PAUL SCHERRER INSTITUT PSI

Wir schaffen Wissen – heute für morgen

Injection into Small Aperture Rings using an „Antiseptum“

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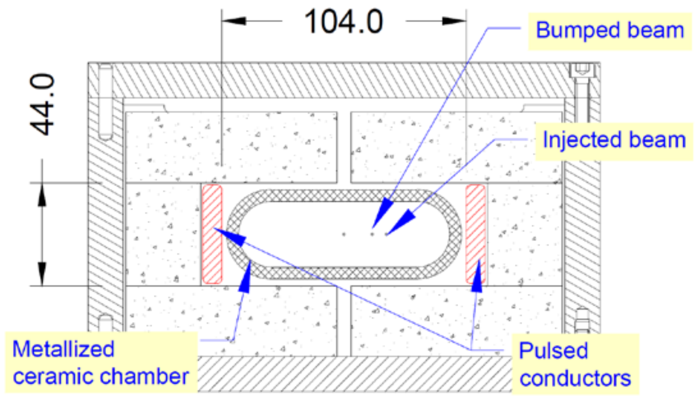
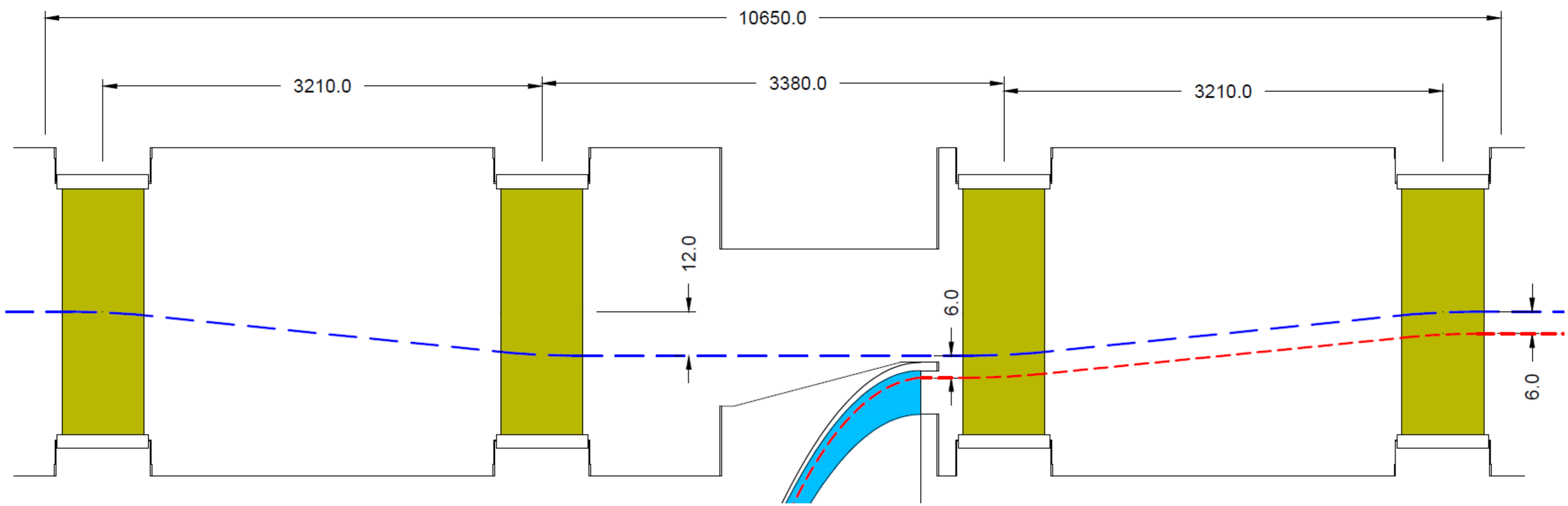
1. **Some Measurements of Present SLS Injection**
2. Antiseptum for SLS-2
3. Summary

Present SLS Injection with 4-Kicker Bump

Metallised ceramic not rigidly connected to ferrite magnet core. Air gaps top and bottom in core was provision for forced air cooling (finally not required) and do no affect homogeneity.

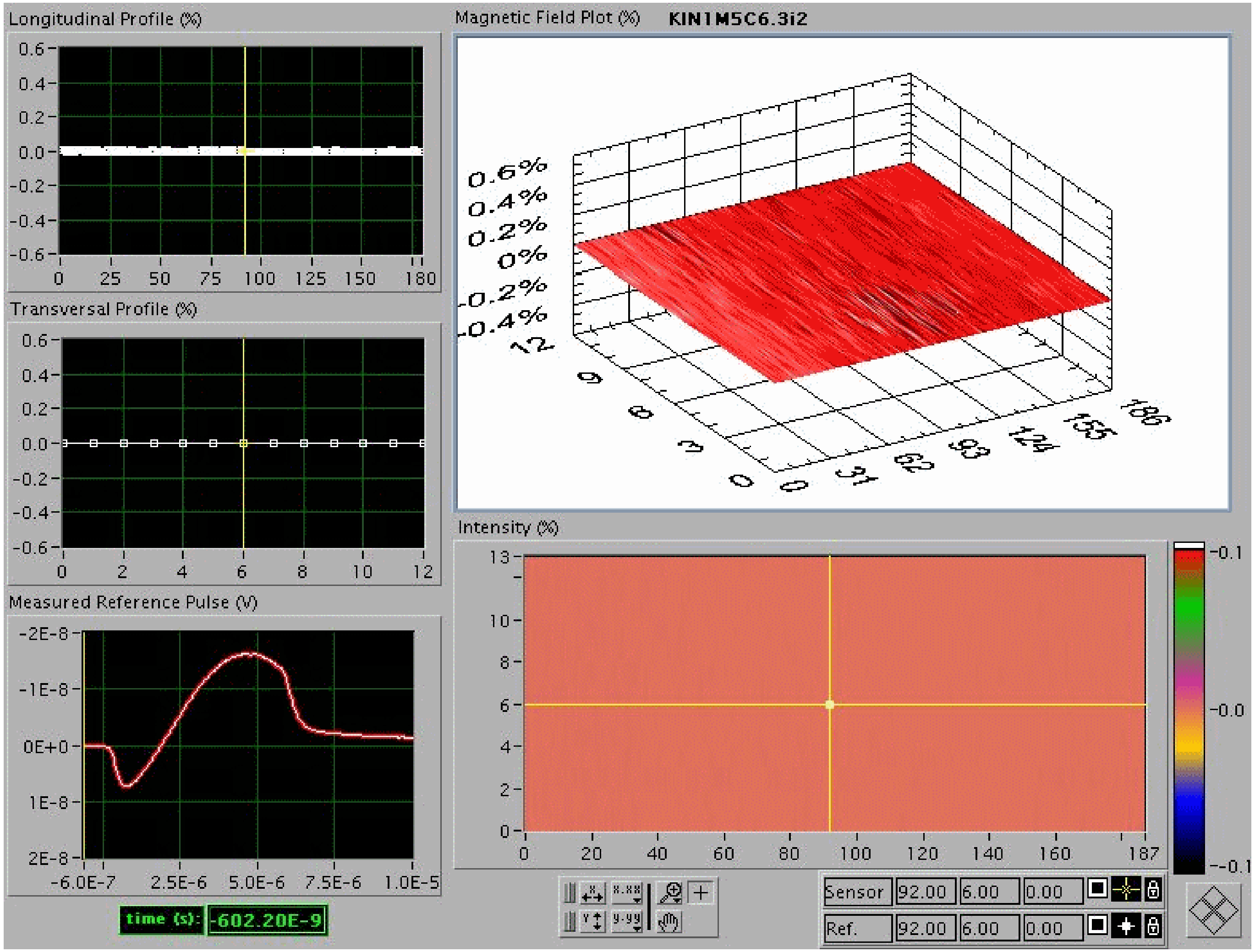




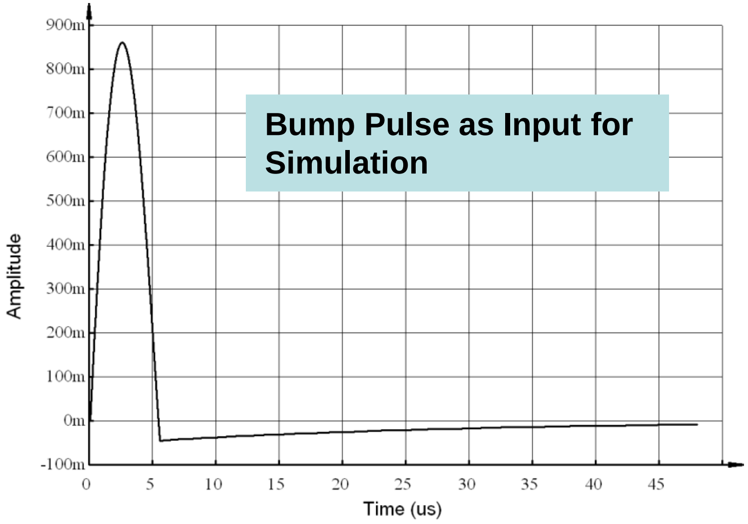
Present SLS Injection with 4-Kicker Bump

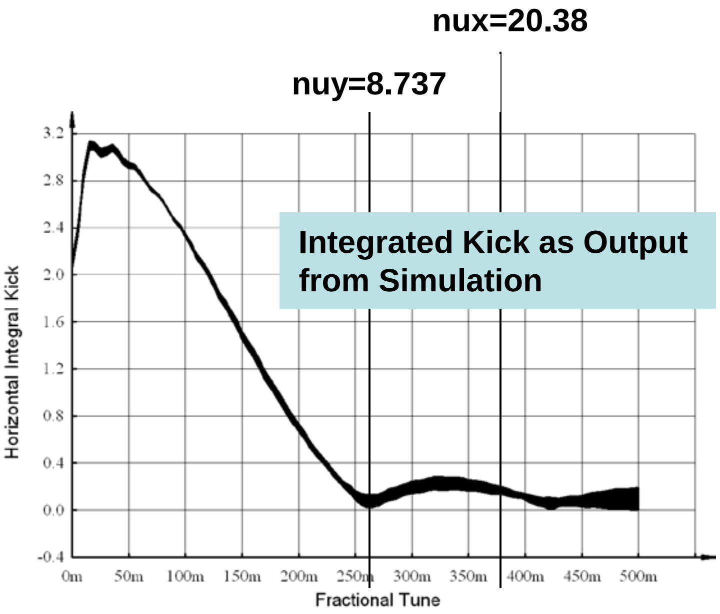
For SLS construction, considerable effort was used to understand and reduce waveform matching errors of the fields in the four kickers.
The matching errors are <+/-0.1%, dominated by the unevenness of titanium metallisation in the ceramic chambers.

Example shown here is transverse field plot through the magnet.



Roll Kickers to Null Vertical Movement





Half sine bump pulse = 5.38us

SR rotation period = 960.7ns

The negative pulse tail is necessary part of pulser turn-off

At all times, the field in the kicker magnets is matched to <+/-0.1%

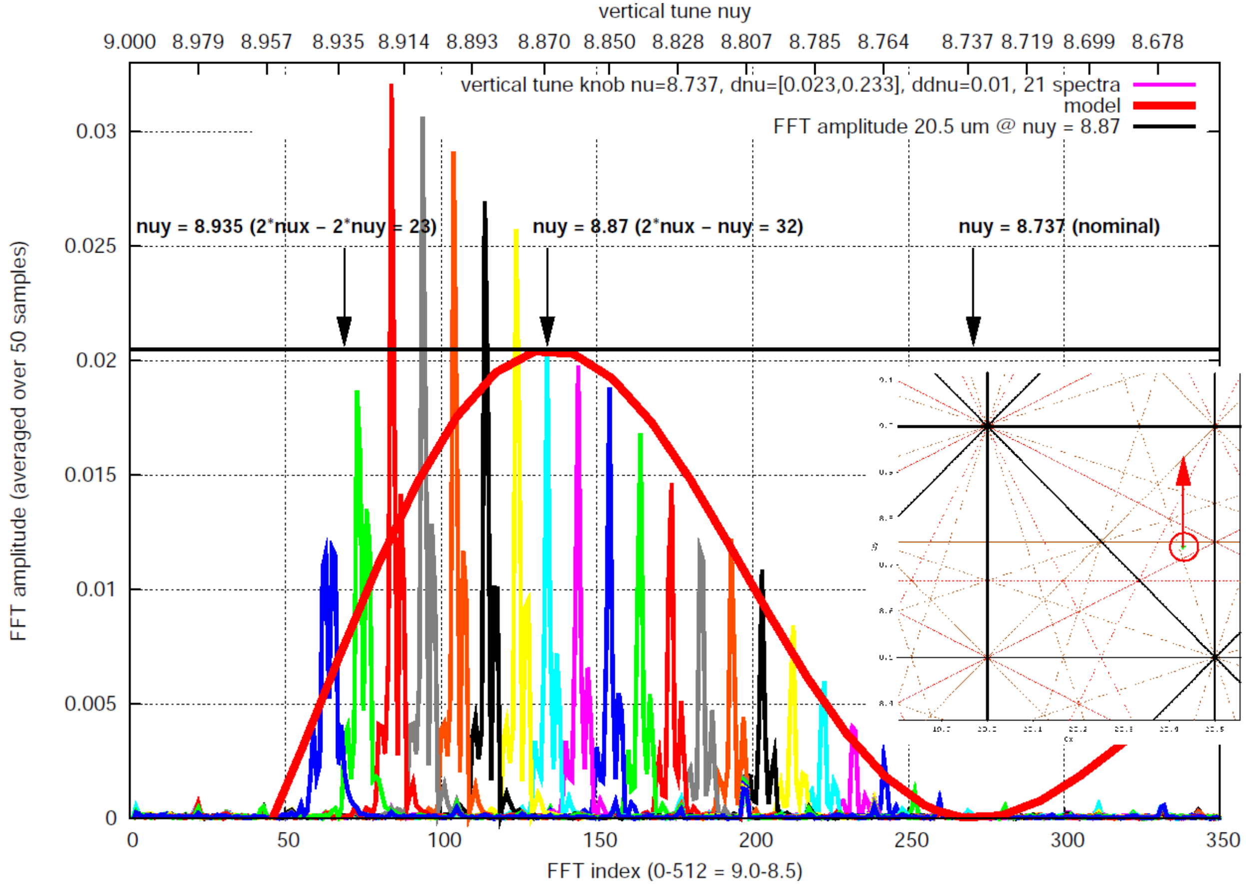
Conclusions:

A pulse lasting ~ 6 revolution periods tends to cancel horizontal bump closure errors

IF a tiny proportion of the horizontal bump appears in the vertical direction, this also tends to cancel out

Roll Kickers to Null Vertical Movement

Step 1 – Change vertical tune to get measurably large signals on pickup

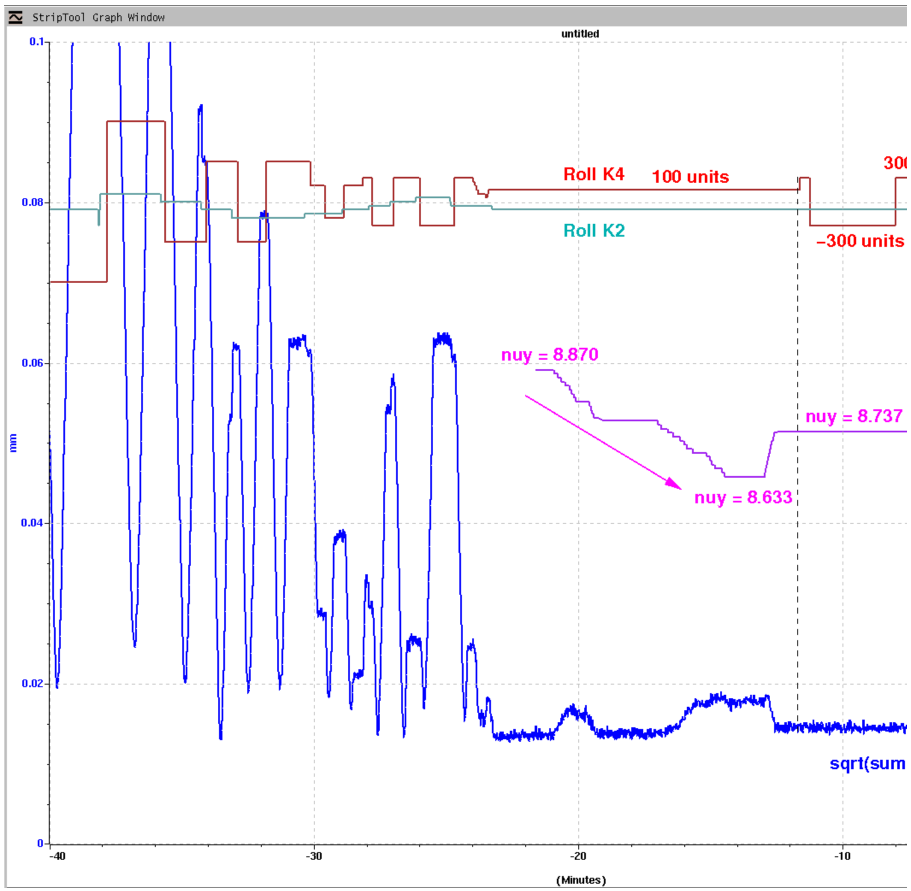


Conclusion:

Moving the vertical tune to about 8.9 maximises the vertical movement – rough agreement with predicted (red curve) and with previous slide.

Roll Kickers to Null Vertical Movement

Step 2 – Stepper motor to roll kicker ferrite cores (not chambers)



Trial and error rolling, typically +/- 1mrad range

Sweeping vertical tune to confirm behaviour

Confirmed, with SLS operating tune of 8.737, the tiny effect of kicker roll is not measurable with the present pickup system.

Roll Kickers to Null Vertical Movement

Summary:

The vertical movement at the location of the tune pickup can be nulled out by small roll corrections of the kickers

By scaling beam size monitor to the location of the tune pickup also gives the beam size:

Horizontal beam size (betax=9.03): 221.9um
Horizontal beam movement (betax=9.03): 57.5um

Vertical beam size (betay=16.13): 11.5um
Vertical beam movement (betay=16.13): 10.3um

By scaling all these to the sensitive location of the U19 Undulator (emittance coupling 0.6%)

Horizontal beam size (betax=1.93): 102.6um
Horizontal beam movement (betax=1.93): 6.3um

Vertical beam size (betay=0.95): 5.7um
Vertical beam movement (betay=0.95): 3.0um

These measurements have hardly begun and these results are provisional, likewise work on horizontal movement suppression (using fast DACs and corrector coils) has not even been started.

X ray intensity fluctuations from injection are not noticeable for many SLS beamline users; as best we know, no user finds it necessary to use the gating signal to mask the data acquisition during the transient.

Conclusion:

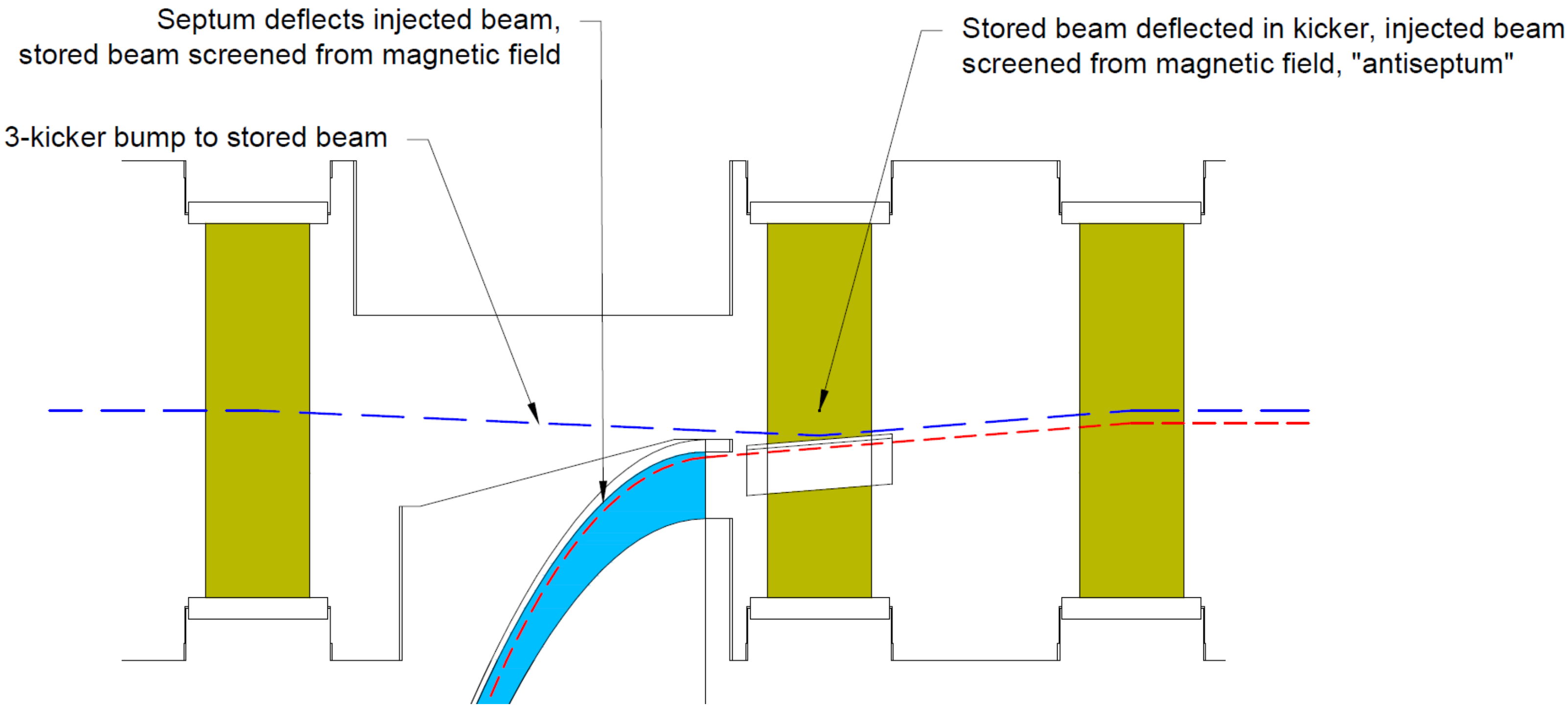
Unwanted beam movement is not a strong reason to abandon dipole kickers for injection

1. Some Measurements of Present SLS Injection
2. **Antiseptum for SLS-2**
3. Summary

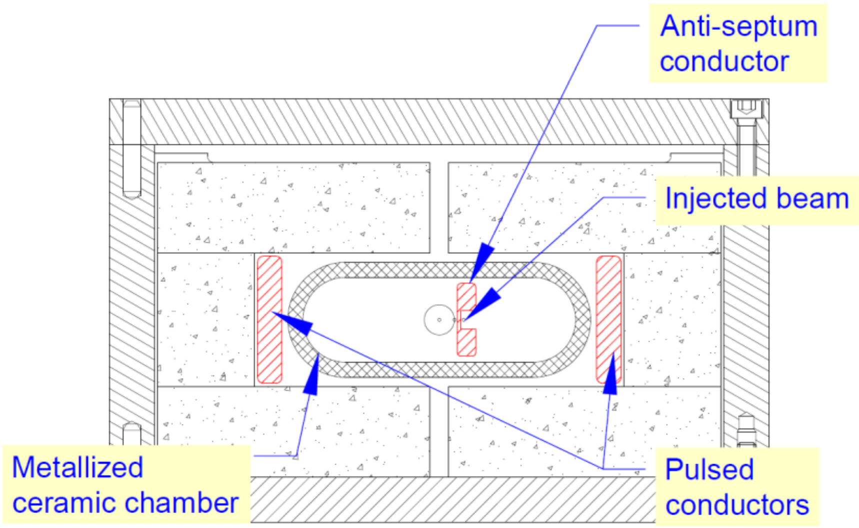
Description of Antiseptum Scheme

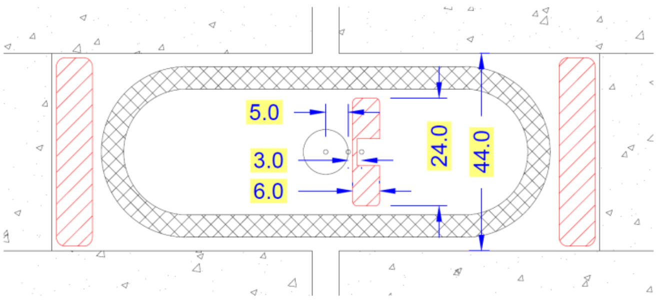
A conventional injection scheme is based on a septum to deflect the injected bunch with a fast pulsed bump using kickers to bring the stored beam close to the septum wall.

With the novel "antiseptum" improvement, the bump kickers are fitted with a metal eddy current conductor which screens the injected bunch from deflection without changing the stored beam bump behaviour. This metal screen then forms the final septum, but inverted in function of the conventional approach, hence the name "anti-septum". The approach does not remove the need for the main septum magnet, but for modest cost it permits the injected bunch to be brought closer to the stored beam.



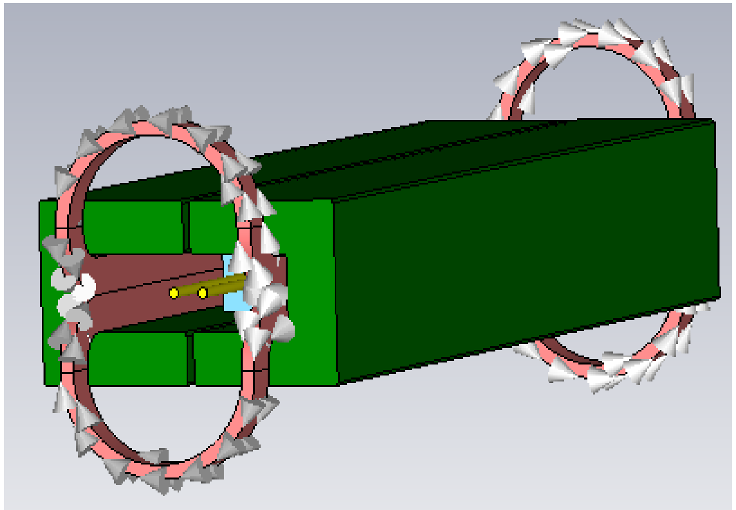
Description of Antiseptum Scheme

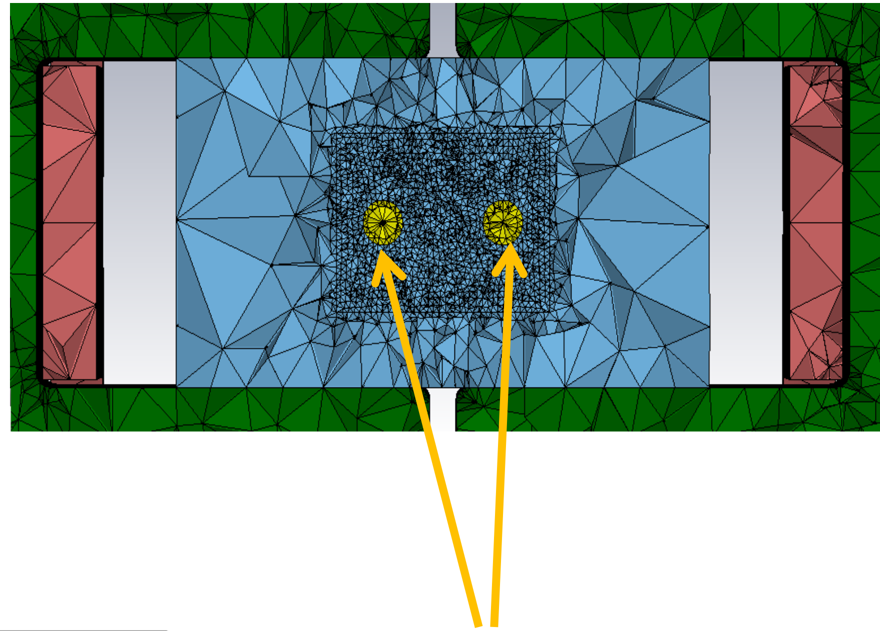


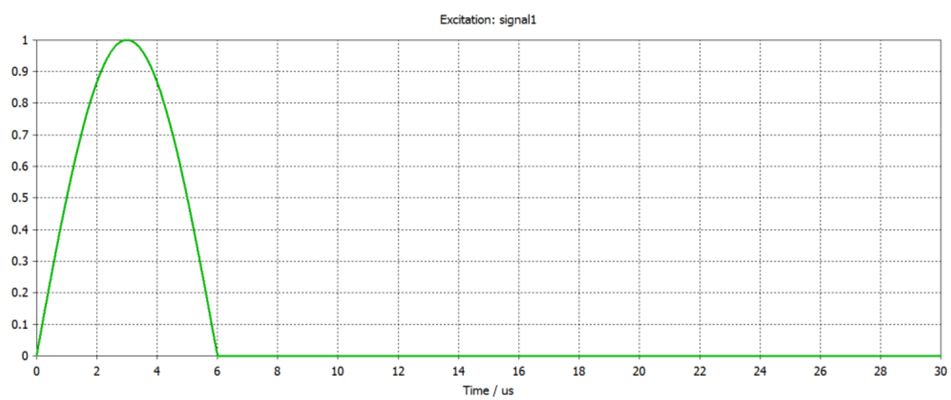


There are reasonable technical solutions to precision placement of the antiseptum conductor, but drawings are not yet available.

Simulation Model in CST





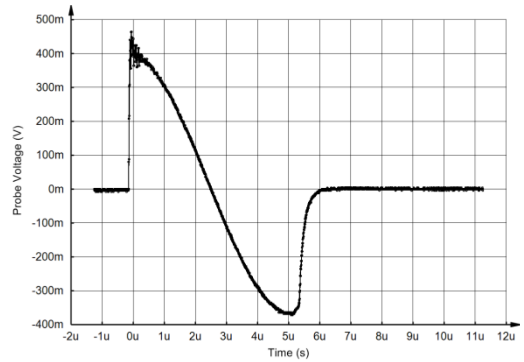


Antiseptum conductors in main field of the kicker magnet, but not electrically connected to anything

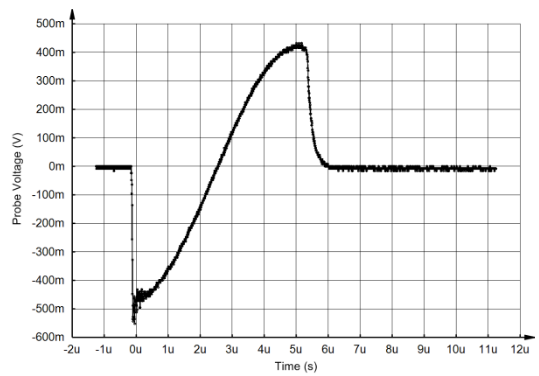
Measurement of Homogeneity with Differential Probe

Arbitrary coil dimensions,
in this case coil center-to-center is 2mm

Coil A

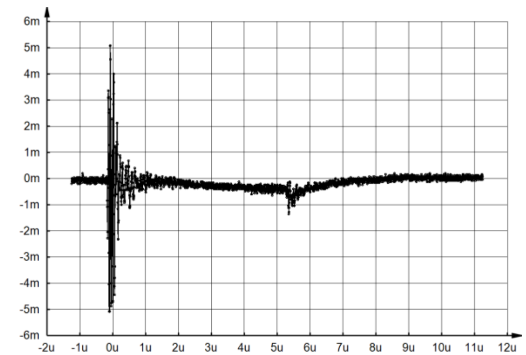


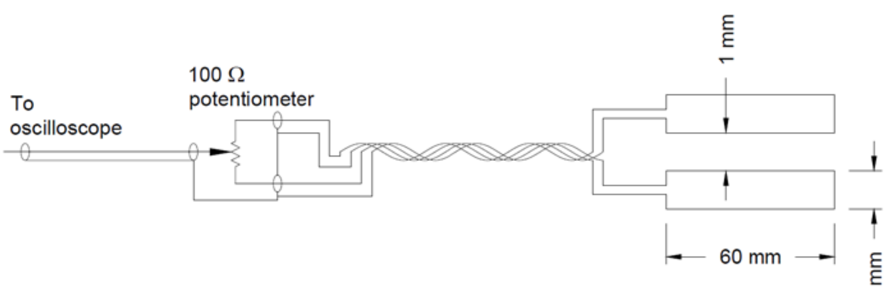
Coil B



Coil A + B summed
in resistive 50Ohm

Scale factor 3.0 (slightly dependent on instance of null point)



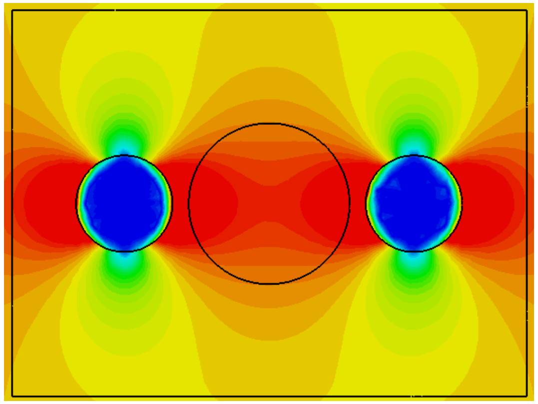


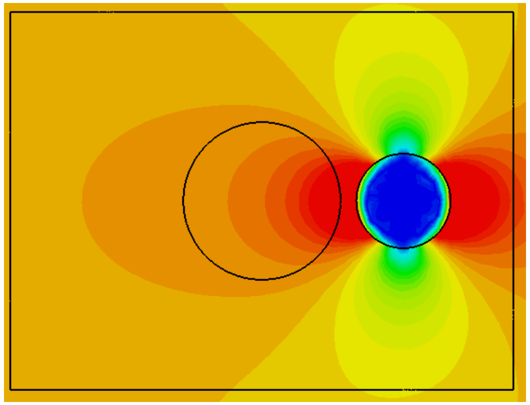
The summed signal is balanced to zero in a homogeneous field. In this case, full scale signal (let's take Coil A as reference) is +/-400mV or 800mVpp
The summed signal above is <500uVpp. So resolution is 3.0 * 500uV/800mV = 0.19% integrated over ~2mm coil separation.

Circular Conductor Pulsed Field

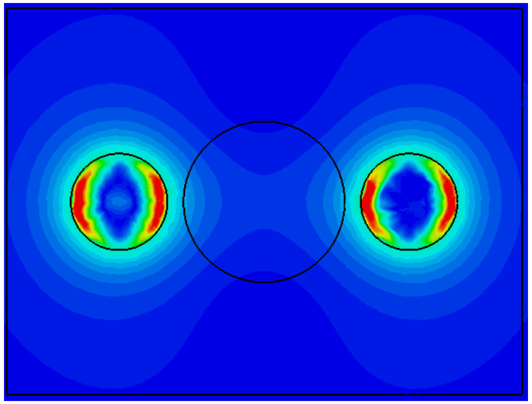
Symmetric Conductors | **Asymmetric Conductors**

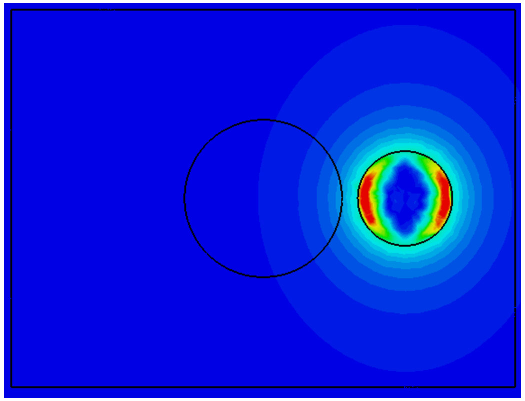
At moment of current peak at 3us:
2kA on main magnet
main field on axis ~65mT





After current has stopped at 9us:
eddy currents still flowing in metal,
leakage field on axis <300uT



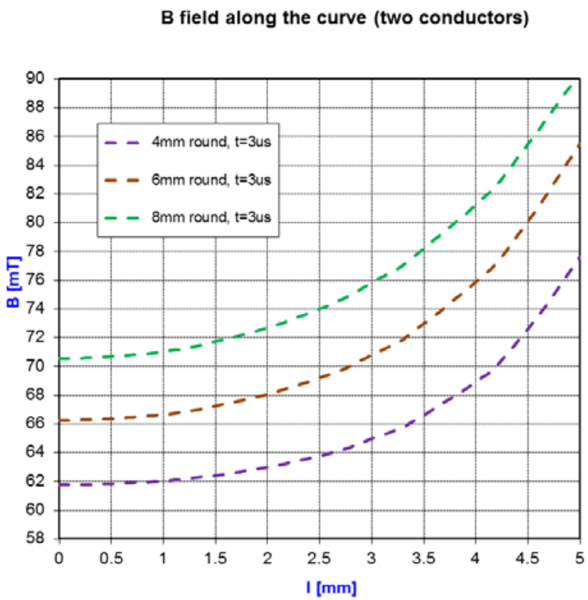


After the main excitation current pulse has disappeared, long term residual fields remain because of the eddy current flowing inside the conductors. However, the residual fields are also homogeneous, are at low level compared to main field and are proportional to the excitation current so they tend to sum to zero through the three or four bump kickers.

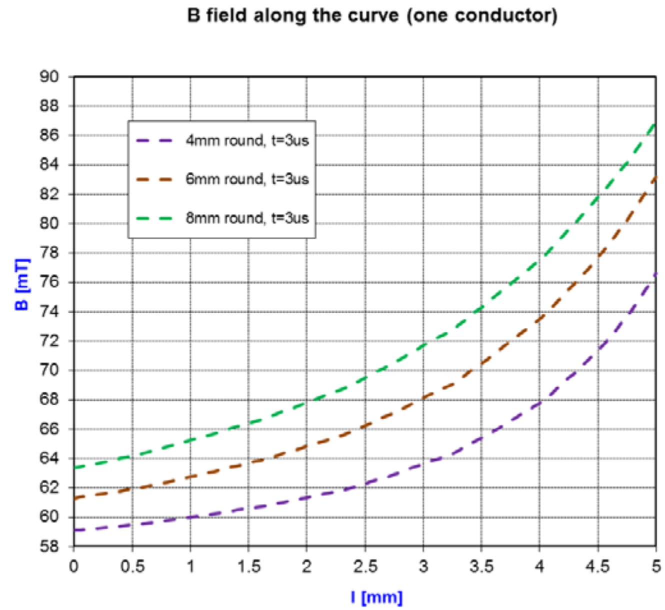
With round conductors, the field homogeneity during the pulse is unusable…

Circular Conductors, Field Homogeneity during the Pulse

Symmetric Conductors



Asymmetric Conductors



The plots show field along a horizontal transverse line from beam axis at x=0 mm to x=5mm, that it to within 1 mm of the anti-septum conductor at x=6 mm. The last millimeter is unstable because of meshing limitations.

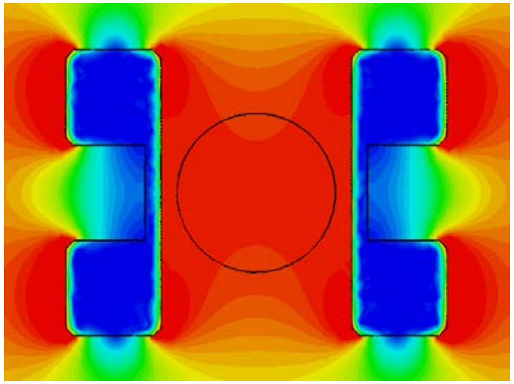
For circular conductors, inhomogenious field is not usable!

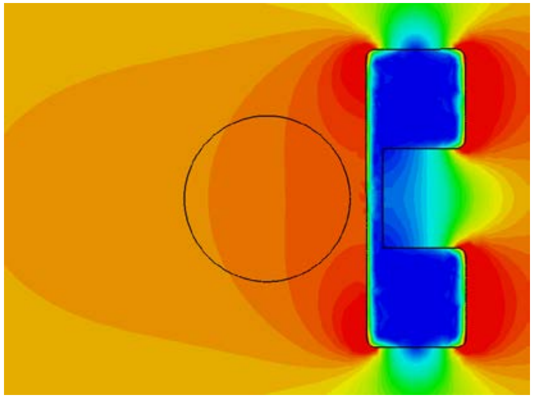
The measurement system (shown later) gives homogeneity as the difference in fields separated by 2mm. For the plot of the asymmetric conductor case above, from x=3 to x=5mm, CST gives ~19% inhomogeneity, the measurement system gives ~20%.

CST Simulation of Pulsed Field, Rectangular Conductor

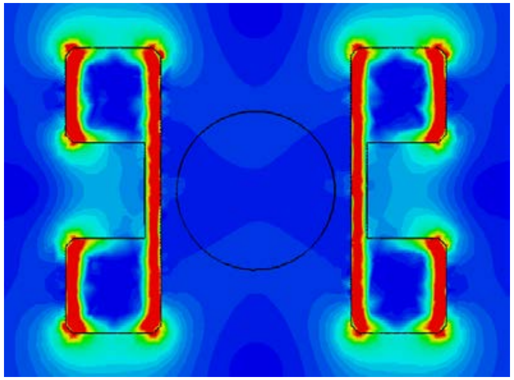
Symmetric Conductors | **Asymmetric Conductors**

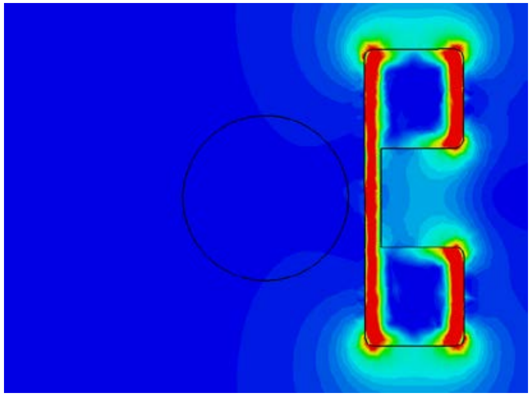
At moment of current peak at 3us:
2kA on main magnet
main field on axis ~65mT





After current has stopped at 9us:
eddy currents still flowing in metal,
leakage field on axis <300uT



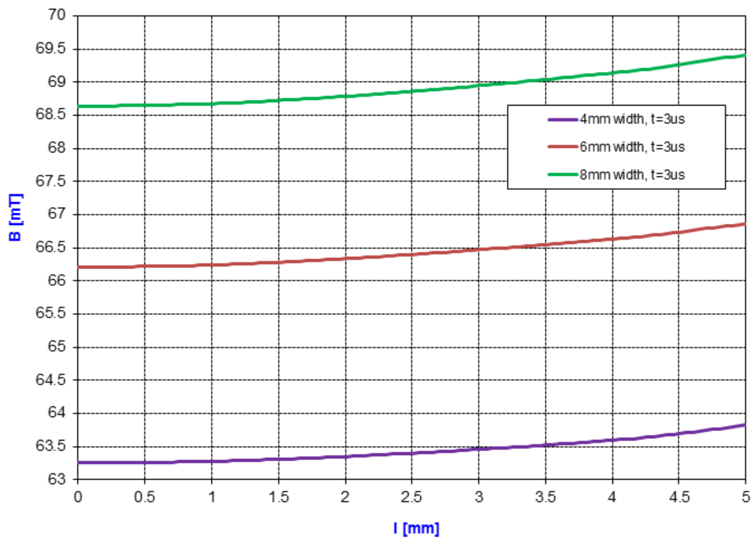


But for rectangular conductors the story changes.

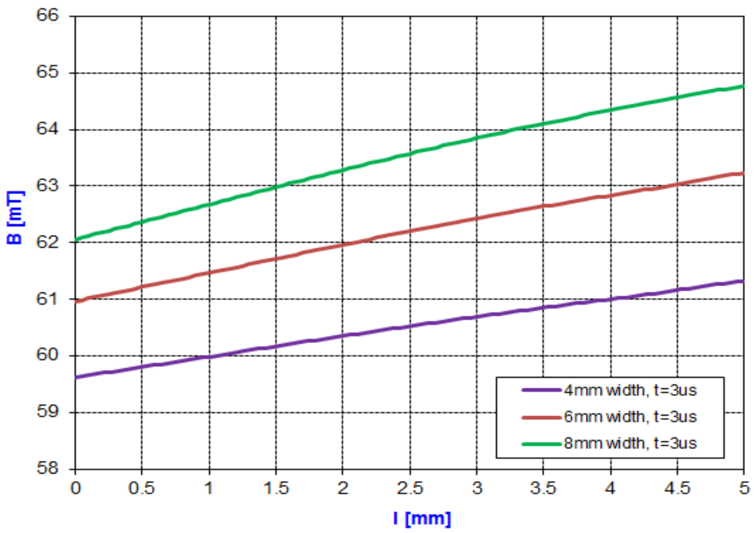
The long vertical edges tend to maintain homogeneity…

Rectangular Conductors, Field Homogeneity during the Pulse

Symmetric Conductors



Asymmetric Conductors



The plots show field along a horizontal transverse line from beam axis at x=0 mm to x=5mm, that it to within 1 mm of the anti-septum conductor at x=6 mm. The last millimeter is unstable because of meshing limitations.

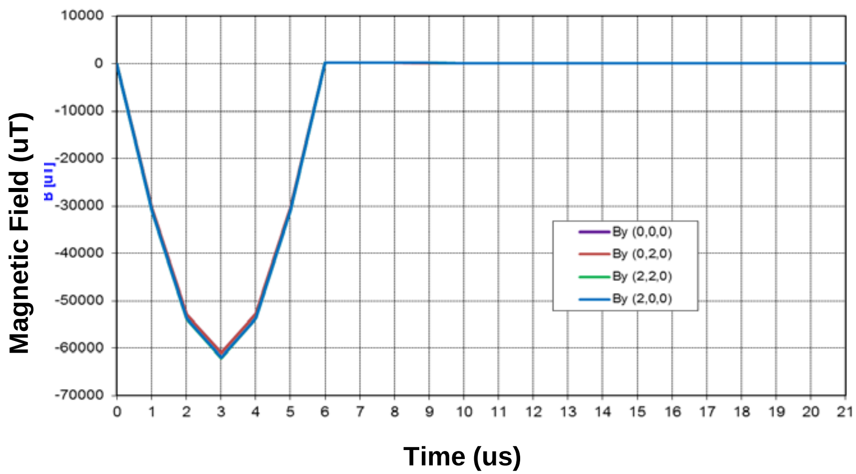
Symmetric configuration with dual conductors is preferred; but the symmetric configuration may not be practical because the outer conductor is subjected to high intensity X-radiation from the up-stream storage ring dipole.

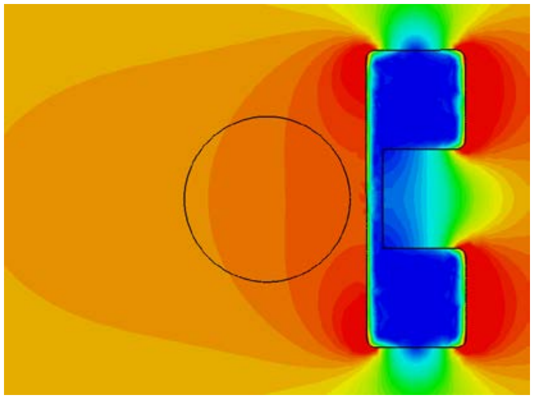
Asymmetric confiugration with single conductor gives poorer homogeneity but may still be usable. This inhomogeneity can be improved by small geometry changes in the shape of the conductors and by asymmetric shimming of the magnet poles. Work is in progress to find the optimum configuration.

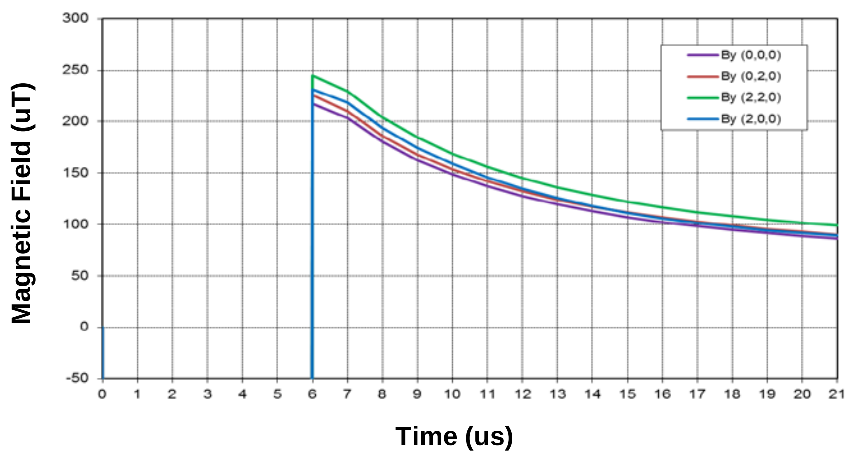
The measurement system in the following slide gives homogeneity as the difference in fields separated by 2mm. For the plot of the asymmetric conductor case above, CST gives ~1.4%, <0.2% is measured. This discrepency needs clarification!

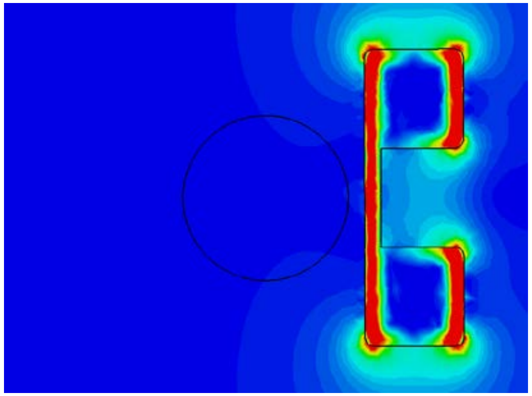
CST Simulation of Pulsed Field, Eddy Current Fields

Asymmetric Conductors



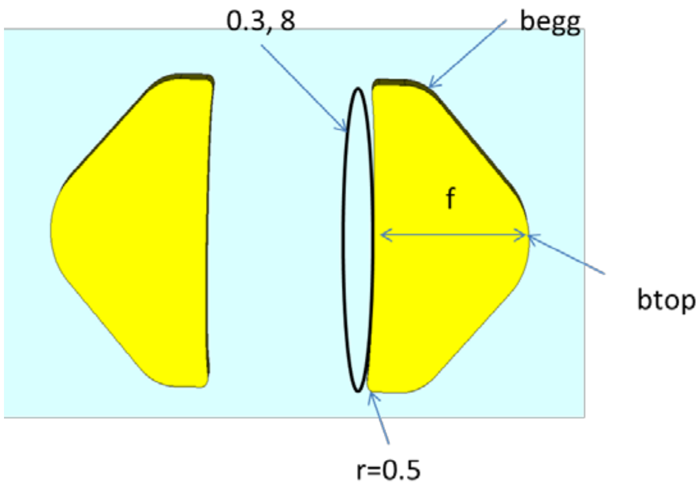


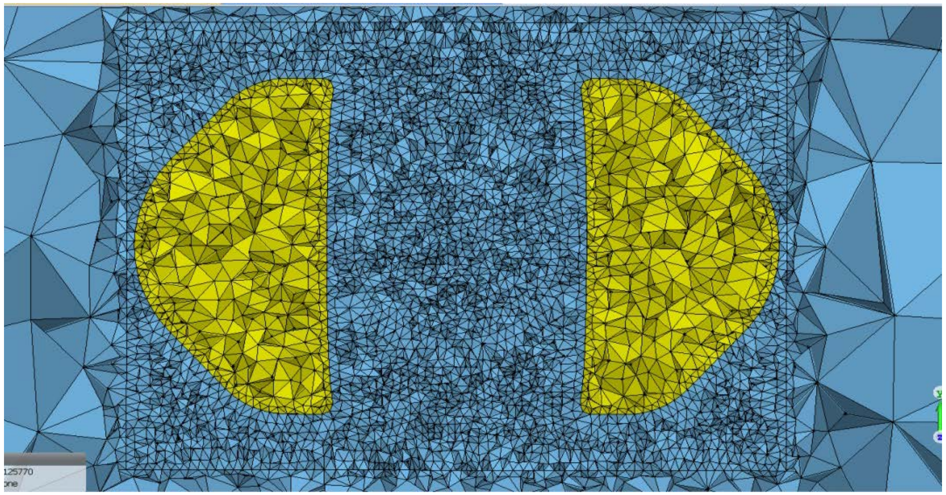


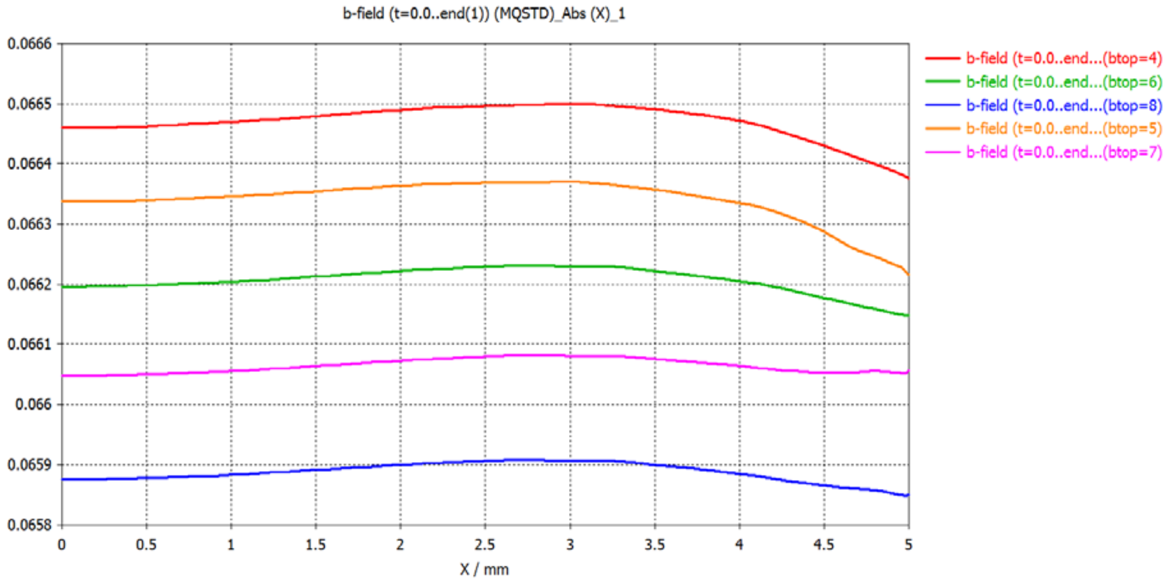


Enlarged scale time plot showing tail from eddy currents.
Through multiple dipole kickers, these tails will sum towards zero

Optimising Conductor Shape







One example of optimising conductor shape for horizontal field homogeneity.

Difficult trade-off of mesh size and simulation run time.

As before, field plot from axis (x=0) to 1mm away from conductor at 6mm.

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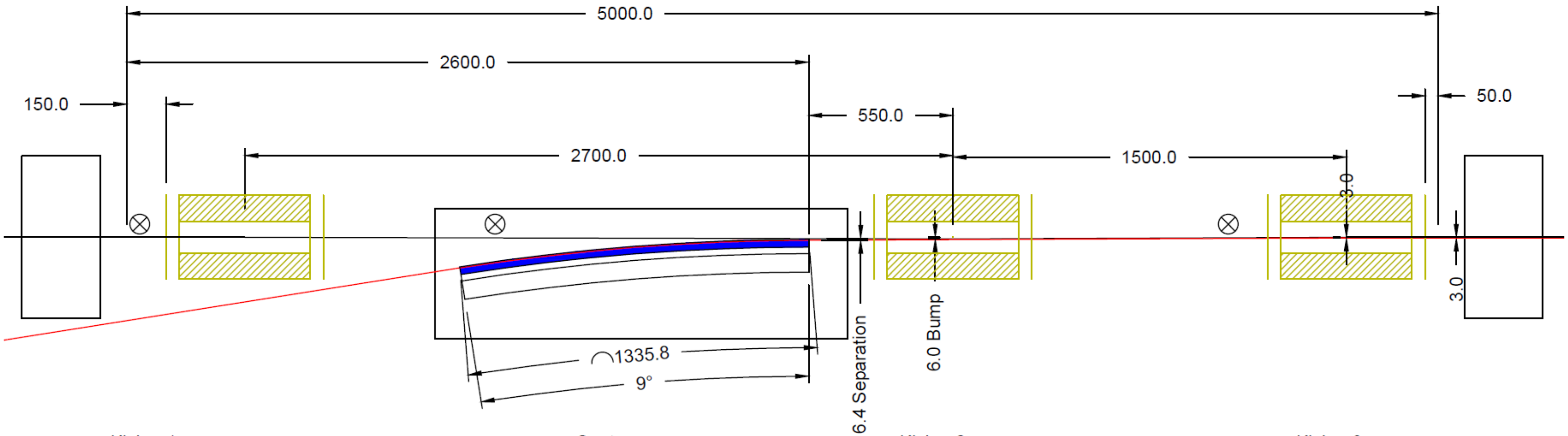
3. **Summary**

Proposed SLS-2 Injection Using Antiseptum



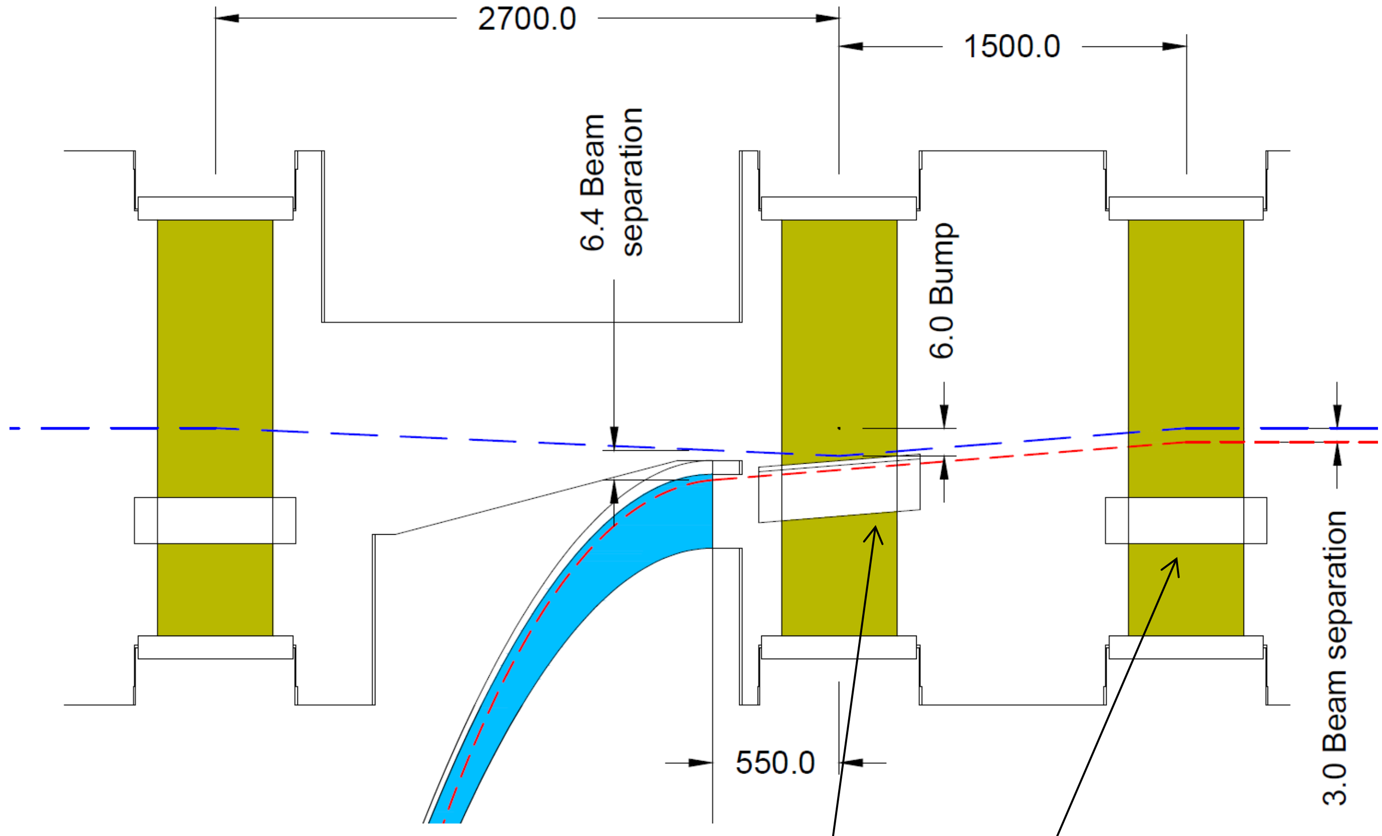
Kicker 1
2.3mrad
120W x 44H x 500L
37mT
1.3kA
1.5kV
6us half sine
passive antiseptum

Septum
157mrad
25W x 6H x 1570L
942mT
4.5kA
1.9kV
70us full sine
3mm septum
in vacuum

Kicker 2
6.3mrad
120W x 44H x 500L
101mT
3.5kA
4.0kV
6us half sine
1mm "antiseptum"

Kicker 3
4.0mrad
120W x 44H x 500L
64mT
2.2kA
2.5kV
6us half sine
passive antiseptum

Proposed SLS-2 Injection Using Antiseptum



“Active” antiseptum in kicker K2

“Passive” antiseptum conductors in kicker K1 and K3 – these preserve the inductance and resistance so the pulse shape is identical

Summary

Antiseptum Scheme for SLS-2

- flat vertical eddy current conductor minimises field inhomogeneity and shields the injected beam

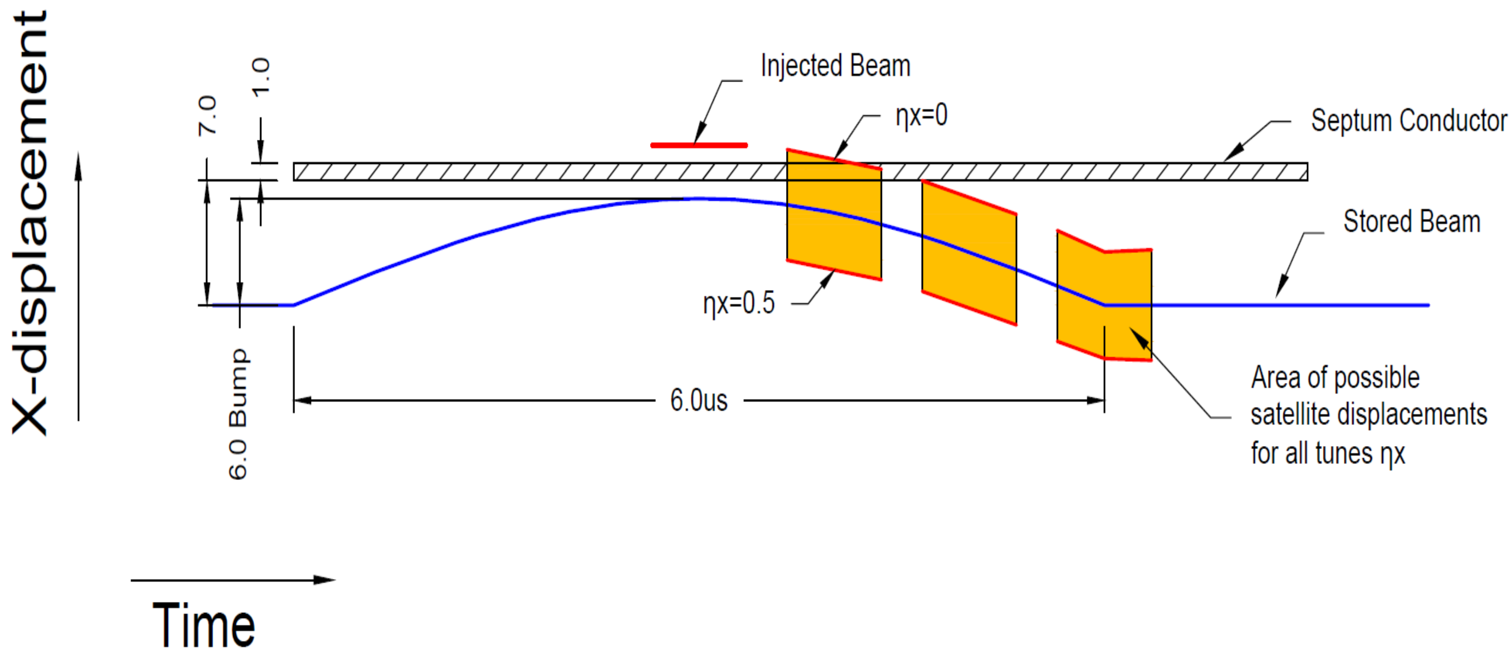
- injected beam can be brought to ~3mm from stored beam

- small separation of injected-to-stored beam has consequence that a small bump (6mm) can be used without restricting the betatron tune

- field inhomogeneity (here defined as field difference with 3mm separation) in the middle kicker K2 will be <1%. Magnet shimming, together with a fast DAC predictive corrector winding is expected to bring this down to +/-0.1%, to correspond to the present SLS waveform matching.

- expected technical difficulties are:
  - long high field septum
  - compact mechanical design of vacuum system
  - uniformity for the kicker ceramic coating

Reserve Material



Tune restriction from injection scheme – more or less none!