TOWARDS REVIVING THE PS NEUTRINO BEAM:

WHAT IT REALLY INVOLVES …

Rende Steerenberg BE-OP

Contents

- The Experiment: aim, lay-out & needs
- The Infrastructure
- PS Proton Beam Production Schemes
- Preliminary Ideas on the Proton Beam Line
- Target System and Decay Tube
- Work packages for Possible Project
- Concluding Remarks

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The Proposed Experiment

Is there a 4th type of neutrino ?

- Abstract of the Letter of Intent:

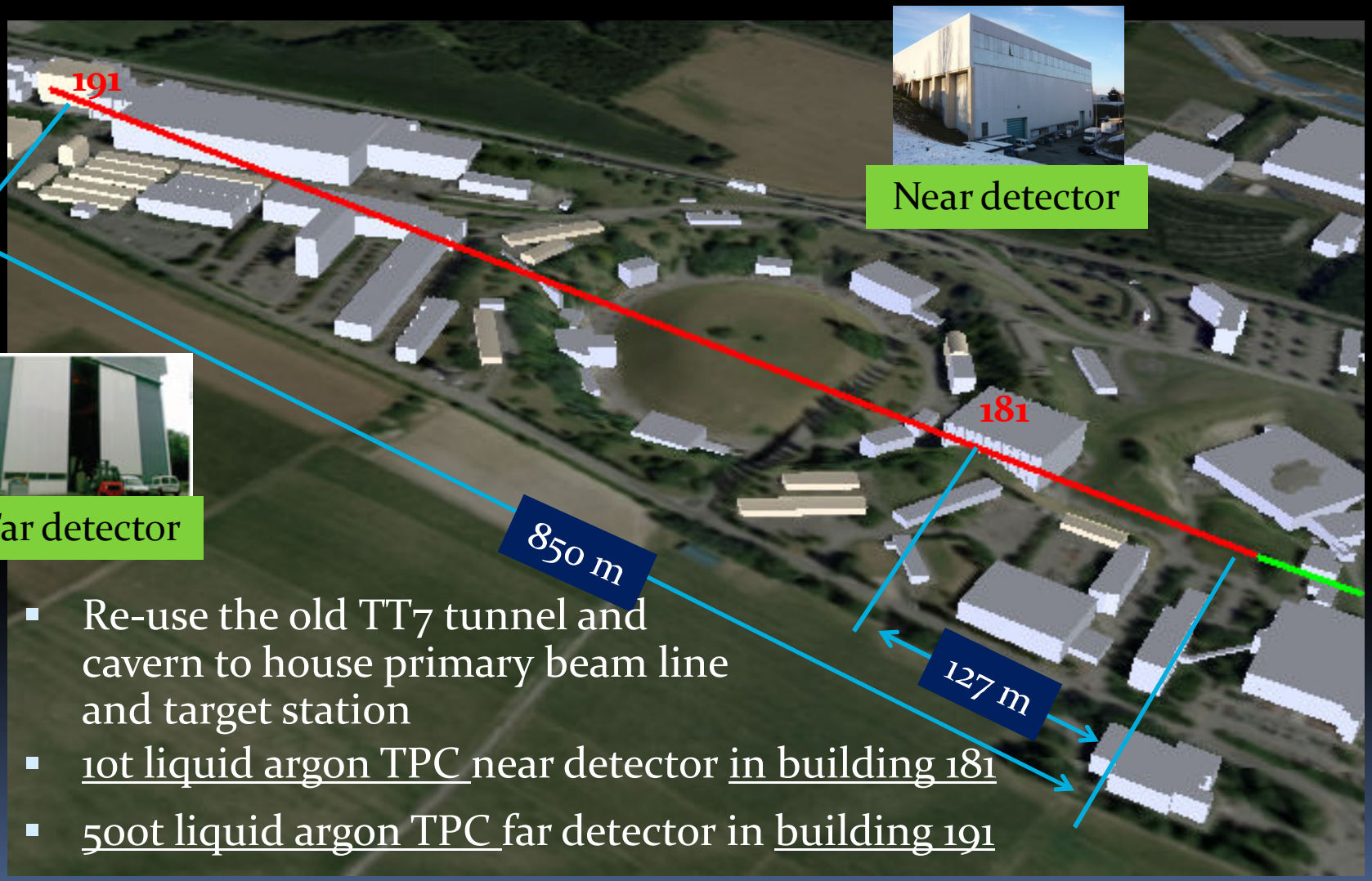
By C. Rubbia et al.

The LNSD experiment at LANSCE has observed a strong 3.8 σ excess of $\overline{\nu}e$ events from an $\overline{\nu}\mu$ beam coming from pions at rest. If interpreted as due to neutrino oscillations, it would correspond to a mass difference much larger and inconsistent with the mass-squared differences required by the standard atmospheric and long-baseline neutrino experiments. ***Therefore, if confirmed, the LNSD anomaly would imply new physics beyond the standard model, presumably in the form of some additional sterile neutrinos.*** *.....*

- Aim:

Investigating the existence of sterile neutrinos *through the measurement of $\nu\mu \rightarrow \nu e$ oscillations by using a low energy $\nu\mu$ or $\overline{\nu}\mu$ beam in combination with a close and far liquid argon time projection chamber.*

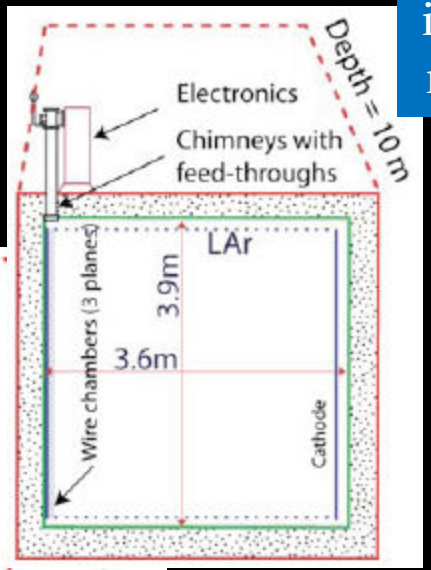
The Proposed Experimental Lay-out



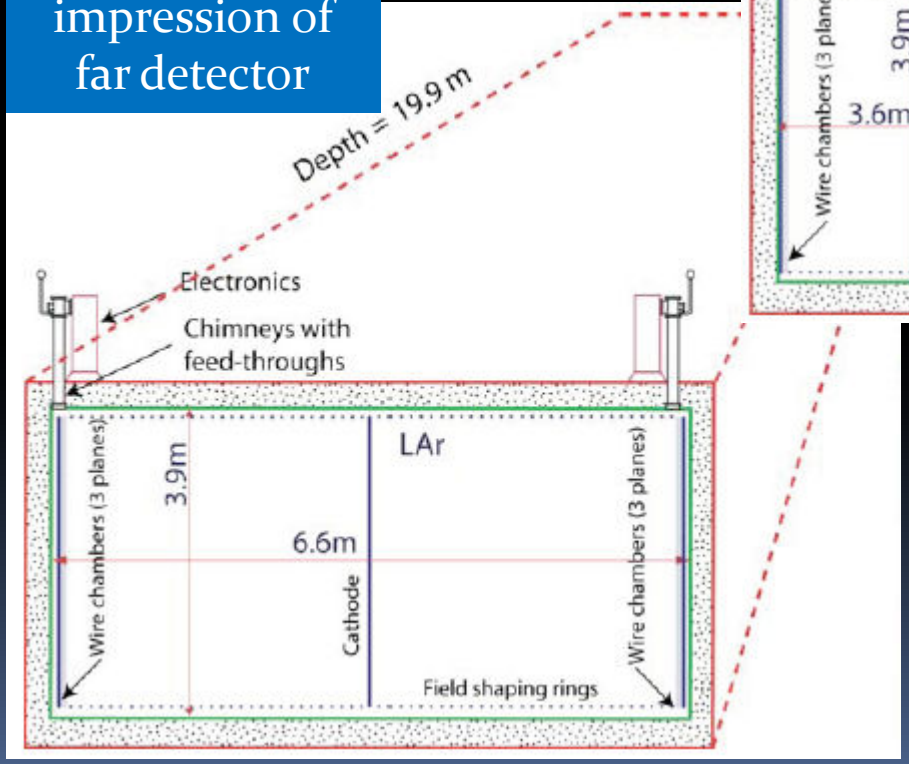
- Re-use the old TT7 tunnel and cavern to house primary beam line and target station
- 10t liquid argon TPC near detector in building 181
- 500t liquid argon TPC far detector in building 191

Liquid Argon TPC (LAr-TPC)

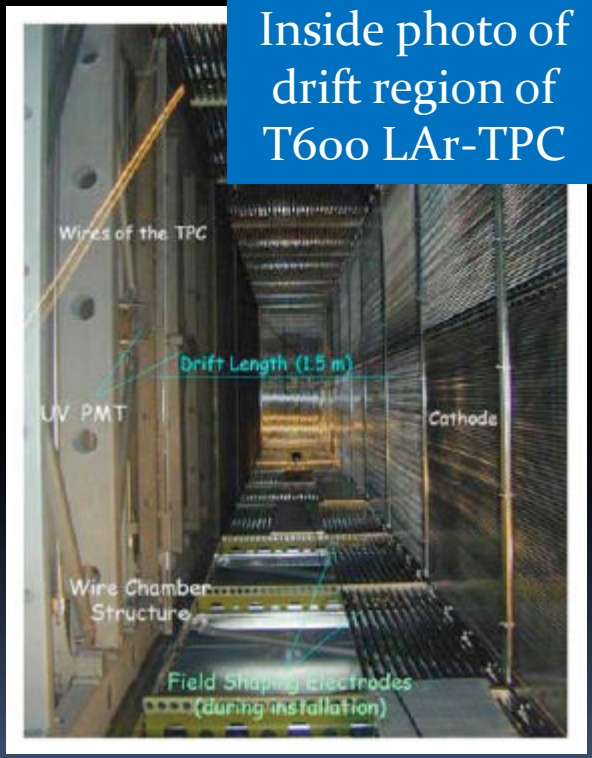
Artistic impression of near detector



Artistic impression of far detector



Inside photo of drift region of T600 LAr-TPC



Images from the Letter of Intent, C. Rubbia et al.

The Experimental requirements

- There are few, but some challenging, requirements:
  - Integrate **1.25 x 10^{20} p.o.t. per year** (2 years)
  - Primary proton beam momentum of ~ 19 GeV/c
  - The proton beam hitting the target should be more or less parallel and interact with a target of ~ 6 mm diameter
  - Secondary beam production (low energy ν_μ beam) , focusing and measurement

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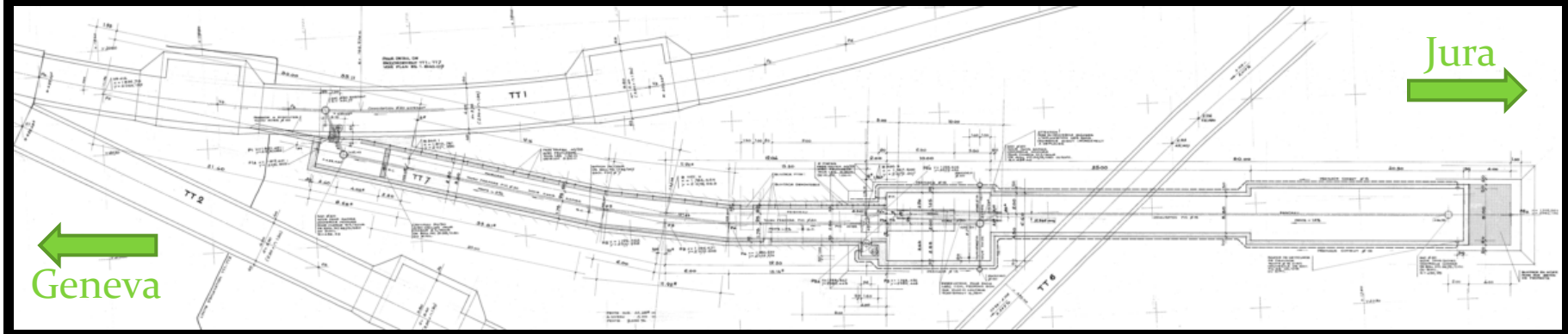
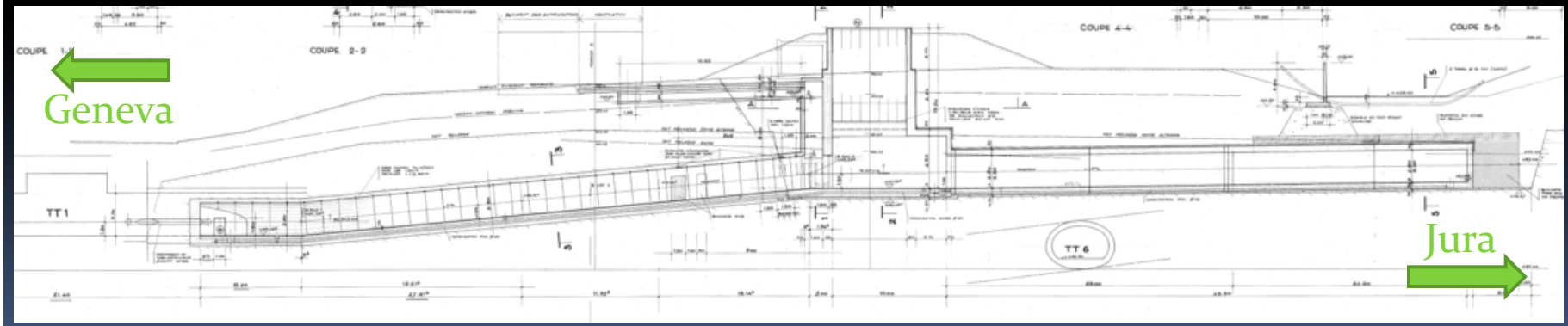
The TT7 Tunnel

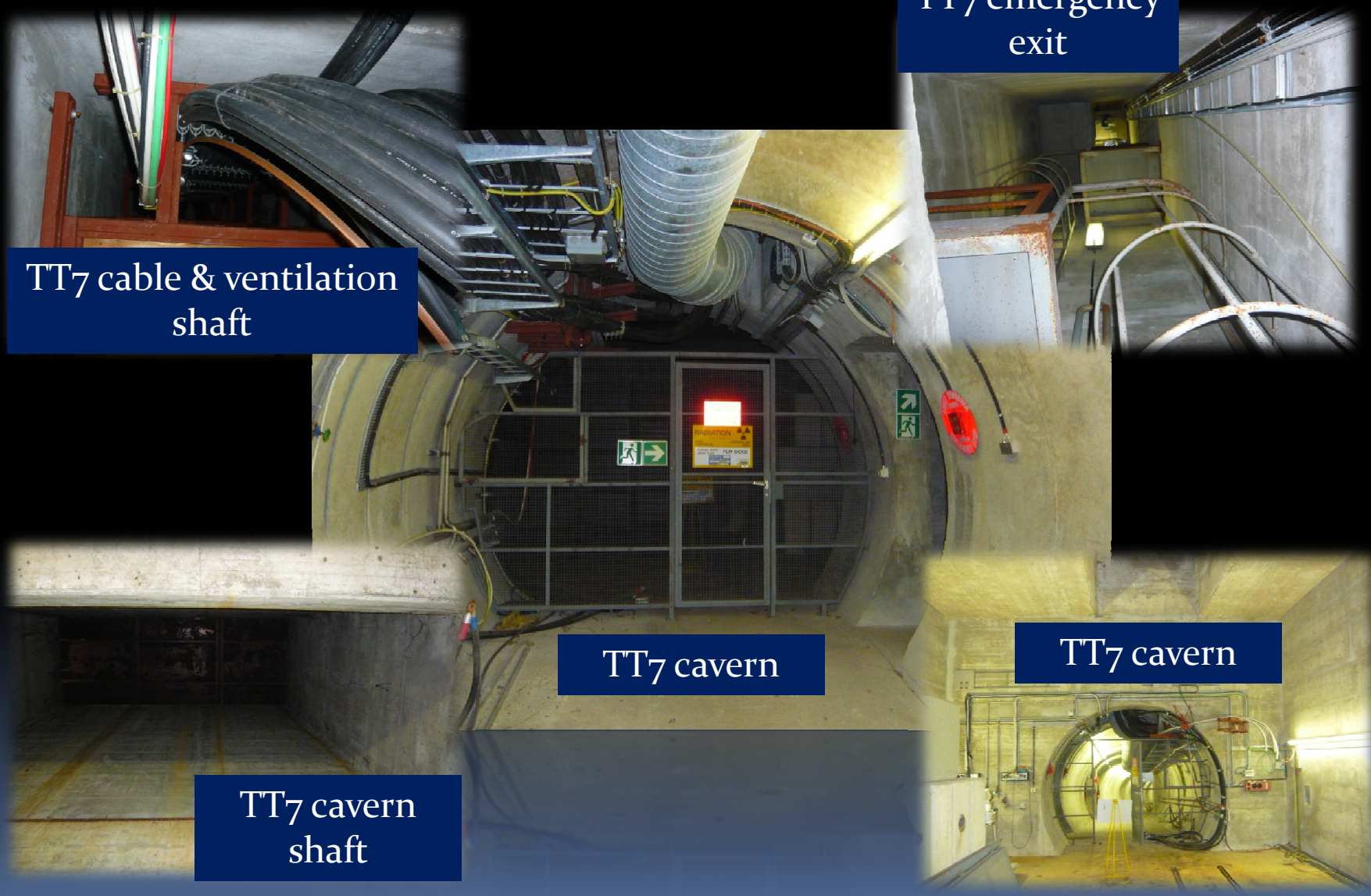
- The TT7 tunnel was used in the past for neutrino oscillation experiments (PS180, BEBC in early 80's)



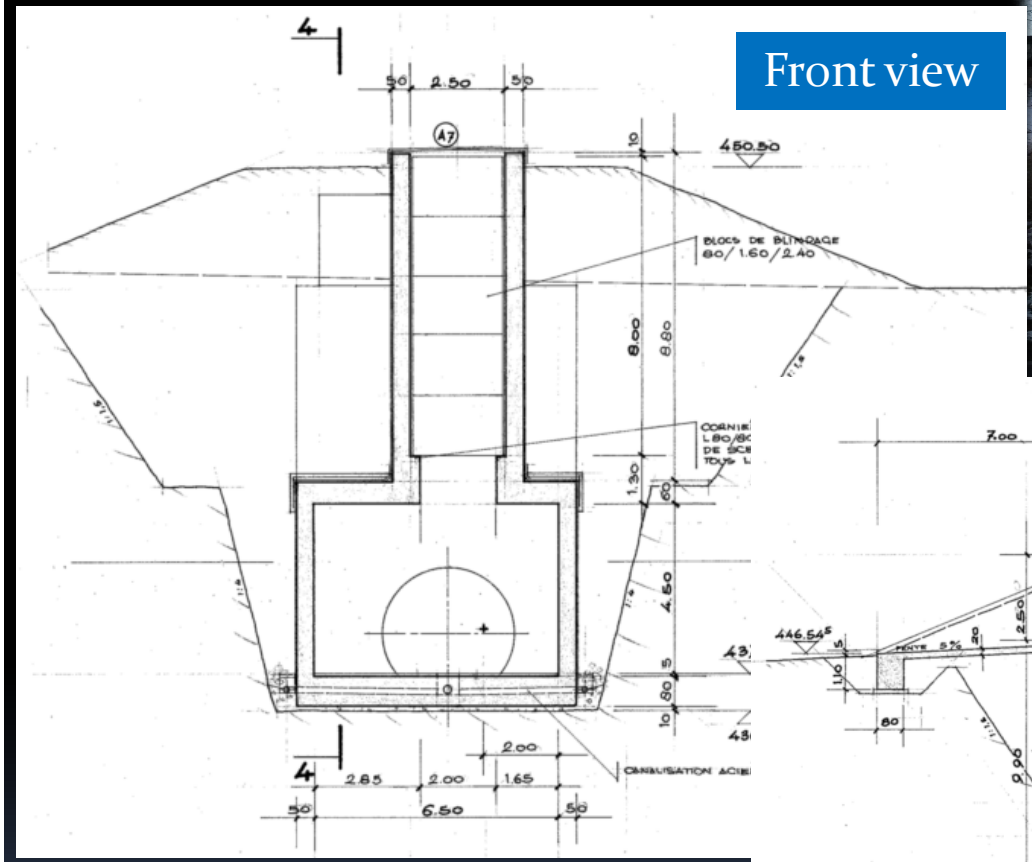


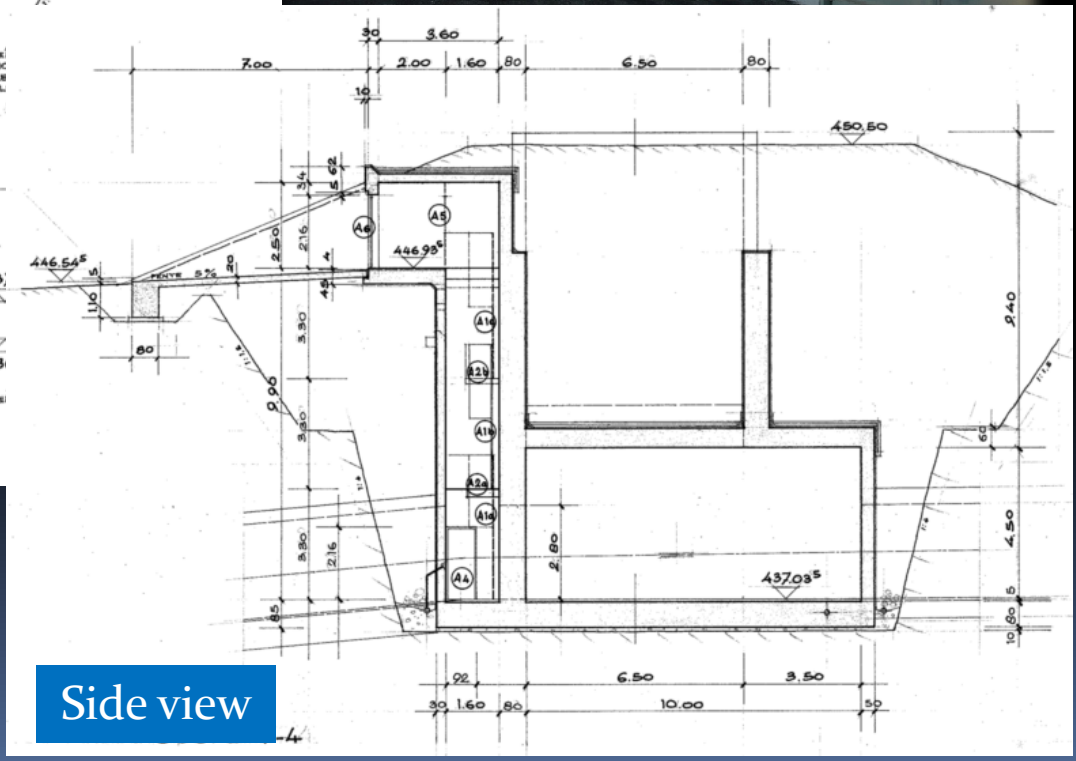
The TT7 tunnel toward the target

The TT7 Target Cavern



TT7 Cavern



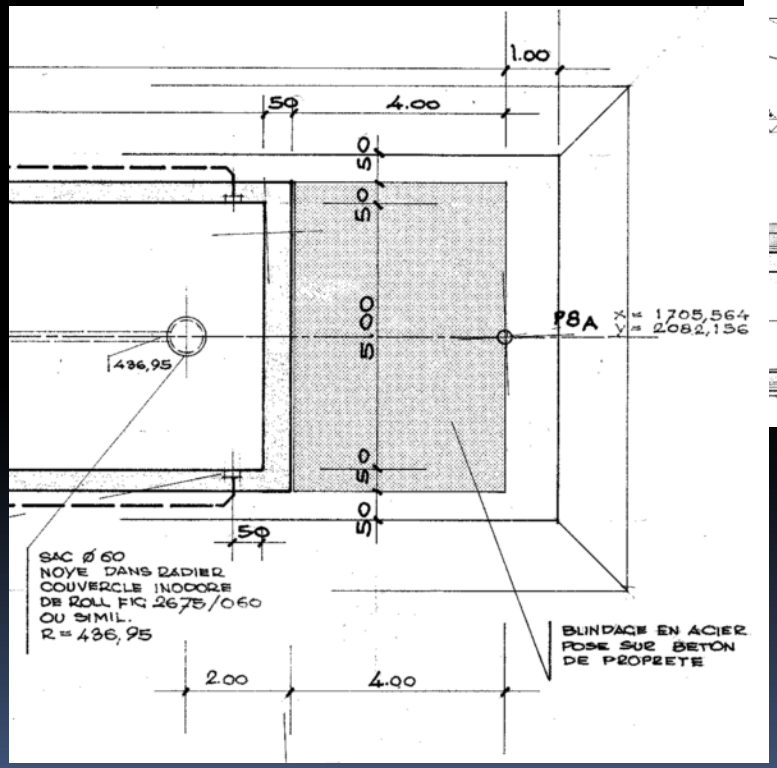


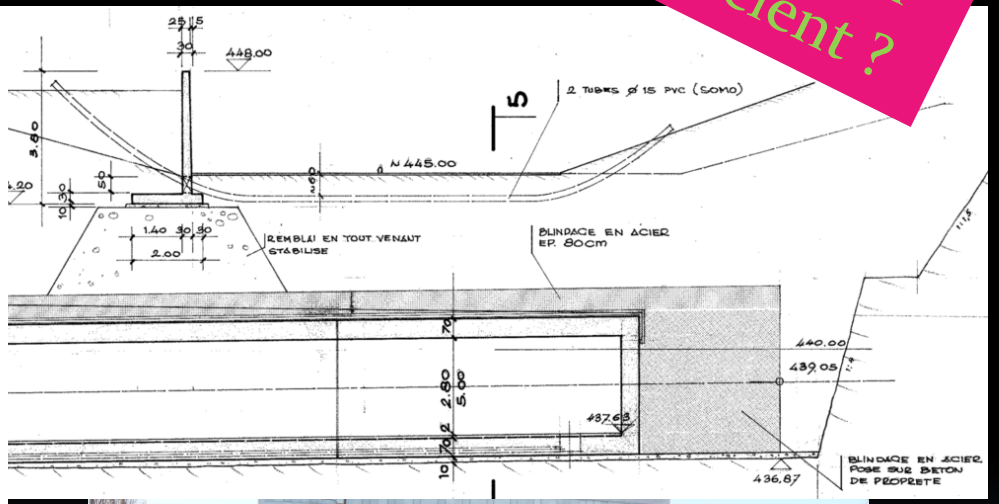
- 8 meter under ground
- Material access shaft

Beam dump / hadron stopper

- 4 meter thick iron beam dump
- 65 meter of earth

Is this still sufficient ?

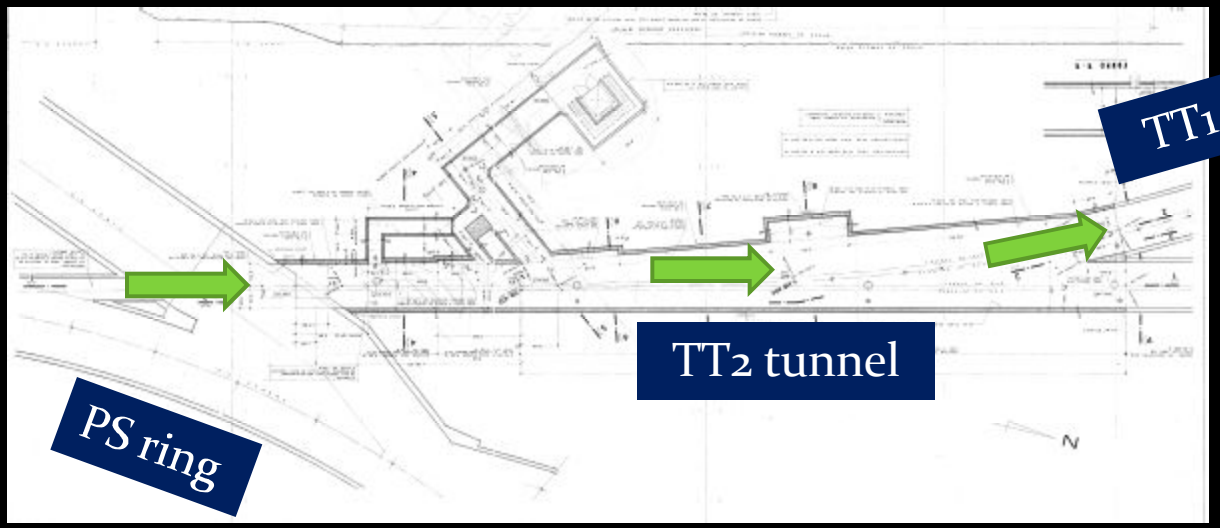


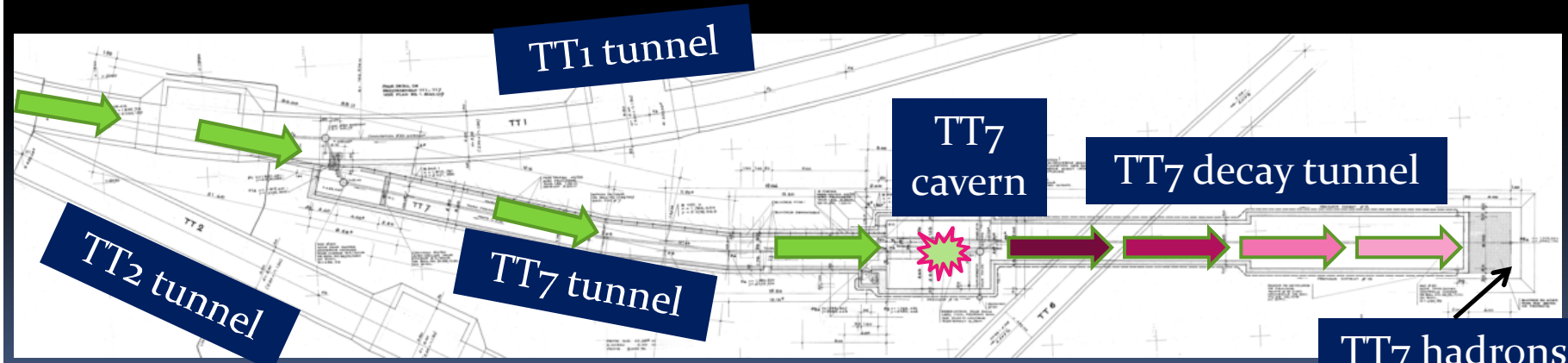


Present status of the TT1/TT7

- The TT1 tunnel is rather humid and is used as storage for radio-active cables.
  - Separation and disposal project is being planned , but will most probably not start before 2014
- TT7 tunnel and cavern are in very good shape
- TT7 decay tunnel is full with radio-active waste, which need to be treated and disposed (under consideration)

How to go from PS to TT7 ?





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Required Integrated Intensity Planning

- Experimental requirement 2.5 x 10^{20} p.o.t. in 2 years
- Assume that the super cycles are similar to the present ones:
  - Daytime (10 hrs): 39 bp, 46.8 seconds (1xFT, 4xCNGS, 1xMD)
  - Night-time (14 hrs): 33 bp, 39.6 seconds (1xFT, 4xCNGS)
- Possible intensity per cycle: 3 x 10^{13} protons
- Assuming we run 180 days per year, then this would require 12 cycles of 1 bp for an average super cycle length of 36 bp, 43.2 seconds (i.e. 33% duty cycle)
- This place is at present not available in the super cycle.

Possible evolution of super cycles

- The DIRAC experiment (PS212) mentioned in an SPSC presentation to have plans to move to the SPS after 2011
  - Presentation at SPSC 16 April 2009:
    - http://cdsweb.cern.ch/record/1172364/files/SPSC-SR-045.pdf
  - They occupy until present 10 bp's in the day and night super cycles
  - However, this would only liberate 5 bp's in the PSB, keeping the ISOLDE duty cycle unchanged
- nTOF requires an increase in number of integrated protons per year and thus number of cycles per super cycle

Assumption for Possible Scenario

- Assume the following:
  - Similar super cycles than at present
  - No EASTB (DIRAC/PS212)
  - Keep ISOLDE duty cycle unchanged
  - Anticipate request for increase of nTOF protons
  - 180 days of physics run per year
  - Machine availability is not taken into account
  - POPS operational
- This would give 7 cycles per super cycles, day and night to be shared between nTOF and TT7

nTOF Cycle and Beam

- The dedicated nTOF cycle produces 1 bunch of 7x1012 protons on harmonic 8
- This bunch is shortened from ~ 50 ns to < 25 ns and fast extracted to the nTOF target
- The 7 remaining buckets are not used
- They could potentially be used for the TT7 neutrino experiment
- This way 1 cycle is efficiently used to share beam between the nTOF and TT7 neutrino experiments.

nTOF & TT7 Cycle sharing Proposal

- Accelerate $3x10^{13}$ protons in 8 bunches on harmonic 8 up to 20 GeV/c
  - Resulting in $3.75x10^{12}$ protons per bunch
- TT7 neutrino's:
  - 7 bunches to the TT7 neutrino target
  - Resulting in $2.63x10^{13}$ p.o.t. per cycle
- nTOF:
  - 1 bunch to nTOF target
  - Resulting in $3.75x10^{12}$ p.o.t. per cycle

Possible yearly integrated intensities

- Under the assumed conditions PS could provide:
  - 7 cycles per s.c. sharing beam for TT7 & nTOF
  - 4 parasitic nTOF cycles per s.c.
- nTOF part:
  - Total integrated intensity of 1.34×10^{19} p.o.t./yr
  - This is 84% more than committed in 2009
  - Note: *if no sharing nTOF would get 200% more*
- TT7 neutrino part:
  - Total integrated intensity of 6.7×10^{19} p.o.t./yr
  - This would require 3.7 runs to obtain 2.5×10^{20} p.o.t.

Two Beam sharing options

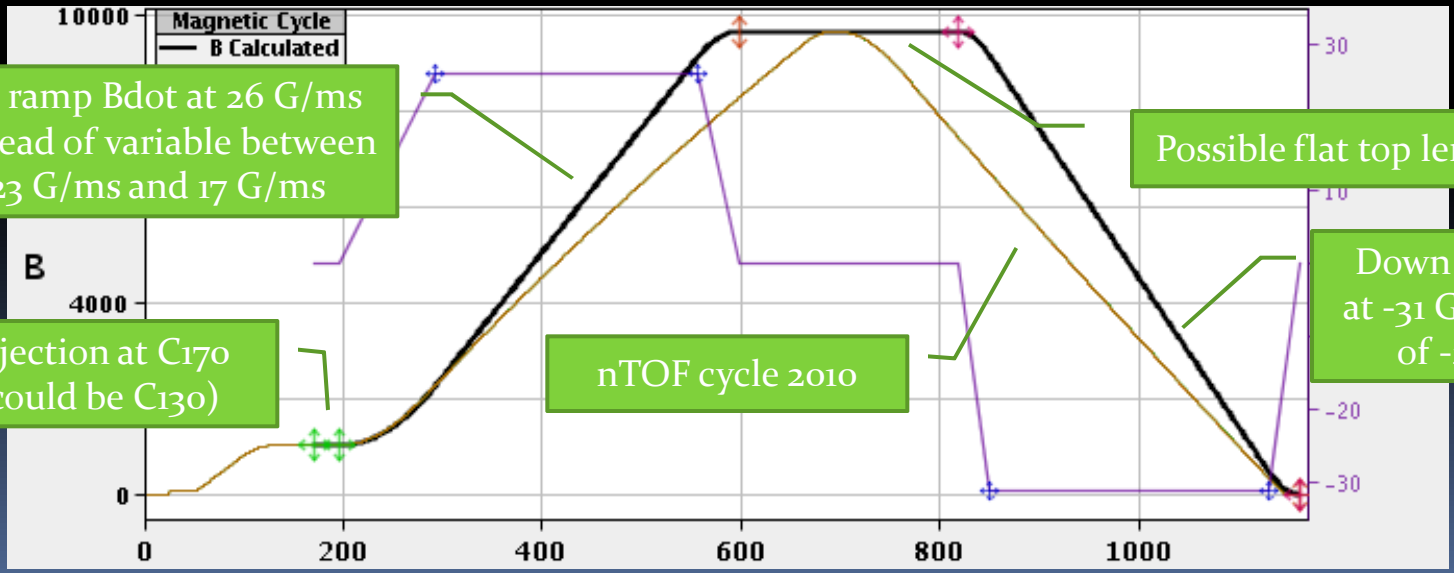
- For sharing the nTOF and TT7 beam there are two options:
  1. Single extraction of 8 bunches
     - Requires (expensive) kicker/septum in TT2
     - All bunches would see bunch rotation required for nTOF bunch
  2. Double batch extraction
     - Requires modifying the extraction element power supplies to pulse twice
     - Required fast switching magnet in TT2
     - 7 non shortened bunches for TT7
     - 1 shortened bunch for nTOF

Single Batch Extraction Scheme

- Present TOF cycle can be used:
  - $3x10^{13}$ protons on harmonic 8 and single fast extraction is fairly standard and clean
  - TT7 will also receive short bunches (large dp/p)
- Kicker and (outside vacuum) septum to be developed
- Maximum TT2 line kicker rise time <200 ns
- More complicated implementation in TT2

Double batch Extraction scheme

- At present the nTOF cycle flat top is too short for the proposed double batch extraction.
  - POPS will allow increase of Bdot and to maintain it constant during the ramp
  - New MPS regulation allows earlier injection by ~ 40 ms
- This results in the following magnetic cycle:



Double Batch Extraction Requirements

- The extraction elements need to be able to pulse twice within ~ 200 ms interval:
  - Extraction bump
    - Requires (adding capacitors, switch and timing)
  - Kick enhancement quadrupoles.
    - Requires (adding capacitors, switch and timing)
  - Extraction septum
    - Requires (adding entire power converter)
    - Additional studies and tests on magnet to be done
  - Extraction kicker
    - The possibility to kick twice on the same flat top with minimum 30 ms interval is already available

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PS to TT7 Transfer Line

- Drawing of old TT7 line are available
  - ~ 14 Main Dipoles
  - ~ 12 Quadrupoles
  - ~ 4 Corrector Dipoles
- TT2 situation has changed since then
- Do we opt for Kicker/Septum or fast switching magnet ?
- It should contain proton beam intensity, positioning and profile monitors
- Can we re-use magnets or do we need new ones ?
- Beam line (optics) study needed (manpower)

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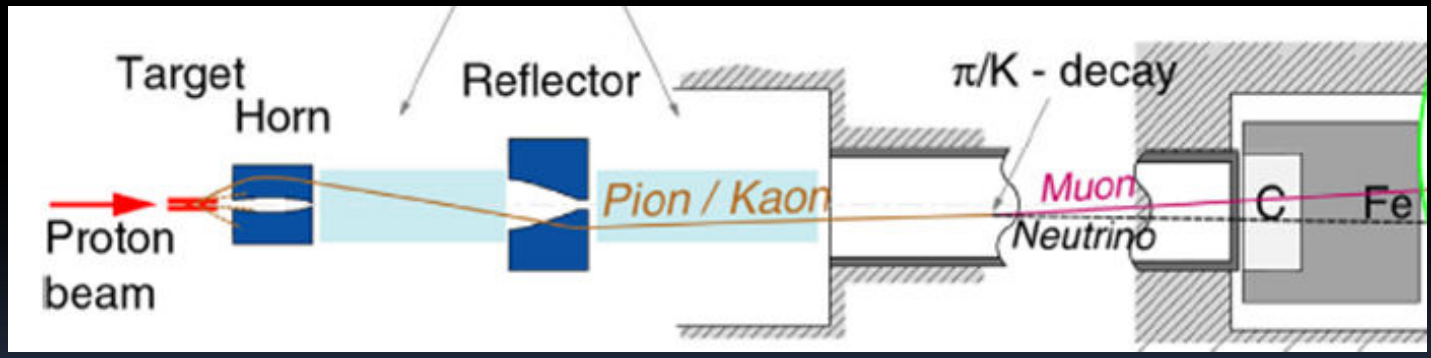
Secondary Beam Production

- The required secondary beam should be a low energy ν_μ beam
  - CNGS uses high energy ν_μ beam
- Use proven CNGS target, horn and reflector technology and scale down by energy
  - CNGS target 450 kW → TT7 target ~ 4 kW

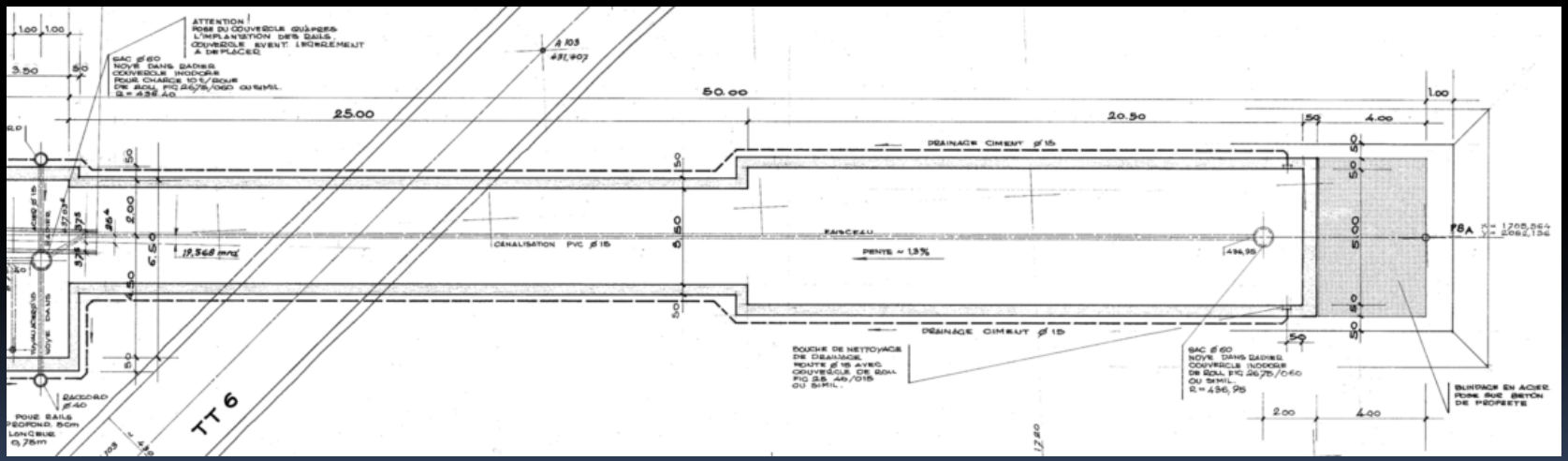


Courtesy of E. Gschwendtner

- Parallel proton beam on target
- Focus secondary beam, using horn and reflector

Decay Tunnel

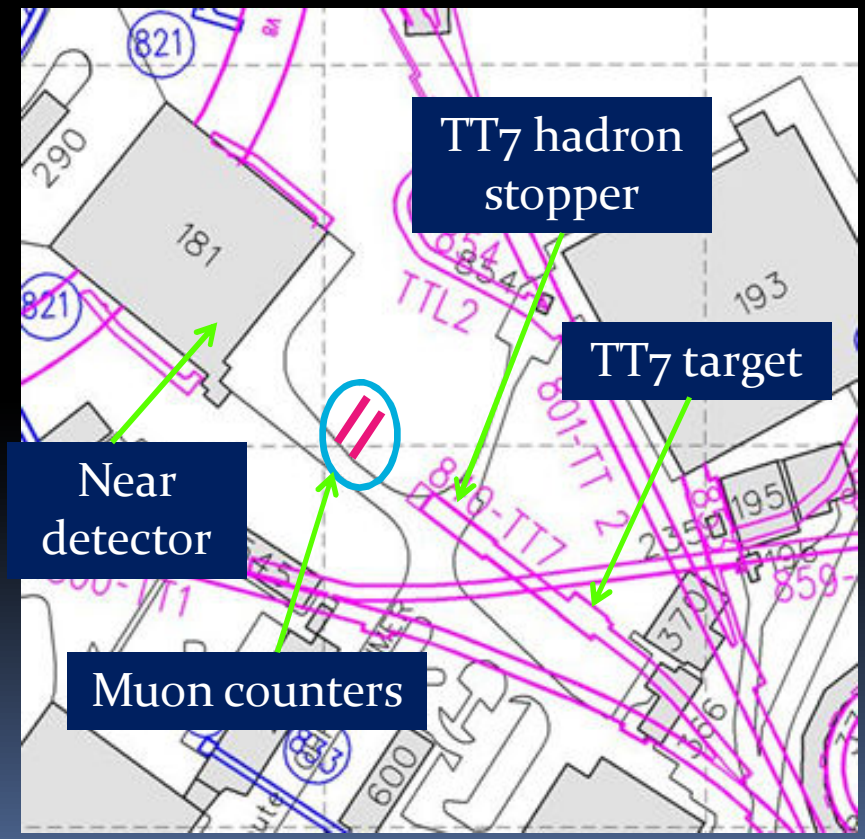
- The available decay tunnel is 50 meters long
- Cross section:
  - 3.5 x 2.8 m2 for the 1st 25 m
  - 5.0 x 2.8 m2 for the remainder



- No (vacuum) decay tube (like CNGS) available

Secondary Beam Measurement

- Installing muon counters after the hadron dump will allow:
  - Monitoring the intensity
  - Measure the distribution
  - Steering with primary beam
  - Target alignment



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Work Packages for a Possible Project (1)

- Primary Proton Beam Production scheme
  - **Adapt fast extraction** or develop kicker/septum in TT2
  - **Power converters and/or Magnets**

- PS to TT7 target transfer line:
  - **Vacuum**
  - **Magnets**
  - Collimation
  - **Optics**
  - **Power Converters**
  - Beam Instrumentation
  - Controls
  - **Radiation protection & shielding**

Work Packages for a Possible Project (2)

- Secondary beam production and measurement
  - **Target** (including cooling, ventilation, target protection and target disposal after use)
  - **Pulsed Horn and Reflector**
  - Decay Tube
  - Muon counters
  - **Radiation protection & shielding**
  - Power Converters

- Infra-structure & General services:
  - Cleaning & **Consolidating** TT1-TT7 Tunnel (waste disposal)
  - **Cooling and ventilation**
  - Access Control & Personnel Safety System
  - Surface building for power converters, etc.
  - **Safety**
  - Transport and handling in cavern and TT7 tunnel

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Concluding Remarks

- Very exciting physics: discovery of new neutrino flavor ?
- For the moment this is a pre-study and not a project
  - For more detailed studies stronger commitment from CERN management is required (manpower needed)
- TT7 and nTOF beam sharing makes efficient use of PS
  - Neutrino experiment could be completed in 3.7 runs (not 2 years)
- Large part of the required infrastructure is available
- Potential work packages are identified
- Secondary beam production should be inspired on CNGS
- The beam line could be re-used after the experiment for other purposes like target and detector R&D (MERIT), etc.

- **Lots of interesting work ahead, but no resources allocated yet: could we get some ?**

Acknowledgements

- Francesco Pietropaolo, Paola Sala, Alberto Guglielmi (INFN) for the discussions on the experiment and its requirements
- Ilias Efthymiopoulos for providing the IEFC-days timeslot and the discussions on the neutrino facilities
- Massimo Giovannozzi for sharing his knowledge and documentation on the old TT7 beam line
- David Nisbet for his help on the technical aspects for powering the double extraction scheme
- Jan Borburg for his information on the use of septa for the double and single batch extraction scheme

Thanks for your attention