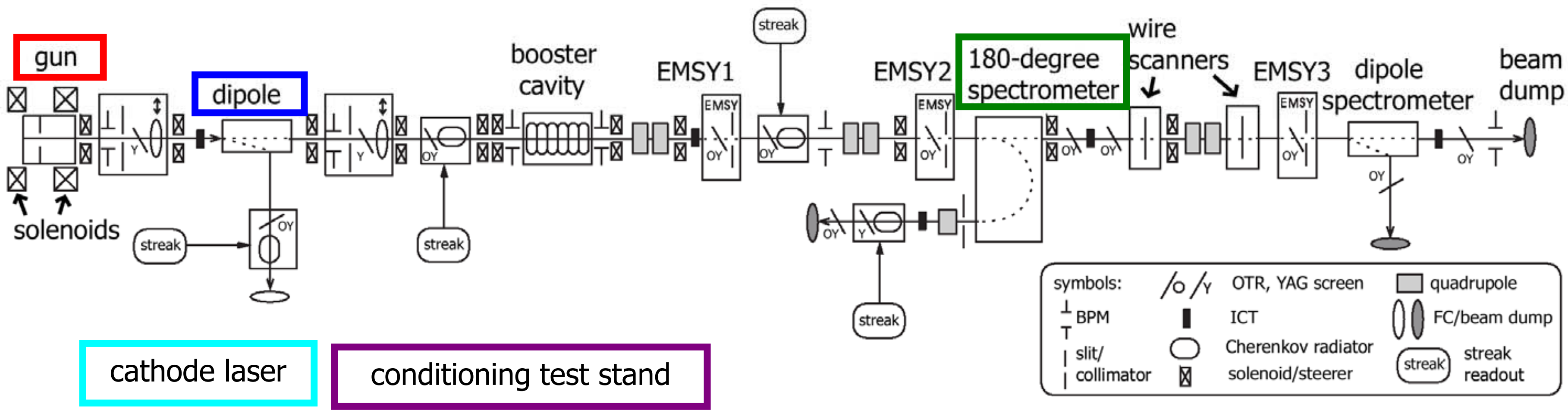
Latest results from the upgraded PITZ facility



Chase Boulware, DESY, Zeuthen, Germany,
for the PITZ collaboration

The PhotoInjector Test facility in Zeuthen (PITZ) characterizes high-brightness electron sources for FELs like FLASH and the planned European XFEL.

	FLASH	XFEL
normalized rms transverse emittance	2 mm mrad	0.9 mm mrad (injector) 1.4 mm mrad (undulator)
bunch charge	1 nC	

Improving from the FLASH requirements to the XFEL *and measuring this emittance* is a real challenge.

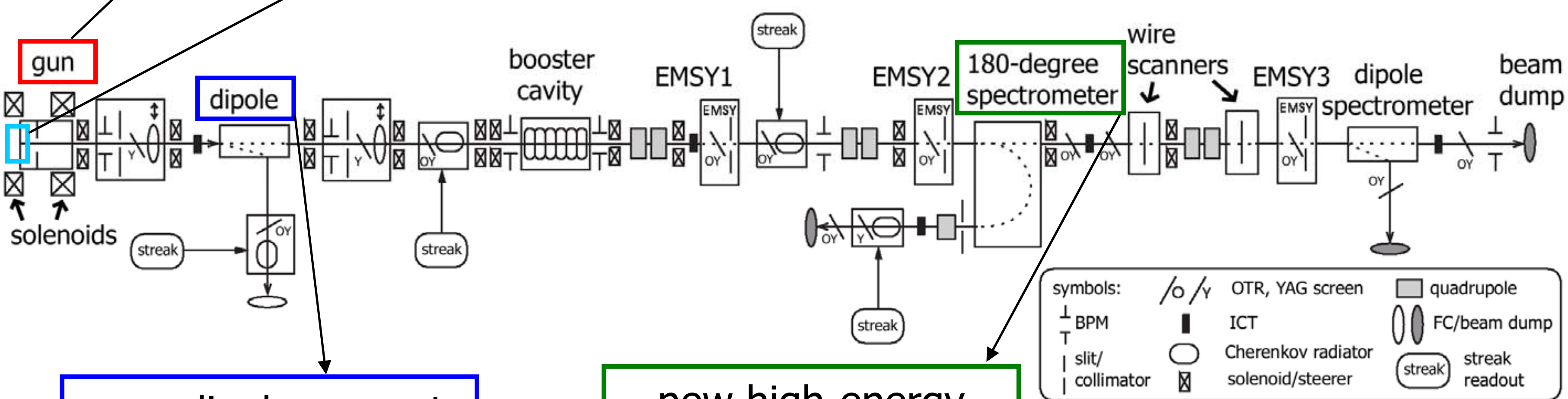
The best measured rms transverse emittance for 1 nC so far at PITZ: 1.26 ± 0.13 mm mrad (100% of detected charge, geometric mean of the transverse planes ± measurement standard deviation).

Overview of upgrades to the PITZ facility

new 1-1/2 cell L-band gun

new photocathode drive laser

Virtually every component of the beamline has been replaced or relocated in the last 8 months.

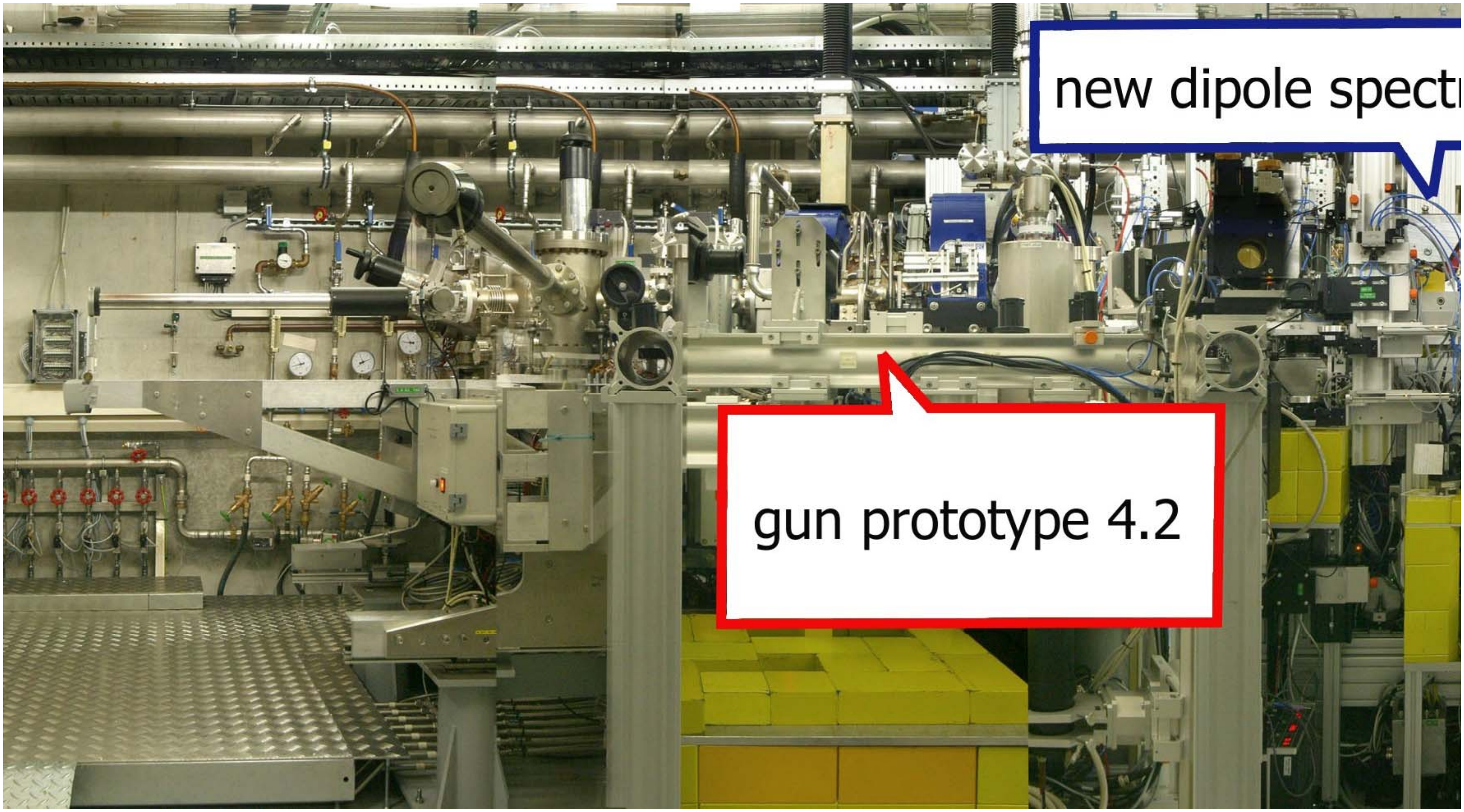


new dipole magnet in low-energy dispersive section

new high-energy spectrometer based on 180-degree dipole magnet

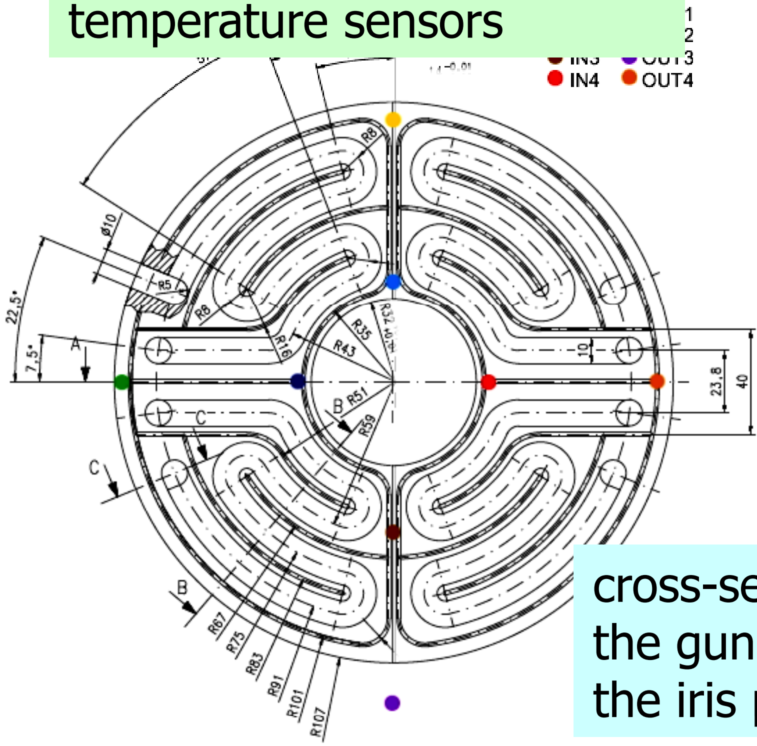
conditioning test stand (separate from main linac)

Panorama of the PITZ tunnel

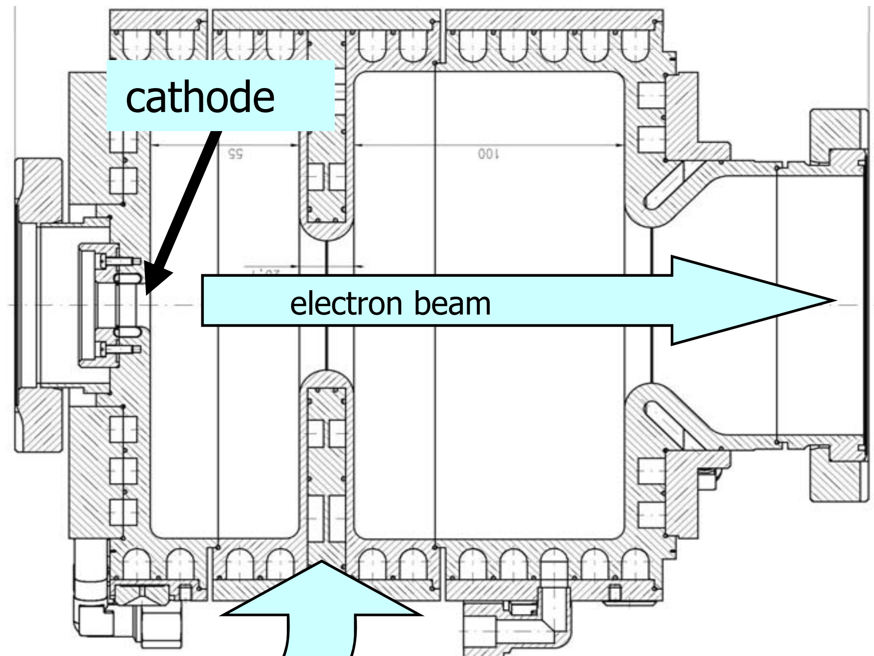


The new gun prototype has a more sophisticated water cooling design than previous guns.

greater surface area for water channels and more temperature sensors

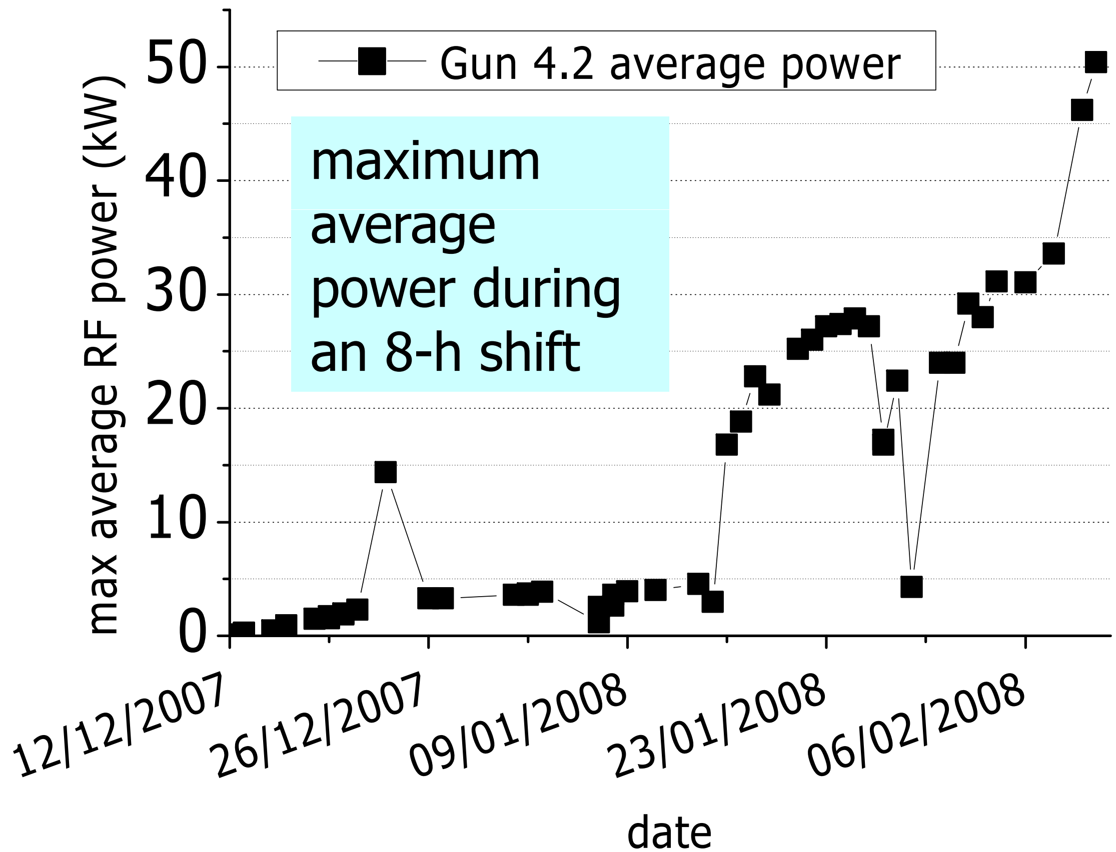


cross-section of the gun cavity at the iris plane



Water flow rates in the 14 input channels of the new gun are independently measured and adjusted.

The new gun cavity has been conditioned up to 50 kW average RF power.



Operation here only with careful tuning

- 7.2 MW peak RF power in the gun

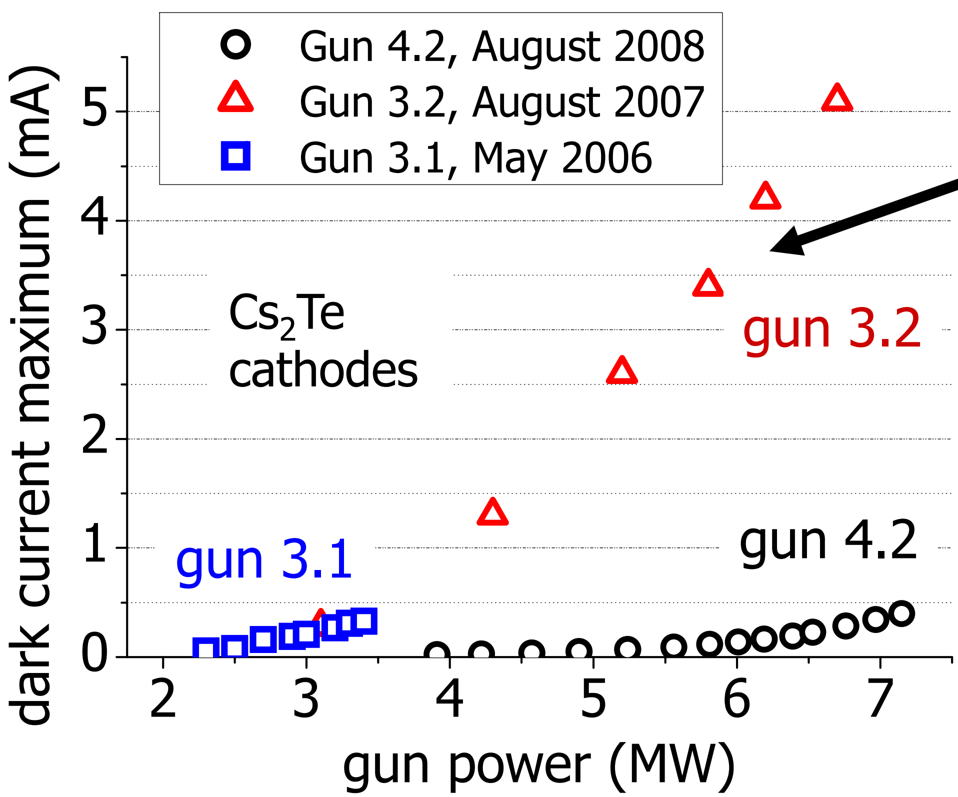
- 700 µs flat-top pulse length

- 10 Hz repetition rate

XFEL RF duty cycle

This conditioning was performed at a dedicated conditioning test stand.

The new cavity, prepared with a dry-ice cleaning procedure, shows markedly reduced dark current and reflected RF power.

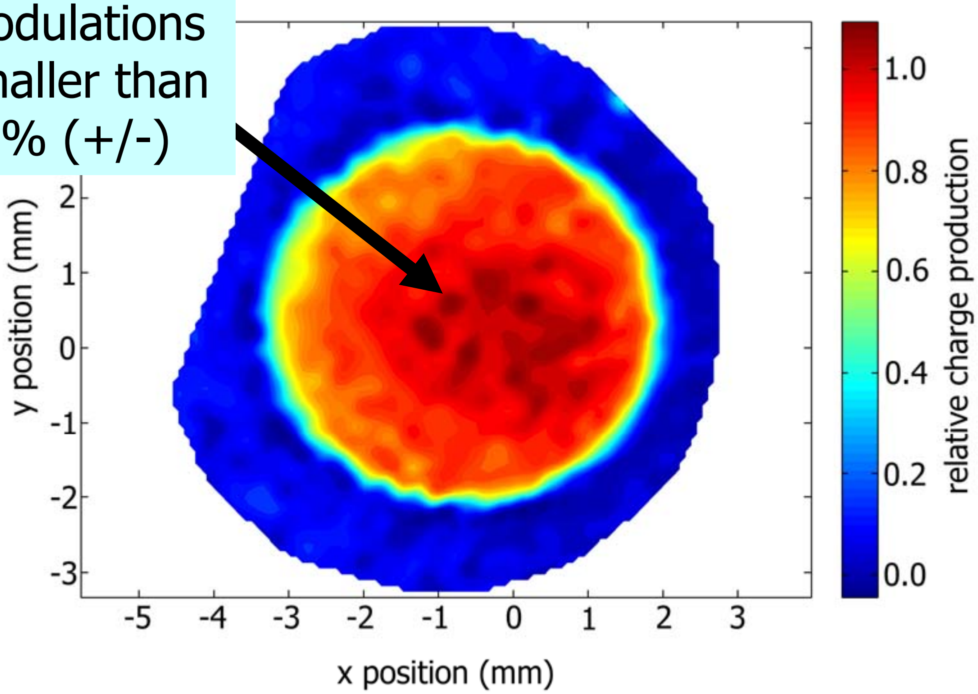


Dark current in the mA range has an adverse effect on cathode lifetime, and creates high radiation levels in the accelerator tunnel.

Reflected RF power from gun cavity 4.2 is also reduced by about an order of magnitude, down to ~0.3% of the input power.

Cathode uniformity can be routinely monitored with quantum efficiency (QE) maps.

modulations smaller than 10% (+/-)



Raster scan with a small UV spot (diameter ~ 200 μm)

The largest spot size used for beam operation has a diameter of 3.0 mm.

Cs_2Te cathode lifetimes*

2007 run:

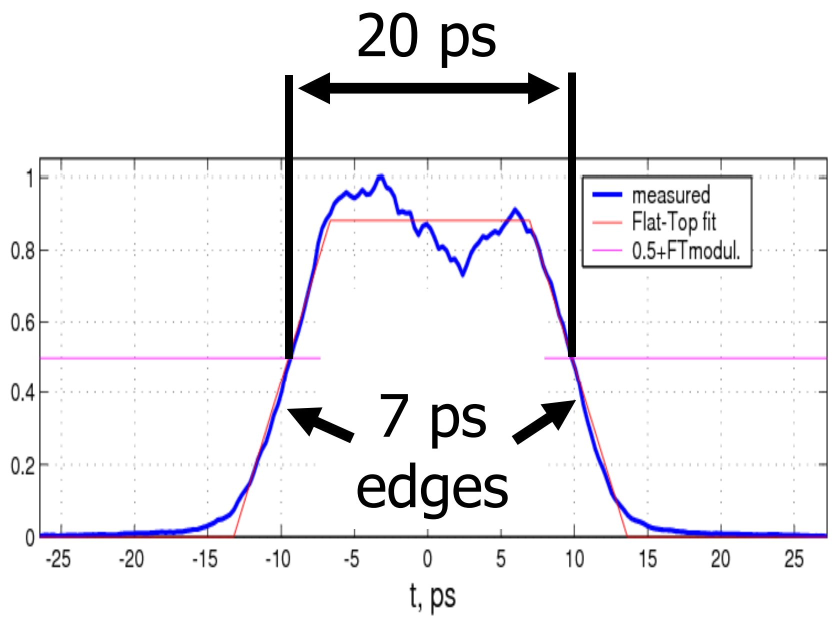
~**100 hours** at high peak field

Present run:

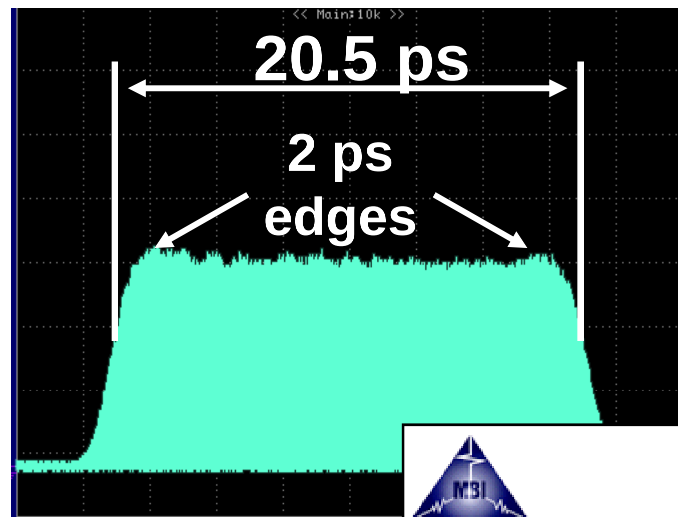
>**180 hours** and still running with QE = 5 – 10% at high field

*requirement to reach 1 nC is around 0.5% QE

The new photocathode laser will produce flat-top pulses with much shorter rise and fall times.



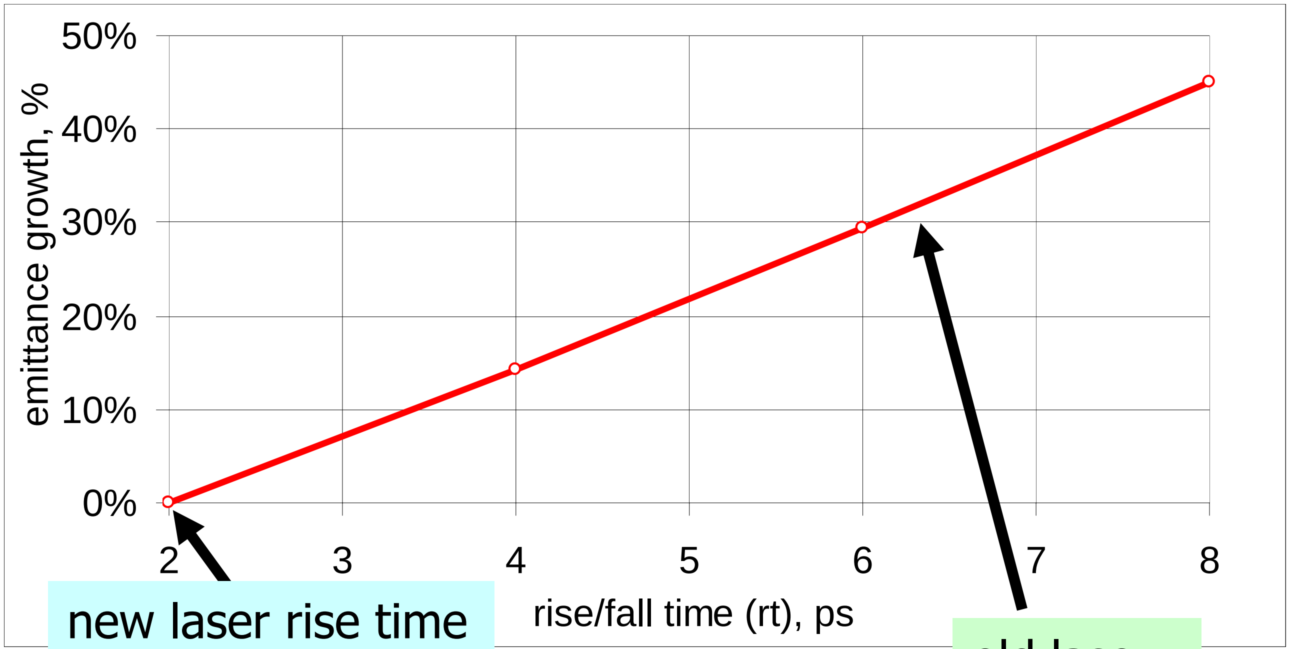
Old laser profile (streak camera measurement)



Temporal profile of the **new** laser system, measured by optical sampling at MBI

Simulation results predict that the shorter rise and fall times of the laser bring a reduction of 20% in the rms projected emittance.

The head and tail of the bunch have around twice the emittance of the central slices, and sharp rise/fall times reduce their influence.



new laser rise time **(XFEL design parameter)**

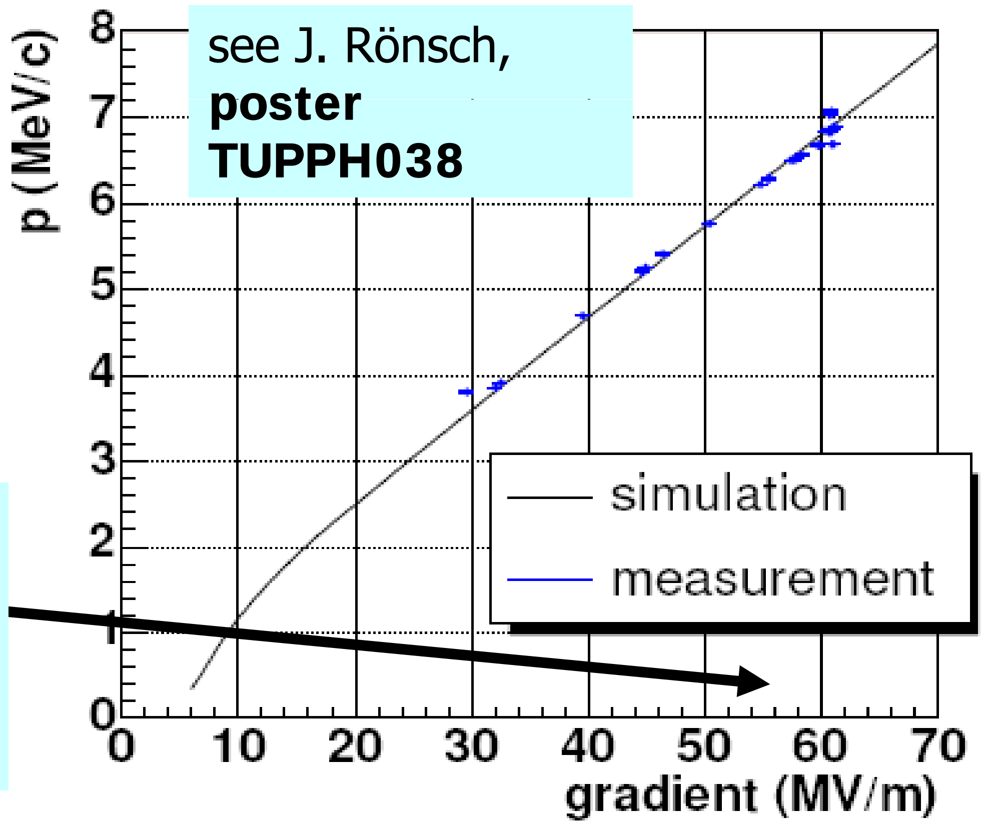
old laser rise time

Measurements of beam momentum before the booster (1.1 m downstream the gun) have been performed with the redesigned dipole magnet.

increased inner chamber width (27 mm) for transmission over a broader range of focusing conditions

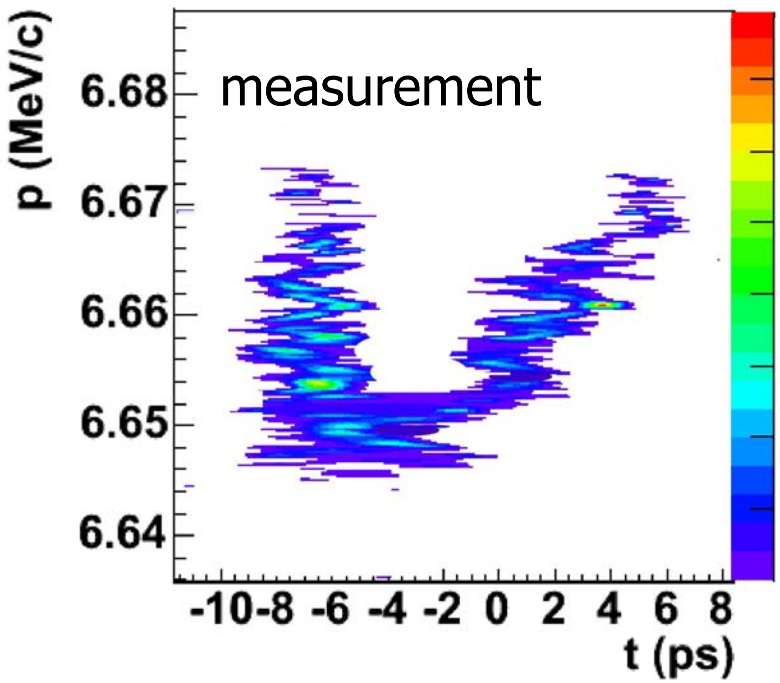
dispersion coefficient at the observation screen = 425 mm

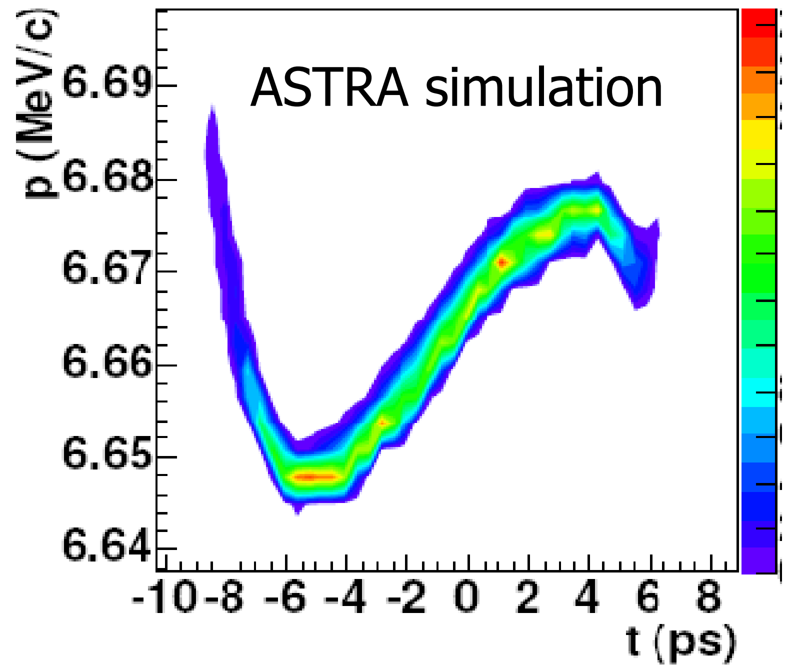
see J. Rönsch, **poster TUPPH038**



Simulations of the momentum vs. RF power measurements confirm gun gradients ~ 60 MV/m **(XFEL design parameter)**.

The longitudinal phase space is measured by combining the dipole dispersion with streak camera measurements.



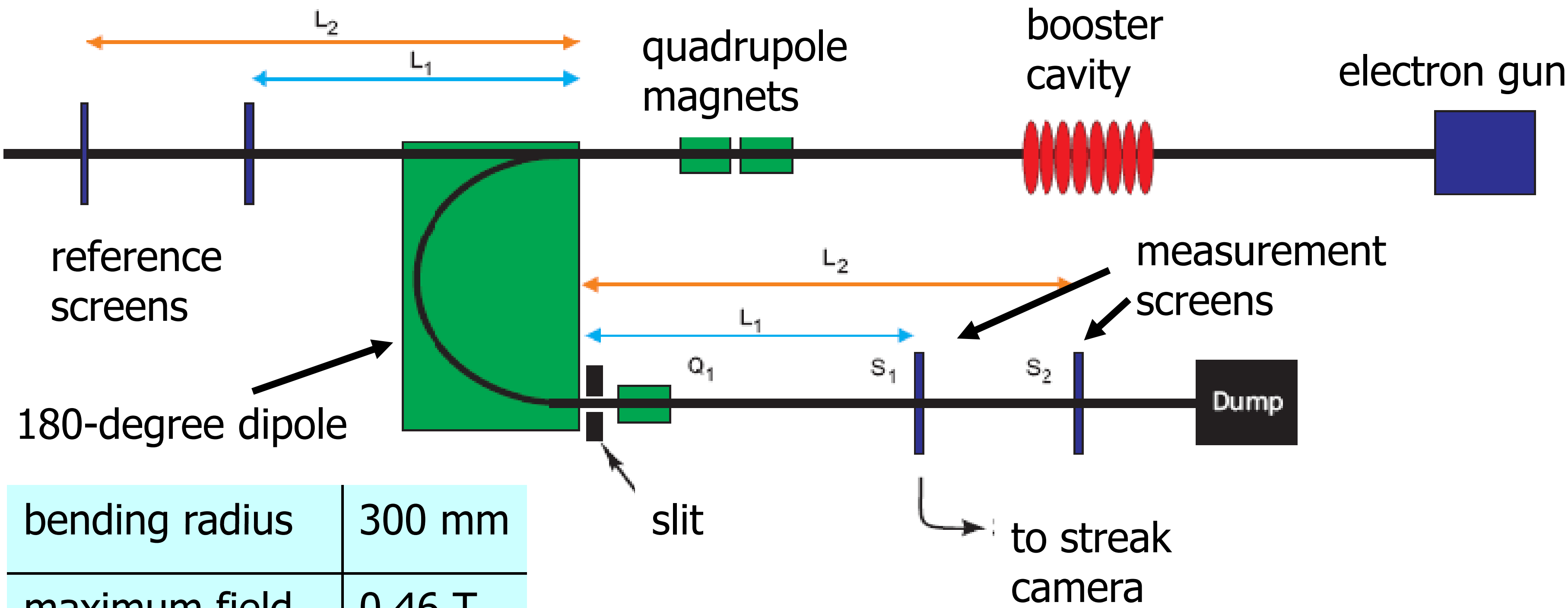


	pulse length (FWHM)
photocathode laser	2.1 ps, Gaussian
electron bunch	13 ps

1-nC bunches

see J. Rönsch, **poster TUPPH038**

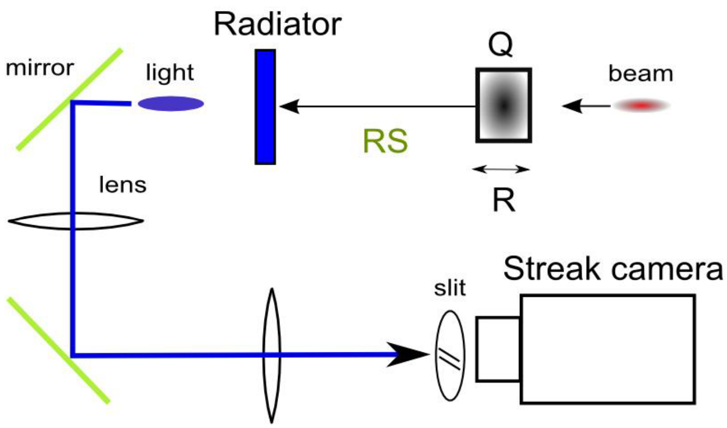
A multipurpose dispersive section has been installed after the booster cavity.

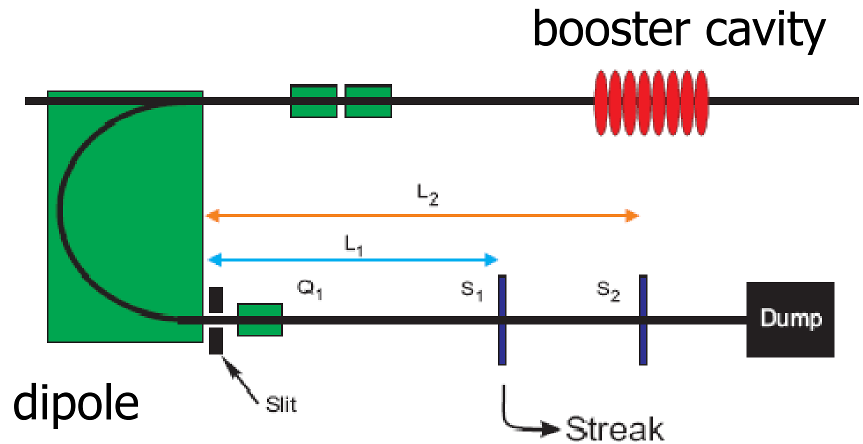


bending radius	300 mm
maximum field	0.46 T
dispersion coefficient	600 mm

This section is designed for beam momentum, longitudinal phase space, and slice emittance measurements.

Two programs for slice emittance measurements are being pursued.





Quadrupole scan with streak camera:
Errors are very large for the single quadrupole scan (optical resolution, lost signal at streak camera slit, space-charge effects), so multiple-quadrupole techniques are being considered.
Poster TUPPH037 (R. Spesyvtsev)

Off-crest acceleration in the booster cavity:
Difficulties include the proper solenoid optimization and errors caused by any steering after the booster, but estimations of error are reasonable (5-10%).
Poster TUPPH079 (Y. Ivanisenko)

The PITZ facility has been substantially upgraded and the measurement program is underway.

new 1-1/2 cell L-band gun

conditioning test stand

improved cooling, dry-ice cleaned

60 MV/m peak field at cathode*, lower dark current and lower reflected RF power (factor of 10)

new photocathode drive laser

rise and fall times of laser pulse shortened from 7 to **2 ps*** → simulation predicts lower transverse emittance

new dipole magnet in low-energy section

momentum and longitudinal phase space measurements already performed

new high-energy spectrometer

designed for beam momentum, longitudinal phase space, and slice emittance measurements

*** European XFEL specifications**

The further beam characterization program is in progress, including thermal emittance and emittance at 1 nC.

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2 postdoc positions and 1 PhD student position are currently open! See **http://pitz.desy.de**