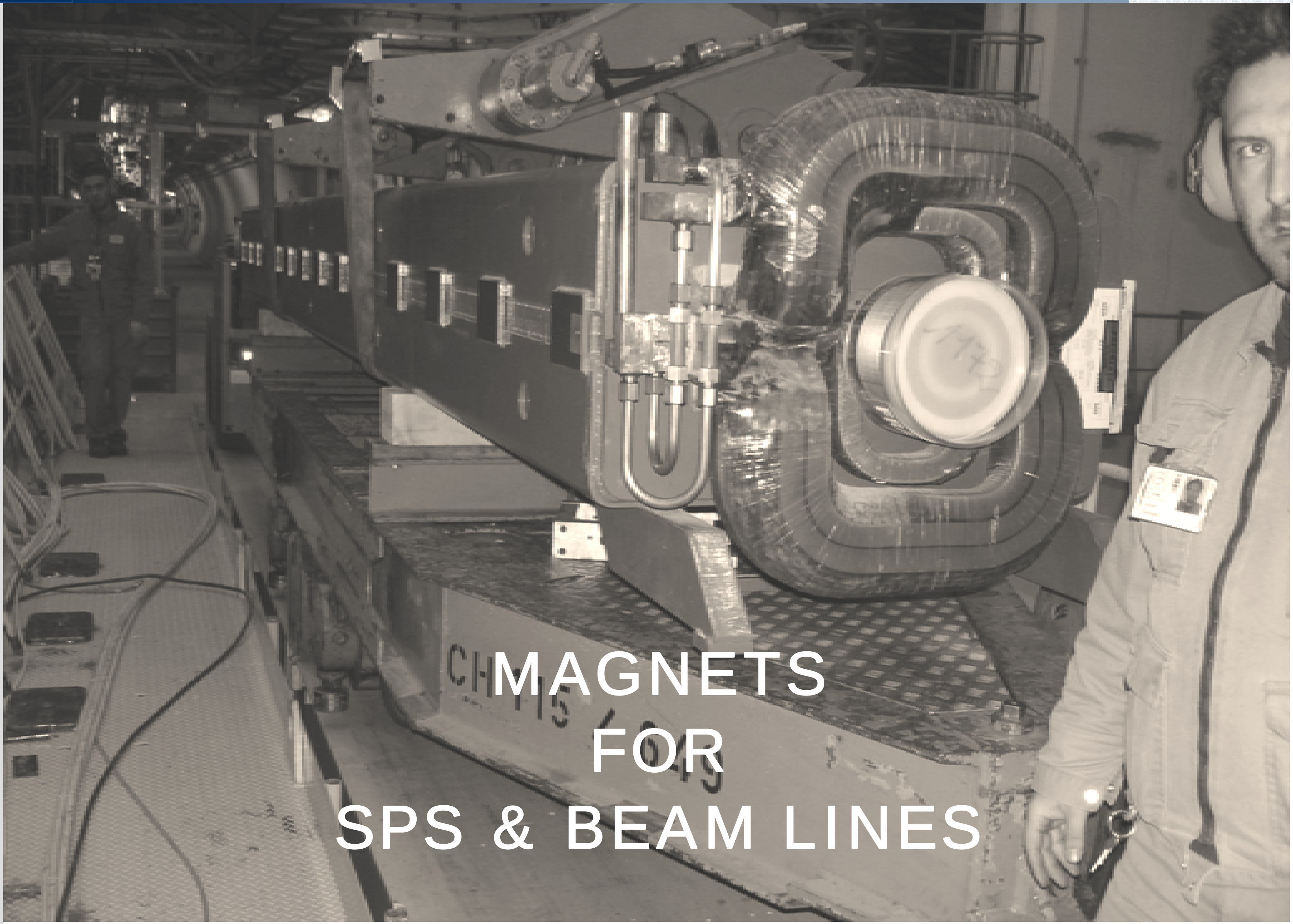

MAGNETS
FOR
SPS & BEAM LINES

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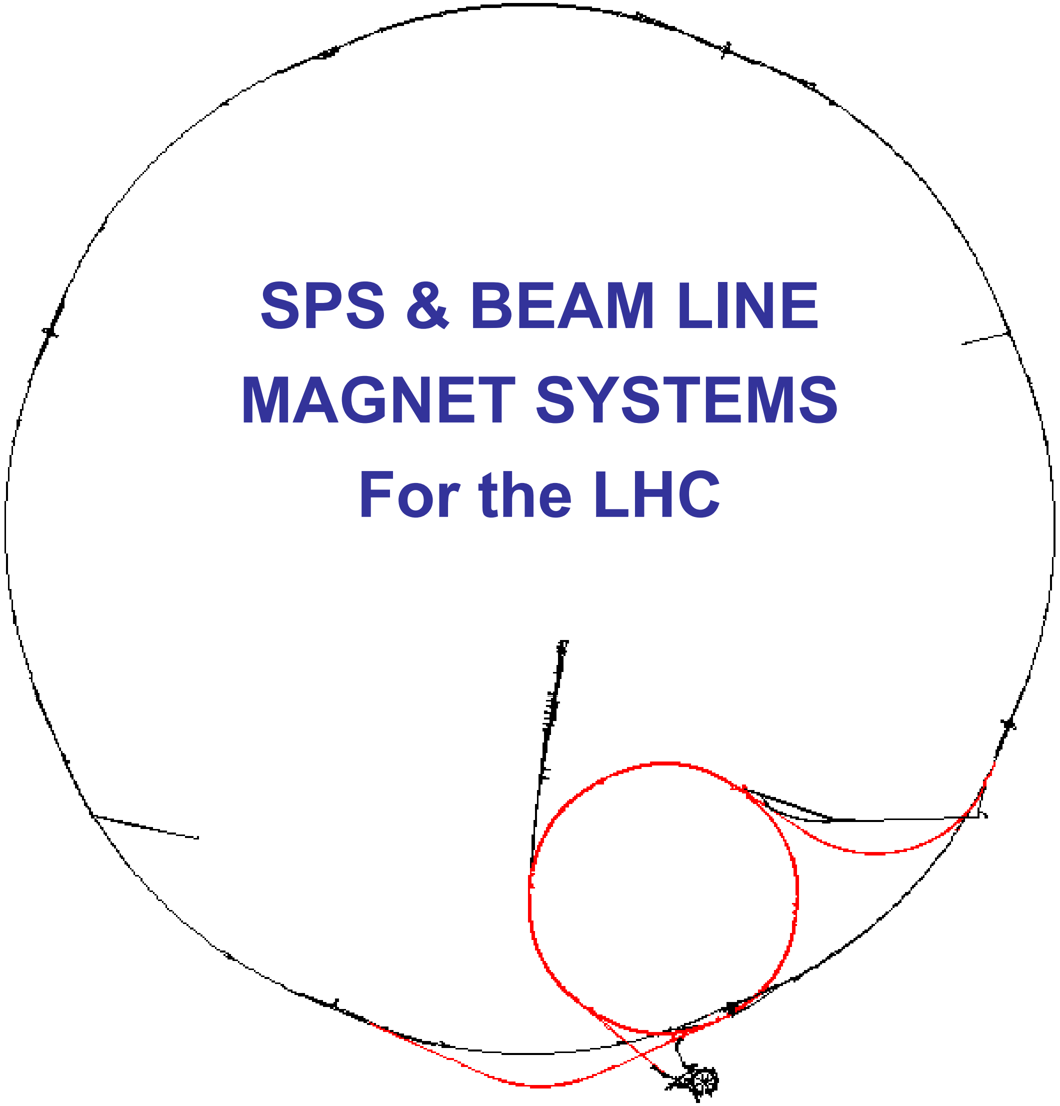
SPS & BEAM LINE MAGNET SYSTEMS For the LHC



SPS as LHC Injector : Overview of the Complex

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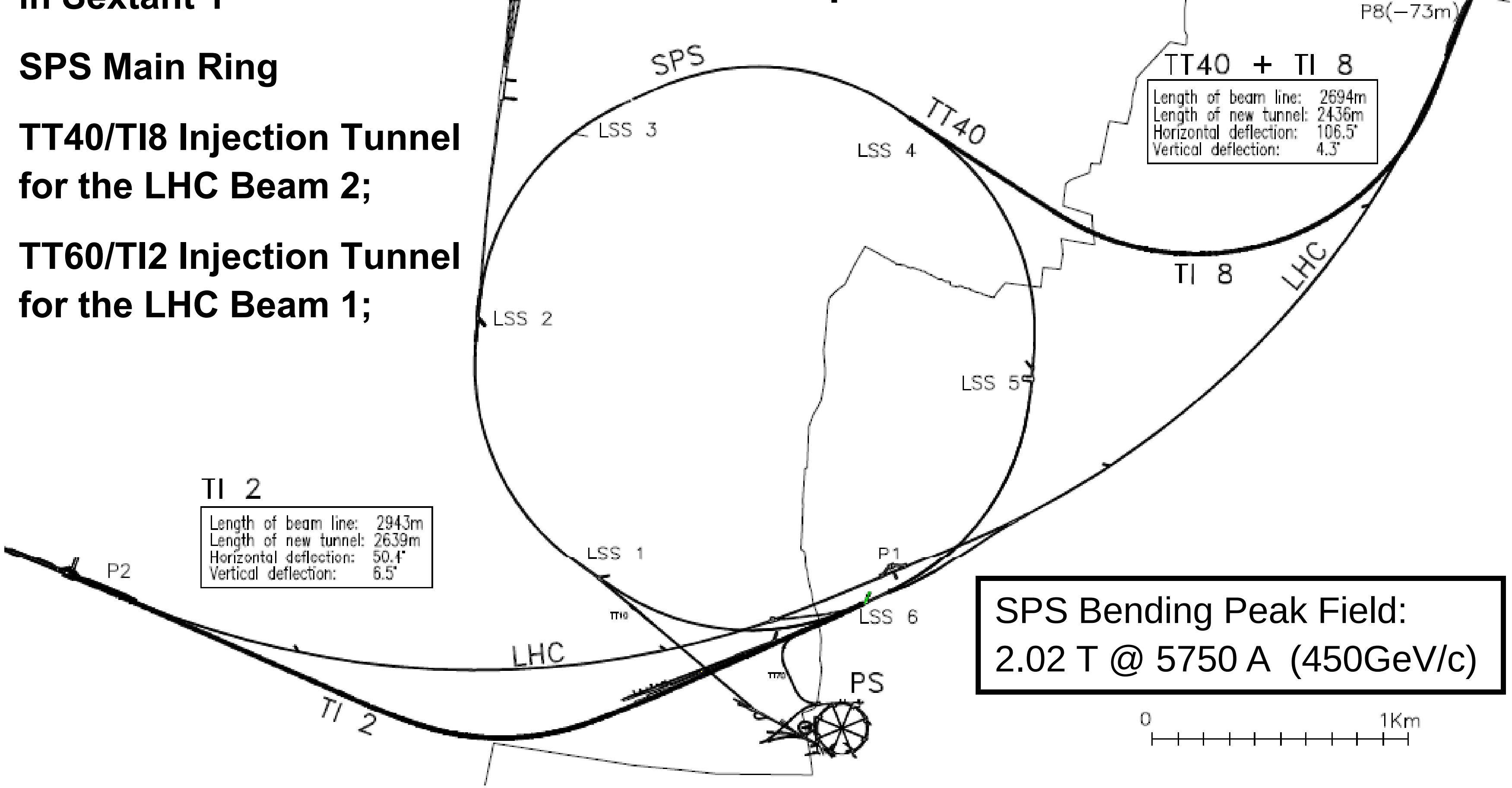
SPS as LHC injector incorporates:

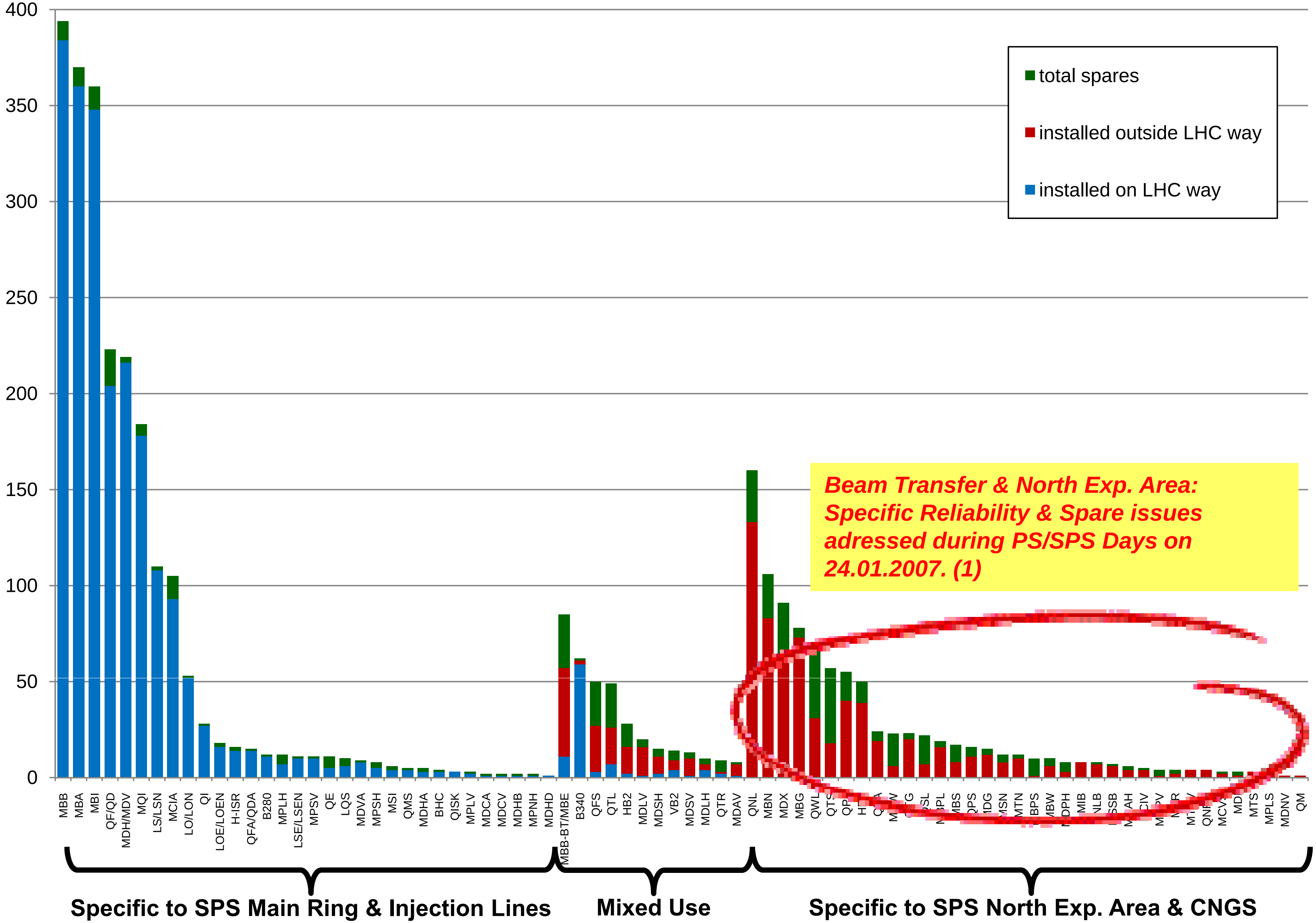
- ➔ **TT10 Beam Transport Tunnel from PS extraction (TT2) to SPS Injection Point in Sextant 1**
- ➔ **SPS Main Ring**
- ➔ **TT40/TI8 Injection Tunnel for the LHC Beam 2;**
- ➔ **TT60/TI2 Injection Tunnel for the LHC Beam 1;**

- ➔ **13500 m of Beam Lines**
- ➔ **2200 Magnetic Elements on the LHC way**
- ➔ **In addition, 809 Magnets installed in the North Exp. Area & in the CNGS**



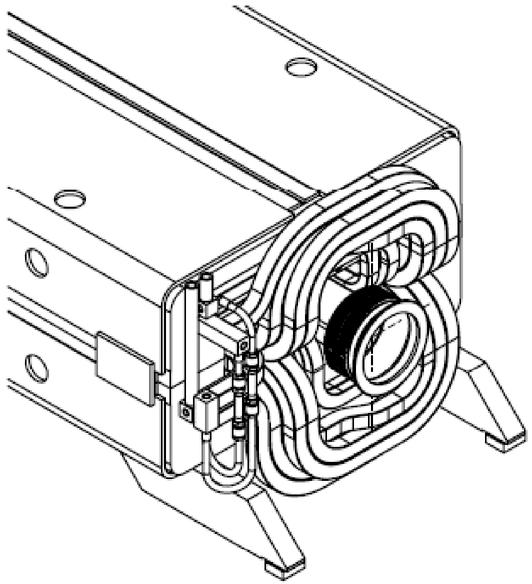
SPS Bending Peak Field:
2.02 T @ 5750 A (450GeV/c)

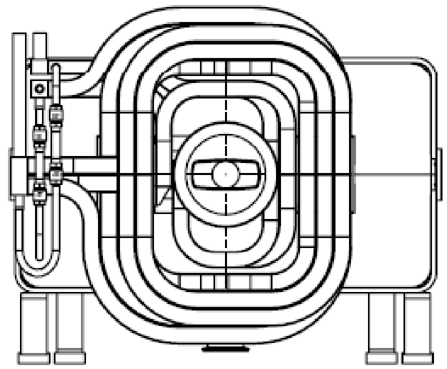
3515 Magnets for the SPS Complex (80 families)

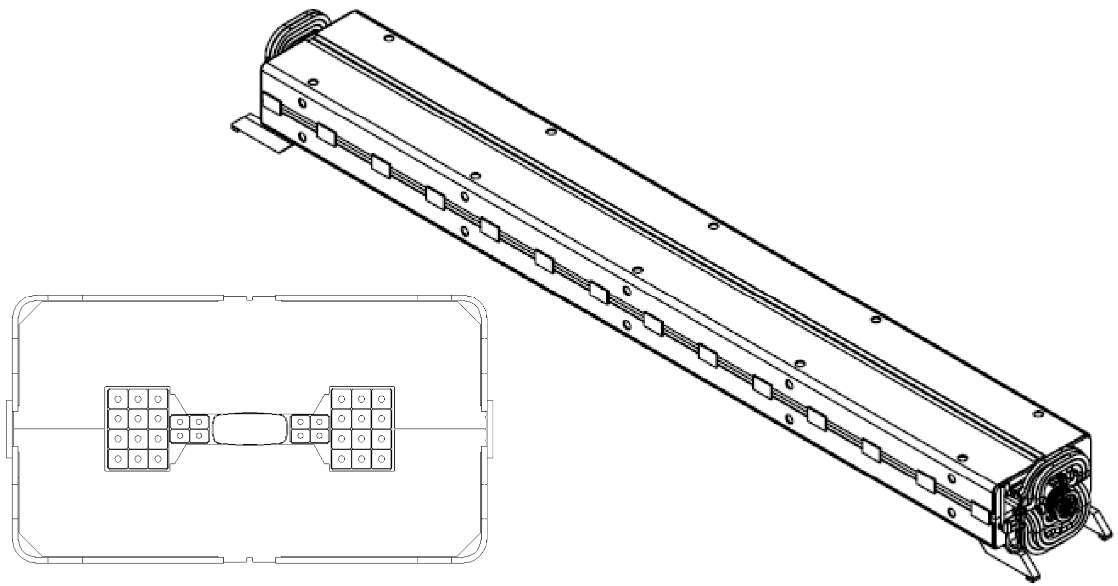


Magnet Technology in Use

- **SPS:**
  - •**Separated Function Machine**
  - •**108 FODO Periods**
  - •**744 Bending Dipoles**
- **TI2 & TI8: similar principle**
  (Half cells of 4 dipoles between focussing/defocussing quadrupoles)
- **Magnet Technology:**
  - •**Laminated Steel Yokes**
  - •**H Shaped Dipoles**
  - •**Welded Structures**
  - •**Water Cooled Copper Coils (excl. Air Cooled Orbit Correctors)**
  - •**Fibreglass/Epoxy Insulation**



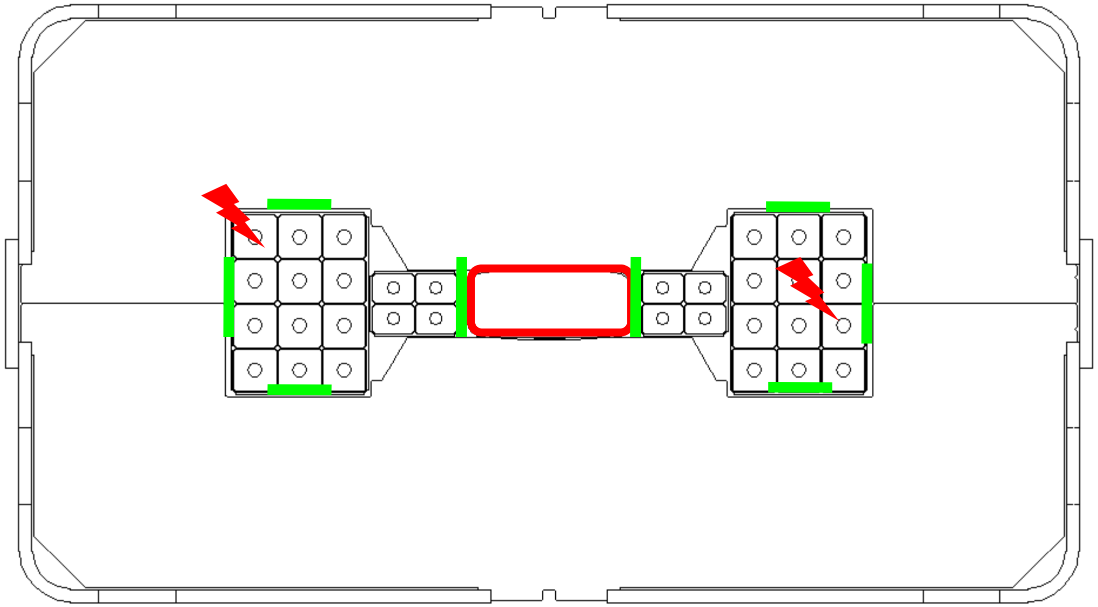


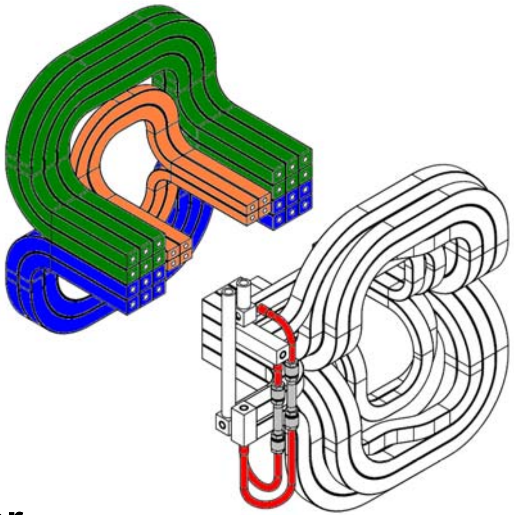


SPS Main Dipole MBB

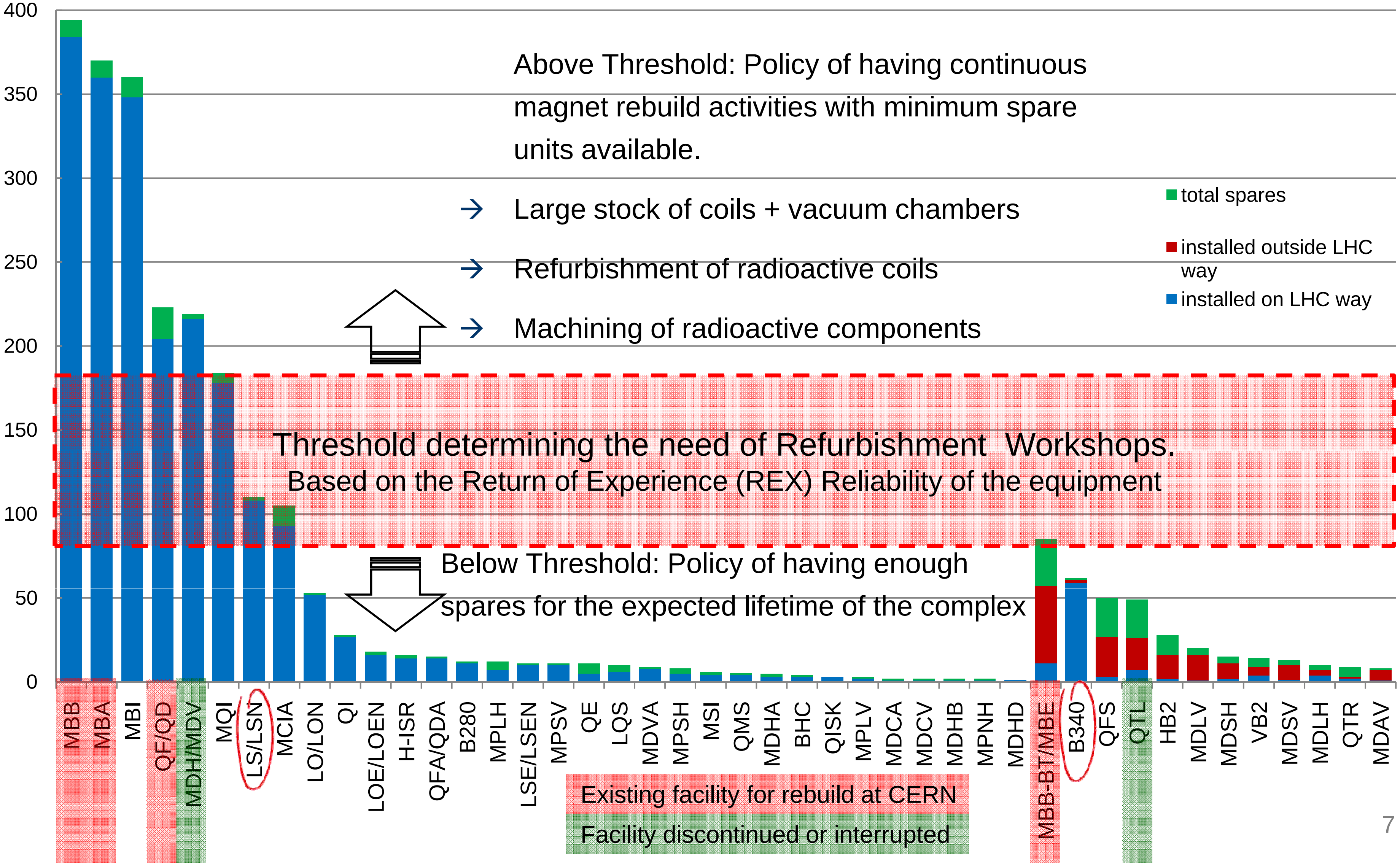
Reliability / Ageing Problems

- ➔ **Failures requiring magnet exchange + overhaul:**
  - ➔ **Vacuum Chamber (Leaks)**
  - ➔ **Coil Interturn Short Circuits**
  - ➔ **Short-Circuit (Coil with Yoke)**
  - ➔ **Waterleak (Erosion induced)**
- ➔ **Ageing problems requiring preventive replacement:**
  - ➔ **Degradation of the soft shimming, inducing coil movements. (fatigue on vacuum chamber inside dipoles, fatigue on coil conductor inside quadrupoles)**



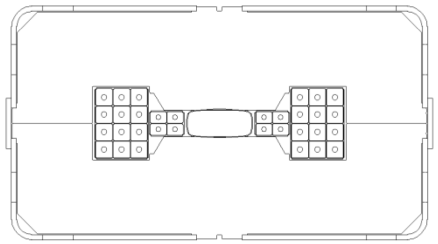


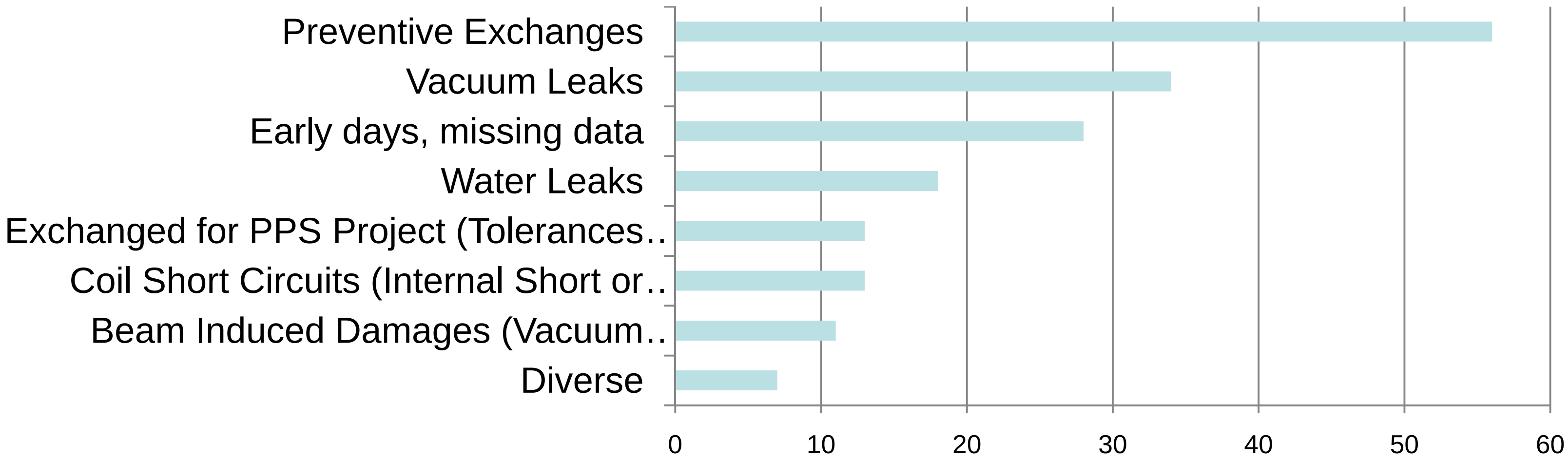
Spare Policy



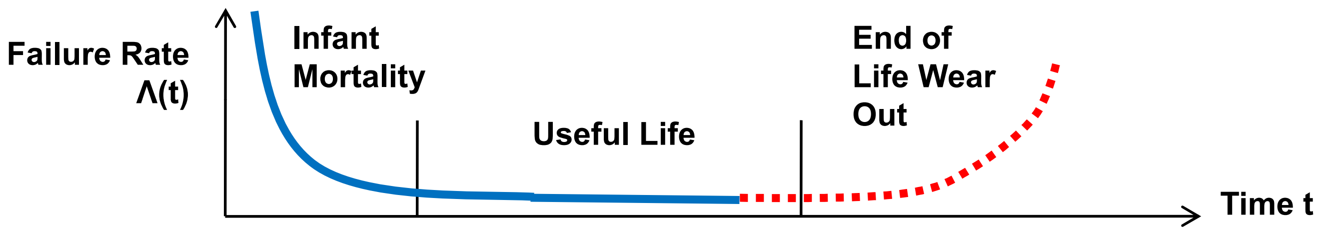
REX Reliability of the SPS Dipoles

- ➔ **744 Main Dipoles in operation since 1975**
- ➔ **76% are still in operation as installed (567 magnets)**





- ➔ **The reliability of the SPS magnets is relatively good (>99 %/year) and relatively stable over the past 33 years.**
- ➔ **Need to understand the evolution of failure rates and the effects of preventive replacements (Bathtub Curve for each magnet component)**



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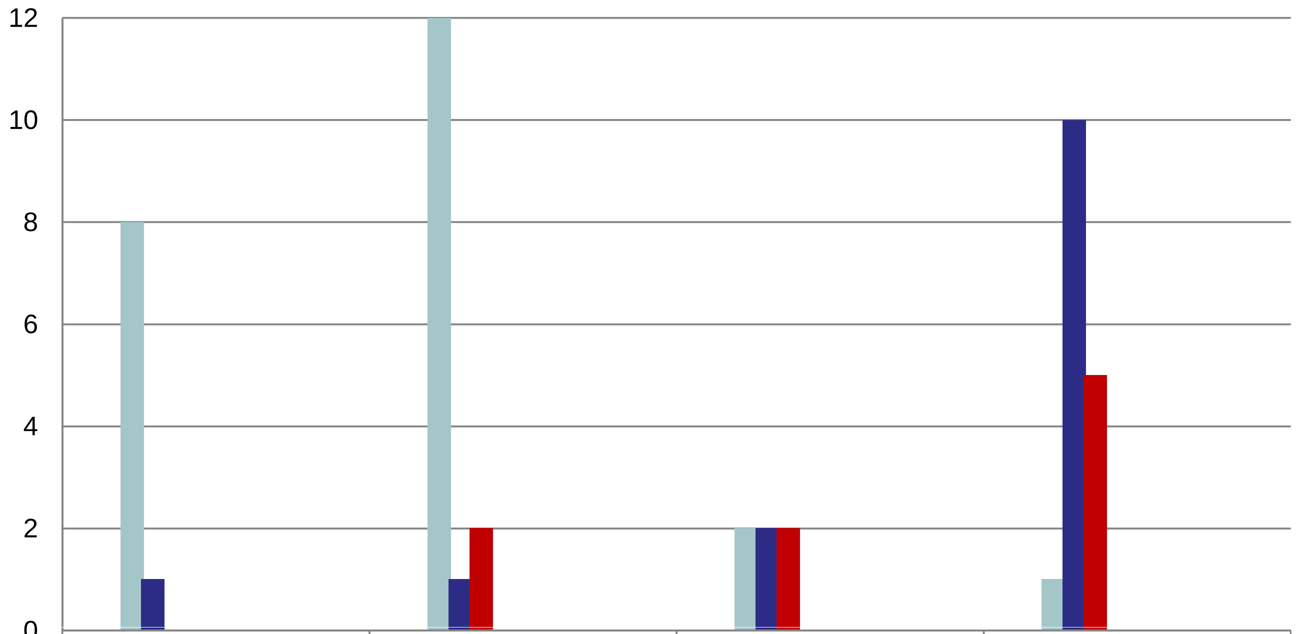
SPS Main Dipoles (MBA&MBB) Evolution of Breakdowns



	1988-1992	1993-1997	1998-2002	2003-2007
vacuum leak	8	12	2	1
Water leak	1	1	2	10
Short	0	2	2	5
Beam induced damages	0	3	3	0
diverse	2	1	2	0
Exchange for PPS project, VC shifted, impossible to install RF shielding	0	0	13	0
Preventive exchange	7	27	15	6
no information available	4	0	0	0
total	22	46	39	22

Impact of Magnet System Failures

➔ Limited Impact:

- No cryogeny, no explosive gas, no pressurized vessels, few flammable materials,…
- Low Risk of severe injury or of loss of life (heavy handling, high voltage)
- Risk of contamination is not significant

➔ Moderate Impact:

- exposure of personnel to radiation
- production of radioactive waste (damaged components)

➔ Possible major impact: Scientific Program

Mitigation of Failure Impact

➔ Impact of magnet failures on the Scientific program can be mitigated by:

- Reducing the failure rate
- Extending the lifetime expectancy of the components

  - preventive exchange of magnets during shutdowns
    - Requires Magnet Rebuild Facilities
  - By means of specific curative actions once a problem is detected
    - Requires a consolidation fund

- Minimizing the MTTR

MTTR follows the dictates of the cool down time (remanent radiation levels), of the method of access for the heavy equipment, of the distance for the transport & of the restoration of the vacuum in the sector.
Minimizing MTTR can conflict with the reduction (mitigation) of the exposure of the personnel to radiation.

M - T - T - R

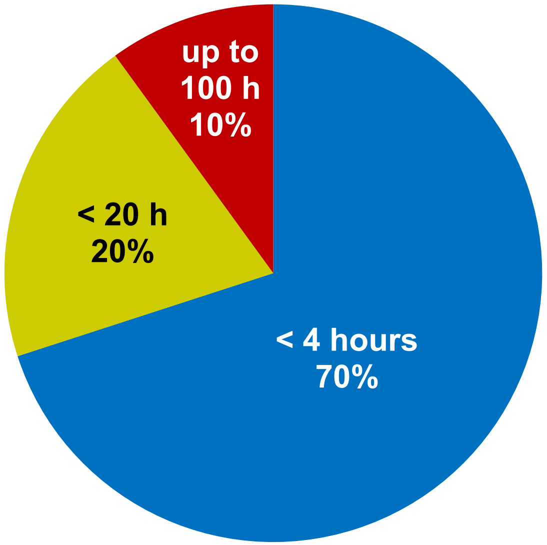
M	T - T	R
Minimum	Time To	Repair
Maximum		Recovery
Mean		Respond
		Replace

MTTR (Repair)	MTTR (Replace)
4 hours	20 hours
•Magnet Cooling Faults •Leaks •Water Pressure Faults • Overheating •Magnet Interlock Faults •Specific Electronic Faults •Imbalance current detector •Null Field Probes	Magnet Exchange Note: Specific issues for the MTTR (Mean Time to Respond): although the acknowledgement of the fault is usually very quick, the initiation of the mitigation can be postponed due to various reasons: -AB/OP (Physics priority) -SC/RP (Safety) - « Trivial »matters (nights, week-ends)

MTTR: Return of Experience

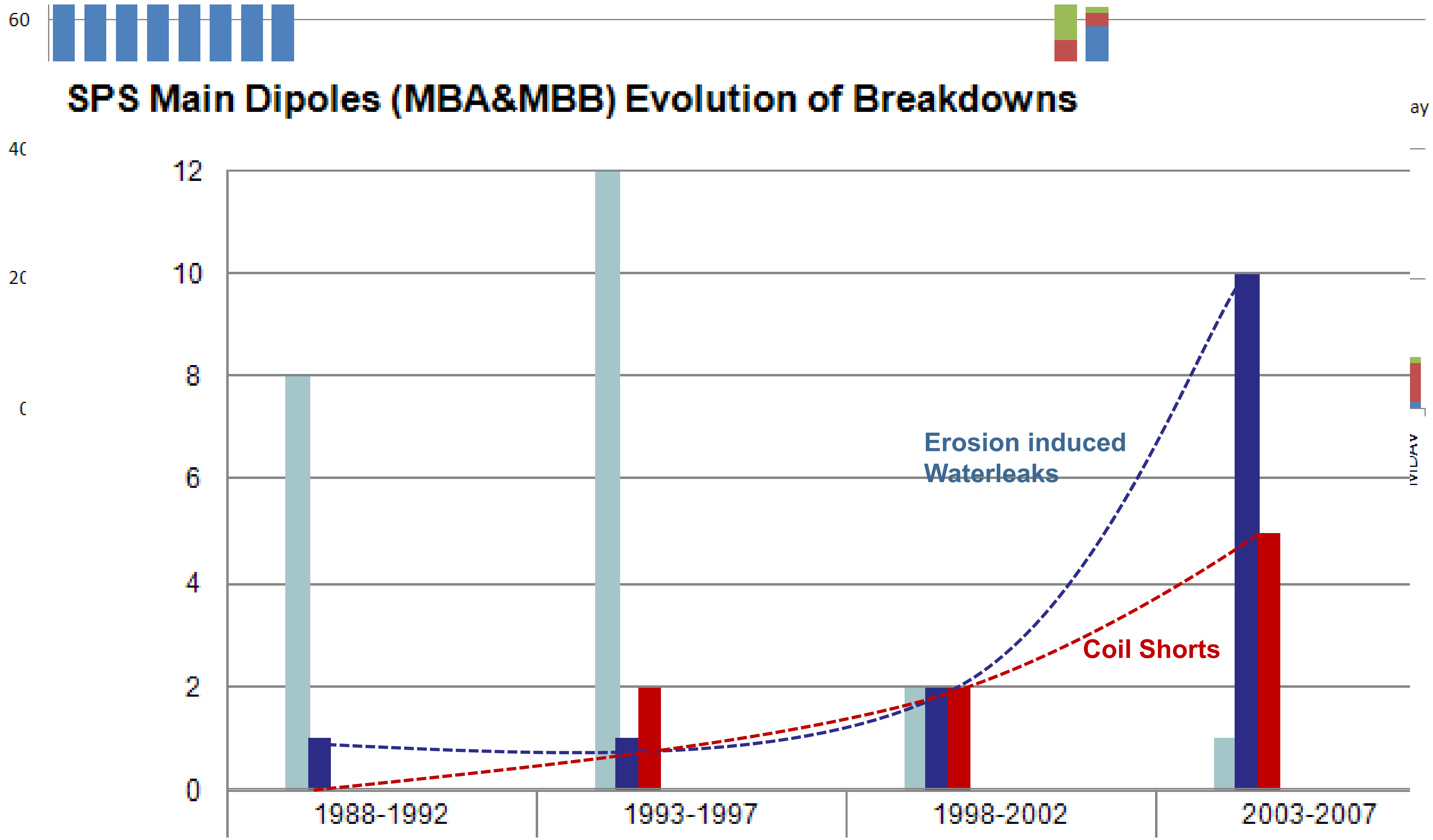
- Breakdowns in SPS Complex :
  - 2006: 35 interventions (27 in Target & North Areas), 4 magnets exchanged
  - 2007: 26 interventions (13 in Target & North Areas), 5 magnets exchanged
  - Objectives: remain below actual statistics (hereunder)

Distribution of MTTR according to 2007 breakdown Log (26 interventions)



Conclusions

→ Spare magnets are available: no specific risk detected on the way to LHC for most of the magnet families



➔ Failure of Associated Ancillary Equipment would have an important impact:

- SPS Main Busbar system (4x SPS circumference), powering dipoles and quadrupoles could still suffer a major damage (as in 1983, flashover). Mitigation: raw material is available, estimated MTTR<2weeks
- Water-Cooled Cables, linking Power converters in surface with the underground SPS main busbar system, and TI2 and TI8 MBI Dipoles could suffer a breakage of the inner cooling duct leading to waterleaks & electrical insulation failure (as in 1993 for SPS, and in 1998 for LEP) (→ No mitigation solution ?)
- Magnet Installation Vehicles, using modern electronic and software controlled will require special maintenance in the future. Those are the only vehicles able to install/remove most of the magnets (and the TED dumps) in the Tis, in the CNGS but also in the LHC Main Ring