Progress on Instrumentation

- Preparation of the Conceptual Design Report
- Today CLIC instrumentation
  - Baseline solutions
  - Alternative scenario(s)
- Perspectives & Conclusions

What was done for the CDR

- R&D on Critical issues: known since long time already: Are they Feasible now ?
  50nm precision BPM – 20fs precision bunch length monitor – 1um transverse profile monitor

- Collect requirements: Overview on the CLIC needs
  Make sure that there is not something big unknown !

- Defined 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

Relatively small group at CERN relying a lot on external collaborations !!

What was done for the CDR

1- First iteration on requirements from Beam Dynamic – first iteration in 2008

- Full set of specifications: More than 200kms of beamlines requiring > 50 000 instruments

What was done for the CDR

1- First iteration on requirements from beam dynamic – first iteration in 2008

- Full set of specifications: More than 200kms of beam lines requiring > 50 000 instruments

- 'From BD simulations to hardware specifications'

- Time resolution seen as sampling rate or true analog bandwidth

- Accuracy / Resolution-Stability

- Full profile or R.M.S value is enough

What was done for the CDR

2- Open discussion with experts to define a road map for feasibility demonstration and define baseline scenario

Beam Instrumentation workshop in June 2009 – 2days and ~50 participants

Mandate of the CLIC Beam Instrumentation Workshop 2 & 3 June 2009

1- Discuss the beam instrumentation requirements for each CLIC sub-systems and identify Critical Items and the need for new R&D

2- Evaluate the performance of already-existing technologies

- **CLIC specific instruments**
    - -Luminosity monitors
- **CTF3 beam diagnostics – importable to CLIC**
- **ILC instruments with similar requirements as for CLIC**
    - Laser Wire Scanner or Cavity BPM
    - Beam Delivery System instrumentation
        - Ex: Polarization monitor, Beam Energy measurements
    - Damping ring instrumentation developed at ATF2
- **3rd and 4th generation light sources**
    - Damping ring instrumentation
    - Bunch Compressor instrumentation very similar to XFEL project

What was done for the CDR

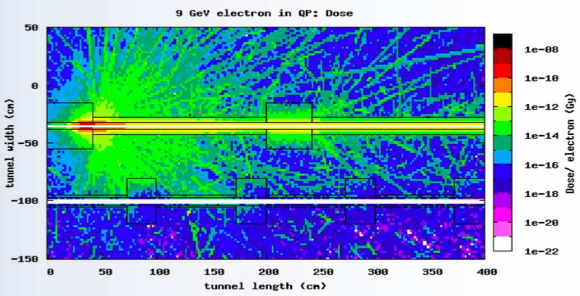
3- Follow-up on the change of beam parameters and take into account additional requests from Machine protection system and Beam commissioning strategy

Specifications on Beam Loss monitors:

<u>*Beam Dynamics*</u> – max tolerated:

10^{-3} of total intensity over 20 km on the MB

10^{-3} of total intensity over each 875m on the DB



<u>*Radiation To Electronics*</u> - Losses required that annual '1 MeV neutron equivalent fluence' and fluences of hadrons with energy >20 MeV, near beam line is less than 10^{10} and 10^{9} cm^{-2} respectively. From simulation, this corresponds to:

10^{-5} of total intensity over 20 km on the MB

10^{-5} of total intensity over each 875 m on the DB

Evaluate the performances of the instruments with reduced beam charge or larger emittance for beam commissioning

Talk on 'Status of CLIC operation and Machine Protection'

by Michel Jonker at 17h20 in Room22 – Floor 0

What was done for the CDR

1- First iteration on requirements from beam dynamic – first iteration in 2008

-Full set of specifications: More than 200kms of beam lines requiring > 50 000 instruments

- Speaking the same language ! 'From simulations to hardware development'

2- Open discussion with experts to define a road map for feasibility demonstration and define baseline scenario

Beam Instrumentation workshop in June 2009 – 2days and ~50 participants

3- Keep tracks on changes and additional requests from working groups on Machine protection system and the Beam commissioning strategy

- Specifications on Beam Loss monitors,

- Evaluate the performances of the instruments with reduced beam charge or larger emittance for beam commissioning

4- Write the CDR …Today !

~ 20 Contributors for beam instrumentation chapter

and ~80-100 pages

What's in the CDR

Review the CLIC Beam instrumentation

by Instrument type

- Explain the requirements
- Describe the baseline choice
- Discuss alternative scenario(s)

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]	[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

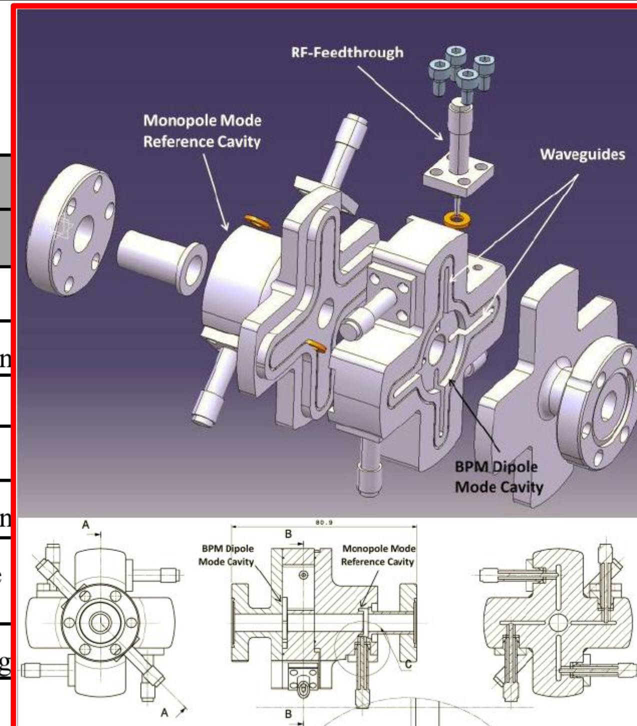
High accuracy (5um) resolution (50nm) BPM in Main Linac and BDS

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

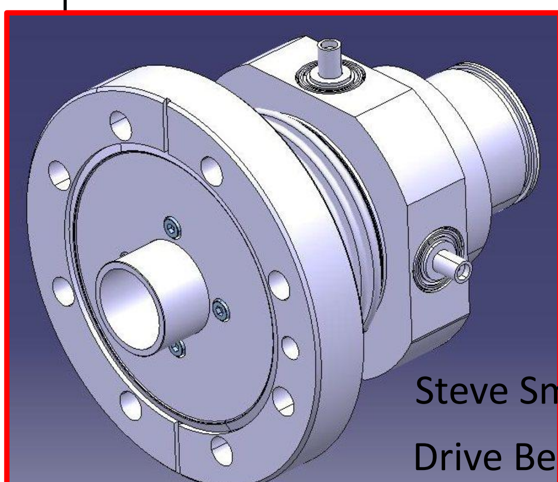
Very high numbers of BPMs for the DB decelerator

Beam Position Monitors

Manfred Wendt on 'BPM R&D for ILC/ CLIC Main linac'



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	14GHz Cavity BPM	Cavity type	
Spent Beam Line	12	Button / Strip line	Direct sampling	
Drive Beam				
DB source and Linac	660	Button 6mm	Downconverting	CERN
	210	Button 6mm	Downconverting	CERN
	872	Button 6mm	Direct sampling	CERN
	1920	Button 6mm	Direct sampling	CERN
	41484	Stripline 25mm	Downconverting	CERN
	96	Stripline 25mm	Downconverting	CERN



Steve Smith on 'CLIC Drive Beam BPM'

Lars Soby on 'CTF3 BPMs: electronic, radiation and operational challenges' at 16h50 in room 5 - floor 3

Transverse Profile Monitors

IWLC

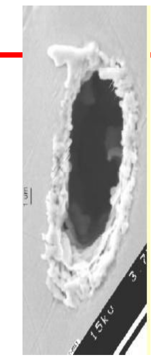
Machine Sub-Systems	Emittance (nm.rad)	Energy (GeV)	Resolution (um)	Quantity	Charge density (nC/cm^2)
Main Beam					
[illegible]	[illegible]	[illegible]	[illegible]	2	$< 5\ 10^5$
[illegible]	[illegible]	[illegible]	[illegible]	4	$< 5\ 10^5$
[illegible]	[illegible]	[illegible]	[illegible]	2	$< 5\ 10^5$
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**	> 1.5 [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

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

Relatively big number of Instruments ~ 1000



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

Transverse Profile Monitors

R&D on Laser Wire Scanners discussed in 'Instrumentation progress at ATF2' by Toshiaki Tauchi at 11h00

High resolution imaging using X-ray SR or LWS for Damping rings developed @ ATF2 and 3rd generation light sources

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

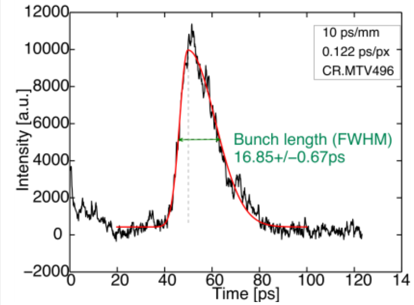
Machine Sub-Systems	Quantity	Technology choice		Place to be Tested
		Baseline	Alternatives	
Main Beam				
e^- & e^+ injector Complex	10	OTR		CERN
Pre-Damping and Damping rings	8	XSR	LWS / OSR-PSF	Sync light sources PSI, PETRA, ..
RTML	70	OTR	OTR/OSR PSF	ATF2
		LWS	XDR	CESR-TA
Main Linac and Beam Delivery system	56	OTR	OTR-PSF	ATF2
		LWS	XDR	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 PSI, PETRA, ..
Decelerator and Dump lines	672	OTR		CERN

Laser technology development by Laura Corner on 'Fibre Laser for advanced beam diagnostics' at 11h20

Longitudinal Profile Monitors

Machine Sub-Systems	Bunch length (mm)	Energy (GeV)	Resolution Bunch (ps)/Train (ns)	Quantity	Charge (nC)
		Main Beam			
e^- injector Complex	5	→ 0.2	2 / 10	3 P	< 5
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	**0.300**	2.86	**0.1 /10**	4 P	
- Booster Linac	**0.300**	2.86 → 9	**0.1 / 10**	0	
- Transfer lines - Turn arounds	**0.300**	9	**0.1 / 10**	4	
- Bunch compressor 2	**0.044**	9	**0.02 / 10**	4 P	
Main Linac	**0.04**	9 → 1500	**0.02 / 10**	**48 L**	**$< 5\ 10$**
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 (mm)/Spacing (GHz)	2.37	1 / 10		**$< 40\ 10^6$**
- Delay Loops	**2 / 0.5**			6	
- TL1	**2 / 1**			2	
- Combiner ring 1	**2 / 3**			2	
- TL2	**2 / 3**			2	
- Combiner ring 2	**2 / 12**			2	
- TL3	**2 / 12**			2	
Transfer to Tunnel	2 / 12	2.37	1 / 10	4	**$< 40\ 10^6$**
Turn arounds		2.37	**0.5 / 10**		$< 1.5\ 10^6$
- Bunch Compressor 1	**2 / 12**			96 P	
- Turn-arounds	**1.4 / 12**			0	
- Bunch Compressor 2	**1 / 12**			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

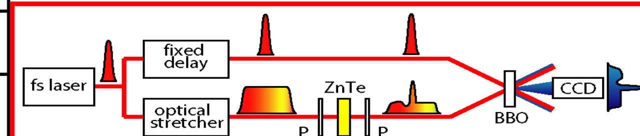
Longitudinal gymnastic for bunch length shortening and lengthening and for DB bunch frequency multiplication

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

Longitudinal Profile Monitors

Machine Sub-Systems	Quantity	Technology 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	EOS / CDR	XFEL's
Main Linac and Beam Delivery system	50	CDR	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



Talk by Konstantin Lekomtsev on 'Longitudinal beam profiling with coherent diffraction radiation' at 17h10 in room 5 floor 3

Instrumentation covered by using profile monitors (Streak and EO techniques) and cheaper bunch length measurement devices (RF pick-up and CDR monitor)

More details by Anne Dabrowski 'Longitudinal Diagnostic for CLIC' at 11h40

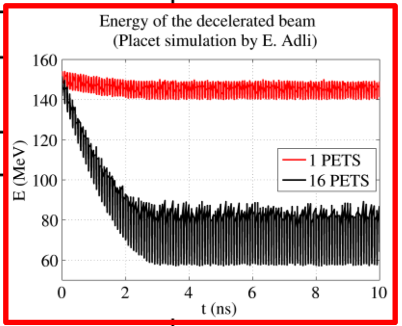
Beam Energy monitoring

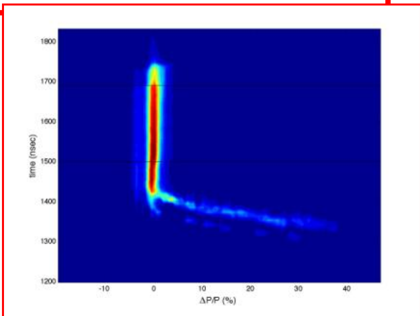
Machine Sub-Systems	Energy (GeV)	Energy spread (%)	Accuracy (%)	Resolution (%)	Time resolution	Quantity	Charge density (nC/cm²)
			Main Beam				
e⁻ injector Complex	→ 0.2	3.5 → 0.1	1	0.5	[illegible]	[illegible]	[illegible]
e⁺ injector Complex	→ 0.2	6 →3.5	1	5	10	4	[illegible]
Injector Linac (e⁻/e⁺)	→ 2.86	0.1 / 2.7	1	0.5	10	2	< 5 10^5
Pre-Damping Rings	2.86	0.5	0.1	0.05	10	2	< 5 10^6
Damping rings	2.86	0.134	0.1	[illegible]	[illegible]	[illegible]	[illegible]
RTML			0.1	[illegible]	[illegible]	[illegible]	[illegible]
- Bunch compressors 1	2.86	1.17					
- Booster Linac	2.86 → 9					2	
- Transfer lines	9					2	
- Turn arounds	9						
- Bunch compressor 2	9	1.26					
Main Linac	9 →1500	1.3→0.3		0.02	[illegible]	[illegible]	[illegible]
Beam Delivery System	1500	0.3→1		0.02	10	4	[illegible]
Spent Beam Line	1500	?	??	??	??	??	< ??
			Drive Beam				
Source and Linac	→ 2.37	1	0.1	0.01	10	10	[illegible]
Frequency Multiplication	2.37	1	0.1	0.01	10	6	[illegible]
Transfer to Tunnel	2.37	1	0.1	0.01	10	0	[illegible]
Turn arounds	2.37		0.1	0.01	10		
- Bunch Compressor 1		0.3				48	
- Turn-arounds							
- Bunch Compressor 2						48	
Decelerator	< 2.37	**→90**	0.1	0.01	10	0	[illegible]
Dump lines	0.237<x< 2.37	**<90**	0.1	0.01	10	**48**	[illegible]

- Ask for 10^{-3} accuracy and 10^{-4} resolution
- Charge limitations - Need for non-intercepting device

Bunch length manipulation → Time-to-Energy correlation → Correlated Energy spread

High current → High Beam loading → Strong energy transient → Time resolved spectrometry (10ns)





High energy spread in the Decelerator

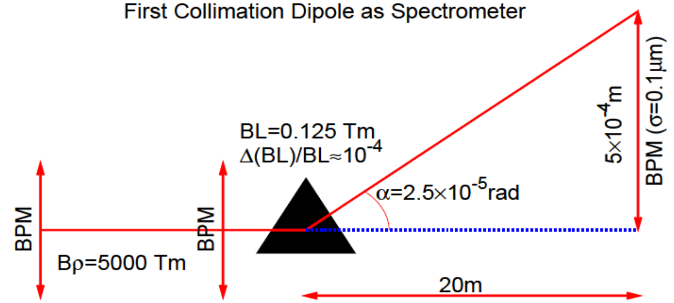
Beam Energy monitoring

Using a bending magnet to create a dispersive region

Machine Sub-Systems	Quantity	Technology choice	Place to be Tested
		Main Beam	
e^- & e^+ injector Complex	8	BPM / OTR	CERN
Pre-Damping and Damping rings	2	BPM / XSR	Sync light sources
RTML	12	BPM / XSR	FEL's
Main Linac and Beam Delivery system	52	BPM	ATF2
		Drive Beam	
DB source and Linac	10	BPM / OTR / Cherenkov	CERN
Frequency multiplication complex	6	BPM / OTR / OSR	CERN
Turn-around	96	BPM / OTR / OSR	CERN
Decelerator and Dump lines	48	BPM / OTR / Cherenkov	CERN

Final measurement in the BDS, see the Talk by Rogelio Tomas on 'Specifications of technical equipment for the BDS' at 12h00

First Collimation Dipole as Spectrometer



$\Delta E/E = \Delta\alpha/\alpha \oplus \Delta(BL)/BL \approx 3.6\times10^{-4}$

- Dedicated measurement lines – often combined with an intermediate beam dump (Magnetic chicane)
- Measure Energy with high resolution BPM and Energy spread with time resolved beam size monitors

  - Talk by Anne Dabrowski on 'CTF3 Instrumentation, opportunities and limitations' at 16h10 in Room 5 Floor 3
  - Profiler based on monitor insensitive to beam energy variations
  - **Segmented dump on CTF3 – Segmented Cherenkov monitor for CLIC to be developed and tested on CTF3**

Beam Intensity Monitors

DB Intensity variation strongly couples to energy variation → DB-to-MB synchronization

‘Update on specifications’ by Javier Serrano at 14h20 in Room 2-floor 0

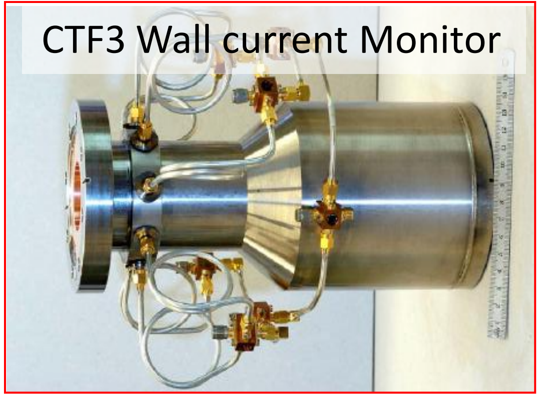
Sub-Systems	(312 x part/bunch)	aperture (mm)	(%)	(%)	resolution (ns)	
Main Beam						
e^- injector Complex	$6\ 10^9$	40	2	0.5		
e^+ injector Complex	$8\ 10^9$	40	2	0.5		
Injector Linac (e^-/e^+)	$4.4 / 6.4\ 10^9$	40	2	0.5		
Pre-Damping Rings	$4.4 / 6.4\ 10^9$	20/9	2	0.5		
Damping rings	$4.1\ 10^9$	20/9	2	0.5		
RTML	$4.1\ 10^9$	tbd	2	0.5		
Main Linac	$3.7\ 10^9$		1	0.1		
Beam Delivery System	$3.7\ 10^9$		1	0.1		
Spent Beam Line	$3.7\ 10^9$		1	0.1	10	3
Drive Beam						
Source and Linac	4.2A	1 / 140.3	0.1	0.01	10	10
Frequency Multiplication			0.1	0.01	10	
- Del						
- TL1						
- Co						
- TL2						
- Co						
- TL3						
Transfer to Tunnel	101A	24 / 243.7	0.1	0.01	10	4
Turn arounds	101A	1 / 243.7	0.1	0.01	10	96
Decelerator	101A	1 / 243.7	0.1	0.01	10	96
Dump lines	101A	1 / 243.7	0.1	0.01	10	48

Drive Beam Stability is an issue for reliability

- ‘Current Stability of the CTF3 beam’ by Guido Sterbini at 17h30 in Room 5 – Floor 3
- ‘Measurement on phase stability in CTF3’ by Giulio Morpugo at 14h40 in Room 2 – Floor 0

- Resolution can reach expected values
- Accuracy is difficult: 1% is on the edge !

Smaller intensity losses should be covered by Beam Loss monitors



Beam Loss Monitors

Machine Sub-Systems	Dynamic Range	Sensitivity (Gy/pulse)	Response time (ms)	Quantity	Additional requirements
Main Beam					
e^- and e^+ injector complex	10^{-4}	10^{-6}	1	2500	
Pre-Damping and Damping Rings	10^{-4}	10^{-6}	1	1200	Insensitive to Synch. Rad.
RTML	10^{-4}	10^{-6}	1	1500	
Main Linac	10^{-7}	$5. 10^{-8}$	1	4196	Distinguish losses from DB
Beam Delivery System	10^{-4}	10^{-6}	1	700	
Spent Beam Line	tbd	tbd	1	tbd	
Drive Beam					
Injector complex	$5. 10^{-4}$	$5. 10^{-6}$	1	4000	
Decelerator	$5. 10^{-6}$	$5. 10^{-8}$	1	41484	Distinguish losses from MB
Dump lines	tbd	tbd	1	tbd	

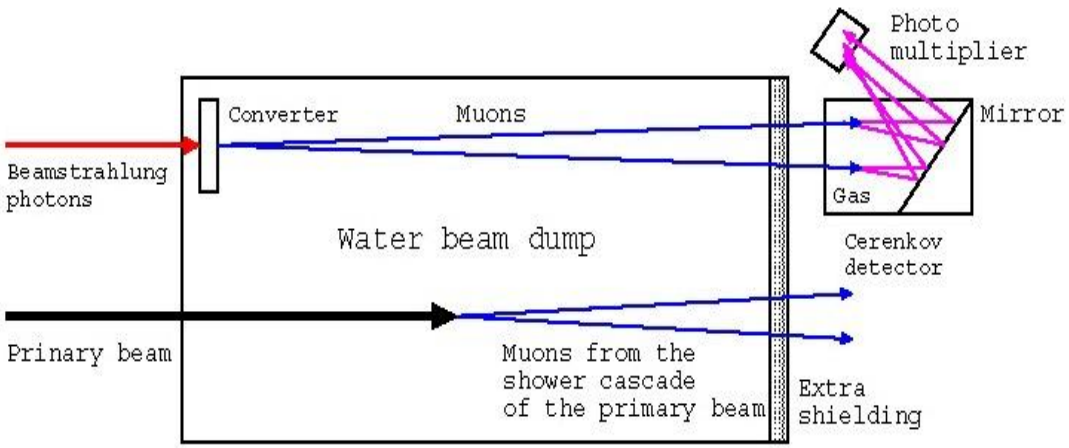
Possibly Cerenkov radiator with PMT

- Two beam modules: 1 BLM per Quadrupoles
  - 41484 Quadrupoles in DB
  - 4020 Quadrupoles in MB
- Cheaper option using Cerenkov Fibers (DESY)

High quality Cerenkov quartz fibers can withstand up to 300MGy ; system on development on CTF3

Luminosity Monitors

EUROTeV-Report-2008-xxx-1



- Luminosity Monitors based on the measurements of very high energy beamstrahlung photons from IP
- Photons → High energy muons and detected downstream the Water dump

The design of the 'Spent beam line' presented in details

by Edda Gschwendtner in WG5 at 14h00

Perspectives & Conclusions

- More Results on Technical developments in the coming talks

- With a Huge amount of devices (beyond what was already achieved in our field), the TDR phase would have to address many remaining issues
  - Prototyping of every single instruments
    - Integration in the Machine layout
    - Design, construction and validation of each instrument
  - Cost optimization
    - Simplicity if applicable (not always compatible with tight tolerances)
    - Standardization is a key concept
    - Gain in Mass production ?
  - Dependability analysis needs to be performed

    Reliability, Availability, Maintainability and Safety

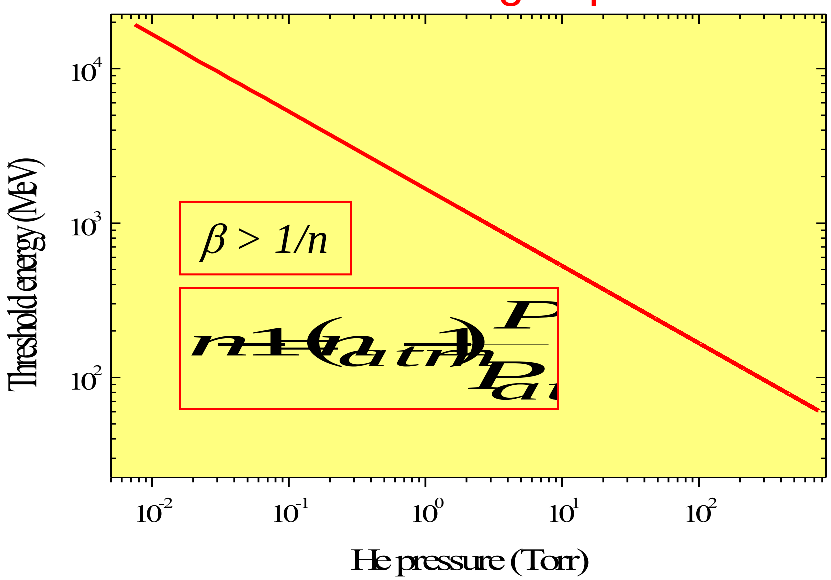
Thanks for your attention

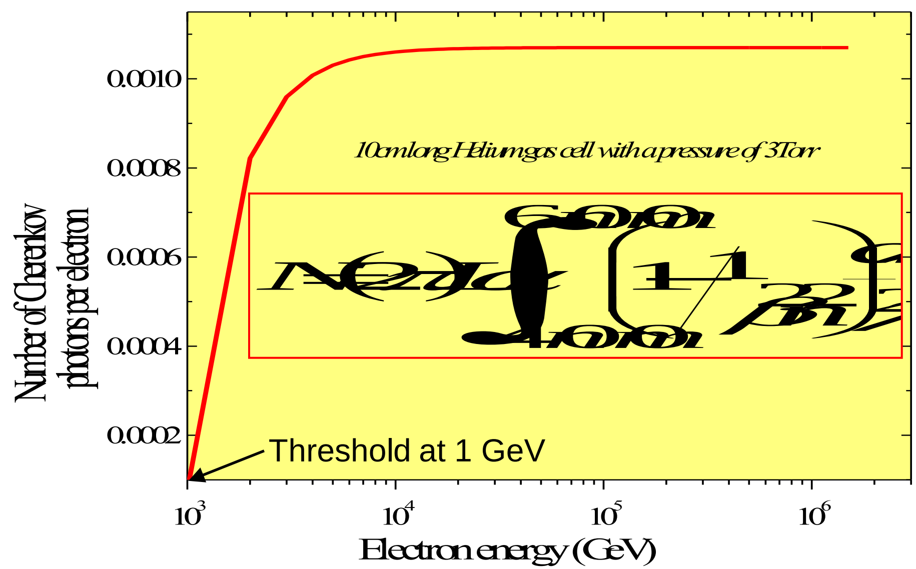
Beam Energy monitoring

Threshold Cherenkov detector : $\beta > 1/n$

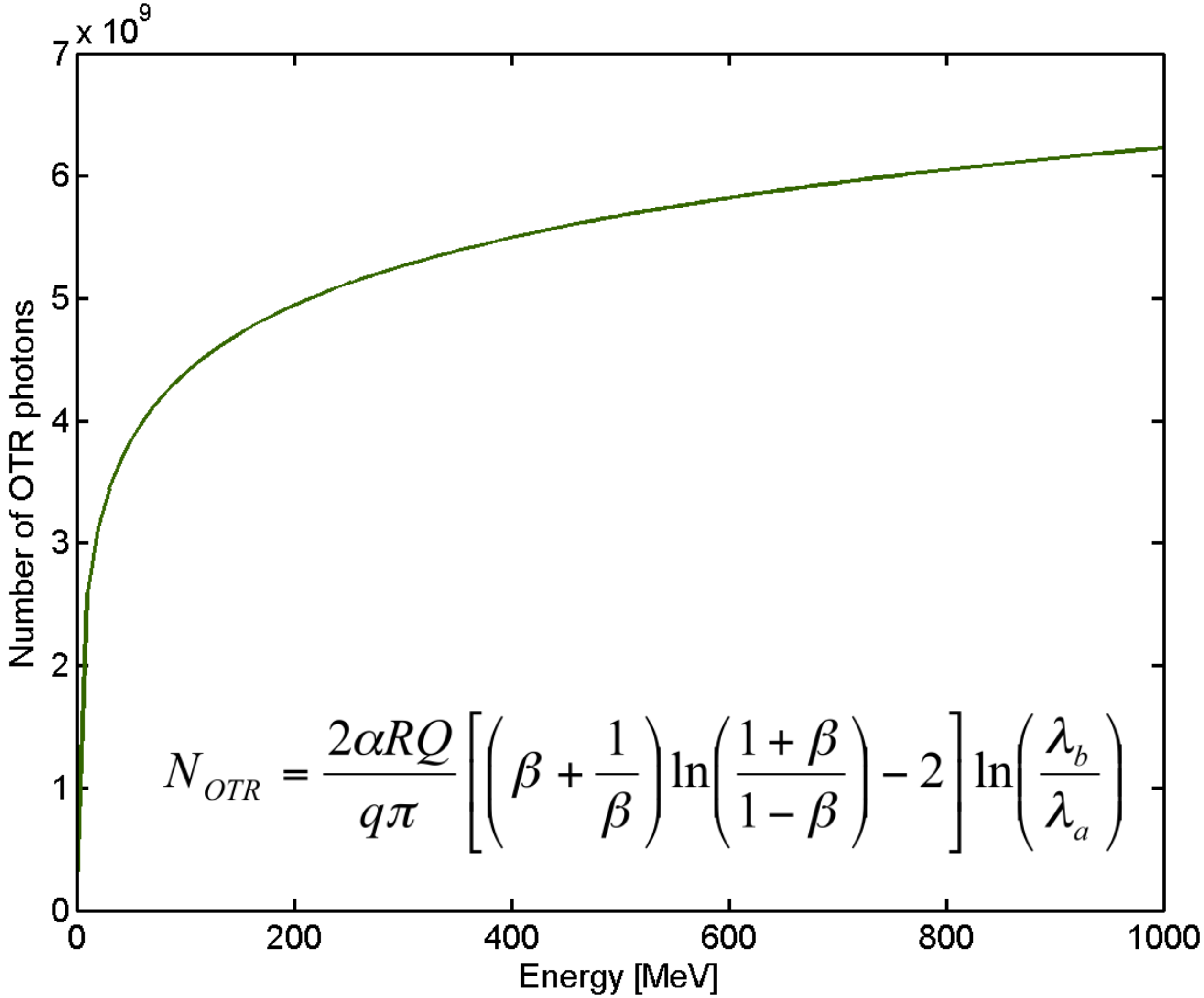
Cherenkov radiator (1atm)	Silica aerogel	Pentane C_5H_{12}	Ethane C_2H_6	Argon Ar	Neon Ne	Helium He
Index of refraction (n-1)	$8.4\ 10^{-3}$	$1.7\ 10^{-3}$	$7.1\ 10^{-4}$	$2.8\ 10^{-4}$	$6.7\ 10^{-5}$	$3.5\ 10^{-5}$
Cherenkov threshold (MeV)	3.5	8.2	13.1	20.9	43.5	60.4

Evolution with the gas pressure





Transverse Profile Monitors



CLIC vs ILC

	CLIC 3TeV	CLIC 500GeV	ILC
Center of mass energy (GeV)	3000	500	500
Main Linac RF Frequency (GHz)	12	12	1.3
Luminosity (10^{34} cm^{-2} s^{-1})	5.9	2.3	2
Linac repetition rate (Hz)	50	50	5
Accelerating gradient (MV/m)	100	[illegible]	33.5
Proposed site length (km)	[illegible]	13	31
Total power consumption (MW)	415	129.4	216
Wall plug to main beam [illegible] (%)	6.8	7.5	9.4

Requirements for CLIC are always tighter

Critical Beam Parameter

	CLIC 3TeV	CLIC 500GeV	ILC
Bunch Length in the Linac (fs)	150	230	900
Typical Beam Size in the Linac (μm)	**1**	**1**	**5**
Beam Emittance H/V (nm.rad)	**660/20**	**2400/25**	**10^4/40**
Beam size at IP : σ_x / σ_y (nm)	40/1	202/2.3	640/5.7

http://clic-study.web.cern.ch/CLIC-Study/

http://www.linearcollider.org/cms/

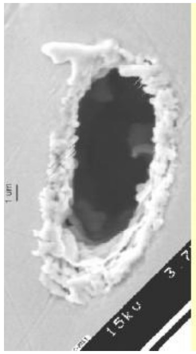
CLIC vs Light Sources

	CLIC DR	SLS	Diamond	Soleil
Beam Energy (GeV)	2.86	2.4	3	2.75
Ring Circonfrence (m)	493	288	561.6	354
Bunch charge (nC)	0.6	1	1	0.5
Energy Spread (%)	0.134	0.09	0.1	0.1
Damping times (x,y,E) (ms)	2,2,1	9,9,4.5	-	6.5,6.5,3.3
Orbit stability (um)	1	1	1	1

	CLIC linac	XFEL	LCLS
Beam Energy (GeV)	3000	20	15
Linac RF Frequency (GHz)	12	1.3	2.856
Bunch charge (nC)	0.6	1	1
Bunch Length (fs)	150	80	73

CLIC vs CTF3

	CTF3	CLIC
Beam Energy (GeV)	0.15	2.4
RF Frequency (GHz)	3	1
Multiplication Factor	8	24
Initial Beam Current (A)	3.75	4.2
Final Beam Current (A)	30	100
Initial Pulse length (us)	**1.2**	**140**
Final Pulse Length (ns)	140	240
Total Beam Energy (kJ)	**0.7**	**1400**
Repetition Rate (Hz)	5	50
Average Beam Power (MW)	**0.0034**	**70**
Charge density (nC/cm^2)	**$0.4\ 10^6$**	**$2.3\ 10^{10}$**



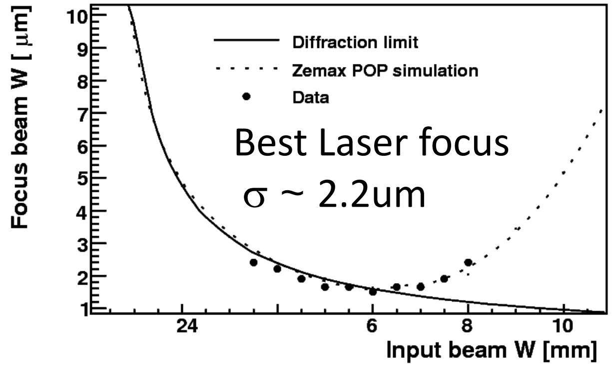
The thermal limit for 'best' material (C, Be, SiC) is 10^6 nC/cm^2

- Still considerable extrapolation to CLIC parameters
- Especially total beam power (loss management, machine protection)
- Development of non-destructive instruments
- Stability and reliability : CTF3 not designed to address these issues

Micron resolution with Laser Wire Scanner

Optimized to measure 20umx1um beam spot size

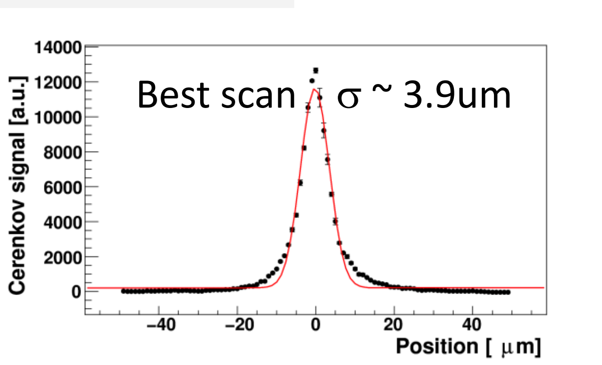
- High energy green (λ=532nm) laser pulses
- Amplify a single pulse from passively mode-locked seed laser
- Frequency locked to ATF RF distribution system at 357MHz
- Pulse duration ~150ps ; Pulse energy ~30mJ
- Laser light is transported collimated to extraction line by series of mirrors and aligned using irises

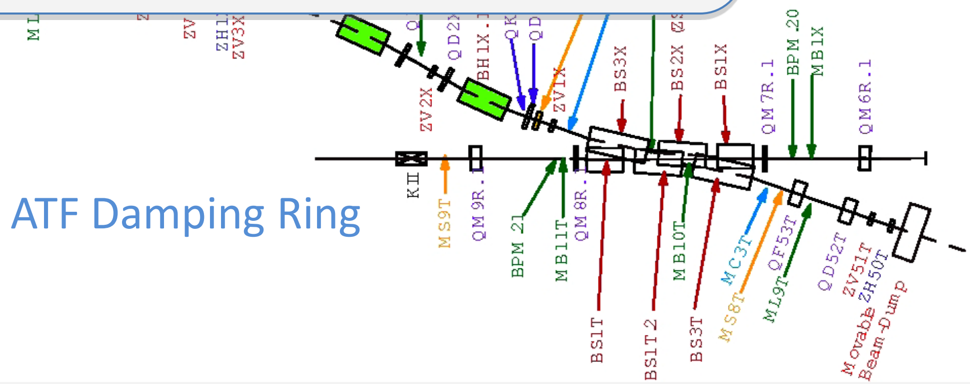


Dete

Need to improve the laser spot size by factor 2-3

Improving the optic and laser quality



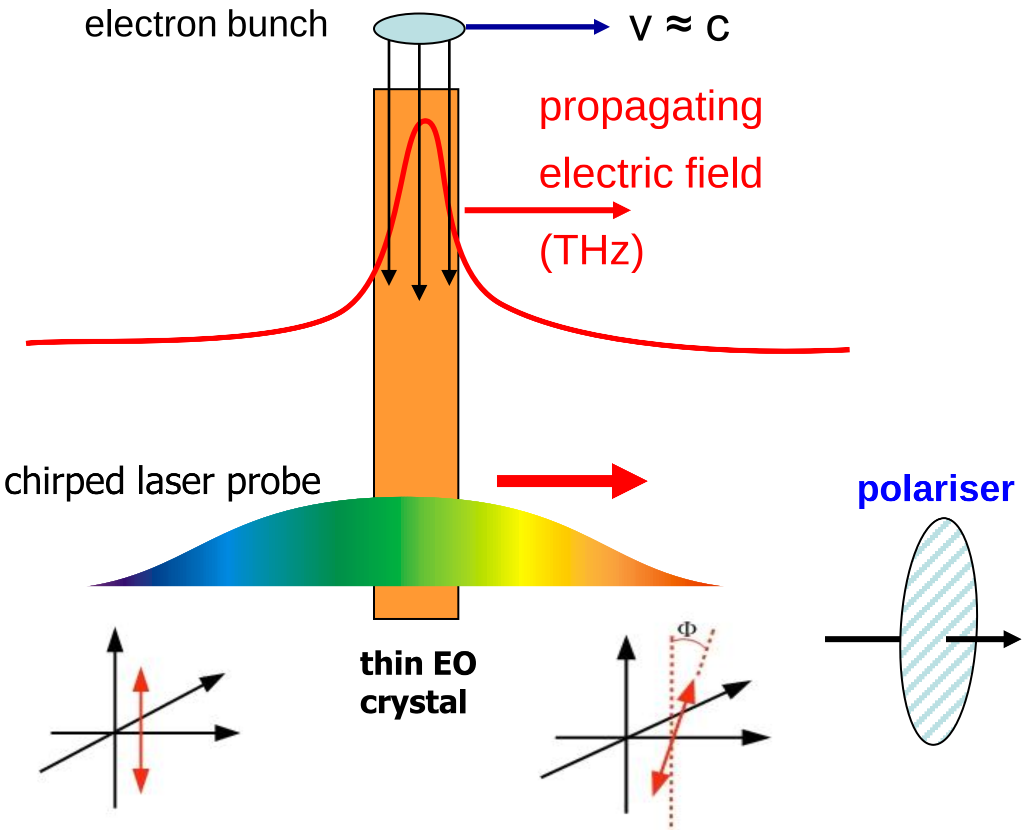


L. Deacon & co

E-O longitudinal bunch profile measurements

Principle: Convert Coulomb field of e-bunch into an optical intensity variation

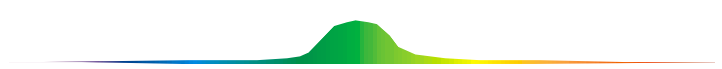
Encode Coulomb field on to an optical probe pulse - from Ti:Sa or fibre laser



$\Phi \sim E_{THz}$

Decoding: via single-shot cross correlation in a BBO crystal

yields the temporal intensity variations in a single laser pulse

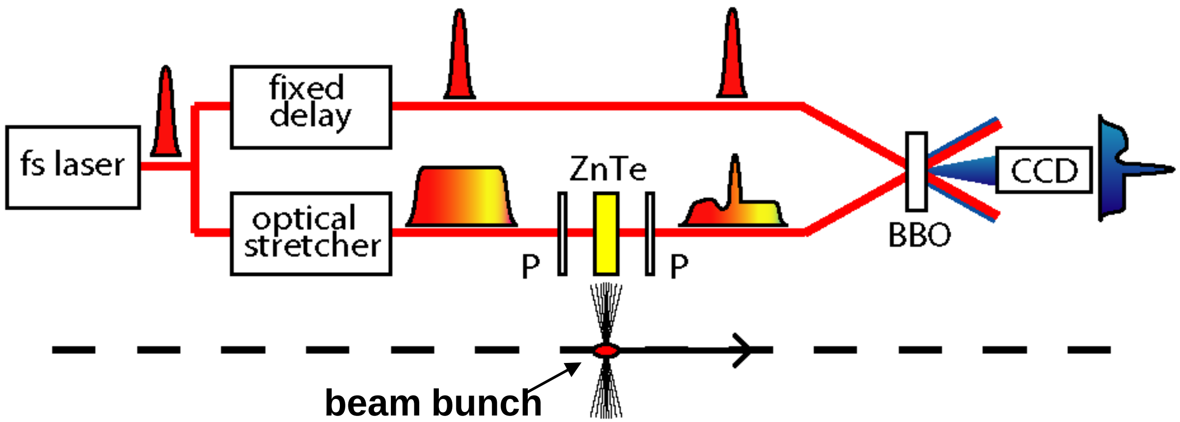


(FELIX & FLASH)

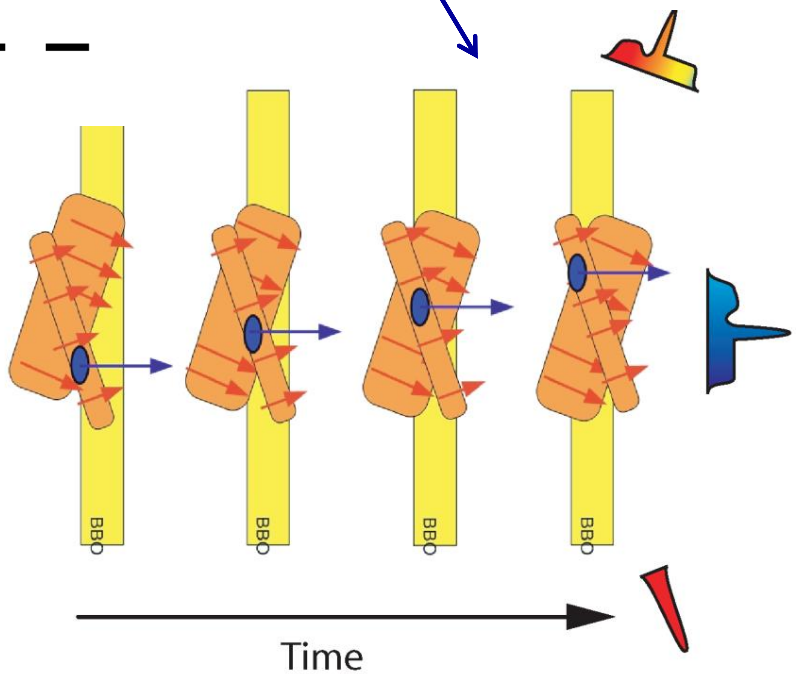
Detect polarisation rotation proportional to E or E^2, depending on set-up

E-O longitudinal bunch profile measurements

Single-shot Temporal Decoding (EOTD)

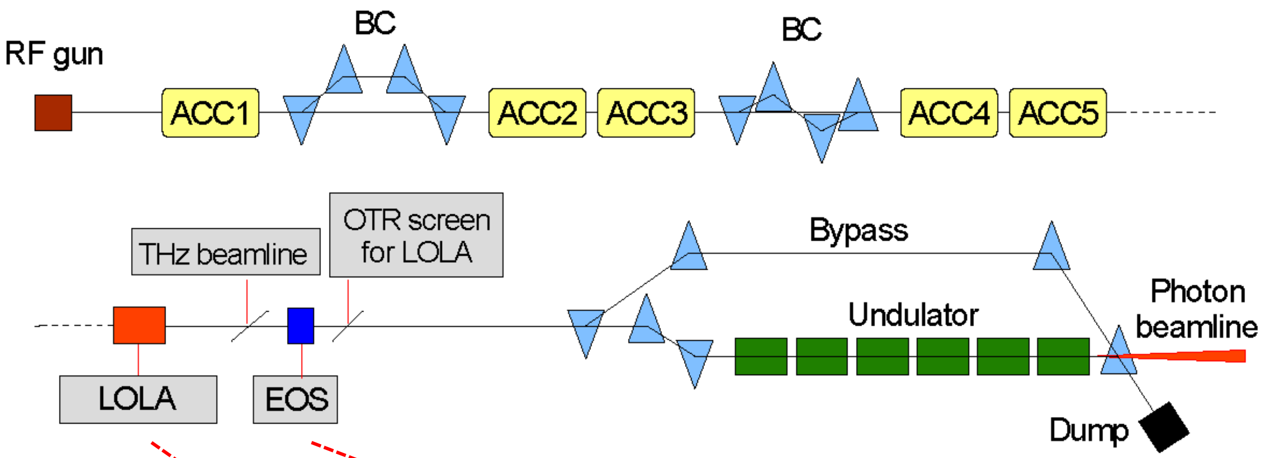


Temporal profile of probe pulse →
Spatial image of SHG pulse

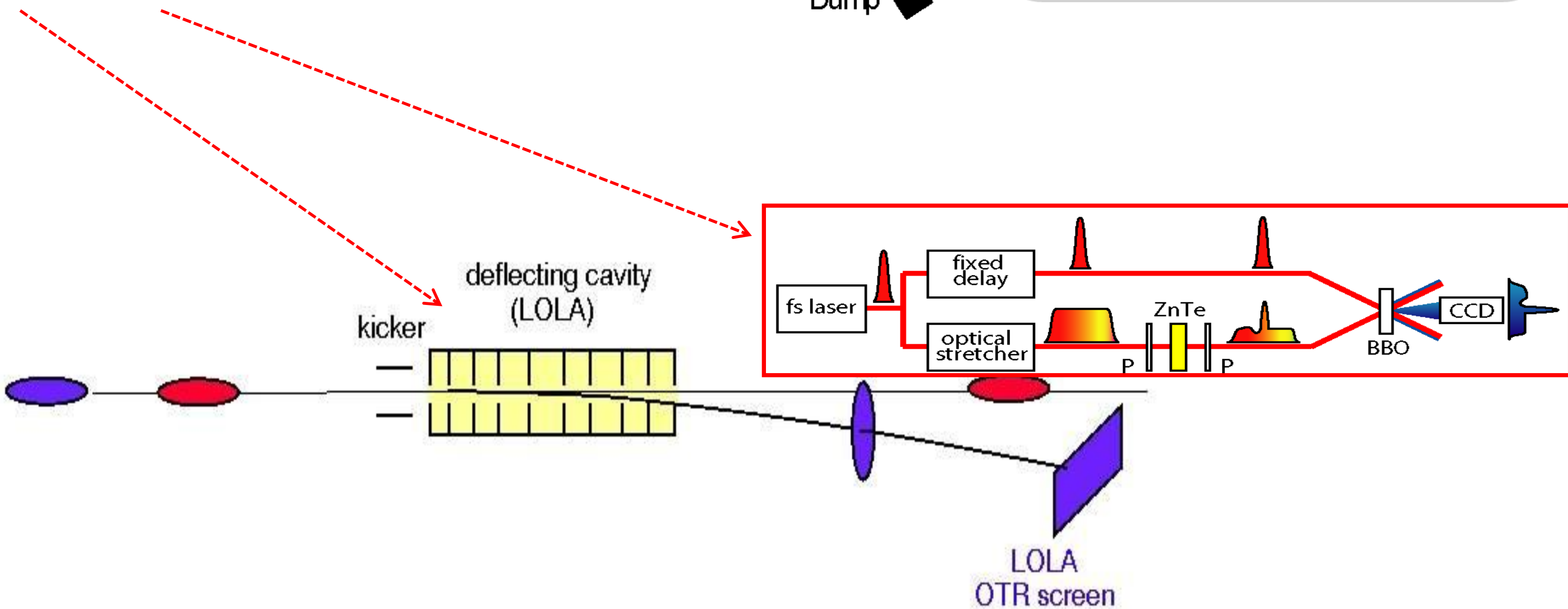


- *stretched & chirped* laser pulse leaving EO crystal assembly measured by short laser pulse via single-shot cross correlation in BBO
- ~1mJ laser pulse energy required (Ti:Sa amplifier)

Benchmarking EO at FLASH against LOLA



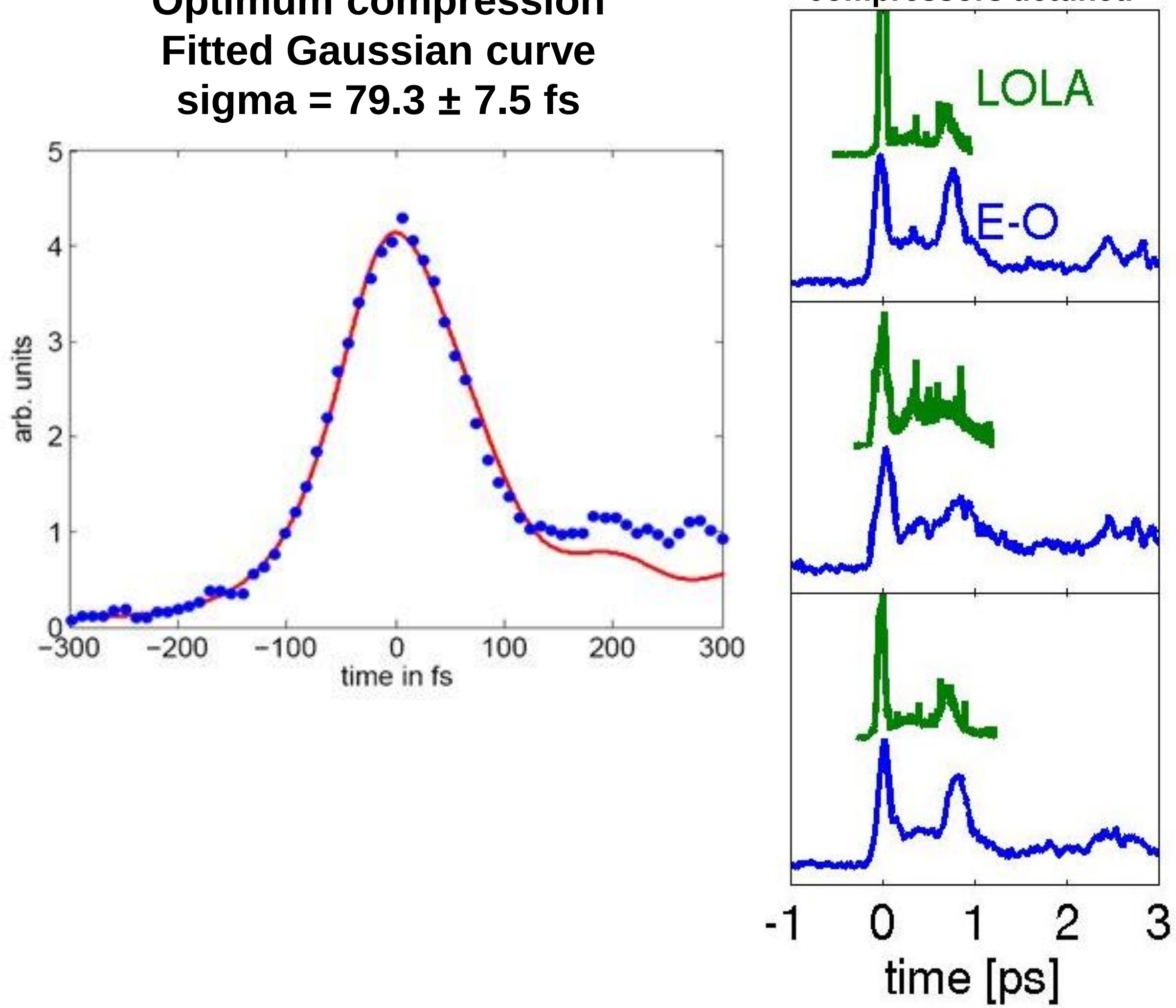
E = 450 MeV, q = 1nC
~20% charge in main peak



Benchmarking EO at FLASH against LOLA

Optimum compression
Fitted Gaussian curve
sigma = 79.3 ± 7.5 fs

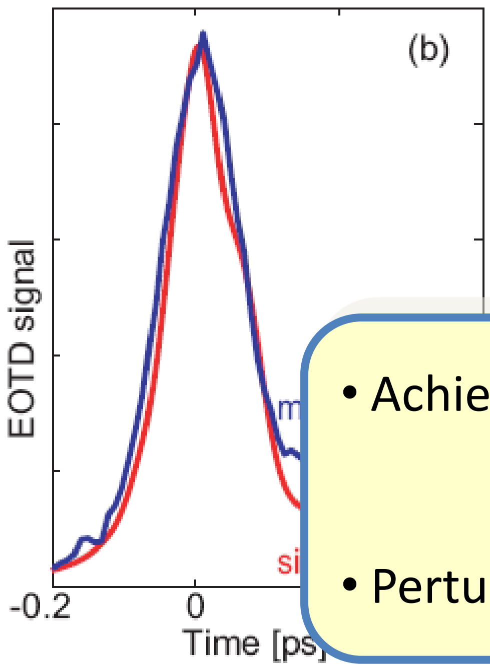
with FLASH bunch compressors detuned



FLASH. Free-electron laser FLASH DESY

Physical Review Special Topics - Accelerators and Beams 12, 032802 (2009)

Benchmarking EO at FLASH against LOLA



FLASH. Free-electron laser FLASH

- Achieved Resolution is fine
- Perturbation due to Wakefield to be investigated

e deflecting

ive)

wakefields

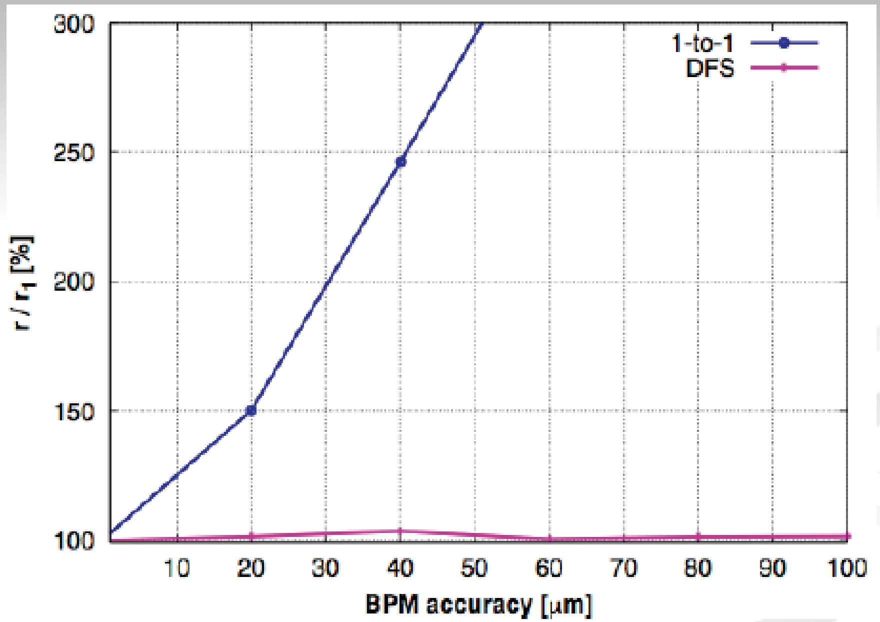
poral decoding

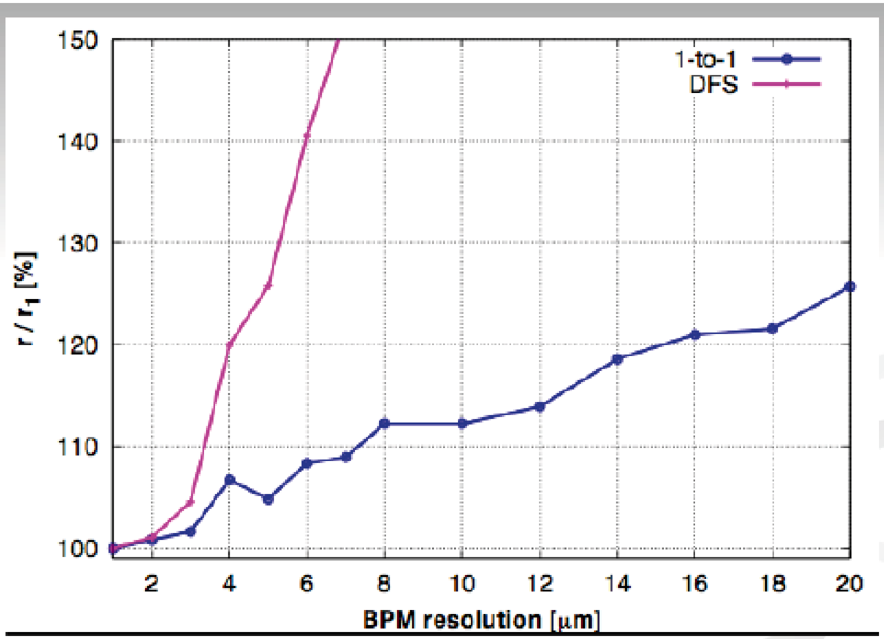
(non-destructive & compact)

Physical Review Special Topics - Accelerators and Beams 12, 032802 (2009)

Reducing the Performance ?

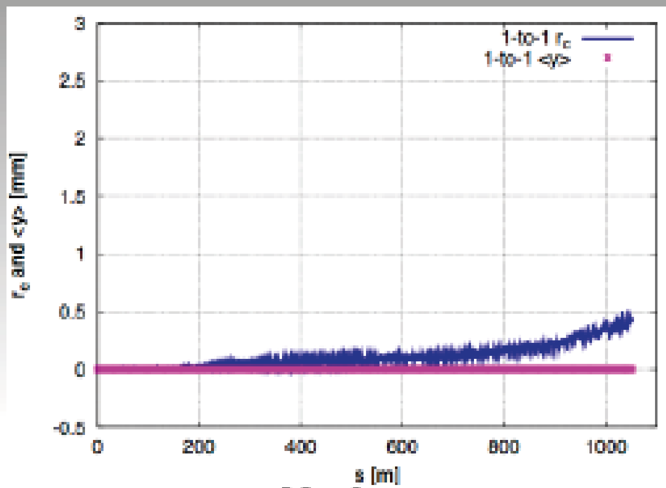
Simulation by E. Adli on DB decelerator performance



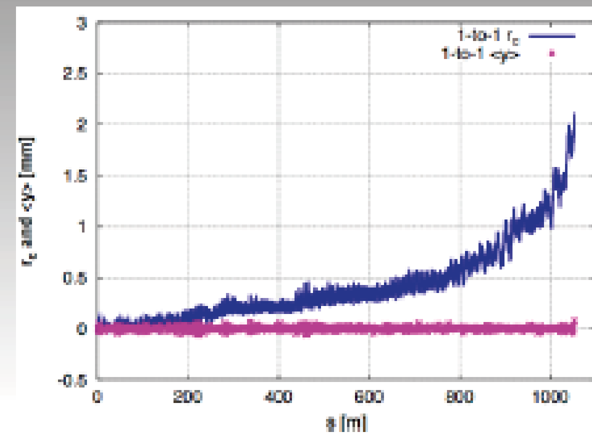


Reducing the Numbers of devices

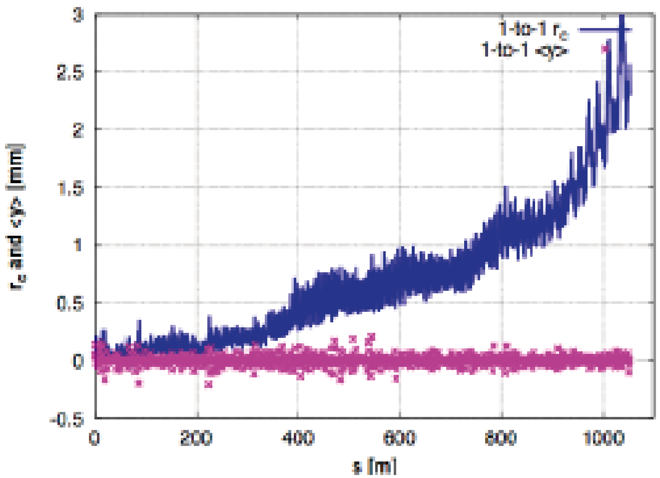
Simulation by E. Adli on DB decelerator performance



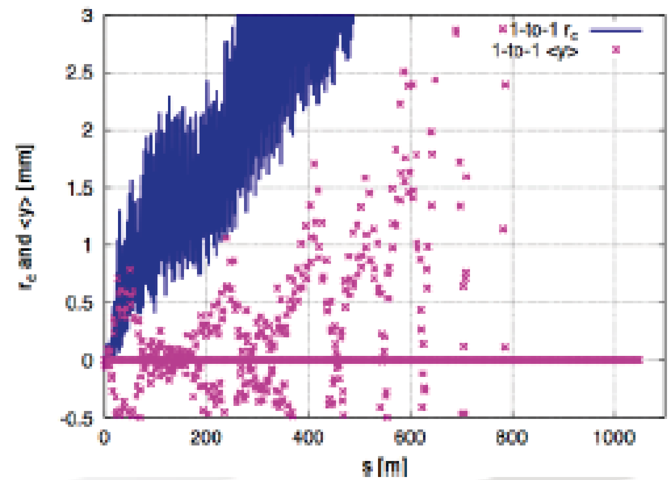
N=1



N=2

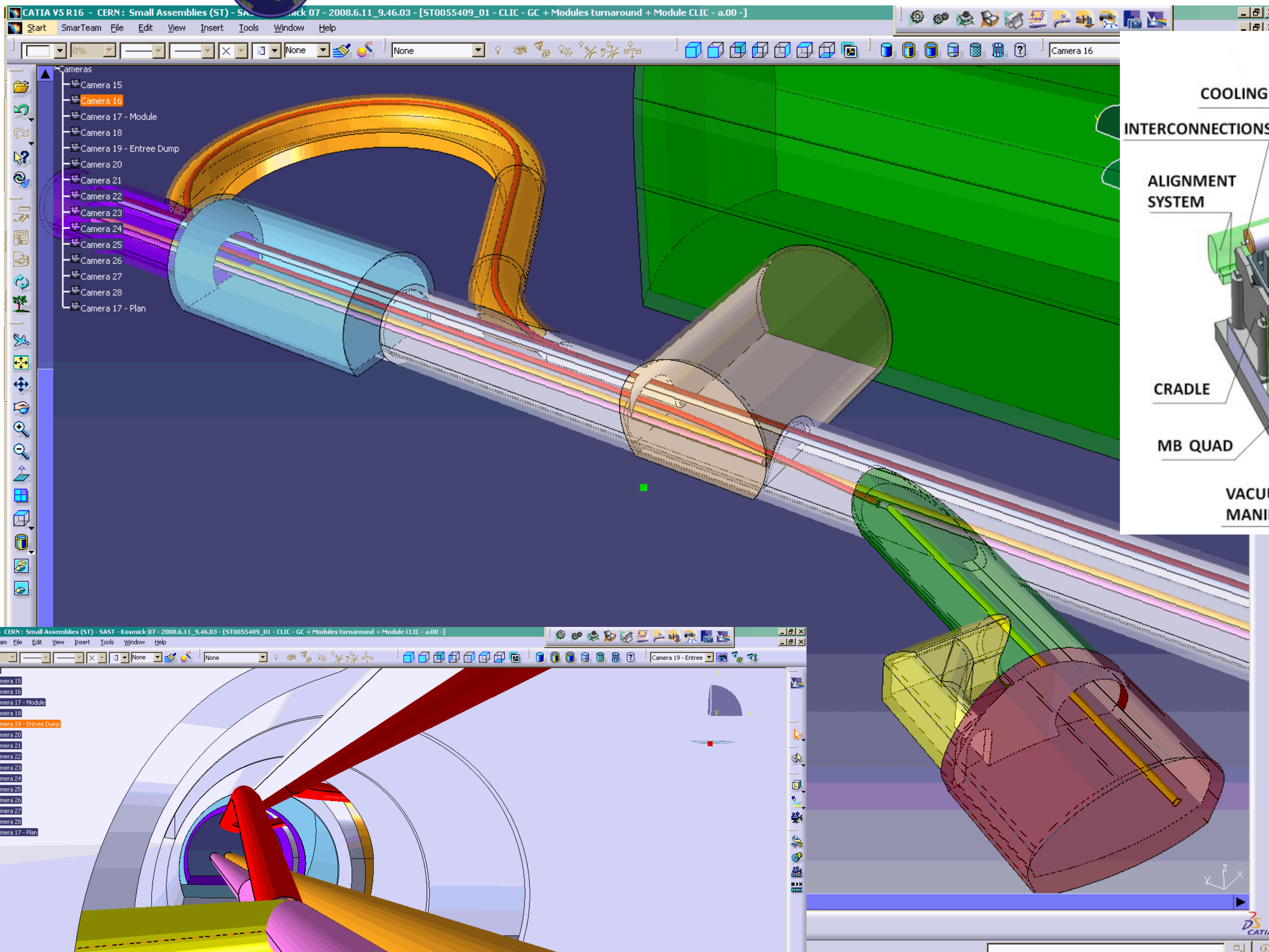


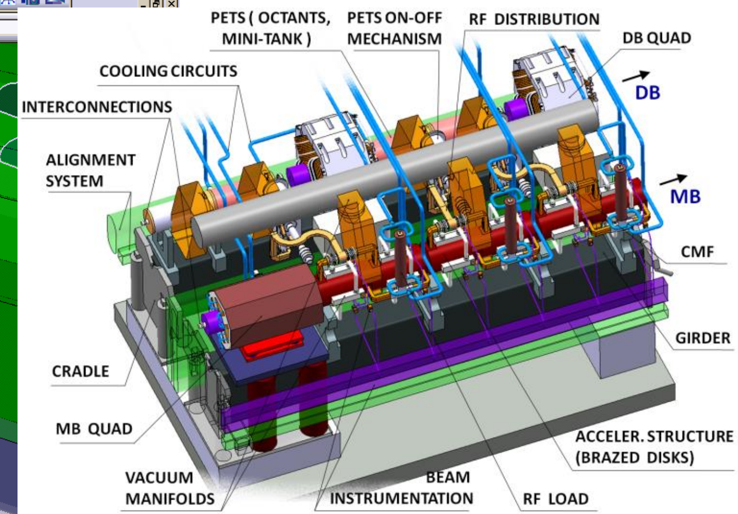
N=3

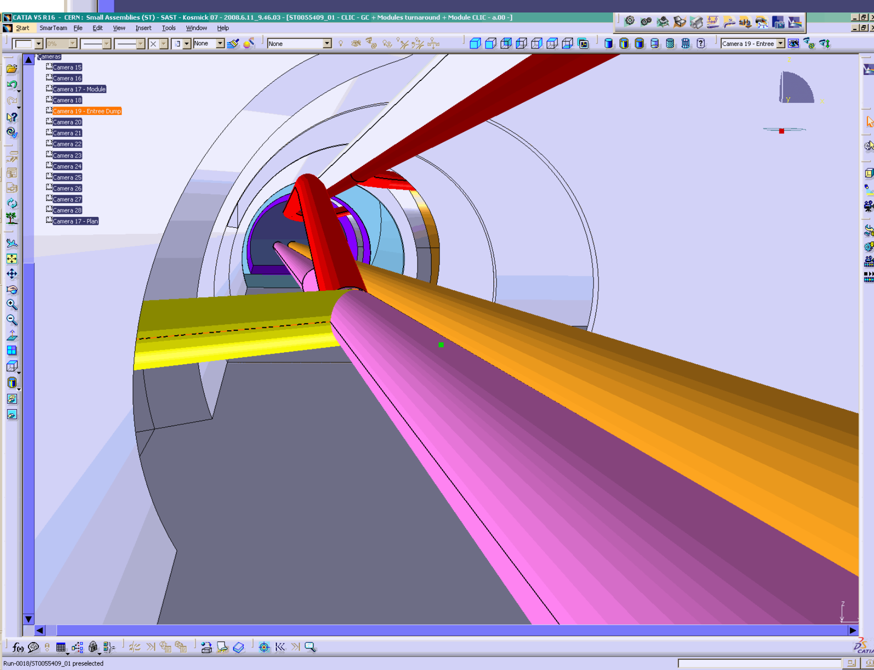


N=4

CLIC Tunnel



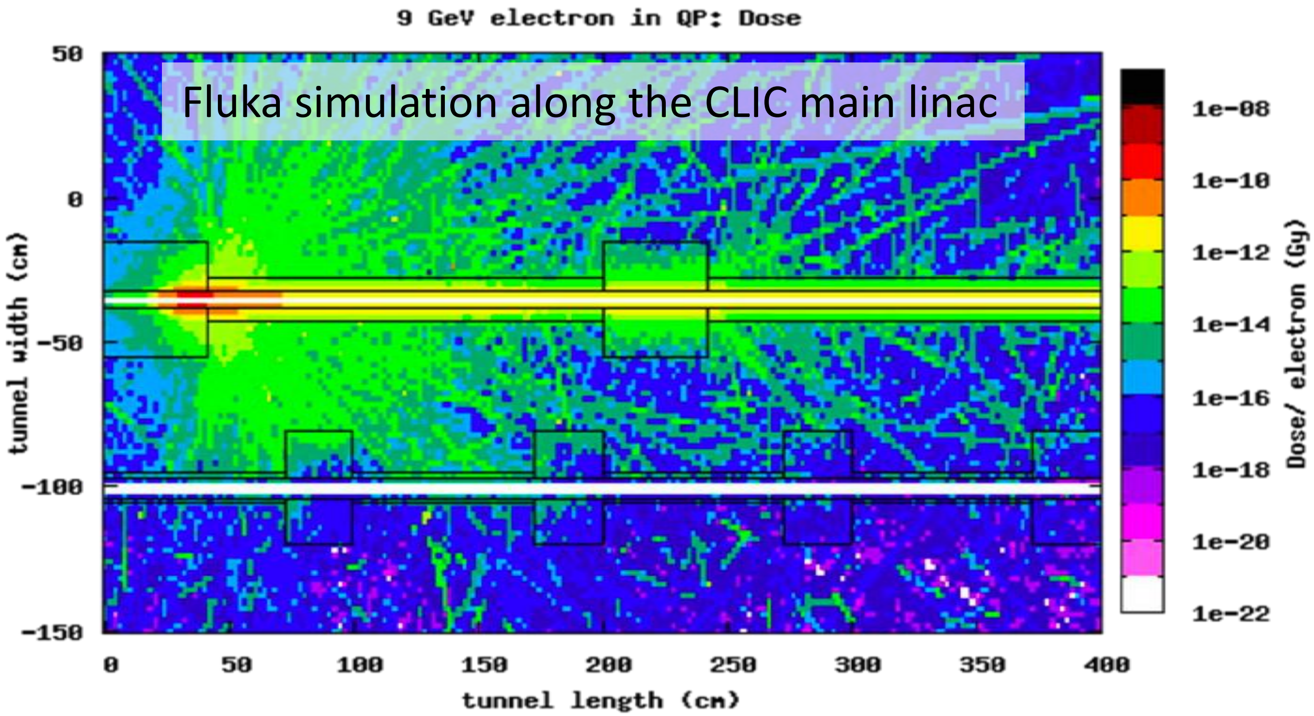




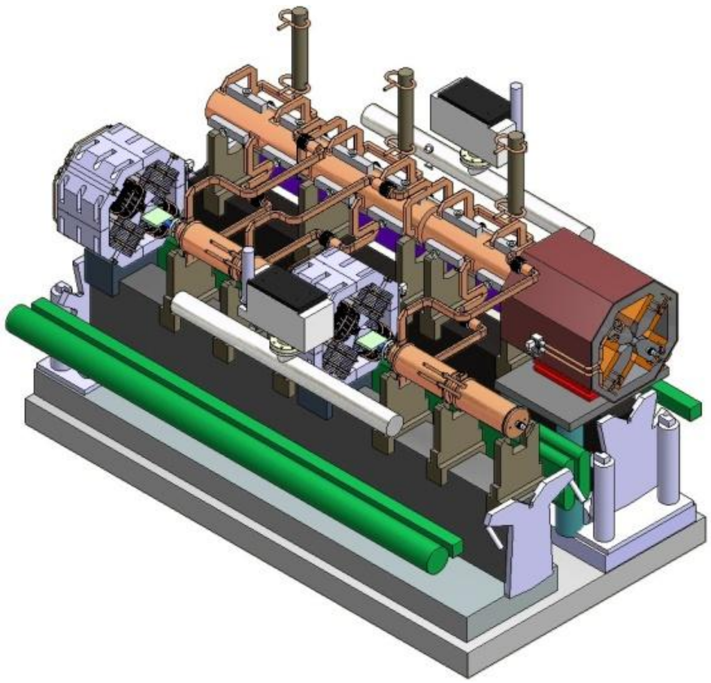
Courtesy of J. Osborne and A. Samoshkin

Beam loss monitors : Simulations

- Work as just started
- Plan to have functional specifications for the CDR by 2010
- For the Cost estimate
  - Choice of Technology (Cerenkov emission in Optical fiber, Ionization chambers, …)
  - Investigation of Safety Integrity Level (Need for redundancy ?)



Major complication: Two beams & Long train!



Exploitation of Cerenkov-radiation in optical fibres

- Based on DESY-Flash work
- 4x2 fibres around vacuum chamber
- Short individual fibres for true 3D analysis

Fast time response

Transverse and longitudinal information

Insensitive against E and B fields

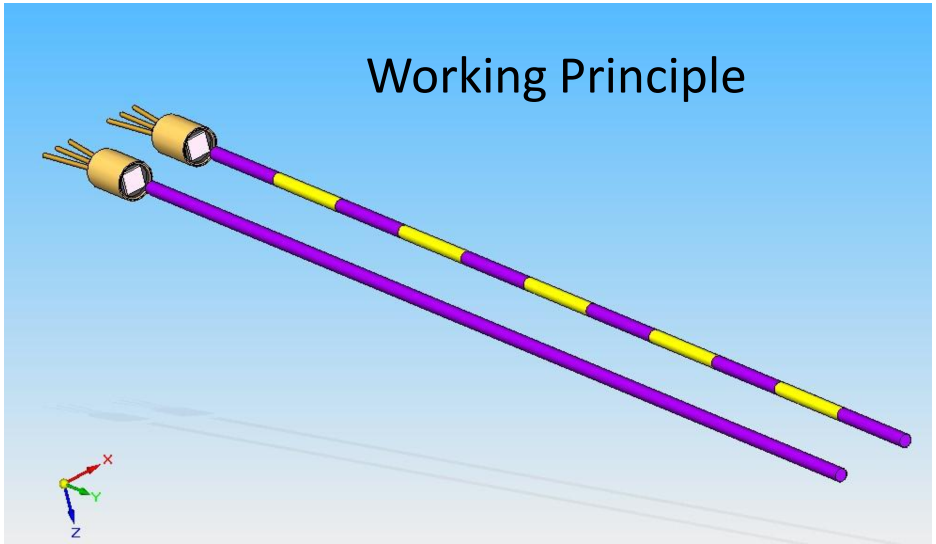
Quite Radiation hard

Limited space requirement of monitor

Beam loss monitors : Hardware development

- Optical Fiber Sensor based on SiPM composed of SPAD Array.

- Two arms:
  - Reference fiber
  - Composite fiber with different losses (~0.45dB)



Features:

- Optical fiber diameter: 1mm^2 as the dimensions of SiPM active surface.
- Numerical aperture of fibers between 0.22 and 0.63.
- Pure silica and PMMA multimode step index fibers with n = 1.46.
- SiPM recovery time ca. 4 ns. (~ better than PMT)
- SiPM quantum efficiency 15 % in the blue wavelength range

ODR R&D

- Optical Diffraction Radiation: (ATF2 – CESR-TA)
    - Used for beam sizes in DB complex in Linear section: Cost saving compared to LWS
    - Used for non interceptive beam energy monitoring along the CLIC Main Beam linac
    - CESR-TA: beam energy 1-5TeV : 1-10um beam size

- Optical Diffraction Radiation by P. Karataev
    - ATF2 – 2E10 electrons 1.28GeV – V<10u and H<100u
    - Synchrotron radiation (from Bends and quads) need to be suppressed to look at ODR using a target with a 1mm diameter hole
    - Silicon wafer with gold coating (aluminium better) :
        - Accuracy of the machining down to fraction of the wavelength

    - ODR:
        - from an edge confirmed
        - from a slit – visibility of the interference can give the beam size
        - very sensitive to parallelism and offset : better than $\lambda/10$
    - Experiment:
        - Need to scan to find the minimum
        - Good scan with PMT and : Resolution limit of 12um compared to wire scanners
        - Optical filter 550+/-20nm
    - Limitations
        - Pre-wave zone effect can be compensated by putting the camera in the focal plane of a lens
        - Photon yield: $2\pi a/\gamma\lambda$ - Beam size resolution: $>0.05\ \gamma\lambda/2\pi$
        - far field approximation: Minimum target diameter - Minimum lens diameter