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Date: 20YY-MM-DD

ENGINEERING CHANGE REQUEST

Installation of MiniDT at SND Experiment

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

This document specifies the procedures, timing, materials, and tooling to organise the works to be carried out in TI18 for the installation of the MiniDT in Q1-2025 during Year-End Technical Stop (YETS) 2024/2025

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
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DOCUMENT SENT FOR INFORMATION TO:

O. Beltramello, ATS groups leaders, SND Technical Board, TREX members.

SUMMARY OF THE ACTIONS TO BE UNDERTAKEN:

- Transport of the MiniDT via PM15, along LSS1R to UJ18.
- Installtion of the MiniDT chambers in TI18.

Note: When approved, an Engineering Change Request becomes an Engineering Change Order.

1. EXISTING SITUATION AND INTRODUCTION

The Scattering and Neutrino Detector at the LHC (SND@LHC) aims to make measurements with neutrinos of all three flavours at the LHC and to search for feebly interacting particles in a hitherto unexplored domain. The detector is a combination of a neutrino target based on the nuclear emulsion technology interleaved with scintillating fibre tracker layers (SciFi), and a system with scintillating bars and iron absorbers that combines the task of timing measurement, hadron calorimetry (Upstream planes) and muon identification (Downstream planes).

The installation and commissioning of the detector in the TI18 tunnel took place November 2021 – March 2022. The TI18 tunnel was chosen due to very low machine-induced background and the possibility to cover a region of interest in pseudo-rapidity at very low angle with respect to the beam-beam axis at the ATLAS Interaction Point (IP1).

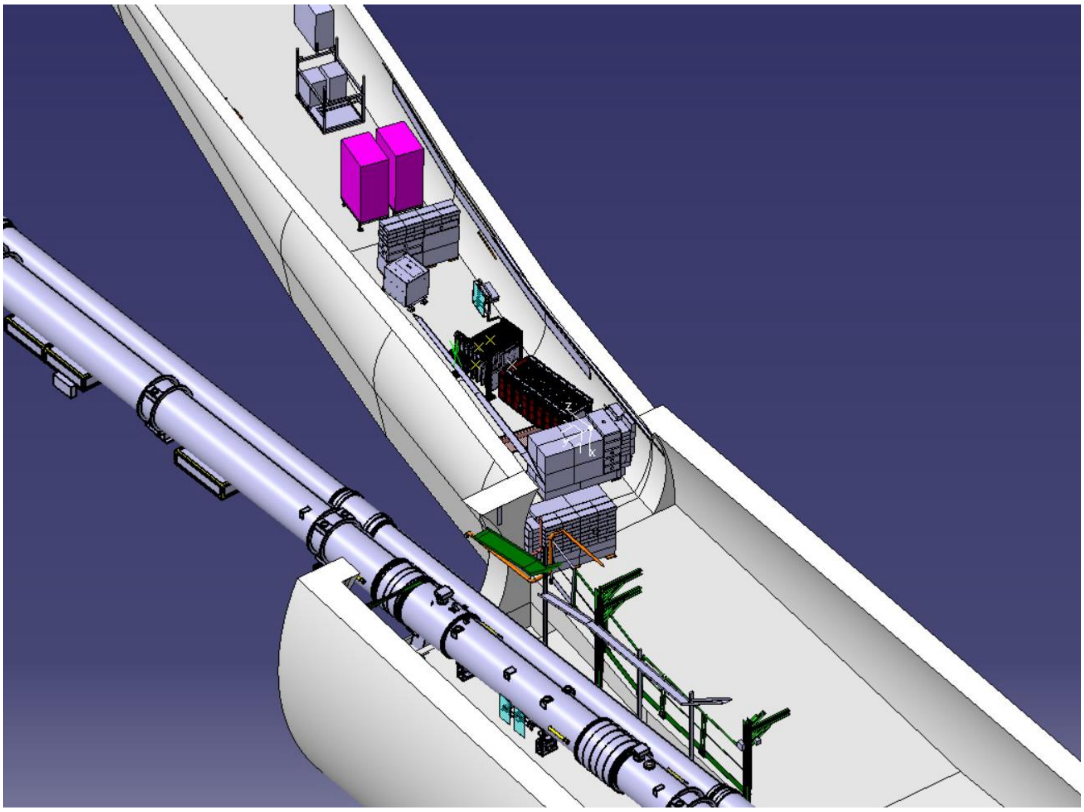


Figure 1 - View of 3D integration model of SND experimental area at TI18 with installed concrete shielding blocks.

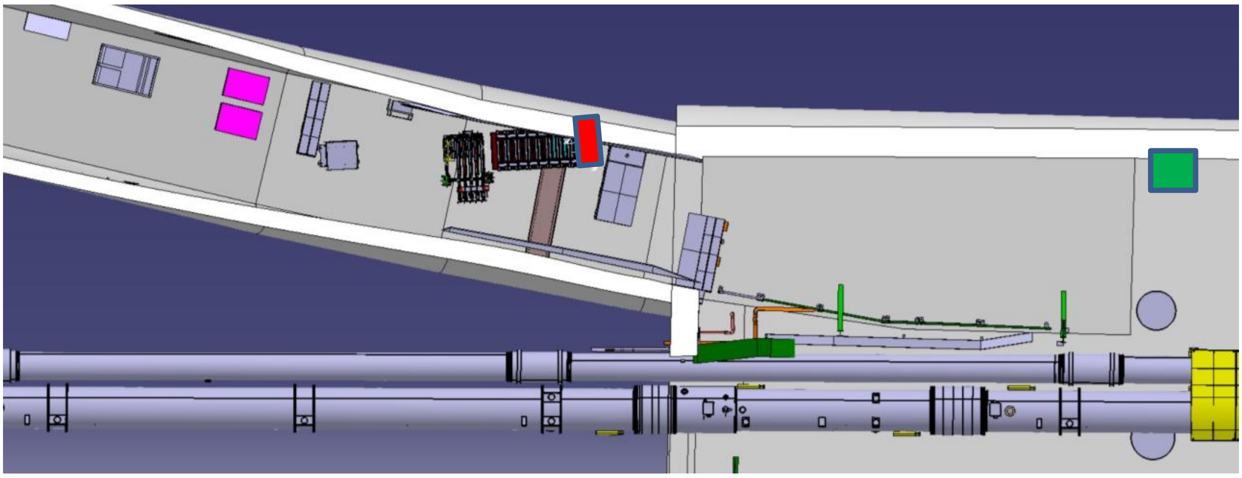
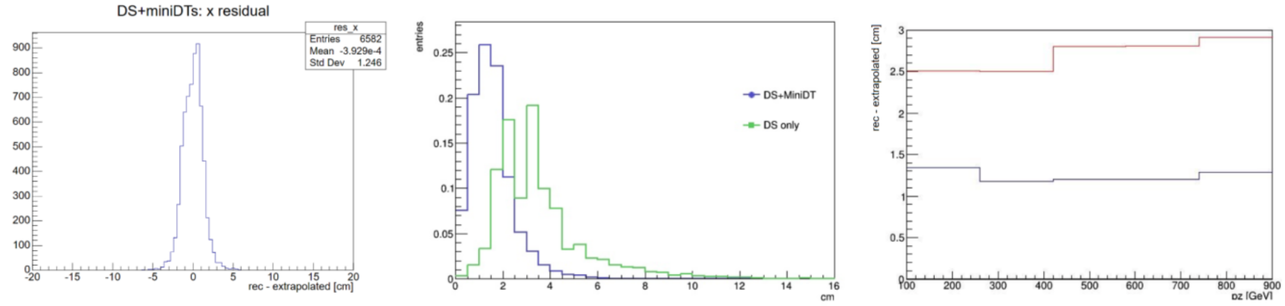


Figure 2 - View of current configuration of SND experimental area in TI18. Highlighted are the position planned for the installation of MiniDTs (red) and the gas bottle location (green).

The current muon track reconstruction is performed using the SciFi layers and then extrapolates straight lines towards the Downstream Modules (DS). The detector technology of SciFi can allow spatial resolution of 150um, while the Downstream layers, built out of 1cm thickness plastic scintillator can achieve at the best 1cm position resolution in on axis and in the opposite axis the position resolution can be estimated based on the light propagation inside the bar. Therefore the muons can be tracked all along the detector with the projection of the SciFi layers towards the DS modules. The muon tracking is a key point in the SND@LHC experiment for two main reasons, first the main background of the experiment comes from all the decay in flight hadrons that turns into muon flux almost uniform across the cross section of the target. [1] These muons are well tagged with a VETO system upstream and later the tracks fully reconstructed removed from the neutrino analysis. Secondary and most important are the muons coming from muon neutrino interactions in the target of the experiment. These muons required a well reconstructed tracks to identify the vertex location of the neutrino interaction to be match with the proton/neutron knock-off.

2. REASON FOR THE CHANGE

The MiniDTs in the SND@LHC detector will improve the present muon tracking performance. Improving the muon track reconstruction is crucial for the analysis both on the signal side, e.g. to precisely locate a muon neutrino vertex in the target, and for the background rejection, given most of it comes from muons crossing the detector from the sides undetected from the veto system. The spatial resolution of each MiniDT layer, around 250 um, is much better than the present SND@LHC muon system. Including the MiniDTs will add up to 8 position measurements to the information from the 4 DS planes, currently dedicated to muon tracking. As shown in F

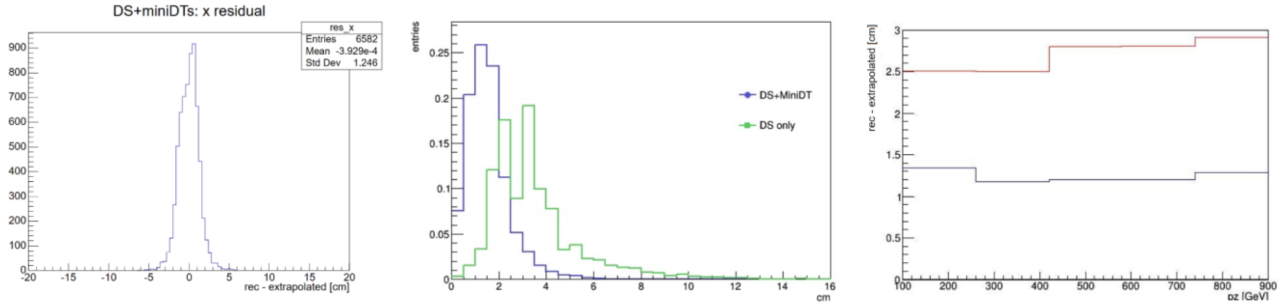


igure 3 , the combination of MiniDT hits into the muon tracking, even in a not yet optimized way, reduces the distance between the extrapolation of the reconstructed muon track and the track starting position measured in SciFi.

Moreover, having more available layers will result in an overall better efficiency: in present SND@LHC framework, 3 DS hits are necessary to attempt a muon track reconstruction.

The change is motivated to perform more precise measurement of muons crossing the SND@LHC detector, which will allow to better reject background events and better resolve interaction vertex of those signals with a muon in the final state. In order to improve the current measurements, the installation of two small scale replicas of CMS Drift Tubes chambers, called MiniDTs (shown in Figure 4) is proposed.

F



igure 3 - Comparison of muon track reconstruction between DS and MiniDT simulated data showing better tracking capabilities. [1]

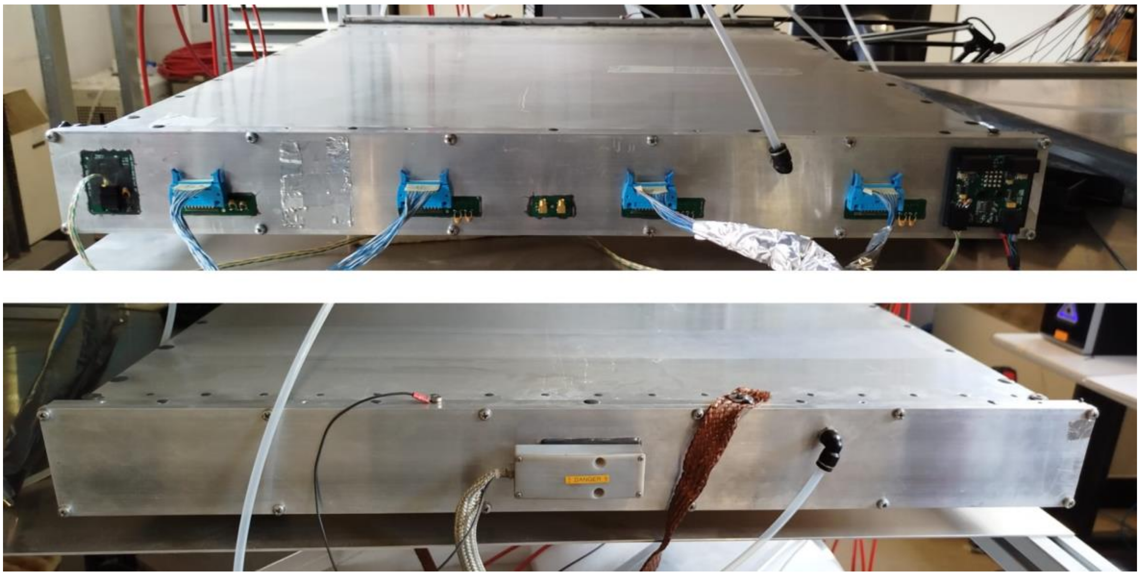


Figure 4 - View of MiniDT modules. Top: front-end side. Bottom: HV side.

Figure 4he proposal consists in the addition to the current muon system of two MiniDT chambers (64 channels per chamber) together with their corresponding Front End Electronics (FEE), and two High Voltage (HV) power supply (PS) boards, one per polarity. The readout of the system is based on a Xilinx VCU118 board, which hosts the firmware to clock, read and configure the OBDT, or On Detector Board for DT, a custom board for triggerless time to digital conversion and readout developed for CMS Phase 2 upgrade. The control and readout of the MiniDTs will be performed with a dedicated server, storing data into an independent stream. The readout electronics will be synchronized by the same TTC distribution system used by the SND DAQ, making it possible to perform.

3. DETAILED DESCRIPTION

Detailed design of MiniDT chambers with the list of materials and their quantity can be found in ATTACHMENT 3.5.2.

3.1 INSTALLATION

The installation of MiniDTs will take place in TI18. A modification to DS4 support structure is proposed for the installation - Figure 5. The MiniDTs will be positioned almost at the end of the current muon system as they are to be inserted between DS3 and DS4. In this position they will not interfere with any work to be done around the detector, e.g. emulsion replacement.

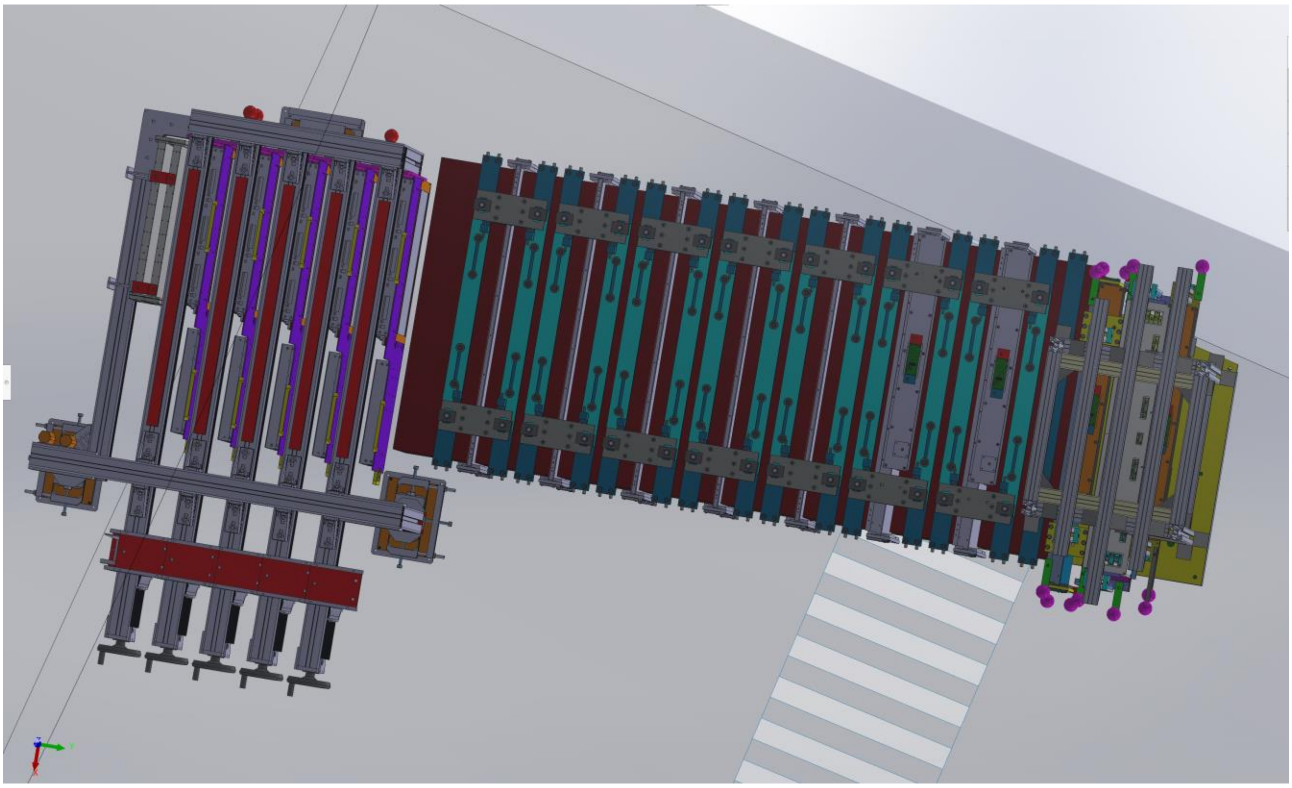


Figure 5 - Top view of MiniDT chambers installed in SND@LHC.

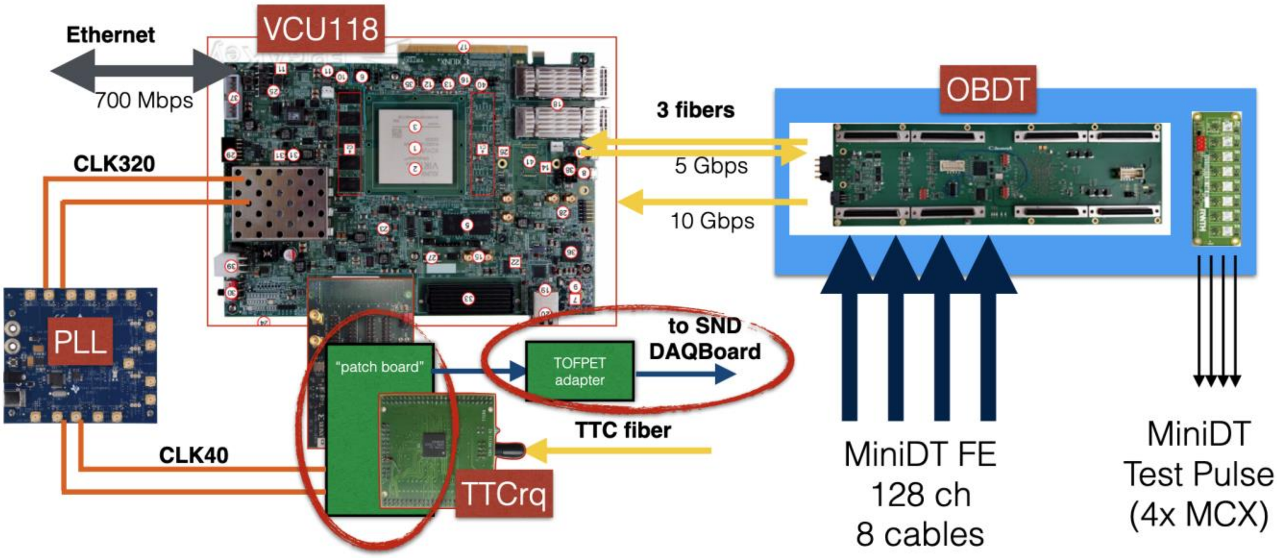


Figure 6 - MiniDTs readout system scheme.

To make space for the new mechanical structure holding the 2 MiniDTs and DS4 the block of iron at the end of the detector will be removed. How? Both the MiniDTs and the DS4 will be equipped with alignment references to survey the new positions. In the final step, the whole assembly will be connected to HV and LV as needed and to readout and control servers via Ethernet cables. The cables will be routed in a manner to leave passages free of obstacles. The ground connection will be made using a copper braid to the closest available mass point.

A gas system will be installed too. A standard (50L, 200 bar) gas bottle with pressure regulator and fluximeter will be stored in UJ18, where wall fixings are already available, and 4-mm copper gas pipe will be installed to reach the MiniDTs at their position in TI18.

The installation will be performed in a team of 5 people, and it's scheduled for the maximum 3-day intervention (2 days + 1 backup day), see work plan 3.4.

The characteristic of MiniDTs chamber is listed in Table 1.

Table 1 - Characteristic of parts to install.

Part	**Quantity**	**Dimensions (m^3)**	**Unit weight (kg)**	**Comments**
MiniDT Chamber	2	0.8x0.9x0.01	50	Dimensions without mechanical structure
Readout Electronics	1	0.4x0.4x0.2	5	Auxiliary box

3.2 ACCESS BY PERSONNEL

The personnel access to TI18 is via PM15 and PM18. PM15 will be used to transport all the materials and related equipment. PM18 provides the fastest evacuation route from UJ18. Access and working hours will be from Monday to Friday 08:00 – 19:00. Personal ODH detectors will be carried by each person.

3.3 TRANSPORT

The MiniDT chambers were assembled in National Laboratory of Legnaro in 2020. Recommissioning and test are now being performed in one of CMS surface laboratories – building SXA5 at P5.

The MiniDTs will be transported by members of the SND@LHC collaboration to the PM15 elevator in building 2155 and later to the installation point in TI18 on a dedicated trolley. The same will be done with the gas tank, stored in building 2155? before the installation in UJ18.

The MiniDTs and the gas tank dimensions allow the passage below the LHC tunnel in the dedicated area, shown in Figure 7.

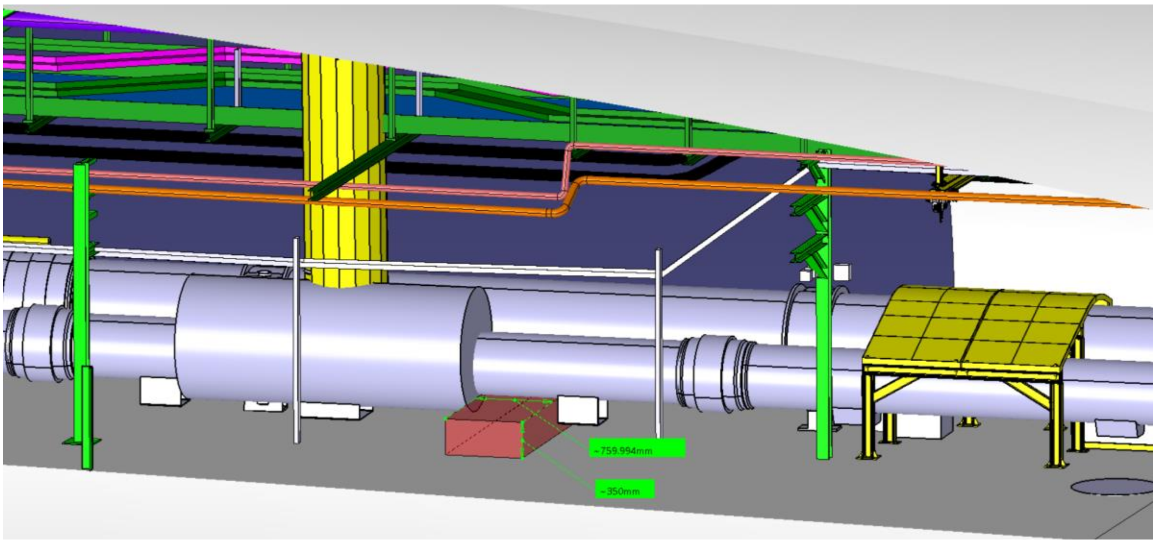


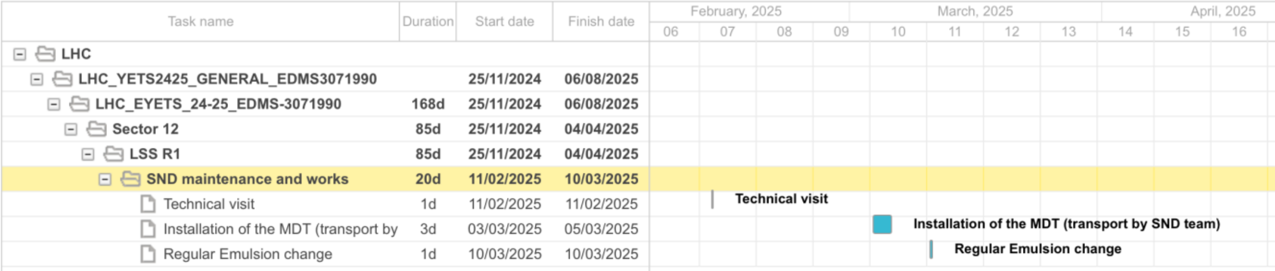
Figure 7 - View of transport passage under the LHC machine in UJ18.

3.4 Work plan

The work schedule is shown in Table 2.

According to the LHC Programmed Stop coordination team (EN-ACE-OSS), there will not be any other parallel activities nor interventions in the concerned zone. The work plan is organized to start the installation after the approval of the Engineering Change Request document, assumed for week 6th 2025.

Table 2 - Work schedule



Task name	Duration	Start date	Finish date
LHC			
LHC_YETS2425_GENERAL_EDMS3071990		**25/11/2024**	**06/08/2025**
LHC_EYETS_24-25_EDMS-3071990	**168d**	**25/11/2024**	**06/08/2025**
Sector 12	**85d**	**25/11/2024**	**04/04/2025**
LSS R1	**85d**	**25/11/2024**	**04/04/2025**
SND maintenance and works	**20d**	**11/02/2025**	**10/03/2025**
Technical visit	1d	11/02/2025	11/02/2025
Installation of the MDT (transport by	3d	03/03/2025	05/03/2025
Regular Emulsion change	1d	10/03/2025	10/03/2025

3.5 ATTACHEMENT

3.5.1 TEMPORARY STORAGE AREA

In case a temporary storage of the materials, the area of 8x2 m² in UJ18 will be used (see Figure 8).

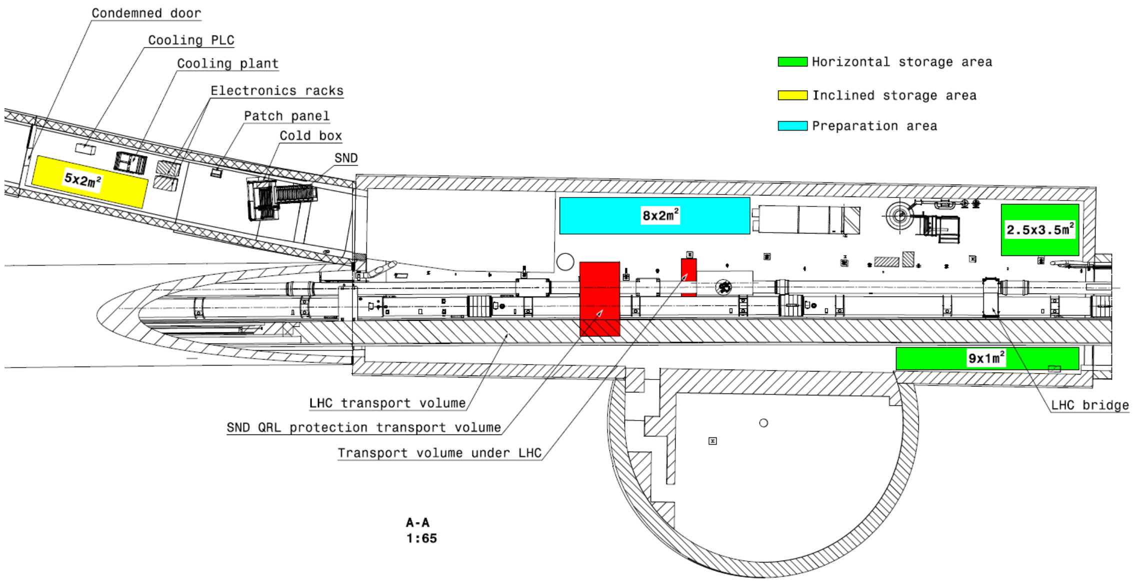


Figure 8 - Overview of possible temporary storage and preparation areas in UJ18 and TI18.

3.5.2 LIST OF MATERIALS

The proposed upgrade for SND@LHC consists of 2 MiniDT planes, each correspond to a CMS DT SuperLayer with an active area of 65x70 cm². Each chamber is made of four layers of rectangular drift cells staggered by half their width, with the mechanical support of five 1.5 mm thick aluminium sheets separated by aluminium I-beams that separate the cells from one another. The cell has a 42 mm pitch and is 13 mm thick. In each cell, there are five electrodes: the anodic wire that collects the signal, two strips that shape the drift field, and the cathodes which are on the I-beams that separate the cell from one another. The FE circuitry is embedded within the gas volume and consists of HV decoupling capacitors connected to the FE boards (FEB) via strips of contacts. The front-end electronics amplify the signals from the detector, compare them to a threshold and send the output logic signal to the following part of the readout chain. The construction of MiniDTs employs all materials and internal electronics and wiring as in the original CMS Drift Tube chambers, see [reference https://cds.cern.ch/record/343814]

Table 3 - List of materials applied in construction of one MiniDT chamber.

Component	Amount	Comment
Aluminium	2 x sheets ~74x80x0.15 cm³ 3 x sheets ~74x73x0.15 cm³ 2 x machined frames (hollow) 74x8x1 cm³ 2 x covers 74x8x0.8 cm³ 8 x side bars 80x1.1x1.1 cm³ 68 x I-beams	
Gold plated steel	64 x wires ~60 cm (50 um diameter)	
DP190 and Araldite glues	All contact surfaces between aluminium parts, with the exception of removable covers, are glued	
Printed circuit board	4 x PCB HV distribution	Inside gas volume

	4 x PCB HV decoupling 4 x PCB Front End boards	
Connectors	4 x FE connectors Yamaichi NFP-34A-0122BF 1 x Custom HV connector 1 x Custom LV/FE connector 2 x MCX 50 Ohm connectors 2 x gas connectors	
Var	1 o-ring for gas tightness, 64 injection-built glass-reinforced noryl plugs to keep wires and cathodes in position	Plugs also inside gas volume

The gas of the MiniDTs consists of a mixture of 85% Ar and 15% CO_2. The MiniDTs will be connected in a single gas loop. The flux required to properly work the MiniDTs is around 2 l/h at atmospheric pressure, to ensure clean gas and avoid any degradation.

Each MiniDT chamber receives the appropriate HV levels via a custom HV connector. Only three power supply channels are used, one for each needed voltage (+3600V, +1800 V, -1200 V), thanks to a splitter box that allows to power both MiniDTs at the same time.

The 64 signals provided by each plane are readout by fast FE electronics.

[3][4].

The signals provided by the FEE are fed into an OBDT (On-detector Board for DT) which performs time-to-digital conversion, shown in Figure 12. The OBDT is optically connected to a VCU118 board which reads the data from the OBDT and provides the slow control signals and the clock. The latter is provided through a Texas Instruments CDCE62005EVM board which receives the machine clock from a TTCrq board, and distributes it to the readout system.￼￼￼, ensuring the synchronization of the MiniDT readout with the rest of SND@LHC data acquisition. The VCU118 firmware will also perform online fitting of tracks crossing the MiniDTs, to allow for a track time measurement. To ease the offline event building, for each MiniDT a time tag is generated, at a fixed latency with respect to the muon crossing time, and output to an adapter to enable the readout by standard SND electronics (TOFPET and DAQ board). The whole system is shown inFigure 913￼. All of the readout electronics will be hosted in a aluminium frame supported by the same mechanical structure holding the two MiniDT planes.

Figure 12 -The OBDT board, connected with power and Front End cables, and optical fibers going to backend electronics.

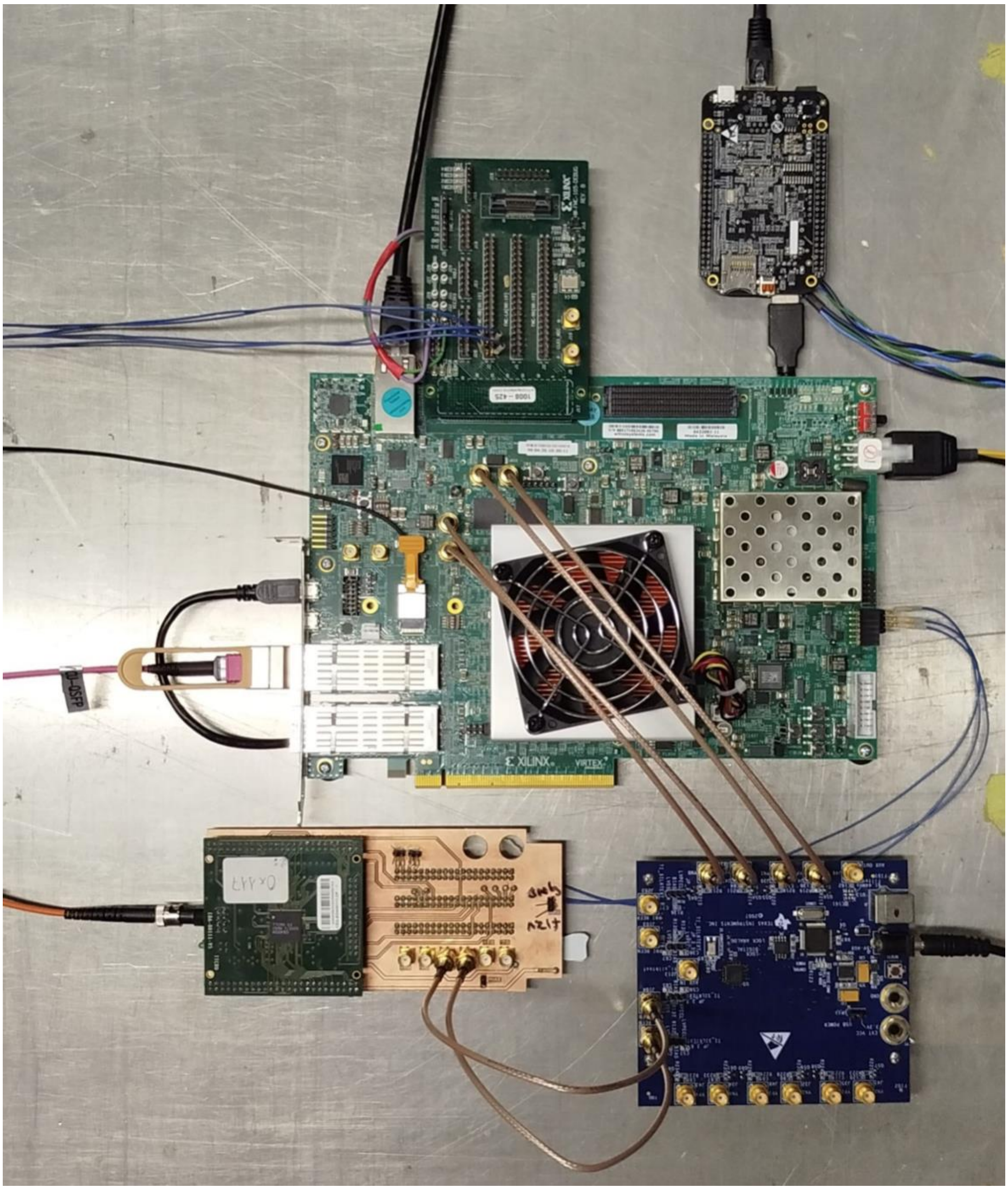


Figure 9 – Picture of the DAQ boards.

Table 4 shows all the elements used on the construction of the telescope.

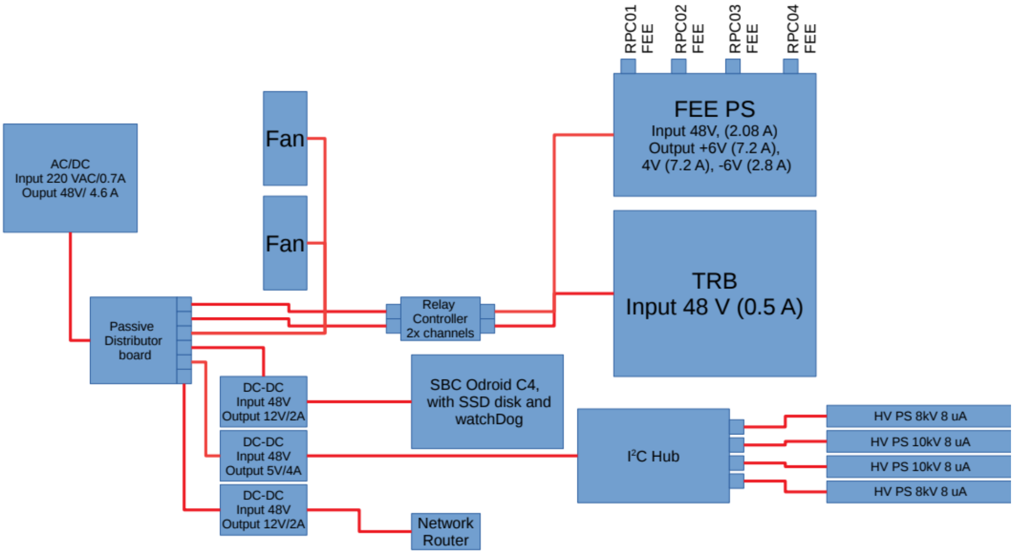


Figure 10 - Power scheme.

Table 4 - Elements used in the construction of the MiniDT system.

Component	Amount	Comment
MiniDT planes	x 2 planes	Described in Table 3
HV splitter box	1	To use only 3 HV channels for both MiniDTs and deliver HV to the custom HV connector
Xilinx VCU118 board	1	[3]
Signal cables	4 x 1.5 m of flat cable	
LV cables		[4]
HV cables		
Optical fibers		
CDCE62005EVM board	1	
DAQ board adapter	1	
OBDT board	1	
DAQ board	1	
HV power supply	A1833P, A7030DN	One per polarity
Technical profile Bosch	x 10 meter	https://store.boschrexroth.com/STRUT-PROFILE_3842992888?cclcl=en_IN
Var	Ethernet cables, other small cables, small custom aluminium parts	

The system requires HV (three channels) and LV (minimum 3, maximum 8 channels) from SND@LHC mainframes, and three Ethernet cables to be operational (readoout, slow control, SND DAQ board). The upper limit of power consumption for the electronics installed close to the detector is overall 80 Watts. There will be no need of cooling. Once connected the system is fully operational. The expected amount of data delivered by the system is around 0.5 Mbytes/second at a coincidence rate of 1 kHz.

4. IMPACT ON OTHER ITEMS

4.1 IMPACT ON ITEMS/SYSTEMS

Item/System xxxxx	No Impact is expected on any of the LHC services or systems.
Item/System xxxxx	

4.2 IMPACT ON UTILITIES AND SERVICES

Alignment and positioning:	The MiniDTs will be equipped with position survey spheres.
Compressed air:	None
Contractor(s):	CERN contact (transport) serge.pelletier@cern.ch
Controls:	None
Cryogenics:	None
DEC/DIC:	None
Demineralized water:	None
Electricity, cable pulling (power, signal, optical fibres…):	Only inside the experimental area; 8xLV patch panel oupts and 2xEthernet sockets will be used from the current switch. 2 CAEN HV PS modules will be installed in the current Mainframe to power MiniDT HV.
GSM/WIFI networks:	
Integration:	[Indicate the reference(s) of the new 3D model(s) taking into account the change.]
Racks:	[Name and location.]
Raw water:	None
Scaffolding:	None
Special transport/ handling:	The MiniDTs and the axualiary equipement wll be transported and handled in the mode described in 3.3. Trained personnel will be performing the operation. PPE will be used.
Surface building(s):	1 spare gas bottle will be installed in the gas storage area in front of SR1, building 2175
Temporary storage of conventional/radioactive components:	None

Vacuum (bake outs, sectorisation…):	None
Others:	

5. IMPACT ON COST, SCHEDULE AND PERFORMANCE

5.1 IMPACT ON COST

Detailed breakdown of the change cost:	No budget is required
Budget code:	None

5.2 IMPACT ON SCHEDULE

Proposed installation schedule:	March 2025 – 03 – 05 of March
Proposed test schedule (if applicable):	05 March
Estimated duration:	1 day + 1 day of testing
Urgency:	The installation of MiniDT must be accomplished before the end of YETS 2024/2025
Flexibility of scheduling:	Preferable during week 10, any day during the week.
Impact on the Technical Stop duration / maintenance needs	None
PLAN Activities:	

5.3 IMPACT ON PERFORMANCE

Electron cloud (NEG coating, solenoid…)	[To be completed with BE-ABP and/or TE-VSC.]
Impedance:	[To be completed with the impedance team (BE-ABP, SY-RF). Check the longitudinal and transverse contributions to minimise beam induced heating and instabilities. In case of potential impedance issues asses the need of: damping resistors (SPS), ferrites (SPS or LHC), coating, tapered transitions… Consider the full integration of the device in the existing beam line (transitions, bellows and insulation).]
Insulation (enamelled flange, grounding…)	[To be completed with SY-RF. Detail insulation requirements. Consider the EMC/EMI aspects of the installed device.]
Mechanical aperture:	[To be completed with BE-ABP and/or SY-ABT. Consider injection, extraction, top energy, resonant excursion, when applicable.]
Optics/MADX	[To be completed by BE-ABP.]
R2E impact on performance and availability:	[To be competed with the R2E team for systems with active electronic components to operate in radiation areas. Linked to R2E Radiation Hardness

	Assurance validation document for concerned equipment (template: EDMS document 2028777)]
Vacuum performance:	[To be completed with TE-VSC.]
Others:	

6. IMPACT ON OPERATIONAL SAFETY

[This chapter aims at assessing the impact of the modification on people safety, on the environment, and on the safety of operations, including maintenance, access, egress, circulation and evacuation.]

[Following the implementation of the change, the Safety File of the facility shall be updated. In the temporary absence of the Safety File, the hazards inventory and risk analysis of the concerned installation shall be established.]

6.1 ÉLÉMENT(S) IMPORTANT(S) DE SECURITÉ

[Indicate if the change will have an impact on an *Elément Important de Sécurité* (EIS). The list of EIS components is available in EDMS document: 1182293 – "Définition et Inventaire des EIS-Faisceau et EIS-Machine en Opération".]

Requirement	Yes	No	Comments
EIS-Access			[Provide further details on the impacted EIS]
EIS-Beam			
EIS-Machine			

6.2 OTHER OPERATIONAL SAFETY ASPECTS

[This chapter aims at assessing the impact of the modification during operation and maintenance of the hardware on people safety, on the environment, including access, egress, circulation and evacuation.

It doesn't concern the installation of the hardware. Worksite safety is addressed in the next chapter.]

What are the hazards introduced by the hardware?	- Is it standard CERN equipment or a new design? - Reference here the risk analysis if it exists. If there is no risk analysis, evaluate here what new hazards are introduced, such as: new chemical, new power supply, possible obstruction of evacuation paths, etc. - Indicate if the hardware complies with CERN safety rules, or if a derogation has been granted.
Could the change affect existing risk mitigation measures?	[e.g. safety systems may need relocation, or additional safety systems or monitoring systems have to be installed, etc.]

What risk mitigation measures have to be put in place?	Indicate here the measures taken to eliminate or reduce the hazards, either by design, by interlocks, or by procedure.
Safety documentation to update after the modification	
Define the need for training or information after the change	

7. WORKSITE SAFETY

[Refer to EDMS document: 1155899 – “Working on the CERN Site”.]

[The information in this chapter, to be prepared with the WSS in charge, are intended to help preparing the operation on the field.]

7.1 ORGANISATION

Requirement	Yes	No	Comments
Alarms deactivation/activation (IS37):			
Electrical lockout:			[Indicate the powering source reference for each equipment requiring electrical lockout, as well as the equipment ID]
Fire risk/permit (IS41) (welding, grinding…):			
IMPACT – VIC:			
Non-radioactive waste:			[Specify waste category as per EDMS 1738461; waste quantity; collection/elimination means (i.e. SCE Dept. centralised services or contractor).]
Operational radiation protection (surveys, DIMR…):			[Consider ALARA. If relevant, at what level?]
Radioactive storage of material:			[Radioactive storage space needed and available?]
Radioactive waste:			[Components become radioactive waste?]
Others:			

7.2 REGULATORY INSPECTIONS AND TESTS

Requirement	Yes	No	Responsible Group	Comments
HSE inspection of pressurised equipment:				
Pressure/leak tests:				

HSE inspection of electrical equipment:				
Electrical tests:				
Others:				

7.3 PARTICULAR RISKS

Requirement	Yes	No	Comments
Confined space working:			
Cryogenic risks:			
Hazardous substances (chemicals, gas, asbestos…):			
Industrial X-ray (*tirs radio*):			
Ionizing radiation risks (radioactive components):			[Traceability by TREC.]
Noise:			
Work at height:			
Others:			

8. FOLLOW-UP OF ACTIONS BY THE TECHNICAL COORDINATION

Action	Done	Date	Comments
Carry out site activities:			
Carry out tests:			
Update equipment drawings:			
Update layout database:			
Update layout drawings:			
Update naming database:			
Update optics (MADX)			
Update procedures for maintenance and operations			

Update Safety File according to EDMS document 1177755:			
Others:			

9. REFERENCES

[1] N. Surname, N. Surname, N. Surname, Title, Reference, EDMS XXXXXXX