Summary of the BI Workshop

48 persons registered + few CERN colleagues
CLIC, CTF3, ILC, 3rd and 4th generation light sources

The list of CLIC instrumentation requirements

Held on the 2nd and 3rd of June 2009 at CERN

Workshop Mandate

- Present an overview of CLIC beam instrumentation need and review their specifications : (8 talks : still few things to be discussed with BD)

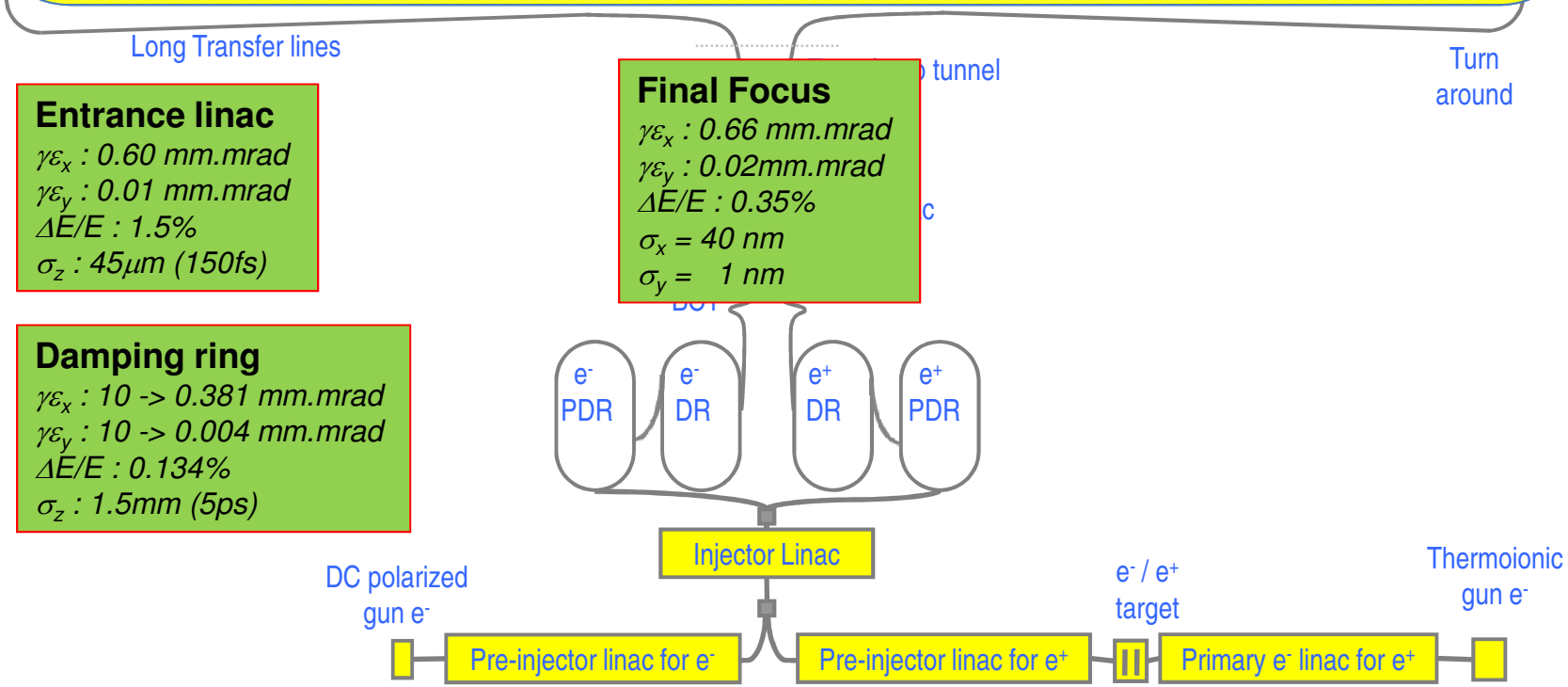
- Present the status of the on-going R&D related to CLIC beam instrumentation : (17 talks covering most of the CLIC instrumentation)

- Review the list of critical items and discuss the R&D required for proof of principle (3h Discussion session)

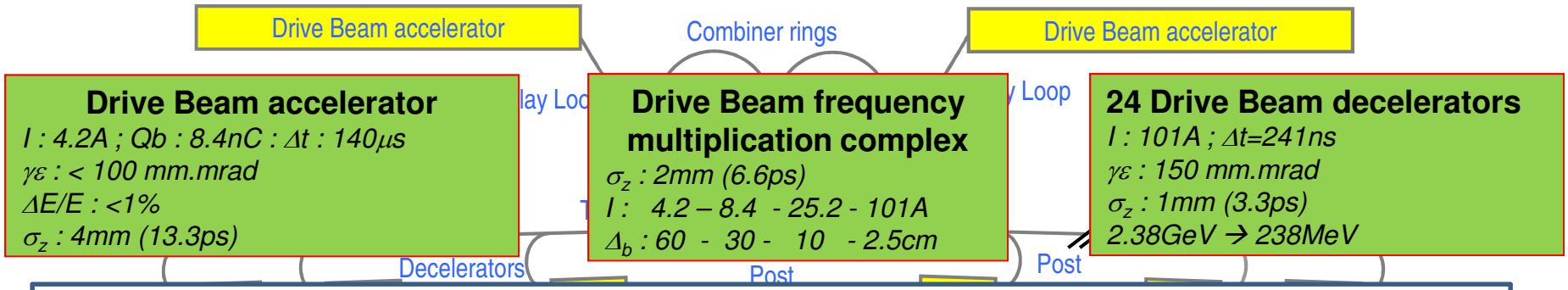
- Organize the work for completion of the CLIC Conceptual Design Report with a cost estimate by the end of 2010 (follow-up on collaborations – MoU in preparation)

Challenges for CLIC Main Beam

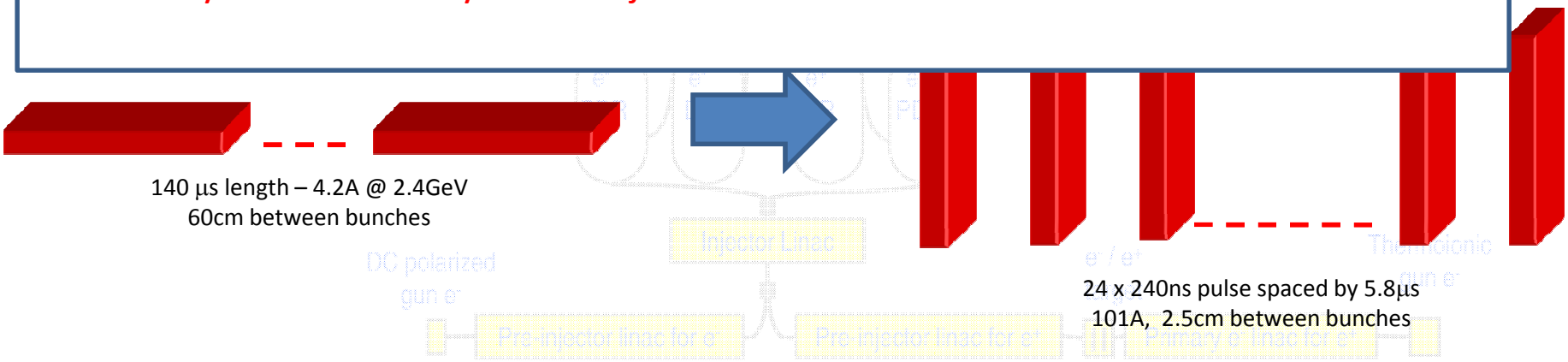
- Producing and measuring **small beam emittance (1micron)**
- Producing and measuring **short Bunches (45microns)**
- Conserving small beam emittance (very strict tolerances/requirements on the **beam position monitor precision and resolution**)
- Dumping the beam correctly



Challenges for CLIC Drive Beam

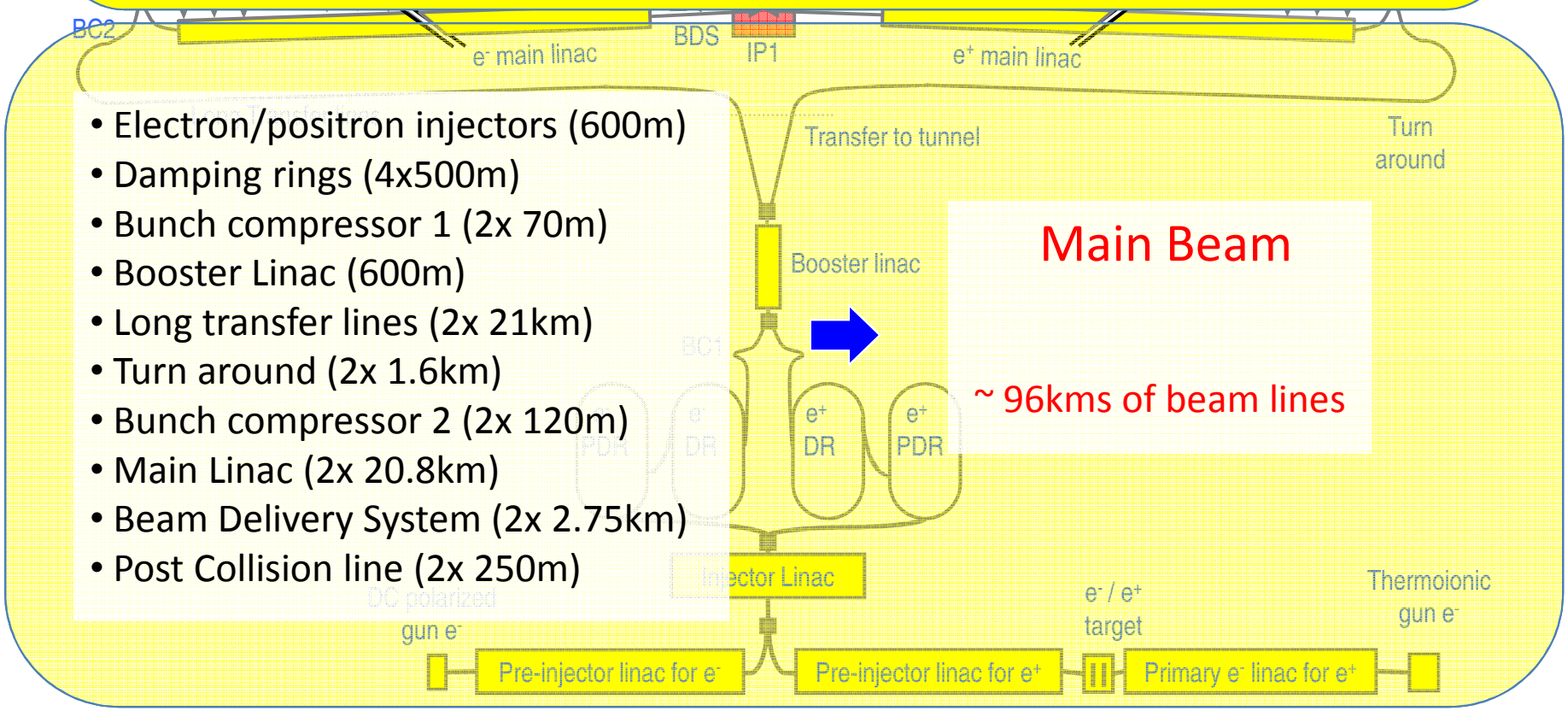


- Manipulating high charge beams (Machine Protection issues, Radiation level, Non intercepting beam diagnostic, ..)
- In addition, there are very strict tolerances/requirements on the beam phase stability (0.1º@12GHz)
- Reliability and availability : This is 'just' the RF Source !



CLIC 3TeV

CLIC RF source



- Electron/positron injectors (600m)
- Damping rings (4x500m)
- Bunch compressor 1 (2x 70m)
- Booster Linac (600m)
- Long transfer lines (2x 21km)
- Turn around (2x 1.6km)
- Bunch compressor 2 (2x 120m)
- Main Linac (2x 20.8km)
- Beam Delivery System (2x 2.75km)
- Post Collision line (2x 250m)

Main Beam

~ 96kms of beam lines

Parameter specifications

Instrument	*Accuracy*	*Resolution*	*Bandwidth*	*Beam tube aperture*	*Stability*	*Non-intercepting device?*	*How many?*	*Used in RT Feedback?*	*Machine protection ?*
Intensity									
Position									
Beam Size / Emittance									
Energy									
Energy Spread									
Bunch Length									
Beam Loss									
Beam Halo									
Beam Phase									
Beam Polarization									
Luminosity									
Wakefield monitor									

Summer 2008 - List of instruments for each sub-systems

- Get an overview of the beam instrumentation (identify what was not studied)
- Identify the critical items in each of the 44 sub-systems: (feasibility, cost, performance)

Dynamic range ? / non-intercepting device ? / Can it be done by a single instrument ?

CLIC 3TeV – Numbers of devices

Instrument	N° Devices
Intensity	386
Position	**49520**
Beam Size	**798**
Energy	166
Energy Spread	166
Bunch Length	384
Beam Loss/Halo	2968
Be	

Drive Beam

54580 devices

Still some changes to expect:
- Design is not completely frozen yet
- Machine Protection system study started recently
- Requirements on reliability not specified yet

Instrument	N° Devices
Intensity	311
Position	**7579**
Beam Size / Emittance	143
Energy	75
Energy Spread	23
Bunch Length	26
Beam Loss/Halo	4
Beam Polarization	23
Tune	8
Beam Phase	96
Luminosity	4
Wakefield monitor	**142812**

Main Beam

8292 devices
+ 142812 wakefield monitors

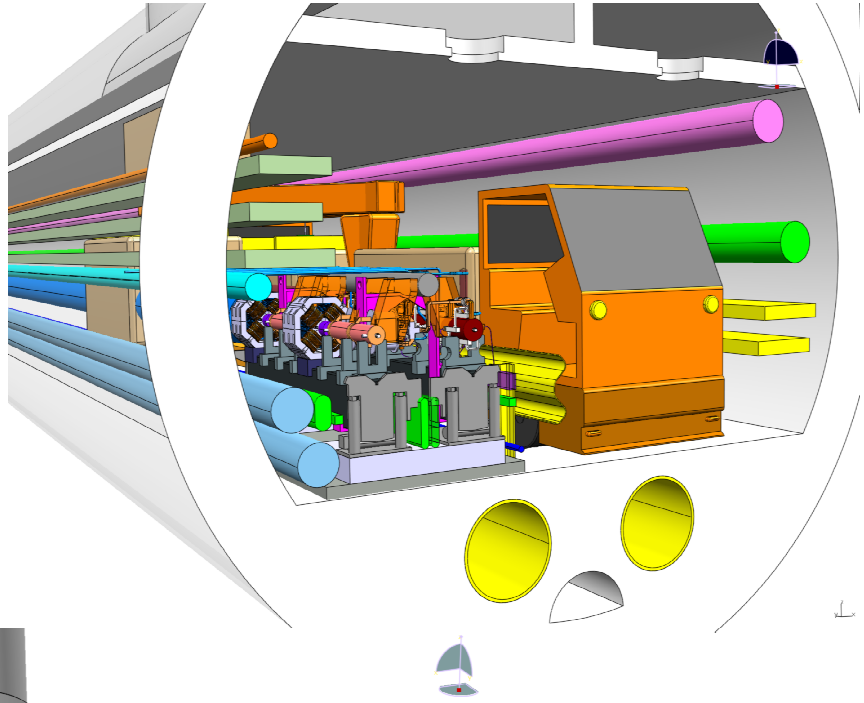
From 500GeV to 3TeV

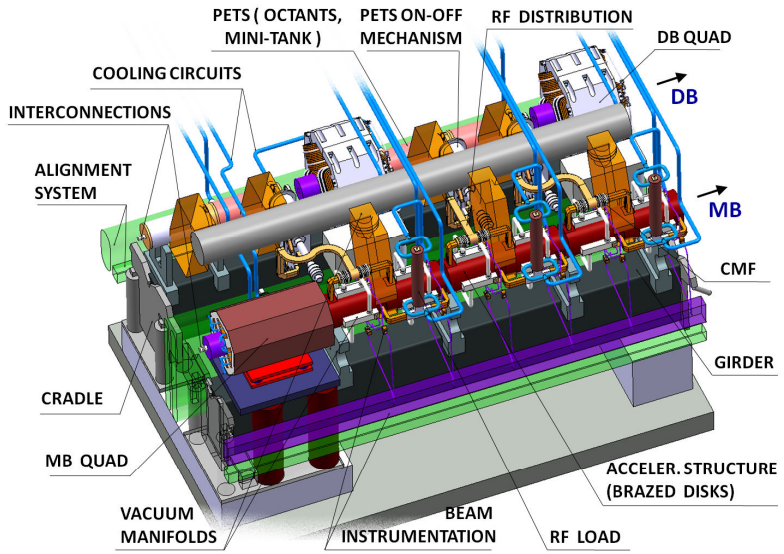
Instrument	Main Beam injector	Main Beam Tunnel		Main Beam Total	
		500GeV	**3TeV**	500GeV	3TeV
Intensity	225	**15**	**86**	**240**	**311**
Position	1539	**1860**	**6040**	**3399**	**7579**
Beam Size	35	**52**	**108**	**87**	**143**
Energy	19	**16**	**56**	**35**	**75**
Energy Spread	19	**4**	**4**	**23**	**23**
Bunch Length	20	**6**	**6**	**26**	**26**
Beam Loss/Halo	4	**0**	**0**	**4**	**4**
Beam Polarization	19	**4**	**4**	**23**	**23**
Tune	8	**0**	**0**	**8**	**8**
Beam Phase	0	**16**	**96**	**16**	**96**
Luminosity	0	**4**	**4**	**4**	**4**
Total	**1888**	**1977**	**6404**	**3865**	**8292**
Wakefield monitor	0	**23802**	**142812**	**23802**	**142812**

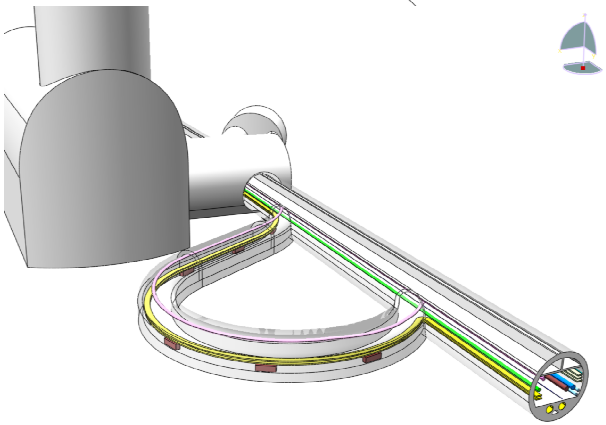
Instrument	Drive Beam injector	Drive Beam Tunnel		Drive Beam Total	
		500GeV	**3TeV**	500GeV	3TeV
Intensity	25/50	**56**	**336**	**81**	**386**
Position	898/1796	**7954**	**47724**	**8852**	**49520**
Beam Size	15/30	**128**	**768**	**143**	**798**
Energy	11/22	**24**	**144**	**35**	**166**
Energy Spread	11/22	**24**	**144**	**35**	**166**
Bunch Length	24/48	**56**	**336**	**80**	**384**
Beam Loss/Halo	284/568	**400**	**2400**	**684**	**2968**
Beam Phase	20/40	**32**	**192**	**52**	**232**
Total	1288/2576	**8674**	**52044**	**9962**	**54620**

96-98% of the instrumentation will be in the tunnel

CLIC Tunnel







Design is well advanced but …

- Where to install the electronic ? Issue on radiation ?
- Specific needs – Optical/laser system

Courtesy of J. Osborne and A. Samoshkin

List of Critical Items

Collaboration with RHUL & Oxford

- **Very tight requirements** for measuring micrometer **beam size**, 40-75microns short **bunch length** and **beam position** with a 50nm resolution

Collaboration with U. Dundee, PSI & RHUL

Collaboration with Fermilab, CEA/Saclay, RHUL

- Need to study the **Machine Protection System** for both the Drive and Main beams and to develop a **Beam loss monitoring system along the CLIC linac** (both beams)

Collaboration with U. Liverpool

- **Reliability and availability** of roughly 5000 high resolution BPM's, 40000 BPM's for the Drive Beam Decelerator and 142812 **Wakefield monitors**, (+ beam loss monitors)

Activity covered by the RF Group - Collaboration with CEA & PSI

- Beam **synchronization** implies a **0.1deg at 12GHz phase measurement** with an adequate feed-forward system

Activity covered by RF group – FP7 – NCL activities

Critical Items covered during the workshop

Working group 5

- Laser wire scanner development: Talk by Lawrence Deacon

- Longitudinal bunch profile: Talk by Allan Gillespie

- Machine Protection System: Talk by Michel Jonker

- Beam loss monitoring system: Talk by Mariusz Sapinski

- 40000 Drive Beam BPM's: Talk by Lars Soby

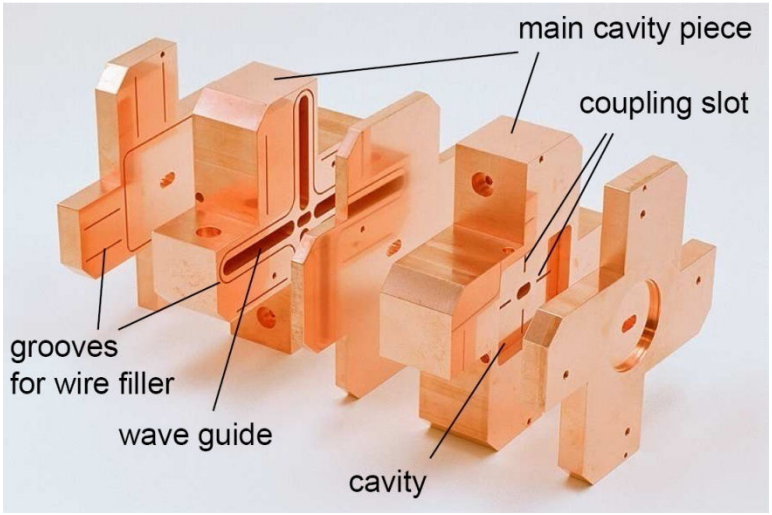
- Precise phase measurement: talk by Alexandra Andersson

- *Test Facilities –*
  - *ATF2 by Toshiyuki Okugi – Covering low emittance instruments (Damping rings & ML & BDS)*
  - *CTF3 by Anne Dabrowski – Covering a collection Drive & Main Beam injector complex instruments*

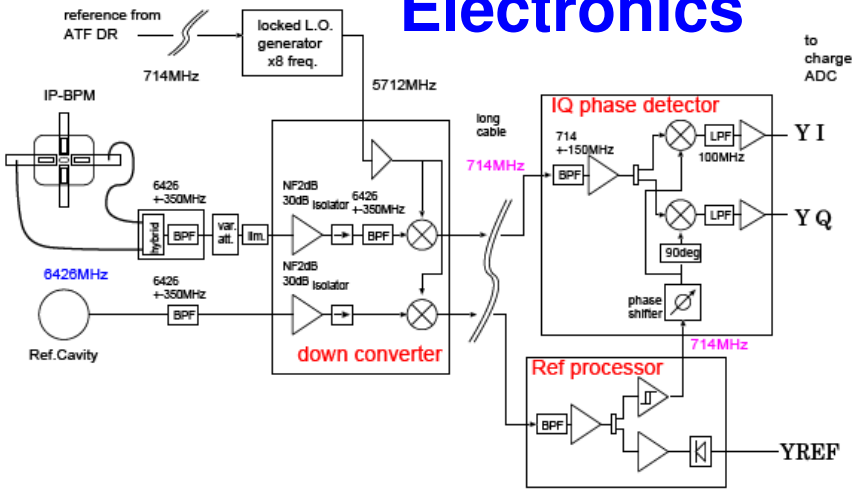
Beam Position Measurements with a 50nm resolution and adequate time resolution

Example: KEK C-Band IP-BPM

Model



Electronics



Characteristics

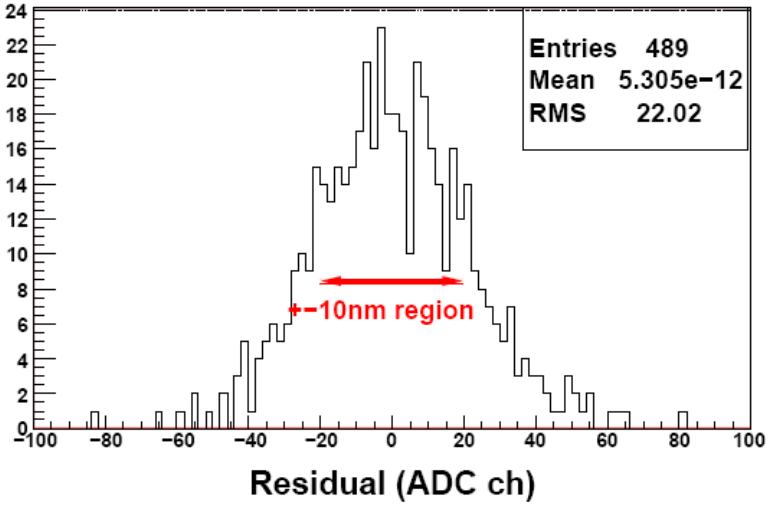
- Narrow gap to be insensitive to the beam angle.
- Small aperture (beam tube) to keep the sensitivity.
- Separation of x and y signal. (Rectangular cavity)
- Double stage homodyne down converter.

Design parameters

Port	f (GHz)	β	Q_0	Q_{ext}
X	5.712	1.4	5300	3901
Y	6.426	2	4900	2442

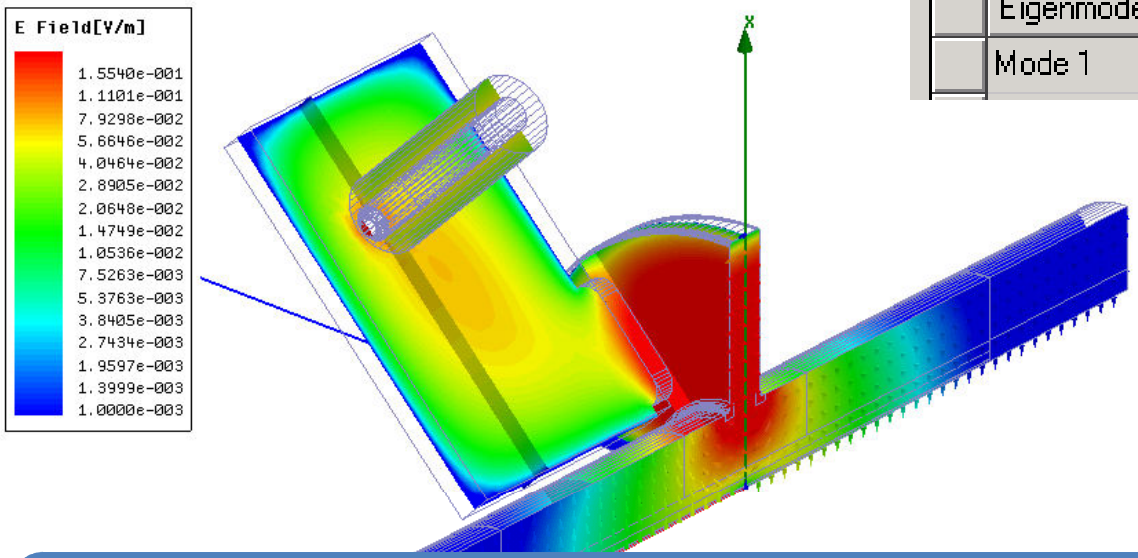
Results

15 nm position resolution!



Cavity BPM @ FERMILAB

Mode TM_{11}



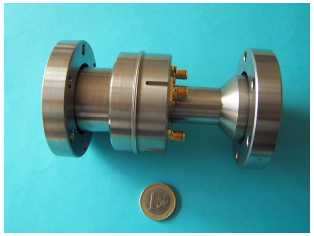
	Eigenmode	Frequency (GHz)	Q
	Mode 1	13.9855 +j 0.0314875	222.081

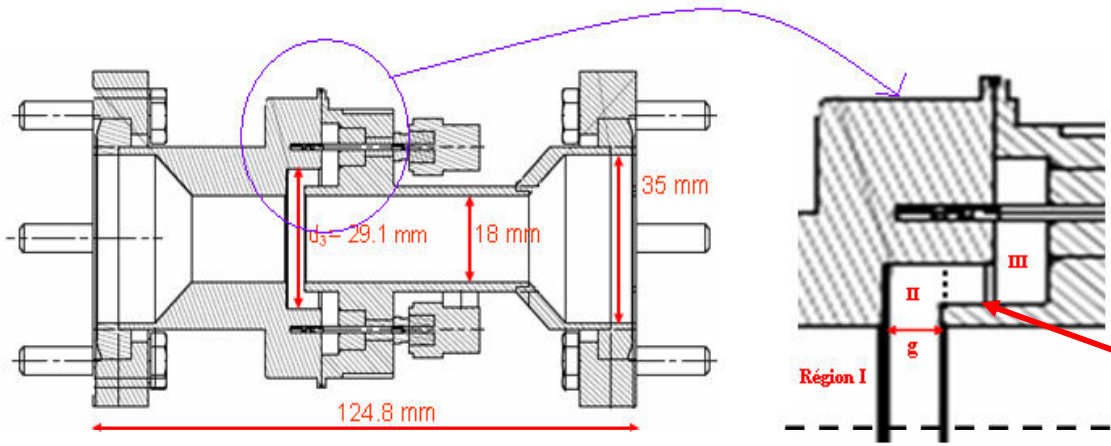
- Work in progress - Design finalized by October 2009 – Prototype 2010 ?

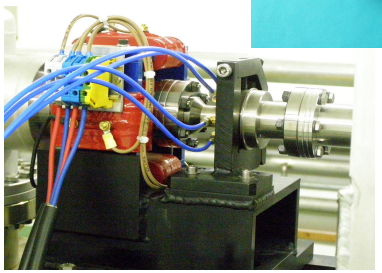
Design of Low-Q low cost cavity BPM (stainless steel)

Reentrant Cavity BPM at CTF3/CALIFES

6 BPMs are installed on the CTF3 probe beam







Reentrant Part

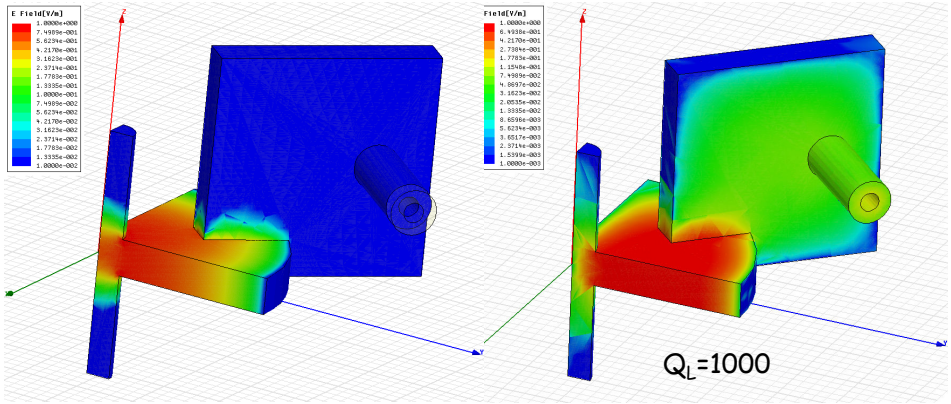
Eigen modes	F (MHz)			
	Measured			d
Monopole mode	3988	29.76	22.3	22.3
Dipole mode	5983	50.21	1.1	7

- Design for CLIC parameter and frequency

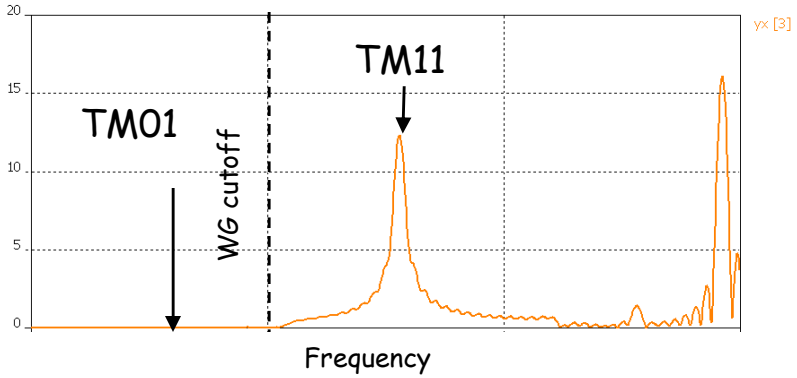
nch and multi-
nodes
- Single bunch resolution potential < 1 µm

‘yet another high resolution BPM’

TM01 TM11



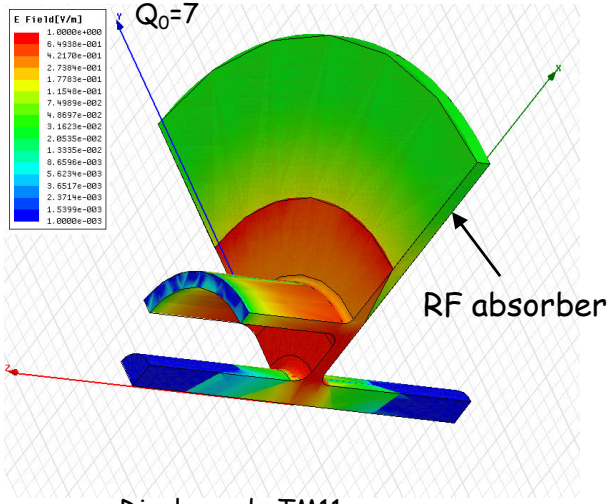
Spectrum of the port signal (single bunch)



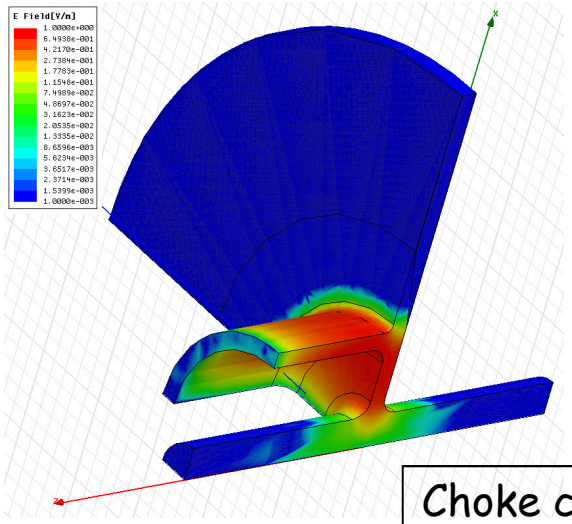
Slotted cavity

I. Syratchev – R. Fandos

Monopole mode TM01
f=7.8GHz
Q_0=7



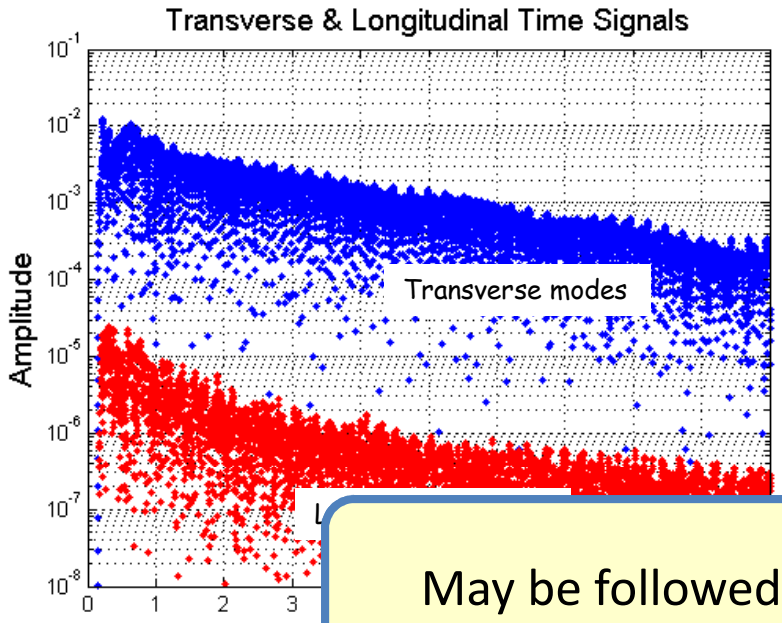
Dipole mode TM11
f=12GHz
Q_0=1600 (Copper)



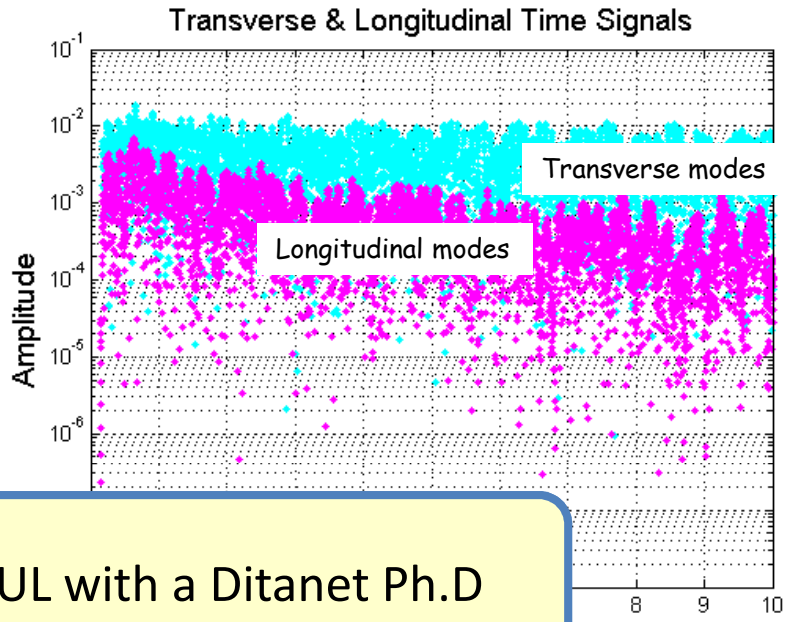
Choke cavity

‘yet another high resolution BPM’

Choke BPM



Slotted cavity BPM



May be followed by RHUL with a Ditanet Ph.D

~ 1 micron ⇐ Internal single bunch resolution ⇒ 500 micron

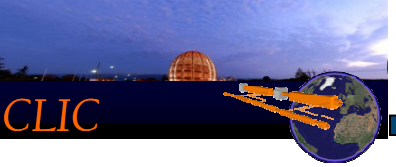
⇓

The two port pairs combination through the hybrid normally reduces the signals induced by the longitudinal modes by at least 20 dB

⇓

~ 10 nm ⇐ Single bunch resolution without post processing ⇒ 5 micron

Wakefield monitors



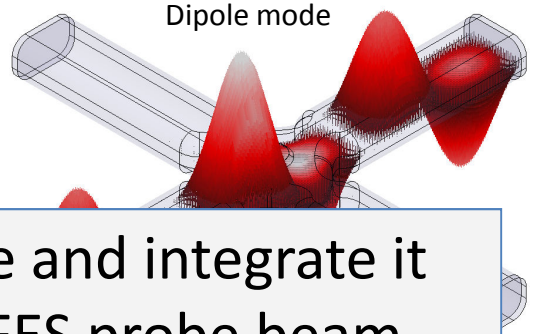
Long waveguide with cut-off above 12 GHz + 90° E-bend

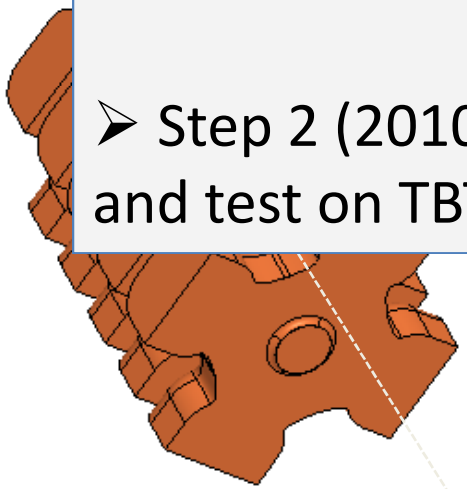
Coax coupler designed to have -10 dB transmission

55 mm

Load location

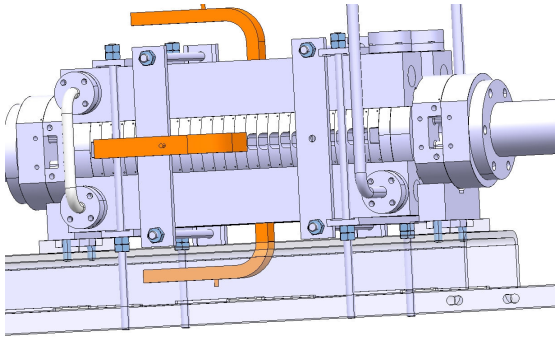
Dipole mode





- Step 1 (2009 - 2010): build one WFM prototype and integrate it into a CERN structure and test on TBTS with CALIFES probe beam
- Step 2 (2010 - 2011): build 2 or 3 structures fully instrumented and test on TBTS + CALIFES

- Cell equipped with WFM must still provide strong damping (SiC loads)
- Cheap and as simple as possible



Beam size measurement

- Micron precision for CLIC Main Beam *(from DR to BDS*)
  - Laser Wire Scanner in Linacs (*limit for OTR to be investigated?*)
  - Synchrotron light in Damping Ring (*interferometery or $\pi-$ polarisation technique*)

- Non-intercepting devices for the CLIC Drive Beam (injector complex)
  - Laser Wire Scanner, Quadrupolar pick-up (resolution ?), Gas/neutral beam scanner,…
  - Synchrotron light in rings

Bunch length Measurement

- Longitudinal profile monitor in Bunch compressors and BDS with high resolution (30fs)
  - RF Deflecting cavity
  - E-O Optics techniques
  - Op*tical Repliqua Technique*

- Bunch Form factor measurements
  - DB decelerator for RF production efficiency verification : 300fs resolution
  - MB for feedback : 30fs resolution

Post collision line

Post collision line

A.Ferrari, V. Ziemann
E. Gschwendtner – A. Apyan

Talk by Edda on wednesday in working group 2

Complex and non-standard beam line

- Luminosity monitors based on beamstrahlung photons detection
- Intensity monitors
- Interferometric dump thermometer
- Tails monitors and/or instrumented collimators

Number of devices

- Electronic Standardisation
  - Single type of digital electronics acquisition card used for the majority of LHC instruments
    - Design more complicated

Follow similar concept for CLIC

- ***Elimination of cables***
- ***Standardized Digital Acquisition on local crate with single connection via synchronous ethernet for timing/clock (White Rabbit – BE/CO - Javier Serrano)***
- ***Radiation hardness ?***

S. Vilalte, J. Jacquemier, Y. Karyotakis, J. Nappa, P. Poulier, J. Tassan

Perspectives for the CDR and beyond

Tasks : for every type of instruments

1. **Collect the beam instrumentation requirements for each CLIC sub-systems : Parameter specifications**

1. **Technology choice**
   1. Evaluate the performance of already-existing technologies (CTF3, ILC, light source)
   2. Perform R&D when necessary : on-going
   3. Choose technology : **CDR – Conceptual specifications (PBS Level 5)**
   4. External limitations : Machine Operation, Machine protection, Radiation damage, Availability, Reliability, Maintainability : Functional specifications (PBS Level 5)
   5. Define needs for Mechanic, Electronic, Cabling, Acquisition, Optic, …
   6. **Technical specifications**

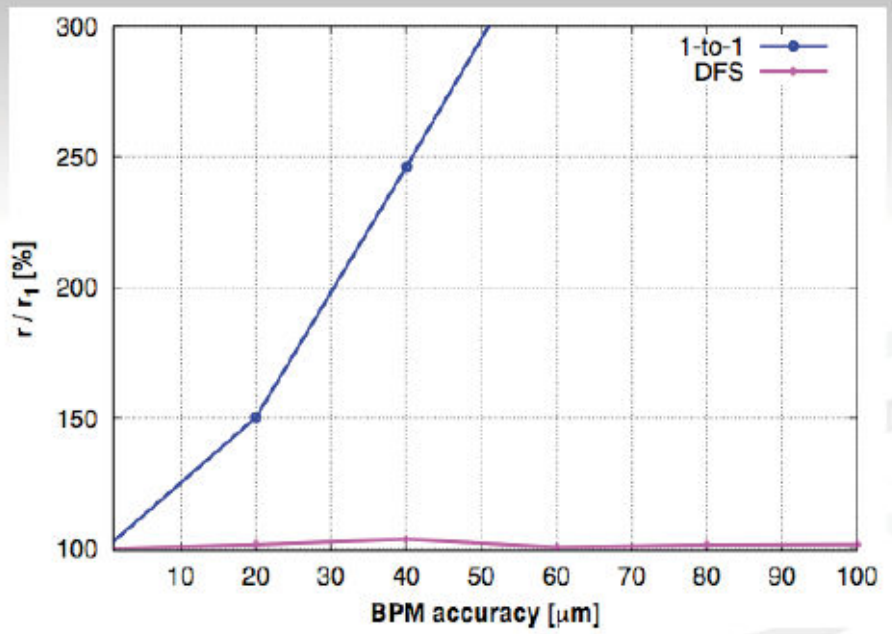
2. Cost estimate
   1. Estimate the Driving part of the cost for every instrument
   2. Performance vs cost (How much do we gain for relaxed performance ?)
   3. Number vs cost (How much do we gain going to mass production ? Factor 2, 10, ~number of equipment)
   4. **Technical specifications**

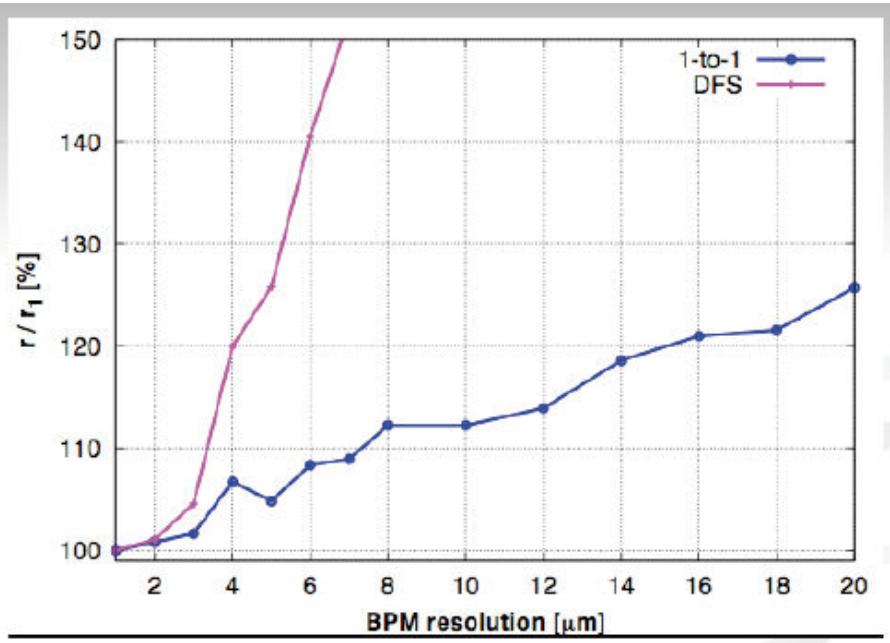
3. **Engineering specifications and production : This is for the TDR phase**

Huge amount of Work before the CDR in 2010 with a realistic cost estimate

Reducing the Performance ?

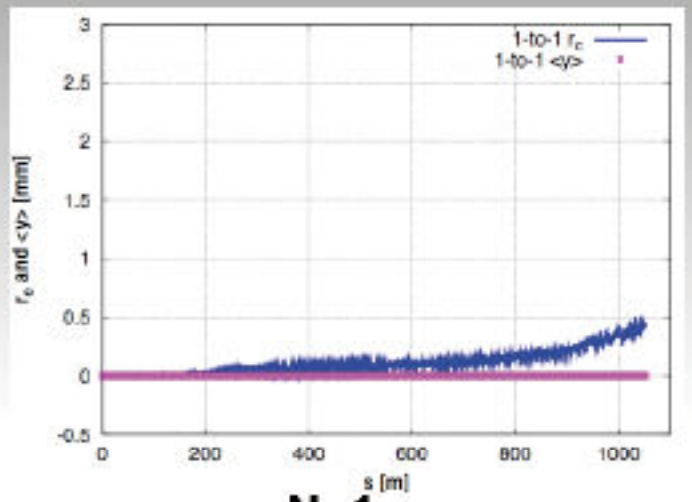
Simulation by E. Adli on DB decelerator performance





Reducing the Numbers of devices

Simulation by E. Adli on DB decelerator performance



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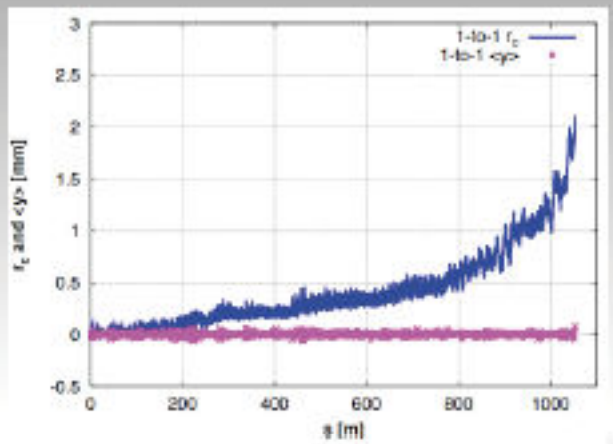

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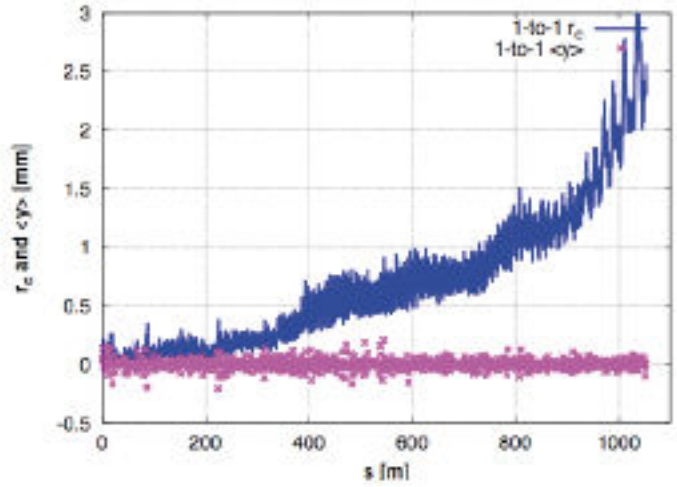

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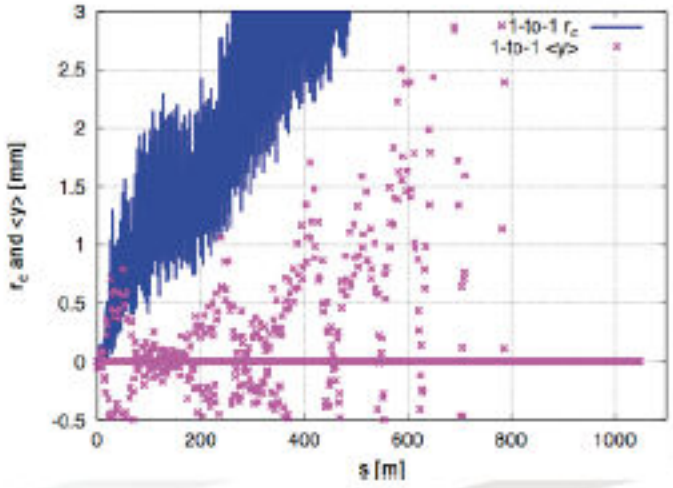

N=4

Conclusions

- Specifications for BI in rather good shape:
  - Waiting for specifications for beam loss monitoring
  - CLIC Layout will be frozen by the end of this year
- For all demands technical solutions exist (within a factor 2...3)
  - Complex and non standard Post-collision beam line not studied in details yet
  - High number of instruments: reliability and availability ?
- Cost optimization and prototyping

  (this will be the main activity in the 2011 – 2016 CLIC TDR phase)
  - Simplicity if applicable (not always compatible with tight tolerances)
  - Standardization (detectors, electronics) is a key concept
  - Gain in Mass production ?

CLIC Instrumentation and ressources

- Development on **Beam loss monitors :** No specification so far
  - Recent collaboration with **University of Liverpool** - Cockcroft Institute for Beam loss detection technique based on Optical fiber
  - Recent collaboration with **Greece** : Students for beam loss shower simulations
  - **CLIC Project Associate** (Mariuzs Sapinski) starting in Oct 2009.

- Development of **micrometer beam size monitor**
  - **JAI-RHUL** and **Oxford University** colleagues involved in ATF2/PETRA laser wire scanner program

  1 micron accuracy to be demonstrated (current achievement 2-3 microns)

  Study the use of LWS for the Drive Beam Complex (easy for top energ but optimize the design for a cheap solution)

- Development of **short bunch length monitoring techniques**
  - **INFN-Frascati** for RF deflector techniques : Longitudinal Profile but limited to low energy (and expensive)
  - **University of Dundee** for Electro-optics techniques : Longitudinal Profile

  resolution to be studied @ Flash/LCLS (current status 20fs)
  - **Northwestern University** using RF pick-up techniques: Form Factor for DB complex : *Test resolution in TBL*
  - **JAI-RHUL** for Coherent Diffraction radiation techniques: Form factor for DB/MB complex : *Test resolution in TBL*

- Development of **Beam Position Monitors**
  - **FNAL** collaboration for 50nm resolution BPM : *Low cost Cavity BPM*
  - **CEA/IRFU** for re-entrant cavity BPM
  - **CLIC Project Associate** (Steve Smith from SLAC) for one year : *Work on DB Decelerator BPM*
  - **JAI-RHUL** for BPM development : 1 Ph.D student and few staff part time : *Choke type Cavity BPM /Wakefield monitor ?*
  - **IFIC Valencia** for Drive Beam Decelerator : *Scale CTF3 Inductive BPM to CLIC Needs*
  - **INFN-Frascati** for Drive Beam delay loop and combiner rings : Not really active at the moment

- Development of **Wakefield monitors** by **CEA/IRFU** (Frank Peauger) Would need help from RHUL – maybe ?

- Development of emittance and energy spread measurement devices with **PSI**

- Development of **post collision line monitor (luminosity monitor)** by **Uppsala university**
  - *Need for a CLIC Project Associate ?*

- Beam synchronization implies a 0.1deg at 12GHz phase measurement with an adequate feed-forward system
  Activity not follow-up by the BI group (RF group and FP7-Eurocard/NCL)

- **Electronic development** for **Large distributed systems**: Need to prepare specifications to be included withtin a global standardization effort (module)
  - **LAPP** for the acquisition system (rad-hard analog and digital solutions)
  - **University Politecnica de Catalunya** for rad-hard analog electronic

Follow-up on collaboration

- RHUL
  - Continue the work on LWS and short bunch length monitoring
  - Start working on Wakefield monitor and/or Choke Cavity BPM
- FNAL
  - Lost cost low-Q cavity BPM : Money / MoU?
- CEA :
  - The design of re-entrant cavity for the CLIC Main linac (low-Q, high bandwidth)
  - Help for Wakefield monitor design
- ESRF :
  - Expertise of PDR & DR instrumentation
- University of Dundee / PSI
  - E-O optics sampling : Revised specifications / collaboration in preparation