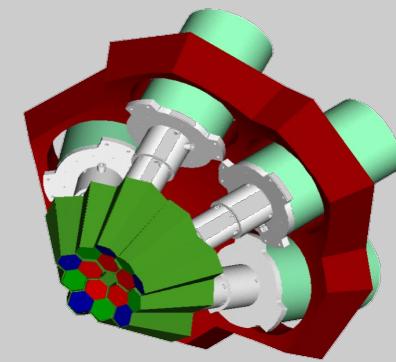
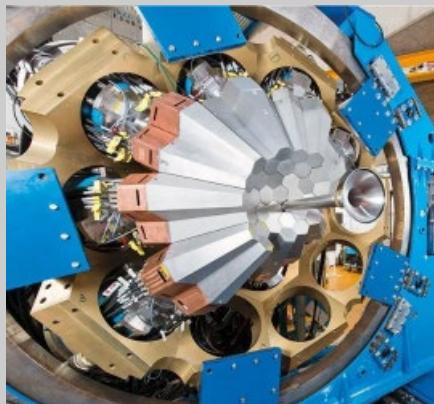




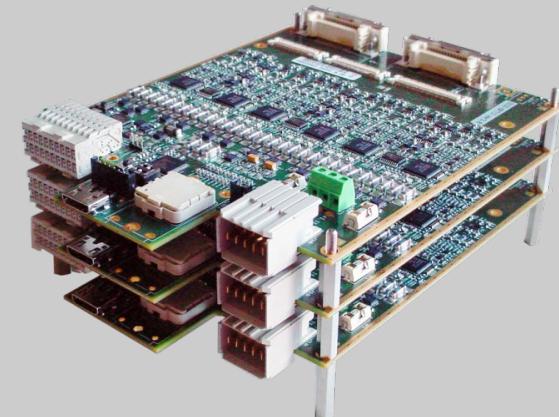
INFN - Milano
University of Milano
Department of Physics



Status and evolution of Digi-Opt12 digitizer cards



Alberto Pullia



AGATA Week
18 September, 2019
LNL, Italy

ГИГИЕНА
и
БИОСЕРВИСЫ

Latest bunch of DIGI-OPT12 cards

Serial	Bar Code	Version	Type	Fired	Control/Ck	All set*	Location	Owner
Production code: 440026773 – fourth run, type: segment								
4-1/75	01	3.6.1 AGATA	Segm	✓✓	backplane	Y	GANIL	INFN-MI
4-2/75	02	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-3/75	03	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-4/75	04	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-5/75	05	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-6/75	06	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-7/75	07	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-8/75	08	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-9/75	09	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-10/75	10	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-11/75	11	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-12/75	12	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-13/75	13	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-14/75	14	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-15/75	15	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-16/75	16	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-17/75	17	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-18/75	18	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-19/75	19	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-20/75	20	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-21/75	21	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-22/75	22	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-23/75	23	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-24/75	24	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-25/75	25	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-26/75	26	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-27/75	27	3.6.1 AGATA	segm	✓✓	backplane	Y	GANIL	INFN-MI
4-28/75	28	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-29/75	29	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-30/75	30	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-31/75	31	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-32/75	32	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-33/75	33	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-34/75	34	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-35/75	35	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-36/75	36	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI

Continue on
next page



*Y = all set; N = Antialiasing filter to be adjusted (24 resistor change each card)

✓✓ = new firmware; ✓ = old firmware

Delivered
17 Oct 2018

Latest bunch of DIGI-OPT12 cards

Serial	Bar Code	Version	Type	Fired	Control/Ck	All set*	Location	Owner
Production code: 440026773 – fourth run, type: segment								
4-37/75	37	3.6.1 AGATA	Segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-38/75	38	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-39/75	39	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-40/75	40	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-41/75	41	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-42/75	42	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-43/75	43	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-44/75	44	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-45/75	45	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-47/75	46	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-46/75	47	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-48/75	48	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-49/75	49	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-50/75	50	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-51/75	51	3.6.1 AGATA	segm	✓✓	backplane	Y	Koeln	IKP Koeln
4-52/75	52	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-53/75	53	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-54/75	54	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-55/75	55	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-56/75	56	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-57/75	57	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-58/75	58	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-59/75	59	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	Finland
4-60/75	60	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-61/75	61	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-62/75	62	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-63/75	63	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-64/75	64	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-65/75	65	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-66/75	66	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-67/75	67	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-68/75	68	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-69/75	69	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-70/75	70	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-71/75	71	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-72/75	72	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-73/75	73	3.6.1 GALILEO	segm	✓✓	backplane	Y	LNL	INFN-MI
4-74/75	74	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	Finland
4-75/75	75	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia/GANIL	Finland

Segment cards

Delivered
17 Oct 2018

Installed in GALILEO,
modified for DNL
characterization

Latest bunch of DIGI-OPT12 cards

Serial	Bar Code	Version	Type	Fired	Control/Ck	All set*	Location	Owner
Production code: 440026772 – fourth run, type: core								
4-1/19	01	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-2/19	02	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-3/19	03	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-4/19	04	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-5/19	05	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-6/19	06	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-7/19	07	3.6.1 AGATA ADC 3 noisy	core	✓✓	backplane	N	Milano	ASCOM
4-8/19	08	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-9/19	09	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-10/19	10	3.6.1 AGATA	core	✓✓	backplane	Y	GANIL	INFN-MI
4-11/19	11	3.6.1 AGATA	core	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-12/19	12	3.6.1 AGATA	core	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-13/19	13	3.6.1 AGATA	core	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-14/19	14	3.6.1 AGATA	core	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-15/19	15	3.6.1 AGATA	core	✓✓	backplane	Y	Valencia/GANIL	INFN-MI
4-16/19	16	3.6.1 AGATA	core	✓✓	backplane	Y	Koeln	IKP Koeln
4-17/19	17	3.6.1 AGATA	core	✓✓	backplane	Y	Koeln	IKP Koeln
4-18/19	18	3.6.1 AGATA	core	✓✓	backplane	Y	Koeln	IKP Koeln
4-19/19	19	3.6.1 AGATA	core	✓✓	backplane	Y	Valencia/GANIL	Finland

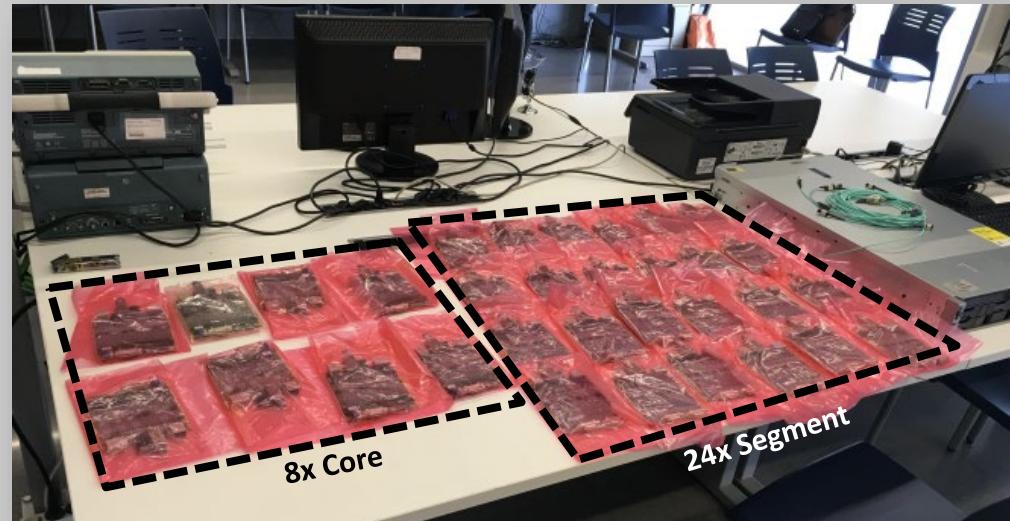
Core cards

Delivered
17 Oct 2018

*Y = all set; N = Antialiasing filter to be adjusted (8 resistor change each card)

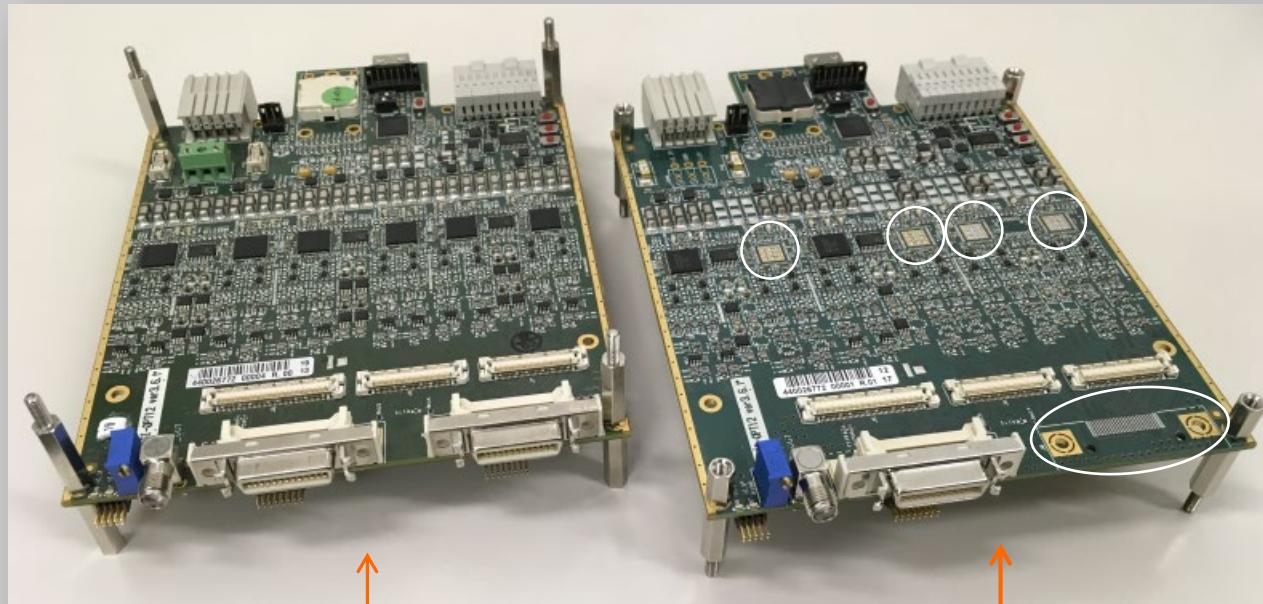
✓✓ = new firmware; ✓ = old firmware

Delivery at Valencia



Core card: old and new generations

We decided not to waste available ADC chips (stock covers another 32 digitizer chs)



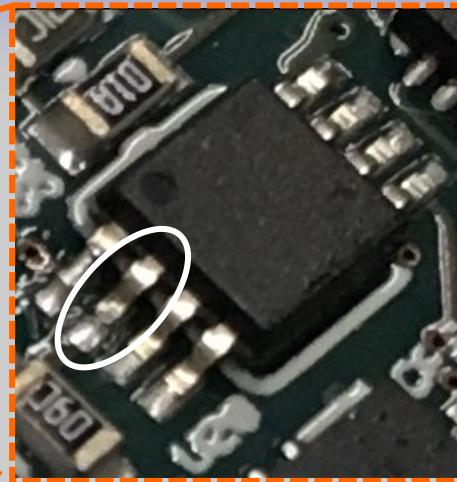
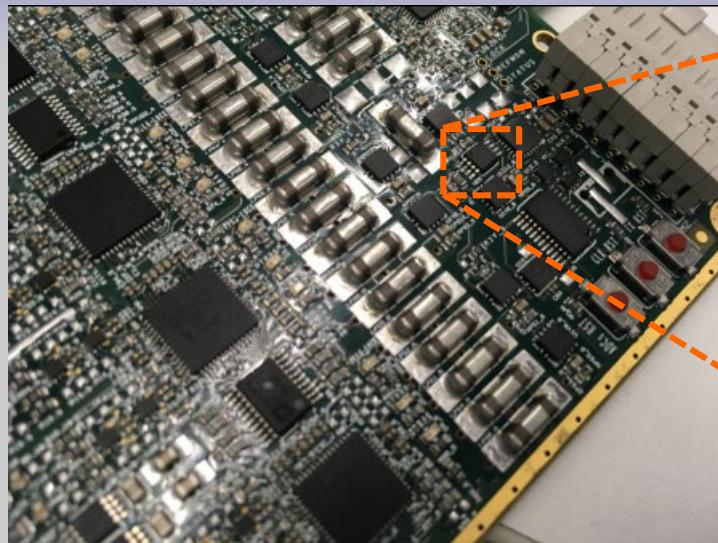
"Old" core card
All ADC footprints populated

"New" core card (run 4)

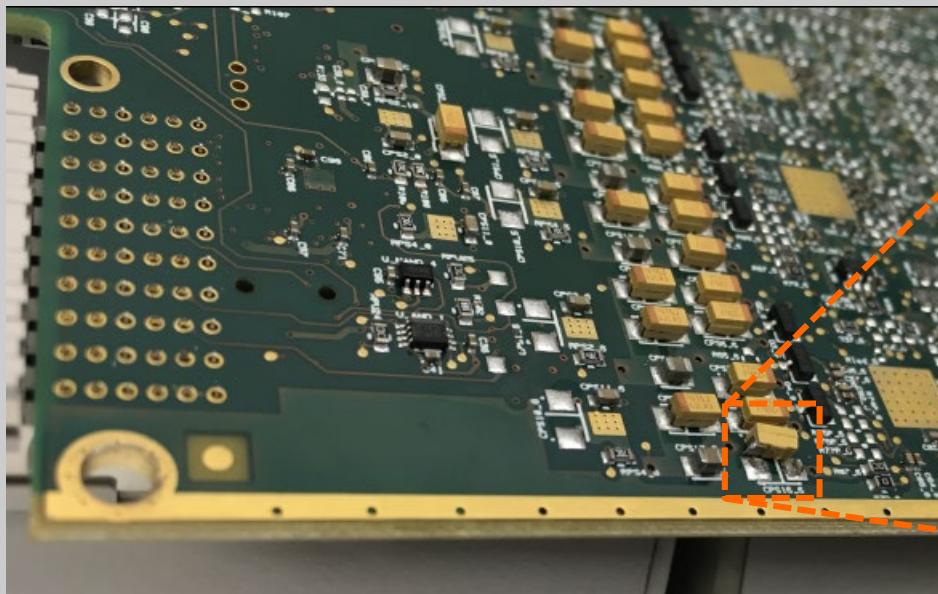
- Unused ADC chips not installed,
- Unused MDR connector not installed

This hardware-level change has no impact on the slow-control initialization procedure. The uninstalled ADC channels are shown as faulty (No Sync)

Digi-Opt12 – repairs – card 18 previous delivery



PS shown
incorrectly
because of
unsoldered pin of
chip U20



High noise in
digitized channel
due to PS filter
capacitor
detachment

Evolution of Digi-Opt12 card

Actual version of Digi-Opt12

Actual version of the card is the **outcome of optimizations and improvements** guided by the user's feedbacks (including range adjustment, fast trigger channel optimization, filtering of the ADC voltage ref, ...)

Random loss of signal (de-sync) issue solved – June 2018

Much effort has been made to address a randomly occurring **loss of synchronization** affecting all channels with non homogeneous unpredictable rate. In June 2018 this problem has been eliminated (!) by adding a reset command of the GTX (ser/des) core of the GGP's FPGA in the startup procedure .

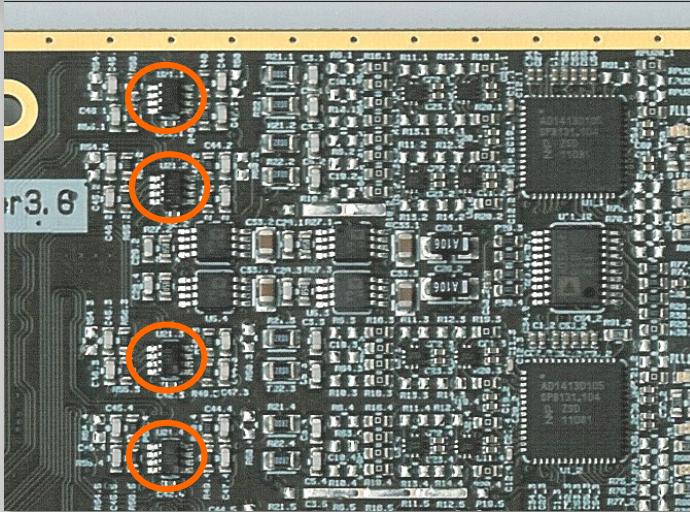
Digi-Opt12 card was not the culprit for this conundrum!!

Current effort: DNL characterization, impact, mitigation

After solving the random de-sync problem we are now focusing on the issues related to **ADC Differential Non Linearity** as seen after Moving Window Deconvolution trapezoidal filtering. We are aware that in nuclear spectroscopy DNL issue is much more critical than in typical applications of flash ADCs. Because DNL is intrinsic of flash ADC architecture we believe that changing ADC model or switching to 16 bit resolution may not be useful. Current ADC, moreover, already has a 16 bit architecture. Two LSB's are not transmitted because they are smaller than the noise (and/or for commercial strategies).

Latest upgrades of Digi-Opt12 card

New opamps for analog signal conditioning



✓ done

“Old” opamp: **AD8030**

$$e_n = 16.5 \text{ nV / Hz}^{1/2}$$

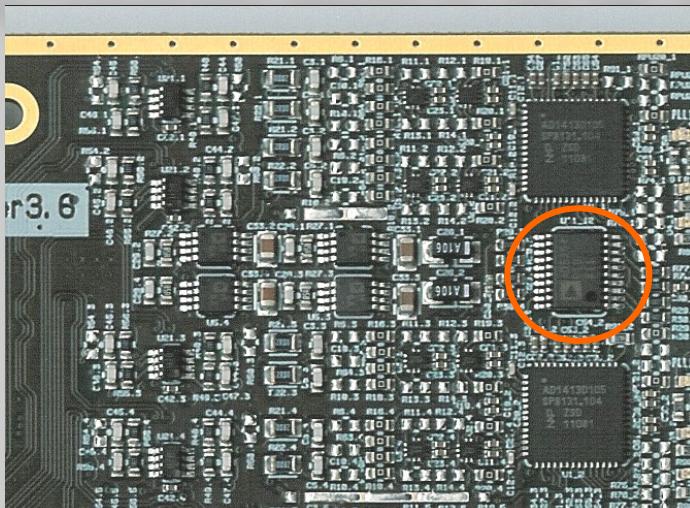


New opamps feature lower noise and larger bandwidth

“New” opamp: **LTC6247**

$$e_n = 4.6 \text{ nV / Hz}^{1/2}$$

DACs instead than Digipots for ADC DNL characterization and sliding-scale correction optimization

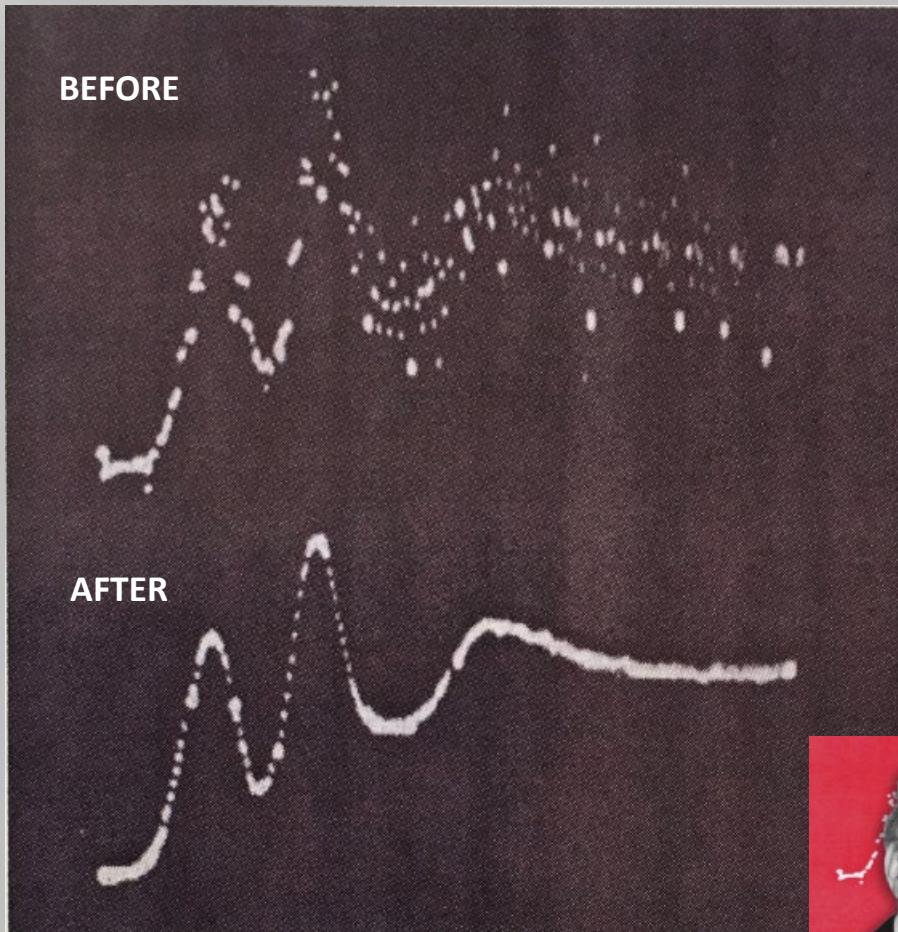


Ok for research, but slow-control compatibility issue

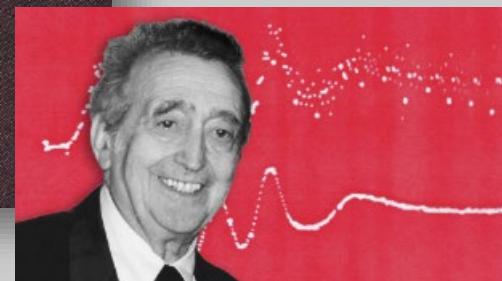
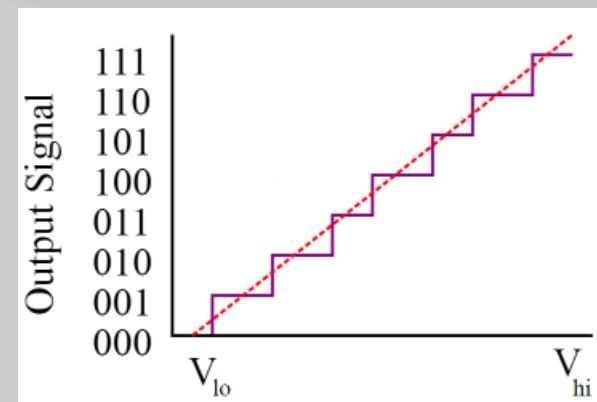
Use of DACs is envisaged in place of Digipots for high-resolution DC offset adjustment over the full ADC range.
The DC offset may then be dynamically changed in order to implement the sliding scale correction as a cure to ADC DNL.

Sliding-scale correction – original context

Add a sliding analog offset, then subtract it digitally

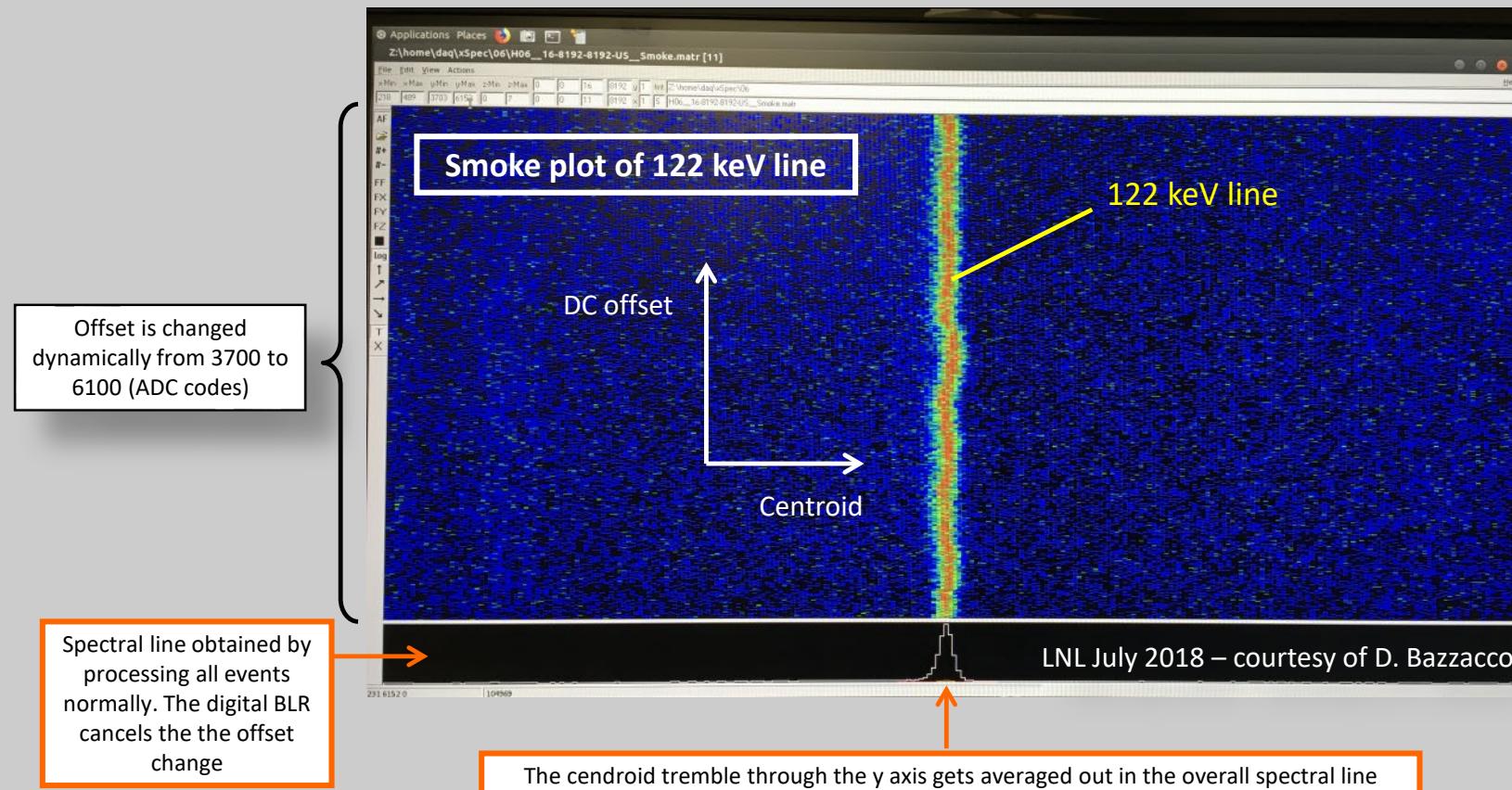


In the original sliding-scale correction context (pulse height sampling with Wilkinson ADC) the DNL error was in the range of 1 LSB, MUCH LESS than the spectral line width



Prof. Emilio Gatti (1922 - 2016)

Characterization and suppression of ADC Differential Non Linearity



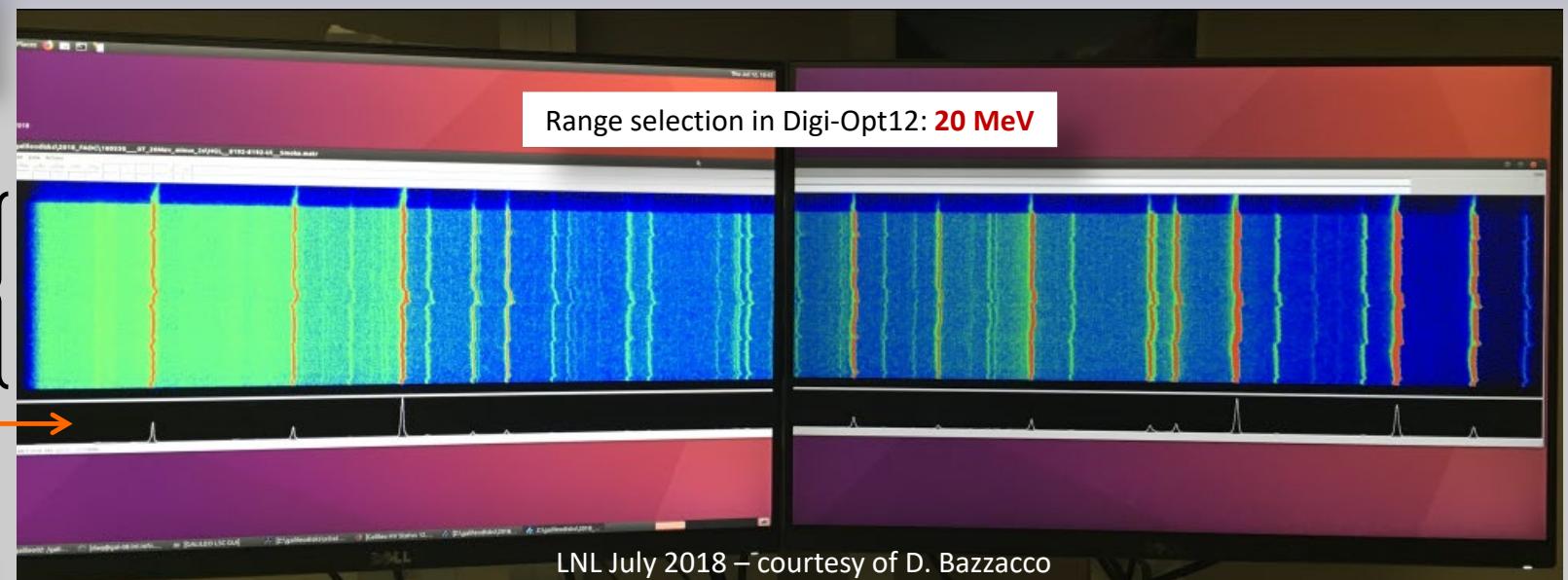
The spectral line (below) is obtained using the standard processing while the DC offset is changed by slow control with a “sawtooth” profile. The overall effect is a “sliding scale” correction, which mitigates the DNL effect

Price to be paid in energy resolution

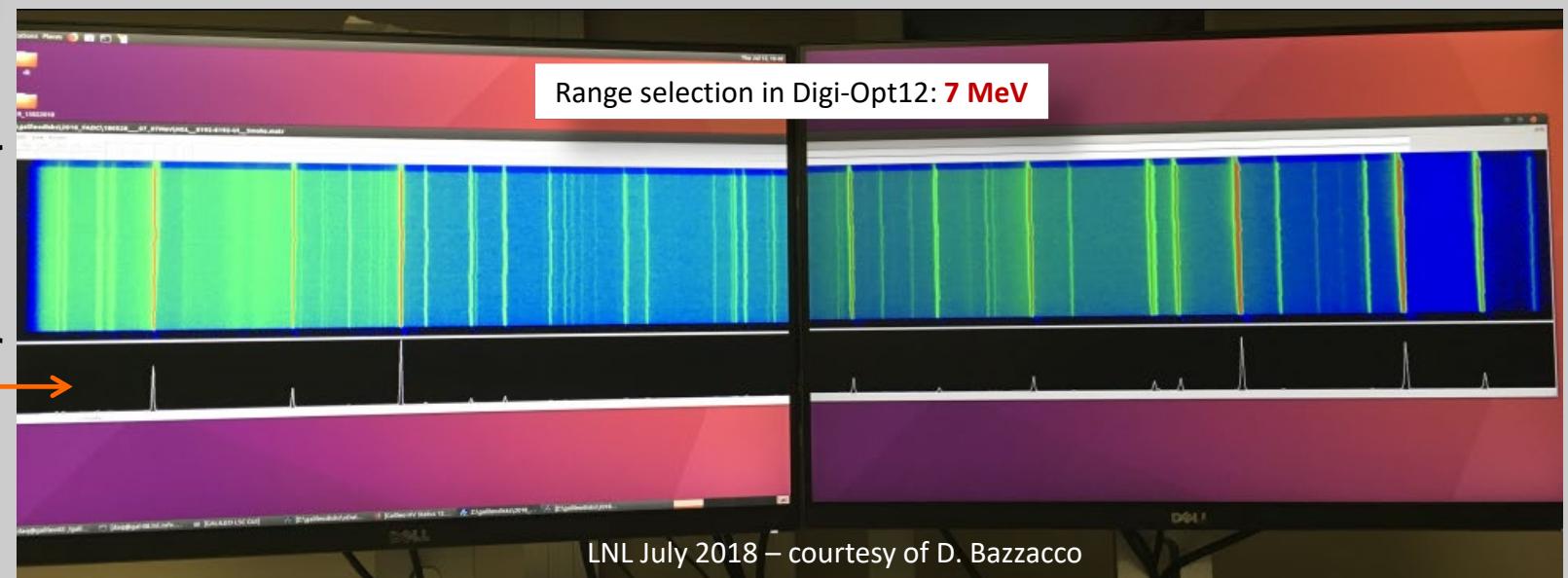
From 1.13 to 1.57 keV in 7 MeV range
From 1.4 to 2.2 keV in 20 MeV range

Characterization and suppression of ADC Differential Non Linearity

^{152}Eu + typical calibration sources



LNL July 2018 – courtesy of D. Bazzacco



LNL July 2018 – courtesy of D. Bazzacco

Conclusions and Perspectives

In the first phase of the New Electronics development the Digi-Opt12 card may be used “as is”, playing the role of a qualified hardware platform for testing the new FPGA-Ethernet (CAP/STARE) subsystem

After completion of the study of the ADC Differential Non Linearity impact we will possibly implement changes aimed to mitigate its effect, such as use of sliding-scale correction, range optimization, use of DACs instead than Digipots for DC offset setting, ...