

MPD/NICA TPC status (18.06.2019)

- TPC main components
- ROC chambers
- front end electronics
- gas, cooling and laser systems
- integration TPC to MPD
- time schedule

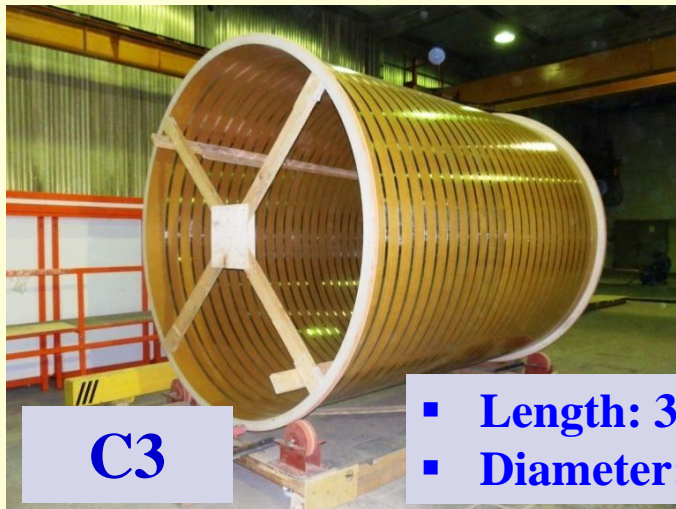
Presented by Sergey Movchan

JINR team: 23+1 persons

Belarus: 5+1 persons

(INP BSU- ARTMASH: A.Litomin, V.Tchekhovskiy, S.Savitskiy, V.Baev, K.Afanasiev, Yu.Fedotova)

TPC cylinders: **C3** assembling



C3

- Length: 3.4 m
- Diameter: 2.66 m



Status:

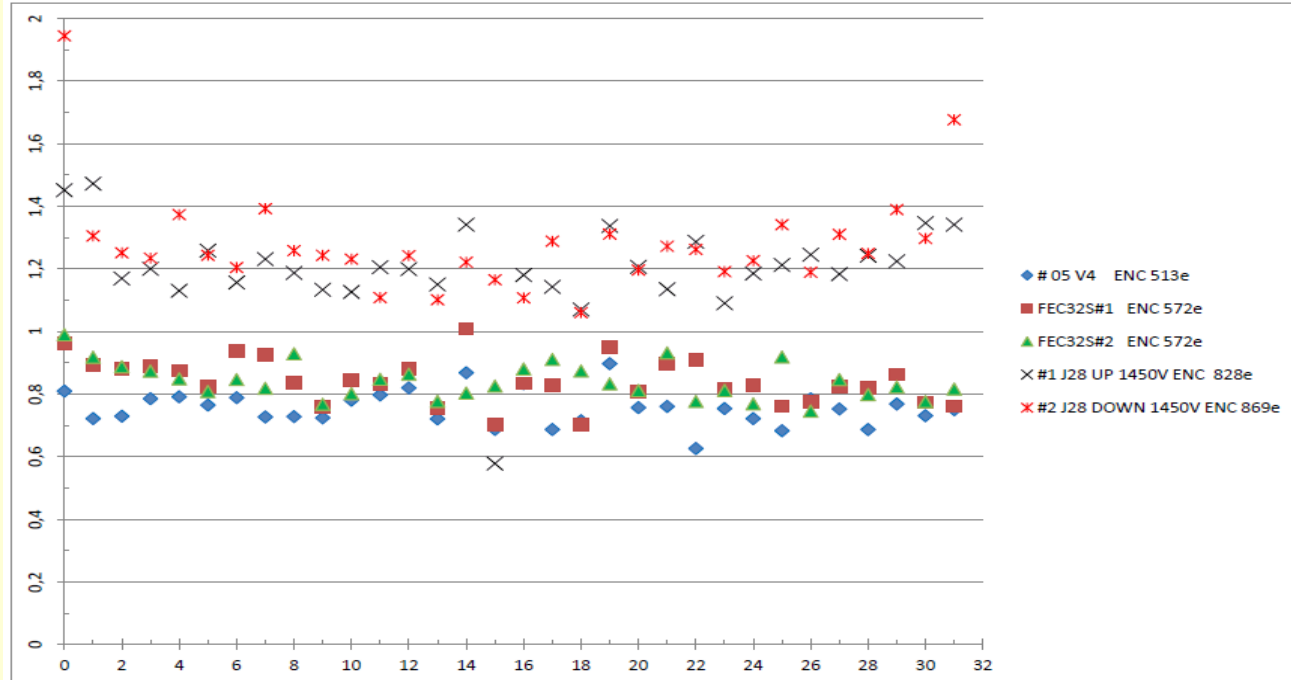
- HV resistive divider assembled
- preparation for gluing

Plans:

- | | |
|----------------------|-------------|
| HV test | - next week |
| gas inlets gluing | - next week |
| delivery C4 | - June 25 |
| start assembly C3-C4 | - July 1 |
| C3-C4 ready | - July 25 |

Start TPC assembly (flanges, HV electrode, field cage) - end of July

ROC chamber: test SAMPA chip with ROC pads



ROC-chamber tested with test board with SAMPA chip (HV=+1450 V):

ENC = 828 e- (for small pads), ENC = 869 e- (for big pads)

Factor – x 1.2 relatively test bench -> due to digital noise - study ...
test FE screening and GND options

TPC and ROCs: summary

TPC assembly:

clean room	– ready
C1-C4 cylinders	– ready
flanges (2pc)	- ready
serial HV electrode	- ready
adjust. and align. TPC assembly tooling	– Feb 2019 -> May 2019 -> July 2019
field cage rods (30 pc + 30 pc)	– March 2019 -> May 2019 -> July 2019
field cage mylar strips manufacture	– April 2019 -> June 2019, ok!
TPC assembly (C3+C4)	- June 2019
flanges + HV electrode + field cage	- Aug 2019, ok!
HV test and leak test	- end of 2019, ok!

ROC chambers:

frames (26 pc)	- ready
serial pad planes (30 pc)	– postponed, ordering 6 pc <--> in progress
HV for ROC gate electrode	– design started, in progress
test chamber with 512 ch r/o system	– Aug 2019 -> Sept 2019
serial ROC chambers manufacture	- 2019-2020, ok!

TPC electronics: requirements

Dose:

Expected dose - **1 kRad** per 10 years

Particles fluence for $R=35$ cm & 10 years (very preliminary):

neutrons + protons - **2.5×10^{10}** p/cm² per year
e- & e+ - **1×10^{10}** p/cm² per year
ions - **0.5×10^5** p/cm² per year

SAMPA v3/v4 tested at:

proton fluence - up to $N=10^{12}$ per cm²

ion fluence - up to $N=10^7$ per cm² & $LET=(3-125)$ MeV cm²/mg

T chip=(45-85) degree \Rightarrow **$SEL=1 \times 10^{-7}$ cm² for $LET=16$ MeV cm²/mg**

TID and SEL - ok!

FPGA Cyclon V (technology -130 nm):

TID – up to 100 kRad, $SEL < 0.5$ sec for $LET=26.6$ MeV cm²/mg

TID – ok!, SEL – BAD or acceptable for MPD conditions ???



2004

TID and SEE Testing Results of Altera Cyclone Field Programmable Gate Array

Stephen L. Clark

Missouri University of Science and Technology, sclark@mst.edu

K. Avery

R. Parker

100 kRad

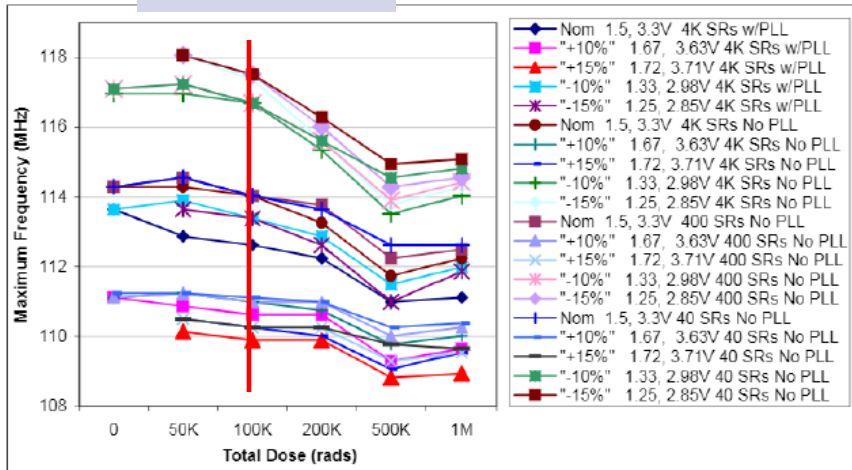


Figure 1. Maximum Frequency vs. TID.

V. CONCLUSION

The Altera Cyclone device exhibited latchup at LET levels below 35 MeVcm²/mg. As a result, the part is deemed unusable in space applications, as it currently exists. If future versions of the Cyclone or the Stratix family do not exhibit this latchup problem, then the remainder of the SEE evaluations can be completed.

The TID results of the Cyclone devices demonstrated the potential of 130 nm bulk CMOS technology. Without any attempt to harden the part, the devices survived to at least 1 Mrad (Si) with little performance degradation. This shows

100 kRad

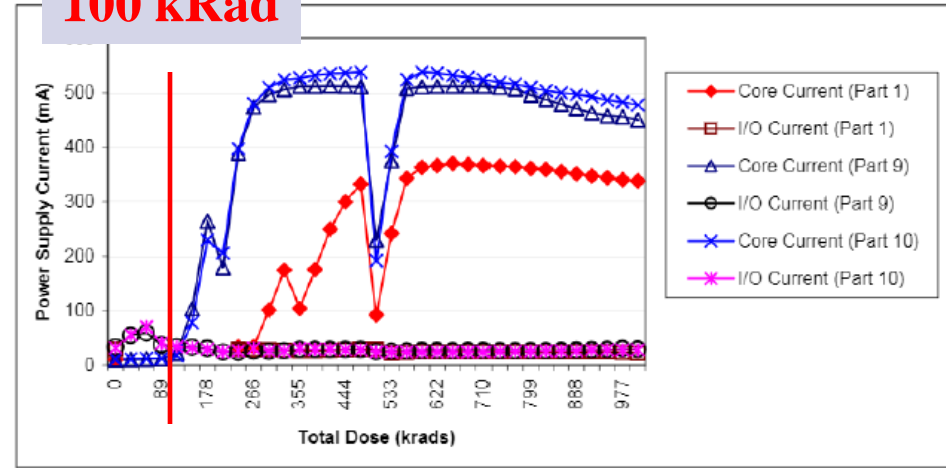


Figure 2. Supply Currents vs. TID.

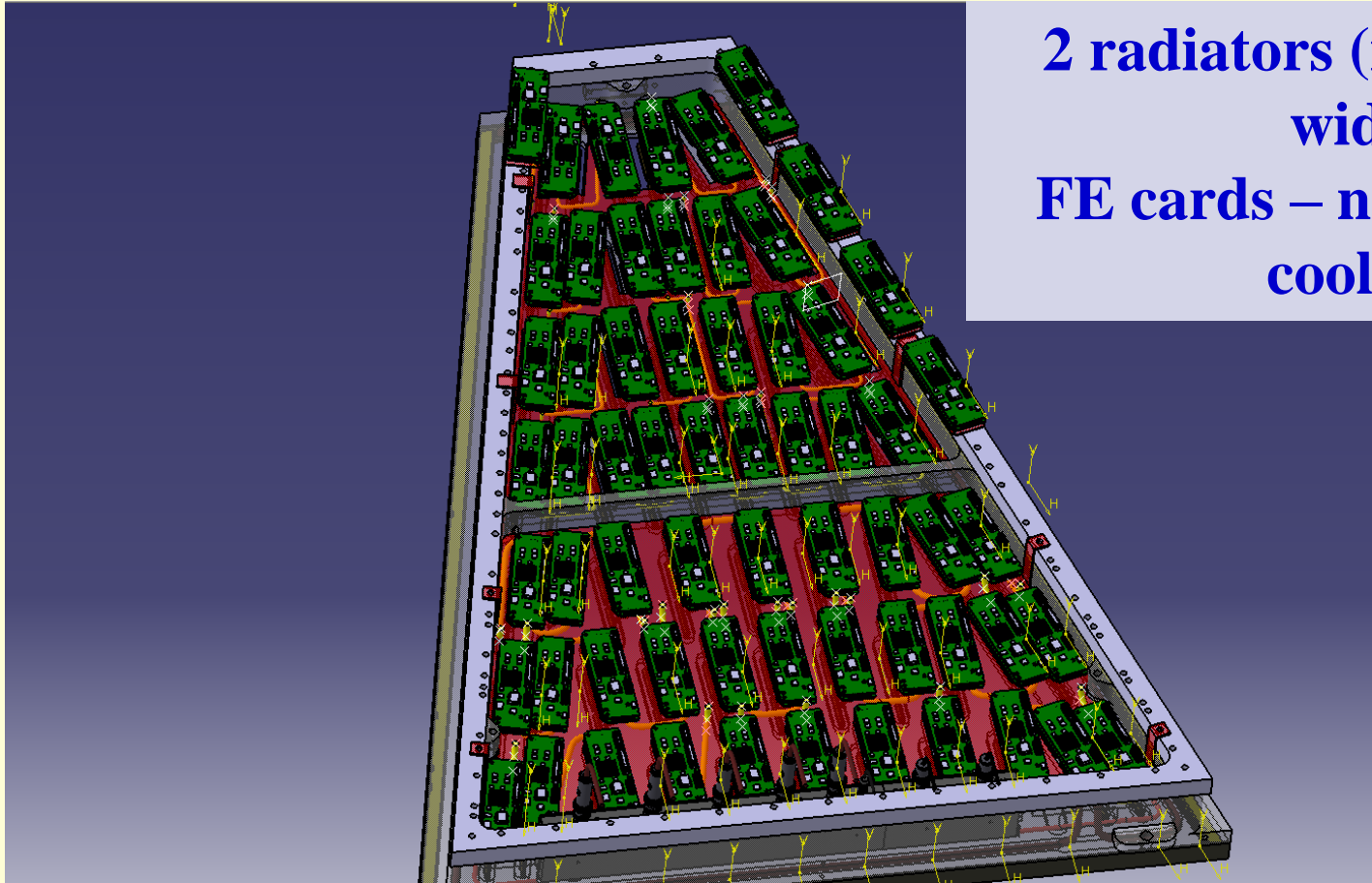
that standard commercial design methodologies are capable of producing devices resistant to TID at the 130 nm technology node.

VI. REFERENCES

[1] Cyclone FPGA Family Data Sheet; Altera Corporation, 101 Innovation Drive, San Jose, CA 95134

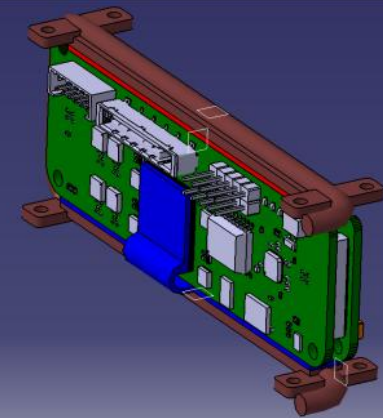
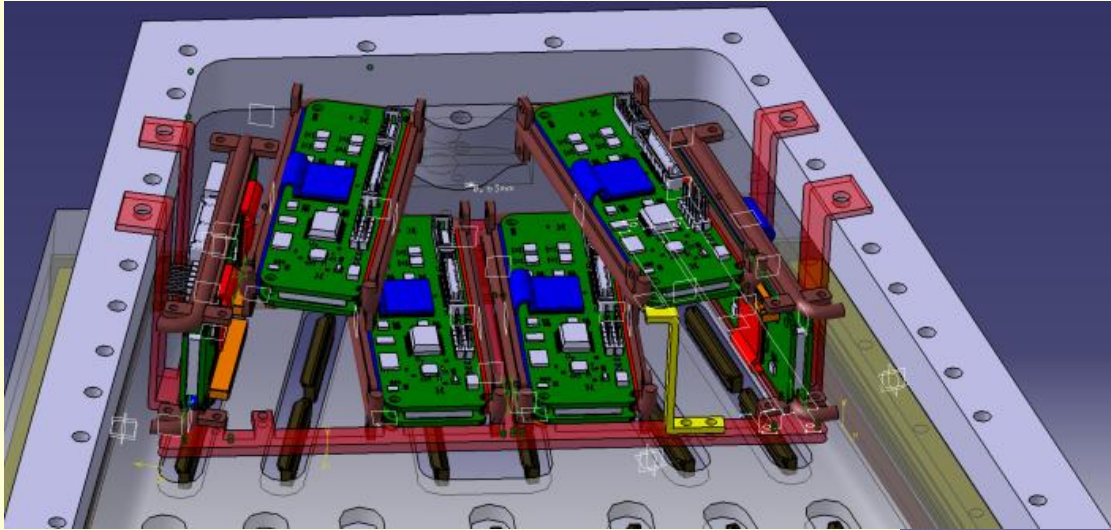
Technology 130 nm:
TID: up to 1 MRad
Latch-up: time < 0.5 sec at
26.6 MeVcm²/mg

TPC electronics: FE cards integration and cooling (option 1 – base line)



2 radiators (narrow and wide)
FE cards – no individual cooling

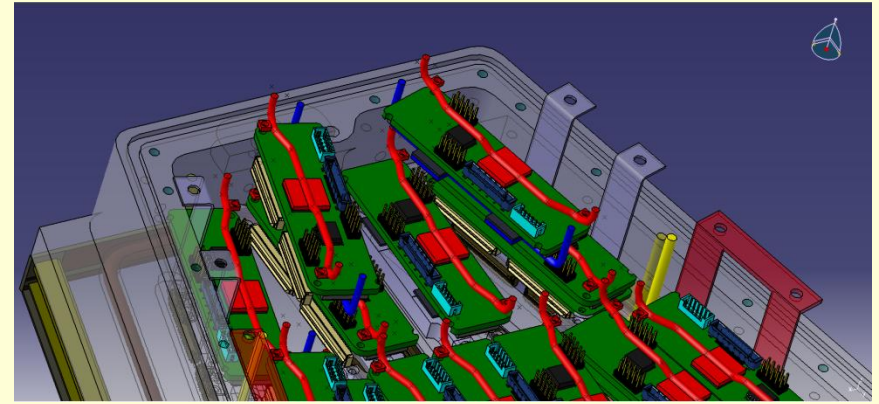
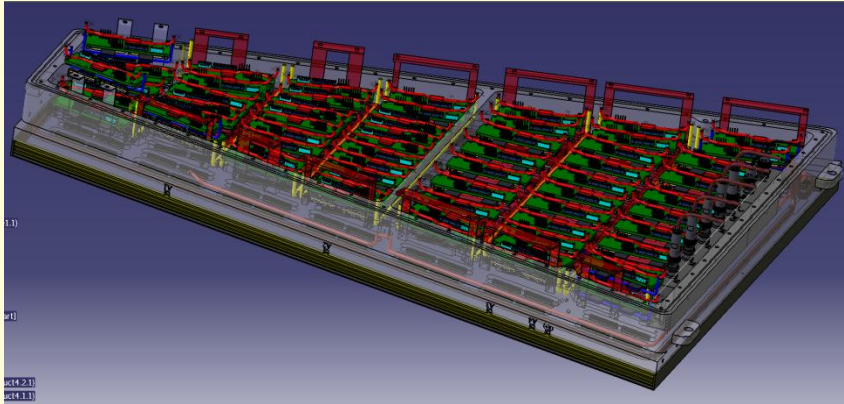
TPC electronics: FE cards integration and cooling (option 2)



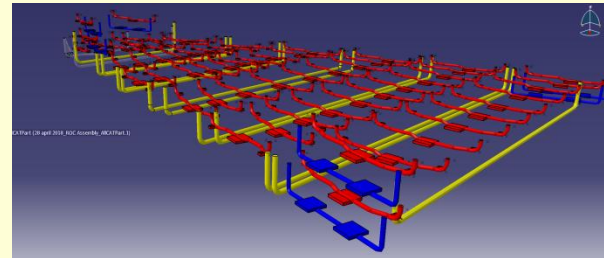
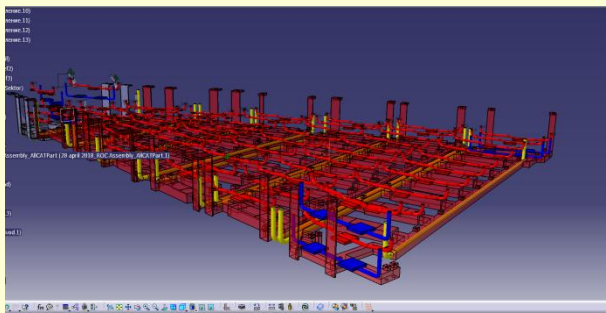
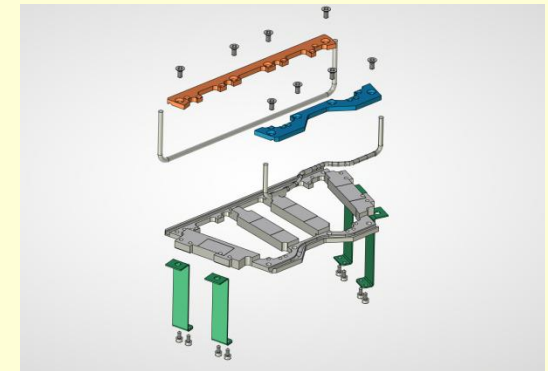
Both FE cards cooling by tube

Status: in progress

TPC electronics: FE cards integration and cooling (option 3)



Many radiators (8pc):
SAMPAs - cooling by radiator
FPGA – cooling by pad with tube



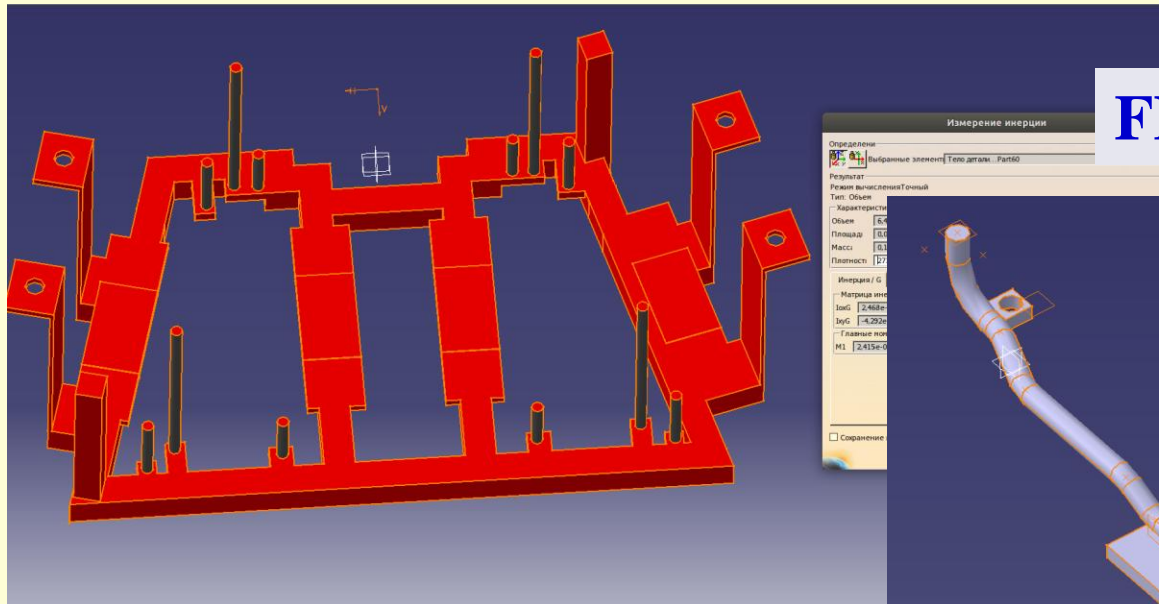
18-Jun-19

S.Movchan MPD/NICA TPC status

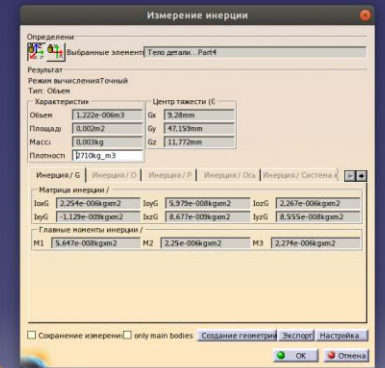
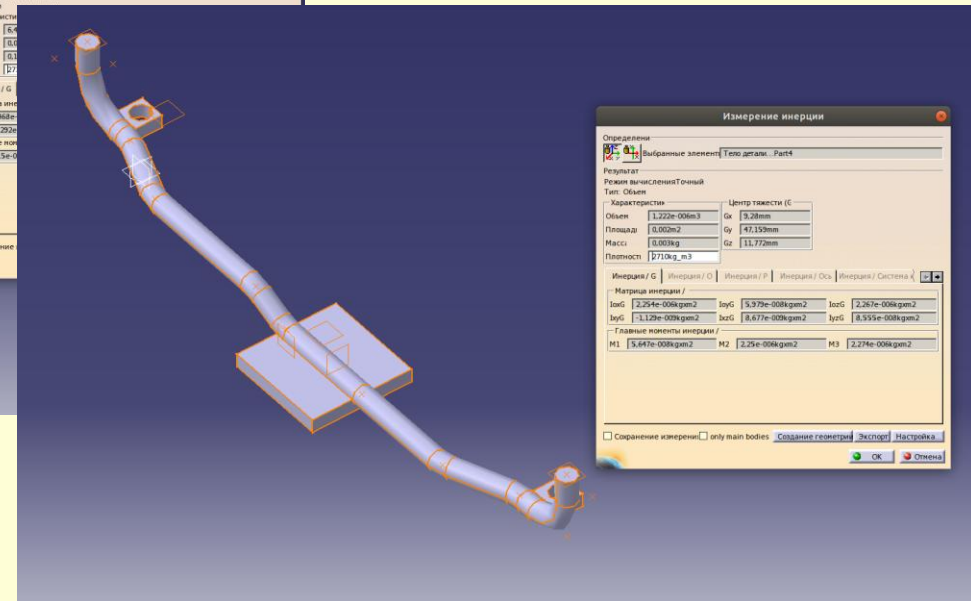
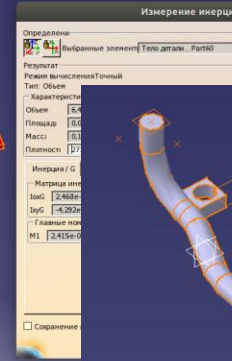
Status: in progress

TPC electronics: FE cards integration and cooling (option 3)

SAMPA cooling radiator

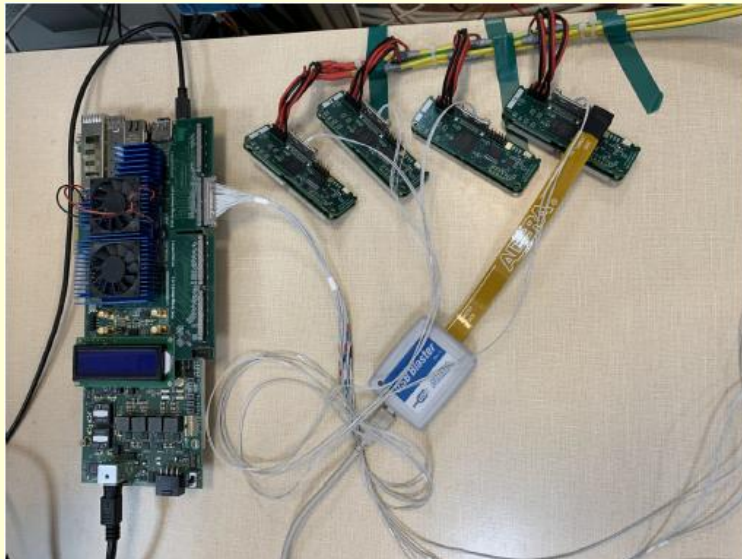


FPGA cooling radiator



TPC electronics: status and schedule

**Test bench
based on commercial kit
(ARIA-10 FPGA)**



Tests – in progress

Item	Date	
Testing FEC v1.0 finished	Feb. 2019	✓
Preproduction version FEC v2.1 PCBs ready	June 2019	Ok!
Delivery of SAMPA v4 chips to Dubna	June 2019	Ok!
Assembly FEC v2.1 boards (32pc)	July 2019	Ok!
Installation of FEC v2.1 boards (32pc) to ROC chamber	Aug. 2019	
Start tests of ROC chamber in Bld.40	Sept. 2019	
Finish tests of ROC chamber in Bld.40	Oct. 2019	
Production version FEC v2.2 PCBs ready	Dec. 2019	
Assembly FECs v2.2 boards (62pc, 1-st ROC, total 1)	Feb. 2020	
Instrumented and test ROC-1 in Bld.40	Apr. 2020	
Assembly FEC v2.2 boards (186pc) (3 ROCs, total 4)	May 2020	
Instrumented and test ROC-2, 3 & 4 in Bld.40	June 2020	
Assembly prod. ver. FECs (620pc, 10 ROCs, total 14)	July 2020	
Assembly prod. ver. FECs (620pc, 10 ROCs, total 24)	Aug. 2020	

TPC electronics: summary

FE electronics:

512 ch system FEC v1.0

test with ROC chamber

SAMPA chips (4500 pc)

Aria 10 GX FPGA for controller (**20 pc**)

Data concentrator chip (NRNU MEPHI)

FEC64SAM v.2 (10 pc)

FE cards integration with ROC chamber

FE cards cooling design

FE card temperature distribution

(T board ~ 40 degree, SAMPAs and FPGA ~ 60 degree) ... in progress

ROC+FE cards temperature distribution – **in progress** (calculations)

controller based on commercial kit

– tested, **links error** – **study**

– Aug 2019 -> **Sept 2019**

– delivery to JINR June 2019, **ok!**

- delivered to JINR, **ok!**

- design in progress -> **postponed**

– delivered, **ok!**

- **in progress**

– in progress, **3 options**

– calculations and meas. started

- **in progress**

INP BSU (Minsk): TPC LV system

- | | |
|---------------------------------------|----------------|
| Pre-serial LVDB prototype | – manufactured |
| cooling plate | – manufactured |
| Pre-serial LVDB prototype tests | – done |
| LVDB mass-production (60 pc) | - done |

Ok!



LV system (2 options):

- Wiener Marathon (Type AL (300G) MDC 02/07)
up to 300 Gauss and 30 Rad
- CAEN EASY3000 LV system (module type A3100B 2÷7V/100A)
up to 5000 Gauss and 200 Rad

https://indico.cern.ch/event/699390/contributions/2868537/attachments/1593340/2522493/Neolite_RandD_effortSummary.pdf

Status for CAEN option:

- invoice for LV test system – **OK!** delivery time – (3÷4) months
- invoice for HV system – **OK!** delivery time – (90÷150) days

in progress ...

TPC gas system

Gas supply



Status - commissioning
in progress

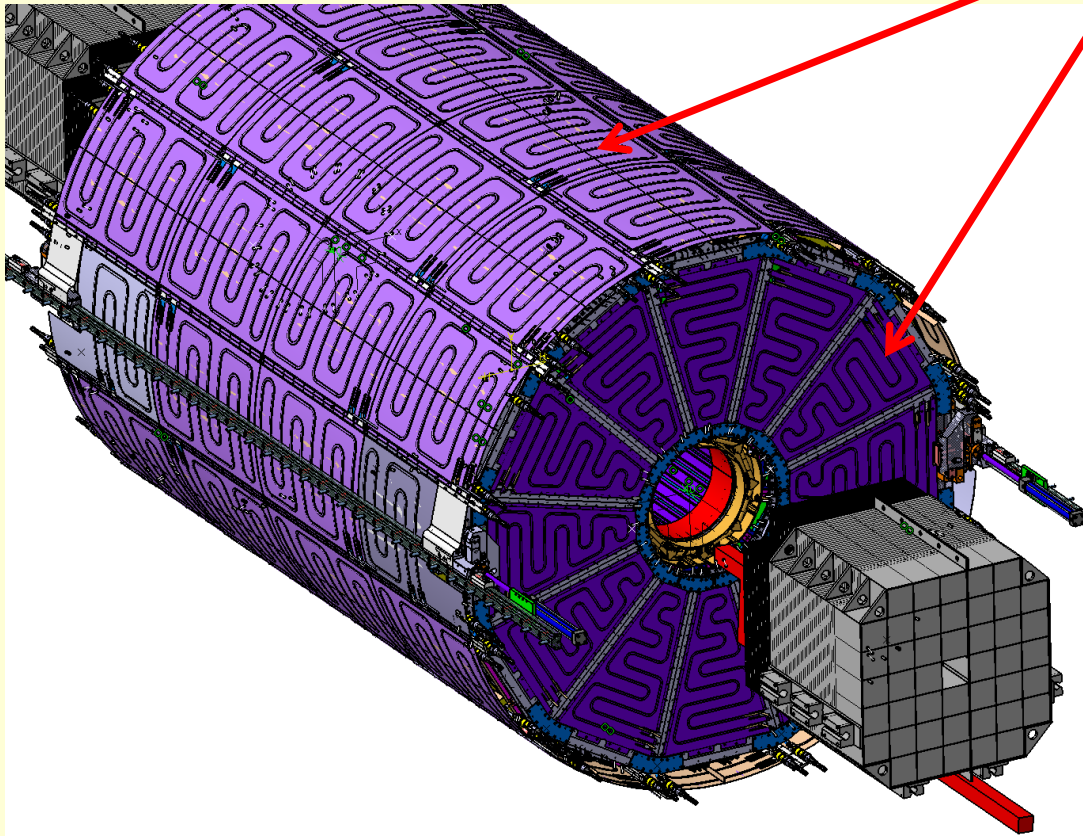
Racks

TPC volume
imitator



Status - commissioned (Bld.217)

TPC cooling system: **new** thermal screens concept

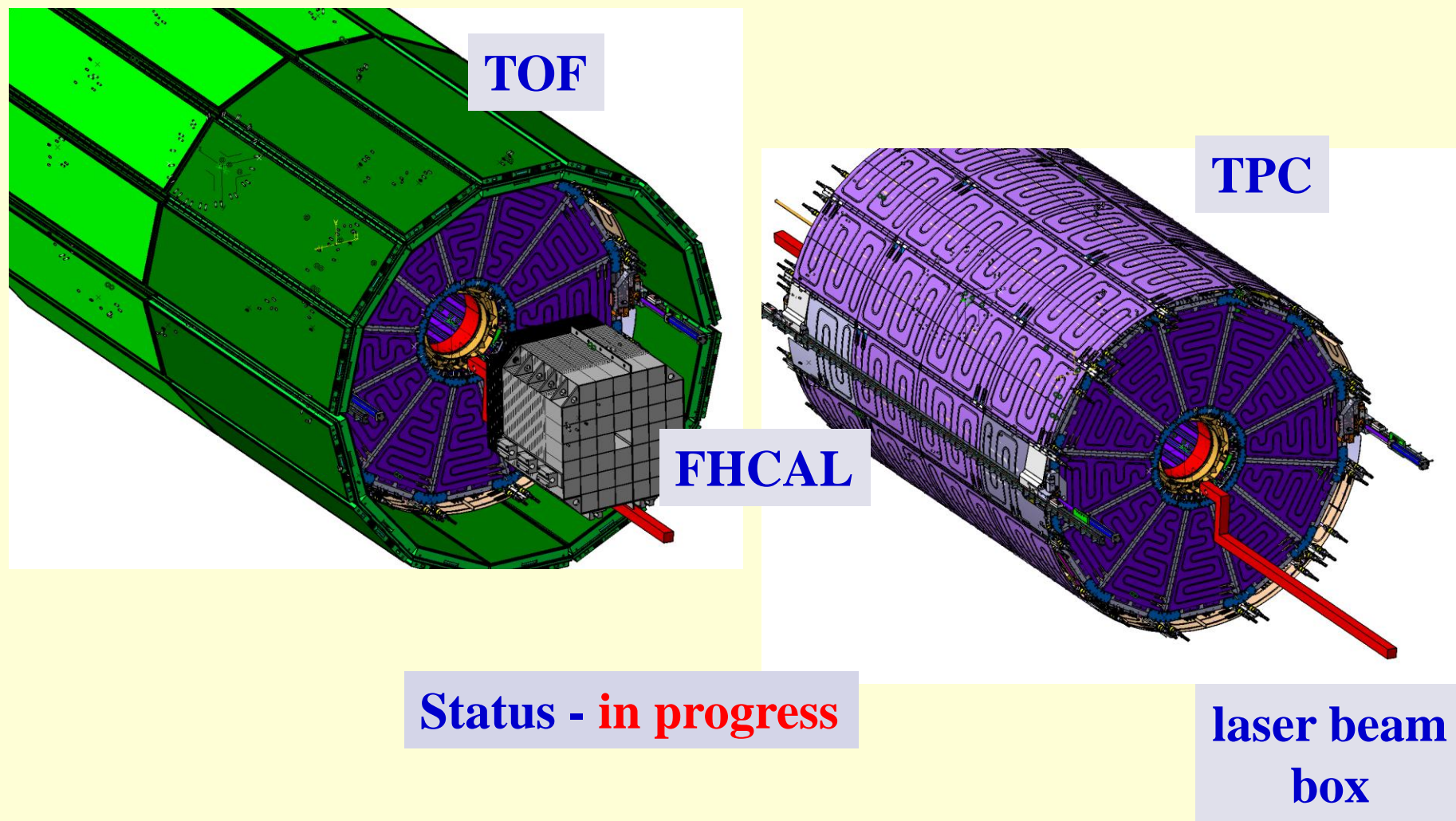


Barrel part – shorter and fixed to TPC instead fixation to ECAL Structure

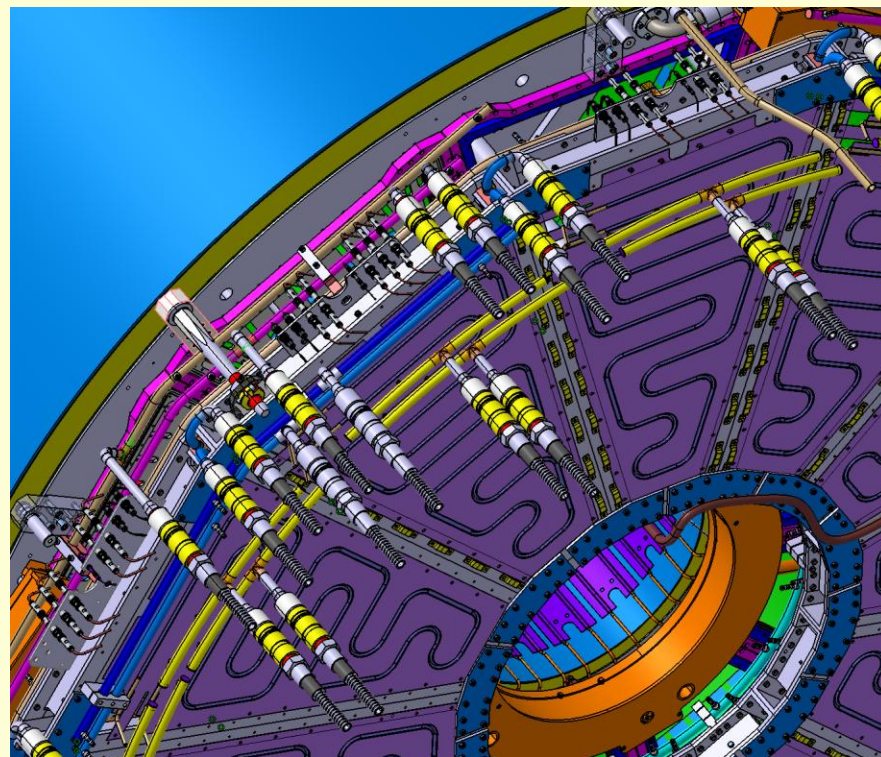
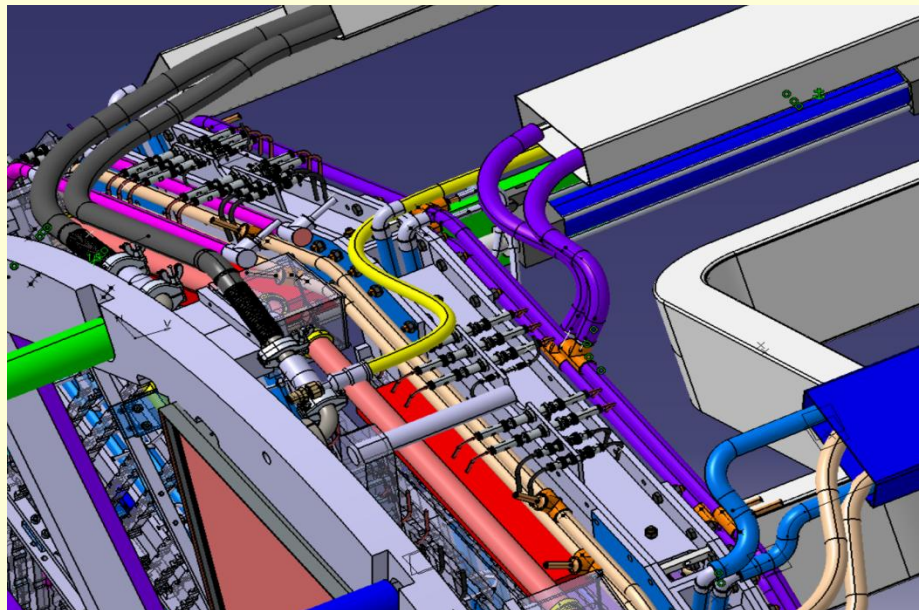
under discussion ...

New thermal panel prototypes - will be **delivered soon**

TPC laser calibration system: laser beam layout (proposal)



TPC: cables and tubes integration



Optimization - in progress

TPC services: summary

LV system:

pre-serial LVDB + cooling plate (4 pc)

serial LVDB (60 pc)

serial LVDB cooling plate

CAEN EASY3000 LV test system

CAEN HV system

Wiener Marathon

– ready, tested

– assembled, tested, **delivered to JINR**

– designed and ordered, **prototyping**

- invoice got, **in progress**

- invoice got, **in progress**

- **under discussion**

HV system:

CAEN HV system (crate + modules)

- invoice got, **in progress**

Gas system:

- commissioned, cryogenic vessels commissioning - **in progress**

Cooling system:

FE cooling prototype

measurements with prototype

barrel and end cap thermal panels

service wheel cooling tubes routine

– **option 1 and 2 - designed, option 3 - ready**

– **in progress**

– new prototypes ordered, **delivered soon**

– prototyping done, optimization- **in progress**

TPC services: summary (continue)



Laser calibration system:

lasers (2 pc)

- commissioned

laser beam splitter and transport system - in production, will be delivered

May 2019 → July 2019

beam monitors (WEB cameras + optics)

- ordered, **in progress**

channel for laser beam inside MPD

- new layout proposed, **in progress**

INTEGRATION:

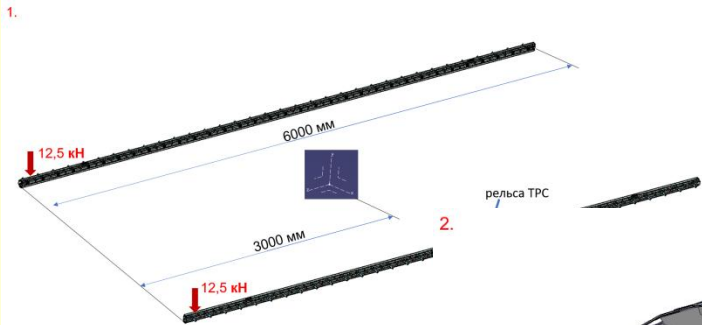
TPC sub-systems integration - in good shape

list of TPC cables and tubes – **updated**

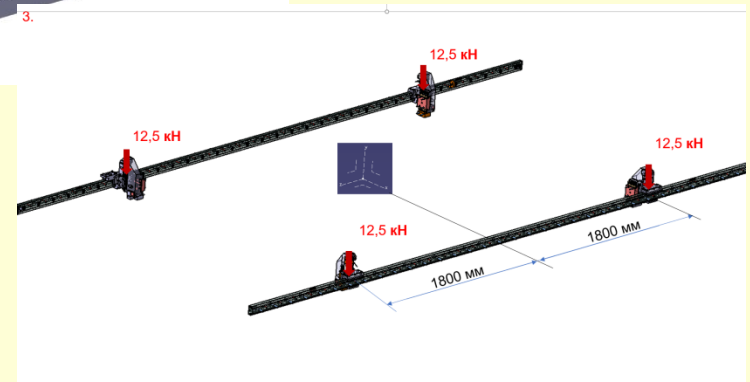
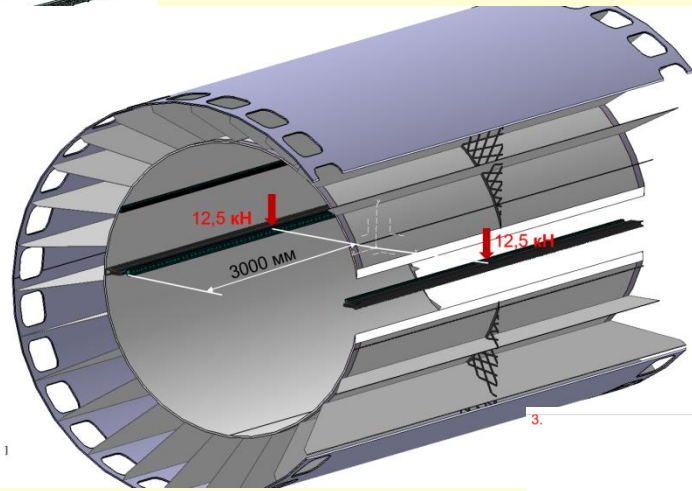
Integration TPC into MPD – **started**

(nevertheless waiting for final ECAL design and sub-system integration to MPD)

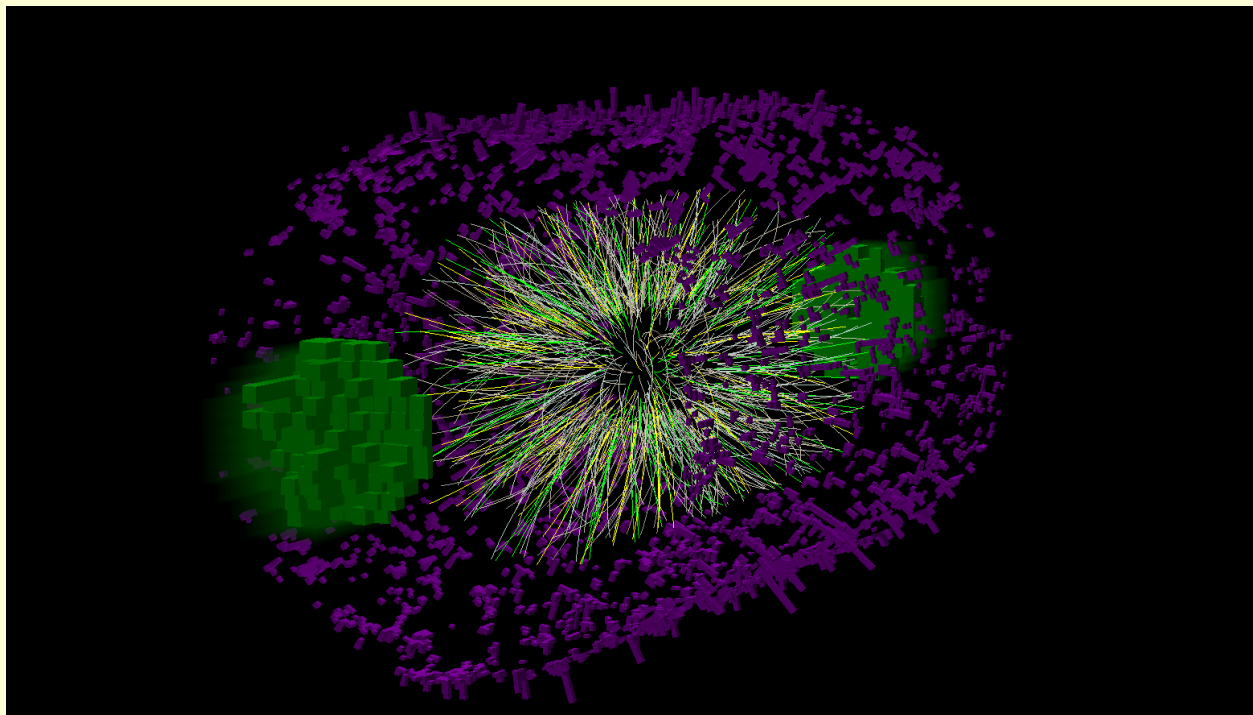
TPC load to rails: scheme



F=5 ton



Thank you for attention!



<http://nica.jinr.ru/>
<http://mpd.jinr.ru/>

TDR TPC – <http://mpd.jinr.ru/wp-content/uploads/2019/01/TpcTdr-v07.pdf>



TPC April 2019 status

(see below)

MPD/NICA TPC status (16.04.2019)

- clean room and tooling for TPC assembly
- TPC main components
- ROC chambers
- front end electronics
- gas, cooling and laser systems
- integration TPC to MPD
- time schedule

Presented by Sergey Movchan

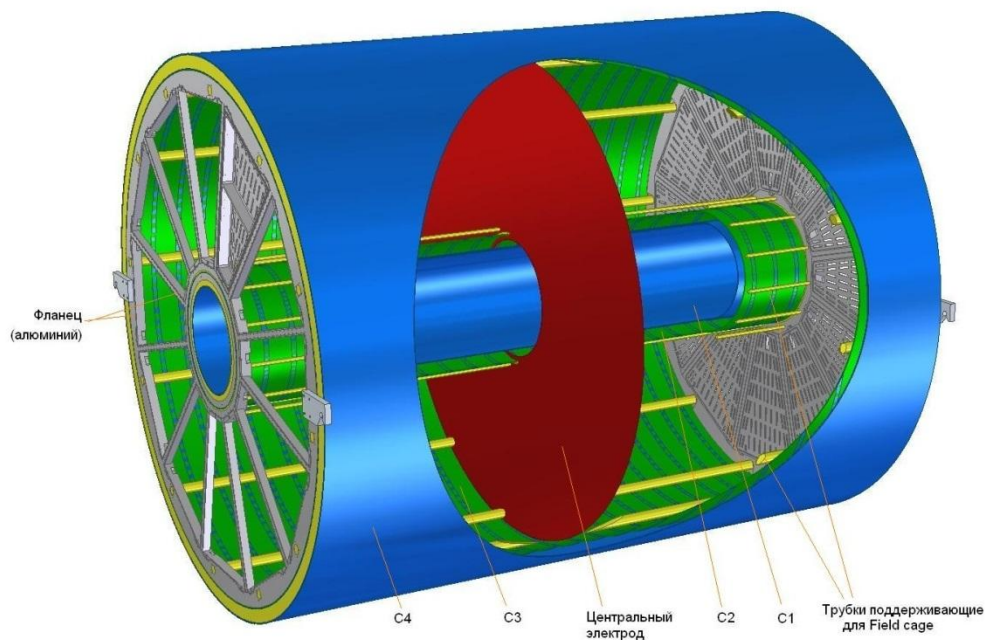
JINR team: 23 persons

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(INP BSU- ARTMASH: A.Litomin, V.Tchekhovskiy, S.Savitskiy, V.Baev, K.Afanasiev)

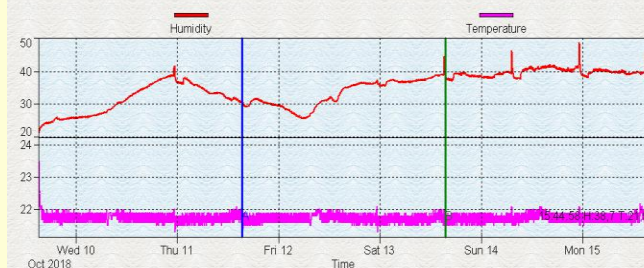
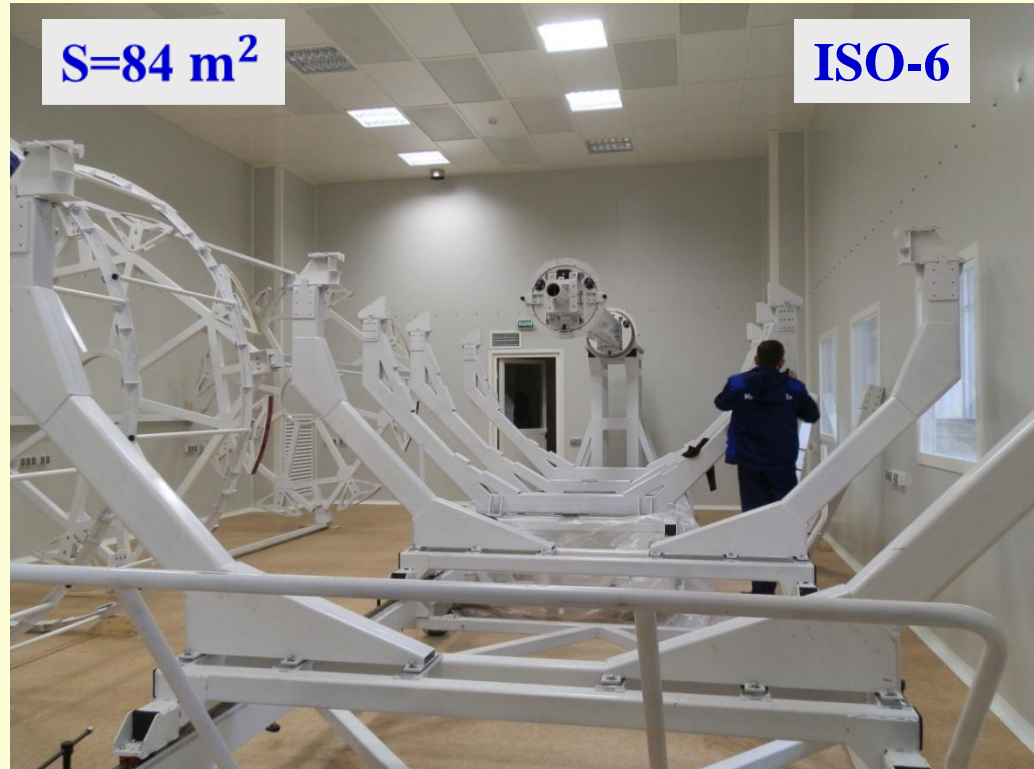
MPD TPC parameters

Корпус TPC/MPD



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 clean room (LHEP, bld.217) – common view



$H \leq 40\%$
 $T = (21.75 \pm 0.25^\circ\text{C})$

TPC cylinders: C1-C4

C1

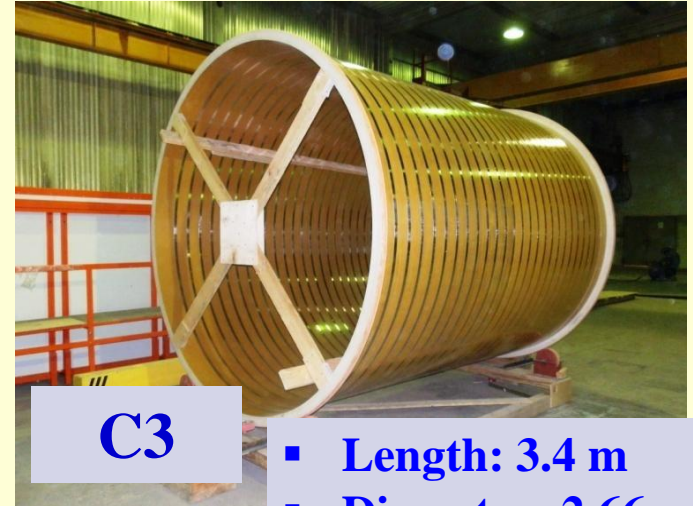


- Length: 3.4 m
- Diameter: 0.54 m

C2



- Length: 3.4 m
- Diameter: 0.676 m



C3

- Length: 3.4 m
- Diameter: 2.66 m



C4

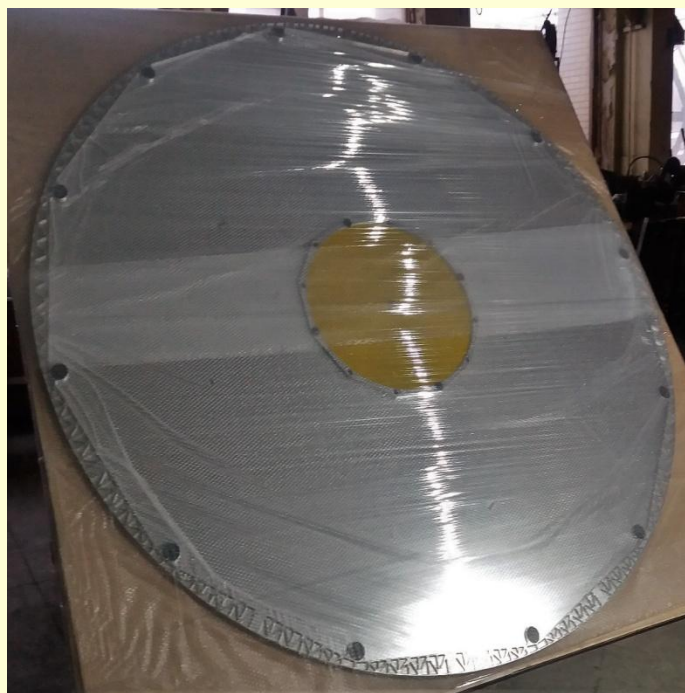
- Length: 3.4 m
- Diameter: 2.814 m

TPC status: delivered to JINR

Tooling for HV rods and strips assembly



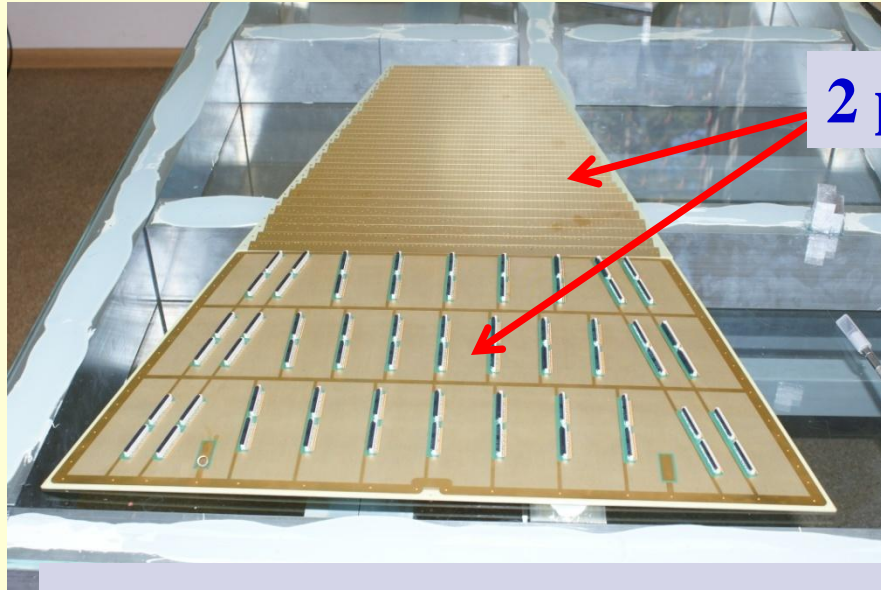
Serial HV electrode



TPC flanges

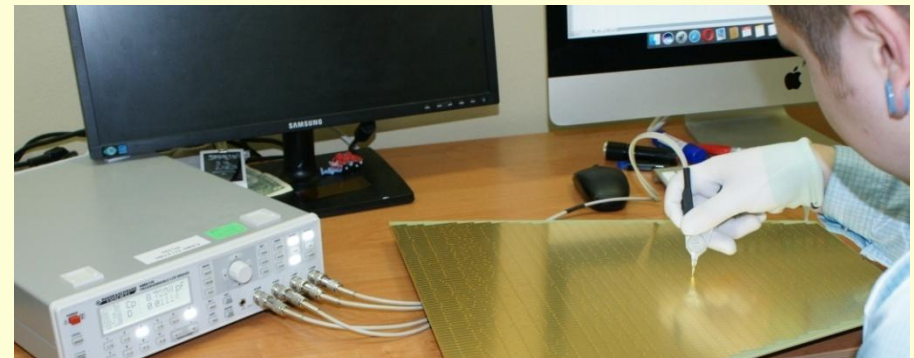


ROC chamber: pad plane from 2 parts



2 parts

Pads capacitor
measurement



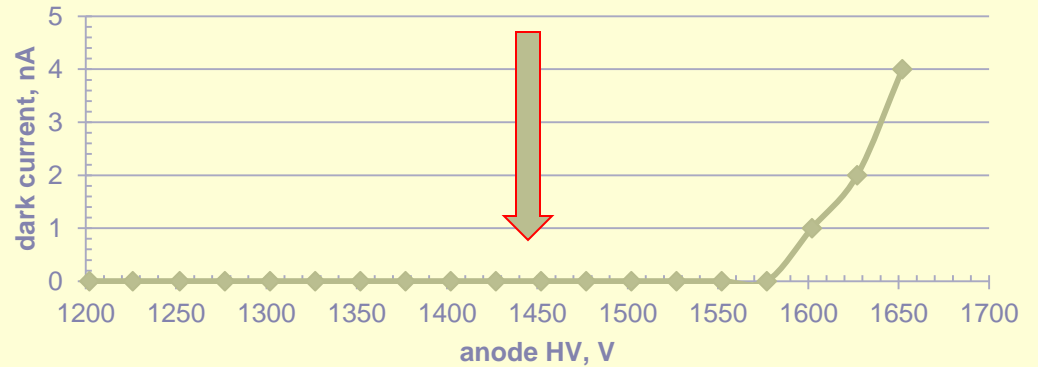
Chamber with 2 sections pad plane - **manufactured and under tested**

New pad plane from Italy - **tested**

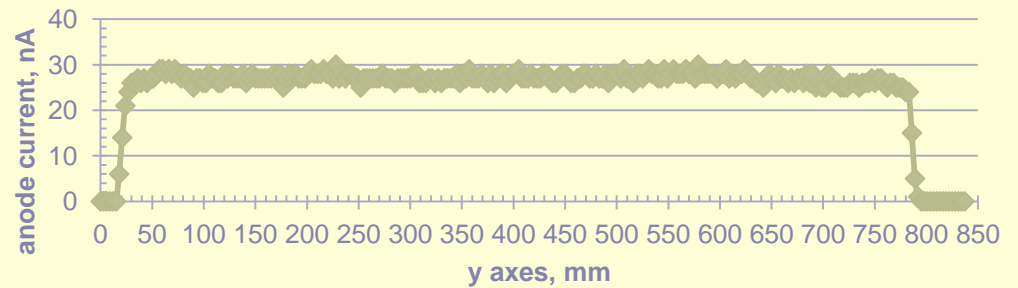
ROC chamber: test results



ROC-14, Ar/CH4 (90/10), dark current



ROC-14, Xray line scan, step 3 mm, Ar/CH4 (90/10), $U_a = 1,45$ kV, $U_{dr} = -1120$ V, **uniformity 18,4%**



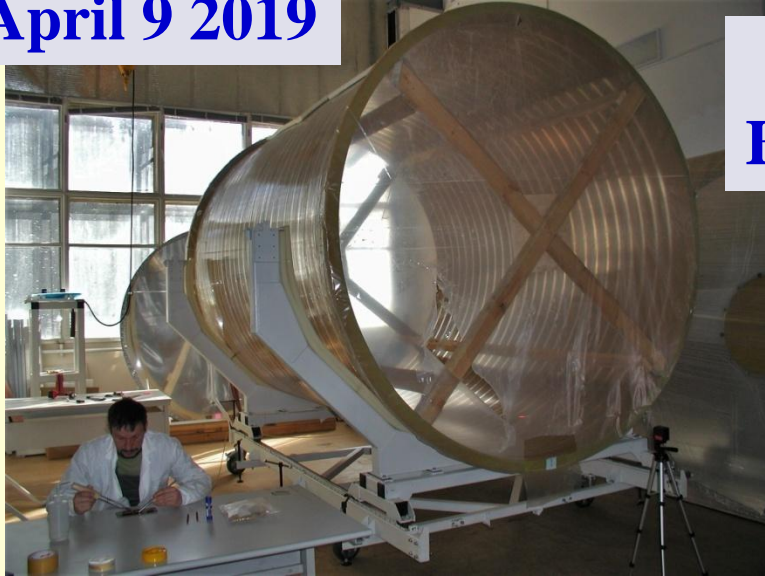
Fe-55: FWHM ~ 20%

Test procedure:

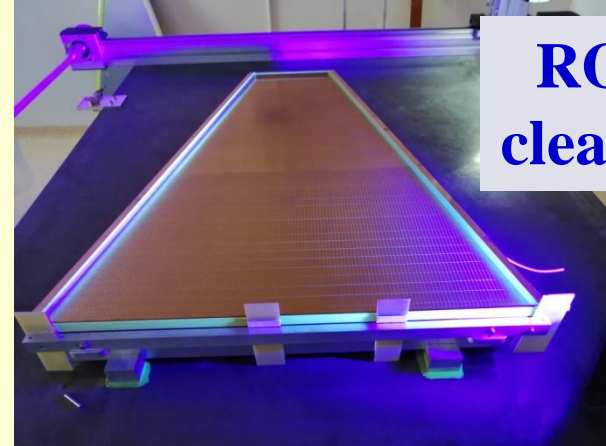
- counting plateau
- dark current
- energy resolution (Fe-55)
- uniformity of gas gain
 - ✓ linear scan
 - ✓ area scan

TPC and ROCs: status

April 9 2019



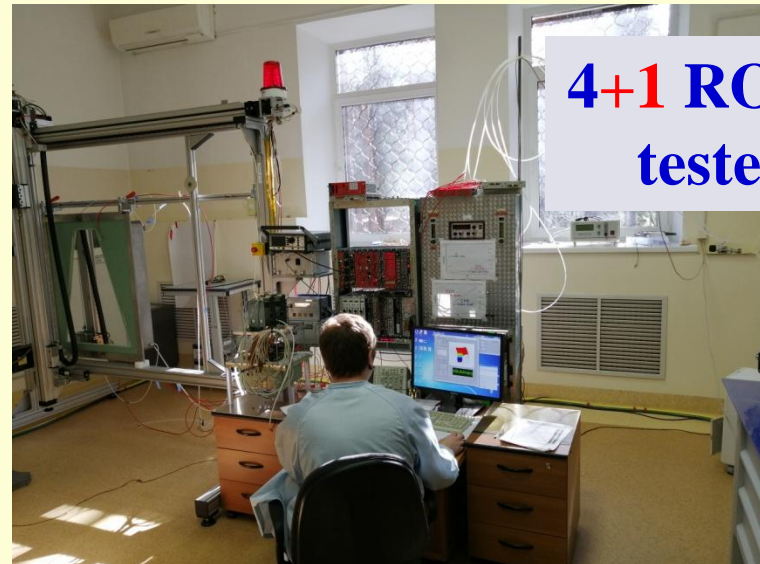
C3 at
Bld.217



ROC
cleaning



ROCs
26 pc



4+1 ROCs
tested

TPC and ROCs: summary

TPC assembly:

clean room	– ready
C1-C4 cylinders	– ready
flanges (2pc)	- ready
serial HV electrode	- ready
adjust. and align. TPC assembly tooling	– Feb 2019 -> May 2019
field cage rods (30 pc + 30 pc)	– March 2019 -> May 2019
field cage mylar strips manufacture	– April 2019 -> June 2019
start of TPC assembly (C3+C4)	- April 10 2019
flanges + HV electrode + field cage	- Aug 2019
HV test and leak test	- end of 2019

ROC chambers:

frames (26 pc)	- ready
serial pad planes (30 pc)	– postponed, ordered only 6 pc
HV for ROC gate electrode	– design started
test chamber with 512 ch r/o system	– Aug 2019
serial ROC chambers manufacture	- 2019-2020

TPC electronics requirements

Data rates:

- trigger mode – **20 GByte/sec** ($N=1000$ tracks)
- continuous readout mode - **300 GByte/sec**

Particle fluence for $R=35$ cm & 10 years (very preliminary):

- neutrons + protons – **2.5×10^{10} p/cm²** per year
- e- & e+ - **1×10^{10} p/cm²** per year
- ions - **0.5×10^5 p/cm²** per year

Dose:

Expected dose - **1 kRad** per 10 years

SAMPA v3/v4 tested at:

proton fluence - up to $N=10^{12}$ per cm²

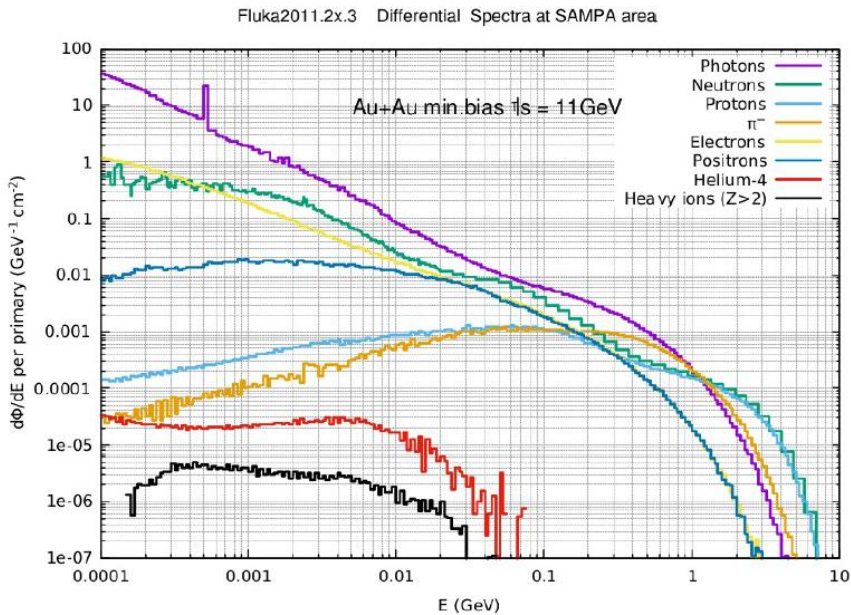
ion fluence - up to $N=10^7$ per cm² & $LET=(3-125)$ MeV cm²/mg

T chip=(45-85) degree => **$SEL=1 \times 10^{-7}$ cm² for $LET=16$ MeV cm²/mg**

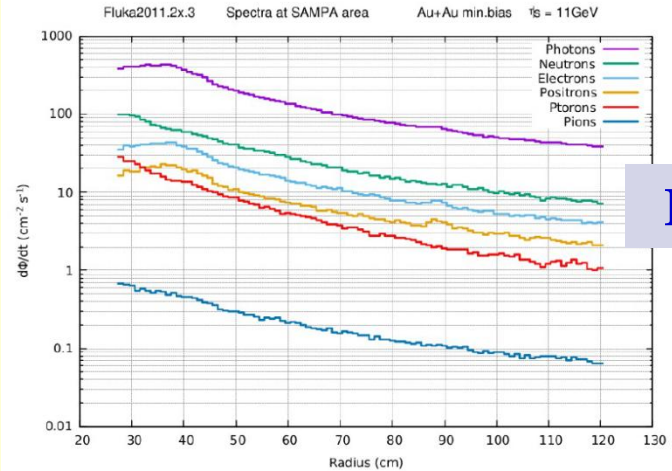
TPC electronics (FLUKA): fluences and dose

I.Semenova, Au-Au min. bias $\sqrt{s}=11$ GeV, Si h=100 μm , PRELIMINARY:

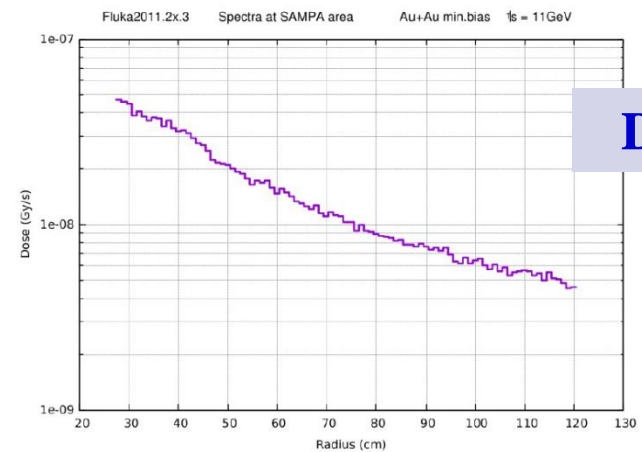
Differential spectra for SAMPA



Status: in progress



Fluence



Dose

TPC electronics (FLUKA): particles fluence and dose

I.Semenova , Au-Au min. bias $\sqrt{s}=11$ Gev (**PRELIMINARY**):

Fluence:

- all charge particles – **600** particles/cm²*sec (**100** - for E>20 MeV)
- 1 MeV neutron equivalent – **150** n/cm²*sec

- gamma - **500** gamma/cm² *sec -> **1x10**11** p/cm² per 10 year
- neutron - **100** neutrons/cm² *sec-> **2x10**10** p/cm² per 10 year
- proton - **25** protons/cm² *sec -> **0.5x10**10** p/cm² per 10 year
- e- & e+ - **60** electrons/cm² *sec -> **1x10**10** p/cm² per 10 year
- pions - **0.6** pions/cm² *sec -> **1x10**8** p/cm² per 10 year
- ions - **0.01** ions/cm² *sec -> **0.5x10**5** p/cm² per 10 year
(1 year =2x10**7 sec)

Dose: D=4x10⁻⁸ Gy/s,

per 10 years Dose is about 10 Gy = **1 kRad**

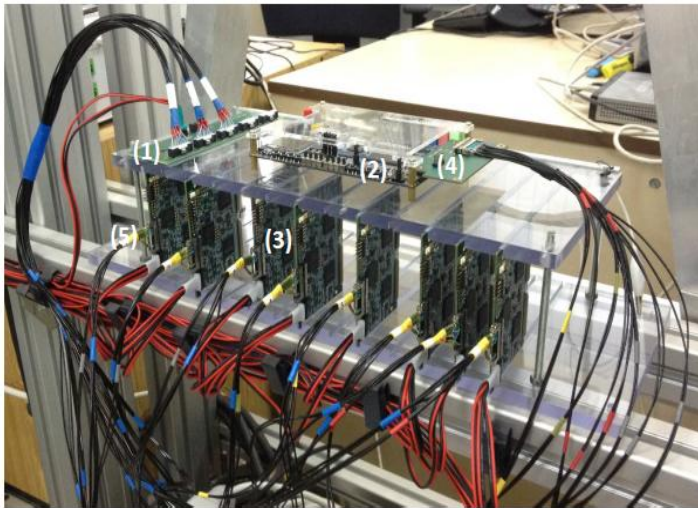
(for Apollo and Shuttle space flights, D=2 Rad/year)

TPC electronics: status

SAMPA chips (4500 pc): expected delivery date - June 2019

Pilot system – 512 ch

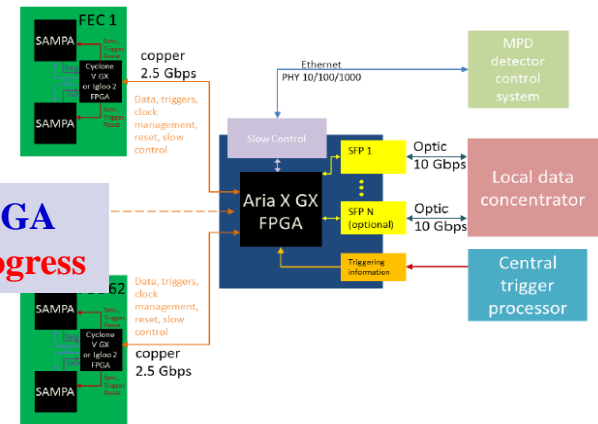
Eight cards pilot system



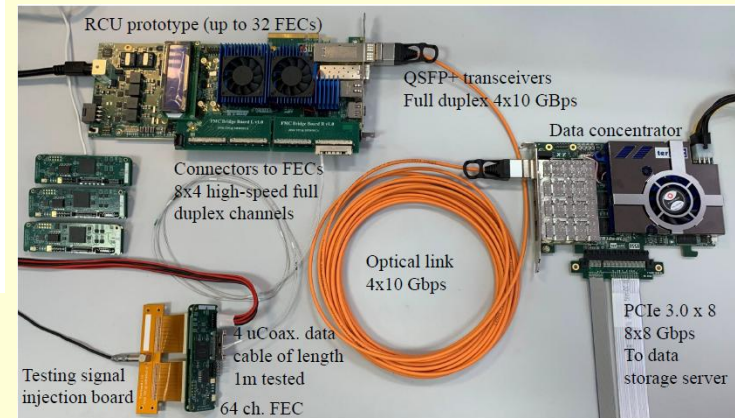
- 1) Trigger, clock, reset distr. board .
- 2) System controller.
- 3) 64-ch SAMPA- FEC.
- 4) HSSI (up to 2.5 GBps; up to 8 FECs).
- 5) Data/conf. full duplex HSSI port; clock 40 MHz, trigger, reset.

Status: tested

Block diagram of one chamber readout

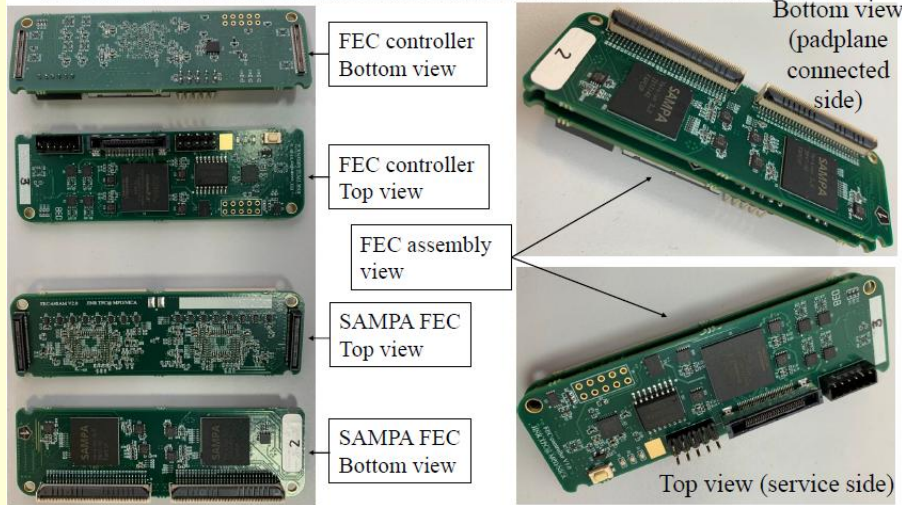


**tests with FPGA
Aria X – in progress**

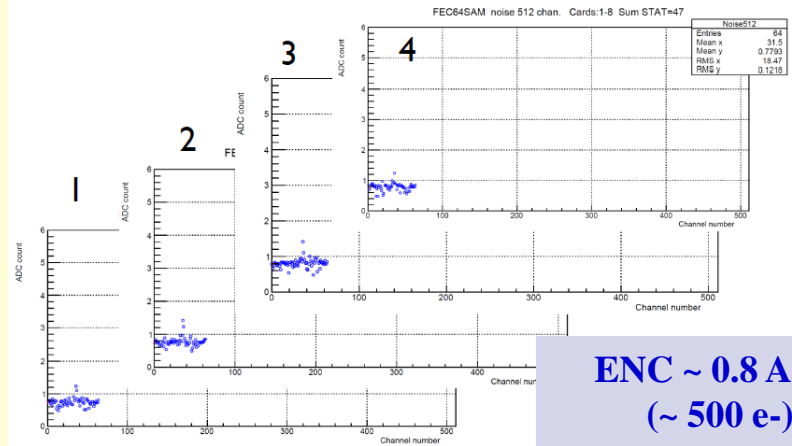


Pilot readout system for few ROCs – proposal

TPC electronics: FE cards

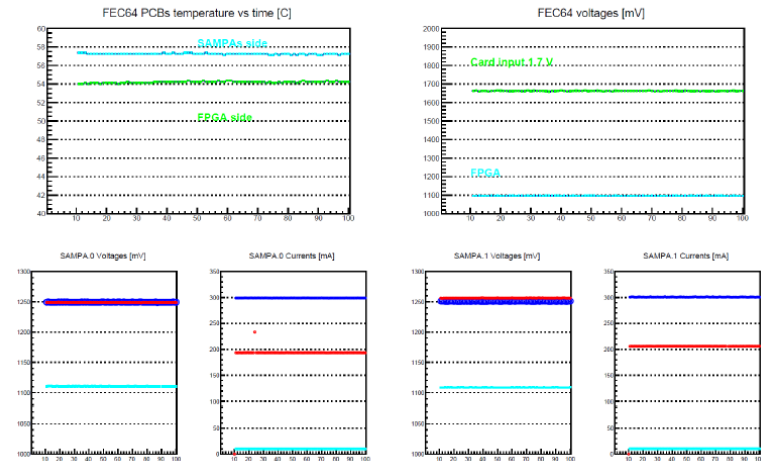


FEC noise estimate for cards 1,2,3,4



ENC ~ 0.8 ADC
(~ 500 e-)

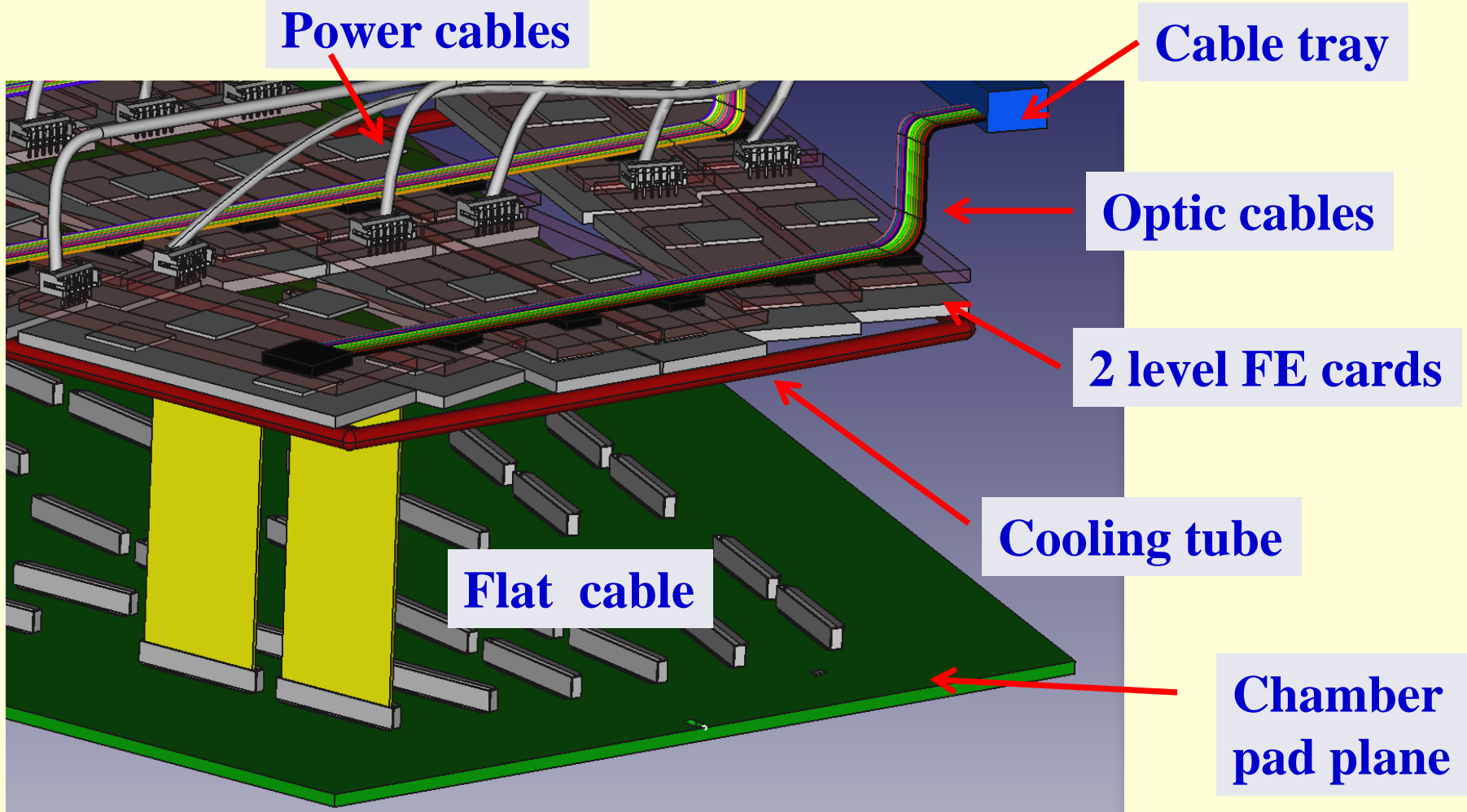
FEC slow control data



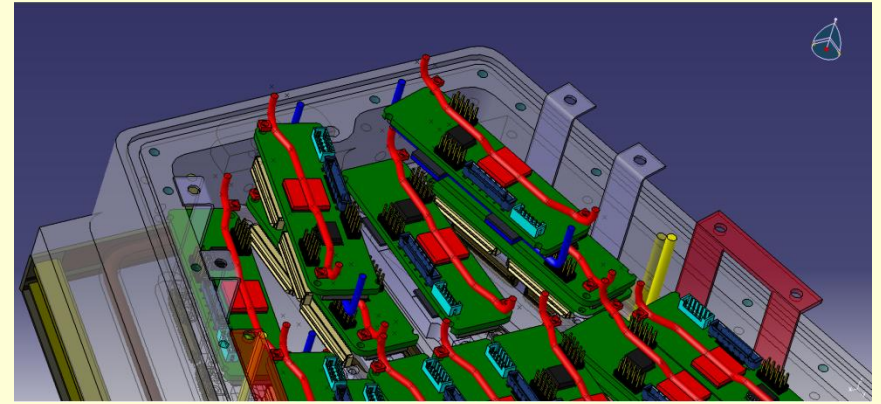
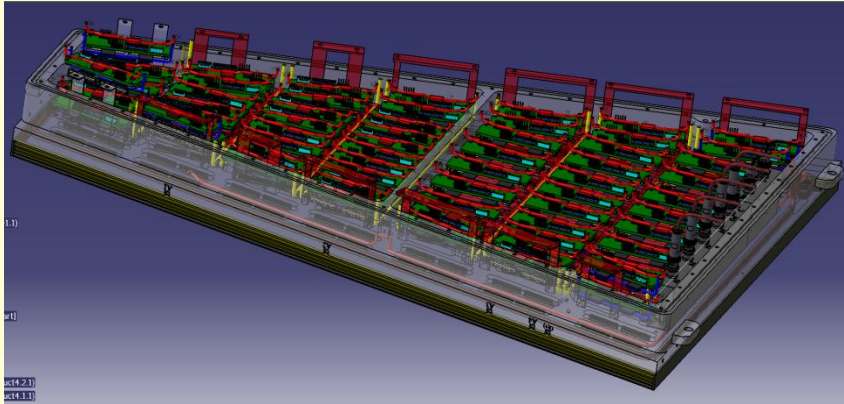
T SAMPA = 57 degree
T FPGA = 54 degree
Board LV: 1.7V & 1.1V
SAMPA (2 pc): 1.25V/500 mA
FPGA: 1.1V/10 mA (stand by mode)

Status: in progress

ROC chamber + electronics integration: **concept**

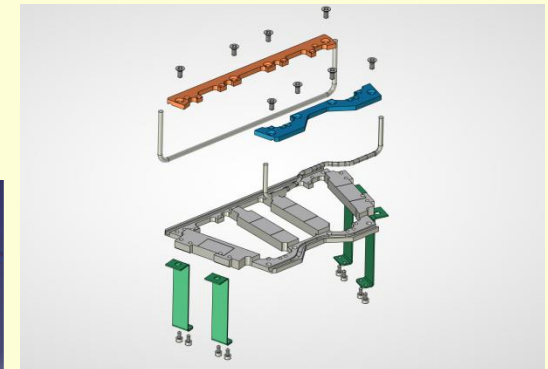
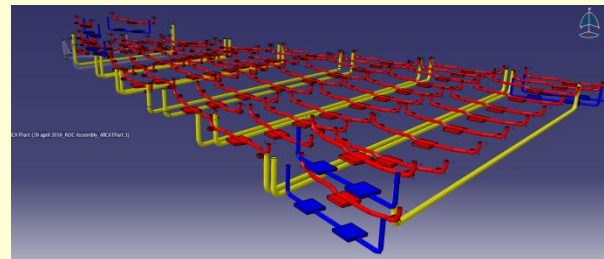
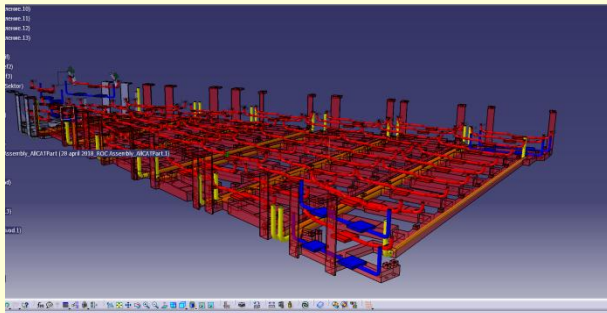


TPC electronics: FE cards integration



**radiators +
tubes**

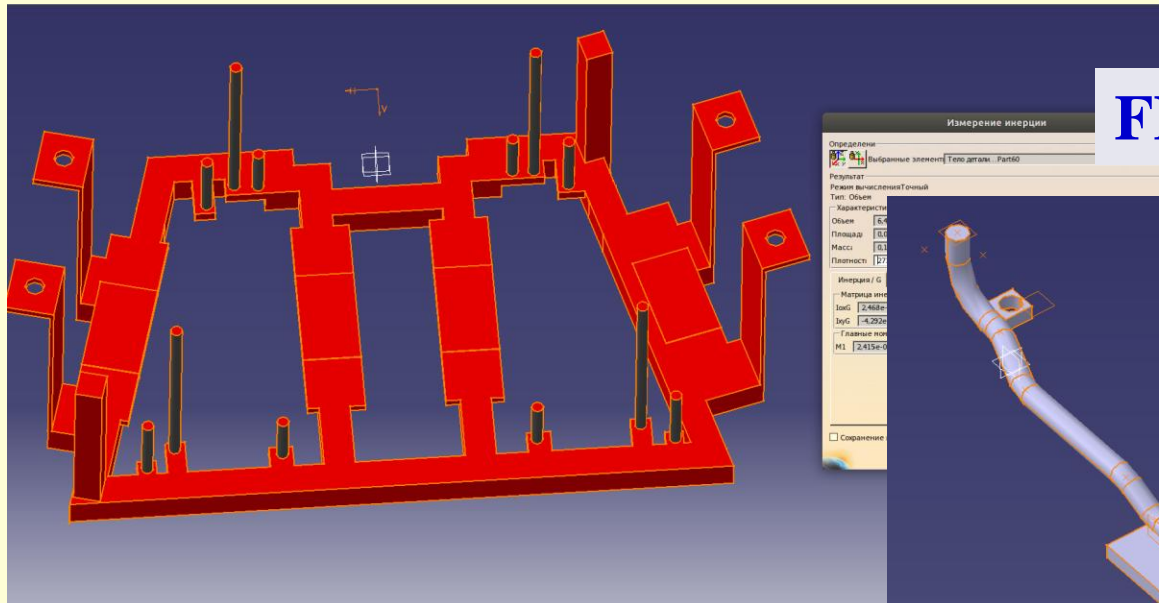
tubes



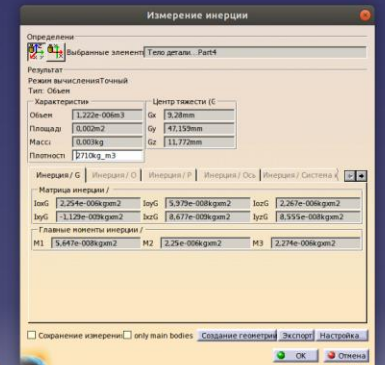
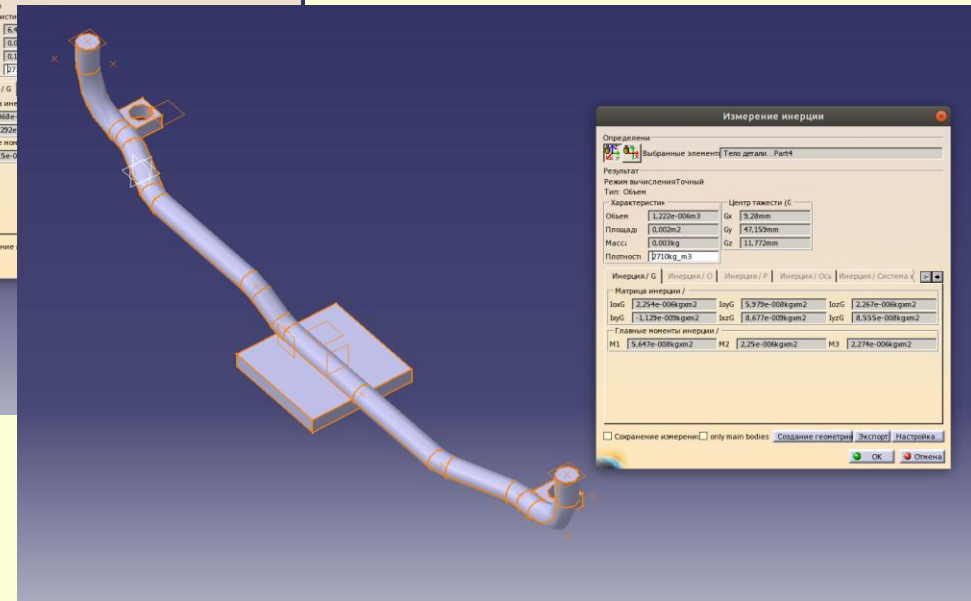
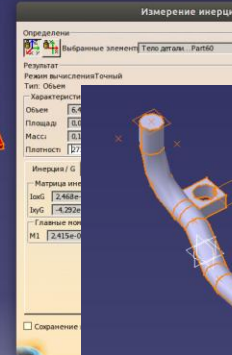
Status: in progress

ROC chamber + electronics integration: design

SAMPA cooling radiator



FPGA cooling radiator



TPC electronics: summary

FE electronics:

- 512 ch system FEC v1.0 – tested
- test with ROC chamber – Aug 2019
- SAMPA chips (4500 pc) – payment done, **delivery-June 2019**
- Aria 10 GX FPGA for controller (16 pc) - delivered to JINR
- Data concentrator chip (NRNU MEPHI) - design in progress
- FEC64SAM v.2 (10 pc) – delivered
- FE cards integration with ROC chamber - in progress
- FE cards cooling design – in progress, mock up – done
- FE card temperature distribution – calculations and meas. started
(*T board ~ 40 degree, SAMPAs and FPGA ~ 60 degree*)
- ROC+FE cards temperature distribution – in progress (calculations)
- controller based on commercial kit - in progress

Electronics radiation environment (**preliminary**, per 10 years):

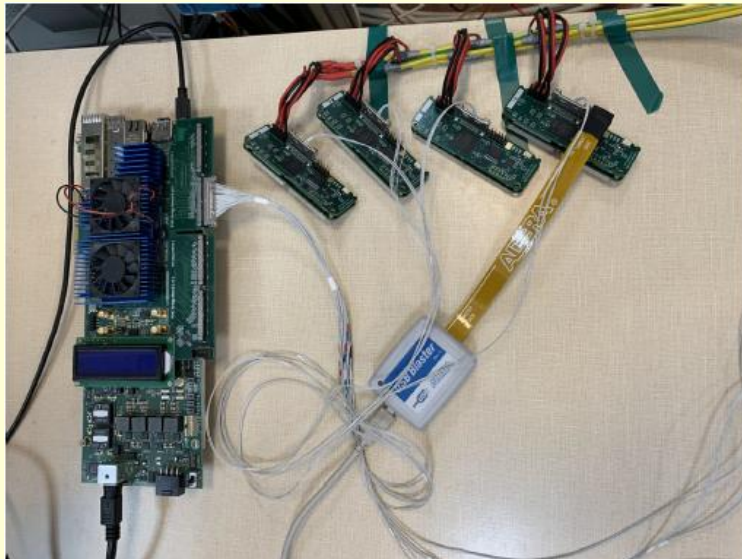
Dose – about **1 kRad** (sor Apollo and Shuttle space flights, D=2 Rad/year)

Data rates:

- trigger mode - **20 GByte/sec** (*N=1000 tracks*)
- continuous readout mode - **300 GByte/sec**

TPC electronics: status and schedule

**Test bench
based on commercial kit
(ARIA-10 FPGA)**



Item	Date
Testing FEC v1.0 finished	Feb. 2019 ✓
Preproduction version FEC v2.1 PCBs ready	June 2019
Delivery of SAMPA v4 chips to Dubna	June 2019
Assembly FEC v2.1 boards (32pc)	July 2019
Installation of FEC v2.1 boards (32pc) to ROC chamber	Aug. 2019
Start tests of ROC chamber in Bld.40	Sept. 2019
Finish tests of ROC chamber in Bld.40	Oct. 2019
Production version FEC v2.2 PCBs ready	Dec. 2019
Assembly FECs v2.2 boards (62pc, 1-st ROC, total 1)	Feb. 2020
Instrumented and test ROC-1 in Bld.40	Apr. 2020
Assembly FEC v2.2 boards (186pc) (3 ROCs, total 4)	May 2020
Instrumented and test ROC-2, 3 & 4 in Bld.40	June 2020
Assembly prod. ver. FECs (620pc, 10 ROCs, total 14)	July 2020
Assembly prod. ver. FECs (620pc, 10 ROCs, total 24)	Aug. 2020

INP BSU (Minsk): TPC LV system

- | | |
|---------------------------------|----------------|
| Pre-serial LVDB prototype | – manufactured |
| cooling plate | – manufactured |
| Pre-serial LVDB prototype tests | – done |
| LVDB mass-production (60 pc) | - done |



LV system (2 options):

- Wiener Marathon (Type AL (300G) MDC 02/07)

up to 300 Gauss and 30 Rad

- CAEN EASY3000 LV system (module type A3100B 2÷7V/100A)

up to 5000 Gauss and 200 Rad

https://indico.cern.ch/event/699390/contributions/2868537/attachments/1593340/2522493/Neolite_RandD_effortSummary.pdf

Status for CAEN option:

- invoice for LV test system – OK! delivery time – (3÷4) months
- invoice for HV system – OK! delivery time – (90÷150) days

TPC gas system

Gas supply



Status - **commissioning**
in progress

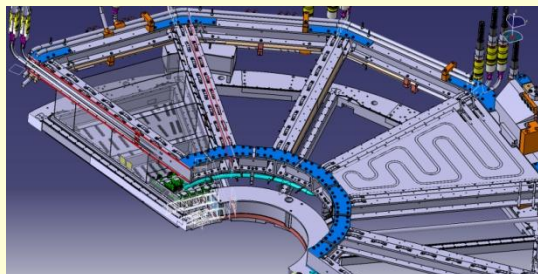
Racks

TPC volume imitator

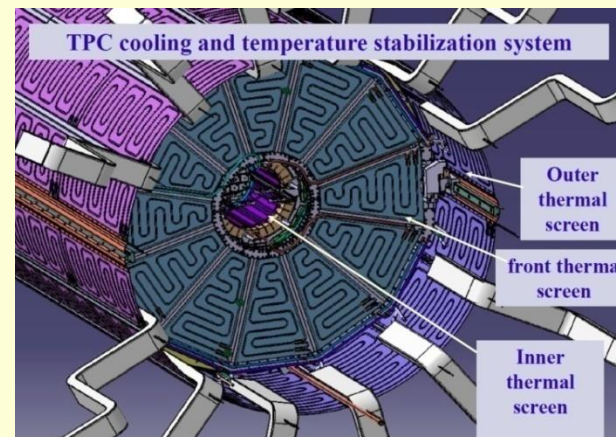


Status - **commissioned** (Bld.217)

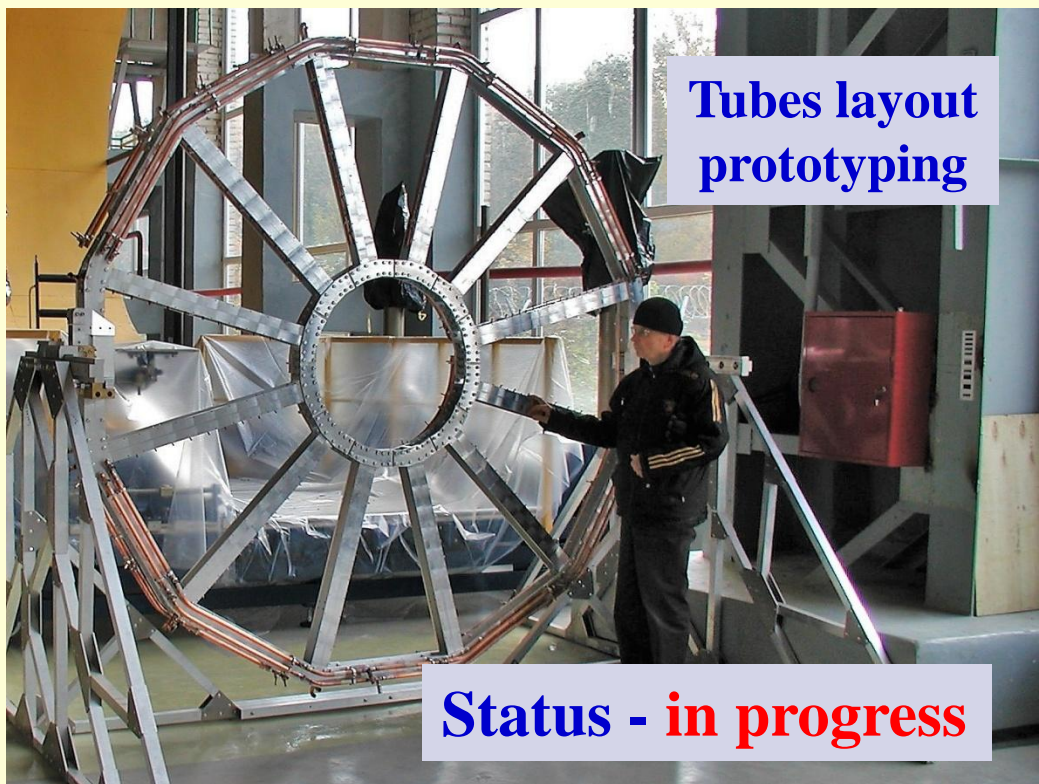
TPC cooling system: tubes layout and set of thermal panel prototypes



Service wheel



Tubes layout prototyping

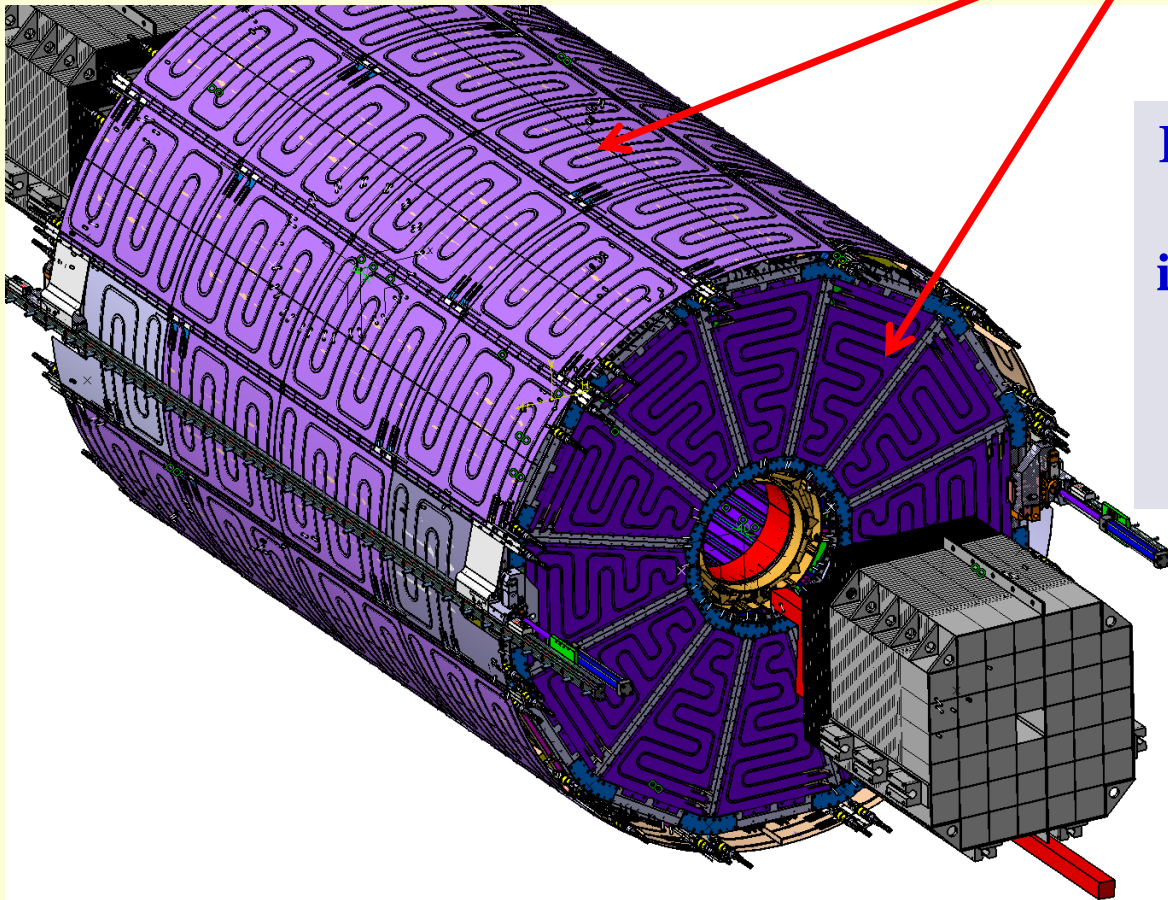


Status - in progress



Al plate – 0.5 mm
Al tube - D=8/6 mm

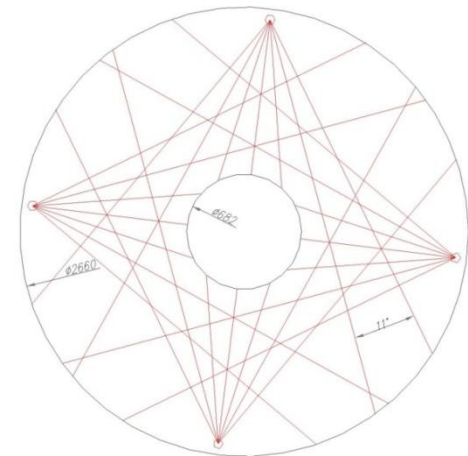
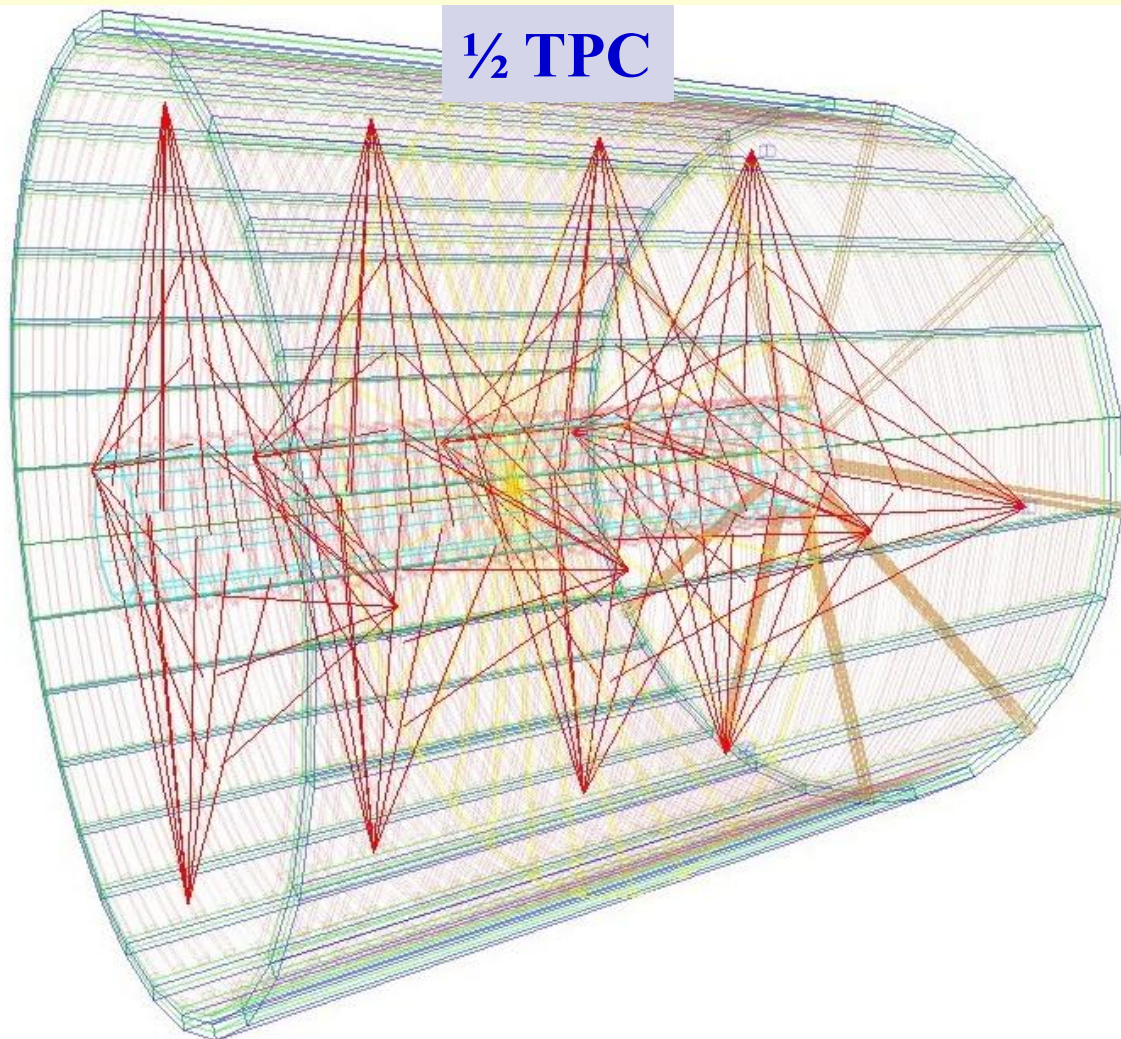
TPC cooling system: new thermal screens concept



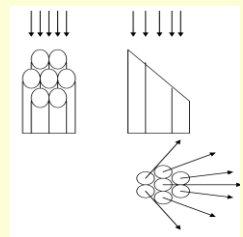
Barrel part – shorter and fixed to TPC instead fixation to ECAL structure

under discussion !!!!

TPC laser calibration system

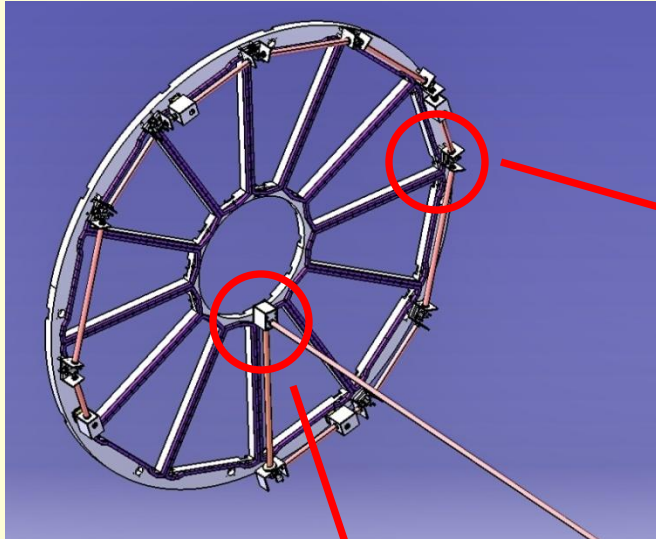


micro-mirror bundles

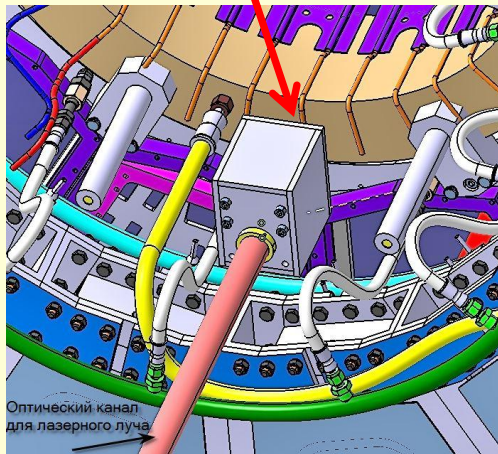
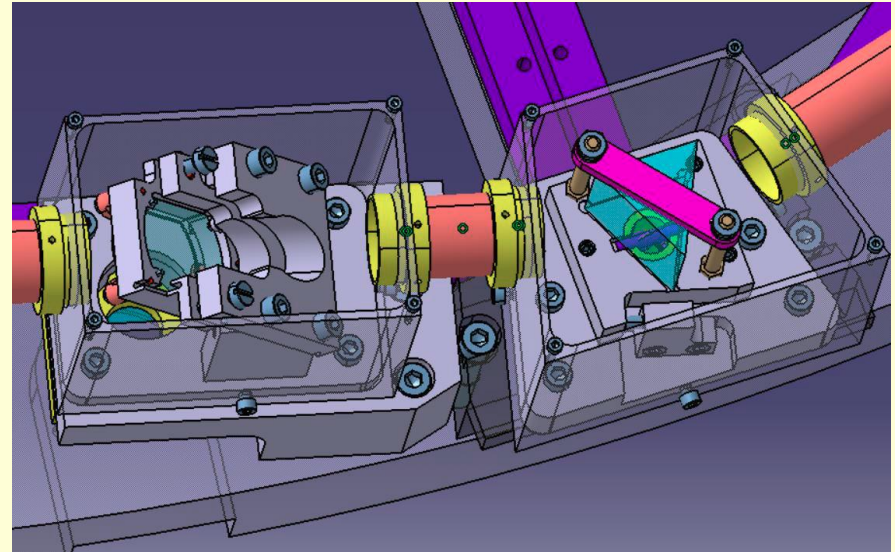


Laser "planes"	- 4+4
Points per plane	- 4
Beams per point	- 7
Laser "tracks", N	- 224

TPC laser calibration system

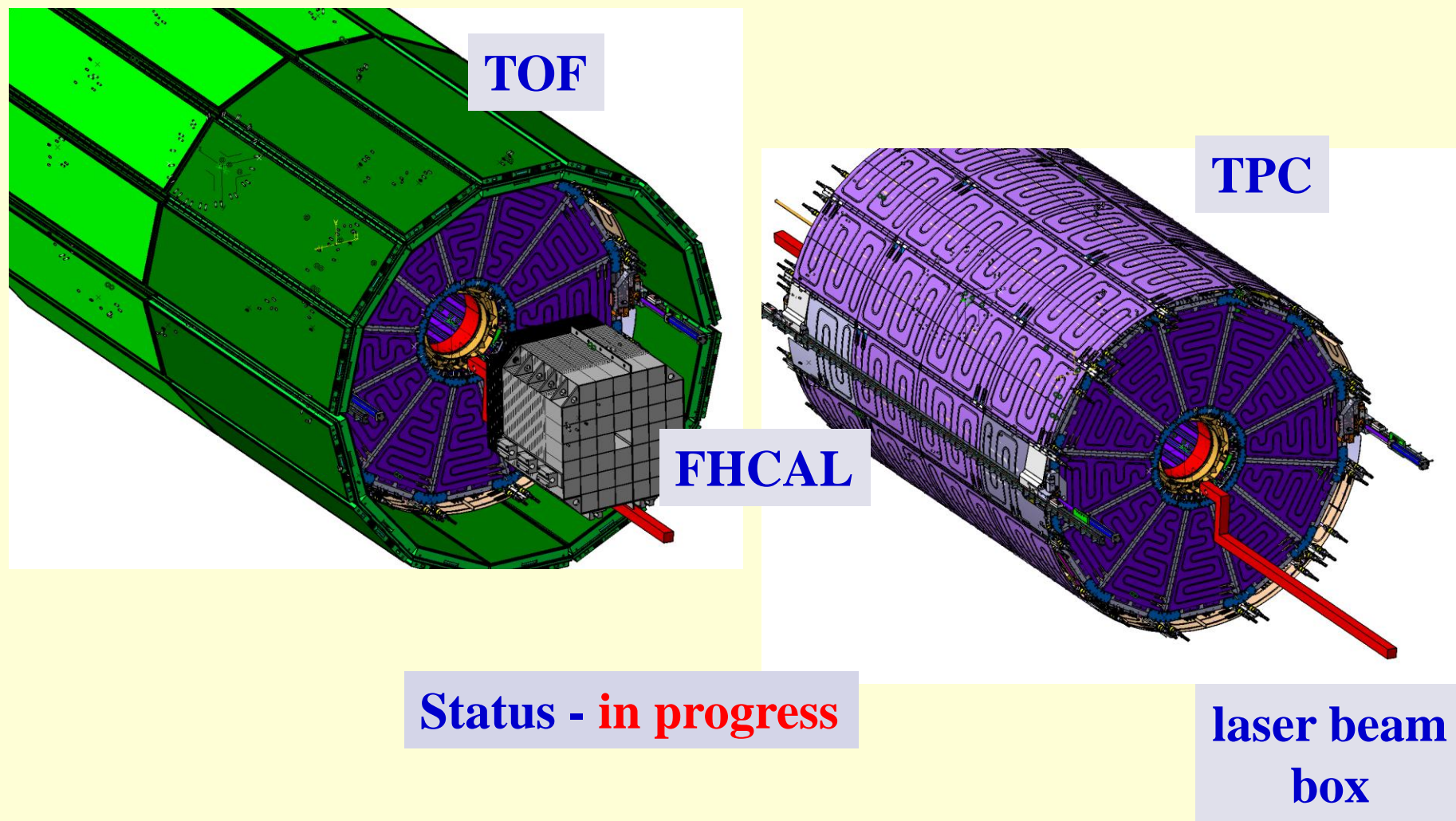


Semi transparency mirror & prism

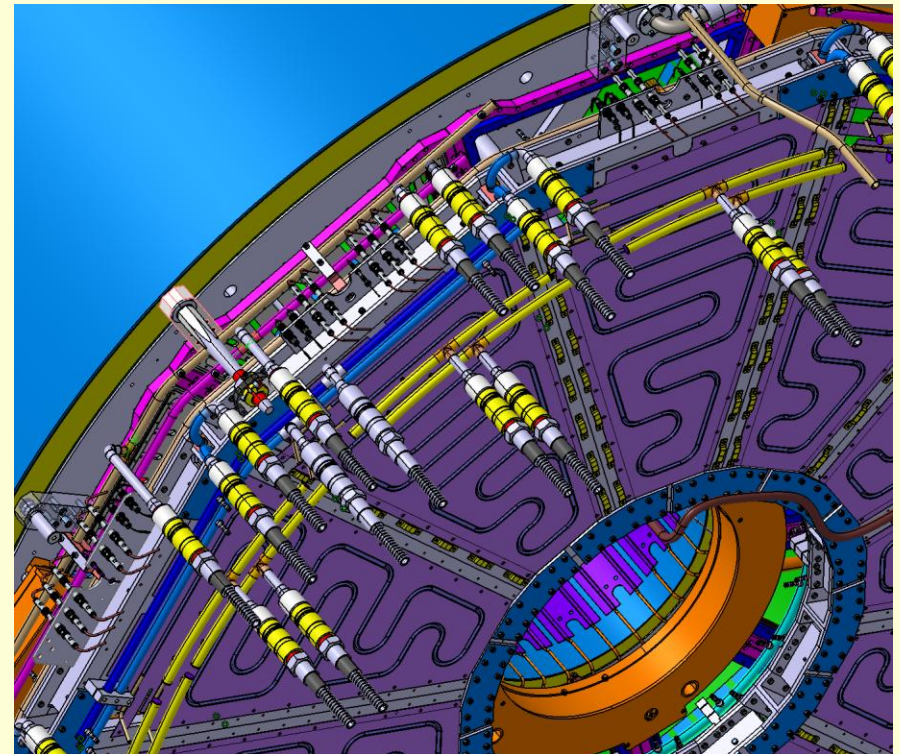
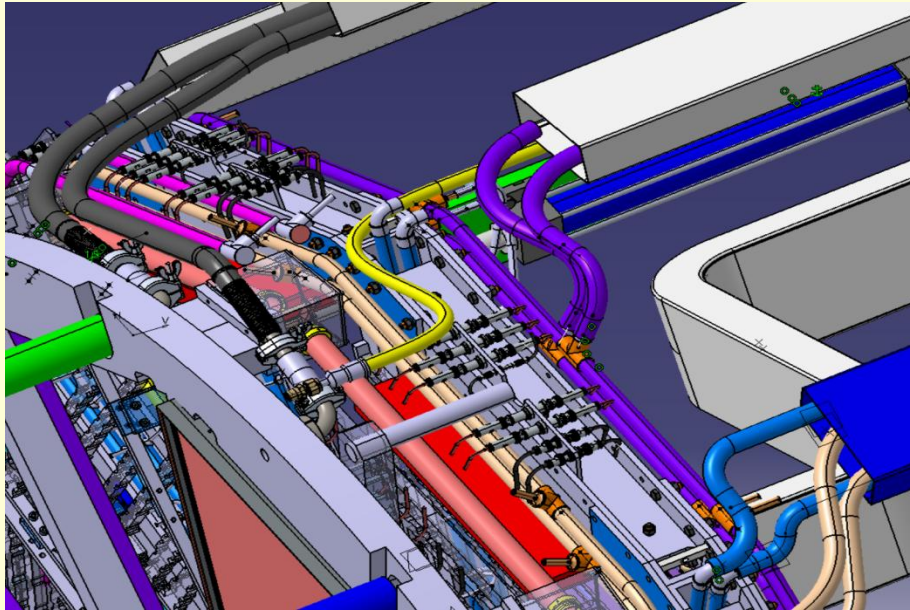


- full set of micro-mirror bundles - **assembled**
- 2 lasers (special option) – **commissioned**
- laser beam splitter and transport system - **in production**
- laser beam monitors - **ordered**

TPC laser calibration system: laser beam layout (proposal)



TPC: cables and tubes integration



Optimization - in progress

TPC services: summary

LV system:

- | | |
|--|------------------------|
| pre-serial LVDB + cooling plate (4 pc) | – ready, tested |
| serial LVDB (60 pc) | – assembled, tested |
| serial cooling plate | – designed and ordered |
| CAEN EASY3000 LV test system | - invoice got |
| CAEN HV system | - invoice got |
| Wiener Marathon | - under discussion |

HV system:

- | | |
|----------------------------------|---------------|
| CAEN HV system (crate + modules) | - invoice got |
|----------------------------------|---------------|

Gas system:

- commissioned

Cooling system:

- | | |
|-------------------------------------|--|
| prototype | – ready |
| measurements with prototype | – done |
| barrel and end cap thermal panels | – new prototypes ordered |
| service wheel cooling tubes routine | – prototyping done, optimization in progress |

TPC services: summary (continue)



Laser calibration system:

lasers (2 pc)

- commissioned

laser beam splitter and transport system - in production, will be delivered

May 2019

beam monitors (WEB cameras + optics)

- ordered

channel for laser beam inside MPD

- new layout proposed

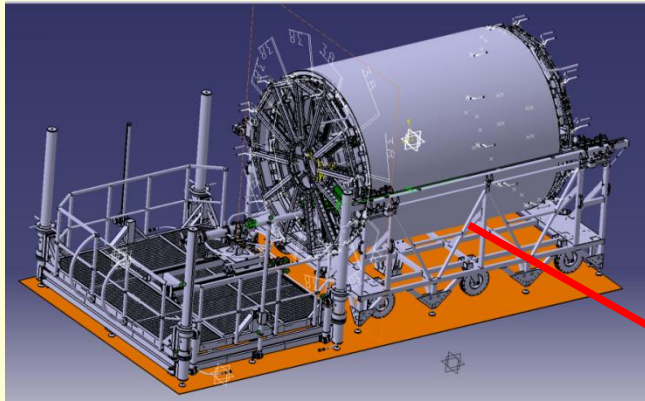
INTEGRATION:

TPC sub-systems integration - in good shape

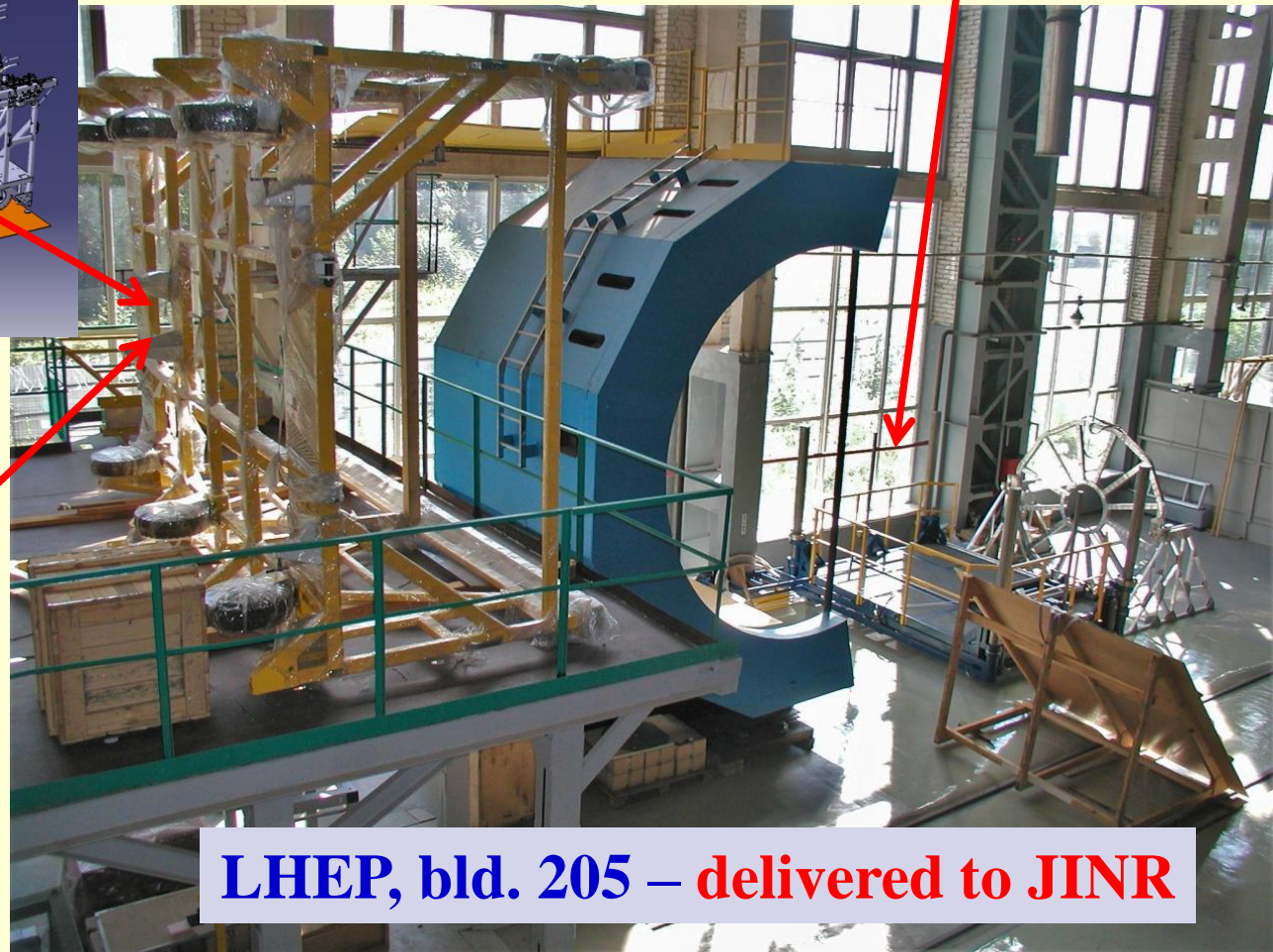
list of TPC cables and tubes – updated

Integration TPC into MPD - **not started yet** (waiting for ECAL design and its integration to MPD)

TPC: transportation platform and ROC manipulator



at Briansk:

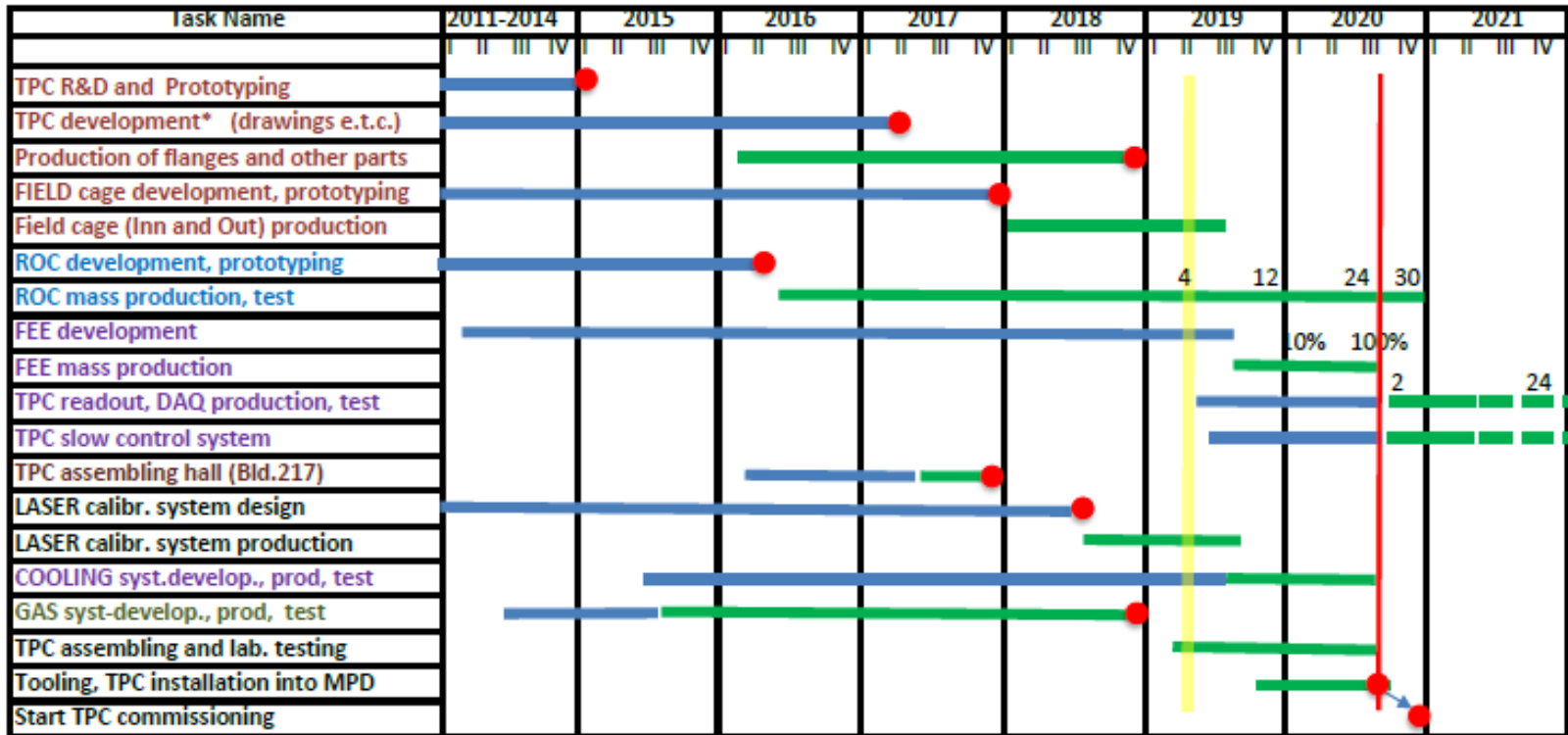


LHEP, bld. 205 – delivered to JINR

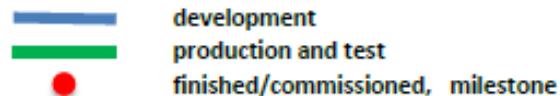
Time schedule

update - 15.04.2019

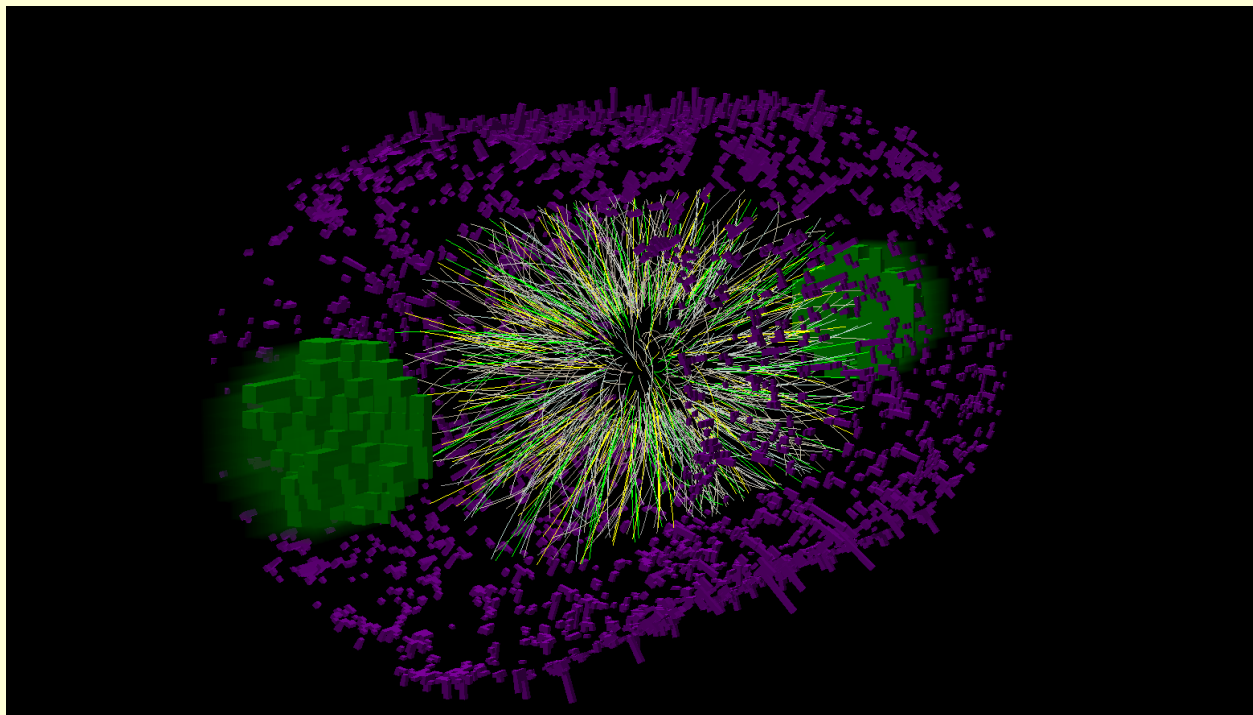
TPC time schedule



* Current version of TPC dimensions was approved of 31.01.2013



Thank you for attention!



<http://nica.jinr.ru/>
<http://mpd.jinr.ru/>

TDR TPC – <http://mpd.jinr.ru/wp-content/uploads/2019/01/TpcTdr-v07.pdf>