# Injection Kicker for HESR at FAIR Using Semi-Conductor Switches

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## ABSTRACT

The High Energy Storage Ring (HESR) for Antiprotons is going to be built at FAIR in Darmstadt on the extended GSI campus. Charged particles (including protons and antiprotons) of 13 Tm magnetic rigidity will be injected into this synchrotron and storage ring. The injection system of the HESR ring is based on 4 UHV 360 mm long ferrite kickers, each kicker having to generate a 25 T.mm integral field, during 500 ns, with rise time and fall time lower than 220 ns. Each kicker is supplied by a 4000A / 40 kV pulser, based on Blumlein topology, with semi-conductor switches. A prototype of the pulser, using water lines instead of conventional coaxial cables, has been developed to feed the UHV kicker. Electric and magnetic measurements are presented, as well as magnetic transient modelling.

## HESR SPECIFICATIONS

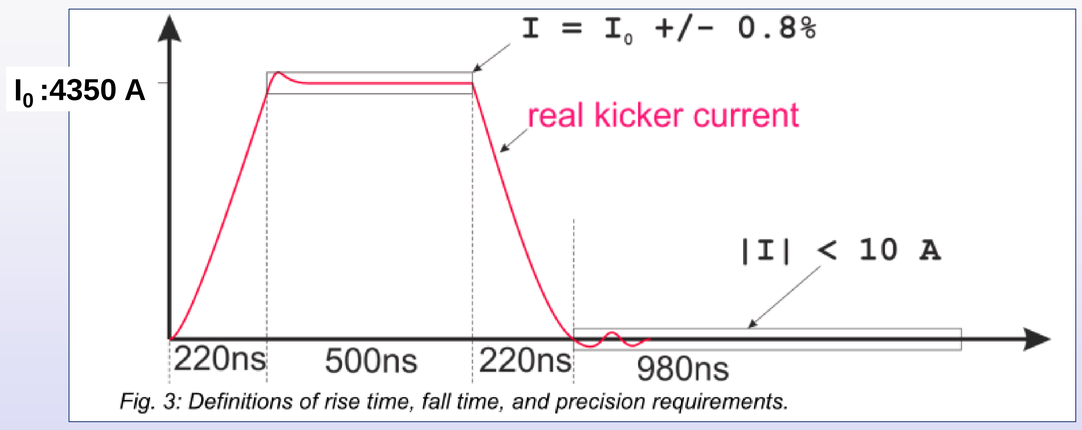


*Fig. 3: Definitions of rise time, fall time, and precision requirements.*

- **Jitter (std deviation) : < 2ns**
- **Ripple after pulse : +/- 0.23% target, but seems very difficult to comply**
- **SIGMAPHI ensures less than +/- 1.2%, but tries its best to reach +/-0.23%**

## CONCEPT

### Pulser topology

- Blumlein structure
- No transmission line
- Solid state switches (IGBT) and SiC diodes

***Advantages***

- Voltage divided by two compared to single forming line
- Best compromise between rise time, amplitude and constraints on HV switch
- Improved reliability

***Drawbacks***

- Forming lines doubled, but no need for transmission line
- More complex than single forming line

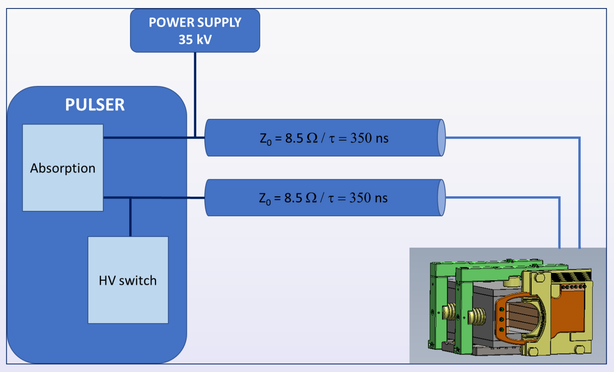
### Kicker magnet

- Single turn ferrite kicker
- UHV environment
- Bakeable at 250 °C
- Four kickers in line / two kickers per chamber
- Polarity reversal on each kicker

### UHV Chamber

- UHV environment
- Bakeable at 250 °C, bakeout system integrated
- Two chambers, designed and supplied by **JULICH**

## PULSER DESIGN

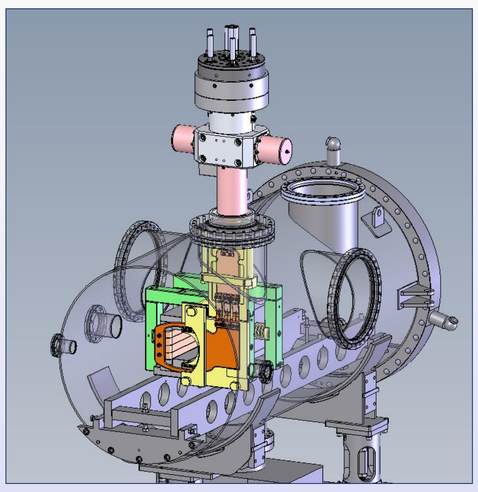



### Structure of the pulser

- **Nominal current : 4.35 kA**
- **Nominal voltage : 38 kV**
- **Line impedance : 8.5 Ω**

**Spice simulation of the system at 4350 A**

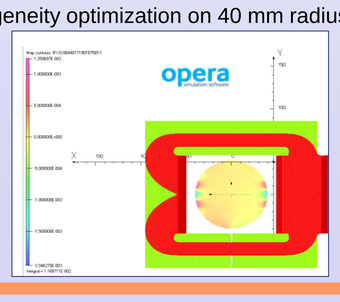
## KICKER DESIGN



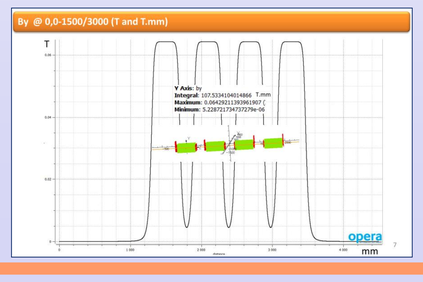
### Kicker parameters

- **Yoke length : 360 mm**
- **Gap: 92 mm**
- **Global field integral (4 kickers) : 98 T.mm**
- **Field integral quality : +/-0.75%**
- **Inductance per kicker : 700 nH**
- **Ferrite type : CMD5005**

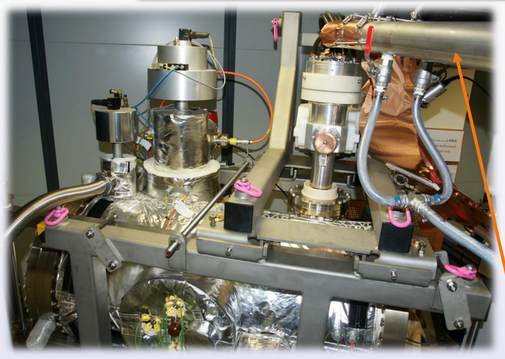
Homogeneity optimization on 40 mm radius GFR

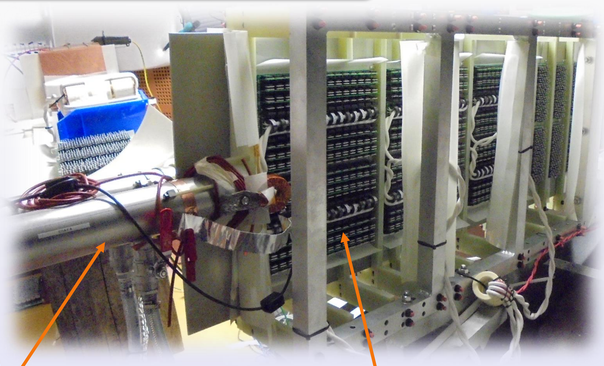


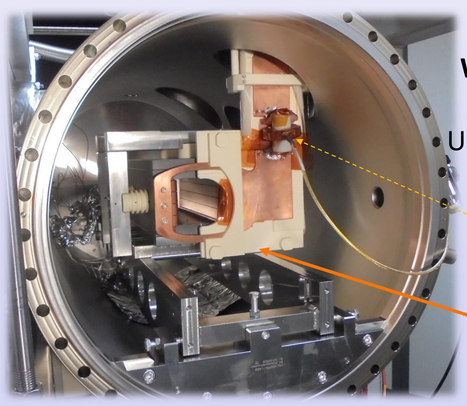

Global field of the four kickers



## PROTOTYPE







**WATER LINES BLUMLEIN**
7.5 meters length
Ultra pure water generator

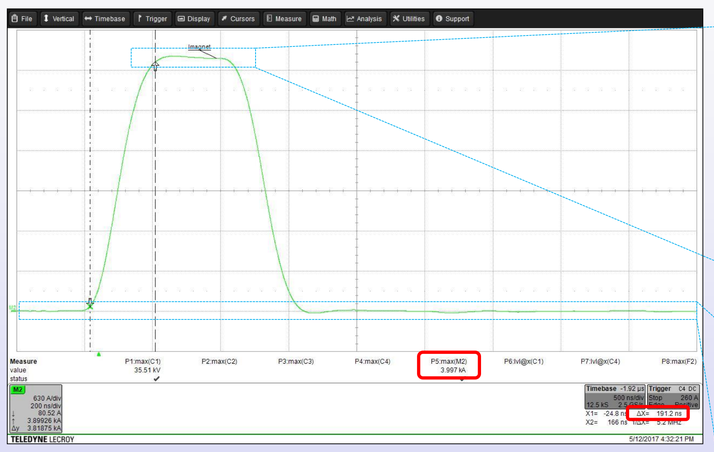
**PULSER**
Composed of 6 HV switch cards in matrix, and SiC diodes

Current sensor
(for tests only)

**KICKER IN UHV TANK,**
in final configuration

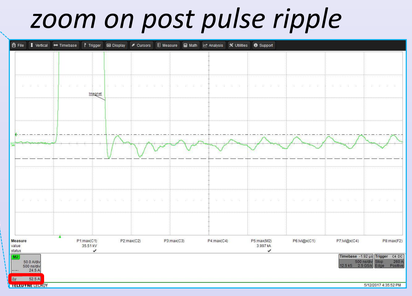
## MEASUREMENTS

Measure at 4 kA (92% of nominal current) / 35.5 kV



*zoom on flat top*

*zoom on post pulse ripple*



| Parameter | Specification | Measured value |
|---|---|---|
| Flat top value | 4350 A | 4000 A |
| Rise time 2%->98% | 220 ns | 191 ns |
| Fall time 98% ->2% | 220 ns | 196 ns |
| Flat top ripple | +/- 0.8% | +/- 0.45% |
| Ripple after fall time | +/- 1.2%<br>+/-0.23% target value | +/- 0.65% |
| Flat top duration | 500 ns | 233 ns |
| Jitter (std deviation) | < 5 ns | < 1ns |

## CONCLUSIONS

Encouraging results have been reached at 92% of nominal current on the prototype. Further tests, up to nominal current, will be performed in the next weeks to match HESR requirements at nominal current. Final configuration will use HV coaxial cables.
The measurements confirm the relevance and versatility of this concept. It could be considered for many other pulsed applications.