On the online monitor for longitudinal beam profile measurements at FLASH.

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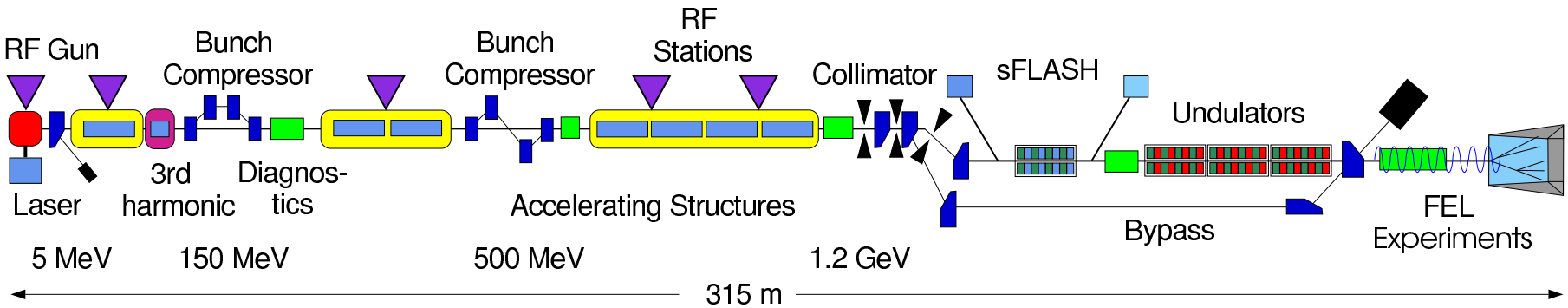
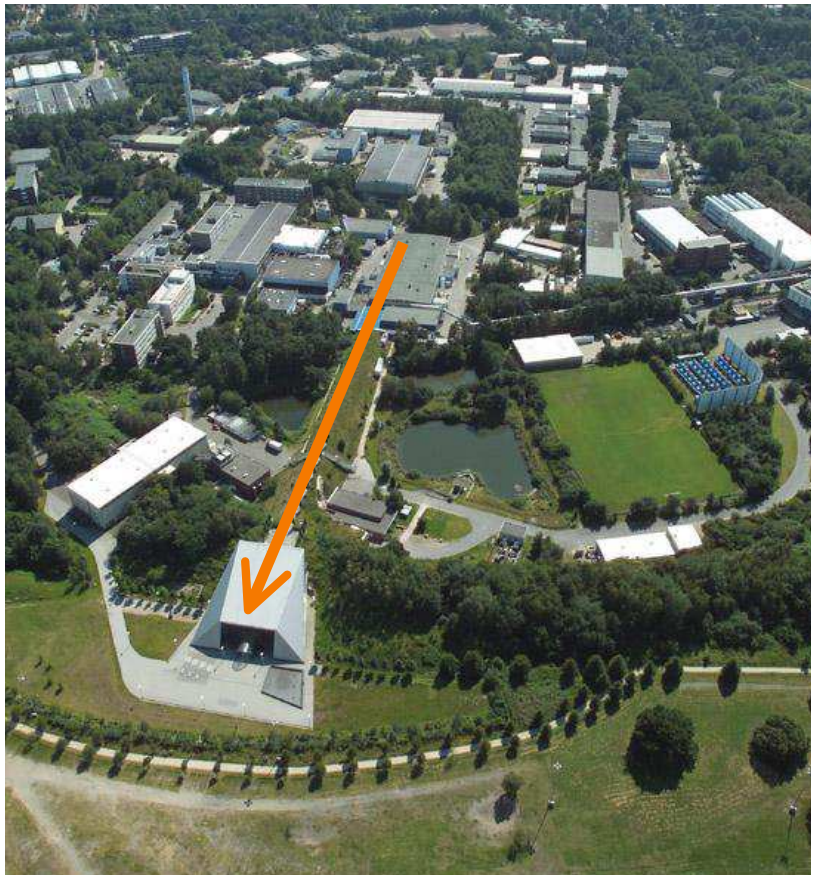
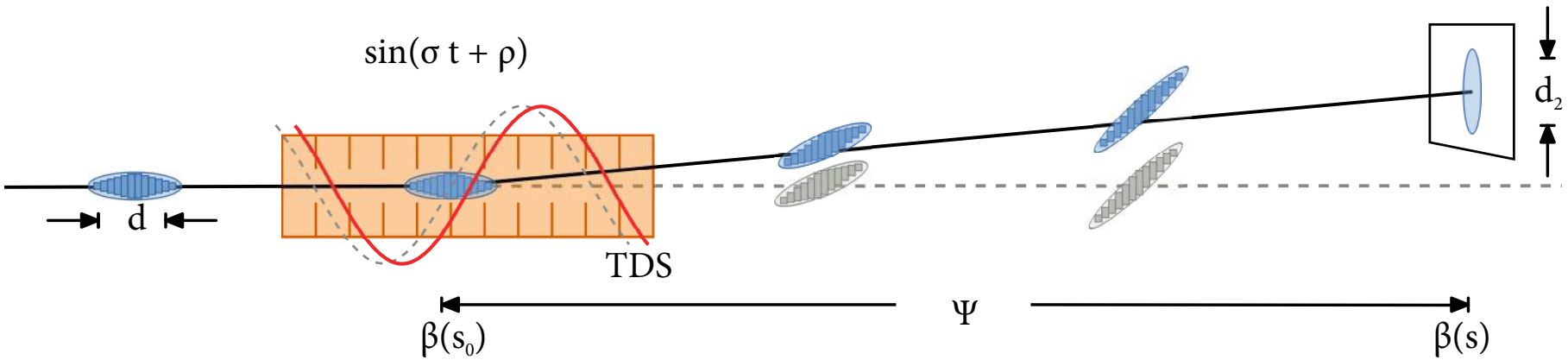
FLASH (Free-Electron Laser in Hamburg).



- single-pass high-gain free-electron laser
- self-amplified spontaneous emission (SASE)
- FEL user facility
- laser pulses in the EUV and soft X-ray wavelength range down to 4.12 nm
- pilot facility and test bed for the European XFEL

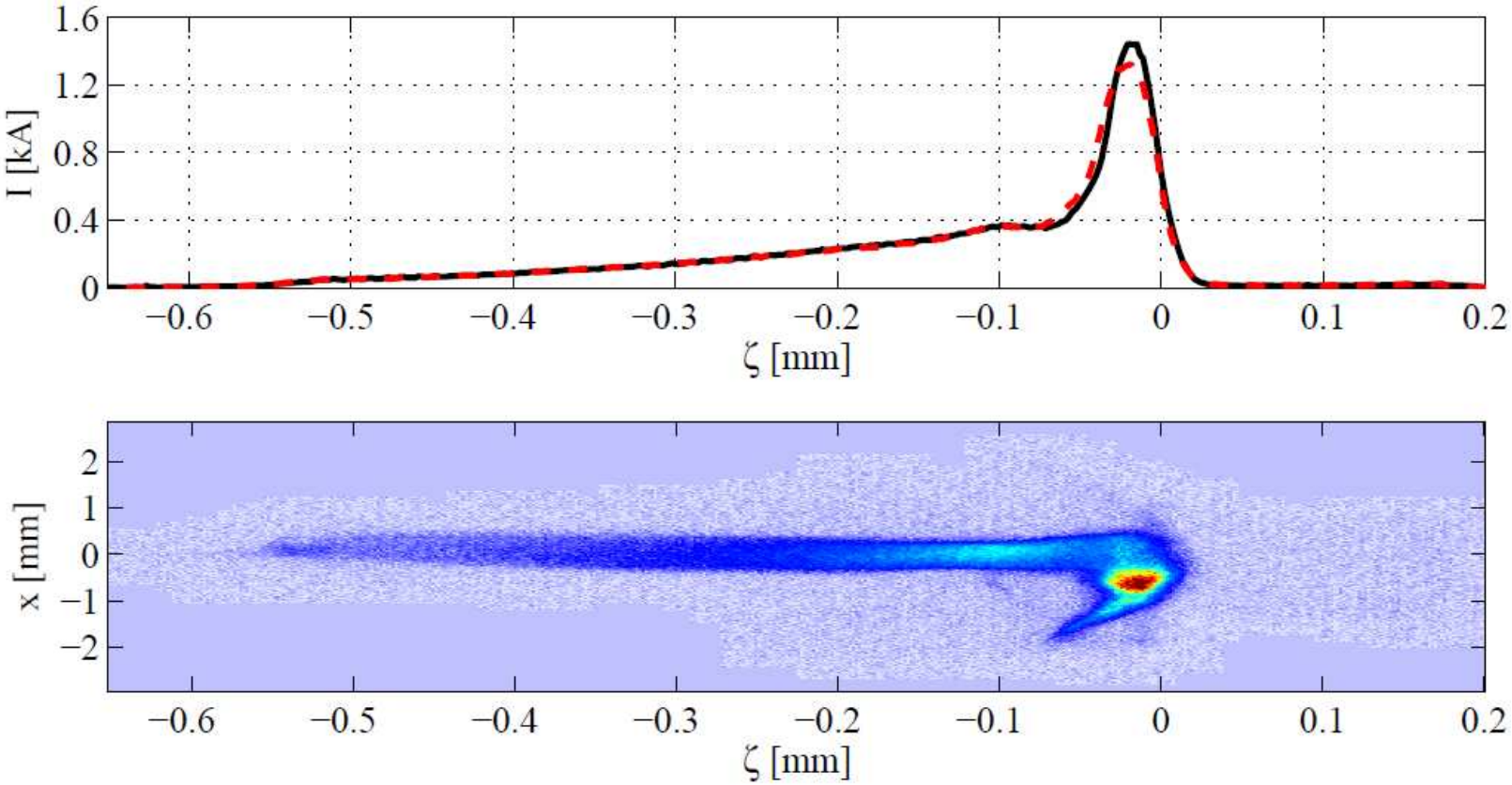


LOLA TDS (transverse deflecting structure).



- TDS imposes a time-dependent transversal kick $\Delta y'(t) \propto sin(t) \approx t$ (at zero-crossing)
- Appropriate beam transport optics (R_{34}) maps $\Delta y'(t) \rightarrow \Delta y(t)$, i.e. $\Delta y(t) \propto t$
- Time information is translated to the horizontal position
  $\rightarrow$ Longitudinal beam profile measurements

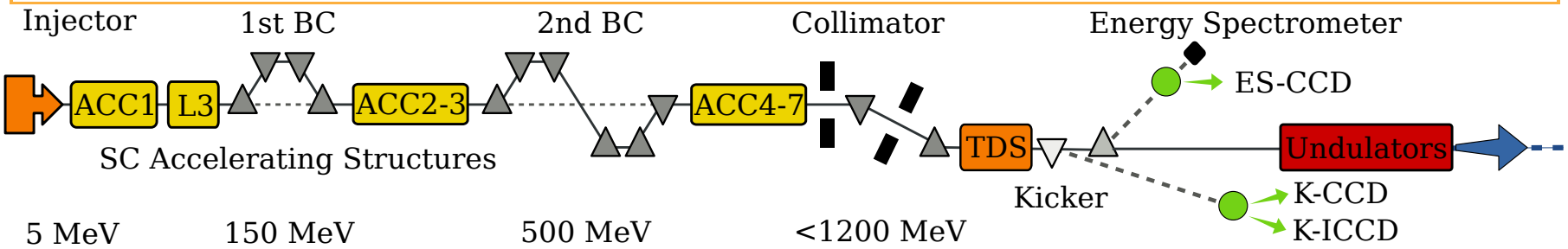
Beam profile measurements.



- Current profile, bunch length and slice emittance can be extracted
  → important parameters for the SASE process

LOLA as an online monitor.

Online measurement of the longitudinal beam profile during FEL operation

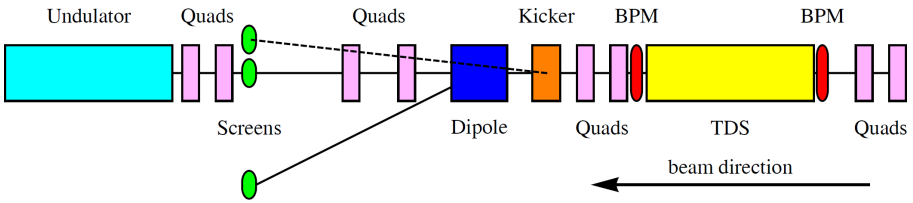


Steps on the way to an online monitor:

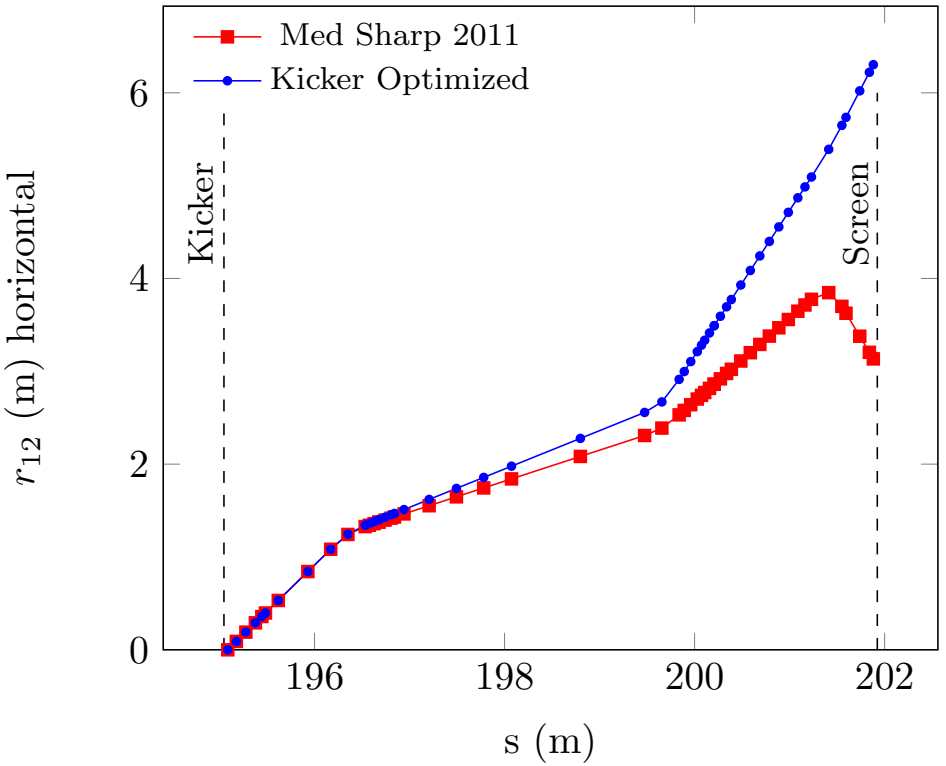
- kick electron bunches onto the screen
  → optimized optics
  → adjust kicker properties
- handle alarms from toroid protection system (TPS)
  → mask TPS signal in case of kicking
- handle alarms from beam loss monitors (BLM)
  → additional shielding
  → mask BLM signal in case of kicking

Optimized optics simulation.

- Kicker introduced offset characterized by $r_{12} = \sqrt{\beta(s_0)\beta(s)}\,\sin\Delta\Phi_x$
- $\Phi_x \overset{!}{\approx} 90^\circ$ (Kicker $\rightarrow$ Screen)
- LOLA longitudinal resolution $\sigma_\zeta \propto \frac{1}{\sqrt{\beta(s_0)}\,\sin\Delta\Phi_y}$
- $\Phi_y \overset{!}{\approx} 90^\circ$ (TDS $\rightarrow$ Screen)



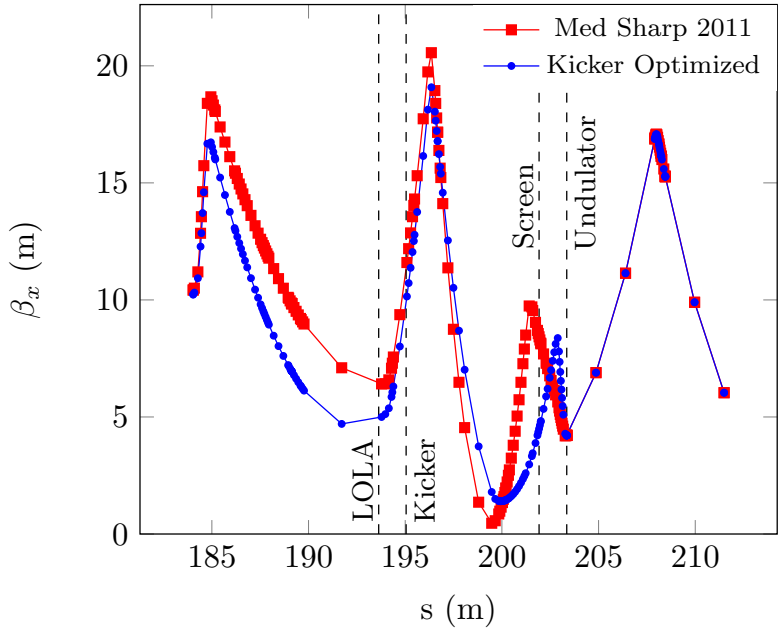
- modification of the last 20 m in front of the undulator section
- matching into undulator section crucial



Optimized optics properties.

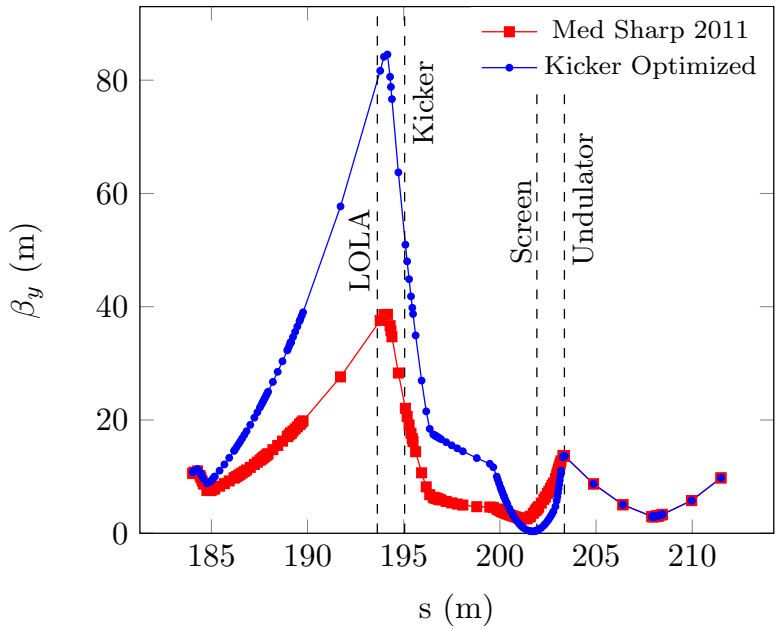
horizontal plane

- similar beta functions compared to the old optics
- $\Phi_x = 110^\circ$ (Kicker $\rightarrow$ Screen)
- introduced offset by the Kicker increased by a factor of 2



vertical plane

- very high beta function at about 195 m
  $\rightarrow$ beam size $\sigma_y \propto \sqrt{\beta}$
  $\rightarrow$ σ_y increases by a factor of 1.4
- $\Phi_y = 135^\circ$ (LOLA $\rightarrow$ Screen)
- slightly increased LOLA resolution



Different kicker properties.

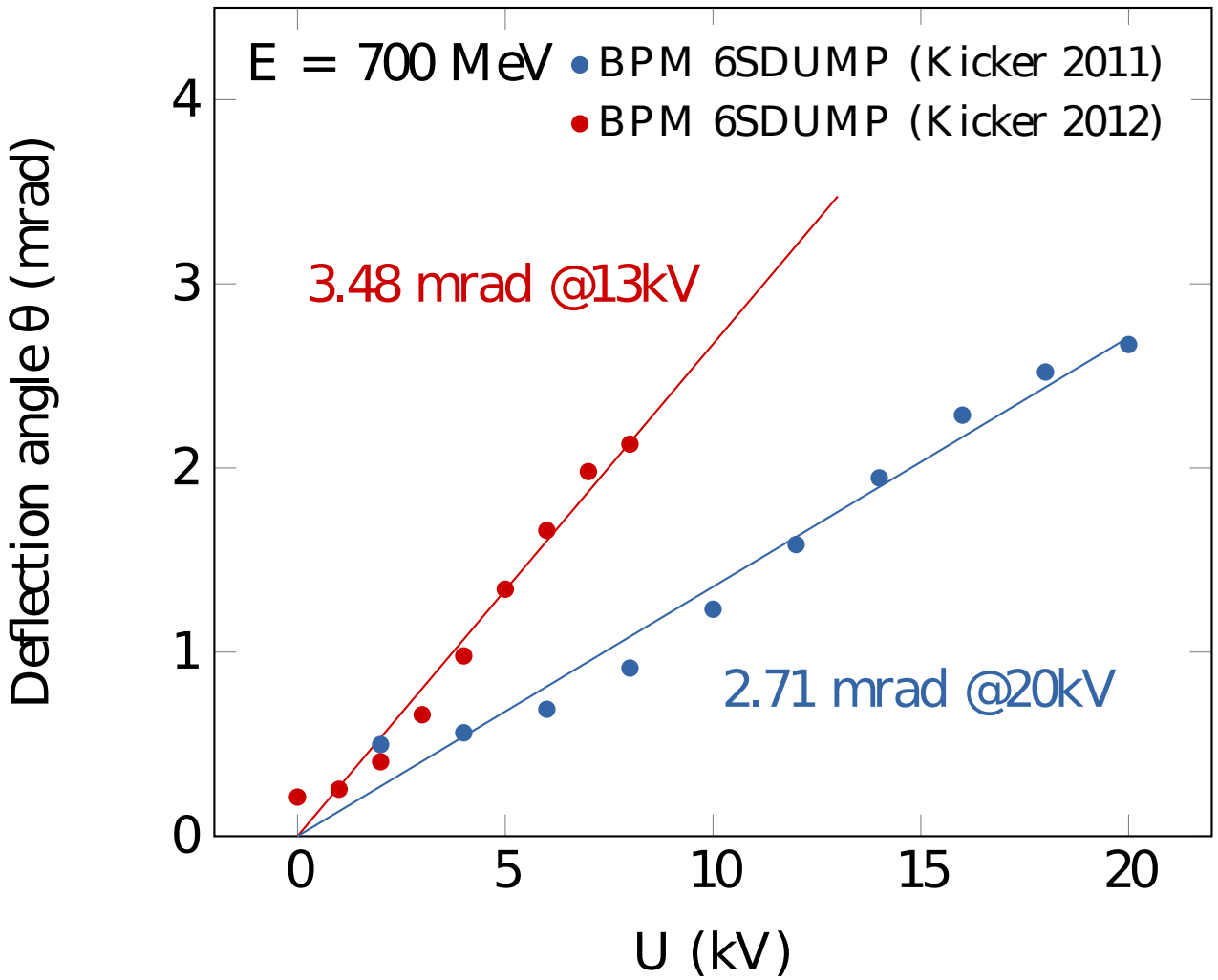
A new pulser has been installed increasing the kicking strength.

before

- 370 ns pulse width (half sine wave)
- I = 2.3 kA for 20kV

after

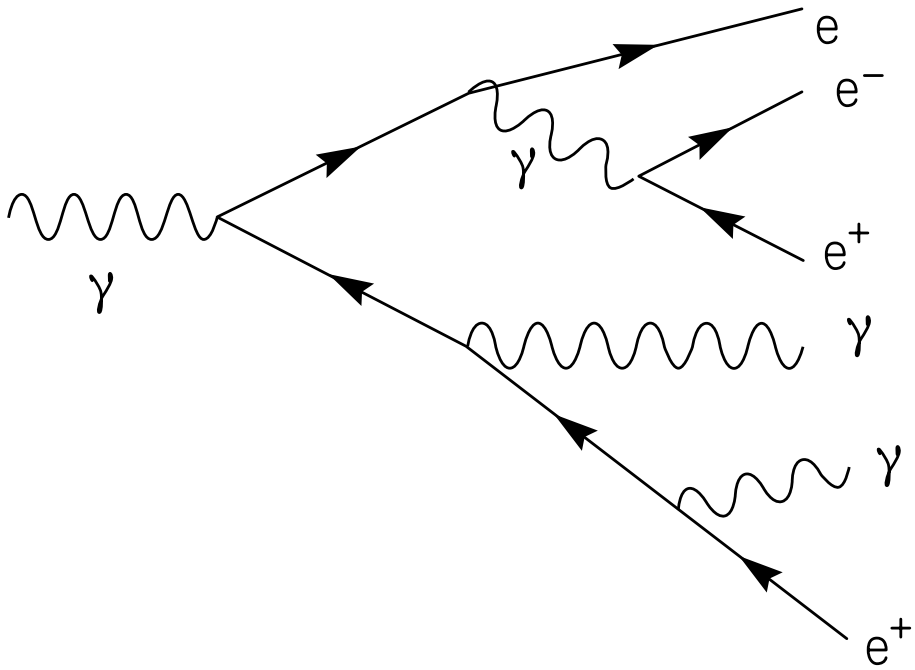
- 1.4 μs pulse width (half sine wave)
- I = 5 kA for 20kV
- U currently limited to 13 kV



→ kicking on screen now possible
→ but tests showed a possible aperture problem

Electromagnetic cascade shower.

- Electron bunches which are kicked on the off-axis screen hit a copper absorber
- dominant photon interactions:
  - photoelectric effect
  - compton scattering
  - pair production
- dominant electron interactions:
  - soft and hard collisions with atoms
  - radiative interactions
- These showers have been observed as beeing a threat to the machine protection system
- Simulations have been performed to study the benefit of additional shielding



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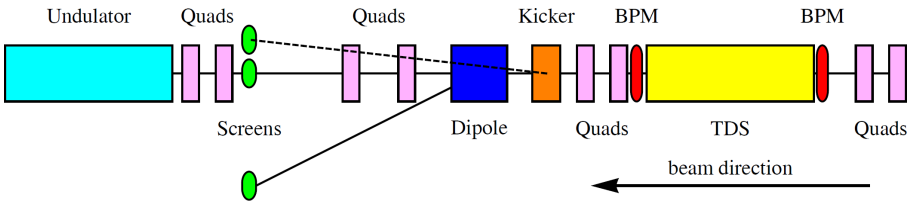
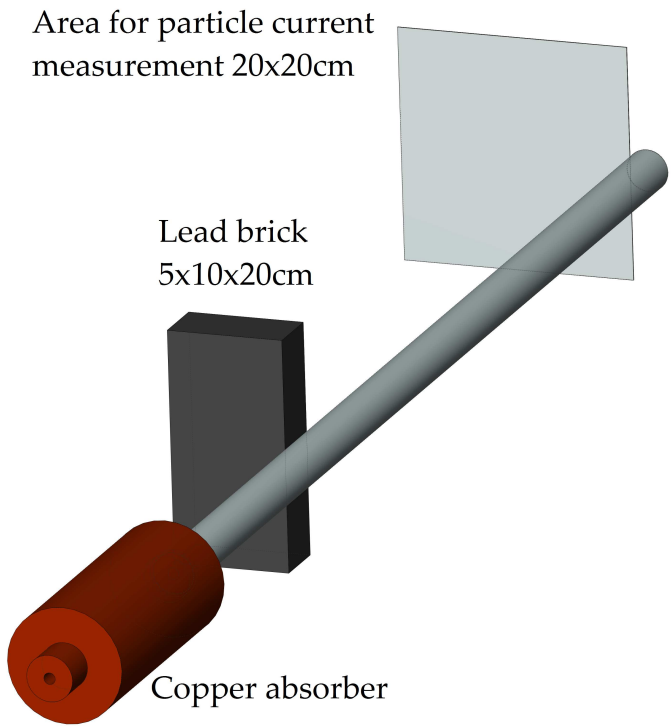
Electromagnetic cascade shower.



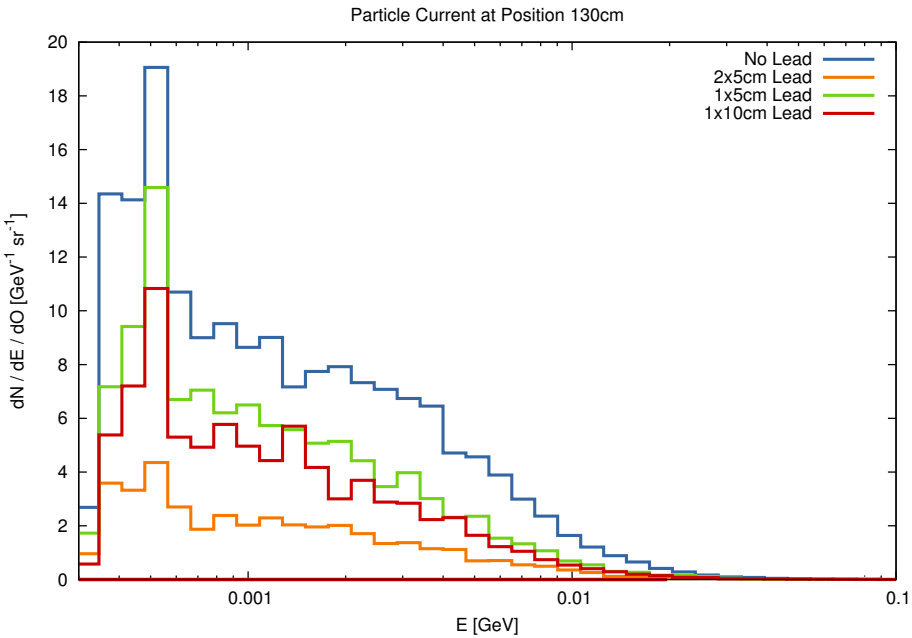
- 13SMATCH screen station is very close to the undulator section
- undulators very sensitive to radiation doses $\rightarrow$ demagnetization
- therefor 38 beam loss monitors (BLM) are placed at undulator positions

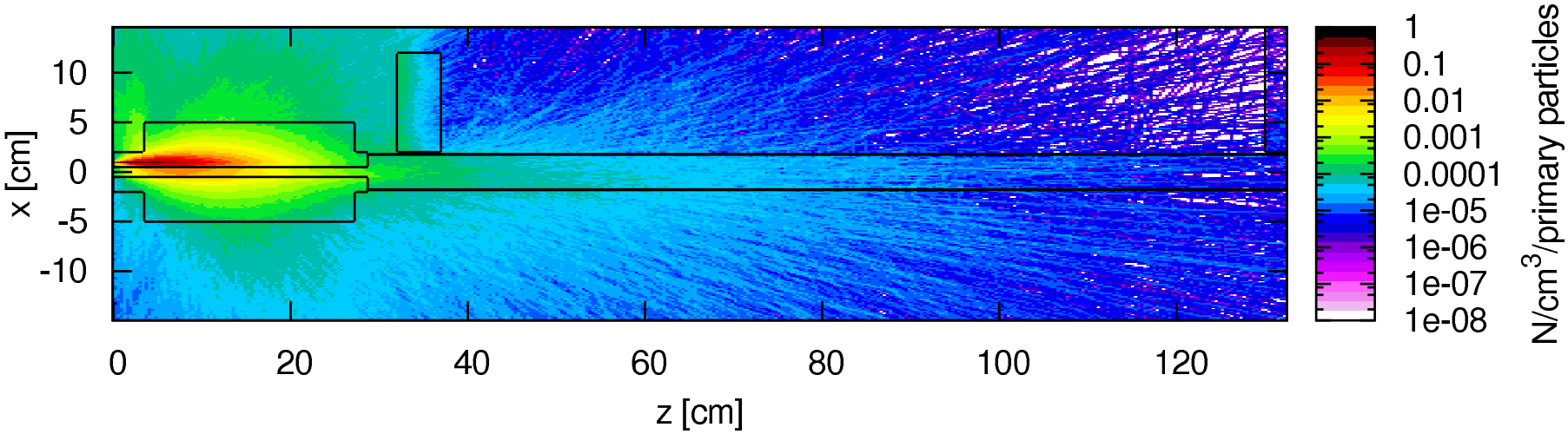
- BLMs are sensitive to those showers $\rightarrow$ Alarm signals to machine protection system



FLUKA simulations.

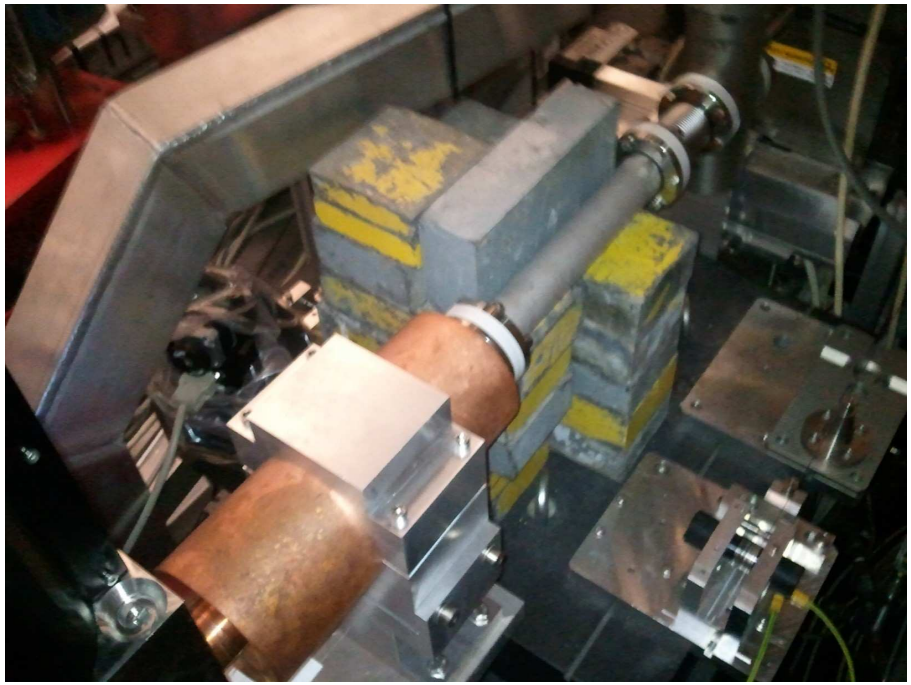
- 100000 primary particles at 1.2GeV
- record of electron particle density
- record of particle current in an test area of 20x20cm at undulator position
- Lead bricks of the size 5x10x20cm have been inserted into the system at different positions

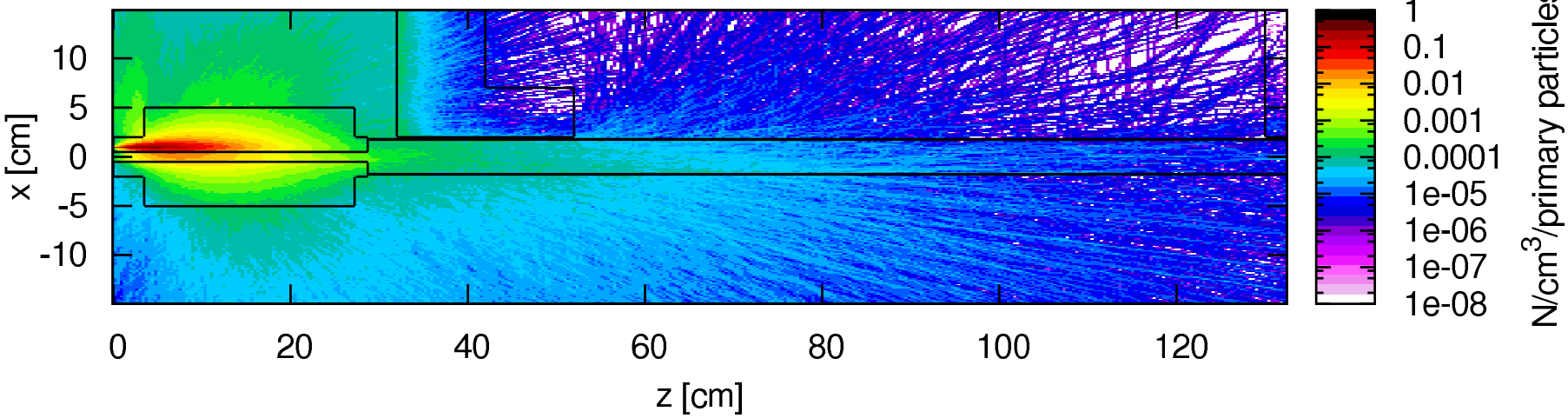




Installation of additional shielding.

- Lead has been installed according to priorities from the simulation
- Particle current near to undulator reduced by 73%
- Still occuring alarm signals need to be masked





Summary and Outlook.

Done New optics were calculated to allow efficient use of the kicker strength

Ongoing New optics will be tested in March

Done Kicker strength has been increased
→ kicking onto the screen now possible

Done EM shower have been minimized due to shielding with lead

Ongoing For still occuring BLM alarms an electronic box will be installed to mask the alarm in case of kicking (March)

Ongoing A device to mask the TPS alarms is under development

The End.