Range (Muon) System Status Report

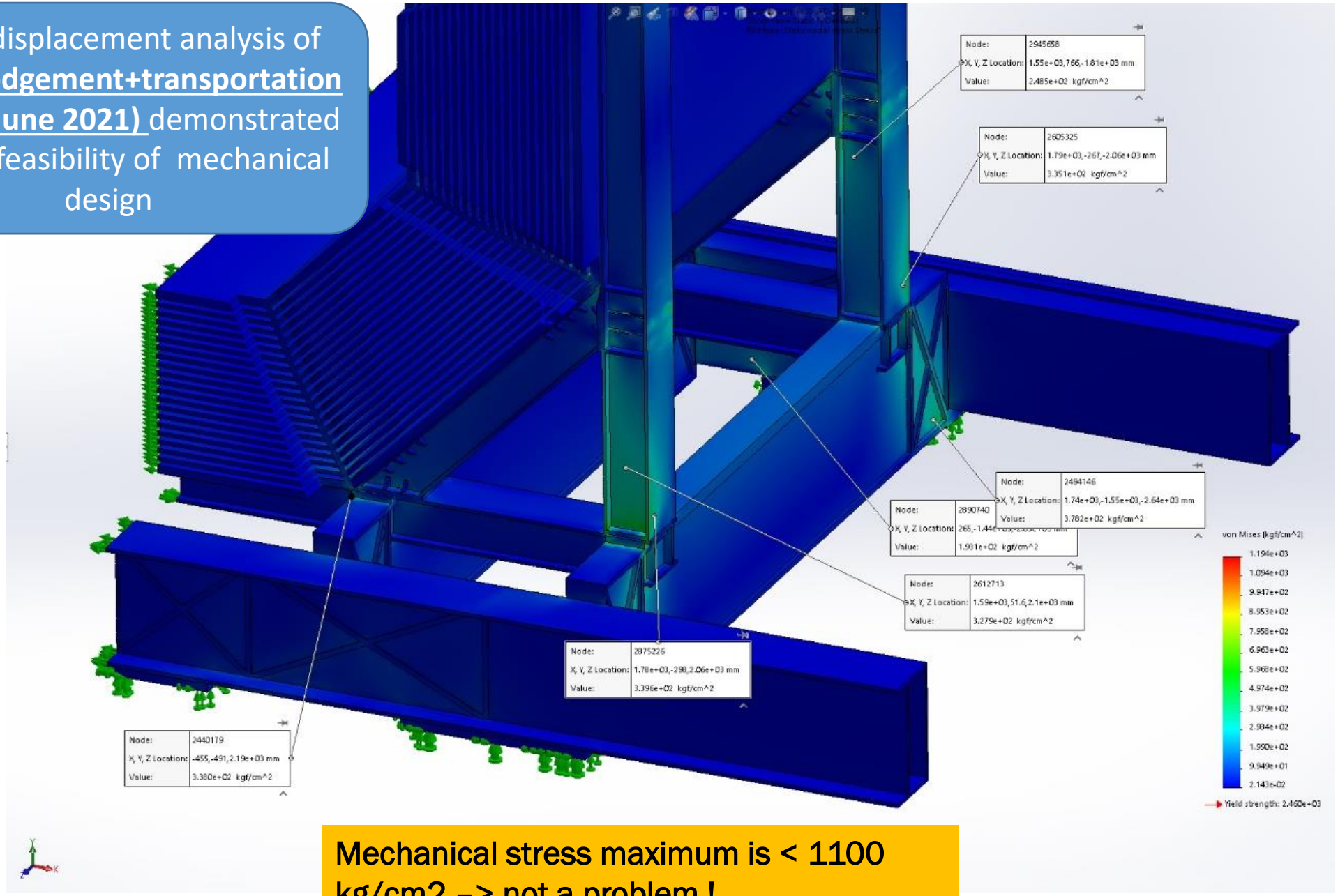
G.Alexeev, SPD collaboration meeting, Dubna, 14 December 2021

- **Main results for last half a year (brief review):**

  - Mechanical FEA calculations (deformation, stress) for RS End Caps in progress
  - The proper building for MDT production workshop is found and being negotiated with Laboratory of Neutron Physics (present owner of bld.73), Technical Design for reconstruction of that building is prepared
  - We got commercial offer for the main part of MDT detector – extruded ALU profile
  - Two out of three test stands needed for MDTs mass production are ready and tested with long (~5m) detectors at CERN
  - Preparation of SPD/RS prototype for Nuclotron test beam (structure/absorber, MDT detectors, analog and digital electronics, Cerenkov counter) in progress
  - New Ampl-8.51 ASIC chip (basis for analog FEE) with very low input impedance for wire and strip readout is manufactured by Integral (Minsk) and it is close to its final version
  - Digital FEE units are ready for SPD Range System Prototype at Nuclotron test beam at JINR
  - Software/algorithms - > particles reconstruction in Range System

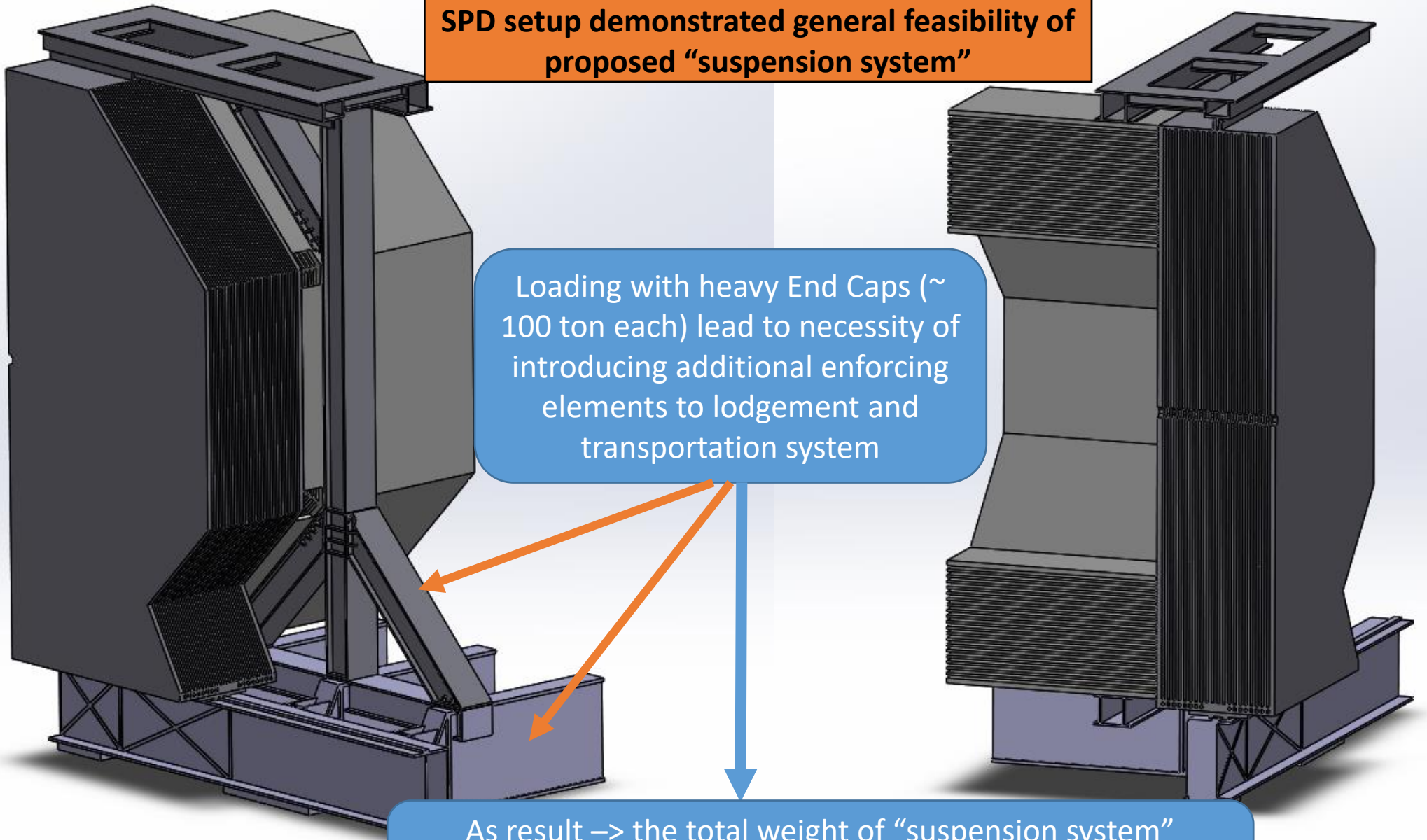
- **Plans for 2022**
- **Conclusion**

Stress/displacement analysis of **Barrel+lodgement+transportation system (June 2021)** demonstrated general feasibility of mechanical design



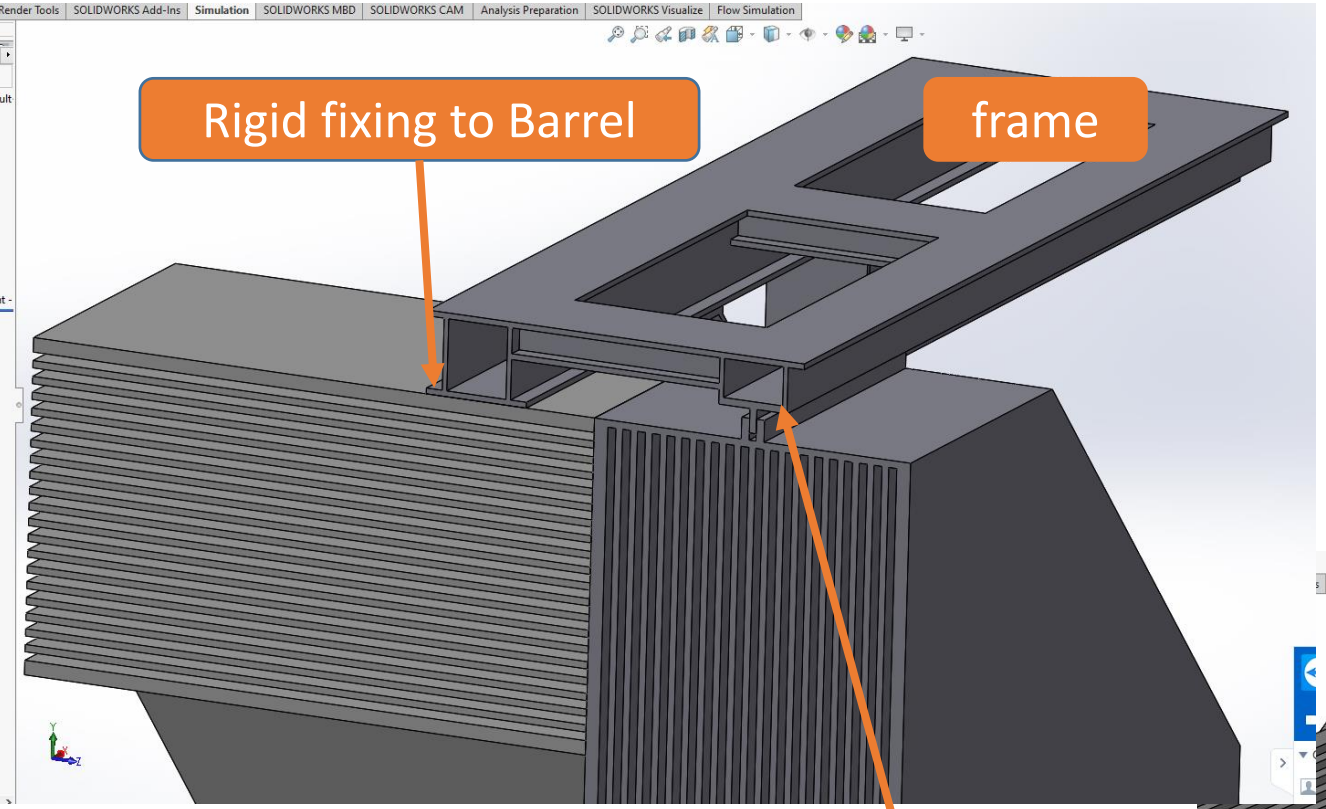
Mechanical stress maximum is < 1100 kg/cm2 –> not a problem !

Stress/displacement FEA analysis of the full SPD setup demonstrated general feasibility of proposed “suspension system”

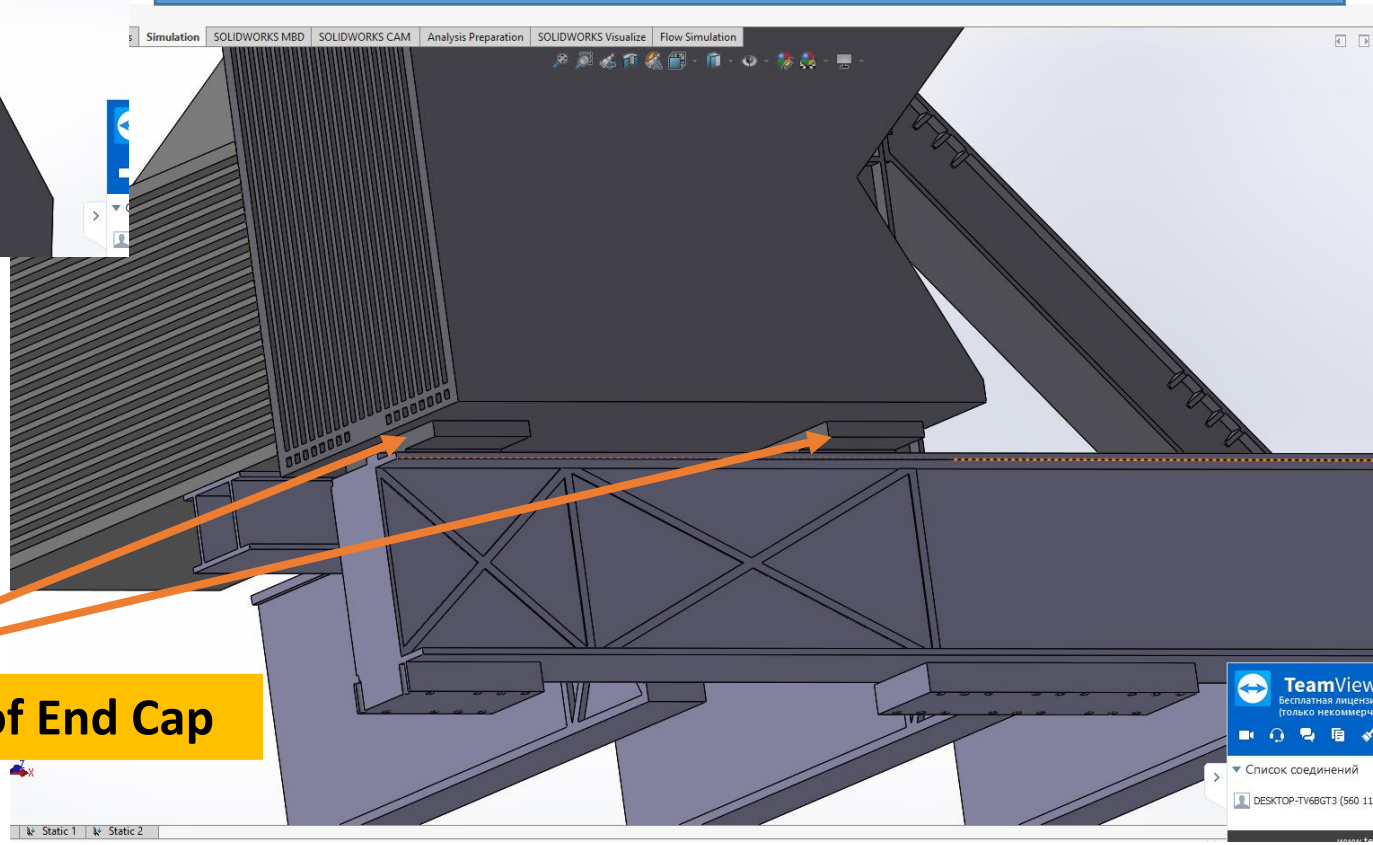


Loading with heavy End Caps (~ 100 ton each) lead to necessity of introducing additional enforcing elements to lodgement and transportation system

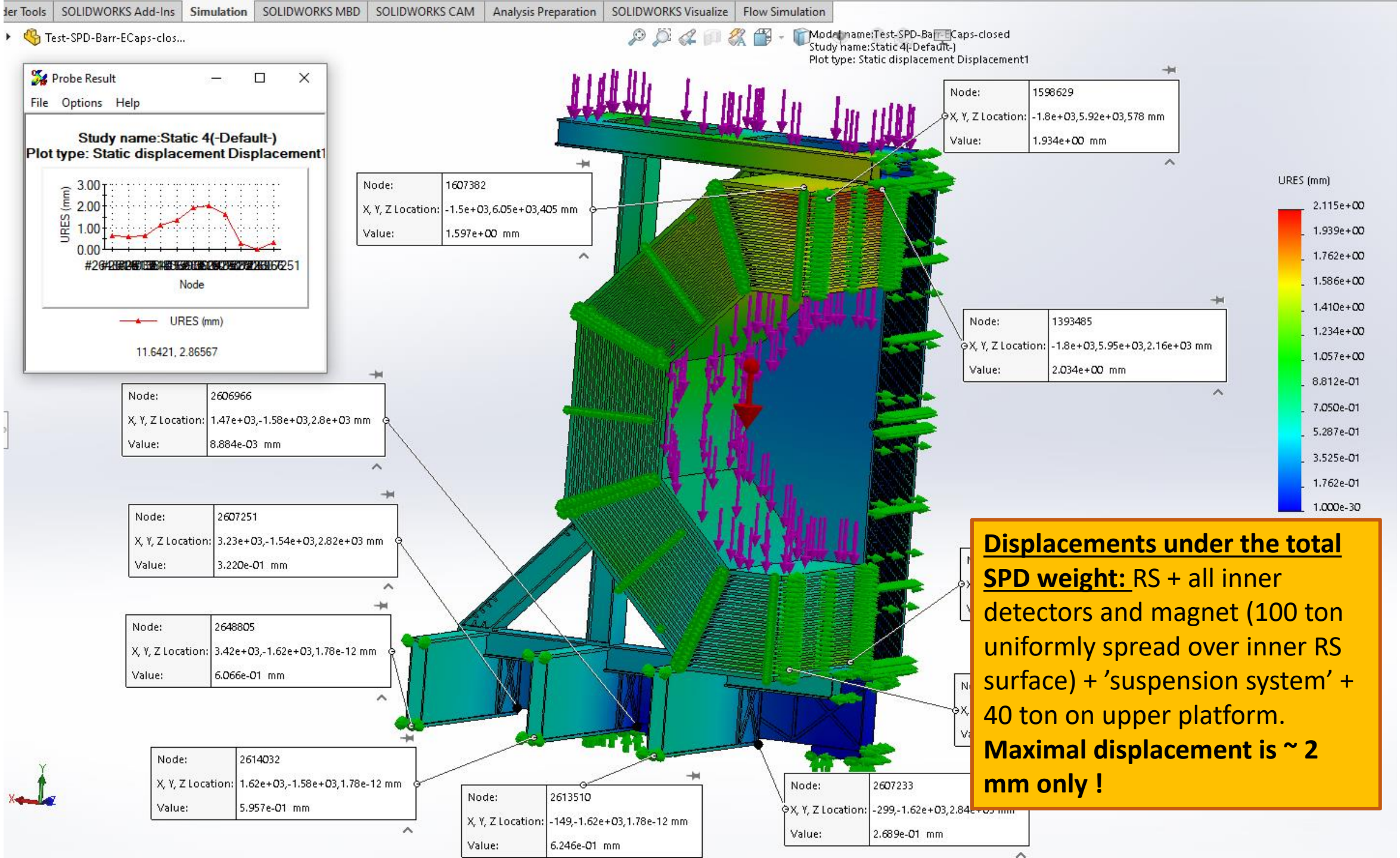
As result –> the total weight of “suspension system” increased by ~ 15 ton (up to 70 ton), **not a problem for total weight ~ 1200 ton , and may be optimized later**

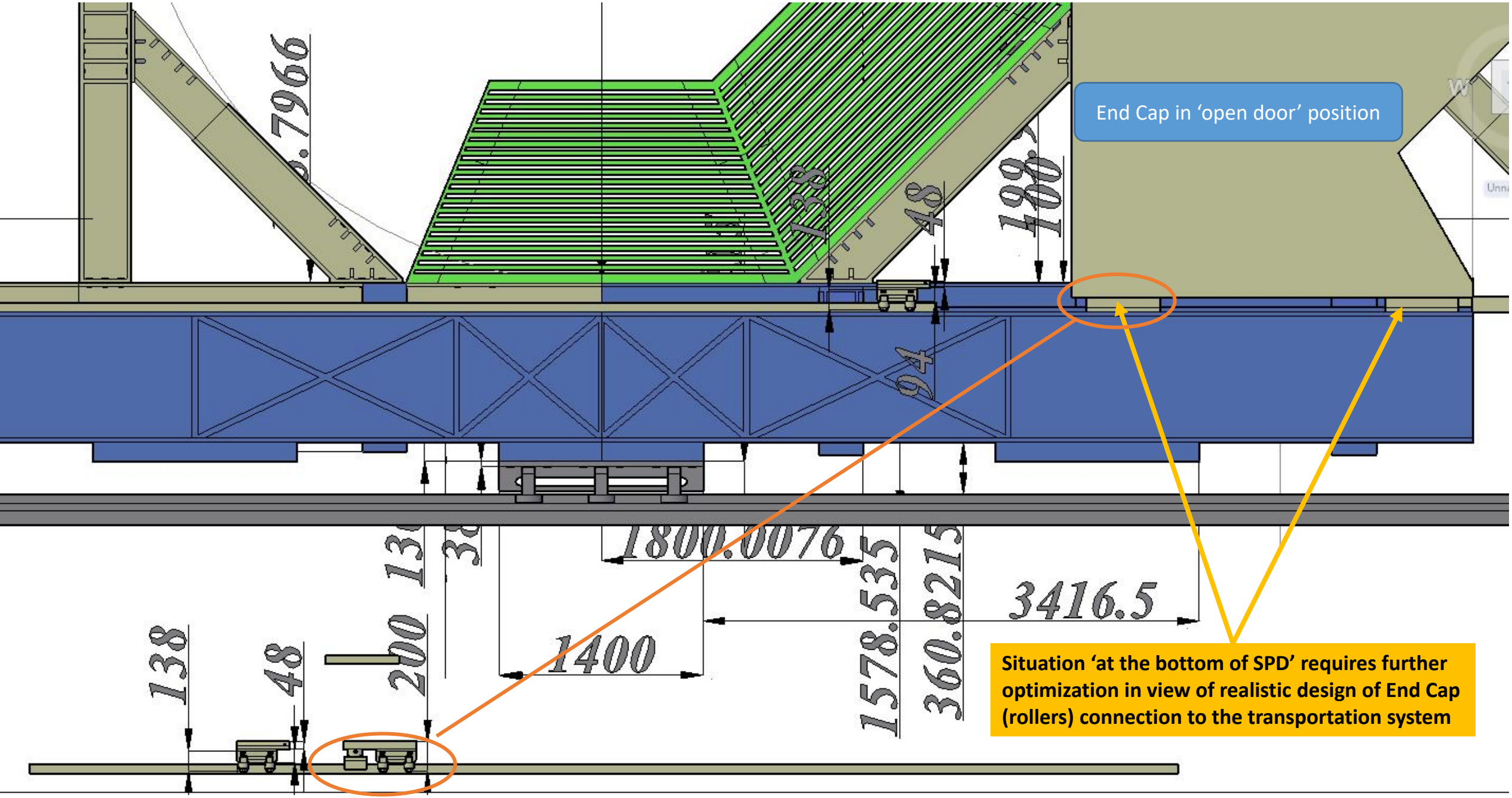


Proposed design of End Cap fixation to Barrel and its transverse movement: frame is rigidly attached to Barrel, but End Cap may glide along the frame with rollers to 'open door' position



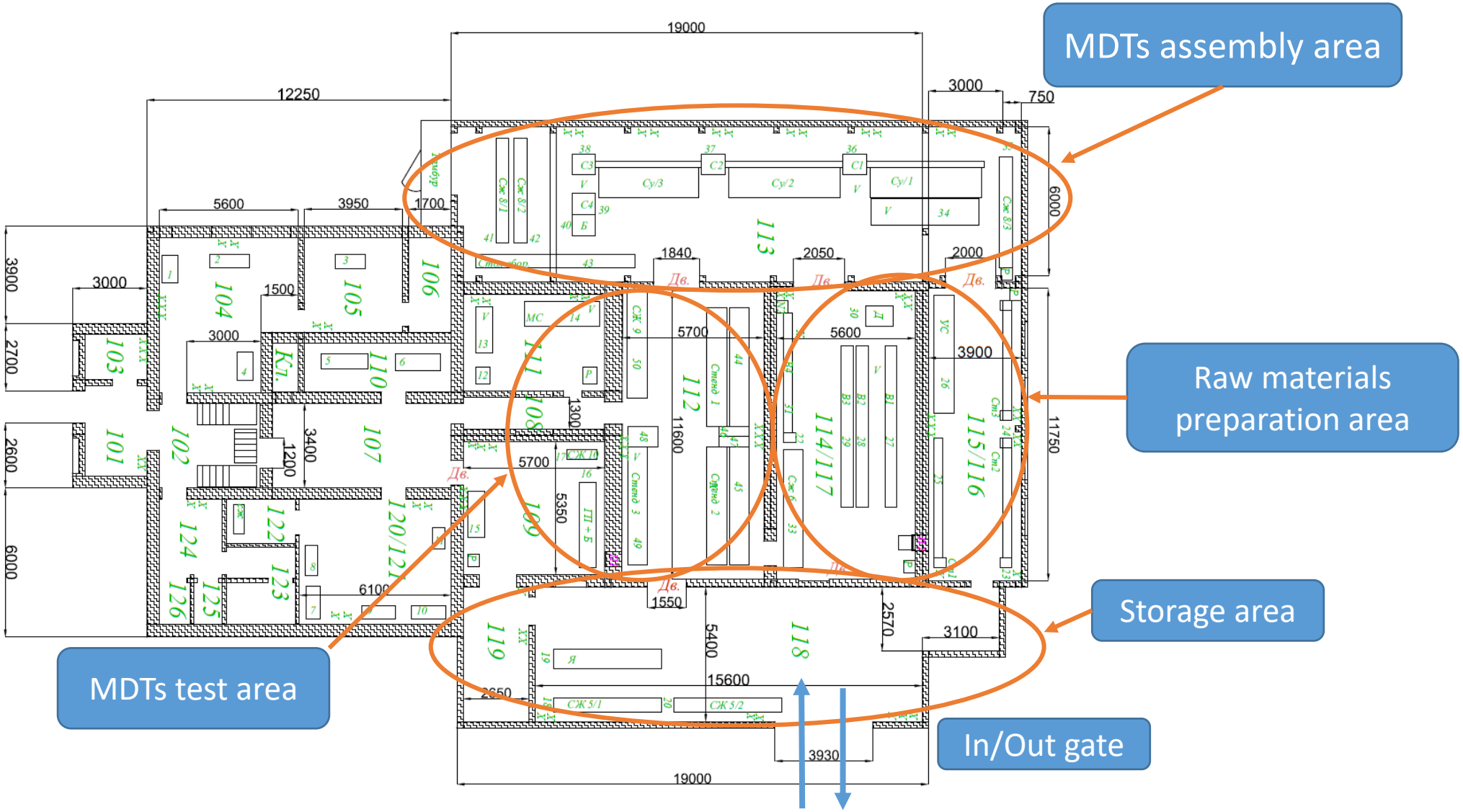
Rollers on top and bottom of End Cap


der Tools
SOLIDWORKS Add-Ins
Simulation
SOLIDWORKS MBD
SOLIDWORKS CAM
Analysis Preparation
SOLIDWORKS Visualize
Flow Simulation
Test-SPD-Barr-ECaps-clos...
Model name:Test-SPD-Barr-ECaps-closed
Study name:Static 4(-Default-)
Plot type: Static displacement Displacement1
Probe Result
File Options Help
Study name:Static 4(-Default-)
Plot type: Static displacement Displacement1
URES (mm)
Node
URES (mm)
11.6421, 2.86567
Node: 1598629
X, Y, Z Location: -1.8e+03,5.92e+03,578 mm
Value: 1.934e+00 mm
Node: 1607382
X, Y, Z Location: -1.5e+03,6.05e+03,405 mm
Value: 1.597e+00 mm
Node: 1393485
X, Y, Z Location: -1.8e+03,5.95e+03,2.16e+03 mm
Value: 2.034e+00 mm
Node: 2606966
X, Y, Z Location: 1.47e+03,-1.58e+03,2.8e+03 mm
Value: 8.884e-03 mm
Node: 2607251
X, Y, Z Location: 3.23e+03,-1.54e+03,2.82e+03 mm
Value: 3.220e-01 mm
Node: 2648805
X, Y, Z Location: 3.42e+03,-1.62e+03,1.78e-12 mm
Value: 6.066e-01 mm
Node: 2614032
X, Y, Z Location: 1.62e+03,-1.58e+03,1.78e-12 mm
Value: 5.957e-01 mm
Node: 2613510
X, Y, Z Location: -149,-1.62e+03,1.78e-12 mm
Value: 6.246e-01 mm
Node: 2607233
X, Y, Z Location: -299,-1.62e+03,2.84e-03 mm
Value: 2.689e-01 mm
URES (mm)
2.115e+00
1.939e+00
1.762e+00
1.586e+00
1.410e+00
1.234e+00
1.057e+00
8.812e-01
7.050e-01
5.287e-01
3.525e-01
1.762e-01
1.000e-30
Displacements under the total SPD weight: RS + all inner detectors and magnet (100 ton uniformly spread over inner RS surface) + 'suspension system' + 40 ton on upper platform.
Maximal displacement is ~ 2 mm only !


End Cap in ‘open door’ position
1800.0076
1578.535
360.8215
3416.5
1400
138
48
200
Situation ‘at the bottom of SPD’ requires further optimization in view of realistic design of End Cap (rollers) connection to the transportation system

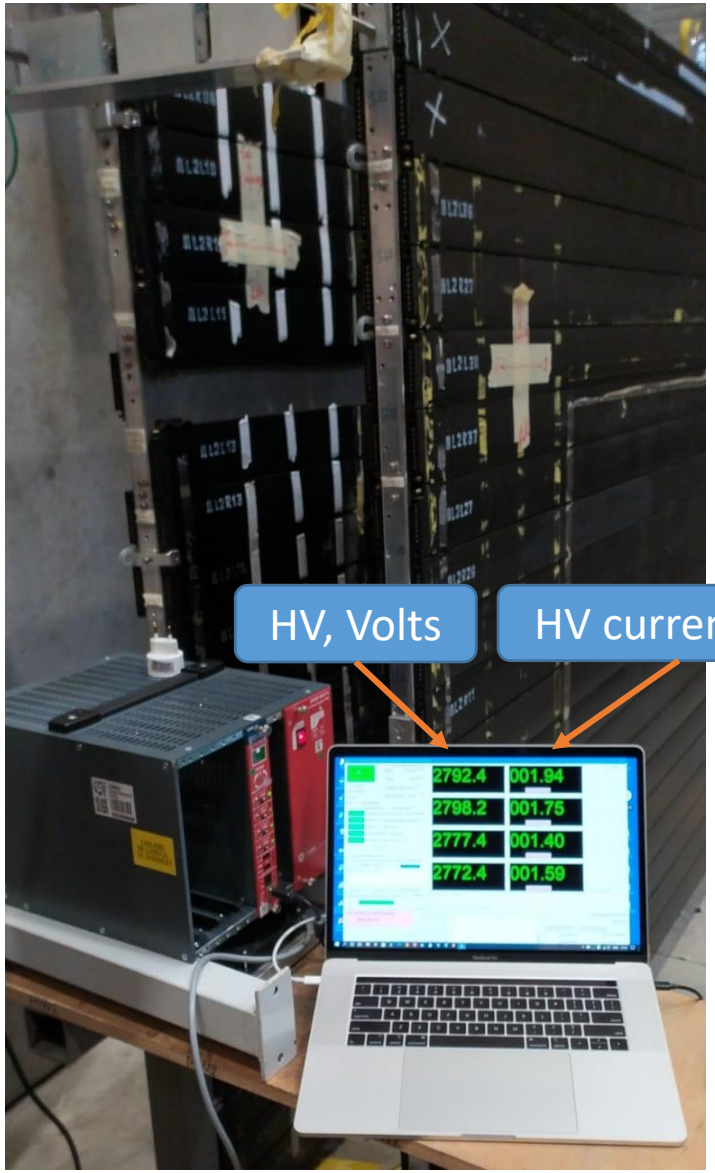
Basis for MDT mass production workshop at JINR

(bld.73 of Laboratory of Neutron Physics, slide shows plan of 1-st floor (~ 400 m2) from our Technical Design on building reconstruction)



HV electrical breakdown test

(conducted at CERN with MDT detectors (~ 500) of Rich Wall/COMPASS, September 2021)

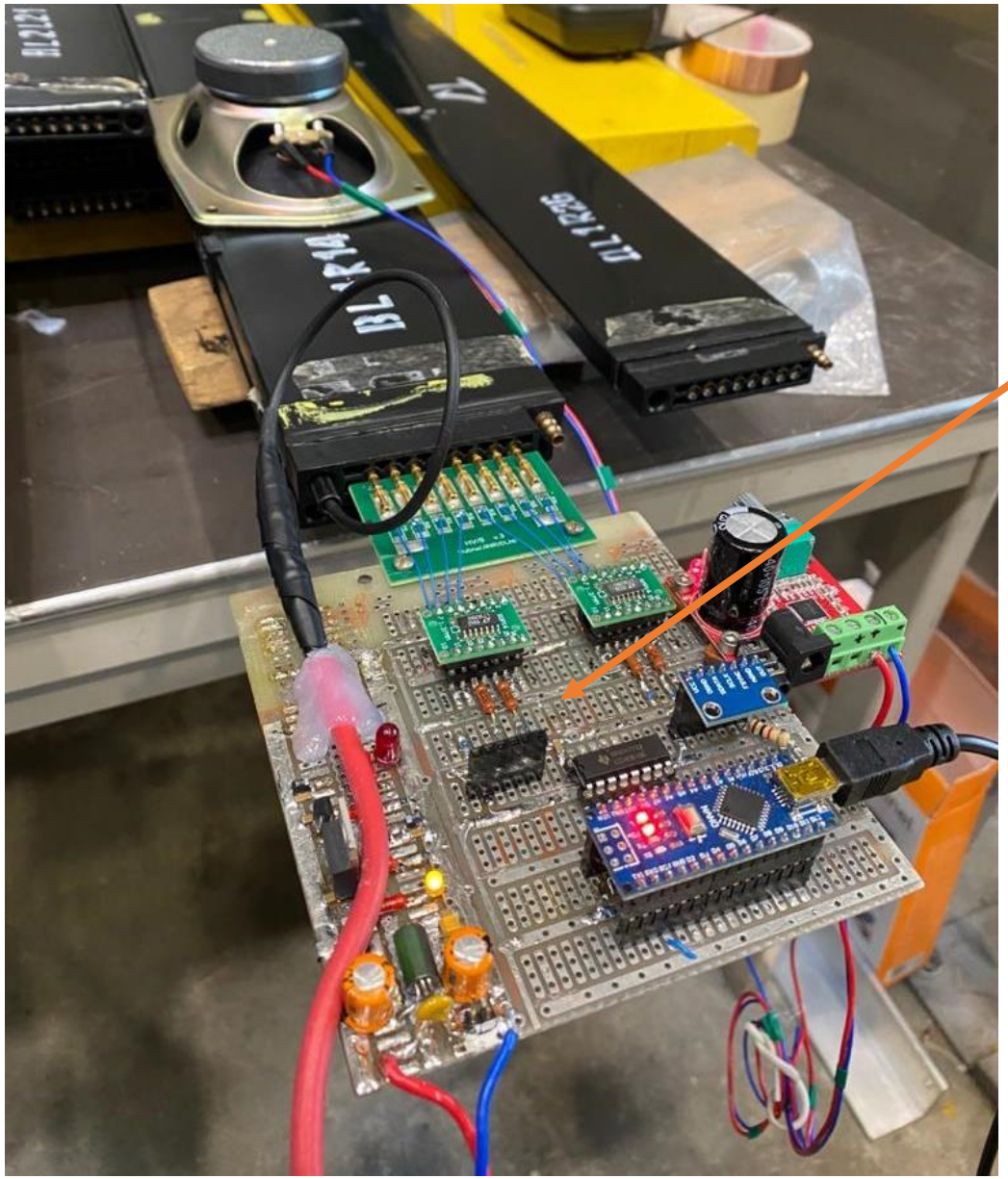


Breakdown test is intended to determine the HV level of individual wire current breakdown for MDT filled with air (when wire current exceeds the preset threshold level).

Test defines presence of any significant wire (MDT channel) defect (when breakdown HV level is more then 3% below the average value)

Test stand consists of 4 channel HV module CAEN N1470 and notebook with control software.

WTTM prototype

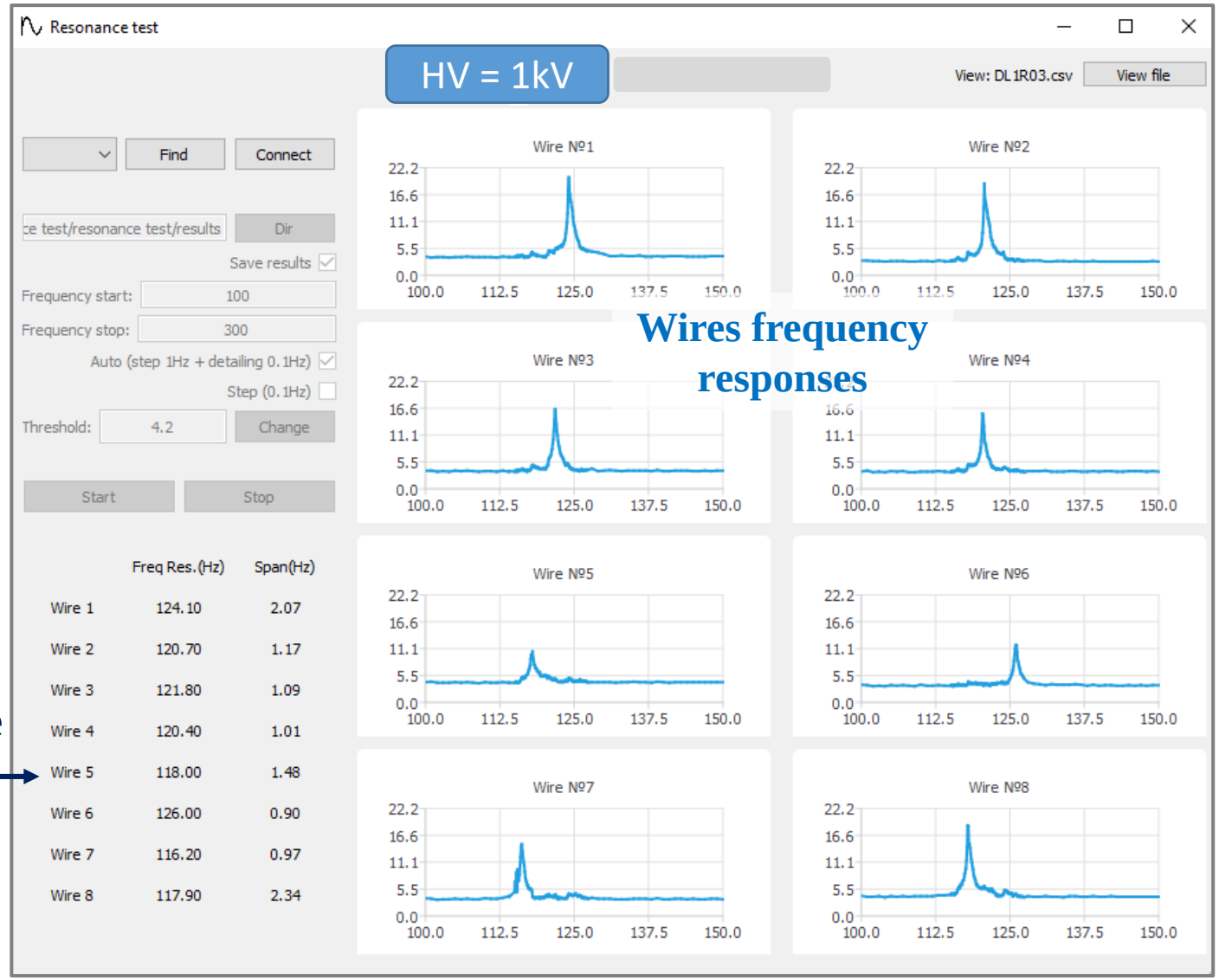


Prototype of the Wire Tension Test Module (WTTM) together with corresponding software were well tested during production of MDTs for the SPD/RS prototype and repair works of the COMPASS/CERN RichWall MDTs.

Result of frequency scan of 8 wires in 5m lond MDT

Program setup:

- File saving option
- Scanning frequency interval
- Detailed or Auto mode
- Threshold level for AutoDetect mode



	Freq Res.(Hz)	Span(Hz)
Wire 1	124.10	2.07
Wire 2	120.70	1.17
Wire 3	121.80	1.09
Wire 4	120.40	1.01
Wire 5	118.00	1.48
Wire 6	126.00	0.90
Wire 7	116.20	0.97
Wire 8	117.90	2.34

Measured resonance frequencies →

Equipping the RS-proto and preparation for transportation from DLNP to Nuclotron

Gas manifolds

Analog FEE ADB-32 cards

Cables support frames

Slots of RS-proto absorber equipped with MDTs

Arrival of RS-proto to Nuclotron and its deployment at test beam area

Ampl-8.51 Individual Channel Tests

Power supply ± 3V

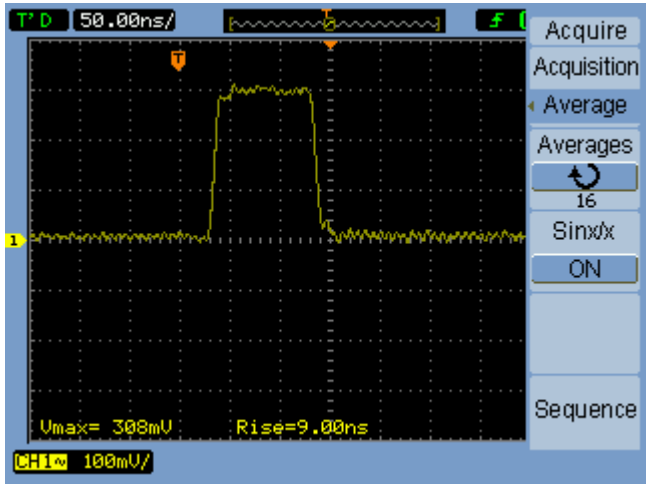
Spice model parameters (Cadence6. Technological spread of circuit elements values is taken into account)

Input impedance (30MHz)	3,32÷8,7 Ohm
Gain	100÷150 mV/µA
Rise time/fall time	8÷12 ns
I_{noise} (C_D= 1,8nF)	315 nA
Dynamic range (C_D= 0nF)	48 dB
Dissipated power	64 mW/ch

Measured parameters

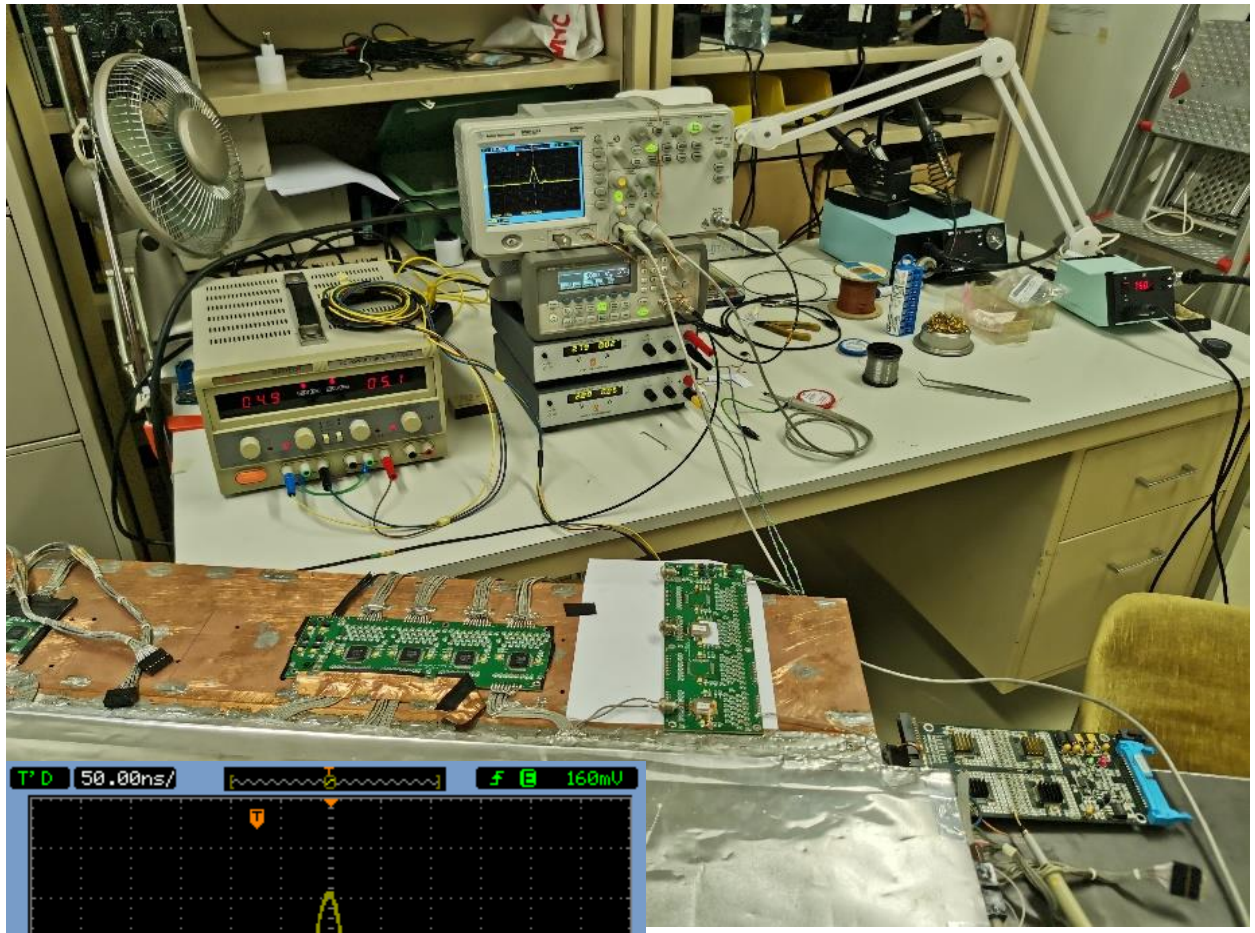
Input impedance (30MHz)	5,4 Ohm
Gain	131 mV/µA
Rise time/fall time	9,2 ns
I_{noise} (C_D= 1,8nF)	550 nA
Dynamic range (C_D= 0nF)	~ 47 dB
Dissipated power	63 mW/ch

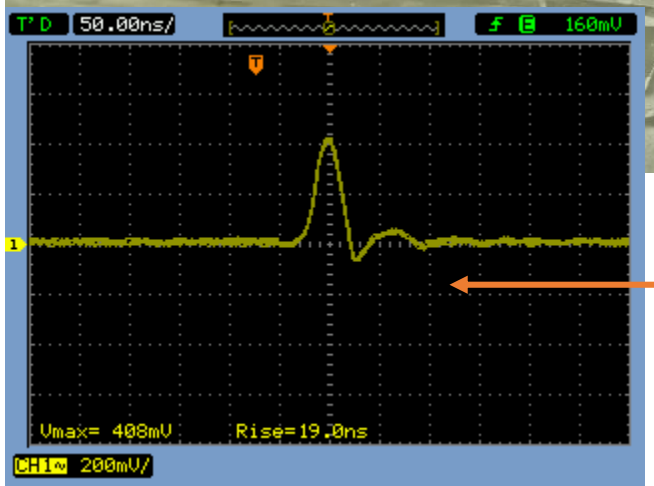
Measured channel parameters perfectly match the technical request.



We still need to achieve a combined 8-channel stable operation of the amplifier chip. We will try to apply all possible of necessary corrections to metal layers of existing chips (with unfinished metallization) to fulfill the task.

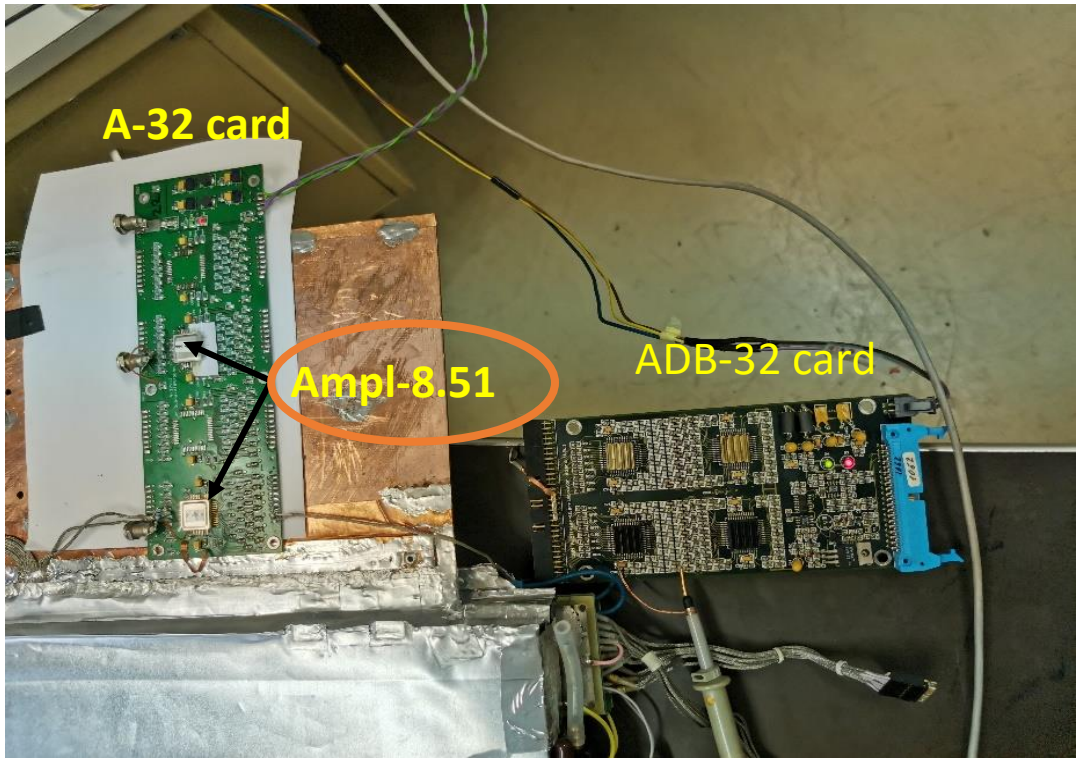
Ampl-8.51 Strip R/O





Positive pulse induced on strip

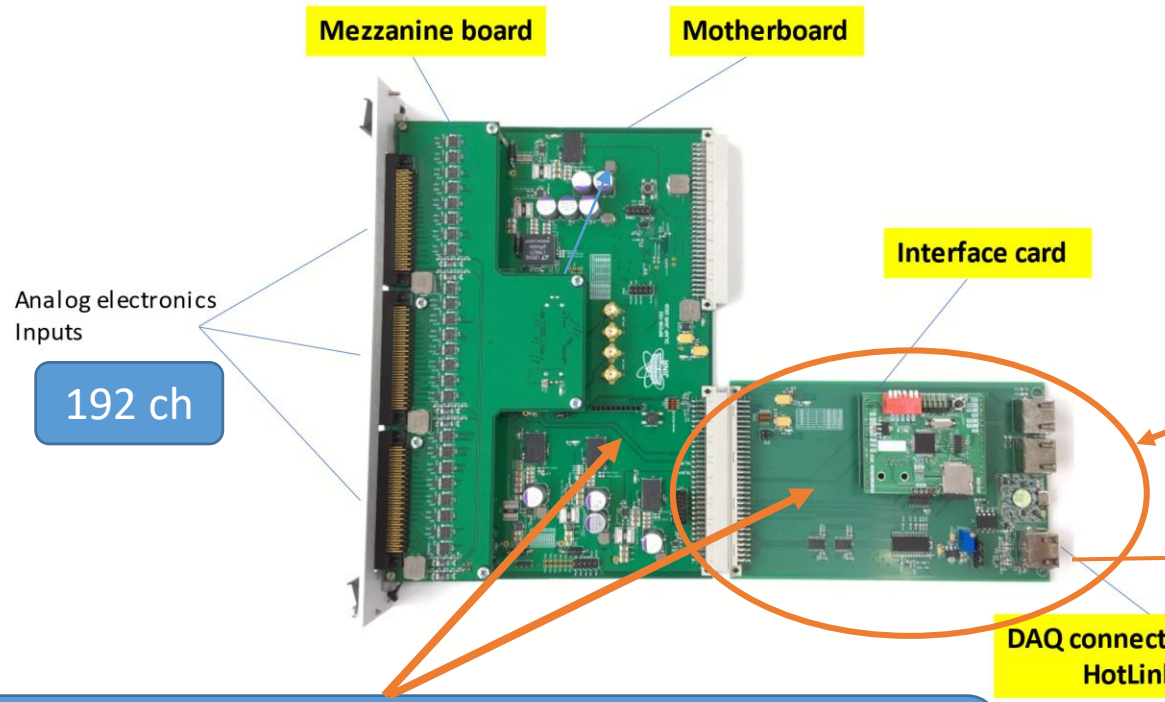
Tests carried out with RSP detector layer at CERN proved that individual Ampl-8.51channel can be reliably used as preamplifier for strip & wire signal R/O



Digital FEE unit based on Xilinx (Artix7) FPGA chip

(7 units (~1300 R/O channels) are produced/tested to equip Range System Prototype of SPD/NICA for testing at Nuclotron test beam in JINR)

Design of digital FEE unit was developed jointly by JINR and MSU/Moscow groups



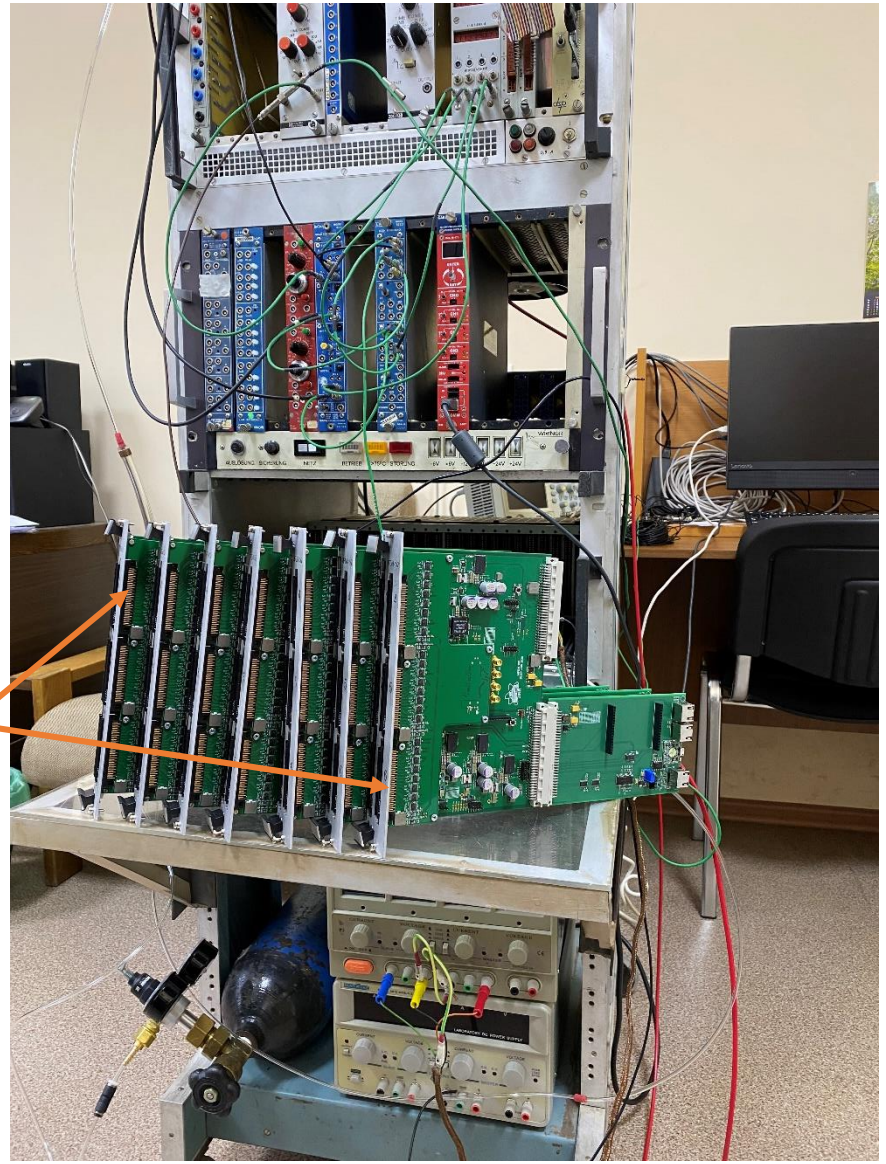
This part will be modified according to the final SPD DAQ design

For RS-proto readout

After finalizing the SPD DAQ design following modifications will be introduced: the whole pcb board (without interface connector) and e-link connection to DAQ

Digital FEE units manufactured, tested and ready for installation on RS-proto

The set of seven VME/6U blocks (FPGA based) provide 1344 R/O channels and fully cover the needs of RS-proto, they may be also used for DAQ tests and at SPD cosmic test stand



Particle reconstruction in Range System

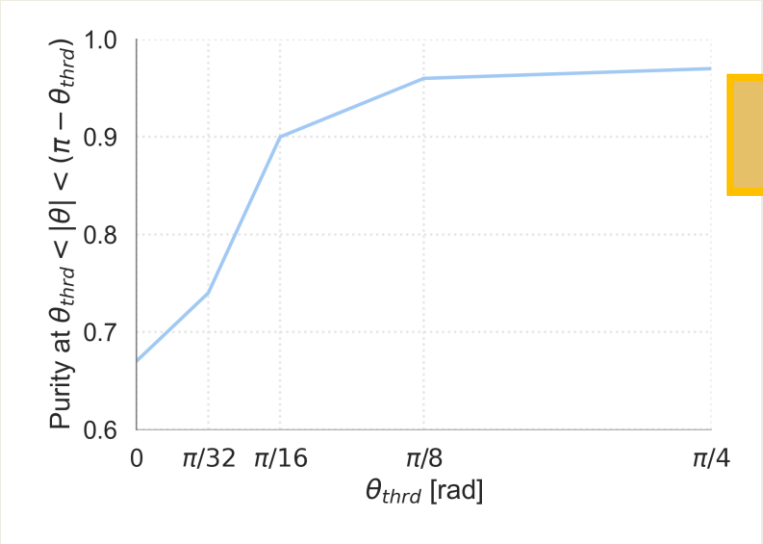
Main goal: to develop algorithms able to reconstruct muons and hadrons based on the information from Range System *standalone* by using machine learning techniques. This is aimed to speed up the reconstruction process instead of slower traditional Kalman Filter technique.

Reconstruction task is split on two steps:

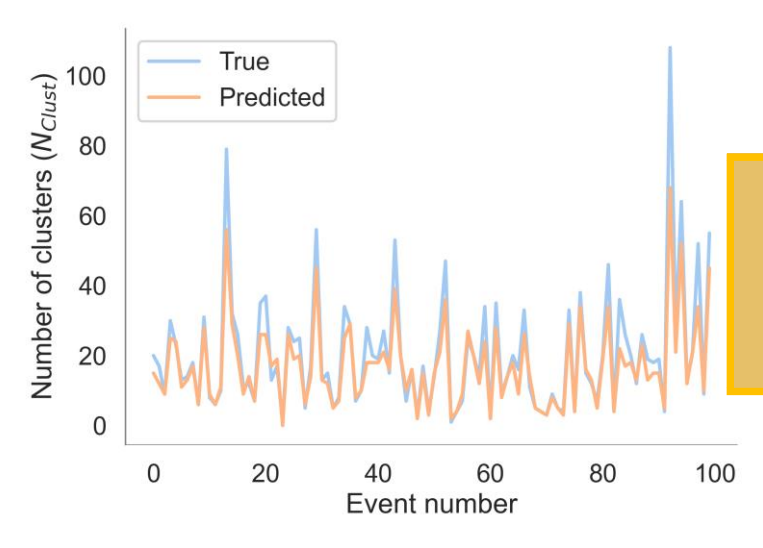
1. ***Clustering***: finds clusters of hits in Range System;
   DBSCAN-based clustering algorithm:
- associates hits to clusters of arbitrary shapes;
- no need to explicitly define number of clusters in an event;
- naturally exploits 3D coordinates of hits (wire/strips);
- reconstructs clusters with >95% (barrel) and 90% ($10° < |\theta| < 170°$ corresponds to $|\eta| < 2.4$) purity on J/ψ events;
- about 10-15% relative error in number of predicted clusters due to clusters with small number of hits.

2. ***Muon/Hadron separation***: separates muon clusters from the clusters associated with hadrons: currently ~95% efficiency using Boosted Decision Tree algorithms *(inefficiency due to similarity of muon/hadron patterns at low momenta);* using Convolutional Neural Network approach is in progress.

Work in progress…



MC is conducted with **full SPD setup**



Example of hundred consecutive events taken at threshold polar angle π/16 (purity ~ 90%)

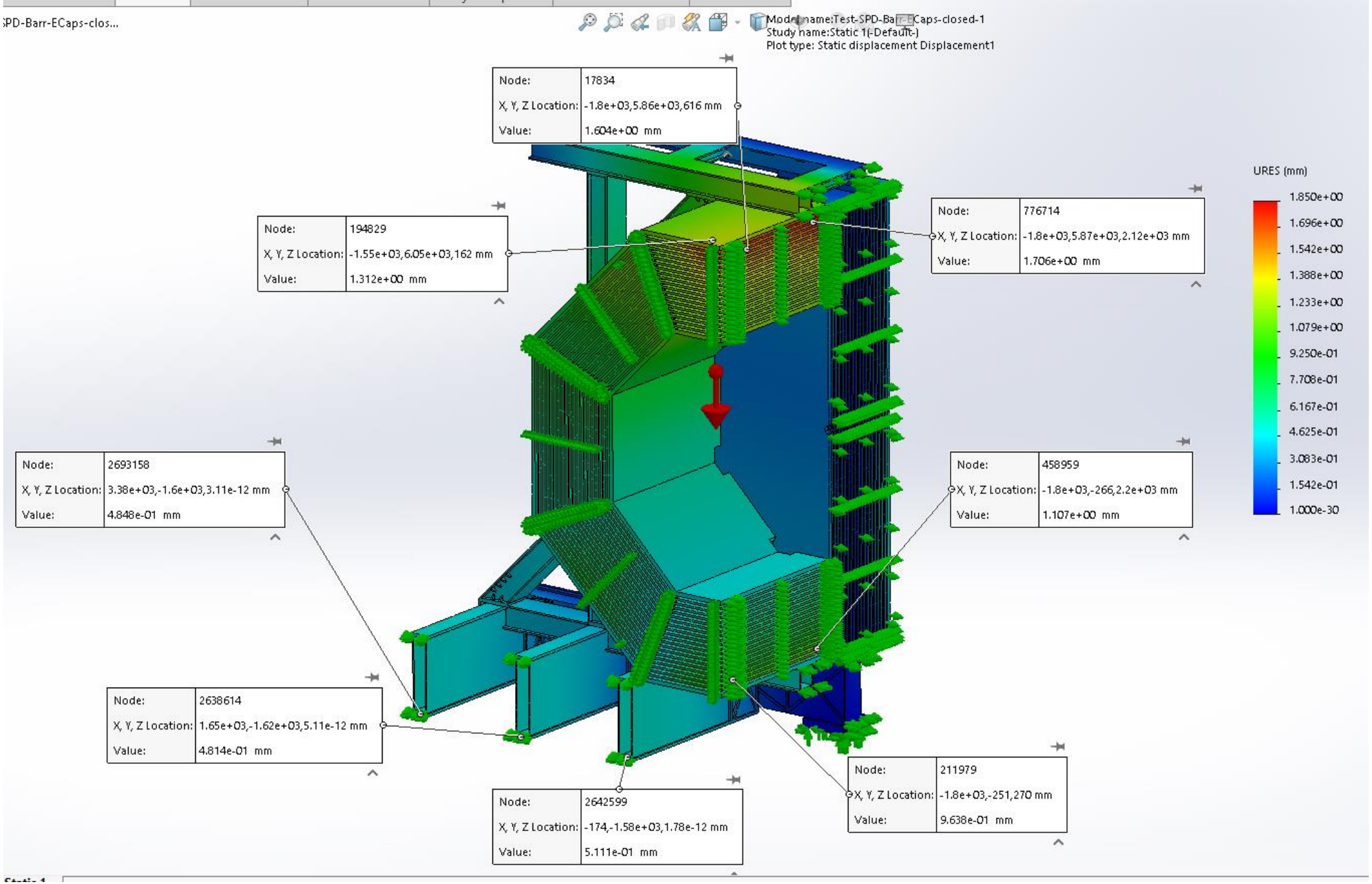
Plans for 2022

- **Writing RS part of SPD TDR -> March/April**
- **Finalizing mechanical FEA calculations (including magnetic forces)**
- **Reconstruct bld.73 of FLNP for deployment of MDT production equipment**
- **Putting RS-prototype and pressurized Cherenkov counter in operation at test beam**
- **Production and tests of the final version of amplifier ASIC chip**
- **Design and production of “final” digital FEE unit with e-link interface**
- **Continue work on software developments**

CONCLUSION

For the short range future SPD Technical Design Report is absolutely needed. The Range System part of SPD TDR will be ready to March-April. To ensure more distant future we need to organize reconstruction of bld.73 as soon as possible to deploy the MDT detectors workshop there. It is one of critical issues. And generally saying - start of SPD/RS construction in 2024 looks for us as feasible task now.

Backup slides


SPD-Barr-ECaps-clos...
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Value: 1.604e+00 mm
Node: 194829
X, Y, Z Location: -1.55e+03,6.05e+03,162 mm
Value: 1.312e+00 mm
Node: 776714
X, Y, Z Location: -1.8e+03,5.87e+03,2.12e+03 mm
Value: 1.706e+00 mm
Node: 2693158
X, Y, Z Location: 3.38e+03,-1.6e+03,3.11e-12 mm
Value: 4.848e-01 mm
Node: 458959
X, Y, Z Location: -1.8e+03,-266,2.2e+03 mm
Value: 1.107e+00 mm
Node: 2638614
X, Y, Z Location: 1.65e+03,-1.62e+03,5.11e-12 mm
Value: 4.814e-01 mm
Node: 211979
X, Y, Z Location: -1.8e+03,-251,270 mm
Value: 9.638e-01 mm
Node: 2642599
X, Y, Z Location: -174,-1.58e+03,1.78e-12 mm
Value: 5.111e-01 mm
URES (mm)
1.850e+00
1.696e+00
1.542e+00
1.388e+00
1.233e+00
1.079e+00
9.250e-01
7.708e-01
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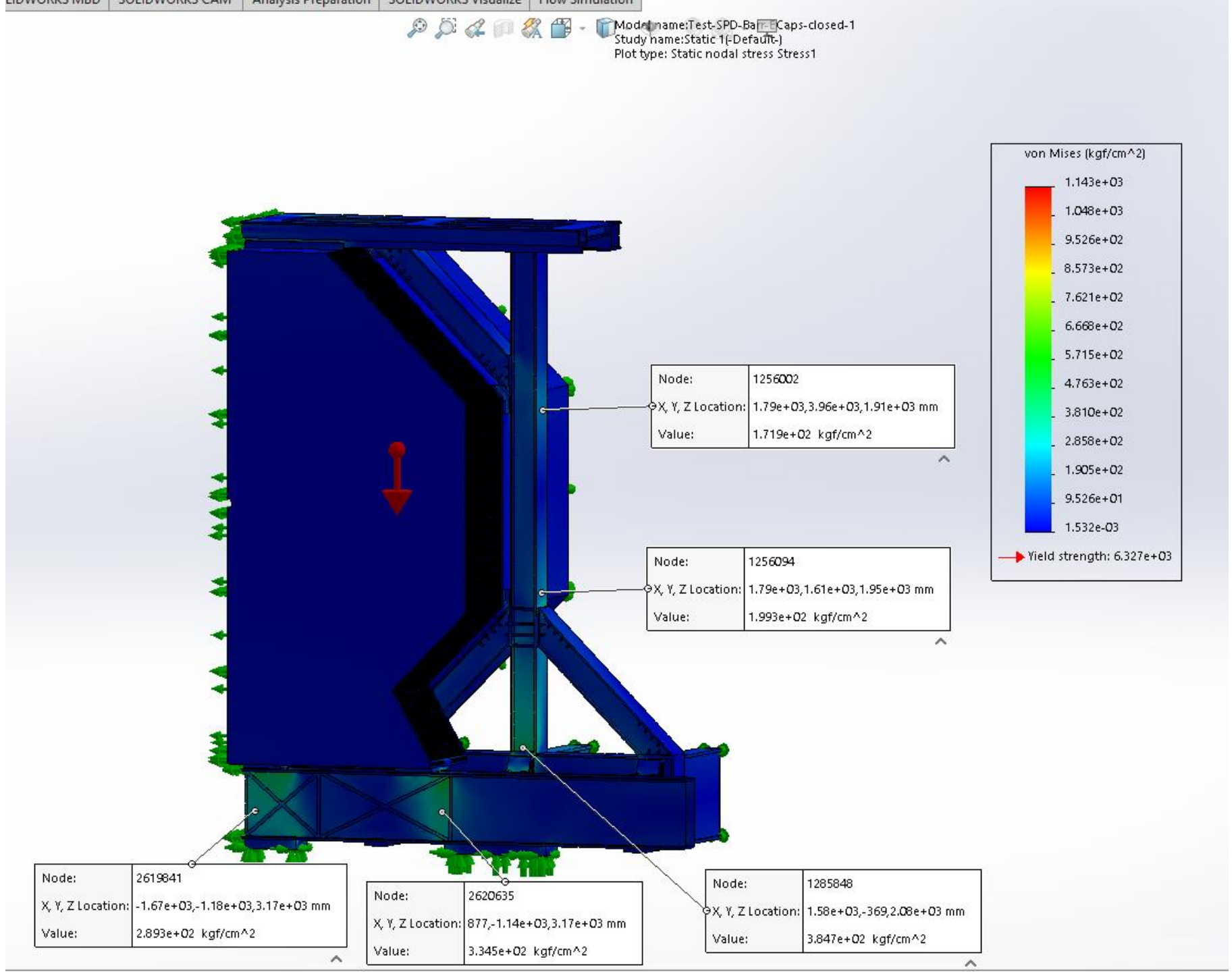
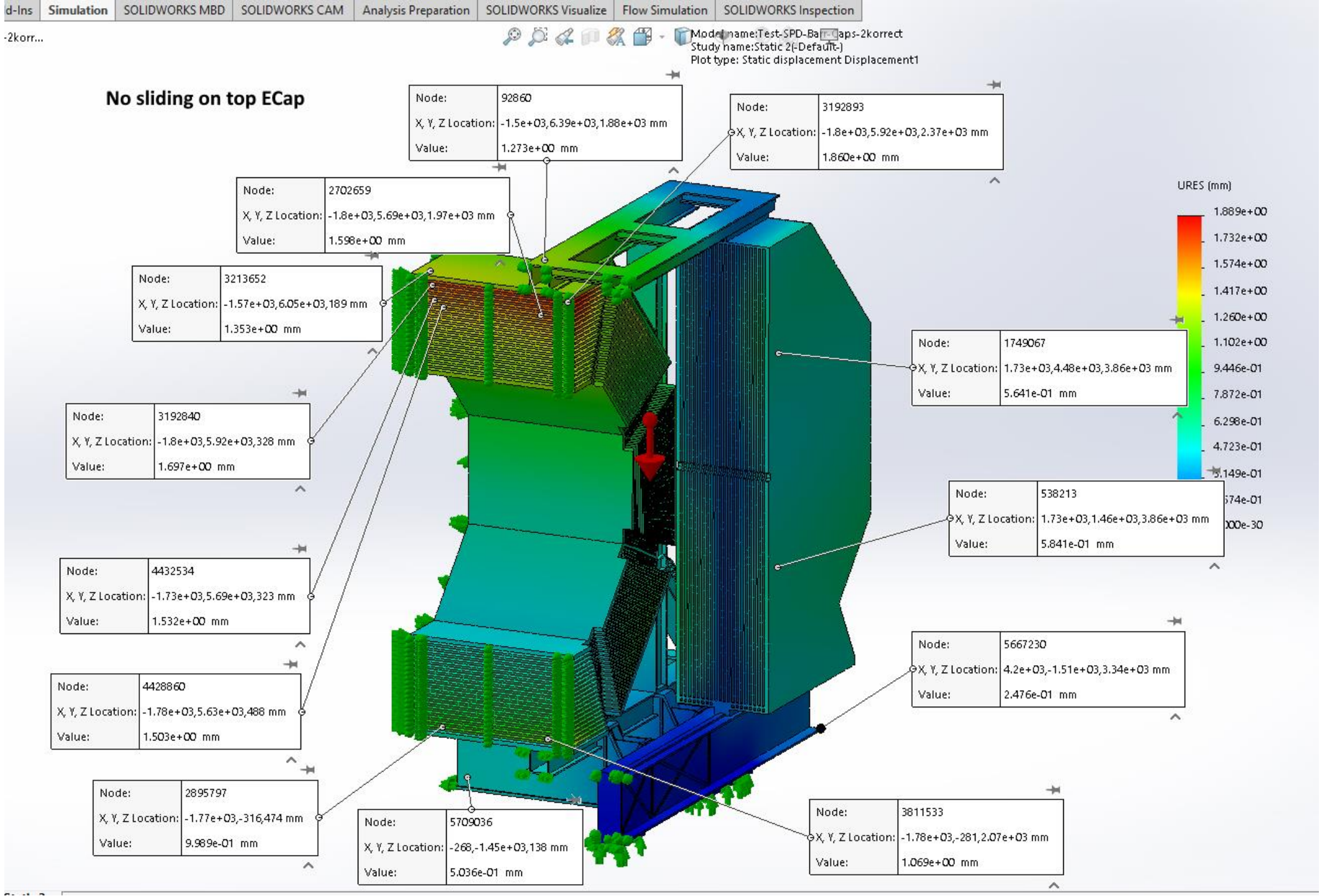
1.542e-01
1.000e-30


Model name:Test-SPD-Ball-Caps-closed-1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (kgf/cm^2)
1.143e+03
1.048e+03
9.526e+02
8.573e+02
7.621e+02
6.668e+02
5.715e+02
4.763e+02
3.810e+02
2.858e+02
1.905e+02
9.526e+01
1.532e-03
Yield strength: 6.327e+03
Node: 1256002
X, Y, Z Location: 1.79e+03,3.96e+03,1.91e+03 mm
Value: 1.719e+02 kgf/cm^2
Node: 1256094
X, Y, Z Location: 1.79e+03,1.61e+03,1.95e+03 mm
Value: 1.993e+02 kgf/cm^2
Node: 2619841
X, Y, Z Location: -1.67e+03,-1.18e+03,3.17e+03 mm
Value: 2.893e+02 kgf/cm^2
Node: 2620635
X, Y, Z Location: 877,-1.14e+03,3.17e+03 mm
Value: 3.345e+02 kgf/cm^2
Node: 1285848
X, Y, Z Location: 1.58e+03,-369,2.08e+03 mm
Value: 3.847e+02 kgf/cm^2


d-Ins
Simulation
SOLIDWORKS MBD
SOLIDWORKS CAM
Analysis Preparation
SOLIDWORKS Visualize
Flow Simulation
SOLIDWORKS Inspection
-2korr...
Model name:Test-SPD-Ba...aps-2korrect
Study name:Static 2(-Default-)
Plot type: Static displacement Displacement1
No sliding on top ECap
Node: 92860
X, Y, Z Location: -1.5e+03,6.39e+03,1.88e+03 mm
Value: 1.273e+00 mm
Node: 3192893
X, Y, Z Location: -1.8e+03,5.92e+03,2.37e+03 mm
Value: 1.860e+00 mm
Node: 2702659
X, Y, Z Location: -1.8e+03,5.69e+03,1.97e+03 mm
Value: 1.598e+00 mm
Node: 3213652
X, Y, Z Location: -1.57e+03,6.05e+03,189 mm
Value: 1.353e+00 mm
URES (mm)
1.889e+00
1.732e+00
1.574e+00
1.417e+00
1.260e+00
1.102e+00
9.446e-01
7.872e-01
6.298e-01
4.723e-01
3.149e-01
Node: 1749067
X, Y, Z Location: 1.73e+03,4.48e+03,3.86e+03 mm
Value: 5.641e-01 mm
Node: 3192840
X, Y, Z Location: -1.8e+03,5.92e+03,328 mm
Value: 1.697e+00 mm
Node: 538213
X, Y, Z Location: 1.73e+03,1.46e+03,3.86e+03 mm
Value: 5.841e-01 mm
Node: 4432534
X, Y, Z Location: -1.73e+03,5.69e+03,323 mm
Value: 1.532e+00 mm
Node: 4428860
X, Y, Z Location: -1.78e+03,5.63e+03,488 mm
Value: 1.503e+00 mm
Node: 5667230
X, Y, Z Location: 4.2e+03,-1.51e+03,3.34e+03 mm
Value: 2.476e-01 mm
Node: 2895797
X, Y, Z Location: -1.77e+03,-316,474 mm
Value: 9.989e-01 mm
Node: 5709036
X, Y, Z Location: -268,-1.45e+03,138 mm
Value: 5.036e-01 mm
Node: 3811533
X, Y, Z Location: -1.78e+03,-281,2.07e+03 mm
Value: 1.069e+00 mm