UPPSALA
UNIVERSITET

**DESIGN OF A
NCR PICK-UP IN
UPPSALA**

Arnaud Ferrari

Goals and
analytical design

Rejection of
parasitic
wakefields

Coupling of the
NCR to the beam

Conclusions

DESIGN OF A NEARLY-CONFOCAL RESONATOR PICK-UP IN UPPSALA

Arnaud Ferrari

Department of Physics and Astronomy
Uppsala University, Sweden

EUROTeV Annual Meeting
LNF Frascati, January 24th 2008

Contents

UPPSALA
UNIVERSITET

**DESIGN OF A
NCR PICK-UP IN
UPPSALA**

Arnaud Ferrari

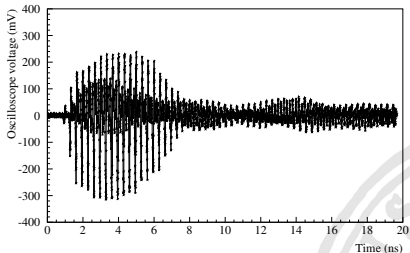**Goals and
analytical design**

Rejection of
parasitic
wakefields

Coupling of the
NCR to the beam

Conclusions

Motivations

Beam diagnostic devices can be perturbed by microwave fields generated by the beam, that propagate in the wake of the bunches.
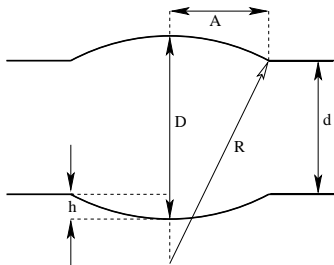

An open resonator pick-up with spherical mirrors can have a high quality factor for the diffraction losses.

Reciprocity then suggests that it couples weakly to external TE or TM fields... while keeping anyway a significant coupling to the beam??

Open resonator with spherical mirrors

The solution of the wave equation between the spherical mirrors is described by Gaussian beams modulated with associated Laguerre polynomials.

$$f = \frac{c}{2D}\left[q + 1 + \frac{1}{\pi}\left(1 + m + 2n\right)\arccos\left(1 - \frac{D}{R}\right)\right]$$

- $q \rightarrow$ number of nodes between the spherical mirrors
- $m, n \rightarrow$ coefficients of associated Laguerre functions

Design of a nearly confocal resonator

Losses and quality factors:

- Diffraction losses depend on the Fresnel number $N_F = A^2/D\lambda \times \sqrt{(2D/R) - (D/R)^2}$ and (m, n).

$$Q_d = \frac{2\pi D}{\alpha_d \lambda} \text{ with } \alpha_d = \frac{2\pi (8\pi N_F)^{1+m+2n} e^{-4\pi N_F}}{(m+n)! \, n!}.$$

- Resistive losses on the spherical mirrors depend only on the geometry and the material.

$$Q_r = \frac{G}{R_s} \text{ with } G = Z_0 \times \frac{\pi}{2} \times \frac{D}{\lambda}.$$

We use a mirror distance $D = 5.345$ cm and a curvature radius $R = 8.908$ cm. This ensures that there is only one eigen-mode at 12 GHz ($m = n = 0$ and $q = 4$):

$Q_d = 3.6 \times 10^6 \gg Q_r = 4.1 \times 10^4$.

UPPSALA
UNIVERSITET

**DESIGN OF A
NCR PICK-UP IN
UPPSALA**

Arnaud Ferrari

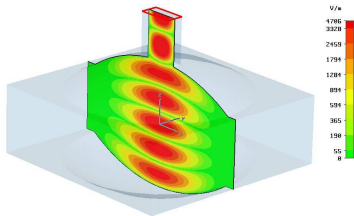Goals and
analytical design

**Rejection of
parasitic
wakefields**

Coupling of the
NCR to the beam

Conclusions

Search for NCR eigen-modes

The CST Microwave Studio simulation package was used to study the electromagnetic properties of the NCR cavity, connected to a waveguide (1.905 cm $\times$ 0.953 cm) through the upper mirror.

Electromagnetic field in the NCR cavity at 12 GHz for the $m = n = 0$ and $q = 4$ mode.

Eigen-modes are identified in the S_{11} spectrum at the waveguide port.
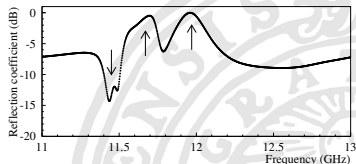
Resonances with a large Q_d translate into a peak close to 0 dB.

UPPSALA
UNIVERSITET

**DESIGN OF A
NCR PICK-UP IN
UPPSALA**

Arnaud Ferrari

Goals and
analytical design

**Rejection of
parasitic
wakefields**

Coupling of the
NCR to the beam

Conclusions

Transmission coefficient of incoming modes

The NCR is inserted into a 11 cm $\times$ 3.7 cm rectangular pipe. Below a cut-off frequency of 12.1 GHz, 38 modes can propagate through the pipe.
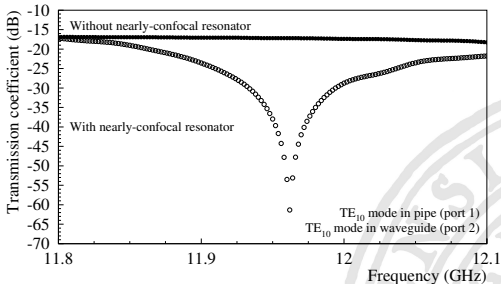
CST simulations show a clear rejection of the TE_{10} mode of the pipe around the resonant frequency of the NCR.

A similar behaviour is observed for all other incoming TE and TM modes.

Experimental prototype

NCR prototype on a pipe:

The horn antenna allows to inject TE and TM modes into the rectangular pipe.

Measurement of reflection and transmission coefficients with a network analyzer in Uppsala.
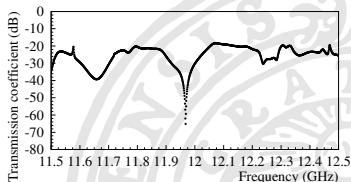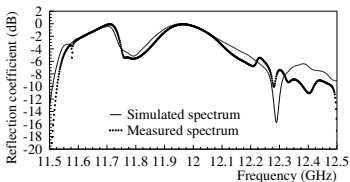
Results with the NCR prototype

Experimental tests confirmed our simulations and provided a clear proof-of-principle for the NCR.

A good agreement between the simulated and measured S_{11} spectrum.

A clear rejection of incoming modes at the NCR resonant frequency.

Published in IEEE Transactions on Microwave Theory and Technology, Vol. 55, No. 10, October 2007.

UPPSALA
UNIVERSITET

DESIGN OF A
NCR PICK-UP IN
UPPSALA

Arnaud Ferrari

Goals and
analytical design

Rejection of
parasitic
wakefields

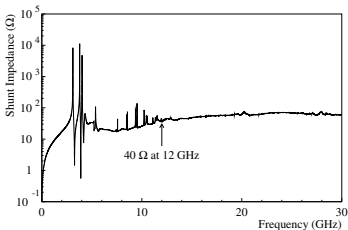Coupling of the
NCR to the beam

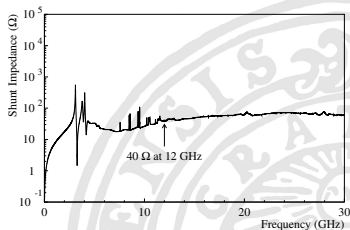Conclusions

GdfidL simulations of the NCR pick-up (1)

To study the signal induced by the CTF3 beam in the NCR pick-up, simulations are performed with GdfidL.

Shunt impedance as a function of frequency:

Only the NCR pick-up:

With SiC damping bricks:

Low-frequency modes couple best to the beam and they can be damped with absorbing material in the beam pipe walls (SiC here).

UPPSALA
UNIVERSITET

**DESIGN OF A
NCR PICK-UP IN
UPPSALA**

Arnaud Ferrari

Goals and
analytical design

Rejection of
parasitic
wakefields

**Coupling of the
NCR to the beam**

Conclusions

GdfidL simulations of the NCR pick-up (2)

The signal induced by one bunch ($q = 3$ nC, $\sigma = 2$ mm) in the NCR extraction waveguide is FFT(E) $\times$ FFT(H):
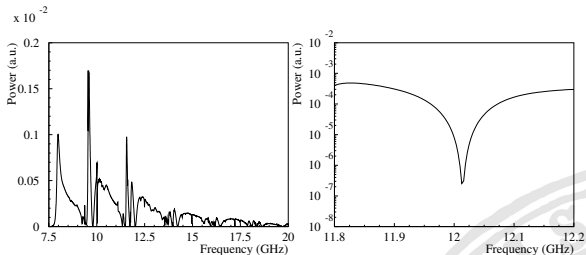
Minimum at 12 GHz: small transit time factor for the mode with $m = n = 0$ and $q = 4$, which has $E_z(s) \propto e^{-s^2/2w_0^2}$:

$$\Delta E = \int E_z(s) \cos\left(\frac{2\pi f}{\beta c} s\right) ds = \exp\left(-\frac{\pi^2 w_0^2}{\lambda^2}\right) \int E_z(s) ds.$$

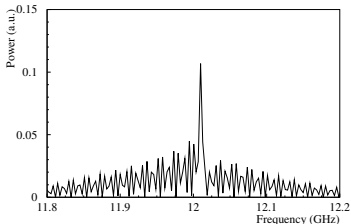The analytical and computed transit time factors are 0.0048 and 0.0035.

UPPSALA
UNIVERSITET

**DESIGN OF A
NCR PICK-UP IN
UPPSALA**

Arnaud Ferrari

Goals and
analytical design

Rejection of
parasitic
wakefields

**Coupling of the
NCR to the beam**

Conclusions

Power spectrum computation (1)
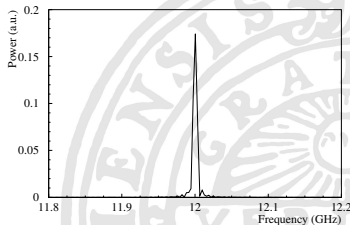
The power induced by N_b bunches (in the right unit) is:

$$P_{bunch}(f) \times \left[\left(\sum_{i=1}^{N_b} cos\left(2\pi f \tau_i\right) \right)^2 + \left(\sum_{i=1}^{N_b} sin\left(2\pi f \tau_i\right) \right)^2 \right].$$

With the NCR pick-up after summing up 420 bunches:

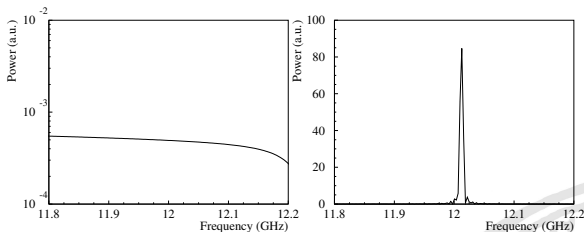With a 140 ns long unitary sine function at 12 GHz:

With a bandwidth of 50/300 MHz, the power coming from the NCR during the passage of a bunch train is 1.0/3.5 W.

Power spectrum computation (2)

For a pick-up with no NCR cavity:

For a bandwidth larger than 50 MHz, the output power during the passage of a bunch train is 500 W.

The two spherical mirrors in the beam pipe:

- reduce the available signal in the NCR waveguide,
- do not allow a significant improvement of the signal-to-noise ratio.

UPPSALA
UNIVERSITET

DESIGN OF A
NCR PICK-UP IN
UPPSALA

Arnaud Ferrari

Goals and
analytical design

Rejection of
parasitic
wakefields

Coupling of the
NCR to the beam

Conclusions

Summary

Positive and negative results were obtained in 2007:

- Simulations and experimental tests of a new NCR pick-up showed a clear rejection of external parasitic modes at the resonant frequency (12 GHz).

- GdfidL simulations show that there is a very weak coupling of the beam to the NCR mode of interest and thereby not a significant improvement of the signal-to-noise ratio.

* EUROTeV-Report-2007-073 in review...

* Many thanks to Shi Cheng and Gabriel Gourie for their collaboration!