Work Progress

Section Meeting, 21 November 2011

Sigrid Wagner

A Failure Catalogue for the LHC

Related Papers:

- S. Wagner et al., A Failure Catalogue for the LHC, IPAC 2011, WEPC174
- B. Todd et al., Machine Protection of the Large Hadron Collider, 6th IET Int. System Safety Conference 2011, Birmingham, UK (accepted)

Intermediate results:

- Approach for the deduction of hazard chains
- Identification of the required information/data

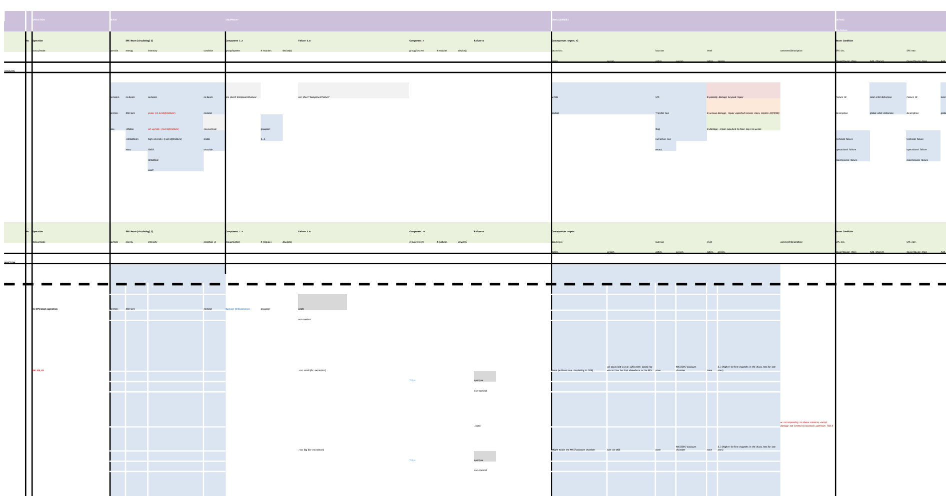
Ongoing:

Collect the 'pieces of the puzzle' on a website (share point), aiming at a basic 'protection case'

Table 2: Equipment-based monitoring systems (not exhaustive)

System	Equipment	Parameter
Kicker Surveillance	Injection, extraction, aperture, tune, AC dipole kicker	Charge, switch, timing
PC Controls	Power converter	Power converter current, faults
FMCM	nc magnet system	Fast current change
WIC	nc magnet system	Temperature
QPS	sc magnet system	Voltage
UPS control	Power supply	Condition
CRYO Interlock	sc magnet system	Temperature, (helium) pressure
Vacuum Interlock	Vacuum valves, vacuum sector	Valve position, vacuum pressure
RF Interlock	RF system	Voltage, frequency, power, temperature
Collimation Interlock	Cleaning collimators	Position, temperature
Experiments Interlock	Experimental magnets, detectors, moveable devices	Current, condition, position

Table 1: Failure catalogue data sheet (under development)



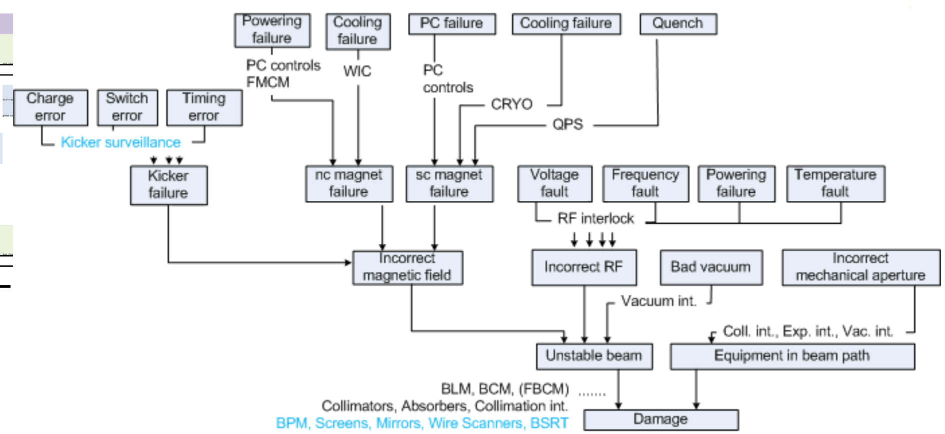
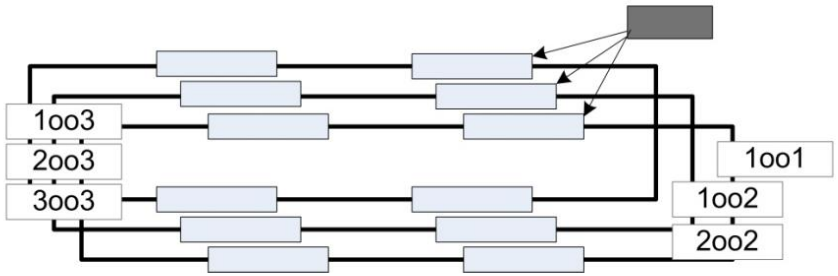


Figure 1: General hazard chain for beam-induced damage (not exhaustive)

Interlock Loop Architectures: Reliability Studies

Goal: Comparison of different interlock architectures in terms of safety and availability



Default parameters:
Lf = 1E-4/h
Lb = 1E-5/h
X = 2E-4/h
T = 720h
4 components per loop

THEOR / SIM, IMP (3.1E8 runs)	1oo1	1oo2	2oo2	1oo3	2oo3	3oo3
Mission completed	0.649897557785	0.487784746419	0.812010369150	0.366109944543	0.731134350171	0.852448378639
False trigger	0.233135522866	0.409506155814	0.056764889919	0.543095666712	0.142327134017	0.01398376787
Demand success	0.116567761433	0.102707560905	0.130427961961	0.09079438217	0.126533918374	0.132374983754
Demand missed	0. 000399157914	1.536860E-06	0.000796778968	6.573E-09	4.597436E-06	0.00119286973

Finding: 2oo3 architecture solely in the 'top three' of both machine safety (↔ *Demand missed*) and availability (↔ *Mission completed*)

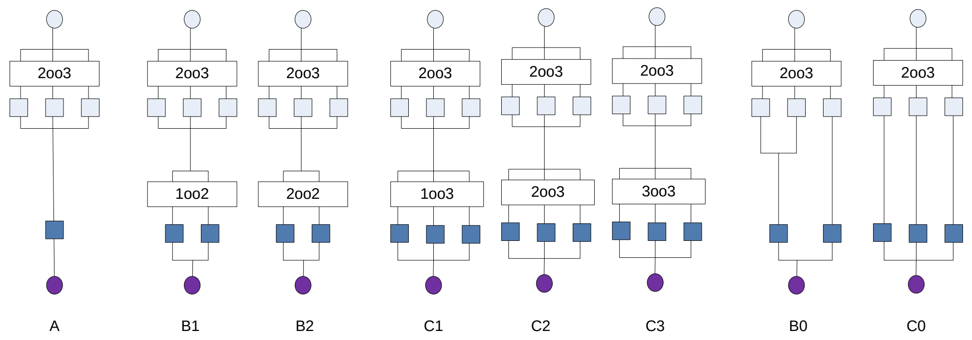
Verification: (by A. APOLLONIO)

Rel. Err (frequent scenarios): order of 1E-6 .. **1E-4**

Abs. Err (frequent scenarios): order of **1E-5** .. 1E-4 → good agreement, opens up alternative approach

Related paper: S. Wagner et al., Architecture for Interlock Systems: Reliability Analysis with Regard to Safety and Availability, ICALEPCS 2011

Interlock Loop Interface: Reliability Studies



Default parameters:
Lf = 1E-4/h
Lb = 1E-5/h
X = 2E-4/h
T = 720h

THEOR / SIM, IMPL (2.06E7)	A	B1	B2	C1	C2	C3	B0	B0, SIM, IMP	C0
Mission completed	0.794900509	0.739878188	0.849922829	0.688664561	0.842305442	0.853731523	0.739872761	0.788706748	0.823763666
False trigger	0.076157726	0.135531124	0.016784327	0.19089764	0.024798093	0.012777444	0.07683858	0.082711602	0.04435782
Demand success	0.128479697	0.124582722	0.132376671	0.120432112	0.132883942	0.132123036	0.124181566	0.128561651	0.131855425
Demand missed	0.000462069	7.96489E-06	0.000916173	5.68622E-06	1.25222E-05	0.001367998	0.000408912	2.00E-05	2.30891E-05
False missed							0.058698		

Finding: C2 solely in ‘top three’, next best C0 → **Next**: address 2oo3 voting logic in detail

Verification: (by A. APOLLONIO)

Rel. Err (frequent scenarios, B0 excluded): order of 1E-5 .. 1E-3

Abs. Err (frequent scenarios, B0 excluded): order of 1E-6 .. 1E-4

Latest simulations (1.316 E8 runs): increase of errors by up to two orders of magnitudes -> to be investigated!

Interlock Loop Interface: Ongoing

THEOR	SIM IMP	SIM EXPL
ok	ok	ok
-		ok
nok	ok	ok
		x
		x

1. Sensitivity analysis, default model: lf +- O(2) → check for C2 and C0
2. Sensitivity analysis, sim. model including loop components → check for C2 and C0

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3. Study on C2 with 2oo3-voting as independent component (i.e. not fault-free, with individual failure rates lf and lb)
4. Study on C2 with redundant 2oo3-voting

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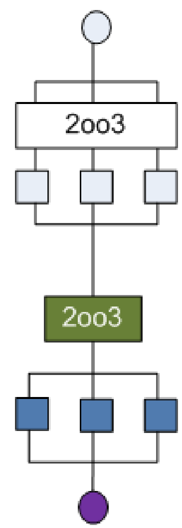
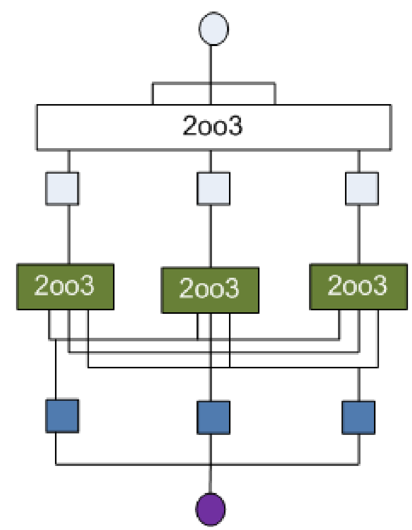
5. Study on 2oo3-voting internal design
6. Study on detectors



C2_vot

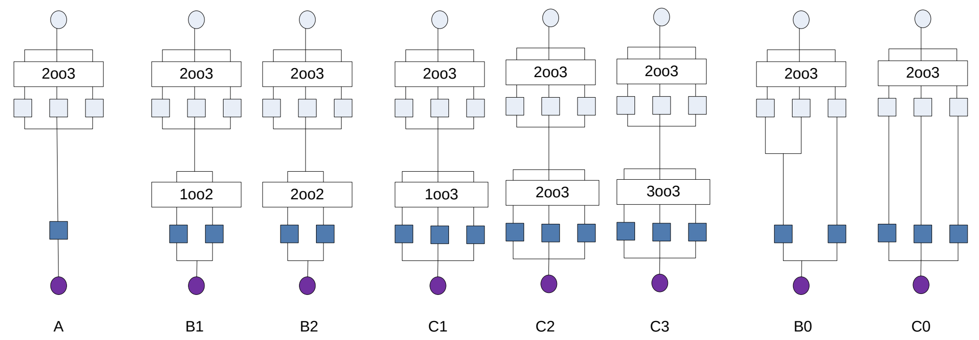


C2_vot_red

Next:
- Continued simulation runs (interface!)
- Advanced studies on the comparison of C2 with C0 (for tasks with at least two matching approaches)
- Migration of theoretical approach from Maple to Matlab
- Other: study on integrated luminosity optimisation

Interlock Loop Interface: Next, Preliminary Results

1. Sensitivity analysis, default model: lf +- O(2) → check for C2 and C0



Default parameters:
Lf = 1E-4/h
Lb = 1E-5/h
X = 2E-4/h
T = 720h

Lf minus O(2):1E-6	SIM: 10E6 *							
THEOR	A	B1	B2	C1	C2	C3	B0	C0
Mission completed	0.865265468	0.864644969	0.865885967	0.864024916	0.865885077	0.865886412	0.864644906	0.865882432
False trigger	0.000669344	0.001336819	1.869504E-06	0.002003826	2.80387E-06	1.40232E-06	0.000664947	5.58152E-06
Demand success	0.133588590	0.134009354	0.133167827	0.133964612	0.134098838	0.132702321	0.133537910	0.134085681
Demand missed	0.000476596	8.856669E-06	0.000944336	6.64505E-06	1.32799E-05	0.001409864	0.000480297	2.63045E-05
False missed							0.000671937	

Lf plus O(2):1E-2	SIM:5E6 *							
THEOR	A	B1	B2	C1	C2	C3	B0	C0
Mission completed	8.746030E-07	4.32786E-07	1.31642E-06	2.59679E-07	7.79E-07	1.585131E-06	2.3E-11	6.52547E-07
False trigger	0.990075218	0.993039318	0.987111119	0.994690388	0.989737178	0.985798089	0.744053612	0.991710902
Demand success	0.009917232	0.006960184	0.012874281	0.005309314	0.010261923	0.014180460	0.006958531	0.008288326
Demand missed	6.6673854E-06	6.4838E-08	1.3282871E-05	3.754E-08	1.19434E-07	1.9864589E-05	0.000001661	1.18368E-07
False missed							0.248986194	

*simulations by A. APOLLONIO