MTTR and spare parts policy for BT equipment

BT equipment with long MTTR
- PSB
- ISOLDE
- LEIR
- PS
- SPS

Stand-by service and expert call-out lists

Conclusions

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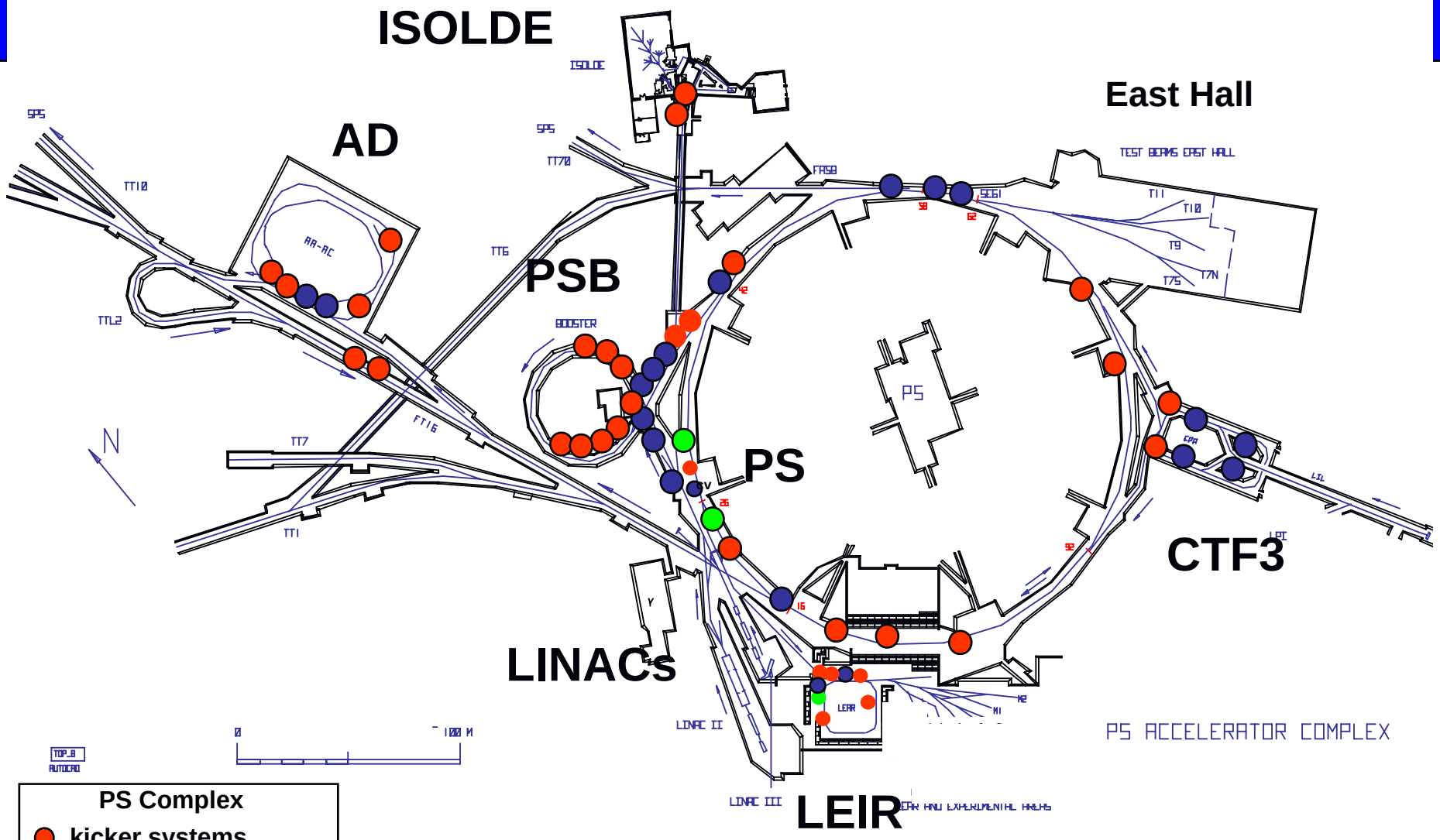
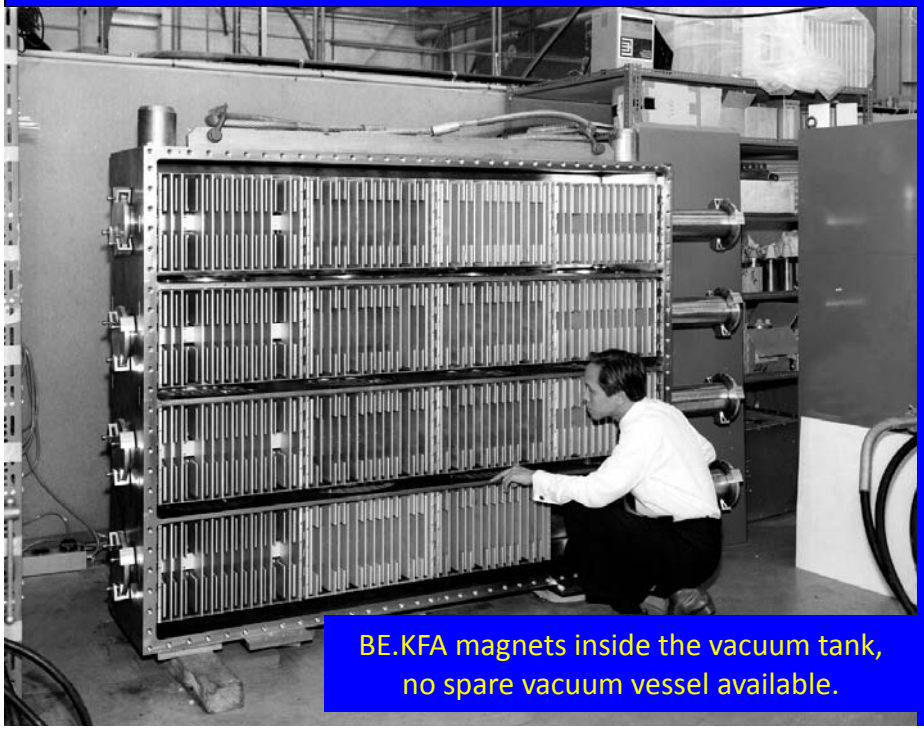
BT equipment in the PS Complex



MTTR and spare parts policy for BT equipment

PSB extraction kickers



BE.KFA magnets inside the vacuum tank, no spare vacuum vessel available.

Common spare (hence not installed) for HV cable for extraction and recombination kickers leads to long MTTR.

Name	Magnets	HV Pulse Generator	Recovery from major fault	Failure likelihood	Spares
BE.KFA	4 per ring connected in parallel.	Individual, one for each ring	HV Pulse generator: *days* Oil/Gas system: *days* HV cable: *weeks*	Medium Medium Low	Full spares for pulse generator Full spares for oil/gas system Common spare with BT.KFA
			Magnet: *weeks* Vacuum tank: *weeks*	Low Low	Magnet spares in parts only **No spare 14L1 vacuum tank**

PSB kickers

Name	Magnets	HV Pulse Generator	Recovery from major fault	Failure likelihood	Spares
BI.DIS	5	Individual	HV Pulse generator: *days* Oil/Gas system: *days*	Medium Medium	Full spares for pulse generator Full spares for oil/gas system
BI.KSW	4 per ring connected in parallel.	Individual, one for each ring	HV Pulse generator: *days* Magnet: *weeks* Vacuum tank (1L1): *weeks*	Medium Low Low	Full spares for pulse generator Spares for all four magnet types **No spare 1L1 vacuum tank**
BE.BSW	3 per ring connected vertically through the four rings	Individual, one for each magnet group	HV Pulse generator: *days* Magnet: *weeks*	Medium Low	Full spares for pulse generator Spares for both magnet types
BT.KFA	3 : R4->R3, R3+4->R2, R1->R2	Individual	HV Pulse generator: *days* Oil/Gas system: *days* HV cable: *weeks* Magnet: *weeks* Vacuum tank: *weeks*	Medium Medium Low Low Low	Full spares for pulse generator Full spares for oil/gas system Common spare with BE.KFA 2 spare magnets plus parts **Spare KFA20 tank only**

Only partial spare parts inventory is defensible because of modularity, some redundancy, combined with low risk and high capital investment to achieve full spares for (sometimes) unique equipment.

PSB Recombination septa BT.SMV10

In 2004 a new strategy was adopted to consolidate the PS complex septa which are part of the LHC injector chain and to build additional spares.

As a result, from 2008 the PSB transfer septa follow a preventative exchange programme to reduce the likelihood of a failure during the run, based on failures of similar equipment. This was previously impossible.

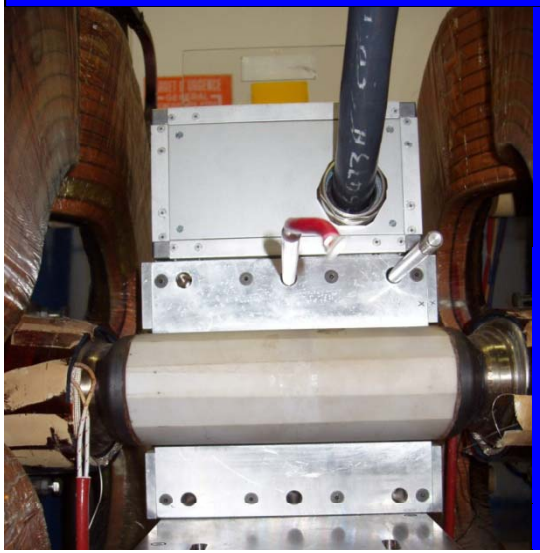
Name	Magnets	Failure likelihood	Recovery from major fault	Spares
BT.SMV10	2 : R4->R3, R1->R2	medium	Magnet: *weeks* Vacuum tank: *weeks*	2 2nd choice spares (to be rebuilt) and 2 full operational spares as from mid 2008.
BT.SMV20	R3+4->R2,	medium	Magnet: *weeks* Vacuum tank: *weeks*	2nd choice spare to be rebuilt. Additional spare to be built 2008.

PSB septa

In the framework of the Linac 4 project, the Booster Injection septa (presently more than 30 years in operation) will be replaced.

Name	Magnets	Failure likelihood	Recovery from major fault	Spares
BI.DIS	5	low	Magnets: *days* Vacuum tank: *weeks*	2 spare magnet blocks No spare magnet tank
BI.SMV	3	possible	Magnet: *weeks* Vacuum tank: *weeks*	Full spare magnet
BI.SMH	4; 1 per ring	possible	Magnet: *weeks* Vacuum tank: *weeks*	2 stacks of spare magnets
BE.SMH	4; 1 per ring	low	Magnet: *weeks* Vacuum tank: *weeks*	full spare system

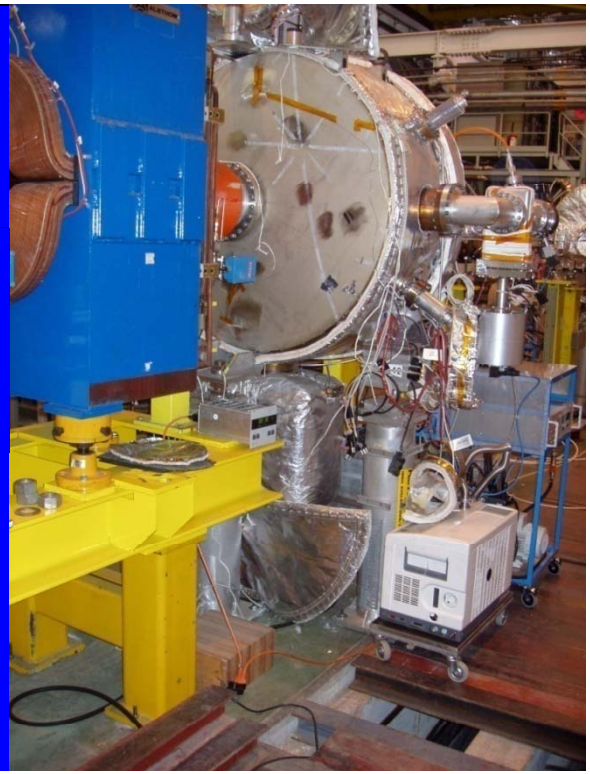
LEIR kickers



Half of DFH21 around its ceramic vacuum chamber (for which a spare is available, but not under BT responsibility)

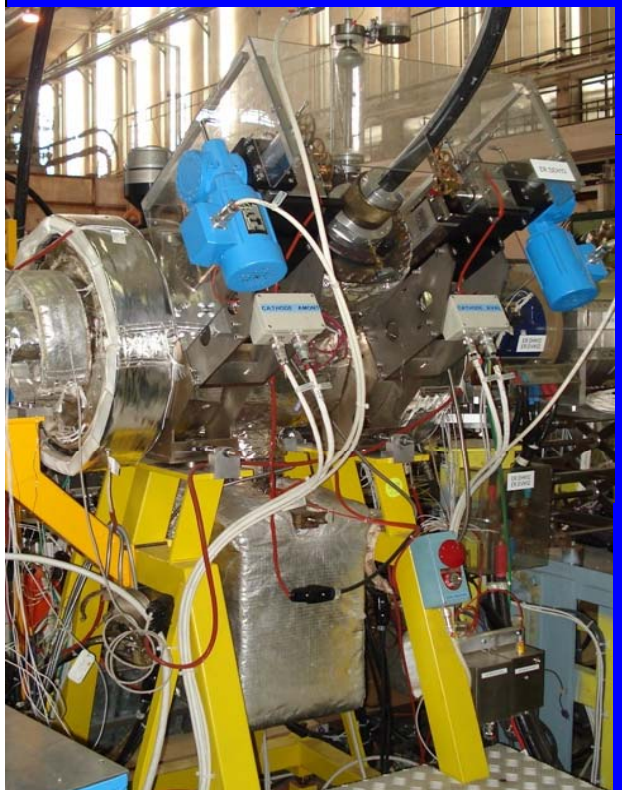
Full spare magnet becoming available in 2008

ER.KFH31 vacuum tank.
No spare foreseen, but it should be possible to extract with only two magnets.



Name	#	HV (Pulse) Generator	Recovery from major fault	Failure likelihood	Spares
ER.KFH	3	Individual	HV Pulse generator: days Oil/Gas system: *days* Magnet: weeks Vacuum tank: weeks	Medium Medium Low Low	Full spares for pulse generator Full spares for oil/gas system No spare magnet No spare vacuum tank (Could be possible to extract with only two magnets)
ER.DFH	4	1 common	HV Pulse generator: days Magnet: days	Medium Low	Full spares for pulse generator Spare magnet should be available end 2008

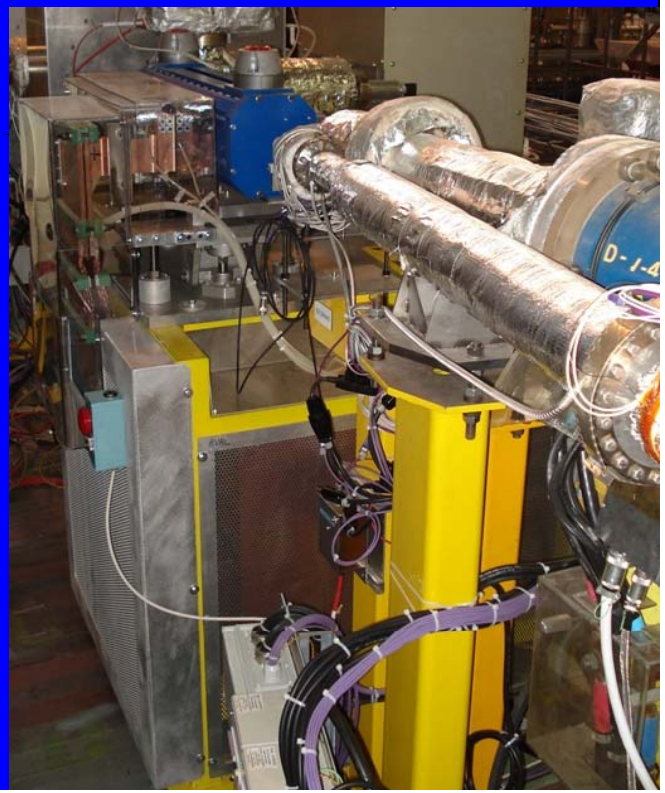
LEIR Injection electrostatic septum ER.SEH10, extraction septum ER.SMH40



LEIR extraction septum SMH40.

Vacuum chamber most stressed component, together with septum insulation. Spare vacuum chamber being finished.

Electrostatic injection septum SEH10. No spare available; only delicate and long lead items are kept in spare.



Name	Magnets	Recovery from major fault	Failure likelihood	Spares
ER.SMH11	1	Magnet: day Vacuum chamber: weeks	Low Low	1 full spare No spare vacuum chamber
ER.SEH10	1	Septum: weeks HV generator: day	Low Low	Spare HV components of critical parts available Failure will need rebuild of installed device. Spare HV generator installed online
ER.SMH40	1	Magnet: day Vacuum chamber: weeks	Low Medium	Spare magnet available. Spare vacuum chamber completed in 2008.

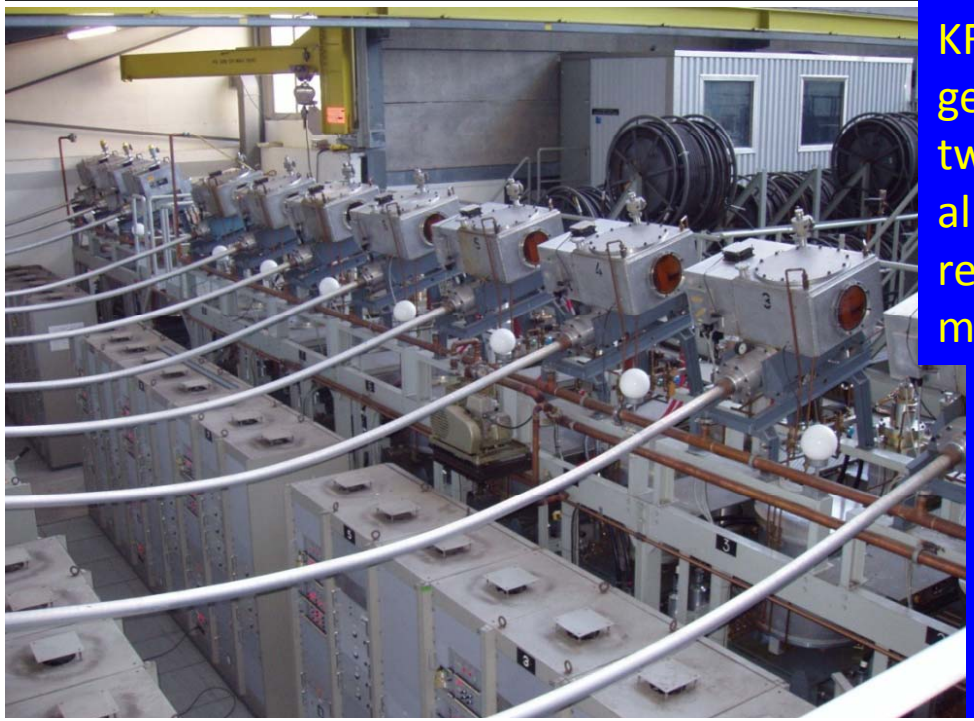
PS injection kickers

KFA45 (protons) vacuum tank. No spare tank available.

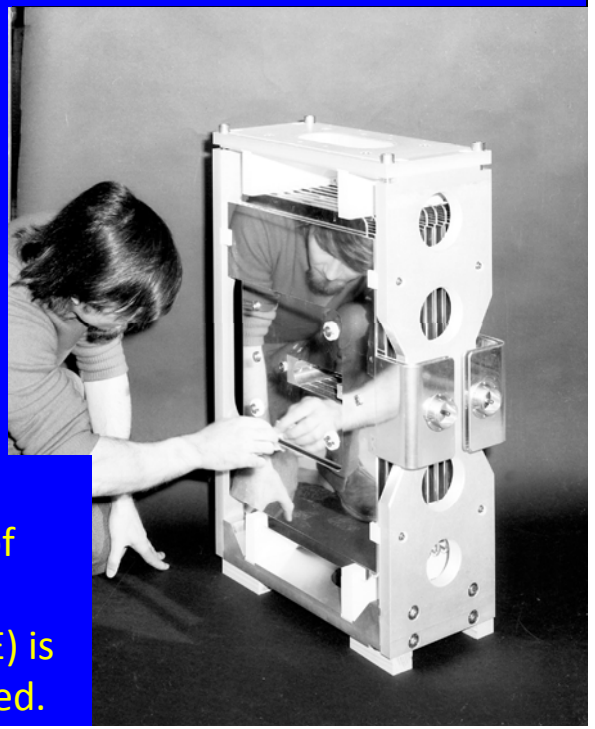
KFA28 (ions) vacuum tank. No spare tank available.

Name	Magnets	Recovery from major fault (worst case)	Failure likelihood	Spares
PI.KFA45	4	HV Pulse generator: *days* Oil/Gas system: *days* HV PFN cable: *weeks* Magnet: *weeks* Vacuum tank: *weeks*	Medium Medium Low Low Low	Full spares for pulse generator Full spares for oil/gas system One spare 80kV PFN cable One spare magnet No spare vacuum tank
PI.KFA28	1	HV Pulse generator: *days* Oil/Gas system: *days* HV PFN cable: *days* Magnet: *weeks* Vacuum tank: *weeks*	Medium Medium Medium Low Low	Full spares for pulse generator Full spares for oil/gas system One spare 40kV PFN cable set Parts for one spare magnet No spare vacuum tank

PS fast extraction kickers



KFA71-79 pulse generators. The twelve modules allow some redundancy on most user cycles.



KFA71-79 kicker magnet. Building of new spares (in common with MTE) is presently postponed.

Name	Magnets	Recovery from major fault (worst case)	Failure likelihood	Spares
PE.KFA 71-79	12 (SS71: 9) (SS79: 3)	HV Pulse generator: days Oil/Gas system: *days* HV PFN cable: days Magnet: *weeks* Vacuum tank: *weeks*	Medium Medium Low Low Low	Full spares for pulse generator Full spares for oil/gas system Redundancy available (normally maximum 10 of 12 modules used) + spare cable in B.367 Two spare tanks, one equipped with 9 spare magnets, one empty (3 magnets taken for use in the new MTE system)

PS CT (MTE) kickers

MTE DFA242/256 pulse generators will re-use > 35 year old cables (missing budget) .

No spare MTE DFA242/256 vacuum tank and magnets. Some parts for DFA magnet will be procured in 2008-2009.

Name	Magnets	Recovery from major fault (worst case)	Failure likelihood	Spares
PE.BFA21-9 & PE.DFA242/256 Will be replaced by new MTE in 2009		HV Pulse generator: *days* Oil/Gas system: *days* HV cable: *days* Magnet: *weeks* Vacuum tank: *weeks*	Medium Medium Low Low Low	Full spares for pulse generator Full spares for oil/gas system One spare BFA magnet per type One spare BFA vacuum tank. No DFA
New MTE system: KFA4, KFA13-21 (2008), KFA9, DFA242-256 (2009)		HV Pulse generator: *days* Oil/Gas system: *days* HV cable: *days* Magnet: *weeks* Vacuum tank: *weeks*	Medium Medium Low Low Low	Full spares for pulse generator Full spares for oil/gas system Some HV cable >35 years old Spare magnets for KFAs 4,9,13,21 Spare vacuum tanks for all positions except DFAs

PS Electrostatic septa

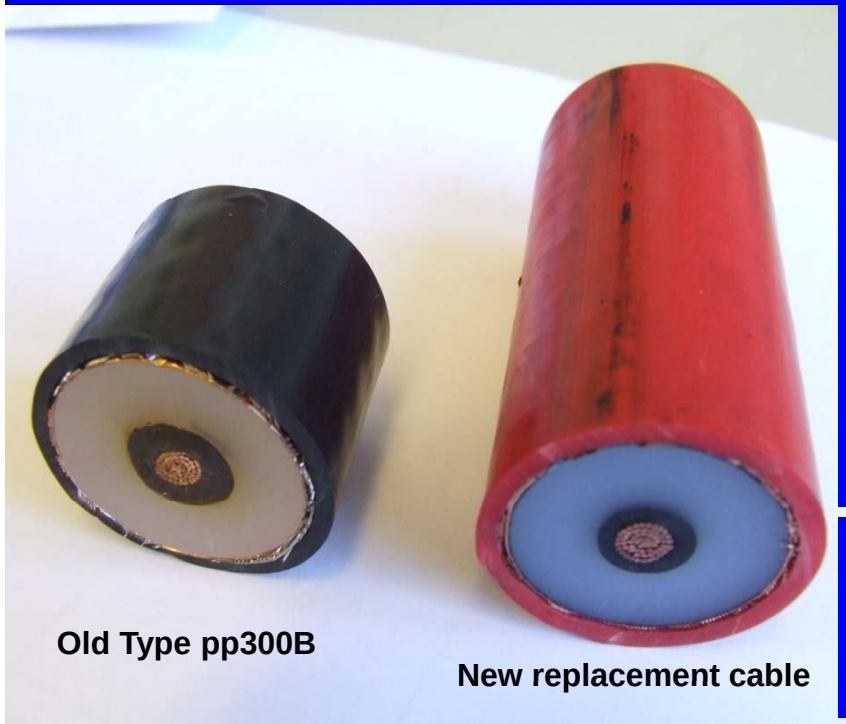
SEH23, only partial spare

MTE will make PE.SEH31 obsolete

All PS septa used for LHC beams as well as the electrostatic septa benefit from a preventative exchange program to reduce the likelihood of a failure during the run, based on past experience.

Name	Septa	Recovery from major fault	Failure likelihood	Spares
PE.SEH23	1	*Septum: week*	Medium	Even years: 2nd choice spare Odd years: full spare
		Vacuum: days	Medium	
		Cable: hours	Medium	**1 spare set of cables available, but old**
		HV generation: hours	Low	Spare generator online
PE.SEH31	1	*Septum: week*	Medium	1 full spare septum+ 2nd choice spare septum
		Vacuum: days	Medium	
		*Cable: hours/**days***	**High**	1 spare set of cable available, but with short life expectancy
		HV generation: hours	Low	Spare generator online

PS septa HV cable



Old Type pp300B

New replacement cable

Searched for pp-300b HV cable for PS electrostatic septa since 2001.

In 2006 received 2 offers. One supplier disqualified on technical grounds during pre-tendering.

The new cable (compatible with old cable dimension) produced using present day insulation (old paper oil insulation not produced anymore) and tested in lab up to 300 kV.

Specification stated cable should resist at least to 1 MGy and materials used are in compliance with this.

Highest annual accumulated doses measured (2001-2006):

SEH23: 84 kGy (in 2001, but similar in 2006)

SEH31: 1 MGy (2002)

2007

Old type lasted up to 10 weeks on SEH31, and the full run on SEH23.

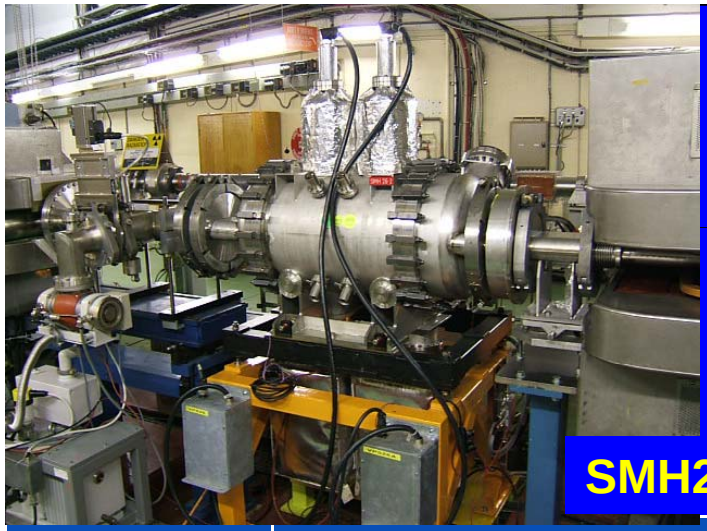
New type lasted 3 weeks on SEH31, with failures in connector (2x) and once in the middle of the cable.

2008

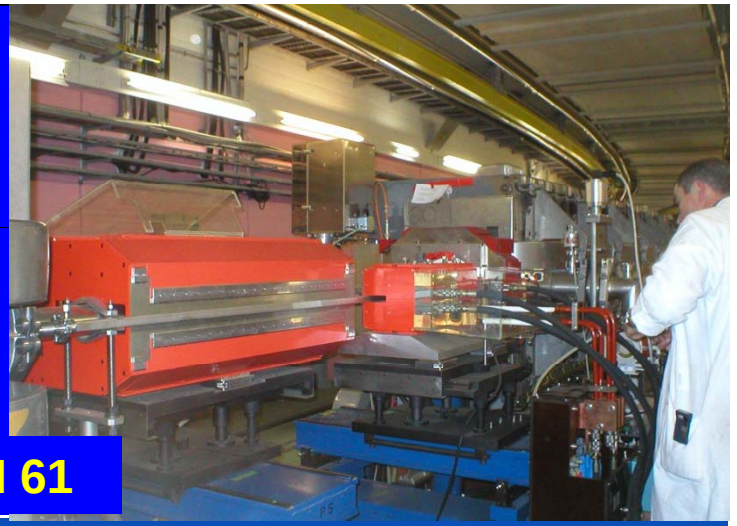
Old cable type will be installed. In parallel a new 90° connector will be developed to allow the use of a larger diameter cable based on EPR insulation (as used in the ZS of the SPS).

The MTE will make the SEH31 obsolete in the course of 2008.

PS septa



SMH26

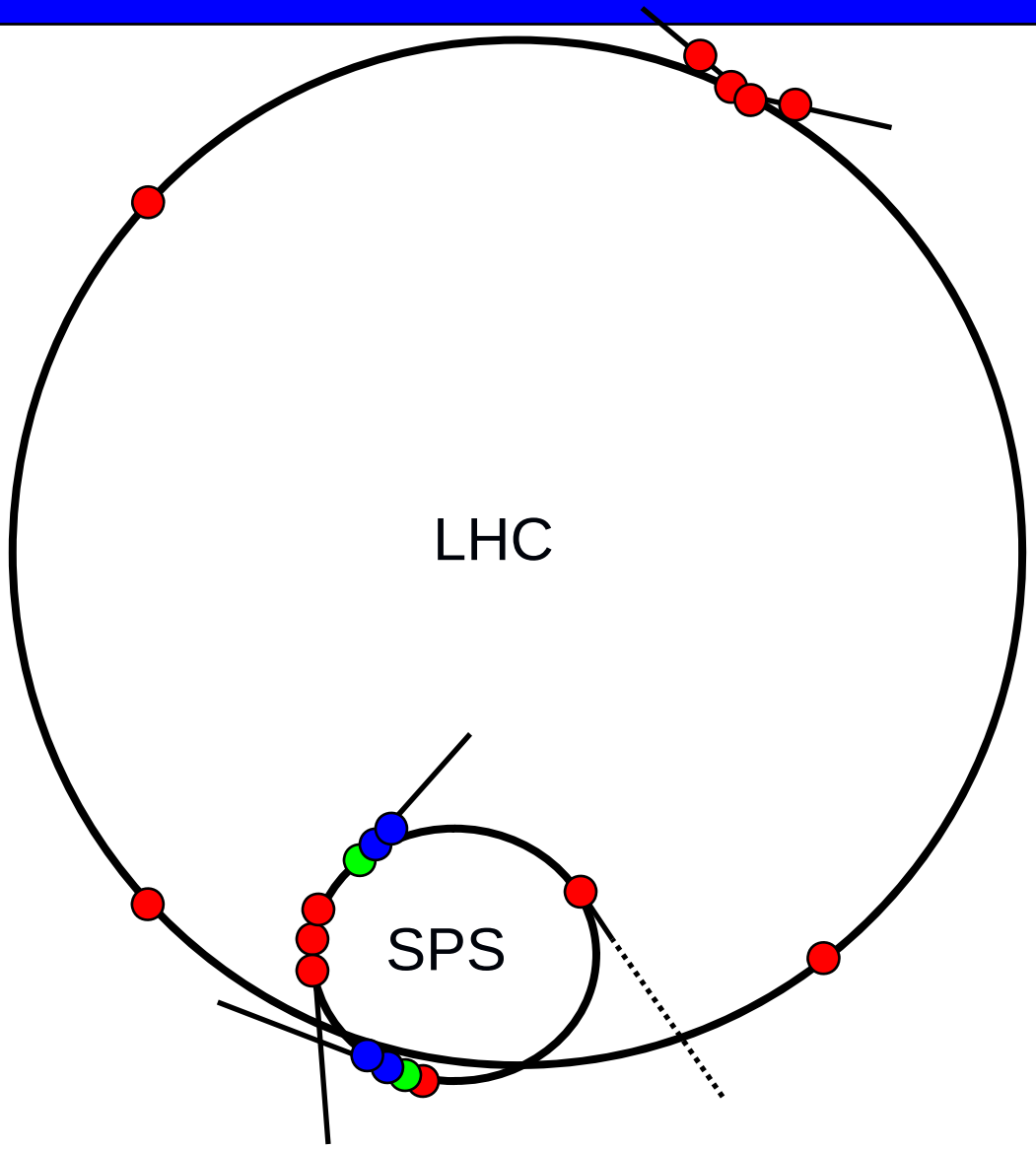


SMH 61

Name	Recovery from major fault	Failure likelihood	Spares
PE.SMH16	Magnet: week Vacuum: week	Medium	2 full spare systems
PI.SMH26	Magnet: week Vacuum: week	Low Low	1 full spare available
PI.SMH42	Magnet: week Vacuum: week	Medium Medium	2nd choice spare (to be rebuilt). Additional spare to be built 2008.
PE.SMH57	Magnet: week Vacuum: week	Medium Medium	1 full spare available
PE.SMH61 extr.	Magnet: day	Low	Spare available

MTTR also dependent of radiation level, to obtain access to the equipment

SPS and LHC involvement

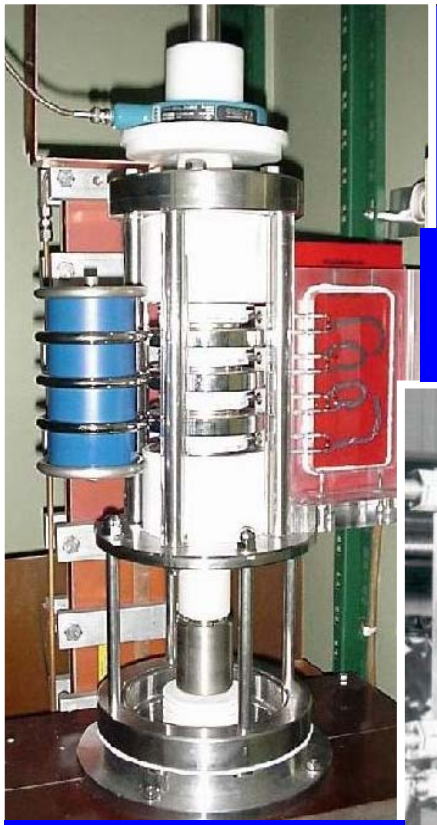


Kicker

Electrostatic septa

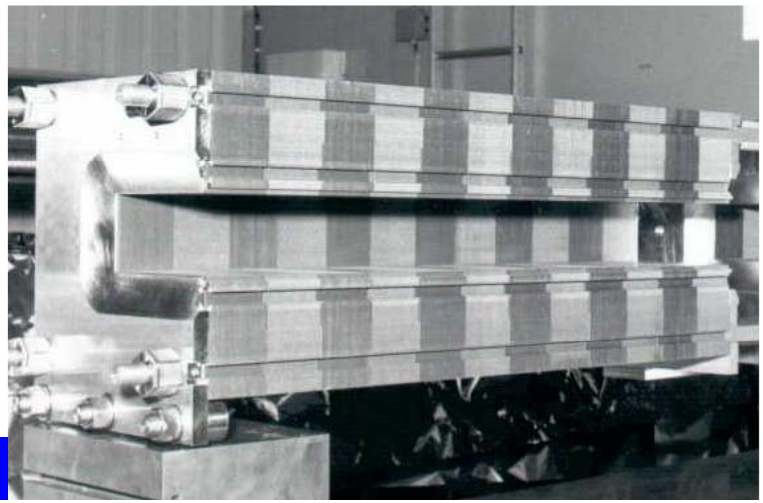
Magnetic septa

SPS Beam Dumping kickers MKDH & MKDV (LSS1)



MKDH magnet

MKDH generator recently equipped with solid-state switches

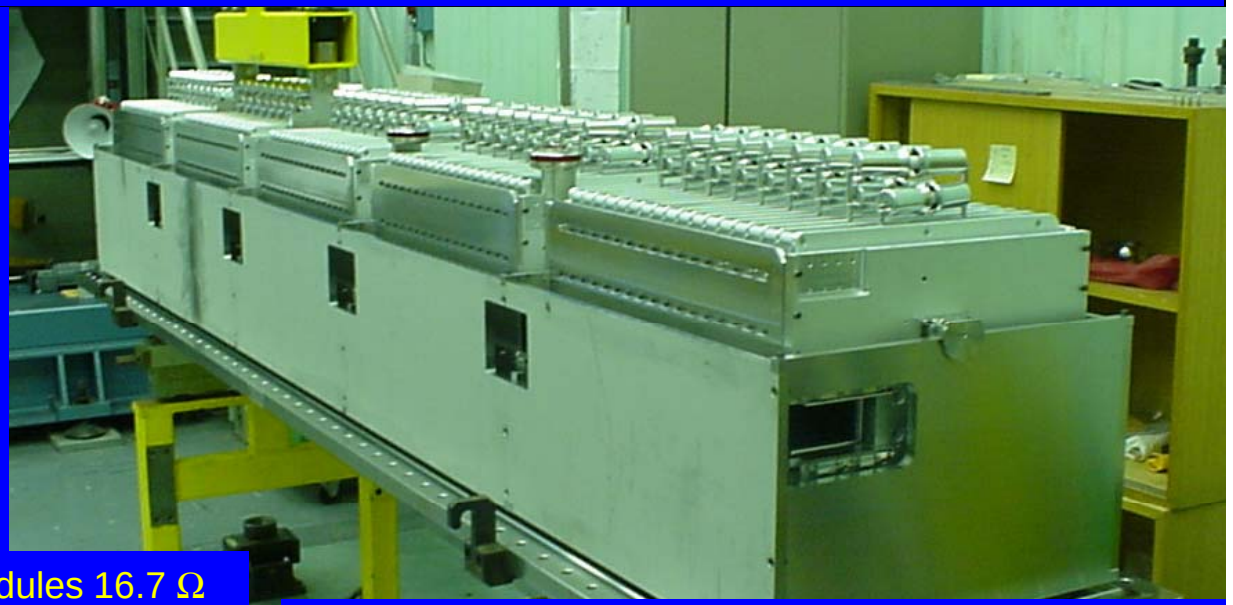


1 spare MKDV magnet and tank being refurbished. Pulse generator to be re-designed in future.

Name	#	HV Pulse Generator	Recovery from major fault (worst case)	Failure likelihood	Spares
MKDH	3	Individual	Magnet: *months* Vacuum tank: *weeks/months* HV Pulse generator: *weeks*	Medium Low Medium	No spare MKDH magnet nor vac tank; 1 spare magnet (in 2008) + spare for vacuum tank MKDV
MKDV	2	3 for 2 magnets	Terminating resistors: *hours* HV coax. cable: *hours*	Medium Medium	Full spares for Pulse generator MKDV; Parts for Pulse generator MKDH Full spares for terminating resistors Full spares for HV coax. Cable

SPS Injection kickers MKP (LSS1)

Thyratron switch to be upgraded

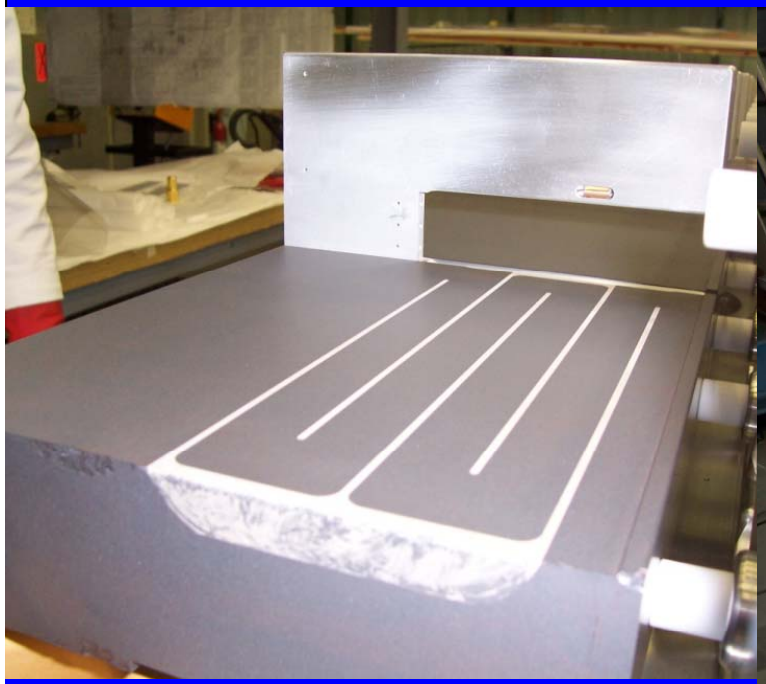


2 vacuum tanks with 5 modules 16.7 Ω
1 vacuum tank with 2 modules 16.7 Ω
1 vacuum tank with 4 modules 12.5 Ω

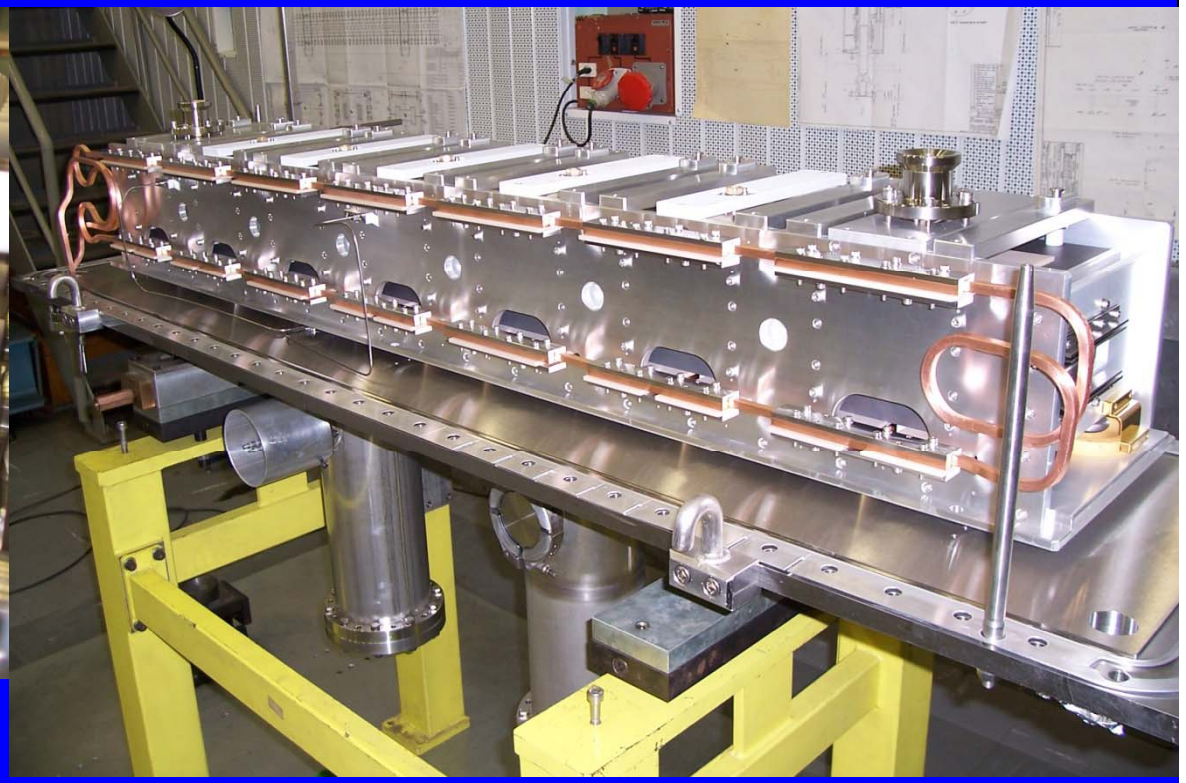
No spare for L type magnet and tank until 2009
Irradiated HV coax. cables to be replaced in 2009

Name	Magnets	HV Pulse Generator	Recovery from major fault (worst case)	Failure likelihood	Spares
MKP	2 x 5 type S 1 x 2 type S 1 x 4 type L	One for 2 magnets	Magnet: *weeks* Vacuum tank: *weeks* Pulse generator: *days* Terminating resistors: *hours* HV coax. cable: *hours*	Medium Low Medium Medium Medium	Full spares for S type magnet + vac tank; none for L type magnets + vac tank Full spares Full spares Full spares for HV coax. cable

SPS Extraction Kickers MKE4 & MKE6 (LSS4 & LSS6)

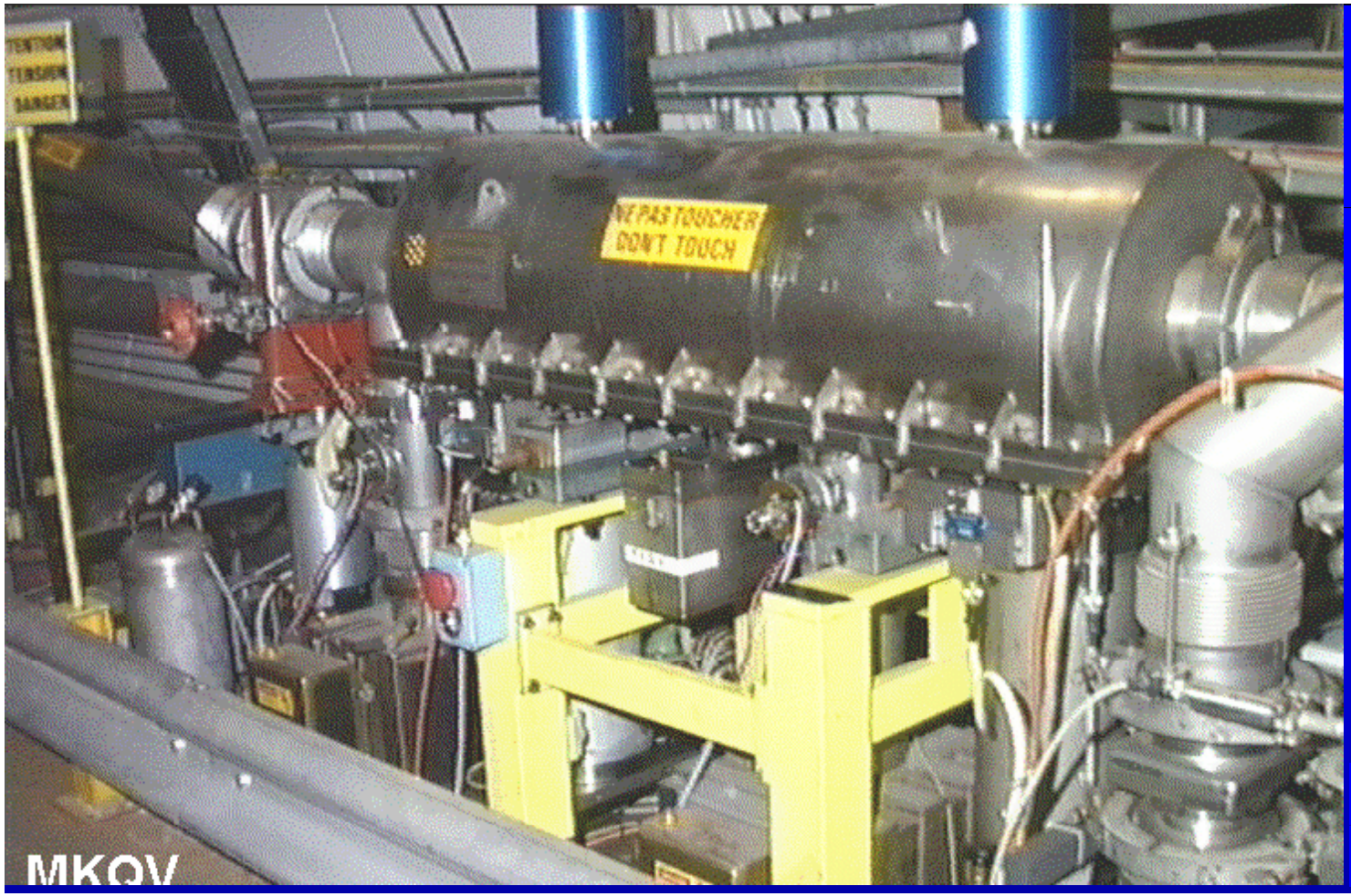


Stripes on ferrite blocks as beam screen to be deployed on all MKE magnets over next few years.



Water cooled magnets to cope with beam induced heating

Name	#	HV Pulse Generator	Recovery from major fault (worst case)	Failure likelihood	Spares
MKE 4	5	Individual	Magnet: *weeks/month*	Medium	Full spares for magnets
			Vacuum tank: *weeks*	Low	Full spares for vacuum tank
			HV Pulse generator: *days*	Medium	Full spares for Pulse generator
MKE 6	3	One for 3 magnets	Terminating resistors: *hours*	Medium	Full spares for terminating resistors
			HV coax. cable: *hours*	Medium	Full spares for HV coax. Cable



MKQ

No spare for magnet nor tank

Name	HV Pulse Generator	Recovery from major fault (worst case)	Failure likelihood	Spares
MKQH	Individual	Magnet: *months*	Medium	No spares for magnets
		Vacuum tank: *months*	Low	No spare for vacuum tank
		HV Pulse generator: *weeks*	Medium	Spare parts for Pulse generator
MKQV	Individual	Terminating resistors: *hours*	Medium	Full spares for terminating resistors
		HV coax. cable: *hours*	Medium	Full spares for HV coax. Cable

SPS electronics

- **Spare location to be studied (presently in BA, in BA/865 or in 865 --> a lot of duplication).**
  - Centralization in Prévessin has to be studied --> more effective in term of maintenance and cost, but less efficient in term of intervention duration
- **-Management of firmware version within electronic spare modules becomes an issue**
  - (same hardware module with different functionalities due to different firmware)... Spares duplication (sometimes 1 spare for 1 operational module) vs single spare + firmware to be downloaded before use (increases intervention time)

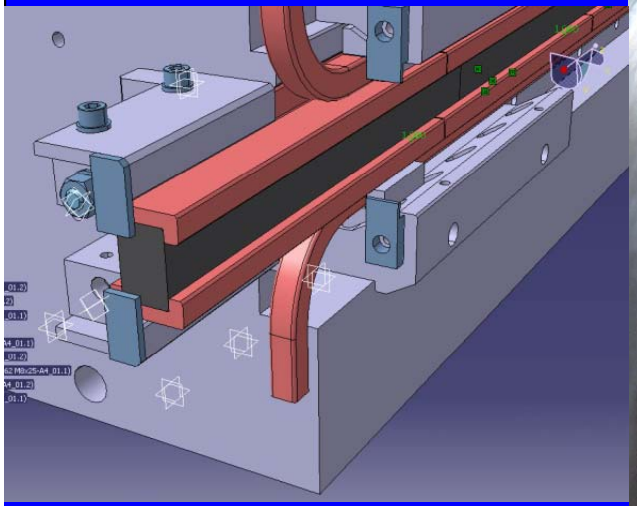
PLC's

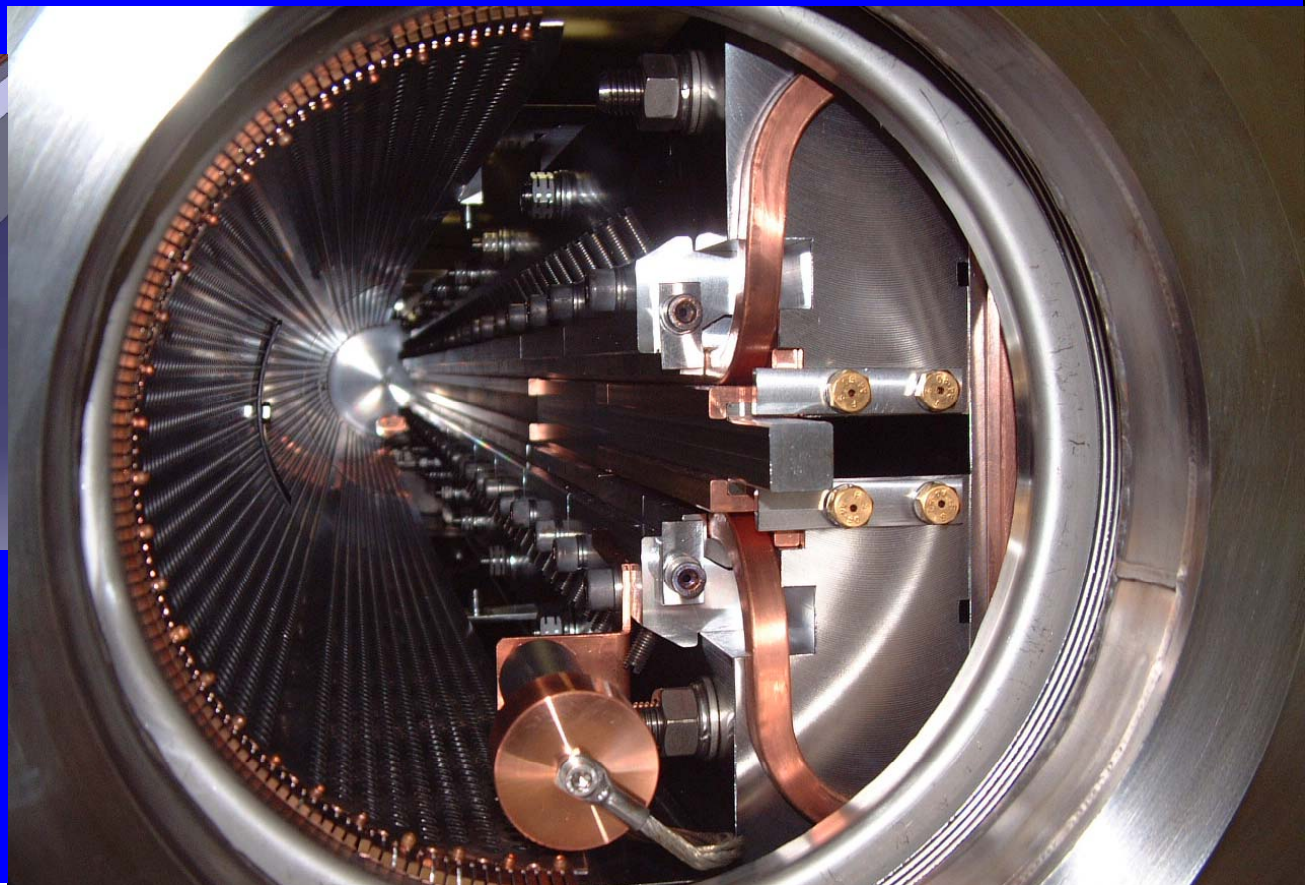
- Spare modules centralised for BT group so far in 865 (the new centralized AB/CO approach is very welcome ... spare cost is high)
- Use of SIEMENS diagnostic tools to identify faulty modules
- Management of operational PLC software (followed up by ATC)

HV Power Supplies

- At least "one" spare available for each type of HV power supply.
- Rotation of power supplies (operational vs spare) each year during shutdown period (electrolytic capacitors)
- Repair can take time (months) → risk when we have only one spare power supply for three power supplies in operation ...
- Consolidation program under progress for MKP, in the pipeline for MKDV and will be done on exploitation budget for MKQ

Extraction protection elements TPSG4, TPSG6



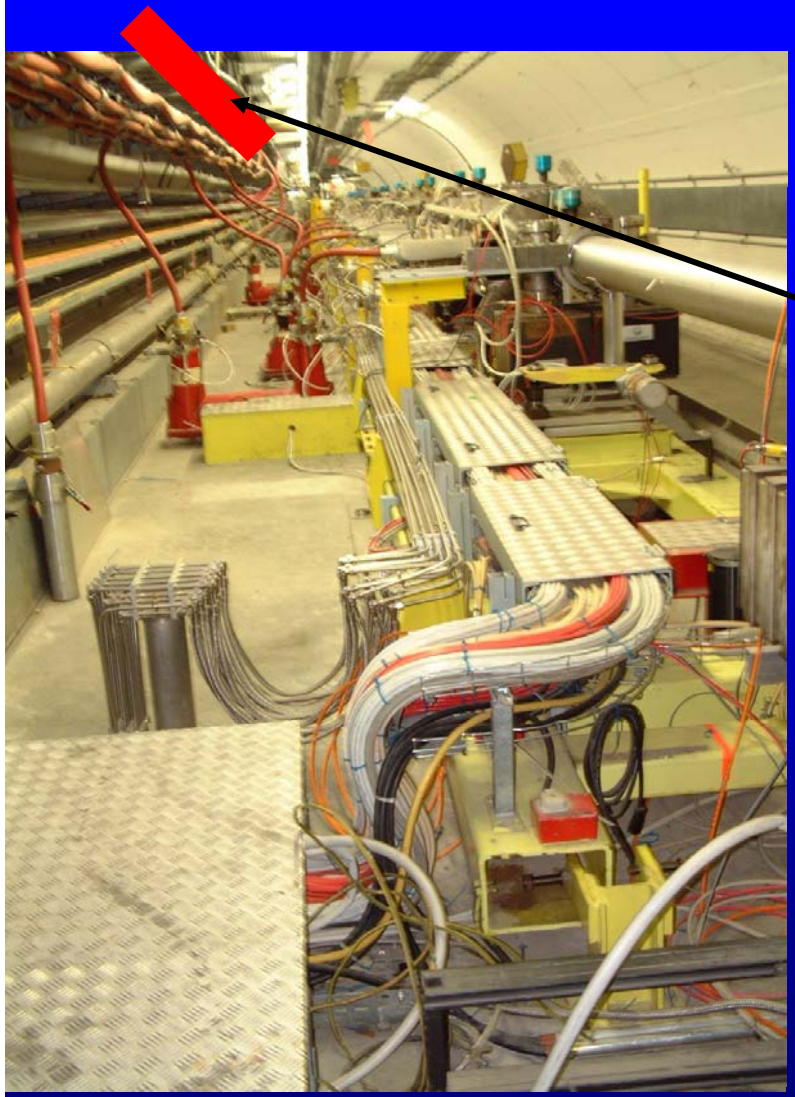


This shutdown the TPSG4 will be modified by substituting some graphite blocks with a C-C composite and by adding additional length, thus making it compatible with LHC ultimate beam in SPS.

Name	Recovery from major fault	Failure likelihood	Spares
TPSG4	Absorber: week Vacuum: week	Low Low	**0: Spare to be constructed in 2008**
TPSG6	Absorber: week	Low	1; Spare operational mid 2008

MTTR and spare parts policy for BT equipment

ZS HV cable



~100 m of 300kV HV cable from ~QD216 to QD219.

Failed early 2007, presently running on spare which saw as much radiation, but was never used before.

Full-length spare available.
However, costly to install (both in CHF and radiation); will be postponed to re-cabling campaign foreseen for SD 2008-2009.

ZS, HV cable (cont'd)

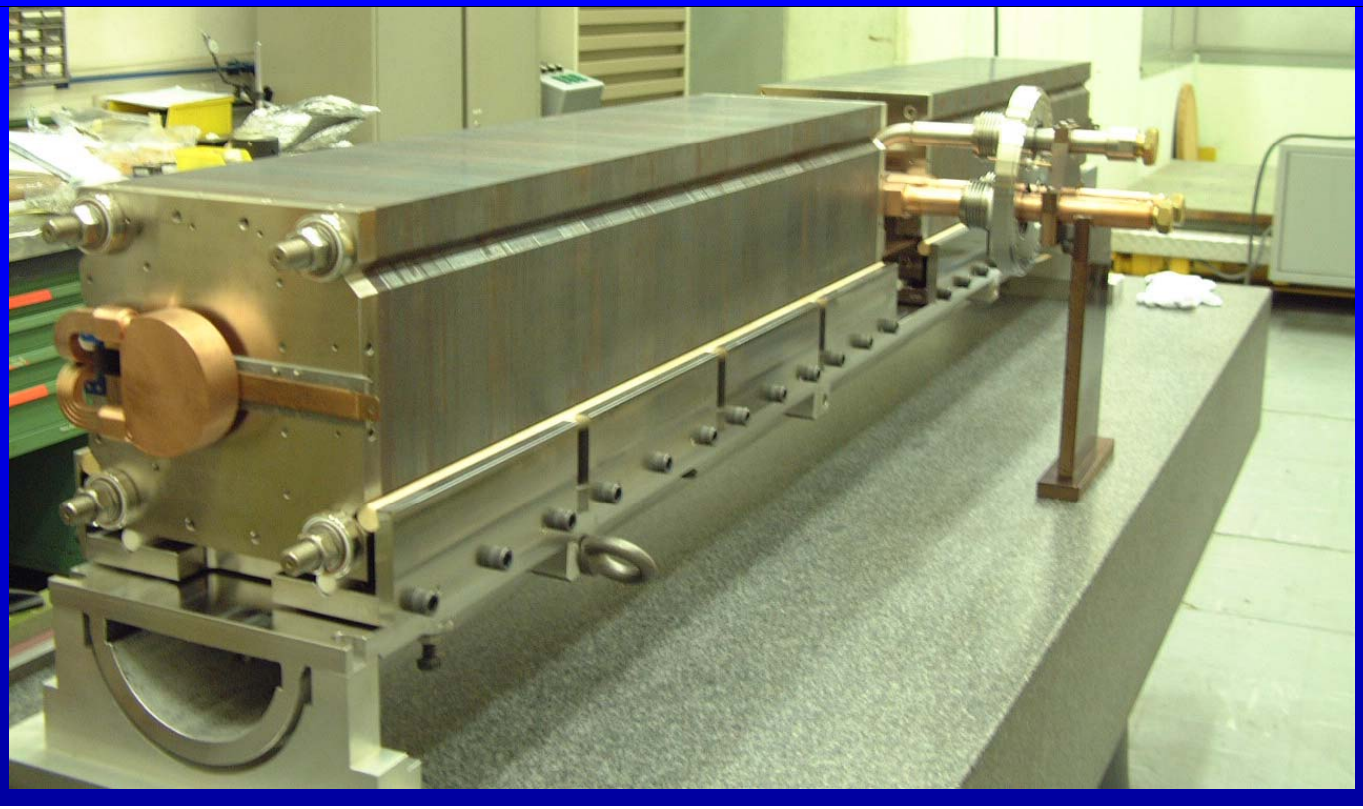
Foreseen for 2008:

Installation of 'easy-to-install' Silec 160 cable as spare, and keep EPR 300 on drum ready to roll out in case of failure of both.

Risk of cable failure increased in 2008, since the ZS1 got killed during the last days of operation of 2007 and will be replaced. This demands reconditioning of the ZS, with associated stress for the HV cables.

Name	#	Recovery from major fault	Failure likelihood	Spares
ZS Invar 60 um wires	2	Septum: weeks Vacuum: week *Cable: day* *HV generation: hours*	Medium Medium Medium Low	2 full spare systems **Spare long cable in tunnel failed early 2007** Spare generator online
ZS Invar 100 um wires	1	*Septum: week* *Vacuum: week* *Cable: hours* *HV generation: hours*	Medium Medium Medium Low	1 spare Spare generator online
ZS Steel 100 um wires	2	Septum: weeks Vacuum: week *Cable: hours* *HV generation: hours*	Medium Medium Medium Low	4 spares Spare generator online

SPS magnetic septa



Name	#	Recovery from major fault	Failure likelihood	Spares
MST	5	*Septum: week* *Vacuum: week*	Medium Medium	3 full spare septa + 1 2nd choice spare septum
MSE	16	Magnet: *week* Vacuum: *week*	Medium Medium	7 spares

Stand-by service, expert lists

Due to the complexity and diversity of the **PS KICKER systems** and **ALL SEPTA**, repairs are ensured by intervention of people on an **EXPERT CALL-OUT list**.

During operation, a **piquet service** ensures the interventions for the **SPS KICKER** systems and associated electronics.

- Works well for "real and obvious" equipment hardware failures
- Less efficient when failures are linked to operational conditions (more than 50 % of the interventions) or for transient failures
- Real source of the fault not always identified by the standby service (→ able to restart the installation but time is required later to solve the problem properly).

Conclusions (1/2)

- **NO ‘shocking’ or ‘striking’ situations identified**
- **Septa HV CABLE situation (delicate components) LESS COMFORTABLE, but PE.SEH31 will be phased out after MTE comes online, and for PE.SEH23 and ZS the situation is under control.**
- **PS SEPTA situation starts to profit from consolidation, and PREVENTIVE EXCHANGE is undertaken for all PSB and PS septa part of the LHC injector chain from this SD onwards.**

Conclusions (2/2)

- **For PS KICKERS only PARTIAL SPARE PARTS inventory is defensible because of their modularity, some redundancy, combined with low risk and high capital investment to achieve full spares for (sometimes) unique equipment.**
- **SPS KICKERS spare situation generally OK. Weak points will be addressed in the coming years.**
- **MTTR strongly dependent on radiation levels (can partly be influenced by operation).**
- **Balanced solution between expert lists and stand-by service .**