LINAC2 PERFORMANCE AND HARDWARE REVIEW

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Timeline

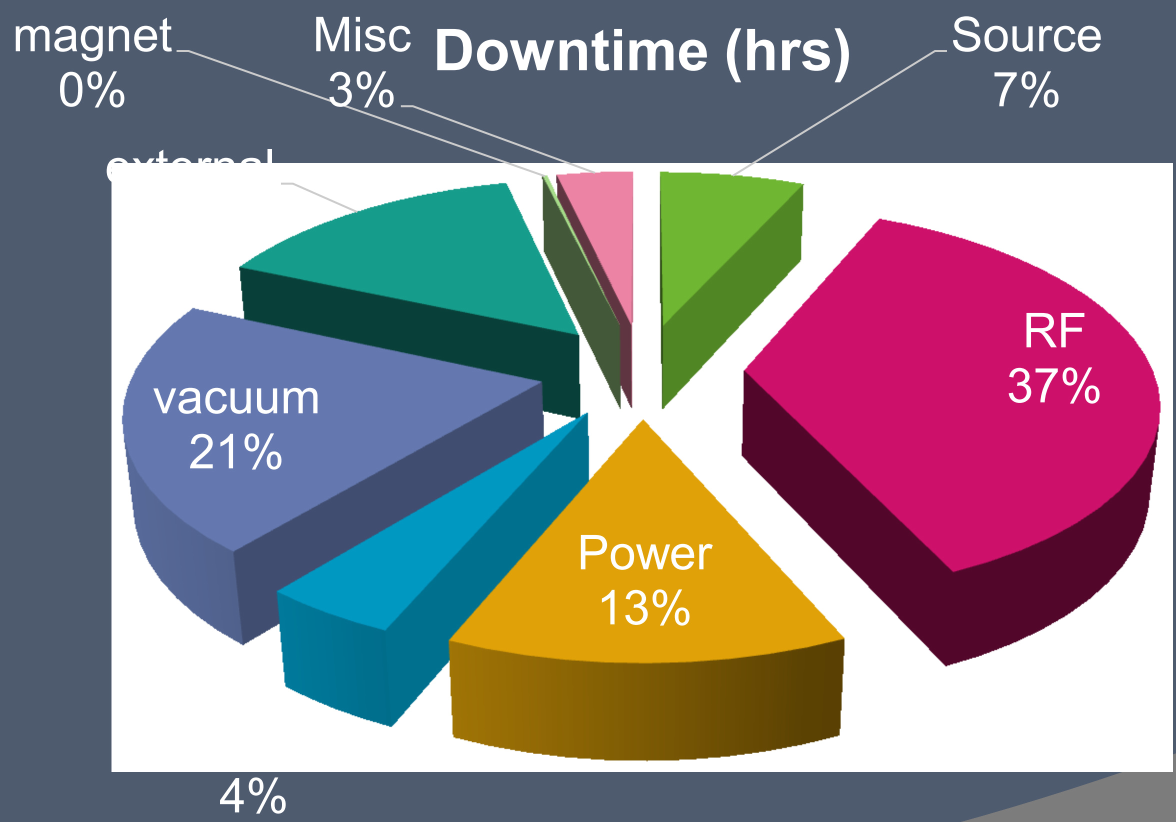
1958	Linac1 commissioning
1973	Linac2 Project study to replace existing 50 MeV linac for higher intensity and better quality beams
1978	Linac2 Commissioning
1993	RFQ installed to replace high voltage Cockroft-Walton column
2010	
2013/ 14	LS1?
2017/ 18	LS2?

1979

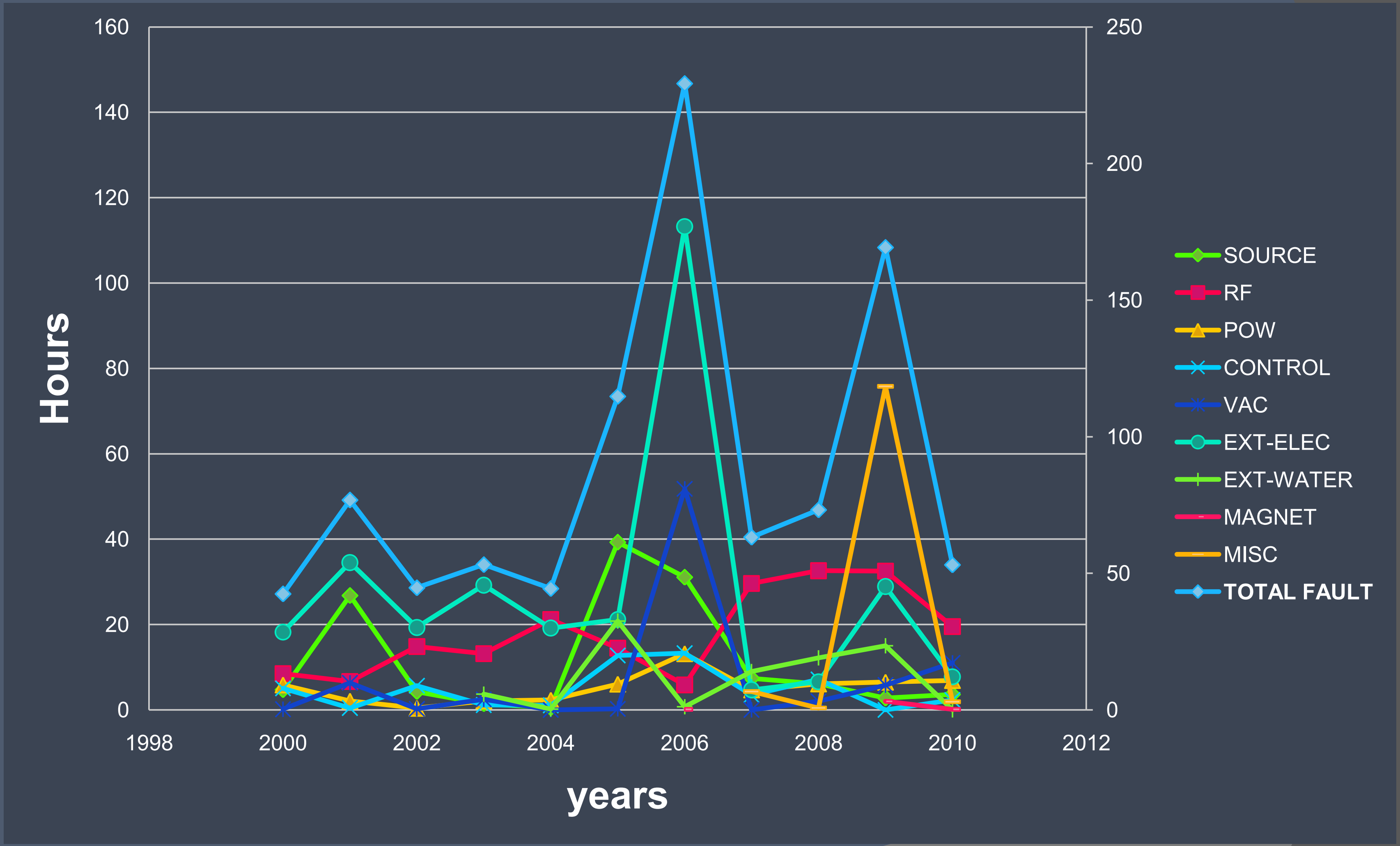
1993

Fast forward →→→ 2010

Linac2 ran from 3 February to 23 November, for a total of 6880 hours, with 53 hours in fault → 99.2% uptime

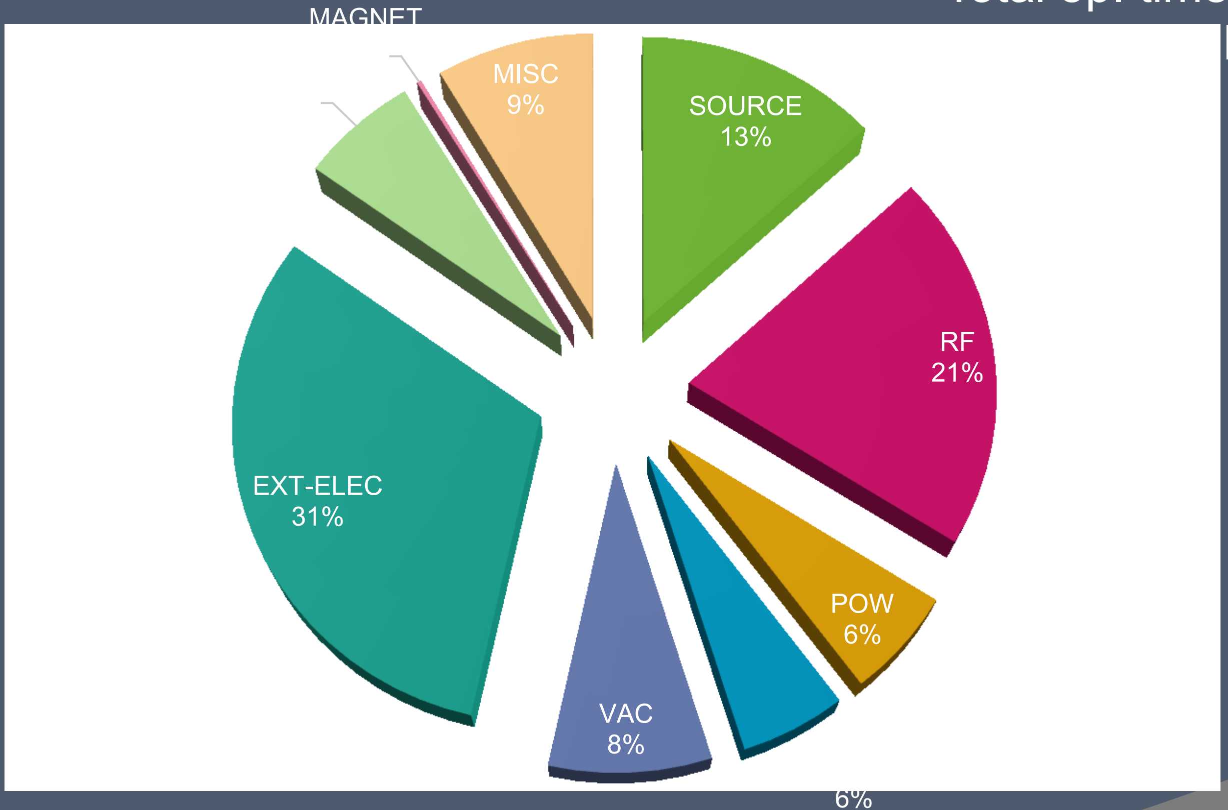


Downtime: recent history year by year

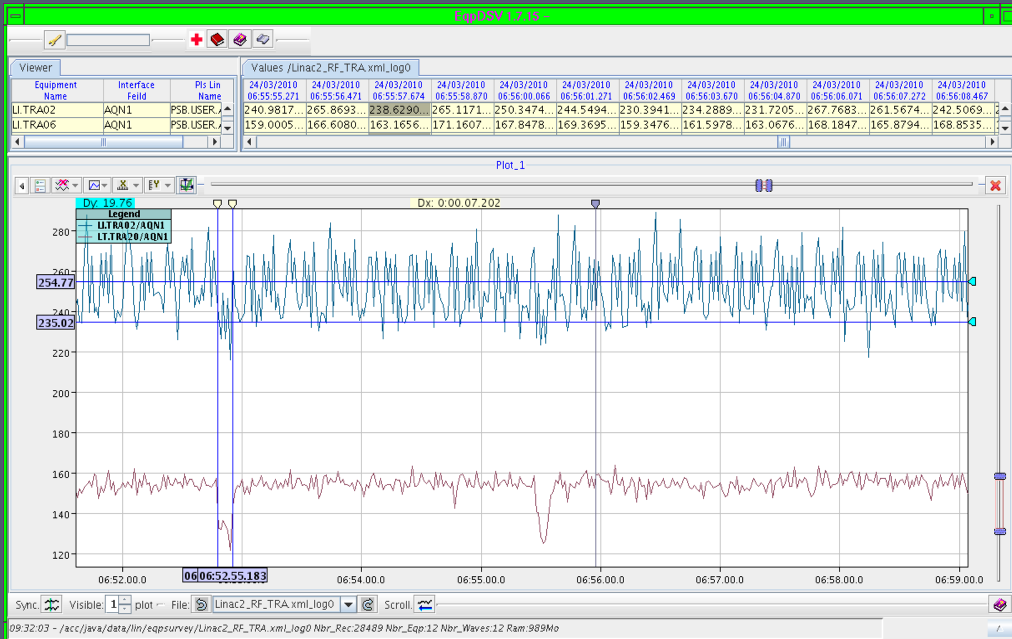


2000-2010 faults – integrated

Total downtime= ~964 hrs
Total op. time = 59994 hrs
lity = 98.4%



2010 in review: the source dip



- 20 % drop in source intensity
- regular 1h-1h30 periodicity
- single events or in doublets

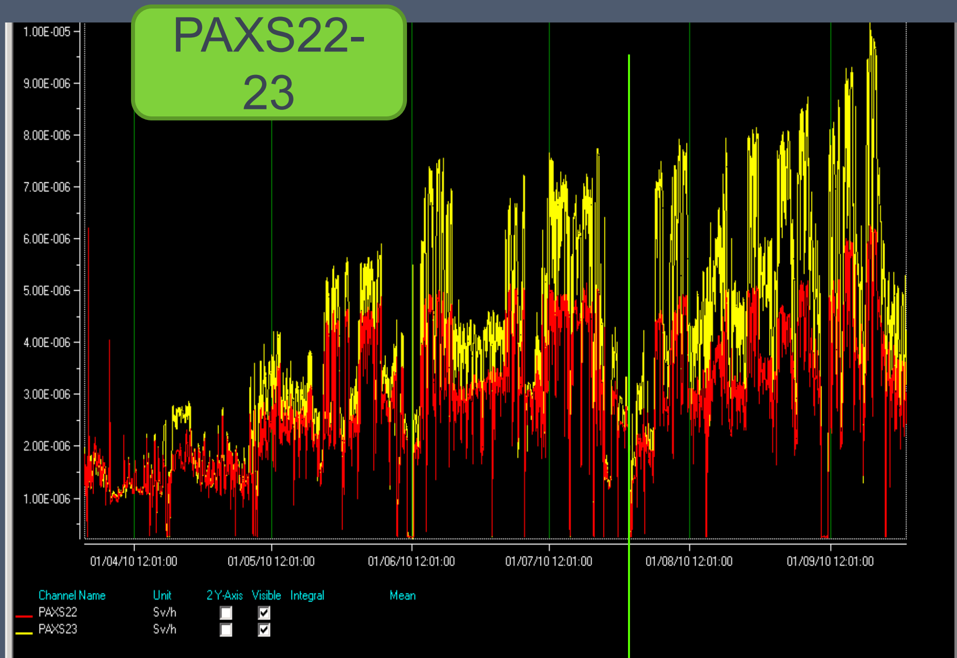
(30 to 60 secs apart).

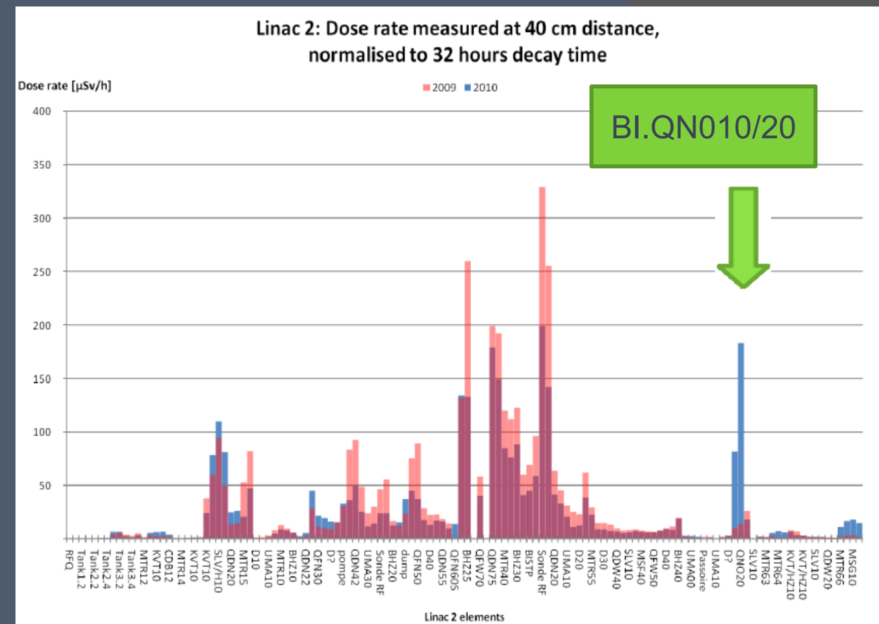
Seen from end of January, and disappeared in November! Only affected by switching off the cathode heating for a few minutes.

Signs of a small water leak were found on the source at the end of the run , with some discharge damage between the plasma chamber and the solenoid coil (drops accumulating and drip running across the cathode to anode circuit, before evaporating, can explain quasi regular period between the dips. after the drip has dried out, no reduction in source performance).

The plasma chamber water circuit was tested using helium leak detection, and no leak was found. For the 2011 run, the plasma chamber and solenoid have been replaced with reserve items.

2010 in review : radiation levels



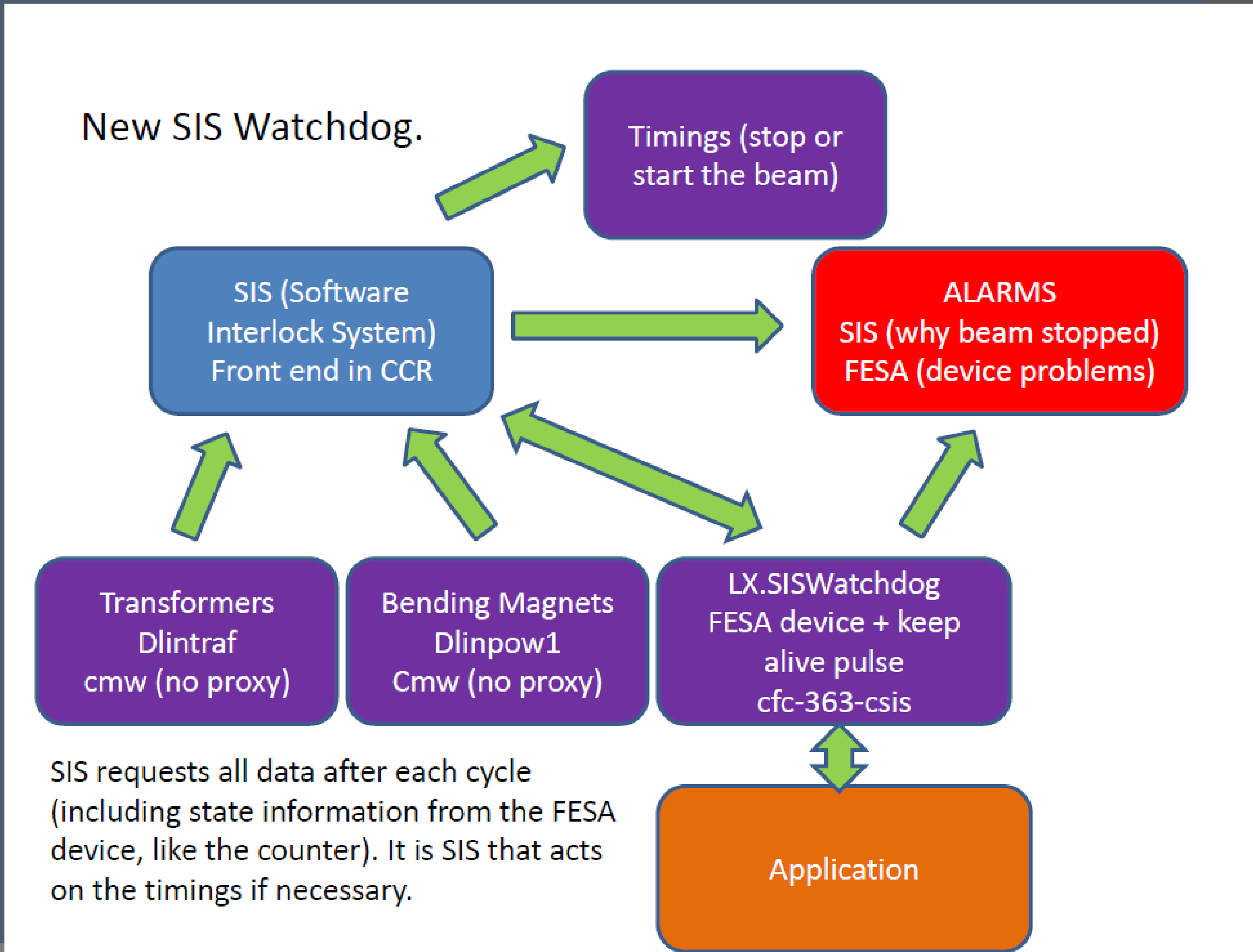


20% increase from Aug-Sept 2010 & regular level 1 alarms

Dec 2010 survey, M Widorski

Increase not understood (higher intensity delivered?). Levels temporarily reduced with optics changes, however the problem was just shifted downstream, as new RP measurements revealed (new hot spots in BI line, 15→172 μSv/hr from 2009 to 2010). New BLMs installed in the shutdown and further optics changes implemented (end of February 2011).

2010 in review: new SIS watchdog



- Systems' check-up

Source

Duoplamastron in service since 1992: 5000-7000 hrs operation/yr

Year	Down time (hrs)	comments
2005	39.3	2 cathode/electrode changes
2006	31.1	One cathode change
2007	7.2	
2008	6.1	
2009	2.75	
2010	3.6	

Annual maintenance (dismounting and cleaning, polishing, electronics testing).

Spare situation:

- 100% availability for mechanical parts and electronics
- Arc power supply has one spare but not easily serviceable (no detailed schematics). If both supplies fail a backup 'delay line' can be used
- CANBUS control system is obsolete and no new spares are available. **For 2016+ operation the system may need to be updated to standard PLC controls (during a shutdown) –** option to run the source in local as last resort (no AQN available, nor ppm arc current value) or light-control version

Vacuum

- Linac2 source, RFQ and vacuum sectors after the DTL are in a correct condition. In case of 2016+ operation all pumps (3 turbo and 5 ion pumps) will need replacing

- Availability of standard spare parts (pumps, gauges and seals) is not a problem and machine can be correctly serviced during a normal year.

- RF tanks have several leaks the most important ones are under control, differential pumping systems are installed and permanently monitored, Penning gauge pressures are stable (since 2007), fluctuations on the ion pump readings of the RF tanks are observed.

Bigger leaks

Date	Fault	Total downtime	Fix
August 2009	Tank2 RF feeder loop 1e-1mbarl/s leak	75 hrs (VAC+RF)	Secondary vacuum dome installed
August 2006	Tank3 5E-5 mbarl/s leak (0.3 mm alignment shift?)	~50hrs	Secondary vacuum system installed

Smaller known leaks:
Drift tube 5 on Tank2 (3E-4 mbarl/s leak found in 2009)
LA1.QFN12 in tank1 (secondary vacuum system installed)

Vacuum: lessons learned – risk management

7 TLC rules…:

- Logging of vacuum pressures.
- Minimizing the venting of the tanks (for example a tooling was built to create a secondary vacuum around the RF tuners to avoid venting of the tanks)
- Maintaining a constant temperature on the structure (improved cooling water regulation, strong surveillance of this, never switching off both the water and the tunnel air conditioning at the same time).
- Greasing the support feet (which had blocked in 2006, contributing to the tank 3 leak we have now).
- Avoid abrupt events
- Geometric survey of tanks each year (need of re-alignment soon?)
- Leak inventory (document to be published soon)

and 2 nightmare scenarios:

- Copper weld cracks: varnishing successfully carried out in 1998 after intertank extraction (materials available, procedure more or less known, very risky for drift tubes and quadrupoles).
- Major vacuum leak on a tank quad that would require opening tank (see quad fault scenario later on..)

RF

Complex design : 3 tanks in Cu clad steel with Al wire seals used for VAC and RF joints (not very reliable) & removable girder system. Large structures, prone to mechanical stress.
4 stages of amplifiers specific to cavity with common HAZEMEYER DC power supply

RF glass insulation tubes – 2 types still in Thales catalogue (markets for tube production shrinking) - decision to stop production overturned and agreement to supply spares at ~50kchf per tube until an alternative solution is put in place (new linac or new amplifiers). → no short term availability problem, can become an issue in the medium-long term.
180mA should be reachable also with old tubes, but faster wear. Carefully plan future orders in view of an increased intensity output ?

RF transformers (2 operational, 1 spare): oil analysed and found in correct condition, but repairs not easy (no in-house competence, company support discontinued?)

Amplifiers have standard problems of ageing, a complete spare high-power unit does not exist but spare parts for the most critical elements are available.

Mercury ignitrons = would have been replaced by solid state switches for safety concerns in case of longer operation, but not in present scenario – operation is still reliable and technology available

Vacuum leak coupler: spare available, problem not understood (need to break the vacuum to inspect the leaking coupler).

Magnets

Concerns:

HV correctors in LT-LTB-BI lines – Following breakdown of LT.DVT20 consolidation budget approved replacement with new Linac4 type correctors (ready by end of 2012, until then covered by spares)

3 spectrometer magnets (LTS.BVT10 and 20, LBS.BVT10) are 37 years old (no spare magnets, and available spare coils are currently broken). New magnets foreseen for Linac4 operation (available mid-2013)

Spares available for all magnets generally, except spectrometers and BHZ20, BHZ30 and BHZ40 (only spare coils available)

Consolidation approved for BHZ20 (order to be placed in coming weeks, available next year)

BI.BVT needs replacing for Linac4 operation – complicated installation –

SMIT-AIR and SMIT-WATER quadrupoles need replacing with existing design (TRIUMF-AIR and TRIUMF-WATER). Study only initiated a few weeks ago, estimate expected soon.

Power supplies

No major critical issues. Bending power converters are very old (BHZ10, BHZ20, BHZ30, BHZ40) but spares are available. In the measurement lines (LTL.BVT10, LTL.BVT20, LBS.BVT10), there are no spares available, only a policy of ‘in situ’ repairs.

The bending converters BHZ20, BHZ30 and BHZ40 will be upgraded in 2013 as part of the L4 project and can be made compatible with Linac2 if required. LBS.BVT10 can be replaced at the same time.

Request passed on EN/EL to study the upgrade of the electrical distribution in building 363 (for TL operation with L4, 2013?).

Spares sufficient for operation until 2018, although availability might sensibly reduce – difficult to quantify.

Intercepting devices

Beam stoppers: status of mechanical parts is good (controlled during last shutdown). Some improvements are needed on the switches (not CERN-standard any more) and the compressed air distribution. There are no spares available, provision of some should be foreseen for longer term operation. Consolidation plan to renovate obsolete control system with PLC-system based remote centralised control of the information (to be completed by 2013)

Slits (LTL, LTE, LBE, LBS) : controls system renovation funded as part of consolidation plans (as for Linac3) to move to a PLC architecture. Some mechanical modifications are required: replacement of old stepping motors with new types, replacement of the old Moore-Reed encoder with a resolver integrated in the stepping motor, new mechanical end-stops for controller reference, new cabling. All ready to install, need suitable planning and priority list of cases (3 months for the full upgrade)

Diagnostics

Very limited instrumentation on Linac 2 – BCTs, position pick ups, 4 measurement lines.

SEM grids: Mechanical upgrade foreseen for SEMs with pendular movement (more reliable jack model) for 2016+ operation. Existing consolidation plans to renovate all SEM electronics in PS complex in 2013 – Linac2 to be added?

UMA pick-ups: Very old. Renovation foreseen for all equipment downstream of LT.BHZ20 as part of L4 planning (to be checked if compatible with L2). Three devices upstream (UMA10, UMA20, UMA30) and only one spare available. Production of a new device is possible according to a new UMA design (a prototype already existing and installed) but would take at least 3-4 months. No budget has been allocated for this.

MTR transformers: very old equipment, ageing issues. Renovation under discussion for L4 watchdog planning.

Controls

No issues for day-to-day exploitation.

ACCOR controls renovation plans:
- Replacement of GFAs obsolete modules by CVORB
- Replace old WES VMEbus Crates with new VMEbus64
- Replacement of TG8 by CTR-V/P/I
- Upgrade of MUX CAMAC system
- Renovate obsolete installations (pulse repeaters, etc...)
- Split of FECs shared for several groups. Ideal situation one FEC is only own by one equipment group.

INCA: Linac2 deployment tied to PSB plans for timing (second half of 2011). Full scale test in April to assess readiness.

Infrastructure

Current issues:

Raw water cooling station is still not appropriate to the use. There were several small upgrade in order to improve a bit the situation but it stays a "bricolage" regarding the importance of that station.

Renovation plans:

The only consolidation which is foreseen is the installation of a sand filter for the chilled water in order to avoid the frequent clogging of the cooling coil of the ventilation.

Access system

Possible conversion to the new PS Complex Access Safety and Control System (see R. Steerenberg, this workshop) in 2013 in the assumption of a longer-term Linac2 operation.

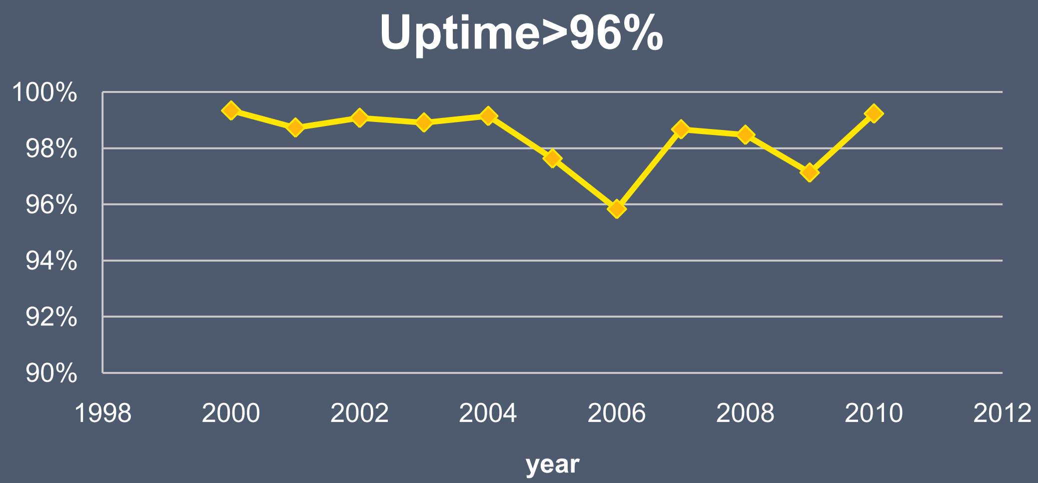
N.B: Deployment should be compatible with possible Linac2-to-Linac4 connection (tight coordination needed during the shutdown activities).

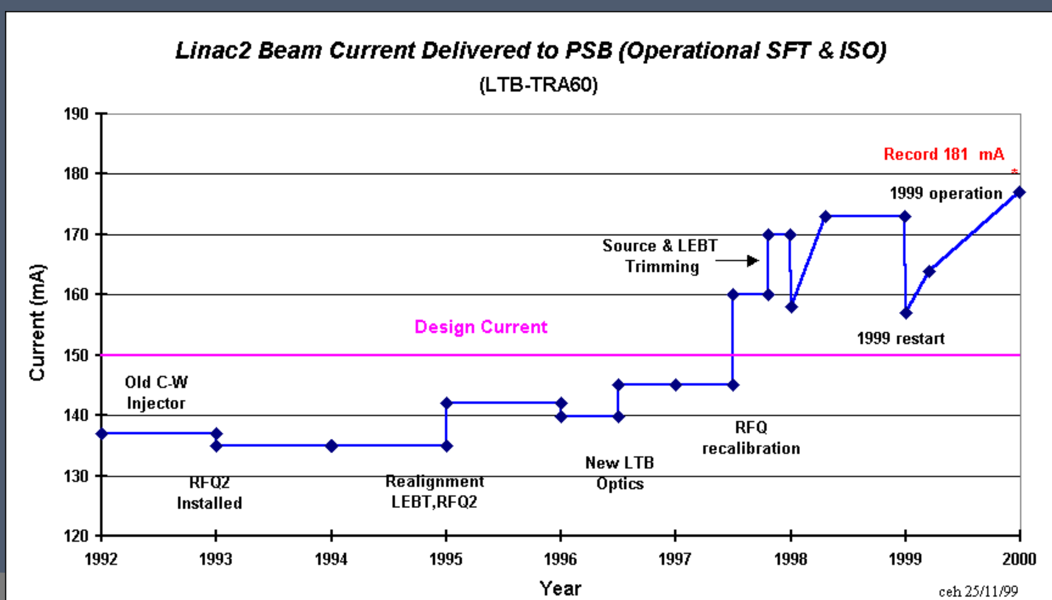
- Present performance

+

assorted dreams and nightmares…

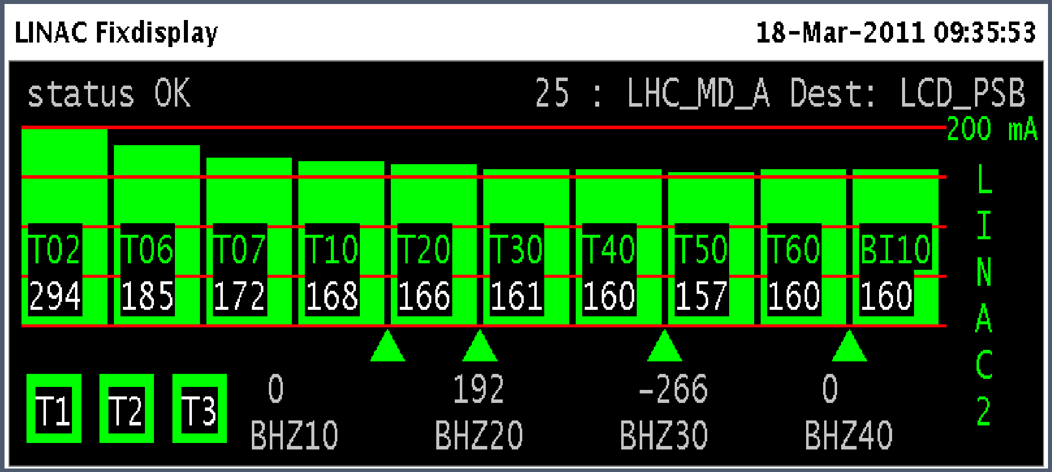
Linac 2 is the source of all primary proton beams at CERN for various customers (LHC, fixed target etc..) . It produces regularly 150 –170 mA for all requested intensity ranges, with solid and reliable performance in the past 10 years. Any scope for improvement?





2000 to 2010:
on average below 170mA

day-by-day



Transformer	Position	Current - mA
TRA02	After source	295
TRA06	After RFQ	185
TRA10	End Tank3	168
TRA60	BHZ40	160
BI10	PSB injection	160

Beam transverse ε (rms, norm) – mm mrad @ 150mA current

Input RFQ	Output RFQ	LTE	LBE
0.4	0.6	~1	~1

15 π mm mrad (90% of the beam) = factor of 2 smaller than PSB acceptance

250% emittance increase between source and end of DTL

BCTs at the DTL input, middle and output are the only diagnostics available!

The beam is injected in the PSB in several turns, each beamlet undergoes several cuts at the injection septum (combined effect of space charge and losses on septum ..)
PSB Injection efficiency: ~100% for small intensity beams (few turns injection)
~70% for high intensity beams (higher number of turns)

From Chamonix 2011:

Q: Higher current from LINAC2 (180mA instead of 160mA) would help increase LHC beam intensity while keeping transverse emittance constant (LHC DR, Vol. III page 15)

A: Linac 2 can produce 180 mA (190 mA in TRA10 were obtained in MDs in 1994 and 2002), by pushing the source with increased arc current and gas flow rate. The RF group would push the amplifier tube anode voltage higher (non-ppm).

Concerns:

- RFQ sparking (often leading to pressure rise → vacuum interlock)
- reduces significantly the lifetime of RF tubes
- PSB injection efficiency?

180mA operation on constant basis too risky and exacting on the machine for what it's worth (5-10% gain).

Possible during a limited period of time (~a week), after installing new RF tubes if enough warning is given (replacement would take approximately 2 hours per tube, or a total of 8 hours beam stop, and is not a risk-free operation). Higher risk of RFQ sparking (affecting all users)→ test at the end of summer (when RFQ traditionally more stable..)?

→ MD requested

Nightmare 1: DTL quad failure

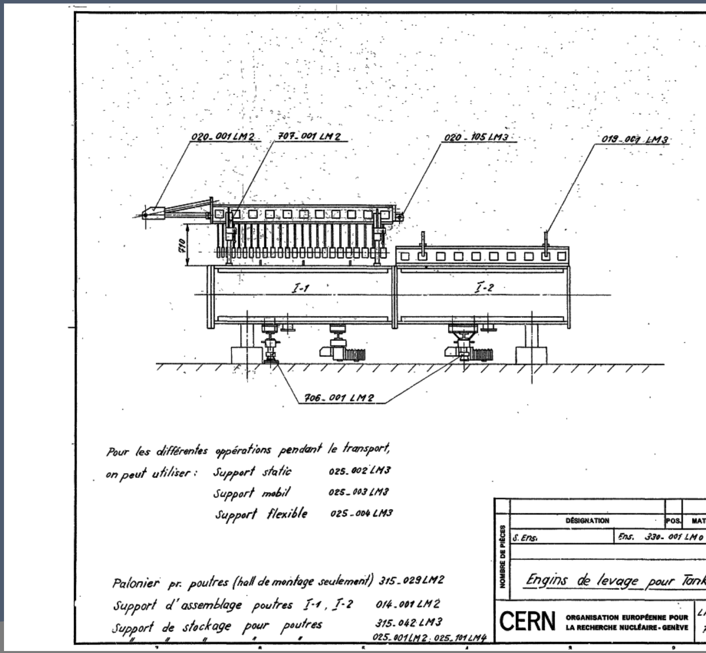
• 131 quadrupoles, (powered in series of 1, 2 or 3) inside the drift tubes pulsed with >300A ~700V every pulse. ~500 M pulses to date.

• The drift tubes are suspended to a girder; they are aligned externally and successively introduced into the tanks. A mechanical positioning system on the outside of the girder together with a bellow on the inside allows positioning of the drift tubes with the required precision.

• No maintenance of these circuits (inside the drift tubes) has ever been made.

• 2 vacuum leaks differentially pumped

• MTTR in case of fault? → R. Scrivens, ATOP days 2009



Short-term operation w/o quadrupoles might be possible with degraded emittance growth and transmission to PSB.

For longer term solution, a repair plan has been put together:

Cranes were installed with sufficient space to lift out the DTs.

Phased pre-study of first

opening tank.alignment c

inventory, copper and se

Not clear how to proceed

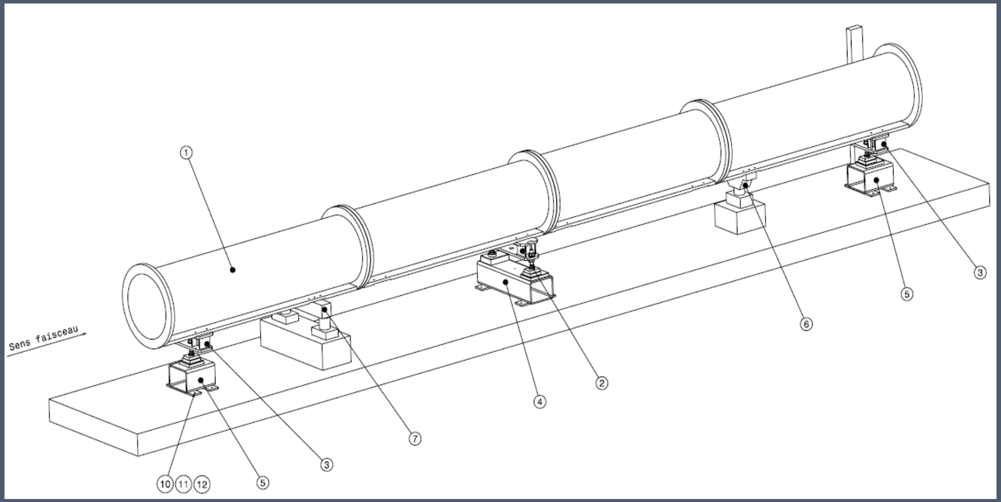
Still to do:

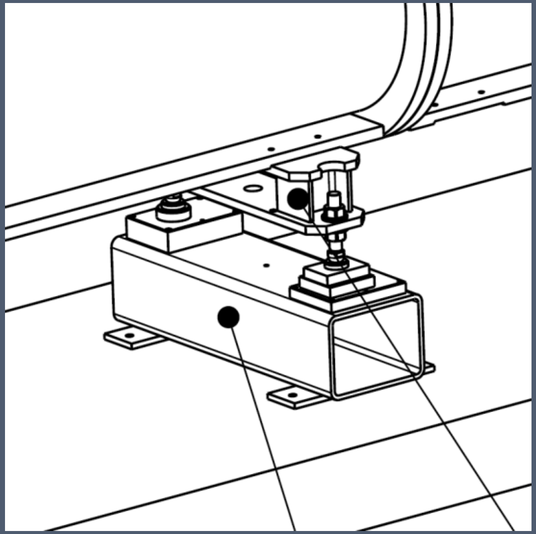
- Study of how to remove girder. Design of tooling.
- Study of repair.
- Study of tooling for drift
- Study of tooling to leak to girder seal.
- Installation and re-align

Need to

Nightmare 2: inter-tank vacuum

No known plan to vent and replace an inter-section seal if it's not possible to make a secondary vacuum.

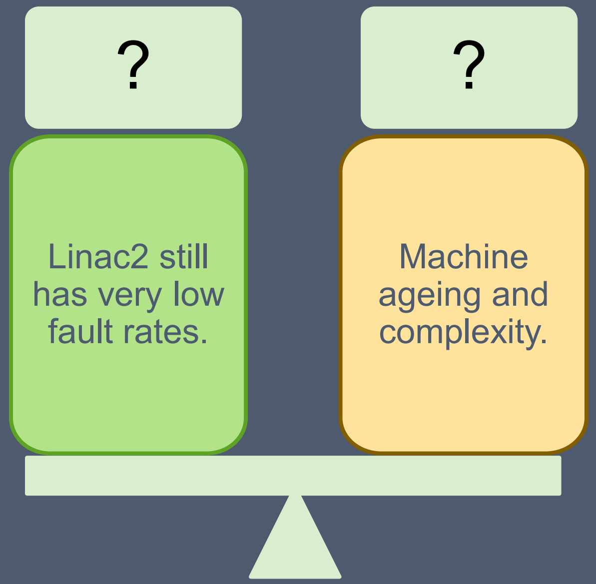




Removal of inter-section very complicated (2 more wire vacuum seals)
Solution known for sections displacement only around movable feet.

Need of study to assess:
-Availability of all necessary tooling
- re-alignment procedures?
-possible mitigation strategies..
-Downtime estimate and intervention plan

In conclusion..



Main causes of worry for next 5 years are:

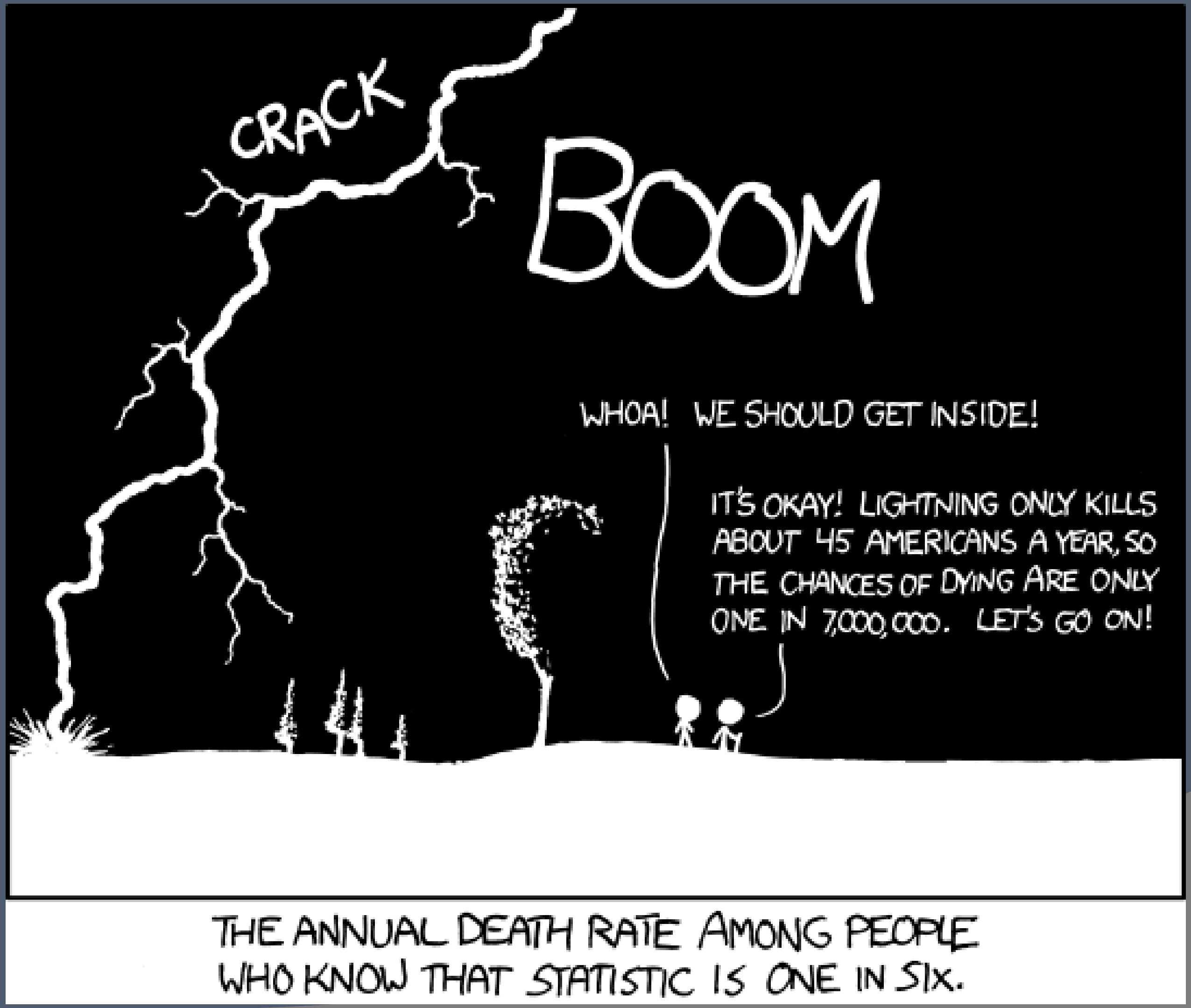
- DTL quad failure
- Vacuum tightness of the RF tanks
- Source instabilities

→ Is high impact risk mitigation to be pursued? How far?

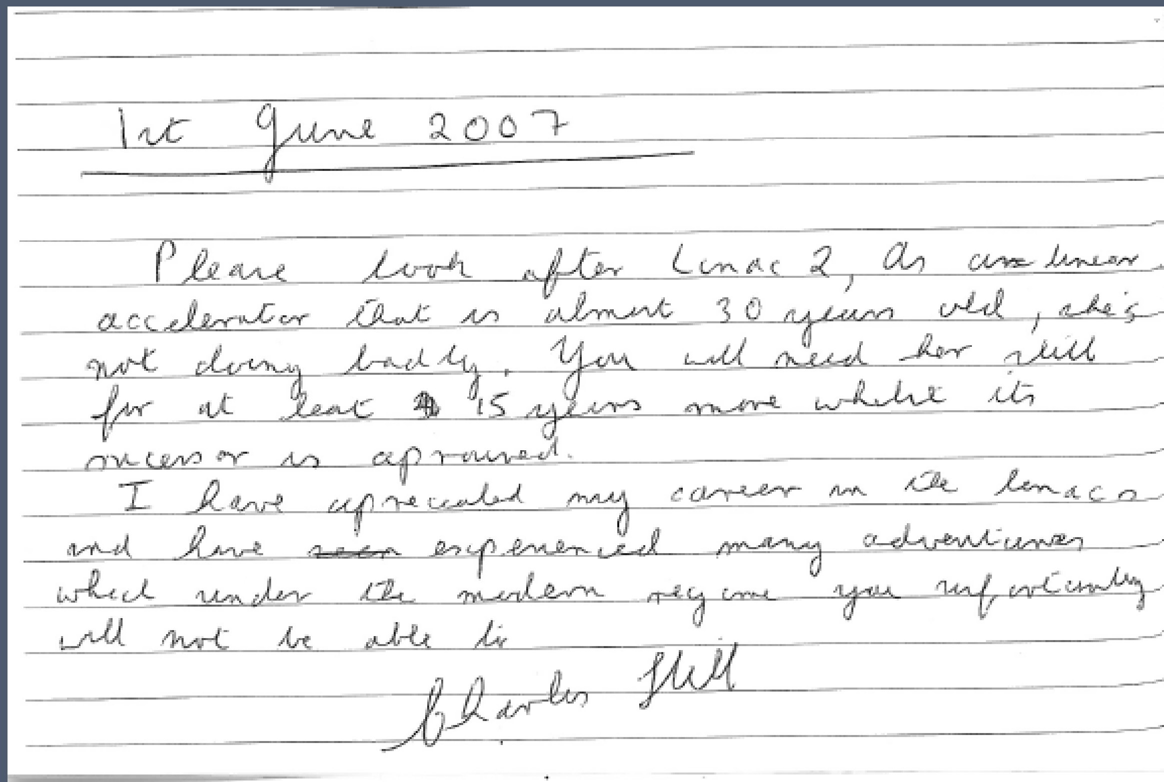
Word of caution: high intensity operation only to be tested in MDs

The high level of inspections needs to be kept up (also during long shutdown)

Conditional risks…



… and Charles's legacy:



1st June 2007

Please look after Linac 2, as a linear accelerator that is almost 30 years old, she's not doing badly. You will need her still for at least ~~4~~ 15 years more whilst its succesor is aproved.

I have apreciated my career in the linacs and have ~~seen~~ experienced many adventures which under the modern regime you unfortunately will not be able to

Charles Hill

"Please look after Linac2, as a linear accelerator that is almost 30 years old, she's not doing too badly. You will need her still for at least 15 years more.."