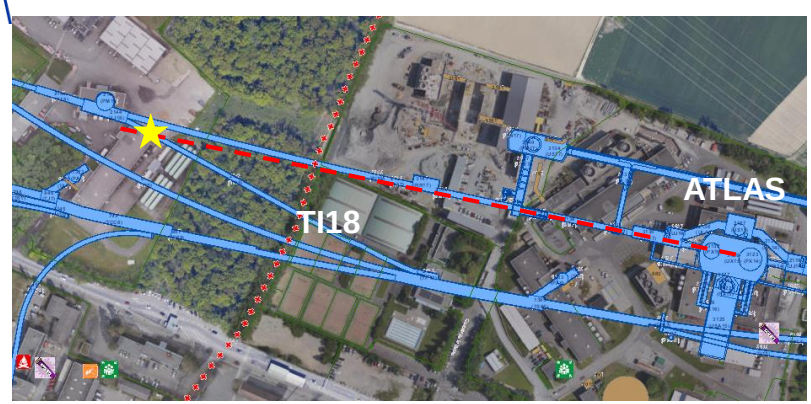
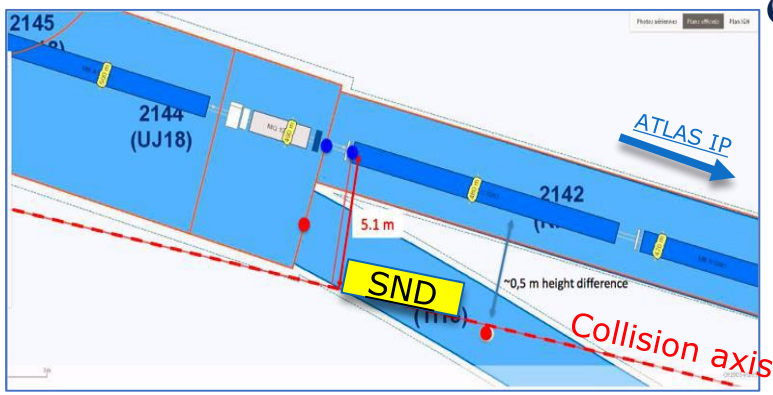

# SND@LHC status report

R. Jacobsson
on behalf of SND@LHC Collaboration

# Refresher: Goals




SND@LHC acceptance: 7.2<$\eta$< 8.6



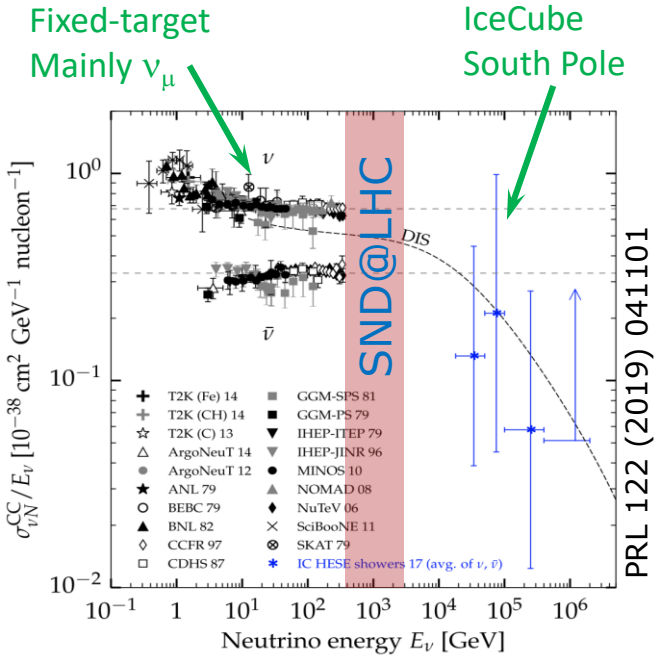
SND@LHC Physics motivation:

- Study neutrino interactions of all flavours in unexplored energy range
- Probe heavy flavor production with neutrinos in unexplored rapidity range ➔ gluon PDFs in unexplored x ($10^{-6}$) range
  ➔ relevant for Future Colliders, and for cosmic-ray physics
- Search for recoil signatures of FIPs (e.g. HS mediators, LDM,…)

First phase, measurement of

- $pp \rightarrow \nu_e\ X$ cross-section
- Charmed hadron yield
- Lepton Flavour Universality $\nu_e/\nu_\tau$ and $\nu_e/\nu_\mu$
- Ratio of Neutral-Current/Charged Current
- Observations of high-energy $\nu_\tau$

\+ FIP search

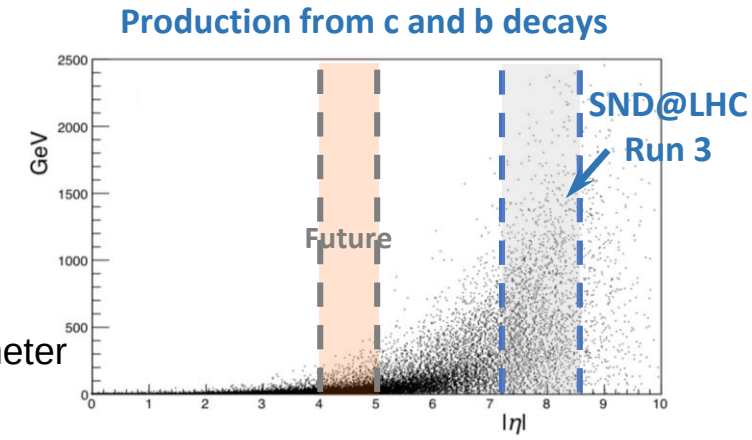



PRL 122 (2019) 041101

# Refresher: Detector

LOCATION:

- $7.2 < \eta < 8.6$
- Intercept good statistics of $n_e$ from heavy flavour

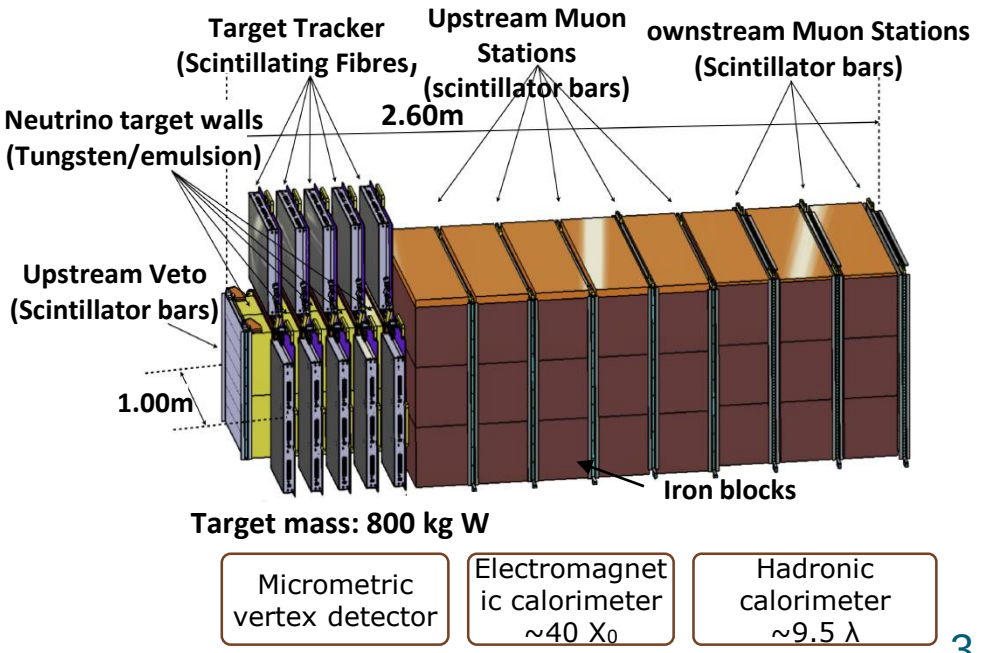



HYBRID DETECTOR CONCEPT:

- Veto plane to tag penetrating muons
- Emulsion Cloud Chambers (ECC) made of emulsion films and tungsten plates as a vertex detector and electromagnetic calorimeter
- Scintillating fibres for timing information. Energy measurement together with ECC
- Iron walls interleaved with plastic scintillator planes as HCAL and muon system

DISTINCTIVE FEATURES

- Time resolution 200 ps (limited by the size of ATLAS luminous region)
- Micrometric vertex resolution
- Identification of three neutrino flavours
- Energy measurement



# General news

- Collaboration:
  - MoU for construction will be discussed by resource coordinator W. Funk
  - Since last LHCC, SAPHIR-Chile joined and LIP-Portugal contribute to construction


  - CERN SASS for A. Di Crescenzo
  - Interest from additional people in CERN EP
  - Outside groups are securing personnel

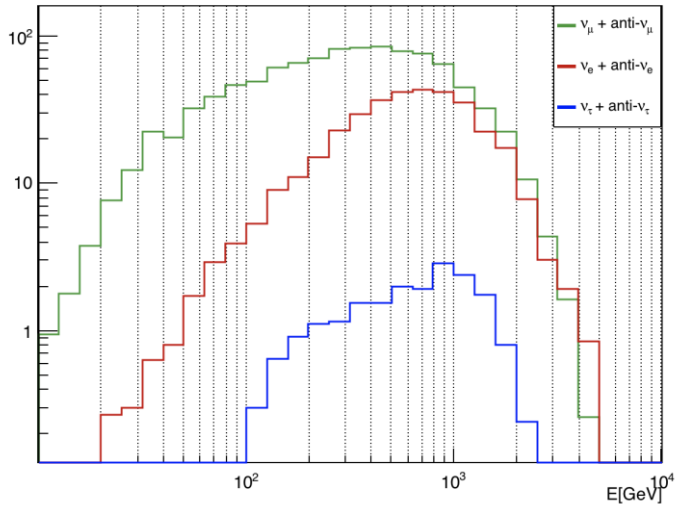
- Support from Neutrino Platform agreed with M. Nessi and DRC
  - ➔ Very convenient storage area made available in EHN1 – NP
  - ➔ Help with grouting, technical discussions ongoing
  - ➔ Possibility to get occasional support from technicians as backup for surface commissioning and installation - involves extra costs

# Update on physics

Reminder: simulation strategy

- DPMJET3 embedded in FLUKA for neutrino production@LHC
- Particle propagation up to detector through the LHC FLUKA model
- GENIE used to simulate neutrino interactions in the detector target
- Neutrino production in pp-collision also simulated with Pythia

Spectrum of neutrinos interacting in SND@LHC

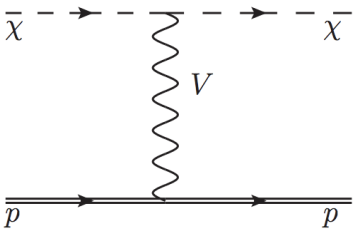


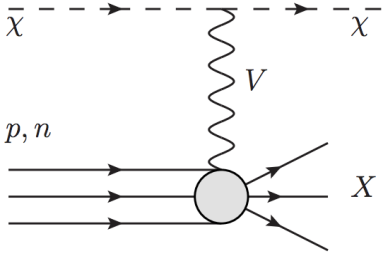

Updated expectations in 150 fb$^{-1}$ with 50/50 upward/downward crossing angle

| Flavour | Neutrinos in acceptance ⟨E⟩ [GeV] | Yield | CC neutrino interactions ⟨E⟩ [GeV] | Yield | NC neutrino interactions ⟨E⟩ [GeV] | Yield |
|---|---|---|---|---|---|---|
| $\nu_\mu$ | 130 | $1.9 \times 10^{12}$ | 452 | 606 | 480 | 182 |
| $\bar{\nu}_\mu$ | 133 | $1.7 \times 10^{12}$ | 485 | 248 | 480 | 93 |
| $\nu_e$ | 339 | $2.2 \times 10^{11}$ | 760 | 182 | 720 | 54 |
| $\bar{\nu}_e$ | 363 | $2.0 \times 10^{11}$ | 680 | 97 | 720 | 35 |
| TOT | | $4.0 \times 10^{12}$ | | 1133 | | 364 |

# Update on physics

Reminder: Detection of $\chi$ elastic/inelastic scattering off nucleons in target



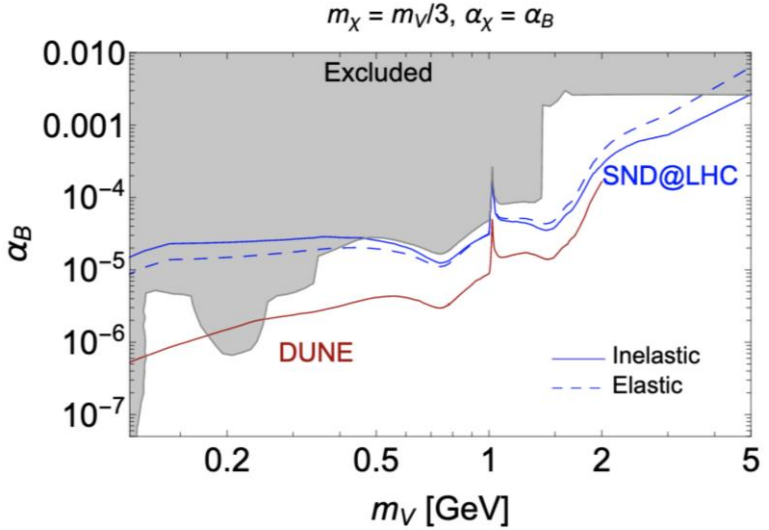




Background yield in DM elastic scattering (same as in TP)

| | $\chi p \to \chi p$ | |
|---|---|---|
| | Selection eff. | Background |
| NC DIS | $2.8\times10^{-3}$ | 1.26 |
| NC RES | $1.7\times10^{-1}$ | 0.48 |

DM inelastic scattering has irreducible background from NC interactions estimated at 400 events
➔ 3σ requiring excess of 60 events

Plot for leptophobic updated with existing constraints (150 fb$^{-1}$)




https://arxiv.org/pdf/2104.09688.pdf

# Update on physics

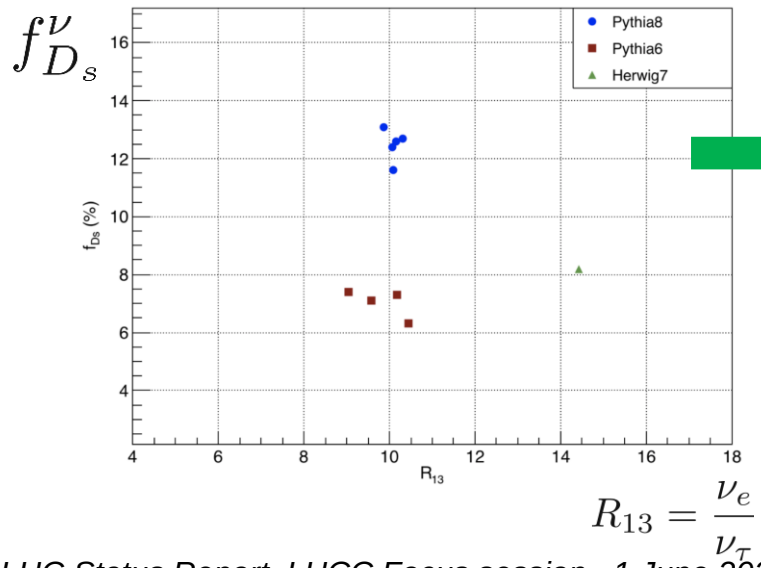
Lepton flavour universality test in $\nu$ interactions

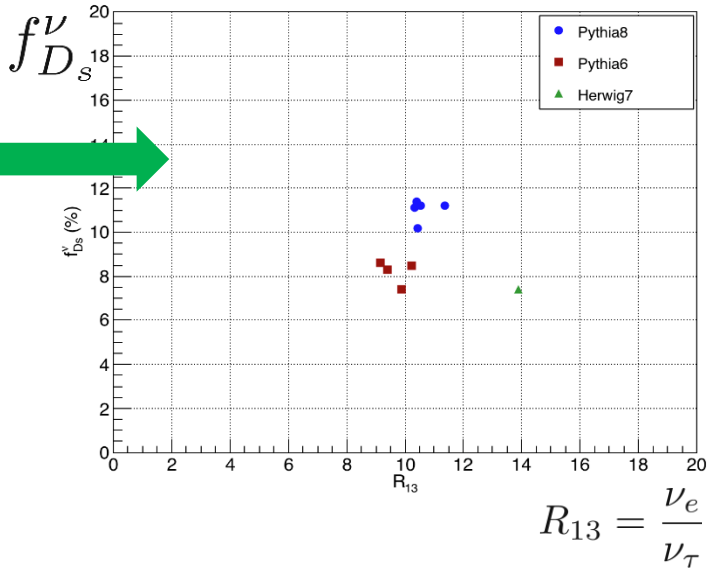
- $\nu_\tau$ produced essentially only in $D_s$ decays
- $\nu_e$ produced in the decay of all charmed hadrons ($D^0$, $D$, $D_s$, $\Lambda_c$)
- The ratio depends only on charm hadronisation fractions
- Sensitive to $\nu$-nucleon cross-section ratio

$$R_{13} = \frac{N_{\nu_e+\bar{\nu}_e}}{N_{\nu_\tau+\bar{\nu}_\tau}} = \frac{\sum_i \tilde{f}_{c_i} \tilde{Br}(c_i \to \nu_e)}{\tilde{f}_{D_s} \tilde{Br}(D_s \to \nu_\tau)},$$

- $f_c$ uncertainty as the discrepancy between Pythia8 and Herwig7 generators: **22%**
- **30%** error due to $\nu_\tau$ statistics

- $f_{D_s}^{\nu}$ defined as the fraction of $D_s$ to all charm producing $\nu$ in acceptance
  - Dependent on Br(c → $\nu$), all $\nu$
- Br($D_s$ → $\nu_\tau$) corrected → discrepancy reduced down to 30%
- Residual difference for similar values of $R_{13}$ due to Br(c → $\nu_e$) and Br(c → $\nu_\mu$)
  - Relative weight lower than for Br($D_s$ → $\nu_\tau$) but affect $D^0$ and $D^+$, i.e. ∽ 85% of charm

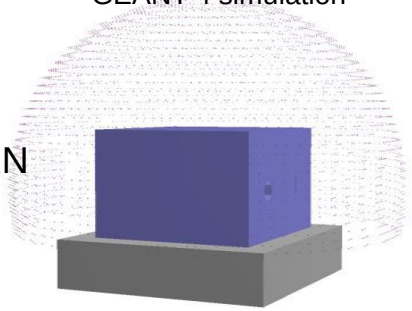


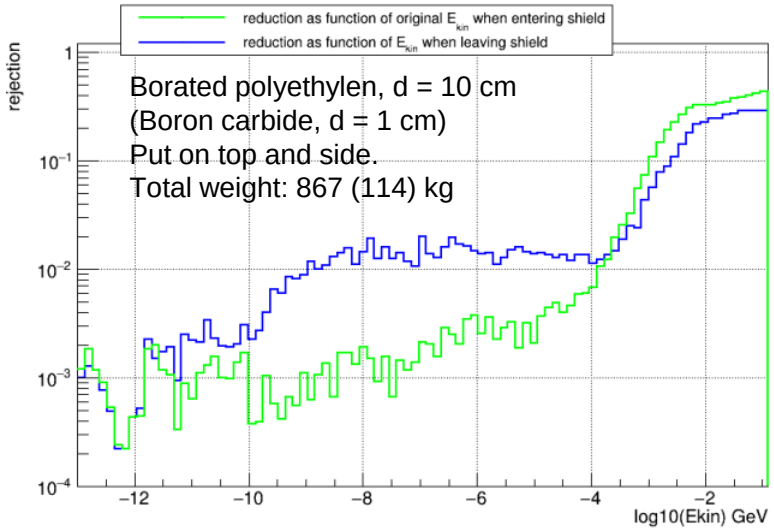



# Update on neutron background

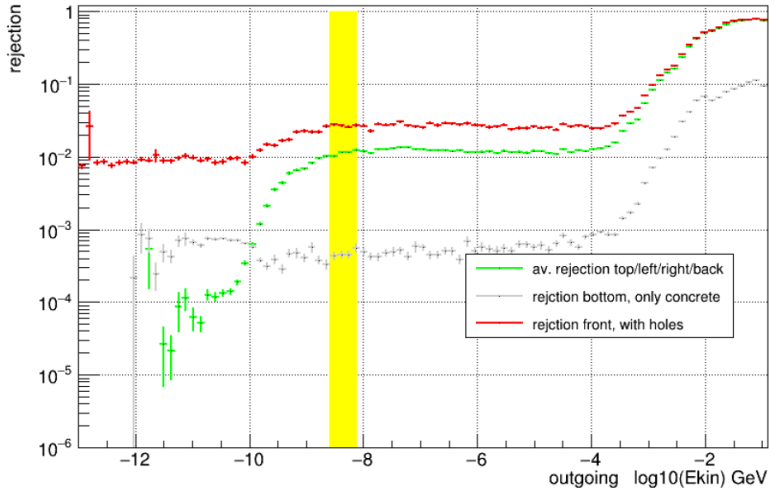
- Simulations:
  - GEANT4 (CERN) using isoptropic flux (half sphere) and Fluka rates as weight
  - FLUKA 1 (Santiago(Chile)): first simulations done to compare different material, mixture of borated polyethylene(30%) and cadmium layers.
  - Chile propose to deliver shielding, cadmium packaged, no manipulations at CERN needed. Air hole and cable duct needs to be implemented.
  - FLUKA 2 (CERN): results expected end of this week.

GEANT 4 simulation






Shielding as function of actual $E_k$ , 10cm borated polyethylene




➔ Neutrons with original low energies($E_k$<10$eV$) are efficiently absorbed.

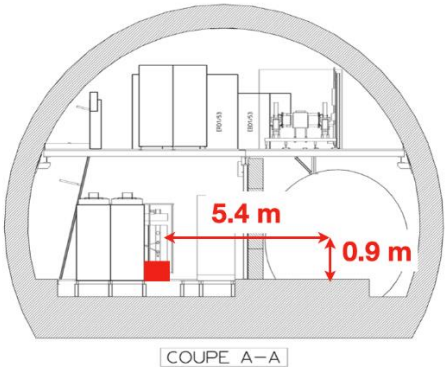
➔ Neutrons of higher energy loose energy in the shielding and populate lower energies, rejection of neutrons at critical energy less efficient as expected

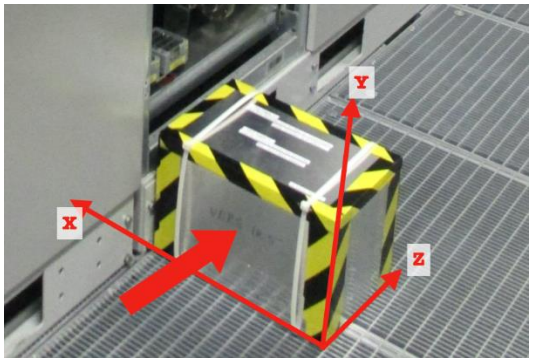
# Update on neutron background

- Based on experience with test run in RR53 during 5 $fb^{-1}$ of integrated luminosity (2018):
  - Borated(5%) polyethylene container, 90mm thick, open at the bottom
  - TI18: spectrum similar but factor 200 less neutron flux

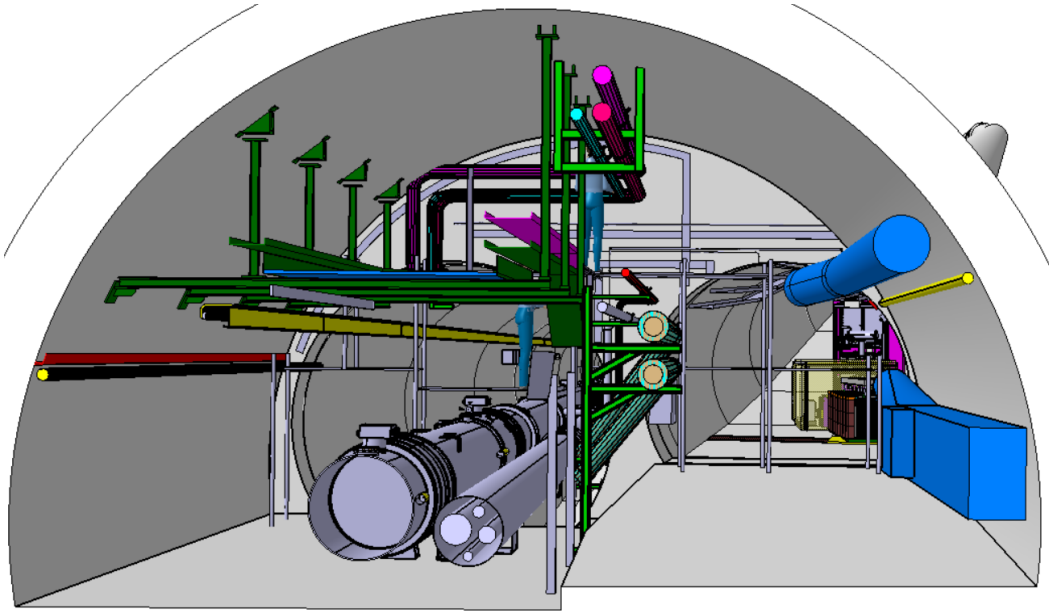
    ➔ Not expecting problems in TI18 as even with 25 $fb^{-1}$ gives safety factor of 40
  - Conclusion: similar shielding as in RR53 and special attention to hermeticity and cold box feedthroughs

Position of ECC in RR53



# Preparatory works for experimental area



CERN
CH-1211 Geneva 23
Switzerland

| EDMS NO. | REV. | VALIDITY |
|---|---|---|
| 2424088 | 0.61 | DRAFT |

REFERENCE: LHC-X1FP-EC-0006

LHC

Date: 2021-04-26

ENGINEERING CHANGE REQUEST

**Preparatory works in UJ18/TI18 and installation of SND detector**

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

SND (LHC Scattering and Neutrino Detector) is a recently approved small stand-alone experiment capable of making measurements with neutrinos in a domain inaccessible to other experiments and searching for feebly interacting particles. The detector is designed to take data in Run 3, and is to be located at the downstream end of TI18. This document reports on the works necessary to prepare the experimental area and to secure the transport of components under and over the LHC for installation in 2021. Special attention has been paid to ensure that all works and installation can be carried out with the LHC in cold conditions with no impact on the machine schedule in 2021/2022.

| DOCUMENT PREPARED BY: | DOCUMENT TO BE CHECKED BY: | DOCUMENT TO BE APPROVED BY: |
|---|---|---|
| P. Santos Diaz, BE-EA<br>R. Jacobsson, EP-LBD | M. Andreini, O. Beltramello, L. Di Giulio, O. Crespo Lopez, A. Infantino, R. Garcia Alia, C. Vendeuvre, J-F. Fuchs, J-L. Grenard, J. Rodriguez, J. Blanc, G. Girardot, Y. Maurer, M. Souayah, M. Collignon, A. Pascal, M. Raymond, O. Pirotte, D. Letant-Delrieux, P. Boisseaux-Bourgeois, M. Bernardini, M. Barberan, M. Brugger, A-L. Perrot, G. Canale, D. Calcoen, R. Denz, R. Fernandez Ortega, J-P. Corso, V. Algoet, K. Brodzinski, E. Duret Bourgoz | M. Lamont<br>(on behalf of LMC)<br><br>(on behalf of TREX)<br><br>J. M. Jimenez<br>(on behalf of LS2C) |

DOCUMENT SENT FOR INFORMATION TO:

LS2 Committee, ATS groups leaders

SUMMARY OF THE ACTIONS TO BE UNDERTAKEN:

In order to install the SND in 2021 the following main work is needed in UJ18/TI18:

- Preparation of electrical power (installation of connection box and power cabling) and optical fibres (installation of tubes for blowing fibres).
- Preparation of experimental area in TI18 (removal of old ventilation duct, installation of lights, power sockets, compressed air line, AUG, optical fibres).
- Installation of transport infrastructure to lift the removed section of the unused ventilation duct, SND cooling unit, and electronics racks over the QRL cryo and LHC beam lines.

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

This document is uncontrolled when printed. Check the EDMS to verify that this is the correct version before use.

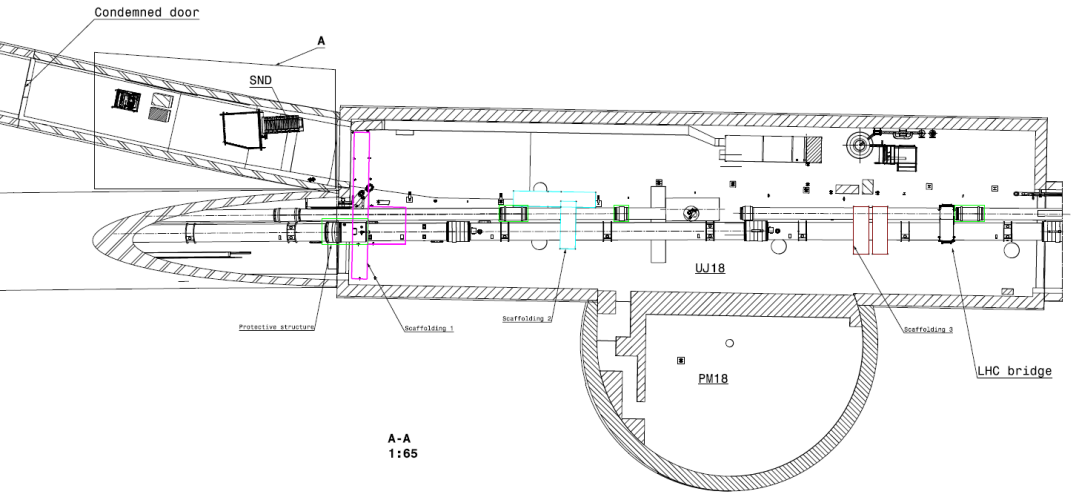
- SND@LHC project presented to LMC April 28
  - ECR passed formal circulation with LMC, formally approved in LMC May 12
  - Budget code and budget assigned for works

    ➔Overshoot from 142 to 156 kCHF covered (difference primarily from cost update by CV)

- Installation activity coordination meetings organised since April 8

# Locations with scaffolding and He risk

Issue identified during safety inspection on April 23:



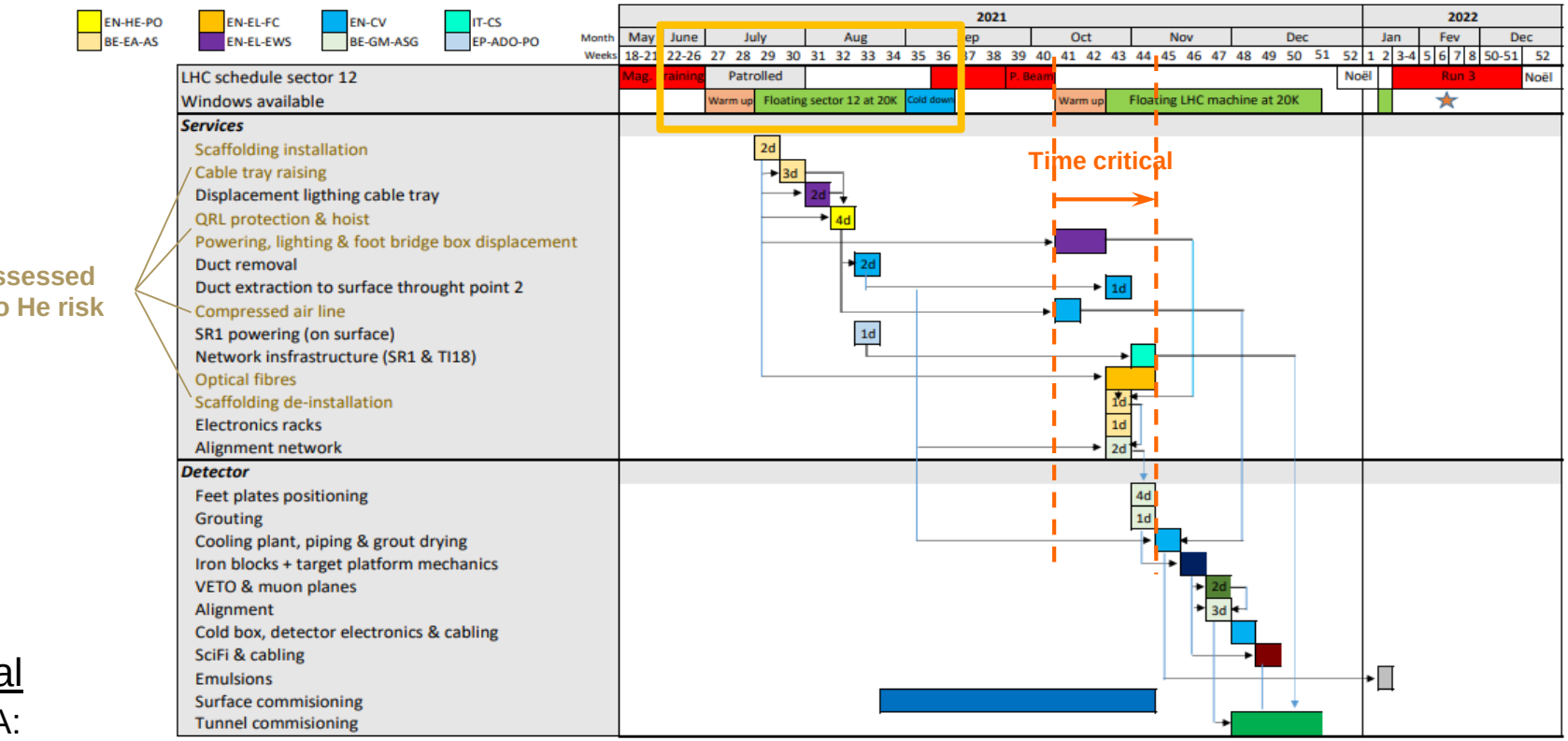

Scaffolding for AUG, compressed air

Displacement of electrical box above foot bridge

Modification to cable tray and installation of hoist and QRL protection

# Proposed workplan (LMC April 28)

- Initial plan: works in July-August with LHC at 2K
  - ➔ Re-assessment of helium risk strongly prefers floating machine at 20K
  - ➔ Moving works to after pilot beam would leave installation short of time, ~4 weeks depending on availability of equipment & service groups

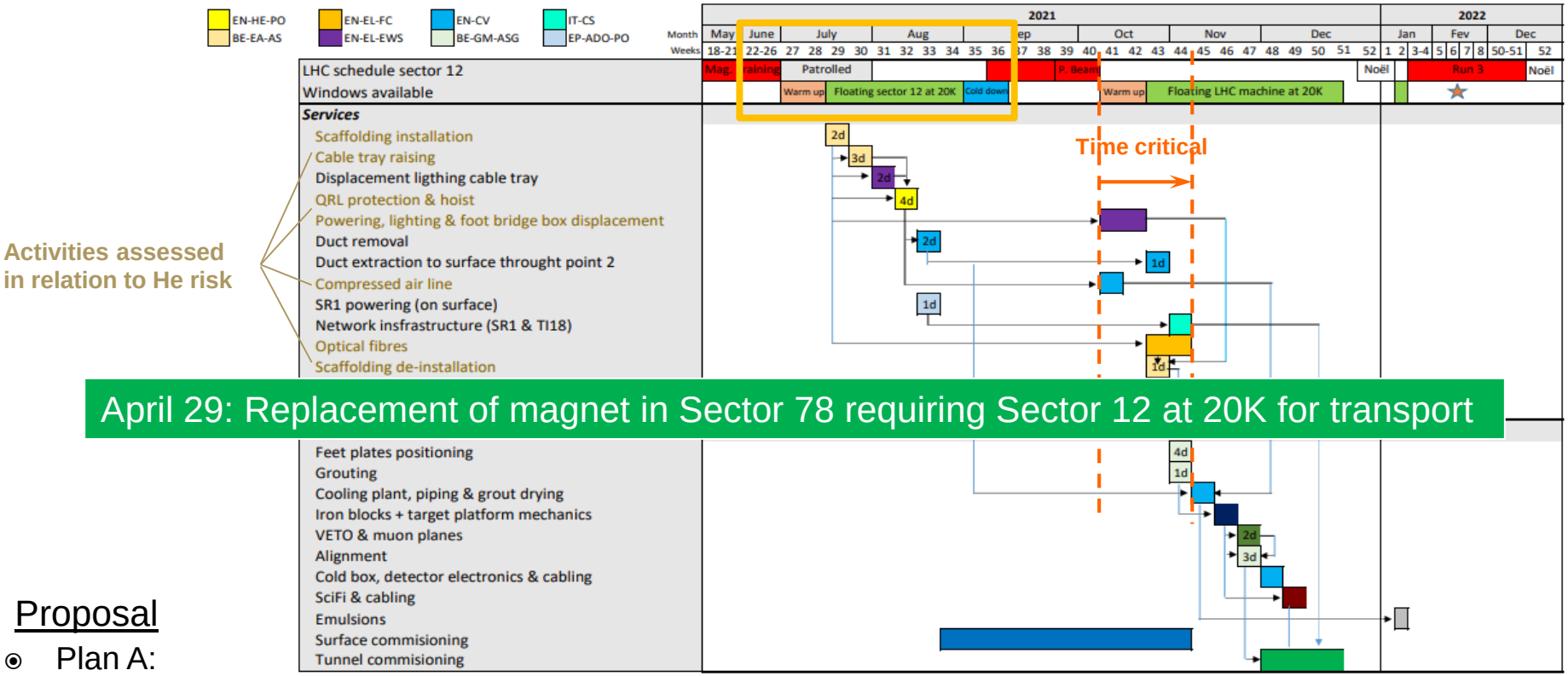



## Proposal

- Plan A:
  - Machine at 20K in July-August, minimize duration (current schedule was to avoid long continuous access)
  - Install light protection on critical parts
- Plan B:
  - Keep flexibility to move to after pilot beam if June 7 schedule review adds a ~month to YETS
  - Delay of pilot beam would shift planning by the same amount

# Proposed workplan (LMC April 28)

- Initial plan: works in July-August with LHC at 2K
  - ➔ Re-assessment of helium risk strongly prefers floating machine at 20K
  - ➔ Moving works to after pilot beam would leave installation short of time, ~4 weeks depending on availability of equipment & service groups

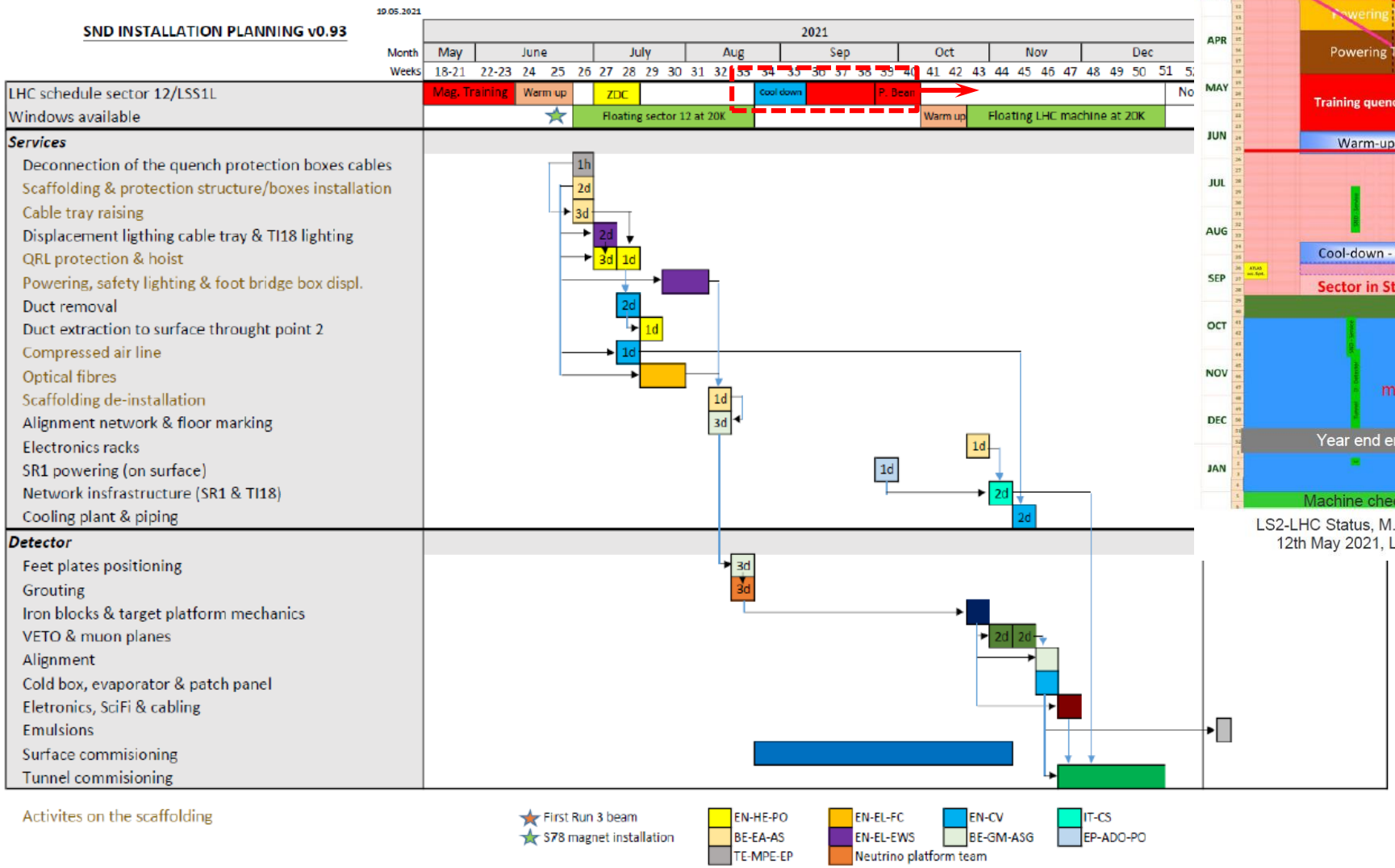



## Proposal

- Plan A:
  - Machine at 20K in July-August, minimize duration (current schedule was to avoid long continuous access)
  - Install light protection on critical parts
- Plan B:
  - Keep flexibility to move to after pilot beam if June 7 schedule review adds a ~month to YETS
  - Delay of pilot beam would shift planning by the same amount

# Intermediate update of workplan (May 20)

- Adjusting workplan to new schedule with magnet replacement
  - ➔ Shift start of works to earlier time and push as much as possible
  - New workplan agreed with machine coordination and all service/equipment groups





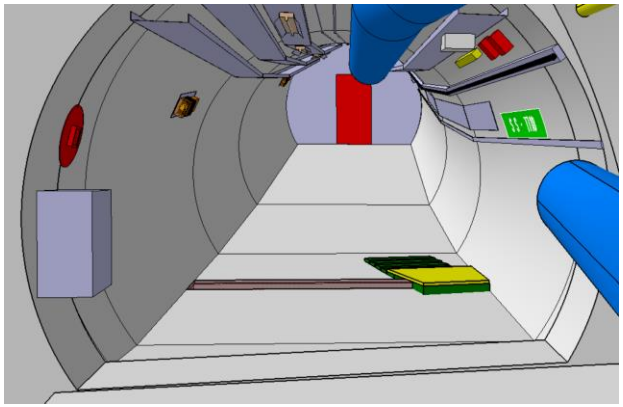


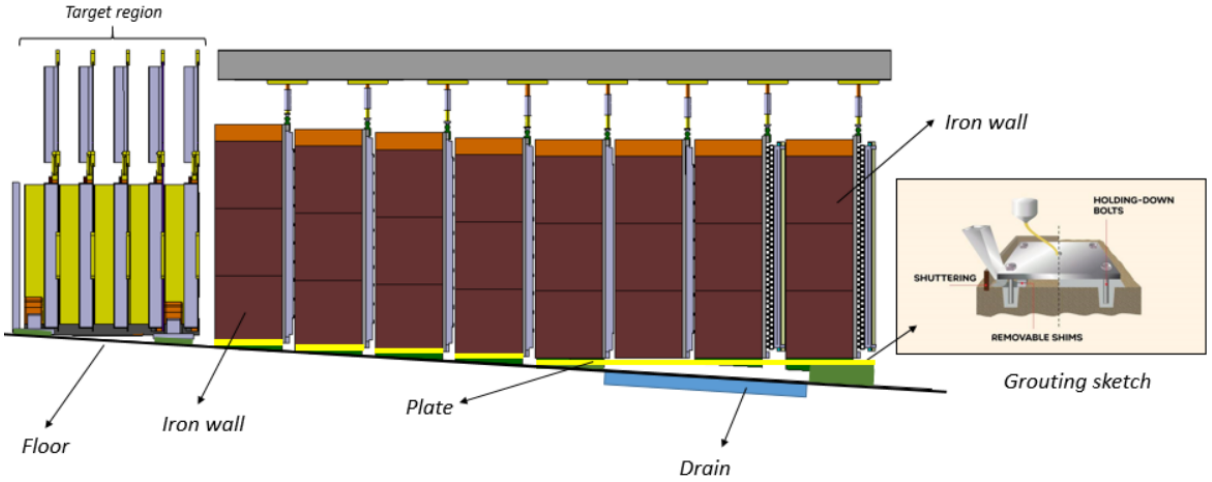
LS2-LHC Status, M. Bernardini, 12th May 2021, LMC #416

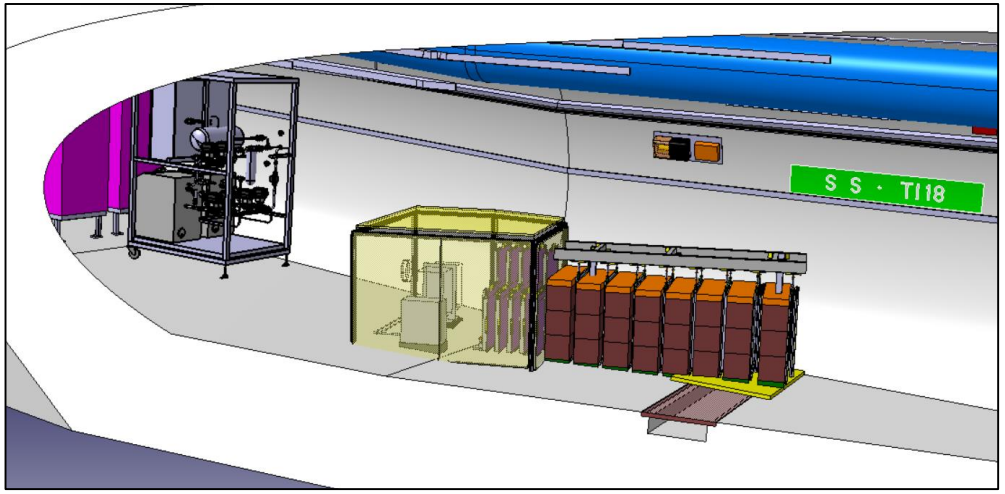
# Critical step for detector installation

Grouting under detector iron blocks, tentatively w.33

- Similar to what was done in FASER
- Support from the same team (Neutrino Platform)



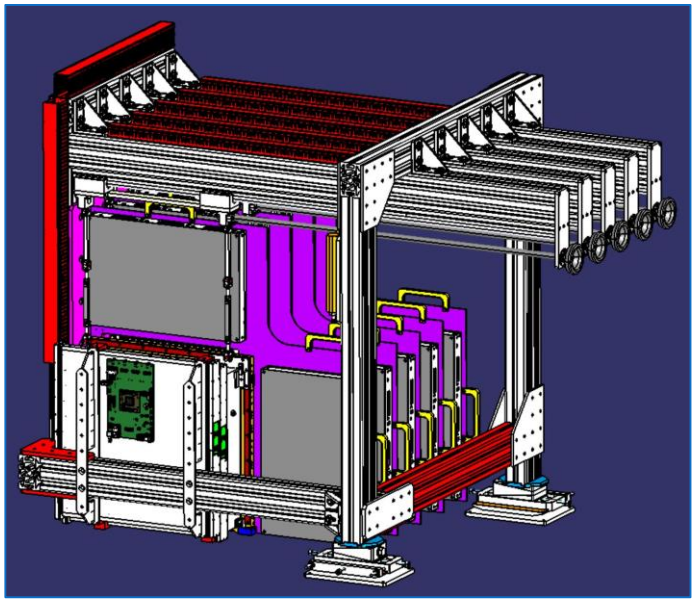


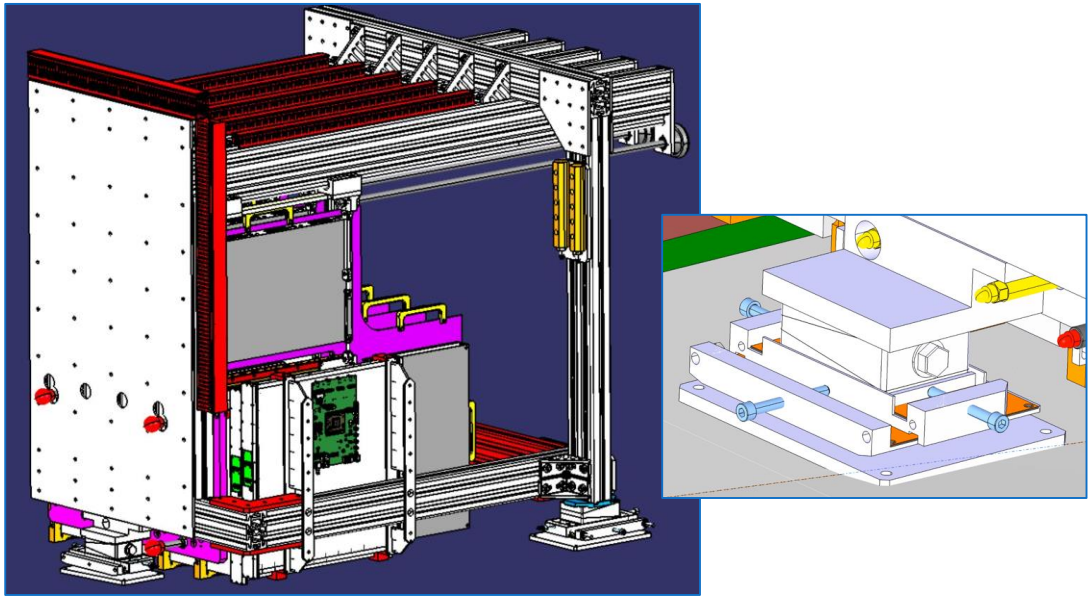



# Status of detector construction – Target system

## Target system

- Counter weight system abandoned
- Mechanical design closed to finalised
- Optimisation of the structure for easier/faster/reliable wall exchange
- FEM simulations to validate maximum deformations
- Integration of Veto and SciFi planes electronics, cables, pipes
- Design of three adjustable feets to match with the slope of TI18
- Definition of alignment pins position with survey team
- Structure and feets production perfomed @INFN Napoli in June-July



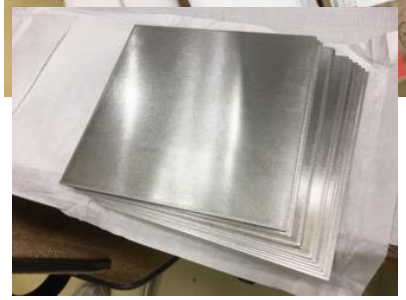


# Status of detector construction – Target system

## Target system, cont'd

- Two Chinese companies selected as tungsten plate providers
- 120 sheets ordered from both companies, arrived at CERN in Feb 2021
- Mechanical properties measured by CERN Metrology Service
  - ➔Both firms are capable to match the specs in term of tolerances. Nominal value of thickness and parallelism needs adjustment
- Both claim they can adjust them for a larger quantity as demanded for mass production.
- Sifon provided directly pure W.
- Bango first delivery was W-alloy. They are sending pure W samples
- Tender will select final provider

**Bango Alloy Technologies Limited**
Add: 704 Room, No.150, Tianhu Building, Binglangxili, Siming District, Xiamen, 361000, CHINA
TEL: 0086 592 2031860 WEBSITE: http://www.bangoalloy.com
CONTACT PERSON: RAY EMAIL: ray@metalsexporter.com



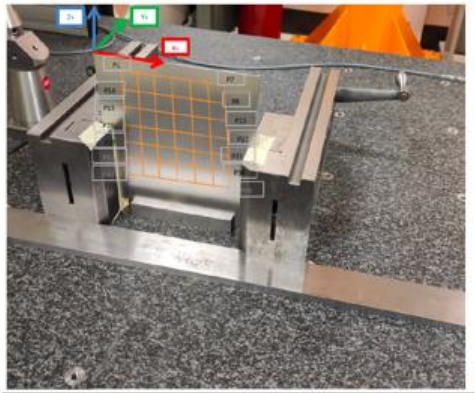
**LUOYANG SIFON ELECTRONIC CO.,LTD**
Heluo road and Jin Xin Road intersection, Luoyang , China
TEL: +86-379-60671005 FAX:+86-379-60671005 E-Mail: suzy.sifon@gmail.com

CERN-METROLOGY SND W Plate 190x190 EDMS N°: 2496298 J 069030

| | | | |
|---|---|---|---|
| Controller: | BURKOWSKI Maciej | Drawing number | N/A |
| Customer | BUONTEMPO Salvatore | Supplier | Sifon |
| Machine | LEITZ PMMC 12 10 7 #336 | Part N° | 13 |
| Temperature | 20°C ±0.1°C | Date: | 09-MAR-2021, 11:12:09 |
| Measuring uncertainty | ±(0.3µm + L/1000) | Program name | SND_w_Parts_Plate190x190 |

| | | |
|---|---|---|
| CONCLUSION | VISA MME | CUSTOMER ACCEPTANCE |
| OK | NAME: | NAME: |
| NOT CONFORM | DATE: | DATE: |

| Text | Eval. | Measured | Nominal | Upp.Tol. | Low.Tol. | Dev. | Graphic |
|---|---|---|---|---|---|---|---|



Measurement positions map

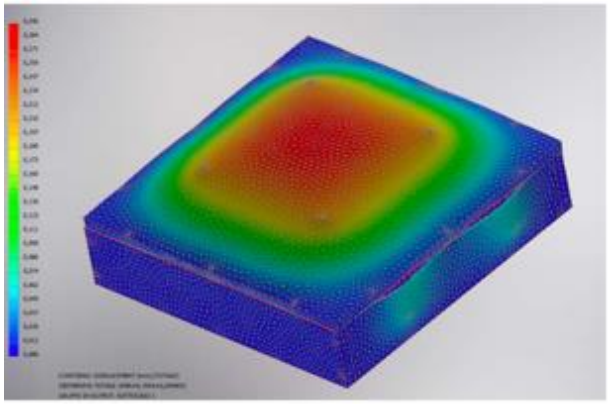
| Text | Eval. | Measured | Nominal | Upp.Tol. | Low.Tol. | Dev. | Graphic |
|---|---|---|---|---|---|---|---|
| Date: 09-Mar-21, 11:12:11 | | | SND_w_Parts_Plate190x190 | | | | Page 1 of 6 |

# Status of detector construction – target system

Target system, cont'd

- Design of brick packaging, wall structure and assembly tools being finalised
- Finite element analysis to validate stresses and deformations of wall box
- Optimisation of transportation trolley design to match with the mechanical structure for easier/faster wall exchange

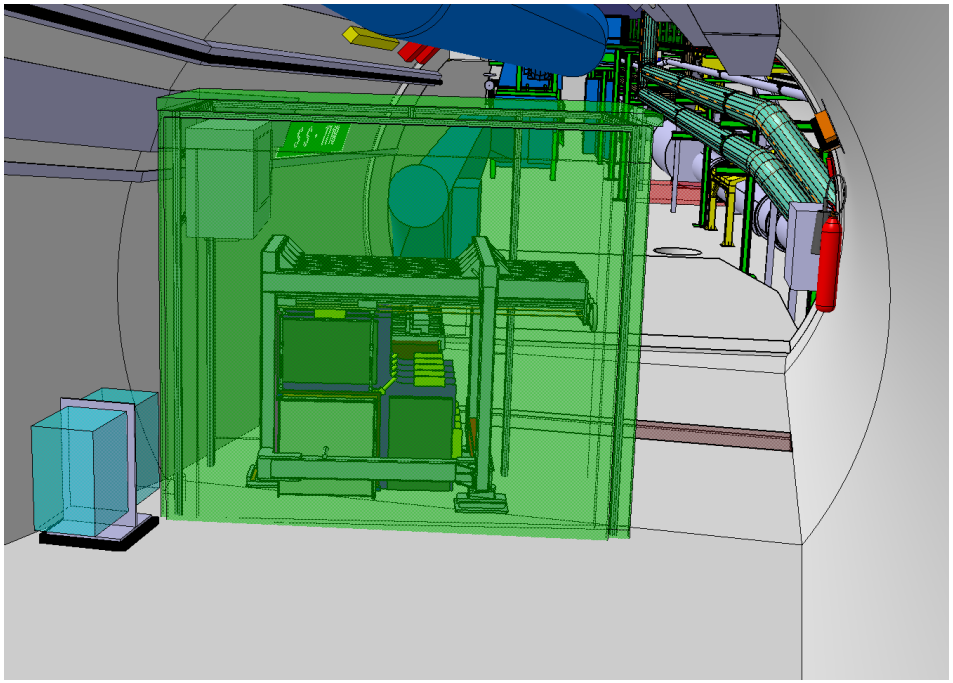
- First wall and trolley prototypes under construction
- Test at CERN with tungsten and emulsion films in July
- Five walls ready by September for surface commissioning

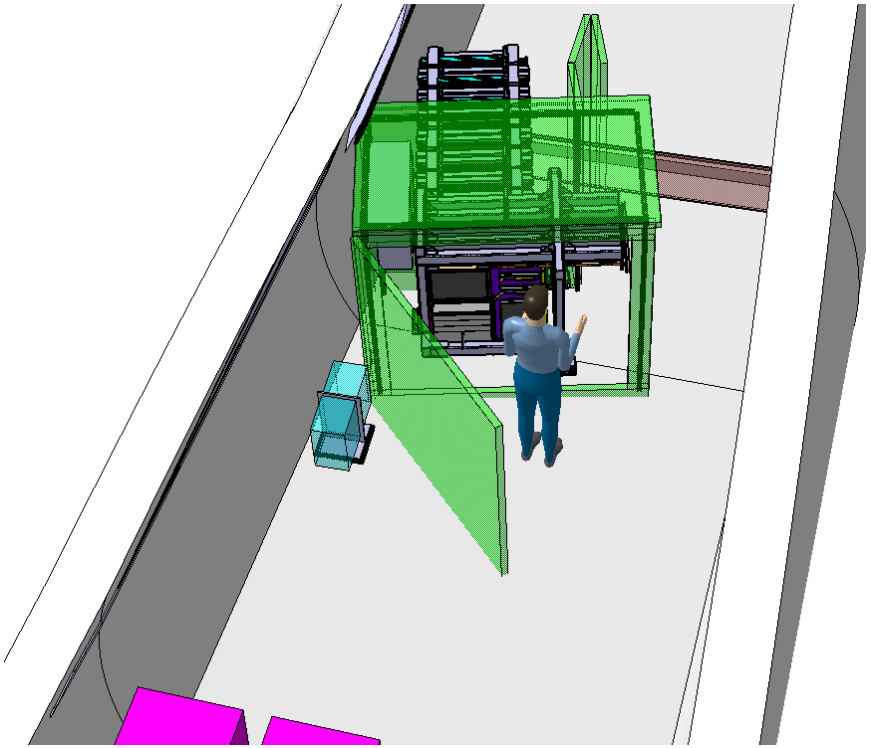


# Status of detector construction – cold box

"Cold box"

- Integration ongoing
- Iterations on neutron shielding, cabling, opening system, accessibility to target walls, target wall trolley design



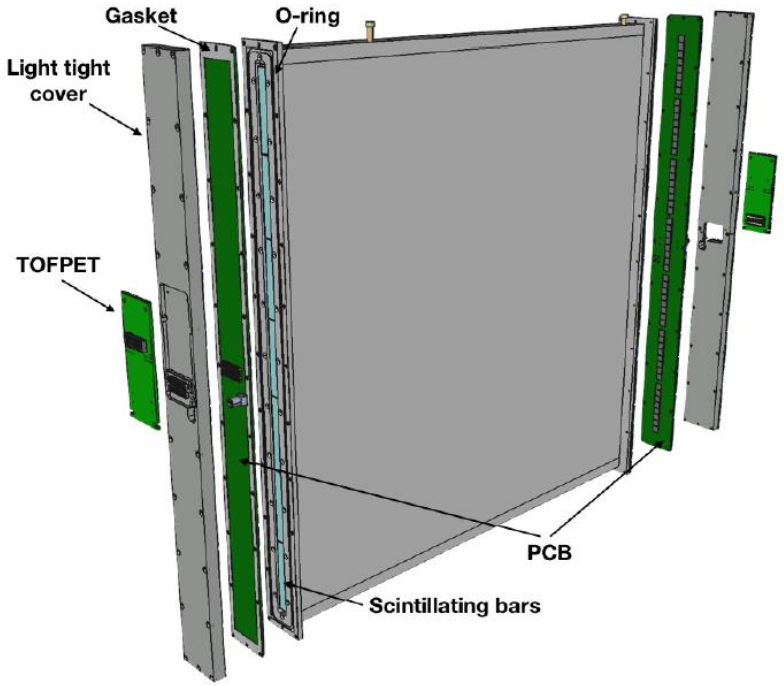


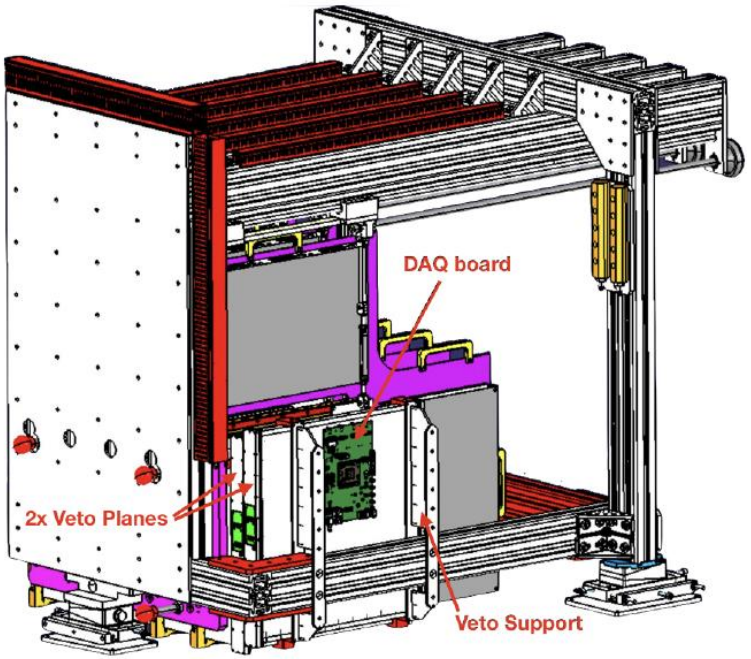
# Status of detector construction - Veto

## Veto system

- 2 planes of staggered scintillating bars r/o by SiPMs
- 7 bars/plane (42 x 6 x 1 cm3), 8 SiPMs per bar end
- Attached to support structure of target system mechanics

- Design finalized
- Frame ready by end of June
- PCBs ready mid July



# Status of detector construction – HCAL/Muon

## HCAL/Muon system

- Stations of scintillating bar (60 x 1 x 1 $cm^3$) detectors between iron filters
- HCAL: First 5 layers, each consisting of 10 stacked bars r/o on each end by 8 SiPMs
- Muon ID: Last 3 layer, each consisting of thin bars in horizontal and vertical direction
  Horizontal bars r/o on each side by single SiPM, vertical bars only from top
  4th vertical layer added to the end to recover efficiency loss from the other vertical layers

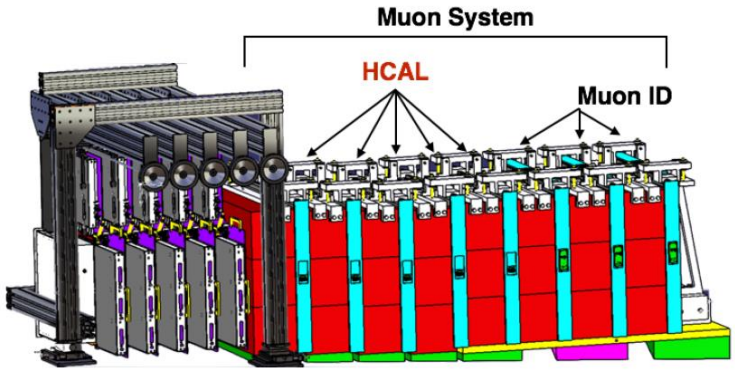
- Design finalized
- Upstream frame production started, ready by end June
- Downstream frame parts ordered, ready by mid August
- PCBs ready by mid July
- Downstream bars ordered, ready by mid July

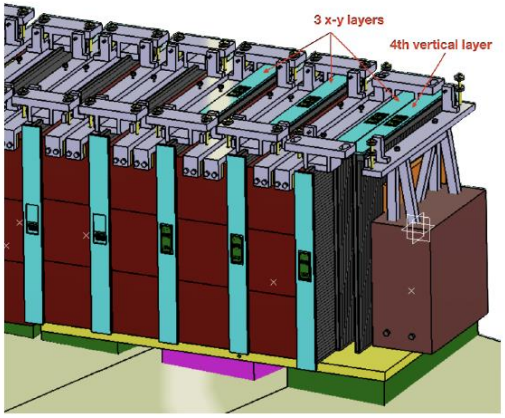
Efficiency measurements with cosmics show ineffiency in 15 cm of the bar furthest from SiPM readout

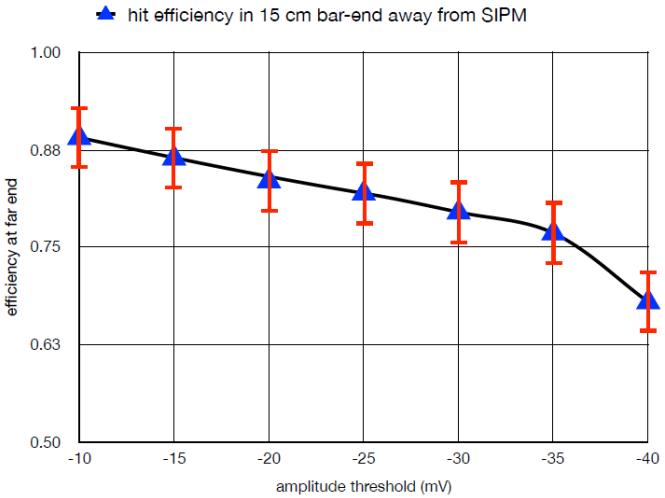
➔ Efficiency 60% for triplet algorithm for the bottom part of the V planes (higher η region)

➔ 4th V plane: Efficiency 90% with 3 out of 4

➔ Enough spare material to build 4th layer



# Status of detector construction – HCAL/Muon

## HCAL/Muon system

- Issue with iron filter blocks...
- Seems that 7x 842-type and 3x 822-type blocks are available at CERN
- We are searching for more but may need to buy the rest (5+2 kCHF)



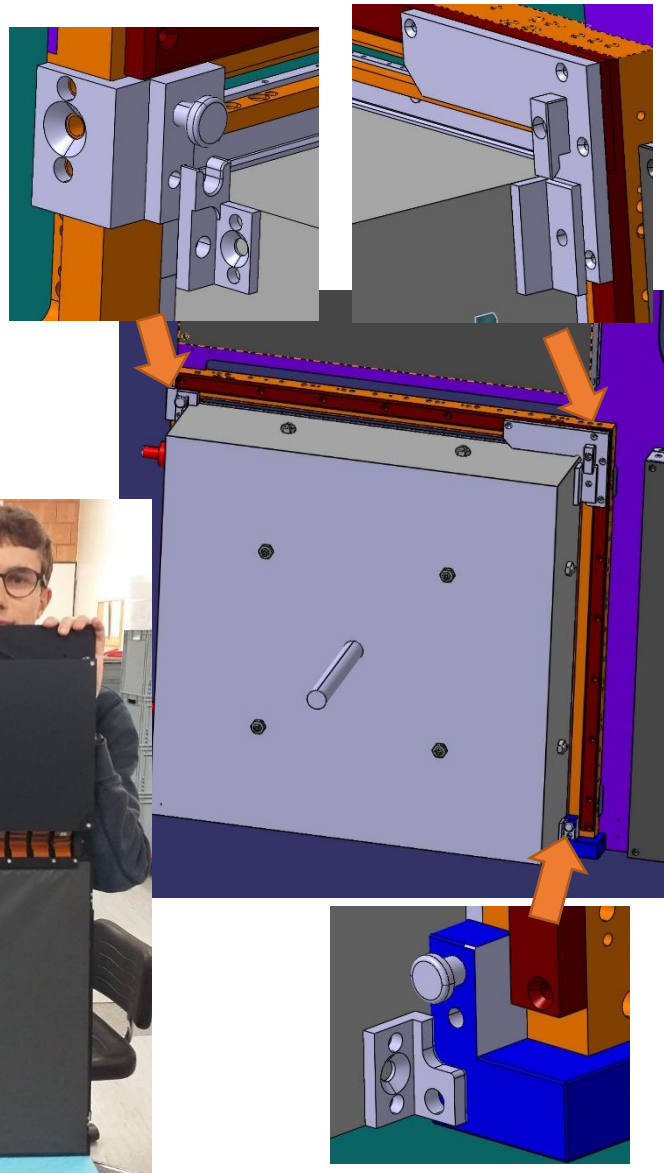
## Veto/HCAL/Muon system

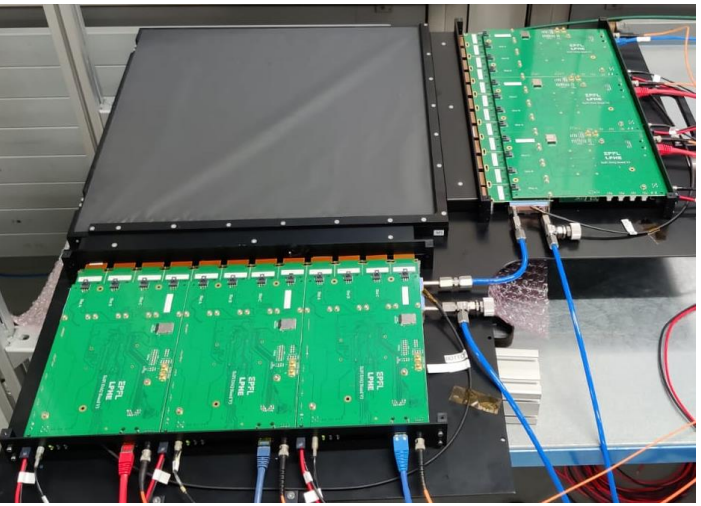
- Sucient person power for assembly and surface commissioning at CERN through September
- Detailed workplan with available people ready
- Assembly space in bld 27 - Thanks to CMS

# Status of detector construction – Target Tracker

## SciFi Target Tracker/ECAL

- Fixation to target system walls with guide pins finalised
- 1st SciFi module is assembled and initial electrical tests done
- All 5 modules assembled within 2 weeks
- Cooling tested (works perfectly)
- Frame for all 5 modules for cosmic testing ready in two weeks

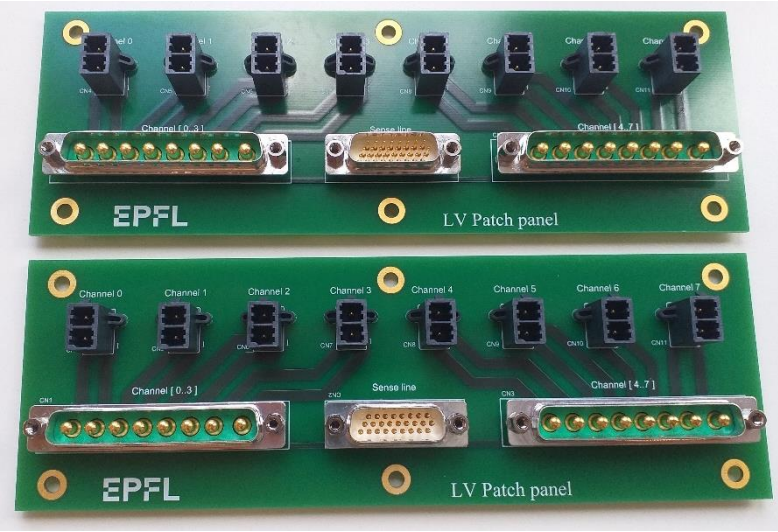


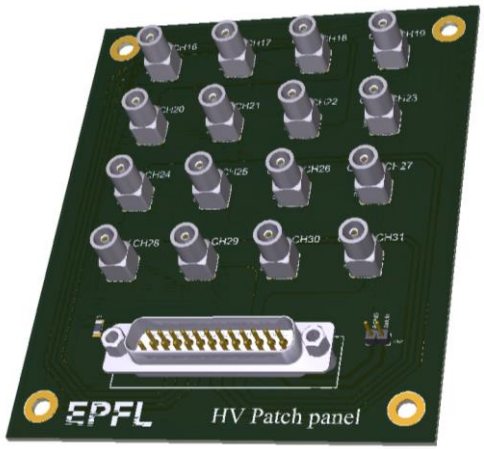


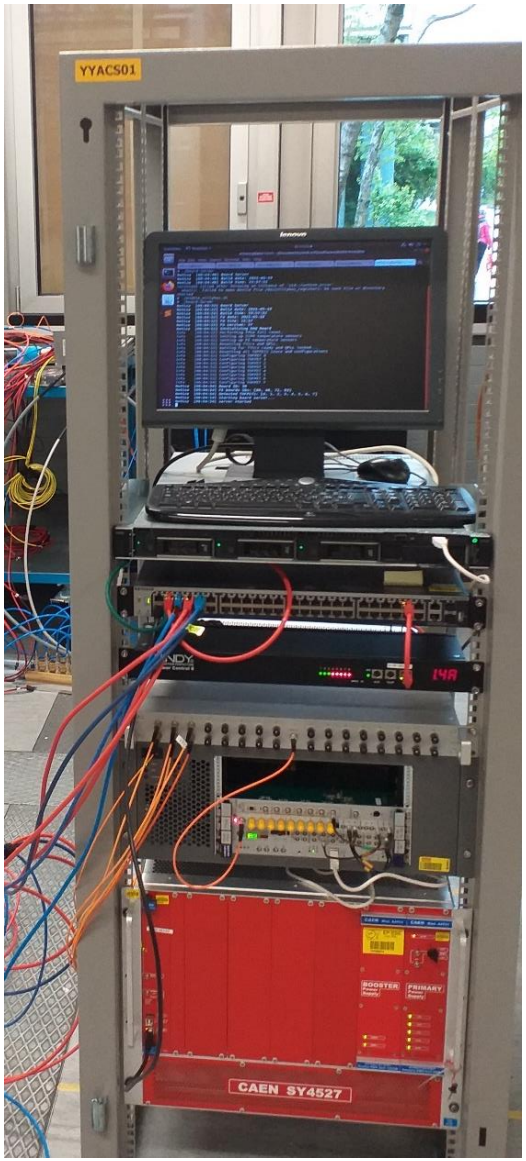
# Status of detector construction – Target Tracker

## SciFi Target Tracker/ECAL + DAQ

- Rack installation advanced state, all components for the operation are now installed, LV,HV,VME for TTC, Eth switch, server and screen
- LV patch panel assembled HV still to go (1 week)
- Cables ordered, still 5 weeks to complete
- Patch panel mechanics (2 weeks to complete)



# Status of detector construction - Online

## Online system

### Electronics

- 30/60 DAQ boards received (37 used in SND)
  → All tested, 1 bad but fixable
- 190 FE boards received (141 used in SND)
  → All tested, 6 bad, probably not fixable
  → Full test (all channels response) to come
- BST mezzanine board requires second iteration
  → Error in the pinout of the connector

### Software

- Additional person power from Sofia and Bologna on DCS and GUIs
- DAQ tutorial for “users” prepared
  - Installation of DAQ software
  - Operation of TOFPET ASIC
- Next steps in development
  - Multiple boards client
  - Triggerless event building
  - Basic data processing

- Online workshop in preparation to define developments of processing, monitoring and ancillary tools for operation

# Status of detector construction - Computing

## Computing

Computing infrastructure at CERN put in place:

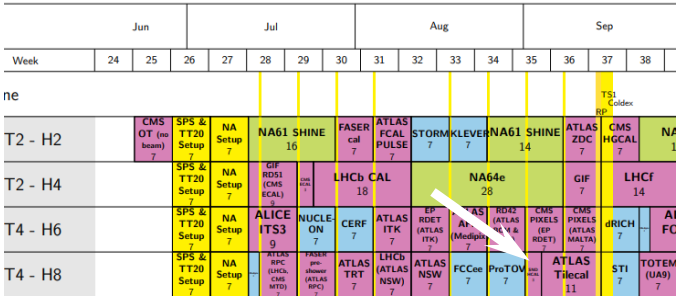
- Computing group
- EOS storage space
- CVMFS (software library repository for slc7, slc8 and ubuntu20.04)
- Virtual machines

Contribution from subdetector groups starting up.

# Surface commissioning

Test beam with muon system for energy calibration in H8 first week of September

- Single energy point (250 GeV) protons to tune MC
- Check dynamic range from single particles
- Single spatial position measurements
- Tight but doable

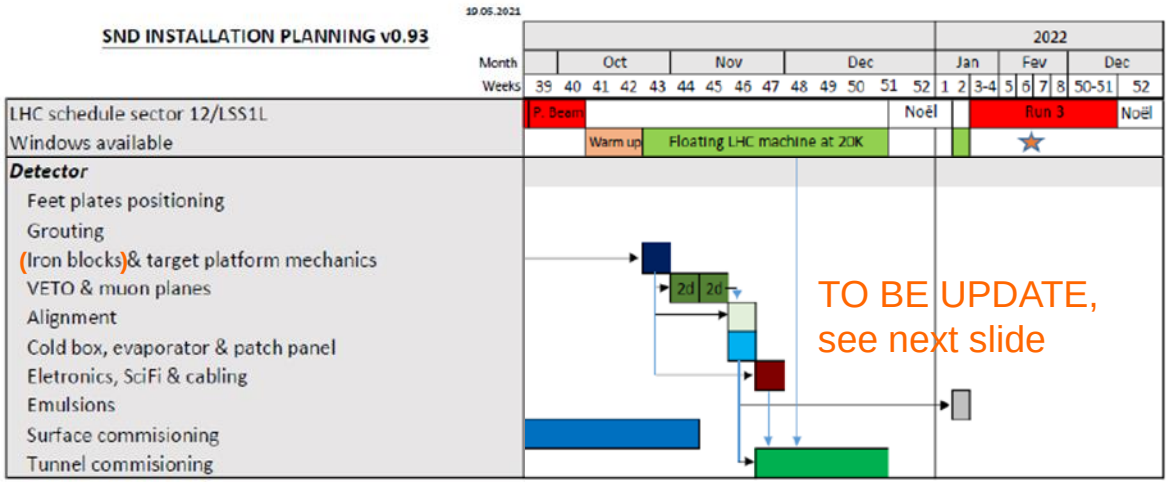



Surface commissioning, now H6C

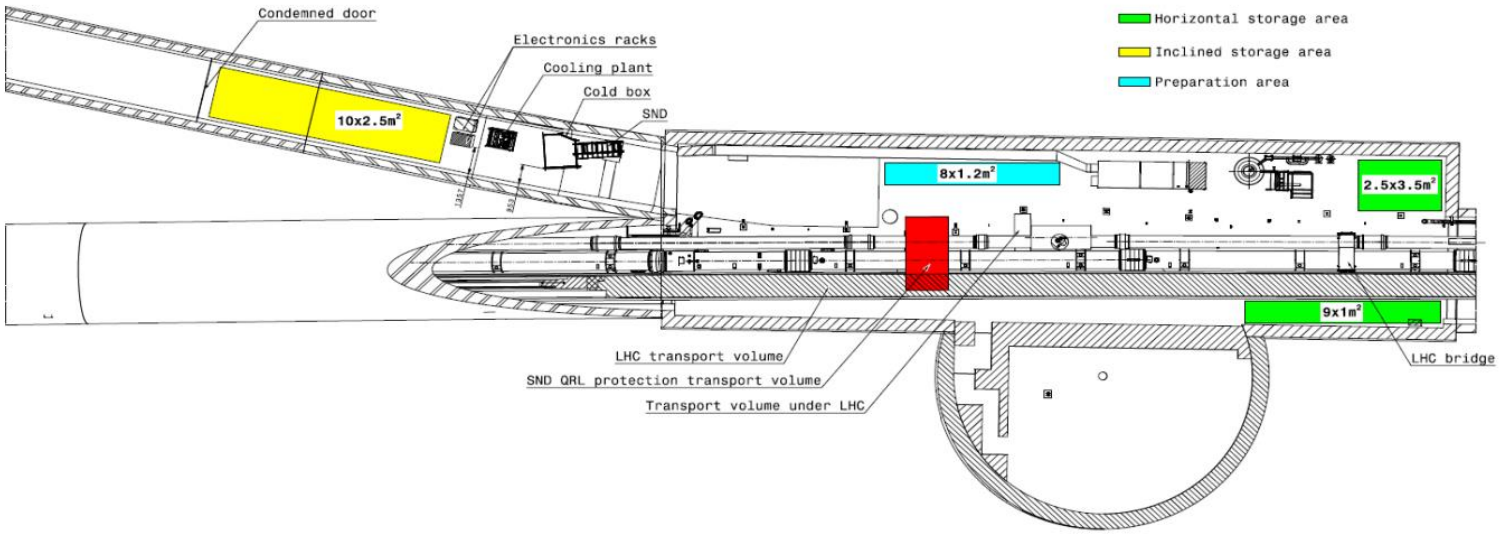
- Very good zone, blocks will be piled to height, and fenced off with access door
- Asking for zone to be setup by end August
- Rehearsal of installation and commissioning
- Major point is if/how to emulate tunnel slope to excercise trolley
  - Alternatively test trolley in TI18 in September

# Detector installation during YETS

- Muon system iron filters and electronics rack installed w. 35-36 if possible



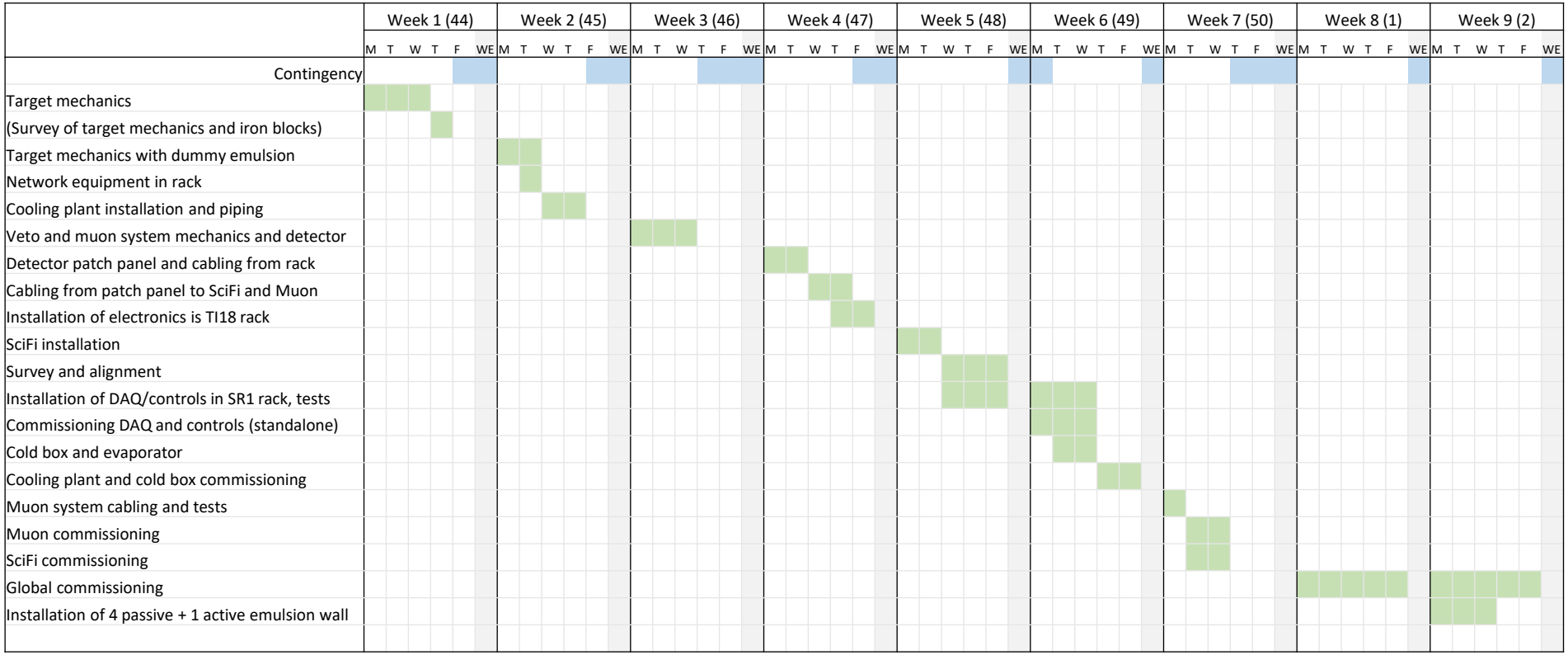

- Bring detector components in batches and make efficient use of floor space around SND to avoid transport bottlenecks



# Detector installation workplan

- Plan below “independent” of starting date, (example) with pilot beam shifted to w. 42 - 43
  - ➔ Machine closure end of January (shifted by three weeks)
  - ➔ Keep w. 3 – 4 as contingency
  - ➔ Keep Christmas closure as additional contingency

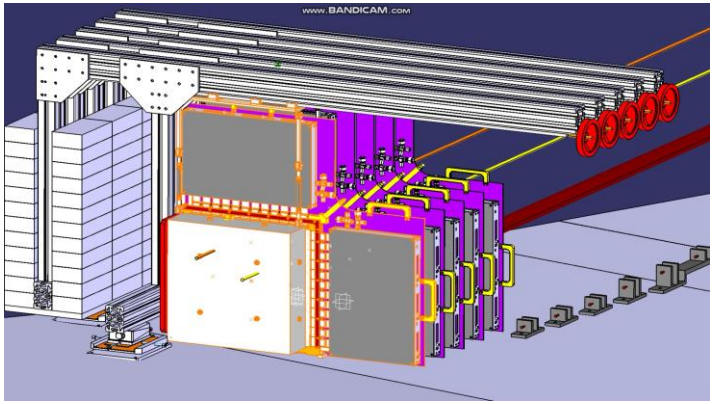
- No parallelism assumed, except for DAQ & controls installation & commissioning stand-alone in underground and surface racks



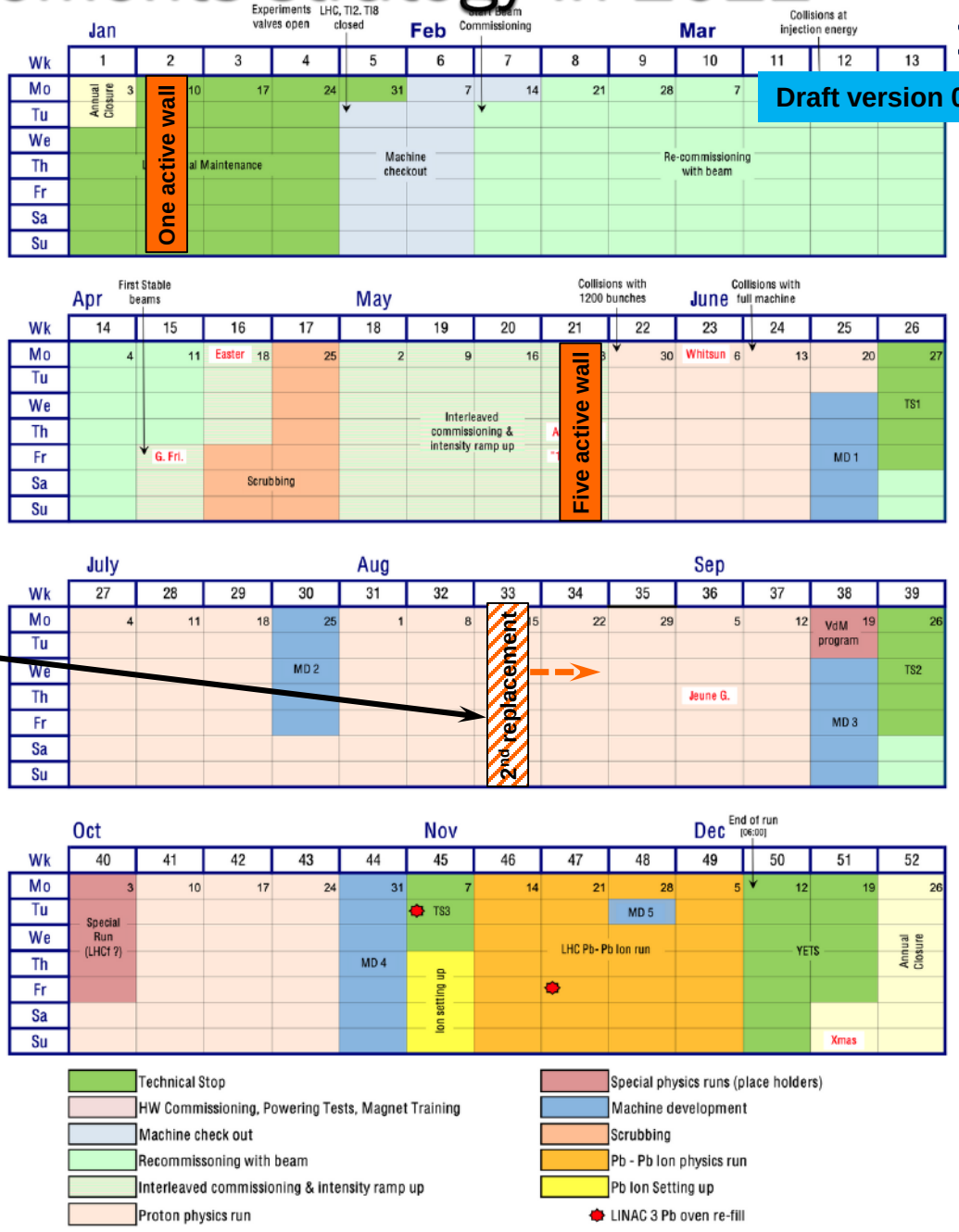

➔ EDMS document (2424085 v1.0) in preparation with detailed work plan for detector installation

# Emulsion replacements strategy in 2022

➔ Access <8h (Probably ~4-5h)




Exact time depends on schedule, collected luminosity and opportunity



# Safety

- Project safety representatives
  - DSO / GLIMOS / LEXGLIMOS: Olga Beltramello (EP-DI)
  - Assistant DSO: Letizia Di Giulio (EP-DI)
  - PESS Correspondent (PESS-CO): Marco Andreini (HSE-OHS)
  - PESS Back-up: Richard Francis Morton (HSE-OHS)
  - PESS Coordinator (CPESS): Owain Edwyn Williams (HSE-OHS)
  - TE-DSO: Delphine Letant-Delrieux (TE-RAS)
  - TE-CSO: Olivier Pirotte (TE-CRG)
  - EROS: Michel Bonnet (EN-ACE)
  - EXSO: R. Jacobsson (EP-LBD)
- Common Inspection Visit for preparatory works: 11 June
  - Works covered by existing Work Safety Authorization
- Launch Safety Agreement for detector in processing
  - Expect Project Safety Requirements back soon
- Project Safety File in preparation
  - Work Safety Authorisation for detector installation being checked

# Dark Room Facility

- Dark room
  - Meeting in-situ with space managers, CV, site manager, safety, and FASERnu
  - Reorgnisation of lab rather clear
  - New space for film drying defined
  - Additional space for storage of material and chemicals available but needs safety check
  - Pending: proposal for renovation of chiller for air conditioning and general intake/outlet

➔ Cleanup foreseen in June (SND@LHC, FASERnu, DsTau, SHiP-charm, OPERA, CHORUS, WA75)

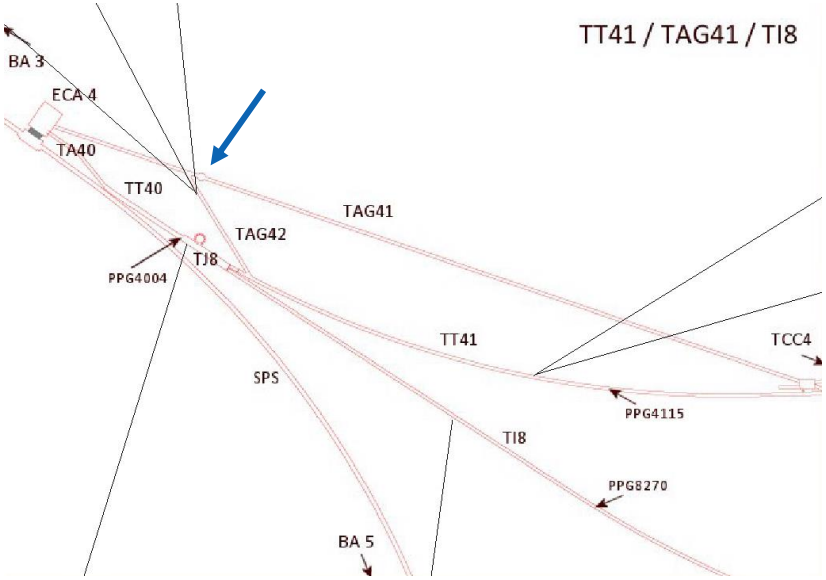
➔ Main issue is need for facility in September – October by DsTau and SND@LHC

➔ Initial non-destructive work as soon as possible

➔ Rest of the works from November

# Underground storage

- Search for underground detector storage ongoing together with FASERν (J. Boyd)
  - Candidate identified in CNGS access tunnel close to SPS P4, checking RP situation
  - Problem is access when AWAKE is running (3 x 3 weeks/year)
  - Different requirements in terms of transport SND@LHC and FASERν may require decoupling the search



# Conclusions

Not yet ready to conclude but impressive progress on all ends!

- Few weeks delay w.r.t initial plan but on track for surface commissioning

Huge thanks to CERN service and equipment groups, LHC coordination, operation, safety!

Thanks for your support!