The Bonn
Electron-Stretcher Accelerator

Status D2

Acceleration of polarized electrons in a medium size stretcher ring up to 5 GeV

Wolfgang Hillert

Physics Institute of Bonn University

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1. Accelerator Status
2. Polarized Electrons @ 3.5 GeV

1. Energy Upgrade to 5 GeV
2. Topics for future Funding

Elektronen Stretcher Anlage ELSA

Wissenschaftliche und technische Leitung: W. Hillert

Physikalisches Institut

Wissenschaftliche Mitarbeiter:

W. v. Drachenfels — F. Frommberger — C. Nietzel

Betriebsingenieur: F.-G. Engelmann

Hochfrequenz	Elektro-Energietechnik	Elektronik	Mechanik	Vakuum	Technische Infrastruktur
W. Kriesten	K.-P. Faßbender	H. Bücking	T. Alscheid	J. Karthaus	T. Becker
	M. Holzhäuser	A. Dieckmann	B. Neff	N. Rick	W. Merfert
	P. Mahlberg	M. Humpert	M. Brock		R. Schulz
	H. Schug	W. Lindenberg			Aytekin Yildiz
	J. Schneider	R. Müller			

Doktoranden: A. Balling, M. Eberhardt, F. Klarner, T. Pusch, J. Wittschen

Diplomanden: S. Aderhold, A. Aqrawi, S. Band, O. Preisner, A. Roth

Relationship with the SFB/TR

- **ELSA** is the "**workhorse**" for all planned hadron physics experiments
- **Polarized electrons @ 3.2 GeV required** for proposals 2, 4, 6 and 7 (4 out of 7!)
- **ELSA design energy (3.5 GeV)** needed in near future (**polarized/unpolarized**)
- **Increase** of maximum electron energy to $E \geq 5$ **GeV** is "**highly desirable**"

Infrastructure Improvement

- new **10kV power station**
- new **cooling plants** and **heat exchangers**
- new **cooling circuits** synchrotron (magnets + RF)
- **temperature stabilization** ELSA tunnel ±0.5°C
- new SPS-based **slow control of infrastructure**
- new SPS-based **radiation security system**
- new ODL system

…and in near future:

- **control room renovated** with TLC.

Accelerator Improvement

- cooling upgrade of **dipole PS for 3.5 GeV**
- pulsed PS's for **septum 3 and septum MSI 30**
- 30 new water cooled **BPM stations**
- improved (fast) **read-out of ELSA BPM's**
- 32 **ion clearing electrodes**
- amplitude **stabilized accelerator RF**

…and in near future:

- new pulsed **PS for Ti:Sa-laser** (polarized source)
- state of the art **capacitor charger** for LINAC II
- general **overhaul LINAC I** with new pulsed gun

Experimental Area

- **concrete pillars** for rail system detectors and PT
- set-up of **bending magnets** and **beam dump**
- **surveying and adjustment** to ±0.2mm
- set-up of **electron and photon beamline**
- **new slow control** for external beamline vacuum
- **new diagnostics** (RF cavity, SR & γ cameras)
- **field map measurement** of tagger magnet

…and in nearest future:

- **external polarized beam** with low background

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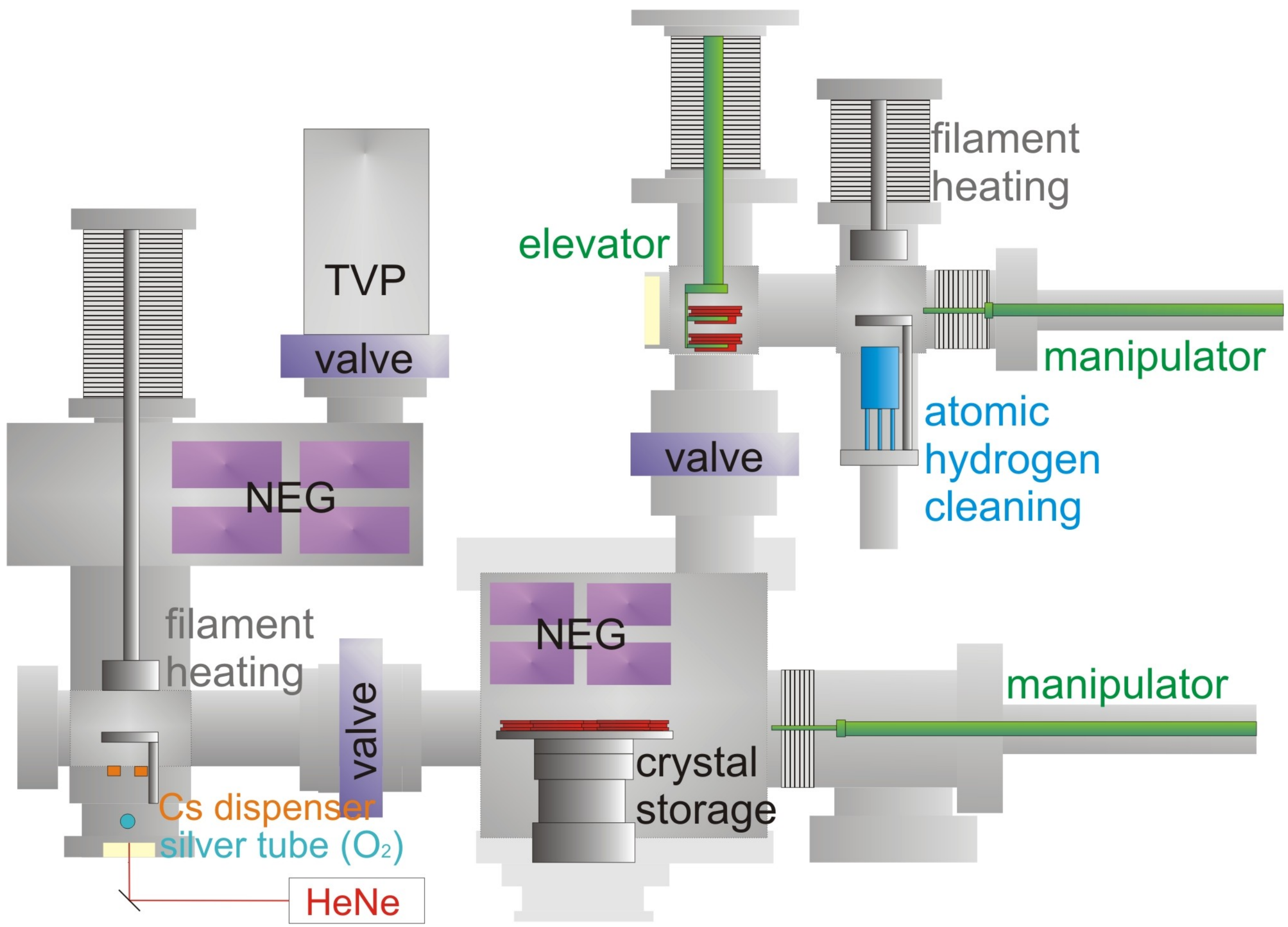
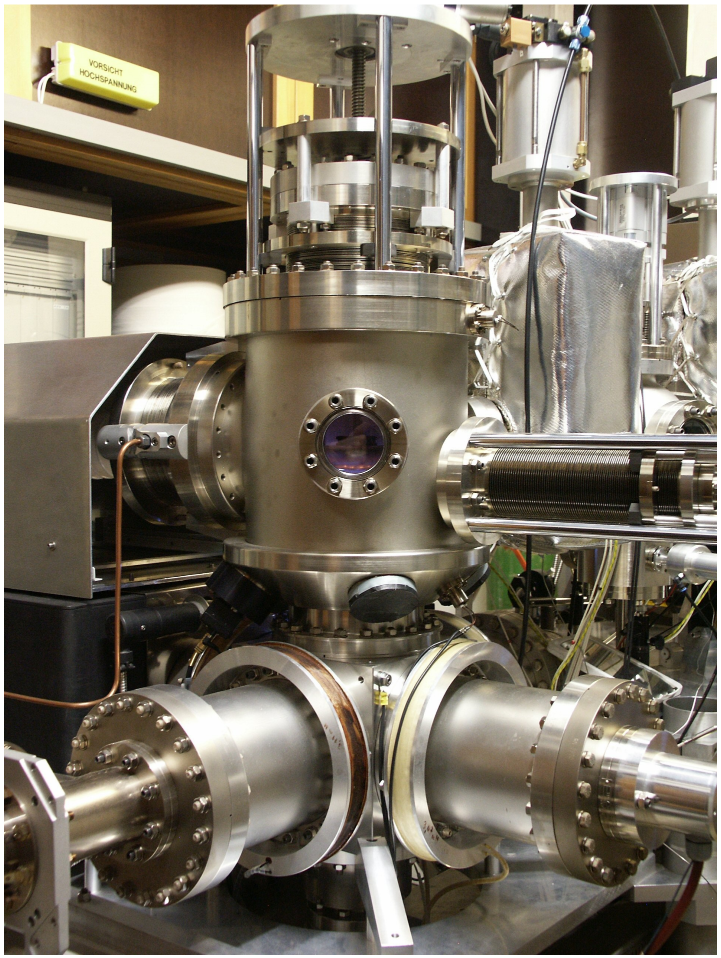
7. Development of **correction schemes** for a fast crossing of **depolarizing resonances** up to 5 GeV

Source of Polarized Electrons



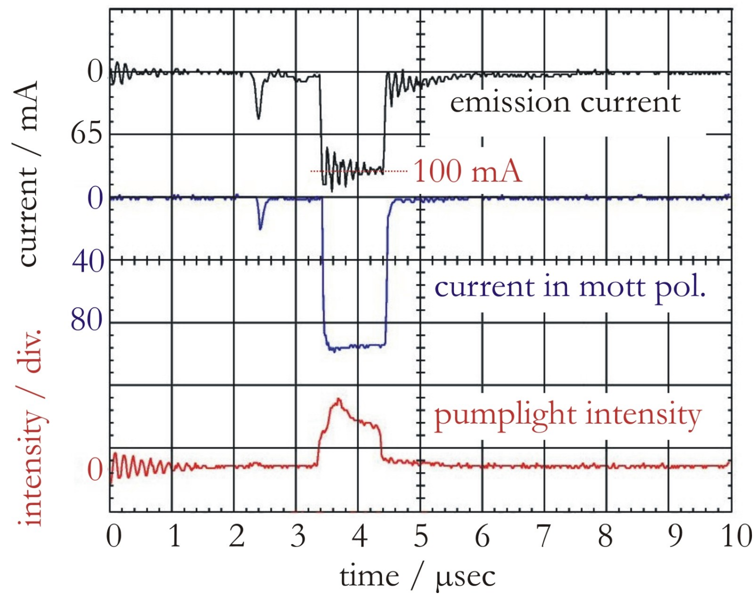
Set up of new loadlock will start beginning of next year

Source of Polarized Electrons



new photocathode loaded:

Be-InGaAs/Be-AlGaAs strained layer superlattice (Nagoya 1998)

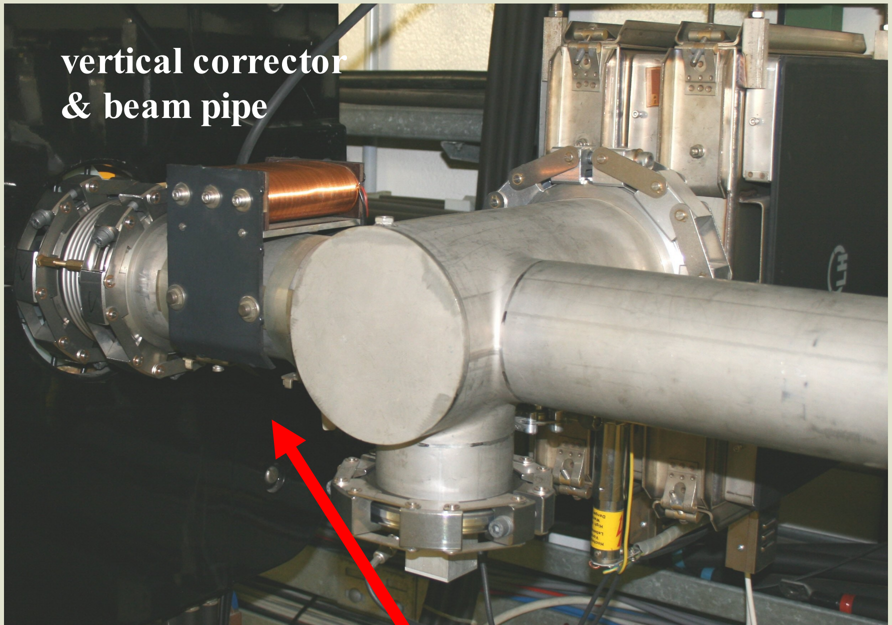


22/09/06: Mott Polarimetry:

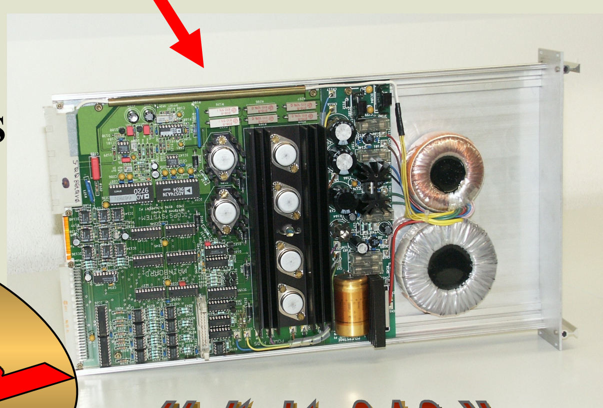
$P \approx 81\% \pm 1\%_{stat} \pm 5\%_{syst}$

Quantum lifetime > 3000 hours at the moment

Correction System



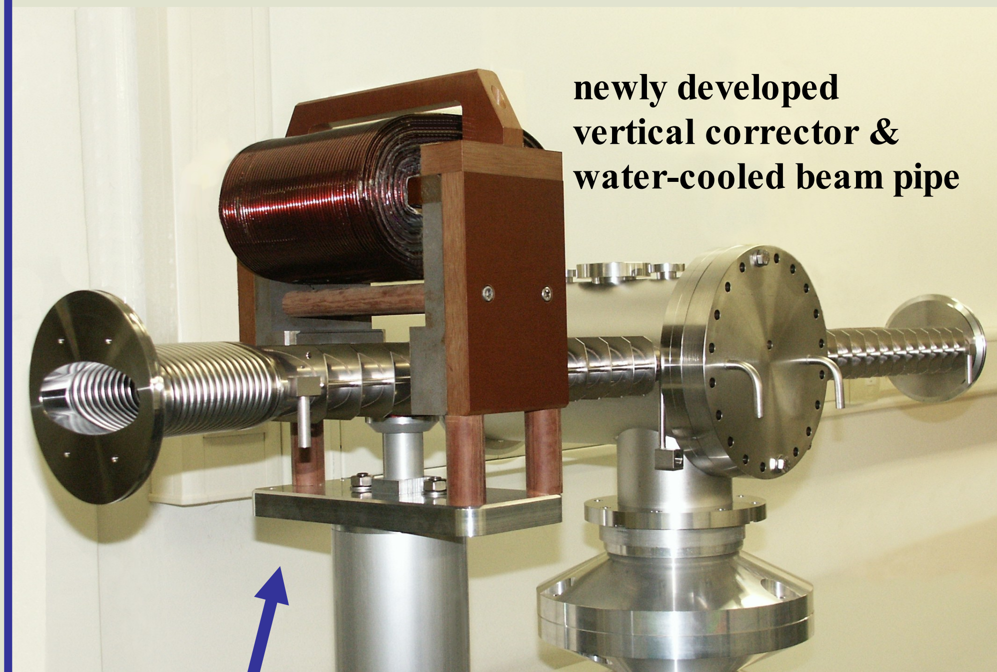
COPS PS



old

Limited to 2.4 GeV

newly developed
vertical corrector &
water-cooled beam pipe

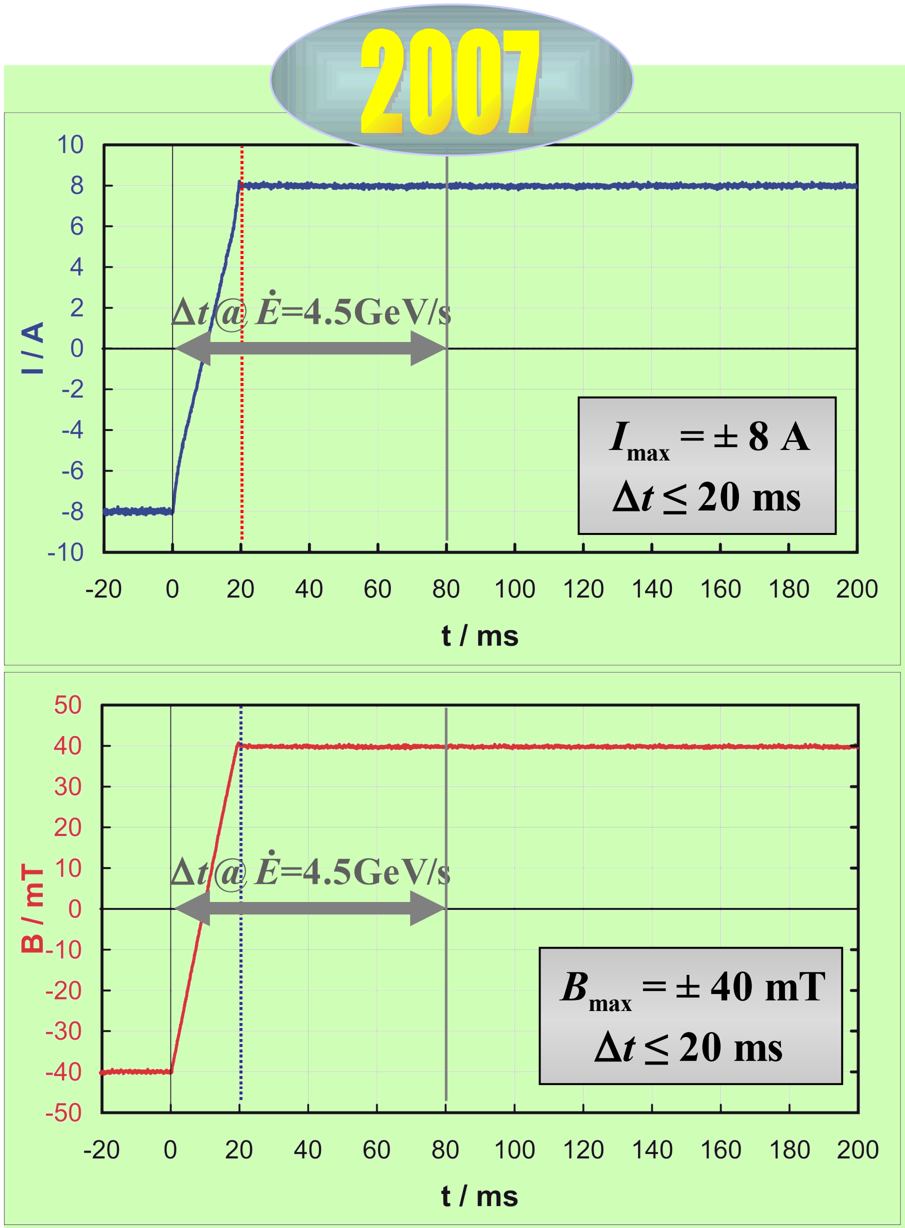


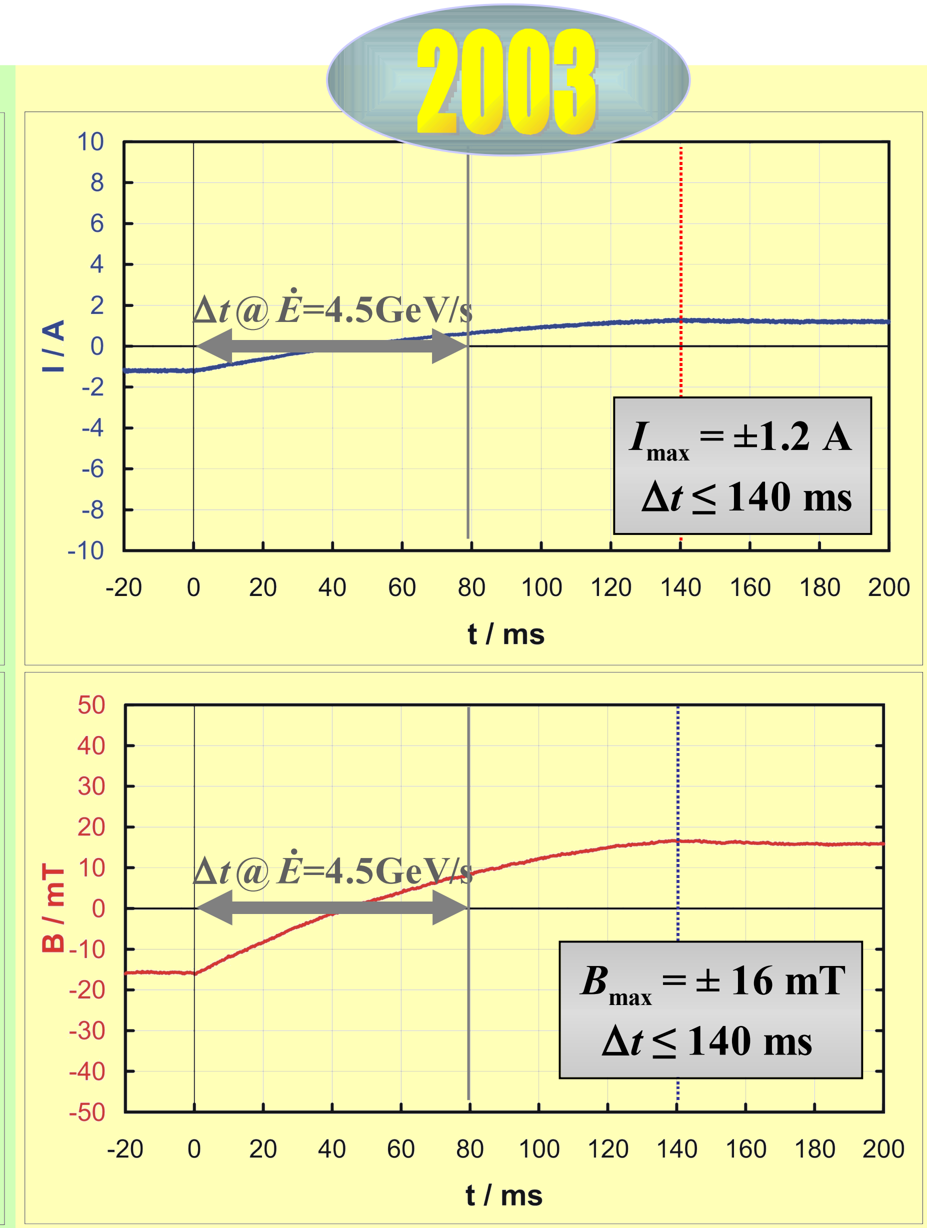
newly developed PS

new

Ready for 5 GeV

Harmonic Correction

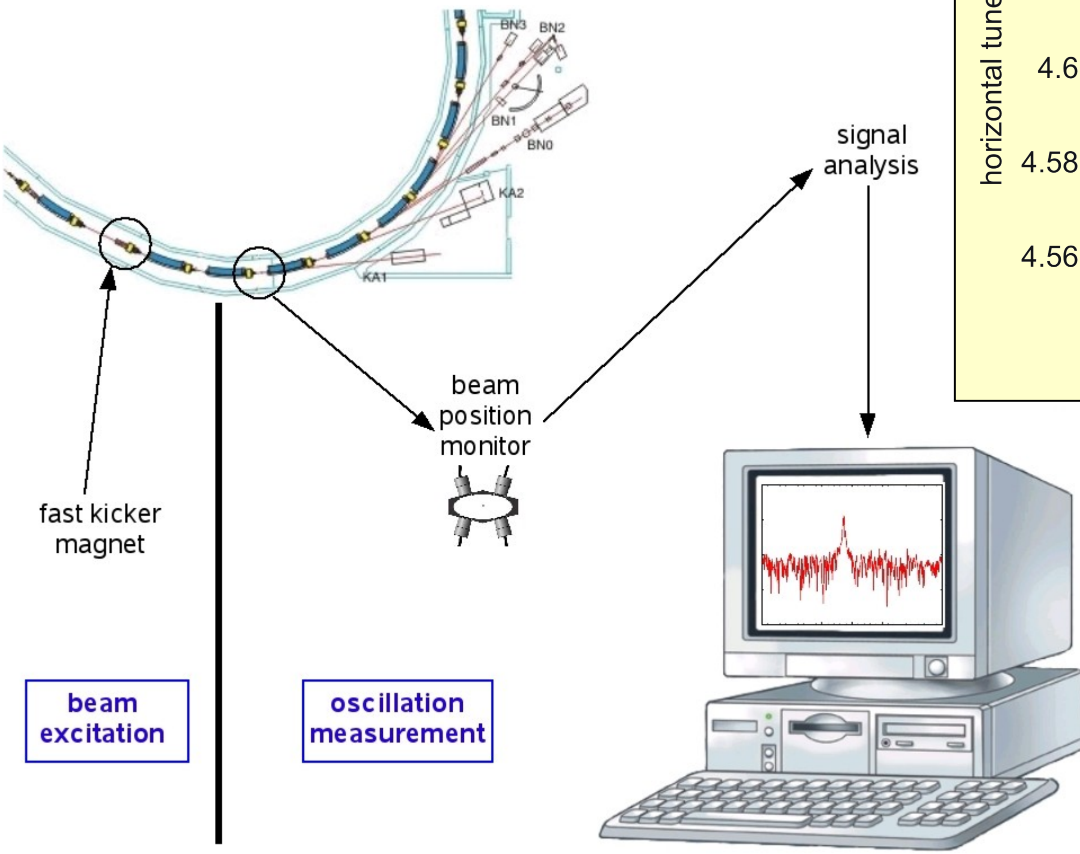


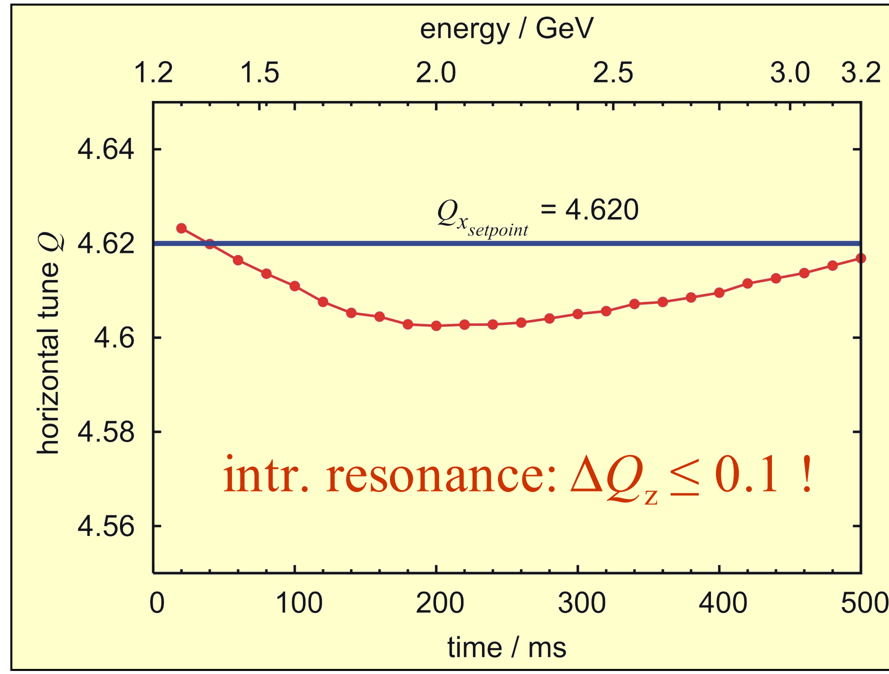


Tune Measurement

Measuring principle:

Exitation of coherent betatron oscillations





Only the horizontal tune is accessible at the moment!

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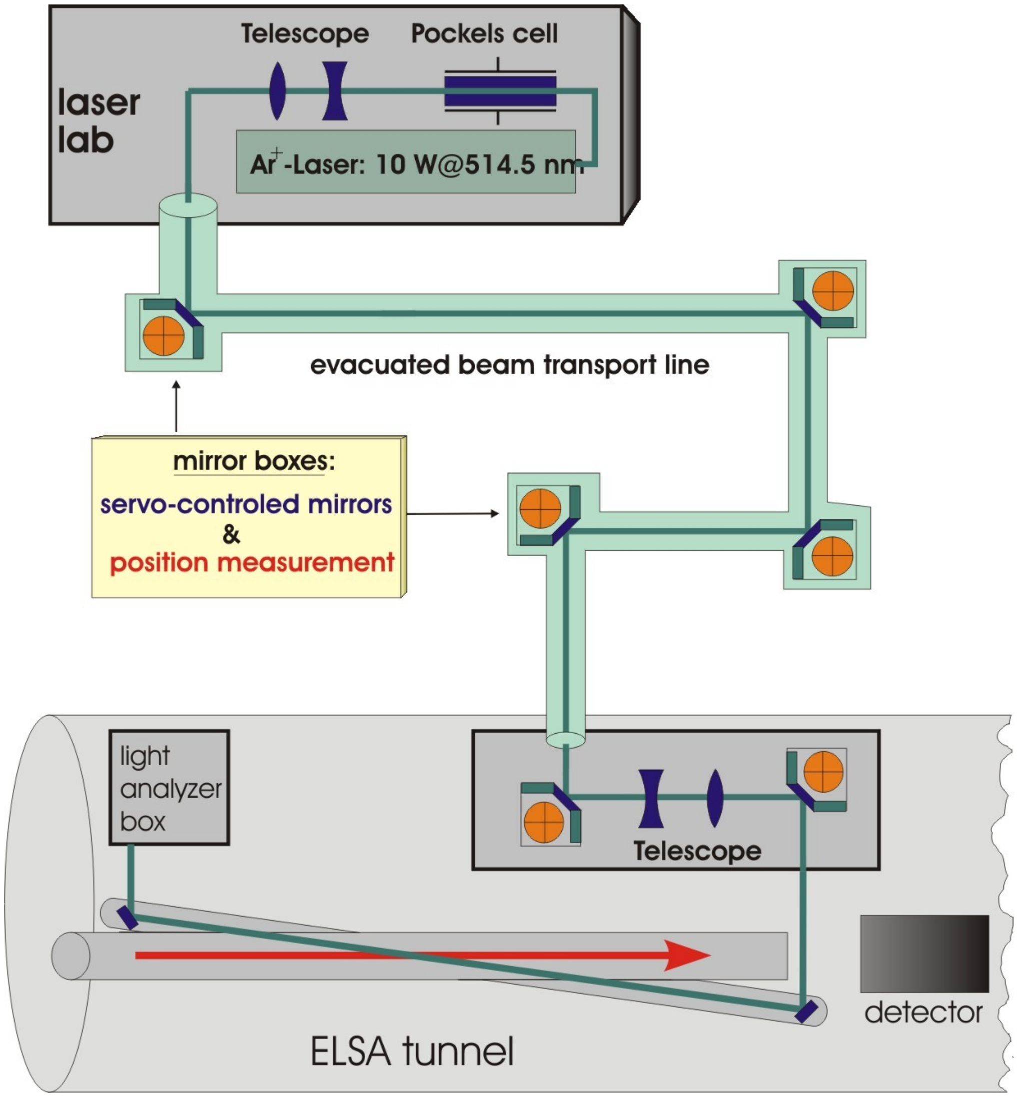
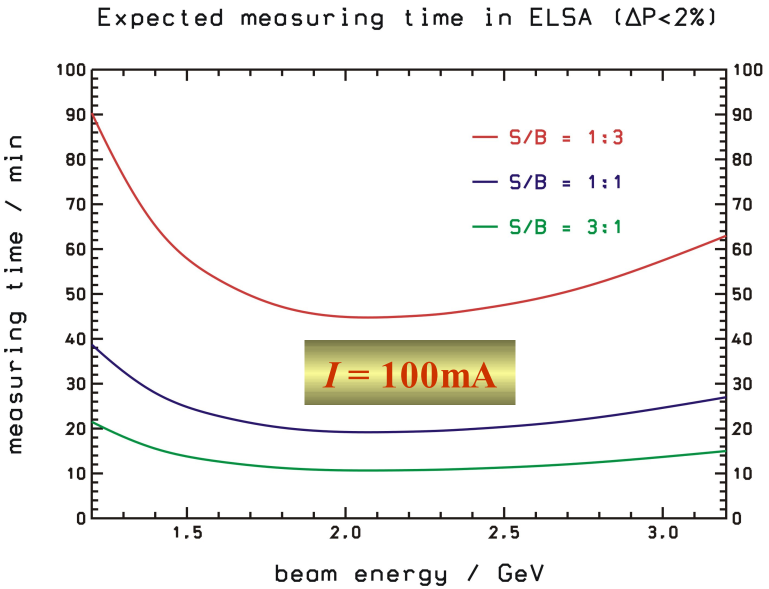
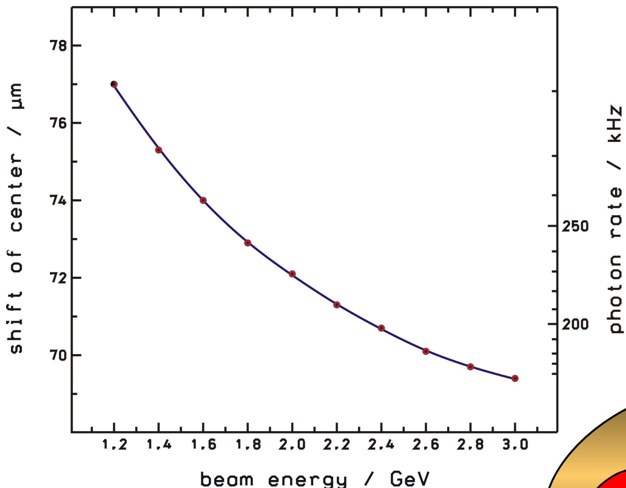
Internal Polarimetry

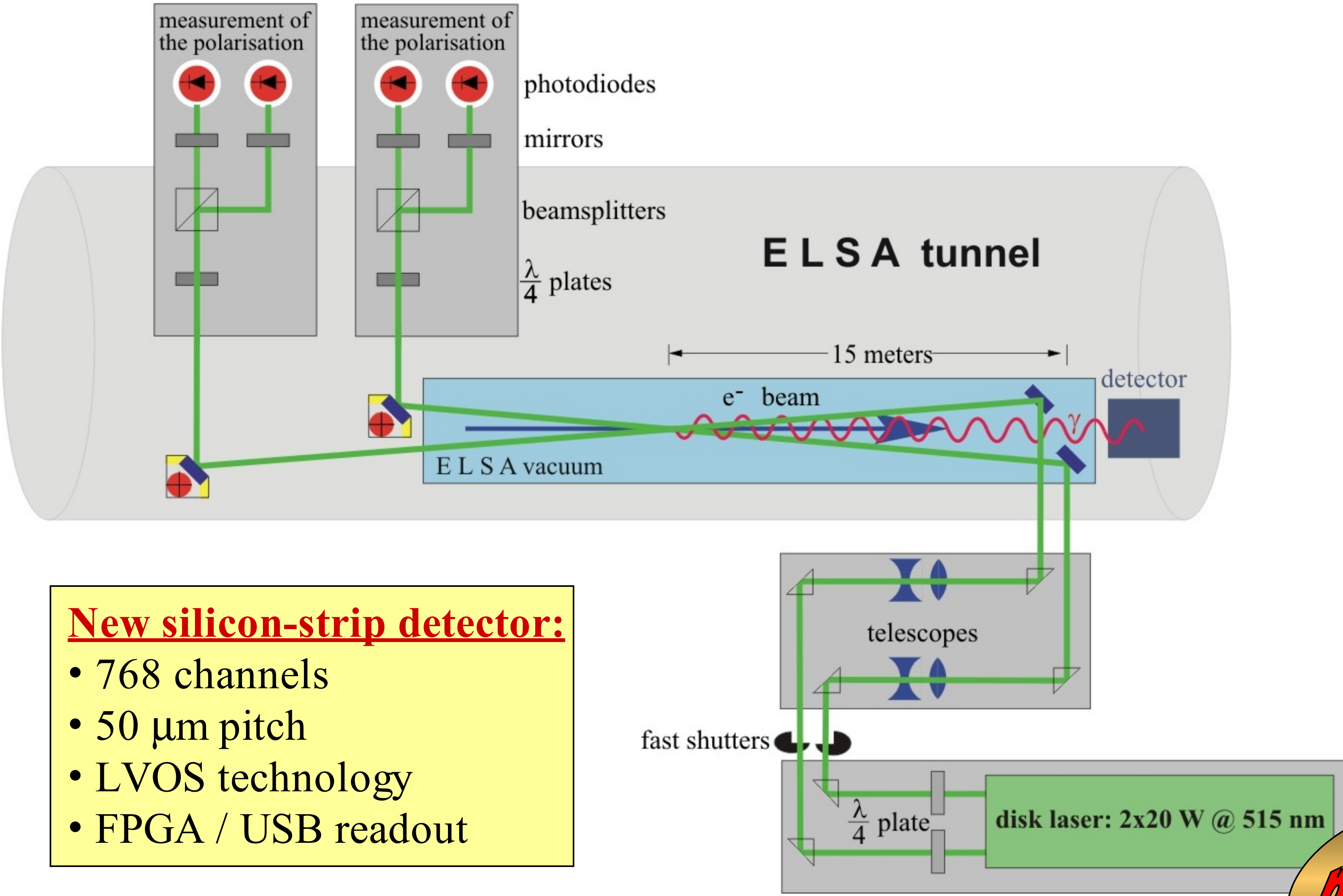






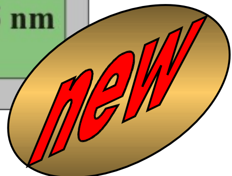
Nucl. Instr. and Meth. **A 492** (2002) 356

Internal Polarimetry



New silicon-strip detector:

- 768 channels
- 50 µm pitch
- LVOS technology
- FPGA / USB readout



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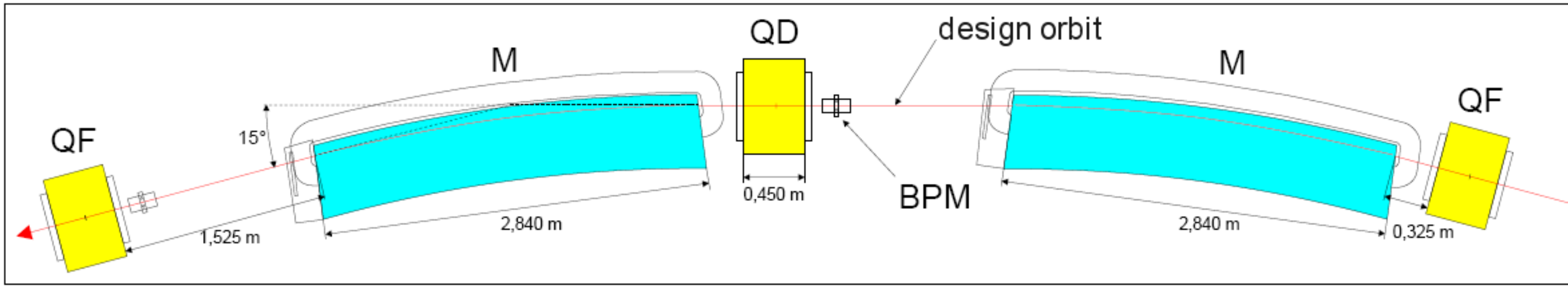
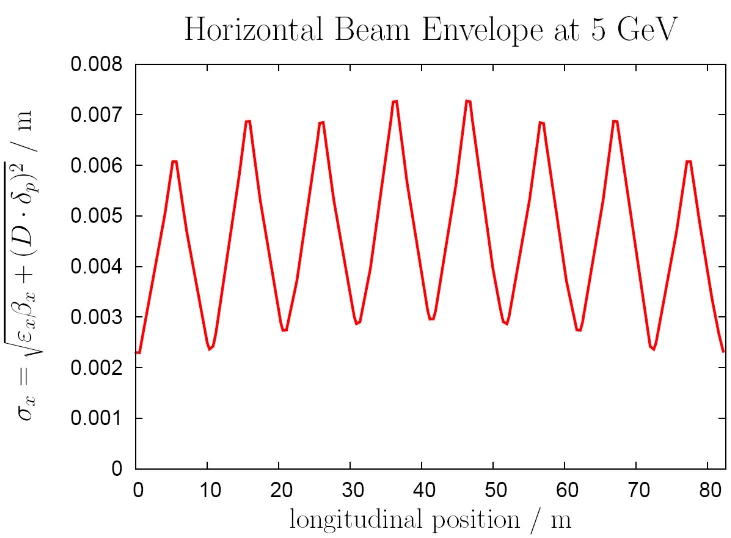
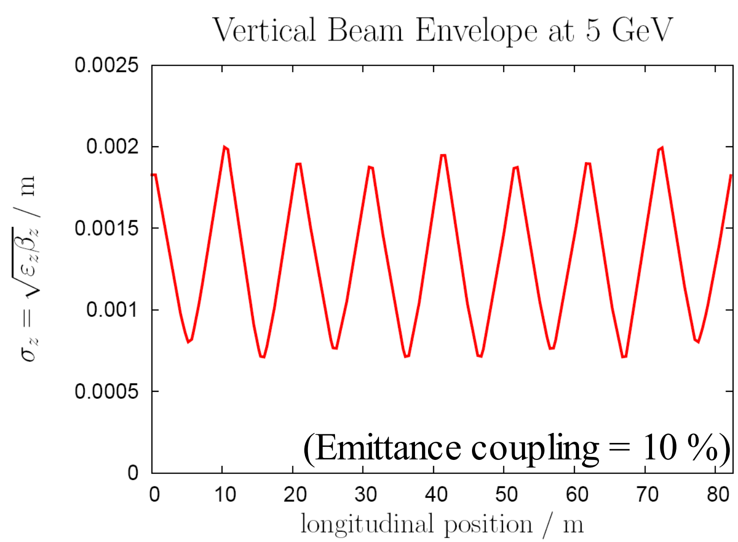
Magnets and Power Supplies

- **Dipole Magnets:**
  - B_{max} = 1.073 T → 1.533 T: new magnets required!
    - gap reduction from 50 mm to 40 mm
    - number of coil pancakes increasing from 3 to 4
  - power supply: major modifications necessary!
- **Quadrupole Magnets:**
  - g_{max} = 10.5 T/m → existing magnets o.k. (10 T/m)
  - power supply I_{max} = 910 A → 970A: minor modifications
- **Setupole Magnets:**
  - g'_{max} = 53.4 T/m² → existing magnets o.k. (100 T/m²)
  - existing power supply o.k.: I_{max} = 190 A << 600 A

Beam Sizes and Apertures



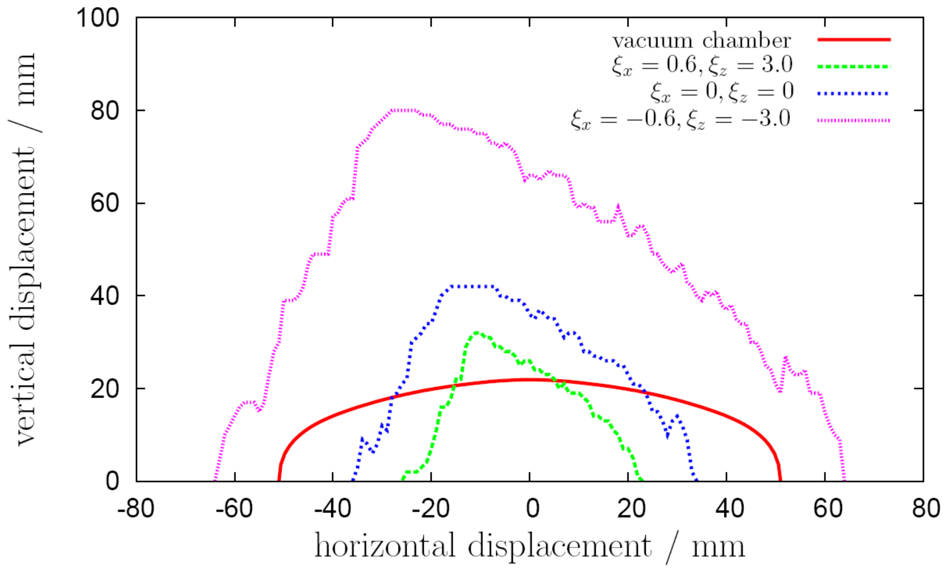




$$\left.\begin{array}{l}\sigma_x \leq 7.3\ \text{mm} = 6.85\ \sigma_A \\ \sigma_z \leq 2.0\ \text{mm} = 7.50\ \sigma_A\end{array}\right\} \longrightarrow \tau \geq 115\ \text{h}$$

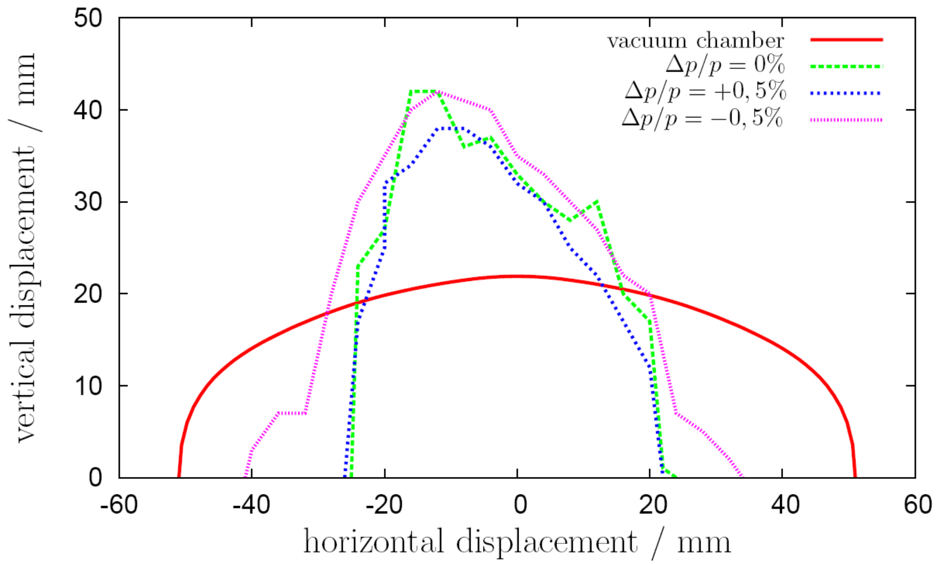
no critical elements except extraction septum magnets

Dynamic Aperture at ELSA



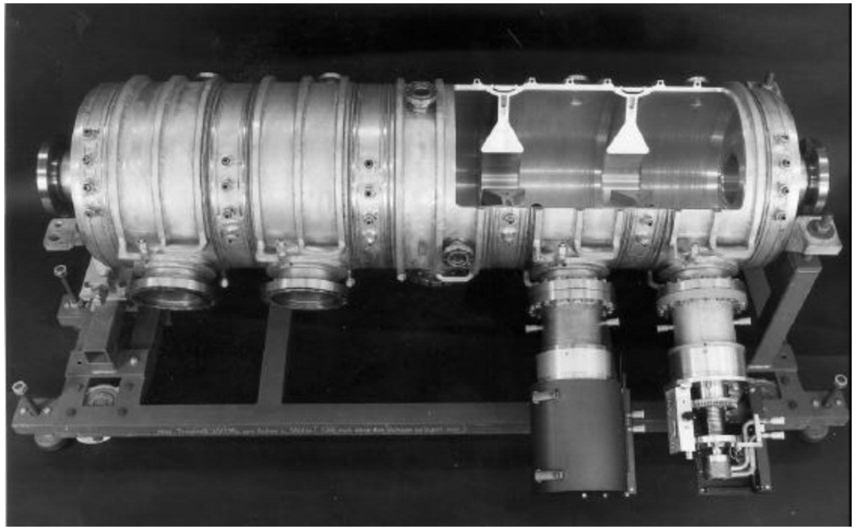
Ideal machine without:
- misalignments
- momentum deviation
- additional multipoles

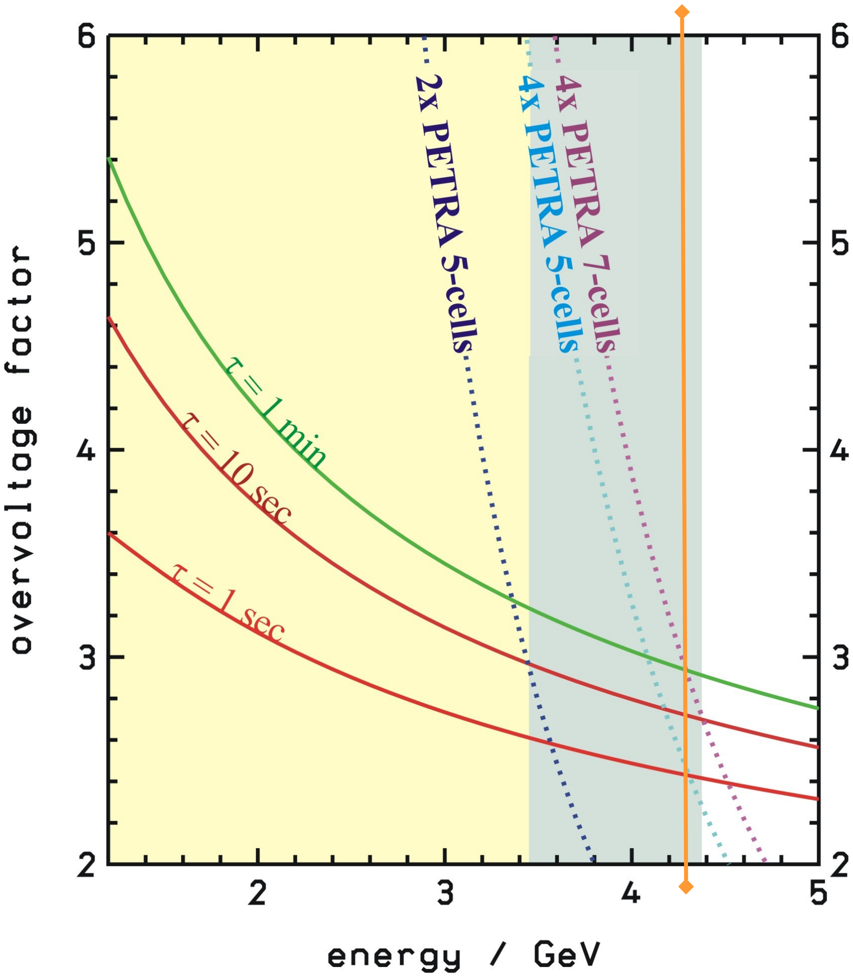
additional sextupole magnets required!



Real machine with $\xi = 0$:
- misalignments $\pm$ 0.2mm
- measured multipoles
- influence of Δp

Accelerating Voltage





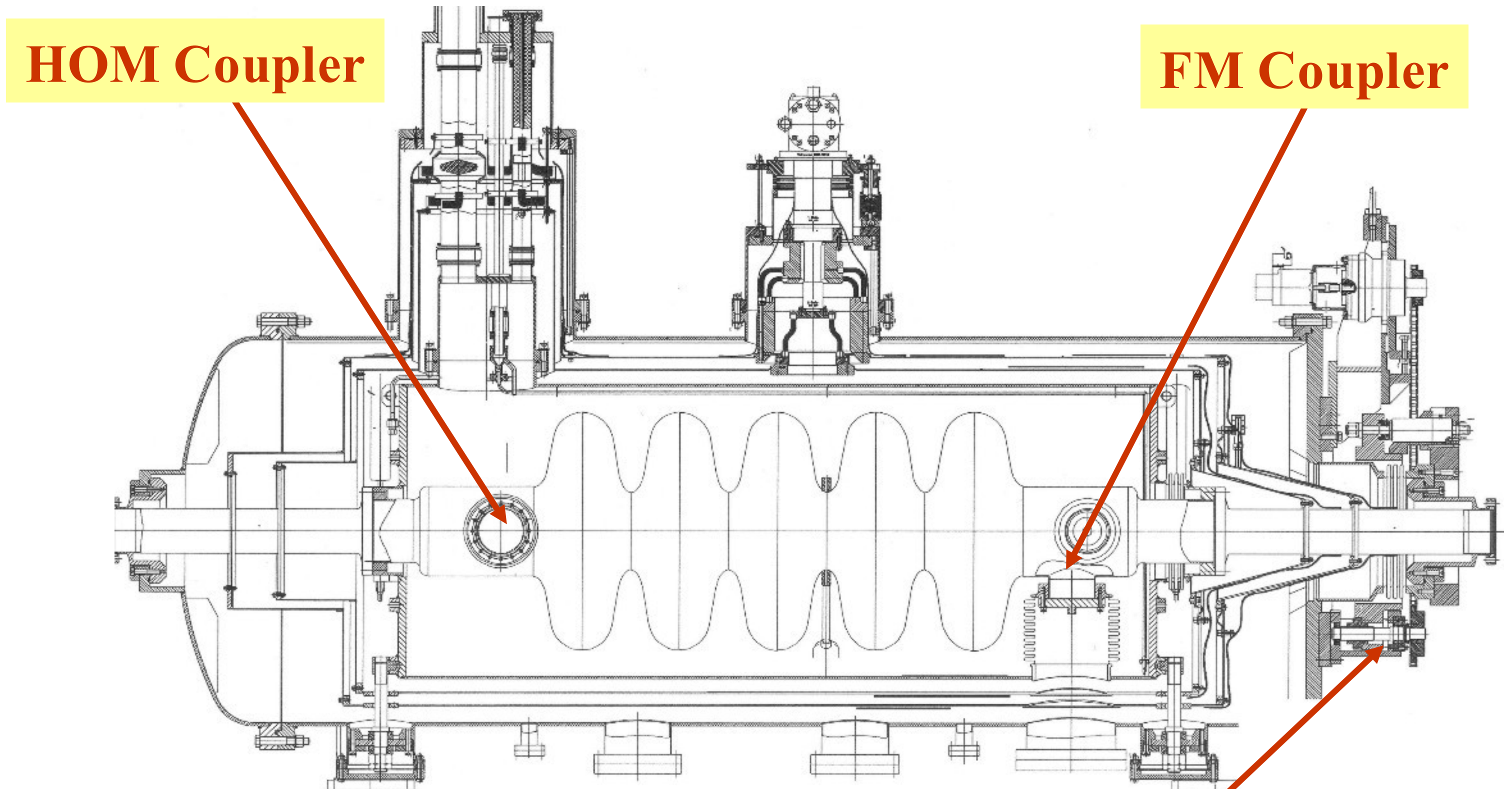
n.c. resonators type PETRA:

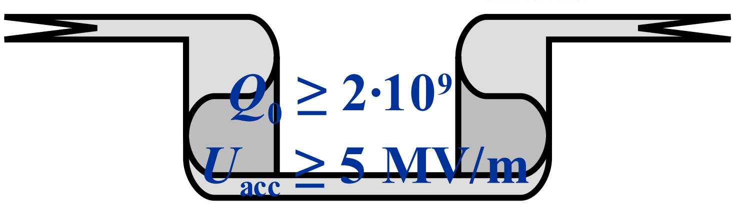
- 5-cells: $Q_0 \approx 10^4$, $R_S \approx 12$ MΩ
- 7-cells: $R_S \approx 17$MΩ
- Input-Coupler: $P_{max} \leq 120$ kW

with 4 n. c. resonators limitation to E ≤ 4.3 GeV

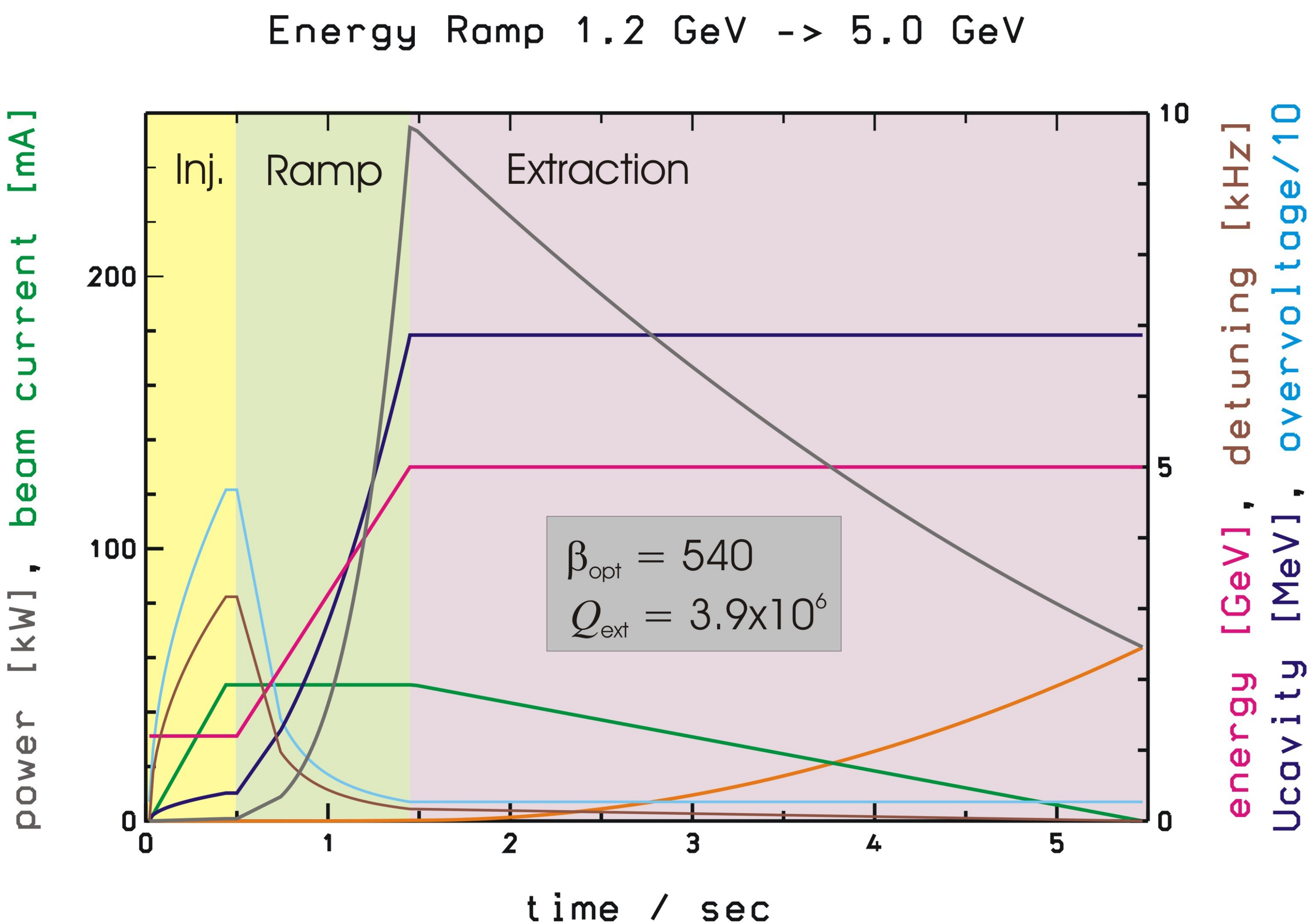
SC Cavities

Operation in a fast ramping circular accelerator puts questions to:

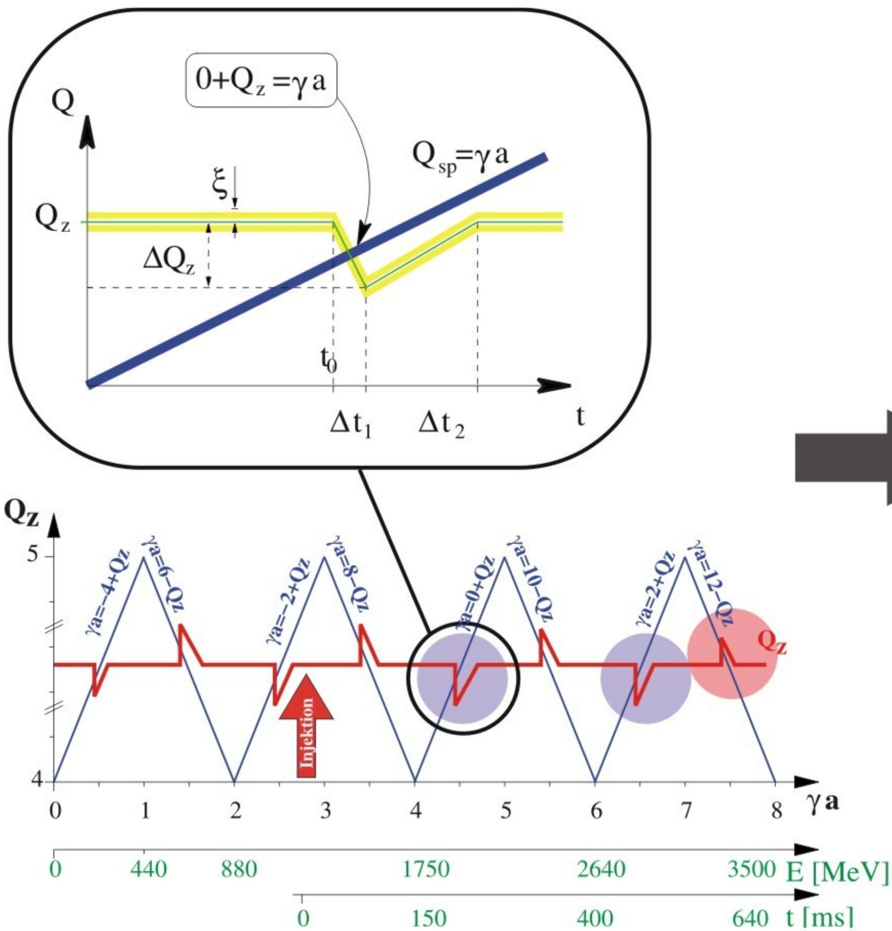


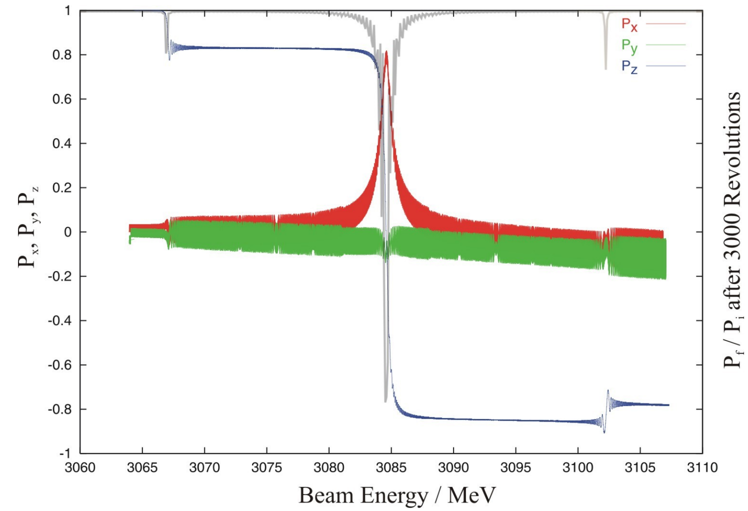


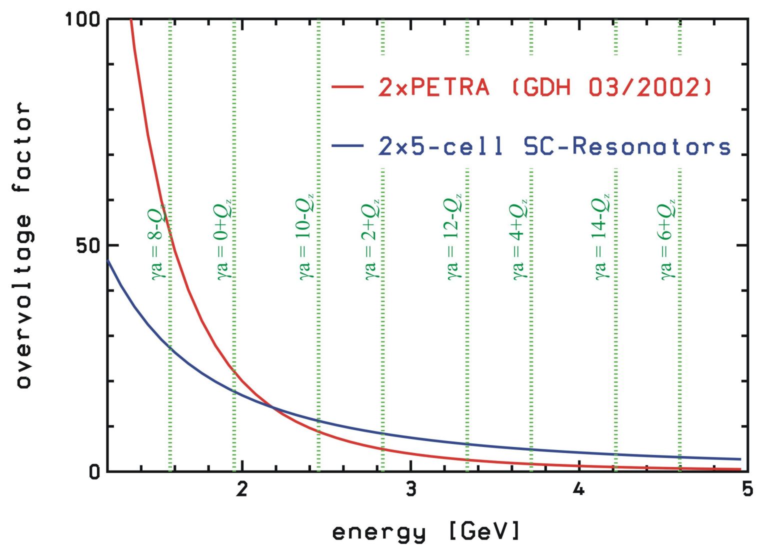
RF Operation Parameters



Crossing of Sy.-Sidebands







SC RF-System:

Acceleration of $I = 50$ mA up to $E = 5$ GeV:

✓ • standard parameters: $Q_0 = 2 \cdot 10^9$, $R_s = 10^{11}$ GΩ

✓ • optimization for 50mA @ 5GeV: $Q_{ext} = 4 \cdot 10^6$, $\beta = 540$

✓ • beam lifetime **t ≥ 1 min @ 5GeV** with $q = 2.7$

✓ • two 5-cell resonators ↔ $U_{Cav} \leq 4.5$ MV/m

✓ • maximum generator power $P_g \leq 260$ kW

✓ • maximum power for input coupler $P_{cp} \leq 130$ kW

? • maximum detuning $\Delta f \leq 3.5$ kHz, depends on R_S/Q

✓ • maximum overvoltage factor $q \leq 50$

? • investigation of HOM-coupler parameters has been started, **no principle problems expected**

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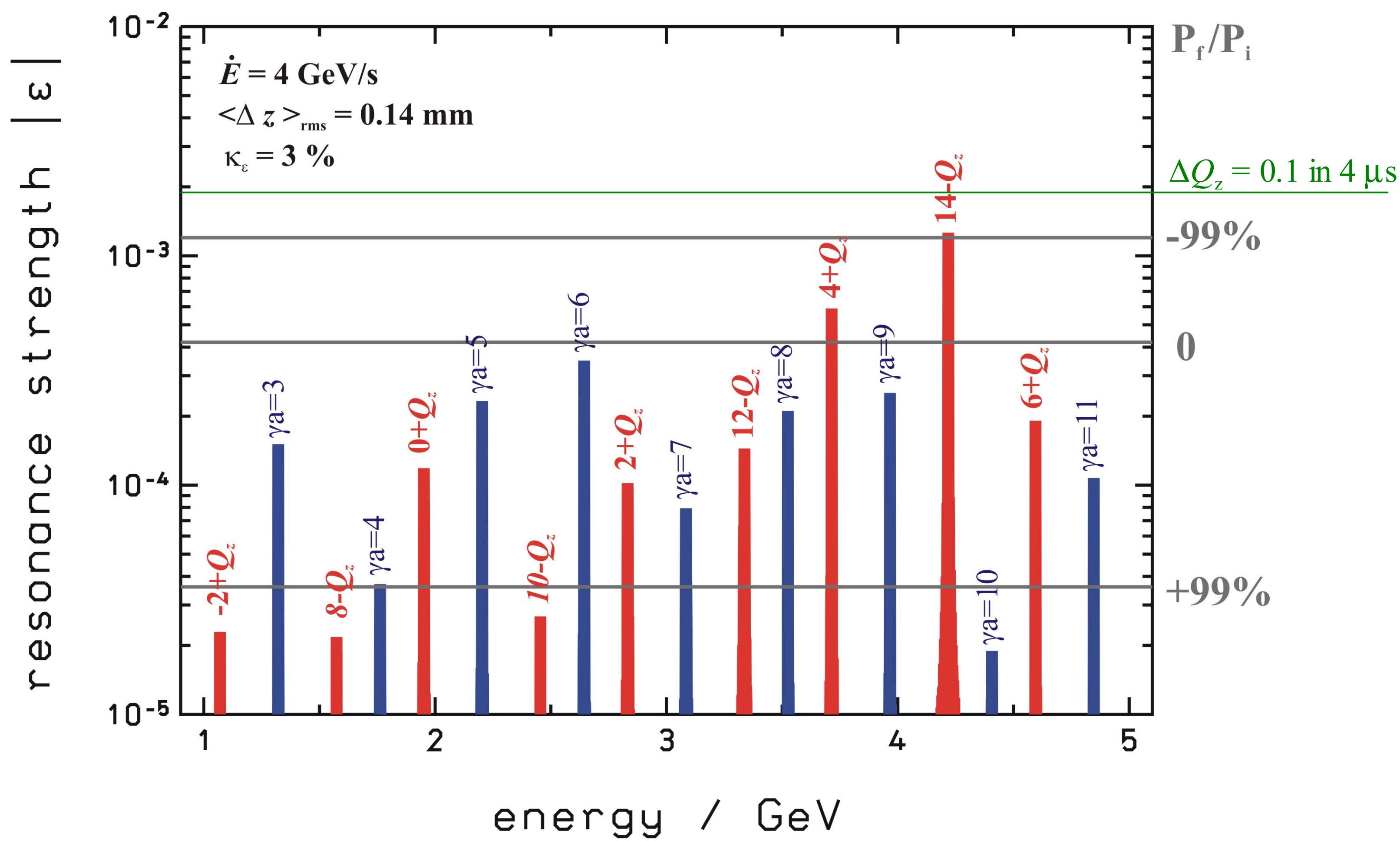
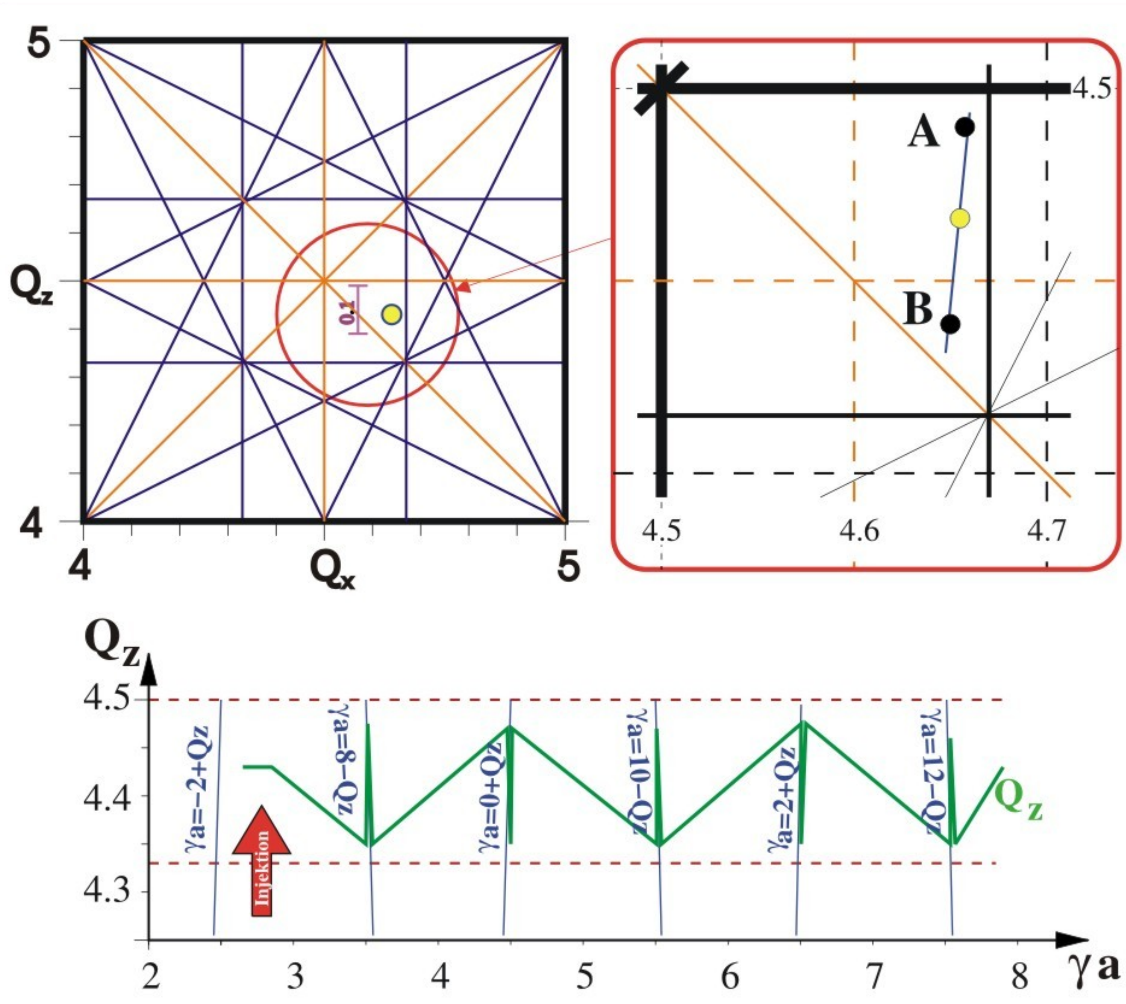
Resonance Strengths



Intrinsic Resonances

1. Variation of the vertical tune on the energy ramp:



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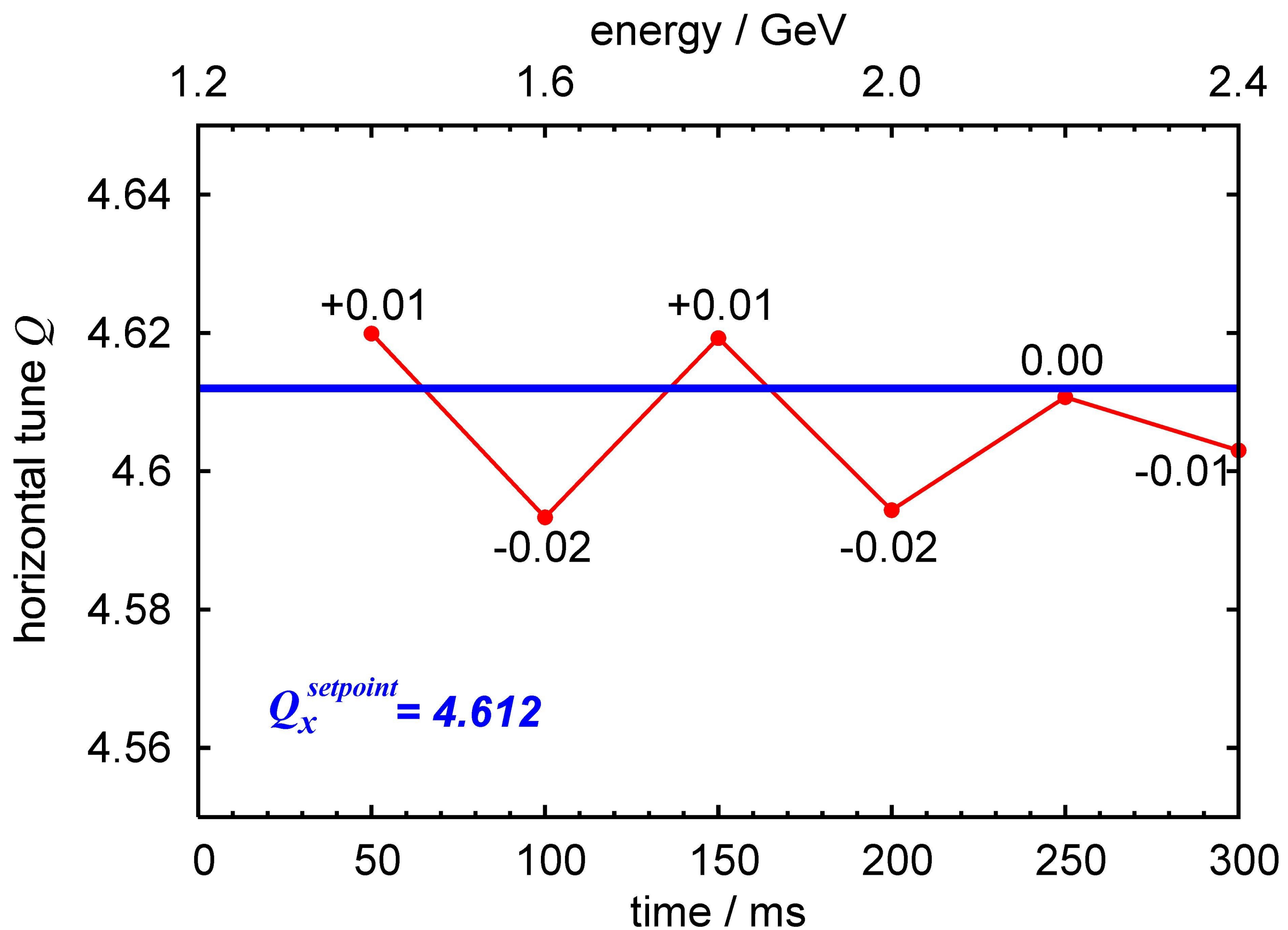
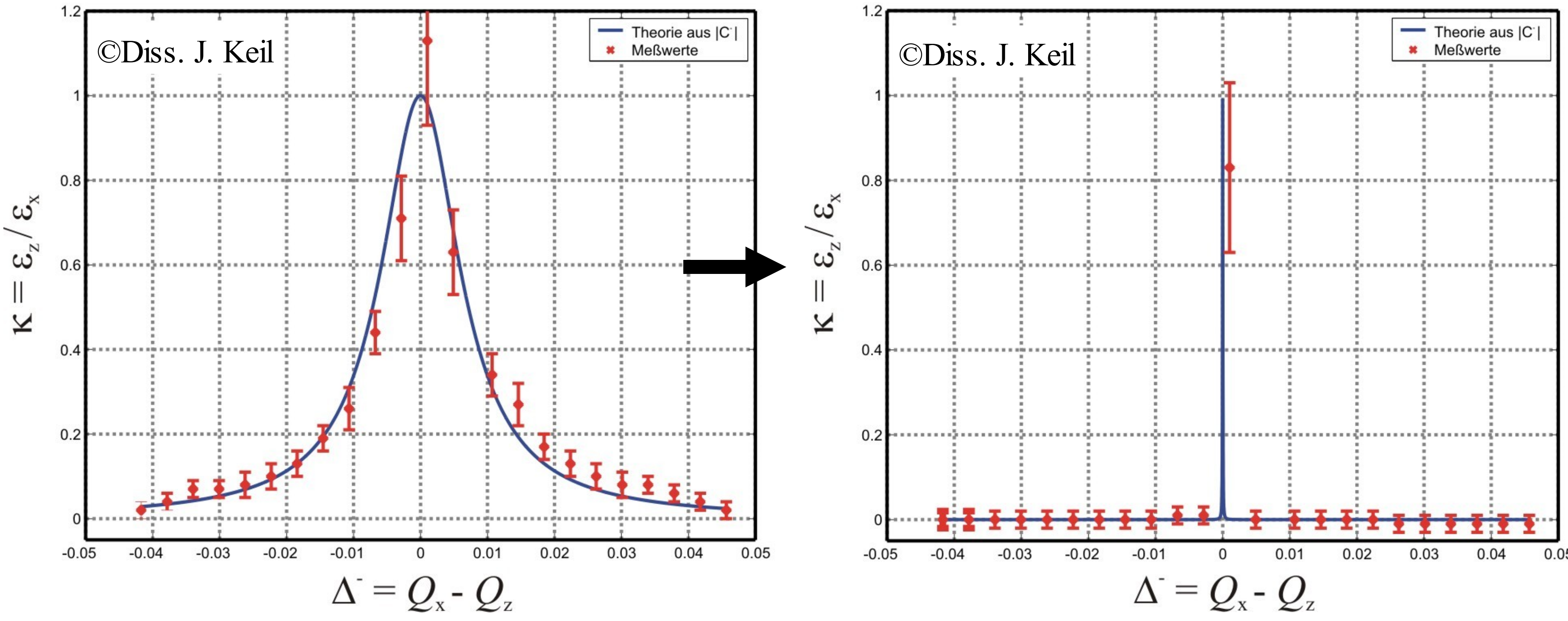


Intrinsic Resonances

1. Reduction of vertical beam size with skew quadupoles



high resolution SR-monitor needed for measurement of the vertical beam size

Final Report SFB/TR

SFB-report will be dealing with follow. topics:

- acceleration of polarized electrons to 3.5 GeV
- internal polarimetry
- design concepts for energy upgrade to 5 GeV
- adv. correction schemes for resonance crossing

In addition, a separate detailed design report will be written, dealing with all aspects of an energy upgrade to 5 GeV

"Next Funding"

Increase of external current:

1 nA → 5 - 10 nA

↓

Increase of internal current:

20 mA → 100 - 200 mA

$I_{\parallel}^{thres} < 20$ **mA observed @ 2.3 GeV**

“Next Funding”

- **incoh./coh. tune shifts due to wall effects:**

$$\Delta Q_{x/z}^{\text{inc}} = -\frac{e I \cdot \oint \beta_{x/z}\, ds}{4\pi^2 \varepsilon_0 m_0 (\beta c)^3 \gamma} \cdot \left\{ \frac{\left(1-\beta^2-\eta\right)}{B}\frac{\varepsilon_{sc}}{a^2} + \left[\beta^2 + \frac{\left(1-\beta^2-\eta\right)}{B}\right]\frac{\varepsilon_1}{h^2} + \beta^2\frac{\varepsilon_2}{g^2} \right\}$$

- **neutralization of residual gas**

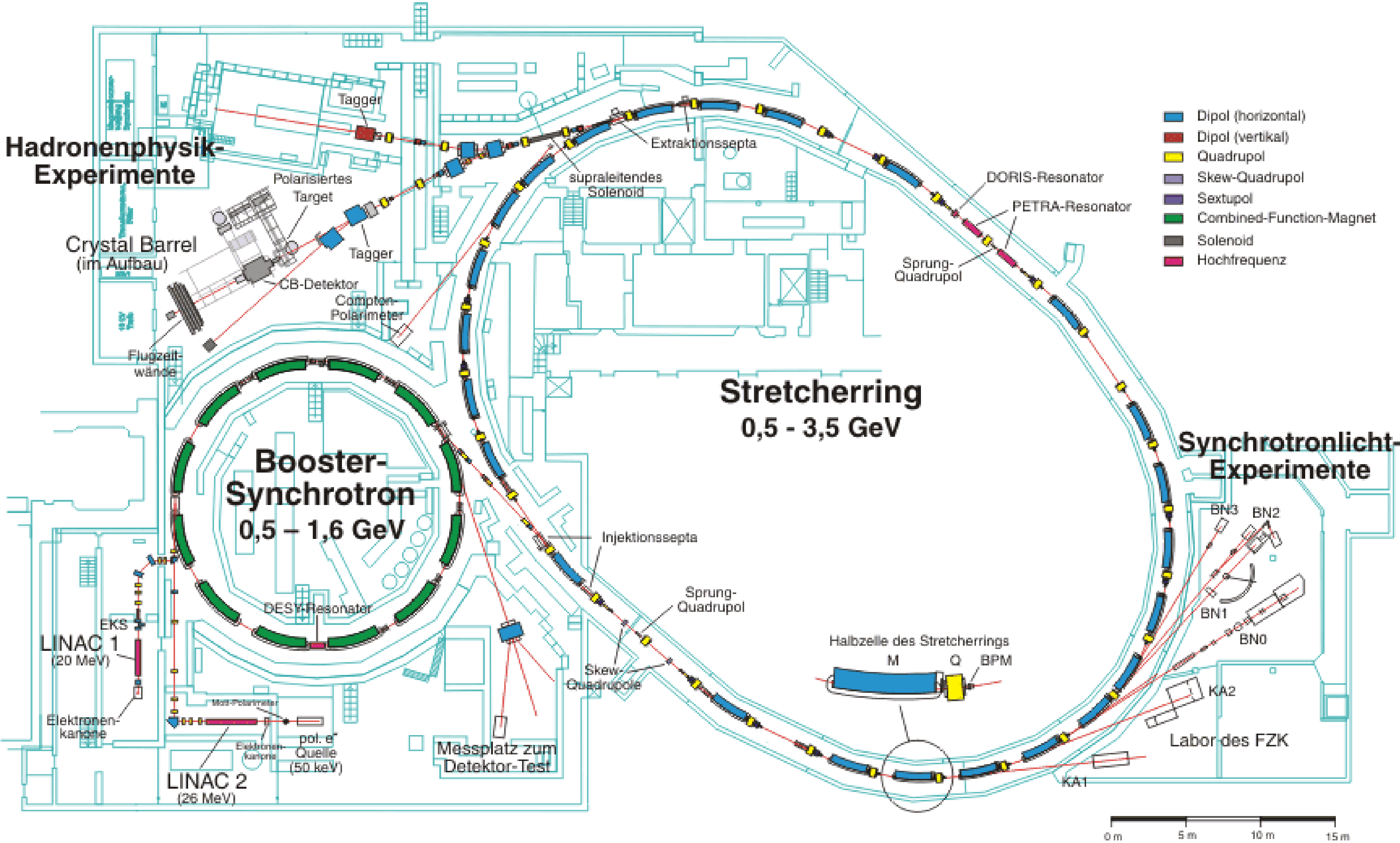
- **collective instabilities: $Z_{\parallel}$, $Z_{\perp}$, HOM**

$$\sum_{l=-\infty}^{\infty} \left(\Omega_c - l\Omega_S\right)\hat{\tau}\, g_l(\hat{\tau})\, e^{-jl\phi} = \frac{2\pi I \Omega_S}{h\omega_0^2 U_{wf}\cos\varphi_S}\frac{\partial g_0(\hat{\tau})}{\partial \hat{\tau}} \sum_{p,k=-\infty}^{\infty} \frac{Z_P(p\omega_0)}{p} j^{k-1} e^{-jk\phi}\, k J_k(p\omega_0\hat{\tau}) \sum_{m=-\infty}^{\infty} S_m(p\omega_0)$$

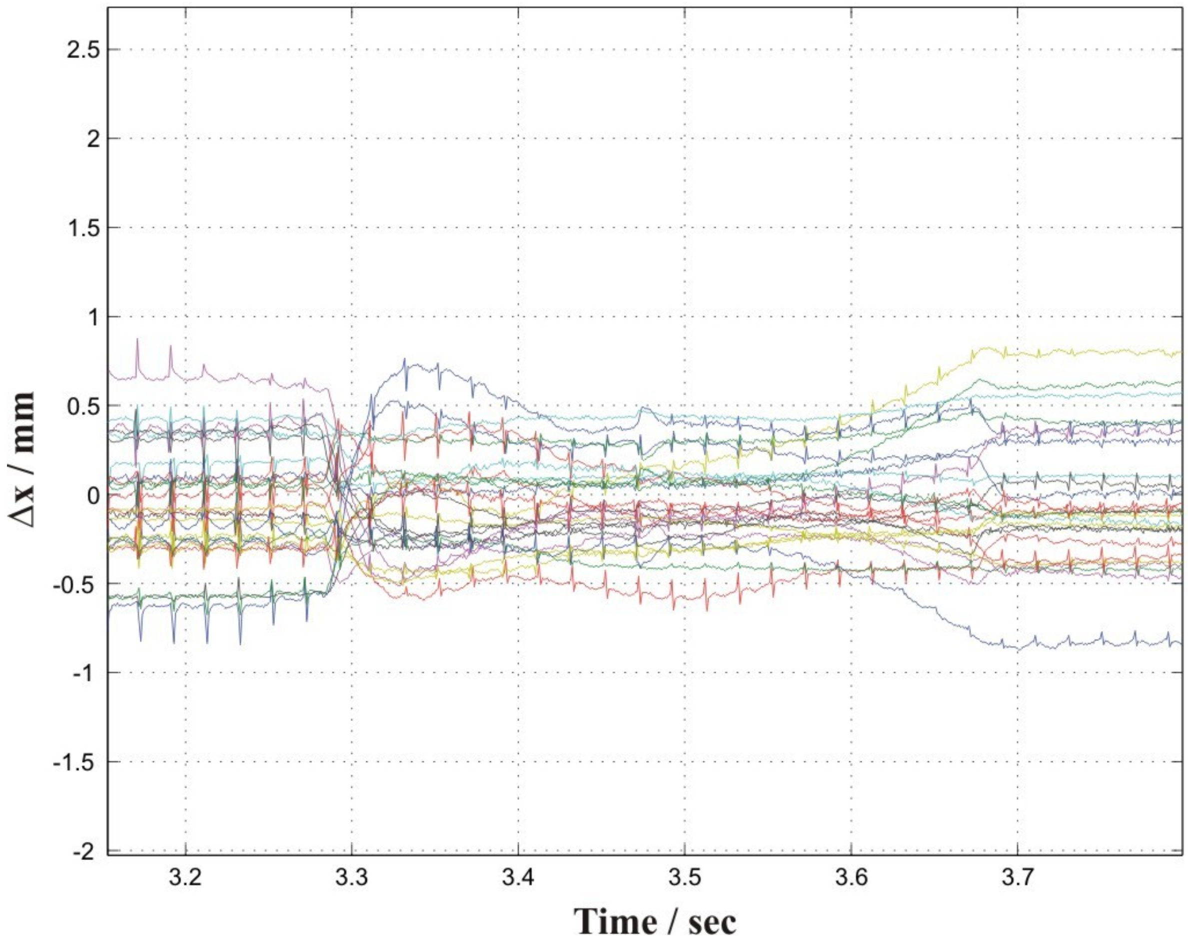
- **long. and transverse feedback systems**

Thank you for your attention!

Elektronen-Stretcher-Anlage (ELSA)



Closed Orbit Correction

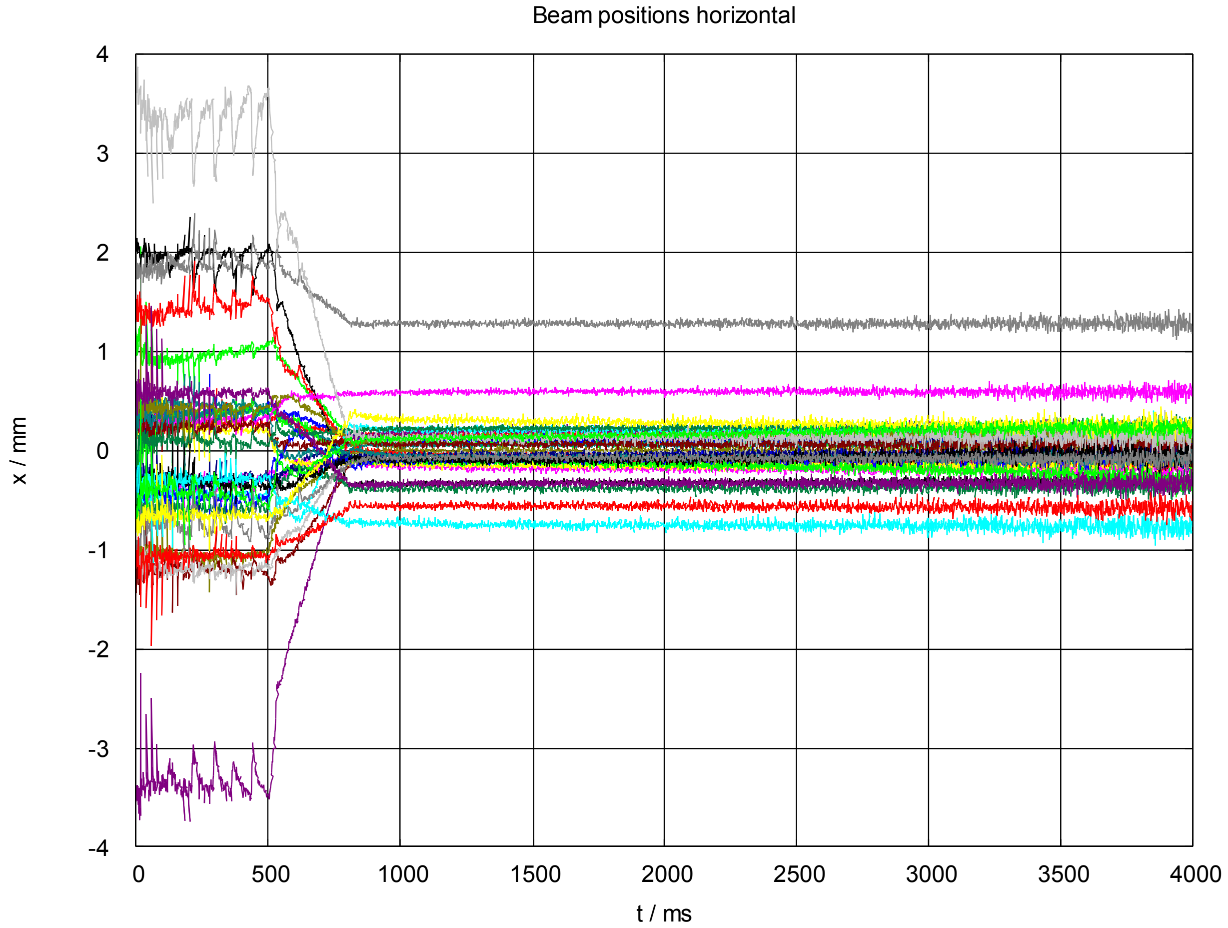


1,2 GeV ⟷ 2,8 GeV

Ramp

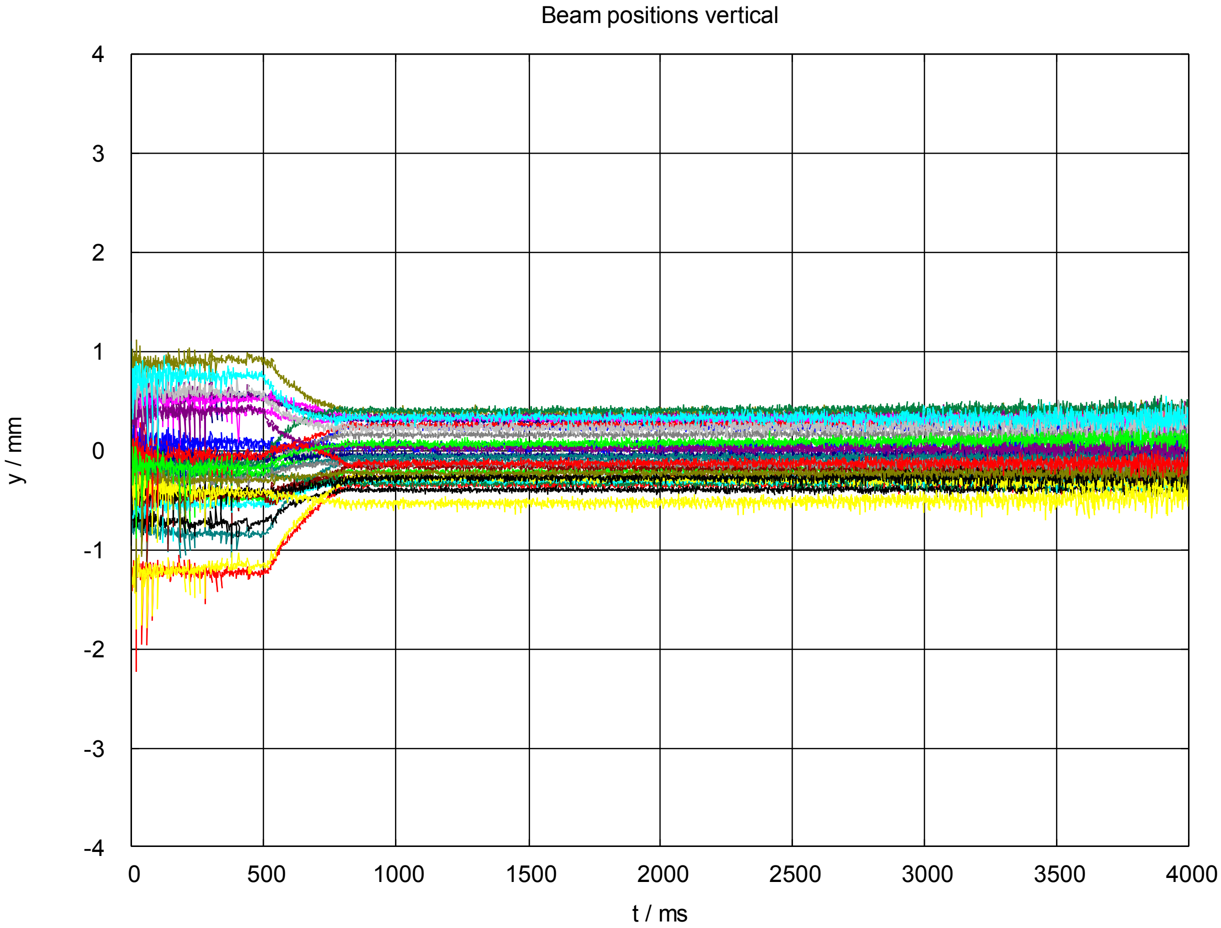
old

Closed Orbit Correction



horizontal orbit, measured in every quadrupole

Closed Orbit Correction



vertical orbit, measured in every quadrupole

Achieved maximum Polarization