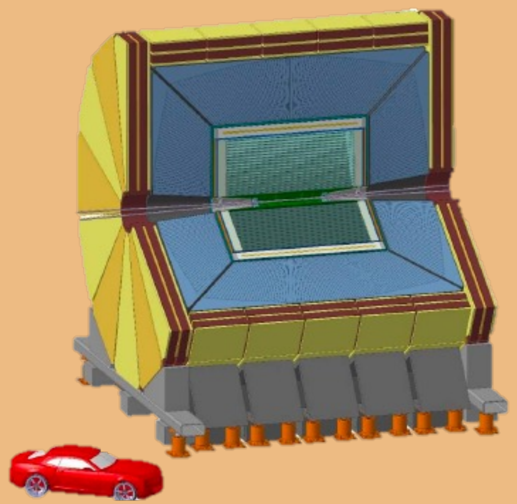


IAS Program on High Energy Physics
(HEP 2023)

IDEA Drift Chamber

Brunella D'Anzi

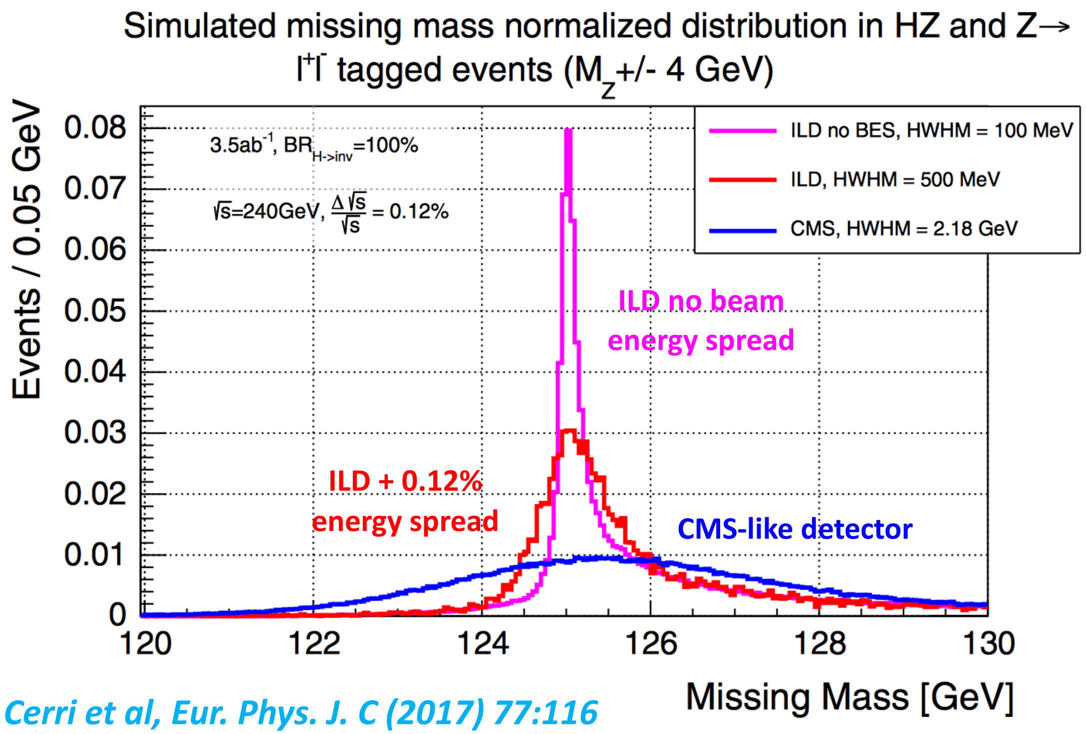
on behalf of the IDEA Chamber Group

(University & INFN – Bari, ITALY)

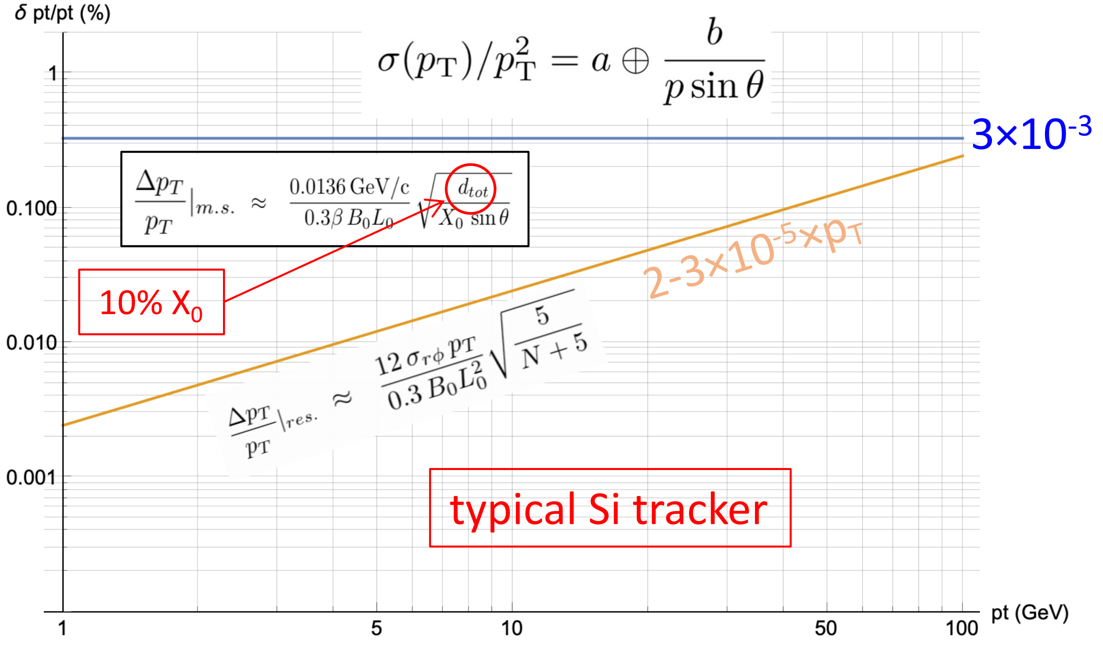
Mini-Workshops in Theory & Experiment and Detector

February 12-13, 2023 – Hong Kong

IDEA Design Guidelines: Momentum resolution



Cerri et al, Eur. Phys. J. C (2017) 77:116



Drasal, Riegler, https://doi.org/10.1016/j.nima.2018.08.078

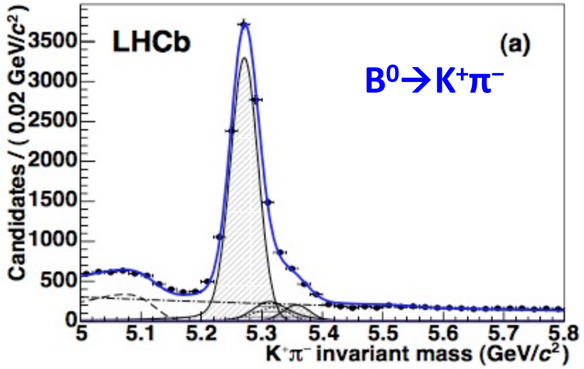
$$\sigma_{p_T}/p_T^2 \approx 2\times10^{-5}\,(GeV/c)^{-1}$$

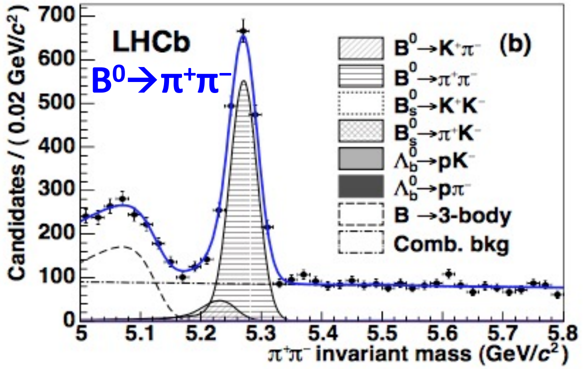
IDEA Design Guidelines: PID mandatory to disentangle same topology final states.

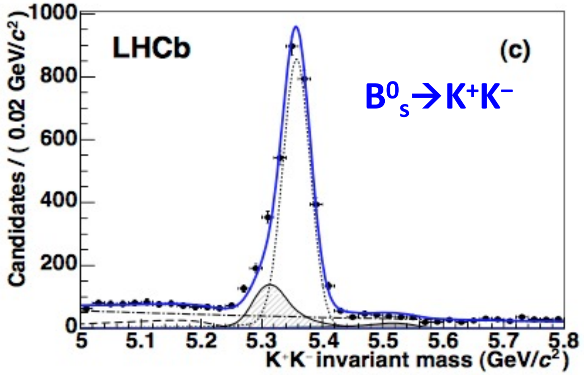
Example: 2-prongs B-decays

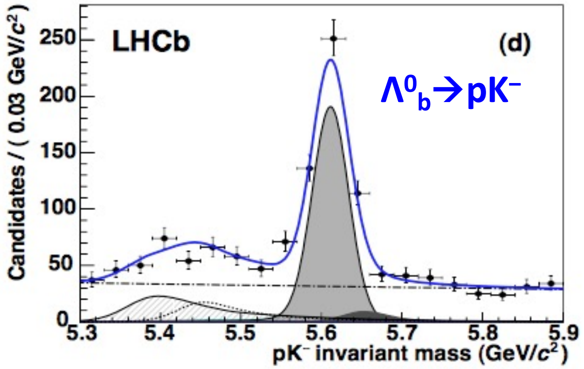
LHCb - JHEP 10 (2012) 037

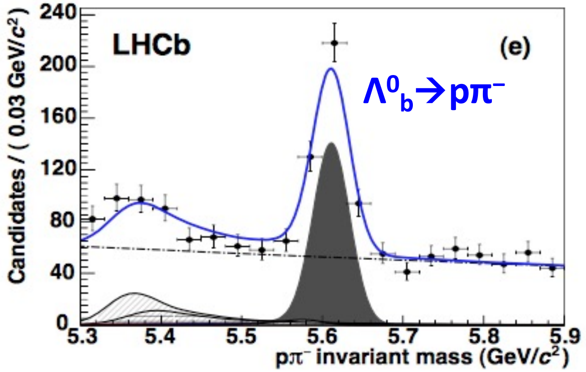
with PID







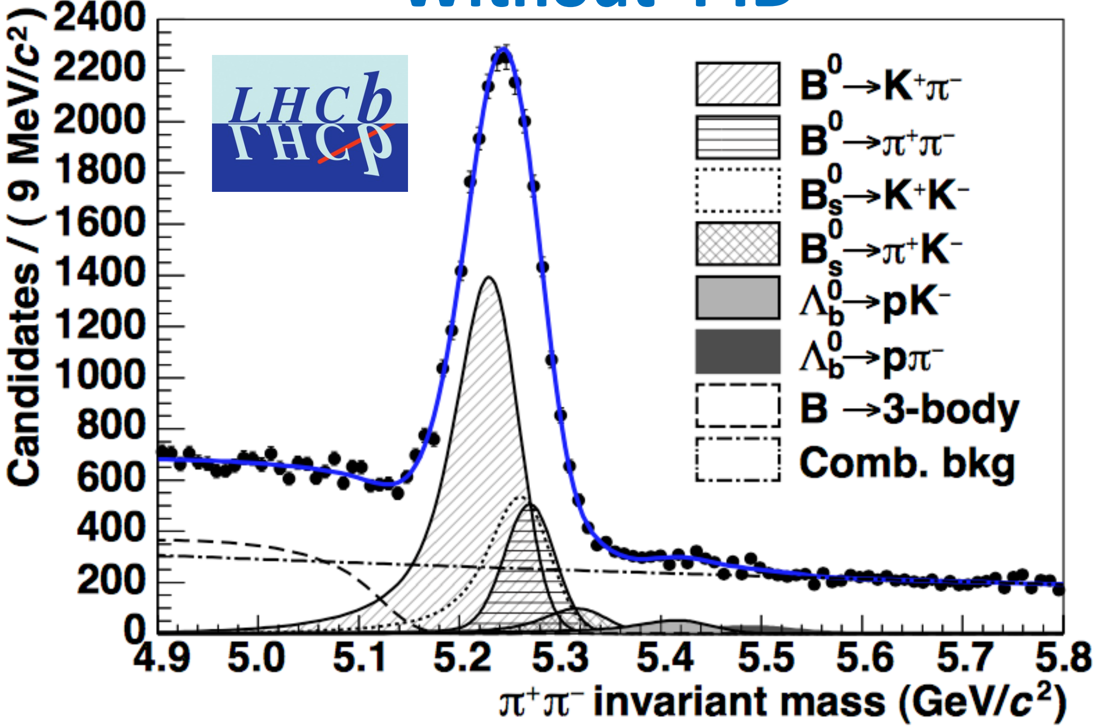




PId cut efficiency and misidentification

	$\pi^+\pi^-$	K^+K^-	$K^+\pi^-$	$p\pi^-$	pK^-
$B^0 \to \pi^+\pi^-$	43.1	0.33	28.6	1.53	0.13
$B_s^0 \to K^+K^-$	0.05	55.0	15.4	0.05	1.63
$B_{(s)}^0 \to K^+\pi^-$	1.40	4.17	67.9	0.72	0.06
$\bar{B}_{(s)}^0 \to \pi^+K^-$	1.40	4.17	2.09	0.02	0.85
$\Lambda_b^0 \to p\pi^-$	1.93	0.92	16.8	35.4	3.16
$\bar{\Lambda}_b^0 \to \pi^+\bar{p}$	1.93	0.92	0.95	0.03	0.18
$\Lambda_b^0 \to pK^-$	0.06	12.2	1.92	1.18	40.2
$\bar{\Lambda}_b^0 \to K^+\bar{p}$	0.06	12.2	4.51	0.03	0.18

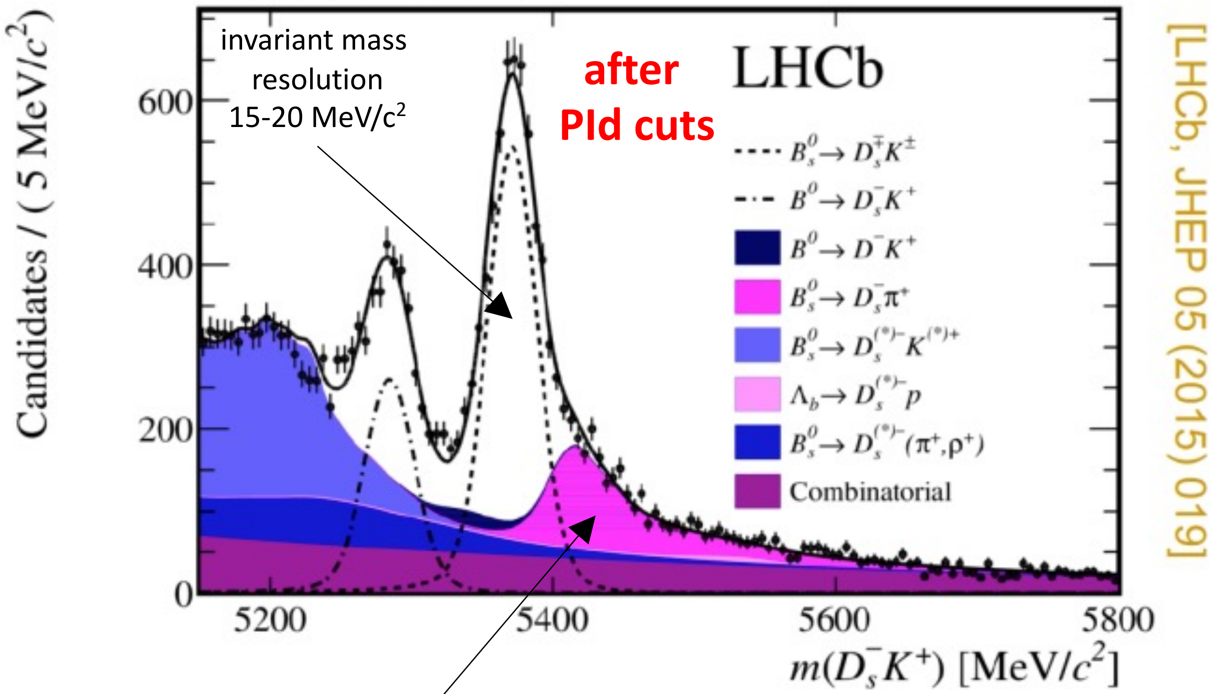
Without PID



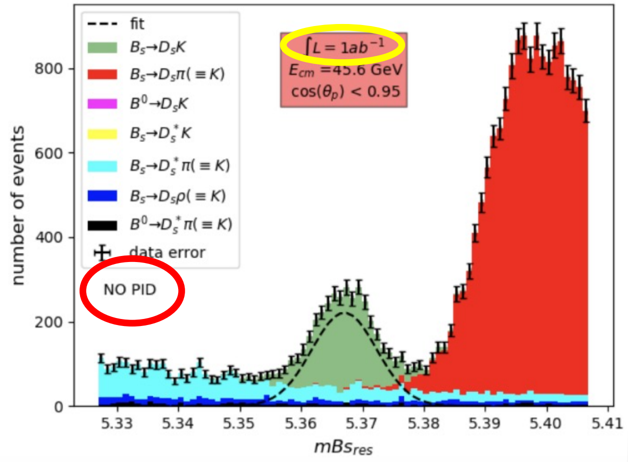
IDEA Design Guidelines: Particle Identification

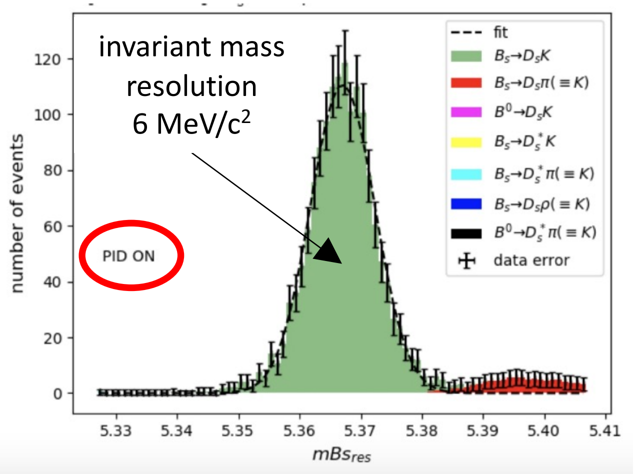
Example: $B_s^0 \to D_s^{\mp} K^{\pm}$

R. Aleksan , L. Oliver and E. Perez - arXiv:2107.02002v1 [hep-ph] 5 Jul 2021



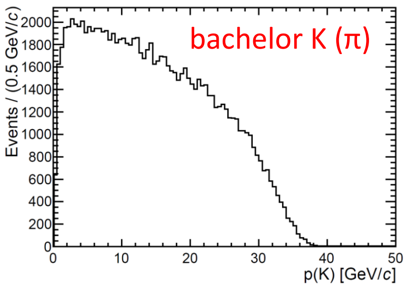
$B_s^0 \to D_s^- \pi^+$
contribution reduced by a factor x10
(60% efficiency – 1% contamination)

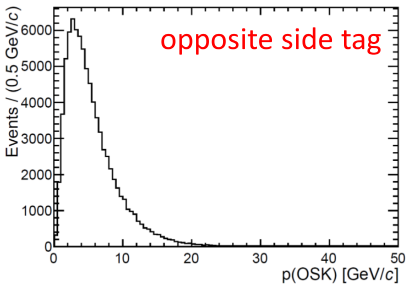


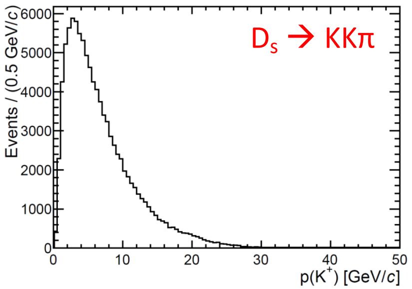


PID at 5% and TOF at 100 ps

Range of momenta







IDEA Design Guidelines: Physics and Tracking

- Large **angular coverage**
- High **angular resolution** ($\Delta\vartheta \leq 0.1$ mrad for monitoring beam spread ($Z \rightarrow \mu\mu$))
- High **granularity** (to cope with occupancy at inner radii)
- High **tracking efficiency**
- High **momentum resolution**

  $\delta p/p^2 \leq$ few x 10^{-5}, small wrt 0.12% beam spread for
  - Higgs mass recoil
  - cLFV processes like $Z \rightarrow e\mu, e\tau, \mu\tau$ (BR $\approx 10^{-54} - 10^{-60}$)

  current exp. limits ($\leq 10^{-6}$) can be improved by > 5 orders of magnitude
- High capabilities for **Particle Identification** (dE/dx resolutions $\lesssim$ 3%)
  - Flavor Physics
  - CPV ($B_s \rightarrow D_s K$)
  - $A_{FB}(b)$, exclusive b-hadron decays reconstruction
  - Hadron spectroscopy
- High **V^0 and kink** capability for CPV (CP eigenstates usually long-lived particles)

IDEA Drift Chamber: Evolution and Innovations

Not just another large volume drift chamber, but an **ultra-light** drift chamber with unprecedented **particle identification** capabilities

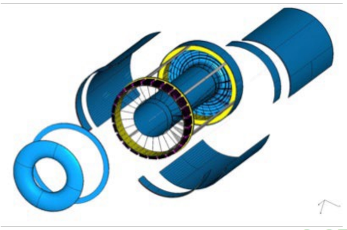
Genesis and evolution

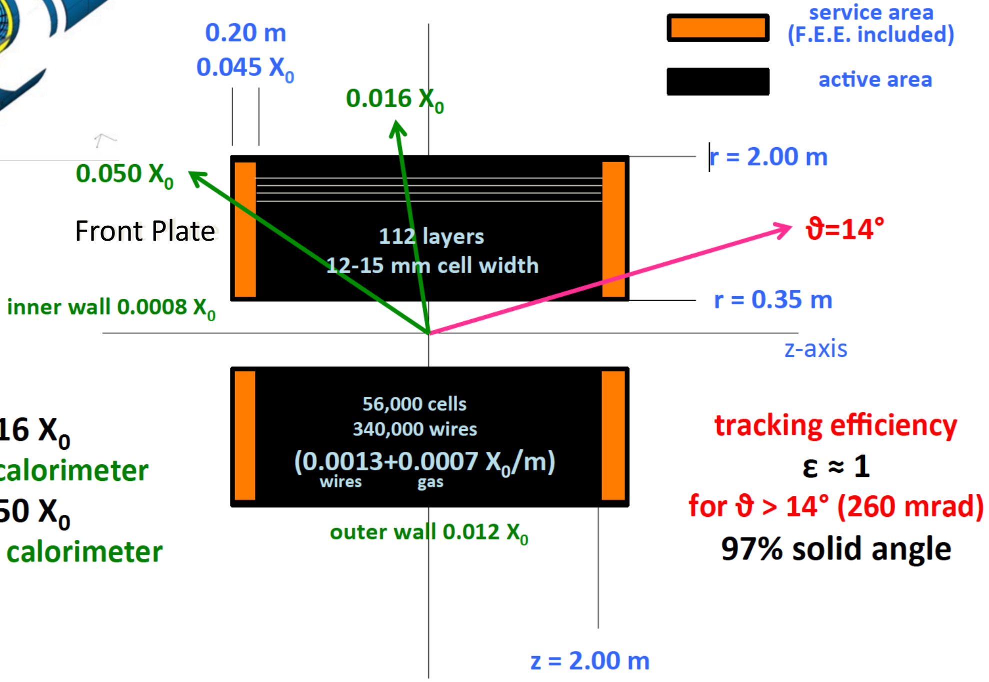
- **Mark2 and Mark3** drift chambers at SLAC in the '80s
- **KLOE** ancestor chamber of a new He-based generation at INFN LNF Daφne ϕ factory (commissioned in 1998 and efficiently operated for over 20 years)
- **CMD-2** drift chamber at VEPP-2000 (2006, still in operation)
- **CluCou** chamber proposed for the **4th-Concept** at ILC (2009)
- **I-tracker** chamber proposed for the **Mu2e experiment** at Fermilab (2012)
- **CDCH** for **MEG2** at PSI (designed in 2014, built in 2018 and currently in data taking mode since 2021)
- **IDEA** drift chamber proposal for FCC-ee and CEPC (2017)

Innovations

- New mechanical assembly procedure by separating the **gas containment** from the **wire support** functions
- New concepts for **wire tension compensation** resulting in end caps with a 5% X_0 (including front end electronics and cables)
- A **larger number** of **thinner** (and **lighter** wires) resulting in less total stress on end plates
- No use of massive **feed-through**
- Use of **cluster counting** for particle identification
- Use of **cluster timing** for improving spatial resolution

IDEA Drift Chamber: Layout and Material Budget





0.016 X_0
to barrel calorimeter
0.050 X_0
to end-cap calorimeter

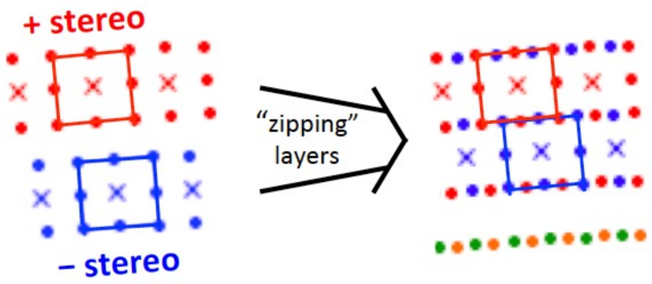
tracking efficiency
ε ≈ 1
for ϑ > 14° (260 mrad)
97% solid angle

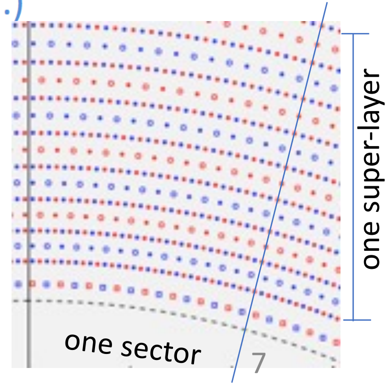
Conservative estimates on Material Budget

- Inner wall (from CMD3 drift chamber) — **8.4×10^{-4} X_0**
  200 µm Carbon fiber
- Gas (from KLOE drift chamber) — **7.1×10^{-4} X_0/m**
  90% He – 10% iC_4H_{10}
- Wires (from MEG2 drift chamber) — **1.3×10^{-3} X_0/m**
  20 µm W sense wires 4.2×10^{-4} X_0/m
  40 µm Al field wires 6.1×10^{-4} X_0/m
  50 µm Al guard wires 2.4×10^{-4} X_0/m
- Outer wall (from Mu2e I-tracker studies) — **1.2×10^{-2} X_0**
  2 cm composite sandwich (7.7 Tons)
- End-plates (from Mu2e I-tracker studies) — **4.5×10^{-2} X_0**
  wire cage + gas envelope
  incl. services (electronics, cables, ...)

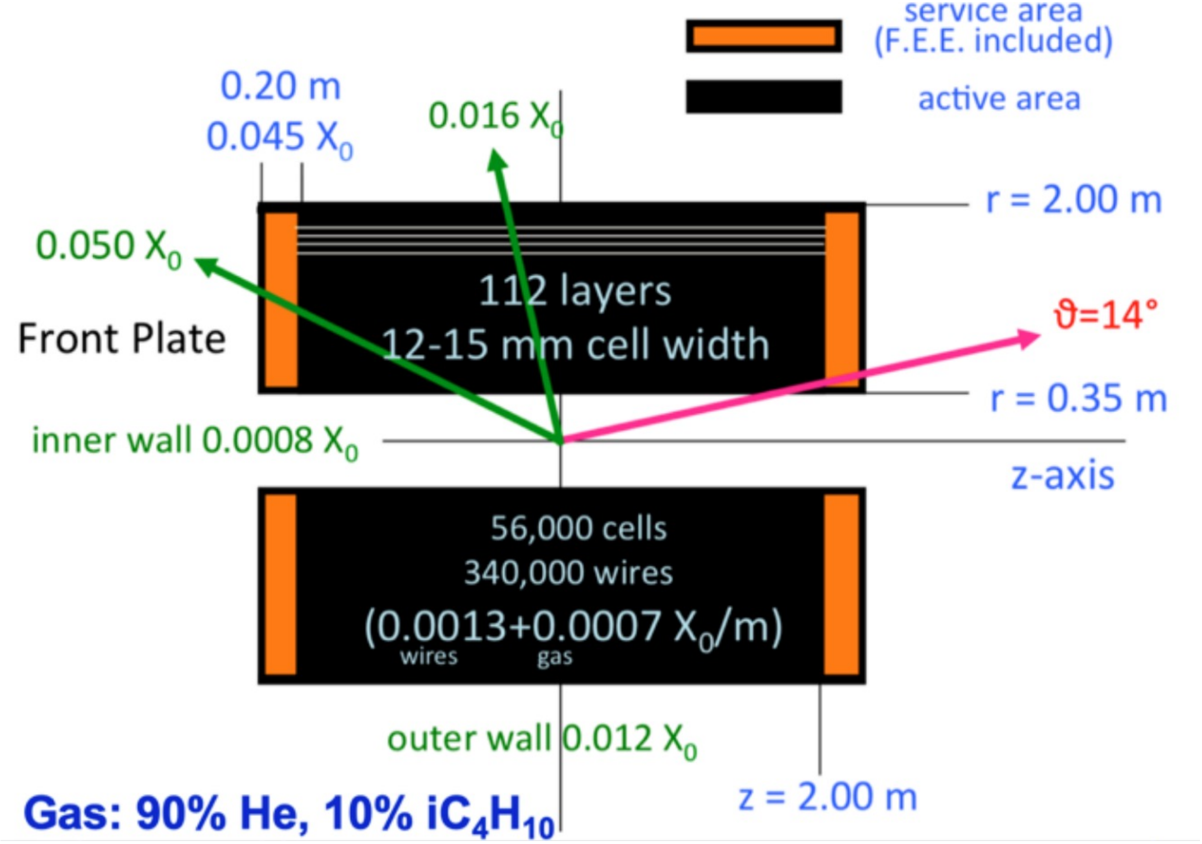
12 to 15 mm wide square cells, 5:1 field to sense wires ratio, 56,448 cells

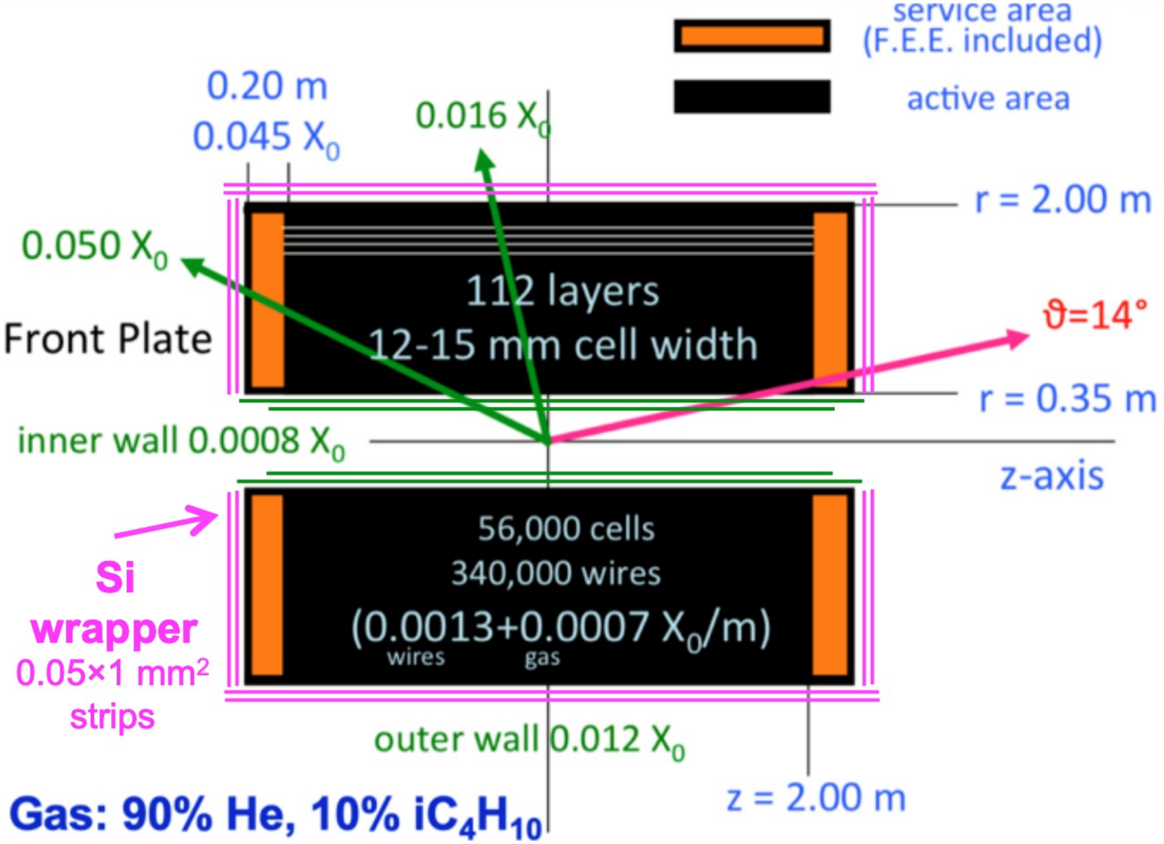
14 co-axial super-layers, 8 layers each (112 total) with alternating sign stereo angles ranging from 50 to 250 mrad, in 24 equal azimuthal (15°) sectors





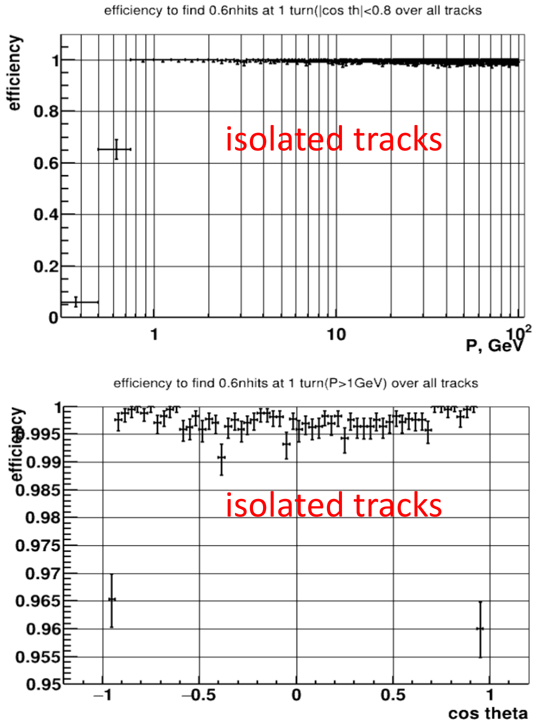
Full Tracking System: drift chamber + Si wrapper



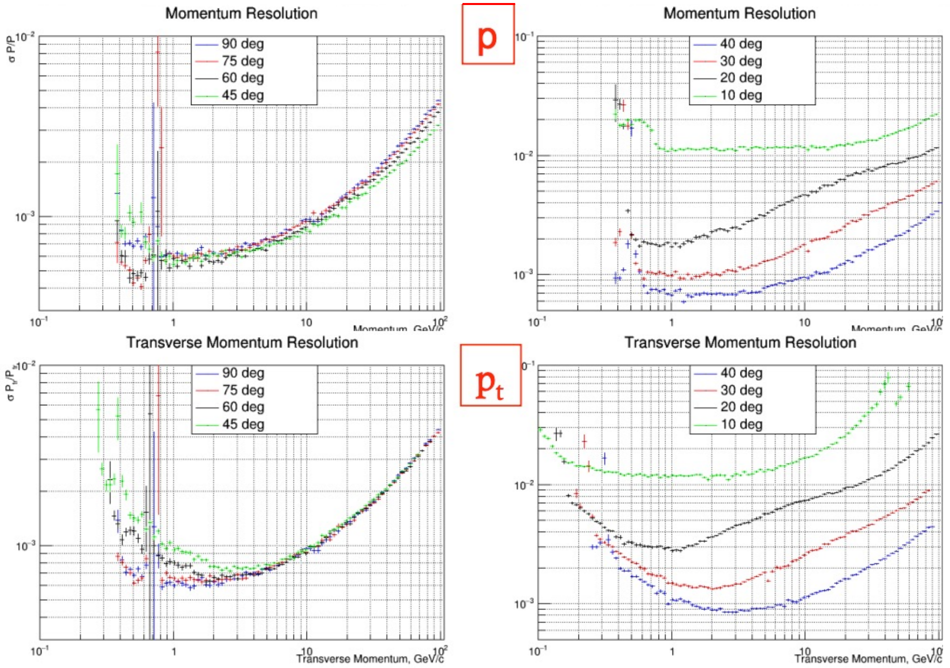


Full Simulation: Expected Tracking Performance

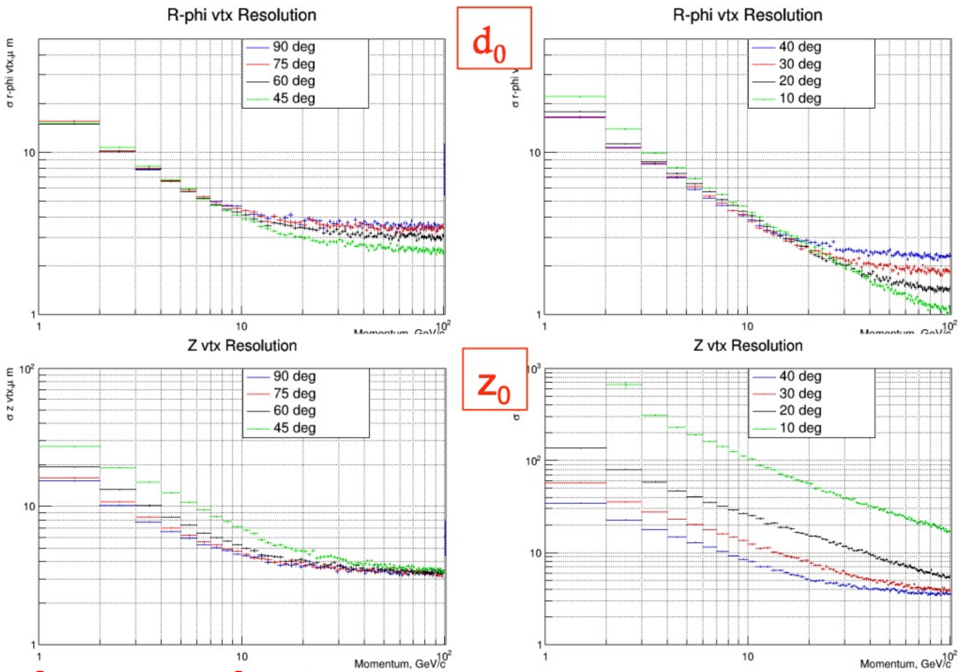
efficiency

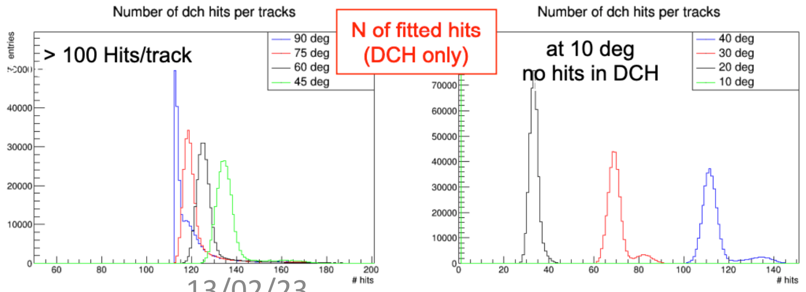


momentum resolution

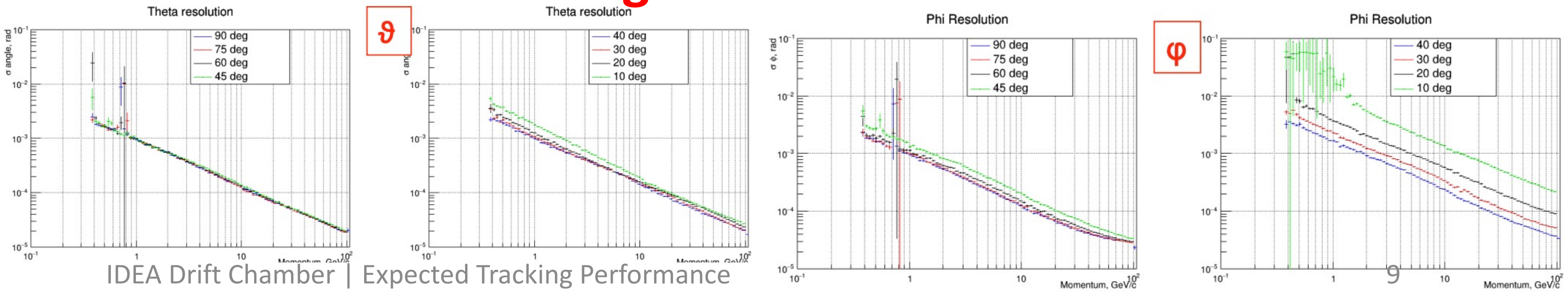


vertex resolution

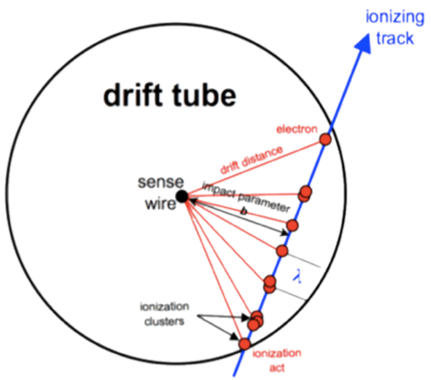




angular resolutions

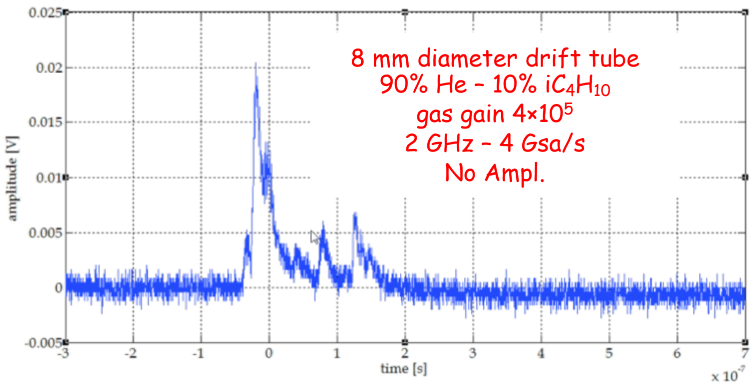


PID technique: Cluster Counting

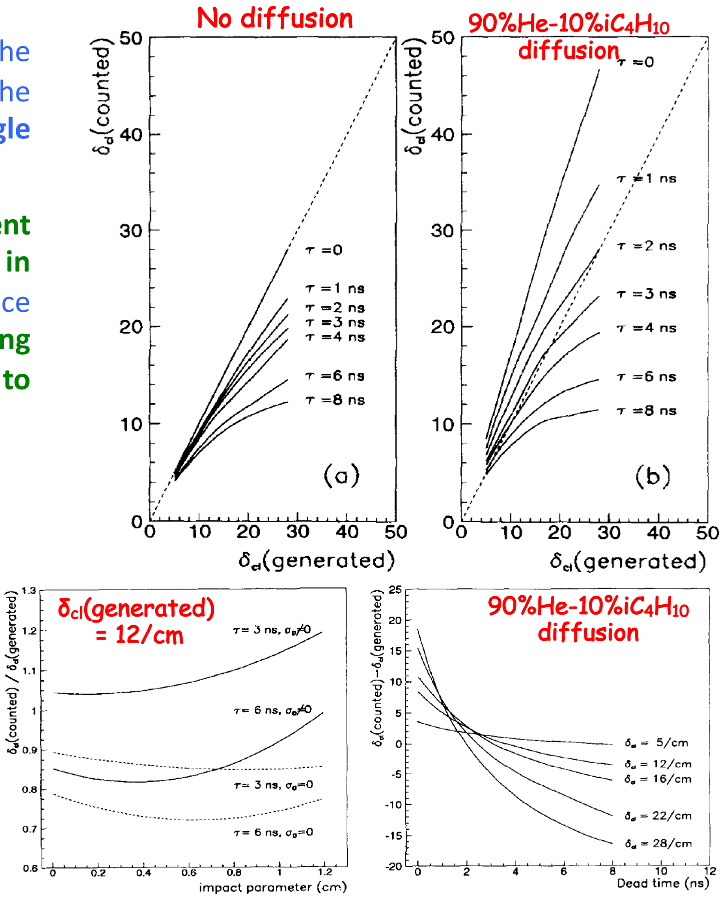


Single out, in every recorded detector signal, the **isolated structures** related to the arrival on the anode wire of the **electrons belonging to a single ionization act.**

Pulses from **electrons belonging to different clusters must have a little chance of overlapping in time** and, at the same time, the time distance between pulses generated by **electrons coming from the same cluster must be small enough to prevent over-counting**.



These requirements involve **incompatible time dependences**. The **optimal counting condition** can, therefore, be reached only as a result of the **equilibrium** between **cluster time resolution τ**, which forbids a fully efficient cluster detection, and **electron diffusion σ_D** causing the time spread among electrons of the same cluster.



G. Cataldi, F. Grancagnolo and S. Spagnolo, *Nucl.Instrum.Meth. A 386 (1997) 458-469*

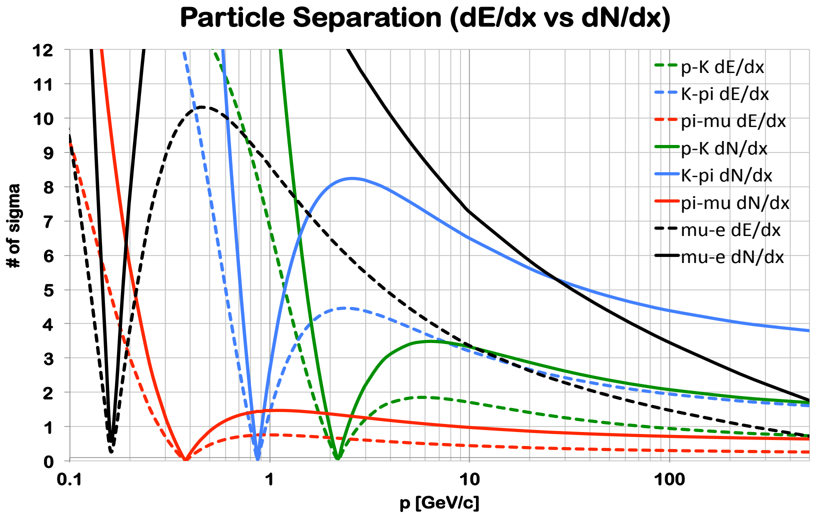
Once the parameters of the experimental set up, like **drift cell size** and **gas mixture** (primary ionization, drift velocity and diffusion) are set, one can define the optimal parameters for the **readout electronics** (frontend and digitizing).

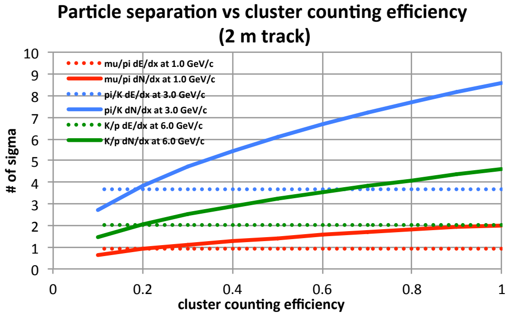
In the case of He/iC_4H_{10} = 90/10 gas mixture and 1.2-1.5 cm cell size, like in the IDEA drift chamber, the optimal choice for the electronics parameters is:

- **analog bandwidth ≥ 1 GHz;**
- **pre-amplifier gain ≥ ×10;**
- **sampling rate ≥ 1.5 GS/s**
- **≥ 12 bit resolution**

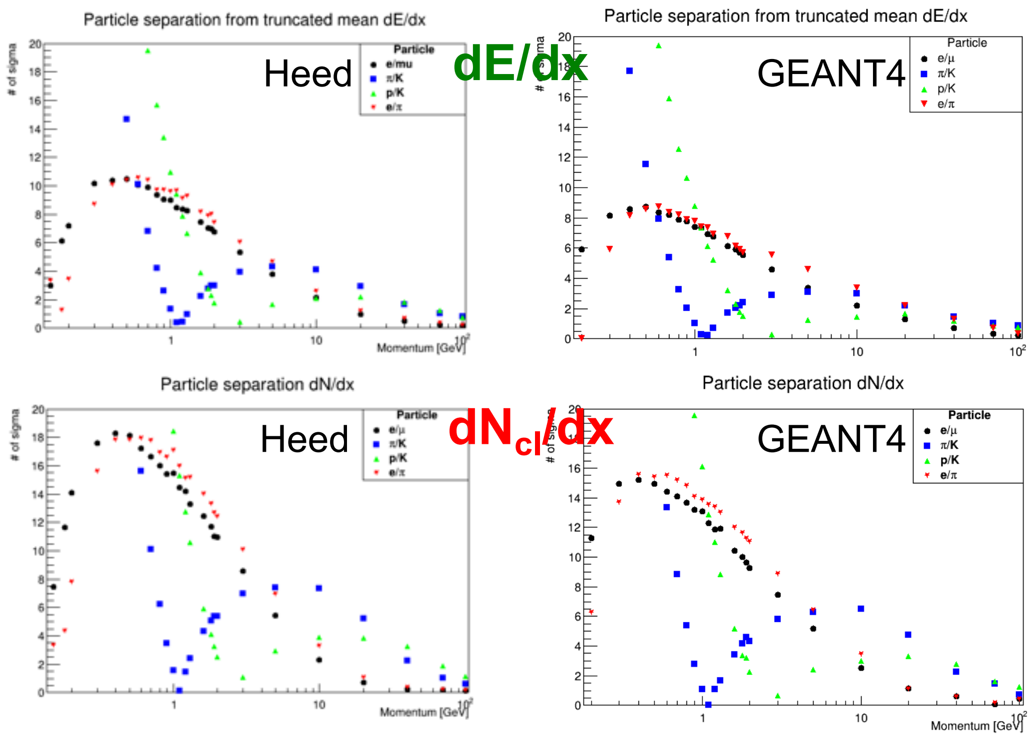
PID technique: Expected Performance (2 m track length)

Analytical calculations





Full Simulation



Comments

dN/dx: consider π/K separation:

Heed (Garfield++) in reasonable **agreement with analytical calculations up to 20 GeV/c** momentum, then **falls much more rapidly at higher momenta**.

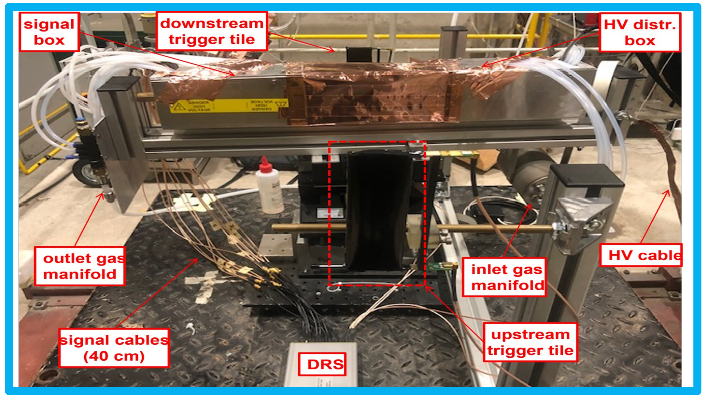
Despite **Geant4** uses the cluster density and the cluster size distributions from **Garfield++**, it **disagrees** from **Garfield++** and, therefore, from the **analytical calculations** also.

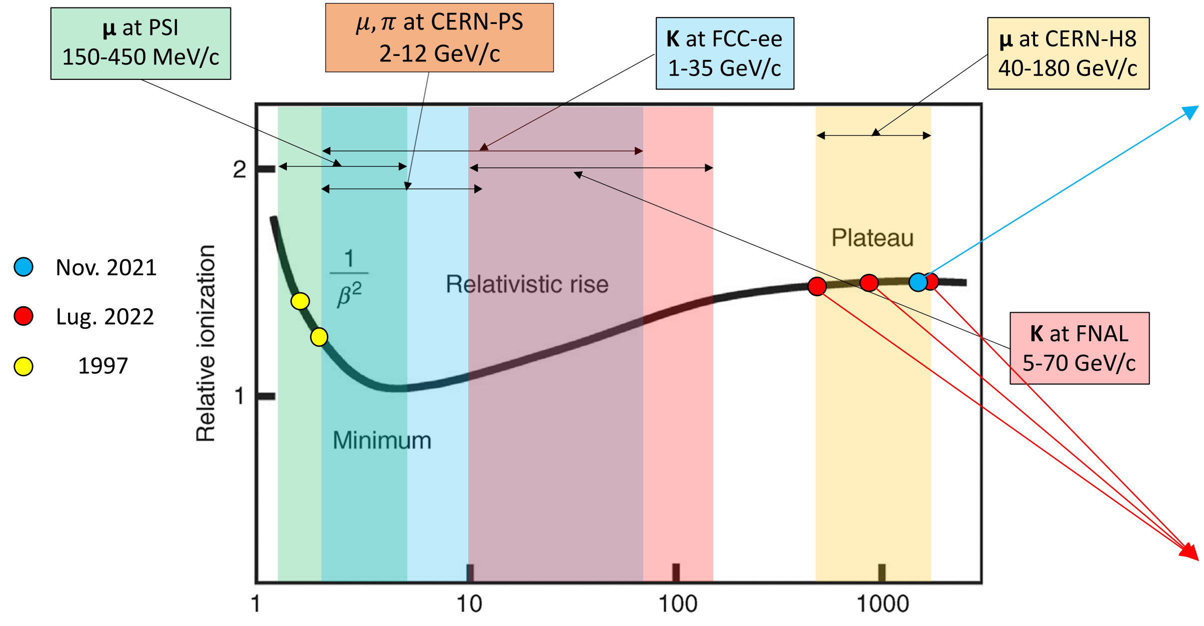
Unfortunately, lack of experimental data on cluster density and cluster population for He based gas. Particularly in the relativistic rise region to compare calculations.

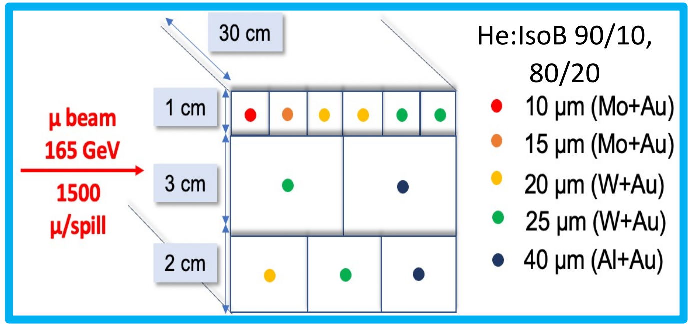
Current R&D efforts: Beam Tests

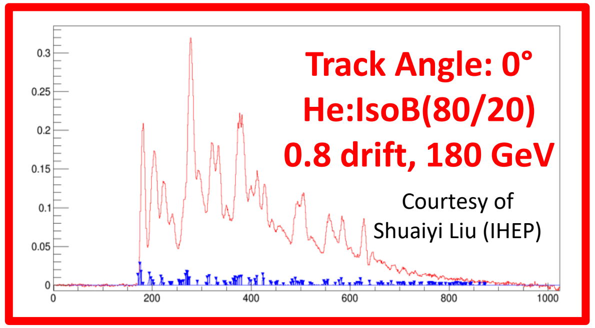
Beam tests to experimentally asses and optimize the **performance of the cluster counting/timing** techniques in strict collaboration with the IHEP Beijing group:

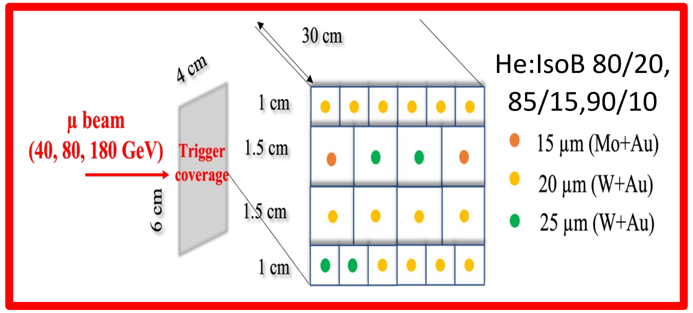
- Two **muon beam tests** performed at **CERN-H8 (βγ > 400)** in Nov. 2021 and July 2022.
- More **muon beam tests** planned in 2023 at **CERN** and **PSI (βγ = 1–4)** in 2023.
- Ultimate test at **FNAL-MT6** with **π** and **K (βγ = 10–140)** to fully exploit the relativitic rise.

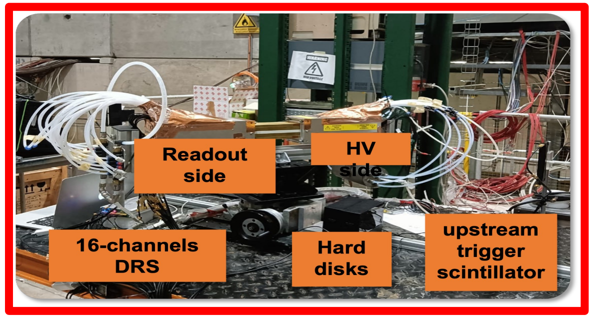






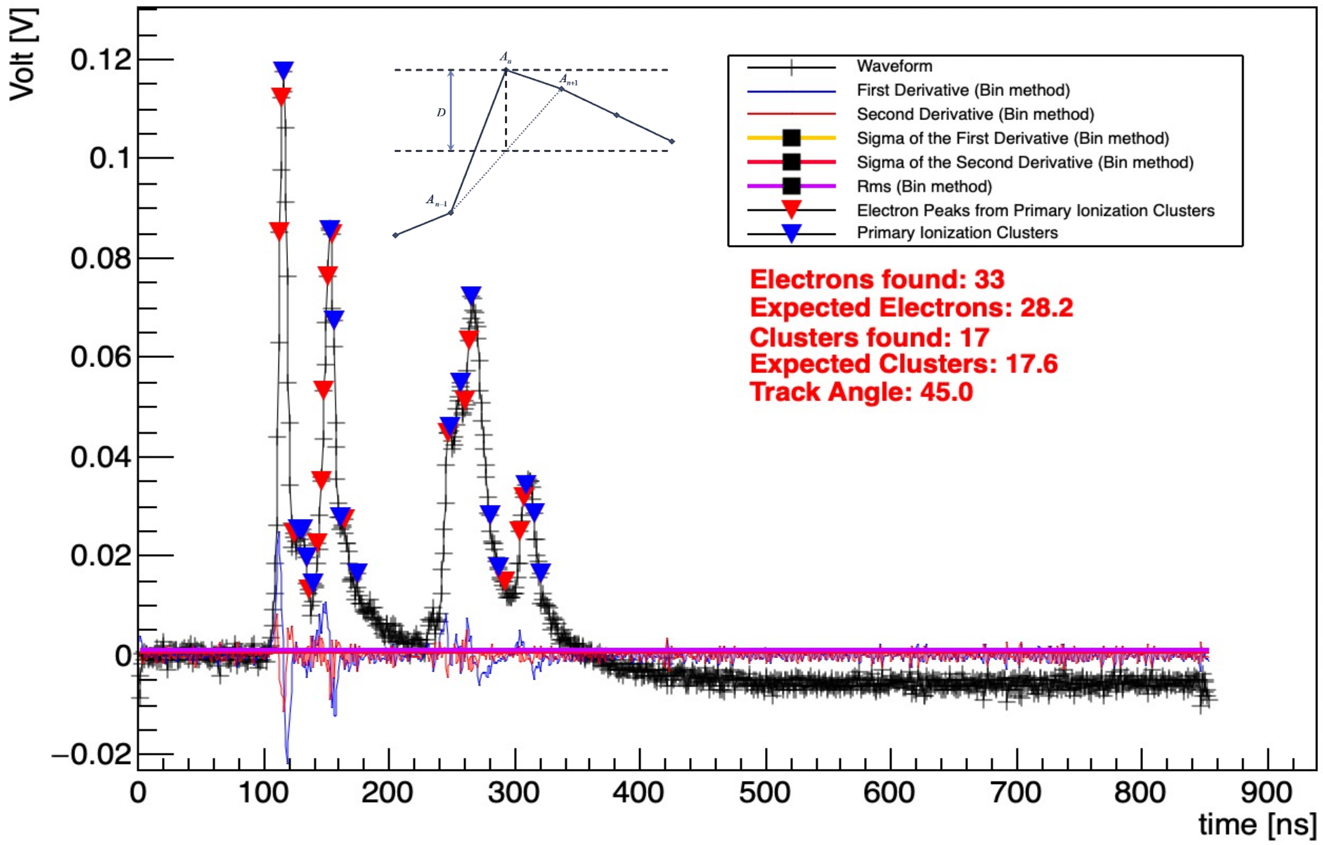






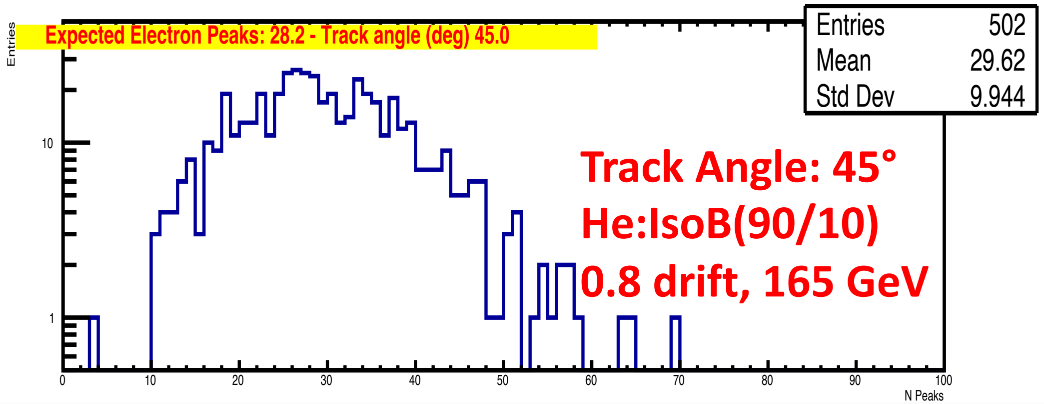
Current R&D efforts: Beam Tests Analysis Results

Reconstruction of Electron Peaks (DERIV Algorithm)



Sense Wire Diameter 10 um – Cell Size 1.0 cm – Track Angle 45° – 1.2 GSa/s – Gas Mixture He:IsoB 90/10 – 165 GeV

Number of Electron Peaks Distribution



Expected number of electrons = δ cluster/cm (M.I.P.) x drift tube size [cm] x 1.6 (cluster size [1]) x 1.3 (relativistic rise [2]) x 1/cos(α)

- **α is the angle of the muon track w.r.t. normal direction to the sense wires**
- **δ cluster/cm (mip) changes from 12, 15, 18 respectively for He:IsoB 90/10, 85/15 and 80/20 gas mixtures**
- **Actual drift tube size are 0.8, 1.2, and 1.8 respectively for 1 cm, 1.5 cm, and 2 cm cell size tubes**

[1] H. Fischle, J. Heintze and B. Schmidt, Experimental determination of ionization cluster size distributions in counting gases, NIM A 301 (1991)

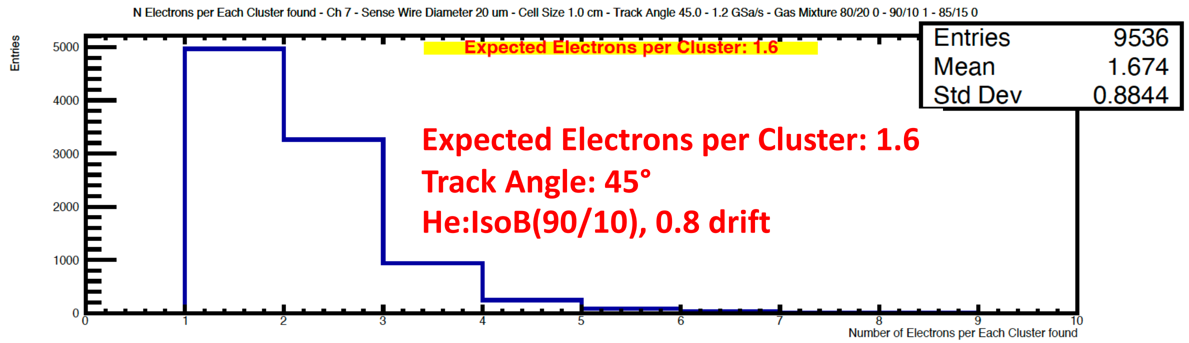
[2] R. G. Kepler, C. A. D'Andlau, W. B. Fretter and L. F. Hansen, Relativistic Increase of Energy Loss by Ionization in Gases, IL NUOVO CIMENTO VOL. VII, N. 1 - 1 Gennaio 1958

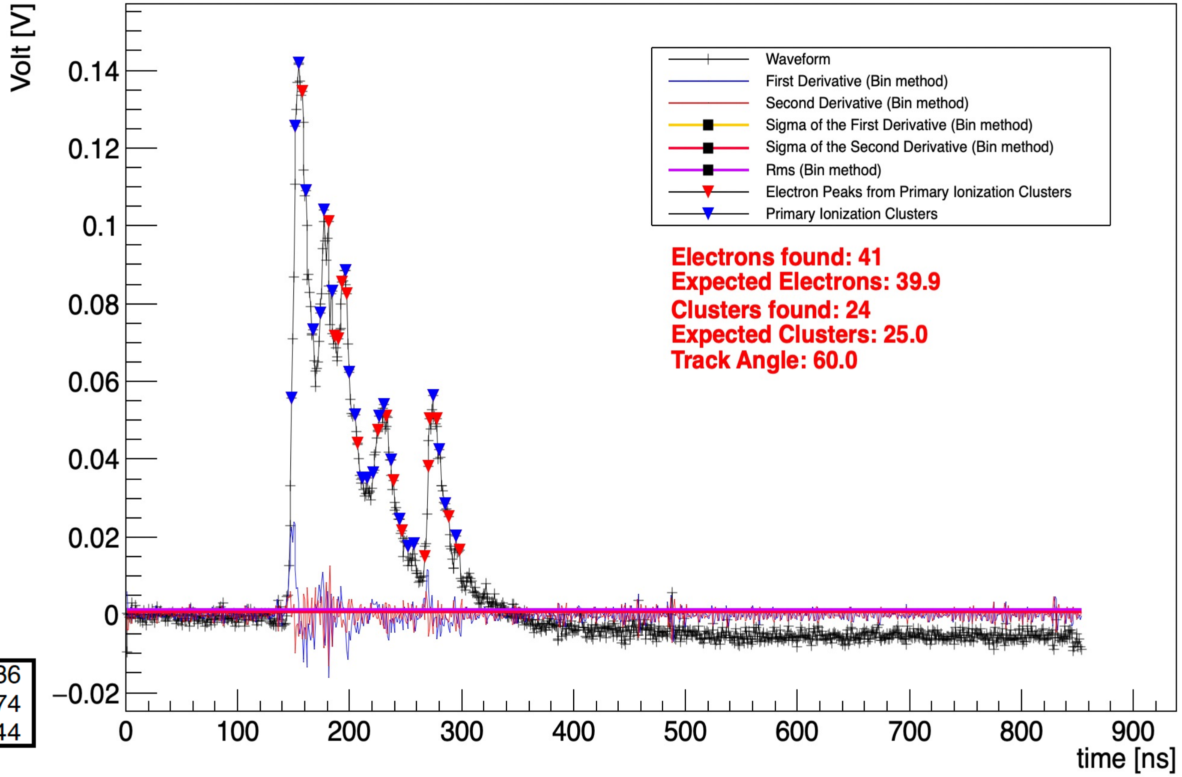
Current R&D efforts: Beam Tests Analysis Results

CLUSTER Algorithm: Reconstruction of Primary Ionization Clusters

- **Merging of electron peaks** in consecutive bins in **a single electron** to reduce **fake electrons counting**.
- **Contiguous electrons peaks** which are compatible with the electrons' diffusion time (it has a $\sim\sqrt{t_{ElectronPeak}}$ dependence, different for each gas mixture) must be considered belonging to the **same ionization cluster**. For them, a **counter** for **electrons per each cluster** is incremented.
- **Position and amplitude** of the **clusters** corresponds to the **position and height of the electron** having the maximum amplitude in the cluster. → **Poissonian distribution** for the **number of clusters**!

Electron per Clusters Distribution

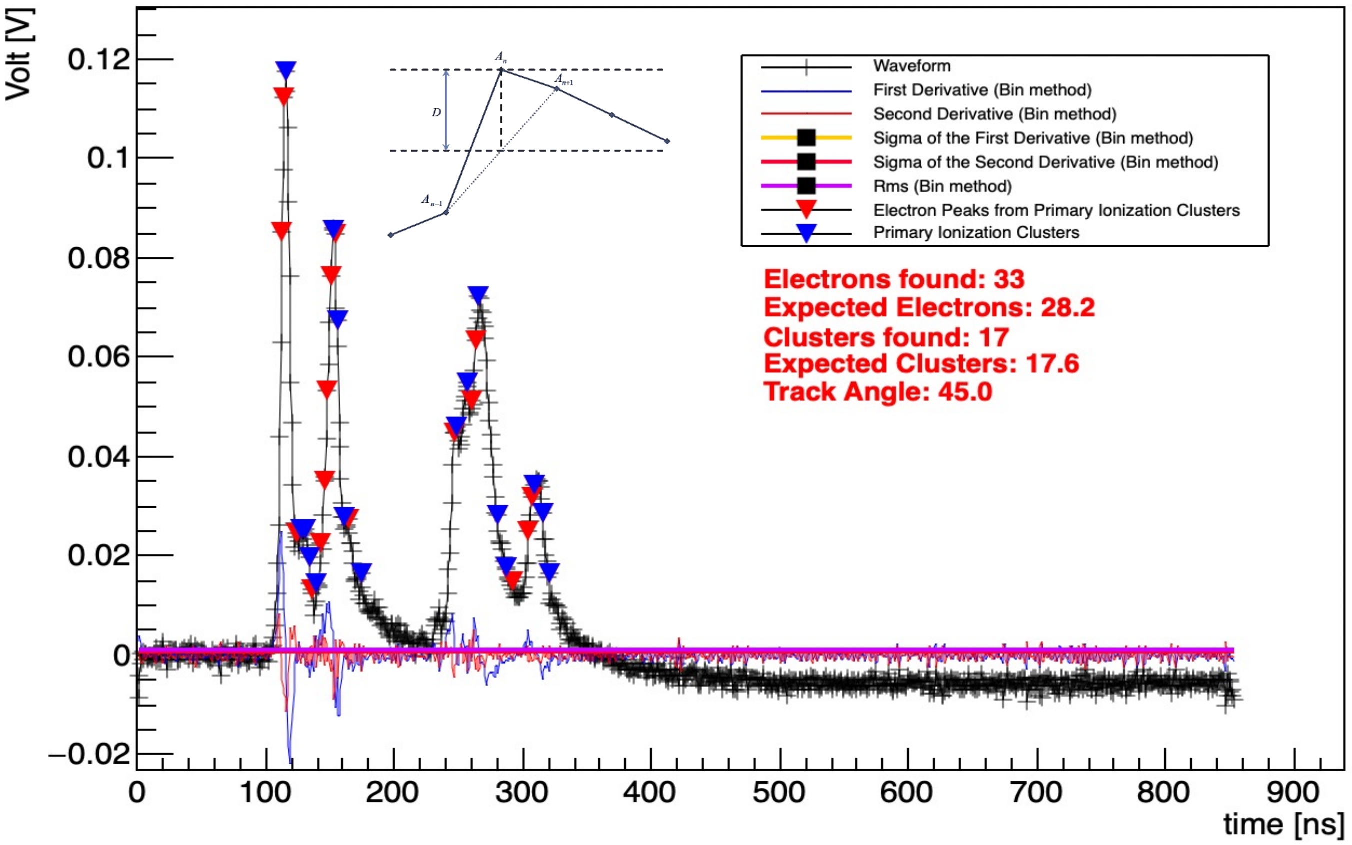




Sense Wire Diameter 20 um – Cell Size 1.0 cm – Track Angle 60° – 1.2 GSa/s – Gas Mixture He:IsoB 90/10 – 165 GeV

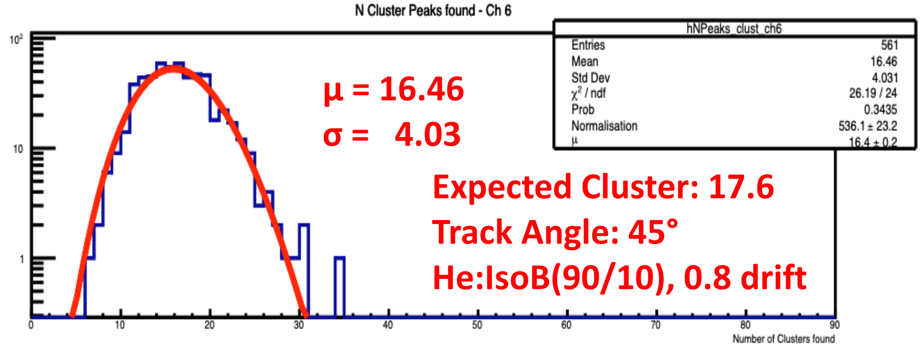
Current R&D efforts: Beam Tests Analysis Results

Reconstruction Primary Ionization Clusters (CLUSTER Algorithm)



Sense Wire Diameter 10 um – Cell Size 1.0 cm – Track Angle 45° – 1.2 GSa/s – Gas Mixture He:IsoB 90/10 – 165 GeV

Number of Cluster Distribution



Expected number of cluster = δ cluster/cm (MIP) x drift tube size [cm] x 1.3 (relativistic rise) x 1/cos(α)

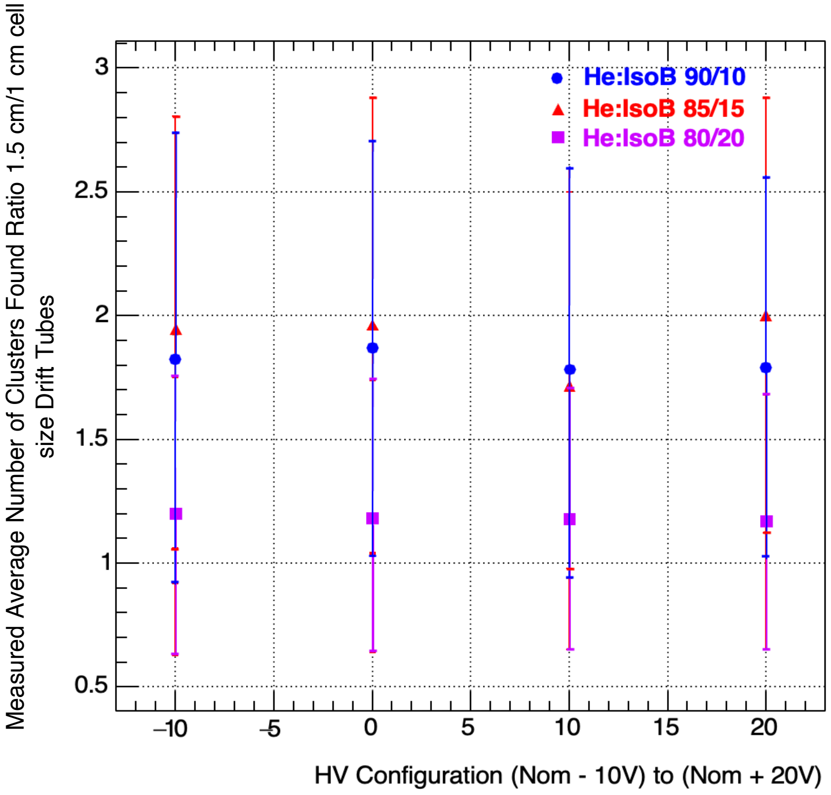
- **α is the angle of the muon track w.r.t. normal direction to the sense wires**
- **δ cluster/cm (mip) changes from 12, 15, 18 respectively for He:IsoB 90/10, 85/15 and 80/20 gas mixtures**
- **Actual drift tube size are 0.8, 1.2, and 1.8 respectively for 1 cm, 1.5 cm, and 2 cm cell size tubes**

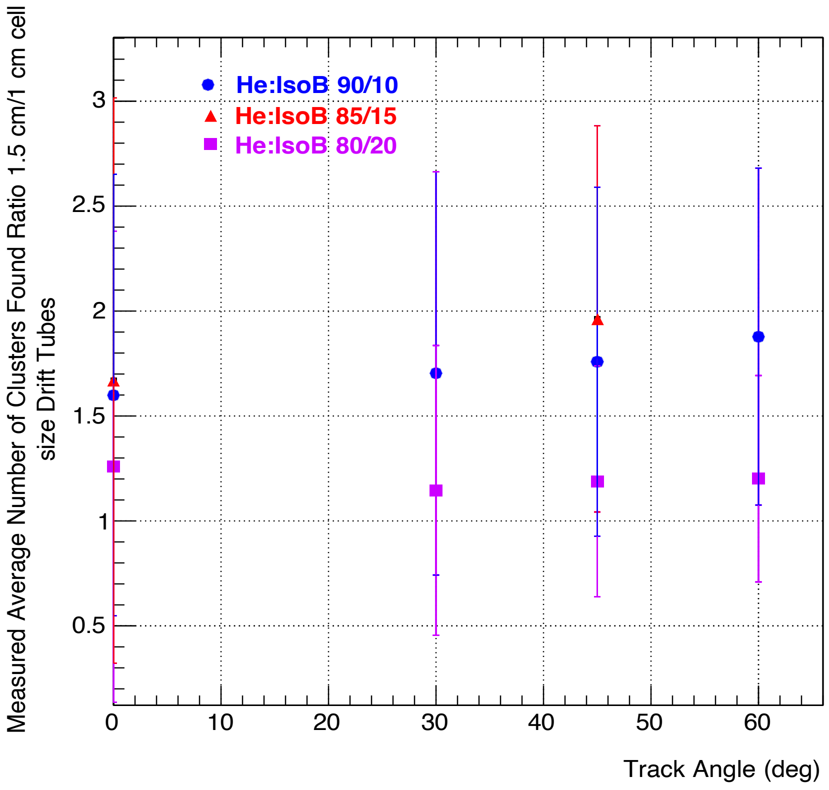
Current R&D efforts: Beam Tests Analysis Results

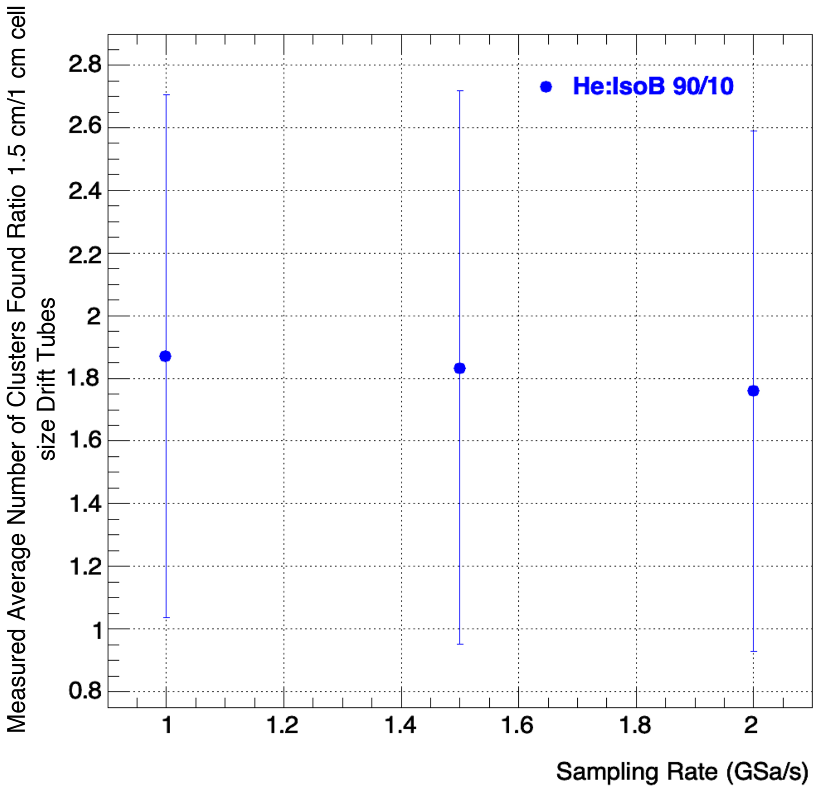
in Ratios

Efficiency w.r.t. Expected Number of Electrons (Clusters) above ~85%.
What about being independent from theoretical assumptions?

Expected number of cluster= δ cluster/cm (MIP) x drift tube size [cm] x 1.3 (relativistic rise) x 1/cos(α)

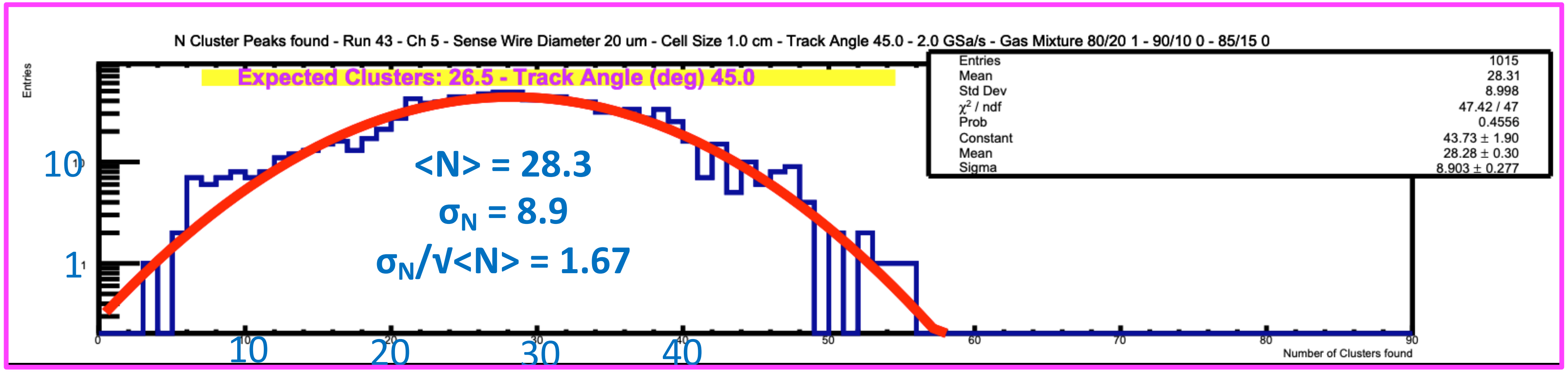




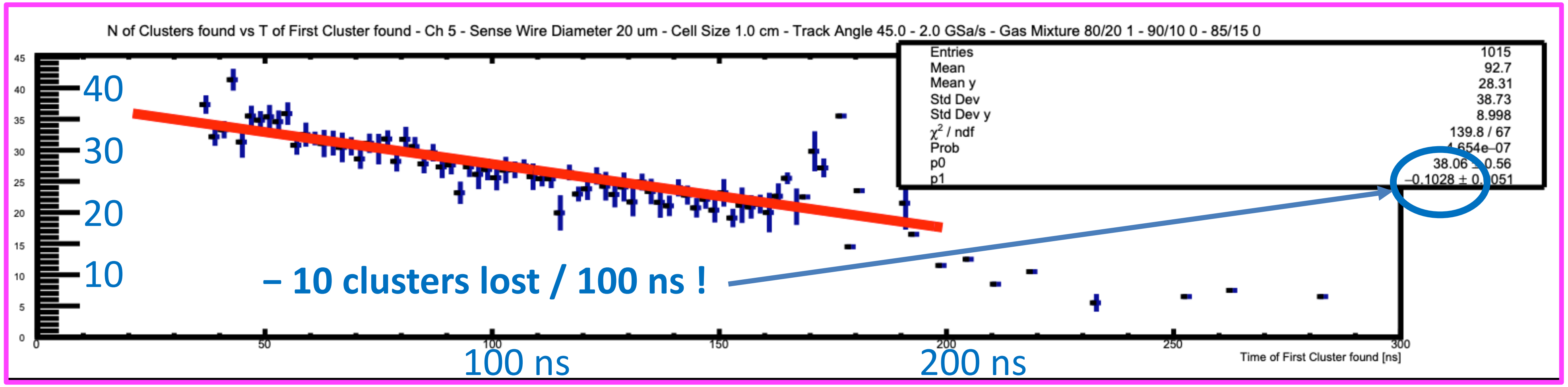


Current R&D efforts: BT Analysis Next Goal

Recombination and Attachment Effects



Number of Clusters found by DERIV+CLUSTER algorithms

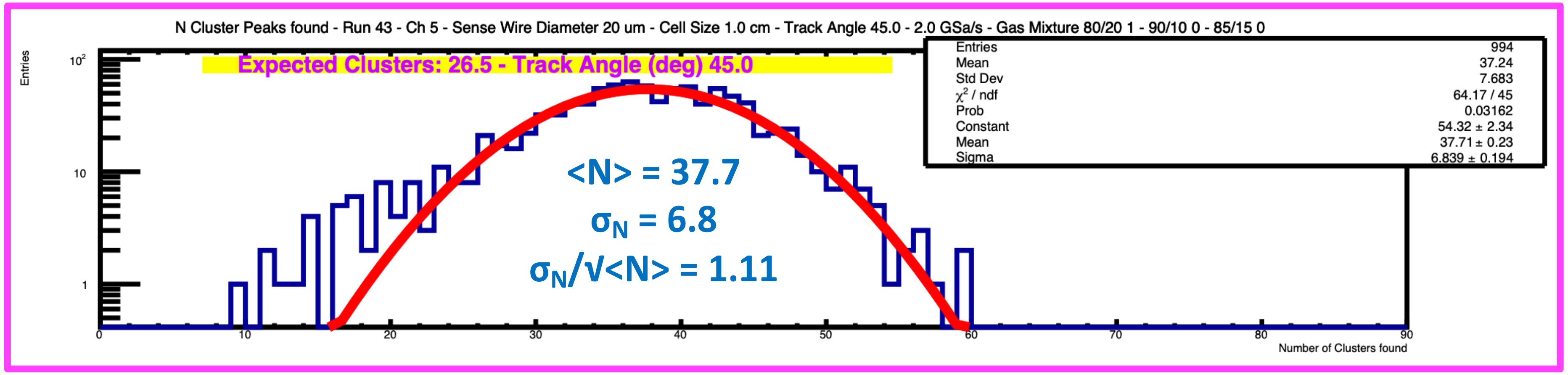


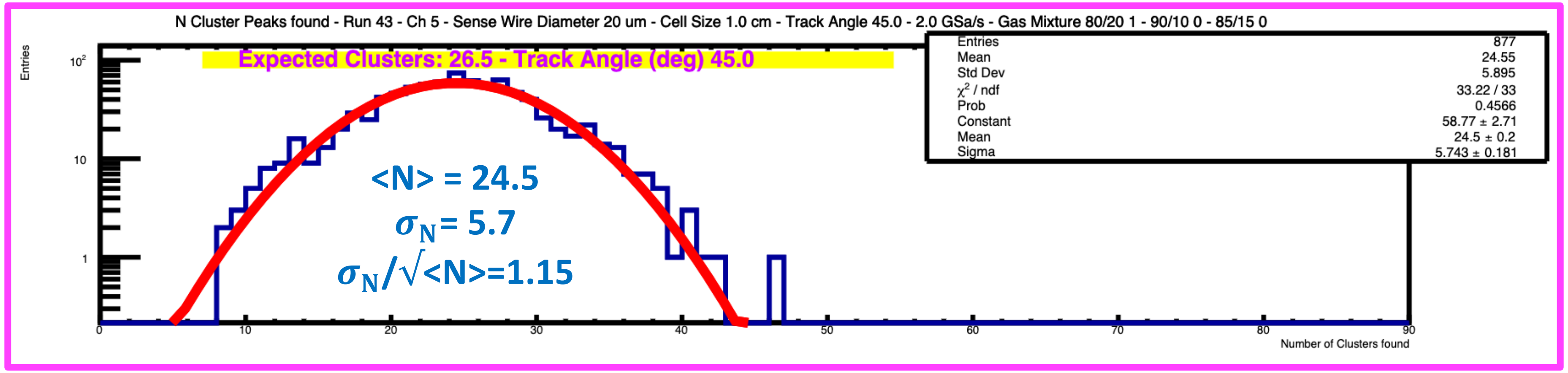
Average Number of Clusters found(@drift time) vs drift time

Combined action of recombination, electron attachment and E-field suppression due to space charge

Current R&D efforts: BT Analysis Next Goal

Apply corrections to recover losses:





Cuts on the derivative algorithm, which were optimized **without including** the recombination and attachment effects, need to be reformulated.
Also, these corrections, strongly depend on the drift length and, therefore, on the drift tube size and must be calculated for each different drift tube configuration.

First attempt of re-tuning cuts on the DERIV algorithm for a 1 cm cell size drift tube

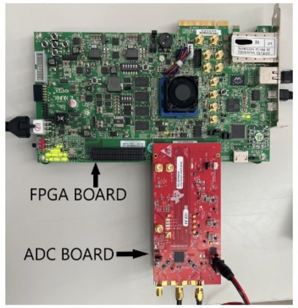
Current R&D efforts: DAQ

Data readout and pre-processing board for **cluster counting/timing DAQ system** (sponsored by AIDA innova)

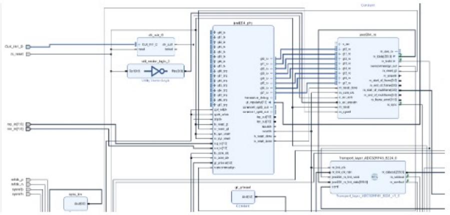
- Successfully accomplished on a single channel board.
- The objective is implementing, on a **single FPGA**, Cluster Counting algorithms for the parallel pre-processing of as many (contiguous) channels as possible in order to define proximity correlations between hit cells, for track segment finding 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.

FPGA-based fast digitizers for the cluster counting regime

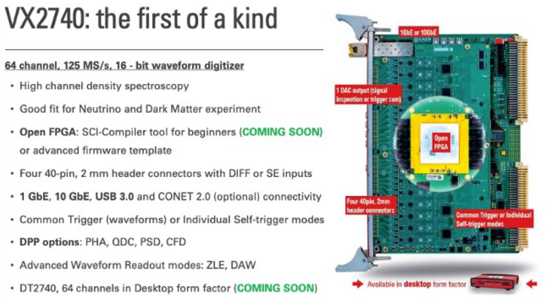
approach #1: KINTEX KCU105 + TEXAS ADC ADC32RF45



some synchronization issues yet to be solved

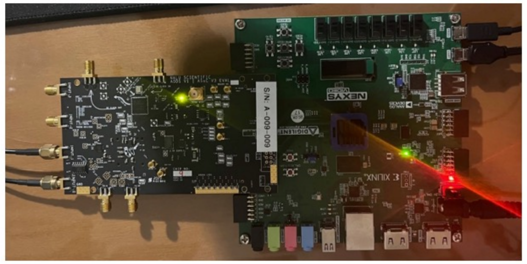


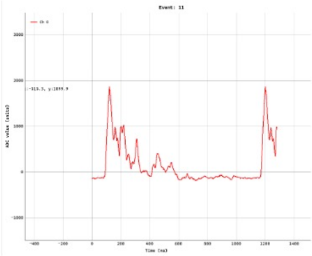
approach #2: CAEN VX2740 (VX2751, when available)



just received the software license to program our cluster finding algorithms

approach #3: NALU Scientific ASoCv3

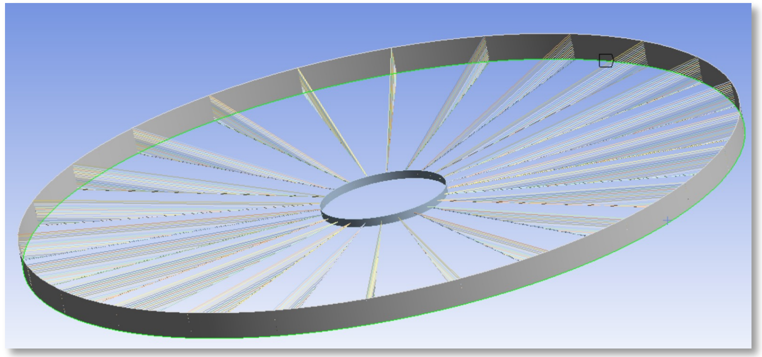




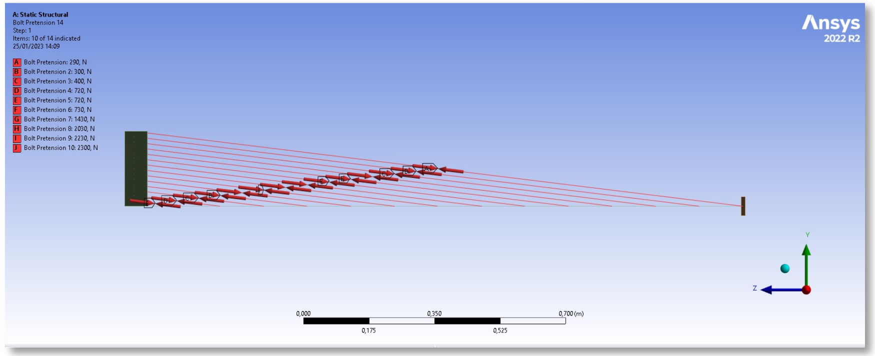
real signals read out with the AsoC chip, (used AWG with low performance: not all peaks detected)

Current R&D efforts: Mechanical structure

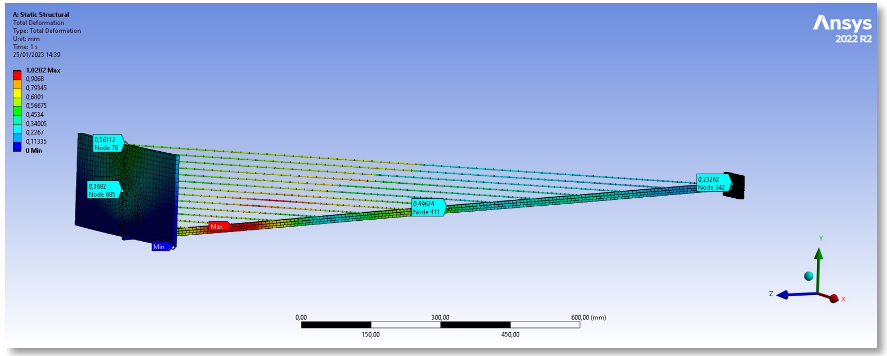
Boundary conditions of the end-plate model



Pre-stressing of stays to compensate DC wires tension



Stays and spoke deformation (to be fully optimized)



- Conceptual design of the IDEA drift chamber completed.
- Preliminary Finite Element Analysis (FEA) with homogeneous materials in conclusive phases.
- Transition to composite materials undergoing.
- Goal is to complete the full design by fall 2023 and to start construction of a full-length, 1/12 wedge, prototype during 2024.

Conclusions and Future Plans

- Overview of the requirements for the IDEA Drift Chamber (DC)
- R&D efforts on Beam Tests, DAQ and Mechanical Structure of the DC

Short Time Future Prospects

- Finalization of Mechanical Structure and DAQ of the Drift Chamber
- Continuation of Beam Tests (the next one will be at CERN-PS)
- Construction of a prototype of a full scale wedge of the drift chamber
  - To verify the electrostatic stability of different wire types (aluminum, titanium and carbon monofilamets for field and guard wires and tungsten, molybdenum for sense wires) of different diameters
  - Optimize the wire tension compensation scheme proposed to minimize the end-plates budget material

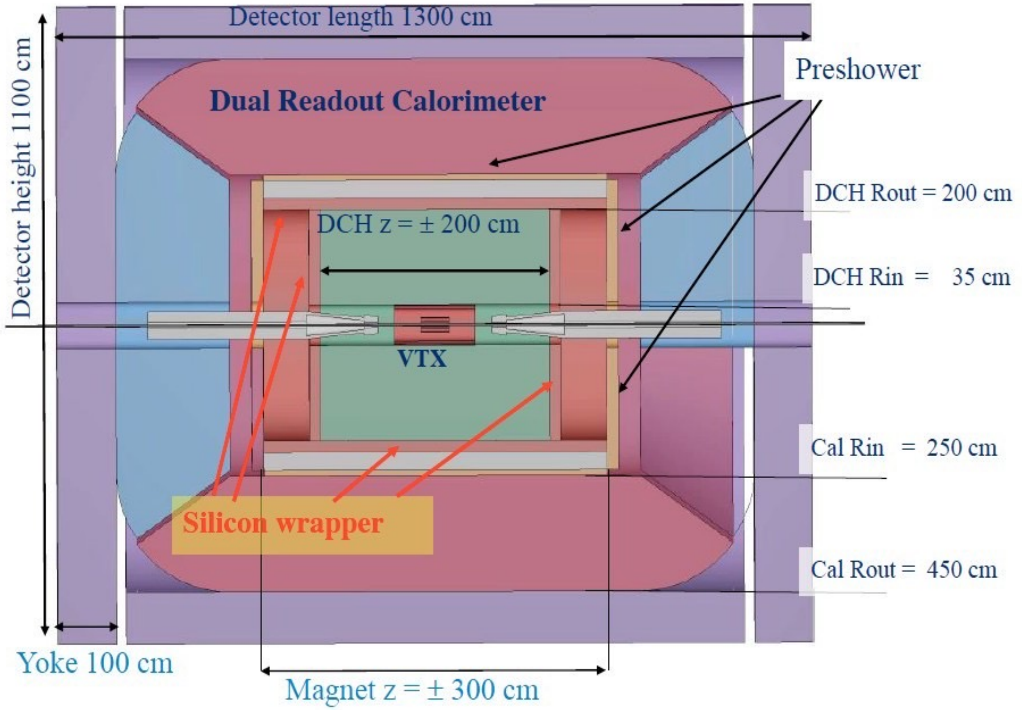
Backup

IDEA: Innovative Detector for e+e- Accelerator

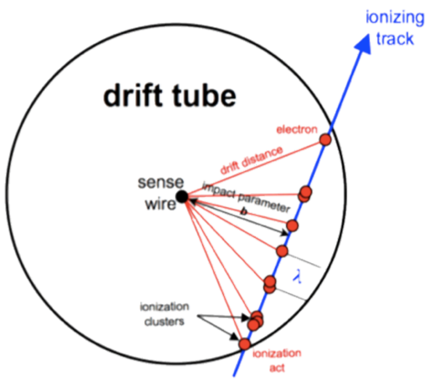
The **IDEA** (**Innovative Detector for E+e- Accelerator**) **general-purpose detector concept** has been designed to study **electron-positron collisions** in a wide energy range provided by a very large (~**100 km**) circular leptonic collider (e.g. **FCC-ee** at **CERN, CEPC** in **China**) for **high luminosity Higgs**, **precision electroweak physics** at the **Z pole** and **flavour physics**.

Inside ↓ Out

- **Silicon pixel vertex** detector
- Large-volume, extremely-light, high transparency, high granularity **drift wire chamber (DCH)**
- Surrounded by a layer of **silicon micro-strip detectors**
- A thin low-mass **superconducting solenoid coil**
- A preshower detector based on **µ-WELL technology**
- A **Dual Read-out calorimeter**
- Muon chambers inside the magnet return yoke, based on **µ-WELL technology**
- Low field detector solenoid (optimized at 2 T) **to maximize luminosity**



Cluster Timing

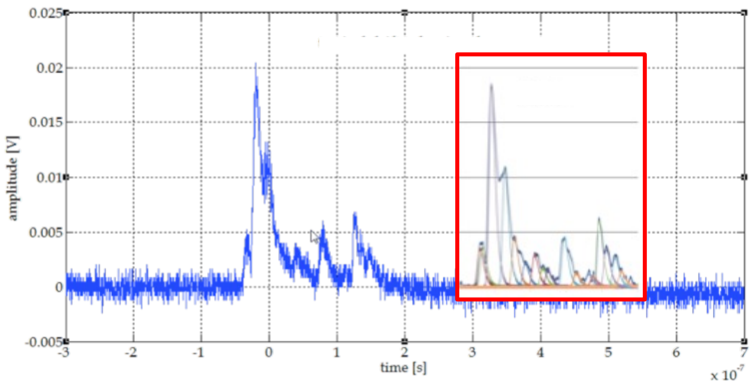


Determine, in the signal, the **ordered sequence of the electrons arrival times**:

$$\{t_j^{el}\} \qquad j = 1, n_{el}$$

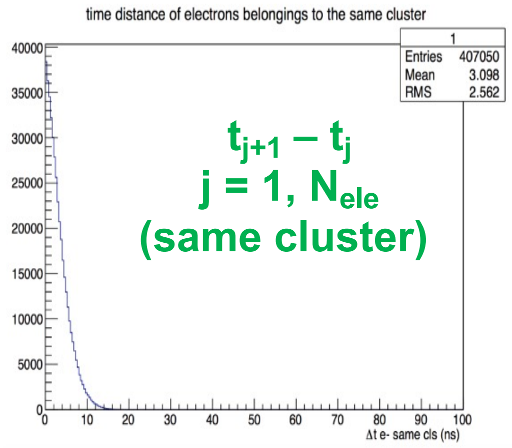
Based on the dependence of **the average time separation between consecutive clusters** and on the **time spread due to diffusion**, as a function of the drift time, **define** the **probability function**, that the **j^{th} electron** belongs to the **i^{th} cluster**:

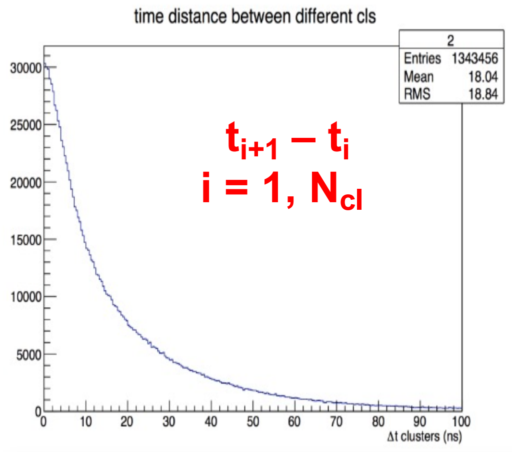
$$P(j,i) \qquad j = 1, n_{el}, \quad i = 1, n_{cl}$$



from this **derive** the most probable **time ordered sequence of the original ionization clusters:**

$$\{t_i^{cl}\} \qquad i = 1, n_{cl}$$





For any given first cluster (**FC**) drift time **t_1**, the **cluster timing technique** exploits the drift time distribution of all successive clusters to statistically (**MPS**) or using **ML techniques**, determine, hit by hit, the most probable **impact parameter**, thus reducing the **bias** and improving the average **spatial resolution** with respect to that obtainable with the FC method alone:

over a 1 cm drift cell, **spatial resolution** may improve by $\gtrsim$ 20%
down to $\lesssim$ 80 μm.

Fringe benefits of the cluster timing technique are:

- **event time stamping (at the level of ≈ 1 ns);**
- **improvements on charge division;**
- **Improvements on left-right time difference.**

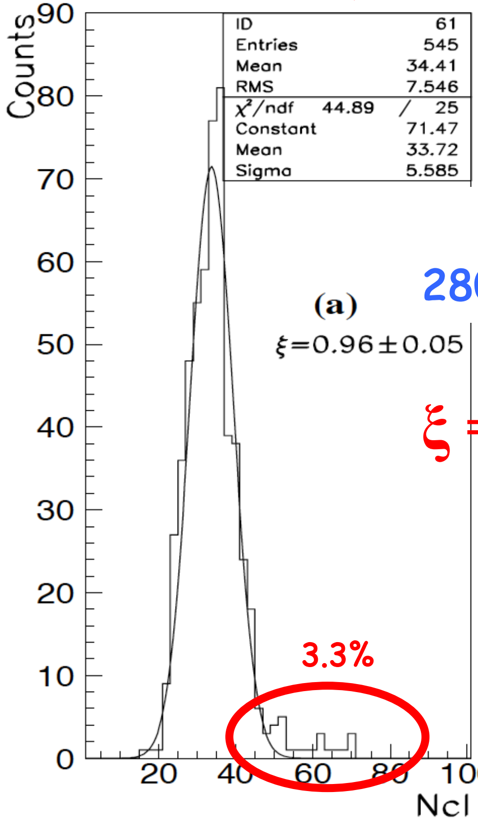
Experimental Results (TB 1997)

G. Cataldi, F. Grancagnolo and S. Spagnolo, *Nucl.Instrum.Meth. A 386 (1997) 458-469*

μ/π separation at p = 200 MeV/c
He/iC_4H_{10} = 95/5
100 samples
3.7 m track lenght

dN_{cl}/dx	3.2σ	(5.0σ ideal)
dE/dx	1.7σ	(2.8σ ideal)

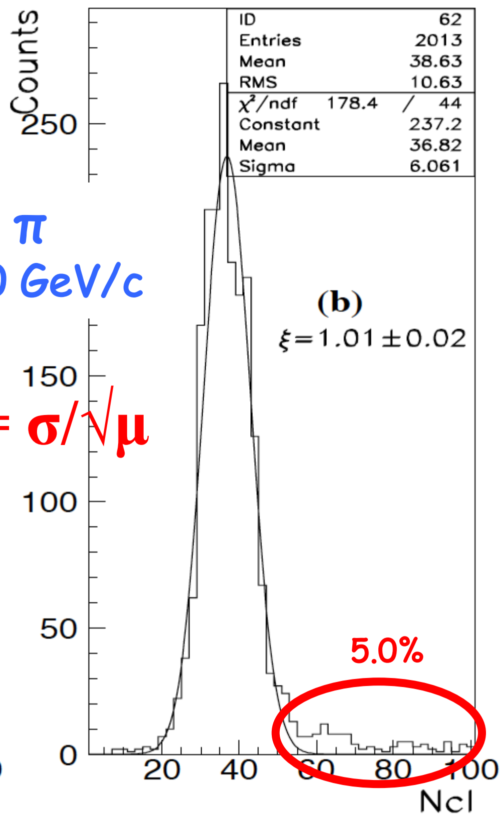
80%He-20%CH_4



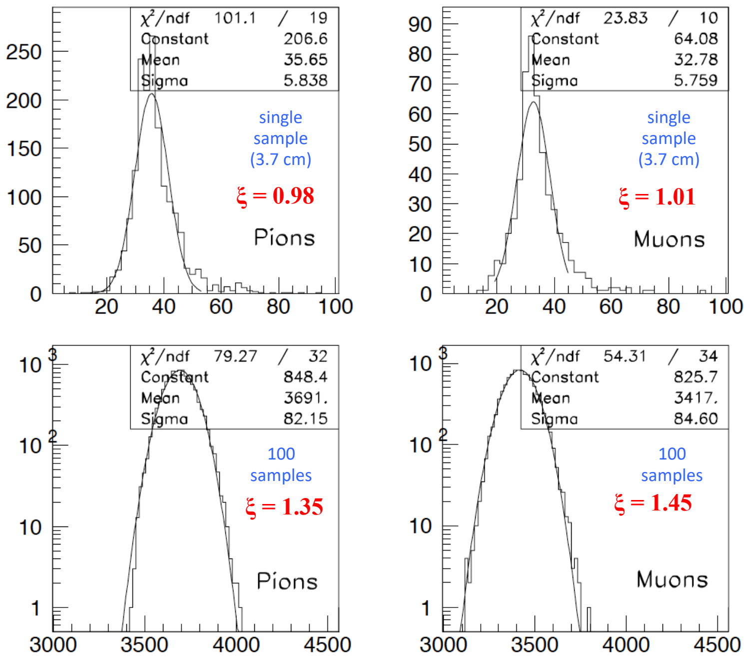
π
280 GeV/c

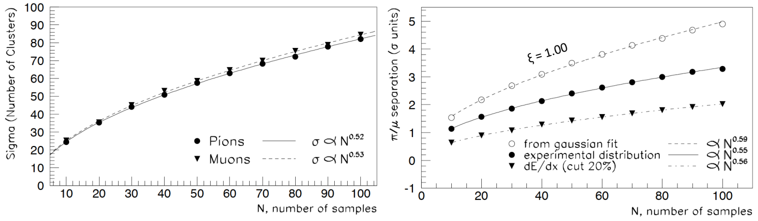
$\xi = \sigma/\sqrt{\mu}$

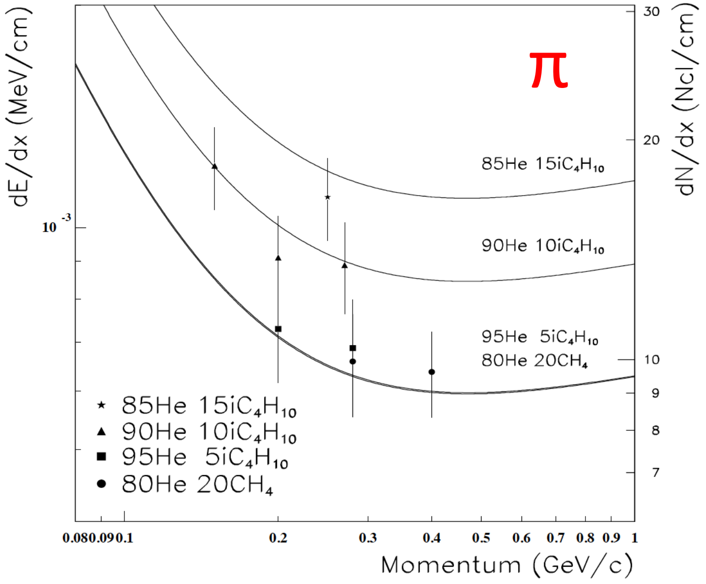
95%He-5%iC_4H_{10}



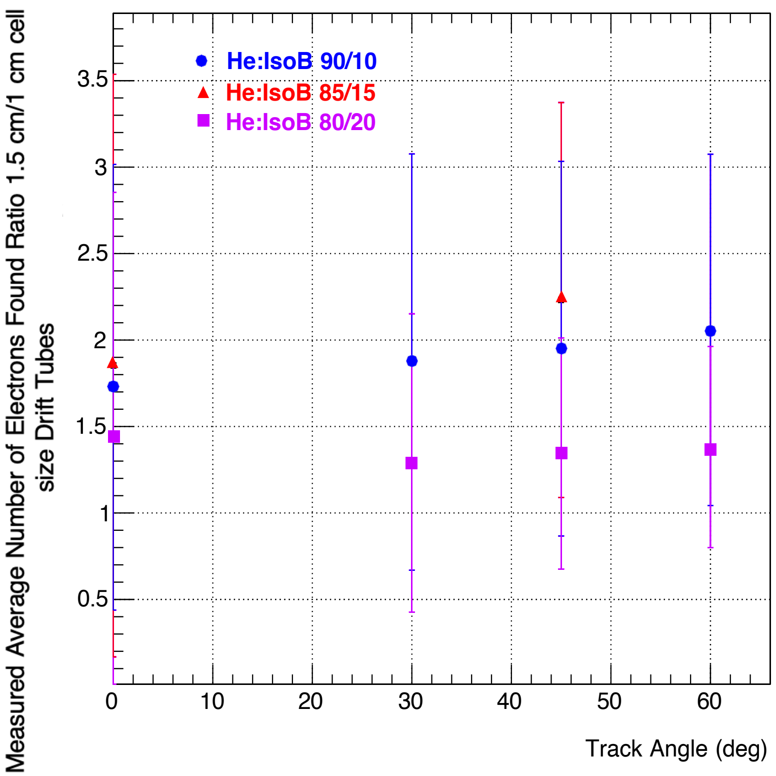
95%He-5%iC_4H_{10} p = 200 MeV/c

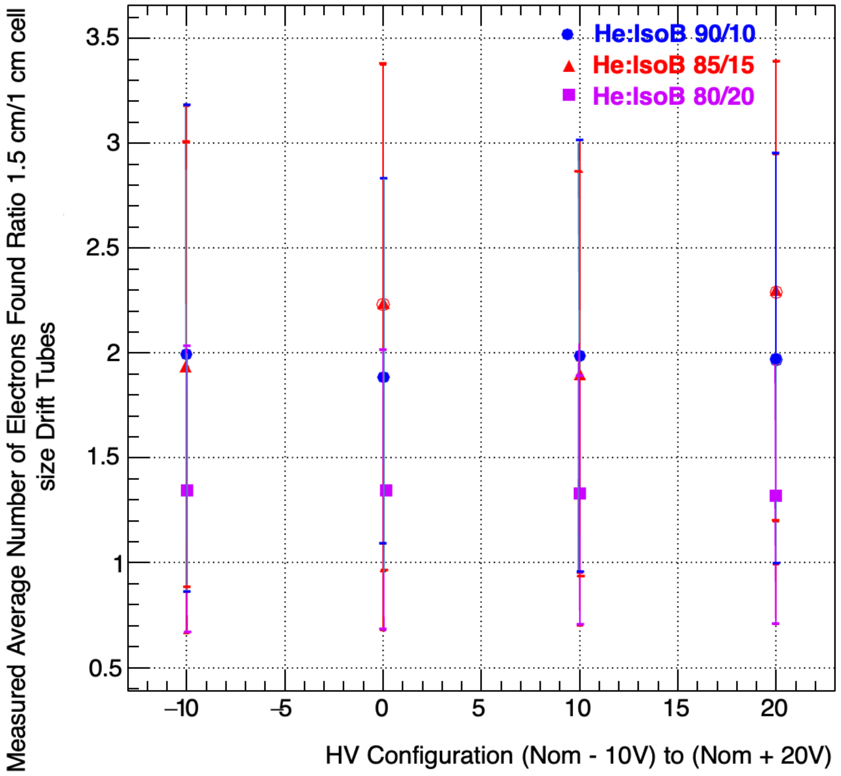


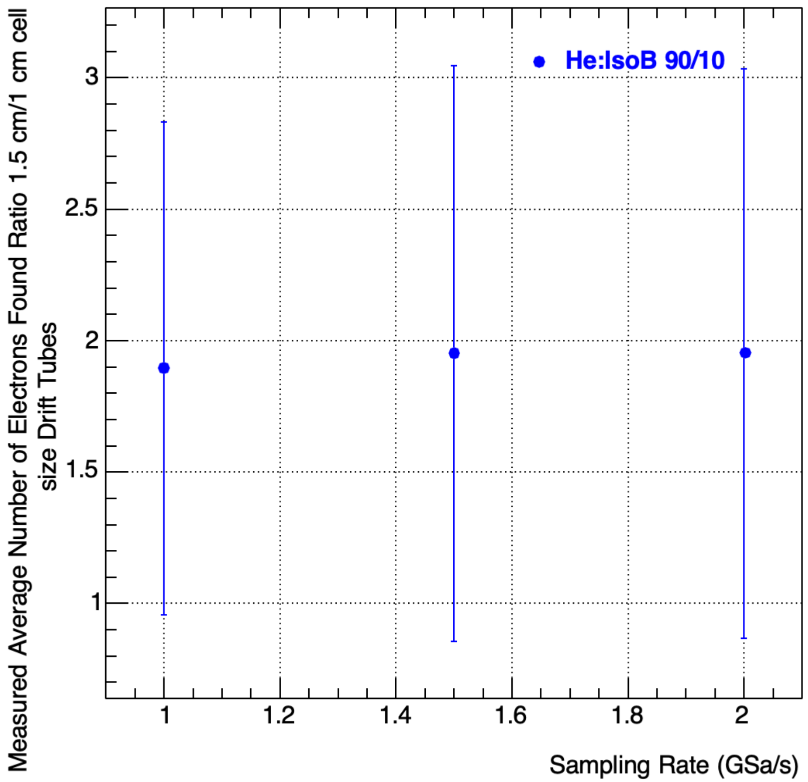




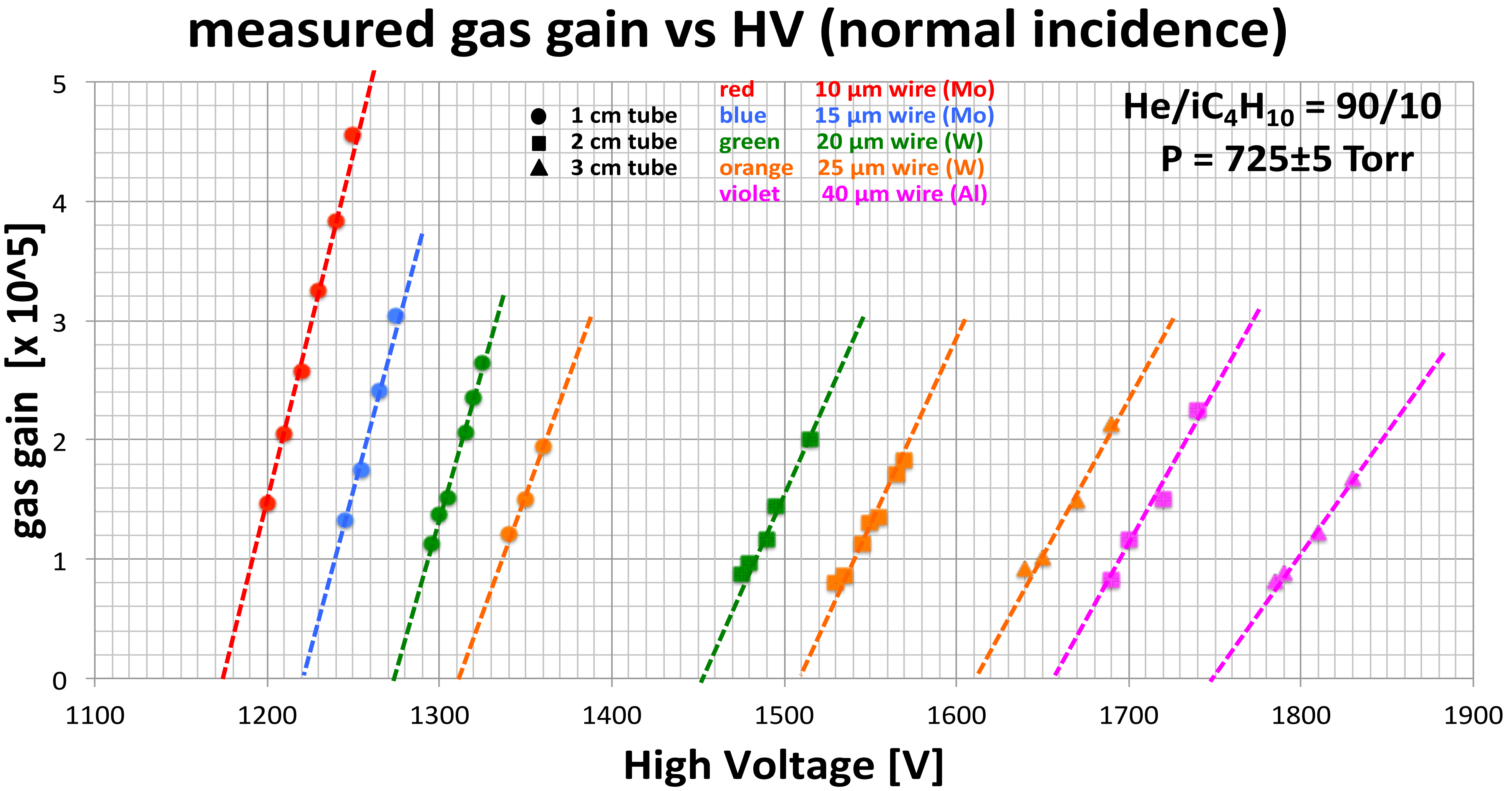
Number of Electron Peaks distributions



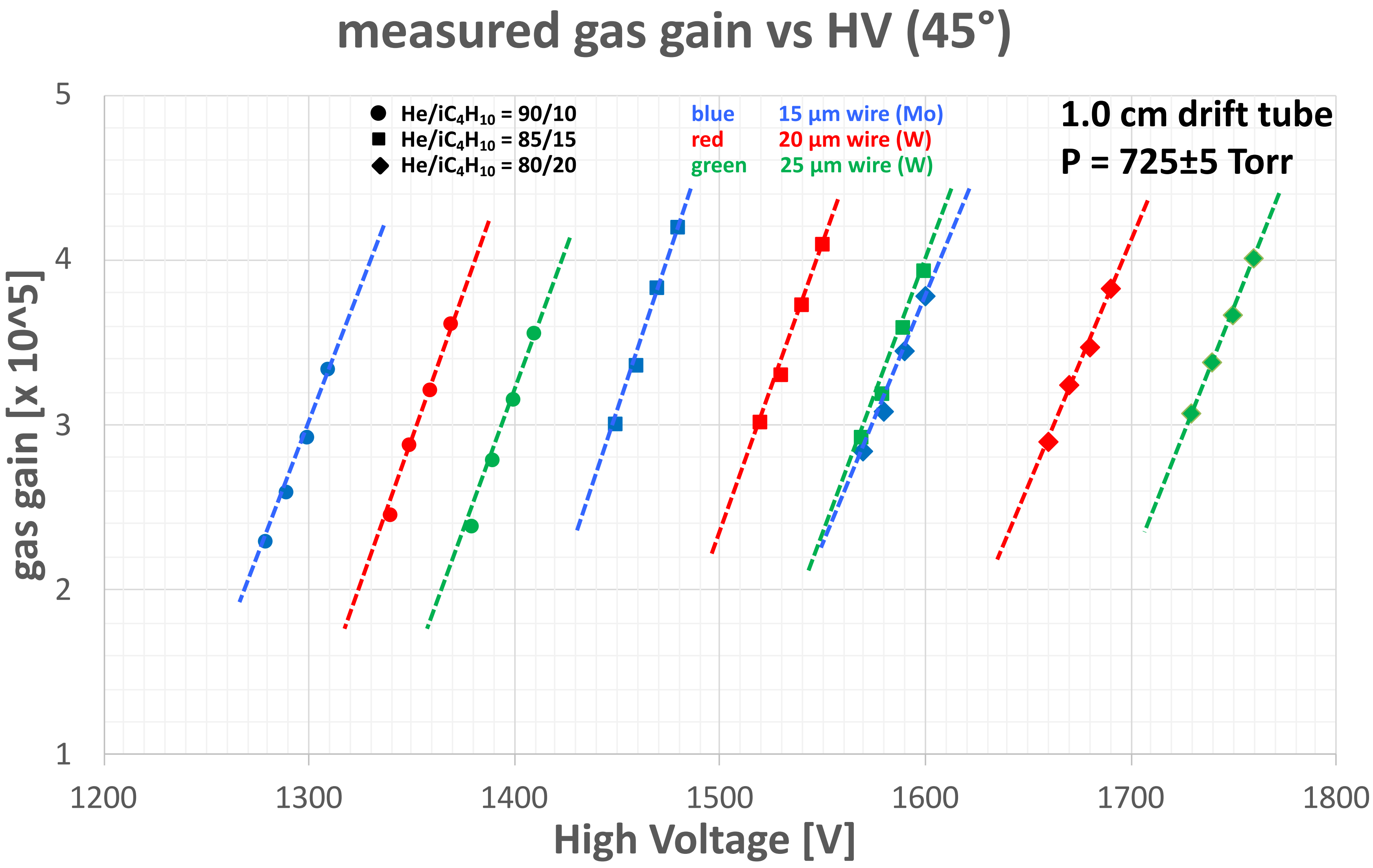




Gas Gain (TB November 2021)

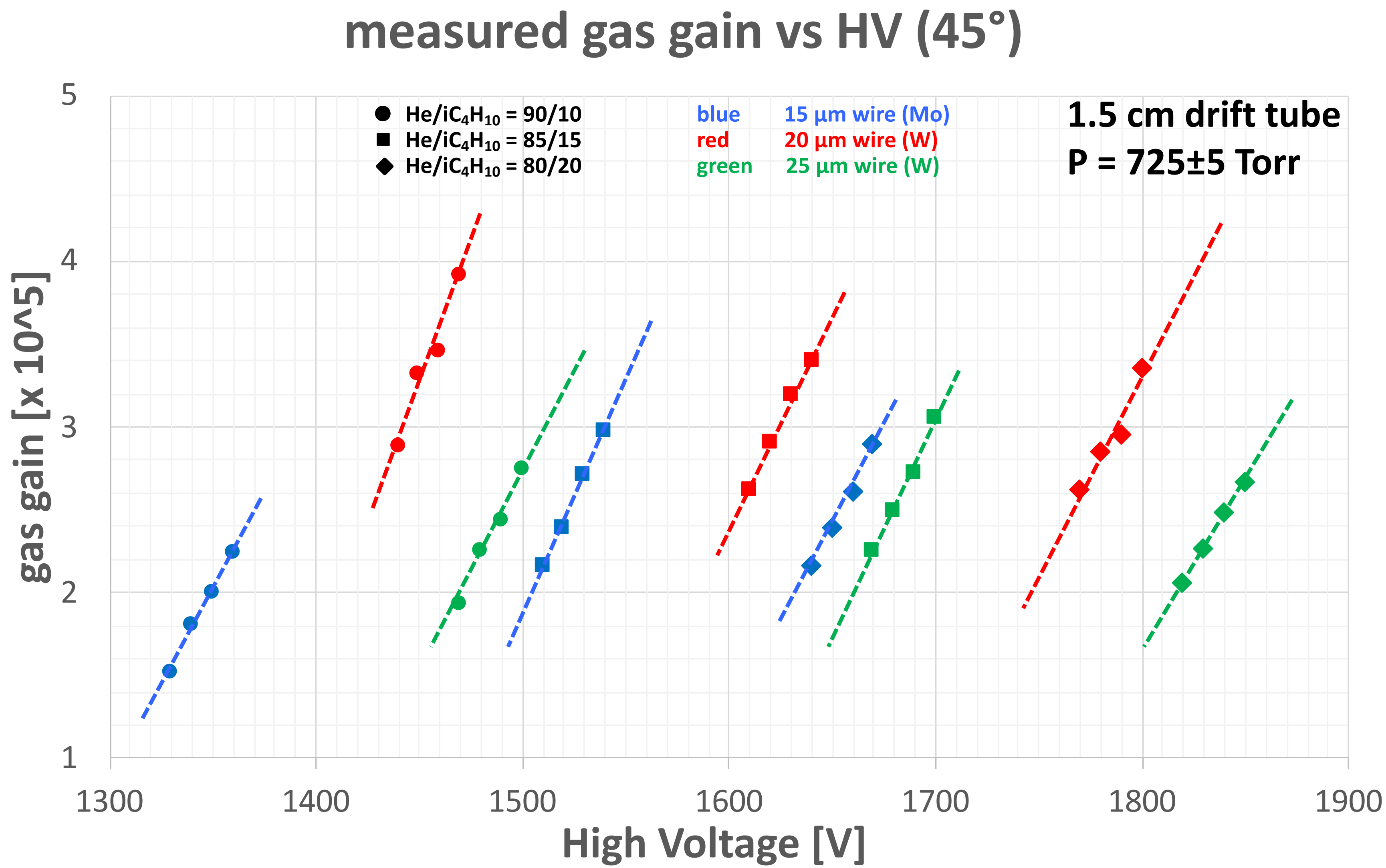


Gas Gain (TB July 2022)



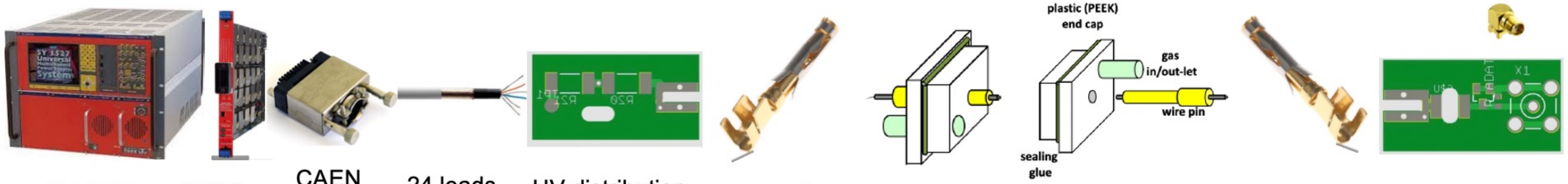
The 25 micron wire He:IsoB 85/15 has the same gain of 15 micron wire He:IsoB 80/20!

Gas Gain (TB July 2022)



20 μm wire excluded from physical quantities mean computation

2021-2022 Test Beams Scheme Connection



SY 1527 Mainframe | 1535P 24ch | CAEN A996 Radiall 691803004 | 24 leads HV cable | HV distribution board | connecting pin | drift tube end cap | connecting pin | HV decoupling board

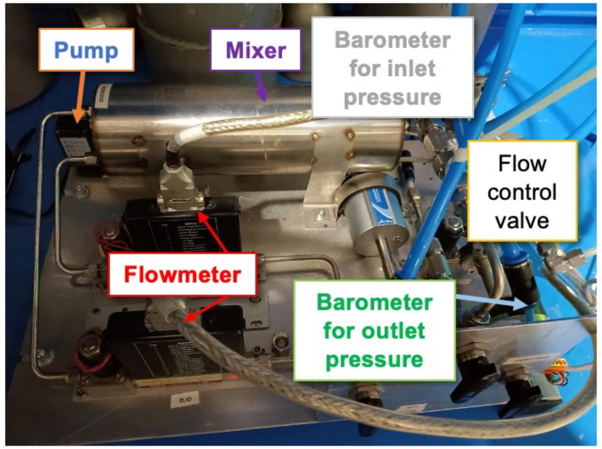
Trigger scintillator

Two scintillator tiles (12 cm x 4 cm), placed **upstream** and **downstream** of the drift tubes pack, instrumented with SiPM.

The gas system

- sets the **needed gas mixture**
- checks the **gas pressure** at the entrance and at the exit of the tubes
- keep the **gas pressure constant** inside the tubes, by using a proportional valve and a pump.

Portable gas system

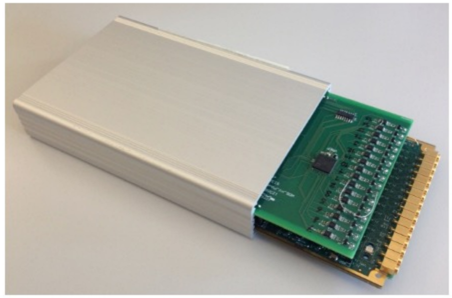


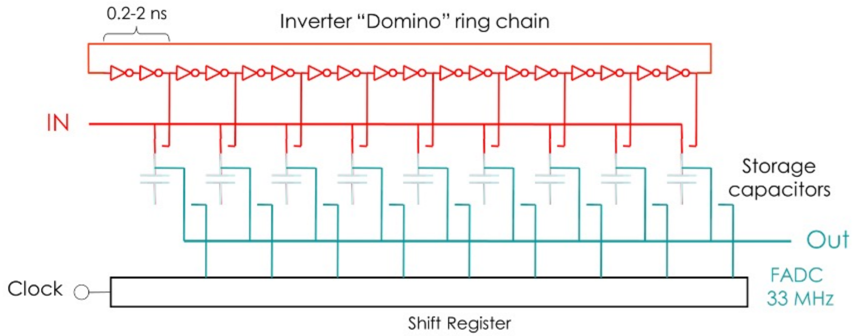
The DAQ system: WDB wave dream board

16 ch **D**rs4 **REA**dout **M**odule

16 channels data acquisition board designed and used by the **MEG-2 experiment** at PSI (μ → e + γ)

Special thanks to the MEG collaboration





- **Analog switched capacitor array**: analog memory with a depth of 1024 sampling cells, perform a "**sliding window**" sampling.

- **500 MSa/s ↔ 5 GSa/s sampling speed** with 11.5 bit signal-noise ratio
  - 8 analog channels + 1 clock-dedicated channel for sub 50 ps time alignment.

- Pile-up rejection: O(~10 ns)
- Time measurement: O(10 ps)
- Charge measurement: O(0.1%)

Details at: Application of the DRS chip for fast waveform digitizing, Stefan Ritt, Roberto Dinapoli, Ueli Hartmann, *Nuclear Instruments and Methods in Physics Research A 623 (2010) 486–488*

The data files have been converted in **ROOT format** to accomplish the data analysis.
Data at **different configurations** have been collected:
- **90%He - 10%iC_4H_{10}**
- 80%He - 20%iC_4H_{10}
- 85%He - 15%iC_4H_{10}
- HV nominal (+10,+20,+30,-10,-20,-30)
- Angle between the anode wire direction and the ionizing tracks **0°, 30°, 45°, 60°**
- **1.2,1.5 and 2.0 GSa/s** sampling rate

The DAQ system: an oscilloscope interface

WDB interface is similar to the interface of an oscilloscope with 16 channels:

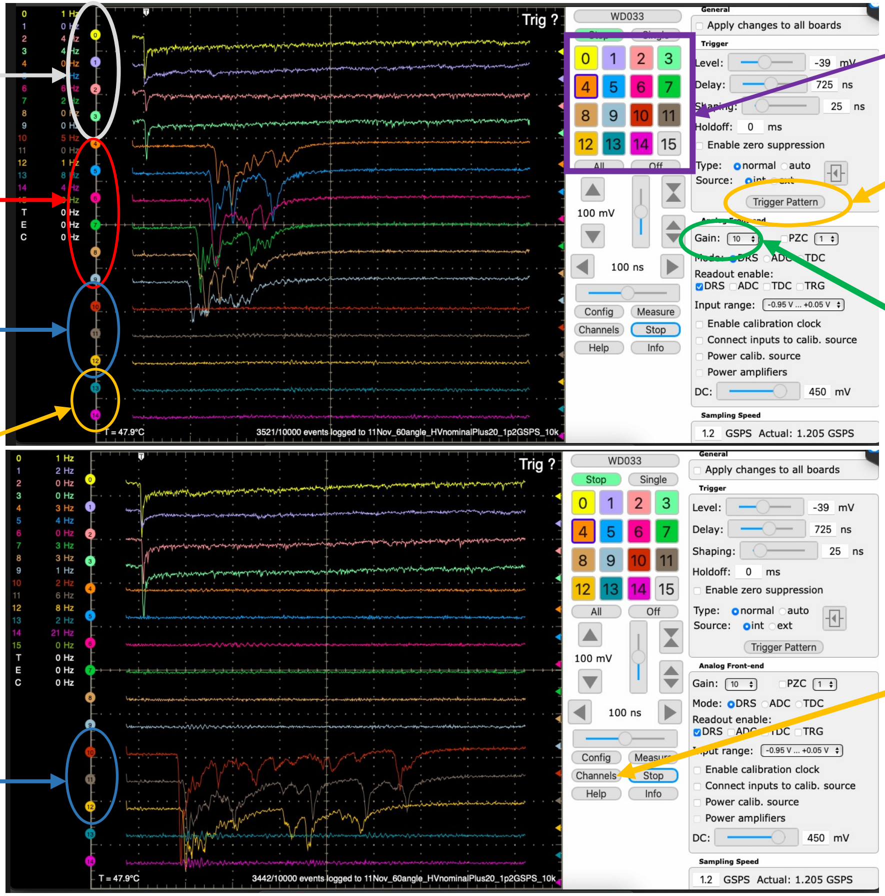
4 trigger channels

6 tubes 1 cm cell size with typical event

3 tubes 2 cm cell size

2 tubes 3 cm cell size

typical event

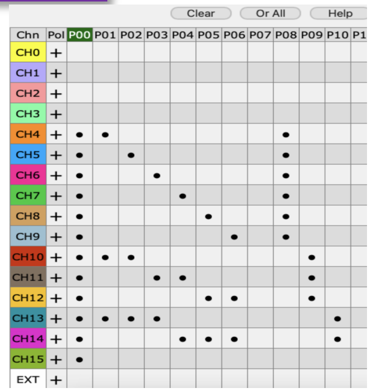


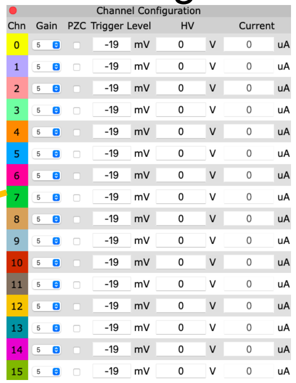
Channel selection panel

Trigger selection pattern

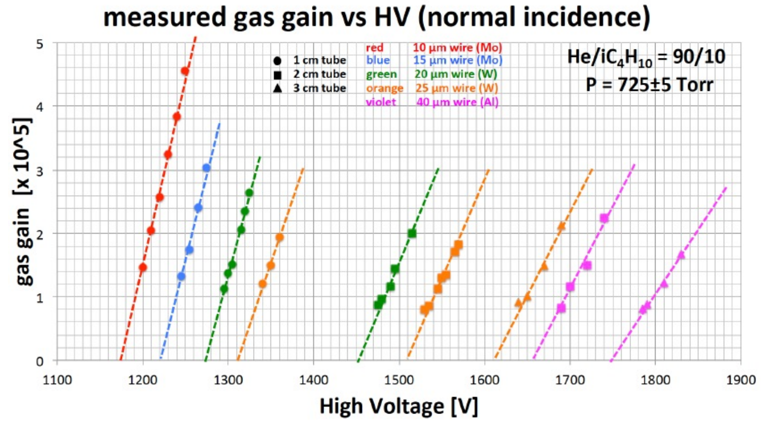
Gain selection

Channels setting





Screenshot from Beam Test November 2021



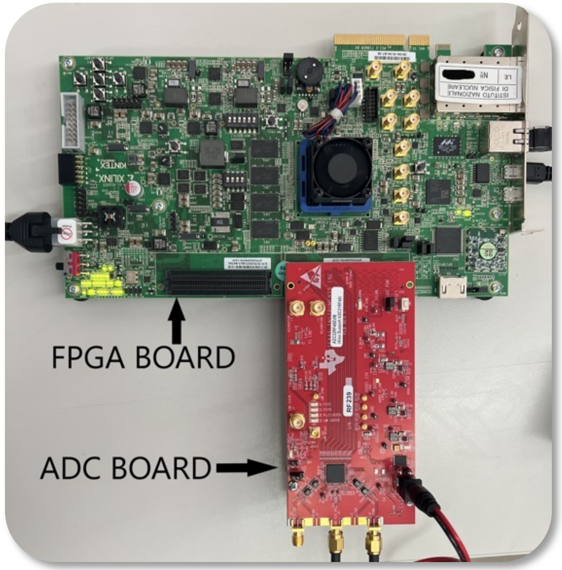
ADC TEXAS INSTRUMENT ADC32RF45

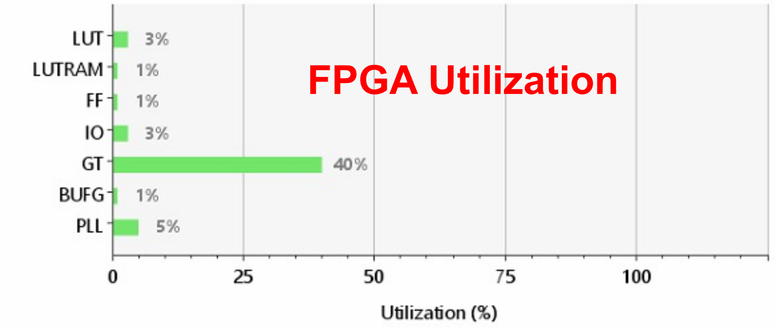
- The new hardware to test the algorithm is:
  - **Xilinx Kintex UltraScale FPGA KCU105 Evaluation Kit**
  - **ADC dual channel ADC32RF45EVM**

- The choice of the FPGA and ADC was made by choosing the **ADC** that ensured **good resolution** and **transfer capacity**.

- The new FPGA allows to have **better time constraints**.

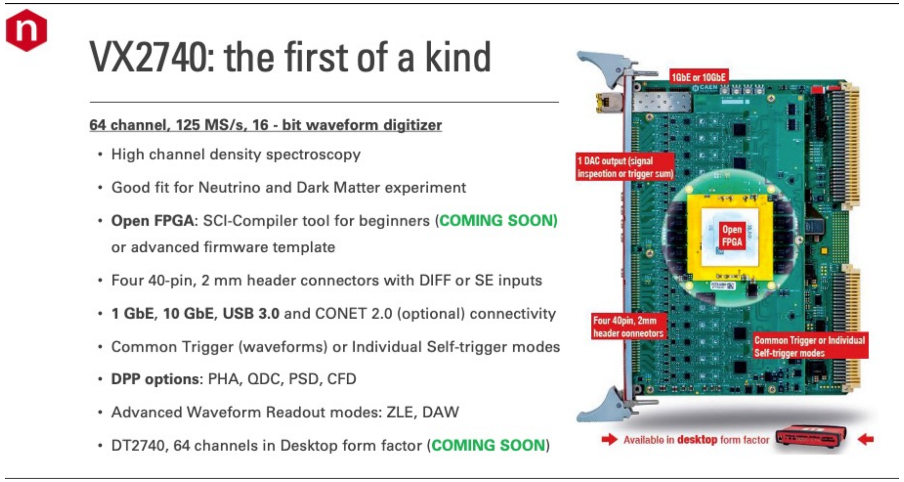
- The ADC has a **higher resolution** than the previous one and also it allows the reading of **two channels simultaneously.**

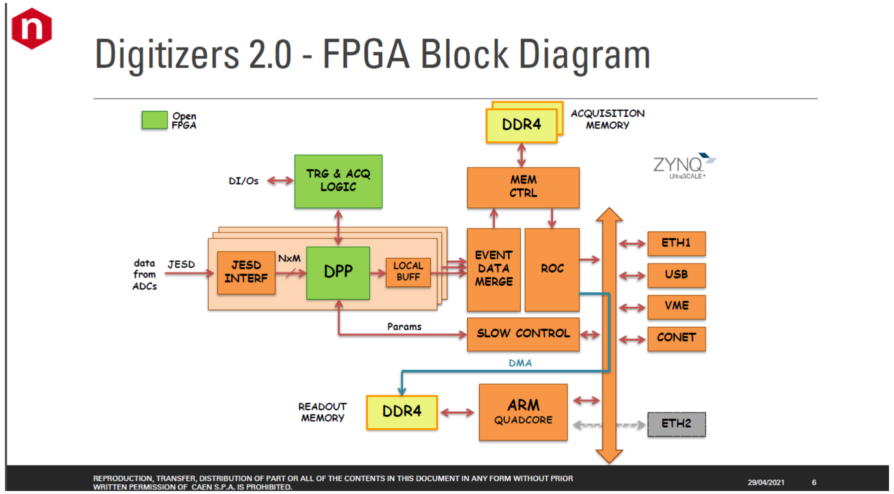




CAEN digitizers

- Test with the **new high performance CAEN digitizers**:
  - start testing their **lower performance digitizer VX2740** (waiting for the **board VX2751**)
  - Use the **"OPEN FPGA" system**
- Using the CAEN HW we do not have access to the **whole firmware infrastructure** but only in the **green areas** (in the figure), where we will implement the cluster counting algorithm.

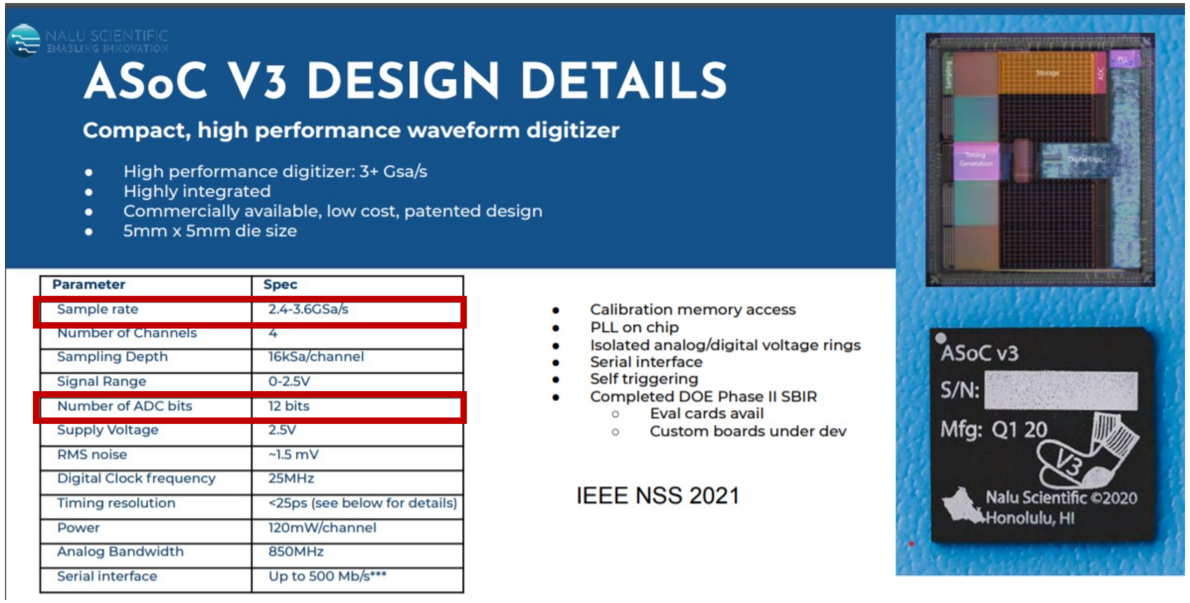




Naluscientific ASoCV3

- Naluscientific is providing us the card with the **ASoCV3 chip**:

  - **4 channel**
  - **Analog Bandwidth 850 MHz**



NALU SCIENTIFIC
ENABLING INNOVATION

ASoC V3 DESIGN DETAILS

Compact, high performance waveform digitizer

- High performance digitizer: 3+ Gsa/s
- Highly integrated
- Commercially available, low cost, patented design
- 5mm x 5mm die size

Parameter	Spec
Sample rate	2.4-3.6GSa/s
Number of Channels	4
Sampling Depth	16kSa/channel
Signal Range	0-2.5V
Number of ADC bits	12 bits
Supply Voltage	2.5V
RMS noise	~1.5 mV
Digital Clock frequency	25MHz
Timing resolution	<25ps (see below for details)
Power	120mW/channel
Analog Bandwidth	850MHz
Serial interface	Up to 500 Mb/s***

- Calibration memory access
- PLL on chip
- Isolated analog/digital voltage rings
- Serial interface
- Self triggering
- Completed DOE Phase II SBIR
  - Eval cards avail
  - Custom boards under dev

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