Fast electronics for Mu2e-II calorimeter

Franco Spinella

MidTerm Review, Pisa, March 4-5, 2019

Web site: risenews.df.unipi.it

European Commission

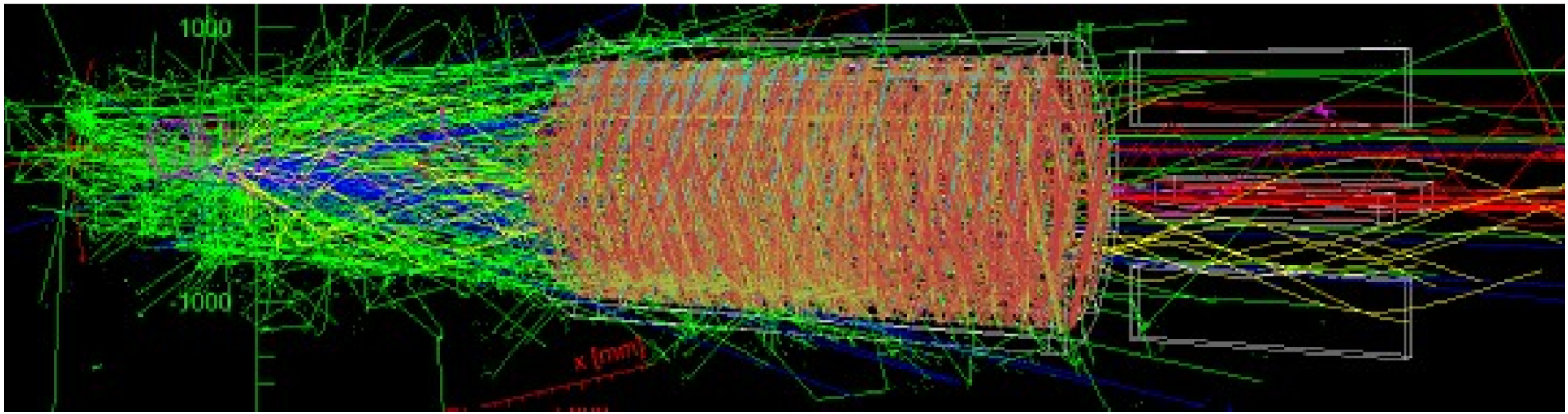
Mu2e-II

Mu2e-II aims to improve of a factor of 10 Mu2e sensitivity, collecting 10 times more events in almost the same time. How ?

It will make use of:

- x10 **beam power**
- **Higher duty cycle** to deliver **x120 POT/year**

The resulting «event» will be much more crowded

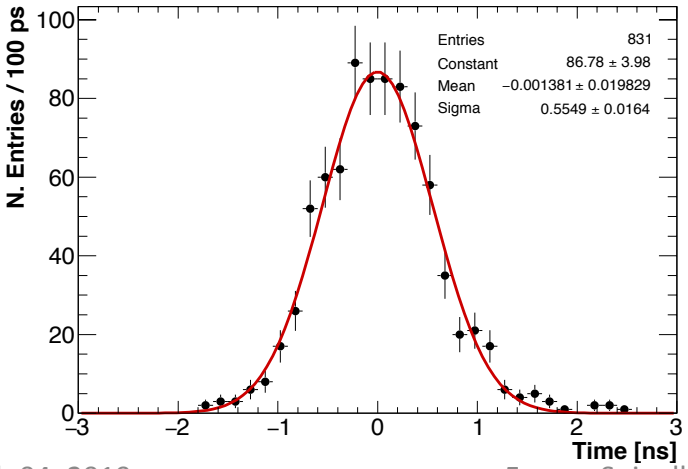


Mu2e-II calorimeter

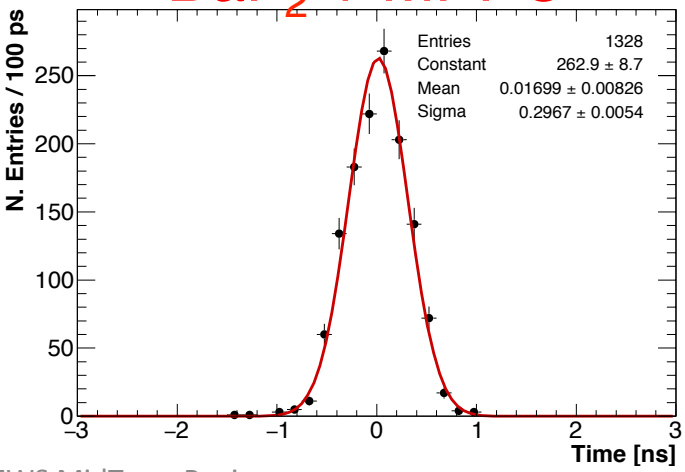
Mu2e calorimeter, based on CsI crystals, is too slow to handle the **increased occupancy**

One possibility is to replace CsI crystals with a **faster crystal: BaF_2**

CsI + MPPC



BaF_2 + MPPC



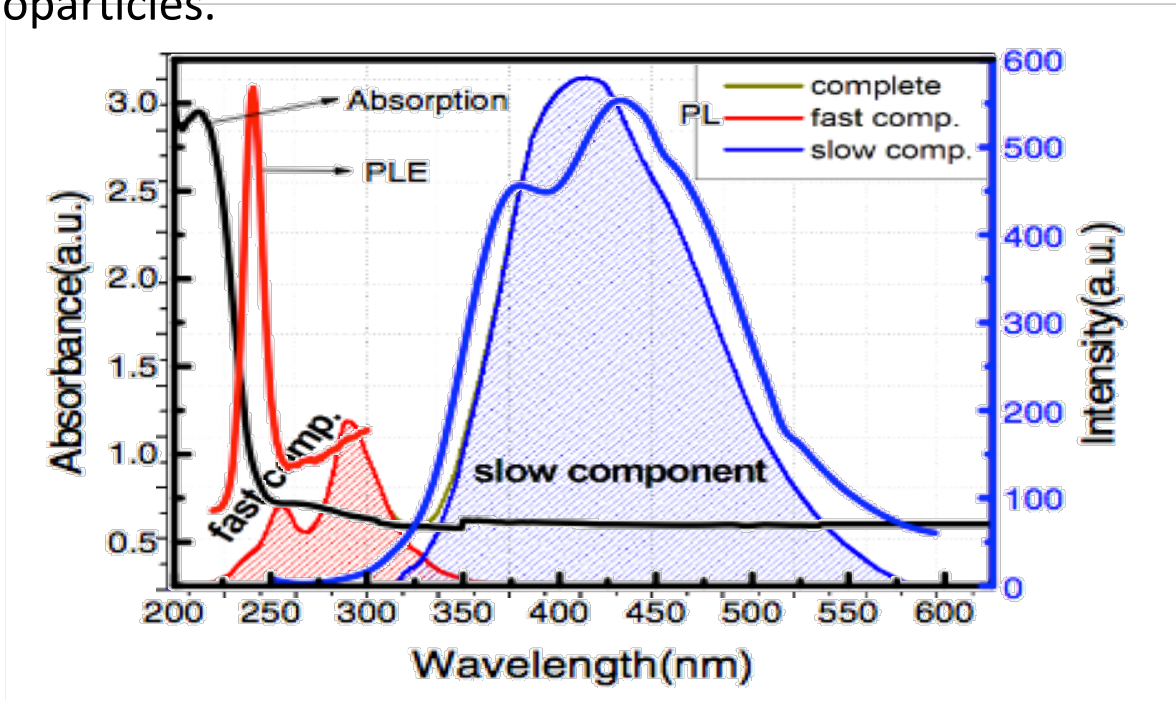
Mu2e-II calorimeter (2)

BaF_2 crystals light emission has 2 components : a fast emission (τ < 1ns) in the 220 nm region and a slow one (τ~ 1μs) in the 300 nm

BaF_2 scint light needs to be filtered -> replace the current Mu2e photosensors

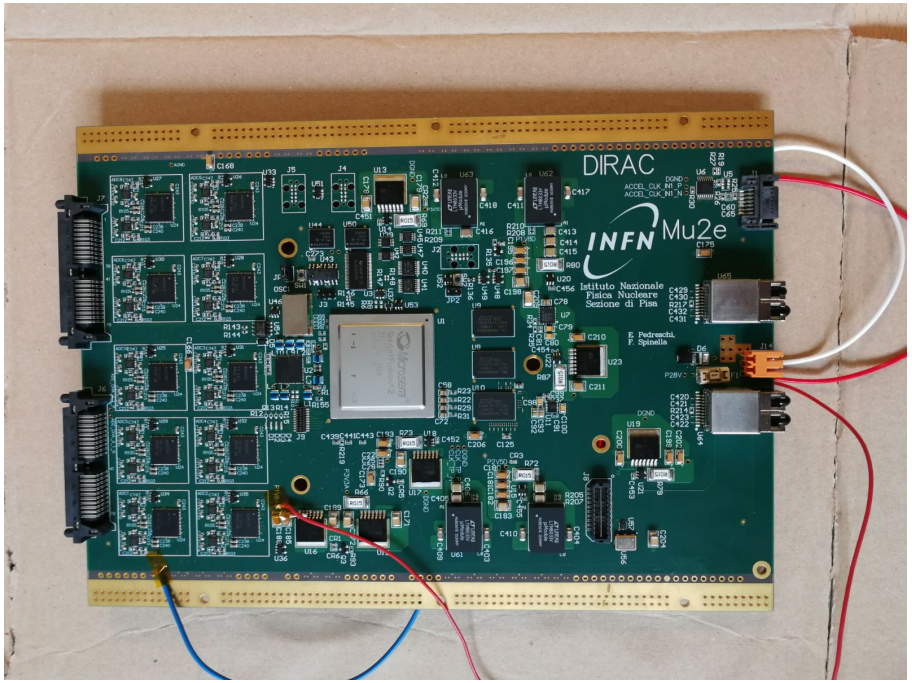
A possible solution is based on a very fast UV-extended SiPM, with a 220 nm filter

The filter is currently under study. A good candidate is based on a molecular layer of LaYO nanoparticles.



New electronics …

BaF_2 crystals coupled with fast photosensors can't be read out with mu2e 200 Ms digitizer …



200 Msamples = 5 ns timestamp

Fast readout …

Mu2e-II calorimeter needs a fast sub-ns readout electronics

But also needs a rad-hard detector system capable of operate @ x10 more radiation dose then Mu2e, operated in a 1T magnetic field and also in vacuum…

Not an easy task …

Possible solutions …

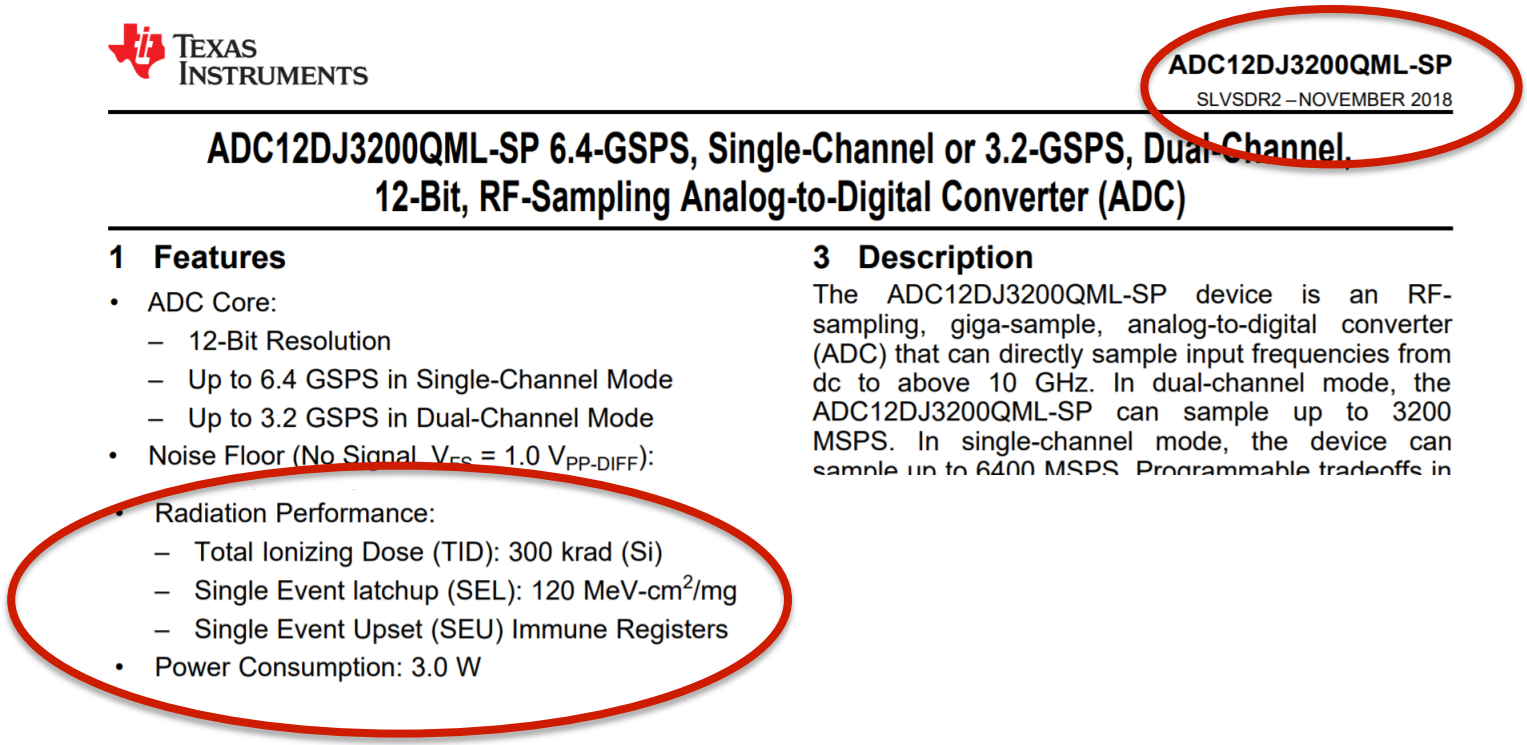
We are starting the discussion with Mu2e Fermilab scientists and experts on the field about possible solutions

My February NEWS secondment was focused on chicking of this discussion

We are currently evaluating 2 possibilities

Solution 1: fast digitizer ADC based

Fast ADC (Analog to Digital Converters) up to several Gsamples are already available on the market …



Texas Instruments

ADC12DJ3200QML-SP

SLVSDR2 – NOVEMBER 2018

ADC12DJ3200QML-SP 6.4-GSPS, Single-Channel or 3.2-GSPS, Dual-Channel, 12-Bit, RF-Sampling Analog-to-Digital Converter (ADC)

1 Features

- ADC Core:
  - 12-Bit Resolution
  - Up to 6.4 GSPS in Single-Channel Mode
  - Up to 3.2 GSPS in Dual-Channel Mode
- Noise Floor (No Signal, V_{FS} = 1.0 $V_{PP-DIFF}$):
- Radiation Performance:
  - Total Ionizing Dose (TID): 300 krad (Si)
  - Single Event latchup (SEL): 120 MeV-cm^2/mg
  - Single Event Upset (SEU) Immune Registers
- Power Consumption: 3.0 W

3 Description

The ADC12DJ3200QML-SP device is an RF-sampling, giga-sample, analog-to-digital converter (ADC) that can directly sample input frequencies from dc to above 10 GHz. In dual-channel mode, the ADC12DJ3200QML-SP can sample up to 3200 MSPS. In single-channel mode, the device can sample up to 6400 MSPS. Programmable tradeoffs in

Solution 1 …

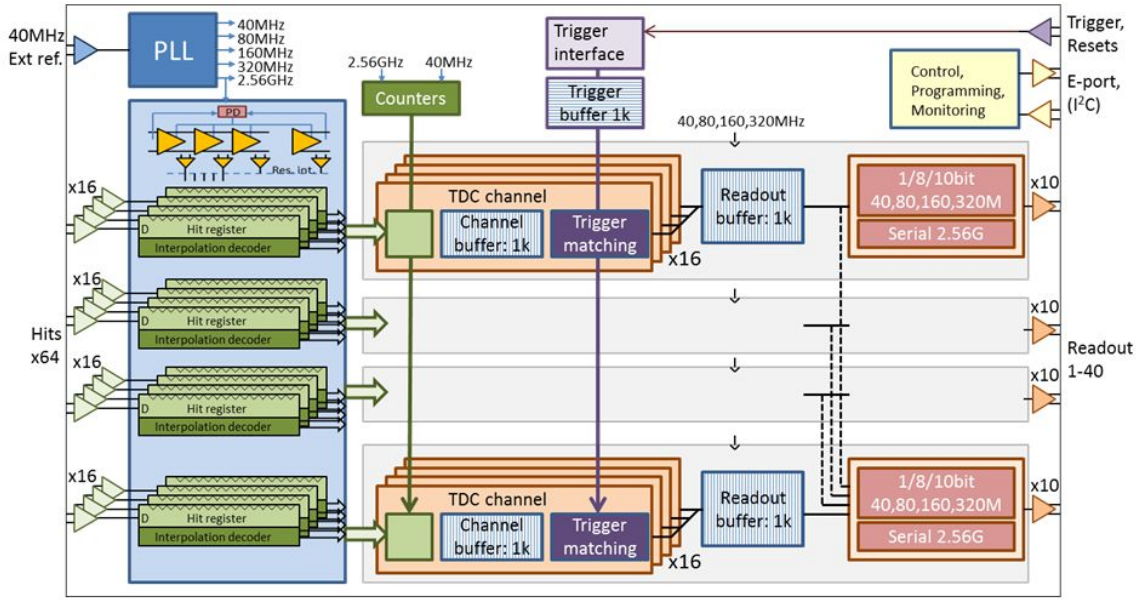
A fast ADC is the best solution to operate in a high pile-up environment, but …

- 3W x 3000 = 9 KW of power to be dissipated in vacuum … just for the ADCs (10 times more then Mu2e)
- Cost 10 times more the Mu2e ADCs …
- Needs a very powerful FPGA to read it …
- Seems rad qualified but must be verified …

Solution 2: fast digitizer TDC based

Fast TDC (Time to Digital Converters), rad-hard qualified, are under development @ CERN

PicoTDC architecture



64 channels, 3ps or 12ps time binning

64 channels, 3ps: ~1W

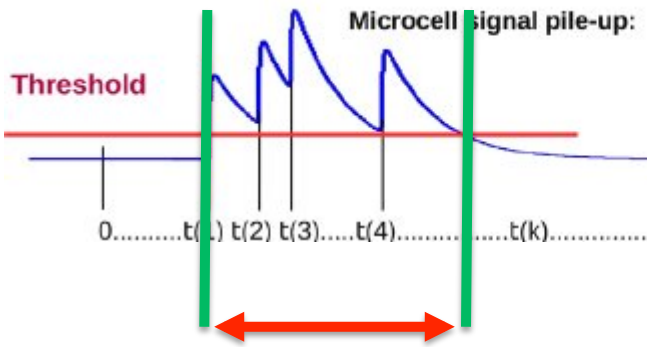
64 channels, 12ps: ~0.4W

32 channels, 12ps: ~0.2W

2

Solution 2 …

- Very good timing resolution for discriminated signals (10 ps)
- Low power …
- Low expensive (relatively …)
- **But** … does not resolve pile-up (big problem for Mu2e-II



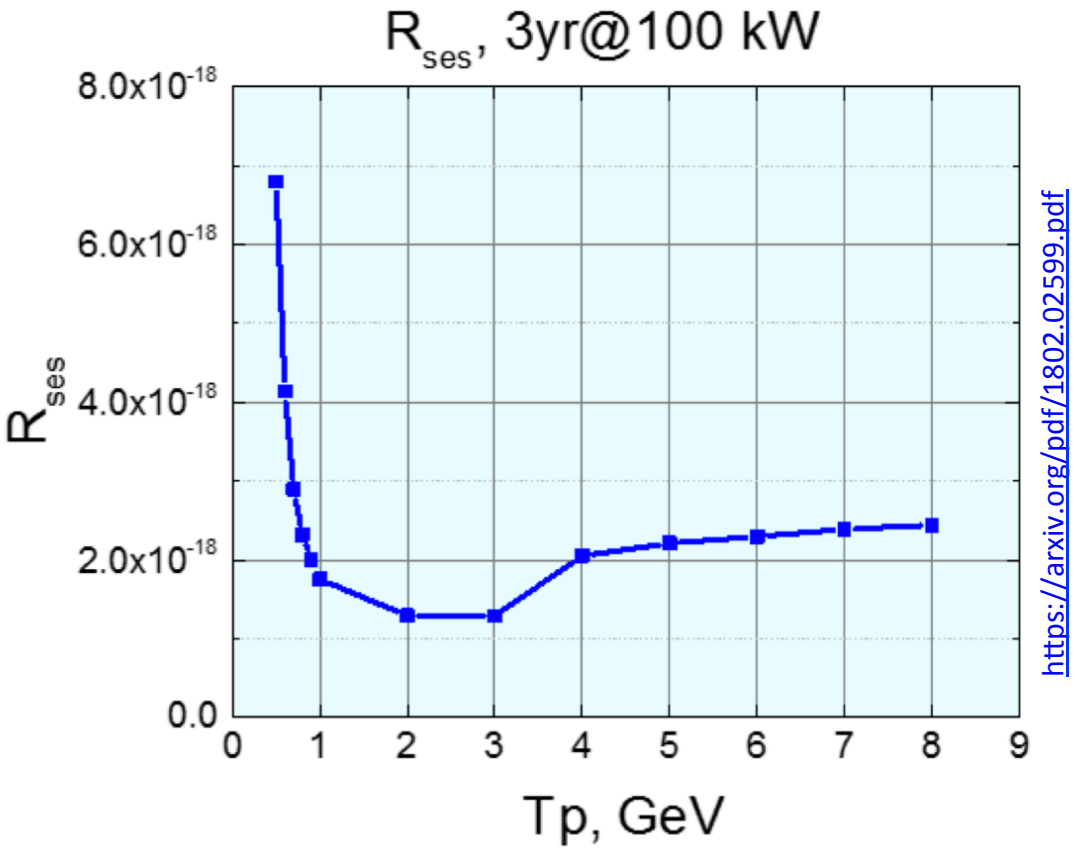
TDC output …

Conclusion

- A simple solution does not exist
- Maybe something hybrid (fast TDC + slow ADC)
- Strong collaboration between INFN and FNAL experts is just started and is ramping up quickly

Mu2e-II sensitivity

- Sensitivity scan w.r.t. the proton-beam energy



https://arxiv.org/pdf/1802.02599.pdf