
CERN

Recurring sources of premature dumps

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Acknoweldegments: D.Nisbet, G.Papotti, M.Albert, A.Apollonio, B.Todd, L.Ponce, A.Lechner, V.Montabonnet, I.Josifovic, A.Antoine and many more

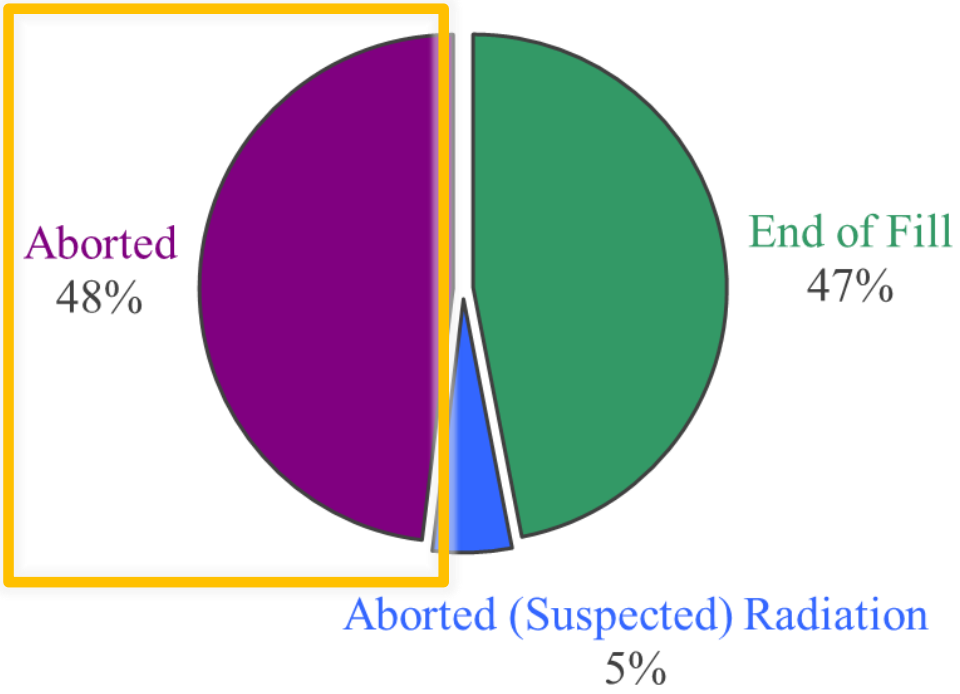
7th Evian Workshop 13-15th December 2016

Outline

- Statistics of aborted fills
- Premature dump causes
- Analysis of top 3 recurring faults
- Conclusions

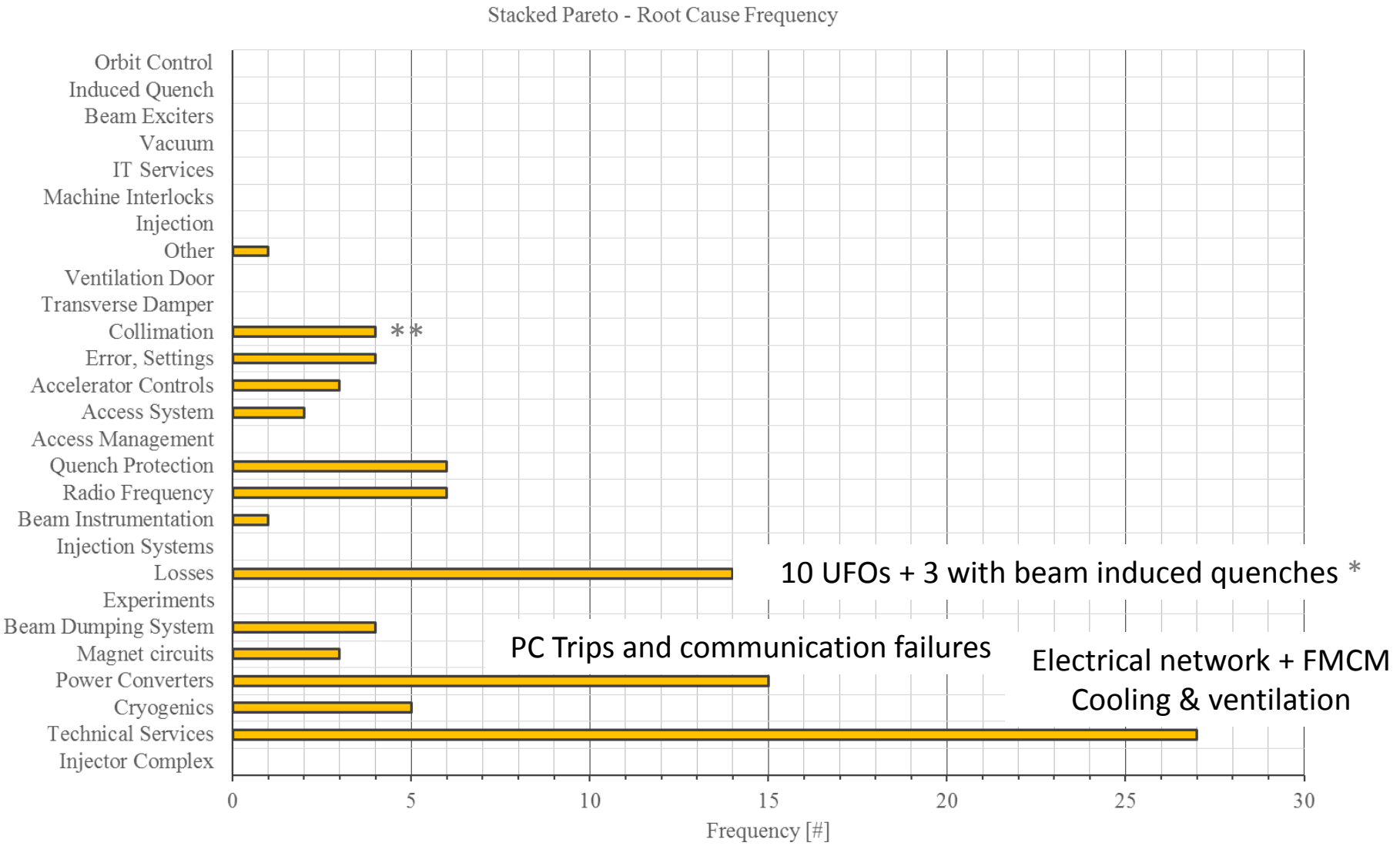
Aborted fills in Stable Beams

	[#]
Total Fills	762
Fills with Stable Beams	175
Fills with Physics in Adjust	4
→ End of Fill	84
→ Aborted	86
→ Aborted (suspected) R2E	9



- 95 fills which did not reach the end of fill = premature beam dumps
- Following analysis will only consider beam aborts from Stable Beams (hence sometimes different counts wrt other presentations)
- 9 fills flagged due to radiation (see talk of Salvatore D.)

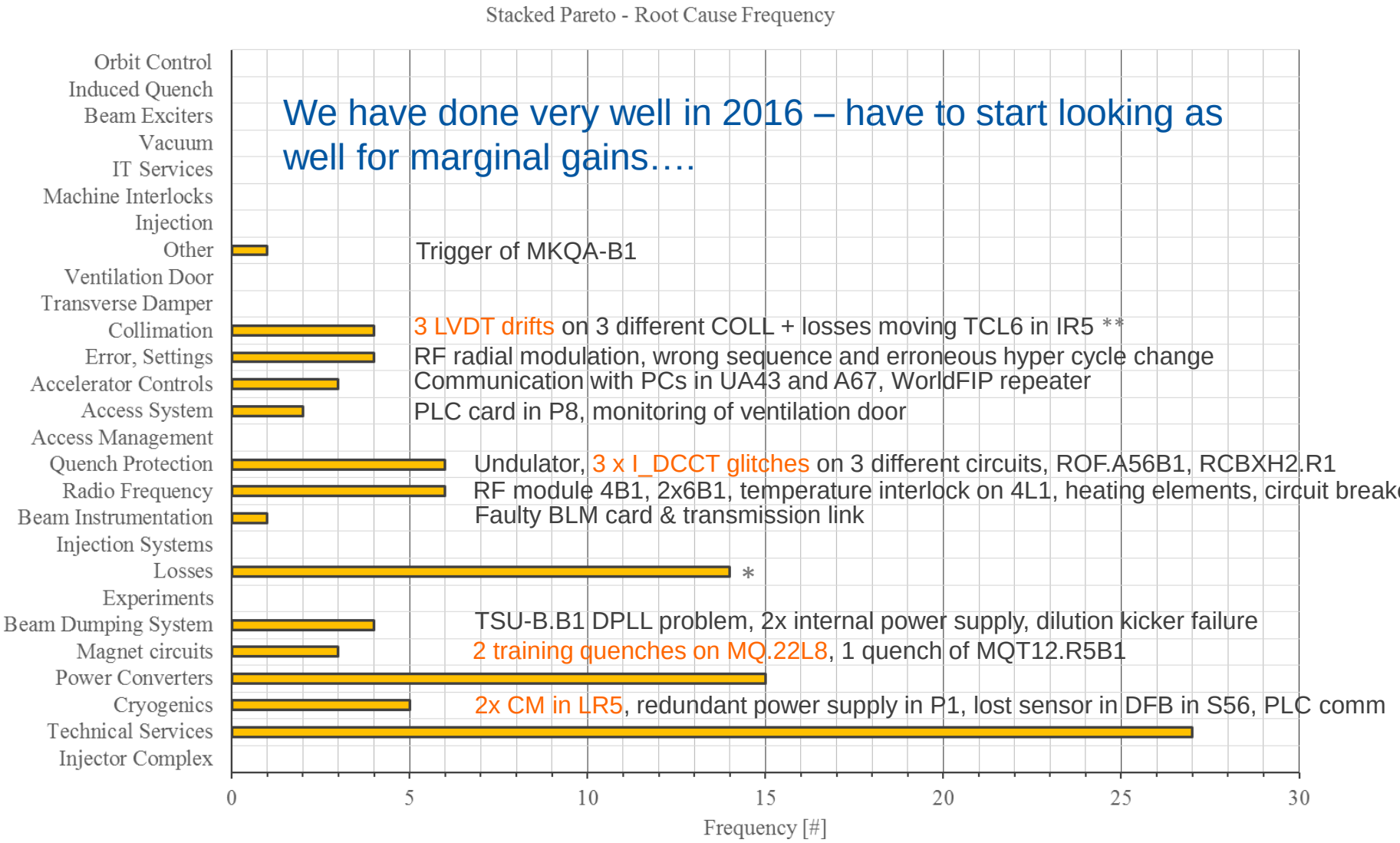
Premature dumps: Root cause



* 1 double counting of fill 4896, i.e. only 13 premature dumps due to losses

** 1 case with (UFO) losses during TCL6 movement

Premature dumps: Root cause

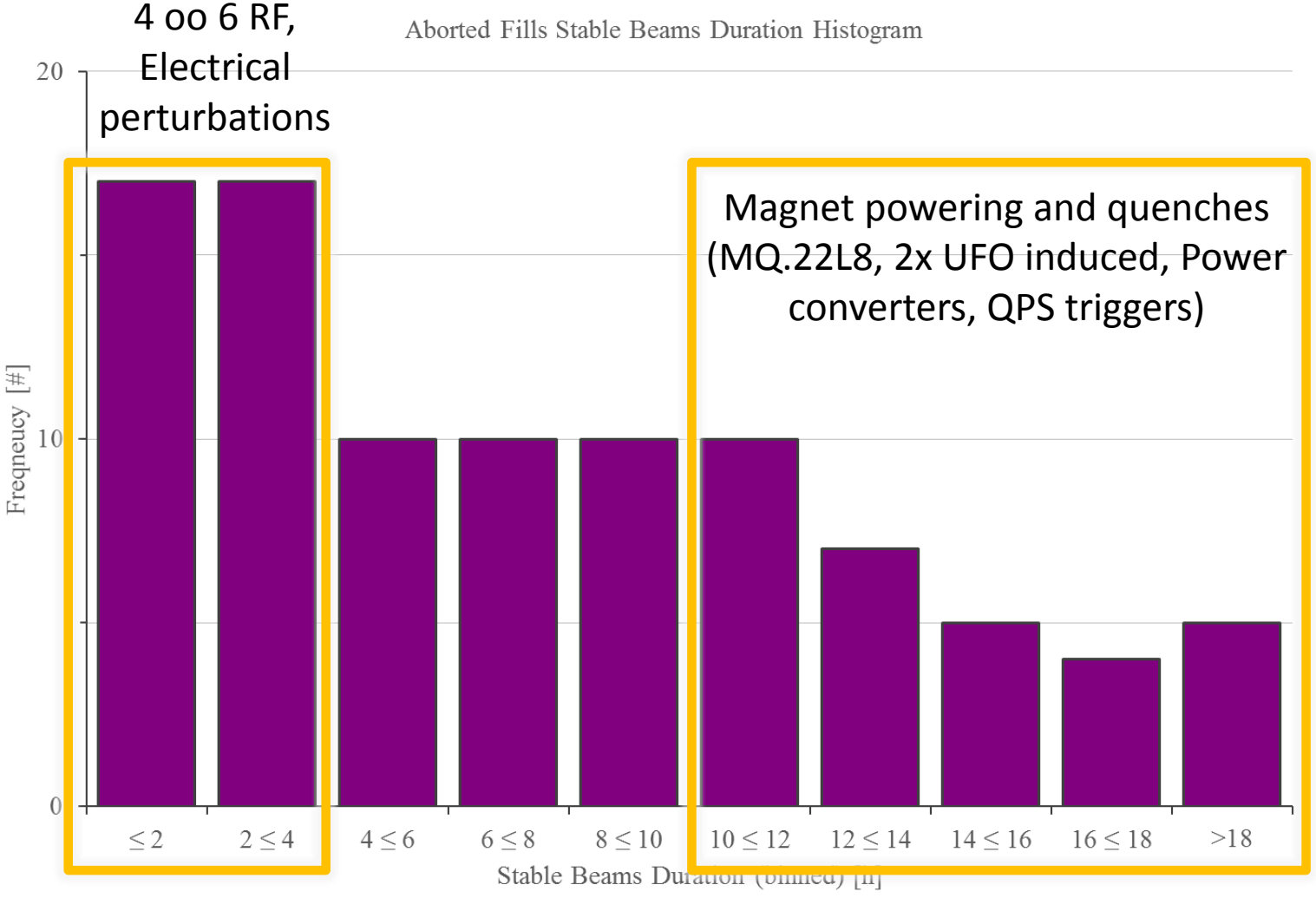


* 1 double counting of fill 4896, i.e. only 13 premature dumps due to losses

** 1 case with (UFO) losses during TCL6 movement

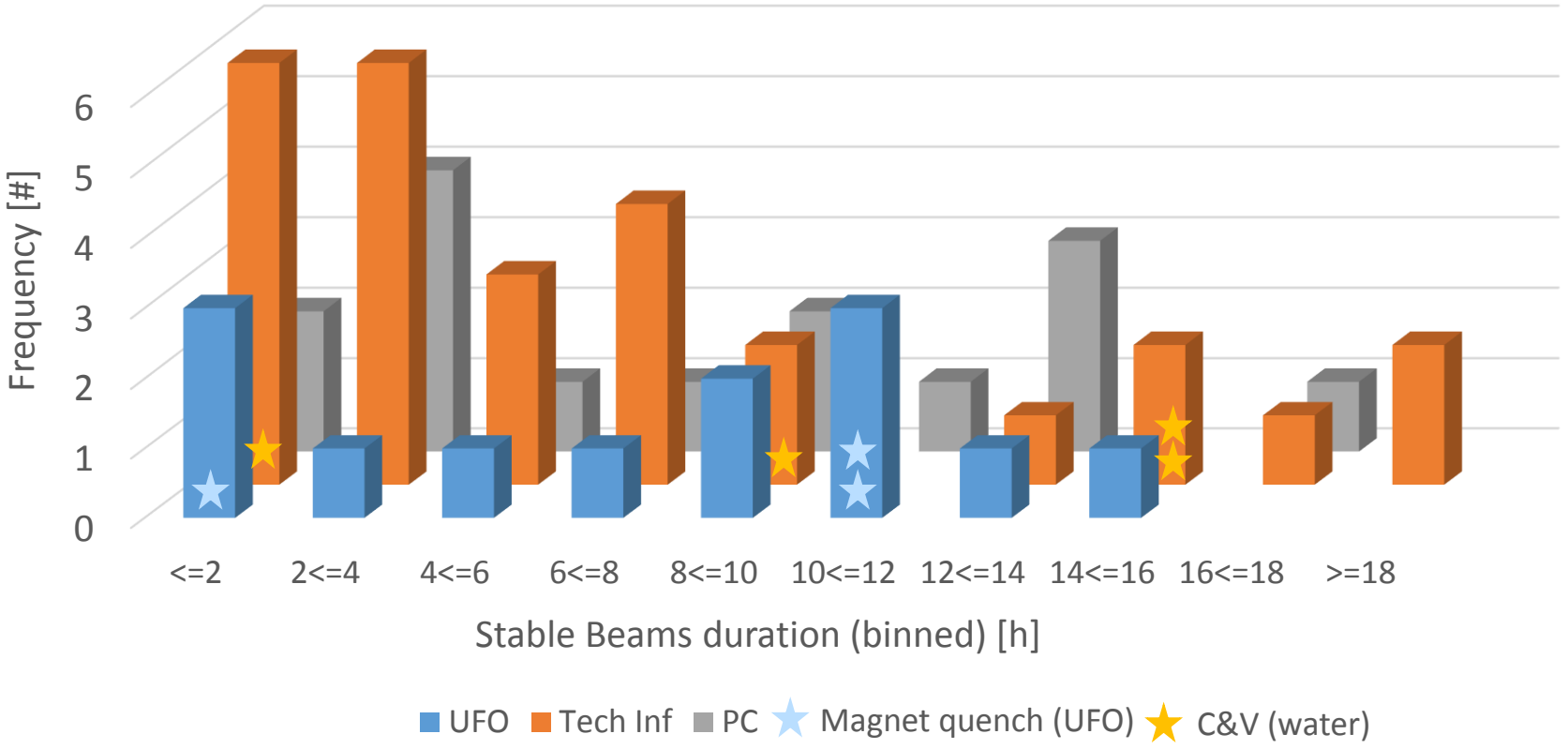
Premature dumps: Duration in SB

All Collimator 4 oo 6 RF, Electrical perturbations



Magnet powering and quenches (MQ.22L8, 2x UFO induced, Power converters, QPS triggers)

Premature dumps: Duration in SB



- No (unexpected) correlation of failures with time in stable beams
- Electrical perturbations expected to be constant in time -> exponential decay of SB time (sensitivity of converter and FMCM only a function of energy)

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  - Power Converters and communication failures
  - UFOs
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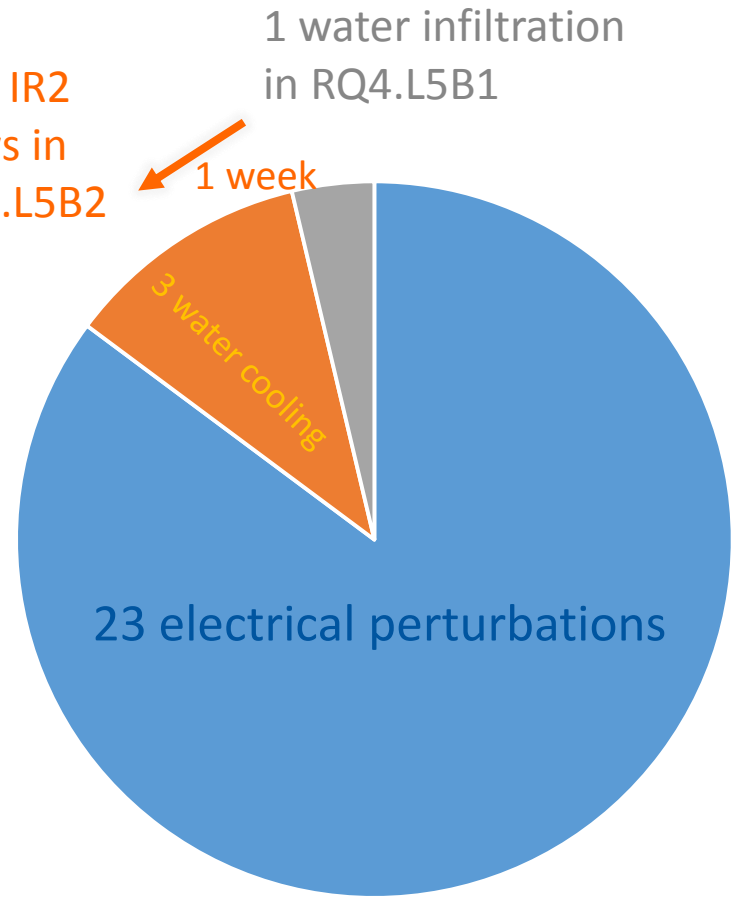
Technical Services



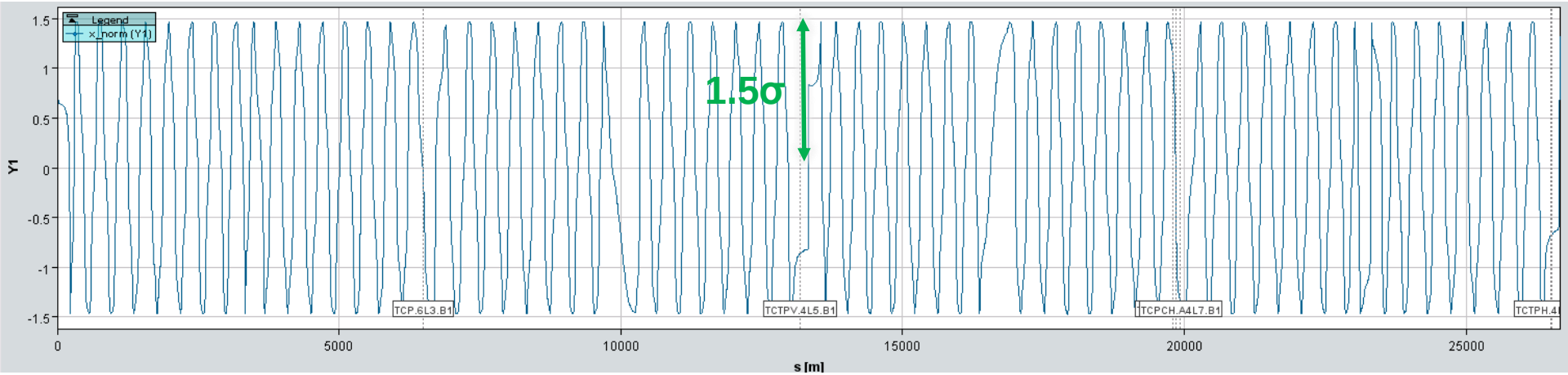
Total of 27 premature dumps
by technical services

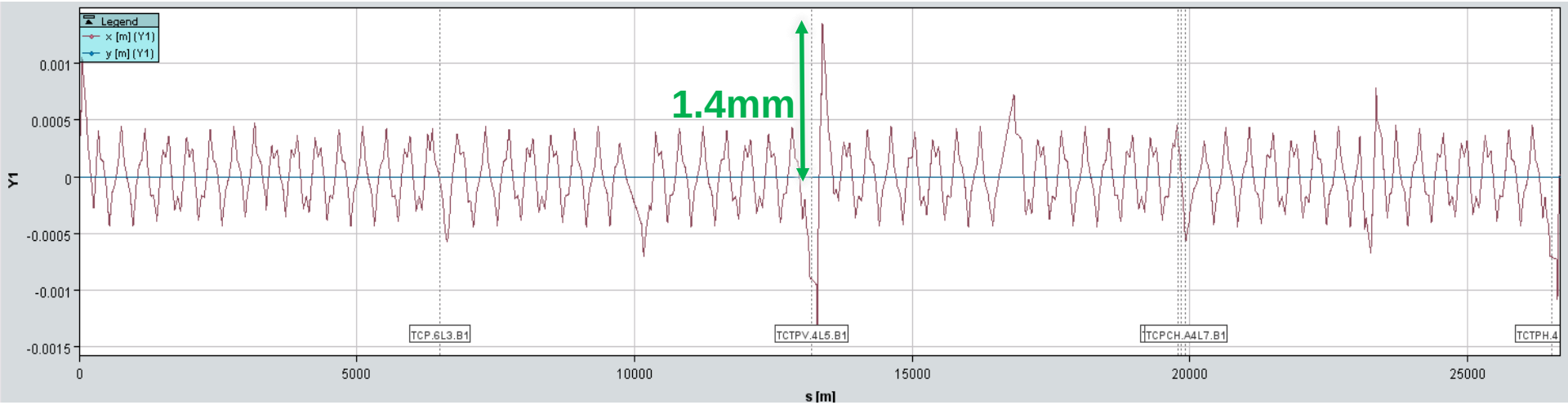
22 dumped by FMCM (including 66kV event)
1 dump by QPS on XL5, XR5

- Fast Magnet Current Change Monitors designed to interlock on unacceptable current changes in normal-conducting magnets (12 systems in LHC)
- Proves to be as well most sensitive detection system for electrical perturbations

Failure simulations: RD1 failure at 6.5TeV

- **6.5TeV, β*=0.4m**, current change RD1.LR1 **+250mA**





Maximum excursion ≃ 1.5σ

Courtesy of M.Valette

Maximum excursion allowed at TCT (IR1 and IR5) = 1σ

Electrical disturbances and FMCM dumps

Fill	Signal / Threshold											
	RD1. LR1	RD1. LR5	RD34. LR3	RD34. LR7	RQ5. LR3	RQ5. LR7	RQ4. LR3	RQ4. LR7	RBXWTV. L2	RBXWTV. R2	RMSD-b1	RMSD-b2
4851		x		x								
4879	x	x	x	x	x	x	x	x	x	x	x	x
4958		x										
4960		x	x	x	x		x					
4976		x	x	x								
4988		x										
5013		x	x	x								
5026		x	x	x	x	x	x	x				
5028	x	x	x	x	x	x	x	x				
5056	x	x	x	x	x	x	x	x	x	x	x	x
5107		x										
5108		x	x	x								
5110		x	x									
5196		x		x								
5206		x	x	x								
5210		x										
5213		x										
5219		x										
5251		x	x	x								
5266		x	x	x								
5405		x	x		x		x					
5450		x										

Electrical disturbances and FMCM dumps

18kV

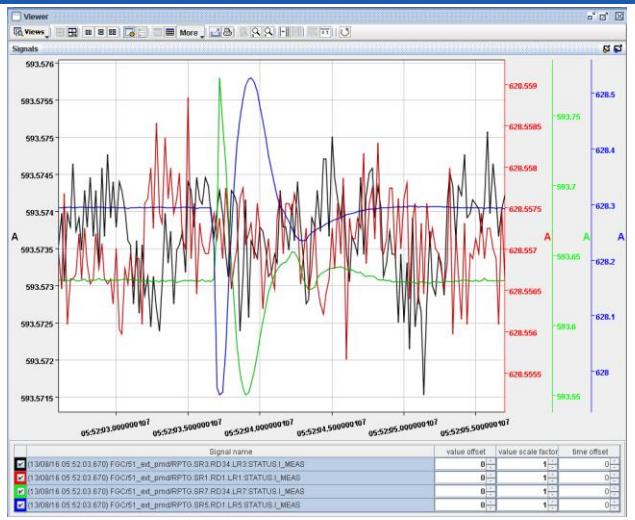
400V

66kV

Fill	Signal / Threshold											
	RD1. LR1	RD1. LR5	RD34. LR3	RD34. LR7	RQ5. LR3	RQ5. LR7	RQ4. LR3	RQ4. LR7	RBXWTV. L2	RBXWTV. R2	RMSD-b1	RMSD-b2
4851		x		x								
4879	x	x	x	x	x	x	x	x	x	x	x	x
4958		x										
4960		x	x	x	x		x					
4976		x	x	x								
4988		x										
5013		x	x	x								
5026		x	x	x	x	x	x	x				
5028	x	x	x	x	x	x	x	x				
5056	x	x	x	x	x	x	x	x	x	x	x	x
5107		x										
5108		x	x	x								
5110		x	x									
5196		x		x								
5206		x	x	x								
5210		x										
5213		x										
5219		x										
5251		x	x	x								
5266		x	x	x								
5405		x	x		x		x					
5450		x										

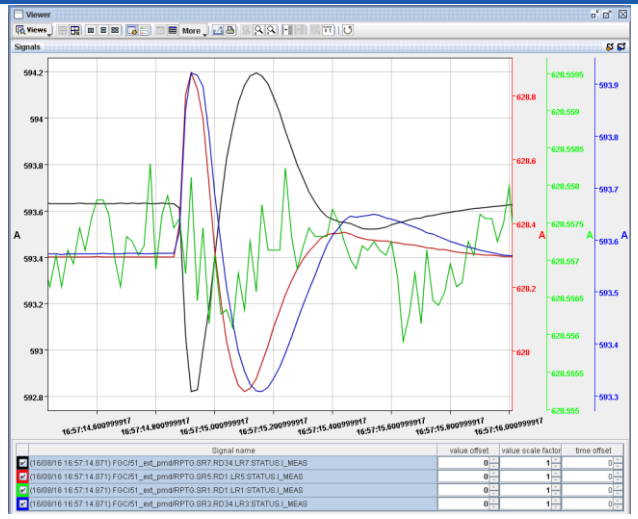
22 FMCM triggers at Stable Beams in 2016
All triggers provoked by electrical network perturbations
At least 9 of them with other equipment affected (PC, RF, CRYO…)

Electrical Perturbations – fill 5196, 5206, 5210



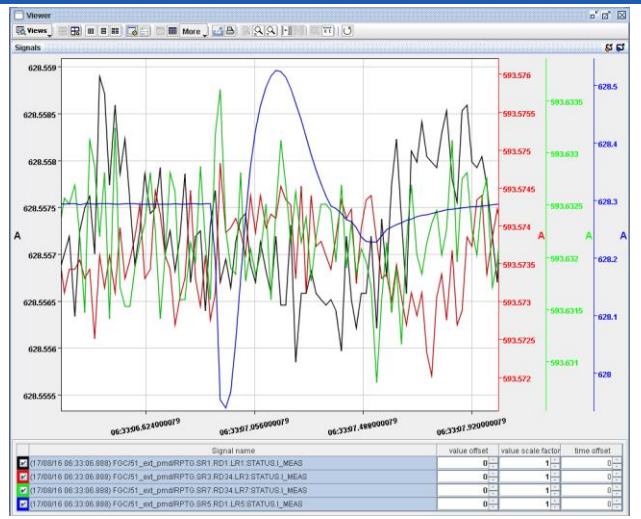
Fill 5196, 13-AUG, 05.52

$\Delta I_{RD1.LR1}$ = none
$\Delta I_{RD1.LR5}$ = 0.6A
$\Delta I_{RD34.LR3}$= none
$\Delta I_{RD34.LR7}$= 0.3A
Δt = 0.5s



Fill 5206, 16-AUG, 16.57

$\Delta I_{RD1.LR1}$ = none
$\Delta I_{RD1.LR5}$ = 1.1A
$\Delta I_{RD34.LR3}$= 0.6A
$\Delta I_{RD34.LR7}$= 0.4A
Δt = 0.5s



Fill 5210, 17-AUG, 06.33

$\Delta I_{RD1.LR1}$ = none
$\Delta I_{RD1.LR5}$ = 0.6A
$\Delta I_{RD34.LR3}$= none
$\Delta I_{RD34.LR7}$= none
Δt = 0.5s

- Impact of network perturbations on converter current strongly dependent on timing, affected phase(s) and network configuration
  - Network of SR1 (network node) much more robust against perturbations than SR5 (fed from 'machine' network of LHC p6)
- Thresholds optimized in 2012, ultimate cure needs new converter type

New power converters for RD1 and RD34

- 4 x SATURN supplies in production in Norway (850A/700V)
- First SATURN finished testing in 287
- Replace converters for RD1.LR1, RD1.LR5, RD34.LR3, RD34.LR7 during EYETS

RPTG

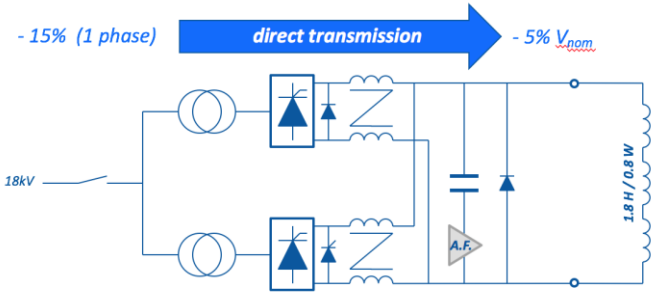
18kV transformer + Thyristor bridges

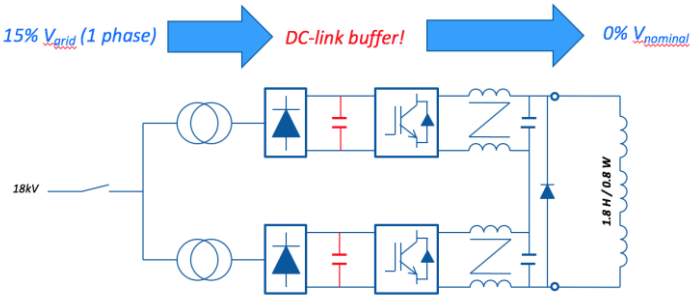
Replacement

Spare

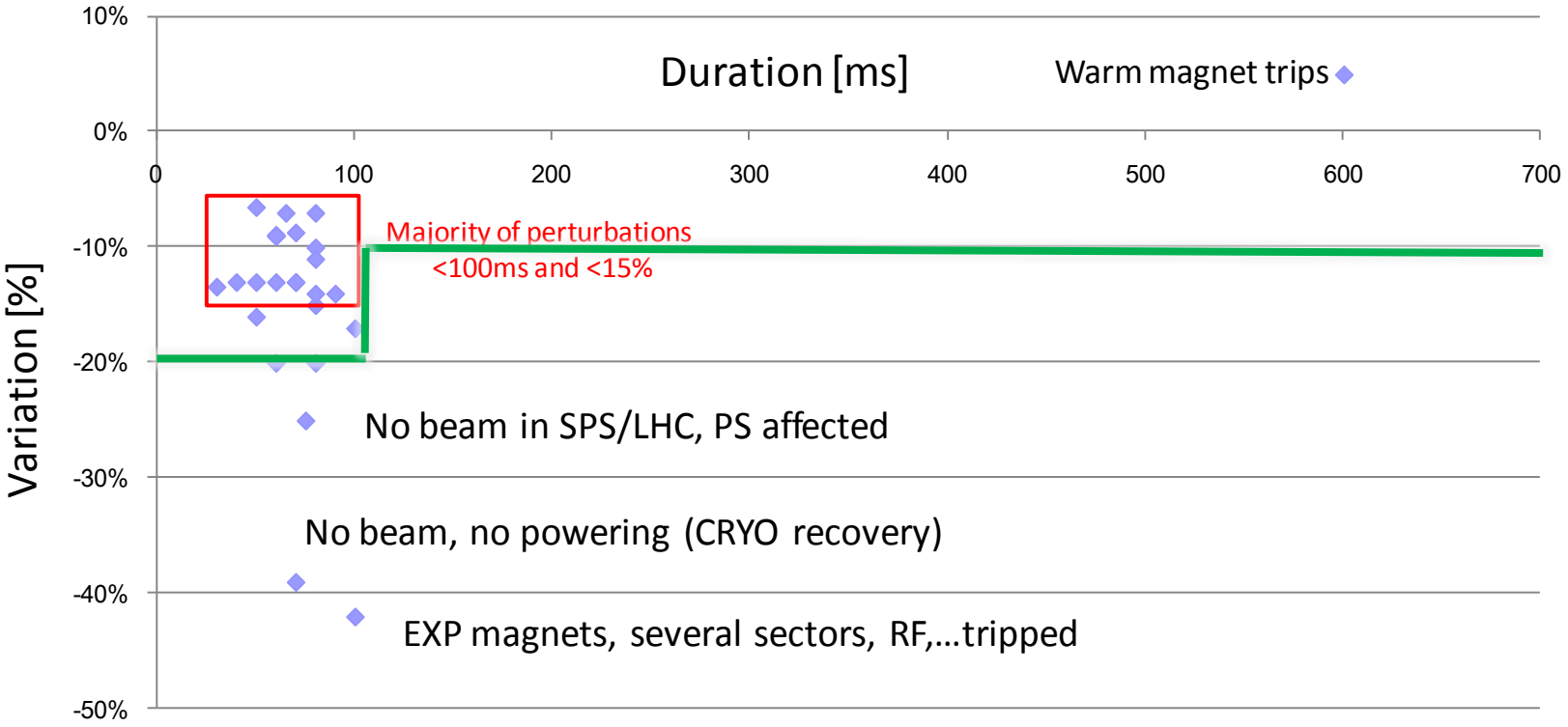
RPADO (SATURN)

18 kV transformer + IGBT switch-mode bridges





Grid perturbation rejection by SATURN



- 10% continuous, up to 20% on 1 phase or 15% on 3 phase for 100ms
- Tests of SATURN converter in conjunction with FMCM ongoing
  - Recommend to aim for deliberate injection of perturbations or long-term test in 287 or in-situ (SR1/SR5) to confirm performance

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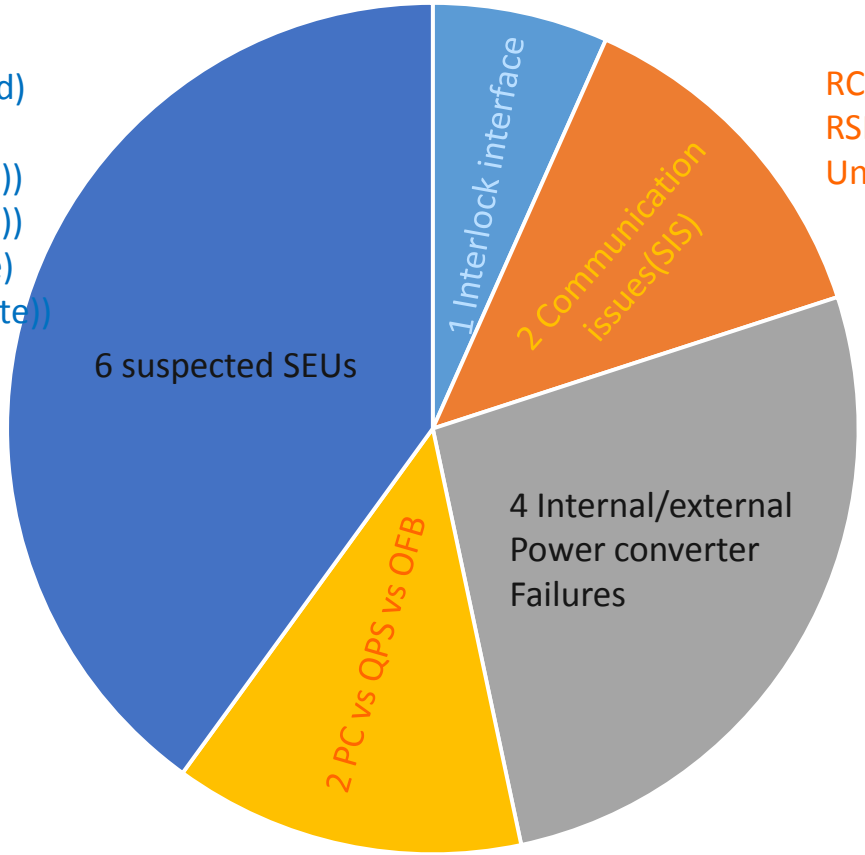
Power Converters and Communication

Total of 15 premature dumps by power converters

RQ10.L8 (FGCs already exchanged in 2015, investigations in TS without success)

6 faults tagged as R2E candidates in AFT:
ROF.A45B2 (FGC, confirmed)
RQ10.L1B2 (VS, candidate)
ROD.A56B2 (VS, confirmed))
ROD.A45B2 (VS, confirmed))
RQT13.L5B1 (VS, candidate)
RQT13.R5B1 (FGC, candidate))



RCBCH10.R2B1 & RCBCV10.R2B2
RSF1.A81B2
Unpowered FGC or entering boot program

ROF.A34B1 (external, current lead over temperature)
RQT13.L4B1 (internal, water fault at rack level – interface CV)
RQ5.LR7 (internal, bad contact?)
RD34.LR7 (internal, bad contact?)

2xRCBXH2.R1
PC vs OFB vs QPS settings

Courtesy of V.Montabonnet

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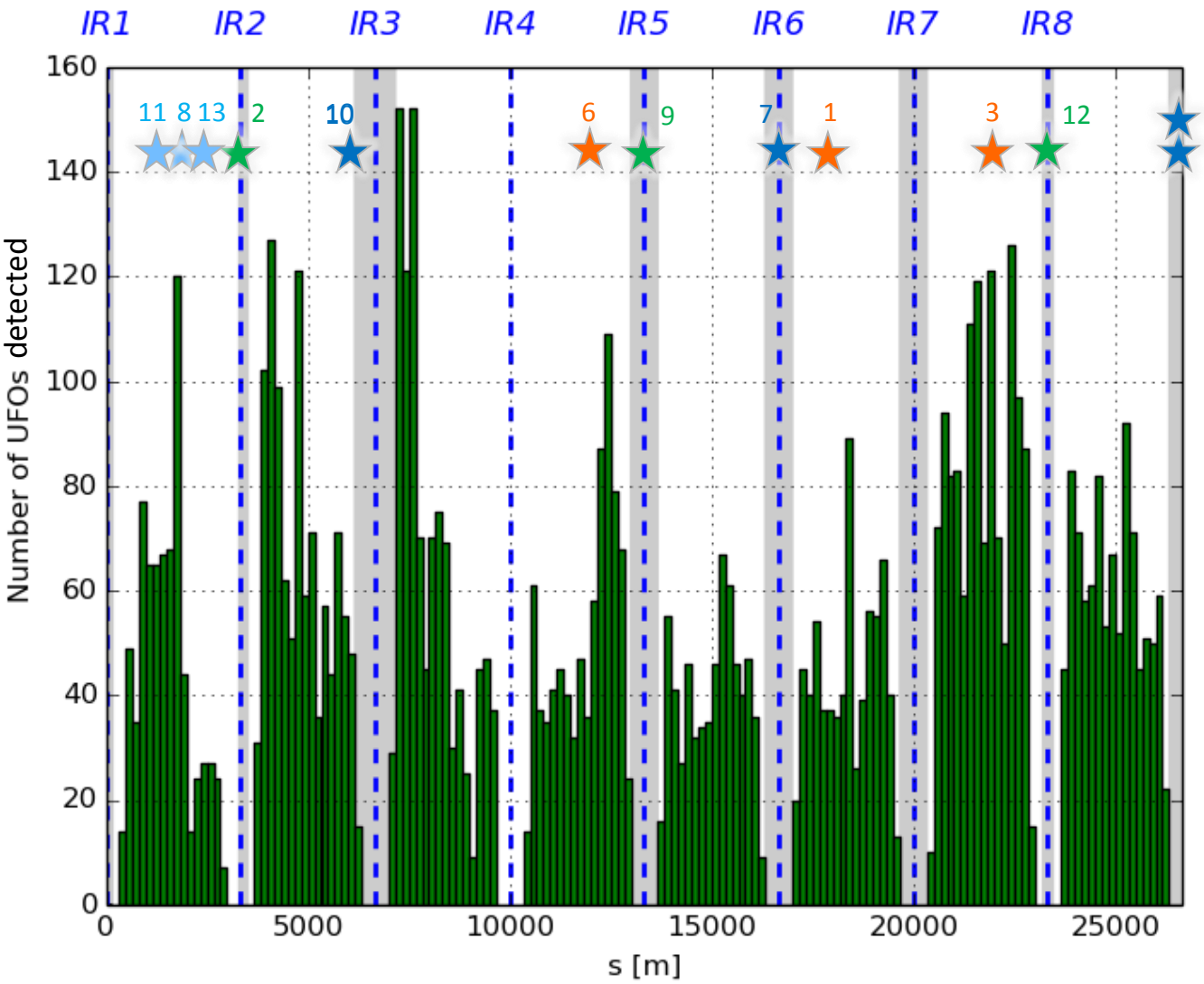
UFOs and beam induced quenches

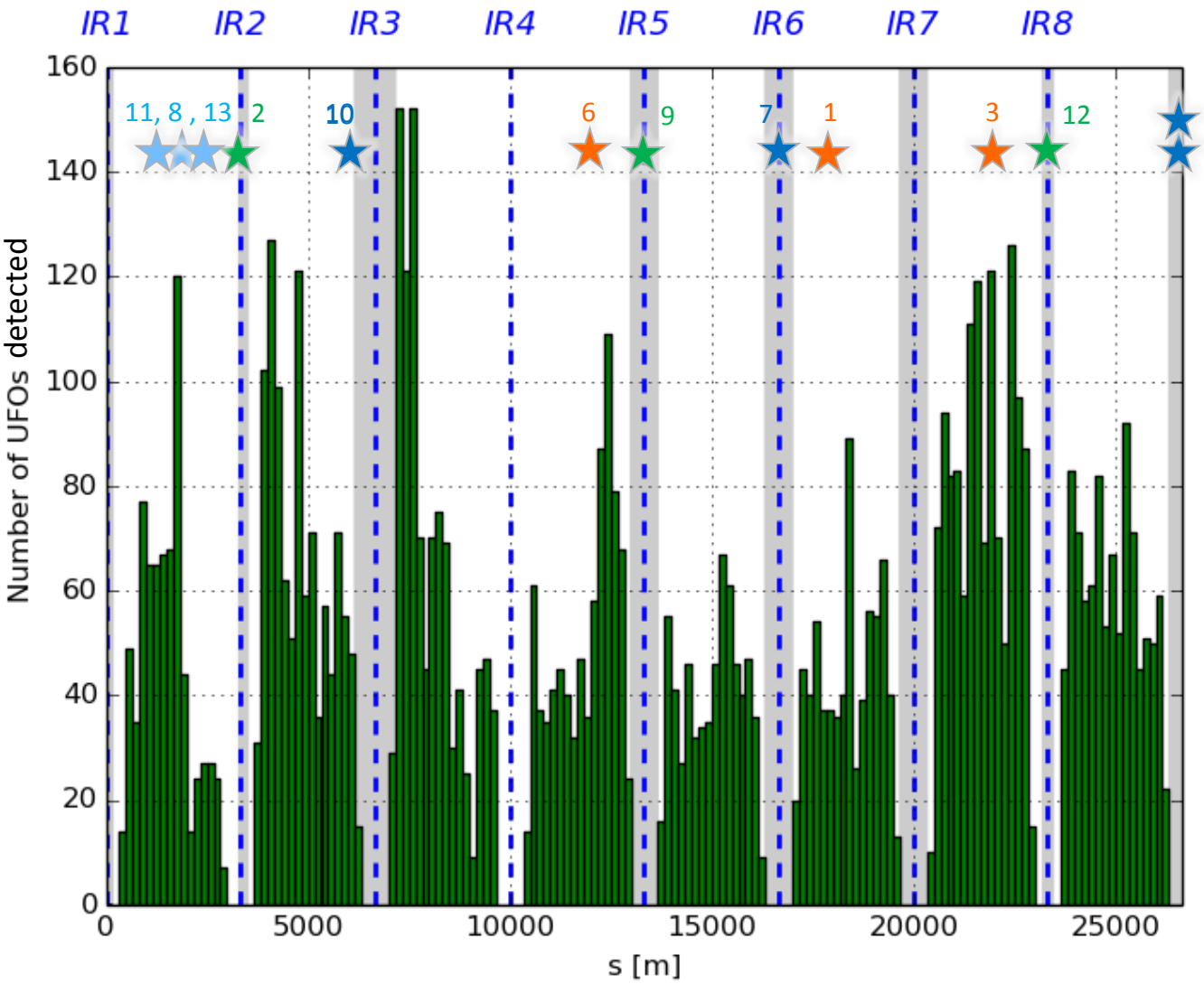


UFO induced dump by:

- Beam Losses
- Beam Losses (S12)
- Experiments (BCM)
- Magnet Quench (very) fast UFO

Note: No spatial distribution in IRs due to many false triggers in UFO buster

UFOs and beam induced quenches



- 6oo13 UFOs in IRs, where still room for BLM threshold corrections for UFOs
- 3oo6 UFO dumps since threshold change in August in S12
- Very small (or no) signals on machine side for BCM dumps by ATLAS and LHCb, should continue understanding of consistent thresholds
- No magnet quench due to UFOs since July 2016, conditioning effect?

Detailed talk of Anton L. tomorrow …

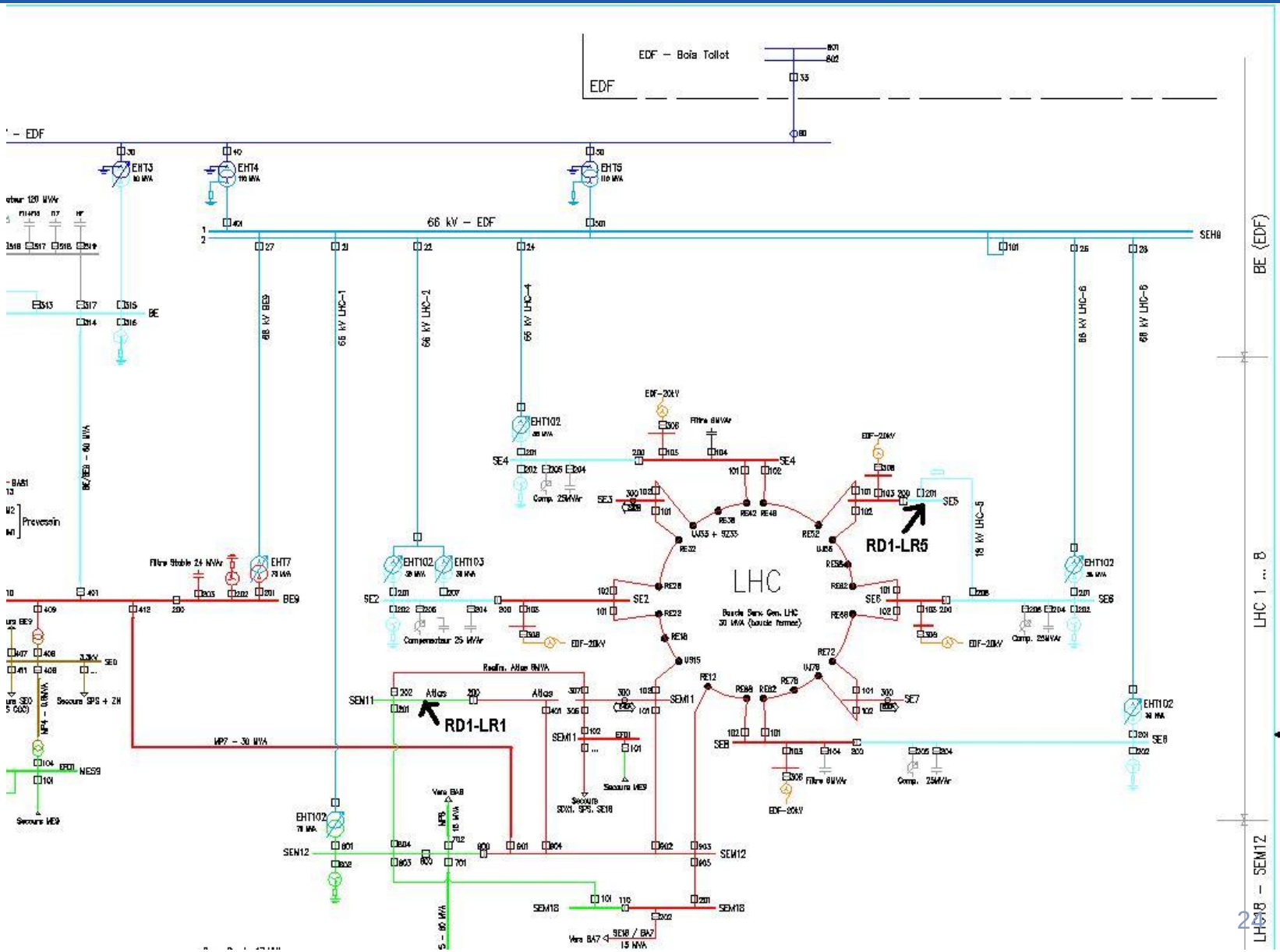
Note: No spatial distribution in IRs due to many false triggers in UFO buster

Conclusions

- Continuous consolidation efforts have efficiently mitigated recurrent failure modes observed prior to 2016 (SEU in QPS, auxiliary power supplies in EPC, …)
  - Little (to no) correlation in remaining fault distribution
- 3 main fault categories remain to be addressed
  - Consolidation of RD1 and RD34 circuits to mitigate additional 15% of 2016 premature dumps
  - Radiation still of concern -> FGCLite, Rad tolerant & redundant 600A PCs, communication issues to be fully understood and mitigated
  - Potential gain for further UFO-BLM threshold optimisations (hoping for conditioning to benefit as well big/fast UFOs?)

SPARES

EL Network at CERN



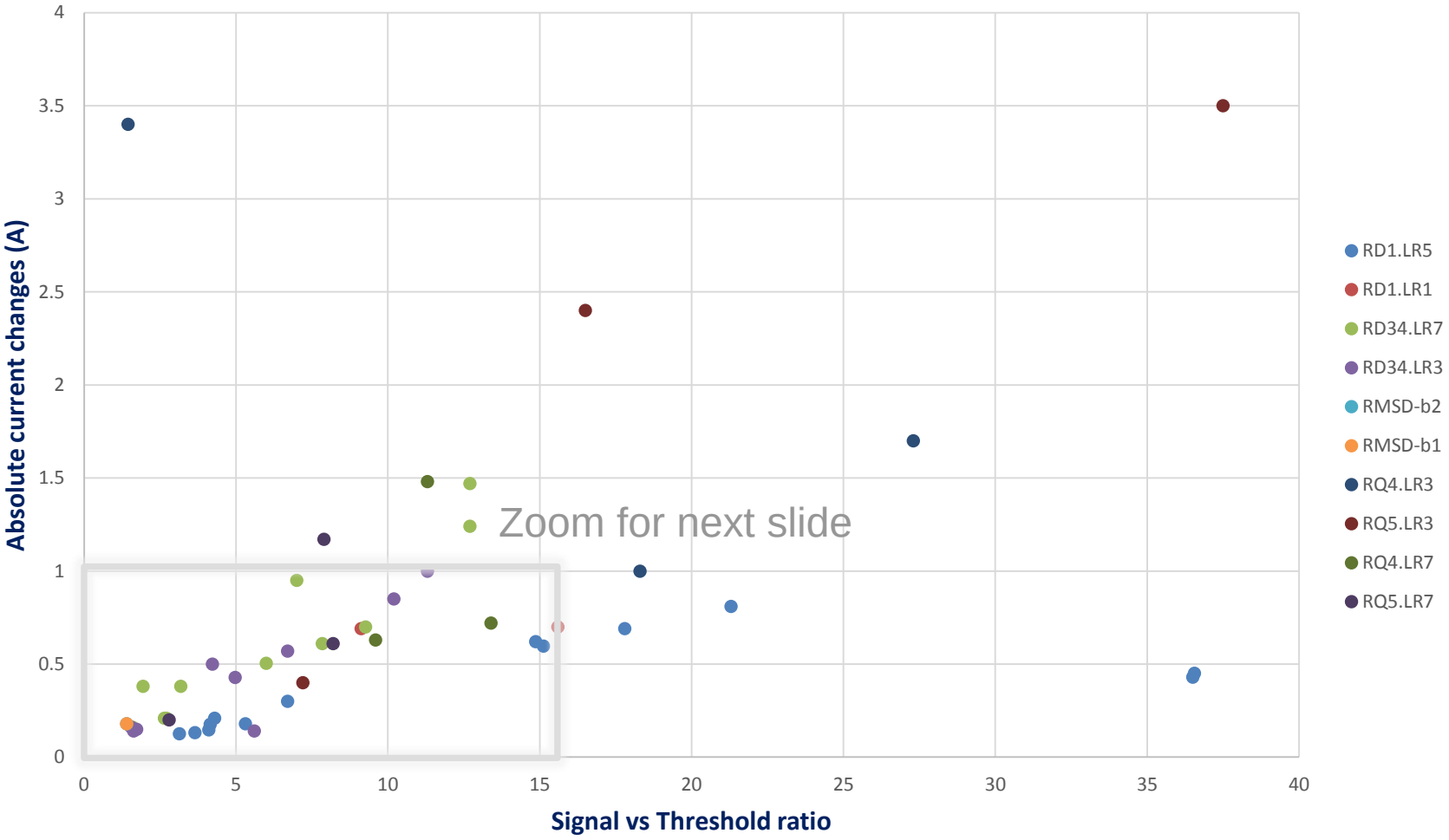
Can we avoid FMCM triggers?

- Required thresholds slightly vary with optics and energy

- Several solutions were proposed in a dedicated review **46th TE-Technical Meeting** in April 2012
  - FMCM Threshold relaxation (RD1, RD34 and RBXWTVL/R)
  - Replacement of RPTG by 4 quadrant switch mode power converters
  - Adding a superconducting inductance

- Outcome:
  - **RBXWTVL/R were relaxed by factor 3 and RD34 by factor 1.5 (ECR)**
  - Recommendation to **replace the 4x RPTG converters for D1 and D34** circuits which will be carried out during EYETS 2016 (i.e. ECR approved at the 264th LMC)

Events above thresholds



Events above thresholds