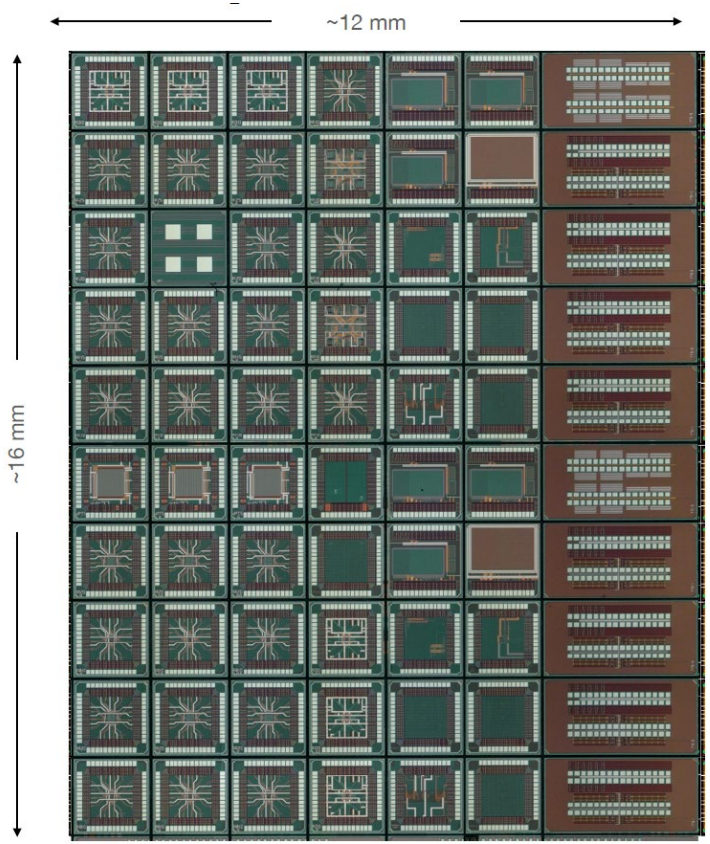
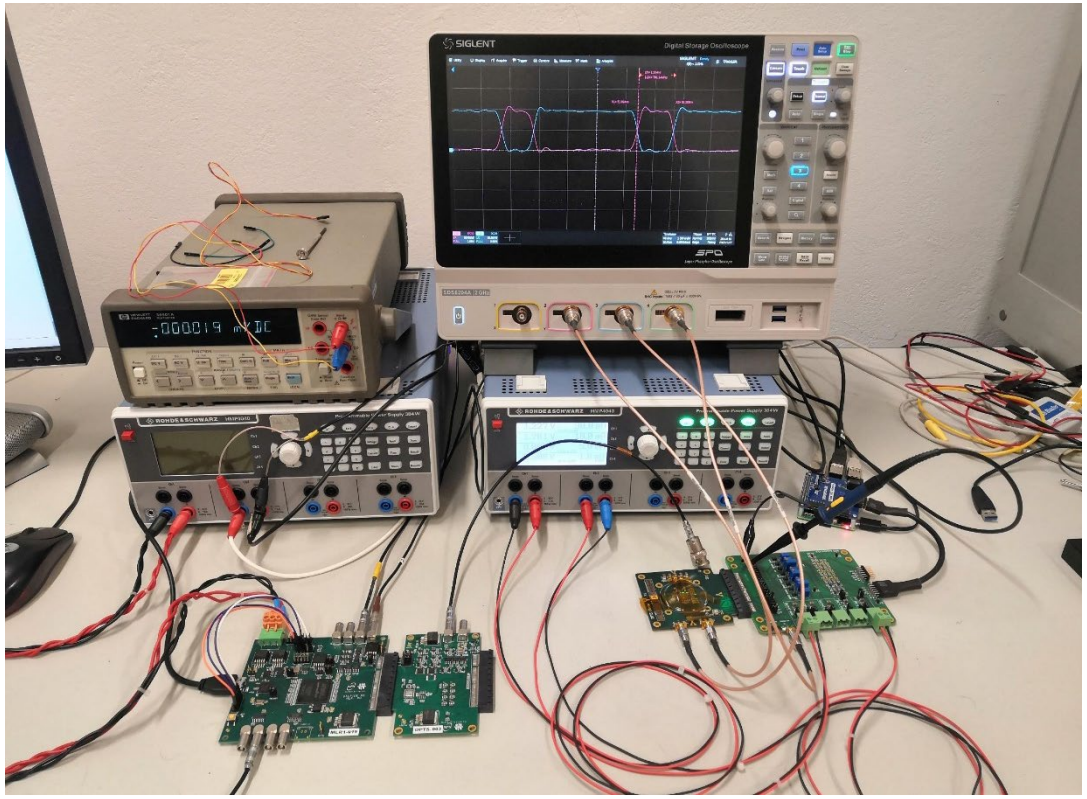
Sensor characterization

Giacomo Contin
Università di Trieste and INFN Sezione di Trieste

EIC Silicon Consortium meeting – Jan 31st 2022

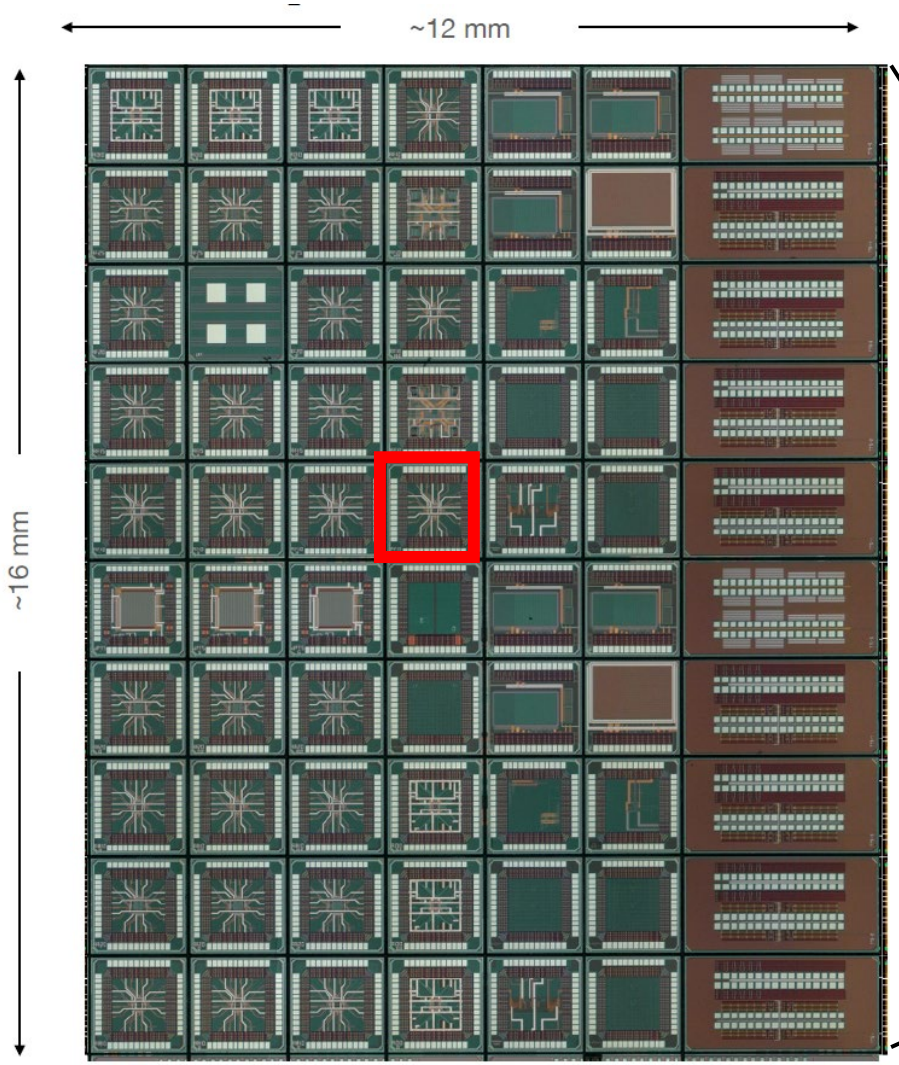




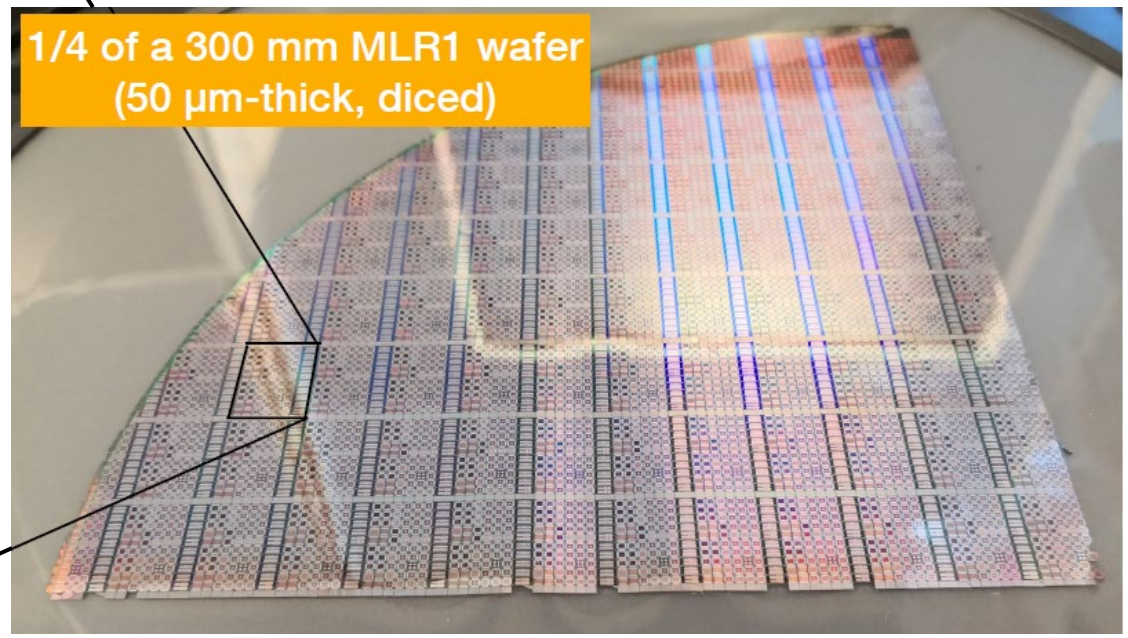
Outline

- ITS3 MLR1 testing update
- EIC SC joining the MLR1 testing campaign

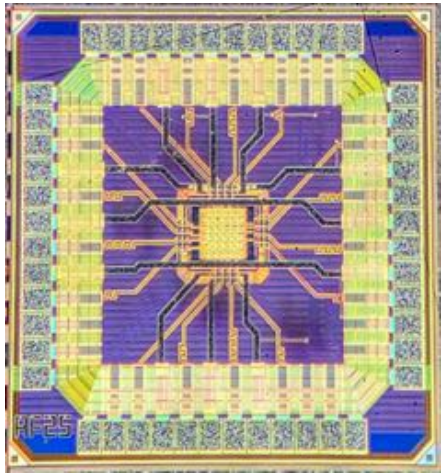
MLR1 reticle: 60 chips (+ 10 transistor test structures)



- Pixel test structures
- Pixel matrices
- Radiation test structures
- Analogue building blocks

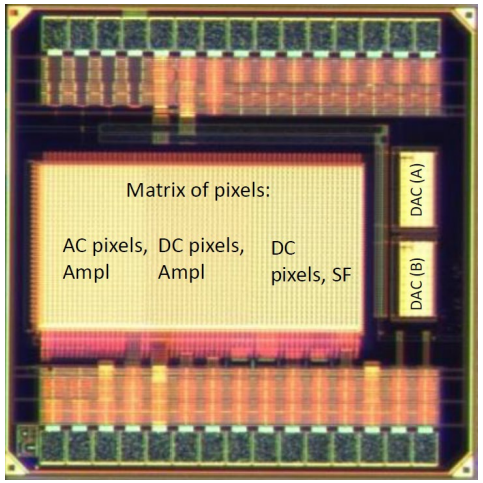


APTS, CE65, DPTS



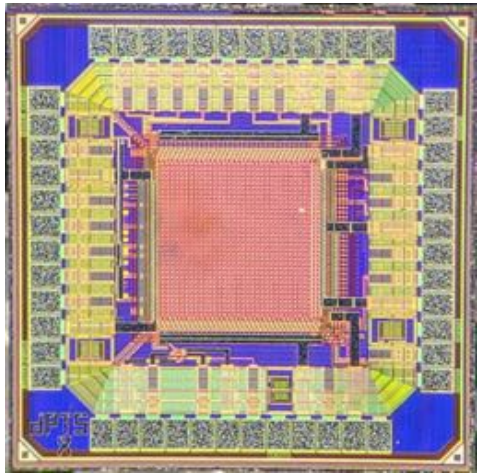
APTS

- Most “simple” chip
- 4x4 pixel matrix
- 10, 15, 20, 25 µm pitches
- Different pixel and amplifier architectures
- Direct analogue readout of all 16 pixels



CE65

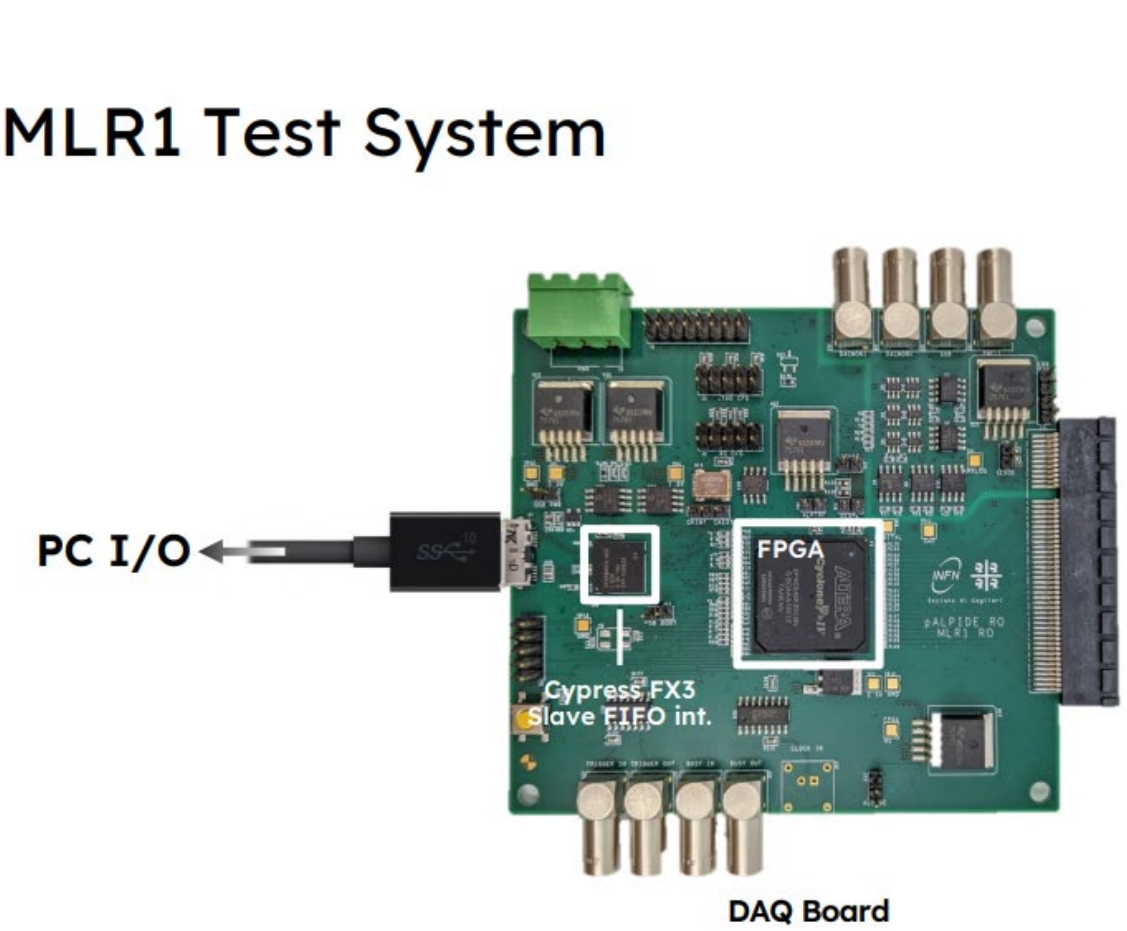
- “Large” area chip with analogue rolling shutter readout
- 64x32 pixel matrix
- 15 µm pitch
- 3 pixel architectures
- 2 currents DACs on same die



DPTS

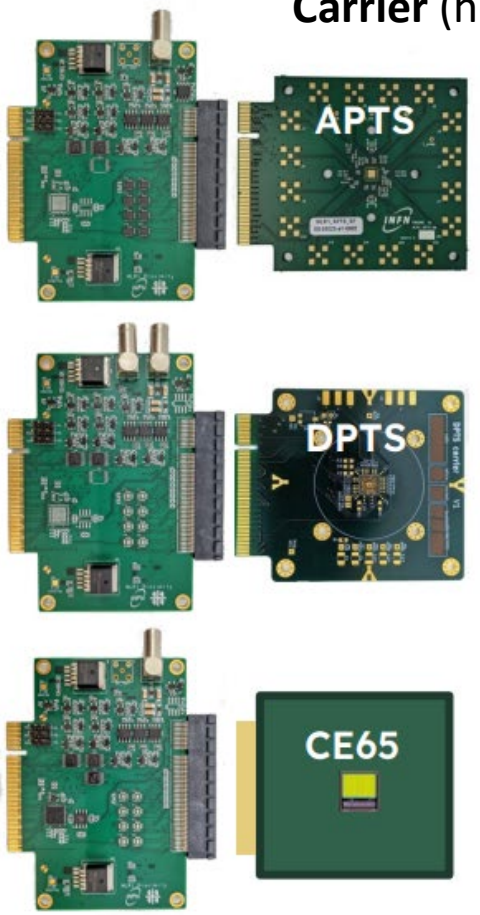
- Most “complicated” chip
- 32x32 pixel matrix
- 15 µm pitch
- Asynchronous digital readout

Common test system: DAQ + Proximity + Carrier

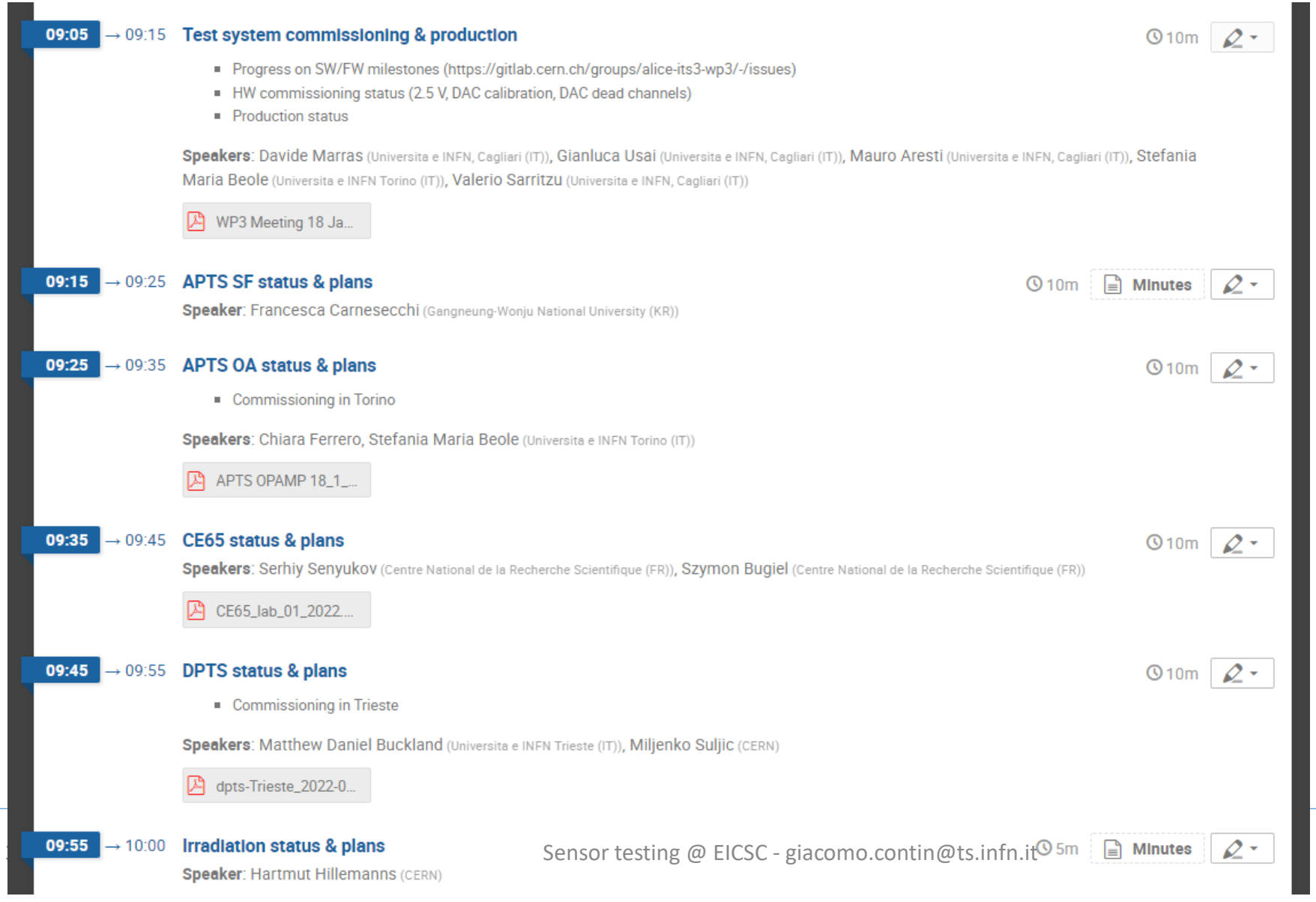


Proximity

Carrier (hosting the chip)



MLR1 testing /1 : test system and chip testing



09:05 → 09:15 **Test system commissioning & production** 10m

- Progress on SW/FW milestones (https://gitlab.cern.ch/groups/alice-its3-wp3/-/issues)
- HW commissioning status (2.5 V, DAC calibration, DAC dead channels)
- Production status

Speakers: Davide Marras (Universita e INFN, Cagliari (IT)), Gianluca Usai (Universita e INFN, Cagliari (IT)), Mauro Aresti (Universita e INFN, Cagliari (IT)), Stefania Maria Beole (Universita e INFN Torino (IT)), Valerio Sarritzu (Universita e INFN, Cagliari (IT))

WP3 Meeting 18 Ja...

09:15 → 09:25 **APTS SF status & plans** 10m Minutes

Speaker: Francesca Carnesecchi (Gangneung-Wonju National University (KR))

09:25 → 09:35 **APTS OA status & plans** 10m

- Commissioning in Torino

Speakers: Chiara Ferrero, Stefania Maria Beole (Universita e INFN Torino (IT))

APTS OPAMP 18_1_...

09:35 → 09:45 **CE65 status & plans** 10m

Speakers: Serhiy Senyukov (Centre National de la Recherche Scientifique (FR)), Szymon Bugiel (Centre National de la Recherche Scientifique (FR))

CE65_lab_01_2022....

09:45 → 09:55 **DPTS status & plans** 10m

- Commissioning in Trieste

Speakers: Matthew Daniel Buckland (Universita e INFN Trieste (IT)), Miljenko Suljic (CERN)

dpts-Trieste_2022-0...

09:55 → 10:00 **Irradiation status & plans** 5m Minutes

Speaker: Hartmut Hillemanns (CERN)

Active groups:

Test system design/production

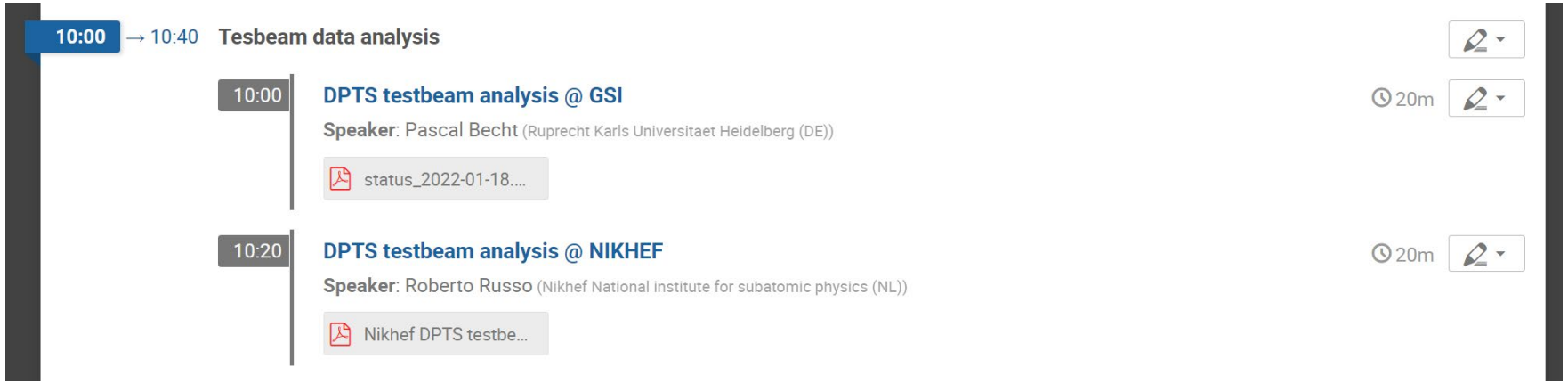
- Cagliari
- Torino
- Strasbourg IPHC
- Trieste
- CERN

Chip tests:

- CERN
- Torino
- Strasbourg IPHC
- Trieste

O(1k) chips to test!

MLR1 testing /2 : beam test data analysis



Data available from:

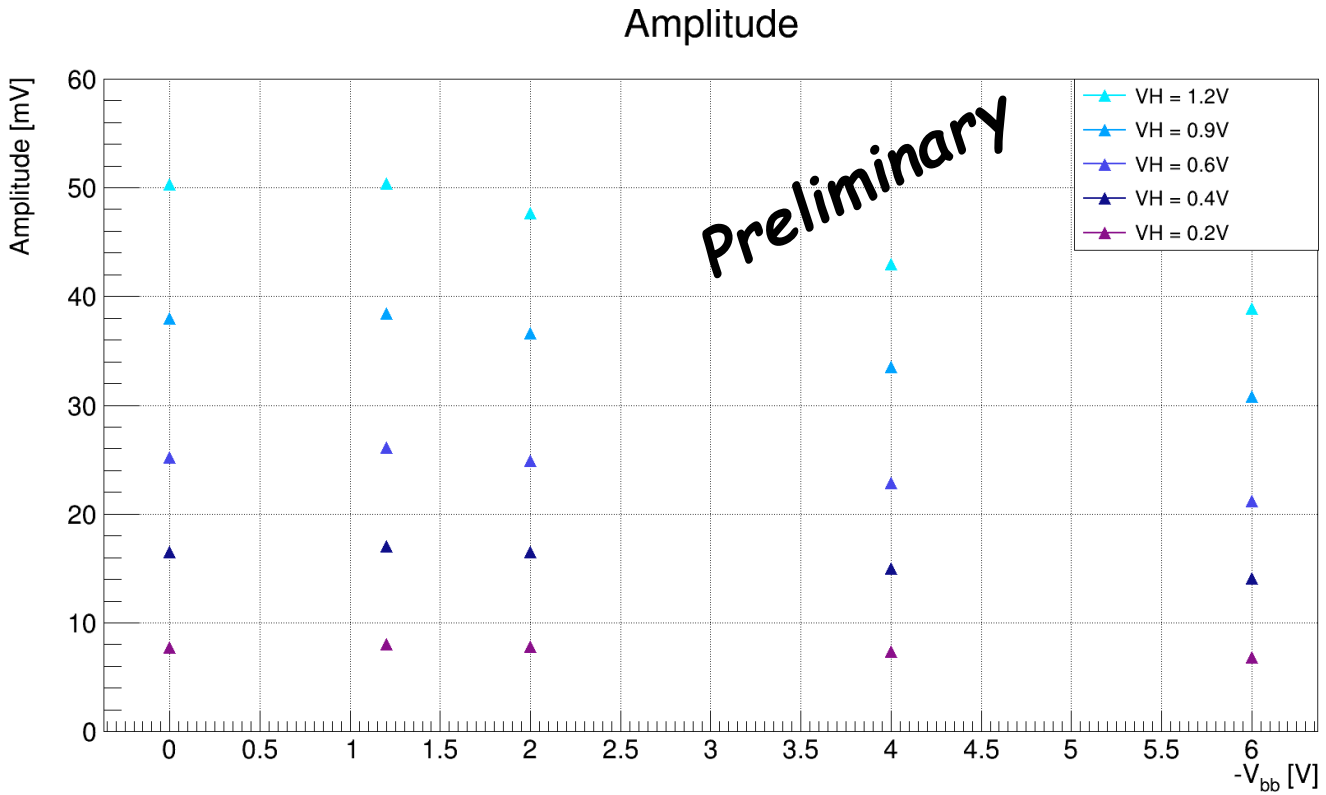
- DESY September 2021 - MLR1, Carbon foam, W-ALPIDE
- NPI September 2021 - DPTS SEU cross-section
- NPI October 2021 - DPTS irradiation & SEU cross-section
- PS October 2021 - MLR1
- SPS November 2021 - MLR1
- DESY December 2021 - MLR1
- NPI December 2021 - DPTS irradiation & SEU cross-section

Active groups in beam test data analysis:

- GSI
- NIKHEF
  - Both these groups joined ITS3 recently

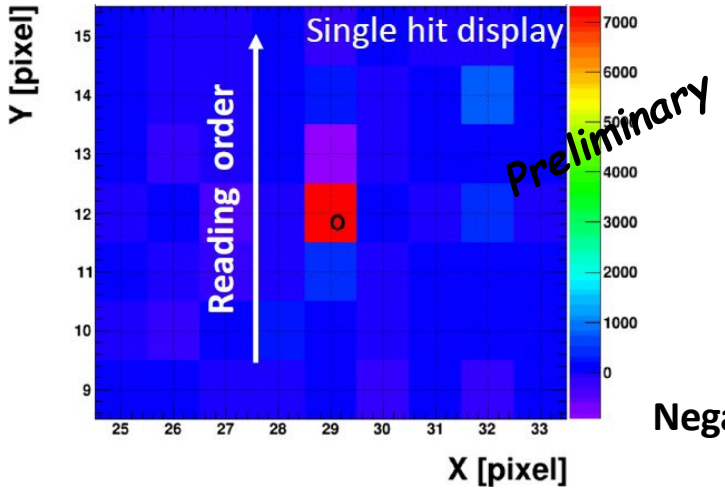
APTS: OA and SF

- **APTS OA**
  - Work started in Turin
  - Modification of the test system for correct operation of the chip
  - First intriguing results:
    - E.g. inverse dependence of signal amplitude vs. back bias voltage
- **APTS SF**
  - Laboratory tests and beam test analysis are on hold
  - Validation of the test system calibration (chip biases DACs) in progress
  - Catania group is joining the effort



Chiara Ferrero et al. (Universita and INFN Torino)

CE65: Investigation of two readout problems

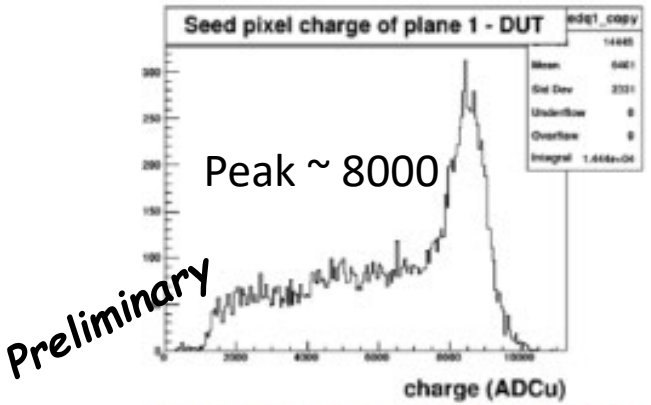


Szymon Bugiel,
Andrei Dorokhov
Kimmo Jaaskelainen
(IPHC Strasbourg)

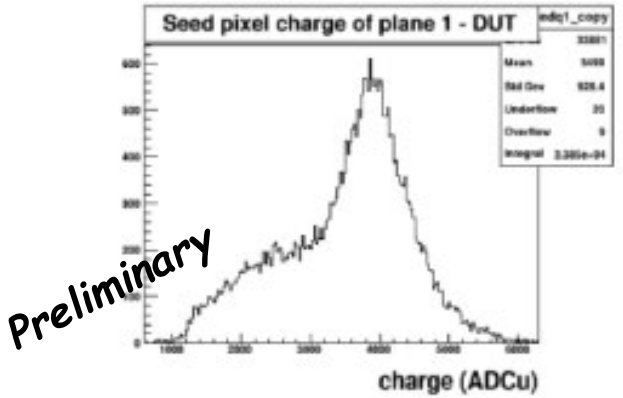
Negative pulse after seed pixel

Readout frequency dependence of signal amplitude

CLK = 40 MHz, VBB = 0, B4:



CLK = 20 MHz, VBB = 0, B4:



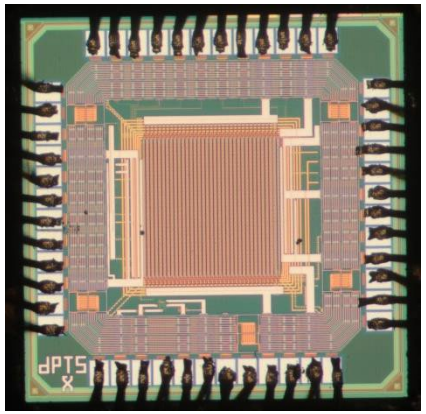
Peak ~ 4000

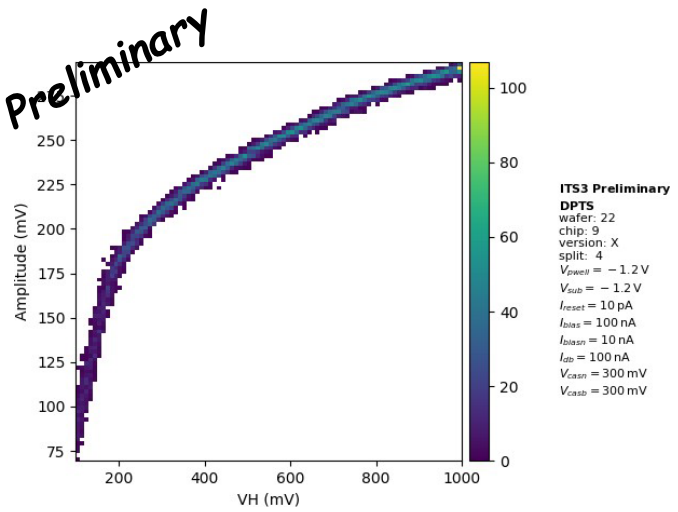
- Both problems seem to be caused by sub-optimal values of resistances on chip carrier and proximity boards.
- After replacement of the resistors:
  1. No more negative pulses
  2. Signal amplitude equal at 20 and 40 MHz rates
  3. Total gain reduced by factor x2
- Optimization in progress

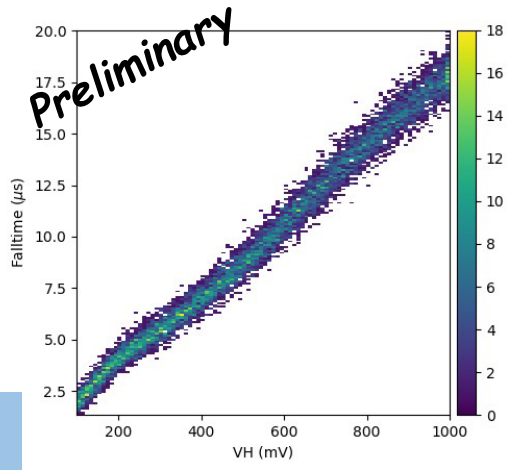
DPTS: laboratory tests

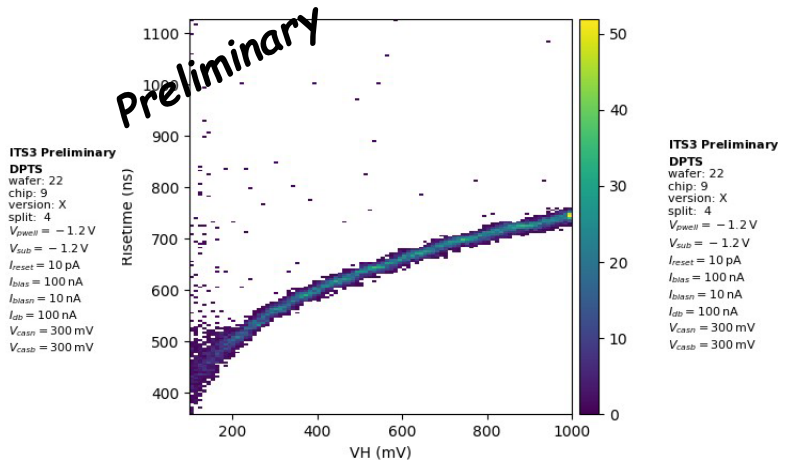
Activities ramping up now:

- Bonding of chips
- Test system commissioning
  - DPTS is readout via oscilloscope
  - Each setup is customized for available hardware
- Setting up readout of analogue pixel output





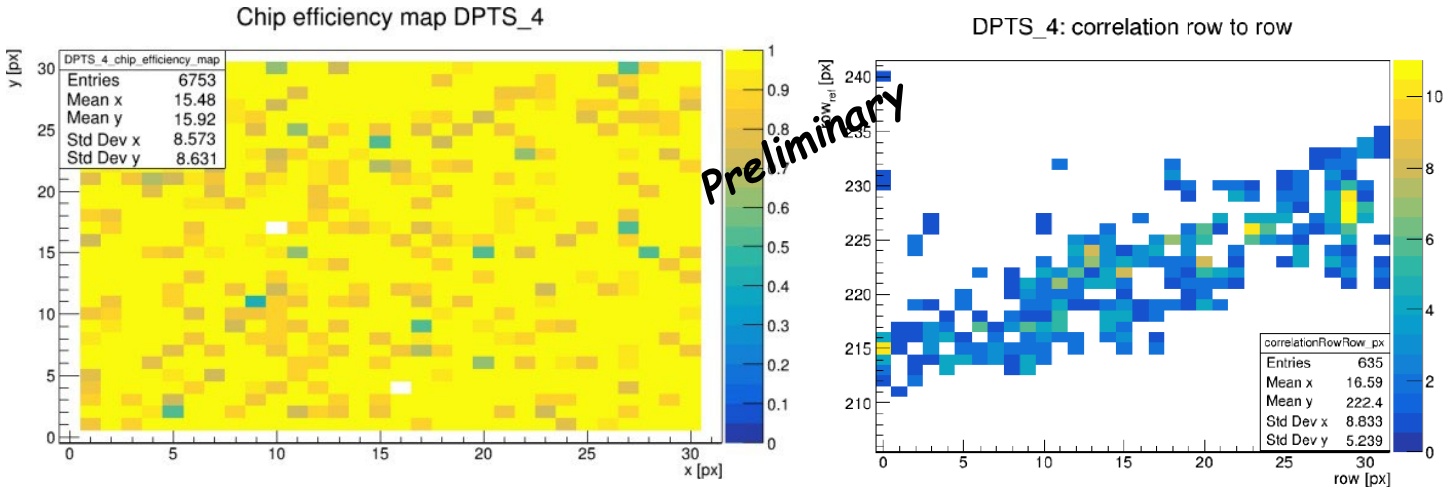


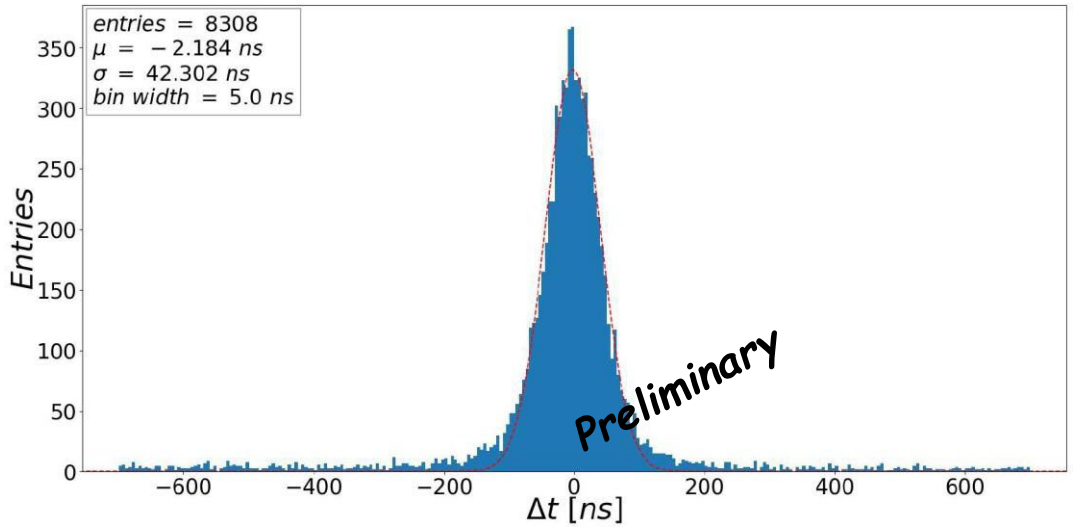


Matthew Buckland et al. (Universita and INFN Trieste)

DPTS: beam test analysis

- Only DESY September data is being analyzed so far:
  - Spatial resolution and efficiency by Pascal Becht (GSI)
  - Time resolution study by Roberto Russo and Bram Van Haastrecht (NIKHEF)
- Efficiency ~ 100%
- Work still in progress
- **Manpower is urgently needed to analyze other beam tests data**





EIC SC joining the MLR1 testing campaign

- Dedicated EIC SC meeting last Friday: https://indico.bnl.gov/event/14561/

- A path to join the ITS3 MLR1 testing campaign was proposed:
  1. Inform/negotiate with Alex Kluge and Magnus Mager at the institutional level
  2. Discuss with Miko Suljic and Sergey Senyukov ITS3 WP3 conveners
  3. Start contributing to testing and/or data analysis *(see next slides)*
     - Task type will be suggested by the WP3 conveners, based on the proposed commitment

- Silicon Consortium will facilitate participation and promote interactions with ITS3

EIC SC Institute participation summary

Institute	Contact person	Also ALICE ITS3	Requested a Test system	Has a test system	Active Tasks
Birmingham	Laura Gonella	no	yes		
RAL	Fergus Wilson	no	yes		
Liverpool	Marielle Chartier	yes	yes		
Lancaster	Harald Fox	no	yes		
Brunel	Liliana Teodorescu	no			
Daresbury	Marcello Borri	yes	yes		
University of Chicago Illinois	Zhenyu Ye	no			
CAPADS Prague	Lukáš Tomášek	no	yes		
ORNL	Jo Schambach	yes	yes		
LBNL/UC	Nikki Apadula, Barbara Jacak	yes	yes		
JLAB	Brian Eng	no	yes		
INFN Trieste	Giacomo Contin	yes	n.a.	yes	DPTS, APTS, Bent ALPIDE characterization

How to contribute to sensor characterization

1. Agree on a task and on a training period with an experienced group *(see Tasklist*)*
   - Characterization tasks are suitable for institutes committing for more than 1 y

2. Join the experienced group for a few weeks to work with them
   - Tests are still in the development/debugging phase → very convenient for learning!
   - Trainee is backed up by long-term committed supervisior and home institute infrastructure

3. In the meantime, procure the necessary equipment for testing at the home institute:
   - ITS3 test systems available from March (priority to ITS groups)
   - Laboratory equipment:
     - PC / Raspberry Pi
     - Electronics laboratory capabilities
     - Radioactive sources / laser system
     - Oscilloscope with BW>1GHz (only for some tests)
     - Wire bonding facility (optional)

* accessible to ALICE members only – working on a solution for external groups

How to contribute to beam test data analysis

A. Medium-term commitment (≥ 6 months):
   - Start from the documentation*
   - Initial ‘in-person’ training with experienced ‘analyzers’ can be agreed, but is not required
   - Supervision and support at the home institute are required
   - Receive support through the dedicated mattermost channel

B. Long-term commitment (> 1 year, at least 50% of time)
   - Special in person training with beam test data analysis expert will be organized
   - Supervision and support at home institute are required
   - Standard documentation/mattermost support always available

* accessible to ALICE members only – working on a solution for external groups

Conclusions

- First intersting results coming from MLR1 characterization
  - Some unexpected results:
    - Require further investigation
    - Useful for test system debugging
  - Some performance confirmed as expected
  - New contributors are more than welcome

- Effective contribution to testing can start immediately
  - **Training with experts at host institution (CERN or other groups)**
  - Local supervision at home institute is required

- Effective contribution to data analysis can start immediately
  - **Remote training and support**

Chip variant phase space

APTS

#	Pitch (um)	Buffer	Coupling	Process
1	10	SF	DC	std
2	10	SF	DC	mod
3	10	SF	DC	gap
4	15	SF	DC	std
5	15	SF	DC	mod
6	15	SF	DC	gap
7	20	SF	DC	std
8	20	SF	DC	mod
9	20	SF	DC	gap
10	25	SF	DC	std
11	25	SF	DC	mod
12	25	SF	DC	gap
13	10	SF	AC	std
14	10	SF	AC	mod
15	10	SF	AC	gap
16	20	SF	AC	std
17	20	SF	AC	mod
18	20	SF	AC	gap
19	10	SF+amp	DC	std
20	10	SF+amp	DC	mod
21	10	SF+amp	DC	gap
22	20	SF+amp	DC	std
23	20	SF+amp	DC	mod
24	20	SF+amp	DC	gap
25	10	SF+amp	AC	std
26	10	SF+amp	AC	mod
27	10	SF+amp	AC	gap
28	20	SF+amp	AC	std
29	20	SF+amp	AC	mod
30	20	SF+amp	AC	gap
31	10	OPAMP	DC	std
32	10	OPAMP	DC	mod
33	10	OPAMP	DC	gap
34	10	OPAMP	AC	std
35	10	OPAMP	AC	mod
36	10	OPAMP	AC	gap
37	10	SF mux	DC	gap
38	20	SF mux	DC	gap

CE65

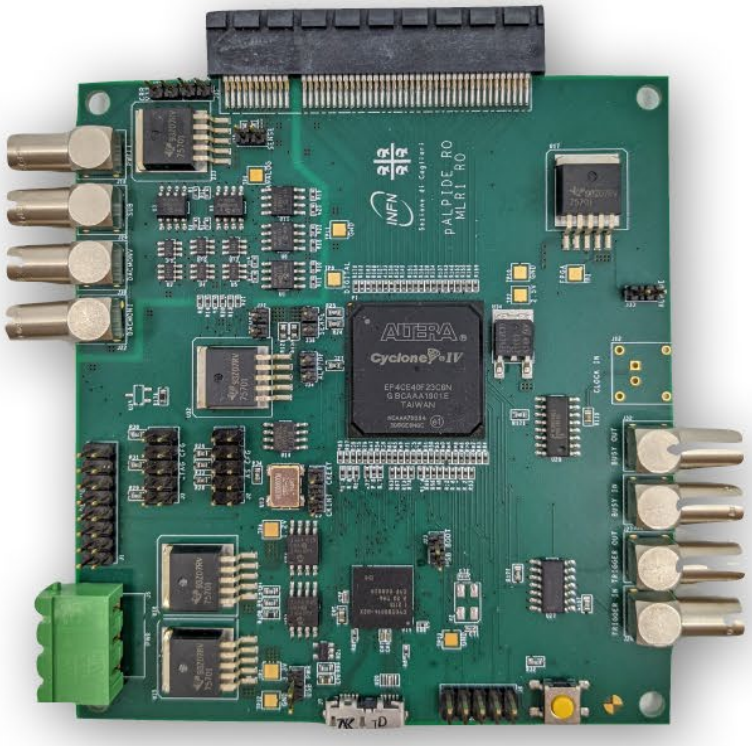
#	Pitch (um)	Buffer [coupling]	Process
A	15	Amp [AC], Amp [DC], SF [DC]	std
B	15	Amp [AC], Amp [DC], SF [DC]	gap
C	15	Amp [AC], Amp [DC], SF [DC]	Mod
D	25	Amp [AC], Amp [DC], SF [DC]	std

DPTS

#	Pitch (um)	Variant
1	15	Base
2	15	Column cross connect
3	15	column cross connect, shorted DVSS AVSS

× 4 splits

MLR1 DAQ board



DPTS Proximity Card

APTS SF Proximity Card

CE65 Proximity Card

APTS OA Proximity Card

20 DAQ + 20 Proximity cards delivered 17.08.

Commissioning ongoing at INFN Cagliari (FW/SW/all variants), CERN (APTS/DPTS), IPHC (CE65)

MLR1 Task List: APTS SourceFollower

APTS SF characterisation	Lab measurements		-	-	Sensor characterisation in the laboratory.
		Software	?	?	Develop software for signal extraction and clusterisation.
		Noise	?	?	Study the noise of the test system, sensor, RTS.
		Calibrate	?	?	Calibrate conversion and pulsing capacitances (55-Fe).
		Charge collection	?	?	Study the response to 55-Fe X-rays. X different variants X different biases.
		Temperature dependence	?	?	Characterise sensor response as function of temperature.
		Separating PWELL and SUB	?	?	Study the behaviour with separate PWELL and SUB.
	Testbeam analysis		-	-	Analyse the testbeam data.
		EUDAQ converter	Mauro	Nov 2021	Write, test and verify APTS converter.
		Charge collection	?	?	Study charge collection MPV and charge sharing. X different variants X different biases.
		Efficiency	?	?	Efficiency vs biasing parameters / threshold for multiple chips.
		Spatial resolution	?	?	Spatial resolution vs biasing parameters / threshold for multiple chips.

MLR1 Task List: APTS OpAmp

APTS OA characterisation	Lab measurements		-	-	Sensor characterisation in the laboratory.
		Software	?	?	Develop software for signal extraction and clusterisation.
		Noise	?	?	Study the noise of the test system, sensor, RTS.
		Pulsing	?	?	Study response to pulsing.
		Calibrate	?	?	Calibrate conversion and pulsing capacitances (55-Fe).
		Charge collection	?	?	Study the response to 55-Fe X-rays. X different variants X different biases.
		Laser response	?	?	Characterise all aspects of the sensor response to laser beam.
	Testbeam analysis		-	-	Analyse the testbeam data.
		EUDAQ SW	?	?	Write, test and verify Producer and Converter.
		Efficiency	?	?	Efficiency vs biasing parameters / threshold for multiple chips.
		Time resolution	?	?	Study time response to MIP beam.

MLR1 Task List: DPTS

DPTS characterisation	Commission DAQ board based test system		Trieste	2021	Commission the MLR1 DAQ board + DPTS Proximity for use with DPTS.
	Lab measurements		-	-	Sensor characterisation in the laboratory.
		Response vs front-end bias	?	?	Threshold, noise, Fake Hit Rate, TOT, Rise time... as a function of all biasing parameters. Subset of pixels, multiple chips (variants, irradiation...).
		Noise	?	?	Understand noise sources and behaviour.
		Dead pixels	?	?	Study pixels unresponsive to pulsing and external stimuli.
		55-Fe	?	?	Study the response to 55-Fe X-rays and try to use it to calibrate the pulsing capacitance/threshold.
		Temperature dependence	?	?	Characterise sensor response as function of temperature.
		Separating PWELL and SUB	?	?	Study the behaviour with separate PWELL and SUB.
		Monitor pixel output	?	?	Characterise AOUT pulse as function biasing parameters.
		Laser response	?	?	Characterise all aspects of the sensor response to laser beam.
	Testbeam analysis		-	-	Analyse the testbeam data.
		Efficiency	?	?	Efficiency vs biasing parameters / threshold for multiple chips.
		Spatial resolution	?	?	Spatial resolution vs biasing parameters / threshold for multiple chips.
		Time resolution	?	?	Study time response to MIP beam.