Recent Developments on ALICE (Accelerators and Lasers in Combined Experiments) at Daresbury Laboratory

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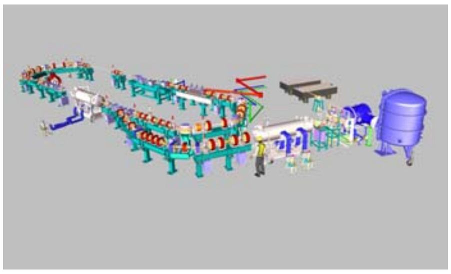
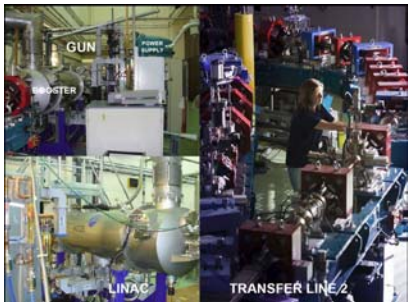
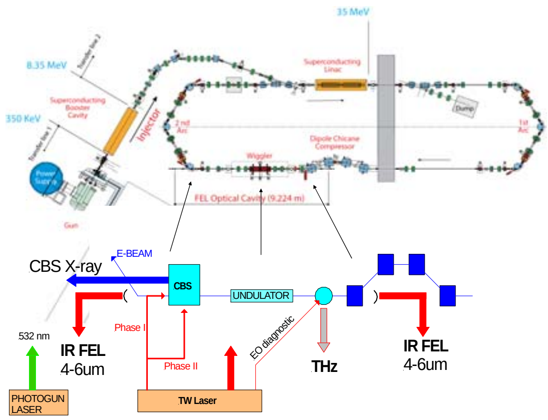






MACHINE STATUS

	Nominal Parameters	Current parameters
Gun DC Voltage	350kV	350kV with nominal HV ceramic; **gun operates at 230kV**
Nominal bunch charge	80pC	200pC can be delivered, machine operates at 40 pC
Laser Nd:YVO4 (2nd harmonic)	532nm	532nm
Laser spot	4.1mm FWHM	Variable
Laser pulse length	28ps FWHM	28ps with laser pulse stacker
Quantum Efficiency	1-3%	~3% (~15% in lab conditions)
Injector Energy	8.35MeV	**6.5 MeV**
Total beam energy	35MeV	**27.5 MeV**
RF frequency	1.3GHz	1.3GHZ
Bunch repetition frequency	81.25MHz	81.25MHz
Train Length	0-100 μs	Up to 100 μs at 40 pC
Train repetition frequency	1-20Hz	1-20Hz
Compressed bunch length	<1ps @80pC	To be measured
Peak current in compressed bunch	150A	To be measured
Maximum Average Current	13 mA	

ALICE has been operating in energy recovery mode since December 2008.

The operating energy is lower than the design energy due to intense field emission in the main linac.

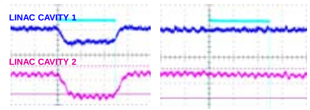
The DC gun operates at 230 kV rather than 350 kV and thus 40 pC charge is used to maintain beam quality with the reduced gun voltage.

Over the past year, a number of changes in gradient settings of the booster and main linac were made to optimise the RF setup and accommodate limitations in the RF system. ALICE can now be routinely operated at 27 MeV.

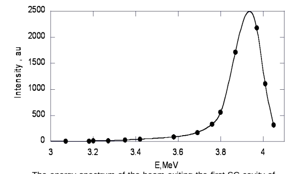
NEA GaAs photcathode lifetime is sufficiently long for ALICE operation at 40 pC. Normally the cathode re-cesiation is performed once a month when the quantum efficiency falls from an initial 3% to 0.5%.

Typically beam-transport losses are 5-7 %. Typical emittance values measured with the slit-method and quadrupole scan are ~ 10 mm mrad.

The bunch length before the compression chicane was measured and found to be 4 mm (13 ps) FWHM. The set-up is being optimised to provide 1.5 mm (5 ps) bunch length for FEL operation. The bunch energy spectrum has been measured in the injector



Main linac RF power demand signals: without (left) and with (right) energy recovery



The energy spectrum of the beam exiting the first SC cavity of the booster BC1. The energy spread here is 150 keV and is compensated by operating BC2 off-crest . The long tail could be a property of the short laser pulse illuminating the GaAs photocathode.

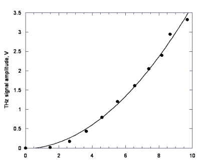
TERAHERTZ RADIATION STUDIES

Coherent THz radiation is generated in the ALICE compression chicane. An optical beamline has been constructed to transport the radiation to a diagnostics room and on to a dedicated tissue culture facility.

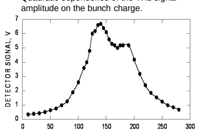
We are currently investigating the THz radiation emerging from the diamond window of the accelerator. We aim to ensure the optimum intensity of the source and minimise the scattered radiation which will not transport efficiently to the culture facility.

We observe a maximum of THz when running the main linac approximately +15 degrees off-crest, in agreement with simulations.

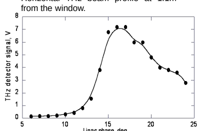
We are also investigating THz intensity through the bunch train using a fast Shottky detector.



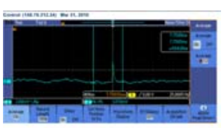
Quadratic dependence of the THz signal amplitude on the bunch charge.



Horizontal THz beam profile at 1.1m from the window.



Intensity of the THz beam on its axis as a function of the linac phase (linac crest = 0 degrees)



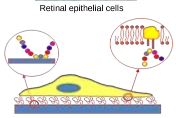
Single bunch THZ signal resolved on Schottky detector

THz radiation at ALICE is being used in two research programmes. The first is to determine the safe limits of human exposure to THz. The second is to explore the influence of THz radiation on mechanisms of biological organisation.

For preliminary cell experiments in-situ, we have constructed a temporary optical beam pipe and installed a shielded cell incubator near the accelerator.

First experiments have included retinal epithelial cells. Anchorage-dependent cells are grown in polystyrene flasks inside the incubator which is exposed to THz radiation

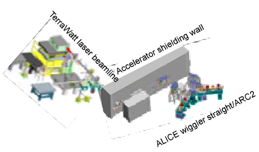
Retinal epithelial cells

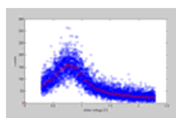


Retinal epithelial cell attaching to the polystyrene flask via an adsorbed protein layer.

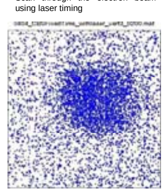
Inside the incubator THz from the beampipe is directed via a mirror to either the flask containing cells or a THz detector

COMPTON BACK-SCATTERING EXPERIMENT





Scan through the electron beam using laser timing



The CBS x-ray image.

Short x-ray pulses from a Compton Back-Scattering (CBS) experiment were successfully demonstrated on ALICE in November 2009. The experiment was conducted with a "head-on" geometry, colliding the 70fs, 800nm, 500mJ Ti:sapphire laser beam with an electron beam of 29.6MeV energy and 40pC bunch charge. Full account of this experiment can be found in WEPD053.

IR-FEL SPONTANEOUS RADIATION

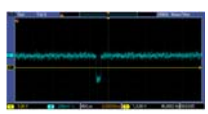
The narrow –gap undulator vacuum vessel and the undulator have been installed and aligned. The FEL optical cavity has been pre-aligned.

Full energy recovery and beam transport in the ALICE machine has been achieved with the FEL installed.

Spontaneous radiation (SE) from the FEL has been detected using a nitrogen-cooled MCT detector. The SE was being stored within the cavity because by blocking the optical round trip path, the SE signal was reduced significantly. After making small angular changes to the FEL mirrors the ratio between the open cavity SE signal and the blocked cavity SE signal was increased to a factor of 14. This indicates that the fraction of intracavity power extracted through the outcoupling hole is 1/14 = 7.1%, in good agreement with the expected figure of 7.5%.

IR:
(design parameters)

λ	4.3μm
Peak Power	15MW
Pulse Energy	10μJ
Pulse Length FWHM	0.5ps



MCT spontaneous radiation signal. The negative going pulse is generated by the undulator radiation making multiple round trips within the laser cavity.

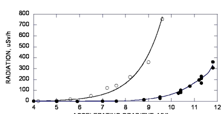
JLAB hybrid permanent magnet undulator, made variable gap for ALICE

Undulator vacuum vessel installed in the ALICE beamline.

RF DEVELOPMENTS

Helium processing of the main linac was performed to reduce the field emission and heat loading to the cryogenic system. The cavities are excited with a high RF field in the presence of a small amount of helium gas. Bombardment of field-emitter sites by ionised He cleans the surface contamination.

Both linac cavities were conditioned separately with a helium pressure of around 5.0 x 10^{-4} Torr. under both pulsed and CW conditions. Improvements were seen in the onset of radiation in the first linac cavity. This has significantly improved the present operation of the linac module at 20 MeV, with a much reduced cryogenic heat loading.



Linac cavity radiation levels pre and post Helium processing

A Digital Low Level RF system is under development for use on the ALICE superconducting cavities

The system has been bench tested extensively in the laboratory, achieving short term phase stability of 0.03° RMS and amplitude 0.05% RMS when set up on the ALICE buncher cavity without beam.

Work is underway to provide effective EMI shielding and power supply regulation to try to minimise noise generated by the LLRF system.

Digital LLRF hardware

OTHER DEVELOPMENTS

First commissioning of EMMA, **E**lectron **M**achine with **M**any **A**pplications, the first non-scaling FFAG, is expected in 2010. A 40 pC, 15 MeV beam has been transported through the EMMA injection line in February 2010. See invited oral THXMH01, poster THPC090