



Status of the AWAKE run 2c photoinjector LLRF at CERN

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AWAKE: Proton driven plasma wakefield acceleration

- Unique to CERN
 - Very successful: showed that a high energy (400 GeV) proton bunch reproducibly selfmodulates, driving strong wakefields.
 - Externally injected low-energy (16 MeV) electrons were accelerated to 2 GeV in under 10 m.
- Staged upgrades (Run 2):
 - Run 2a: demonstrate reproducible self-modulation via electron seeding. (Done 2022)
 - Run 2b: New vapour source with density step to stabilise microbunches. (Ongoing 2023-24)

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Current Electron Injector RF System architecture



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station 2

Second Electron injector

- 160 MeV electron energy
- Emittance 2mm mrad
- S-band photo cathode gun
- X-band buncher
- X-band accelerating structures with 80 MV/m
 - Option for 3x, 55 MV/m structures also studied.
- 3 drive signals to be to be controlled.





LLRF system specifications for run 2c

- 3GHz and 12GHz signals to be acquired and generated.
 - Arbitrary amplitude and phase control is required to operate the system in a closed loop fashion and to provide the necessary phase manipulation for the RF pulse compressors.
- Timing jitter between seed and witness ebunches to be below 50fs to achieve optimal placement of the witness e- bunch into the plasma wakefield.
 - LLRF modulator must have an additive phase jitter of less than 30 fs.
- Slow drifts must be compensated for by the LLRF system.

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• Temperature variations in signal cables, long waveguides, driver amplifiers, klystrons, pulse compressors.



	S-band	X-band					
Operating frequency	2.997899 GHz	11.9915962 GHz					
Pulse length	1-10 µs	100-1500 ns					
Bandwidth	> 20 MHz	> 20 MHz					
Pulse repetition rate	9.97 Hz	9.97 Hz					
Number of signals to	14 + Reference	18 + Reference					
be acquired							
Number of signals to	2	2					
be generated							
Jitter	<30 fs	< 30 fs					
Amplitude stability	10 ⁻⁴	10 ⁻⁴					

LLRF architecture

- Use SIS8300KU and DWC8VM1 • AMC+RTM.
- Uppsala University as collaborator to develop the LLRF system for tests at **CERN's CLEAR (formerly CTF)** facility.
- Last year's WS we asked DESY and KVG to launch the development of the DeRTM-LOG 3GHz for REF, LO and CLK distribution on the RF backplane.
- For X-band stations use middleware (a la DESY¹) to up/down convert between 3GHz and 12GHz.



1: https://indico.fnal.gov/event/21836/contributions/64954/attachments/40833/49435/PUBLIC_VERSION - LLRF19_MReukauff_Talk.pdf



LO

DESY FWK BSP: an external perspective

- The FWK/demo facilitated the developer to go from absolute beginner to modest expert in +/-1 year.
- The FWK/demo is now (fall 2023) in a stable phase with initial glitches ironed out.
- The appeal (for us) is that FWK/demo keeps the delay overhead (between ADC > DAC) down without too much tuning.
- Understanding the FWK/demo helped understanding other efforts as well.

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• The core of FWK/demo includes efficient memmap management.



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-Kristiaan Pelckmans

Progress so far...

- System shipped to CERN from Uppsala, installed in the form CLIC test facility.
- RF signal acquisition, generation and feedback/forward loops tested.
- Use of DESY BSP and python GUI.
- External trigger injection through RJ45 connector on SIS8300KU AMC, distributed to mLVDS lines.
 - Currently under test/development (still some bugs to iron out)
- Work progressing well on a DESYRDL to CERN/Cheby convertor script.





Next steps

- Fully validate the external trigger injection and synchronise to the CLEAR accelerator complex.
- Replace DESY RDL register map with CERN Cheby based one.
- Develop FESA class for acquisition and control.
- Install CTRA (CERN timing infrastructure card), to fully integrate into the CERN controls infrastructure.
 - AMC FMC carrier (AFC) and CERN developed timing receiver FMC.
- Connect the VM to the RF power plant and close the loops.
- 3GHz DeRTM-LOG still under development at DESY and KVG. We would like to use this for the final system with 5+ cards.





AFC FMC carrier: https://ohwr.org/project/afc DeRTM-LOG



AWAKE Run 2c photocathode gun installed in former CLIC Test Facility



Advertisement: Cheby + Reksio

Register map tool now open source:

Cheby:

- File format to describe the HW/SW interface (the memory map)
- A set of tools to generate HDL, drivers, documentation... from these files

https://gitlab.cern.ch/be-cem-edl/common/cheby

Reksio: GUI to interface with Cheby.

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https://gitlab.cern.ch/Cheburashka/gui

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Thank You!



Questions?





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Extra Slides



AWAKE run 2c upgrade

- Two RF photocathode guns with S-band and X-band structures.
- Requires pulse to pulse stability of 30 fs \rightarrow active stabilisation with LLRF loops.
- Prototype microTCA LLRF system, currently undergoing tests at CERN through collaboration with Uppsala University.





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