DESIGN OF SiPM MASS TESTING SYSTEM

Arseny Rybnikov

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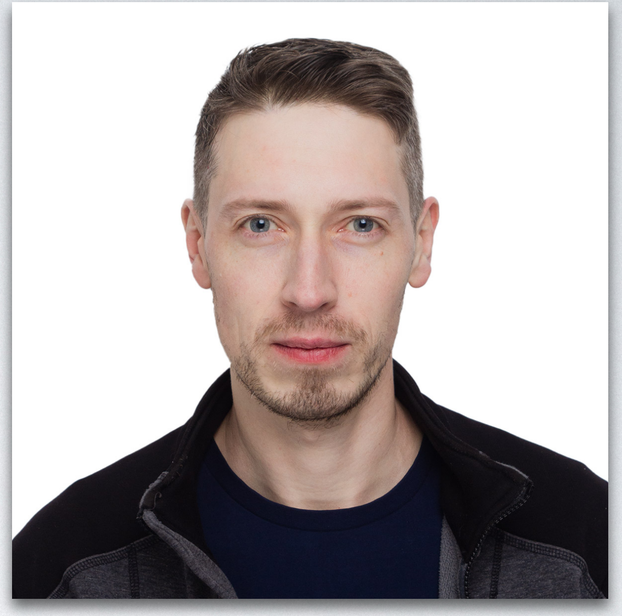
FINAL DESIGN REVIEW
06.07.2022

WHO AM I



Arseny Rybnikov

- Background in EM-calorimetry for COMPASS-II, PD and scintillator studying for COMPASS (CERN), Belle, NICA (JINR), 20-inches PMT scanning and testing for JUNO (China), SiPM testing for TAO (China).
- Scientific researcher of the Sector of Experimental Methods, Experimental Department of Particle Physics, Dzhelepov Laboratory of Nuclear Problems, Joint Institute for Nuclear Research
- Start working since 2012

OUTLINE

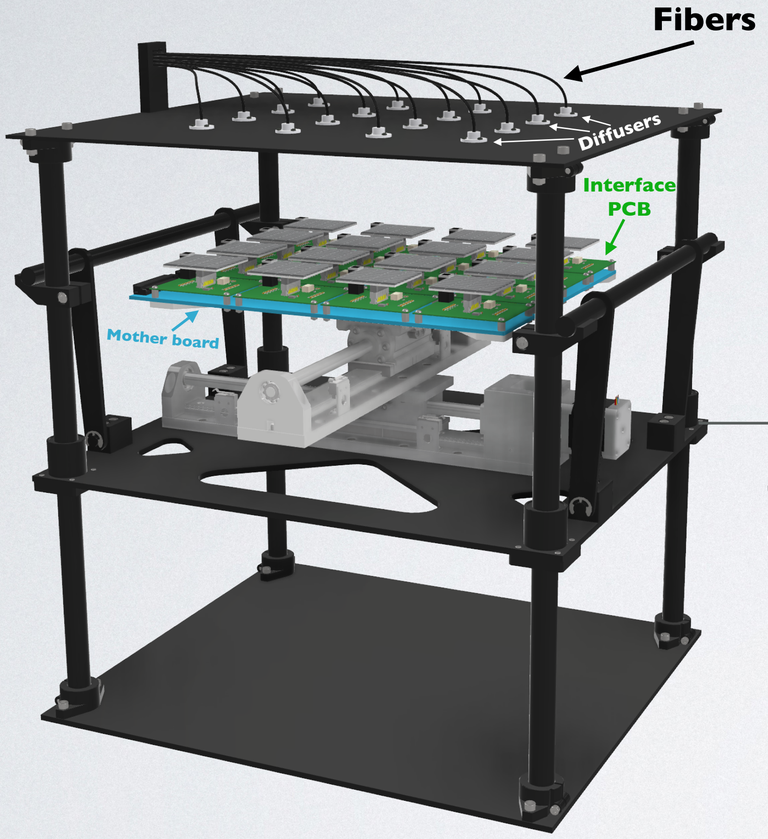
- **Part I: Design of the measurement stand**
  - Overview of mass testing stand
  - Measurement equipment
  - SiPM Power supply
  - Digitizer
  - Multifunctional control unit
  - Current-measurement equipment
  - Interface and Mother boards
  - Translation stage
  - Light delivery system
- **Part II: Overview of testing procedures**
  - Testing of SiPM Tiles
    - Pre-scan procedure
    - Charge and Current scan
  - Calibration of the light field
  - Timing of mass testing
- **Backup solutions**
- **Schedule and manpower**
- **References**
- **Summary**

PART I: DESIGN OF THE MEASUREMENT STAND

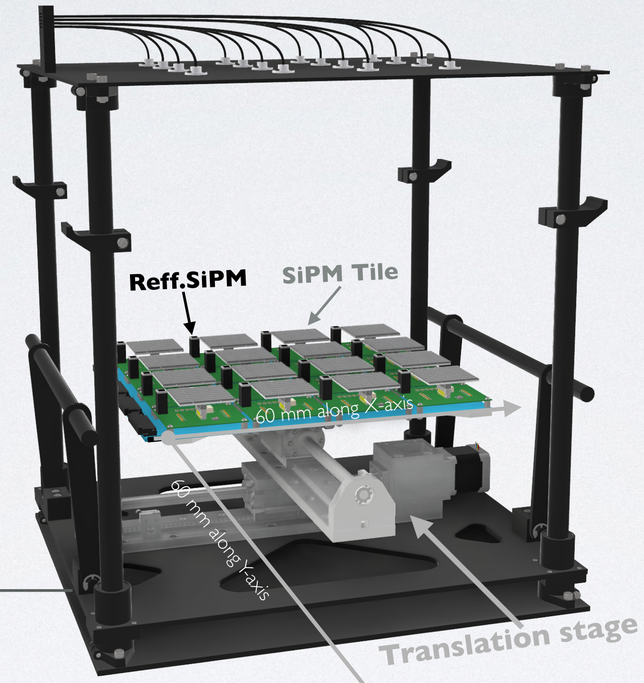
- Overview of mass testing stand
- Measurement equipment
- SiPM Power supply
- Digitizer
- Multifunctional control unit
- Current-measurement equipment
- Interface and Mother boards
- Translation stage
- Light delivery system

MASS TESTING STAND OVERVIEW (1)

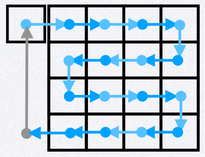
Working position



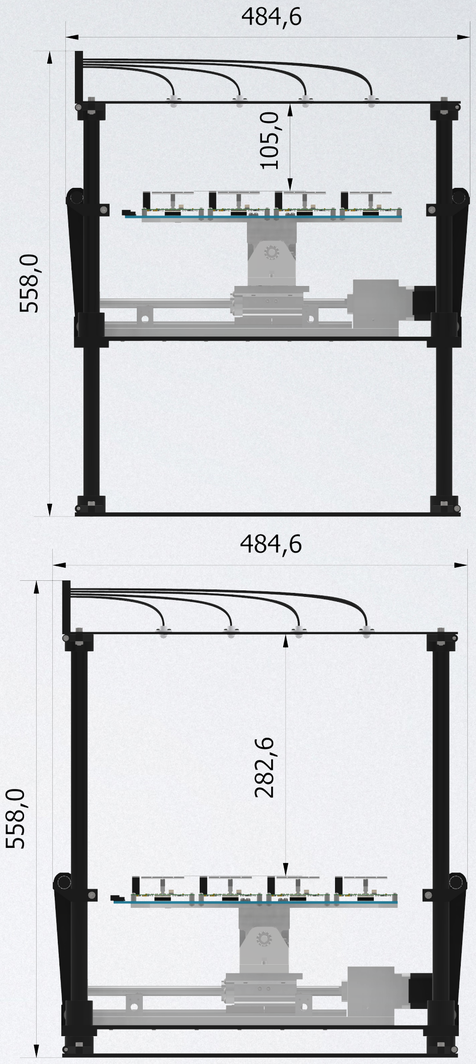
Service position



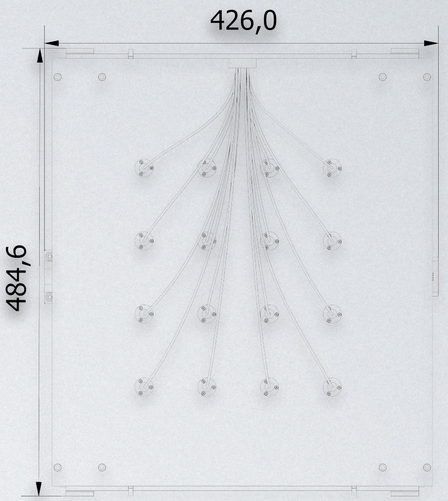
can be lifted up



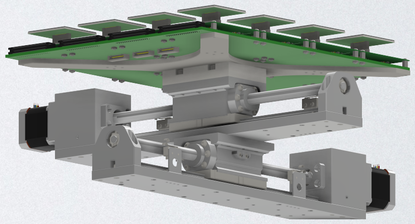
Free movement on two axes



Side view



Top view



Bottom view

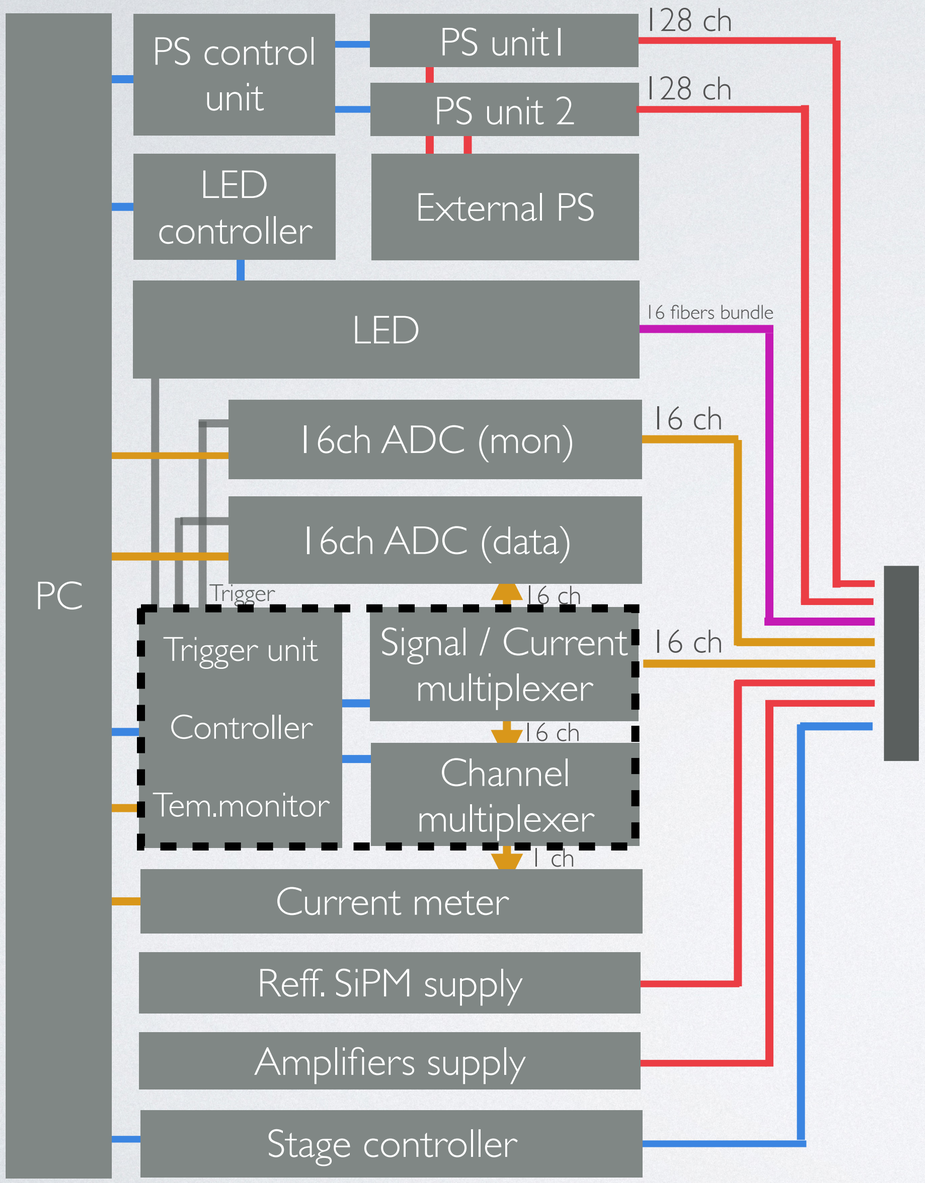
Dimensions of environmental chambers:

IHEP: 700mm (L) x 800mm (W) x 900mm (H) - main

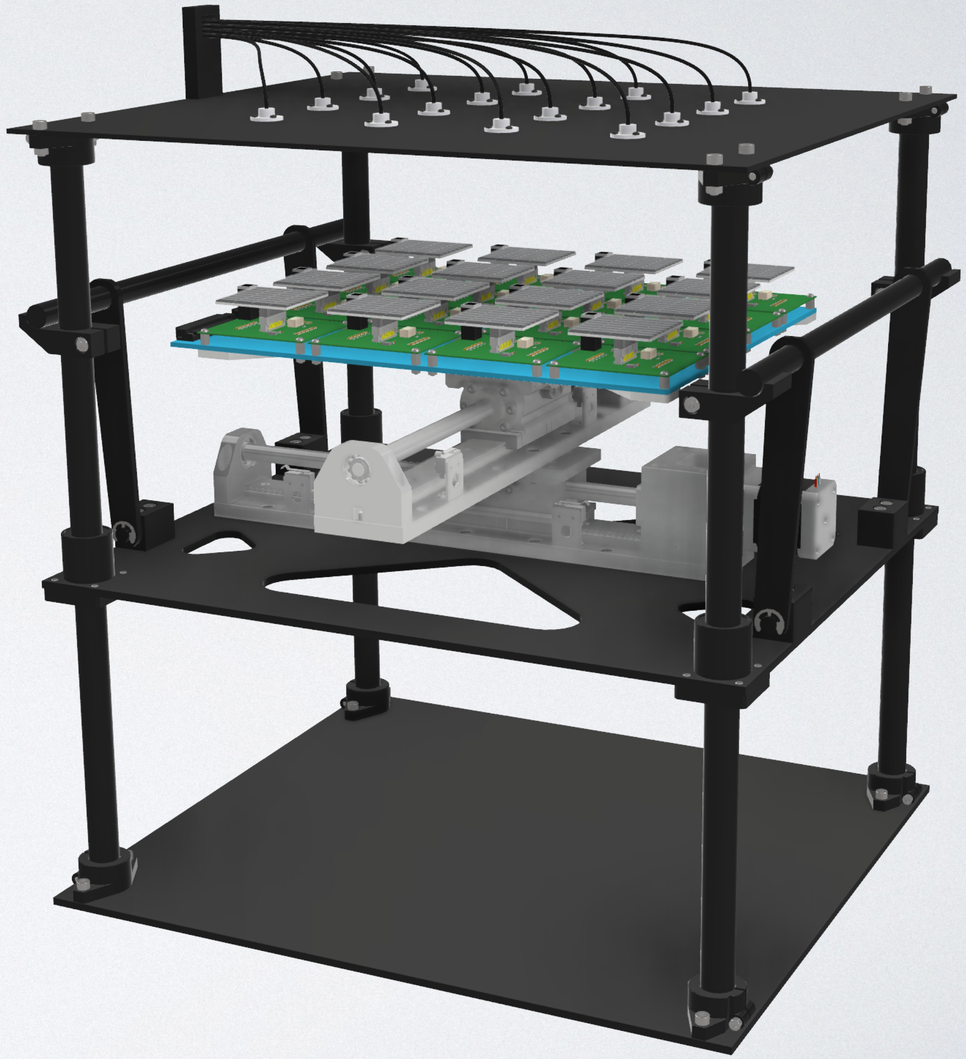
JINR: 500mm (L) x 600mm (W) x 600mm (H) - Reff.

Catania: 600mm (L) x 801mm (W) x 694mm (H)

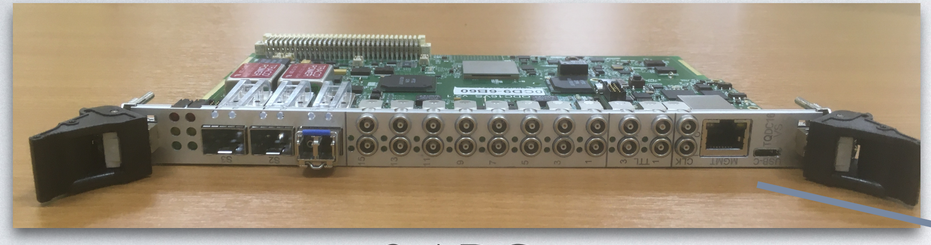
MASS TESTING STAND OVERVIEW (2)



Environmental chamber

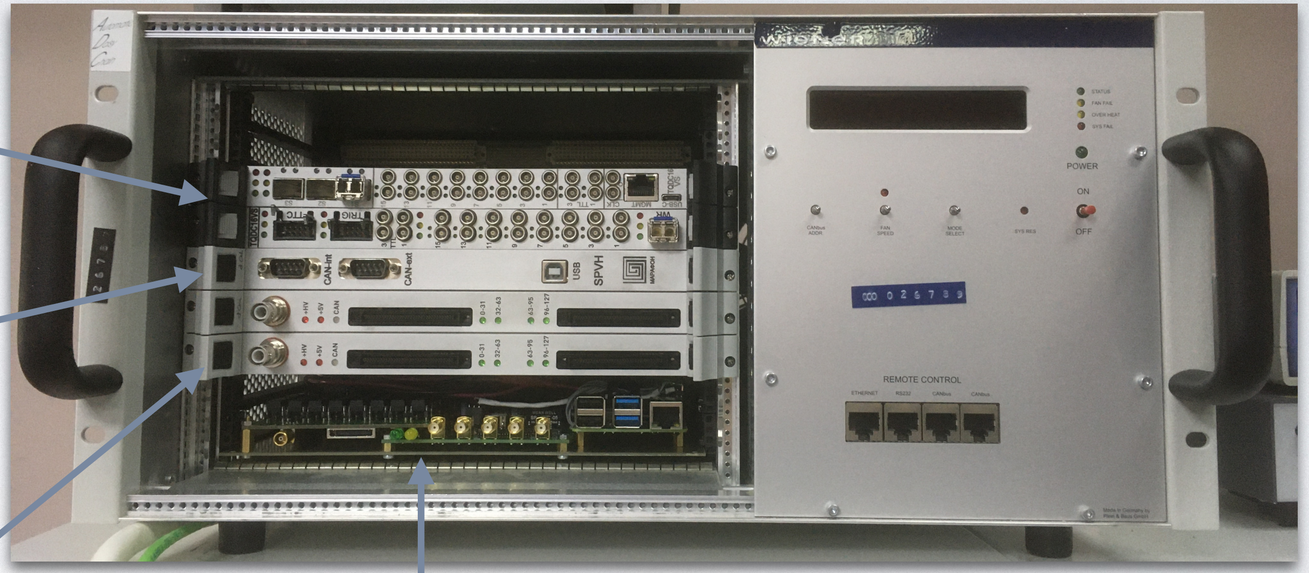


MEASURING EQUIPMENT

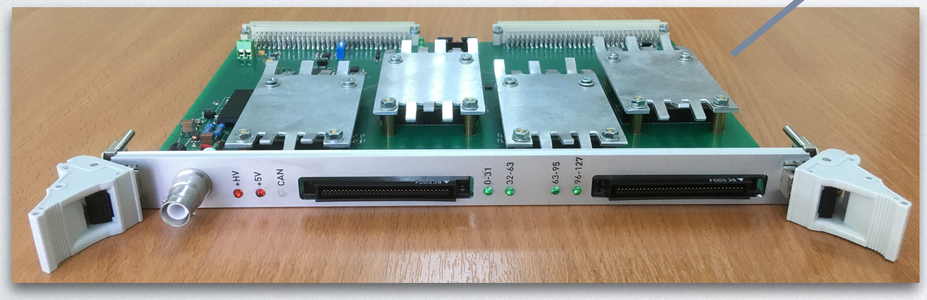


2 ADCs

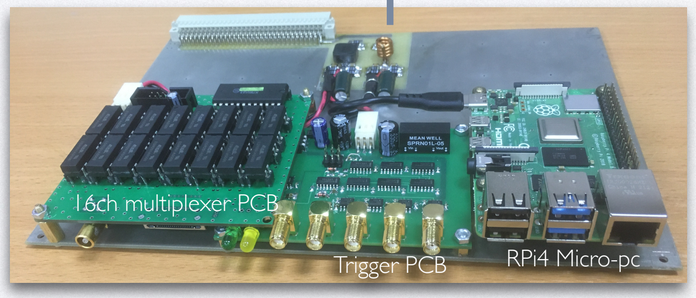
Wiener VME Crate



PS Control Unit



2 Power supply Units



Trigger-Temperature-Current Unit

Current meter

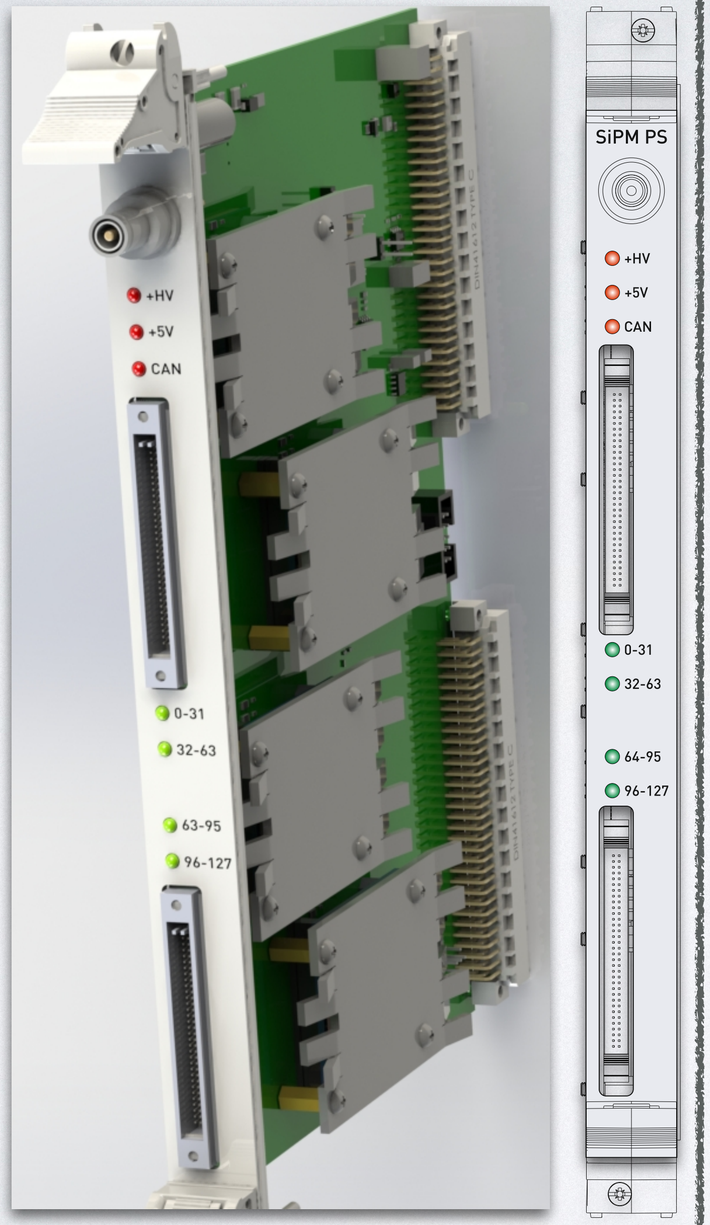
LED

LED controller

POWER SUPPLY SYSTEM

Power unit

- VME mechanics
- 128 channels
- up to 200V/ch
- up to 550uA/ch
- 1xSHV connector
- 2x 68pin IDC connectors
- Output voltage monitor (24bit ADC)
- 4x 14bit DAC chips
- CANOpen protocol



Tested

Control unit

- VME mechanics
- Built in CAN-BUS controller
- Communication with Power units via SPI interface on the back plane connectors
- Power from PC

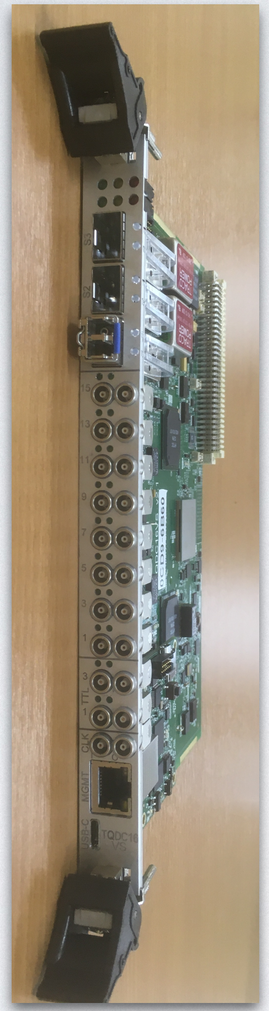
Tested

DAQ SYSTEM

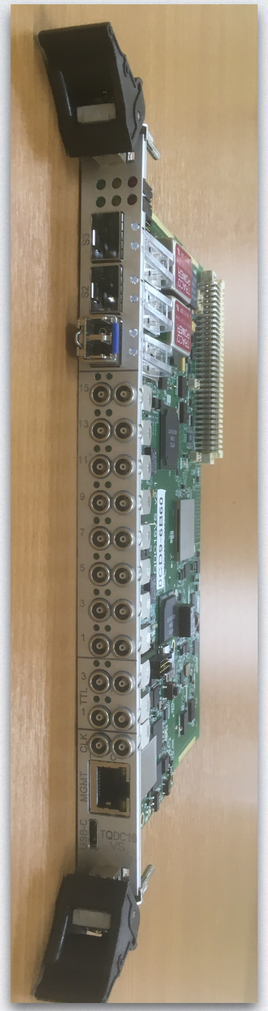
VME crate

JINR ADC

- 16 channels
- 125 MHz
- 14 bit / 2 V
- 16us window
- 10 GB optical link



Data ADC

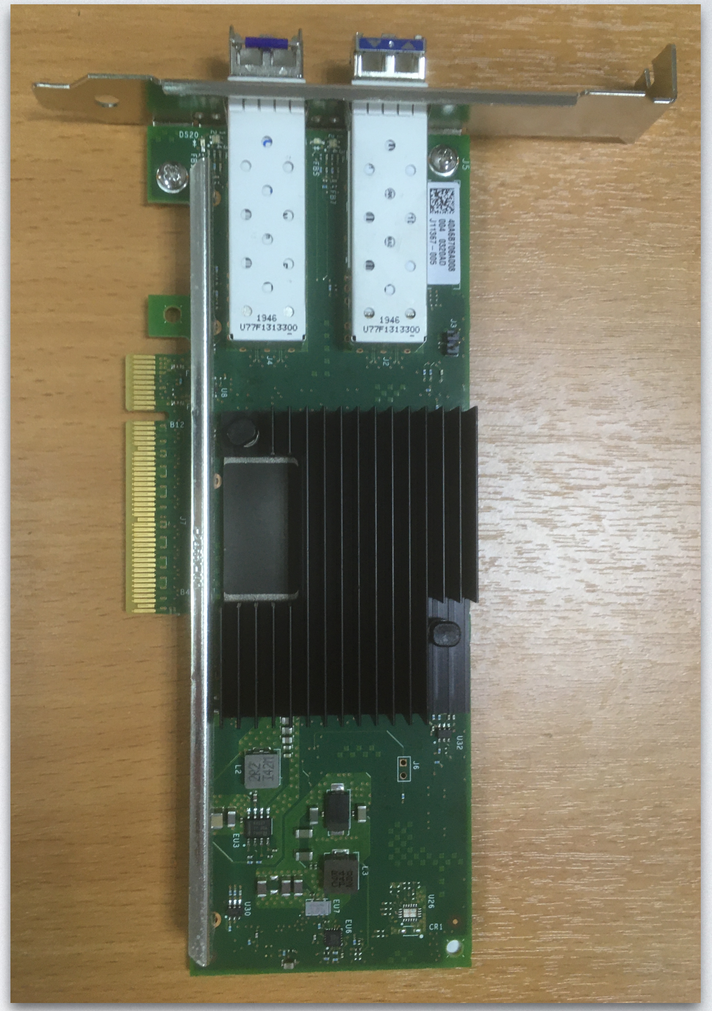


Monitor ADC

connection via optical link

Tested

PC

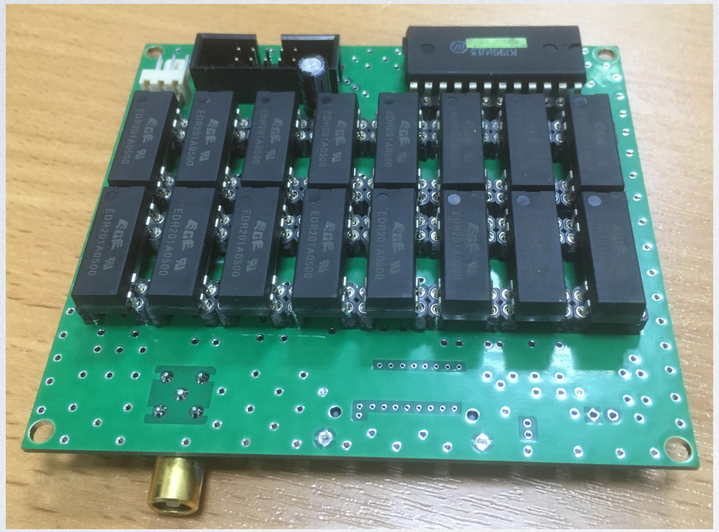


Optical PCI express Ethernet controller

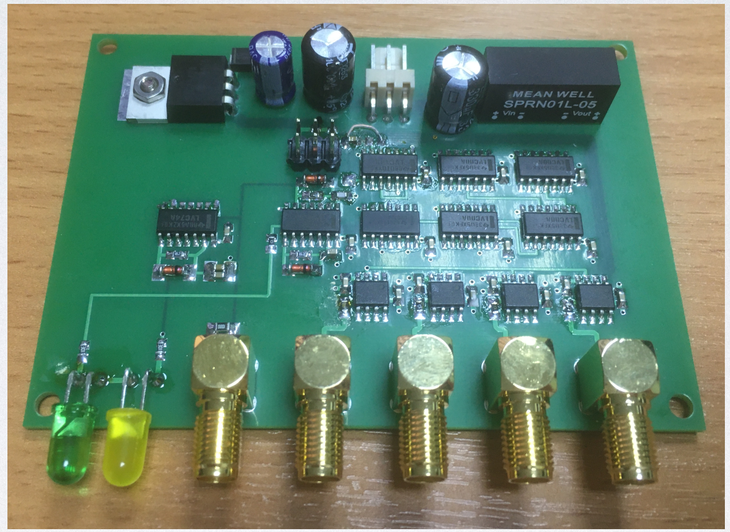
MULTIFUNCTIONAL CONTROL UNIT

Trigger-Temperature-Current unit (MultiC)

VME 6U form factor

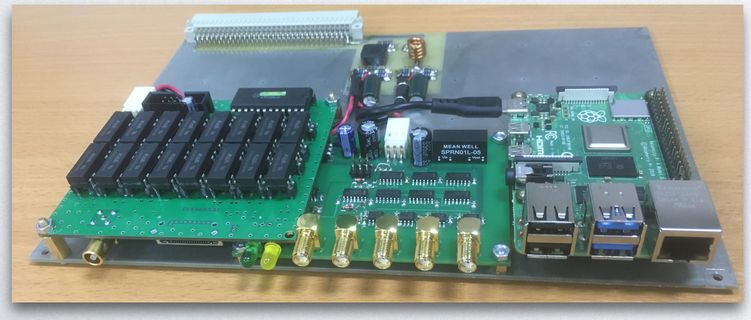


16ch Current Multiplexer



Trigger PCB

Raspberry Pi MicroPC



VME 6U form factor

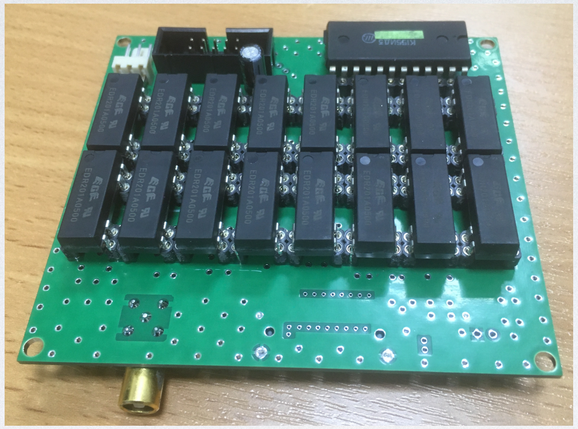
Functionality:

- switching btw channels to measure the dark current of SiPMs
- synchronisation of the Light system and Digitizers
- temperature monitoring (16 Temp.sensors)

Tested

CURRENT MEASUREMENT EQUIPMENT

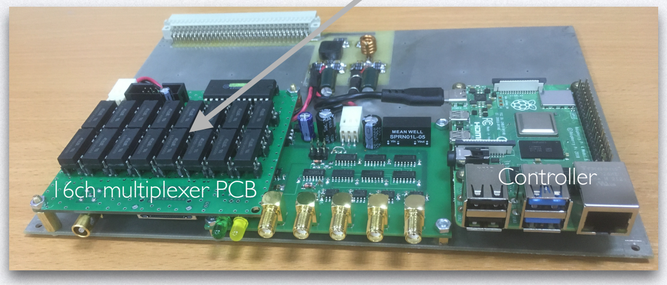
16 SiPM Tiles



16ch multiplexer PCB

Keithley 6487 picoammeter

PC



Integrated to
Trigger-Temperature-Current
VME unit

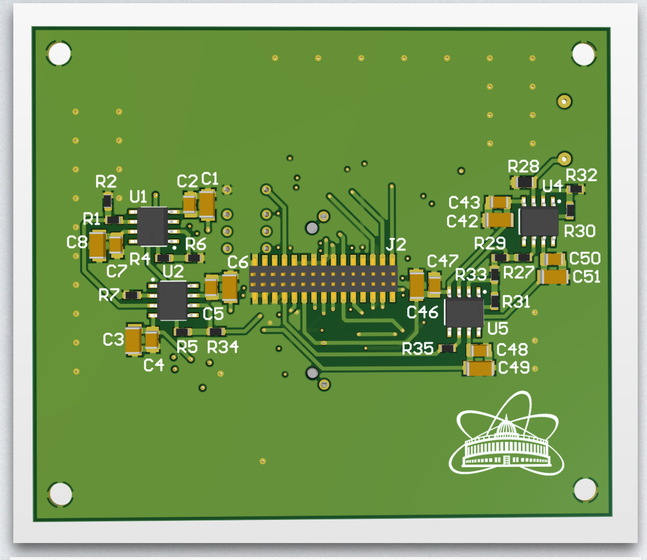
Sequential measurements of each SiPM on each tile in a single voltage point

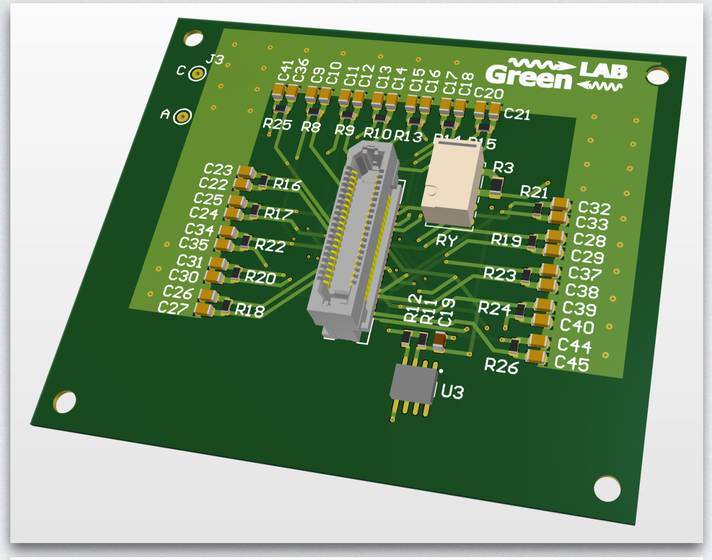
1. Bias 1st SiPMs on each Tile
2. Measure the current of each SiPM by switching multiplexer (~30s)
3. Turn off 1st SiPMs on each Tile
4. Repeat these steps for the next group of SiPMs (2 ÷ 16th)

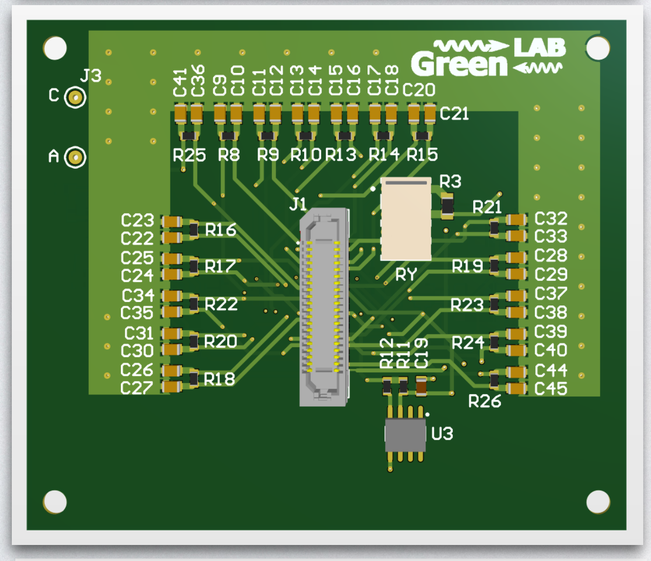
Measurement time: <10min/voltage point

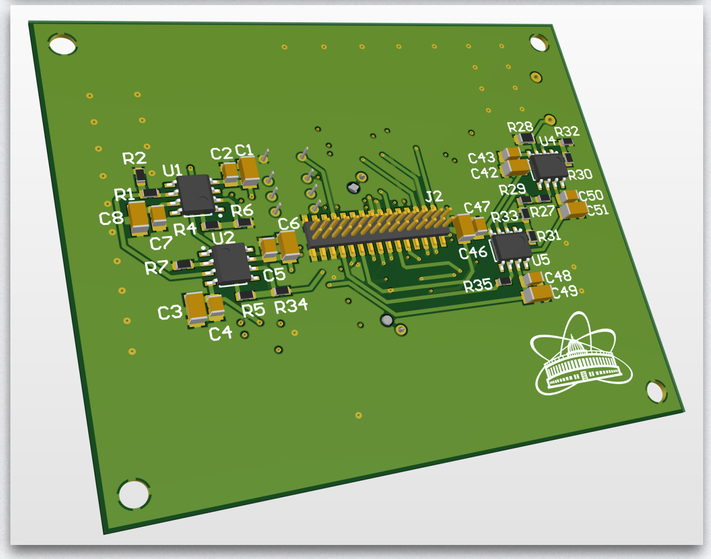
Tested

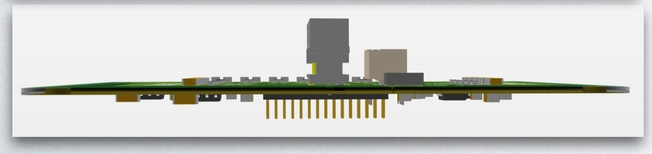
INTERFACE AND MOTHER BOARDS



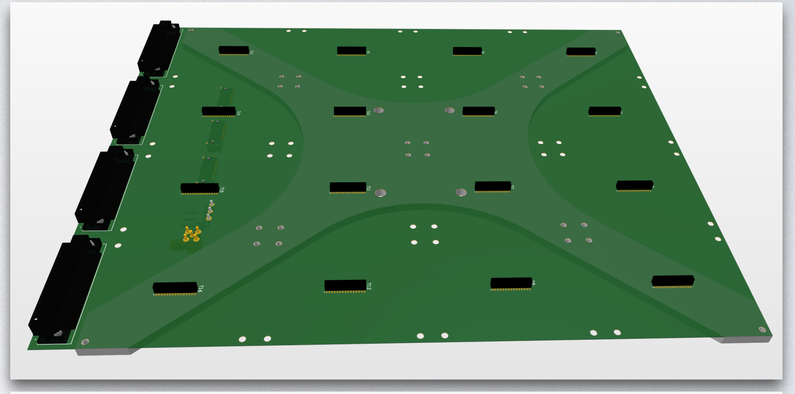


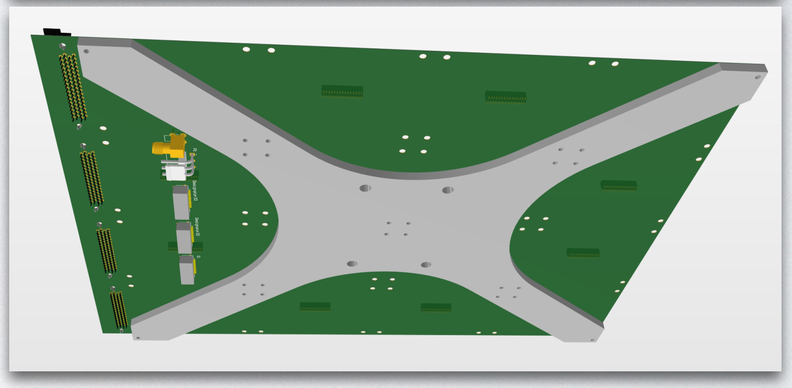




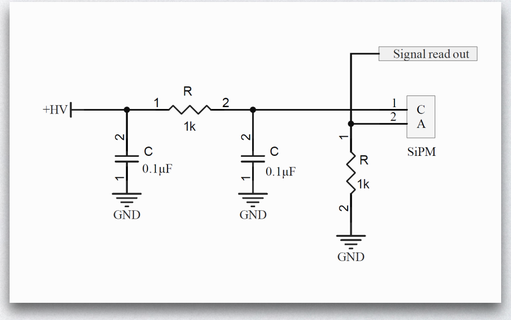


Interface board



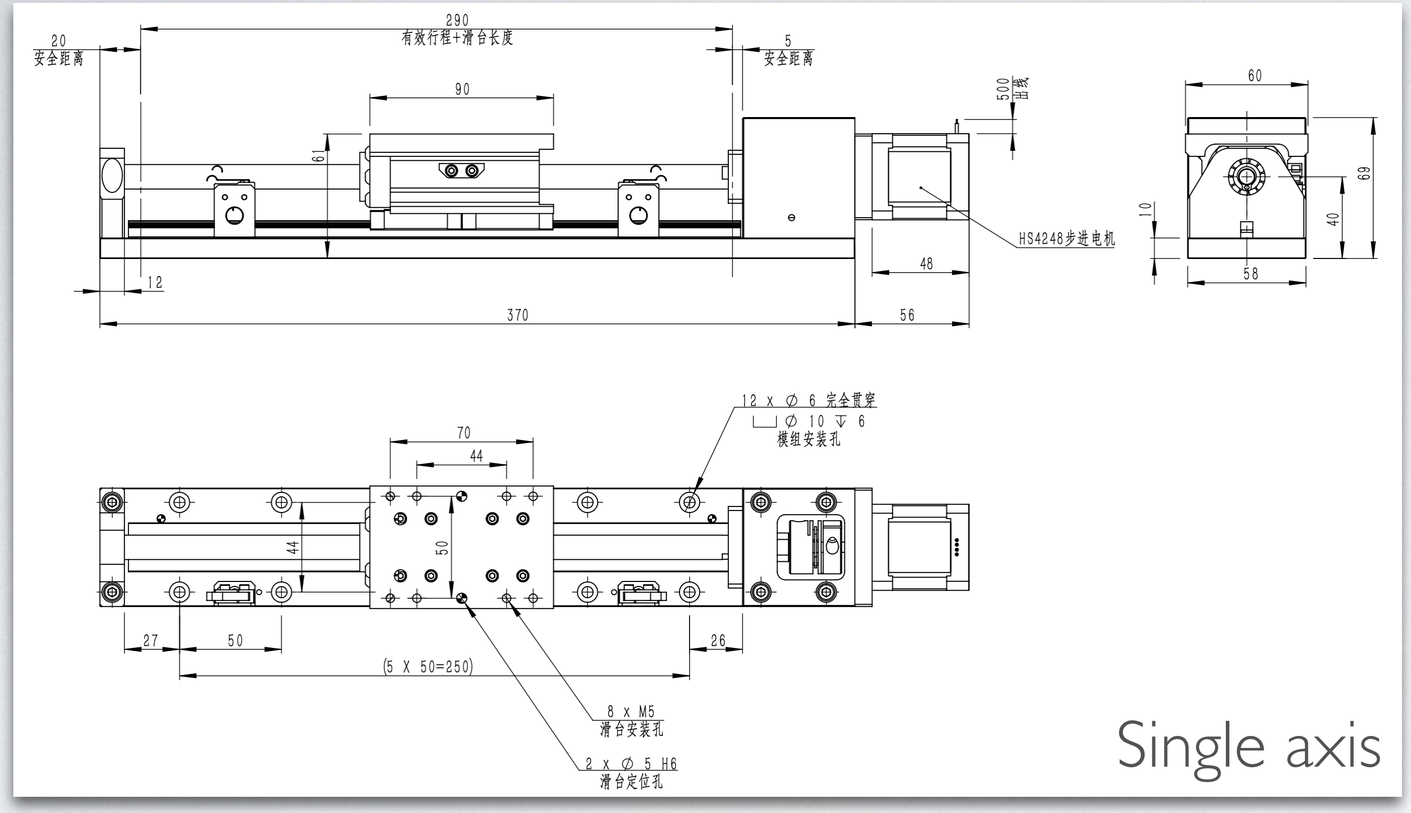


View of mother board

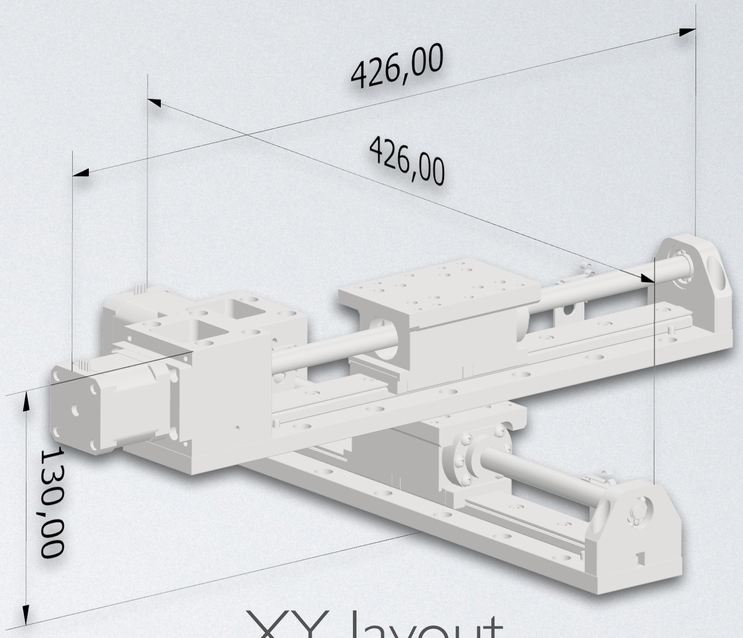


Channel readout scheme

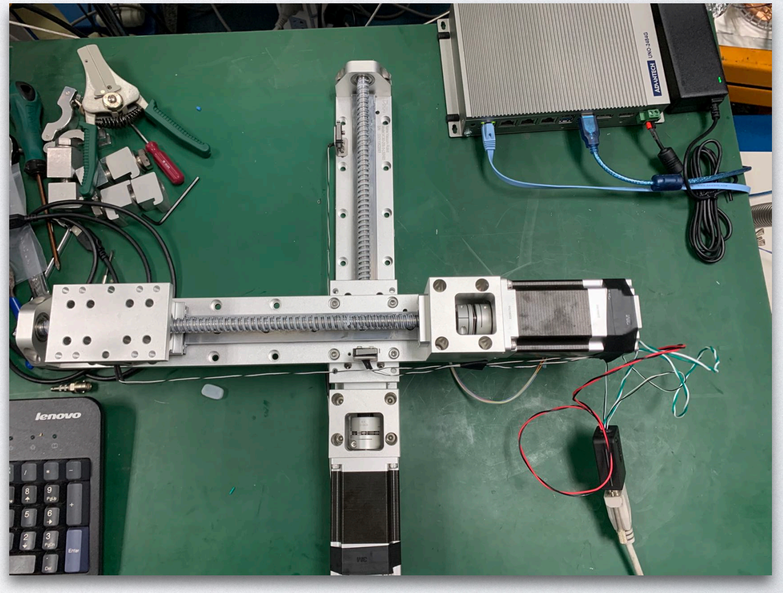
TRANSLATION STAGE



Single axis



XY layout

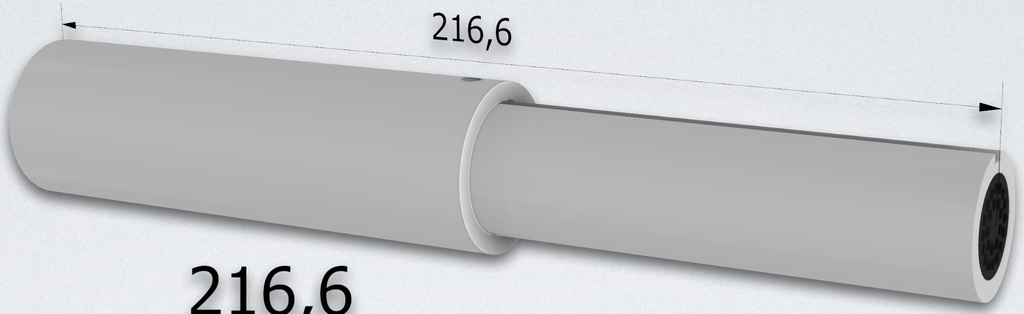


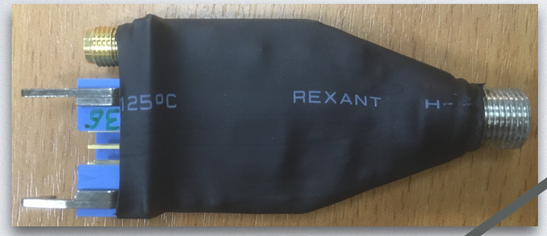
List of parameters:

Parameter	Value
Travel range:	200 mm
Max speed:	5 mm/sec
Operation temp.:	-50 ÷ +85 C
Weight:	3 kg

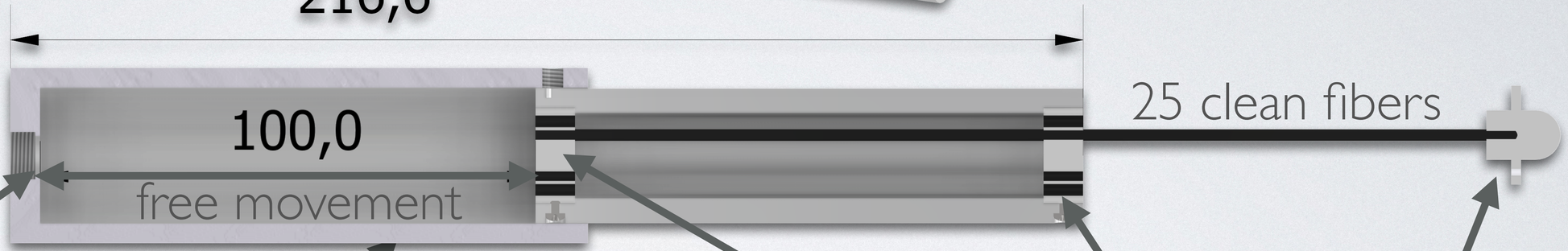
LIGHT DISTRIBUTION SYSTEM (1)

LED controller





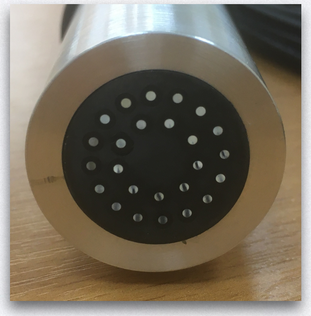
LED

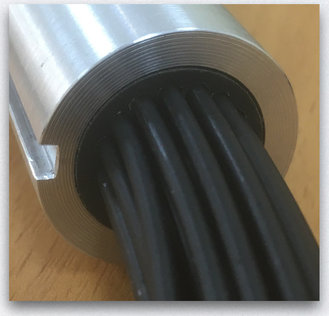


Attenuator-
Diffuser
PTFE/0.5 mm

Main tube

Tested



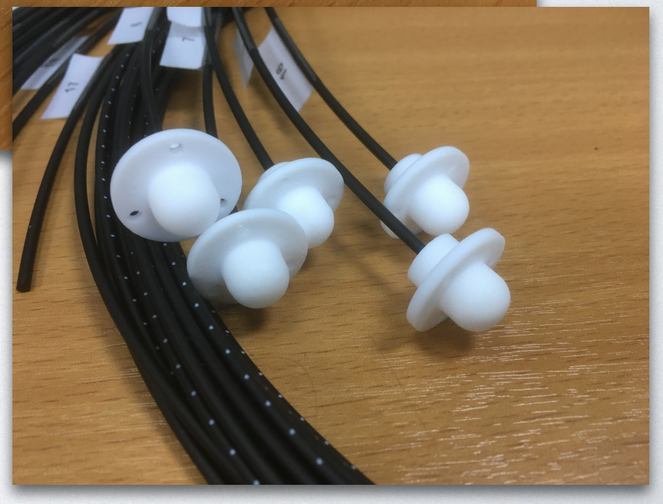


Fiber's holder

16 main fibers
9 spare fibers

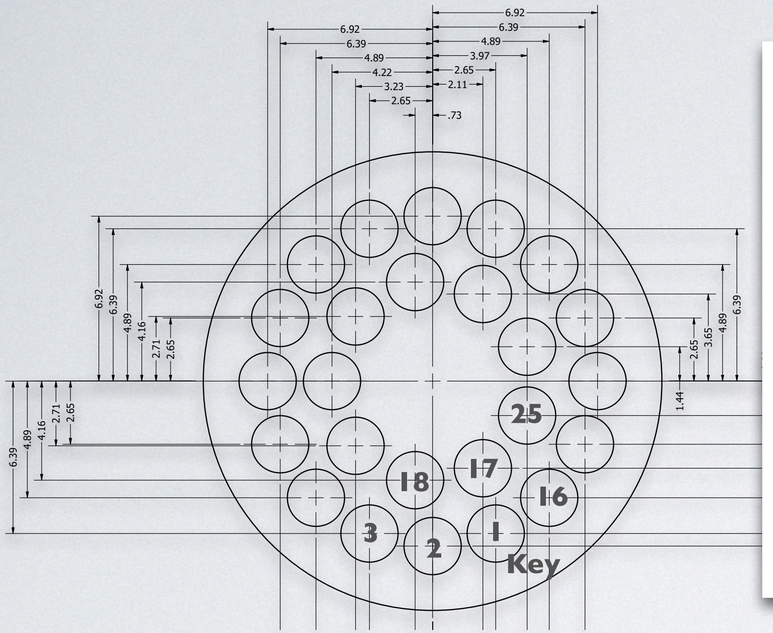
each fiber
ends with the
diffuser

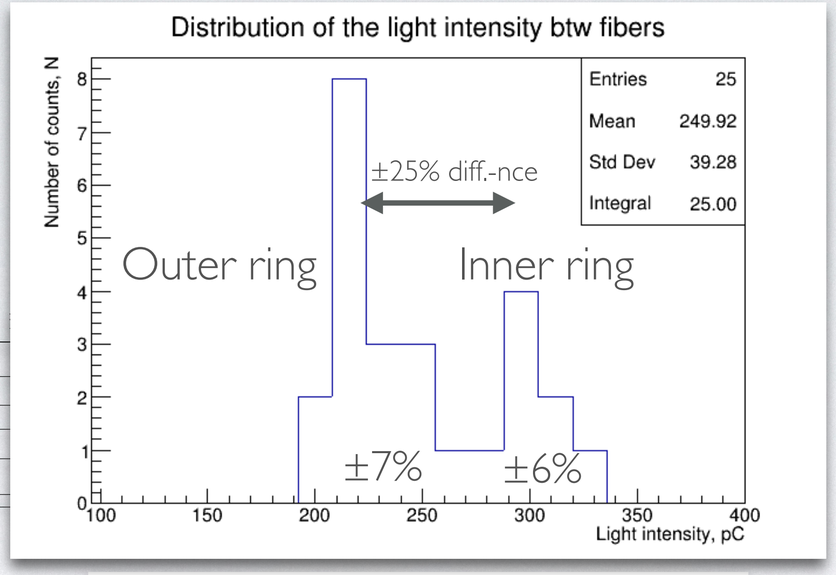
LIGHT DISTRIBUTION SYSTEM (2)

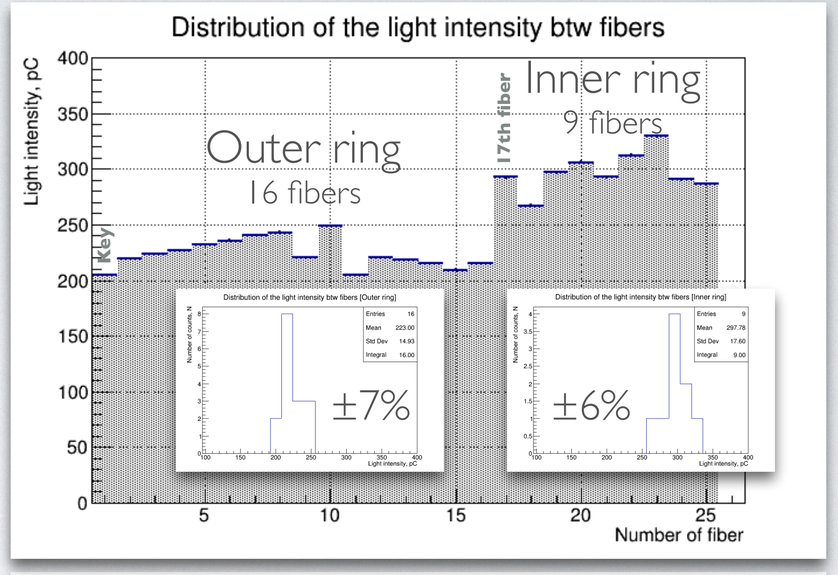


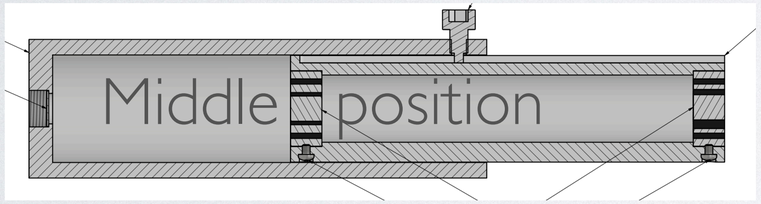
LIGHT DISTRIBUTION SYSTEM (3)

Fibers

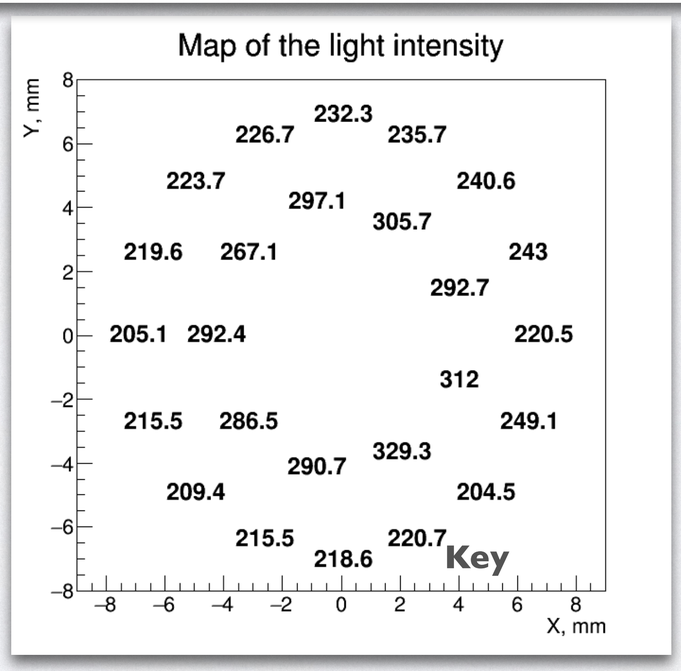


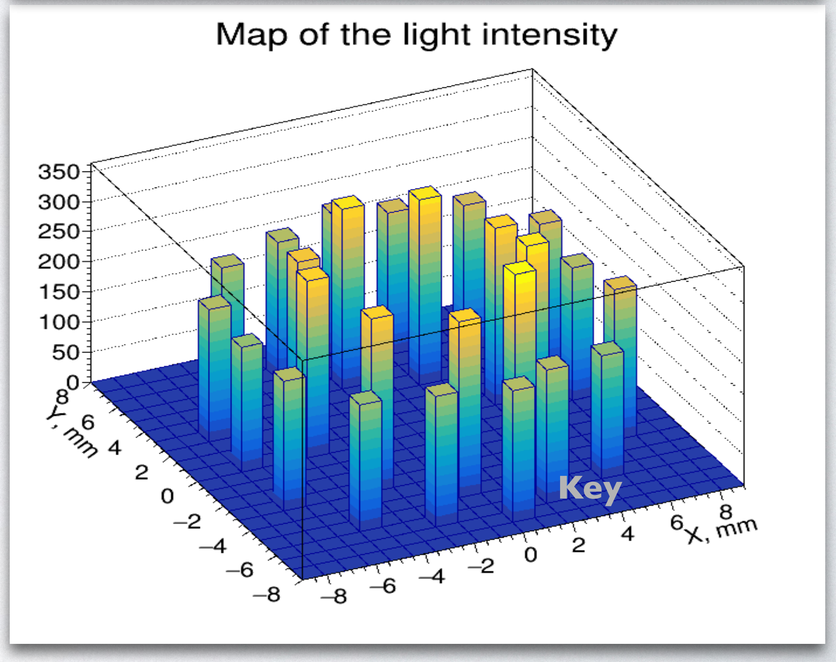






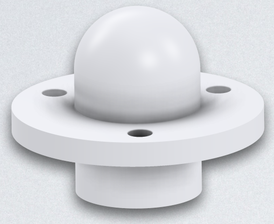
Attenuator-
Diffuser
PTFE/0.5 mm





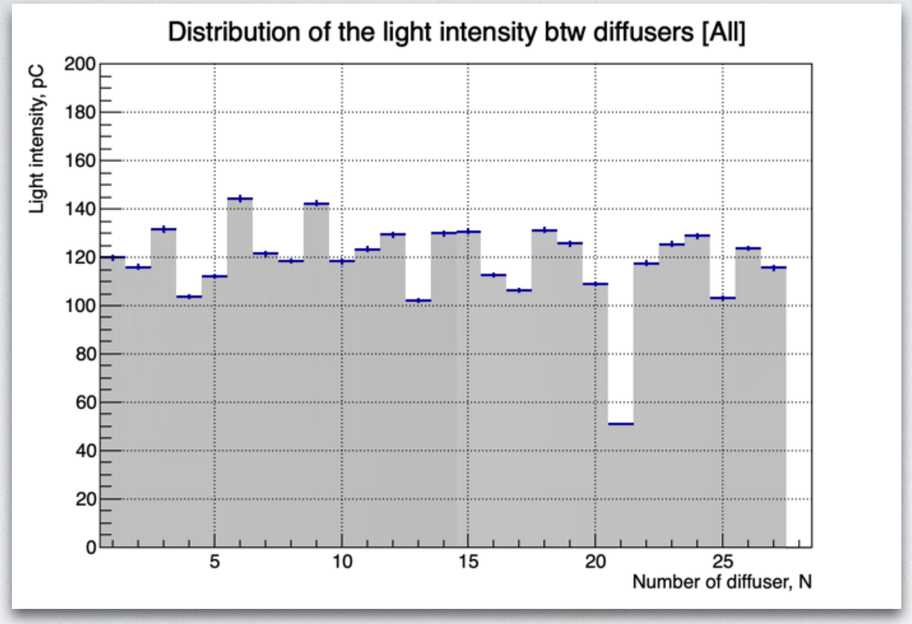
LIGHT DISTRIBUTION SYSTEM (4)

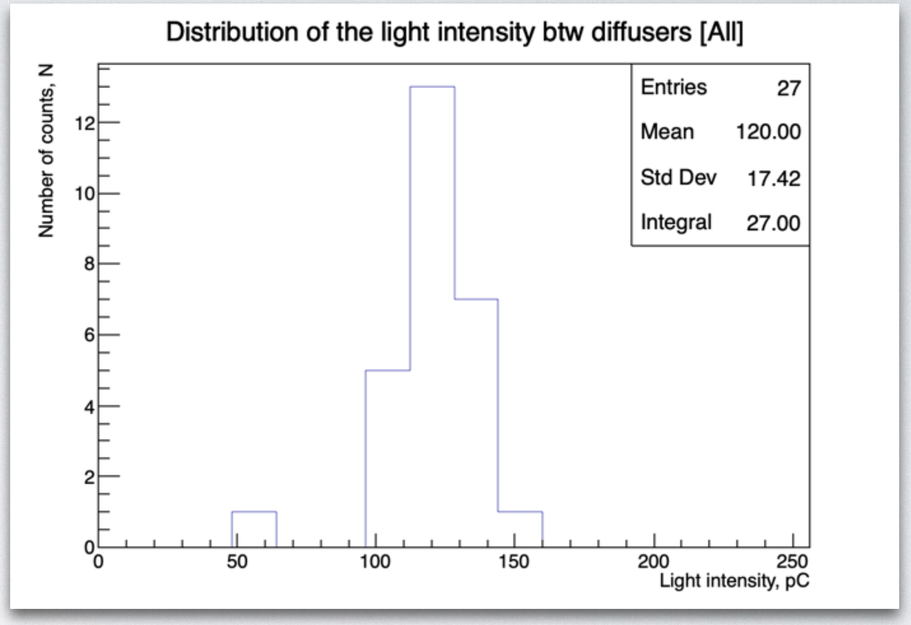
27x



The last 7 diffusers have scratches and inhomogeneous surface of the hemisphere

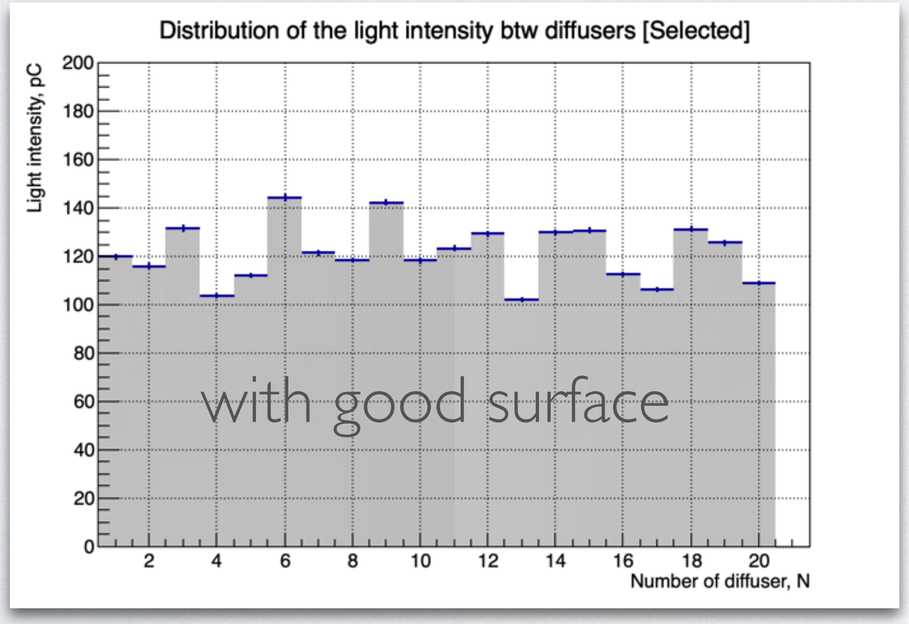
20x

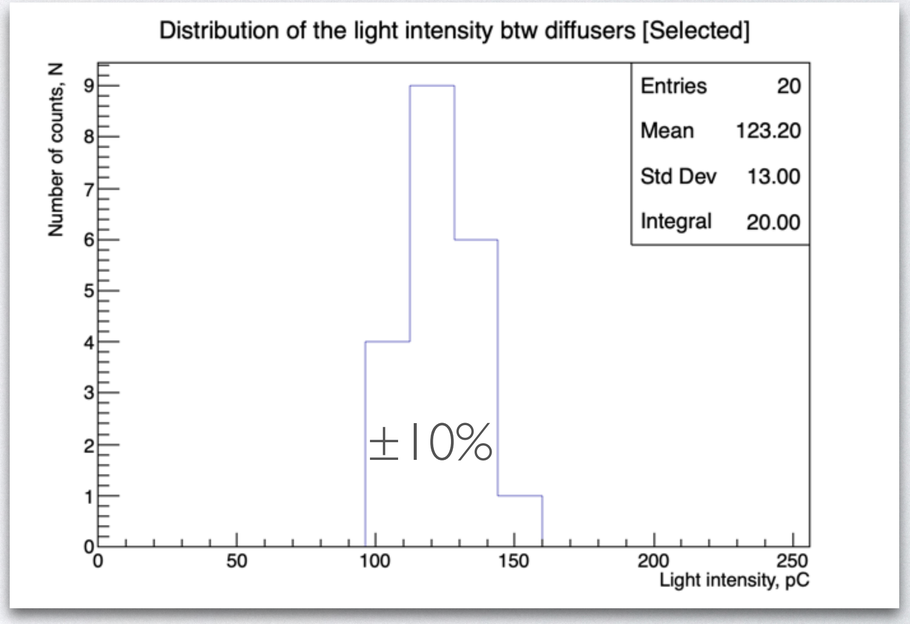




Number of diffusers

All 27 pcs

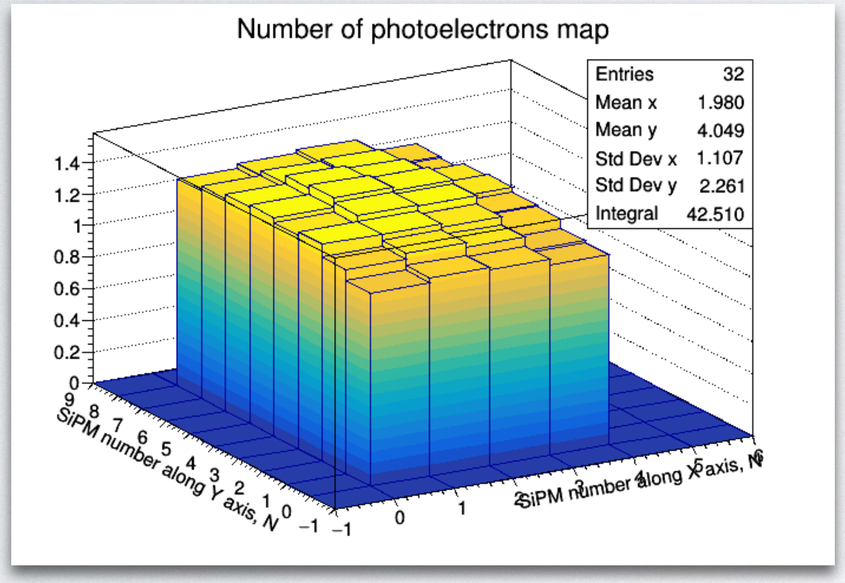


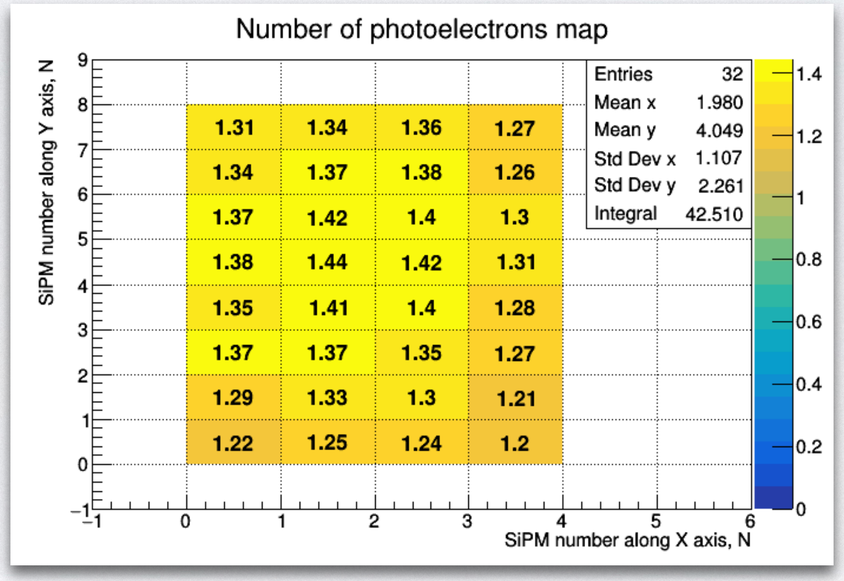


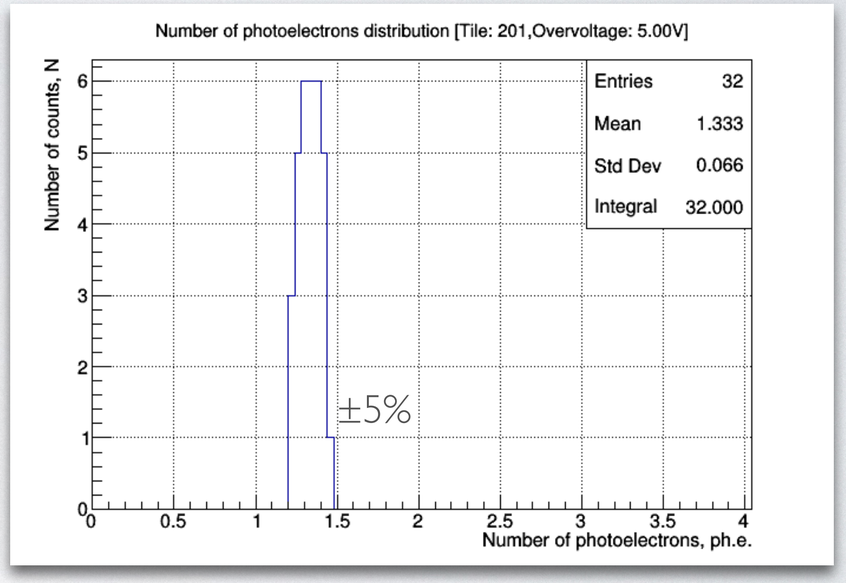
Selected only 20 pcs

LIGHT DISTRIBUTION SYSTEM (5)

LED → Light splitter → First fiber → First diffuser → HPK SiPM tile





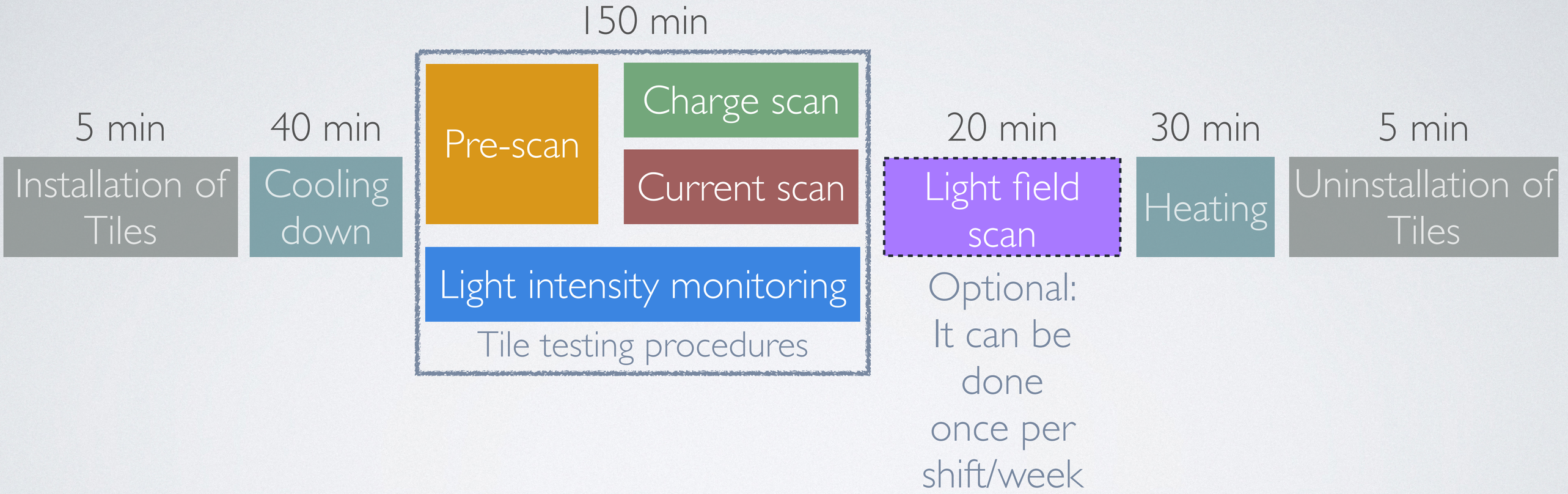


Tested

PART II: TESTING PROCEDURES

- Overview of testing procedures
- Testing of SiPM Tiles
  - Pre-scan procedure
  - Charge and Current scan
- Calibration of the light field
- Timing of mass testing

OVERVIEW OF TESTING PROCEDURES



PRE-SCAN PROCEDURE

During **Pre-scan**

150 min

10 min | 140 min

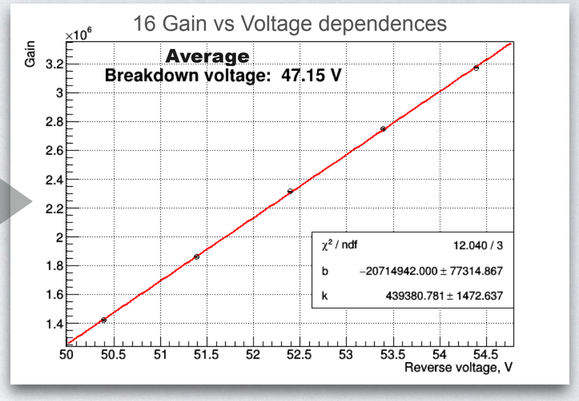
Pre-scan | Charge scan | Current scan

Light intensity monitoring

Tile testing procedures

Run 01	Run 02	…	Run 06
HV **+2V**	HV **+3V**		HV **+7V**
Tile 01 All SiPMs HV On	Tile 01 All SiPMs HV On	…	Tile 01 All SiPMs HV On
⋮	⋮		⋮
Tile 16 All SiPMs HV On	Tile 16 All SiPMs HV On		Tile 16 All SiPMs HV On
LED On	LED On		LED On
ADC Data Run	ADC Data Run	…	ADC Data Run
ADC Mon. Run	ADC Mon. Run	in parallel	ADC Mon. Run

Scan over voltage (time line)



Result:

Pre-estimation of average breakdown voltage for each Tile

CHARGE-CURRENT SCAN PROCEDURE

During **Charge&Current scan**

OV Point 01 … OV Point 06

HV **+2V** … HV **+7V**

Run 01 | Run 02 | … | Run 16

Tile #01 **1st** SiPM is biased … Tile #01 **16th** SiPM is biased

Tile #16 **1st** SiPM is biased … Tile #16 **16th** SiPM is biased

Scan over SiPMs on the Tile

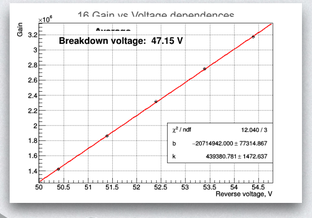
LED On / LED Off

ADC Data Run / Current meter Meas.

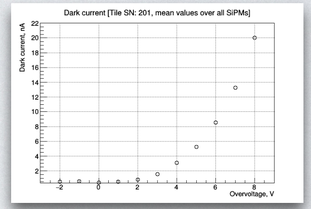
ADC Mon. Run (in parallel)

Scan over voltage&SiPM (time line)

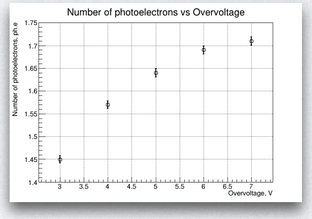
For each SiPM on each Tile



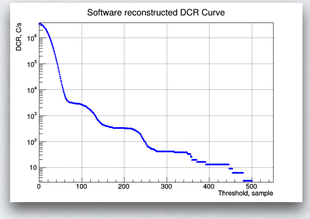
GAIN, V_{BD}



Dark current



PDE



DCR

Result:

Estimation of PDE, GAIN, V_{BD}, DCR, Dark current and their distributions

CALIBRATION OF THE LIGHT FIELD

During **Light field scan**

Position 00 (Home) | Position 01 | ... | Position 16 (64)

Run 01 | Run 16

correspondes to | correspondes to

Out of SiPMs | centre of the **1st** SiPM Tile #01 | ... | centre of the **16th** SiPM Tile #01

Out of SiPMs | centre of the **1st** SiPM Tile #16 | ... | centre of the **16th** SiPM Tile #16

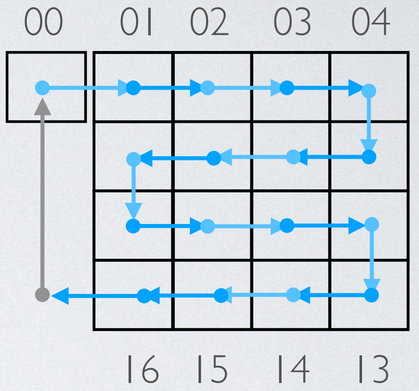
moving of all the Tiles at the same time

Reff. SiPMs are biased only

LED On

ADC Mon. Run | ADC Mon. Run | ... | ADC Mon. Run

Scan over SiPM location (time line)



Scanning map

TIMING OF MASS TESTING

Single scan

Procedure	Duration, minutes	Comments
Installation of tiles	5	16 Tiles
Cooling down	40	-
Pre-scan	10	5 diff. volt. points
Charge&Current scan	140	16 SiPMs x 5 diff. volt. points
Calibration of the light field scan	20 (optional)	16 points
Heating	30	-
Unistallation of tiles	5	16 Tiles
Total time:	3h 40min + 20 min	

Total time of mass testing:

4100 tiles / (16 tiles x 2 scans/day) ≈ 128 days

4100 tiles / (16 tiles x 3 scans/day) ≈ 86 days

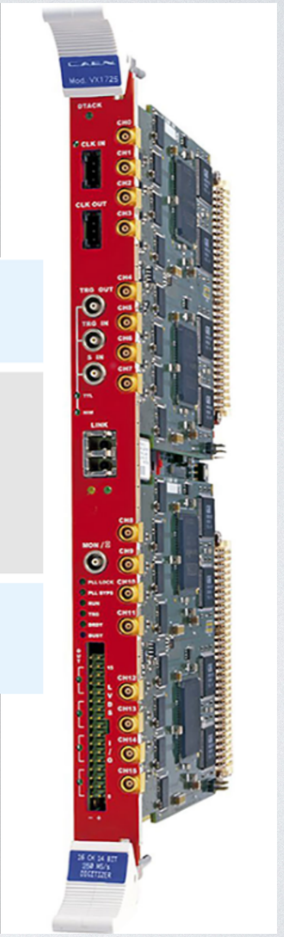
BACKUP SOLUTIONS

ALTERNATIVE DIGITIZER

CAEN Digit VX1725
16 chs; 125 MHz; 14 bit/2V; 16 µs windows 3 kEvents/s;

GENERAL	**Form Factor** 1-unit wide, 6U VME64X		
ANALOG INPUT	**Channels** 16/8 channels single ended	**Connector** MCX	**Bandwidth** 125 MHz
	Impedance 50 Ohm	**Full Scale Range** 0.5 or 2 Vpp (SW selectable)	**Offset** Programmable DAC for DC offset adjustment in the full scale range
DIGITAL CONVERSION	**Resolution** 14 bits	**Sampling Rate** 250 MS/s Simultaneously on each channel	

9600 € + VAT
90d after purchasing



ALTERNATIVE POWER SUPPLY

No. of Channels	48 (Common Floating Return)
Output Voltage	0 ÷ 100 V
Polarity	Positive / Negative depending on purchased version
Max. Output Current	1 mA
Voltage Set Resolution	2 mV
Voltage Monitor Resolution	0.2 mV
Current Set Resolution	20 nA
Current Monitor Resolution	2nA
VMAX hardware	0 ÷ 100 V common for all the board channels
VMAX hardware resolution	1 V
VMAX hardware accuracy	± 2% of FSR
VMAX software	0 ÷ 100 V settable for each channel
VMAX software resolution	1 V

CAEN A7040 PS
only 48 chs (instead 128 Marathon PS)

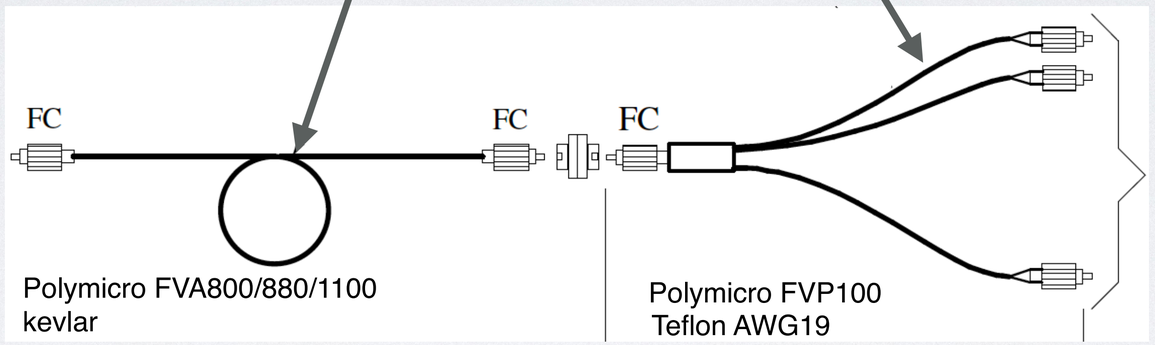
5140 € + VAT
90d after purchasing

LIGHT DISTRIBUTION SYSTEM

Inside the chamber

Outside the chamber

LED



20 output cable to end with diffuser

Alternative light distributions: same idea, different materials.
Materials choosen to work well up to -75 °C

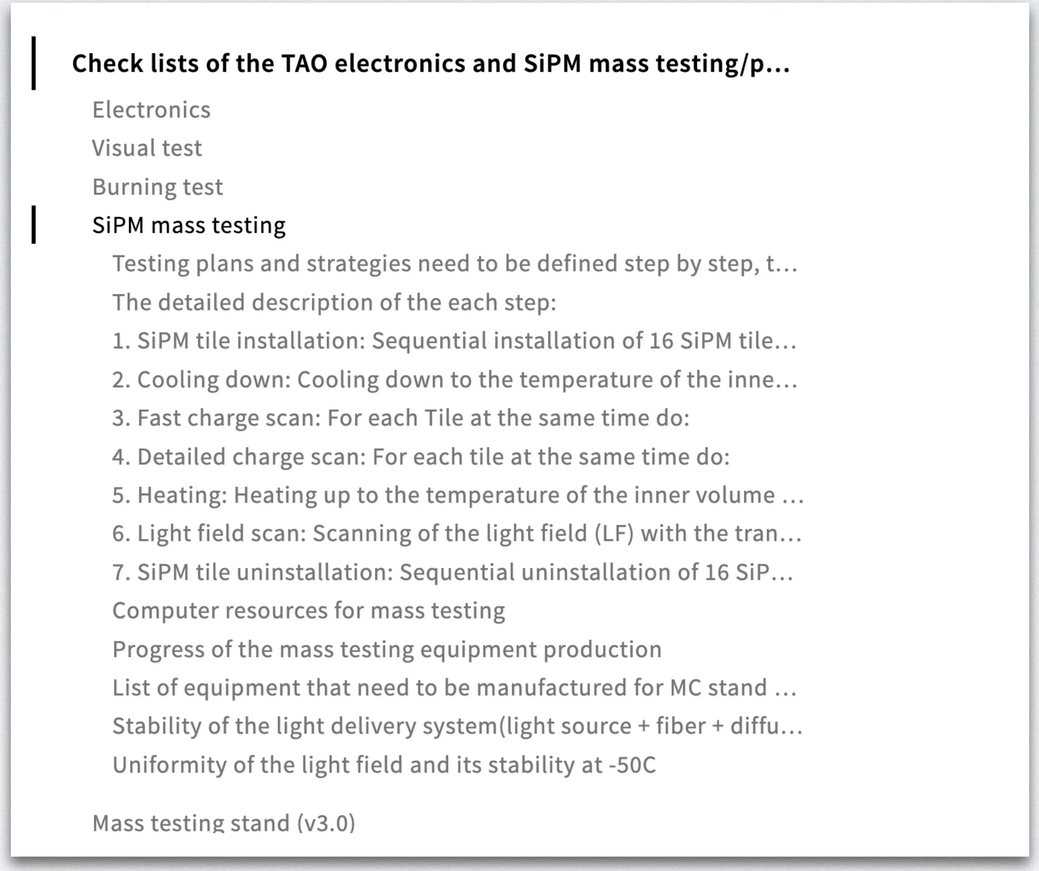
SCHEDULE AND MANPOWER

#	Person	Group	Remote availability	Onsite availability
1	Arseny Rybnikov	JINR	0.5 FTE expert	2 months
2	Alexei Chetverikov	JINR	0.25 FTE shifter	2 months
3	Vladislav Sharov	JINR	0.25 FTE shifter	1 months
4	Claudio Lombardo	Catania	0.5 FTE expert	2 months
5	Cristina Tuvè	Catania	0.25 FTE shifter	1 months
6	Post-doc #1	Catania	0.25 FTE shifter	1 months
7	Post-doc #2	Catania	0.25 FTE shifter	1 months
8	Student/Post-doc	IHEP	-	1.0 FTE shifter

REFERENCES

Jupyter check list

https://jupyter.ihep.ac.cn/nqICwsPGSACQzF54zDXWxA?view#sipm-mass-testing



BOM, drawings, gerbers, schematics of Mass testing measurement equipment:

https://disk.jinr.ru/index.php/s/Df2GqLmrdBcRgkH

SUMMARY

- Equipment maturity ~50%
  - Existing components: PS boards, ADCs, Light system, Current system, Trigger unit
  - Missing components: mechanics, interface and mother PCBs
- Software maturity ~70%
  - ADC SW no CLI, PS SW no CANOpen support, Analysis SW no WF analysis
- Export restrictions from Russia
  - Partial production in China
- Total cost: ~60k$ (Onsite)
- Semi-clean room, gloves, ESD protection, wearing