R&D at the Electron-Stretcher Accelerator

ELSA

"Clients":

CB-ELSA

TAPS

B1

PT

panda

Belle II

Status, Goals, Projects

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Physikalisches Institut der
universitätbonn

Funding:

universitätbonn

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

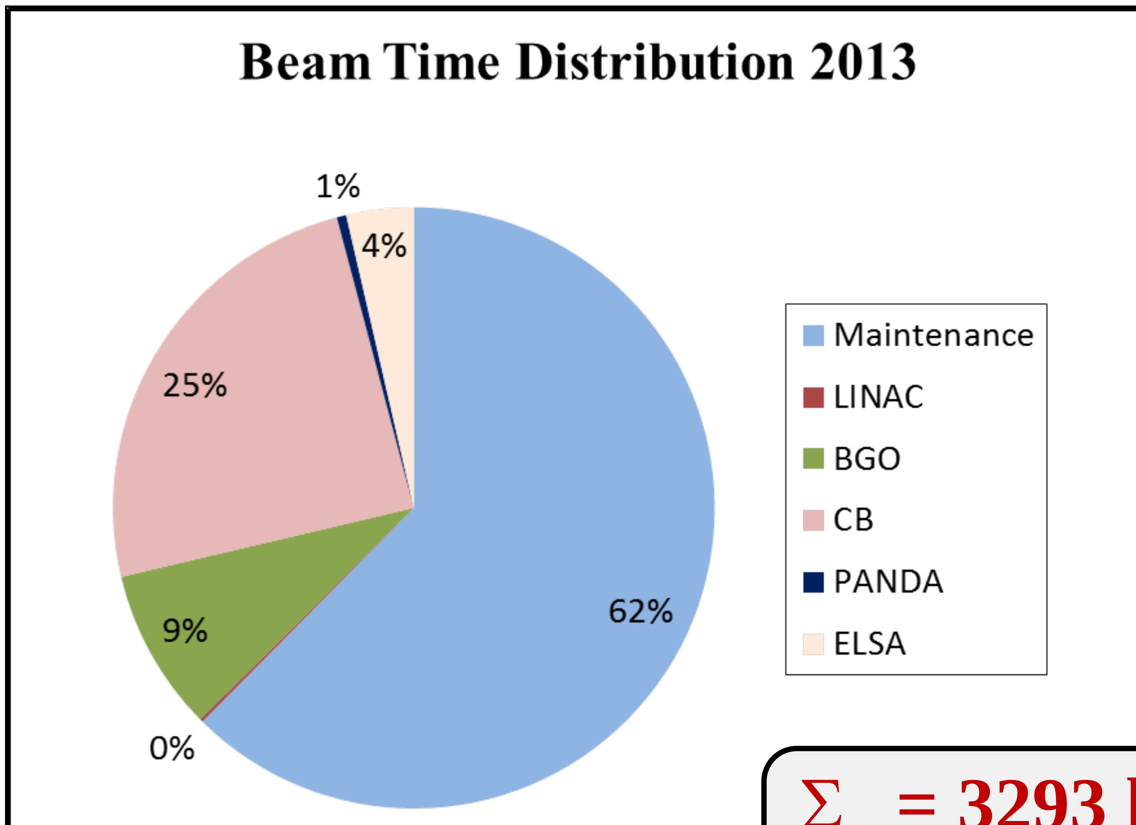
DFG-SFB/TR16

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Bundesministerium für Bildung und Forschung
Spindynamik in Leptonen-Beschleunigern

ELSA - Statistics:

- **CB:** **Σ=2152**
  Apr: 15h
  Jul: 285h
  Aug: 375h
  Sep: 211h
  Oct: 436h
  Nov: 519h
  Dec: 313h
- **BGO:** **Σ=766**
  Feb: 107h
  Mar: 7h
  May: 46h
  Jul: 106h
  Sep: 165h
  Nov 146h
  Dec: 190h
- **PANDA:** Jun: **Σ=69**
- **ELSA:** **Σ=317**



Target and HEP @ LINAC I: 14 h

Σ = 3293 h
/ = 3610 h

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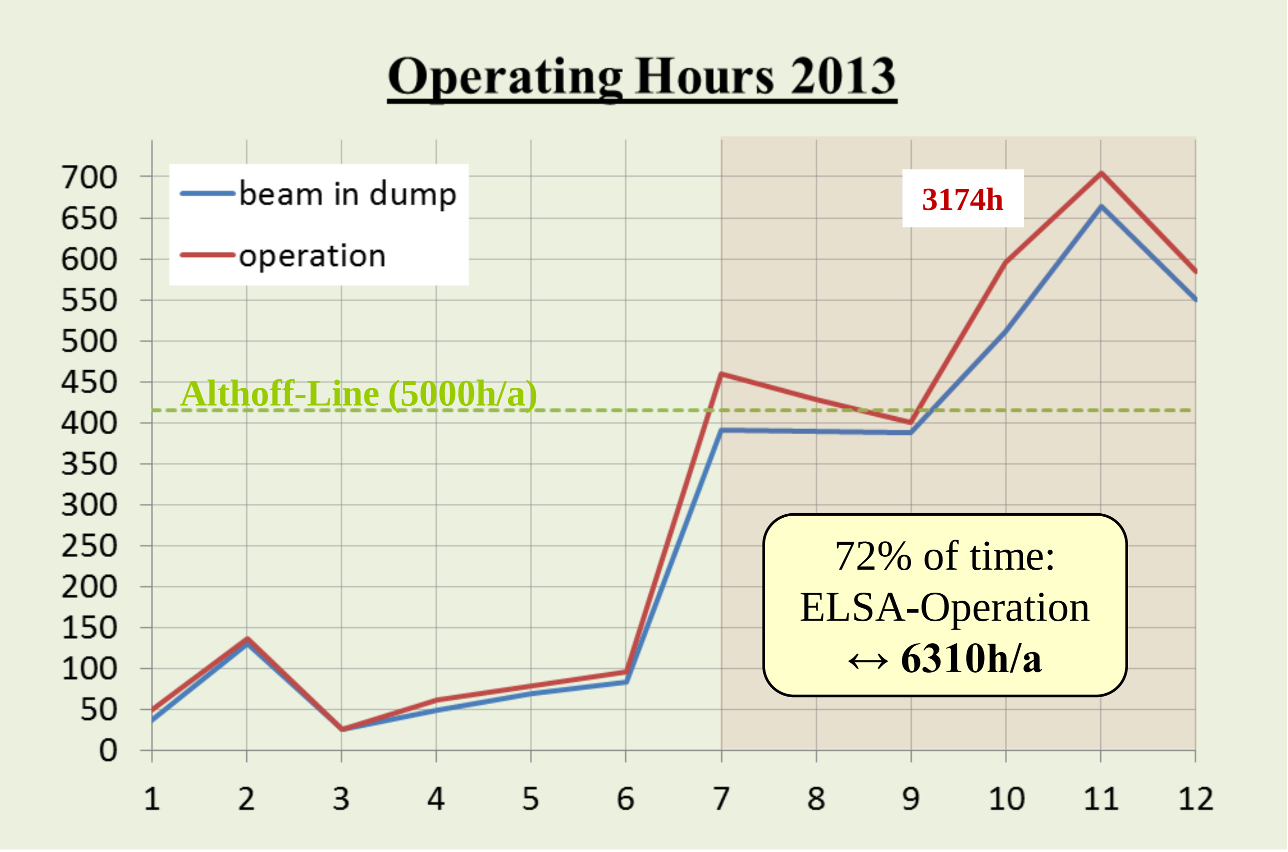


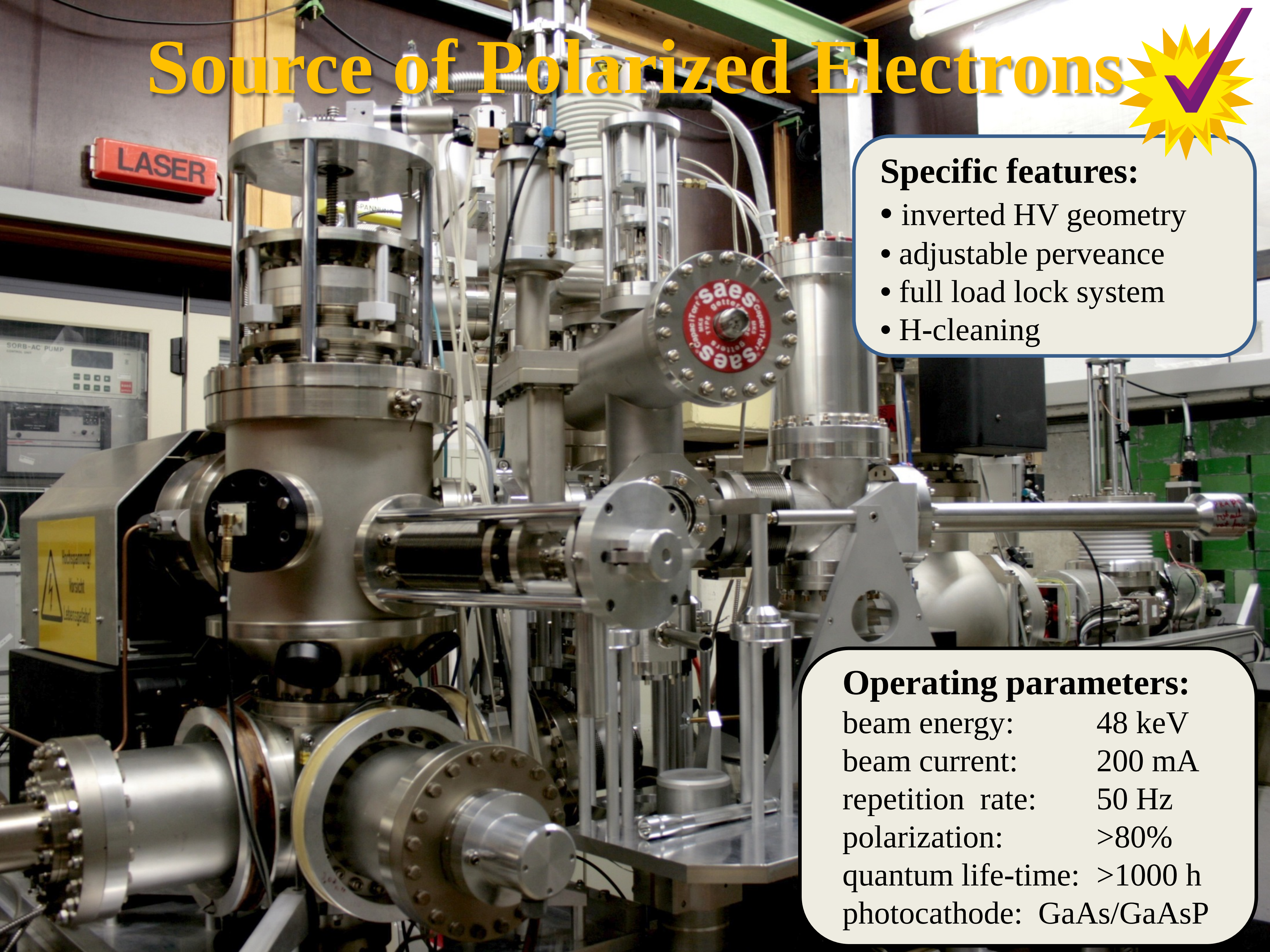
R&D @ ELSA: Goals

- **Polarized Electrons @ 3.2GeV:**
  - reliable operation (source, ELSA)
  - suppression of beam depolarization utilizing novel correction schemes
  - efficient polarimetry (Møller, Compton)
- **High-Intensity Operation of ELA:**
  - 3D bunch by bunch feed-back systems
  - powerful LLRF for amplitude- and phase stabilization
  - sufficient RF power (new RF system)
  - low impedance chambers, HOM suppression, vacuum upgrade
  - high current (single bunch) injector
- **Low-Intensity Beams for Detector Testing:**
  - reliable low-intensity operation of ELSA
  - new dedicated experimental area with flexible magnet optics
- **High-Performance Non-Invasive Beam Diagnosis:**
  - Cavity-based low-intensity and position monitoring
  - 3D ps-Diagnosis with Streak Camera
  - Low-intensity monitoring using synchrotron radiation

pol e^-

Highest possible polarization @ 3.2 GeV

Source of Polarized Electrons



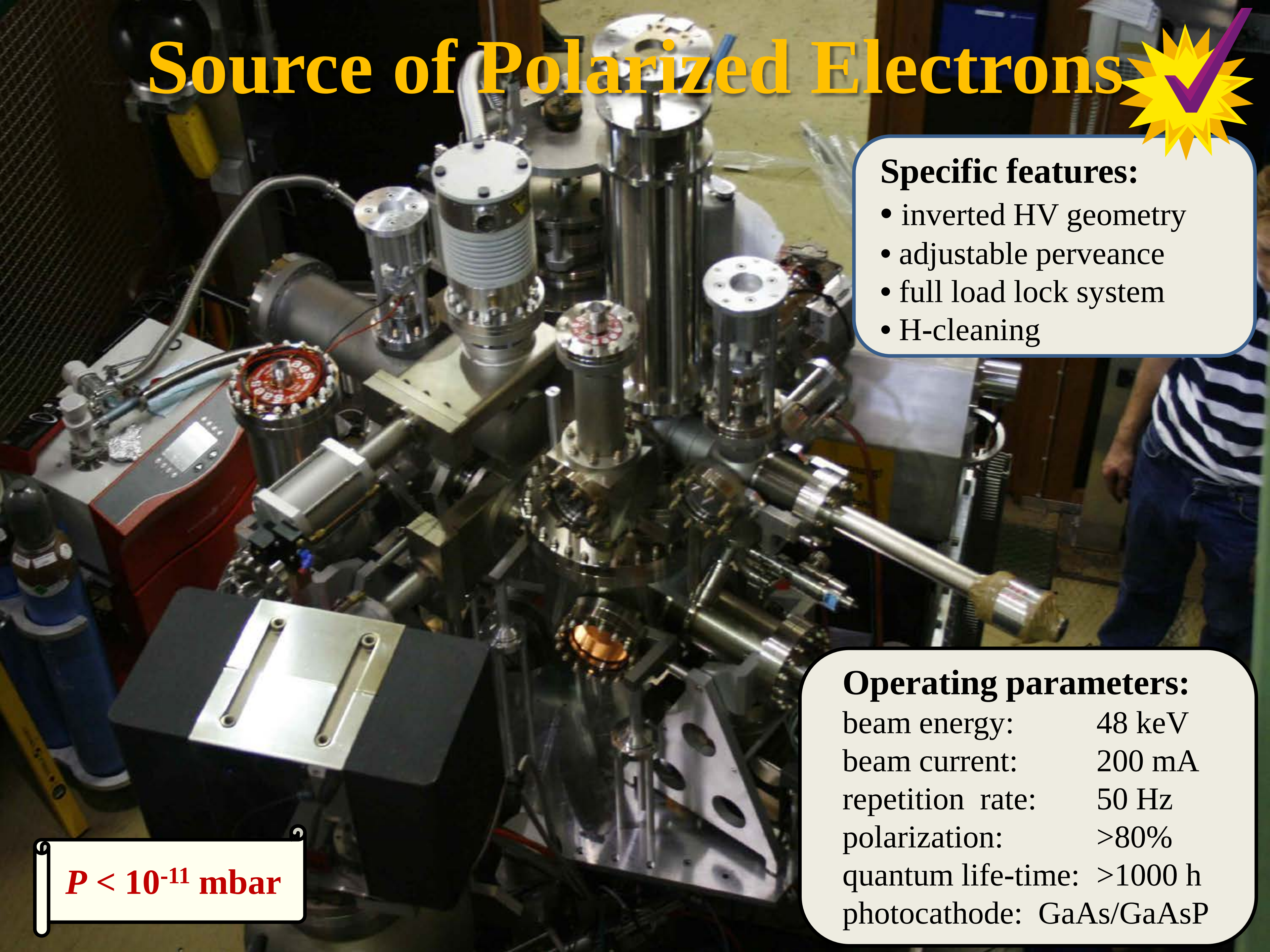
Specific features:

- inverted HV geometry
- adjustable perveance
- full load lock system
- H-cleaning

Operating parameters:

beam energy:	48 keV
beam current:	200 mA
repetition rate:	50 Hz
polarization:	>80%
quantum life-time:	>1000 h
photocathode:	GaAs/GaAsP

Source of Polarized Electrons



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$P < 10^{-11}$ mbar

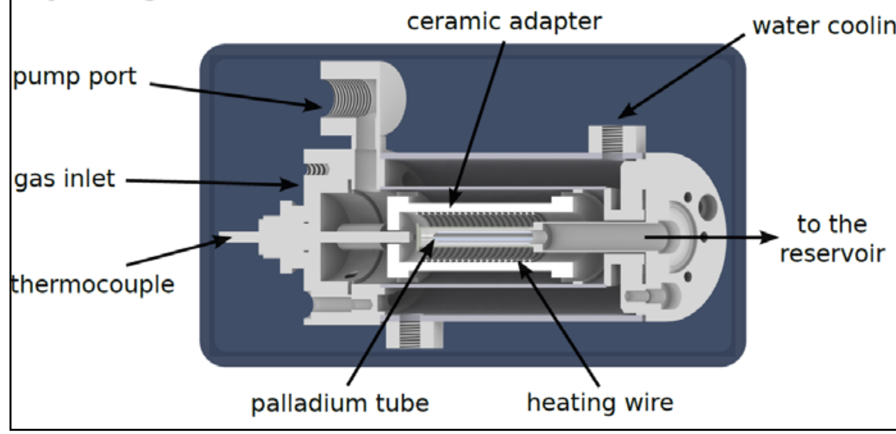
Hydrogen Cleaning

$$Ga_2O_3 + 4H \rightarrow Ga_2O + 2H_2O \uparrow$$

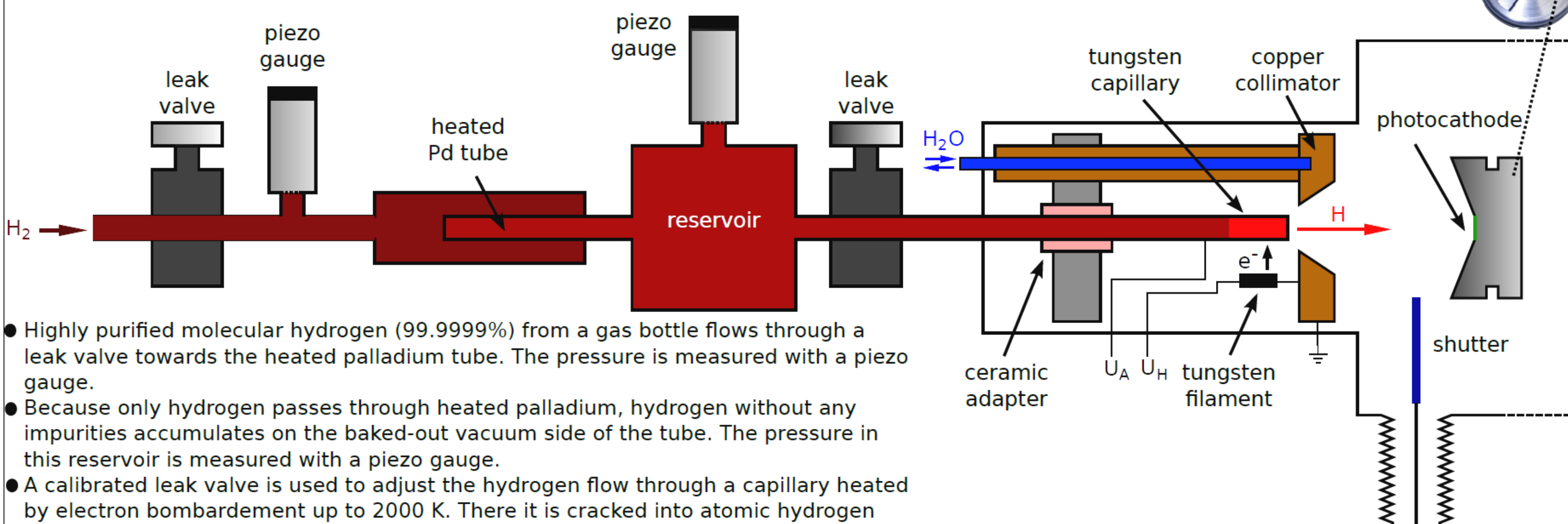
$$Ga_2O + 2H \rightarrow 2Ga + H_2O \uparrow$$

$$As_2O_x + 2xH \rightarrow As_2 + xH_2O \uparrow$$

Hydrogen Filter



Hydrogen filtering and inlet

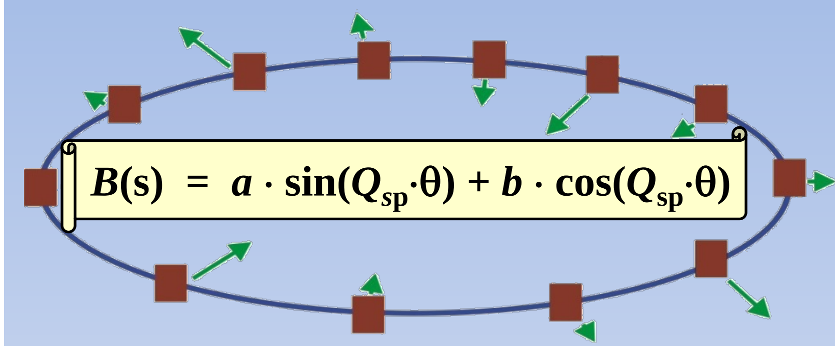


- Highly purified molecular hydrogen (99.9999%) from a gas bottle flows through a leak valve towards the heated palladium tube. The pressure is measured with a piezo gauge.
- Because only hydrogen passes through heated palladium, hydrogen without any impurities accumulates on the baked-out vacuum side of the tube. The pressure in this reservoir is measured with a piezo gauge.
- A calibrated leak valve is used to adjust the hydrogen flow through a capillary heated by electron bombardement up to 2000 K. There it is cracked into atomic hydrogen and is directed to the photocathode.

Acc. of Polarized Electrons

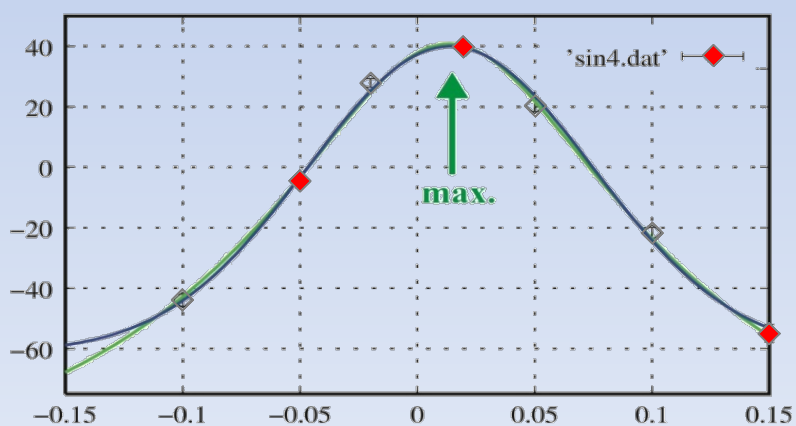
Integer Resonances: $\gamma a = n$

- precise CO correction ($z_{rms} < 80\mu$m)
- harmonic correction:



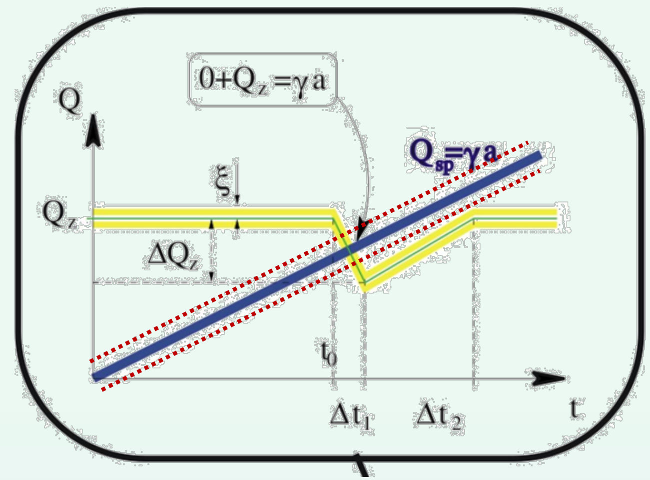
$$B(s) = a \cdot \sin(Q_{sp} \cdot \theta) + b \cdot \cos(Q_{sp} \cdot \theta)$$

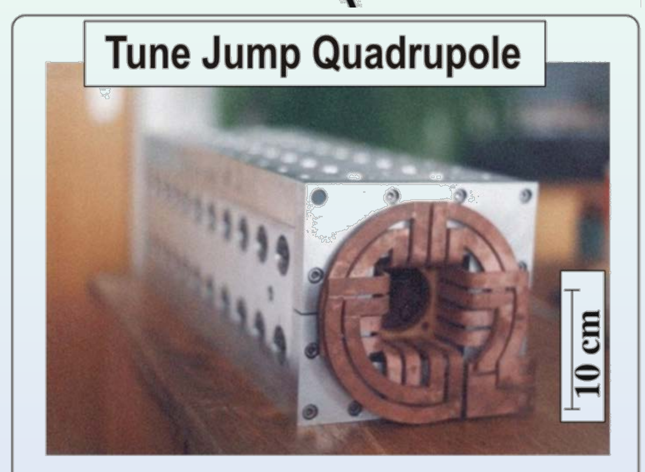
→ scan of sin amplitude:



Intr. Resonances: $\gamma a = nP \pm Q_z$

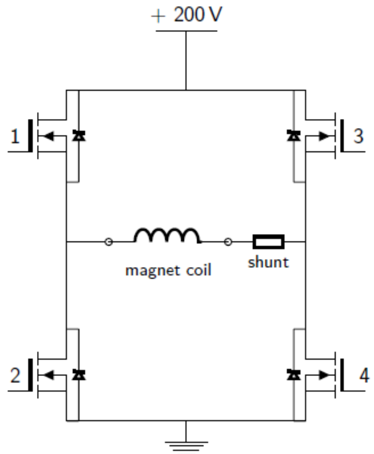
- small vertical beam size
- tune jumping with pulsed quads

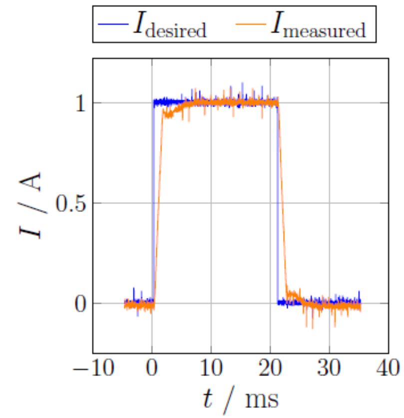




Fast Steerer System

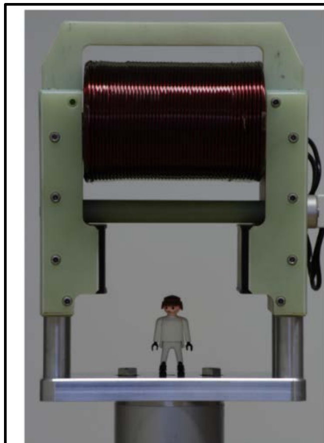
Programmable 4-Quadrant PS:





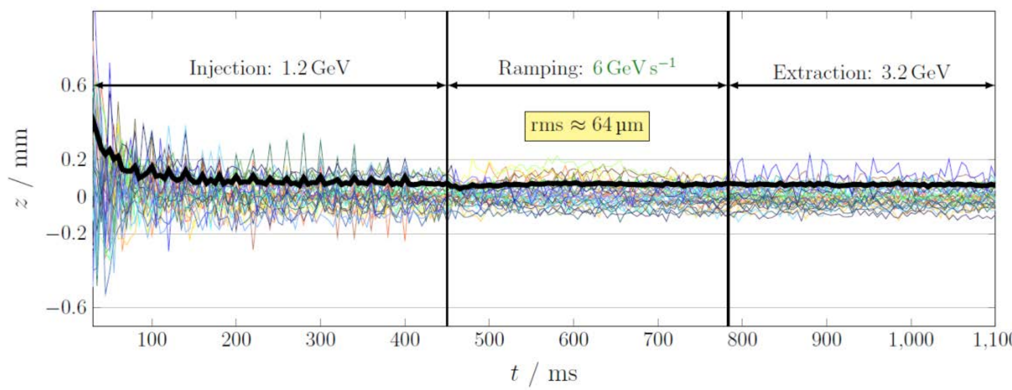
- 20 kHz pulsed H-bridge
- PI-controller
- current precision ≈ 1 ‰
- CAN-Bus module
- stored current ramps
- external trigger
- in total 54 power supplies distributed in 14 cabinets along the ELSA tunnel

Correction Coils:



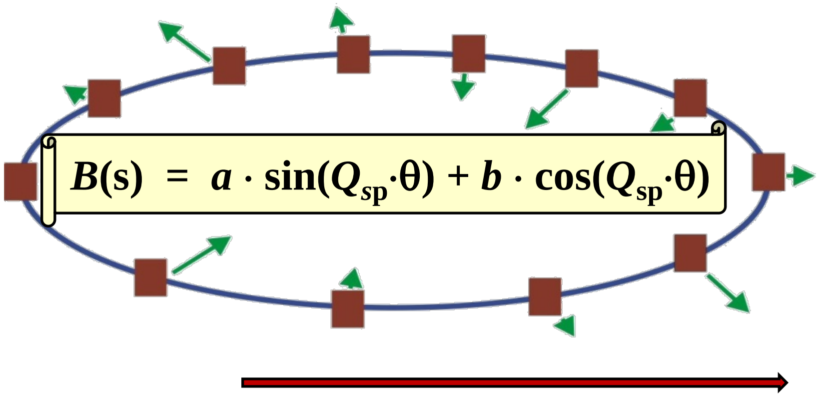
	new
voltage	200 V
max. current	8.0 A
inductance	260 mH
max. field	40 mT
weight	30 kg
field integral	9.8 mT m

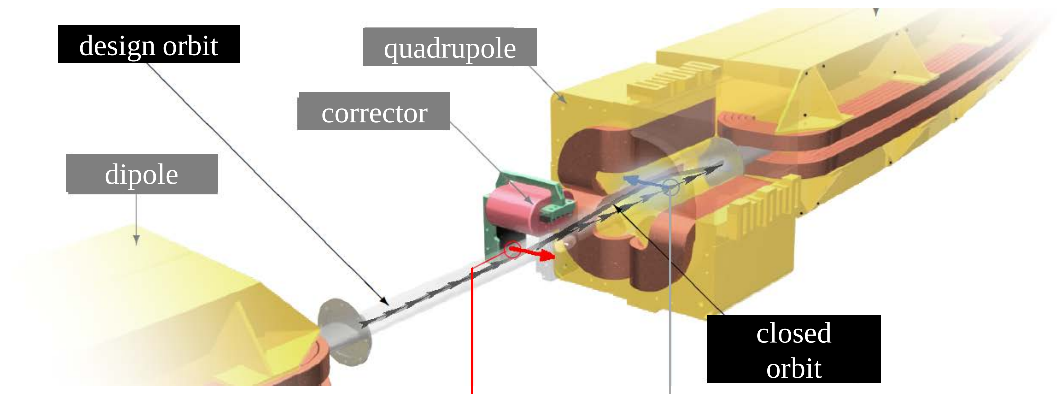
$\dot{I} = 400$ A/sec ↔ $\dot{B} = 2$ Tesla/sec

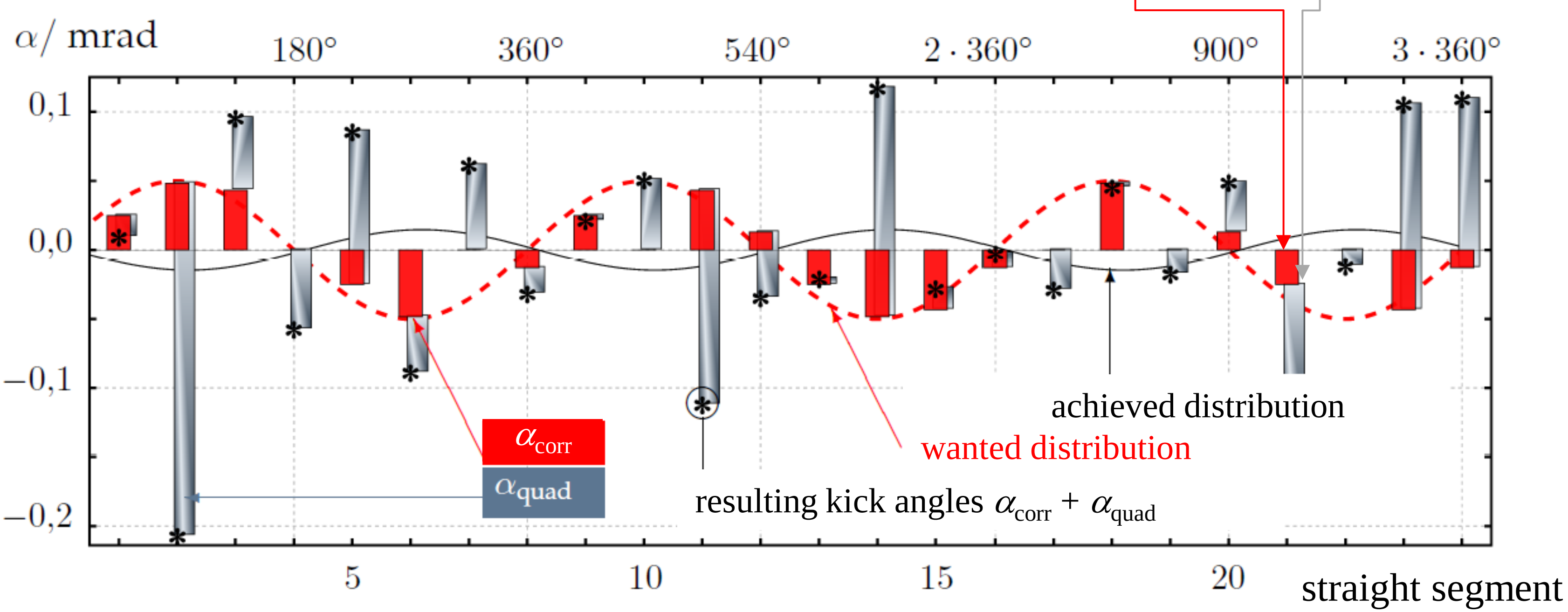


Harmonic Correction

(simple approach)

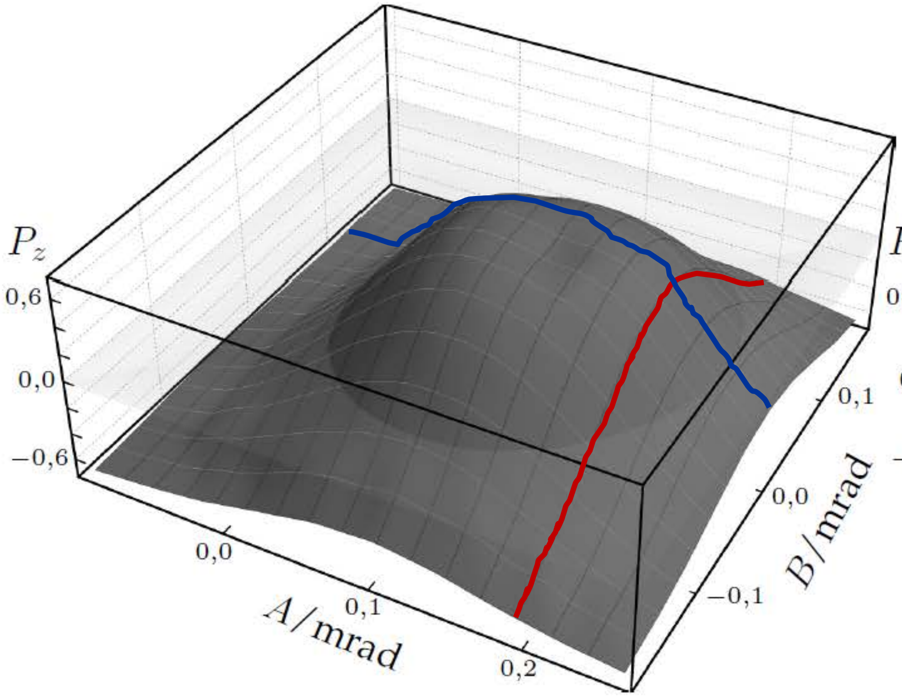




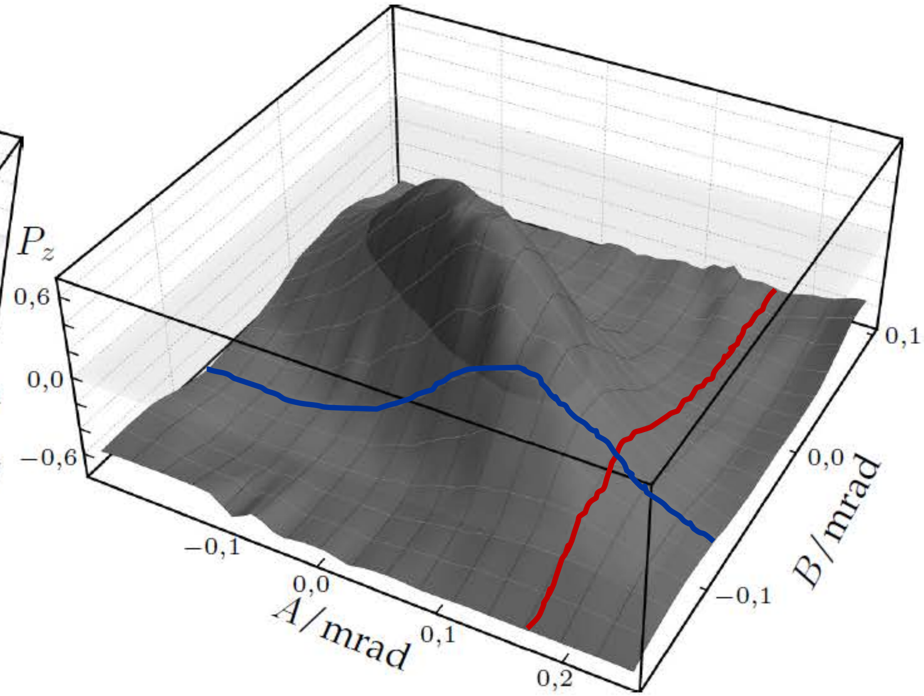


Harmcorr Optimization

$$\alpha_{corr} = A \cdot \cos(2\pi n / 24) + B \cdot \sin(2\pi n / 24)$$

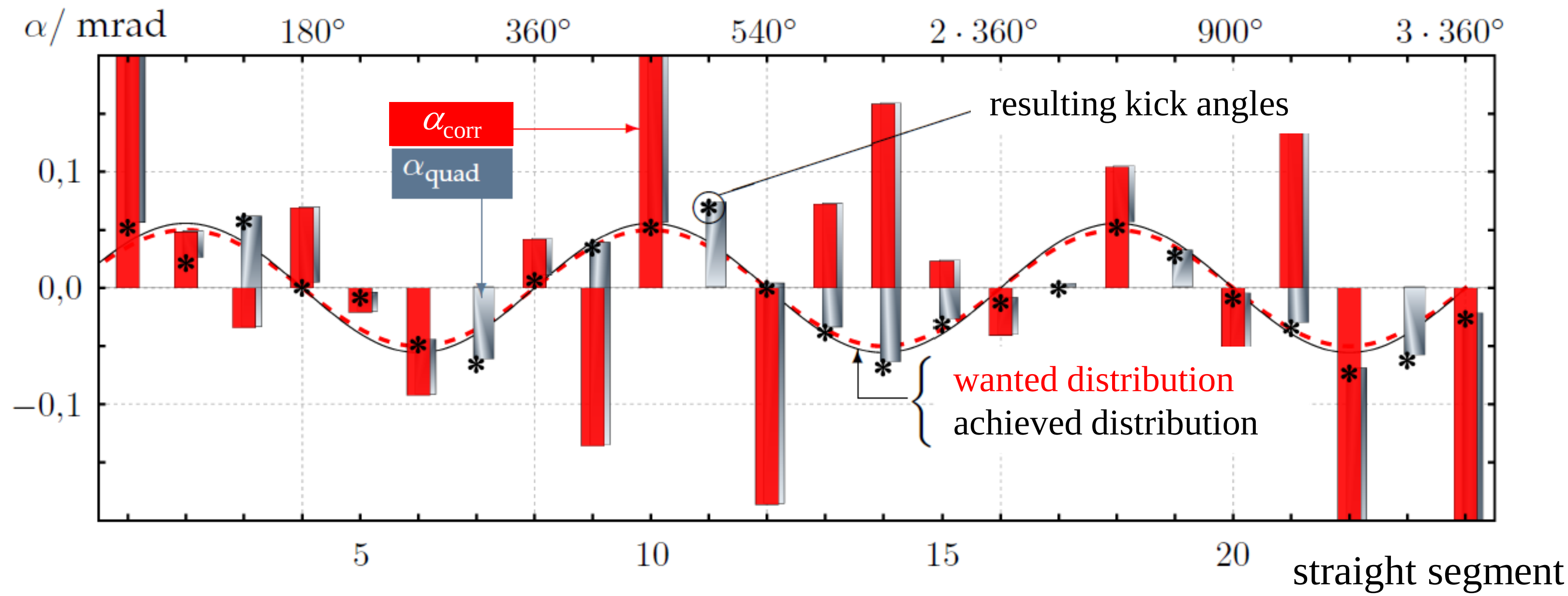


(a) Polarisationsoptimierung bei $a\gamma = 3$



(b) Polarisationsoptimierung bei $a\gamma = 6$

Spin-Orbit Response Technique

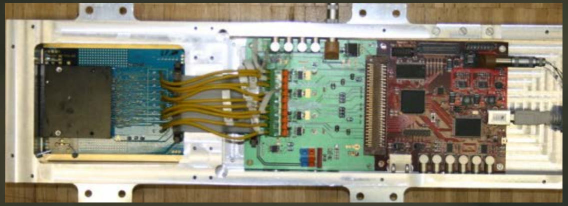


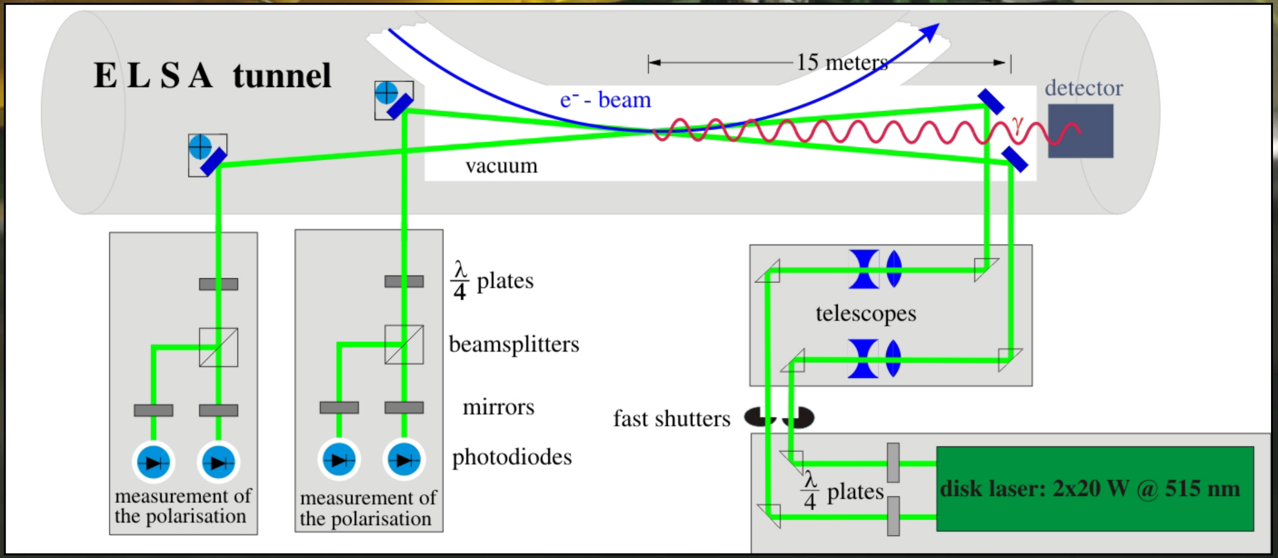
Spectral Distribution:

Compton Polarimeter

Coming 2014

Si microstrip detector
768 channels, 50 µm pitch





high intensities

10 nA external ↔ 200 mA stored current

eLINAC

- *modulator*
- *waveguides*
- *hybrids*
- *EKS*
- *prebuncher*
- *timing*

Thermionic Gun:
- U = 90 kV
- I = 800 mA (1-2μs) / 2 A (1ns)

Bunching:
- 500 MHz prebuncher
- 3 GHz TW buncher (4 cells)

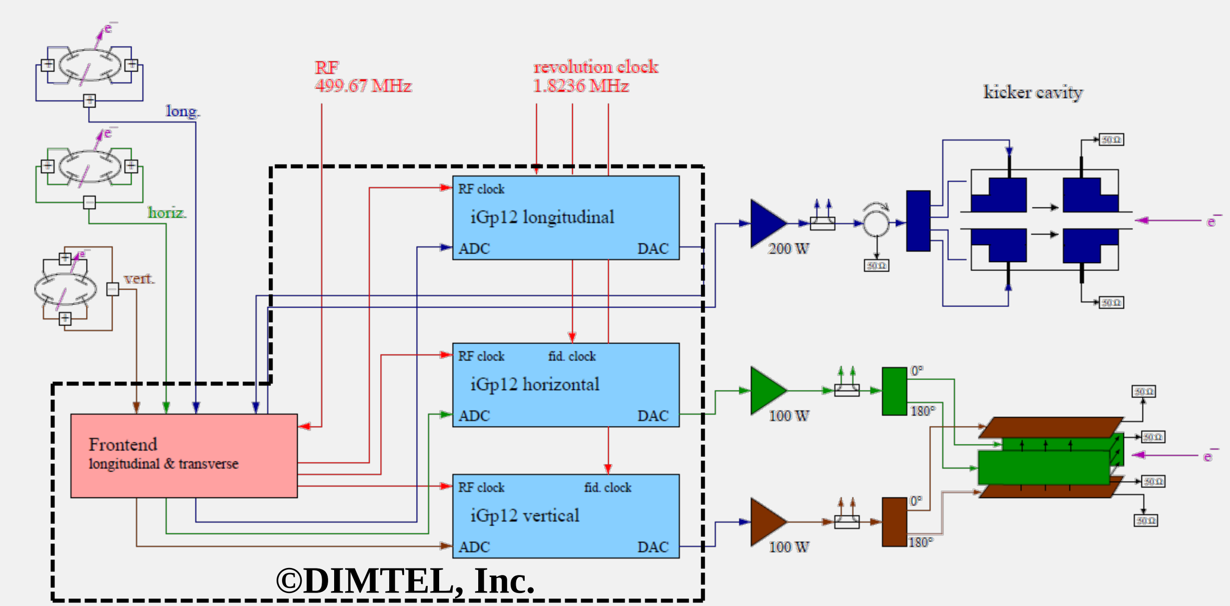
LINAC:
- 20 MV 3GHz TW structure (constant gradient)
- ongoing overhaul of modulator and waveguides

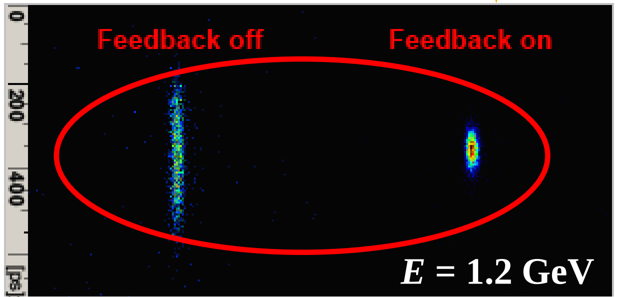
Energy Compression System:
- 3-bend magnetic chicane
- 3GHz TW structure

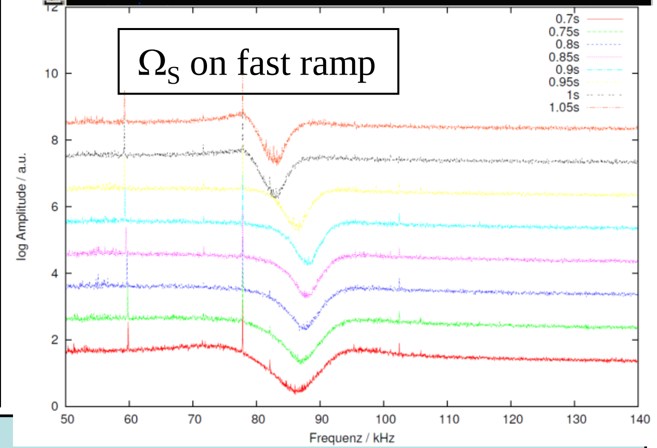
Coming 2014

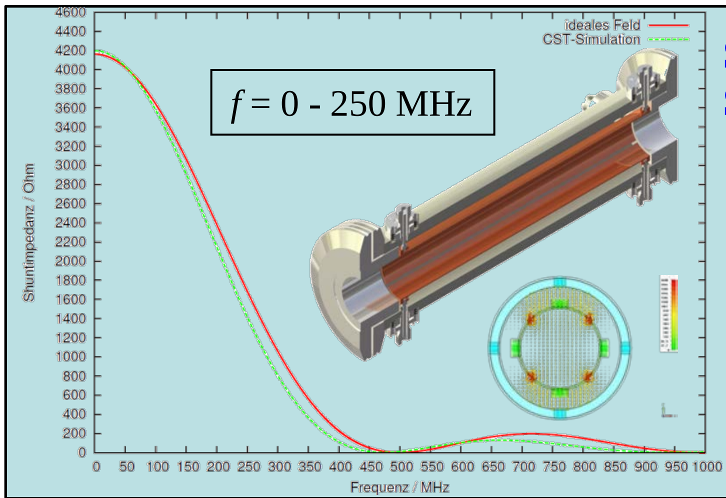
3D Bunch by Bunch Feed-Back in a fast ramping machine

System Layout:

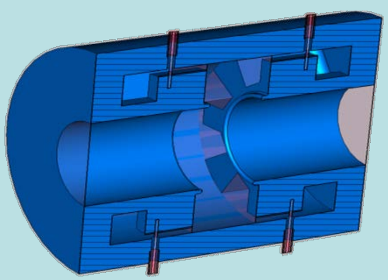




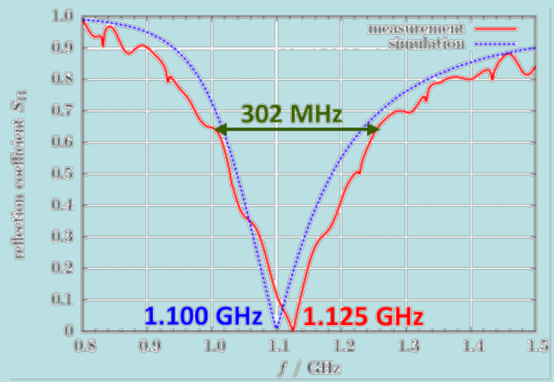




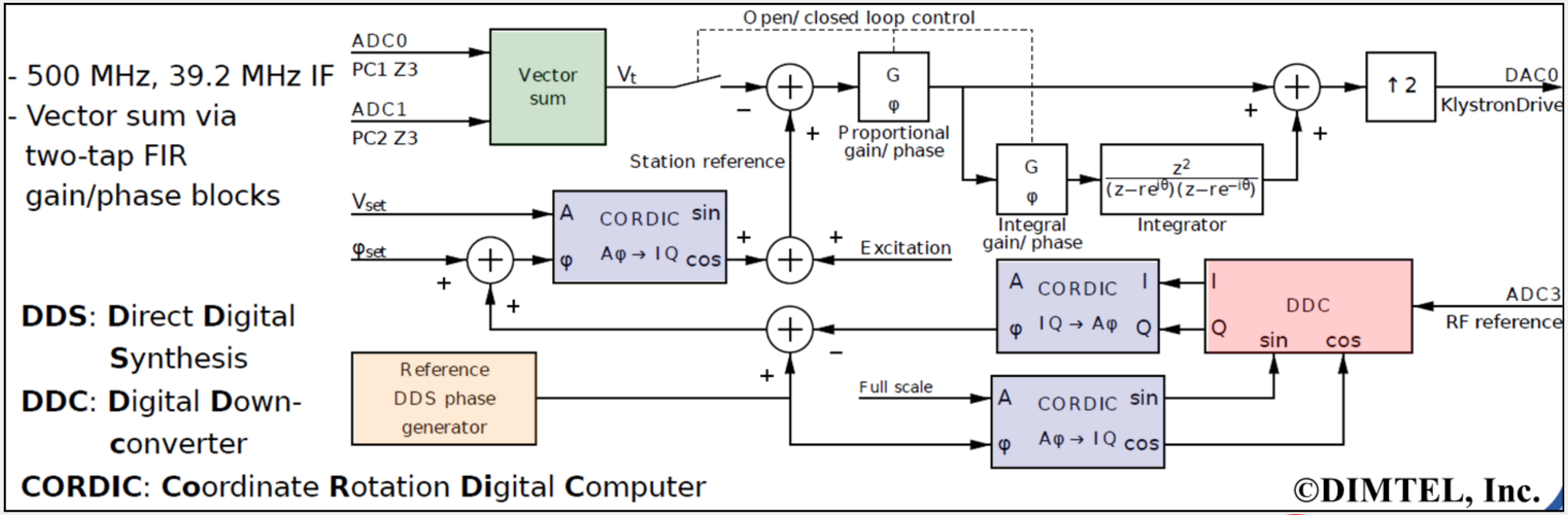
Simulation with CST Microwave Studio & In-house fabrication

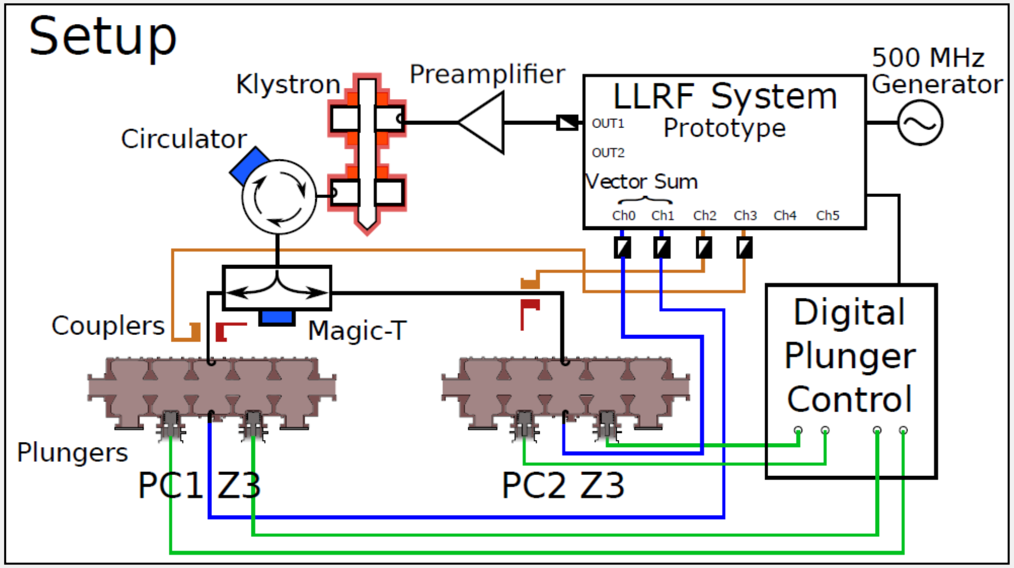


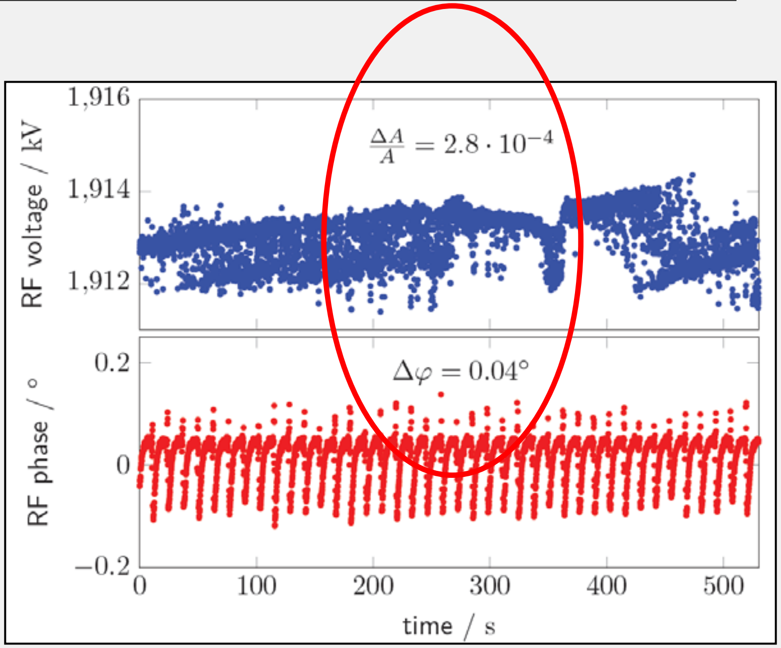
f = 1125 ± 150 MHz



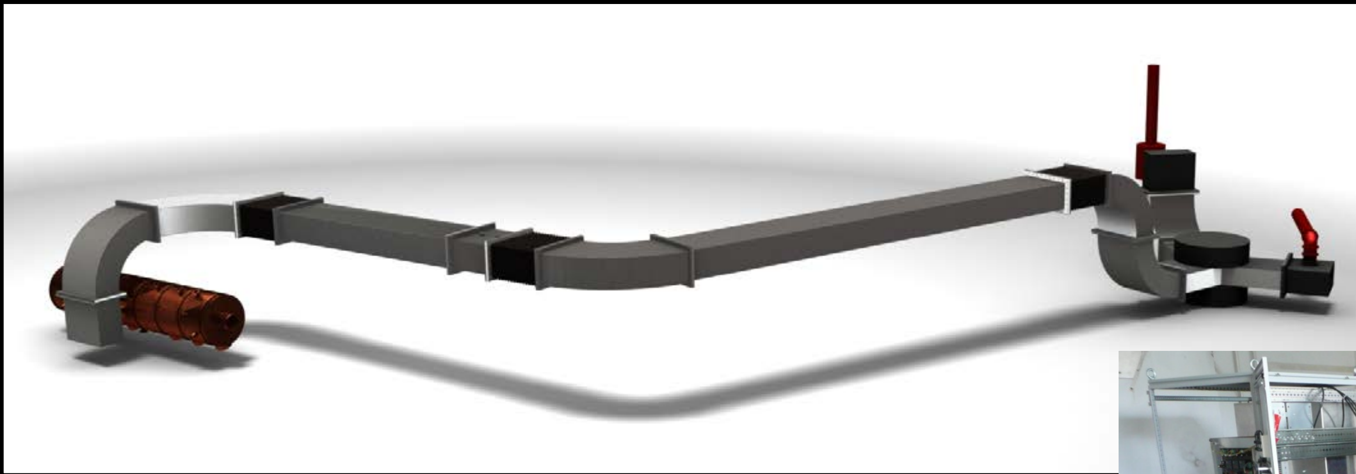
RF Control & Stabilization

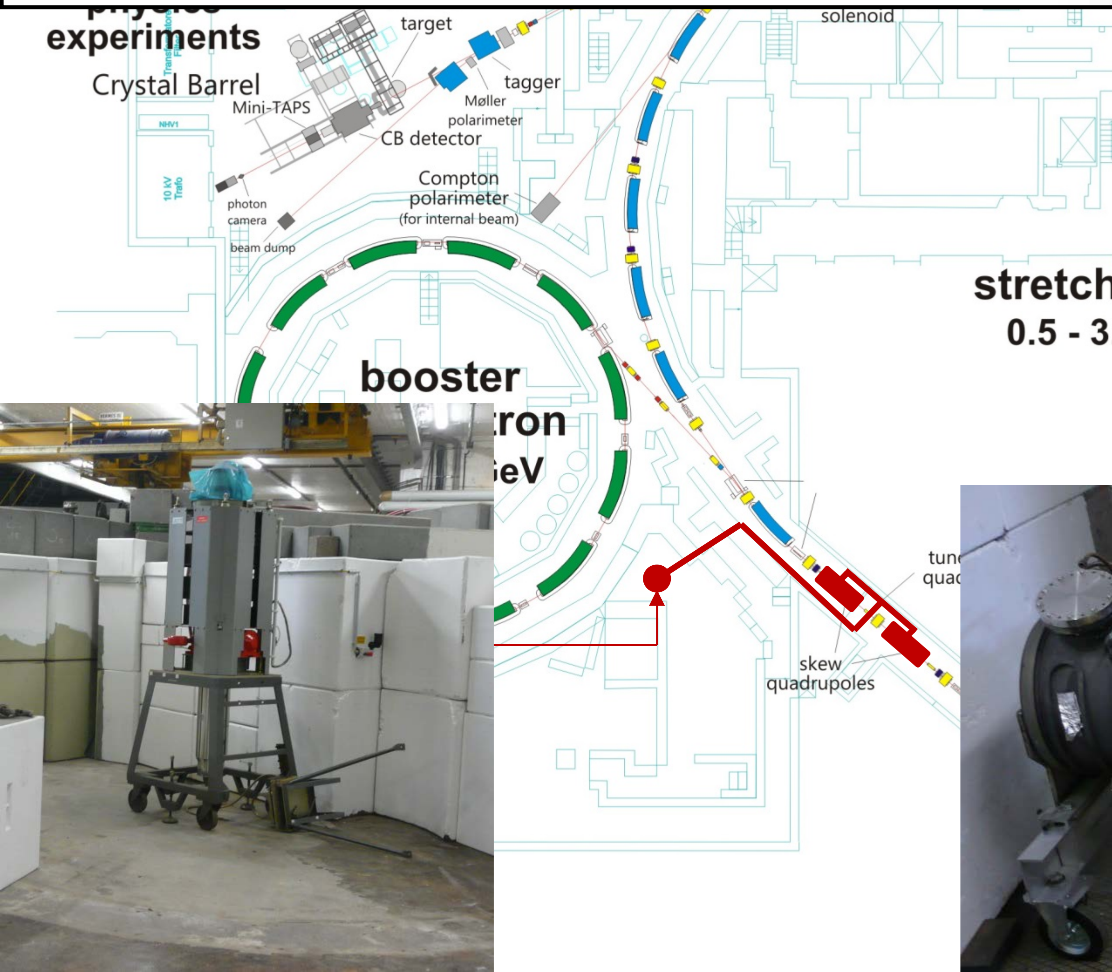




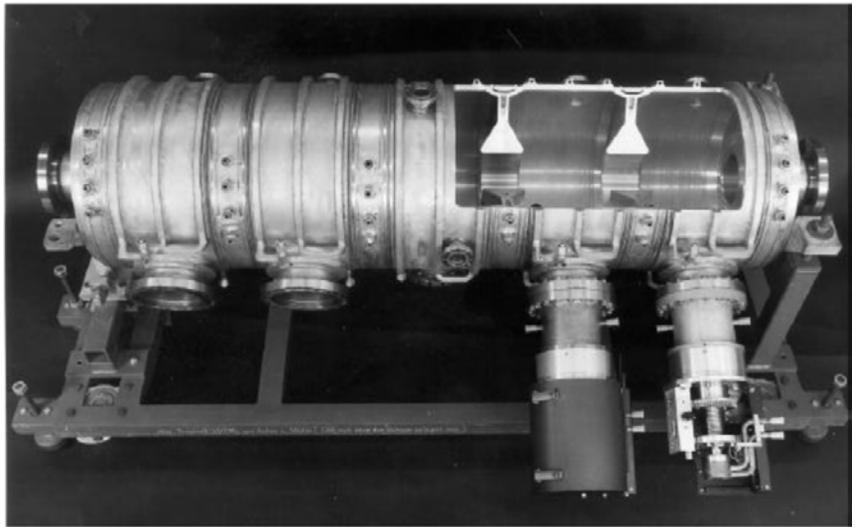


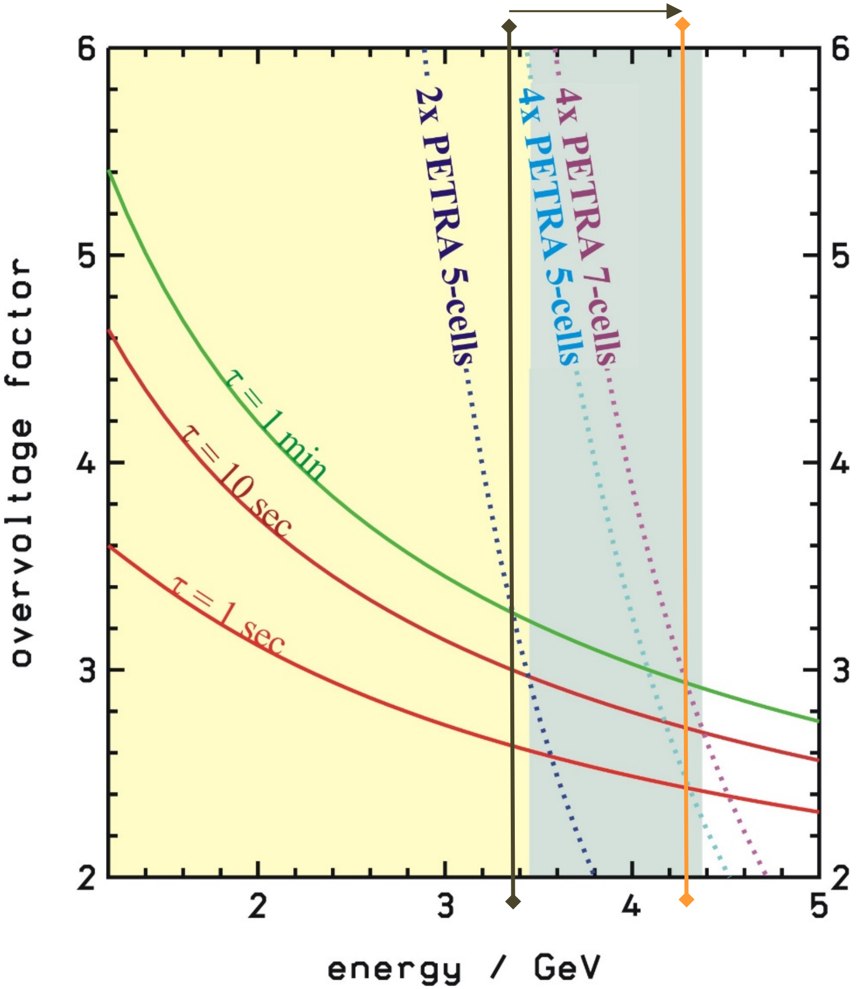
r (ELSA)




experiments
Crystal Barrel
Mini-TAPS
target
tagger
Møller
polarimeter
CB detector
Compton
polarimeter
(for internal beam)
photon
camera
beam dump
solenoid
stretch
0.5 - 3.
booster
skew
quadrupoles

Accelerating Voltage



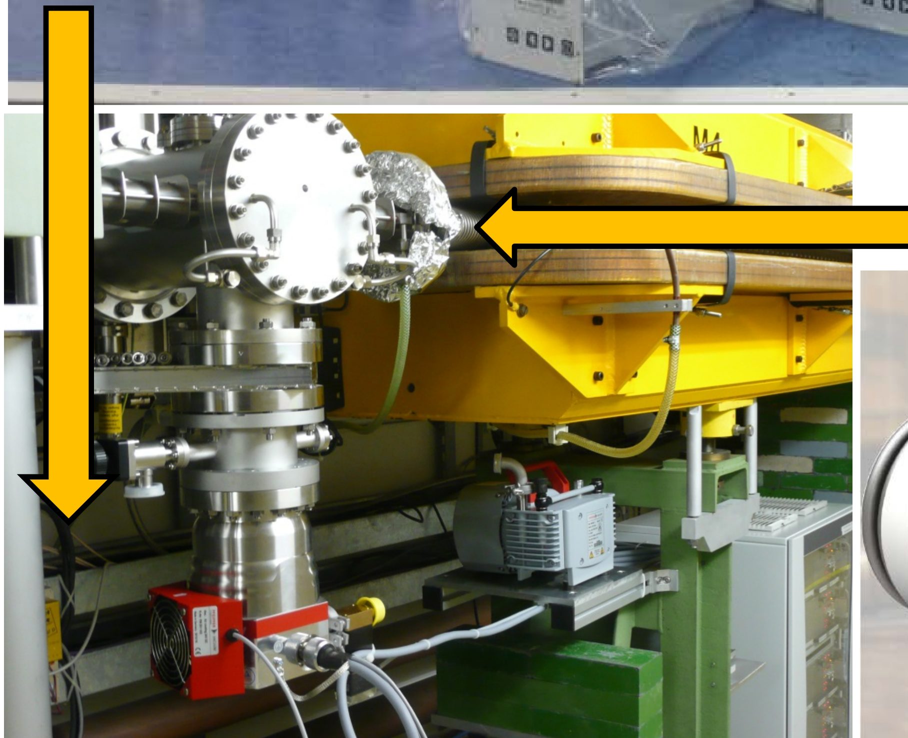


n.c. resonators type PETRA:

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

with four 7-cell resonators $\boldsymbol{E} \leq$ **4.3 GeV** @ $\tau = 1$ min

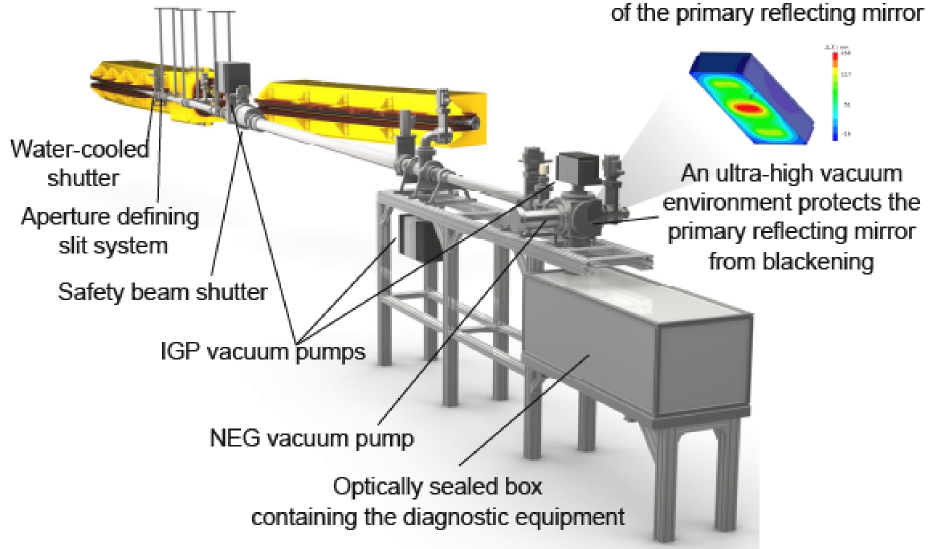
Vacuum and Impedances



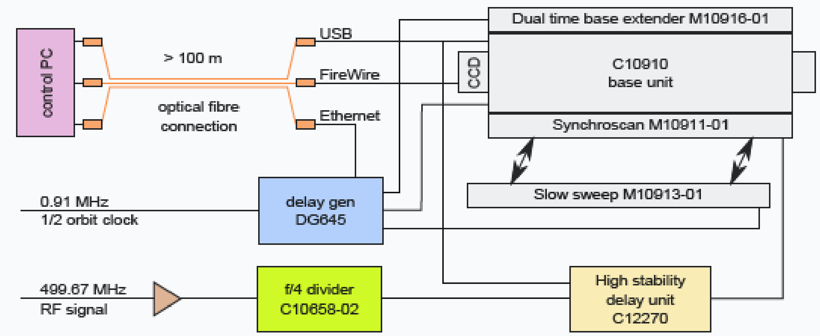
Bridging of ceramic brakes:

ps Diagnosis: Streak Camera

Beamline

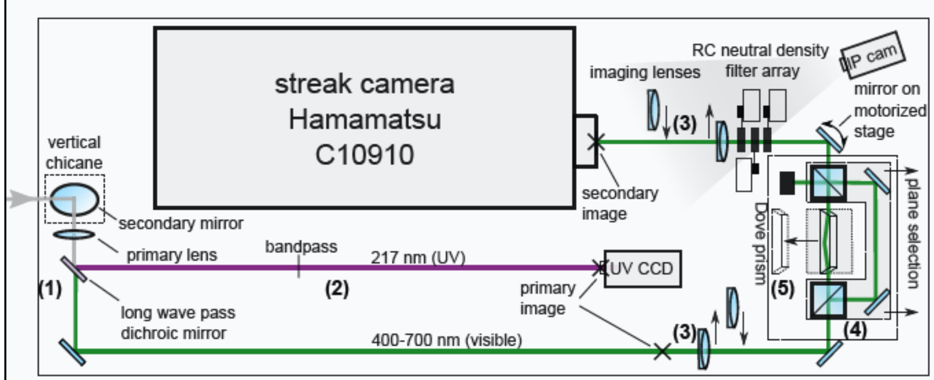


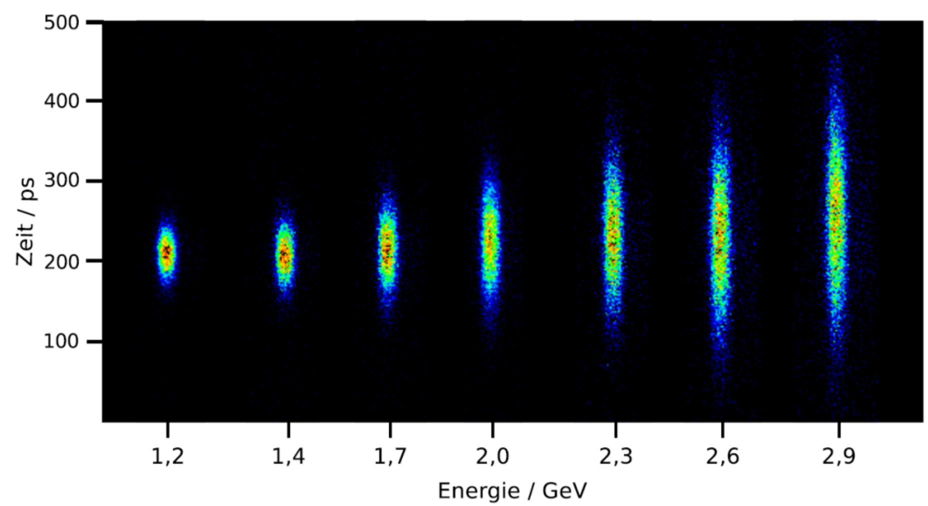
Streak Camera Setup & Application



Sweep Unit	Sweep Range	Field of Study
Synchroscan	100 ps to 1.3 ns	Charge distributions
+		+
Dual time base	60 ns to 100 ms	Longitudinal beam dynamics
Slow sweep	1.2 ns to 1 ms	Transverse instabilities

Optics Layout





low intensities

Test-beam with intensities down to < 1 fA

New Area for Detector Testing

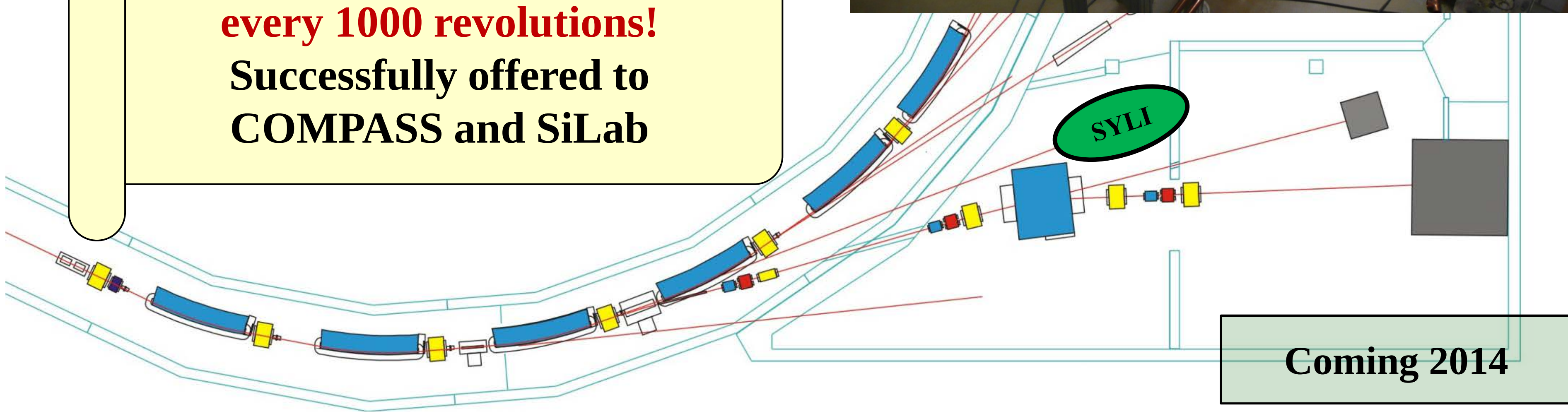
External Electron Beam:

- Beam Energy: **1.0 GeV < *E* < 3.5 GeV**
- Beam Current: **1 fA < *I* < 100 pA**
- Beam Radius: **0.5 mm < *σ* < 7 mm**

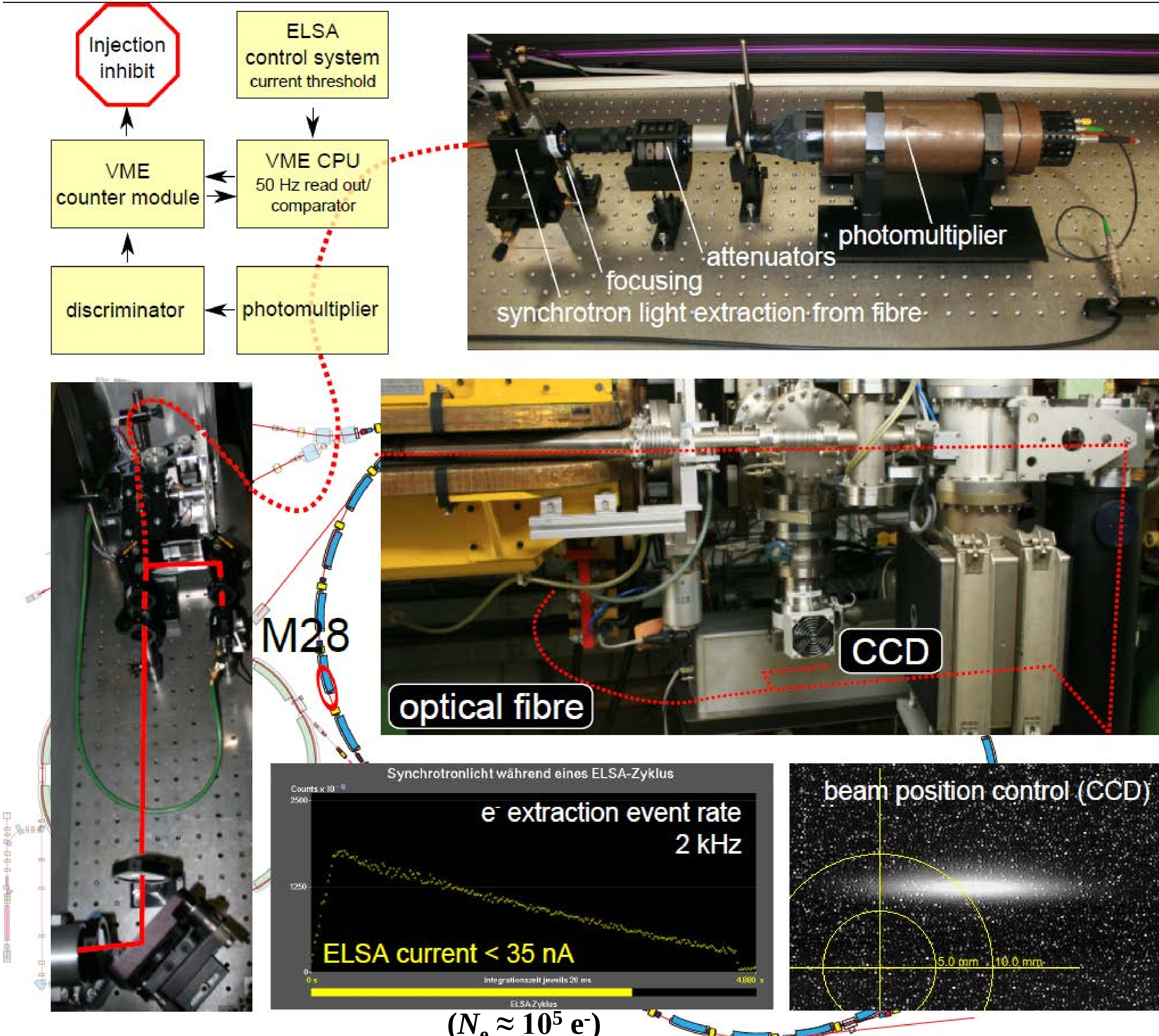
Low-Intensity Operation:

extraction of a single electron every 1000 revolutions!

Successfully offered to COMPASS and SiLab



Coming 2014


Injection inhibit
ELSA control system current threshold
VME counter module
VME CPU 50 Hz read out/ comparator
discriminator
photomultiplier
photomultiplier
attenuators
focusing
synchrotron light extraction from fibre
M28
optical fibre
CCD
Synchrotronlicht während eines ELSA-Zyklus
2500
1250
e- extraction event rate
2 kHz
ELSA current < 35 nA
Integrationszeit jeweils 20 ms
ELSA-Zyklus
beam position control (CCD)
5.0 mm
10.0 mm
($N_e \approx 10^5$ e$^-$)

Conclusions

Status:

- reliable operation, fulfils all actual requirements

Ongoing work:

- preparing for pol e^- @ 3.2 GeV
- upgrade to high intensities (energies?)
- setting up a variable low-intensity test-beam and area

… laying the basis for a future beyond the TR16 ?!