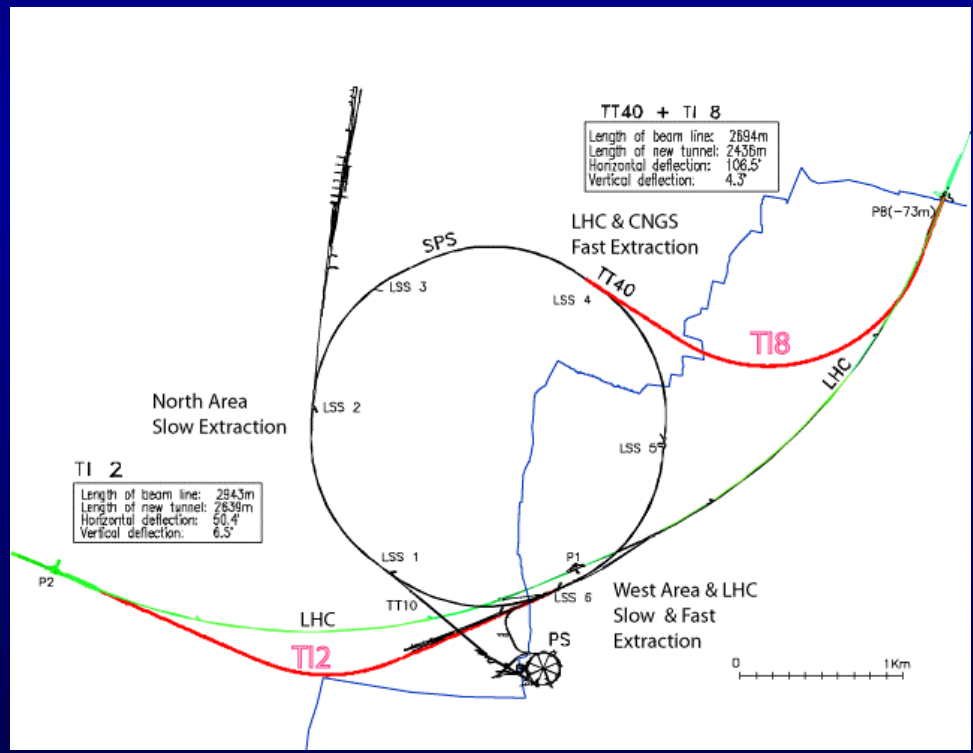
LHC Injection test 2006

- Overview
- Motivation
- Impact
- Proposed tests with beam
- Radiation / INB
- Access & Interlocks
- LHCb
- Planning
- Conclusions

Upcoming Beam Tests

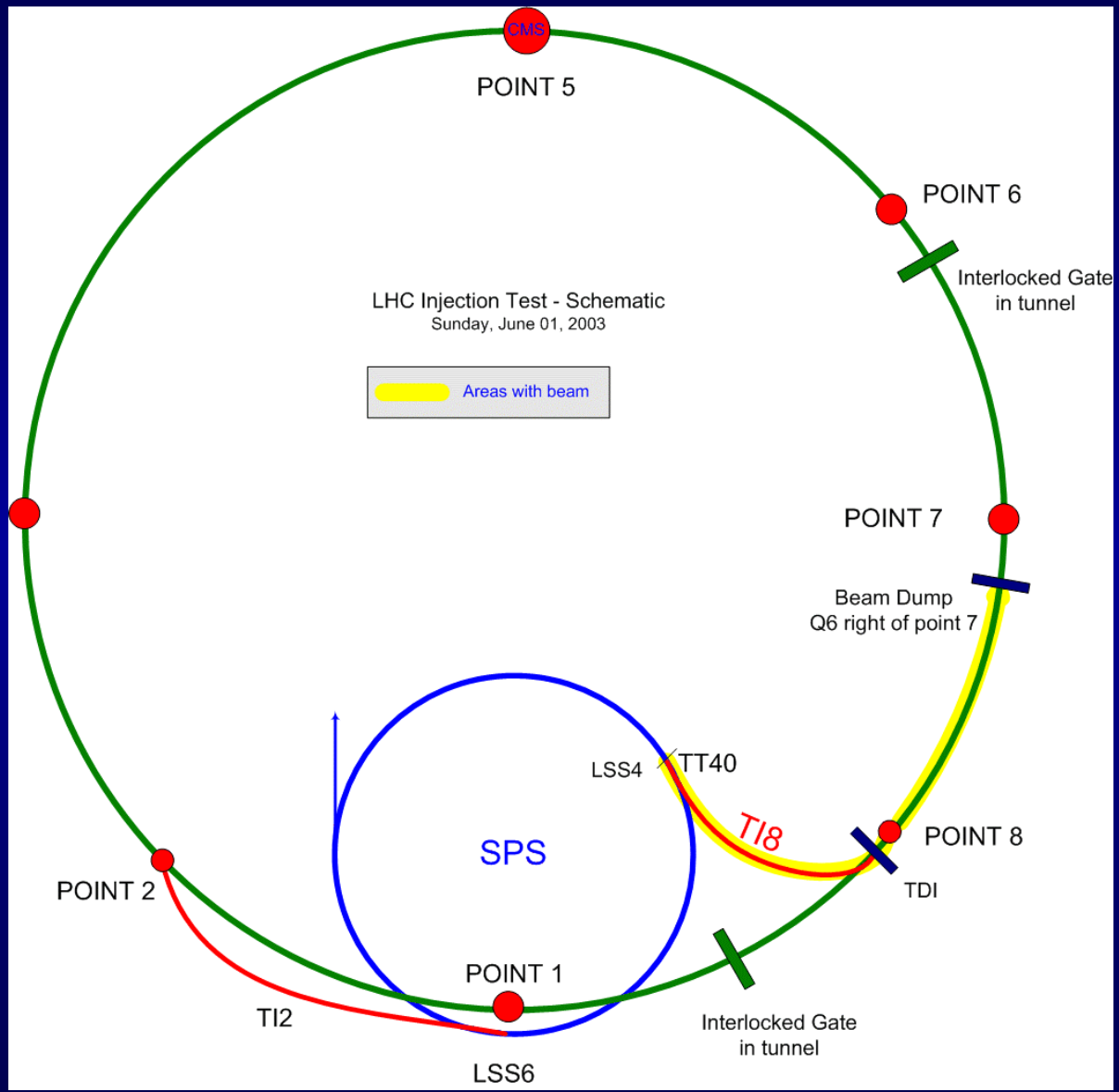
- TT40
  - 2 x 24 hours, September/October 2003
- TI8
  - 4 x 24 hours, September 2004
- LHC Injection test (?)
  - 2 weeks, April 2006
- TI2 commissioning
  - April 2007
- LHC commissioning
  - April onwards 2007



Injection test in 2006

- The installation schedule version 1.7 recently approved includes a ‘possible injection test’ - foreseen in April 2006
- Injection of beam:
  - down TI8,
  - into LHC at the injection point right of point 8,
  - though IP8 (LHCb),
  - through sector 8-7,
  - to a temporary beam dump to the right point 7.
- Many good arguments for performing this test
- Also numerous consequences

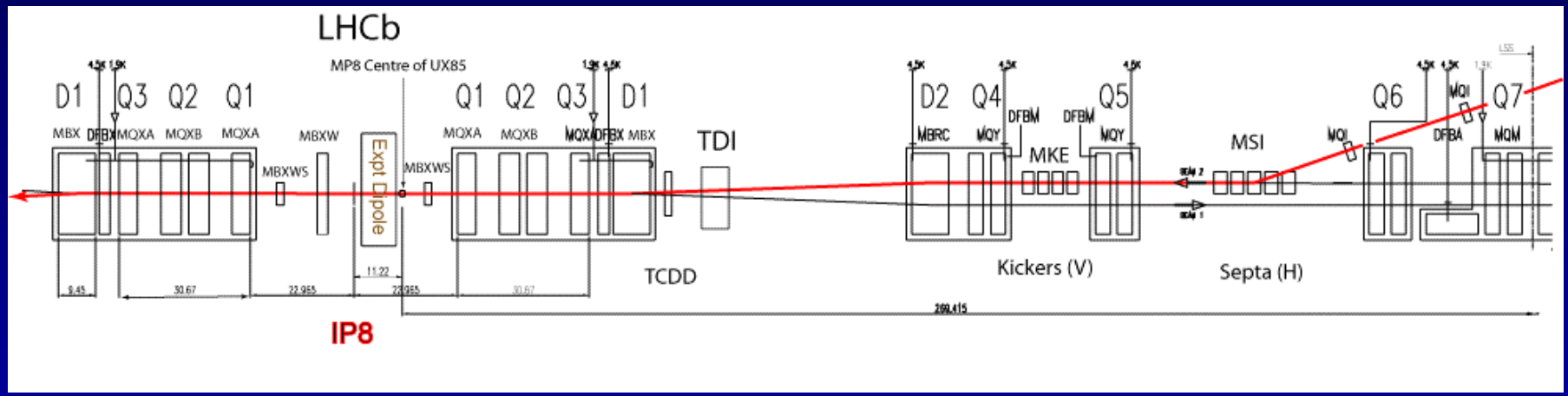
Overview



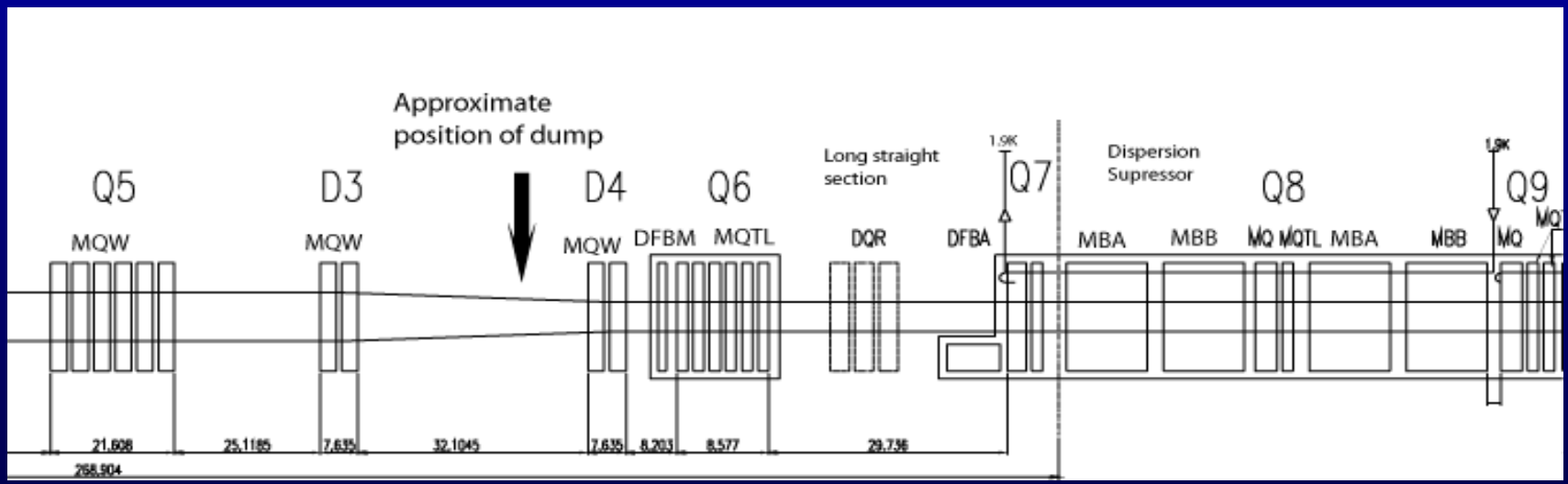
3.3 km of the LHC including one experiment insertion and a full arc

Layout

Layout – point 8



Layout – point 7



Motivation

- 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: Arc, IR8, crossing angle.
- Beam witnesses all electro-magnetic fields in the vacuum pipe and tells us about them: *polarity of design fields, field errors to 1 unit, large offsets between beam and magnet, corrector cabling.*
- Beam provides the only way to verify the proper functioning of the diagnostics *timing, BPM resolution, BPM cabling, BPM offsets, BLM resolution*
- Beam tests our control and correction power (correctors, cabling, control system, software, procedures, …): *Bumps, trajectory correction, kicker timing, injection stability, beam threading*
- Hardware exposure to beam will allow first reality checks of assumptions: *quench limits, BLM thresholds*

For example : Getting the beam through

Expected maximum travel length: **4-5 half cells with 99% probability**
(A. Verdier, LHC Project Note 308)

Reasons: **Smaller design aperture, larger beta functions, larger quadrupole offsets**

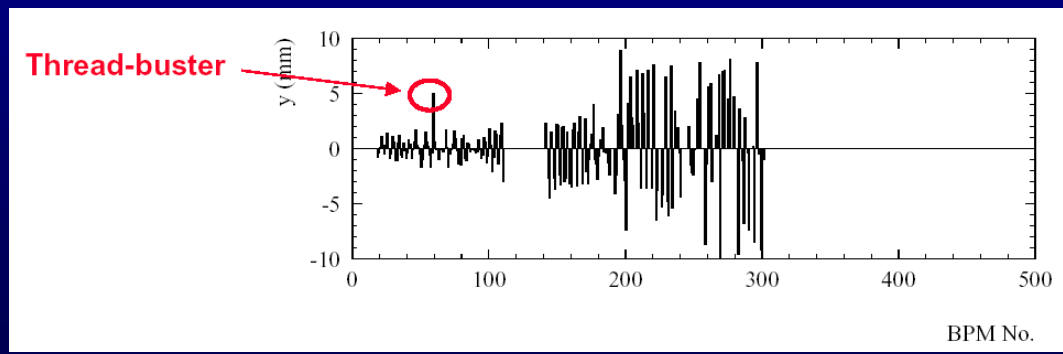
Threading:
- Put the low intensity beam (pilot) which is lost before the dump
- Measure the BPM's
- Expect large trajectory offsets before beam is lost (15 mm)
- Correct some range of BPM's
- Measure and expect beam to go further now

Iterate… (1 - 4 iterations for LHC sector?)

Should work OK… However, care and some careful thinking is required:

- BPM's with **large unphysical offsets**.
- BPM's with **wrong cabling** (inverted planes, signs, …).
- Orbit correctors/quad's with **wrong polarity**.
- Large quadrupole **misalignments**.

LEP
Last years: 30-45 minutes for first turn.
First years: days++



J. Wenninger, R. Assmann

Motivation

- **Integration - major challenge to bring everything together for beam: full-blown system integration tests**
  - **Highlight oversights, debug problems**
  - **Stress test beam related equipment and instrumentation such as: power converters,, beam transfer, kickers, septa, dumps**
  - **Stress test controls infrastructure and all that goes with it. There will be problems.**
  - **Validate the ongoing installation and integration & the performance of critical components**

- **Would provide a very important milestone:**
  - **for beam-based instrumentation and equipment, diagnostics and control**
  - **These system are absolutely critical for the effective operation of the machine and it cannot be stressed enough how important it is that they are ready and tested when we come to commission the whole machine.**

See LEP

Motivation

Commissioning of the first sector will have to be done. We will have to wrestle with the problems that will be encountered during this phase.

Discovering the problems during a sector test will give us a year at least to resolve any problems, perform a critically analysis of the performance of the systems involved and implement improvements.

Operationally, any time spent in 2006 on an injection test will be paid back many fold during the first year's commissioning, and enable us to deliver physics considerably faster.

Strongly endorsed at Chamonix 2003

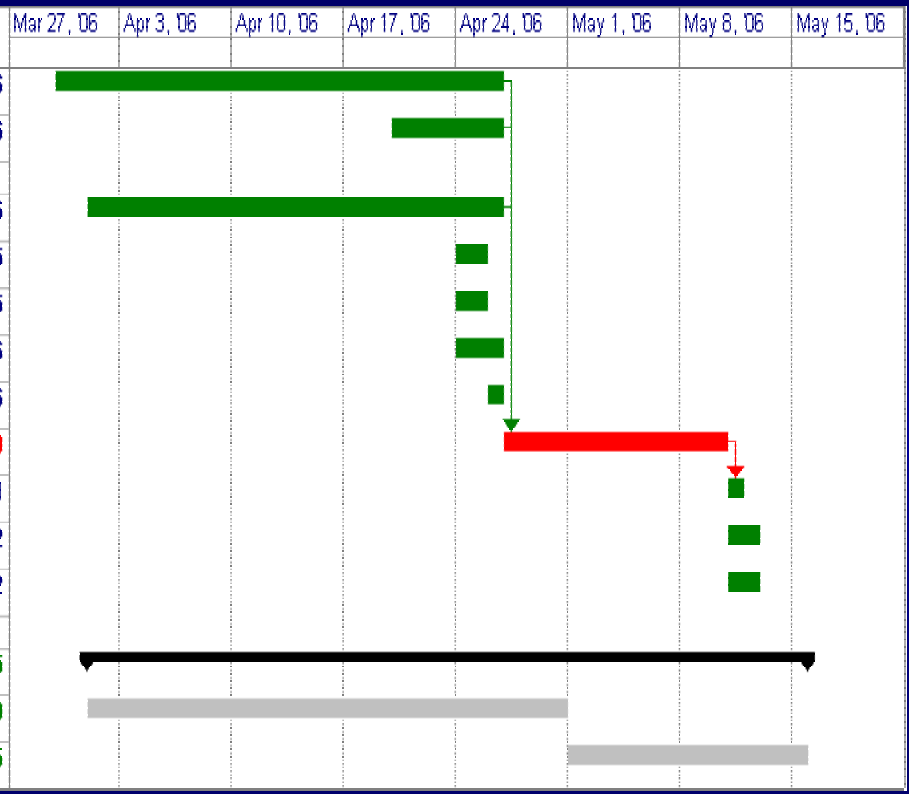
Impact

- On-going installation of 3-4, 5-6, 6-7
  - before, during and after the test.
  - disruption of installation in sector 6-7
- Hardware commissioning 4-5
  - Test will pull in resources from the above in preparation for the test and during the test itself
- Force the installation schedule of some systems
  - e.g. access and interlocks
- Consequences for installation and commissioning LHCb
- Radiation after the event: 7-8 potentially to be declared simple controlled radiation area with some knock-on effects
- Resources

Reservations expressed at Chamonix 2003

Impact

ID	Task Name	Duration	Start	Finish
3	Hardware recommissioning 7-8	28 days	Thu Mar 30	Wed Apr 26
4	Cold checkout, system tests	7 days	Thu Apr 20	Wed Apr 26
5				
6	SPS commissioning (after 2005)	26 days	Sat Apr 1	Wed Apr 26
7	TI commissioning	2 days	Mon Apr 24	Tue Apr 25
8	Install beam dump and shielding	2 days	Mon Apr 24	Tue Apr 25
9	Install Access Gates in tunnel	3 days	Mon Apr 24	Wed Apr 26
10	Commission access system	1 day	Wed Apr 26	Wed Apr 26
11	Test with beam	14 days	Thu Apr 27	Wed May 10
12	Radiation Survey	1 day	Thu May 11	Thu May 11
13	Remove Gates	2 days	Thu May 11	Fri May 12
14	Remove Dump	2 days	Thu May 11	Fri May 12
15				
16	Installation 6-7	45 days	Sat Apr 1	Mon May 15
17	Magnet transport 2-3-4-5-6	30 days	Sat Apr 1	Sun Apr 30
18	Magnet transport 2-1-8-7	15 days	Mon May 1	Mon May 15



Timing of test

- **PS and SPS will be starting up after 2005 shutdown**
  - **SPS under energy consumption restrictions unable to pulse before April 1st.**
  - **Given need for cold checkout & re-commissioning estimate 4 weeks to re-commission**
- **Injection test pushed to end April unless provision is made to start SPS earlier.**
- **For LHCb, April 2006 is the most convenient time slot for the injection test.**
  - **Taken in account in their planning**
  - **A delay of the sector test by more than 10 weeks beyond April 2006 would jeopardize the LHCb overall commissioning.**
  - **The interruption to the LHCb installation due to the injection test should not exceed three weeks.**

Beam tests

- **Pilot Beam for the most part:**
  - **Single bunch**
  - **Intensity: 5 to 10 x 10^9 protons per bunch**
    - **Below quench limit if loss over > 5 m.**
    - **2 orders of magnitude below damage threshold.**
- **Two main stipulations**
  - **Don't irradiate LHCb**
  - **Don't irradiate the rest of the ring too much**
- **Clear aim to minimise losses and use beam sparingly when we know where it's going.**
- **Possible gentle pushing of intensity to probe quench limits**

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	12	3.6E+11	10	3.60E+12	start with pilot and work slowly up… localise loss appropriately
13	Effects of thermal cyclin					ng time scale - low priority
14	Squeeze at 450 GeV					on triplet errors? Coupling?
	TOTAL	180		2562	1.82E+13	
	DAYS	7.5				

Coupled with high operational inefficiencies

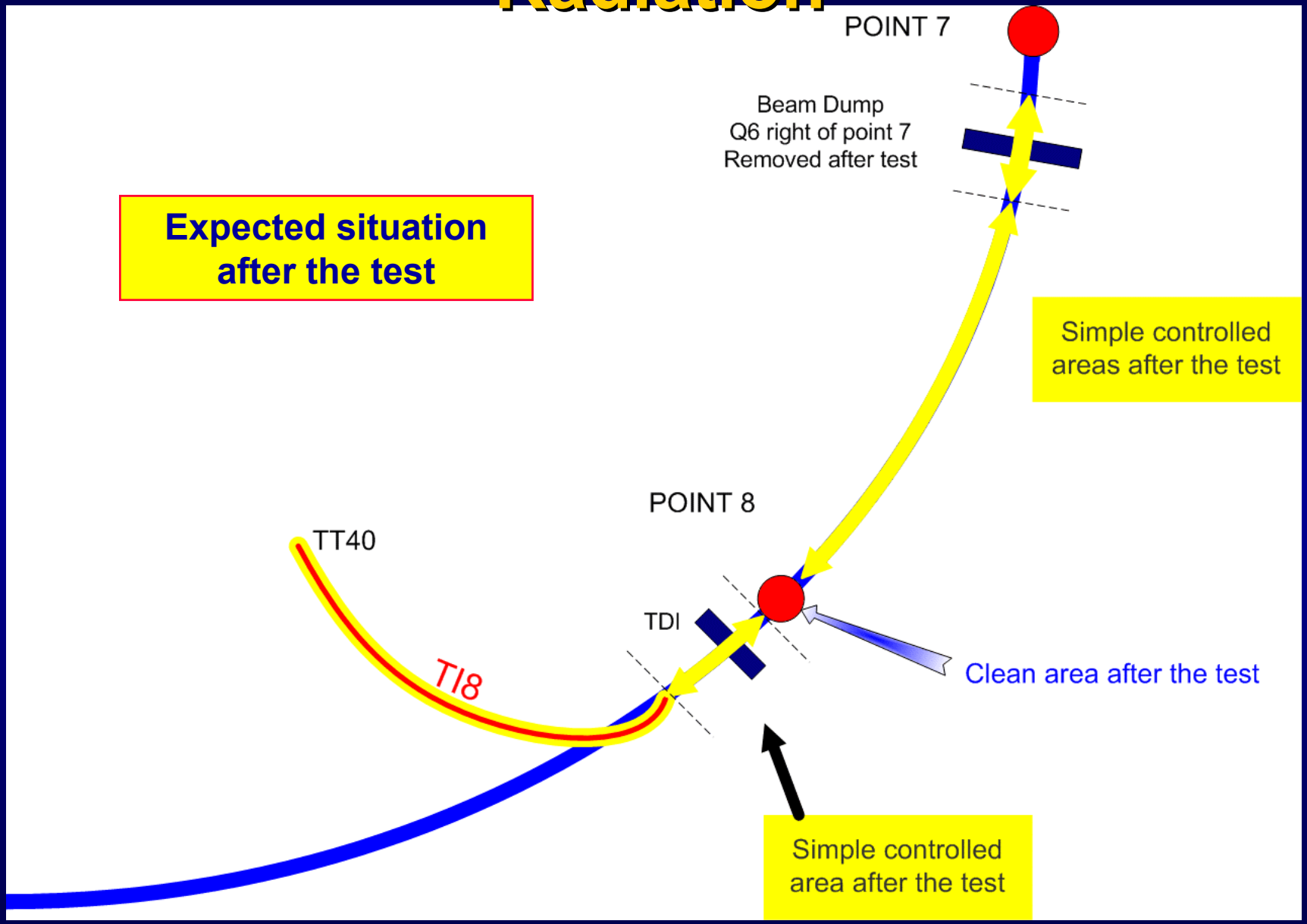
Radiation

- ~ 3000 shots giving a totally intensity of 2 x 10^{13} protons
- Following simulations by RP group: typical dose rates for 1 day irradiation and 1 day cooling (at 50% efficiency):
- TED
  - Along side TED: 6 μSv/h
  - Downstream face of TED: 140 μSv/h
  - Would have a extra beam stop (Iron/concrete) after the TED
  - 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 and 10 μSv/h
- This figures would be diluted even further by the extended cooling period

Radiation cont.

- Activation should be negligible in arcs and LHCb
- Two potential warm spots to be declared “Simple Controlled Areas” :
  - Near dump location. Localised losses at the dump will lift levels. Will remove dump. Need to check activation of walls.
  - Injection region - around the TDI.
- Some potential impact for transport through these zones, no impact for experiments

Radiation


POINT 7
Beam Dump
Q6 right of point 7
Removed after test
Expected situation after the test
Simple controlled areas after the test
POINT 8
TT40
TDI
TI8
Clean area after the test
Simple controlled area after the test

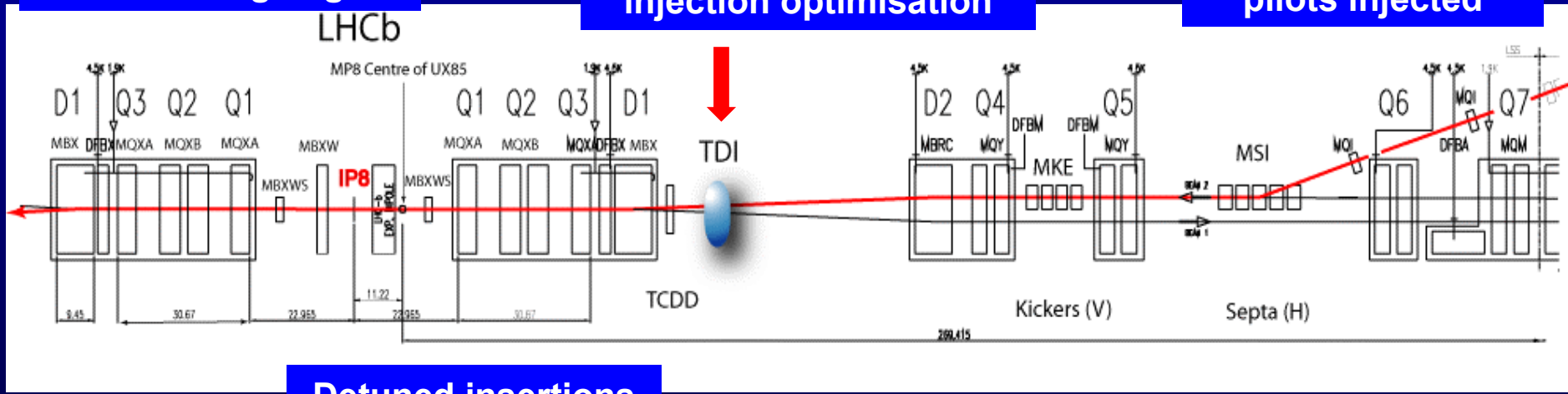
LHCb

- 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.
- 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.

Reasonable aperture
≈ 50 mm ≈ 18σ
No crossing angle

TDI: Can be closed as far as possible during injection optimisation

Low emittance pilots injected



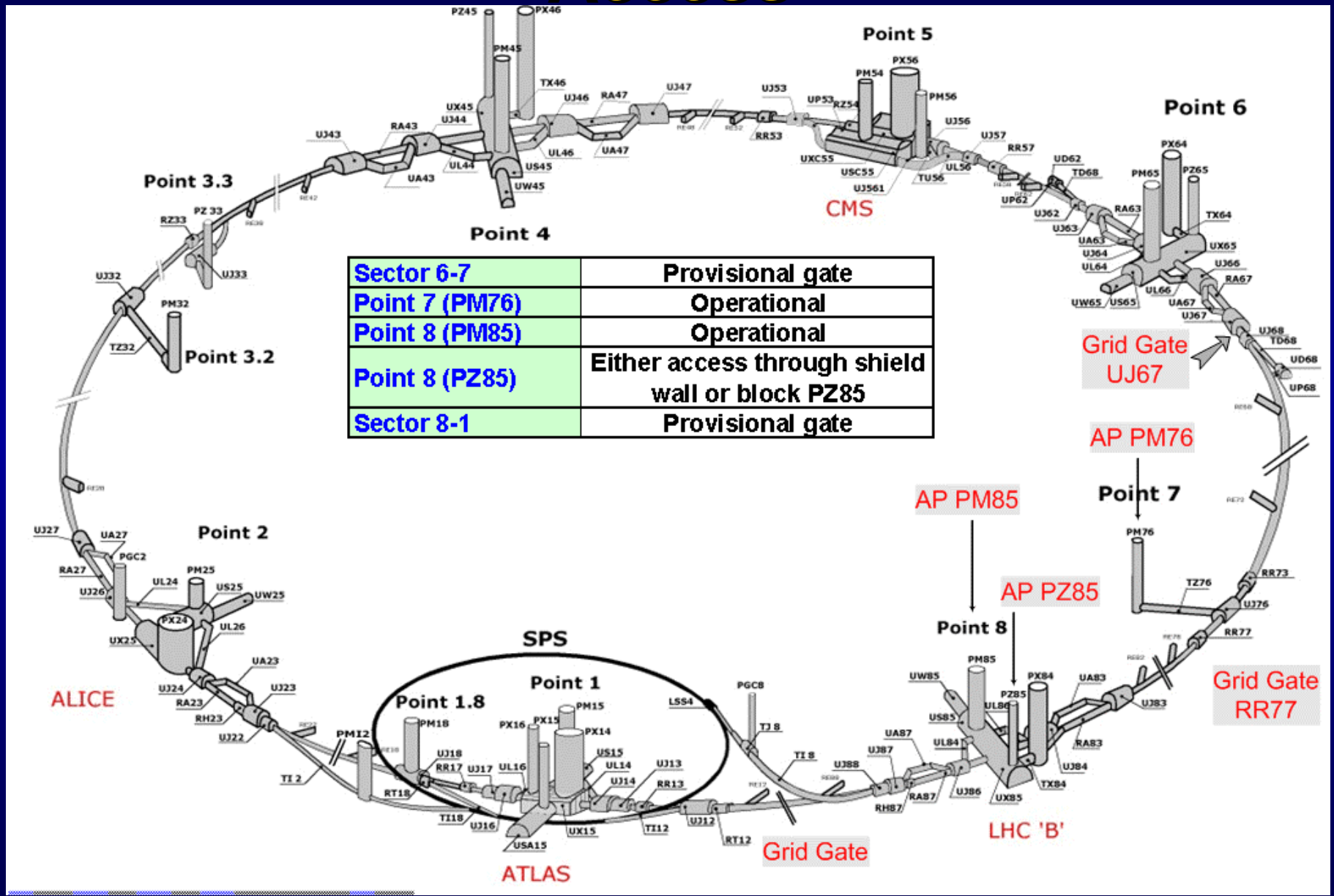
Detuned insertions
Smaller beam size

Monitoring

- **Radiation monitoring**
  - Radiation Monitors will be provided by TIS
  - RAMSES have injection test as milestone
  - Extra monitors available
- **Beam Loss Monitors**
  - Sensitive to losses at 1% level with pilot bunch intensity
- **Beam Intensities**
  - Beam extracted, injected and to dump to be logged
- **LHCb**
  - Monitoring to ensure minimal losses at all times
- **RPG survey after the event**

- **INB**
  - Tell them estimated intensities, estimates of likely activation, and estimates of personnel dose.
  - Report to be presented in 2004 at the same time as the Dossier de sûreté.

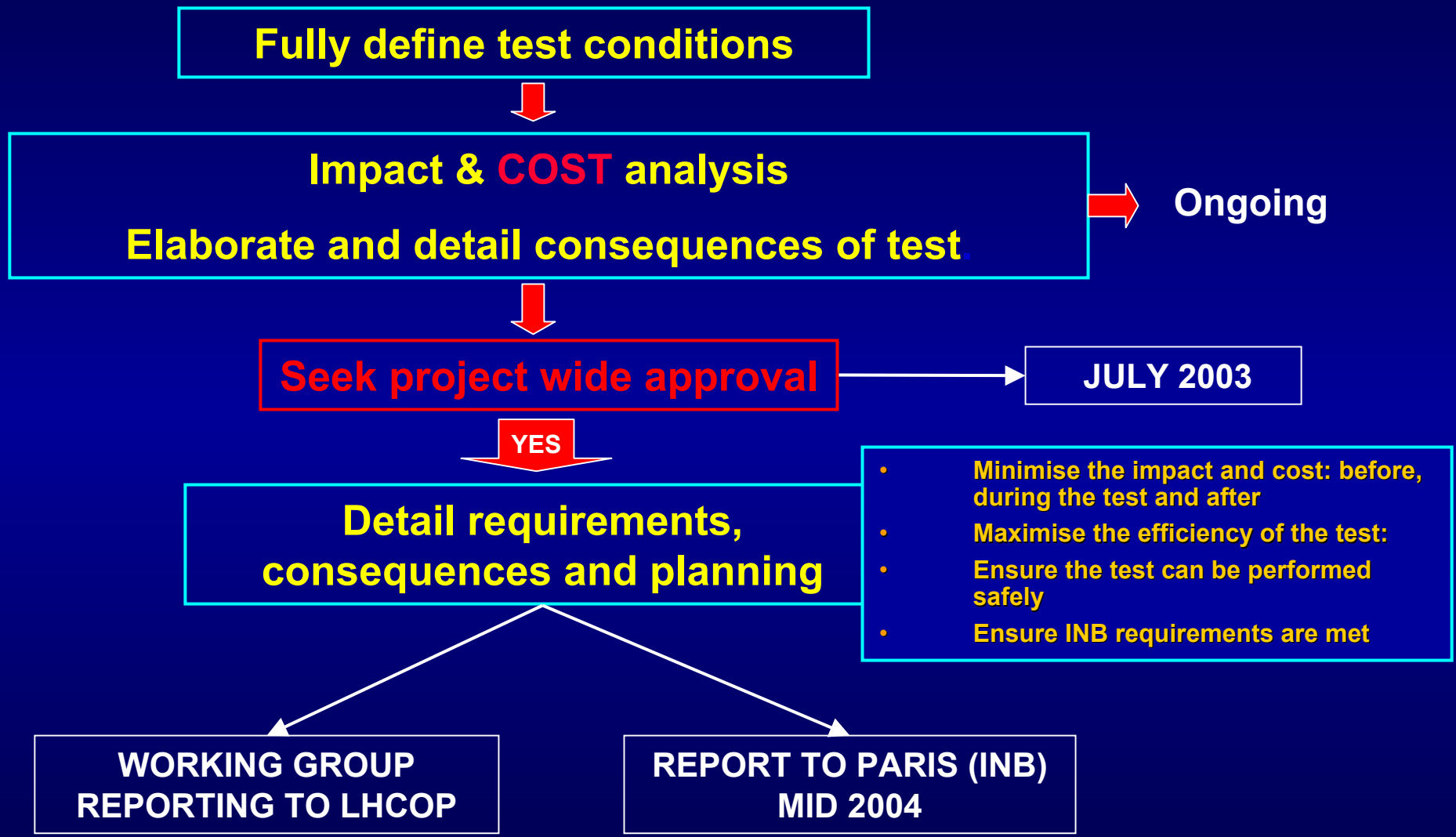
Access


Point 5
Point 6
Point 4
Point 3.3
Point 3.2
Point 2
Point 1
Point 1.8
Point 7
Point 8
CMS
ALICE
ATLAS
LHC 'B'
SPS
Grid Gate UJ67
Grid Gate RR77
Grid Gate
AP PM76
AP PM85
AP PZ85
Sector 6-7 | Provisional gate
Point 7 (PM76) | Operational
Point 8 (PM85) | Operational
Point 8 (PZ85) | Either access through shield wall or block PZ85
Sector 8-1 | Provisional gate

Access

- For sector 7-6, a gate must be installed and interlocked right of 6, either near UJ67, or possibly mid-arc.
- The machine access point at Point 7 (PM76) should be operational.
- The machine access point at Point 8 (PM85) will be operational.
- Either the planned access point between the experimental service cavern and the LHCb experiment must be operational with the shield wall in place, or a new interlocked gate must be placed at the top of PZ85. To be decided.
- A gate in sector 1-8 must be operational & interlocked. Foreseen but will be provisional.

Plan


Fully define test conditions
Impact & COST analysis
Elaborate and detail consequences of test.
Ongoing
Seek project wide approval
JULY 2003
YES
Detail requirements, consequences and planning
Minimise the impact and cost: before, during the test and after
Maximise the efficiency of the test:
Ensure the test can be performed safely
Ensure INB requirements are met
WORKING GROUP REPORTING TO LHCOP
REPORT TO PARIS (INB) MID 2004

Conclusions

- The intensities we plan to use are low, with care there should be only a low level of activation.
  - assume restrictions appropriate to simple controlled area where required
- Very careful putting beam through LHCb, with appropriate monitoring we will ensure it remains a surveyed area.
- Non-negligible cost and impact
  - Injection test "cost to completion" under evaluation
- The test is a potentially an extremely valuable exercise which could go a long way to easing the commissioning of the whole machine.
  - A lot can be learnt with beam and in preparing for beam.
  - The test would provide an important milestone for all beam related systems.

If we can put beam in, we should put beam in.

Acknowledgements

- Roger Bailey & LHC-OP,
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- Roberto Saban, Felix Rodriguez-Mateos,
- Ralph Assmann,
- Andre Faugier, Ghislain Roy
- Enrico Cennini
- And others…

More details…

cern.ch/lhc-injection-test