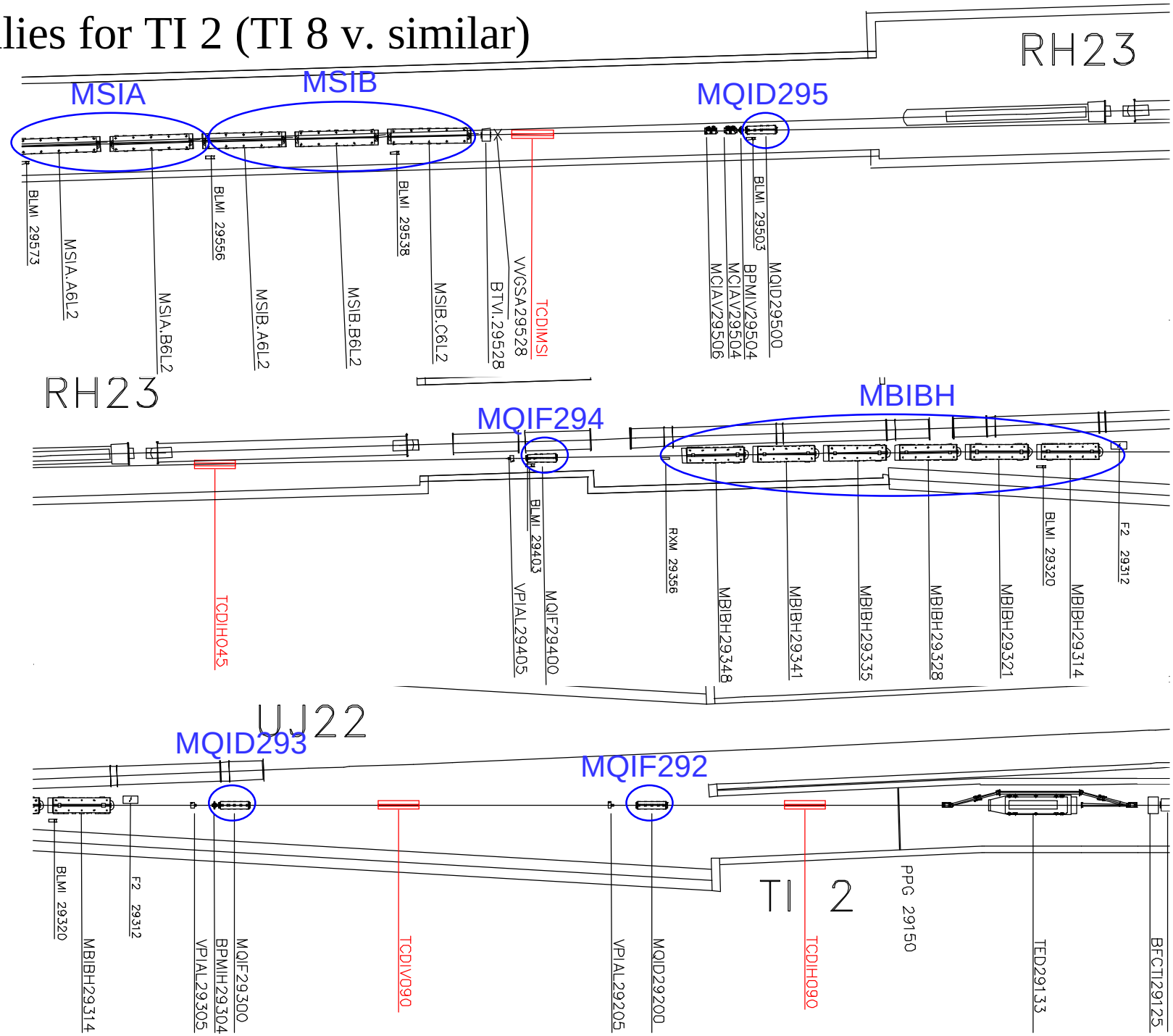
Failures not covered by the LTI collimator family

Input from Rüdiger, Helmut, Wim, Verena, Marcel plus from AB/PO Denis Hundzinger & Roger Genand.

Families for TI 2 (TI 8 v. similar)



Power supplies assumed to be interlocked at given level, with surveillance loop reacting in 5ms if out of tolerance.

Possible maximum error given by interlock level + exponential decay of current over these 5ms.

Typically ~4% for quads, ~1% for dipoles (L/R)

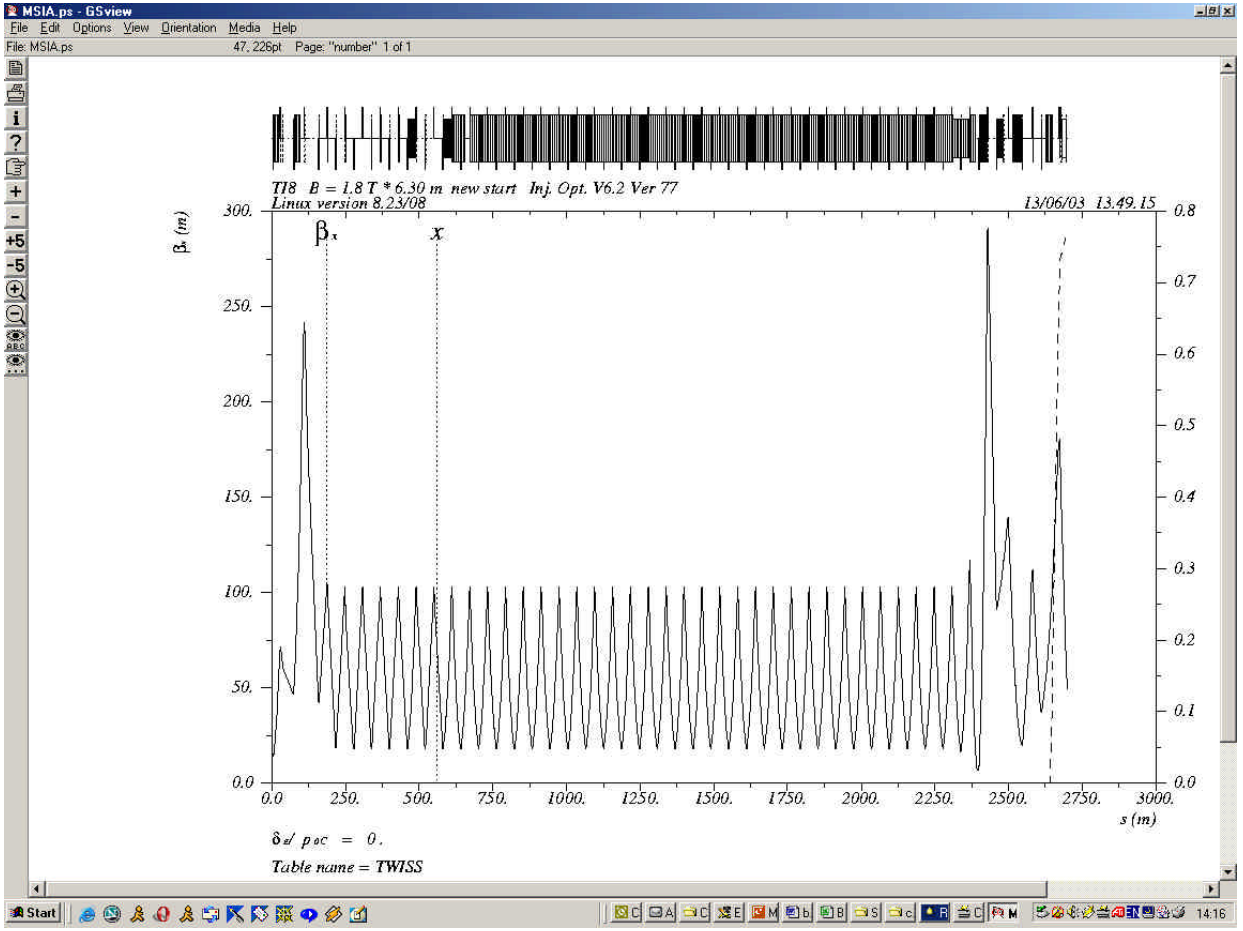
Magnet Name (Install)	Magnet Name (Optics)	Magnet Type	Number of magnets in series	R per magnet (20º C) [mW]	L per magnet [mH]	R cables [mW]	Total R [mW]	Total L [mH]	Time constant L/R [ms]	Error in 5ms (a)	Interlock level (b)	Max error in worst failure case (a+b)
MBIBH	BH2	B280	6	66	103	36	477	618	1295	0.004	0.002	**0.006**
MSIB	BH3B	MSIB	3	16	31.6	26	83	95	1148	0.004	0.005	**0.009**
MSIA	BH3A	MSIA	2	11	14.9	26	53	30	567	0.009	0.005	**0.014**
MQIF 29200	Q13	MQI	1	31	13	72	113	13	115	0.042	0.001	**0.043**
MQID 29300	Q14	MQI	1	31	13	70	111	13	117	0.042	0.001	**0.043**
MQIF 29400	Q15	MQI	1	31	13	65	105	13	124	0.040	0.001	**0.041**
MQID 29500	Q16	MQI	1	31	13	61	101	13	129	0.038	0.001	**0.039**
MBIAH	BH4	B340	7	37.6	120	27	319	840	2631	0.002	0.001	**0.003**
MSIB	BH5B	MSIB	3	16.4	31.6	22	78	95	1209	0.004	0.005	**0.009**
MSIA	BH5A	MSIA	2	10.9	14.9	22	48	30	618	0.008	0.005	**0.013**
MQIF87800	Q14	MQI	1	31	13	71	112	13	116	0.042	0.001	**0.043**
MQID87900	Q15	MQI	1	31	13	64	104	13	125	0.039	0.001	**0.040**
MQIF88000	Q16	MQI	1	31	13	60	100	13	130	0.038	0.001	**0.039**
MQID88100	Q17	MQI	1	31	13	57	97	13	135	0.036	0.001	**0.037**

Used these errors in MAD to produce orbit offsets/angles x/x’ at observation point (known αβγ), then translated into offset *DX/s*

$$DX/s = \ddot{O}([gx^2 + 2axx' + bx'^2] / e)$$

Dipoles – easy

Quadrupoles – messy (made 4mm h. bump at the quad using orbit correctors then introduced error and compared x x’).



Results

TI 8

Family	t ms	Dk/k	x	x'	alpha	beta	e mm mrad	dx/s
MBIAH	2631	0.003	0.1804	-0.071	1.689	49.13	0.0078	5.15
MSIA	618	0.013	-1.5225	-0.007	1.689	49.13	0.0078	5.31
MSIB	1209	0.009	-2.5087	0.016	1.689	49.13	0.0078	6.88
MQIF878	116	0.043	0.1226	-0.002	1.689	49.13	0.0078	0.26
MQID879	125	0.040	-0.048	0.004	1.689	49.13	0.0078	0.20
MQIF880	130	0.039	0.4380	-0.015	1.689	49.13	0.0078	0.71
MQID881	135	0.037	-0.1524	0.003	1.689	49.13	0.0078	0.27

TI 2

Family	t ms	Dk/k	x	x'	alpha	beta	e mm mrad	dx/s
MBIBH	1295	0.006	8.9754	-0.396	2.028	52.203	0.0078	**14.57**
MSIA	567	0.014	1.5656	0.004	2.028	52.203	0.0078	5.84
MSIB	1148	0.009	2.3605	-0.021	2.028	52.203	0.0078	6.86
MQIF292	2220	0.043	-0.1990	0.01	2.028	52.203	0.0078	0.36
MQID293	2179	0.043	0.4492	-0.02	2.028	52.203	0.0078	0.72
MQIF294	2004	0.041	0.1349	-0.006	2.028	52.203	0.0078	0.20
MQID295	1881	0.039	-0.1665	-0.004	2.028	52.203	0.0078	0.25

Cross-check using

$DX/s \approx 11.7\, Dk\ddot{O}b_{av}$

k	n magnets	beta av m	dx/s
3.5	7	38	5.33
1.86	2	94	5.48
2.76	3	71	7.36

k	n magnets	beta av m	dx/s
3.0	6	140	14.58
1.86	2	106	6.18
2.76	3	71	7.63

Note that:

- these are all in the horizontal plane (v. plane for quads not checked but magnitude will be similar)
- all mean the full batch impacting in one spot (ignoring sweep from kicker waveforms).

Expected occurrence rate

- Identified 6 families (all the dipoles considered) where trips might be dangerous for LHC.
- Power supply trip rate : worst case 1 per supply/y
- Supply pulses for ~300ms
- *Assuming random distribution of trip time within this 300ms* (tbc!), with 5ms dead time the rate of dangerous trips per year is just

$$6 \times 5/300 = 0.1$$

And now…?

- Look in more detail at repercussions in MPWG (18/7)
  - Can this (admittedly pessimistic) once per 10 years be accepted?
  - If not, can we improve on it, by better surveillance /interlocks (i.e. <5ms loop, tighter limits) on these 6 power convertors?