CLIC Beam Instrumentation

- Beam instrumentation effort for the Conceptual Design Effort
- Beam Instrumentation Effort for the Project Preparation Phase
- CERN-UK BI Activities

Work done for the CDR

- Before 2000 – Most of the beam instrumentation developed for the needs of CTF's

- Since 2000
  - R&D on Critical issues (ILC - XFEL related activities)

    High precision BPM – Short bunch length monitor – Small beam size measurement

    University of Dundee   Royal Holloway University of London

  - Development of CTF3 instrumentation – CLIC Drive Beam

Relatively small group at CERN relying on external collaborations !!

CTF3 BI Collaboration

- INFN Frascati :

Beam instrumentation for Magnetic Chicane and DL and CR - (RF deflector and BPMs)

- Uppsala University : TBTS instrumentation

Development RF pick-up to monitor the accuracy of the frequency multiplication in DL and CR

- RHUL :

Development of Coherent Diffraction monitor for bunch length measurements on CTF3

- Northwestern University of Illinois:

Development of cost effective bunch length monitor for Drive Beam Complex

- CEA Saclay : Califes beam instrumentation

The design of re-entrant cavity BPM on Califes / Wakefield monitor design

- LAPP – Annecy:

Development of the Electronic module

- IFIC – Valencia :

Development of the CTF3 Test Beam Line inductive BPM and CLIC Drive Beam BPM body

Work done for the CDR

- Since 2008 – Preparation of the Conceptual Design Report
  - Collect requirements: Overview on the CLIC needs (200kms of beam lines and more than 50000 instruments specified)
  - Open discussion with experts to define a road map for feasibility demonstration
    Beam Instrumentation workshop in June 2009 – 2days and ~50 participants
  - Define Baseline CLIC instrumentation with appropriate technology choice
  - Propose and study Alternative solutions which would impact either on cost or performance
  - Look for standardization and technological developments for cost reduction and/or an improved reliability and maintenance

CDR is done ~ 20 Contributors for beam instrumentation chapter and ~60 pages document

CLIC Project Preparation phase

2011-16

- ✓ Technical design for key Beam Instruments
- ✓ First step of Industrialization phase: Cost and schedule
- ✓ Follow-up on technical implementation and operation scheme

- WP 1: Refinement of specifications
  - R&D on Beam intensity, polarisation, luminosity measurements
  - Follow-up on Damping rings instrumentation development in collaboration with B factories and light sources
- WP 2: Beam Position Monitor designs
  - Design and test of CLIC type BPMs (MB and DB)
  - Wakefield simulations
- WP 3: Long. & Tr. Emittance measurements:
  - Desig, implementation and test of CLIC type emittance measurements
  - Development of cheaper alternative solutions
- WP 4: Beam loss monitors
  - In collaboration with the Machine protection working group finalize the specifications for the BLMs
  - Monte carlo Simulations
  - Develop a BLM only sensitive to charged particle for the Damping rings
  - Develop and Qualify a cost effective detector technology for CLIC modules

CERN-UK BI workpackages

Beam Position Monitors

Machine Sub-Systems	Intensity (A)	Train duration (ns) / Bunch frequency (GHz)	Accuracy / Resolution (um)	Time Resolution (ns)	Quantity	Beam aperture (mm)
Main Beam						
e^- & e^+ injector Complex	0.5	156 / 1	100 / 50	10	83	40
Pre-Damping Rings	0.5	156 / 1	tbd./ 20	10 Turn by turn	600	20 / 9
Damp[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]00	20 / 9
RTML	1	156 / 2	100 / 10	10	1424	various
Main Linac	1	156 / 2	5 / 0.05	10	4196	
Beam Delivery System	1	156 / 2	5 / 0.05	10	600	
Spent Beam Line	1	156 / 2	tbd / 1000	100	12	various
[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	660	40
[illegible] Complex	[illegible]	[illegible] 0.5 → 12	[illegible]	[illegible]	210	80
Transfer to Tunnel	100	24 x 240ns / 12	40 / 10	10	872	200
Turn around	100	240ns / 12	40 / 10	10	1920	40
Decelerator	100	240ns / 12	20 / 2	10	41484	26
Dump lines	100	240ns / 12	20 / 2	10	96	40

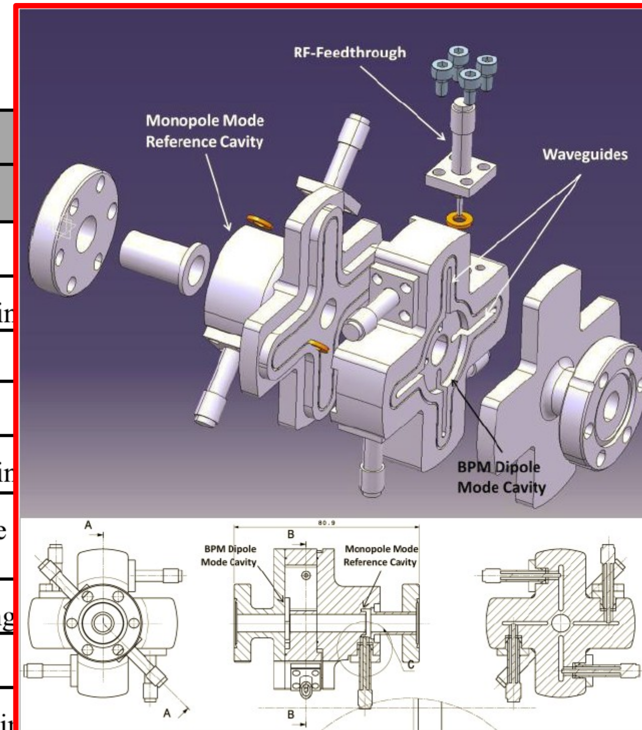
High accuracy (5um) resolution (50nm) BPM in Main Linac and BDS

Various range of beam pipe diameters from 4mm to 200mm all over the complex (to minimize resistive wakefield effects)

Very high numbers of BPMs for the DB decelerator

Beam Position Monitors

Main Beam cavity by Manfred Wendt



Machine Sub-Systems	Quantity	Technology choice		
		Pick-up	Processor	
Main Beam				
e^- & e^+ injector Complex	83	Button 6mm	Direct samplin	
Pre-Damping rings	600	Button 6mm	DR type	
Damping rings	600	Button 6mm	DR type	
RTML	1424	Button 6mm	Direct samplin	
Main Linac and Beam Delivery system	4796		Cavity type	
Spent Beam Line	12	Button / Strip line	Direct sampling	
Drive Beam				
DB source and Linac	660	Button 6mm	Downconverti	
Frequency multiplication complex	210	Button 6mm	Downconverting	CERN
Transfer to tunnel	872	Button 6mm	Direct sampling	CERN
Turn-arounds	1920	Button 6mm	Direct sampling	CERN
Decelerator	41484	Stripline 25mm	Downconverting	CERN
Dump lines	96	Stripline 25mm	Downconverting	CERN

Followed-up by RHUL

BI workpackage – Task 2

WP: CTC-006	Purpose/Objectives/Goals	Deliverables
Task 2: BPM development	- Demonstrate the high resolution of CLIC cavity BPM prototype (linac and BDS) and its read-out electronic - lab and beam test - RF simulations for estimation of wakefield effects and interference due to the presence of high field in PETS and Acc. Cav.	- Prototype of 14GHz cavity BPM -- Engineering specifications and cost estimate

Ressources	2011	2012	2013	Total
Total P (FTE)	**3.3**	**3.6**	**2.6**	**9.5**
FTE from M>P	**1**	**1.8**	**1.8**	**4.6**
UK FTE ressources	1.7	1.2	0.2	3.1
CERN-UK FTE ressouces	0	0.8	0.8	1.6
CERN FTE	0.6	0.6	0.6	1.8
CERN-UK M budget (kCHF)		20	20	40

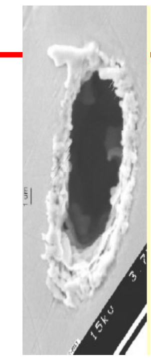
- ✓Lars Soby (CERN) – S. Boogert (RHUL) – M. Wendt (FNAL) – S. Smith (SLAC)
- ✓One project associate based at CERN
- ✓50% Manpower resources in the UK
- ✓M to P budget in M ~ 50% / Few CERN staffs part-time
- ✓Small amount of Material budget: Production of BPM's is not covered by this nudget

Transverse Profile Monitors

Machine Sub-Systems	Emittance (nm.rad)	Energy (GeV)	Resolution (um)	Quantity	Charge dens (nC/cm^2)
Main Beam					
[illegible]	[illegible]	[illegible]	[illegible]	2	$< 5\ 10^5$
[illegible]	[illegible]	[illegible]	[illegible]	4	$< 5\ 10^5$
[illegible]	[illegible]	[illegible]	[illegible]	2	$< 5\ 10^5$
Pre-Damping Rings (H/V)	63000/1500	2.86	50/10	4	$< 5\ 10^6$
Damping rings (H/V)	< 500/5	2.86	**10/1**	4	**$< 5\ 10^8$**
RTML	510/5	2.86 → 9	**10/1**	70	**$< 5\ 10^8$**
Main Linac	600/10	9 →1500	**10/1**	48	**$< 5\ 10^8$**
Beam Delivery System	660/20	1500	**10/1**	8	**$< 5\ 10^8$**
Spent Beam Line	>660/20	< 1500	1000	6	$< 5\ 10^3$
Drive Beam					
[illegible]	[illegible]	→ 2.37	50	10	**$< 40\ 10^6$**
[illegible]	[illegible]	2.37	50	20	**$< 40\ 10^6$**
Transfer to Tunnel	100	2.37	50	2	**$< 40\ 10^6$**
Turn around	100	2.37	50	**96**	$< 1.5\ 10^6$
Decelerator	150	< 2.37	50	**576**	$> 1.5\ 10^6$
Dump lines	> 150	< 2.37	100	**96**	> 1.[illegible]

Critical Issue on micron resolution beam profile measurements > 100 monitors

Charge limitation problems in many places / Strong need for non-interceptive devices : two systems required to cover the total dynamic range



The thermal limit for 'best' material (C, Be, SiC) is $10^6\ nC/cm^2$

Imaging of high energy spread beams at the end of the decelerator

Relatively big number of Instruments ~ 1000

Transverse Profile Monitors

R&D on Laser Wire Scanners

Machine Sub-Systems	Quantity	Technology choice: Baseline	Technology choice: Alternatives	Place to be Tested
Main Beam				
e^- & e^+ injector Complex	10	OTR		CERN
Pre-Damping and Damping rings	8	XSR	LWS / OSR-PSF	Sync light sources PSI, PETRA,
RTML	70			ATF2 CESR-TA
Main Linac and Beam Delivery system	56		OTR-PSF XDR	ATF2 CESR-TA
Spent Beam Line	6	OTR	Scintillating screens	CERN
Drive Beam				
DB source and Linac	10	OTR / LWS	ODR	FEL's
Frequency multiplication complex	20	OSR	XSR	Sync light sources PSI, PETRA, ..
Transfer to tunnel	2	OTR / LWS	ODR	FEL's
Turn-arounds	96	OSR	XSR	Sync light sources
Decelerator and Dump lines	672	OTR		CERN

LWS expensive → High resolution OTR & XUV Diffraction Radiation as alternative solutions to be investigated
R&D program for DR @ CESR-TA

Technology development using Fibre Laser for advanced beam diagnostics

Followed-up by RHUL

BI workpackage – Task 3

WP: CTC-006	Purpose/Objectives/Goals	Deliverables
Task 3: Emittance measurement	- Design and integration of Laser Wire Scanner in BDS and Drive Beam complex - Technology development for high power fibre laser - Study alternative option for high spatial resolution non-destructive profile monitors (UV Diffraction radiation)	- Experimental validation of a CLIC Laser Wire Scanner on ATF2 with BPM - Experimental validation of a CLIC UV DR monitor on CESRTA - Engineering specifications and cost estimate

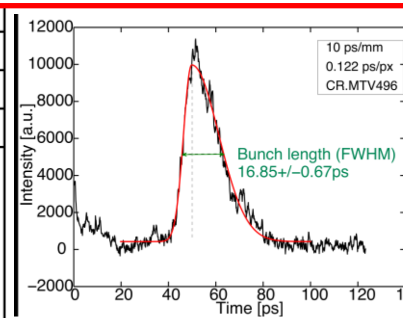
Ressources	2011	2012	2013	Total
Total P (FTE)	**2.75**	**3.4**	**3.5**	**9.65**
FTE from M>P	**0.5**	**2.4**	**2.75**	**5.65**
UK FTE ressources	*2.15*	*0.9*	*0.65*	3.7
CERN-UK FTE ressouces	*0*	*1.4*	*1.75*	3.15
CERN FTE	0.1	0.1	0.1	0.3
CERN-UK M budget (kCHF)	50	60	55	165

- ✓CERN (T. Lefevre) – RHUL (G. Blair, S. Boogert , P. Karataev et al) – CESRTA (M. Palmer, M. Billing)
- ✓*A CERN Ph.D Student starting in mid 2011 to work on Diffraction Radiation*
- ✓More than 70% Manpower resources based in the UK
- ✓M to P budget in M ~ 60% / Very limited CERN Manpower resources
- ✓Upgrade on the laser system and the experimental part of the DR test are not financed through this budget

Longitudinal Profile Monitors

Machine Sub-Systems	Bunch length (mm)	Energy (GeV)	Resolution Bunch (ps)/Train (ns)	Quantity	Charg (nC
Main Beam					
e^- injector Complex	5	→ 0.2	2 / 10	3^P	< [illegible]
e^+ injector Complex	11	→ 0.2	5 / 10	5^P	< $5\ 10^5$
Injector Linac (e^-/e^+)	1 / 5	→ 2.86	0.5 /10	2^P	< $5\ 10^5$
Pre-Damping Rings (H/V)	5	2.86	2 / 10	2^P	< $5\ 10^6$
Damping rings (H/V)	1.5	2.86	0.5 /10	2^P	< $5\ 10^8$
RTML					**< $5\ 10^8$**
- Bunch compressors 1		2.86	**0.1 /10**	4^P	
- Booster Linac		2.86 → 9	**0.1 / 10**	0	
- Transfer lines - Turn arounds		9	**0.1 / 10**	4	
- Bunch compressor 2		9	**0.02 / 10**	4^P	
Main Linac	**0.044**	9 → 1500	**0.02 / 10**	**48^L**	**< 5 10[illegible]**
Beam Delivery System	**0.044**	1500	**0.02 / 10**	2^P	**< $5\ 10^8$**
Drive Beam					
Source and Linac	4 / 0.5	→ 2.37	1 / 10	8	**< $40\ 10^6$**
Frequency Multiplication	length [illegible]/Spacing	2.37	1 / 10		**< $40\ 10^6$**
- Delay Loops				6	
- TL1				2	
- Combiner ring 1				2	
- TL2				2	
- Combiner ring 2				2	
- TL3				2	
Transfer to Tunnel		2.37	1 / 10	4	**< $40\ 10^6$**
Turn arounds		2.37	**0.5 / 10**		< $1.5\ 10^6$
- Bunch Compressor 1				96^P	
- Turn-arounds				0	
- Bunch Compressor 2				96^P	
Decelerator	1 /12	< 2.37	**0.5 / 10**	48^L	> $1.5\ 10^6$
Dump lines	1 / 12	< 2.37	**0.5 / 10**	48^L	> $1.5\ 10^6$

Full longitudinal Profile (P) versus Bunch length (L)
Complexity and Price



Critical Issue on measuring 150fs bunches with 20fs resolution

Longitudinal gymnastic for bunch length shortening and lengthening and for DB bunch frequency multiplication

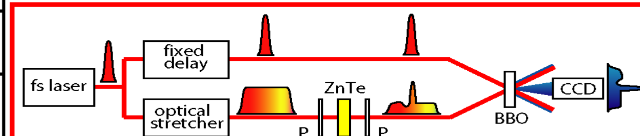
Difficult to have both profile measurement and to provide the bunch length evolution over the pulse train: two separate devices

Longitudinal Profile Monitors

High resolution and cost effective bunch length monitor using Coherent diffraction Radiation (RHUL)

		hnology choice	Place to be Tested
Main Beam			
e^- & e^+ injector Complex	10	Streak / RF pick-up	CTF3
Pre-Damping and Damping rings	4	Streak / RF pick-up	CTF3
RTML	12	CDR	XFEL's
Main Linac and Beam Delivery system	50		XFEL's
Drive Beam			
DB source and Linac	8	Streak / RF pick-up	CTF3
Frequency multiplication complex	16	Streak / RF pick-up	CTF3
Transfer to tunnel	4	RF pick-up	CTF3
Turn-arounds	192	Streak / RF pick-up	CTF3
Decelerator and Dump lines	96	RF pick-up	CTF3

Collaboration with U. Dundee and Daresbury on Electro-Optical techniques for CLIC-type high resolution profile measurement



Followed-up by U. Dundee

BI workpackage – Task 3

WP: CTC-006	Purpose/Objectives/Goals	Deliverables
Task 3: Emittance measurement	- Development of 20fs time resolution longitudinal profile monitor using EO techniques - Improved single shot XFROG technique for signal decoding - Development of new E-O Crystals	- Prototype on Cailfes at CTF3 - Test of CLIC prototype on a short bunch length facility -Engineering specifications and cost estimate

Ressources	2011	2012	2013	Total
Total P (FTE)	**2.4**	**2.4**	**2.4**	**7.2**
FTE from M>P	**1**	**1.5**	**2**	**4.5**
UK FTE ressources	*0.3*	*0.3*	*0.3*	0.9
CERN-UK FTE ressouces	*1*	*1*	*1*	3
CERN FTE	1.1	0.6	0.1	1.8
CERN-UK M budget (kCHF)	50	100	75	225

- ✓CERN (T. Lefevre) – U. Dundee (A. Gillespie) & Daresbury (S. Jamison)
- ✓CERN fellow (Marie-Curie till Mid 2012 and then M--P)
- ✓More than 50% of Manpower resources in UK
- ✓M to P budget in M > 60% / Limited CERN Manpower resources
- ✓New UK-based project associate
- ✓Development for CTF3/Califes is not covered by this budget

Thanks for your attention