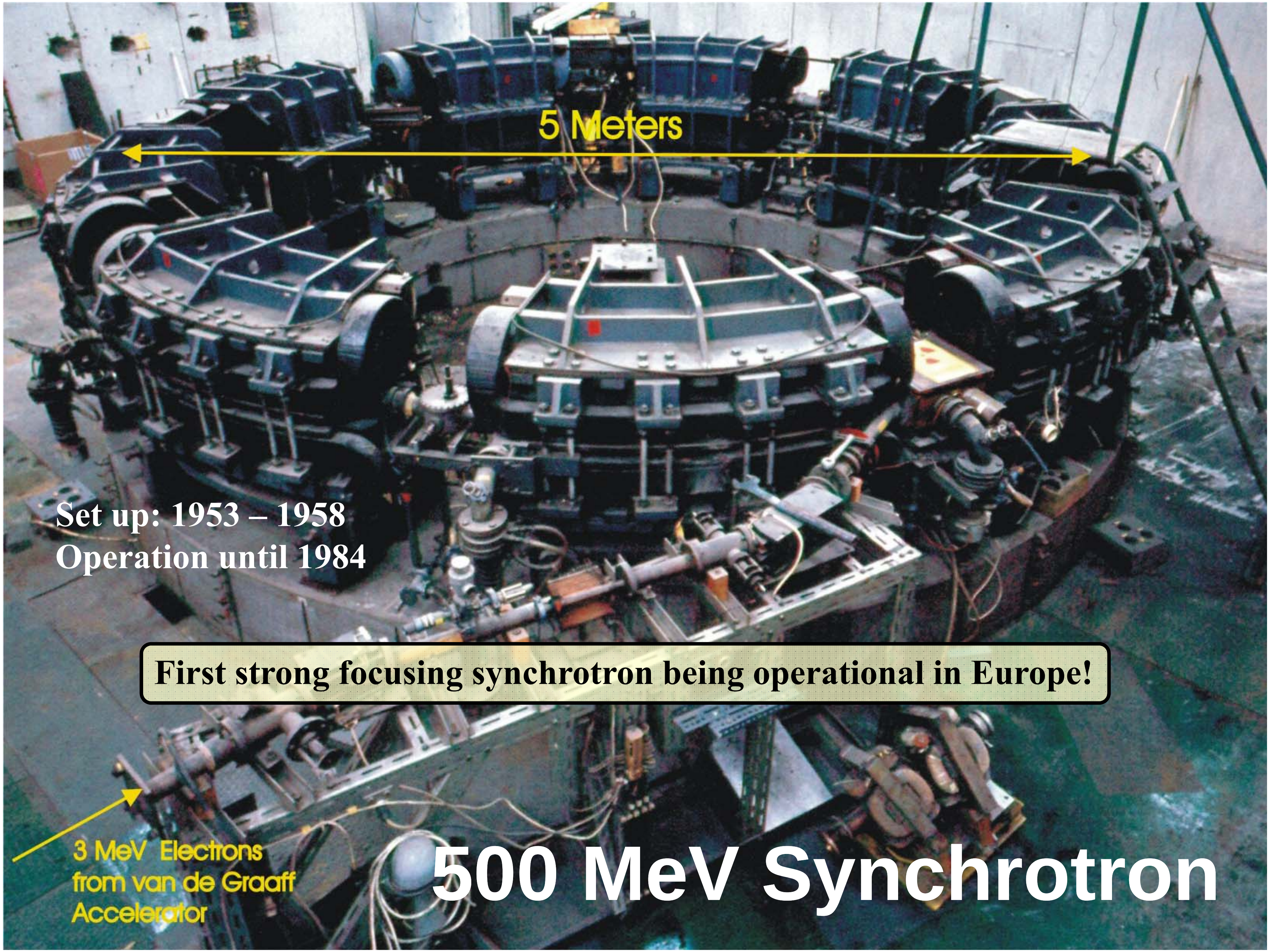
# The Bonn
# Electron-Stretcher Accelerator

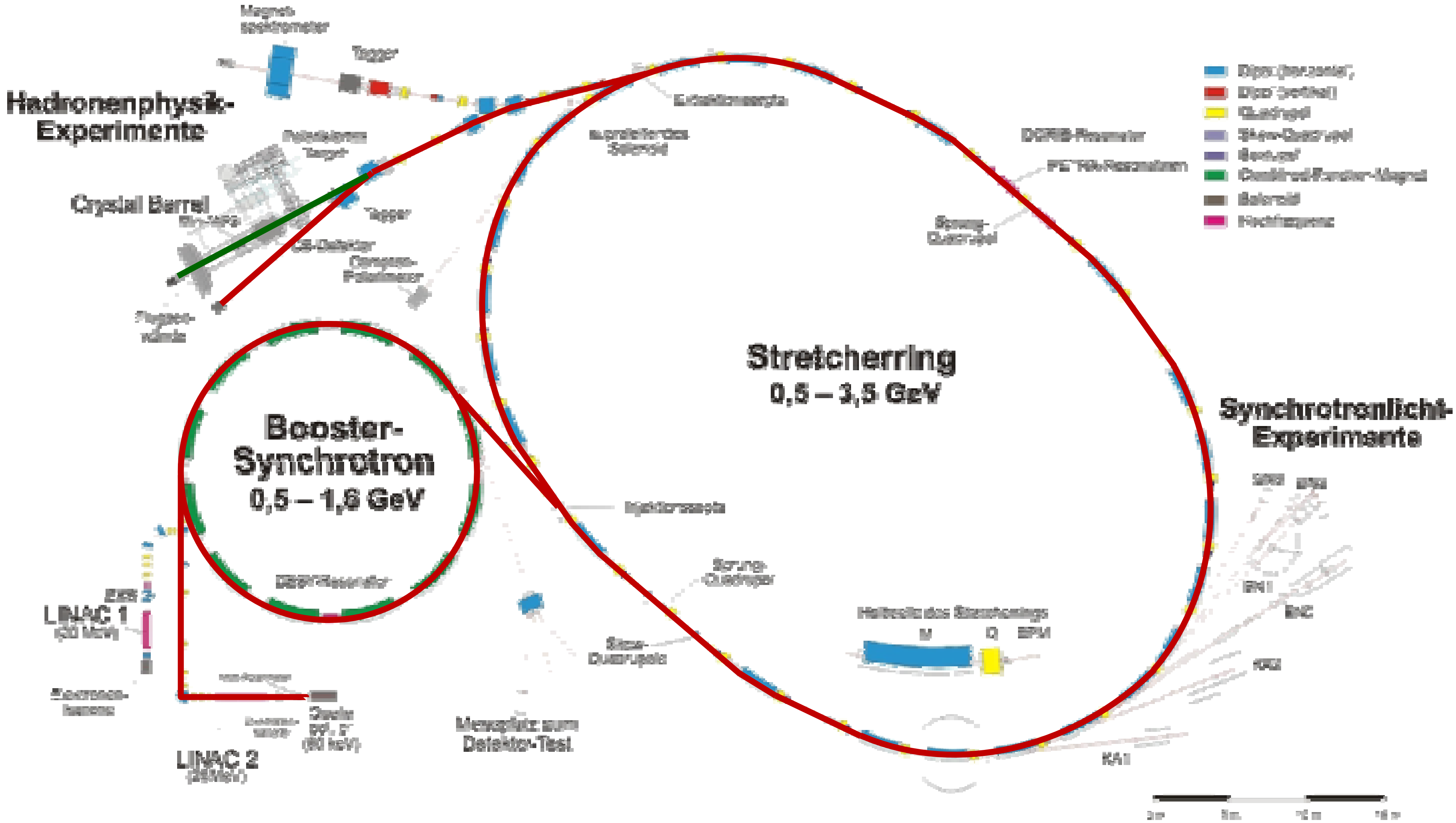
*Wolfgang Hillert*

***Physics Institute of Bonn University***

November Workshop
IAP / Uni Frankfurt
Nov. 13th – 14th, 2008


5 Meters
Set up: 1953 – 1958
Operation until 1984
First strong focusing synchrotron being operational in Europe!
3 MeV Electrons
from van de Graaff
Accelerator
500 MeV Synchrotron

# Elektronen-Stretcher-Anlage (ELSA)



# Booster Synchrotron

## 50 Hz Operation, max. Energy 2.3 GeV (1.6 GeV)

**12 Combined function Magnets of type F/2 – D/2**

**in operation since 1967**

**Bending Radius:**

$\rho = 7.65$ m

**max. Dipole Strength:**

$B_{max} = 1$ Tesla

**Field Indexes:**

$n_f = -22.26 \rightarrow g_f = 29.2$ T/m

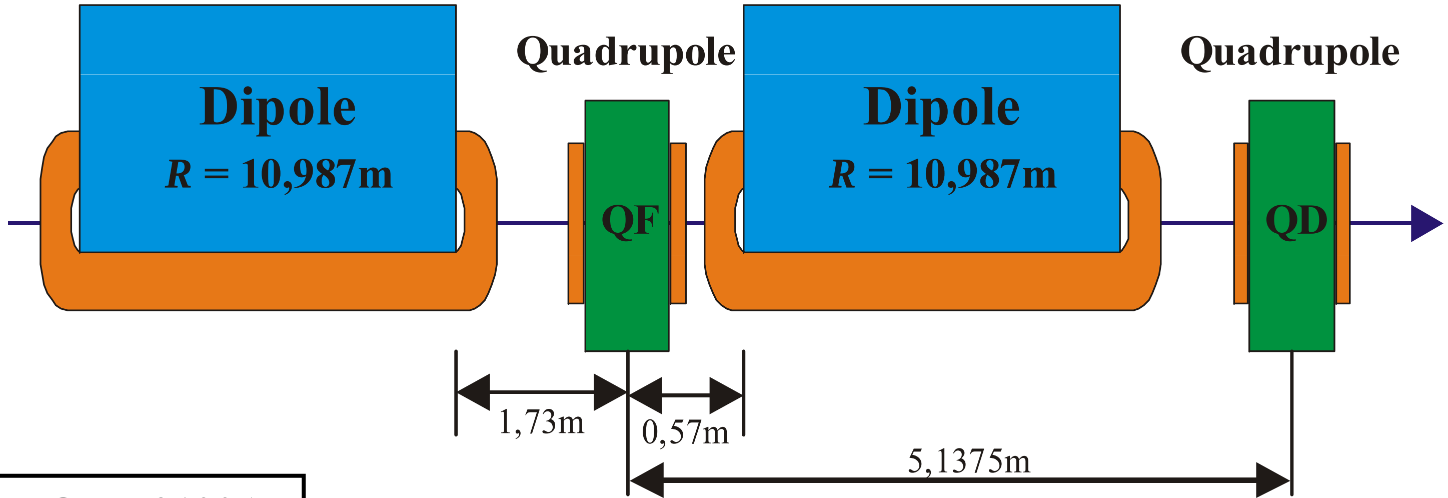
$n_d = 23.26 \rightarrow g_d = 30.5$ T/m

**Total Weight:**

$m = 18.5$ t (incl. girder)

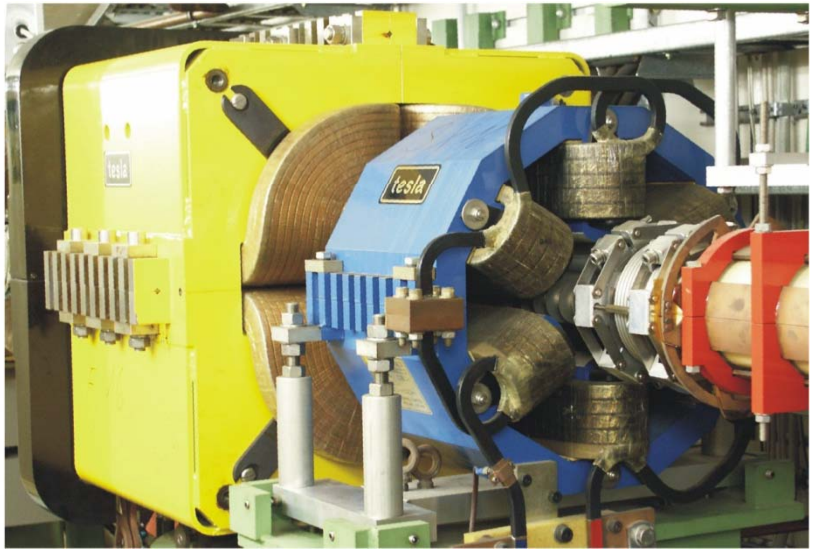
Number of Windings = 36, Maximum Current = 1380 A

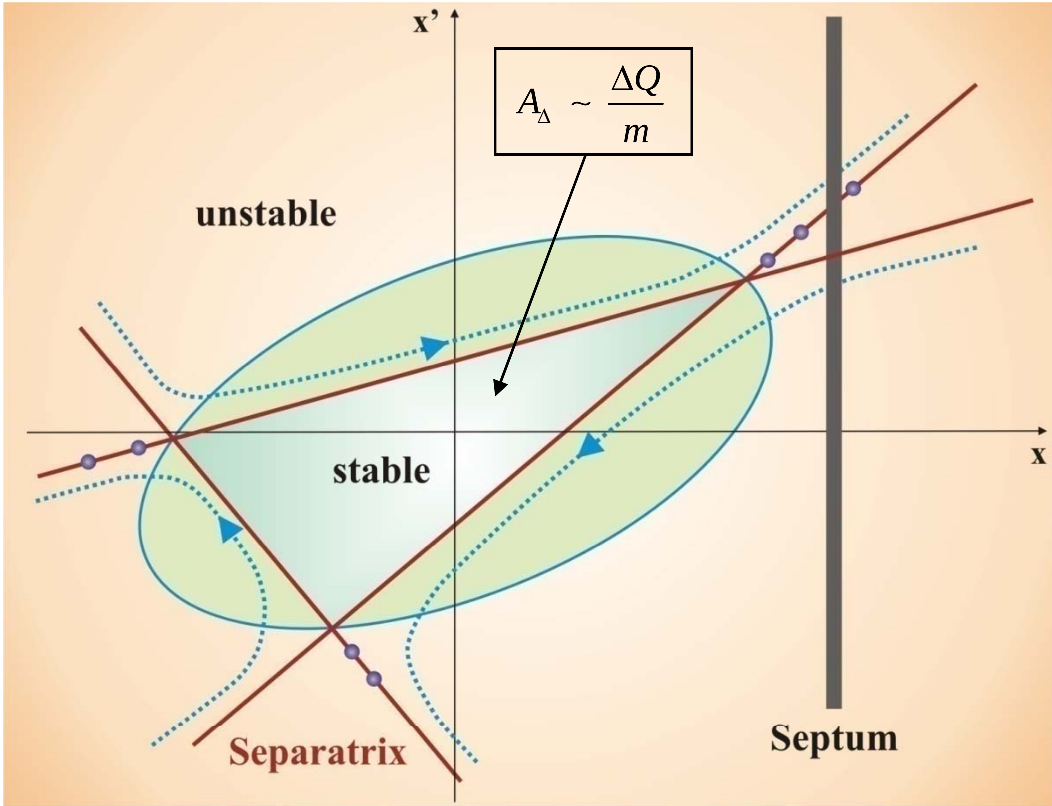
# ELSA: FODO-Lattice




$B_{max}$= 1,07 T @ I = 3100A
$g_{max}$ = 10 T/m @ I = 915A

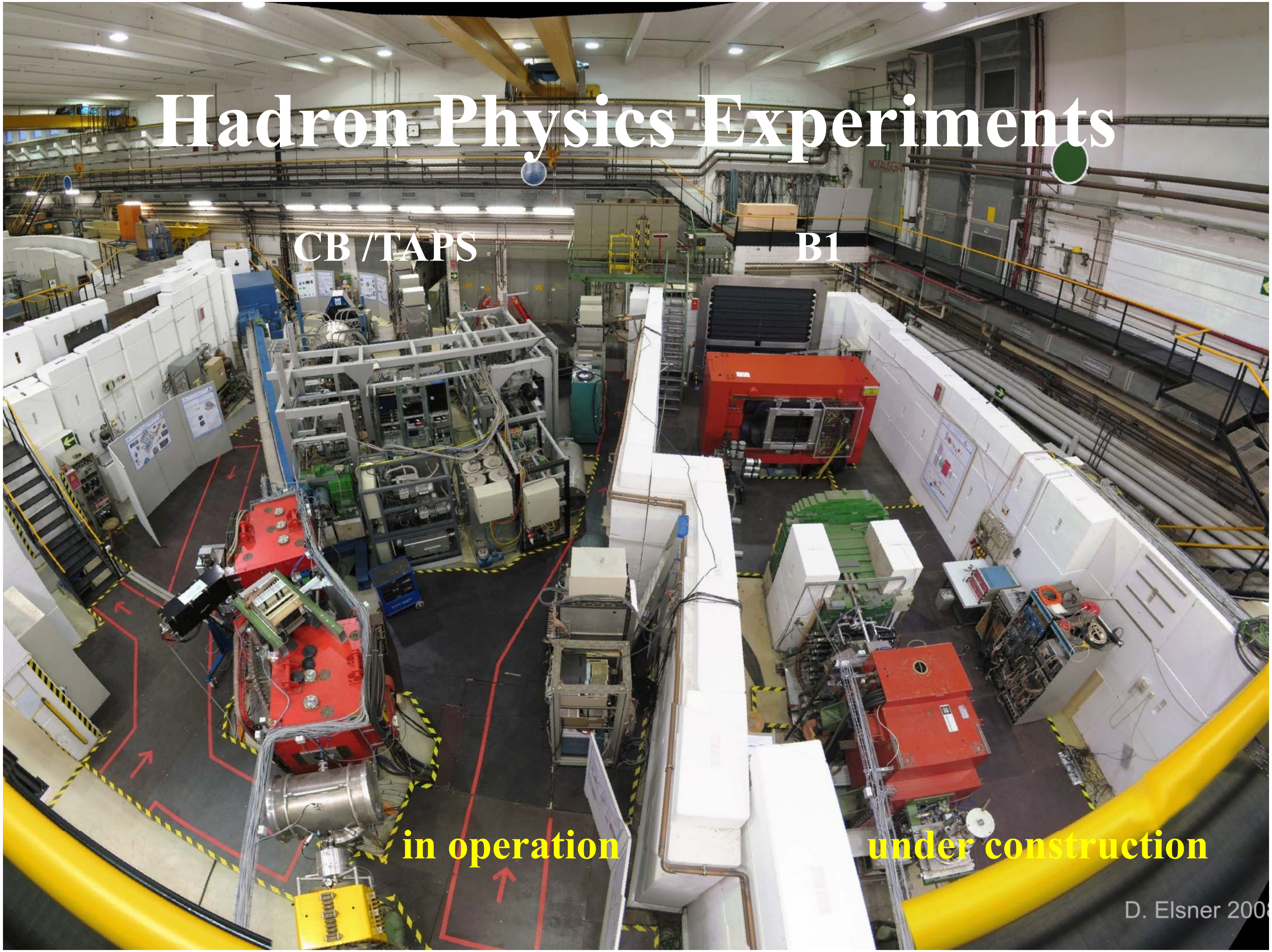
# Slow Extraction




**Extraction Sextupole-Magnets:**
excitation of a 3rd integer resonance

**Extraction Quadrupole-Magnets:**
tune-shift close to a 3rd integer resonance, feedback (TAG-OR) stabilizes the external current


Hadron Physics Experiments
CB /TAPS
B1
in operation
under construction
D. Elsner 200

# Facility Parameters

**External beams of Electrons:**

- **Two (three as of 2009?!) experimental areas**
- **Energy range:** 1.0 GeV < ***E*** < 3.5 GeV
- **Current range:** 10 pA < ***I*** < 1 nA
- **Polarized electrons** available routinely
- **Tagged photon** operation with **linearly and circularly polarized photons**

# Electron Stretcher Accelerator ELSA

Physikalisches Institut

universitätbonn

**Director:** F. Klein

**Head of the Acc. Department:** W. Hillert

**Research Associates:**

F. Frommberger    C. Nietzel

**Operating Engineer:** F.-G. Engelmann

| Radio Frequency | Electro-Installations | Electronics | Mechanics | Vakuum | Technical Infrastructure |
|---|---|---|---|---|---|
| M. Thelen | K.-P. Faßbender | H. Bücking | M. Brock | H. Blank | T. Becker |
| | M. Holzhäuser | A. Dieckmann | B. Neff | J. Karthaus | W. Merfert |
| | P. Mahlberg | M. Humpert | J. Schelske | N. Rick | R. Schulz |
| | H. Schug | R. Müller | | | Aytekin Yildiz |

**PhD Stud.:** A. Balling, M. Eberhardt, F. Klarner, O. Preisner, T. Pusch, A. Roth, J. Wittschen, S. Zander
**Diploma Stud.:** B. Aurand, O. Boldt, D. Heiliger, D. Krönung, S. Patzelt

**Radiation Protection:** S. Goertz (conductor), H. Blank, H. Dutz, F.-G. Engelmann, F. Frommberger, W. Hillert, N. Joepen, D. Walther, M. Lang

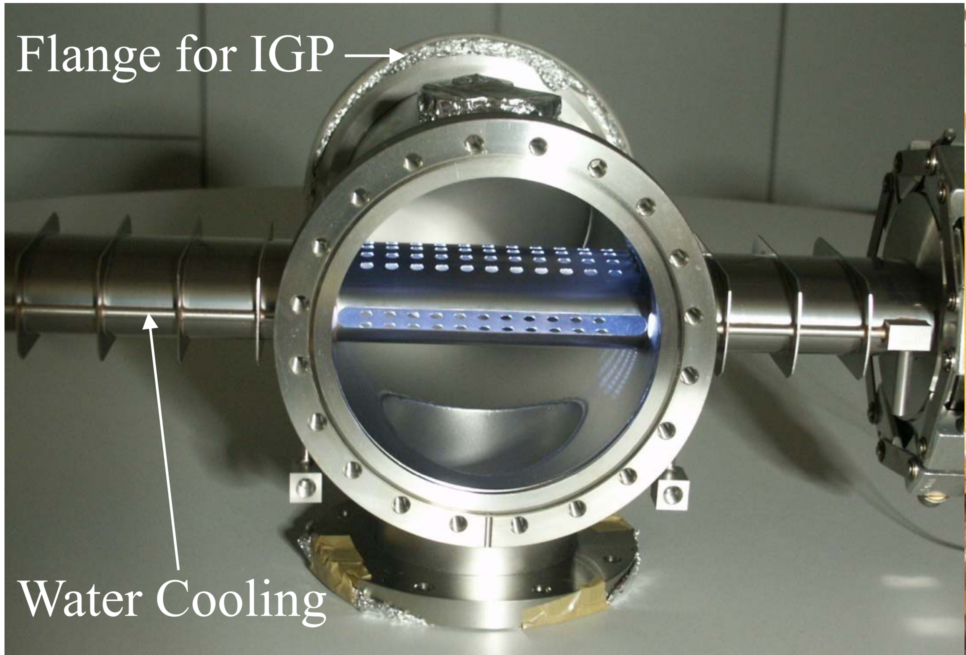
**Laser Protection:** W. Hillert, F.-G. Engelmann

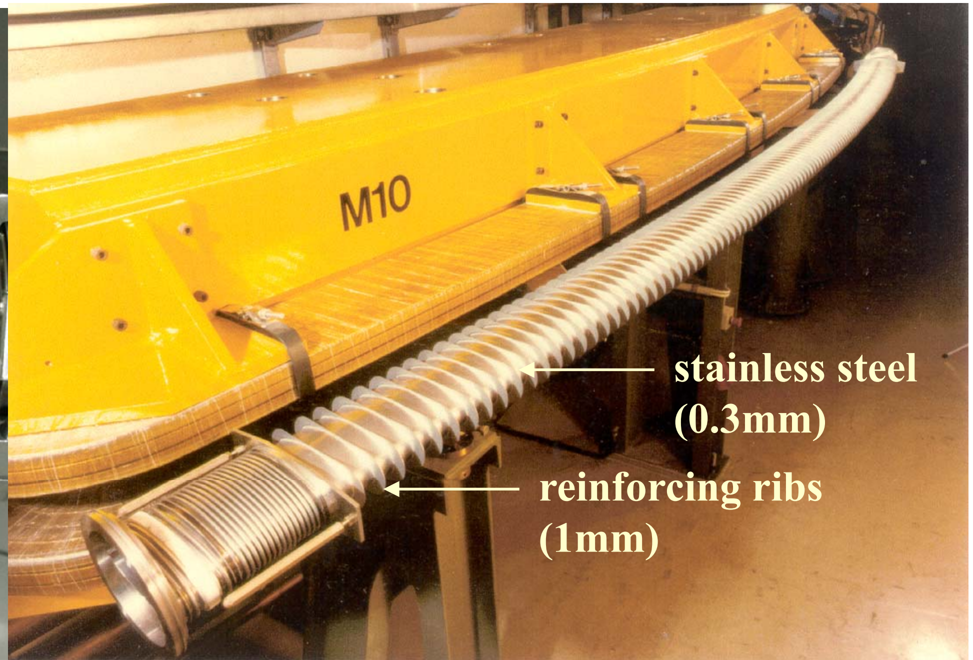
# Research & Development at

- **Accelerator control:** control system developed in house
- **Stretcher operation:** fast ramping and beam extraction
- **Polarized beams:** generation (source) and post-acceleration
- **Beam diagnostics:** position and intensity monitors, polarimetry
- **High current operation:** single and multi bunch instabilities, feed-back

**ELSA / Bonn is participating in the Helmholtz Alliance @ DESY:**
***Physics at the Terascale***: R&D in beam diagnostics and dynamics, electron sources

# “Fast” ramping Stretcher Ring

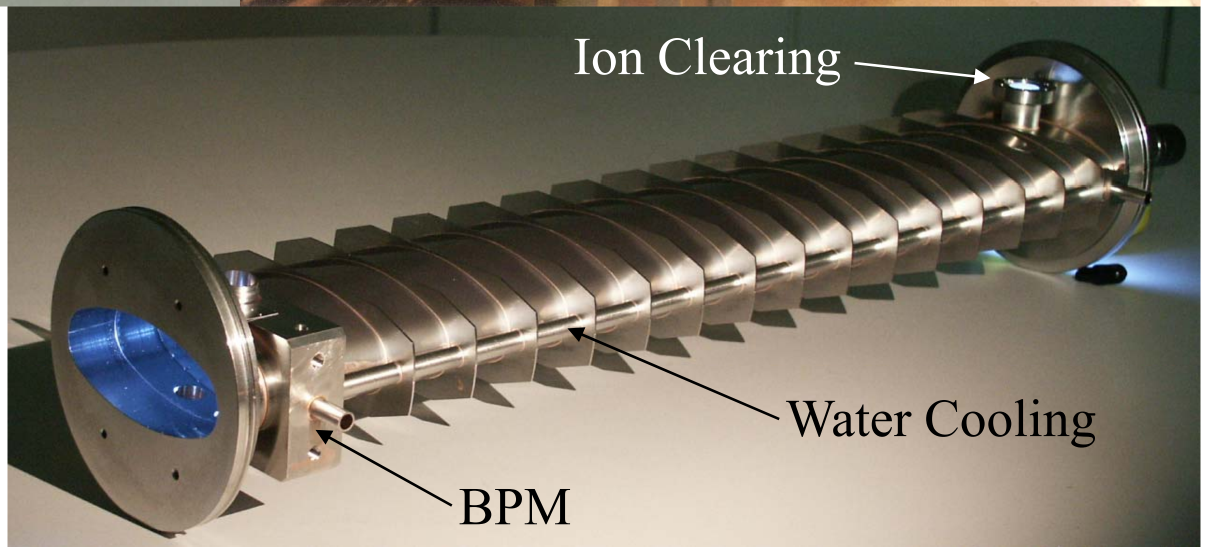



**“Fast” Ramping Operation:**

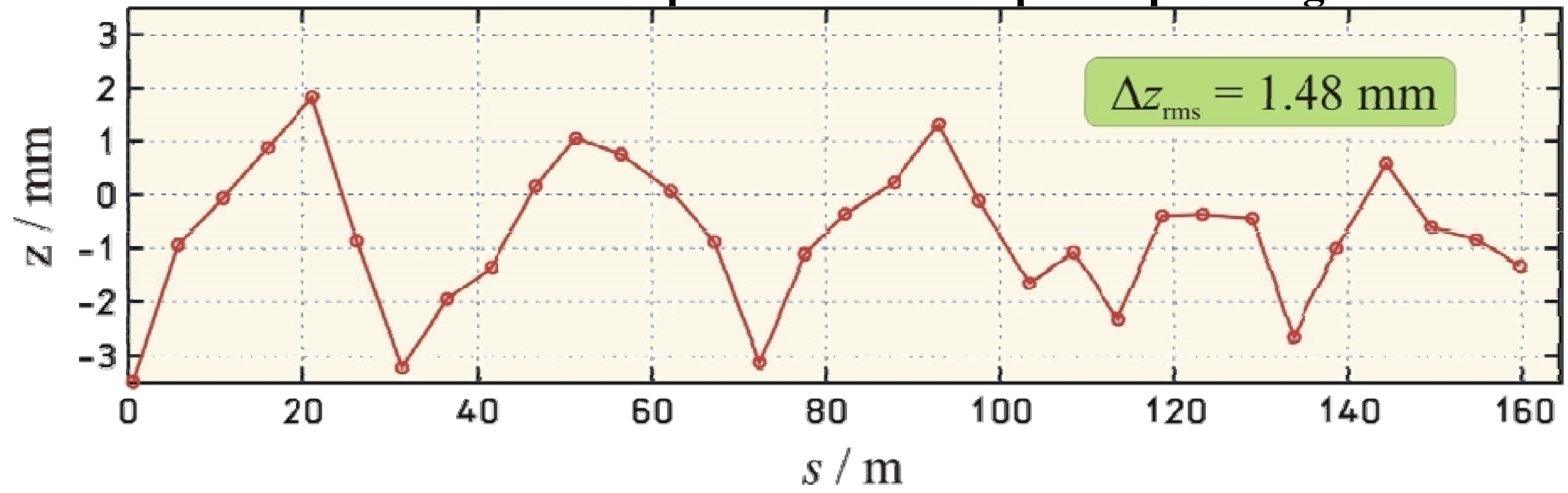
- ➢ $\dot{E} \leq 7.5$ GeV/s
- ➢ $\dot{B} \leq 2.1$ Tesla/s

→ reduction of **eddy currents**

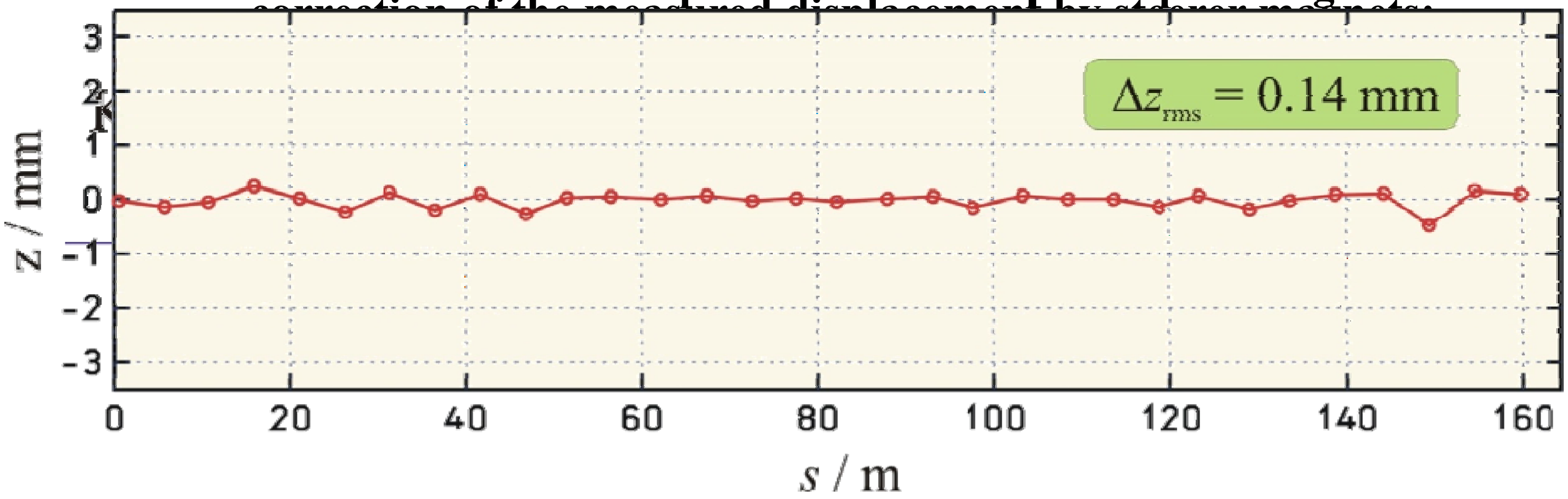


# Closed Orbit

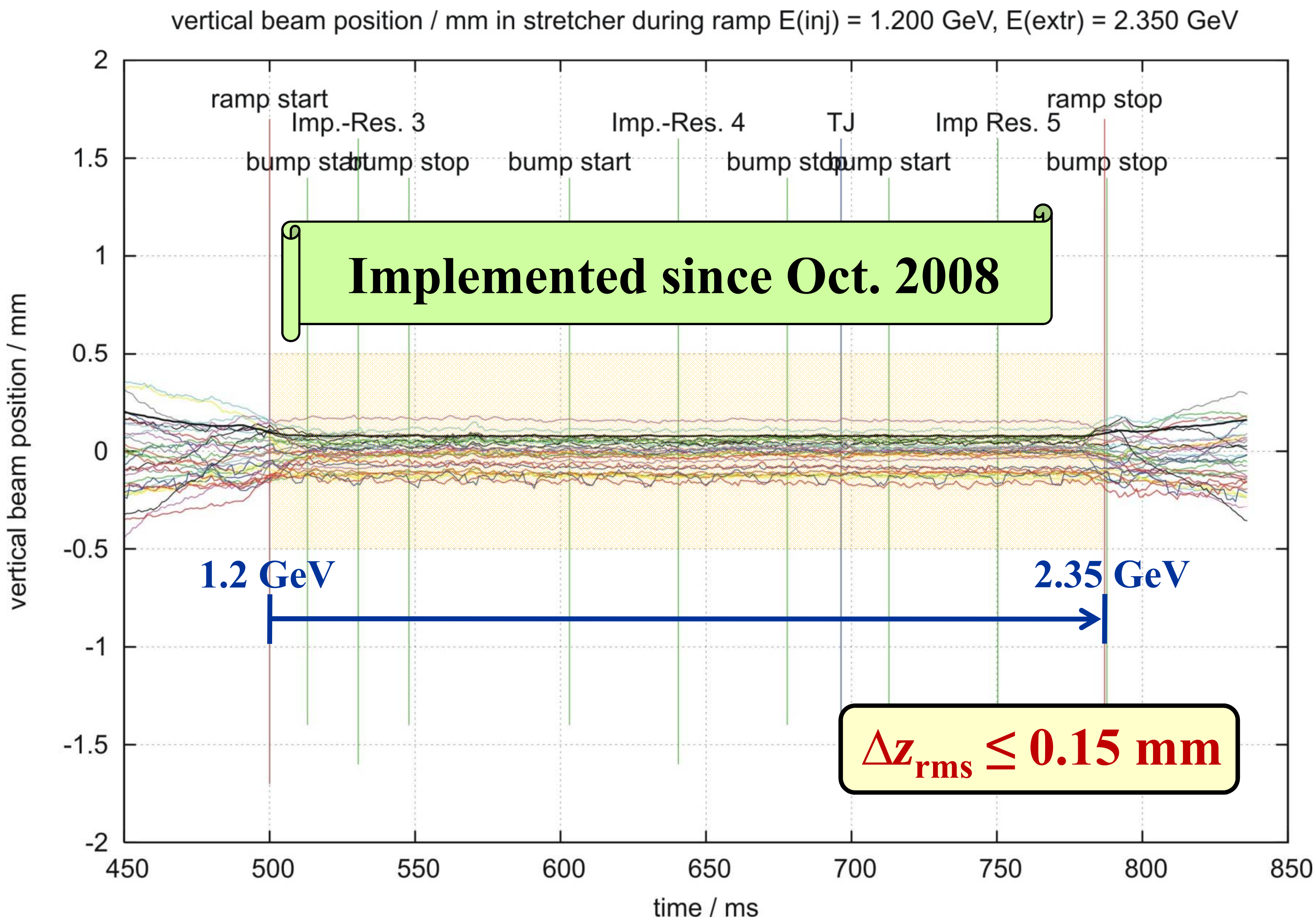
**vertical orbit displacement in the quadrupole magnets**



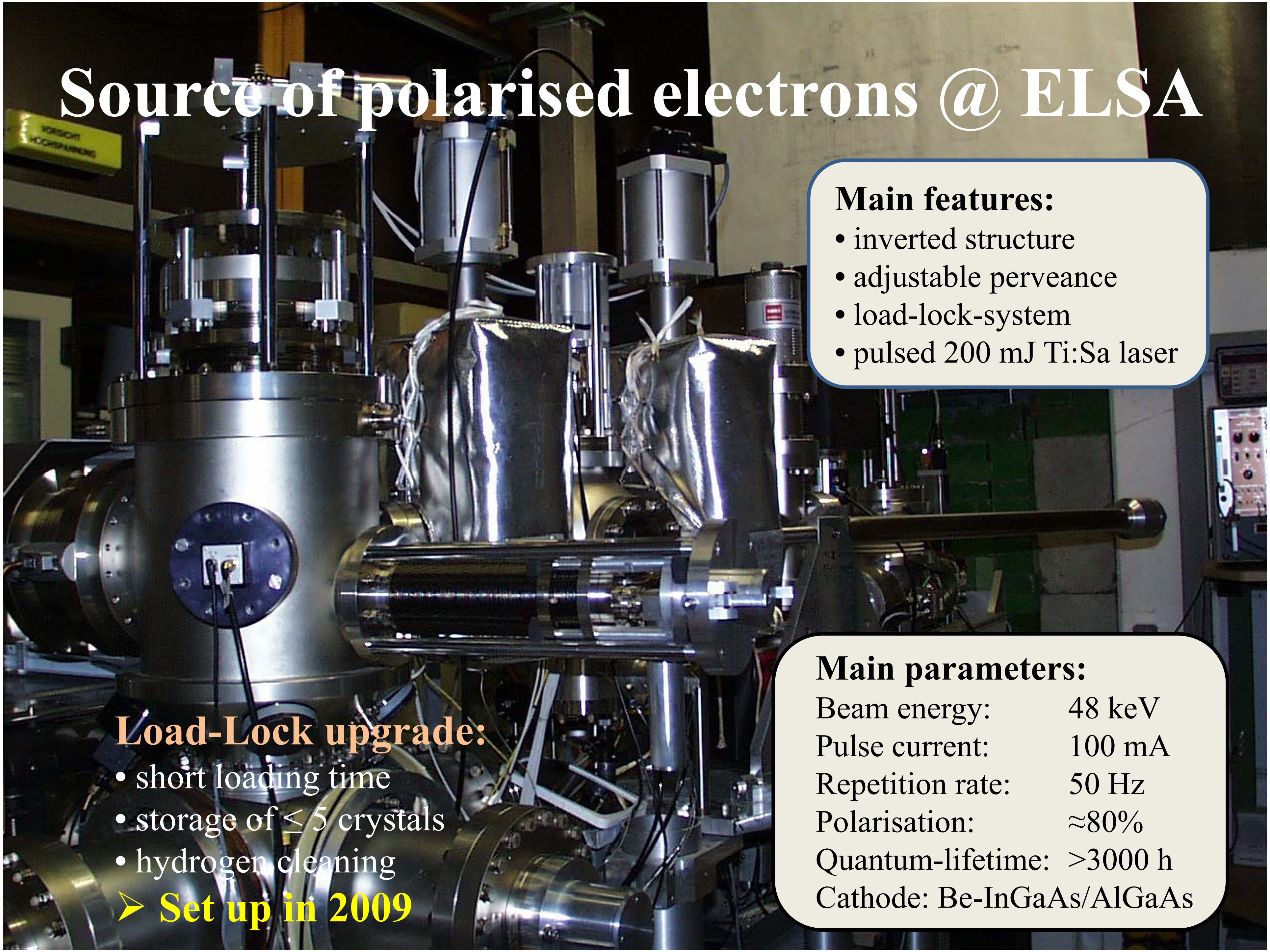

**vertical orbit displacement in the quadrupole magnets**



# Orbit Correction on the Ramp



# Source of polarised electrons @ ELSA



**Main features:**

- inverted structure
- adjustable perveance
- load-lock-system
- pulsed 200 mJ Ti:Sa laser

**Main parameters:**

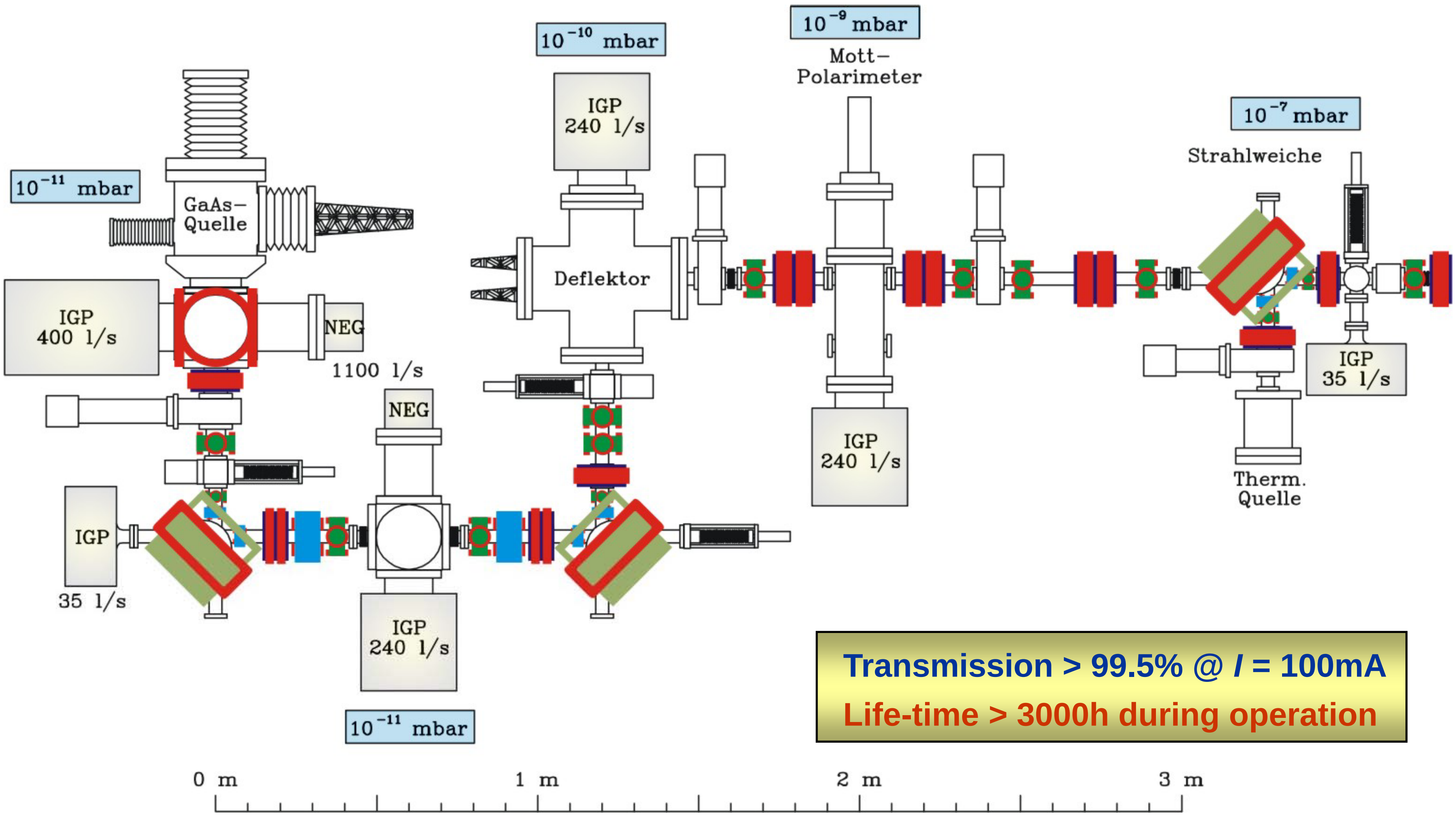
| | |
|---|---|
| Beam energy: | 48 keV |
| Pulse current: | 100 mA |
| Repetition rate: | 50 Hz |
| Polarisation: | ≈80% |
| Quantum-lifetime: | >3000 h |
| Cathode: Be-InGaAs/AlGaAs | |

**Load-Lock upgrade:**

- short loading time
- storage of ≤ 5 crystals
- hydrogen cleaning

➢ **Set up in 2009**

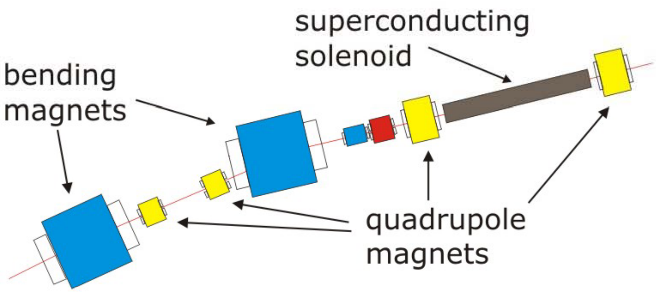
# Low Energy Transfer Line

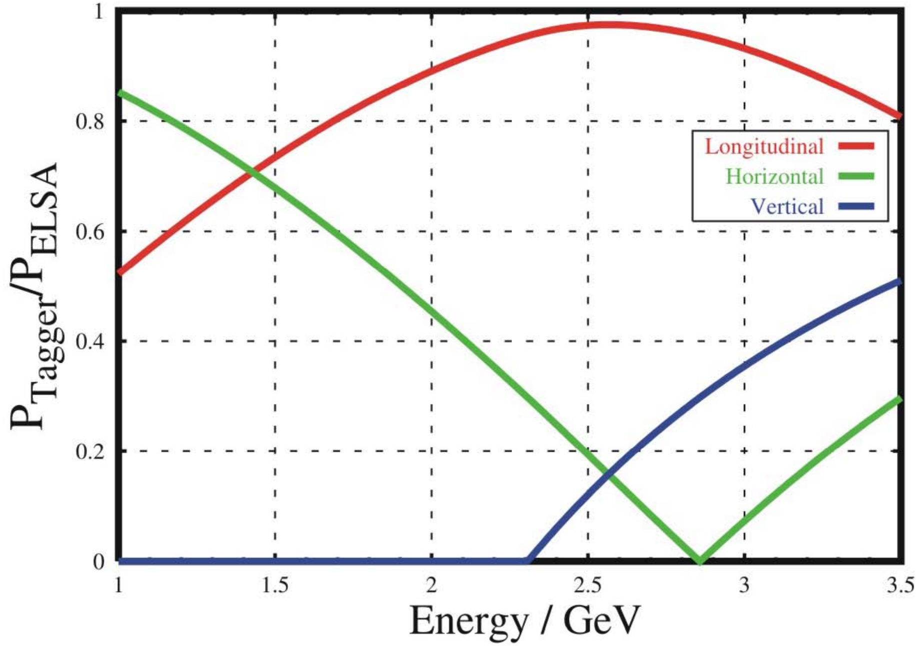



**Transmission > 99.5% @ *I* = 100mA**

**Life-time > 3000h during operation**


# Spin Rotation II

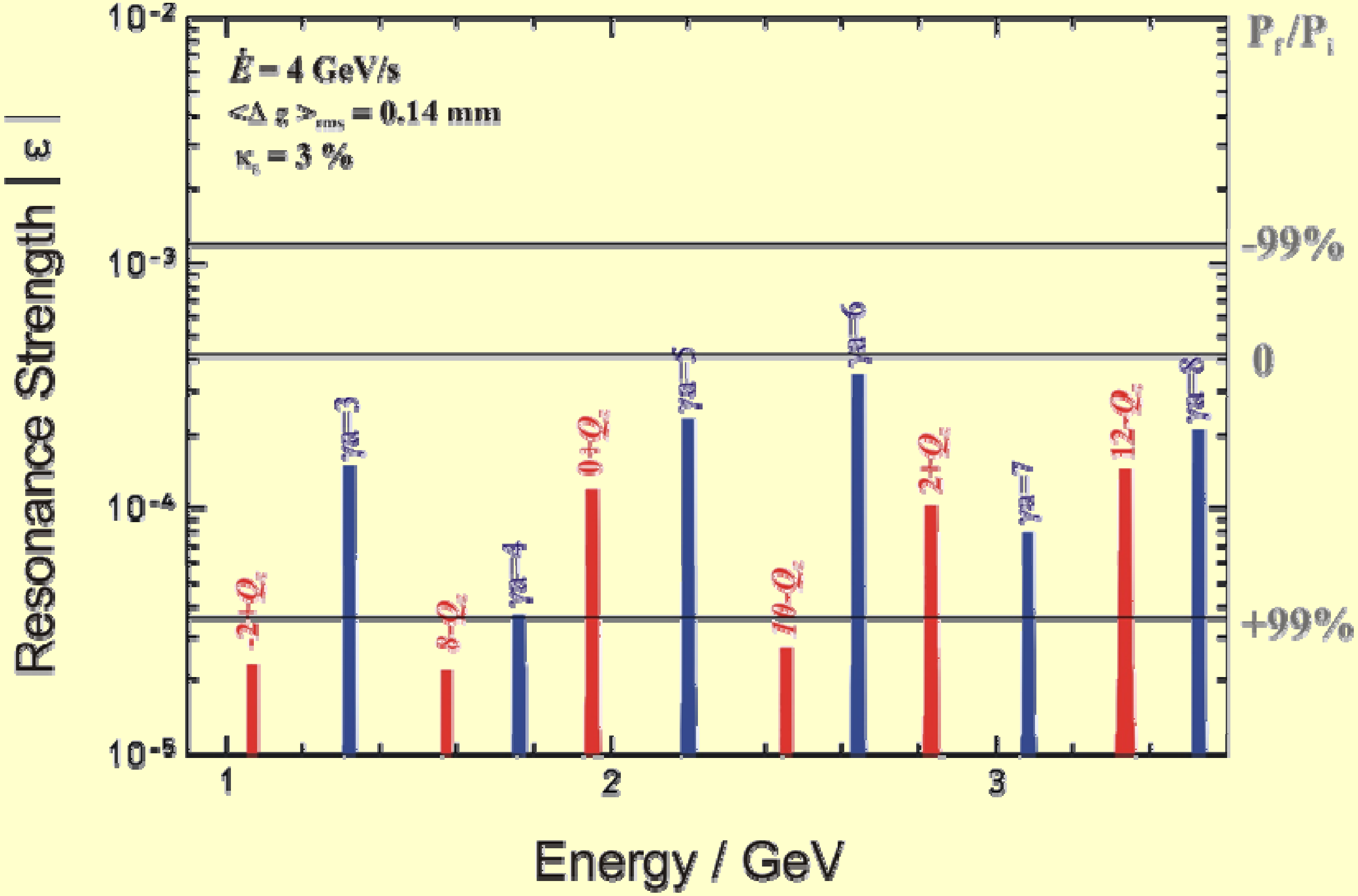




**Spin Transfer to the Tagger of the GDH Experiment**

Lamor Precession $$\Delta\phi = -\frac{e}{m_0 c}\cdot\frac{1+a}{\sqrt{\gamma^2-1}}\cdot\int B_s(s)\cdot ds$$

Thomas Precession $$\Delta\phi = \gamma\cdot a\cdot\vartheta$$

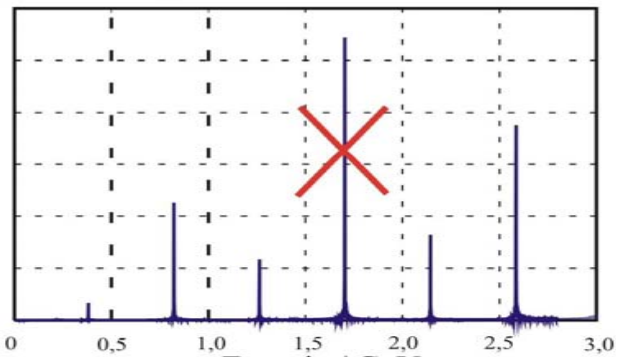
## Depolarizing Resonances @ ELSA

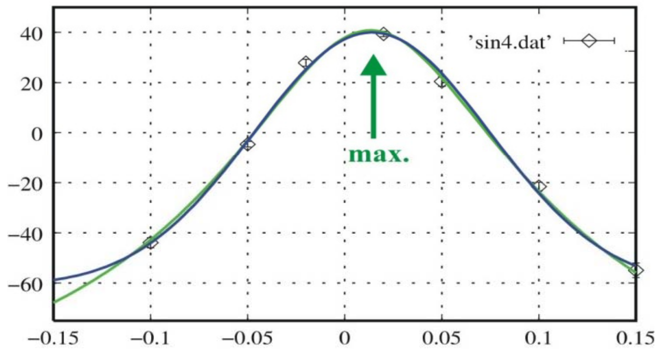


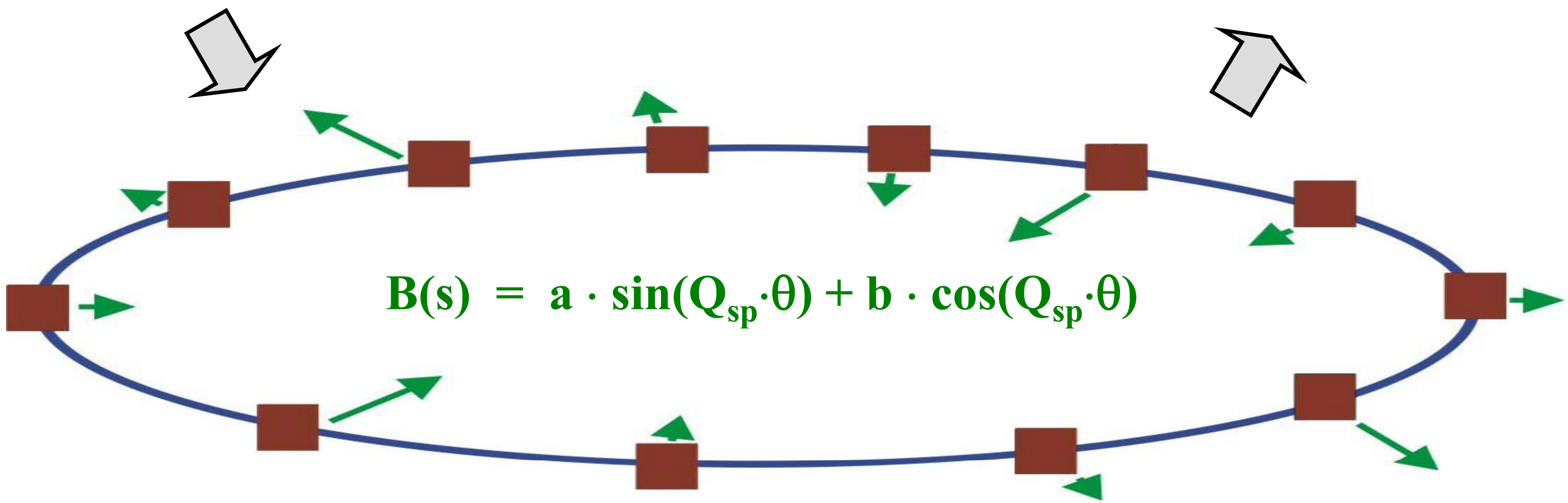

intrinsic resonances: $\gamma a = nP \pm Q_z, \quad n \in Z$

# Harmonic Correction

## (Imperfection Resonances)

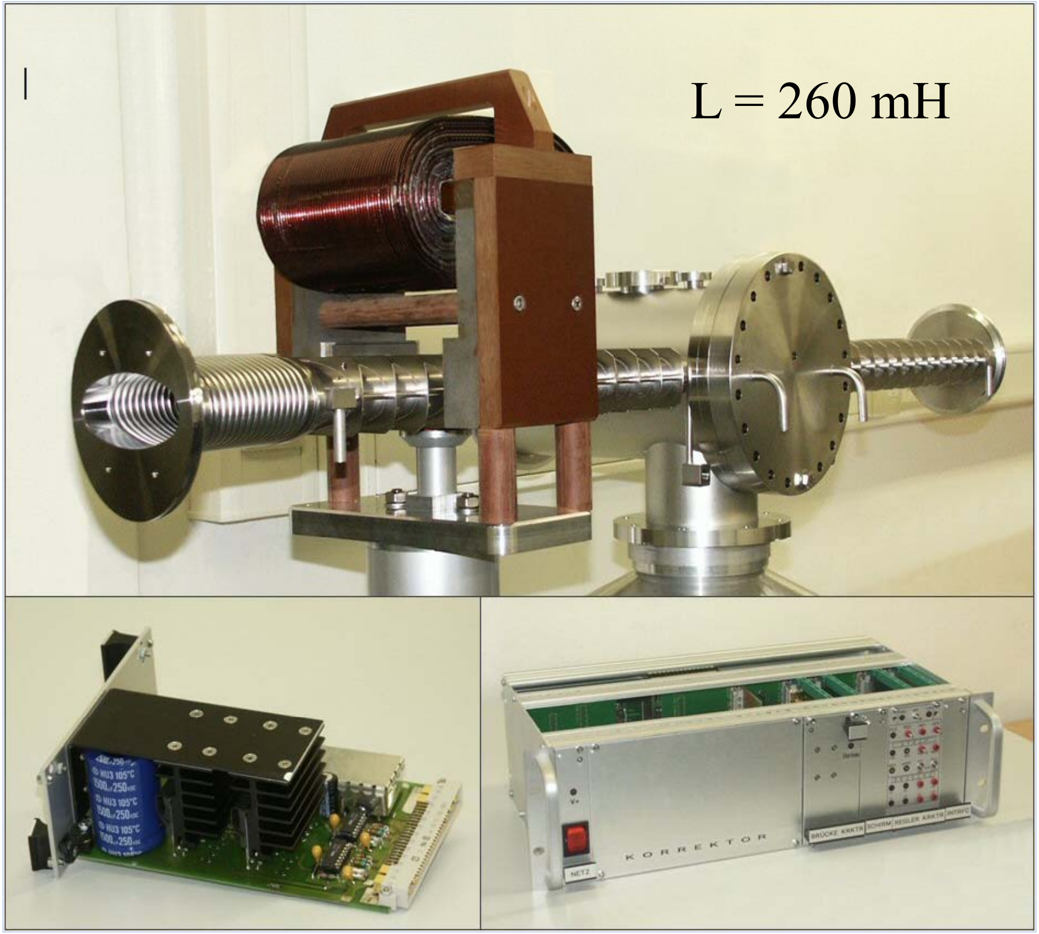


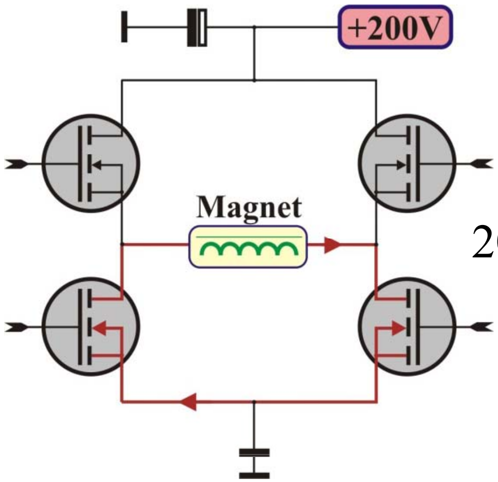
# Orbit Correction System

**New corrector magnet & fast switching power supply**




Beam pipe optimized for eddy current suppression

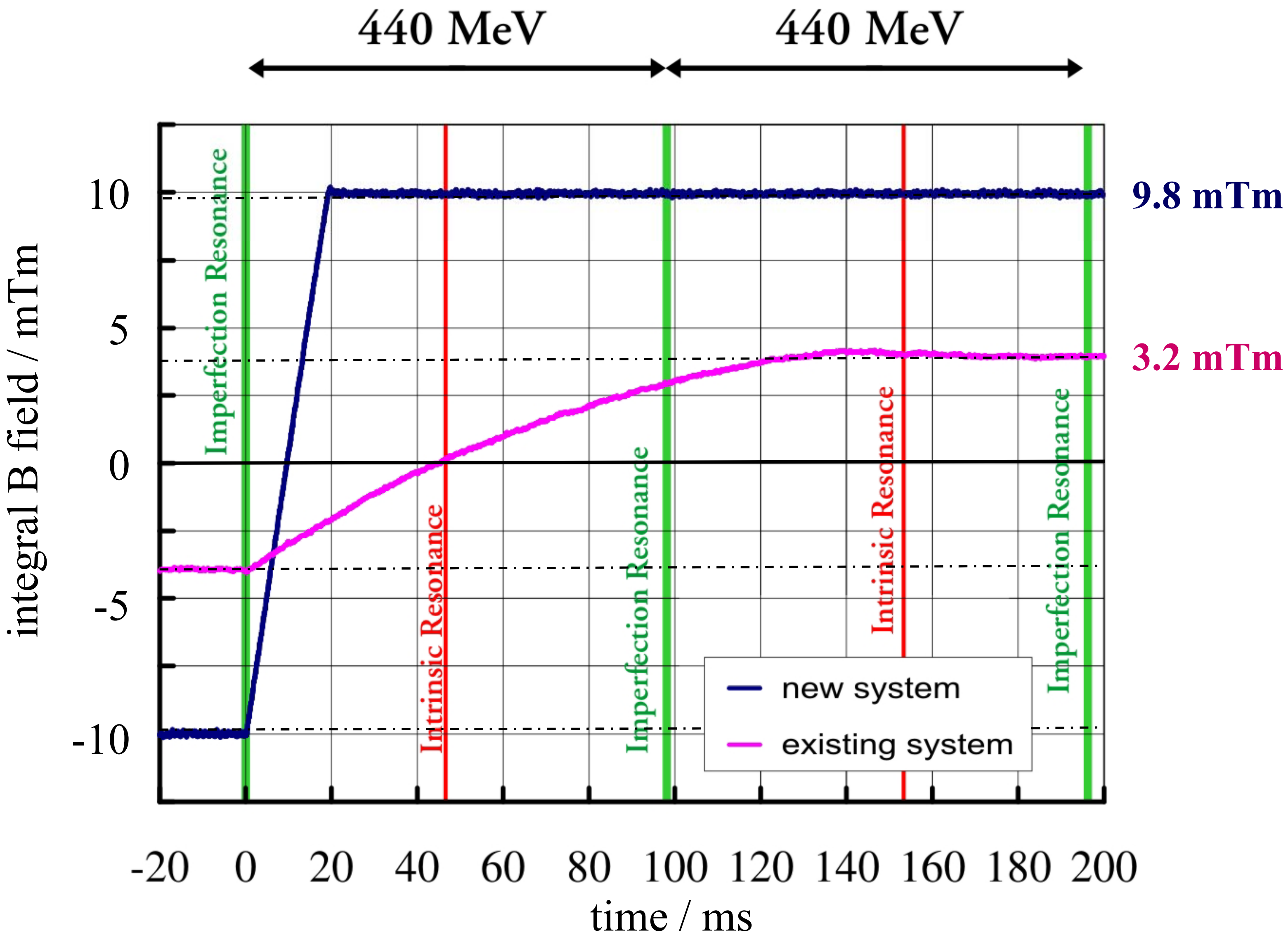
Programmable 4-quadrant power supply with microcontroller




20 kHz

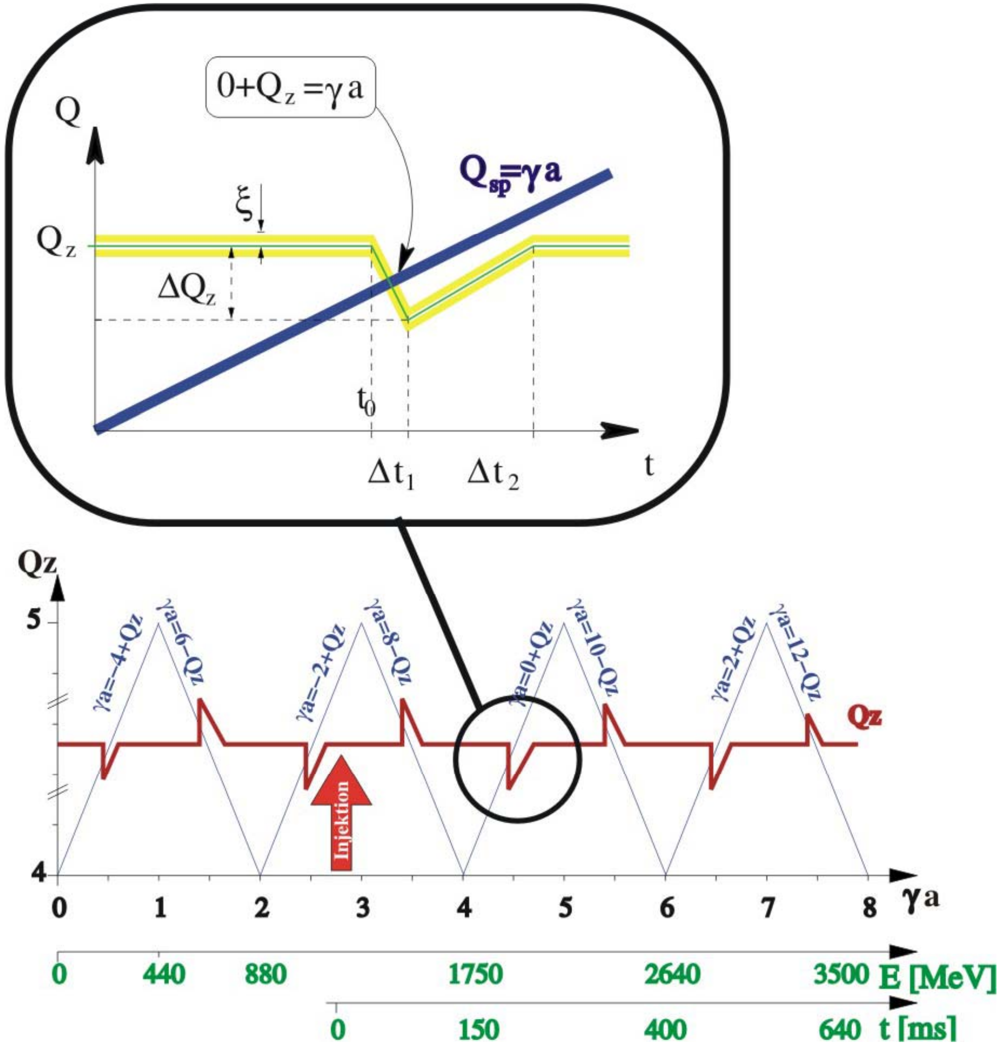
**Implementation in 2009**

# Orbit Correction System

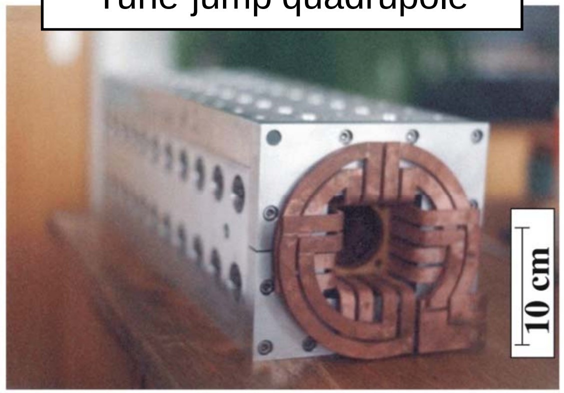


# Tune Jumping

## (Intrinsic Resonances)



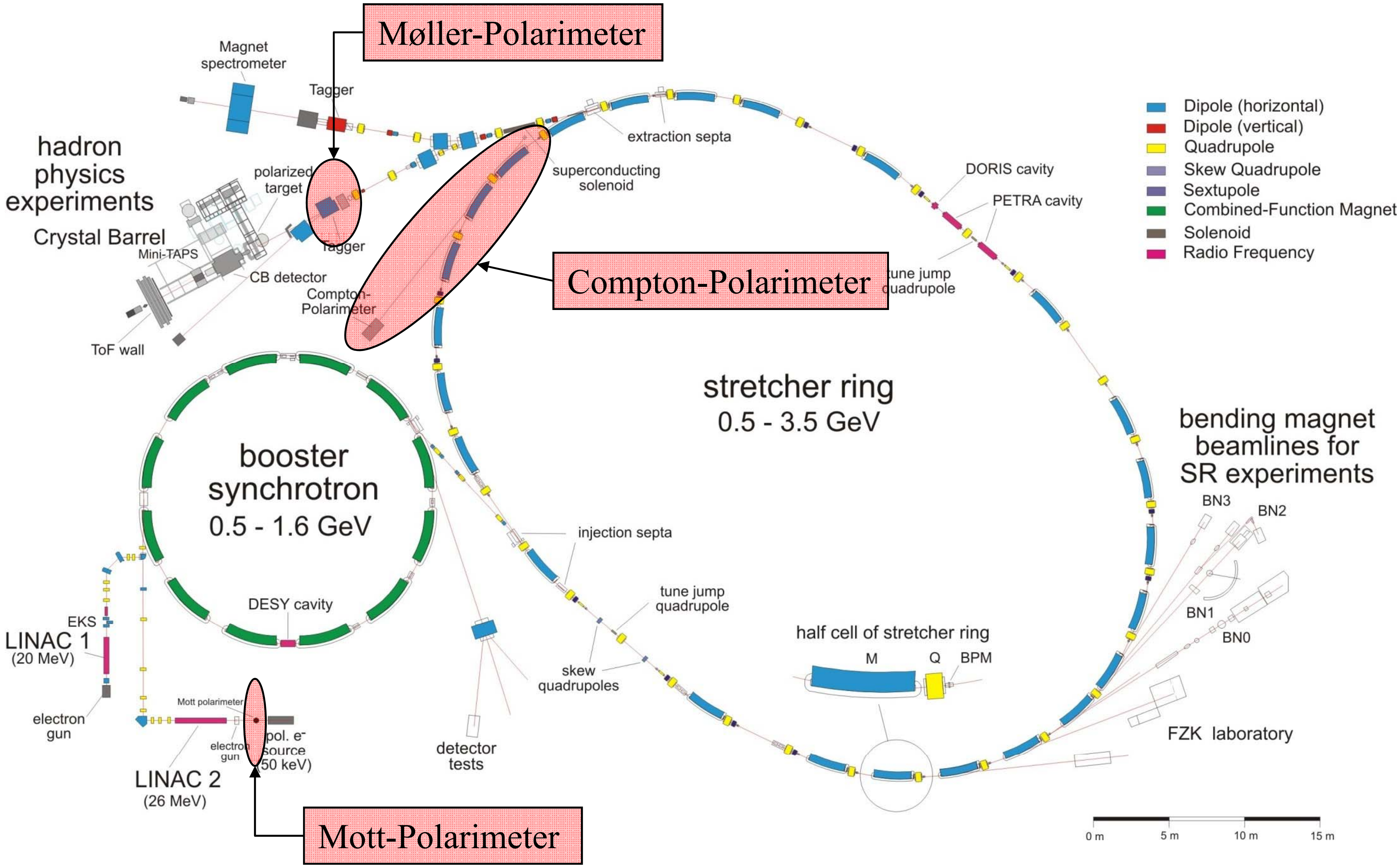

Tune-jump quadrupole



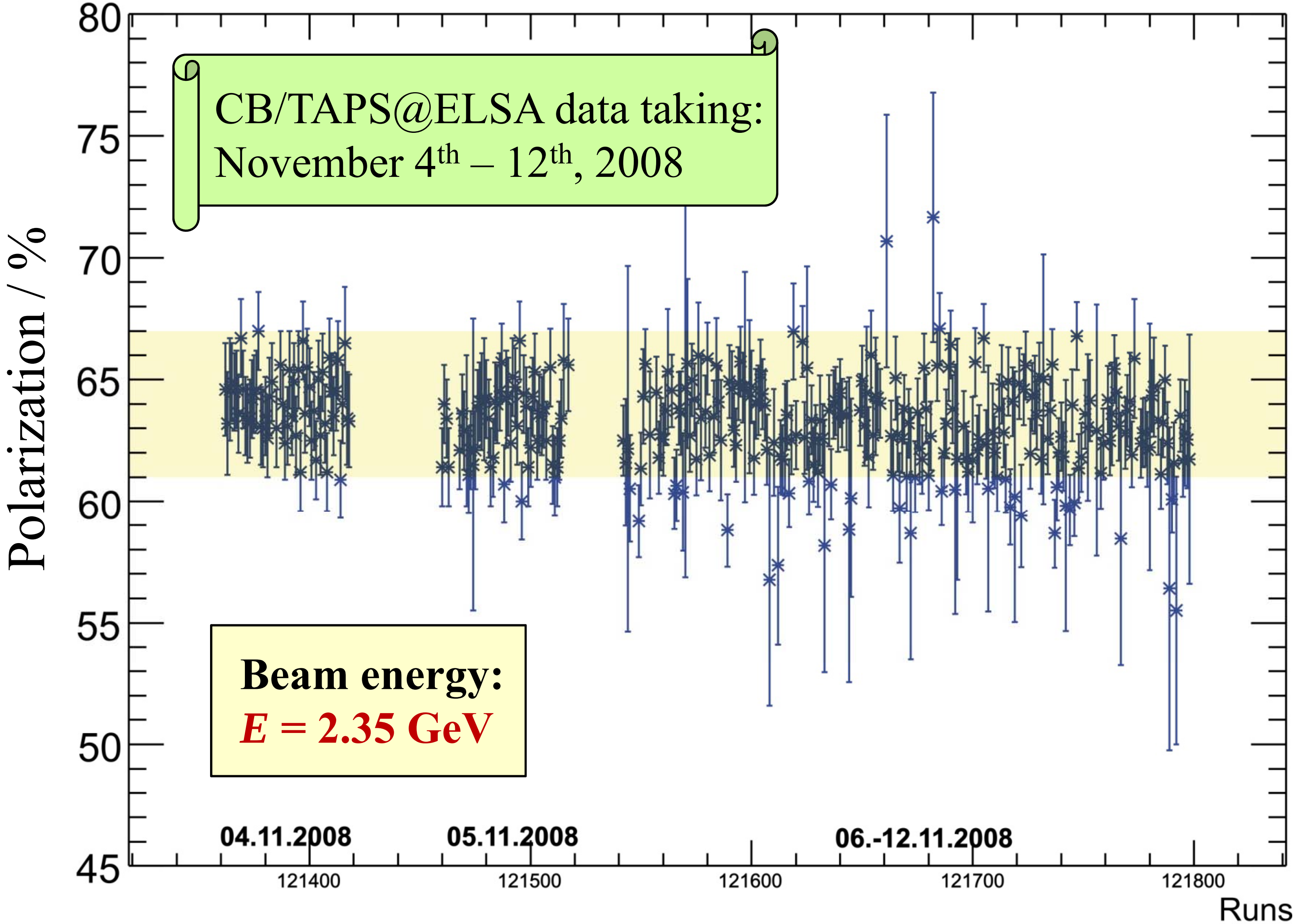

Panofsky-type quadrupole with ferrite yoke

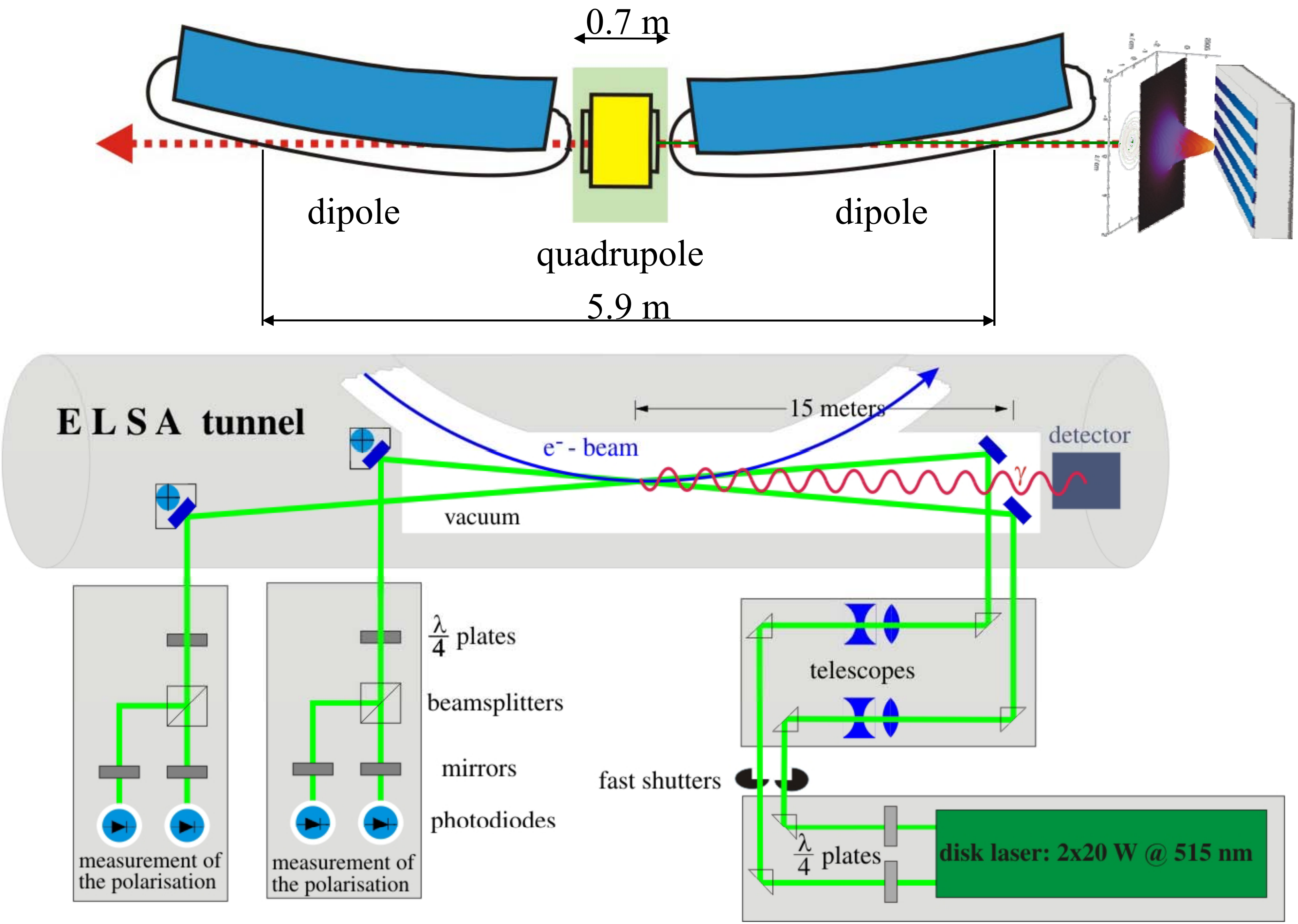
| | |
|---|---|
| Vacuum chamber: | $Al_2O_3$ ceramics with 10 μm titanium coating |
| Resistivity: | (4.298 ± 0.001) mΩ (DC) |
| Inductivity: | (9.0 ± 0.1) μH (DC) |
| Max. pulse current: | 500 A |
| Max. field gradient: | (1.1241 ± 0.005) T/m |
| Rising edge: | 4 – 15 μs |
| Falling edge: | 4 – 20 μs |

# Electron Stretcher Accelerator (ELSA)

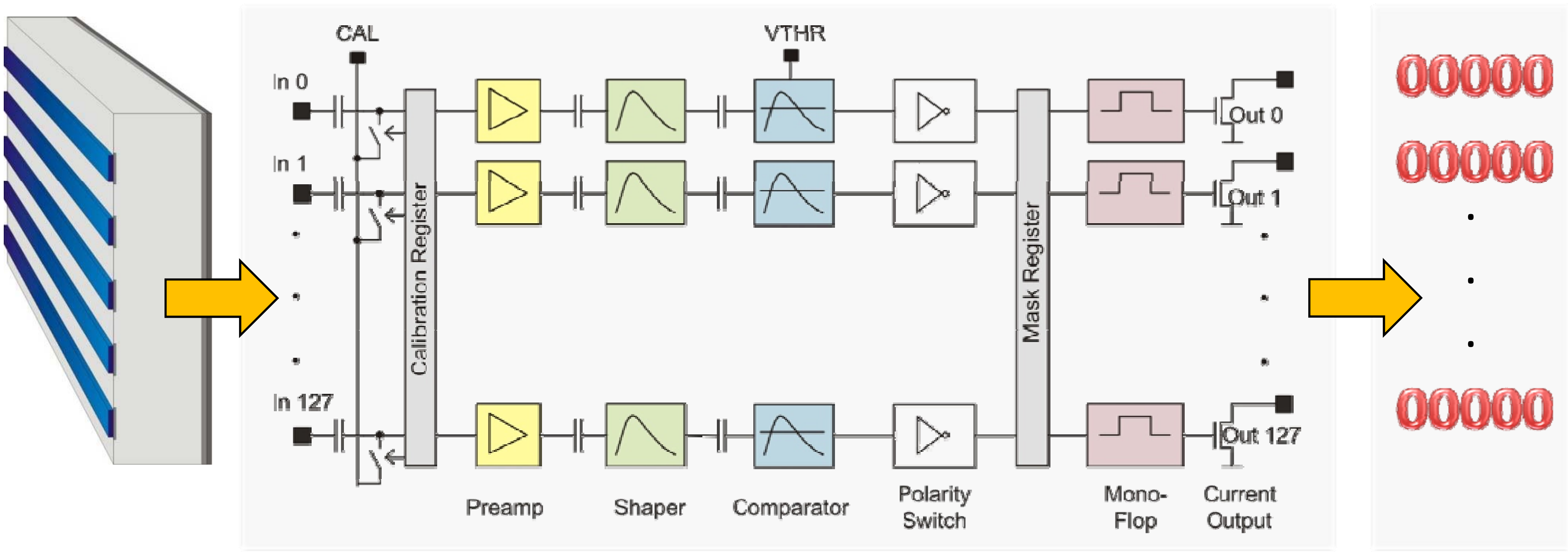


# Achieved Polarization




0.7 m
dipole
quadrupole
dipole
5.9 m
E L S A tunnel
15 meters
e⁻ - beam
detector
γ
vacuum
λ/4 plates
beamsplitters
mirrors
photodiodes
measurement of the polarisation
measurement of the polarisation
telescopes
fast shutters
λ/4 plates
disk laser: 2x20 W @ 515 nm

# Counting Microstrip Detector

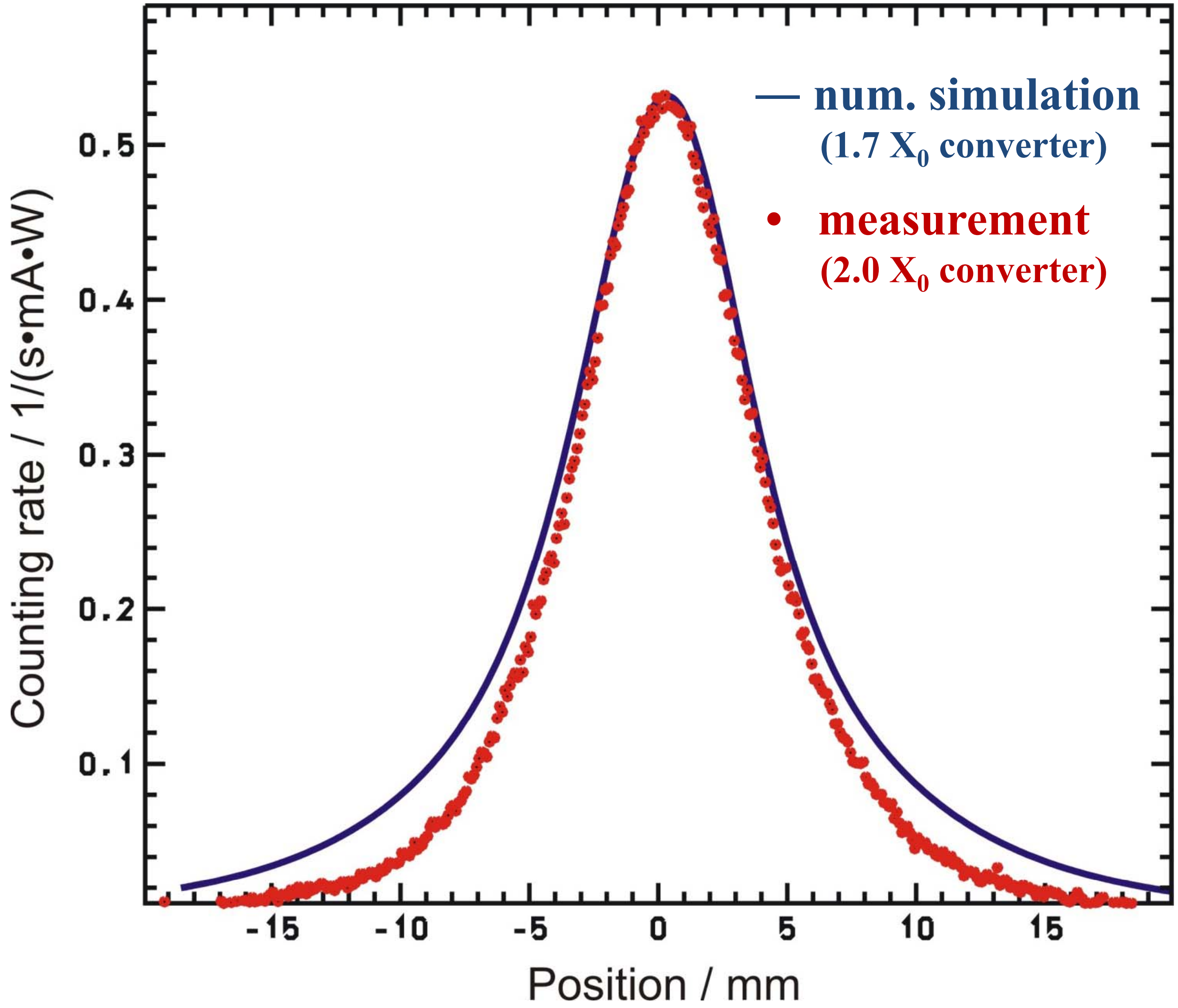



**Detector:** (BABAR 1)
- 768 strips
- 50 µm pitch
- ➢ **resolution 14 µm**

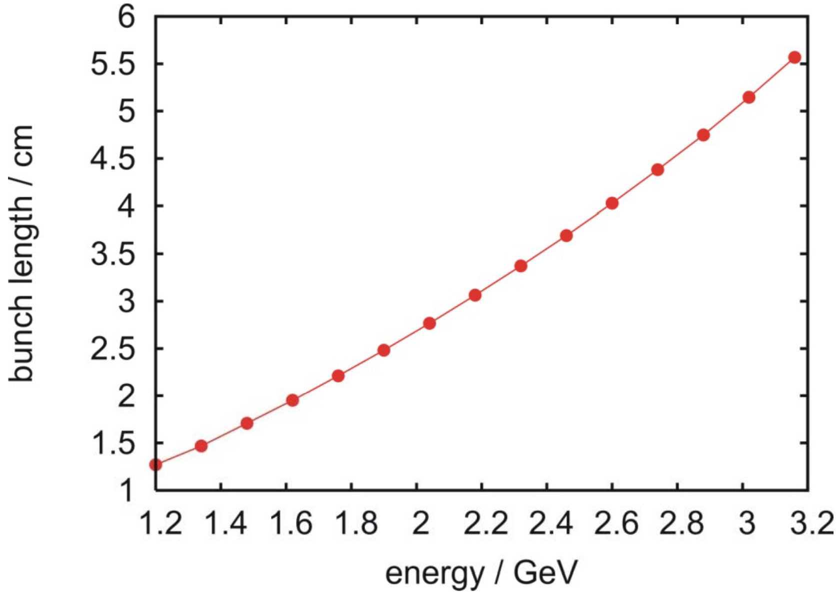
**6 front-end chips:** amplifier, shaper, discriminator, counter
- high rate acceptance (10 - 150 MHz, single channel!)
- digital part built in LVDS technology
- FPGA controlled

***Developed in close collaboration with ATLAS pixel-detector group of Prof. N. Wermes, PI Bonn***

# Beam Profile

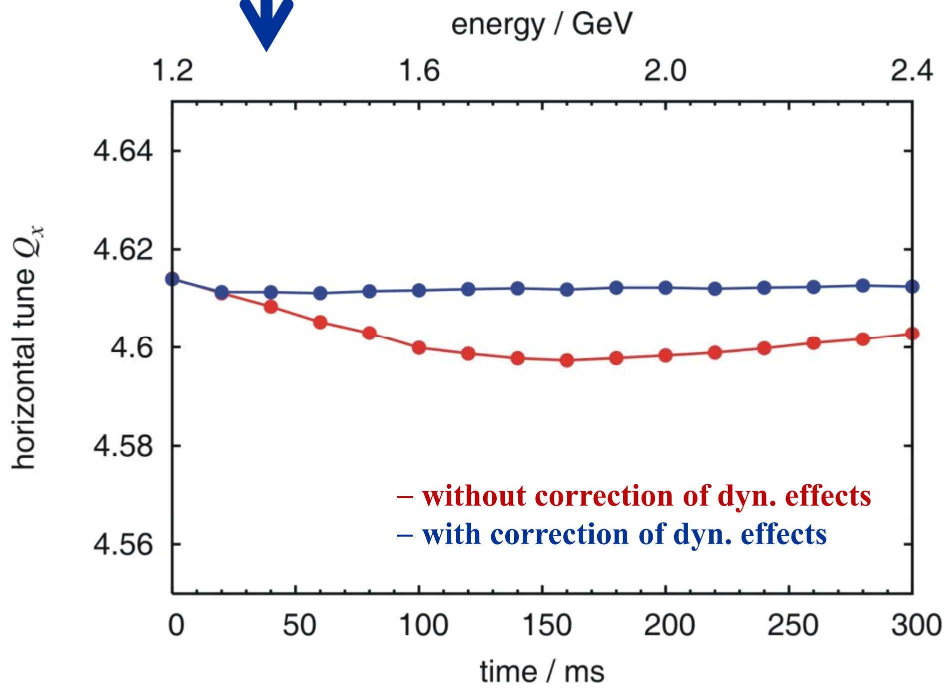


# Tune Measurements and Stabilization on the Ramp



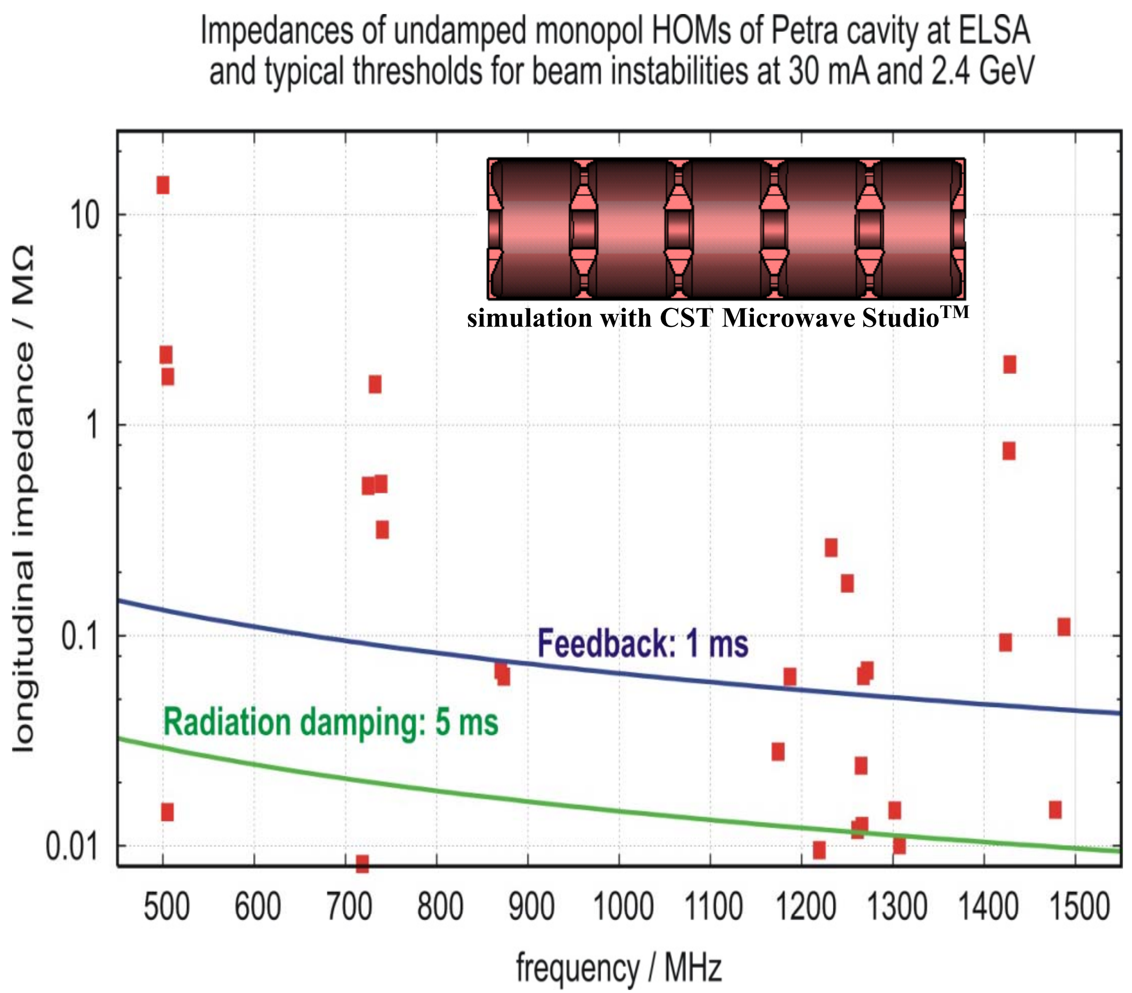

**Excitation of coherent oscillations on the fast energy ramp:**

- kicker magnets
- RF phase jumps




- Design of tune kickers
  (num. simulations with CST™)
- Tune kicker power supplies
  (in collaboration with co. PPT)

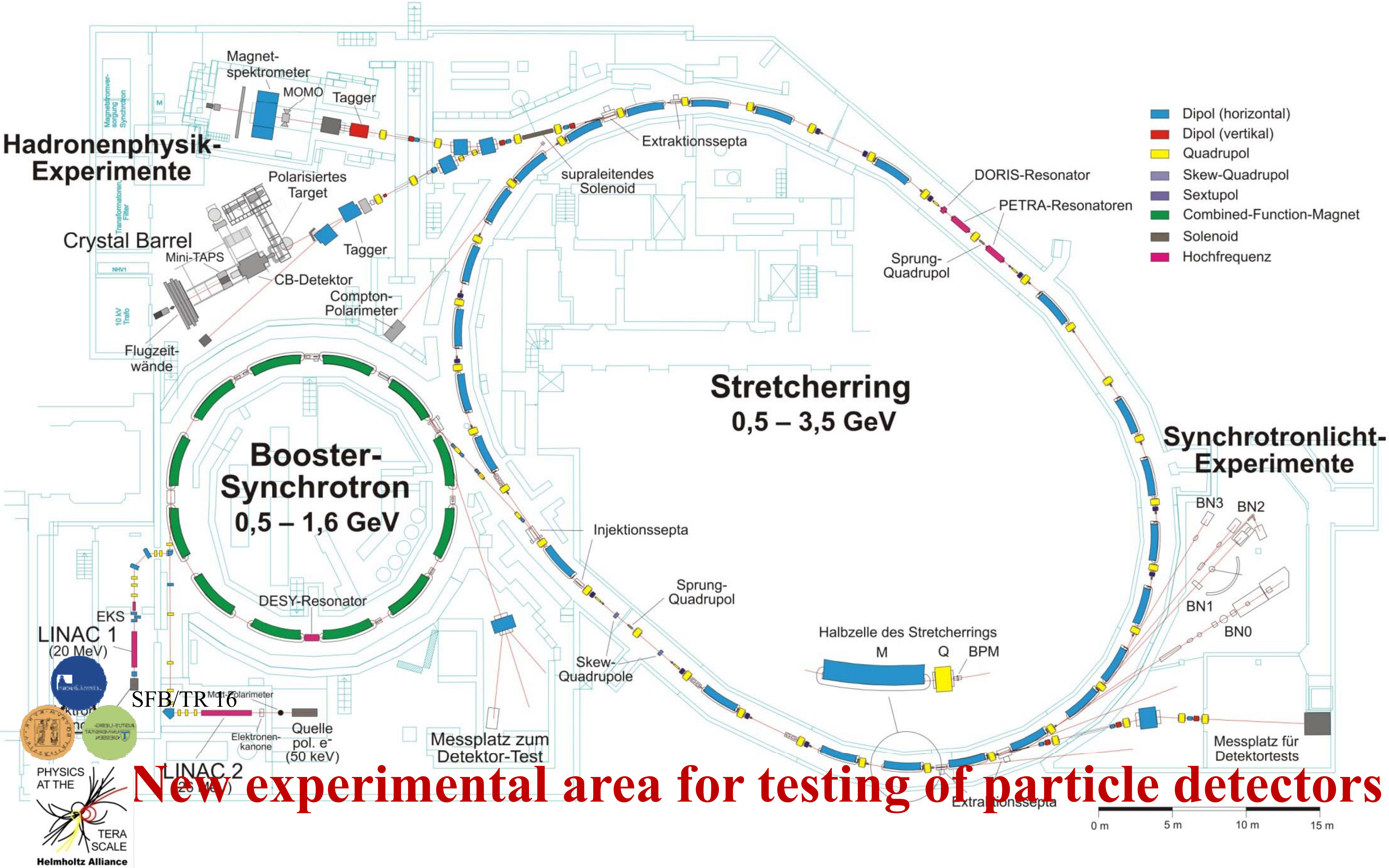
# High Current Operation




**<u>Single and multi bunch operation:</u>**

- investigation of instabilities
- influence of cavity HOM's
- methods of HOM damping
- multi bunch feed-back system
- ion clearing

# Elektronen-Stretcher-Anlage (ELSA)




**New experimental area for testing of particle detectors**

# Design Study Energy Upgrade

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

## Superconducting RF Cavities in a fast ramping strecher:

- ✓ two 5-cell resonators 500MHz JAERI-type: $U_{Cav} \leq 4.5$ MV/m
- ✓ standard parameters: $Q_0 = 2 \cdot 10^9$, $R_s = 10^{11}\Omega$, $Q_{ext} = 4 \cdot 10^6$, $\beta = 540$
- ✓ generator power: $P_g \leq 260$ kW, power input coupler: $P_{cp} \leq 130$ kW
- ✓ maximum detuning: $\Delta f \leq 3.5$ kHz, overvoltage factor: $q \leq 50$
- ➢ **large number of HOM's need to be damped, HOM-coupler design!**

## Magnet Optics and Dynamic Aperture:

- ✓ geometric aperture sufficient for 5 GeV
- ✓ dynamic aperture ok, 4 additional sextupoles may be required
- ➢ **dipole magnets have to be replaced by stronger ones (1.5 T)**

# Conclusions

## Operation of ELSA for hadron physics experiments:

- serves two experimental areas with large acceptance detectors
- well suited energy range 1.0 – 3.5 GeV
- polarized beams, high beam pointing stability

## Accelerator Physics R&D at ELSA:

- generation and acceleration of polarized electrons
- beam dynamics in a fast ramping stretcher ring
- advanced beam diagnostics and polarimetry
- operation with high currents: ion clearing, HOM's suppression, multi bunch feed-back system