Radiation Protection Aspects of the LHC Transfer line and Sector Tests

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AB-OP

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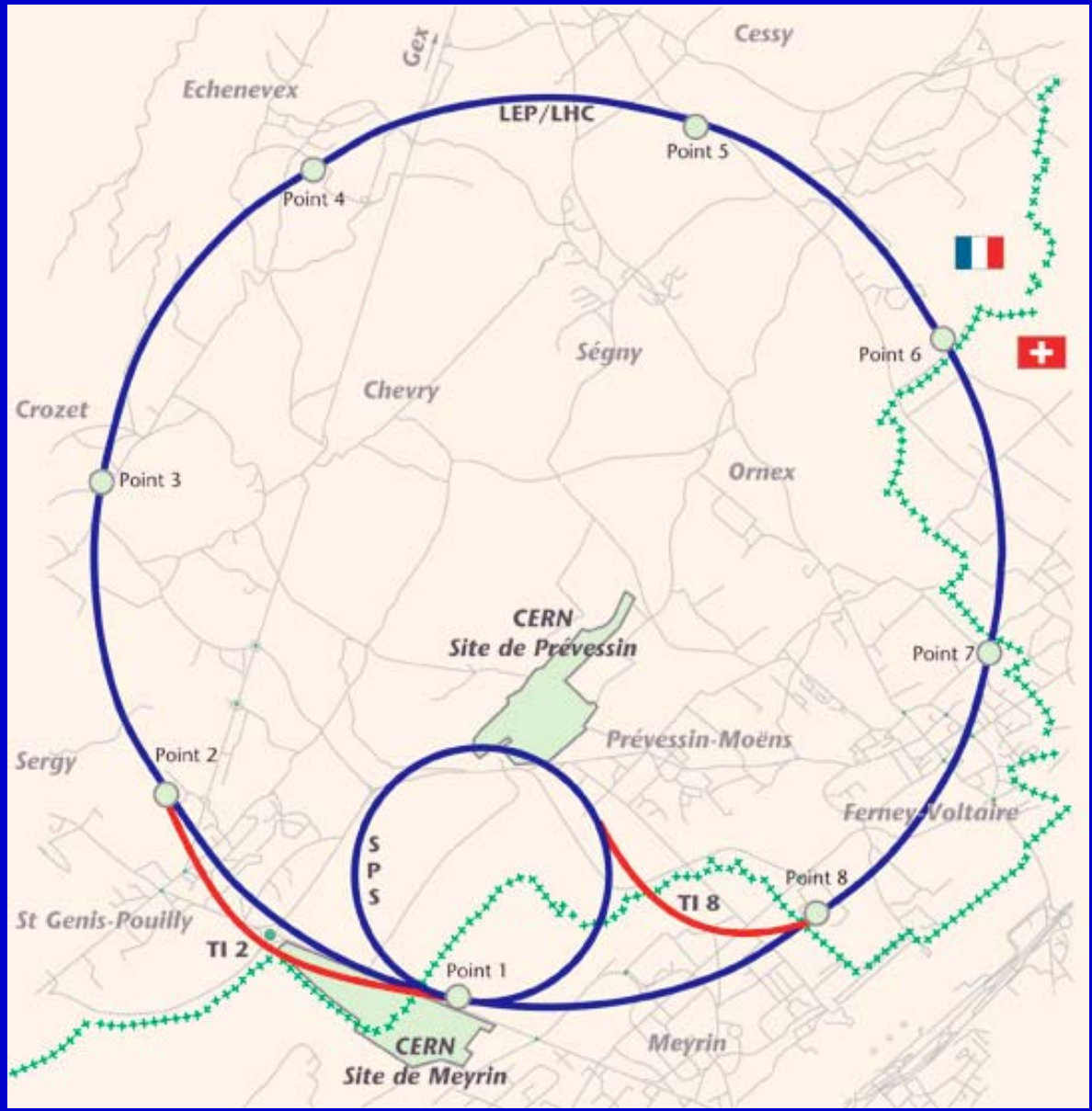
TIS-RP

5 December 2003


Gex
Cessy
Echenevex
LEP/LHC
Point 5
Point 4
Ségny
Point 6
Chevry
Crozet
Point 3
Ornex
CERN
Site de Prévessin
Point 7
Prévessin-Moëns
Sergy
Point 2
Ferney-Voltaire
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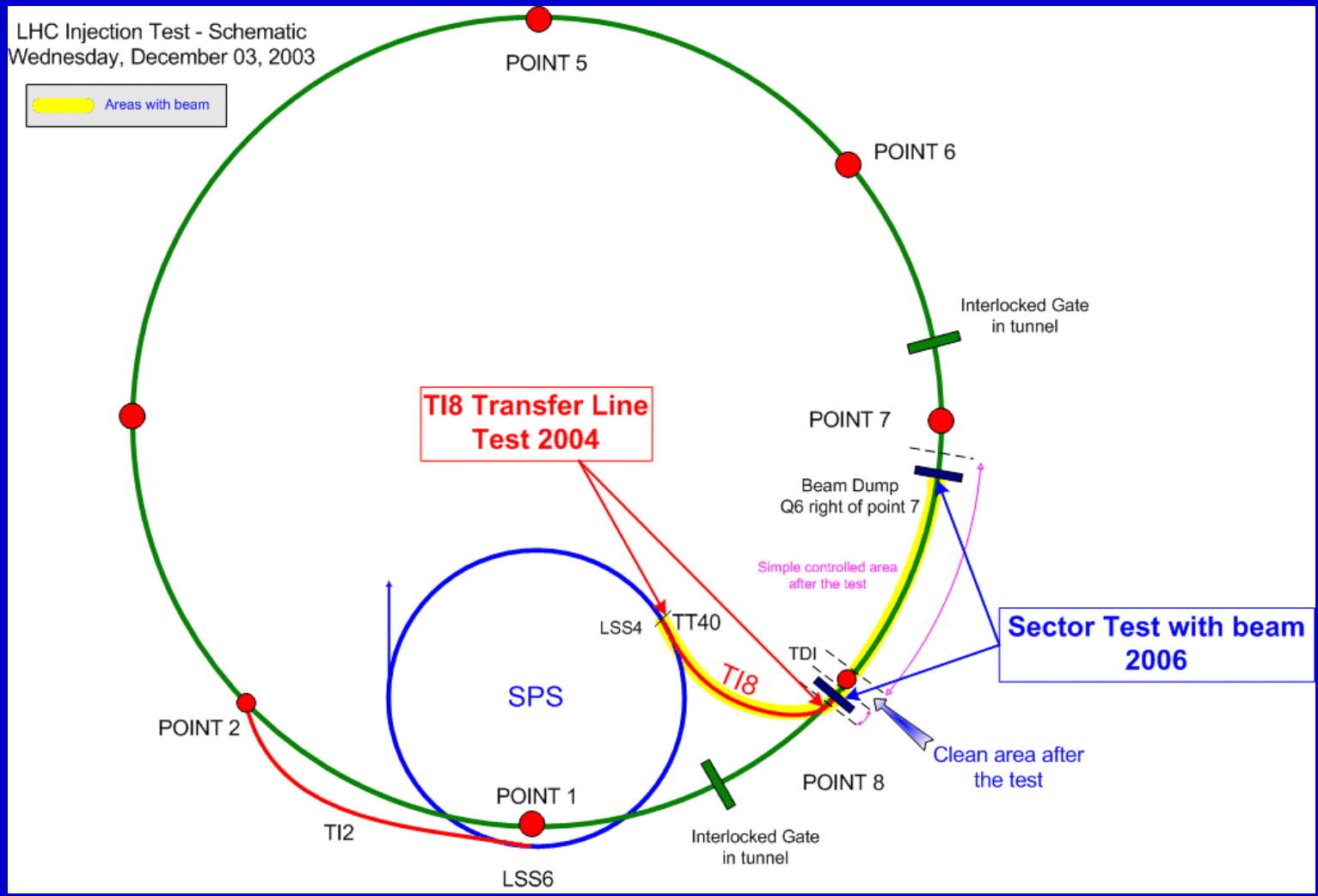
Point 8
TI 8
St Genis-Pouilly
TI 2
Point 1
CERN
Site de Meyrin
Meyrin

Upcoming beam tests



TI8: 4 x 24 hours, Sept/Oct 2004

LHC Injection Test: 2 weeks, May 2006

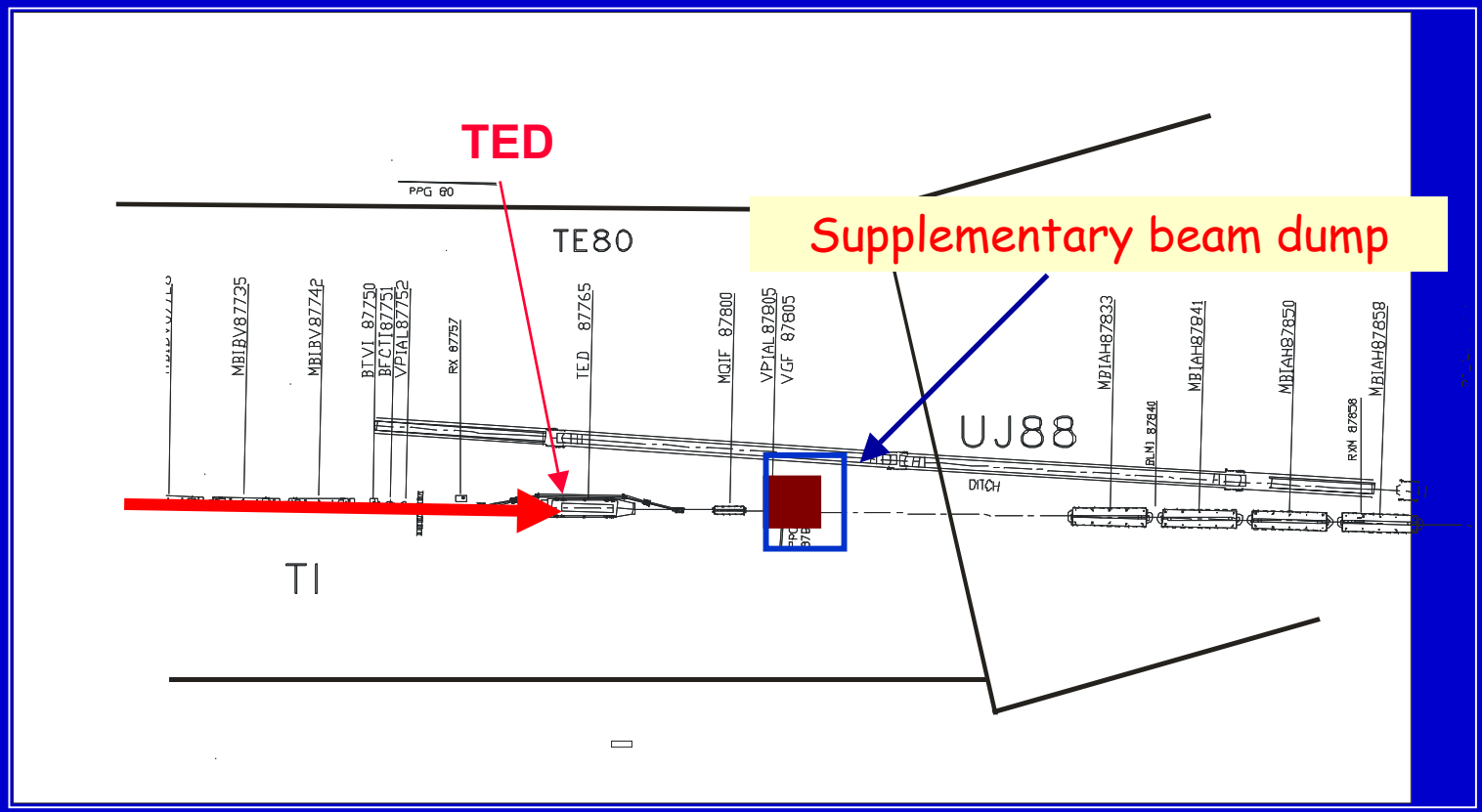
TI8 – test with beam

Aim: extract beam to TED (Dump) at end of TI8

- **September – October 2004**
- **Length 2 x 48 hours**
- **Intensity**
  - **LHC pilot beam (one bunch of 5 to 10 x 10^9 protons) foreseen for the most part.**

TI8 injection test

Beam will be extracted from the SPS down the TI8 transfer line to a beam dump (TED 87765)



5 x 10^9 p/pulse, 5 x 10^{13} total/24 hours 450 GeV

TI8

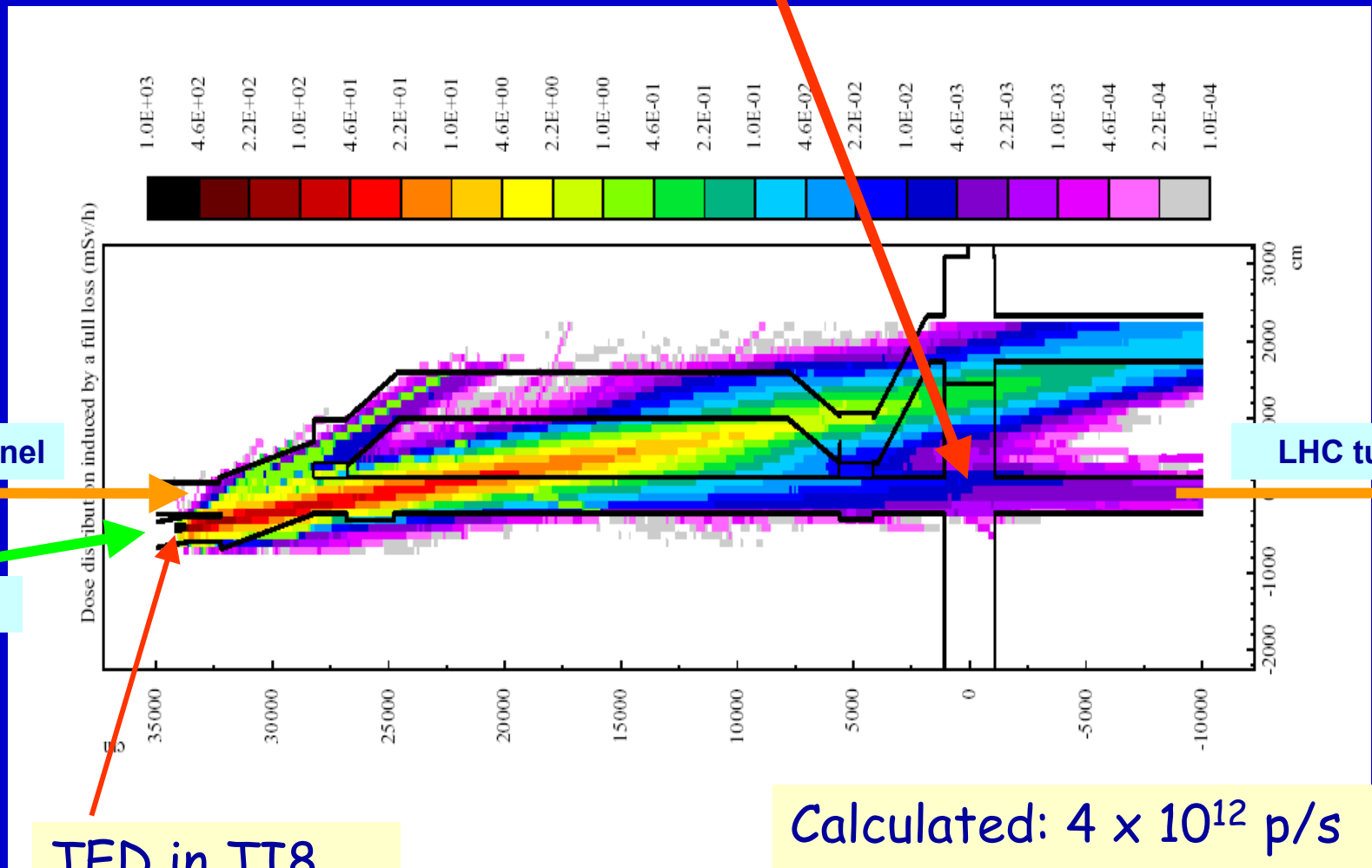
Objectives

- **Verify equipment functionality:**
  - Bumpers, Extraction Kickers, Extraction Septa, Magnetic elements, Power converters, Interlocks, control system, surveillance systems, vacuum
- **Commission beam instrumentation**
  - BPMs, BLMs, BCT, Screens, BST
- **Beam measurement & correction**
  - Trajectory acquisition and correction
  - Reproducibility of trajectory
  - Matching from SPS
  - Optics in line, tilts, matching to LHC
  - Aperture
  - Check corrector and BPM polarities
- **Preparation for LHC injection test…**

TI8

Monte Carlo Simulations

High Energy Muons – Impact on LHC-b

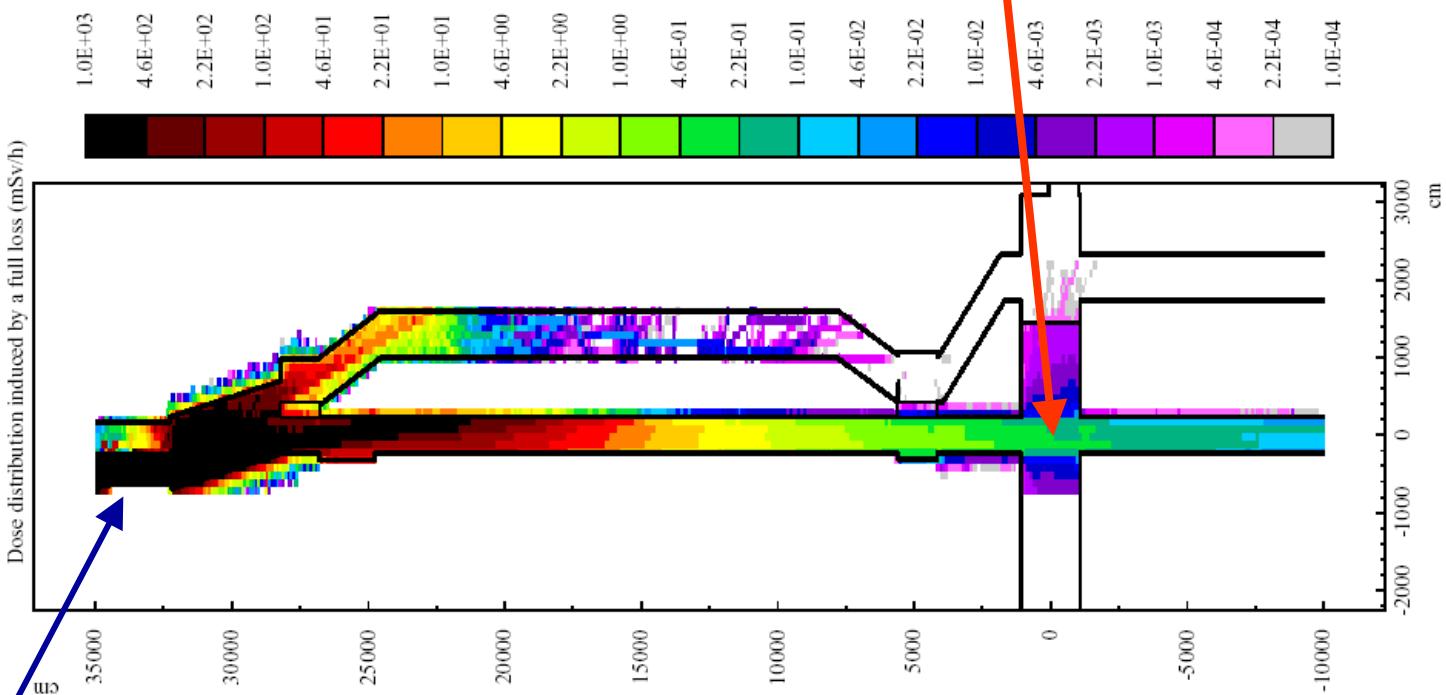


Calculated: 4×10^{12} p/s

Test: 5×10^{8} p/s

Monte Carlo Simulation

Hadrons – Impact on LHC-b

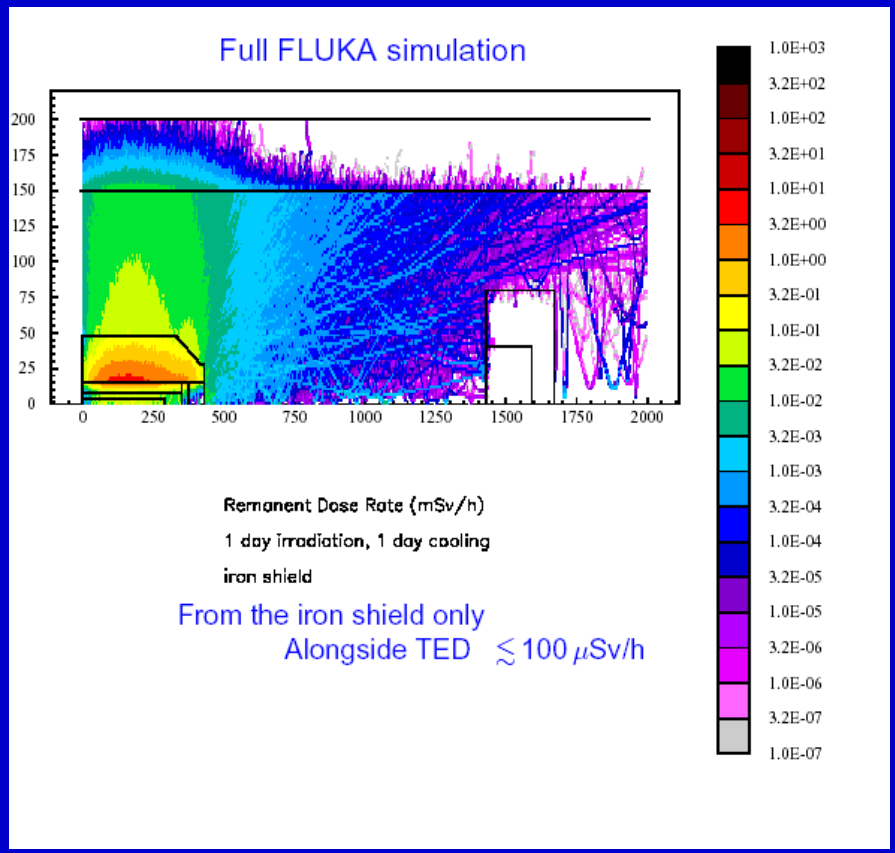


TED in TI8

Calculated: 4 x10^{12} p/s
Test: 5 x 10^{8} p/s

TI8

TED Remenant Dose rates



Dose rates calculated for : 6.25×10^9 p/s;

Test: 5×10^8 p/s

Contribution from TED only

Dose rates for 1 day irradiation and 1 day cooling

Intensity 6.25×10^9 p/s

Alongside TED: 120 μSv/h

Downstream face of TED: 3 mSv/h

TED Remenant Dose rates

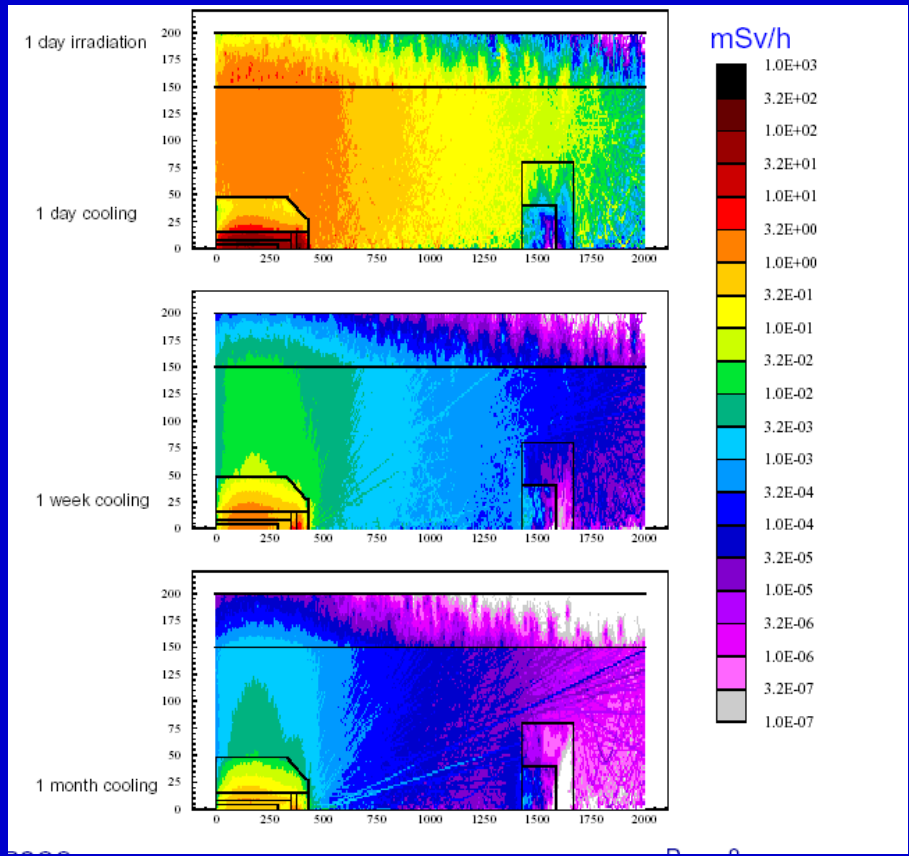
We have to deal with particles that escape from the dump: There will be 3×10^5 hadrons per second with energies greater than 1 GeV leaving the downstream face of the TED.

An extra beam stop $160 \times 80 \times 80$ cm^3 of iron surrounded by 80 cm concrete will be required after the TED to prevent activation of the downstream areas.

We also have to deal with activation of the concrete walls. The dose rates alongside the dump become:

1 day cooling:	1 mSv/h
1 week cooling:	100 μSv/h
1 month cooling:	25 μSv/h

Dose rates behind the secondary dump are 100 μSv/h after 1 day of cooling but are negligible after 1 month.



TED + Concrete Wall

< 1 mSv/h (^{24}Na, $T_{1/2}$ = 15 h)

Dose rates calculated for : 6.25 x 10^9 p/s; Test: 5 x 10^8 p/s

Radiation

- **Simulations performed assuming:**
  - **6.25 x 10^9 p/s i.e. 5.4 x 10^{14} protons in 24 hours**
- **Remnant dose rates (after one day irradiation & one week's cooling)**
  - **Along side TED: ≈ 100 μSv/h**
  - **Downstream face of TED: ≈ 3 mSv/h (max.)**
  - **Some irradiation of concrete walls around TED**
- **UX85**
  - **On Beam line 1.5 μSv/h (muons)**

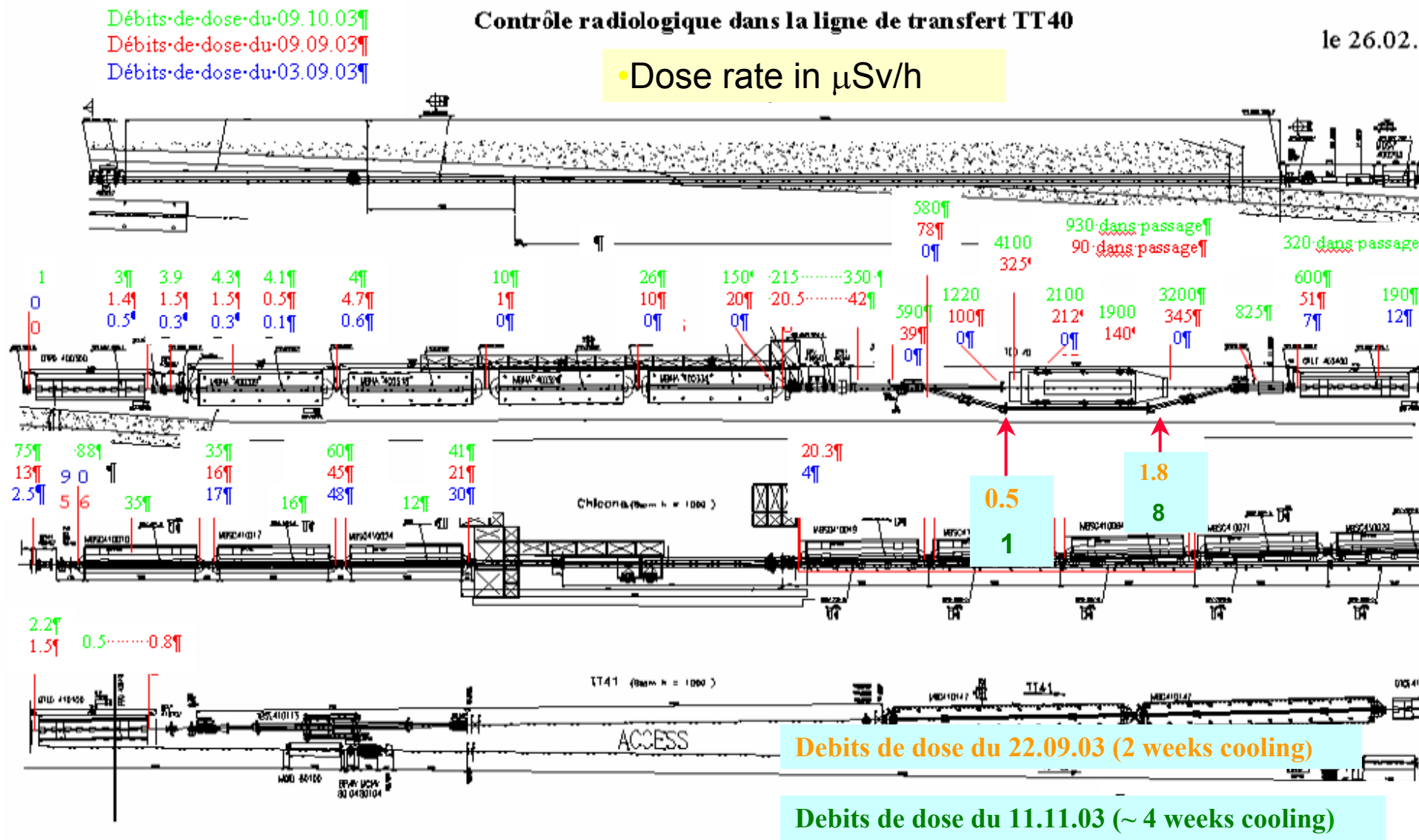
Planned total intensity in 24 hours: ≅ 5 x 10^{13}

TIS

TT40 test

- Extraction from SPS into TED just downstream.
- 2 * 24 hours
- 8-9th September 2003
  - 24 hours with 5 to 10 x 10^9 protons per extraction
  - Total $\approx$ 1.3 x 10^{13}
- 8-9th October 2003
  - 24 hours with 5 to 10 x 10^9 proton per extraction
  - and for a period 12 bunch extraction
  - Total $\approx$ 1.4 x 10^{14}

- Careful measurements performed before and after by RP group $\rightarrow$


Débits de dose du 09.10.03
Débits de dose du 09.09.03
Débits de dose du 03.09.03
Contrôle radiologique dans la ligne de transfert TT40
le 26.02.
Dose rate in μSv/h
0.5
1
1.8
8
ACCESS
Debits de dose du 22.09.03 (2 weeks cooling)
Debits de dose du 11.11.03 (~ 4 weeks cooling)

Results of TT40 tests – activation of concrete

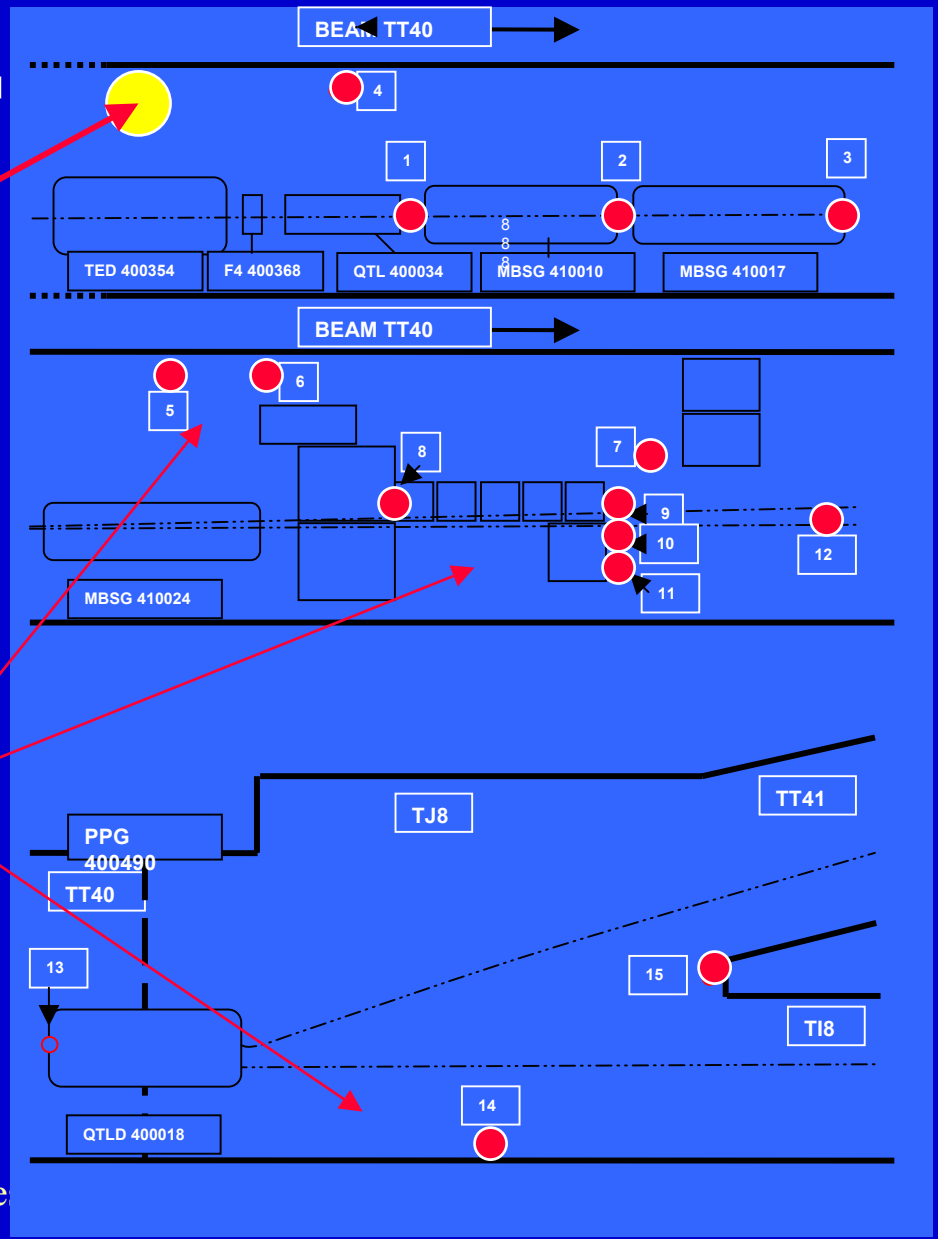
Date de mesure	^{24}Na	^{42}K	^{152m}Eu	^{153}Sm
10/09/03	5000 ± 400	745 ±104	127 ± 36	64 ±13
17/09/03	< 5	< 30	< 45	< 9

Specific activity in mBq/g of the "carrotte"

Echantillons 1 à 15	^{24}Na	^{54}Mn
Lot entier 1-15	< 2	1.1 ± 0.7
7	5 ± 1	< 4
8	< 6	< 3

Specific activity in mBq/g (No. 1 – 15)

Negligible!



Access Doors interlocked in Access Safety CHAIN 2 for the Extraction Test TI8

24.-25. September 2004
30.-31. October 2004

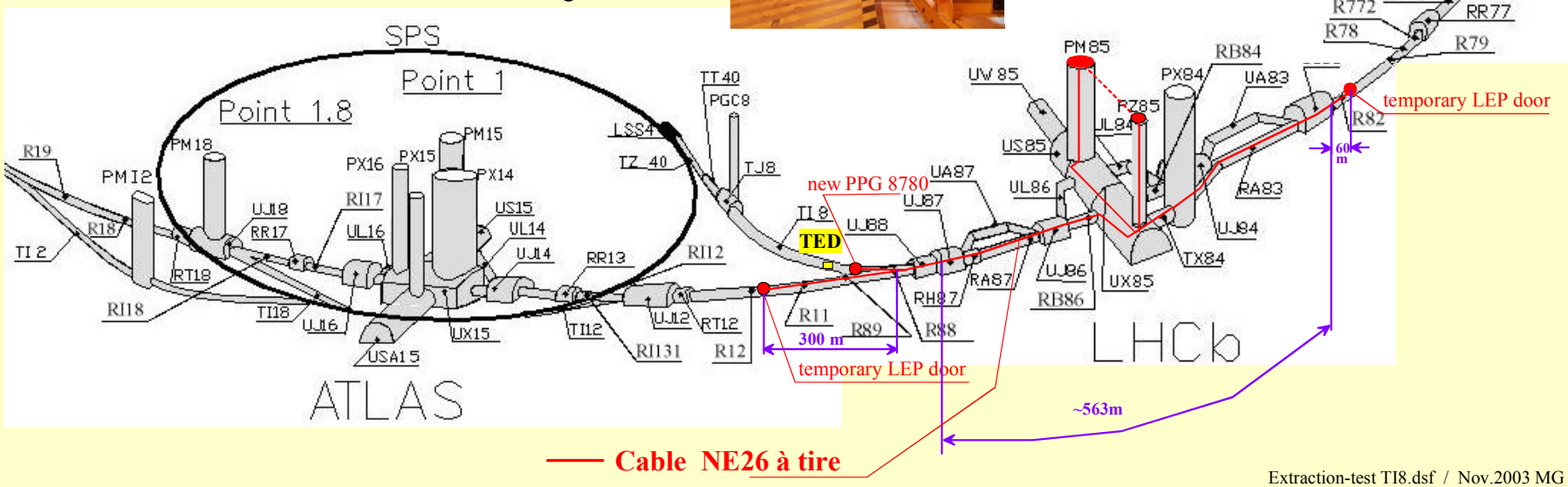
Elements interlocked in Machine Safety CHAIN 2

Kickers MKE
Septa MSE
Bends BHC
TED TT40
} OK

Elements interlocked in Machine Safety CHAIN 3

TBSEL	OK
MBI	cable missing
MBIA V815	cable missing
TED TI8	cable missing

PM 85, PZ 85
Interlock on sliding doors



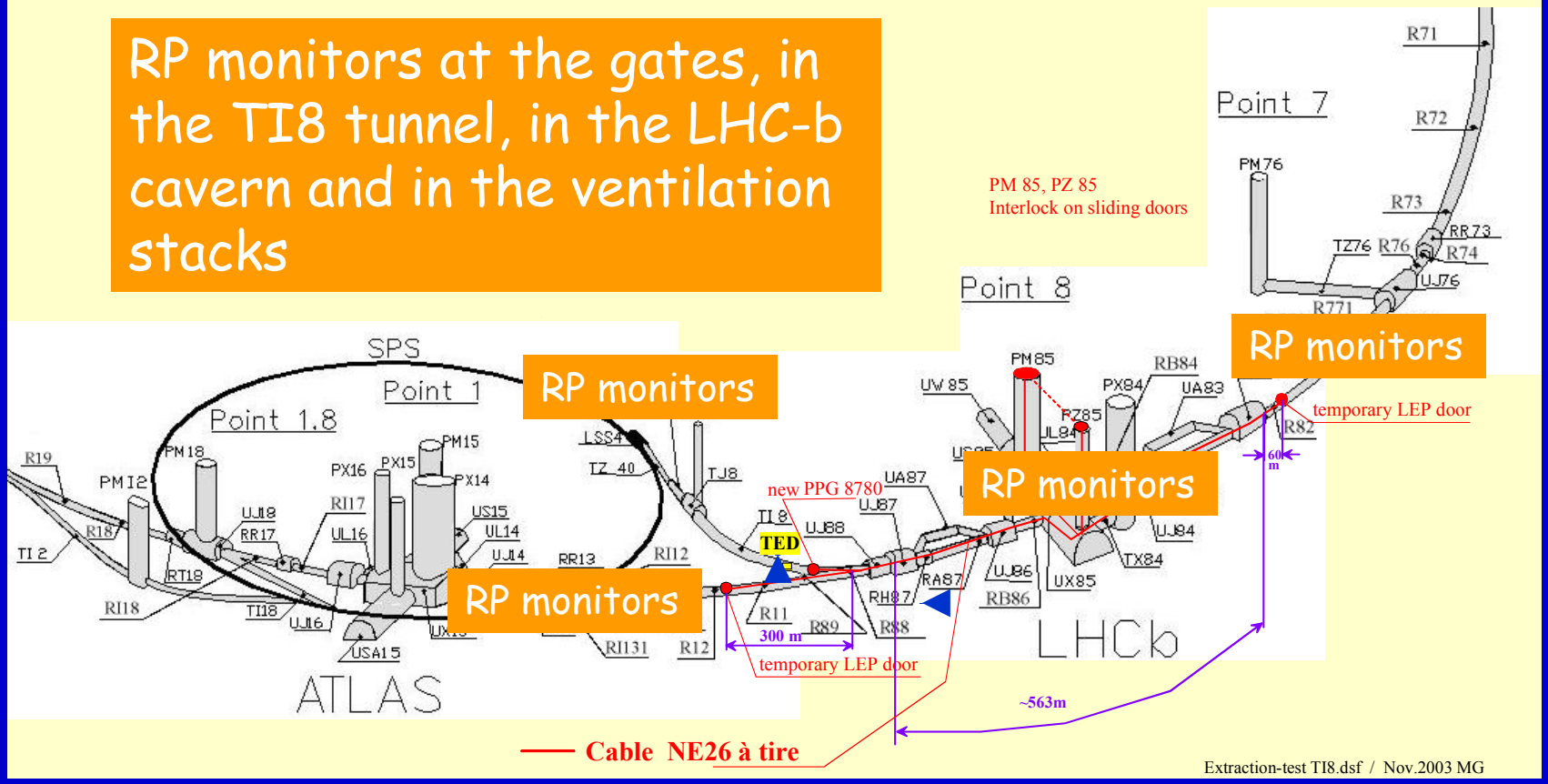
Extraction-test TI8.dsf / Nov.2003 MG

Access and RP Monitoring

Access Doors interlocked in Access Safety CHAIN 2 for the Extraction Test TI8

24.-25. September 2004
30.-31. October 2004

RP monitors at the gates, in the TI8 tunnel, in the LHC-b cavern and in the ventilation stacks



Access

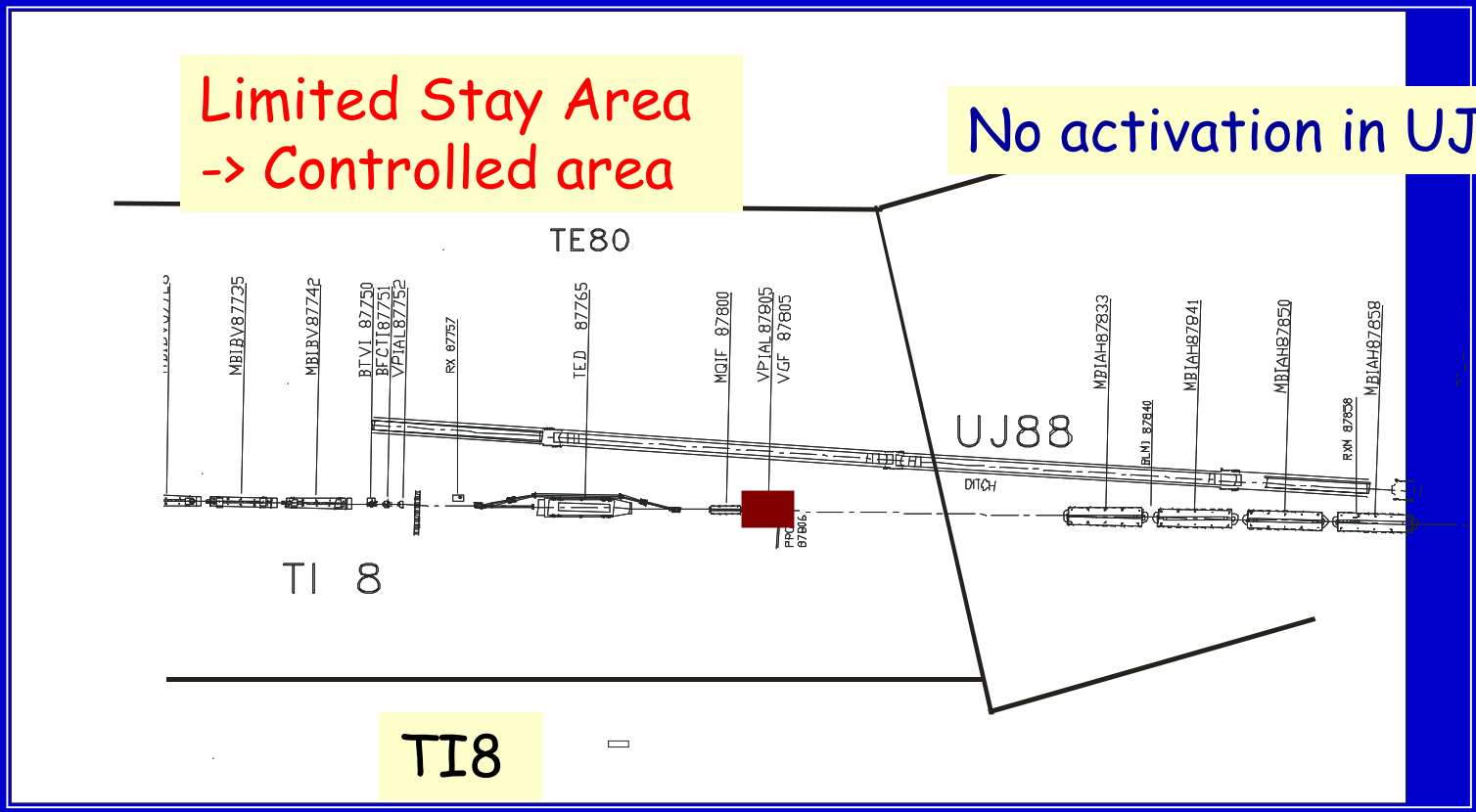
- No access to underground areas around point 8
  - PM85
  - PZ85
  - Sector 7-8
  - Sector 8-1

- All gates will be interlocked.
- All gates will have radiation monitors also in the interlock chain.
- Permitted radiation level outside zone < 0.5 μSv/h
- Decommissioning procedures:
  - Radiation survey will be performed before removal of access gates etc

TIS

Radiological classification

After the test:



After test : TI8 including TED → Simple Controlled Radiation Area

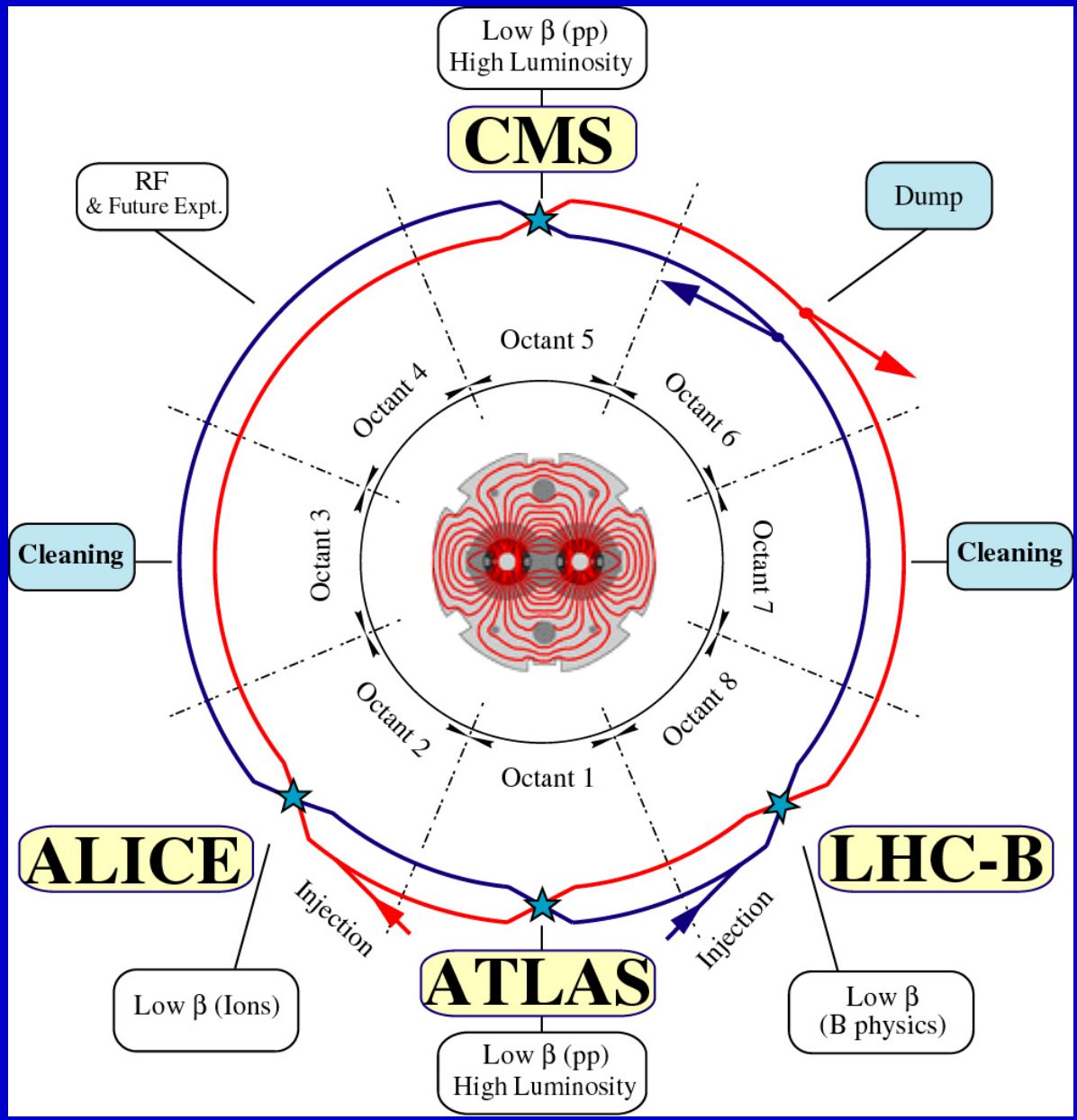
UJ88 -> Supervised Area (< 0.5 μSv/h)

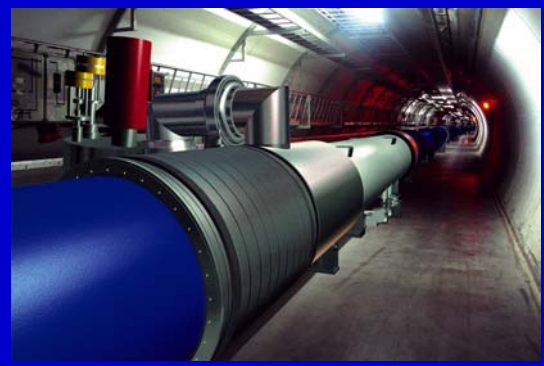
TI8 conclusions

- 4 days with low intensity beams
- Beam on to dump plus supplementary dump
- Area which sees beam is already a Simple Controlled Area and will remain so.
- Proposed access zone sees < 0.5 μSv/h
- Negligible Activation
  - Confirmed by measurements in TT40
- Radiation Monitoring
  - At all gates
  - Ventilation
  - LHCb cavern
  - Dump Area

TI8

LHC Injection test 2006



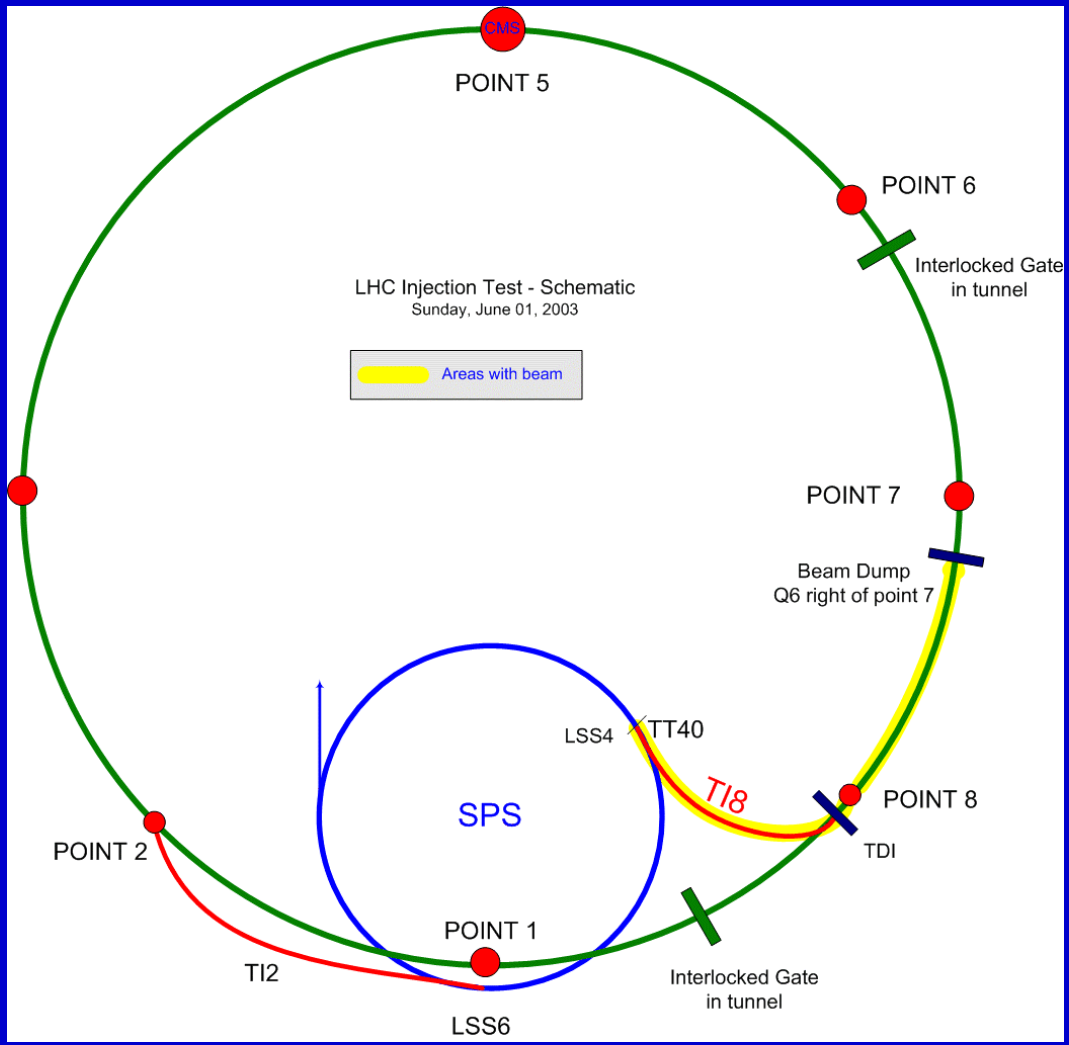


Nominal performance:

- **2808 bunches per beam**
- **1.15 x 10^{11} particles per bunch**
- **L ≈10^{34} cm^{-2} s^{-1}**

Injection test in 2006

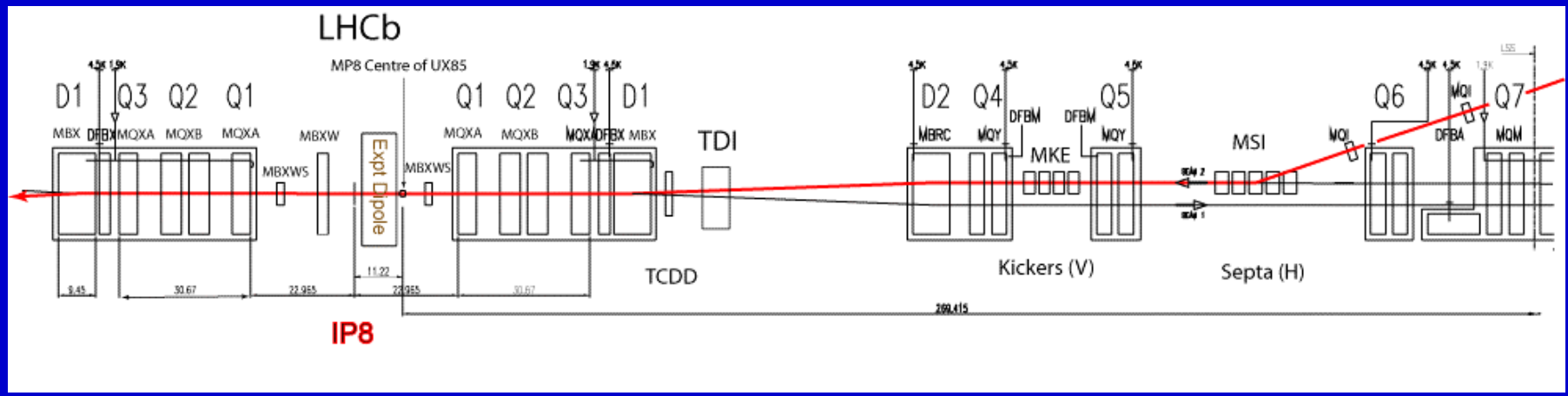
Recently approved - 2 weeks, May 2006



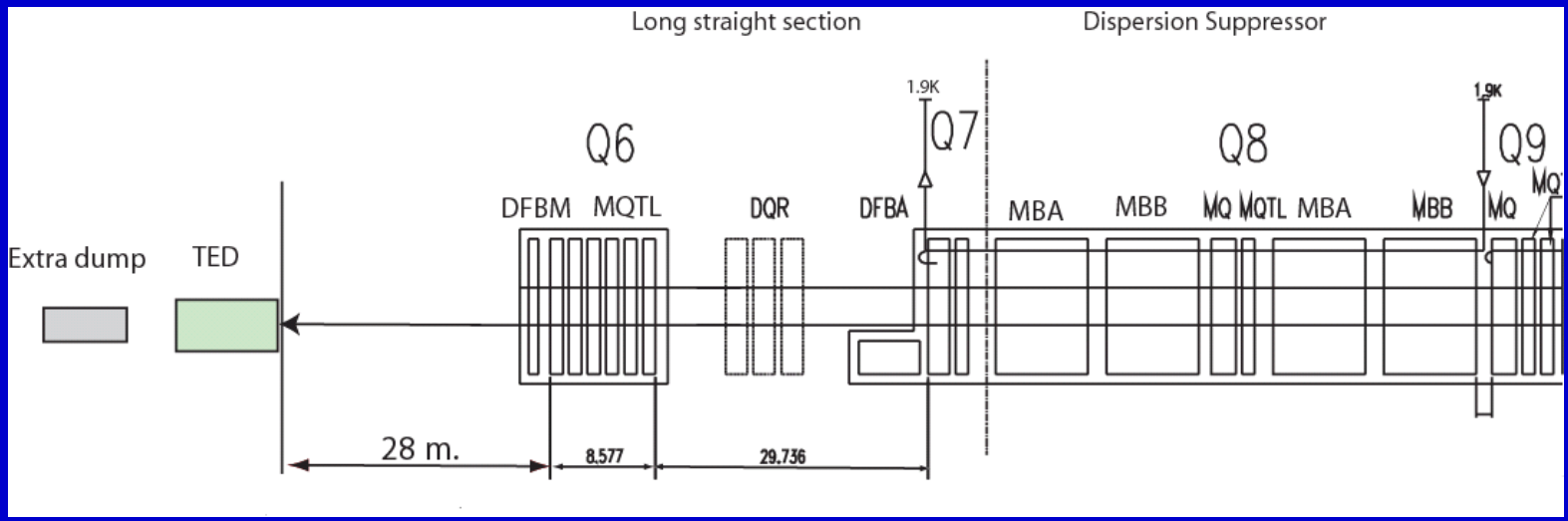
3.3 km of the LHC including one experiment insertion and a full arc

Layout

Point 8



Point 7



Motivation

1. Check that it works, no problems with ongoing installation

- Beam is the most powerful diagnostic tool in accelerators:
- Beam gives us the only 100% sure diagnostic that the aperture in the cold machine is free and has the expected size
- Beam witnesses all electro-magnetic fields in the vacuum pipe and tells us about them

2. Pre-commission essential acquisition and correction procedures

- Beam provides the only way to verify the proper functioning of the diagnostics:
- Beam tests our control and correction systems (correctors, cabling, control system, software, procedures, …):
- Hardware exposure to beam will allow first reality checks of assumptions: *quench limits, BLM thresholds*

Motivation

3. Integration: full-blown system wide integration test

- Field test beam related equipment and instrumentation and get them all working together
- Stress test controls infrastructure and all that goes with it.
- Fully validate integration

4. Provide a major milestone

- Beam instrumentation, Controls, Interlocks, Access, Radiation Protection, Operations, Hardware Commissioning etc. etc.

Test outline

	Test	Duration [hours]	Intensity	Number of shots	Integrated Intensity	Comments
1	Injection Steering, commission screens, IBMS, timing	12	5.00E+09	144	7.20E+11	TDI in, protecting LHCb
2	Trajectory acquistion commissioning, trajectory correction, threading	24	5.00E+09	288	1.44E+12	To beam dump
3	Linear Optics from kick/trajectory, coupling, BPM polarity checks, corrector polarity checks	24	1.00E+10	288	2.88E+12	
4	Aperture limits, acceptance	12	5.00E+09	360	1.80E+12	Pi bumps, BLMs, BCT
5	Momentum aperture	6	5.00E+09	60	3.00E+11	Move energy of SPS beam
6	IR bumps, aperture	6	5.00E+09	60	3.00E+11	Careful in LHCb
7	Commission normal cycle	12	5.00E+09	100	5.00E+11	
8	Energy offset versus time on FB	12	5.00E+09	100	5.00E+11	Cycle & repeat
9	Study field errors	12	1.00E+10	72	7.20E+11	Collect data, off-line analysis
10	Effects of magnetic cycle, variations during decay, reproducibility	24	5.00E+09	360	1.80E+12	12 cycles
11	Calibrate BLMs	24	5.00E+09	720	3.60E+12	couple with below
12	Multi-bunch injection - determination of quench level					start with pilot and work slowly calise loss appropriately
13	Effects of thermal cycling					time scale - low priority
14	Squeeze at 450 GeV					Handle on triplet errors? Coupling?
	TOTAL	180		2562	1.82E+13	
	DAYS	7.5				

Coupled with high operational inefficiencies

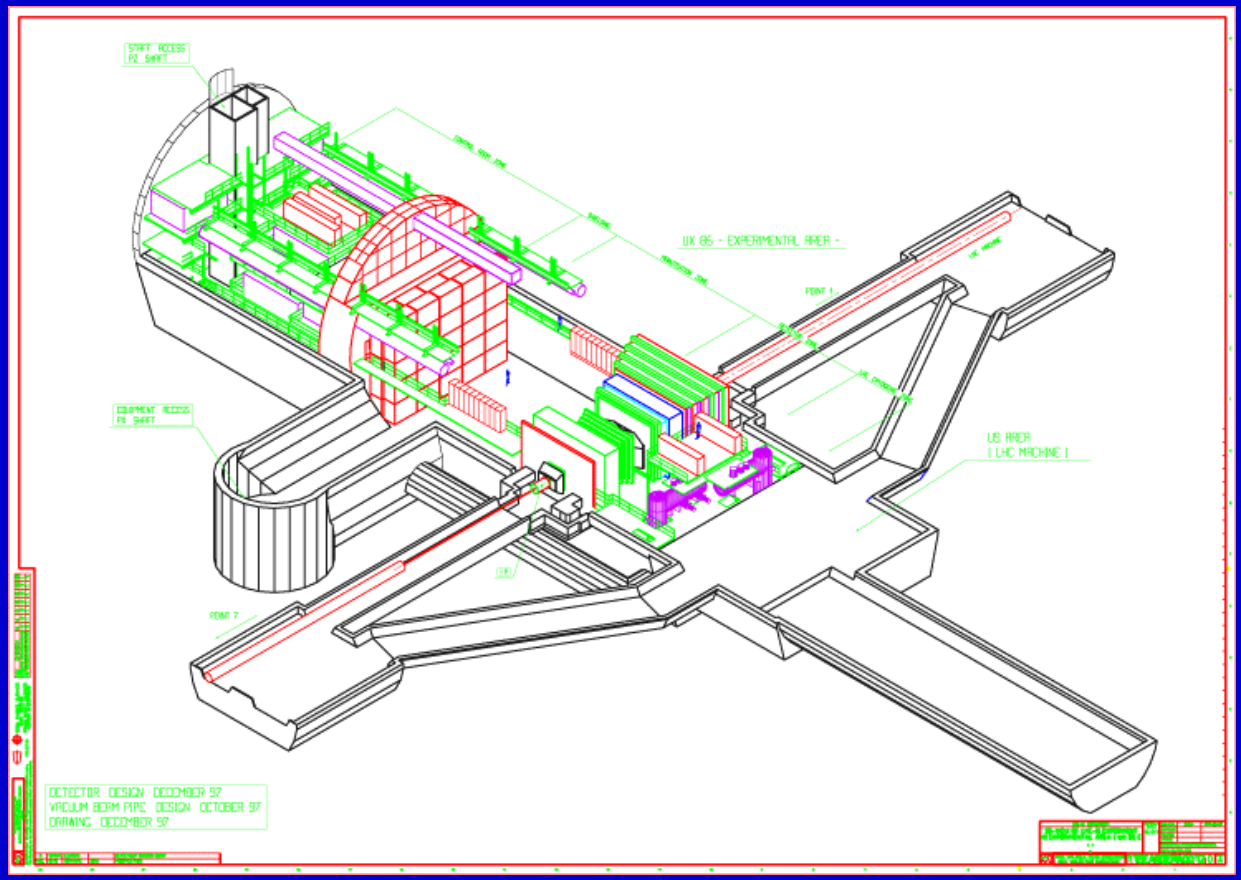
Beam

- **LHC Pilot Beam for the most part:**
  - **Single bunch**
  - **Intensity: 5 to 10 x 10^9 protons per bunch**
    - **Below quench limit if losses are diluted over > 5 m.**
    - **2 orders of magnitude below damage threshold.**
  - **Clear aim to minimise losses and use beam sparingly when we know where it's going.**

- **Total intensity: $\approx$ 2 x 10^{13} protons**

LHCb

- It has to be ensured that the experimental cavern at point 8 will be treated as a surveyed area after the injection test and not as a controlled area.
- Thus it has to be ensured that no part of the beam pipe or nearby detector will receive a radiation dose that would leave either activated after the test.



Radiation

- ~ 3000 shots giving a totally intensity of 2 x 10^{13} protons
- Scaling the simulations performed by RP group based on a total of 1.3 x 10^{15} protons in 24 hours. Expect typical dose rates if the above total of 2 x 10^{13} were delivered in 1 day and after 1 day cooling:
- TED
  - Along side TED: ≈40 μSv/h
  - Downstream face of TED: ≈500 μSv/h
  - Extra beam stop after the TED as for TI8
  - Some irradiation of concrete walls around TED
- ARC
  - Assume beam is lost uniformly along the sector between point 8 and point 7: negligible
  - Assume beam is lost in one dipole repeatedly: 4 - 10 μSv/h

These figures would be lowered even further by the extended cooling period

Radiation continued

- Low level of activation foreseen
- Concrete in this area will have some activation.
- Dump will be removed after cooling period
- All areas will be surveyed after the test
  - I.e. LHCb cavern, Injection region, Arc, dump…
- Zones will be declared
  - "Surveyed" (< 0.5 uSv/h)
  - or "Simple Controlled Areas" as appropriate. Personal dosimeters required.
- Potential fencing off of elements to minimise exposure.
- Number of people:
  - ≈ 20 needing regular access
  - ≈ 50 needing sporadic access

Monitoring

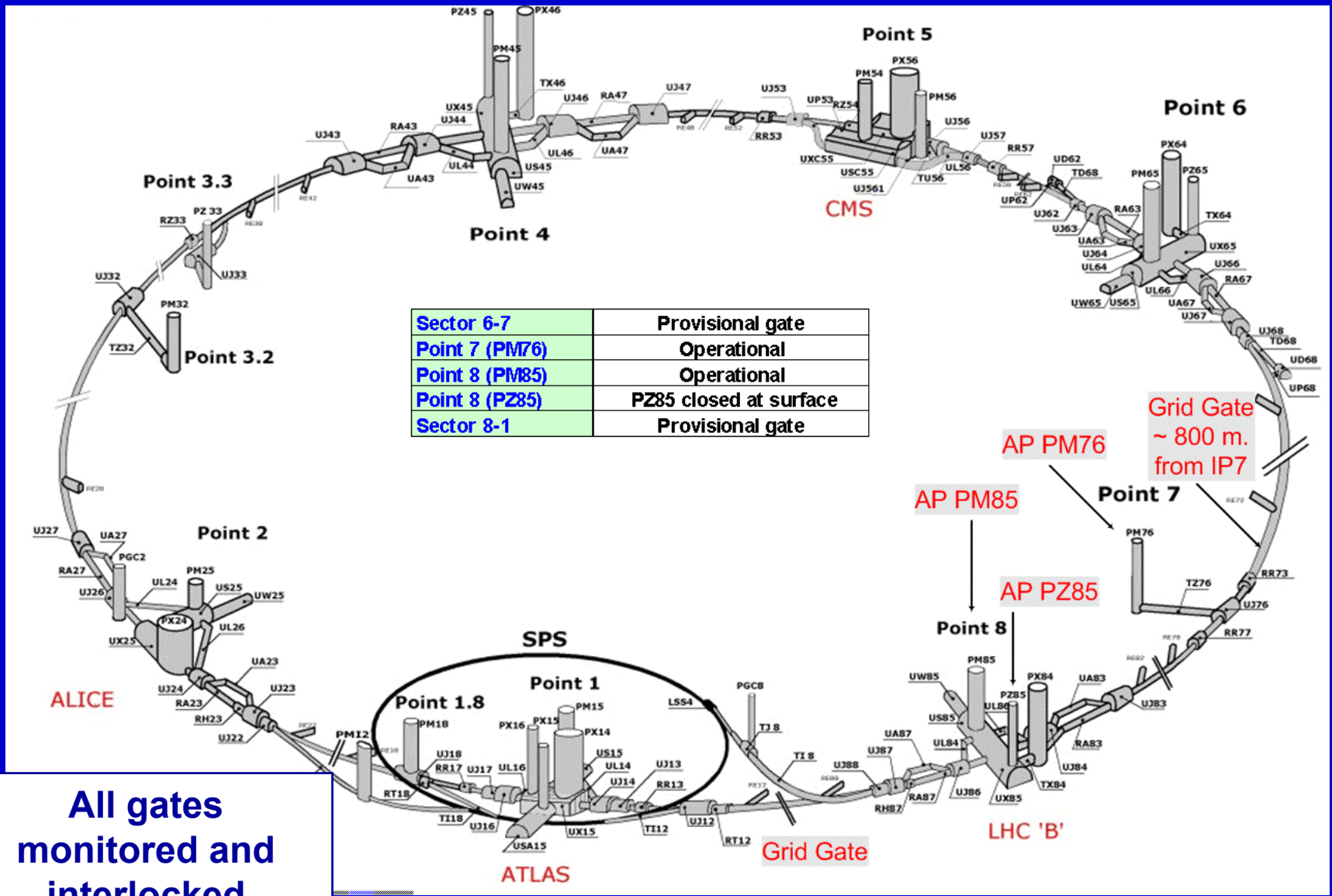
- **Radiation monitoring**
  - RAMSES has the injection test as milestone
  - LHCb: 4-5 monitors planned under RAMSES
  - **Extra monitors required to ensure < 0.5 μSv/h,** PMI monitors planned, modern data monitoring + interlocks.
  - Ventilation
  - Access gates
- **Beam Loss Monitors**
  - Sensitive to losses at 1% level with pilot bunch intensity
  - Additional BLMs in LHCb
- **Beam Intensities**
  - Beam extracted, injected and to dump to be logged
- **RPG survey after the event and perhaps during the test to ensure that activation remains low.**
  - Careful survey afterwards planned after the test near the injection dump and dump itself.

Interlocks

- Intensity interlocks in SPS to avoid extraction of too much intensity. Already tested.
- Beam Loss Monitors
- Radiation monitors at access gates
- Radiation monitors in LHCb cavern
- Any equipment faults will disable extraction from the SPS

- Personnel protection via access system

Access



Sector 6-7	Provisional gate
Point 7 (PM76)	Operational
Point 8 (PM85)	Operational
Point 8 (PZ85)	PZ85 closed at surface
Sector 8-1	Provisional gate

All gates monitored and interlocked

Sector test: conclusions

- 2 weeks low intensity beam, May 2006
- There should be only a low level of activation. Careful limits on intensity plus interlocks.
- Full access restrictions during test plus interlocked radiation monitoring.
- Very careful putting beam through LHCb, with appropriate monitoring we can ensure it remains a surveyed area.
- After the test: full survey and then assume restrictions appropriate to Simple Controlled Area where required.

- Report to the DGSNR (Direction Générale de la Sûreté Nucléaire et de la Radioprotection) in 2004.

Acknowledgements

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