The SPL: basic parameters for HOM simulations

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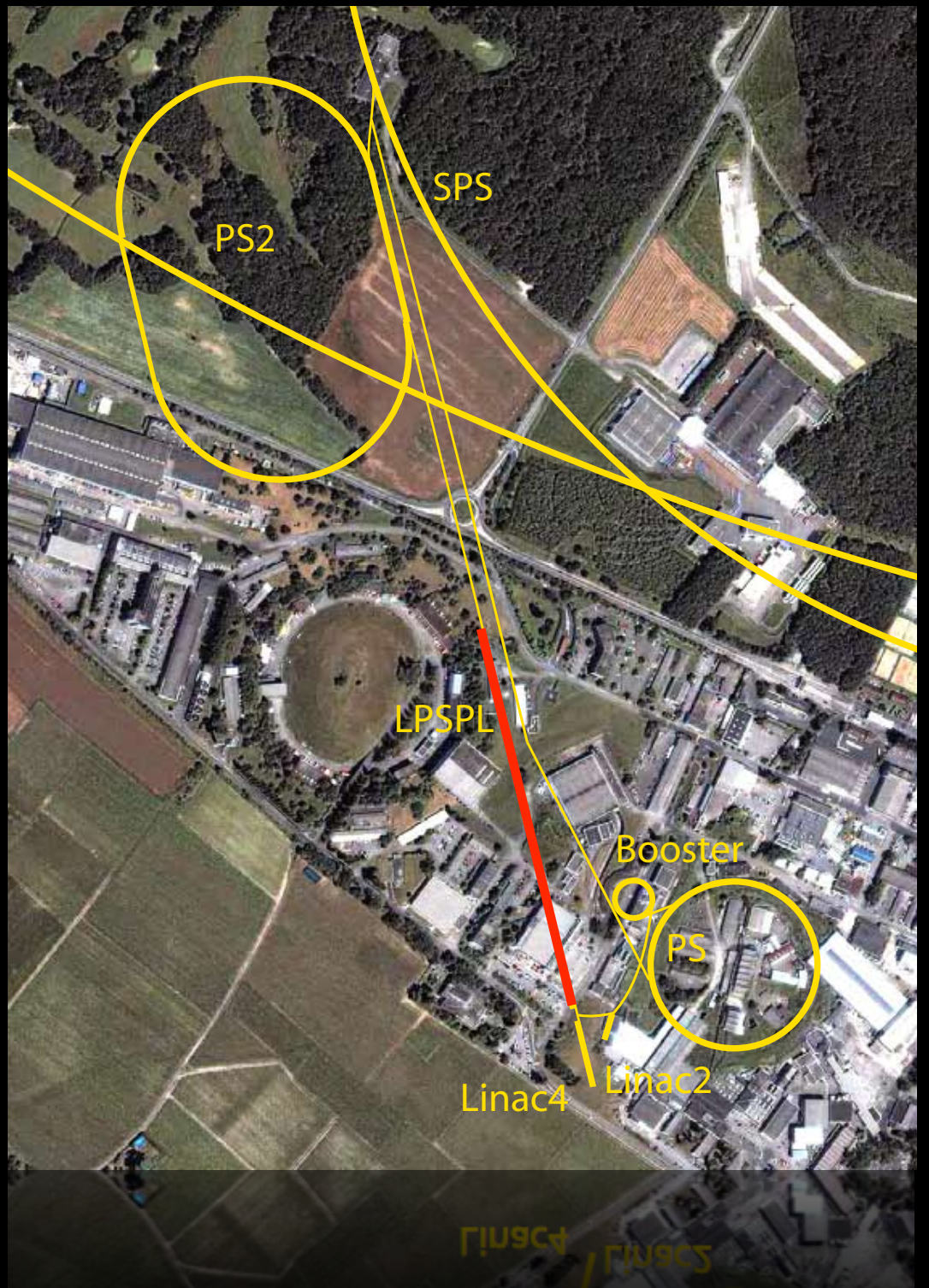
SPL HOM workshop,
CERN, 25.06.2009

http://www.cern.ch/project-spl

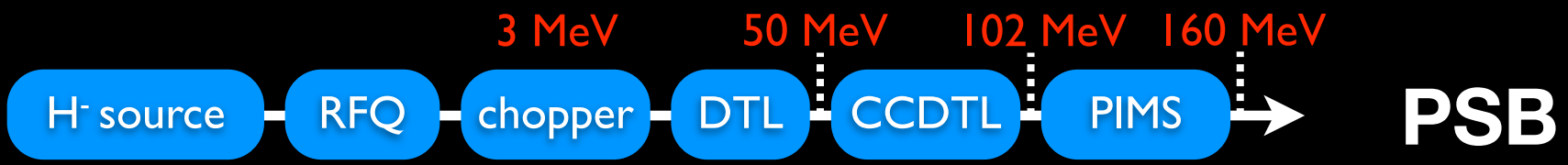


Outline

- introduction,
- SPL staged construction,
- main parameters,
- HOM parameters & input for simulations,

SPL construction, stage 1:

Linac4 (160 MeV)

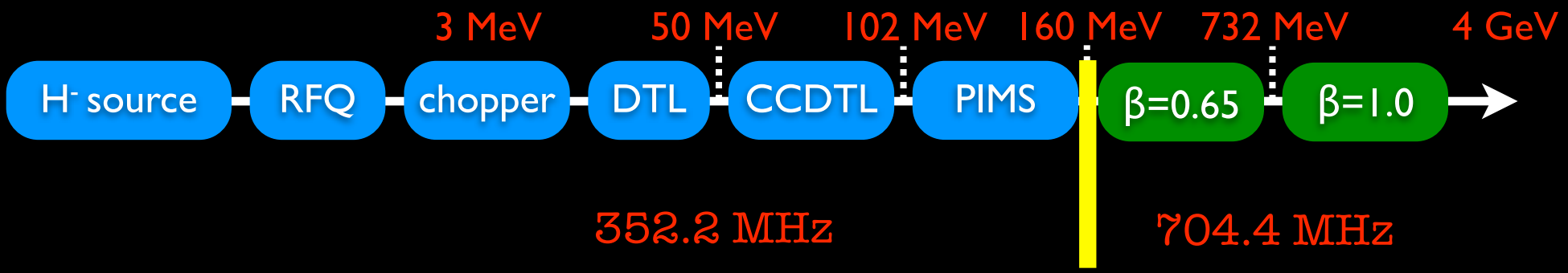


352.2 MHz

- low-power (<5 kW), low duty cycle (0.1%) PSB injector
- under construction and designed for high duty cycle (HP-SPL),
- tunnel can be extended in a straight line for the SPL,
- radiation protection and civil engineering works foresee high-duty cycle operation (up to 10%),
- start of operation foreseen for 2014,

SPL construction, stage 2:

LP-SPL (4 GeV)

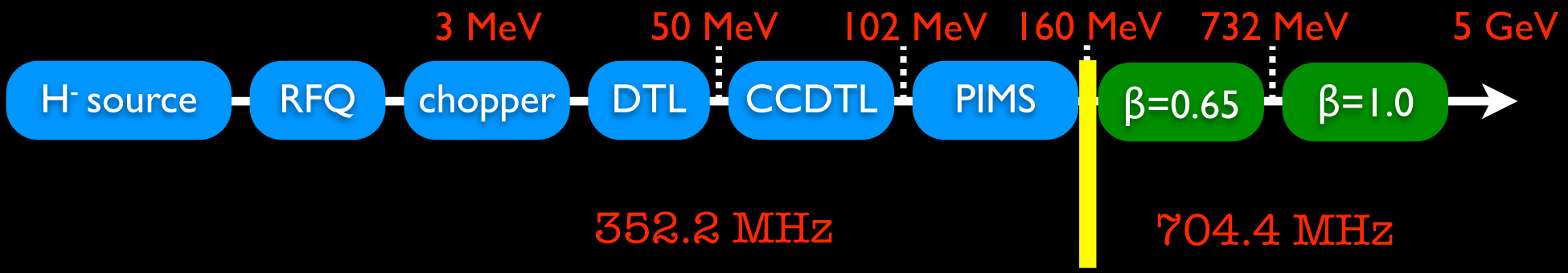


- construction of Low-Power SPL together with PS2,
- main users: PS2 (LHC), ISOLDE upgrade, EURISOL-0 (?),
- operation in 2020

kinetic energy	4 GeV
beam power (@ 4 GeV)	0.14 MW
repetition rate	0.6 - 2 Hz
pulse length	0.9 ms
average pulse current	20 mA
protons p. pulse	$1.1\ 10^{14}$
length (SC linac)	427 m

SPL construction, stage 3:

HP-SPL (5 GeV)

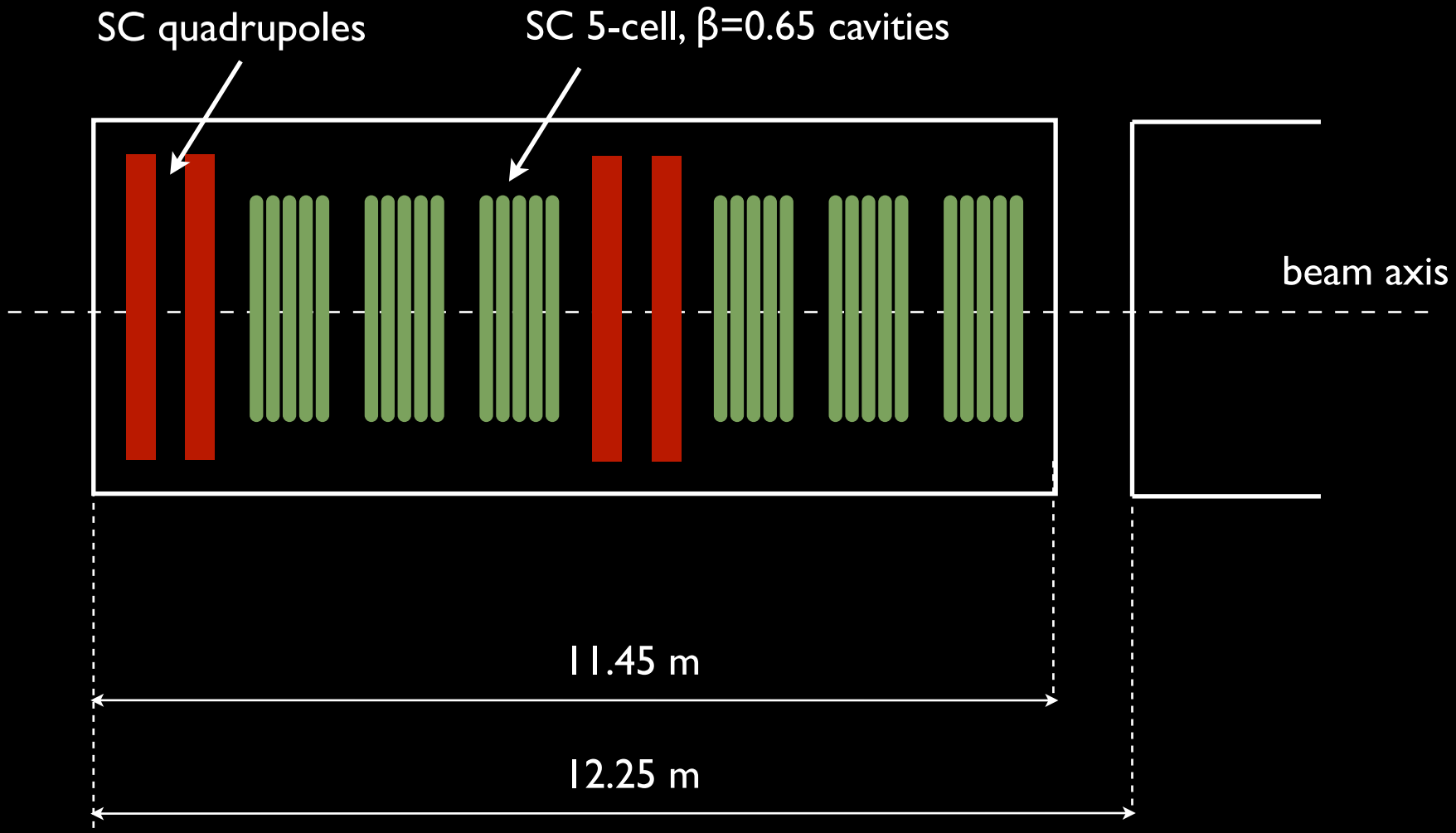


- addition of klystrons,
- cavities from 4 to 5 GeV,
- replacement of all modulators,
- upgrade of electric/cryogenic infrastructure,
- possible high-power users: EURISOL, neutrinos, LHeC,
- possible start of operation: 2020

kinetic energy	5 GeV
beam power	3-8 MW
repetition rate	50 Hz
pulse length	up to 1.2 ms
average pulse current	0-40 mA
protons p. pulse	$1.5\ 10^{14}$
length (SC linac)	502 m

low-beta cryo-module

doublet focusing, 6 cavities (704 MHz) per cryo-module

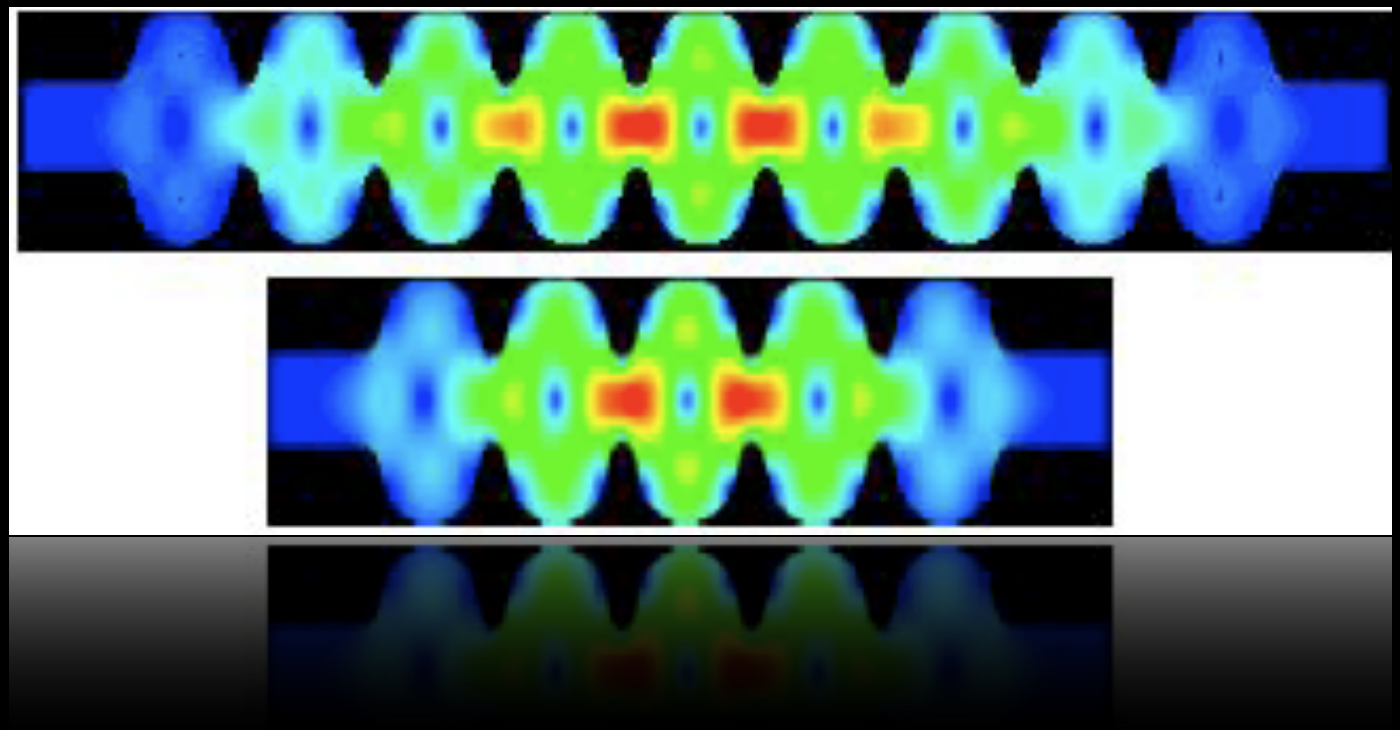


high-beta cryo-module

doublet focusing, 8 cavities (704 MHz) per cryo-module

SPL parameters

operation type	low-power	high-power low-current	high-power high-current
E [GeV]	4	2.5 (**or** 5)	2.5 (**and** 5)
P_{beam} [MW]	0.192	3 (6)	4 (+4)
f_{rep} [Hz]	2	50	50
$I_{average}$ [mA]	0-20	0-20	0-40
t_{pulse} [ms]	≤0.9	≤1.2	≤0.8 (+0.4)
$n_{protons/pulse}$ [10^{14}]	≤1.1	≤1.5	≤2 (+1)
main user	PS2/ISOLDE	PS2/neutrinos/ EURISOL	PS2/neutrinos/ EURISOL
		+ LHeC (tbd)	



HOM parameters

HOM frequency scatter

beam current (safety factor & fluctuations)

(R/Q)Q

Collection of SPL HOM data

collaborate with TWiki

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r4 - 23 Jun 2009 - 09:08:35 - FrankGerigk

HOM working group

https://twiki.cern.ch/twiki/bin/view/SPL/SplHom

collection of data relevant for HOM studies in the SPL

assumed input parameters for HOM BBU simulations

HOM parameters

Monopole modes in SPL cavities

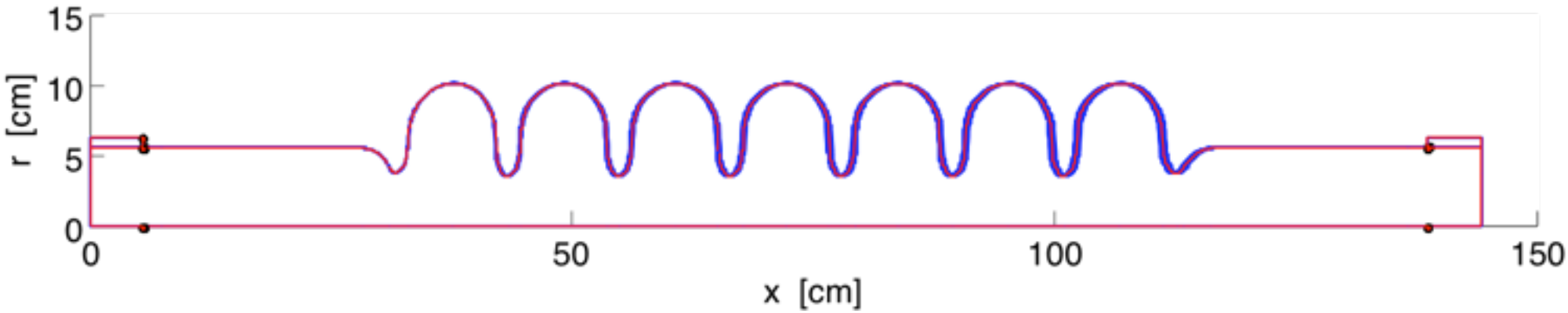
mode	frequency [MHz]	(R/Q)† [Ω]	Comment	Time stamp
low beta section: β=0.65, 5-cell cavity				
$TM_{010,4/5\pi}$	703.7	1	HFSS	28 May 2009
$TM_{010,\pi}$	704.4	318	HFSS, accelerating mode	28 May 2009
$TM_{011,3/5\pi}$	1765	3	HFSS	28 May 2009
$TM_{011,4/5\pi}$	1774	4	HFSS	28 May 2009
high beta section: β=1.0, 5-cell cavity				
$TM_{010,\pi}$	704.5	525	HFSS, accelerating mode	28 May 2009
$TM_{011,4/5\pi}$	1328	37	HFSS	28 May 2009
$TM_{011,\pi}$	1332	137	HFSS	28 May 2009
$TM_{021,\pi}$	2090	25	HFSS	28 May 2009

† linac definition

Dipole modes in SPL cavities

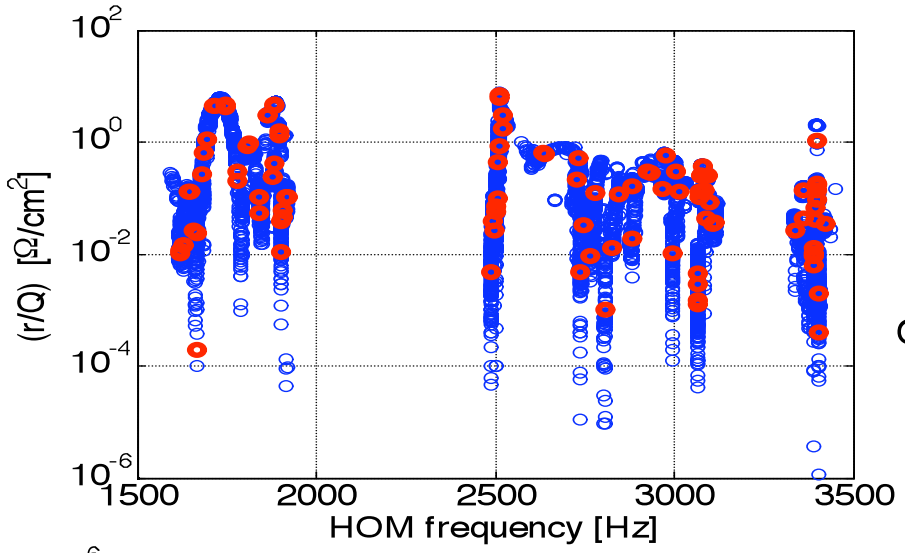
mode	frequency [MHz]	(R/Q) [Ω]	Comment	Time stamp

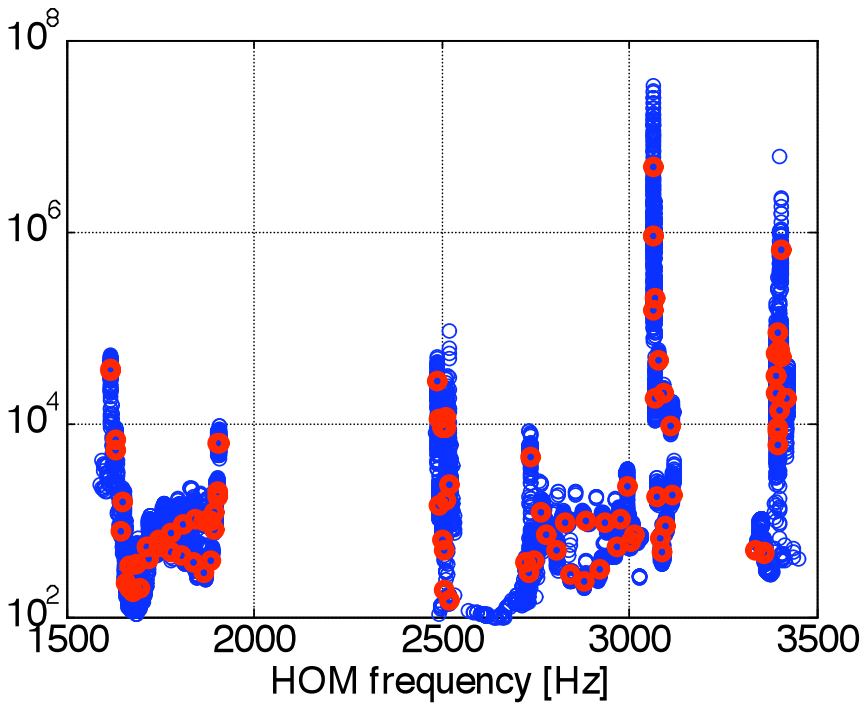
Cornell study: M. Liepe (TTC 6/09)

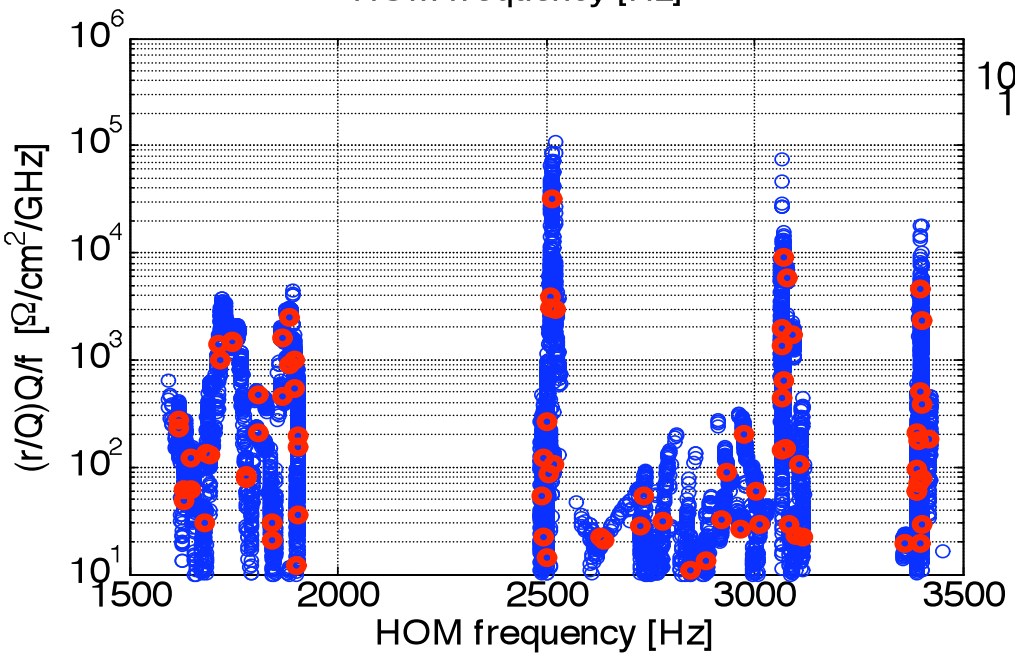


- Deformation of cavities due to tuning of the fundamental mode frequency,
- assuming ± 1MHz error after fabrication ⇔ ± 1/16 mm random deformation of all cavity dimensions,
- Cornell ERL 7-cell cavity, 1300 MHz

Example: Cavities with +-1/16 mm Deformations







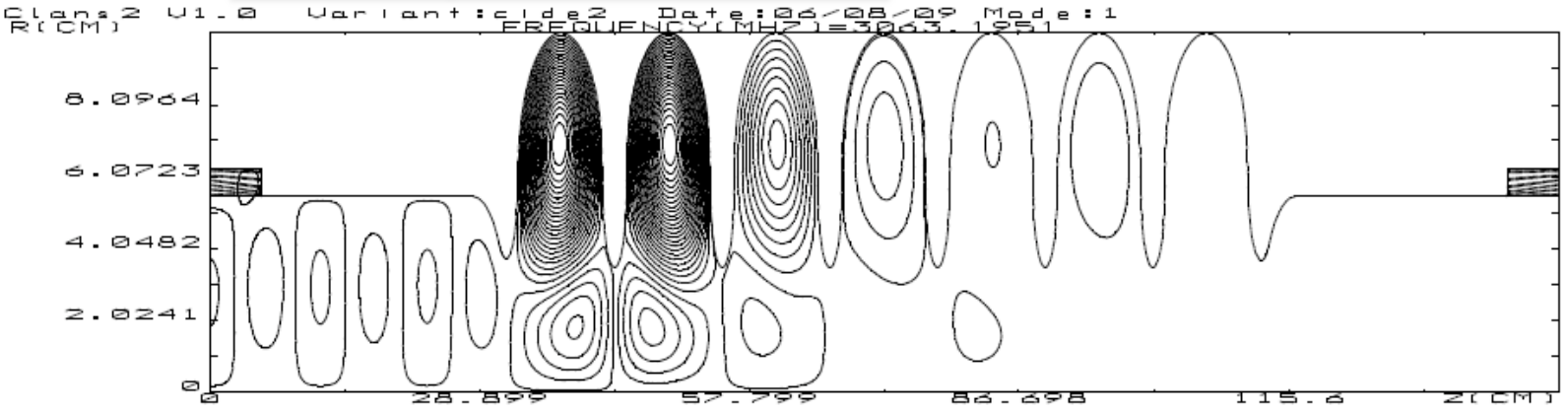
Red: ERL Main Linac 7-cell Cavity without deformations

Blue: with deformations (100 cavities)

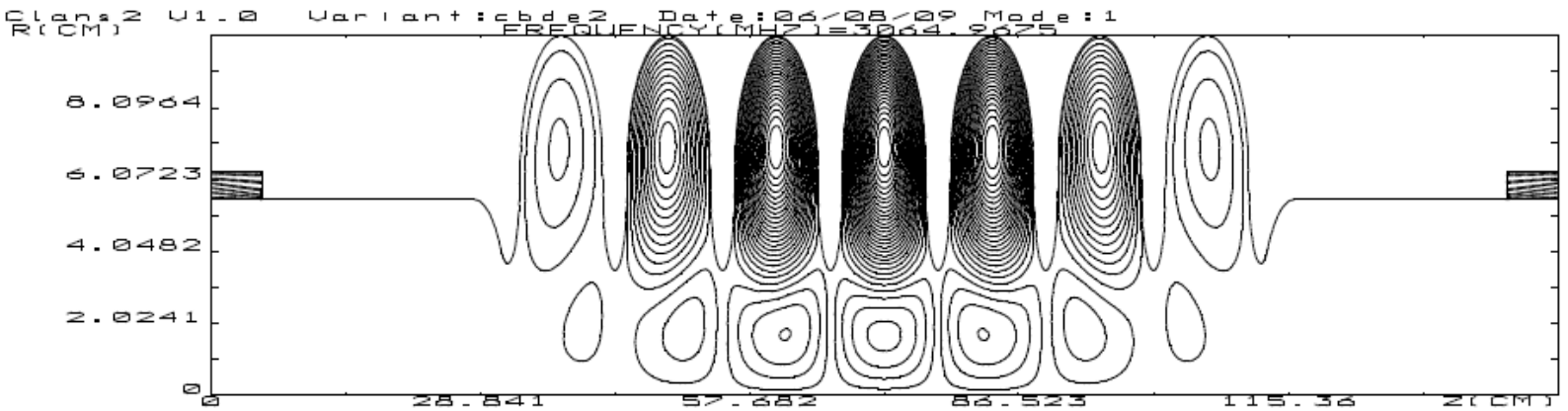
⇒ Significant impact on BBU threshold current!

Example of Trapping of HOMs in Deformed Cavities: 3.06 MHz mode in cavity type #3

In cavity #m: Q = 7000



In cavity #n: Q = $3.6 \cdot 10^6$



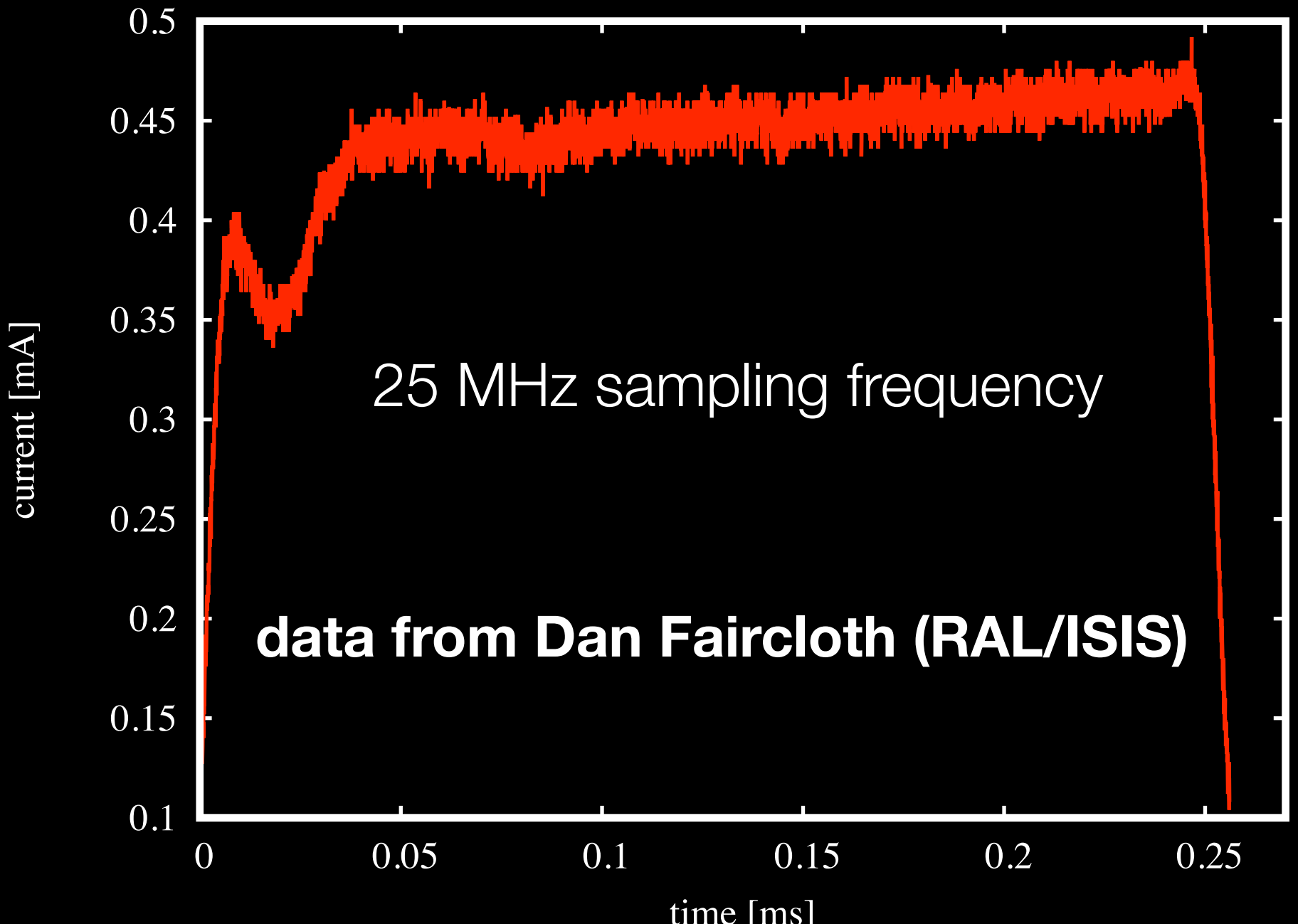
HOM frequency scatter

- Cavity shape deformations introduce HOM frequency scatter (good) but also variations in (R/Q) and Q (bad).
- Factors of 10 to 100 have been observed at TTF/FLASH and JLAB.
  - ➡explains differences in calculated (R/Q) values for Tesla cavities by different teams,
  - ➡**safety factor of 10 (for Q x (R/Q)**, or the beam current) seems reasonable!
- HOM scatter in FLASH/TTF: between 1-10 MHz, 3 MHz measured (in all FLASH cavities) for dipole mode at 1.7 GHz,
  - ➡**1 MHz scatter for 704 MHz** SPL cavities seems to be a reasonable value,

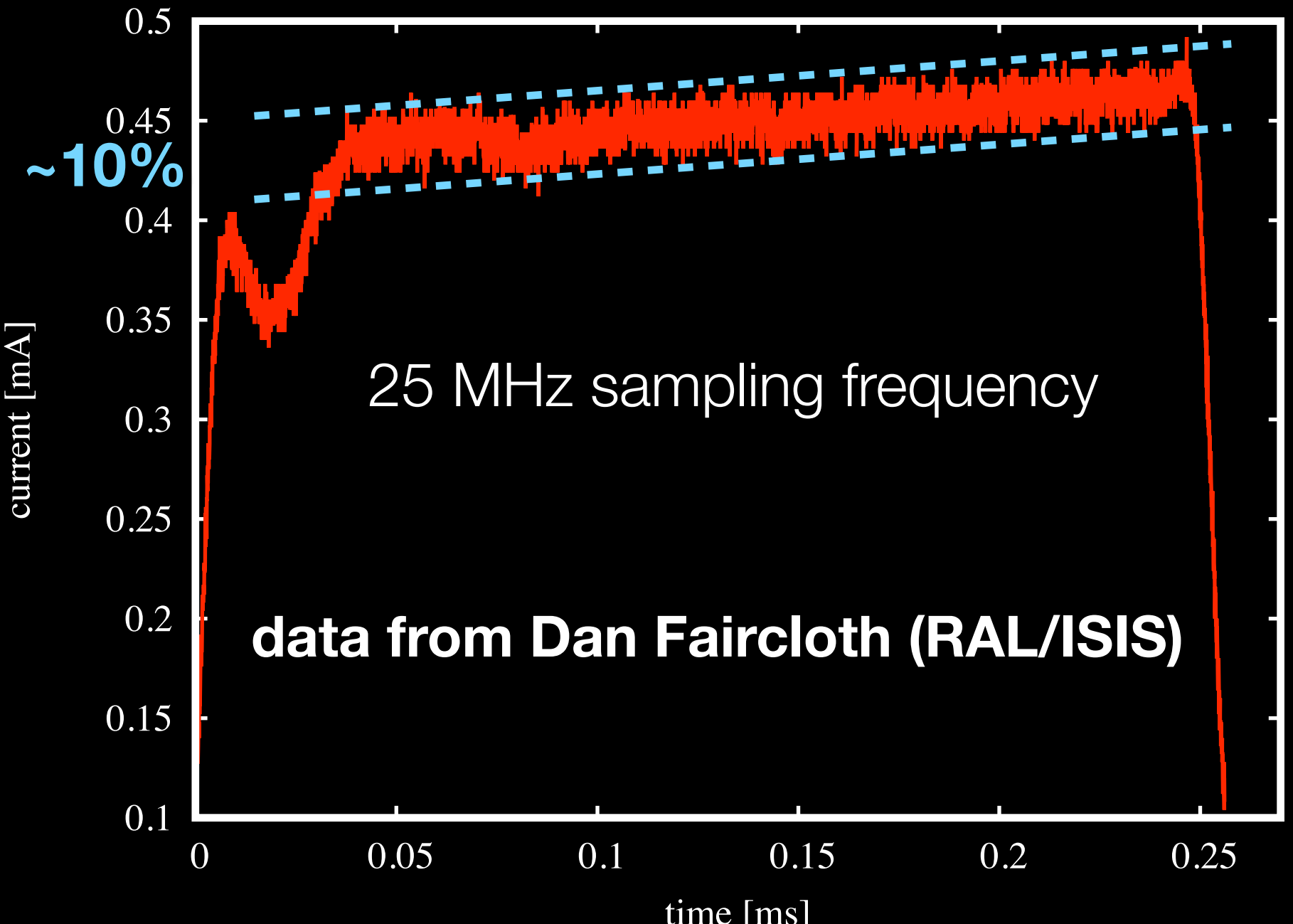
Bunch charge fluctuations

- **longitudinal plane:** bunch charge jitter drives HOM voltage build-up for frequencies outside of machine lines
  - ➡so far we have assumed 10% random variation (bunch to bunch),
  - ➡10% seems realistic (SNS, expectations for Linac4), but how random is the change?
  - ➡no-one has bunch to bunch measurements.
- **transverse plane:** HOM voltage build-up outside of machine lines is driven by the changing amplitudes (transverse position of bunches),
  - ➡bunch charge jitter does not seem to change the picture (see talk of M. Schuh),

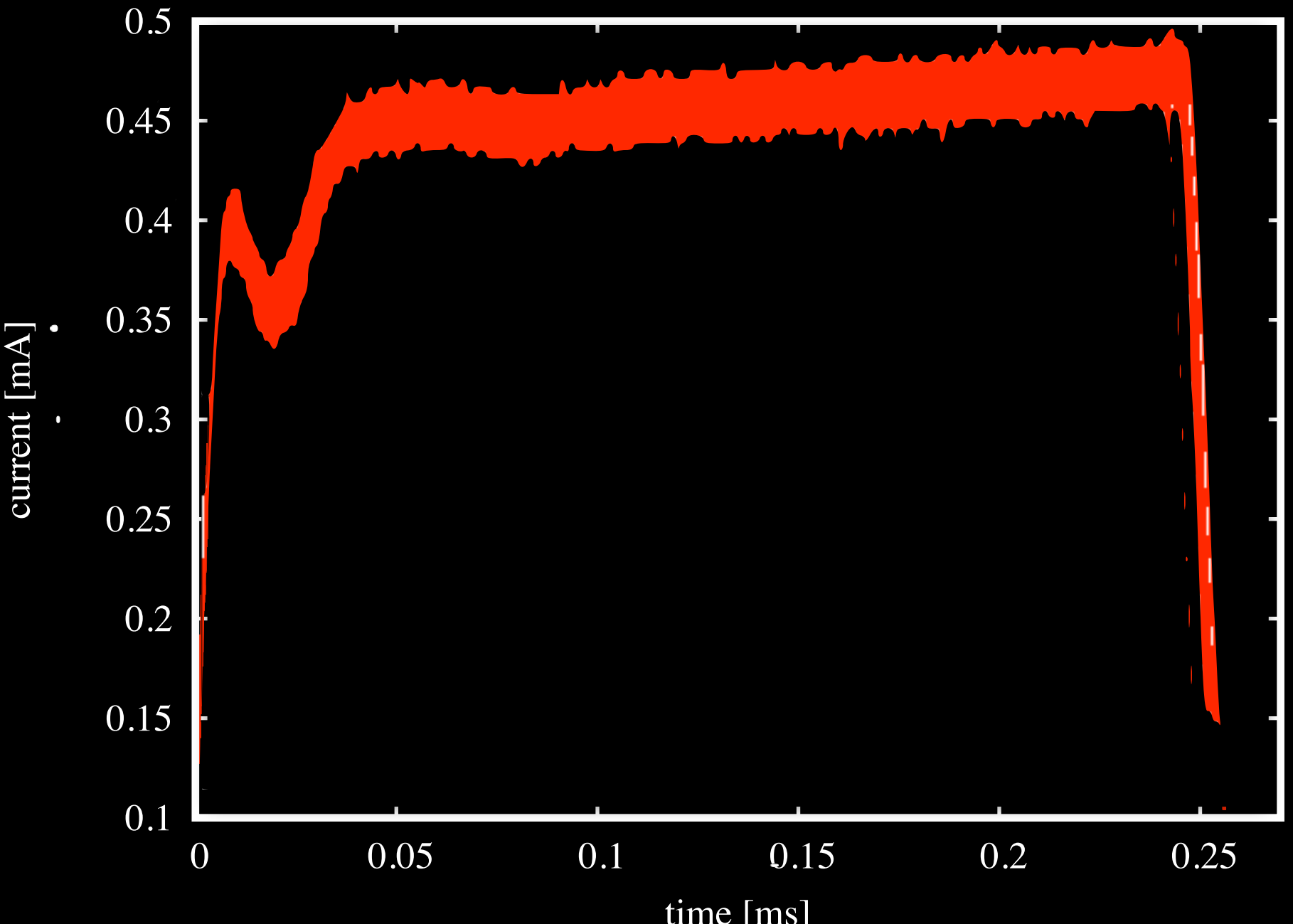
ISIS H- source test stand



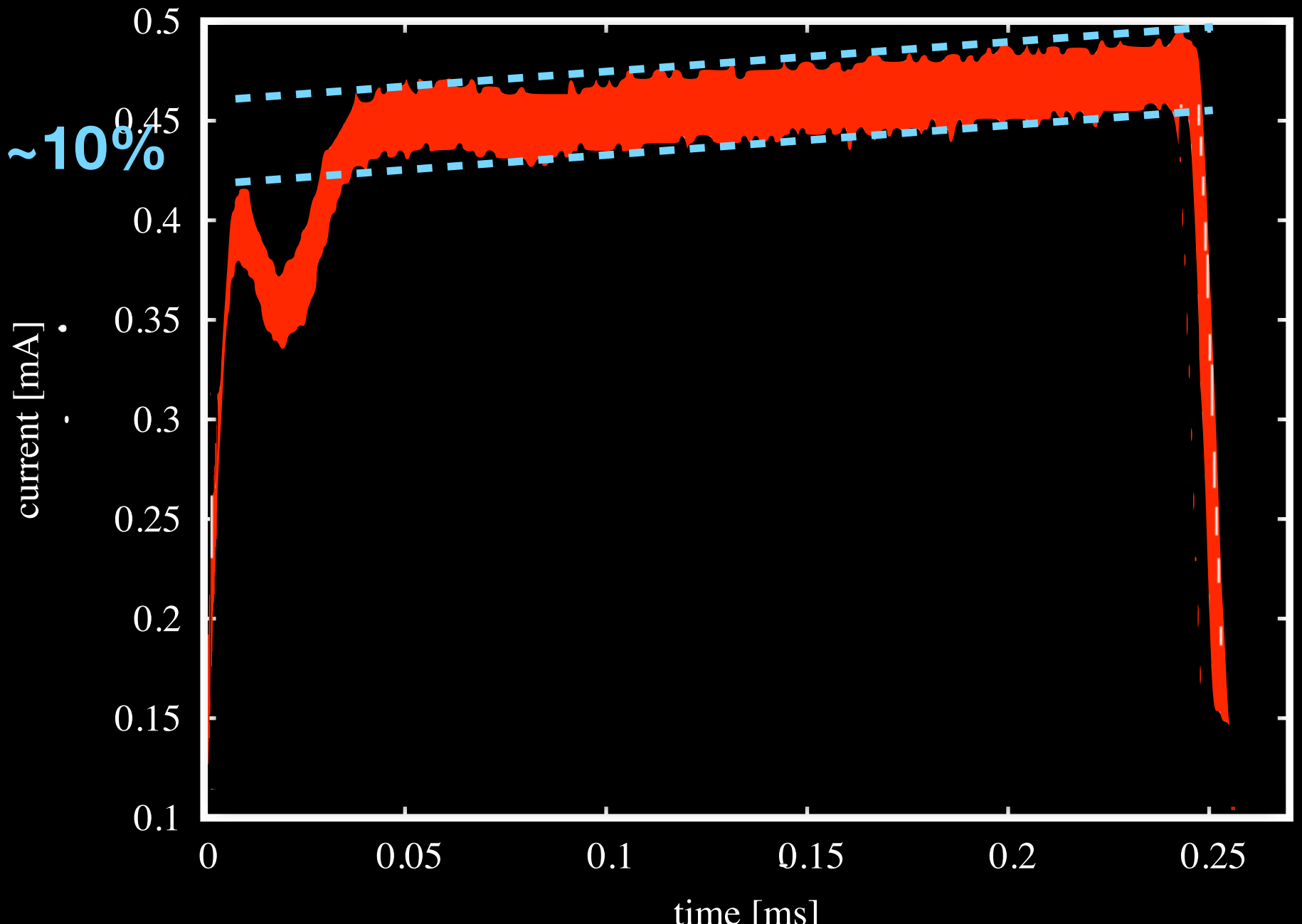
ISIS H- source test stand



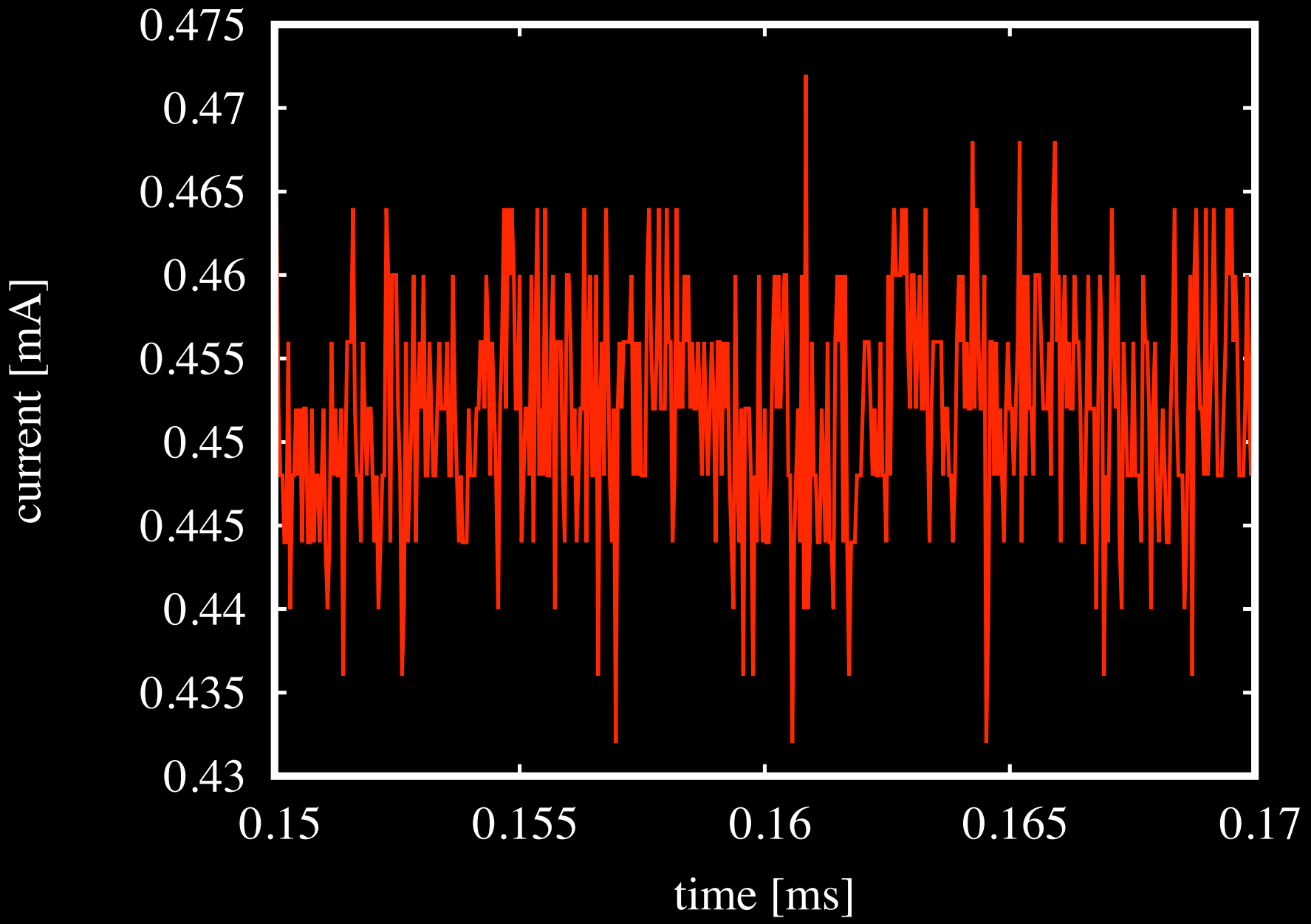
5 pulses


0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
current [mA]
0
0.05
0.1
0.15
0.2
0.25
time [ms]

5 pulses


~10%
current [mA]
time [ms]
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0
0.05
0.1
0.15
0.2
0.25

ISIS H- source test stand



bunch charge fluctuations

- **ISIS measurements** indicate that the fluctuations take place with a high frequency (MHz range),
  - ➡10% in amplitude is confirmed,
  - ➡assumption of random fluctuation seems realistic, though the measurement data will be analysed in more detail (~1000 data sets are available),
  - ➡**more data from different source types needed!!**

Conclusions

- HOM characteristics for SPL cavities are available but subject to change when beam pipe apertures, irises, etc are defined,
- safety factor of 10 for (R/Q)*Q (or the current) seems justified because of (R/Q)*Q changes during the cavity tuning
- bunch charge fluctuations need more experimental data, for now the assumption of a random 10% variation (bunch to bunch) seems not too bad.