

Overview of STT Activities

S. Di Falco

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*STT working group Meeting
13 April 2022*

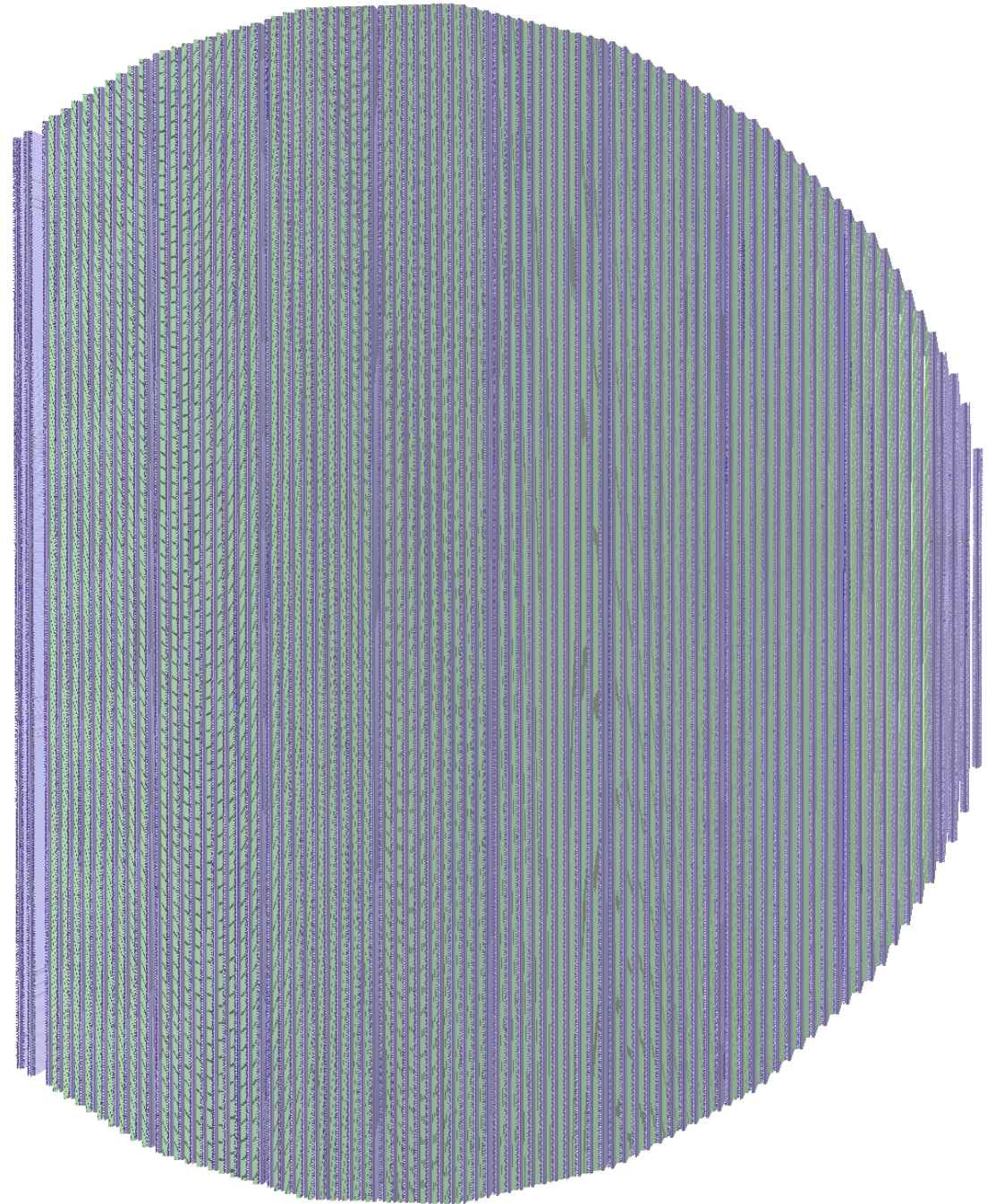
- ◆ *Activities related to the **design and construction of the STT for SAND**, the assigned goals being the completion of the detector installation and its readiness for operation.*
- ◆ *Initial WG chairs: G. Sirri, S. Di Falco, R. Petti*
- ◆ *Dedicated **mailing list DUNE-ND-SAND-STT***
 - ⇒ *Encourage any interested people to subscribe (if not done yet)*
- ◆ *Material presented and discussed during WG meetings available on Indico:
<https://indico.fnal.gov/category/1402/>*
- ◆ ***By-weekly regular meetings on Wednesday at 11am Central Time / US***
 - ⇒ *May circulate a new Doodle survey at a later time, if needed*

STT FOR SAND

*70 CH₂ modules
8 C modules
6 tracking modules*

*~220,000 straws
average straw length 3.2 m
maximal straw length 3.8 m
internal gas volume ~14 m³
nominal gas pressure ~2 bar*

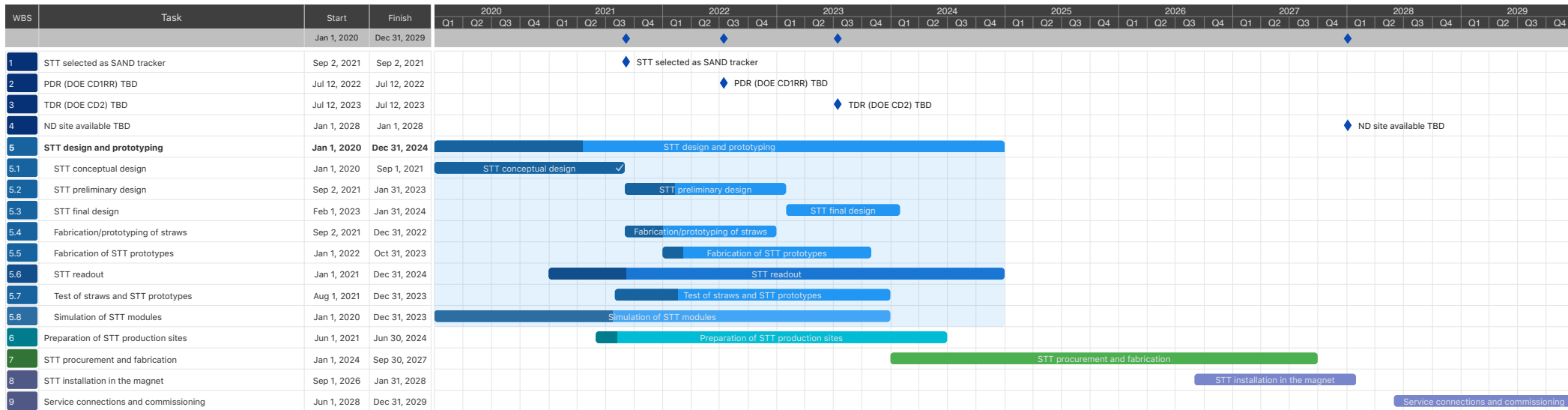
FV mass:
~4.7 t CH₂
~600 kg C



STT ACTIVITIES & SCHEDULE

- ◆ *Defined scope of activities* required for the completion and installation of the STT.
- ◆ *Preliminary schedule and related deliverables:*
 - *Input for discussions to be revised following comments/suggestions;*
 - *Uncertainties on availability of ND site and current situation (covid19, conflict, supplies, etc.).*

STT for SAND



DESIGN ACTIVITIES

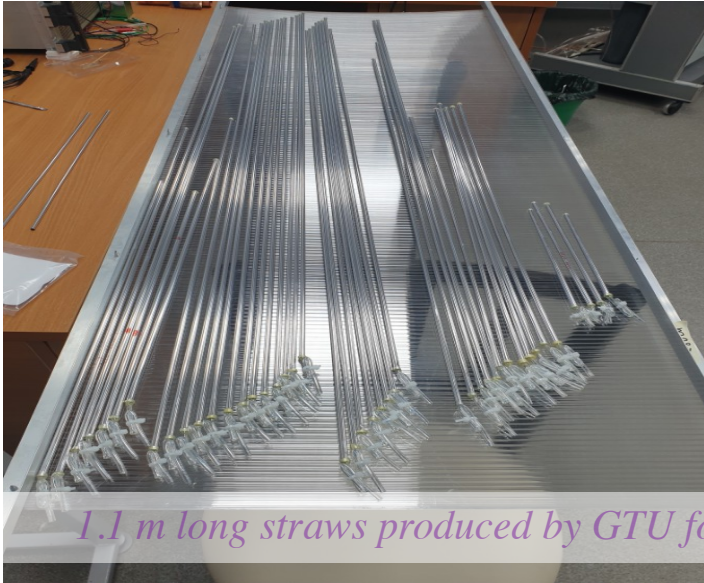
WBS	Task	Start	Finish	2020					2021				2022				2023				2024				2025				
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	
		Jan 1, 2020	Dec 31, 2029	◆																									
1	STT selected as SAND tracker	Sep 2, 2021	Sep 2, 2021	◆ STT selected as SAND tracker																									
2	PDR (DOE CD1RR) TBD	Jul 12, 2022	Jul 12, 2022	◆ PDR (DOE CD1RR) TBD																									
3	TDR (DOE CD2) TBD	Jul 12, 2023	Jul 12, 2023	◆ TDR (DOE CD2) TBD																									
4	ND site available TBD	Jan 1, 2028	Jan 1, 2028																										
5	STT design and prototyping	Jan 1, 2020	Dec 31, 2024	STT design and prototyping																									
5.1	STT conceptual design	Jan 1, 2020	Sep 1, 2021	STT conceptual design ✓																									
5.2	STT preliminary design	Sep 2, 2021	Jan 31, 2023																										
5.2.1	Design straw tubes	Sep 2, 2021	Dec 31, 2022	Design straw tubes																									
5.2.2	Design mechanical wire fixtures	Sep 2, 2021	Dec 31, 2022	Design mechanical wire fixtures																									
5.2.3	Design C-composite frame	Sep 2, 2021	Dec 31, 2022	Design C-composite frame																									
5.2.4	Integration with readout electronics	Sep 2, 2021	Dec 31, 2022	Integration with readout electronics																									
5.2.5	Design mechanical support structure	Jun 1, 2022	Dec 31, 2022	Design mechanical support structure																									
5.2.6	Design polypropylene target	Jun 1, 2022	Dec 31, 2022	Design polypropylene target																									
5.2.7	Design graphite target	Jun 1, 2022	Dec 31, 2022	Design graphite target																									
5.2.8	Design radiator	Jun 1, 2022	Dec 31, 2022	Design radiator																									
5.2.9	Design gas system	Jun 1, 2022	Dec 31, 2022	Design gas system																									
5.2.10	Develop assembly procedure for STT modules	Sep 2, 2021	Dec 31, 2022	Develop assembly procedure for STT modules																									
5.2.11	Design 1.2m x 0.8m prototype	Sep 2, 2021	Sep 30, 2022	Design 1.2m x 0.8m prototype																									
5.2.12	Design 4m x 0.5m prototype	Nov 1, 2022	Dec 31, 2022	Design 4m x 0.5m prototype																									
5.2.13	Conduct preliminary design review	Jan 1, 2023	Jan 15, 2023	Conduct preliminary design review																									
5.2.14	Incorporate preliminary design review comments	Jan 16, 2023	Jan 31, 2023	Incorporate preliminary design review comments																									
5.3	STT final design	Feb 1, 2023	Jan 31, 2024																										
5.3.1	Perform final design of STT modules	Feb 1, 2023	Dec 31, 2023	Perform final design of STT modules																									
5.3.2	Perform final design of polypropilene target	Feb 1, 2023	Dec 31, 2023	Perform final design of polypropilene target																									
5.3.3	Perform final design of graphite target	Feb 1, 2023	Dec 31, 2023	Perform final design of graphite target																									
5.3.4	Perform final design of radiator	Feb 1, 2023	Dec 31, 2023	Perform final design of radiator																									
5.3.5	Perform final design of mechanical support structure	Feb 1, 2023	Dec 31, 2023	Perform final design of mechanical support structure																									
5.3.6	Perform final design of gas system	Feb 1, 2023	Dec 31, 2023	Perform final design of gas system																									
5.3.7	Conduct final design review	Jan 1, 2024	Jan 15, 2024	Conduct final design review																									
5.3.8	Incorporate final design review comments	Jan 16, 2024	Jan 31, 2024	Incorporate final design review comments																									

Demonstrate all aspects of the STT design in increasing order of complexity:

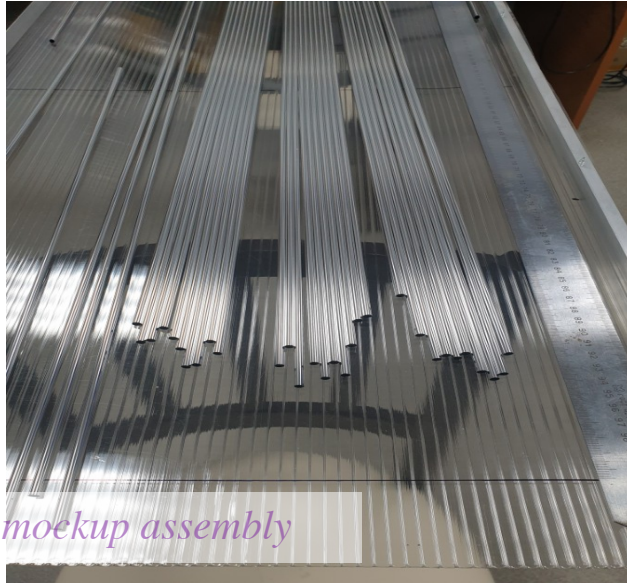
- Produce straws of required quality & maximal length with ultrasonic welding (UW)*
⇒ *Validation of model production lines at JINR (5m) and GTU (2m)*
- Verify UW straws fulfill requirements from STT conceptual design & assembly procedure*
⇒ *Measurement of maximal internal pressure, radial and longitudinal deformations vs. pressure, relaxation vs. time and humidity, gas tightness, etc.*
- Verify XXYY straw layer assembly*
⇒ *Gluing and pressure tests of 1m × 1m XXYY test assembly*
- Verify assembly procedure of XXYY straws to frame, gas tightness, etc.*
⇒ *Mockup prototype(s) with plexiglass frame (in progress)*
- Verify module design with C-composite frame and related performance*
⇒ *Complete 1.2m × 0.8m prototype with XXYY straws and actual STT frame design*
- Verify full scale module (module 0) with maximal straw length and complete assembly*
⇒ *Complete 4m × 0.5m prototype with XXYY straws and C-composite frame*

Demonstrate readout performance:

- Verify charge measurement with ^{55}Fe source & cosmics*
⇒ *Readout small STT prototype with Mu2e FE boards with VMM3/VMM3a ASICs*
- Verify time measurement with signal generator*
- Verify time and charge measurement at testbeam*
⇒ *Readout small STT prototype with FE boards with VMM3/VMM3a ASICs*



1.1 m long straws produced by GTU for moekup assembly

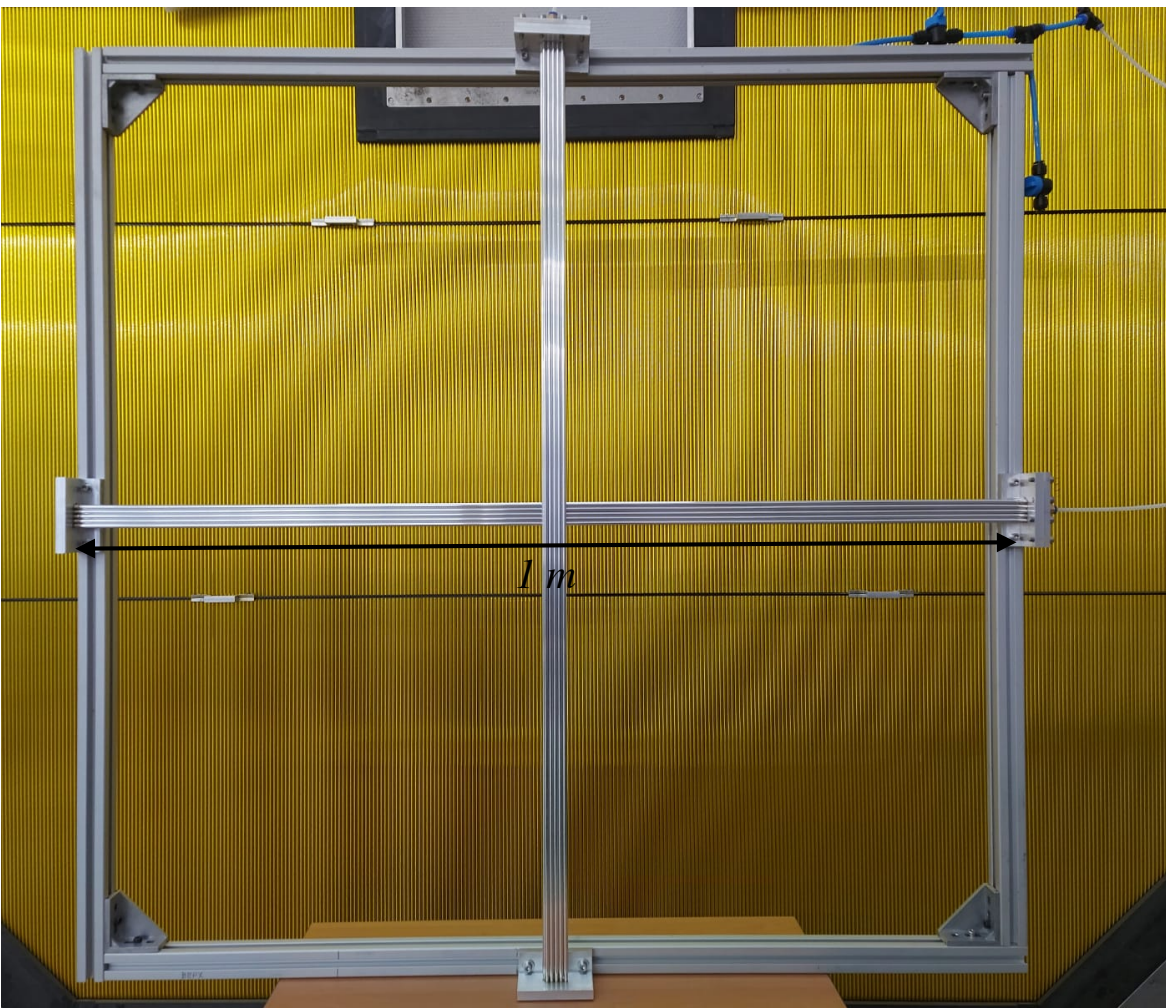


5 m long straws produced at JINR for the gluing tests

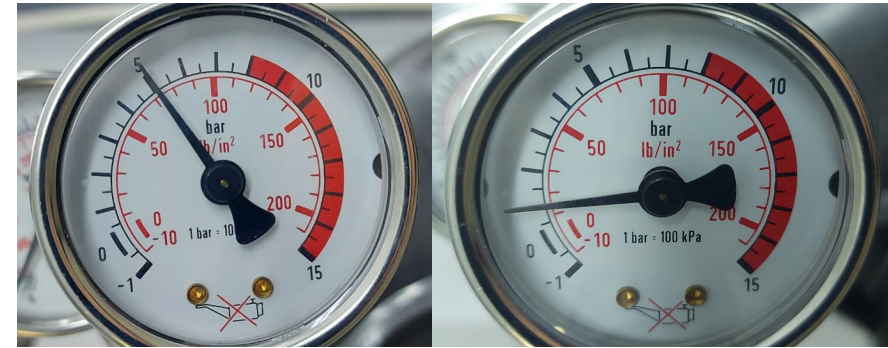


Pressure tests (GTU)

*Cycled multiple times
complete glued XXYY assembly
from 1 bar to 5 bar:
no problems nor apparent damages
for the straw assembly*

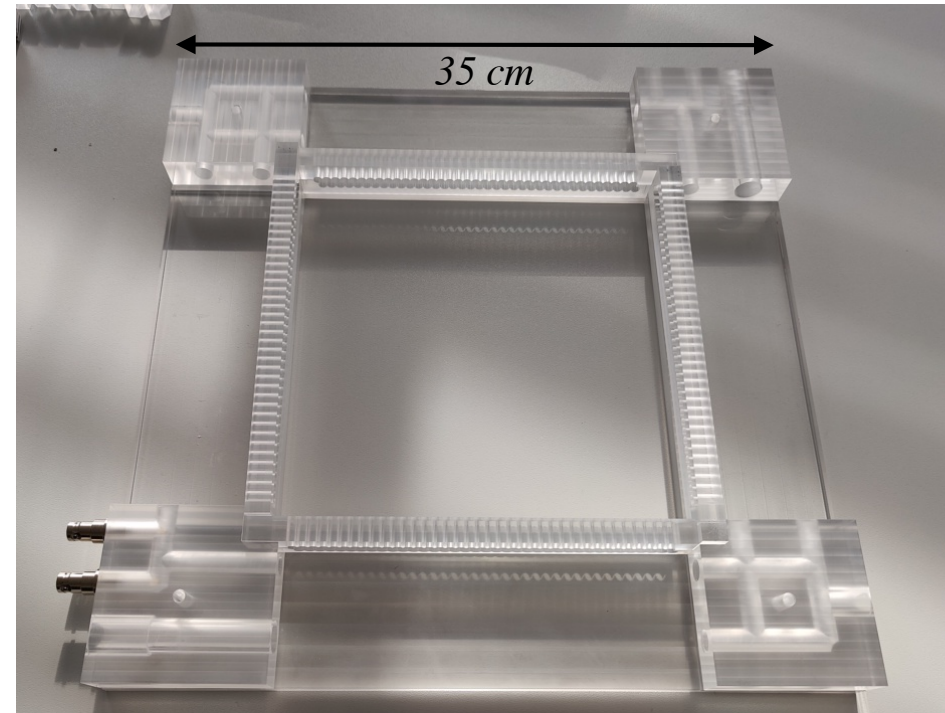
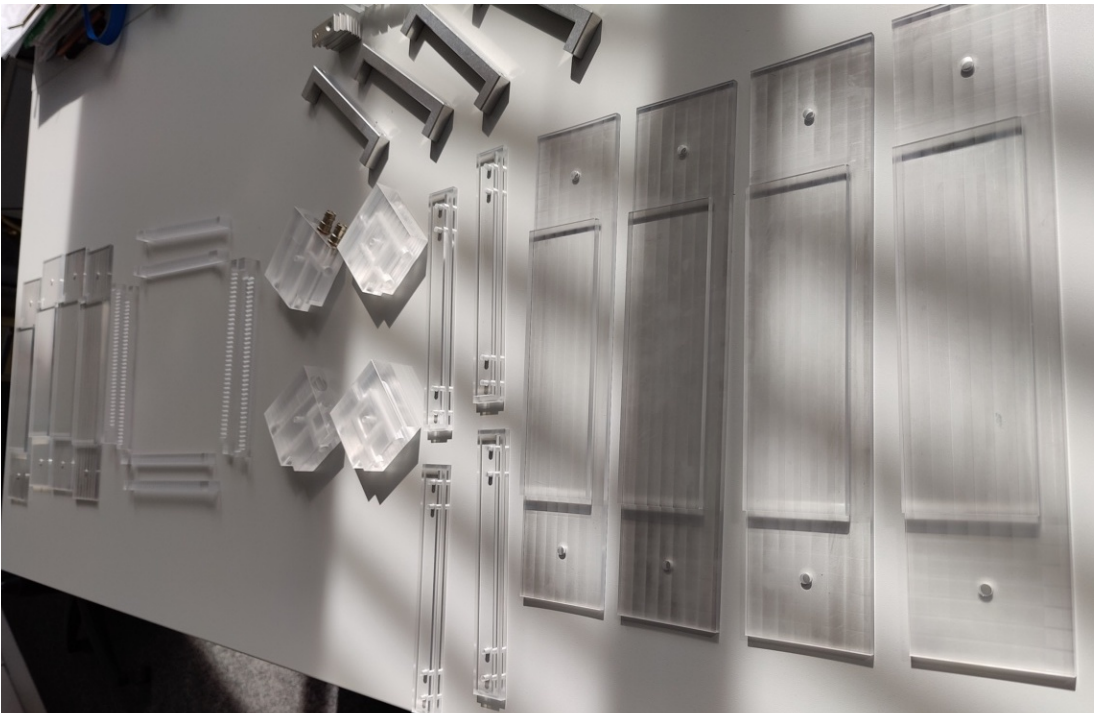
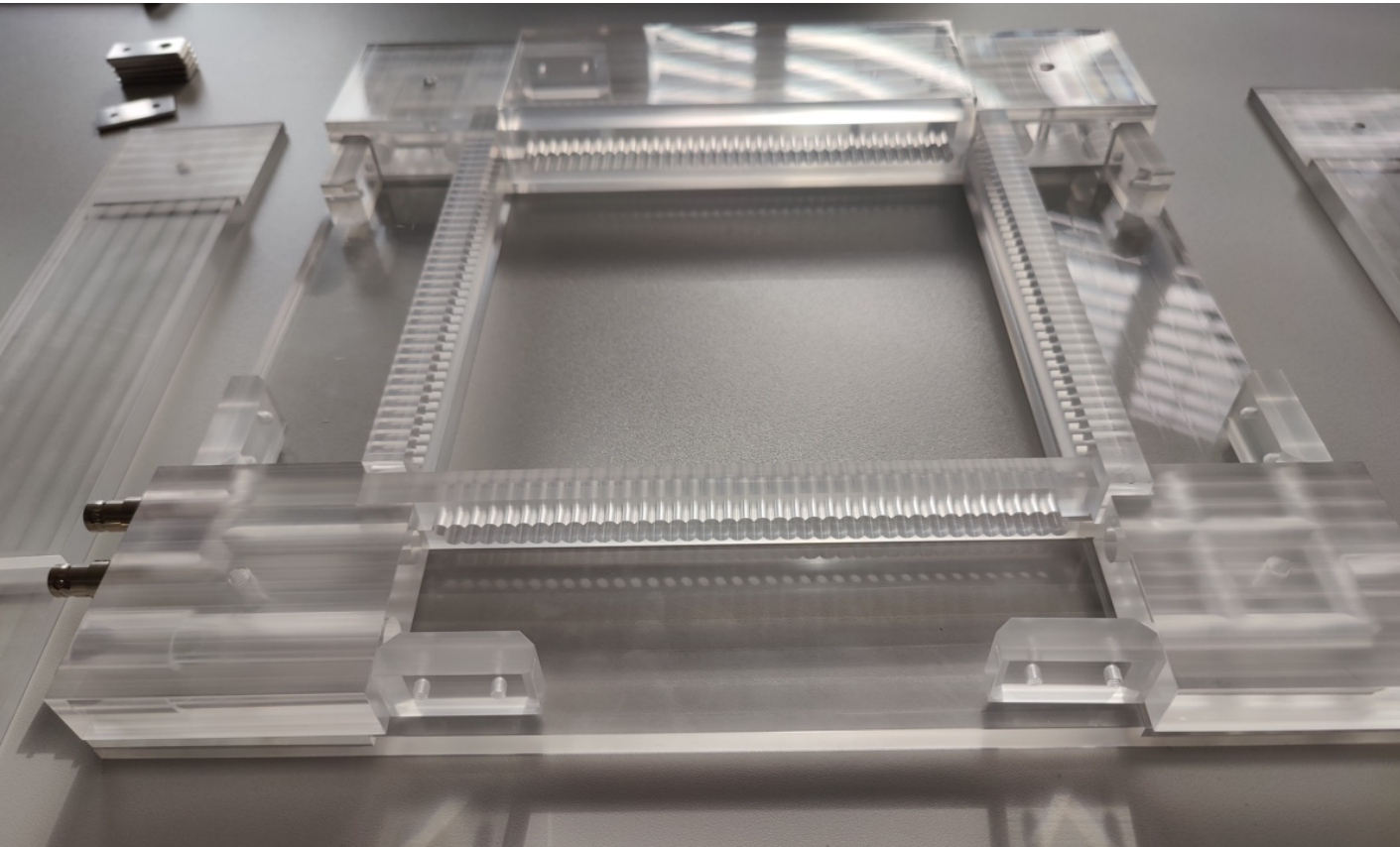


Straws glued together with epoxy ELK5 (~ 20cm spacing)



D. Bick (Hamburg)

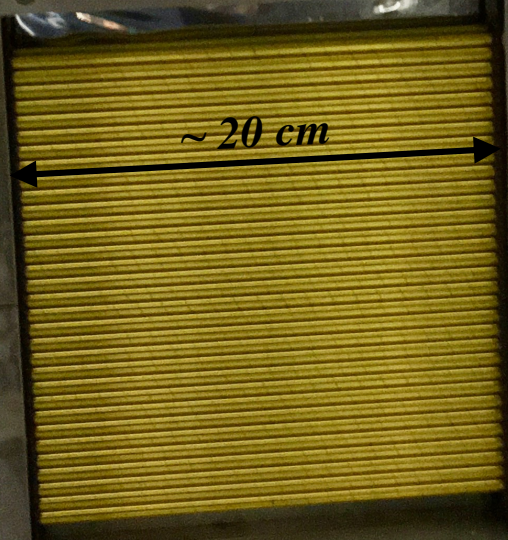
*Plexiglass frame for the
mockup prototype
ready for assembly*



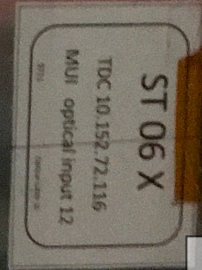
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VMM3a readout
(64 YY straws)

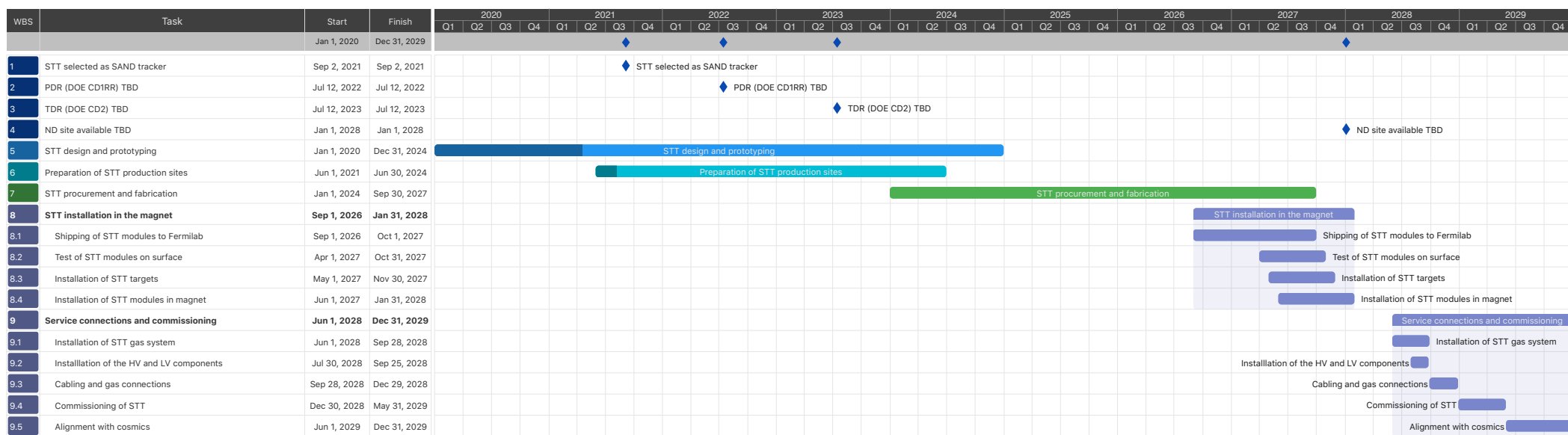


Straw tracker:
two double layers
XX + YY



VMM3a readout
(64 XX straws)

INSTALLATION & COMMISSIONING



Tasks to be completed by *early summer 2022*:

- ◆ *Preparation for CD1RR review (July 2022)*
⇒ *Based on conceptual design, review resources and costs*
- ◆ *Decision about VMM3 readout and need of ASIC revision*
⇒ *Validation of ASIC capabilities with testbeam exposure at CERN in May-June*
- ◆ *List of candidate sites for production of straws and/or STT modules*
⇒ *Required for resource planning and site preparation*
- ◆ *Completion of assembly and test of first mockup prototype*
⇒ *Required to finalize design of 1.2m × 0.8m prototype and for preliminary design of STT modules*
- ◆ *Testbeam exposure of small XX+YY prototype and mockup with VMM3 readout*
⇒ *Required to verify that VMM3 performance fulfills STT requirements*

◆ *Contributing institutions (expressed interest / already working):*

- *Georgia: Georgian Technical University;*
- *Germany: University of Hamburg;*
- *India: IIT Guwahati, NISER, Panjab University, University of Lucknow;*
- *Italy: INFN/Univ. Bologna, Genova, Pisa; INFN/Lab. Frascati, INFN/Lab. Catania;*
- *Joint Institute for Nuclear Research (JINR), Dubna;*
- *USA: BNL, Duke University, University of South Carolina, Virginia Tech.*

◆ *Assign resources to various tasks identified*

⇒ *Encourage anybody interested in specific tasks to contact WG conveners by 27 April*

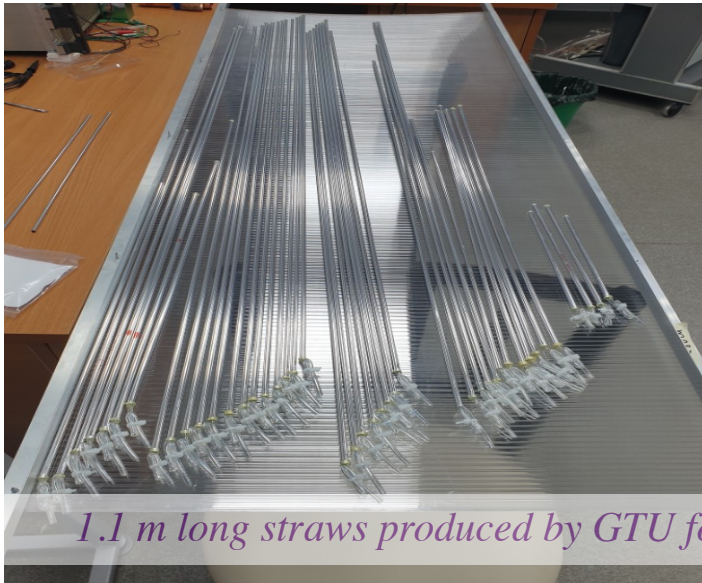
◆ *Preliminary survey indicates need of electronics experts for readout tasks.*

◆ *Evaluate impact of Russia-Ukraine conflict and possible mitigations*

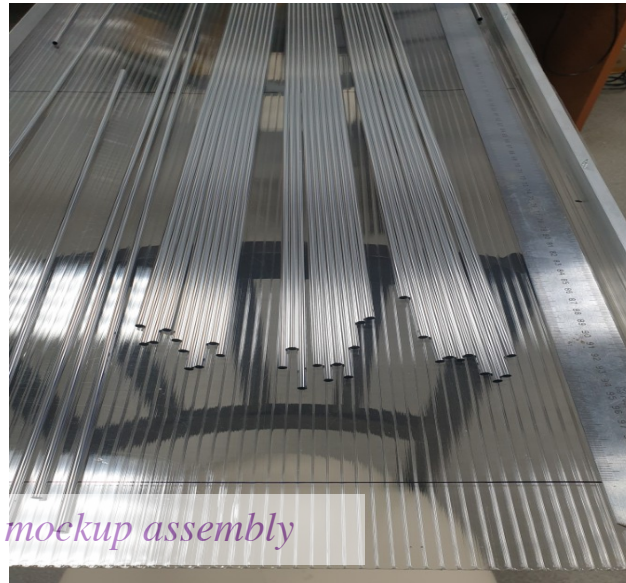
Backup slides

STRAW PRODUCTION

- ◆ Production of straws with *ultrasonic welding technology*:
 - JINR line producing 5m long straws \sim 6 straws/hour;
 - GTU line producing <2 m long straws \sim 80 straws/day.
- ◆ Demonstrated double Al coating on inner and outer surfaces:
 - Protection against humidity for more reliable long term operation;
 - Improved gas tightness from reduction of diffusion through straw walls;
 - May simplify ground connections through external layer.
- ◆ Tested/compared different straw types (4.9 ± 0.05 mm):
 - Wall thickness $12 \mu\text{m}$ with single Al metallization 70 nm ;
 - Wall thickness $20 \mu\text{m}$ with single Al metallization 70 nm ;
 - Wall thickness $20 \mu\text{m}$ with double Al metallization $70 \text{ nm} + 40 \text{ nm}$.



1.1 m long straws produced by GTU for moekup assembly



5 m long straws produced at JINR for the gluing tests

MEASUREMENTS OF STRAW PROPERTIES

- ◆ *Measurement of maximal internal pressure* achievable without plastic deformations.

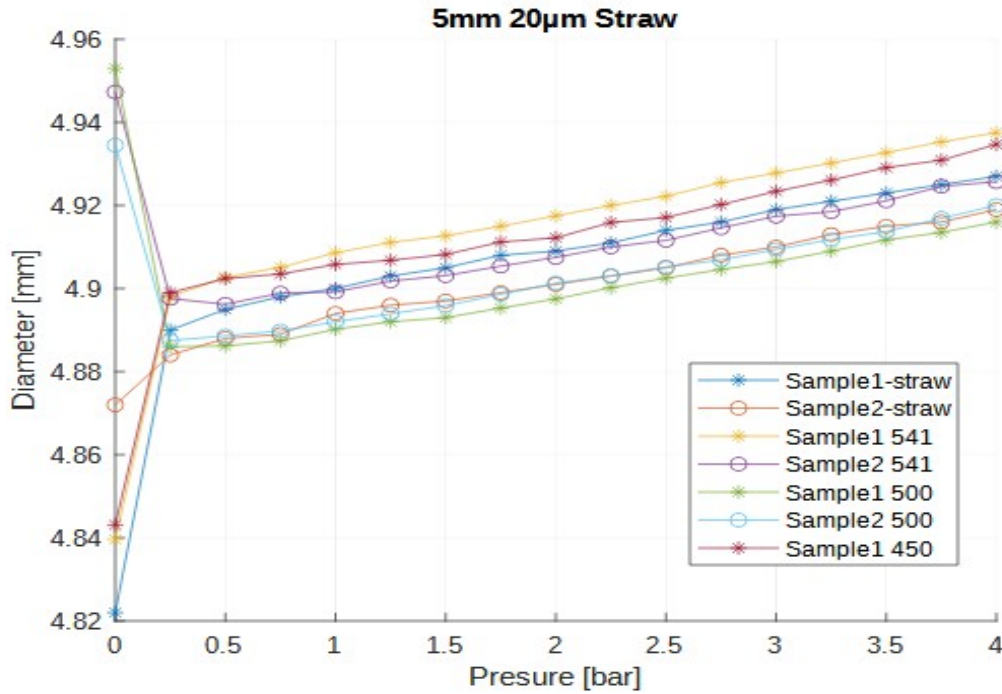
- ◆ *Measurement of radial deformations* vs. *internal gas pressure (GTU)*:
 - *Straws with 4.9mm diameter, 20 μm walls, produced by both JINR and GTU;*
 - *Comparison of different types of mylar film and Al metallization.*

- ◆ *Measurements of straw elongation and tension* vs. *internal gas pressure (GTU)*:
 - *Straws with 4.9mm diameter, 12 μm & 20 μm walls;*
 - *Studied tension drop with increase of internal pressure starting from initial pre-tension.*

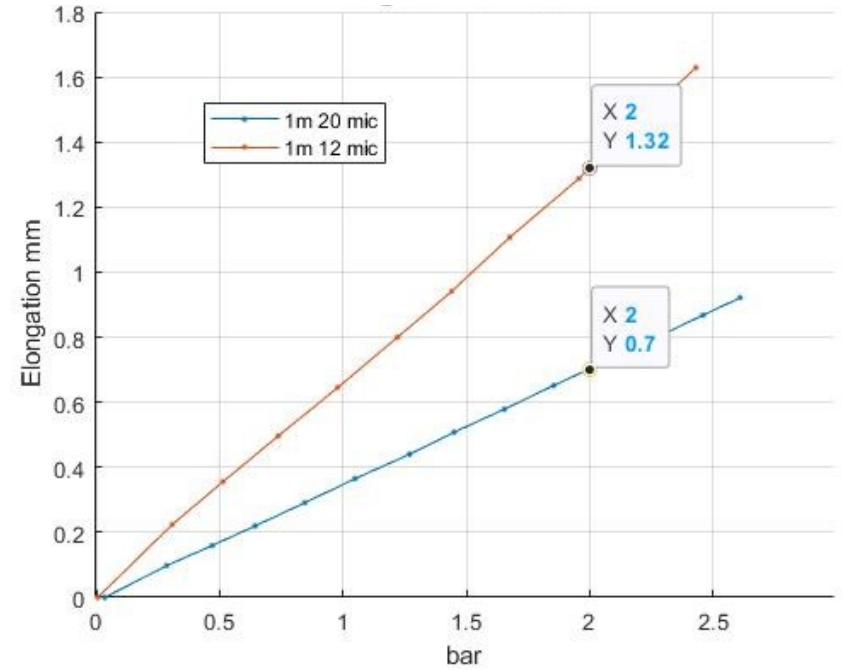
- ◆ *Measurement of straw relaxation* vs. *time and humidity* starting from initial tension.

<i>Production</i>	<i>Diameter</i>	<i>Wall</i>	<i>Metallization</i>	<i>Length</i>	<i>P_{max} tested</i>
<i>JINR</i>	<i>4.92 mm</i>	<i>20 μm</i>	<i>Single 70 nm</i>	<i>20 cm</i>	<i>6 bar</i>
<i>GTU</i>	<i>4.96 mm</i>	<i>20 μm</i>	<i>Double 70+40 nm</i>	<i>20 cm</i>	<i>6 bar</i>





Measurement of radial deformation vs. pressure for straws 1.1 m long



Measurement of elongation and tension vs. pressure for straws 1.0 m long

GLUING AND PRESSURE TESTS

- ◆ *Completed first gluing tests of a XXYY straw layer assembly (JINR):*
 - *Built test stand 1m × 1m allowing a variation of internal gas pressure in the glued straws;*
 - *Straws glued together with ELK5 (NA64) epoxy and internal overpressure;*
 - *Initial spacing left between glued points ~20 cm.*

⇒ *Validation of the concept of XXYY glued assembly*

- ◆ *Measurement of deformations of glued XXYY assembly vs. internal gas pressure.*

- ◆ *Additional measurements on XXYY glued assembly:*
 - *Gas leak test to verify damages to straw walls;*
 - *Straw resistivity to check metallization damage induced by pressure.*

MOCKUP PROTOTYPE(S)

- ◆ *Mockup prototype(s) 35cm × 35cm for preliminary validation tests:*
 - *Completed design of mock frame (Hamburg, UofSC);*
 - *Machining of first plexiglass mockup frame being completed in Hamburg;*
 - *Required straws produced by GTU (4.9mm diameter, 20 μm walls);*
 - *End-plugs machined from simplified design;*
 - *Assembly of first mockup prototype at JINR.*

- ◆ *Main goals of mockup prototype(s):*
 - *Validate assembly procedure using same geometry/frame as in STT;*
 - *Test the connection/gluing of straws to the frame;*
 - *Test sealing and gas leaks vs. internal pressure;*
 - *Evaluate different design options.*

- ◆ *Additional mockup prototypes expected to be built at various collaborating institutions following the completion of the first one at JINR.*

TESTS OF VMM3 READOUT

- ◆ *Tests and calibration of FE boards from Mu2E (BNL) with VMM3 at JINR:*
 - *Timing calibration using signal generator and timing resolution;*
 - *Readout of small straw tracker and tests with ^{55}Fe source & cosmics.*

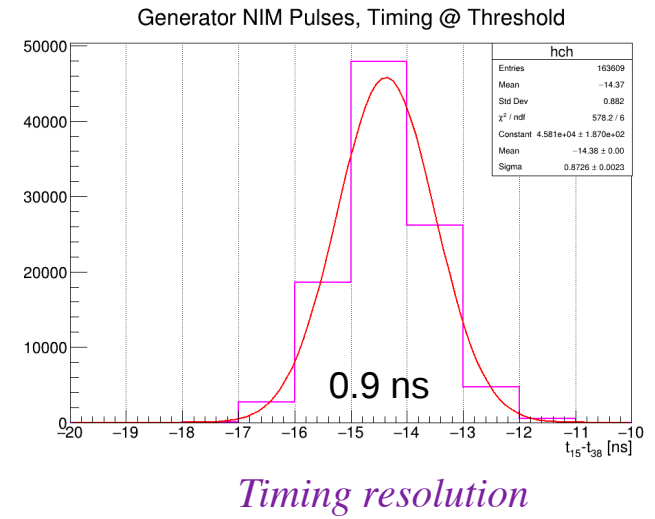
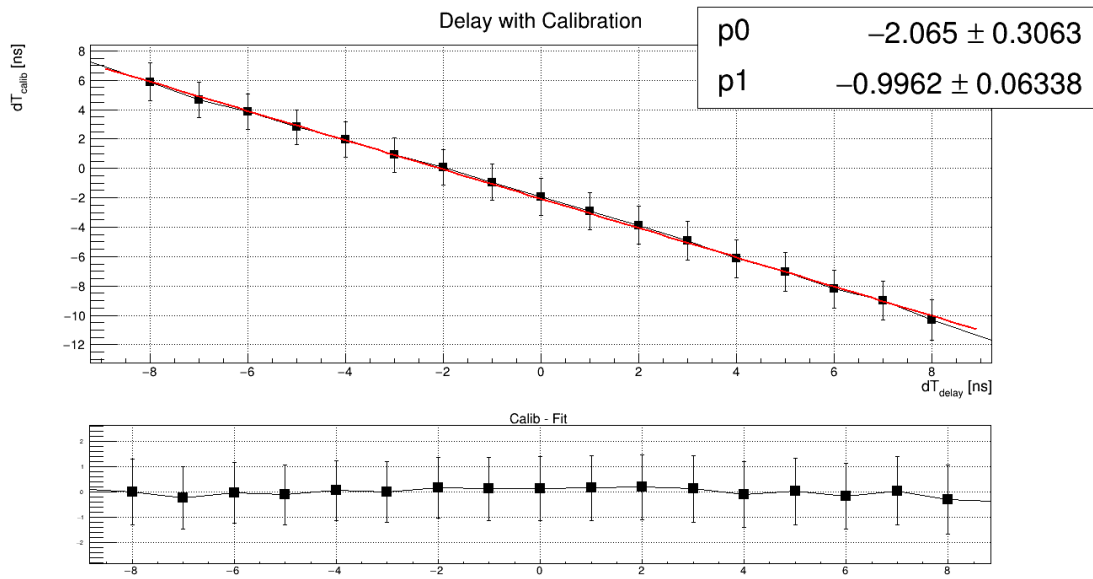
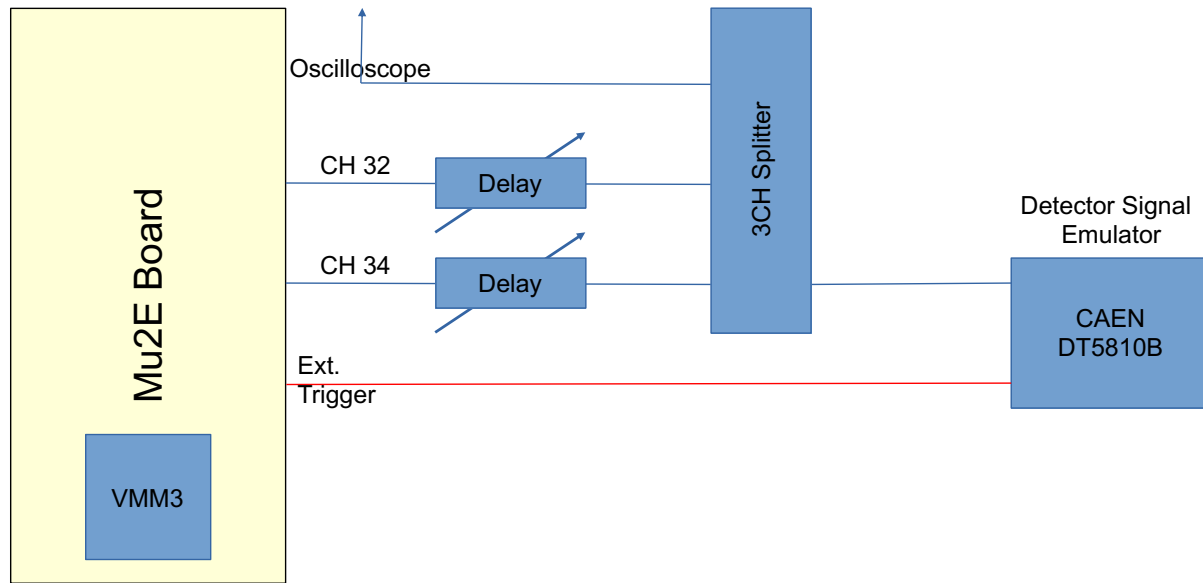
- ◆ *Testbeam exposure of small straw tracker with VMM3 readout in RD51 at CERN:*
 - *Two double layers $XX+YY$ with straws staggered by half diameter ($20\text{cm} \times 20\text{cm}$ active area);*
 - *Independent tracking system with 3 GEM detectors ($\sigma \sim 50\mu\text{m}$) equipped with VMM3 readout;*
 - *Setup installed in H4 beamline (JINR) and exposed to μ, π with $E \sim 160$ GeV;*
 - *Usable data taken in Oct.-Nov. 2021 (JINR, PNPI, UofSC).*

- ◆ *Ongoing analysis of testbeam data:*
 - *DAQ instability found at high rates in Time-over-Threshold mode being investigated;*
 - *Stable data taking when operated with peaking time.*

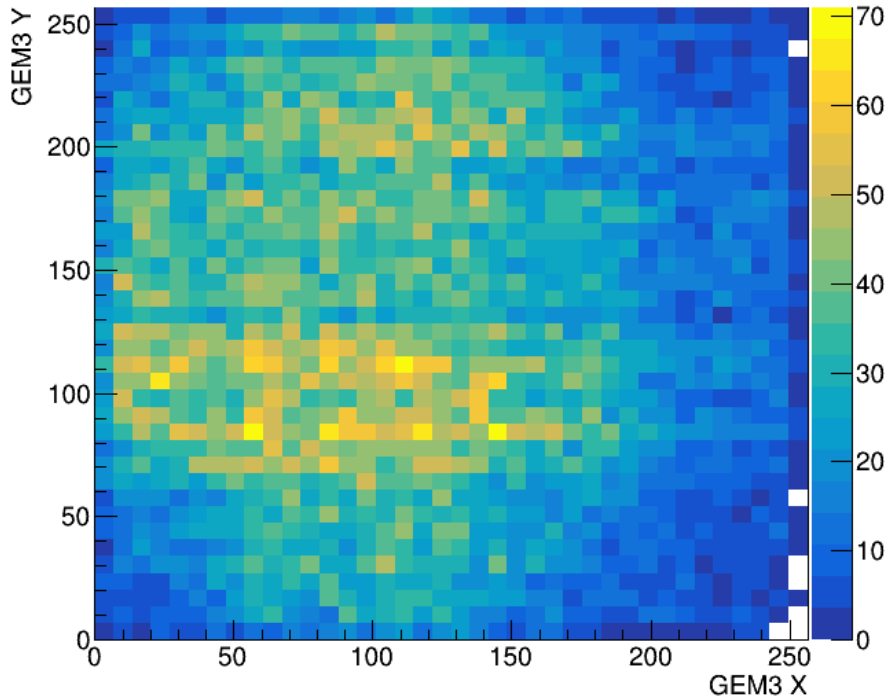
⇒ *New testbeam exposure with VMM3 readout at CERN in May 2022*

TIMING CALIBRATION

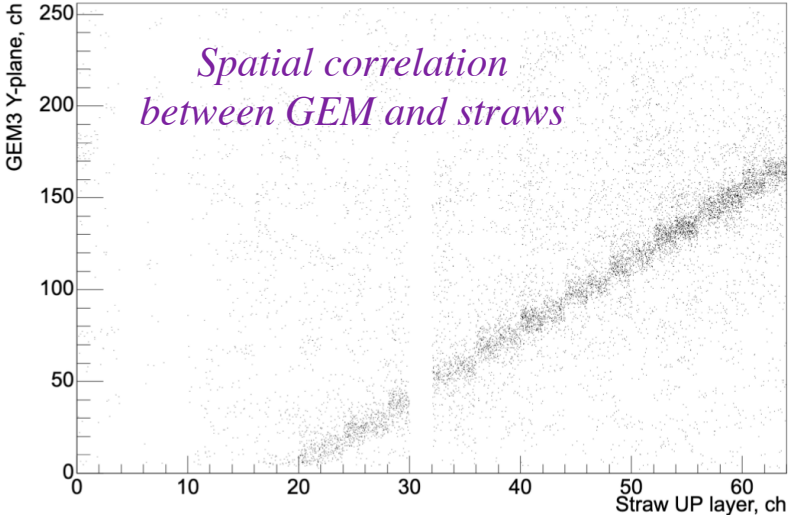
Vitalii Bautin (JINR)



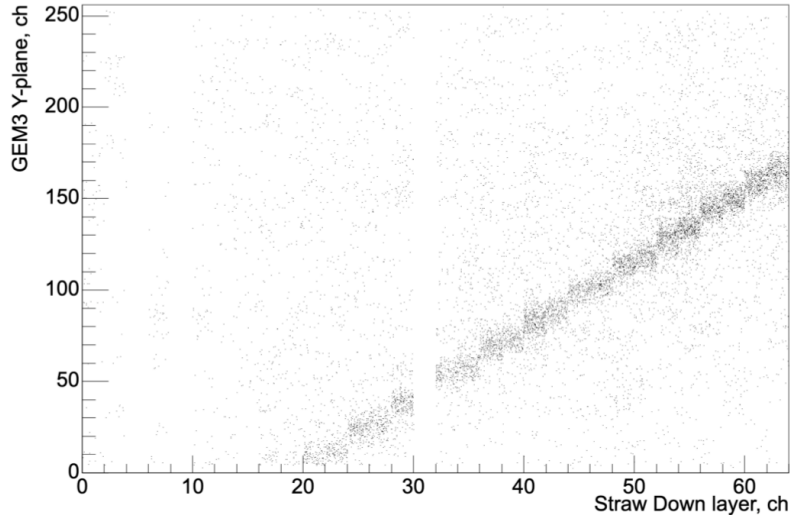
M. Demichev (JINR)



Beam profile seen by GEM 3 tracker

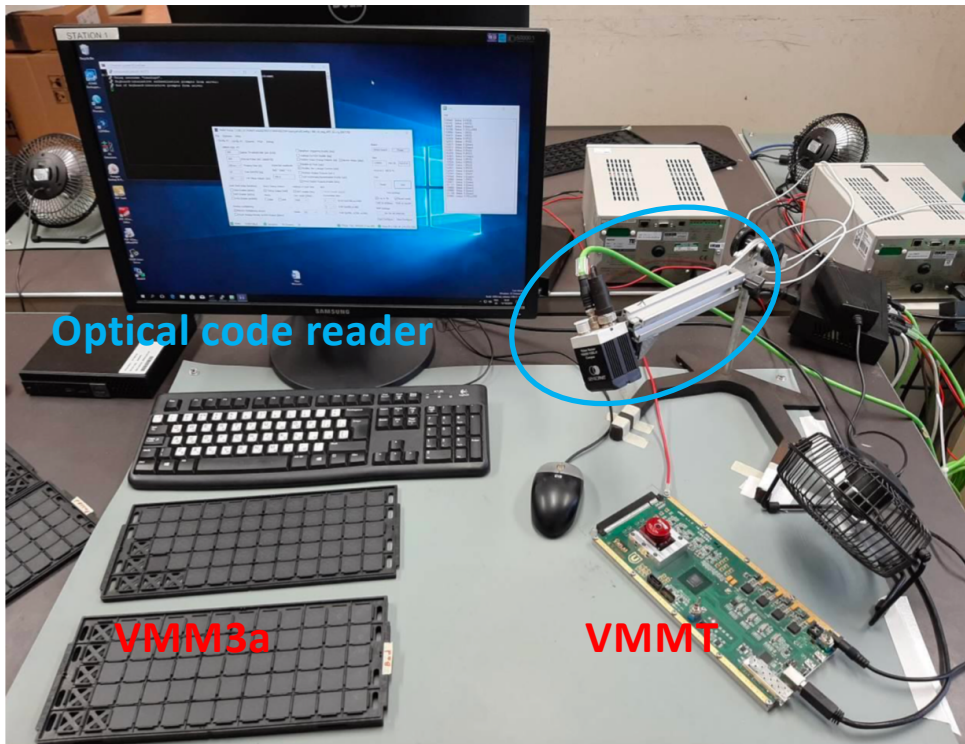


Spatial correlation between GEM and straws



VMM3A TESTING

- ◆ Procedure to test and validate VMM3a ASICs used for 42,000 chips in ATLAS NSW



- ◆ Automatized VMM3a test stand
- ◆ Optical system to read serial numbers of the VMM3a chips being tested
- ◆ VMMT: multi-functional test board for testing and characterization of VMM3 ASICs developed by Tomsk State University (Russia) for ATLAS

- ◆ All VMM3a chips procured by UofSC tested at CERN using ATLAS NSW procedure: average yield about 70% for best selection (green) for a total of 150 chips.

PREPARATION FOR 1.2m × 0.8m PROTOTYPE

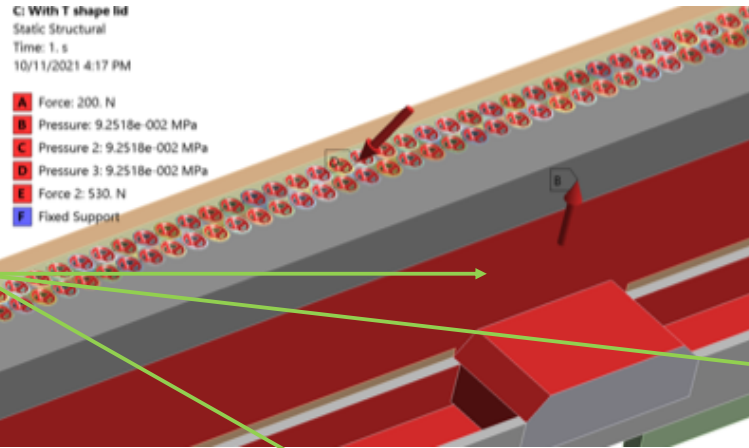
- ◆ *Prototype 1.2m × 0.8m based on design & parts as in full scale STT modules:*
 - *Build at JINR with help from GTU & other institutions;*
 - *Maximal size compatible with existing tooling & similar to NA64 detectors recently built at JINR;*
 - *4 straw layers XYYX: 672 straws total, no target, no radiator;*
 - *C-composite frame and assembly as in STT modules.*

⇒ *Aim to build the prototype in 2022 (summer?)*

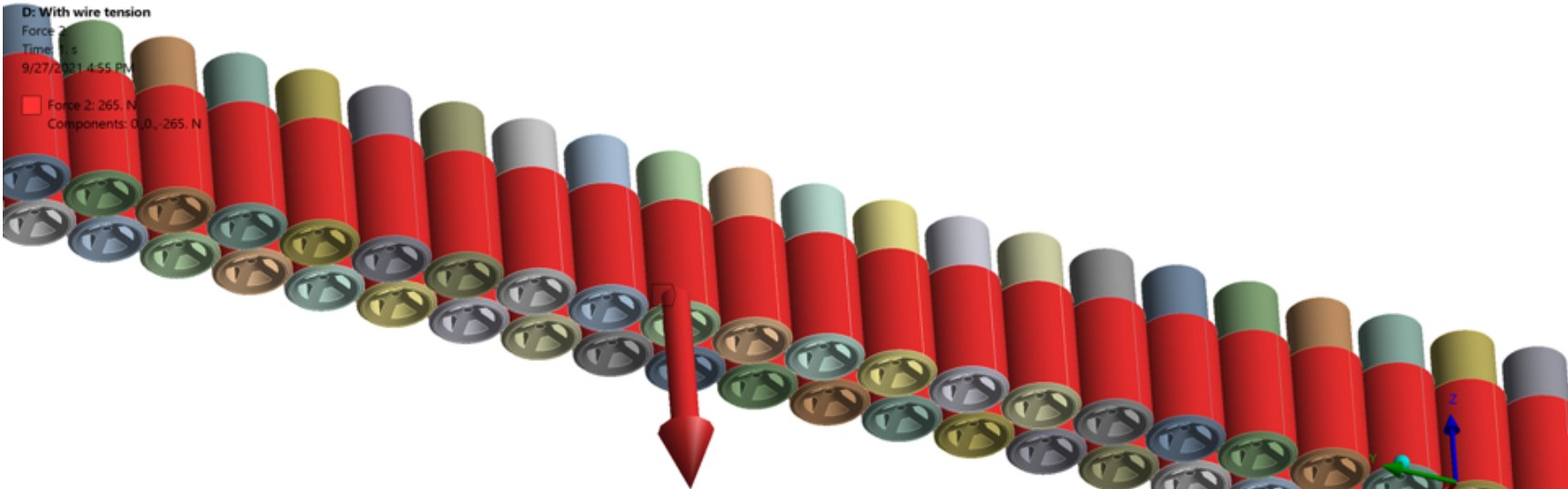
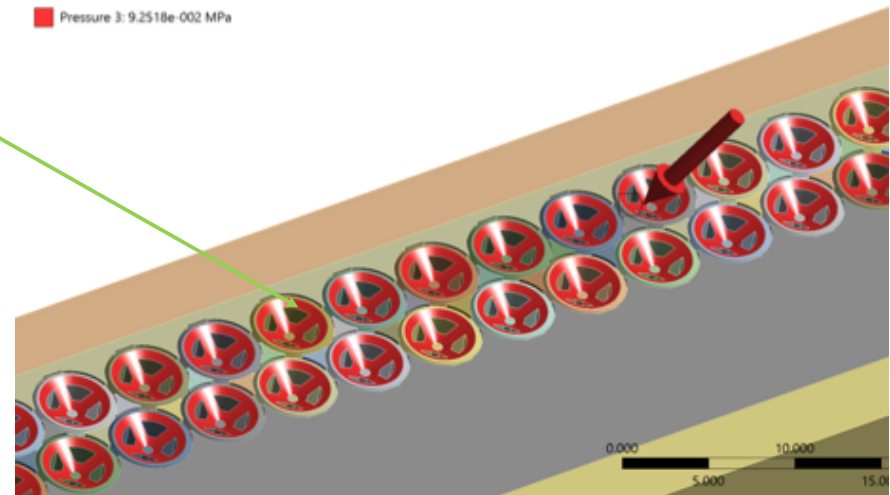
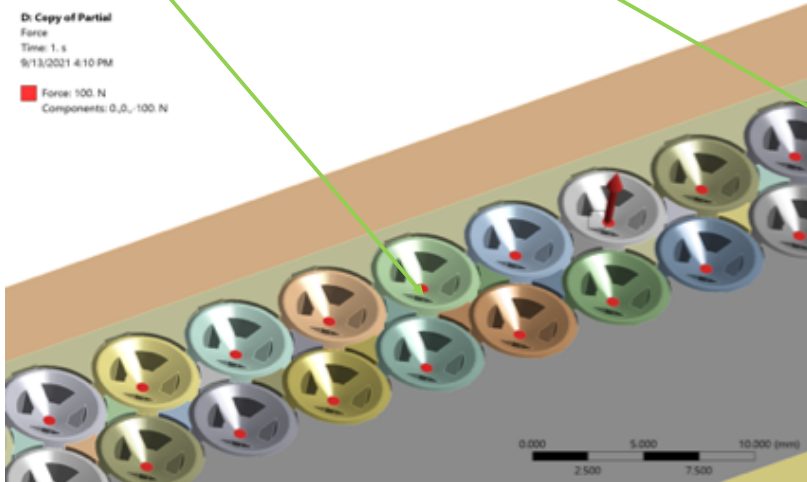
- ◆ *FE analysis of deformations induced by gas pressure, wire and straw tension:*
 - *Removable lids giving access to gas manifolds and FE boards, gas tightness (O-rings, etc.);*
 - *Connection of individual straws to C-composite frame and related gas sealing;*
 - *Study interplay between internal overpressure and wire/straw tension.*

- ◆ *Evaluating options for procurement of required components.*

- ◆ *Contributing institutions:*
JINR, GTU, IIT Guwahati, Panjab, Duke, INFN, Hamburg, UofSC.

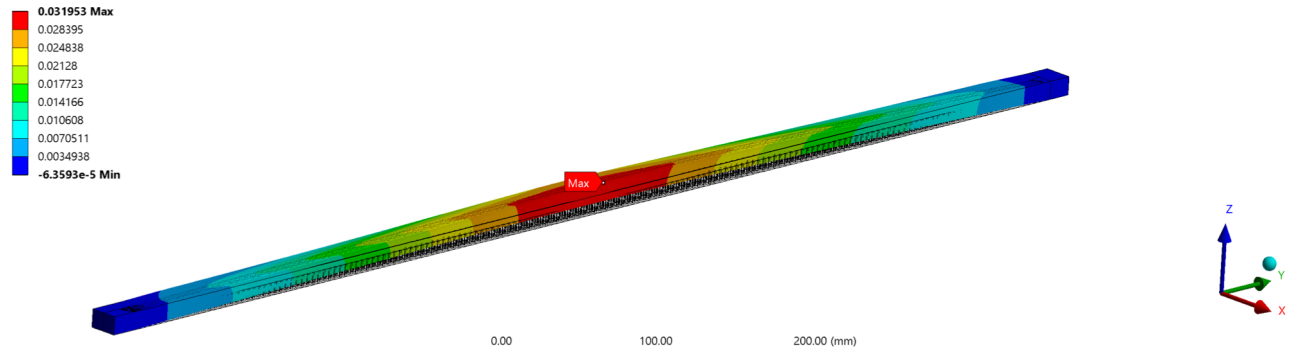


Applied pressure:
0.092 MPa
Applied Force:
100N (for 336 wires)



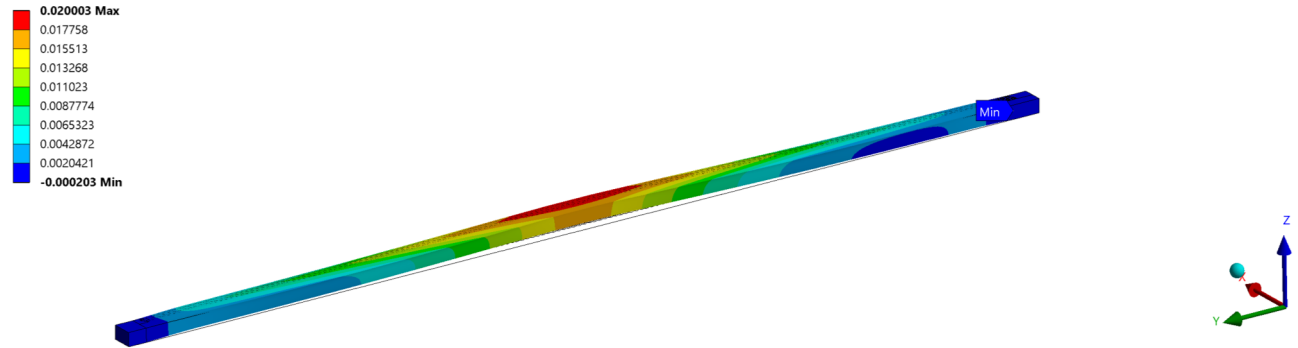
Gas pressure only:

- +Z 0.032 mm
- Z 0 mm



Gas pressure + wire tension:

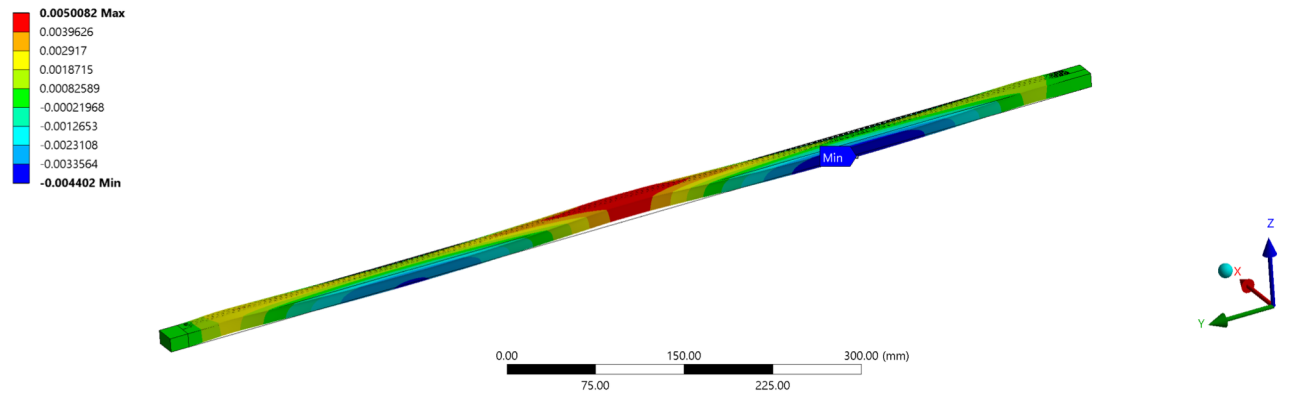
- +Z 0.02mm
- Z 0.0002mm

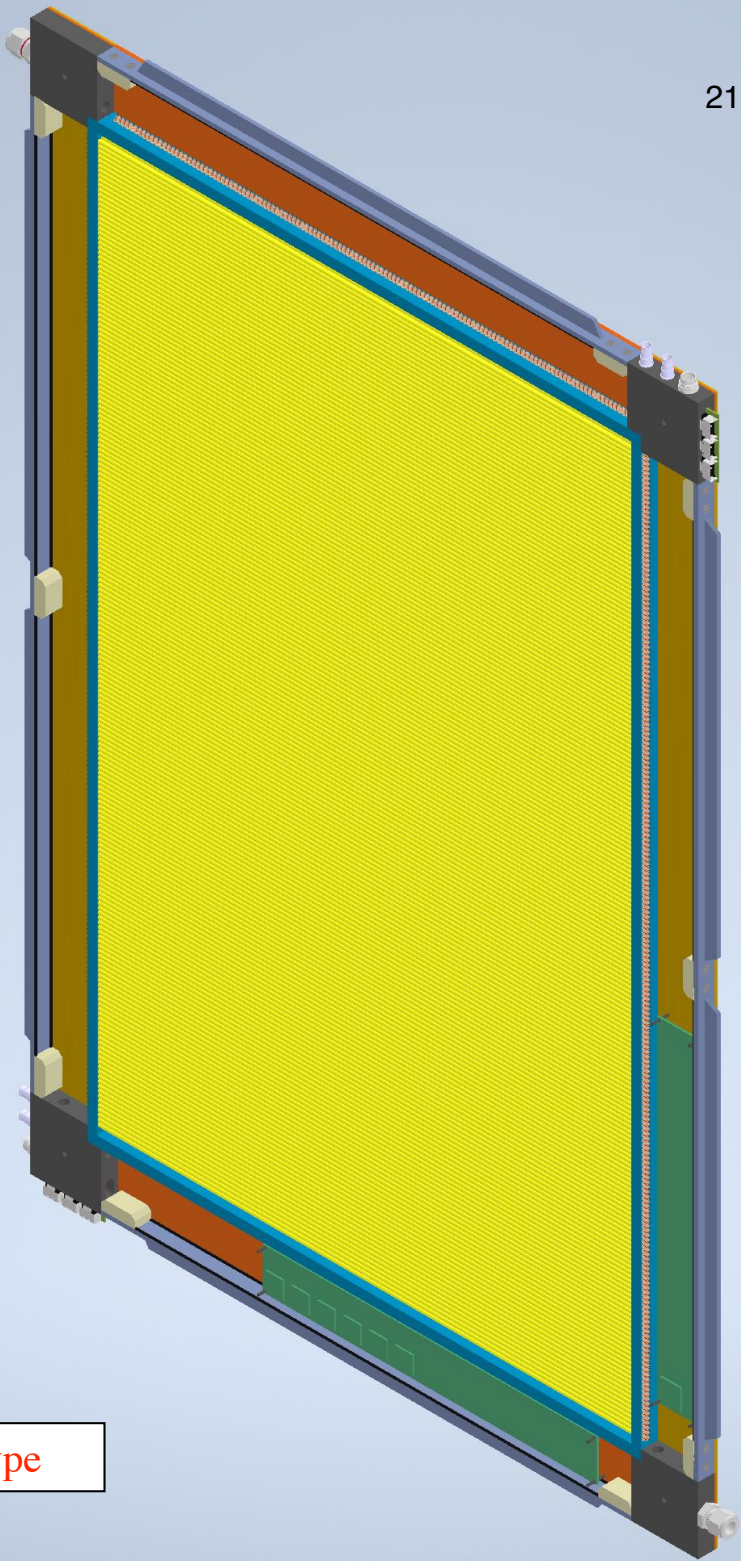
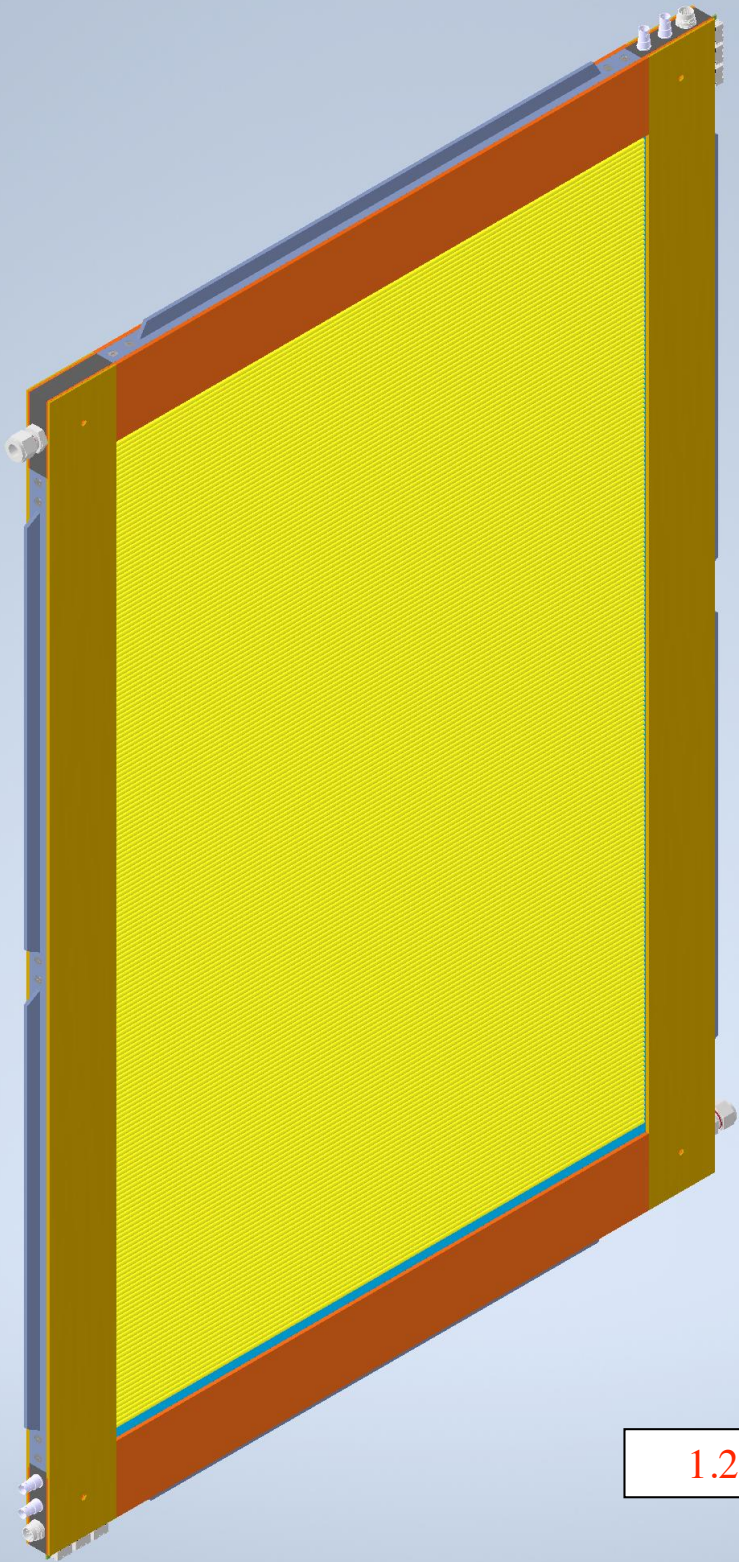


Gas pressure + wire tension

+ tension from straw walls:

- +Z 0.005mm
- Z 0.004mm





1.2 m x 0.8 m prototype