iPACI: a 16-channel charge sensitive amplifier with current output ASIC

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measurements and simulations

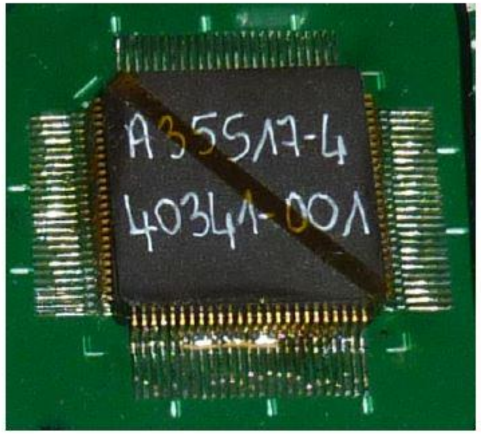
iPACI at IPN Orsay : iPACIv1 and iPACIv2

- iPACIv1 :

Test on DSSSD detector (GRIT prototype) with alpha source in 2015

Experiment at Tandem-ALTO facilities in october 2017

iPACI v2 CQFP100 package



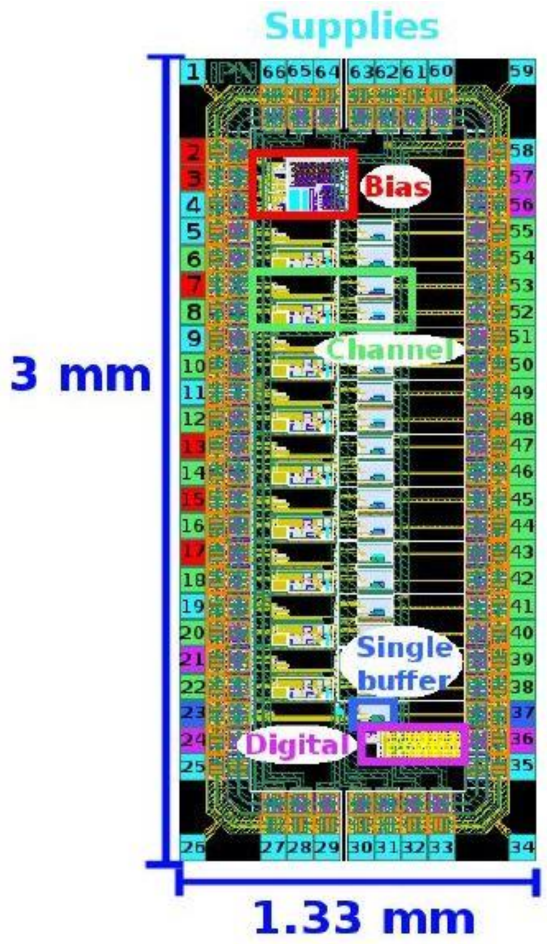
- iPACIv2 :

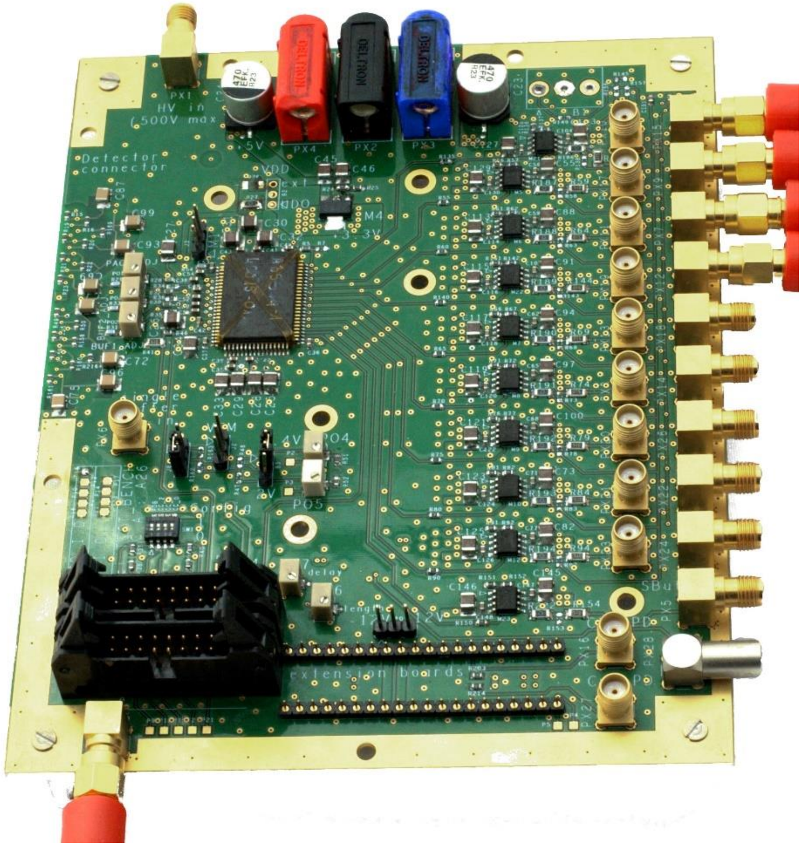
Received in august 2018

First basic tests in winter 2018 with non optimized test-bench

New test-bench expected in january 2020

iPACIv1 : characteristics

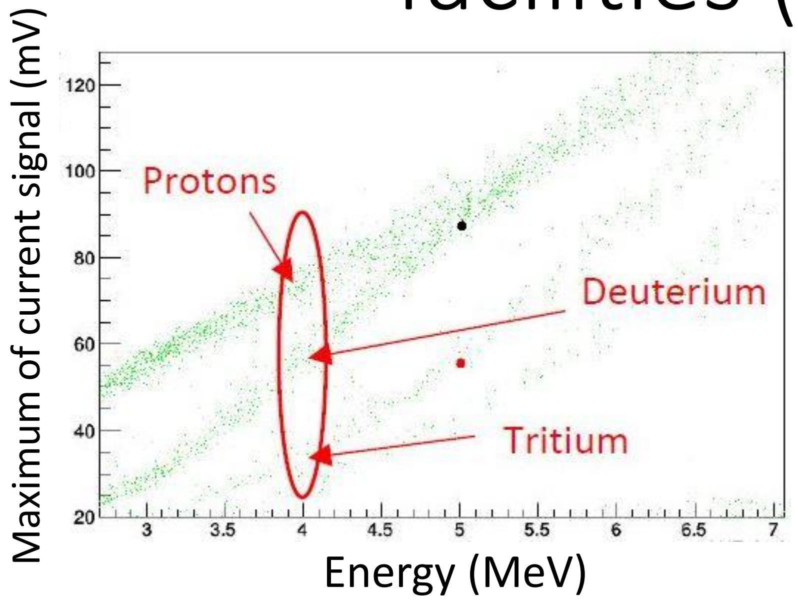


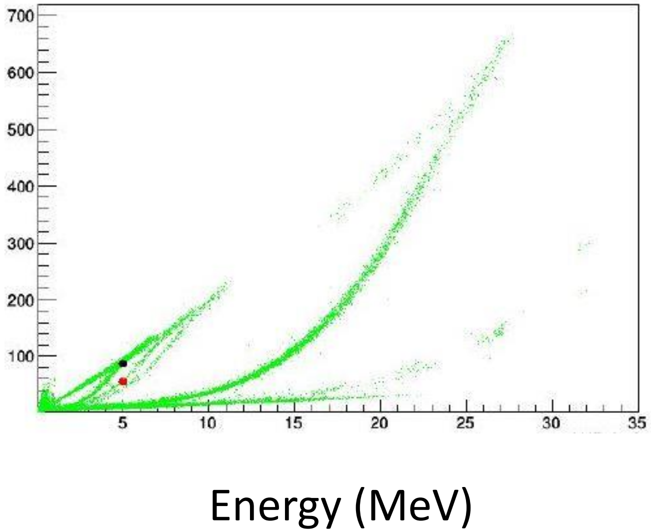


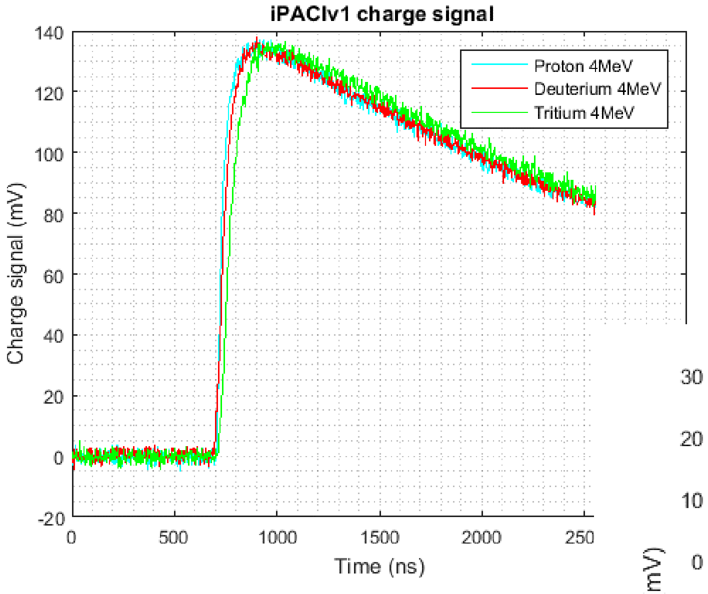
Characteristics (measured) of iPACIv1

- AMS 0,35µm, 4mm2
- 9 detector channels
- Compatible DSSSD 20pF/ch
- Dynamic range = 50MeV
- Charge output gain =32mV/MeV
- Resolution =100keV-FWHM without any shaping
- Resolution=12keV-FWHM with analog shaper about 0,5µs shaping time
- Resolution = 30keV-FWHM with alpha source and with digital filtering (about 100 points of moving average)
- Bandwidth=150MHz on current output
- Independent charge and current outputs per channel

iPACIv1 : beam tests at tandem-ALTO facilities (IPN Orsay) in october 2017



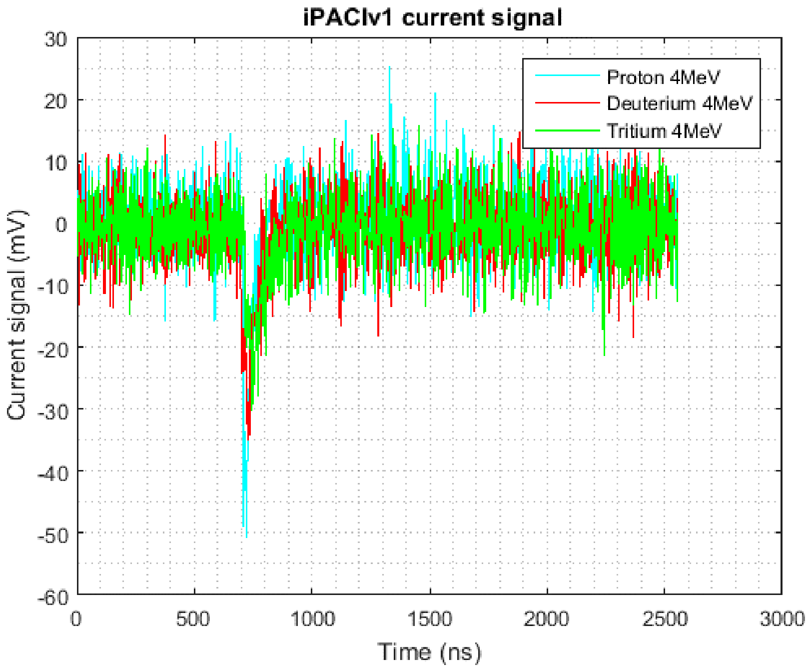




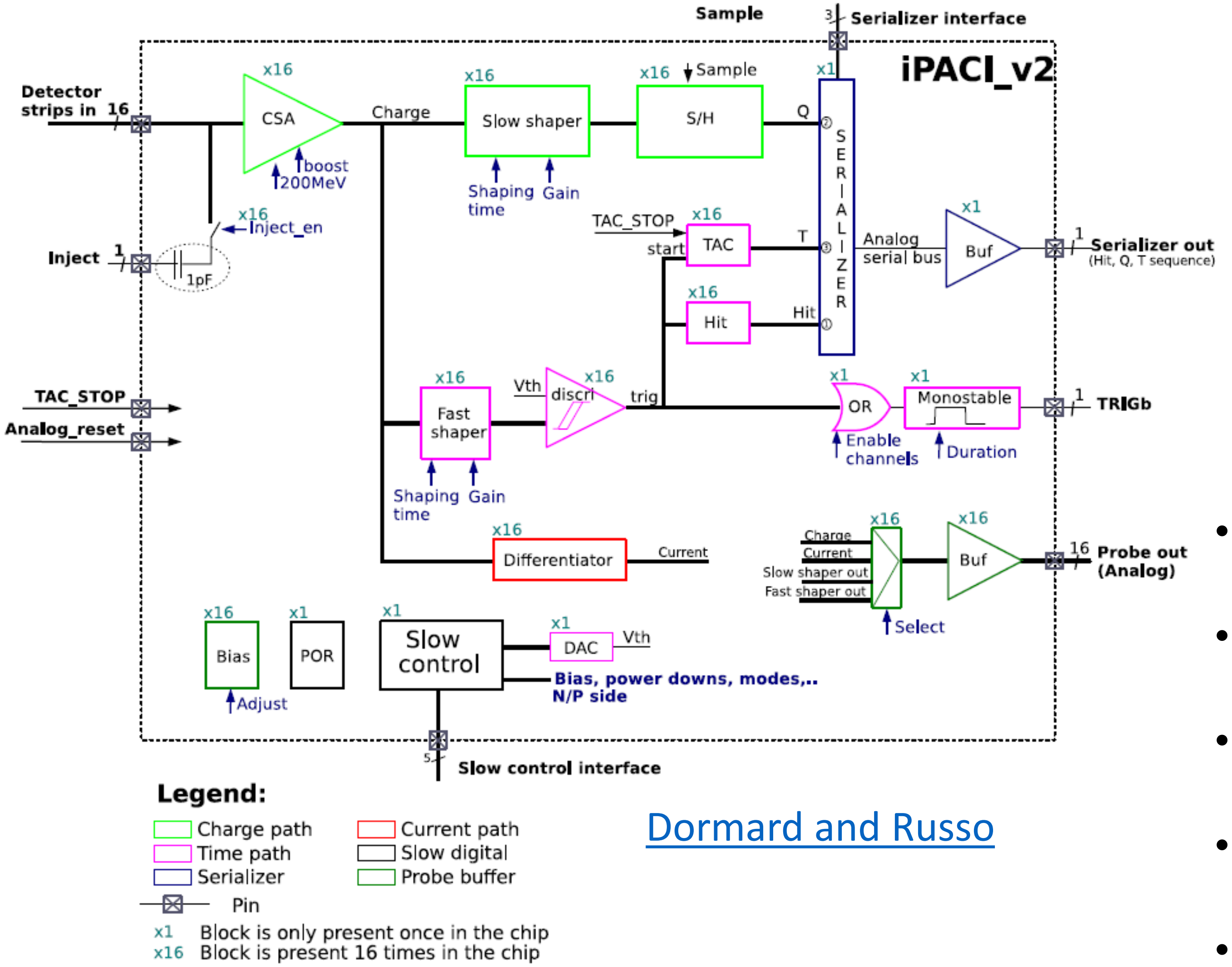
- Maximum of Current signal versus Energy (MeV)
- Energy = maximum of charge signal

The best way to discriminate light particles is to plot Maximum of current signal versus energy (ref [1])

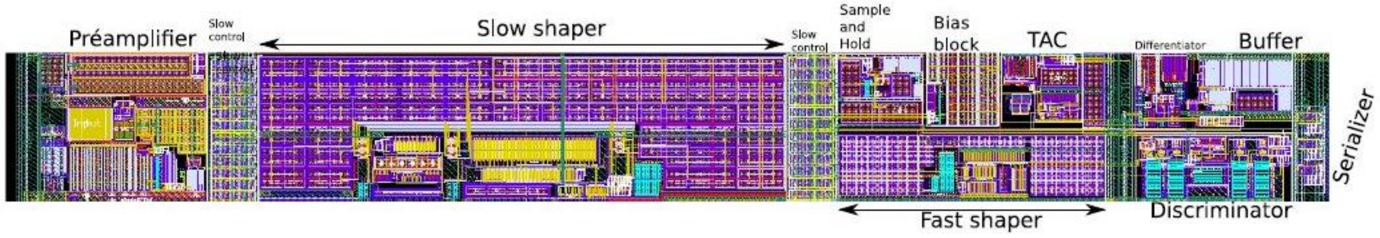
[1] M. Assié, et al., Eur. Phys. J. A 51 (2015) 11.



iPACIv2 : architecture



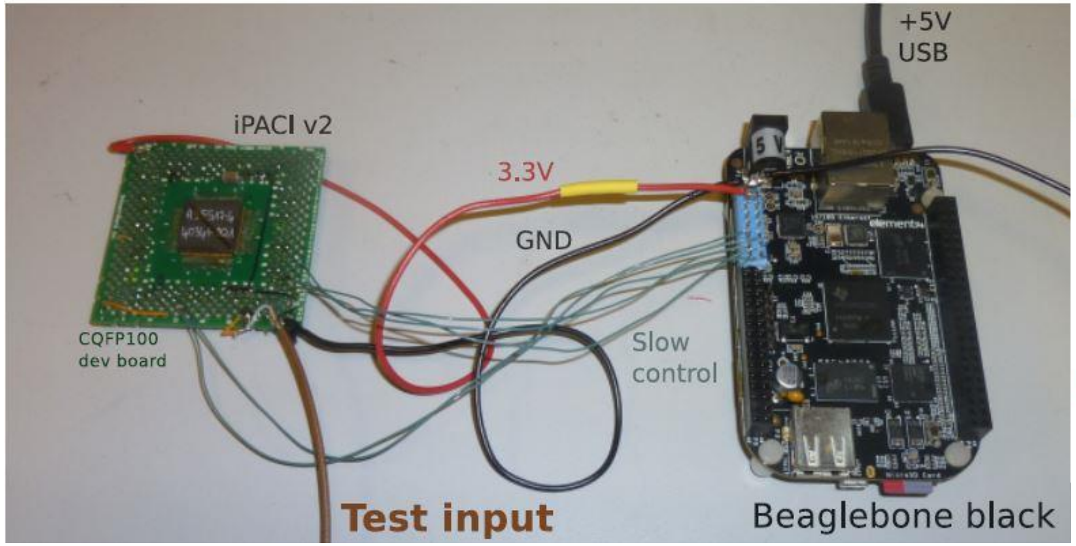
Dormard and Russo



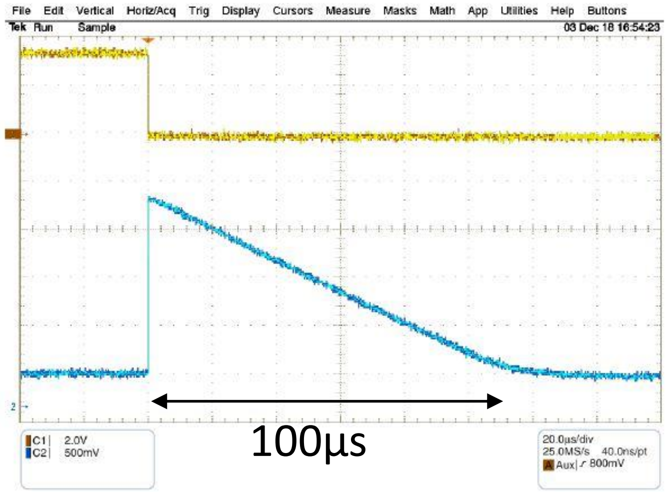
Performance (simulated):
- AMS 0.35µm, 12mm²
- Draws 0.5W on 3.3V
- 16 detector channels
- Compatible whth DSSSD 20pF/ch
- Charge output: 70 MeV/200 MeV @ 15 keV FWHM
- current output : Charge differentiation. BW=150MHz
- Time output : TAC 400ns/800ns @ 500 ps FWHM

- Charge path : CSA + slow shaper with shaping time constant switchable by slow control
- Time path : CSA + fast shaper + discriminator + TAC (Time to Amplitude Converter)
- Energy and time informations for 16 channels are serialized on 1 bus
- Current path => analog derivative of charge signal
- At the Probe output, possibility to check, charge , slow shaper, fast shaper or current signals

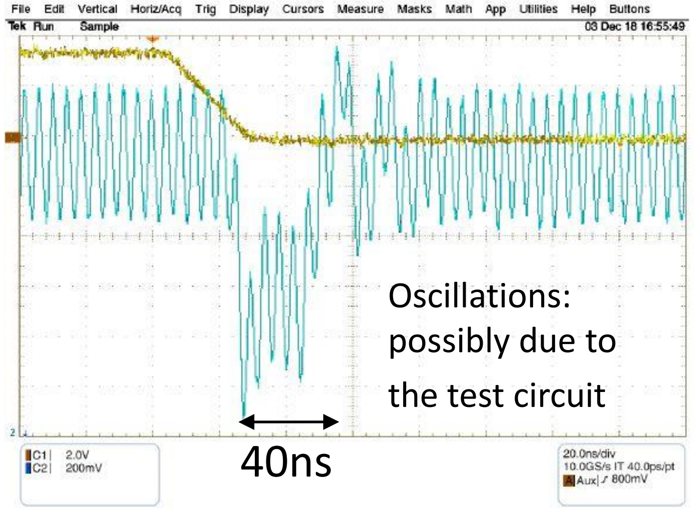
iPACIv2 : measurements



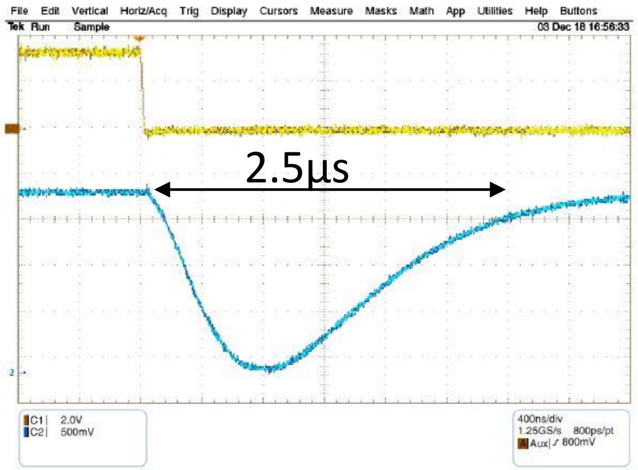
1. Charge 70MeV



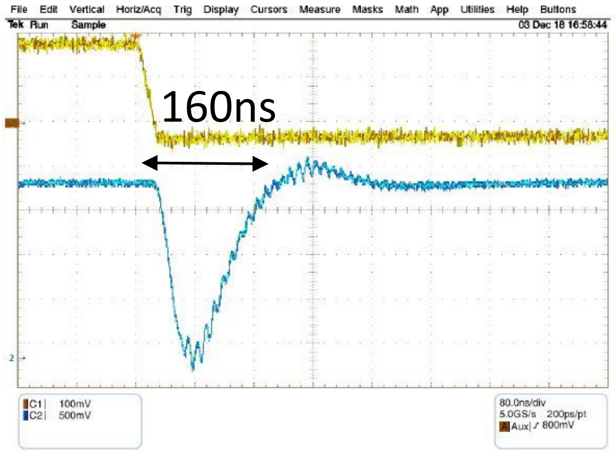
2. Current 70MeV



3. Slow Shaper 70MeV



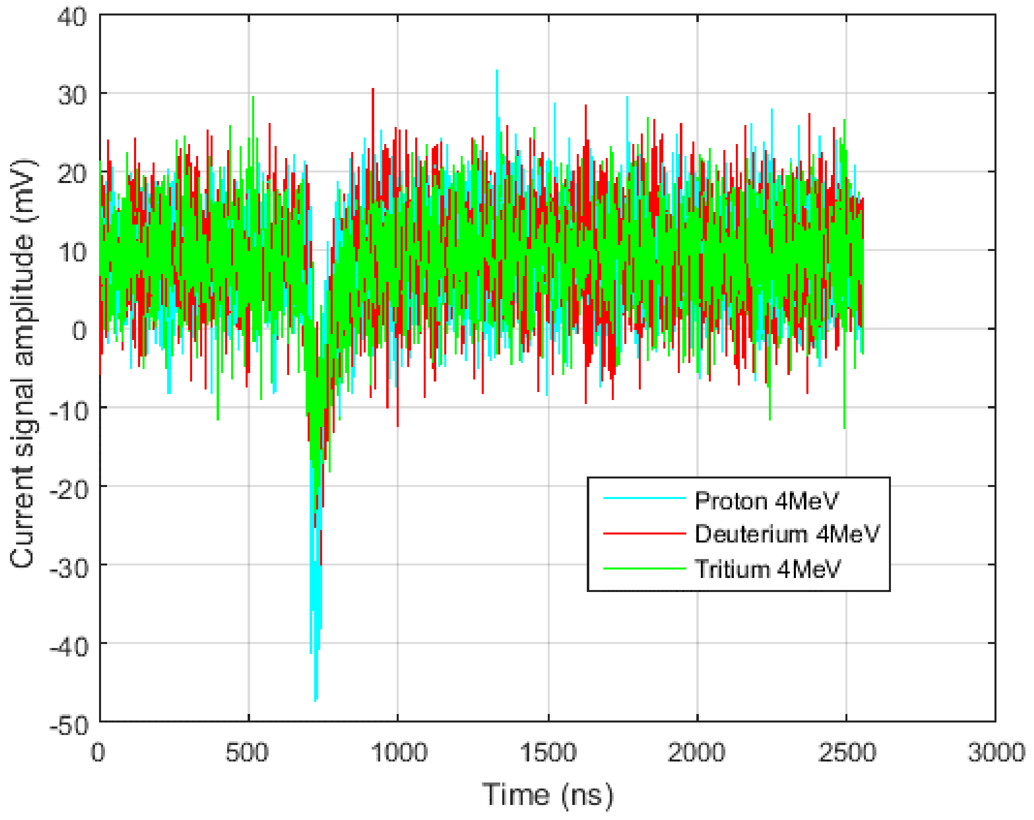
4. Fast shaper 4MeV



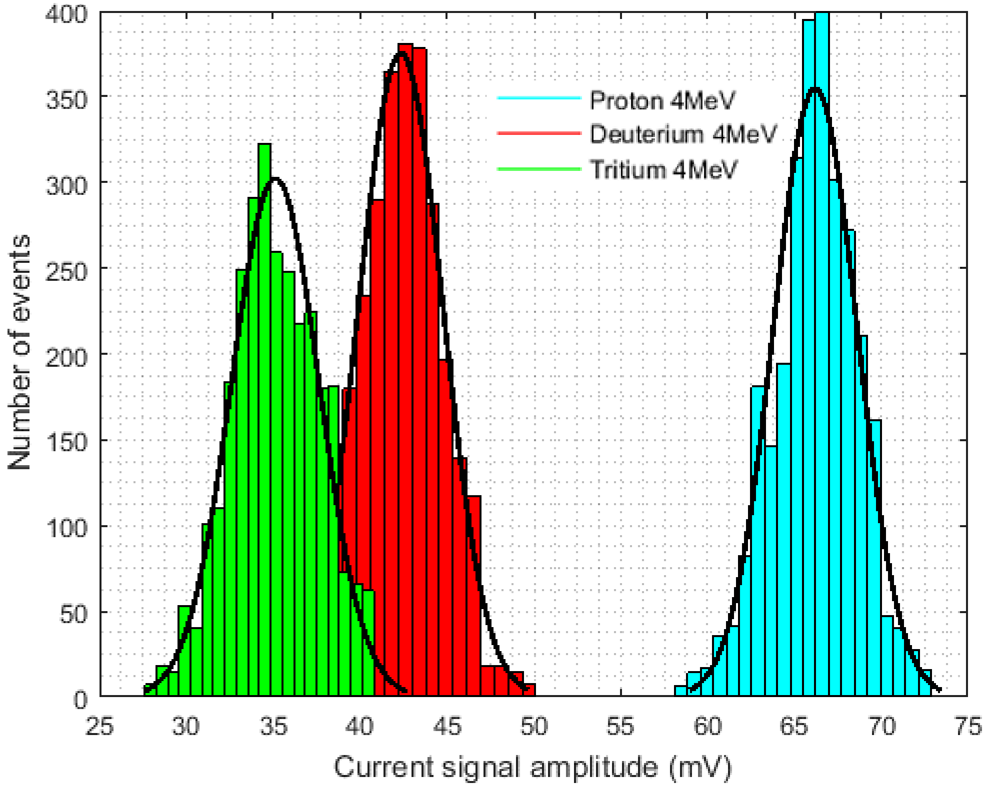
Signal processing simulations

Original current signals without filtering

Results of october 2017 experiments with iPACIv1
Current signals selected at 4MeV

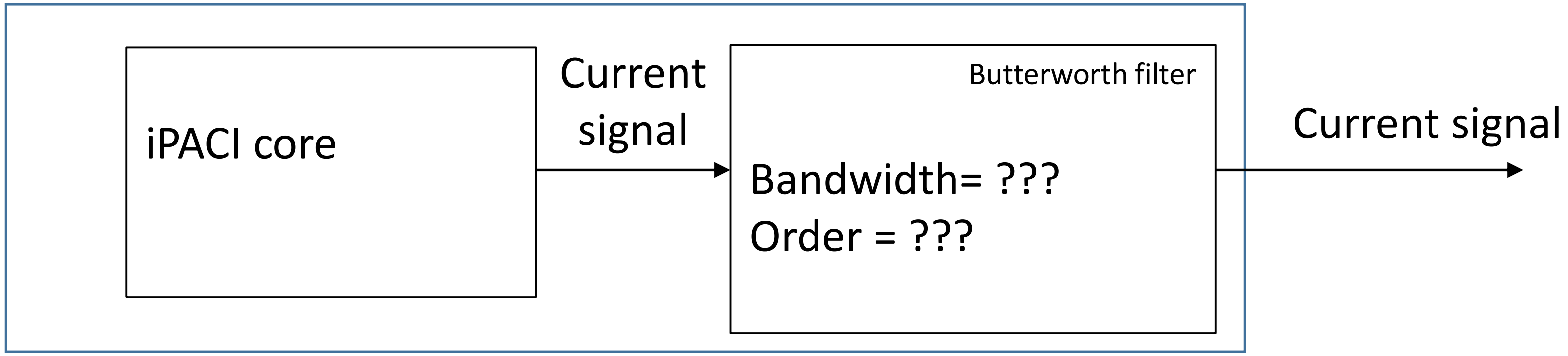


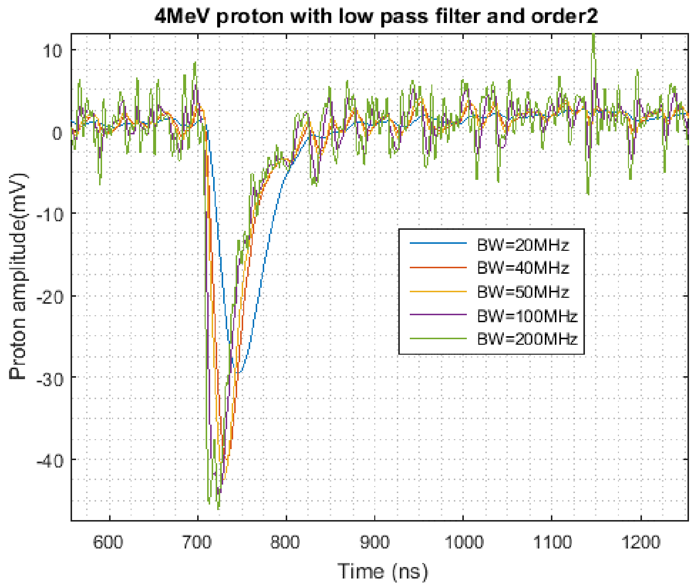
Original current signals distributions



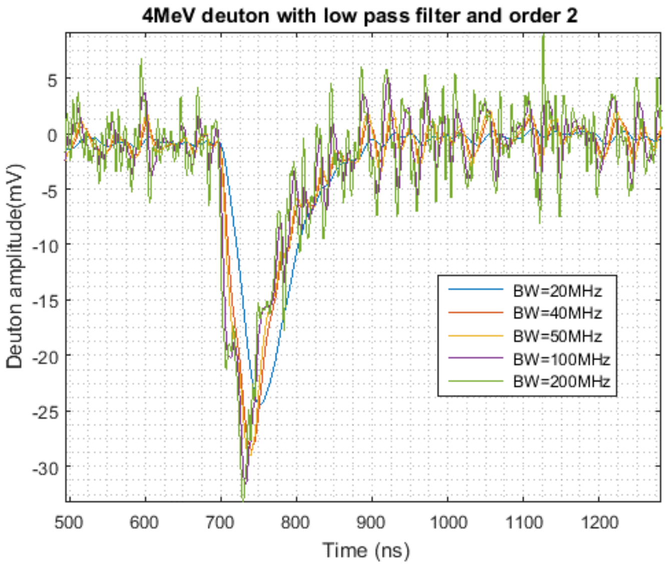
Which bandwidth to use for current signal ?

Analog chain for Pulse Shape Analysis = iPACI + PLAS



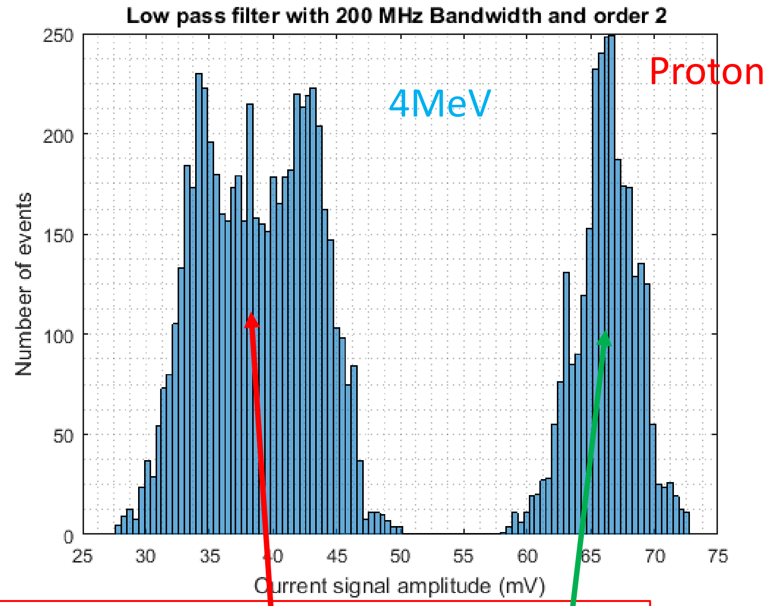


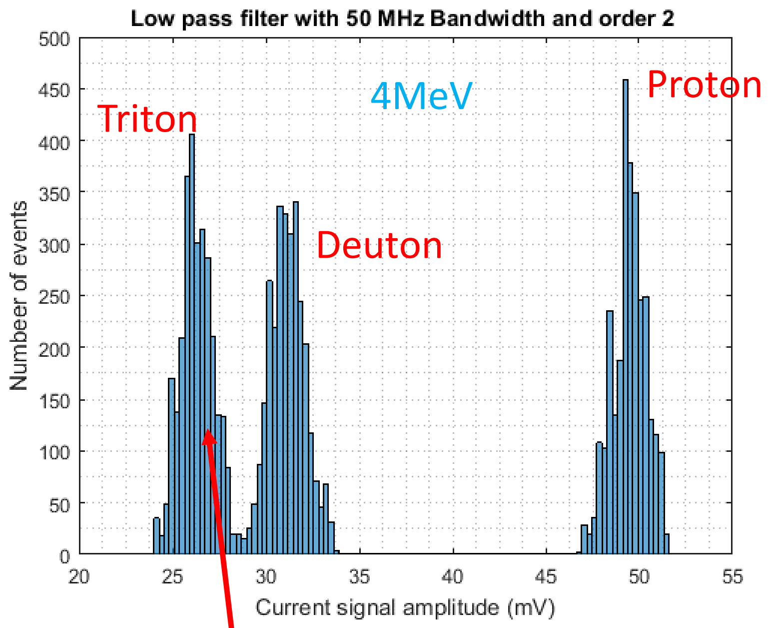
In the next slides we will try to estimate Bandwidth necessary to have the best signal to noise ratio for current signal
Use of MATLAB simulation
Low pass filter can be implemented inside iPACI as analog filter
Or
Low pass filter can be implemented as digital filter in FASTER board
In this slide => need to oversample current signal (5Gsamples/sec) not to be dominated by sampling rate

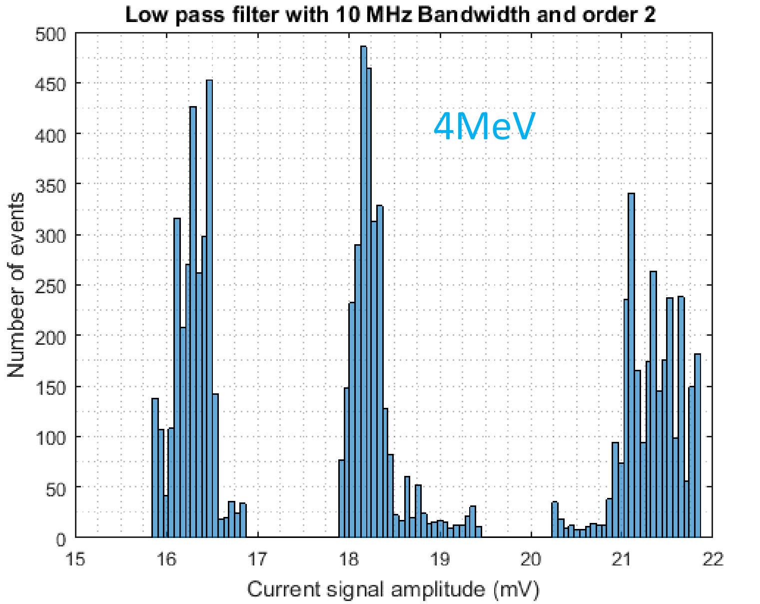


How to choose BW to optimize FOM ?

As we do not have many events to treat (experiment 2017), we choose 1 signal for proton, 1 signal for deuton and 1 signal for triton, we calculte amplitude of this current signals for each isotope and we add artificially noise distribution (base line) on each calculated amplitude. Then we obtain distributions below







Original current signals

⇒ Deuton and triton peaks are entangled/mixed

⇒ Proton events are well discriminated

50MHz low pass filter

Deuton and Triton events are well separated

10MHz low pass filter

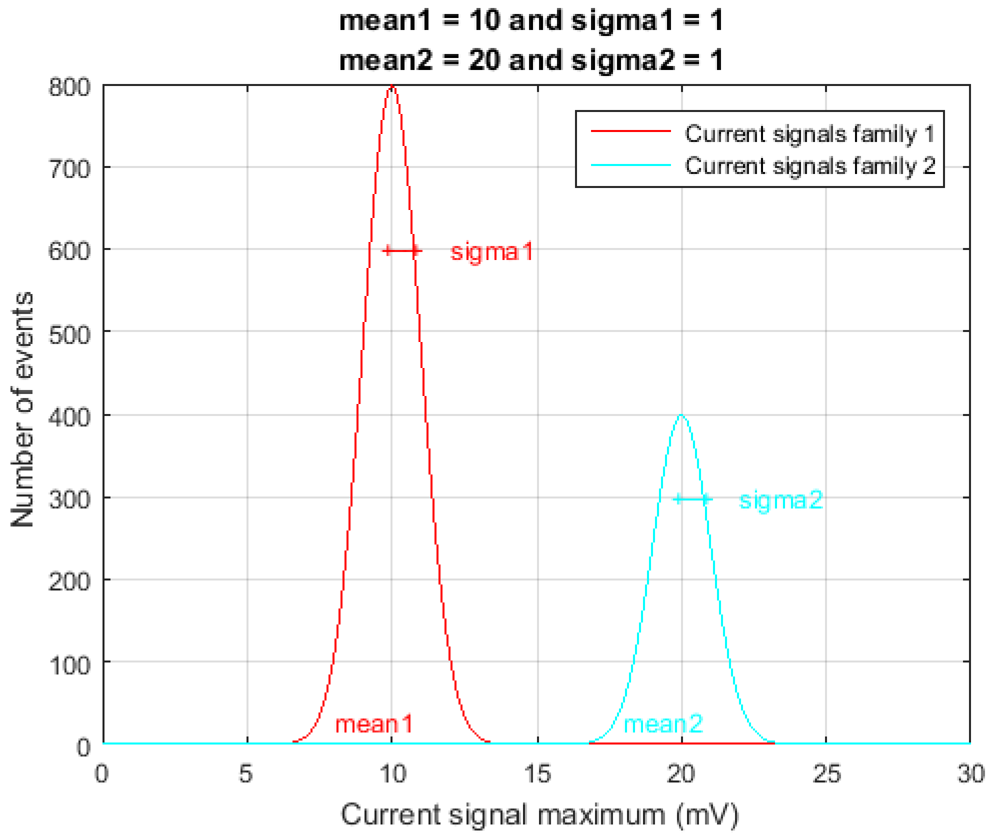
Deuton and Triton events are well separeted but FOM is not good.
See next page

Factor Of Merit: definition

To evaluate discrimination ability between 2 particles 1 and 2, we first plot distribution of current signal maximum (in mV) for a selected energy. Then we measure characteristics of gaussian distributions (mean1, mean2, sigma1 and sigma2). Finally we calculate Factor Of Merit (FOM).

$$FOM = \frac{2 \times |mean2 - mean1|}{2{,}35 \times (sigma1 + sigma2)}$$

For good discrimination, Factor Of Merit FOM should be higher than 1.4 (to be discussed) see references below



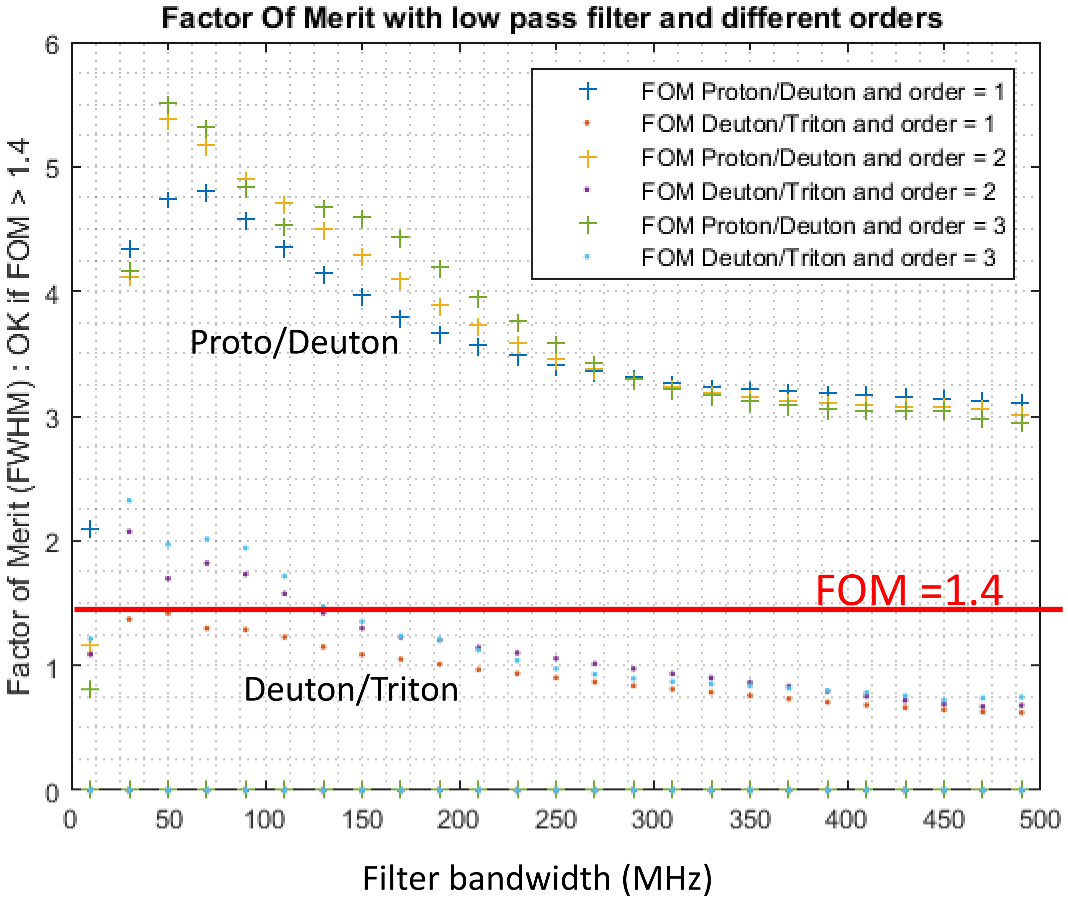
[1] R.A. Winyard, J.E. Lutkin, G.W. McBeth, Nucl. Instr. and Meth. 95 (1971) 141.

[2] Bardelli, et al, Nuclear Instruments and Methods in Physics Research A 654 (2011) 272–278.

[3] Carboni, et al, Nuclear Instruments and Methods in Physics Research A 664 (2012) 251–263.

[4] M. Assié, et al., Eur. Phys. J. A 51 (2015) 11.

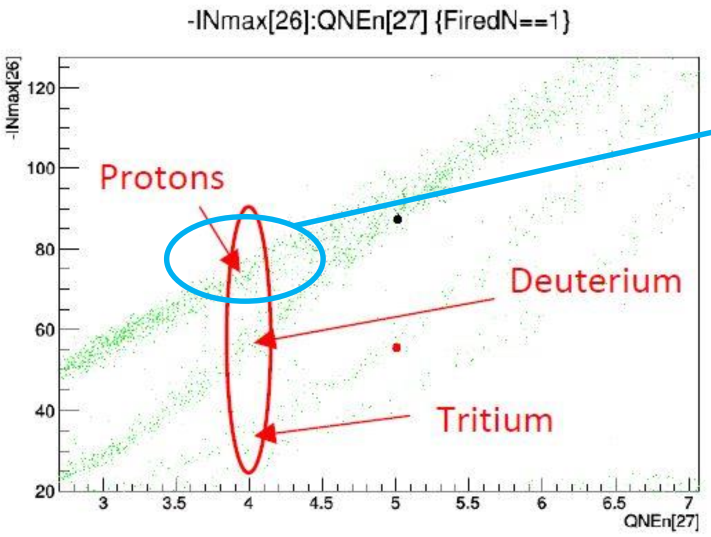
Factor Of Merit : FOM



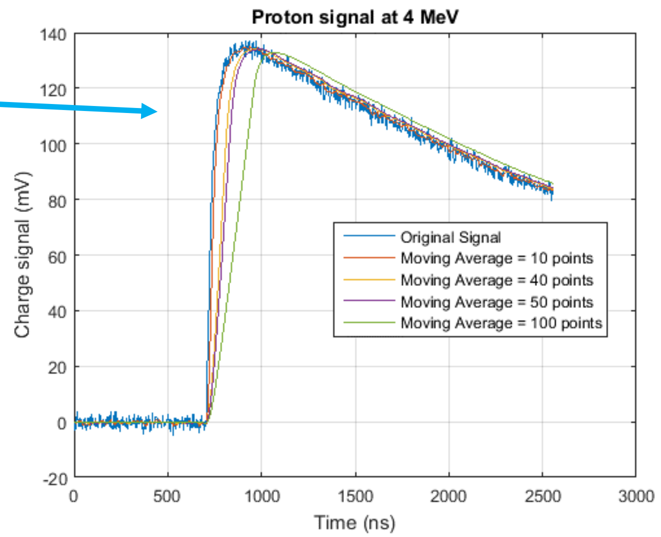
- 4MeV current signals for 3 isotopes
- Proton/Deuton discrimination is always possible => FOM >> 1.4
- However a maximum for FOM occurs for analog bandwidth (BW) close to 50MHz
- Deuton/Triton discrimination possible if we decrease BW (about 50MHz with order≥2)

Charge signal filtering

- Use of digital chain : Charge signal + ADC (Analog to Digital Converter) + Faster board
  Moving Average or band-pass algorithms can be implemented in FPGA (Faster board)



To validate Moving average algorithms, we choose charge signal from october 2017 experiments (digitizer=400Msamples/sec)
and we implement digital filter with MATLAB

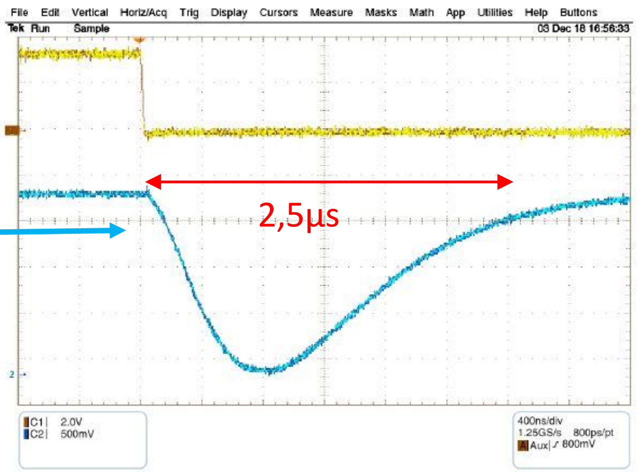


- Use of analog chain : Charge signal + analog band-pass filter

Band-pass filter = slow shaper

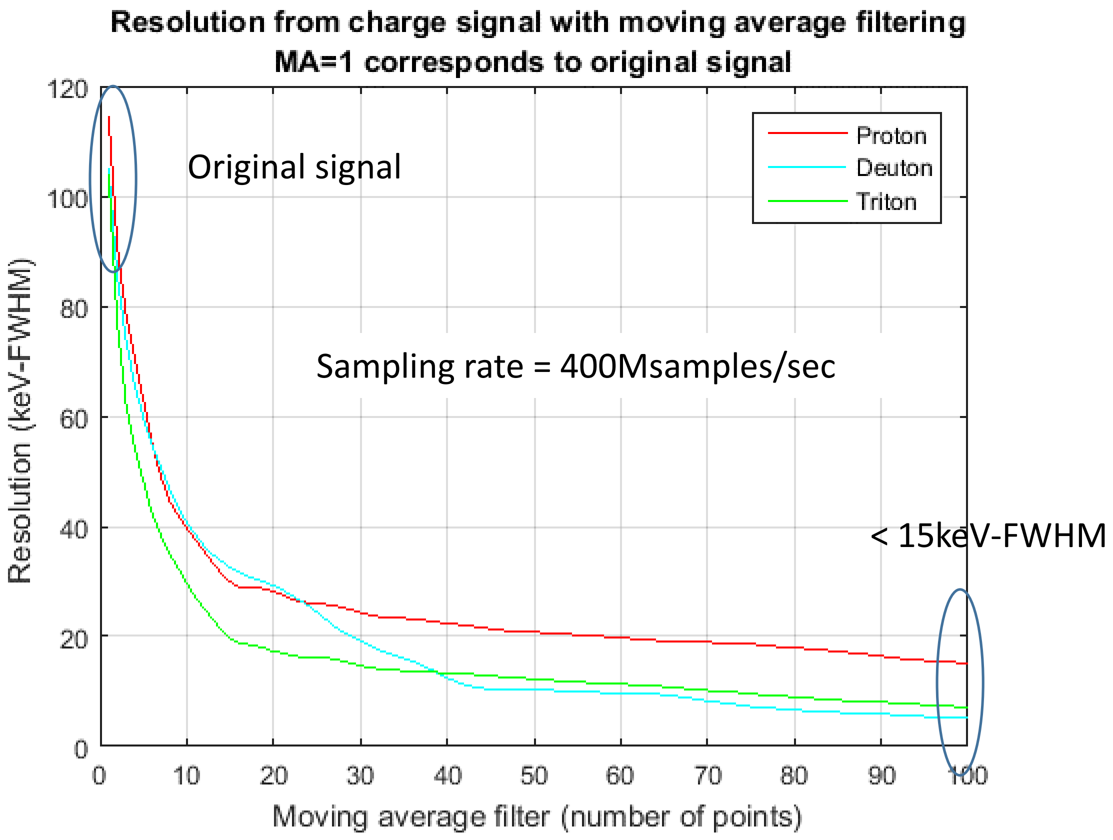
iPACIv2 => analog slow shaper is implemented inside ASIC
Shaping time can be switchable by slow control

3. Slow Shaper 70MeV



Energy resolution optimization : use of analog or digital filtering ?

Digital filtering : Moving Average (equivalent to low-pass filter) or band-pass filter



Analog filtering : Band-pass filter

Cut-off frequency=1/(2*π*shaping time)

Use of iPACIv1 signals with LAL analog shaper