TTF Dark Current Kicker and NML Simulations

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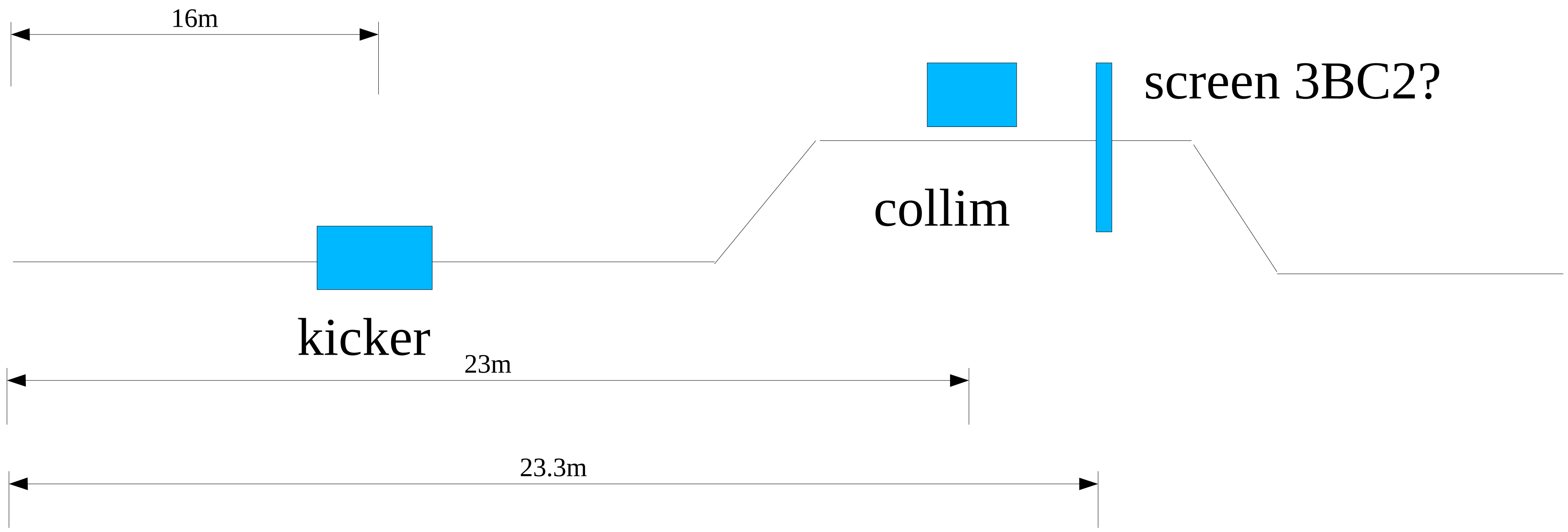
Overview

- A summary of what TTF has measured and plan to do
  - This comes from “Dunkelstrom Kicker TTF2”
  - Caveat: I don't speak German, so interpretation of slides should be taken with a grain of salt.
- Simulations done with ASTRA for NML
  - Goal is to have some idea of the dark current energy distribution
  - Baseline for the dark current kicker.

Layout



Energy of beam at kicker = 130MeV

35cm dispersion at screen

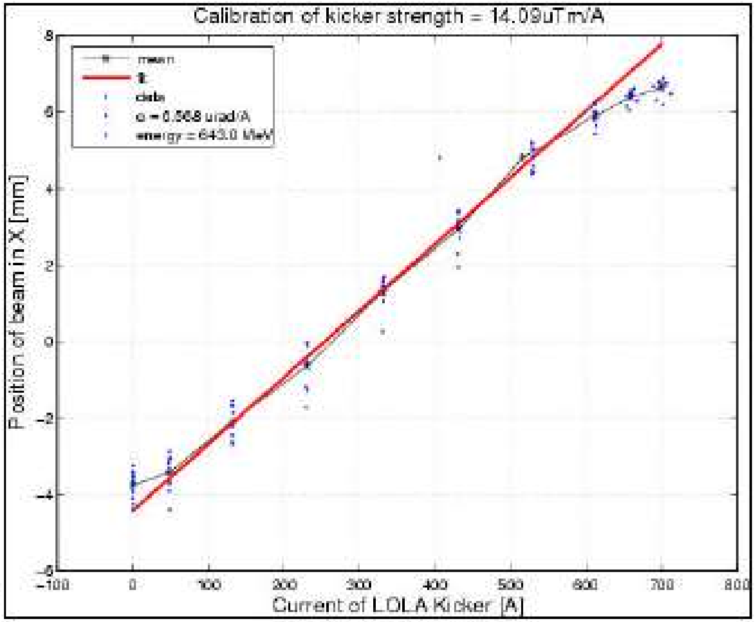
2. Berechnung magnetischen Feldes und des Pulsstromes

$$\delta_x = \frac{Bdl \cdot c}{E}$$

$$Bdl = \frac{\delta_x \cdot E}{C}$$

$$Bdl = \frac{1mrad \cdot 100MeV}{3*10E8}$$

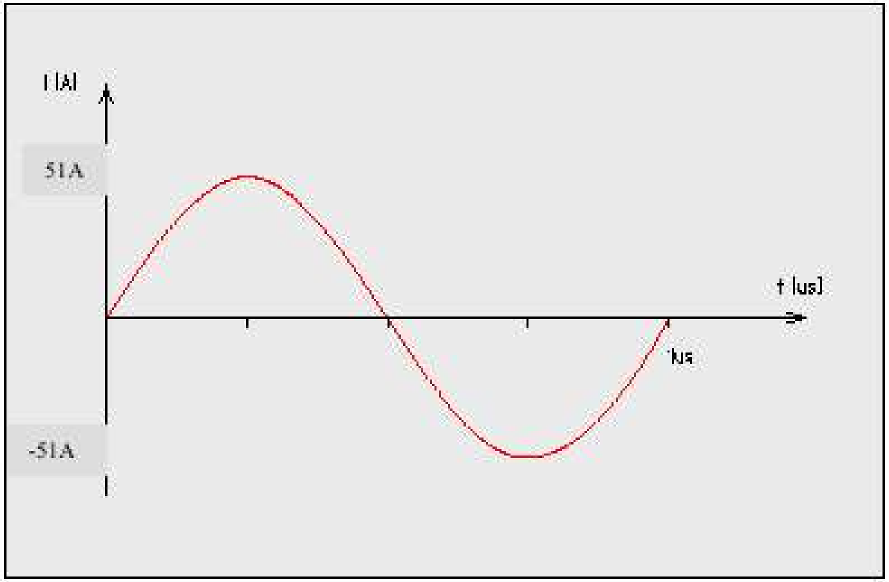
$$Bdl = 333\mu Tm$$



LOLA Kicker hat ein Bdl = 6,5µTm /A (gemessen mit Strahl bei TTF2)

$$I = \frac{333\mu Tm}{6{,}5\mu Tm / A}$$

$$I = 51{,}23A$$



9. Messung mit Strahl bei TTF2

We start the dark current kicker experiment:
- panel available in the injector overview panel
- it kicks with a max amplitude of 50 A -> 1.6 mrad

with a 1 MHz sine wave, so +- kicks are produced, so +- 1.6 mrad

(details: measured strength at LOLA with an identical kicker using a BPM:
BdL = 14 uT m/A
kick (rad) = 300 B(T)*L(m)/p(MeV) = 32 urad/A for 130 MeV)

We measure the kick on screen BC2 as a function of start time of the kick.
As expected, we see a sine wave behaviour.
Max kick to high energy side of BC2 is for 3.0414, no kick at 3.0417, max kick to min Energy side
at 0.0420 roughly

Horizontal beam position (beam energy) at in screen 3BC2 as a function of the dark current
kicker trigger (trigger delay/ms). 5000 is low energy part and 3000 is high energy part

Dispersion on the position of 3BC2 screen about 0.35 m . Energy kick on the screen about +- 1 MeV (see plot below). Beam energy about 127 MeV. (1/127)* 0.35 m = 0.0028 m = 2.8 mm

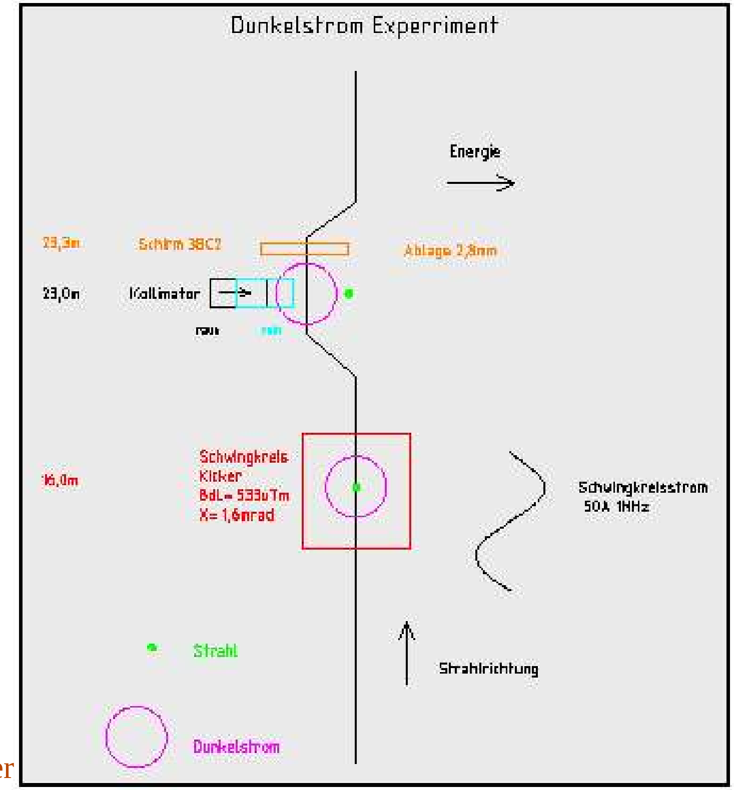
If we assume that the distance from the kicker from the screen is 3.5 m, and the kick angle is 1.6 mrad the displacement should be 3.5 m * 0.0016 = 5.6 mm, i.e. factor of
2.0 larger than measured. Or is this calculation wrong ?

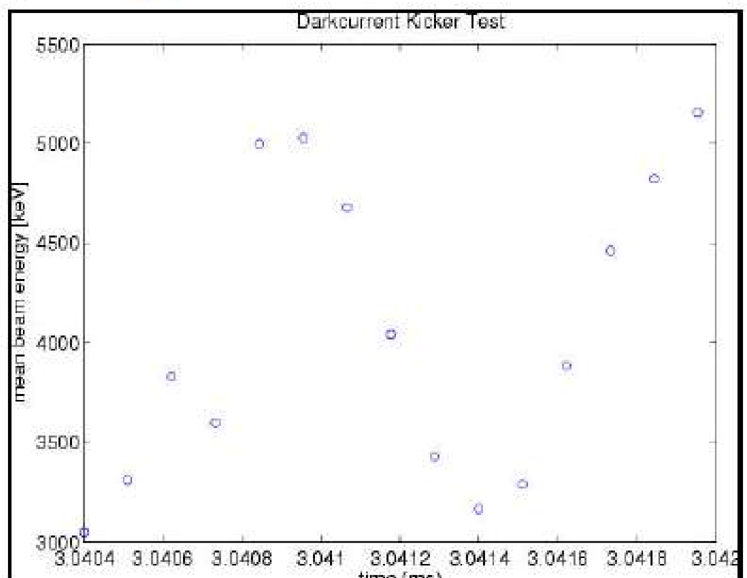
Not 50A but 25A! See Slide 15 of original paper

from Pedro: 1 mrad at 16.5 m produces an offset at the collimator of 4 mm (takes optics into account)

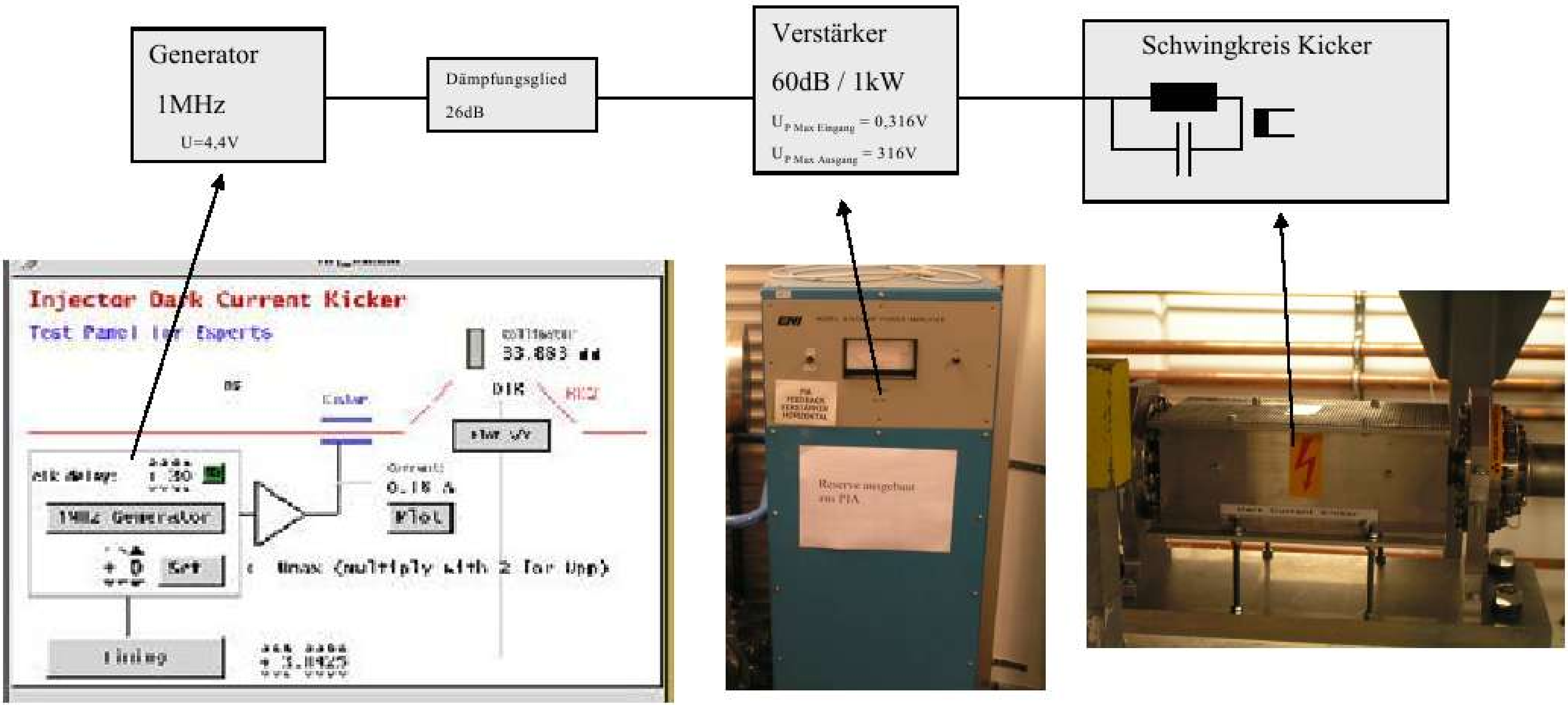
now the kicker is at 19 m, the screen at 23.3 m, the collimator at 23 m about
so the distance kicker screen = 3.5 m
Pedro assumed 6.5 m -> displacement for 1 mrad should be 2.1 mm, we kick with 1.6 mrad ->
expected displacement 3.4 mm, measured 2.8 mm, not too bad

from Yujong:
simulation of the kick
kicker is at 19 m, the screen at 23.3 m, the collimator at 23 m about so the distance kicker screen = 3.5 m
When there is 1.6 mrad kicking by the dark current kicker which is located
at about 19.0 m from the cathode,
horizontal orbit offset at 3BC2 screen = 4.930414 mm.
Therefore orbit difference is about 5 mm at 3BC2 screen for with kicking and without kicking cases.

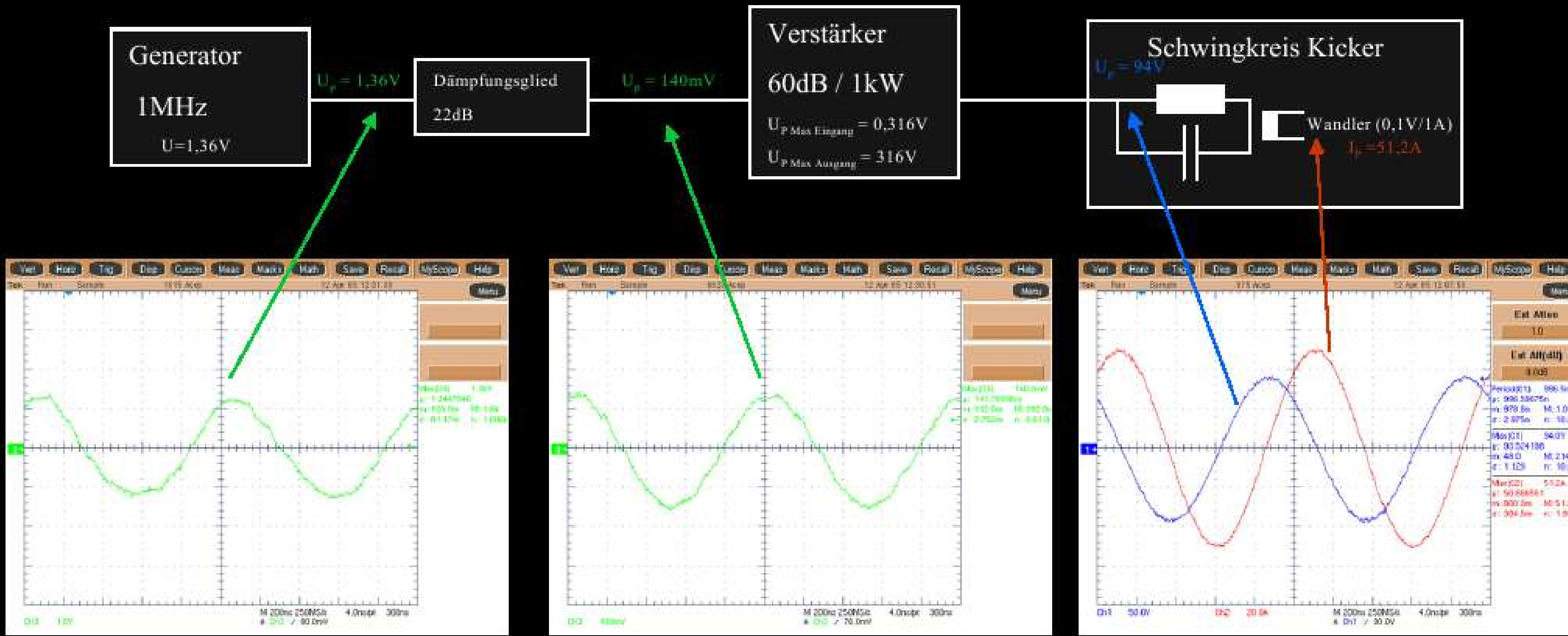




3. Prinzipschaltung

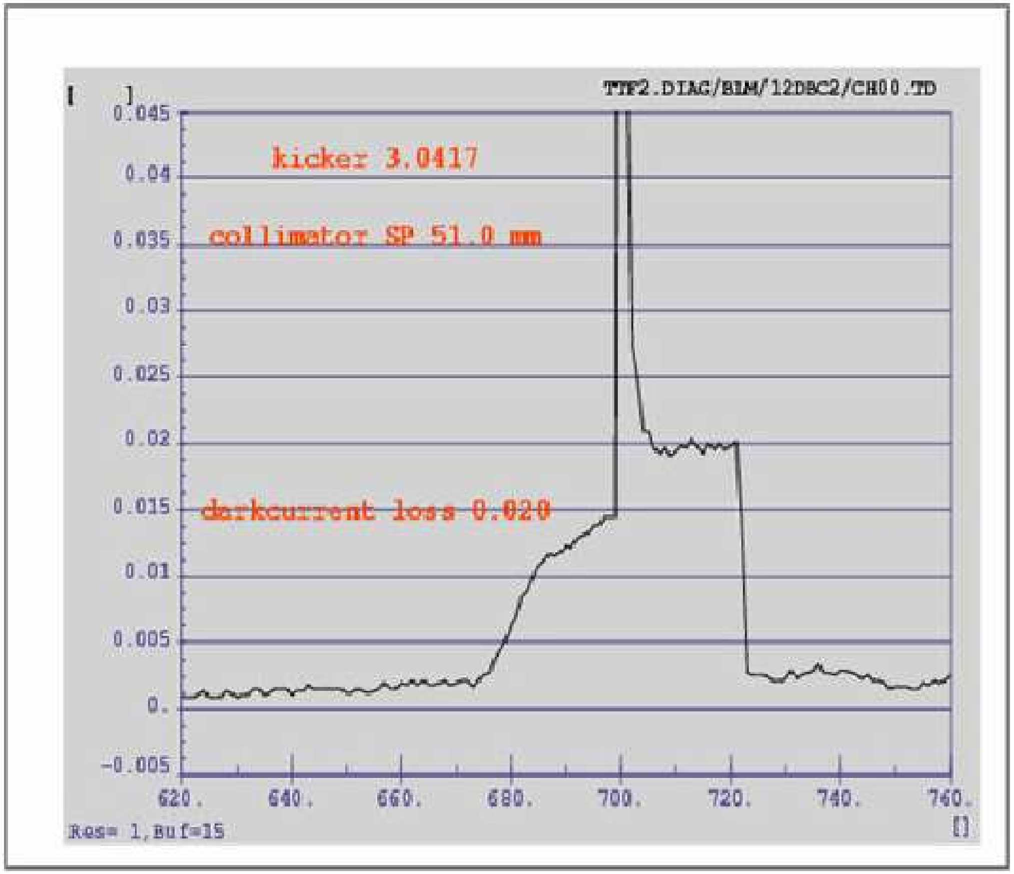


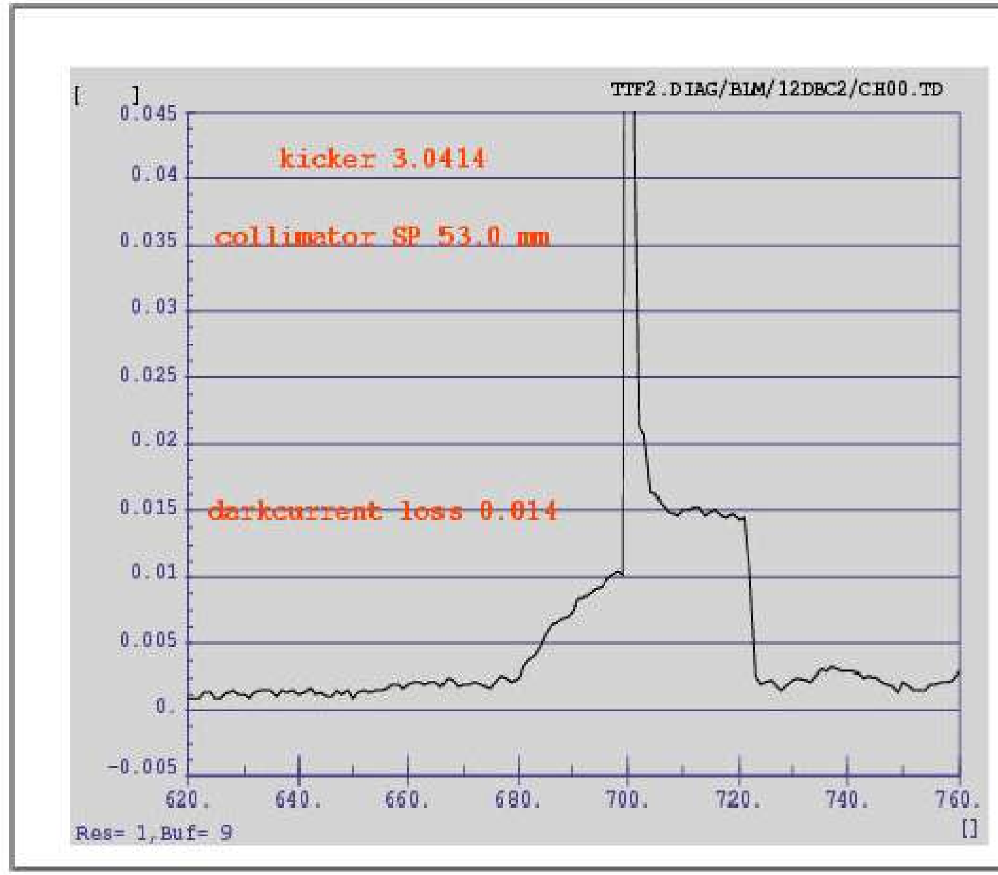
8.Messung mit Strahl bei TTF2



Generator Ausgangsspannung	Verstärker Eingangsspannung	Verstärkeranzeige	Schwingkreisstrom
$1{,}36V_{PP}$	$140mV_{PP}$	$51V_{RMS}$	$100A_{PP}$
$2{,}76V_{PP}$	$284mV_{PP}$	$100V_{RMS}$	$200A_{PP}$

10. Messung mit Strahl bei TTF2

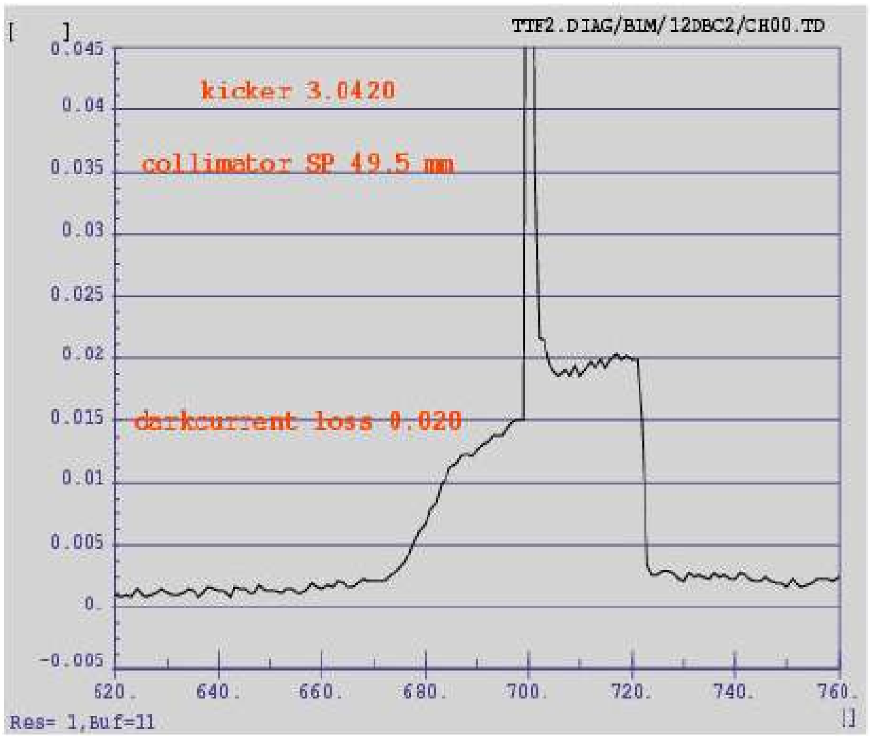


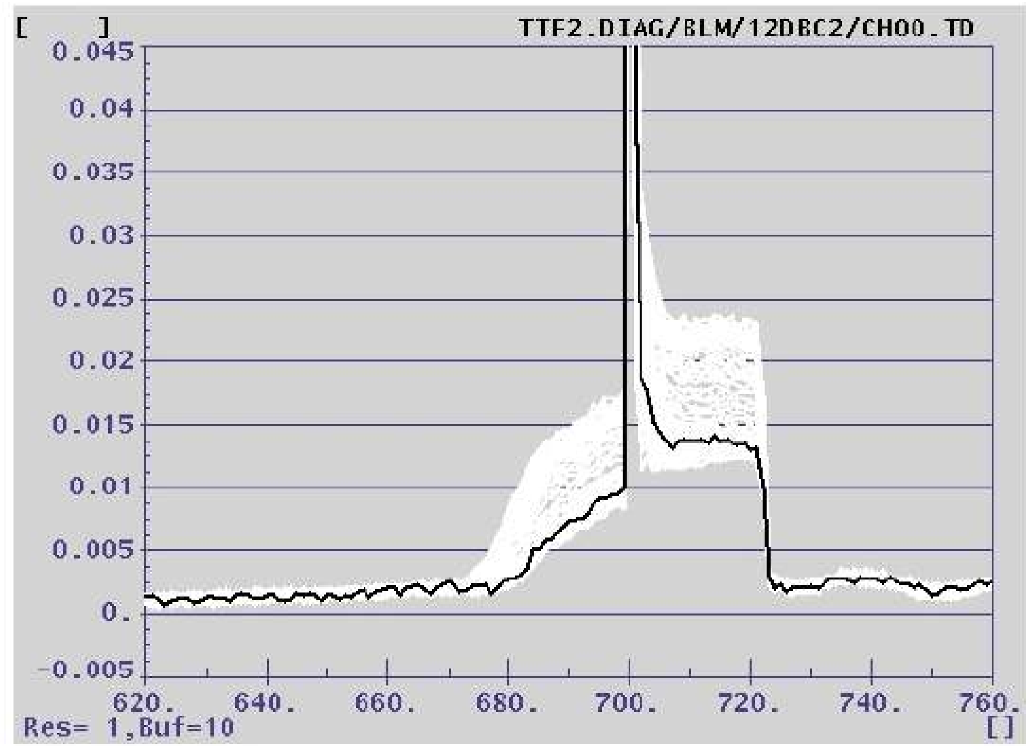


BC2 collimator always moved as close as possible to the beam Kicker works at 50 A corresponding to 1.6 mrad. Screen 3BC2 is in.
No kick.

Kicker max kick 50 A corresponding to 1.6 mrad.
Screen 3BC2 is in.
Max positive kick (direction to high energies)

11. Messung mit Strahl bei TTF2



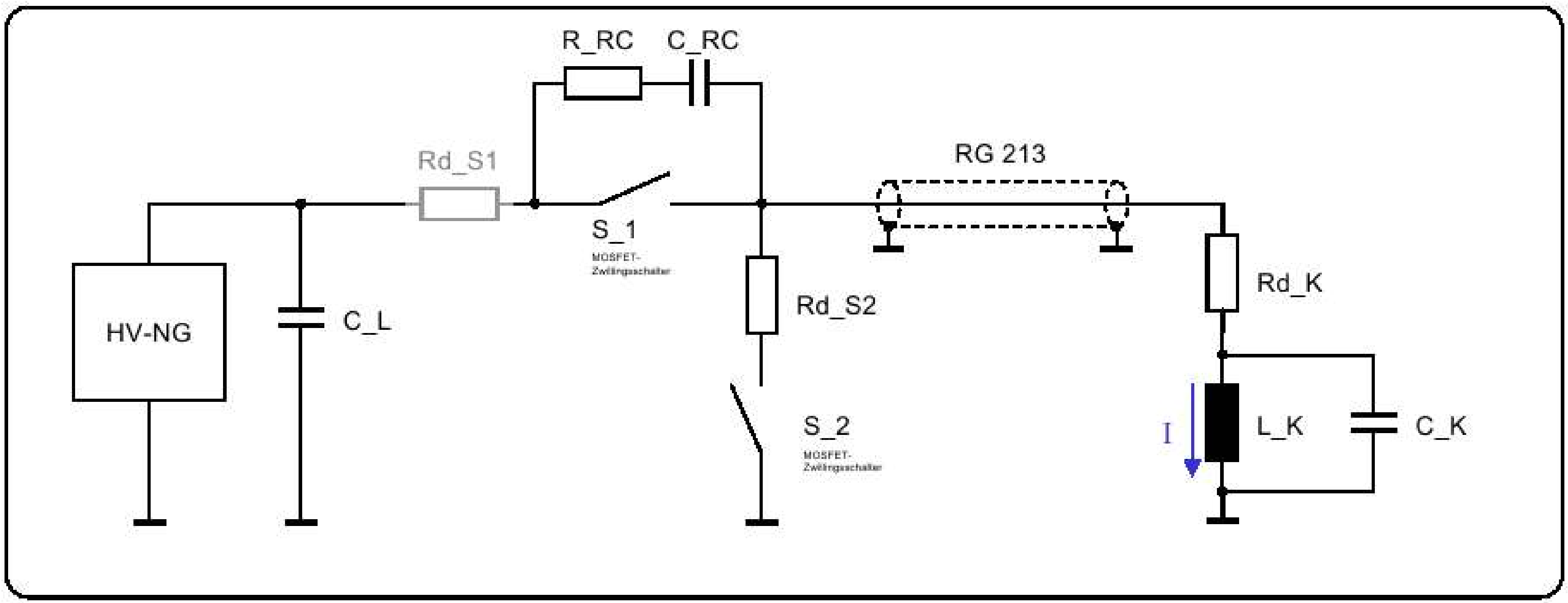


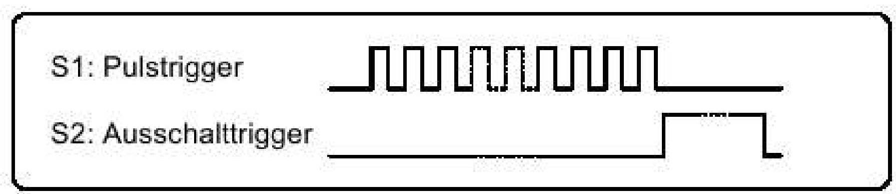
BC2 collimator always moved as close as possible to the beam Kicker works at 50 A corresponding to 1,6 mrad. Screen 3BC2 is in.
Max neg. kick (direction low energies)

Reduction of dark current in BC2 section about 30 % ((0.02-0.014)/0.02 = 0.3)

Beam kicked timing 3.0414. The black line is collimator in at 53.0 mm and white collimator moved out to position 49.5 mm.

Schaltskizze MOSFET-Pulser mit RC-Beschaltung und Ausschalter





C_L	8800 µF
L_K	310 nH
C_K	72 nF
Rd_S1	0 Ω
Rd_S2	25 Ω
Rd_K	5 Ω
R_RC	5 Ω
C_RC	2,2 nF
RG 213	~30 m

RC-Beschaltung dämpft Spannungsüberhöhung an S1 zu Beginn eines Pulszugs

Rd_K entkoppelt Kabelkapazität vom Kicker

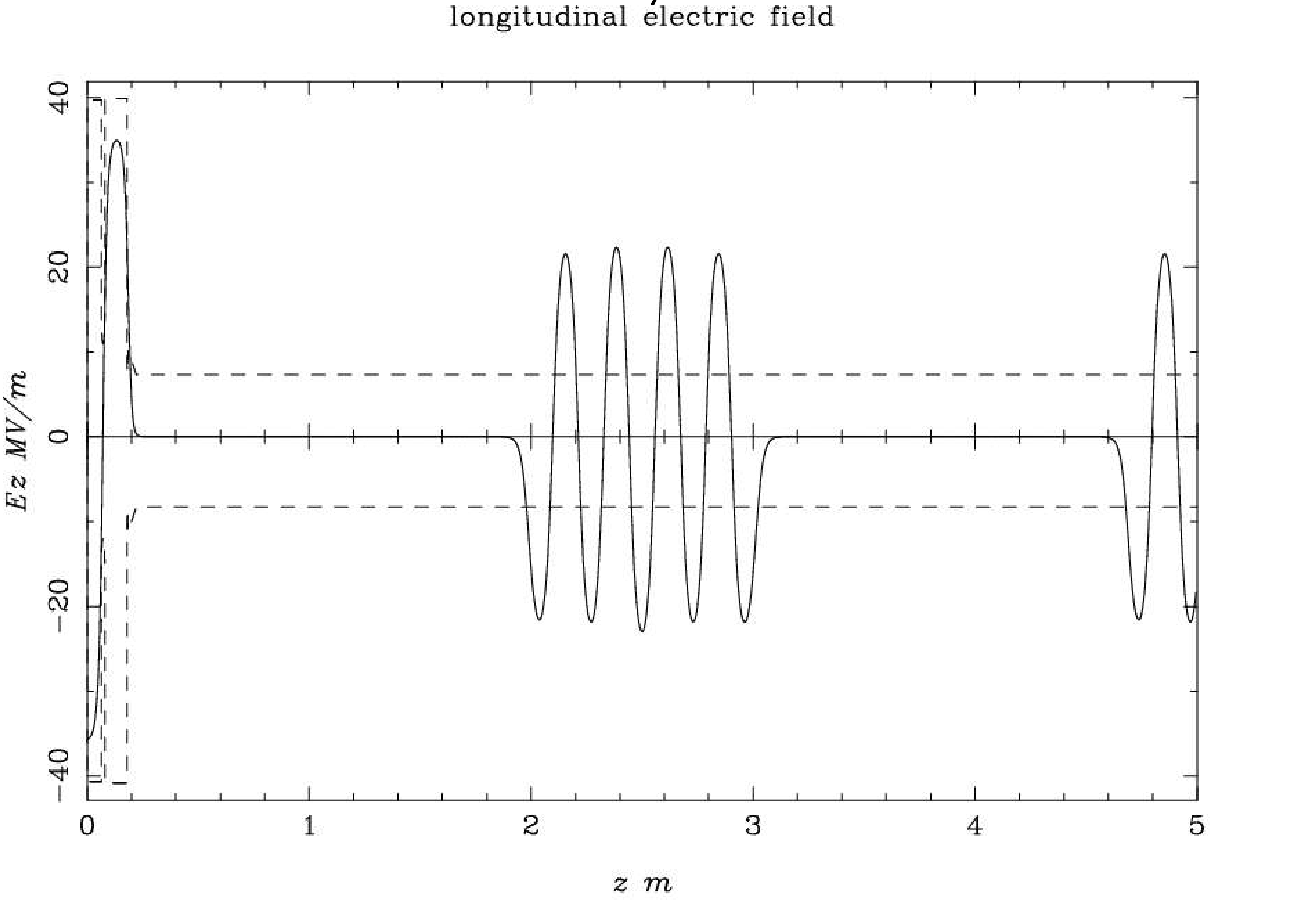
Rd_S2 (Ausschaltwiderstand) dämpft Spannungsüberhöhungen an S1 am Ende eines Pulszugs, die durch Kabelkapazität entstehen

MOSFET-Pulser

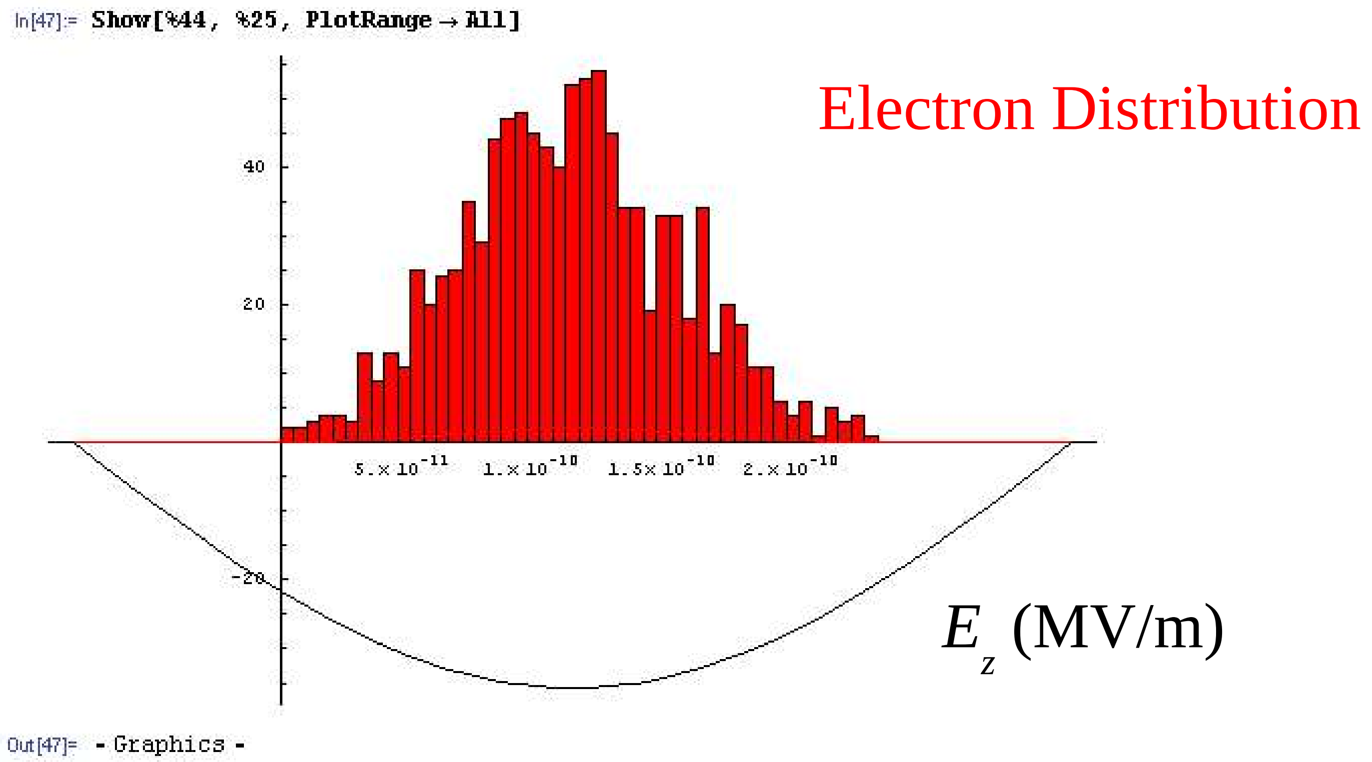
Simulations Started for NML

- Create dark initial distribution using Fowler-Nordheim
- Match the simulated current to that measured by Fliller et al., "Time Dependent Quantum Efficiency and Dark Current Measurements in an RF PhotoCathode Injector with a High Quantum Efficiency Cathode", Fermilab-Conf-05-185-AD.
- Calculate the energy distributions at the various points at NML.
- See where particles are lost. Will kicked dark current cause a quench?
- Calculate the efficiency of the kicker.

Layout



The Initial Distribution

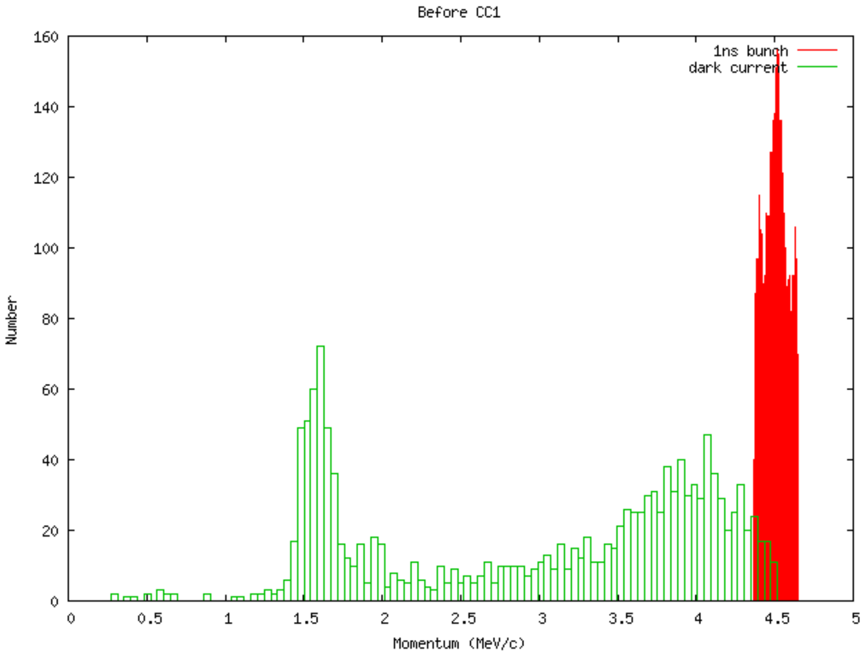


$$I_{\text{dark}} = \alpha\, 46.2\times10^{-6} A(\beta E)^{2.5} \exp\left(-\frac{6.654\times10^{4}}{\beta E}\right)$$

$$E = E_{\max} \sin(\omega_{\text{RF}} t)$$

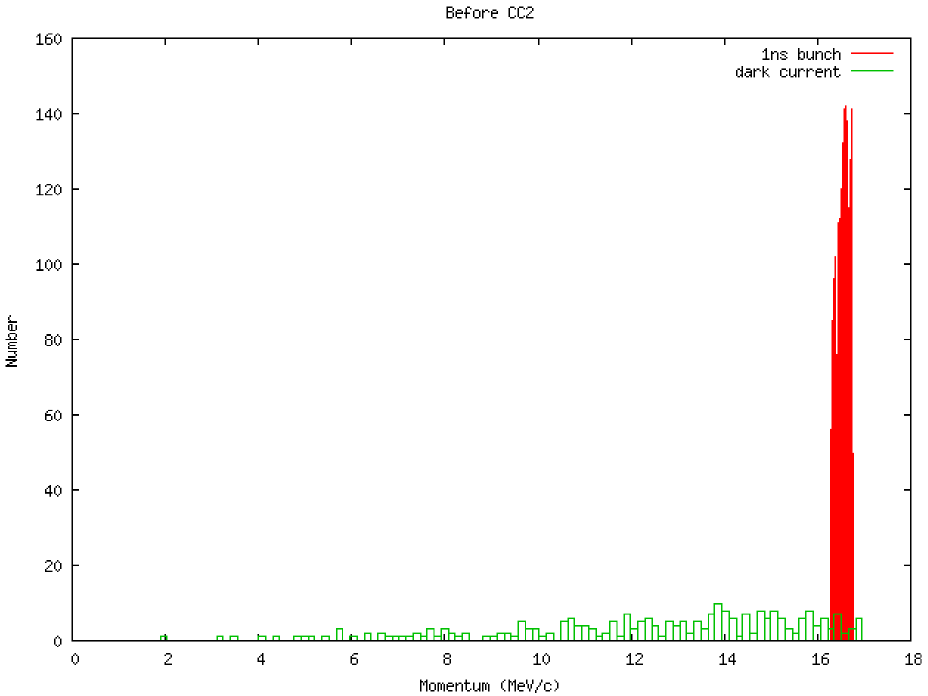
α, β, A are free parameters to fit with observations. Assume dark current from cathode. See J.H. Han's thesis

Some Preliminary Results



Before CC1:
Lost 85% (1448/10000) of dark current before CC1!
Only 2% of main bunch

Before CC2:
Lost another 80% (257/10000) of dark current going through CC1!
0% lost in main bunch.



Compare with J.H. Han's Measurements

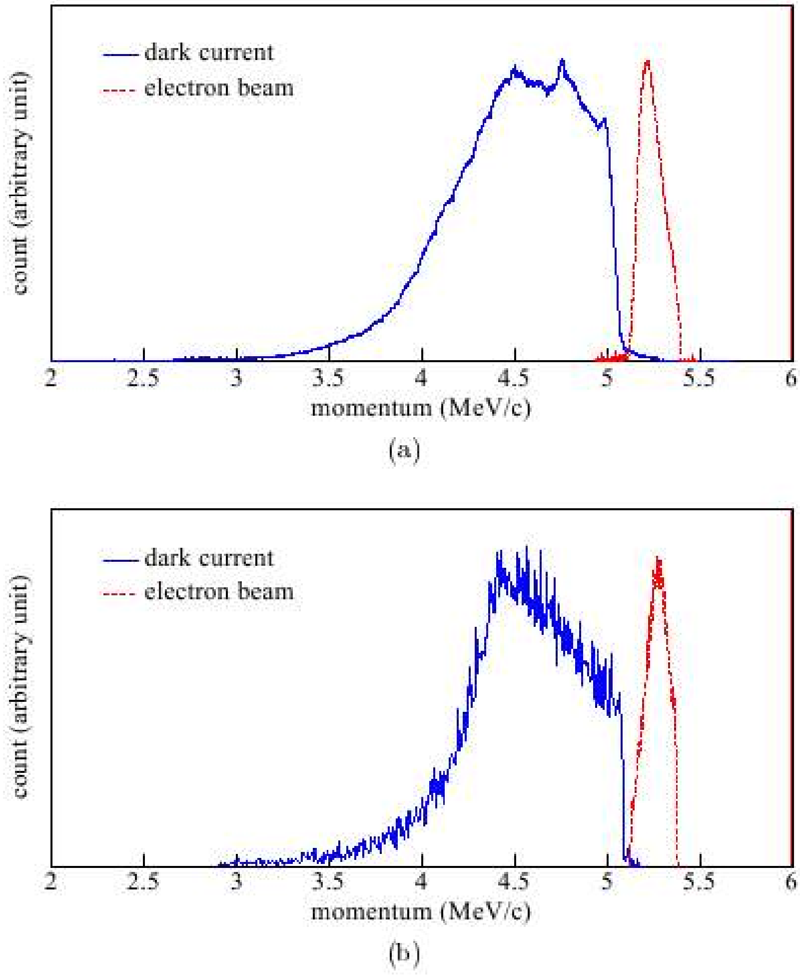


Figure 5.8: Momentum spectra of dark current and electron beam: (a) measurement with a spectrometer dipole and (b) simulation assuming 46.5 MV/m maximum field at the cathode. The vertical axes show relative intensities.

Conclusion

- Work has started on NML dark current kicker.
- Start initial design of kicker.
  - Get some engineering tolerances.