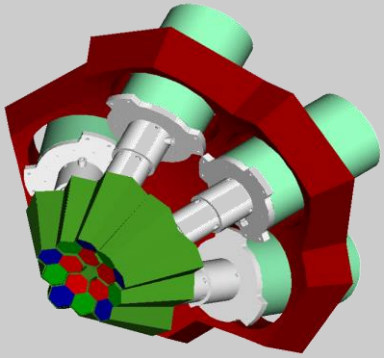
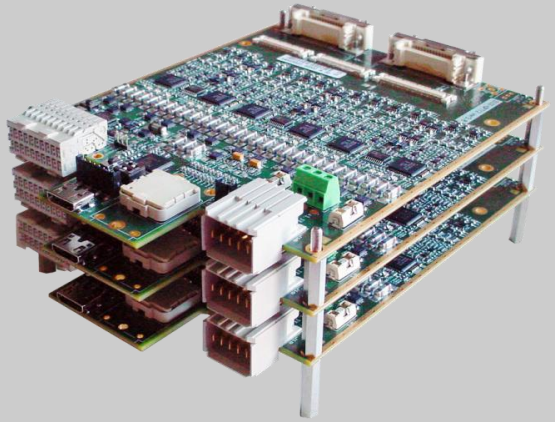
INFN - Milano
University of Milano
Department of Physics



Status and evolution of Digi-Opt12 digitizer cards



AGATA Week
10-14 September, 2018
Strasbourg, France

New bunch of DIGI-OPT12 cards

Segment 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	Valencia	INFN-MI
4-2/75	02	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-3/75	03	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-4/75	04	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-5/75	05	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-6/75	06	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-7/75	07	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-8/75	08	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-9/75	09	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-10/75	10	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-11/75	11	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-12/75	12	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-13/75	13	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-14/75	14	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-15/75	15	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-16/75	16	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-17/75	17	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-18/75	18	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-19/75	19	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-20/75	20	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-21/75	21	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-22/75	22	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-23/75	23	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-24/75	24	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-25/75	25	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-26/75	26	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-27/75	27	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	INFN-MI
4-28/75	28	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-29/75	29	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-30/75	30	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-31/75	31	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-32/75	32	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-33/75	33	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-34/75	34	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-35/75	35	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI
4-36/75	36	3.6.1 AGATA	segm	✓✓	backplane	Y	Milano	INFN-MI

Continue on next page

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

✓✓ = new firmware; ✓ = old firmware

New 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	N	Milano	INFN-MI
4-38/75	38	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	INFN-MI
4-39/75	39	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	INFN-MI
4-40/75	40	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	INFN-MI
4-41/75	41	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	INFN-MI
4-42/75	42	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	INFN-MI
4-43/75	43	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-44/75	44	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-45/75	45	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-47/75	46	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-46/75	47	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-48/75	48	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-49/75	49	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-50/75	50	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-51/75	51	3.6.1 AGATA	segm	✓✓	backplane	N	Milano	IKP Koeln
4-52/75	52	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-53/75	53	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-54/75	54	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-55/75	55	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-56/75	56	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-57/75	57	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-58/75	58	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	INFN-MI
4-59/75	59	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	Finland
4-60/75	60	3.6.1 GALILEO	segm	✓✓	backplane	N	Milano	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	Finland
4-75/75	75	3.6.1 AGATA	segm	✓✓	backplane	Y	Valencia	Finland

Segment cards

Installed in GALILEO, modified for DNL characterization

New bunch of DIGI-OPT12 cards

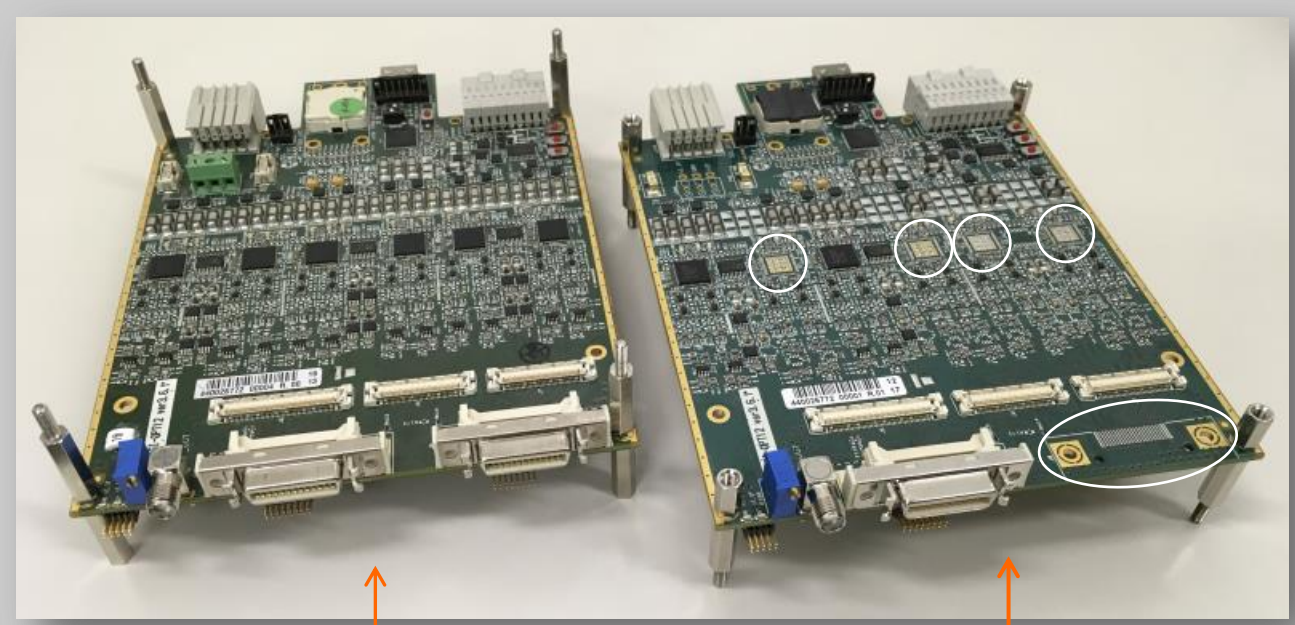
Core cards

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	**Valencia**	INFN-MI
4-2/19	02	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	INFN-MI
4-3/19	03	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	INFN-MI
4-4/19	04	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	INFN-MI
4-5/19	05	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	INFN-MI
4-6/19	06	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	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	**Valencia**	INFN-MI
4-9/19	09	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	INFN-MI
4-10/19	10	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	INFN-MI
4-11/19	11	3.6.1 AGATA	core	✓✓	backplane	Y	Milano	INFN-MI
4-12/19	12	3.6.1 AGATA	core	✓✓	backplane	N	Milano	INFN-MI
4-13/19	13	3.6.1 AGATA	core	✓✓	backplane	N	Milano	INFN-MI
4-14/19	14	3.6.1 AGATA	core	✓✓	backplane	N	Milano	INFN-MI
4-15/19	15	3.6.1 AGATA	core	✓✓	backplane	N	Milano	INFN-MI
4-16/19	16	3.6.1 AGATA	core	✓✓	backplane	Y	Milano	IKP Koeln
4-17/19	17	3.6.1 AGATA	core	✓✓	backplane	N	Milano	IKP Koeln
4-18/19	18	3.6.1 AGATA	core	✓✓	backplane	N	Milano	IKP Koeln
4-19/19	19	3.6.1 AGATA	core	✓✓	backplane	Y	**Valencia**	Finland

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

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 negative impact on the slow-control initialization procedure.
The uninstalled channels are shown as faulty (No Sync)

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

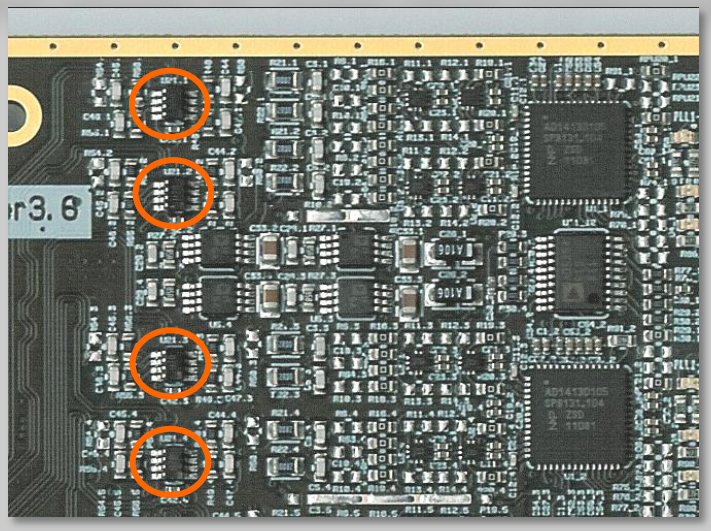
Much effort has been made to address a randomly occurring **loss of synchronization** affecting all channels with non homogeneous unpredictable rate. In June 2018 this problem has been eliminated (!) by adding a reset command of the GTX (ser/des) core of the GGP's FPGA in the startup procedure .
Digi-Opt12 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).

Evolution of Digi-Opt12 card

New opamps for analog signal conditioning

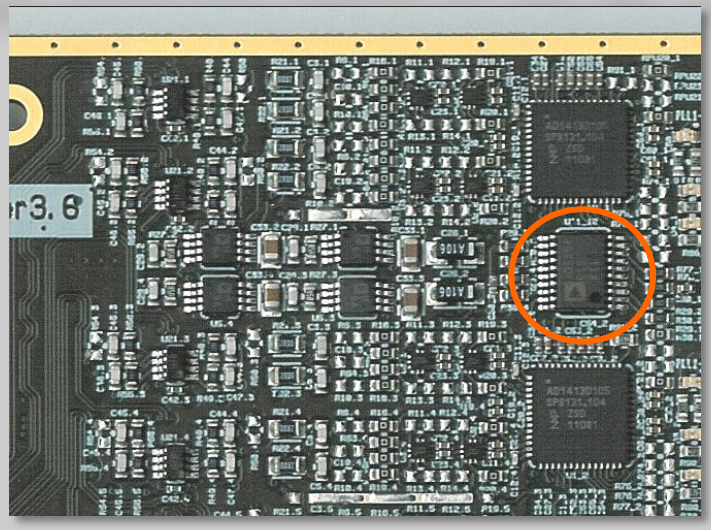


"Old" opamp: **AD8030**
e_n = 16.5 nV / $Hz^{1/2}$

"New" opamp: **LTC6247**
e_n = 4.6 nV / $Hz^{1/2}$

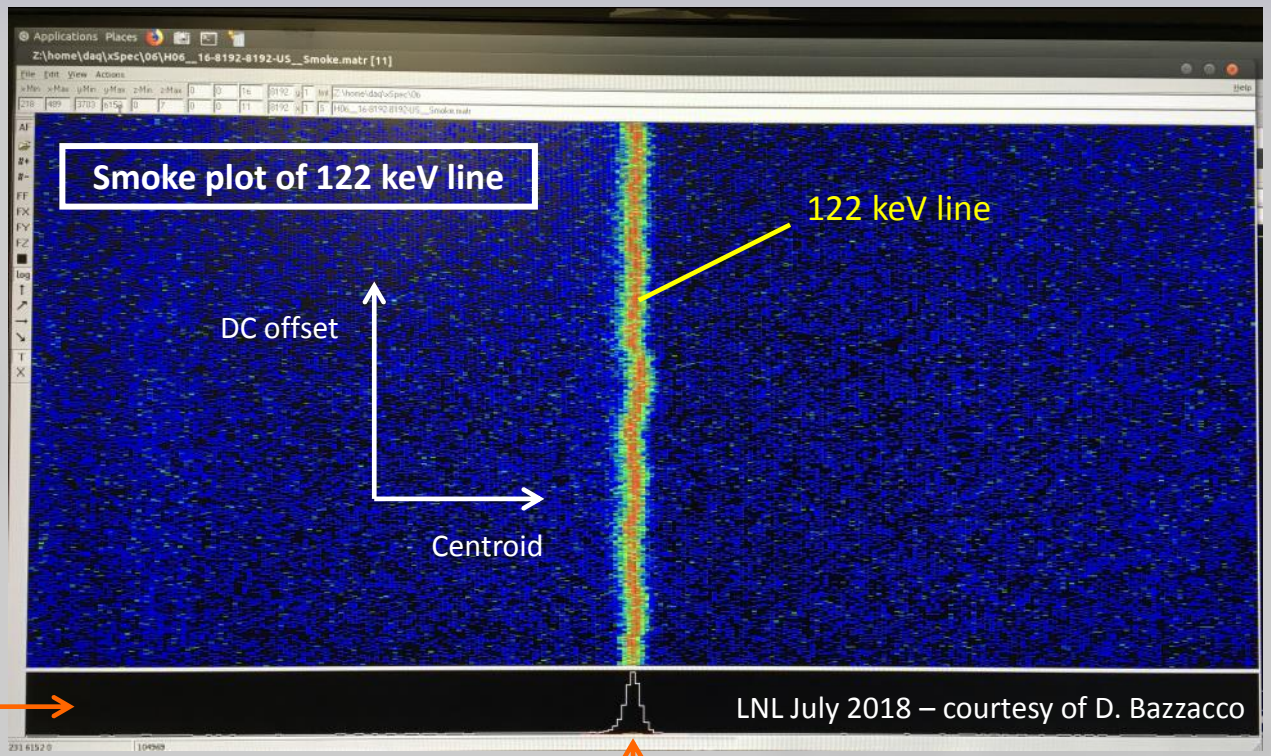
New opamps feature lower noise and larger bandwidth

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



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.

Characterization and suppression of ADC Differential Non Linearity: preliminary results



Offset is changed dynamically from 3700 to 6100 (ADC codes)

Spectral line obtained by processing all events normally. The digital BLR cancels the the offset change

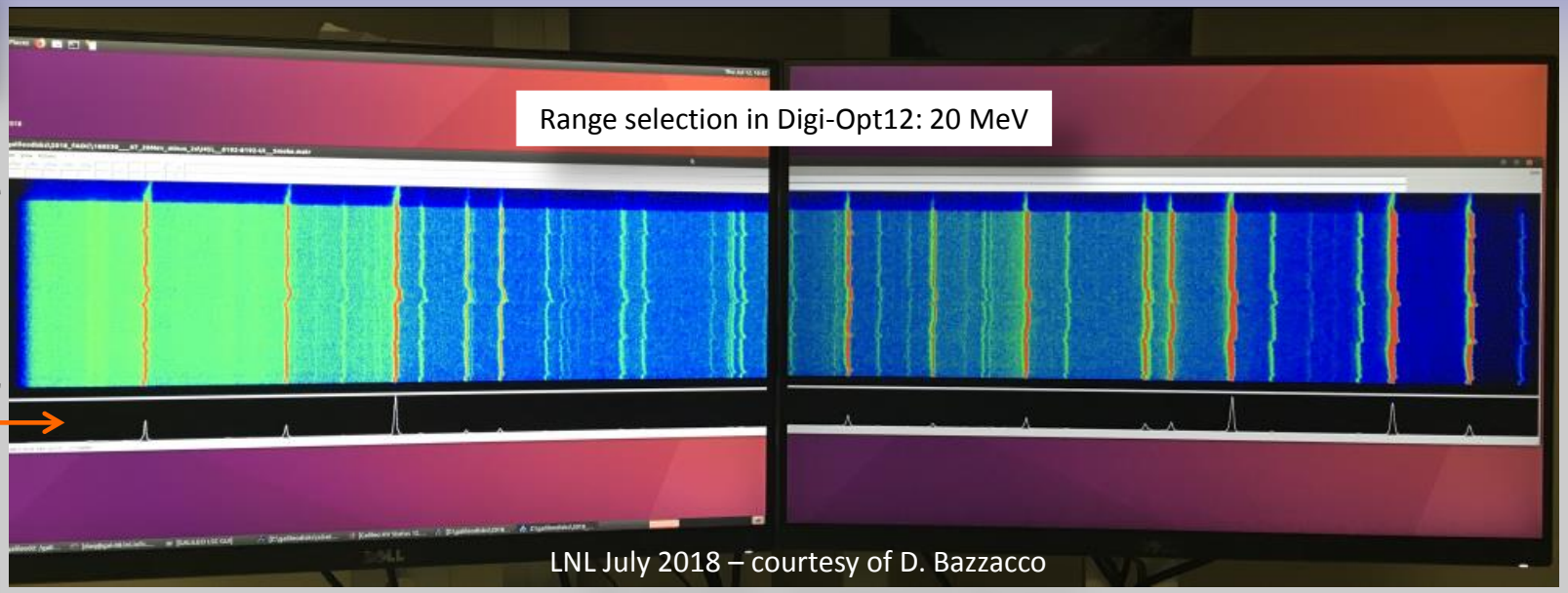
The cendroid tremble through the y axis gets averaged out in the overall spectral line

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

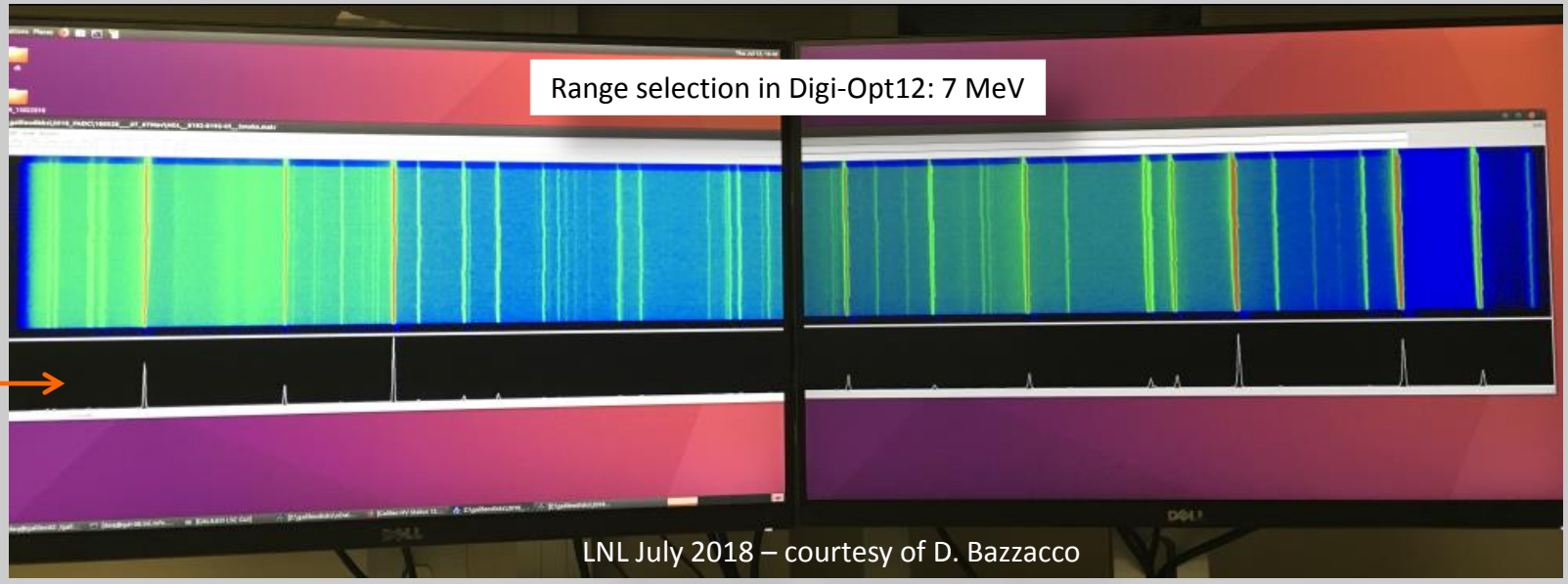
Characterization and suppression of ADC Differential Non Linearity: preliminary results

^{152}Eu + typical calibration sources



BLR cancels offset change in spectrum

Offset changed dynamically from 3400 to 6100 (ADC codes)



BLR cancels offset change in spectrum

Digi-Opt12 in the New Electronics setup

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 (in progress) we will implement all 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