EUROTeV ACHIEVEMENTS AT UPPSALA UNIVERSITY

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Contents

The EUROTeV project: overview

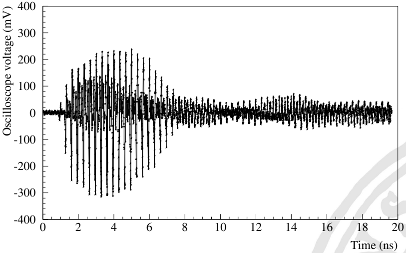
- EUROTeV: European Design Study Towards a Global TeV Linear Collider
- 22 participating institutes, a total budget of 9 MEuros over 2005-08, funded by the 6th Framework Program (FP6) of the European Commission.

Scientific work packages:

- Beam Delivery System (BDS)
- Damping Rings (DR)
- Polarised Positron Sources (PPS)
- Diagnostics (DIAG)
- Integrated Luminosity Performance Studies (ILPS)
- Metrology and Stabilisation (METSTAB)
- Global Accelerator Network Multipurpose Virtual Laboratory (GANMVL)

Motivations for a Nearly-Confocal Resonator

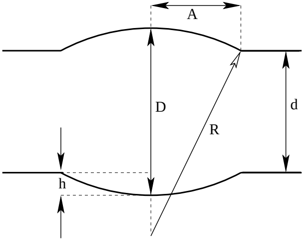
Beam diagnostic devices can be perturbed by microwave fields generated by the beam, that propagate in the wake of the bunches.

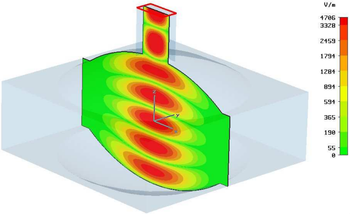


An open resonator pick-up with spherical mirrors can have a high quality factor for the diffraction losses.

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





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

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

We use a mirror distance $D = 5.345$ cm and a curvature radius $R = 8.908$ cm. There is only one eigen-mode at the frequency of interest (12 GHz $\Leftrightarrow m = n = 0$, $q = 4$), with a large Q-factor for diffraction losses: $Q_d \simeq 4 \times 10^6$!

Experimental prototype

NCR prototype on a pipe:

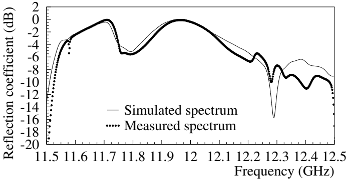
The horn antenna allows to inject TE and TM modes into the rectangular pipe.

Measurement of reflection and transmission coefficients with a network analyzer in Uppsala.

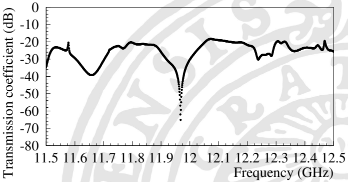
Results with the NCR prototype

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.



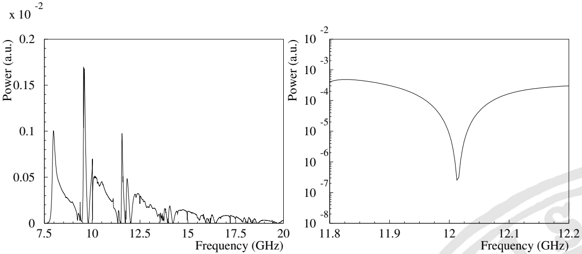
A clear rejection of incoming modes at the NCR resonant frequency.



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

GdfidL simulations of the NCR pick-up

The signal induced by one bunch ($q = 3$ nC, $\sigma = 2$ mm) in the NCR extraction waveguide is $\mathrm{FFT}(E) \times \mathrm{FFT}(H)$:



Minimum at 12 GHz: small transit time factor for the mode with $m = n = 0$ and $q = 4$, which has $E_z(s) \propto e^{-s^2/2w_0^2}$:

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

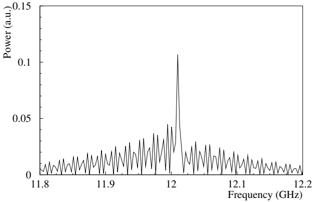
The analytical and computed transit time factors are 0.0048 and 0.0035.

Power spectrum computation

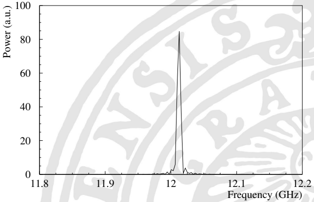
The power induced by N_b bunches is:

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

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



For a pick-up with no NCR cavity (420 bunches):



The two spherical mirrors in the beam pipe reduce the available signal in the NCR waveguide by 2-3 orders of magnitude and do not allow a significant improvement of the signal-to-noise ratio.

Motivation for a CLIC post-collision line

At CLIC, the incoming beams experience very strong electromagnetic fields at the interaction point.

→ Increased angular divergence of the disrupted beam, emission of beamstrahlung photons (thus a large energy spread) and production of e^+e^- coherent pairs.

All these particles must be transported to their dump with minimal losses in the extraction line.

First design: EUROTeV-Report-2007-001 (January 2007).
Updated design: EUROTeV-Report-2008-021 (May 2008, after a change of the CLIC beam parameters).

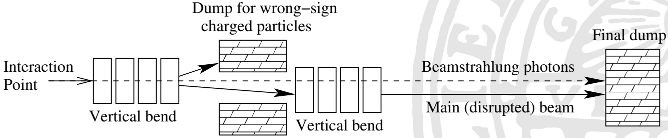
Incoming beam parameters

Parameter	Symbol	Value	Unit
Center-of-mass energy	E	3	TeV
Acceleration frequency	f_{RF}	12	GHz
Acceleration gradient	g_{ACC}	100	MV/m
Particles per bunch	N_b	3.72	10^9
Bunches per RF pulse	n	312	
Bunch spacing	Δt_b	0.5	ns
Repetition frequency	f	50	Hz
Primary beam power	P_b	14	MW
Horizontal normalized emittance	$(\beta\gamma)\epsilon_x$	660	nm.rad
Vertical normalized emittance	$(\beta\gamma)\epsilon_y$	20	nm.rad
Horizontal rms beam size	σ_x^*	40	nm
Vertical rms beam size	σ_y^*	1	nm
Rms bunch length	σ_z^*	45	μm
Peak luminosity	L	$5.9 \cdot 10^{34}$	$\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$

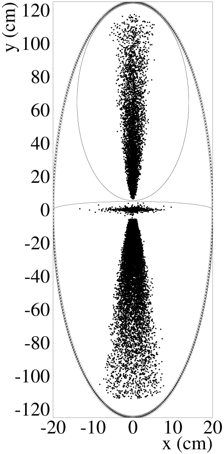
CLIC post-collision line conceptual design

The design relies on the separation by dipole magnets of the disrupted beam, the beamstrahlung photons and the particles from e^+e^- pairs with the wrong-sign charge. It is followed by a transport to the dump in dedicated lines:

- a short one for the wrong-sign charged particles of the coherent pairs, to prevent the transverse beam size from increasing too much.
- a much longer one for the disrupted beam and the beamstrahlung photons, to avoid a too small spot size for the undisrupted beam at the dump window.

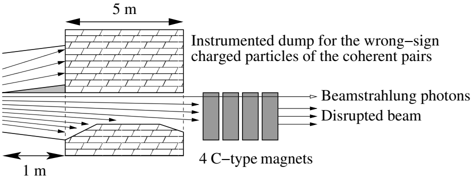


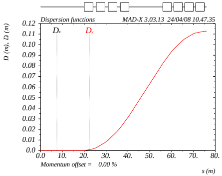
Physical beam separation after 49 m



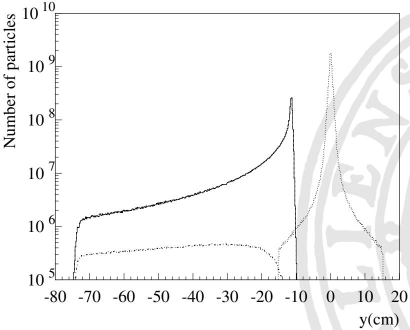
- The wrong-sign charged particles of the e^+e^- pairs are separated from the other outgoing beams when $D_y = 6$ cm. Measuring their vertical profile allows to derive the energy spectrum of the e^+e^- pairs.
- The beamstrahlung photons and the right-sign charged particles of the e^+e^- pairs are transported, together with the disrupted beam, until the final dump located 100 m downstream.

Transport of the main outgoing beam



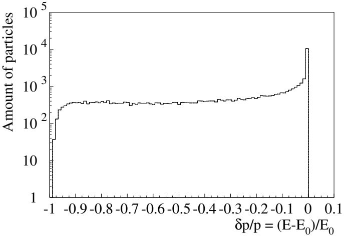


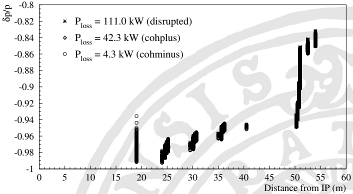
An accurate analysis of the final transverse beam profiles allows to derive information on the e^+e^- collisions.



Beam losses along the post-collision line

All charged particles with $\delta > -0.84$ and beamstrahlung photons reach the final dump. The low-energy tails are lost in either collimators or the intermediate dump, due to (mostly vertical) aperture restrictions.





Results are in excellent agreement for different particle tracking codes. Back-scattered particles are now under study using the GEANT4 interface to BDSIM.

What to measure and how?

The post-collision line should be used to measure the quality of the e^+e^- collisions and monitor beam-beam offsets during the machine tuning.

- Measurement of the energy spectrum and flux of the wrong-sign charged particles of the coherent pairs at the intermediate dump.
- Monitor the low-energy tails, using reverse-biased PIN diodes in the collimators sandwiched between the window frame magnets.
- Monitor the temperature dependent refractive index of the water in the dump with an interferometer, and derive the vertical beam profile.
- Beamstrahlung monitor: detect the high-energy muons produced by the beamstrahlung photons in the main dump and derive the corresponding flux.

Summary

* Simulations and experimental tests of a NCR pick-up showed a clear rejection of external parasitic modes at the resonant frequency (12 GHz), however simulations with GdfidL suggest a weak coupling to the beam, and thus no significant increase of the signal-to-noise ratio.

* A design of the instrumented CLIC post-collision beam line(s) was performed. A paper was recently submitted to Phys. Rev. ST-AB.

* The final EUROTeV scientific workshop was held in Uppsala, 26-28 August 2008.