ESS detectors with VMM3a readout NMX and AMOR Multi-Blade

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2023-12-06

RD51 Collaboration Meeting

OUTLINE

- Generic VMM3A ESS readout chain
- NMX Gd-GEM detector
- Gd-GEM VMM3A readout
- Multi-Blade detector
- Multi-Blade and VMM3A AMOR

VMM3a readout

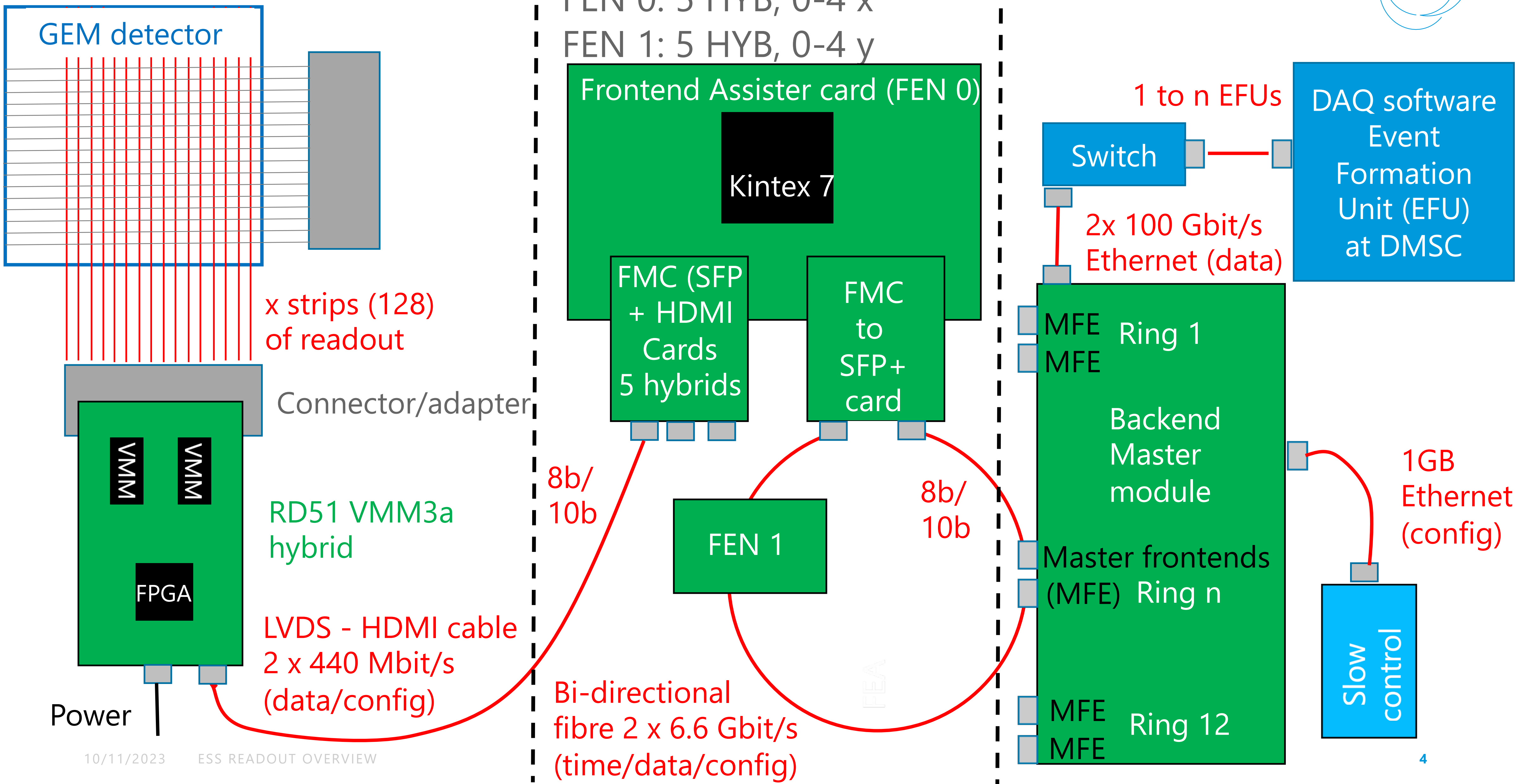
For ESS instruments

- ESTIA (Multiblade)
- FREIA (Multiblade)
- NMX (Gd-GEM)
- TREX (Multigrid)

NMX Detector with 4 quadrants, 10 RD51 VMM3a hybrids per quadrant

KC705 Assister in crate
2 FEN per quadrant
FEN 0: 5 HYB, 0-4 x
FEN 1: 5 HYB, 0-4 y

Master module in rack



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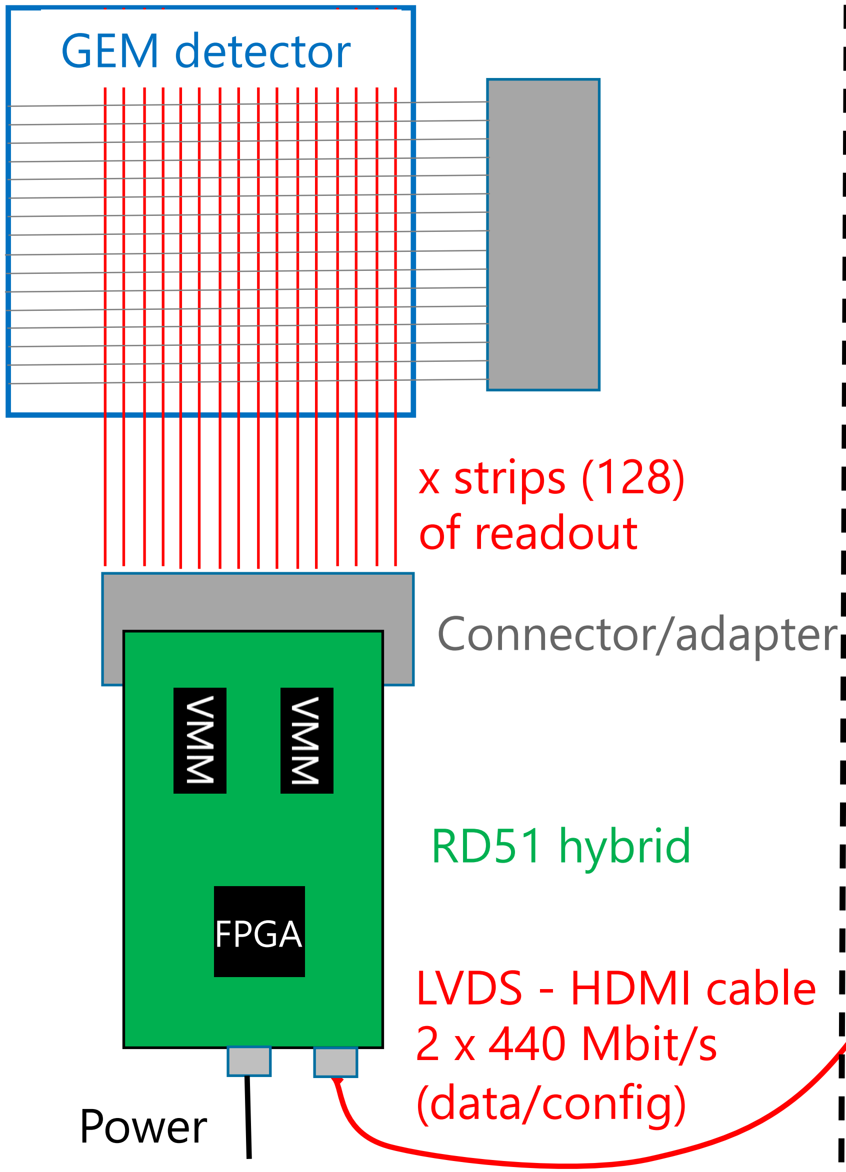
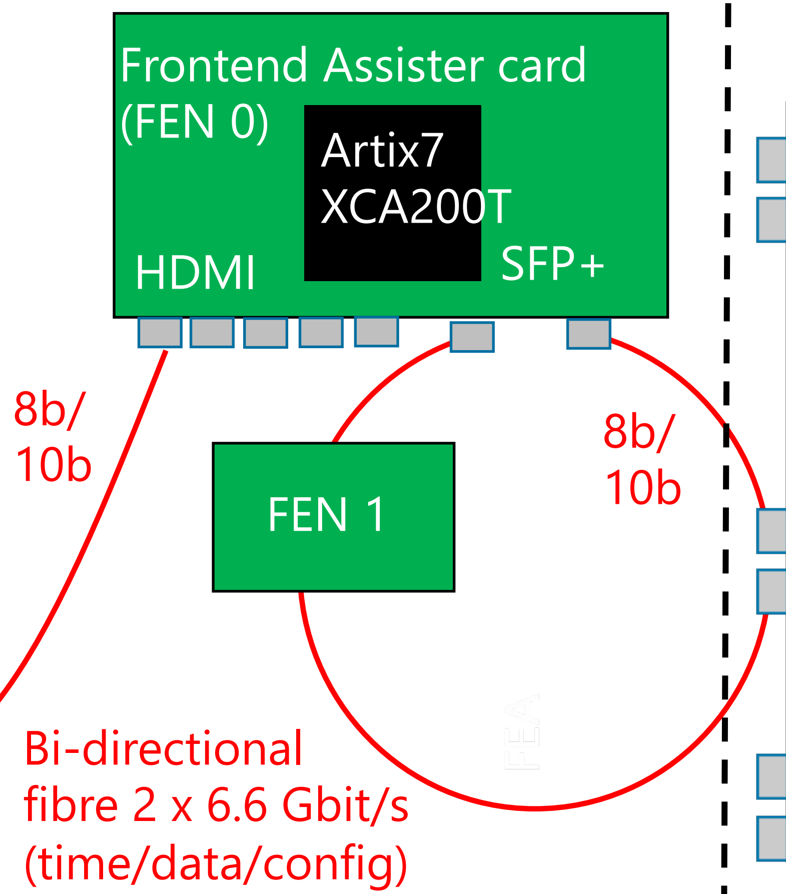
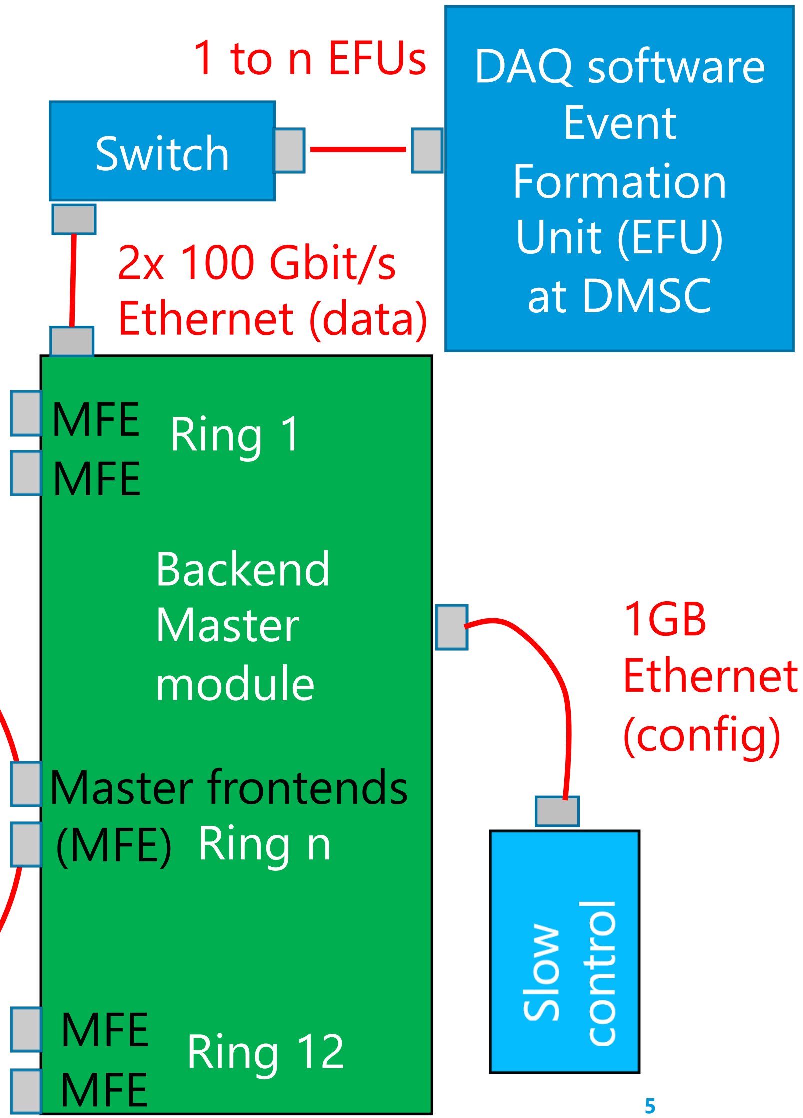


Upgrade:
Mini assister,
Designed by Angel,
Can be put directly
At detector



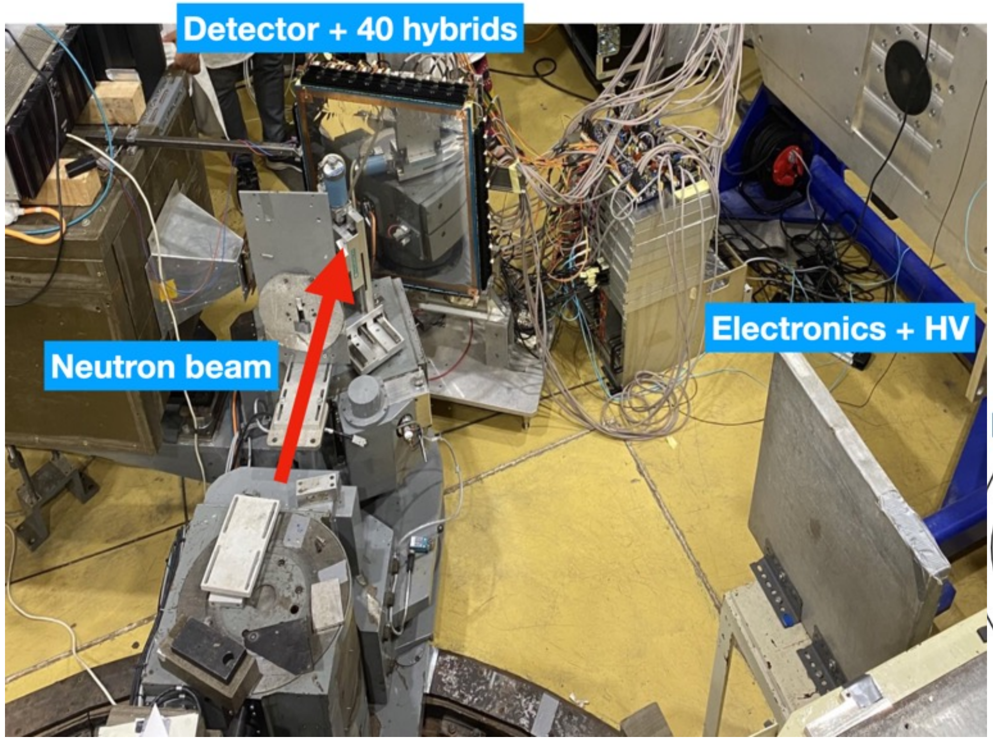
Master module in rack



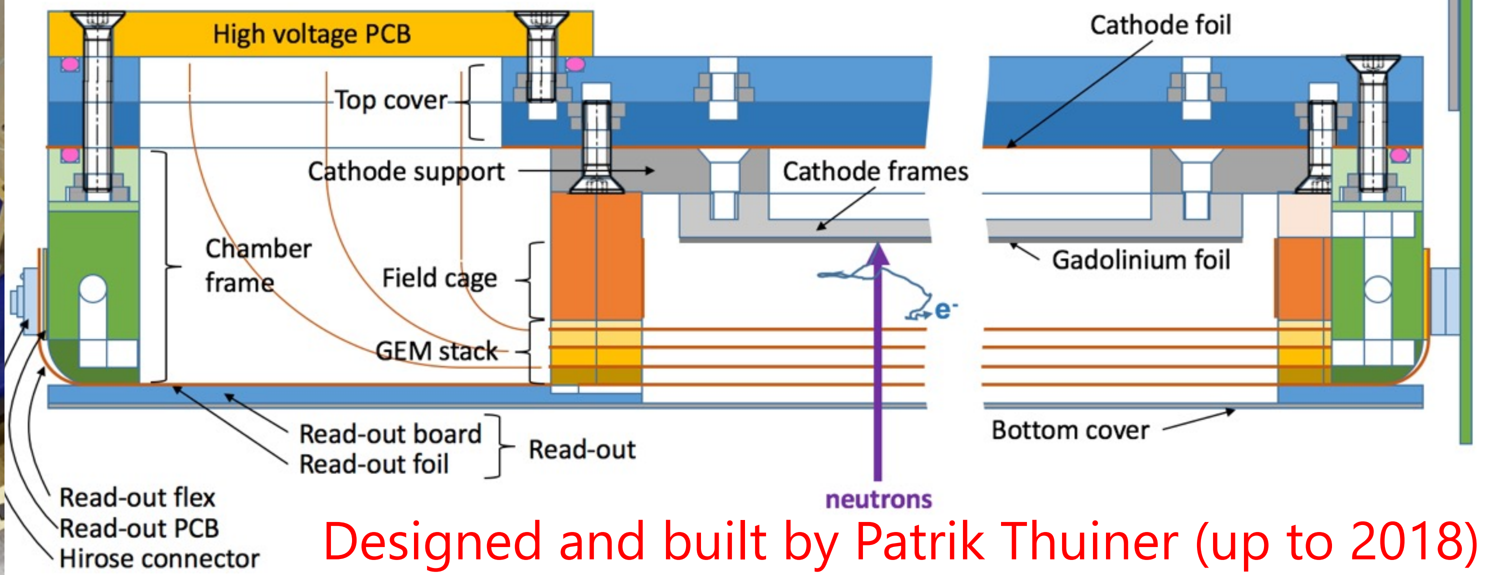
NMX detector

NMX detector, readout and software test

BNC Budapest September 2023



- D. Pfeiffer et al., Demonstration of Gd-GEM detector design for neutron macromolecular crystallography applications, JINST (18) 04 2022, https://doi.org/10.1088/1748-0221/18/04/P04023
- D. Pfeiffer et al., First measurements with new high-resolution gadolinium-GEM neutron detectors, JINST (11) 05 2016, https://doi.org/10.1088/1748-0221/11/05/P05011

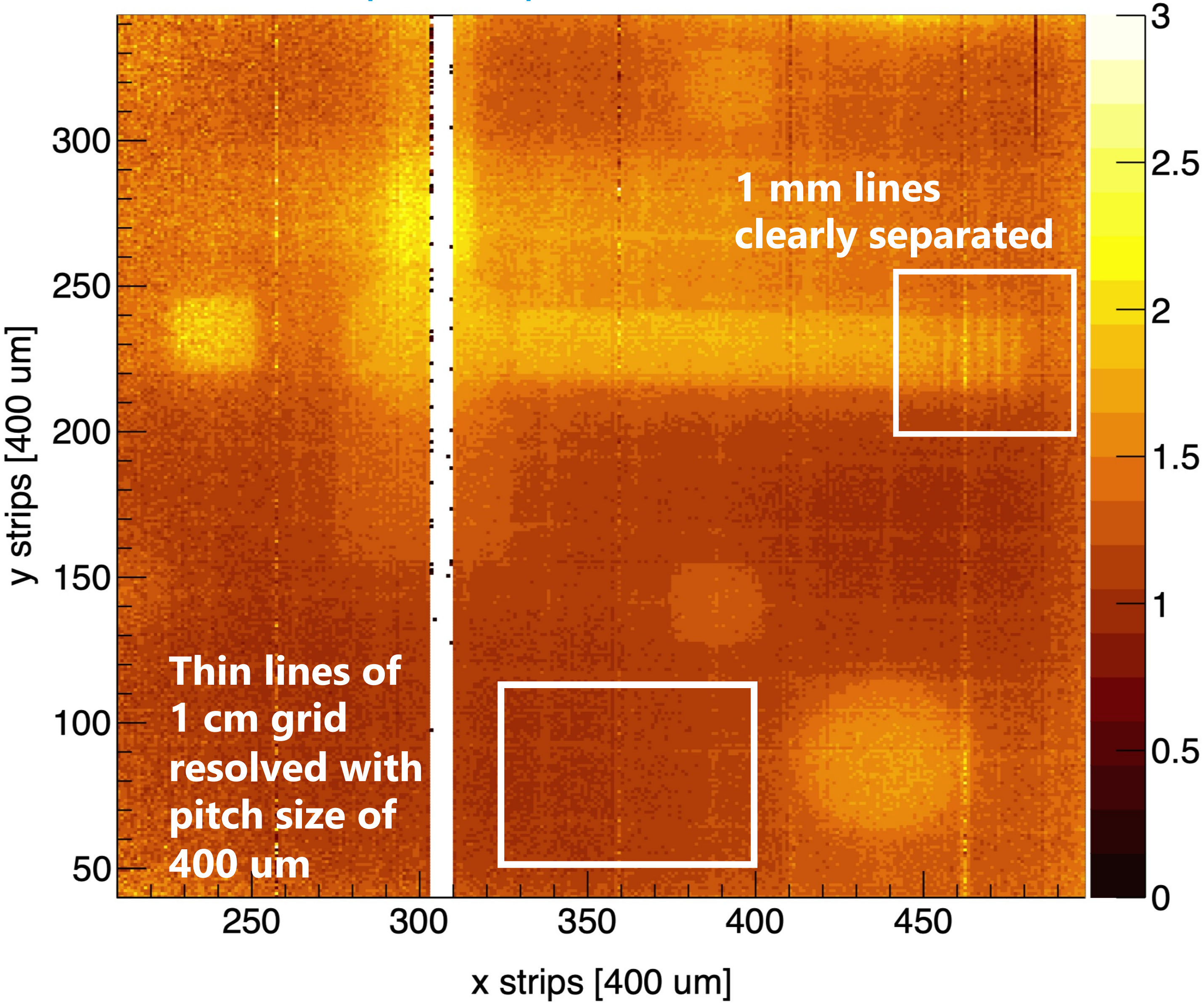


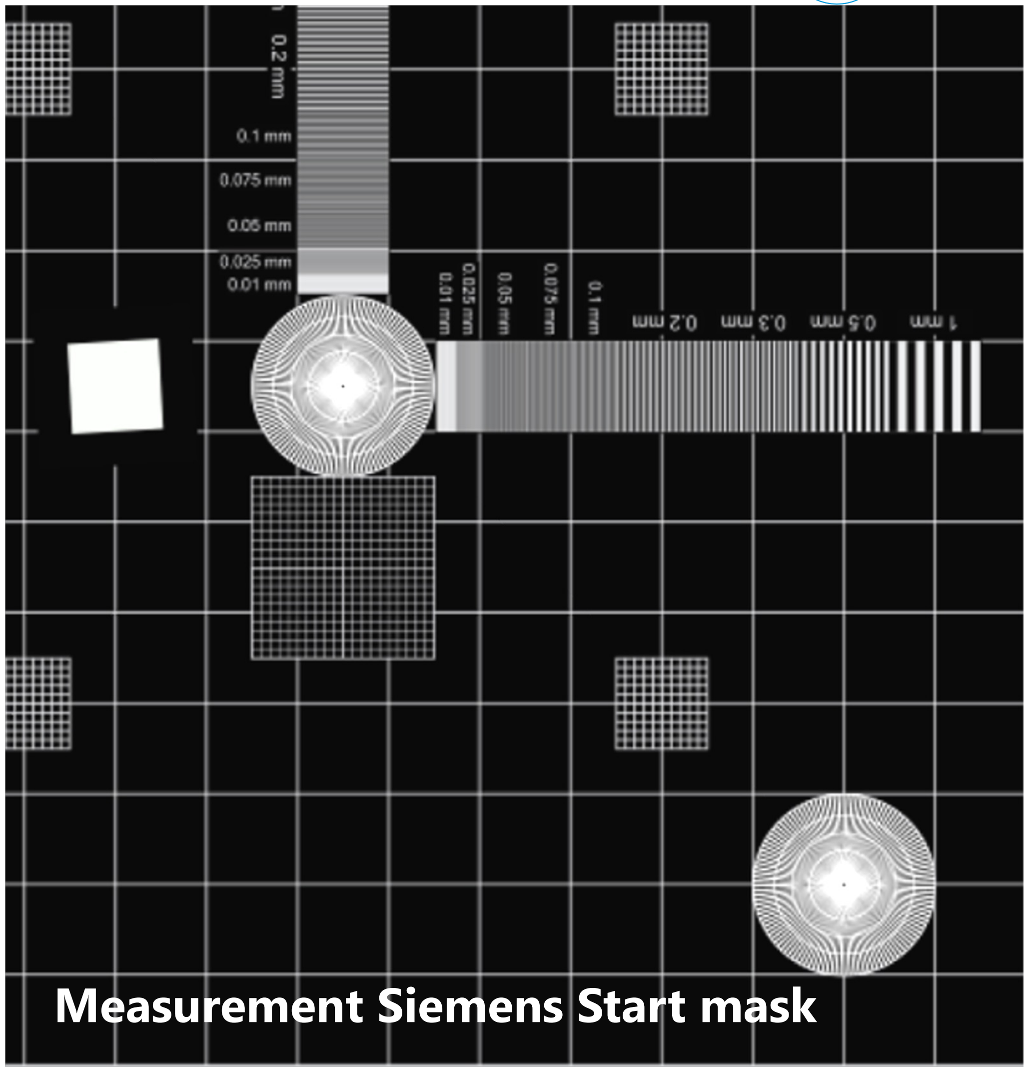
Designed and built by Patrik Thuiner (up to 2018) and Jerome Samarati (since 2019)

- Two of the four quadrants were read using 20 hybrids, four assisters and one master crate
- Whole ESS readout chain successfully tested
- Present online clustering in software works well up to neutron rates of 1 MHz

NMX detector, readout and software test

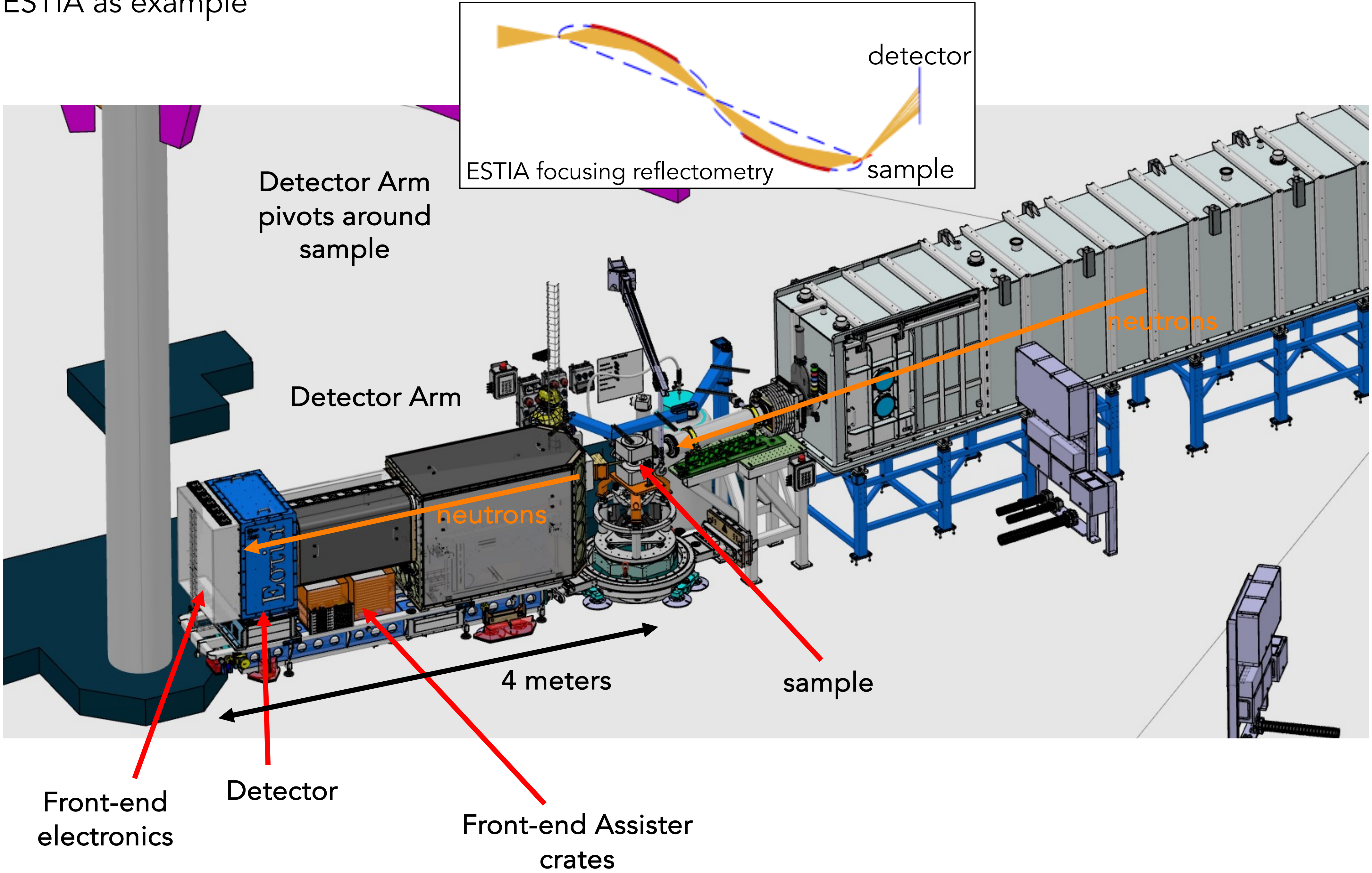
BNC Budapest September 2023



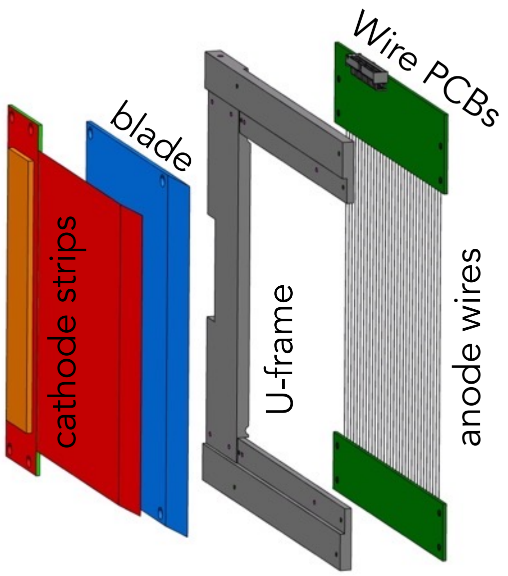


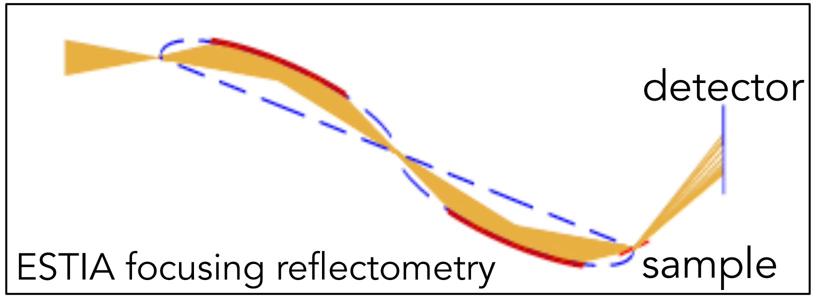
MB det

MB.ESTIA as example

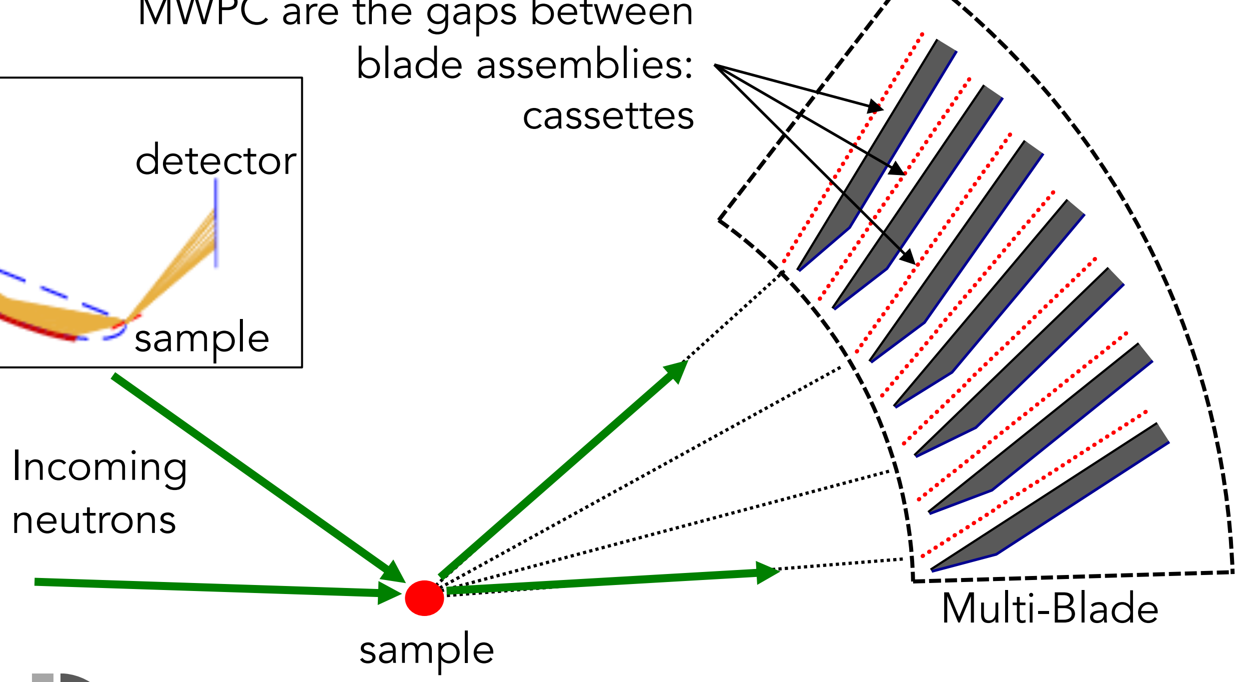


Multi-Blade detector

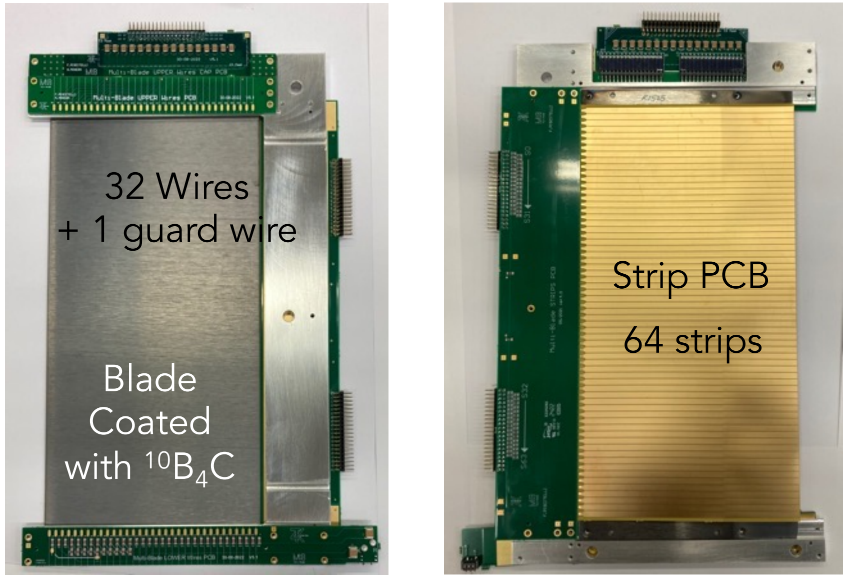


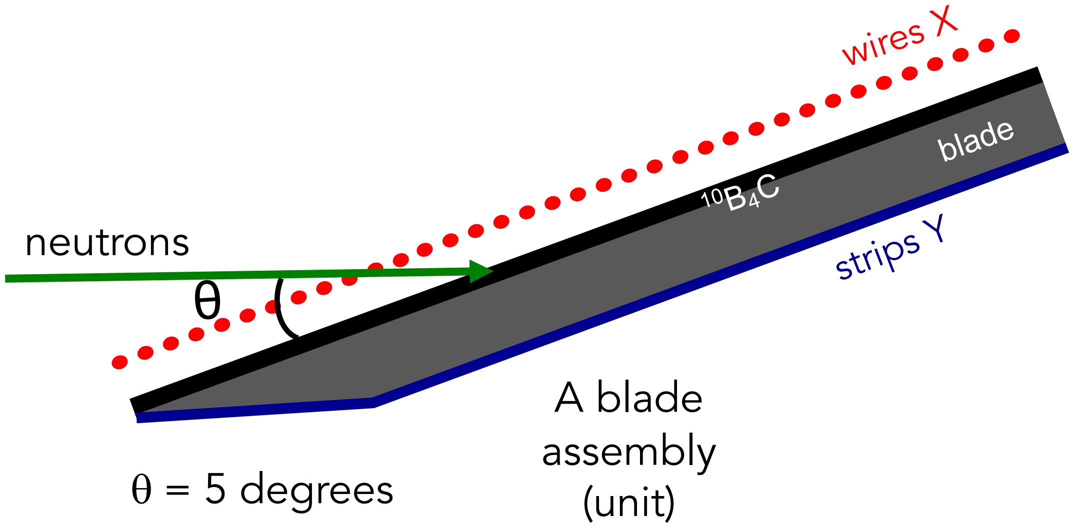


MB Detector is modular

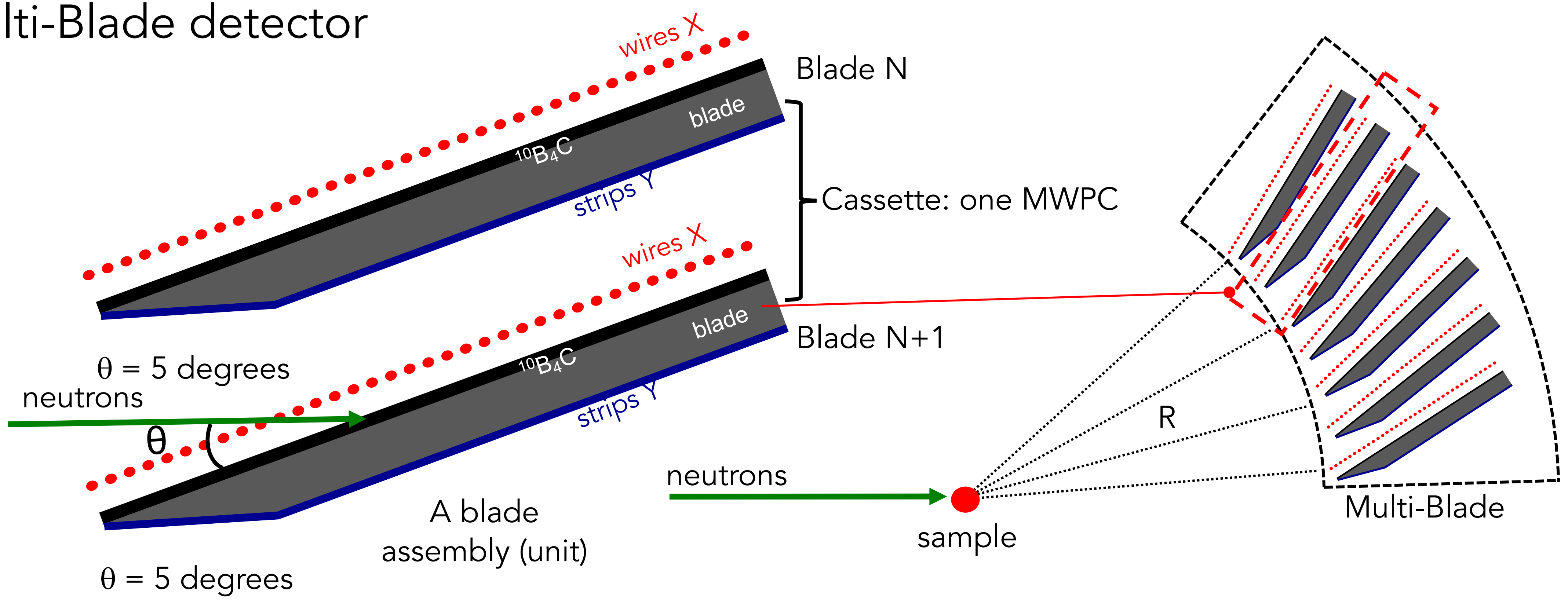


A blade assembly (unit)

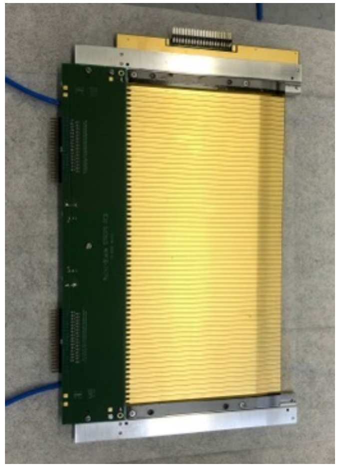




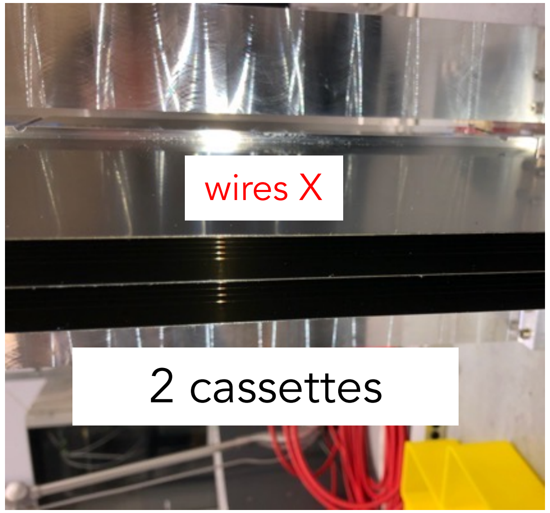
Multi-Blade detector

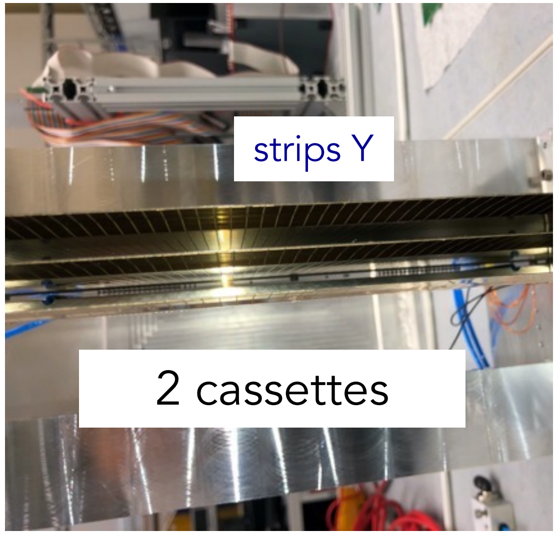


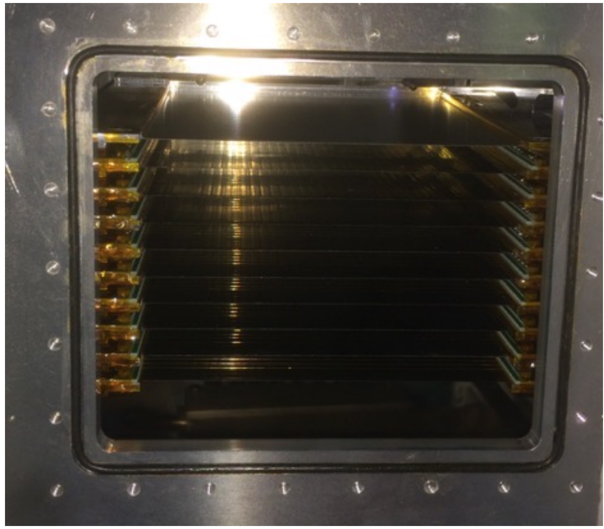
Wire side



strip side



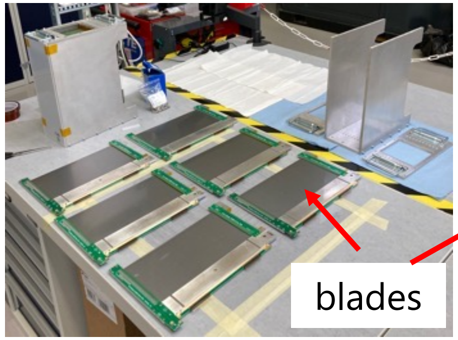


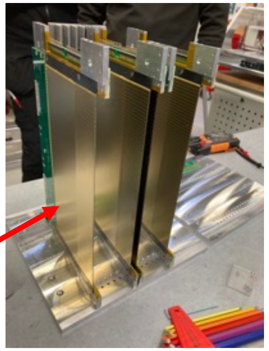


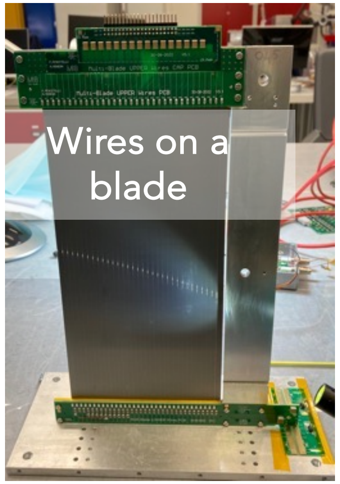
Resolution 0.5mm x 3 mm

Multi-Blade detector project status for ESTIA, FREIA and TBL + AMOR

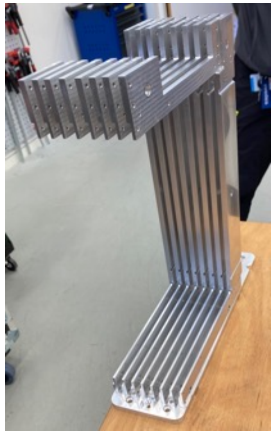
140 blades for all detectors produced and stored



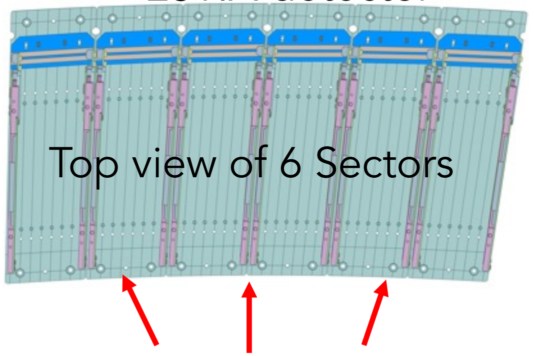




First sector for ESTIA detector produced in Utgard

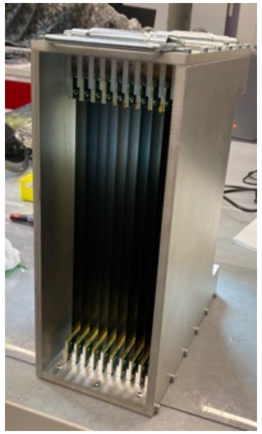


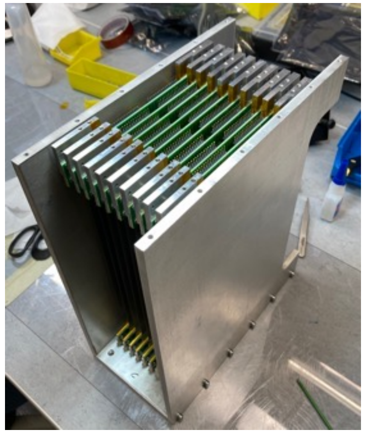
ESTIA detector



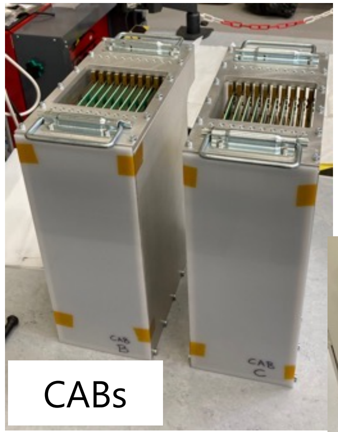
Neutrons from sample at 4 m distance

Storage, testing and shipment equipment is in place





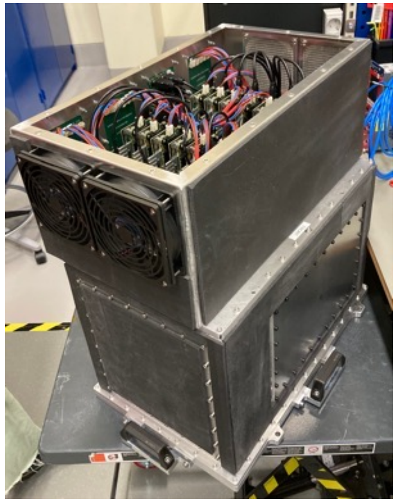
CABs with 10 blades each

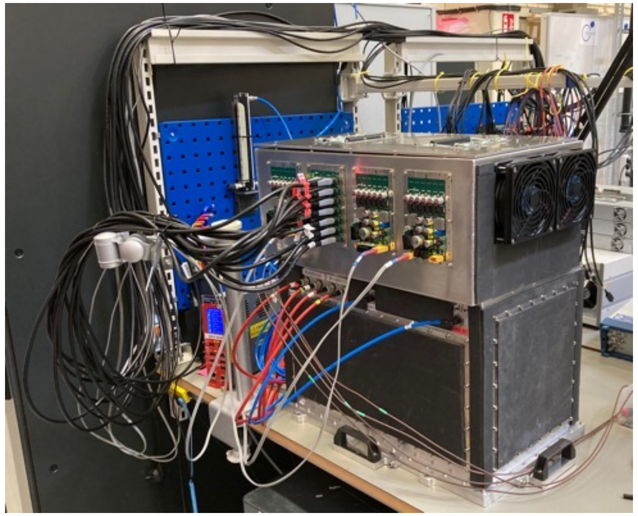


Shipment, 3 CABs in box

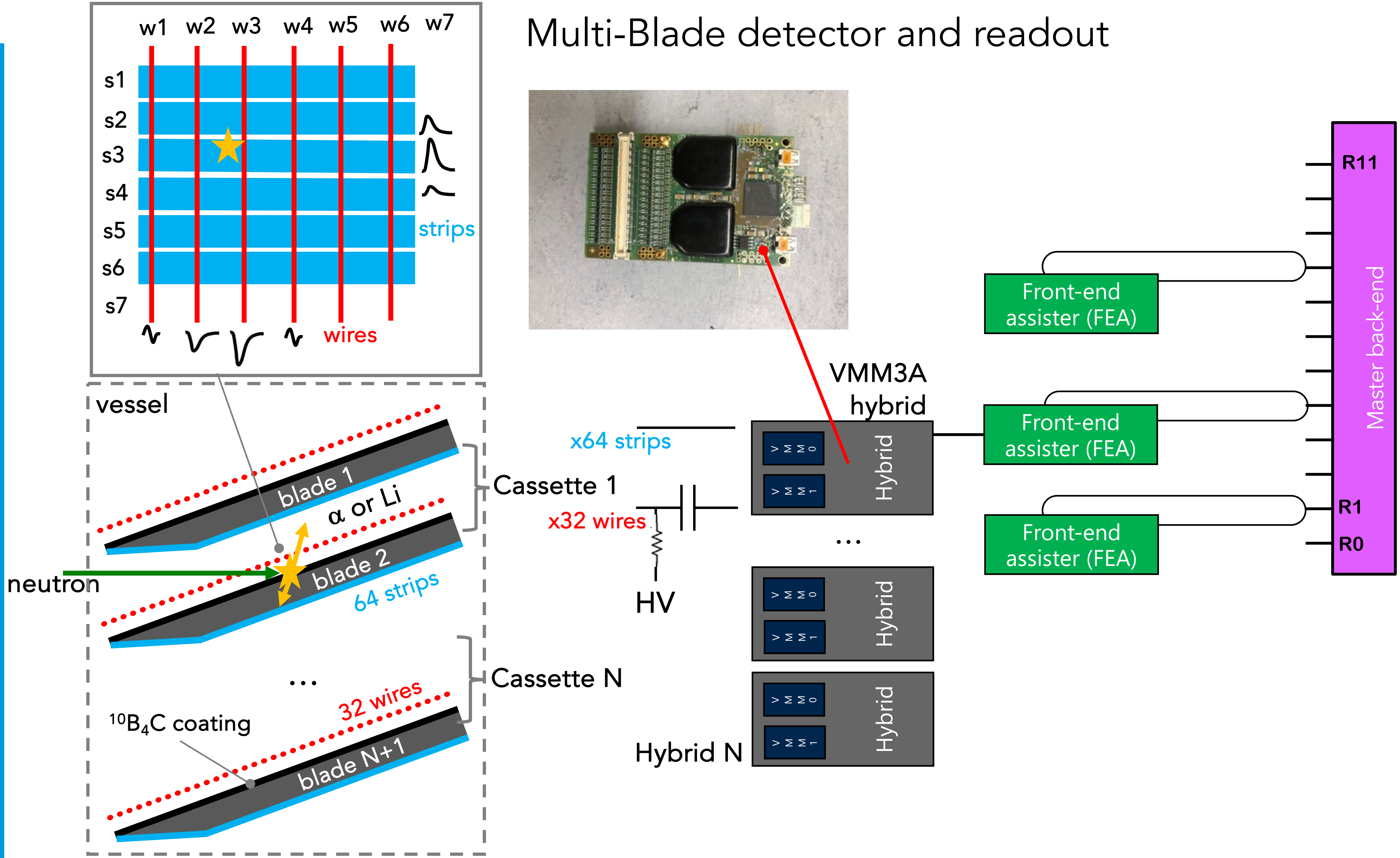
MB.AMOR is a 14 units MB detector 1:1 to TBL detector,
1/3 of ESTIA -> Installation @ PSI (Nov 2023) to start user program

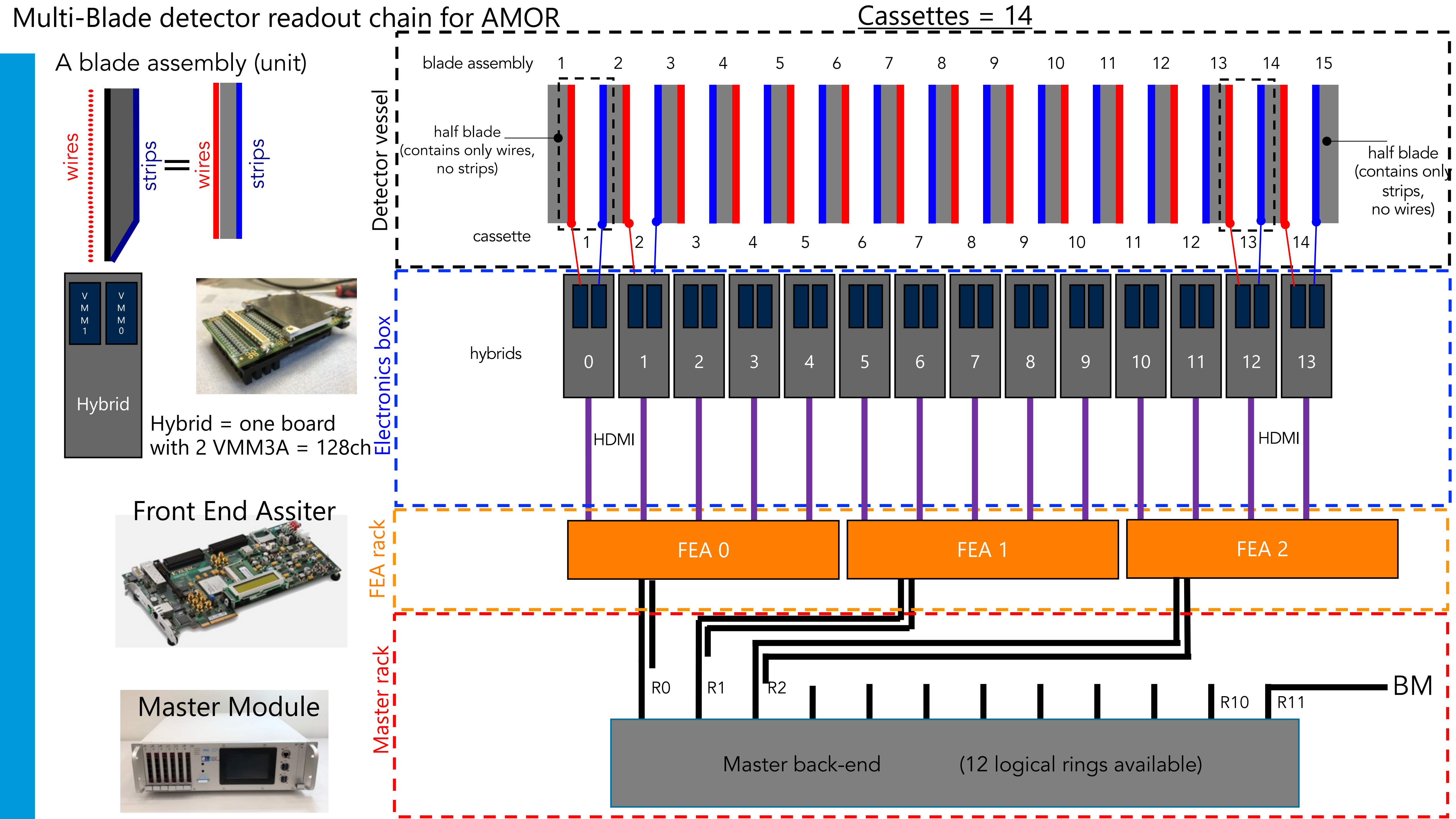
MB.AMOR is a pilot to test the detector and the full readout and data chains





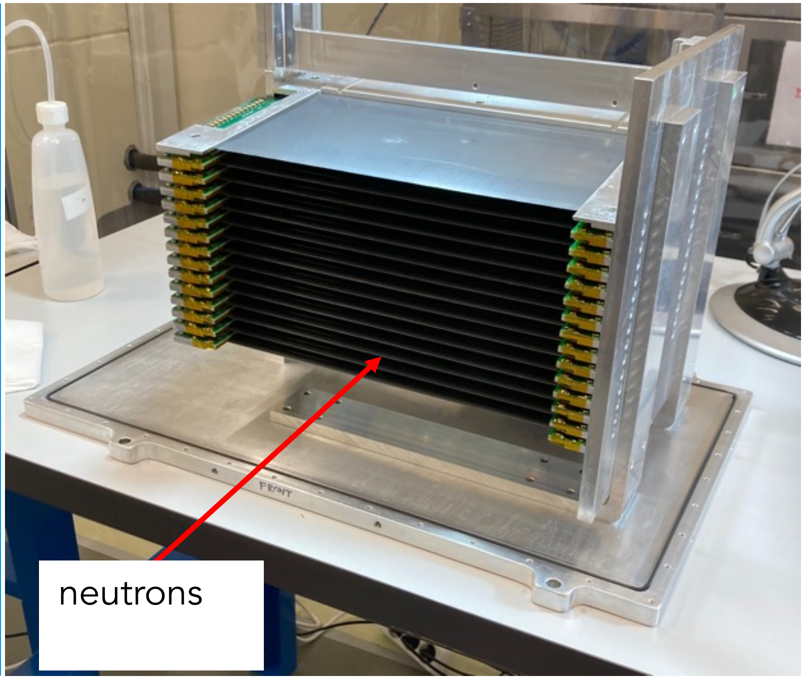
Multi-Blade detector and readout

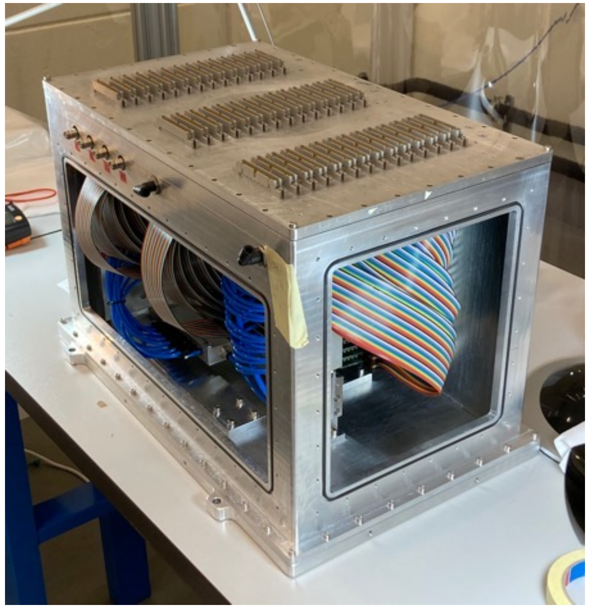


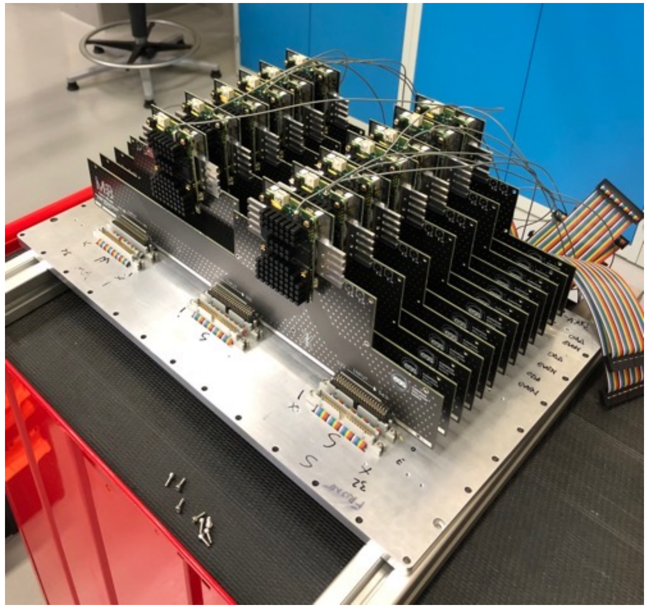


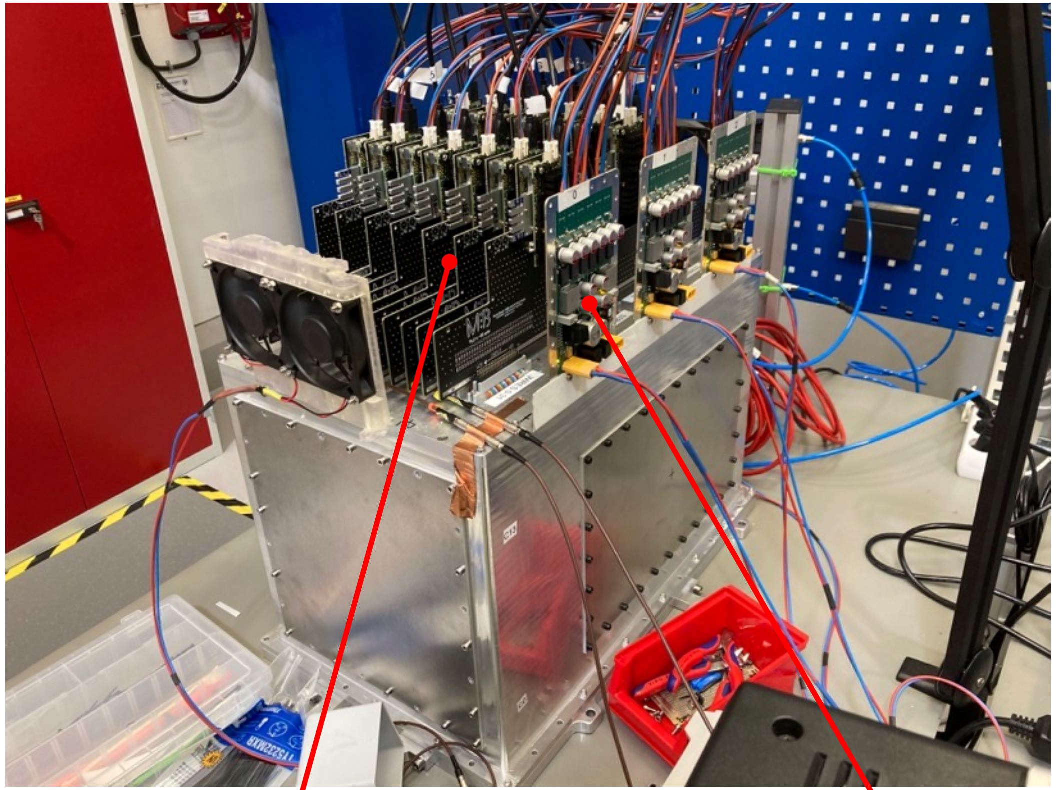
Multi-Blade detector readout chain for AMOR
Cassettes = 14
A blade assembly (unit)
wires
strips
=
wires
strips
V M M 1
V M M 0
Hybrid
Hybrid = one board
with 2 VMM3A = 128ch
Front End Assiter
Master Module
Detector vessel
blade assembly
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
half blade
(contains only wires,
no strips)
half blade
(contains only
strips,
no wires)
cassette
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Electronics box
hybrids
0 1 2 3 4 5 6 7 8 9 10 11 12 13
HDMI
HDMI
FEA rack
FEA 0
FEA 1
FEA 2
Master rack
R0
R1
R2
R10
R11
BM
Master back-end
(12 logical rings available)

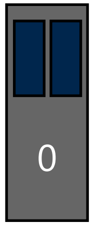
Multi-Blade 14 cassettes – 14 hybrids





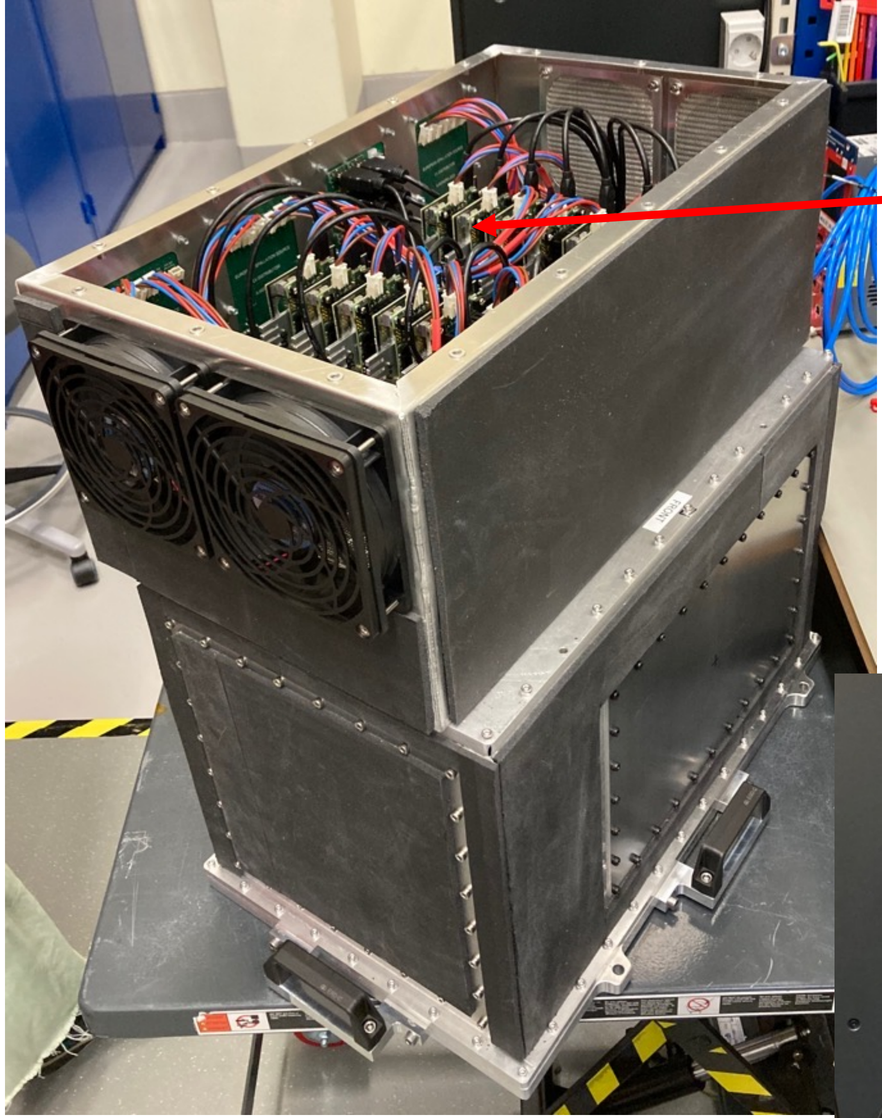




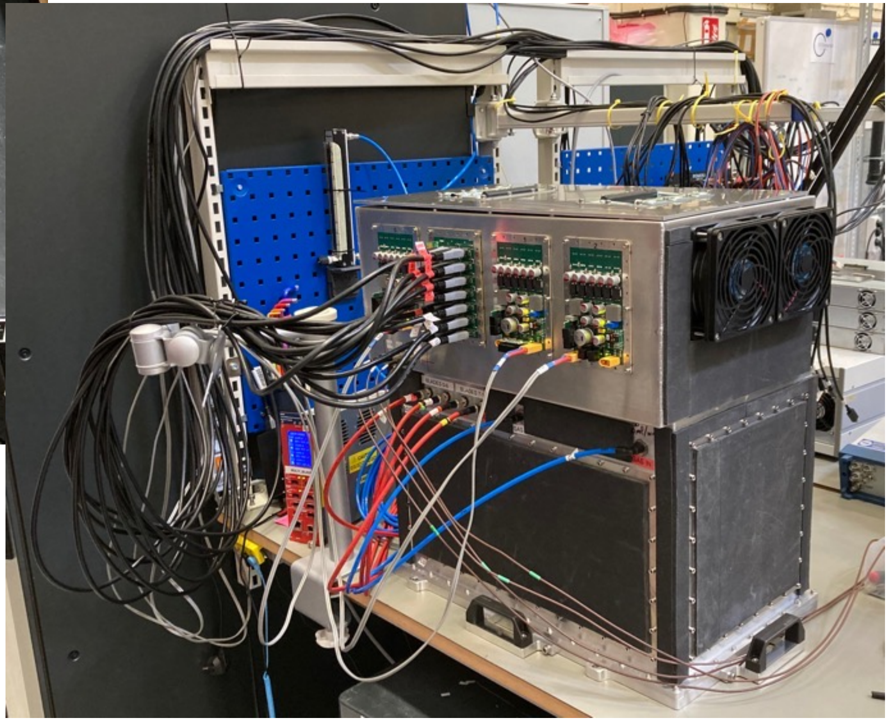


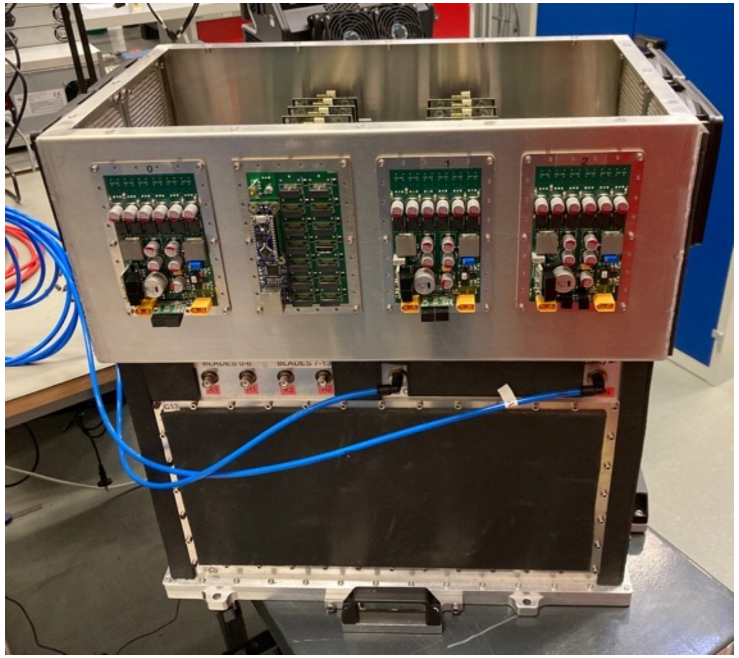
LV distrib

14 hybrids one on each cassette of MB

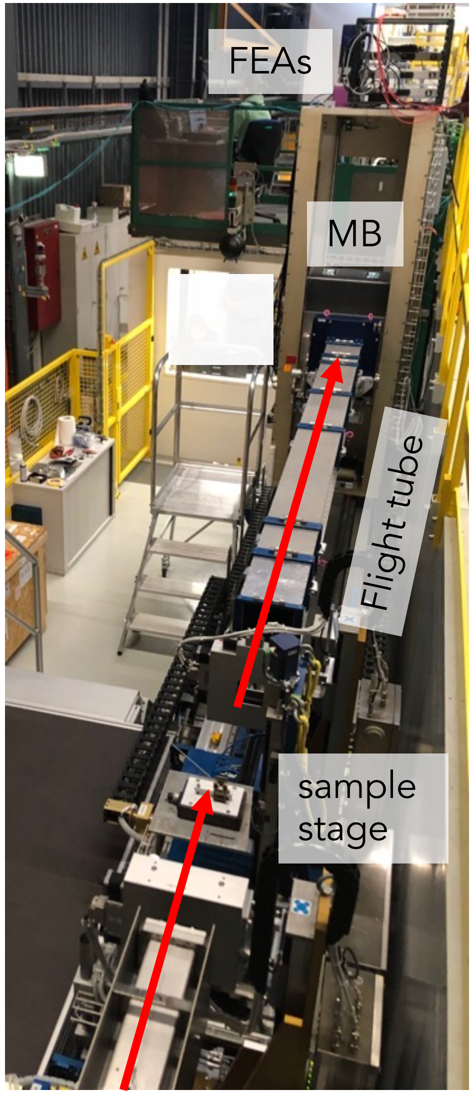


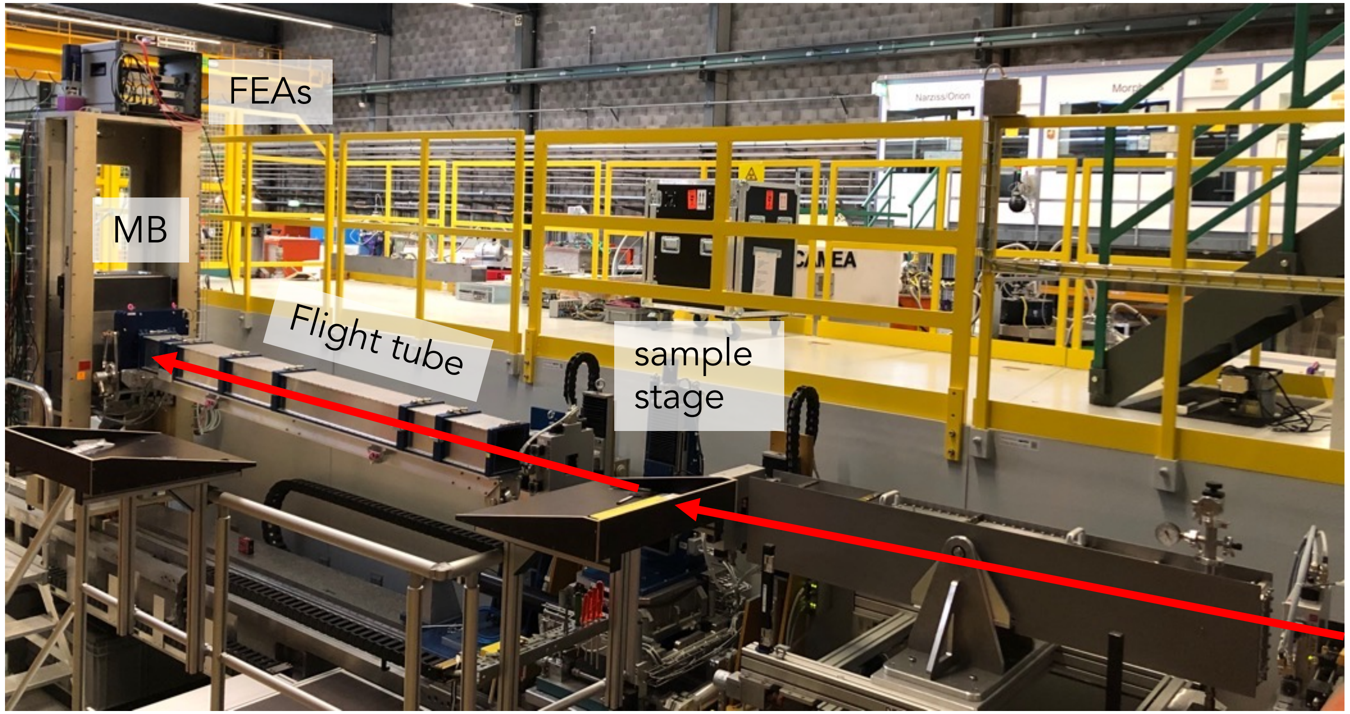
14 hybrids one on each cassette of MB





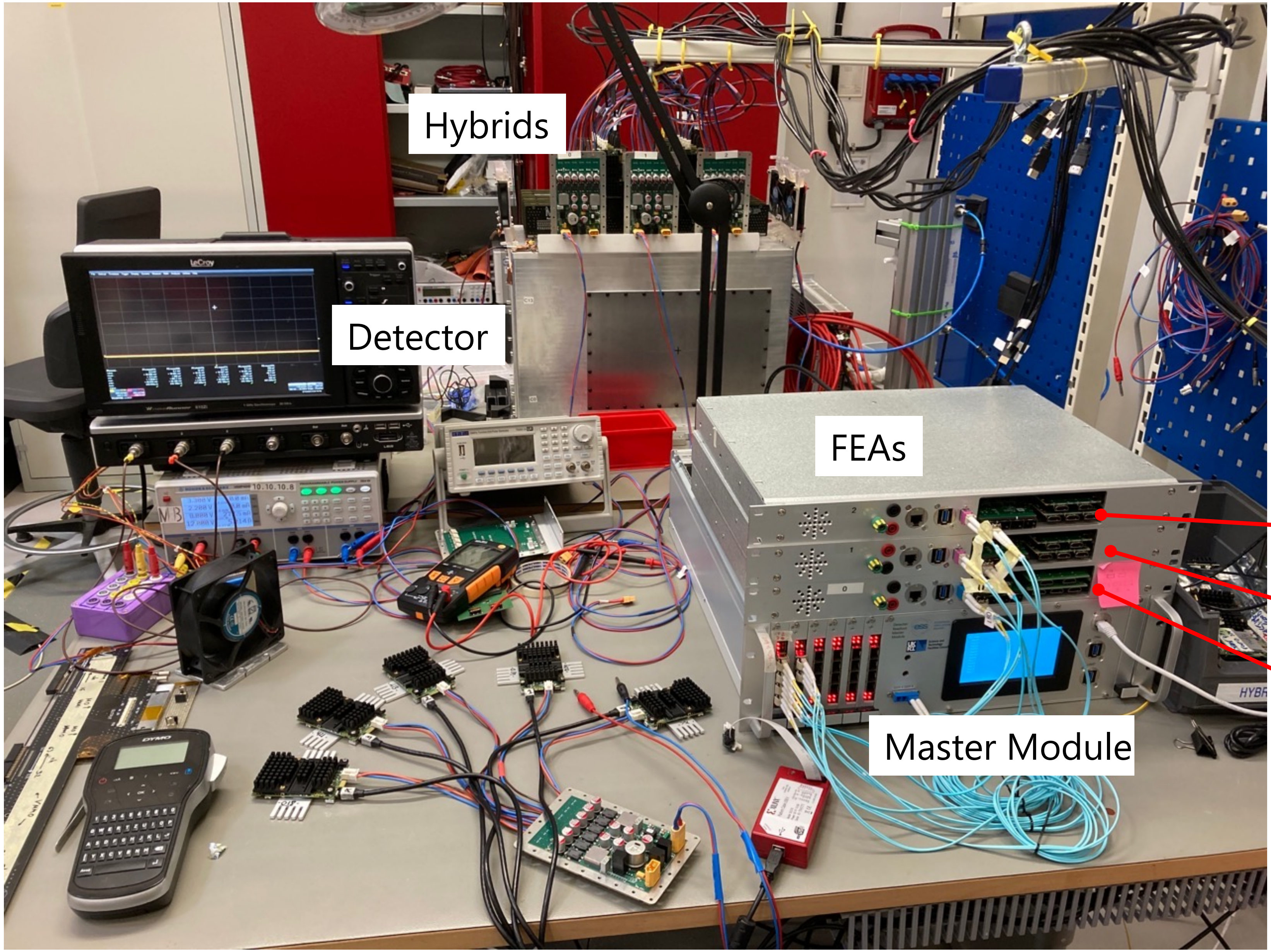
Multi-Blade installed at AMOR

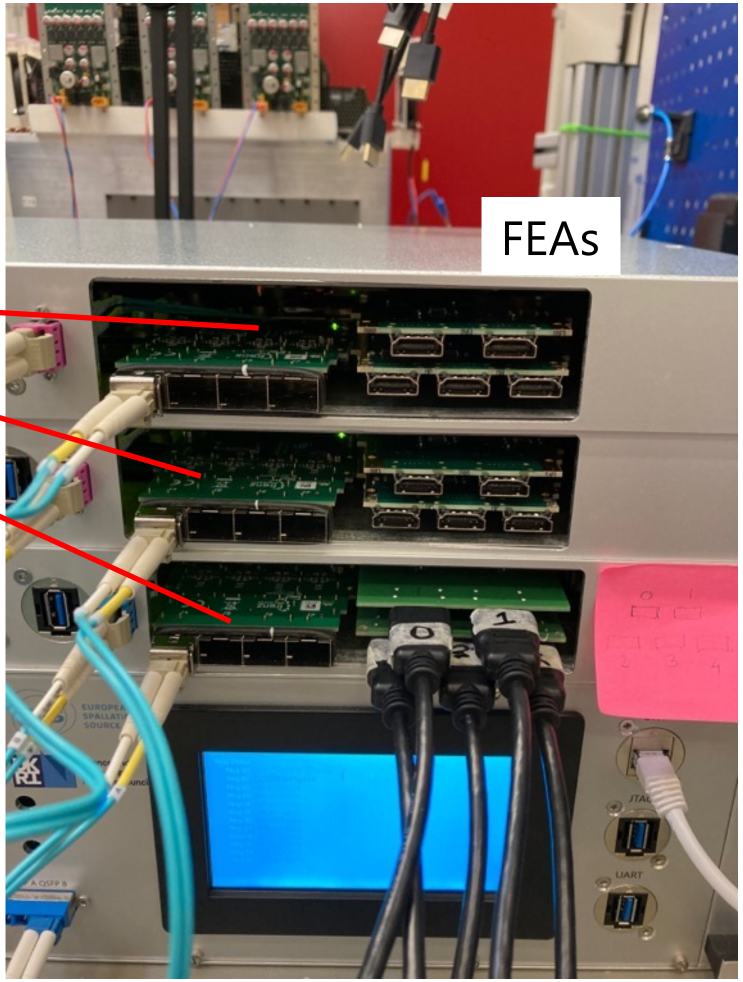




FEA 0

FEA front-end assister
For now 5 hybrids 1 assister
1U crate

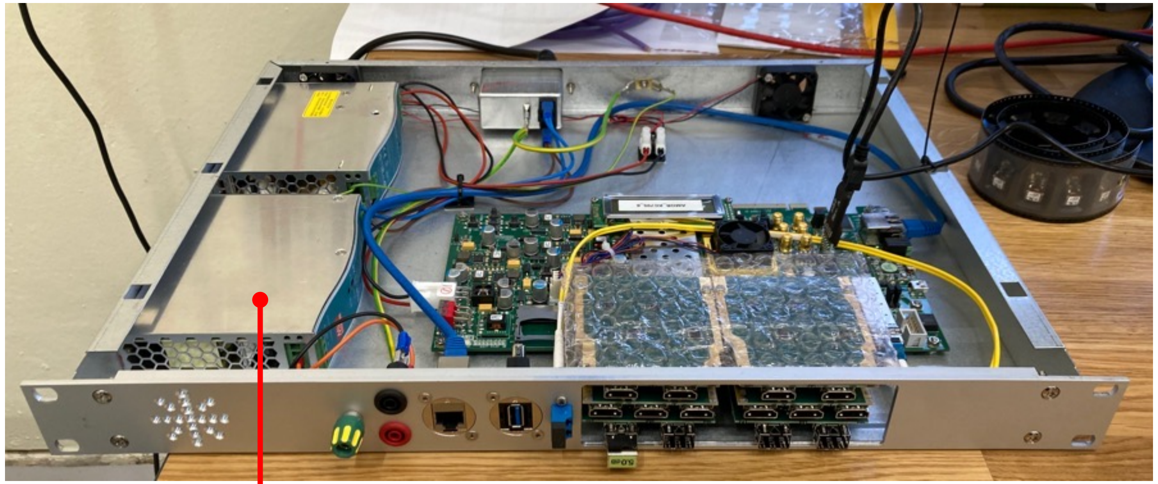




Two options for Assister

<u>Current Assister</u>

FEA



Optical

5 HDMI
Or 10 HDMI

LV 24V for LV distribution board

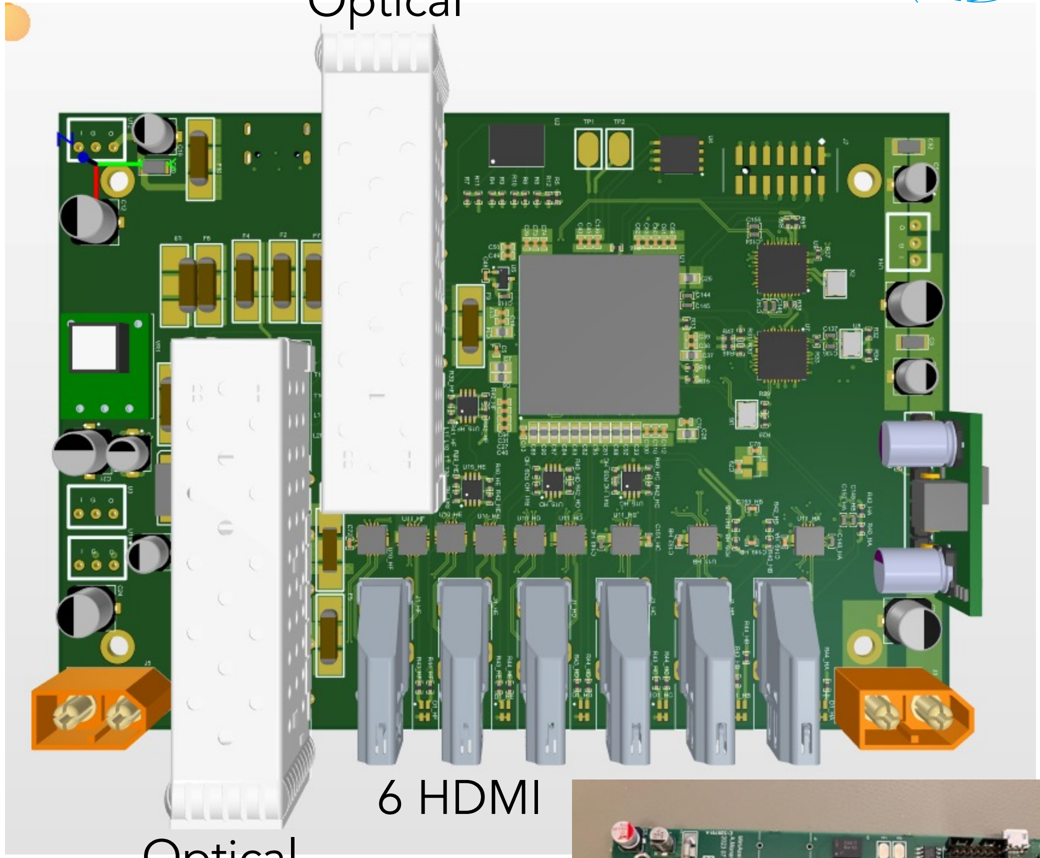
kc705 board in a 1U crate

Now 5 hybrids per one FEA

Upgrade to 10 hybrids per FEA (as in pict)

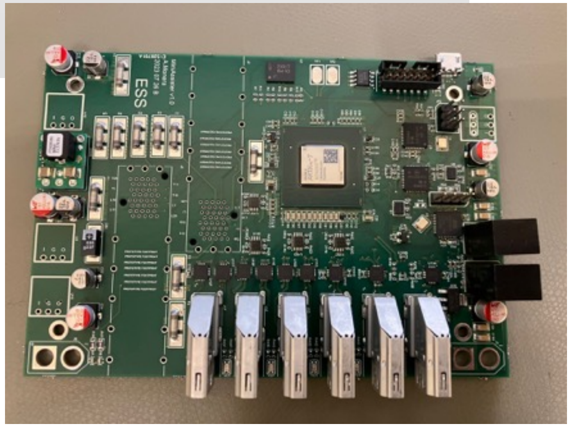
<u>MINI Assister</u>

Optical



6 HDMI

Optical

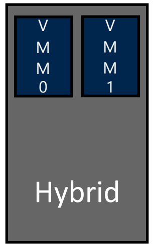


Designed by Angel,
6 hybrids per FEA
~ 13 x 9 cm2

LV distribution board

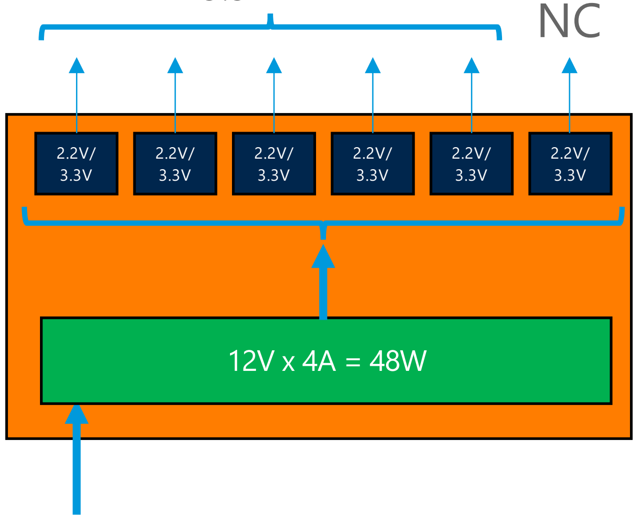
Output 2.2V/3.3V

Input 24V

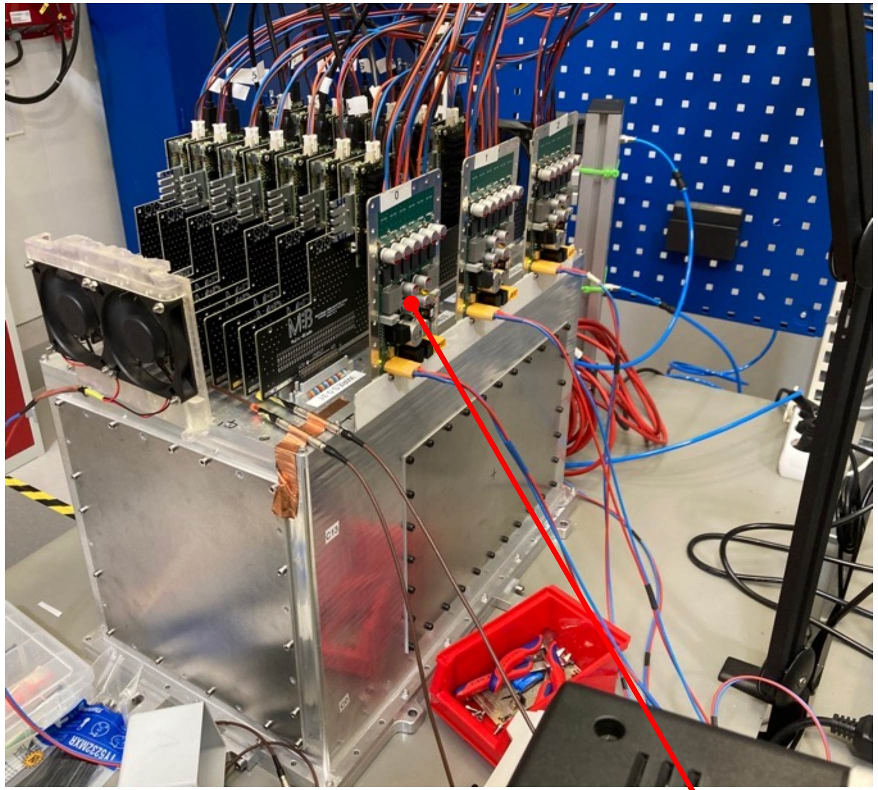


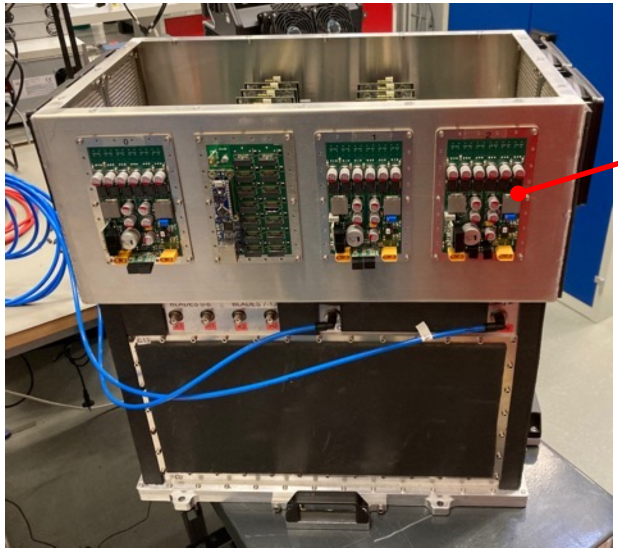
1 Hybrid power:
2.2V x 2A + 3.3V x 400mA =
= 4W + 1.32W = 5.32W ~ 6W

5.32W x 5 = 26.6W ~ 30W
2.2V x 10A
3.3V x 2A



24V x 3A = 72W

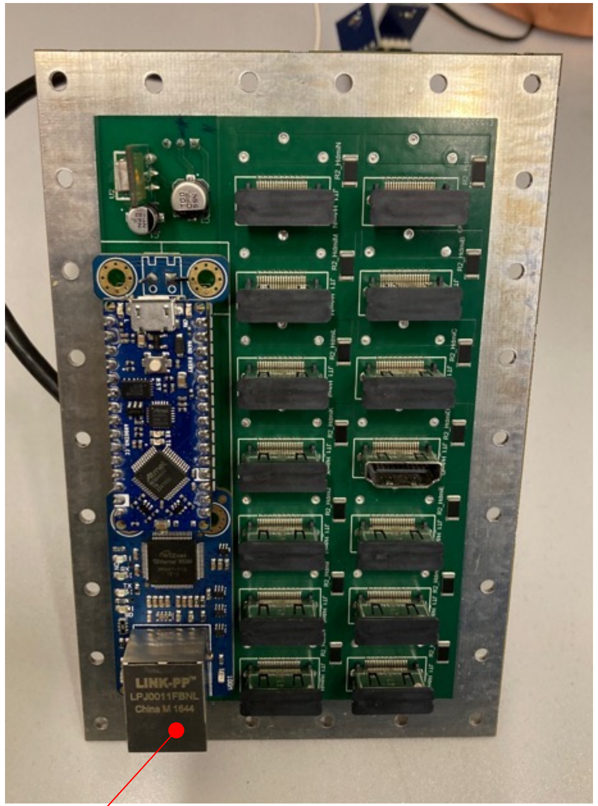




LV distrib

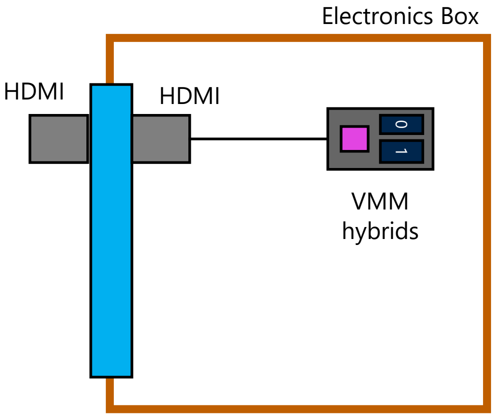
HDMI interface

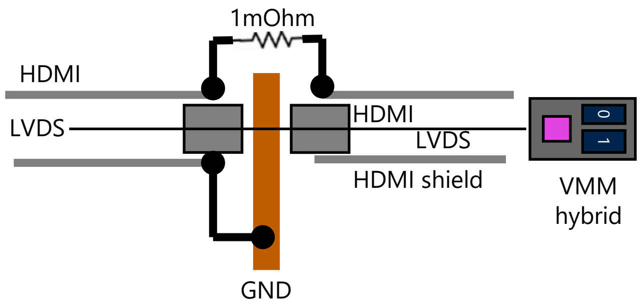
HDMI interface PCB

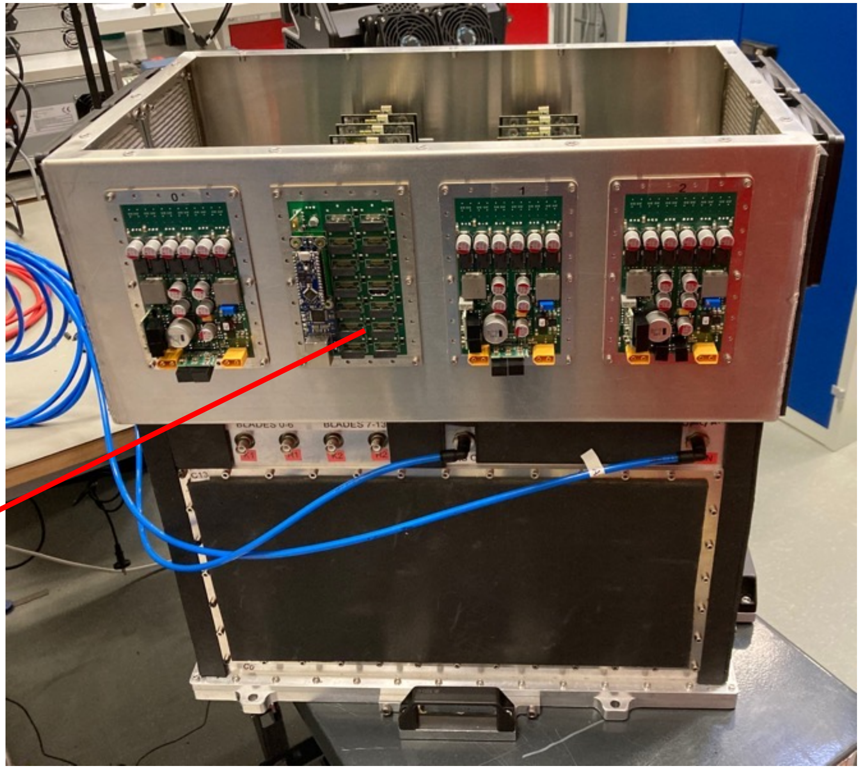


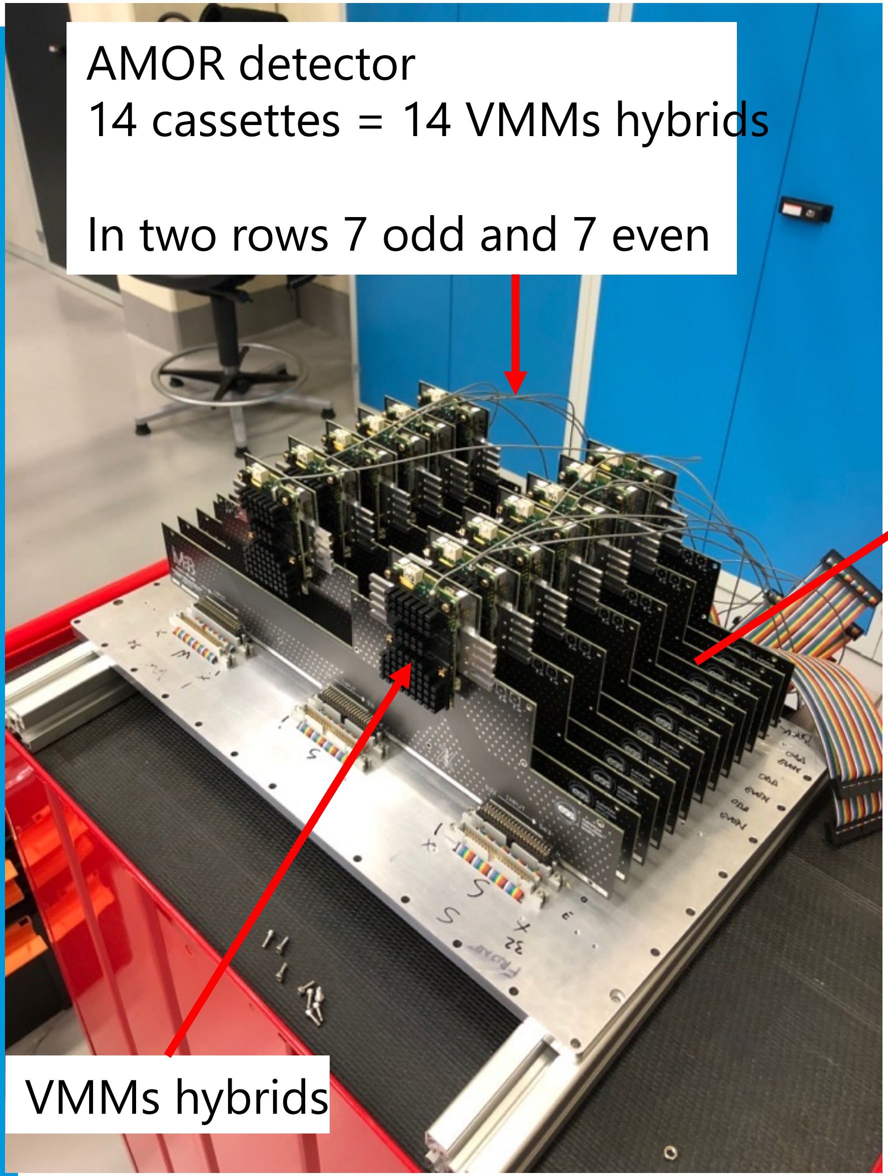
Arduino for atmospheric sensors

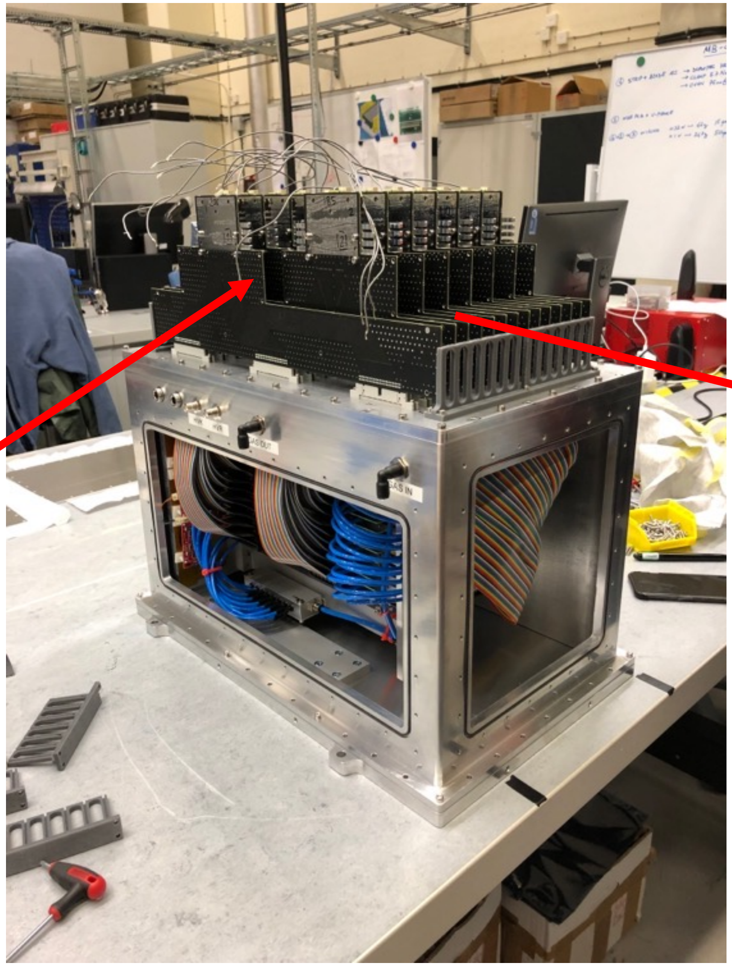
HDMI

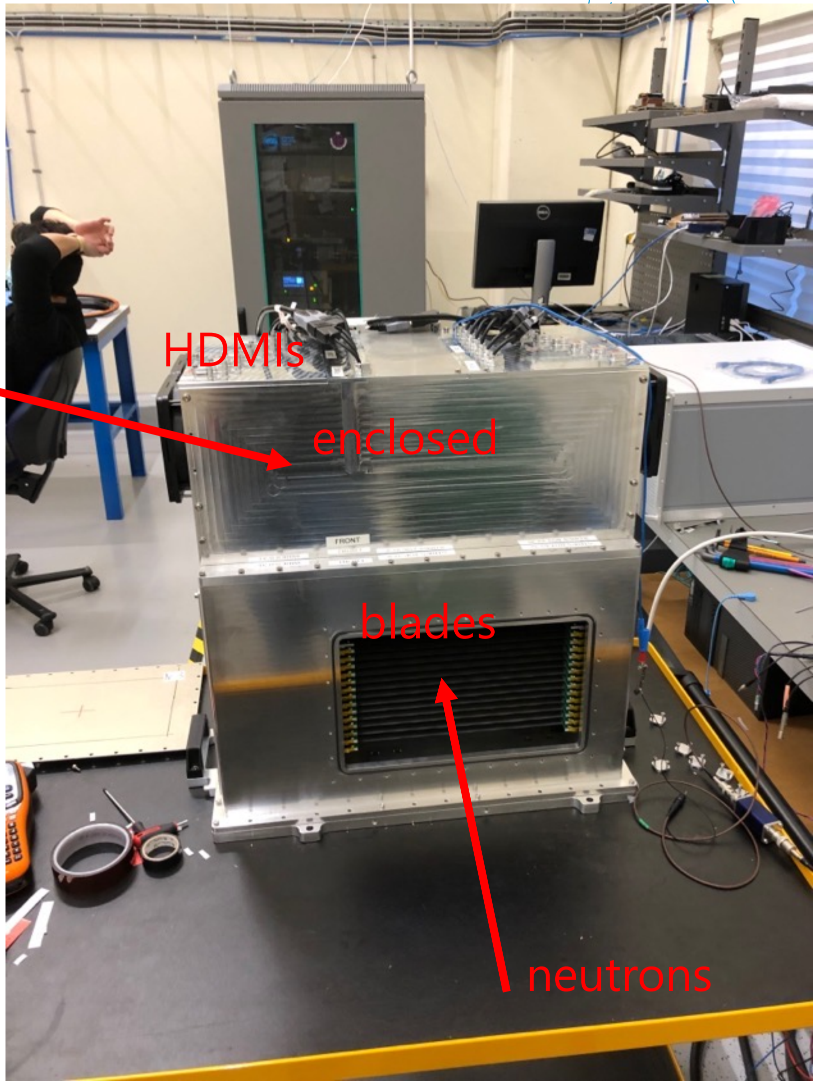




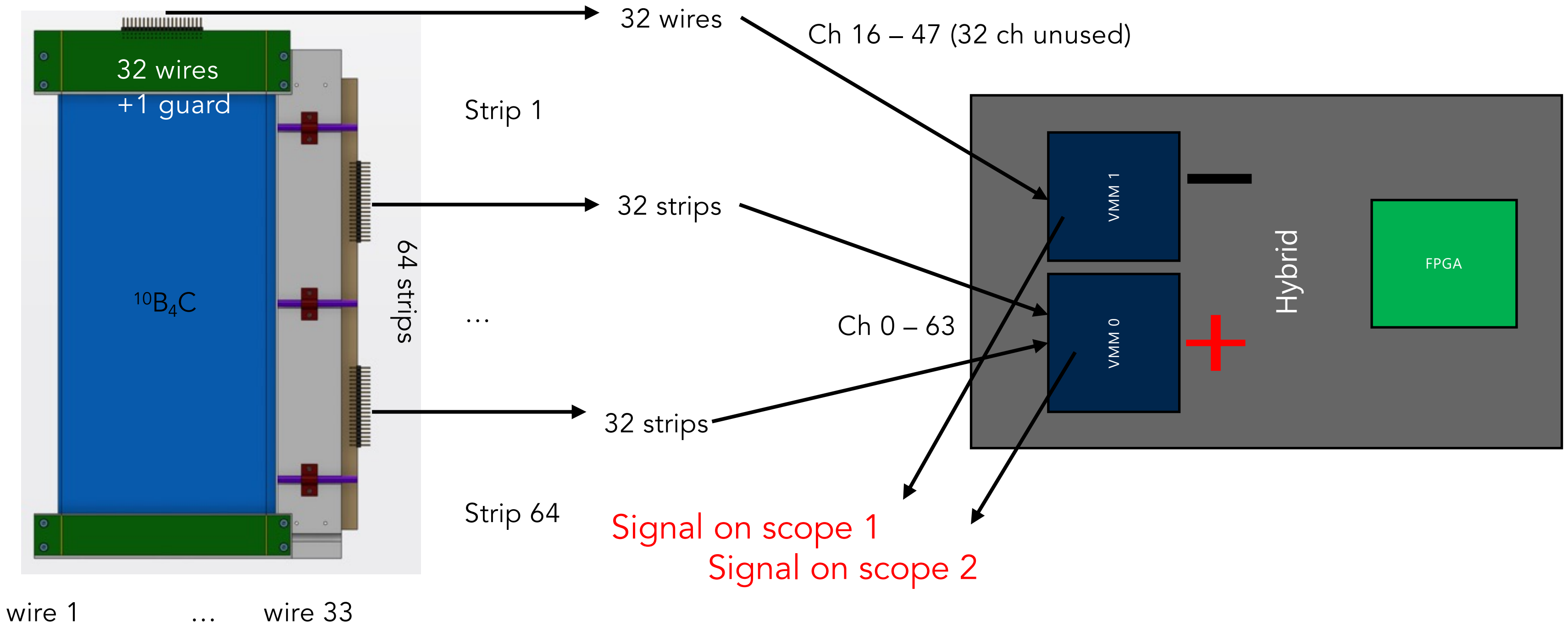



AMOR detector
14 cassettes = 14 VMMs hybrids
In two rows 7 odd and 7 even
VMMs hybrids

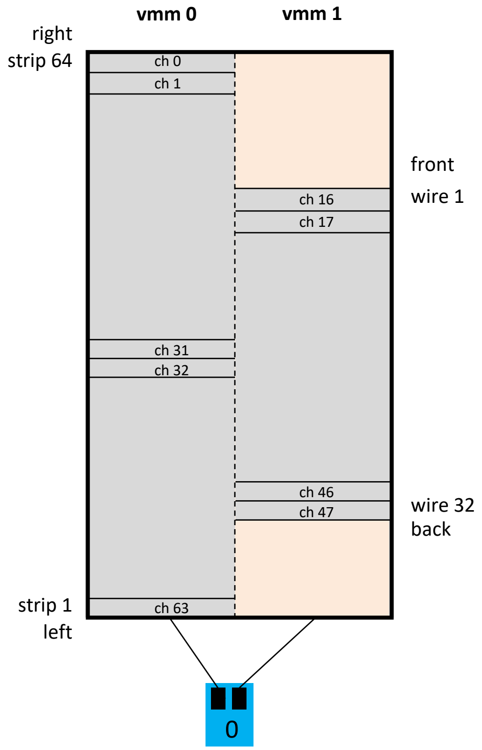



HDMIs
enclosed
blades
neutrons

One blade



Hybrid = one board with 2 VMMs = 128ch,
We use 96 ch

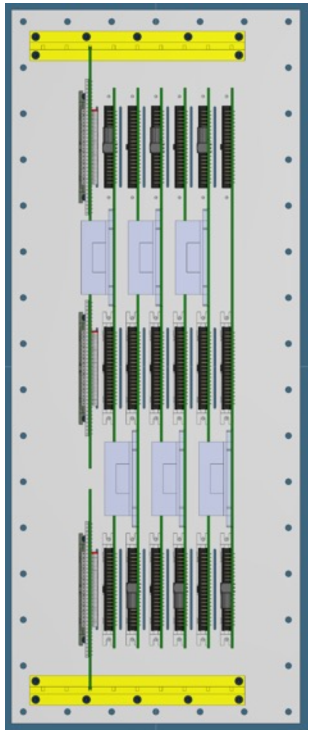


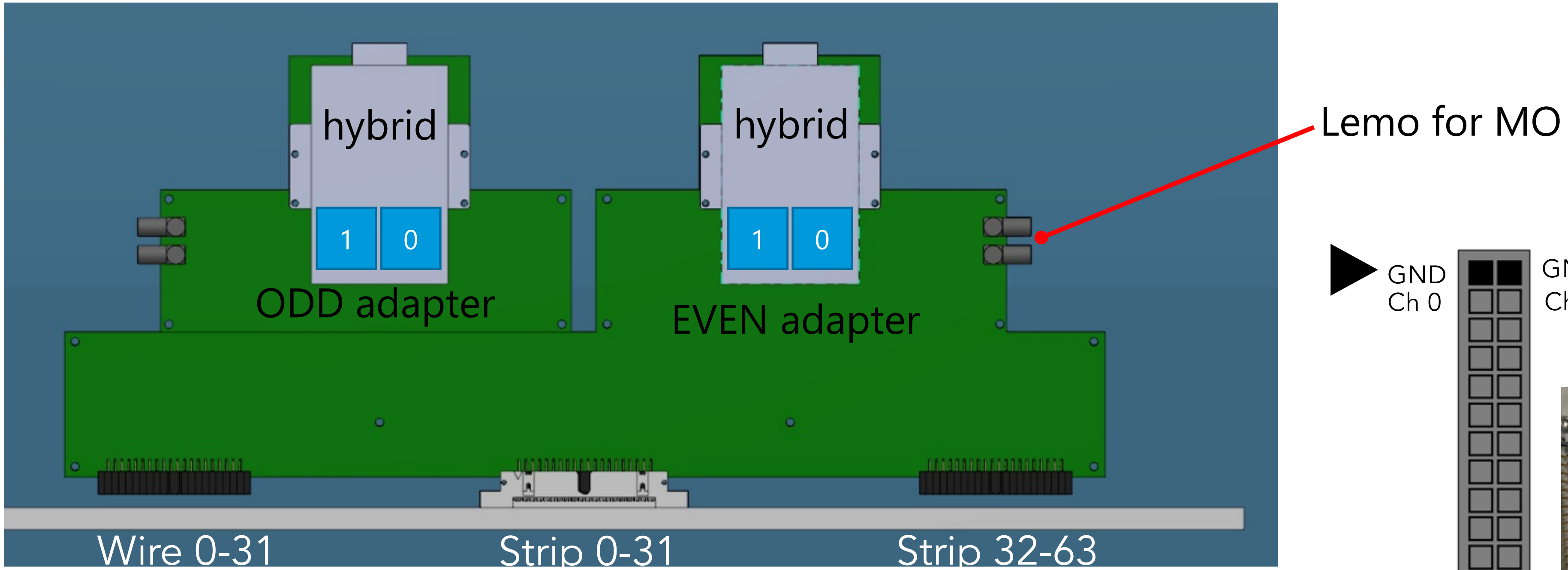
Wires AC coupled 10nF each
Negative signal

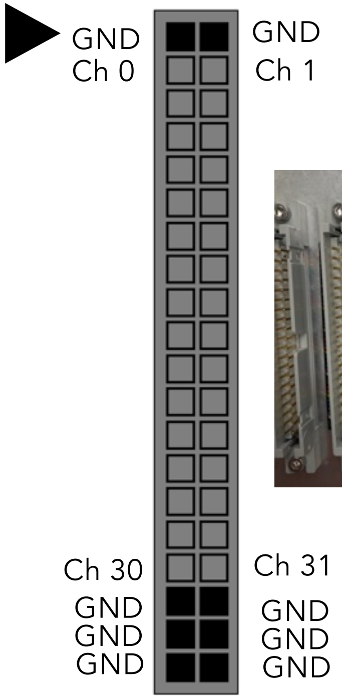
Strips DC coupled
Positive signal

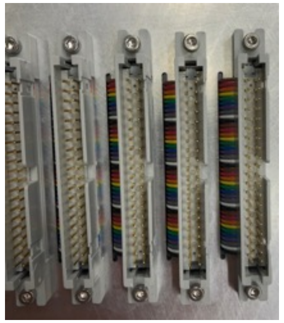
Charge max 0.5pC

200/300ns peak time is sufficient for MB



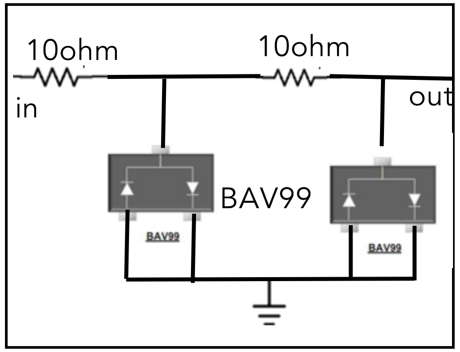




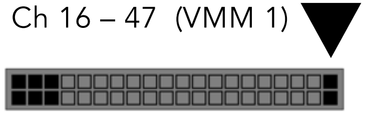


40 pins on 2 rows
2.54mm spacing

Each wire



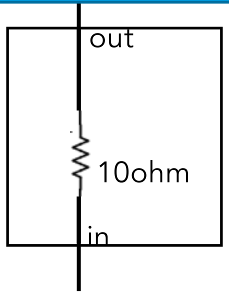
Ch 16 – 47 (VMM 1)



Wire 0 - 31

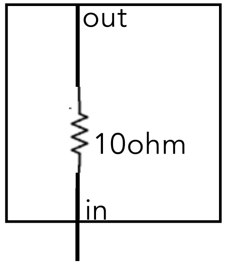
FX10A-140S

Hirose connector to hybrid
160 pins



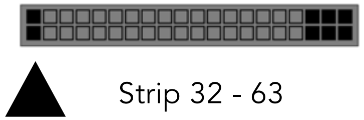
Ch 63 – 32 (VMM 0)

Strip 0 - 31



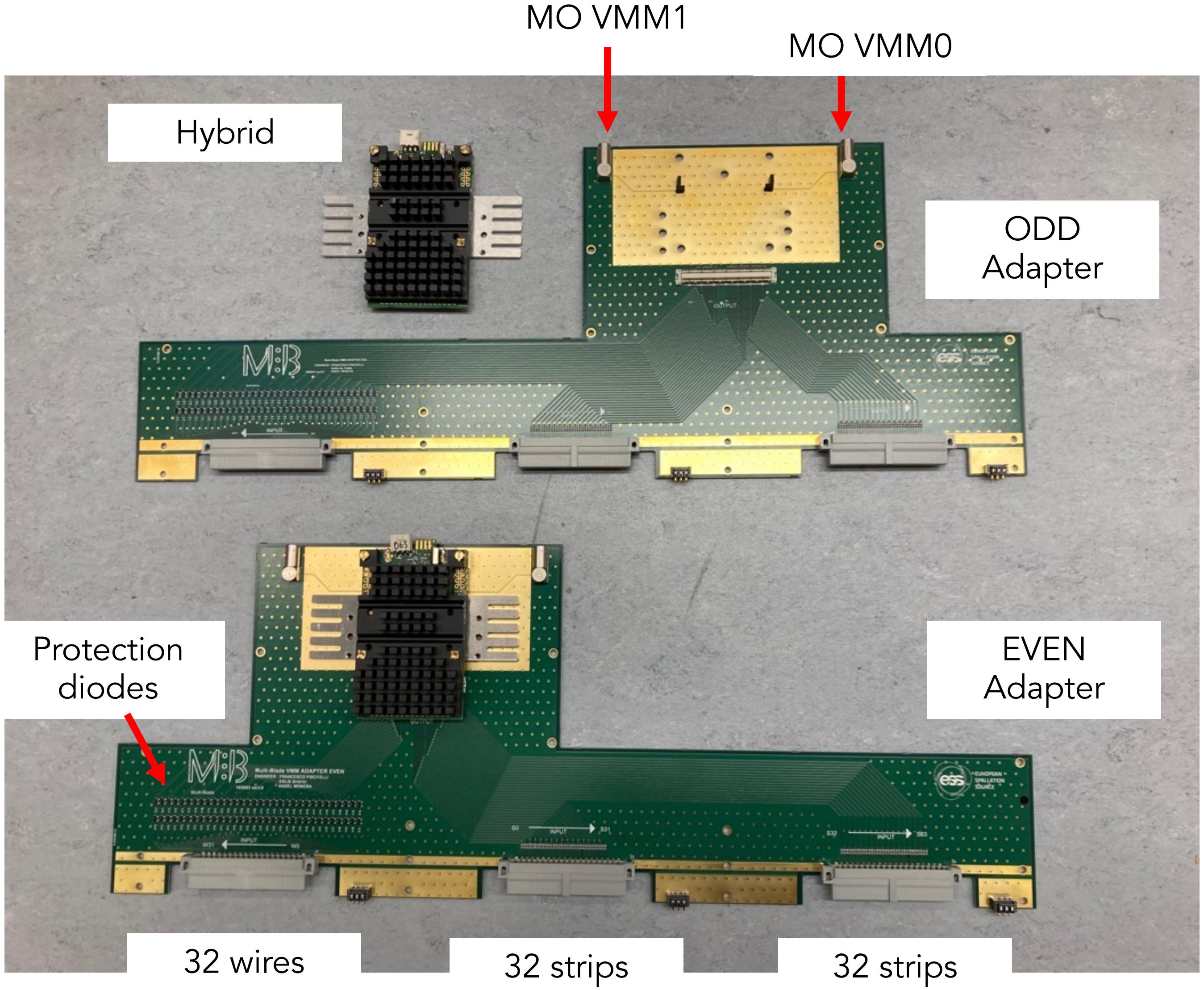
Each strip

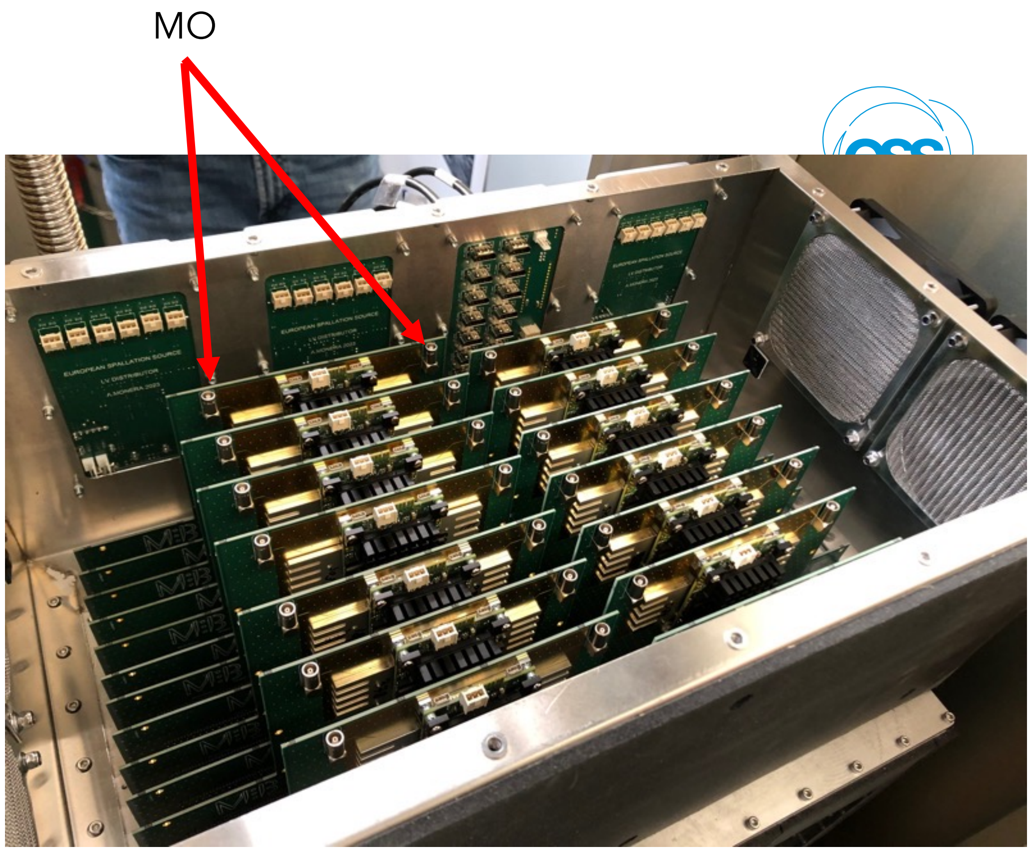
Ch 31 – 0 (VMM 0)



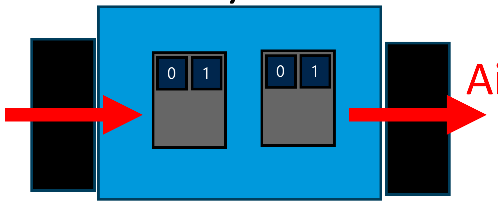
Strip 32 - 63

3 connectors per cassette


MO VMM1
MO VMM0
Hybrid
ODD
Adapter
Protection
diodes
EVEN
Adapter
32 wires
32 strips
32 strips

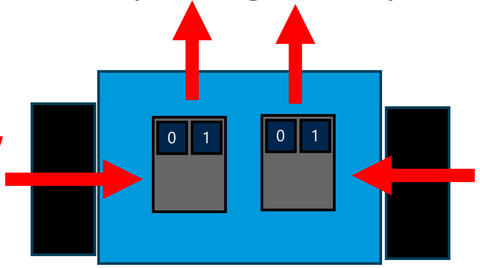

MO

even odd
14 hybrids



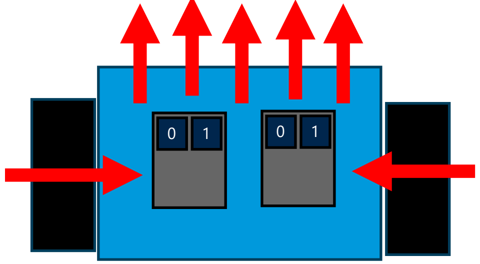
4X FAN 0.33A 12V

2 openings at top



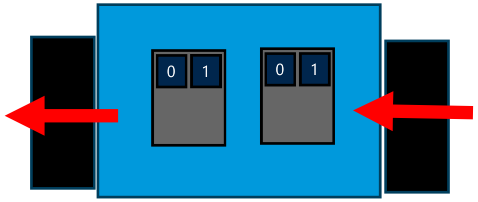
4X FAN 0.33A 12V

Top fully open, just mesh

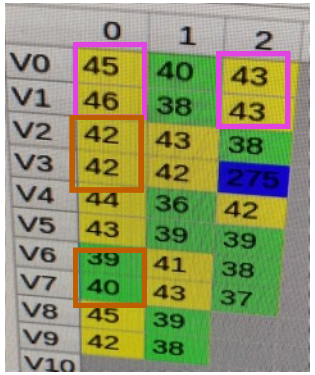


4X FAN 0.33A 12V

even odd

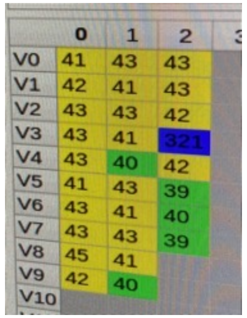


4X FAN 0.5A 24V



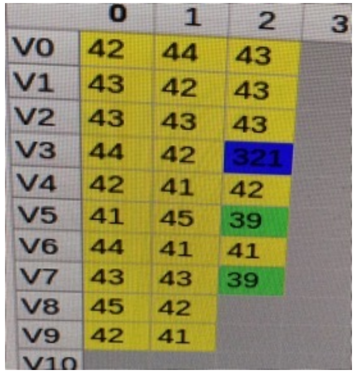
	0	1	2
V0	45	40	43
V1	46	38	43
V2	42	43	38
V3	42	42	275
V4	44	36	42
V5	43	39	39
V6	39	41	38
V7	40	43	37
V8	45	39	
V9	42	38	
V10			

48h



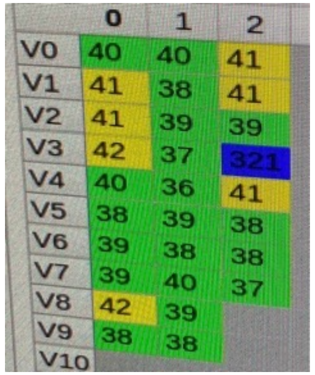
	0	1	2	3
V0	41	43	43	
V1	42	41	43	
V2	43	43	42	
V3	43	41	321	
V4	43	40	42	
V5	41	43	39	
V6	43	41	40	
V7	43	43	39	
V8	45	41		
V9	42	40		
V10				

1h



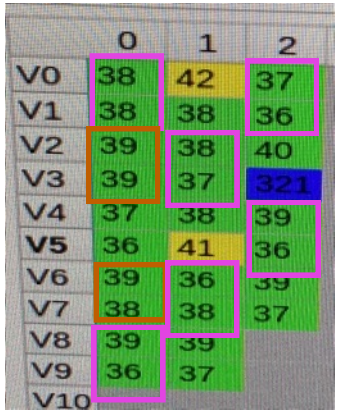
	0	1	2	3
V0	42	44	43	
V1	43	42	43	
V2	43	43	43	
V3	44	42	321	
V4	42	41	42	
V5	41	45	39	
V6	44	41	41	
V7	43	43	39	
V8	45	42		
V9	42	41		
V10				

24h



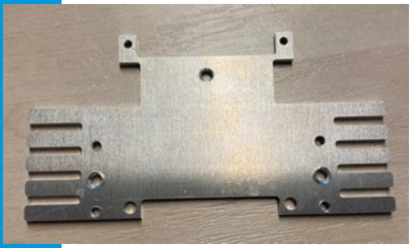
	0	1	2
V0	40	40	41
V1	41	38	41
V2	41	39	39
V3	42	37	321
V4	40	36	41
V5	38	39	38
V6	39	38	38
V7	39	40	37
V8	42	39	
V9	38	38	
V10			

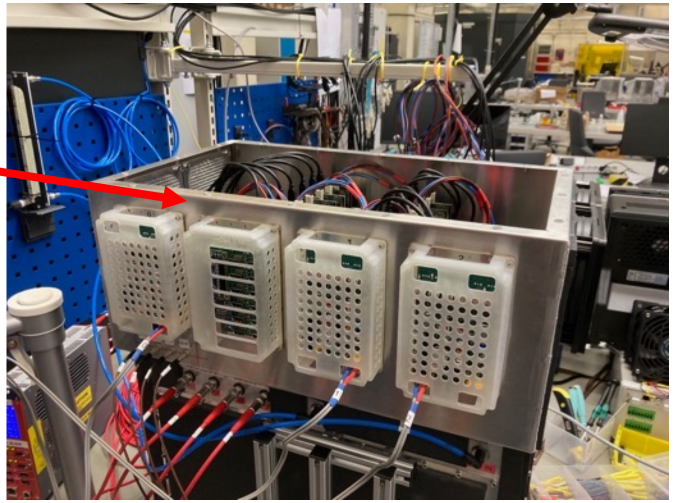
1h

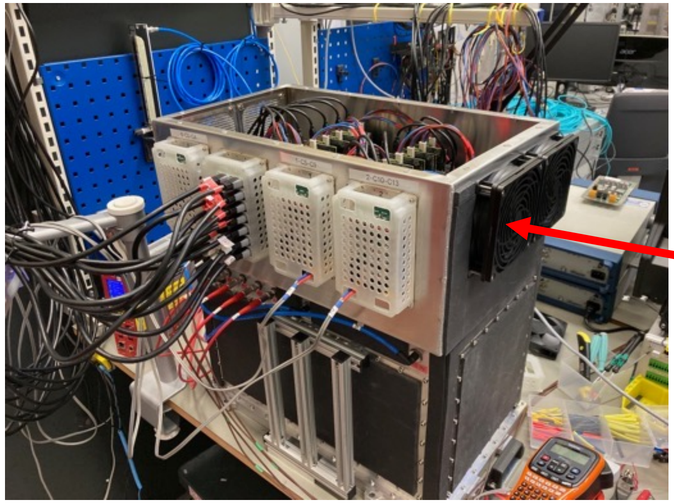


	0	1	2
V0	38	42	37
V1	38	38	36
V2	39	38	40
V3	39	37	321
V4	37	38	39
V5	36	41	36
V6	39	36	39
V7	38	38	37
V8	39	39	
V9	36	37	
V10			

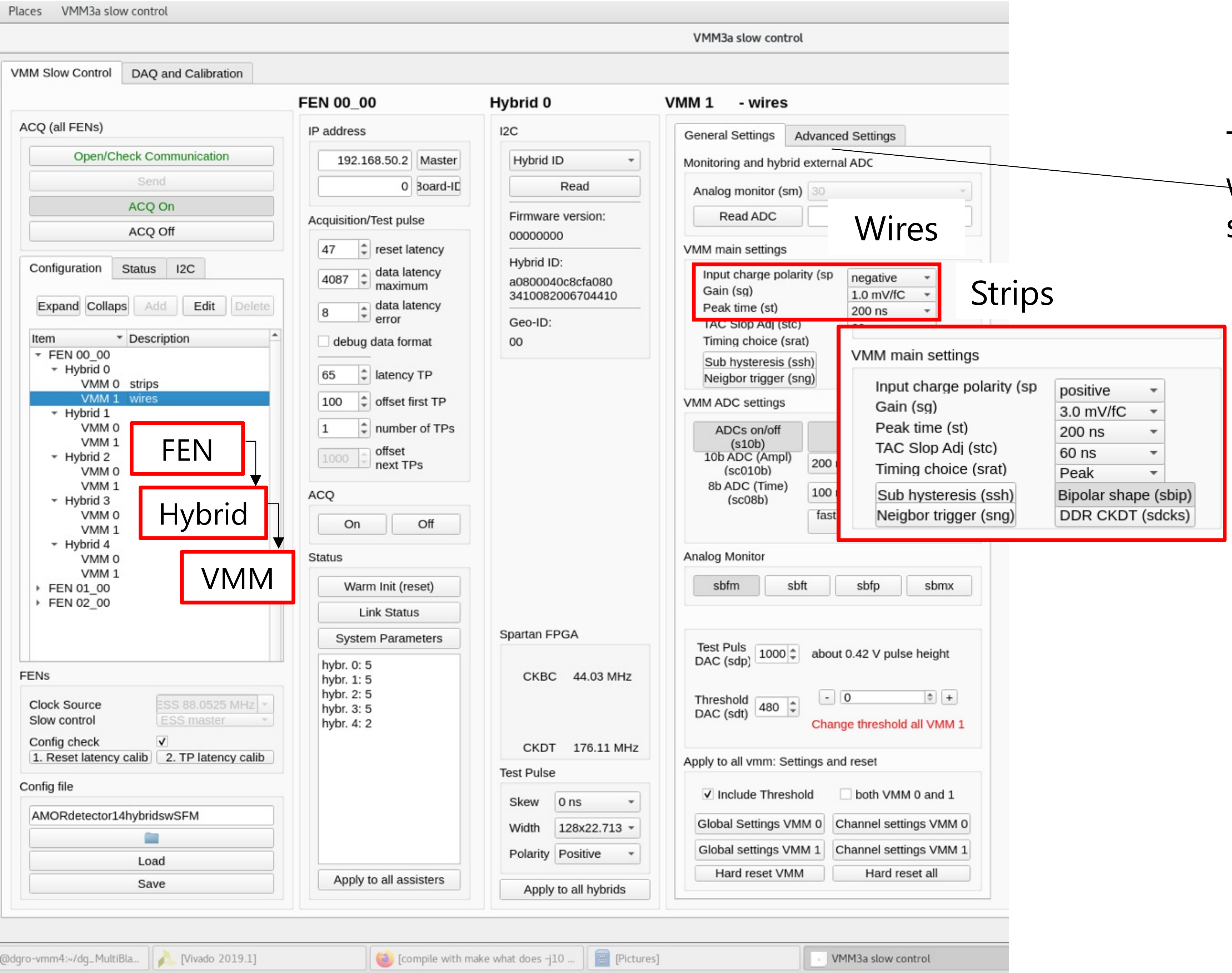
FAN



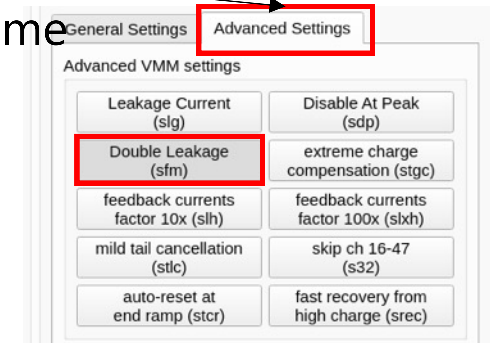




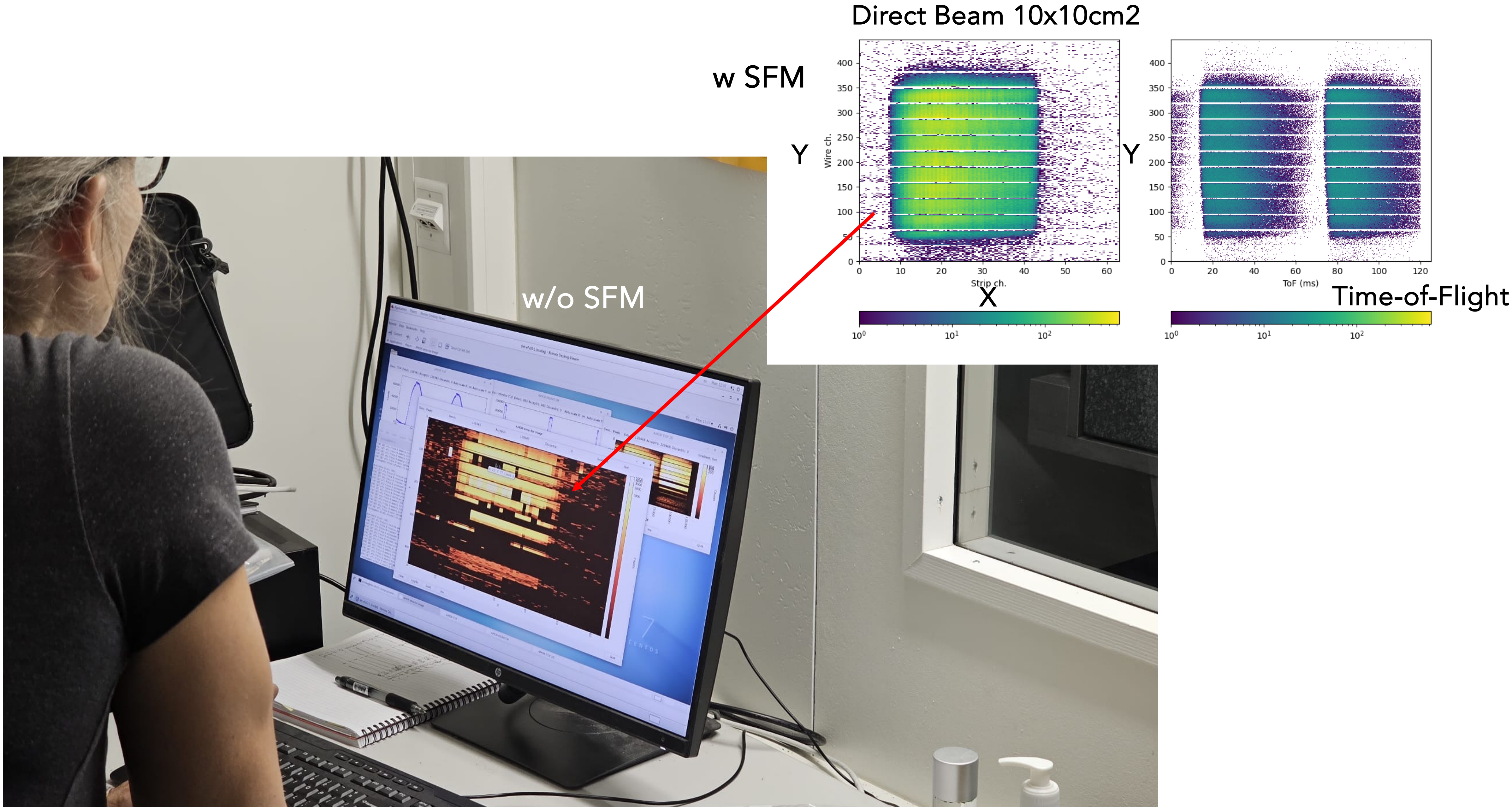
FAN



The settings for each wire/strip should be the same



Ensure sfm is enabled for all VMMs – strips and wires


Direct Beam 10x10cm2
w SFM
Y
Wire ch.
Strip ch.
X
ToF (ms)
Time-of-Flight
w/o SFM
10^0
10^1
10^2

Yield With and w/o SFM enabled

Sample of 129 hybrids (30 shown)

			w/o SFM +	w/o SFM −	w SFM +	w SFM −	w/o SFM enabled	w SFM enabled
Type	Num	Hybrid #	Strips missing VMM0v	Wires missing VMM1	Strips mising VMM0	Wires missing VMM1	Verdict	Verdict w sfm
wing MB	1	304	1	0	0	0	0	0
wing MB	2	318	3	0	2	0	3	2
wing MB	3	251	1	0	0	0	1	0
wing MB	4	253	0	0	0	0	0	0
wing MB	5	029	2	0	2	0	2	2
wing MB	6	299	0	1	0	1	1	1
wing MB	7	328	2	0	1	0	2	1
wing MB	8	232	2	1	2	1	3	3
wing MB	9	223	1	0	0	0	1	0
wing MB	10	154	100	0	1	0	100	1
wing MB	11	151	100	0	0	0	100	0
wing MB	12	139	0	0	0	0	0	0
wing MB	13	141	100	0	0	0	100	0
wing MB	14	136	100	0	1	0	100	1
wing MB	15	065	1	1	1	0	2	1
wing MB	16	161	0	0	0	0	0	0
wing MB	17	120	64	0	64	0	64	64
wing MB	18	153	2	0	2	0	2	2
wing MB	19	402	100	0	0	0	100	0
wing MB	20	303	0	0	0	0	0	0
wing MB	21	220	0	0	0	0	0	0
wing MB	22	156	100	0	0	0	100	0
wing MB	23	413	100	0	0	0	100	0
wing MB	24	375	1	0	1	0	1	1
wing MB	25	198	64	0	1	0	64	1
wing MB	26	353	0	0	0	0	0	0
wing MB	27	086	0	0	0	0	0	0
wing MB	28	230	0	1	0	1	1	1
wing MB	29	143	1	100	1	2	101	3
wing MB	30	043	100	0	0	0	100	0

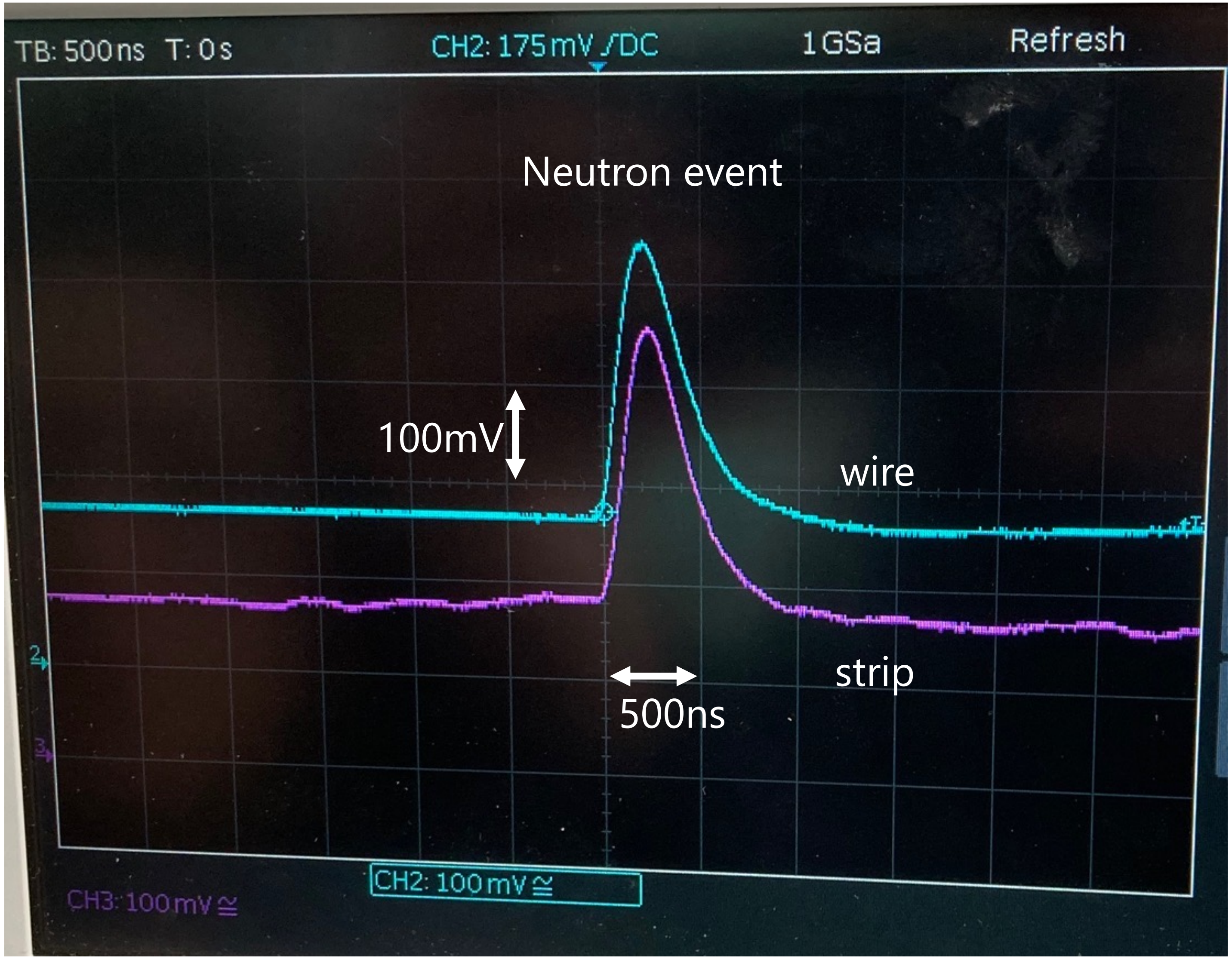
	Good O ch missing	Max 4 ch missing	> 4ch missing
w/o SFM	20%	30%	50%
w SFM	63%	34%	2%

Missing ch can be mapped to a specific detector that does not use them

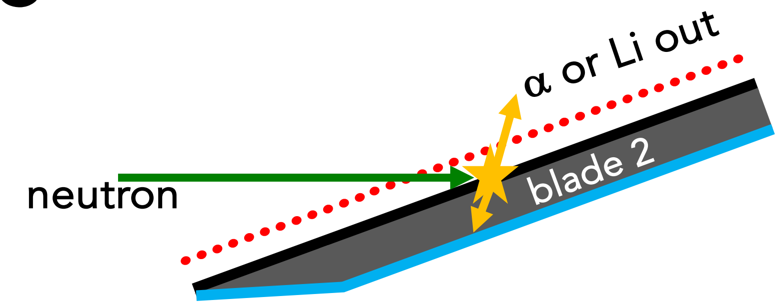
In 2021 production yield was 40%

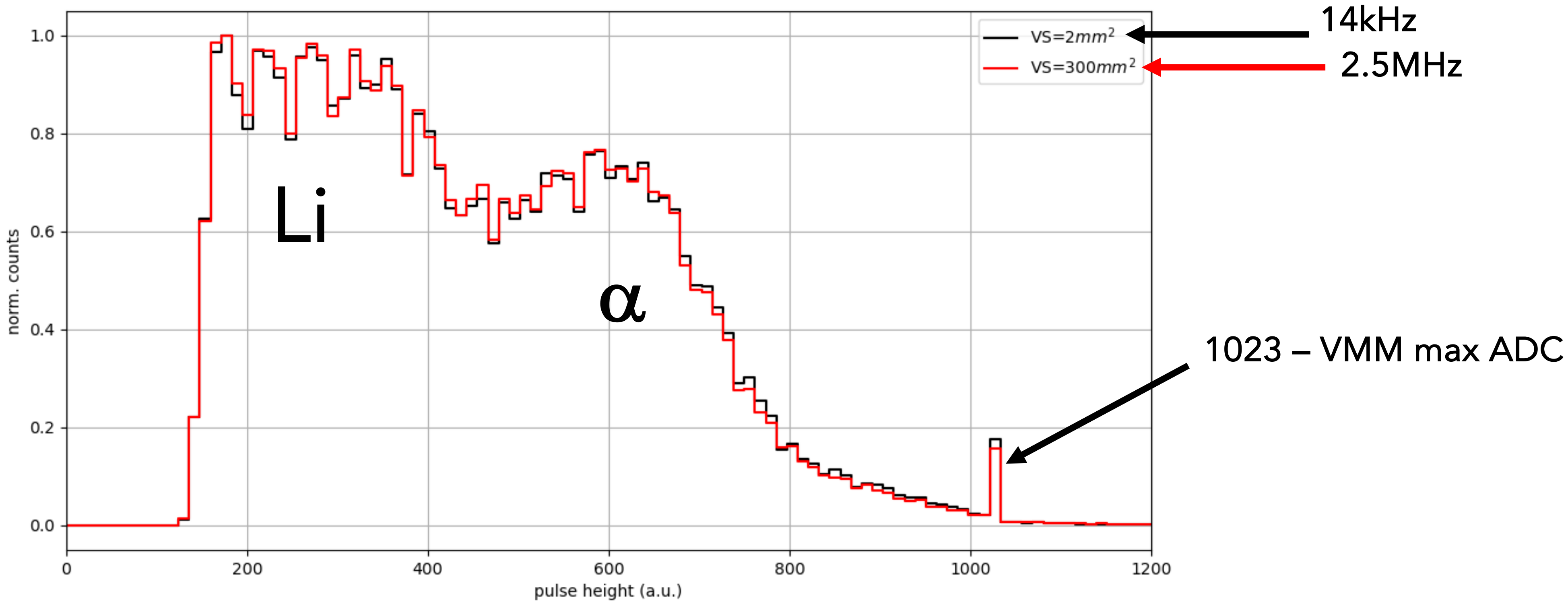
129+129 for MB+NMX in-hand (delivered 2023)

300+300 in production, delivery 2024

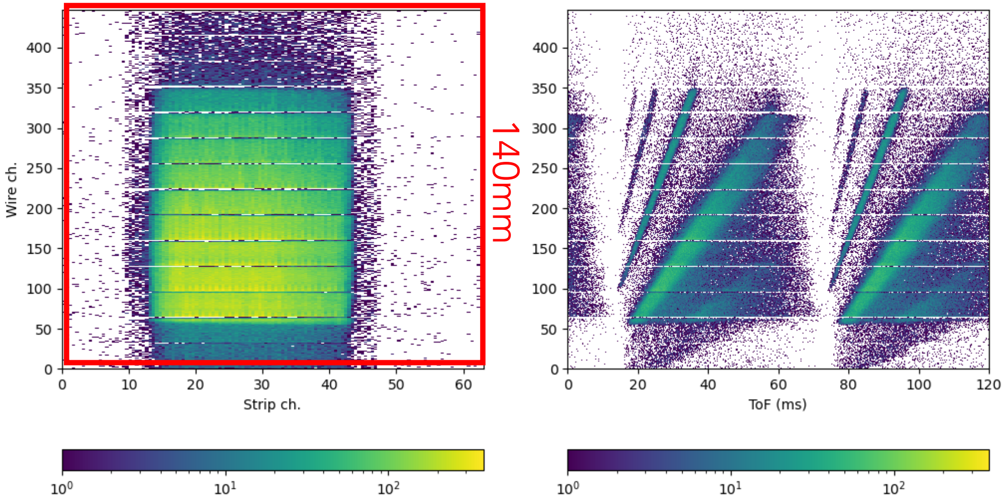

TB: 500ns T: 0s
CH2: 175mV /DC
1GSa
Refresh
Neutron event
100mV
wire
strip
500ns
CH3: 100mV ≅
CH2: 100mV ≅

PHS


α or Li out
neutron
blade 2

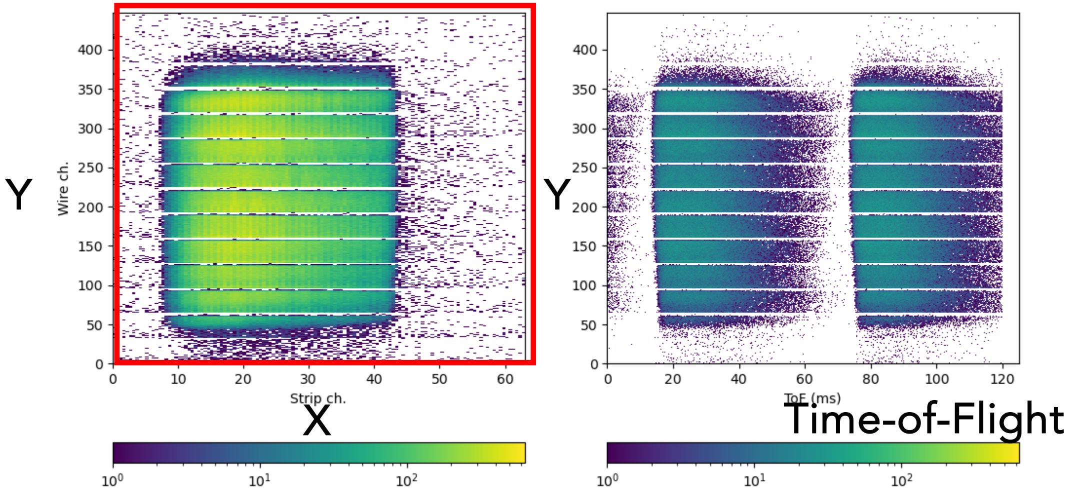

VS=2mm^2
VS=300mm^2
14kHz
2.5MHz
Li
α
1023 – VMM max ADC
norm. counts
pulse height (a.u.)
0.0
0.2
0.4
0.6
0.8
1.0
0
200
400
600
800
1000
1200

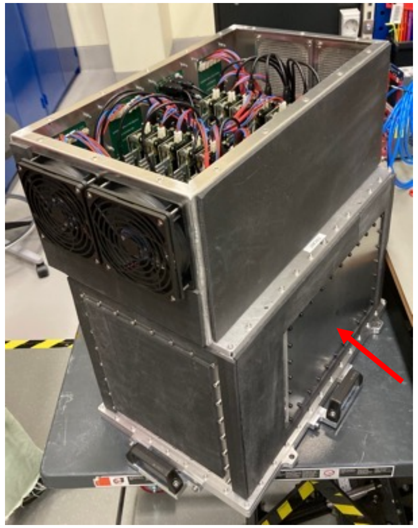
NiTi sample

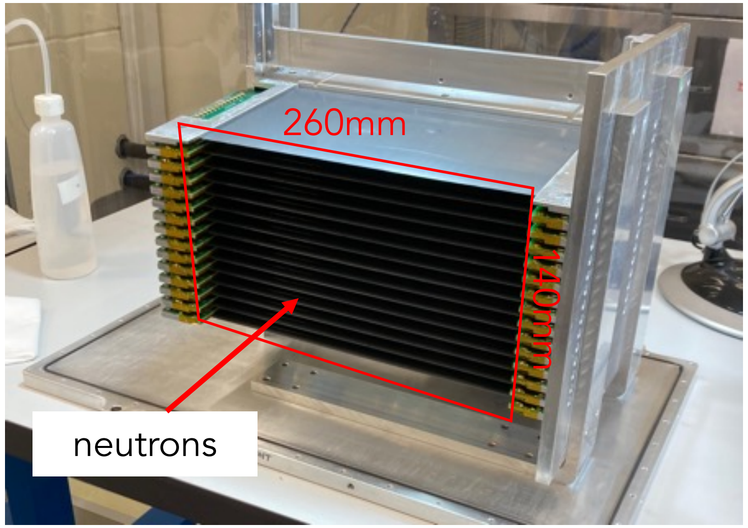


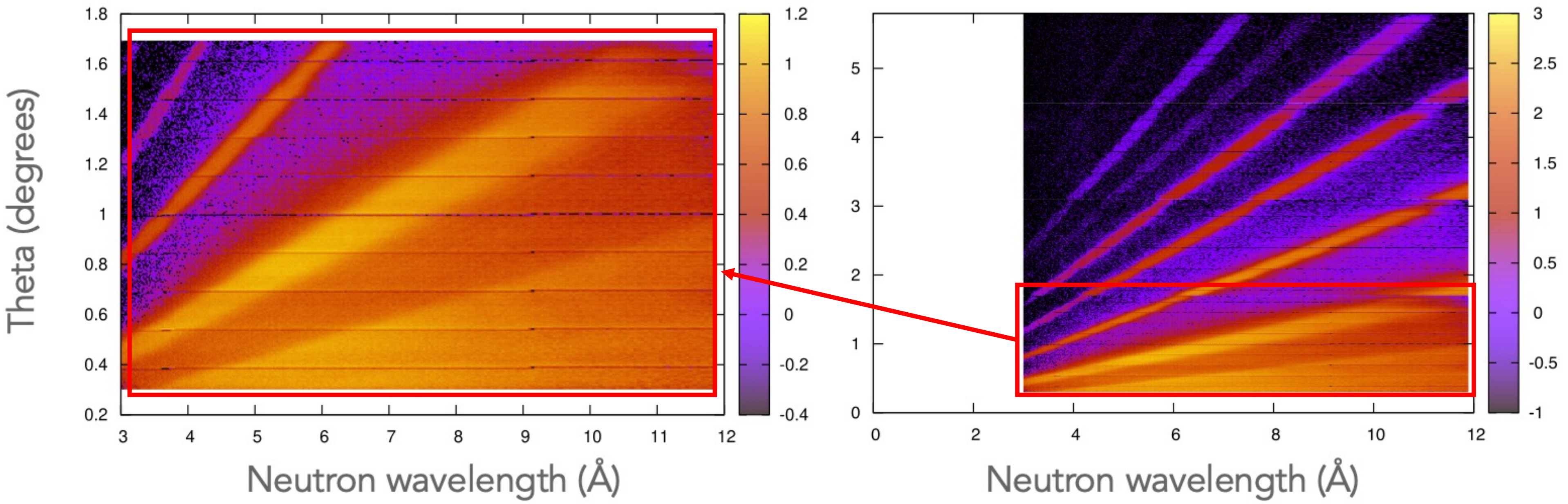
w SFM

Direct Beam 10x10cm2

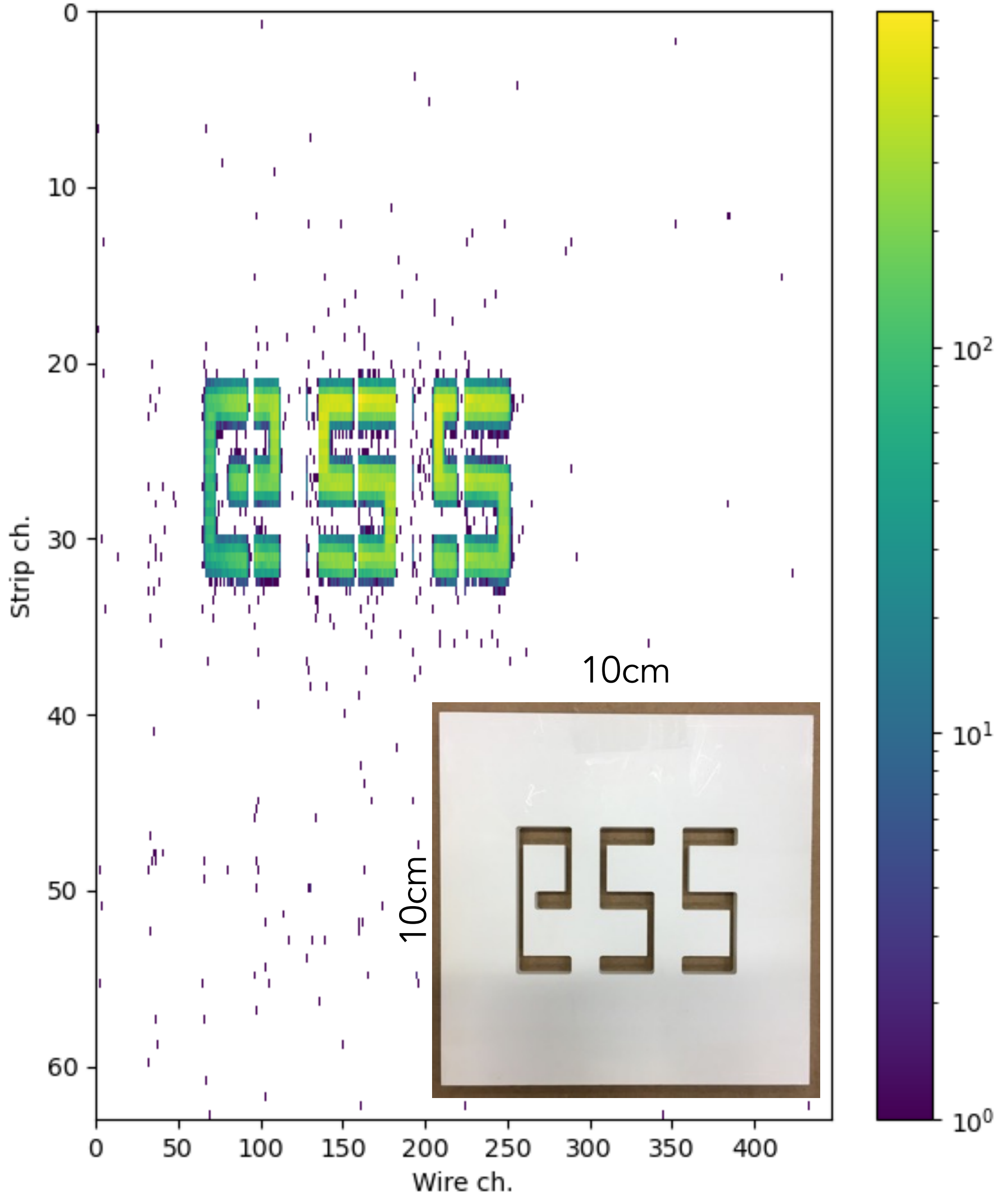




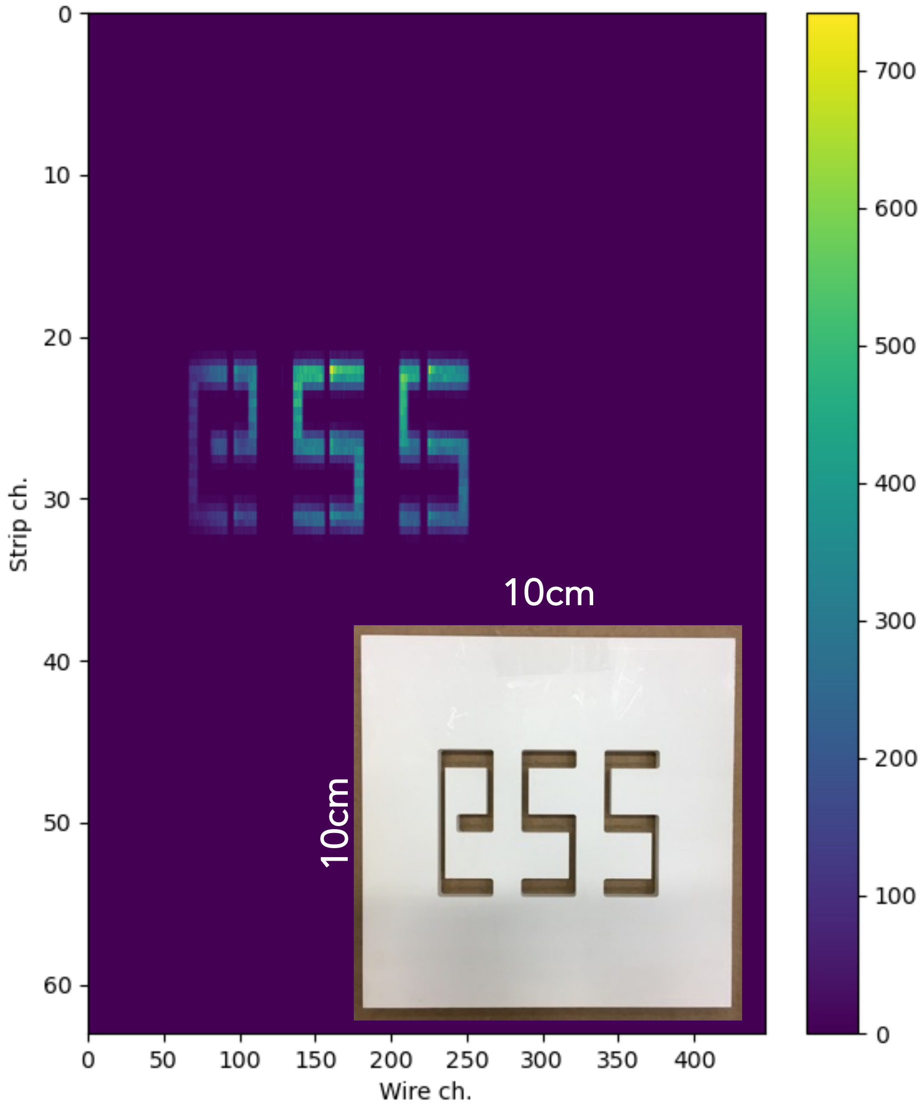




Theta (degrees)
Neutron wavelength (Å)
Neutron wavelength (Å)



Strip ch.
Wire ch.
0
10
20
30
40
50
60
0
50
100
150
200
250
300
350
400
10^0
10^1
10^2
10cm
10cm

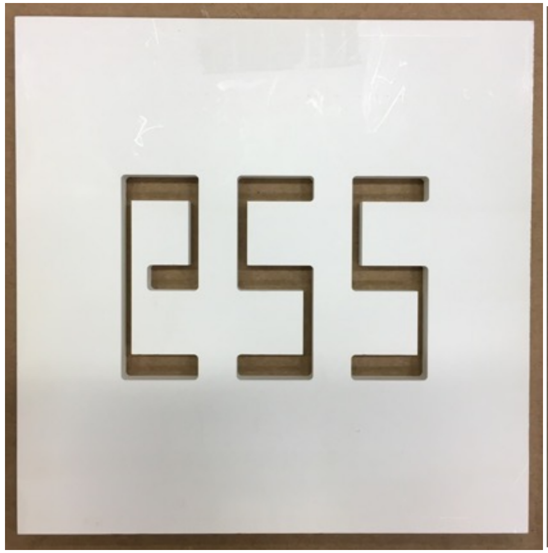


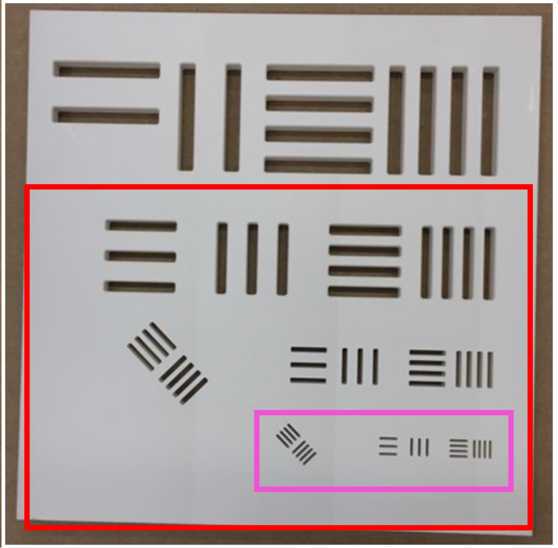
Strip ch.
Wire ch.
0
10
20
30
40
50
60
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
10cm
10cm

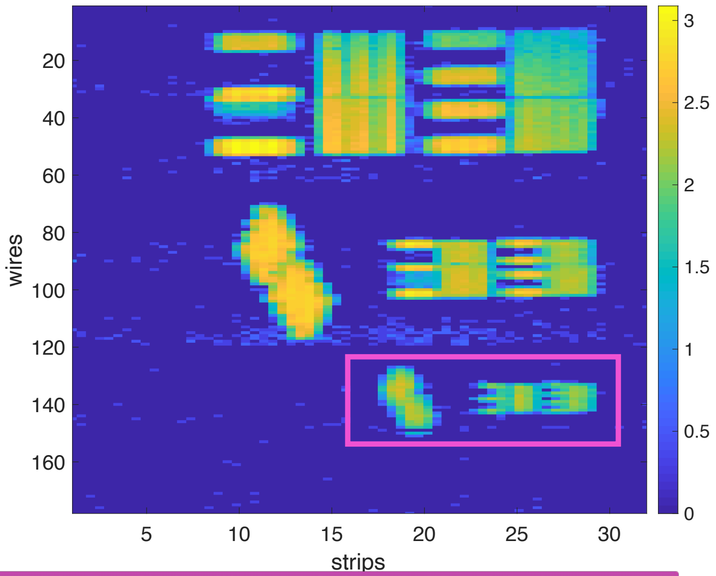
END

SPATIAL RESOLUTION

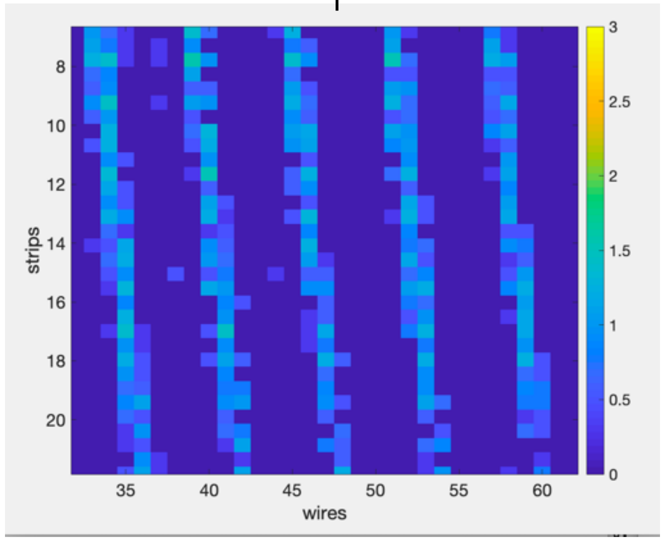
100x100mm^2 BN tiles

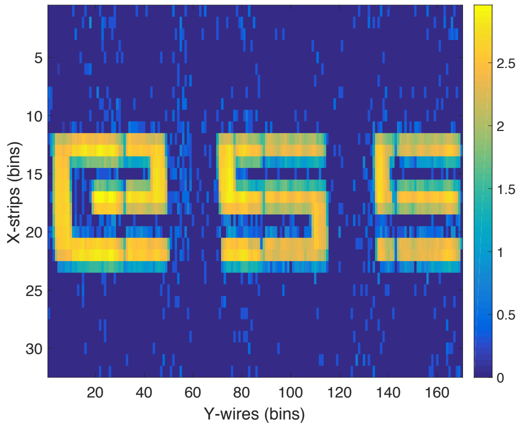


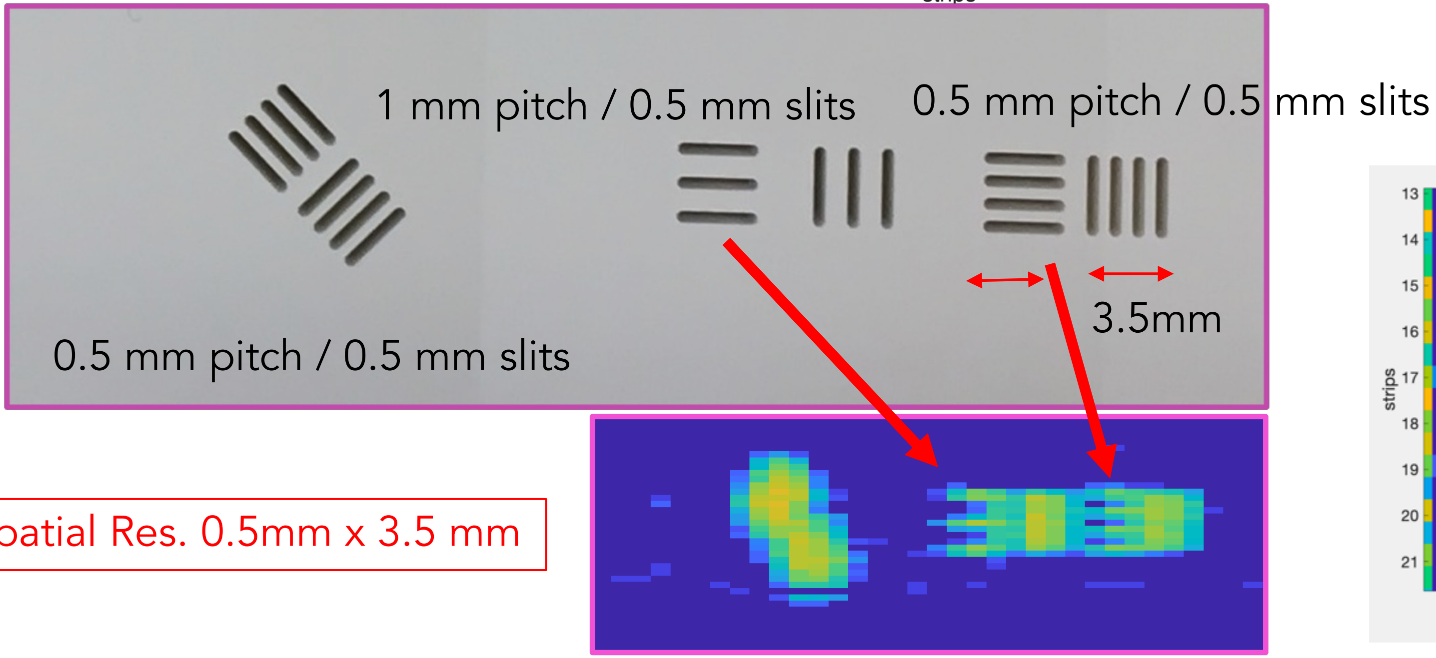




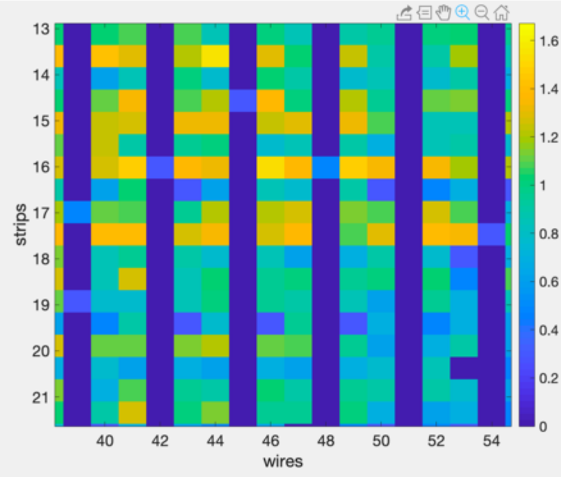
1mm pitch



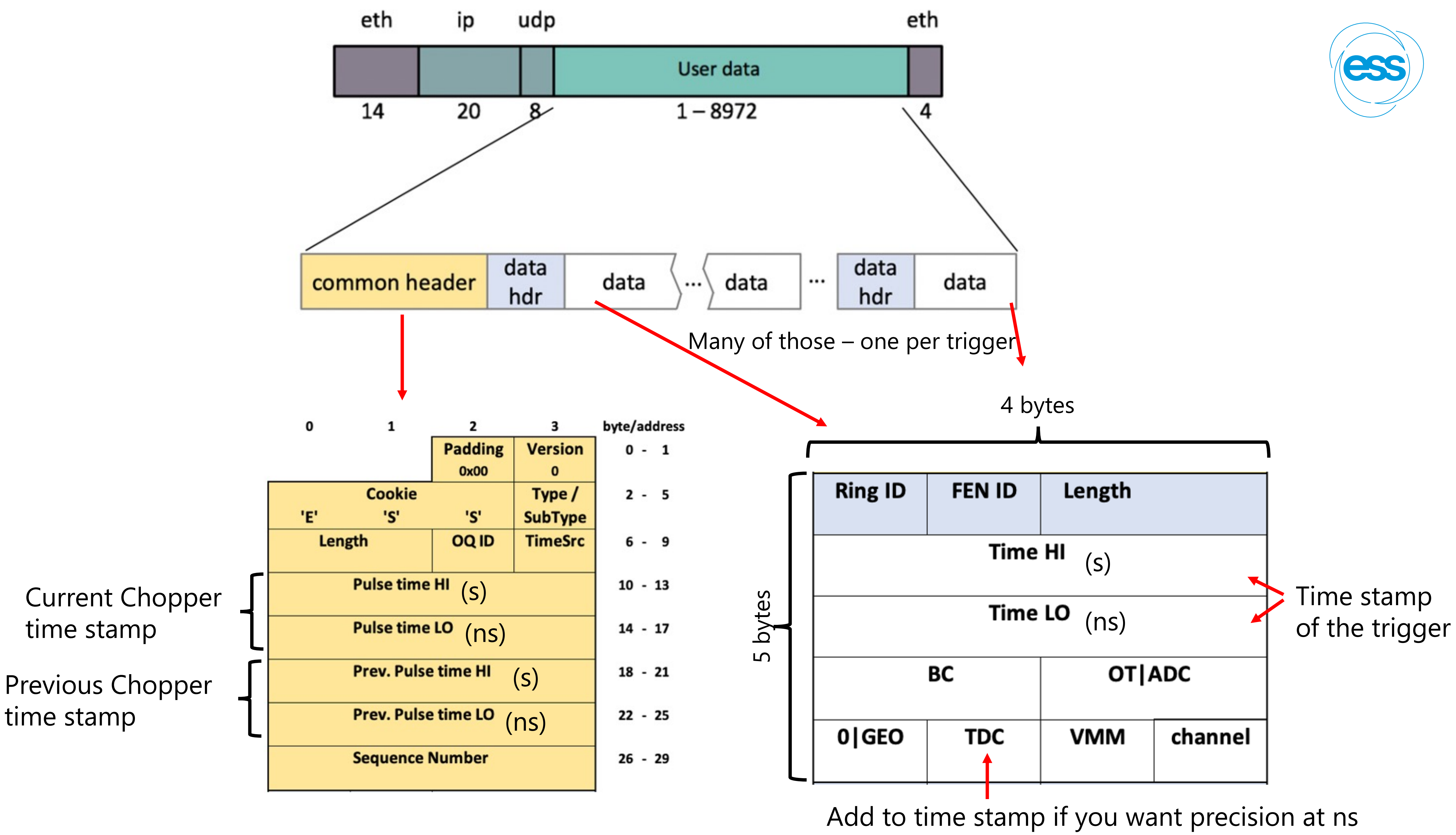




0.5mm pitch

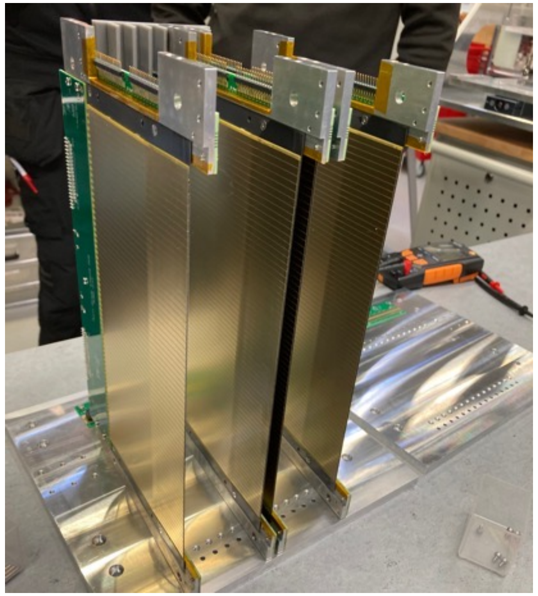
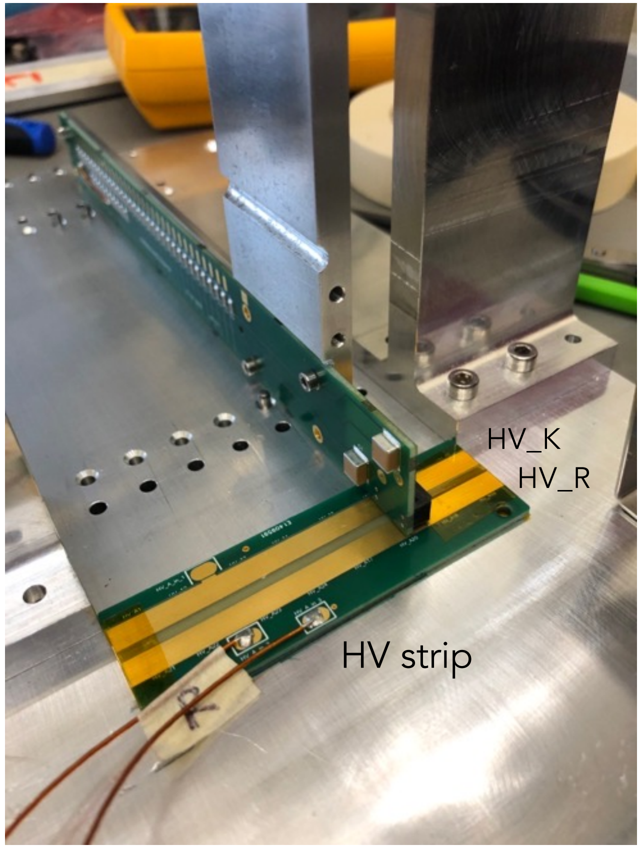
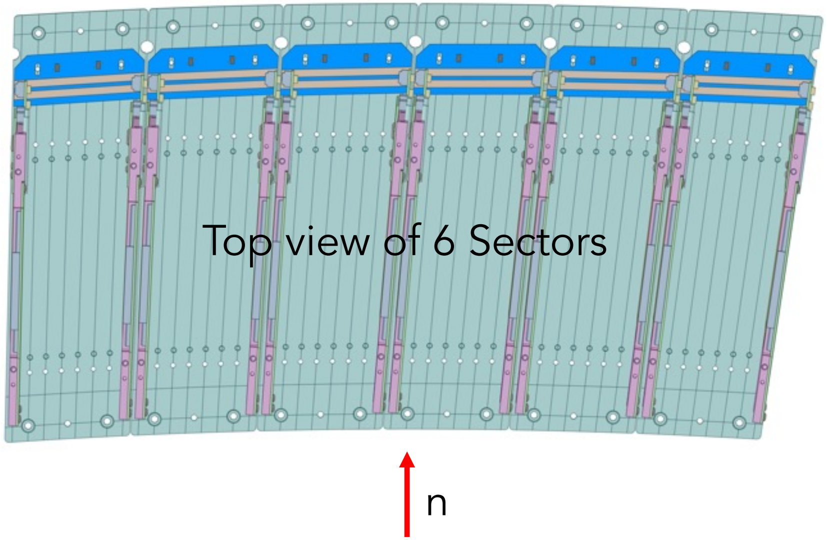
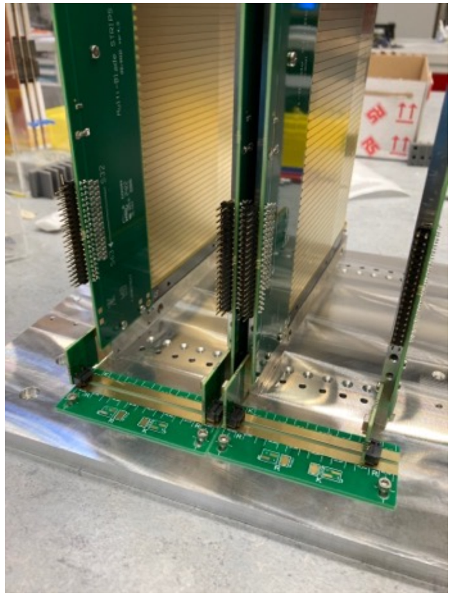
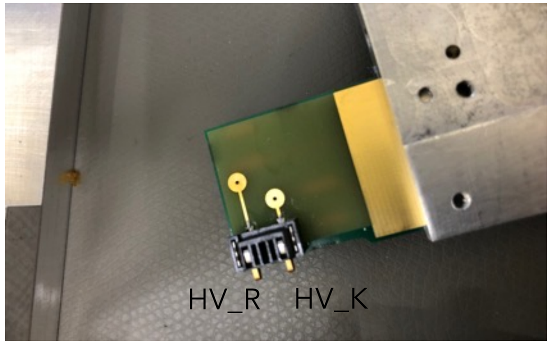


Spatial Res. 0.5mm x 3.5 mm



eth
ip
udp
eth
User data
14
20
8
1 – 8972
4
common header
data hdr
data
…
data
…
data hdr
data
Many of those – one per trigger
0
1
2
3
byte/address
Padding 0x00
Version 0
0 - 1
Cookie
'E'
'S'
'S'
Type / SubType
2 - 5
Length
OQ ID
TimeSrc
6 - 9
Current Chopper time stamp
Pulse time HI (s)
10 - 13
Pulse time LO (ns)
14 - 17
Previous Chopper time stamp
Prev. Pulse time HI (s)
18 - 21
Prev. Pulse time LO (ns)
22 - 25
Sequence Number
26 - 29
4 bytes
5 bytes
Ring ID
FEN ID
Length
Time HI (s)
Time LO (ns)
Time stamp of the trigger
BC
OT|ADC
0|GEO
TDC
VMM
channel
Add to time stamp if you want precision at ns

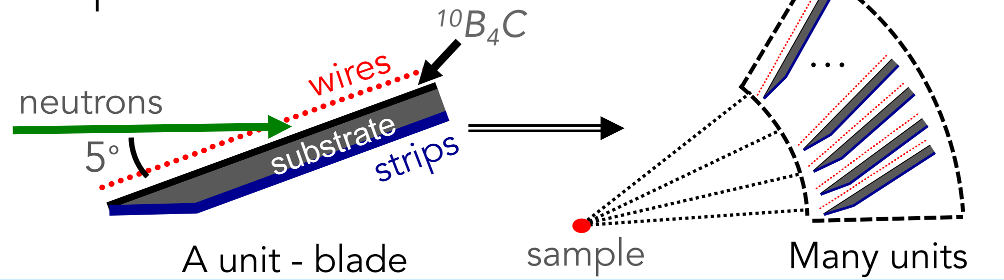


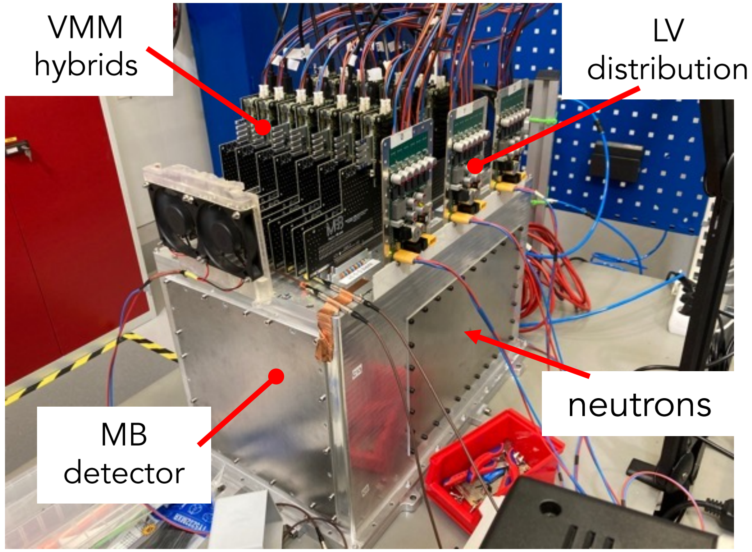


HV_K
HV_R
HV strip

Top view of 6 Sectors
n


HV_R
HV_K

AMOR / TBL Multi-Blade detector

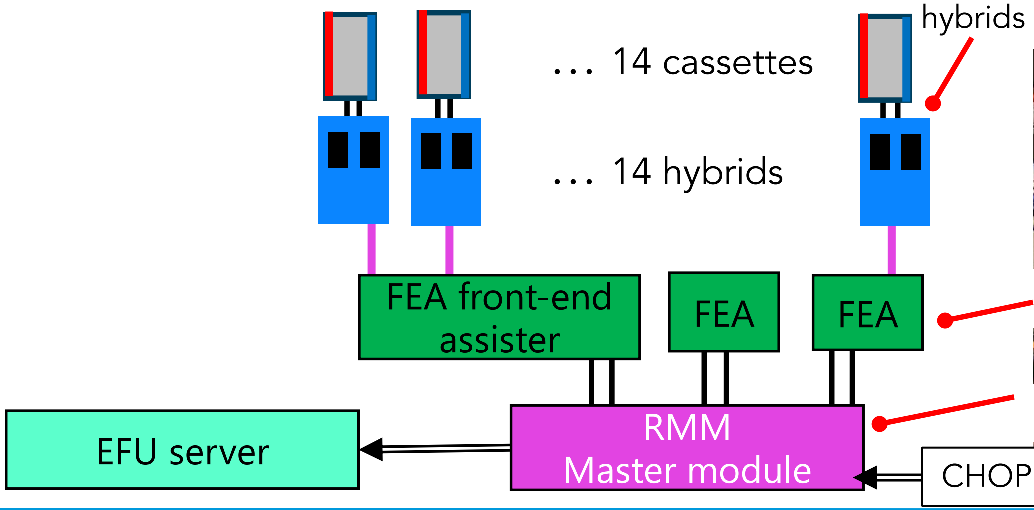
MB.AMOR is a 14 units MB detector 1:1 to TBL detector
Installation @ PSI (Nov 2023) to start user program
And demonstration of the full ESS readout system
(detG and ECDC)
TBL to be built in fall

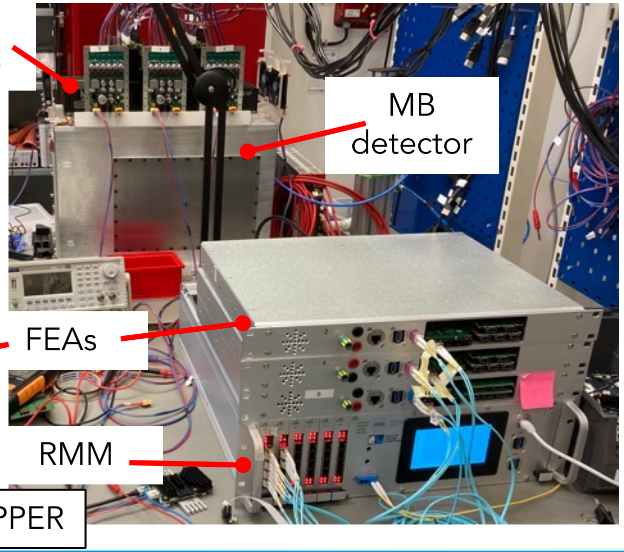
Principle



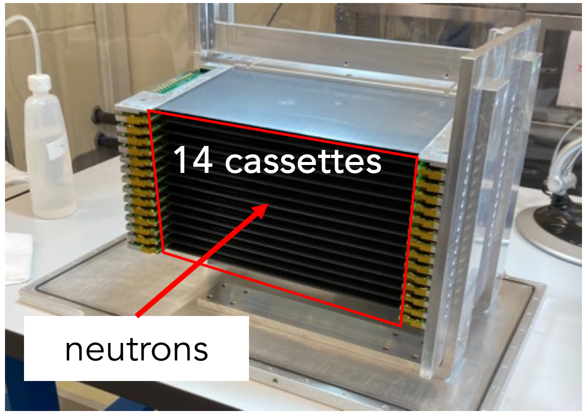


ESS readout chain

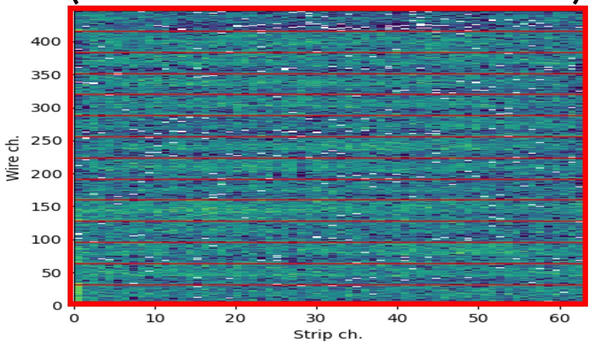


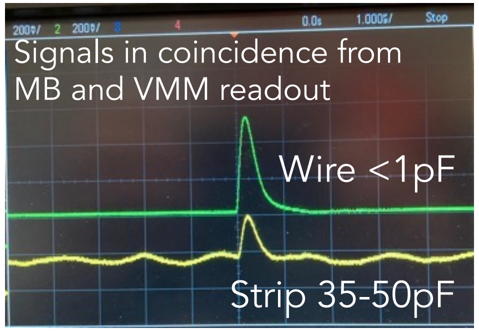


Commissioning @ Utgard with muons

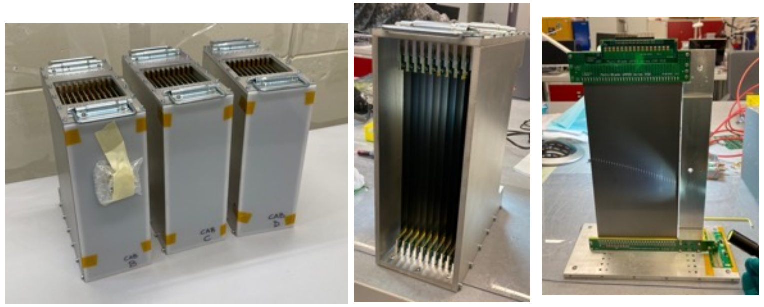


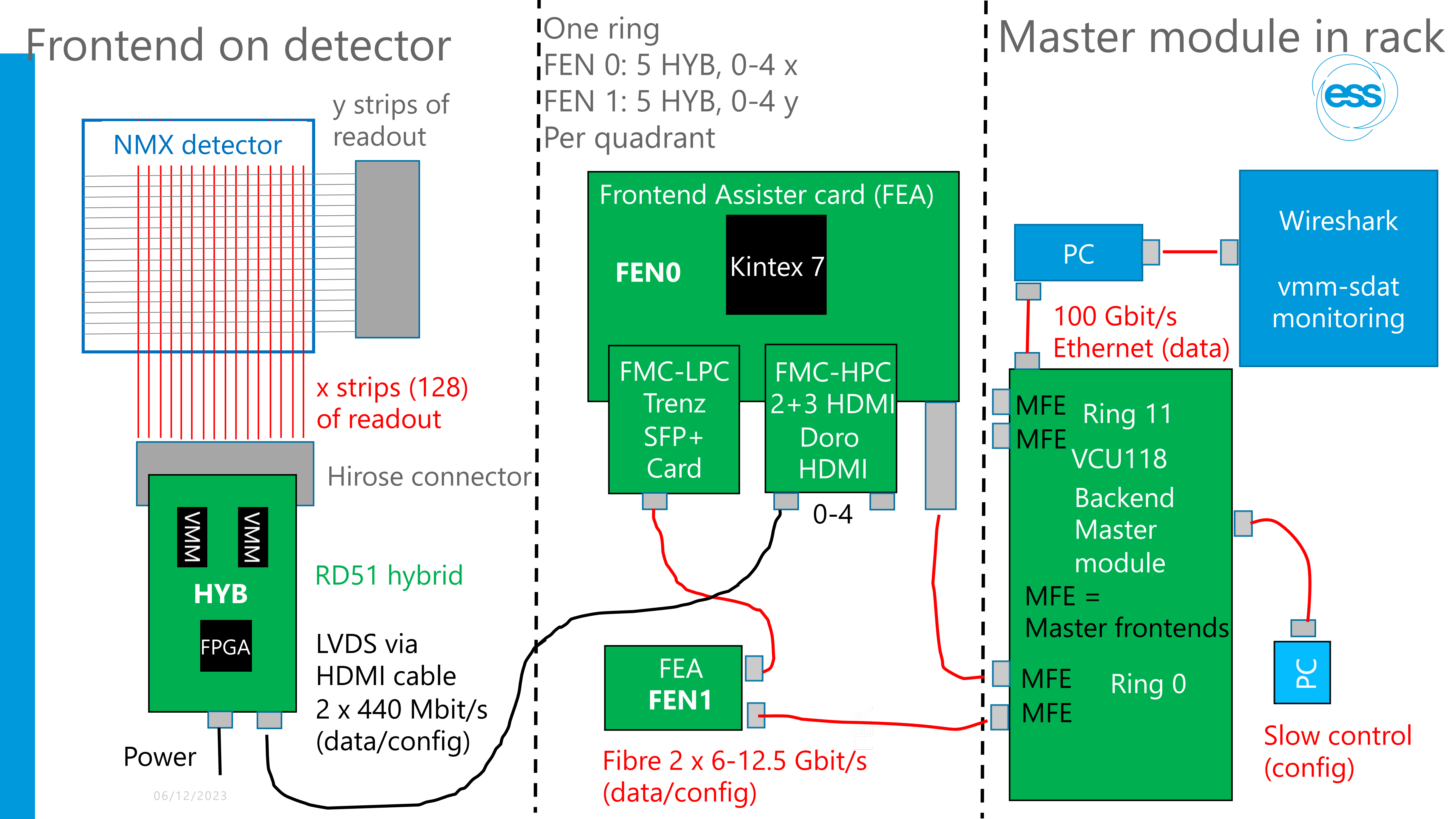
2D image of the detector
(14 cassettes - 1344 channels)





140 Blades assembled and ready for ESTIA, FREIA, TBL and AMOR
Stored @ Utgard




Frontend on detector
One ring
FEN 0: 5 HYB, 0-4 x
FEN 1: 5 HYB, 0-4 y
Per quadrant
Master module in rack
ess
NMX detector
y strips of readout
x strips (128) of readout
Hirose connector
VMM
VMM
HYB
FPGA
RD51 hybrid
LVDS via HDMI cable 2 x 440 Mbit/s (data/config)
Power
Frontend Assister card (FEA)
FEN0
Kintex 7
FMC-LPC Trenz SFP+ Card
FMC-HPC 2+3 HDMI Doro HDMI
0-4
FEA
FEN1
Fibre 2 x 6-12.5 Gbit/s (data/config)
PC
Wireshark
vmm-sdat monitoring
100 Gbit/s Ethernet (data)
MFE
MFE
Ring 11
VCU118
Backend Master module
MFE = Master frontends
MFE
MFE
Ring 0
PC
Slow control (config)
06/12/2023

System Overview

HDMI

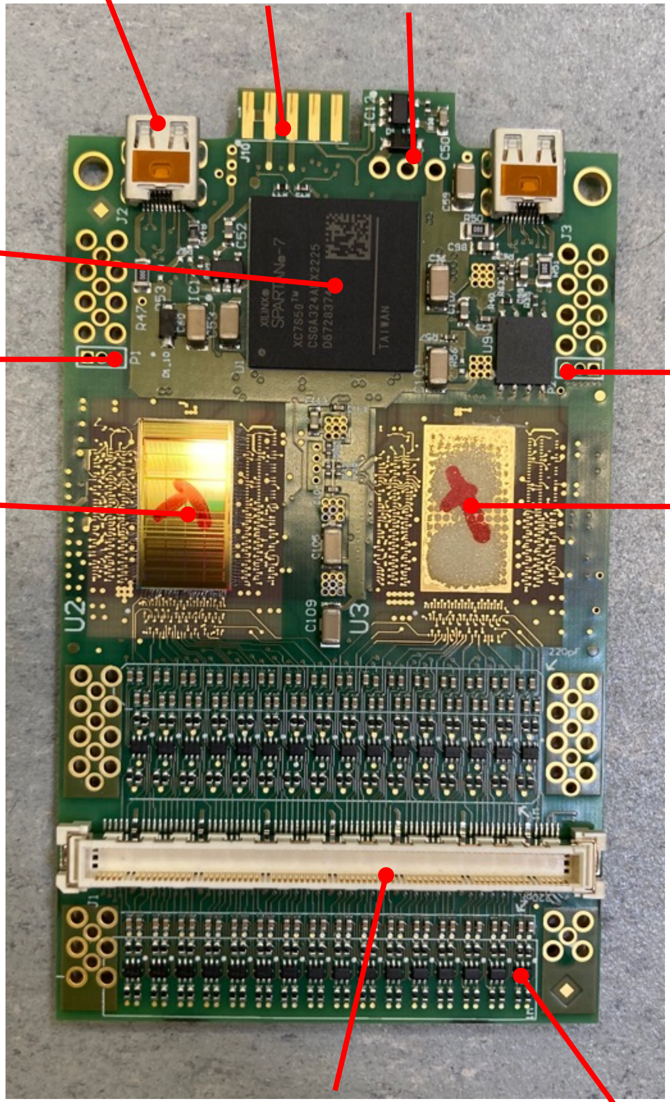
JTAG

PWR

FPGA

MO
VMM0

VMM0
(64ch)



CONNECTOR
128ch

Protection circuit
TVS = NUP4114

Dimensions 80 mm x 50 mm

PWR 2A @ 2V and 200mA @3.3V

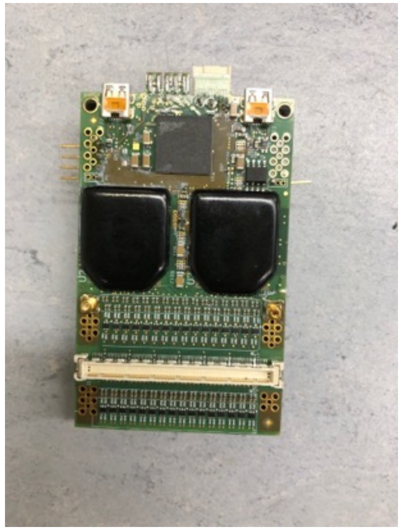
Ch can be + or – polarity
(common per VMM)

Adjustable gain

MO
VMM1

Monitor Output -> can be used to see analgue pulses
of each channel, one at the time

VMM 1 (64ch)



INTERNAL PULSER
Ch can be injected interanlly with a porgrammable pulser amplitude and a C = 300fF

Not enough for wire chambers we added an extra layer

- 130 nm CMOS technology
- 64 self triggered input channels
- Pos. & neg. polarity sensitive
- Digital block w/ neighbouring logic, FIFO, multiplexer
- Gain 0.5 – 16 V/pC
- Shaping time from 25 ns – 200 ns
- Input capacitance from few pF – 1 nF
- Time resolution ~ 0.2 ns
- Max hit rate per channel 4 MHz
- 38 bit per hit (ch, time, charge)

VMM3a ASIC

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- 64 self triggered input channels
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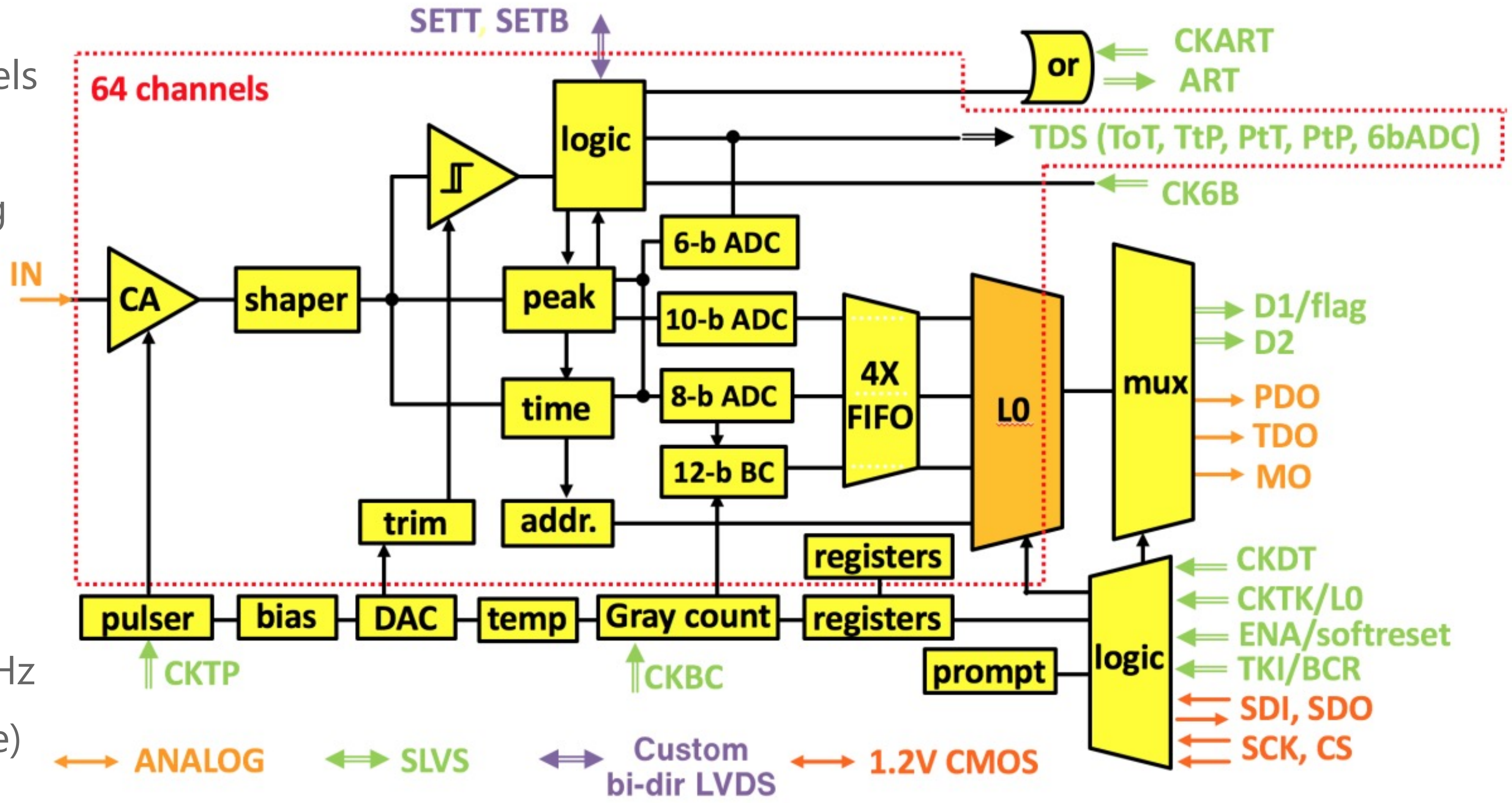

EUROPEAN
SPALLATION
SOURCE