HIGH RADIATION TO MATERIALS FACILITY AS TEST BED FOR PHASE-II COLLIMATORS

Outline

- Why a HiRadMat facility?
- Facility specifications : *beam line & experimental Area*
- Implementation layout in TT60/WANF tunnel
- Schedule & budget envelop estimate

Further information : http://cern.ch/lhc-collimation-project/HiRadMat.htm

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…. on behalf of the HiRadMat working group

EDMS No : 984446

Collimator Phase-II Review
CERN, April 2, 2009

Why a HiRadMat facility?

HiRadMat Facility

3 Why is needed?

- Study the impact of **intense pulsed beams** on materials
  - LHC beam well above damage threshold limits for most materials

- **Effects:**
  - Thermal management (heating)
    - Material damage even below melting point
    - Material vaporization (extreme conditions)
  - Radiation damage to materials – change of properties
  - Thermal shock - beam induced pressure waves

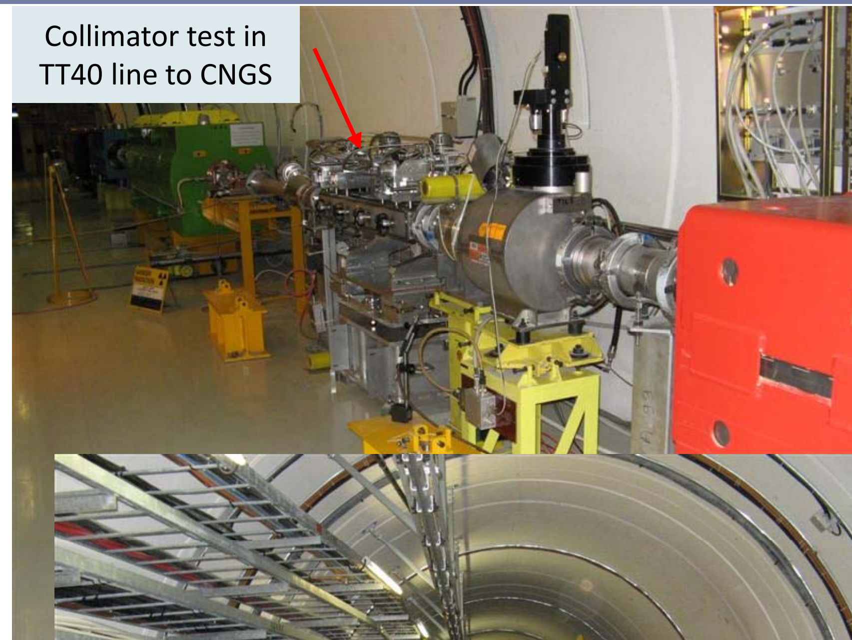
- **Fields of interest**:
  - Beam intercepting devices for LHC : collimators, scrapers, absorbers, dumps
  - Cryo sc magnets : effect of thermal shock waves, radiation damage to sc cables, …
  - Beyond LHC : targetry (targets, beam windows, dumps, etc.) for present (kW) and future (MMW) concepts

HIRADMAT Facility

Why a new facility?

- Necessary to test materials and assemblies **before their operation at LHC**
  - high risk in case of a catastrophic failure inside the machine
- Ad-hoc tests (past experience) **not the proper way to go**
  - several limitations, and interferences with normal operations
  - not recommended from RP view therefore not possible anymore
- Dedicated, well designed facility – **HiRadMat**, included in the collimator Phase-II project as mandatory step for the evaluation of collimator assemblies for LHC and SLHC
- HIRADMAT is included in the proposal of the working group on future irradiation facilities at CERN
- HIRADMAT is included as WP in FP7/EUCARD project as open access facility

Collimator test in TT40 line to CNGS



Facility specifications

- Incoming proton beam
- Experimental area
- Safety issues involved

HiRadMat study group

Coordination
Safety

R. Assmann
Minutes: A. Rossi

Experimental area, ex-perimental infrastruc-ture, handling equipment

technical specification, design, procurement, installation, commissioning

*I. Efthymiopoulos et. al., **EN/MEF***

Radiation impact

*Helmut Vincke, **DG/SCR***

Beam line up to experiment, accelerator infrastructure:

functional and technical specification, design, procurement, installation, commissioning

*C. Hessler, M. Meddahi, B. Goddard, **TE/ABT***

Beam dump, windows, energy deposition and radiation estimates

technical specification, design, procurement

CERN ⇔SLAC (tbc) collaboration

Possibly later: Contribution of other equipment (vacuum, magnets, instrumentation, power supplies, experimental area…)

User specification

R. Assmann
A. Bertarelli
B. Goddard
R. Schmidt
collaborators

Design office contact

*A. Bertarelli, **TE/ABT***

… and interfaces to several CERN groups for technical issues

HiRadMat facility

Specifications

Specification for a Test Facility with High Power LHC Type Beam

R. Assmann, A. Bertarelli, I. Efthymiopoulos, B. Goddard, C. Hessler, T. Markiewicz[1], M. Meddahi, R. Schmidt, J. Sheppard[1], H. Vincke

Abstract

The characteristics of the LHC beam mean that the energy deposited in the event of interaction with accelerator components can be much above the damage thresholds of materials. This report specifies a test facility with high intensity LHC-type beam, as included in the framework of the "phase 2 LHC collimation project" and the "EUCARD proposal to FP7". The specified facility is required to test accelerator components and materials for sufficient robustness with beam shock impact, prior to installation into the LHC or its injectors. A 7 μs long pulse can be extracted about every 30 seconds and delivered into a small transverse area (controllable around 1 mm^2), carrying an energy of up to 2 MJ. The corresponding pulsed peak power is 340 GW for protons and 2.3 GW for lead ions. The facility will also provide opportunity for reproducing and analyzing any possible primary and secondary effects from beam-induced damage encountered during LHC operation.

HiRadMat facility

Proton beam parameters

Specification document

Parameter	**Unit**	**Value (proton beam)**	**Value (lead ion beam)**
Beam energy	GeV	**450**	36.9×10^3 (177.4 GeV/n)
Bunch intensity	particles	5×10^9 to **1.15×10^{11}**	5×10^9 to 4.1×10^{10}
Bunch length	cm	11.2	11.2
Number of bunches	-	1 – **288**	1 – 592
Bunch spacing	ns	25	≥ 25
Pulse energy	MJ	2.4	28×10^{-3}
Pulse length	µs	7.2	7.2
Peak power	GW	340	2.3
Normalized emittance (1σ)	µm	3.5	1.4
$\sigma_x \times \sigma_y$ at exp. (baseline)	mm^2	1.0	1.0
$\sigma_x \times \sigma_y$ at exp. (request)	mm^2	**0.25 – 4.0**	0.25 – 4.0

HiRadMat facility

Design parameters for the experimental area

Specification document

Parameter	Value
Experiments per year	10
Maximum intensity per experiment	1×10^{15} protons <30 full intensity pulses
Waiting time after experiment for de-installation	≥ 2 weeks
Access during experiment (except urgent interventions)	no
Control of experiment and data taking	remote
Maximum intensity per year	1×10^{16} protons

Parameter	Value
Installed experiments	1
Material exposed to beam	C, CFC, Cu, W, hBN, Al, Be, …, advanced composite materials
Volume of exposed material	≤ 16,800 cm^3
Equipment size ▪ Length (flange-to-flange) ▪ Width ▪ Height below beam line ▪ Height above beam line	 ▪ ≤ 7.0 m ▪ ≤ 1.0 m ▪ 1.1 m ▪ ≤ 0.8 m
Weight	≤ 4,000 kg
Handling zone (L × W × H)	15 × 2.0 × 2.2 m^3
Equipment support	comes with experiment – quick installation interface required
Cool-down space	see equipment size
Crane support	mobile cranes sufficient
Handling	no full remote handling, prepare fast handling (e.g. rails)
Beam size/orientation	Controllable beam size to vary energy density, scanning possibility

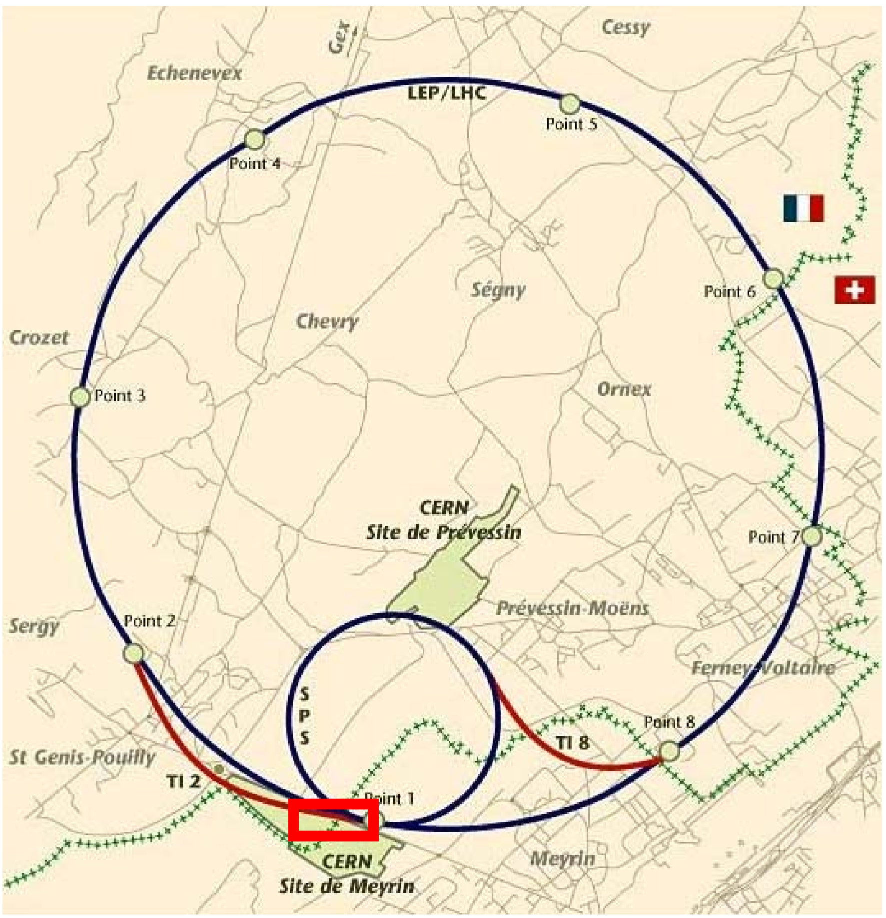
- Additional requirements for the exp. area will depend on the type of equipment and test planned
- Safety and RP constraints should come in addition
- The facility goes along with an RP certified lab (~available today)
- Details including M&O and waste management to come with the technical design of the facility

Implementation layout

After considering several options, the conclusion was to re-use the old WANF tunnel and the TI2 extraction from SPS to LHC

- The TI2/TT60 beam line for HiRadMat
- HiRadMat Experimental Area in the WANF tunnel

Implementation layout

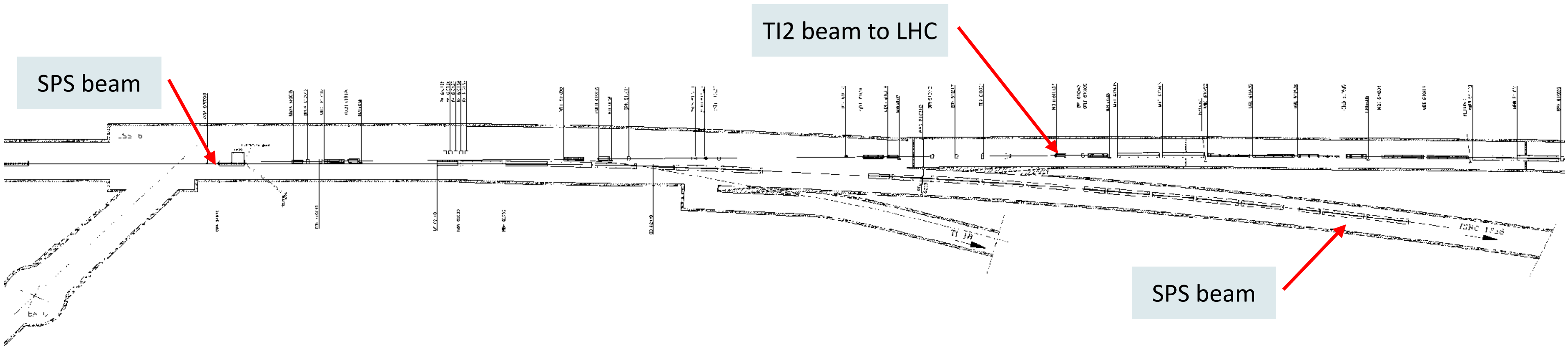


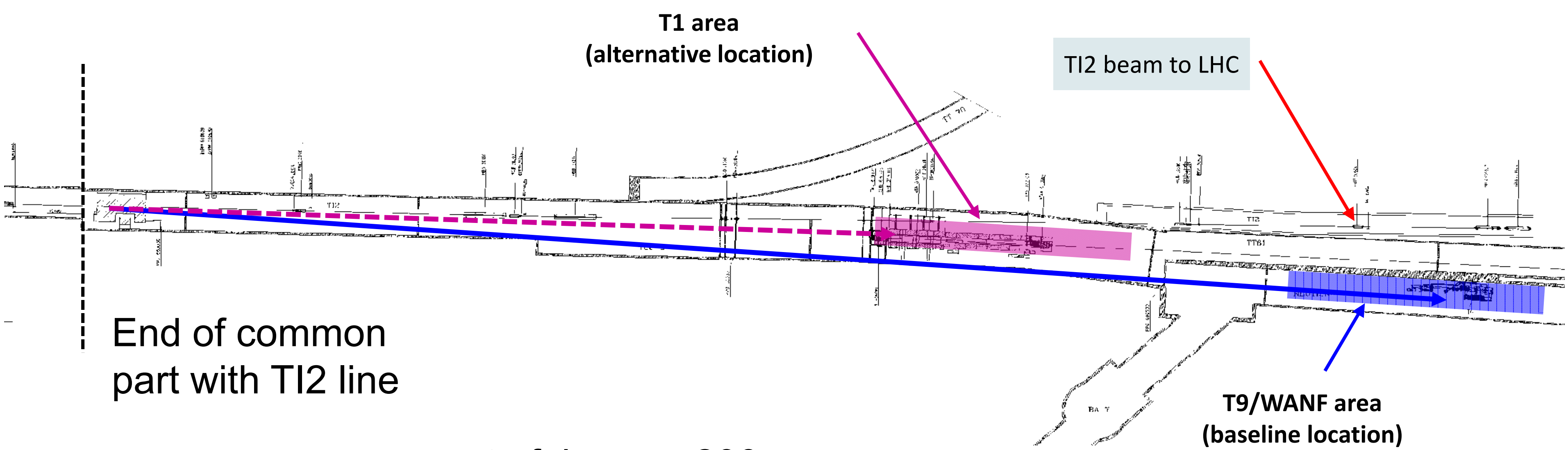
HIRADMAT in the ex-WANF tunnel

- use the existing extraction to LHC/TI2 from SPS
- deviate mid-way the beam towards the TCC6/WANF tunnel
- reuse the old WANF tunnel (T9 target area and secondary neutrino beam) to house the irradiation facility

Implementation layout

The proton beam (LHC type – fast extraction from SPS)



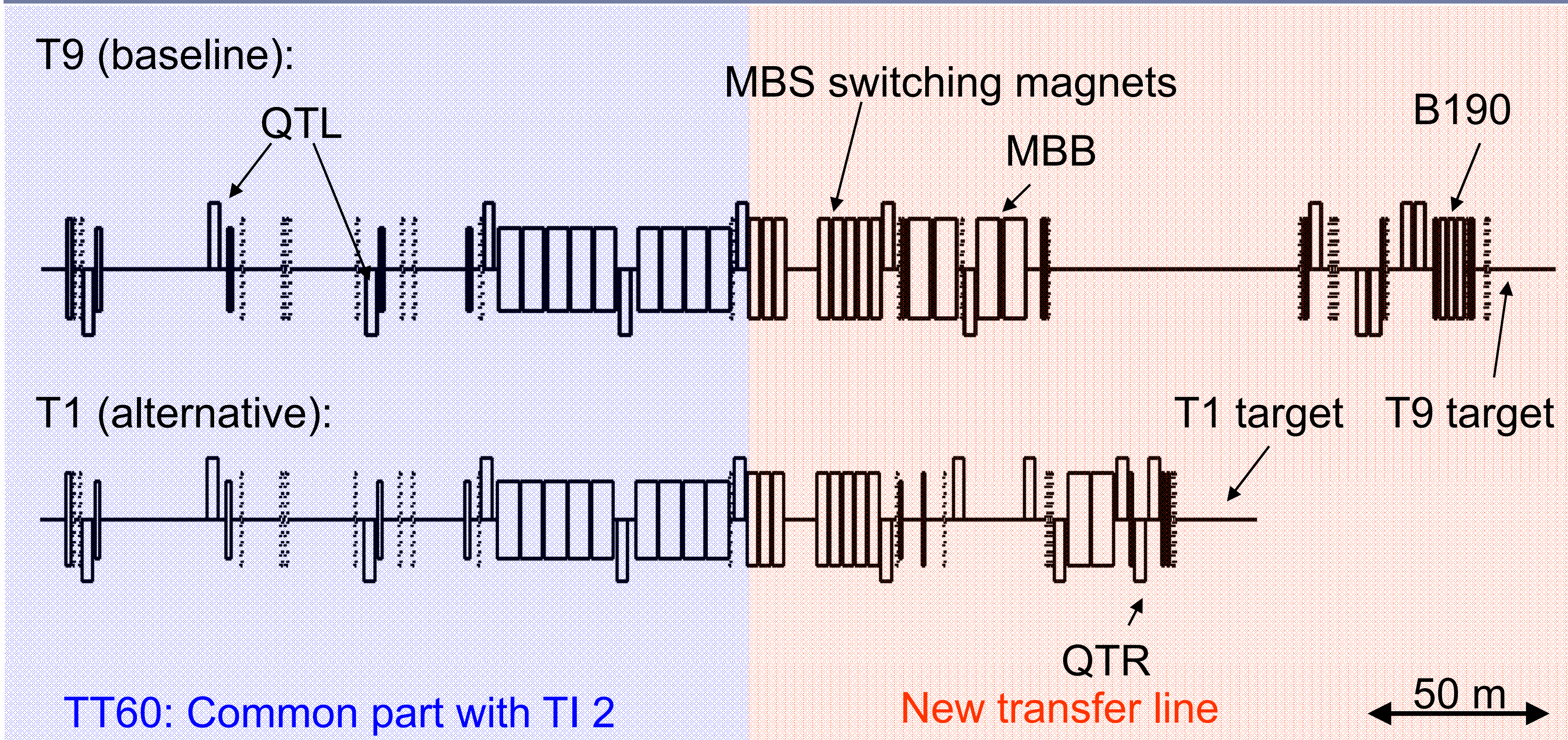


… new part of beam ~200m

I.Efthymiopoulos, CERN

The TI2/TT60 beam line for HiRadMat

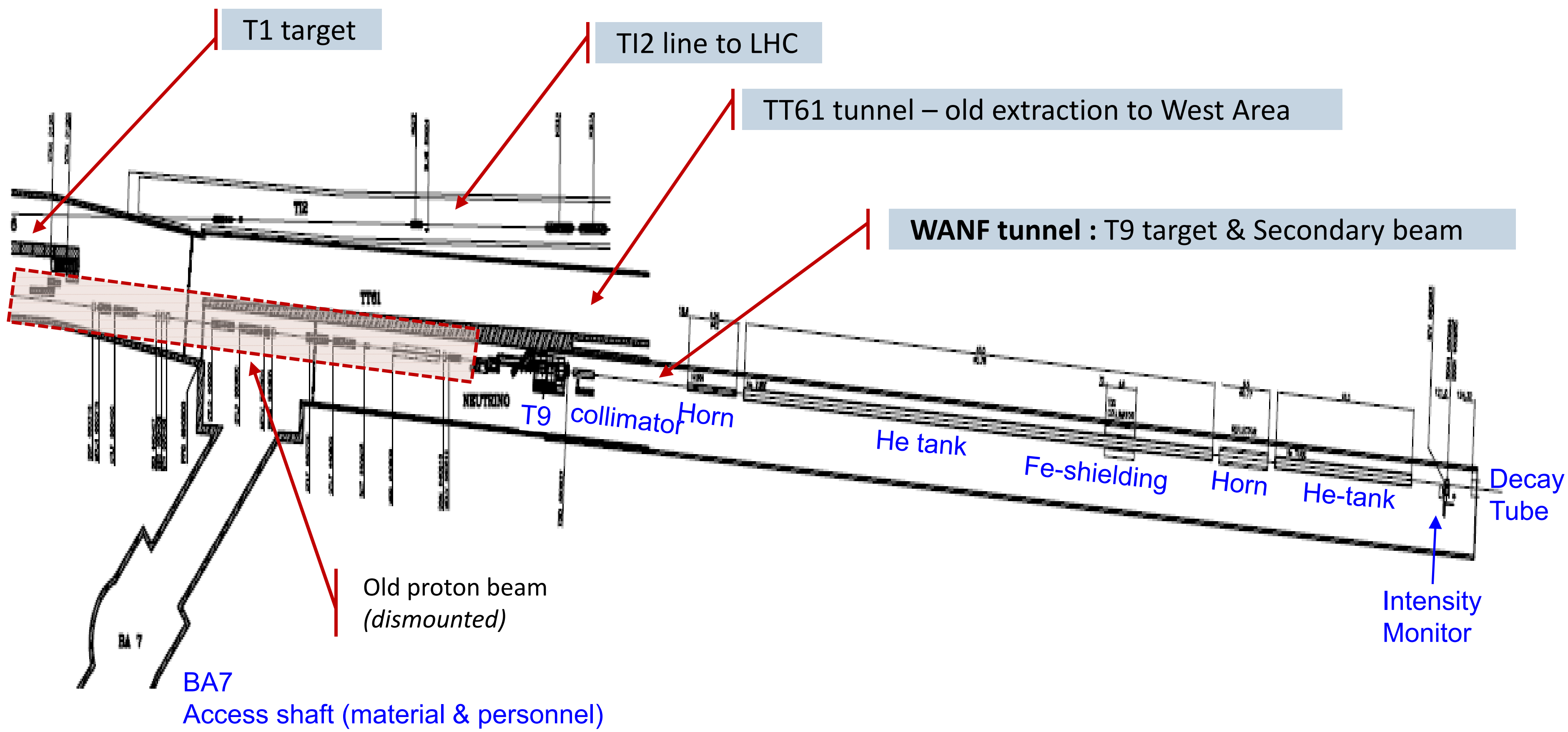
13 The proton beam (LHC type – fast extraction from SPS)



- New beam line similar to the old line to WANF/T1 (almost!)
- No new magnet is required (tbc), power supplies, services, vacuum etc. to refurbish from existing or revive old pieces..

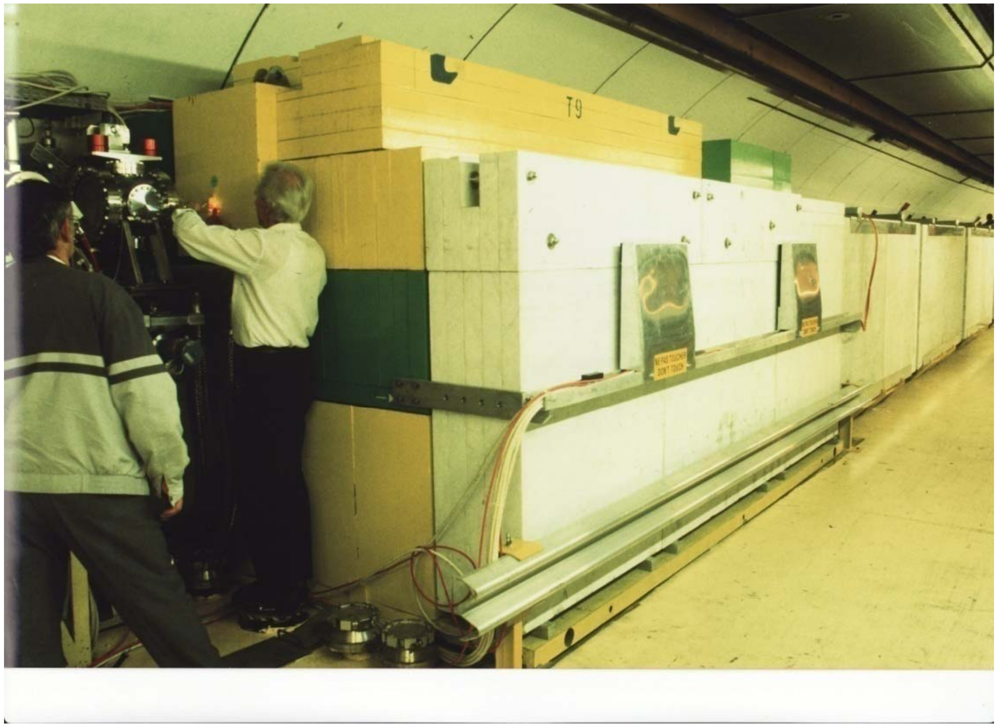
HiRadMat in the WANF tunnel

14 | Layout – status today



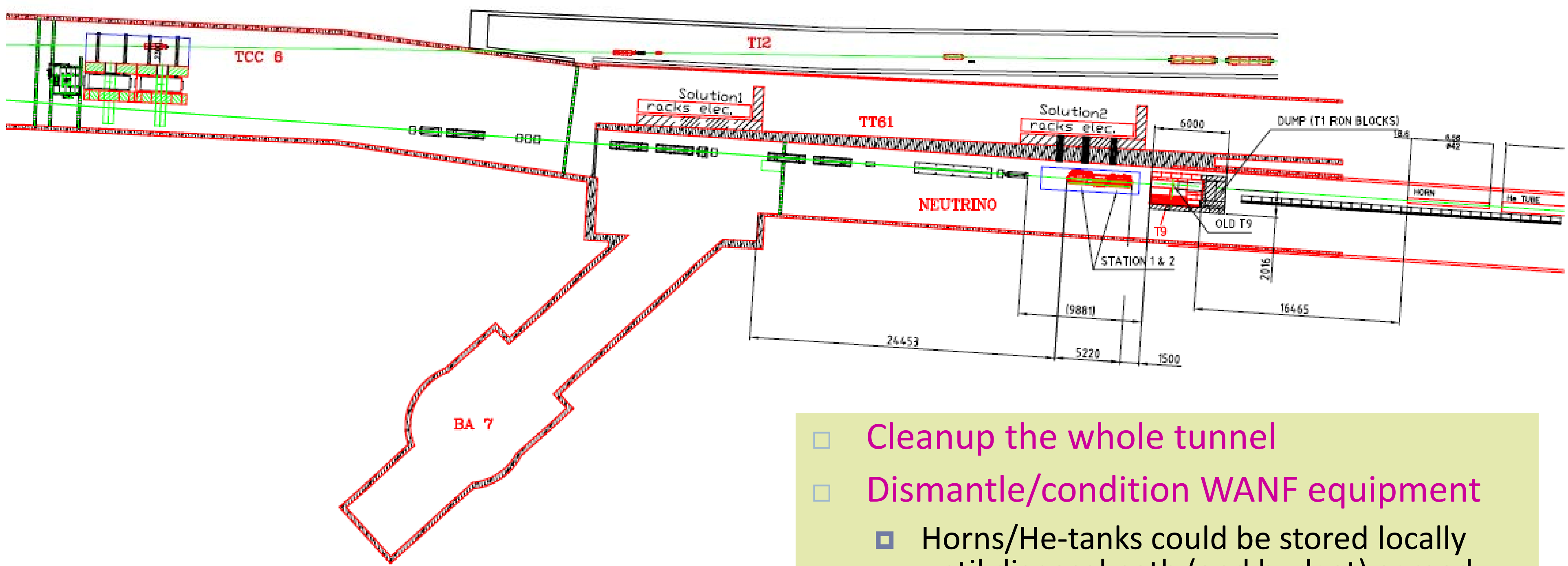
HiRadMat in the WANF tunnel

WANF installation - 1992



HiRadMat in the WANF tunnel

16 | Layout proposal



- Cleanup the whole tunnel
- Dismantle/condition WANF equipment
  - Horns/He-tanks could be stored locally until disposal path (and budget) agreed
  - Move the rest to waste
- Maintain escape passage from tunnel end

- Test area upstream the T9 target
- Convert T9 to a beam dump
  - Remove target head and replace with special blocks like in CNGS hadron stop: Graphite core, Al plates with cooling
  - Add lateral shielding (concrete)
  - Reuse blocks from T1 (TAX area) to add downstream shielding

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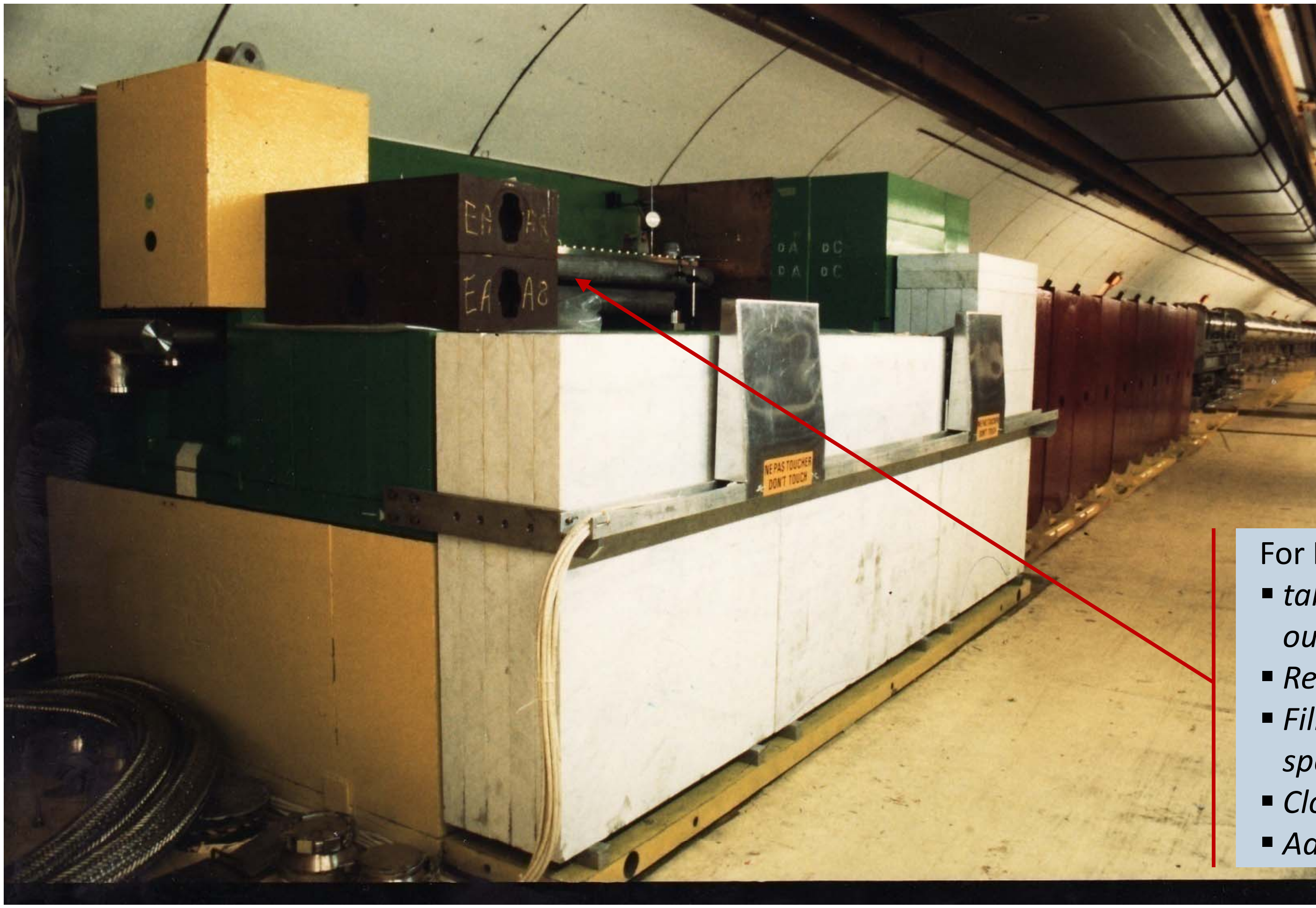
HiRadMat in the WANF tunnel

WANF Tunnel during installation - 1992



For HiRadMat:

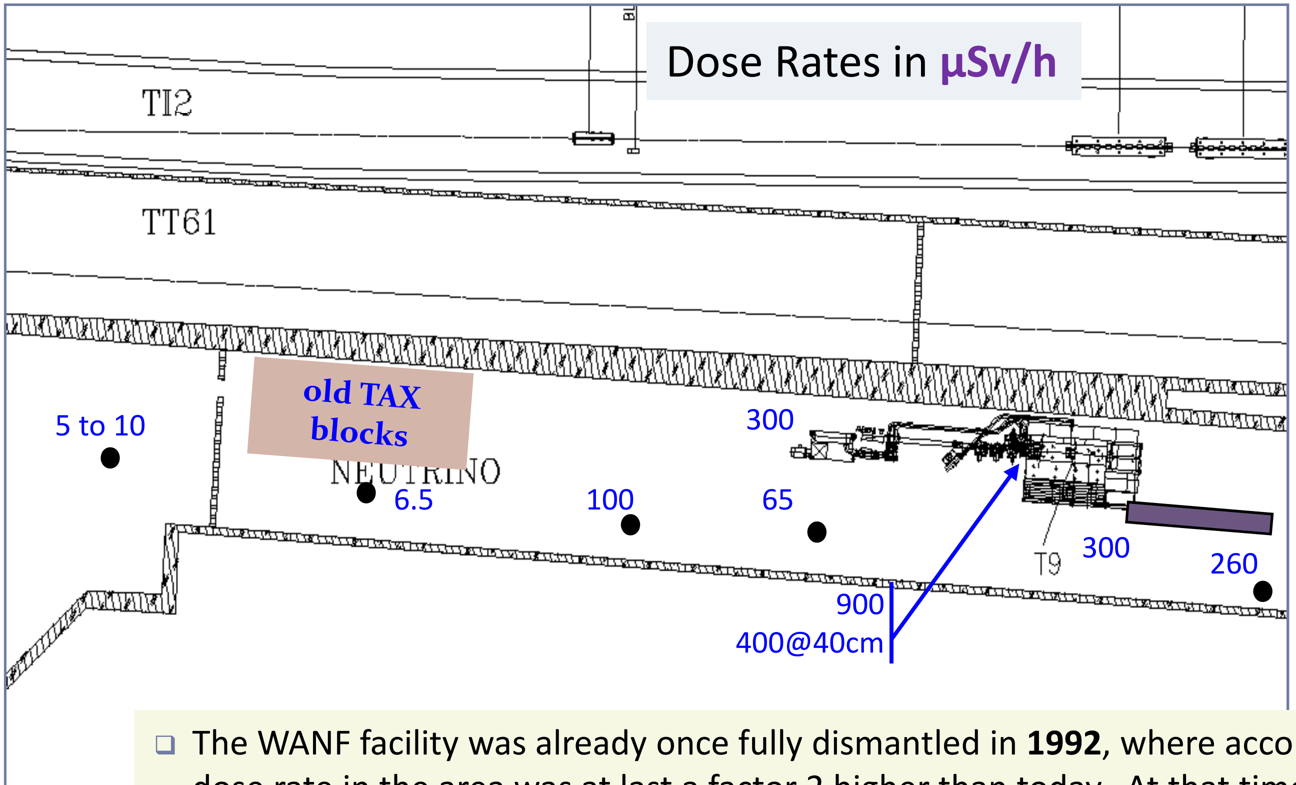
- *take top part of the T9 shielding out (remote operation)*
- *Remove target head (remote)*
- *Fill target head space with special blocks to act as dump*
- *Close top shielding*
- *Add shielding downstream*

HiRadMat in the WANF tunnel

WANF tunnel – September’08

HiRadMat in the WANF tunnel

Radiation survey (24/09/08)



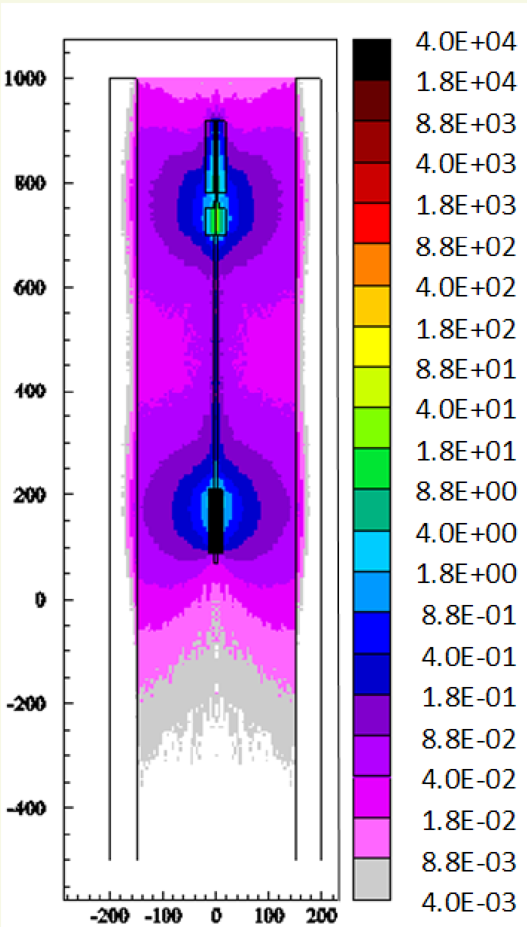
- Dose rate inside and downstream the target shielding will be significantly higher than 1 mSv/h
- Gamma spectroscopy of concrete samples taken in the area showed that the concrete tunnel structure is radioactive

- The WANF facility was already once fully dismantled in **1992**, where according to available reports the residual dose rate in the area was at last a factor 2 higher than today. At that time a collective dose of 210 mSv was taken by the personnel. The full refurbishment of the area caused an additional collective dose of 170 mSv.
- Hence, as a first order estimate at least a factor of 2 is gained, that can be further reduced since the T9 target shielding won't be dismounted and the "new" WANF was made in view of a future dismounting
- Detailed studies and dismantling procedure will be established with help of outside expert companies and RP safety specialists

HiRadMat Operation

Radiation environment during collimator testing

Dose rate after1E16 protons in 200 days + 1 month of cooling



	10 full SPS beam cycles (3.3E13 protons per cycle)		**1E16 protons** equally distributed over 200 days	
Cooling time	Dose rate between wall and beam line	Max. value	Dose rate between wall and beam line	Max. value
	[mSv/h]	[mSv/h]	[μSv/h]	[mSv/h]
1 hour	26	1300	800	32
12 hours	2	66	600	24
1 day	0.660	15	480	20
1 week	0.066	3.3	280	12
1 month	0.026	0.7	200	6

- The dose rate level in the tunnel after one year of operation is higher than the dose rate in the empty WANF tunnel.
- The long term irradiation levels are mainly caused by the two elements installed in the beam line and not by the concrete walls
- In case the carbon jaws are replaced by copper or tungsten jaws, the dose rate will increase significantly

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Schedule and budget envelop

HIRADMAT in the WANF tunnel

Schedule

- Possible project schedule "green light" :
  - **July'09 :** prepare detailed study – review
  - **July'09-Oct'09 (before LHC startup):**
    - Prepare dismantling of WANF ; system/services maintenance
    - Dump design, *procurement, construction*
  - **Oct'09 – Nov'10 :** limited access due to LHC operation
    - prepare services, power building etc. at surface
  - **Shutdown'10 :** installation
  - **Apr'11 – Sep'11:** commissioning
  - **Oct'12 :** Facility ready for operation

- Tendering & Finance committee will be an important factors in the planning
- Resources in various groups must be discussed/agreed

HIRADMAT in the WANF tunnel

Budget

Beam line	[KCHF]
Magnet refurbishment	250
Cabling	360
Transport/installation	110
Survey	45
Power converters	600
Vacuum system	245
Beam instrumentation	240
Water cooling	125
Controls	55
Interlock	55
Drawings	15
total	**2’100**

Exp. Area	Baseline [KCHF]	Upgrade
T9 target/dump	190	20
Crane refurbishment	200	280
Ventilation	250	350
Transport	140	
EL services	200	
Civil engineering	60	
HIRADMAT installation	120	
Aux.	76	
total	**1’236**	**650**
WANF dismantling	**464**	
M&O/year	**70**	
Dismantling	**600**	

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Summary

HIRADMAT in the WANF tunnel

Summary

- The HiRadMat is a key facility for the collimation Phase-II project to test and validate the foreseen collimators using a **450 GeV/c high-power pulsed beam** before their installation at LHC
- The proposed facility will also serve as test bed to address the needs for the **near beam assemblies** and **other sensitive material** like sc magnets, instrumentation, beam windows, masks etc for LHC and its upgrades
- The **baseline implementation in the WANF tunnel** satisfies all the requirements, and is in agreement with RP and safety guidelines
  - dismantling the old WANF tunnel is an issue but can be properly handled, including external expertise from specialized companies
- The budget estimate for its construction: **3.5 MCHF (beam line + base facility) + 0.5MCHF (WANF dismantlng) + 0.6 MCHF (upgrades)**, goes beyond what is foreseen for the collimation Phase-II project.
- Support is needed to find additional funds to advance the study and construct the facility on time for the Phase-II collimator project, sometime in 2011.