LHC Injectors Upgrade
PSB Recombination kickers rise time
(Update January 2017)

L. Sermeus TE/ABT/FPS
Contents

- Installed BT.KFAs systems and measured kick (quick reminder).
- Tests performed in the laboratory up to now.
- PSB LIU kickers roadmap (update).
BT.KFA10 as installed

- 1 vacuum tank installed in ~1970.
- 4 magnets (2 per transfer line, 2 types) designed for 800 MeV beam deflection.
- Glued ferrite C cores of 4L1 type (not optimum for fast kickers and vacuum performance).
- No spare.
- 1 pulse generator per line supplying 2 magnets in parallel.
- PFL voltage for 1.4GeV: ~43kV (at 2GeV: ~56kV)
BT1.KFA10 kick (measured waveform at 50 kV)

Kick measurement in the PSB with a small inductive loop hidden in magnet ground conductor (unknown frequency response, probably not very good)

Kick rise time:
- (5-95)% 100ns
- (2-98)% 125ns

Scope: 100MHz BW, 13 bits vertical resolution

LIU: 105ns for LHC
BT4.KFA10 kick (measured waveform at 50 kV)

Kick measurement in the PSB with a small inductive loop hidden in magnet ground conductor (unknown frequency response, probably not very good)

Kick rise time:
(5-95)% 103ns
(2-98)% 122ns LIU:105ns for LHC

Scope: 100MHz BW, 13 bits vertical resolution
One generator supplying two magnets in parallel. Magnets equipped with CMD5005 ferrite blocks. Magnets are charged with the PFLs up to 36.5 kV (breakdown limit is 37 kV). LIU 2GeV requires 36.5kV.
BT2.KFA20 kick (measured waveform at 27 kV)

Kick measurement in the PSB with a matched strip-line (Scope: 100MHz BW, 13 bits)

Kick rise time:
- (5-95)%: 78ns
- (2-98)%: ~94ns (LIU 105ns for LHC)
- (1-99)%: 270ns

BT2.KFA20 normalised kick (upstream magnet)

211ns bunches, h=1, 2GeV, 316ns spacing
One generator supplying only one magnet connected the same way as KFA10.
Two cables connected for 12.5Ω impedance.
Magnets equipped with CMD5005 ferrite type.
Filters disconnected.
PFL voltage: 56kV (required for 2GeV beam)
Magnet current: ~4500A (=thyatron current)

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BT.KFA10 test 1 in B867: kick

Kick measurement with a matched strip-line (large bandwidth)

Normalised kick of 1 magnet. Measured with strip-line probe – Simulated with PSPICE (~1000 components). Discrepancy in the rise due (I think) to magnet conductor skin effect not modelled in PSPICE due to convergence problems.

First peak 96.2%

Pre-pulse ripple due to 2-gap thyratron switching

Measured  Calculated
Rise (2-96.2)%  ~95ns            ~95ns
One generator supplying only one magnet connected the same way as KFA10.
Two cables connected for 12.5Ω impedance.
Magnets equipped with CMD5005 ferrite type.
Filters disconnected. Saturating inductor at magnet input.
PFL voltage: 56kV (required for 2GeV beam)
Magnet current: ~4500A (=thyratron current)
BT.KFA10 test 2 in B867: kick

Normalised kick of 1 magnet. Measured with strip-line probe – Simulated with PSPICE
Discrepancy in the rise due (I think) to magnet conductor skin effect not modelled in PSPICE + saturating inductor behaviour.

<table>
<thead>
<tr>
<th>Measured</th>
<th>Calculated</th>
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<tbody>
<tr>
<td>Rise (2-96.6)%</td>
<td>~91ns</td>
<td>(2-95.6)%</td>
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One generator supplying only one magnet connected the same way as KFA10.
Two cables connected for 12.5Ω impedance.
Magnets equipped with CMD5005 ferrite type.
Filters added. Saturating inductor at magnet input.
PFL voltage: 56kV (required for 2GeV beam)
Magnet current: ~4500A (=thyratron current)
Normalised kick of 1 magnet. Measured with strip-line probe – Simulated with PSPICE
This is the best rise time we could achieve with a reasonable overshoot.

Rise (2-98)%

Measured
~89ns

Calculated
90ns
One generator supplying two magnets connected the same way as KFA10.
Four cables connected for 6.25Ω impedance.
Magnets equipped with CMD5005 ferrite type.
Filters added. Saturating inductor at magnet input.
PFL voltage: 56kV (required for 2GeV beam)
Magnet current: ~4500A (thyratron current: 9000A)
BT.KFA10 test 8 in B867: kick of upstream magnet

Normalised kick of upstream magnet. Measured with strip-line probe – Simulated with PSPICE

The low system impedance increases the influence of the parasitic inductances, mainly the switch inductance.

Rise (2-98)% Measured ~107ns Calculated 117ns

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BT.KFA10 test 7 in B867: kick

Two magnets connected with saturating inductor and filters, MS cathode&anode filters.

One generator supplying two magnets connected the same way as KFA10.
Four cables connected for 6.25Ω impedance.
Magnets equipped with CMD5005 ferrite type.
Filters added. Saturating inductor at magnet input.
PFL voltage: 56kV (required for 2GeV beam)
Magnet current: ~4500A (thyatron current: 9000A)
BT.KFA10 test 7 in B867: kick of upstream magnet

Normalised kick of upstream magnet. Measured with strip-line probe – Simulated with PSPICE

First peak 100%
First peak 98.4%
Hole 94%
Pre-pulse ripple cancelled

Rise (2-98)% Measured ~111ns Calculated 112ns
Present status:
Optimisation of kick rise time and flat-top not finished but it appears that the 105ns figure will not be met. 120ns seems to be more realistic to limit the ripple to ±2%. This value will confirm the BT.KFA10 measurements in the PSB.

Next step: add two filters to the main switch output.

Possible solution: add a second main switch to the generator in order to half the switch current and double the impedance of each branch.
The estimated cost is about 160kCHF per generator.

Another option: add a saturating inductor at the main switch output to help the thyratron switching. To be tested without guarantee. A gain of 5 to 10ns is expected but the ripple might increase.
Estimated cost: ~15kCHF per generator.
Dual main switch configuration. This is also valid for BT2.KFA20.

Total additional cost would be ~480kCHF for the BT.KFAs.
The updated plans for PSB-LIU kickers are:

- Measurements in the lab to be continued.
- Quick decision to be taken to allow or not ~480kCHF to produce 3 new main switches.
- Production of a spare BT.KFA10 with CMD5005 ferrite blocks. Expected to be ready end 2017. Installation in the ring during LS2.
- Re-cabling of BT2.KFA20 in BT.KFA10 configuration to reduce the risk of magnet breakdown. This was not in the LIU PSB kickers initial plan (only an option).

(- Production of a spare BE.KFA14L1. Expected to be ready end 2017)