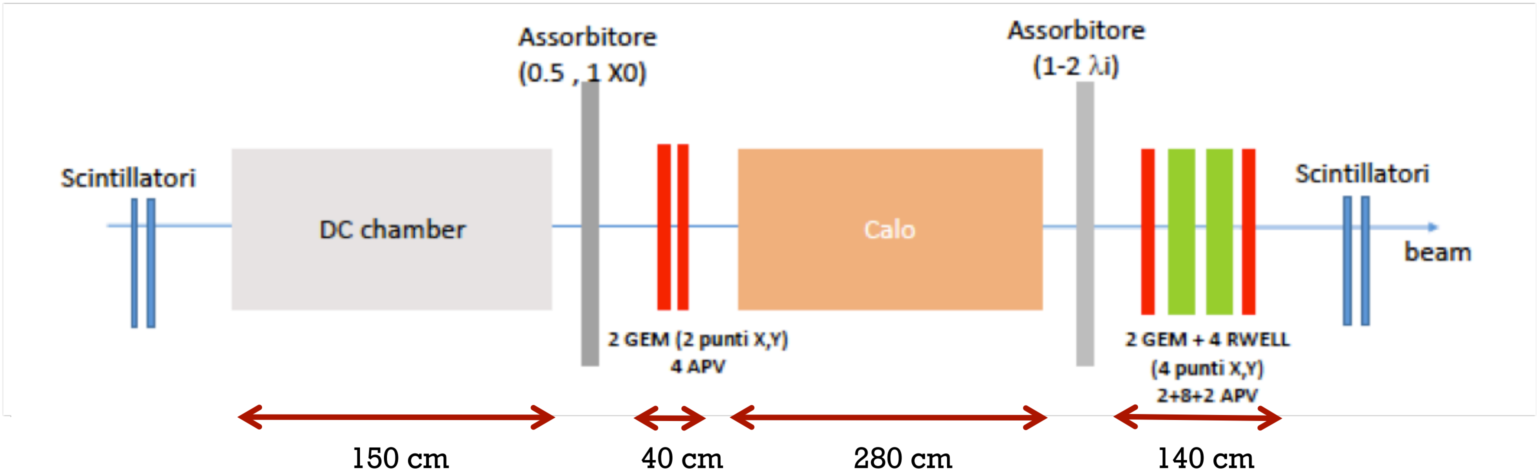
IDEA: Vertical Slice Test

Romualdo Santoro

Obiettivo del test

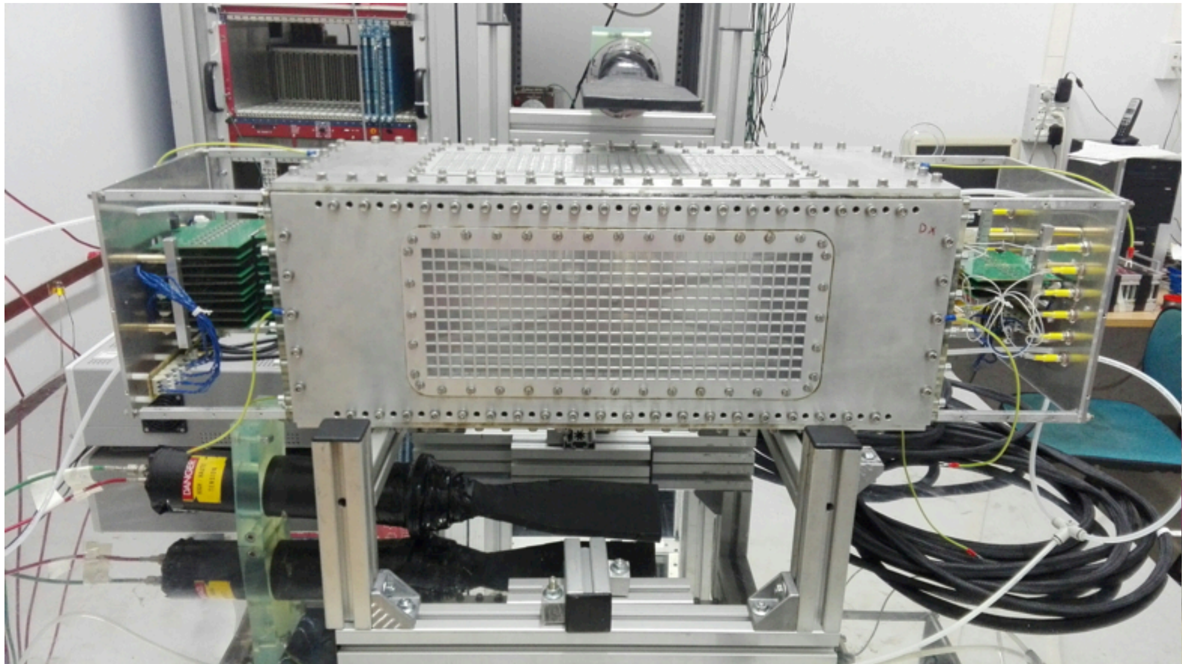
- Particle Identification
  - Camere a fili (p, π, k) con dE/dx VS cluster counting
  - Calorimetro (e, π)
  - μ RWell (μ)
- Ottimizzazione sistema combinato preshower calorimetro
- Caratterizzazione del tracciamento
- Test con targhetta per studiare ambiente single/multi particelle

IDEA Vertical Slice Test



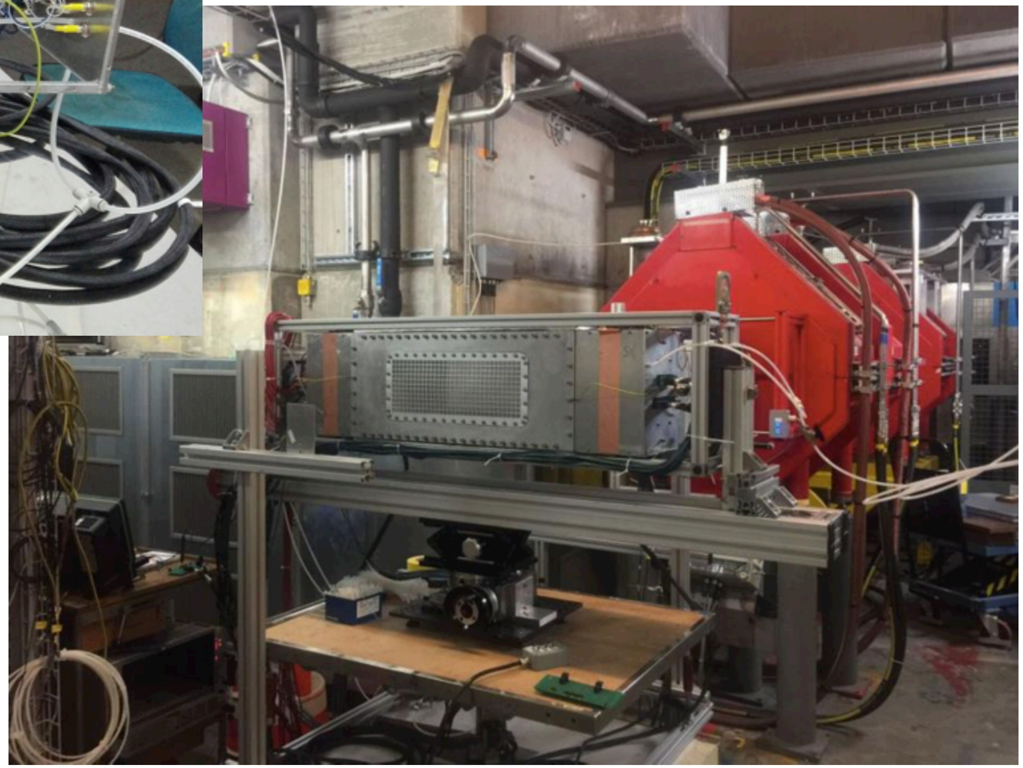
- Trigger: 2 scintillatori in coincidenza + veto
- Camere a fili
- Preshower: 2 punti xy con GEM
- Calorimetro Dual Readout
  a) Calorimetro RD52
  b) Modulo con fibre disallineate
  c) Modulo SiPM
- Camera muoni μ RWell: 4 punti xy

The Drift Chamber Prototype



in laboratory
at INFN Lecce

at PSI
September 2017



12 layers X 12 cells = 144 channels
1X1 cm^2 drift cells, 5 field:sense
instrumented with MEG2 front-end
and readout with

- DRS4 8 channels
- LeCroy 12 bit 16 channels
- discriminator + TDC 96 channels

Particle Identification (in theory)

$$\frac{\sigma_{dE/dx}}{(dE/dx)} = 0.41 \cdot n^{-0.43} \cdot \left(L_{track}[m] \cdot P[atm]\right)^{-0.32}$$

from *Walenta parameterization (1980)*

versus

$$\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl}/dx)} = \left(\delta_{cl} \cdot L_{track}\right)^{-1/2}$$

from *Poisson distribution*

dE/dx

truncated mean cut (70-80%) reduces the amount of collected information

***n* = 112** and a **2m track** at **1 atm** give

σ ≈ 4.3%

Increasing ***P*** to 2 atm improves resolution by 20% (σ ≈3.4%) but at a **considerable** cost of multiple scattering contribution to momentum and angular resolutions.

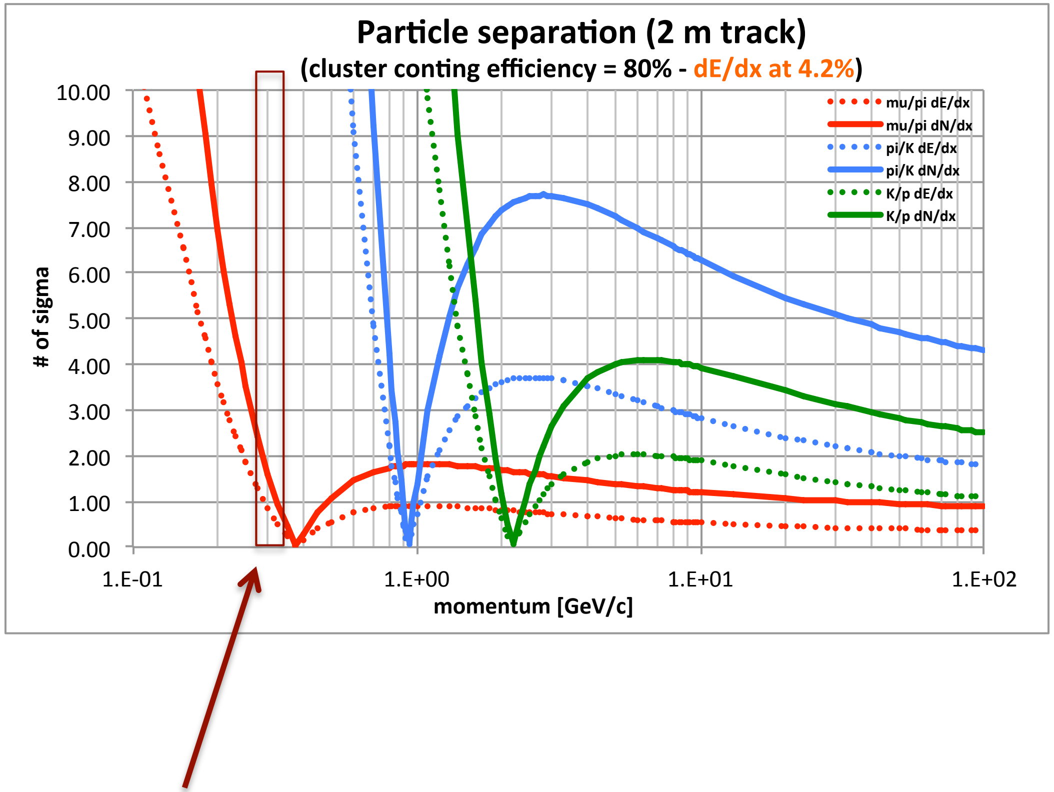
dN$_{cl}$*/dx*

δ_{cl} = 12.5/cm for He/iC_4H_{10}=90/10 and a **2m track** give

σ ≈ 2.0%

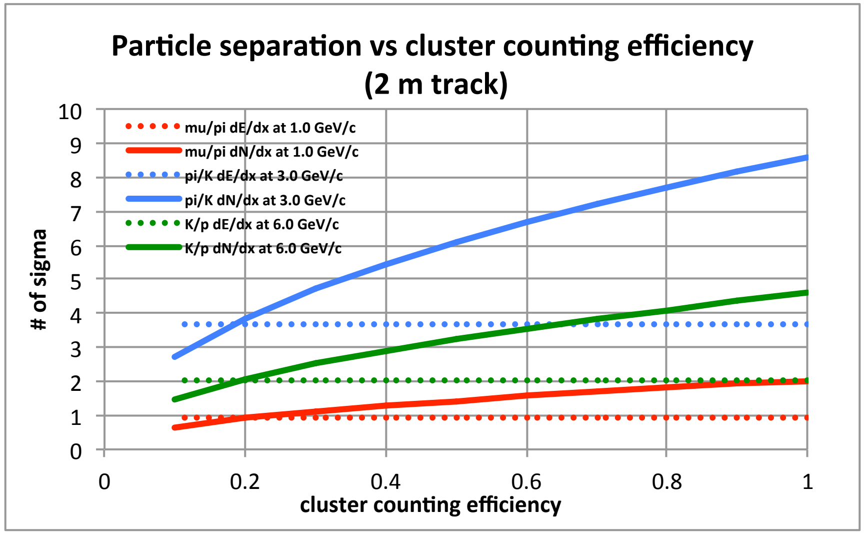
A small increment of iC_4H_{10} from 10% to 20% (δ_{cl} = 20/cm) improves resolution by 20% (σ ≈1.6%) at only a **reasonable** cost of multiple scattering contribution to momentum and angular resolutions.

IDEA D.C. expected Particle Id.



dE/dx VS dN_{cl}/dx

Andamenti basati su formule analitiche



- Zona studiata in precedenti test beam: NIM A386 (1997) 458-469
- In questo test si vuole studiare la PID ad energie superiori e confrontare la risposta del rivelatore con quanto descritto dalle formule

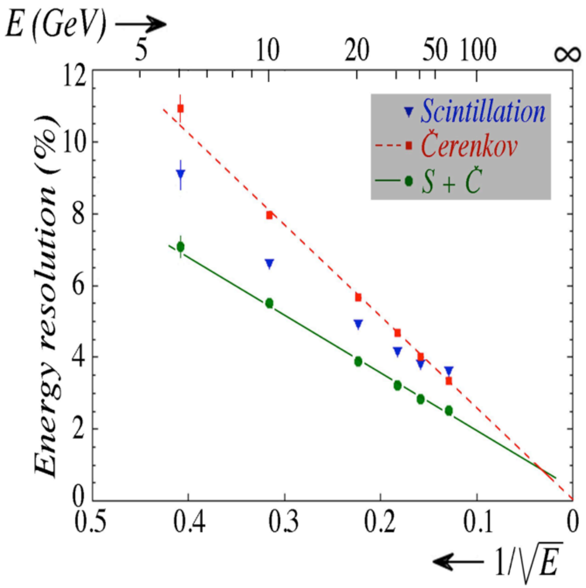
Dual Readout calorimeter

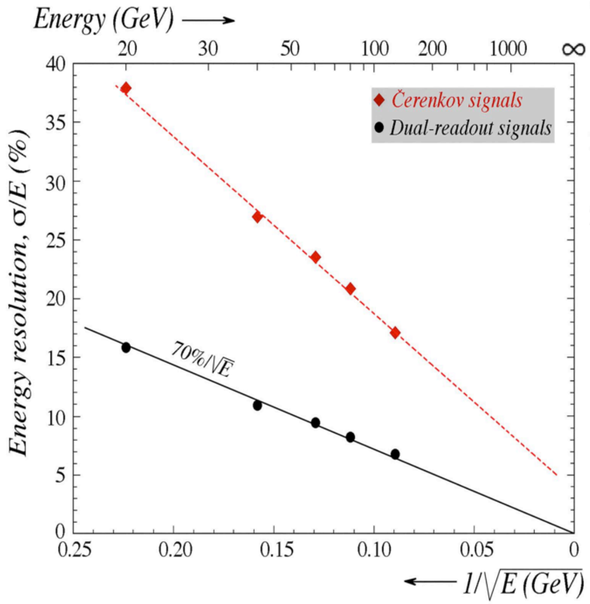
- Dual readout calorimeter offers a unique possibility to correctly reconstruct the energy of electrons and hadrons with a detector calibrated at the electromagnetic scale.
- In the past 20 years the DREAM/RD52 Collaboration built and tested three different prototypes that confirmed the feasibility of this calorimetric technique.

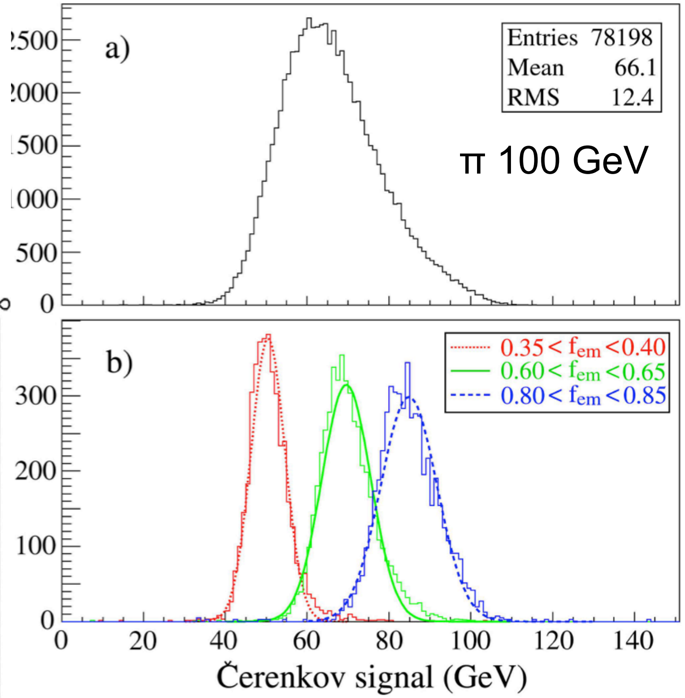
Em resolution: $\dfrac{11\%}{\sqrt{E}} + 1\%$

Had resolution: $\dfrac{70\%}{\sqrt{E}}$

Leakage dominated





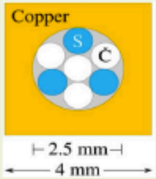


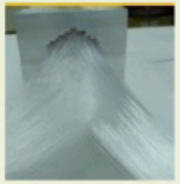
$$S = E[fem + (h/e)_s(1 - fem)]$$
$$C = E[fem + (h/e)_c(1 - fem)]$$
$$\frac{C}{S} = \frac{fem + (h/e)_c(1 - fem)}{fem + (h/e)_s(1 - fem)}$$

Calorimetro RD52 (PMT-readout)

2003
DREAM

Copper
2m long, 16.2 cm wide
19 towers, 2 PMT each
Sampling fraction: 2%

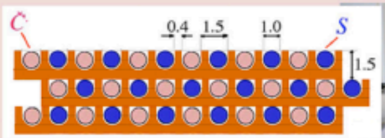




2012
RD52

Copper, 2 modules

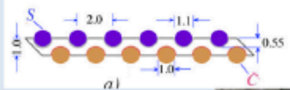
Each module: 9.3 * 9.3 * 250 cm^3
Fibers: 1024 S + 1024 C, 8 PMT
Sampling fraction: 4.5%, 10 λ_{int}



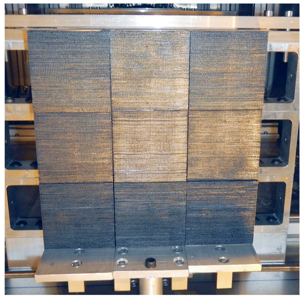
2012
RD52

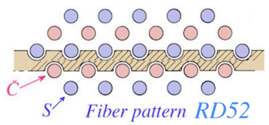
Lead, 9 modules

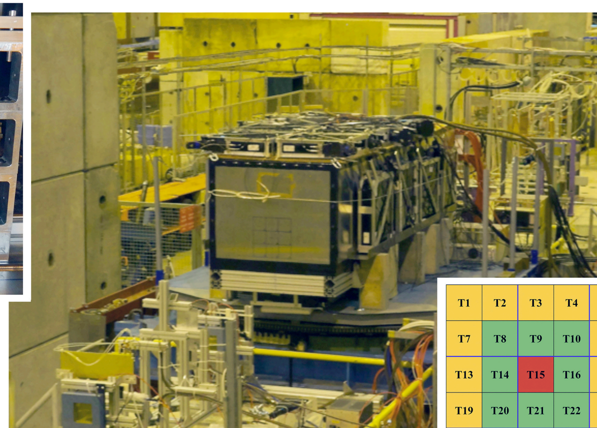
Each module: 9.3 * 9.3 * 250 cm^3
Fibers: 1024 S + 1024 C, 8 PMT
Sampling fraction: 5%, 10 λ_{int}

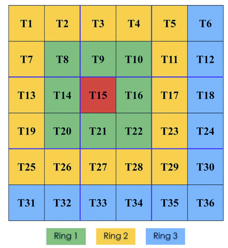


Modulo per TB2018



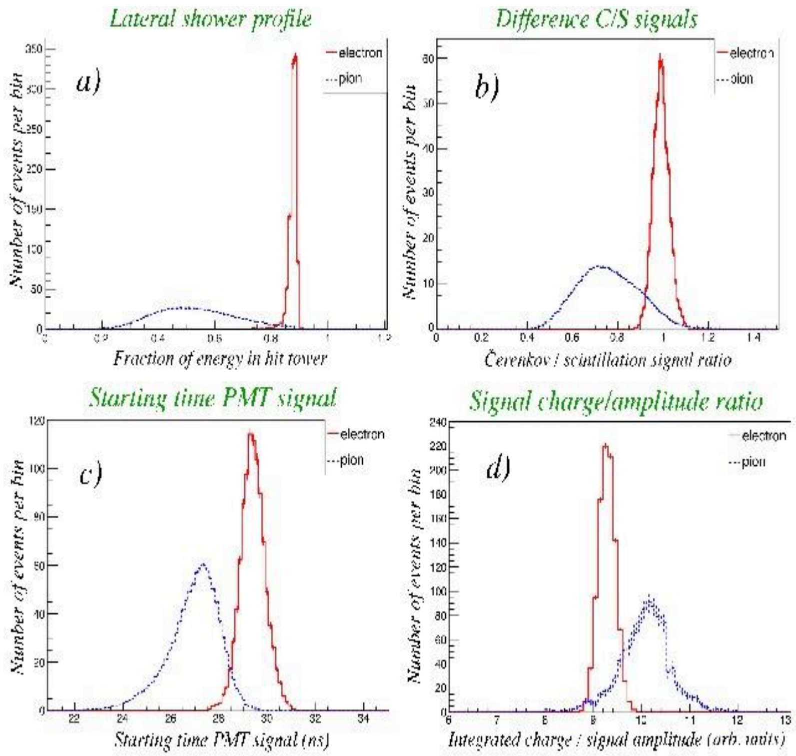






PID and segmentation

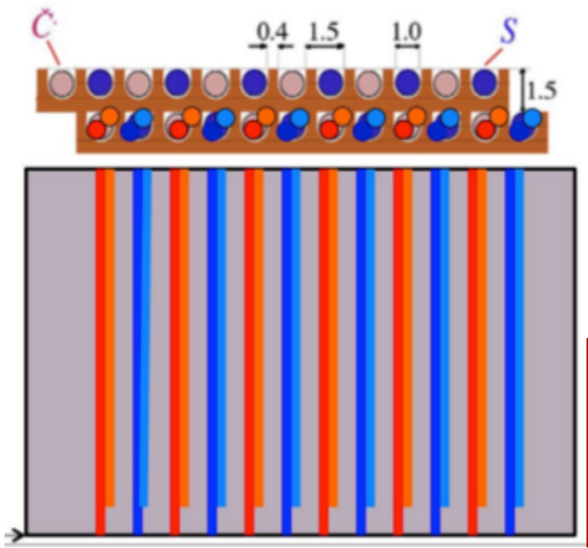
- A dual readout fibre calorimeter offers at least four different methods for electron/pion separation. This has been investigated both with data and simulations
  - Lateral shower profile
  - Difference C/S signal
  - Starting time
  - Signal charge/amplitude ratio

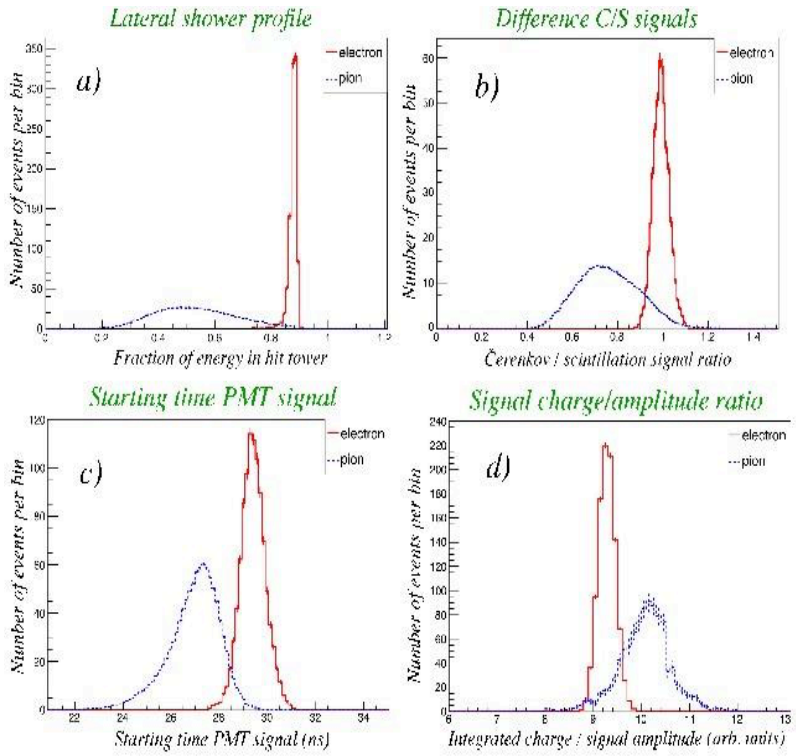


PID and segmentation

- A dual readout fibre calorimeter offers at least four different methods for electron/pion separation. This has been investigated both with data and simulations

- However, particle identification capability in a multiparticle environment has never been studied. This could be studied using a longitudinally segmented device or by taking the signals time of arrival



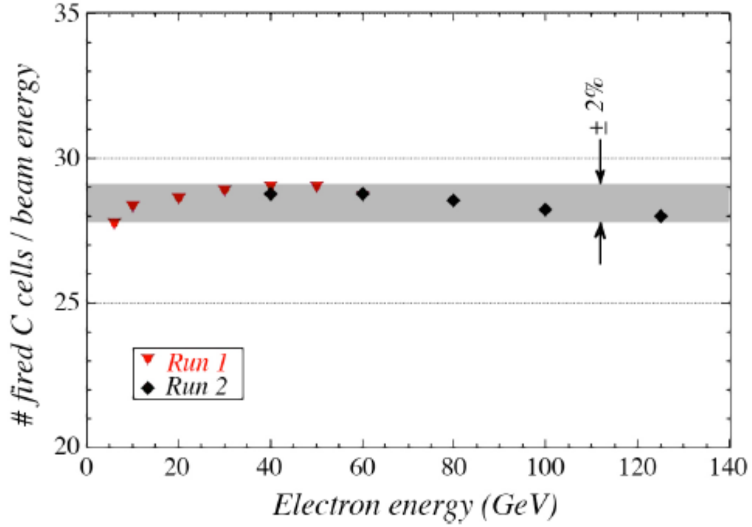


In collaborazione con i colleghi di FCC-ee:
in prima approssimazione si vuole riutilizzare un modulo sito a Pavia dopo averlo opportunamente modificato (considerati solo i costi di trasporto)

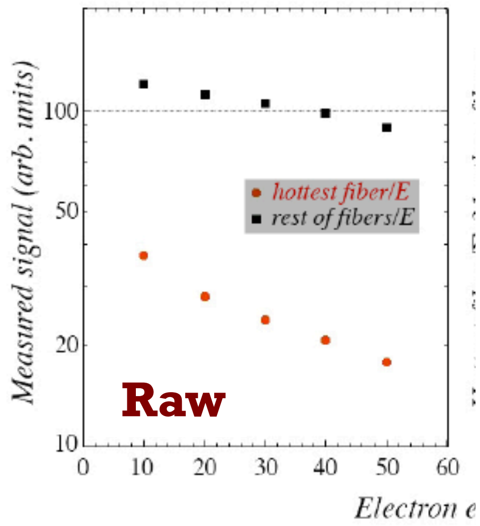
Calorimetro: SiPM-readout

TestBeam 2017

Andamento dei segnali Cherenkov



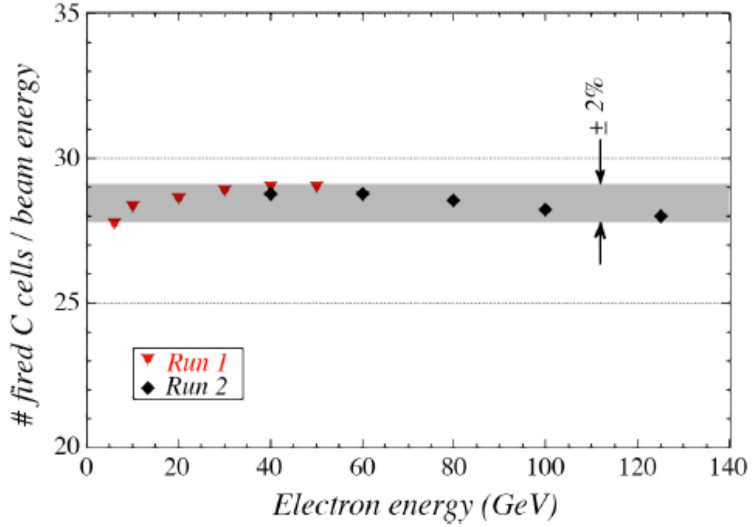
- Andamento dei segnali Scintillanti
  - segnale nel seed
  - segnale nelle restanti fibre



Calorimetro: SiPM-readout

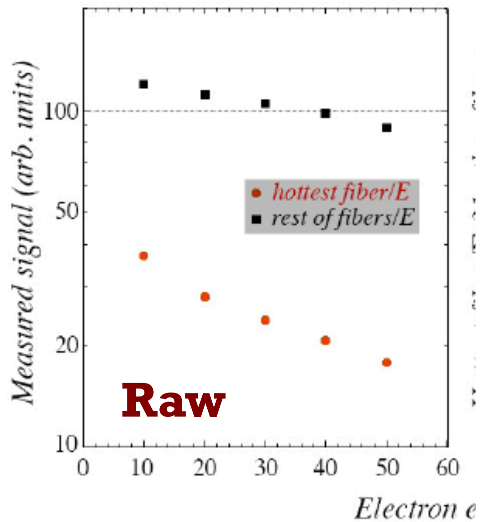
TestBeam 2017

Andamento dei segnali Cherenkov

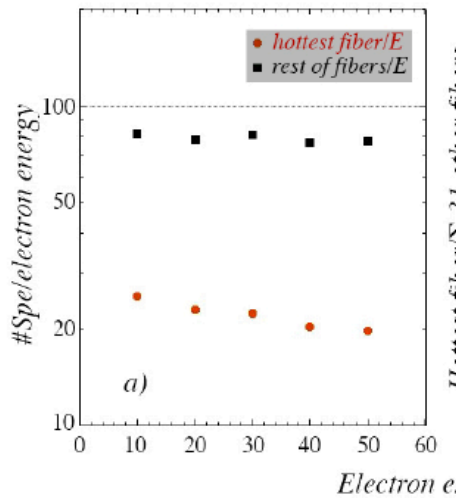


- Andamento dei segnali Scintillanti
  - segnale nel seed
  - segnale nelle restanti fibre
- Correzione per non-linearità

$$N_{fired} = N_{total} \times \left[1 - e^{-\frac{N_{photons} \times PDE}{N_{total}}}\right]$$



Corrected



Test Beam 2018

- Cross-Talk misurato: è stato ridotto da ≈25% misurato nel 2016 a ≈0.3% nel 2017
- Rapporto segnali luce scintillante/Cherenkov dopo la correzione del crosstalk: ≈ 60
- Numero di fotoni attesi nella leading fiber: ≈100 ph/GeV
- Idee in fase di studio:
  - ottimizzazione dynamic range e PDE del SiPM per la lettura delle fibre scintillanti
  - Attenuare la luce scintillante
  - migliorare l'isolamento delle fibre per ridurre ulteriormente il cross-talk

Si sta verificando la possibilità di un test beam dedicato ad Ottobre insieme alle μ RWell

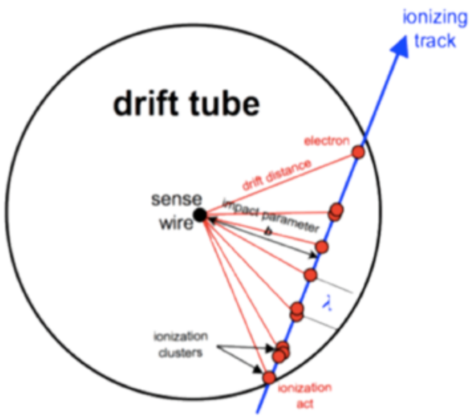
Costi

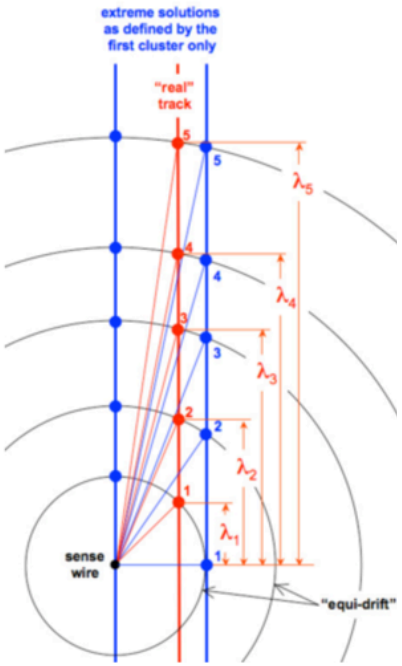
- Consumi
  - Camere a Fili: 2 keuro
  - Calorimetro:
    - modulo SiPM: 4 keuro
    - Modulo RD52: 1 keuro
  - μ RWell: 5 keuro
    - 1 SRU + 4 APV master, 4 APV slave, cavi, transciver
- Missioni
  - Camere a fili: 2 persone x 10 giorni
  - Calorimetro: 5 persone x 10 giorni
  - μ RWell: 3 persone x 10 giorni
  - Modulo con fibre disallineate: 2 keuro (costi trasprto)
  - Smantellamento area RD52: circa 3 keuro

backup

- ....

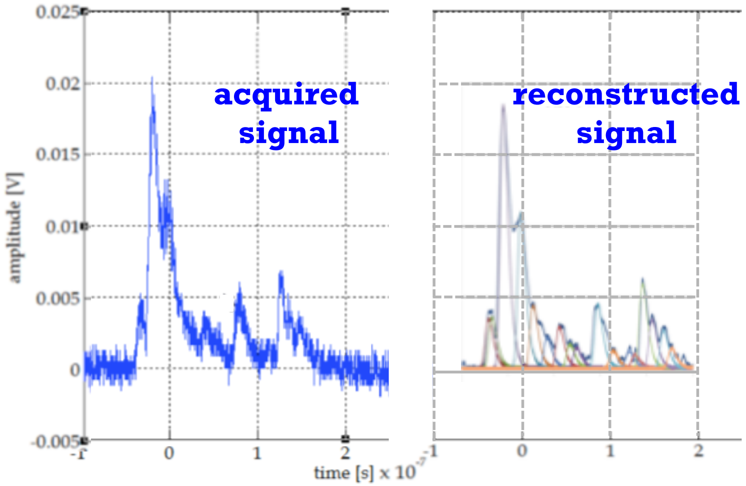
Cluster Timing/Counting

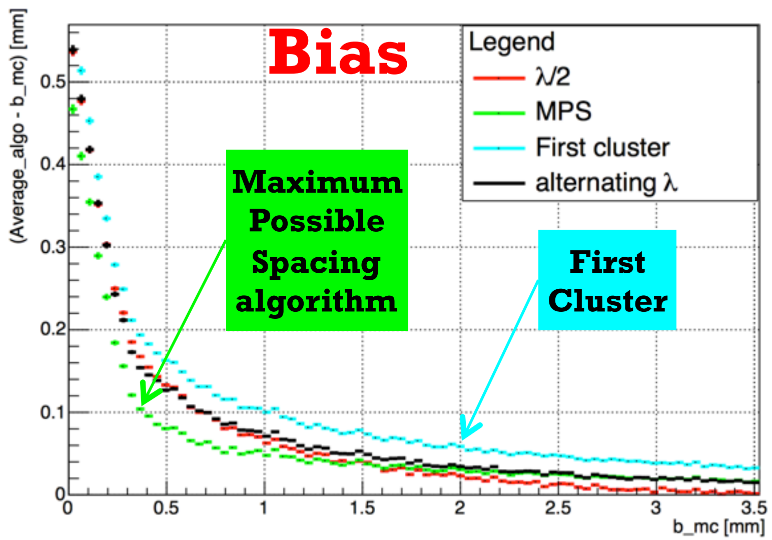




From the **ordered sequence of the electrons arrival times**, considering the average time separation between clusters and their time spread due to diffusion, **reconstruc** $\{t_i^{cl}\} \quad i = 1, N_{cl}$ **probable sequence of ers drift times:**

For any given first cluster (**FC**) drift time, the **cluster timing technique** exploits the drift time distribution of all successive clusters $\{t_i^{cl}\}$ to determine the most probable impact parameter, thus reducing the **bias** and the average **drift distance resolution** with respect to those obtained from with the FC method alone.

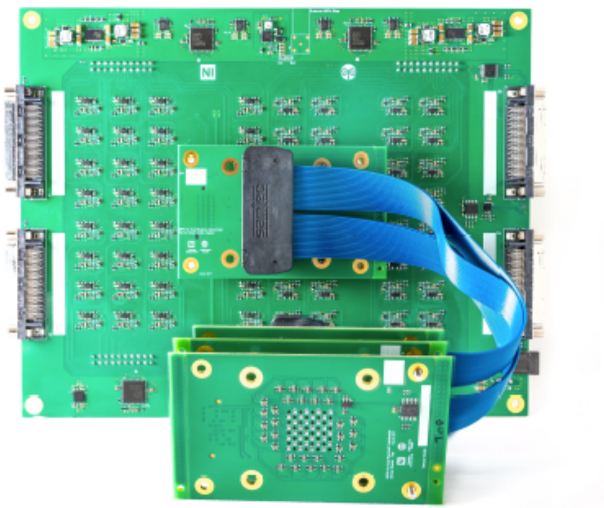




Calorimetro: SiPM-readout

TestBeam 2017

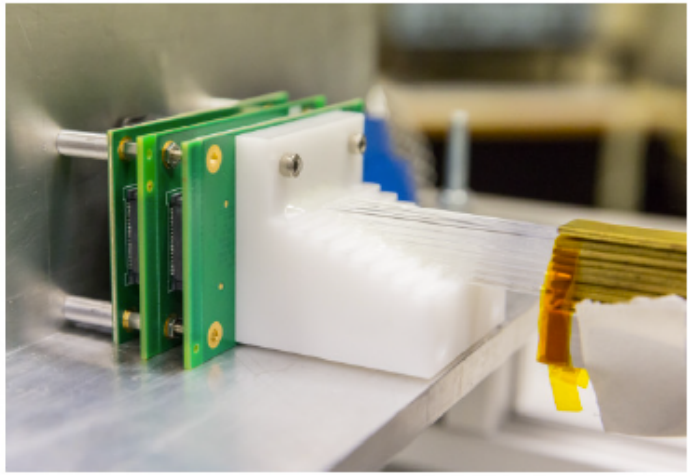
FEE-Board

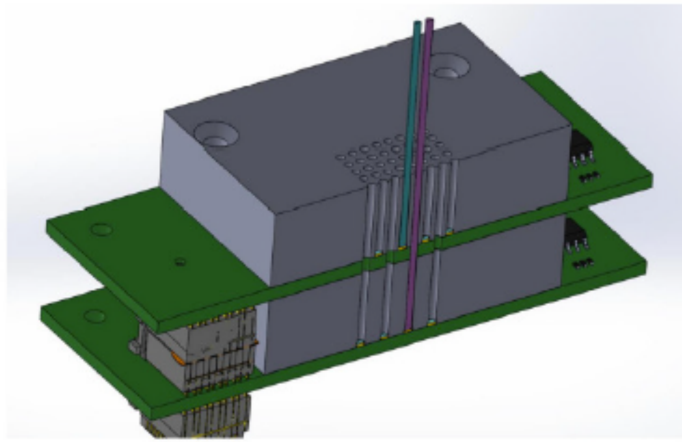


DAQ-System

- The MADA is a 32 channel digitizer with on-board intelligence
- Sampling rate 80MSpS/14-bit ADC
- FPGA based charge integration algorithm

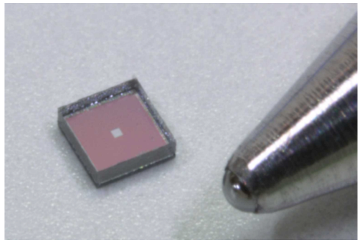
Connessione Fibre



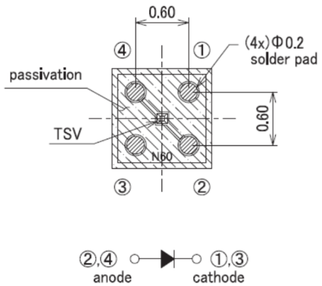


Selected SiPM

TestBeam 2017



Parameters	S13615		Unit
	-1025	-1050	
Effective photosensitive area	1.0x1.0		mm^2
Pixel pitch	25	50	μm
Number of pixels / channel	1584	396	-
Geometrical fill factor	47	74	%



Parameters		Symbol	S13615		Unit
			-1025	-1050	
Spectral response range		λ	320 to 900		nm
Peak sensitivity wavelength		λp	450		nm
Photon detection efficiency at λp[*3]		PDE	25	40	%
Breakdown voltage		V_{BR}	53 ±5		V
Recommended operating voltage[*4]		V_{op}	V_{BR} + 5	V_{BR} + 3	V
Dark Count	Typ.	-	50		kcps
	Max.		150		
Crosstalk probability	Typ.	-	1	3	%
Terminal capacitance		Ct	40		pF
Gain[*5]		M	7.0×10^5	1.7×10^6	-