



Bunch length monitoring at CTF3

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(CERN)

On behalf of all involved

CTF3 Technical Meeting
22 January 2008



Outline

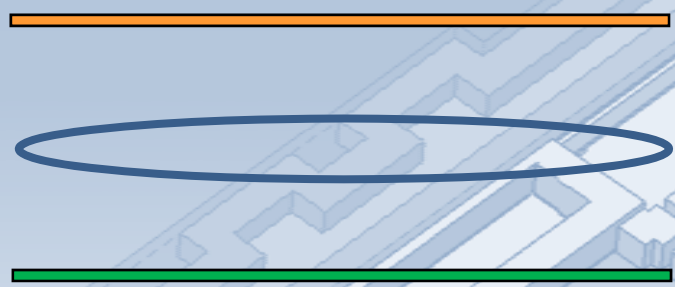
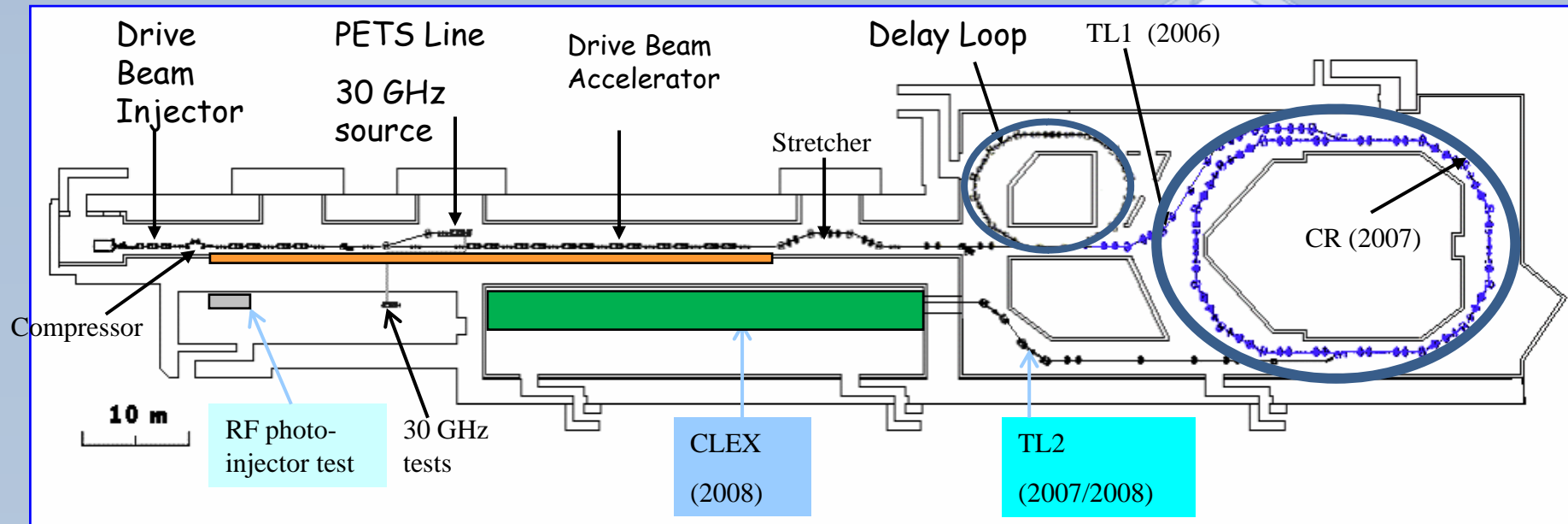


- Bunch length manipulation at the CTF3
- Diagnostics to monitor bunch length at the CTF3
 - BPR with WR-28 waveguide port
 - RF deflector and Streak Camera
 - "RF-pickup"
- Highlights of Bunch length (and longitudinal dynamics) measurements at CTF3 (2005 - 2007)
- New bunch length monitoring required for 2008 → and foreseen improvements to the setup of 2007
 - RF pickup
 - Combiner ring measurements
 - Measurements in CLEX





Bunch length @ CTF3



LINAC \approx 1- 6 ps

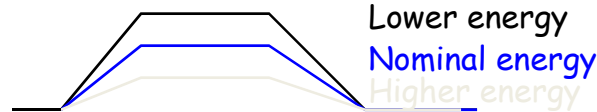
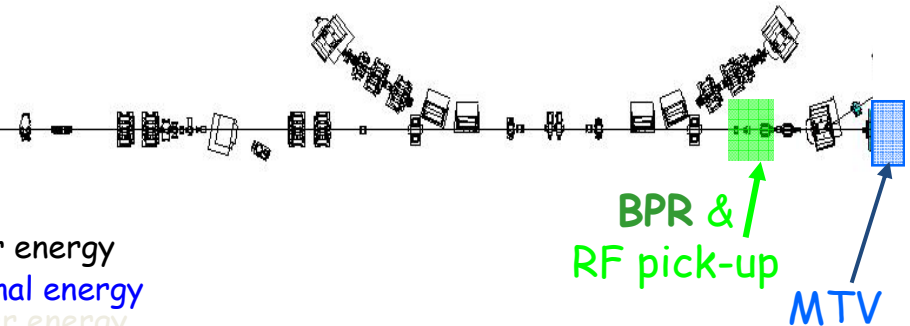
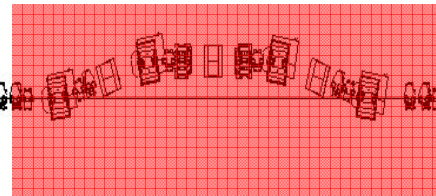
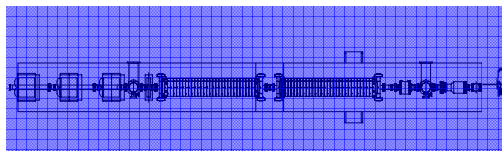
Delay Loop and Combiner Ring $>$ 8 ps

CLEX \approx 1- 2 ps r.m.s. and Califes $<$ 1 ps r.m.s
 → monitoring system to be developed CERN & CEA/Saclay

Accelerating structures
@Girder 15

4 Bends INFN-
Frascati Chicane

Delay Loop



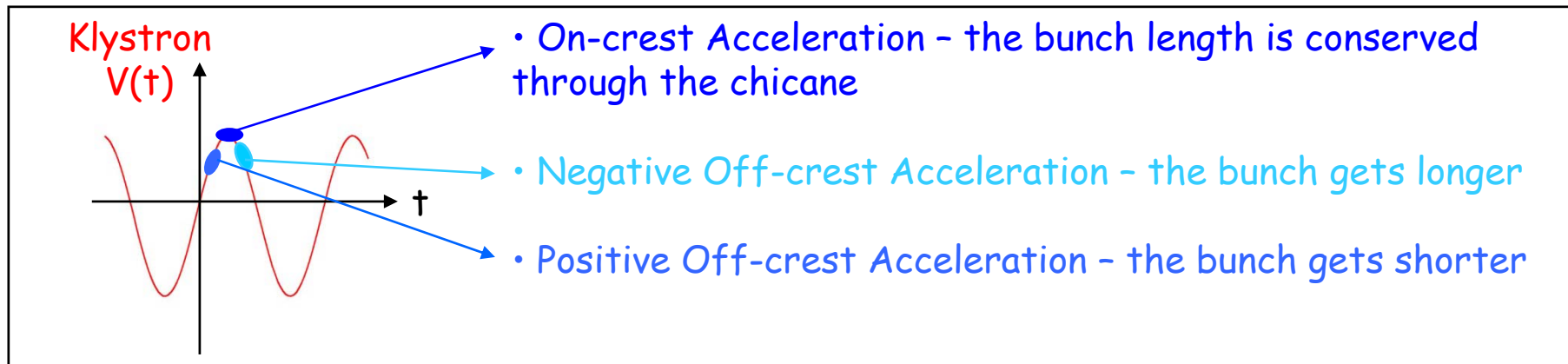
Changing the phase
of Klystron 15 to
insert a time to
energy correlation
within the bunch



Convert energy
correlation into path
length modification
and time correlation



Measure the Bunch
frequency spectrum
Measure bunch shape &
length using RF deflector
and OTR screen





▪BPR with WR-28 waveguide port

- power measurement at 30 GHz (see talks Lars Soby, CTF3 collaboration meeting 2003)
- For given beam current & position, maximise the signal → minimise bunch length

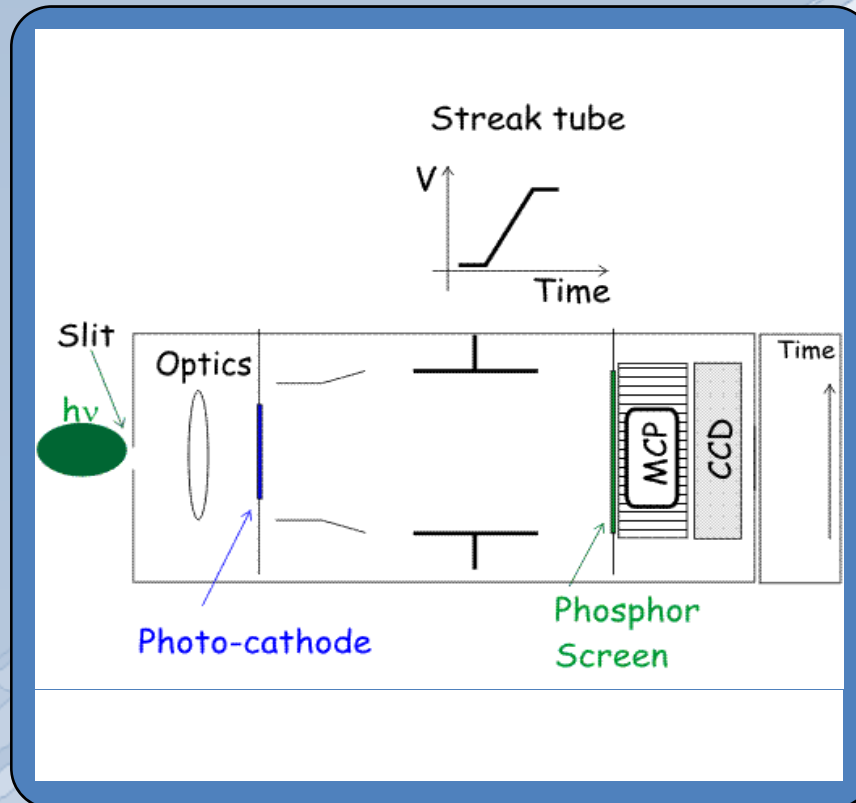
http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Techn_Mtgs/2003/Presentations/LSoby30903.pdf)

•BPR's installed in the CTF3:

- after injector
- After chicane (girder 4)
- After INFN/Frascati Chicane end of the Linac. Waveguide port shared with the "RF-pickup"
- Combiner ring
- TL2 before entrance to CLEX / TBL



Synchrotron
or OTR light
from the
beam



- 2 Optical lines installed in **2006** in and after Delay Loop
- 2 Optical lines installed in **2007** in Combiner Ring
- **2008** → Optical lines foreseen for CLEX

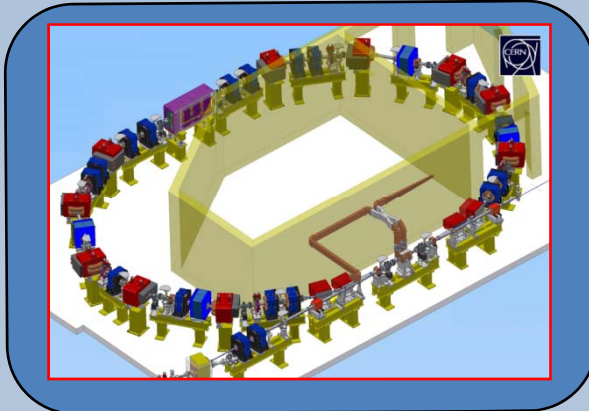
Max sweep
10ps/mm



Streak Camera @ CTF3



Long optical lines to the streak camera Laboratory



2 Optical lines in 2006

- Synchrotron Radiation in the Delay Loop
- OTR in the linac in TL1

OTR@ linac

$\sigma = 4.5\text{ps}$ (1.4 mm)

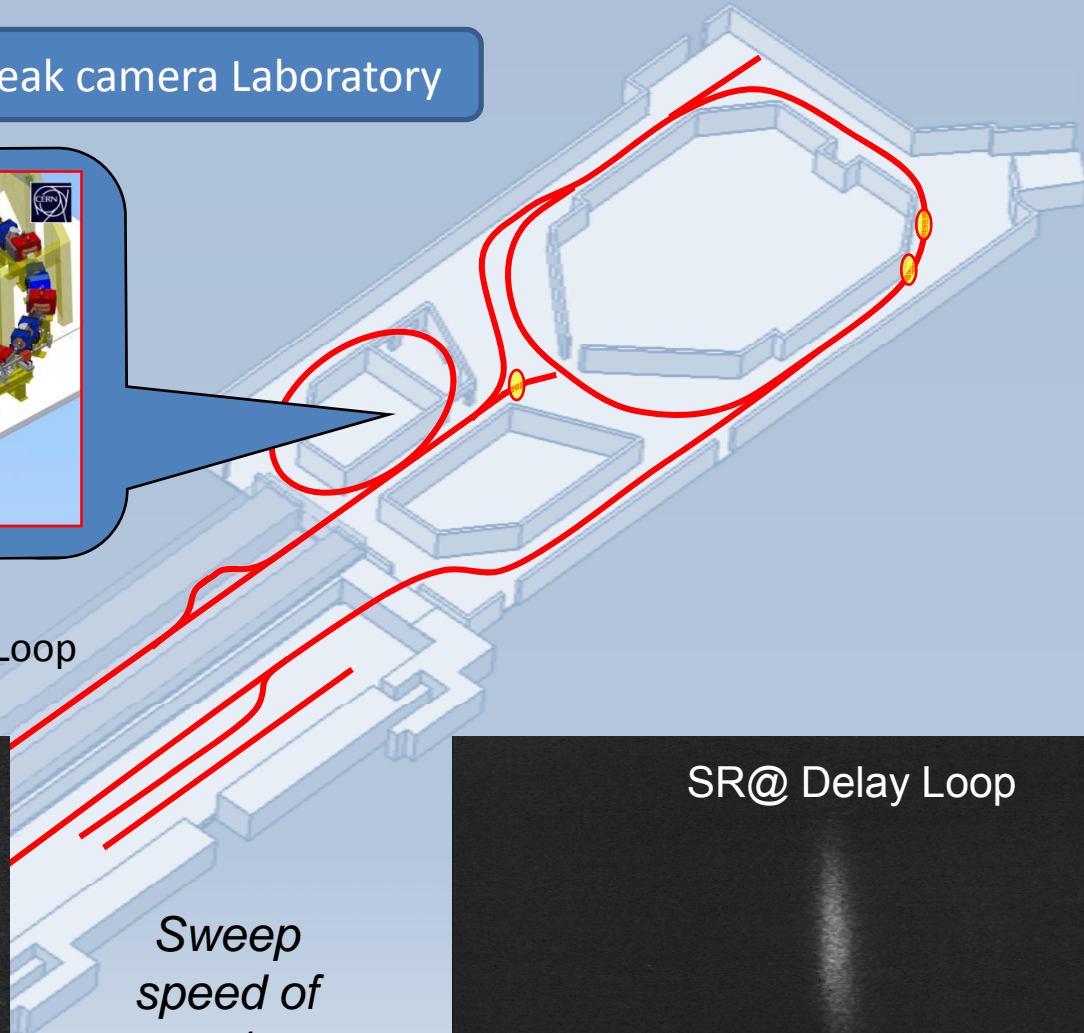
time ↑

SR@ Delay Loop

“Nominal” chicane - $R56 = 0.45$
 $\sigma = 8.9\text{ps}$ (2.7 mm)

time ↑

Sweep
speed of
10ps/mm

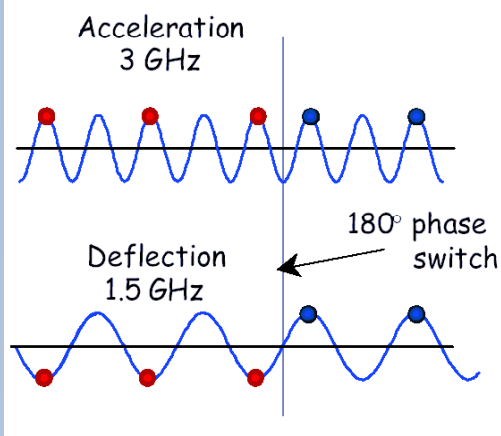




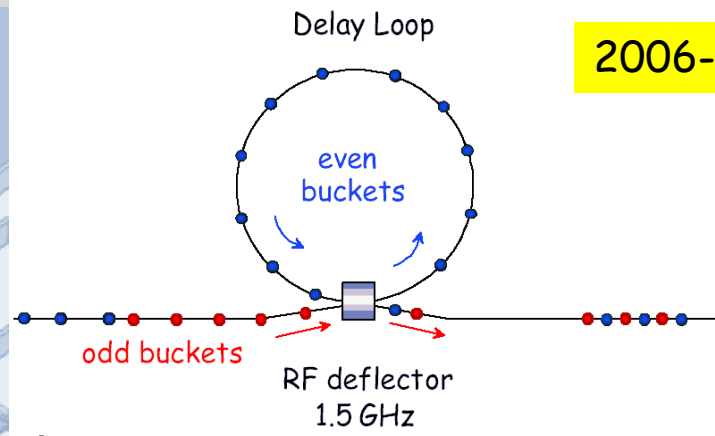
Streak Camera @ CTF3



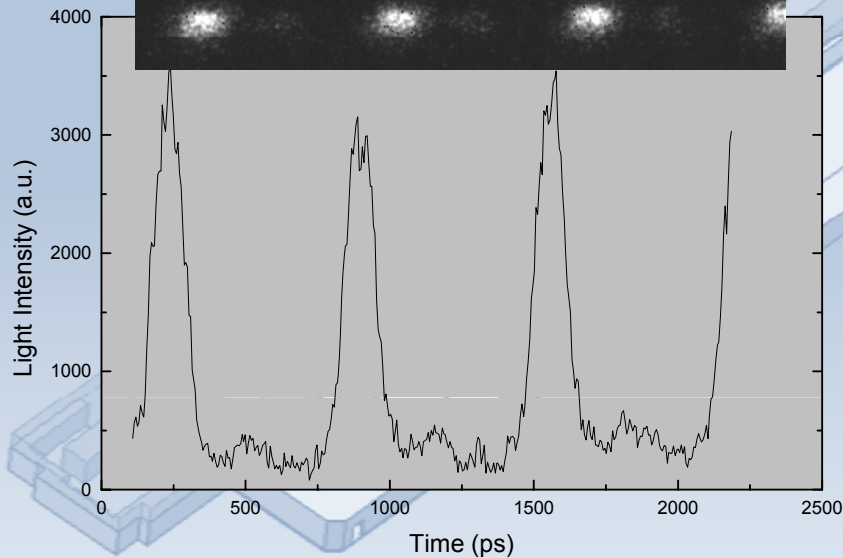
Phase coding in the sub-harmonic bunching system



Bunch frequency multiplication in delay loop

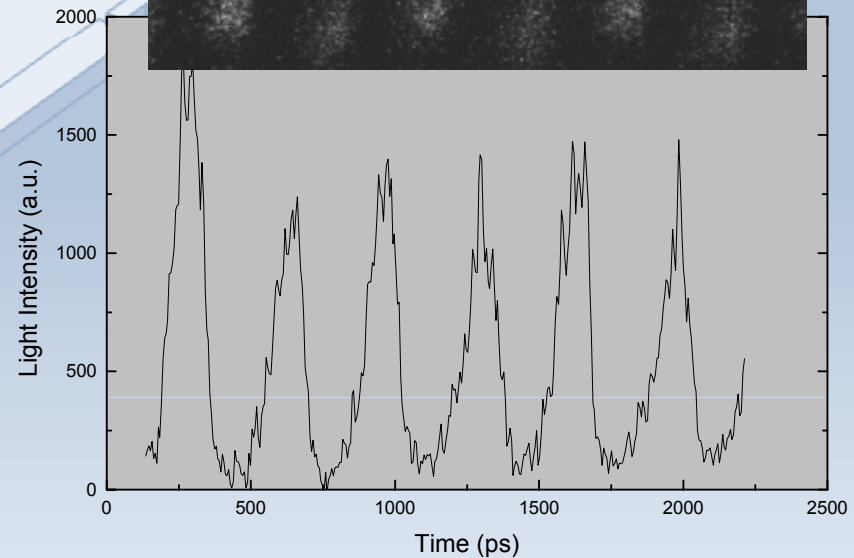


SR light in the Delay Loop



Sweep speed
250ps/mm

OTR light after recombination

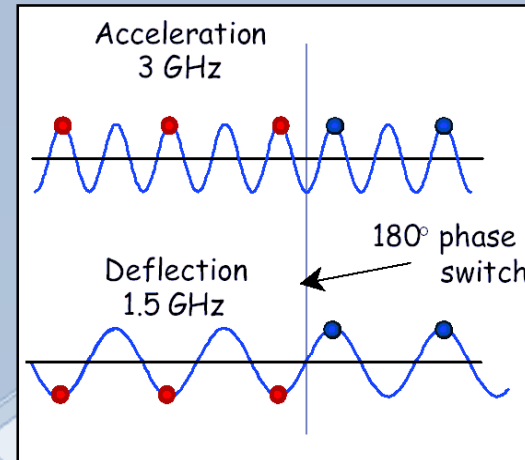




Streak Camera @ CTF3



Phase coding in the sub-harmonic bunching system

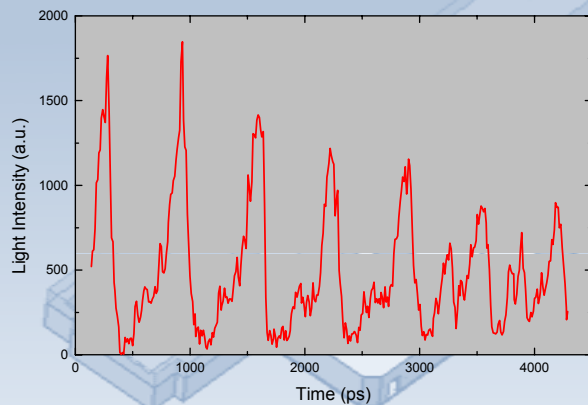
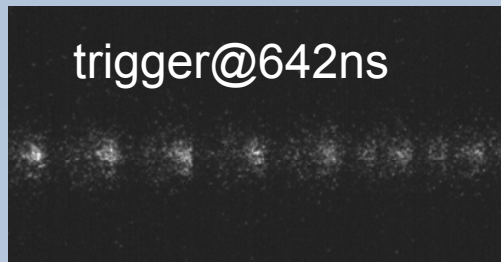


2006-2007

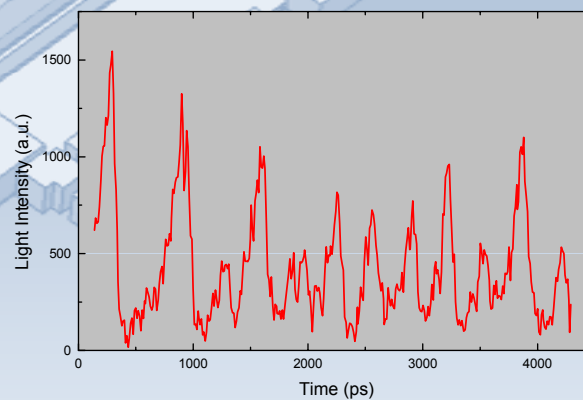
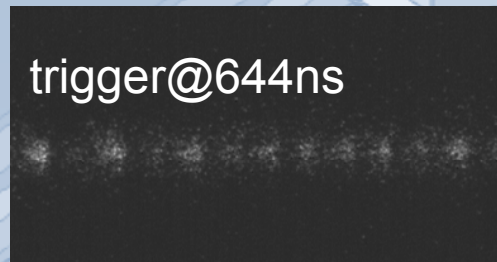
Streak camera sweep speed 500ps/n

Phase Switch ~ 5-6 ns ; 8 % satellite

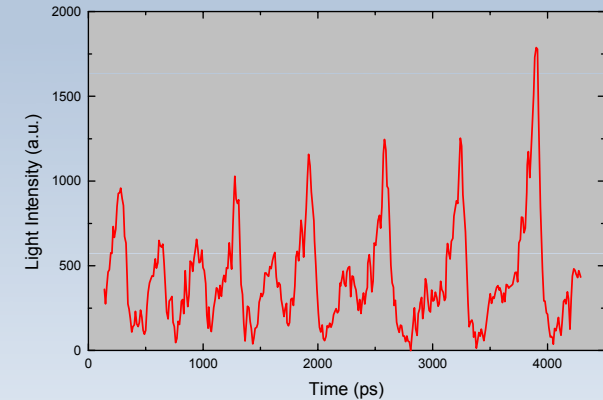
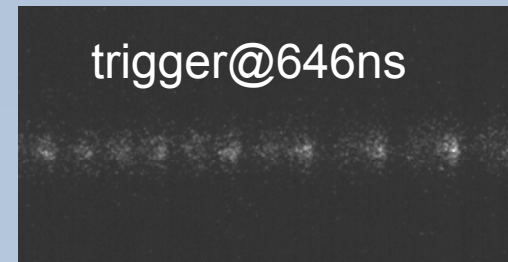
trigger@642ns



trigger@644ns

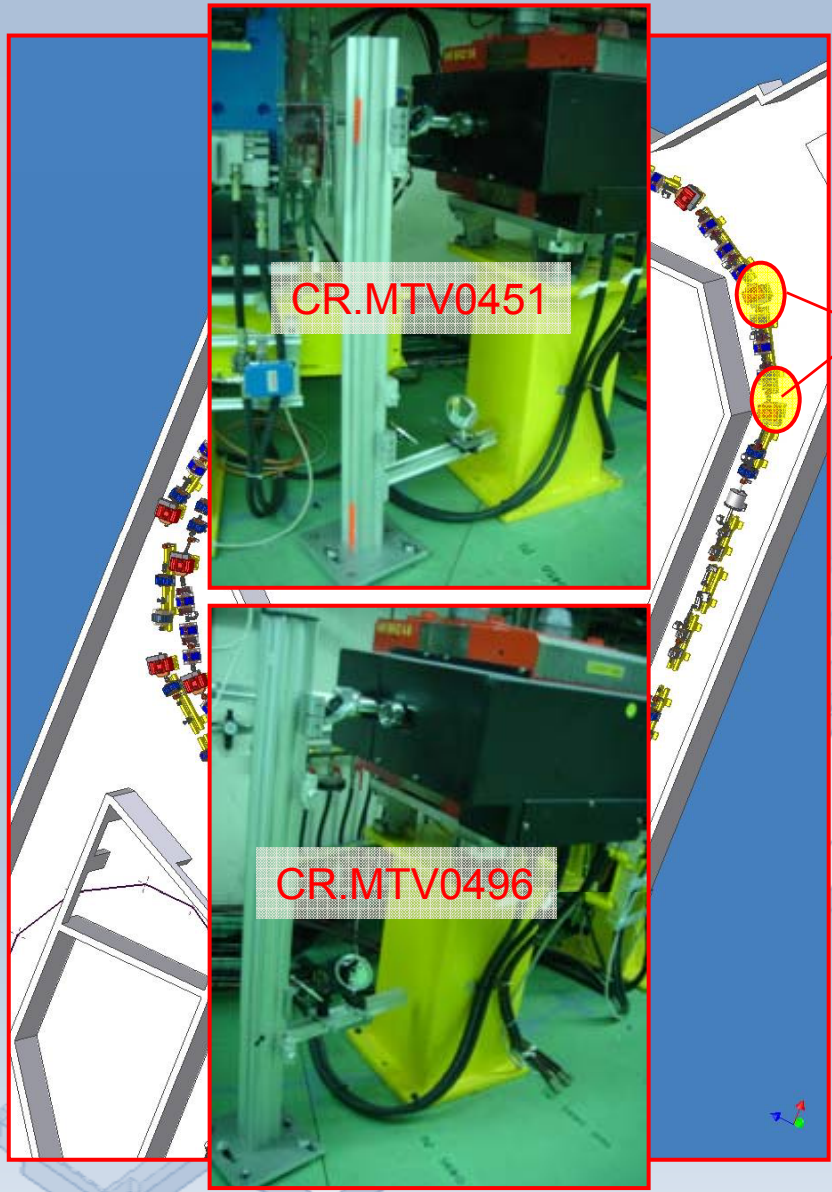


trigger@646ns





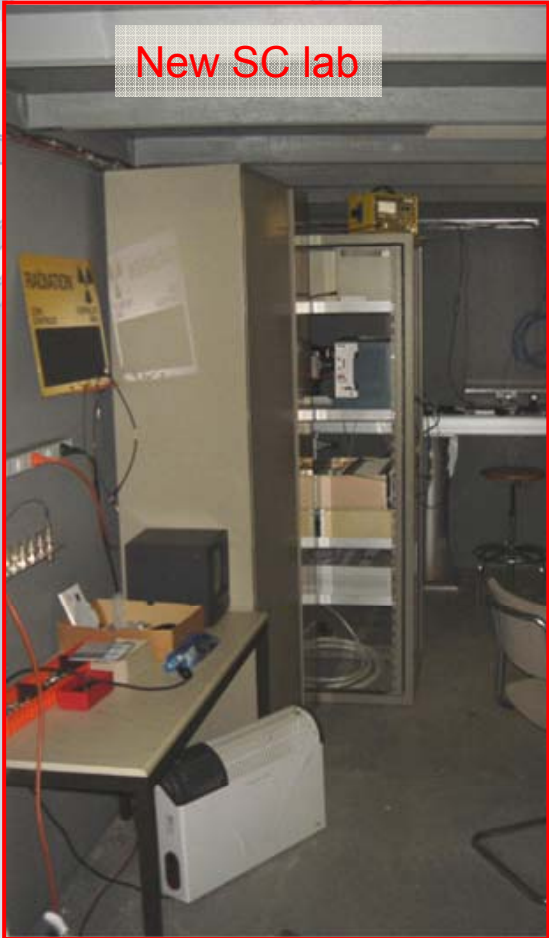
Streak Camera @ CTF3



2 new optical lines installed in 2007 on the Combiner ring



Optical Chicane



New SC lab

2007



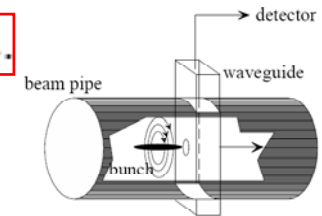
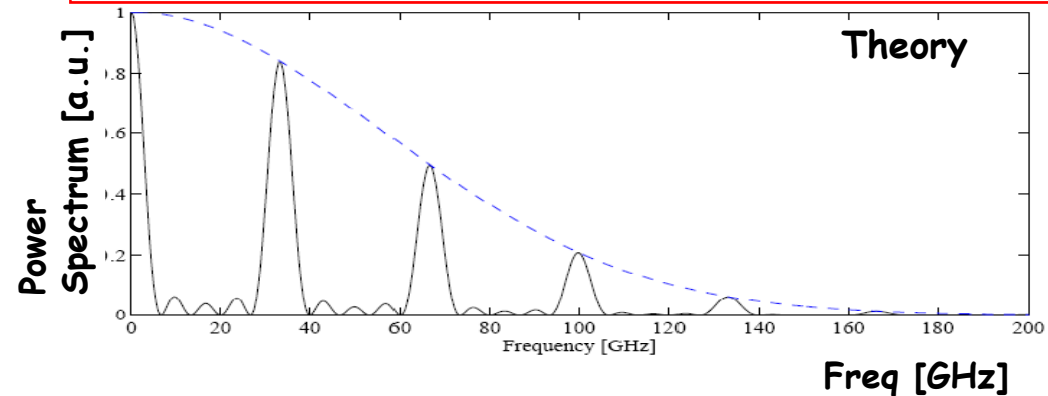
Filters to separate signal into 4 frequency bands

2 down-mixing stages in each band

Stage 1 = synthesizer 2-14 GHz

Measure the power spectrum of the beam at each frequency band: 26.5, 56.5, 75 and 157 GHz

Frequency spectrum of a train of 5 bunches.



(30 - 39) ; (45-69) ; (78-90) & (157-171) GHz

Setup @ CTF3 was installed & first data taking in Nov 2006

→ Non-intercepting device, easy to implement in machine, sub-ps resolution, self calibrating if bunch length scan is performed

→ RF deflector and/or a streak camera @CTF3 provide an excellent cross calibration of device

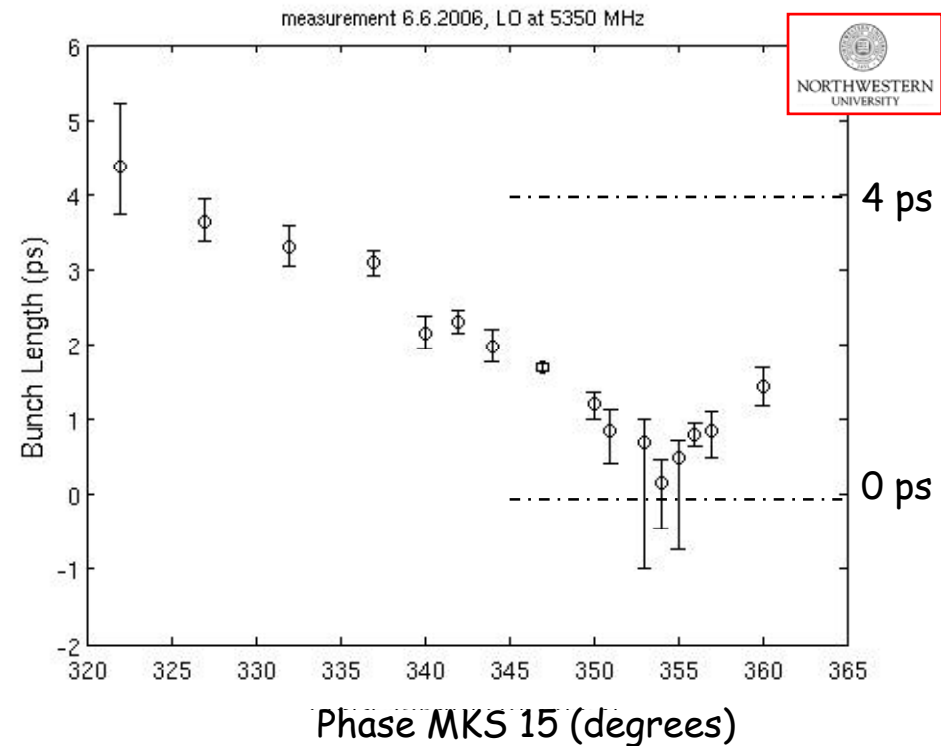
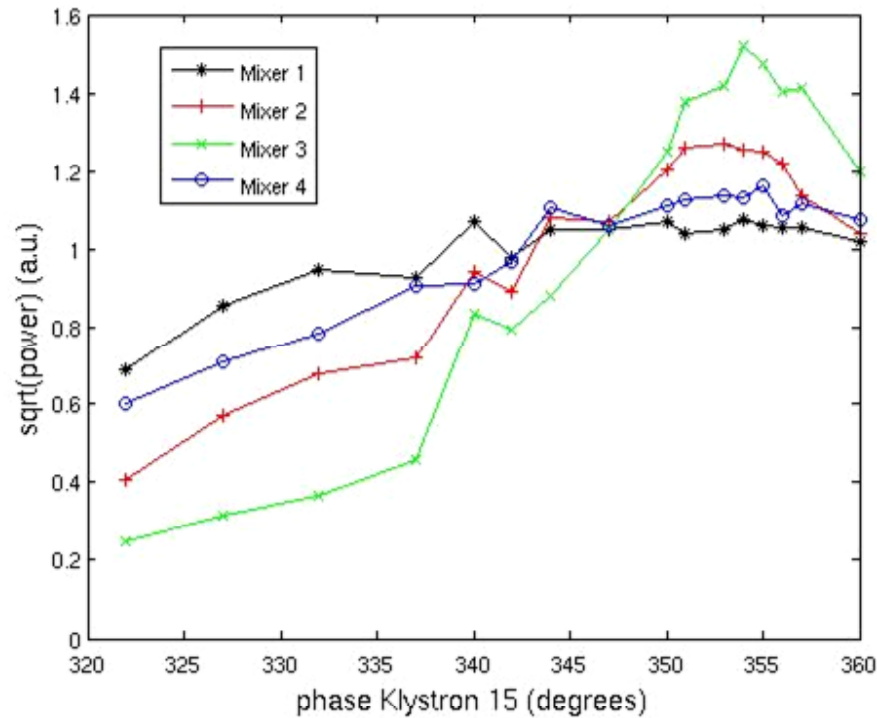
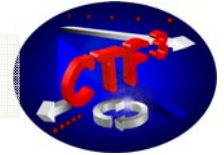
PAC07 proceedings:

<http://doc.cern.ch/archive/electronic/cern/preprints/ab/ab-2007-070.pdf>





Bunch Length measurement using "RF Pick-up" @ CTF3 2006



Goal 2007:

- Optimise highest frequency measurement > 143 GHz
- Cross calibrate device with RF deflector measurements

$$\chi^2 = \sum_j \sum_i^{16} (A_i e^{-(2\pi f_i)^2 (\sigma_j)^2} - y_{ij})^2$$

- Fit done with lowest 3 mixing stages (< 100 GHz).
- 19 free parameters fit → 3 response amplitudes and 16 bunch lengths

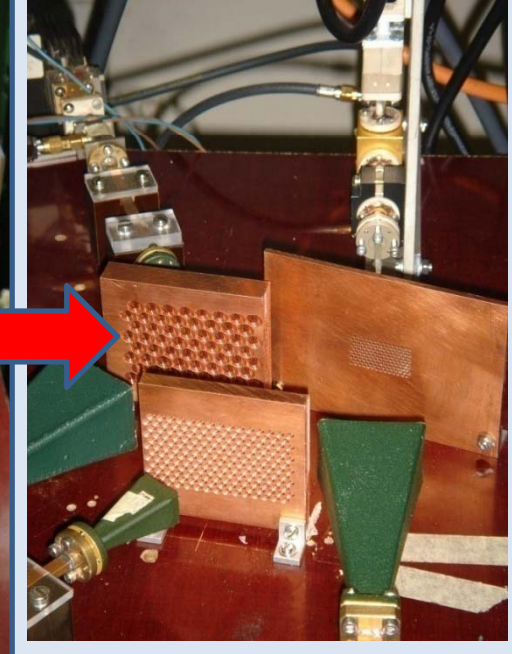
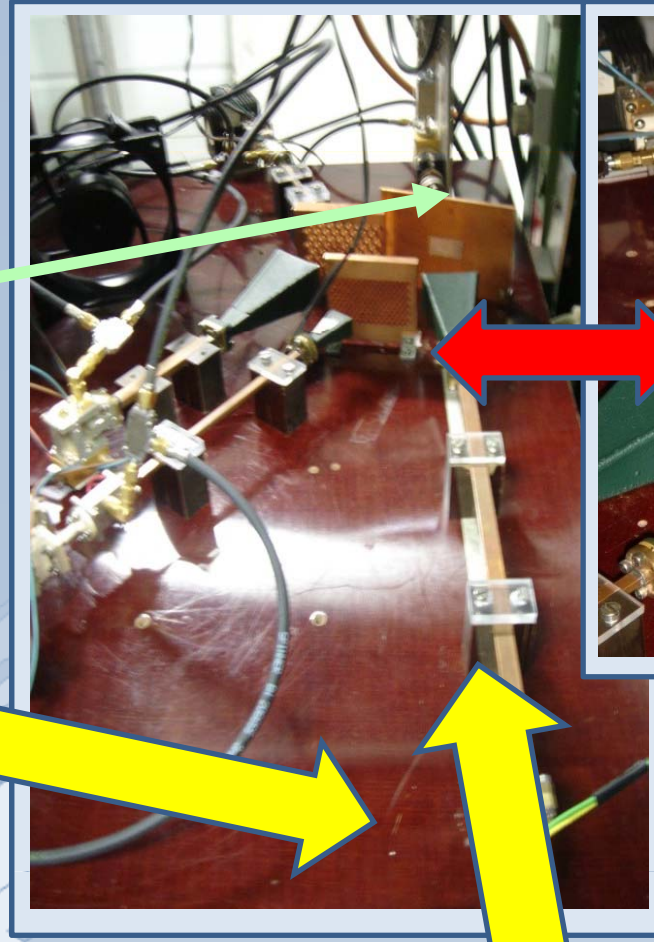
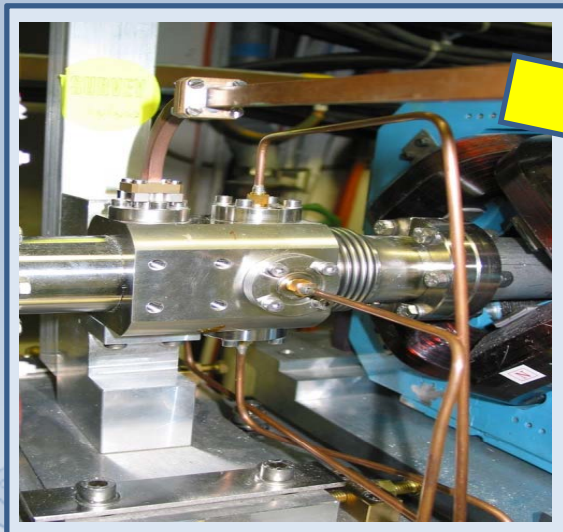


RF Pick-up @ CTF3 2007



Improvements to setup in 2007:

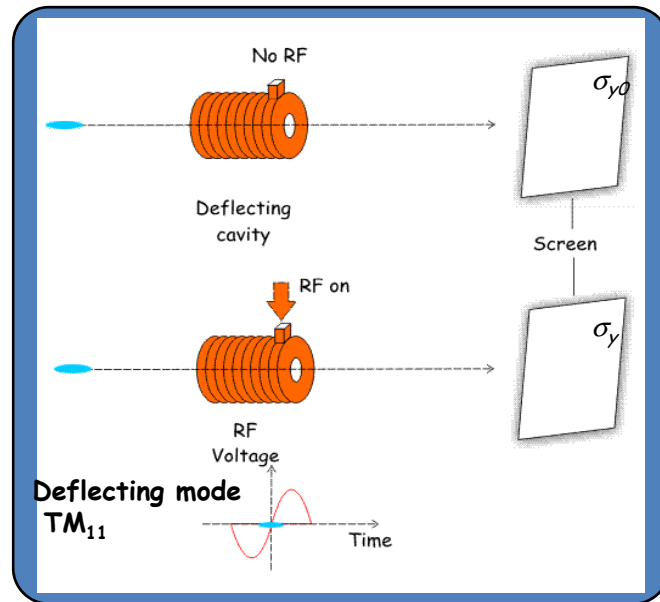
- RF Diamond window (0.500 ± 0.005 mm thick) prototype installed previously ~ 3 mm thick Al_2O_3
- Parabolic filter @ 143 GHz (measure beam frequencies (157 ± 14) GHz) & re-focus better reflecting signal
In 2006 Filter was @ 157 GHz



Hardware inc. D-band Waveguide Components, RF Window and fast ADC's provided by Northwestern Univ.

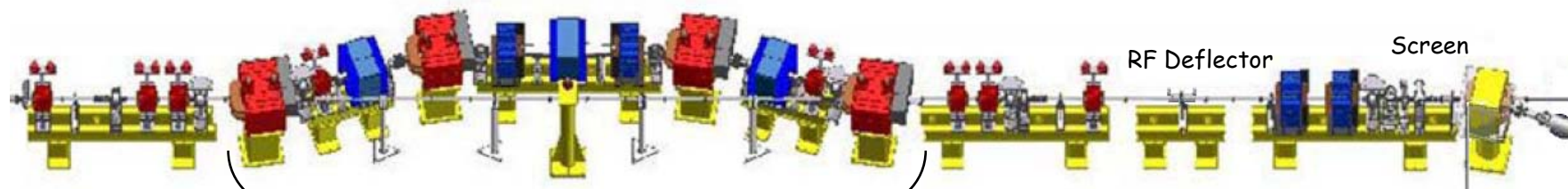
2007

Chicane optics & bunch length measurements - 2004

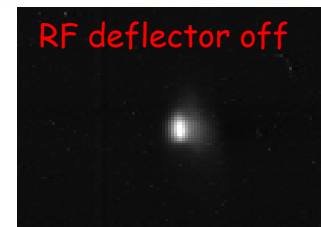


$$\sigma_y = \sqrt{\sigma_{y0}^2 + \sigma_z^2 \beta_c \beta_p \left(\frac{2\pi e V_0}{\lambda_{rf} E_0} \sin \Delta\psi_y \cos \phi_{rf} \right)^2}$$

Deflecting Voltage: $2\pi e V_0$
 RF deflector phase: ϕ_{rf}
 Bunch length: σ_z
 Beta function at cavity and profile monitor: $\beta_c \beta_p$
 RF deflector wavelength: λ_{rf}
 Beam energy: E_0
 Betatron phase advance (cavity-profile monitor): $\sin \Delta\psi_y$



Magnetic chicane (4 dipoles)





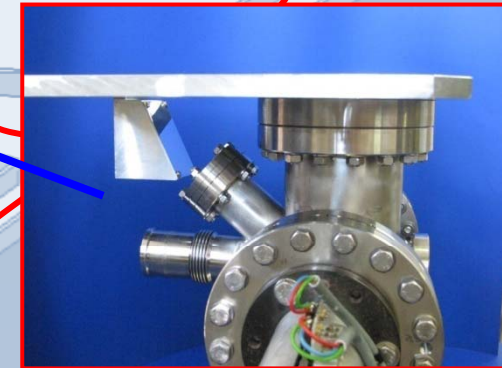
RF deflector @ CTF3



2006-2007

- Bunch Length Measurement with the 1.5GHz RF Deflector of the Delay Loop -

- Maximum power of 20MW
- 5degrees @1.5GHz = 9.25ps



OTR screen



RF deflector
on : 0 Xing

$$\sigma_{\text{noRF}} = 0.35\text{mm}$$
$$\sigma_{0\text{Xing}} = 2.9\text{mm (6.7ps)}$$



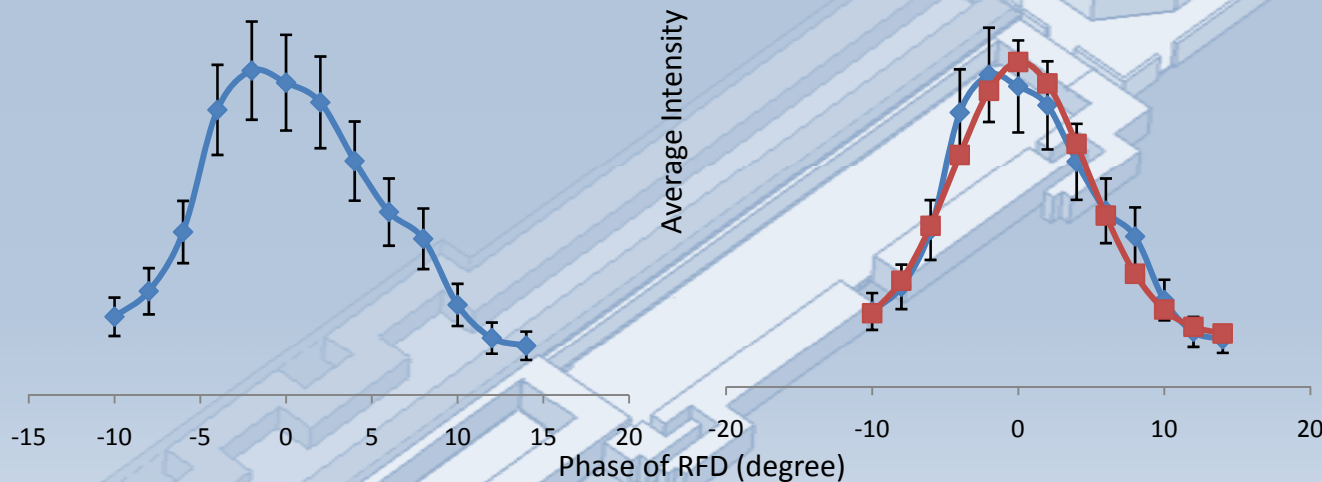
Measurement RF deflector 2007



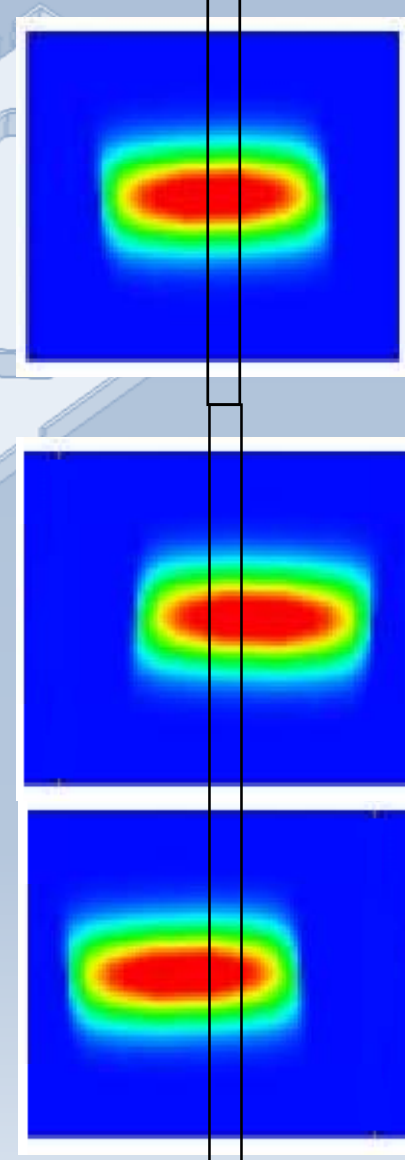
Measurement method ("scan" method)

Change the 1.5 GHz RF deflector phase and measure the average intensity of a thin band on the middle of screen per each phase. The phase of RFD related to bunch length by c/f factor. (c is speed of light and $f=1.5$ GHz)

→ Matlab code written for automisation of the scan



**Standard deviation * c/f =
 2.84 ± 0.35 mm**





Measurement RF deflector 2004-2007



“Single Image” method:

- 1) Measure the bunch length in monitor in pixel units for a **single image**
- 2) **Calibrate** the monitor by finding the equivalence between pixel unit and length unit (mm) by measuring the relationship between the center of the image position per RF deflector phase

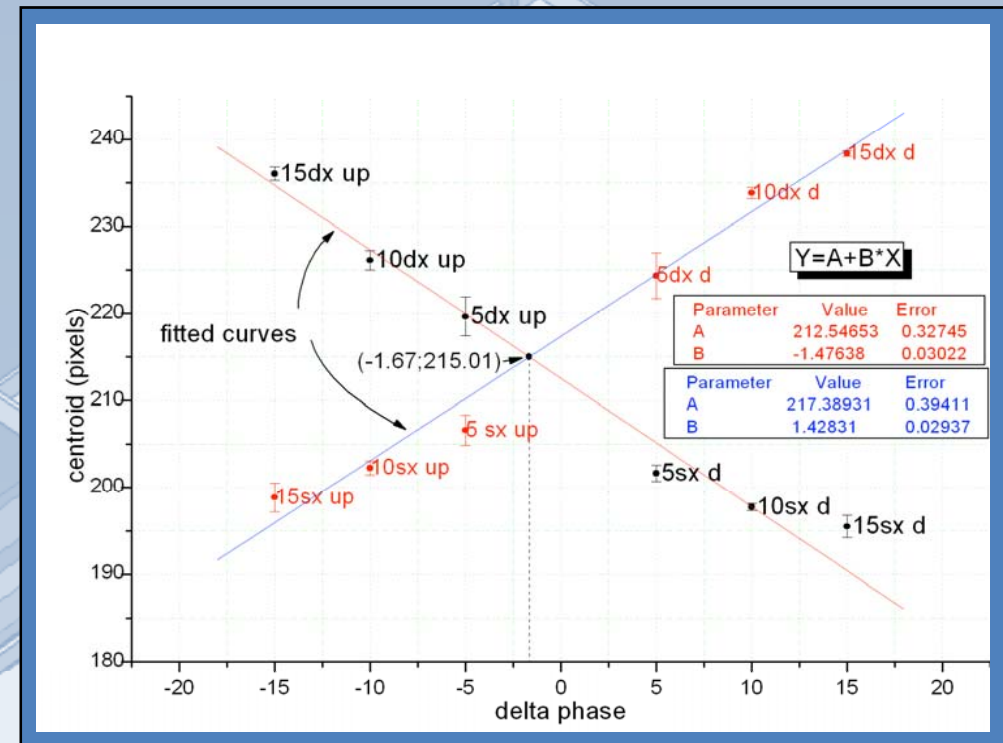
Advantage “Scan” method vs. “Single Image” method:

- **Avoid non-linearity** effects from the screen
- Image can be bigger than the screen (**improved resolution**)

Disadvantage “Scan” method vs. “Single Image” method:

- Need to **assume bunch shape remains constant** during the scan

Slide H. Shaker



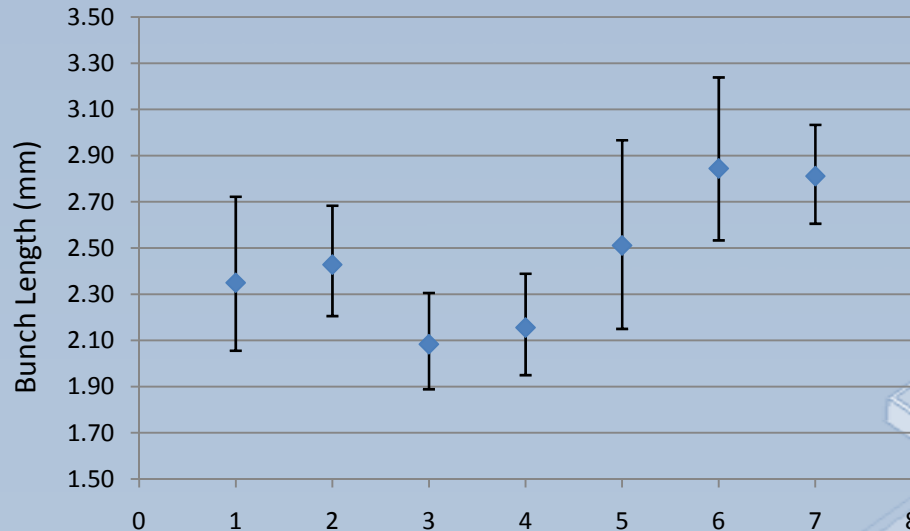
Example of Calibration curve for “Single Image” method ref. *D.Alesini et al* CTF3-010 INFN

Used in bunch length measurement from CTF3 2005 data





Measurement RF deflector 2007



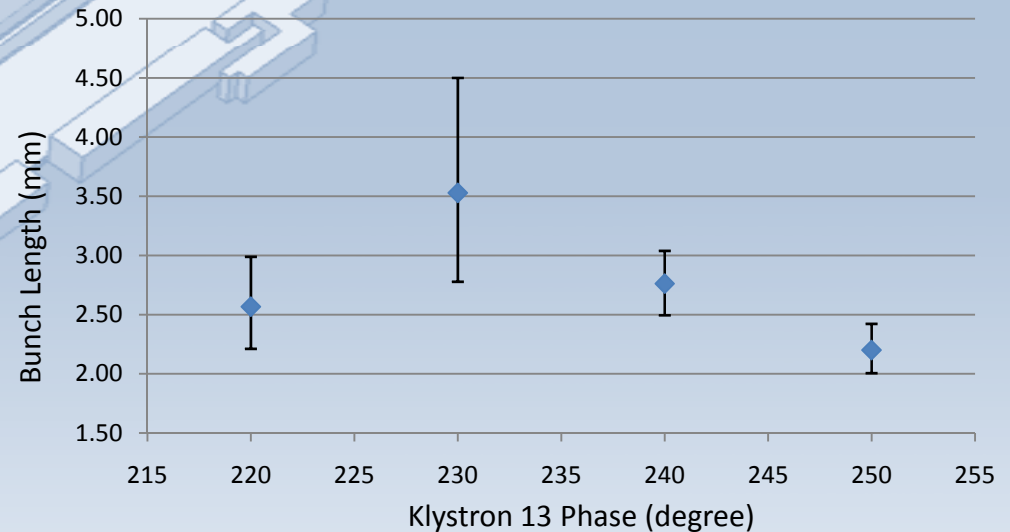
May 2007

Bunch length = 2.45 ± 0.28 mm
Phase of MKS constant for 7 measurements, "Scan" method used

December 2007

Wanted to calibrate "RF-pickup" with RF deflector measurements
Procedure established, but beam not stable enough for reliable calibration (beam shape not constant, large current contribution in satellites)

To be completed in 2008





For 2008



- Make absolute **calibration** of the “RF pickup” already installed after delay loop & understand resolution (use RF deflector and compare)
- Learn from “RF pickup” already installed to design most **cost effective solution** & **sensitive design** for **bunch length monitoring in CLEX**
 - Selection of down mixing frequency stages
 - Length of waveguide vs. down mixing closer to machine?
 - Requirements on ADC's
 - Need for 2 stage down mixing?? Save on cost of synthesizer?
 - Optimal RF window
- Development of RF pick-up / RF deflector for **TL2 and Califes** (collaboration with CEA/Saclay) → characterise the longitudinal dynamics of the beam
- Prepare a new Streak Camera **laboratory for CLEX**
- Invest in **New Streak Camera** (± 180 K euro) for CLEX



Conclusion



→ Optical lines to **Streak Camera in & after DL** successfully measured:
** bunch length, ** 180 degree phase switching & ** Bunch frequency multiplication

2005-2007

→ **Two new optical lines** have been **installed in CR**, to the New CR Streak Camera Laboratory **2007**

→ Bunch length measurements with **RF deflector** performed using **2 methods 2004-2007**

→ **“RF pickup”** with improvements in 2007 commissioned to measure bunch length at end of LINAC (or after delay loop) **2006-2007**

→ **Absolute calibration** of “RF pickup” with RF deflector started → **finish 2008**

2008 focus

→ **Fully characterising the “RF pickup”**

→ Designing a monitoring system for **TBL & Califes (collaboration with CEA/Saclay)**
→ characterise the longitudinal dynamics of the beam

→ Prepare a new **Streak Camera laboratory for CLEX**

→ Would need to **Invest in New Streak Camera (± 180 K euro) for CLEX**



Thank you's



RF-pickup installation acknowledgements and thank you's must be made to:

Hans Braun and Thibaut Lefevre for advising and collaboration in the design of the system

Alberto Rodriguez for collaborative advice in the Labview Acquisition and DAQ for pickup

Roberto Corsini, Peter Urschütz, Frank Tecker, Piotr Skowronski and Steffen Döbert for general collaboration, and in particular for the machine setup of the bunch compression scan to do the first measurement.

Stephane Deghaye for Aquiris card installation

Jonathan Sladen and Alexandra Andersson general consultation

Erminio Rugo and Frank Perret for mechanics

Romain Ruffieux and Christian Dutriat for electronics (BLMs & pickup)

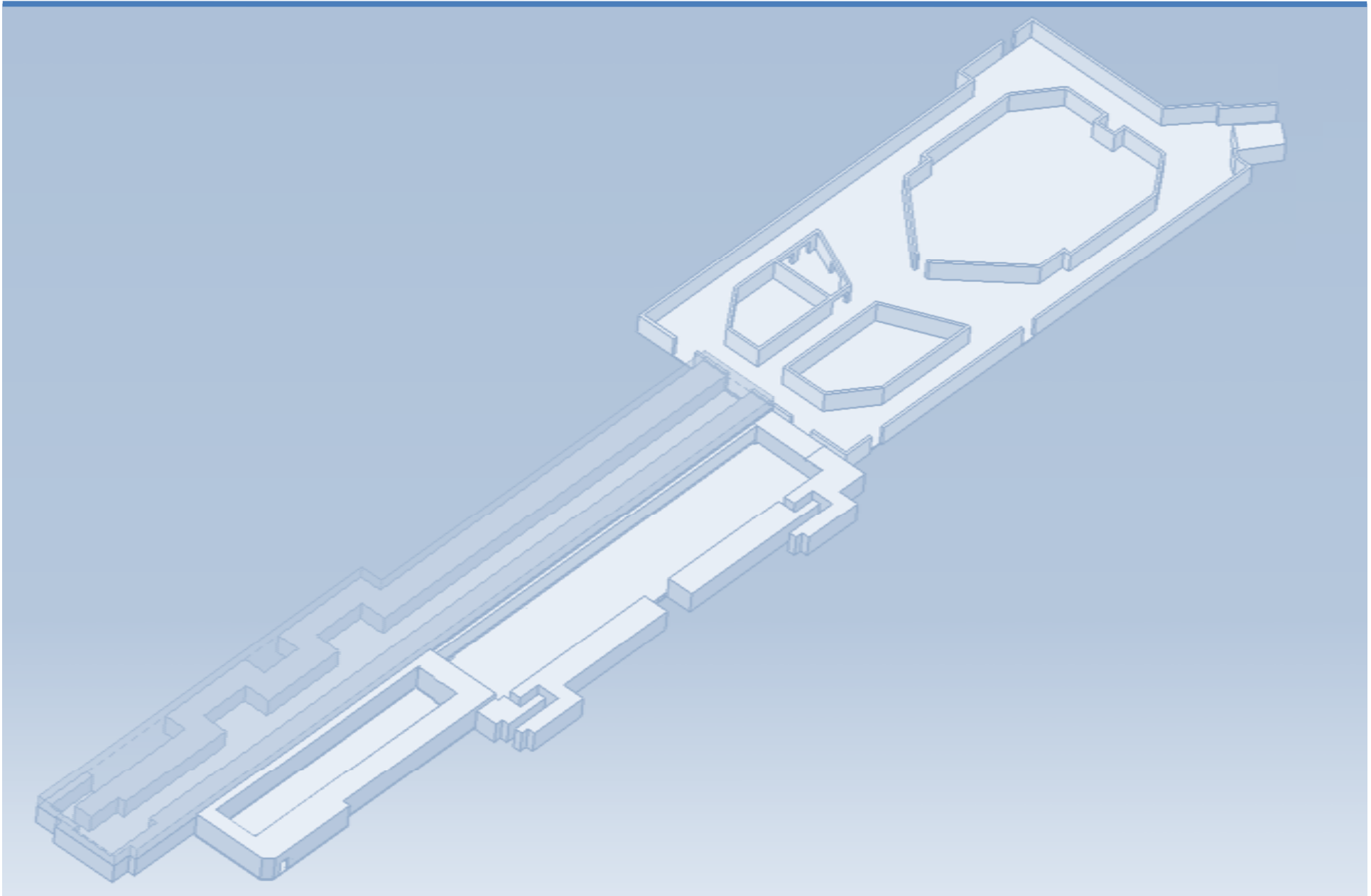
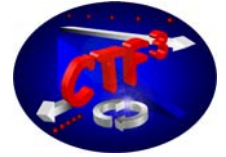
Mayda Velasco, Northwestern University and DOE

Support from the BI groups at CERN

All Collaborators on bunch length measurements inc Andrea Ghigo & the Frascati team

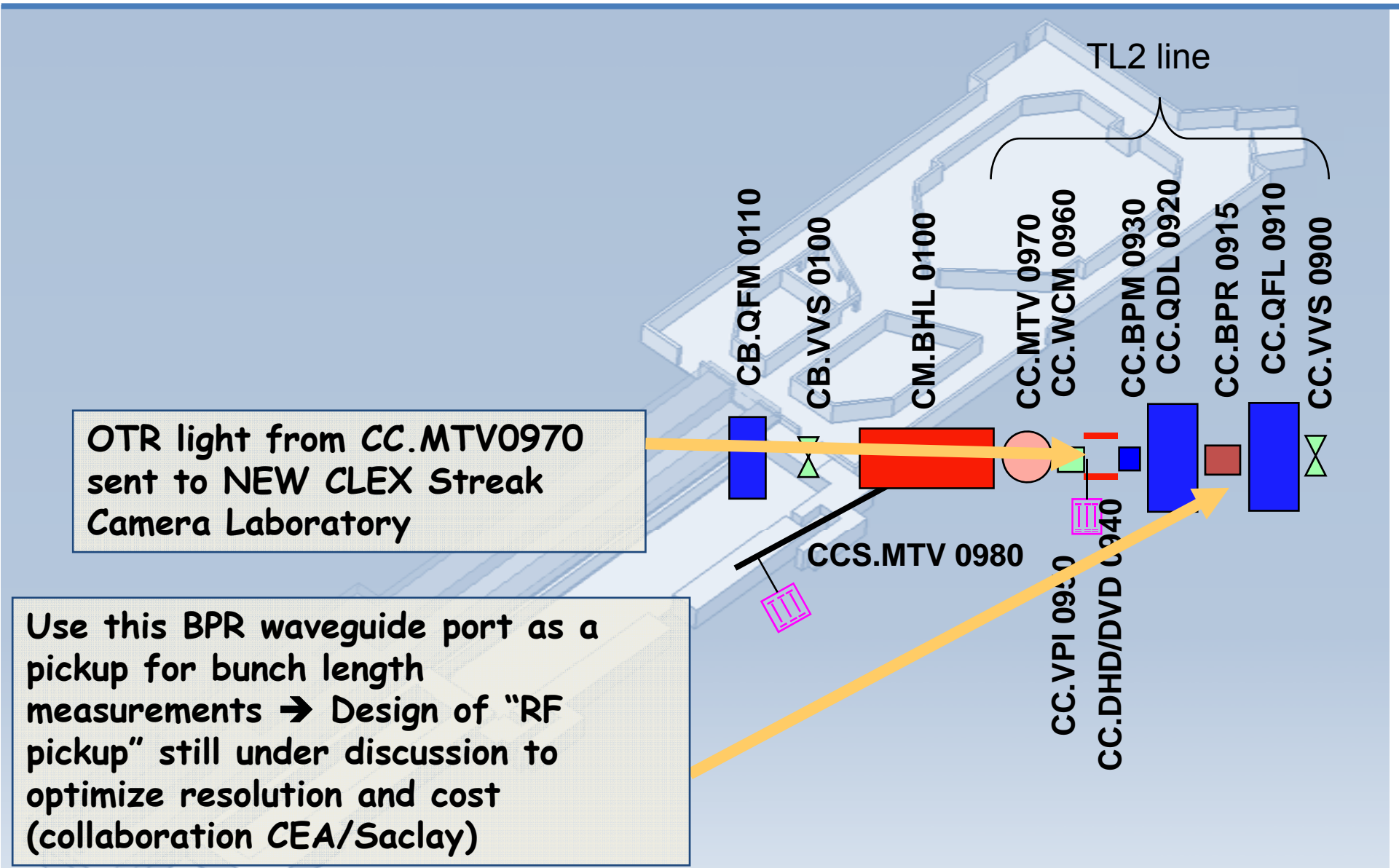


Extra slides

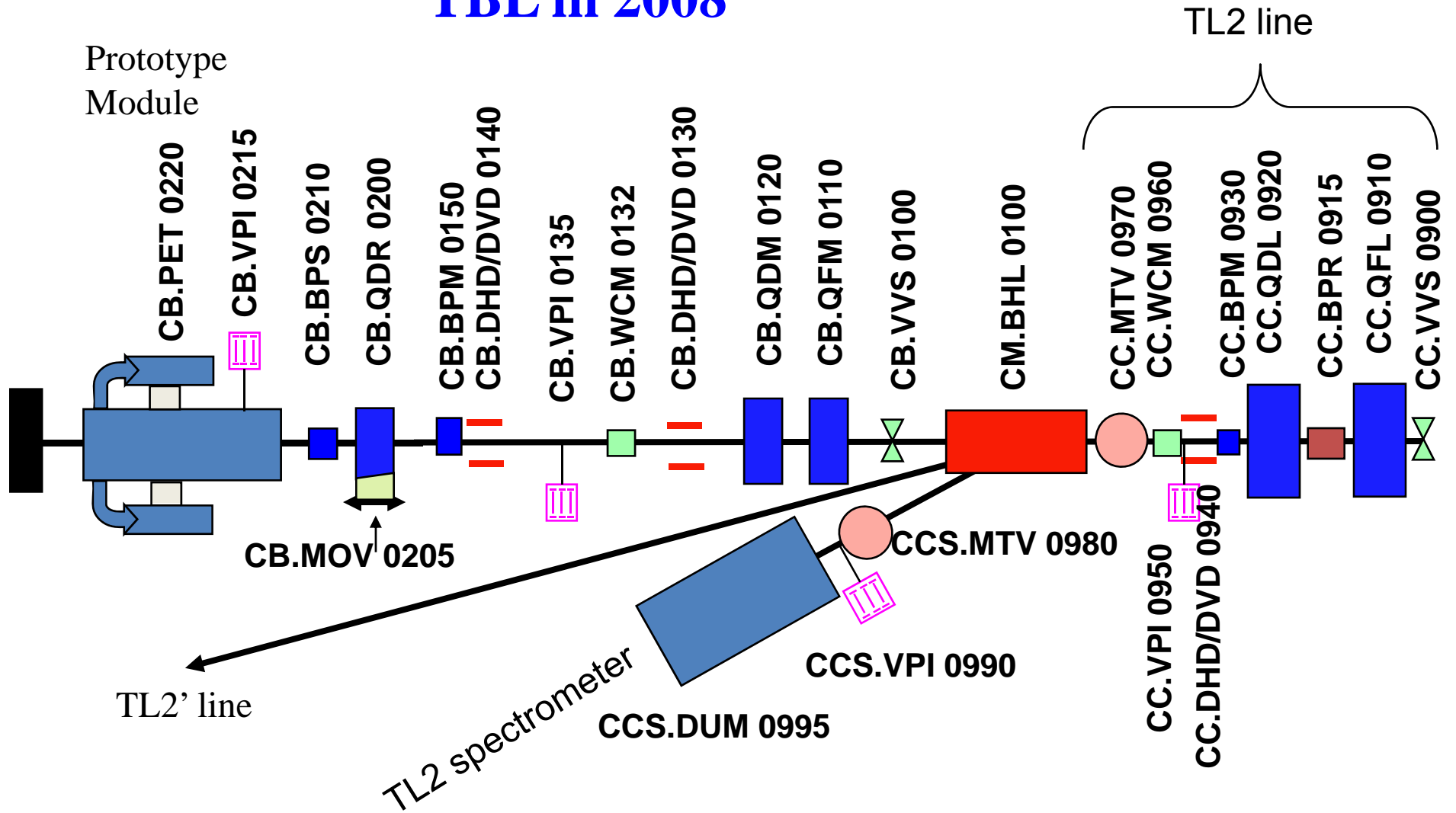




TL2 line, bunch length monitoring



TBL in 2008



17th December 2007

1st October 2007

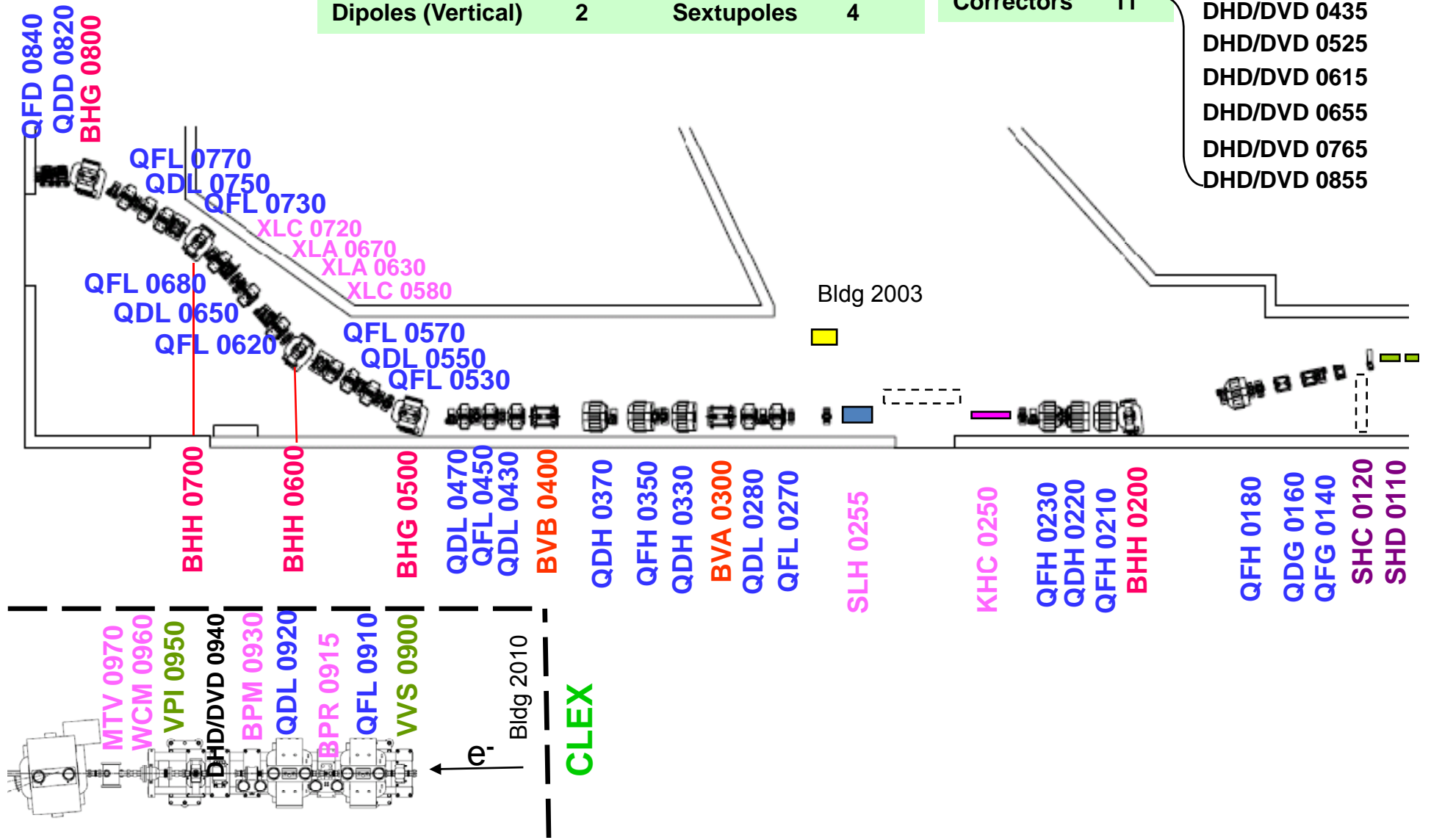
TL2 Magnet Layout

All names with prefix CC.

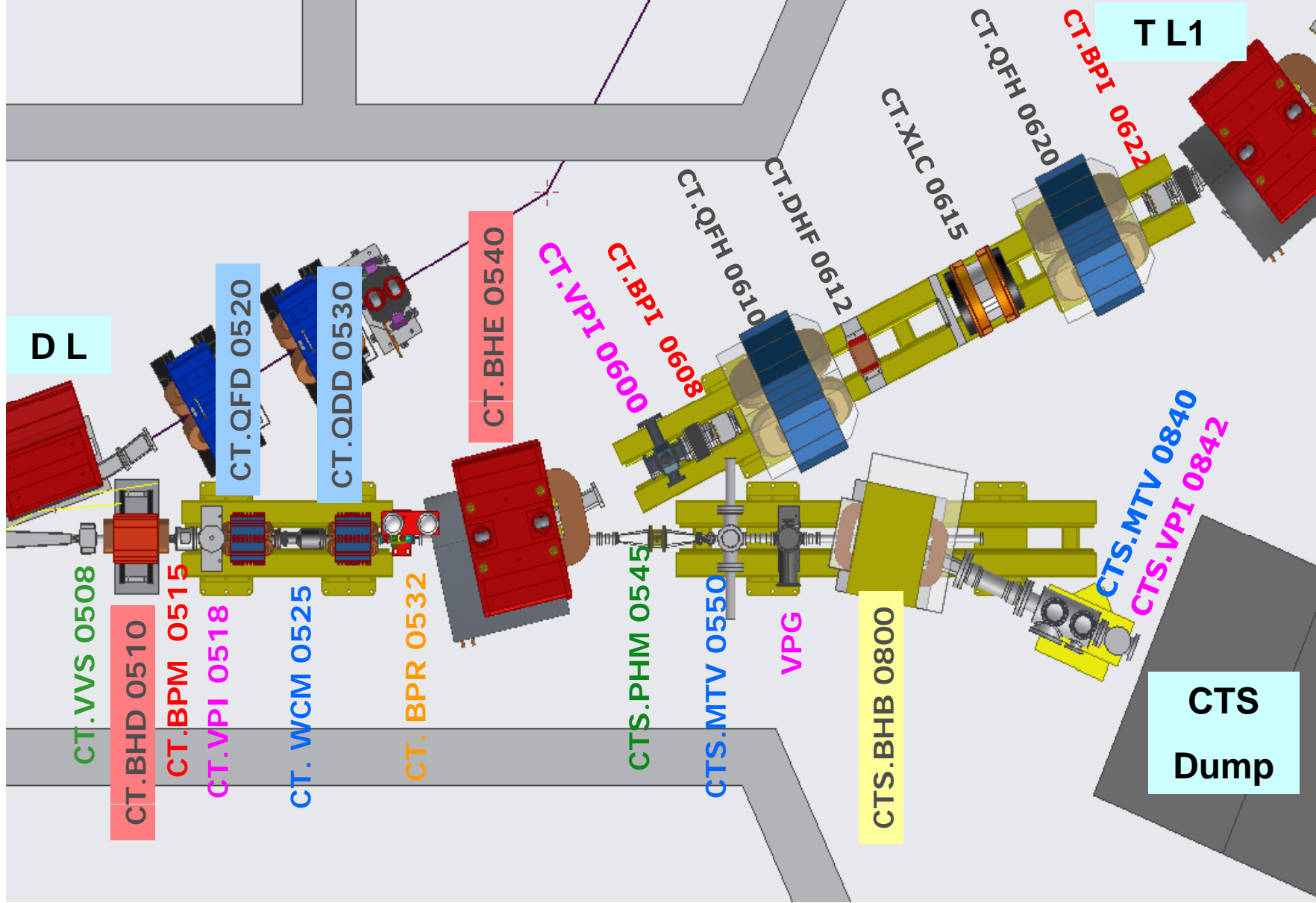
Dipoles (Horizontal)	5	Quadrupoles	25
Dipoles (Vertical)	2	Sextupoles	4

Correctors 11

- DHD/DVD 0125
- DHD/DVD 0175
- DHD/DVD 0225
- DHD/DVD 0265
- DHD/DVD 0345
- DHD/DVD 0435
- DHD/DVD 0525
- DHD/DVD 0615
- DHD/DVD 0655
- DHD/DVD 0765
- DHD/DVD 0855



CT and CTS lines





Bunch length monitoring requirements for CLIC



Location in CLIC Machine	Bunch Length	
	mm	ps
Drive beam	1.0	3.3
Main Beam at injection	0.044	0.15
Beam Delivery System (IP)	0.044	0.15
Main Beam in damping ring before extraction	1.50	5.00
Combiner Rings	2.00	6.70

<http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html>

- Bunch length need to be monitored throughout the machine
- dynamic range 0.1 ps \rightarrow 10 ps