CARBON MONOFILAMENT PRODUCT PRICE LIST
Effective October 1, 2017

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



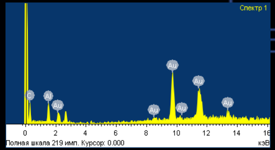
High-power impulse magnetron sputtering (HiPIMS)

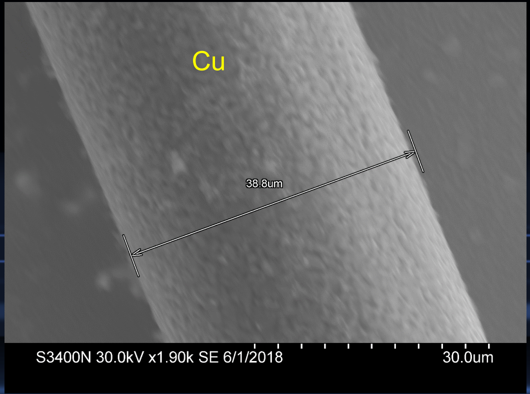
physical vapor deposition of thin films based on magnetron sputter deposition (extremely high power densities of the order of kW/cm^2 in short pulses of tens of microseconds at low duty cycle <10%)



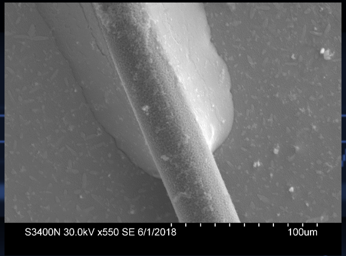
soldering attempt

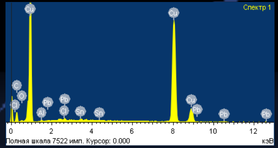
Lead forms intermetallic compound with gold and completely dissolves the 50 nm Au layer.





good solder wettability on Cu





A. Popov
V. Logashenko

Attività prevista nel 2019

- Analisi dati del beam test ad H8
- Full simulation della cluster deposition e della generazione dello spettro di segnale
- Full simulation dei vari background per l'ottimizzazione della geometria e dei parametri operativi (gain, gas, HV)
- Continuazione degli studi sugli algoritmi (globali?) di tracciamento
- Costruzione di piccoli prototipi con fili di C (anodo e catodi)
- Studi su gas non infiammabili
- Individuazione componentistica per scheda ADC+FPGA
- Analisi di eventi bench mark di fisica (HZ in muoni)

Richieste 2019

Anagrafica INFN

	2018	2019
Carola ESPOSITO CORCIONE	30%	-
Francesco GRANCAGNOLO	30%	40%
Alfonso MAFFEZZOLI	20%	-
Marco PANAREO	10%	20%
Giovanni Francesco TASSIELLI	20%	30%
Giorgio ZAVARISE	20%	-
totale	**1.3 fte**	**0.9 fte**
officina meccanica	**2 m.u.**	**3 m.u.**

Richieste 2019

Anagrafica INFN

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Giovanni Francesco TASSIELLI	20%	30%
Giorgio ZAVARISE	20%	-
totale	**1.3 fte**	**0.9 fte**
officina meccanica	**2 m.u.**	**3 m.u.**

Nuove Collaborazioni

Sergey GRIBOV
Fedor IGNATOV
Ivan LOGASHENKO
Alexander POPOV
Alexander RUBAN

Budker Institute for Nuclear Physics, Novosibirsk, Russia

...

+ for the H8 beam test:

Francesco Renga, Gianluigi Chiarello
Sapienza University, Rome, Italy

master student (Mogens DAM)
Niels Bohr Inst., Copenhagen, Denmark

master student + bachelor student
Salento University, Lecce, Italy

master student (Nicola De Filippis)
Bari University, Italy

Richieste 2019

Consumi

Studi sui file	**5.0 K€**
• filo di C (600 m)	2.0 K€
• campioni di filo di Ti	1.0 K€
• metalli per HiPIMS coating C and Ti wires	2.0 K€
Scheda ADC + FPGA	**5.0 K€**
• Analog Device AD9625-2.0EBZ or similar	1.5 K€
• Xilinx Zynq-7000 SoC ZC706 Evaluation Kit	2.5 K€
• cavi e connettori di collegamento	1.0 K€
Costruzione piccoli prototipi	**3.0 K€**
• meccanica tubi a drift con anodi di C	0.5 K€
• meccanica cameretta con catodi di C e Ti	1.5 K€
• componentistica gas ed elettronica	1.0 K€
Studi su miscele di gas non infiammabili	**2.0 K€**
• bombole e riduttori di pressione	2.0 K€
Metabolismi	**2.0 K€**

Missioni

Riunioni RD_FA	**X.X K€**
• 2 riunioni all'anno per 2 persone	X.X K€
Coordinamento FCCee-WG11	**X.X K€**
• riunioni mensili al CERN (6 riunioni) X.X K€	
Altro	**X.X K€**
• Workshop CEPC (2 x 2 persone)	X.X K€
• FCCee weeks (2 x 2 persone)	X.X K€
• 2 viaggi a BINP (in attesa di agreement)	X.X K€

in attesa di definizione

Attività prevista nel 2020-2021

- Disegno finale della camera in preparazione del TDR
- Realizzazione scheda FPGA multicanale (16 canali?)
- Prototipo "full length" (5 m)
- Prototipo di camera "trasversa"
- Beam test dei prototipi

TraPId chamber for JLEIC

Cylindrical tracker:

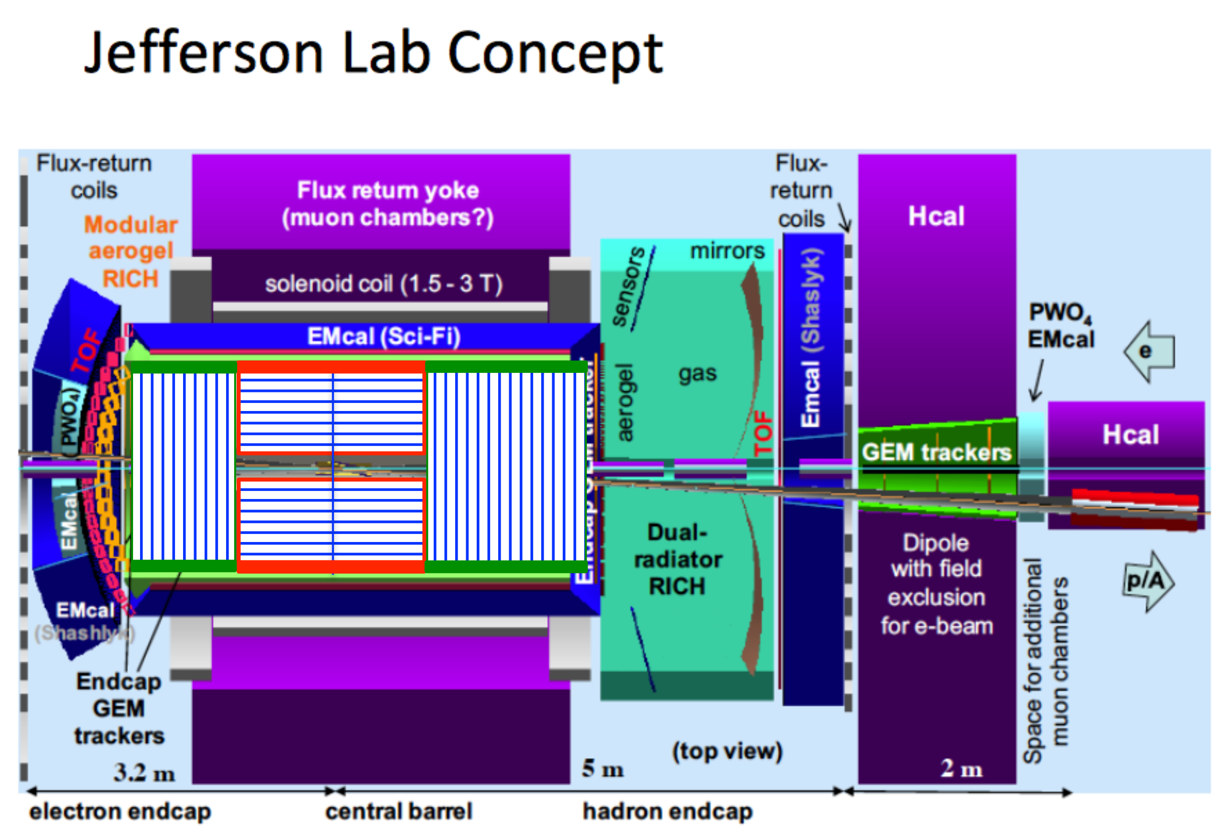
Length 140 cm, R_{in} ~ 10 cm R_{out} ~ 90 cm
|η| ≤ 0.7 (52° ≤ ϑ ≤ 142°)
Solenoid field 3 Tesla
10x8 layers in 24 sectors
average stereo angle 100 mrad
average square cell size 1.0 cm
25,000 drift cells, 150,000 wires

Forward/Backward trackers:

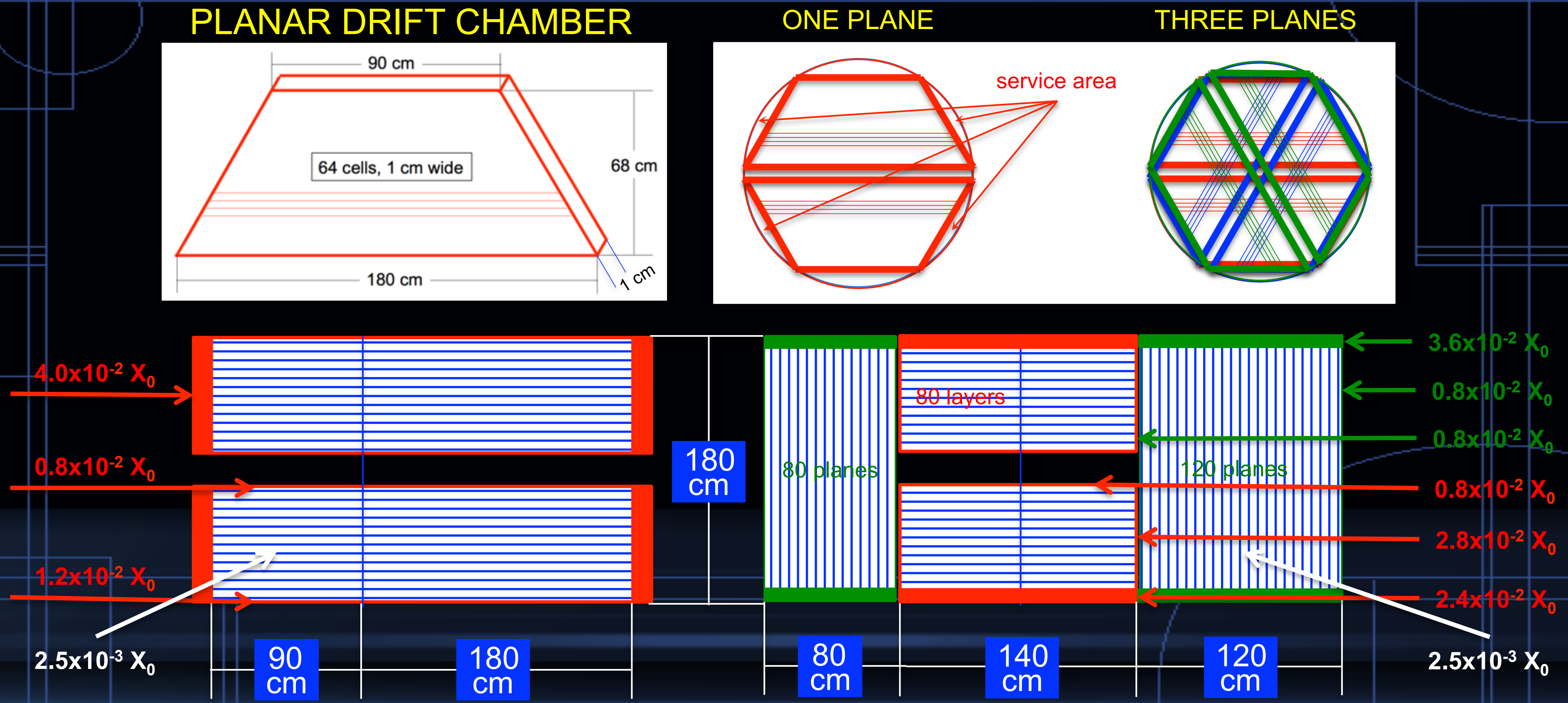
hadrons:
- L = 120 cm, 120 planes
- 0.7 ≤ η ≤ 3.5 (3.6° ≤ ϑ ≤ 52°)

electrons:
- L = 80 cm, 80 planes
- −0.7 ≤ η ≤ −3.2 (142 °≤ ϑ ≤ 175.2°)

wires orientations 0°, ±60°
square cell size 1.0 cm
128 drift cells, 1500 wires /plane
15,360 + 10,240 drift cells, 150,000 wires



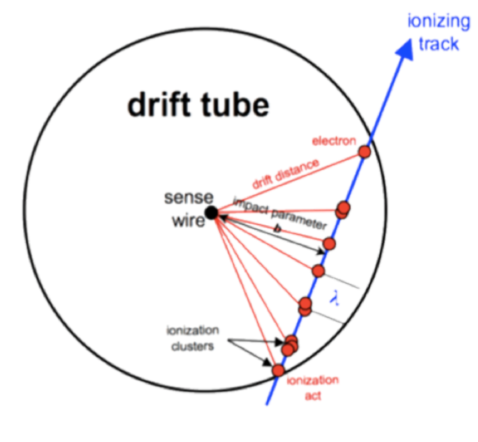
TraPId chamber for JLEIC



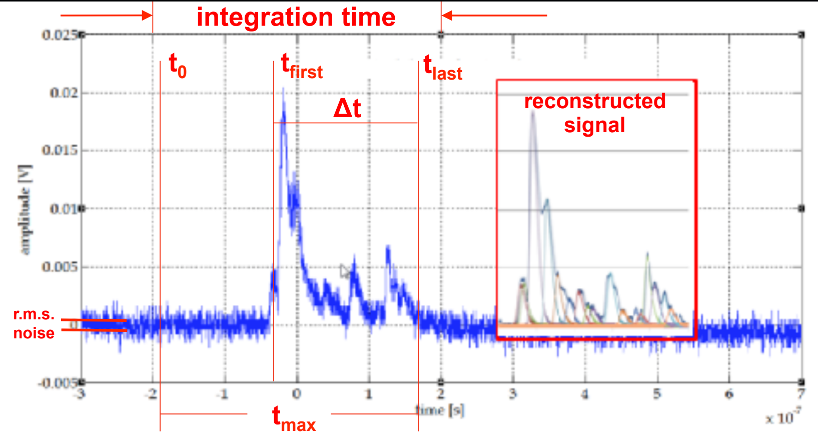
Back up

A few facts

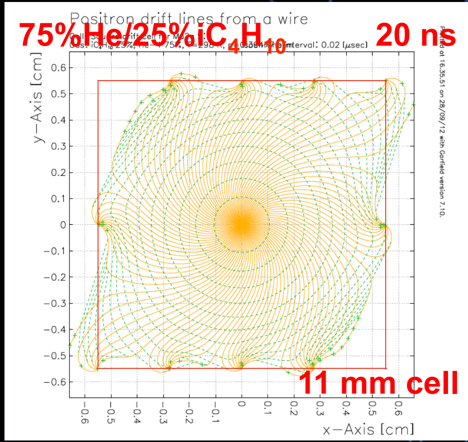
Ideal case: drift tube



Digitized signal (1 GHz, 2 GSa/s)

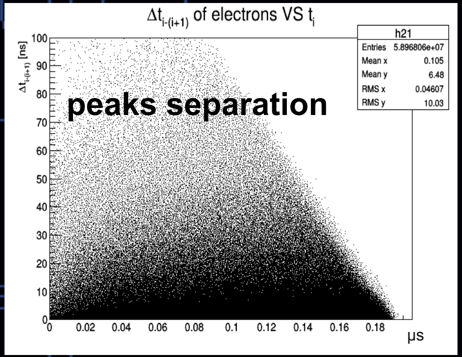


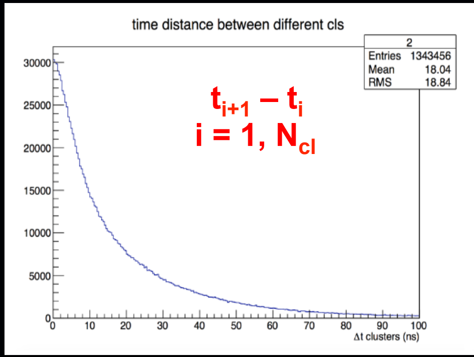
Real case: drift cell

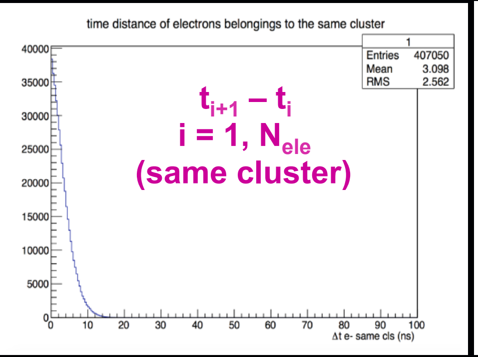


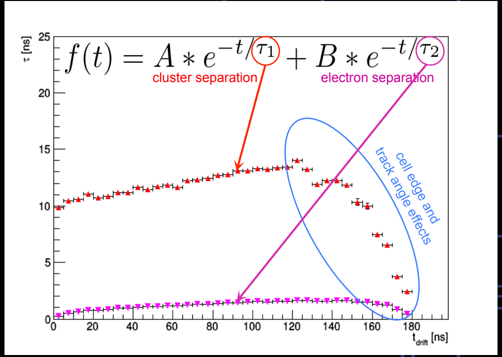
- $t_{i+1} - t_i \approx$ **a few ns** at small t_i, $t_{i+1} - t_i \approx$ **a few × 10 ns** at large t_i
- t_{max} **constant** in ideal case (slightly depends on track angle in drift cell case)
- $\Delta t \le t_{max}$, length of digitized signal, depends on impact parameter **b** (t_{first})
- N_{cl} depends only on **Δt** (or **b**, or t_{first}) in cylindrical drift tube case
- N_{cl} doesn't depend on **b** in square drift cell case, but only on the track angle
- t_{last} **constant** in the ideal case => defines the **trigger time** $t_0 = t_{last} - t_{max}$

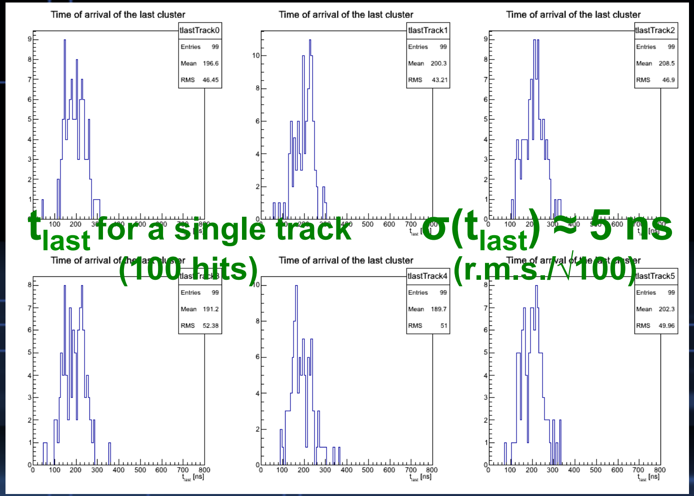
A few facts (7 mm cell, faster gas)

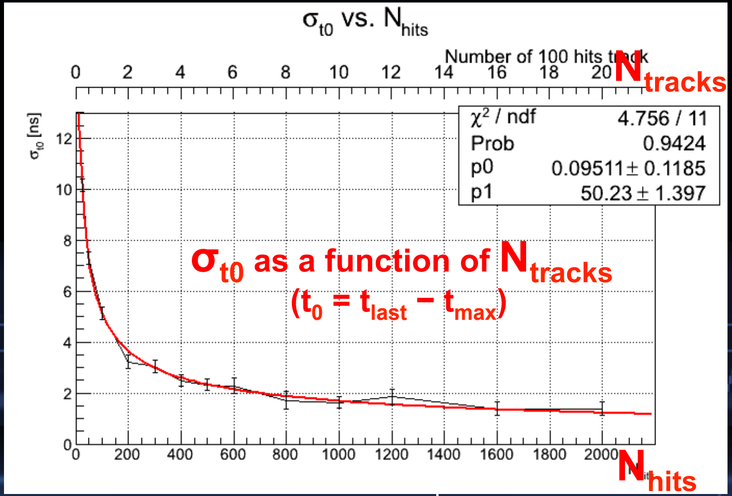




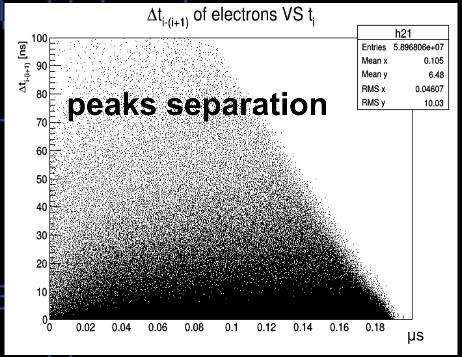


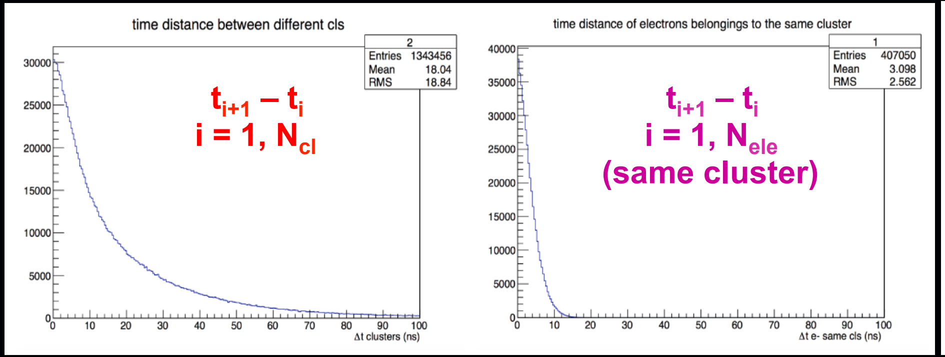


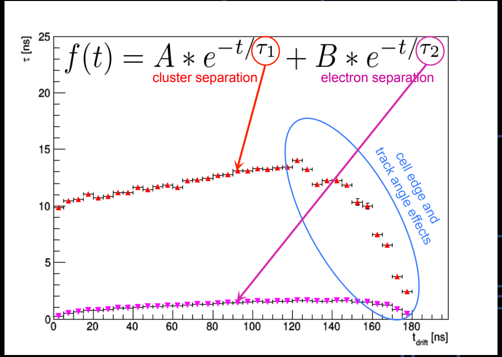


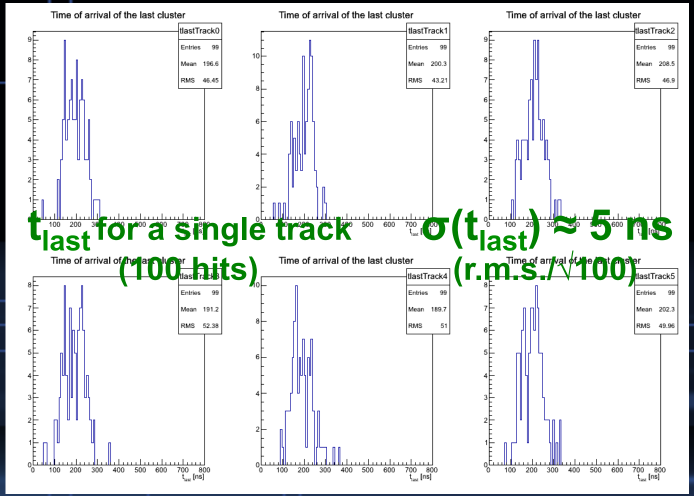


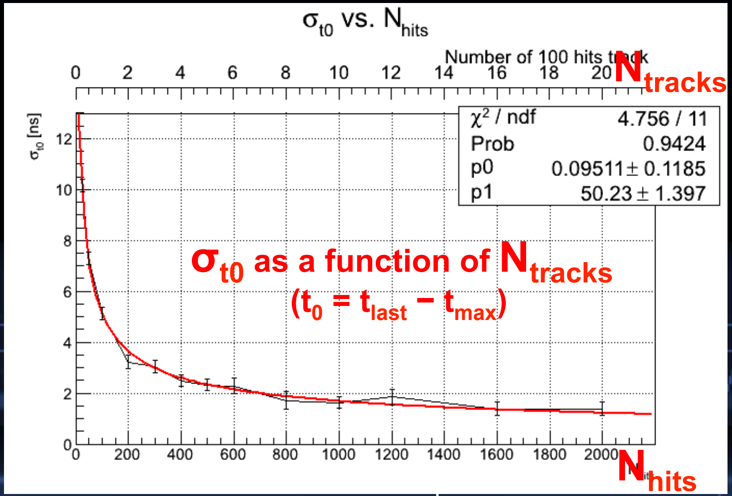
A few facts (7 mm cell, faster gas)











Bunch Xing identification!

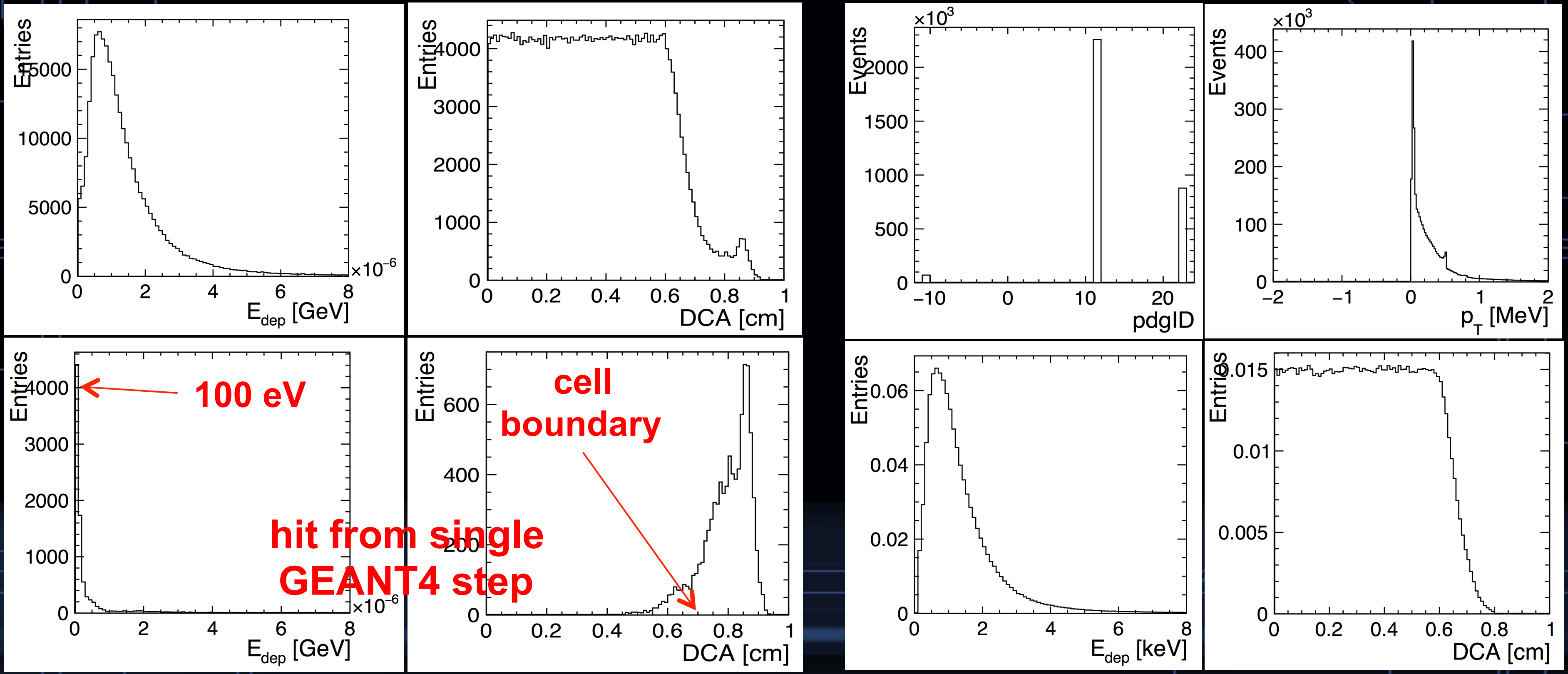
Track filtering!

Trigger capabilities?

Consideration about occupancy

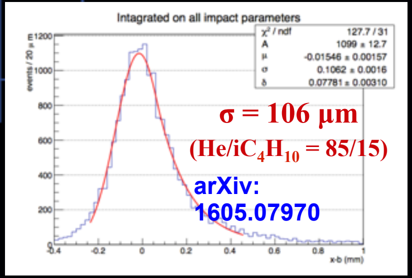
- Average drift signal duration: **$<\Delta t> = t_{max}/2$** (slightly larger given the time compression at small impact parameters) and **$<t_{first}> = t_0 + t_{max}/2$**.
- A peak in the signal is identified as an electron if above threshold and with proper rise and fall times.
- A physical hit must contain at least a few electron peaks spaced by no more than the cluster separation time, **δt_{cl}**.
- An isolated electron peak is suppressed if its time differs from t_{first} of the track hit by $> \delta t_{cl}$. Otherwise, it slightly affects the impact parameter and negligibly the particle identification.
- Two synchronous tracks overlapping in the same cell are indistinguishable, the promptest one defines the impact parameter.
- Two tracks delayed in time (i.e., belonging to different BX) can be separated if t_{last} of the earlier one and t_{first} of the later one differ by $> \delta t_{cl}$.

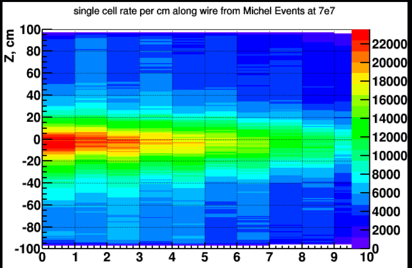
Consideration about occupancy

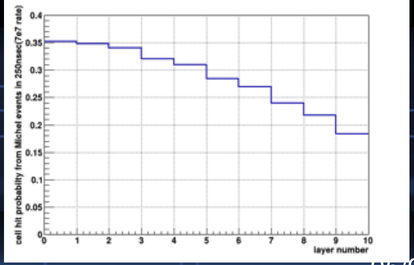


MEG2 DCH high occupancy

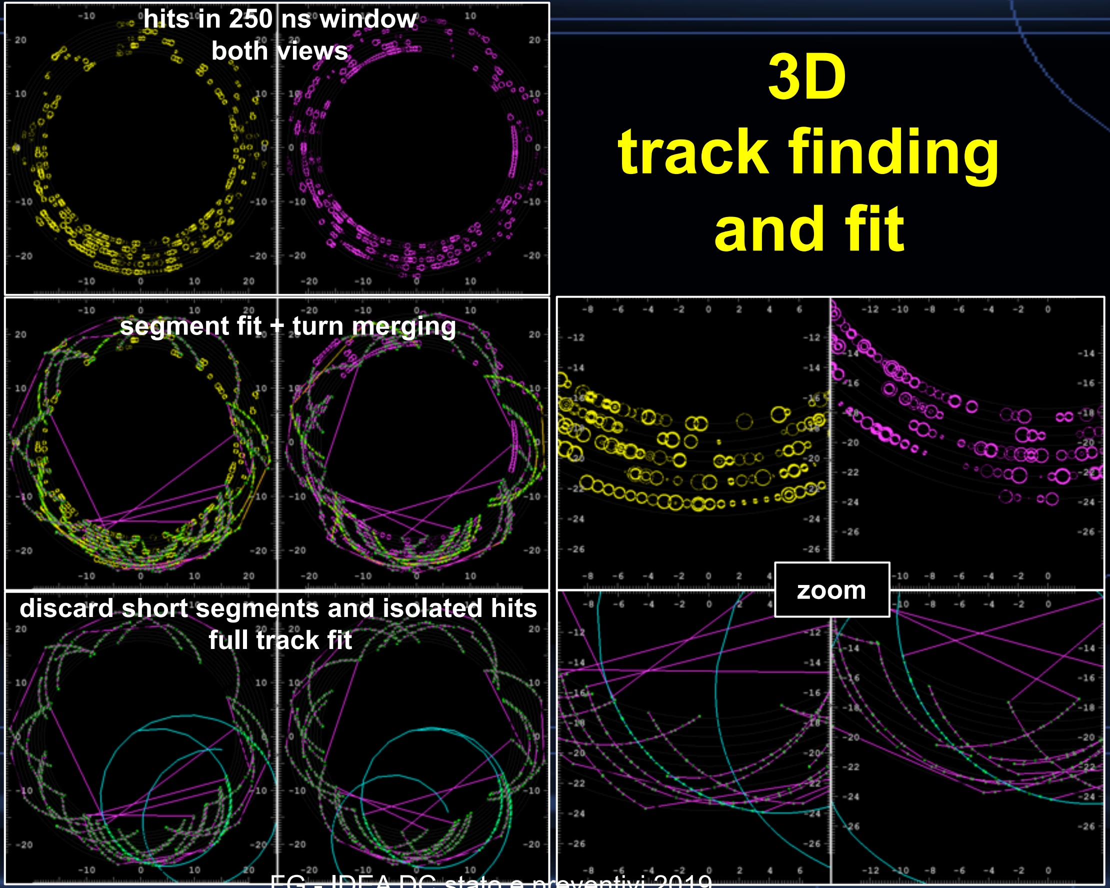
spatial resolution on 7 mm cell







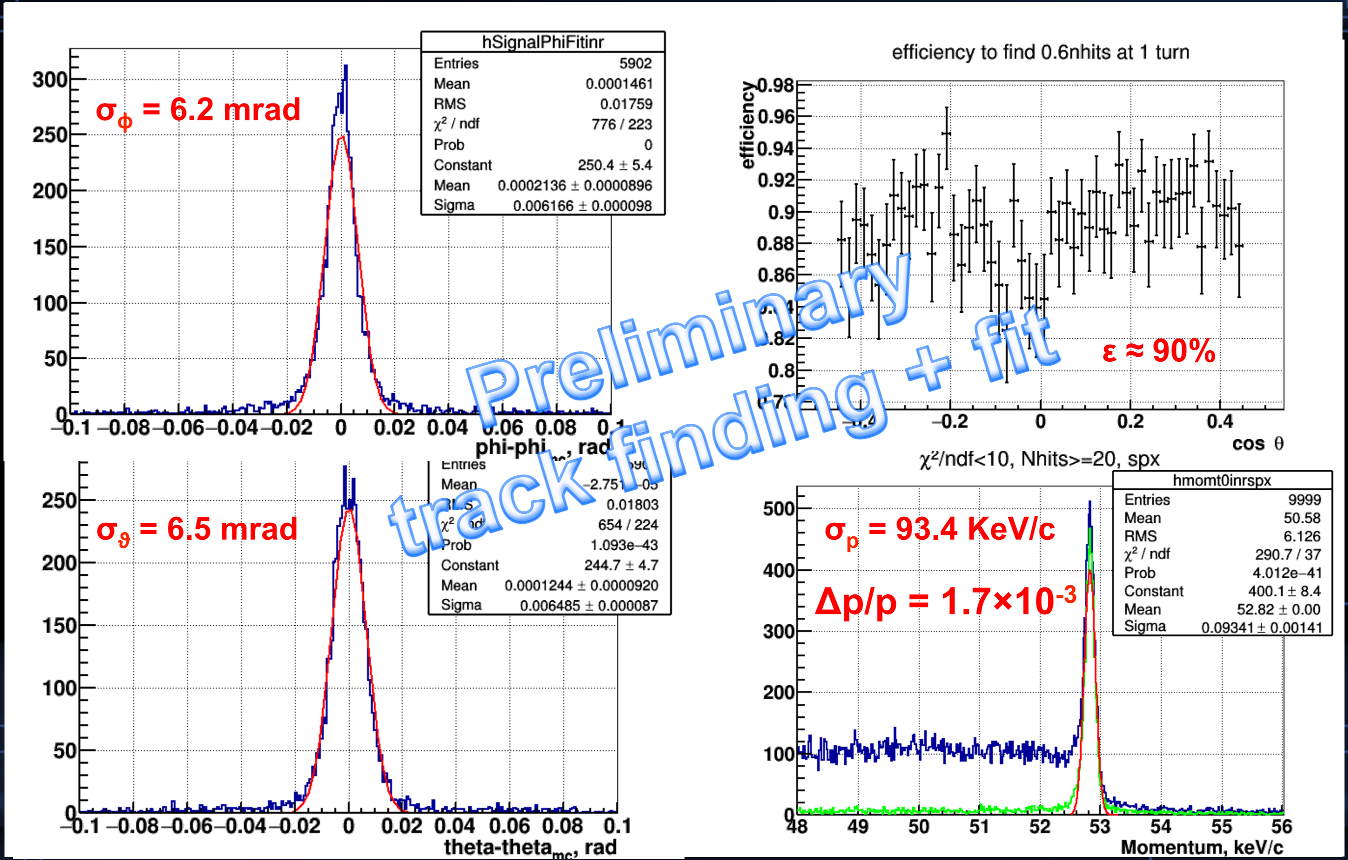
3D track finding and fit



signal track

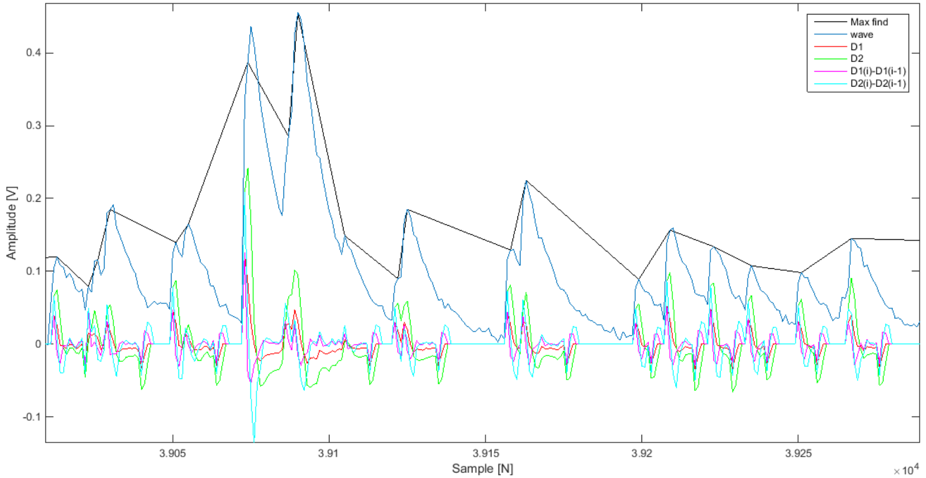
michel tracks

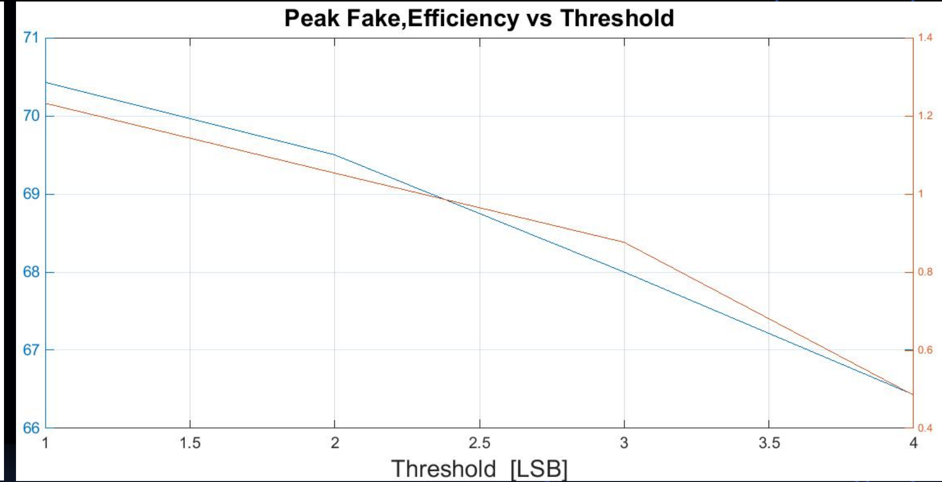
MEG2 DCH Performance



Example: CluTim algorithm

At the beginning of the signal processing procedure, a counter starts to count providing the timing information related to the signal under scrutiny.
The determination of a peak is done by relating the i-th sampled bin to a number n of preceding bins, where n is related to the rise times of the signal peak. Details of the algorithm can be found in next slide.

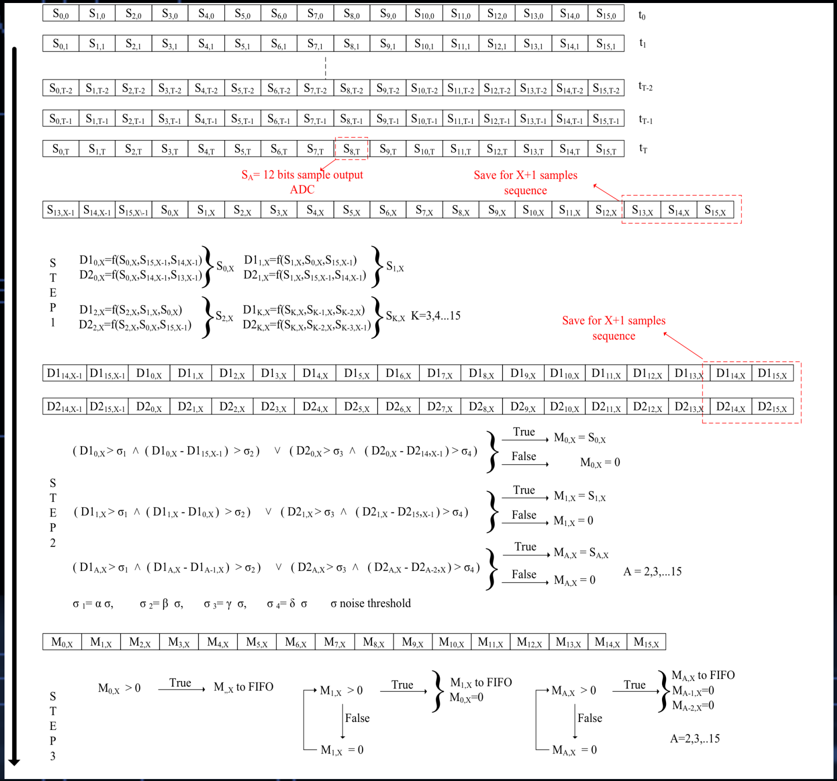




the input signal to the ADC, the peaks found, and the values of the auxiliary functions used and of their differences.   Efficicency

The memories are continuously filled as new peaks are found. When a trigger signal occurs at time t_0, the reading procedure is enabled and only the data relative to the found peaks in the $[t_0; t_0 + t_{max}]$ time interval are transferred to an external device

Example: CluTim algorithm



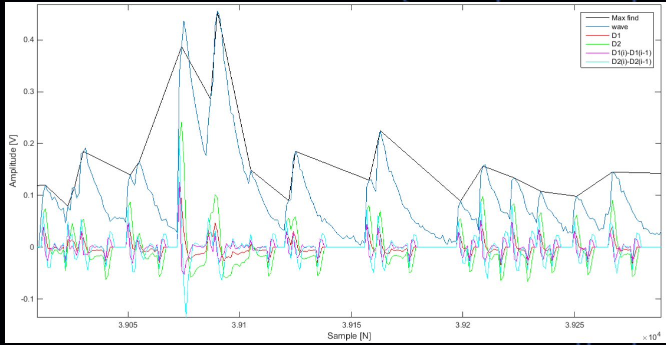
Sixteen samples $S_{K,X}$ at 125 MHz to the FPGA input.

STEP 1: Of the Sixteen samples $S_{K,X}$,where K is the sample number among those available, and X is the time instant at which they are present, the functions $D1_{K,X}$ e $D2_{K,X}$ are calculated with use of the following equations :

$$D1_{K,X}=((2*S_{k,X}-S_{K-1,X}-S_{K-2,X})/16)*3$$
$$D2_{K,X}=((2*S_{k,X}-S_{K-2,X}-S_{K-3,X})/16)*5$$

STEP 2: The values of $D1_{K,X}$ and $D2_{K,X}$ and the differences between $D1_{K,X}$ and $D1_{K-1,X}$ and between $D2_{K,X}$ and $D2_{K-1,X}$ are compared with the thresholds proportional to the level of noise present in the input signal.

STEP 3: In order to transfer the data in memory, the last step before being sent to an external device is to check that there are no adjacent peaks



Input signal to the ADC, peaks found, results of the functions D1, D2 and their differences