3rd Annual workshop: Physics at the Terascale
DESY, 12.11.2009
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Multi Bunch Feedback Systems for ELSA

- Collective beam instabilities
- Layout of feedback systems
- Feedback systems at ELSA

Electron bunches interact with the beam surroundings:

- cavities: higher order modes
- vacuum chamber: resistive wall
- other chamber discontinuities (BPMs,...)

Problem: short- and long-range wake fields remain and act back on the beam!

Consequence: coherent bunch oscillations

→ single and multi bunch instabilities

$$U_{\text{wake}}(\omega) = Z(\omega)\, I(\omega)$$

Intensity of electron beam

Impedance and beam spectrum of accelerator

If natural damping times are too long, multi bunch oscillations cause an enlargement of beam size and finally beam loss

Collective effects basically limit the brightness and the luminosity of accelerators

Counteraction: Feedback Systems

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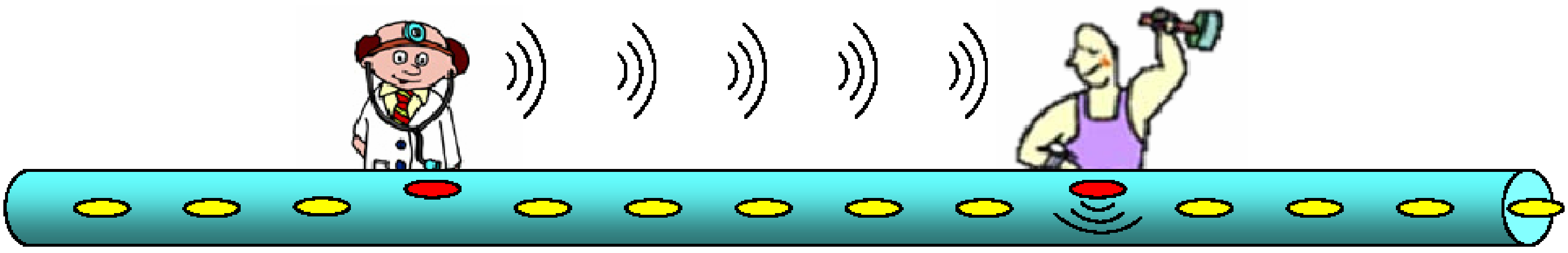
Bunch by bunch feedback systems

Active damping of multi bunch oscillations



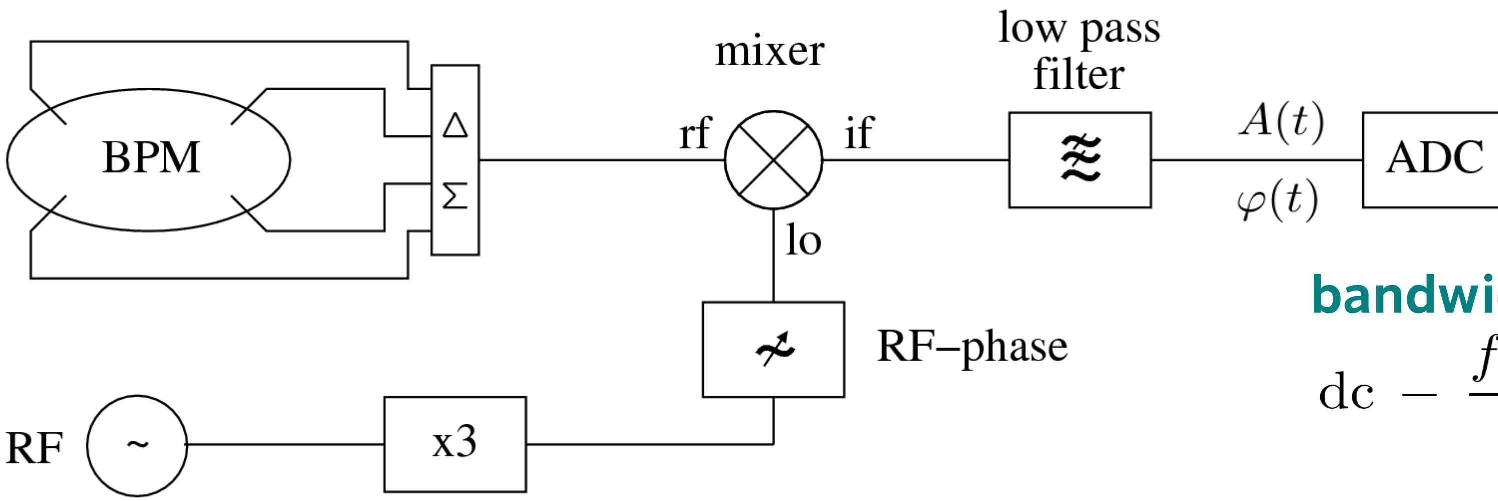
[M. Lonza]

1. Detection: broadband BMP signals

2. Signal processing: bunch by bunch filtering, digital

3. Correction: powerful damping of beam motion

1. Detection of bunch oscillations via BMP signals



bandwidth:

$$\mathrm{dc} - \frac{f_{\mathrm{RF}}}{2}$$

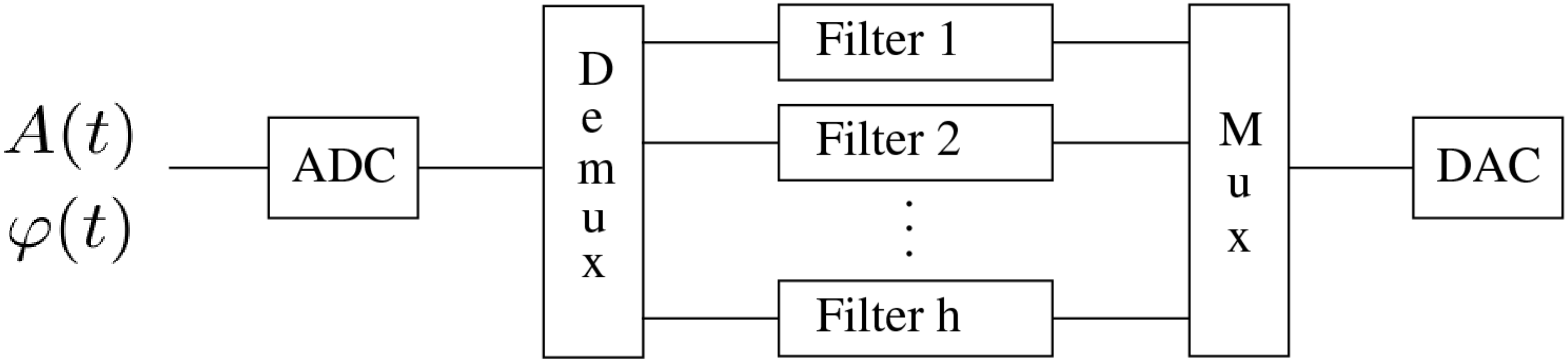
Betatron oscillation: amplitude demodulation of Δ-signal

$$A(t)\ \sin\left(3\,\omega_{\mathrm{RF}}\,t\right)\cdot\sin\left(3\,\omega_{\mathrm{RF}}\,t\right)\ \propto\ A(t)$$

Synchrotron oscillation: phase demodulation of Σ-signal

$$\sin\left(3\,\omega_{\mathrm{RF}}\,t\ +\ \varphi(t)\right)\cdot\sin\left(3\,\omega_{\mathrm{RF}}\,t\ +\ \pi/2\right)\ \propto\ \varphi(t)$$

2. Digital signal processing (DSP): FPGA based



- turn-by-turn measurement of each bunch (**h** = # bunches)

- design of **h** digital filter for each bunch

  a) band pass filter at tune frequency

  b) required for damping: phase shift of 90°

  because the correction signal must be proportional
  to the time derivative of the bunch oscillation!

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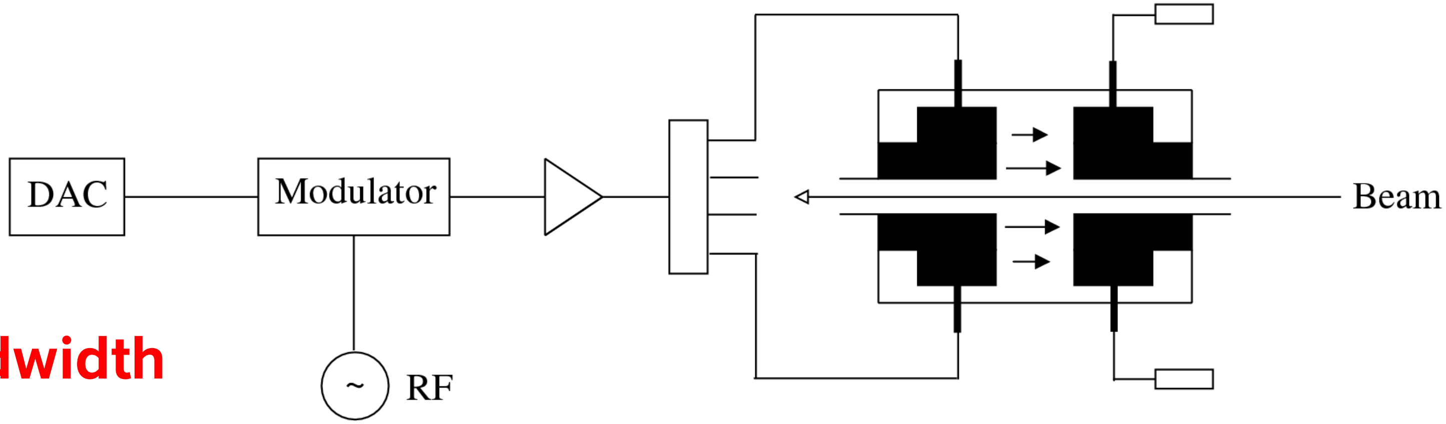
3. Application of correction signals by broadband kickers

longitudinal:

pill-box cavity

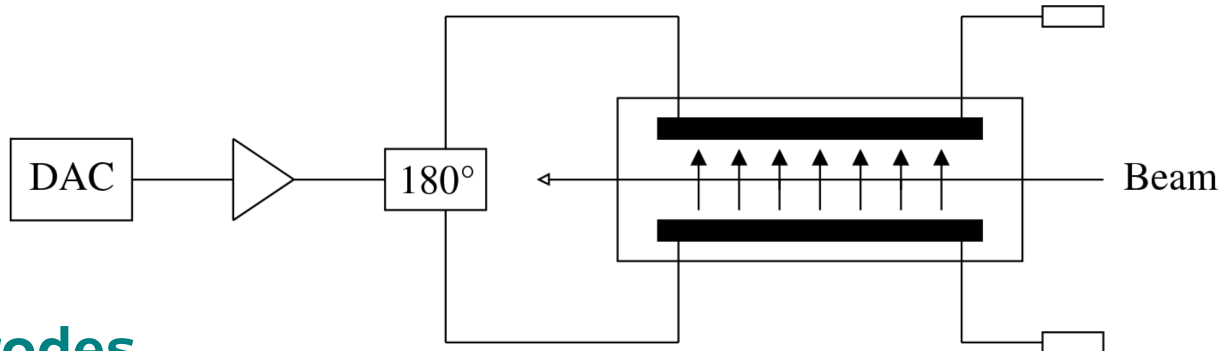
with f_{RF} / 2 bandwidth



transverse:

stripline-kicker

with 2 pairs of electrodes



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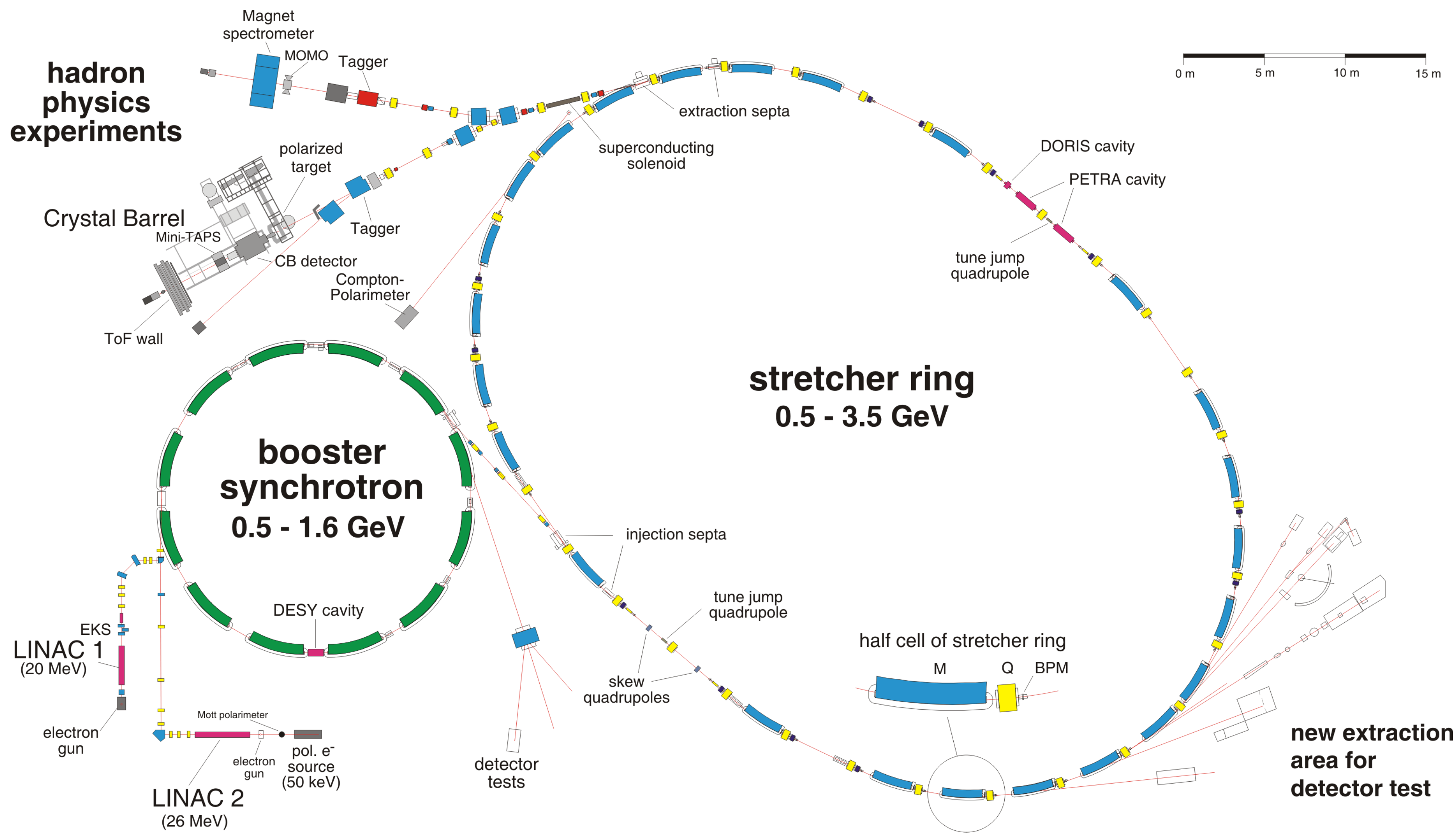
At ELSA: significant current upgrade: I_{Beam} = 100 - 200 mA



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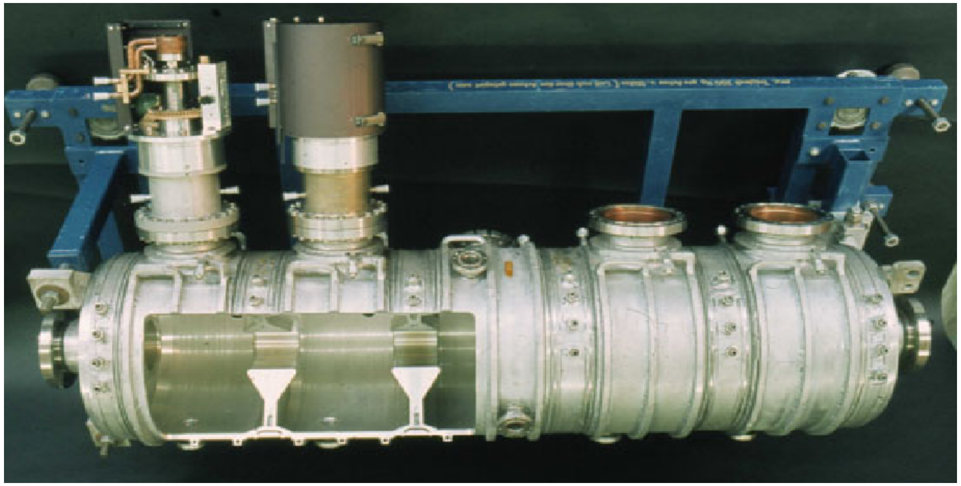
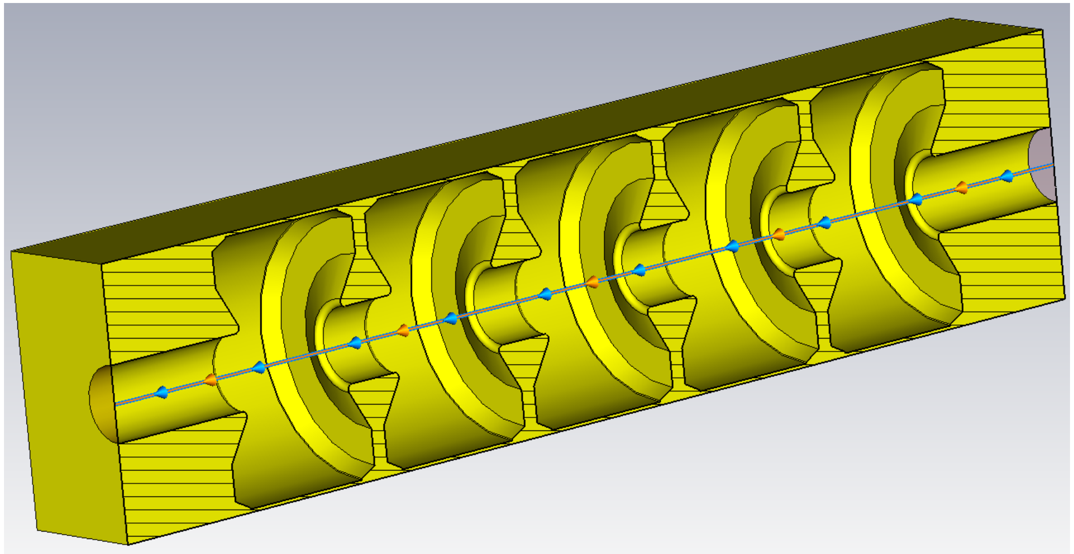
Main source of long range wakes and multibunch instabilities at ELSA:



➡ **HOMs of 2 Petra cavities without HOM damping**

Numerical simulations with CST microwave and particle studio (eigenmode & wake field solver)



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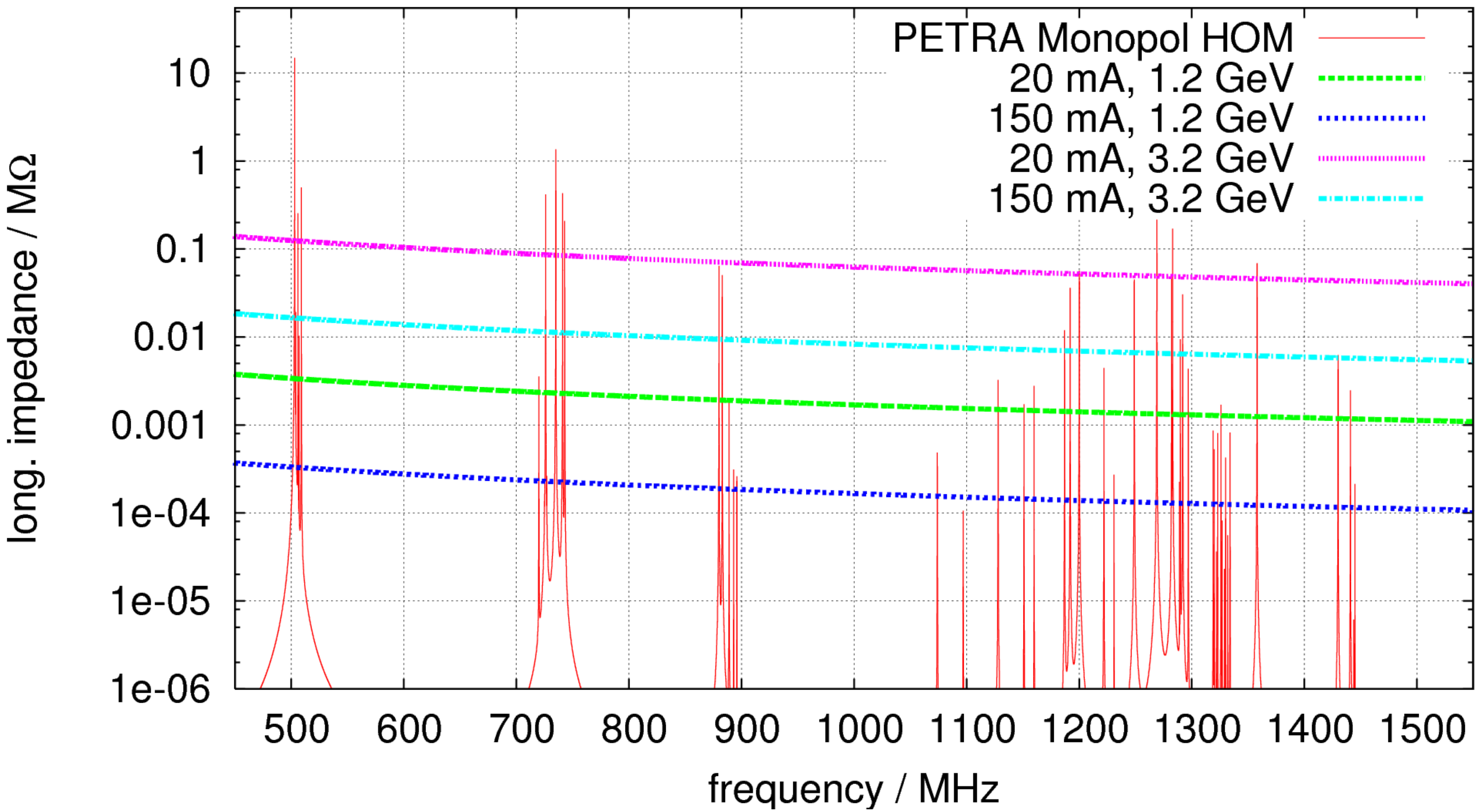
Impedances of HOMs are well above multi bunch instability thresholds due to radiation damping!

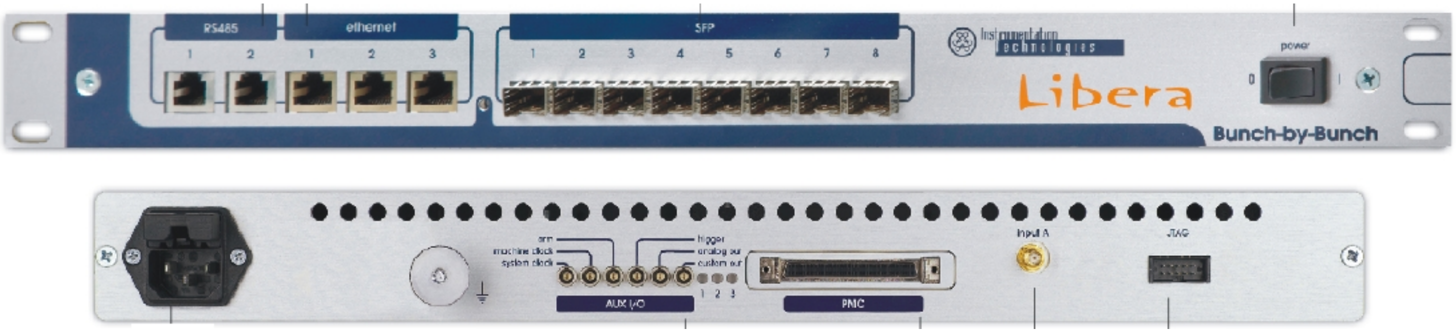
longitudinal situation:



Installation of longitudinal & transverse feedback systems at ELSA

1. DSP: "industrial" FPGA solutions are available

ITech/Libera (Slovenia)



Dimtel (USA)

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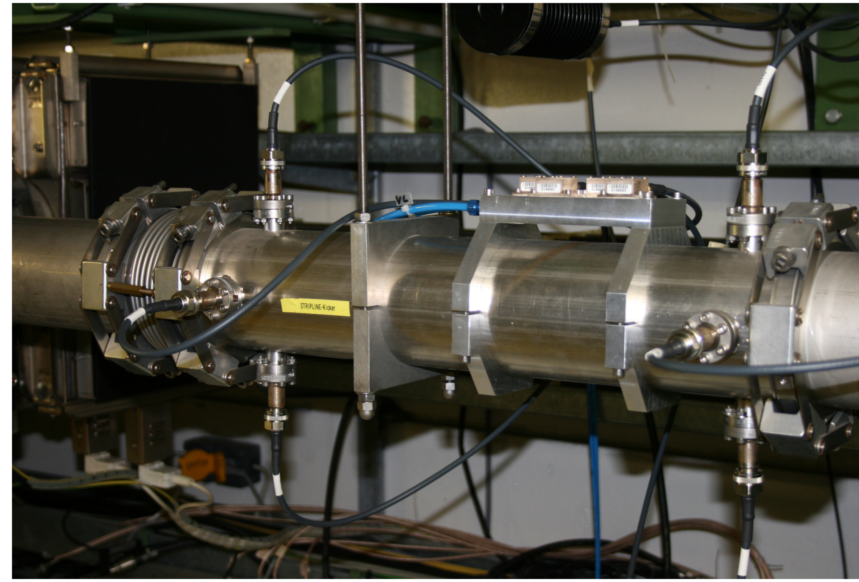
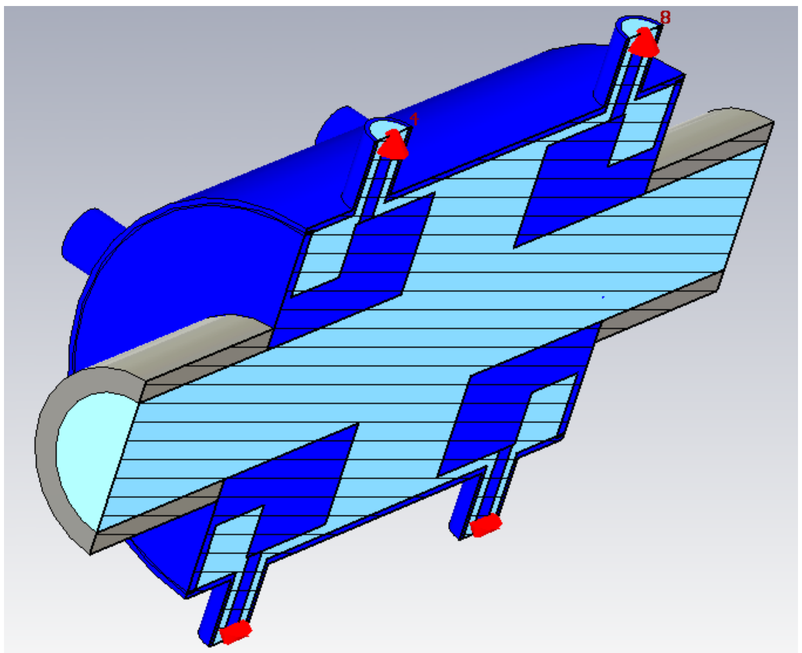
2. Kickers: still existing / in development

horizontal & vertical stripline kicker



broadband longitudinal kicker cavity:



- based on DAΦNE, BESSY & DESY designs
- pill box cavity with low Q: 5.5
- center frequency: 1375 MHz

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3. Further plans of R&D at ELSA

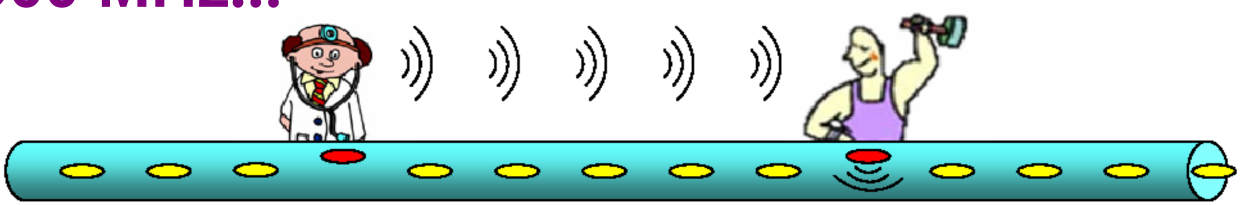
- Which feedback damping times are necessary and achievable for up to 200 mA at 1.2 GeV in ELSA?
- Fast energy ramp (1.2 to 2.4 GeV in 0.3 s!): synchronous phase of bunches will change!
- Beam diagnostics: Fast tune measurements during ramp
- Single bunch mode is essential: Investigations of instabilities & required for feedback timing

Conclusion

- Bunch by bunch feedback systems are essential for modern accelerators to fight against collective beam instabilities

- Feedback systems are also very powerful tools for beam diagnostics at accelerators

- The installation of feedback systems should start at ELSA in 2010 and we are happy to beat the beam with 500 MHz...



[M. Lonza]

Thank you for your attention!

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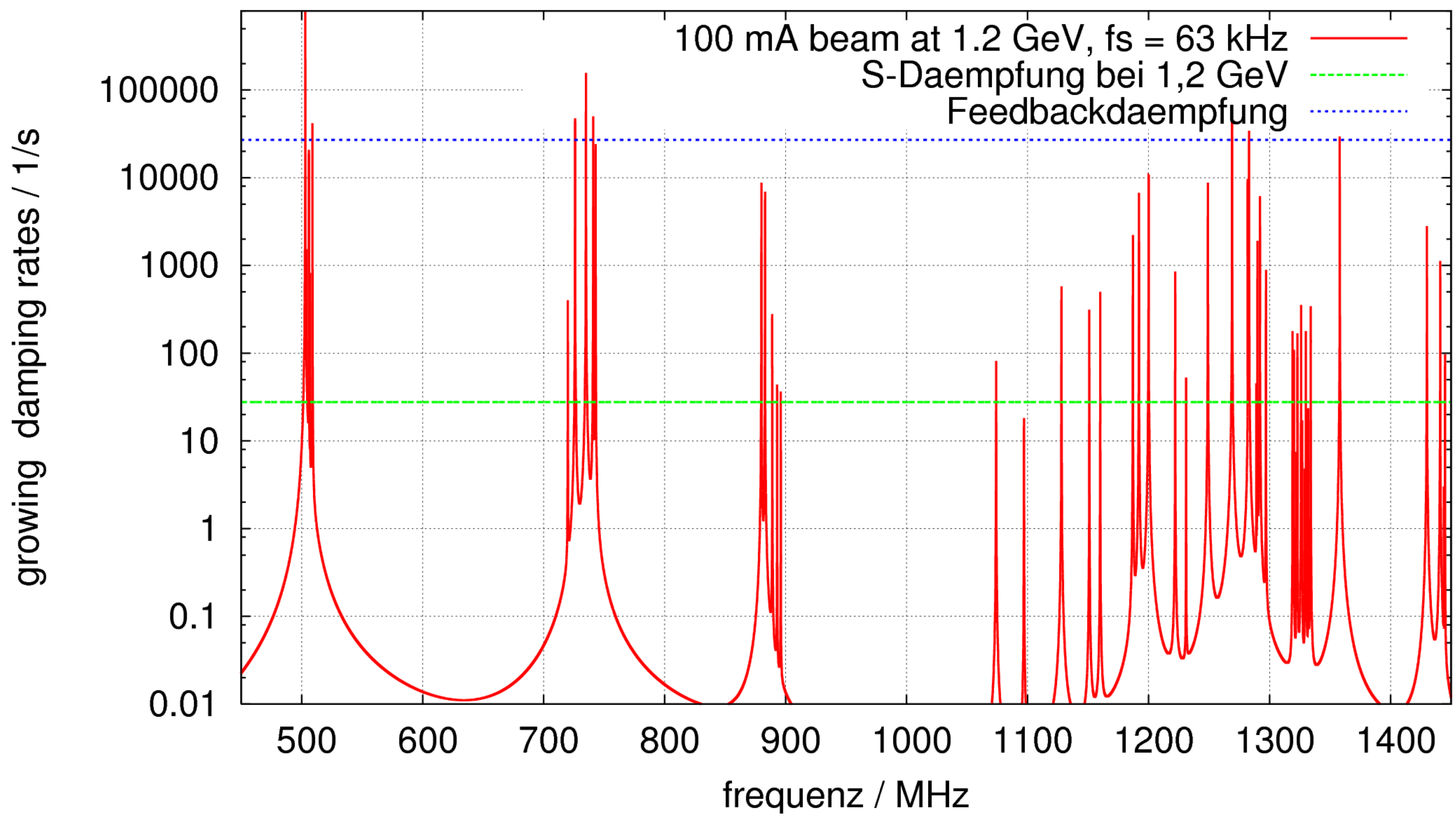
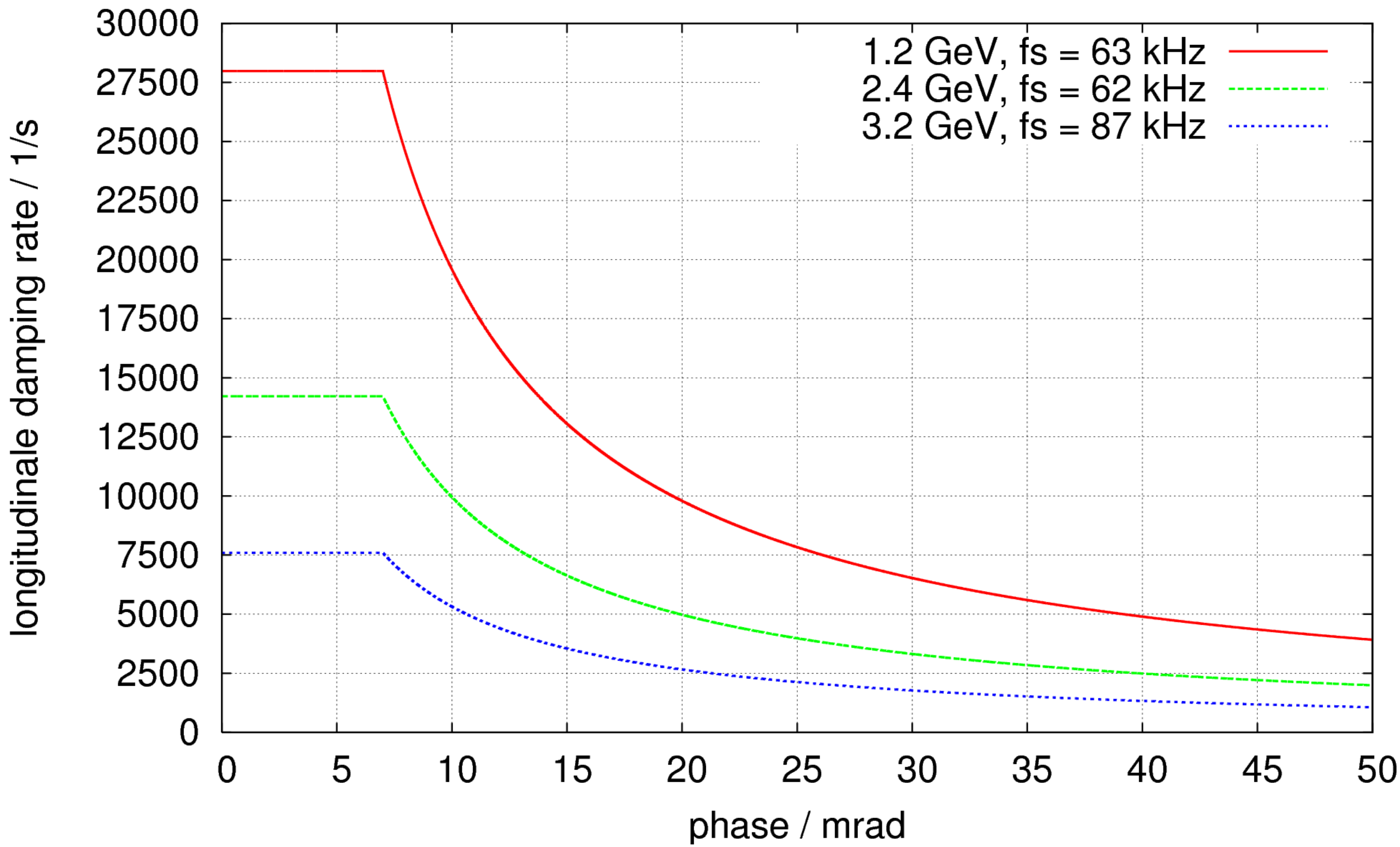


100 mA beam at 1.2 GeV, fs = 63 kHz
S-Daempfung bei 1,2 GeV
Feedbackdaempfung
growing damping rates / 1/s
100000
10000
1000
100
10
1
0.1
0.01
500
600
700
800
900
1000
1100
1200
1300
1400
frequenz / MHz


1.2 GeV, fs = 63 kHz
2.4 GeV, fs = 62 kHz
3.2 GeV, fs = 87 kHz
longitudinale damping rate / 1/s
phase / mrad
30000
27500
25000
22500
20000
17500
15000
12500
10000
7500
5000
2500
0
0
5
10
15
20
25
30
35
40
45
50

Thresholds for long. instabilities

$$\tau_{\mathrm{inst}} < \tau_{\mathrm{rad}}$$

exponential growing of coupled bunch oscillations !

$$\tau_{\mathrm{inst}} = \frac{2\,Q_{\mathrm{S}}\;E/\mathrm{e}}{\alpha_{\mathrm{C}}}\;\frac{1}{f_{\mathrm{CBM}}\;I\;R_{\mathrm{S}}}$$

ELSA parameter list	
Energy range	1.2 - 3.5 GeV
f_{Rev}	1.8236 MHz
Bunches	274
PETRA-cavities	2
α_{C}	0.063
τ_{rad} @ 1.2 GeV	36 ms
τ_{rad} @ 3.2 GeV	2 ms