D2 protection studies

1- Protection scheme

2- Roxie model

2- Quench test cases

3- Simulation results vs measurements

4- Conclusions

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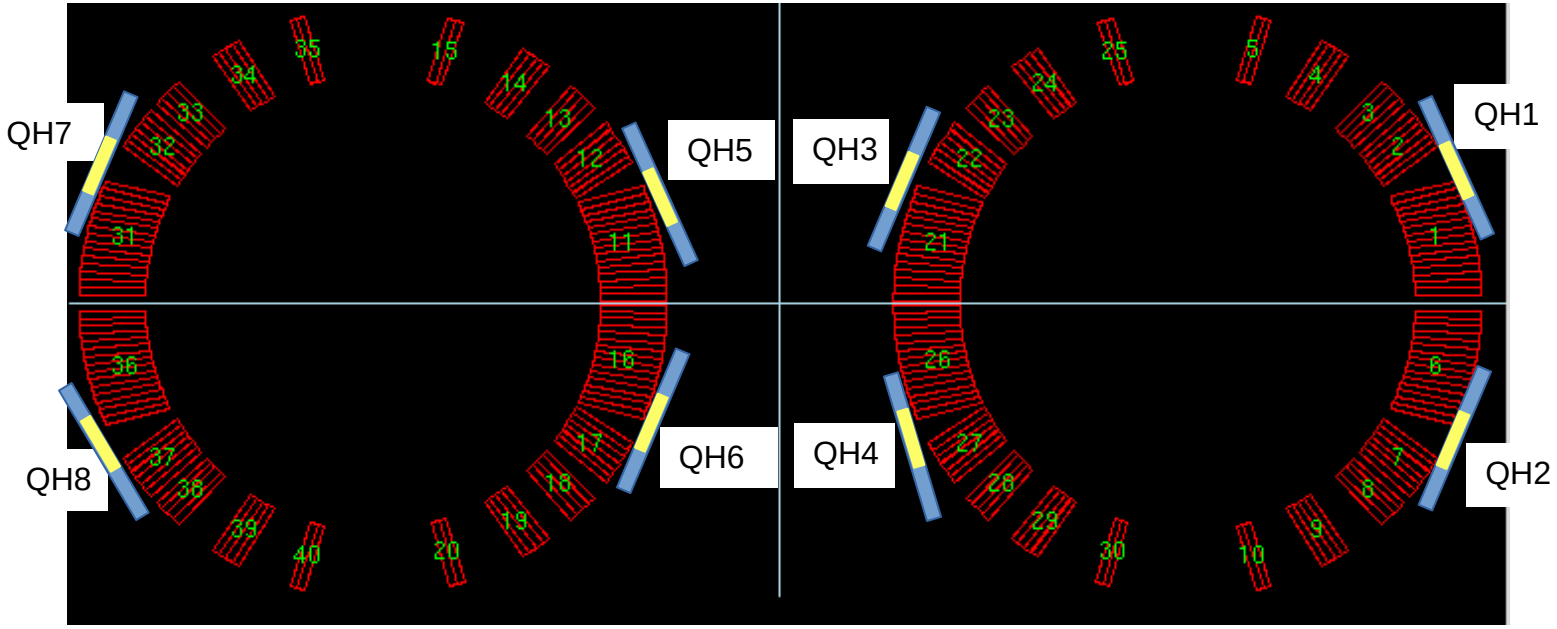
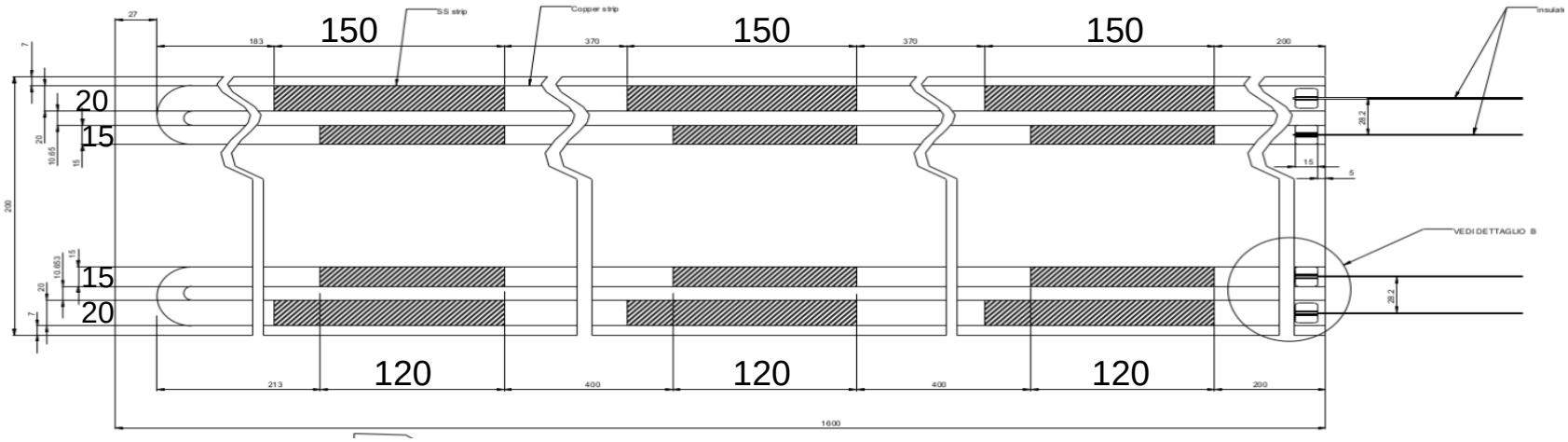
1.Protection scheme

Design configuration



- 8 QHs (2 per coil)
- 4 QHs to be used (1,4,6,7)
- WRFS: 1 QH failing

1.Protection scheme



- LF strip: covers conductors 4-14 of block 1
- A_1= 0.150*0.02=0.003 m^2, $A_{tot}=A_1x3=0.009$ m^2
- N=3 number of repetitions, thickness=25 μm
- R=0.51 Ω

- HF strip: covers entirely block 2
- A_1= 0.120*0.015=0.0018 m^2, $A_{tot}=A_1x3=0.0054$ m^2
- N=3 number of repetitions, thickness=25 μm
- R=0.57 Ω

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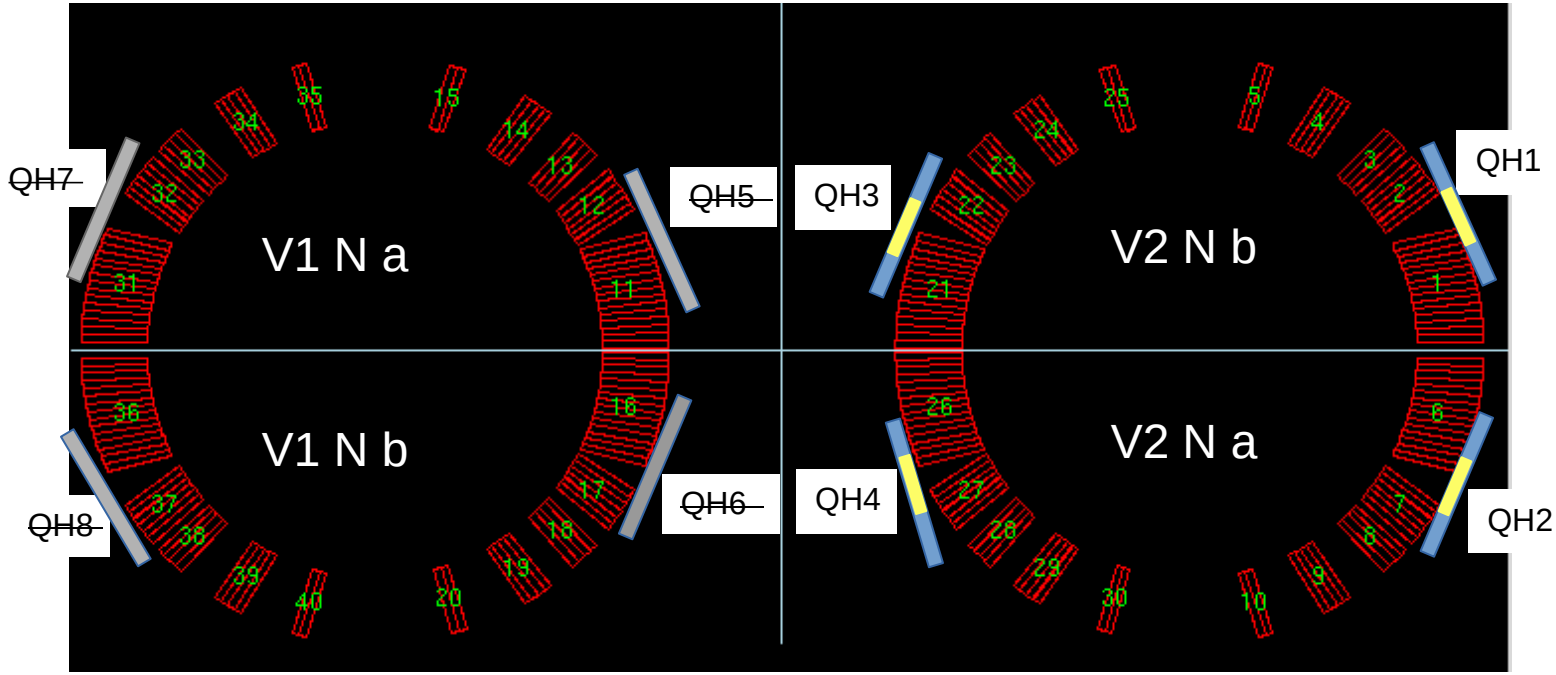
1.Protection scheme

Current configuration



- 4 QHs in coil V2N
- New baseline: 2QHs used

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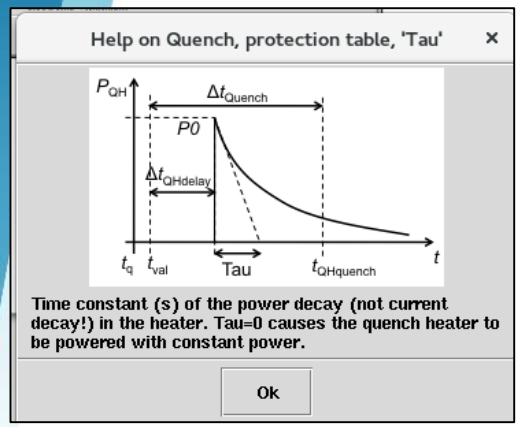
2.Roxie model

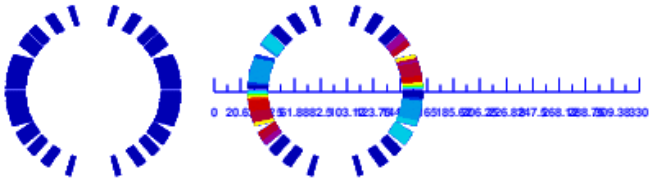


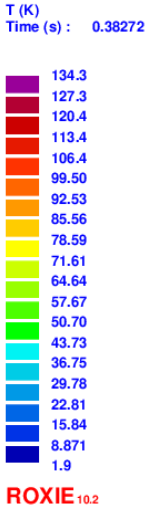
R_{LF}=0.51 Ω , R_{HF}=0.57 Ω, R_{tot}≃ 6 Ω (also exit extra lengths are considered)
V=900 V
$I=V_{QH}/R_{ALL}$ = 900V / 6 Ω= 150 A
$P=R_{QH\text{-}LF}I_{QH}^2$=1.15 10^4 W → P/A(low field)=P/A^{tot}_{LF}=1.15 10^4/ 0.009=1.28 MW/m^2
$P=R_{QH\text{-}HF}I_{QH}$ =1.23 10^4 W → P/A(high field)=P/A^{tot}_{HF}=1.25 10^4/ 0.0054= 2.28 MW/m^2
τ=0.042 s (τ=RC R_{ALL}=6 Ω, C=7 mF)

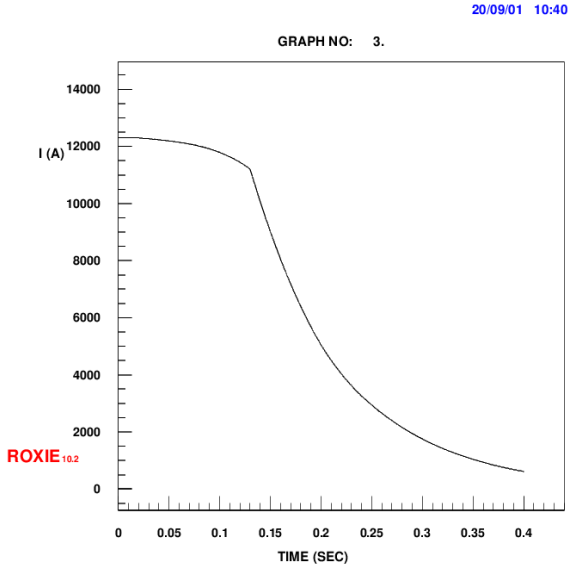
- At t=0 QHs 1 & 4 are fired

I_{op}=12330 A

Temperature distribution @ 10% I_{op}







V_{peak} [V] (to ground)	T_{peak} [K]	MIITS [MAAs]	t_{tot}[ms] (10% I_{op})	Ediss[MJ](mag)	Ediss[MJ] (ext)
446	134	24	383	0.17	0.23

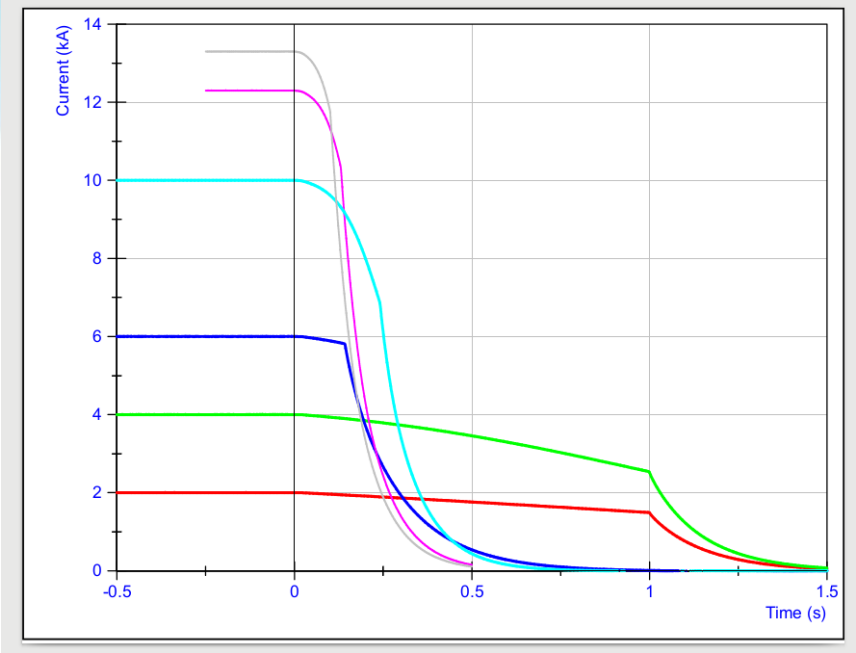
2.Quench test cases

Current [kA]	R_dump [mOhm]	L_magnet [mH]	Delay_dump [ms]	QI_dump [MA²s]	V_max [V]
2	40	6.40	**999**	3.3	60
4	40	6.40	**999**	12	91
6	40	6.40	**800**	18	87
8	40	6.40	**420**	21	175
10	40	6.40	**240**	24	298
12.3	40	6.40	**130**	24	446
13.3	40	6.40	**100**	24	501

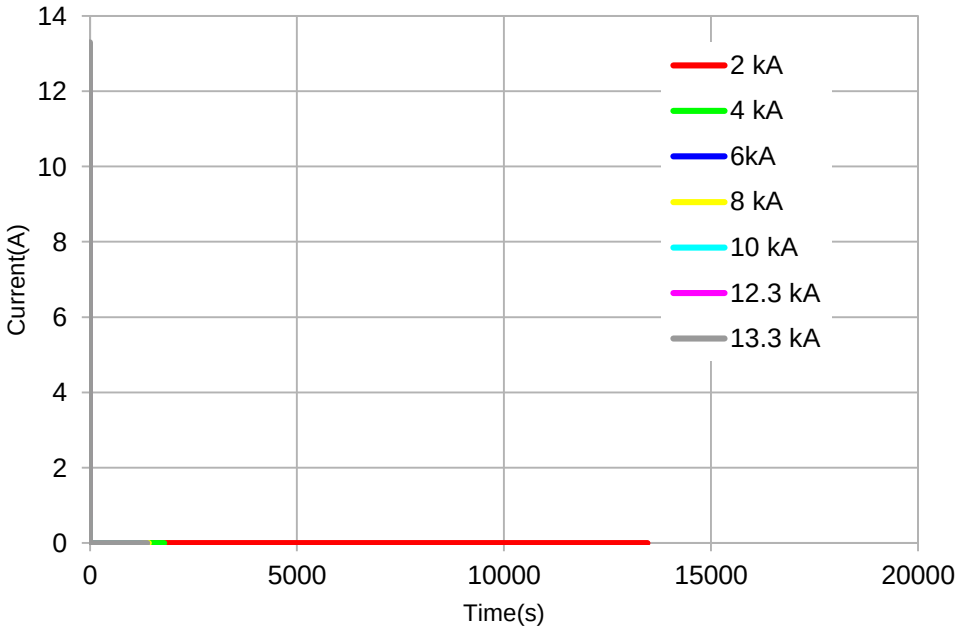
When the measurement plan was defined the standard protection was designed with 1 QH per coil and only 1 QH failure allowed, so missing the QHs of one aperture the test with only 2 QHs working was not included. Indeed in the meantime the new failure scenario include 2 QHs failing, but the test plan was not changed

3.Simulation results vs measurements

Measurements

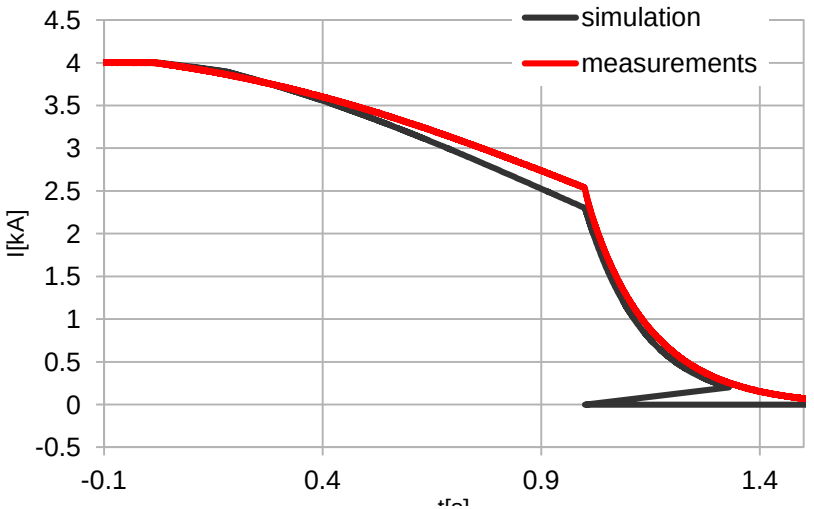


Roxie simulation

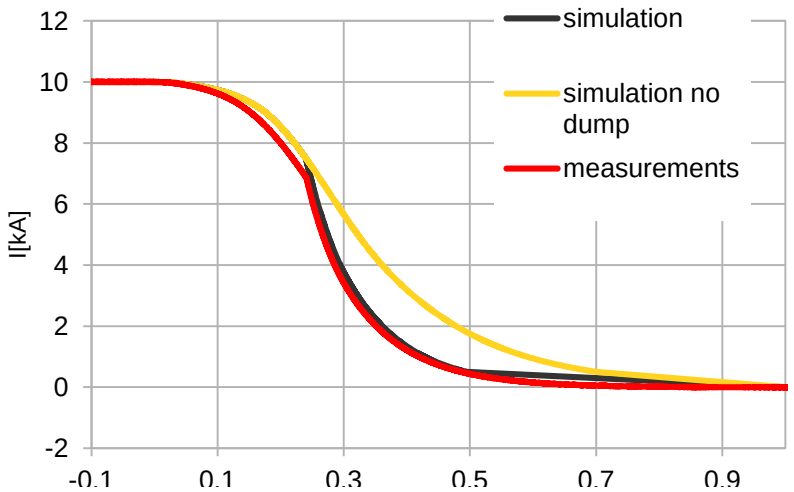


3.Simulation results vs measurements

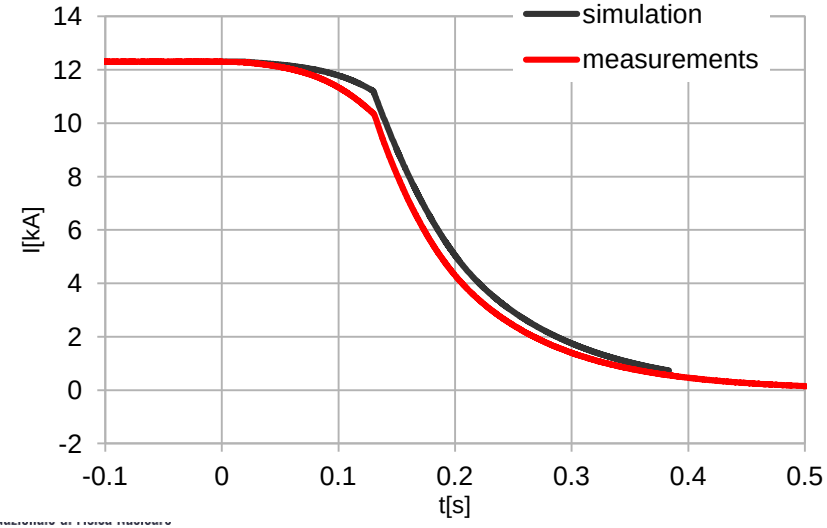
4 kA



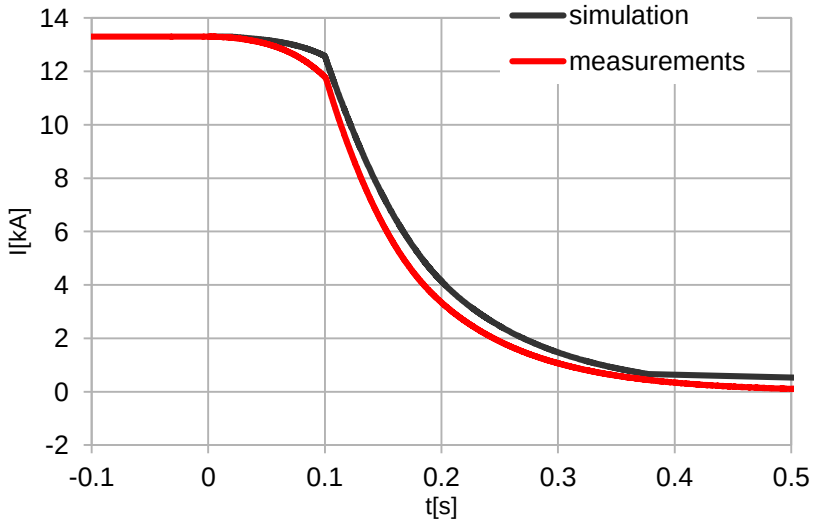
10 kA



12.3 kA

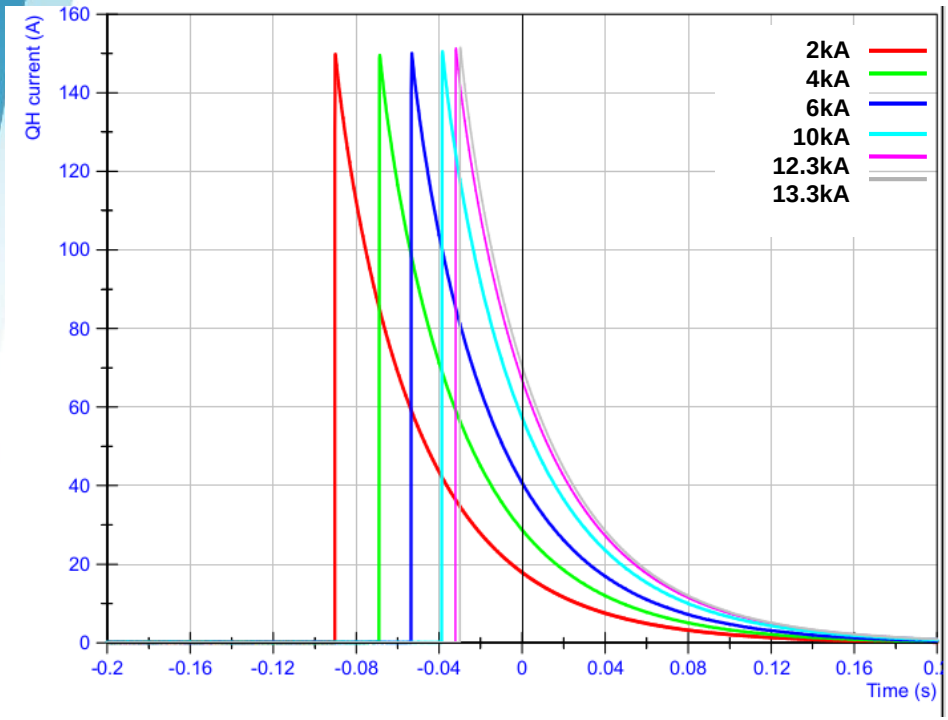


13.3 kA



3.Simulation results vs measurements

Time between QH activation and quench



	Measurements	Roxie
t(2kA)	90 ms	28.8 ms
t(4kA)	75 ms	26.5 ms
t(6kA)	45 ms	24.6 ms
t(10kA)	40 ms	21.2 ms
t(12.3kA)	38 ms	19.4 ms
t(13.3kA)	37 ms	18.9 ms

3.Conclusions

- Quench calculations were performed with Roxie, simulating the QHs protections schemes including dump resistor in the conditions of the tests.

- Simulations and measurements show good agreement.