

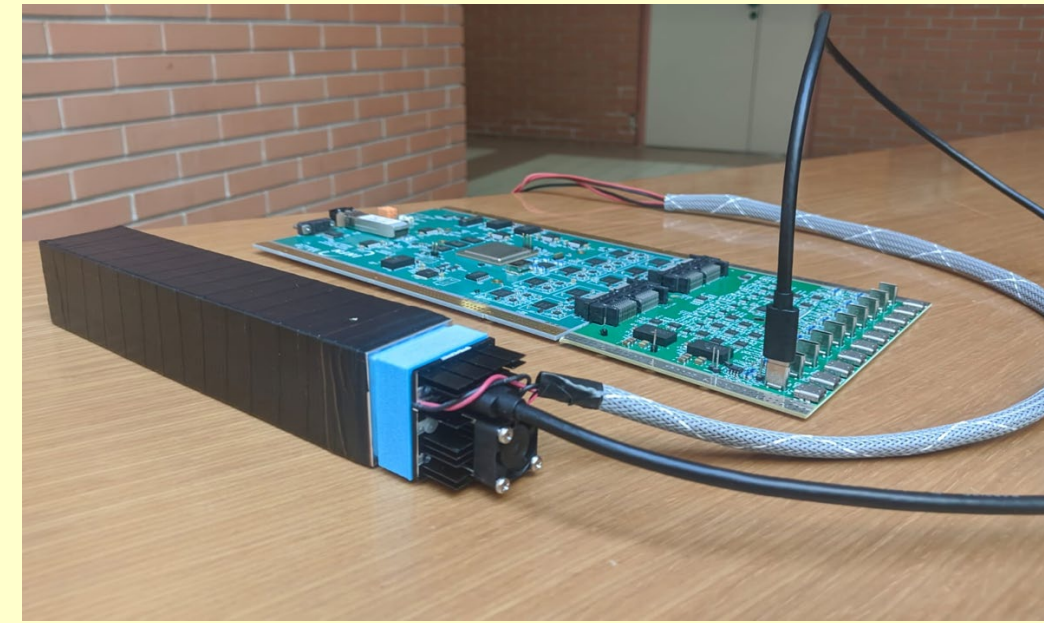
## HAMLET: the IDEA

«Development of a fast, high resolution data acquisition system, qualified for hostile environments and easily interfaced with a wide range of sensors»

- We started from the project of the 20-channel digitizer developed as part of the electromagnetic calorimeter project of the Mu2e experiment at Fermilab:
  - Mu2e has developed a fast digitizer qualified for use in extreme environments (vacuum, magnetic field, ionizing and non-ionizing radiation)
  - The project and the qualification tests required a significant commitment in terms of human and economic resources by the INFN
- We did not find commercial analogues
- There was interest in this device in fields other than high energy physics (nuclear, space, medical and industrial)

## HAMLET: the PROJECT

- Development of a 20-channel digitizer based entirely on commercial components and easily interfaced to different types of signals
- A demonstrator based on an array of SiPMs coupled to a scintillating crystal and connected to the digitizer was developed.



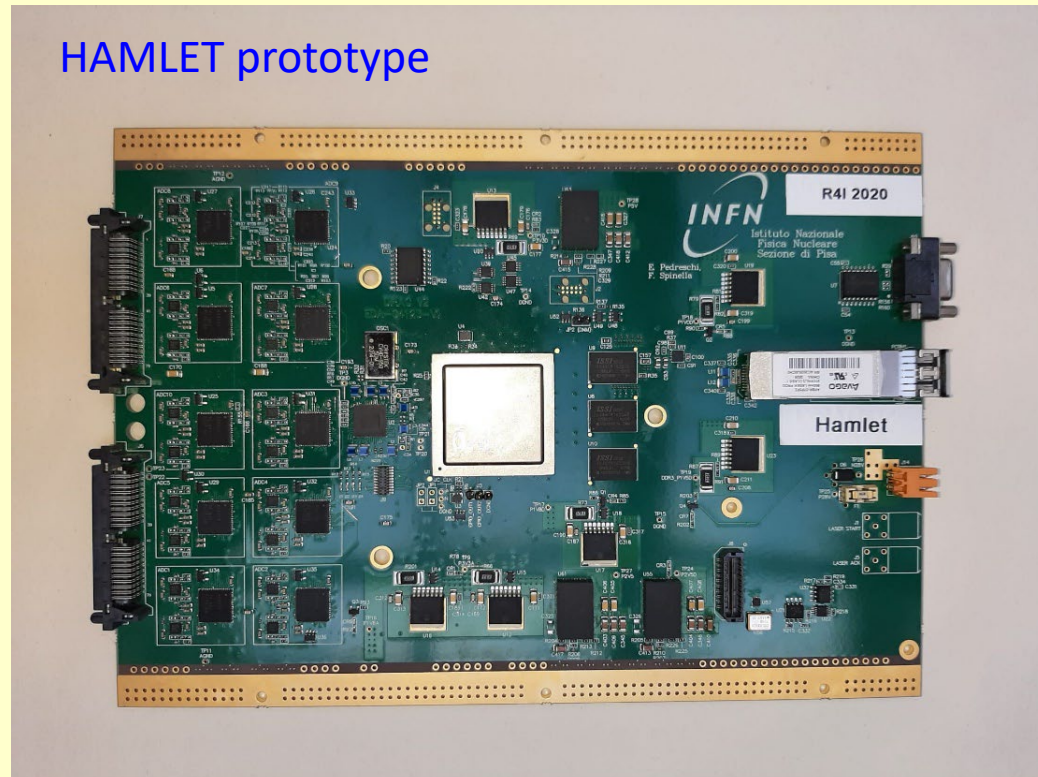
## The DIGITIZER - Specs

Specification:

- 20 channels
- 12 bit @250Msamples/s
- Fully differential inputs
- Qualified for hostile environments
- 4 interfaces:
  - optical fiber (up to 10 Gbit)
  - UART
  - Gigabit Ethernet
  - Can Bus

Qualification levels:

- TID  $\rightarrow$  30 krad
- neutrons  $\rightarrow$   $10^{11}$  n/cm<sup>2</sup> @1 MeV<sub>eq</sub> (Si)/y
- B  $\rightarrow$  1 T
- Vacuum  $\rightarrow$   $10^{-4}$  Torr



## Qualification tests

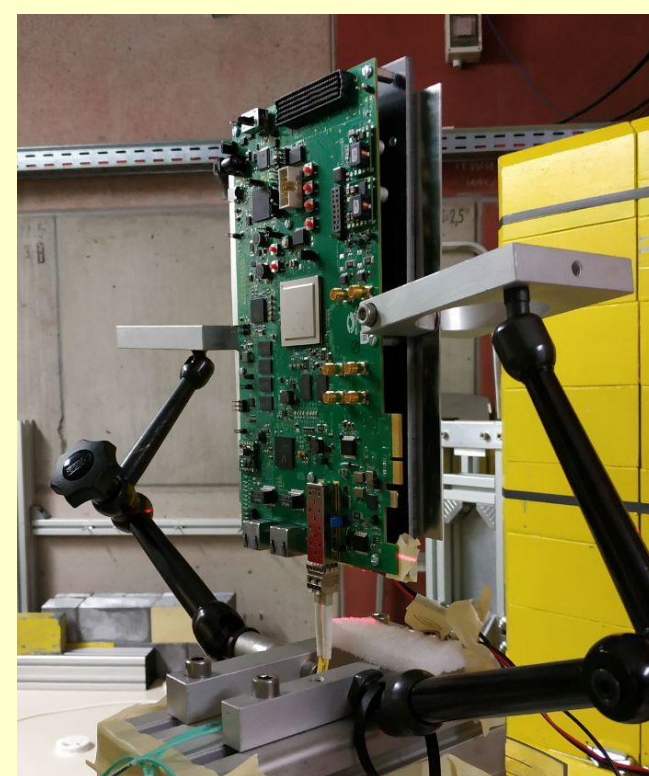


Test campaigns carried out:

- Total Ionizing Dose (TID)
  - gELBE@HZDR
  - Calliope@ENEA
- Magnetic field (B)
  - LASA@INFN Milano
- Neutrons:
  - FNG@ENEA

## Total Ionizing Dose

- Test of the board up to 30 krad
- Special care for the optical transceiver (need to replace VTRx custom CERN part)
- Tested several 850 nm commercial transceiver
- Selected AVAGO Technologies AFBR-709SMZ : tested up to 230 krad
  - Bit Error Rate (BER) after 20 h of flux @ 12krad/h
  - BER < 10e-15



Debug TRANSCEIVER						
Configuration Report	Smart BERT	Loopback Modes	Static Pattern Transmit	Eye Monitor		
Transceiver Hierarchy	EQ- NearEnd	TX PLL	RX PLL	Lock to Data	Cumulative Error Count	Data Rate (Gbps)
SmartBERT Core 0: DSsmartBER	Enable				0	2.5
LANE0						5.45e-15

AVAGO Technologies AFBR-709SMZ

## Neutron test

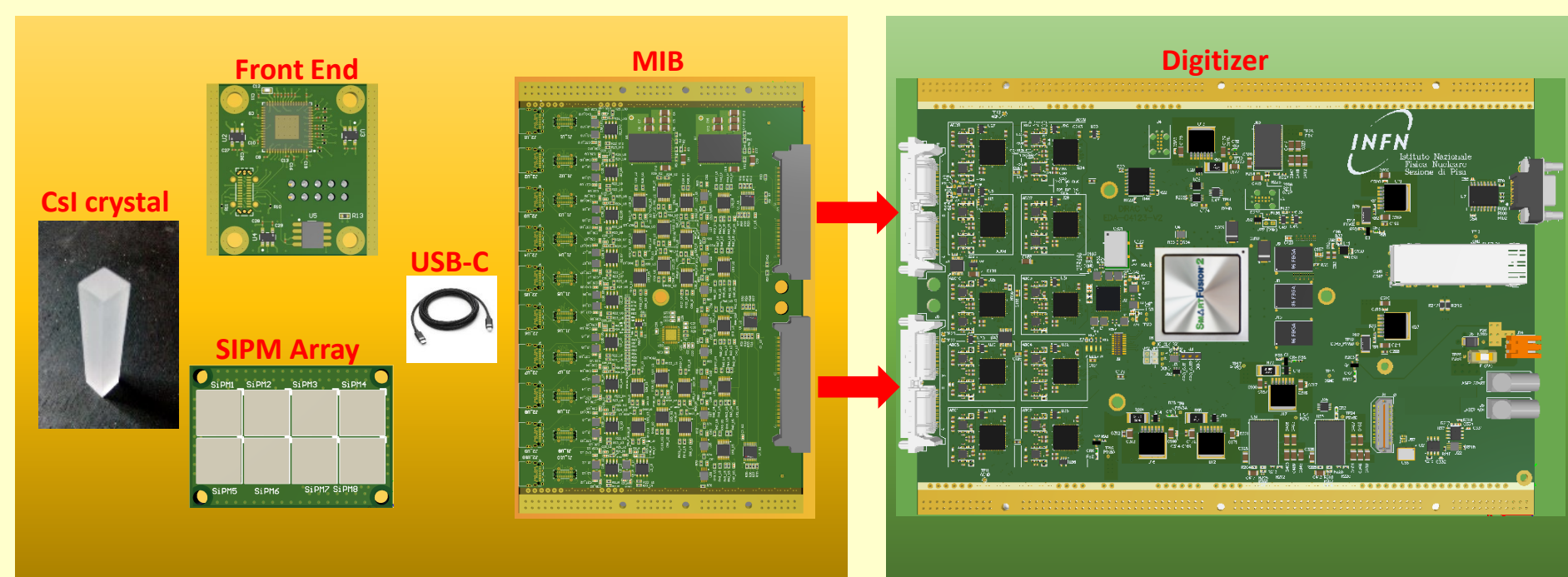
3 days test @FNG (14Mev n)

- Tested up to  $1.6 \times 10^{11}$  n/cm<sup>2</sup> 1 MeV eq
  - No evidence of permanent damage
- Optical transceiver AFBR- 709SMZ tested up to  $10^{12}$  n/cm<sup>2</sup> 1 MeV eq
  - No SEU, no evidence of damage



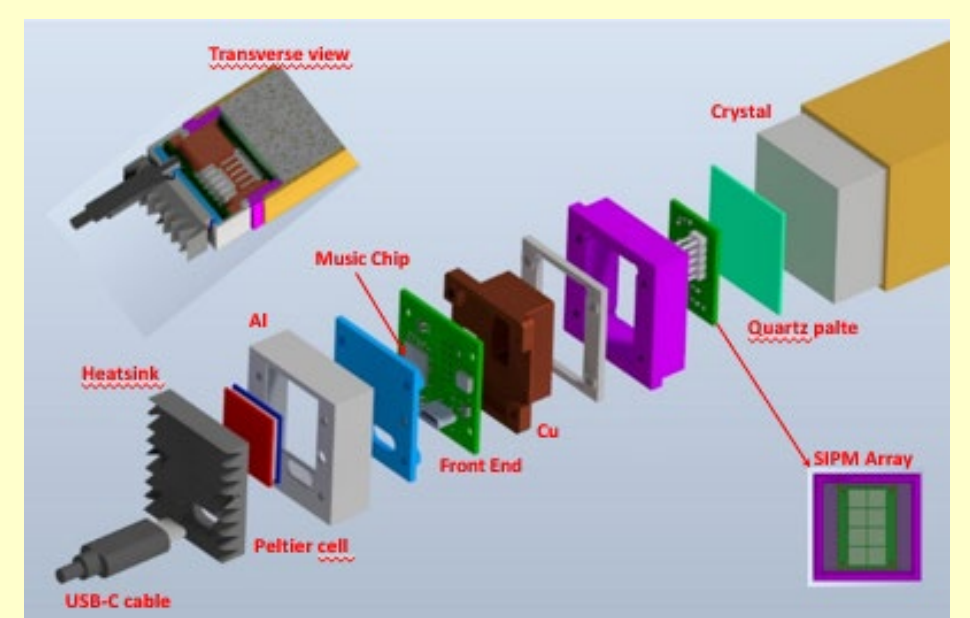
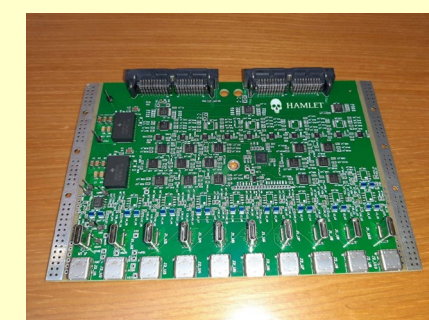
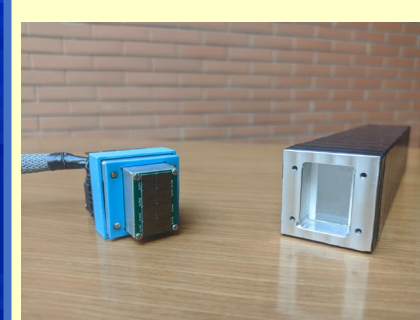
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Transceiver Hierarchy	EQ- NearEnd	TX PLL	RX PLL	Lock to Data	Cumulative Error Count	Data Rate (Gbps)
SmartBERT Core 0: DSsmartBER	Enable				0	2.5
LANE0						4.8 e-15

## Proof of concept



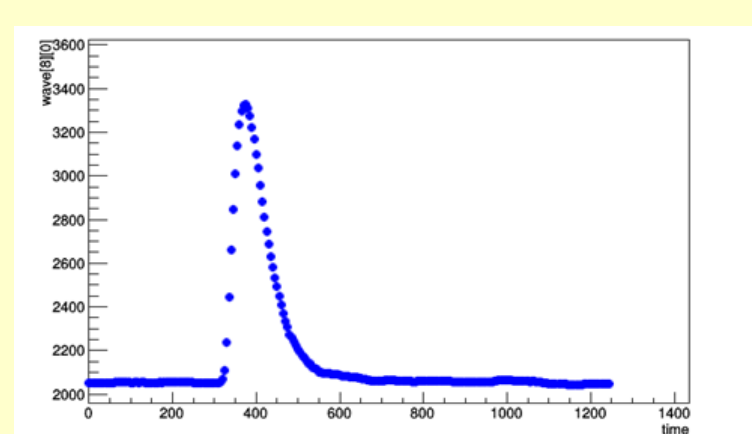
## Crystal based detector

- Crystal: CsI  $\rightarrow$  rad hard, 34\*34\*200 mm<sup>3</sup>
- Front End: Chip Music  $\rightarrow$   $\Sigma$ , shaping, amplification
- SiPM Array  $\rightarrow$  8 SiPM BROADCOM® 6\*6 mm<sup>2</sup>
- Standard USB-C connection

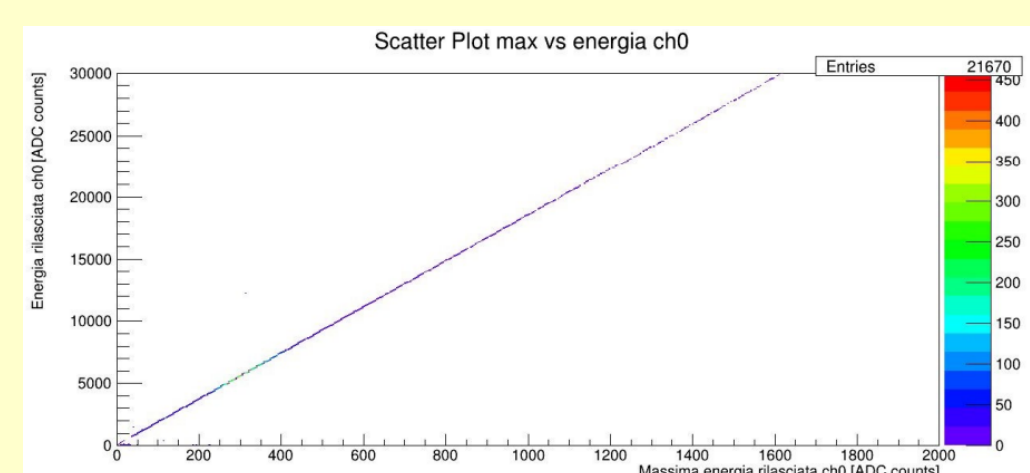


## Test with cosmic

Cosmic data from the complete system (one CsI crystal)



Digitized pulse from music



Pulse charge linearity plot

## Conclusions

- A fast, high resolution data acquisition system has been developed with entirely commercial components, qualified for hostile environments and easily interfaced with a wide range of sensors
- As an example of application, a demonstrator based on an array of SiPMs coupled to a scintillating crystal and connected to the digitizer was developed.