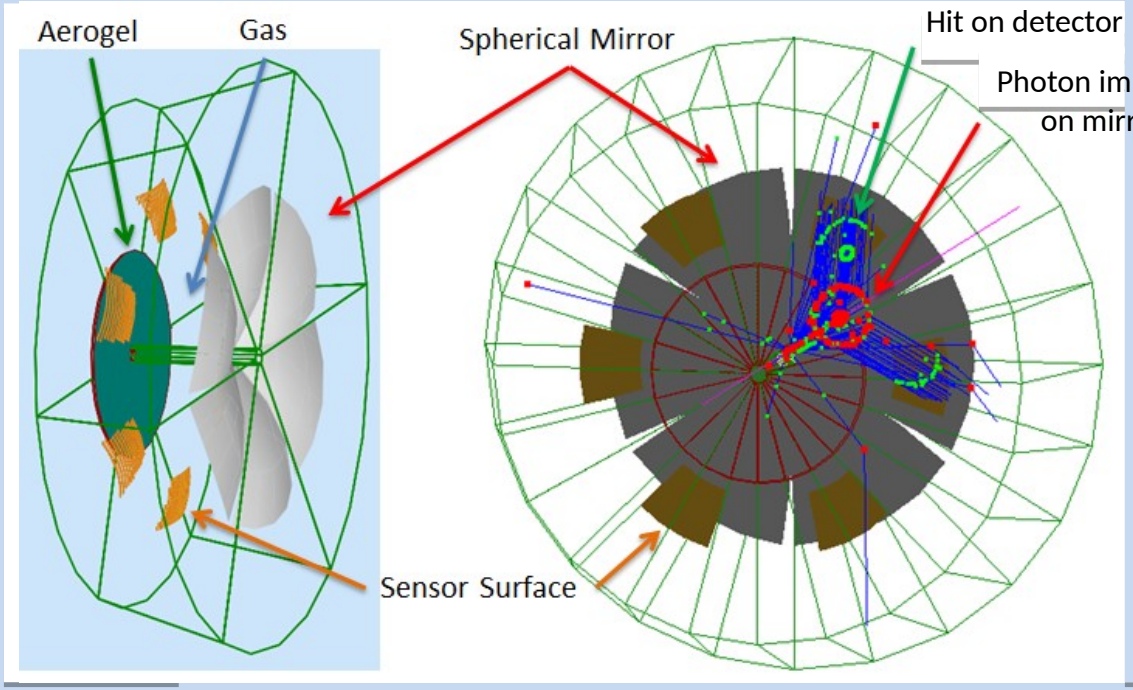
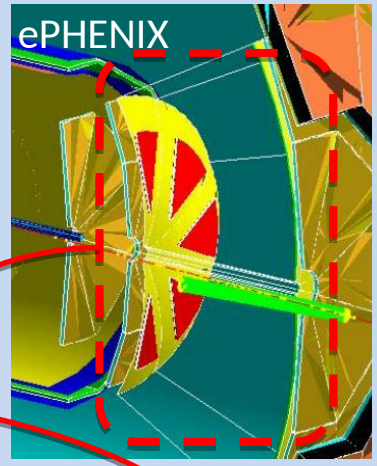
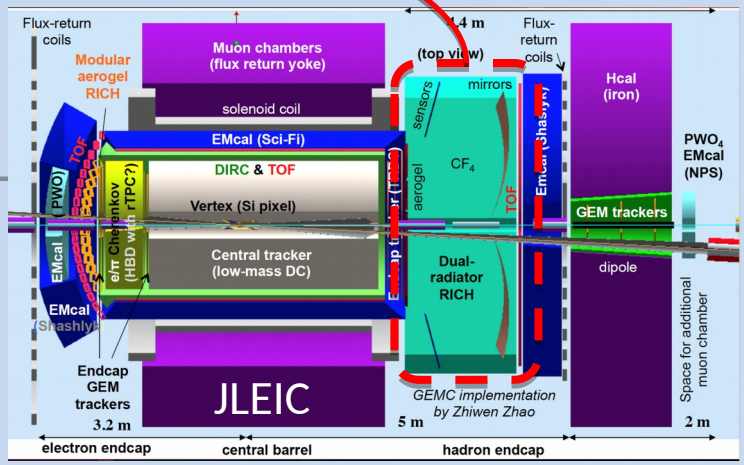
Dual Radiator RICH in EIC Hadron-endcap







dRICH: flexible configuration (JLEIC, ePHENIX)

Radiators: Aerogel (n_{AERO}~1.02) + Gas (n_{C2F6} ~ 1.0008)

Detector: 0.5 m^2/sector , 3x3 mm^2 pixel

Single-photon detection in ~1T magnetic field

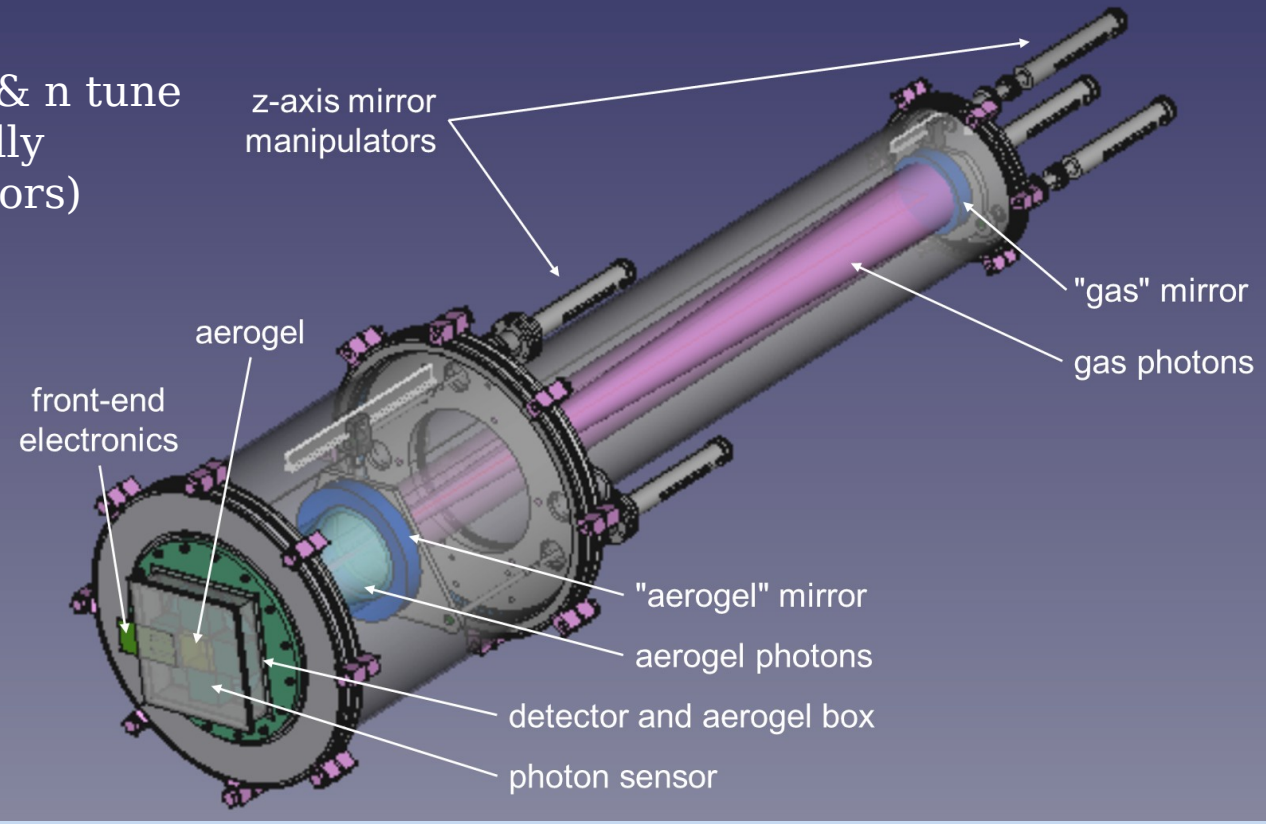
Outside acceptance, reduced constraints

best candidate for SiPM option

Phase Space:
- Polar angle: 5-25 deg
- Momentum: 3-60 GeV/c

dRICH Prototype

Dual radiator imaging
Pressure vessel for gas & n tune
Sensor & readout friendly
(interchangeable detectors)



Procurement initiated (INFN in-kind):

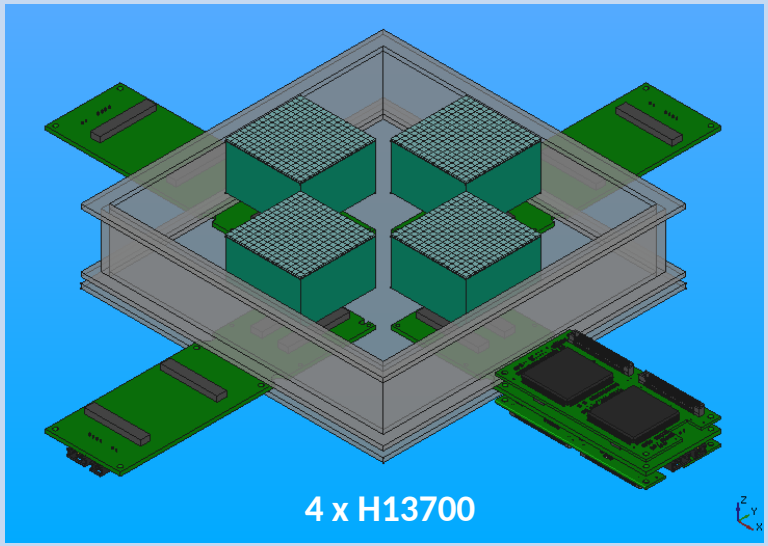
* Aerogel (n=1.02, n=1.03) with dimensions compatible with mRICH
- Standard vacuum components (pipes, clamps, o-rings)
- Custom flanges

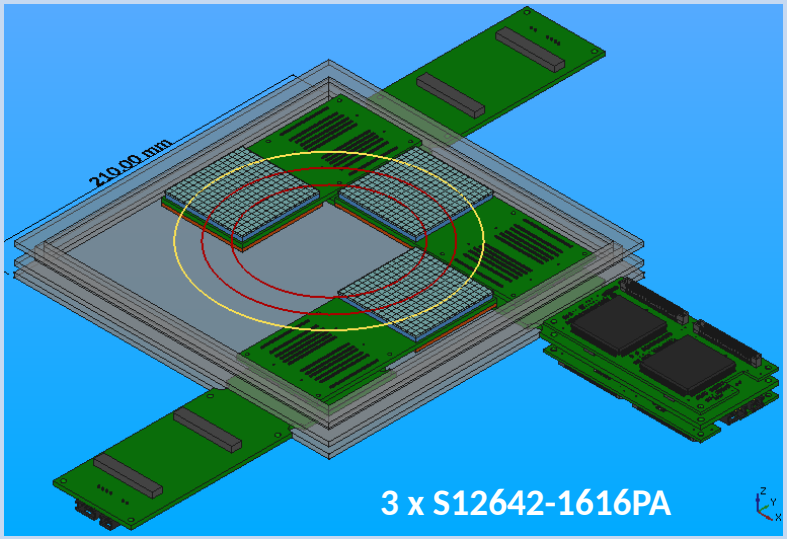
Survey ongoing:

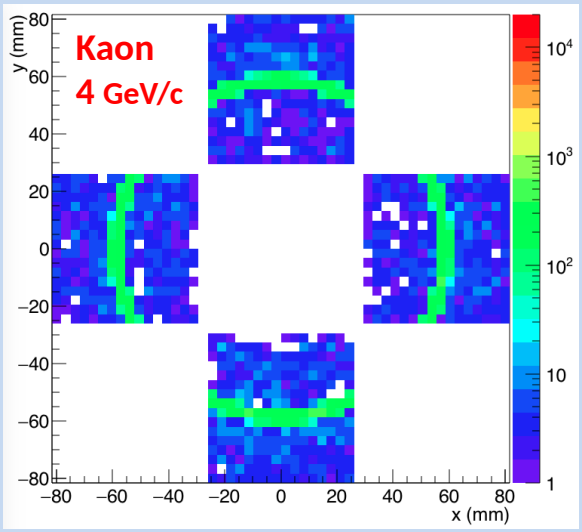
- Gas / mirrors / mechanics

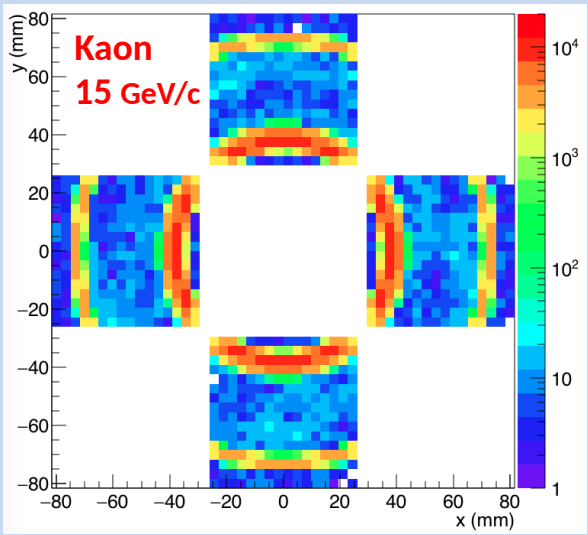
dRICH Imaging

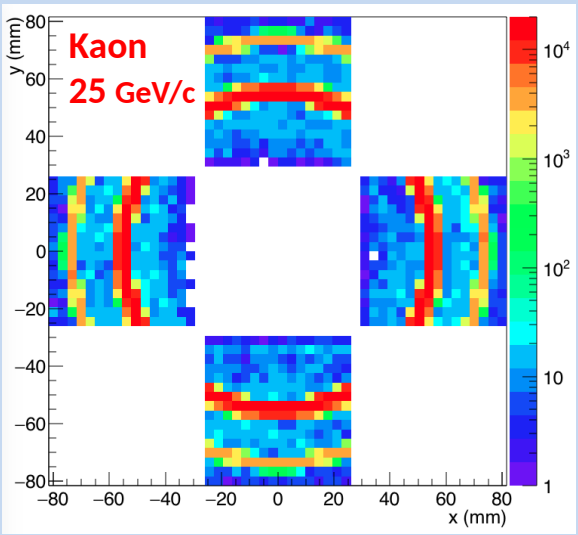
House the same principles and readout units used for mRICH test-beams
Compatible with H13700/S12642 + MAROC front-end
Allows to study the working principles and optical performance of the components



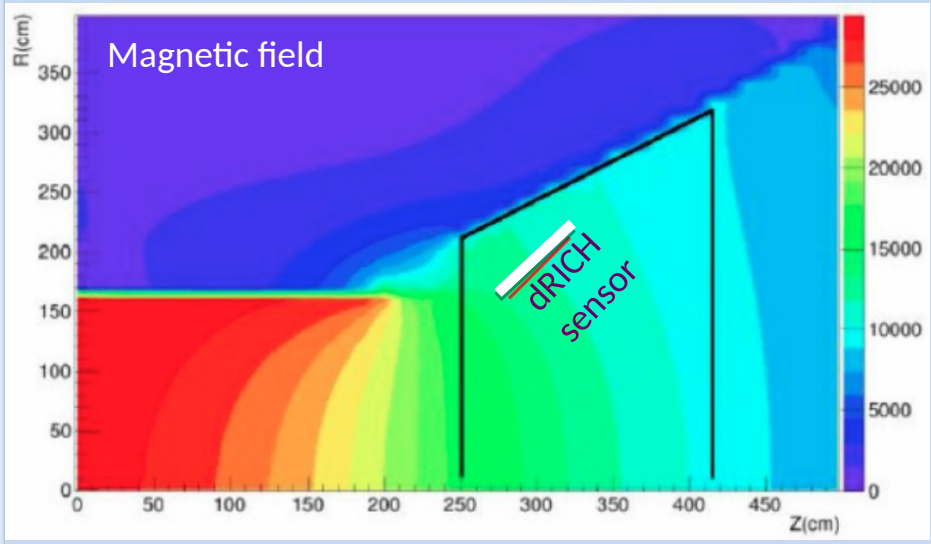


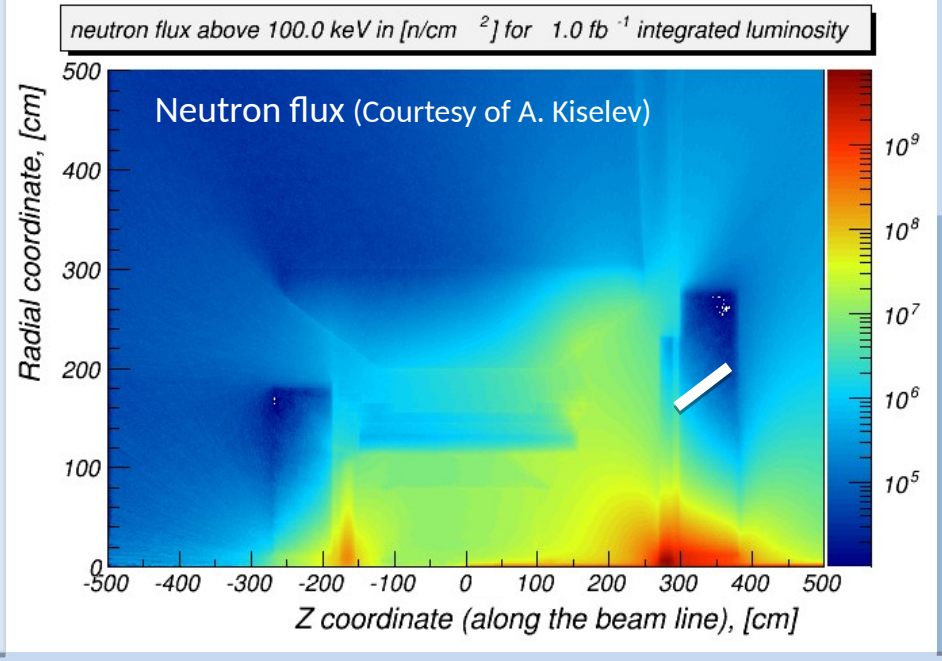






dRICH Detector Environment





dRICH sensor location relaxes requirements on neutron dose tolerance and material budget

Magnetic Field

~ 1 T order of magnitude, varying orientation

SiPM: PET study up to 7 T 10.1109/NSSMIC.2008.4774097

Neutron Fluence

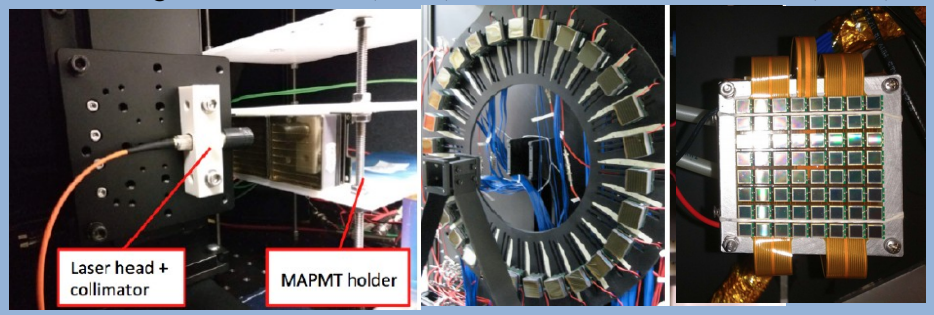
~ 10^{11} n_{eq}/cm^2

reference value for several years at max lumi (10^{34})

SiPM: radiation mitigation for SPE actively studied till 10^{11} n_{eq}/cm^2 and above 10.1016/j.nima.2019.01.013 10.1016/j.nima.2018.10.191

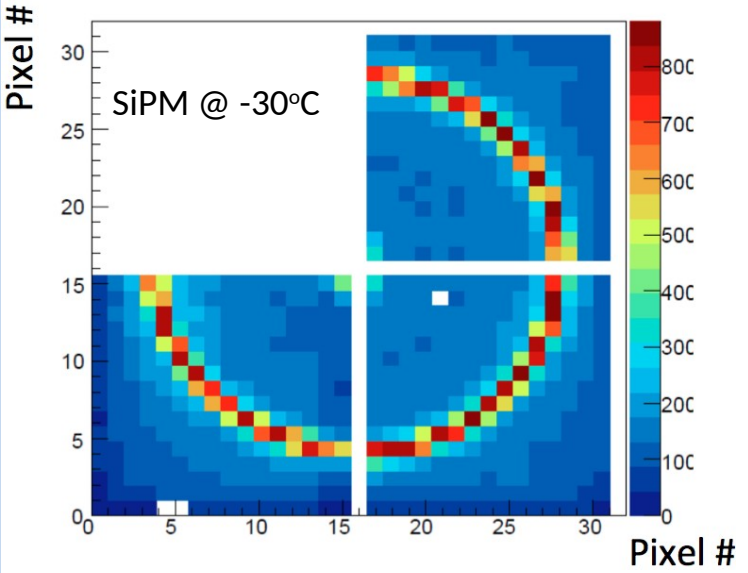
SiPM SPE capability under study since 2012 @ INFN

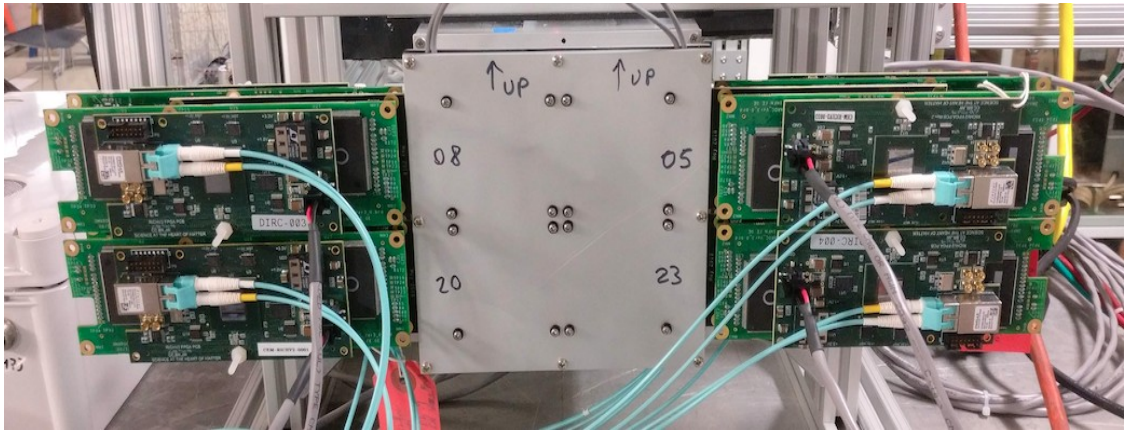
Contalbrigo++ NIMA 766 (2014) 22, Balossino ++ NIMA876 (2017) 89

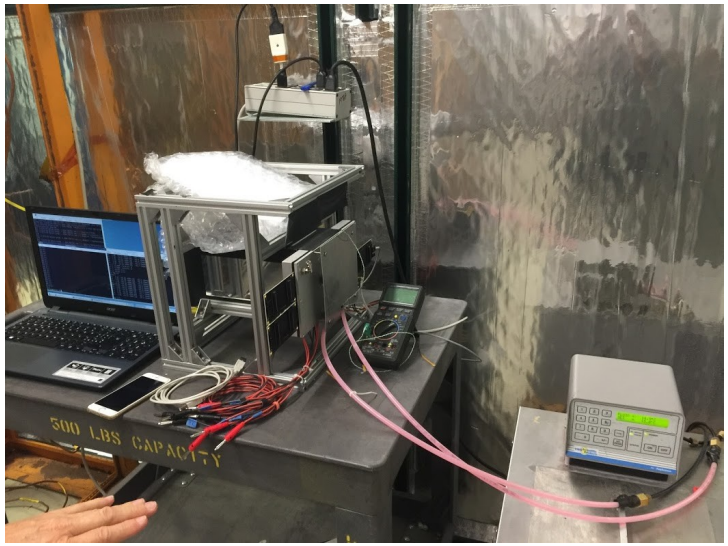


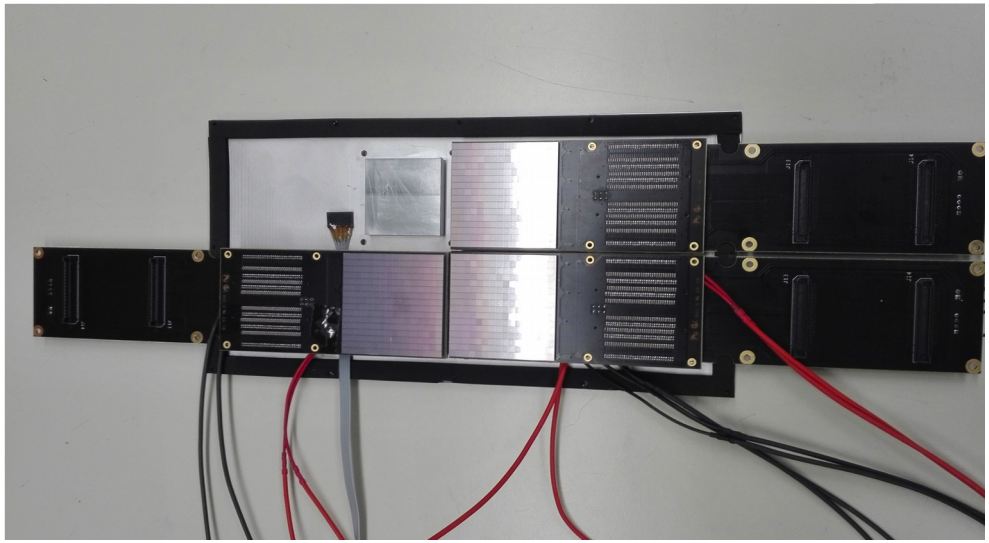
SiPM and Electronics

mRICH test-beam @ Fermilab 2018



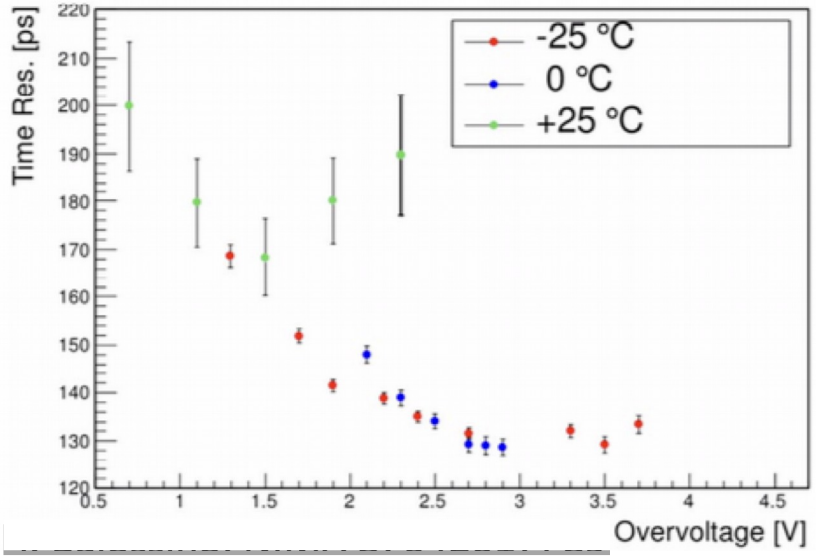


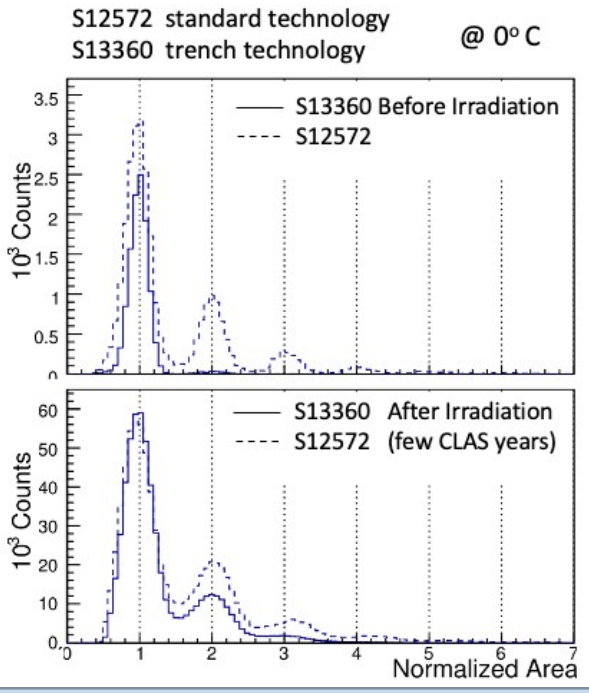




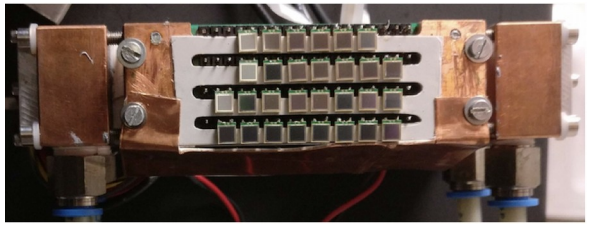
SiPM and Electronics

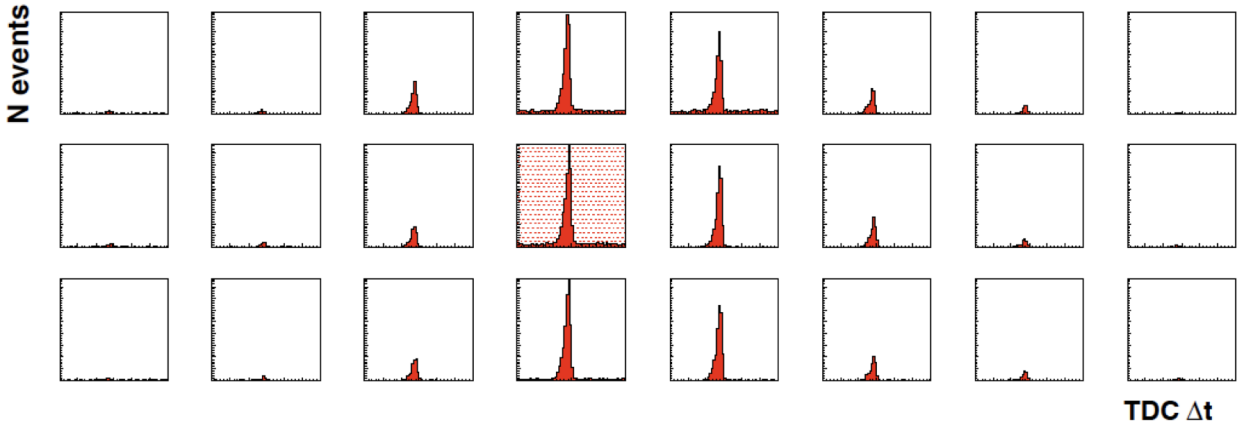
SiPM irradiation 2016 NIMA 876 (2017) 89





SiPM & CLAS12 prototype
2016 NIMA 766 (2014) 22





Irradiation Tests (spring 2021)

Work on electronics

Organize groups of SiPM in 4x8 customized matrices, each group with

- specific producer
- different n_{eq} integrated dose

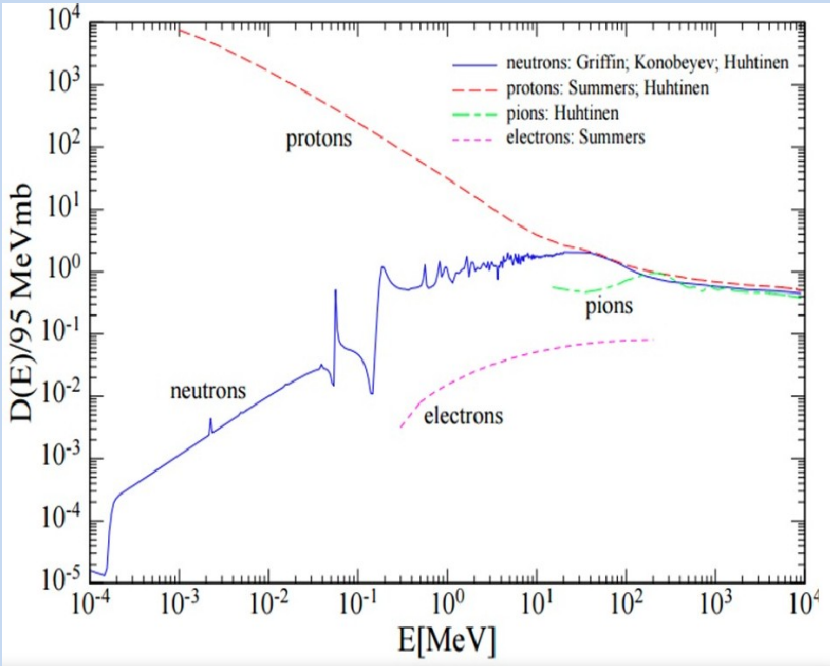
0	e9	e10	e11

(cm^{-2})

- alternative designs (micro-cell size, quench resistor, wavelength range, ...)

Use available facilities in Italy (**protons: TIFPA**, LNS neutrons: ENEA)

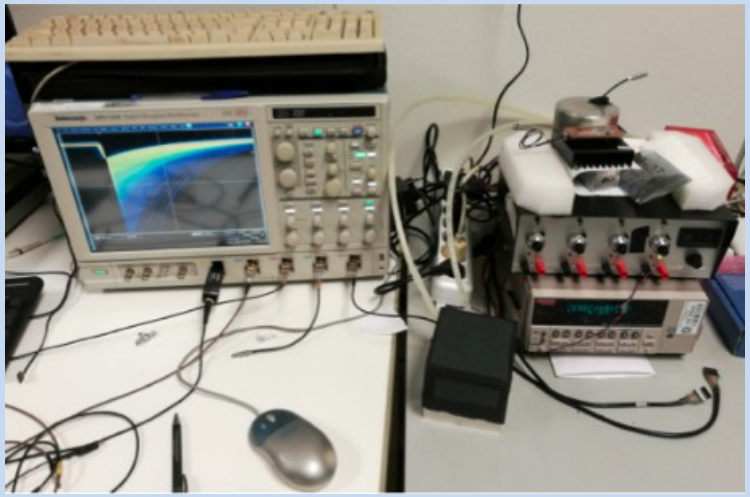
30	30	30	30		
20	20	20	20		
30	30	30	30		
20	20	20	20		
30	30	30	30		
20	20	20	20		
30	30	30	30		
20	20	20	20		



Designed to be used for irradiation tests and at test-beams after irradiation

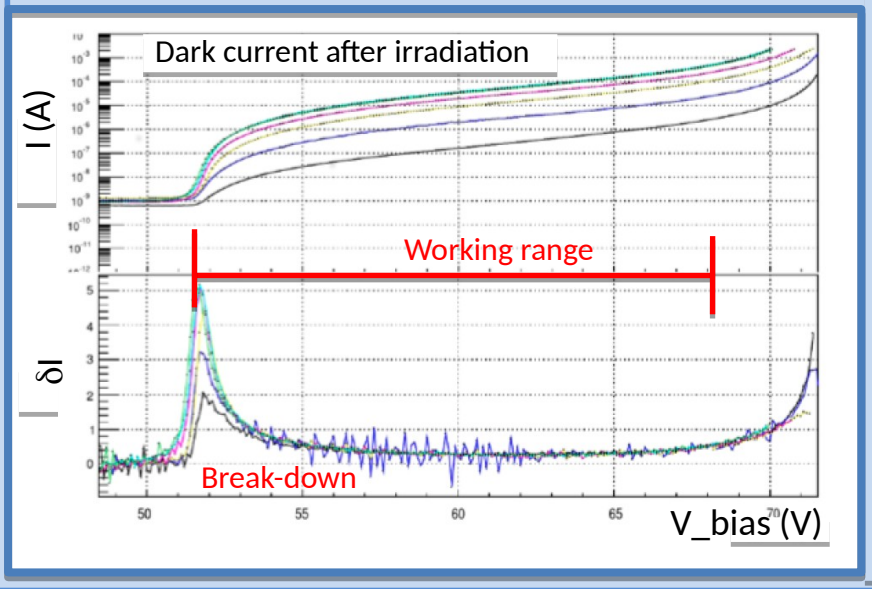
SiPM Characterization

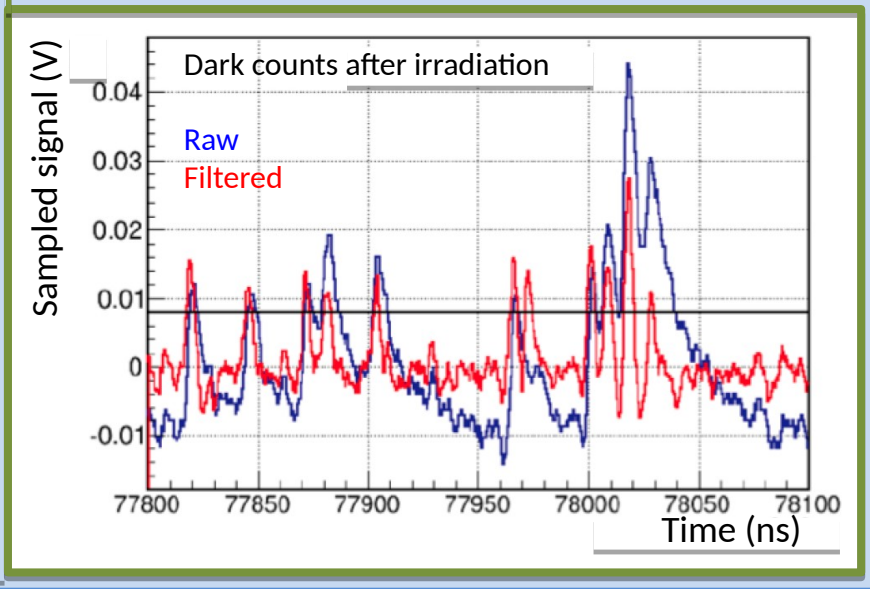
SiPM characterization and proton irradiation @ Proton Therapy Center of Trento, IT



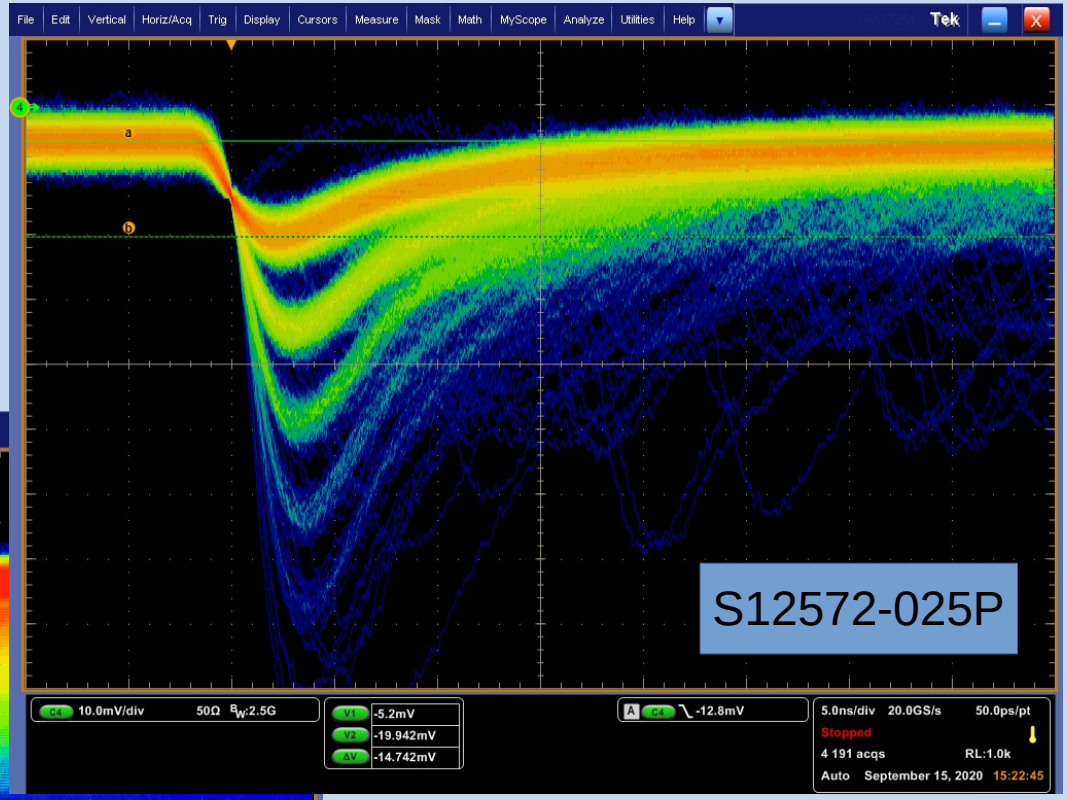
I-V characteristics & Signal sampling

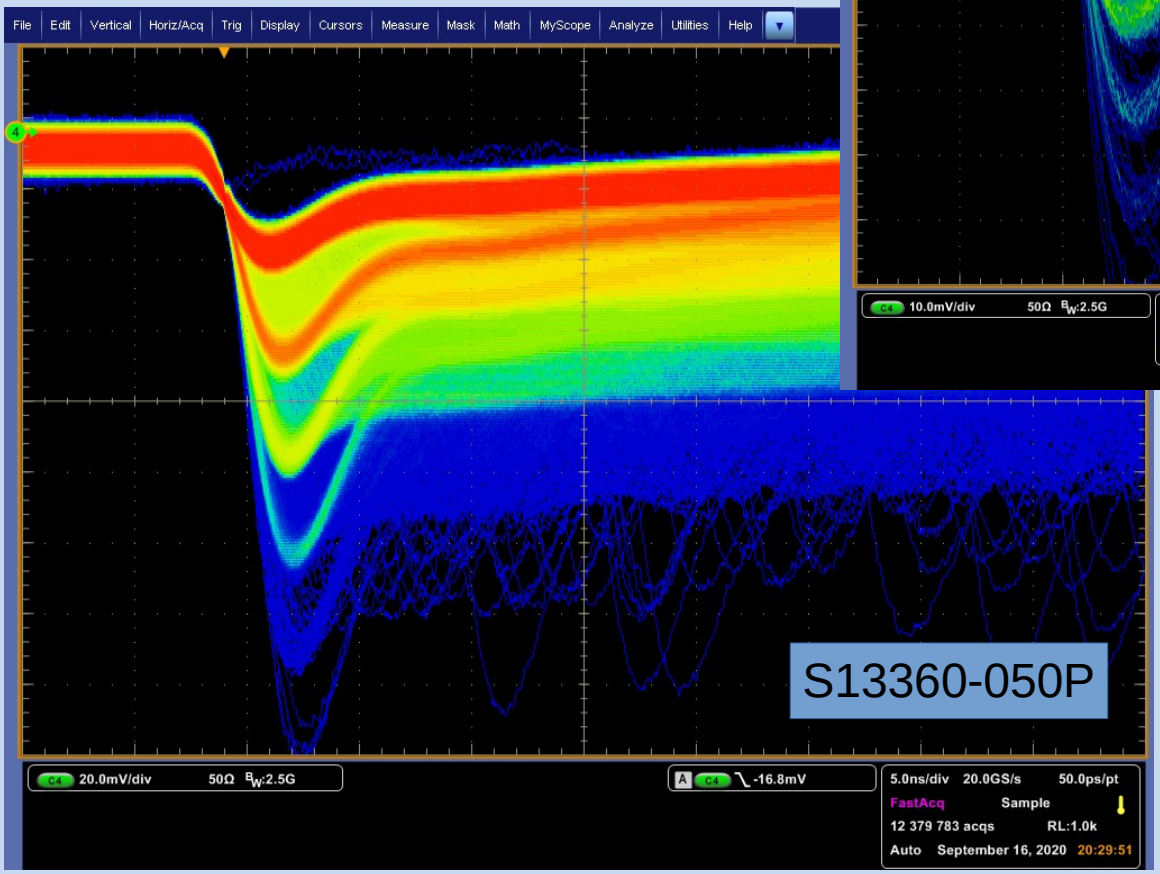
Temperature control and treatments

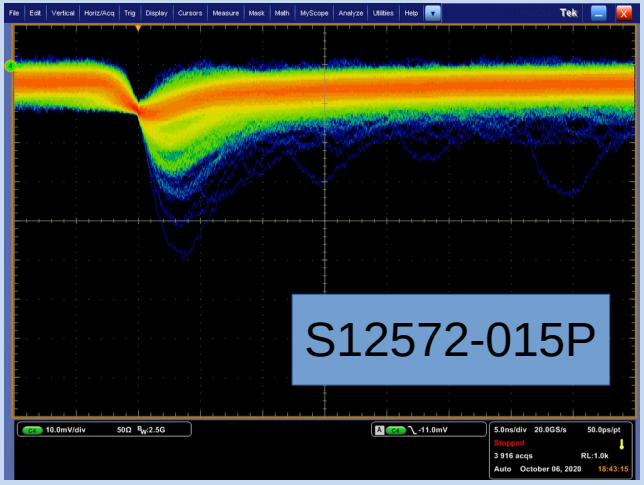




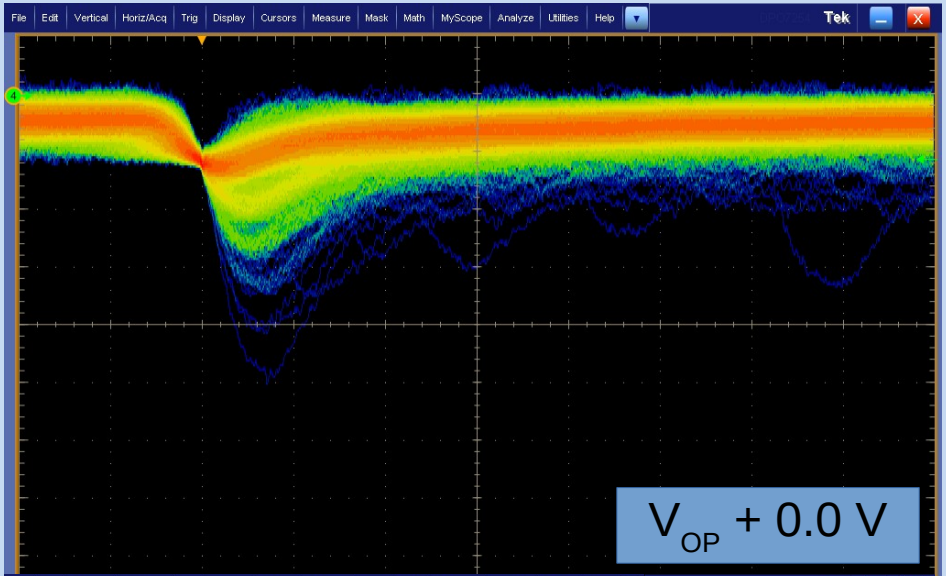
Hamamatsu (old) SiPM

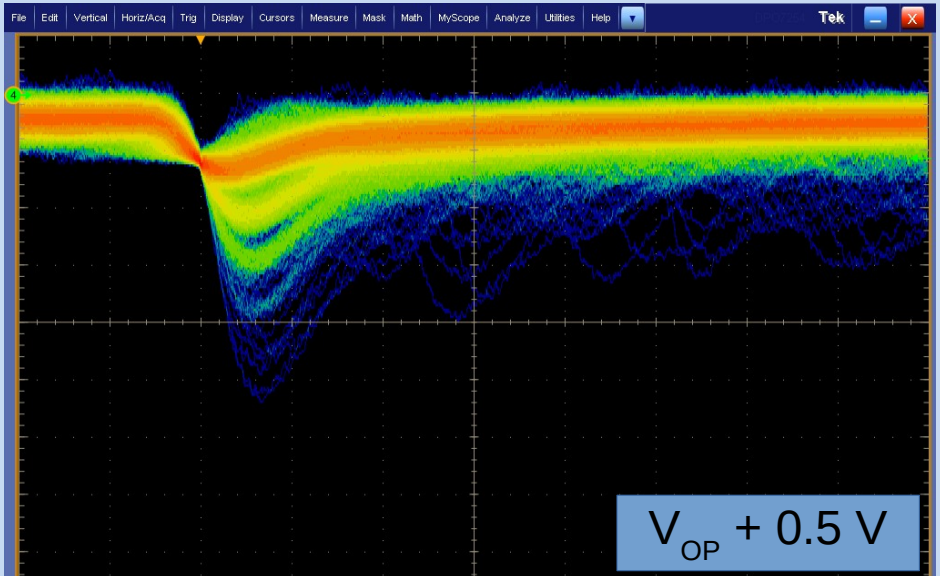


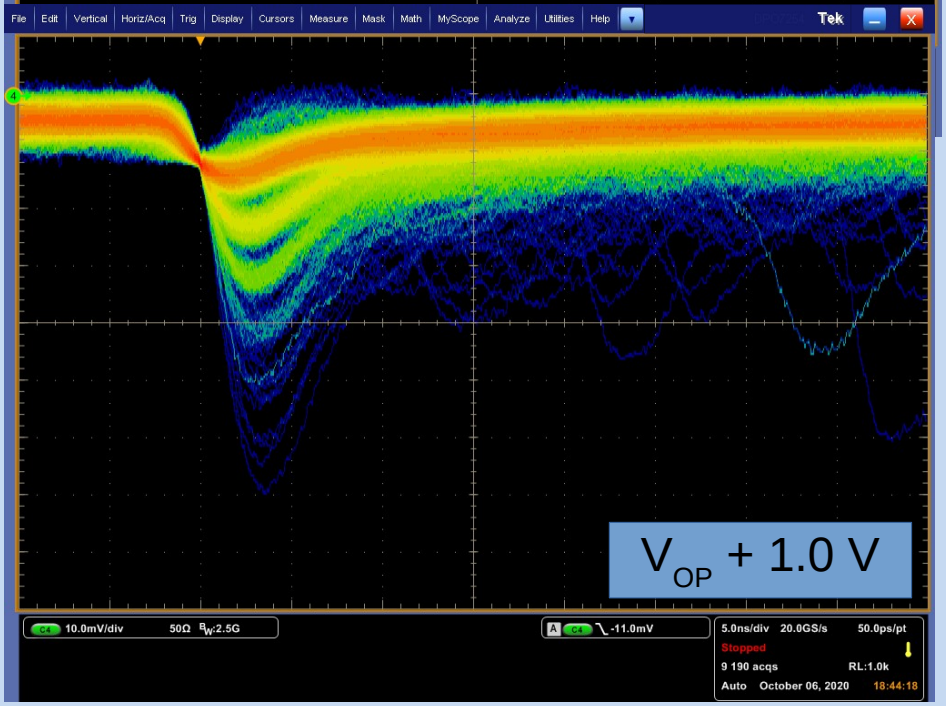


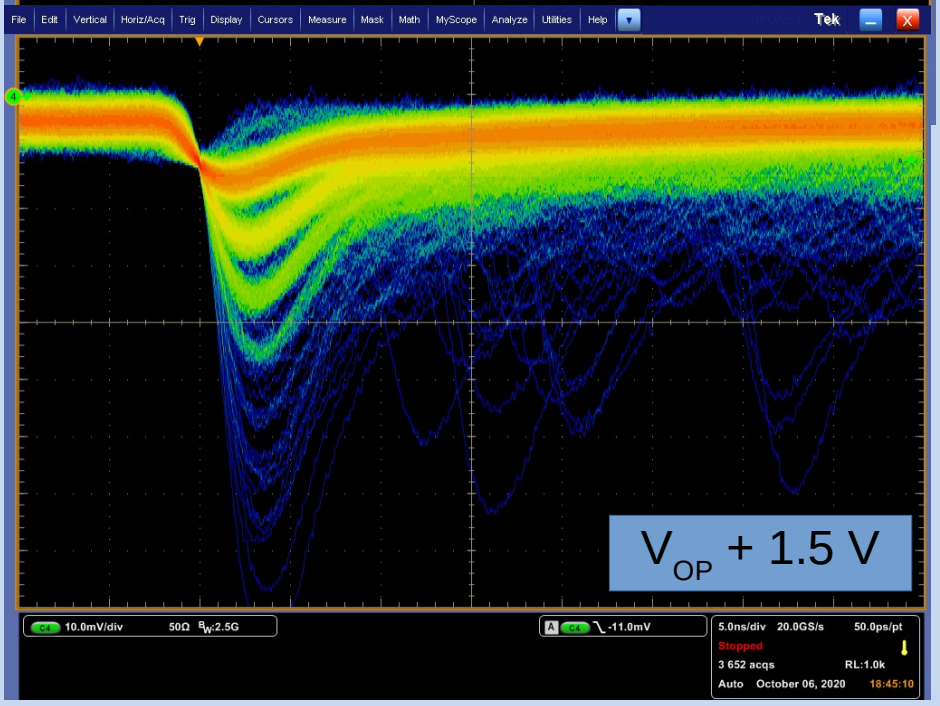


Hamamatsu SiPM 15P

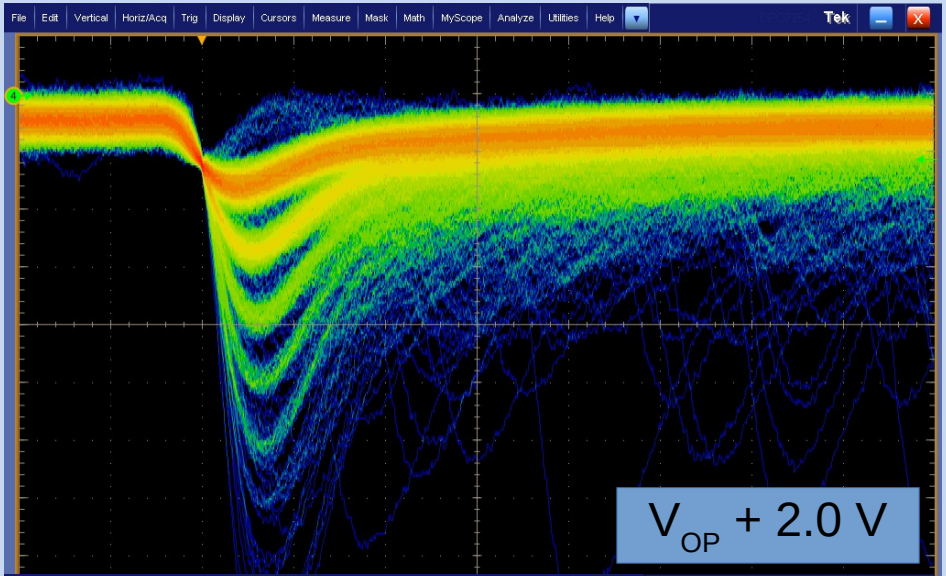


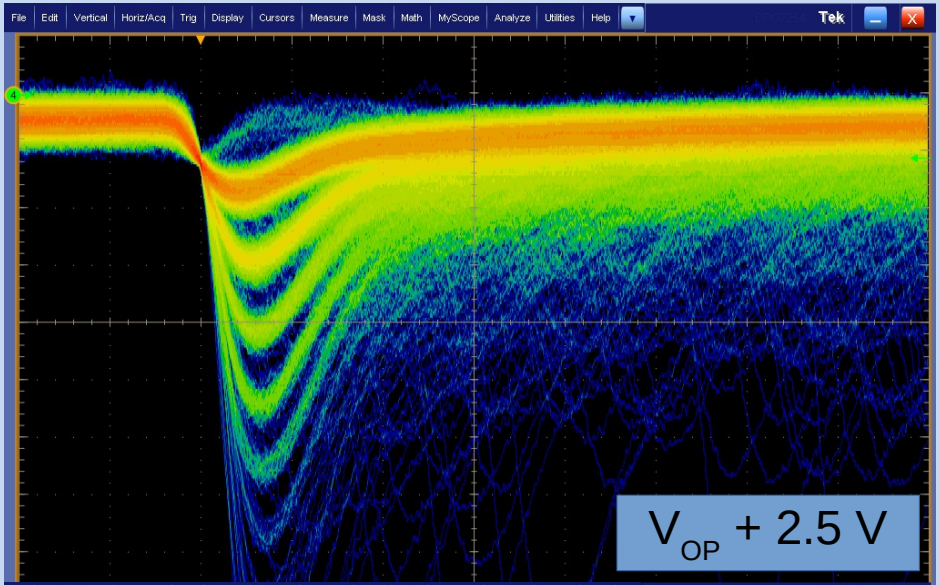


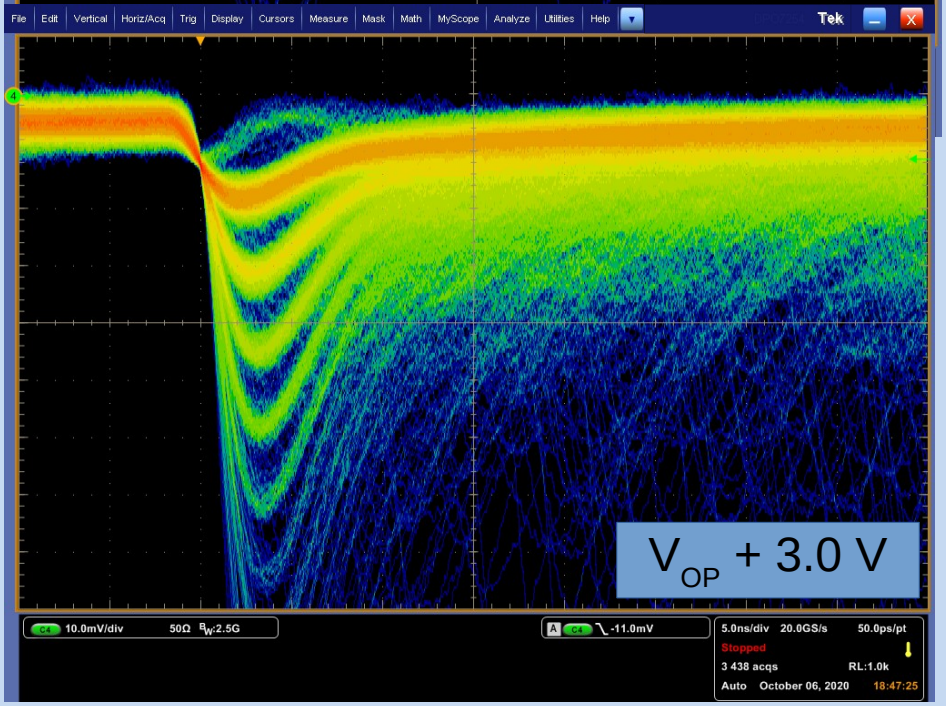


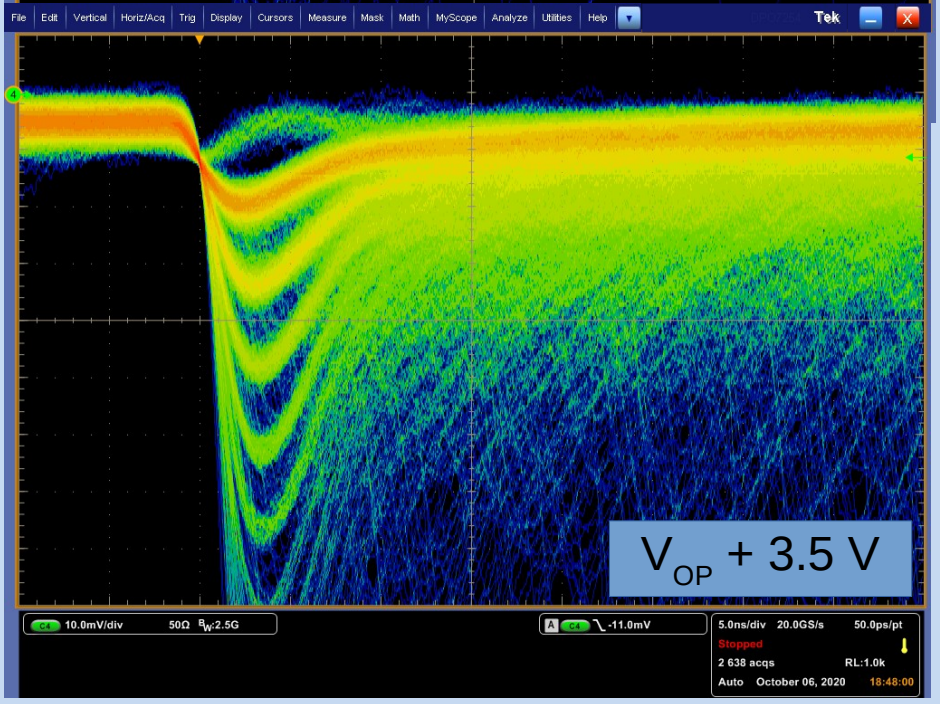


Hamamatsu SiPM 15P









SiPMs producers

supplier	model	vendor	price [10 pcs,matrix] (EUR)	type	pixel (mm)	cell (um)	mount / connector	window	PDE (%) peak	DCR (kHz/mm2)	PDE / sqrt(DCR)	package fill factor (%)	x-talk (%)
Ketek	PM3325-WB-D0	self	159	single	3	25	smt	glass	45	125	4.02	82	26
Ketek	PM3315-WB-C0	self	159	single	3	15	smt	glass	31	125	2.77	82	18
Ketek	PA3325-WB-0404	self	310	4x4	3	25	Samtec	glass	45	125	4.02	80	26
Hamamatsu	S13360-3025CS	self		single	3	25	ceramic	silicone	25	45	3.73	23	1
Hamamatsu	S13360-3025PE	self		single	3	25	smt	epoxy	25	45	3.73	54	1
Hamamatsu	S13360-3050CS	self		single	3	50	ceramic	silicone	40	55	5.39	23	3
Hamamatsu	S13360-3025PE	self		single	3	50	smt	epoxy	40	55	5.39	54	3
Hamamatsu	S13360-3050VE	self		single	3	50	smt	epoxy	40	55	5.39	78	3
Hamamatsu	S13361-3050NE-04	self		4x4	3	50	smt	epoxy	40	55	5.39	85	3
Hamamatsu	S14160-3050HS	self	290	single	3	50	smt	silicone	50	165	3.89	78	7
Hamamatsu	S14161-3050HS-04	self		4x4	3	50	smt	silicone	50	165	3.89	85	7
Hamamatsu	S14520-3050VS	self	320	single	3	50	smt	silicone	49	133	4.25	78	5
Hamamatsu	S14160-3015PS	self	480	single	3	15	smt	silicone	32	78	3.62	54	< 1
Hamamatsu	S13362-3050DG	self		single	3	50	metal	glass	40	25	8.00	4	3
SensL	C-Series 30050			single	3	50	smt	compound	35	33	6.09	56	10
SensL	ARRAYC-30035-16P-PCB			4x4	3	35	Hirose	compound	31	33	5.40	56	7
SensL	MICROFJ-30035-TSV-TR	Mouser	211	single	3	35	smt	glass	38	50	5.37	94	8
SensL	MICROFJ-30035-TSV-TR1	Mouser	523										
SensL	MICROFJ-30020-TSV-TR1	Mouser	475	single	3	20	smt	glass	30	50	4.24		
SensL	ARRAYJ-30035-16P-PCB			4x4	3	35	Hirose	glass	38	50	5.37	86	8
AdvanSid	ASD-NUV3S-P				3	40		epoxy	43	100	4.30	65	
Broadcom	AFBR-S4N44P163	Mouser	312	4x4	3	30	smt	glass	55	255	3.44	92	
Broadcom	AFBR-S4N33C013	Mouser		single	3	30	smt	glass	54	255	3.38	91	
Broadcom	AFBR-S4N44C013	Mouser	202	single	3.72	30	smt	glass	55	270	3.35	92	

ALCOR board (Manuel D. Da Rocha INFN-TO)

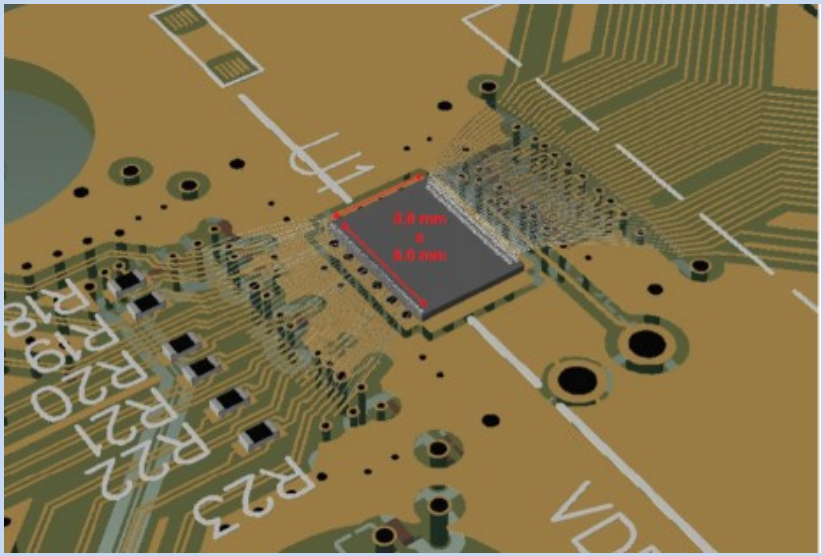
SiPM board*: 4 SiPM samples for each vendor, type and dose mounted as 8 x 4 matrices for tests & imaging; compatible with irradiation, annealing cycles and laboratory characterization

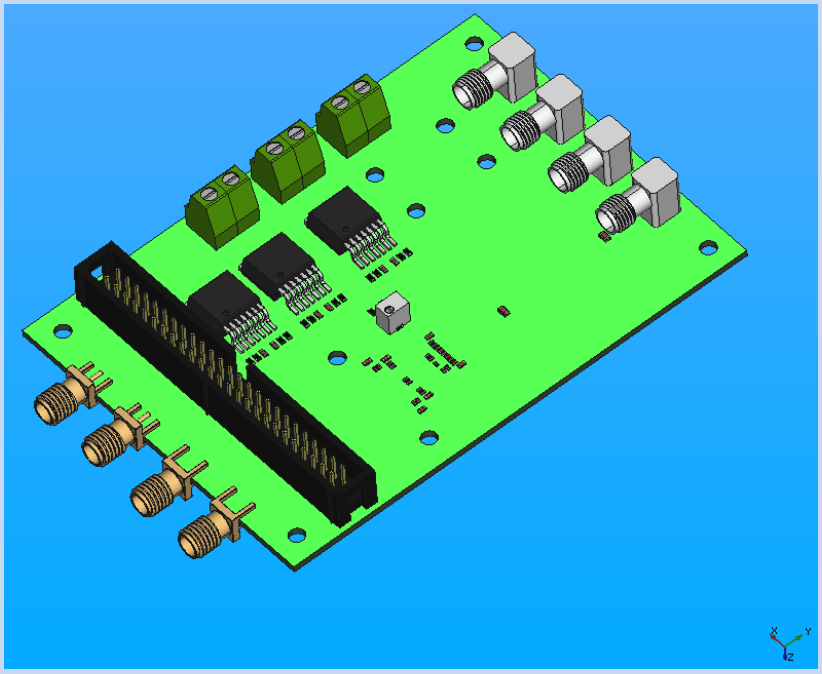
(Adapter board*: bias distributors and signal pre-conditioning)

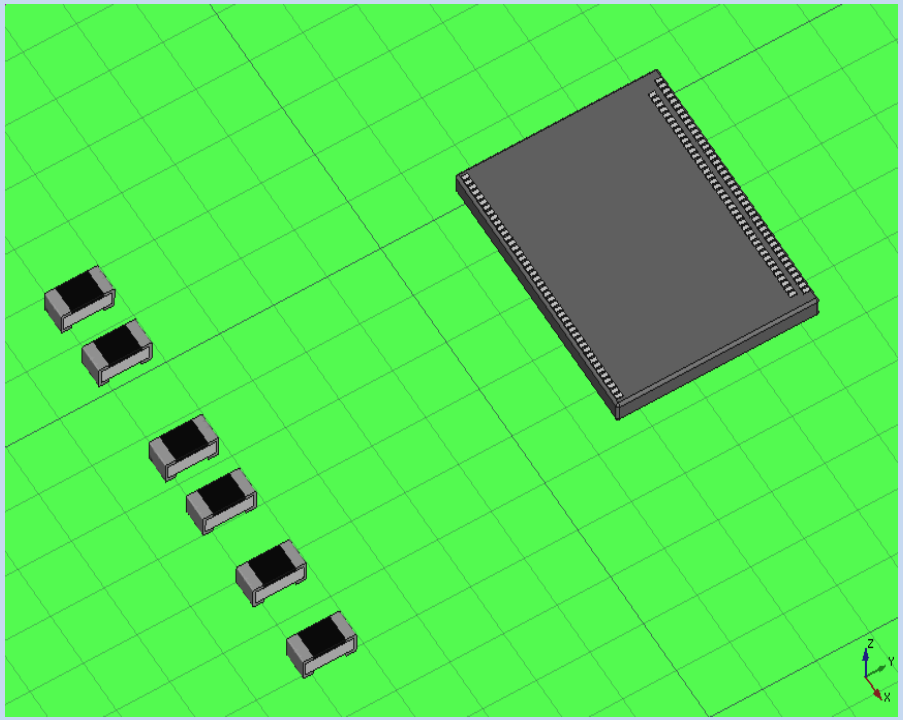
ALCOR board*: ALCOR chip + firefly DAQ

ALCOR chip: under development at INFN (DARKSIDE)
ToT architecture for cryogenic application
32 channels, 50 ps TDC, >500 kHz/channel

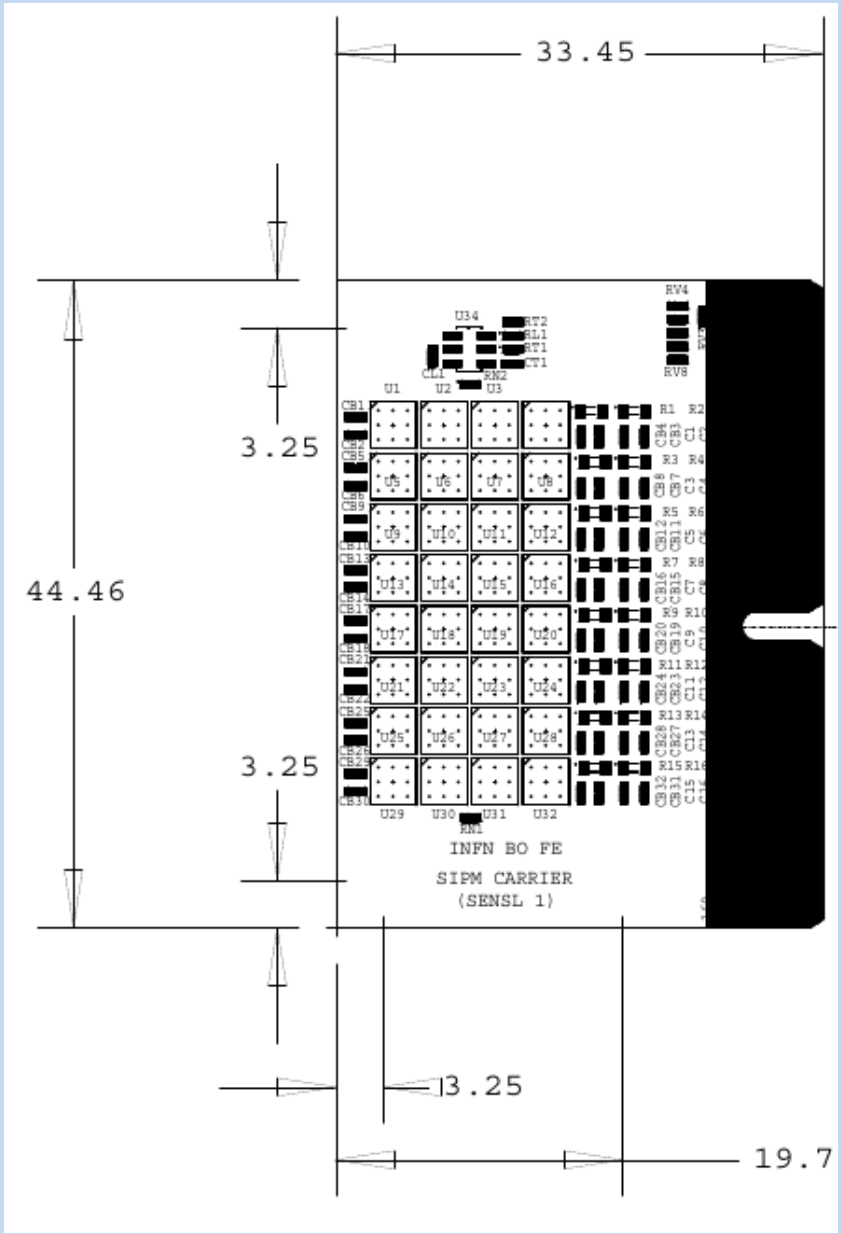
Firefly DAQ: derived from ARCADIA INFN GR5 project

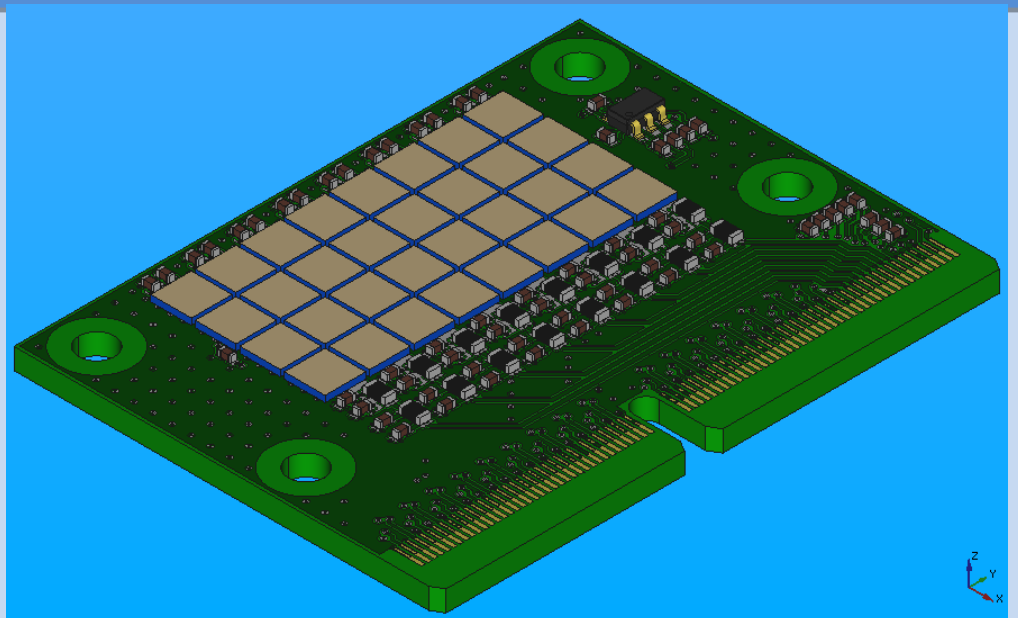


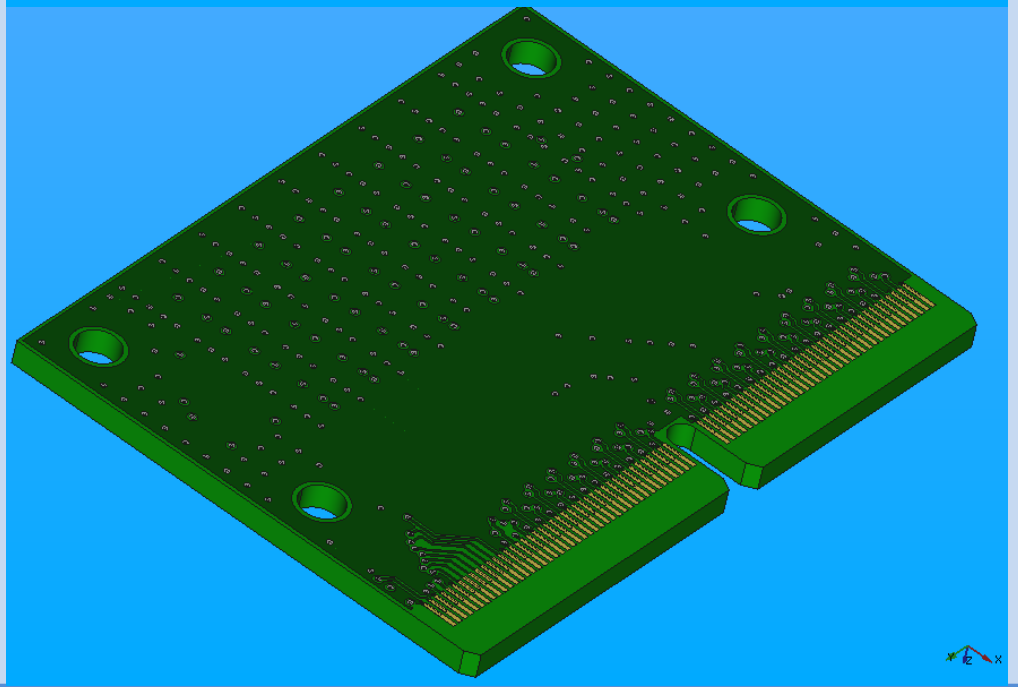




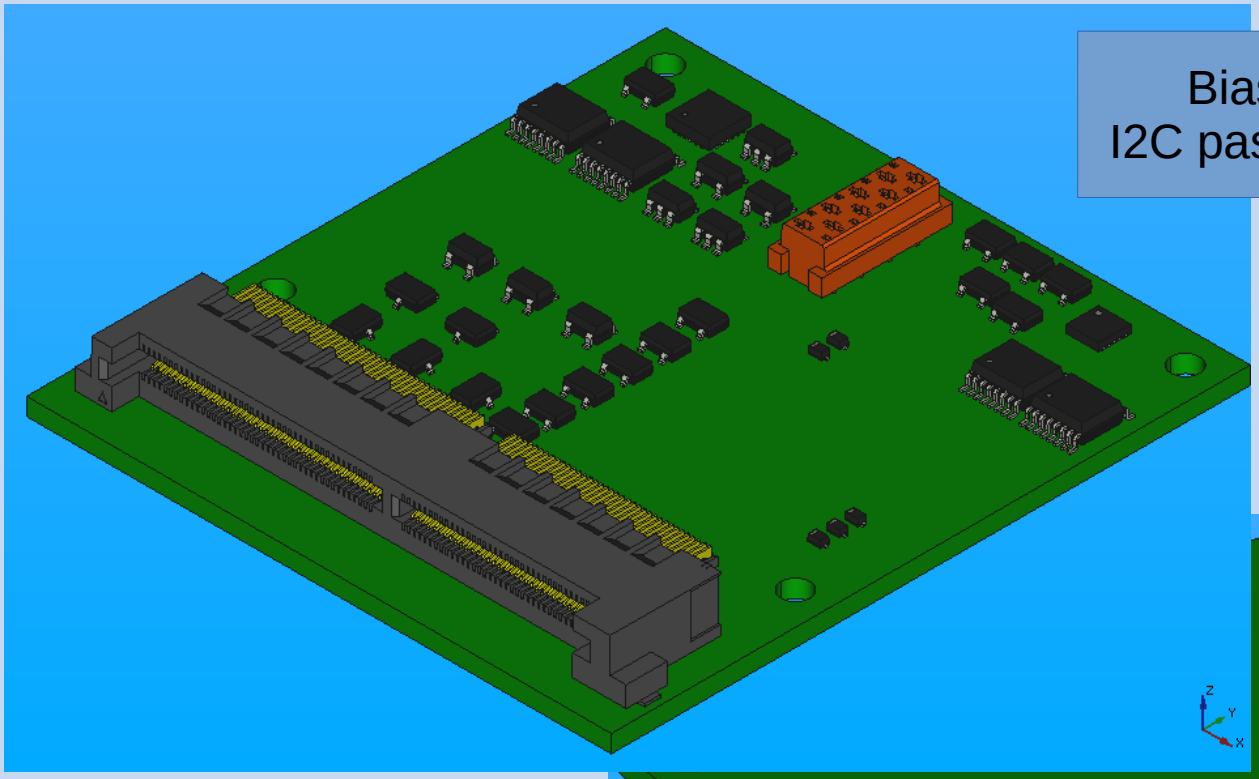
Carrier (Casimiro Baldanza INFN-BO)



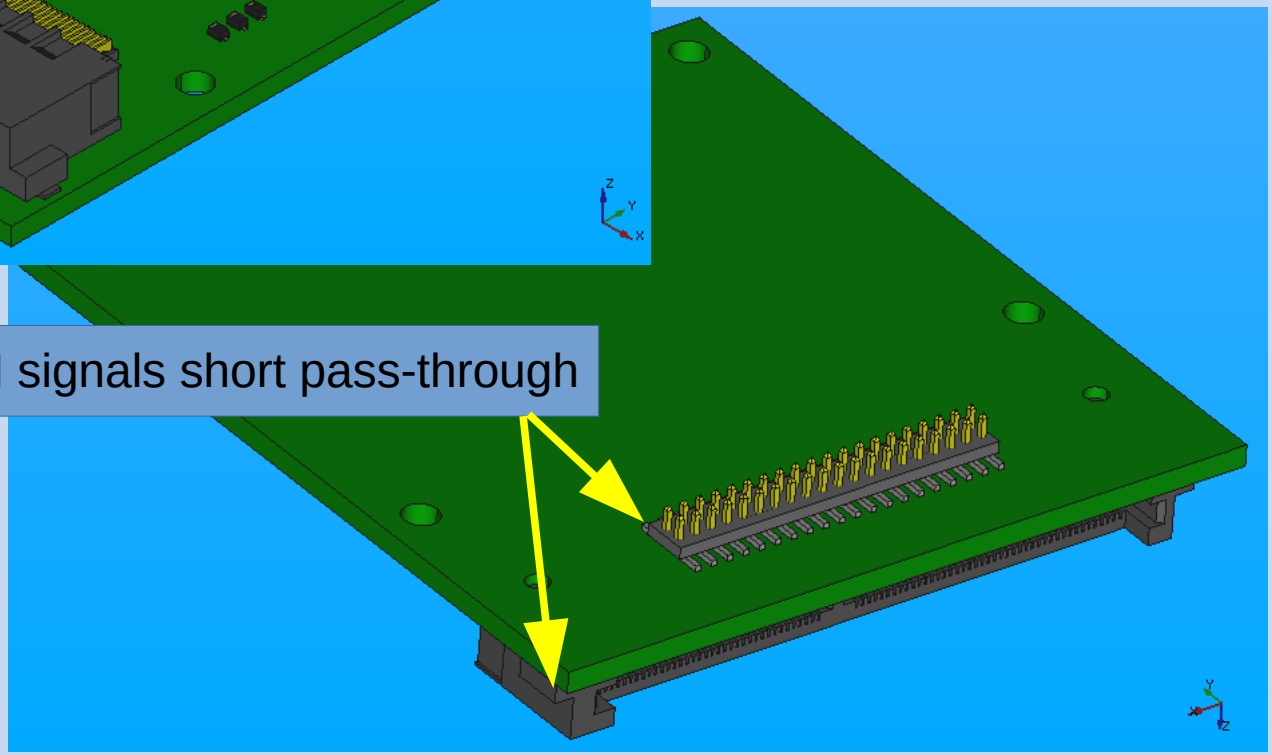




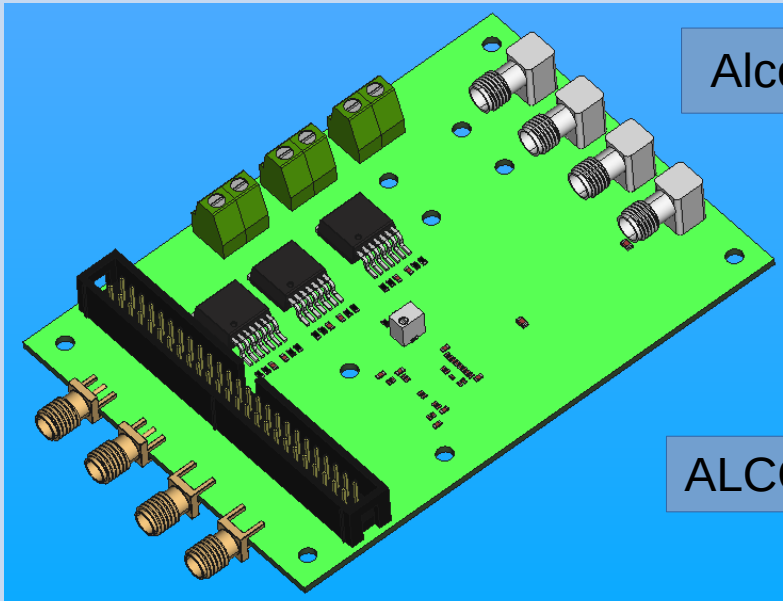
Adapter (Roberto Malaguti, INFN-FE)



Bias distributor (+trimmer)
I2C pass-through for temperature

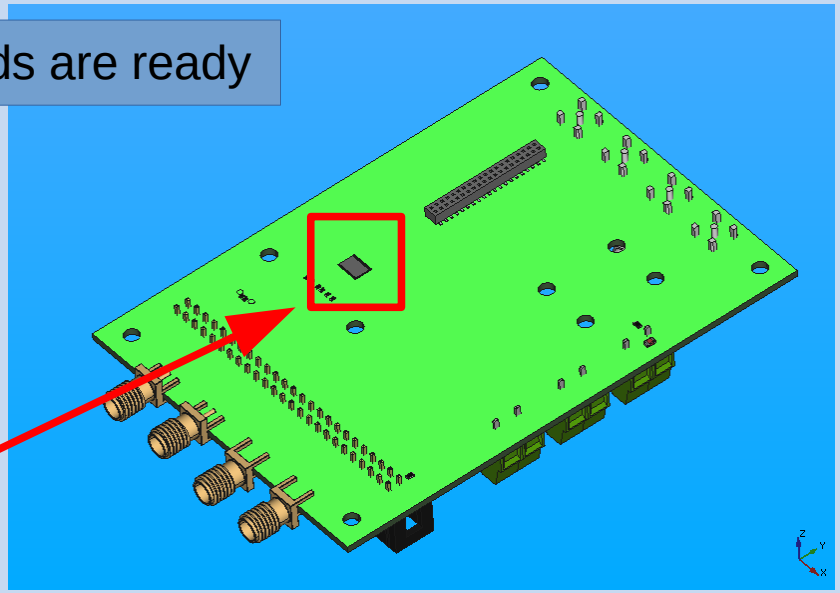


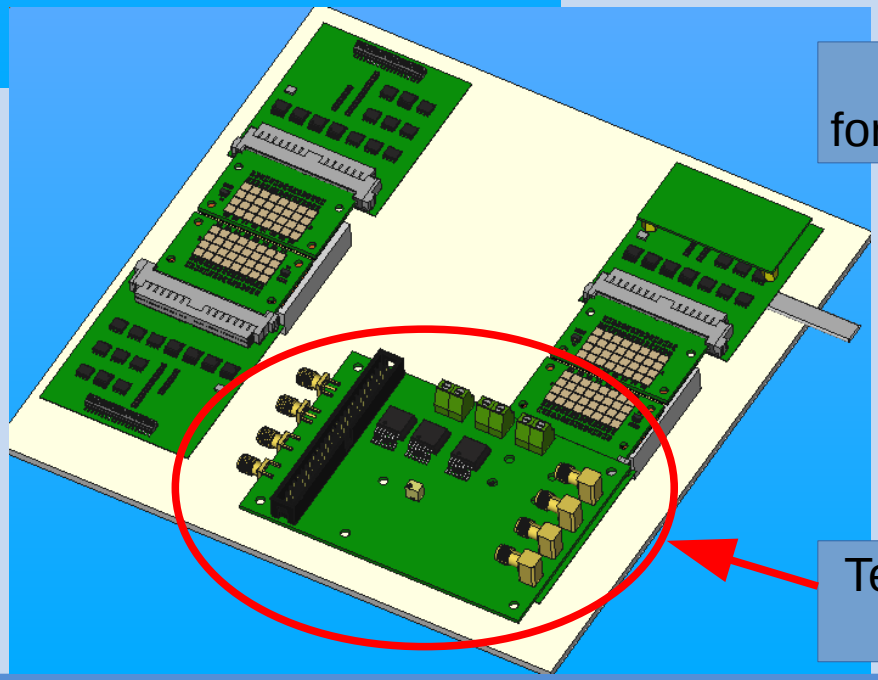
Fast (SensL only)/slow SiPM signals short pass-through



Alcor TestBoards are ready

ALCOR chip

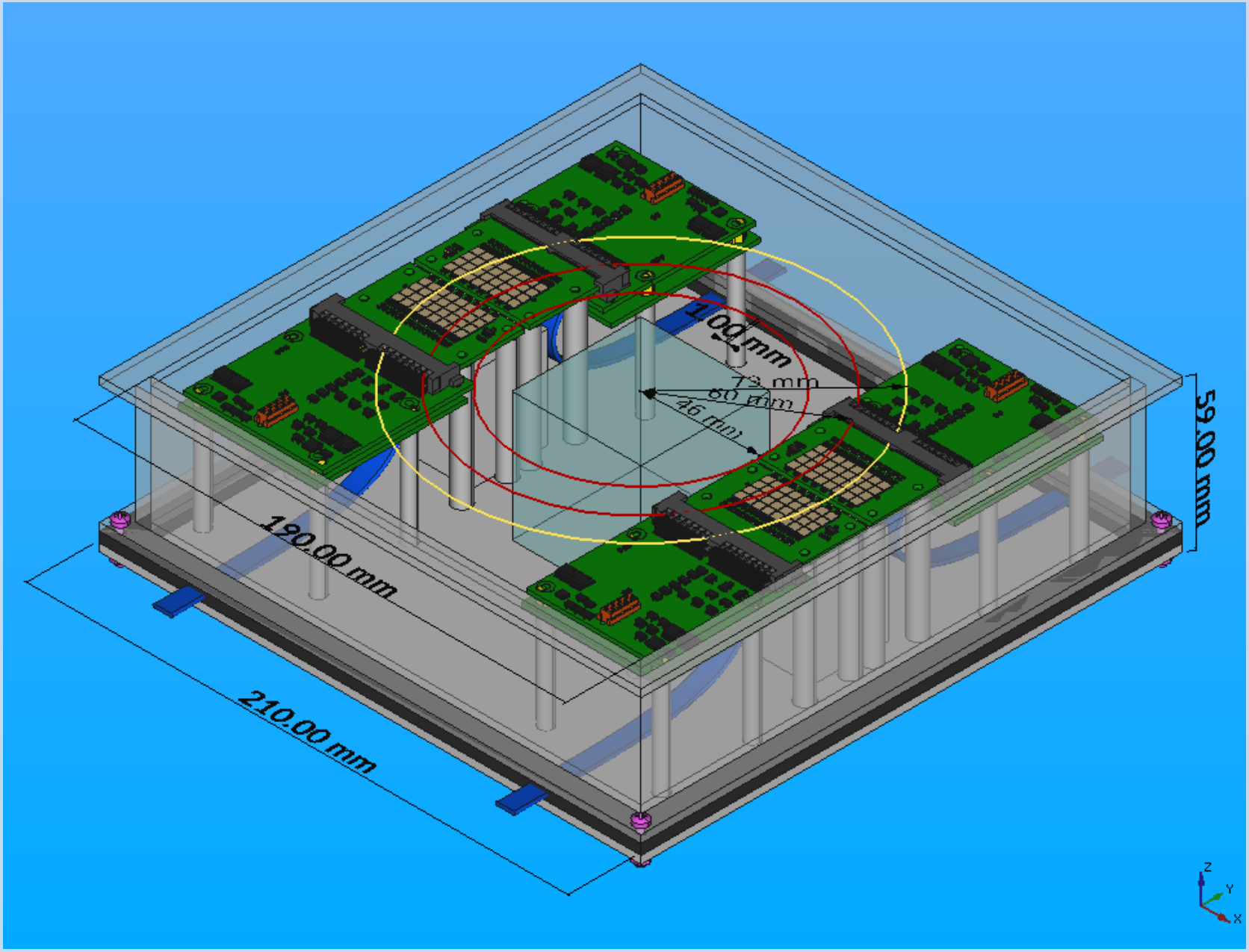




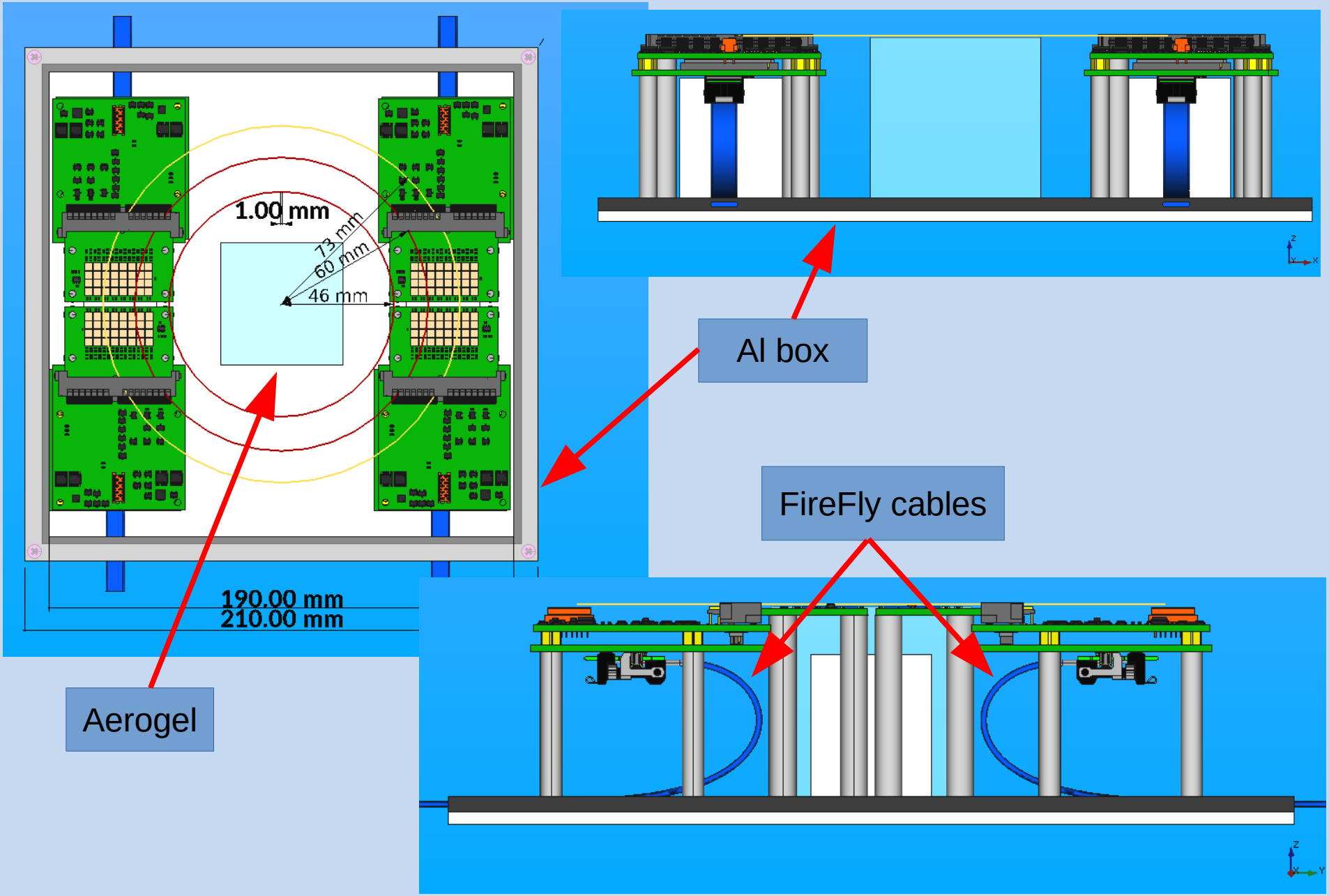
10 ALCOR chips available
for the prototype dedicated readout

TestBoards designed for test only,
too big for test-beam

dRICH box



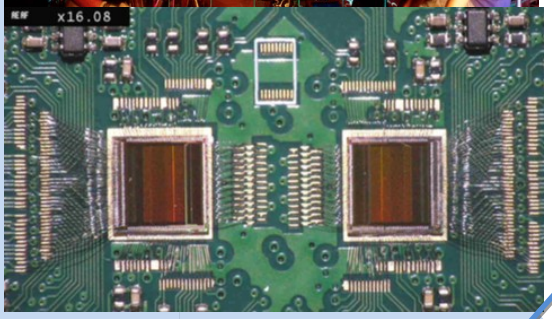
dRICH box

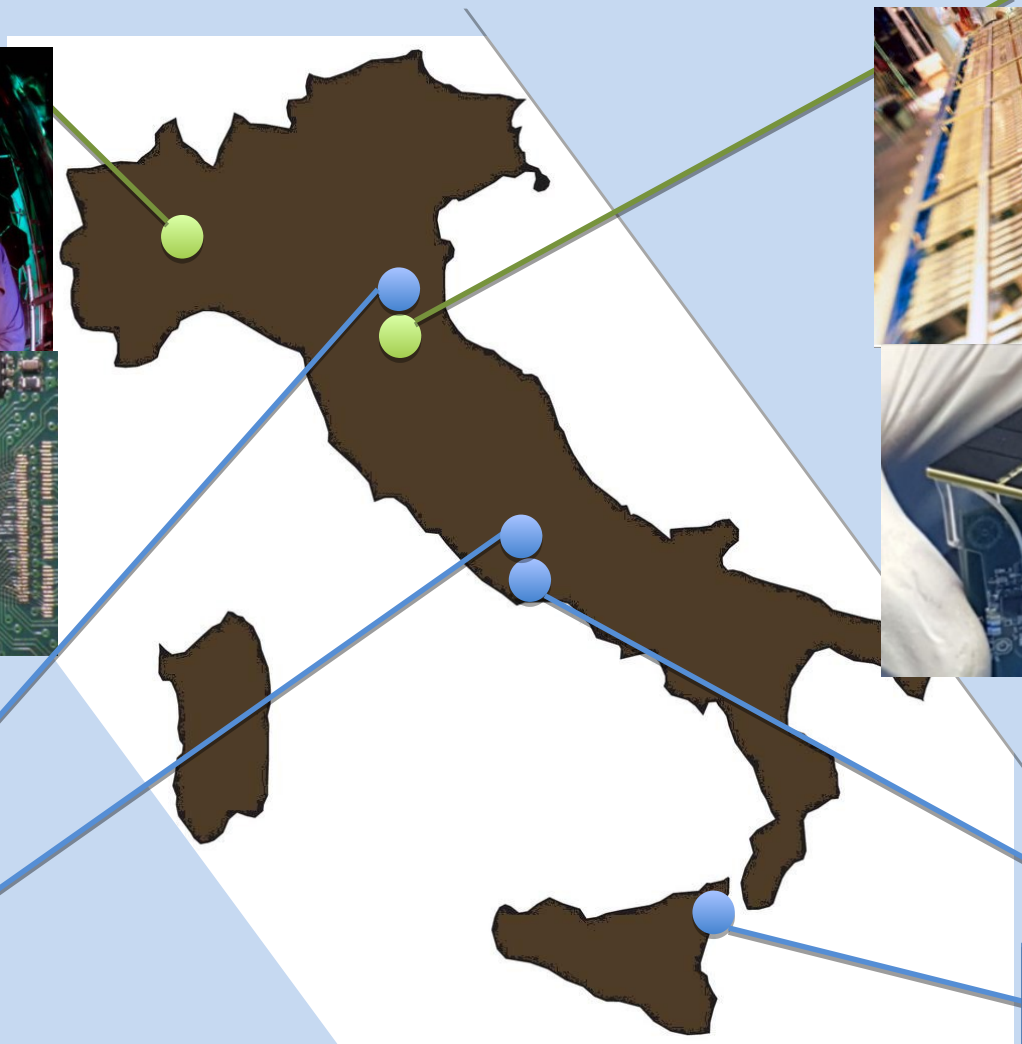

1.00 mm
73 mm
60 mm
46 mm
190.00 mm
210.00 mm
Al box
FireFly cables
Aerogel

INFN Groups and eRD14

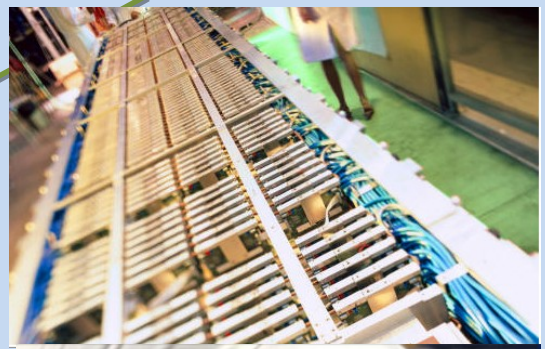
Enriched INFN expertise and manpower
to support dRICH, SiPM (and eRD14) program

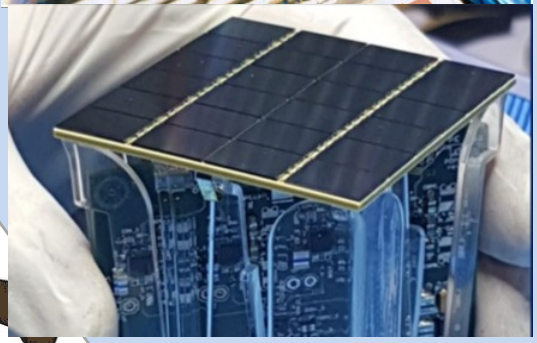
INFN-TO
COMPASS RICH F-E
DARKSIDE F-E





INFN-BO
ALICE TOF
DARKSIDE SiPM





INFN-FE
CLAS12 RICH

INFN-RM1
HERMES RICH
Hall-A Tracking

INFN-LNF
CLAS12 RICH

INFN-CT
Hall-A HCAL