MPD TPC ASSEMBLING STATUS (10.09.2024)

TPC:

- vessel assembly, ROC chambers, gating grid system

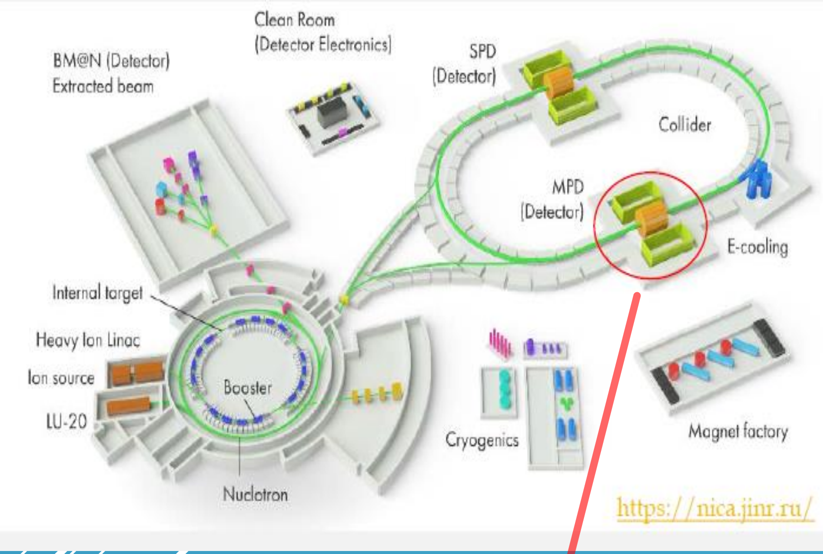
Sub-systems:

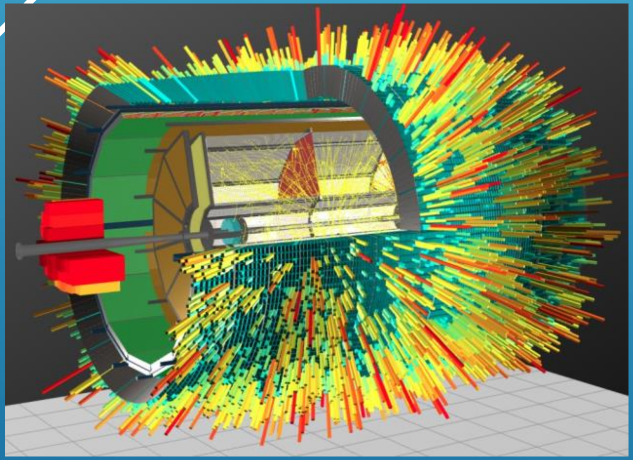
- Electronics
- LV+HV system (CAEN)
- Gas and cooling systems
- Laser calibration system
- Slow control

Integration TPC to MPD

- Electronics platform
- Cabling and piping
- Installation TPC to MPD

Time schedule

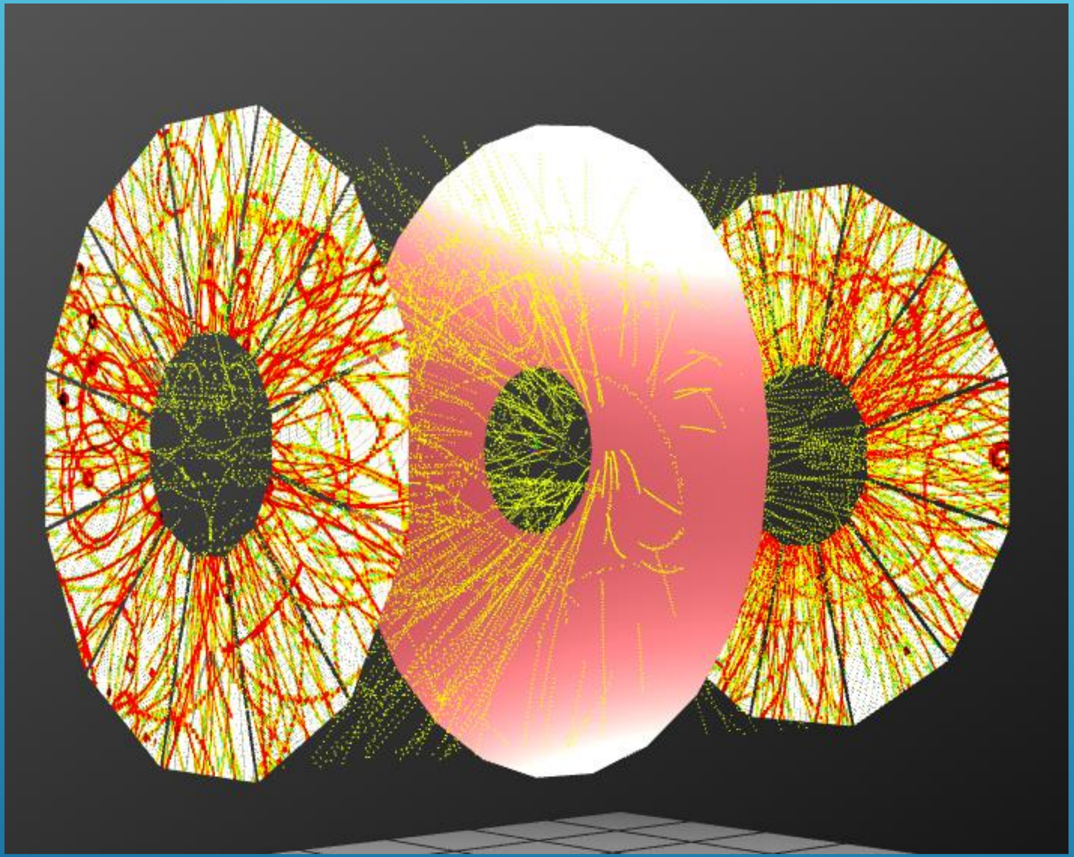




Presented by S.Movchan

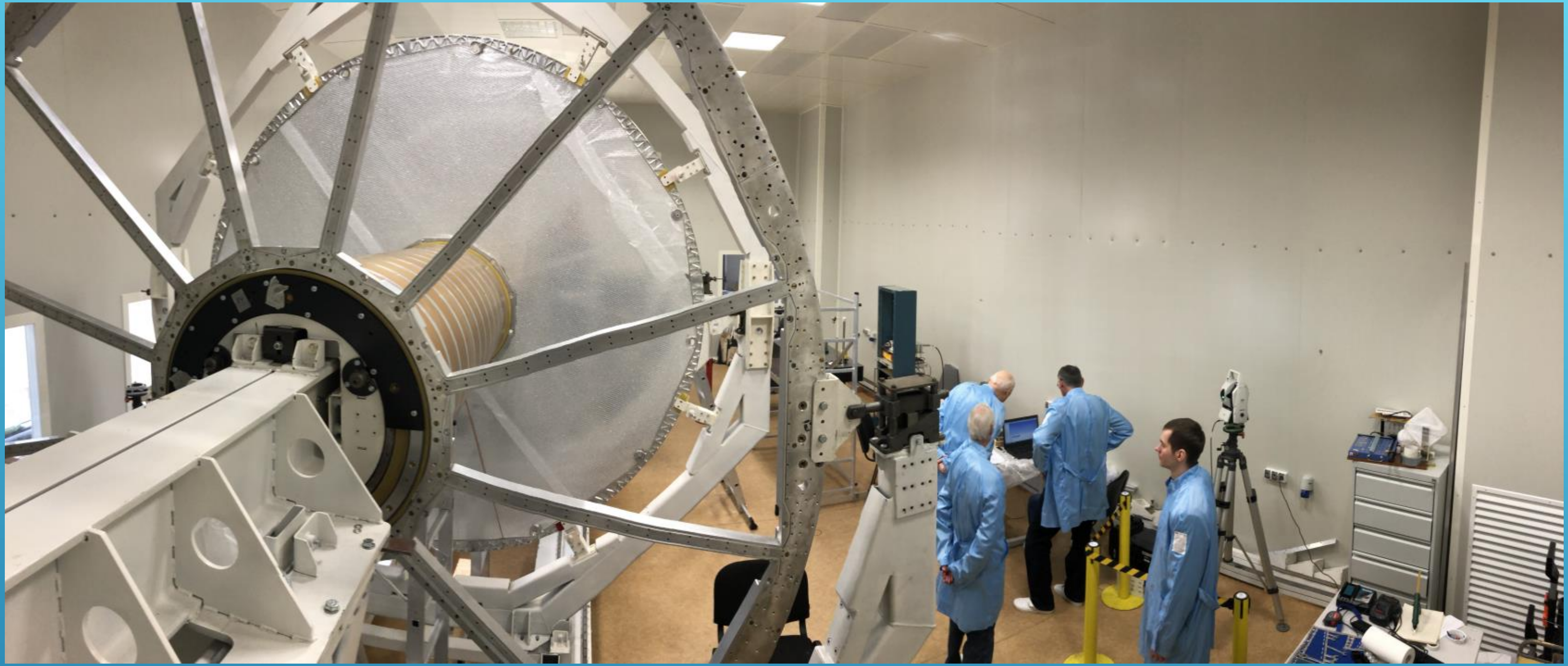
TPC team – 29 (JINR) + 20 (Belarus)

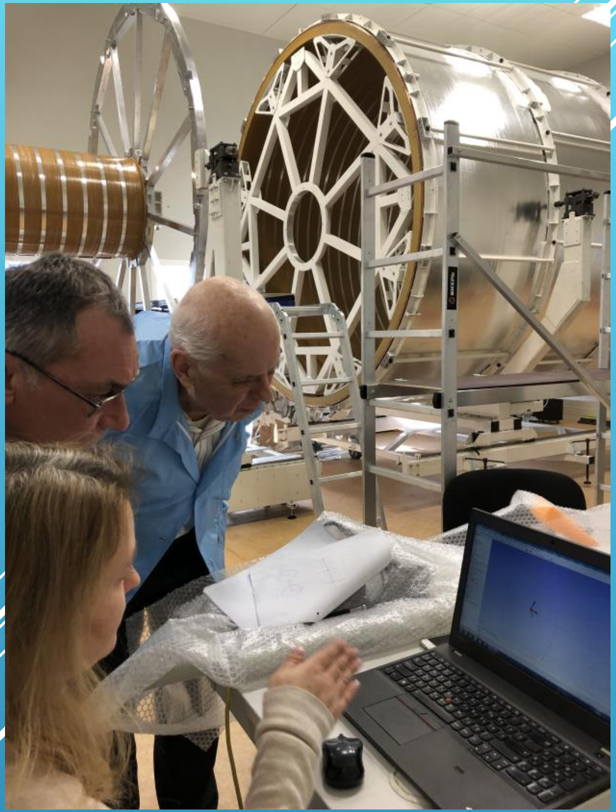
MPD TPC MAIN PARAMETERS



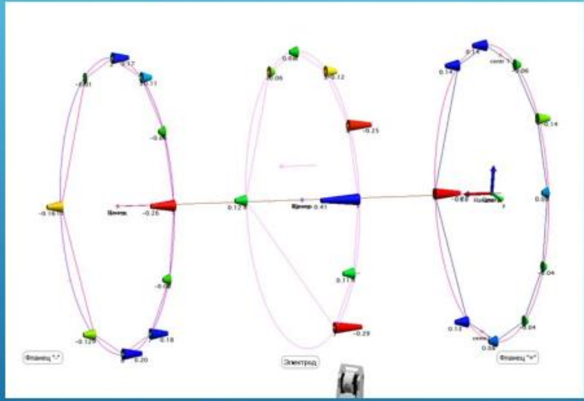
Item	Dimension
Length of the TPC	340cm
Outer radius of vessel	140cm
Inner radius of vessel	27 cm
Outer radius of the drift volume	133cm
Inner radius of the drift volume	34cm
Length of the drift volume	170cm (of each half)
HV electrode	Membrane at the center of the TPC
Electric field strength	~140V/cm;
Magnetic field strength	0.5 Tesla
Drift gas	90% Ar+10% Methane, Atmospheric pres. + 2 mbar
Gas amplification factor	~ 10^4
Drift velocity	5.45 cm/μs;
Drift time	< 30μs;
Temperature stability	< 0.5°C
Number of readout chambers	24 (12 per each end-plate)
Segmentation in φ	30°
Pad size	5x12mm^2 and 5x18mm^2
Number of pads	95232
Pad raw numbers	53
Pad numbers after zero suppression	< 10%
Maximal event rate	< 7 kHz (Lum. 10^{27})
Electronics shaping time	~180 ns (FWHM)
Signal-to-noise ratio	30:1
Signal dynamical range	10 bits
Sampling rate	10 MHz
Sampling depth	310 time buckets

TPC VESSEL ASSEMBLING





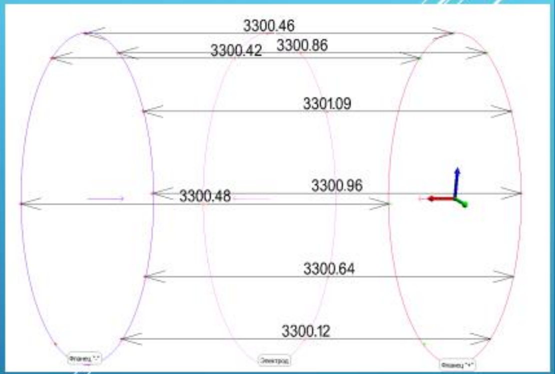
Flanges and HV electrode unflatness



Flanges unflatness – about 0.5 mm

HV electrode unflatness – about 0.7 mm

Flange to flange distance



L=(3300.5 +/-0.5) mm
(nominal – 3300.0 mm)

TPC body assembled with test rods for check TPC geometry by laser tracker AT-402 *(reflector type -TBR (R=6.35 mm)*:

- flanges unflatness – 0.5 mm
- asymmetry - $L_{left}=L_{right}+2$ mm

ROC CHAMBERS AND GGS - GATING GRID SYSTEM : STATUS

Test set up for ROC certification

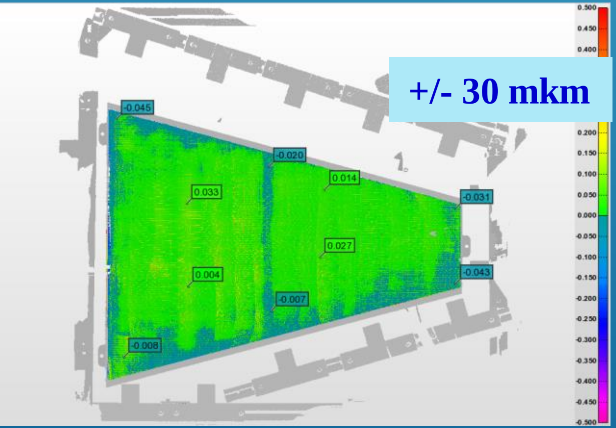
28 pc ROCs – tested

24 pc serial ROCs + 4 spare – READY!

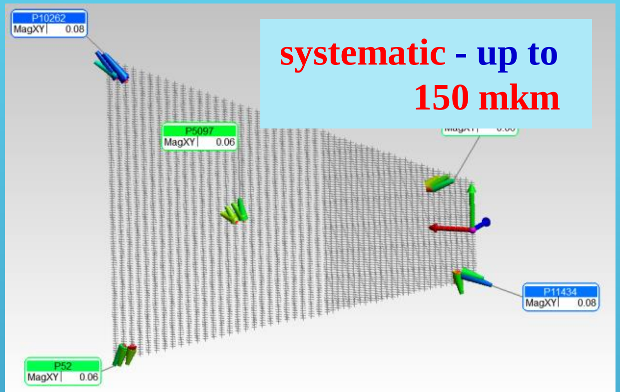
Test set up for pads calibration

Leica MS60 - 1 second resolution
Leica AT960 +/-10 mkm +5 mkm/m
Leica AT403 +/-15 mkm +6 mkm/m
Scanner AS1+AT960 +/-50 mkm

Pad plane unflatness: example



Check pads geometry

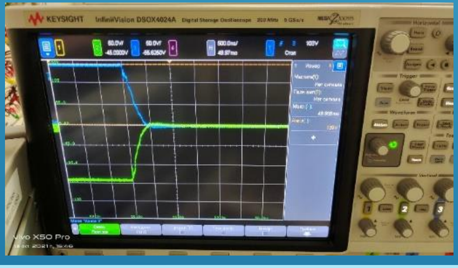


Full set of ROC alignment marks

Summary:
- measurements to do for all ROCs
- calibration of ROC marks and 3968 pads respect to ROC “reference hole” - in progress

ROC gating grid system: test set up

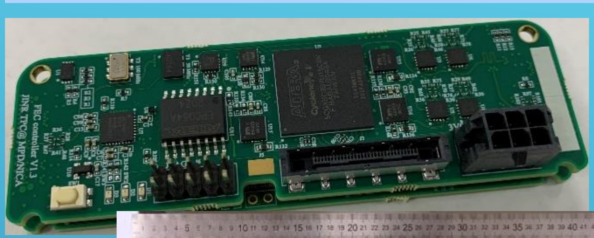
Pulse rise time ~ 900 ns, OK!



Mass-production – in progress
Delivery to JINR – Dec 2024

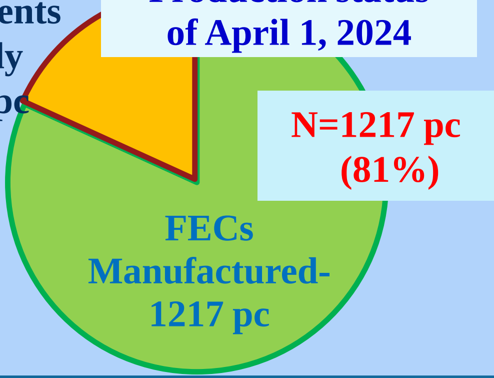
TPC SUB-SYSTEMS: FE ELECTRONICS

Production version of the FE card:



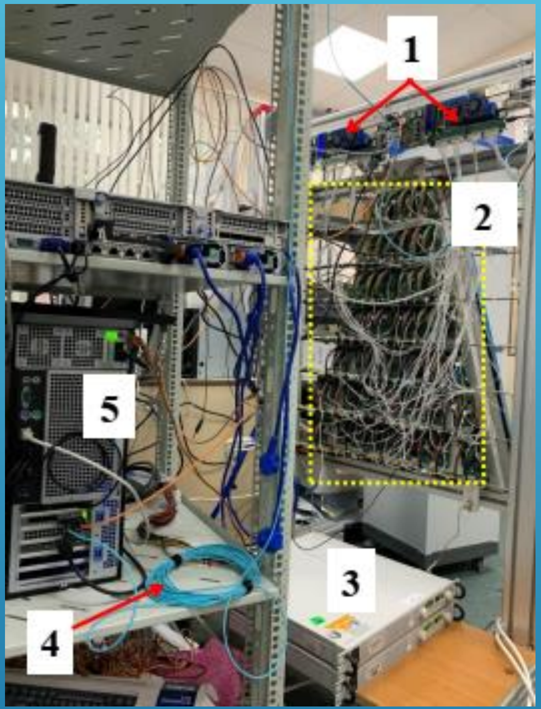
PCBs & components are ready for 271 pc

TPC Front-End Cards Production status of April 1, 2024



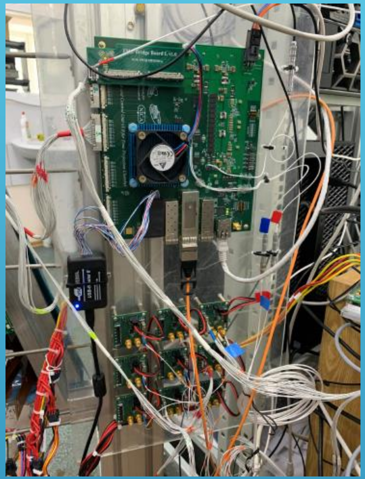
19 ROCs chambers can be completed (from 24 ROCs)

DAQ prototype:
62 FE cards, RCU prototypes, ROC, 2pc LVDBs, server interface board - tests ongoing



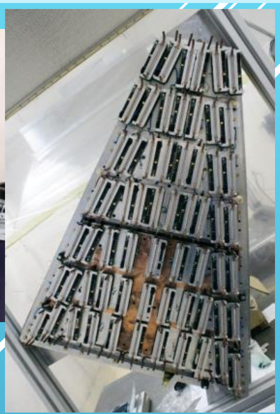
1. RCU prototypes
2. FECs on the ROC (62 pc)
3. LV power supply
4. DCU card connected with RCUs via fibers
5. Readout server

RCU-64 controller:
testing with FEE



LVN9 - LV stabilization module

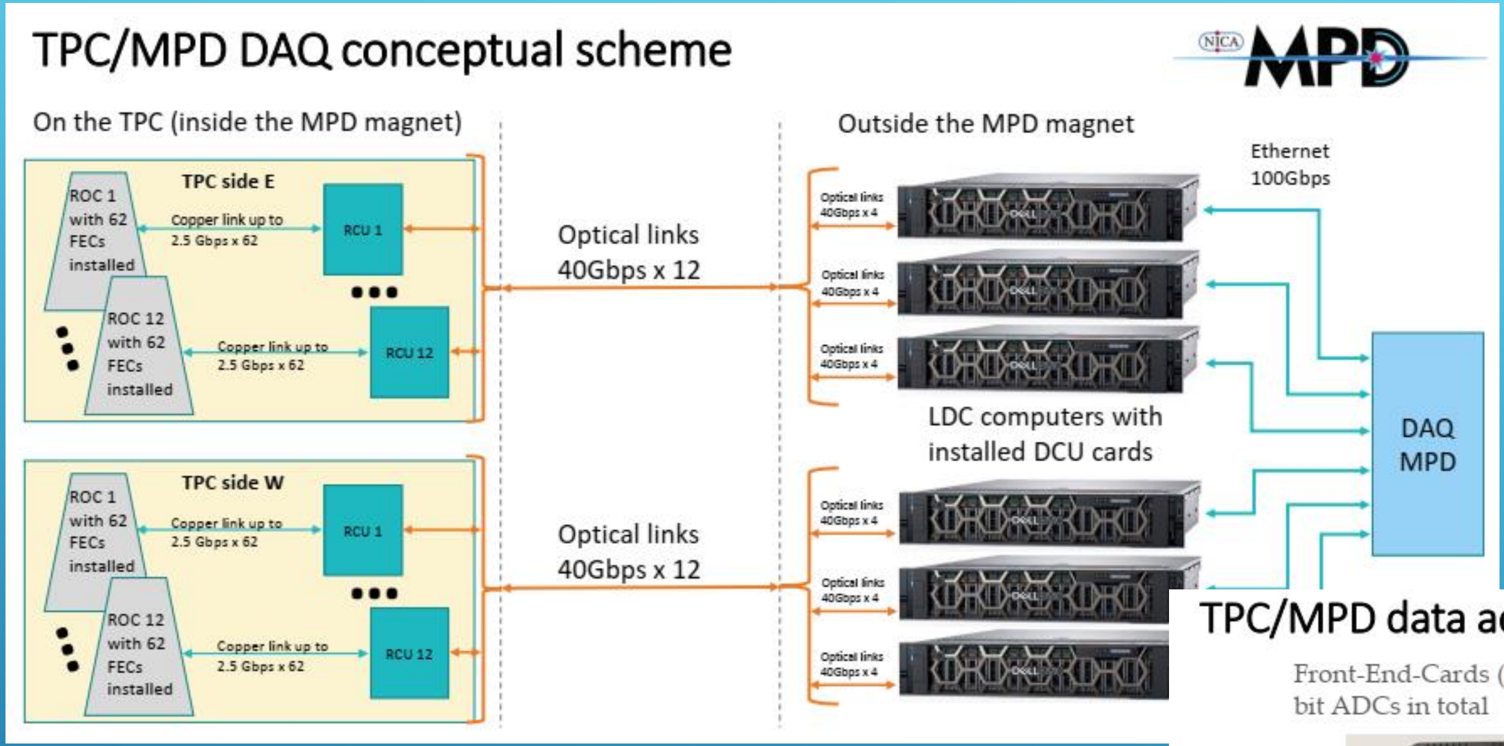
FE radiators (water cooling)

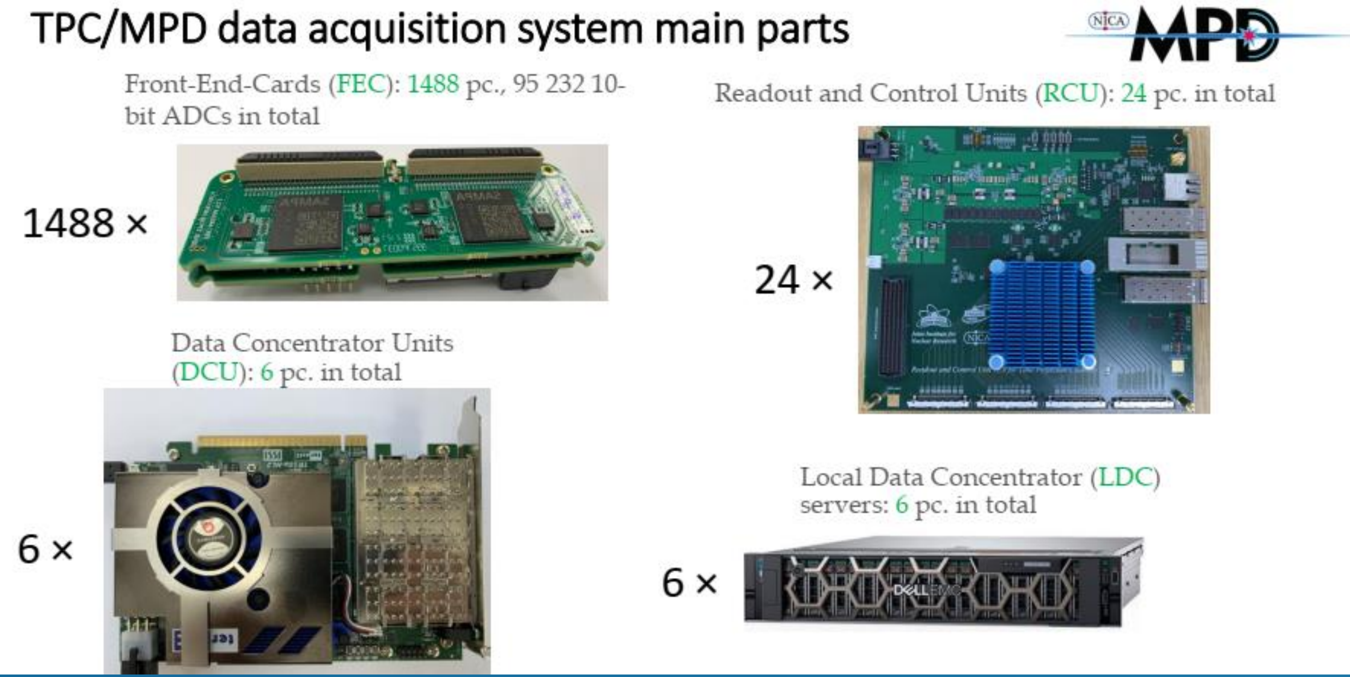


60 pc LVN9 (INP BSU, Minsk):
- modification LVN9 - in progress
- modification of LVN9 output voltage cables to FECs - in progress
- test of LVN9 with cooling radiator under full load (analog – 70 A, digital – 50 A) – done

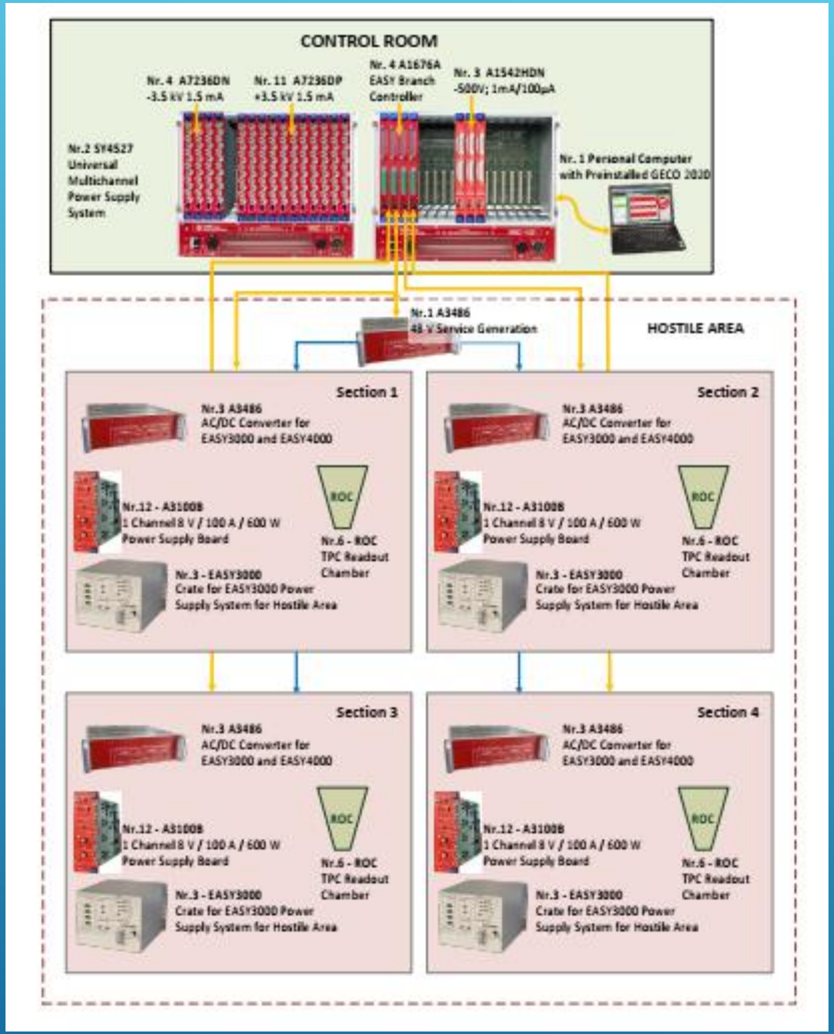
- 1217 FECs of 1500 were produced.
- Tests of the FEC basic functionality were shown the target characteristics (noise and stability).
- Testing of the readout system (on two ROCs) is ongoing
- RCU-64 controller v1.1 –ready for tests

TPC SUB-SYSTEMS: DAQ





TPC SUB-SYSTEMS: LV+HV



LV&HV system based on CAEN rad. hard design:

(up to 2000 Gauss and 15 kRad)

- **power converters A3486 AC/DC (380 V -> 48 V) – 15+3 pc**
- **EASY3000 crates - 14+2 pc**
- **LV module - A3100B (8V/100A) - 48+8 pc**
- **LV module - A3100HBP (14V/50A) - 6 +2 pc**
- **HV modules –A3540P (+4kV/1mA) - 8+3 pc**
- **HV modules –A3540N (- 4kV/1mA) - 2+2 pc**

Status:

LV+HV system: JINR-CAEN contract signed

Expected delivery date to JINR: September 2023

test system – tests ongoing

LV cables (halogen free, low smoke):

S=25 mm2 and 50 mm2 – delivered

HV cables - delivered

TPC SUB-SYSTEMS: GAS

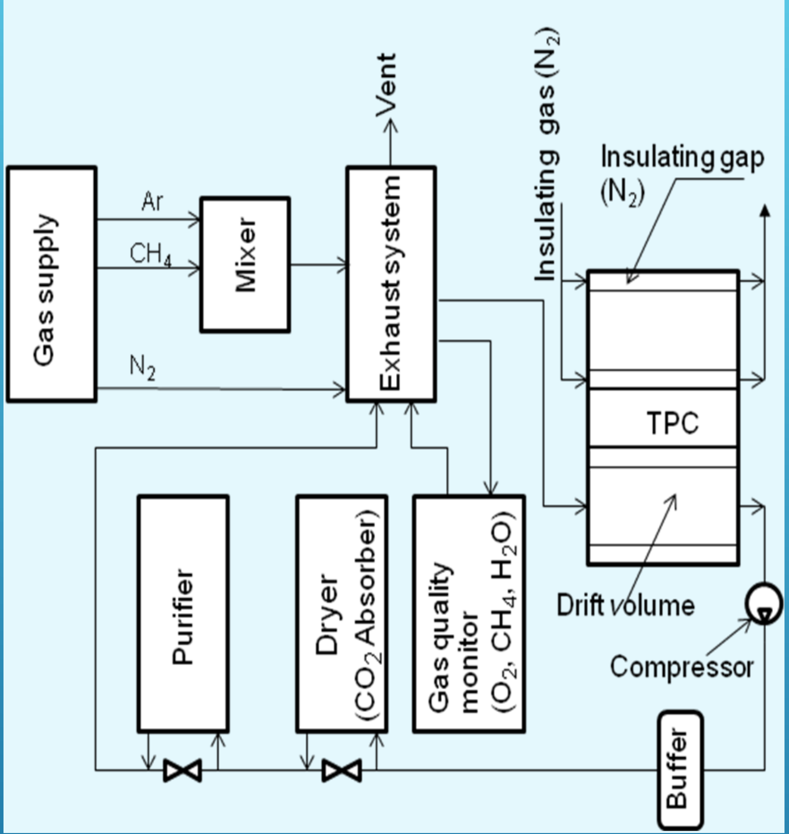
Gas system main features:

- Drift gas mixture: 90%Ar + 10%CH_4 (P10);
- Insulating gas: N_2;
- Operating pressure: atmospheric + 2.0 ± 0.03 mbar;
- Drift volume: 17640 liters;
- Insulating gaps volume: 2380 liters;
- Oxygen content: 5 ppm;
- Moisture content: 10 ppm;
- Recirculation rate of outer loop: 30 L/min;
- Recirculation rate of inner loop: 20 L/min

Gases consumption:

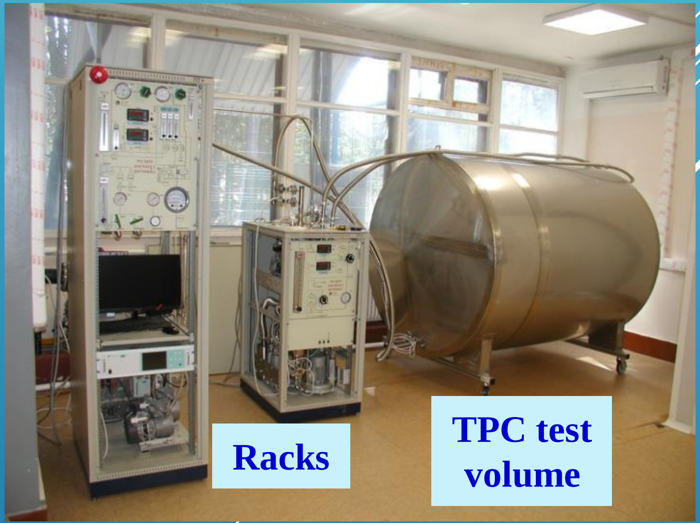
Mode	Argon, m^3	Methan, m^3	Nitrogen, m^3
TPC purging	84	5.4	36
Experiment:			
Per day	7.8	0.86	8.6
Per month	234	25.9	259

Scheme



Gas system (Ar/CH4, 90:10)

Gas supply tanks



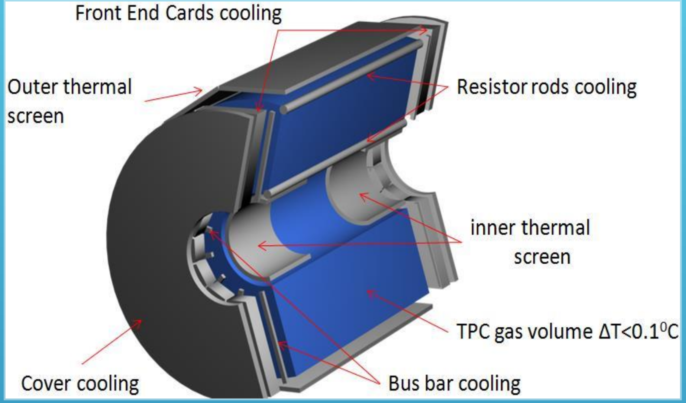
Racks

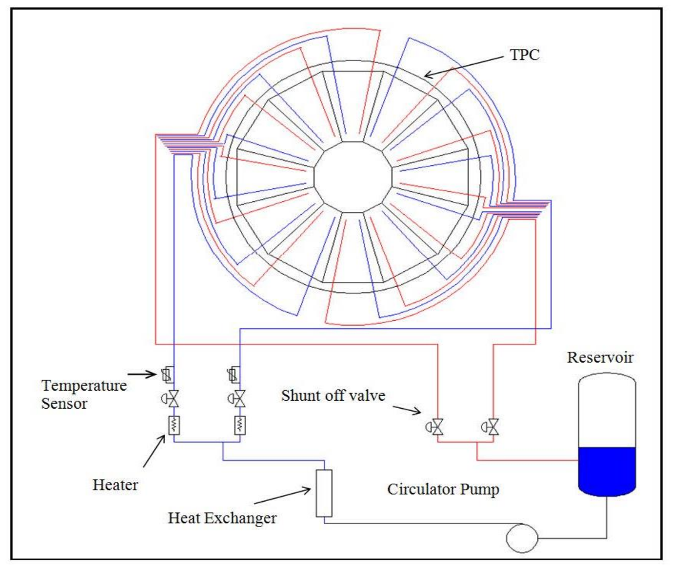
TPC test volume

Tests - in progress
(H20 and O2 sensors are replaced)
Ready for piping

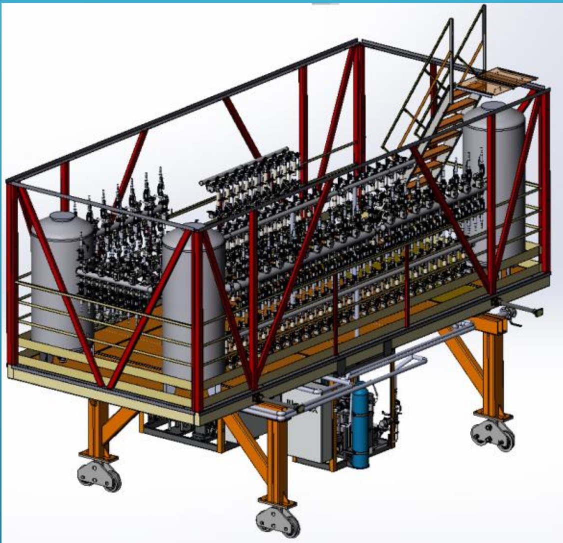
TPC SUB-SYSTEMS: COOLING

Water cooling system – leak less option

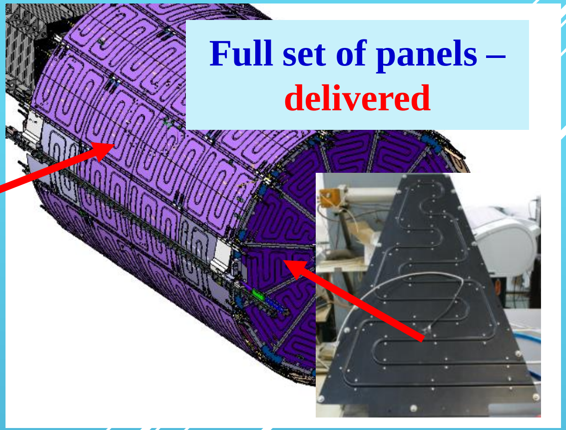




Cooling system - 1-st floor of the South platform



Design, optimization and procurements - done



Full set of panels – delivered

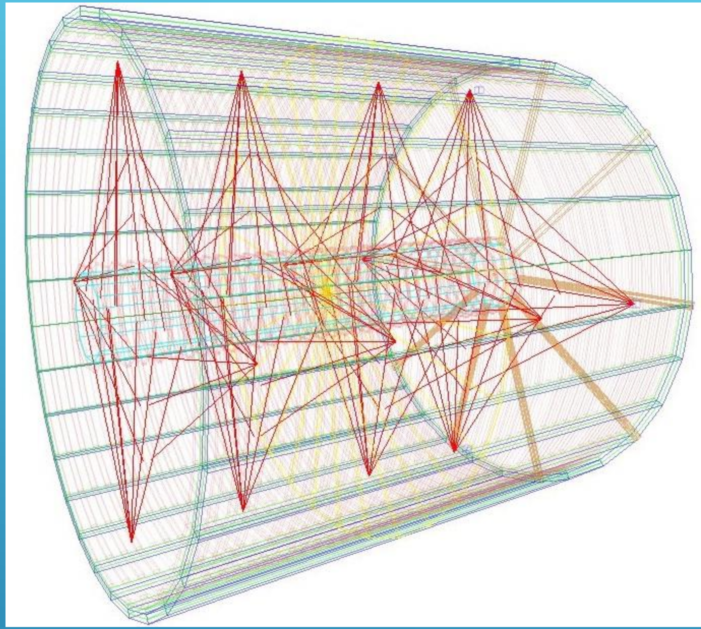
Vacuum tanks

Heat exchanger

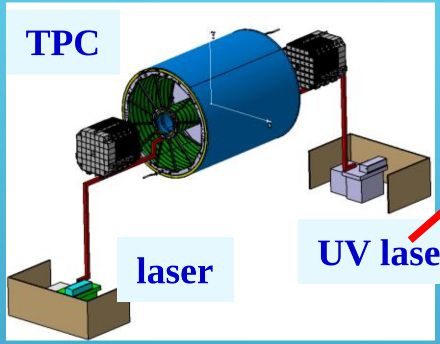
contract JINR - INP BSU (Minsk):
components delivery – September 30 2024
commissioning– December 25 2024

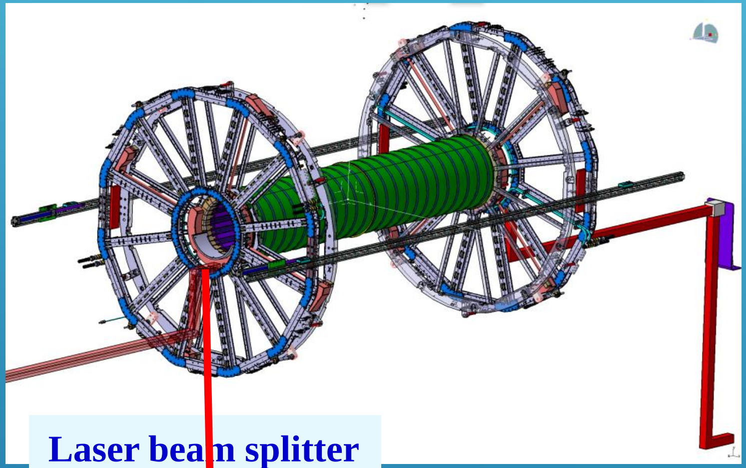
TPC SUB-SYSTEMS: LASER CALIBRATION SYSTEM

Scheme for ½ TPC

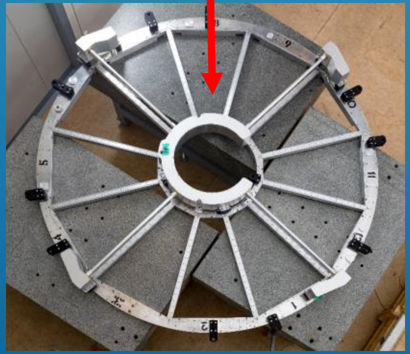


Laser "planes"	-	4
Micro-mirrors bundles per plane	-	4
Beams from micro-mirrors bundle	-	7
Laser "tracks" (N =112x2)	-	224

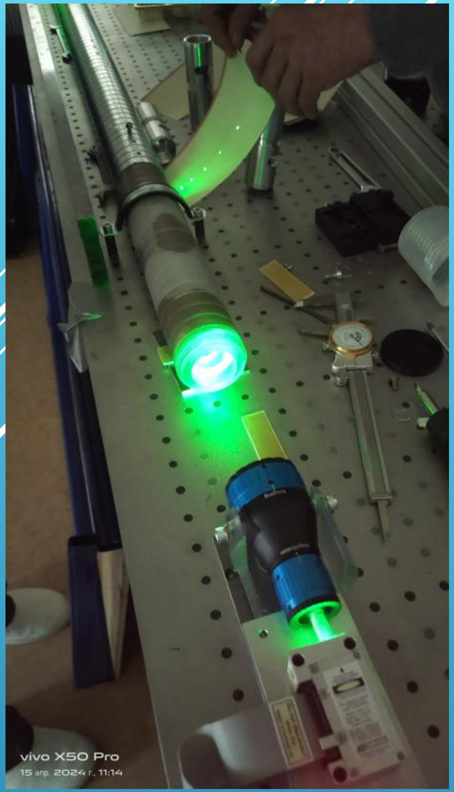




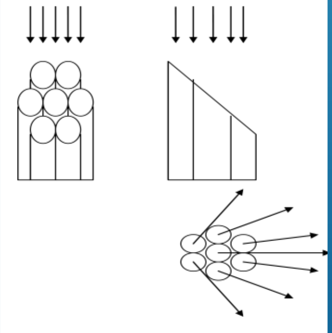
Laser beam splitter



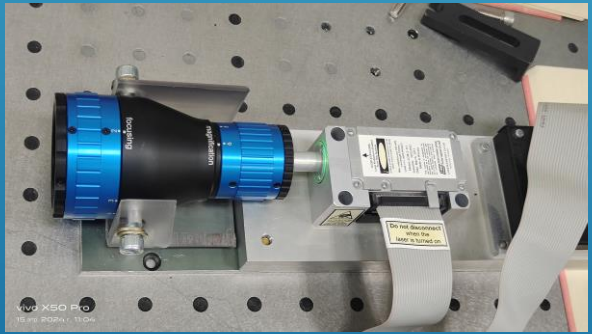
Test setup



micro-mirror bundles



Laser beam monitor

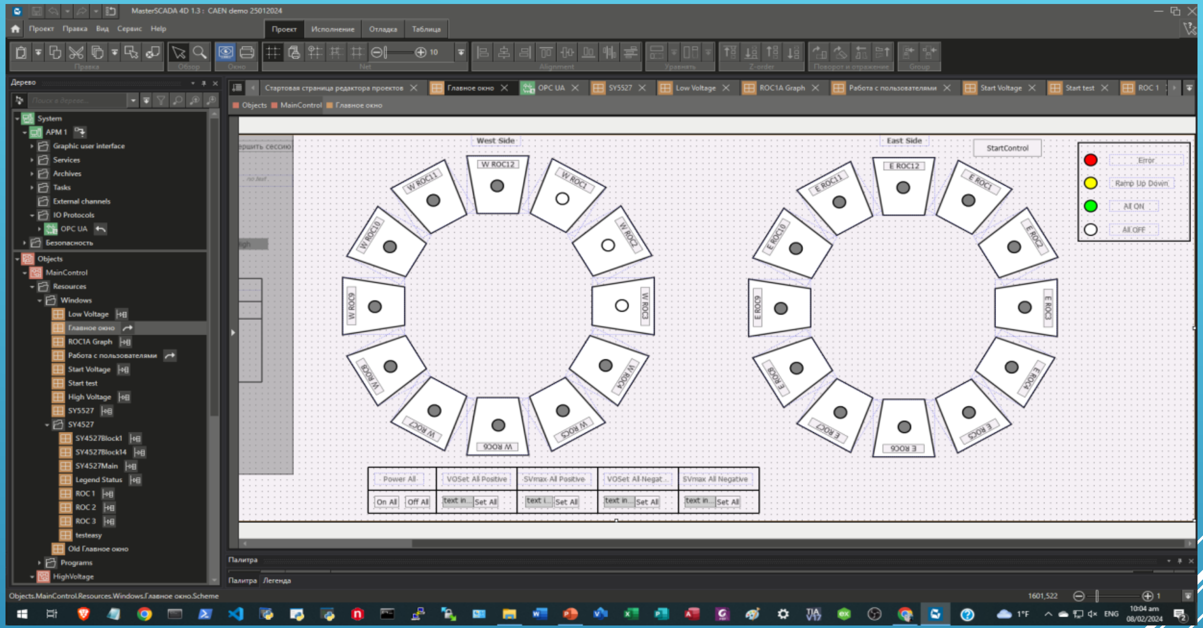


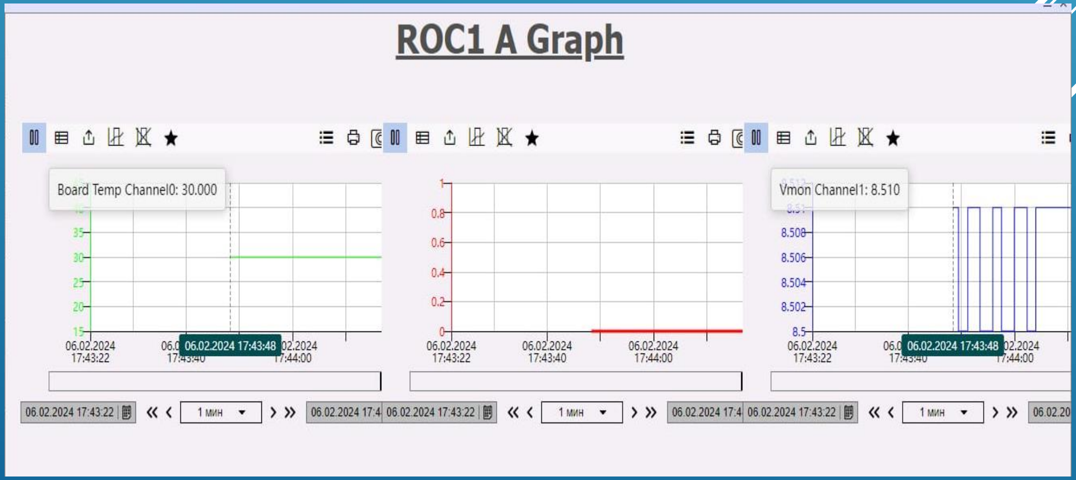
in progress …

TPC SUB-SYSTEMS: SLOW CONTROL

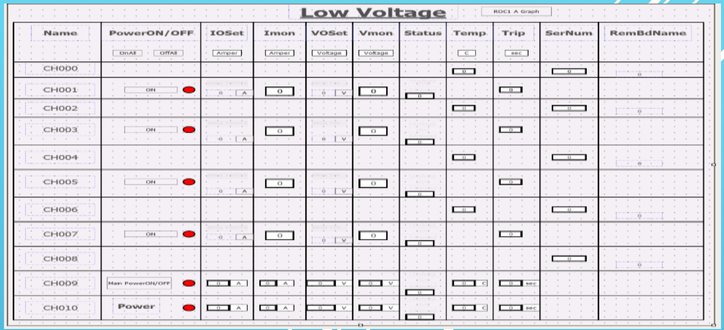
CAEN LV test setup

Main window of LV+HV GUI based on MasterScada 4D

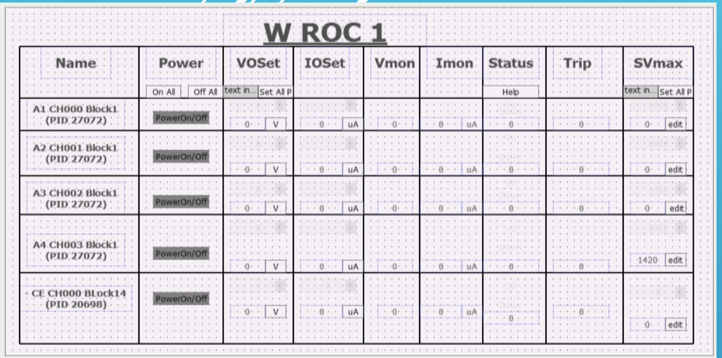




LV



HV

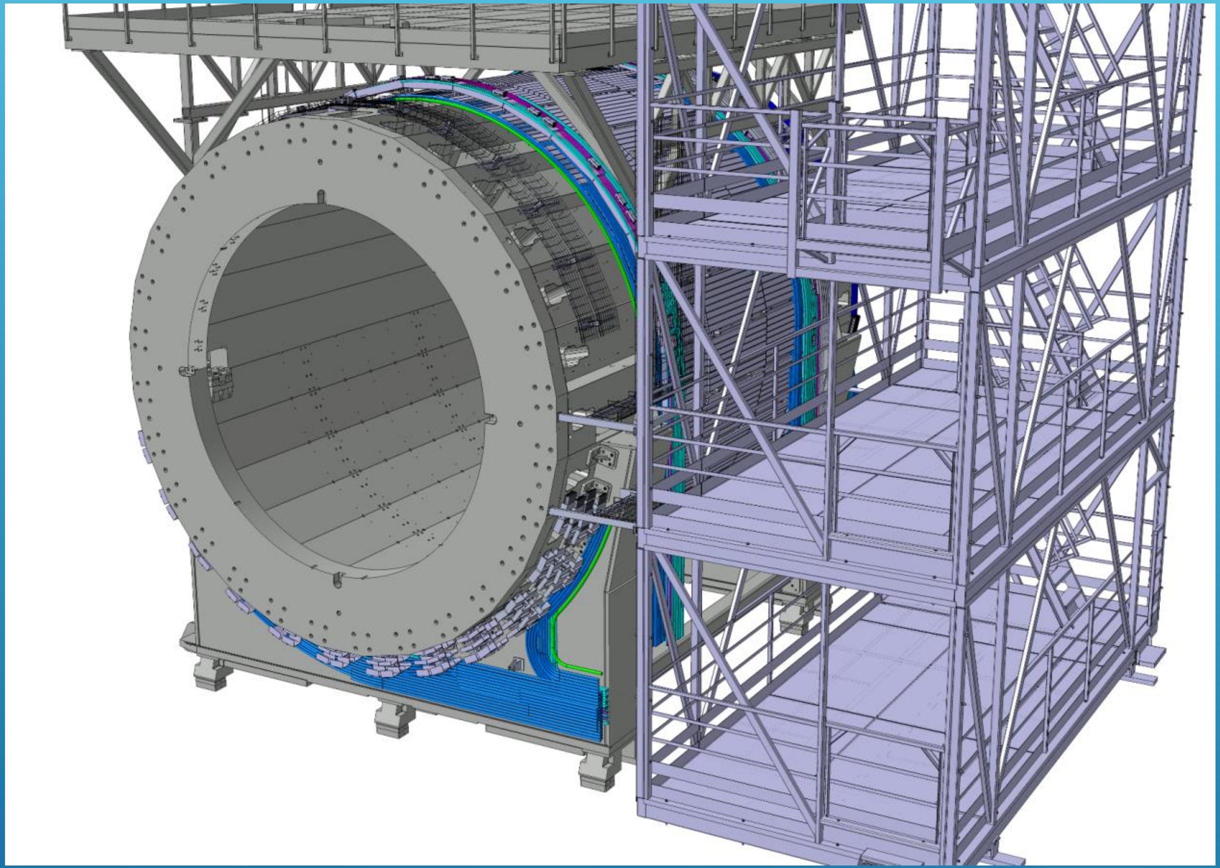


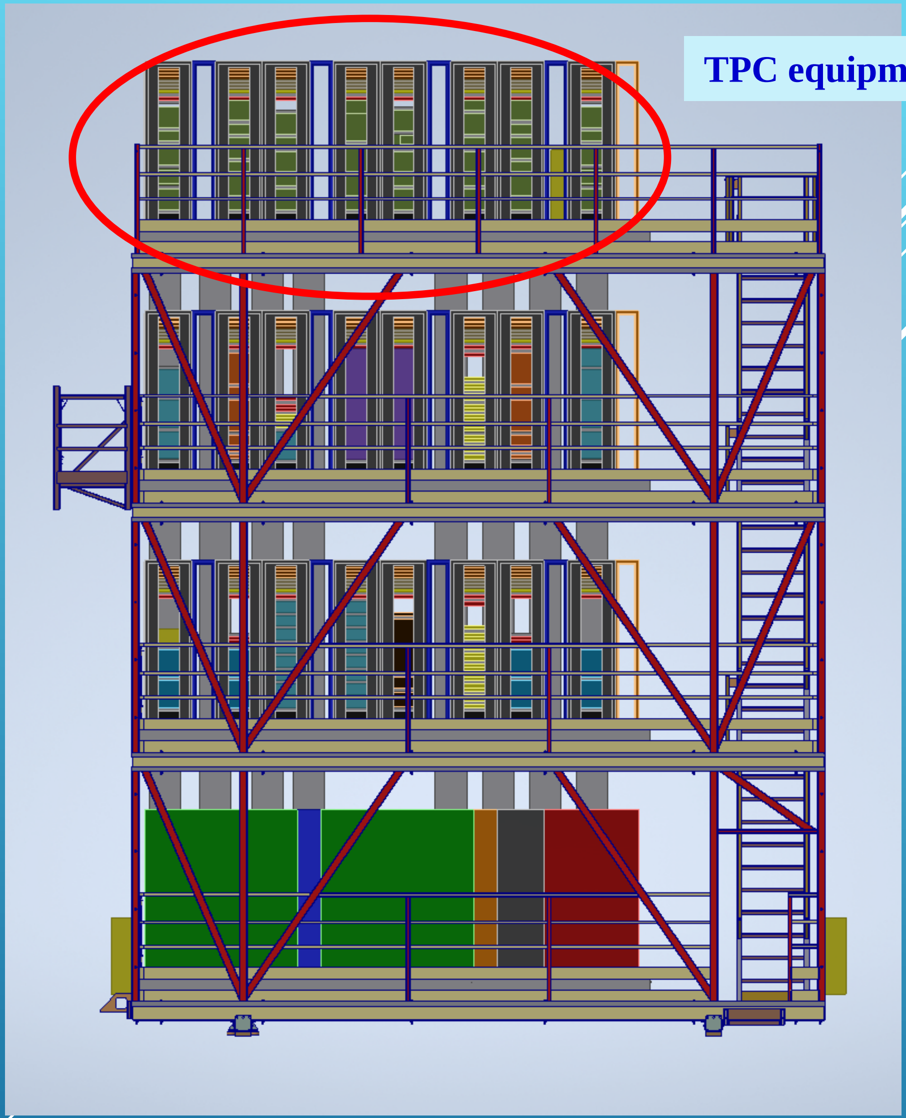
DATA transfer from MasterScada 4D to the DB POSTGRESQL16 – OK!

in progress …

INTEGRATION: TPC RACKS

Common view of North platform

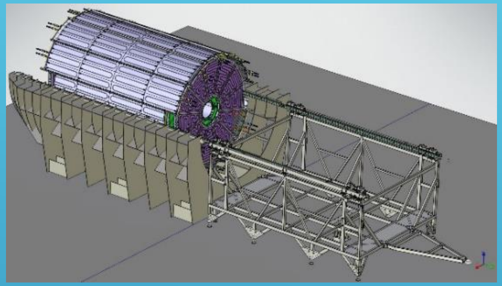




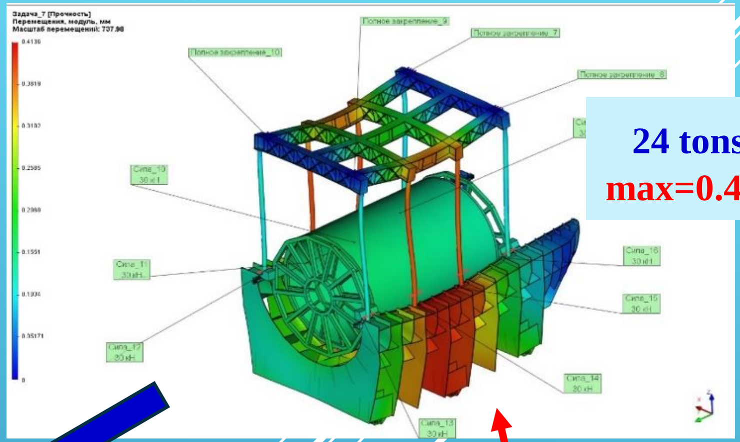
Integration – in progress …

TOOLING FOR INSTALLATION TPC TO MPD

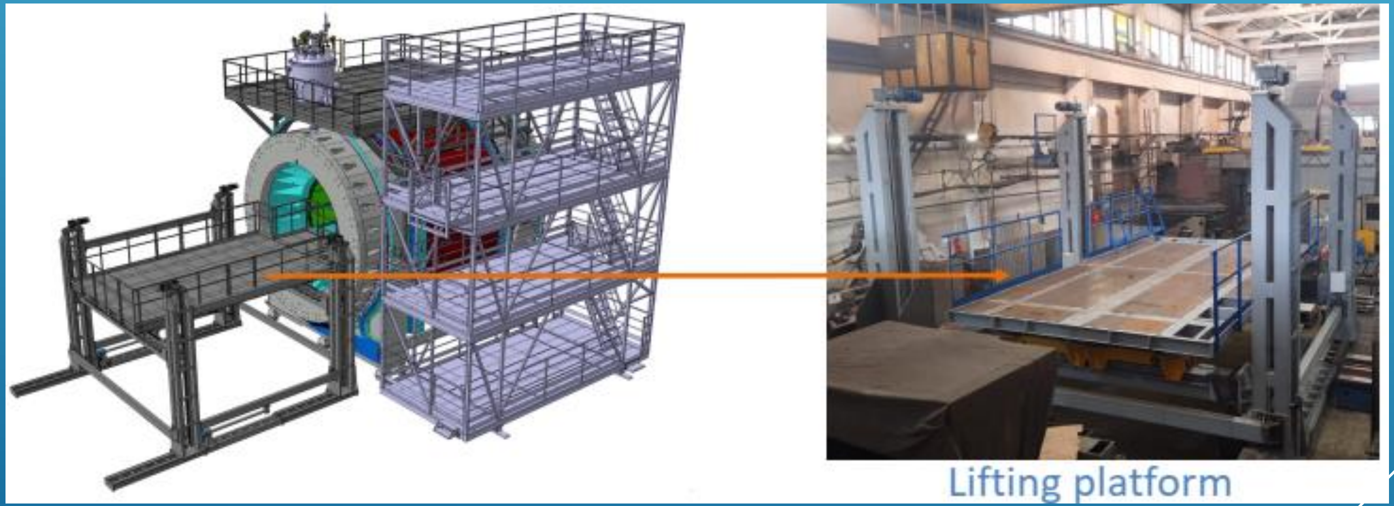
Bld. 217



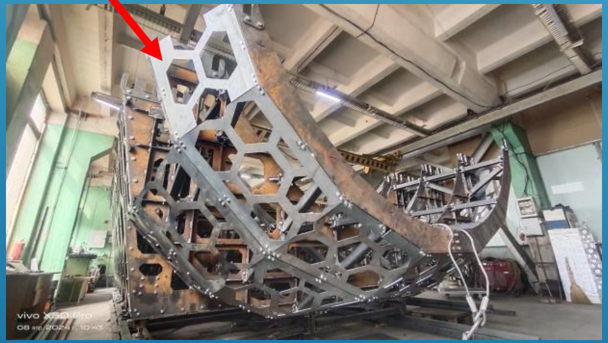
Bld. 17 (MPD)



24 tons,
max=0.41 mm



Tooling for installation TPC to MPD delivery - August 2024
TPC installation to MPD - April 12 – June 10 2025



Tooling for installation TPC to MPD – manufactured
Delivery to JINR – December 30 2024

STATUS AND TIME SCHEDULE

Status:

TPC vessel	in progress
ROCs (24+6 spare)	ready
FE electronics	81% manufactured (1217 FECs from 1500)
Gating grid system	ready
HV+LV systems	ready for start installation
Gas system	ready for start piping
Cooling system	in progress
Laser system	in progress
Slow control system	in progress

TPC assembling:

TPC:	
TPC vessel assembled	Dec 30 2024
ROC chambers installation	Jan 2025
TPC tests (with laser tracks and cosmic ray)	Feb - May 2025
TPC rails and installation tooling	
Rails installation to ECAL support structure	July 2 2024
Tooling for installation TPC to MPD delivery	October 30 2024
TPC+ECAL cooling systems (INP BSU, Minsk):	
Delivery to JINR	Sept 30 2024
Systems assembling and piping	Oct-Nov 2024
Commissioning	Dec 25 2024
TPC installation to MPD	April 12 - June 10 2025
Cabling	Jan-June 2025
MPD commissioning	June - July 2025
Strat of technical RUN with beams	July 27 2025

Thank you !

MPD TPC UPGRADE

TPC base line option:

- **radiation length**
- **results of radiation length optimization**

Spark protection:

- **diamond like carbon (DLC) coating of a anode**

Upgrade options:

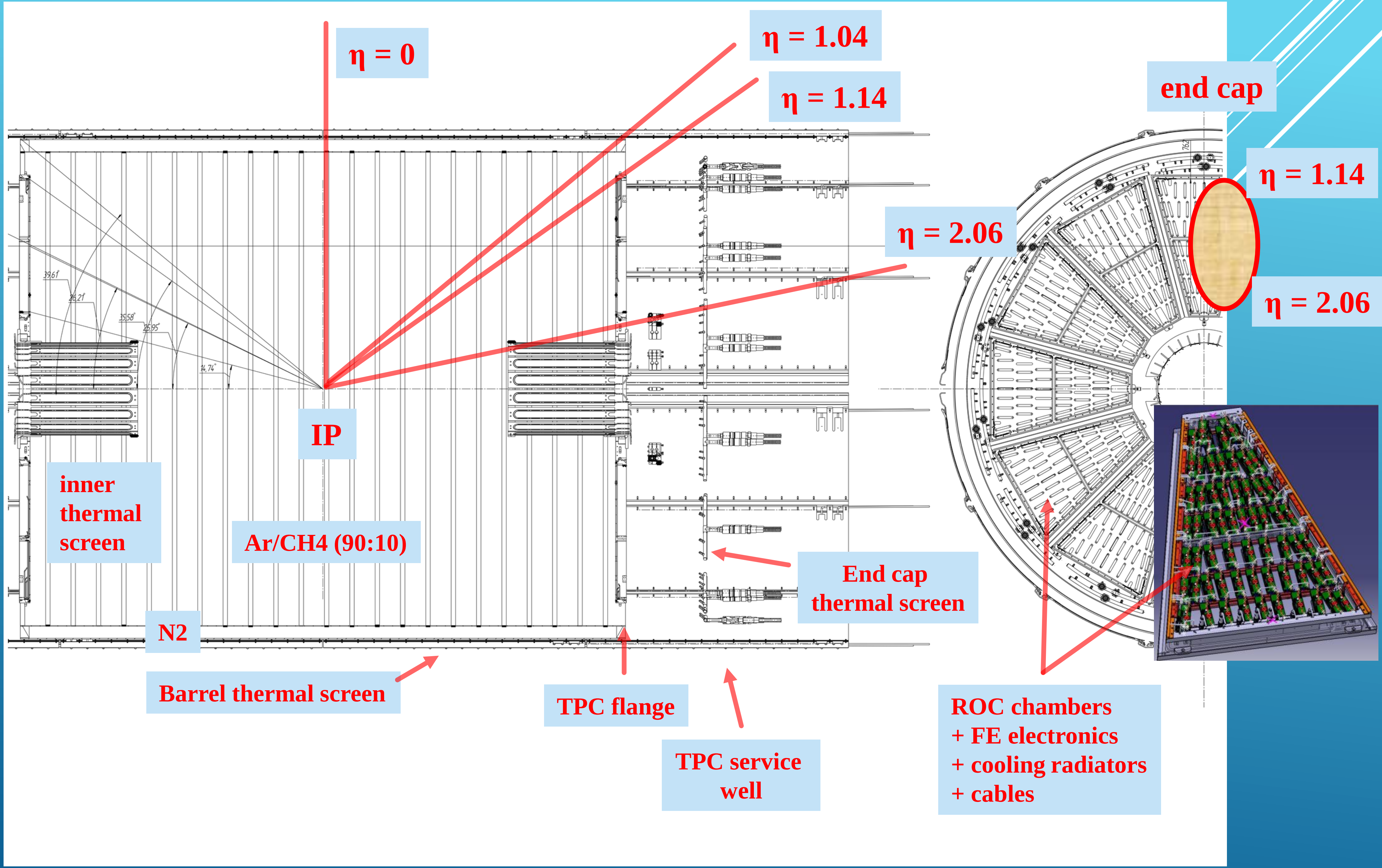
- **WEM+ DLC prototype**
- **MictoMegas + DLC prototype**

  or typical solutions

  - **Standard GEMs (like ALICE)**
  - **Micromegas + GEM (CERN)**

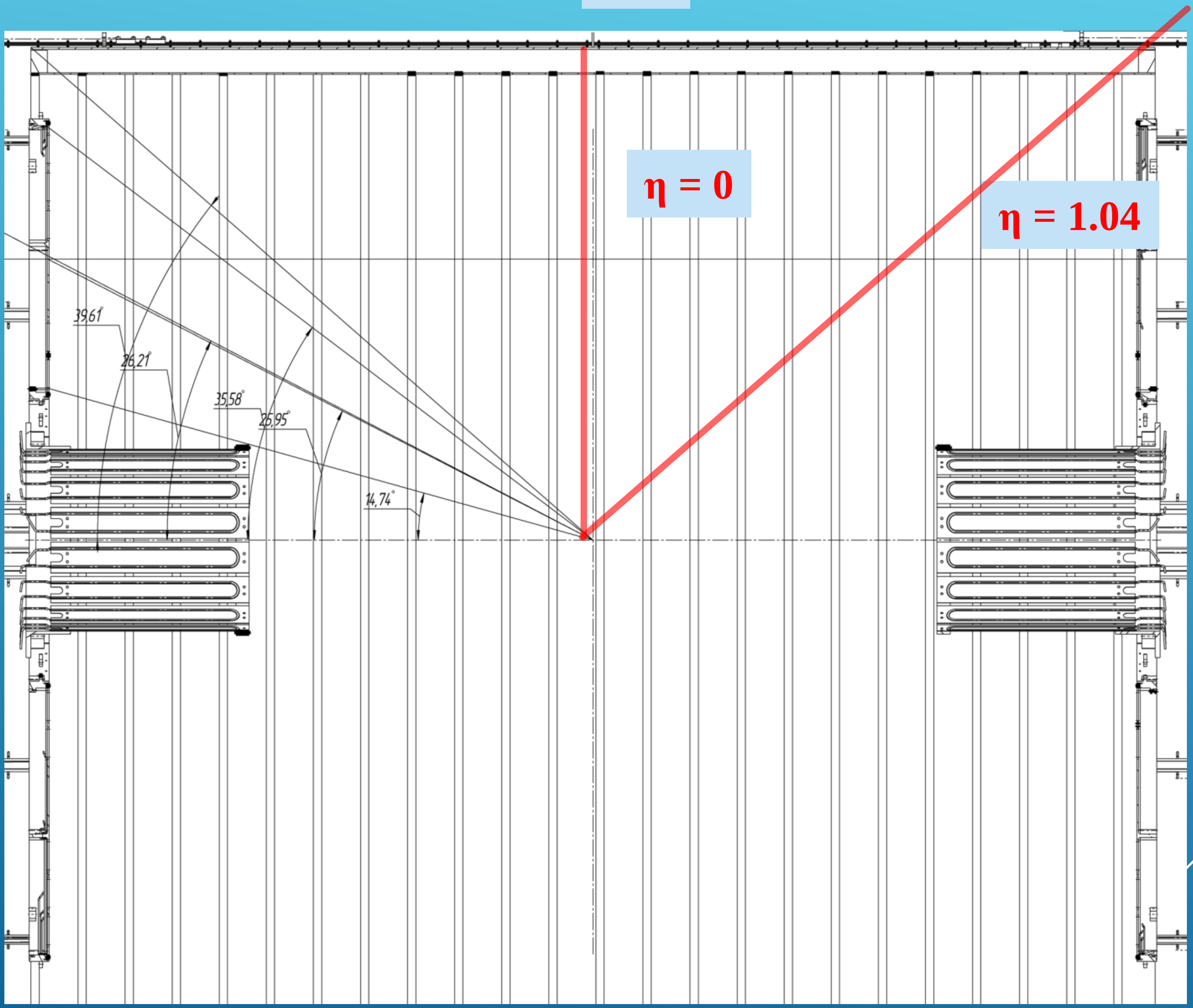
Presented by S.Movchan

MPD TPC RADIATION LENGTH



MPD TPC RADIATION LENGTH: BARREL $\eta = (0 \div 1)$

TPC



	Base line option	
	for $\eta = 0$ $\Theta = 90^{o}$	for $\eta = 1.04$ $\Theta = 38.87^{o}$
C1 h=3 mm + Al foils	1.061	1.689
N_2 (gap C1-C2) h=65 mm	0.020	0.032
C2 h=3 mm + Al strips on C2	0.958	1.525
TPC gas mixture	0.771 (L=989 mm)	1.228 (L=1574.8 mm)
Potential degrader rods + field cage	0.085	0.135
C3 h=4.05 mm + Al strips	1.275	2.030
N_2 (gap C3-C4) h≈67 mm	0.020	0.032
C4 h=6.4 mm	1.972	3.140
TPC shielding Al, h=0.1 mm	0.112	0.178
TPC thermal-screen (top) Al + H_2O, h=1.5mm	2.943	4.686
TPC thermal-screen (bottom) Al + H_2O, h=1.5mm	-	-
Air (C4 up to TOF) h = 60 mm	0.020	0.032
Sum:	≈ 9.24	≈ 14.71

for barrel (up to η=1):
$X/X_0 = (9.24 \div 14.71)$ %

MPD TPC RADIATION LENGTH: UPGRADE

TPC radiation length for flange (horizontal)					
MWPC	for perpendicular to chamber	for Θ ≈ 25.03° η = 1.51	**GEM+optimization**	for perpendicular to chamber	for Θ≈25.03° η = 1.51
C1+C2 +N2 +Ar/CH4			C1+C2 +N2 +Ar/CH4		
Sum [C1+N2(gap C1-C2) + C2 + gas mixture (L=1164.8mm)]:	-	5.65	Sum [C1+N2(gap C1-C2) + C2 + gas mixture (L=1164.8 mm)]:	-	5.65
ROC	-		ROC	-	
1. Wires	0.30	0.33	1. 4 GEM foils (Cu - 8x5μm =40 μm, kapton - 4x50μm =200 μm)	0.35	0.385
2. Pad plane h=3.4mm + inside glue	2.83	3.12	2. Pad plane h=3.4 mm (new) + inside glue	~2.24	~2.47
3. Insulating plate h=3 mm	1.88	2.08	3. Insulating plate h=1.5 mm	0.94	1.04
4. Al frame h=5 mm & ROC reinforce rib + ROC cooling tube (Cu) with water	6.54 + 0.91	7.22 + 1.00	4. Carbon frame h=2.5 mm & ROC reinforce rib + ROC cooling tube (Al) with water	1.89 + 0.59	2.09 + 0.65
5. Epoxy glue (2x0.1 mm)	0.056	0.062	5. Epoxy glue (2x0.1 mm)	0.056	0.062
6. Connectors + solder	0.34	0.38	6. Connectors+ solder	0.34	0.38
Air gap L=100 mm	0.033	0.036	Air gap L=100 mm	0.033	0.036
ROC MWPC sum:	12.89	14.23	ROC GEM sum:	~6.44	~7.11
FE (based on SAMPA chip)			FE (based on SAMPA chip)		
Components FE PCB – (2x12 layers)x2 Connectors + Solder	0.33 2.32 0.34	0.36 2.56 0.38	Components (new) FE PCB – 2x12 layers → FE Controller card will be removed to sides of ROC Connectors + Solder	0.165 1.16 0.34	0.18 1.28 0.38
FE sum:	2.99	3.30	FE sum:	1.67	1.84
FE Cooling			FE Cooling		
Al radiators + Cu & Al pipes + water	7.10 + 3.68	7.84 + 4.06	Al radiators + Al pipes + water	3.81+ 2.07	4.21+ 2.28
FE Cooling sum	10.78	11.90	FE Cooling sum:	5.88	6.49
LV & DAQ+SC cables			LV & DAQ+SC cables		
LV + DAQ+SC cables + flat cables (Cu)	~ 8.82 + 0.19	~ 8.82 + 0.21	LV & DAQ+SC cables (Al) + flat cables (Cu)	~ 2.36 + 0.19	~ 2.36 + 0.21
TPC thermal screen			TPC thermal-screen		
TPC thermal-screen Al (flange) +Al (clamps) [m(Al) = 21 kG] + H_2O	~1.46 ~0.01	~1.61 ~0.01	TPC thermal-screen Al (flange) + Al (clamps) [m(Al) = 21 kG] + H_2O	~1.46 ~0.01	~1.61 ~0.01
Summary:	~37.14	~45.73		~18.01	~25.28

for end caps η = (1.14÷2.06) X/X0:
46 % -> 25%

MPD TPC RADIATION LENGTH: OPTIMIZATION (UPGRADE)

Goal - decrease X/X_0 from 40% up to (20÷25)% for TPC End Caps:

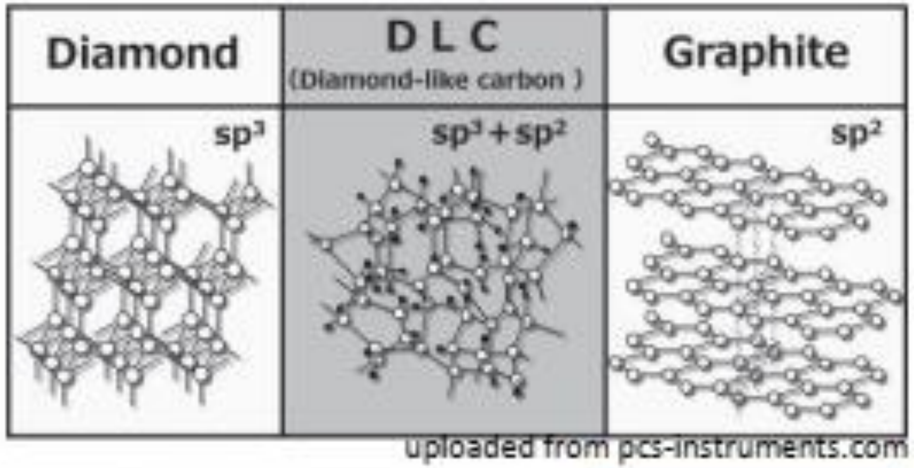
- **MWPC - > MPGD (GEMs, MicroMegas, ThGEM …)**
- **ROC chamber Al frame -> to composite frame**
- **FE electronics: -> integrate SAMPA chips with ROC chamber pad plane**
  -> move boards with FPGAs from chamber to flange arms
- **LV Cu cables - > Al cables**

MPGD DISCHARGE ROBUSTNESS: DLC COATING

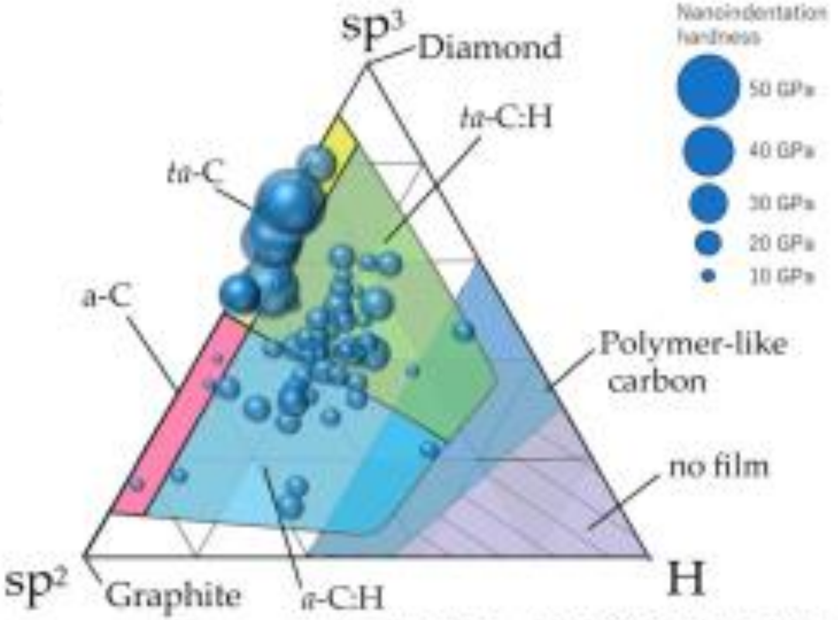
MPGD discharge robustness:

- diamond like carbon (DLC) coating of a electrodes

DLC – Diamond-Like Carbon



Widely used as a hardening coating, anti-reflective optical coating, decorative

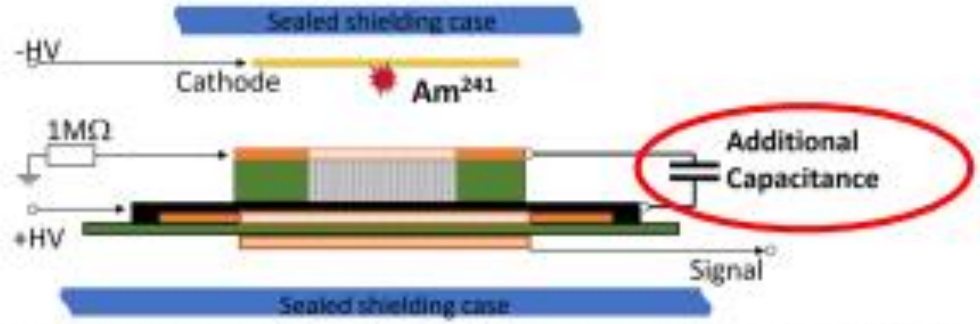


by Naoto Ohtake *Materials* 2021, *14*(2)

In High Energy Physics is used as a resistive coating for MPGDs

EXAMPLE: R-WEM PROTOTYPE WITH DLC ANODE

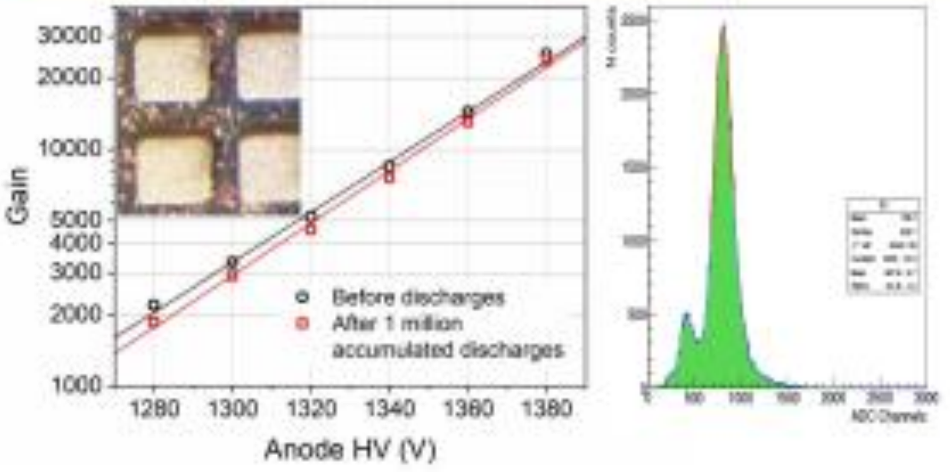
Effect of Multiple Discharges on Accumulated Damage in R-WEM with DLC Anode



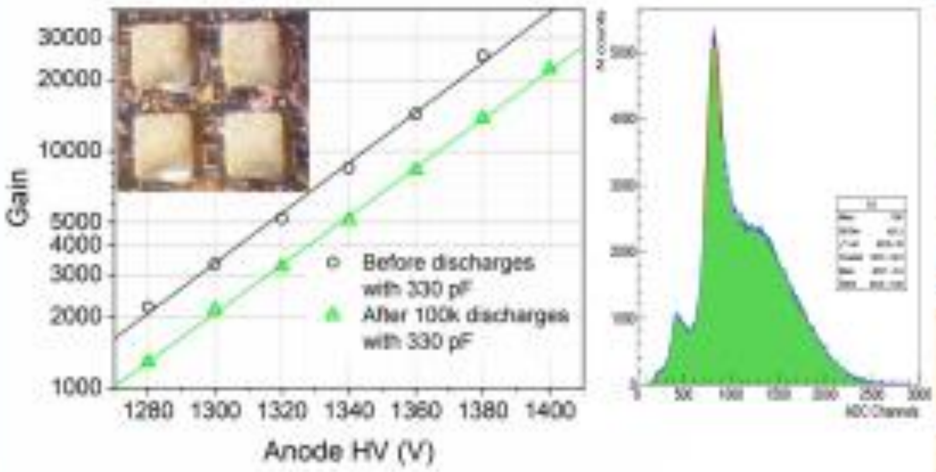
To simulate a large area R-WEM we used an Additional Capacitance, in parallel with R-WEM anode and top electrode

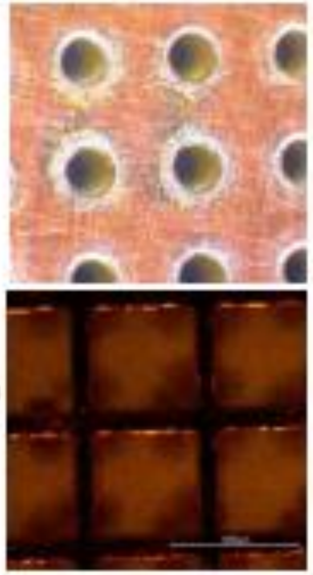
The discharge events initiated by an **Am^{241} alpha** source.
The circular alpha source 3 mm in diameter, activity of **33 Bq**

Active Area	Capacitance with the frame	Energy of discharges	Number of discharges
10 x 10 mm²	**34 pF**	**29 µJ**	**1,000,000**
60 x 60 mm²	**360 pF**	**0.3 mJ**	**100,000**
100 x 100 mm²	**1 nF**	**0.9 mJ**	**100,000**



No damage is observed after **1,000,000 discharges** for active **area 10 x 10 mm²**



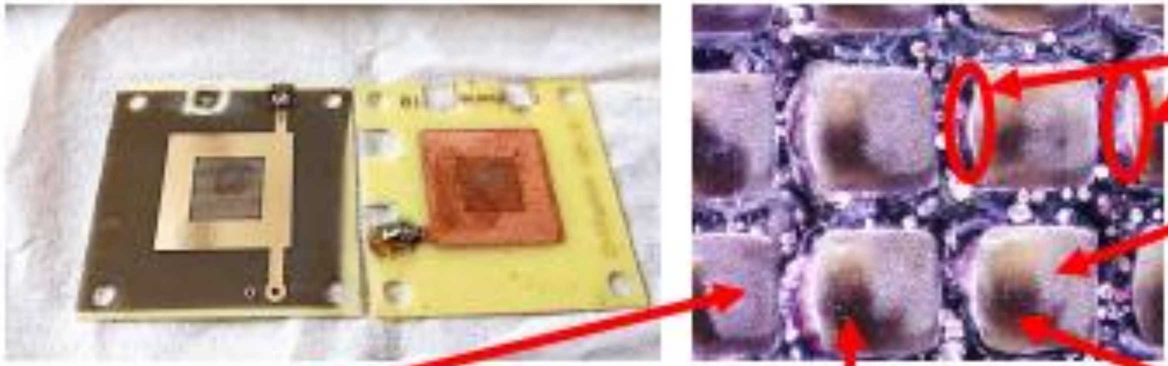


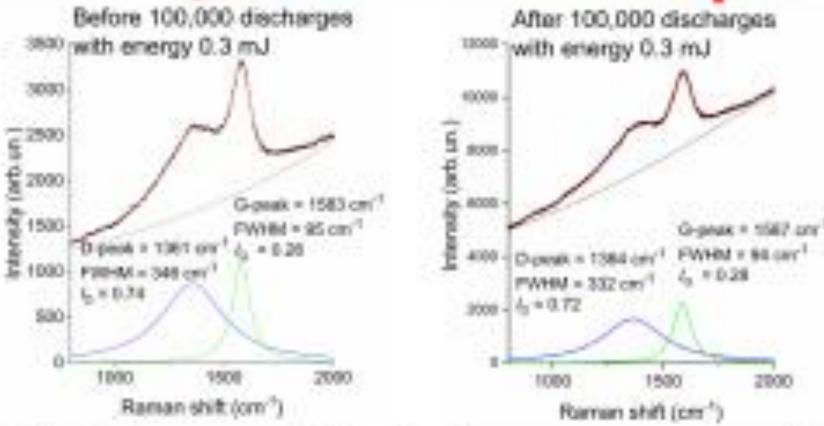
After **100,000 discharges** for active **area 60 x 60 mm²** a slight visible damage was observed

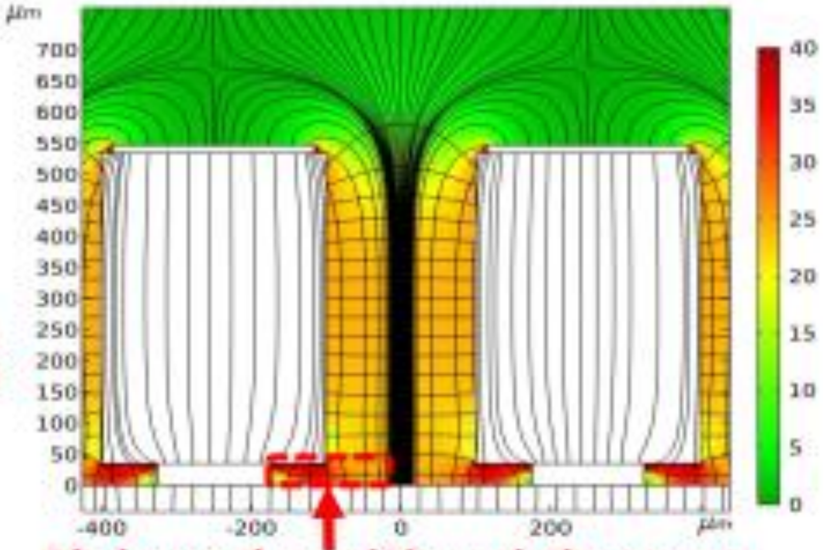
V.Bayev at al. IWAMSN-2024

EXAMPLE: R-WEM PROTOTYPE WITH DLC ANODE

Effect of Multiple Discharges on Accumulated Damage in R-WEM with DLC Anode







The further increase of the discharge energy by adding a capacitance up to C = 1 nF (active area **100 x 100 mm²**) resulted in a significant damage to the DLC layer and the perforated FR4 board after **100,000 discharges**.
Both plates of the detector were significantly damaged

- The HV-grid has a thickness of 35 µm and this results in a gap between the Perforated FR4 board and the Anode board.
- The electric field strength in this gap has a local maximum relative to the center of the multiplication hole.
- When the discharge occurs, the discharge channel does not terminate on the resistive layer directly under the multiplication hole but instead goes above the resistive layer through the gas in the gap and terminates into the metal of the charge evacuation grid.
- In this case the resistive DLC layer is completely bypassed and do not provide the expected detector protection.

The damage of DLC layer itself is small, because the discharge current pass through the gas gap

V.Bayev at al. IWAMSN-2024

WEM+DLC PROTOTYPE

Jinst

PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

RECEIVED: *March 30, 2023*
ACCEPTED: *May 22, 2023*
PUBLISHED: *June 1, 2023*

7TH INTERNATIONAL CONFERENCE ON MICRO PATTERN GASEOUS DETECTORS
REHOVOT, ISRAEL
11–16 DECEMBER 2022

Effect of multiple discharges on accumulated damage to the DLC anode layer of a resistive Well Electron Multiplier

V. Bayev,[a] K. Afanaciev,[a,b,*] S. Movchan,[c] A. Kashchuk,[d] O. Levitskaya[d] and V. Akulich[e]

[a]*Institute of Power Engineering of National Academy of Sciences of Belarus, 15/2 Academicheskaya st., Minsk, 220072, Belarus*

[b]*Dzhelepov Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, 6 Joliot-Curie st., Dubna, 141980, Russia*

[c]*Veksler and Baldin Laboratory of High Energy Physics, Joint Institute for Nuclear Research, 4 Baldin st., Dubna, 141980, Russia*

[d]*Petersburg Nuclear Physics Institute of National Research Centre "Kurchatov Institute", 1 Orlova Roshcha, Gatchina, Leningrad district, 188300, Russia*

[e]*Physical-Technical Institute of National Academy of Sciences of Belarus, 10 Kuprevich st., Minsk, 220141, Belarus*

WEM+DLC PROTOTYPE

Prototype sketch

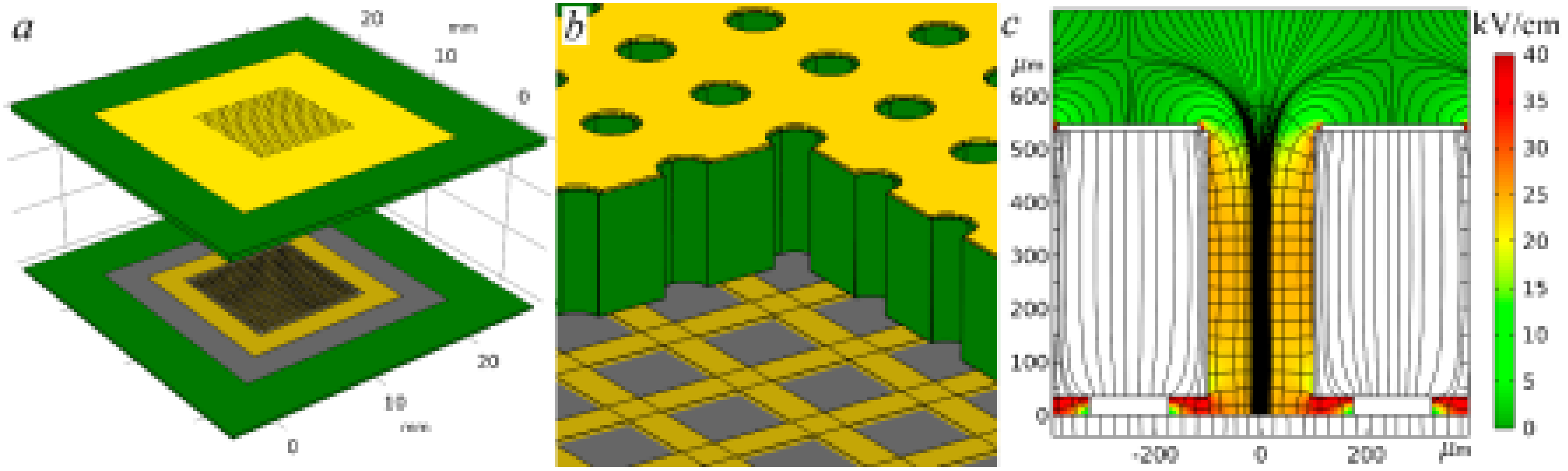


Figure 1. The sketch of WEM detector as a composition of two boards (*a*), Close-up sketch showing the position of the perforated FR4 board relative to the anode (*b*), electric field distribution modeled by Comsol Multiphysics software for +1300 V anode voltage (*c*).

Well Electron Multiplier (WEM)
(hole pitch=400 mkm, D=200 mkm thickness h=400 mkm, active size = 10x10 mm, Cd=34 pF)

DLC R= 30 MOhm/sq

Ar/CO_2 (90:10)

Edrift=1 kV/cm

Ua=+1310 V (gas gain G=3500)

Fe-55 - for gas gain control
Am-241, 33Bq – alpha particles (induce discharges with rate about N=30 cps)

WEM+DLC PROTOTYPE

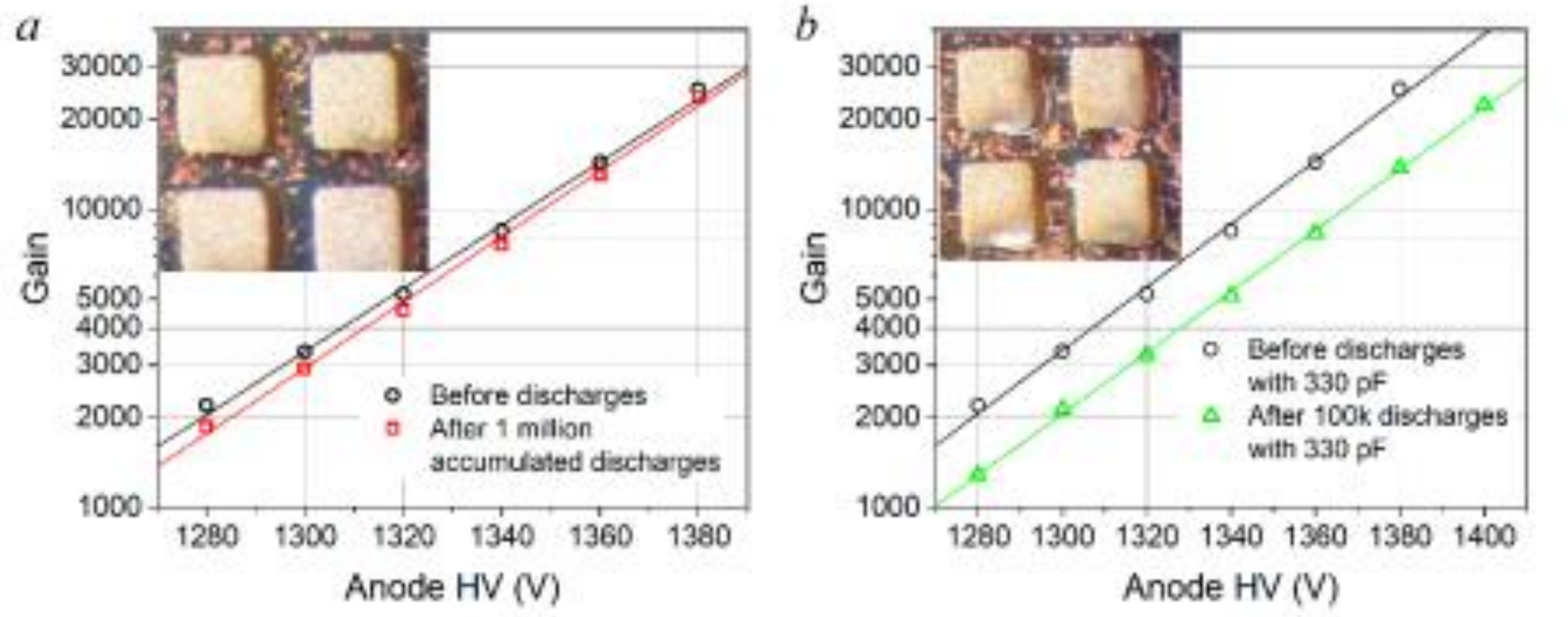


Figure 2. Gain vs HV before and after accumulating 10^6 (*a*) and 10^5 (*b*) discharges with an energy of 29 μJ and 0.3 mJ, respectively. The insets to the figures show the photographs of the anode plate with DLC layer after discharges of the corresponding energy.

For energy discharge:
29 mkJ (Cd=34 pF) : 1 million discharges – NO effect
300 mkJ (Cd=330 pF) : 100 k discharges – gas gain drop, but NO DLC degradation yet
900 mkJ (Cd=1nF): 100 k discharges – visible DLC damage
=> max segment size is 60x60 mm

MICROMEGAS + DLC PROTOTYPE

Nuclear Inst. and Methods in Physics Research, A 1031 (2022) 166528

ELSEVIER

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

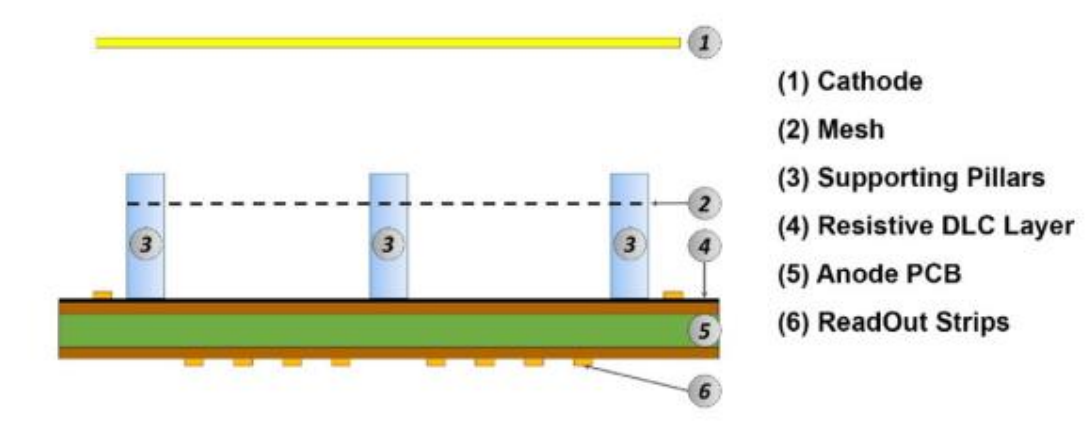
Improving the robustness of Micromegas detector with resistive DLC anode for the upgrade of the TPC readout chambers of the MPD experiment at the NICA collider

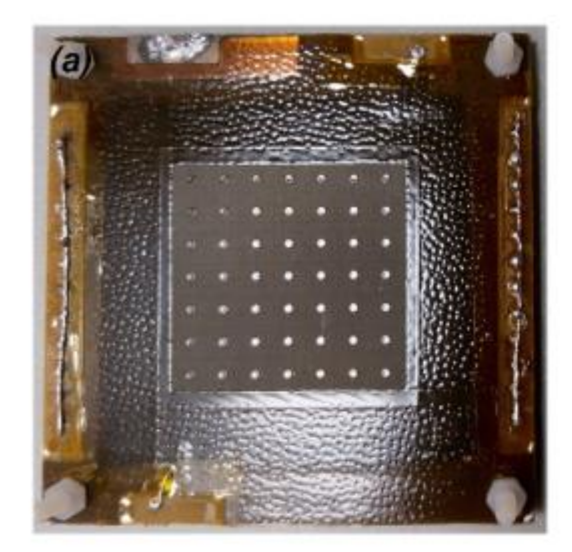
V.G. Bayev [a,*], K.G. Afanaciev [a,b], S.A. Movchan [c], A. Gongadze [b,d], V.V. Akulich [e], A.O. Kolesnikov [b], N. Koviazina [b], L. Gongadze [b], R. Sotenskii [b], I. Minashvili [b], Z. Chubinidze [b], I.A. Svito [f], O.L. Orelovich [g]

[a] *Institute of Power Engineering of National Academy of Sciences of Belarus, Minsk, Belarus*
[b] *Dzhelepov Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, Dubna, Russia*
[c] *Veksler and Baldin Laboratory of High Energy Physics, Joint Institute for Nuclear Research, Dubna, Russia*
[d] *Andronikashvili Institute of Physics, Tbilisi State University, Tbilisi, Georgia*
[e] *Physical-Technical Institute of National Academy of Sciences of Belarus, Minsk, Belarus*
[f] *Faculty of Physics, Belarusian State University, Minsk, Belarus*
[g] *Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia*

MICROMEGAS + DLC PROTOTYPE

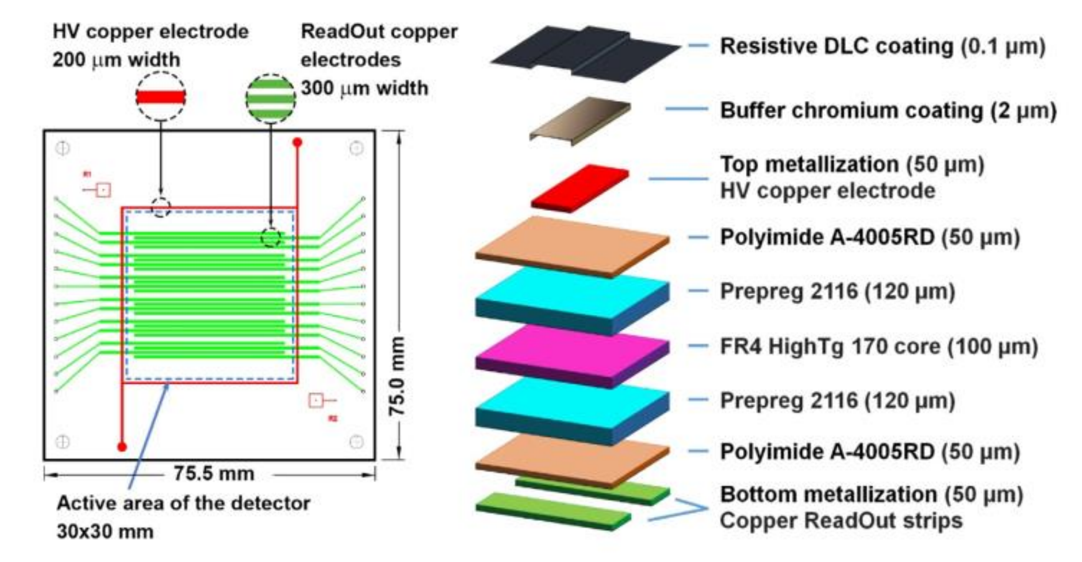
Prototype cross-section

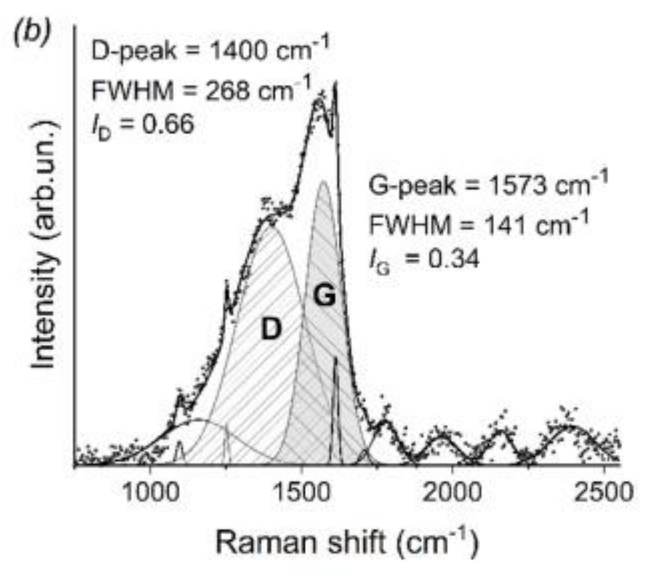




Active area: 30x30 mm

PCB layout and stack-up sketch





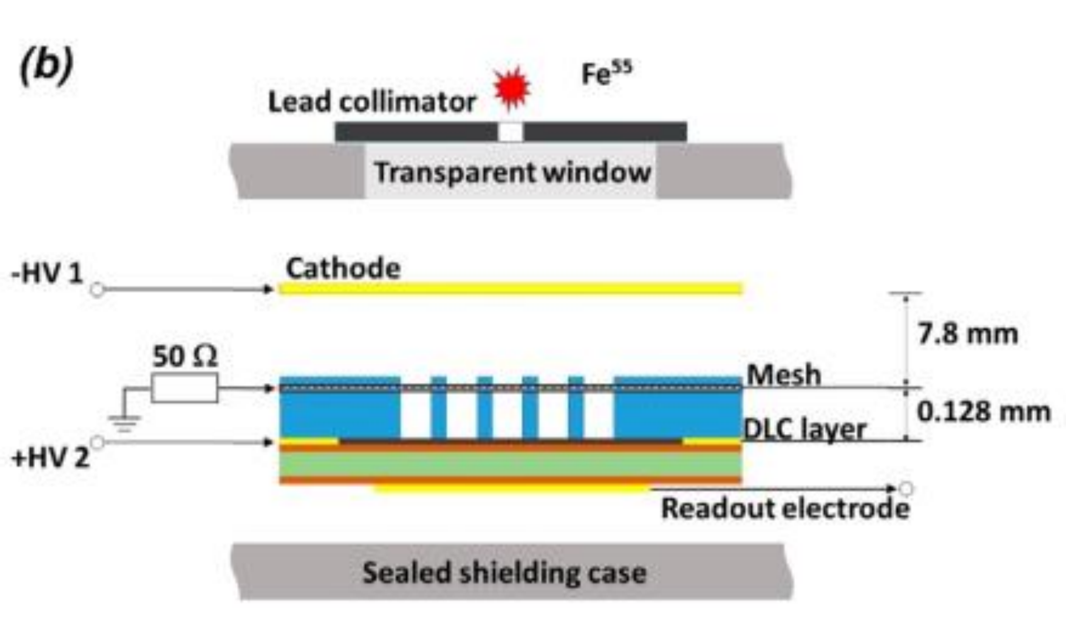
DLC:
- PVD method
- thickness – 100 nm
- R= 30 MOhm/sq

G peak – sp3 – “diamond”
D peak – sp2 – “carbon”

“Diamond” fraction – 34%

MICROMEGAS + DLC PROTOTYPE

Test setup



Test results

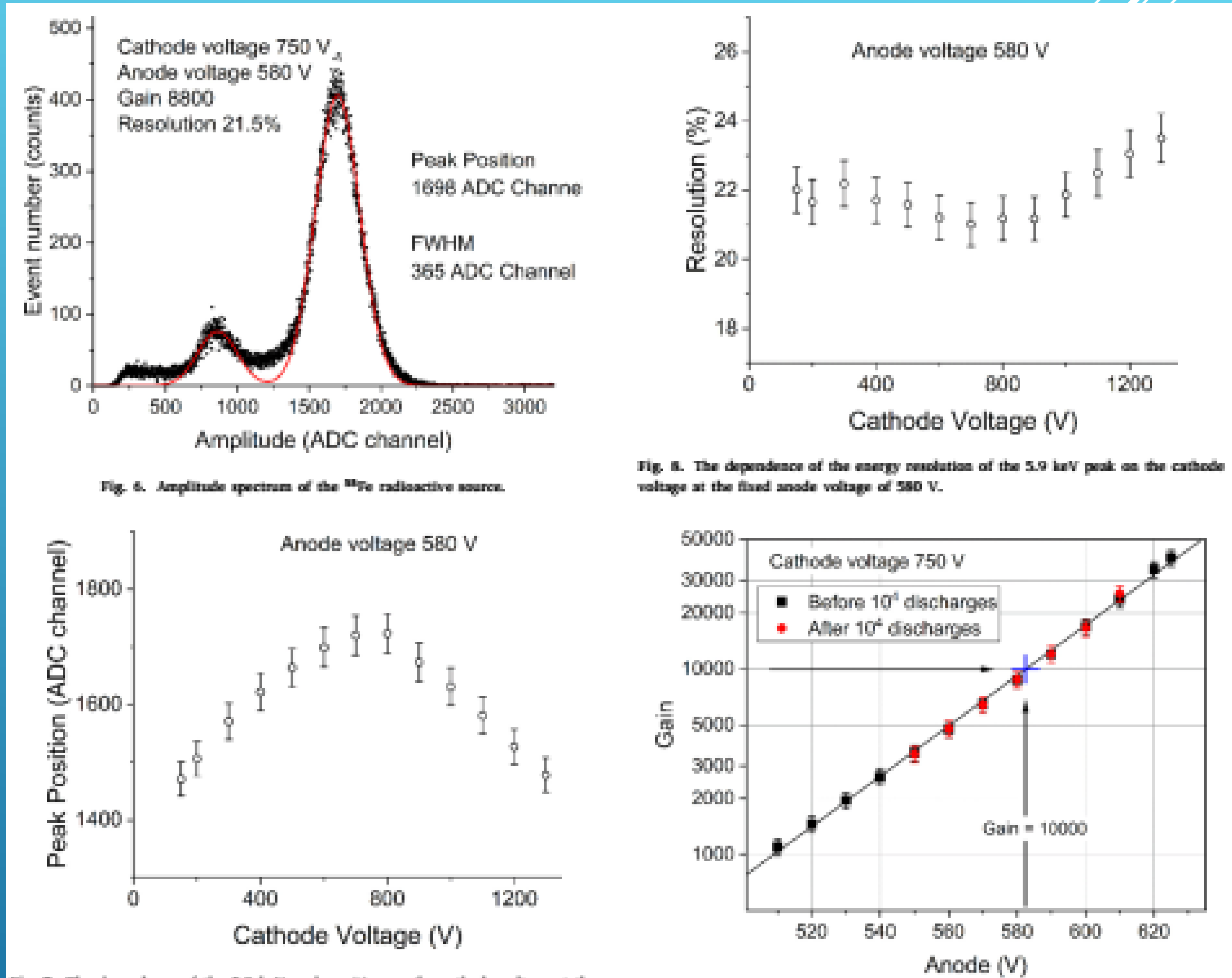


Fig. 6. Amplitude spectrum of the ^{55}Fe radioactive source.

Fig. 8. The dependence of the energy resolution of the 5.9 keV peak on the cathode voltage at the fixed anode voltage of 580 V.

Fig. 7. The dependence of the 5.9 keV peak position on the cathode voltage at the fixed anode voltage of 580 V.

Fig. 9. The dependence of gas gain on anode voltage.

10 000 discharges – NO visible DLC degradation

Dear colleagues!

WELCOME to MPD TPC upgrade program:

- **minimization of TPC End cap radiation length:**
  - **new ROC chamber R&D (carbon frame, GEM, ThGEM, MicroMegas, WEM …)**
  - **FE electronics (preamps on pad plane, links to FPGAs, rad hard FPGAs …)**
  - **Al LV cables**

- **R&D: DLC properties study and search other resistive materials (for spark protection)**

- **R&D: MPGD + DLC prototypes and study**

- **manufacture of new serial ROC chambers (30 pc)**

- **upgrade TPC gas system**

Thank you !!!