Ionisation Cooling Demonstrator

“L’INFN e la strategia Europea per la Fisica delle Particelle”

R. Losito, CERN

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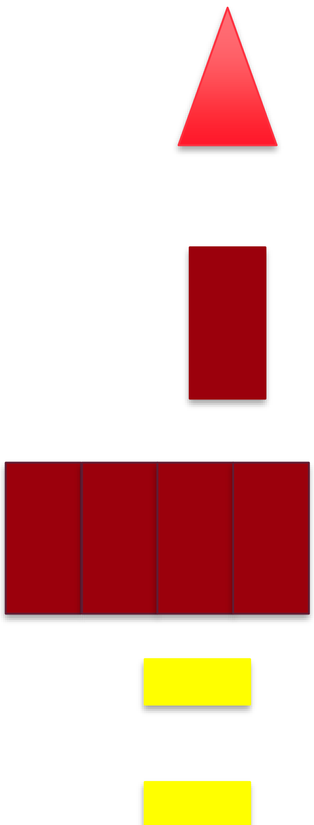
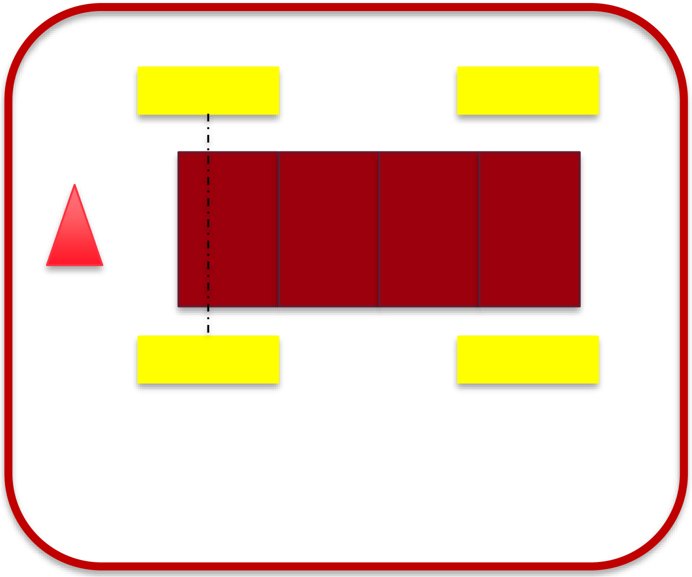
Demonstrator

- The demonstrator is a ~100 m long linear accelerator for muons, that shall
  - Demonstrate that we are able to reduce the transverse emittance of a muon beam by at least a factor 2
  - Serve as platform to:
    - Train future generations of accelerator physicists/engineers
    - Develop and test the technologies necessary to build a MC
      - High Temperature Superconducting magnets (10÷20K)
      - High Efficiency RF power sources
      - Reliable RF cavities in magnetic fields
      - Material for absorbers
      - Target and beam dump strategies
      - Beam Instrumentation for muons and detectors

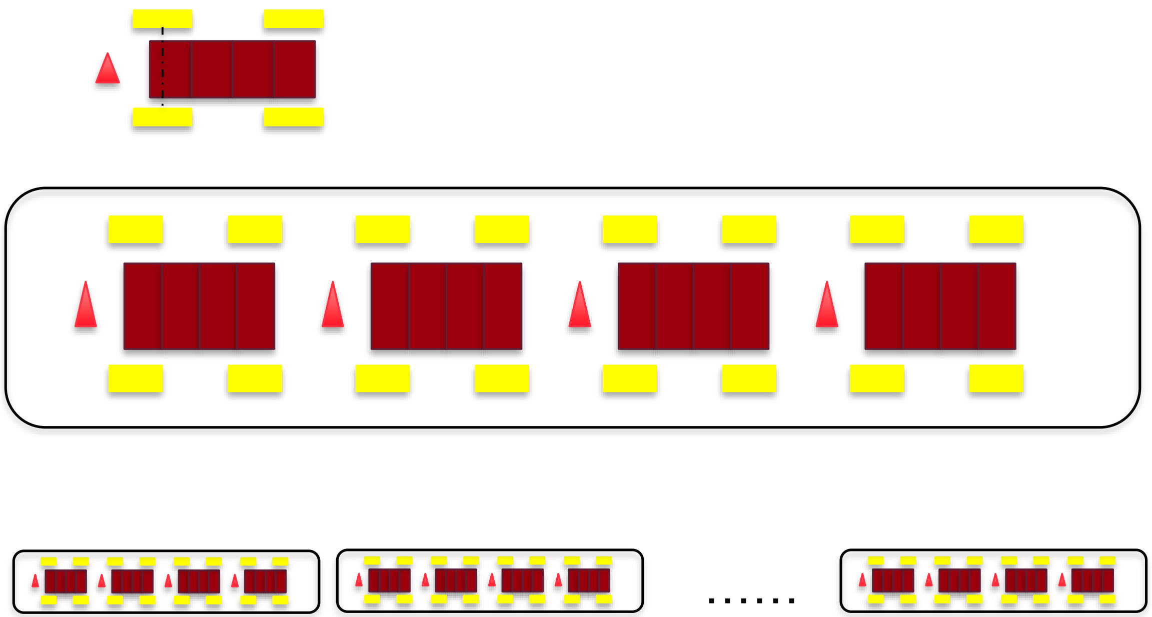
Terminology



- Absorber
- RF Cell
- RF Structure
- Solenoid



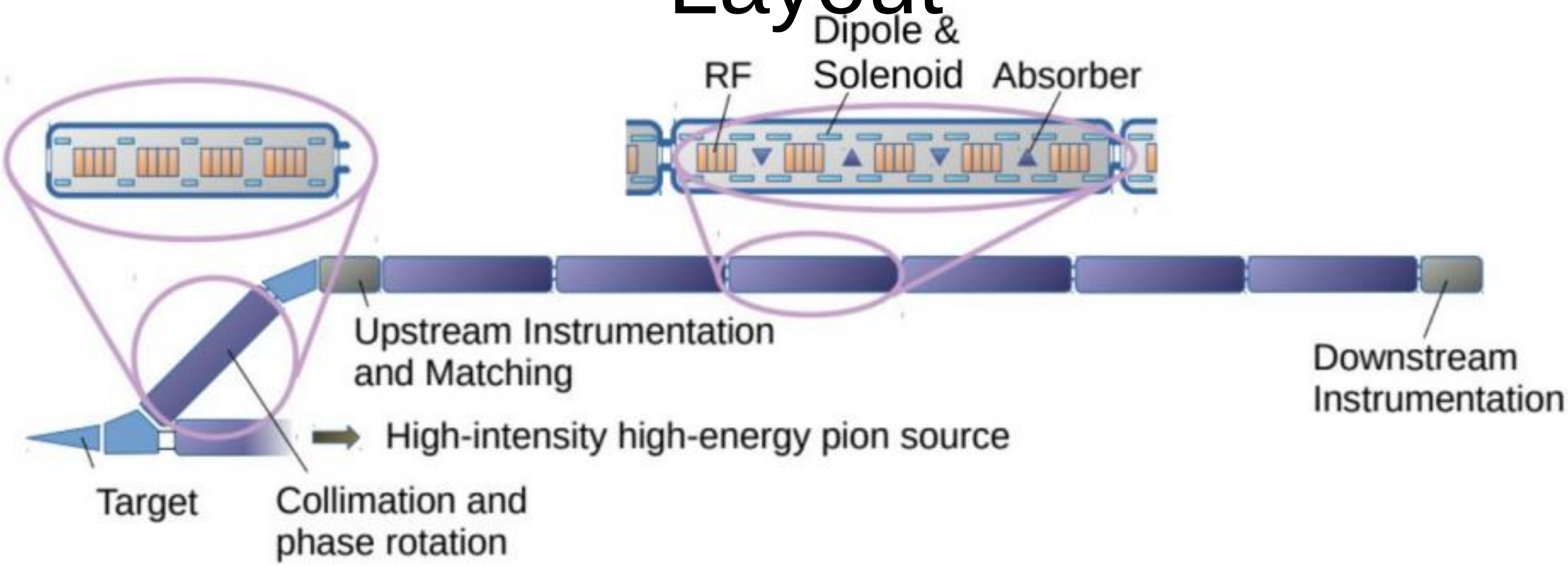
Terminology



- Cooling Cell
- Cooling Module
- Cooling section

Muon Cooling Demonstrator – Layout

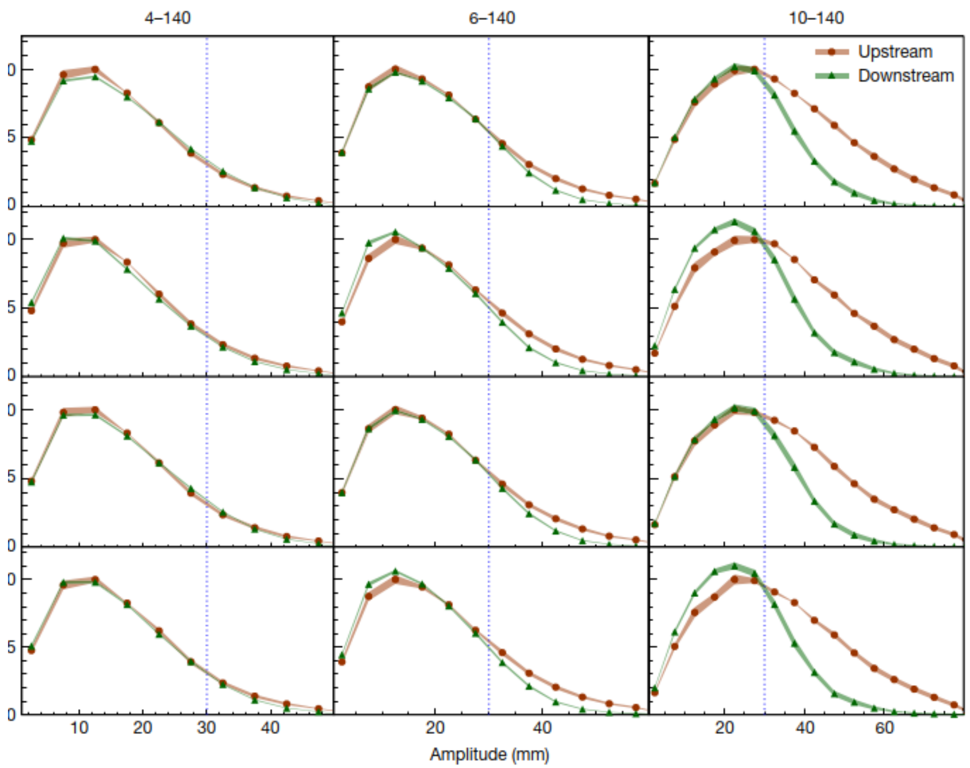
Layout



- Design in progress
  - Muon source – target and pion capture
  - Beam transport
    - Pion decay
    - Chicane (momentum selection & beam dump)
    - Muon phase rotation & collimation (beam preparation system)
    - Matching section
  - Cooling channel/lattice
- Design process may be informed by the siting options

Why it is useful

- MICE has demonstrated already that the principle work
- It was mostly a qualitative experimental proof
- Full benchmarking of the simulation codes is necessary before building the entire line.



easured by MICE. The measured upstream red circles while the downstream distributions are 3oth upstream and downstream distributions are the most entries in the upstream distribution (see the estimated standard error, which is dominated by systematic uncertainties. Vertical lines indicate acceptance above which scraping occurs. The num is listed in Extended Data Table 2. Data for each exp were accumulated in a single discrete period.

Why it is useful

- We will develop Solenoids based on REBCO tapes
  - Will open new possibilities for magnet designers
  - Technology already selected by the Nuclear Fusion community, sinergies already being exploited
  - Development will be faster than with dipoles and quadrupoles, we will learn a lot and transfer knowledge for the design of other types of magnets.
  - We will test them in harsh environment (underground, submitted to radiation, integrated with High Power RF etc…).

Why it is useful

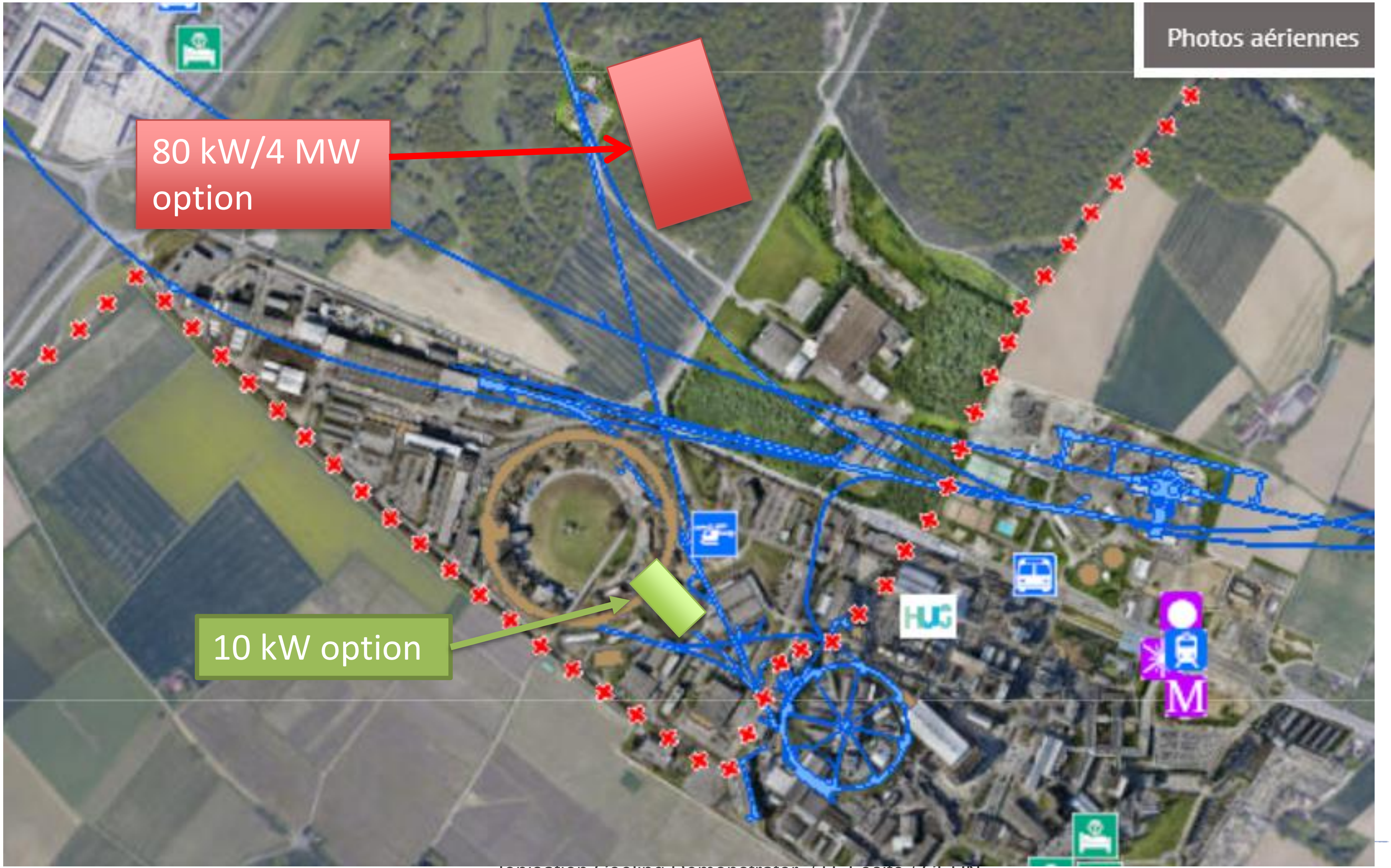
- It will provide a strong impulse to the development of efficient RF power sources:
  - We need very high Electric fields (40÷50 MV/m) in multicell structures
  - 20÷30 MW per pulse
  - Needs at least 80% efficiency to maintain reasonable power requirement
  - No klystron with such performances is available on the market
  - Features very common to any future collider, opportunity to test a decent number of such innovative klystrons in real conditions before any large production for future colliders

Why it is useful

- Absorbers/Target/Dump

- Strategy for targets/dumps and Absorber still mostly paperwork
- The real MC will require extreme performances from them
- It is essential to test those technologies and learn how to use different types of absorbers

Demonstrator at CERN

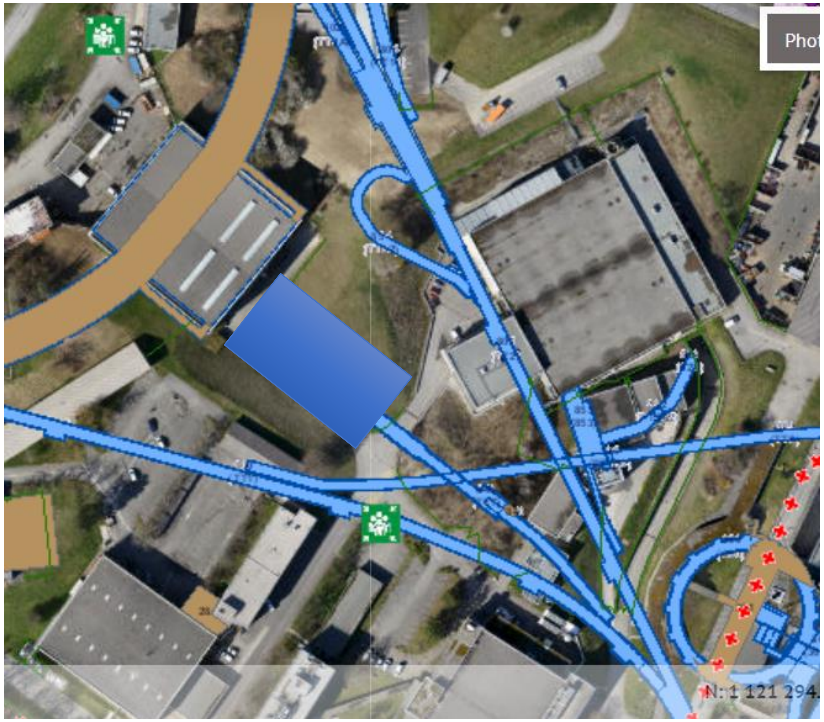


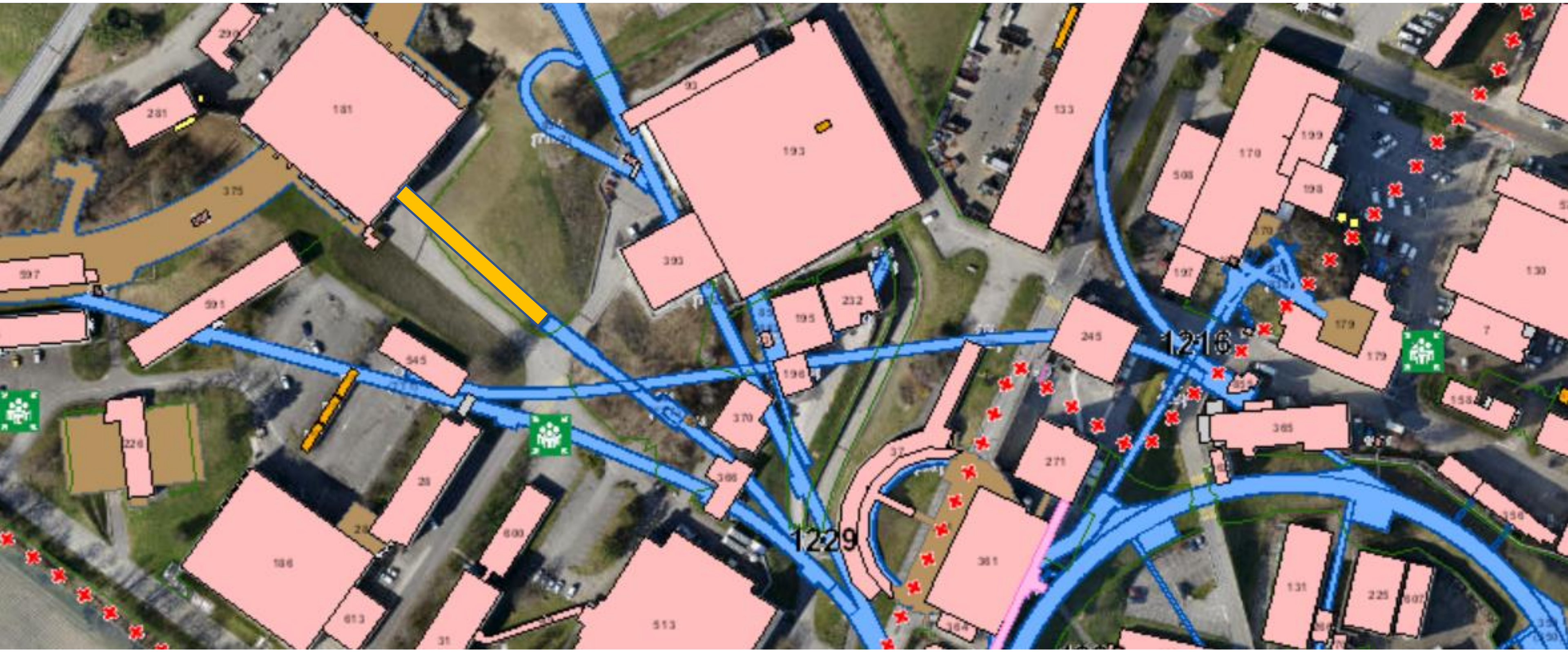
Demonstrator Options at CERN

- Two options are being studied at CERN for the implementation of the Muon Cooling Demonstrator
- Both options allow using the maximum intensity per pulse 10^{13} ppp (or more) in pulses of few ns at 20+ GeV.
- The difference is in the repetition rate:
  - Up to one pulse every few seconds on the high-power site
  - One or two per minute on the low-power site.
- Cost and timeline are different as we will see in the next slides

TT7 Low Power option

- Reusing the line of the BEBC-PS180 Collaboration, presently decommissioned.
- Extending it towards B181 (presently used as magnet factory)
- Shallow tunnel (10m underground)

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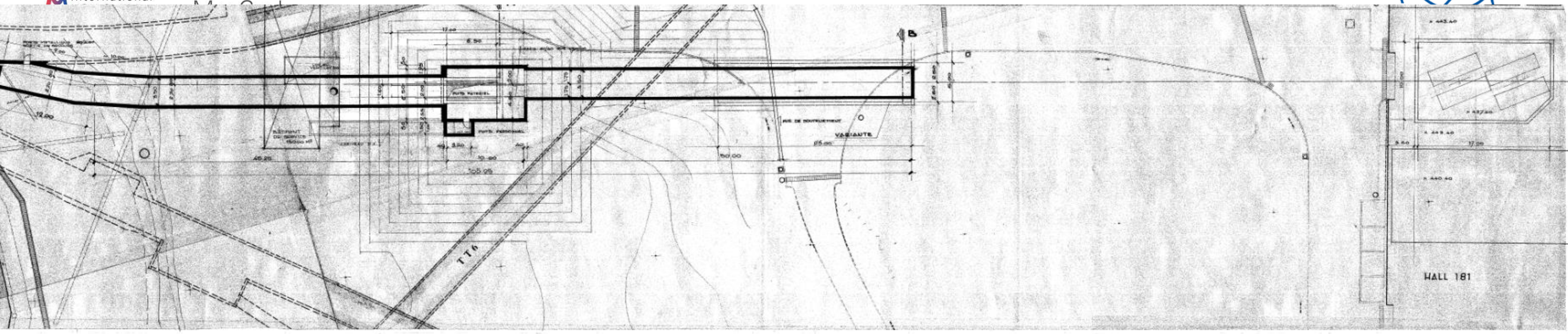
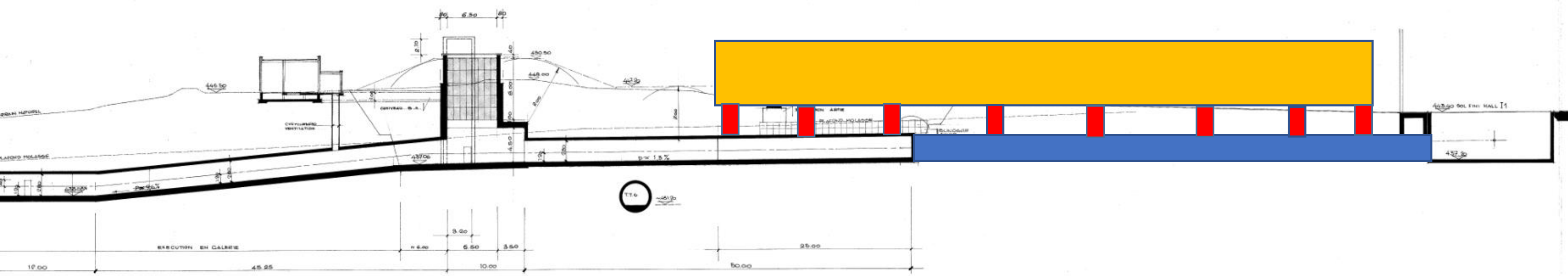
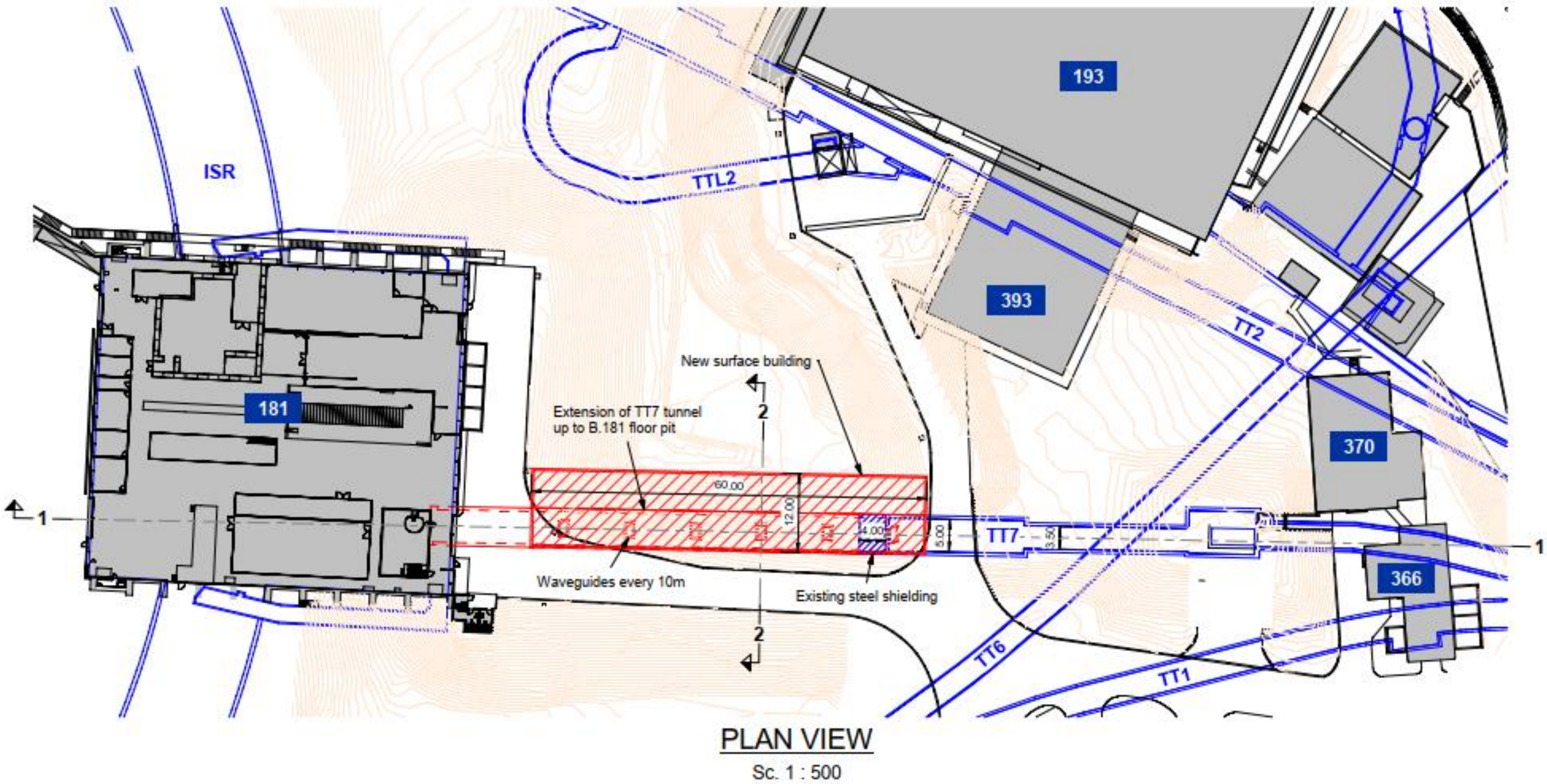




Building above the tunnel with waveguides every 10m

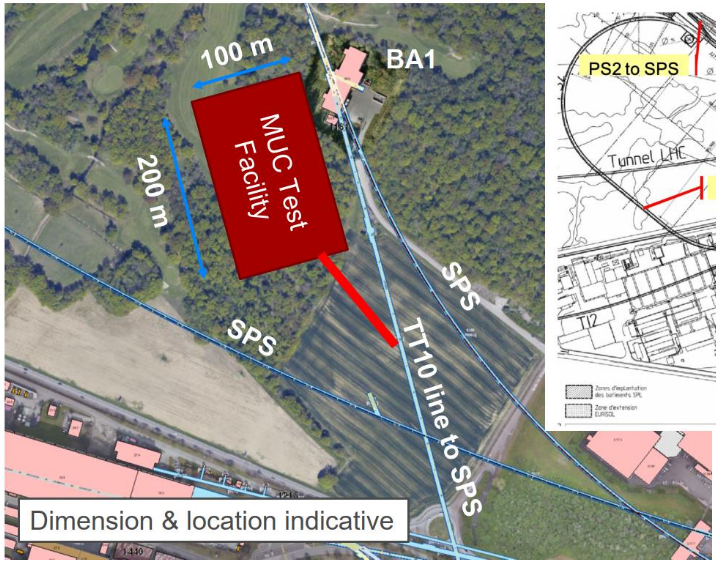
TT7 Low Power option



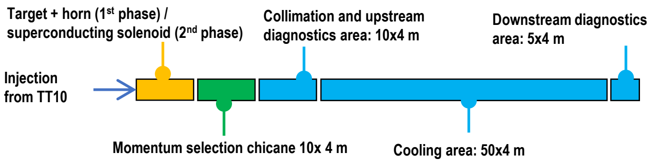
High-Power Option

TT10 line High Power option

- TT10 is the transfer line from the CERN PS (≤26 GeV) to the CERN SPS.
  - O(80kW) on target can easily be achieved.
  - $>10^{13}$ protons can be sent on a target at 20GeV+ in pulses of few nsec (n_TOF beam).
  - 4 MW does not appear to be a showstopper in this layout with beam at a depth of 40 m (detailed studies will have to be performed).
  - Future upgrades towards a collider and HP-SPL are in principle compatible with this layout.

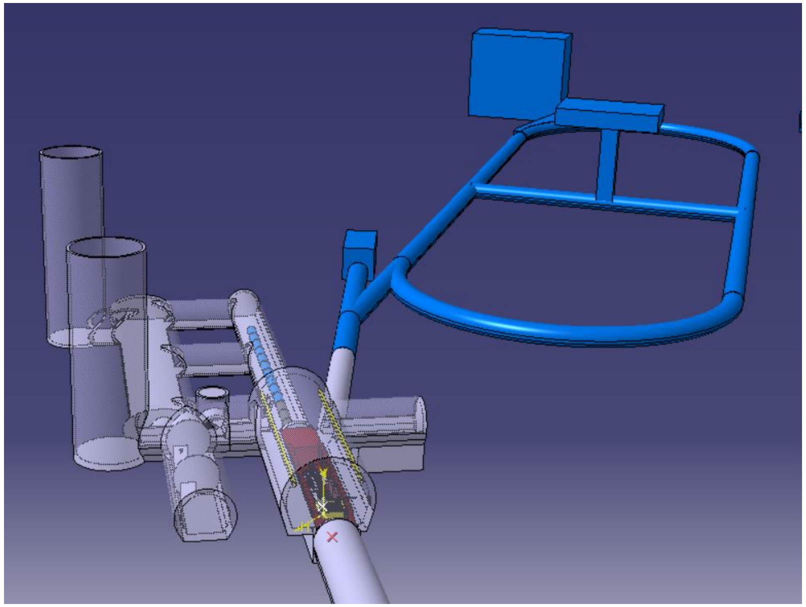


Conceptual layout



MUC Demonstrator VERY Conceptual layout

- The Facility is flexible enough to accommodate other experiments.
- nuSTORM and potentially ENUBET could be branched from the MUC Demonstrator Facility.
- The same target complex would be used profiting from its shielding and general target systems infrastructure, utilities, and accesses.
- The double deflection of the beamline could reduce radiation streaming towards the nuSTORM ring.
- Synergies between experiments would reduce costs on both sides.
- 26 GeV/c beam from the PS is appropriate for nuSTORM



What do we need in the next 5÷10 years

- 2024: feasibility study of the Low power TT7 option
  - Cost and possible schedule to be ready for March 2025
  - Main risk: tunnel too small?
- 2025 onwards:
  - Increase resources for the study of main components
    - Refine layout, define observables and Beam Instrumentation
    - RF cavities in magnetic field
    - HTS magnets
    - High Efficiency Klystrons
    - Absorbers/dumps/targets
- Depending on EUSPP conclusions (2028?):
  - Start emptying the tunnel, do eventual civil engineering
  - Build the first components

Implementation at CERN: a possible roadmap

- If we assume approval of the European Strategy Update in 2028 by CERN council, we have the following scenario scenarios:
- *Period from **today until 2028***
  - Need to increase our budget in order to build a few prototypes: Cooling cell, RF test stand, Mover system mock up etc…
  - Advance the design in order to have execution drawings available for construction
  - Build prototypes, test them before 2027/28
  - Funds to clean up TT7, evacuate radioactive waste, install a fast extraction in the PS and the beam transfer line to TT7
  - Preliminary test of some material with Protons.

Implementation at CERN: a possible roadmap

- 2028-2035
  - FCC is approved:
    - We (already have) convinced the management that the demonstrator is essential
    - We continue on the low power side, at a pace compatible with running HL-LHC and the FCC programme, still aiming at a reasonable facility by 2035.
  - FCC is further delayed or not clearly approved
    - We request the full budget for the high-power option
    - We speed up in order to start installation in TT10 by 2033, first beam 2035.

Spare Slides

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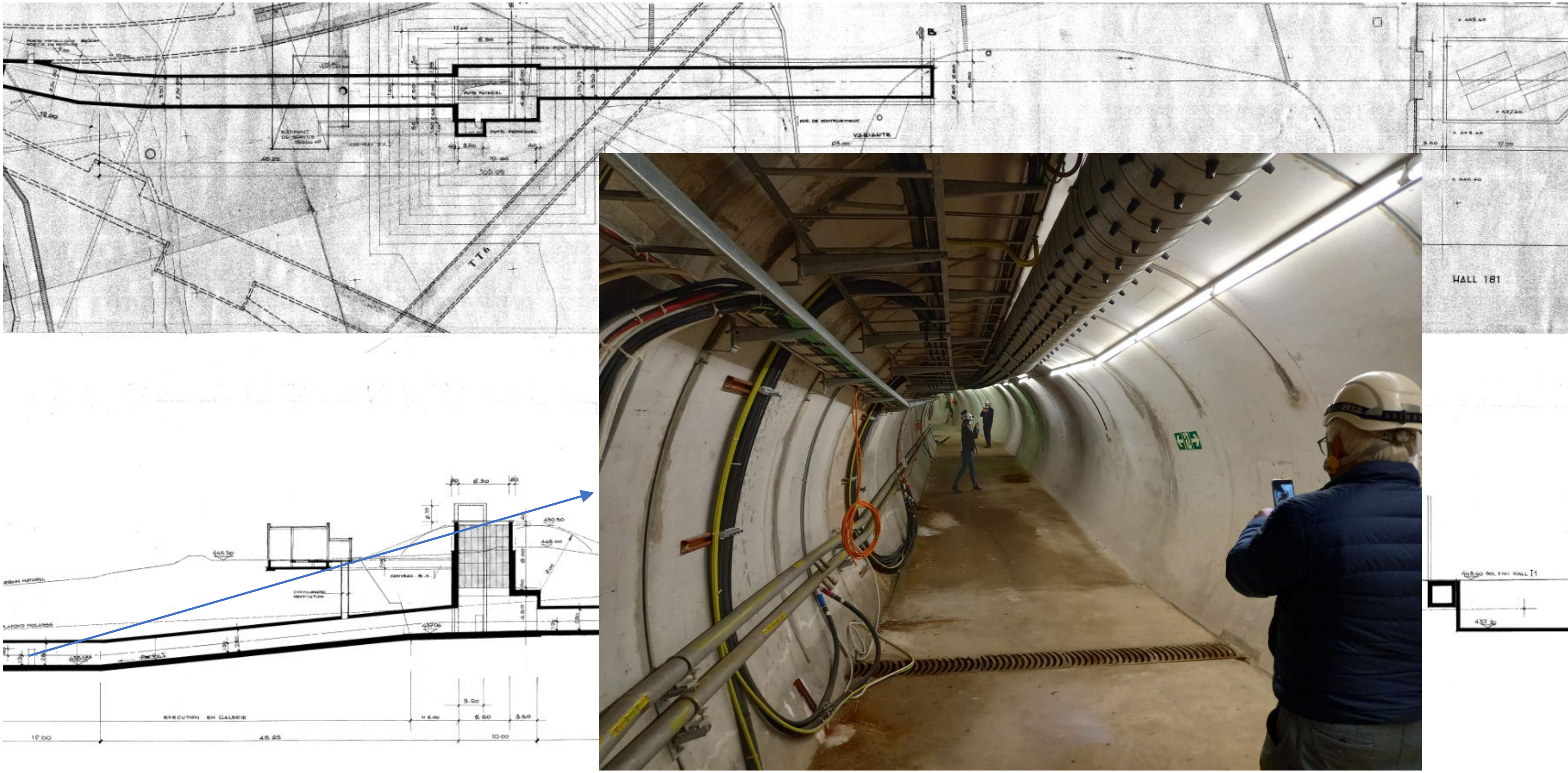
Surface

Access gallery (locked during runs)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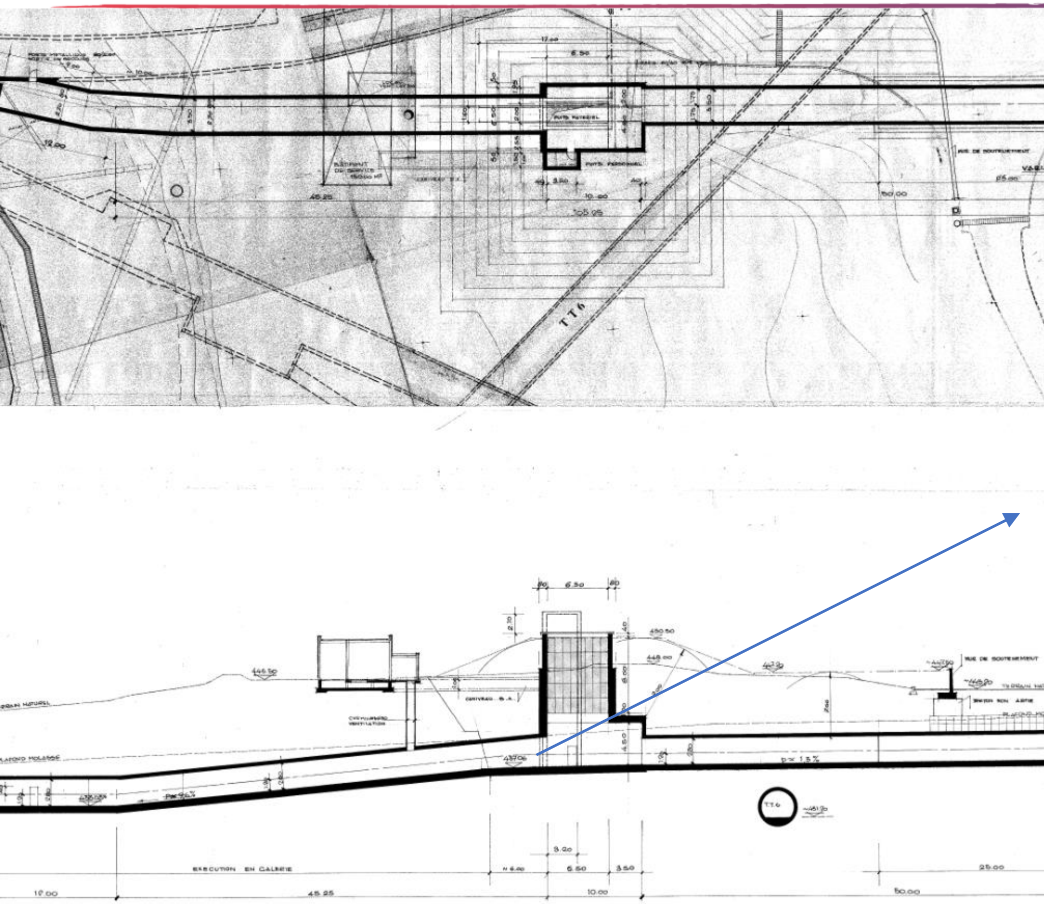

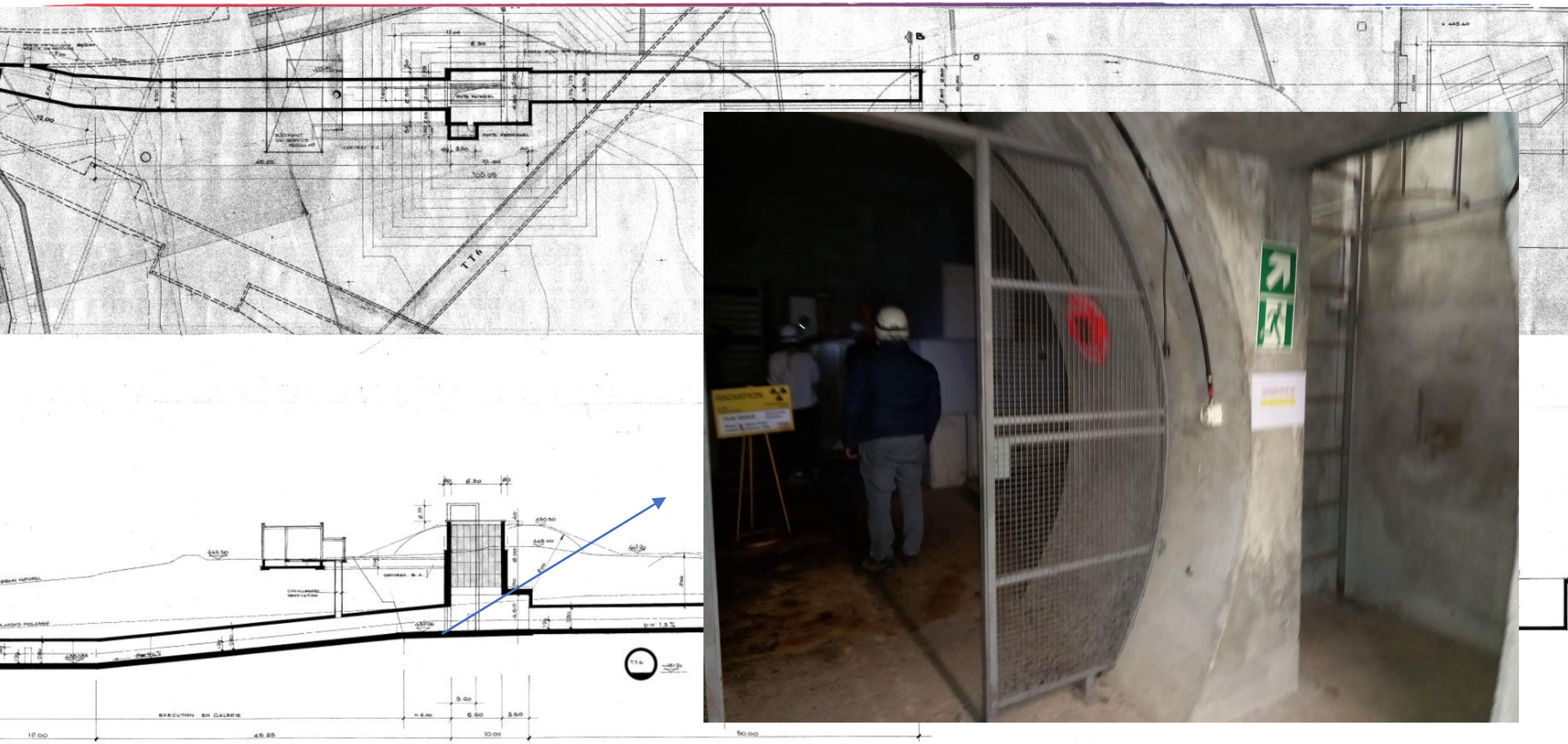

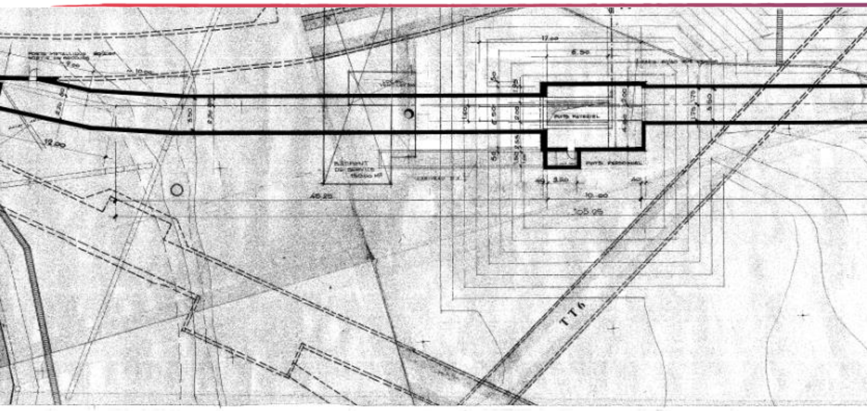

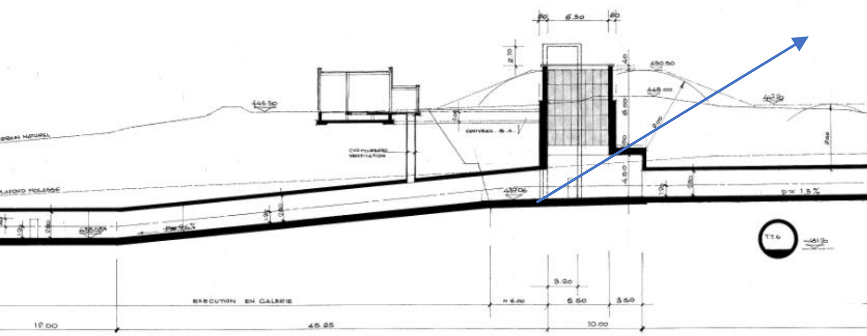

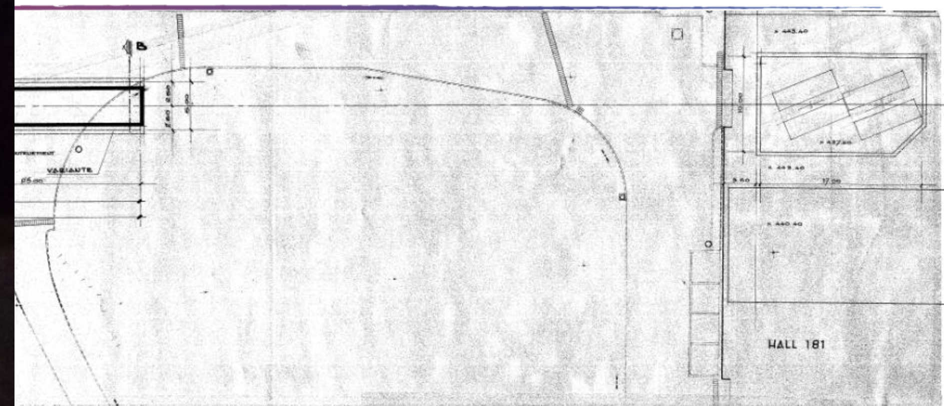
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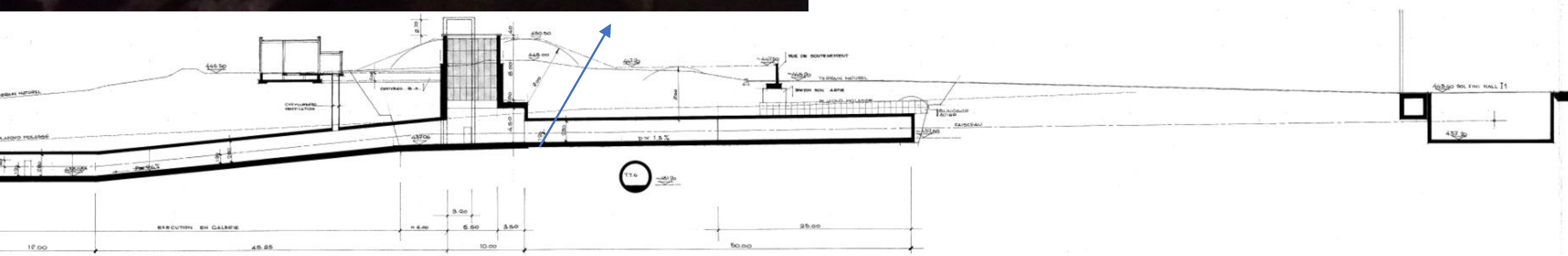
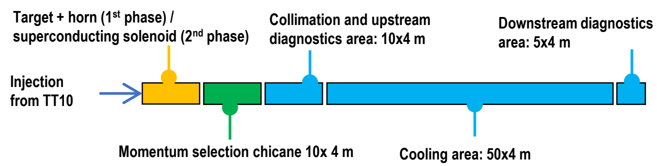
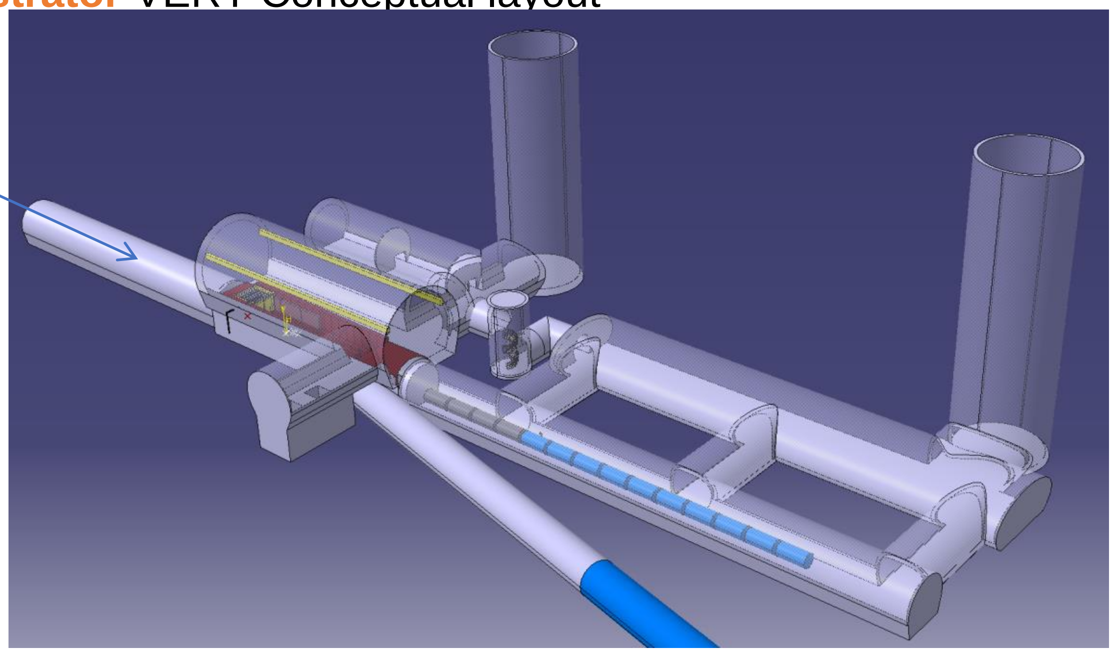


Conceptual layout

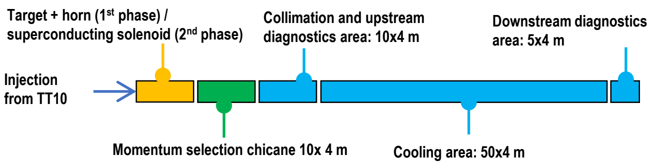


MUC Demonstrator VERY Conceptual layout

CERN TT10 branch

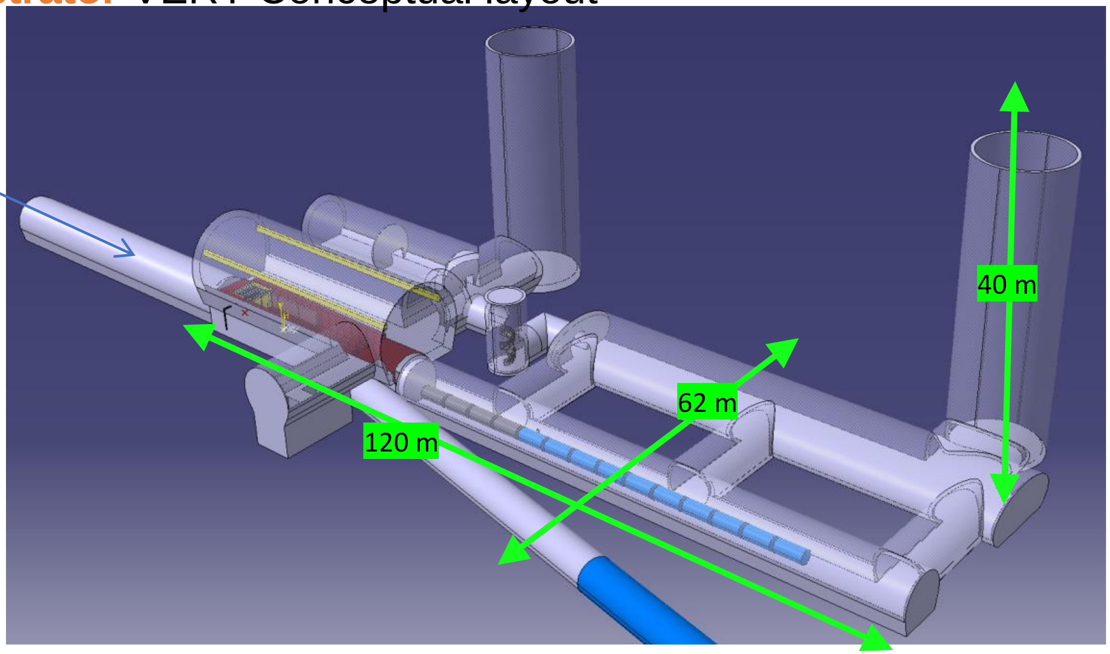


Conceptual layout



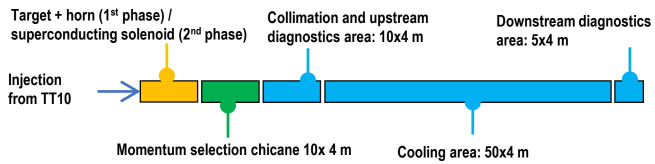
MUC Demonstrator VERY Conceptual layout

CERN TT10 branch

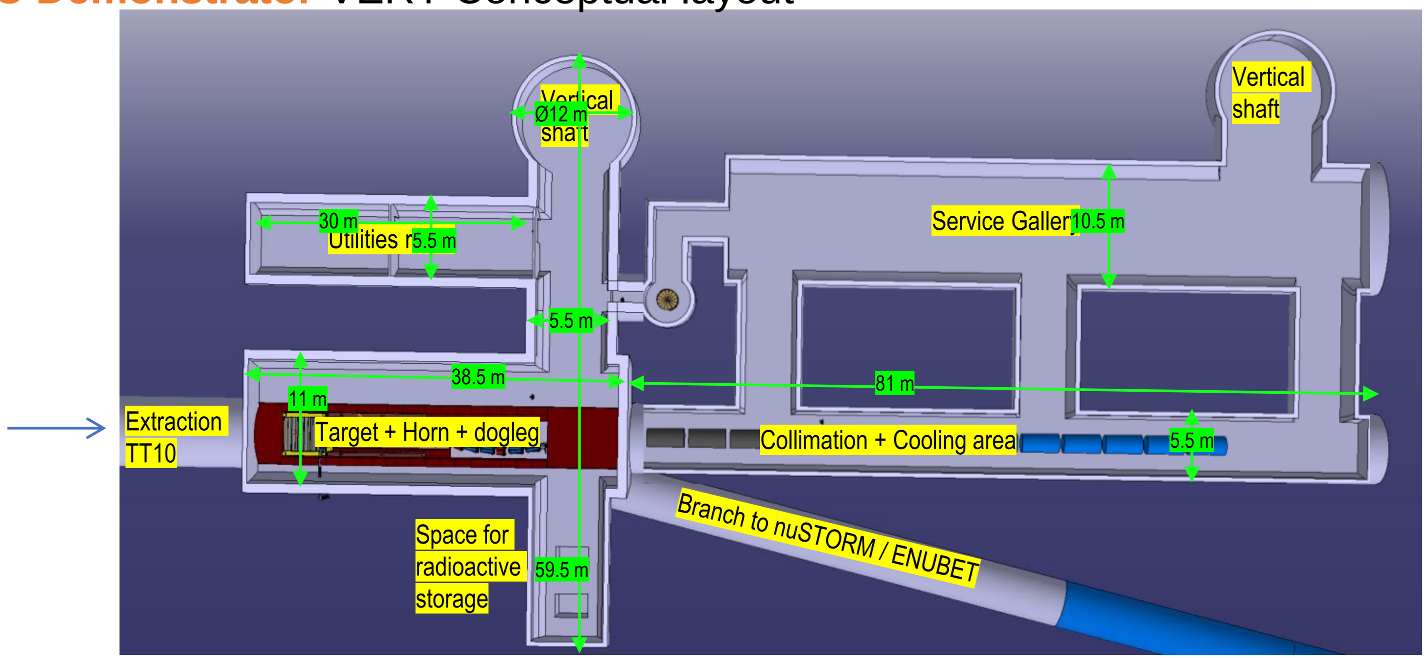


Indicative dimensions. Model is very flexible at this stage

Conceptual layout



MUC Demonstrator VERY Conceptual layout

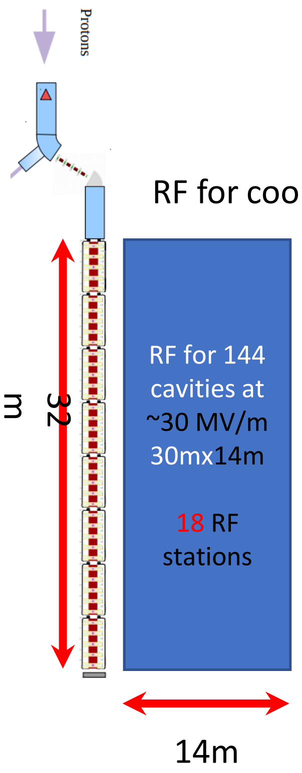


Indicative dimensions. Model is very flexible at this stage

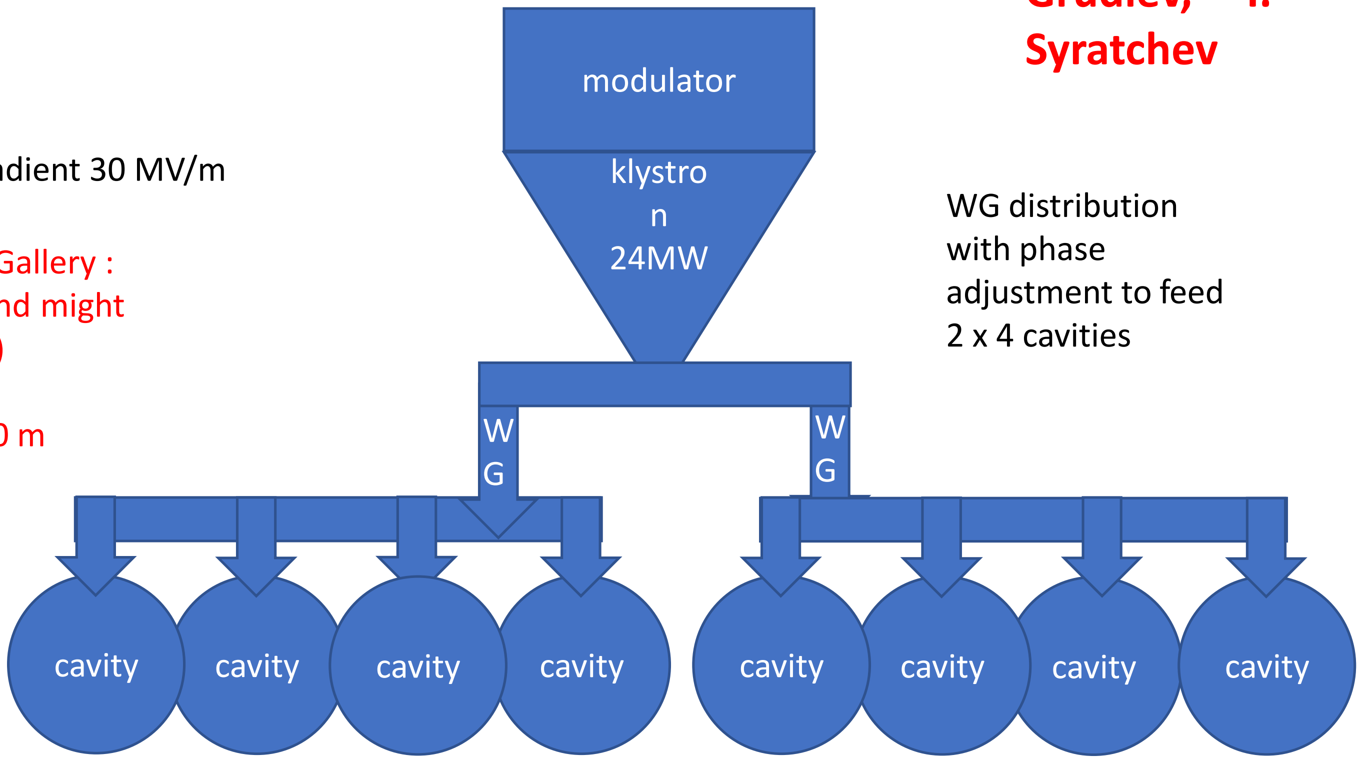
Muon cooling demonstrator layout
High peak power klystron: 24 MW

Courtesy A. Grudiev, I. Syratchev

RF for cooling: Max. gradient 30 MV/m



Building -> Gallery :
(underground might be possible)
30m x **15m**
Height: 8-10 m



WG distribution with phase adjustment to feed 2 x 4 cavities

Safety

- We will have many hazards underground:
  - High Magnetic Fields
  - “High” Power target
  - Cryogenic fluids
  - Liquid/Gaseous Hydrogen
- Cost of safety mitigation measures might become important if not adequately foreseen in the design of the infrastructure.

International MUON Collider Collaboration

MuCol

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