update on SPS impedance localization

two outstanding actions
(APC 26/05/2005, reminder GA 29.01.06):

- the available information on the transverse impedance from rf cavities (or others?) should be included in the model
- explore possibility that the impedance source in Sextant 5 is compatible with a localized source in 517 (instrumentation - IPM in particular)

(1) include rf ‘broadband’ impedance?

rf impedance - knowledge

meeting with Elena Shaposhnikova on 02.02.2006, providing two papers:

T. Bohl/U. Wehrle, ‘RF Installations in the SPS’ updated 2006-01-25

T.P.R. Linnecar, E.N. Shaposhnikova, ‘Resonant Impedances in the SPS,’ SL-Note 96-49 RF

TW 200 MHz, fr=938.5 MHz (V), R/Q=16.4 Ω, Q=1500, Ztotal=2.49 MΩ/m, 4 cavities, at locations 2832.32 m,2866.35 m, 2897.95 m, 2928.62 m

TW 800 MHz, fr=1146 MHz, R/Q=335 Ω, Q=1000, Ztotal=4.0 MΩ/m, 2 cavities at locations 2843.80 m, 2854.87 m

Form of the transverse resonator impedance:

RF Group seems to use following formula for the transverse broadband impedance:

$$Z_\perp = \frac{\omega}{c} \frac{R_s}{1 + iQ\left(\frac{\omega_R}{\omega} - \frac{\omega}{\omega_R}\right)}$$

where R_s is in units of Ω

Alex Chao's textbook:

$$Z_\perp = \frac{\omega_R}{\omega} \frac{Z_t}{1 + iQ\left(\frac{\omega_R}{\omega} - \frac{\omega}{\omega_R}\right)} = \frac{c}{\omega} \frac{R_s}{1 + iQ\left(\frac{\omega_R}{\omega} - \frac{\omega}{\omega_R}\right)}$$

where R_s is in units of Ω/m^2

SL Note 96-49 RF:

$$Z_\perp = \frac{R_1}{Q} Q \frac{L}{4} \frac{2\pi f_{rf}}{c}$$

travelling wave cavity

$$Z_\perp = \frac{R_\perp}{Q} Q \frac{2\pi f_{rf}}{c}$$

standing wave cavity

if I use these last relations which is the functional form of the impedance?

tentatively I now take transverse impedance Z_t from SL note, but then I identify it with Z_t in the expression derived from Alex' textbook, and employ this latter formula for computing an effective impedance

doing so I obtain:

Z_{eff} ~ -i 1685 Ω/m for 200-MHz system
Z_{eff} ~ -i 4040 Ω/m for 800-MHz system

these numbers are much smaller than total SPS transverse system Z_{eff} ~ -i 20 MΩ/m

lowest mode is not sufficient to estimate effective impedance for a single bunch

summary rf impedance

two problems:

(1) do not have any reasonable estimate for the broadband impedance, only data for 1 HOM

(2) formula for transverse HOMs does not seem to comply with standard theory (Chao, Ruggiero,…)

I cannot pursue this action further until these problems are resolved

(2) repeat previous analysis using different weights etc., in particular w.r.t. impedance of sector 5

normalize data differently to allow for direct comparison with result of coherent tune shift measurement

current-dependent quadrupole strength is converted into effective impedance:

$$\frac{1}{\sqrt{\pi}}\frac{\sigma_z}{c}\int_{-\infty}^{\infty}\mathrm{Im}\, Z_{\perp}(\omega)\exp\left(-\frac{\omega^2\sigma_z^2}{c^2}\right)d\omega = -\frac{\beta}{\langle\beta\rangle}\frac{2\pi\gamma}{r_p}\frac{Z_0 c}{4\pi}\left[\frac{\Delta K}{\Delta N}\right]\frac{1}{\sqrt{\pi}}\frac{\sigma_z}{c}$$

||

$$\mathrm{Im}\, Z_{\perp,eff} \approx 3.2\times 10^{20}\,\Omega\frac{\Delta K}{\Delta N}$$

for 14 GeV/c & σ_z=0.3 m

potential impedance locations:

MKQ: 1165-1167
MKD: 1173-1175
MKP: 11931-11955
MKE: 41631-41654
RF: 31637-31934
IPM: 4169?
instrumentation: 517
…

all quadrupoles

initial weight=1, SVD cutoff=5, λ=10

fit quality: $((\Delta\phi/\Delta N)_{fit} - (\Delta\phi/\Delta N)_{meas})_{r,s} = 0.00234\ (2\pi/10^{11})$

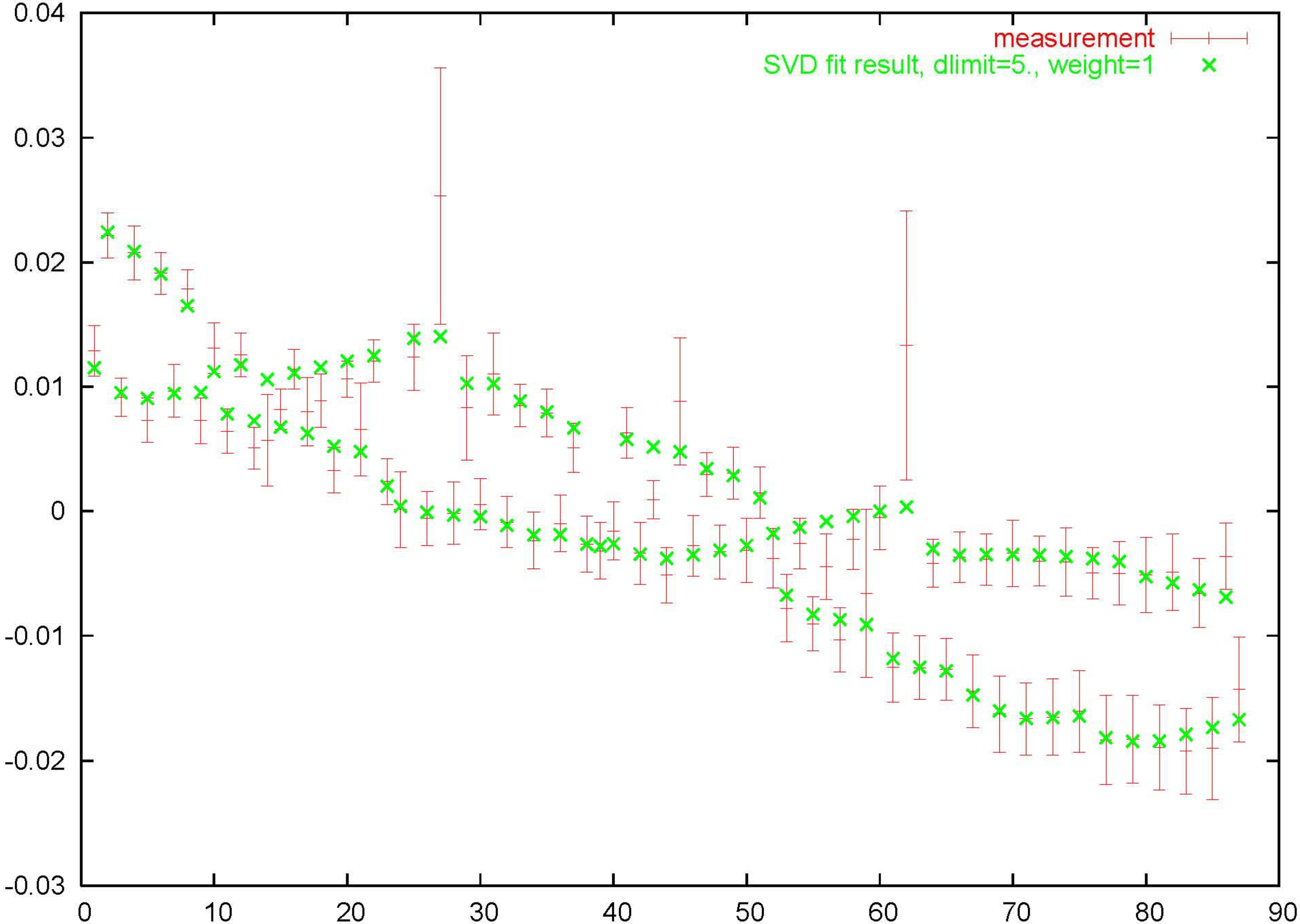
rms impedance strength: 4.86×10^{-5} [$m^{-1}/10^{11}$]

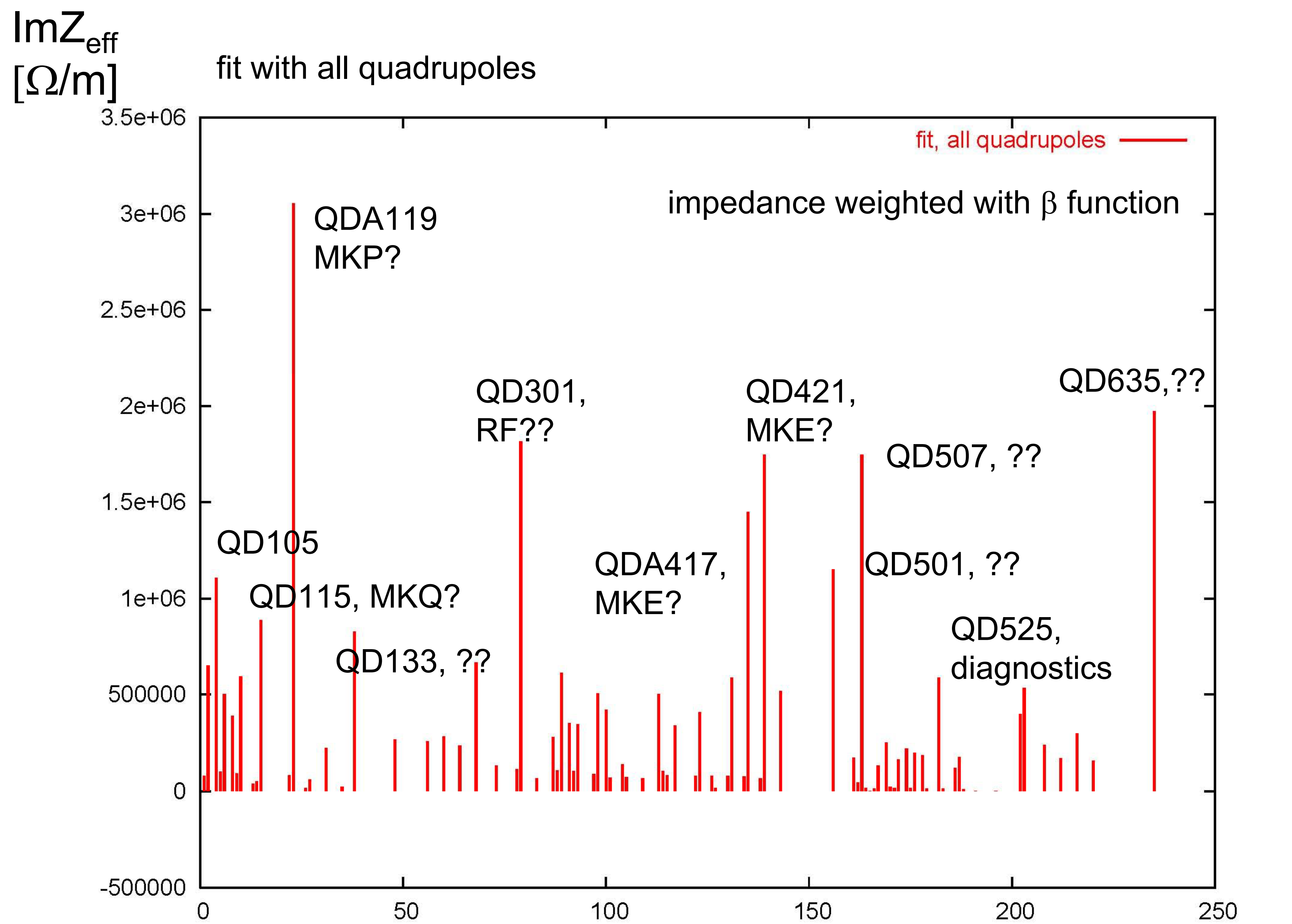
total impedance $\Sigma\ \beta/\langle\beta\rangle$ Im (Z) = 30.9 MΩ/m

QDA11910	3.05 MΩ/m
QD63510	1.97 MΩ/m
QD30110	1.82 MΩ/m
QD42110	1.75 MΩ/m
QD50710	1.75 MΩ/m
QDA41710	1.45 MΩ/m
QD50110	1.15 MΩ/m
QD10510	1.11 MΩ/m
QD11510	0.89 MΩ/m
QD13310	0.83 MΩ/m

…

fit with all quadrupoles




ImZ$_{eff}$
[Ω/m]
fit with all quadrupoles
fit, all quadrupoles
impedance weighted with β function
QDA119
MKP?
QD301,
RF??
QD421,
MKE?
QD635,??
QD507, ??
QD105
QDA417,
MKE?
QD501, ??
QD115, MKQ?
QD525,
diagnostics
QD133, ??
3.5e+06
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
-500000
0
50
100
150
200
250

without 11 quadrupoles

(w/o QD301, QF300, QD305, QD309, QE302, QF308, QD313, QF304, QECD306, QD501, QD507), initial weight=1, SVD cutoff=5, λ=10

fit quality: $((\Delta\phi/\Delta N)_{fit}-(\Delta\phi/\Delta N)_{meas})_{r,s}=0.00255\ (2\pi/10^{11})$

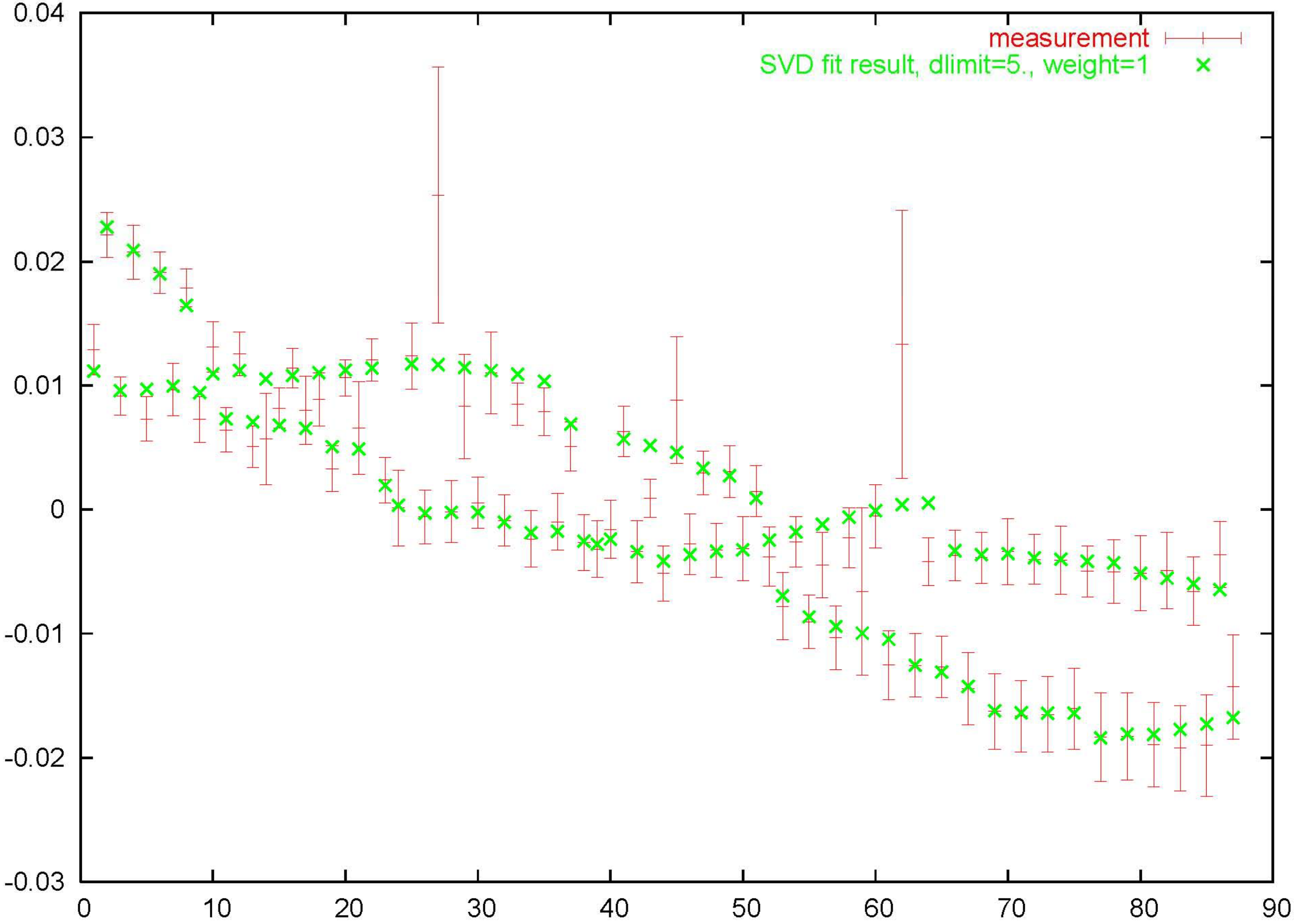
rms impedance strength: $4.63\times10^{-5}\ [m^{-1}/10^{11}]$

total impedance $\Sigma\ \beta/\langle\beta\rangle\ \mathrm{Im}(Z) = 29.5\ M\Omega/m$

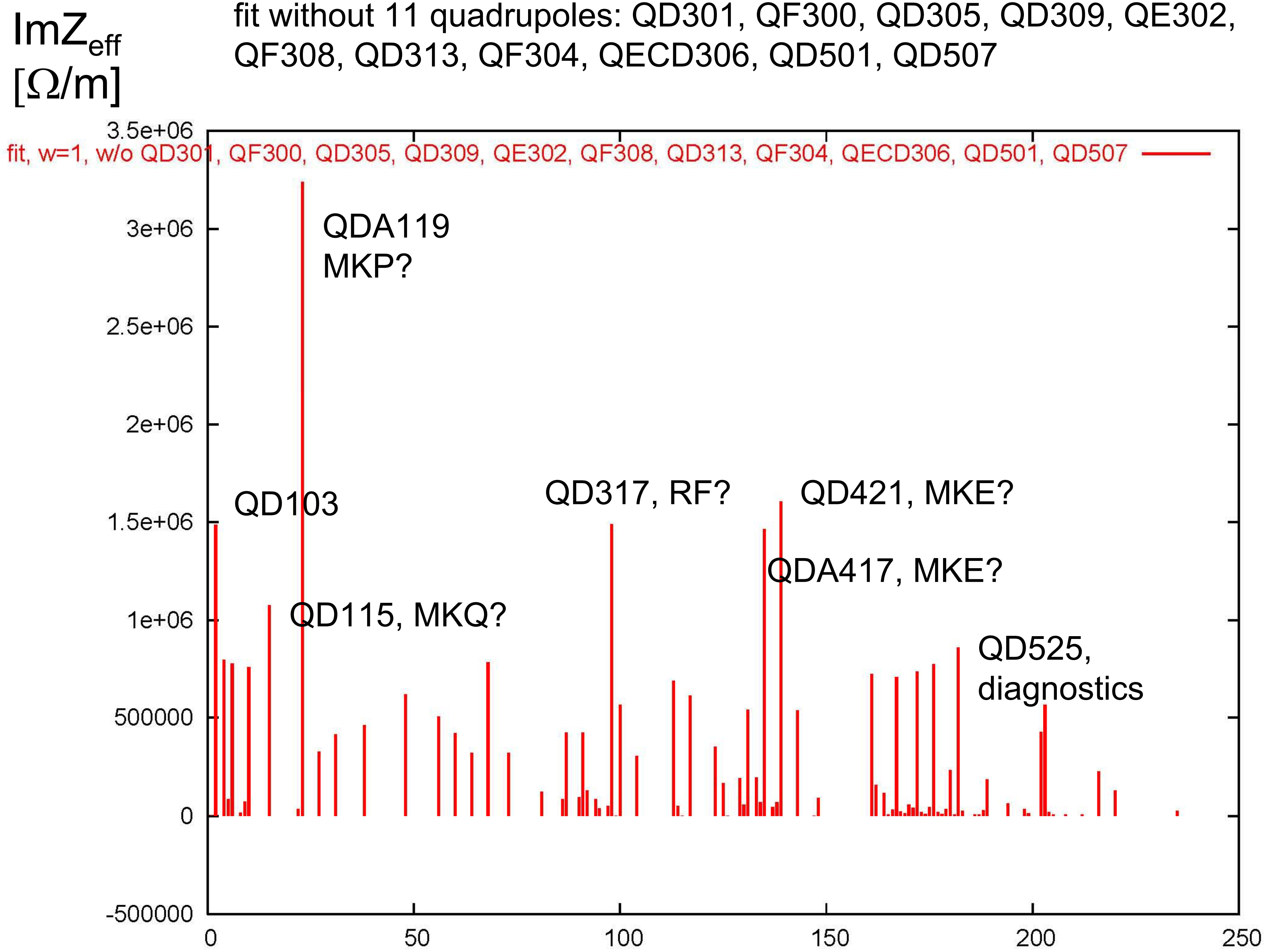
QDA11910	3.24 MΩ/m
QD42110	1.60 MΩ/m
QD31710	1.49 MΩ/m
QD10310	1.49 MΩ/m
QDA41710	1.46 MΩ/m
QD11510	1.08 MΩ/m
QD52510	0.86 MΩ/m

…

fit without 11 quadrupoles: QD301, QF300, QD305, QD309, QE302, QF308, QD313, QF304, QECD306, QD501, QD507



fit without 11 quadrupoles: QD301, QF300, QD305, QD309, QE302, QF308, QD313, QF304, QECD306, QD501, QD507



another fitting attempt

consider all ‘H/V kicker’ and ‘rf cavity’ elements as potential impedance sources instead of the quadrupoles; there are 308 such elements in the SPS MAD model

with kickers and rf cavities

initial weight=1, SVD cutoff=5, λ=10

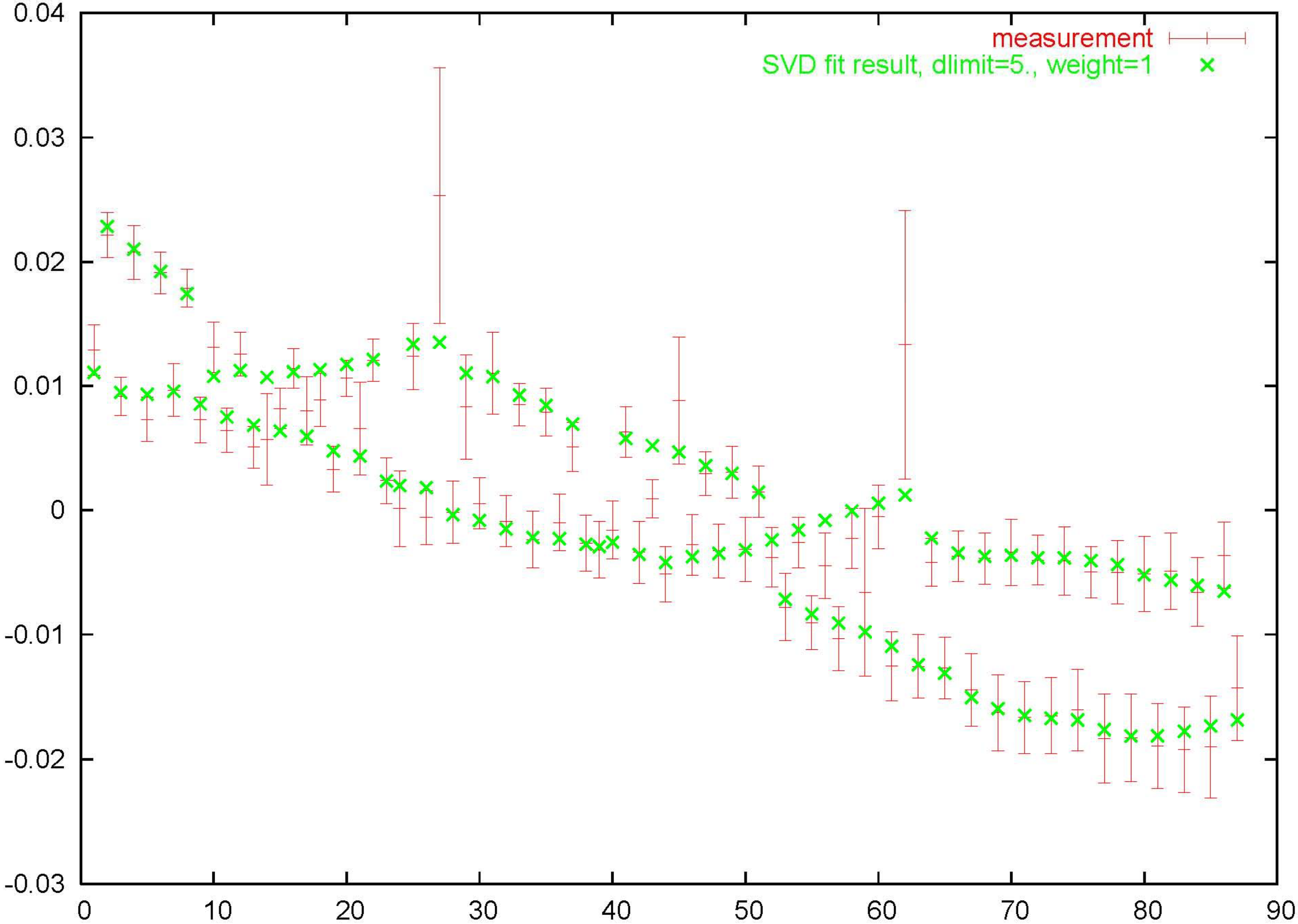
fit quality: $((\Delta\phi/\Delta N)_{\mathrm{fit}}-(\Delta\phi/\Delta N)_{\mathrm{meas}})_{r,s}=0.00236\ (2\pi/10^{11})$

rms impedance strength: 3.95×10^{-5} [$m^{-1}/10^{11}$]

total impedance $\Sigma\ \beta/\langle\beta\rangle$ Im (Z) = 29.4 MΩ/m

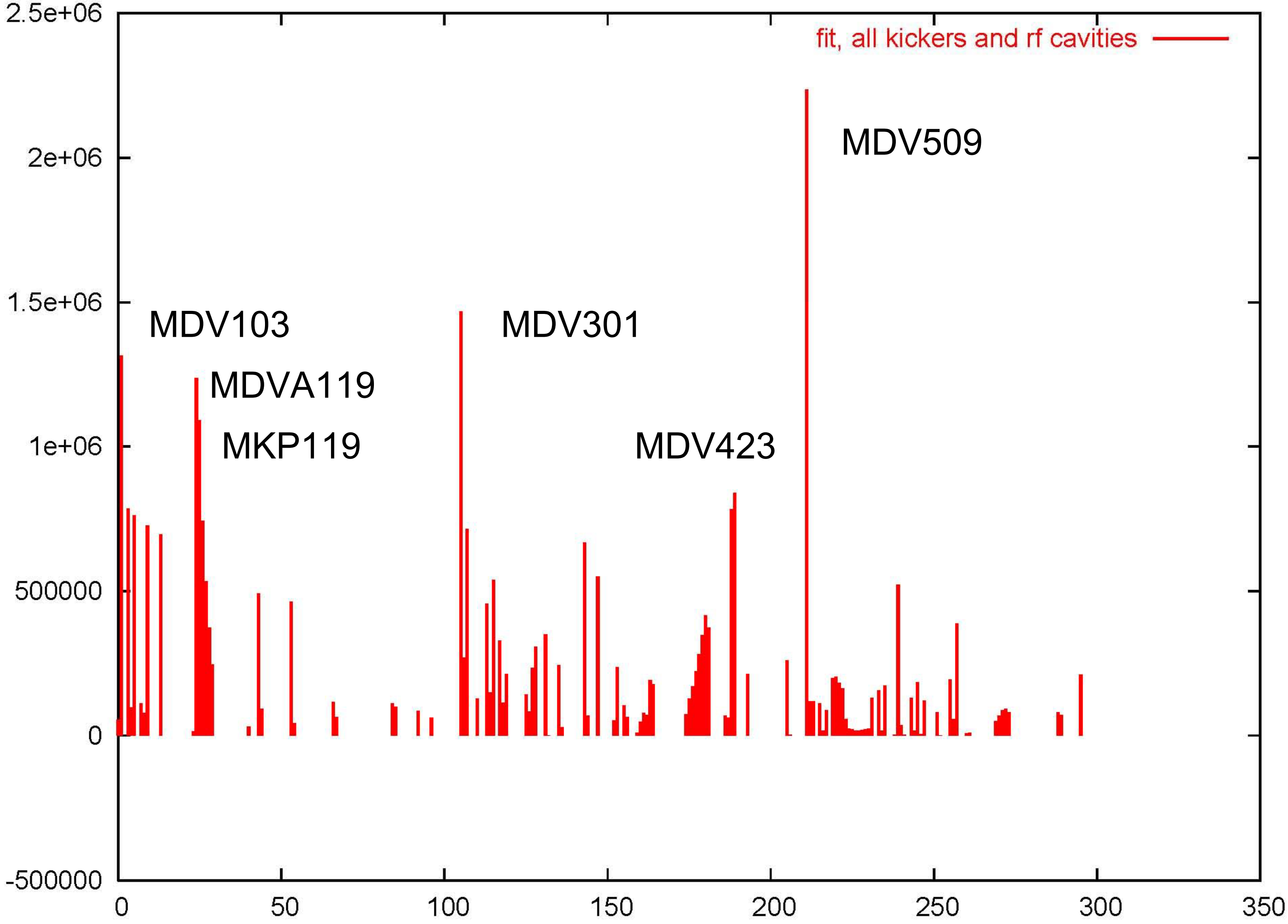
MDV50907	2.24 MΩ/m
MDV30107	1.47 MΩ/m
MDV10307	1.31 MΩ/m
MDVA11904	1.24 MΩ/m
MKP11931	1.09 MΩ/m
MDV42307	0.84 MΩ/m

fit with all kickers and rf cavities (no quadrupoles)



ImZ_{eff} [Ω/m]

fit with all kickers and rf cavities (no quadrupoles)



summary of new fitting studies

large impedances are consistently found at the following five locations (both when fitting to quadrupoles and to kickers/rf):

103-105

119 (MKP?)

301 (→317(RF?) w 9 quads suppressed)

417-423 (MKE?)

501-509 (disappears if quads 501&507 are removed from the fit)

accurate optics model is essential!