Dark Current Kicker Studies at FLASH

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History of the dark current kicker

2005

- Vertical kicker was installed after the first module
- Oscillation circuit kicker with a resonance at 1 MHz (sinusoidal pulse)
- Power amplifier
- Reduction of dark current
- Problems: dark current lost in BC3 and phase drift of power amplifier

2006

- The same kicker
- Oscillation circuit kicker with a resonance at 1 MHz (sinusoidal pulse)
- We built a new pulser
- Reduction of dark current
- The same problem: dark current lost in BC3
- The stability is better due to exchange of the amplifier against the pulser

History of dark current kicker

2008

- **Installed a new kicker in the gun section and a collimator**
- **Reduction of dark current transmitted to BC2 by 70%, but we have timing drifts.**
- **Installed a synchronization board with 81 MHz from the master oscillator**

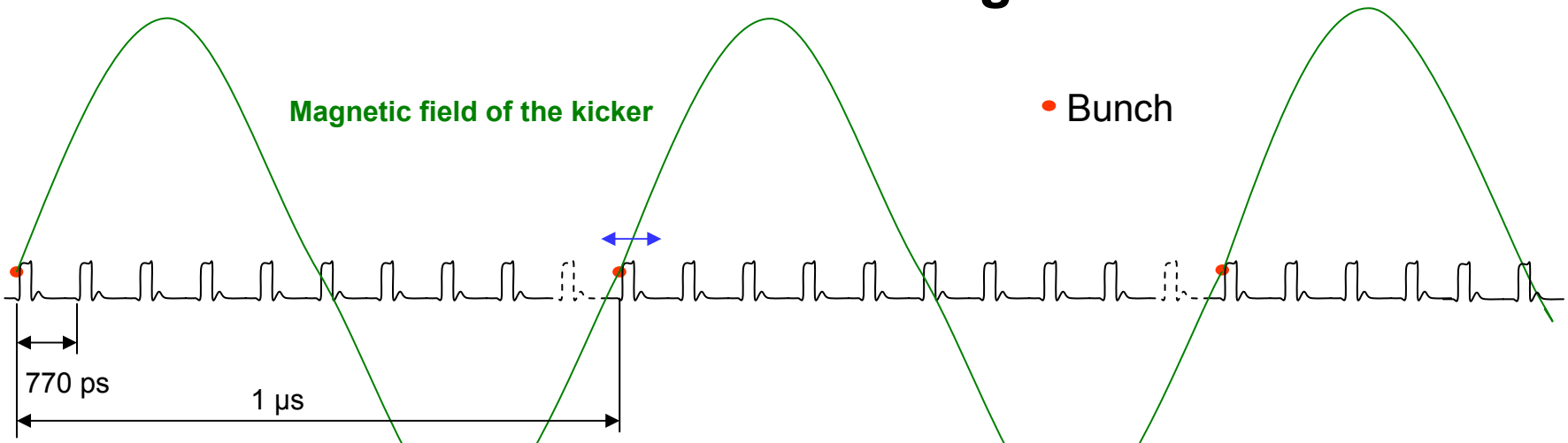
2009

- **Tested of new flat top pulser with a rectangular pulse current**
- **Needed a new kicker (8.3 Ohms)**
- **Problem: the kicker has not enough magnetic field to kick the dark current into collimator**

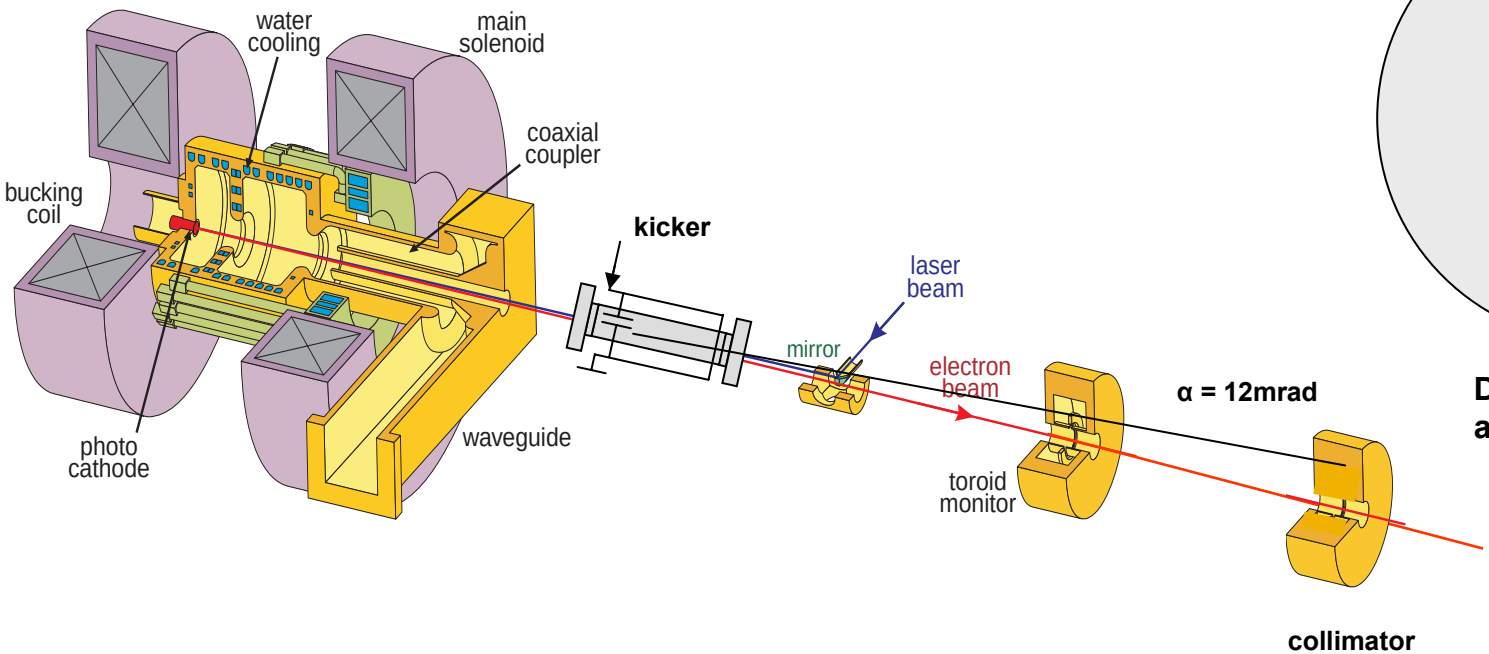
2010

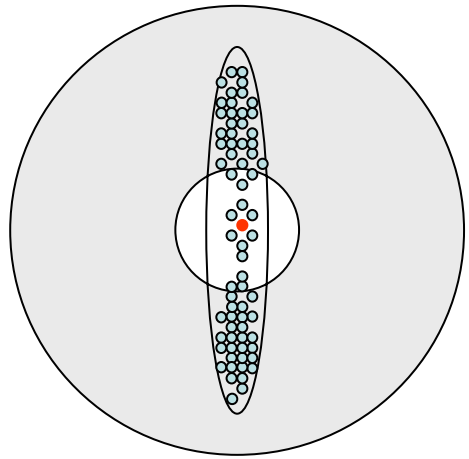
- **Installing a new kicker. The kicker works with 1 or 3 MHz.**

Dark current of RF gun



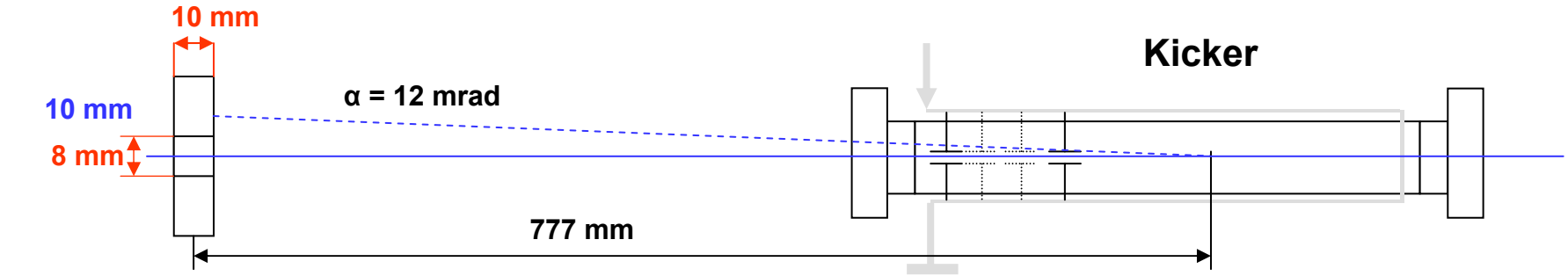
The system is very sensitive to drifts and jitter

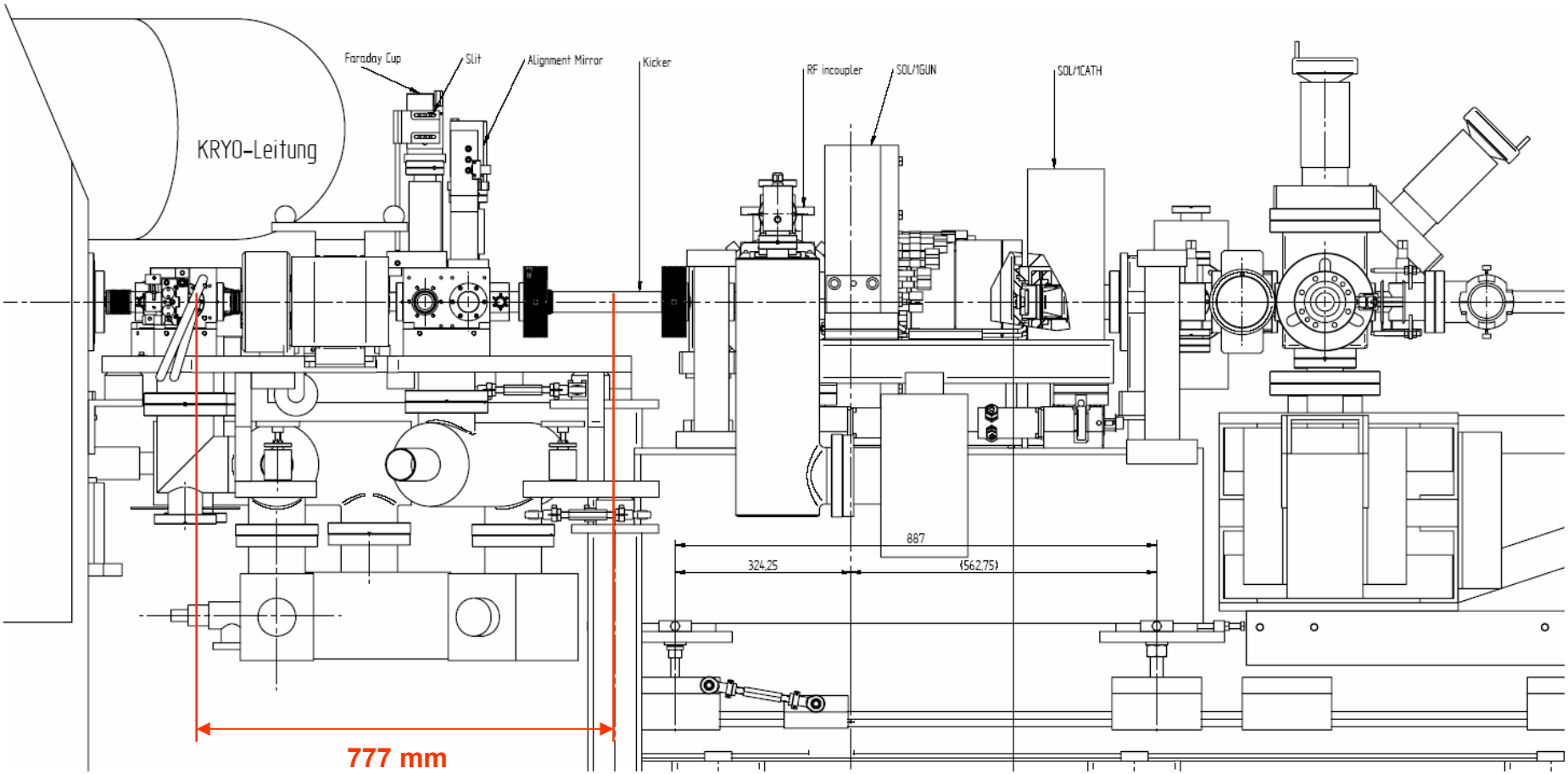




Dark current distribution at the collimator

Gun-Section


Collimator
10 mm
10 mm
8 mm
α = 12 mrad
Kicker
777 mm


KRYO-Leitung
Faraday Cup
Slit
Alignment Mirror
Kicker
RF incoupler
SOL1GUN
SOL1CATH
887
324,25
(562,75)
777 mm

Specification

	FLASH 1 MHz	FLASH 3 MHz
Burst frequency	1-10 Hz	
Pulse frequency	1 MHz	3 MHz
Burst length	1ms	
Burst nb of pulses	1000	3000
Pulse form	sinus	
Max. pulse voltages	0-250 V	0-250 V
Max. pulse current I_{PP}	0-480 A	0-240 A
Amplitude stability	< 1%	
Energy	5 MeV	
Kick angle	12 mrad	
Kicker current I_{PP}	175 A	
Kicker active length	200 mm	
Bdl (Mafia)	2.3 µTm/A	

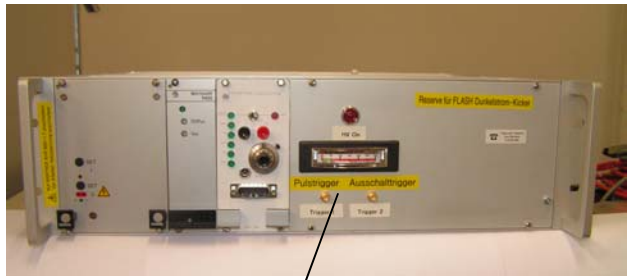
Setup of the dark current pulser with kicker

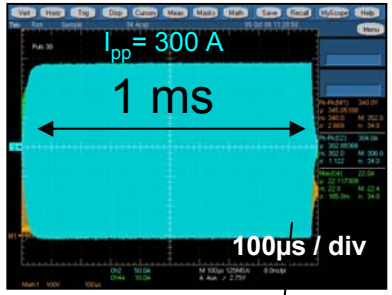
Pulser data:

Voltage U = 250 V

Pulse current I = 480 A

Frequency f = 1 MHz

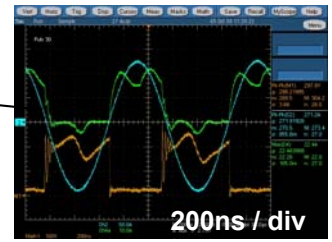




Power supply 0-250V

24V

Resonance circuit Kicker

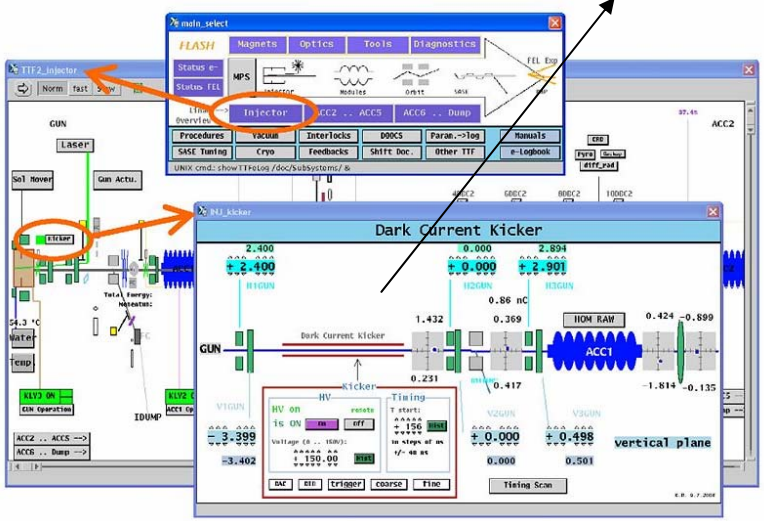


Pulse trigger

Switch-off trigger

Control system

Adjustment of burst length



Timing board

Fine delay

Coarse delay

1 ns

81 MHz

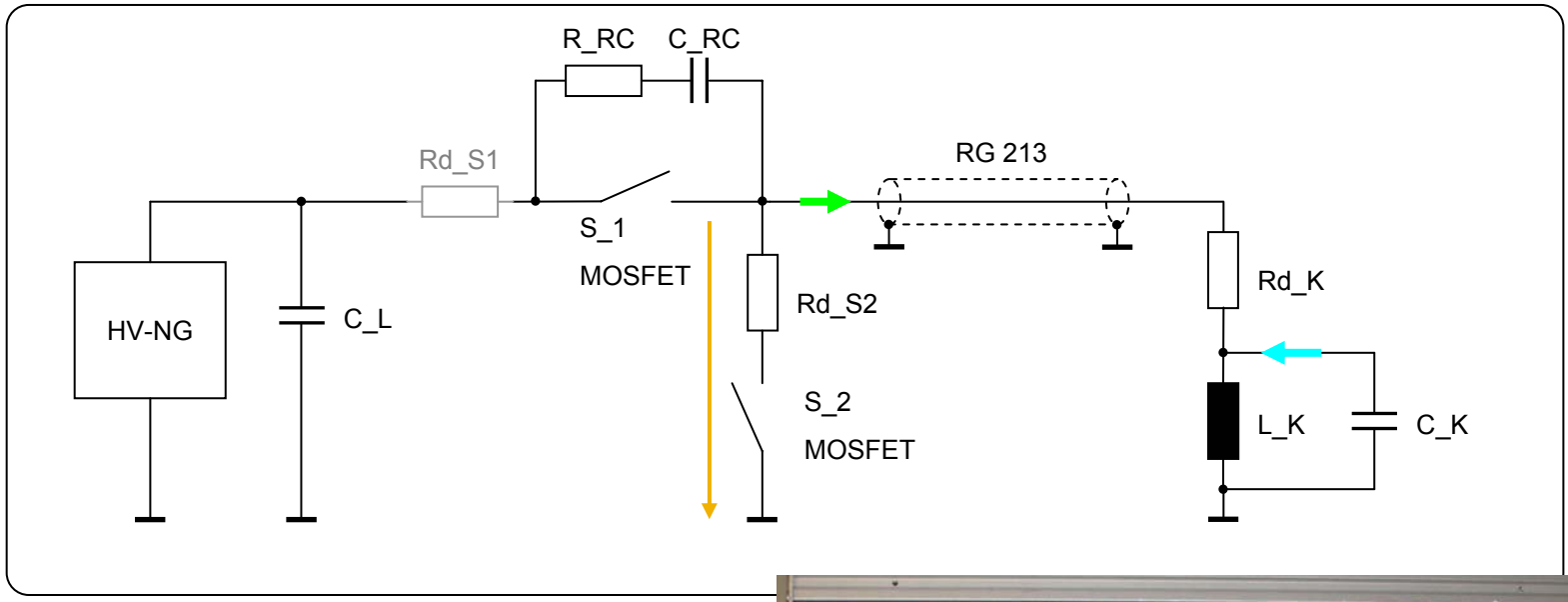
4 ns

1 MHz

Synchronization board

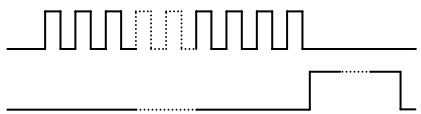
5 Hz
(10 Hz)

Principle layout of the pulser

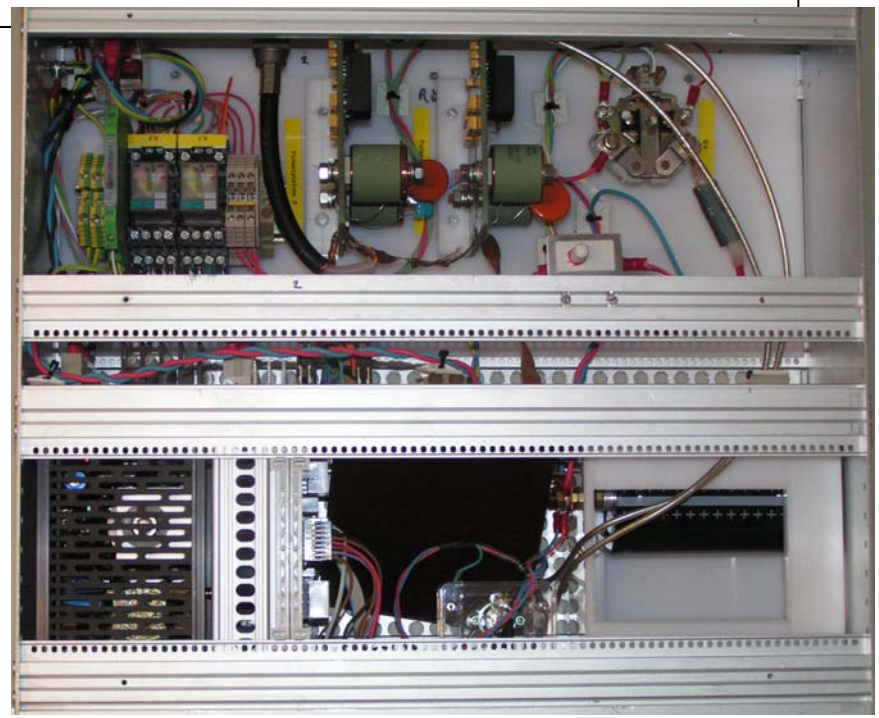


S1: pulse trigger

S2: switch-off trigger



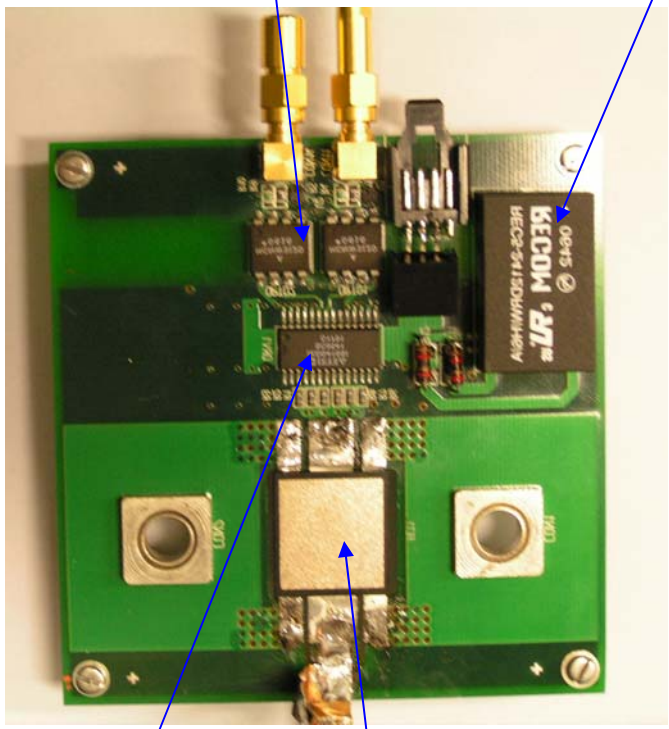
C_L	8800 µF
L_K	310 nH
C_K	72 nF
Rd_S1	0 Ω
Rd_S2	25 Ω
Rd_K	5 Ω
R_RC	5 Ω
C_RC	2,2 nF
RG 213	~30 m



MOSFET module

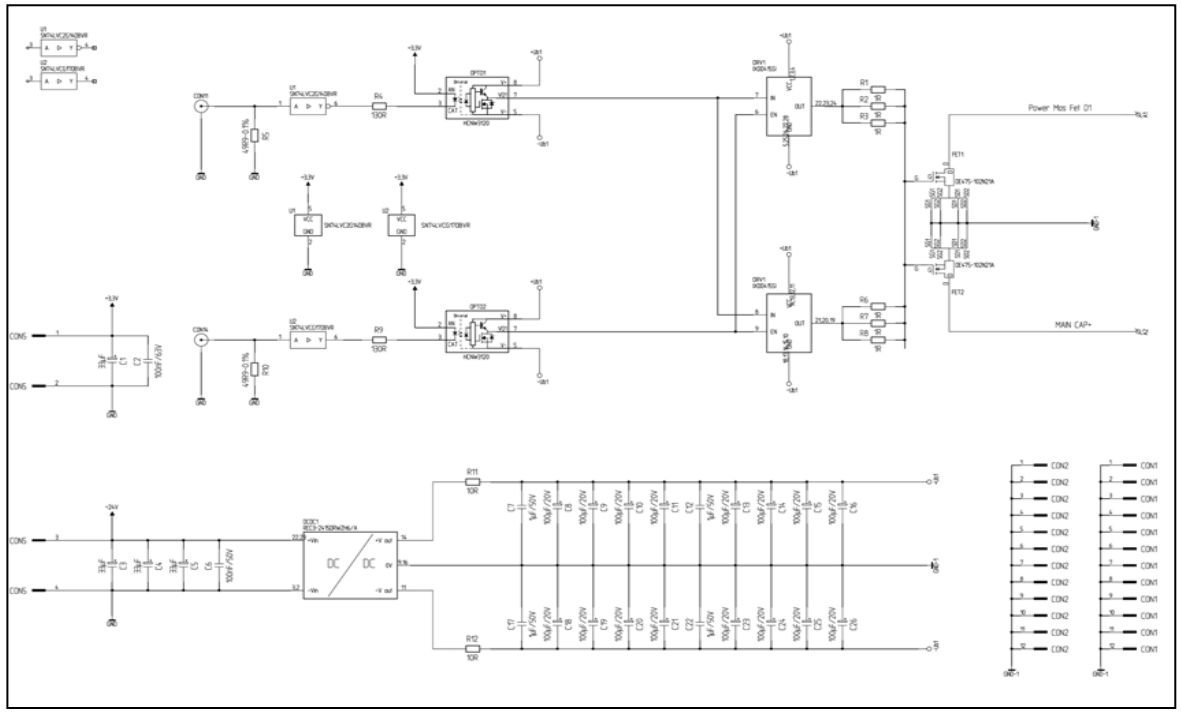
Optocoupler

DC/DC Transformer



Driver unit

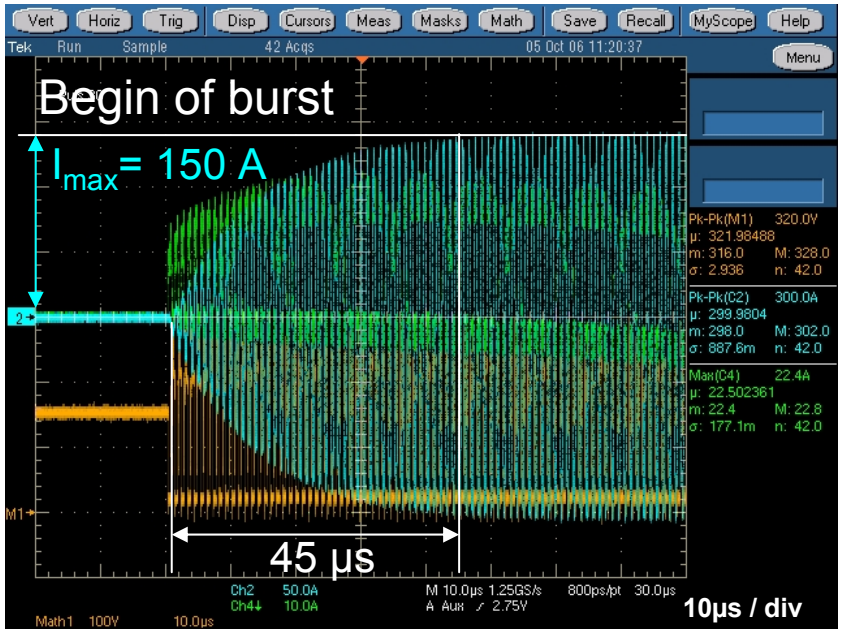
MOSFET

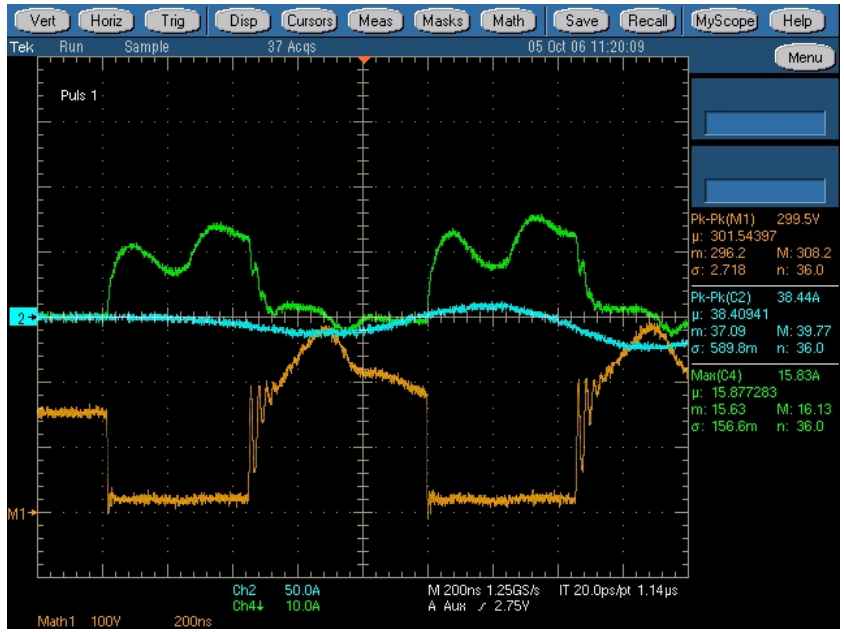


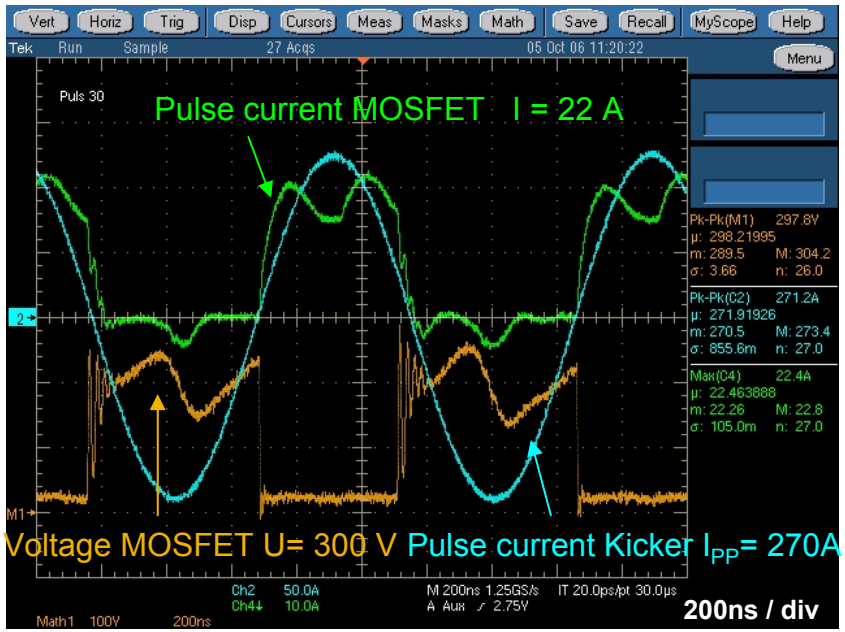
Pulser data:

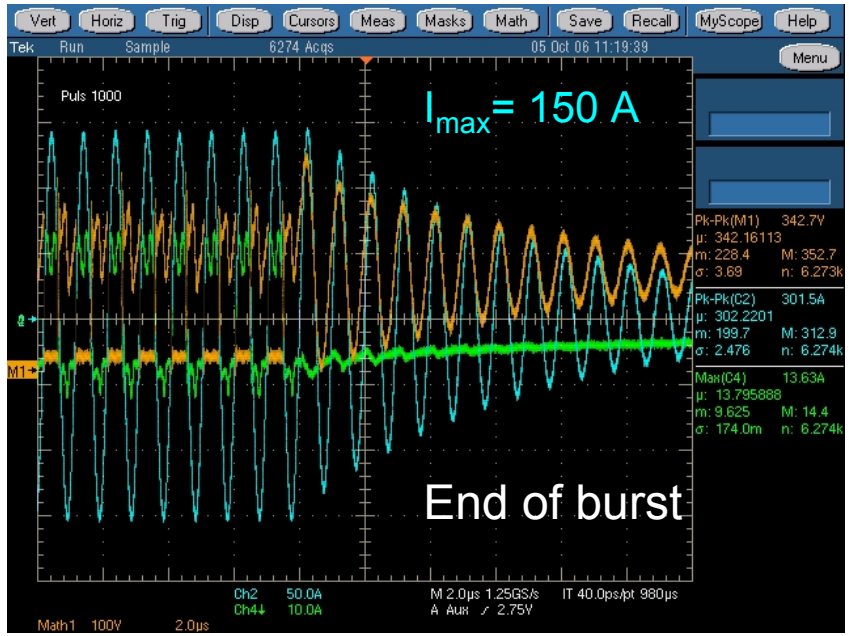
Voltage	U = 1000 V
Pulse current	I = 80 A
Frequency (burst)	f = 5 MHz

Characteristics of the pulse current

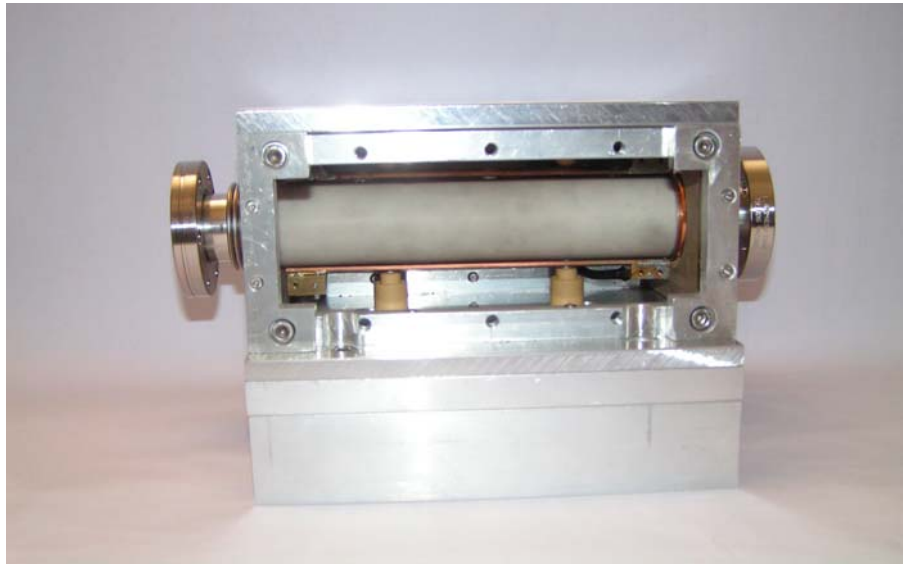




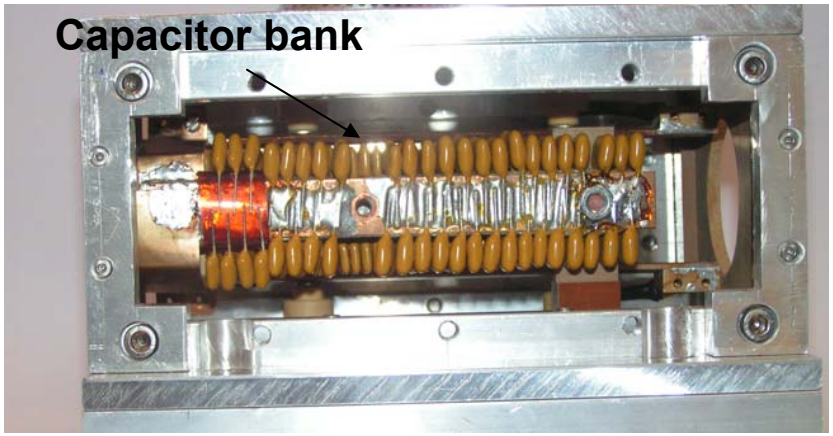




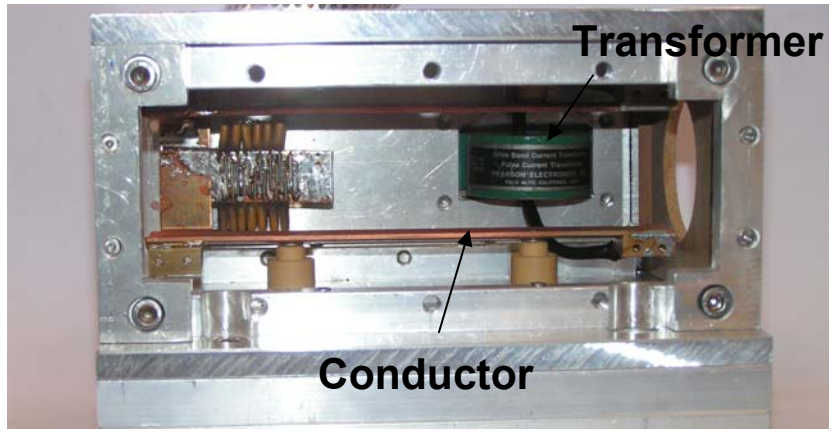
New horizontal kicker magnet



- Strip line kicker outside of vacuum
- Ceramic vacuum chamber
- Coating material is stainless steel 4.4541 (titan stabilised)

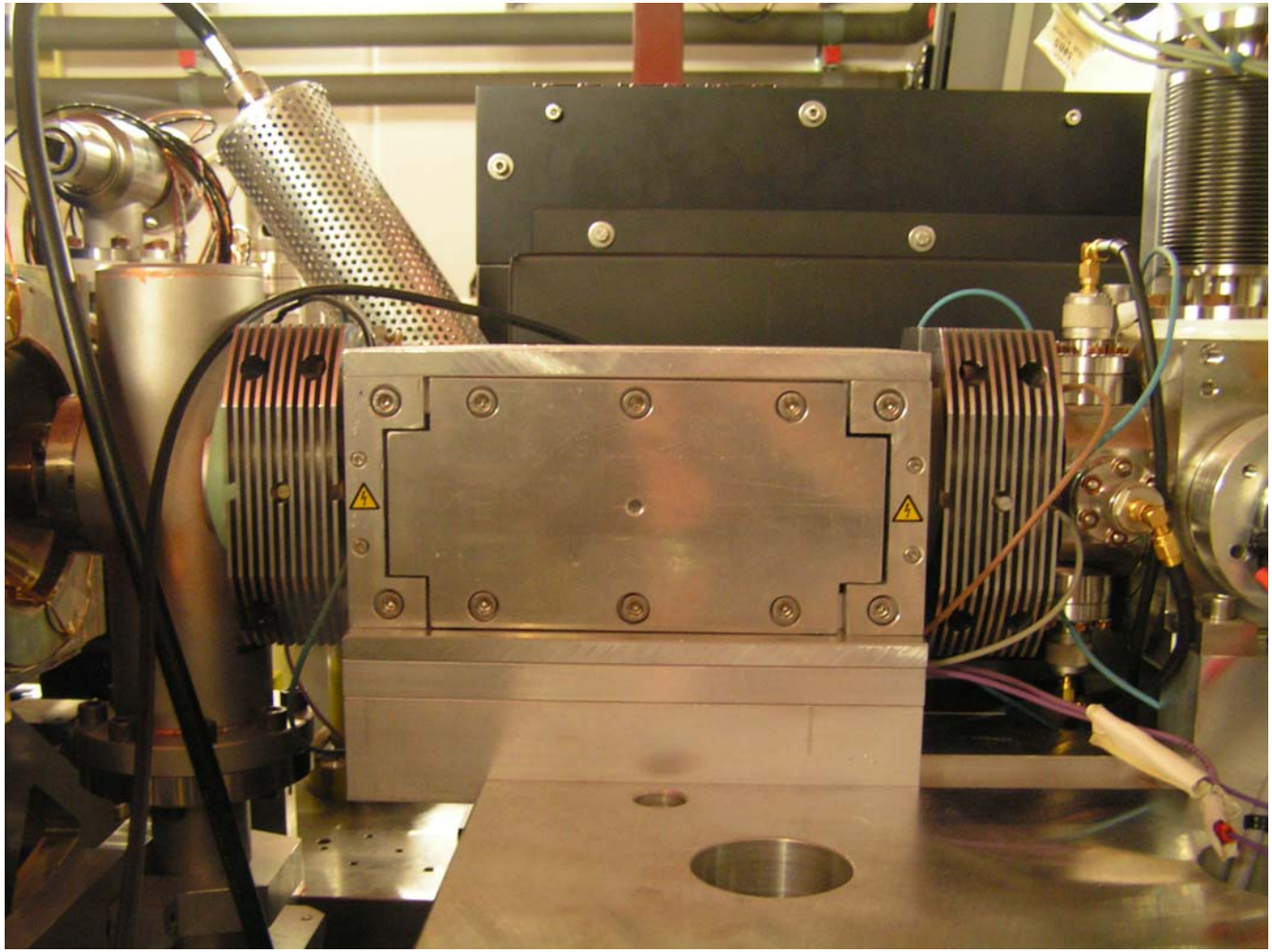


Kicker for the 1 MHz operation with 122 µF

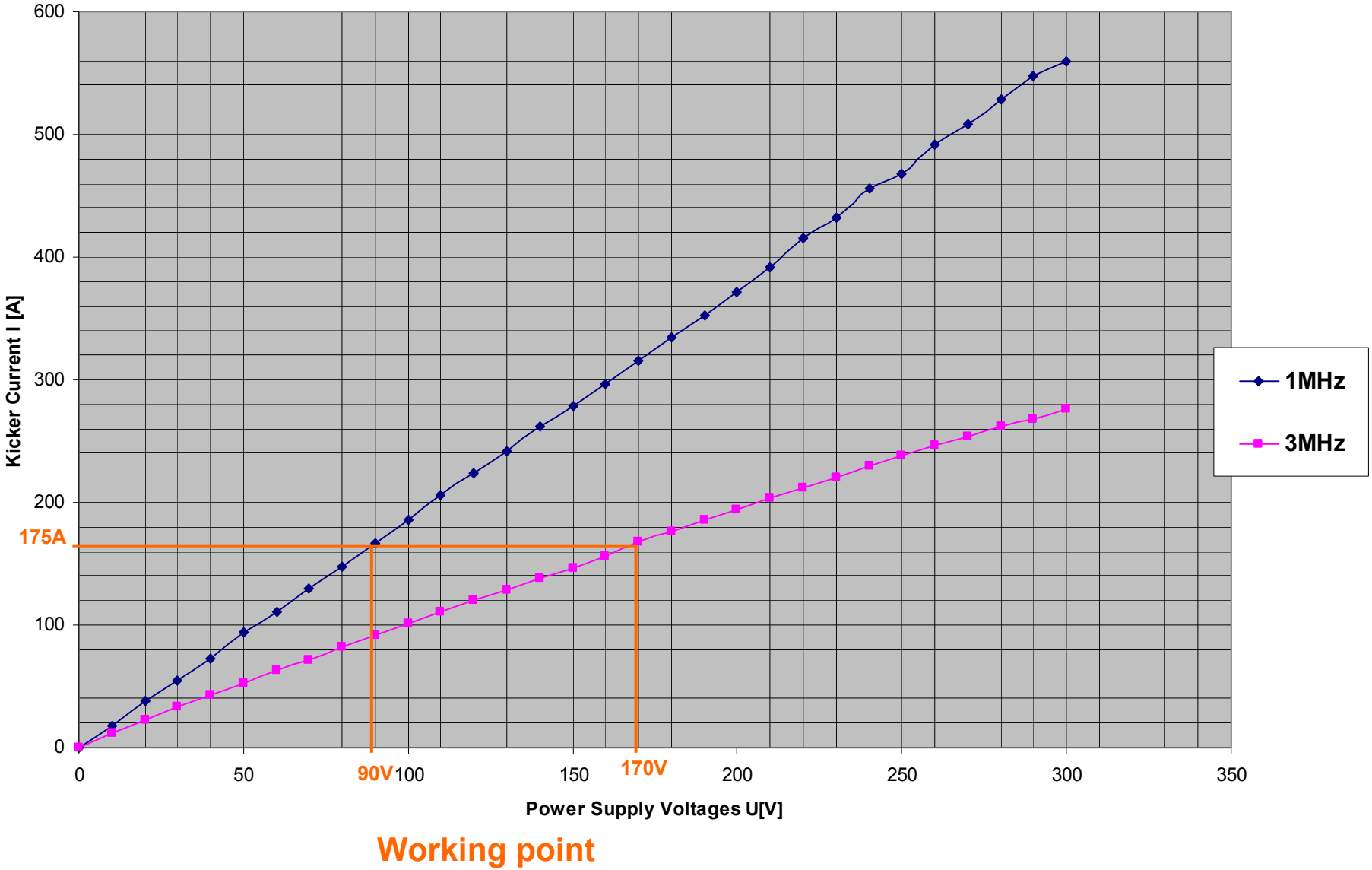


Kicker for the 3 MHz operation with 13 µF

New horizontal kicker magnet



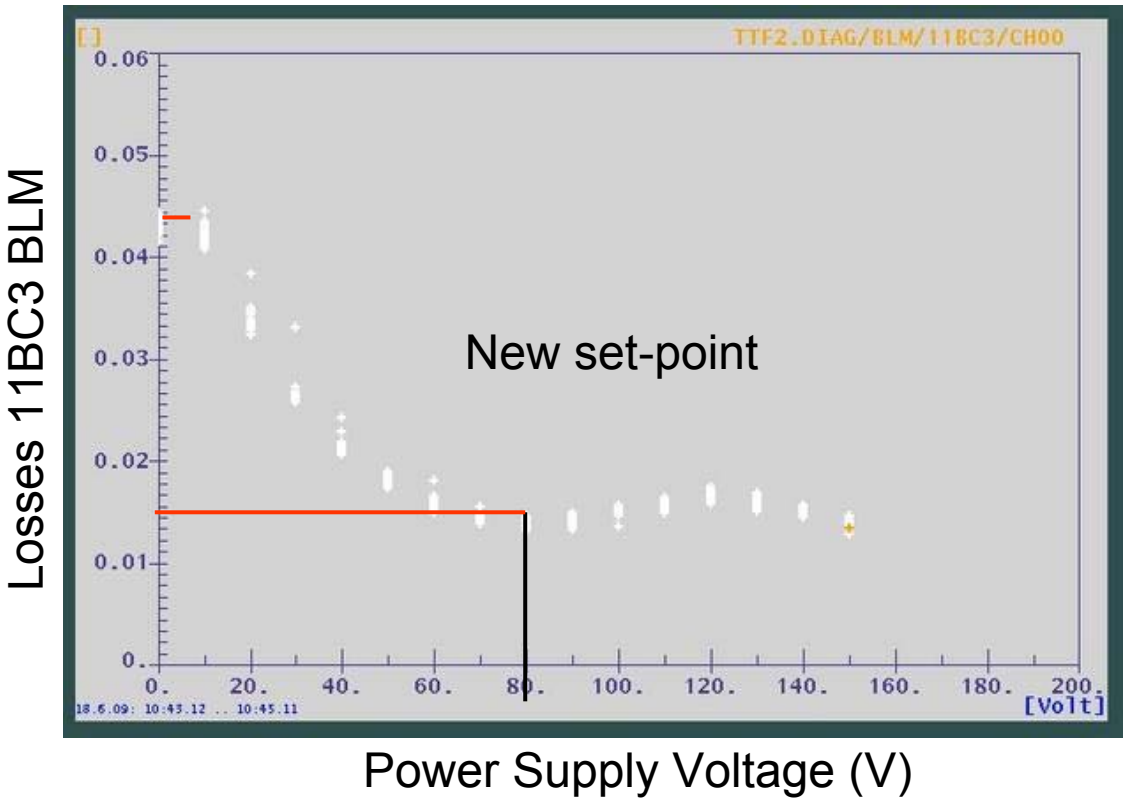
Voltage-current characteristic of pulser



Working point

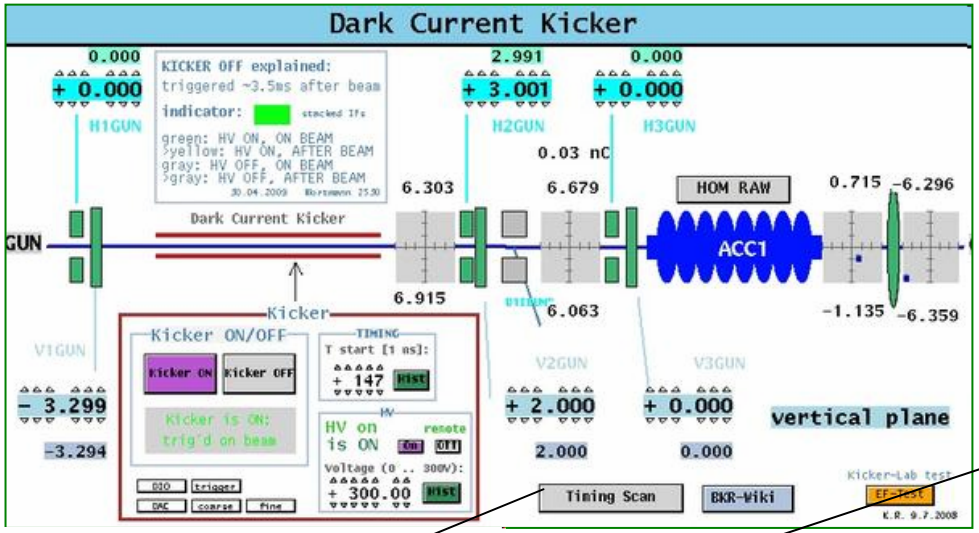
Check the set-point of the high voltage

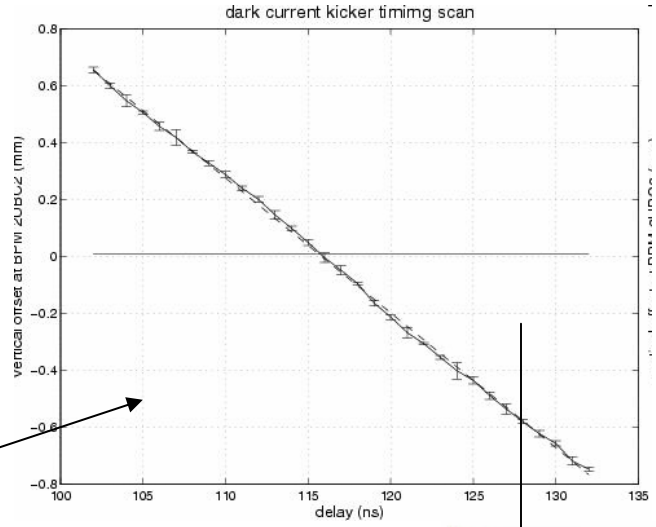
Reduction by 70%

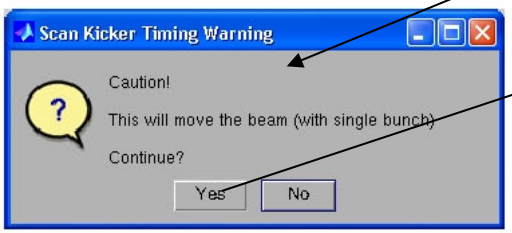


Losses in the BC3 section measured with BLM11BC3 against kicker high voltages. The maximum voltage is 150 V. With 80 V we reach the same reduction in dark current (at least at this monitor) as with 150 V.

Check/set the timing with scan





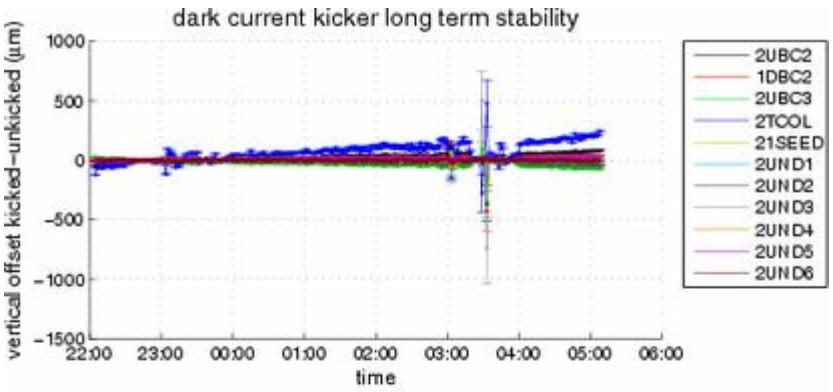


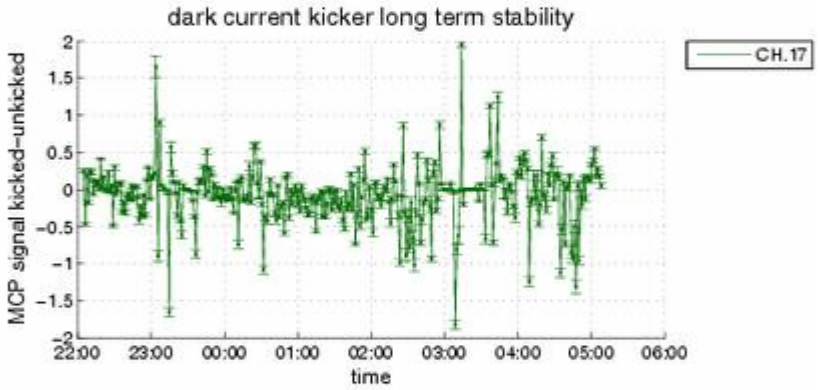
With the Button *Timing Scan* you start a MATLAB-Skript.
It measures beam position at BPM 2UBC2.

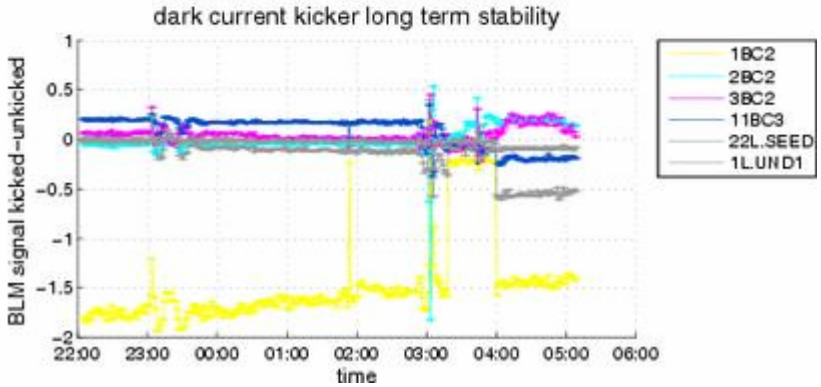
- **The kicker is switched off.**
- **The beam position is measured.**
- **The kicker switches on**
- **The beam position is measured.**
- **The timing is scanned in 1 ns steps.**

Results are plotted and the optimal timing (zero crossing) is calculated.

Check the long term stability







Shown are only the difference signals.
Some machine parameters were changed during the nightshift!

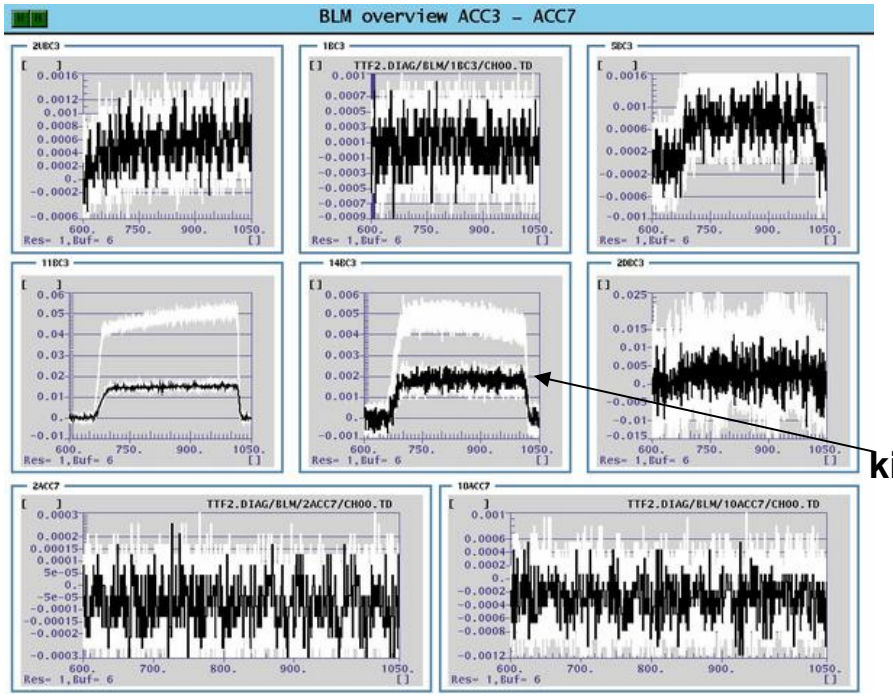
- **Dark current kicker tested with SASE signal.**
- **BLM signal at 1BC2 can be reduced by a factor of 3.**
- **SASE signal (MCP) differs by ± 20% between kicked and unkicked beam.**
- **Timing drifts/jumps of up to 6 ns observed, which result in increased residual kicks of the beam.**

Temperature drifts effecting the pulser MOSFET are likely to be the reason for the observed timing drifts

→ we are working on a slow feedback using a beam pick up signal downstream BC2
→ better temperature stabilization

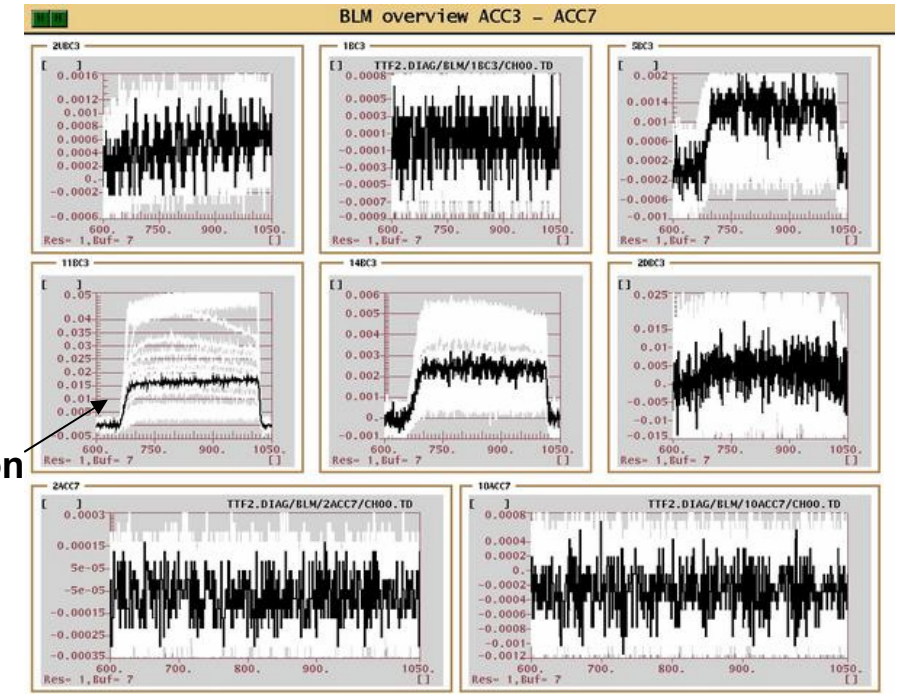
Study of kicker operating at zero crossing versus top of sinusoidal

Kicker at zero crossing



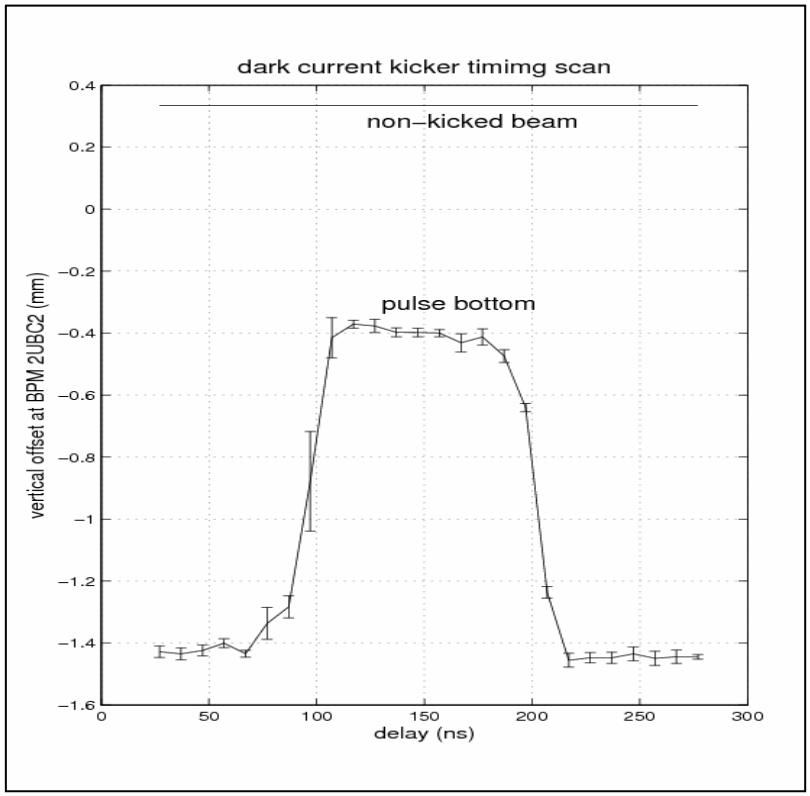
kicker on

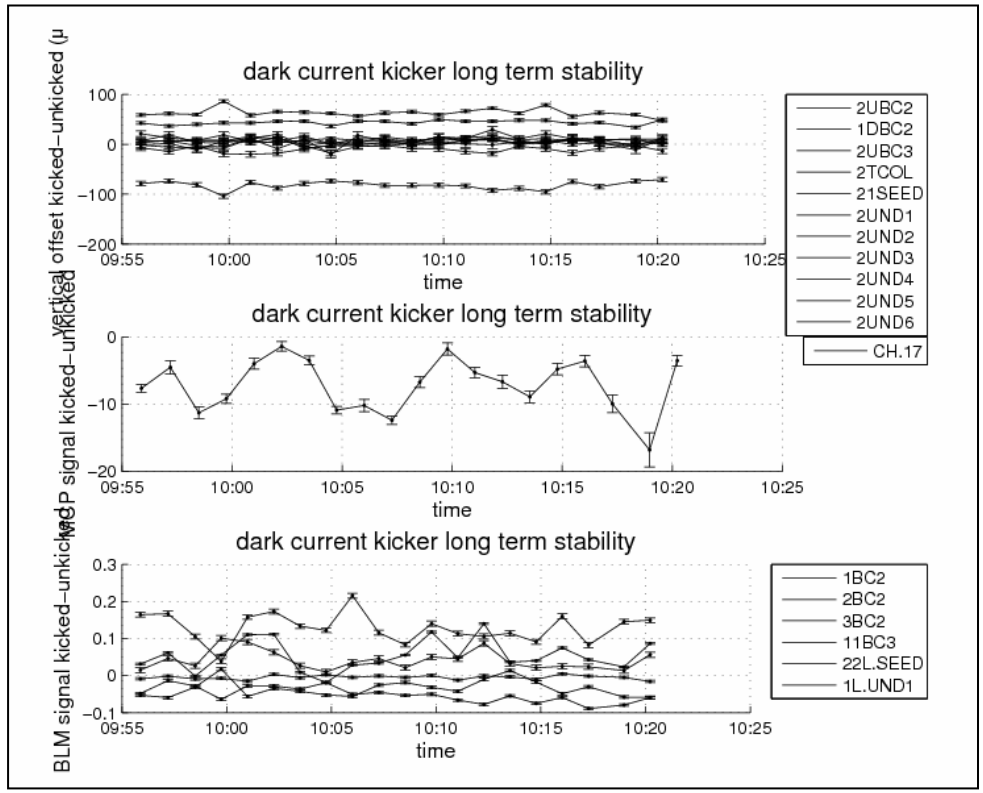
Kicker on top



- **It is possible to move the dark current kicker on crest**
- **The dark current suppression is similar to the zero crossing mode, as expected, the sensitivity to the timing is much reduced**
- **However, the GUN corrector magnets need to be on their limits to compensate the kick**
- **For the operation running zero crossing is favored, since the kicker voltage can be changed or switched off easily**
- **Emittance growth due to the kicks?**

Measurement with a flat top pulser





Difference Signals kicked-unkicked beam.
Note that the kicker does kick the beam. This effect is cancelled by steering with V2GUN (-3A).
Correction is not perfect, thus a systematic offset of the MCP and the orbit is expected.

- **Measure the kicker strength and stability of kicker pulse.**
- **Scan the kicker pulse with a step width of 4 ns and taking 5 pulses for each data point.**
- **Kicker amplitude is to small, we measured around 4 mrad .**
- **Flat bottom is kicking the beam with 1.6 mrad as well (should not be).**
- **Long term stability (measured over 25 minutes) suggest that stable operation is possible without impacting SASE.**

Summary

- **Kicker is driven in resonant mode (1 MHz) with pulser using MOSFET switches**
- **Dark current reduction by ~70 % in BC2 with kicker/collimator in GUN section**
- **Phase stabilization with 81 MHz master RF to ~ps or ~dg of 1.3 GHz**
- **Temperature effects likely the reason for residual timing drifts**
  → Slow feedback and temperature stabilization
- **Kicker now with 1 MHz and 3 MHz**
- **On crest operation works as well, but large bump required**
  → Operation at zero crossing preferred
- **Flat/top kicker tested, deflection angle too small**
  → New magnet is being developed and will be tested soon