Report from STT Working Group

S. Di Falco

INFN Pisa, Italy

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SAND technical meeting
10 May 2022

STT WORKING GROUP

- *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*

  $\Longrightarrow$ *Encourage any interested people to subscribe (if not done yet)*

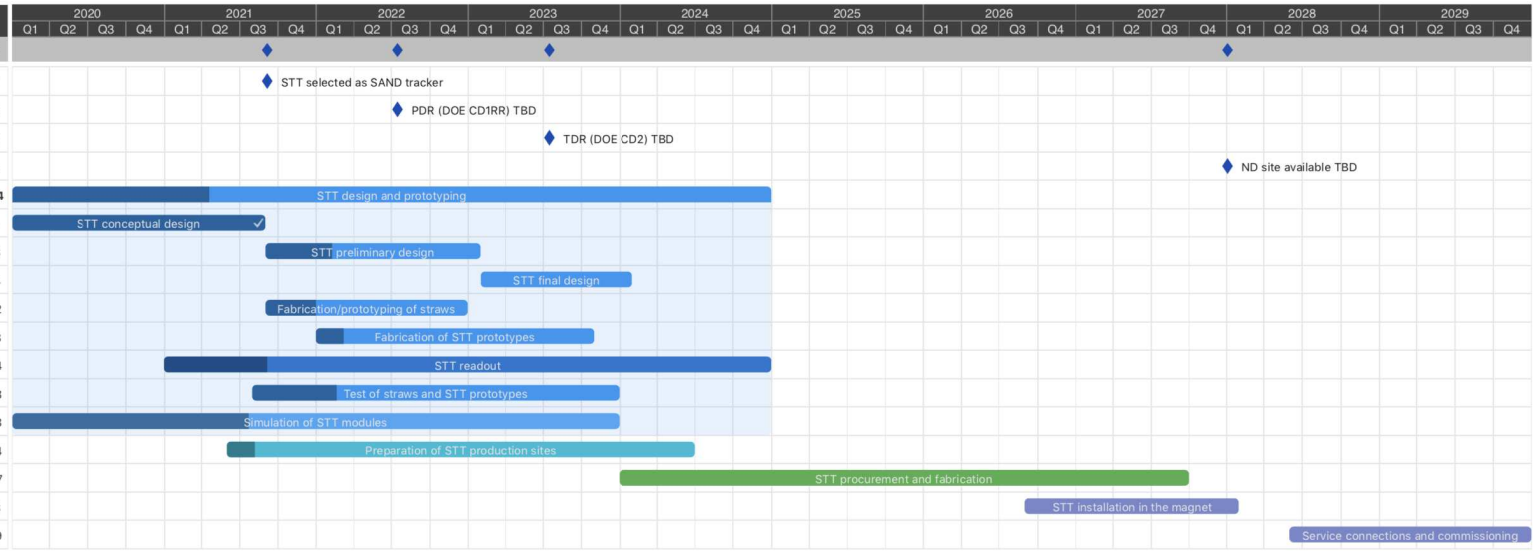
- *Material presented and discussed during WG meetings available on Indico:*
  `https://indico.fnal.gov/category/1402/`

- *By-weekly regular meetings on Wednesday at 11am Central Time / US*
  - *First meeting 13 April 2022: overview of STT activities and schedule;*
  - *Meeting 27 April 2022: testbeam activities, prototype preparation;*
  - *Meeting 11 May 2022: testbeam activities, preliminary gas leak tests.*

STT ACTIVITIES & SCHEDULE

- *Defined scope of activities* required for the completion and installation of the STT.
- *Preliminary schedule* and related deliverables:
  - *Identified main tasks and tentative timeline (to be revised following inputs/developments);*
  - *Uncertainties on availability of ND site and current situation (covid19, conflict, supplies, etc.).*

WBS	Task	Start	Finish
		Jan 1, 2020	Dec 31, 2029
1	STT selected as SAND tracker	Sep 2, 2021	Sep 2, 2021
2	PDR (DOE CD1RR) TBD	Jul 12, 2022	Jul 12, 2022
3	TDR (DOE CD2) TBD	Jul 12, 2023	Jul 12, 2023
4	ND site available TBD	Jan 1, 2028	Jan 1, 2028
5	**STT design and prototyping**	**Jan 1, 2020**	**Dec 31, 2024**
5.1	STT conceptual design	Jan 1, 2020	Sep 1, 2021
5.2	STT preliminary design	Sep 2, 2021	Jan 31, 2023
5.3	STT final design	Feb 1, 2023	Jan 31, 2024
5.4	Fabrication/prototyping of straws	Sep 2, 2021	Dec 31, 2022
5.5	Fabrication of STT prototypes	Jan 1, 2022	Oct 31, 2023
5.6	STT readout	Jan 1, 2021	Dec 31, 2024
5.7	Test of straws and STT prototypes	Aug 1, 2021	Dec 31, 2023
5.8	Simulation of STT modules	Jan 1, 2020	Dec 31, 2023
6	Preparation of STT production sites	Jun 1, 2021	Jun 30, 2024
7	STT procurement and fabrication	Jan 1, 2024	Sep 30, 2027
8	STT installation in the magnet	Sep 1, 2026	Jan 31, 2028
9	Service connections and commissioning	Jun 1, 2028	Dec 31, 2029



PROTOTYPING & TESTS

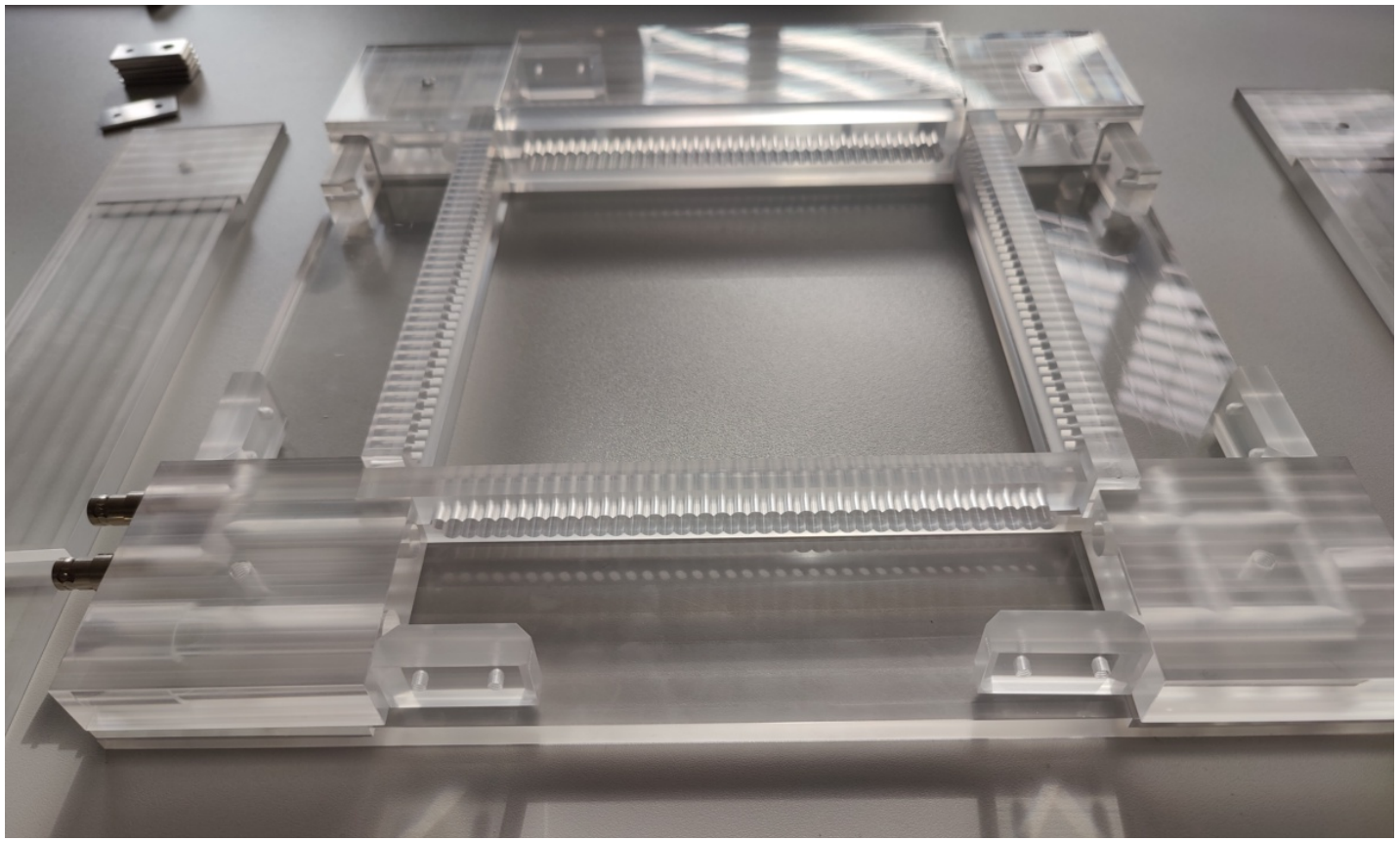
Demonstrate all aspects of the STT design in increasing order of complexity:

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

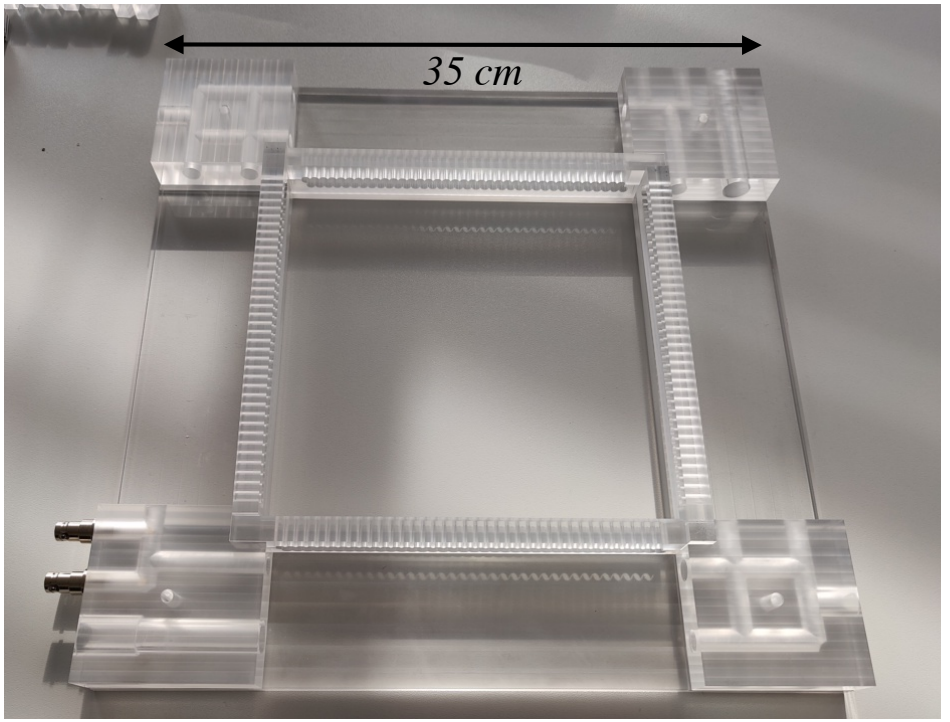
Demonstrate readout performance:

- ☑ *Verify charge measurement with ^{55}Fe source & cosmics*
  $\Longrightarrow$ *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*
  $\Longrightarrow$ *Readout small STT prototype with FE boards with VMM3/VMM3a ASICs*

D. Bick (Hamburg)

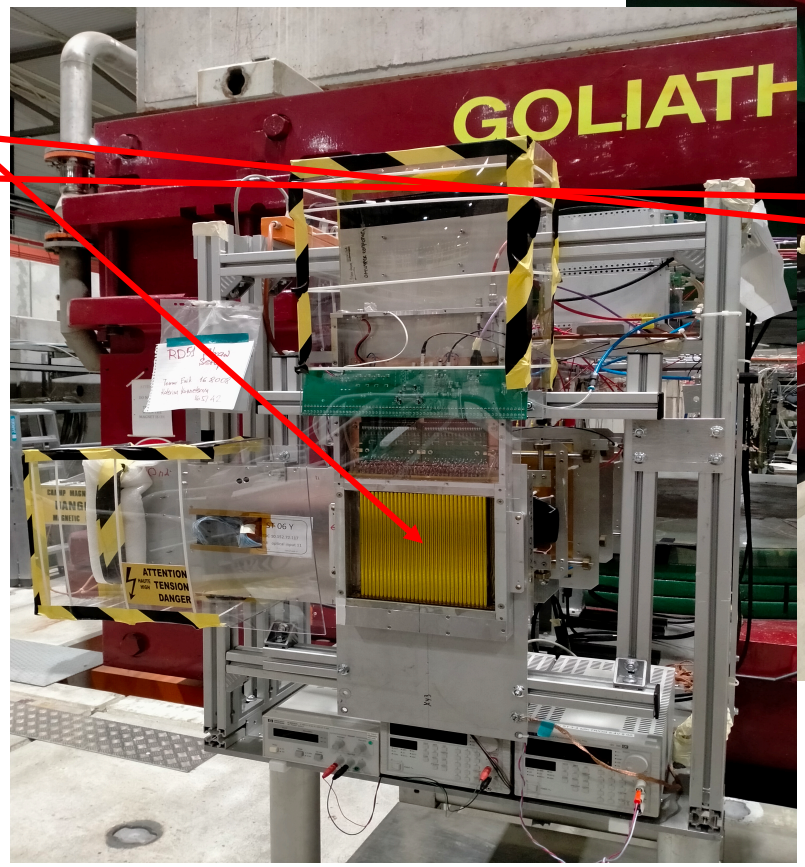


Plexiglass frame for the mockup prototype ready for assembly



V. Maleev (PNPI)

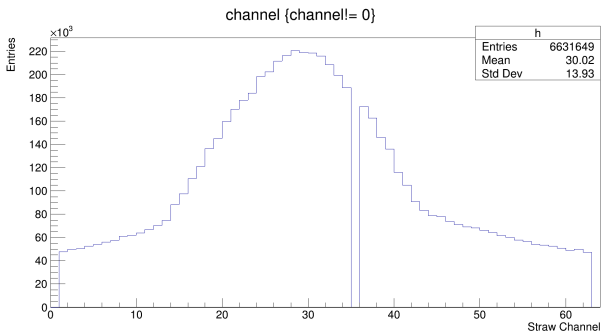
Start with minimal setup:
- One plane of 6 mm straws equiped with mu2e board (one VMM3 chip)
- Scintilator for trigger
- 3 MM trackers with APV read-out

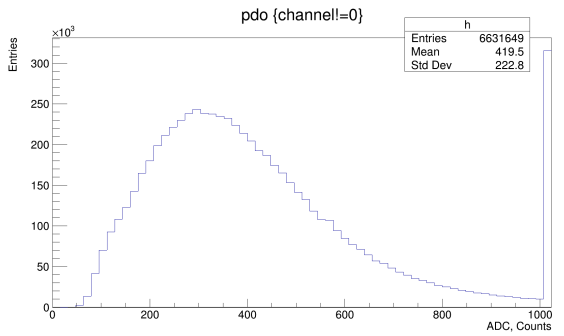


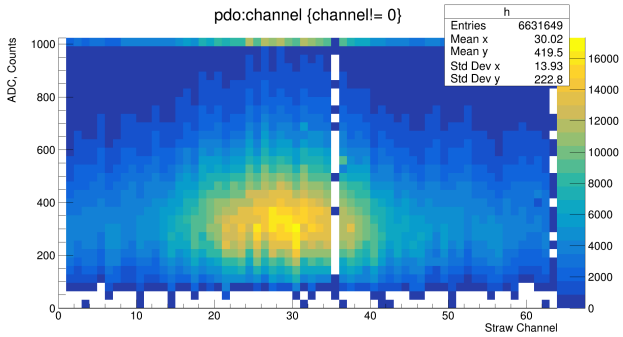
Test beam schedule:
25 April – 3 May parasitic
18 Mai – 24 May main user
25 Mai – 8 June parasitic

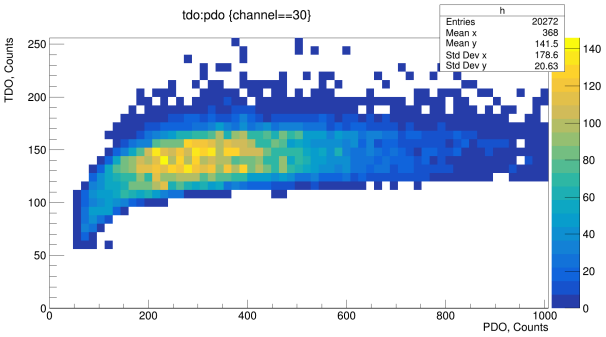
First result with muon beam

We want to measure:
Possibility to measure T@Th with VMM3
RT dependence and time resolution if VMM3 hybrid boards will be available









URGENT TASKS

Tasks to be completed by early summer 2022:

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

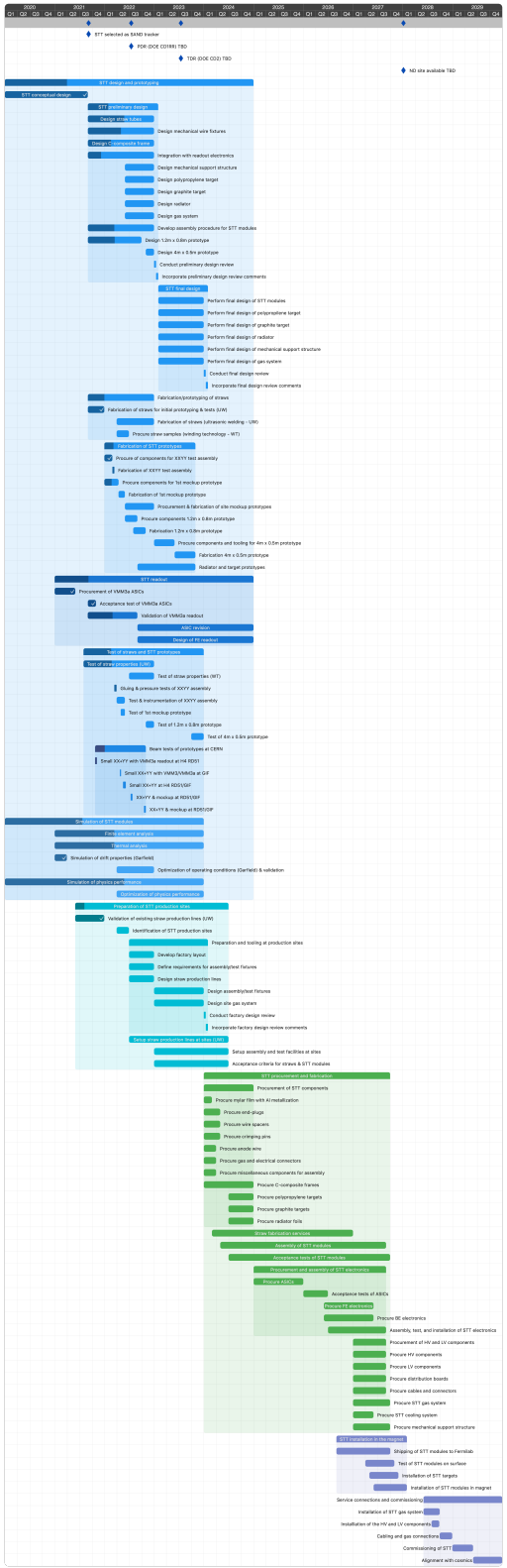
AVAILABLE RESOURCES

- *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*
  $\Longrightarrow$ *Organization of work along various tasks*

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

- *Evaluate impact of Russia-Ukraine conflict and possible mitigations*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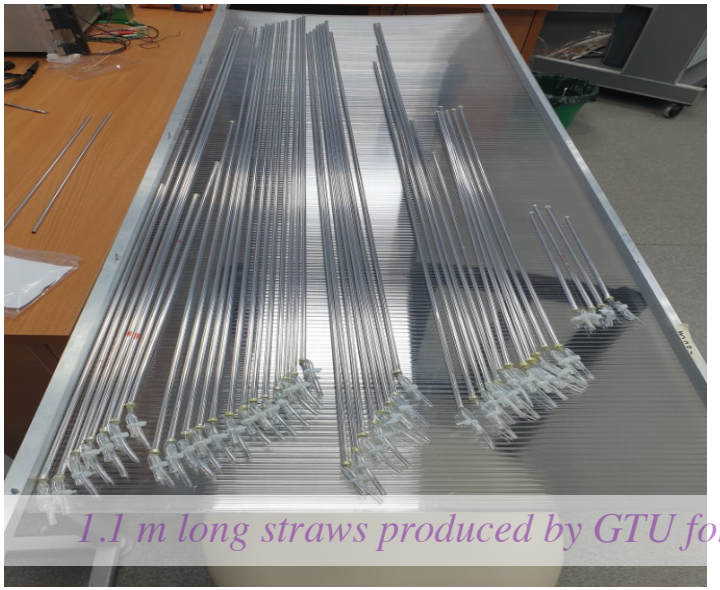
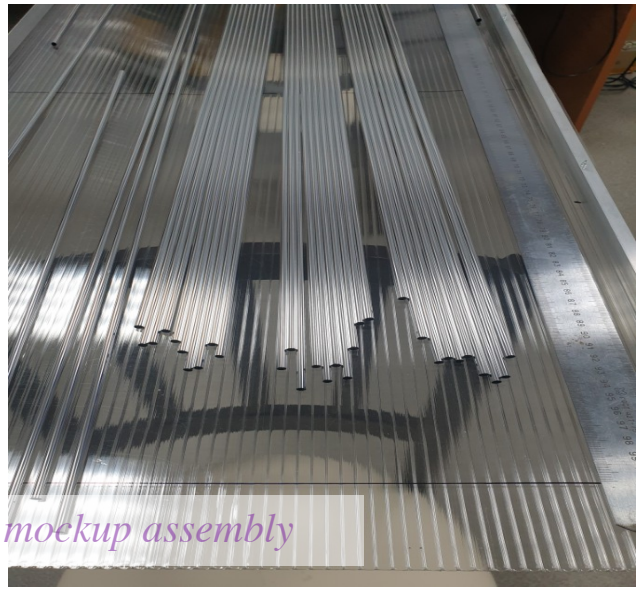
STT selected as SAND tracker
PDR (DOE CD1RR) TBD
TDR (DOE CD2) TBD
ND site available TBD
STT design and prototyping
STT conceptual design
STT preliminary design
Design straw tubes
Design mechanical wire fixtures
Design C-composite frame
Integration with readout electronics
Design mechanical support structure
Design polypropylene target
Design graphite target
Design radiator
Design gas system
Develop assembly procedure for STT modules
Design 1.2m x 0.6m prototype
Design 4m x 0.5m prototype
Conduct preliminary design review
Incorporate preliminary design review comments
STT final design
Perform final design of STT modules
Perform final design of polypropilene target
Perform final design of graphite target
Perform final design of radiator
Perform final design of mechanical support structure
Perform final design of gas system
Conduct final design review
Incorporate final design review comments
Fabrication/prototyping of straws
Fabrication of straws for initial prototyping & tests (UW)
Fabrication of straws (ultrasonic welding - UW)
Procure straw samples (winding technology - WT)
Fabrication of STT prototype
Procure of components for XXYY test assembly
Fabrication of XXYY test assembly
Procure components for 1st mockup prototype
Fabrication of 1st mockup prototype
Procurement & fabrication of site mockup prototypes
Procure components 1.2m x 0.6m prototype
Fabrication 1.2m x 0.6m prototype
Procure components and tooling for 4m x 0.5m prototype
Fabrication 4m x 0.5m prototype
Radiator and target prototypes
STT readout
Procurement of VMM3a ASICs
Acceptance test of VMM3a ASICs
Validation of VMM3a readout
ASIC revision
Design of FE readout
Test of straws and STT prototypes
Test of straw properties (UW)
Test of straw properties (WT)
Gluing & pressure tests of XXYY assembly
Test & instrumentation of XXYY assembly
Test of 1st mockup prototype
Test of 1.2m x 0.6m prototype
Test of 4m x 0.6m prototype
Beam tests of prototypes at CERN
Small XX×YY with VMM3a readout at H4 RD51
Small XX×YY with VMM3/VMM3a at GIF
Small XX×YY at H4 RD51/GIF
XX×YY & mockup at RD51/GIF
XX×YY & mockup at RD51/DP
Simulation of STT modules
Finite element analysis
Thermal analysis
Simulation of drift properties (Garfield)
Optimization of operating conditions (Garfield) & validation
Simulation of physics performance
Optimization of physics performance
Preparation of STT production sites
Validation of assisting straw production lines (UW)
Identification of STT production sites
Preparation and tooling at production sites
Develop factory layout
Define requirements for assembly/test fixtures
Design straw production lines
Design assembly/test fixtures
Design site gas system
Conduct factory design review
Incorporate factory design review comments
Setup straw production lines at sites (UW)
Setup assembly and test facilities at sites
Acceptance criteria for straws & STT modules
STT procurement and fabrication
Procurement of STT components
Procure mylar film with Al metallization
Procure end-plugs
Procure wire spacers
Procure crimping pins
Procure anode wire
Procure gas and electrical connectors
Procure miscellaneous components for assembly
Procure C-composite frames
Procure polypropylene targets
Procure graphite targets
Procure radiator foils
Straw fabrication services
Assembly of STT modules
Acceptance tests of STT modules
Procurement and assembly of STT electronics
Procure ASICs
Acceptance tests of ASICs
Procure FE electronics
Procure BE electronics
Assembly, test, and installation of STT electronics
Procurement of HV and LV components
Procure HV components
Procure LV components
Procure distribution boards
Procure cables and connectors
Procure STT gas system
Procure STT cooling system
Procure mechanical support structure
STT installation in the magnet
Shipping of STT modules to Fermilab
Test of STT modules on surface
Installation of STT targets
Installation of STT modules in magnet
Service connections and commissioning
Installation of STT gas system
Installation of the HV and LV components
Cabling and gas connections
Commissioning of STT
Alignment with cosmics

Backup slides



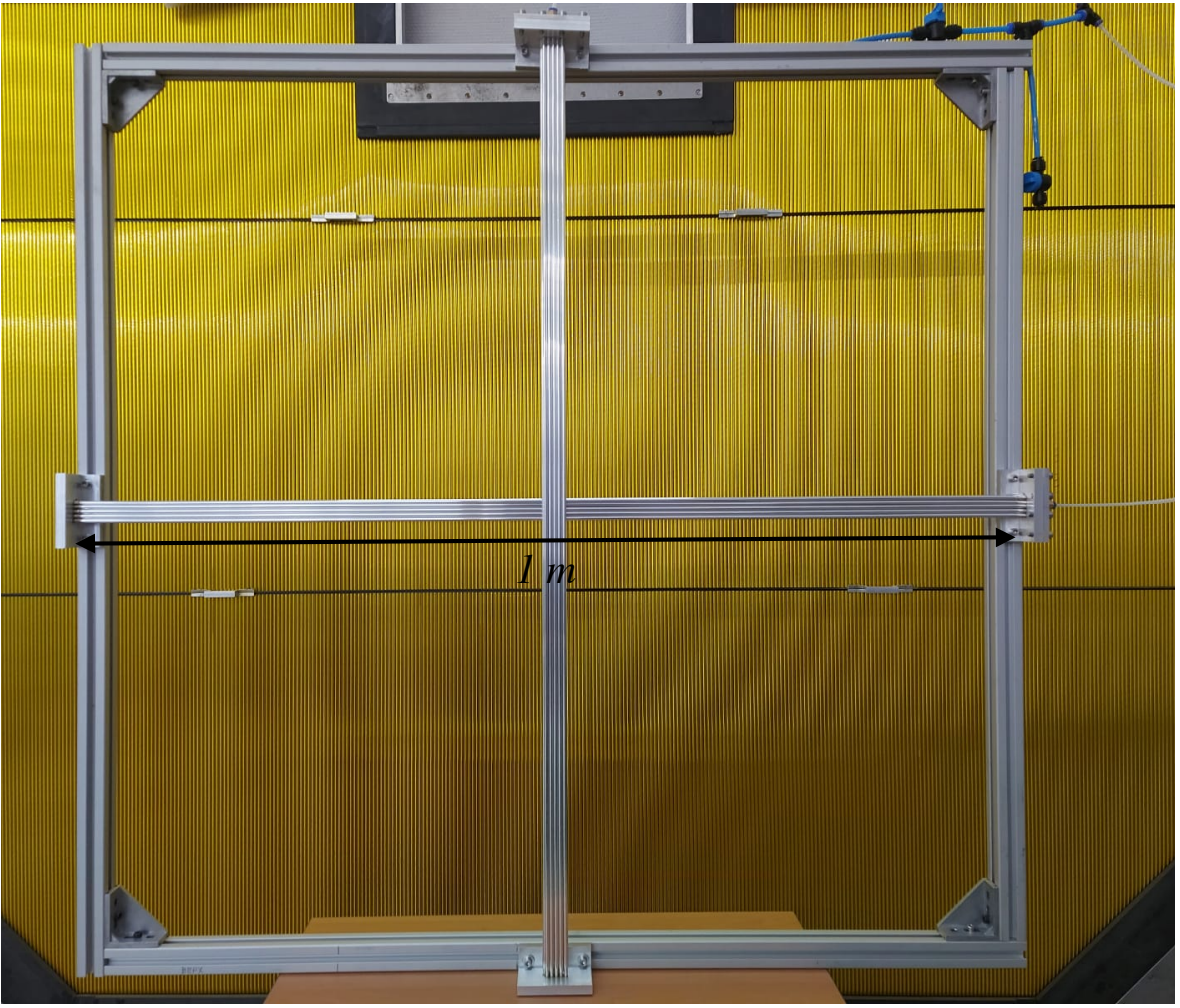
1.1 m long straws produced by GTU for moekup assembly



Pressure tests (GTU)

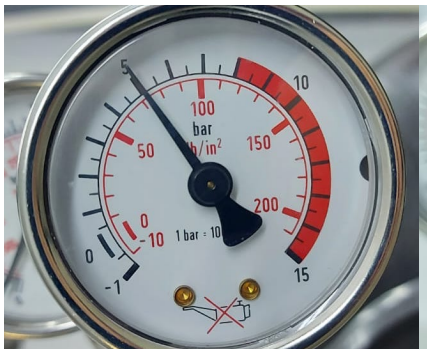
5 m long straws produced at JINR for the gluing tests

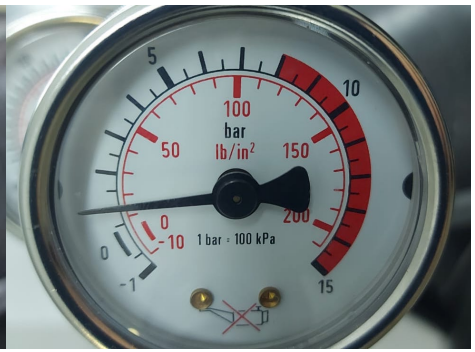
T. Enik (JINR)

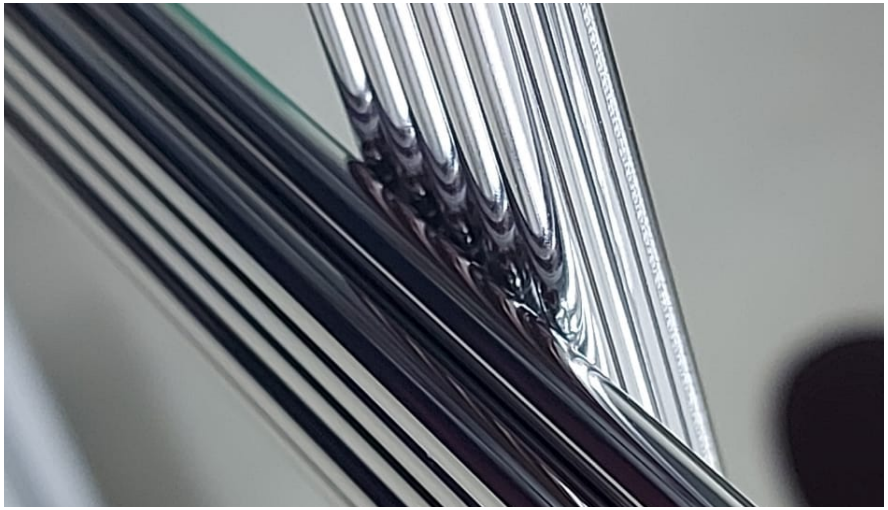


Straws glued together with epoxy ELK5 (~ 20cm spacing)

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

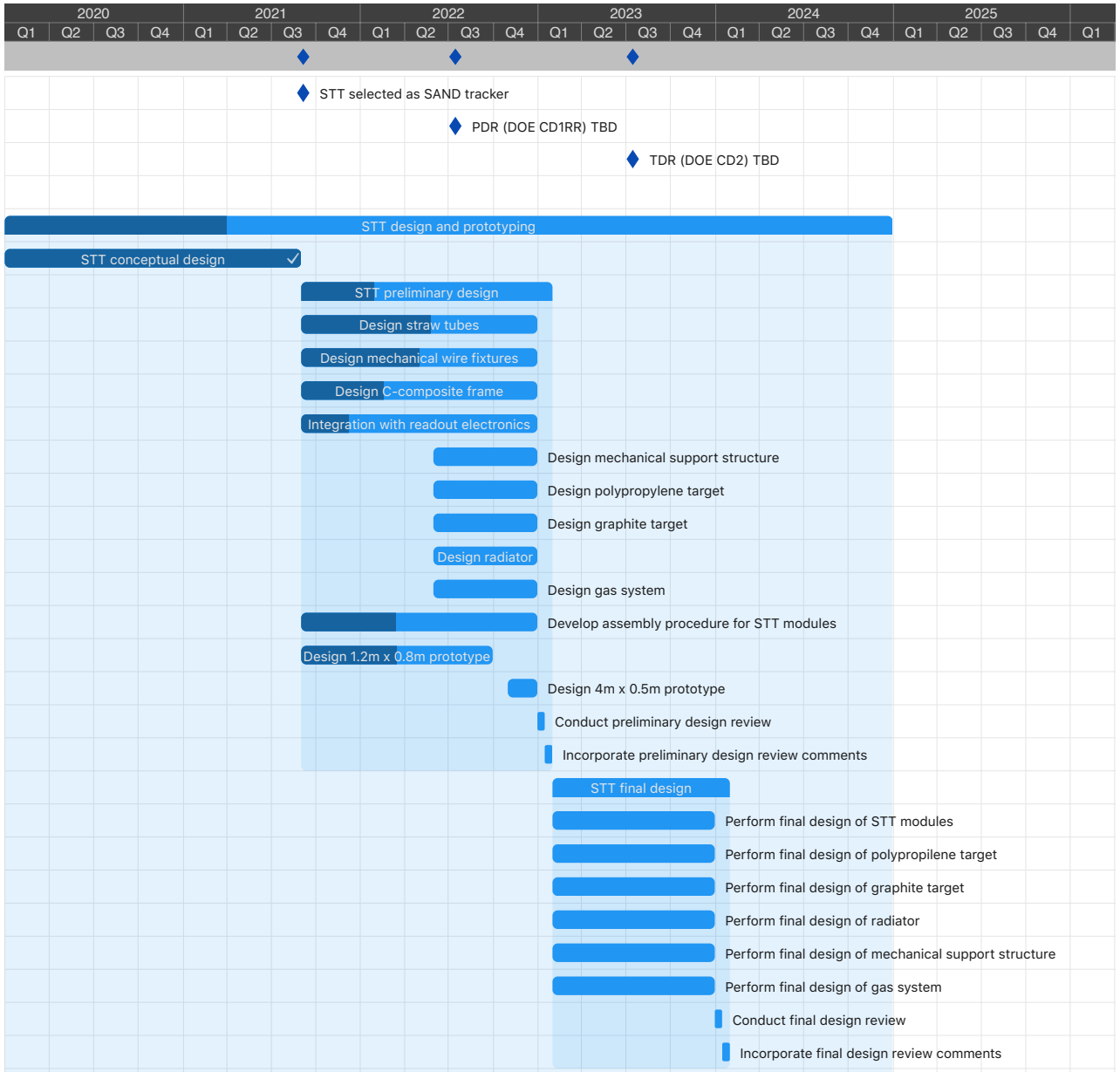






DESIGN ACTIVITIES

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



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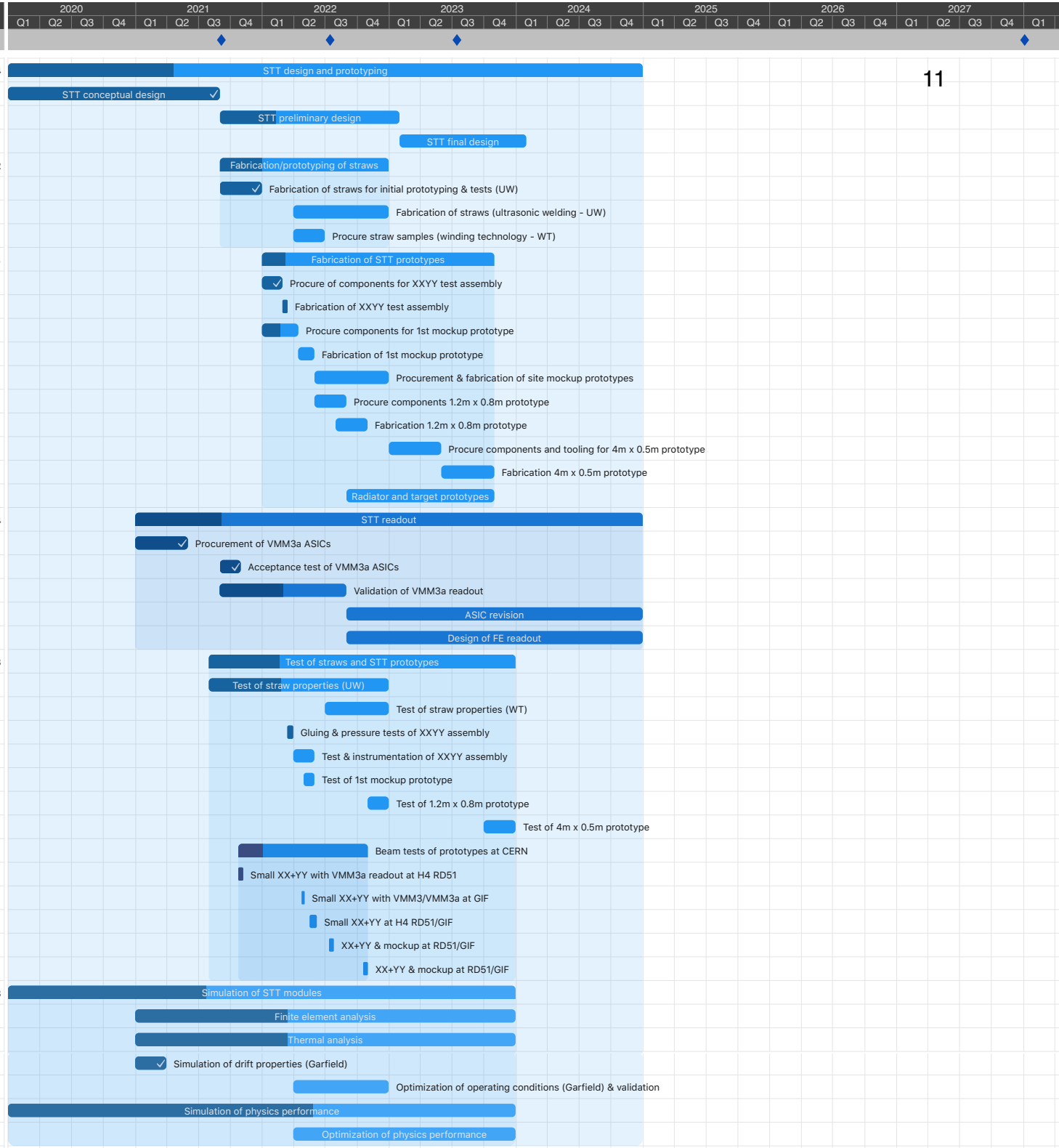
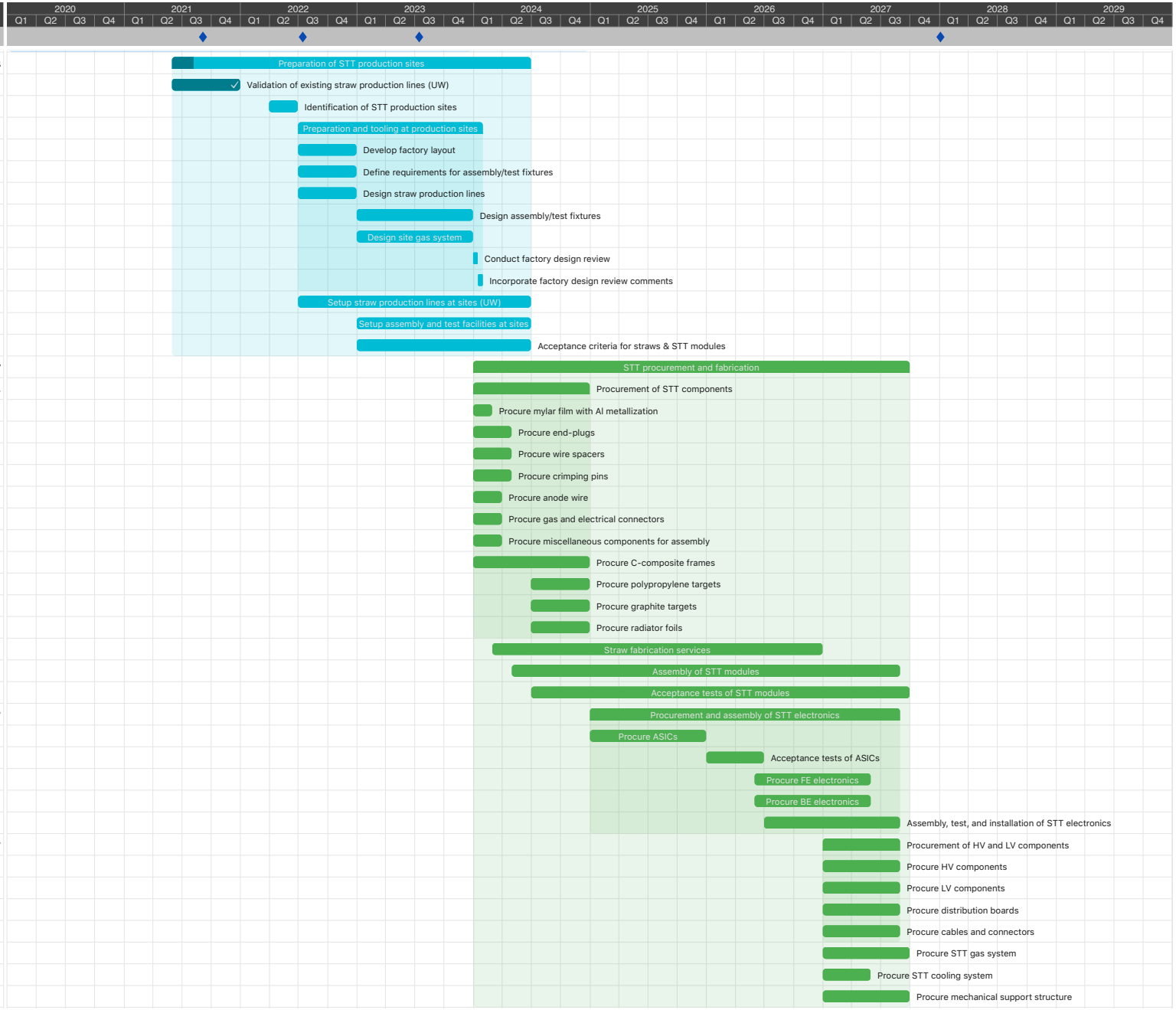
5.1	STT conceptual design	Jan 1, 2020	Sep 1, 2021
5.2	STT preliminary design	Sep 2, 2021	Jan 31, 2023
5.3	STT final design	Feb 1, 2023	Jan 31, 2024
5.4	**Fabrication/prototyping of straws**	**Sep 2, 2021**	**Dec 31, 2022**
5.4.1	Fabrication of straws for initial prototyping & tests (UW)	Sep 2, 2021	Dec 31, 2021
5.4.2	Fabrication of straws (ultrasonic welding - UW)	Apr 1, 2022	Dec 31, 2022
5.4.3	Procure straw samples (winding technology - WT)	Apr 1, 2022	Jun 30, 2022
5.5	**Fabrication of STT prototypes**	**Jan 1, 2022**	**Oct 31, 2023**
5.5.1	Procure of components for XXYY test assembly	Jan 1, 2022	Feb 28, 2022
5.5.2	Fabrication of XXYY test assembly	Mar 1, 2022	Mar 15, 2022
5.5.3	Procure components for 1st mockup prototype	Jan 1, 2022	Apr 15, 2022
5.5.4	Fabrication of 1st mockup prototype	Apr 15, 2022	May 31, 2022
5.5.5	Procurement & fabrication of site mockup prototypes	Jun 1, 2022	Dec 31, 2022
5.5.6	Procure components 1.2m x 0.8m prototype	Jun 1, 2022	Aug 31, 2022
5.5.7	Fabrication 1.2m x 0.8m prototype	Aug 1, 2022	Oct 31, 2022
5.5.8	Procure components and tooling for 4m x 0.5m prototype	Jan 1, 2023	May 31, 2023
5.5.9	Fabrication 4m x 0.5m prototype	Jun 1, 2023	Oct 31, 2023
5.5.10	Radiator and target prototypes	Sep 1, 2022	Oct 31, 2023
5.6	**STT readout**	**Jan 1, 2021**	**Dec 31, 2024**
5.6.1	Procurement of VMM3a ASICs	Jan 1, 2021	Jun 1, 2021
5.6.2	Acceptance test of VMM3a ASICs	Sep 2, 2021	Oct 31, 2021
5.6.3	Validation of VMM3a readout	Sep 1, 2021	Aug 31, 2022
5.6.4	ASIC revision	Sep 1, 2022	Dec 31, 2024
5.6.5	Design of FE readout	Sep 1, 2022	Dec 31, 2024
5.7	**Test of straws and STT prototypes**	**Aug 1, 2021**	**Dec 31, 2023**
5.7.1	Test of straw properties (UW)	Aug 1, 2021	Dec 31, 2022
5.7.2	Test of straw properties (WT)	Jul 1, 2022	Dec 31, 2022
5.7.3	Gluing & pressure tests of XXYY assembly	Mar 15, 2022	Mar 31, 2022
5.7.4	Test & instrumentation of XXYY assembly	Apr 1, 2022	May 31, 2022
5.7.5	Test of 1st mockup prototype	May 1, 2022	May 31, 2022
5.7.6	Test of 1.2m x 0.8m prototype	Nov 1, 2022	Dec 31, 2022
5.7.7	Test of 4m x 0.5m prototype	Oct 1, 2023	Dec 31, 2023
5.7.8	**Beam tests of prototypes at CERN**	**Oct 25, 2021**	**Nov 1, 2022**
5.7.8.1	Small XX+YY with VMM3a readout at H4 RD51	Oct 25, 2021	Nov 7, 2021
5.7.8.2	Small XX+YY with VMM3/VMM3a at GIF	Apr 25, 2022	May 3, 2022
5.7.8.3	Small XX+YY at H4 RD51/GIF	May 18, 2022	Jun 7, 2022
5.7.8.4	XX+YY & mockup at RD51/GIF	Jul 13, 2022	Jul 26, 2022
5.7.8.5	XX+YY & mockup at RD51/GIF	Oct 19, 2022	Nov 1, 2022
5.8	**Simulation of STT modules**	**Jan 1, 2020**	**Dec 31, 2023**
5.8.1	Finite element analysis	Jan 1, 2021	Dec 31, 2023
5.8.2	Thermal analysis	Jan 1, 2021	Dec 31, 2023
5.8.3	Simulation of drift properties (Garfield)	Jan 1, 2021	Mar 31, 2021
5.8.4	Optimization of operating conditions (Garfield) & validation	Apr 1, 2022	Dec 31, 2022
5.8.5	Simulation of physics performance	Jan 1, 2020	Dec 31, 2023
5.8.6	Optimization of physics performance	Apr 1, 2022	Dec 31, 2023



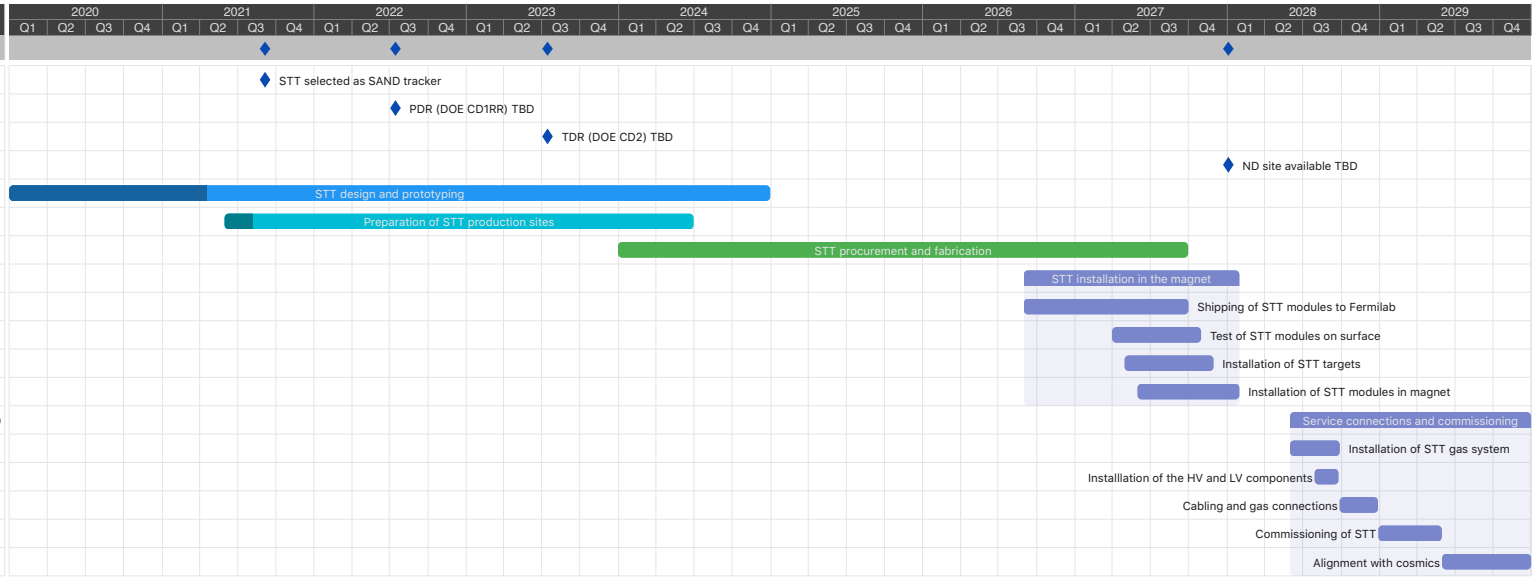
PRODUCTION SITES, PROCUREMENT & FABRICATION

WBS	Task	Start	Finish
		Jan 1, 2020	Dec 31, 2029
6	**Preparation of STT production sites**	**Jun 1, 2021**	**Jun 30, 2024**
6.1	Validation of existing straw production lines (UW)	Jun 1, 2021	Dec 31, 2021
6.2	Identification of STT production sites	Apr 1, 2022	Jun 30, 2022
6.3	**Preparation and tooling at production sites**	**Jul 1, 2022**	**Jan 31, 2024**
6.3.1	Develop factory layout	Jul 1, 2022	Dec 31, 2022
6.3.2	Define requirements for assembly/test fixtures	Jul 1, 2022	Dec 31, 2022
6.3.3	Design straw production lines	Jul 1, 2022	Dec 31, 2022
6.3.4	Design assembly/test fixtures	Jan 1, 2023	Dec 31, 2023
6.3.5	Design site gas system	Jan 1, 2023	Dec 31, 2023
6.3.6	Conduct factory design review	Jan 1, 2024	Jan 15, 2024
6.3.7	Incorporate factory design review comments	Jan 16, 2024	Jan 31, 2024
6.4	Setup straw production lines at sites (UW)	Jul 1, 2022	Jun 30, 2024
6.5	Setup assembly and test facilities at sites	Jan 1, 2023	Jun 30, 2024
6.6	Acceptance criteria for straws & STT modules	Jan 1, 2023	Jun 30, 2024
7	**STT procurement and fabrication**	**Jan 1, 2024**	**Sep 30, 2027**
7.1	**Procurement of STT components**	**Jan 1, 2024**	**Dec 31, 2024**
7.1.1	Procure mylar film with Al metallization	Jan 1, 2024	Feb 29, 2024
7.1.2	Procure end-plugs	Jan 1, 2024	Apr 30, 2024
7.1.3	Procure wire spacers	Jan 1, 2024	Apr 30, 2024
7.1.4	Procure crimping pins	Jan 1, 2024	Apr 30, 2024
7.1.5	Procure anode wire	Jan 1, 2024	Mar 31, 2024
7.1.6	Procure gas and electrical connectors	Jan 1, 2024	Mar 31, 2024
7.1.7	Procure miscellaneous components for assembly	Jan 1, 2024	Mar 31, 2024
7.1.8	Procure C-composite frames	Jan 1, 2024	Dec 31, 2024
7.1.9	Procure polypropylene targets	Jun 30, 2024	Dec 31, 2024
7.1.10	Procure graphite targets	Jun 30, 2024	Dec 31, 2024
7.1.11	Procure radiator foils	Jun 30, 2024	Dec 31, 2024
7.2	Straw fabrication services	Mar 1, 2024	Dec 31, 2026
7.3	Assembly of STT modules	May 1, 2024	Aug 31, 2027
7.4	Acceptance tests of STT modules	Jul 1, 2024	Sep 30, 2027
7.5	**Procurement and assembly of STT electronics**	**Jan 1, 2025**	**Aug 31, 2027**
7.5.1	Procure ASICs	Jan 1, 2025	Dec 31, 2025
7.5.2	Acceptance tests of ASICs	Jan 1, 2026	Jun 30, 2026
7.5.3	Procure FE electronics	Jun 1, 2026	May 31, 2027
7.5.4	Procure BE electronics	Jun 1, 2026	May 31, 2027
7.5.5	Assembly, test, and installation of STT electronics	Jul 1, 2026	Aug 31, 2027
7.6	**Procurement of HV and LV components**	**Jan 1, 2027**	**Aug 31, 2027**
7.6.1	Procure HV components	Jan 1, 2027	Aug 31, 2027
7.6.2	Procure LV components	Jan 1, 2027	Aug 31, 2027
7.6.3	Procure distribution boards	Jan 1, 2027	Aug 31, 2027
7.6.4	Procure cables and connectors	Jan 1, 2027	Aug 31, 2027
7.7	Procure STT gas system	Jan 1, 2027	Sep 30, 2027
7.8	Procure STT cooling system	Jan 1, 2027	May 31, 2027
7.9	Procure mechanical support structure	Jan 1, 2027	Sep 30, 2027



INSTALLATION & COMMISSIONING

WBS	Task	Start	Finish
		Jan 1, 2020	Dec 31, 2029
1	STT selected as SAND tracker	Sep 2, 2021	Sep 2, 2021
2	PDR (DOE CD1RR) TBD	Jul 12, 2022	Jul 12, 2022
3	TDR (DOE CD2) TBD	Jul 12, 2023	Jul 12, 2023
4	ND site available TBD	Jan 1, 2028	Jan 1, 2028
5	STT design and prototyping	Jan 1, 2020	Dec 31, 2024
6	Preparation of STT production sites	Jun 1, 2021	Jun 30, 2024
7	STT procurement and fabrication	Jan 1, 2024	Sep 30, 2027
8	**STT installation in the magnet**	**Sep 1, 2026**	**Jan 31, 2028**
8.1	Shipping of STT modules to Fermilab	Sep 1, 2026	Oct 1, 2027
8.2	Test of STT modules on surface	Apr 1, 2027	Oct 31, 2027
8.3	Installation of STT targets	May 1, 2027	Nov 30, 2027
8.4	Installation of STT modules in magnet	Jun 1, 2027	Jan 31, 2028
9	**Service connections and commissioning**	**Jun 1, 2028**	**Dec 31, 2029**
9.1	Installation of STT gas system	Jun 1, 2028	Sep 28, 2028
9.2	Installlation of the HV and LV components	Jul 30, 2028	Sep 25, 2028
9.3	Cabling and gas connections	Sep 28, 2028	Dec 29, 2028
9.4	Commissioning of STT	Dec 30, 2028	May 31, 2029
9.5	Alignment with cosmics	Jun 1, 2029	Dec 31, 2029

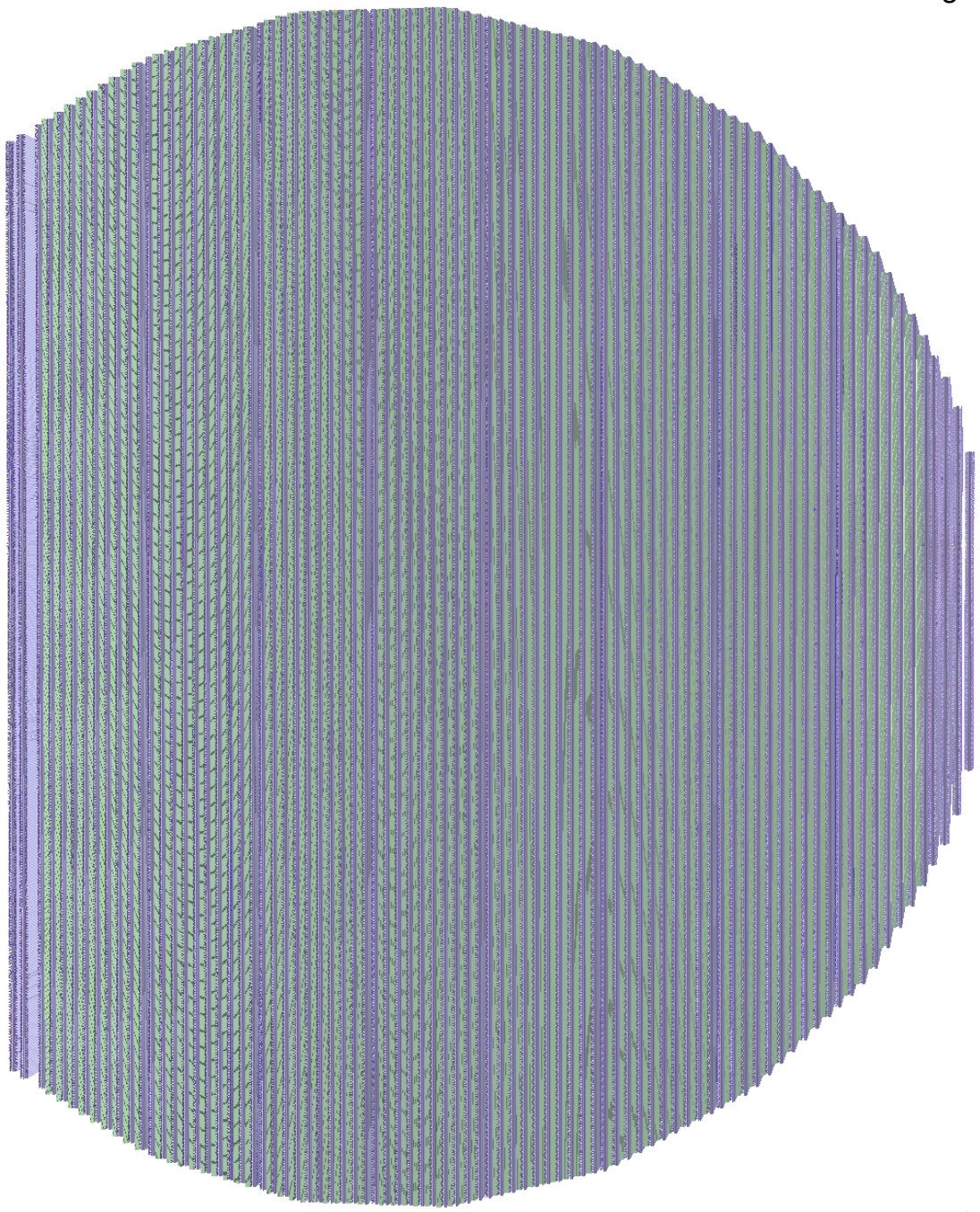


STT FOR SAND

70 CH_2 modules
8 C modules
6 tracking modules

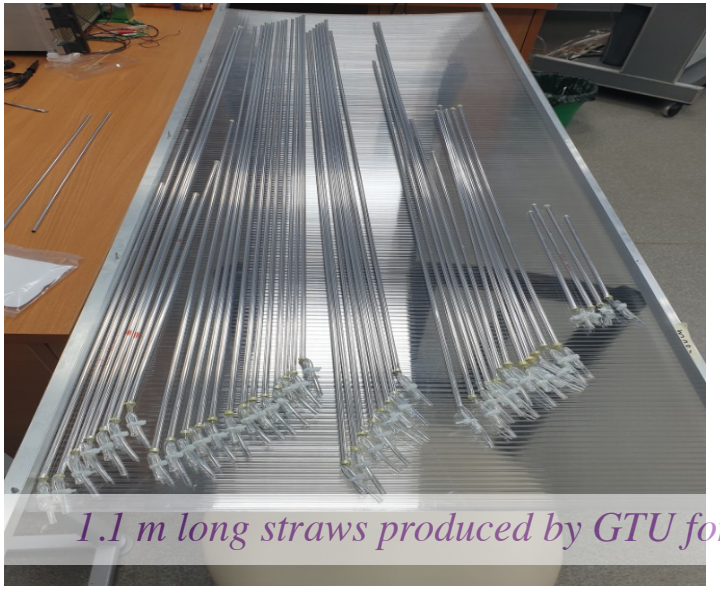
~220,000 straws
average straw length 3.2 m
maximal straw length 3.8 m
internal gas volume ~14 m^3
nominal gas pressure ~2 bar

FV mass:
~4.7 t CH_2
~600 kg C

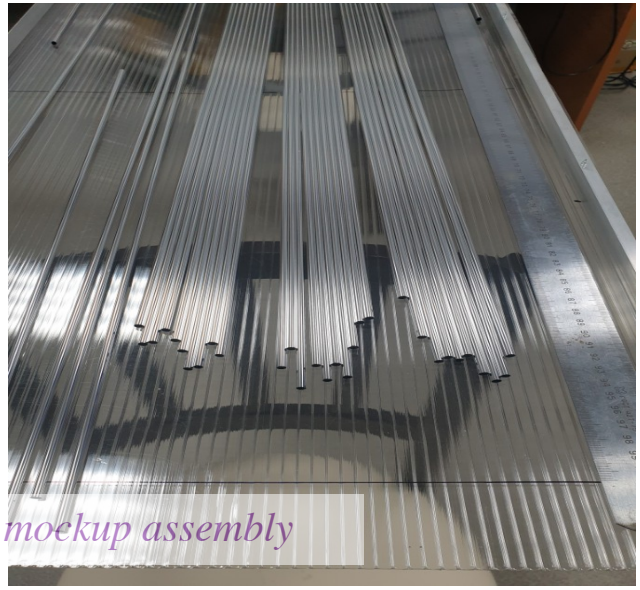


STRAW PRODUCTION

- *Production of straws with ultrasonic welding techology:*
  - *JINR line producing 5m long straws $\sim$ 6 straws/hour;*
  - *GTU line producing $<$2m 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 μm with single Al metallization 70 nm;*
  - *Wall thickness 20 μm with single Al metallization 70 nm;*
  - *Wall thickness 20 μm with double Al metallization 70 nm + 40 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.

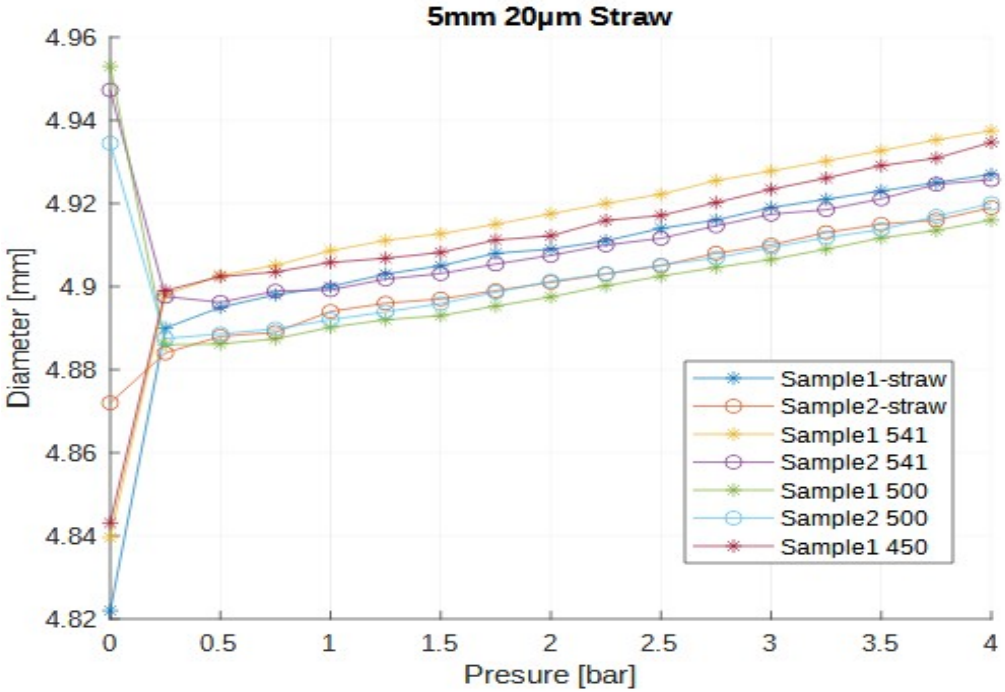
- *Measurements of straw elongation and tension* vs. internal gas pressure (GTU):
  - Straws with 4.9mm diameter, 12 μm & 20 μm walls;
  - Studied tension drop with increase of internal pressure starting from initial pre-tension.

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

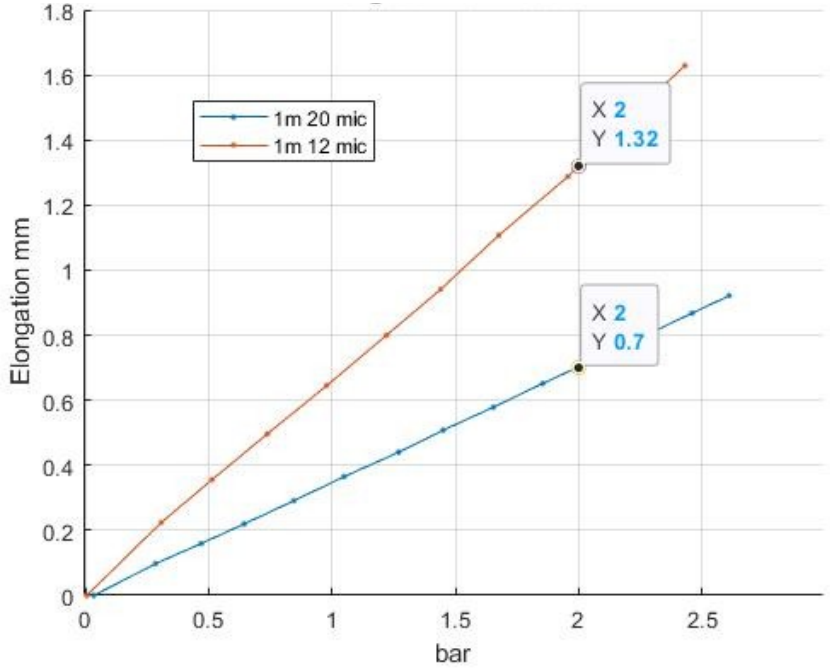
G. Adamov, N. Tsverava (GTU)

Production	*Diameter*	*Wall*	*Metallization*	*Length*	$P_{\max}$ *tested*
JINR	*4.92 mm*	*20* μm	*Single 70 nm*	*20 cm*	*6 bar*
GTU	*4.96 mm*	*20* μm	*Double 70+40 nm*	*20 cm*	*6 bar*

Pressure tests (GTU)



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 $\times$ 1m allowing a variation of internal gas preessure in the glued straws;*
  - *Straws glued together with ELK5 (NA64) epoxy and internal overpressure;*
  - *Initial spacing left between glued points $\sim$20 cm.*

  $\Longrightarrow$ *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 $\times$ 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.*

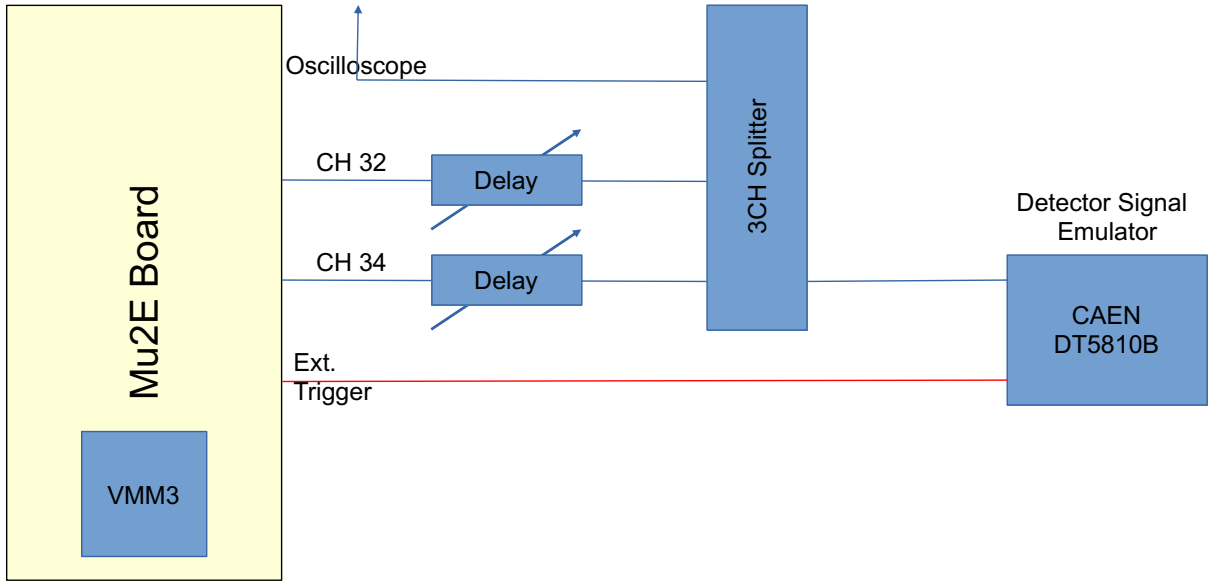
- *Testbeam exposure of small straw tracker with VMM3 readout in RD51 at CERN:*
  - *Two double layers XX+YY with straws staggered by half diameter (20cm $\times$ 20cm active area);*
  - *Indepedent tracking system with 3 GEM detectors ($\sigma \sim 50\mu m$) equipped with VMM3 readout;*
  - *Setup installed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

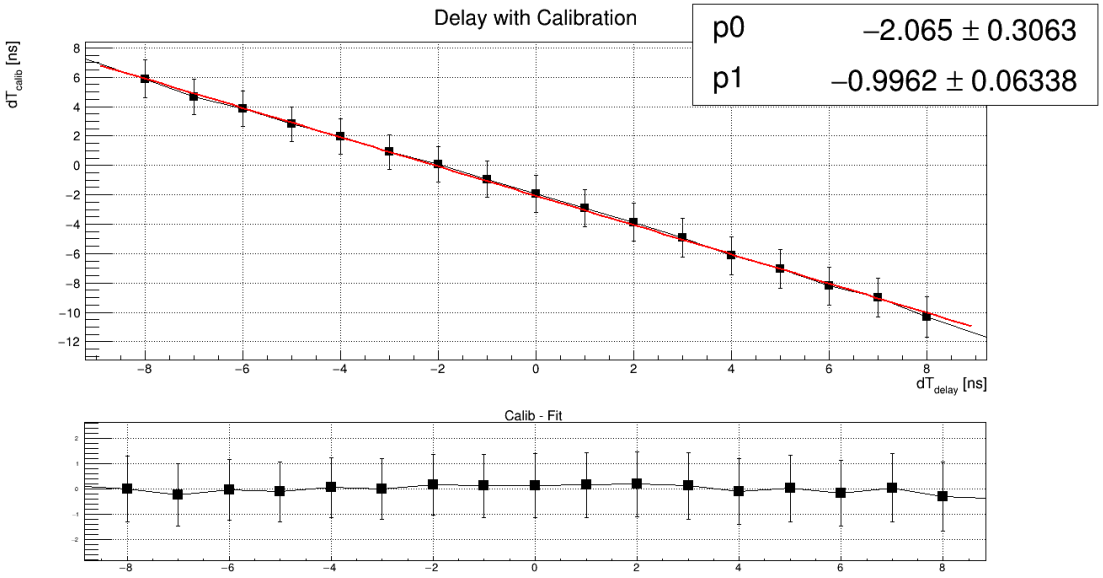
- *Ongoing analysis of testbeam data:*
  - *DAQ instability found at high rates in Time-over-Threshold mode being investigated;*
  - *Stable data taking when operated with peaking time.*

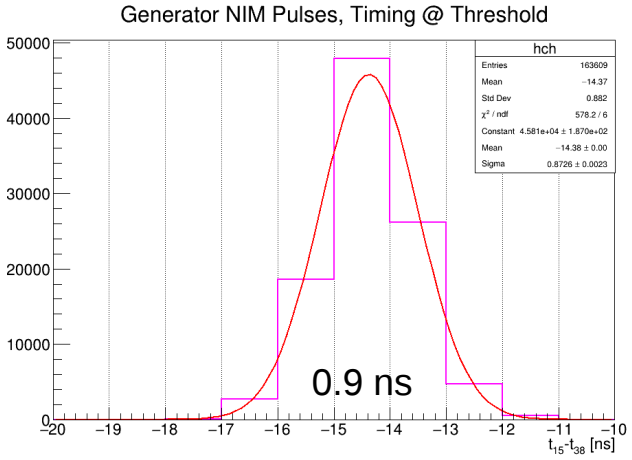
  $\Longrightarrow$ *New testbeam exposure with VMM3 readout at CERN in May 2022*

TIMING CALIBRATION

Vitalii Bautin (JINR)

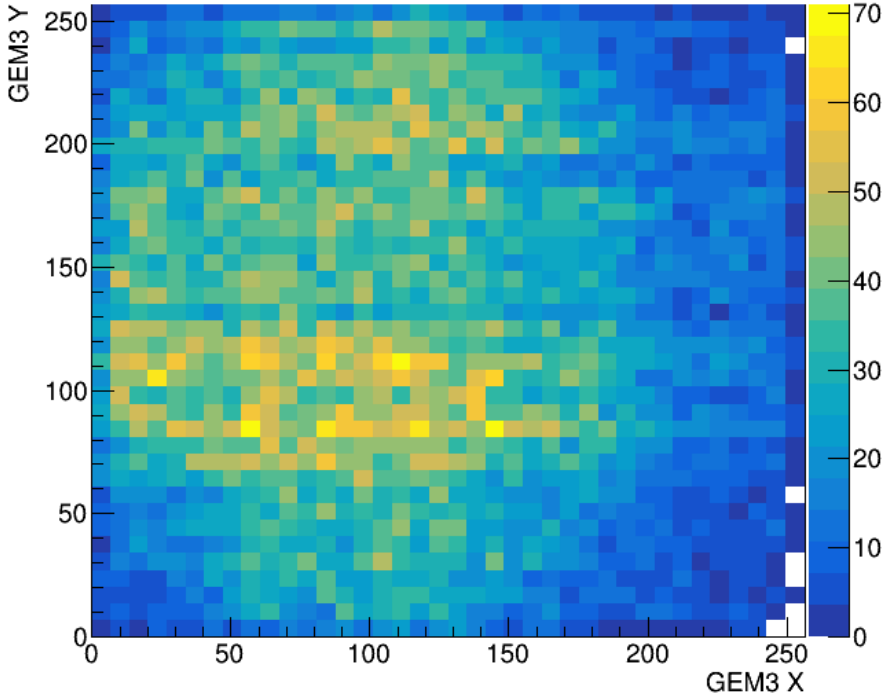






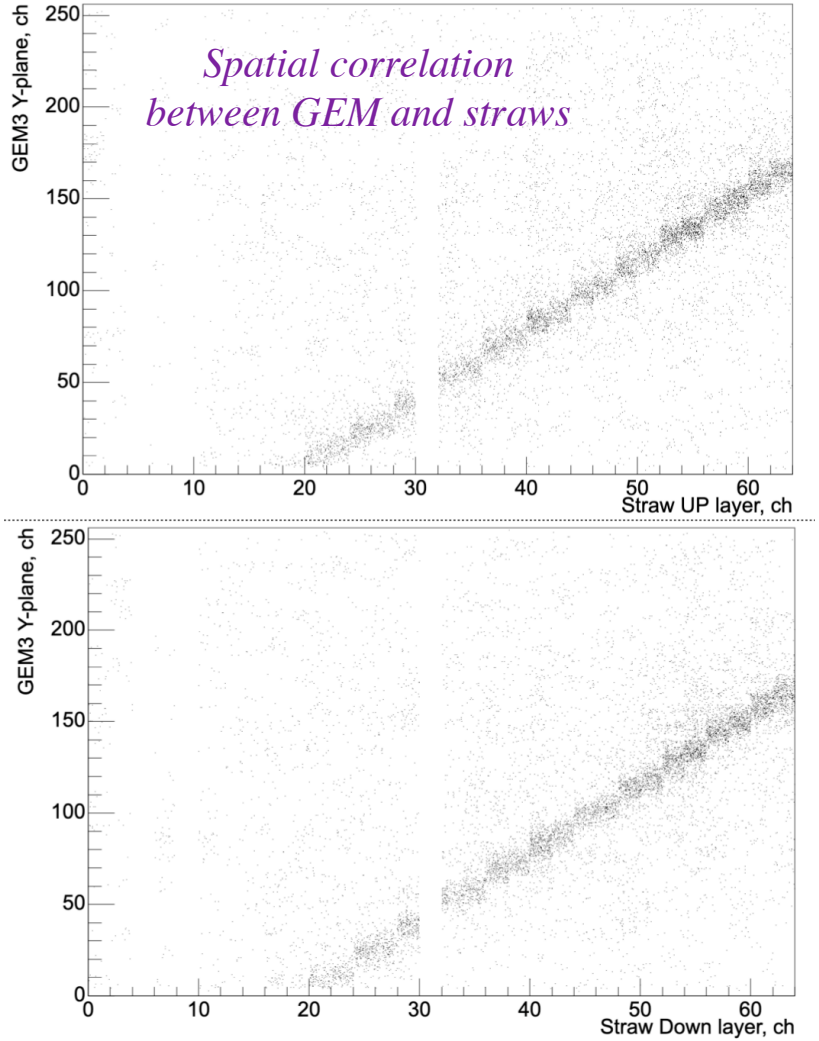
Timing resolution

M. Demichev (JINR)



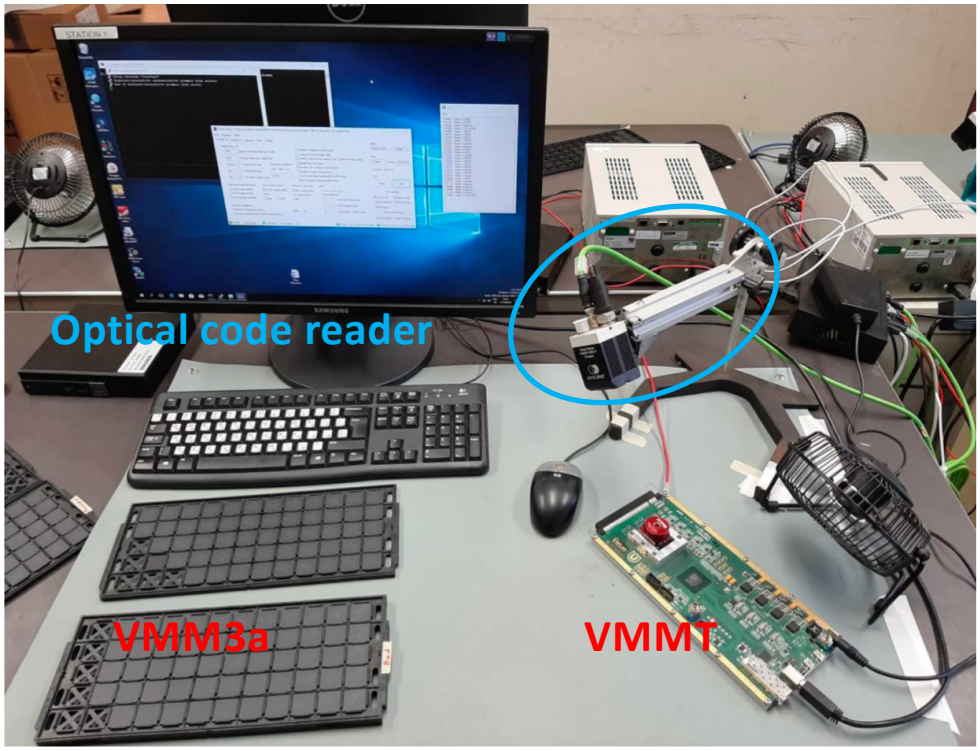
Beam profile seen by GEM 3 tracker

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 $\times$ 0.8m PROTOTYPE

- *Prototype 1.2m $\times$ 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 XXYY: 672 straws total, no target, no radiator;*
  - *C-composite frame and assembly as in STT modules.*

  $\Longrightarrow$ *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.*

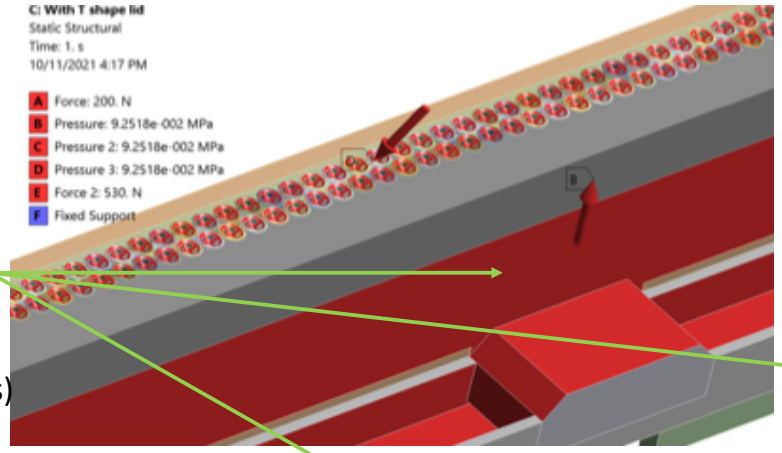
- *Evaluating options for procurement of required components.*

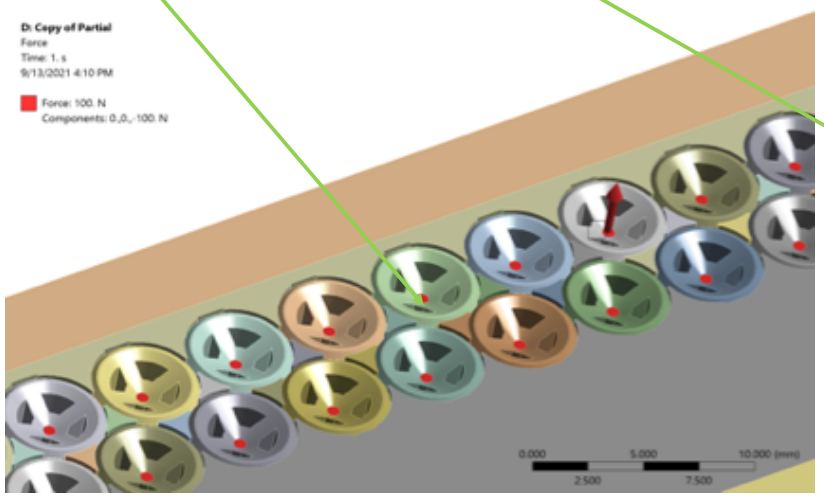
- *Contributing institutions:*
  JINR, GTU, IIT Guwahati, Panjab, Duke, INFN, Hamburg, UofSC.

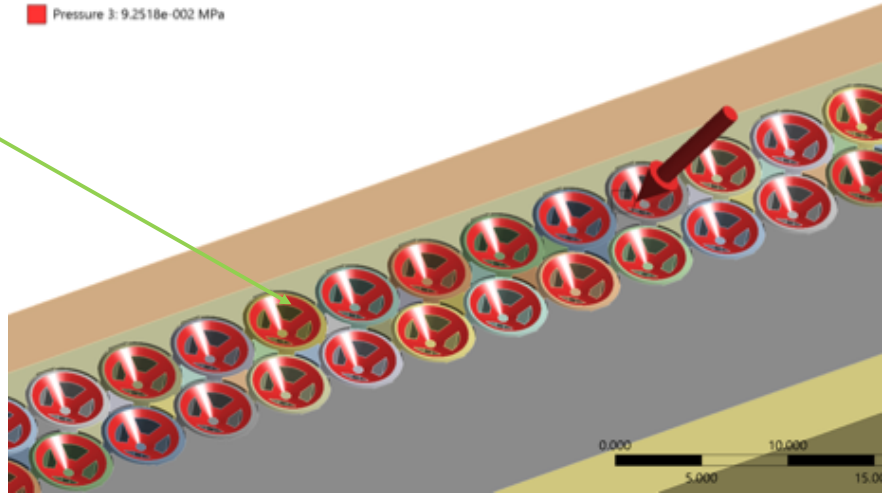
Otari Kemularia (GTU)

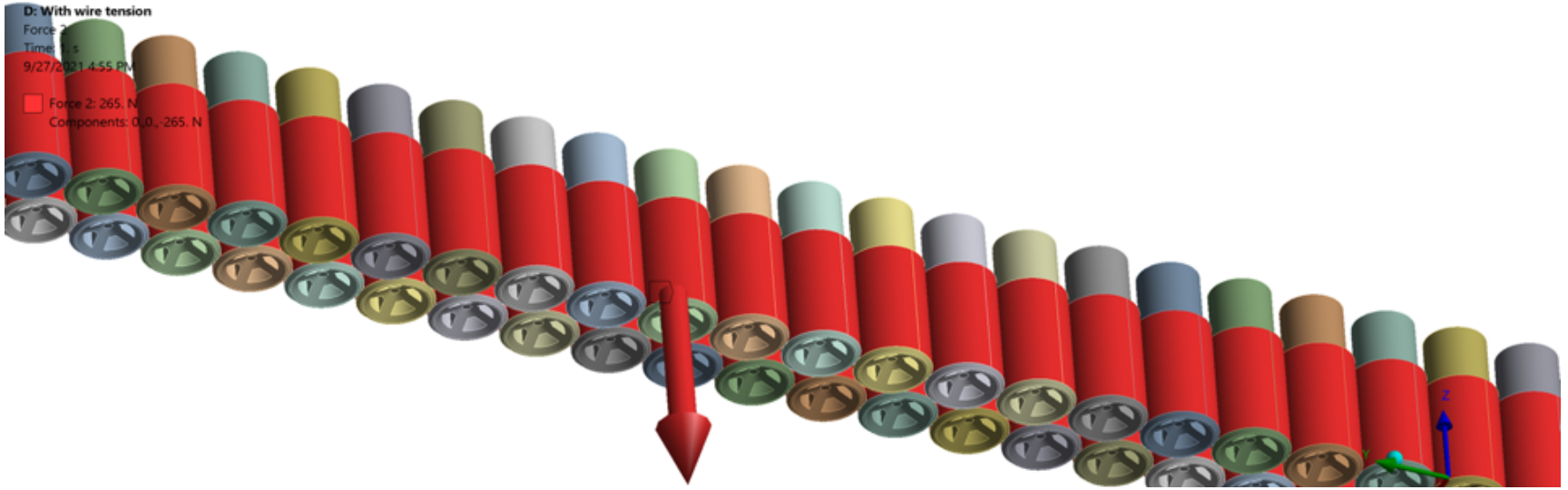
Applied pressure:
0.092 MPa

Applied Force:
100N (for 336 wires)

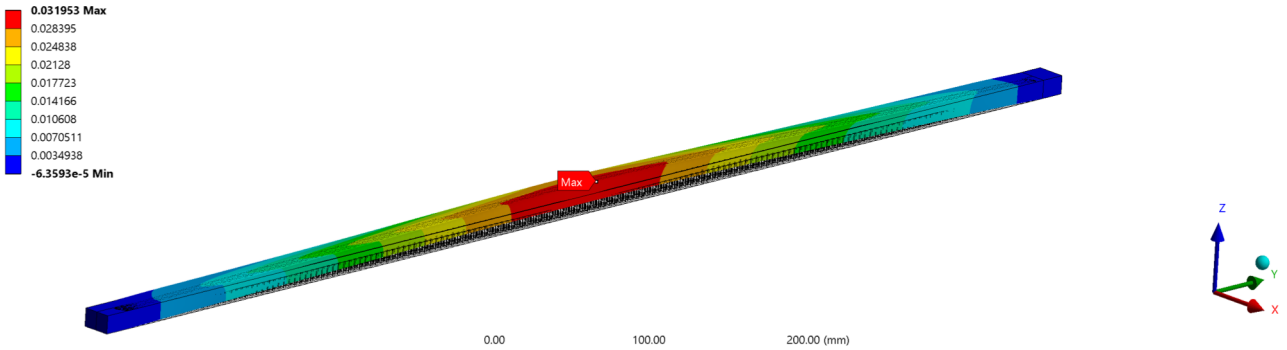




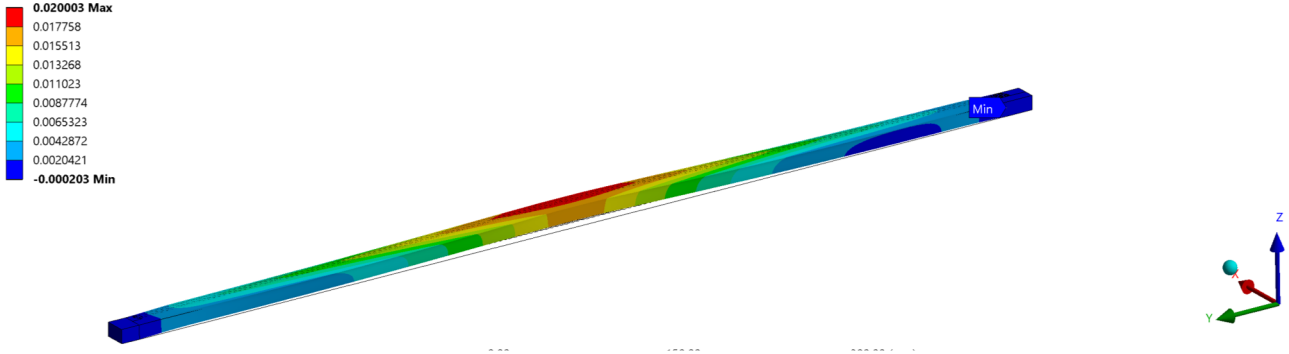




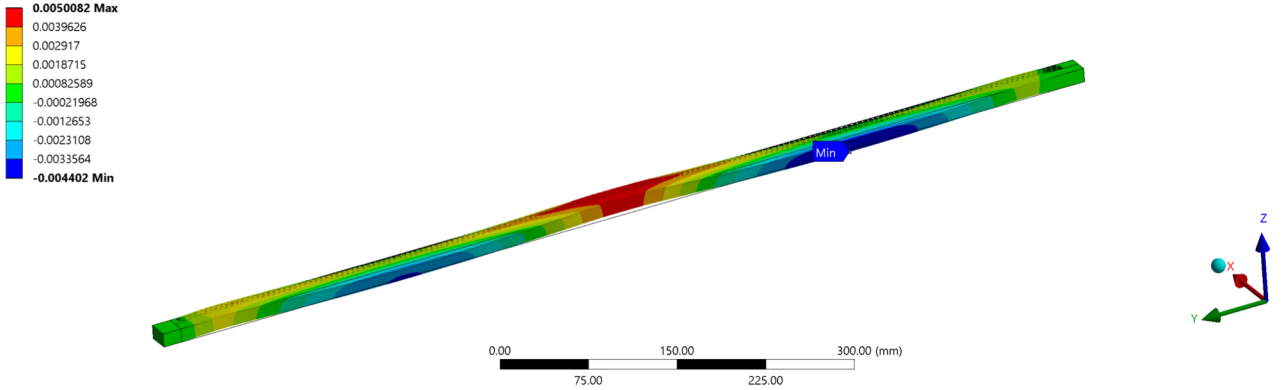
Gas pressure only:
+Z 0.032 mm
-Z 0 mm

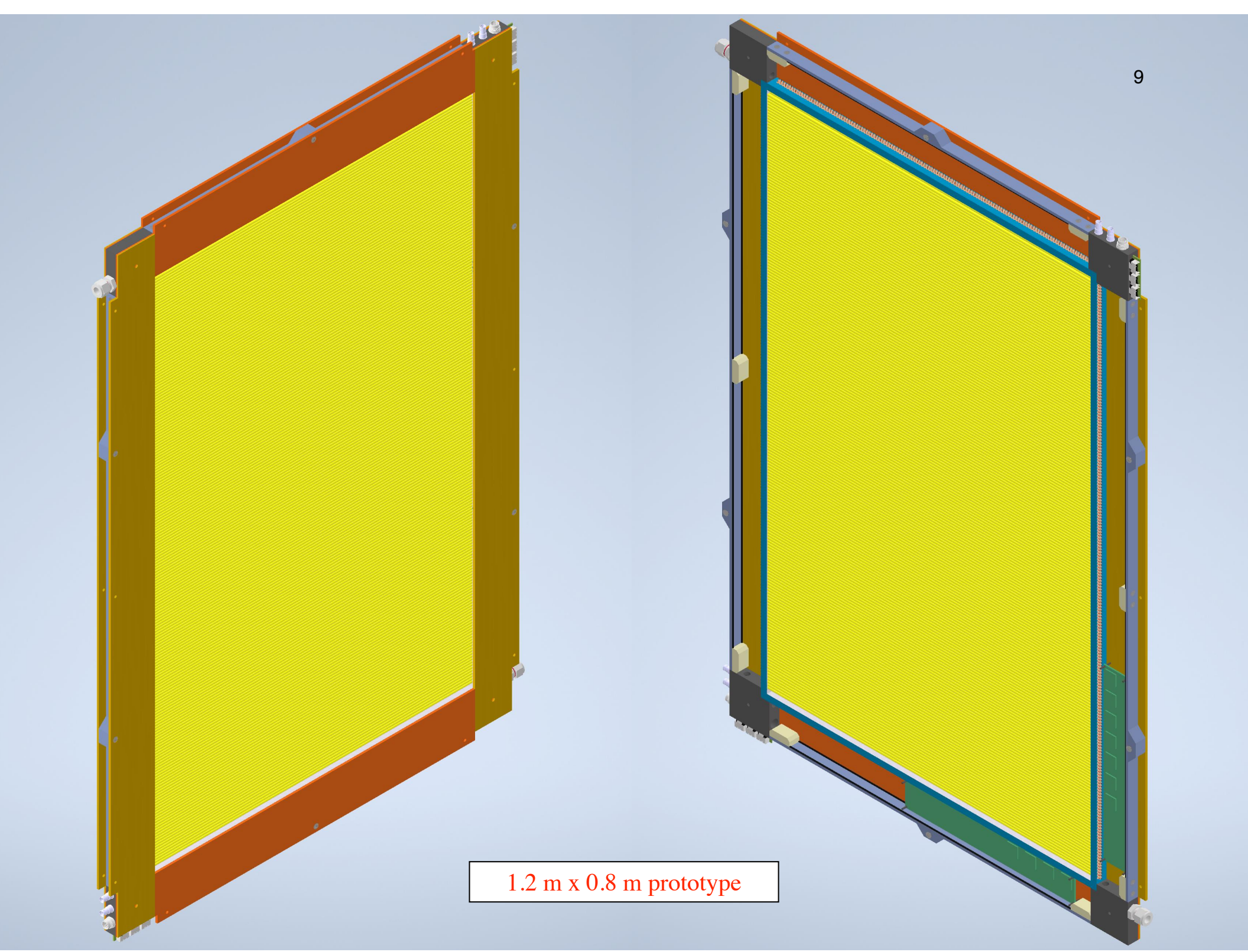


Gas pressure + wire tension:
+Z 0.02mm
-Z 0.0002mm



Gas pressure + wire tension
+ tension from straw walls:
+Z 0.005mm
-Z 0.004mm





1.2 m x 0.8 m prototype